8.701

Introduction to Nuclear and Particle Physics

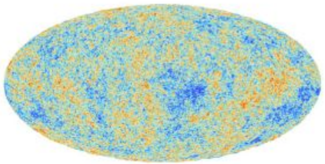
Markus Klute - MIT

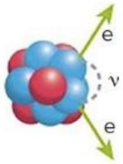
8. Neutrinos

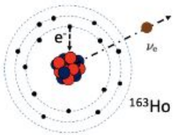
8.6 Mass Scale and its Nature

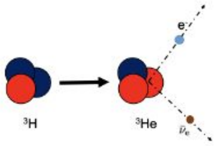
Complementary Approaches

Three different combination of masses



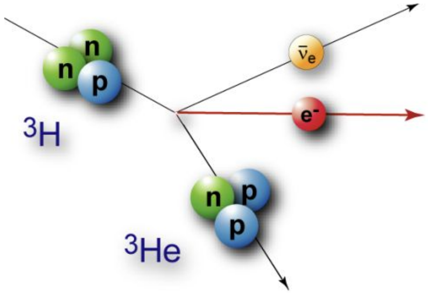






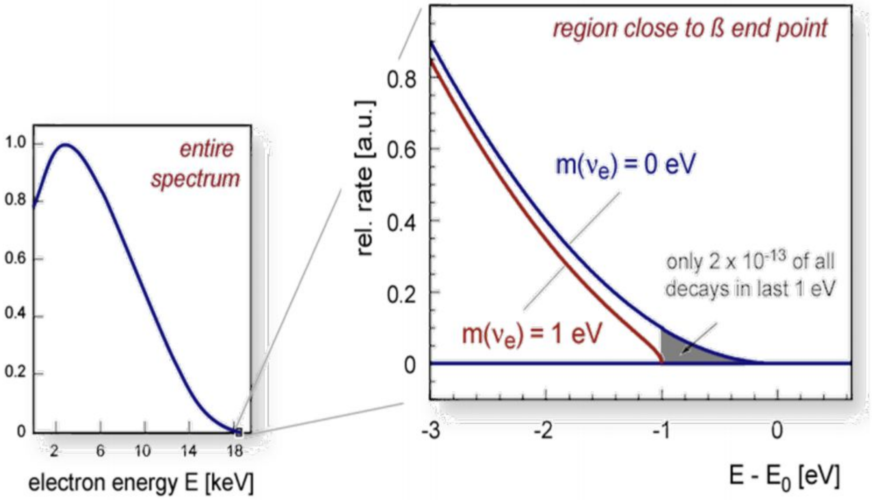
Tool	Cosmology CMB + BAO + LSS	0νββ - decay	β⁻ decay endpoint and EC
Observable	$m_{\cos} = \sum_{i=1}^{3} m_i$	$m_{0\nu\beta\beta} = \sum_{n=1}^{3} \lvert U_{e,n}\rvert^2 e^{i\alpha_n} m_n$	$m_\beta = \sqrt{\sum_{n=1}^{3} \lvert U_{e,n}\rvert^2 m_n^2}$
Present best limit	0.15 - 1 eV	0.2 - 0.4 eV	1.1 eV
Potential reach	20-50 meV	20-50 meV	40 meV
Model dependence	Multi-parameter cosmological model	Majorana or Dirac? Nucl. matrix elements Phase cancellation	Kinematic: Momentum and Energy conservation

Neutrino Mass Measurement



	^3H
	super-allowed β-decay
$T_{1/2}$	12.3 years
E_0	18.56 keV

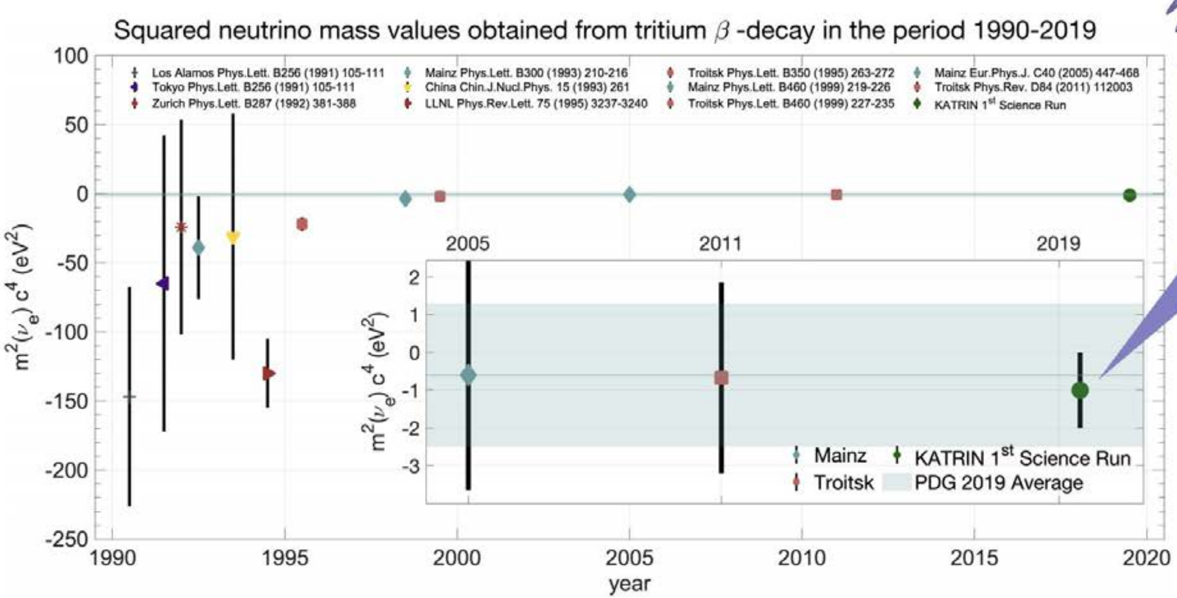
$$m^2(\nu_e) = \sum_i |U_{ei}|^2 \cdot m_i^2$$



Katrin Result

$m_\nu < 1.1$ eV (90% C.L.)

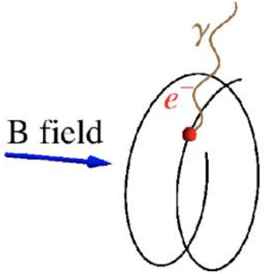
Historical context



Effective 5 days of data

- Stat. error: ÷ 2
- Syst. error: ÷ 6

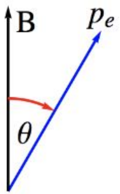
Project 8

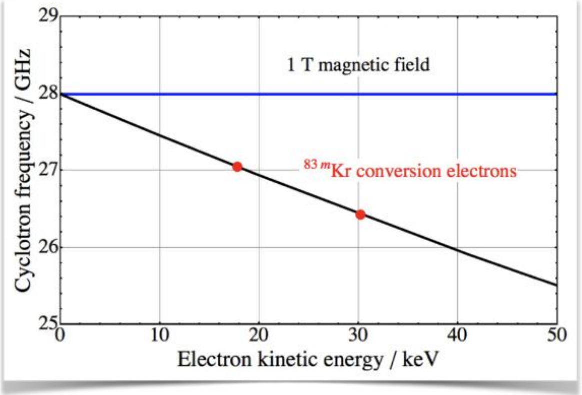


Novel approach: J. Formaggio and B. Monreal, Phys. Rev D 80:051301 (2009)

- Cyclotron radiation from single electrons
- Source transparent to microwave radiation
- No e- transport from source to detector
- Highly precise frequency measurement

$$f_c = \frac{1}{2\pi} \frac{eB}{m_e + E_{kin}/c^2}$$





$$P(E_{kin}, m, \theta) = \frac{1}{4\pi\epsilon_0} \frac{2}{3} \frac{e^4}{m^4 c^5} B^2 \left(E_{kin}^2 + 2\, E_{kin}\, m\, c^2\right) \sin^2\theta$$

Searches for Majorana Neutrino

Nuclear 0νββ-decay