Glimpse of the KATRIN tritium analysis
NOW 2018

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**Outline**

1. Introduction
2. Data
3. Model components
4. Fitting
5. Unbiased analysis
6. Conclusion
Neutrino mass from $\beta$ spectrum

- Analyse electrons from molecular tritium $\beta$-decay

⇒ Transport electrons

⇒ Select energy

⇒ Model comparison
Karlsruhe Tritium Neutrino experiment

- 70-metre beam-line
- Gaseous $T_2$ from Tritium Laboratory Karlsruhe (40 g d$^{-1}$)
- eV-resolution spectrometer
- 95% efficiency Si-PIN diode wafer
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First tritium: commissioning phase

- First injection on 18th May
- Loop operation from 5th to 18th June
- 0.5% tritium atoms in D₂
- 0.1% stability
Counting hits

- Set retarding potential \( U \)
- Integration over the region of interest
Integrated rate stability

- Spectrometer retarding potential set 1 keV below endpoint
- Rate averaged on minute-basis

⇒ Stable over hours

⇒ Start analysis?
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Tritium $\beta$-decay spectrum

- Super-allowed decay
- Radiative corrections
- $1s$ screening
- ...
- Roughly:

$$\frac{d\Gamma}{dE}(E) \propto F(E) \phi_e(E) \int f(V) \phi_\nu(E + V) \Theta(Q - E - V - m_\nu) \, dV$$

$$\phi_\nu(E) = (Q - E) \sqrt{(Q - E)^2 - m_\nu^2}$$
HeT or HeD molecules after decay

- Spectrum $f$ of excitations
- Theoretical work
- Likely dominant 5-year term systematic
- **Learn** from data (spectroscopy, KATRIN, TRIMS)
Magnetic Adiabatic Collimation & Electrostatic filter

- Align electrons along electrostatic field
- Select all signal electrons with \( E > qU_A \left( 1 + \frac{B_A}{B_{\text{max}}} \right) \)
Response function with scattering in the source

- Mitigate scattering with $\theta < 51$ deg acceptance
- Upcoming scattering energy loss spectrum measurements

⇒ KATRIN model is semi-analytical (arXiv:1806.00369)
Minimisers, samplers and systematics

Minimisers & samplers

- Minuit
- Custom with analytical derivatives
- Markov Chain (BAT)

Systematics: work in progress

- Covariance matrices
- Monte Carlo propagation: pull terms or priors
  ⇒ Learn from data
- Dominated by column density for First Tritium
  ⇒ Normalisation (activity)
  ⇒ Shape (scattering)
First 3h-run fit: custom minimiser

- Fit Endpoint, Normalisation, Background
- Fix $m^2_{\nu} = 0$ eV$^2$
- Poisson likelihood, statistical errors only, 400 eV range

⇒ Already agreement
Endpoint evolution: Minuit-based

- $\chi^2$ expression

⇒ Endpoint reproduced
⇒ Distributions exhibit no inconsistencies
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Prevent observer’s bias

- Limit **blind** sensitivity to $m_\nu < 2 \text{ eV}$ (95\% C.L.) at best

$\Rightarrow$ Add fluctuations or **systematics** to $m_\nu^2 : \sigma_{\text{blind}}$
Data and model blinding methods

- Sensitivity studies for data-based and model-based methods

⇒ Three out five very suitable
Blind analysis of commissioning data

- Test on First Tritium runs
- Increase systematic uncertainty on $m^2_{\nu}$ by smearing $s$

$\Rightarrow$ Matches theoretical Taylor expansion $2s^2$

$\Rightarrow$ Other fit parameters unscathed
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✓ Stable running experiment

✓ Promising data analysis

✓ Towards a blind analysis

✓ Already doing analysis with systematics

✓ On-going measurements

✓ $\nu$-mass runs in early 2019
Thank you for your attention