CHAPTER 4.1

Birthplace of a new physics – the early history of the Niels Bohr Institute

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Abstract

The foundation in 1921 of the Niels Bohr Institute in Copenhagen was to prove an important event in the birth of modern physics. From its modest beginnings as a small three-storey building and a handful of physicists, the Institute underwent a rapid expansion over the following years. Under Bohr's leadership, the Institute provided the principal centre for the emergence of quantum mechanics and a new understanding of Nature at the atomic level. Over sixty physicists from 17 countries came to collaborate with the Danish physicists at the Institute during its first decade. The Bohr Institute was the first truly international centre in physics and, indeed, one of the first in any area of science. The Institute provided a striking demonstration of the value of international cooperation in science and it inspired the later development of similar centres elsewhere in Europe and the United States. In this article I will discuss the origins and early development of the Institute and examine the reasons why it became such an important centre in the development of modern physics.

Key words: Niels Bohr Institute; development of quantum mechanics; international cooperation in science.

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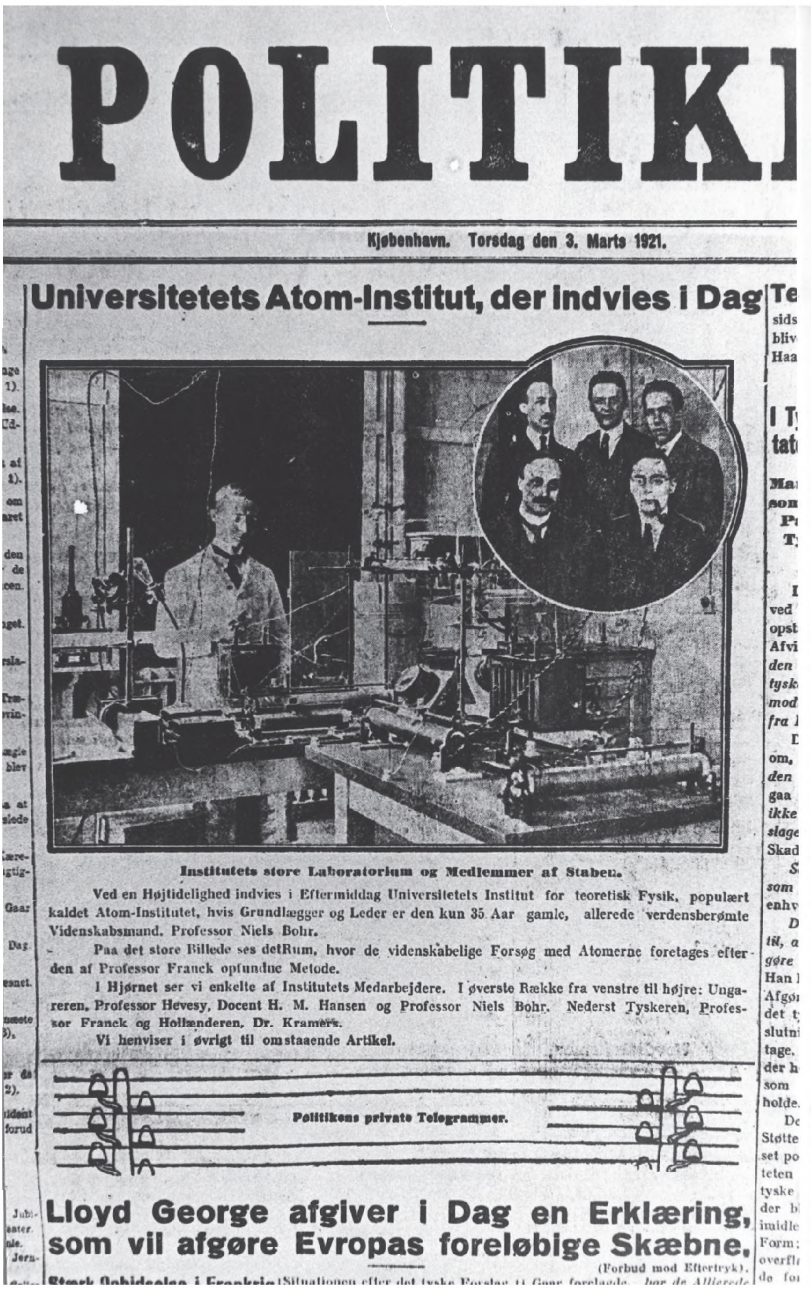
1. Planning and construction of the Institute

In 1916 Niels Bohr returned home to Copenhagen over four years since his first visit to Cambridge, England, and two years after a second visit to Manchester, working in the group led by Ernest Rutherford. Bohr had been appointed as the inaugural Professor of Theoretical Physics at the University of Copenhagen, largely on the basis of his trilogy of papers "On the constitution of atoms and molecules" published in 1913. At this time the university's physics department was located in its sister institution, known as the Polyteknisk Læreanstalt (or Technical University), and this is where Bohr worked for the next four years.

By modern standards the facilities for physics were in a very primitive state. Bohr had one small room which he shared with his assistant, Hendrik Kramers, a Dutchman who had arrived in 1916 to work with Bohr. Even worse, there was no laboratory or equipment to carry out experimental work. In 1917 Bohr began planning a new physics institute where both theoretical and experimental studies on atomic physics could be carried out. He managed to persuade the University authorities to put 200,000 kr (kroner) towards the project, while a wealthy group of family friends and businessmen privately raised a further 80,000 kr to help fund the new building and its equipment.

With enough funds to proceed, the next question to be settled was the location of the new institute. Initially Bohr wanted to build the institute next door to the Polyteknisk Læreanstalt, but the botany department of the University of Copenhagen refused to give up land within the botanic gardens. Instead the City of Copenhagen (known as the Kommune) decided to sell a strip of land in Fælledparken, bordering Blegdamsvej, to the north of the city. The University was able to buy a parcel of land as the site for the new institute. Excavations on the foundations were underway at the time of the Armistice in November 1918 and the expectations were that the building would be completed in late 1919. There were, however, unforeseen problems. At the end of the war there was a critical shortage of building materials, as well as industrial unrest that saw frequent strikes by tradesmen working on the building.



POLITIKEN

Kjøbenhavn. Torsdag den 3. Marts 1921.

Universitetets Atom-Institut, der indvies i Dag

Institutets store Laboratorium og Medlemmer af Staben.

Ved en Højtidelighed indvies i Eftermiddag Universitetets Institut for teoretisk Fysik, populært kaldet Atom-Institutet, hvis Grundlægger og Leder er den kun 35 Aar gamle, allerede verdensberømte Videnskabsmand, Professor Niels Bohr.

Paa det store Billede ses detRum, hvor de videnskabelige Forsøg med Atomerne foretages efter den af Professor Franck opfundne Metode.

I Hjørnet ser vi enkelte af Institutets Medarbejdere. I øverste Række fra venstre til højre: Ungareren, Professor Hevesy, Docent H. M. Hansen og Professor Niels Bohr. Nederst Tyskeren, Professor Franck og Hollænderen, Dr. Kramers.

Vi henviser i øvrigt til omstaaende Artikel.

Politikens private Telegrammer.

Lloyd George afgiver i Dag en Erklæring, som vil afgøre Evropas foreløbige Skæbne.

(Forbud mod Eftertryk).

Figure 1. "The University's Atom Institute is inaugurated today," as reported in *Politiken* on the morning of the inauguration. The physicist J. C. Jacobsen is shown in one of the basement laboratory rooms. Source: *Politiken*.

Figure 2. The Institut for Teoretisk Fysik was inaugurated on 3 March 1921. The top two floors formed the residence of the Bohr family, while the ground and basement floors contained offices, a lecture theatre, a library, laboratory rooms and a workshop.

Even worse was the severe inflation of the krone that led to a cost blowout. The delays and the funding problems meant that, rather than 12 months, the construction took nearly two and a half years to complete. One casualty of the delay was that Bohr was forced to cancel plans for Ernest Rutherford to perform the official opening of the building.[1]

The "Institut for Teoretisk Fysik" was eventually inaugurated in March 1921, an event considered important enough to be reported on the front page of Copenhagen's newspaper *Politiken* (Figure 1). It is worth noting two aspects of the new institute (Figure 2):

- The building was in fact only "half" a physics institute. It was common practice at the time for Danish professors to live onsite. The top two floors were the home of Bohr, Margrethe and their children, including a guest room and a self-contained apartment for their maid. The ground floor consisted of offices, a library

1. See Robertson (1979) for a detailed account of the planning and construction of the Institute; see also Moore (1966), Chapter 6; Pais (1991), Chapter 9.

and a lecture theatre, while the basement consisted of laboratory rooms and a workshop.

- It is useful to clarify the word "Teoretisk" in the title. At this time the word had a different meaning from the current usage of "theoretical" which is meant to be the opposite of "experimental." With its basement laboratories, quite clearly the Institute was set up to do experimental work in atomic physics. The word at this time really meant "fundamental," to distinguish itself from more practical work in applied physics. Thus, today the appropriate title would probably be the "Institute for Fundamental Physics."

2. Growth and expansion of the Institute

A year after the opening of the Institute, Bohr's career received another boost, one of the highest order. In November 1922 the Swedish Academy announced that he had been awarded the Nobel Prize for Physics "for his services in the investigation of the structure of atoms and of the radiation emanating from them." The award of

Figure 3. The first staff photograph [standing from left]: J. C. Jacobsen, Svein Rosseland (Norway), George de Hevesy (Hungary), Hans M. Hansen, Niels Bohr and [sitting] James Franck (Germany), Hendrik Kramers (Netherlands) and Betty Schulz.

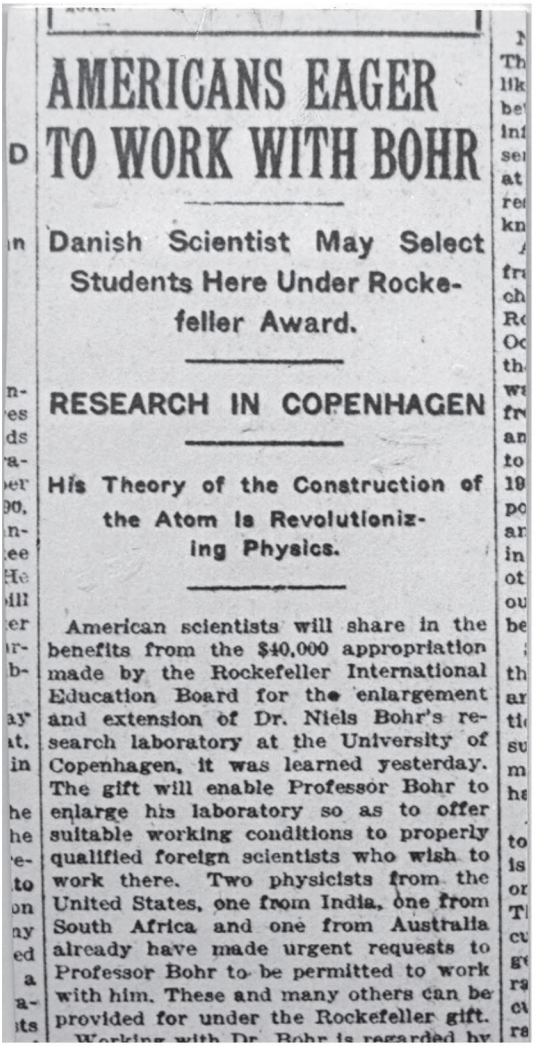
course meant that the Institute became an even more attractive centre for young researchers wanting to work at the cutting edge of atomic physics.

The Institute grew rapidly during the early 1920s. Although the number of permanent university staff remained unchanged at five (Figure 3), the number of international visitors grew from five in 1921, to nine in 1922, ten in 1923, and about 15 were expected in 1924. As mentioned above, with the office space limited to the ground floor and parts of the basement, the Institute was starting to burst at the seams. It was clear that the Institute needed to expand, but where would the funding come from? At the time the government was slashing public spending in an attempt to solve Denmark's serious economic problems. It was highly unlikely that new public funds would be provided for an institute completed only a few years earlier.

At this time Bohr travelled internationally and built up a network of physicists in other countries. As one example, in June 1922 he delivered a series of lectures on atomic theory in Göttingen. He met Werner Heisenberg for the first time, beginning a collaboration that would be of central importance to the foundation of quantum mechanics three years later. In June 1923 he made one of several trips to England, usually to visit his former mentor Ernest Rutherford, who had moved from Manchester to become head of the famous Cavendish Laboratory in Cambridge. After this visit Bohr sailed to the United States where he made a lecture tour up and down the east coast (Figure 4).

During a visit to New York, Bohr was advised by a Danish colleague to make contact with the International Education Board, a new funding body that had been established earlier in the year. The Board was part of the Rockefeller empire of philanthropy (which included the prestigious Rockefeller Foundation) and its charter was the "promotion and advancement of education" in countries outside the United States. Bohr arranged a meeting with Wickliffe Rose, president of the Board, and explained the difficulties he faced in finding funds within Denmark to finance an expansion of the Institute. The meeting obviously went well, as a short time later the International Education Board announced a grant of $US40,000

Figure 4. With eldest son Christian at the central railway station in Copenhagen. Bohr sailed to the United States where he conducted a lecture tour on the east coast during the summer of 1923.



AMERICANS EAGER TO WORK WITH BOHR

Danish Scientist May Select Students Here Under Rockefeller Award.

RESEARCH IN COPENHAGEN

His Theory of the Constraction of the Atom Is Revolutionizing Physics.

American scientists will share in the benefits from the $40,000 appropriation made by the Rockefeller International Education Board for the enlargement and extension of Dr. Niels Bohr's research laboratory at the University of Copenhagen, it was learned yesterday. The gift will enable Professor Bohr to enlarge his laboratory so as to offer suitable working conditions to properly qualified foreign scientists who wish to work there. Two physicists from the United States, one from India, one from South Africa and one from Australia already have made urgent requests to Professor Bohr to be permitted to work with him. These and many others can be provided for under the Rockefeller gift.

Figure 5. A report of the grant made by the International Education Board appeared in the *New York Times* on 27 January 1924. Source: *NY Times*.

(approximately 250,000 kr) to fund a substantial expansion, almost as much as the cost of the original building (Figure 5).

Similar to the first building, there were unforeseen problems and delays in the construction of the new buildings. Inflation continued to be a problem and there were several industrial disputes, including a general strike that lasted several months. The inevitable cost increase was covered by two grants from the Danish Carlsberg Foundation. The construction was finally completed late in 1926,

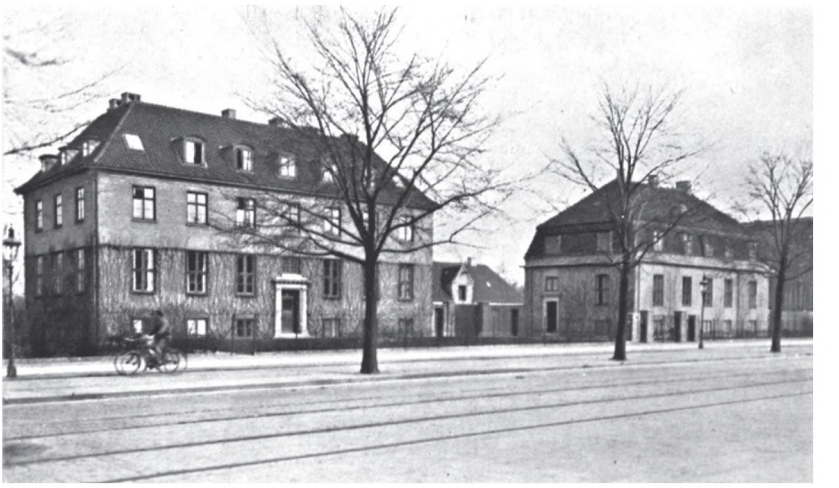


Figure 6. The Institute after the completion of the extension in 1926. To the right is the new residential villa for the Bohr family. Part of the new laboratory and workshop building can be seen between the villa and the original building.

with the addition of two new buildings and the conversion of parts of the original building (Figure 6):

- A building, known as the Villa, became the new residence for the Bohr family, which by then included five sons
- A single-storey building to the rear of the original building housed a new set of laboratories and a workshop
- The original building could now be used to accommodate the growing number of international visitors, with more than a doubling of floor space available for offices and work areas.[2]

3. Quantum mechanics: Why Copenhagen and not elsewhere?

Here it will not be possible to give even a brief overview of the birth of quantum mechanics during the years 1925 to 1927, a revolutionary development that has been extensively researched and present-

2. For the further expansion and development of the Institute in the 1930s see Aaserud (1990).

ed in numerous publications. It is, however, well worth noting that at some stage many of the principal players came to work with Bohr. The Institute became the most important centre in a story that involved a significant number of people from a number of different countries. It is interesting to ask why Copenhagen became the principal centre for this revolution in modern physics. Why wasn't it Max Born and his group in Göttingen or Arnold Sommerfeld's group in Munich? Why wasn't it Rutherford's group in Cambridge, which at the time boasted the greatest concentration of physics talent anywhere in the world?

There are arguably two main reasons. In my view the first reason is the 'big picture' or what might be called the broad geo-political situation in the 1920s. It is important to note that Denmark, and indeed Scandinavia, had been neutral during the First World War. At the end of the war England, France and their allies set out to isolate and punish Germany and the Central Powers. For example, when the League of Nations was established at the end of the war, Germany and her allies were excluded. Germany was not invited to join until 1926 and the other Central Powers had to wait even longer.

The same policy of exclusion and punishment occurred on a scientific level. After the war English and French scientists formed the International Research Council (the forerunner of the International Council of Scientific Unions) and excluded Germany and the other Central Powers from any of its activities. Many of the scientific organisations established by the IRC during the early 1920s followed a similar policy. As one example, the International Union of Pure and Applied Physics, founded in 1922 with a charter "to encourage and aid international cooperation in the field of physics," hypocritically excluded physicists from Germany, Austria and Hungary.

As a result, there was very little interaction between physicists from these two postwar blocks of countries. Very few journals were exchanged, they did not attend the same conferences and there was very little contact on a personal level. But here Denmark was ideally placed, not just geographically and politically, but also scientifically. The Institute could provide a neutral meeting ground where physicists from both blocks could freely interact. In fact, the Institute was the only physics centre during the early 1920s where there

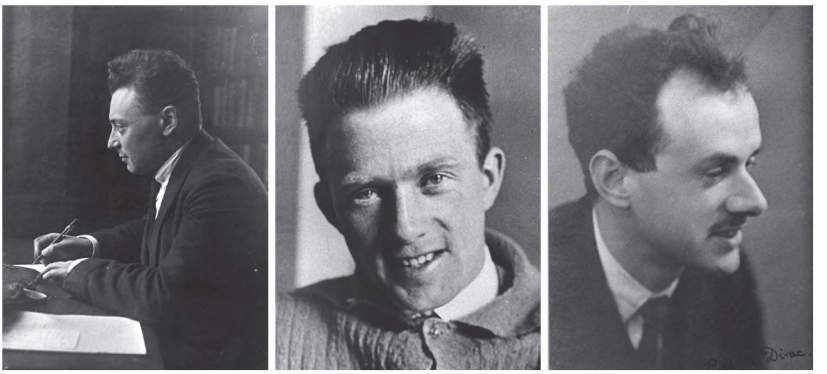


Figure 7. Three of the principal figures in the foundation of quantum mechanics: Wolfgang Pauli (Austria), Werner Heisenberg (Germany) and Paul Dirac (England). All three were frequent visitors to the Institute.

was any significant interaction between physicists from the English and German blocks (Figure 7).

In my view, the second main reason why Copenhagen became the centre for quantum theory was Bohr himself. As well as his native Danish, Bohr grew up learning both German and English. He was also the product of the Danish educational system, which was very similar to the German system and which placed a strong emphasis on formal or theoretical learning. Thus, Bohr understood very well the German approach to physics. At the same time, Bohr had spent several years in England and learnt the Anglo-Saxon approach to physics, which was more pragmatic and less formal than in Germany. It is probably no accident that Germany produced theoretical giants such as Max Planck and Albert Einstein, while England produced experimentalists of the calibre of J. J. Thomson and Rutherford. Bohr understood both these approaches to physics and was in a position to combine them into his own unique approach to physics.

Perhaps the most important reason why the Institute became the focal point for quantum theory was Bohr's personal view on international cooperation in science. In his non-scientific writings, particularly later in life, he returned to this topic time and time again. He believed that science would progress most effectively, most rapidly, by encouraging international cooperation, by bringing togeth-

er scientists with different backgrounds and different approaches to science. Bohr also believed that international cooperation would help to break down the barriers and prejudices between countries, the type of barriers that had led to the dreadful carnage of the Great War. Einstein was another who was widely applauded for promoting international cooperation in science, but with Bohr we can see that the Institute was the place where he was able put his thoughts into action, his ideas into practice.

4. An overview of the decade

To conclude I will take a brief overview of the Institute during the period 1921-1930. Over the decade there were 63 visiting scientists from 17 different countries, which made the Institute the first truly international centre for physics: USA 14; Germany 10; Japan 7; Netherlands 6; UK 6; Norway 4; Sweden 4; USSR 3; Austria, Belgium, Canada, China, Hungary, India, Poland, Romania and Switzerland 1.

Perhaps the only rival as an international centre was the Cavendish Laboratory in Cambridge, which also had a high proportion of physicists from overseas. However, the majority of these visitors were from countries within the British Empire, such as Australia, Canada and South Africa, and so there was not the same diversity of countries (or cultures) as represented by the visitors to Copenhagen. I should add that all of the 63 visitors were scientists who spent a minimum of one month at the Institute. Many of them spent much longer than a month, some spent more than a year, and some made multiple visits. There were many more who spent less than a month at the Institute and who are not included in the 63 (Figure 8).

The great majority of visitors to the Institute were funded by some form of post-doctoral fellowship. Fourteen different sources of funding have been identified. The most common were the International Education Board fellowships, which funded 15 of the 63 scientists. Thus, not only did the IEB fund the expansion of the Institute in the mid 1920s (see Section 2), it also provided financial support for more visiting scientists than any other source of funding. It is worth noting that the IEB also played a similar role in Göttingen,

Figure 8. Five of the international visitors to the Institute in 1925: [back] David Dennison (USA), Ralph de L. Kronig (Netherlands) and Bidhubishan Ray (India); [front] Yoshio Nishina (Japan) and Walter Kuhn (Switzerland). Source: Dennison family.

funding a new physics institute and providing fellowships to physicists visiting Max Born and his group.

The other main funding body was the Rask-Ørsted Foundation, named after two famous Danish scientists, Rasmus Rask (1787-1832), recognised as the founder of comparative philology, and the physicist Hans Christian Ørsted (1777-1851). The foundation was funded by the Danish government and had been set up immediately after the war specifically to support foreign scientists visiting Denmark. The foundation supported 13 of the visiting scientists. Most of the other visitors were funded by their home countries; for example, five Japanese visitors were supported by the University of Tokyo Scholarship program.

It is interesting to look at the publications produced by the Institute over the decade. In 1931 Erik Rasmussen, a physicist on the Institute's staff, carried out a survey that counted 273 publications, where at least one author on each publication gave the Institute as their home address.[3] There was a fairly even spread

3. Rasmussen (1931). For a discussion see Robertson (1979), p. 159.

between theoretical (55%) and experimental (40%) papers, with a further 5% classed as review papers. It is also interesting to note that the two most popular journals were the leading German journal *Zeitschrift für Physik*, with 79 publications, and the leading British journal *Nature* with 38. This is another illustration of how the Institute helped to build a bridge between English physics and German physics during the postwar 1920s.

A further and particularly interesting statistic is the number of those 63 visiting scientists who went on to have distinguished careers back in their home countries, and who went on to win the ultimate prize. Ten of the 63 visitors later became Nobel Laureates, seven in physics and three in chemistry. Again, the Cavendish Laboratory in the 1920s was the only other centre in world physics to attract such a rich galaxy of talent.

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