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THE NIELS BOHR INSTITUTE AS AN INTERNATIONAL CENTRE OF PHYSICS

by

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(The views expressed by the author do not necessarily
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The Niels Bohr Institute as an International Centre of Physics

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The creation of his Institute for Theoretical Physics was one of Niels Bohr's most remarkable achievements, and its role as an international centre of scientific activity is an enduring tribute to its founder. In this centenary year of Bohr's birth, it is fitting to survey the history and the accomplishments of what has been known through most of its existence as The Niels Bohr Institute.[1]

The Beginnings

In 1916, at the young age of 31, Bohr was appointed to a chair of theoretical physics, specially created for him, at the University of Copenhagen. The University did not, however, have a physics laboratory of its own, and Bohr (and other professors of science) taught and did their research at the Polyteknisk Laeranstalt (the Technical University) which was the sister institution to the University; it had been founded in 1829 by Hans Christian Oersted.

Even at the Laeranstalt the facilities were extremely limited. Bohr himself had only one small room, which he had to share with his assistant (at that time H. A. Kramers), and there was no laboratory available for doing experimental work related to his own research interests. There were only two other professors of physics in Denmark at this time: Peter Prytz and Martin Knudsen, both classical physicists. J. Rud Nielsen, who became a graduate student at the University at about that time, recalls Knudsen's lack of sympathy for Bohr's ideas. Nielsen was helping Knudsen to write a textbook, and when he tried to indicate places where the new concepts in atomic physics were called for, Knudsen's response was: "If we have to use quantum theory to explain this, we may as well not explain it!"[2]

It became clear, especially to Bohr, but also to Knudsen, that a major expansion of facilities was necessary if physics in Denmark was to grow and flourish. Knudsen's solution was to

build additional laboratories at the Laeranstalt. However, in 1916 the Laeranstalt had introduced its own doctorate degree, and this foreshadowed a loosening of the ties between the Laeranstalt and the University. Bohr, therefore, proposed that the University should establish its own institute for theoretical physics, and in April, 1917 he submitted a detailed proposal for its creation.

Bohr's proposal took the form of a letter addressed to the Faculty of Science and Mathematics. Despite its proposed name, Bohr from the outset envisaged that the institute should contain experimental facilities.* To quote from Bohr's letter:

> "...the institute must also...offer the possibility for carrying out numerical calculations of a scientific nature and the related experimental investigations... This is closely related to the fact that through the great discoveries in physics around the turn of the century, hitherto unsuspected ways have opened to form concrete conceptions on the inner structure of matter... While previously one supposed for apparently good reasons that we possessed with the so-called classical mechanics and electrodynamics an indisputably secure basis for our scientific conceptions, and that one could therefore to a large degree undertake the mathematical calculation of physical problems without a direct connection to experiment, at present this circumstance has decidedly changed... In the elaboration of the theories referred to, one is faced at each moment with having one or another consequence of the theory tested experimentally, before the choice between the various possibilities can be made..."

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* In Denmark at that time (as also in Germany, though not in Britain) the phrase "theoretical physics" was understood to mean what we would now call fundamental physics, whether theoretical or experimental.

Bohr's specific plans envisaged a modest building with two main floors, plus a basement and an attic, totalling about 350 m^2 of floor space, and containing living quarters for the Professor of Theoretical Physics and for a resident mechanic, in addition to the basic requirements of work rooms, laboratories, an auditorium and a library.

The proposals were promptly supported by the University, but their implementation required approval by Parliament after a specific site had been identified and agreed upon. The Municipality of Copenhagen finally agreed to sell a suitable plot of land in Faelled Park, about 2 km north of the city centre, alongside the road named Blegdamsvej ("Bleaching-ground Road") after the linen bleachers who had practised their trade in this area centuries previously, and excavations began just as World War I was ending.

Postwar turmoil delayed the actual construction of the building, and its cost rose to more than three times Bohr's original estimate. An official opening, with Rutherford as guest of honour, had been planned for September, 1920. Rutherford came, but the Institute itself was not ready. Finally, however, in January, 1921, Bohr was able to begin working in his new office. The official inauguration of the institute took place on March 3 of that year. The Rector of the University (the famous philologist Otto Jespersen), in declaring the Institute open, said to Bohr: "You have known to gather around you both native and foreign researchers and have thus, in the most beautiful way, resumed the international work which was severed during the World War." In his own inaugural address as Director of the Institute, Bohr emphasized its importance as a centre of education, where young scientists could be brought into the mainstream of productive research. Even he, however, could hardly have guessed how spectacularly his ambitions in this regard were to be realized.

The Institute's First Years

The establishment of the Institute could scarcely have come at a more propitious time. That it came into existence at all

was, of course, a tribute not only to Bohr's foresight and immense energy, but also, even more, to his professional stature as the man who had transformed the theory of atomic structure. That theory had burst upon the world in the year immediately preceding the beginning of World War I, but then most of the younger physicists of Europe were swept into military service or, if they were lucky, into war-related research. Many of them, as we know, never came back. Within the warring countries themselves, the opportunities for pursuing basic physics research had shrunk almost to zero, and Germany, in particular, came out of the war almost crippled in this respect.

The creation of the new Institute in Denmark, a country that had retained its neutrality, was like a beacon of hope to physicists the world over. Arnold Sommerfeld, who despite the adversities of war had managed to continue to work on the extensions of Bohr's atomic theory, had written eloquently on this theme in a letter he wrote in 1919:

> "The war burdens and unbearable peace terms have made scientific efforts in Germany impossible for a long time to come... Together with Germany, almost the whole European continent has become impoverished. But happy Denmark can step into the breach here. Denmark will enjoy doing this the more as such an act would honour the name of one of its most outstanding sons. The Institute of Mr. Bohr should not only serve the up-and-coming generation of Denmark, it will also be an international place of work for foreign talent whose own countries are no longer in a position to make available the golden freedom of scientific work. Just as in the past at the Vienna Institute of Radium Research, future researchers of all countries should meet one another in Copenhagen for special studies and to pursue common cultural ideals at the Bohr Institute of atomic physics"

The timing of the establishment of the Institute had another aspect that almost certainly could not have been fore-

seen. The passions generated by the war did not subside with the armistice in November, 1918. Scientists coming from Germany and her former allies became the object of hostility and ostracism. Even Einstein, that least nationalistic of scientists, had been unsure of his reception when, as late as 1921, he came to London to lecture about relativity. (In the event, all went well and the visit was a significant contribution to the re-establishment of good relations between Britain and Germany.) The general feelings of hostility, however, even took official form. The Solvay Committee excluded physicists from Germany and the other Central Powers from the Solvay Conferences of 1921 and 1924. Germany was also excluded from most other international organizations, in particular the International Research Council, founded in 1919. And the International Union of Pure and Applied Physics, although established (in 1922) under a charter "to encourage and aid international coperation in the field of physics," failed to include physicists from Germany, Austria or Hungary. It was only after 1926, when Germany joined the League of Nations, that this situation was rectified.

Such attitudes were anathema to Bohr, and in the circumstances the opening of his institute had an even greater importance for the development of science as a coperative enterprise, blind to considerations of race or nationality. Some years later he commented: "...the formation after the war of a scientific body [the International Research Council] that was not truly international always appeared to me to be a most fatal blunder in the management of human affairs..." By contrast, the international character of the Institute was immediately established. Bohr persuaded James Franck, just appointed as Professor of Experimental Physics in Göttingen, to come to Copenhagen for the first few months. Hendrik Kramers, from the Netherlands, and George de Hevesy from Hungary were already there, as was Oskar Klein from Sweden. A powerful source of support in this regard was the Rask-Oersted Foundation (named after the Danes Rasmus Rask, a philologist, and Hans Christian Oersted, both of whom did their major work in the early part of the 19th century). The Foundation, established by Act of

Parliament in October, 1919, had among its main purposes the support of scientists from other countries by giving them grants for research in Denmark, and the sponsorship of international conferences. This magnanimous programme was a direct expression of Denmark's desire, as a country that had escaped the ravages of war, to do all it could to restore and promote international cooperation in science. Thirteen of the 63 foreign scientists who were to work for extended periods at the Institute during its first ten years came there as Rask-Oersted fellows.

Progress at the Institute was inevitably slow at first, as in any research facility just getting under way. But, in addition to the theoretical activity, centred in Kramers, Klein, the Norwegian Sven Rosseland, and of course Bohr himself, the necessary steps were taken to initiate an active experimental programme. James Franck set up equipment, similar to that used in the famous Franck-Hertz experiment, for the study of electron-atom collisions, George de Hevesy established a chemical laboratory, and two Danes, H. M. Hansen and J. C. Jacobsen, devoted much effort to setting up laboratories in the all-important field of spectroscopy, both optical and X-ray.

Nothing could have more dramatically vindicated Bohr's insistence on the partnership of theoretical with experimental activity than the discovery in 1922, at his institute, of the element hafnium. Ever since the creation of his model of the hydrogen atom, Bohr had been working on the extension of the theory to heavier atoms. In the process he developed a theoretical scheme for the electron configurations in all the atoms in the Periodic Table, including those for the then "missing" elements of atomic numbers 43, 61, 72, 75, 85 and 87. In particular, interest focused on element 72, which Bohr decided must be chemically similar to zirconium. Not long after he reached this conclusion, there joined the Institute (as a Rask-Oersted fellow) the young Dutchman Dirk Coster, who had just been learning the techniques of X-ray spectroscopy from Manne Siegbahn in Lund, Sweden. Joining forces with George de Hevesy, who was a master of delicate chemical separations, Coster was

able to demonstrate that element 72, identified through its X-ray signature, did indeed have the properties predicted by Bohr. The discovery of the new element, christened hafnium after the ancient Latin name for Copenhagen, came just in time for Bohr to announce it at his Nobel Prize lecture in Stockholm in December, 1922. It was a stirring demonstration of the fruits of international co-operation in science.

On the heels of this triumph, in the autumn of 1923, Bohr made his first visit to the United States, and during a stay in New York he met with officials of the Rockefeller International Education Board. The result was a $40,000 grant to help pay for an extension of the premises of the Institute. Additional rooms became available for long-term visitors, whose numbers had risen from five in 1921 to ten in 1923, and were to rise further. The International Education Board also helped this expansion by funding a programme of fellowships for study abroad. The Bohr Institute was not the only beneficiary, but the programme brought fifteen outstanding young physicists from seven different countries to Copenhagen between 1924 and 1930. Thus the international character of the Institute was still further reinforced.

The Institute's Golden Age

It was, however, with the birth of the new formulations of quantum theory around 1925-1926 that the Bohr Institute really came into its own. The groundwork had been laid when first Wolfgang Pauli, in 1922-1923, and then Werner Heisenberg, in 1924-1925, each spent the best part of a year working at the Institute. These two brilliant physicists had both studied under Arnold Sommerfeld in Munich and then served as assistants to Max Born in Göttingen; they were also close friends. Bohr had met them both on the occasion of the "Bohrfestspiele" in Göttingen in 1922, and each of the three made essential contributions to the formulation of the new quantum theory, even though Heisenberg, as the creator of matrix mechanics, was properly recognized by the other two, and by the world at large, as the central figure.

Although it was in Göttingen, in 1925, that Heisenberg completed his historic first paper on the subject, it was at Bohr's institute that the implications of the new theory were most

vigorously debated and its consequences explored. Erwin Schrödinger, who in 1926 published his seemingly quite different wave-mechanical approach to atomic dynamics, was invited to the Institute by Bohr, there to engage in a round of exhaustive and exhausting discussions with Bohr and Heisenberg. And then, between about 1927 and 1933, Copenhagen became what has often been described as a Mecca for the theoretical physicists of the new age. Almost all those who subsequently became world leaders in this field are in the list of those who, under Bohr, created the Copenhagen School of physics. By present standards of the profession they were not numerous -- in 1927, the peak year of this phase, the number of long-term visitors to the Institute was only 24 -- but the quality was incomparable.

The role of the Institute as a world centre of physics was further strengthened when, in 1929, Bohr initiated a series of annual conferences on theoretical physics. He himself continued to be the dominant figure; his own publications during this period were not numerous, but his deep insight and his burning concern with all fundamental ideas acted as a magnet for other physicists to come to Copenhagen.

At about the end of this period, as the quantum theory of atoms and molecules was moving into its maturity, Bohr and the Institute as a whole found new sources of interest and activity in the fields of nuclear physics and biological physics. The latter had, in fact, been a part of the Institute's agenda since the earliest days, for George de Hevesy, as long ago as 1923, had been the world pioneer in using radioactive elements as tracers in biological systems. In 1934 Bohr was able to persuade the Rockefeller Foundation to provide fresh funds for research in this area, and even, on this basis, to obtain approval and financial support for construction of a cyclotron -- whose value in addition for pure nuclear physics research he had certainly not overlooked!

It was in nuclear physics, in fact, that the Bohr Institute enjoyed its other great surge of activity during the 1930's. Rutherford's discovery of the atomic nucleus in 1911 had, of course, provided the real beginning to Bohr's own scientific

career, and he came back into nuclear physics in 1928, when the application of quantum mechanics to nuclear reactions and nuclear structure began to make headway. The change of direction brought to the Institute a new crop of outstanding young physicists -- both theoretical and experimental -- and once again Copenhagen provided world leadership, this time in developing new concepts in nuclear dynamics culminating, in 1939, in fundamental experimental and theoretical studies of the completely unexpected phenomenon of nuclear fission. But these topics are too well known to need further discussion.

A Dark Decade

Already, in 1933, life at the Niels Bohr Institute began to be influenced by the political upheavals in Germany. Adolf Hitler had come to power in January of that year, and Jewish scientists began losing their jobs and in other ways falling victim to discrimination. Over the next few years, of course, their situation became progressively more dangerous and desperate.

Bohr lost no time in addressing this problem. In October, 1933, he himself joined the executive board of the newly formed Danish Committee for the Support of Refugee Intellectual Workers. He also took prompt steps to make the Institute a temporary haven for refugees. In addition to being a centre of physics, it now became a centre for expatriate physicists. Bohr worked closely with the Rockefeller Foundation, which, as well as taking over the International Education Board's fellowship programme, had set up an emergency programme for academic refugees. The new programme aimed at establishing positions for distinguished senior scientists. Bohr was able to draw on both programmes, and one consequence was that he was able to bring both James Franck and George de Hevesy back to the Institute in 1934. Franck moved on to the United States in 1935, but Hevesy stayed until 1942, when he made a perilous escape to Sweden.

Denmark itself had been invaded in April, 1940, and from then on was under Nazi domination. The Institute, however, continued to operate, though with a reduced staff and, of course, without any new foreign visitors. Finally, in September, 1943, Bohr was warned that he himself was about to be arrested by the

Germans, and he made his escape to Sweden and then, almost immediately after, to Britain and the United States.

For two months, at the end of 1943, the Institute itself was occupied by German troops. It was handed back to the Danes in February, 1944. However, its rebirth had to wait until the end of the war, when at the end of August, 1945, Bohr himself was able to return to Denmark and resume his role as Director, just a few weeks before his sixtieth birthday. The Institute, happily, had suffered no physical harm during the occupation, and was ready to go to work once again.

The Institute after World War II

It was probably not in the nature of things that the Institute should resume the full character that it had known in the 1930's. Bohr himself came back filled with his own concerns about the future use of nuclear energy and the urgent need for international cooperation in this sphere. In any case, he was now an elder statesman of physics; the various demands on him almost precluded his close involvement in current research. Nevertheless, his intense curiosity about what was new in physics was unabated, and the Institute quickly began to be once again a place of pilgrimage for foreign scholars. The Rask-Oersted fellowship programme was reactivated, and in March, 1946, the Institute celebrated its 25th anniversary.

Continuing the trend set just before the war, the Institute's interests (reflecting Bohr's own) were focused on nuclear and particle physics. However, it had to be recognized that in the meantime the requirements, in terms of machines and equipment, for frontier experimental research in these areas had increased drastically, and a modest establishment such as the Institute would have to pick its projects carefully. Since the main interest of the Institute had been in theory, however, this was not a crippling conclusion. Recognizing the new shape of things, Bohr threw himself into the planning for a new international centre for experimental research, which in due course (in 1953) became established as CERN, in Geneva. But he also played an important role in creating the Nordic Institute for Theoretical Atomic Physics (NORDITA), which was founded in 1957 and stands

next to the Niels Bohr Institute; it has become a leading international centre for nuclear structure research.

The Institute itself, under Bohr's direction, resumed its annual conferences and its tradition of complete internationality. After the Cold War began in 1950, the first paper published jointly by an American and a Russian physicist came from the Institute, which also pioneered postwar collaborations involving American, Soviet and Chinese scientists.

In November, 1962, Niels Bohr died, but his Institute lives on as an embodiment of his commitment to the idea of the essential internationality of science. As he himself put it over sixty years ago, at a time when the scars of World War I were still not fully healed:

> "The advances which have been made in recent years... have depended on the closest collaboration of a large number of scientists from different nations. Their contributions are bound together as links on a chain to such a degree that, for any single researcher, it is hardly possible to speak of his independent contribution. Just in these years, when so much has thrown the sharpest light upon differences in human traditions and sympathies, anyone who has had occasion to participate in this work will have received a strong impression of the universal character of science." [3]

We must hope that the tradition he set will never be allowed to fade since, more than ever, our world needs the vision to transcend national divisions and boundaries, not only in science but in all its dealings.

Notes and References

1. This paper draws extensively on information contained in Peter Robertson, The Early Years: The Niels Bohr Institute 1921-1930 (Copenhagen: Akademisk Forlag, 1979.) Other valuable sources have been S. Rozental, ed., Niels Bohr: His Life and Work as Seen by His Friends and Colleagues (Amsterdam: North-Holland, 1967), and Finn Aaserud, "Niels Bohr as Fund Raiser," Phys. Today, Oct. 1985, pp. 38-46.

2. J. Rud Nielsen, "Memories of Niels Bohr," Phys. Today, Oct. 1963, pp. 23-30.

3. Niels Bohr, Speech upon receiving the H. C. Oersted Medal, Copenhagen, 1924.