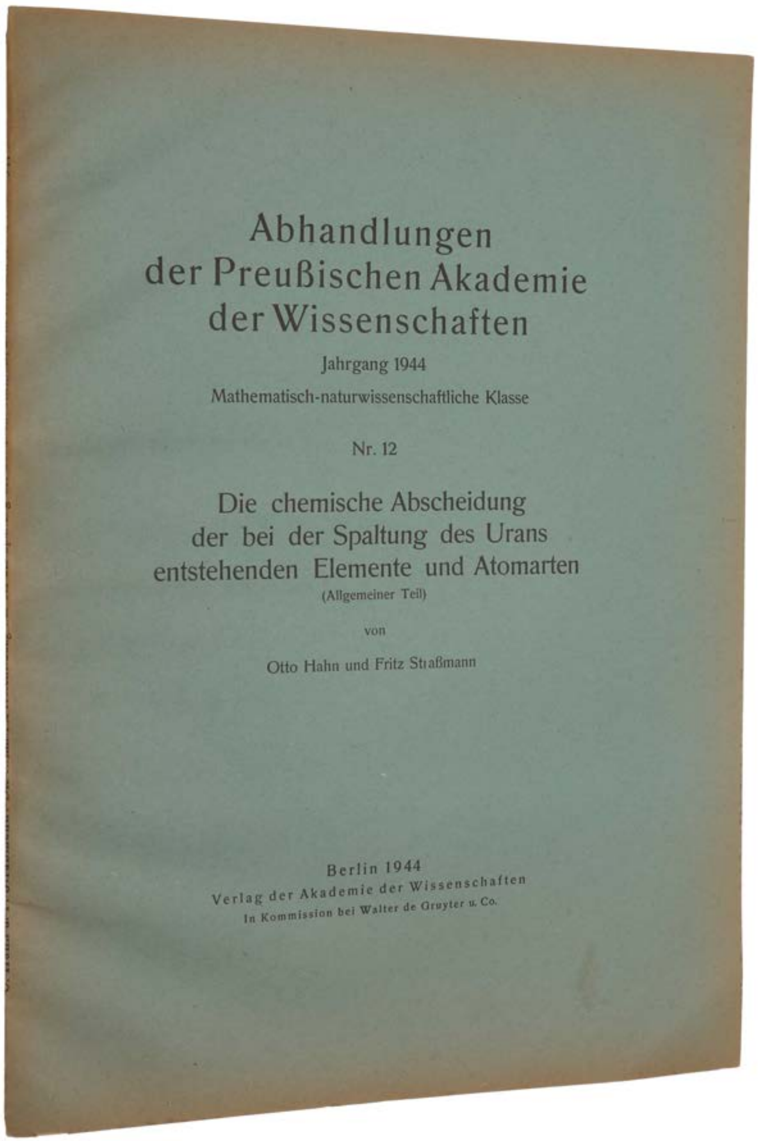

Abhandlungen
der Preußischen Akademie
der Wissenschaften
Jahrgang 1944
Mathematisch-naturwissenschaftliche Klasse
Nr. 12
Die chemische Abscheidung
der bei der Spaltung des Urans
entstehenden Elemente und Atomarten
(Allgemeiner Teil)
von
Otto Hahn und Fritz Straßmann
Berlin 1944
Verlag der Akademie der Wissenschaften
In Kommission bei Walter de Gruyter u. Co.

Physics under Hitler

8.225 / STS.042, Physics in the 20th Century
Professor David Kaiser, 19 October 2020

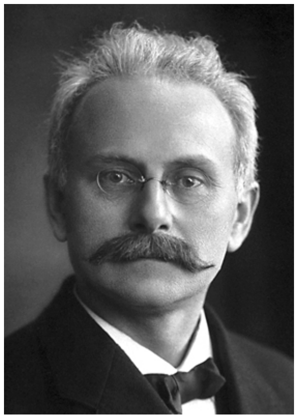
1. *deutsche Physik* Revisited

2. Nuclear Fission*

3. Heisenberg and the "Uranium Machine"

* See *Lecture Notes* on "Energy released from nuclear fission"

deutsche Physik Revisited



Johannes Stark

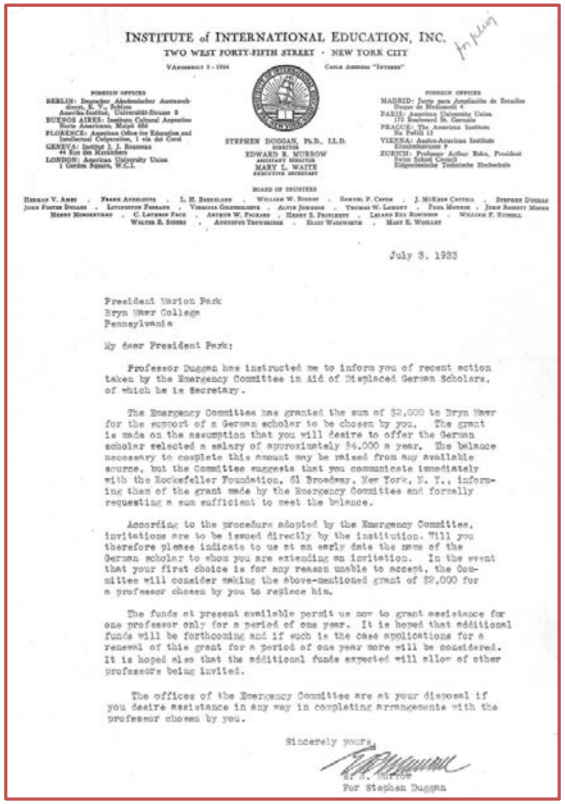
Philipp Lenard

Beginning as early as spring 1920, political opportunists took advantage of *Albert Einstein's* new fame to stage "anti-relativity" rallies. The public faces of the movement included German physicist Nobel laureates *Johannes Stark* and *Philipp Lenard.*

The rhetoric of the *deutsche Physik* movement was that of the "*tatmensch*": the "man of action." Newton, Galileo, and Faraday had all been "Aryan," according to Lenard; he argued that they partook of the same leadership spirit as Hitler.

Though the group began on the fringes, they quickly gained powerful adherents, especially once the Nazis achieved power in January 1933. Then advocates of *deutsche Physik* took charge of the German Education Ministry, with authority over all professorial appointments in the universities.

deutsche Physik Revisited



INSTITUTE of INTERNATIONAL EDUCATION, INC.

TWO WEST FORTY-FIFTH STREET · NEW YORK CITY

STEPHEN DUGGAN, PH.D., LL.D.

EDWARD R. MURROW

MARY L. WAITE

July 3, 1933

President Marion Park
Bryn Mawr College
Pennsylvania

My dear President Park:

Professor Duggan has instructed me to inform you of recent action taken by the Emergency Committee in Aid of Displaced German Scholars, of which he is Secretary.

The Emergency Committee has granted the sum of $2,000 to Bryn Mawr for the support of a German scholar to be chosen by you. The grant is made on the assumption that you will desire to offer the German scholar selected a salary of approximately $4,000 a year. The balance necessary to complete this amount may be raised from any available source, but the Committee suggests that you communicate immediately with the Rockefeller Foundation, 61 Broadway, New York, N. Y., informing them of the grant made by the Emergency Committee and formally requesting a sum sufficient to meet the balance.

According to the procedure adopted by the Emergency Committee, invitations are to be issued directly by the institution. Will you therefore please indicate to us at an early date the name of the German scholar to whom you are extending an invitation. In the event that your first choice is for any reason unable to accept, the Committee will consider making the above-mentioned grant of $2,000 for a professor chosen by you to replace him.

The funds at present available permit us now to grant assistance for one professor only for a period of one year. It is hoped that additional funds will be forthcoming and if such is the case applications for a renewal of this grant for a period of one year more will be considered. It is hoped also that the additional funds expected will allow of other professors being invited.

The offices of the Emergency Committee are at your disposal if you desire assistance in any way in completing arrangements with the professor chosen by you.

Sincerely yours,

E. R. Murrow
For Stephen Duggan

Letter from the Emergency Committee in Aid of Displaced German Scholars, July 1933

By spring 1933, the Nazis had begun to implement new "civil service" laws, which barred non-Aryans from holding government positions (including university faculty). This triggered a large exodus of scholars out of Germany.

About 100 physicists and mathematicians emigrated to the UK and US: *Albert Einstein* to the Institute for Advanced Study in Princeton; *Erwin Schrödinger* to Oxford and then Dublin; *Emmy Noether* to Bryn Mawr; *Max Born* to Cambridge and then Edinburgh; *Hans Bethe* to Cornell; *James Franck* to Chicago; *Felix Bloch* to Stanford; *Viki Weisskopf* to Rochester and then MIT, ...

These were not easy transitions: the US was deep into the Great Depression, so there were many US scholars looking for university positions. Plus, entrenched anti-Semitism within US universities further hindered placements (e.g., *J. Robert Oppenheimer* at Berkeley in 1929). Dartmouth: a refugee faculty candidate "shouldn't seem too Jewish."

deutsche Physik Revisited

Adolf Hitler with several of other Nazi party leaders, Nürnberg 1927.

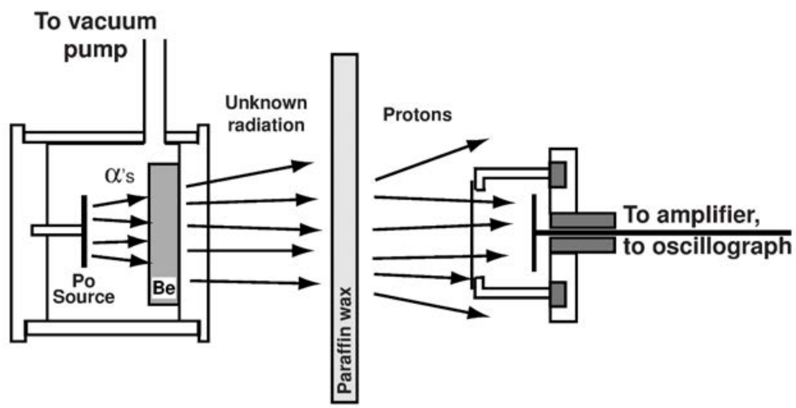
Within Germany, Nazi officials criticized non-Jewish physicists who seemed to demonstrate insufficient loyalty to the regime, e.g., by continuing to teach "Jewish physics" (such as relativity).

In 1937, they blocked *Werner Heisenberg* from becoming the successor to *Arnold Sommerfeld* as Ordinarius professor in Munich. They organized a press campaign against Heisenberg, labeling him a "white Jew" and attacking him in the Gestapo press. The attacks only subsided after Heisenberg's mother interceded directly with a close family friend: the mother of *Heinrich Himmler*, chief of the paramilitary *Schutzstaffel* (SS).

The power of the *deutsche Physik* movement declined soon after that. Physics was no longer associated for the regime only with philosophy or ideology. New variable: *power*. By the late 1930s, the Nazis began to think that physicists could be *useful* to the Reich. What had changed? *Nuclear physics*.

Questions?

The Neutron



Schematic of James Chadwick's 1932 experiment at the Cavendish Laboratory (Cambridge, UK)

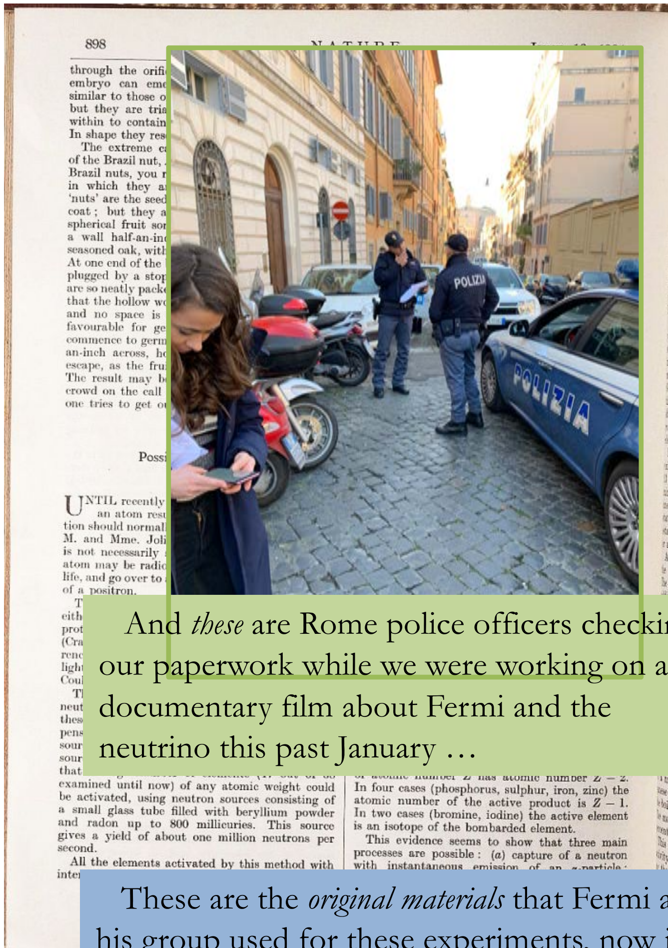
Throughout the late 1920s and early 1930s, several research groups working on radioactivity suspected there might exist a *second* kind of particle within atomic nuclei: an electrically neutral particle with mass close to the mass of the proton. *Irène* and *Frédéric Joliot-Curie* in Paris were especially active in this area. (They shared the 1935 Nobel Prize in chemistry for their studies of "artificial" or induced radioactivity.)

In January 1932, British physicist *James Chadwick* (former student of *Ernest Rutherford*) followed up on one of their suggestions and conducted a new experiment:

$$\alpha_2^4 + \mathrm{Be}_4^9 \rightarrow \mathrm{C}_6^{12} + n_0^1$$

Chadwick inferred the mass of the new particle (the "*neutron*") from the *recoil velocity* of protons scattered from (hydrogen-rich) paraffin wax. (Chadwick received the 1935 Nobel Prize in Physics for this work.)

“Transuranic Elements”



And *these* are Rome police officers checking our paperwork while we were working on a documentary film about Fermi and the neutrino this past January …

Right away, *Enrico Fermi* and his group in Rome began bombarding each element of the periodic table with *neutrons*, to induce radioactive reactions. They got all the way to uranium — the heaviest naturally occurring element in the periodic table — and found significant reaction rates, *especially* when Fermi placed a block of paraffin between the neutron source and the uranium target. They *assumed* they were measuring

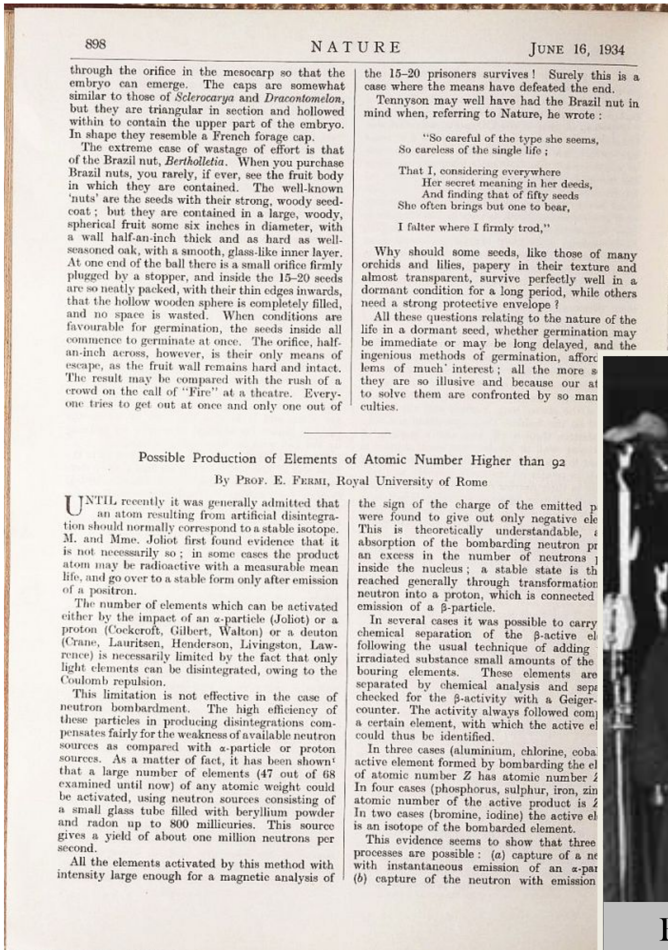
$$U^{238}_{92} + n^1_0 \longrightarrow U^{239}_{92} \longrightarrow Np^{239}_{93}$$

$$n \rightarrow p^+ + e^- + \bar{\nu}$$

“Neptunium”: the first *transuranic* element, just as the planet Neptune is the next planet in our Solar System beyond Uranus.

These are the *original materials* that Fermi and his group used for these experiments, now in a new Fermi museum in Rome!

“Transuranic Elements”



898 NATURE JUNE 16, 1934

through the orifice in the mesocarp so that the embryo can emerge. The caps are somewhat similar to those of *Sclerocarya* and *Dracontomelon*, but they are triangular in section and hollowed within to contain the upper part of the embryo. In shape they resemble a French forage cap.

The extreme case of wastage of effort is that of the Brazil nut, *Bertholletia*. When you purchase Brazil nuts, you rarely, if ever, see the fruit body in which they are contained. The well-known 'nuts' are the seeds with their strong, woody seed-coat; but they are contained in a large, woody, spherical fruit some six inches in diameter, with a wall half-an-inch thick and as hard as well-seasoned oak, with a smooth, glass-like inner layer. At one end of the ball there is a small orifice firmly plugged by a stopper, and inside the 15–20 seeds are so neatly packed, with their thin edges inwards, that the hollow wooden sphere is completely filled, and no space is wasted. When conditions are favourable for germination, the seeds inside all commence to germinate at once. The orifice, half-an-inch across, however, is their only means of escape, as the fruit wall remains hard and intact. The result may be compared with the rush of a crowd on the call of "Fire" at a theatre. Everyone tries to get out at once and only one out of the 15–20 prisoners survives! Surely this is a case where the means have defeated the end.

Tennyson may well have had the Brazil nut in mind when, referring to Nature, he wrote:

"So careful of the type she seems,
So careless of the single life;

That I, considering everywhere
Her secret meaning in her deeds,
And finding that of fifty seeds
She often brings but one to bear,

I falter where I firmly trod,"

Why should some seeds, like those of many orchids and lilies, papery in their texture and almost transparent, survive perfectly well in a dormant condition for a long period, while others need a strong protective envelope?

All these questions relating to the nature of the life in a dormant seed, whether germination may be immediate or may be long delayed, and the ingenious methods of germination, afford
lems of much interest; all the more s
they are so illusive and because our at
to solve them are confronted by so man
culties.

Possible Production of Elements of Atomic Number Higher than 92

By PROF. E. FERMI, Royal University of Rome

UNTIL recently it was generally admitted that an atom resulting from artificial disintegration should normally correspond to a stable isotope. M. and Mme. Joliot first found evidence that it is not necessarily so; in some cases the product atom may be radioactive with a measurable mean life, and go over to a stable form only after emission of a positron.

The number of elements which can be activated either by the impact of an α-particle (Joliot) or a proton (Cockcroft, Gilbert, Walton) or a deuton (Crane, Lauritsen, Henderson, Livingston, Lawrence) is necessarily limited by the fact that only light elements can be disintegrated, owing to the Coulomb repulsion.

This limitation is not effective in the case of neutron bombardment. The high efficiency of these particles in producing disintegrations compensates fairly for the weakness of available neutron sources as compared with α-particle or proton sources. As a matter of fact, it has been shown[1] that a large number of elements (47 out of 68 examined until now) of any atomic weight could be activated, using neutron sources consisting of a small glass tube filled with beryllium powder and radon up to 800 millicuries. This source gives a yield of about one million neutrons per second.

All the elements activated by this method with intensity large enough for a magnetic analysis of

the sign of the charge of the emitted p
were found to give out only negative ele
This is theoretically understandable,
absorption of the bombarding neutron pr
an excess in the number of neutrons
inside the nucleus; a stable state is th
reached generally through transformation
neutron into a proton, which is connected
emission of a β-particle.

In several cases it was possible to carry
chemical separation of the β-active el
following the usual technique of adding
irradiated substance small amounts of the
bouring elements. These elements are
separated by chemical analysis and sepa
checked for the β-activity with a Geiger-
counter. The activity always followed com
a certain element, with which the active el
could thus be identified.

In three cases (aluminium, chlorine, coba
active element formed by bombarding the el
of atomic number Z has atomic number
In four cases (phosphorus, sulphur, iron, zin
atomic number of the active product is
In two cases (bromine, iodine) the active el
is an isotope of the bombarded element.

This evidence seems to show that three
processes are possible: (a) capture of a ne
with instantaneous emission of an α-par
(b) capture of the neutron with emission

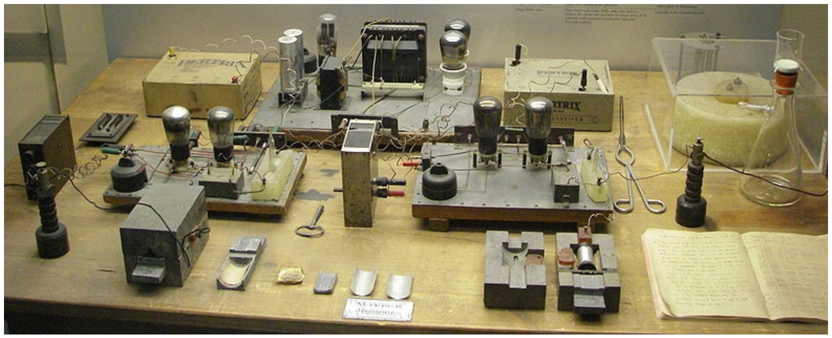
$$U^{238}_{92} + n^{1}_{0} \longrightarrow U^{239}_{92} \longrightarrow Np^{239}_{93}$$

$$n \rightarrow p^{+} + e^{-} + \bar{\nu}$$

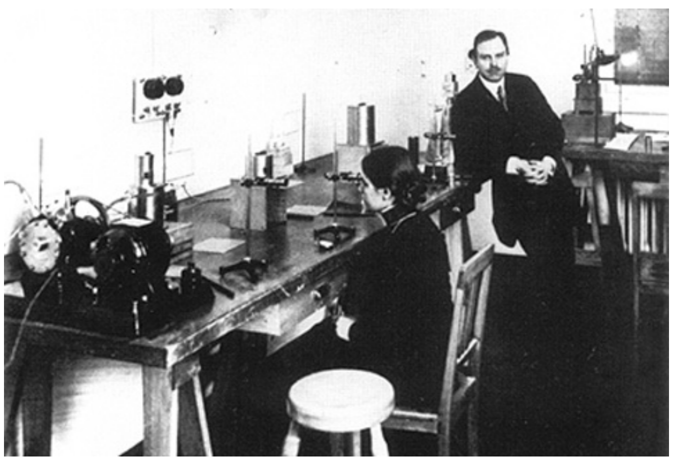
Fermi receiving the Nobel Prize, December 1938

Benito Mussolini, Italian dictator

Revisiting Transuranics



Hahn and Strassmann's experimental arrangement, 1938
(reconstructed in the Deutsches Museum, Munich)



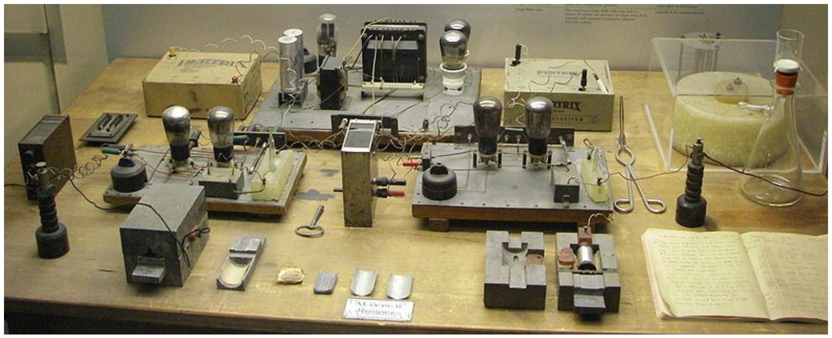
Lise Meitner and Otto Hahn in Berlin, ca. 1938

Other groups actively worked on nuclear transformations associated with neutron capture, including a team in Berlin: nuclear chemists *Otto Hahn* and *Fritz Strassmann* together with nuclear physicist *Lise Meitner*.

Meitner, from a Jewish family in Austria, was only allowed to attend formal school until age 14. After reforms, she rushed through the standard high school curriculum, via self-study, in a few months and passed the entrance exam to study physics at the University of Vienna. She was among the first women to earn a PhD in physics *anywhere*. After her degree (1905), she began to collaborate with Hahn in Berlin—in the *basement*, since women were not yet allowed in the main Institute.

After the *Anschluss* in March 1938, when Nazi Germany took over Austria, Meitner became subject to the Nazi employment laws, and lost her job.

Revisiting Transuranics



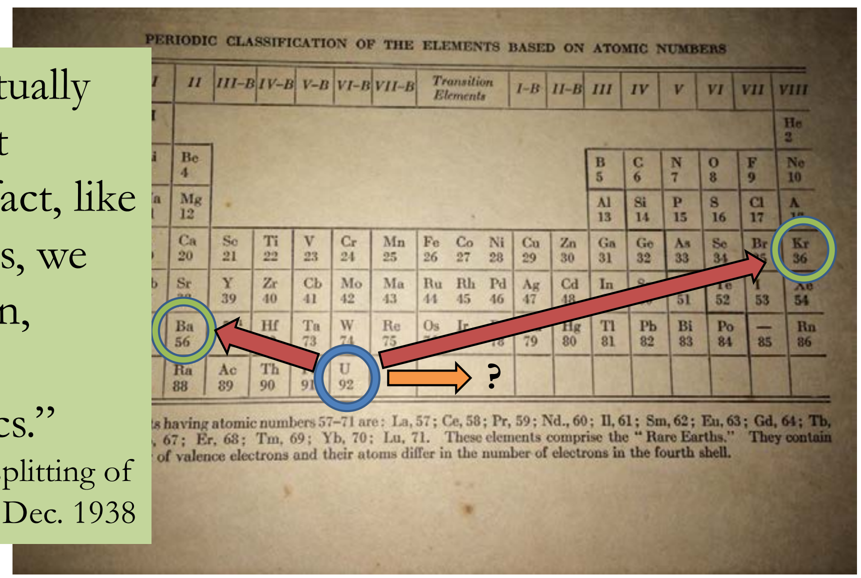
Hahn and Strassmann's experimental arrangement, 1938
(reconstructed in the Deutsches Museum, Munich)

While Meitner fled Germany and sought shelter in Scandinavia, Hahn and Strassmann continued their neutron-bombardment experiments. They re-did Fermi's famous experiment multiple times—just as Fermi was receiving his Nobel Prize for that work—and concluded that *neither* Fermi *nor* they had produced transuranic elements. Instead:

$$U_{92} + n \longrightarrow Ba_{56} + Kr_{36}$$

"As chemists, we must actually say the new particles do not behave like radium but, in fact, like barium; as nuclear physicists, we cannot make this conclusion, which is in conflict with all experience in nuclear physics."

Hahn and Strassmann, "On the splitting of Uranium nuclei by slow neutrons," Dec. 1938



Nuclear Fission

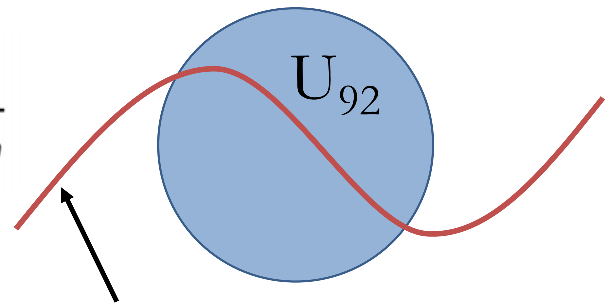
Lise Meitner
(1878 – 1968)

Otto Robert Frisch
(1904 – 1979)

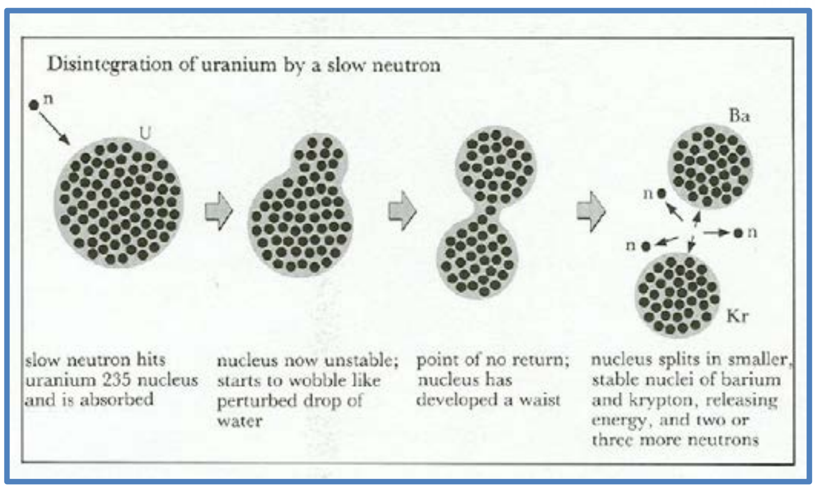
In December 1938, Meitner received an update from Hahn about the latest experiments, indicating the presence of barium. While skiing with her nephew, theoretical physicist *Otto Robert Frisch*, near Stockholm, they worked out a *physical model* for nuclear fission.

Slow neutrons were key, because of quantum theory. The neutron's de Broglie wavelength becomes *large* for slow velocities:

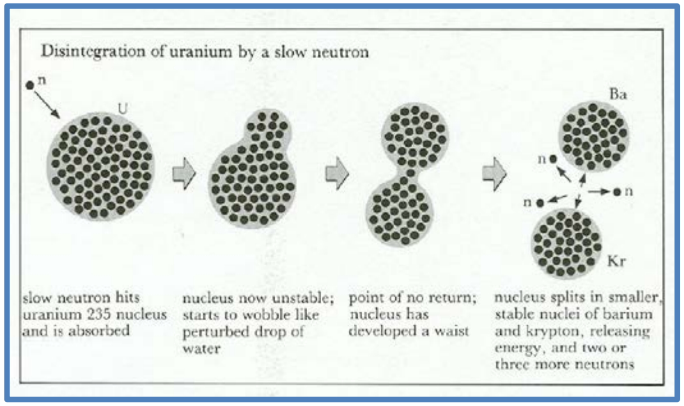
$$\lambda = \frac{h}{mv}$$



n wavelength: comparable in size to the entire U nucleus. Can set the nucleus *wobbling* like a liquid drop



Nuclear Fission



$$E_{\text{nuc}} \sim \frac{(qe)^2}{R_{\text{nuc}}}, \quad q \sim 100,\ R_{\text{nuc}} \sim 10^{-12}\ \text{cm}$$

$$E_{\text{chem}} \sim \frac{(qe)^2}{R_{\text{atom}}}, \quad q \sim 1,\ R_{\text{atom}} \sim 10^{-8}\ \text{cm}$$

$$\frac{E_{\text{nuc}}}{E_{\text{chem}}} \sim 10^8\ !$$

After splitting, each piece carries about $E_{\text{piece}} \sim \frac{1}{3} E_{\text{whole}}$. That leaves

$$E_{\text{whole}} - 2E_{\text{piece}} \sim \frac{1}{3} E_{\text{nuc}}$$

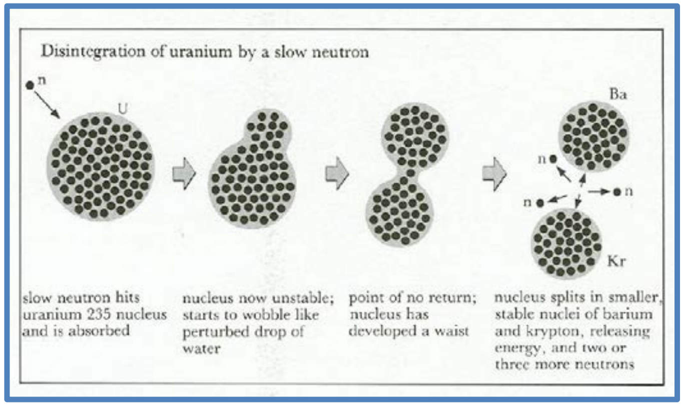
to be released as "raw" energy, *every time* a uranium nucleus splits. And $E_{\text{nuc}} \sim 10^8\, E_{\text{chem}}$.

That estimate — based on simple Coulomb repulsion between the two smaller nuclei — matched an independent estimate, based on *binding energy*:

$$m_{\text{U}} = (m_{\text{Ba}} + m_{\text{Kr}}) + \Delta m \implies E_{\text{release}} \sim \Delta m\, c^2 \sim \frac{1}{3} E_{\text{nuc}}$$

* See *Lecture Notes* on "Energy released from nuclear fission"

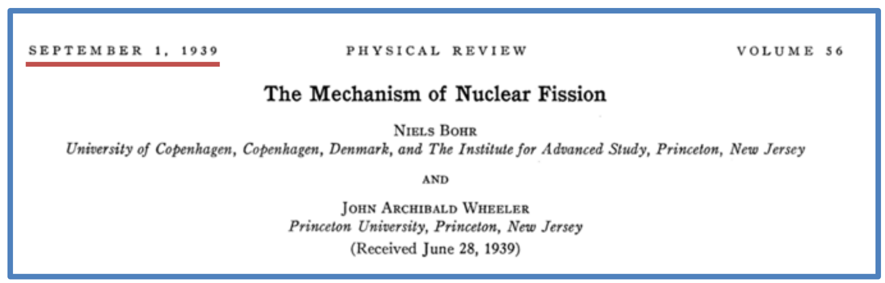
Nuclear Fission



Frisch returned to *Niels Bohr's* Institute in Copenhagen and told Bohr all about his and Meitner's ideas about fission. He swore Bohr to secrecy, so he and Meitner could check their work and perform some follow-up tests.

Bohr sailed to the US in January 1939 to spend a semester at Princeton. He was met at the docks in New York City by *Enrico Fermi* and *Samuel Goudsmit*, and told them *immediately* all about Meitner's and Frisch's work — then he told *Eugene Wigner*, *Albert Einstein*, and *John Wheeler* (Bohr's former postdoc) in Princeton. Within days, several laboratories up and down the East Coast had verified fission. (Easy to do once one knows to conduct tests for barium among the reaction products.)

Together with Wheeler, Bohr worked out a more detailed, quantitative analysis of nuclear fission, drawing on Meitner's work to identify the most fissionable uranium isotope to be U^{235}. Their article was published *the same day* that Nazi troops invaded Poland, triggering the start of the Second World War.


SEPTEMBER 1, 1939 PHYSICAL REVIEW VOLUME 56

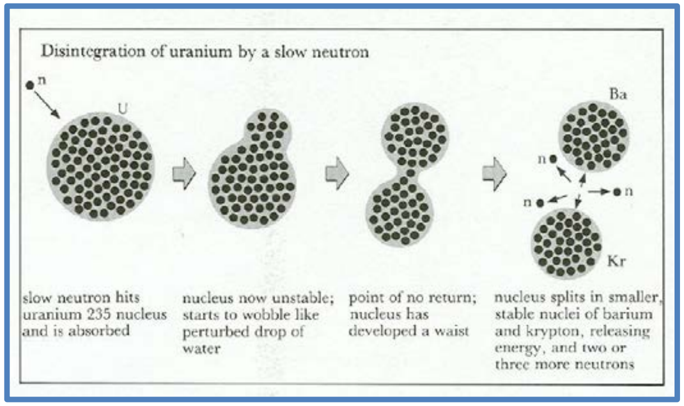
The Mechanism of Nuclear Fission

Niels Bohr
University of Copenhagen, Copenhagen, Denmark, and The Institute for Advanced Study, Princeton, New Jersey

and

John Archibald Wheeler
Princeton University, Princeton, New Jersey
(Received June 28, 1939)

Nuclear Fission



Everyone in physics knew immediately that nuclear fission could lead to *bombs*. *And* they knew that the *Germans* must know this, too!

Fission had been identified in a Berlin laboratory. Although many researchers had fled Nazi Germany, it remained the world's center for nuclear physics at the time: *Werner Heisenberg*, *Otto Hahn*, *Hans Geiger*, *Walther Bothe*, *Max Planck*, *Max von Laue*, *Carl Friedrich von Weizsäcker*, and more.

At exactly the same time, the Second World War erupted:

March 12, 1938: Nazi *Anschluss* of Austria.

December 1938: Hahn and Strassmann identify barium among reaction products; Meitner and Frisch work out nuclear fission

January 1939: Bohr arrives in NYC, tells others about fission

March 15, 1939: Nazis occupy Czechoslovakia.

September 1, 1939: Nazis invade Poland.

September 3-10, 1939: UK, France, Australia, New Zealand, and Canada declare war against Germany.

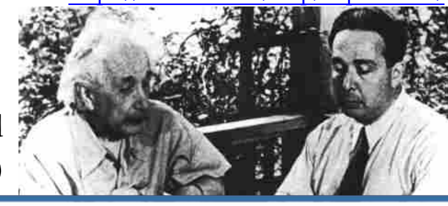
September 17, 1939: Soviets invade Poland.


The New York Times. EXTRA

GERMAN ARMY ATTACKS POLAND; CITIES BOMBED, PORT BLOCKADED; DANZIG IS ACCEPTED INTO REICH

German tanks crossing into Poland, September 1939

Nuclear Fission

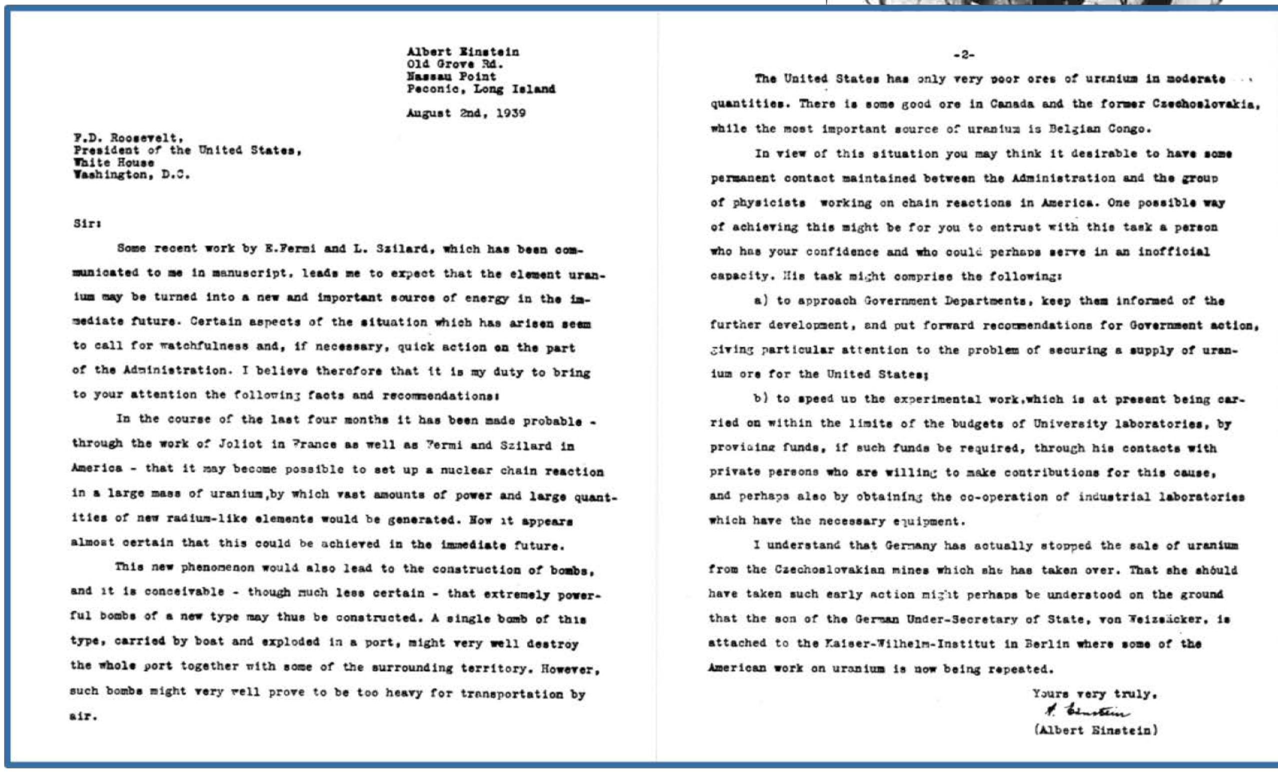


Einstein with Leo Szilard (1898 – 1964)

April 1939: German Reich Ministry of Education holds secret meeting on military applications of nuclear fission, bans uranium exports.

April 1939: Japanese government begins secret nuclear-weapons project ("Project Ni"); underfunded, not seen as high priority for current war.

Fall 1939: UK considers fission weapons, ramps up larger effort early in 1940 after *Frisch-Peierls* memo (Frisch having emigrated to the UK). They *underestimated* amount of U^{235} required by ~20.



Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

Fall 1939: *Igor Kurchatov* informs Soviet government about military applications of nuclear fission. As in Japan, the project is given a low priority at first, and then further slowed after the German invasion in 1941.

Questions?

Heisenberg and the "Uranium Machine"

Kaiser Wilhelm Institut für Physik, Berlin-Dahlem

By September 1939, the German Army Ordnance Office assumed control of the Kaiser Wilhelm Institut für Physik in Berlin-Dahlem, to coordinate research on nuclear fission. *Werner Heisenberg* became an early member of the *Uranverein* ("Uranium club") and advised the military multiple times about possibilities for both weapons and (civilian) power-generation from nuclear fission (bombs and reactors). In summer 1942, he was placed in charge of the nuclear effort.

Heisenberg was also sent on diplomatic missions throughout neutral countries and (soon) German-occupied territories, including Denmark. To some of his colleagues, he often sounded explicitly *nationalistic*: not pro-Nazi, but proudly German and (at times) even suggesting that Germany *should* rule all of Europe, given its traditions of culture and learning.

His visit to *Bohr* in Copenhagen in 1941 was part of those scientific-diplomacy missions. They were afraid that Bohr's house might be bugged by the Nazis, so they took long strolls in the gardens. *What did they (and Margrethe Bohr) really talk about?*

Heisenberg and the "Uranium Machine"

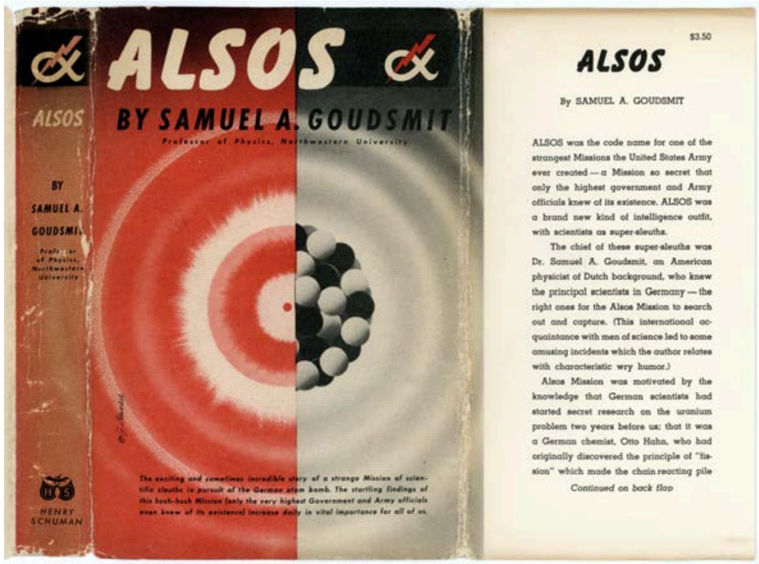
Kaiser Wilhelm Institut für Physik, Berlin-Dahlem

Heisenberg advised the German military authorities that nuclear *bombs* were possible, though probably not during the present war — because, with the early success of the *Blitzkrieg*, everyone expected that Germany would win the war by 1941 or 1942. But the authorities still saw *future* promise of nuclear weapons, so they continued to fund Heisenberg's effort and also seized the Belgian Congo and mined uranium.

Walther Bothe estimated that carbon / graphite moderators (to slow neutrons and increase fission rates) would need to be *very* pure so as not to absorb too many neutrons, so the German team turned to *heavy water* as a moderator instead. (Allied commando mission to blow up heavy-water plant in Norway, Feb 1942 ...) Also, *Heisenberg* overestimated how much enriched U^{235} would be needed for a critical mass (opposite to Frisch-Peierls error!).

As the war dragged on, the bomb project was given lower priority, because the *Reich* needed to direct resources to short-term military priorities.

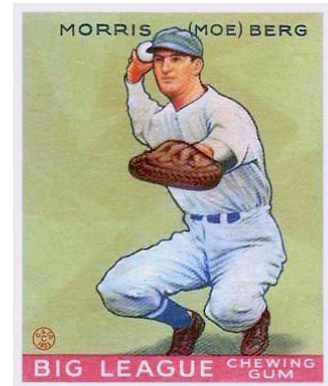
Heisenberg and the "Uranium Machine"

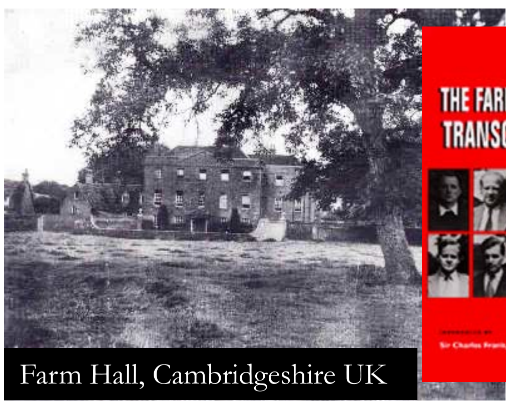


"Alsos" is Greek for "Grove" (like Gen. Leslie Groves...)

Samuel Goudsmit had emigrated to the US in the late 1920s; his family later perished in Auschwitz. He led the Allied reconnaissance missions inside Germany to learn about the Nazi nuclear effort and "collect" (kidnap) German nuclear scientists.

As early as 1942, American baseball player Moe Berg was sent to listen to Heisenberg lecture in Switzerland, armed with a pistol. If it sounded like the Germans were getting close to a working weapon, Berg was to kill Heisenberg! He was convinced they were not very close.





Farm Hall, Cambridgeshire UK

During spring 1945 the Alsos mission captured 10 German nuclear scientists and took them to *Farm Hall*, near Cambridge, UK (*Operation Epsilon*). The house was bugged; their conversations were constantly audiotaped, transcribed, and translated. The transcripts were sealed for (nearly) 50 years, first released in 1992.

Heisenberg and the "Uranium Machine"

First reaction (to paraphrase):

"I didn't lose the race, because they didn't really make a nuclear weapon."

Second reaction (to paraphrase):

"I didn't lose the race, because I didn't *want* to make a nuclear weapon."

Farm Hall transcript of August 6, 1945 (reactions to news about bombing of Hiroshima):

Otto Hahn: "If the Americans have a uranium bomb, then you're all second-raters. Poor old Heisenberg."

Heisenberg: "Did they use the word uranium [in the BBC report] in connection with this atomic bomb?"

All: "No."

Heisenberg: "Then it's got nothing to do with atoms. ... All I can suggest is some dilettante in America who knows very little about it has bluffed [the reporters] in saying, 'If you drop this it has the equivalent of 20,000 tons of high explosive' and in reality it doesn't work at all."

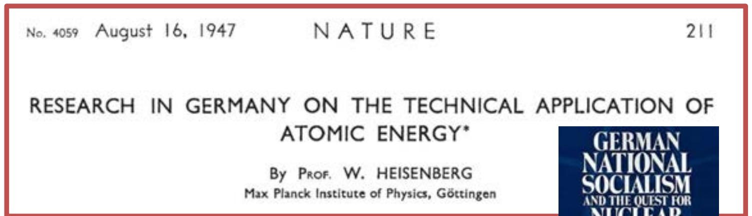
Hahn: "At any rate, Heisenberg you're just second-raters. ... They are fifty years further advanced than we."

Heisenberg: "I am willing to believe that it is a high pressure bomb and I don't believe it has anything to do with uranium but that it is a chemical thing."

(About 10 minutes later:) *Carl Friedrich von Weizsäcker*: "I believe the reason we didn't do it was because all the physicists *didn't want to do it*, on principle. If we had wanted Germany to win the war we would have succeeded."

(A few minutes later:) *Heisenberg*: "I would say that I was absolutely convinced of the possibility of our making a uranium engine [reactor] but I never thought that we would make a bomb and at the bottom of my heart I was really glad it was to be an engine [reactor] and not a bomb. I must admit that."

Heisenberg and the “Uranium Machine”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RESEARCH IN GERMANY ON THE TECHNICAL APPLICATION OF ATOMIC ENERGY*

By Prof. W. HEISENBERG

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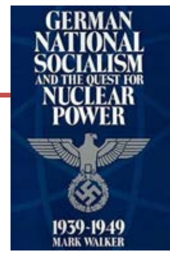
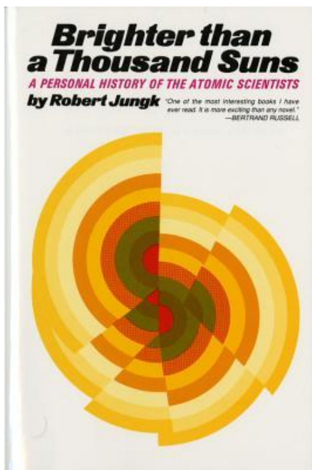
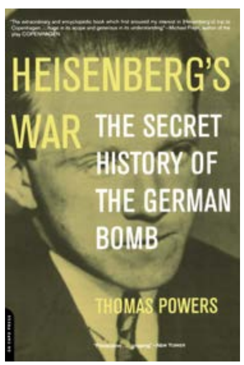
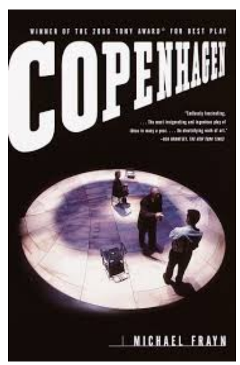


As early as 1946 (upon his return to Germany), Heisenberg gave several descriptions of the wartime German nuclear effort. He emphasized the group’s interest in *reactors* for civilian energy production. Yet Heisenberg himself had emphasized in reports to the German Army Ordnance office as early as 1941-42 that reactors could produce *plutonium*, which could be used for *bombs*.



In 1956, Austrian journalist *Robert Jungk* published *Brigher than a Thousand Suns*, in which he argued that Heisenberg had *purposely, actively resisted* Hitler by dragging his feet on nuclear weapons — suggesting that Heisenberg was a stronger moral figure than the Allied scientists who had worked on the Manhattan Project.





Decades later, journalist *Thomas Powers* echoed Jungk’s thesis in his book *Heisenberg’s War* (1993). Powers’s book inspired playwright *Michael Frayn* to compose *Copenhagen* (1998).

Heisenberg and the "Uranium Machine"

In *private correspondence*, Heisenberg consistently distanced himself from the "active resistance" interpretation.

Heisenberg to *Jungk*, November 1956: "You speak here towards the end of the second paragraph about active resistance to Hitler, and I believe — pardon my frankness — that this passage is determined by a total misunderstanding of a totalitarian dictatorship. [...] *I would not want this remark to be misunderstood as saying that I myself engaged in resistance to Hitler.*"

Heisenberg to other correspondents, 1957: For "material and technical reasons in 1941-42," the German nuclear scientists *did not have to decide* whether to build a bomb. German victory seemed assured, so complicated new weapons were not given priority.

"Jungk's book is written carefully and with the best of intentions; nonetheless, I am still always somewhat afraid about these popular representations, since they can never exactly represent the very complicated circumstances and psychological situations of wartime."