8. Neutrinos

8.6 Mass Scale and its Nature
## Complementary Approaches

Three different combination of masses

<table>
<thead>
<tr>
<th>Tool</th>
<th>Cosmology CMB + BAO + LSS</th>
<th>$0\nu\beta\beta$ - decay</th>
<th>$\beta^+\beta^-$ decay endpoint and EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observable</td>
<td>$m_{\text{coll}} = \sum_{i=1}^{3} m_{i}$</td>
<td>$m_{0\nu\beta\beta} = \sum_{n=1}^{9}</td>
<td>U_{e,n}</td>
</tr>
<tr>
<td>Present best limit</td>
<td>0.15 - 1 eV</td>
<td>0.2 - 0.4 eV</td>
<td>1.1 eV</td>
</tr>
<tr>
<td>Potential reach</td>
<td>20-50 meV</td>
<td>20-50 meV</td>
<td>40 meV</td>
</tr>
<tr>
<td>Model dependence</td>
<td>Multi-parameter cosmological model</td>
<td>Majorana or Dirac? Nucl. matrix elements Phase cancellation</td>
<td>Kinematic: Momentum and Energy conservation</td>
</tr>
</tbody>
</table>
Neutrino Mass Measurement

$\begin{align*}
\begin{array}{l}
\text{super-allowed } \beta\text{-decay} \\
T_{1/2} & 12.3 \text{ years} \\
E_0 & 18.56 \text{ keV}
\end{array}
\end{align*}$

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

© Source unknown. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse.
Katrin Result

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

Historical context

Squared neutrino mass values obtained from tritium $\beta$-decay in the period 1990-2019

Effective 5 days of data
- Stat. error: $\pm 2$
- Syst. error: $\pm 6$
**Project 8**


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

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

\[ P(E_{\text{kin}}, m, \theta) = \frac{1}{4\pi\varepsilon_0} \frac{2}{3} \frac{e^4}{m^4 c^5} B^2 \left( E_{\text{kin}}^2 + 2 E_{\text{kin}} m c^2 \right) \sin^2 \theta \]
Searches for Majorana Neutrino

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

© GERDA. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse.