



SFB 1258

Neutrinos:
Dark Matter
Messengers



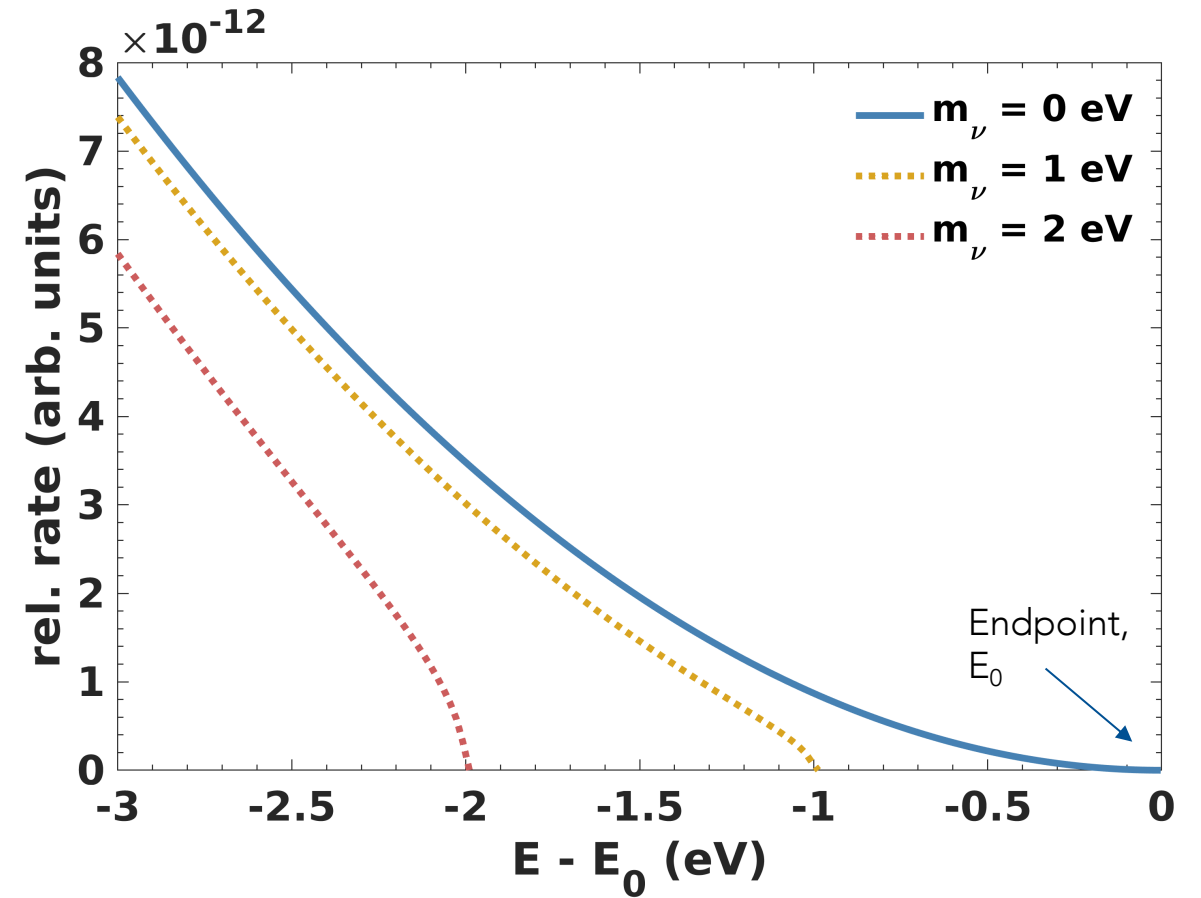
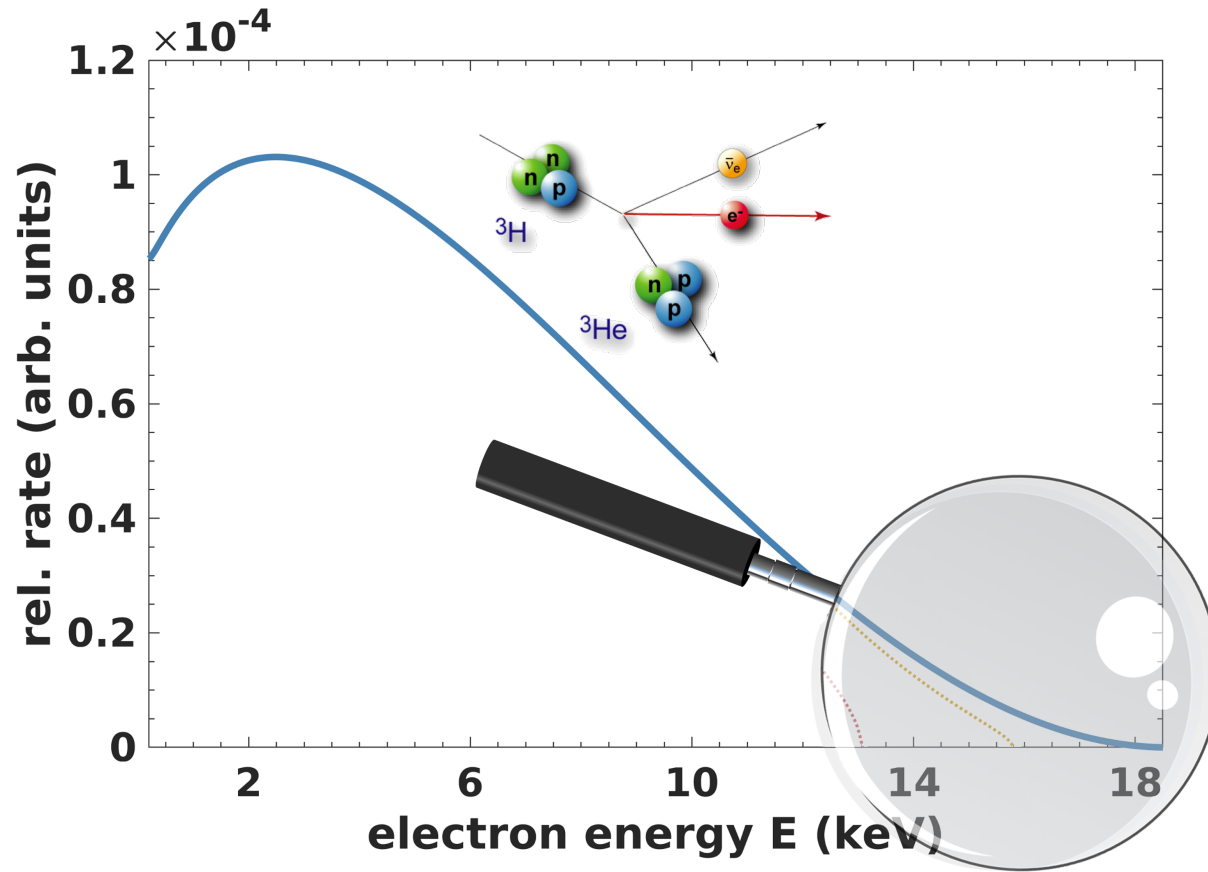
The First KATRIN Neutrino Mass Result

KATRIN Symposium, KIT, 16/09/2019

Thierry Lasserre (CEA & SFB1258)

On behalf the KATRIN collaboration

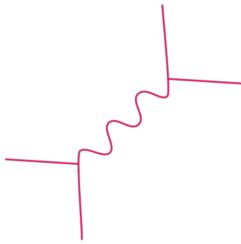
The Neutrino Mass Imprint



Search for a specific shape distrorsion of the electron energy spectrum

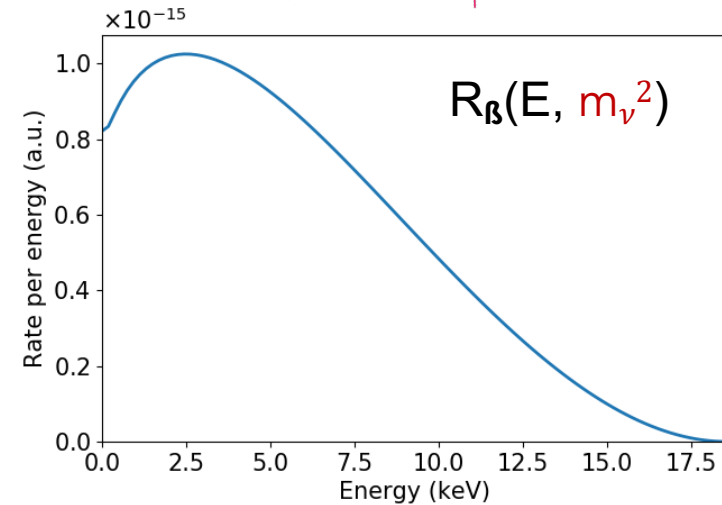
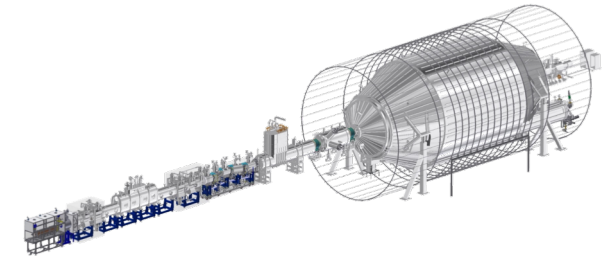
Observable: the Integral β -spectrum

tritium β -decay theory

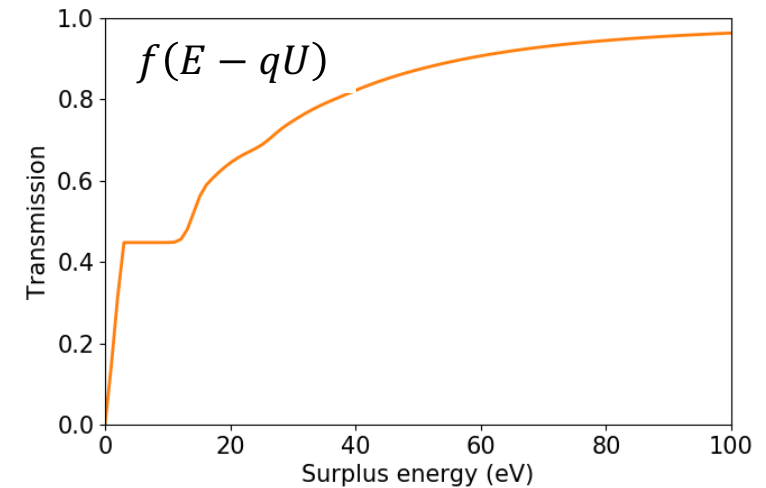
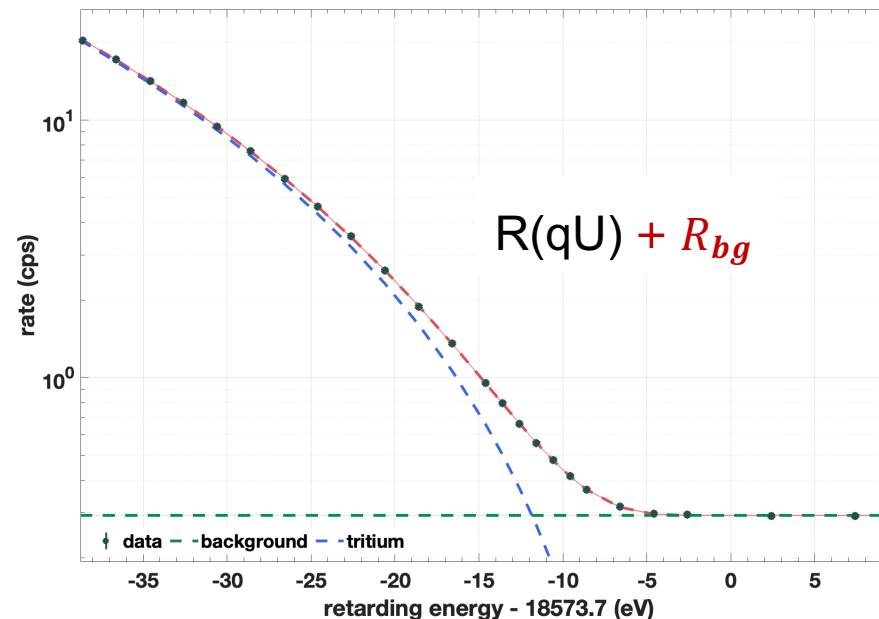


$$R(qU) = A_s \cdot N_T \int_{qU}^{E_0} R_\beta(E, m_\nu^2) \cdot f(E - qU) dE + R_{bg}$$

experimental setup



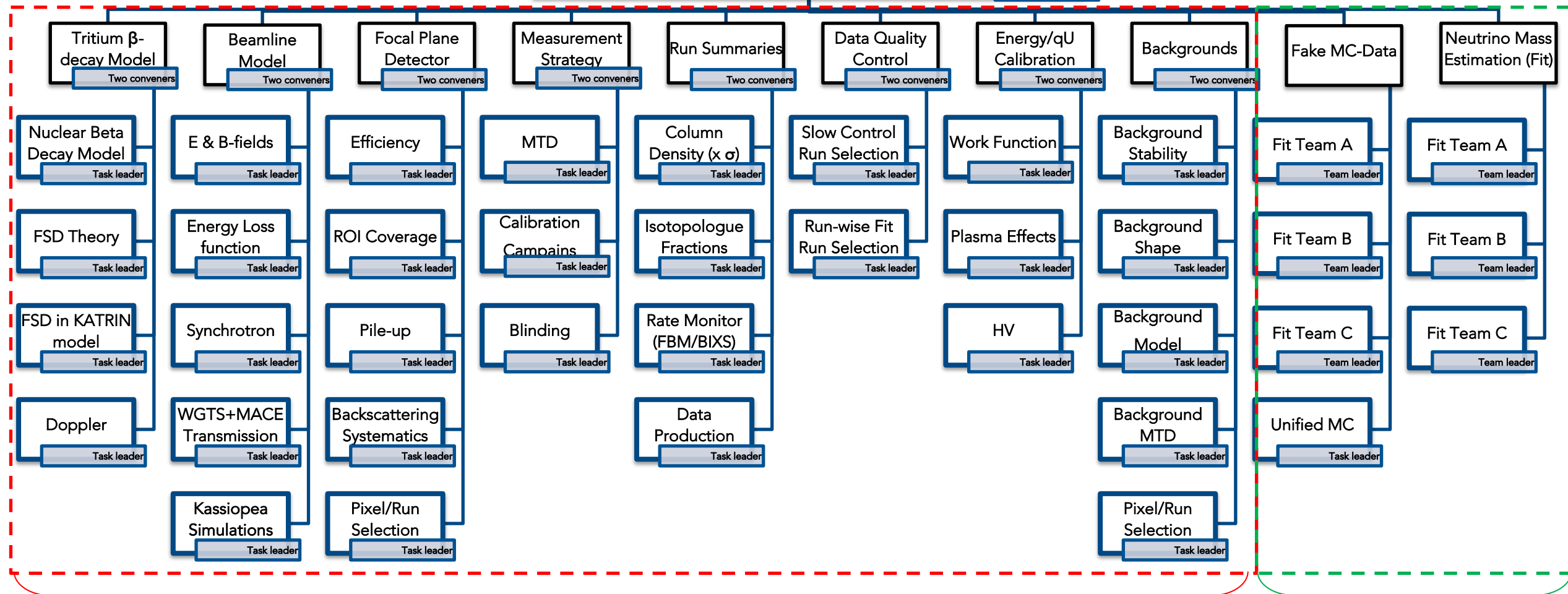
integral β -spectrum



$\leftarrow R_{bg}$

KATRIN First Neutrino Mass Analysis Project (KNM1)

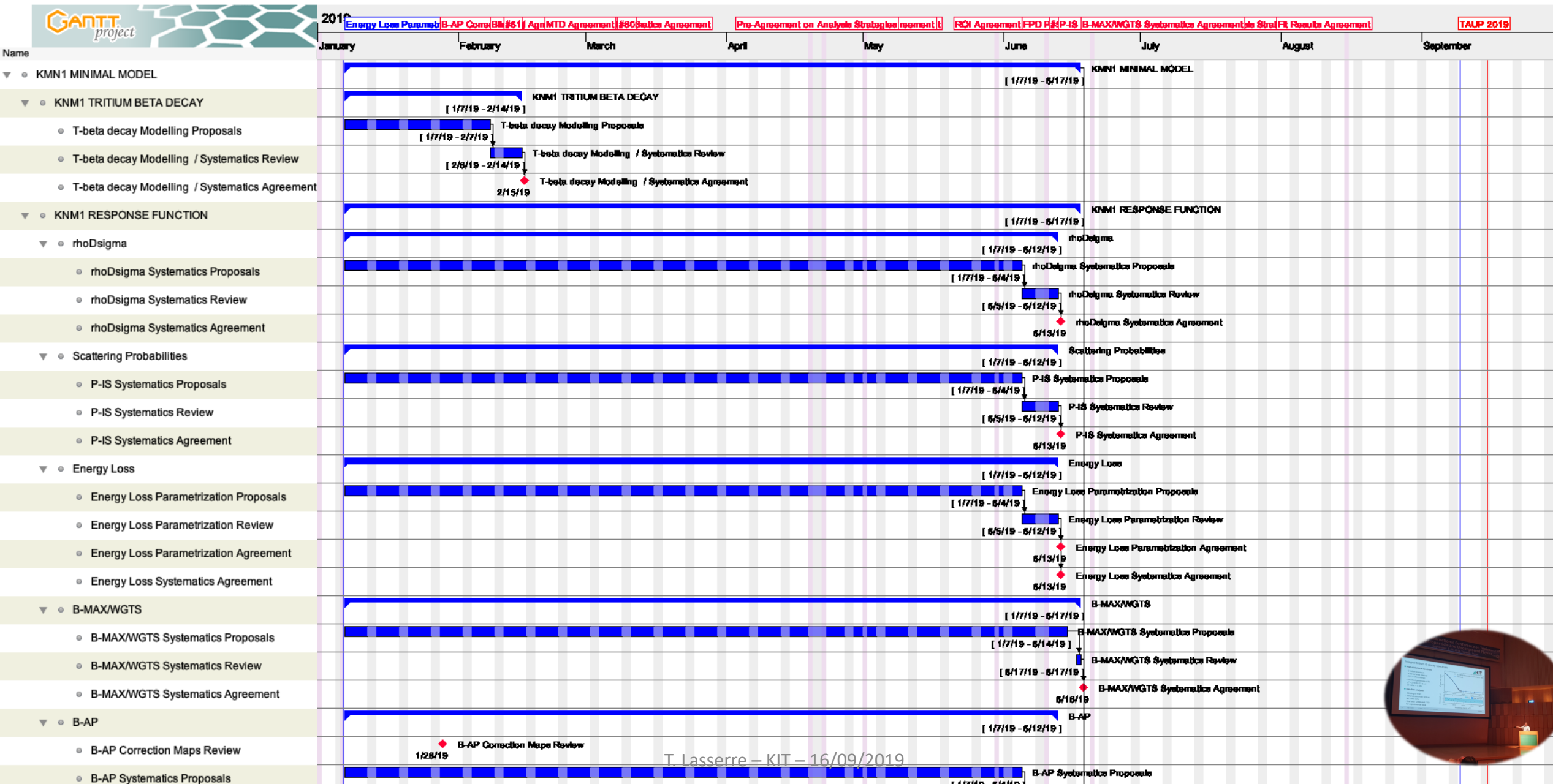
Analysis coordinator



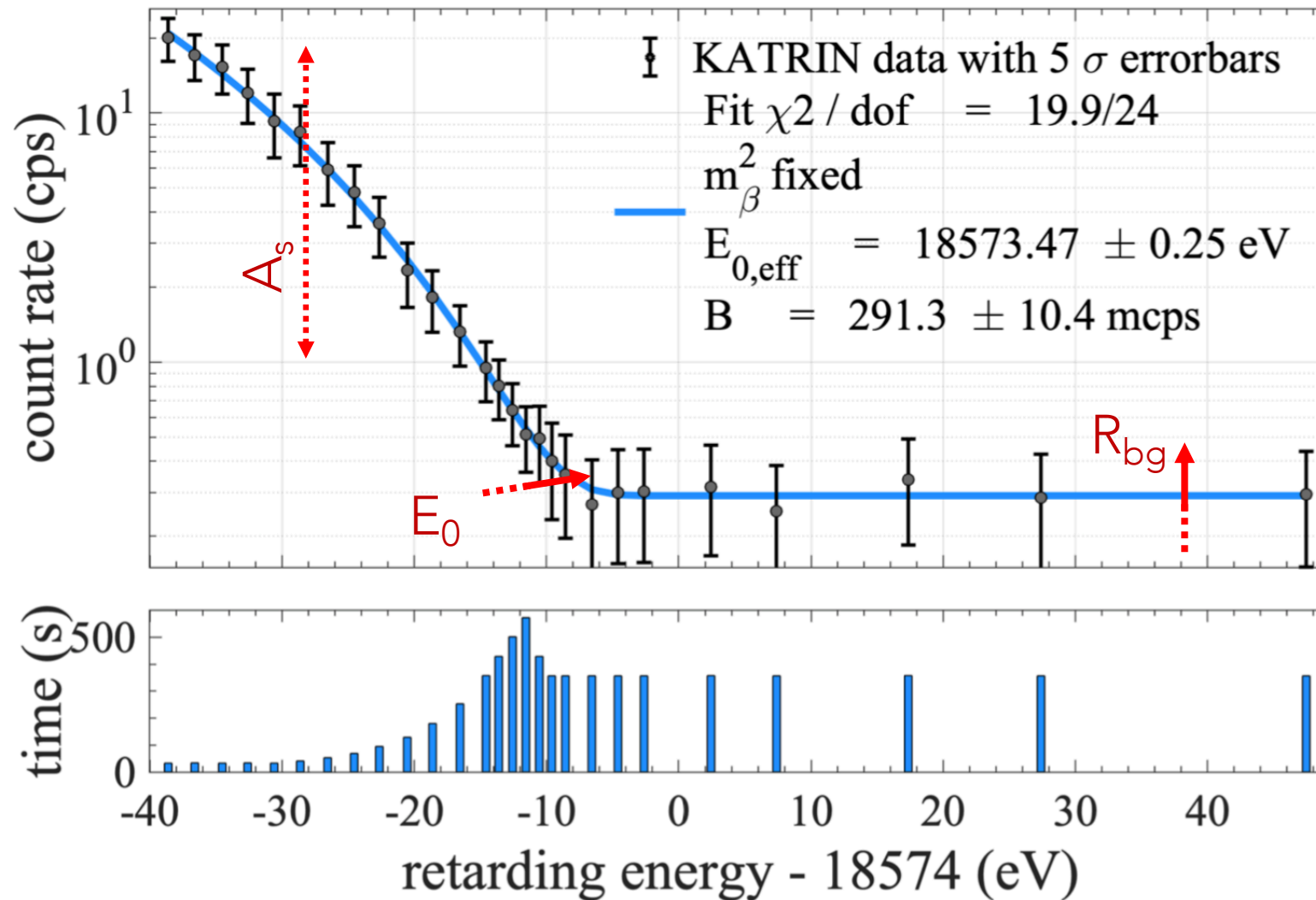
Common Trunk = all what concerns modeling & calibration

final fits
(2 independent methods)

Analysis Schedule



Integral spectrum fit of a single β -scan (Data)

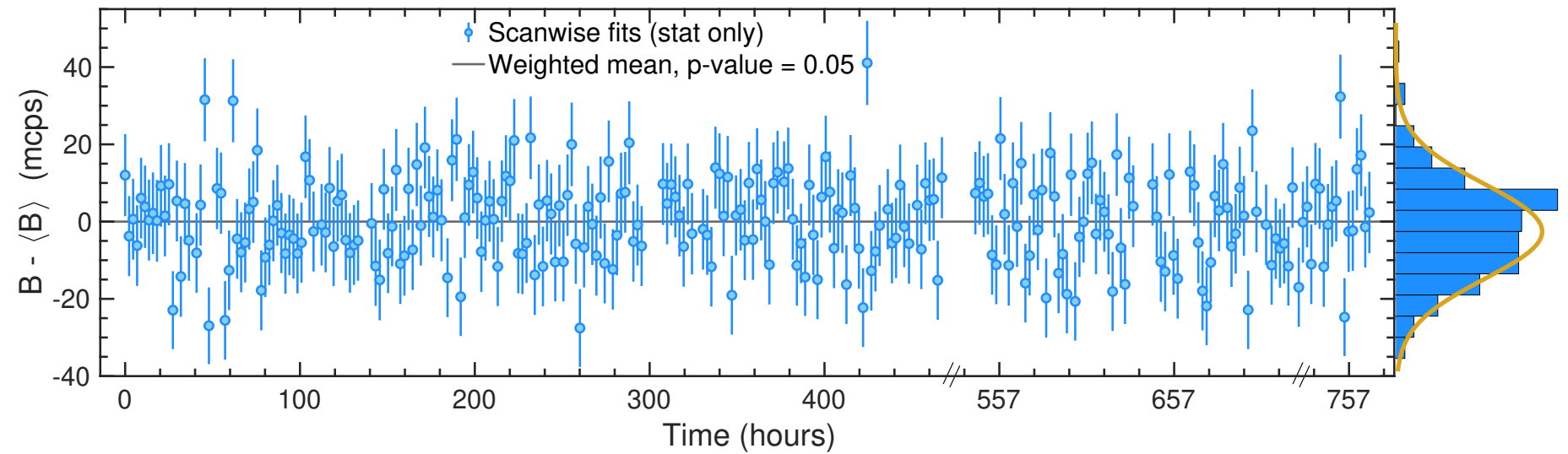


- A single 2h β -scan
- m_ν fixed to 0
- 3 parameter fit
 - Tritium Activity, A_s
 - Endpoint, E_0
 - Background, R_{bg}
- High quality data

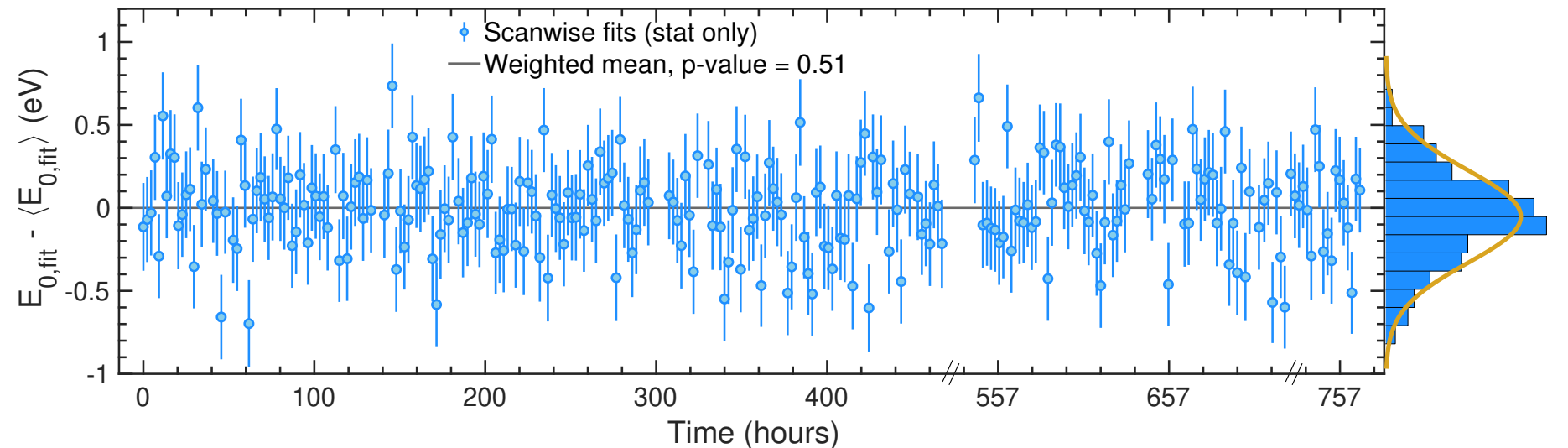
β -scan Fit Parameters Stability over 780 hours (Data)

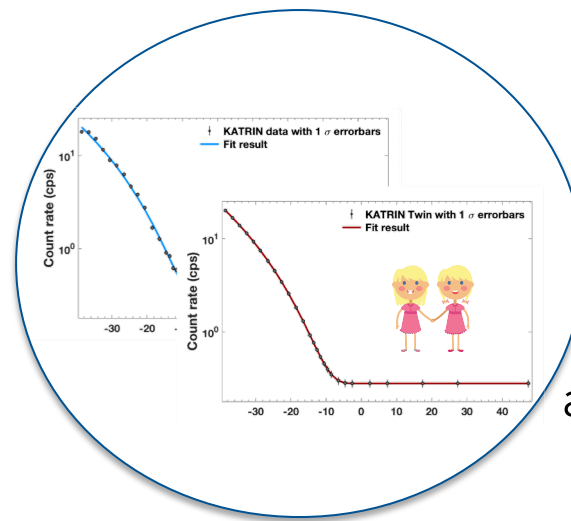
274 single
 β -scan fits

Stable
Background



Stable
Endpoint



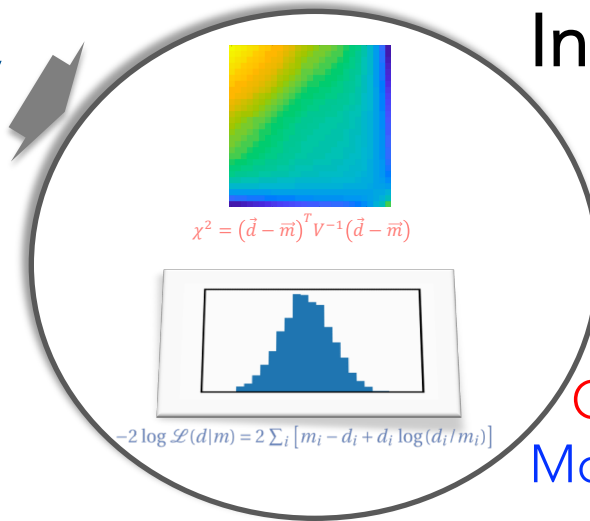
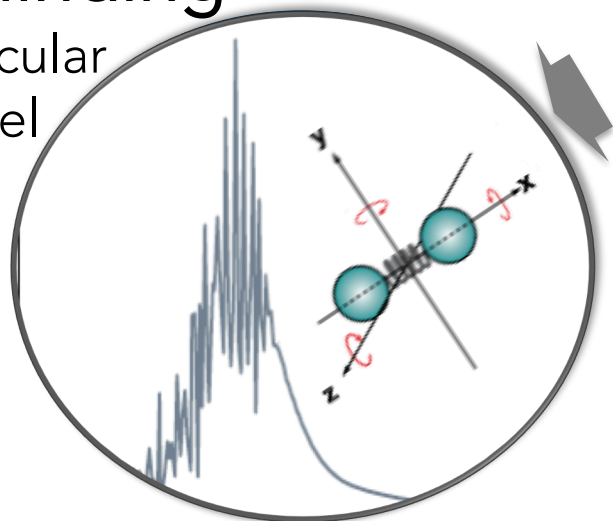


Analysis on fake data
 implement & freeze analysis
 using fake data mimicking
 actual 1st science run

Bias Free Analysis Strategy

Model blinding

modified molecular
 physics model
 veiling m_ν^2 only



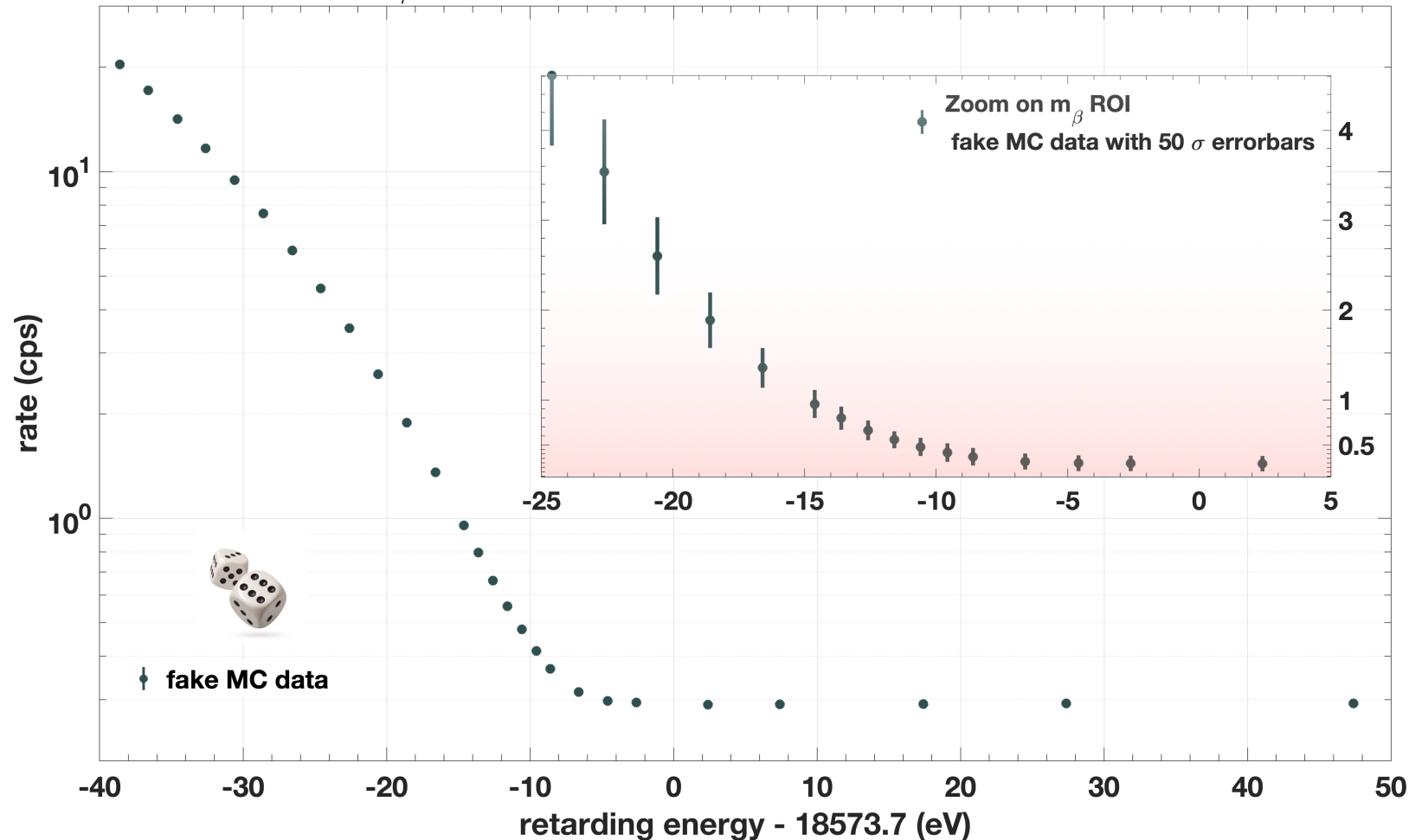
Independence & Complementarity

2 independent
 approaches to
 assess systematics

Covariance matrix
Monte Carlo propagation

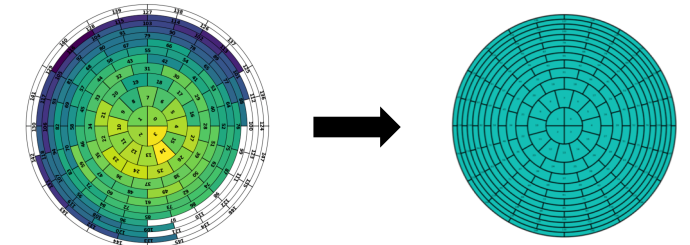
Integral tritium β -decay spectrum: Fake Data

KATRIN First m_β Run (fake MC data) - 561 hours, $2 \cdot 10^6 e^-$ in $[E_0-39 ; E_0+47]$ eV



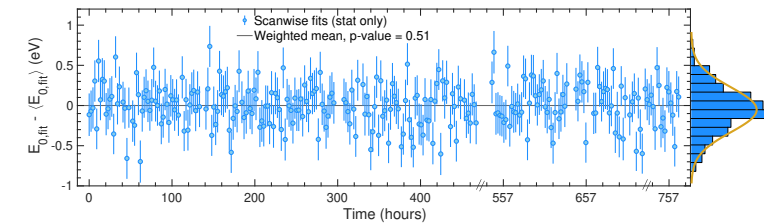
Pixel Combination

- Sum all pixel counts

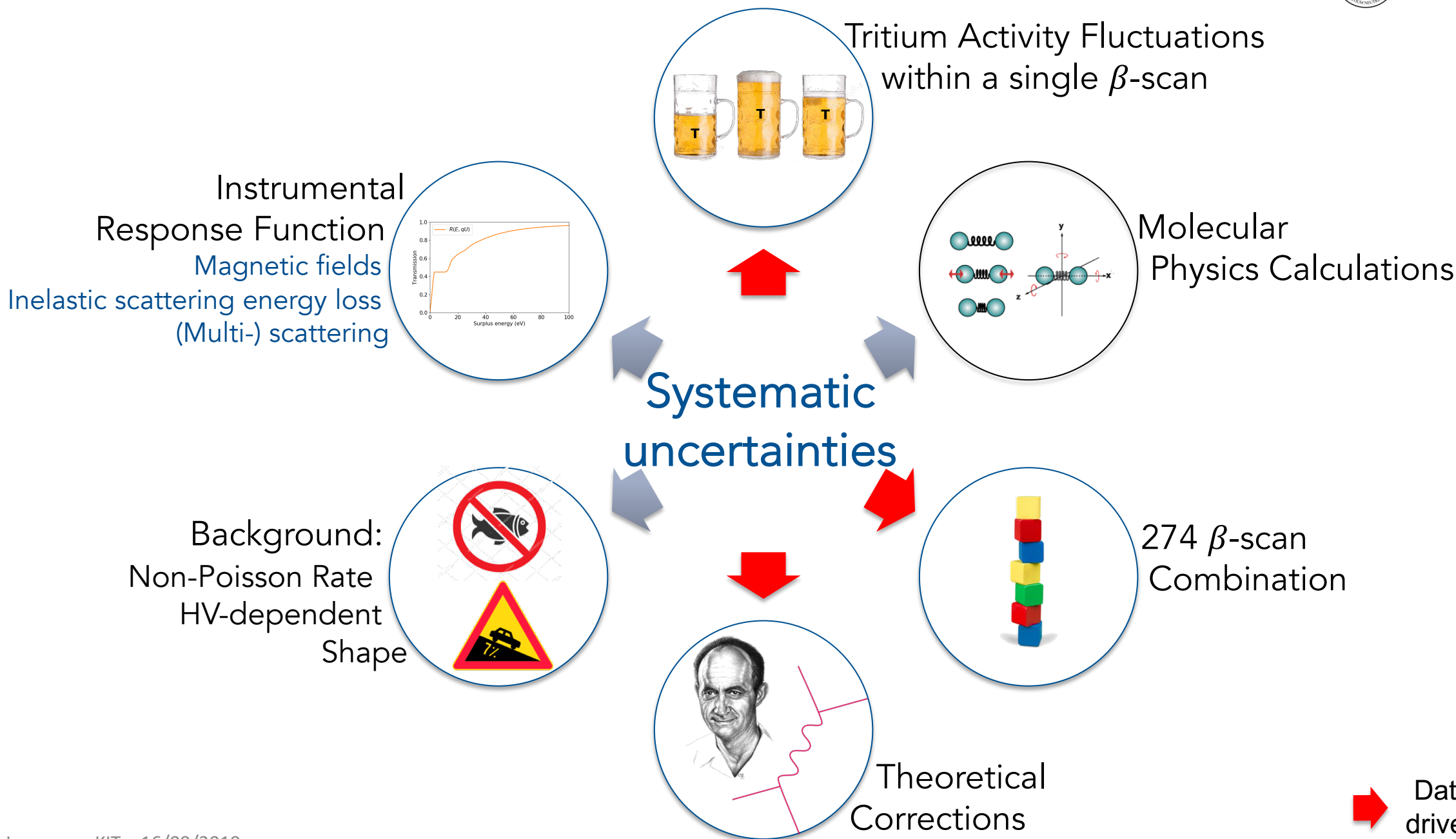


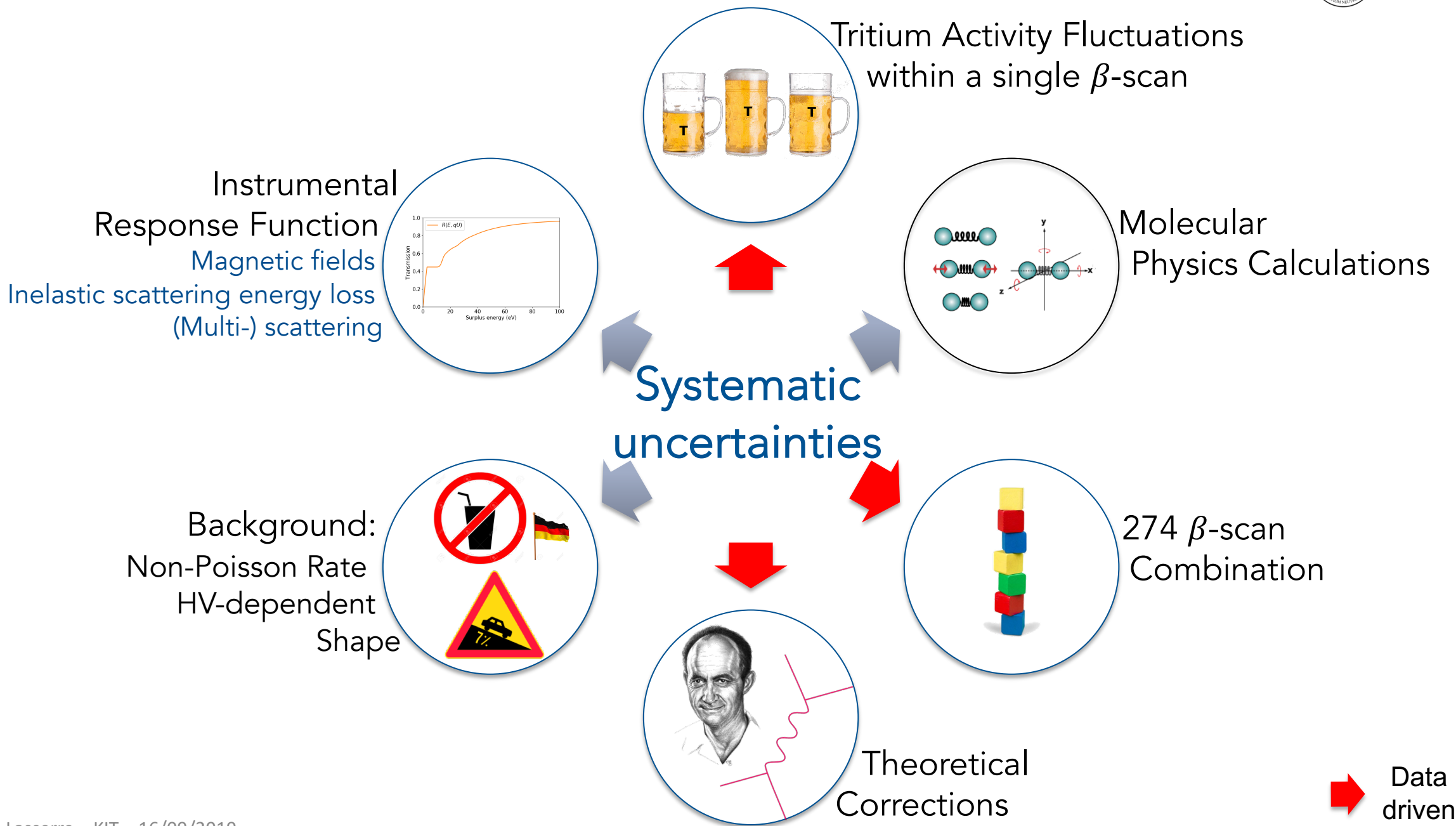
β -scan Combination

- Stack 274 β -scans



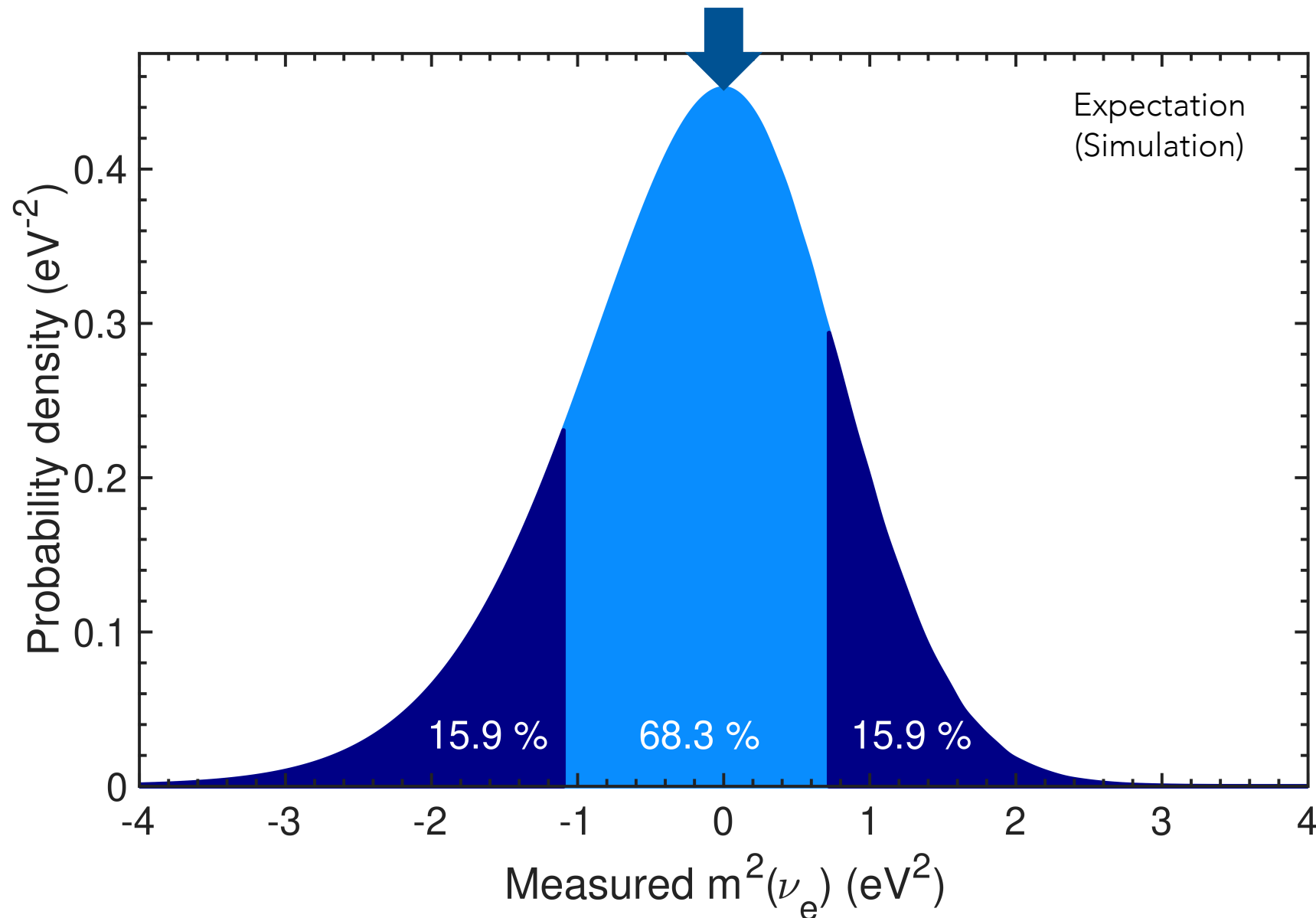
Full analysis chains developed with simulated fake data, before turning to real data





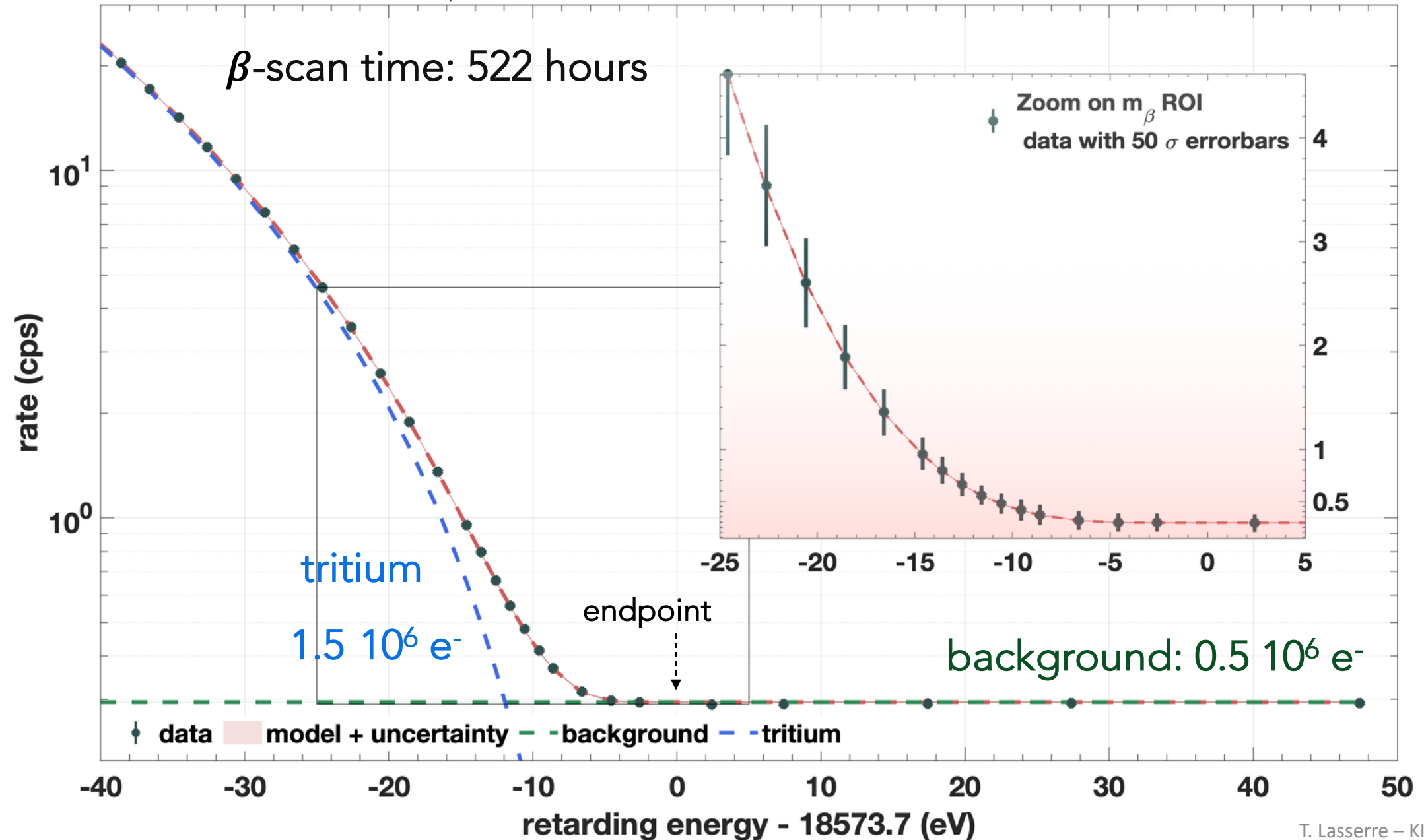
Expected Result Based on Simulation

true m_ν^2 ?

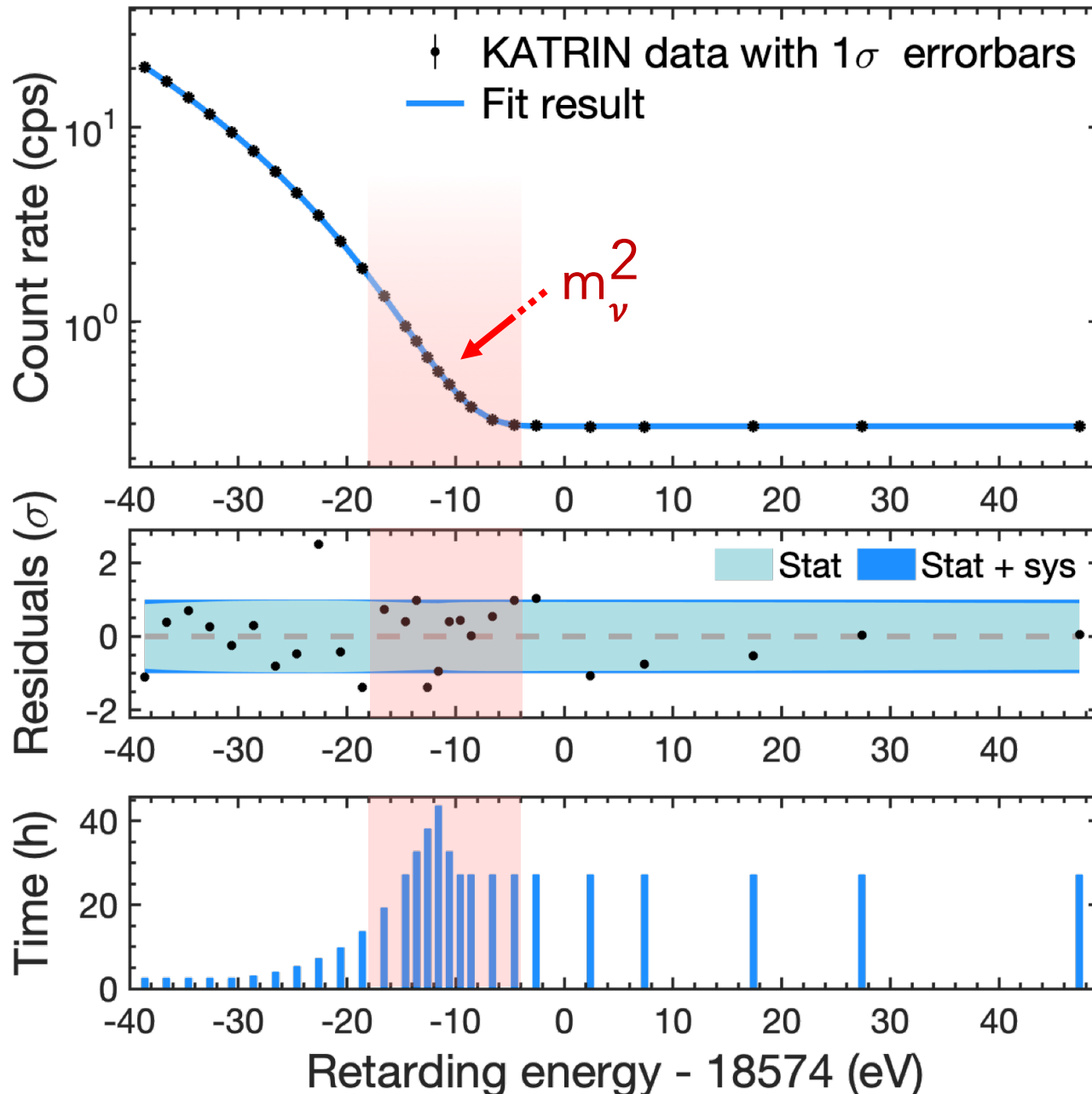


95% probability
to find m_ν^2
in $[-2 ; +2] \text{ eV}^2$

Integral tritium β -decay spectrum: Real Data



Neutrino Mass Inference

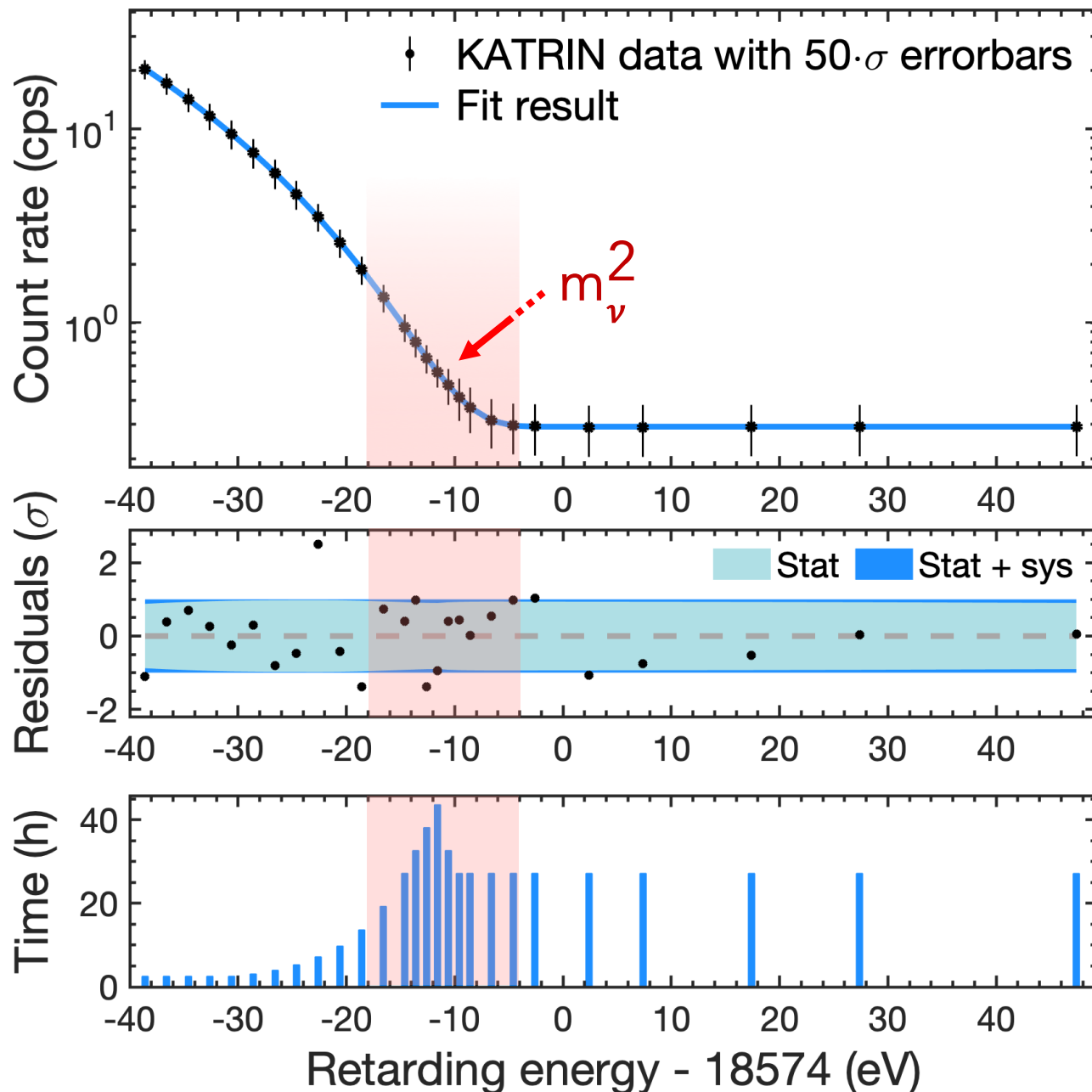


- 2 million of events
- 4 free parameters: background, tritium activity, E_0 , m_ν^2
- excellent goodness-of-fit: p-value = 0.56
- Neutrino mass best fit

$$m_\nu^2 = -1.0^{+0.9}_{-1.1} \text{ eV}^2$$

- Uncertainties dominated by statistical fluctuations (0.97 eV²)

Neutrino Mass Inference



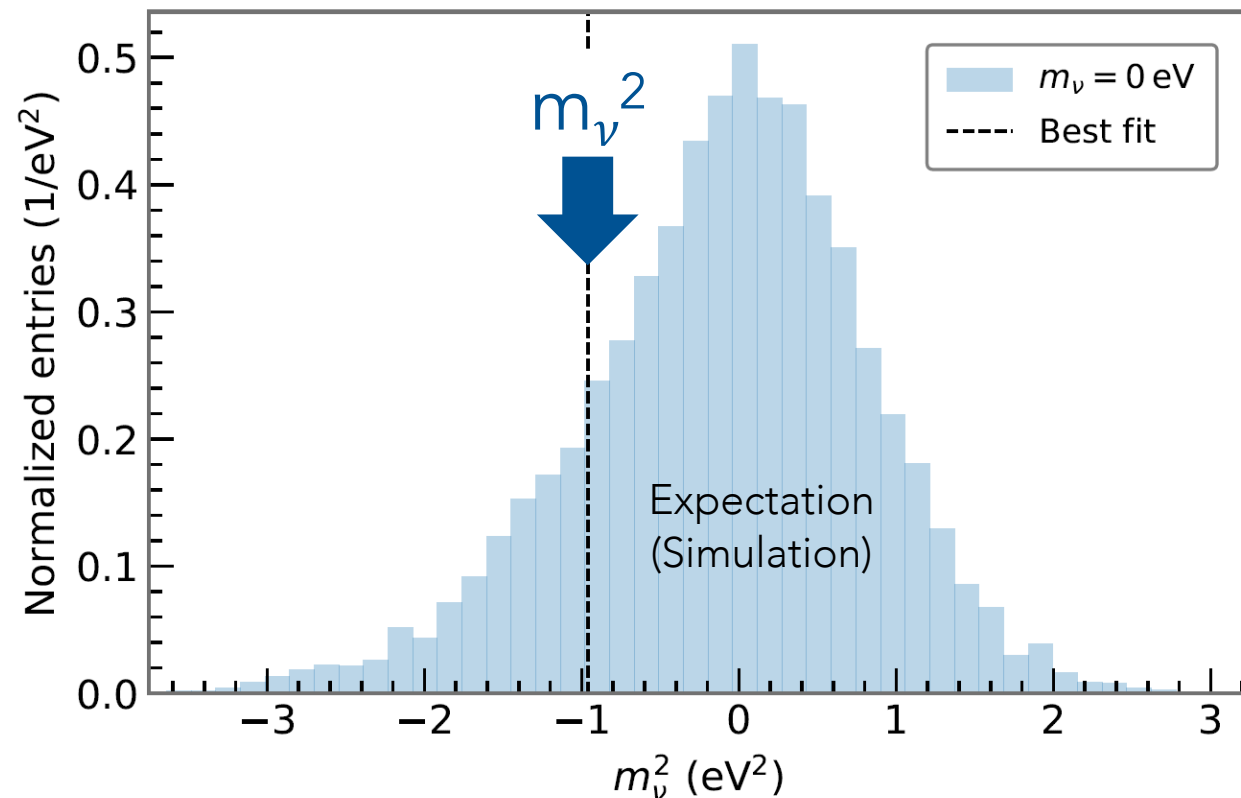
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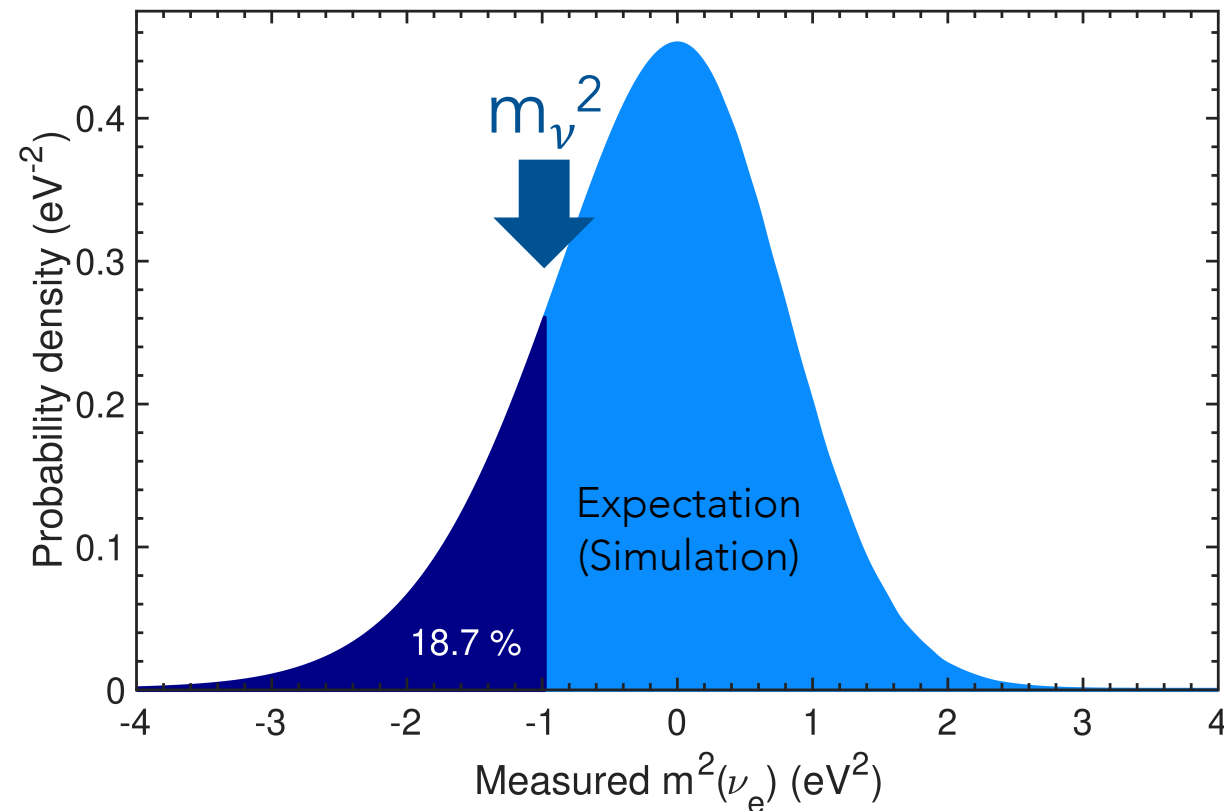
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Actual Result Compared to Expectation

MC-Propagation Method

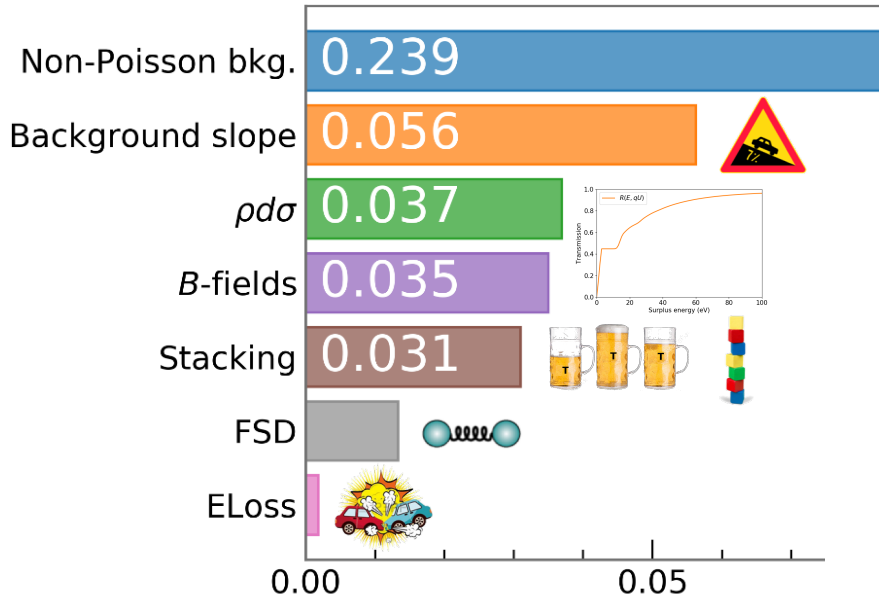


Covariance Matrix Method



Best-fit m_ν^2 is fully consistent with our expectations
(1σ statistical fluctuation)

Systematic Uncertainties Breakdown

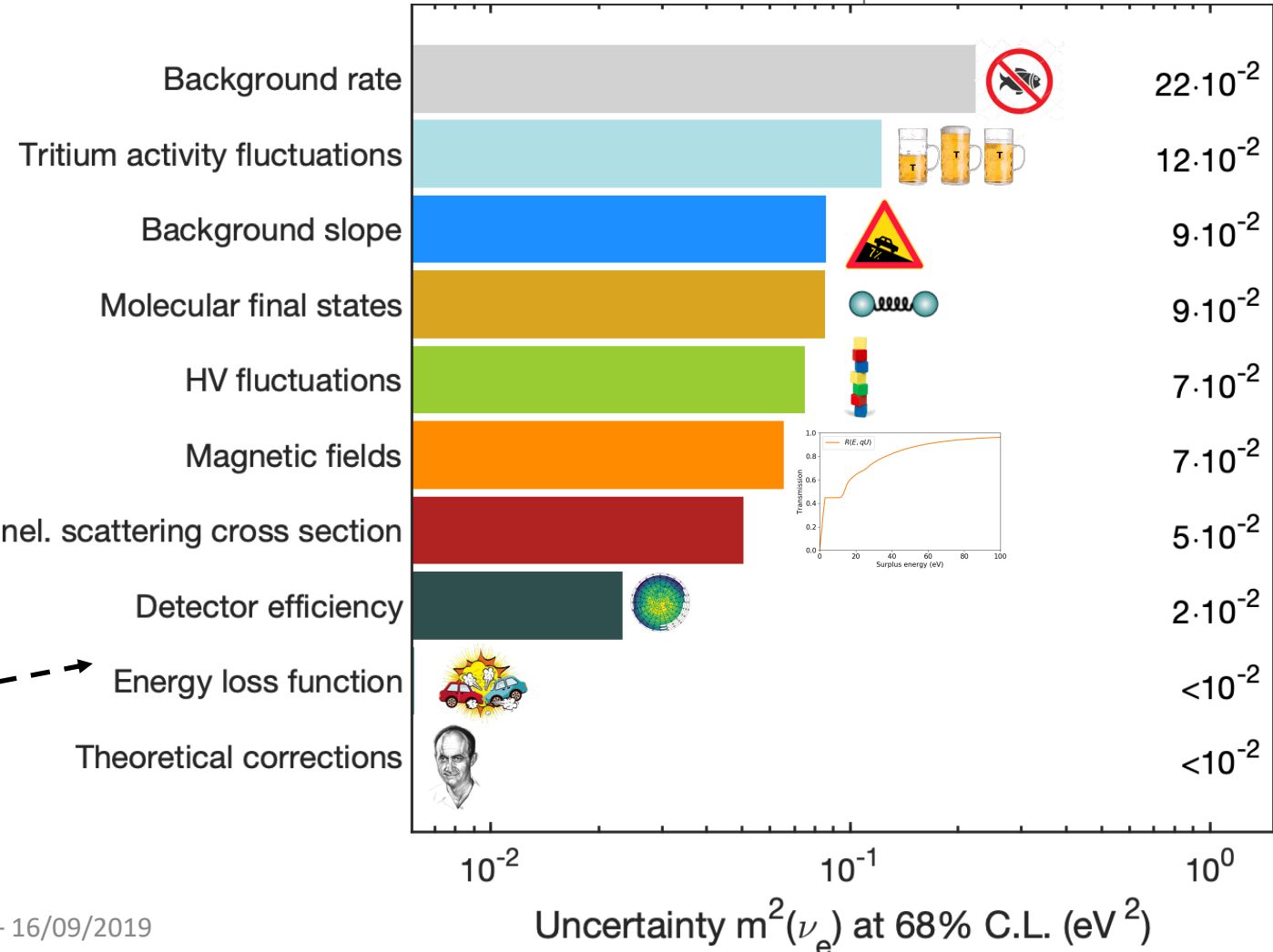


Monte Carlo propagation

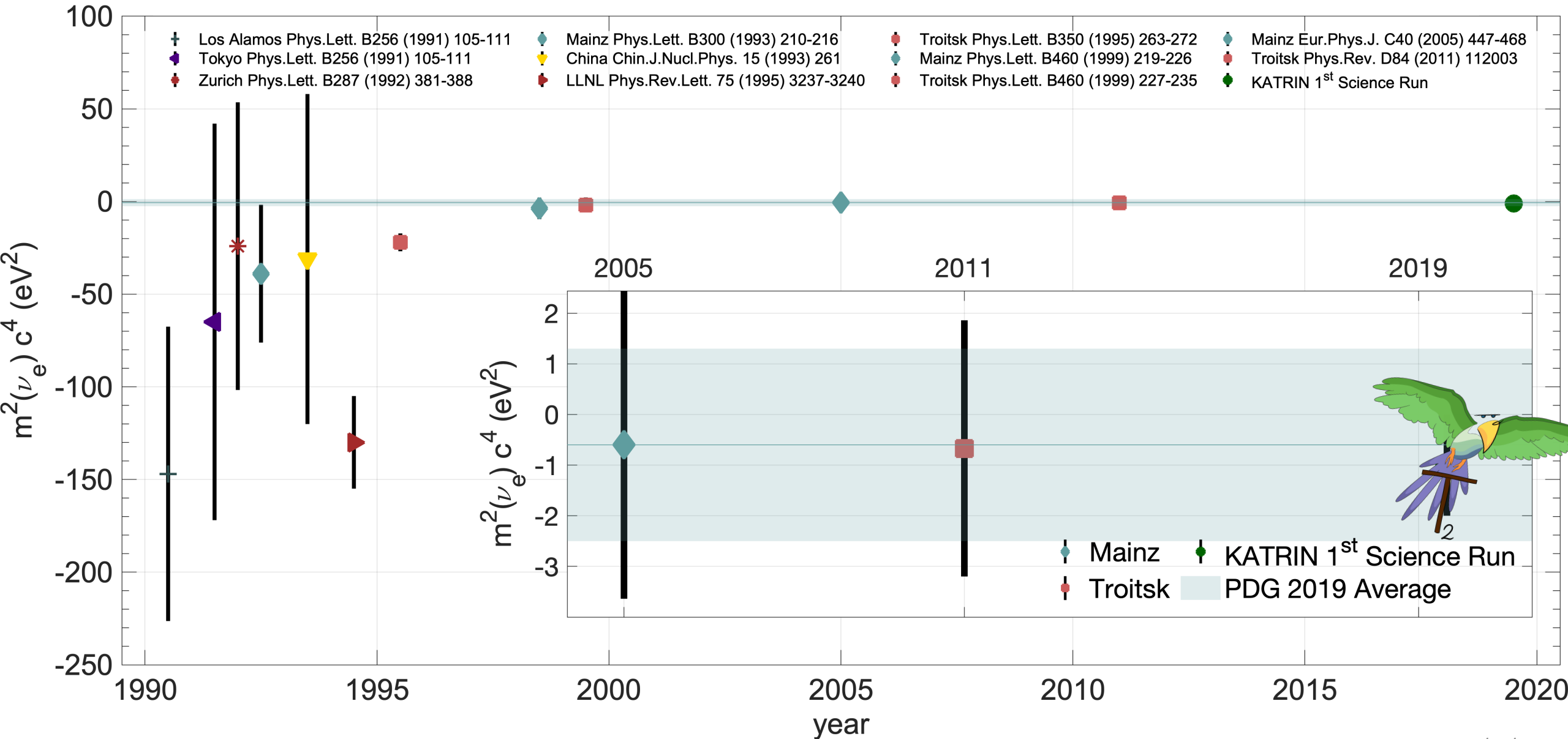
Systematics on m_ν^2
0.3 eV² at 68.3% C.L.

Systematics identified & evaluated independently

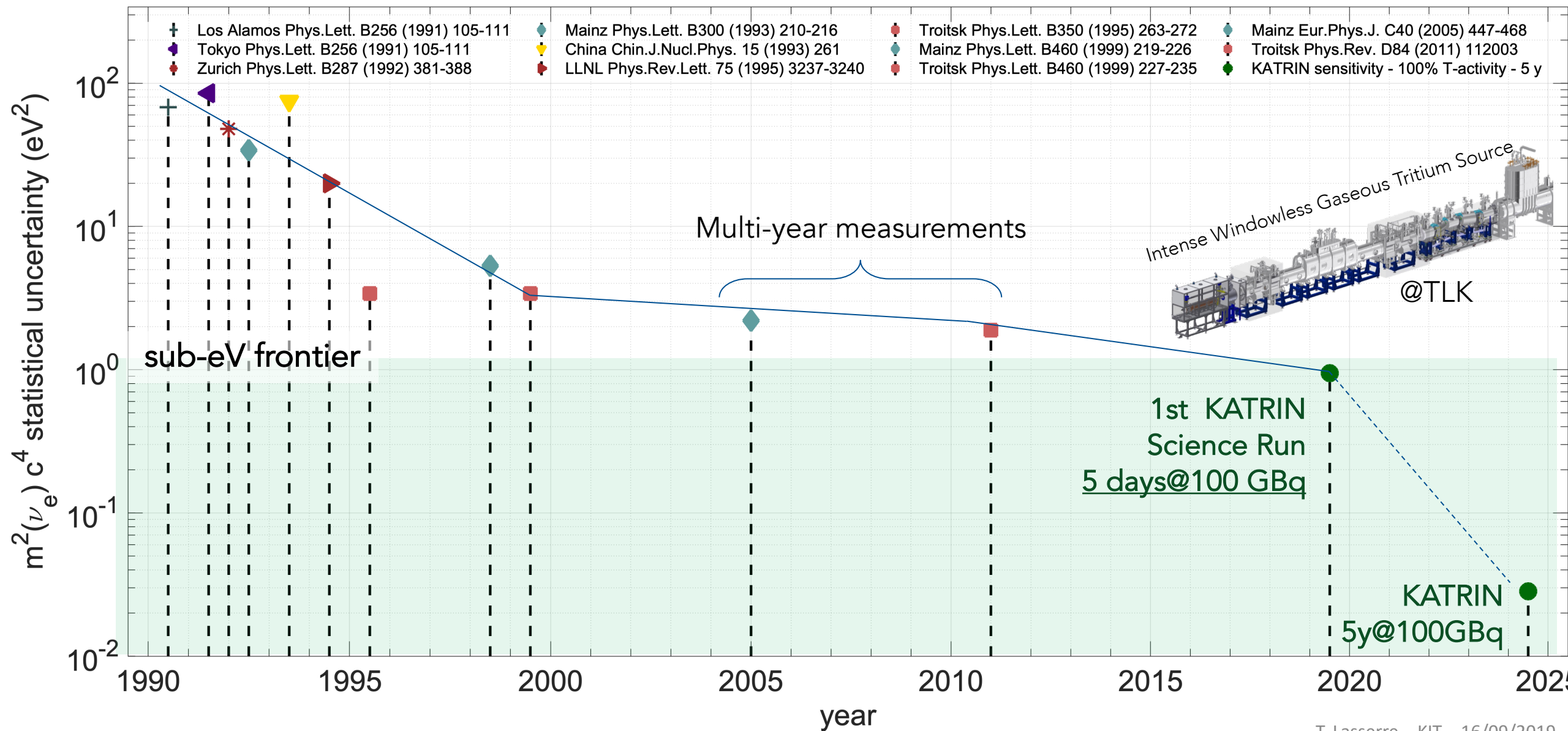
Covariance matrix



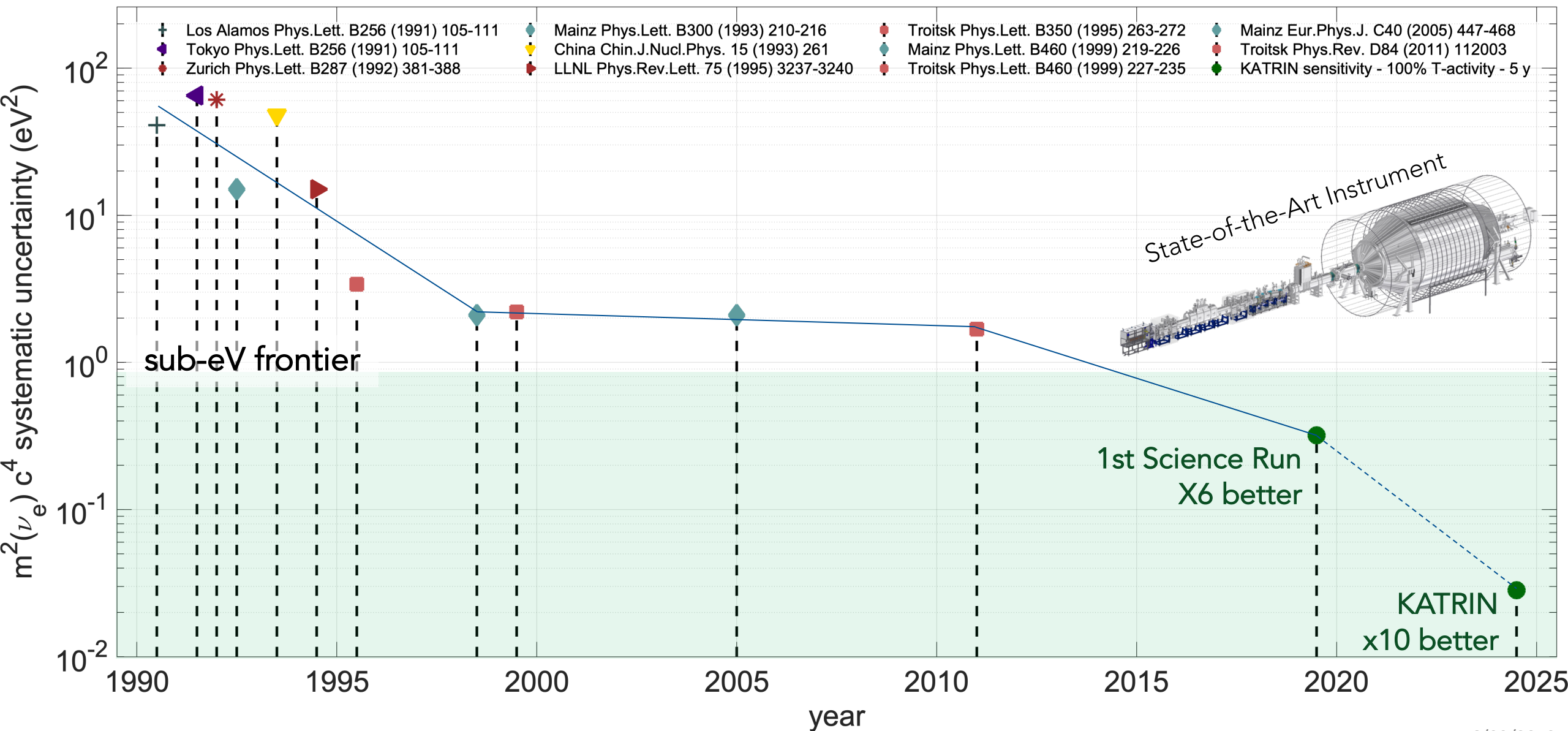
1st Science Run the light of previous results



Improvement of Statistics

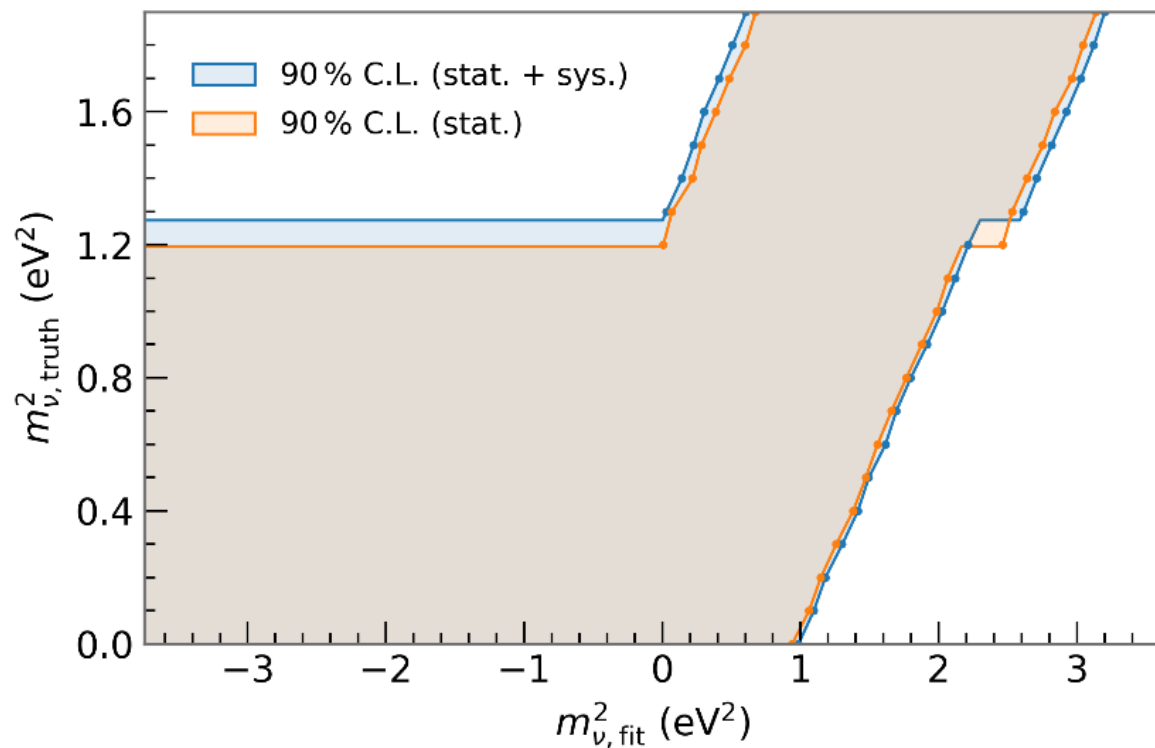


Improvement of Systematics

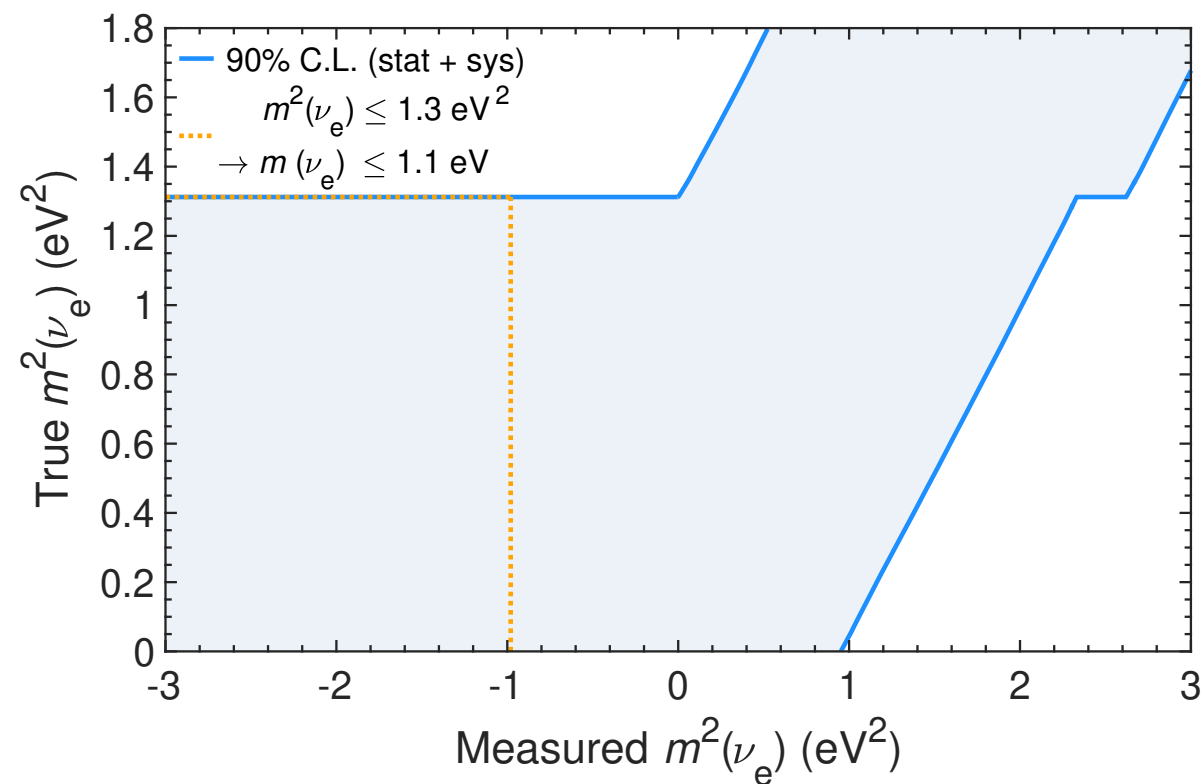


Conservative Upper Limit on the Neutrino Mass

MC-Propagation Method

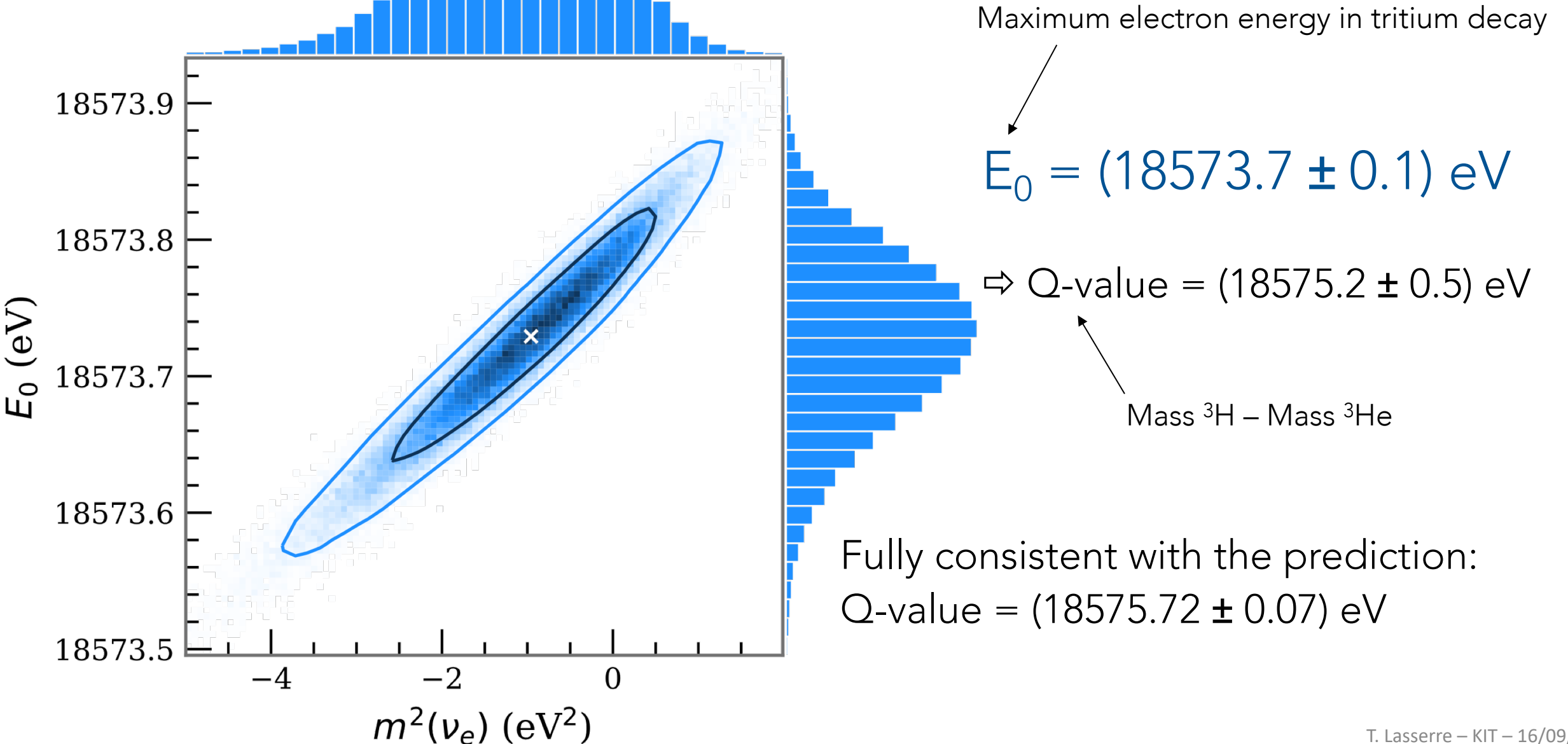


Covariance Matrix Method



$m_\nu < 1.1 \text{ eV}$ at 90% CL (Lokhov-Tkachov)

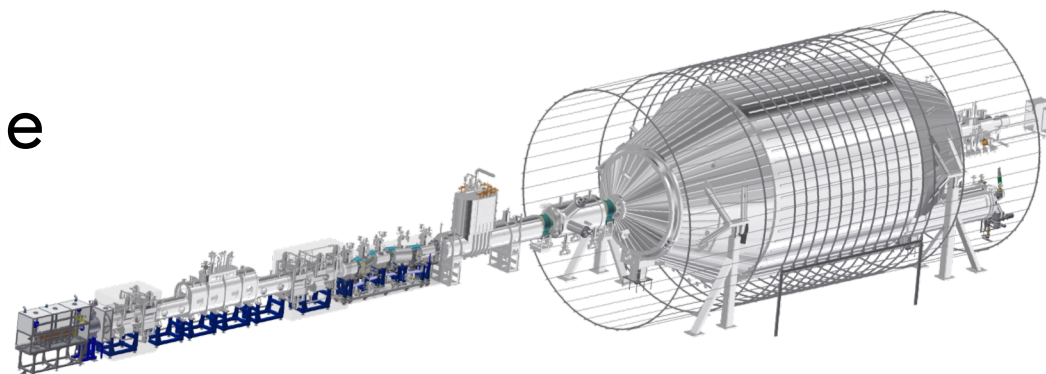
Endpoint Measurement



First KATRIN Neutrino Mass Results

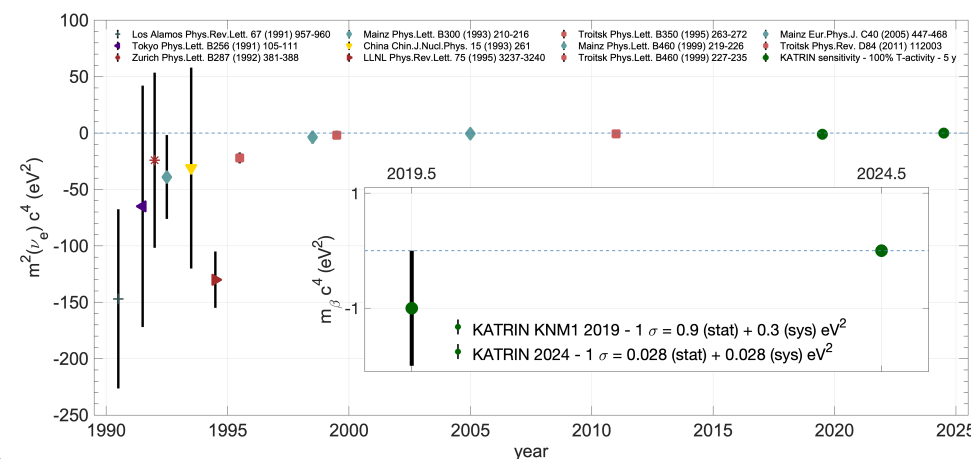
- Data collected over 780 hours @25 GBq → ~5 days of nominal KATRIN @100GBq

- High quality data acknowledging the State-of-the-Art KATRIN Hardware



- World Best Direct Neutrino Mass Measurement: $m_\nu < 1.1$ eV (90% C.L.)

- Statistics improved by a factor 2
- Systematics uncertainties reduced by a factor 6
- <http://arxiv.org/abs/1909.06048>



- Expected sensitivity $m_\nu < 0.2$ eV (90% CL) within 5y



Thanks a lot
to the Analysis Team
for all their longstanding efforts