Neutrinoless Double Beta Decay Experiments and Leptogenesis Scenario of Early Universe

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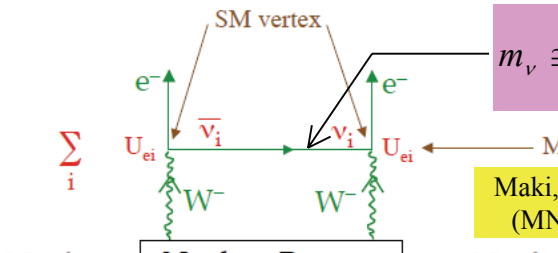
Abstract: Neutrinoless double beta decay (0νββ) takes place only when neutrinos are Majorana neutrinos that have the nature of no distinction between particles and their own anti-particles. Majorana neutrino plays important role in the theory called Seesaw Mechanism, in which a left-handed Majorana neutrino (LMN) can obtain its mass independently of a right-handed Majorana neutrino (RMN). The product of two masses of LMN and RMN is equal to a Dirac particle mass squared. Therefore, when the mass of RMN is extremely large, the one of LMN naturally becomes very small. The LMN is considered as known neutrino weakly interacting. In the Leptogenesis scenario, heavy RMNs have been produced in early universe. The heavy RMNs can asymmetrically decay to leptons over anti-leptons. This is the reason why the present universe is filled with matter without anti-matter. Observation of 0νββ would be evidence of Seesaw Mechanism and Leptogenesis. The R&D of tracking detectors for 0νββ are developed at KEK and in Europe under the program of France Japan Particle Physics Laboratory (FJPPL).

Neutrinoless Double Beta Decay (0νββ)

Lepton Number Violation Process
ΔL=2



A: Mass number
Z: Atomic number

(From Boris Kayser at APS – JPS meeting at Hawaii, Oct. 13, 2009)

$\nu = \overline{\nu}$

$m_\nu \cong \frac{m_D^2}{m_N} < 0.4\ \text{eV}$

Mixing matrix

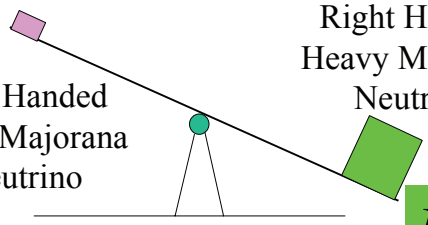
Maki, Nakagawa, Sakata (MNS Matrix) (1962)

$T_{1/2}^{0\nu} \propto \frac{1}{m_{\beta\beta}^2}$

$\approx 10^{26}$ y

Effective neutrino mass: $m_{\beta\beta} = \left|\sum m_i U_{ei}^2\right| \approx 0.05\text{eV}$

Seesaw Mechanism



Yanagida
Gell-Mann, Ramond, Slansky (1979)
Mohapatra, Senjanovic
Minkowski

$N = \overline{N}$

$m_N \approx \frac{m_{top}^2}{m_\nu (\approx 0.05\text{eV})}$

$\approx 10^{15}$ GeV

Leptogenesis

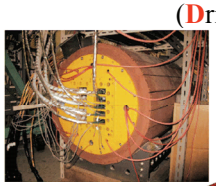
N would have been made in the hot Big Bang

$\Gamma(N \to l^- H^+) \neq \Gamma(N \to l^+ H^-)$

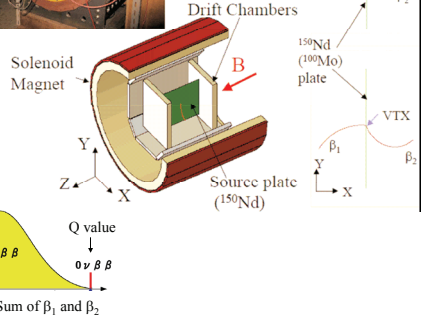
Fukugita, Yanagida (1986)

0νββ Experiment DCBA at KEK

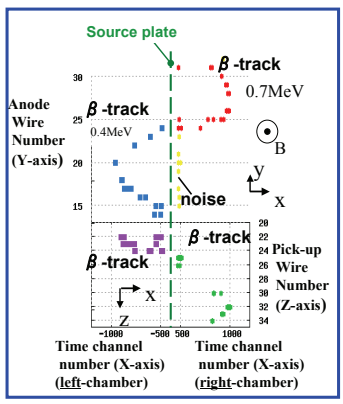
(Drift Chamber Beta-ray Analyzer)



DCBA-T2



2νββ event



Baryon Asymmetry

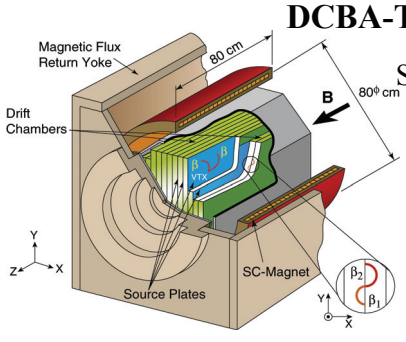
The Standard-Model *Sphaleron* process, which does not conserve Baryon Number *B*, or Lepton Number *L*, but does conserve *B* – *L*, acts.

Initial state from N decays

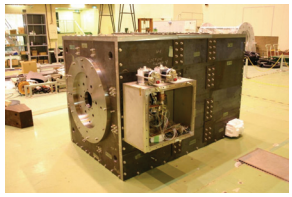
Final state

(From Boris Kayser at APS – JPS meeting at Hawaii, Oct. 13, 2009)

DCBA-T3

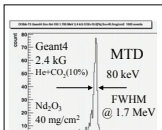


Super Conducting Magnet



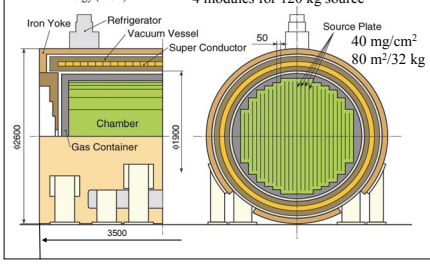
Under construction

R&D of Future Tracking Detectors for 0νββ under France Japan Particle Physics Laboratory (FJPPL)



Magnetic Tracking Detector (MTD) based on DCBA

4 modules for 120 kg source



SuperNEMO in Europe based on NEMO3