

Merci for invitation

SuperGlad

to be here

for a special  
reason

a few years ago

A blue-tinted portrait of Gunnar Källén, a man with short dark hair, looking slightly to the right. The portrait is the background for the text.

# Portrait of Gunnar Källén

A Physics Shooting Star and Poet  
of Early Quantum Field Theory

Made a strange (for me frightening) discovery

Wolfgang Pauli is my scientific grandfather

Made an unexpected (frightening) discovery

# Wolfgang Pauli

[the mother of neutrino]

is my scientific GRANDPA.

GREAT to honour

# Famous French Lemma:

“cherchez la femme”

*Cherchez la femme, pardieu ! cherchez la femme!*

Indeed, we do find a woman behind the scene but of a  
very special kind

***much respected, highly devoted to  
science, and with great integrity***



Die Annielen im Fabrikhaus, Wien, 1910  
Foto: Hermann-Zimmermann, Berlin für Marie Wilms und Ernstig



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Foto: Hermann-Zimmermann, Berlin für Marie Wilms und Ernstig

**you may know her  
last "postdoc" 1949-50**

# Bei Lise Meitner in Stockholm



# Herwig Schopper

...  
DG of CERN 1981-88  
...

Working together with an excellent physicist

# *Pauli's web, connecting many, covering several areas*

More than 3000 letters collected in eight spacious volumes  
(primarily thanks to K. von Meyenn)

Involve hundreds of people: Heisenberg, Bohr, Einstein, Fierz, Born, Schrödinger ...

Pauli wants to know “everything” that is going on in theory, experiment, and beyond





Letter # [3075] Pauli to Delbrück [worked with Lise, came up with the Delbrück effect on her request]

Pauli writes:  
don't forget to wish Lise a happy birthday

The history of this “foolish child” [nährisches Kindes] of my life's crisis 1930/1931 ... started from her heated debate with Ellis on the continuous beta spectrum.  
What ever happened to Ellis (earning money?) ?

Talks about his experiences in the America, about the famous congress in Rome 1931

dancing party with you, Gamow, Ellis, Blacket, ...and a number of ladies

“But for me personally the history of the neutrino is unseparably connected with your - very unsuccessful – flirtation with Eve Curie at that party. ”

Pauli presents his theory for why Delbrück was unsuccessful  
[he didn't know that MD was going to be successful in getting the NP in 1969]

Concerning the famous letter Dec 4, 1930 – the pre-birth certificate of neutrino

It was sent to Lise and Lise alone

Geiger was professor at Tübingen (appointed in 1929)

In a **letter to Rasetti**, Pauli writes: “Thanks due Miss Meitner, who still had a copy of the enclosed letter from December 4, 1930. (I remembered the existence of this letter, but I did not know anymore the date and the exact content of it. Therefore I recently wrote to Lise Meitner, which turned out to be successful.” December 1956

Fortunately Lise kept the original which was found posthumously, in her state (Nachlass)

In his letter Pauli called his particle neutron; Fermi converted it to neutrino  
(sounds susy-like)

**“It is difficult to find a case where the word “intuition” characterises a human achievement better than in the case of the neutrino invention by Pauli”**  
BP-1980

From its invention neutrino was praised, loved and very popular in several sectors;  
but there were those who didn't believe in it, among them  
Niels Bohr, Arnold Sommerfeld, and Arthur Eddington

Where in the atom was the neutrino hiding before getting out?

One of the very first scientists who applauded the arrival of neutrino was

Francis Perrin (1901-1992)

(son of Jean Perrin, Nobel Prize 1926, brownian motion)

FP: Comptes Rendus 197 (1933) 1625; 198 (1934) 2086 [not easy to look up]

Fermi, in his 1934 monumental paper on beta decay refers to Perrin

A second person of interest  
our dear Niels Bohr



Lund 1954

Pauli to Bohr [postcard, March 1929]

**What is the current status [clarification] of your new ideas? Do you intend to continue with maltreatment of the poor energy law**

[means law of conservation of energy]?

For Pauli abandoning the “energy law”, a law which had so faithfully/successfully served humanity, was a crime. Bohr thought otherwise.

Pauli to Bohr (July 1929)

**Anyhow, don't publish the note [that Bohr had sent him]  
And let the stars shine in peace**

There were only two elementary particles in those days, in addition to the photon:

**Electron (born 1897) & Proton (born 1919)**

speculation concerning the existence of neutron by Rutherford. But its discovery by his student Chadwick came later

# Pauli to Blackett, April 1933

Dear Blackett!

- Your and Occhialinis paper about the positive **electron** is very interesting and the existence of the positive electron is very supported now by the paper of **Meitner and Philipp** in Naturwissenschaften
- [By the way, the positron was also confirmed by Curie and Joliot. Years later C.D. Anderson noted that the discovery of positron would have been extremely easy if he had known more theory]
- In this moment I come back to my old idea of the existence of a “neutrino” ...
- What think the experimental physicists of the Cavendish laboratory now about those possibilities? Besides, I don't believe on the Dirac-“holes”, even if the positive electron exist.

The first  
“underground  
neutrino  
experiment”



# **Performed by Maurice Nahmias (student of Chadwick), reported by Blackett in 1934**

Was done at the underground station

a source of 7 mg Ra (D,E,F)

RaE = lead

2 Geiger Müller coun.

**Expecting  $6.2 \times 10^9$  neutrinos  
crossing per minute**

Apparently Holborn is not a popular station

•A woman commented: if I was a neutrino

•Wouldn't stop there either





Patrick Blackett (1897-1974)  
[was a giant]



James Chadwick  
1891-1974

“Rutherford’s boys”, both Nobel Laureates in Physics (1948, 1935)  
Lord Rutherford is one of the most spectacular personalities we have ever had

It is amazing that “leaders” such as Rutherford and Fermi achieved to “create” so many great scientists in a rather short time.

Q: What did T. D. Lee (Nobel Laureate 1957) learn from Fermi?

# $\nu$ enjoyed a great deal of popularity among theorists

Pauli talked about it at several places (Pasadena, Michigan, Princeton, ...

And also at a Congress in Rome October 1931 – organized by Enrico Fermi

Later at Solvay Conference October 1933

By 1933 also the neutron (Chadwick 1932) and positron (Anderson 1932) were added to the family of known elementary particles giving a total of five particles

One of the very first scientists who applauded the arrival of neutrino was

Francis Perrin (1901-1992)

Comptes Rendus 197 (1933) 1625; 198 (1934) 2086 [not easy to look up]

Presented by M. Jean Perrin

FP is the son of Jean Perrin, Nobel Prize 1926, brownian motion)

Fermi, in his 1934 monumental paper on beta decay refers to Perrin

Perrin argues that it is more natural (my word) to have a massless neutrino.  
Points out how this can be tested by measuring the shape of the spectrum.

Another interesting early papers is:

H. Bethe and R. Peierls (1934)

I. Curie and F. Joliot had observed decays where instead of an electron a positron is emitted.

This supports the hypothesis that the electron/positron and neutrino are created in these processes “as one can scarcely assume the existence of the positive electrons in the nucleus”

Bethe and Peierls estimated the penetrating power of the neutrino to be  $10^{16}$  km  
And concluded “there is no practically possible way of observing the neutrino”

The “super-physicist” Bethe (born in Strasbourg 1906) published a long review Article [Bethe & Bacher, Rev Mod Phys 8 (1936)]

in which two sections were devoted to neutrino.

**Shows how serious the neutrino was taken.**

He received the 1967 Nobel Prize in Physics for

"his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars"

# Neutrino theory of light light is “a bound state” of two neutinos

Some of the advocates were distinguished mathematical physicists:

Paul Jordan (collaborator of Heisenberg)

Ralph Kronig (assistant of Pauli, had worked with Kramers)

These articles are loaded with heavy mathematics

Hard to understand

Where does the binding energy come from?

# Neutrino Theory of Light

A person who truly “loved” this approach was

Louis de Broglie (Nobel 1927, very important for creation of wave mechanics by Schrödinger)

Wrote a book *Matière et Lumière* (1937) translated to English (1939)

A lovely book, makes you dream but where has the critical thinking gone? Excited about the discovery of neutron and the positron he writes:

“No doubt it is on such lines that we shall gather the data needed to understand the character of the photon. **The Theory of Light**”, **then has a long and striking history; and a fine career lies before it.**”



As you can imagine Pauli was against ... [Quatsch]

# Other theoretical neutrino-induced paths

Double-beta decay 1935

Pioneered by Maria Goeppert-Mayer (1906-72)

Nobel laureate 1963

Neutrinoless double-beta 1939

Pioneered by Wendell Furry (1907-84)

Furry was terribly optimistic ...



Requires neutrino to be its own antiparticle, “wrongly” referred to as a Majorana particle  
Majorana wanted the electron to be its own antipart.

It is said that Fermi thought of Majorana as a real genius, like Newton, and that there was no problem that he couldn't solve. Majorana disappeared on March 25th 1938 at the age of 32.

- de Broglie (1892-1987) is so happy in 1937
- He talks about the striking experiments by Jean Thibaud, proof of the hole theory, ...
- “The theory of light, then, has a long and striking history; and a fine career lies before it”
- He couldn't know that light was going to end up as it did, just one gauge boson among the 12

**What is the mass of this  
“unborn baby”?**

- From 1934 paper of Fermi

Original in German, translated to English in Nuovo Cimento

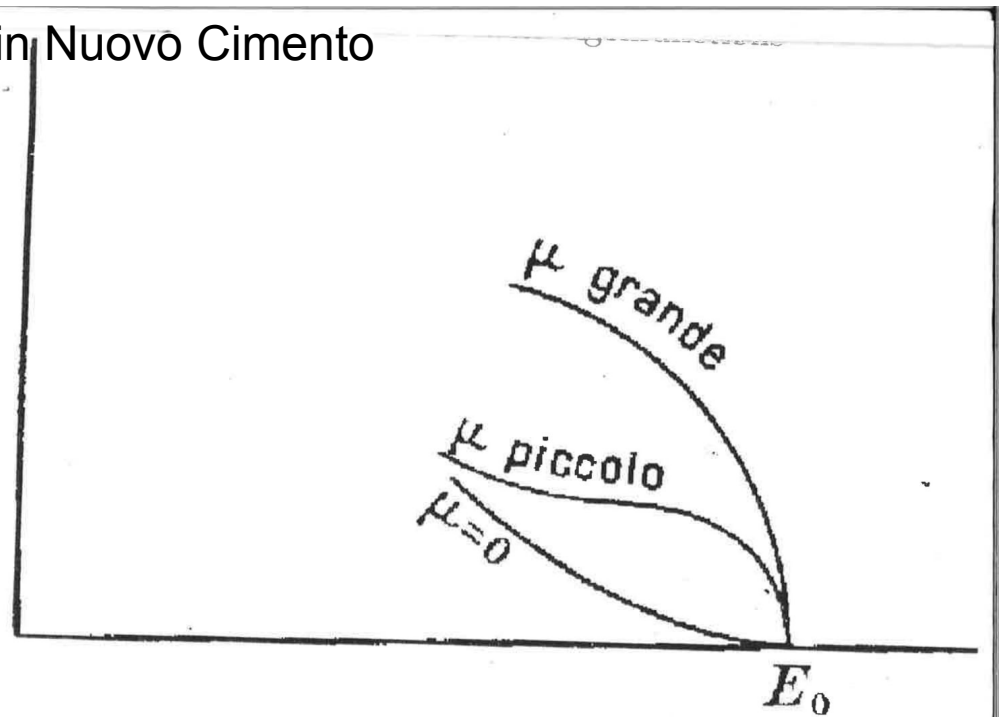


Fig. 1

Henderson 1935

Shape of the spectrum near the end-point is sensitive to neutrino mass

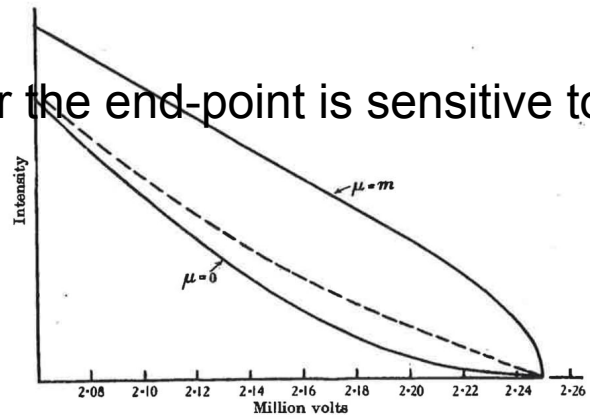


Fig. 2. (Thorium C.)

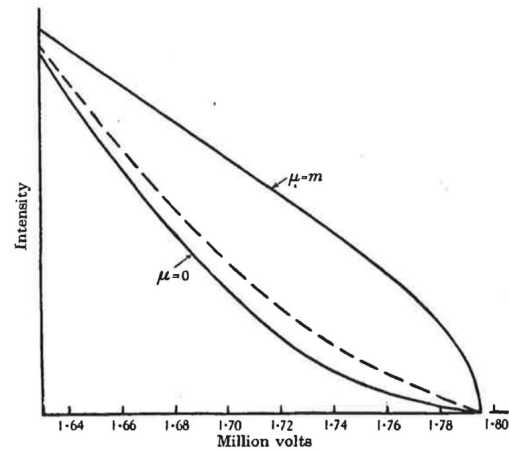


Fig. 3. (Thorium C'')

# **Disasterous events that followed**

In addition to incredible human sufferings led to huge changes in the scientific landscape

**The rise of Nazis to power (1933) & introduction of race laws**

which threatened the existence of almost all distinguished scientists. Many fled but some didn't make it.

**The Second World War (1939 - 1945)**

Resulted in spreading the horror to new territories

communications among scientists were much reduced