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'Helicity of Neutrinos'

M. Goldhaber et al.
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Shibata lab.
TAMORI Midori

Contents

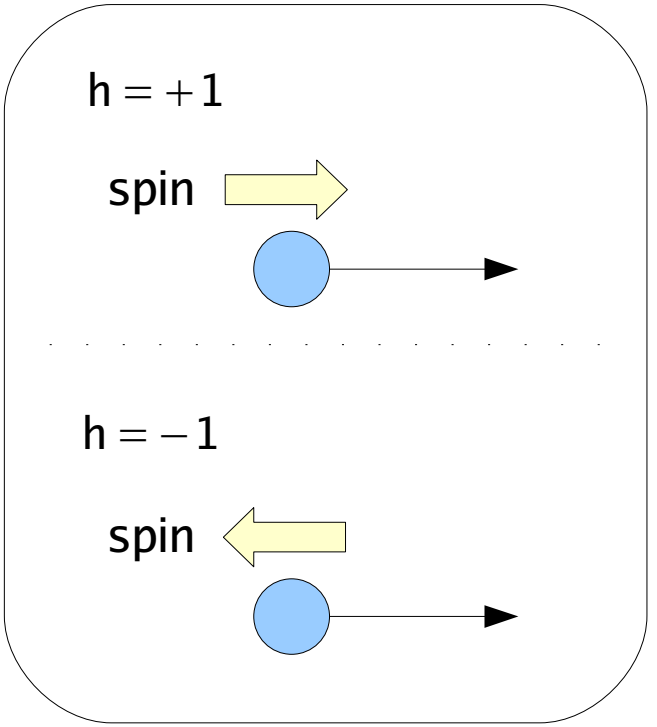
1. Introduction

helicity :

the projection of spin
to the direction of momentum

$$h = \frac{\mathbf{s} \cdot \mathbf{p}}{|\mathbf{s}| \cdot |\mathbf{p}|}$$

s : spin
p : momentum



Spin of neutrino is 1/2.

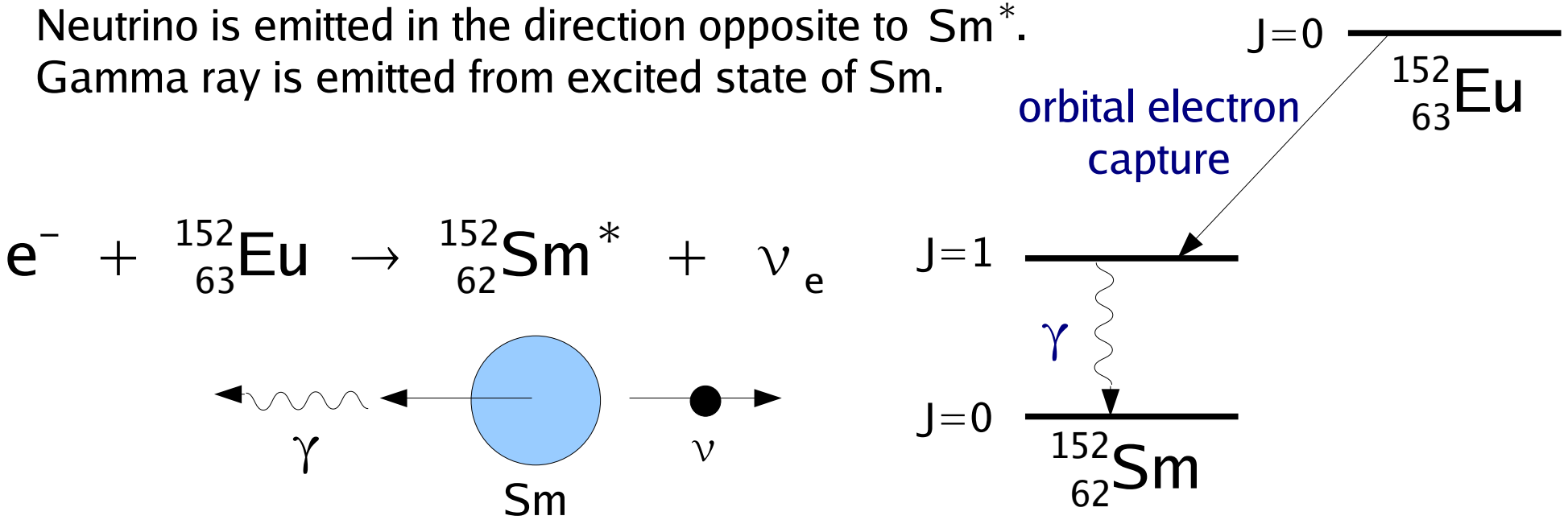
Helicity can either be +1 or -1.

2. Experiment

^{152}Eu is used.

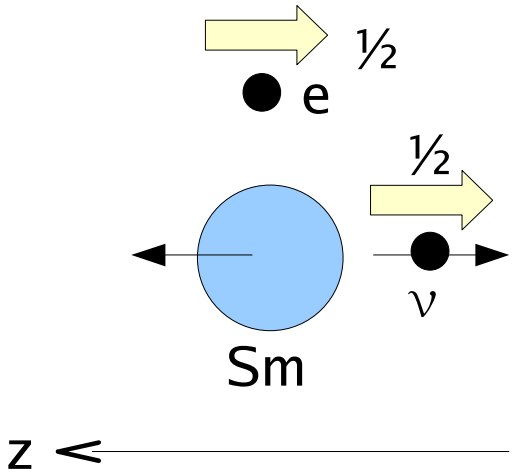
kinematics

It decays by orbital electron capture.
Neutrino is emitted in the direction opposite to Sm^*.
Gamma ray is emitted from excited state of Sm.



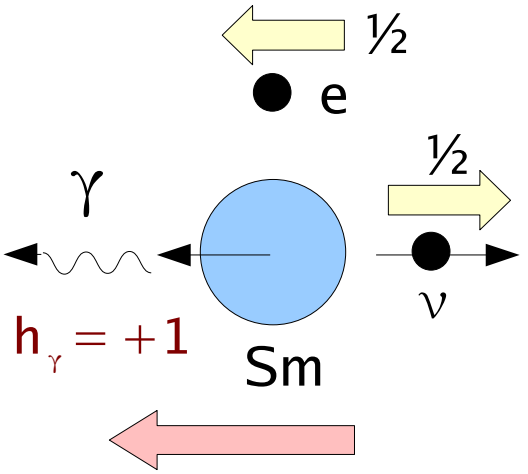
If a gamma ray is emitted in the ^{152}Sm momentum direction, its energy is increased by Doppler effect, which is needed for resonance scattering on ^{152}Sm. (see a later page)

Conservation of angular momentum



m=0

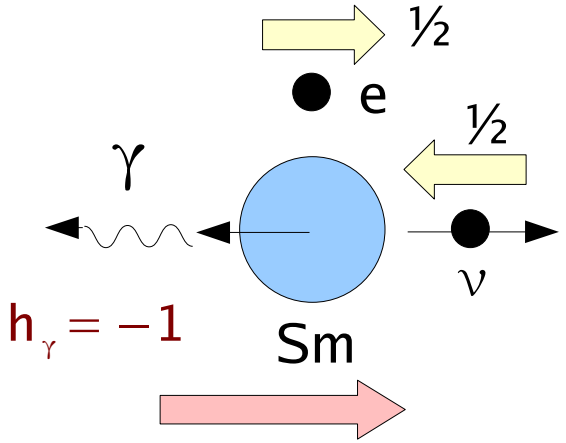
no circular polarization



m=+1

j=1

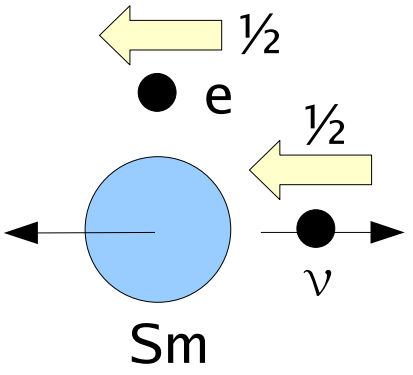
circular polarization



m=-1

j=1

circular polarization



m=0

no circular polarization

If circular polarization is observed,
and

if $h_\gamma = +1$

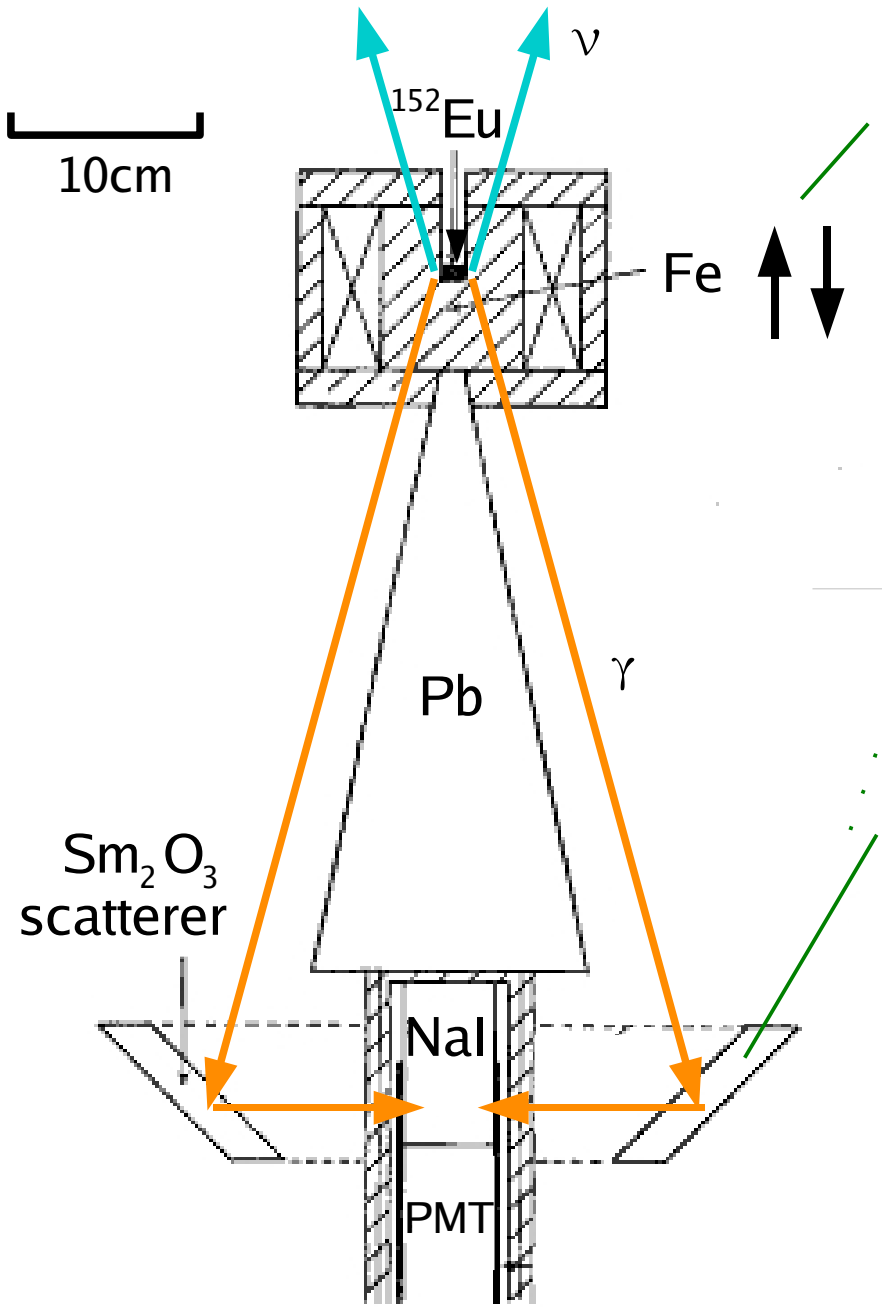
$\longrightarrow$ $h_\nu = +1$

if $h_\gamma = -1$

$\longrightarrow$ $h_\nu = -1$

The neutrino helicity can be measured this way.

Experimental arrangement



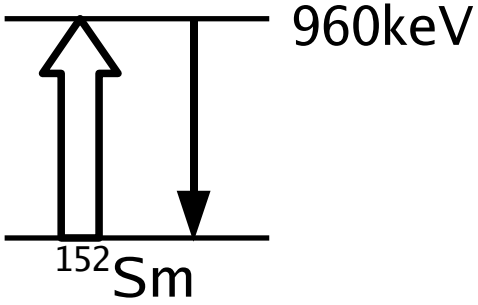
magnetic field:
up or down direction
(every 3 minutes)

Spin of electrons in Fe atom and γ
parallel : electron spin cannot flip
antiparallel : electron spin flips

Cross section of Compton scattering for antiparallel is larger than parallel.

$$\gamma + {}^{152}Sm \rightarrow {}^{152}Sm^{*} \rightarrow {}^{152}Sm + \gamma$$

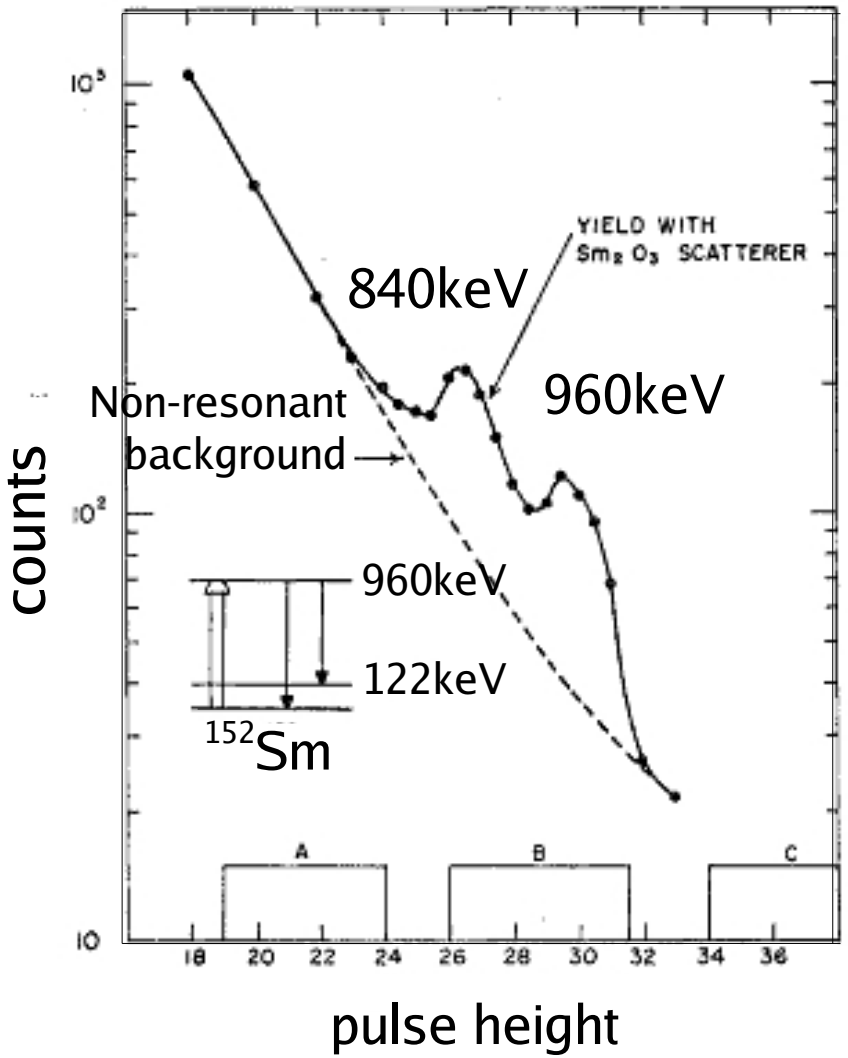
resonance scattering



$$E_{\gamma} = E_{resonance} + E_{recoil}$$

Only Doppler shifted (forward emitted) gamma rays can have resonance scattering.

3. Result



$$\delta = \frac{N_- - N_+}{1/2\,(N_- + N_+)} = +0.017 \pm 0.003$$

N_- : counting rate with magnetic field pointing down
(spin of electrons in Fe up)

N_+: pointing up

estimation

$$\delta = \begin{cases} +0.025 \cdots\cdots \text{if } h_\gamma = -1 \\ -0.025 \cdots\cdots \text{if } h_\gamma = +1 \end{cases}$$

$$N_- > N_+$$

N_- : spin of electrons in Fe up,
Compton cross section is small.
The lager transmission of gamma rays in Fe.

$$h_\gamma = -1 \longrightarrow h_\nu = -1$$

Helicity of neutrino is negative

4. Summary

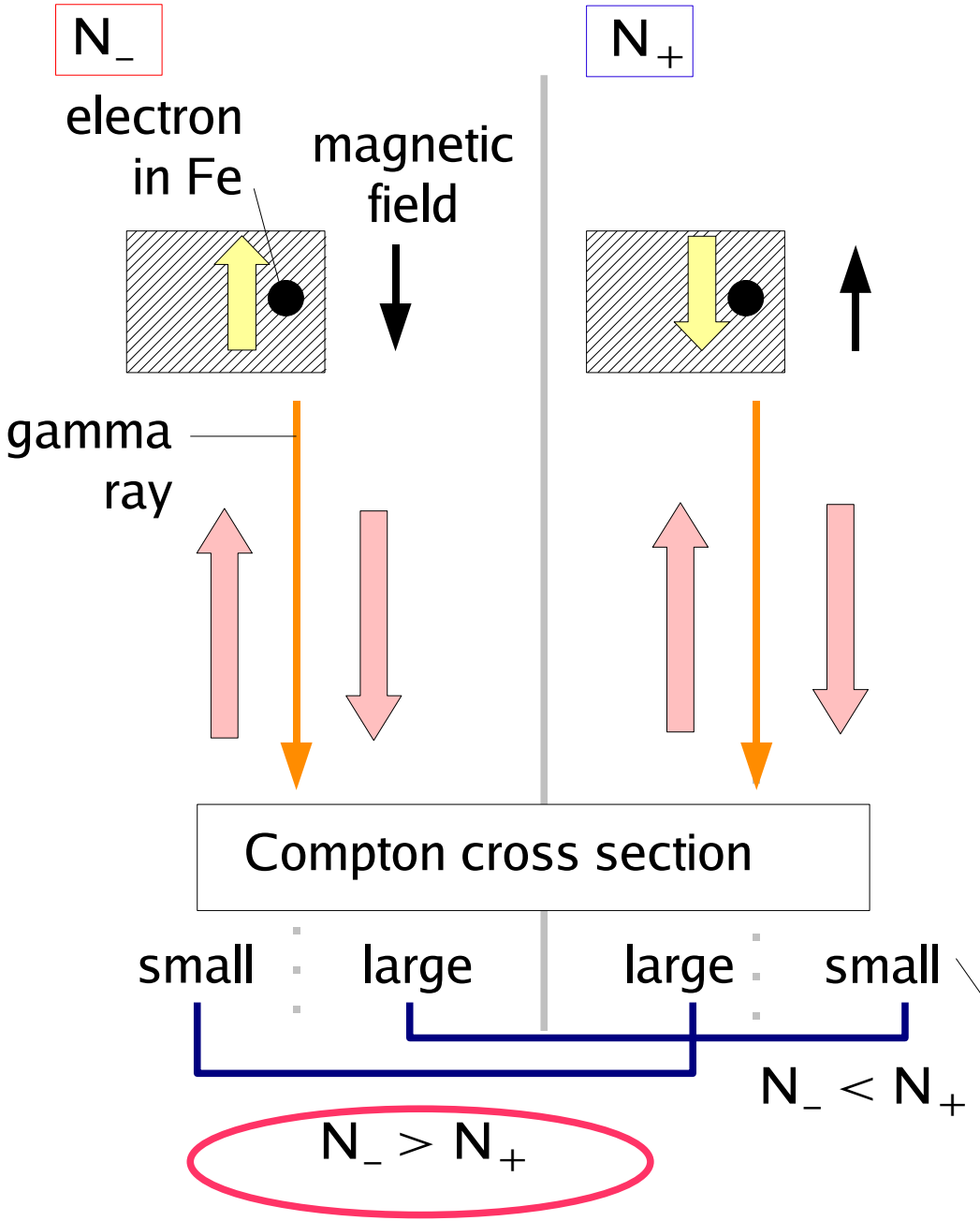
- The objective of this experiment is to determine the helicity of neutrino.
- Orbital electron capture of ^{152}Eu was used:

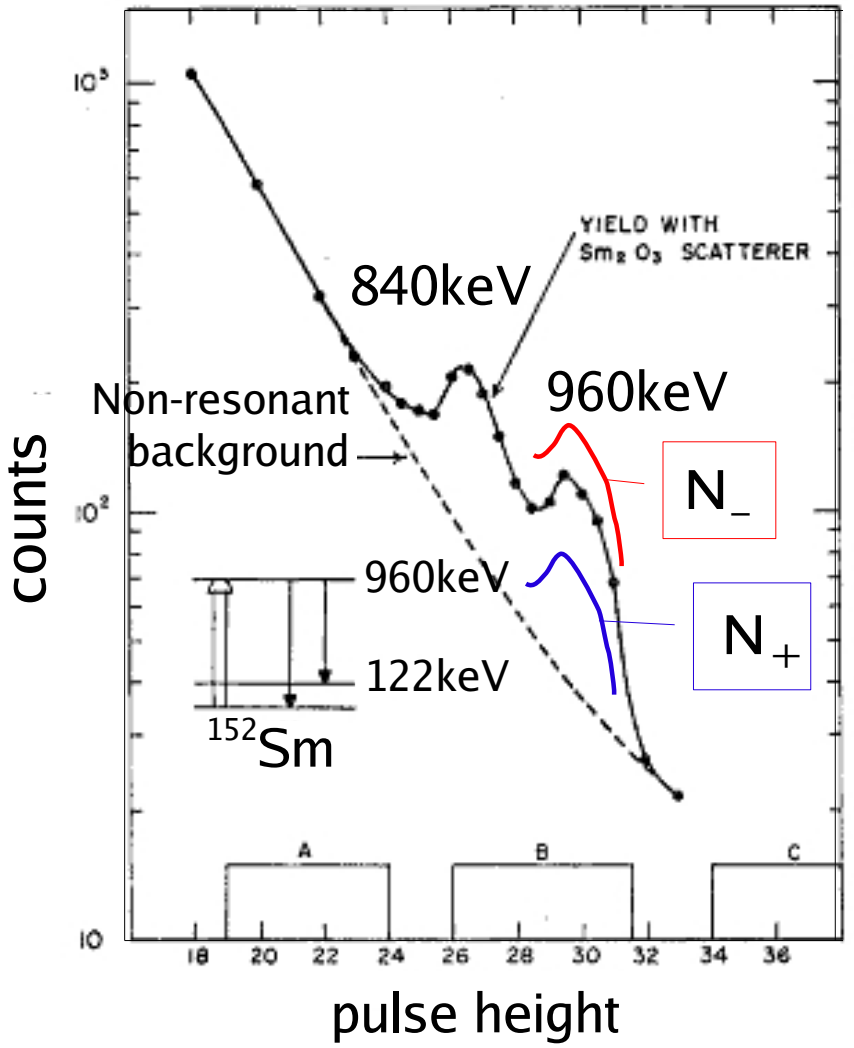
$$e^- + {}^{152}_{63}Eu \rightarrow {}^{152}_{62}Sm^* + \nu_e$$

- Gamma rays emitted in the ^{152}Sm momentum direction were selected by means of resonance scattering.
- Helicity of gamma ray was measured with a Compton polarimeter of Fe atom.
- The helicity of gamma ray was negative, which indicates $h_\nu = -1$.

→ my comment:

If helicity of neutrino is always -1, it means that neutrino travels at light velocity.
It then means that neutrino mass is 0.
So, neutrino helicity is related to neutrino mass.





Spin of electrons in Fe atom and γ cross section for antiparallel is larger than parallel.