First Experimental Limit on the Thermal Solar Neutrino Flux

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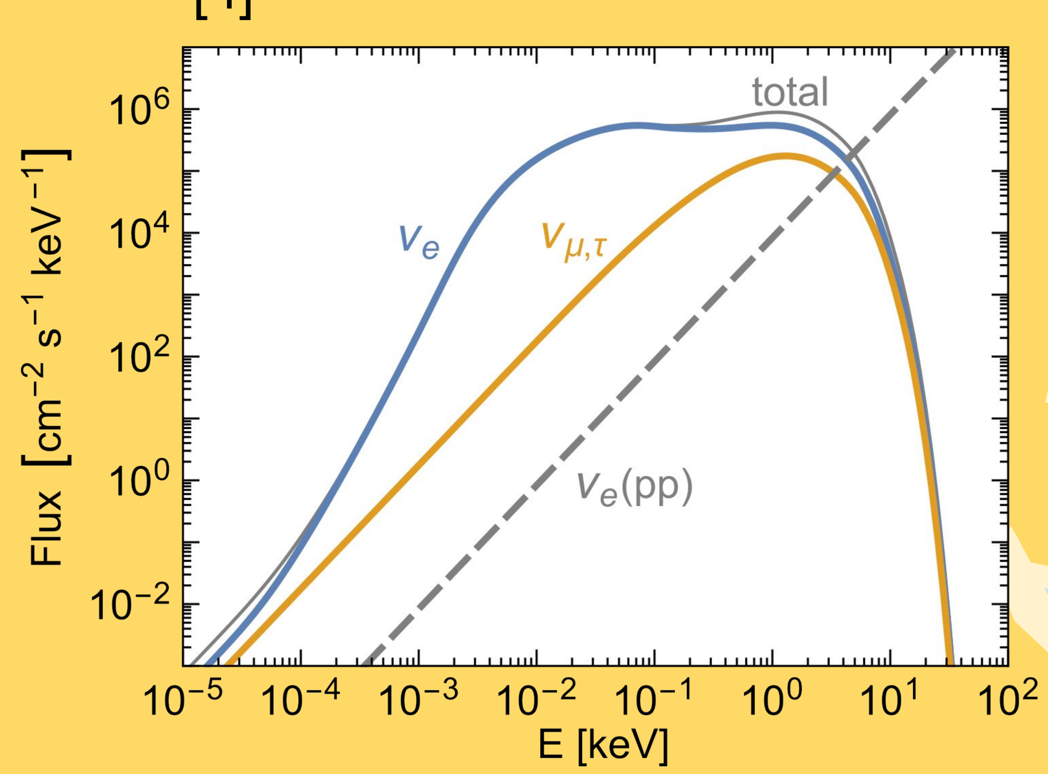
We set the **first** experimental upper limit on the **thermal solar neutrino flux**, exploiting the neutrino capture on tritium nuclei technique [1,2], using KATRIN publicly released data [3].

1 Thermal Solar Neutrinos

Thermal solar neutrinos play a pivotal role in the **stellar cooling mechanisms** in red giants, pre-supernovae, white dwarfs, and neutron stars.

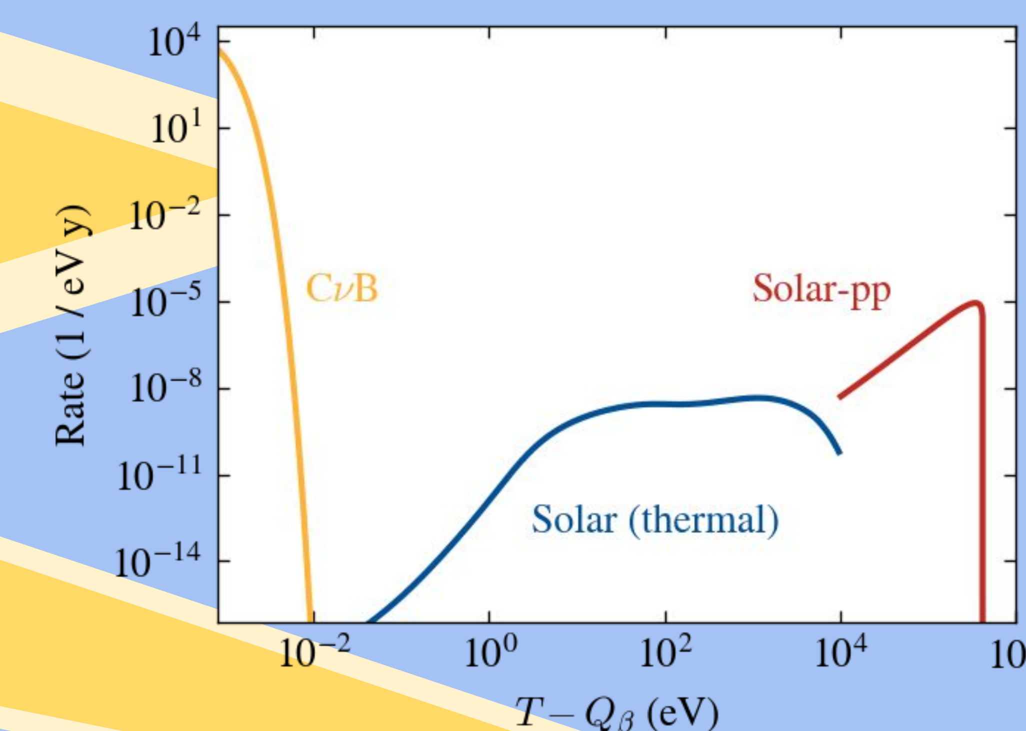
These neutrinos are produced through thermal processes in the solar core, with a **peak flux** of about **10^6cm^{-2}s^{-1}keV^{-1}** and **energies E ≲30 keV.**

[4]



At these low energies, it is impossible to use standard neutrino detection techniques. **Neutrino capture on beta-active tritium nuclei** offers a possible solution for direct detection.

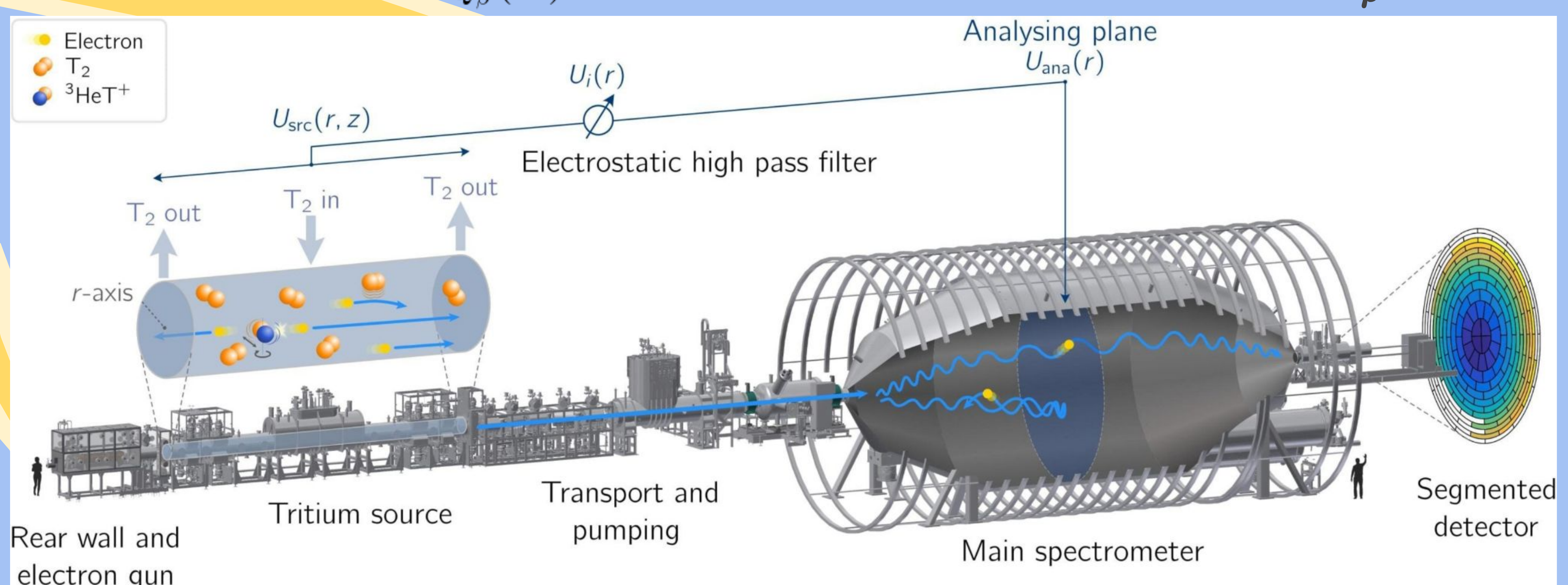
2 The Expected Signal in the KATRIN Experiment



The kinetic energy (T) differential capture rate spectrum for solar thermal neutrinos is computed for a **100 g tritium target mass** assuming the SSM flux normalization

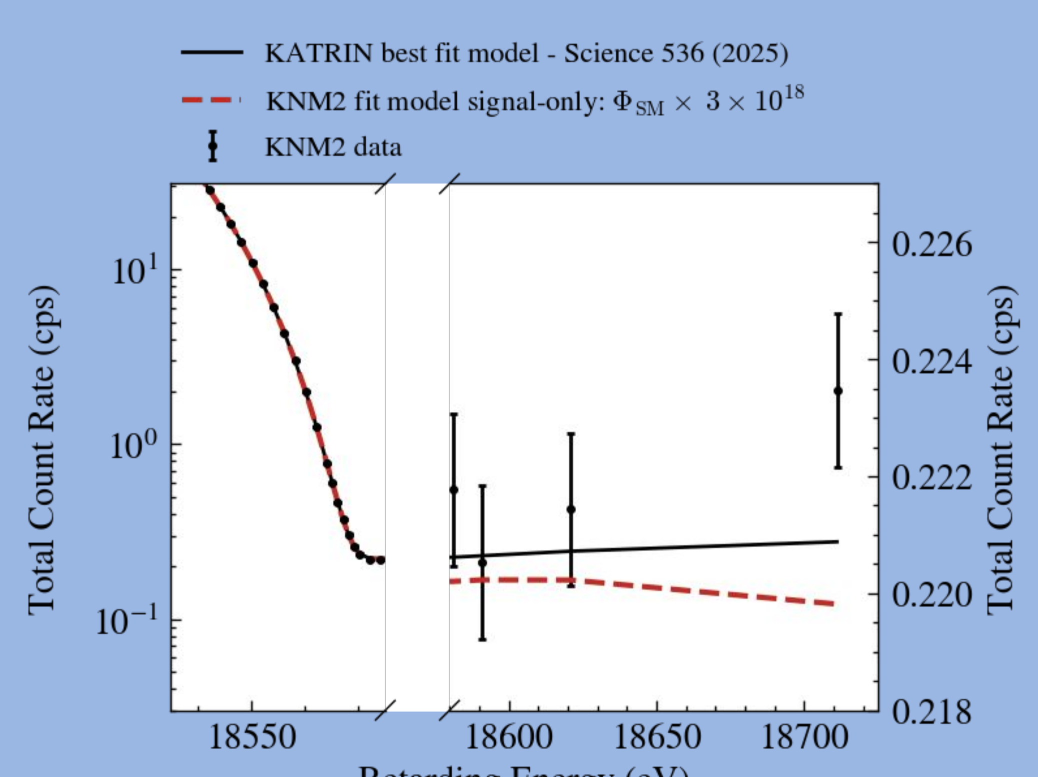
For comparison, CνB and solar-pp capture rate spectra are also shown.

Thermal neutrinos capture spectrum **extends above the tritium Q-value (Q_β) by 10 keV.**



We used the 2025 public data from the **KATRIN experiment**, featuring an exposure of 259 days, to derive the first thermal solar neutrino flux limit.

3 The Results



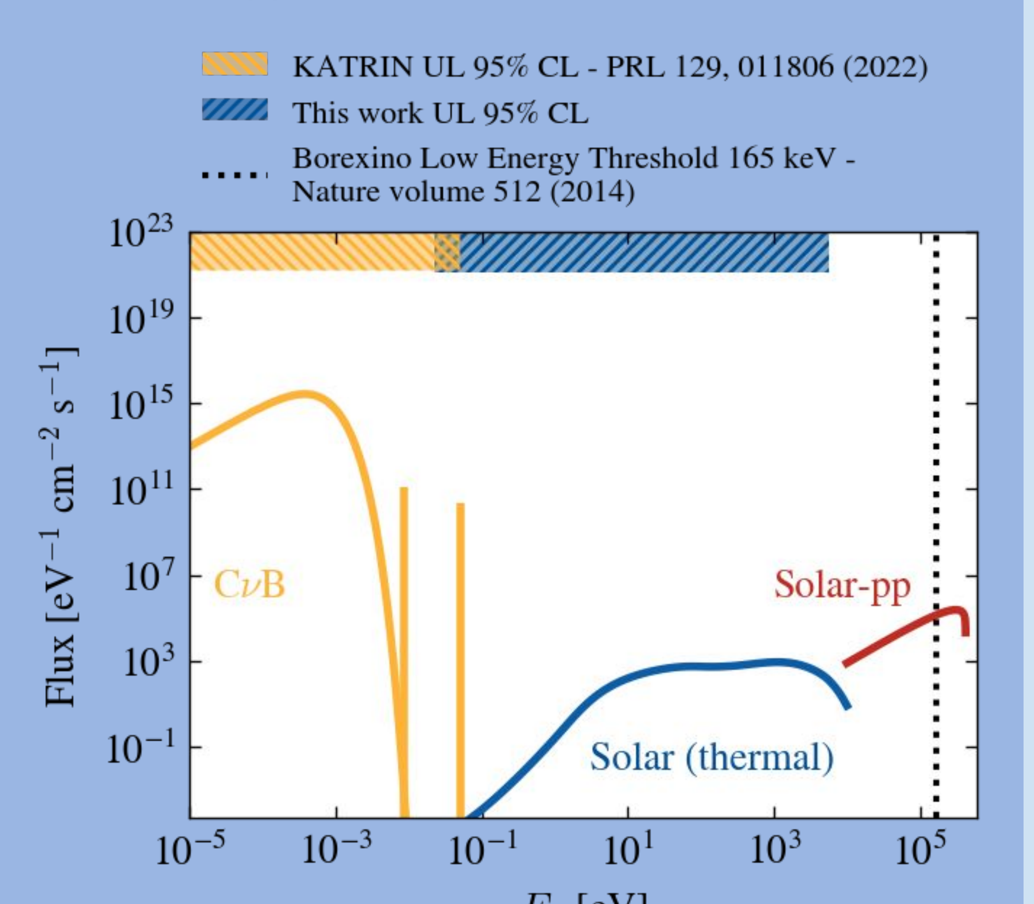
To search for the thermal solar neutrino capture signal (R_{diff}), we considered only the KATRIN data recorded with a retarding energy (qU) larger than Q_β and modified the fit function:

$$R(qU)_i = A\frac{m_i}{m_1}\int_{qU}^{E_{\max}} R_{\rm diff}(E)\,\bar{f}(E-qU)\,dE + R_{\rm bg,i} + R_{\rm s}(qU)\,,$$

where *A* is the flux normalization factor taking into account the efficiency terms and the **flux normalization (Φ/Φ_{SSM})**, f is the transfer function, and R_{bg} and R_s are background terms.

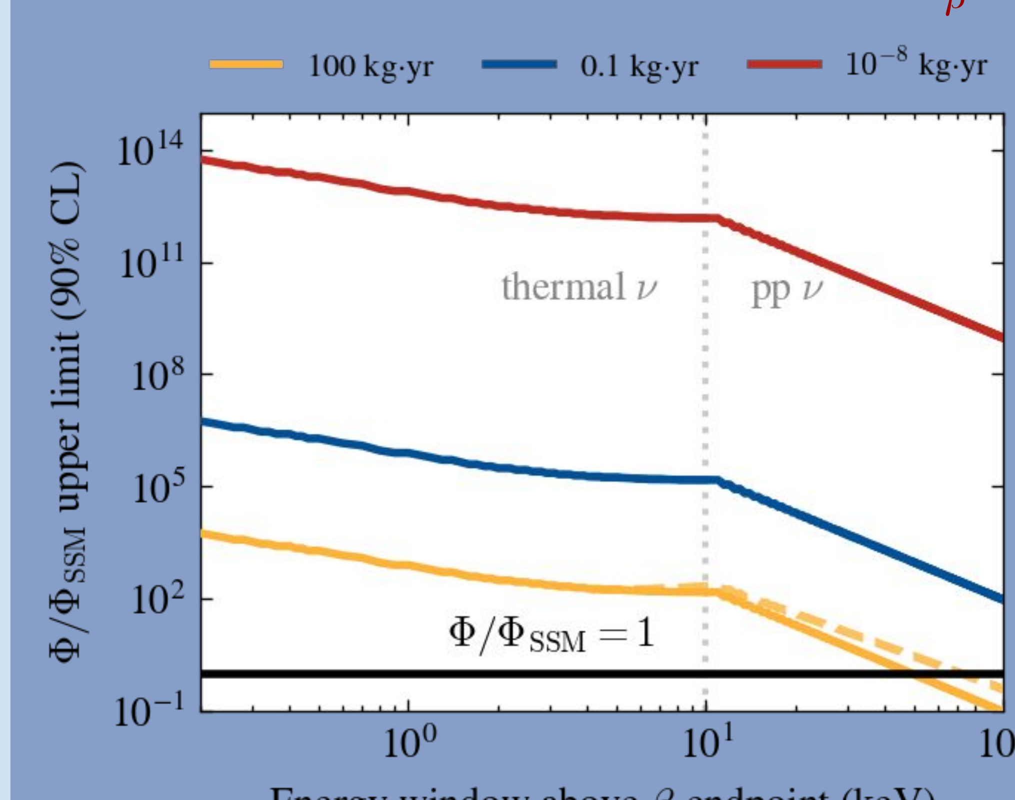
The Bayesian fit returns an upper limit on the A parameter of about 5x10^{10} at 95% CL. By considering the total detector efficiency of Ref. [3], we find a flux normalization upper limit of:

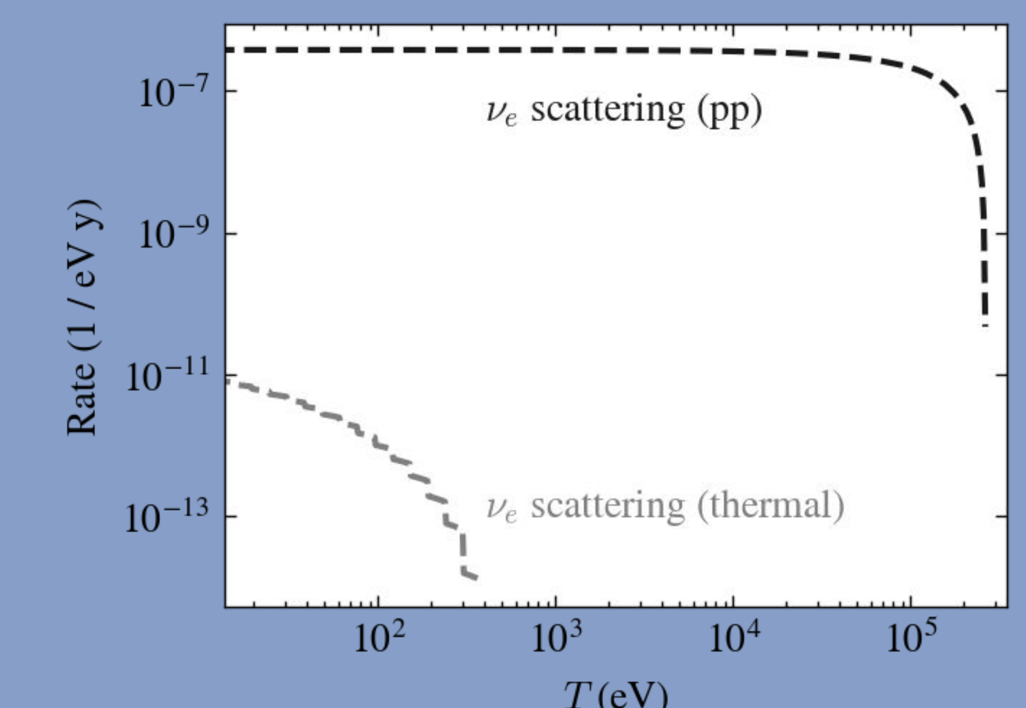
$\Phi/\Phi_{SSM}<1.86\times10^{18}$ (95% CL)



4 Future Prospects

Solar-pp neutrinos are responsible for an **irreducible background** that will eventually limit future experiments. Indeed, the ν_e-e scattering on tritium atomic electrons induces a flat background above Q_β.





Our sensitivity study reveals that the impact of the ν_e-e background is limited and shows that **a 100 kg·yr exposure would** detect low-energy pp neutrinos at SSM level while **constraining thermal neutrinos to Φ/Φ_SSM ≲10^4.**

References

[1] S. Weinberg, Phys. Rev. 128, 1457 (1962)
[2] A. G. Cocco, G. Mangano, and M. Messina, JCAP 06, 015 (2007)
[3] KATRIN Collaboration, Science 10, 1126 (2025)
[4] E. Vitagliano, I. Tamborra, and G. Raffelt, Rev. Mod. Phys. 92 (2020)

Acknowledgments
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