Direct neutrino mass measurements with KATRIN experiment

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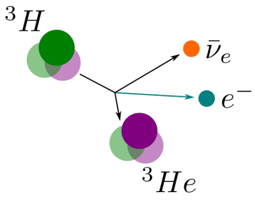
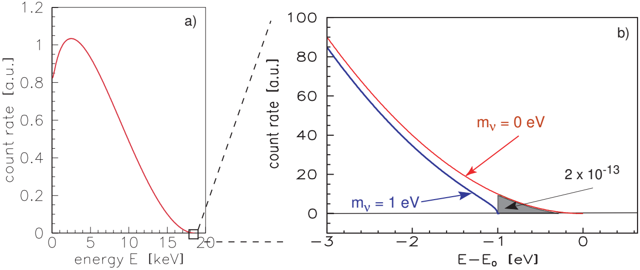
Tritium beta decay and neutrino mass





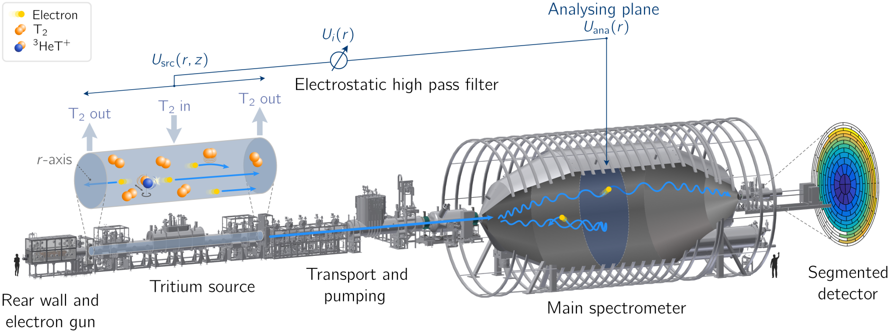
- Determine the neutrino masses with ...

	Cosmology	**$0\nu\beta\beta$**	**Single β decay**
Observable	$\sum_i m_i$	$\lvert\sum_i U_{ei}^2 m_i\rvert^2$	$\sum_{i=1}^3 \lvert U_{ei}\rvert^2 m_i^2$
Upper limit	0.12eV	0.18eV	1.1eV*
Dependency	ΛCDM	Majorana m_ν	Kinematics

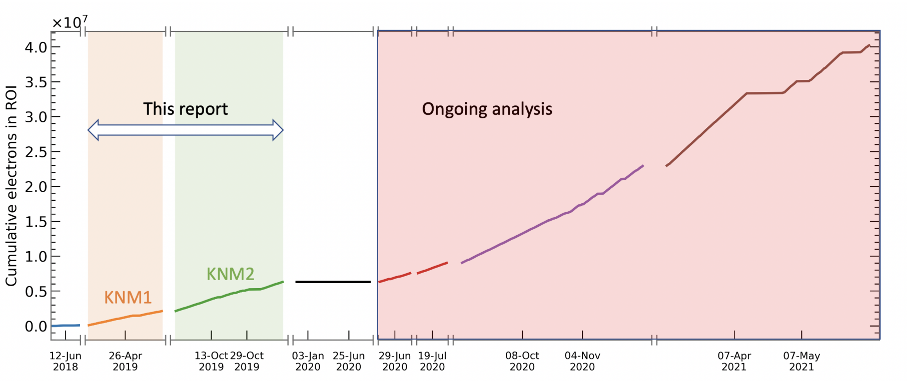
* *KATRIN Collaboration, PRL 123, 221802 (2019)*

Karlsruhe Tritium Neutrino (KATRIN) experiment

- Precise measurements with the Magnetic Adiabatic Collimation with an Electrostatic (MAC–E) filter, energy resolution $\sim$ 1eV

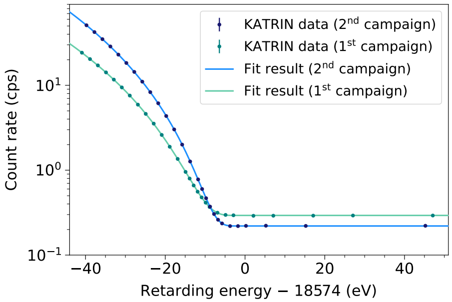


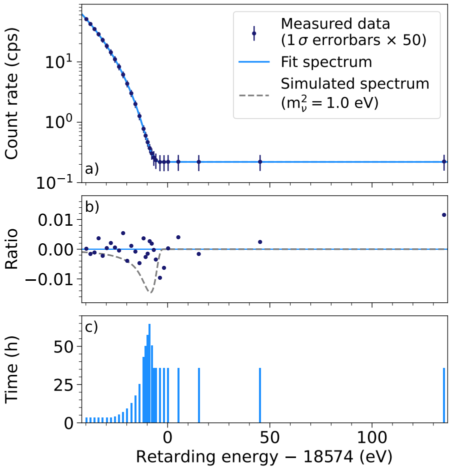
KATRIN timeline



KNM1 + KNM2: 5% of the full KATRIN statistics

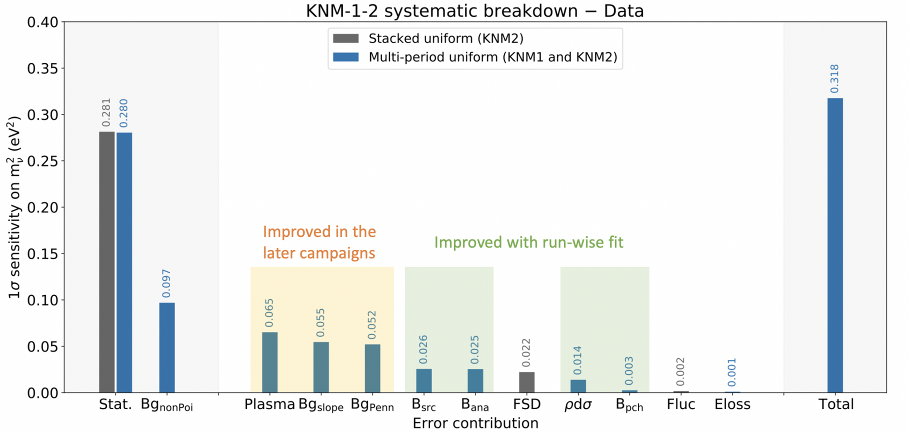
Measured electron spectra





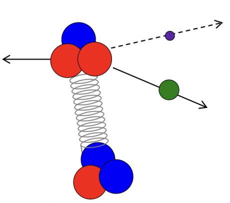
Main background: Radon decay

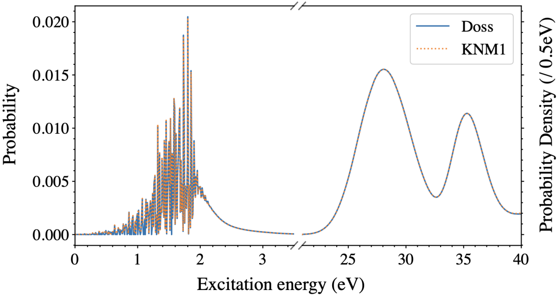
Breakdown of uncertainty



Observable non-Poissonian background due to time-correlated events from single ^{219}Rn decay. See *PRD 104, 012005 (2021)* for details.

Challenge: molecular final state distribution



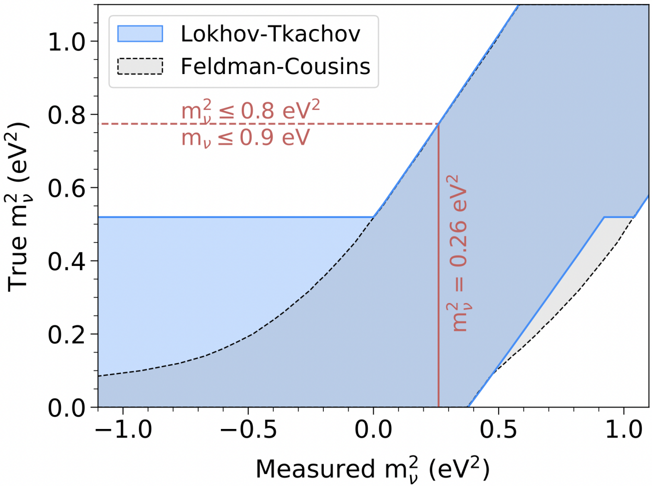


- Theoretical calculation in *PRL 84, 242 (2000)*, with updated results to be published this year
- Confirmation on branching ratio by TRIMS, *PRL 124, 222502 (2020)*
- Quantum computation and simulation under investigation

Analysis strategy and results – Frequentist

- Independent approaches for systematic uncertainties
  - Covariance matrix, MC propagation, Pull-terms
- Blind analysis
  - Artificial final state distributions
- Ring-wise fitting for golden run lists
  - 1 common m_ν^2, 12 $\times$ ring-wise endpoint, signal and background rates
- Best fit value for m_ν^2, with extrapolated model in the negative region
  - KNM1: $m_\nu^2 = -1.0^{+0.9}_{-1.1}\mathrm{eV}^2$
  - KNM2: $m_\nu^2 = 0.26^{+0.34}_{-0.34}\mathrm{eV}^2$

First sub-eV upper limit on neutrino mass

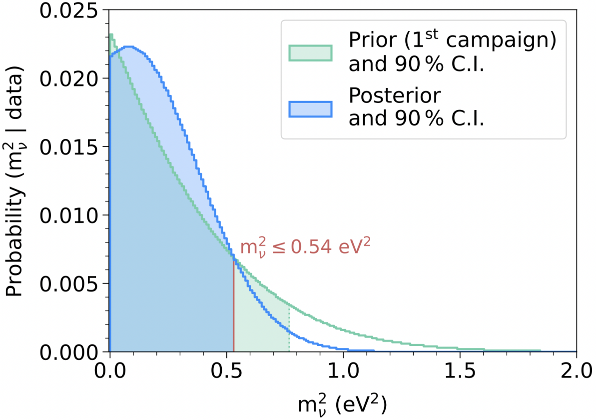


- KNM1 at 90% C.L.:
  $m_\nu < 1.1$eV
- KNM2 at 90% C.L.:
  $m_\nu < 0.9$eV
- Combined result at 90% C.L.:
  $m_\nu < 0.8$eV

arXiv:2105.08533 submitted to Nature Physics

Reference for the Lokhov-Tkachov construction:
Phys. Part. Nucl. 46, 347-365 (2015)

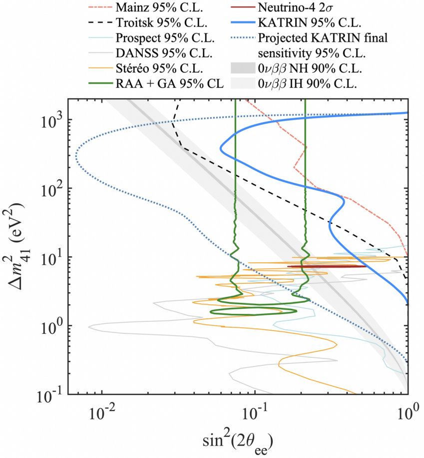
Bayesian combination of the two campaigns



- Flat prior for KNM1
- KNM1 prior for KNM2
- Bayesian limit at 90% C.I.:
  $m_\nu < 0.7$eV

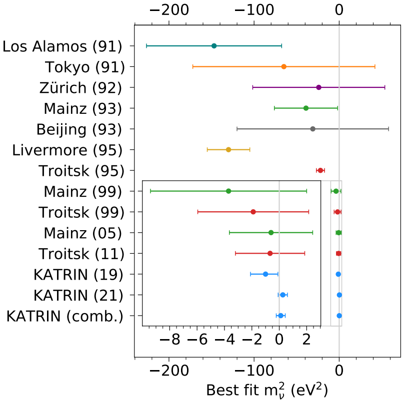
Beyond neutrino mass: new physics with KATRIN

- Sterile neutrinos
  - 1st campaign results in *PRL 126, 091803 (2021)*
  - 2nd campaign results coming soon
  - TRISTAN detector upgrade for keV-sterile searches
- Relic neutrinos
  - Sensitivity in *PRD 82, 062001 (2010)*
- Lorentz violation, new interactions, etc.



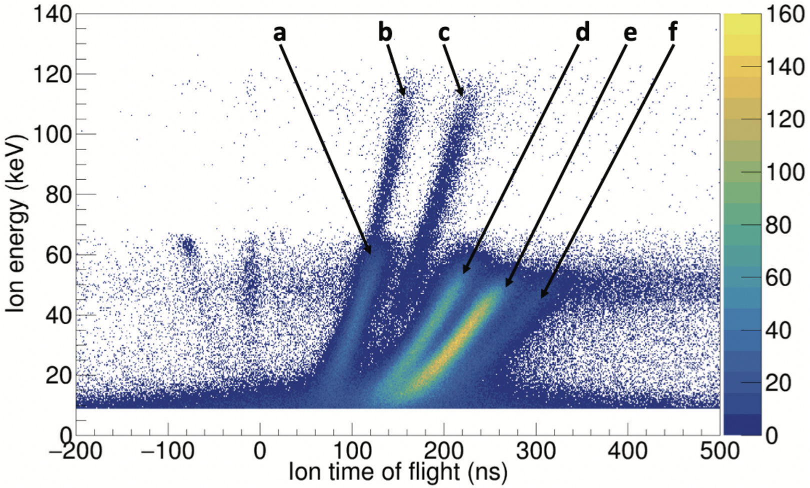
Summary

- KATRIN has improved the model-independent upper limit of $m_\nu < 0.8$eV at 90% C.L. with the first two measurement campaigns
- KATRIN is now running smoothly to reach the 5-year 0.2eV sensitivity
- New techniques under investigation for a precise calculation of molecular final states



Thanks for your attention!

Backup: TRIMS results



Backup: detector response