First glance at the latest science runs of the KATRIN neutrino-mass experiment

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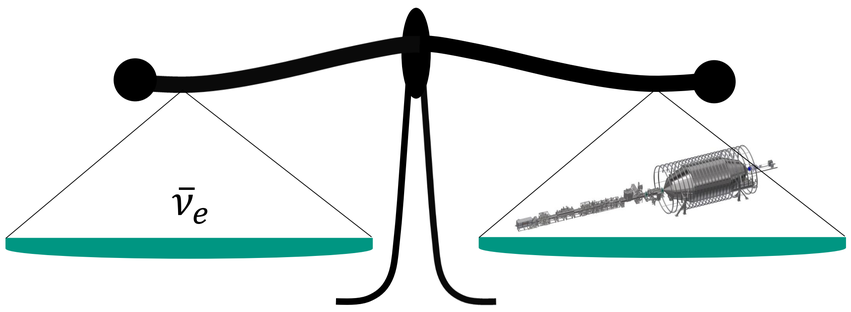
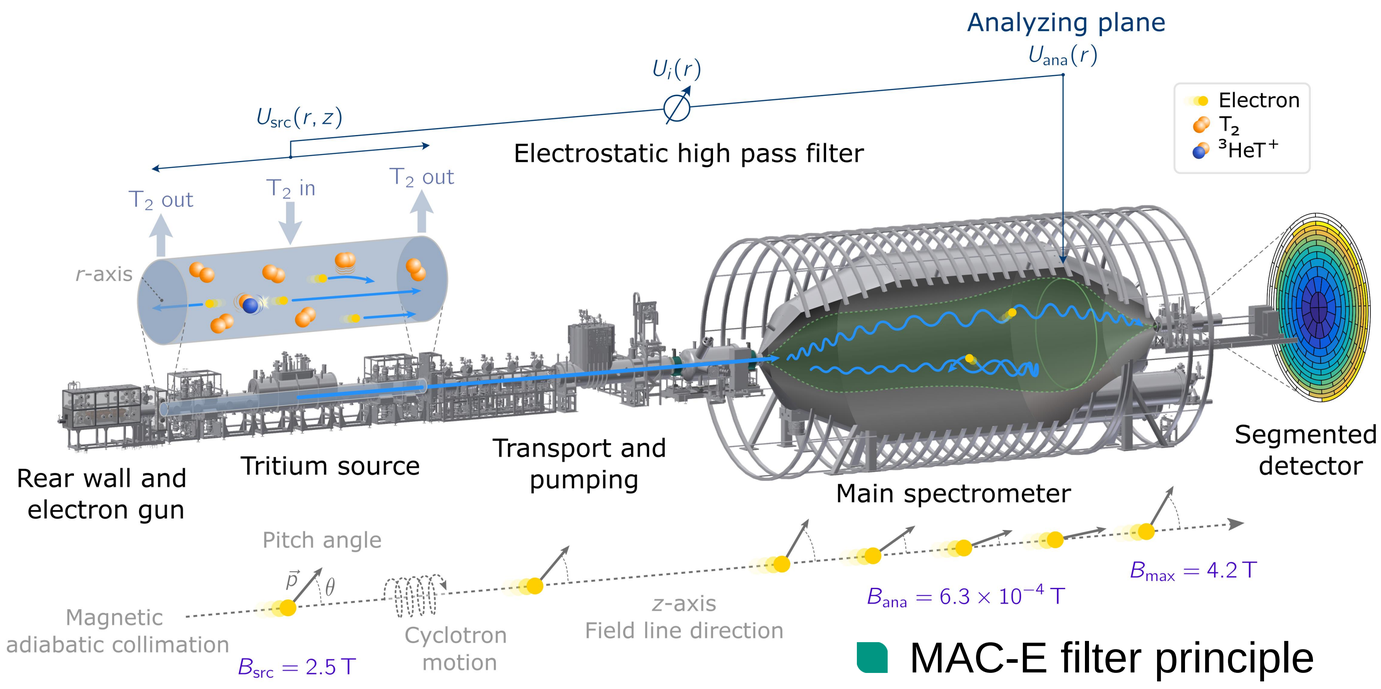
KATRIN experiment



- Direct neutrino-mass measurement via tritium beta decay
- World leading neutrino-mass upper limit $m_{\nu_e} < 0.45\ \mathrm{eV/c^2}$ (90% C.L.) [1]

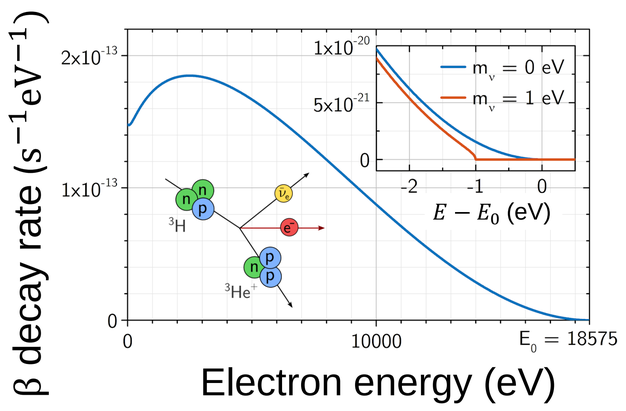


- MAC-E filter principle

T_2 beta decay

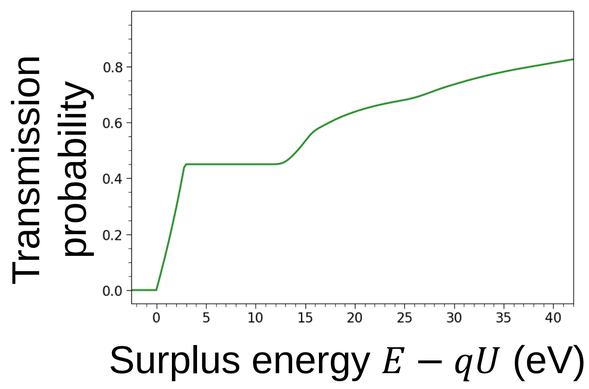
$$m^2_{\nu_e} = \sum |U_{ei}|^2\, m_i^2$$

- $\mathrm{T_2} \rightarrow {}^3\mathrm{HeT}^+ + \mathrm{e}^- + \bar{\nu}_\mathrm{e} + Q(\mathrm{T_2})$
- $\frac{d\Gamma}{dE} \propto (E_0 - E) \cdot \sqrt{(E_0 - E)^2 - m^2_{\nu_e}} \cdot \theta(E_0 - E - m_{\nu_e})$



Response function R

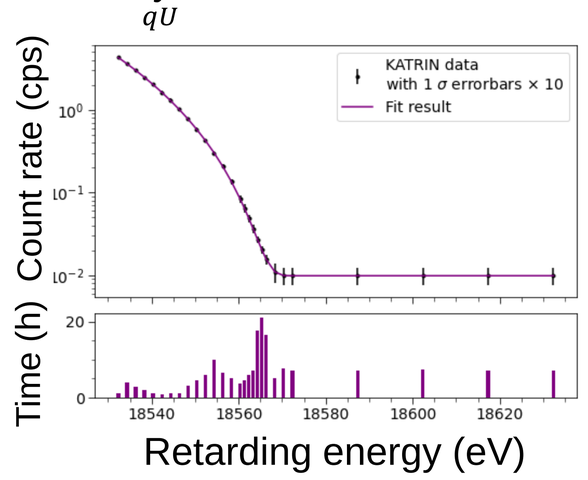
- Determined by magnetic fields and scattering probabilities
- Energy resolution $\frac{\Delta E}{E} \sim \frac{B_{ana}}{B_{src}} \sim 10^{-4}$



Observed spectrum

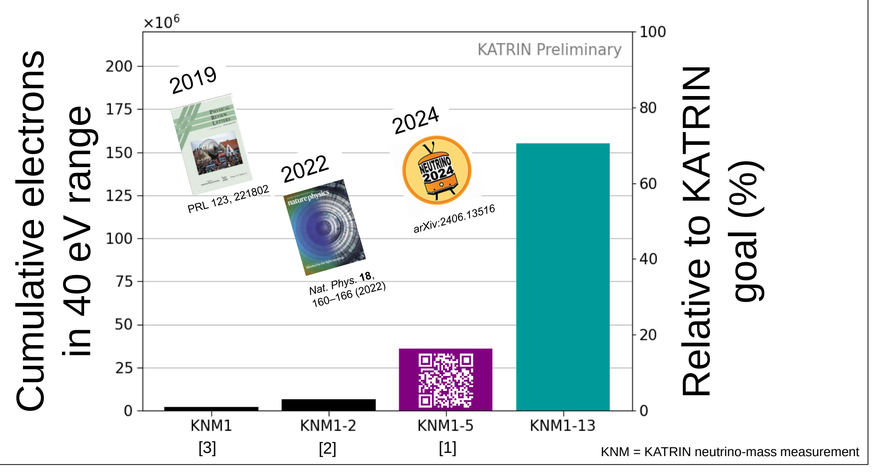
- 4 free fit parameters: $A_S, E_0, m^2_\nu, R_{bg}$

$$\dot{N}(U) = A_s \cdot N_T \int_{qU}^{E_0} \frac{d\Gamma}{dE}\left(E, m^2_\nu\right) \cdot R(E,U)\mathrm{d}E + R_{bg}$$



150 million collected electrons

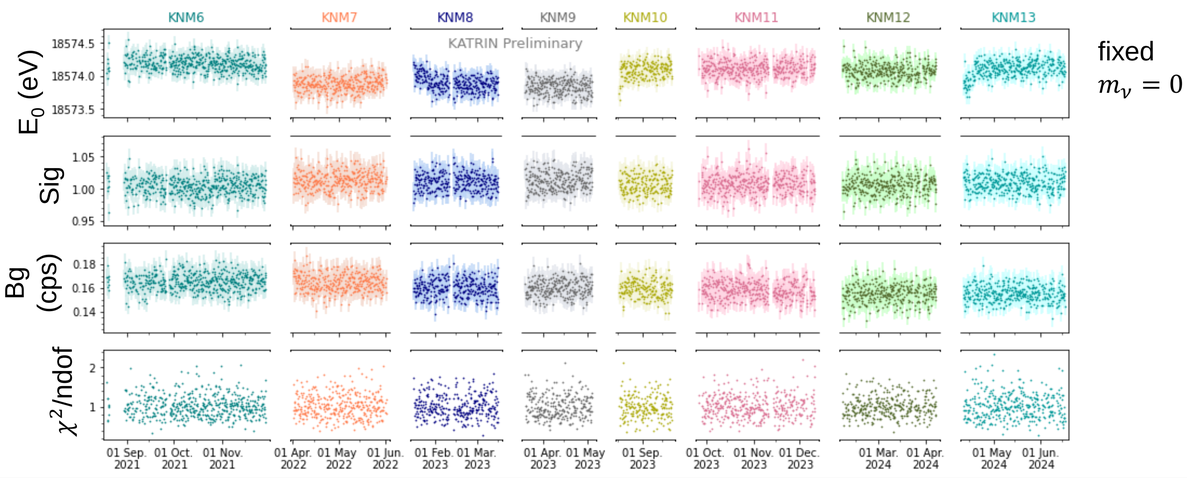
- 4 times more than 2024 release dataset
- Circa 70% of the anticipated goal



Optimal measurement conditions

- Background suppression by reconfigured electromagnetic fields
- Optimized measurement time distribution

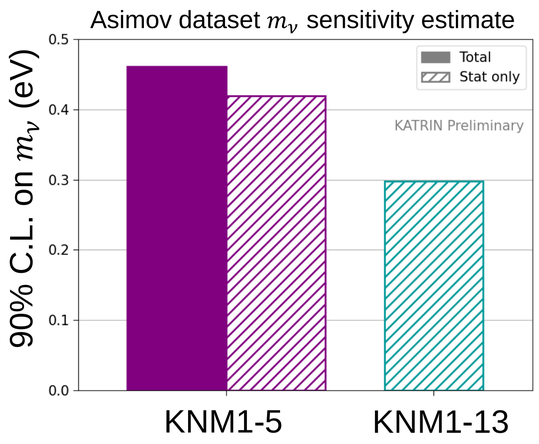
KNM = KATRIN neutrino-mass measurement



Analysis procedure

- Data selection and combination
- Evaluation of systematic effects
  - Column density, scattering energy loss, magnetic and electric fields, ...
- Minimization of one combined likelihood

$$-\ln \mathcal{L} = \sum_i -\ln \mathcal{L}_i\left(m^2_\nu, E_{0i}, \mathrm{Sig}_i, \mathrm{Bg}_i\right)$$



KNM1-13 simulation results

- Preliminary selection of runs and pixels
- Preliminary input parameters
- 4745 data points, 514 free parameters
- With the already collected data we reach m_ν statistical sensitivity of 0.3 eV
- Work in progress: improvements in systematics w.r.t. KNM1-5

Outlook

- Finalization of the data selection and the input parameters
- Optimize data combination to reduce number of fit parameters
- Collect another 70 Mio. electrons by end of 2025

References

[1] M. Aker et al. (KATRIN Collaboration), *arXiv:2406.13516 [nucl-ex]*; **[2]** M. Aker et al. (KATRIN Collaboration), Nature Physics volume 18, pages 160–166 (2022); **[3]** M. Aker et al. (KATRIN Collaboration), Phys. Rev. Lett. 123, 221802

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