

Sensitivity of Future Tritium Decay Experiments to New Physics

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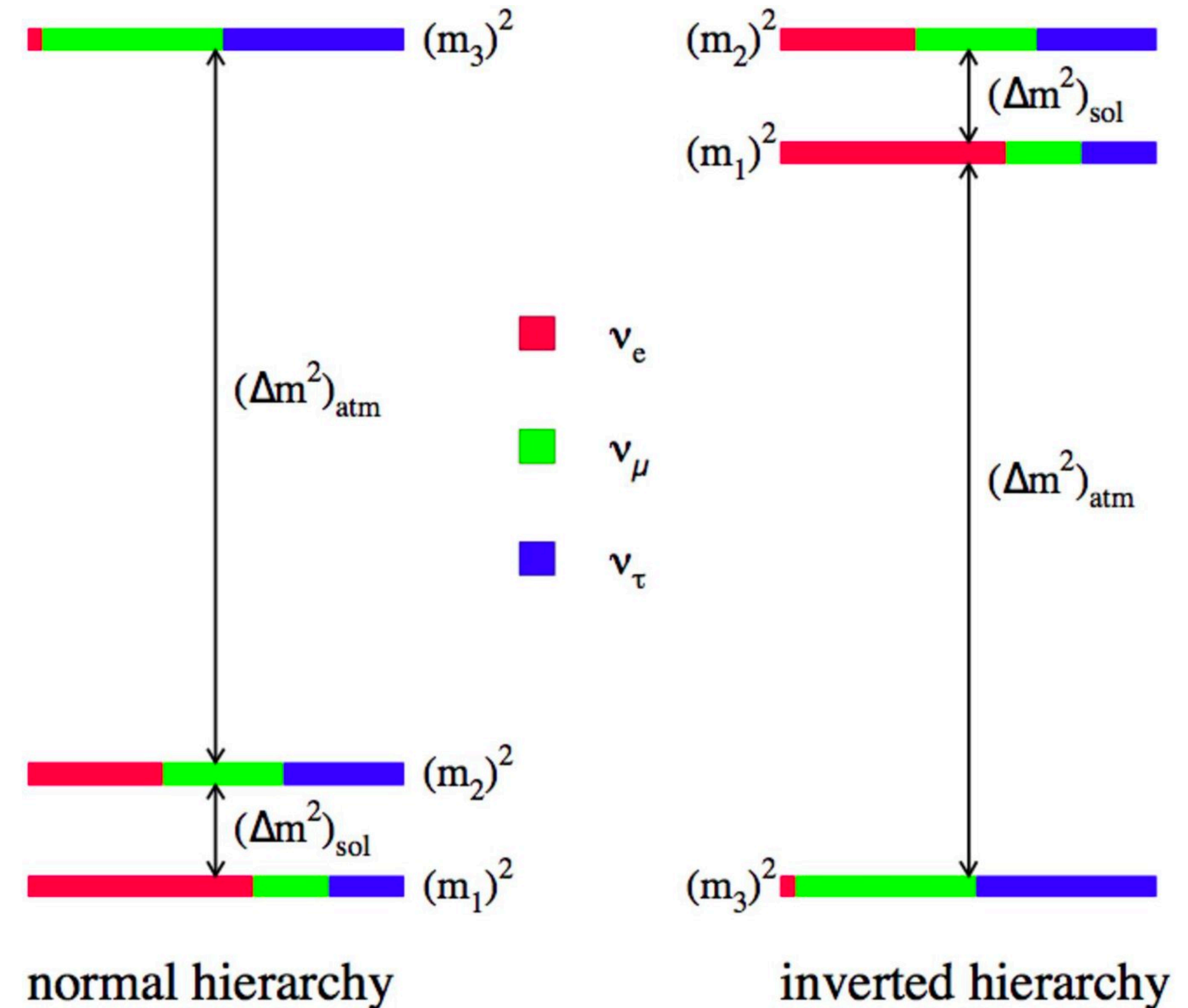
NExT, April 26

Oscillations & Mass Hierarchy

- Oscillation of SM neutrinos between flavour states observed
- Neutrinos are massive
- Oscillation only provides information about mass splittings, not the actual mass scale

$$\nu_\alpha = \sum_i U_{\alpha i} \nu_i$$

- Two possible mass orderings: Normal Ordering (NO) and Inverted Ordering (IO)
- Currently mass ordering is unknown



Cosmology

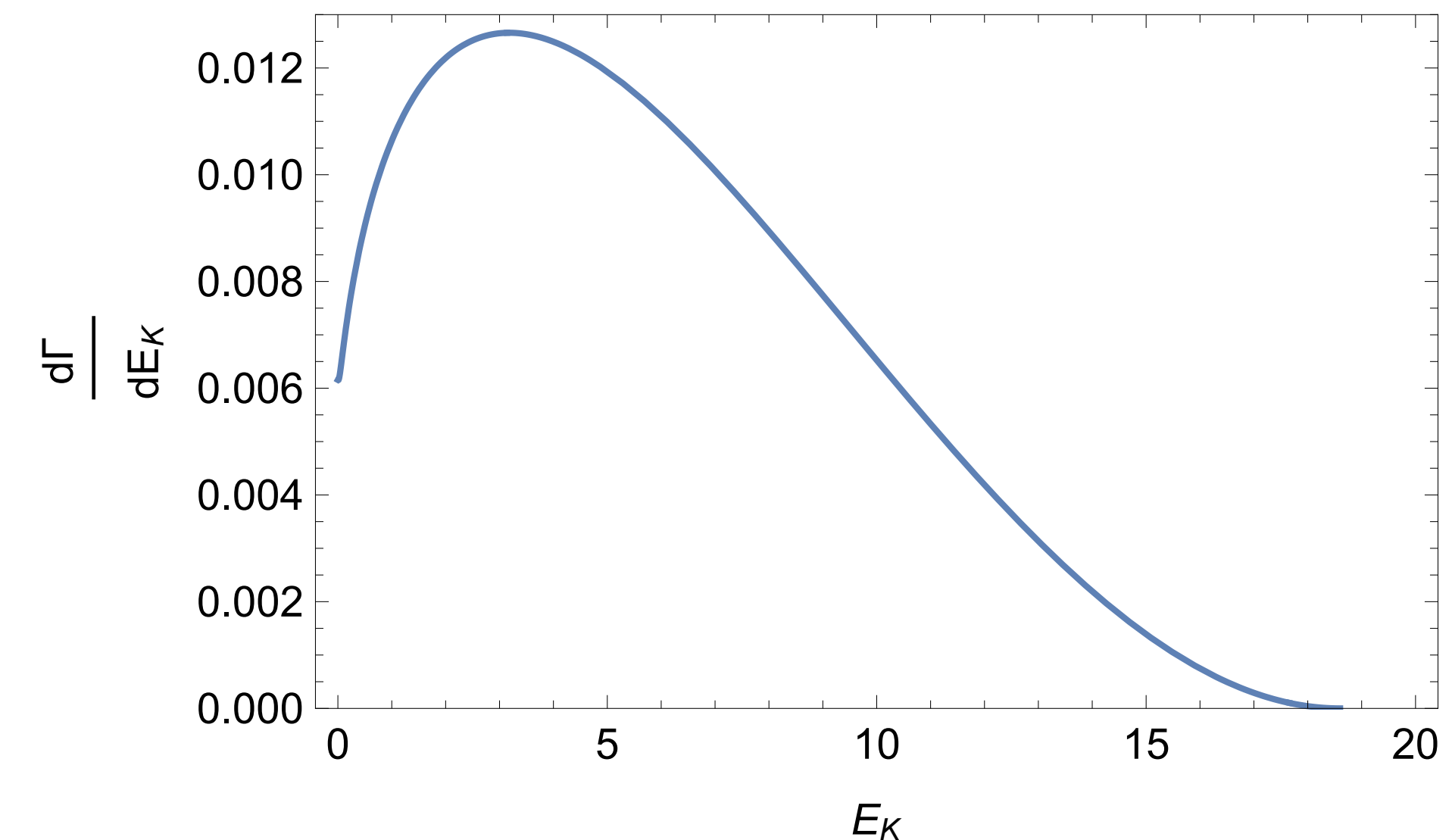
- CMB, BAO, H
- Strongest upper-bound
- Model dependent

$0\nu\nu\beta$

- Two simultaneous beta-decays with neutrino exchange
- Requires neutrinos to be **Majorana**
- Model dependent

Beta-decay

- Model **independent**
- Focus of this talk



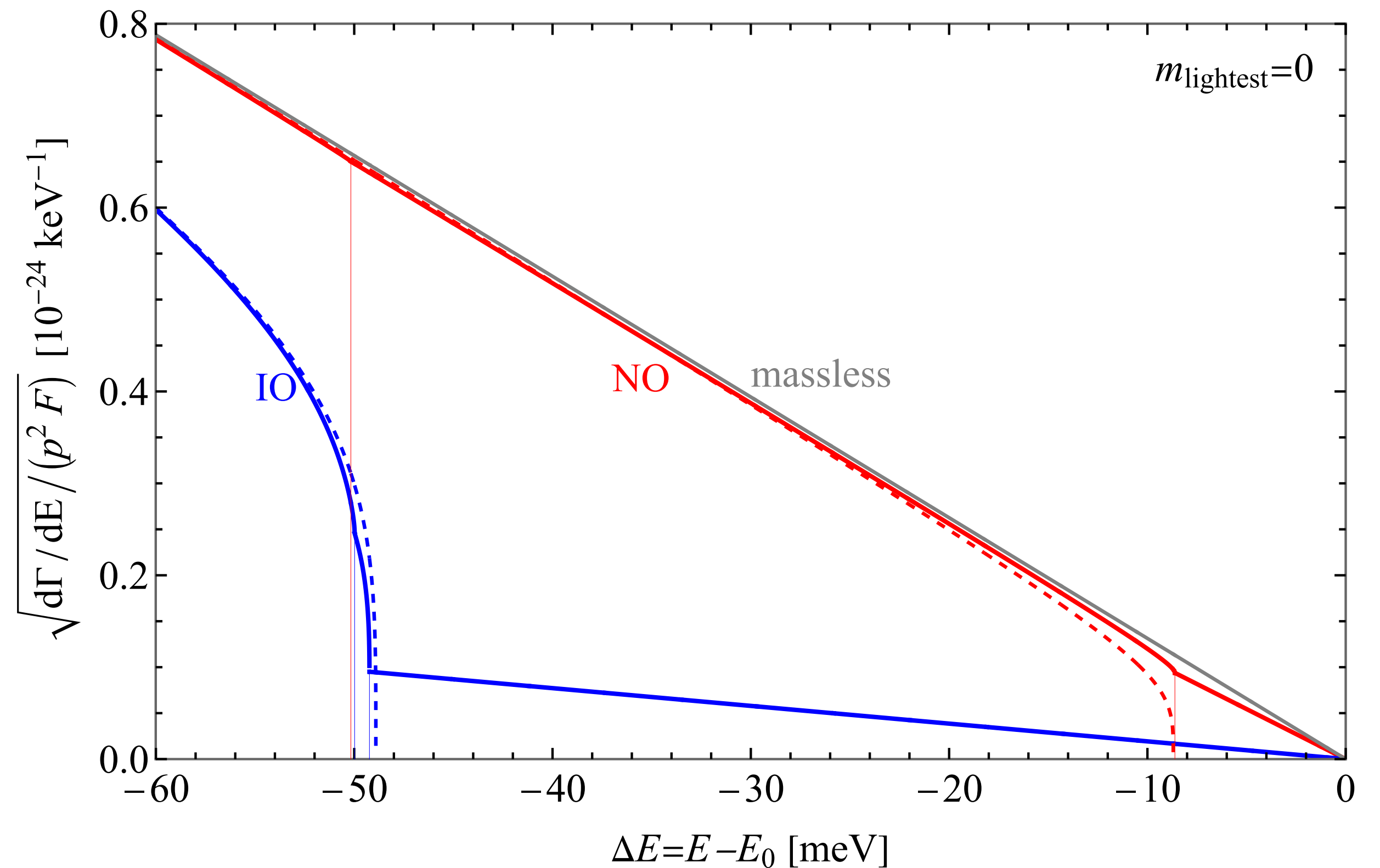
Beta-decay

- Electron and anti-neutrino emitted
- Beta-decay experiments attempt to perform precision measurements near **end-point** of energy distribution, where the neutrino signature is most pronounced

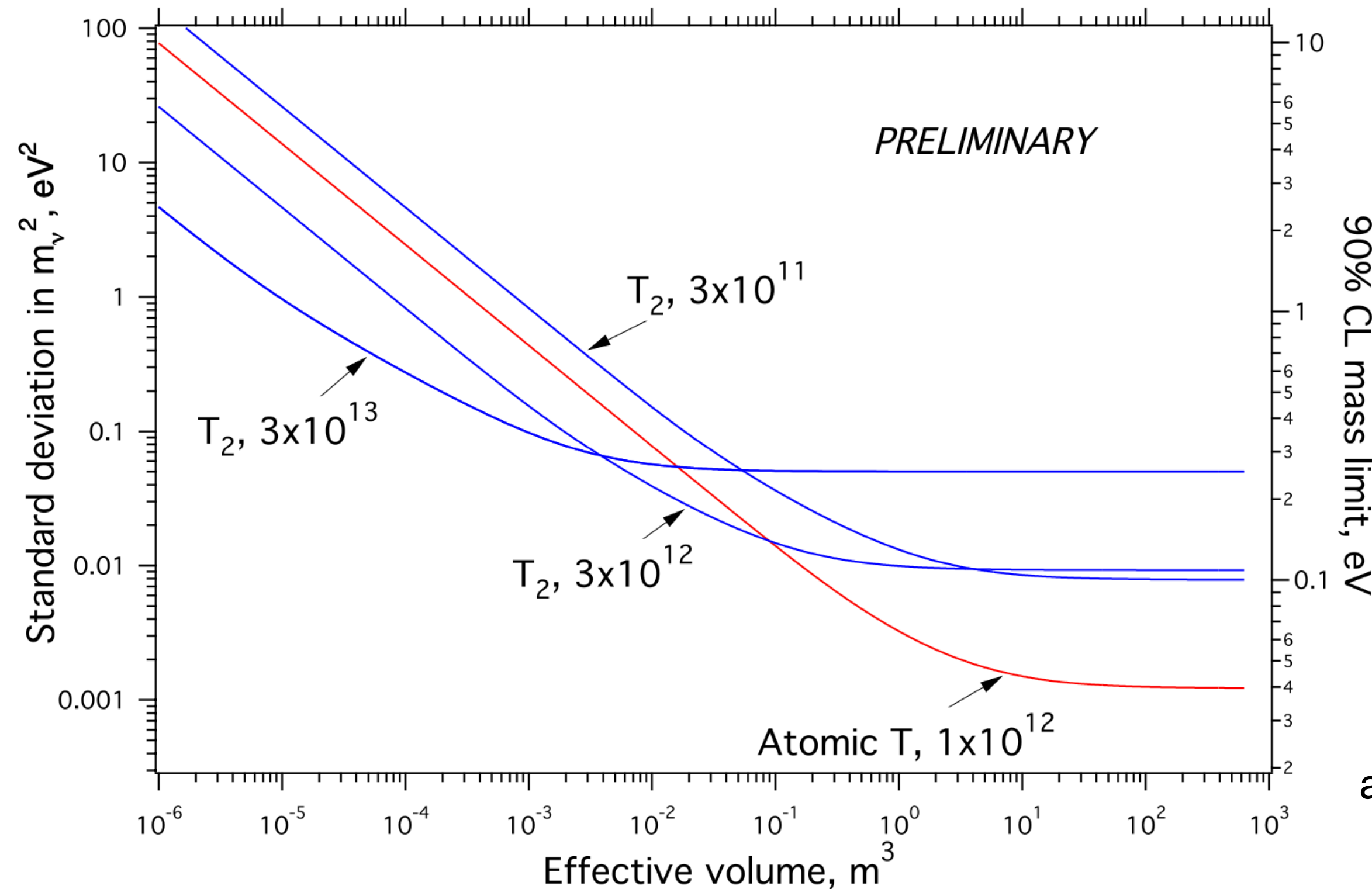
effective mass

$$m_{\beta}^2 = \sum_{i=1}^3 |U_{ei}|^2 m_i^2$$

Current best bound is
0.8 eV by KATRIN



- Low measurement uncertainty required
- Novel idea of Cyclotron Radiation Emission Spectroscopy (**CRES**)
- CRES and use of atomic tritium promising combination



Project 8 and CRES Demonstration Apparatus (CRESDA)

$$f = \frac{1}{2\pi} \frac{eB}{E_e}$$

arXiv: 1309.7093v1

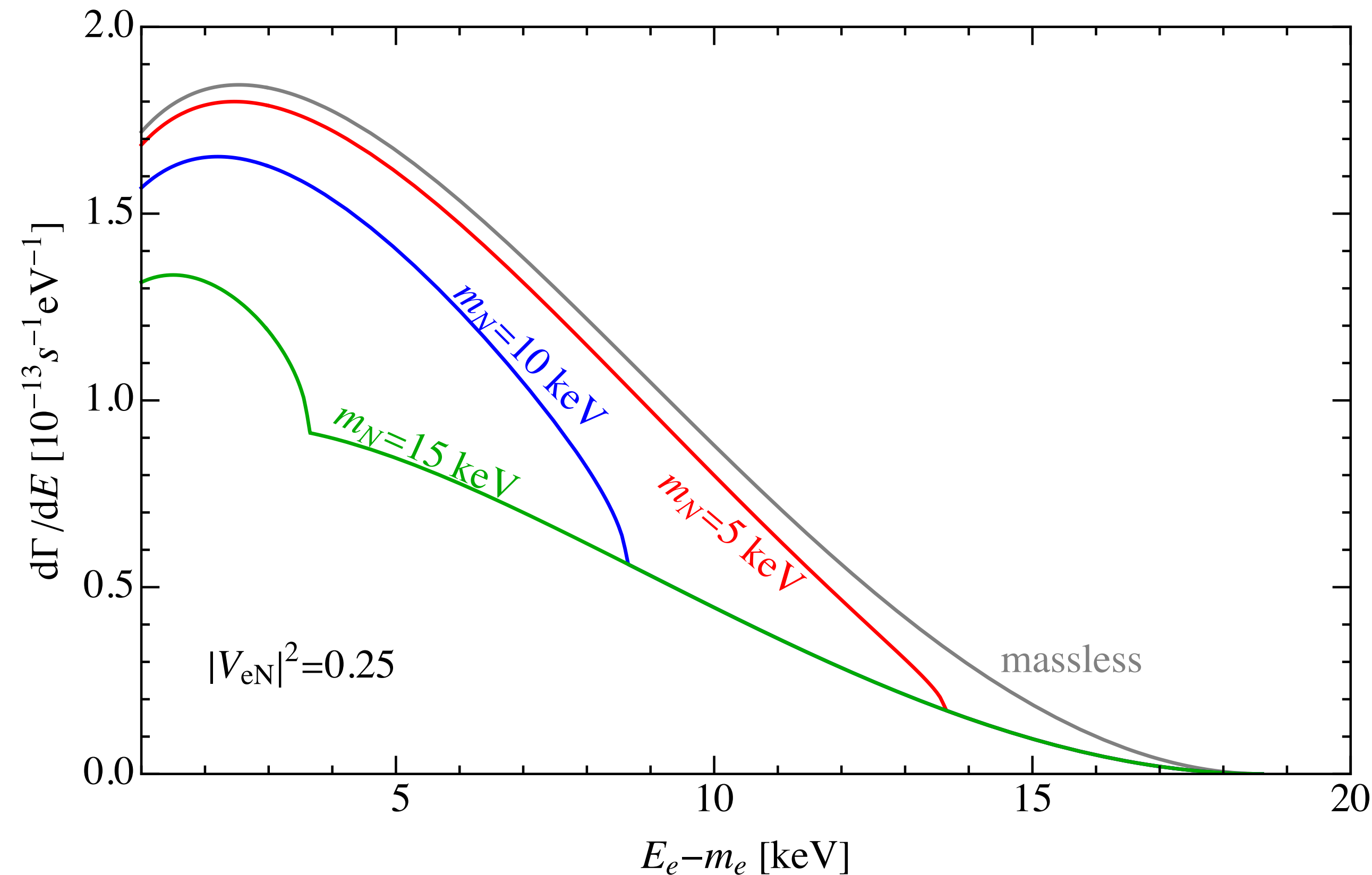
Sterile States

- In one active + one sterile model
- Sterile neutrino with mass $0 < m_N \leq 18.6$ keV produces kink
- **CRES experiments with aim of measuring active mass could also be used for sterile searches**

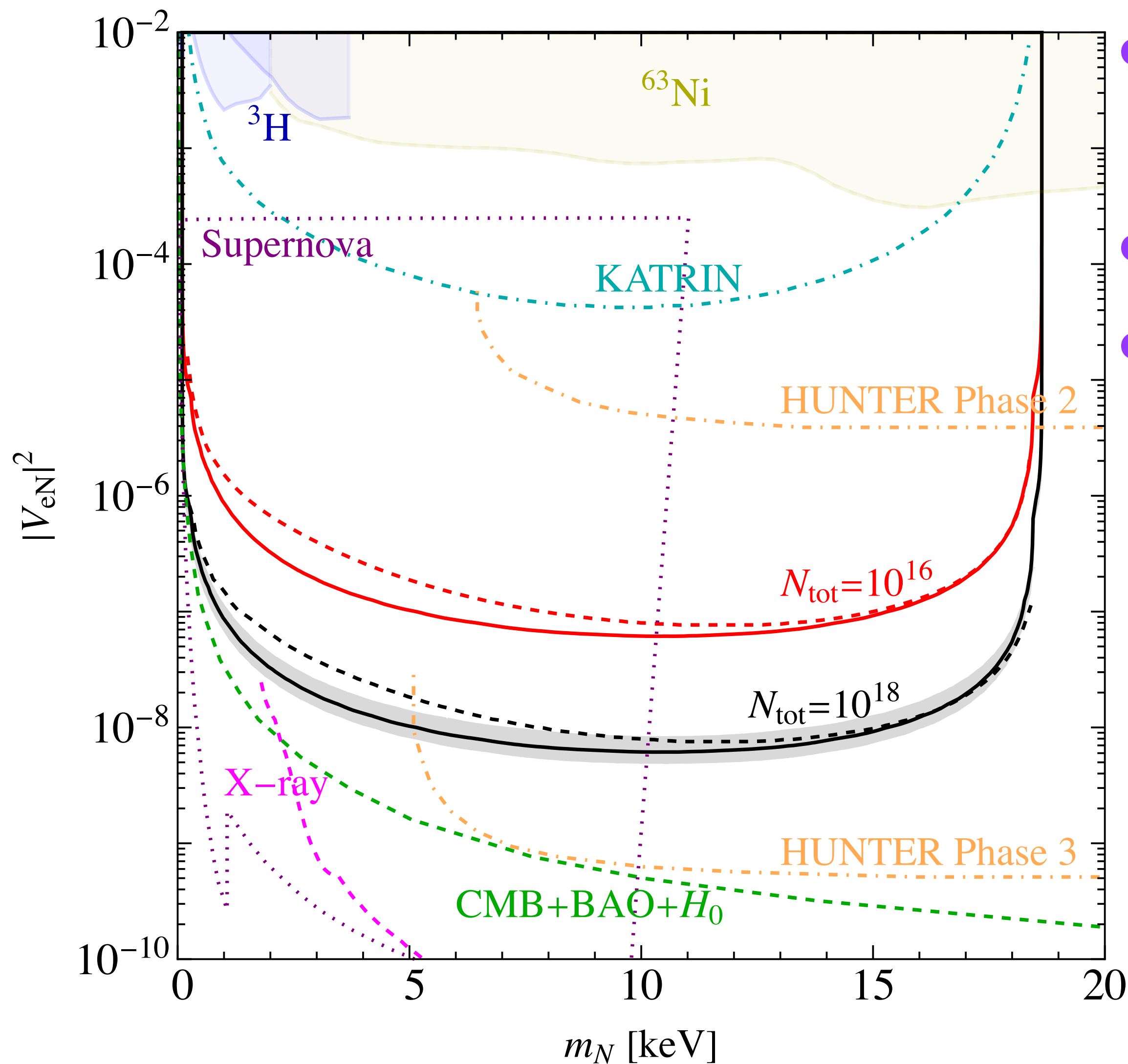
$|V_{eN}|^2 \longrightarrow$ active-sterile mixing angle

$$\frac{d\Gamma_{tot}}{dE_K} = (1 - |V_{eN}|^2) \frac{d\Gamma_{SM}}{dE_K} + |V_{eN}|^2 \frac{d\Gamma_{sterile}}{dE_K}$$

$$\begin{cases} \nu_e = \sqrt{1 - |V_{eN}|^2} \nu_1 + |V_{eN}| \nu_2 \\ N = -|V_{eN}| \nu_1 + \sqrt{1 - |V_{eN}|^2} \nu_2 \end{cases}$$



Projected Limits



- In this mass range, currently best bound is of order $10^{-2} - 10^{-3}$
- Performed χ^2 and used Asimov data set
- Our analysis shows **sensitivities of order 10^{-8} are achievable**, for a total statistics of 10^{18} events (black line = statistical limit)

Sufficient to distinguish between NO and IO hierarchies

$$t \stackrel{\text{min}, A}{=} \left[\sum_{i=1}^{N_{bins}} \frac{(N_{BSM}^{(i)} - (1 + A)N_{SM}^{(i)})^2}{(1 + A)N_{SM}^{(i)}} + \left(\frac{A}{\sigma_A} \right)^2 \right]$$

Exotic Lagrangian

$$\mathcal{L}_{SM} = -\frac{G_F}{\sqrt{2}} V_{ud} U_{ei} (\bar{e}_s \gamma^\alpha (\mathbb{1} - \gamma^5) \nu_{i,s}) \left(\overline{{}^3H} e_s \gamma_\alpha (g_V \mathbb{1} - g_A \gamma^5) {}^3H_s \right),$$

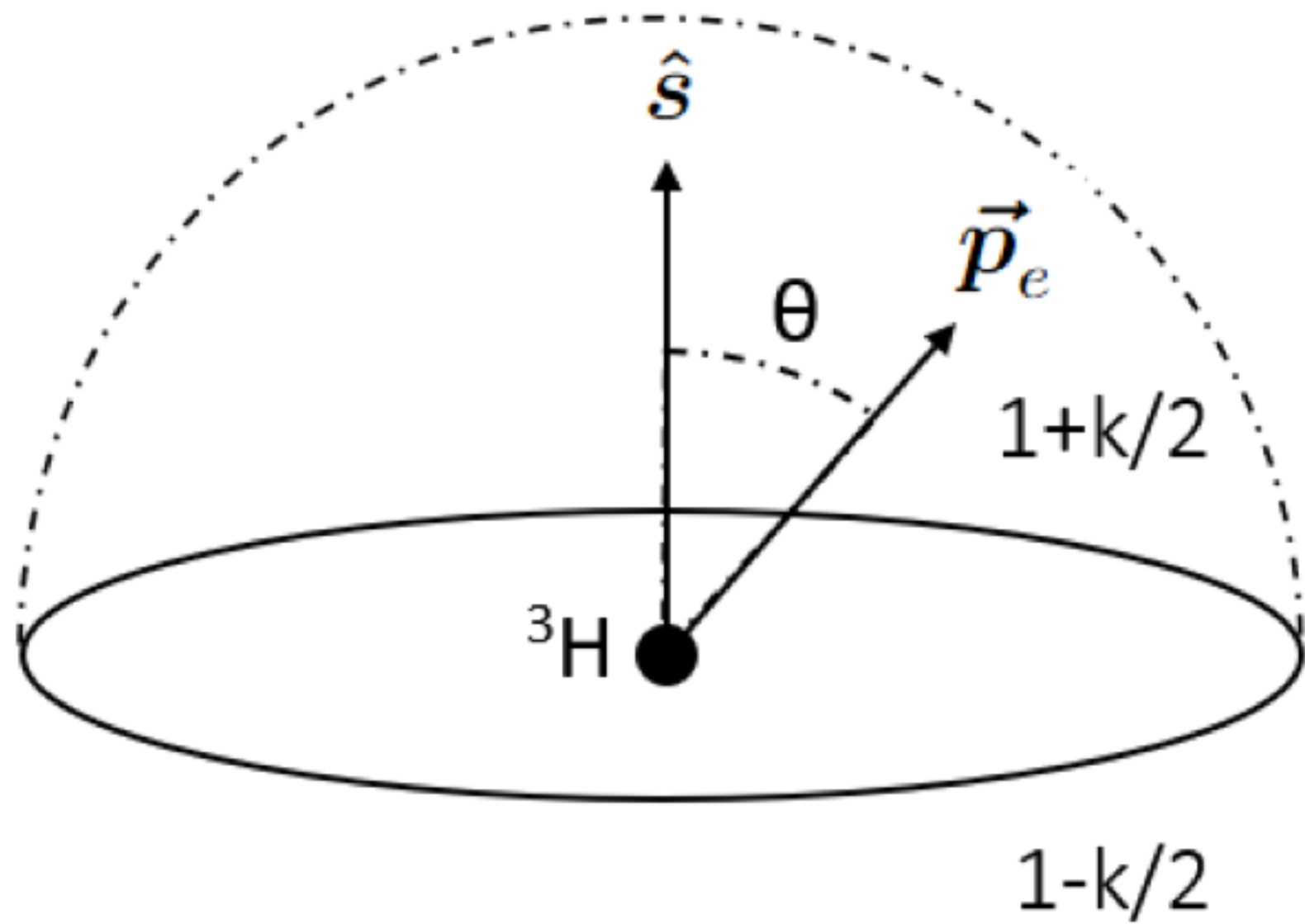
$$\mathcal{L}_{\text{exotic}} = -\frac{G_F}{\sqrt{2}} V_{ud} \left(\tilde{\epsilon}_L H_{V-A}^\mu \dot{J}_{\mu,V+A} + \epsilon_R H_{V+A}^\mu \dot{J}_{\mu,V-A} + \tilde{\epsilon}_R H_{V+A}^\mu \dot{J}_{\mu,V+A} + \dots \right)$$

$$\mathcal{L}_{\text{exotic}}^N = -\frac{G_F}{\sqrt{2}} V_{ud} \left(\epsilon_L^N H_{V-A}^\mu J_{\mu,V-A} + \tilde{\epsilon}_L^N H_{V-A}^\mu J_{\mu,V+A} + \dots \right)$$

$$\frac{d\Gamma}{dE_e} = a_{SM}(E_e) + \text{Re}(\epsilon_Y) a_{LL,Y}(E_e) + |\epsilon_Y|^2 a_Y(E_e)$$

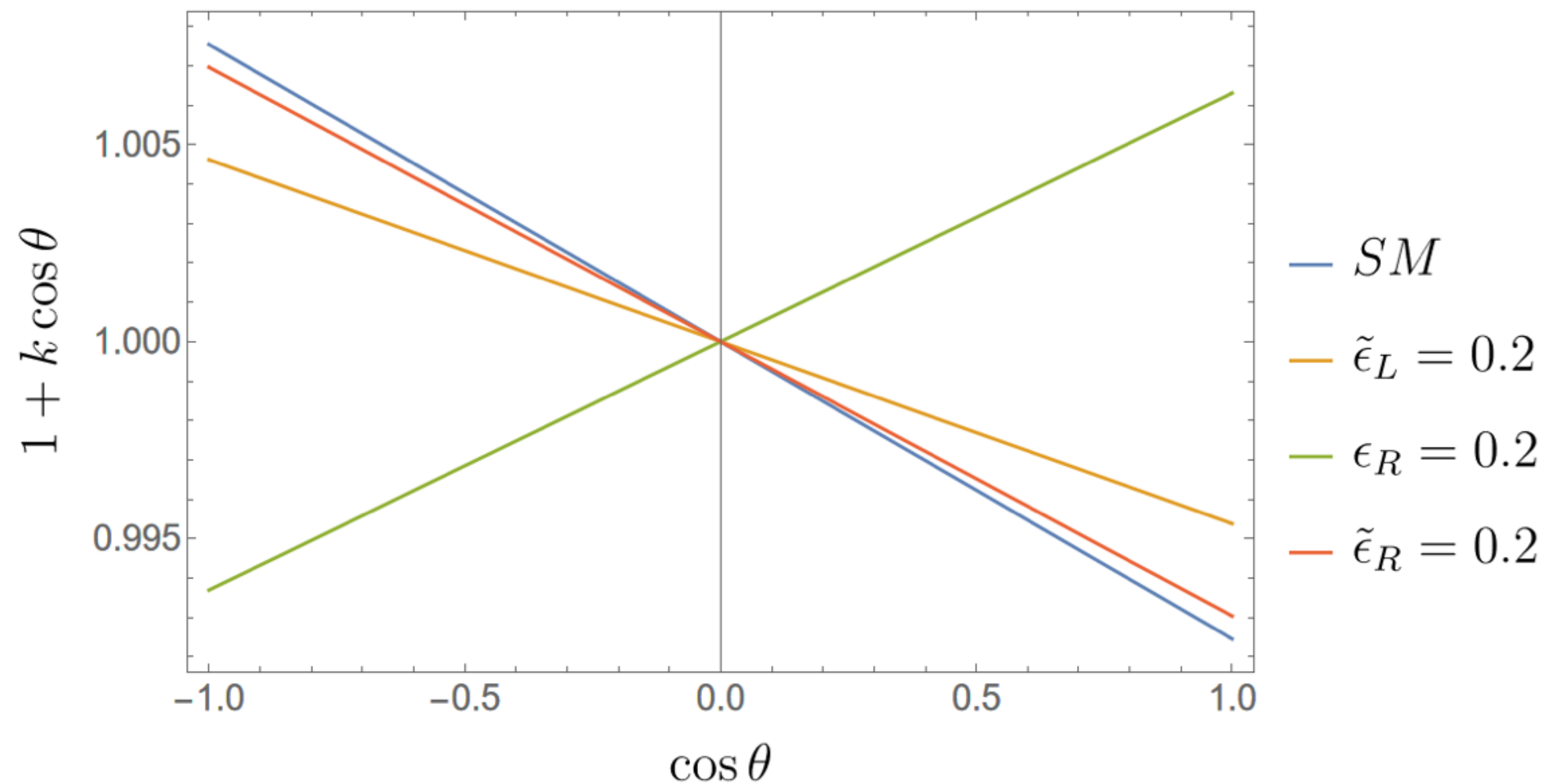
- Exotic currents produce active or sterile neutrinos
- We want to constrain the ϵ

Polarised Tritium



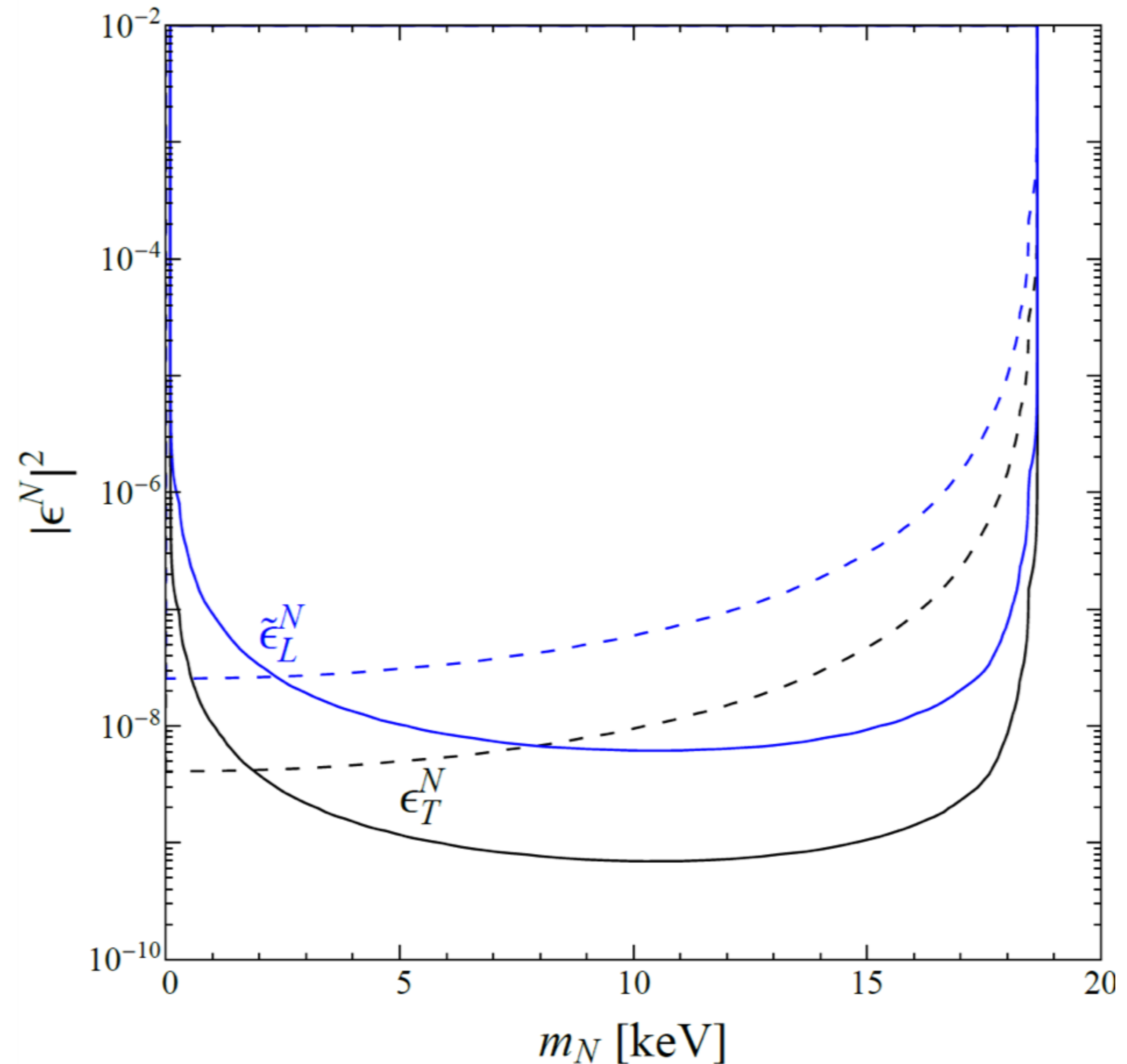
For polarised tritium, we use **angular correlations** as an additional probe

$$\frac{1}{\Gamma} \frac{d\Gamma}{d \cos \theta_e} = \frac{1}{2} (1 + k \cos \theta_e)$$

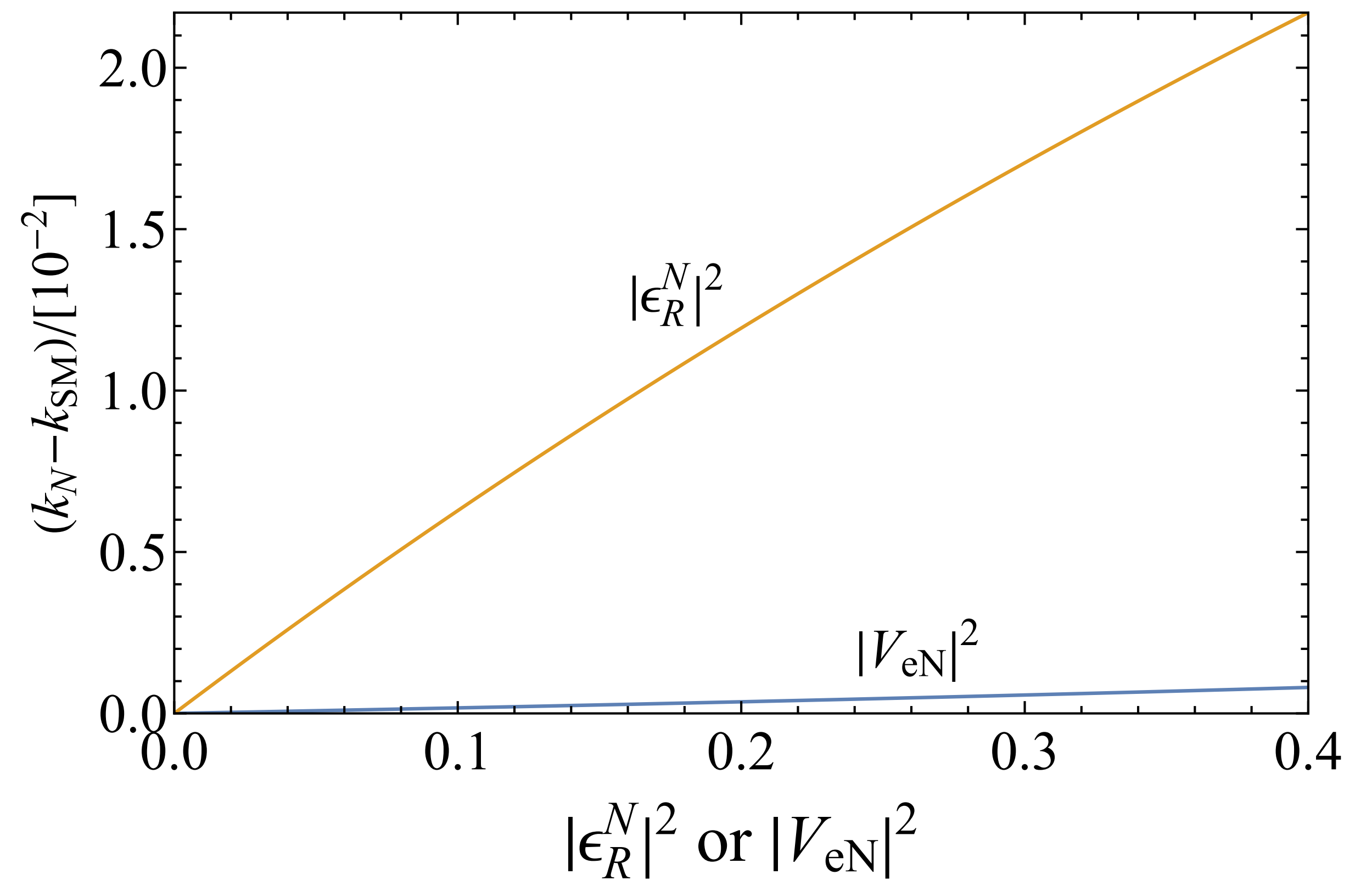
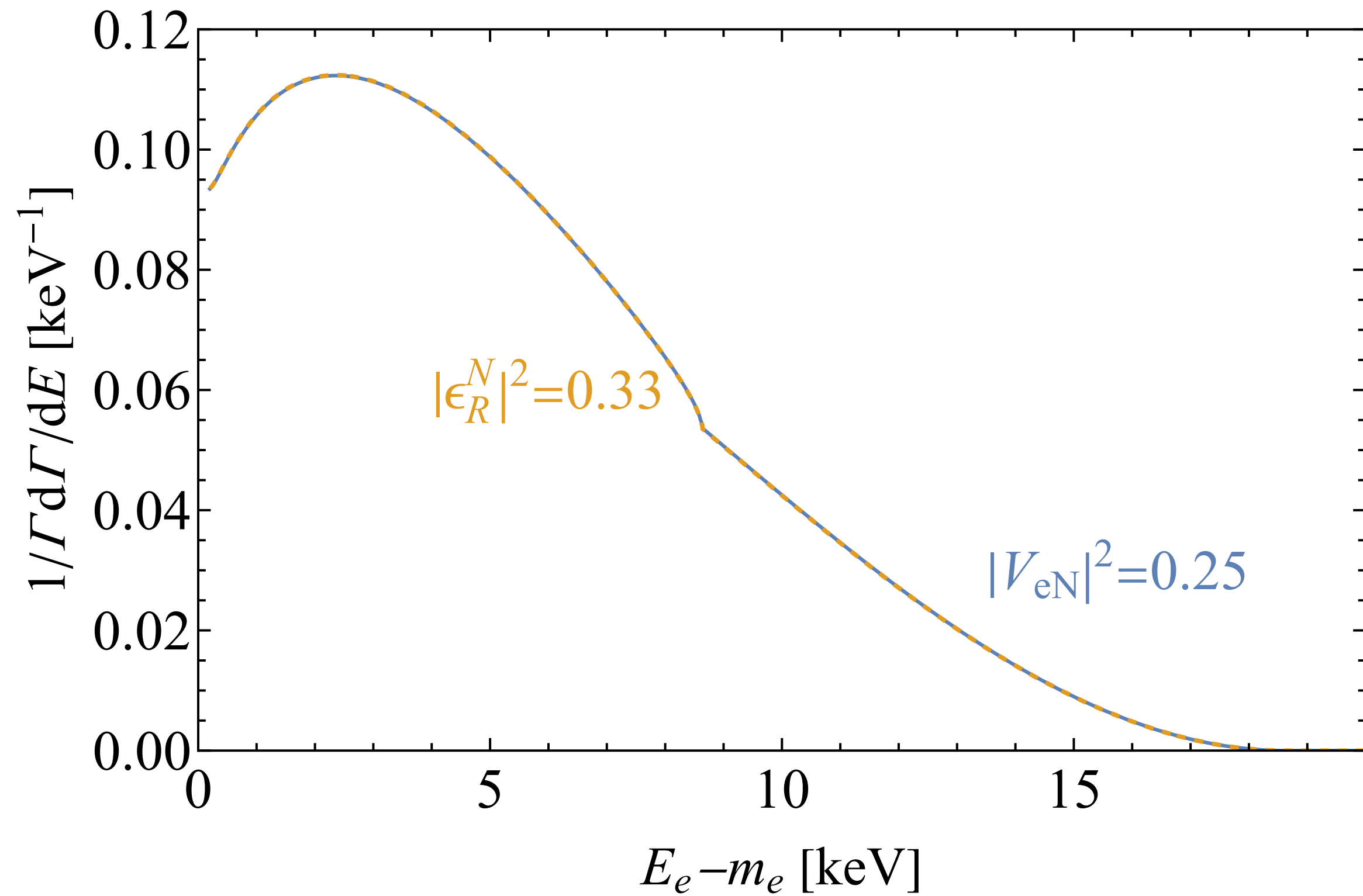


Exotic Limits

- The limits we place are sterile mass dependent
- Measuring angular and energy distributions generate different, concurrent limits



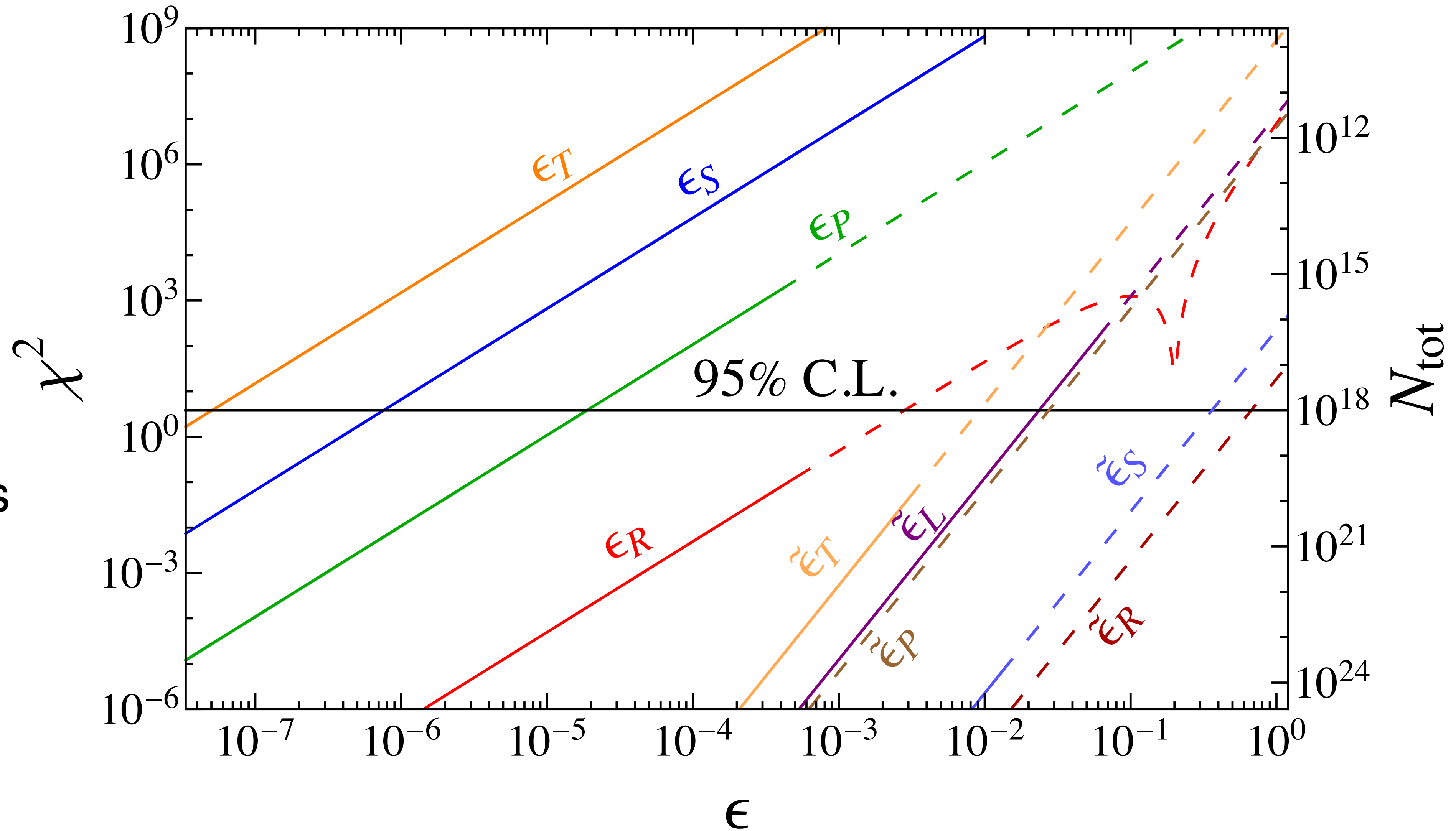
Resolving Degeneracies



Parameter values that lead to degenerate energy distributions are distinguishable in the angular distribution.

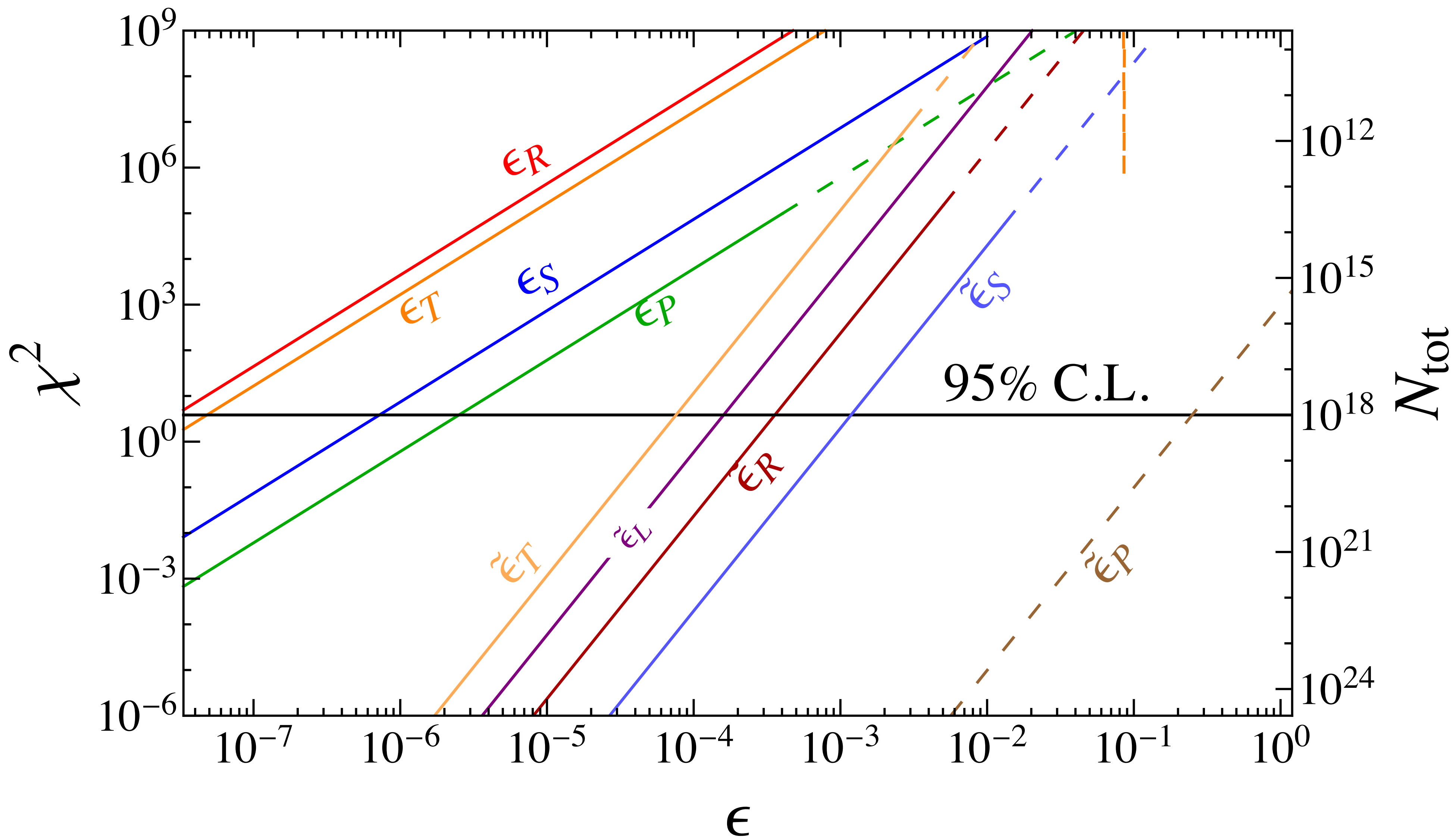
Energy Upper Bounds

- Considering currents individually gives upper bounds on the ϵ parameters
- Pre-existing limits are shown by dashes



Angular Upper Bounds

These results
assume full
polarisation but
can be extended
for partial



Thank You!