KeV Neutrino Search in Tritium β-Decay

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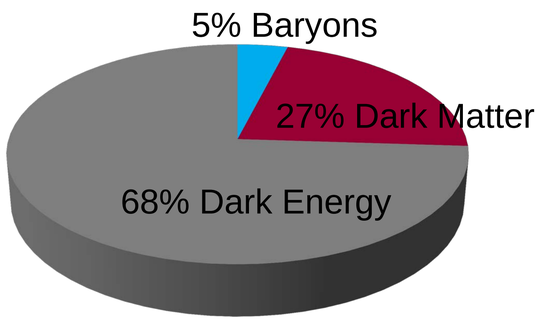
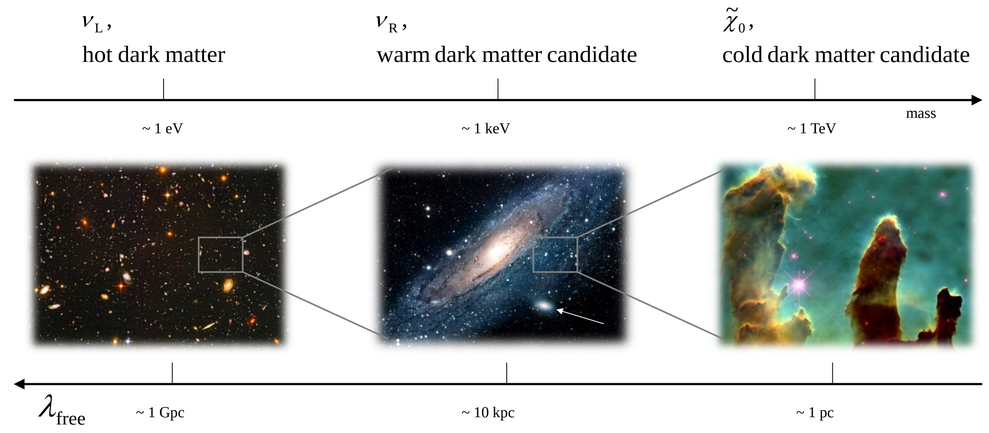
Motivation



$$\begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} c \\ s \end{pmatrix}_L \begin{pmatrix} t \\ b \end{pmatrix}_L \quad u_R \quad c_R \quad t_R \quad d_R \quad s_R \quad b_R$$

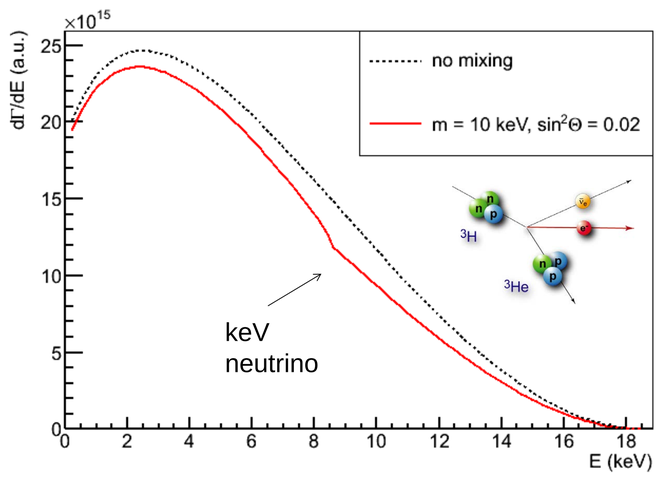
$$\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L \quad - \quad - \quad - \quad e_R \quad \mu_R \quad \tau_R$$

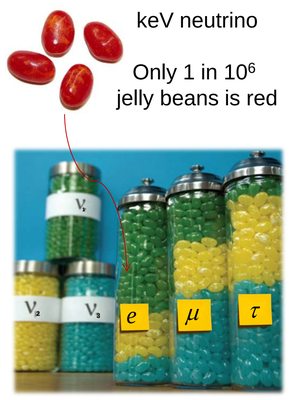


Right handed (sterile) neutrinos are theoretically well motivated
Sterile neutrinos can mix with active neutrinos, forming new mass eigenstates
Neutrinos in the keV mass range could contribute to cold and warm dark matter

Relic Neutrinos affect formation of structure in the early universe

Imprint of keV Neutrinos on β-spectrum



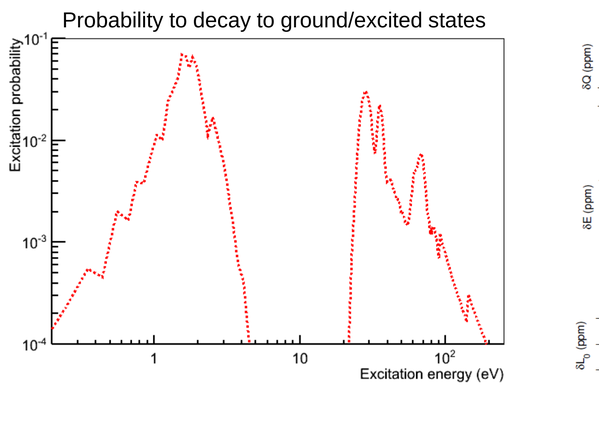


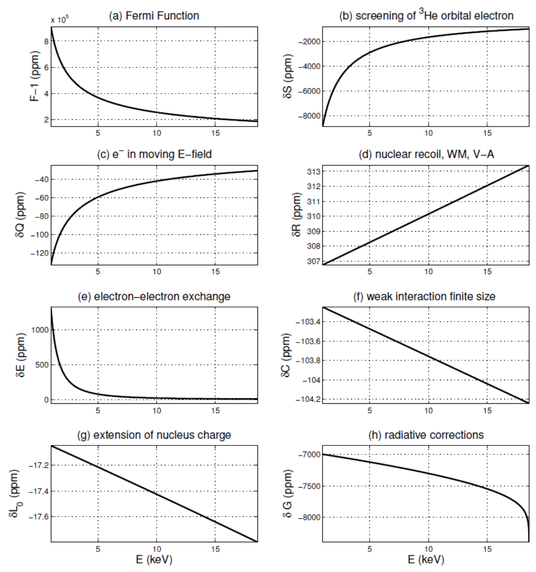
$$\frac{d\Gamma}{dE} \propto \cos^2(\theta)\frac{d\Gamma}{dE}(m_{\nu_{light}}) + \sin^2(\theta)\frac{d\Gamma}{dE}(m_{\nu_{heavy}})$$

A neutrino in the keV range leaves a kink signature in the β-spectrum
Cosmological constrains: $\sin^2\Theta < 10^{-7}$, 2 keV < m_{heavy} < 50 keV

Particle, Nuclear, Atomic and Molecular Corrections

$$\left(\frac{d\Gamma}{dE}\right)^{corr} = \frac{d\Gamma}{dE}\cdot\left[\prod_{\Psi=I_0,\,S,\,E,\,Q,\,R,\,G}\Psi(E)\right]$$

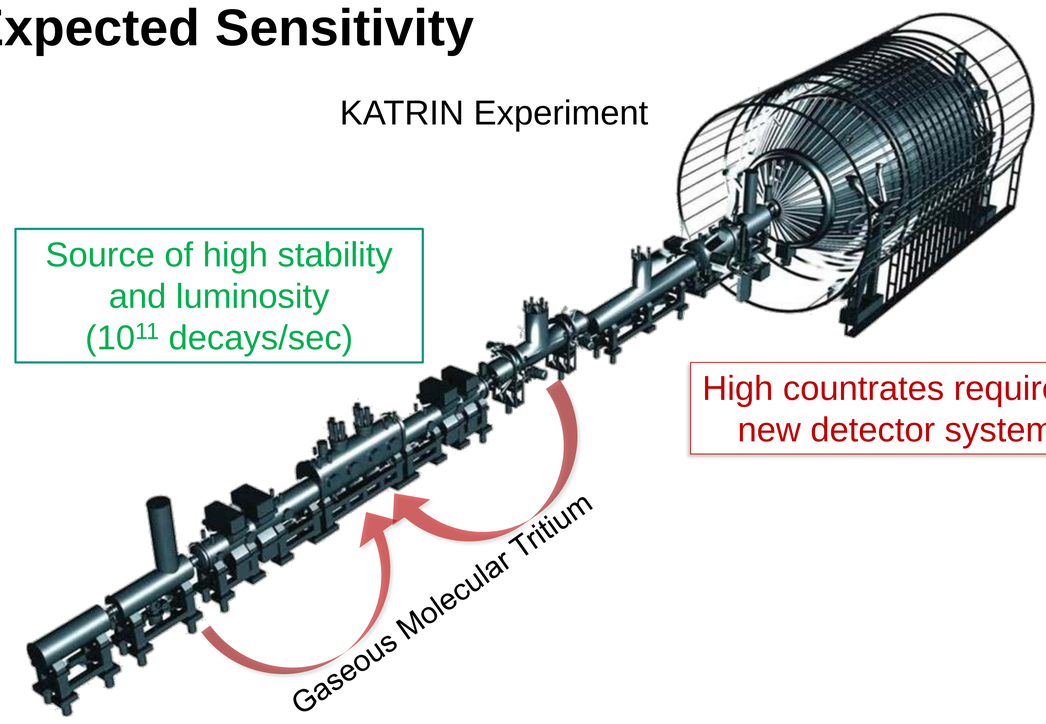




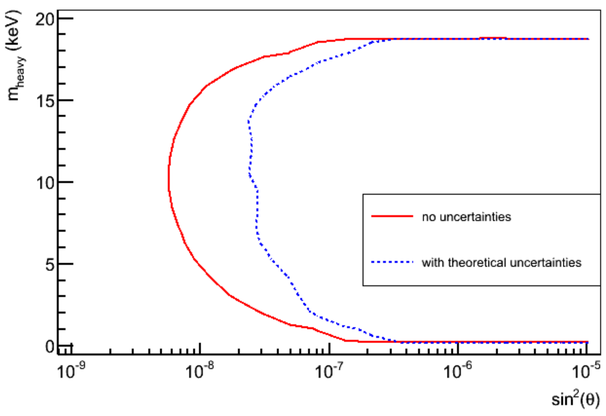
A non-negligible (10-10000 ppm) but smooth correction
Decay to excited states: largest and least known correction

Expected Sensitivity

KATRIN Experiment



Spectral fit approach

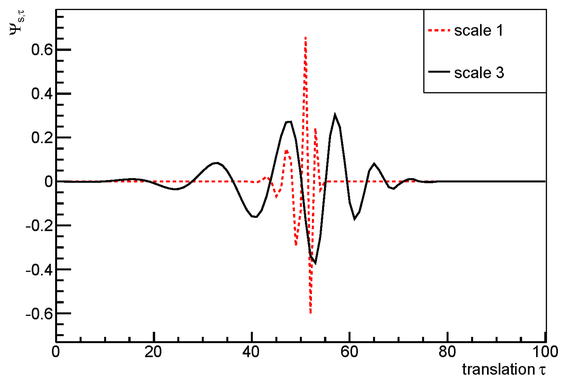


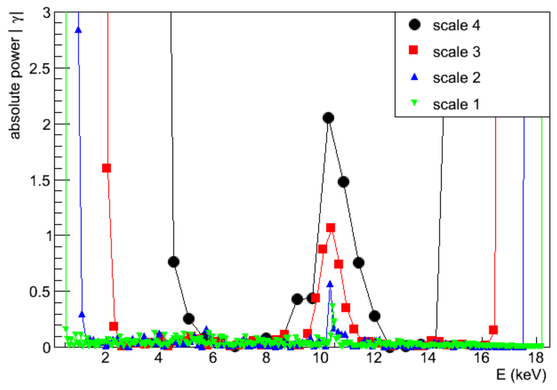
Fit β-decay spectrum

Leave theoretical corrections free to fake a keV neutrino signal

Smooth corrections do not prevent detecting a kink-signature down to $\sin^2\theta > 10^{-7}$

Wavelet approach

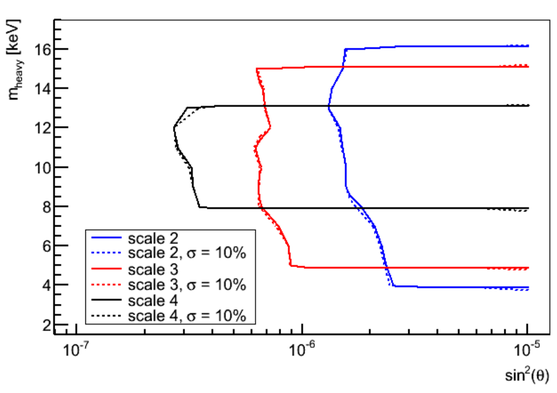




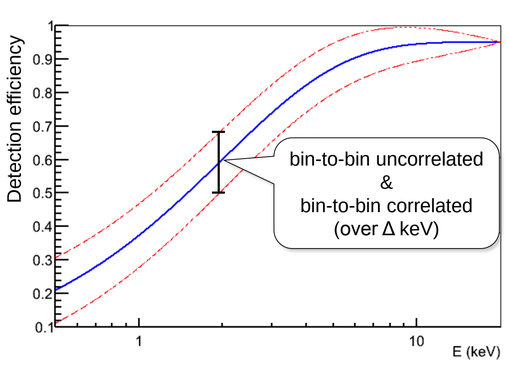
Use wavelet transformation to detect „kink“ feature in the spectrum

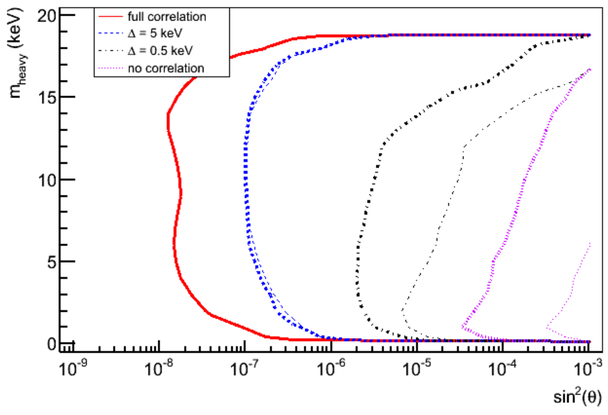
Kink search independent of exact knowledge of the spectrum shape

Good energy resolution (≈100 eV) required



Impact of experimantal uncertainties





Construct realistic covariance matrix to investigate experimental uncertainties in a generic way

Uncorrelated errors affect the sensitivity: require calibrations, simulations, and good understanding of correlations

S. Mertens gratefully acknowledges support of a Feodor Lynen fellowship by the Alexander von Humboldt Foundation and support by the Helmholtz Association.
Th. Lasserre thanks the European Research Council for support under the Starting Grant StG-307184.