

8.701

Introduction to Nuclear
and Particle Physics

Markus Klute - MIT

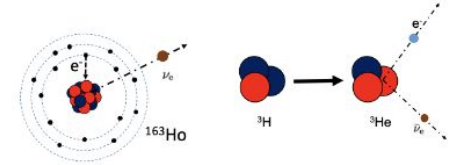
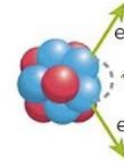
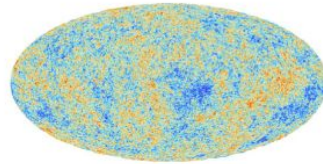
8. Neutrinos

8.6 Mass Scale and its
Nature



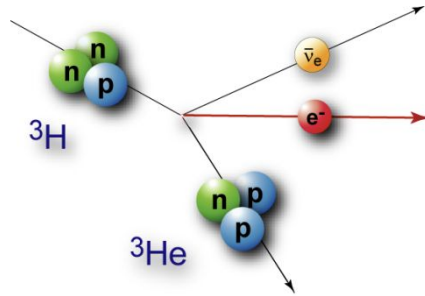
Complementary Approaches

Three different
combination of
masses

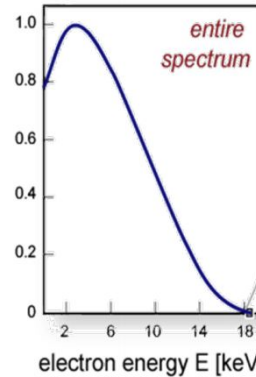


Tool	Cosmology CMB + BAO + LSS	$0\nu\beta\beta$ - decay	β - decay endpoint and EC
Observable	$m_{\text{cos}} = \sum_{i=1}^3 m_i$	$m_{0\nu\beta\beta} = \sum_{n=1}^3 U_{e,n} ^2 e^{i\alpha_n} m_n$	$m_\beta = \sqrt{\sum_{n=1}^3 U_{e,n} ^2 m_n^2}$
Present best limit	0.15 - 1 eV	0.2 - 0.4 eV	1.1 eV
Potential 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

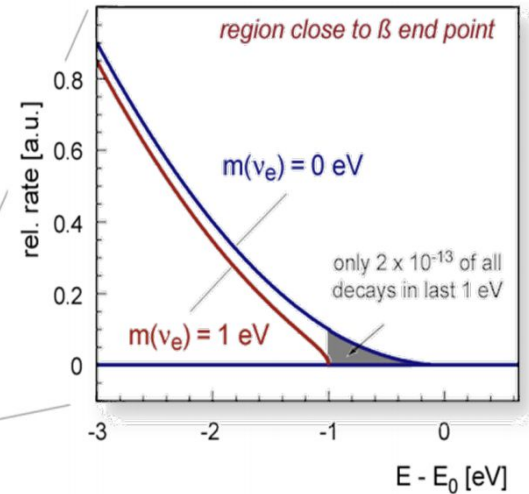
Neutrino Mass Measurement



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



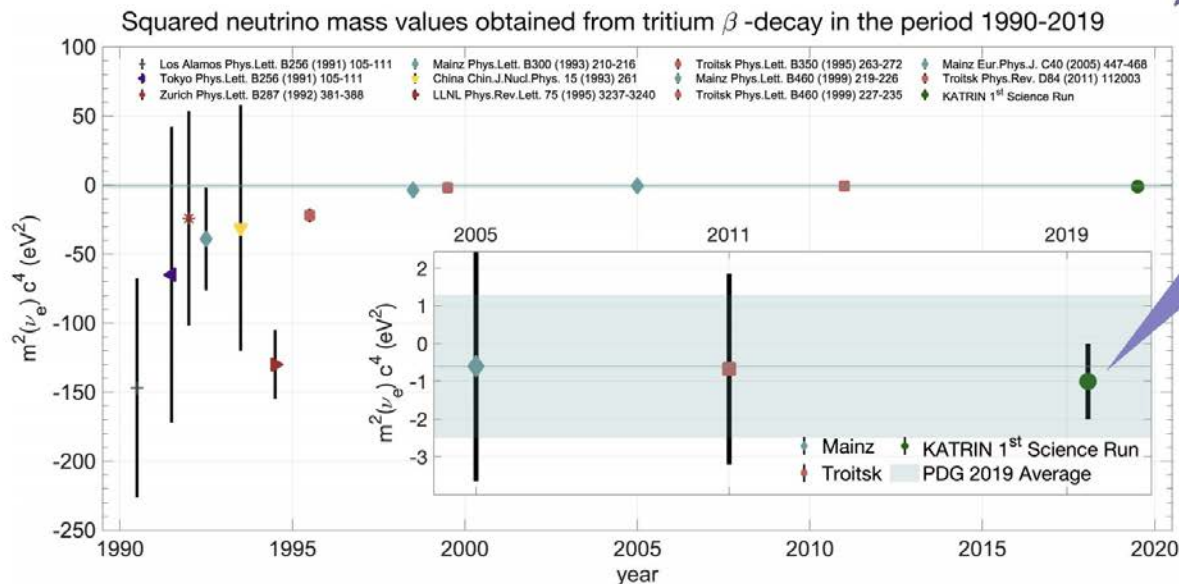
$$m^2(\nu_e) = \sum_i |U_{ei}|^2 \cdot m_i^2$$



Katrin Result

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

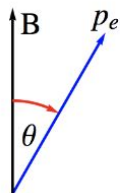
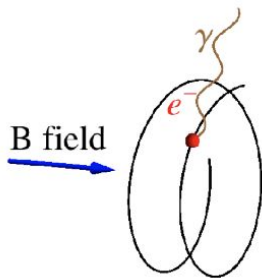
Historical context



Effective 5 days of data

- Stat. error: ± 2
- Syst. error: ± 6

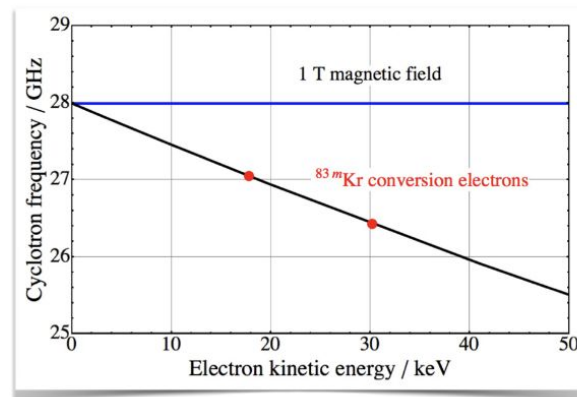
Project 8



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

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

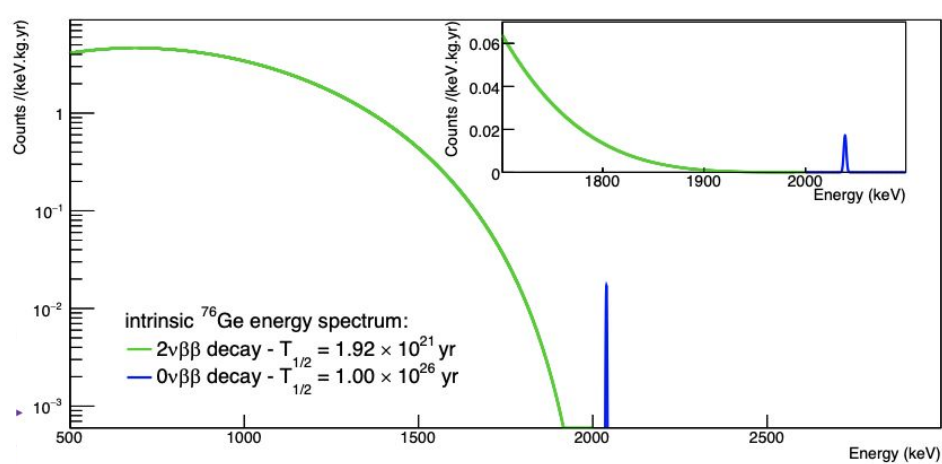
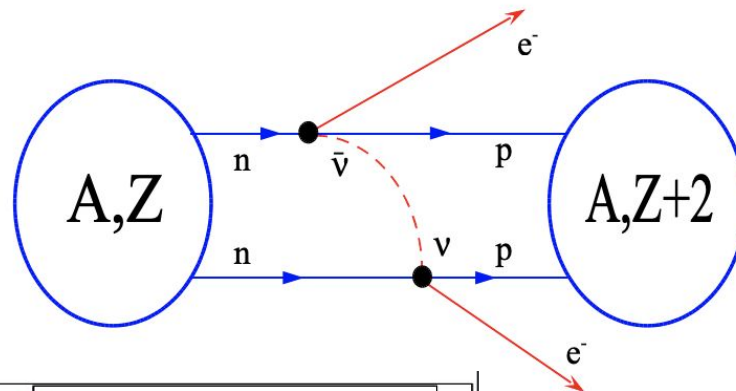


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$$P(E_{\text{kin}}, m, \theta) = \frac{1}{4\pi\epsilon_0} \frac{2}{3} \frac{e^4}{m^4 c^5} B^2 (E_{\text{kin}}^2 + 2 E_{\text{kin}} m c^2) \sin^2 \theta$$

Searches for Majorana Neutrino

Nuclear $0\nu\beta\beta$ -decay



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