The Early History of Nuclear Physics at Notre Dame

A Thesis

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Introduction

The seed of a vision of a University which truly actualized its charter yielded new fruit at Notre Dame in the decade of the nineteen thirties. The development of the Graduate School and programs of research filled out this vision which was being articulated anew in the years of Father John O'Hara's Presidency. While Father O'Hara moved the University mightily in this direction as its leader, he shared the vision with those whose help he needed to give form to it.

Within the same decade nuclear physics became the frontier field in science. The most challenging puzzles and most stubborn problems of modern physics drew many of the ablest in the physics community toward nuclear physics. At stake was the understanding of the fundamental relationships between particles and energy which would make possible enormous strides in pure science and technology alike.

At Notre Dame these two elements united to form the background for some of the most exciting years in the University's history. The development of a vital, progressive Graduate School enthusiastically committed to faculty and student research gave the University a new life. Pushed from behind by the administration's desire and pulled in front by the attractive force of exciting investigations into the nucleus, a very different educational enterprise emerged from the decade than entered it.

In this thesis, the role of research in nuclear physics in Notre Dame's transformation and its interplay with the administration's vision of a greater Notre Dame is examined. Early success in the area of nuclear research strongly supported the aims of expansionist forces within the University. In turn, the administration's support and encouragement vitalized a research effort which, though poorly endowed, was characterized by great enthusiasm. By placing in relief the accomplishments of this small Department of Physics in one field, it is hoped a broader story may be told of the University's growth in conformance with the vision which nurtured it.

Chapter I begins with a depiction of the administrative background to the expansion of Notre Dame toward a posture which reflected the importance of research. The development of the Graduate School within the University was central to this expansion. Secondly, the status of the Department of Physics before this growth in the Graduate School is portrayed to bring out the conditions in which research in nuclear physics was initiated.

Chapter II deals with the early, gradual growth of the Department of Physics, and, in particular, with the construction of the Van de Graaff generator, beginning in the summer of 1935. This machine allowed the faculty to attempt research in nuclear physics as its initial experimental effort.

In Chapter III, the development of the faculty, the specific accomplishments of the Department in research and the interaction of theoretical and experimental components in these accomplishments is examined. A consideration of the contributions of work in nuclear physics to the University's progress concludes the study.

CHAPTER I

Understanding the development of research in nuclear physics at Notre Dame requires a perspective much broader than any which could be drawn from the decade of the 1930's when such work began. The pursuit of this perspective leads to a period fifty years before the first beginnings of research in physics at the University. That research may be seen as a concrete fulfillment of the hopes and plans for a greater Notre Dame nurtured by some members of the Congregation of Holy Cross, the governing body at the University during the intervening years.

Founded in 1842 by Father Edward Sorin, C.S.C., a priest of the Congregation, the school was chartered two years later as the University of Notre Dame du Lac "with full power and authority to confer and grant, or cause to be conferred and granted, such degrees and diplomas in the liberal arts and science, and in law and medicine as are usually conferred and granted in other universities of the United States." It was not, however, a university in fact, and its strength lay more in its high school and manual training schools than in its college division. In the latter division the program of studies was essentially a six-year Collegiate Course leading to the Bachelor of Arts degree. The first breakthrough in the academic structure occurred when the Scientific Course was inaugurated in 1865 which was significant since it manifested Sorin's concern for growth and

for education in science as a practical subject.[1]

With respect to the intentions of the Congregation of Holy Cross toward its growth as an academic institution, Father Philip Moore, C.S.C., in his study of the academic development of Notre Dame states:

> We seem safe in saying that in 1883 the men at Notre Dame had no idea that it should become a university in our present meaning of the term, a place of specified advanced programs of study and research beyond the bachelor's degree, organized in a Graduate School.

Changes in this attitude came about as the result of the input of a few men of greater vision and progressive spirit who helped set the University's course in its present direction. The lives of these men are interconnected, and it is possible to see their influence on each other through the period before serious graduate work became an integral part of the University's life. This is not to ignore or belittle the contributions or vision of others who are part of Notre Dame's history, but rather to single out these men as having been possessed of this particular vision and to credit them for their work toward a greater Notre Dame.[2]

Father Sorin was in every way the builder of Notre Dame. Upon him rested the responsibility for her growth,

1 Arthur J. Hope, C.S.C. Notre Dame; One Hundred Years (Notre Dame: University Press, 1948, revised), p. 59. Hereafter cited as Hope, Notre Dame; Philip S. Moore, C.S.C., "Academic Development, University of Notre Dame -- Past, Present and Future," (Mimeographed copy, University of Notre Dame, 1960), p. 5. Hereafter cited as Moore, "Academic Development."

2 Moore, "Academic Development," p. 7.

and the rebuilding whenever disaster had struck her. The school he worked so hard to establish, however, was not focused on scholarship, but on preparing young men to lead a sound life. The man who most clearly saw the possibilities for a vital intellectual University in Notre Dame was Father John Zahm, C.S.C. As a result of his urging, a new Science Hall was opened in 1884, making Science the first School to have its own quarters. This building has been described as a "monument to the academic orientation that John Zahm envisioned for the University" in Thomas Schlereth's portrait of Notre Dame's history and campus.[3]

Zahm aimed for the improvement of Notre Dame's faculty, enrollment, reputation, and educational facilities. His belief in higher education led him to develop science at Notre Dame, and as Vice-President from 1885 to 1892 and as Provincial of the American province, i.e., the religious superior in charge of all Holy Cross men in the country, from 1898 through 1906, he directed the University toward the goal of acquiring a learned and saintly body of teachers.[4]

Schlereth characterizes Zahm in summarizing the issue which separated him from others in the administration at Notre Dame and in the Congregation:

[3] Thomas J. Schlereth, The University of Notre Dame: A Portrait of Its History and Campus (Notre Dame: University Press, 1976), p. 134. Hereafter cited as Schlereth, Portrait.

[4] Ralph E. Weber, Notre Dame's John Zahm (Notre Dame: University Press, 1961), pp. 33, 129. Hereafter cited as Weber, Zahm.

> Father John Zahm, assuredly one of the most brilliant minds Notre Dame ever had the opportunity to nurture, had intellectual aspirations for the University that exceeded the less ambitious plans of Father Andrew Morrissey, University president from 1893 to 1906. Historians of this period in Notre Dame history rightly juxtapose the different objectives of these two men and see the last decade of the nineteenth century as a period when the University experienced an intensive, although largely internal, debate over its future direction. . . .Briefly summarized, Morrissey felt that Notre Dame had already achieved a solid reputation as a prep school and that it should not expand rapidly in physical plant, personnel, or academic programs; it simply could not, in Morrissey's estimate "compete with all those schools so heavily endowed". Zahm, on the other hand, envisioned Notre Dame as potentially "the intellectual center of the American West", an institution with large undergraduate, graduate, and professional schools equipped with laboratories, libraries and research facilities; Notre Dame should strive to become the University its charter claimed it was.[5]

During his time as faculty member and administrator at Notre Dame, Zahm inspired others by his own scholarship and devotion to academic excellence. In his zeal to improve the intellectual tone at the University he influenced many of the young priests of the Congregation who would later work to bring Zahm's dreams for Notre Dame into reality. His own lectures and writings brought Notre Dame to national prominence.[6]

However, Zahm's disillusionment with the degree to which Notre Dame attained his goals for it are evident in a letter to his brother, the scientist Albert Zahm, written dur-

[5] Schlereth, Portrait, pp. 104-106.

[6] Moore, "Academic Development," p. 8; Weber, Zahm, chapter 4 "Famous Apologist for Science."

ing the period John Zahm spent in Rome (1897) as Procurator General of the Order:

> It would indeed be a trial for me to return to the dull, humdrum, unintellectual, dwarfing environment where I spent, or rather, wasted, the best years of my life. What a pity it is that our people do not realize the necessity of a higher culture for their numbers, especially those who are here to devote their lives to the ennobling work of education. With possibly one or two exceptions among the younger priests, no one at Notre Dame has the faintest conception of the wants of a university, and the demands of the age in which we live. I look forward to the young men now being educated at the Catholic University in the hope that they will effect eventually the much deserved change, but this will require time and patience. The old generation must die out before any real progress can be made. Notre Dame ought to be one of the first educational institutions in the land, whereas it is in reality nothing more than a large boarding house for elementary students.[7]

In light of developments, Zahm's words seem almost prophetic.

Another historian of Notre Dame reports the opposition of Father Morrissey:

> When he succeeded to the provincialship in 1906, Father Morrissey had rejected the grand plans of Father Zahm because he felt that the community could not afford them, and the fact that usually the community and University were without actual financial resources by the end of the summer seemed painful proof that notable expansion was impossible.[8]

One of those men who shared Zahm's ideals had joined him in the Science Department. He would be an educa-

[7] Weber, Zahm, p. 105.

[8] Thomas T. McAvoy, C.S.C., Father O'Hara of Notre Dame (Notre Dame: University Press, 1967), p. 67. Hereafter cited as McAvoy, O'Hara.

tor of young men in Washington, and a Notre Dame President who moved her mightily in the direction of becoming a true University. This young priest was Father James Burns, C.S.C.

After graduating from the Manual Labor School at Notre Dame, Burns continued through the Collegiate Department, having been one of Zahm's students in chemistry and physics. He entered the Congregation of Holy Cross immediately after graduation in 1888, and was ordained in 1893, returning to the University to teach and rejoin Father Zahm. In her study of Burns as an educator, Anna Kearney describes the connection between the two, and, incidentally, illuminates the difference in attitude between these two and Sorin about higher education:

> During the years that Burns had been a student at Notre Dame, he had become the protege of Zahm. Like Burns, Zahm had come to Notre Dame as a lay student and later entered the Congregation of Holy Cross. His specialty was science, and Father Edward Sorin, the founder of Notre Dame, had encouraged him to pursue this interest--a somewhat unusual thing for Sorin to do since he envisioned Notre Dame as a producer of good Catholics rather than good scholars.[9]

Burns would stand beside Zahm in his hopes for Notre Dame, especially taking part in Zahm's goal of a more and better educated Holy Cross community. Zahm had pushed for a house of studies at Catholic University in Washington, D.C., where young priests-to-be could take their philosophy and theology. Leaving Notre Dame in 1901, Burns became

[9] Anna Rose Kearney, "James A. Burns, C.S.C.--Educator." (Unpublished Doctoral Dissertation, University of Notre Dame, 1975), pp. 1-5, 6. Hereafter cited as Kearney, "Burns."

superior at Holy Cross College, as this house came to be called, and directed the studies of the men Notre Dame would have to rely on when the time came for the University to develop along the lines of Zahm's vision. After treating Burns' influence on the young members of the Congregation through his encouragement of their studies, Kearney concludes:

> During the nineteen years that he was at Holy Cross College, he has been credited with turning out a generation of 'zealous, saintly, and well educated priests, men who came back to Notre Dame and served as a leaven for a new intellectualism'.[10]

One of those who studied at Holy Cross College during Burns' tenure was John F. O'Hara, C.S.C. He, too, had come to Holy Cross following graduation from Notre Dame as a lay student, and would become a protege of Burns, dedicated to the growth and excellence of Notre Dame. On the connection between them, Kearney stresses: "[Burns'] influence on O'Hara during these formative years cannot be overemphasized." Both men were to become Presidents of the University and played large roles in setting her on a course which would lead to a strong graduate school. Without their orientation toward this, it never could have been accomplished by even the most enthusiastic faculty.[11]

[10] Kearney, "Burns," pp. 33-34. Quoting James P. Doll, C.S.C., "The History of Graduate Training for Holy Cross Priests," Educational Conference Bulletin of the Priests of Holy Cross, XXV, (Dec., 1957), p. 35.

[11] Kearney, "Burns," p. 36. Cf. also McAvoy, O'Hara, p. 56.

O'Hara returned to Notre Dame before Burns did in 1917. He taught in the Department of Commerce working toward its expansion. In 1921 he became the first Dean of the College of Commerce, the expansion from Department to College indicating how successful his efforts had been. In his biography of O'Hara, Father Thomas McAvoy, C.S.C. reports:

> The peak of Father O'Hara's efforts for his commerce program came when he announced in March, 1922, that if fifteen students applied within a few days for graduate work in commerce for the next academic year, a graduate program would be established. There were not fifteen applications, apparently, and there was certainly no staff to teach the program or additional facilities for graduate work. Instead the aims of the program began gradually to level off to the means at hand.[12]

Father O'Hara gradually withdrew from his involvement in Commerce because of an increasing involvement with his work as Prefect of Discipline, a post in which he served until he reluctantly joined the administration. The limiting factor on his plans had been the lack of resources. This same limitation effectively checked all the academic expansion plans at Notre Dame until the following decade. The man who would perhaps do the most to remove this limit was O'Hara's former superior and mentor, James Burns.[13]

While at Holy Cross College, Burns found time to get a Ph.D. of his own, and to write extensively on education which was his field of study. He was active as well

[12] McAvoy, O'Hara, pp. 61-87, 89.

[13] McAvoy, O'Hara, p. 69.

in the Catholic Educational Association, battling to create some unity in Catholic education. In 1919 he was recalled from Washington to become President of the University, principally because the need for a strong religious superior was evident to the Congregation. The situation into which he returned was somewhat complex, but Kearney offers this judgment of the decision:

> Although the election of Burns was based primarily on his suitability as a religious superior, it constituted a significant turning point in the development of Notre Dame into a first rank university. Burns was the first president who had received graduate training; he had a true scholar's appreciation of the value of research and academic excellence and he wanted to move Notre Dame in these directions.[14]

In the three years of his Presidency, "Burns constructed a new and stronger Notre Dame through his reorganization of the University's management structure, finances, curricula, and the raising of educational standards." When Burns became President, just after the first World War, the University had experienced a remarkable influx of students in the Collegiate Division. In order to make room for them, he urged the closing of the prep school at Notre Dame. As this had been the most successful element in the educational complex at the University, at least financially, he met resistance from members of the Congregation, but he successfully initiated the elimination of the high school students.[15]

[14] Kearney, "Burns," pp. 43,60,112.

[15] Kearney, "Burns," p. 110.

The philosophy of education which motivated Burns in moving toward the greater Notre Dame he imagined is revealed in an address to the Catholic Educational Association given in 1920.

> Great teachers, and great teachers only, can fill our Catholic colleges and universities with eager and ambitious students and arouse that public interest in our work which will bring us needed material resources and endowment.[16]

While there was still a need for physical development on the Notre Dame campus, there was no financial basis on which Burns could undertake this development. Kearney gives this assessment:

> When Burns became president, he confronted two pressing University needs: more money to pay adequate salaries to the lay professors; and more buildings for use as dormitories. Burns correctly gave the higher priority to the Endowment drive so that faculty salaries could be increased.[17]

Burns, therefore, approached foundations known to aid colleges and universities, and with the promise of some matching funds from them, set out to raise a million dollar endowment for a Notre Dame which, in 1919, had no endowment. His hope was that thereby he could raise lay faculty salaries so as to attract a stronger faculty to Notre Dame, one which through its scholarship would make a place for the University in the academic world. Since the faculty included equal

[16] Kearney, "Burns," p. 161. Quoting from Catholic Educational Association Bulletin, XVII (1920) 46-56, reported in the Notre Dame Scholastic, LIV (1920) 5-9, pp. 8,9.

[17] Kearney, "Burns," p. 142.

numbers of laymen and members of the Congregation, he worked steadily as well toward improving the intellectual preparation of the religious destined for faculty positions.[18]

Two other administrative decisions had a great impact on the future of the University. Burns created a Board of Lay Trustees, which would shepherd the funds raised as an endowment and give the benefit of years of experience in the business world in guiding the financial fortunes of the University. This took place in 1920, as did the reorganization of the University into colleges and departments. He also organized a University Council, or Academic Council, as it was also called, to pass on all major academic matters and to make policies and regulations. This Council, in turn, appointed a Committee on Graduate Studies, actually the reactivation of a committee of the faculty on graduate studies dating from 1905 which had exerted no leadership. This Committee took over the administration of all graduate work which had been under the colleges.[19]

While James Burns was able to do the planning for future growth of the University and also work toward ensuring that the necessary financial support would be there, the time was not yet ripe to plunge the University into research activities on any large scale. After his term as President,

[18] David Joseph Arthur, "The University of Notre Dame, 1919-1933: An Administrative History." (Unpublished Doctoral Dissertation, University of Michigan, 1973), pp. 118-131.

[19] Kearney, "Burns," p. 115.

Burns continued as President Emeritus, and remained in charge of the effort to build the endowment. In 1928, when he became Provincial of the American province of the Congregation, he continued to exercise his leadership in education as the superior of Presidents. As Provincial, he made it possible for many young priests to go on to advanced study, including Father Henry Bolger, C.S.C., who would return as head of the Department of Physics at Notre Dame. It was at Burns' urging that Father O'Hara was made Vice-President and Acting President for the 1933-1934 school year, in view of the illness of the President, Father Charles L. O'Donnell, C.S.C. O'Hara became President the following year, with Burns behind him as Provincial, and the stage was set for dramatic growth within the post-baccalaureate sphere at the University.[20]

An important task for the Committee on Graduate Studies was the specification of requirements for advanced degrees. Though Master's degrees in course had been given from at least 1883 and the Ph.D. from 1906, in practice graduate work had a very small role in the life of the University. For example,

> Between 1906 and 1919, sixteen Master of Arts degrees, fourteen Master of Science degrees, most of them unqualified by subject, and four Master of Science degrees in the departments of Engineering were conferred. During these same years four Doctor of Philosophy and two Doctor of Science degrees were awarded, the first in 1911 and the last in 1917. Of these, four were to men on the Notre Dame Faculty.[21]

[20] McAvoy, O'Hara, p. 124.

[21] Moore, "Academic Development," p. 134.

The strongest department in the University, and the only one eventually seen to have the solid base of scholarship which would allow it to grant the Ph.D. through the twenties, was Father Nieuwland's Department of Chemistry. Nieuwland's work on acetylene and synthetic rubber made a name for the University, and drew to his side other men who would make the Department known in the academic world and considered with the strongest in the land. There was a slow growth in graduate study in the years after Burns reorganized the University. In the 1924-1925 Bulletin of the University is found the statement:

> Graduate study until recent years did not form a regular part of work at the University. The few students who pursued degrees did so under the direction of and by special arrangement with the faculty.

When it was realized that the University was offering advanced degrees without adequate library resources or other conditions essential to genuine graduate work, including, in most of the sciences, proper laboratories, the fields in which these degrees were offered were cut back. In 1932, the Graduate School was formally established and Father J. Leonard Carrico, who had become Director of Studies in 1931, began to sort out and separate graduate from undergraduate courses. Later, Father Philip Moore, C.S.C., who was to become the first Dean of the Graduate School, gave this judgment of the 1932 clarification:

> The measures taken in 1932 cleared up much of the uncertainty about the graduate programs in the

> University, defined more precisely the status of graduate studies, and prepared the ground for their development. From this year, therefore, dates the Graduate School not only in name, but also in fact, though it would be another twelve years before it was given an adequate and effective administrative organization.[22]

In 1933 the University began graduate studies in Medieval Philosophy under Father Moore, who had recently returned from studies in Europe. The Department of Metallurgy was set up at the same time, with the possibility of its offering a Doctor's degree. Part of the credit for the growth of the Graduate School belongs to Father Moore. On his return he was named Secretary of the Committee on Graduate Studies. Two years later, i.e., in the spring of 1935, he wrote to Burns as Provincial and Chairman of the Board of Trustees concerning the raising of Notre Dame to true university status through the establishment of a Graduate School. He suggested that five of the following could, with proper preparation, offer the Ph.D.: chemistry, philosophy, history, education, English, classics or physics. Though it would take years to carry out all of Moore's plans for the Graduate School, the basis was laid during O'Hara's administration.[23]

As he began his administration, Father O'Hara showed great concern for the lack of funds and of qualified

[22] Moore, "Academic Development," pp. 135-138. The citation for the quotation from Bulletin is Bulletin of the University of Notre Dame, XIX, separate Graduate Bulletin, p. 9. Hereafter cited as Bulletin U.N.D.

[23] McAvoy, O'Hara, p. 132; Kearney, "Burns," p. 182.

teachers which were necessary for expansion. With the help of others he planned the development of a faculty and the use of the financial resources of the University. In particular, his friendship with two men supported him as he entered administration. McAvoy identifies them:

> On educational policies Father O'Hara had the advice and experience of Father James Burns, C.S.C. on which to draw. On the condition of the physical plant he could always rely on Father Thomas Steiner, C.S.C., an engineer become priest and a long time devoted friend.[24]

Burns needs no introduction here. Steiner and O'Hara had first become friends when they lived together at Notre Dame while they were teaching there before deciding to enter Holy Cross and the priesthood. When O'Hara was elected President, Steiner, who had worked for many years as a civil engineer, was the Dean of the College of Engineering which naturally encompassed Dr. Caparo's Department of Electrical Engineering.

O'Hara's plan then was to develop Notre Dame along the lines laid down in Burns' administration. He would seek a stronger faculty, encourage laymen to develop their research interests, recruit renowned scholars from Europe to visit, and even woo them to his faculty. He was interested in seeing that capable members of the community received a chance for advanced study or to develop special talents. He knew that for any expansion there must be new funds raised, for the endowment had ceased to grow under the onslaught of

[24] McAvoy, O'Hara, p. 146.

the depression. He approached the chief educational foundations in search of these necessary funds, as had Burns.[25]

Father O'Hara's remarks at the banquet celebrating his consecration as bishop in January, 1940 are highly significant. Forced to leave Notre Dame because of his appointment as auxiliary bishop of the Military Ordinariate, he summed up his administration in these words:

> I could not close without a special word of thanks to Father Burns, here on my right. He is the last man who would ever want a word of thanks, but I feel that I should say at this particular time that all the beautiful things that have been said about me during the administration of the last six years should be said of Father Burns, because all I tried to do was to carry out the plans Father Burns prepared during his administration, and he, in turn, carried out the plans of Father Zahm and other predecessors.[26]

Turning now to the development of the Department of Physics, and the growth of interest in research within it, it is necessary to characterize the state of the Department through the twenties. Dr. Lawrence Baldinger, Dean of the College of Science in 1965 when it celebrated the centennial of Science at Notre Dame described it so:

> Prior to 1934, the Department of Physics existed primarily for the teaching of those students whose schedules called for a background in physics. Except for the sections taught for the premedical students, the teaching was oriented almost completely toward engineering, although some effort had been directed to teaching of graduate courses; during this period many of the teachers listed on the staff of the Department of Physics were also engaged in the teaching of engineering

[25] McAvoy, O'Hara, p. 147.

[26] McAvoy, O'Hara, p. 202.

subjects and of mathematics courses.[27]

Throughout this period the staff included a number of Holy Cross priests. The first head of the Department when it came into existence following the reorganization of 1920 was Father Joseph N. Donahue, C.S.C., who served for three years. He was remembered by a member of the Department during the twenties as a man who was inclined toward the establishment of a graduate program, and who would have worked in that direction. Father Donahue was not listed under the faculty at Notre Dame after the 1923-1924 school year. Most probably he had been assigned to St. Edward's University in Austin, Texas, or Columbia College (now the University of Portland) in Portland, Oregon, institutions which were also run by the Congregation. It was quite common for Holy Cross religious to be moved in order to strengthen these other institutions. Moreover, though he might have returned via the same assignment process as many others did, Father Donahue died in the summer of 1928 at the age of 39.[28]

Replacing Father Donahue as head of the Department was Father Thomas Irving, C.S.C., who was Vice-President of

[27] Lawrence H. Baldinger, "Science at Notre Dame -- The Last Hundred Years" in The Centennial of Science at Notre Dame 1865-1965 (University of Notre Dame, n.d.), 14-39, pp. 35-36.

[28] Interview with Walter L. Shilts. Hereafter cited as Shilts Interview. Records of service in these years exist in the numbers of the Notre Dame Bulletin which served as a general catalog. The practice of the Bulletin was to publish course offerings for the upcoming school year, along with a list of faculty members of the preceding year. Thus,

the University in the years 1922-1925. Though he had taken a doctorate in physics from Catholic University while at Holy Cross College under Father Burns, he was heavily involved as a superior of affiliated religious houses at the University, and exerted no leadership toward a progressive program of research in the Department. In the September, 1929 Bulletin of the University, Mr. Daniel Hull was listed as head of the Department. Hull had been at Notre Dame since 1922 and had some training in physics. An older man, he was fully engaged in the service courses the Department was teaching. He also taught mathematics and astronomy, but this flexibility in subject matter was characteristic of the faculty in physics at the time. Other priests who served in physics were Father Frederick T. McKeon, C.S.C., Father William H. Malony, C.S.C. and Father Dominic Cannon, C.S.C. Father Henry J. Bolger, C.S.C. joined the Department in 1929 after getting a Master's degree in physics from Catholic University, and, apparently, he was the only one of these men who imagined the Department could be more than it was.[29]

Laymen teaching in the Department besides Hull included Dr. Jose Caparo of Electrical Engineering, Walter Shilts of Mathematics and Civil Engineering, and Eugene O'Connell, who was listed in Mathematics and Physics. Besides the services of these men, it appears that help was

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a full year would often pass before a new faculty member would be listed.

[29] Bulletin U.N.D. XXIV No. 3 (Sept., 1929), p. 155; Shilts Interview.

needed in directing the laboratories filled by students from the strong engineering departments. A succession of men who had taken Bachelor's degrees in Electrical Engineering filled this gap in manpower services for two years at a time, usually, as Graduate Assistants, though most often their graduate work was in math.[30]

The curriculum administered by these men was for the most part two years of general physics, with labs. In the late twenties, courses were listed in Advanced Laboratories and Mathematical Physics. The latter course was taught by Hull, who was Professor of Physics and Mathematics throughout this time. Some graduate courses were created for summer students by enlisting the aid of Dr. Caparo. These courses were taken principally by religious who were continuing their professional education, and the Master's degrees which resulted from them may be characterized as "book work". Though theses were required, these degrees manifestly differed in quality from those which culminated from true graduate work. Table 1 gives the degree recipients in the years through 1932, with the theses topics. Cursory examination of the topics reveals the derivative nature of these studies. No director was mentioned in these theses.[31]

With regard to laboratory space, the Department was confined to the basement of the Science Hall, increased

[30] Shilts Interview.

[31] Shilts Interview.

TABLE 1

Early Recipients of the Master of Science Degree for Work in the Department of Physics*

Degree Recipients	Date of Degree	Topic
Angelus, Br. Charles	Aug. 1922	"A Study of Self and Mutual Induction, and a Comparison of Methods Used to Determine Their Values"
Lieb, Sr. Mary de Chantal	Aug., 1922	"Lissajous Curves"
Ryan, Br. John Berchmans	Aug. 1923	"Some Properties of the Magnetic Field Surrounding Circular and Rectangular Conductors"
Assisi, Sr. Mary Clare	Aug. 1924	"Electrostatic Capacity and the Determination of the Coefficients of Capacity for Various Conductors Using Direct Methods and Also by Means of LaPlace's Equation"
de Paul, Sr. Mary Vincent	Aug. 1926	"The Newtonian Potential Function, Its Historical Development, Characteristics and Application to Equi-Potential Surfaces"
Water, Sr. Ann Elizabeth	Aug. 1930	"The Trajectories of Bodies Under Various Laws of Attraction"
Kenna, Rev. James H.	Aug. 1932	"Various Models of the Dynamic Atom"
Croke, Br. Patrick Berchmans	Aug. 1932	"The Development of Modern Atomic Theories"

* (Source: The Bulletin of the University of Notre Dame XII-XXX (1913-1935).

somewhat in size by a four-story addition completed in 1924. The 1921 Bulletin gives the following description: "The Department of Physics occupies three rooms in the south end of the first floor of Science Hall and five rooms in the basement." By 1929, the Bulletin included mention of "two laboratories set aside for advanced work in electricity and heat measurements." These labs were allocated for a second level lab course styled simply as "Advanced Laboratory".[32]

The attitude in the Department can be gathered from personal testimony of men who remember the time. Walter Shilts, who taught in the Physics Department from 1924 to 1936 when he undertook additional duties as Assistant Dean of the College of Engineering, states:

> Almost all the physics students were engineers and the physics courses taught were service courses. The members of the "department" taught engineering courses, mathematics courses and astronomy courses as well. No one was interested in research. The department had grown up in this way to take care of the needs of those students who required physics as part of their undergraduate curriculum.[33]

Dr. Edward Coomes, who later had a part in changing the attitude toward research, remembers the atmosphere in much the same way. Coomes came to Notre Dame as a freshman in 1927, remained after graduation in 1931 with a B.S. in Electrical Engineering and took an M.S. in Mathematics in

[32] Bulletin U.N.D. XVI (April, 1921); Bulletin U.N.D. XXIV, No. 3 (Sept., 1929), p. 222.

[33] Shilts Interview.

1933.

> In the early days, they didn't want any research. The University was young, and wanted good teachers; it had very successful undergraduates. . . . Once they got people they knew could teach and were around students, then that was enough. And they had no idea how everything compared on the outside. It was just a matter of teaching and preparing Catholic boys to go out, and an undergraduate degree was plenty.[34]

[34] Interview with Edward A. Coomes. Hereafter cited as Coomes Interview.

From this perspective, and with this background, it is possible to understand the gradual growth of research in nuclear physics at Notre Dame within the decade of the thirties. The thrust to do research was initiated within the Department of Physics, and it met with the encouragement of the administration due to the farsighted thinking already outlined. If it had not caught Notre Dame in its ascent to excellence, there would have been little place for nuclear physics at the University. By the same token, had it not been for the drive and leadership of those in the Department, its service role could have remained its bounds until the present.

Growth occurred in many departments, particularly during Father O'Hara's six years as President, effectively commencing in 1933. In fact, one of the main goals and achievements of his Presidency was the development of a Graduate School. Prominent in this growth were the departments in the Colleges of Science and Engineering, as well as in areas especially dear to O'Hara's heart, such as medieval philosophy and apologetics. In Kearney's study of Burns, she offers an explanation for this concentration:

> By 1938 new doctoral programs were offered in metallurgy, physical chemistry, philosophy, mathematics, physics and politics [political science]. This strong emphasis on the sciences reflected Burns' theory that a University acquired prestige through research in the sciences.[1]

[1] Kearney, "Burns," pp. 181-182.

Of course a particular chain of events led to research in physics and early concentration of that research in the sub-field of nuclear physics. While this text follows that development, it is important to remember that 1932 has been characterized as the "annus mirabilis" of the twentieth century physics because of the outstanding number of discoveries that occurred during that year. In fact, in the words of Victor Weisskopf, one of the most noted practitioners of the field:

> It is generally said that nuclear physics was born or really took a strong momentum in 1932, the great year when the neutron was discovered, accelerators were built, the deuteron was discovered, and artificial radioactivity was about to be discovered.[2]

The history of nuclear physics at Notre Dame may be connected to a major fire, since opportunity for research developed when fire struck the Engineering Building, In the words of a campus historian:

> In the predawn hours of June 29, 1928, an electrical storm struck a high-tension line leading to the building's top floor, setting the floor afire and causing over a hundred thousand dollars damage. The partial destruction of this building, never considered adequate by its faculty, caused William Benitz, professor of civil engineering, to comment, ' 'Isn't it too bad that the fire department got here too soon.' While the University constructed a temporary roof over the building's first floor, engineering classes were held in the basement of Badin Hall until the present Cushing Hall of Engineering was constructed in 1933.

[2] Charles Weiner, ed., Exploring the History of Nuclear Physics (New York: American Institute of Physics, 1972), p. 7. The remark occurs during a discussion of the exact birth date of nuclear physics.

By the time Cushing Hall was built, the men of the Engineering Departments had had a chance to study structures at other universities.[3]

As Professor Edward Coomes, a man in close contact with the Engineering faculty at the time, remembers:

> Nobody had any idea how to build a Hall of Engineering. So Father Steiner got all the department heads together and asked them to give their ideas of how to build the new Engineering Building. So Caparo and Benitz went out to see other engineering buildings . . . [Caparo] went down to Purdue and got information there, and Benitz went to other places. When they returned each of them suggested that the building contain research labs.

Father Steiner, as Dean, had strong reservations about the advisability of research. The reasons for this resistance lay in the attitude toward research activity at Notre Dame. Though the work of Father Nieuwland and others in Chemistry was well known, research, in general, was frowned upon. In a time long before the ideal of scholar-teacher took hold at Notre Dame, it was felt that research activity took time away from teaching. In Coomes' words:

> Faculty members didn't even have offices out there. The emphasis was to do your teaching, not to sit around in an office and talk to students. You taught classes and gave examinations.[4]

In addition, the faculty was isolated from the intellectual leadership of other universities. While characterized as competent men and good teachers, they had little

[3] Schlereth, Portrait, p. 158.

[4] Coomes Interview.

or no contact with the outside. Thus, the motivation and excitement which existed at other leading universities had, in the main, not infected the Notre Dame faculty. One factor which contributed to this isolation was the economic stringencies of the time. There could be little institutional financial support for an individual's wider interests. Few teachers could afford to undertake participation in national or regional meetings for the same reason. One long-time faculty member, Walter Shilts, recalls:

> If anyone wanted to go to an academic meeting, he paid his own expenses, or he went before the Academic Council, and they might allow you twenty-five dollars say, and you pay the rest. . . . You couldn't spend one nickel for travel without the definite approval of the Academic Council.[5]

Nevertheless, Professor Caparo insisted that space be allowed in the new building for the research of graduate students in Electrical Engineering. Personally, Father Steiner could be very gruff, but he was not unreasonable.

> Caparo got two research rooms on the second floor, a great big generator lab, and then, in the back, Caparo insisted on this enormous transformer laboratory. He had been down to Purdue, and they had a voltage transformer testing laboratory there, and all he did was double the size. So that's how the big room got there.[6]

The first description of this room appears in a December, 1931 issue of the Bulletin devoted to the new Hall of Engineering then being constructed:

> In the south part are the machine shop, the mechan-

[5] Shilts Interview.

[6] Coomes Interview.

> ics testing laboratory, and the high-tension laboratory. The latter is an impressive room, about forty feet square and forty feet in height, to be used by graduate students for experiments requiring high voltage.

Plans for this "cubic room" which was known as the "High Tension Laboratory" for the next few years, were amplified in the September, 1932 Bulletin:

> The High Tension Laboratory, in the new Hall of Engineering, has been especially designed for high tension experiments. A transformer having a rating of more than a million volts is to be installed in the center of the laboratory, with ample provision for the study of high tension transcients, insulator and insulation strength, and of corona effects and corona losses.

This announcement was repeated in the September, 1933 and 1934 Bulletins and dropped in 1935. Two reasons can be given for the failure to complete these plans: 1) there was never any money to equip the lab; and 2) there was no one willing and able to pursue a research program in the space provided. The High Tension Laboratory would remain an empty room until the construction of the generator in 1935.[7]

Though space had been provided for research, no plans emerged for immediate use of these facilities. The task at hand was the outfitting of the undergraduate laboratory spaces. One of the top students in Electrical Engineering from the Class of 1931, Edward Coomes, was invited to assist in this job:

> In 1931, when I graduated, there were no jobs, and

[7] Bulletin U.N.D. XXVI No. 4 (Dec., 1931), p. 20; Bulletin U.N.D. XXVII No. 3 (Sept., 1932), p. 41; Coomes Interview.

> Steiner asked me to stay on and help install equipment in the generator laboratory. . . . When one of the instructors got sick, Father Steiner asked me to help him out by taking his class in mechanics. I took this on and some other things which developed, so at the end of the year, I was teaching full time. The thing of it is, this got me in very strong with Father Steiner.

The confidence which Father Steiner had in the young Coomes as a result of this working relationship led him to agree when Professor Caparo asked Steiner's permission for Coomes to use the two small research rooms. Coomes thereafter moved into the empty space, where he began to work with electronics. In addition, many of his supplies came through his friendships with the maintenance department and Father Steiner, because there was no money budgeted for research.[8]

Utilization of the High Tension Laboratory came more slowly, and the story of its evolution into a laboratory for research in nuclear physics is long and complicated. In the course offerings for the 1929-1930 school year, mention was made of a new two-semester course: Modern Atomic Physics, carrying two hours credit for each semester. The subject matter included the following topics: "the mathematical foundations for the quantitative study of cathode rays, electrons and ions; the photo-electric effect, quantum theory, line spectra, x-ray spectroscopy and radioactivity." The course was to be taught by Daniel Hull who remained one of those unconvinced by many modern ideas, such as, for example, Einstein's theory of relativity. The course was at-

8 Coomes Interview.

tended by Father Bolger and Edward Coomes, who found the presentation quite discouraging, as they had wanted a good deal more. Modern Atomic Physics, though listed in 1930-1931 and 1931-1932, was not taught again until 1932-1933, when it was repeated at three hours credit for each semester.[9]

By the time it was offered again, the construction of the Engineering Building, and the attendant withdrawal of engineering classes from Science Hall had allowed for some changes. Principally, this resulted in the introduction of more laboratory courses. Walter Shilts recalls:

> It was decided that we would have three laboratories; one was in optics, one was in modern physics, and one was in x-rays. They had brought in a Professor O'Connell by this time. He was to do the X-rays, I was to do the Optics, and Father Bolger was to do the Modern Physics.

These labs resulted from pressure to get in line with the offerings of other schools. Late in 1932 Hull was still getting approval for the funds needed to equip the lab associated with the Modern Physics course, as an expense of $1,000 was authorized to ready the Modern Physics lab for the second semester. In his November, 1933 report to the Board of Lay Trustees, Father O'Hara, who was serving as Acting President, noted that three new labs had been added to the Department of Physics.[10]

9 Bulletin U.N.D. XXIV No. 3 (Sept. 1929), p. 156; Coomes Interview.

10 Shilts Interview; letter from Charles L. O'Donnell, C.S.C. to Daniel Hull, December 24, 1932, Presidential Papers of Charles L. O'Donnell, C.S.C. 1928-1932, File:H, Archives

Part of the pressure to improve the Department certainly originated in Father Henry Bolger, who was to teach the lab in Modern Atomic Physics. He was at the University from 1929 to 1932, prior to four years' graduate work at California Institute of Technology. Edward Coomes remembers his attitude at the time:

> Classes were terrible at that time, and he got the dream of a good physics department. I first knew Father Bolger when I was a Junior. He studied physics at Catholic University. We were both very interested in it, and he was very disturbed about the state of things [at Notre Dame].

The main part of Father Bolger's role in building up the Physics Department still lay in the future.[11]

Another man in the Department felt that more should be done in the area of experimentation, however. Eugene O'Connell had come to the University when Father Irving left the Department in 1927, in order to teach the second year physics laboratory. Though it was generally difficult to attract faculty to Notre Dame at that time, O'Connell had a large family and needed to support them. He had worked with Arthur Compton, later a Nobel Laureate, and one of America's most famous physicists, in x-rays at the University of Chicago, receiving a Master's degree in 1928. He had taught at Loyola University from 1924-1927. It was O'Con-

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to the University of Notre Dame. Hereafter cited as UNDA; copy of report to Board of Lay Trustees in Presidential Papers of Charles L. O'Donnell, C.S.C. 1928-1934, File: Board of Lay Trustees UNDA; McAvoy, O'Hara, p. 132; Bulletin U.N.D. XXVII No. 3 (Sept., 1932), pp. 183-184.

11 Coomes Interview.

nell who strongly urged the graduate laboratory in x-rays. Coomes reconstructs the development this way:

> He had gotten the spirit of research from Arthur Compton, and [as] part of coming here, he insisted he be allowed to give a graduate course in x-rays. This was put on the books.[12]

Indeed, in September, 1932, the Bulletin listed a course, "Graduate Laboratory in X-rays and Crystal Analysis". This course was not to be taught till the 1933-1934 school year, and Mr. O'Connell was to be the instructor. In addition, he taught all the sophomore laboratories. However, after speaking at a political rally for Franklin Roosevelt in South Bend late in October, 1932, he took sick and died suddenly. At the insistence of Father Carrico, who was then Director of Studies, the course, once listed, had to be taught. Coomes was shifted to Physics to cover the sophomore labs, but a new instructor was sought for the x-ray lab.[13]

Normally, a department in search of additional faculty members would have resorted to personal consultation with colleagues in Ph.D.-granting universities for the recommendation of candidates. Notre Dame was more isolated, however, and it was left to Father Carrico to recruit a new

[12] Coomes Interview; Bulletin U.N.D. XXIV No. 3 (Sept., 1929), p. 24.

[13] Bulletin U.N.D. XXVII No. 3 (Sept., 1932), p. 184; Notre Dame Scholastic 66 : 7 (Nov. 4, 1932), p. 11. This was Notre Dame's weekly student news magazine. Hereafter cited as Scholastic; Coomes Interview.

member of the faculty. Hiring would have been accomplished by the central administration in any event. The man selected was an enthusiastic young experimentalist from Johns Hopkins University, George Briggs Collins, anxious to get a job and anxious to do research. He had worked with R.W. Wood in optics and had absorbed the Wood tradition of doing good work with a minimum of expense and elegance. As Coomes characterizes him, "[Wood] did everything with sealing wax and gum -- that's the kind of guy George was." This quality was to stand him in good stead at a University which had precious few dollars to spend on research.[14]

Collins came to Notre Dame in September, 1933. He had no training in x-ray apparatus or crystallography, but he had "the spirit of research". Every one who describes him at that time uses the word "enthusiastic" usually qualified by "very". It is not clear why Notre Dame sought him out if it was looking for someone who could teach a course in x-rays, but it may be suspected that its salary scale would not allow Father Carrico to employ someone more knowledgeable in the field. For Collins' part, it was the depression, and throughout the thirties any job in physics was a

[14] Coomes Interview. For background on Wood, see R.B. Lindsey, "Wood, Robert Williams" in Dictionary of Scientific Biography, XIV, C.C. Gillispie, editor-in-chief (New York: Schribner's, 1976), 497-499. Lindsey points out Wood's "zest for experimentation and great ingenuity in devising relatively simple ways to exhibit spectacular effects." The "sealing wax" appellation is often applied to Rutherford's Cavendish Laboratory tradition also. It signifies a style of making do with simple apparatus at minimum expense.
George Collins is not related to the author.

job.

It is worthwhile to make a connection to the larger picture at this point. Actually, specialization played a much smaller role in the job orientation of the physicists of the thirties, partly because fields were not concretized and new problems were emerging almost every day. Nuclear physics, in particular, was an emerging field, and many physicists would move into it without specialized training. The pressure from lack of funds under which everyone labored had a great deal to do with practical decisions of where to work and what to do.

In general, the situation can be illustrated by the following quotation.

> Nuclear physicists who experienced it need not be reminded of the effect that the Depression had on their careers. Jobs were scarce for everyone in physics, and nuclear physics was not generally regarded as a particularly valuable specialty for government or industrial employment. The university was the natural home for nuclear physicists, with the outstanding exception of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The general reduction in university budgets and junior faculty most affected the younger men who had recently earned their doctorates in physics. Their problem was not where to obtain an opportunity in nuclear physics, but rather where to get any employment whatsoever in physics.

Although George Collins was not trained in nuclear physics at Johns Hopkins, the situation of nuclear specialists described above was much his own, and he came to the University ready to learn what he had to learn. This was a great deal,

for he had not yet encountered an x-ray tube![15]

It is of no little significance that Edward Coomes was not teaching in the sophomore labs of the Physics Department. As in any organization, the web of relationships already established eased the way to get things done. The fact that Coomes had assisted Father Steiner in teaching whenever called upon had won the good favor of this key priest who headed the College of Engineering, and oversaw the maintenance of the University. In addition, Coomes had been a superior student in the College of Engineering, and maintained good relationships with the men who ran the machine shops and workshops within it. The working relationship that grew up between Collins and Coomes is described in the latter's words:

> [George] confessed to me he had never made an x-ray tube. . . . But we had to get up a lab, so we got to be real good friends, and we got to be father-confessors to each other. . . . I knew everybody over in Engineering. Harry McClellan [in charge of the machine shop] let us come over and build x-ray tubes in the machine shop; in fact, he helped us. That's how the x-ray tubes got built!

In addition, Collins requested funds from the University Council, and, with Coomes' help, got the course under way. Collins was the first Ph.D. physicist trained under a long-standing tradition of research to come to Notre Dame. The

[15] Coomes Interview; Charles Wiener, ed. Exploring the History of Nuclear Physics (New York: American Institute of Physics, 1972), p. 256. The quote is taken from a study paper supplied to participants in a conference on the history of nuclear physics, which was written by Joan Bromberg, Barry Richman and Charles Wiener.

impact of his arrival was not long in making itself felt. He took over courses in Quantum Theory and Wave Mechanics which had been initiated the year of his arrival by Professor Wenske, a member of the Department of Chemistry, in the fall, 1934 term.[16]

A capsule picture of the state of the University can be gleaned from the President's Annual Report to the members of the Board of Lay Trustees, presented at the November semi-annual meeting. In his November 16, 1934 report to the Board newly elected President O'Hara was able to include this statement:

> Four new theoretical courses have been offered in undergraduate and graduate physics, and a seminar in nuclear physics is being held for graduate students and members of the faculty. Laboratory courses are offered in Optics, Electronics, Vacuum Tubes, and X-rays. There are now five graduate students in this department, two of whom are receiving no financial aid from the university.

Mr. Hull was teaching a course in Mathematical Physics, and the Electronics and Vacuum Tubes courses were taught by Mr. Coomes, but the ferment within the Department was manifest. This was, after all, a Department in which one new course had been offered in the last ten years![17]

In order to prepare his reports to the Board of Lay Trustees, Father O'Hara usually asked, either directly or indirectly, for a brief descriptive statement of develop-

[16] Coomes Interview; Bulletin U.N.D. XXIX No. 3 (Sept., 1934).

[17] Report to the Board of Lay Trustees, Nov., 1934, copy in Papers of the Office of Public Relations and Development, UNDA.

ments from the various departments within the University. The above item was drawn from a letter signed by Hull, Collins and Coomes in response to such a request. In that letter, they also stressed important pieces of apparatus that had been purchased for the Department, and its gratitude for the generous support given to it by the administration. This support was to continue through the O'Hara years, as will be manifest. One further item from this letter is worthy of note:

> The Department of Physics has been given the services of a graduate student to make apparatus in the shops of the Engineering Building. He has constructed two metal x-ray tubes, four powder diagram cameras and one Bragg x-ray spectrometer in addition to many smaller items.[18]

Several points need to be made about this brief announcement. The allocation of resources in favor of the Department and continued evidence of cooperation with Engineering stand out. The graduate student, John Staunton, received the first non-summer Master's degree for work in the Department of Physics in June, 1934. His thesis was a description of the construction of the Bragg spectrometer mentioned. Many more Master's degrees were to result from theses involving the construction of needed equipment in the next five years. Though Staunton's thesis was unsigned, it was certainly Collins who motivated him to initiate con-

[18] Letter from Daniel Hull, George Collins and Edward Coomes to Rev. J.L. Carrico, C.S.C., October 29, 1934, copy in Director of Studies Papers, Before 1952, File : Physics Department, UNDA.

struction, for it was Collins who was teaching the X-ray course. Collins would continue to be primarily responsible for the direction of all Master's work over the next five years.

Before leaving O'Hara's November, 1934 report, attention should be drawn to the change in climate surrounding graduate work signalled by the new President. Father McAvoy has underscored this in his biography of O'Hara:

> Probably the part of the report that was most characteristic of the forward look of Father O'Hara was his insistence on the development of graduate work in chemistry, metallurgy and in medieval studies and on the necessity of bringing in scholars from outside the university, particularly from Europe, to stimulate its intellectual growth. He understood that if Catholic education was to expand at Notre Dame, the leadership would have to come from without, possibly from Catholic scholars of Europe.

In addition, O'Hara emphasized that results and reports were expected soon from the departments doing graduate work. He lauded the Chemistry Department for its graduate work, which had been recognized when the American Council of Education rated the Department's graduate work with that of the foremost institutions of learning in the United States. He wished to increase the capabilities of departments doing graduate work, obtain funds for graduate students, and push for the construction of a graduate student dormitory. This orientation was closely aligned with the hopes of the young members of the Department of Physics. What O'Hara was saying is doubly impressive because in the fall of 1934 there

were only 57 students in the Graduate School.[19]

The next step toward the development of research in nuclear physics followed after the suggestion of a visitor to the University. Of course, the idea of doing nuclear physics was in the air in the international physics community, but there had to be some concrete possibility to pursue. At Notre Dame, active interest in the field is signalled by the Seminar in Nuclear Physics begun in the fall of 1934. The moment of conception of work on a generator is recounted in the words of Edward Coomes:

> It was in the winter of 1934 when the big break came. We were working in the electrical engineering lab upstairs, trying to build a transformer needed for an oscillograph. Somebody had given us a [cathode ray] tube. A guy stopped by from MIT to call on Caparo. This was Harold Edgerton, who was the world's expert on high speed photography. Caparo wasn't there and he just dropped in on us. He introduced himself, and was so impressed that we were trying to build a transformer for an oscillograph, whereas he had laboratory after laboratory at MIT worth millions of dollars, with all the equipment that he needed, he asked me to take him around. So we showed him the place. For part of the tour, we went into this great big empty room. He says, 'Oh, wouldn't Van de Graaff love to have this room.' Van de Graaff at this time was building his generator in an old hangar though it didn't yet work at that time. George Collins happened to come around when he was there in this big room. He said to us, 'You guys really ought to get acquainted with Van de Graaff. . . .' After this, George got to thinking: why don't we build a generator there. I know Hafsted and Tuve down at the Bureau of Standards (sic) where they have a generator.[20]

[19] McAvoy, O'Hara, p. 151; Report to the Board of Lay Trustees, Nov., 1934, copy in Papers of the Office of Public Relations and Development, UNDA.

[20] Coomes Interview.

Because the generator which Coomes and Collins would build was the crucial vehicle for research activities in nuclear physics, a brief description of the development, structure and functioning of particle accelerators is called for. Particle accelerators were developed to satisfy a need for an abundant supply of variable energy particles with which experimentalists could probe the nucleus. Early work in nuclear disintegration had depended upon naturally radioactive alpha and beta sources.[21]

In the early thirties, three separate types of high-energy accelerators were developed each using a different mechanism to cause particles to emerge with large energies through evacuated acceleration tubes. Livingston gives a succinct description of one idea:

> The simplest and most obvious method of producing high-velocity particles is the application of dc potential to an evacuated tube through which the particles are accelerated. Particle energies are limited by the available dc potential difference, which is itself limited by breakdown of insulation or by corona from the high-potential terminal. For convenience in experimentation the source of particles is usually located in the high-potential terminal and the beam emerges into a laboratory

[21] M. Stanley Livingston, ed. with commentary, The Development of High-Energy Accelerators, (New York: Dover, 1966), p. 3. Hereafter cited as Livingston, Accelerators. Livingston credits Rutherford with this challenge, given in a 1927 address before the Royal Society: "It has long been my ambition to have available for study a copious supply of atoms and electrons which have an individual energy far transcending that of the α- and β- particles from radioactive bodies. I am hopeful that I may yet have my wish fulfilled. . . ." E. Rutherford, Proc. Roy. Soc. (London) 117 (1928), 310-316, p. 310, "Address of the President, Sir Ernest Rutherford, O.M., at the Anniversary Meeting", November 30, 1927.

at ground potential. The terminal is positively charged for acceleration of protons and negatively charged for electrons.

The first to succeed in disintegrating nuclei were J.D. Cockcroft and E.T.S. Walton in the Cavendish Laboratory using a voltage multiplier to accelerate protons artificially. The June, 1932 report of this work may be taken as the starting point in accelerator history.[22]

A few months later the first practical cyclotron entered the field. The cyclotron utilizes the concept of resonance acceleration in which particles acquire high energy through many successive traversals of a low-voltage radio-frequency. Designed by E.O. Lawrence and M.S. Livingston at the University of California, Berkeley, this machine was quickly applied to the bombardment of light mass targets, which were the only ones accessible to the particle energies which could then be developed.[23]

The modern belt-charged electrostatic generator originated in the experiments by R.J. Van de Graaff in 1929-1930. In Van de Graaff's scheme, charges would be continuously deposited on a belt conveyor of insulating material and carried to a large metal sphere, supported vertically by insulating legs, where a large potential could be built up

[22] Livingston, Accelerators, pp. 4, 9; J.D. Cockcroft and E.T.S. Walton, Proc. Roy. Soc. (London), A137 (1932), 229-242, "Experiments with High Velocity Positive Ions. II -- The Disintegration of Elements by High Velocity Protons."

[23] Livingston, Accelerators, pp. 4, 87.

gradually and maintained. The size of the sphere was important because charges would be accumulated on its surface until their density would cause breakdown along the insulators which supported the sphere or of the air surrounding it. Thus, the bigger the sphere, the higher the voltage attainable, all other things being equal. The violence of these breakdowns, known as sparking, was also a danger to sensitive equipment. The actual discharge of sphere to ground resembles lightning, which is just such a high voltage discharge at an atmospheric level. In 1933, Van de Graaff and his fellow workers at MIT published plans for a very large generator they were trying to get into operation in an aircraft hangar in South Dartmouth, Massachusetts. The considerable distance from Cambridge is an indication of the respect with which voltages on the order of millions of volts were regarded. Officials did not want machines capable of producing high voltages in a heavily urban area.[24]

Meanwhile a group at the Department of Terrestrial Magnetism of the Carnegie Institution in Washington, under the leadership of M.A. Tuve, adopted the electrostatic generator as a potential source. This was the first electrostatic generator to be used for nuclear experiments, primarily for the study of proton range-energy relations. This

[24] Livingston, Accelerators, p. 27; R.J. Van de Graaff, K.T. Compton and L.C. van Atta, Phys. Rev. 43 (1933), 149-157, "The Electrostatic Production of High Voltage for Nuclear Investigations;" Coomes Interview.

was a vertical machine, as was Van de Graaff's. Though it had been developed over a four-year period, a comprehensive description of the high energy techniques involved was not published until 1935.[25]

At the University of Wisconsin, a group under the leadership of R.G. Herb designed and built a sequence of machines of increasing size and energy rating, starting about 1933. Limited by low ceilings, they chose to build horizontal machines, which also could be easily enclosed in a large steel tank and pressurized, thereby eliminating many of the vicissitudes to which open-air machines were subject. Sparking at low voltages was a significant problem for open-air machines, particularly in the summer months when the increased humidity of the air would lower its breakdown point so that high voltages were not possible. As a result, open-air machines were realistically limited to operation between November and April.[26]

The work of developing the electrostatic generator was principally accomplished by these three groups. Others, including the men at Notre Dame, would base their designs on the machines at MIT, Washington or Wisconsin, and turn to

[25] Livingston, Accelerators, p. 27; M.A. Tuve, L.R. Hafsted, and O. Dahl, "High Voltage Technique for Nuclear Physics Studies," Phys. Rev. 48 (1935), 315-317.

[26] R.G. Herb, D.B. Parkinson and D.W. Kerst, "A Van de Graaff Generator Operating Under High Air Pressure," Review Scient. Inst. 6 (1935) 261-265; Interview with Bernard Waldman. Hereafter cited as Waldman Interview.

groups there for advice. Thus, it was natural for George Collins, who returned home to Washington between semesters in the winter of 1934 to consult with Hafsted and Tuve at the Department of Terrestrial Magnetism. Meanwhile, Coomes approached Steiner to arrange for using the "cubic room". Though Steiner took little stock in the kind of research these two young enthusiasts were interested in, he gave permission. Coomes had helped him out in the classroom in the past, and he had some more teaching in store for him. There were, however, some additional reservations when the nature of the project was explained to Steiner:

> I told him: 'It's going to cost you some money.' He asked, 'How much?' 'I don't know', I said, 'We want to build a generator in here.' 'How big?' he asked. 'Oh', I said, 'About a million volts.' 'Ooooh', he said, and threw up his hands. He was scared to death of electricity. 'We can't have anything like that on campus; we'll kill somebody!'[27]

Assured that everything would be perfectly safe, Father Steiner was soon drawn into the project himself. When Collins returned, having talked to Tuve and Hafsted, the first problem which faced the two young experimenters was how they could build the large-diameter sphere necessary for the terminal. As an engineer, Father Steiner was quite used to challenges in building, and suggested a bridgework

[27] Coomes Interview. This concern for the high voltages was not unusual, as already mentioned. Robert Van de Graaff was working far from Cambridge for much the same reason. In research areas when high voltages and high radiation levels are expected, many precautions are taken to limit the access of non-research personnel to the area, and great care is taken to provide more than adequate shielding. In 1935,

to build a wooden ball, which could then be covered with metal. He also helped them get the wood from a friend, and managed to obtain supplies which were covered by the maintenance budget.

What they proposed to build was an enlarged version of the machine in operation at the Department of Terrestrial Magnetism. Knowing in principle what they wanted, they used no drawings in the construction but had the assistance of the shops and craftsmen at Notre Dame.[28]

Construction was pushed hard throughout the summer of 1935. Two recent graduates in Electrical Engineering caught up by the enthusiasm of the two physicists and having no immediate job opportunities to pursue, remained at Notre Dame to assist them. The first formal request for University assistance appears in a letter to Father O'Hara in May, 1935:

> We wish to obtain the University's approval of the plans for a high voltage generator submitted to Father Steiner last week. Mr. Al Hiegel and Mr. Ed Kenefake have generously offered to stay here this summer and assist in constructing the generator if arrangements could be made to offer them board and room. We would greatly appreciate their assistance which would facilitate the work of construction.

The action of the University Council at its meeting May 8, 1935, was supportive, indicating the intercession of Father

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high voltage machines were not the everyday objects that they are today.

[28] Coomes Interview.

Steiner, who was a member of the Council:

> Upon recommendation of Father Steiner, the Department of Physics was granted an appropriation of $900.00 to purchase a high voltage generator to be used for experimental purposes in the room set aside for this in the Engineering Building.[29]

Hiegel and Kenefake, following in the footsteps of John Staunton, remained at the University as Graduate Assistants in Physics, and were recipients of Master's degrees (M.S. in Physics) in June, 1936. Their theses are the first to bear the signature of a director, that of George Collins. Each had taken his Bachelor's degree in Electrical Engineering, but there was no graduate work in engineering, outside Metallurgy, at the University at the time; thus, their degrees were conferred in Physics. It was not until 1938 that the Department graduated anyone whose undergraduate work had not been in Electrical Engineering at Notre Dame.[30]

The generator was not purchased, as the approval from the University Council indicates. Parts were purchased and enormous amounts of labor were expended by the principals

[29] Coomes and Collins to O'Hara, May 6, 1935, Vice-President's Papers of John F. O'Hara, C.S.C., 1933-1934, File : University Council, UNDA; Notice, dated May 9, 1935, Vice-President's Papers of John F. O'Hara, C.S.C., File : University Council, UNDA.

[30] Bulletin, U.N.D. XXX (Sept., 1934), Alfred J. Hiegel, "The Construction and Operation of a High-Voltage Belt-type Electrostatic Generator," (unpublished Master's thesis, Physics Department, University of Notre Dame, 1936); Edwin W. Kenefake, "An Electrostatic Generating Voltmeter," (unpublished Master's thesis, Physics Department, University of Notre Dame, 1936); Shilts Interview.

to make construction possible. Figures 1 and 2 show the completed generator without accelerating tube and some details of its construction, respectively. It was no small accomplishment to get approval for an amount of money as large as was received.

> They got enough from Father O'Hara to get the minimum amount of money that they required, but it was a battle all the way. Back in those days, we didn't operate on budgets; there were no departmental budgets at all. When you got to fifty or a hundred dollars, this had to go before the Academic Council for approval. Every little item had to go up there. Well, they were talking about something like a thousand dollars! They had quite a time fighting their way through for all that. They were two very enthusiastic young men. That's what sold it.[31]

The spirit and enthusiasm of Collins and Coomes were infectious. As work proceeded over the next two years the attention of many people was drawn to the accomplishments in the Engineering Building. After the sphere had been constructed and the charging mechanism had become operational, Father Steiner and Father O'Hara brought campus visitors to the site so that they could be shown the "lightning". Coomes recalls that these two priests, who were long-time friends, would even come over during the evening hours and lend a hand. Perhaps the excitement of those years is best captured in Coomes' words:

> It's just a fantastic story. The people that are really responsible for that first generator -- the suggestion by Edgerton of MIT . . . and Van de Graaff himself who gave these hints, and the

[31] Shilts Interview. The figures are taken from Hiegel's thesis.

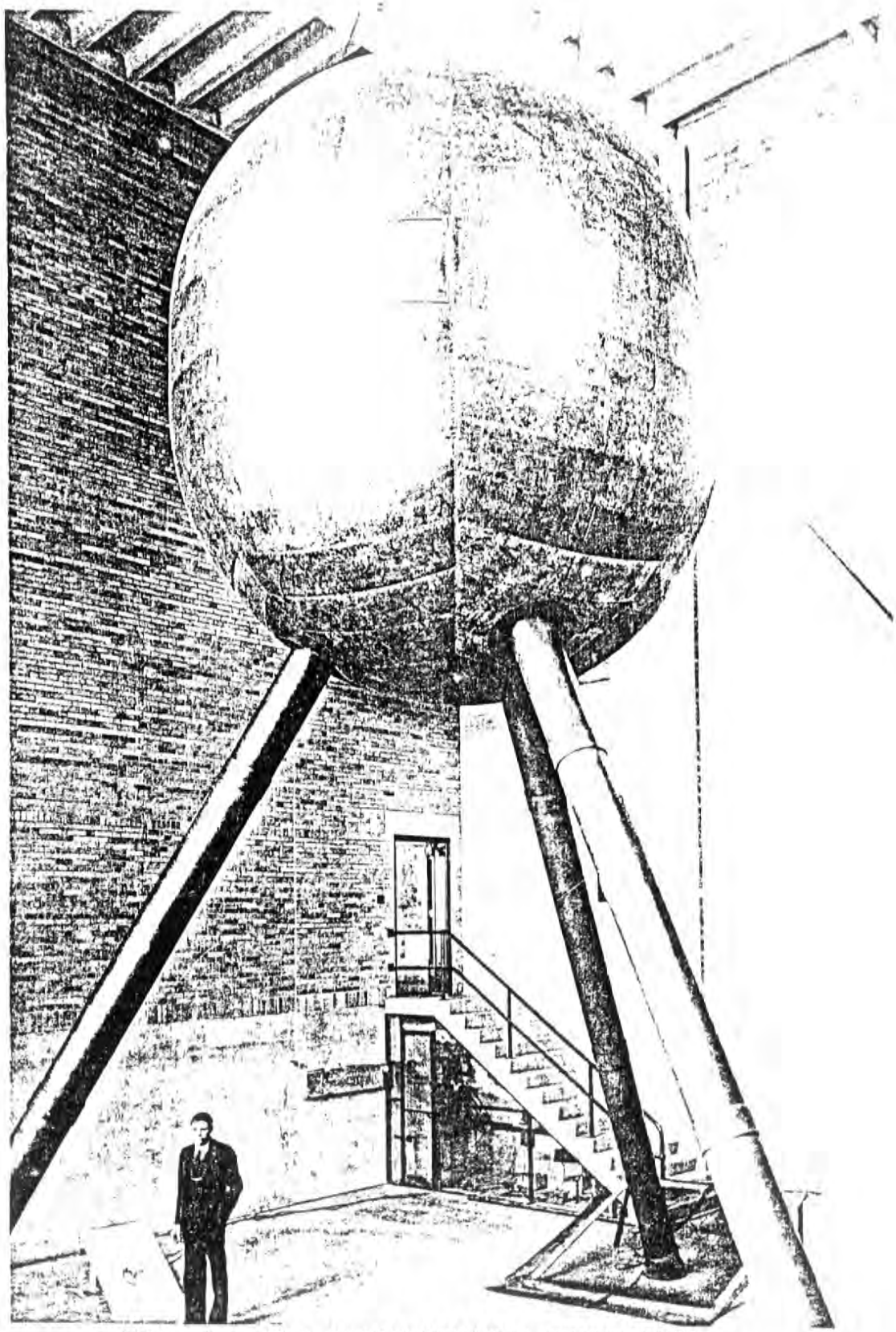

FIG. 1. THE ELECTROSTATIC GENERATOR

Source: Alfred Hiegel's Thesis, facing Title page.

FIG. 2a.

FIG. 2b.

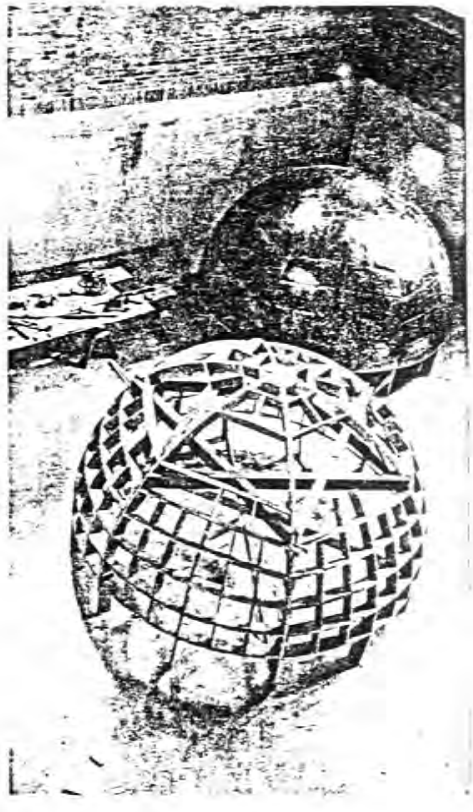

FIG. 2c.

STRUCTURAL DETAILS OF ELECTROSTATIC GENERATOR

Source: Alfred Hiegel's Thesis, following page 10.

> fact that Collins and I were interested in research that this thing grew. And then the fact that people were there who were really very far-sighted. I was teaching 20 hours a week and thought nothing of it. We were all teaching 20 hours a week and working at nights, and working in the summertime for nothing. But we were just having a glorious time![32]

Beyond this construction, of course, a program of research was required. The generator was not ready to accelerate a beam till the spring of 1937, due partly to the limited time its builders could devote to it. In the interim, however, Father O'Hara was perspicacious enough to plan for the future. He was persistent in reporting the progress being made in the Department to the Board of Lay Trustees and to the alumni. In a letter to the alumni, published November, 1935, O'Hara set before them, as he had set before the Lay Board that same month, a statement of the needs of the University. In pressing these needs, he highlighted progress made in several departments, including the following report of activities in Physics:

> Through the unselfish work of two instructors and two graduate assistants, Professors Collins and Coomes, and Messrs. Kenefake and Hiegel, the room reserved in the Cushing Engineering Hall for high tension experiments has been furnished with full equipment for a fine field of research. Because these men were unselfish enough to give their whole summer to manual labor, the equipment of this room has cost approximately 10% of what it would have

[32] Coomes Interview; the summers of 1935 and 1936 O'Hara spent principally at Notre Dame, concerning himself with planning for the future, and, in particular, planning to get benefactors to help support the new research at the University. Since he was quite concerned with the Departments, it is likely that during these summer months he found the time to visit them physically; McAvoy, O'Hara, pp. 156, 171.

> cost had commercial equipment been purchased. The University has spent about $3,000 on the equipment for this laboratory, and has expended $1,500 additional for new equipment for the closely related laboratory of Electrical Engineering.[33]

Going beyond asking those who were already friends of Notre Dame for their aid in developing the University, O'Hara approached the Carnegie Foundation for the Advancement of Teaching, hoping to elicit support for the scientific departments. Foremost in his request were the new generator with its promise of opening up research in the nuclear field and the work of Professor Arthur Reyniers with germ-free animals. In the previous year, O'Hara had asked for the Foundation's help, with emphasis on the fine arts. Though the Foundation's Board of Directors finally turned him down on October 1, 1935, they encouraged him to apply again.[34]

O'Hara did so immediately, since he was to be soon in New York, writing that he hoped to gain an audience with President Keppel. In the same letter, he specifically men-

[33] John F. O'Hara, "A Letter from the President of the University," The Notre Dame Alumnus, XIV (November, 1935), p. 39; McAvoy, O'Hara, p. 160; Presidential Papers of John F. O'Hara, C.S.C., 1935-1937, File : Board of Lay Trustees, UNDA. Hereafter the Presidential Papers are cited as O'Hara Papers.

[34] McAvoy, O'Hara, pp. 148,149. The encouragement was quite pronounced. In a letter from the Foundation's President, Frederick Keppel, to O'Hara, he puts it: "Let me add, however, that sooner or later the Board does wish to make some contribution to Notre Dame and its work, not necessarily and perhaps not probably in the arts, so that I hope you will keep us in touch with the plans and developments of the University." Keppel to O'Hara, Oct. 1, 1935, O'Hara Papers, 1934, File : Carnegie Corporation, UNDA.

tioned the generator project:

> During the summer we have equipped a new high tension laboratory, and we have the assurance of the Bureau of Standards that the room in which this is installed will make for better results than have been yet achieved in this field.[35]

Before going to New York, O'Hara asked Collins and Coomes for a descriptive account of the high voltage work to date, so that he would be prepared to plead the University's case. From the physicists' response, the status of the generator and plans for its use may be gleaned. After describing the installation physically and comparing it to only two comparable machines in the country, at the Department of Terrestrial Magnetism and at MIT, the letter continues:

> Profiting by the experience of others, we are using extremely long supporting legs and belts, and have streamlined the openings where these are admitted into the sphere. Our tests so far have indicated that such modifications will contribute to the stable operation of the generator. With negative charge on the collecting sphere, and with unfavorable humidity, 19 foot spark discharges have been obtained. Research in both physics and electrical engineering is now under way. We have plans for the construction of an accelerating tube which is to be used in problems in nuclear disintegration and high voltage x-rays in particular, we hope to investigate the disintegration of lithium by protons into helium, and the absorption coefficients of different elements for x-rays above a million volts.[36]

35 O'Hara to Keppel, October 3, 1935, O'Hara Papers, 1934, File : Carnegie Corporation, UNDA.

36 Collins and Coomes to O'Hara, October 7, 1935, O'Hara Papers, 1934, File : Carnegie Corporation, UNDA. They hoped the generator would reach 2.3 million volts, but had, as yet, had no opportunity to build measuring instruments.

O'Hara's efforts on this occasion were as fruitless as they had been the year before. He still faced the task of providing the finances for his plans of a greater Notre Dame. In the entire pre-war period, the University would be the sole support of research in nuclear physics.

The method of funding research at Notre Dame may be seen in a response of the University Comptroller to an inquirer who asked about the University's policy on gifts:

> When gifts are made to the University without any provision or restriction by the donor, these benefactions are generally put to immediate use and for the most part are applied to research at the instance of the president of the University, after consultation with the University Local Council.[37]

O'Hara's practice in these matters is indicated by the following instance, found in a letter addressed to the University Treasurer:

> The enclosed check for $500.00 is to be applied to a current expense fund for the Department of Electrical Engineering. It is possible that the designation may be changed within the week, but it will do as a tag just now.[38]

With the construction of this machine and the Administration's support in using it for research the Department of Physics was prepared to enter a new era, one in which nuclear physics was a central concern.

37 F.W. Lloyd to Leo B. Bozell, copy in Presidential Papers of J. Hugh O'Donnell, 1940-1942 Personal, File : Bo-Bq, UNDA.

38 O'Hara to Brother Engelbert, December 2, 1935, O'Hara Papers, 1935-1937, File : Treasurer, UNDA.

CHAPTER III

Any attempt to understand the growth of Notre Dame University's Physics Department between 1936 and 1940 must recognize the decision to develop the capacity to offer validly the Ph.D. degree in physics. Additions to the faculty and an allocation of resources for research in the Department fell within a master plan for the development of the Graduate School. To this end a study of the curriculum development within the period might be appended to this study. However, this growth was organic in that it flowed from the immediate needs of the Department as well. Historically, the center of those needs lay in the area of nuclear physics. By considering the men added to the faculty, their interests and their cooperation with each other, it is possible to trace the contribution of nuclear physics research to the reconstitution of the University that the Graduate School's development entailed.

At this juncture, then, the chronological sequence of events will be broken to consider two separate but integrally related sequences: additions to the faculty and the progression of research within nuclear physics. Finally, the success of nuclear research will be related to the goals of the Department and of the University.

A) Additions to the Faculty

In the 1935-1936 academic year increased burdens on the teaching staff in the Department of Physics, concom-

itant with the effort to develop the generator, indicated the need for more faculty. O'Hara, as seen above, was also anxious to improve the faculty. The unrest in Europe which caused an "intellectual migration" of those displaced by the Nazis helped him in this project. In Physics, two theoreticians of international reputation would be added, one in 1936 and one in 1937, who would ease the teaching load and benefit immeasurably the research program of George Collins as well. Additional help in the experimental area would be sought and finally obtained by adding one man in 1937 and another in 1938.

There must have been several conversations between Collins and Father O'Hara in the spring of 1936 in regard to a new man for the Physics Department. On learning that there might be a delay in appointing a new man, Collins wrote O'Hara forcefully about the teaching load in the Department:

> The department instructs about 250 students each semester in undergraduate theory courses and approximately the same number in laboratory courses. To make matters worse some of these laboratory courses are of such a nature that only eight or ten students can be handled at one time. In addition, a program of graduate courses is carried on.[1]

Collins himself was at the time the only member of the staff who devoted his full time to physics. Even Coomes, who was so vitally involved in the generator construction, was teaching in Engineering as well. Earlier in the year,

[1] Collins to O'Hara, May 12, 1936, O'Hara Papers, 1935-1937, File : Physics Department, UNDA.

O'Hara had written a young Holy Cross priest who had suggested to him possible teachers for the year to come:

> Our chief need seems to [be] in Physics, where we will have to have a man if Father Bolger does not return from California this year. You have probably heard that Mercury poisoning has delayed his work.[2]

One answer to the teacher shortage came in the person of Dr. Arthur Haas, a world-recognized theoretical physicist, who had written a score of volumes on theoretical and atomic physics. His obituary in the American Journal of Physics contains a brief summary of his major contributions:

> This genial scientist was conspicuous both in research and teaching. Among his notable achievements in the field of research was his development, in 1910, of the formula for Rydberg's constant which contained only elementary constants. This formula differs only by a numerical factor from the famous formula developed three years later by Niels Bohr; this difference was due to the fact that Haas used the Thomson atomic model then in vogue, whereas Bohr used the Rutherford model. In 1920, Professor Haas developed the theory of the isotopic effect in band spectra independently of Loomis and Dratzer, who were also developing the same theory. In later years, his interest in atomic and cosmic constants led to the discovery of relations that were used subsequently by Eddington, Jordan and others.[3]

After Hitler's rise to power, Haas had left the University of Vienna, where he had headed the Department of Physics, and became a teaching fellow at Bowdoin in 1935-

2 O'Hara to Father Howard Kenna, C.S.C., April 6, 1936, O'Hara Papers, 1936-1937, File : K-Ke, UNDA. Previously Father Kenna had been the recipient of a Master's degree in physics from the University.

3 Eugene Guth, "Arthur Erich Haas, 1884-1941," American Journal of Physics IX (1941), p. 198.

1936. He was looking for a place in the United States; George Collins was looking for help in the Physics Department; and Father O'Hara wanted to add distinguished scholars to the faculty. Haas and Collins met at an American Physical Society meeting. As a result Haas visited Notre Dame in the spring of 1936. Soon thereafter the President's office was deluged by recommendations for Haas from distinguished physicists all over the country. These letters stressed his teaching ability, grasp of modern physics and the broad range of his interests. O'Hara originally feared Haas would have no interest in a position which offered little contact with graduate students and a heavy load in undergraduate teaching as well, besides not paying a salary which was commensurate with his qualifications. However, he found Haas interested and willing. By late May his teaching load was being discussed; in June a contract was offered and accepted. Haas came to the University at a time when it was beginning to develop a major graduate program. He offered the University his very strong reputation in theoretical and atomic physics.[4]

George Collins' ideas about the needs of the De-

[4] O'Hara Papers, 1935-1936, File : Dr. Haas, UNDA; Armin Hermann, The Genesis of Quantum Theory (1899-1913), trans. Claude W. Nash (Cambridge, Ma. : The MIT Press, 1971), 87-102; A. Hermann, "Haas, Arthur Erich," Dictionary of Scientific Biography, V, C.C. Gillispie, ed. (New York : Schribner's, 1972), 609-610; Coomes Interview. It seems clear that part of the reason for hiring Haas lay in the hope that his reputation could draw other fine physicists to Notre Dame.

partment are found in the above mentioned letter to Father O'Hara:

> Mr. Coomes and I have found it impossible with the present load to do efficient research which is a matter of considerable disappointment to me in view of the possibilities of establishing the reputation of the university in the field of high voltage work. . . . As may be seen from the publicity high voltage work is receiving, this field of physics is becoming of greater and greater importance. It seems to me it would be a pity if we should lose our opportunity to be a leader in the work. Tremendous emphasis is being placed on this work at many institutions however, and I fear that delay in getting started will be a serious handicap. What is needed, if real progress is to be made, is two young full-time instructors capable of teaching advanced subjects and doing research. I wish to express my gratitude for your interest and support of the high voltage work.[5]

Collins was pushing for someone who could simultaneously help him to meet the Department's needs and to get the research program going in the laboratory. He and O'Hara had talked about a highly regarded young experimentalist who was then working with R.A. Millikan at the California Institute of Technology, measuring fundamental constants. A delay in contacting him, however, occurred in May, 1936 while O'Hara and Steiner waited until Father Burns, then Provincial, returned to the University, so that they could lay the matter before him. In response to Collins' strong letter, O'Hara was able to write him:

> With the return of Father Burns, the prospect of settling the faculty problems is much better than

[5] Collins to O'Hara, May 12, 1936, O'Hara Papers, 1935-1937, File : Physics Department, UNDA.

when I wrote you the other day.[6]

An additional complication at the time was that Father Bolger, studying at the California Institute of Technology, had been afflicted with mercury poisoning while completing his doctoral researches. If he stayed to finish more teaching help would be required for Collins. Ultimately, Bolger returned to the faculty in September, 1936 with his doctoral degree unfinished. While he was still in California, however, O'Hara wrote him asking for a personal recommendation of the young experimentalist under consideration as to whether he would fit in as a member of Notre Dame's faculty. Upon receiving a positive response as to his character, O'Hara wrote offering this man a job.[7]

The correspondence with the prospective teacher over the next year is enlightening, because O'Hara and Collins were called upon to describe the situation at Notre Dame. In the letter in which he made the job offer, O'Hara gave the reasons why the position was open:

> During the past year, Dr. Collins and Mr. Coomes have undertaken some interesting work in high voltage, but they have been handicapped in their research by their teaching load in undergraduate

[6] O'Hara to Collins, May 13, 1936, O'Hara Papers, 1935-1936, File : Coa-Com, UNDA. The consultation with Father Burns indicates the caution with which the decision to build up the faculty was approached, and the continued importance of the guidance of Father Burns as well. Later the Department would be able to guide its own destiny.

[7] O'Hara to Father Henry Bolger, C.S.C., May 25, 1936; telegram, Bolger to O'Hara, May 26, 1936, O'Hara Papers, 1935-1936, UNDA.

> physics. We want to divide this load then with some man who will be interested in the research they are doing. Since this work is not endowed, a certain amount of undergraduate teaching is required of our research professors.

Collins also wrote to him describing the Department from his point of view:

> The opportunities for research here are, I believe, unusual. The administration is both sympathetic and generous to members of the faculty who are interested in doing investigational work, and every effort is made to reduce the teaching load to the point where efficient research can be carried on. In my last three years here I have found life to be most congenial and free from supervision and petty duties.[8]

In response, while describing the research problem at Notre Dame as "interesting as well as timely", the young physicist emphasized that he wished to remain in California until his present experiment could be completed. The work was sufficiently important to be pursued to its conclusion, and he and Millikan were seeking funding so that he might continue. He wondered if Notre Dame could wait. O'Hara wrote Millikan:

> We would like to have him this year. We have engaged Dr. Arthur Haas, who is so proficient on the theoretical side of nuclear physics, and we want to fill out our practical staff for experimentation in this field.[9]

As a result of these negotiations, Father O'Hara very generously intervened with his friend, Francis Garvan,

[8] O'Hara Papers, 1935-1936, UNDA; copy of the Collins letter found in O'Hara Papers, 1935-1936, UNDA.

[9] O'Hara to Robert A. Millikan, June 15, 1936, O'Hara Papers, 1935-1936, UNDA.

of the Chemical Foundation in New York to help the young physicist get the funds he needed to finish the work in California with Millikan. After getting a positive result from this intervention, O'Hara wrote saying he would hold the job at Notre Dame until the following academic year. The return of three priests who had been absent from the University to complete studies in mathematics provided additional help with the load in Physics without forcing him to hire anyone.[10]

As the summer of 1936 came on, Notre Dame's intent was clear: O'Hara was making a major step toward bringing the Department of Physics to the point where it could offer quality graduate work and draw to itself good graduate students. The thrust of the Department's research was in nuclear physics because this field was "becoming of greater and greater importance". It was able to enter the field at relatively low cost due to the enthusiasm of its staff. But, significant publishable work was required if this goal were to be obtained. This necessitated further additions to the faculty, i.e., first class physicists who could guide the energies of the staff in fruitful directions, given the limitations implicit in the heavy teaching loads faculty members carried at Notre Dame. The locus of the recruitment was to be nuclear physics for this reason: drawn by the excitement generated by this frontier, Collins had already es-

10 Copies of these letters may be found in O'Hara Papers, UNDA.

tablished a beachhead in the area.[11]

A major figure in the Department's maturation rejoined Collins at this time. Father Henry Bolger's return to the faculty was conspicuous in its impact on the Department. Leaving the California Institute of Technology with his doctoral work unfinished, at least partly for reasons of health, Father Bolger became head of the Department in September, 1936. His dynamic leadership in this position helped to bring about continued academic progress, as he worked assiduously to provide for the needs of the Department's faculty. Because of his determination that the Department would become a source of pride such as the one he had been part of in California, he strove constantly to improve the quality of education, both undergraduate and graduate, given by the Department.

Since he was also a Holy Cross priest, Father Bolger served as a bridge between the administration and the Department in a special way that flowed from his membership in the religious community of Holy Cross. He was only one of many Holy Cross religious who shared the vision of a greater Notre Dame coming to be. One of the many intangible aspects of years of common life was revealed when the need

11 It should be remembered that although in hindsight nuclear physics was clearly a profitable area to pursue, at the time there was no assurance that a small university of extremely limited budget could successfully pursue it and contribute to the bank of knowledge then being built up concerning the nucleus. Yet, at the time there could hardly have been a more fundamentally interesting course to take.

arose of convincing the administration, also made up of Holy Cross religious, that it was important to move forward even though substantial expense would be incurred. As a department head, Father Bolger functioned as a liaison between faculty members with research programs and administrators charged with balancing the University's slim budget. His community membership aided him markedly in this role.[12]

In the summer of 1936, Edward Coomes decided to leave the University for further study. Until this time, laymen had not been allowed to take a sabbatical leave for study. While Coomes' position as an Instructor was secure at Notre Dame, he felt the importance of deepening his own knowledge of physics. During that summer, he attended the famous summer school at the University of Michigan, where he had the opportunity to hear lectures by such internationally known men as Hans Bethe, Ernest Lawrence and Enrico Fermi. In the course of the summer, he became confident of two things: that Notre Dame was headed in the right direction by pursuing experimental nuclear physics because nuclear physics was an important area of interest in which reliable experimental data were available; and that he, himself, wanted to continue to study and pursue his own research interests in electronics. In order to convince Father O'Hara that he was serious, he was willing to quit his job at the University, but once O'Hara saw Coomes' resolve, he inter-

[12] Shilts Interview; Waldman Interview.

ceded on his behalf, again with Francis Garvan in New York. The result was that the Chemical Foundation provided funds to support his graduate work. In taking such a step, Notre Dame was once more looking to the future when the health of the Department would require a faculty more deeply committed to research than previously.[13]

As the school year of 1936 opened, Arthur Haas and George Collins were teaching a formidable load of upper-level undergraduate and graduate courses, giving further evidence of the mood of expansion in the Department. Two graduate students emerged from the Department of Electrical Engineering to continue the effort to make the generator useful for doing research. These men, Richard Schager and Albert Vitter, attended the staff seminars given by Haas with the intention of catching up with current thinking about nuclear physics. Meanwhile they pushed forward in the laboratory to make the generator a functioning research tool.[14]

In his November, 1936 report to the Board of Lay Trustees, Father O'Hara emphasized the urgent need of expansion in certain departments. That Physics was one of them

13 Coomes Interview; Edward Coomes to O'Hara, Aug. 10, 1936, O'Hara Papers, 1936-1937, File : Con-Coz, UNDA; O'Hara to Coomes, Aug. 11, 1936, ibid. UNDA. Father O'Hara had also been instrumental in Coomes' matriculation at Notre Dame ten years earlier.

14 Collins to O'Hara, Oct. 19, 1936, O'Hara Papers, 1934-1935, File : Materials for President's Report to Board of Lay Trustees, UNDA.

cannot be doubted. Having been named in Father Moore's "master plan" a year and a half earlier, and already the site of commitment of University resources, it was within two years of announcing that doctoral programs in physics could be pursued at the University. Any expansion of faculty would have to consider the need for diversification of research within the Department and at the same time assist the infant program in nuclear research.[15]

Though the young experimentalist from California finally chose to work at an Eastern university, two men were added to the Department for the academic year 1937-1938 through the intercession of Arthur Haas. The better known of the two was Eugene Guth, who had taken his Ph.D. from the University of Vienna in 1928, while Haas was still there. A refugee from Europe, Guth had left his homeland so abruptly that he had to leave relatives behind. As was the case with many displaced academic personnel, he needed a position in America. The University's need corresponded to his own. Haas, having known him in Vienna, interested him in Notre Dame. This instance reveals that Notre Dame, as did many other American universities, benefited substantially by the worsening situation in Europe. Guth's record placed him in a class above that which Notre Dame's small department with its exceedingly low national profile might realistically

15 Memorandum in O'Hara Papers, 1934-1935, File : Material for President's Report to Board of Lay Trustees, UNDA.

have been expected to be able to hire. Sufficiently well thought of to be invited to write the section on quantum mechanics in the Handbuck der Physik, a major contribution to a famous encyclopedia, Guth brought with him an extensive publishing record and vital interests in many fields.[16]

The second man was a young Ph.D. recipient from Yale, Robert Anthony, whose thesis area lay within nuclear physics, and who, it was hoped, would assist the nuclear research effort. Instead, Anthony teamed with Guth to found an entirely new research area in the physics of rubber. This should be taken as a sign of the health of the Department, since this collaboration broadened the base from which it could attract students to its expanding graduate program.[17]

Though both men immediately undertook to share the teaching load, evidence of such efforts is delayed until later issues of the Notre Dame Bulletin. From these their role in curriculum modification and expansion is evident. In a similar fashion, their collaboration on the "physics of rubber" project is invisible in the records of the Department, until it bore fruit in publications. With regard to nuclear physics, however, Guth, as a theoretical consultant for the experimentalists at Notre Dame proved invaluable during the course of early development of a research program. An im-

16 Eugene Guth, Development and Foundations of Quantum Physics, Handbuck der Physik, eds. H. Geiger and K. Schmel, Bd. IV, Art. 5 (Berlin : Springer, 1929).

17 Waldman Interview; Interview with Robert Anthony.

aginative and well-read physicist, his input into the experimental research program included a vast number of suggestions. Many of these were impossible for the young research group to accomplish, but a few lay within the range of energies of which the generator was capable. To these, they could bend their imaginations and efforts. In turn, the existence of an experimental group engaged in serious pursuit of results suggested by his theory spurred the theoretician into further development of his initial ideas.[18]

In September, 1938 Edward Coomes returned to Notre Dame, having earned his D.Sc. degree from MIT. At the same time, the final faculty addition to the Department during this period came in the person of Bernard Waldman. Upon finishing his doctorate at City College of New York, he came to assist George Collins as a research associate, the first research associate Notre Dame ever had. In itself, this fact is significant, since he was not hired to teach, but to assist in the research effort. The commitment to do research in the Department was strong enough by that time that a post-doctoral position which did not involve teaching could be

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Hereafter cited as Anthony Interview. The article taken from Anthony's thesis: "Collisions of Alpha Particles with Sulphur Nuclei" was published in Phys. Rev. 50, (1936), 726-732.

18 Bulletin U.N.D. XXXIII No. 3 (Sept., 1938), XXXIV No. 3 (Sept., 1939). Evidence of the gratitude of the experimentalists for Guth's input often appears in their published work. Interview with Walter Miller. Hereafter cited as Miller Interview; Waldman Interview.

considered. Though Waldman began to teach some classes as early as the spring semester of 1939, he was not contracted at the rank of Instructor until 1940.[19]

It is instructive to contrast the physics faculty in 1938 with that of five years earlier. In September, 1933 George Collins had come, as virtually its first Ph.D., to a Department in which the primary orientation was one of service. He joined three faculty members and two graduate assistants, whose backgrounds were in Electrical Engineering and whose courses were in Math. Of these five men, there was only one whose primary work lay in physics: the Department's head, Daniel Hull. His highest degree was an M.S. from Notre Dame itself. None of these men was still associated with the Department in 1938 except Edward Coomes, who was just returning from MIT with his doctoral degree. At that time, in addition to Father Bolger, who as Department head was the driving force in the Department's rapid growth, the faculty was made up of six men, all with degrees at the doctoral level, two with distinguished publishing records.

Other changes clearly manifest the Department's growth as well. The Department possessed an electrostatic generator used for research as well as incipient research groups in electronics, rubber physics and theoretical physics.

[19] Waldman Interview; Bulletin U.N.D. XXXIV No. 3 (Sept., 1939), XXXV No. 3 (Sept. 1940). The beginning of Waldman's tenure is listed as 1940 in later Bulletins in recognition of this distinction.

The September, 1938 Bulletin announced the possibility of doctoral studies in physics for the first time:

> The Department of Physics offers courses leading to the degrees of master of science and doctor of philosophy. Courses leading to the master's degree are given regularly, and courses required for the doctor's degree are provided as needed. In addition to laboratories equipped for general research problems, special equipment is available for work in the field of high energy electrons. Adequate reference material for research in theoretical physics is available in the department library.

The program of doctoral studies was made more concrete the following year.[20]

One further event which demonstrated the progress of these years was the Symposium on the Physics of the Universe and the Nature of Primordial Particles. Organized by Dr. Haas and others at the University, this Symposium took place May 2-3, 1938. Attendants came from across the nation and included two Nobel prize winners. In addition to lectures given by Guth and Haas of the Department, Notre Dame was represented by one lecture delivered by Canon Georges Lemaître, the originator of the theory of the expanding universe, who was a visiting professor for one semester at the University. That Notre Dame could serve as host for some of the outstanding scientists of the country, including Arthur N. Compton of Chicago, Harlow Shapley of Harvard and Carl D. Anderson of California, was a signal of the Depart-

[20] Bulletin U.N.D. XXXIII No. 3 (Sept., 1938), p. 353.

ment's enormous growth.[21]

The curriculum in physics had been completely transformed both for undergraduates and for the graduate students who were beginning to come. One of the clearest indicators of the new philosophy of the Department emerged after the first doctoral students were already at Notre Dame. In December, 1940 a special number of the Bulletin featured the Department of Physics. The following statement is concise as to the thinking which had prompted the development of the Department.

> In order that the student may get the most and the best from his training in the field of physics, it is necessary that he come in contact not only with good teachers of the science but also with men who are actively engaged in productive research. To this purpose the effective teacher of physics must be devoted not only to the science but to worthwhile research no less. The instructor who is intensely interested in the progress of physics and in the contributions that can be made to this progress naturally inspires more interest and enthusiasm than the teacher who is merely a good pedagogue.[22]

B) Research in Nuclear Physics

Turning from the addition of faculty and the generator development of the Department, it is helpful to consider work specifically in the area of nuclear physics. In June of 1936, Collins wrote O'Hara a brief statement of de-

21 Eugene Guth, Arthur E. Haas, George B. Collins, "Notre Dame Symposium on the Physics of the Universe and the Nature of Primordial Particles," Science 87 (May 27, 1938) 487-490; "Annual Report of the Department of Physics 1937-1938." O'Hara Papers, 1937-1938, File : Report to Board of Lay Trustees, UNDA; McAvoy, O'Hara, p. 181.

22 Bulletin U.N.D. XXXV No. 4 (Dec., 1940), pp. 11-12.

velopments in the Physics Department over the previous year. O'Hara incorporated the substance of this letter into his address to the Alumni at Commencement. The statement is full of the optimistic spirit with which work was proceeding and the contagion produced by nuclear physics at that time. The latter was by no means confined to Notre Dame, for the field was on the very frontier of the physics of the thirties. In taking up nuclear physics, the University was stepping to the forefront of the research of the day. The following paragraph describes Notre Dame's resources and plans at this juncture.

> An electrostatic generator, consisting essentially of a twelve foot copper ball, has been constructed in the high voltage laboratory of the Engineering Building. It is capable of producing potentials greater than one and a half million volts. In conjunction with this generator a glass tube 9 inches in diameter and twenty four feet long has been set up and evacuated to one ten millionth of an atmosphere. With this equipment research in nuclear physics is to be started soon. In particular production and study of the newly discovered positive electron is planned.[23]

Additional equipment was required, however, before experimentation could begin. During 1936-1937 this work was to be accomplished and investigations initiated. The above mentioned graduate students, Richard Schager and Albert Vitter, contributed to this effort. The machine with accelerat-

[23] Collins to O'Hara, June 4, 1936, O'Hara Papers, 1935-1937, File : Physics Department, UNDA. Rev. John F. O'Hara, C.S.C. '11, "President of University Outlines N. D. Progress," The Notre Dame Alumnus XIV (June, 1936), pp. 259-260, 274.

ing tube added is pictured in Figure 3.[24]

In July of 1936, Dr. Collins wrote the President submitting a list of periodicals which were necessary for the library of the Department. This, of course, was another important step in putting the men of the Department into a position in which they could keep up with current progress in nuclear physics. O'Hara's positive response to this request signaled a decisive move from the relatively isolated status which had previously been allowed at the University.[25]

The September 1936 Bulletin was the first to make mention of the budding research in nuclear physics.

> The High Tension Electrical laboratory, in the College of Engineering, is designed for theoretical and practical research at potentials above a million volts. The room is cubical, forty feet on the edge. Installed in it is an electrostatic generator, having a 12-foot spherical anode. This generator is at present being set up for work in atomic disintegration.[26]

Though the prestige of the young Physics Department had been materially advanced by the addition of Arthur Haas to its faculty, it was imperative that it succeed in its experimental efforts if it was to draw graduate students from beyond the University. To achieve this goal, in turn, re-

[24] Richard J. Schager, "An Accelerating Tube for Two Million Volt Electrons," (unpublished Master's thesis, University of Notre Dame, 1937). The picture is from Schager's thesis.

[25] Collins to O'Hara, July 6, 1936, O'Hara Papers, 1935-1937, File : Physics Department; O'Hara to Collins, July 8, 1936, ibid. UNDA.

[26] Bulletin U.N.D. XXXI No. 3 (Sept., 1936), p. 48.

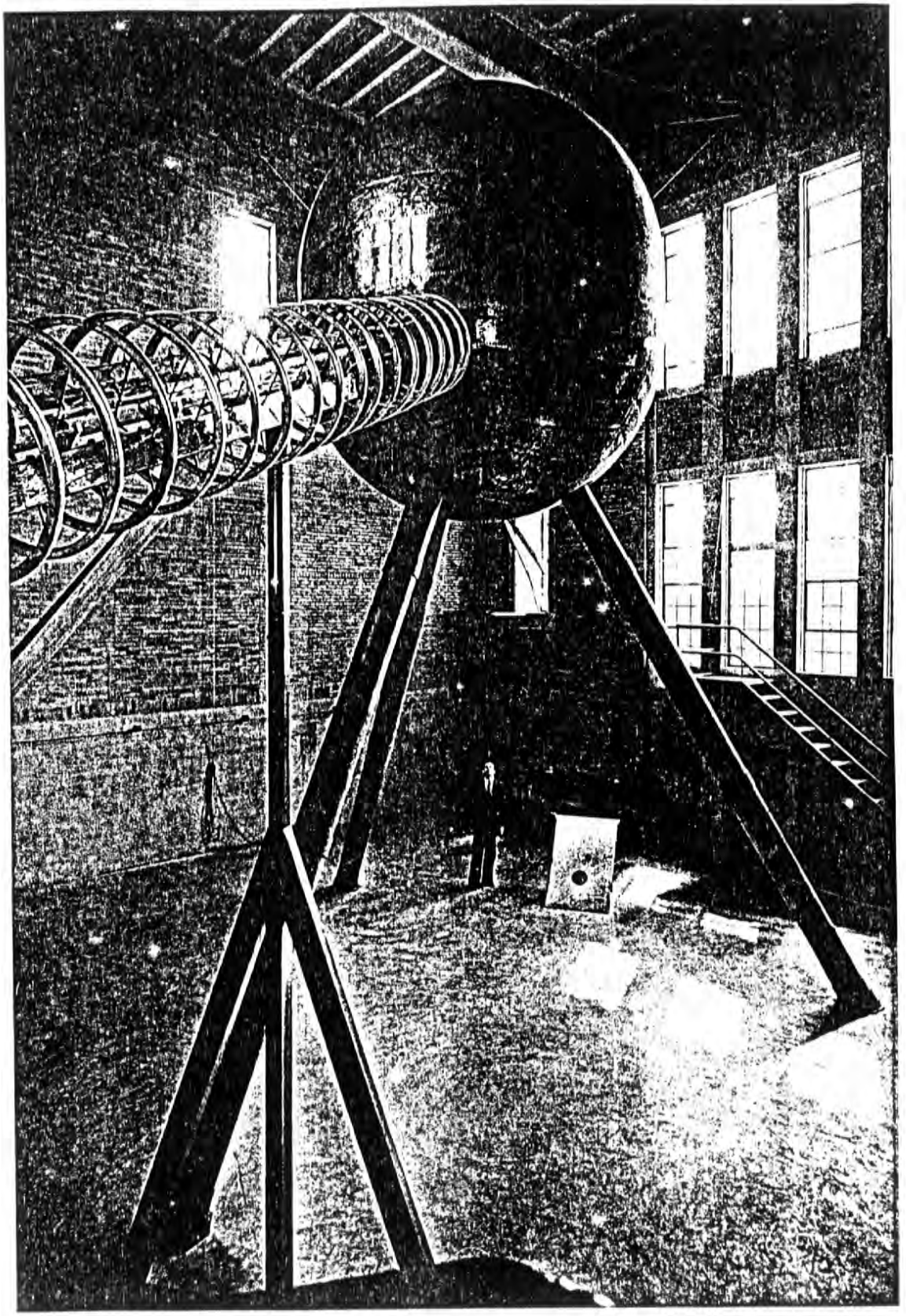

FIG. 3. ACCELERATING TUBE FOR THE ELECTROSTATIC GENERATOR

Source: Richard Schager's Thesis, following page iv.

quired an increase of available manpower in the high voltage lab, both in faculty and graduate students. With the addition of faculty and experimental success, graduate students could be expected to seek out Notre Dame for their own education.

As the Notre Dame generator neared completion with the development of an accelerating tube it was decided that this machine would accelerate electrons. All the other existing Van de Graaff-type generator labs were accelerating protons in an attempt to investigate light nuclei and to produce nuclear reactions utilizing the relatively low energy particles they could produce. The reasons for the Notre Dame group's choice of electrons were twofold: 1) the opportunity to do something not being done by the other labs; and 2) the relative ease of making an electron source. To have tried to produce a positive ion source would have taxed the limited resources of the Department still further. Thus, for the first experimental work done on the machine the nuclear group planned to study the interaction of high energy electrons with matter. Their original intention was to use electrons from the new generator to make high energy x-rays, which would interact with matter to produce positrons, if the x-ray energy was sufficiently high. The acceleration of electrons had remained a trademark of the Notre Dame accelerator labs through the years.[27]

27 Waldman Interview; Coomes Interview; Albert Vitter,

Apparently early plans were not completely solidified, however. In a letter of May 13, 1937 to the President requesting summer jobs for two graduate students, Collins wrote: "The high voltage generator and accessories are now in working condition, and I am very anxious to start work on the very important problem of scattering of electrons by electrons and neutrons."[28]

As the year drew on, and as experimental difficulties with the control of the generator's voltage were overcome, the weaknesses of the open-air generating system became evident. South Bend's humid climate made it difficult to reach the voltages required for the research. Already in the spring of 1937, George Collins was thinking of building a pressurized generator even while he pursued research on the open-air machine. Realizing, however, the enormous cost in time and energy as well as monetary expense in starting again, he saw how important it was to produce some results with the equipment at hand. One of the fruits of the increasing contact of Notre Dame physicists with the wider physics community was evident in a note to Father O'Hara which Collins penned that spring upon returning from the American Physical Society meeting in Washington:

The research which I have considered doing with

"The Interaction of High Energy Electrons with Matter." (unpublished Master's thesis, University of Notre Dame, 1937.)

28 Collins to O'Hara, May 13, 1937, O'Hara Papers, 1935-1937, File : Physics Department, UNDA.

> our present generator has very recently assumed considerable importance and in view of this I felt it would be better if no energy or time were diverted from bringing these problems to a conclusion as soon as possible. . . . I was also advised by Dr. Tuve of the Carnegie Institution and Dr. Wells of the Westinghouse Corporation to wait six months until they had their generators up, so that we could profit by their experience and perhaps thus avoid some costly mistakes.[29]

The following September Notre Dame added to the faculty the heretofore mentioned Eugene Guth who would aid tremendously in the research program in nuclear physics. While the presence of Haas, a theorist, was a great aid to the Department in answering research problems of a theoretical nature, what it really needed was someone who could direct the energies of the experimental group into fruitful areas. In this period close cooperation between theorist and experimentalist was a requisite, as many of the experimental problems of nuclear physics were challenging puzzles yet to be defined.

Guth's name is mentioned in connection with virtually all the work accomplished on the generator after his arrival. Though the results of this experimental work were published in the Physical Review, as will be noted, a more complete summary is provided by consideration of the Master's theses completed by students who used this generator. The titles of these theses are presented in Table 2. The interrelation of theory and experiment emerges upon further con-

[29] Collins to O'Hara, May 13, 1937, O'Hara Papers, 1935-1937, File : Physics Department, UNDA.

TABLE 2

Master's Theses Completed on the Open-Air Generator*§

Hiegel, Alfred J.	"The Construction and Operation of A High-Voltage Belt-type Electrostatic Generator" (June, 1936)
Kenefake, Edwin A.	"An Electrostatic Generating Voltmeter" (June, 1936)
Schager, Richard J.	"An Accelerating Tube for Two Million Volt Electrons" (June, 1937)
Vitter, Albert L.	"The Interaction of High Energy Electrons with Matter" (June, 1937)
Petrauskas, Alexander A.	"Results of the Bombardment of Beryllium with Electrons" (June, 1938)
Reiling, Victor G.	"Cerenkov Radiation" (June, 1938)
Polye, William R.	"The Electrodisintegration of Beryllium" (Aug., 1939)
Stubblefield, Edward M.	"The Nuclear Excitation of Indium by X-rays" (Aug., 1939)
Allaire, Royal P.	"The Scattering of High-Velocity Electrons by Thin Foils" (June, 1940)
Feldmeier, Joseph R.	"Pair Production by Electrons" (June, 1940)

*All of these theses were directed by George B. Collins.

§(Source: The Bulletin of the University of Notre Dame XXXI-XXXVI (1936-1941).

sideration of this work.

One of Guth's suggestions led to the first published work of the nuclear research group at Notre Dame. The subject was Čerenkov radiation, a newly discovered physical process for the production of light. Stimulated by the announcement of the Russian scientist, Čerenkov, that it was possible to cause light radiation when electrons entered a material in which the speed of light was less than the velocity of the electrons, the Notre Dame group used its electron accelerator to investigate the phenomenon. The result was the first quantitative verification of the "theoretical relationship which expresses the direction of emission of light produced when very fast electrons pass through matter". Under Collins' direction, the work was undertaken by Victor Reiling, who, with a B.S. in Electrical Engineering from the University of Dayton, was the first physics graduate student to be drawn from outside the Electrical Engineering Department at Notre Dame. This first practical use of the accelerator, coming some three years after the decision was made to go ahead with a generator, was extremely gratifying. The first paper to be published was a sign of the emergence of the Department into the wider world of physics.[30]

30 A. Čerenkov, Phys. Rev. 52 (1937), 378-379; George B. Collins and Victor G. Reiling, "Asymetric Radiation Produced by High Velocity Electrons," Phys. Rev. 53 (1938), 205 and "Cerenkov Radiation," Phys. Rev. 53 (1938), 948; George B. Collins and Victor G. Reiling, "Cerenkov Radiation," Phys. Rev. 54 (1938), 499-503. The paper concludes with the statement: "The authors are indebted to Dr. E. Guth for many

The time lapse in the completion of this work was actually not long. Begun in the fall of 1937, the paper was not submitted until July 29, 1938. The date of publication was October 1, 1938. An indication is thereby given that it was only in the summers that time could be found to ready the results of experimental work for publication. For the most part, during the academic year, time was so limited that tasks such as paper writing had to be put off until the summer months.

Further evidence of Guth's contributions is found in Father Bolger's report to the President for the 1937-1938 year. The direct effect on experimental efforts was substantial:

> Calculations were made on the interaction of high energy electrons with matter. Based on the results, it was suggested to disintegrate beryllium with the electron beam of the Notre Dame electrostatic generator of Dr. Collins and collaborators, which would mean a new effect hitherto unobserved. Preliminary experiments are contained in the thesis of Mr. Petrauskas, June, 1938. Further experiments are now in progress. Suggestions were made in connection with experiments on pair production and radiation using electrons.[31]

By the fall of 1938, when Bernard Waldman joined the staff, publishable results had already been obtained through the cooperation of theorist and experimentalist.

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helpful suggestions and discussions while the work was in progress."

[31] Annual Report of the Department of Physics 1937-1938 (signed Henry J. Bolger, C.S.C.), O'Hara Papers, 1937-1938, File : Report to Board of Lay Trustees, UNDA.

Though annoyed by the limitations of the open-air machine, George Collins had sufficient work to pursue with it. As has been seen, the Department was coming together around the effort and was now ready to take on broader interests. A picture of Notre Dame's accomplishment is found in Father O'Hara's report to the Lay Trustees in November, 1938:

> The reorganization of the Department of Physics, which began three years ago, is now approaching completion. With the return of Professor Coomes, who was given a two-years leave of absence to take a doctorate at the Massachusetts Institute of Technology, the University has set up a well-equipped television laboratory. Professor Collins and his staff have amplified the facilities for x-ray and vacuum tube study, and have worked with Dr. Coomes in the installation of a system of laboratory workshops. The University has spent upwards of thirty thousand dollars in the reorganization of these facilities, and in the purchase of new equipment.[32]

The research problems which next occupied the nuclear group involved the attempt to disintegrate a nucleus with electrons. Working on a suggestion by Dr. Guth and with his calculations for the problem, they wished to establish experimentally that "A disintegration of ionization of a nucleus by fast electrons can occur provided the energy of the electrons exceeds the binding energy of one of the constituents of the nucleus." The possibility of electrodisintegration occurred to Guth by analogy with photodisintegration, in which x-rays of sufficiently high energy had been used for the same purpose. Initially, the group was thwarted

32 Report of the President of the University to the Members of the Board of Lay Trustees, Nov. 11, 1938, O'Hara Papers, 1937-1938, File : Board of Lay Trustees, UNDA.

because the energy calibration for the electrons erroneously led them to believe they were above the threshhold for electrodisintegration of beryllium, the nucleus Guth calculated to have the lowest threshhold. In fact, they were still below threshhold, and after correcting the calibration, they had to wait for winter's drier climate to get the energy of the machine high enough. In December they succeeded in producing the first example of a disintegration of a nucleus with electrons. The close cooperation of theoretical and experimental physicists had once more led to a significant result.[33]

Another problem which was the subject of research at Notre Dame that winter of 1938 was suggested by a visitor from the University of Illinois, Maurice Goldhaber. He and a graduate student had been able to excite a stable nucleus to a metastable state having a short but measurable lifetime, and suggested that this could also be accomplished with x-rays. In this process, the nucleus absorbs an x-ray, bringing it to an excited state. De-exciting by gamma ray decay, it may possibly land in a metastable state, i.e., an excited state which has a lifetime long enough so as to be observable. Eventually it decays to the ground state by gamma

[33] George B. Collins, Bernard Waldman and William R. Poyle, "Electrodisintegration of Beryllium," Phys. Rev. 55 (1939), 412; Eugene Guth, "Theory of Electrodisintegration of Beryllium," Phys, Rev. 55 (1939), 411; G.B. Collins, B. Waldman and W. Poyle, "Electrodisintegration of Beryllium," Phys. Rev. 55 (1939), 1122; Waldman Interview; George B. Collins, Bernard Waldman and Eugene Guth, "Disintegration of

radiation. In effect, the process produces artificial radioactivity without conversion of the nucleus to one of a different atomic number, as would occur with alpha or beta emission from a nucleus.

This study of metastable states was initiated with Indium 115 and led to another 1939 paper after experimental success in the winter of 1938-1939. In turn, it suggested further research on metastable states of other isotopes. This continued to be a fruitful field of research for some years.[34]

Further exploration with the open-air machine made possible an additional investigation. Having shown that the disintegration of beryllium by electrons was possible, the group reached the conclusion that it should be possible to excite with electrons the metastable states of nuclei. Concern for this problem, the energy distribution of continuous x-rays and the possibility of pair production by electrons

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Beryllium by Electrons," Phys. Rev. 56 (1939), 876-880.

34 Waldman Interview. Bernard Waldman, Edward M. Stubblefield and M. Goldhaber, "Nuclear Excitation of Indium by X-rays," Phys. Rev. 55 (1939), 507 (letter, dated Feb. 15, 1939); Bernard Waldman, G.B. Collins, E.M. Stubblefield and M. Goldhaber, "Nuclear Excitation of Indium by X-rays," Phys. Rev. 55 (1939), 1129; B. Waldman and George B. Collins, "Nuclear Excitation of Lead by X-rays," Phys. Rev. 57 (1940), 338. The method of study was turned to advantage in later years by Marcellus Wiedenbeck, one of the early Ph.D. students in nuclear physics. "The Spectroscopy of Some Heavy Nuclei," (Unpublished Master's thesis, University of Notre Dame, 1942); "Nuclear Excitation of Indium by X-rays and Electrons," (Unpublished doctoral dissertation, University of Notre Dame, 1945).

occupied the interest of the experimental group for the remaining time of operation of the generator. In addition, Guth continued to explore the interaction of high energy electrons with matter and the excitation of nuclei by x-rays theoretically.[35]

After these successes, which marked the debut of a Department of Physics vitally engaged in research, Collins and Bolger were ready to push for the construction of an accelerator which could be used year round and provide more energetic electrons. Patterned after Dr. Raymond Herb's machines at Wisconsin, it would be horizontal and pressurized so that the humidity of its atmosphere could be controlled to prevent sparking. Backed by the positive results obtained in nuclear physics and fortified by the hope for growing respect which would follow further contributions to the growing field of nuclear physics, the Department approached Father O'Hara in the spring of 1939 for funds to go ahead with the construction. It was imperative that the University back the nascent research group's effort in order that it could compete with progressive departments in other univer-

35 George B. Collins and Bernard Waldman, "Nuclear Excitation of Indium by Electrons," Phys. Rev. 57 (1940), 1088; Eugene Guth, "Interaction of Electrons with Nuclei," Phys. Rev. 57 (1940), 349; J.R. Feldmeier and George B. Collins, "Pair Production by Electrons," Phys. Rev. 58 (1940), 200; George B. Collins and Bernard Waldman, "Energy Distribution of Continuous X-rays," Phys. Rev. 59 (1941), 109; Eugene Guth, "On the Excitation of Nuclei by X-rays," Phys. Rev. 59 (1941), 107; J.R. Feldmeier and George B. Collins, "Excitation of Nuclei by X-rays," Phys. Rev. 59 (1941), 937.

sities. Though Father O'Hara's sympathies lay with the advance a new accelerator would mean, money was still a difficult problem for the President. He agreed to provide the funds, which comprised a tremendous sum in 1939 dollars, though naturally the men of the Department would again supply an enormous amount of labor, the cost of which would never appear in any Treasurer's ledger.[36]

This approach was entirely within the style of pre-World War II physics, and was, indeed, a given for the enthusiastic young men at Notre Dame. An addition was planned for the back of the Science Building, and construction was completed during the summer of 1940. With the task of the accelerator's construction in addition to their teaching loads, the Physics faculty awaited the new machine's completion before they could again undertake significant new research.[37]

36 Waldman Interview; "New Generator Produces 8,000,000 Volts," Scholastic 74 (Sept. 20, 1940), p. 19; McAvoy, O'Hara, p. 178. As seen above, Collins was considering this project as early as the spring of 1937! On May 13 of that year he began a letter to Father O'Hara: "As a result of my visit to the Physical Society in Washington it seems desirable to postpone plans for the construction of the high pressure electrostatic generator which was being considered. . . . The project has great and permanent possibilities, however, and I do not wish to suggest that the idea of erecting this apparatus be abandoned." The remainder of this letter has already been quoted in another connection. Collins to O'Hara, May 13, 1937, O'Hara Papers, 1935-1937, File : Physics Department, UNDA.

37 Bulletin, U.N.D. XXXV No. 4 (Dec., 1940), pp. 14-18; Waldman Interview. The new accelerator was not in operation until 1942, by which time the war entailed much altered plans for use.

In the interim, however, the Department was much more broadly developed than when the first accelerator was built four years earlier. It boasted ten graduate students, some of whom were in doctoral studies. Haas continued to be productive until he suffered a heart attack after delivering a paper at an American Physical Society regional meeting in Chicago on November 23, 1940. Guth remained as prolific as ever and graduate students joined him to bolster the theoretical contributions. Research was continuing in electronics under Coomes and in the physics of rubber under Guth and Anthony. These groups would continue to grow and contribute during the hiatus in the nuclear group's productivity forced by the construction.[38]

C) Contributions of the Work in Nuclear Physics to the Goals of the University

The sense of accomplishment which emerged from this work in nuclear physics is clearly revealed by Father Bolger in a July, 1939 letter to Father O'Hara. Enclosing some correspondence in reference to the research work done in the Physics Department, he wrote:

> It is very gratifying and encouraging to us to know that scientists at other institutions, both educational and industrial, are aware of and in-

38 Bulletin U.N.D. XXXV No. 4 (Dec., 1940), pp. 16-22, 25-26; Scholastic 74 (Feb. 21, 1941), 10. Hospitalized in Chicago, Dr. Haas did not die until Feb. 20, 1941. Contributions of research groups other than the nuclear group appear in Appendix II.

> terested in the work we are trying to do here. All with whom we have come in contact have praised the progress we have made. It has always been my opinion that good work will be recognized no matter where it is done, and letters such as these are a strong indication of the proof of my opinion.[39]

It is difficult to isolate totally the work in nuclear physics from the remainder of the research done after September, 1938. Guth, in particular, while contributing to progress with the electron accelerator by his theoretical input, was constantly active in other fields. Moreover, it was extremely important that the Department develop a diversity in research interests. This did occur, but nuclear physics played the central role in the emergence of graduate programs, in the outside world's awareness of physics at Notre Dame, and, hence, in the development of the Graduate School and the University as far as the Department was concerned.

During the period of research with the vertical generator, roughly 1937-1940, four of the seven members of the faculty and eight of eleven graduate students participated under the direction of George Collins. The activities of the Department at this time were at the frontiers of the research pursued anywhere in the world in the same time period. An early demonstration of Cerenkov radiation, the first disintegration of a nucleus by electrons and significant work on metastable levels in nuclei comprised the pub-

[39] Bolger to O'Hara, July 19, 1939, O'Hara Papers, 1938-1939, File : Bl-Bz, UNDA.

lications during these years. The research activities had helped to give birth to the fledgling Ph.D. program which had its first fruits with five degrees conferred in 1942. In many ways this was the most exciting and fundamentally interesting period in the history of the Department. Not only did the Department contribute to physics, but it carried a significant part of the burden in the University's change from a primarily undergraduate institution to one with a strong and healthy graduate school. Its successes could be pointed to as an affirmation of the value of graduate programs at Notre Dame, viz., the undergraduate program was strengthened remarkably by the growth of the faculty and its new philosophy regarding the role of the scholar-educator. The published work helped make the University known in the academic community. In this sense, it was a superb example of adaptation for the realization of the vision of a greater Notre Dame, which harkened back to John Zahm.

CHAPTER IV

At the time of the United States' involvement in the second World War, a critical juncture had been reached in the development of research activities. While Notre Dame's financial support of the research effort had been enthusiastic, her resources were limited. In a pamphlet addressed to the alumni, J. Hugh O'Donnell, C.S.C., who had replaced Father O'Hara as President, expressed it thus:

> In the absence of endowment, Notre Dame, with the aid of a few benefactors, has been financing the program of graduate study out of operating income. In these circumstances, the school may be conducted on the present scale, but, without additional aid from outside sources, it cannot grow -- neither can provision be made for a number of other studies that should be taught at Notre Dame.[1]

The war was to interrupt any plans the Physics Department had for the growth of its research effort, even if O'Donnell had been able to secure the funds. With the war came a change in the structure of supported research in the physical sciences which had nationwide ramifications. At Notre Dame, the pressurized accelerator, when completed, was turned to the uses suggested for it by the Manhattan Project through its University of Chicago Metallurgical Laboratory center. For the most part, this meant use as a high intensity x-ray source so that the effects of intense radiation on materials could be studied. Such use aided materially

1 J. Hugh O'Donnell, "Do You Remember?" (letter to the Alumni, dated Sept. 14, 1941). Issued as a pamphlet, p. 6.

in construction of the Hanford reactor, but almost all projected work was postponed, to be picked up after the war.

Although some of the faculty and graduate students remained at Notre Dame for a good part of the war to aid in the enormous work of instruction that came to the University because of its Navy programs, the key faculty in nuclear physics were scattered. Even before the United States entered the war, Dr. Collins was called to the Massachusetts Institute of Technology to work on defense projects. Though Dr. Waldman remained for some time to operate the accelerator for the Metallurgical Lab, he, too, joined the Manhattan Project, first in Chicago and then at Los Alamos in March, 1943. Whereas Waldman returned in the fall of 1945 to pick up research where it had been left off, Collins at the war's conclusion assumed a position as head of the Department of Physics at the University of Rochester. Many other things would be different after the war, too, but the nature of the Department had been established.[2]

The focus of this study has been the interaction of the general intent of the University to grow toward greatness and the enthusiasm for growth felt by the men interested in nuclear physics within one department of that University. The desire to do research on the part of those

[2] B. Herzog, "Professor George Collins Leaves for Defense Work," Scholastic 74 (Feb. 21, 1941), 21; "Sessler, Waldman Leave for War Work," Scholastic 78 (Mar. 19, 1943), 12; Waldman Interview; Miller Interview.

individuals exerted a pressure on an administration which was willing, and even anxious, to allow growth in that direction. One final key ingredient was the presence of a leader whose role was to apply effectively that pressure. Thus, three men, in particular, emerge as central figures: Fathers John O'Hara and Henry Bolger and Dr. George Collins.

The summer of 1936 was a pivotal period for the Department of Physics. The events of that summer placed it on a course destined to bring it to maturity within the University. Decisions which were made that summer looked toward an expansion and a permanent investment of the Department's personnel in research. Work on the generator had made possible future investigations of the nucleus, which would become the center of research activity in the Department before the war, and, in large measure, establish the reputation it would enjoy in the years immediately after the war's conclusion.

Clearly, however, the decision to do research and to add faculty members to the Department was not made trivially. A consideration of the background of this decision reveals how much the situation of the University had changed in the years of O'Hara's presidency. Those years had produced a climate of growth in which the enthusiasm of men like Collins could prosper. Father Bolger's goal of a truly modern department, linked with the thrust of Father Moore's more general plan of growth to excellence, made the Physics

Department a natural choice for expansion. The financial burdens for such a move, given the University's structure, lay squarely on Father O'Hara's shoulders. Yet, it must be emphasized, this decision was an extension of a prior determination regarding the role of a research-oriented graduate school in the University's future.

APPENDIX I

Publications in the Physical Review Concerning Nuclear Physics Authored by Members of the Department of Physics at the University of Notre Dame, 1938-1942

George B. Collins and Victor G. Reiling, "Asymetric Radiation Produced by High Velocity Electrons" 53 (1938) 205. Abstract from the Chicago meeting of the American Physical Society (APS), November 26-27, 1937.

George Collins and Victor G. Reiling, "Čerenkov Radiation" 53 (1938) 948. Abstract from the Washington meeting of the APS, April 28-30, 1938.

George B. Collins and Victor G. Reiling, "Čerenkov Radiation" 54 (1938) 499-503. Received July 29, 1938; issue dated Oct. 1, 1938.

B. Waldman (at CCNY) et al. "Location of Resonances in Boron Plus Proton Reactions" 54 (1938) 543. Letter dated Sept. 9, 1938; issue dated Oct. 1, 1938.

B. Waldman (at Notre Dame) et al. "Resonance Porcesses in the Disintegration of Boron by Protons" 54 (1938) 1017-1020. Received Oct. 17, 1938; issue dated Dec. 15, 1938.

George B. Collins, Bernard Waldman and William R. Polye, "Electrodisintegration of Beryllium" 55 (1939) 412. Letter dated Feb. 1, 1939; issue dated Feb. 15, 1939.

Eugene Guth, "Theory of Electrodisintegration of Beryllium" 55 (1939) 411. Letter dated Feb. 1, 1939; issue dated Feb. 15, 1939.

George B. Collins, Bernard Waldman, Edward M. Stubblefield and M. Goldhaber, "Nuclear Excitation of Indium by X-rays" 55 (1939) 507. Letter dated Feb. 15, 1939; issue dated Mar. 1, 1939.

G. B. Collins, B. Waldman and W. Polye, "Electrodisintegration of Beryllium" 55 (1939) 1123. Abstract from the Washington meeting of the APS, April 27-29, 1939.

B. Waldman, G.B. Collins, E.M. Stubblefield and M. Goldhaber, "Nuclear Excitation of Indium by X-rays" 55 (1939) 1129. Abstract from the Washington meeting of the APS, April 27-29, 1939.

George B. Collins, Bernard Waldman and Eugene Guth, "Disintegration of Beryllium by Electrons" 56 (1939) 876-880. Received Aug. 18, 1939; issue dated Nov. 1, 1939.

E. Guth, "Interaction of Electrons With Nuclei" 57 (1940) 349. Abstract from Columbus meeting of the APS, Dec. 28-30, 1939.

Bernard Waldman and George B. Collins, "Nuclear Excitation of Lead by X-rays" 57 (1940) 338. Letter dated Jan. 30, 1940; issue dated Feb. 15, 1940.

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The Notre Dame Alumnus. This was the organ of communication of the University with the Alumni group.

The Notre Dame Scholastic. This was Notre Dame's weekly student news magazine. Some information appears only in news items. Other information occurs in formal articles, some of which are signed and some are not. Of the articles, the following may be cited:

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Robert L. Anthony

Edward A. Coomes

Walter C. Miller

Walter L. Shilts

Bernard Waldman

Oral interviews with these men yielded not only specific points of information but also much general background on the Department of Physics. In addition, the sense of the times which emerged in these interviews aided significantly in interpreting manuscript materials.

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