Neutrino Physics: Lecture 2

Before oscillations: mass, helicity, Parity violation, interactions with matter

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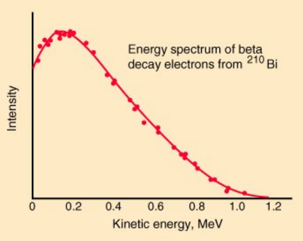
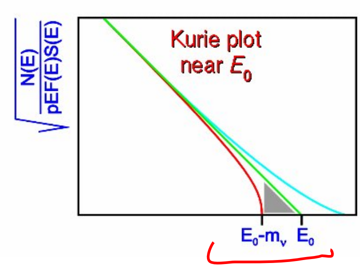
Outline

1. Direct mass measurement
2. Parity violation
3. Helicity measurement
4. Neutrino scattering in matter

Outline

The nuclear beta decay





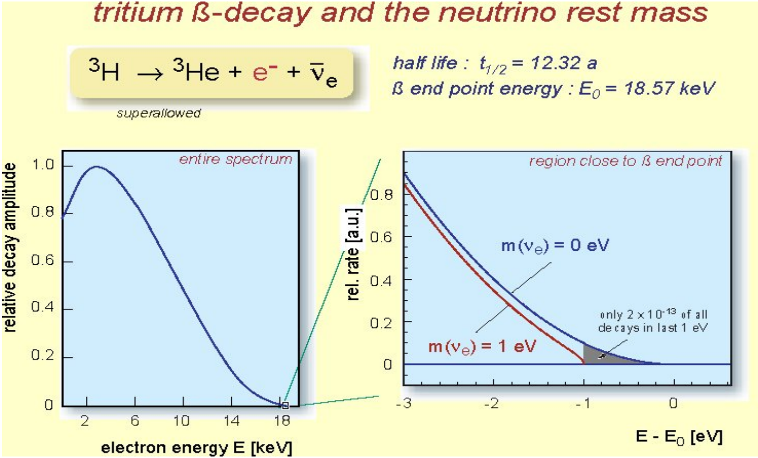
$$\frac{d\Gamma}{dE_e} \propto p_e E_e p_\nu E_\nu = p_e E_e (E_0 - E_e)\sqrt{(E_0 - E_e)^2 - m_\nu^2}$$

Kurie plot:

$$\left(\frac{d\Gamma/dE_e}{p_e E_e}\right)^{1/2} \propto \left[(E_0 - E_e)\sqrt{(E_0 - E_e)^2 - m_\nu^2}\right]^{1/2}$$

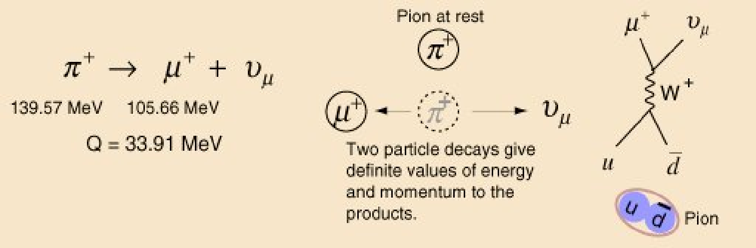
Straight line for a massless neutrino ! → $(E_0 - E_e)$

Tritium beta decay experiment



- Mainz exeriment: $m < 2.2$ eV (95% C.L.)
- Troitsk experiment: $m < 2.05$ eV (95% C.L.)
- Next generation expt: KATRIN (reach 0.2 eV)

Muon neutrino mass

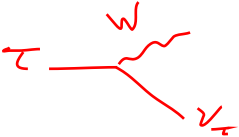


- Mass of ν_μ decides the energy of μ^+.

$$E_\mu = \frac{m_\pi^2 + m_\mu^2 - m_\nu^2}{2m_\pi}$$

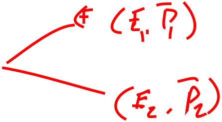
- Current limit: $m_{\nu_\mu} < 170$ keV

Tau neutrino mass



- Three-prong tau decay $\tau^- \to 2\pi^-\pi^+\nu_\tau$
- Five-prong tau decay $\tau^- \to 3\pi^-2\pi^+\nu_\tau, \tau^- \to 3\pi^-2\pi^0\nu_\tau$
- ALEPH: $m < 18.2$ MeV (95% C.L.)

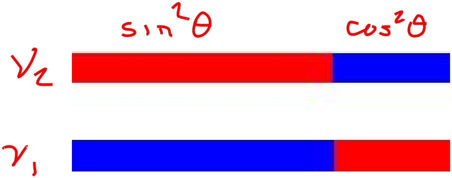
$$m^2 = (E_1+E_2)^2 - (\bar{p}_1+\bar{p}_2)^2$$



$$(E_1+E_2, \bar{p}_1+\bar{p}_2)$$

ν_e, ν_μ, ν_τ do not have fixed masses !

Mass eigenstates and flavour eigenstates:



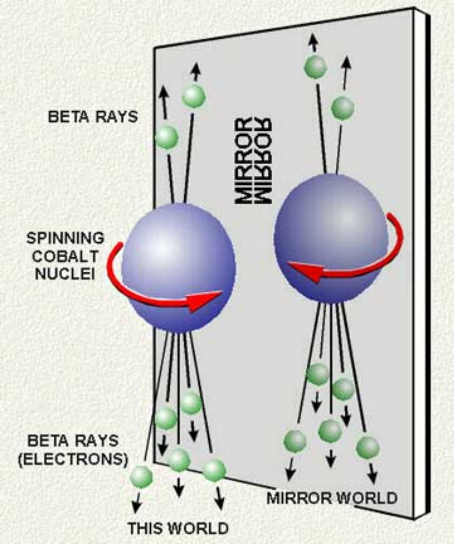
$\nu_2 = -\nu_e \sin\theta + \nu_\mu \cos\theta$

$\nu_1 = \nu_e \cos\theta + \nu_\mu \sin\theta$

Outline

Cobalt decay experiment

(Wu et al)



Pion decay experiment

(Garwin, Lederman, Weinrich)

$\pi^- \to \mu^- \to e^-$

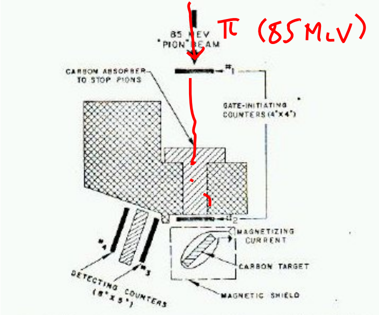


FIG. 1. Experimental arrangement. The magnetizing coil was close wound directly on the carbon to provide a uniform vertical field of 79 gauss per ampere.

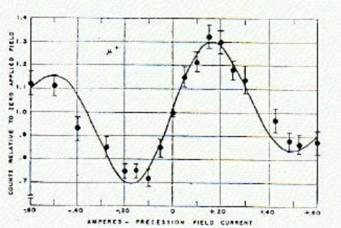
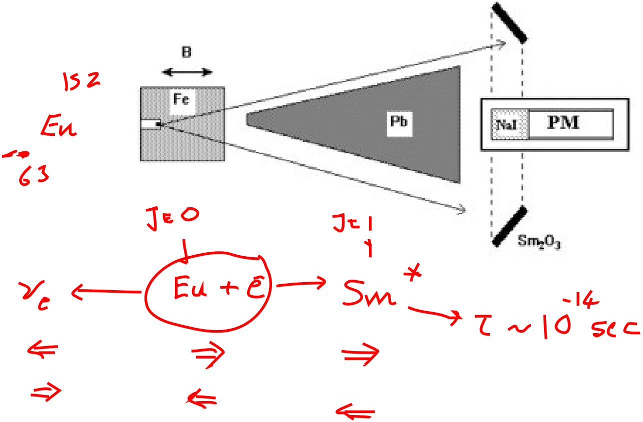


FIG. 2. Variation of gated 3–4 counting rate with magnetizing current. The solid curve is computed from an assumed electron angular distribution $1-\frac{1}{3}\cos\theta$, with counter and gate-width resolution folded in.

Angular dist of e^-

Outline

Goldhaber experiment

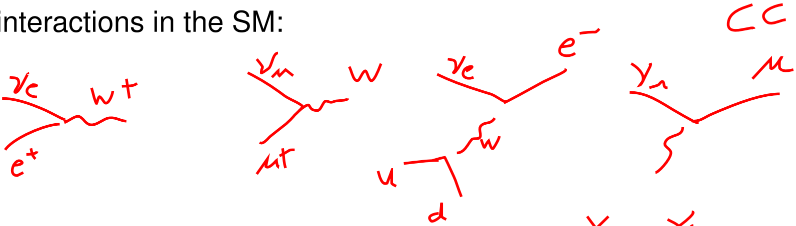


Goldhaber et al, PRL 1957
http://qd.typepad.com/6/2005/01/spinning_neutri.html

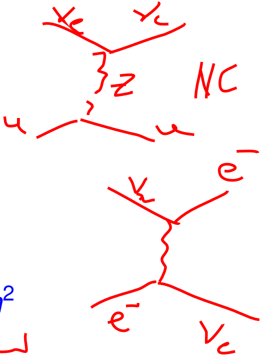
Outline

Cross section calculation

ν interactions in the SM:



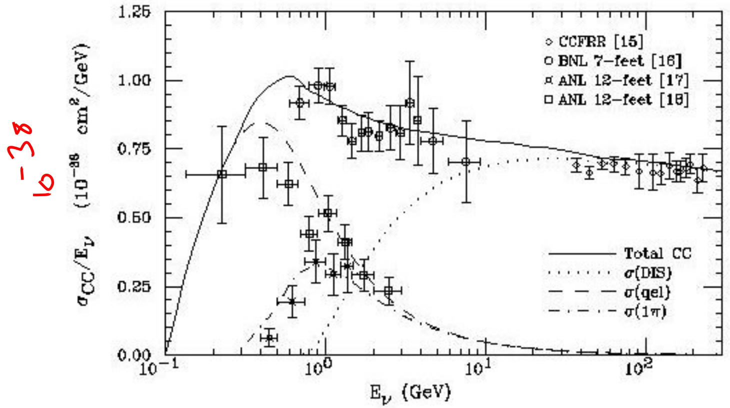
Cross sections:
http://cupp.oulu.fi/neutrino/nd-cross.html



Cross section estimation at high energies:

$$\sigma \sim G_F s \sim 10^{-44} \frac{E_\nu}{GeV} \; m^2$$

Quasi-elastic and deep inelastic scattering



Cross section in a scintillator detector: various processes