Glimpse of the KATRIN tritium analysis

NOW 2018

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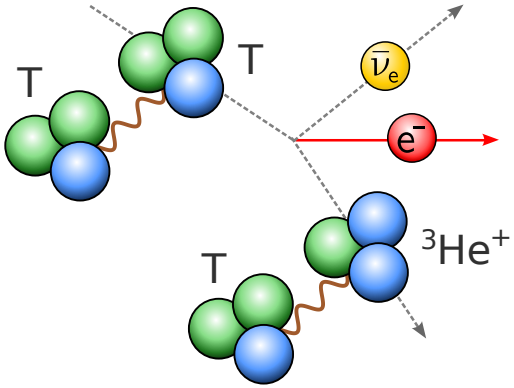
KATRIN

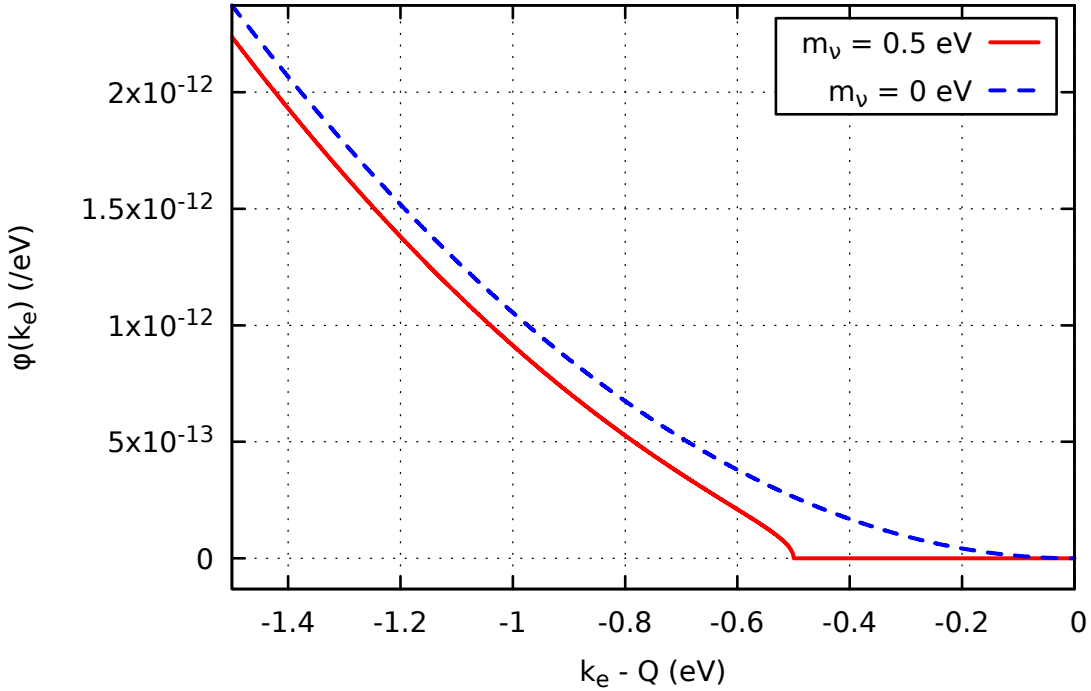
KARLSRUHE TRITIUM NEUTRINO EXPERIMENT

Outline

Neutrino mass from β spectrum

- Analyse electrons from molecular tritium β-decay





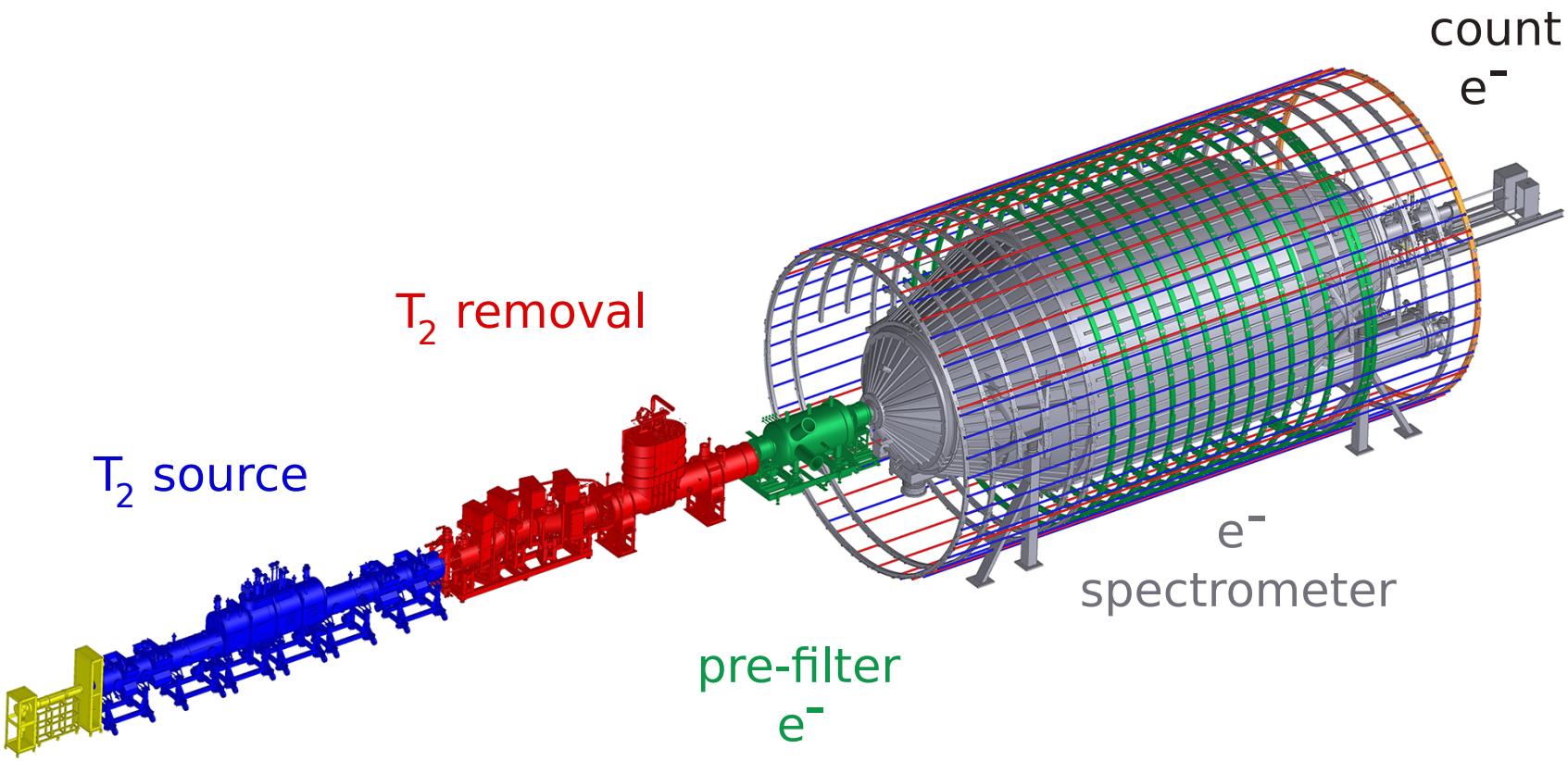
$\Rightarrow$ Transport electrons

$\Rightarrow$ Select energy

$\Rightarrow$ Model comparison

Karlsruhe Tritium Neutrino experiment

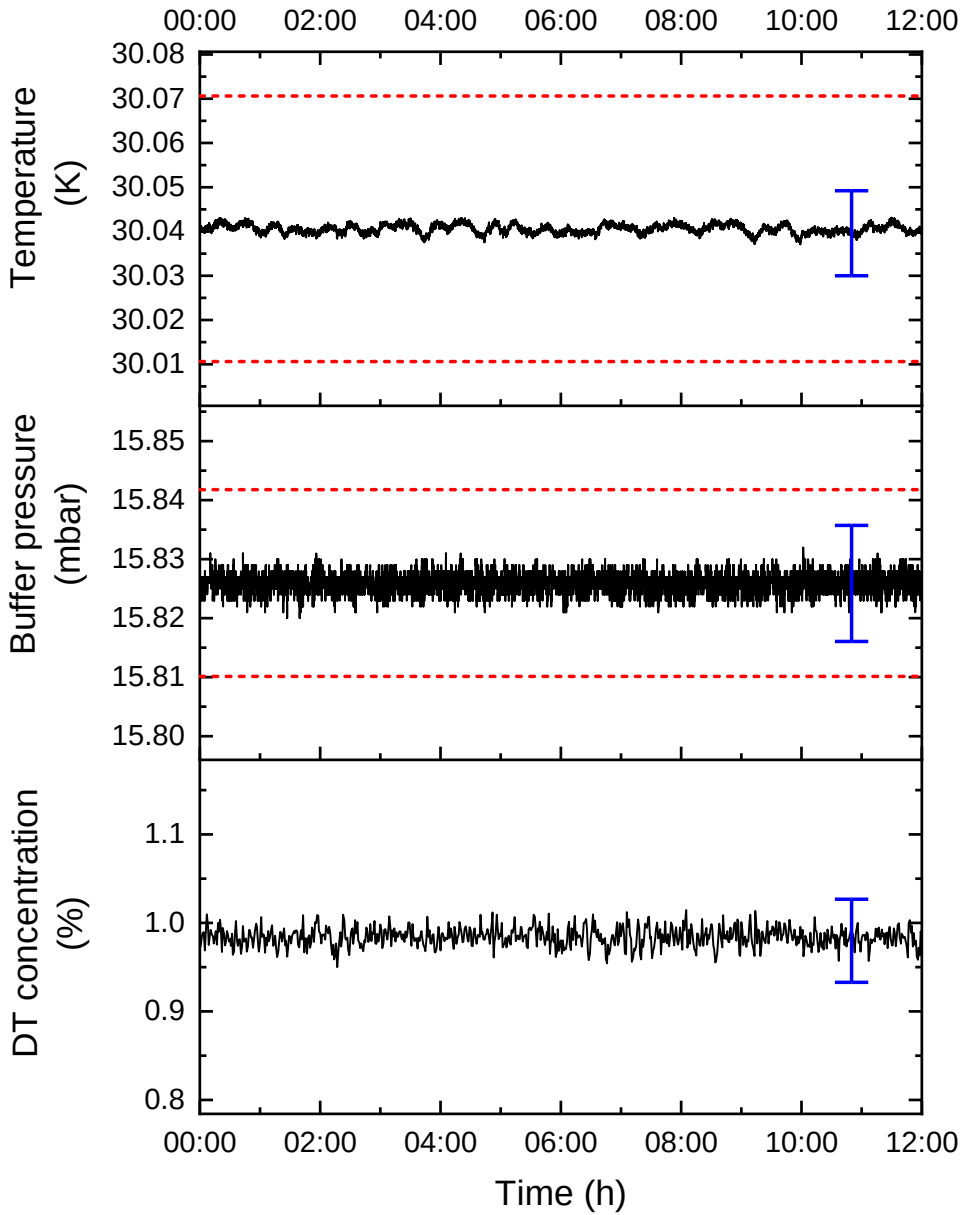
- 70-metre beam-line
- Gaseous T_2 from Tritium Laboratory Karlsruhe ($40\,\mathrm{g\,d^{-1}}$)
- eV-resolution spectrometer
- 95%-efficiency Si-PIN diode wafer



Outline

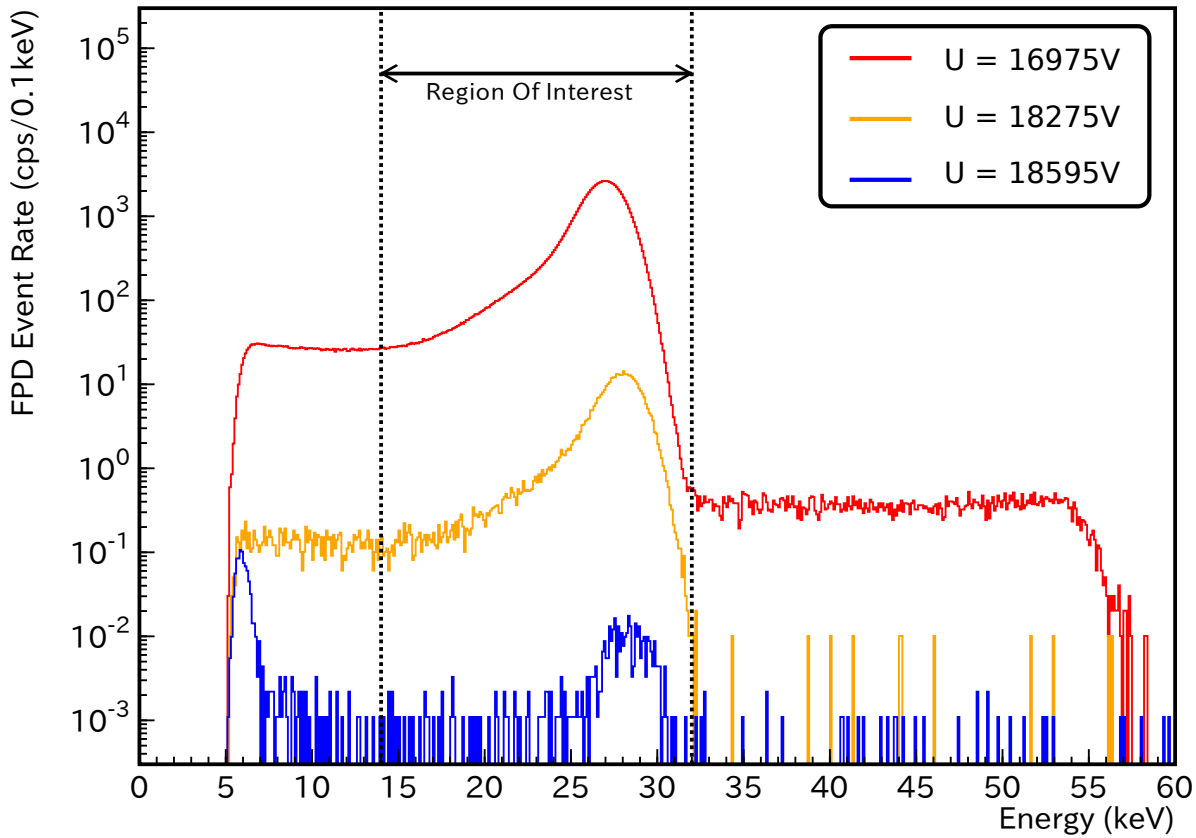
First tritium: commissioning phase

- First injection on 18th May
- Loop operation from 5th to 18th June
- 0.5% tritium atoms in D_2
- 0.1% stability



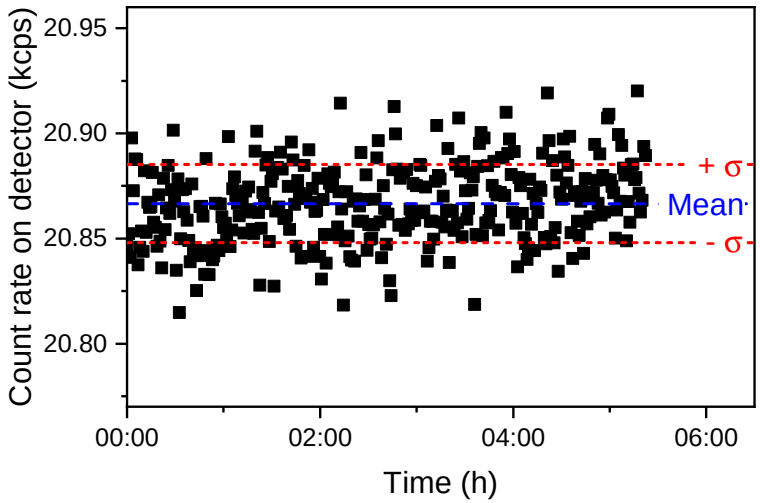
Counting hits

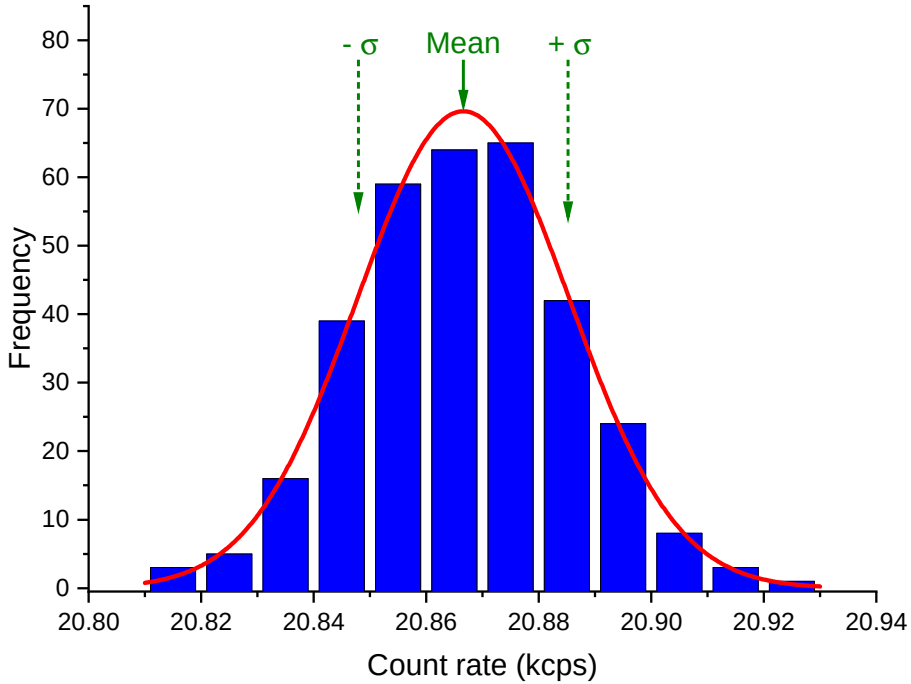
- Set retarding potential U
- Integration over the region of interest



Integrated rate stability

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





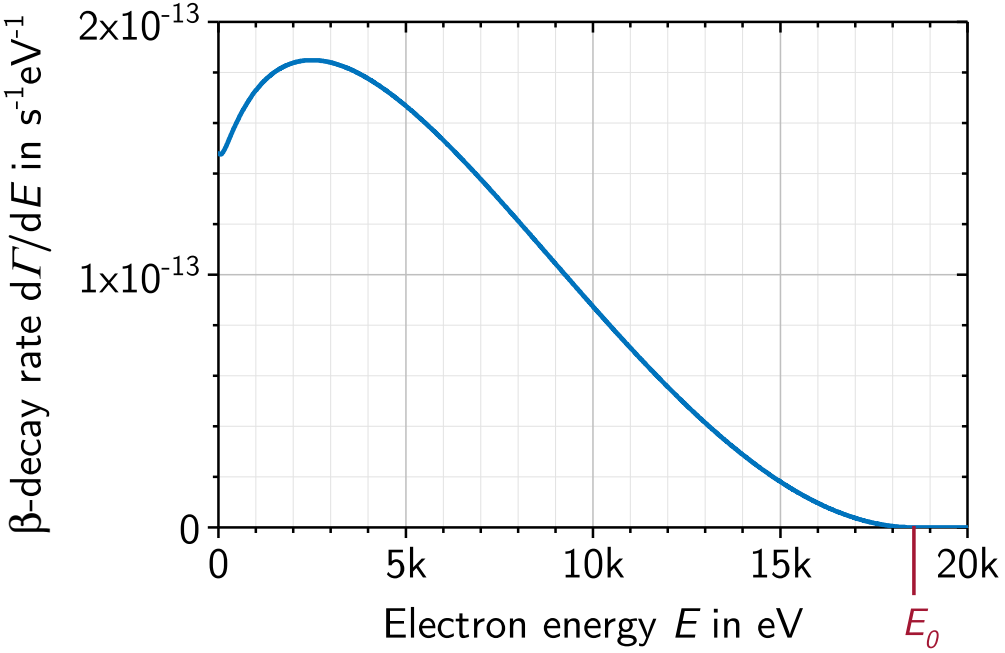
⇒ Stable over hours

⇒ Start analysis?

Outline

Tritium β-decay spectrum

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

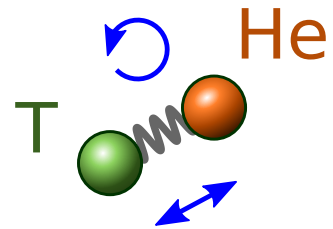


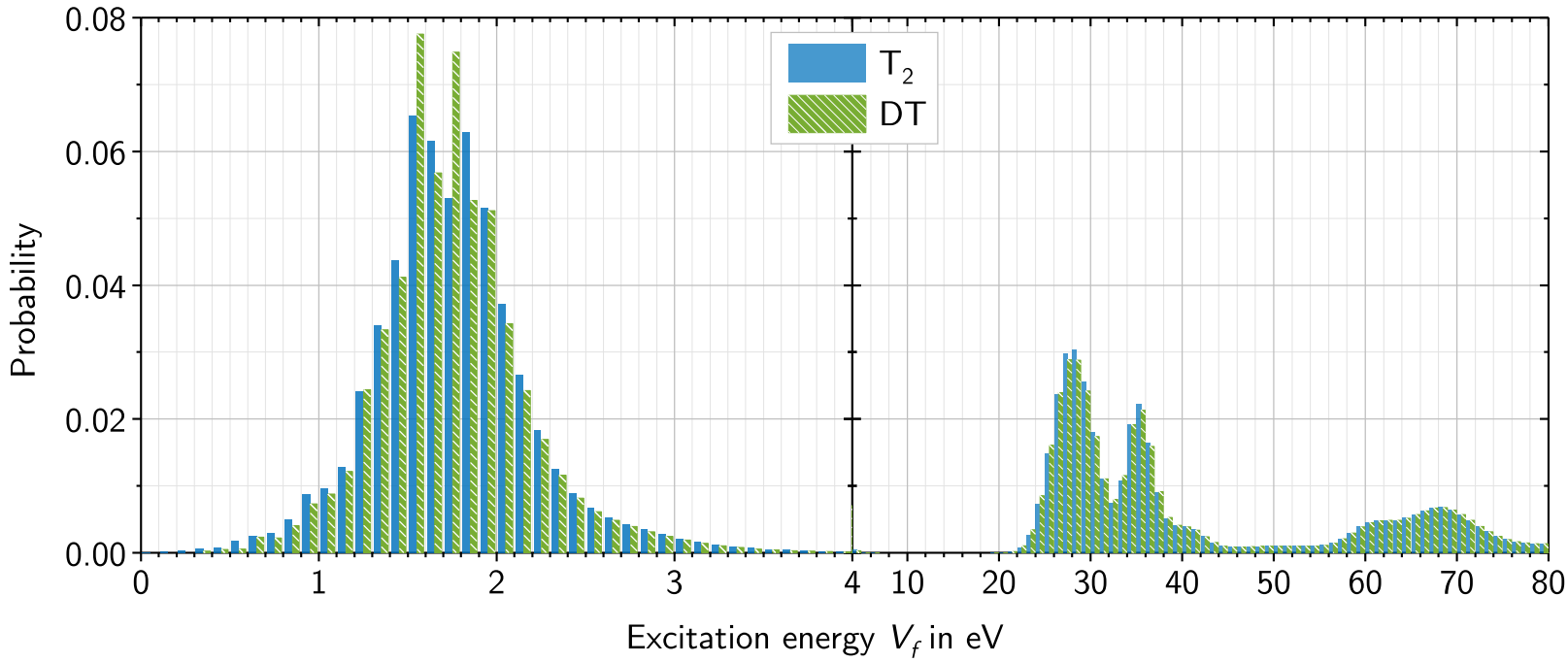
$$\frac{\mathrm{d}\Gamma}{\mathrm{d}E}(E) \propto F(E)\,\phi_e(E) \int f(V)\;\phi_\nu(E+V)\Theta(Q-E-V-m_\nu)\,\mathrm{d}V$$

$$\phi_\nu(E) = (Q-E)\sqrt{(Q-E)^2 - {m_\nu}^2}$$

HeT or HeD molecules after decay

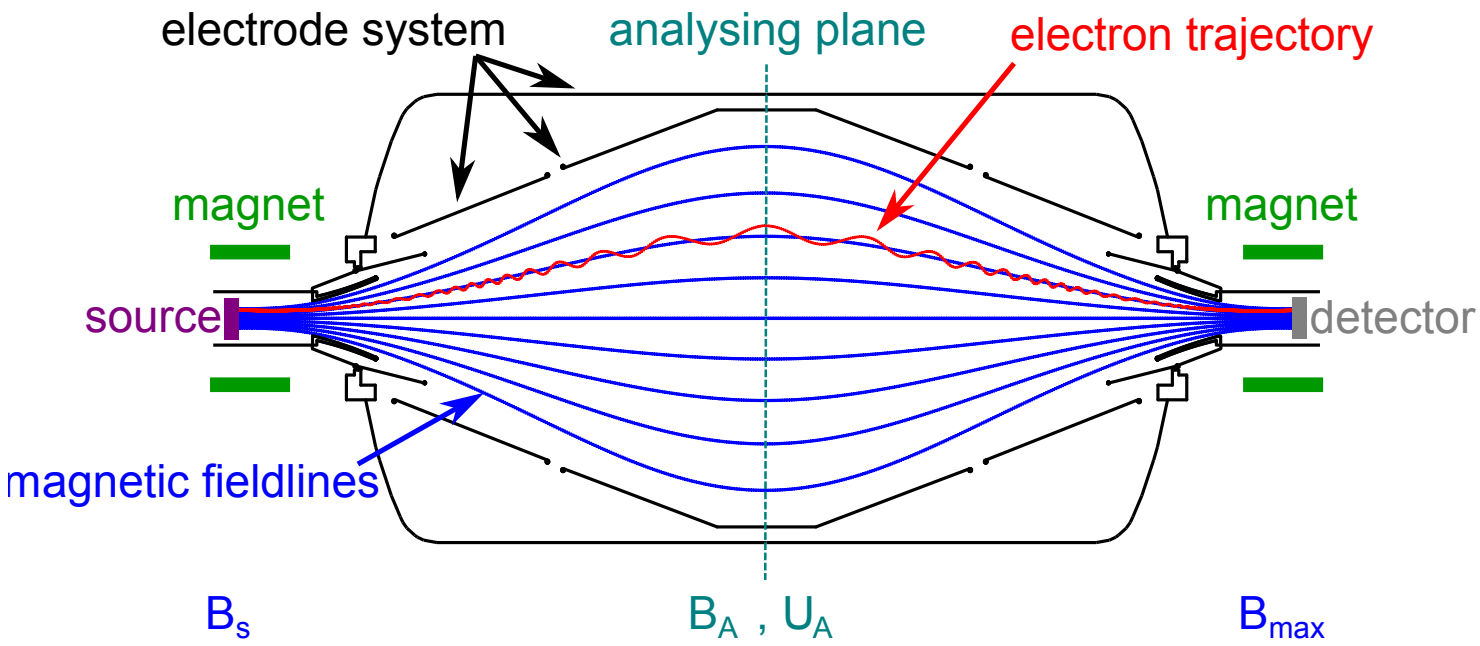
- Spectrum f of excitations
- Theoretical work
- Likely dominant 5-year term systematic
- Learn from data (spectroscopy, KATRIN, TRIMS)





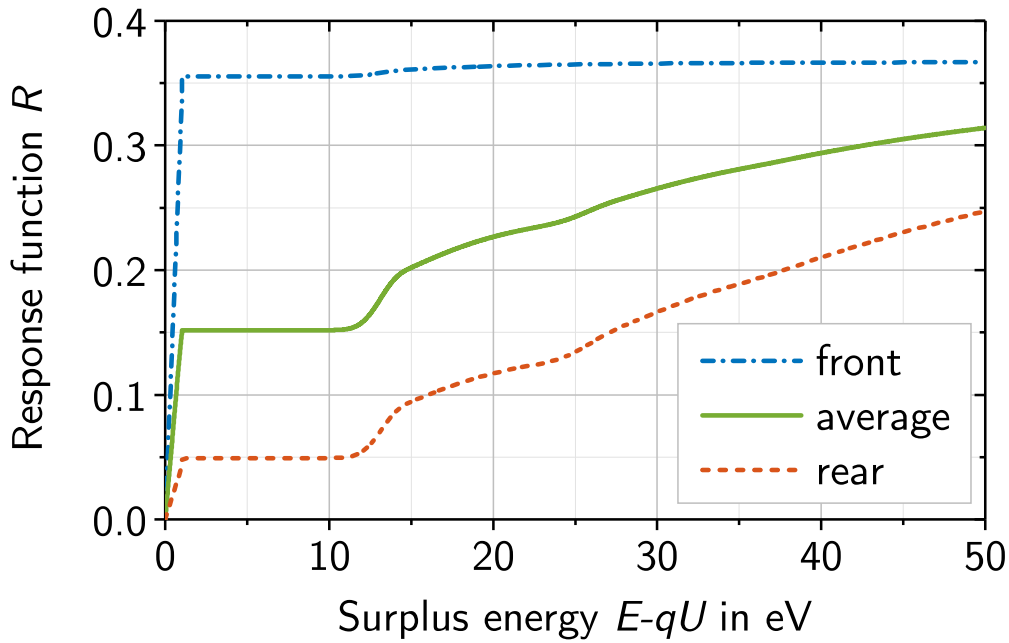
Magnetic Adiabatic Collimation & Electrostatic filter

- Align electrons along electrostatic field
- Select all signal electrons with $E > qU_A \left(1 + \frac{B_\mathrm{A}}{B_\mathrm{max}}\right)$



Response function with scattering in the source

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



⇒ KATRIN model is semi-analytical (arXiv:1806.00369)

Outline

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

  $\Rightarrow$ Learn from data

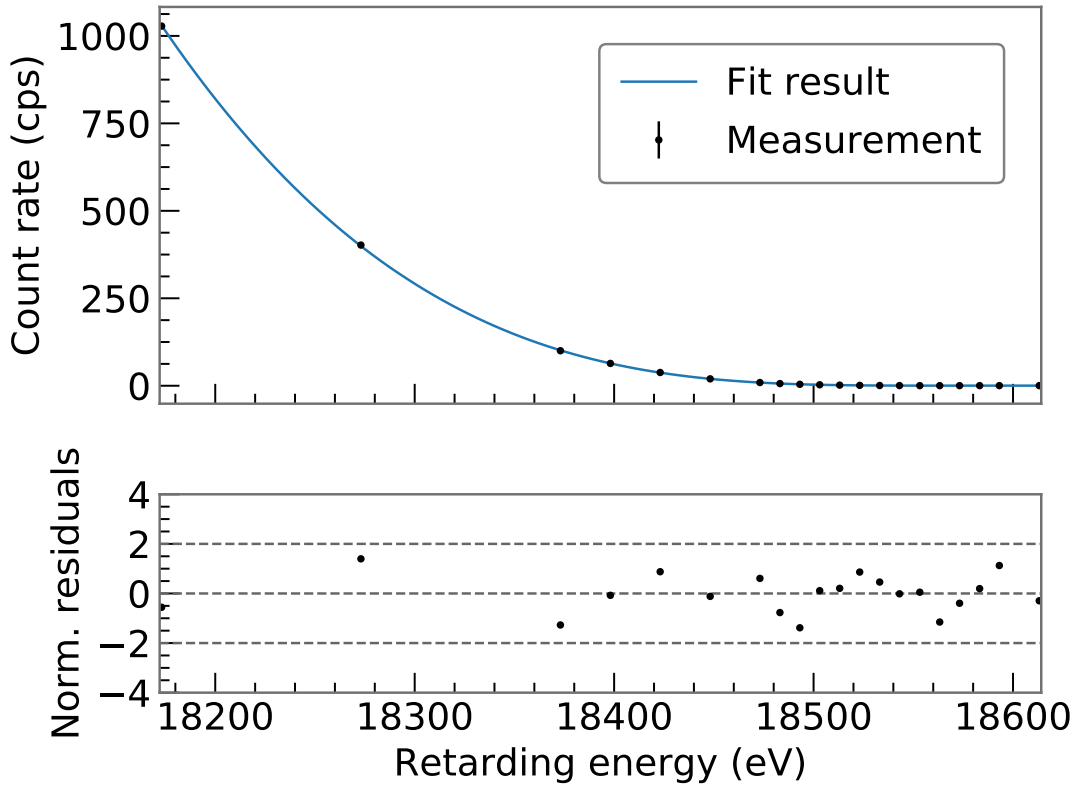
- Dominated by column density for First Tritium

  $\Rightarrow$ Normalisation (activity)

  $\Rightarrow$ Shape (scattering)

First 3h-run fit: custom minimiser

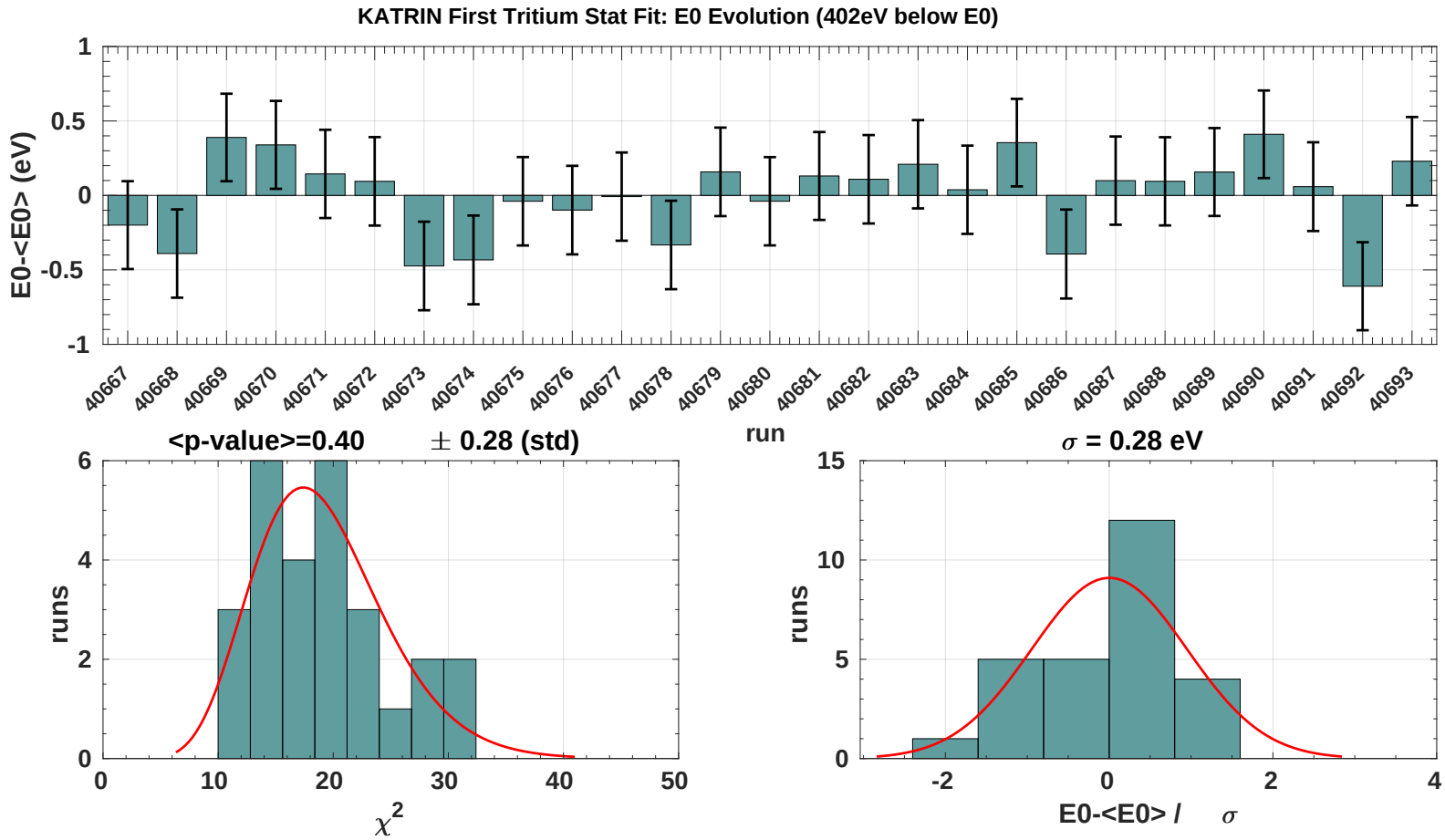
- Fit Endpoint, Normalisation, Background
- Fix $m_\nu^2 = 0\,\mathrm{eV}^2$
- Poisson likelihood, statistical errors only, 400 eV range



⇒ Already agreement

Endpoint evolution: Minuit-based

- χ^2 expression



⇒ Endpoint reproduced

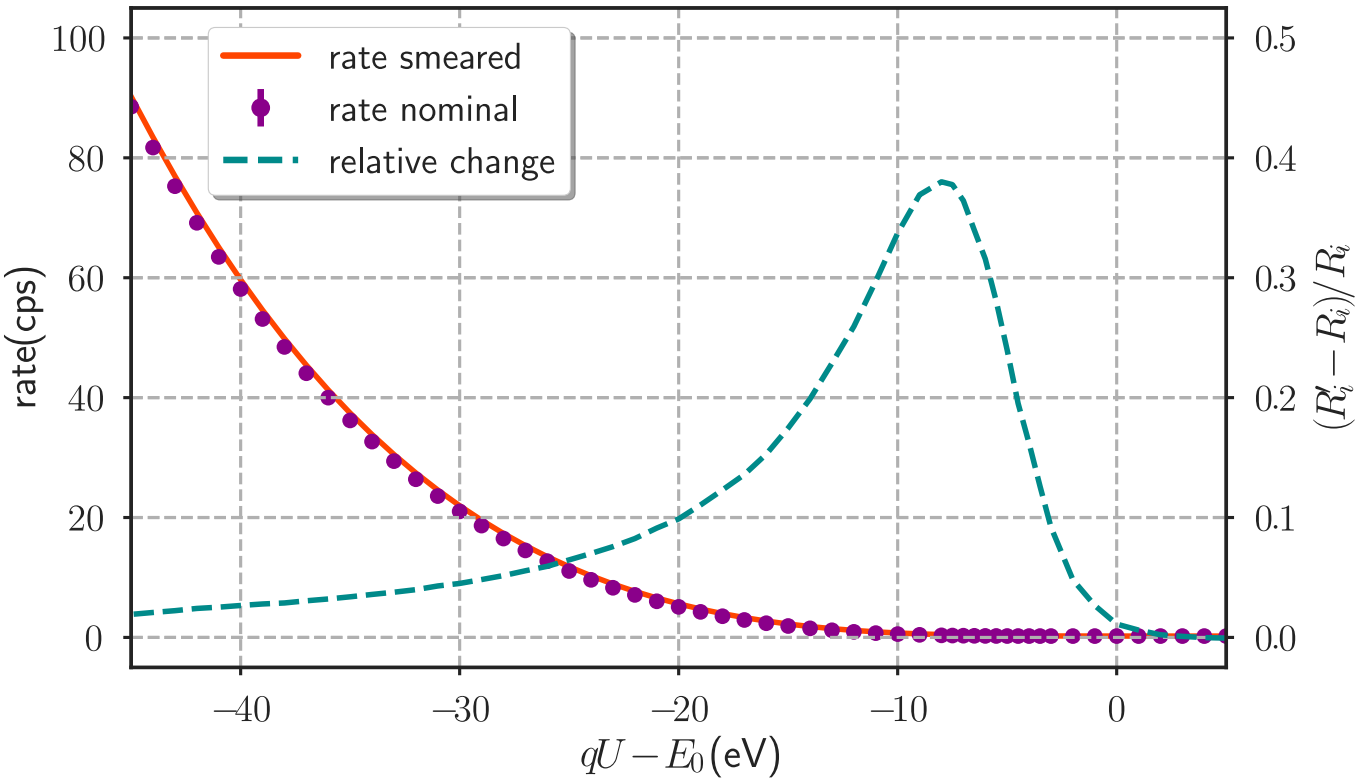
⇒ Distributions exhibit no inconsistencies

Outline

Prevent observer's bias

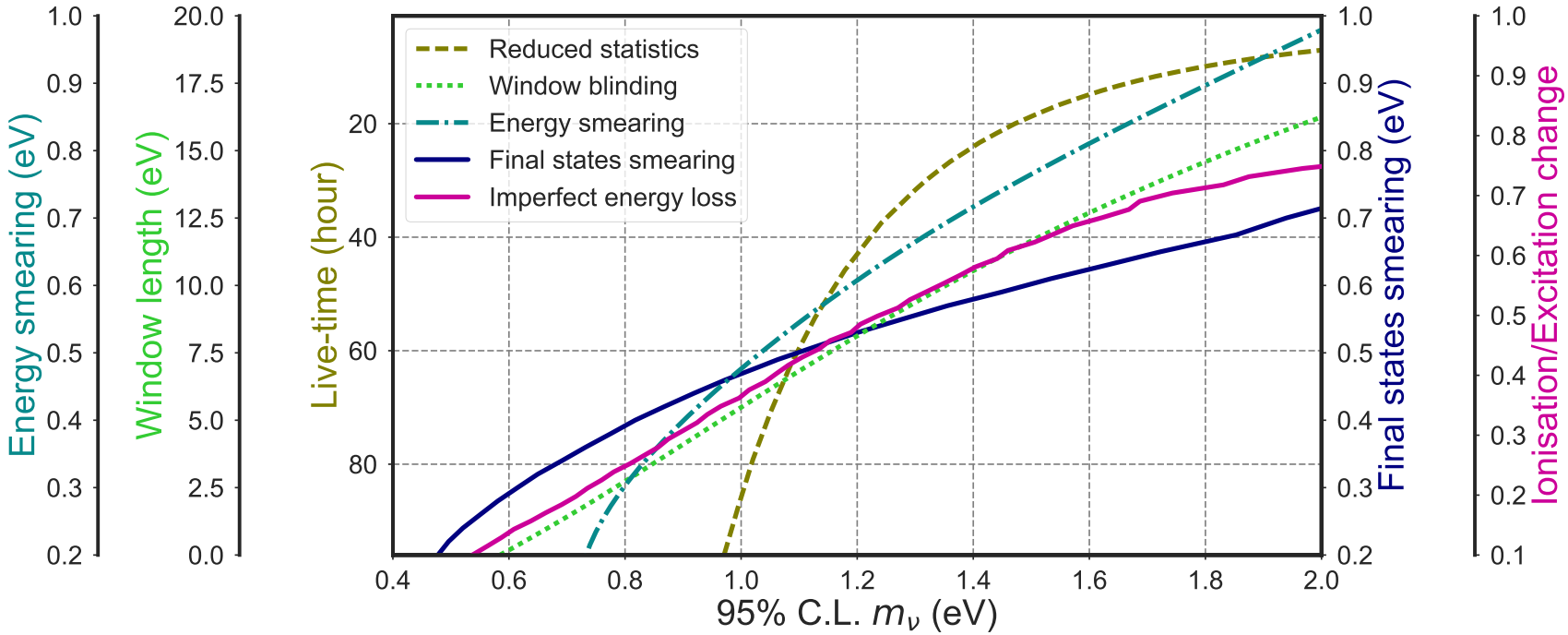
- Limit blind sensitivity to $m_\nu < 2\,\text{eV}$ $(95\%\,\text{C.L.})$ at best

  $\Rightarrow$ Add fluctuations or systematics to m_ν^2 : σ_{blind}



Data and model blinding methods

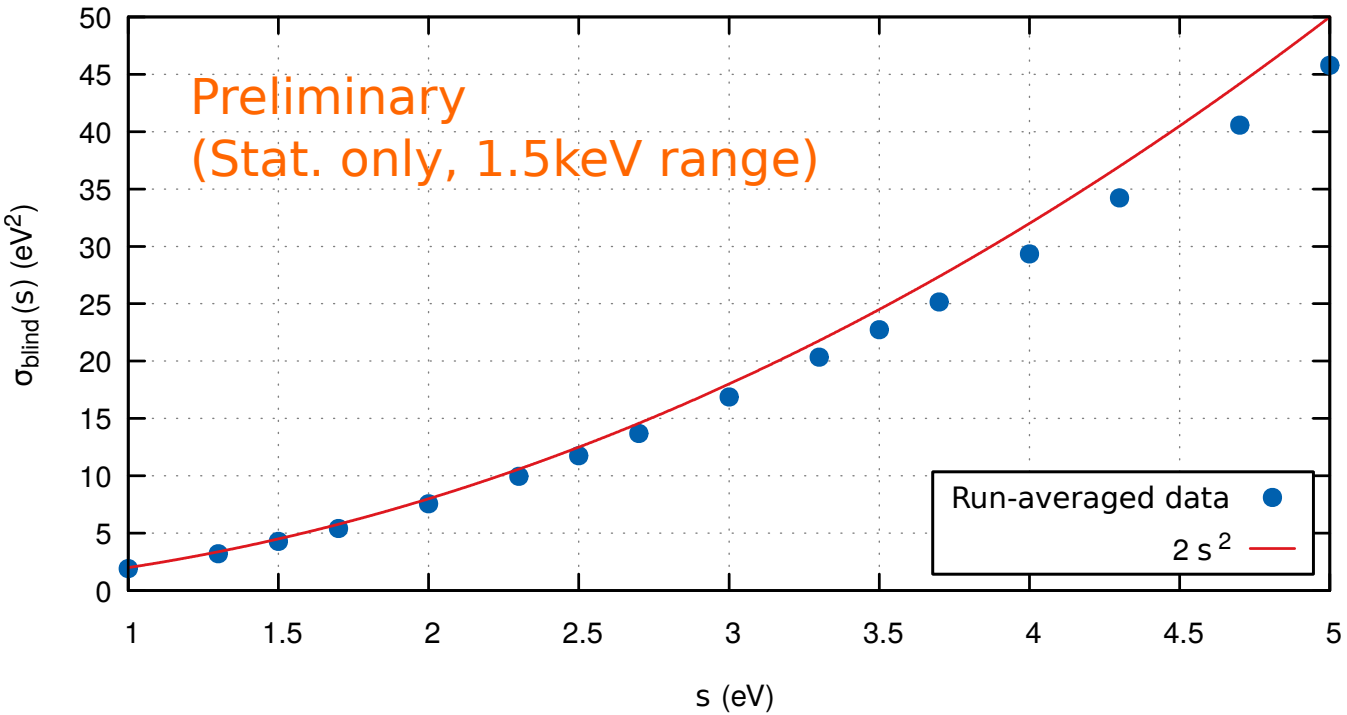
- Sensitivity studies for data-based and model-based methods



⇒ Three out five very suitable

Blind analysis of commissioning data

- Test on First Tritium runs
- Increase systematic uncertainty on m_ν^2 by smearing s



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

$\Rightarrow$ Other fit parameters unscathed

Outline

Conclusion & prospects

- ✓ Stable running experiment
- ✓ Promising data analysis
- ✓ Towards a blind analysis
- ✓ Already doing analysis with systematics
- ✓ On-going measurements
- ✓ ν-mass runs in early 2019

Thank you

Thank you for your attention