Analysis methods and the Bayesian approach for the KATRIN experiment

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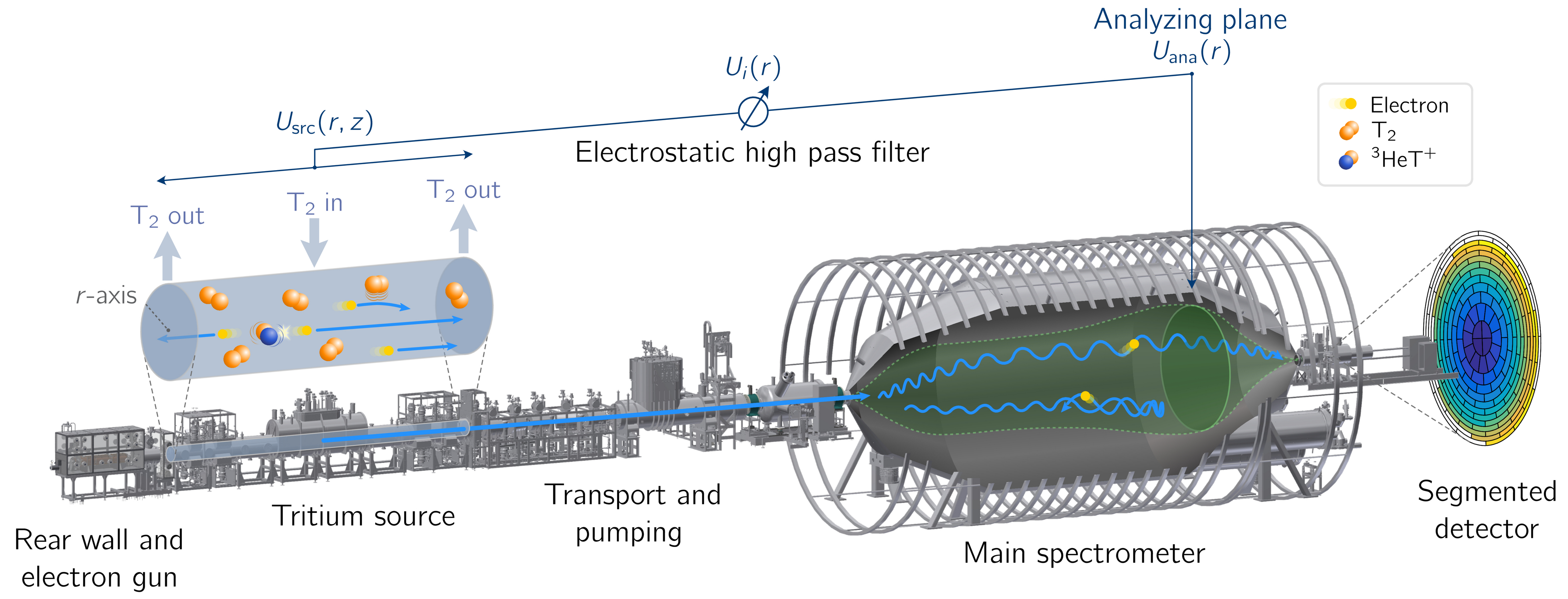
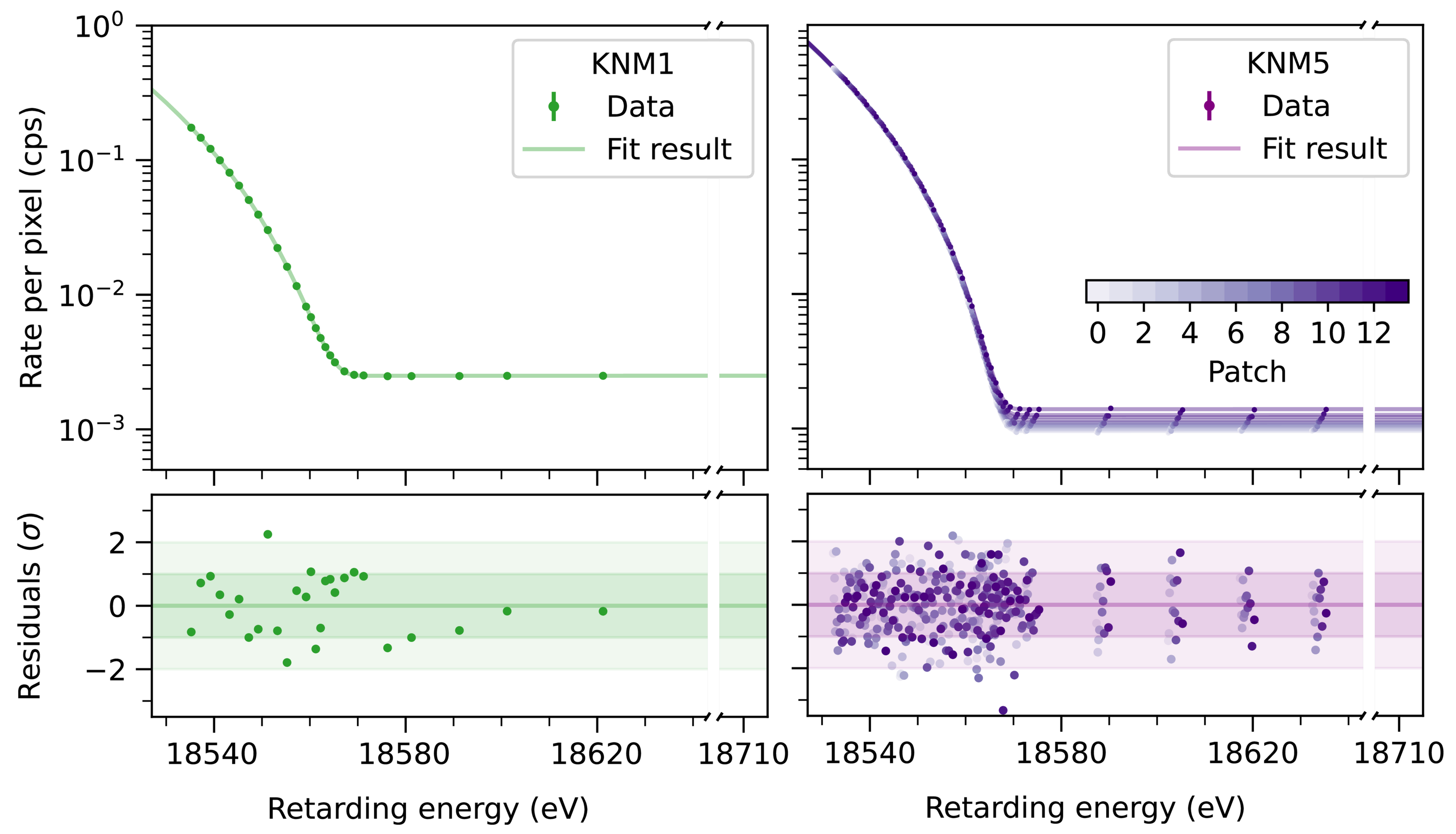
Neutrino mass measurement with MAC-E-filter spectroscopy

KATRIN aims for a final sensitivity of $m_\nu < 0.3$ eV at 90% confidence level, by measuring tritium β-decay electrons with a Magnetic Adiabatic Collimation and Electrostatic (MAC-E) filter.

- β-decay of T_2 molecules
  - Spectral distortion from non-zero m_ν
  - Low Q-value, short half-life
    $\rightarrow$ large statistics near the endpoint
- Adiabatic transportation
  - Filter width of $\mathcal{O}$(1eV) represents transverse energy at analyzing plane

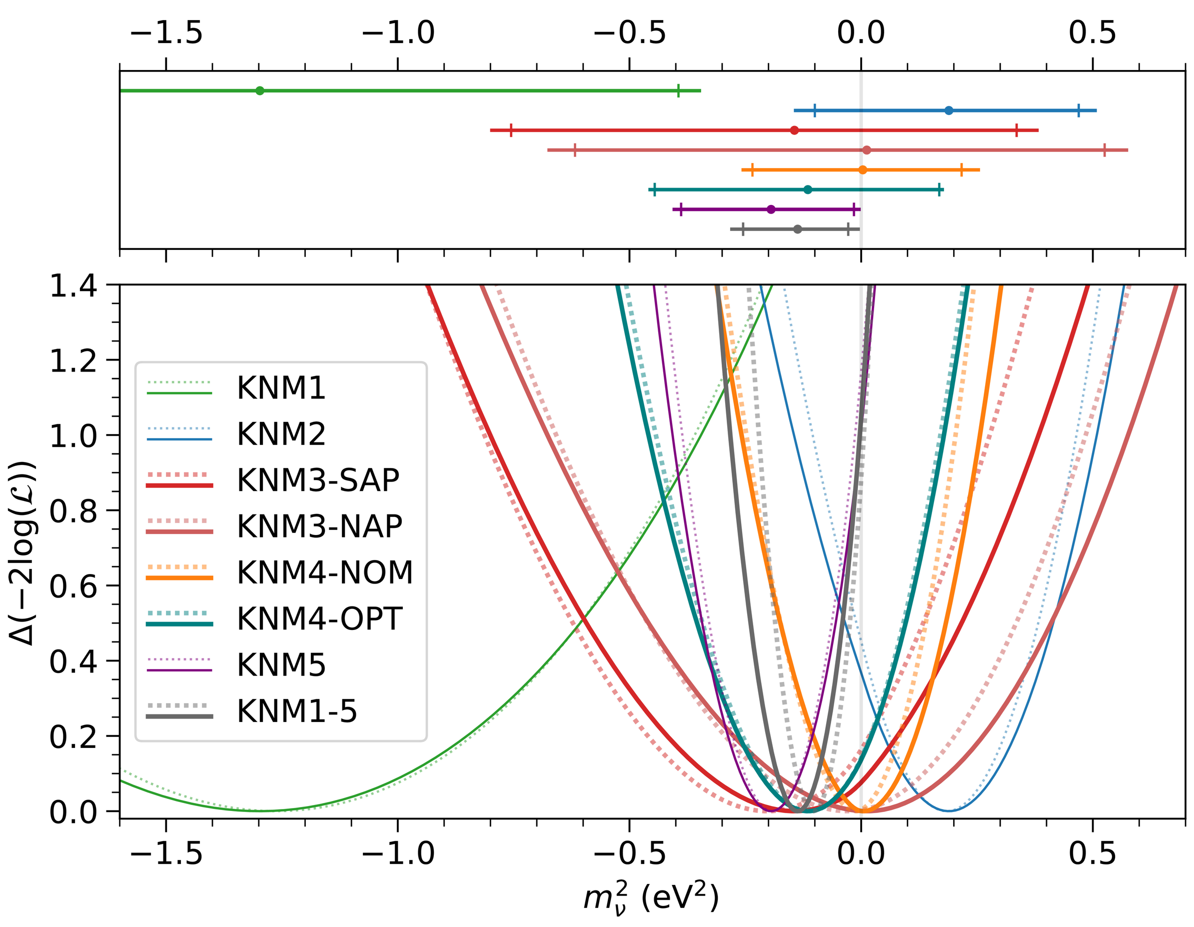


KATRIN improvements over time



80% reduction on systematic uncertainties and 50% reduction on background rate. Details in A.Schwemmer, Poster ID 12.

The frequentist results



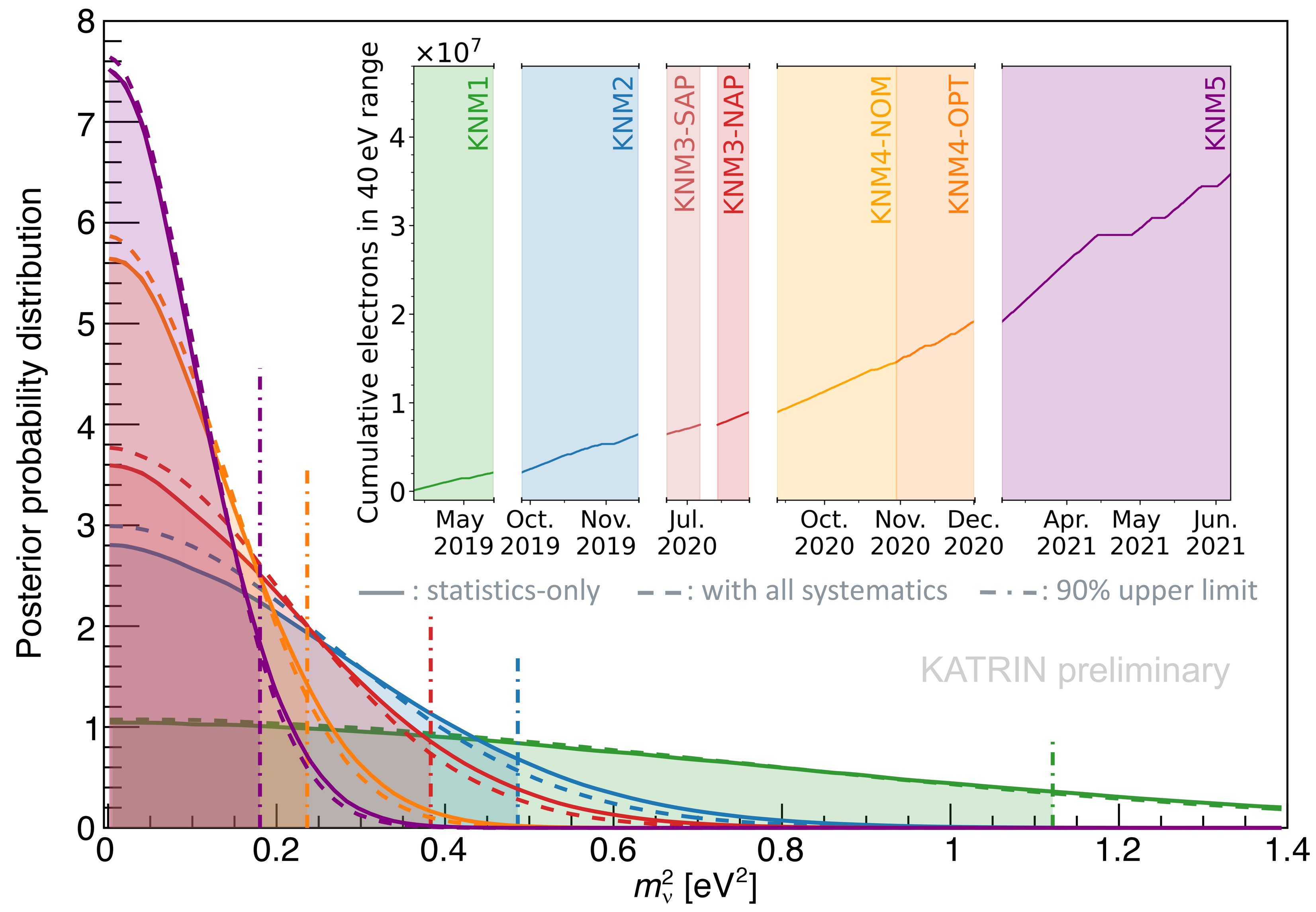
Upper panel:
best-fit values and the 1σ uncertainties.
- Horizontal bars:
  - with all systematics
- Vertical bars:
  - only statistical error

Lower panel:
likelihood profiles.
- Solid lines:
  - with all systematics
- Dashed lines:
  - only statistical error

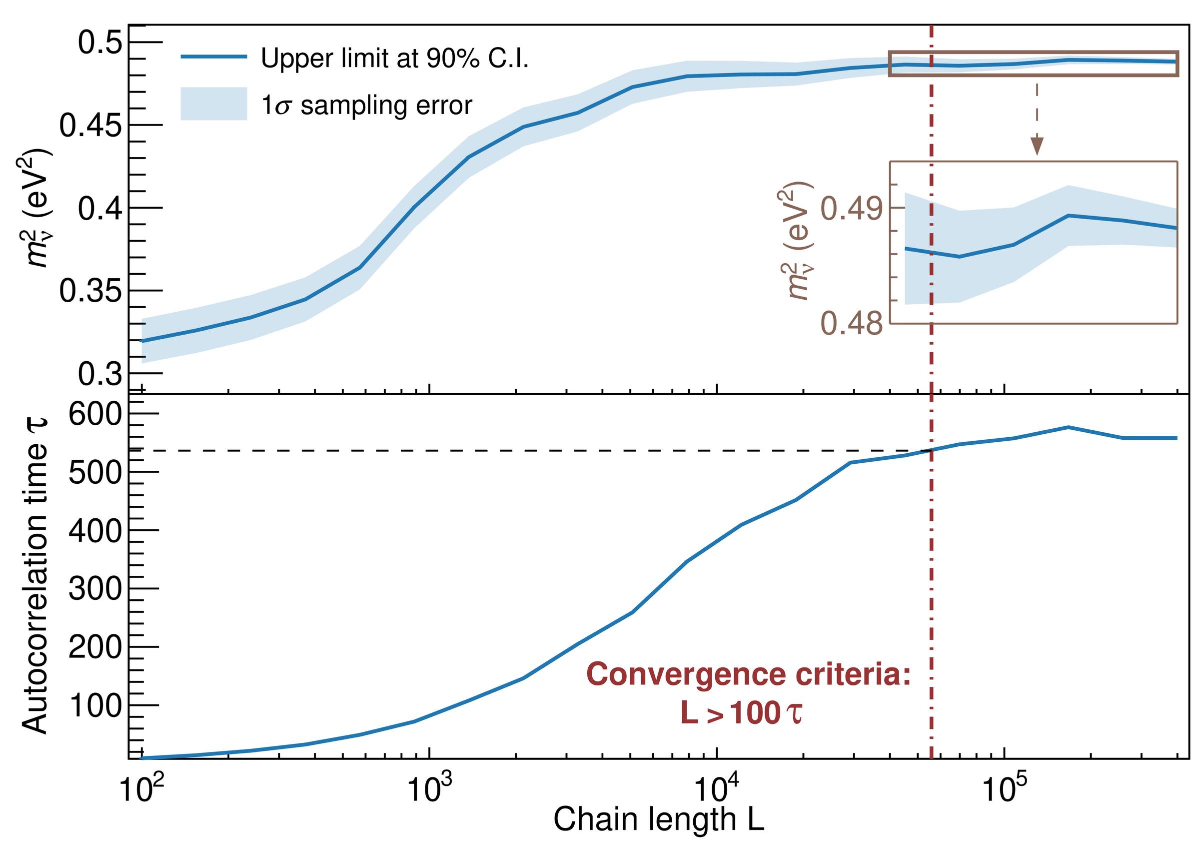
- Best-fit values [1] from maximum likelihood estimation, based on highly optimized model evaluation (this work).
- Upper limit of $m_\nu < 0.45$ eV at 90% C.L. with the Lokhov-Tkachov method [2] to force no gain from fitted $m_\nu^2 < 0$ eV^2.

The Bayesian approach

- Evolution of Bayesian sensitivity at 90% credible interval, with a flat-positive prior on m_ν^2:



- Bayesian advantage in KATRIN analysis
  - no model extension by adopting $m_\nu^2 \geq 0$ eV^2 as prior
  - linear scalability in sampling time with expanding statistics: combine data sets with m_ν^2 (this work) / multi-variate priors
- Analysis methods fixed with Monte Carlo studies, providing unbiased results on real data (to be published soon).



Chain evolution for KNM2 campaign with *emcee* [3]:
- Stretch-move proposal:
  - parallel sampling of unimodal distribution
- Convergence:
  - first 50τ removed before convergence
- Sampling error:
  - originate from finite size of Markov chains
  - estimated by Monte-Carlo simulation

REFERENCES

[1] Released at NEUTRINO 2024.
[2] A. Lokhov, & F. Tkachov, *Phys. Part. Nucl.* **46**, 347 (2015).
[3] D. Foreman-Mackey, D. Hogg, D. Lang, & J. Goodman, *arXiv:1202.3665* (2013).

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MORE INFORMATION

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