



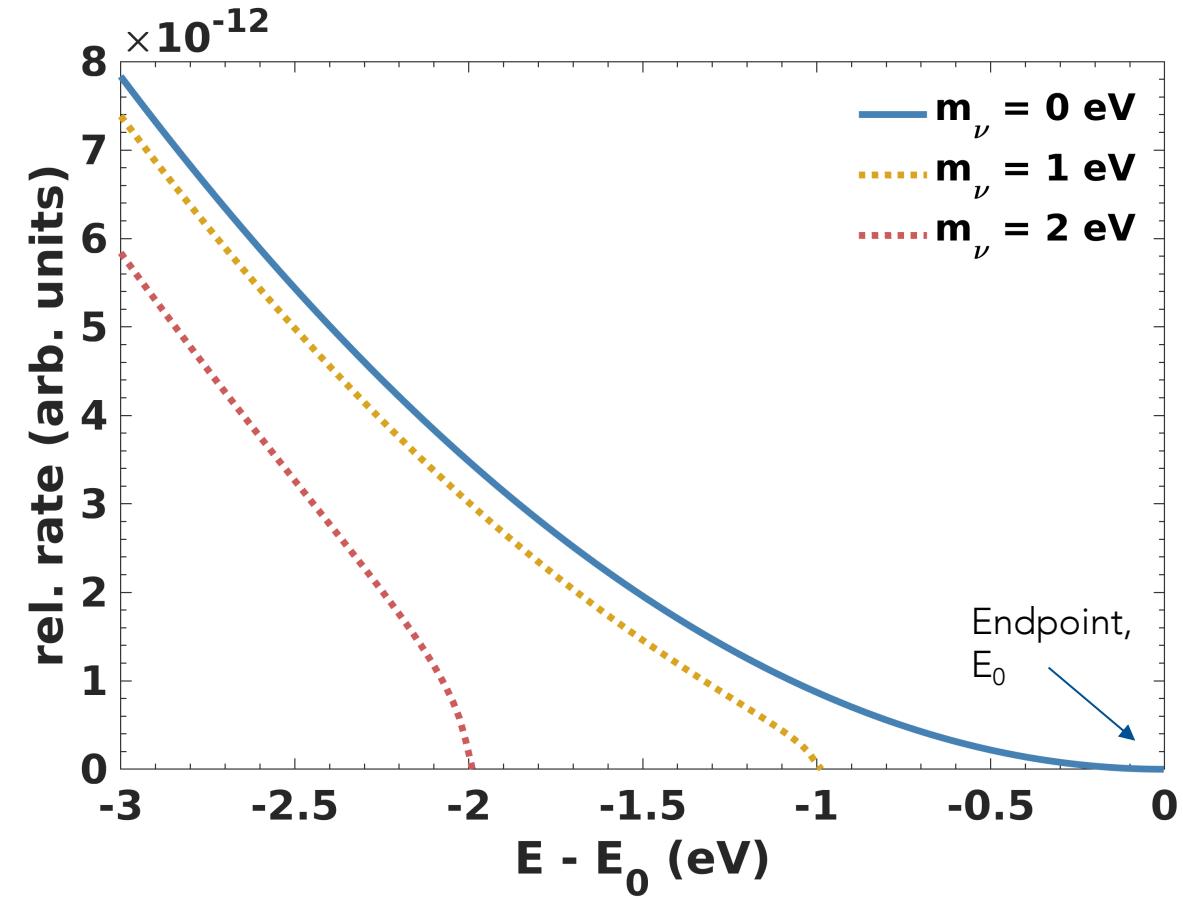
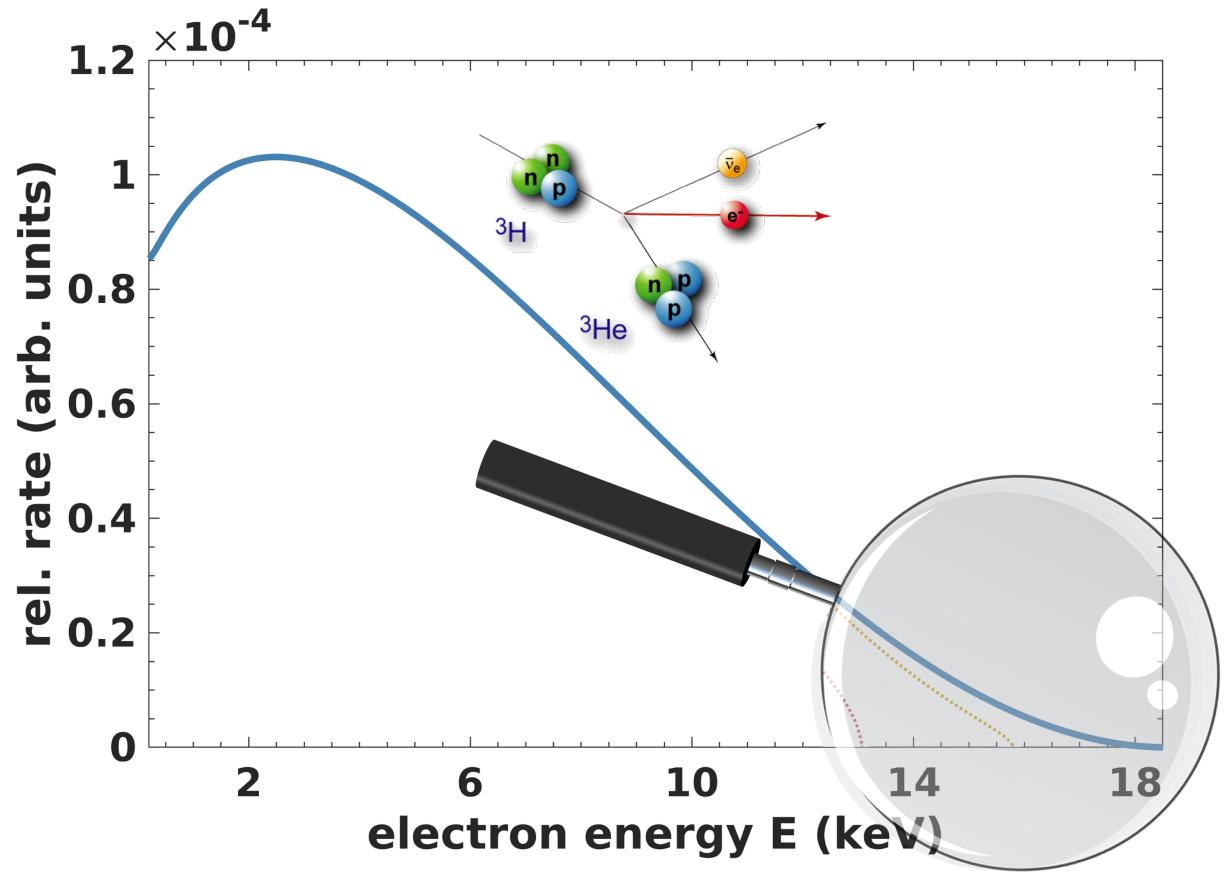
The First KATRIN Neutrino Mass Result

KATRIN Symposium, KIT, 16/09/2019

Thierry Lasserre (CEA & SFB1258)

On behalf the KATRIN collaboration

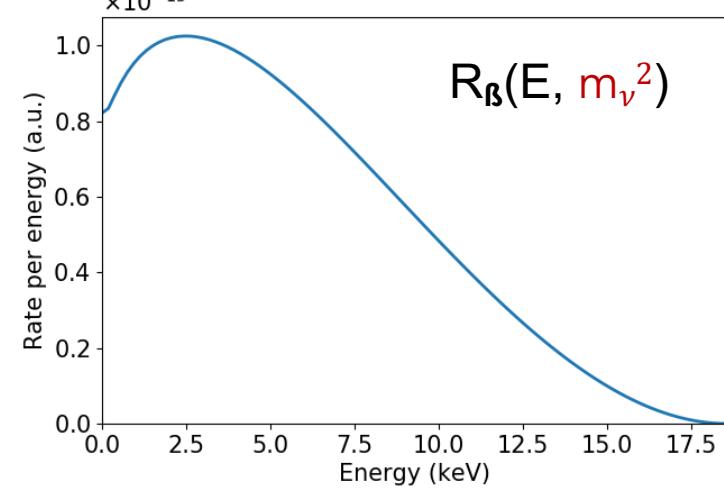
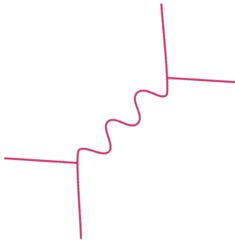
The Neutrino Mass Imprint



Search for a specific shape distortion of the electron energy spectrum

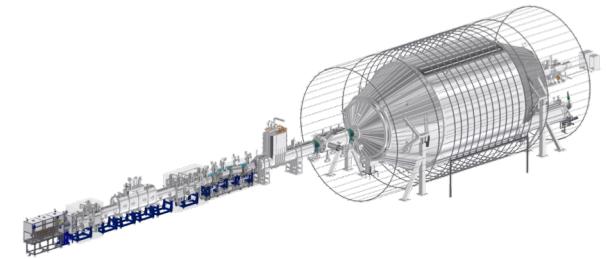
Observable: the Integral β -spectrum

tritium β -decay theory

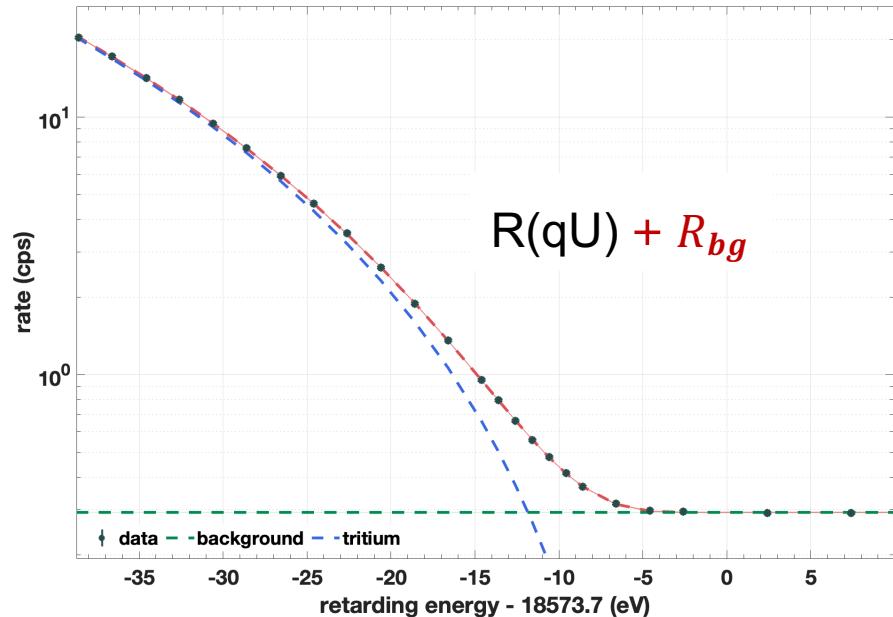


$$R(qU) = A_s \cdot N_T \int_{qU}^{E_0} R_\beta(E, m_\nu^2) \cdot f(E - qU) dE + R_{bg}$$

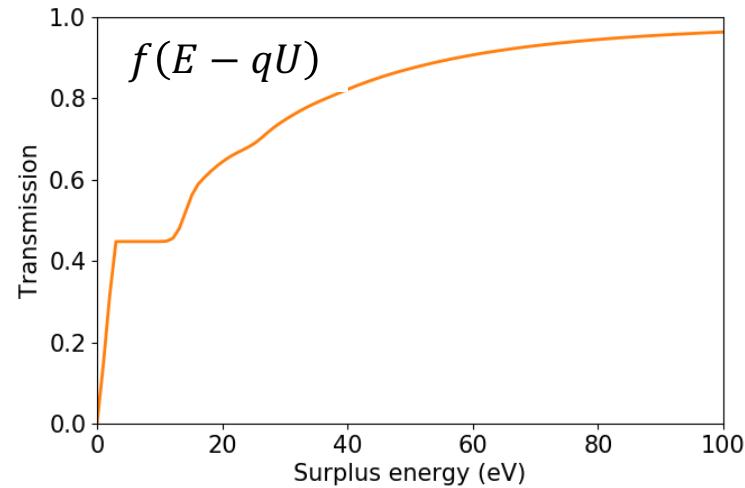
experimental setup



integral β -spectrum

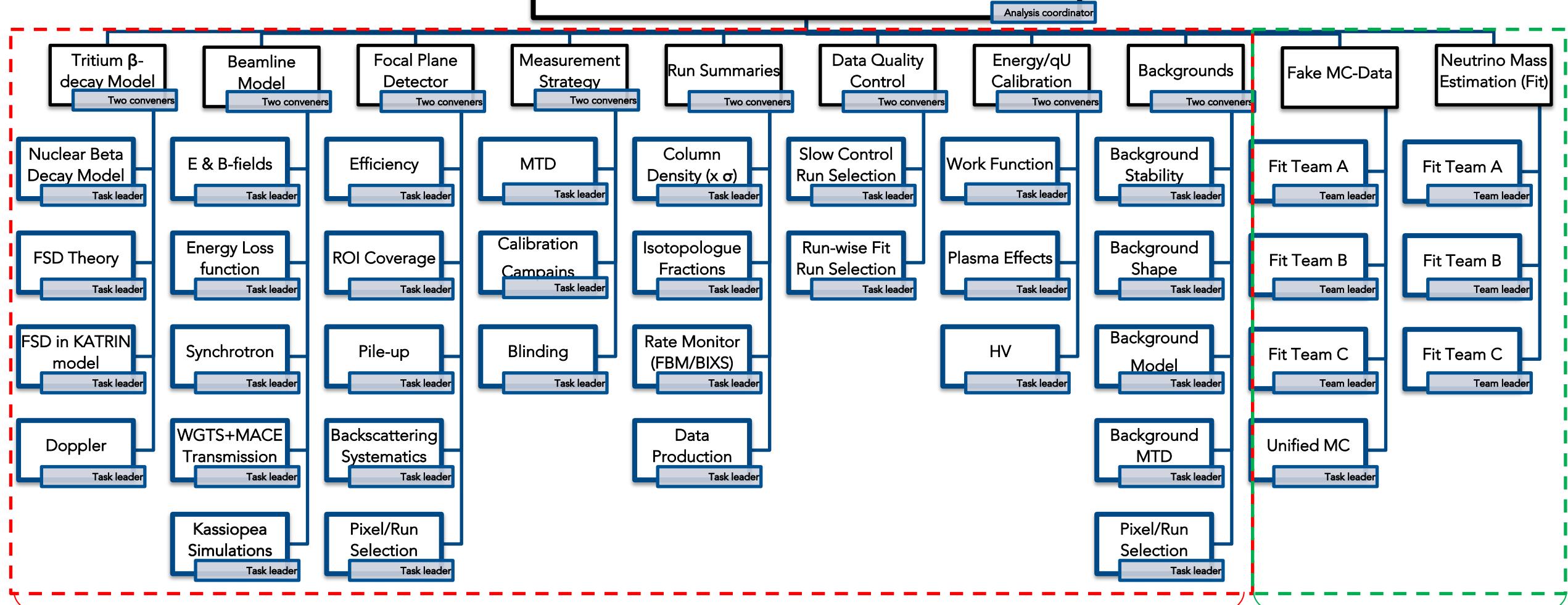


← R_{bg}



KATRIN First Neutrino Mass Analysis Project (KNM1)

Analysis coordinator



Common Trunk = all what concerns modeling & calibration

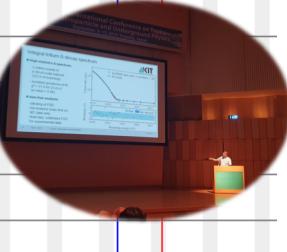
final fits
(2 independent methods)

Analysis Schedule

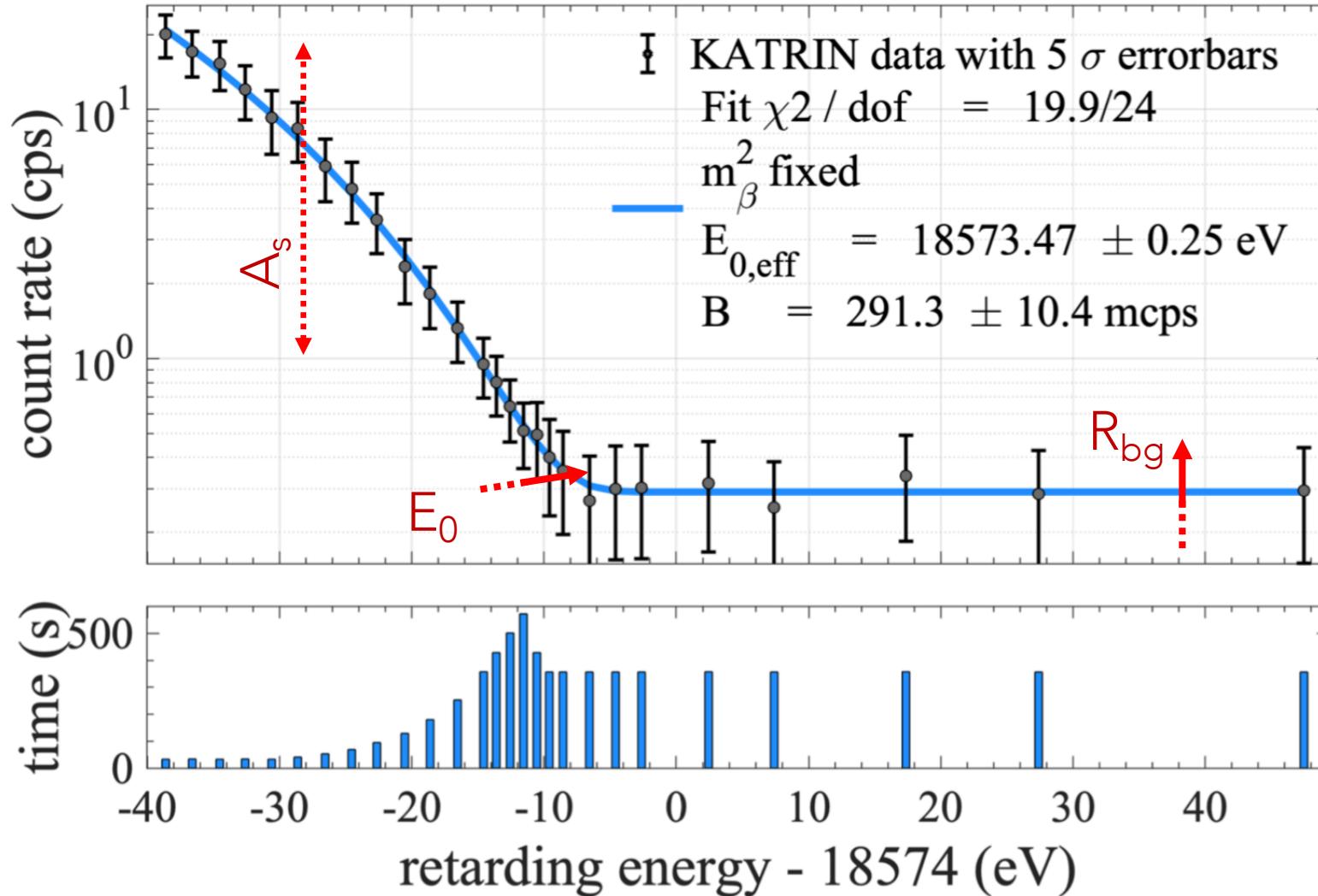
GANTT project

2019 Energy Loss Parametrization | B-AP Corrections | Agm MTD Agreement | B-MAX/WGTS Systematics Agreement | Pre-Agreement on Analysis Strategy | RCI Agreement | FPD F | P-18 | B-MAX/WGTS Systematics Agreement | B-AP Results Agreement | TAUP 2019

Name	January	February	March	April	May	June	July	August	September
KNM1 MINIMAL MODEL						[1/7/19 - 6/17/19]			
KNM1 TRITIUM BETA DECAY		[1/7/19 - 2/14/19]							
T-beta decay Modelling Proposals		[1/7/19 - 2/7/19]							
T-beta decay Modelling / Systematics Review		[2/8/19 - 2/14/19]							
T-beta decay Modelling / Systematics Agreement		2/15/19							
KNM1 RESPONSE FUNCTION					[1/7/19 - 6/17/19]				
rhoDsigma						[1/7/19 - 6/12/19]			
rhoDsigma Systematics Proposals						[1/7/19 - 6/4/19]			
rhoDsigma Systematics Review						[6/5/19 - 6/12/19]			
rhoDsigma Systematics Agreement						6/13/19			
Scattering Probabilities					[1/7/19 - 6/12/19]				
P-IS Systematics Proposals						[1/7/19 - 6/4/19]			
P-IS Systematics Review						[6/5/19 - 6/12/19]			
P-IS Systematics Agreement						6/13/19			
Energy Loss					[1/7/19 - 6/12/19]				
Energy Loss Parametrization Proposals						[1/7/19 - 6/4/19]			
Energy Loss Parametrization Review						[6/5/19 - 6/12/19]			
Energy Loss Parametrization Agreement						6/13/19			
Energy Loss Systematics Agreement						6/13/19			
B-MAX/WGTS					[1/7/19 - 6/17/19]				
B-MAX/WGTS Systematics Proposals						[1/7/19 - 6/14/19]			
B-MAX/WGTS Systematics Review						[6/15/19 - 6/17/19]			
B-MAX/WGTS Systematics Agreement						6/18/19			
B-AP					[1/7/19 - 6/12/19]				
B-AP Correction Maps Review	1/26/19								
B-AP Systematics Proposals									



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



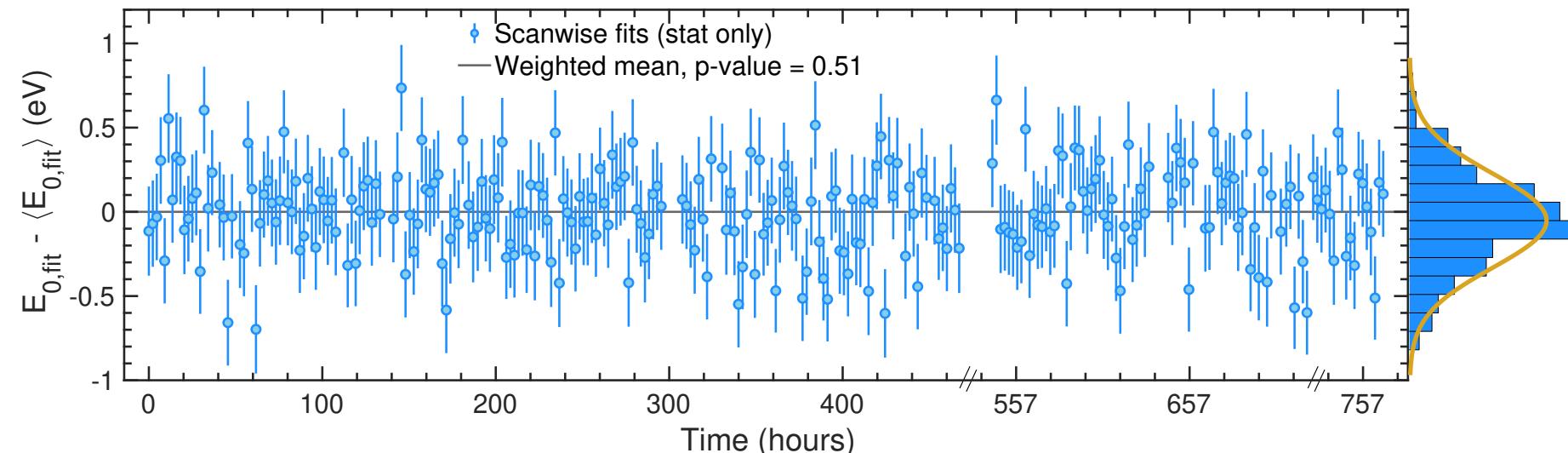
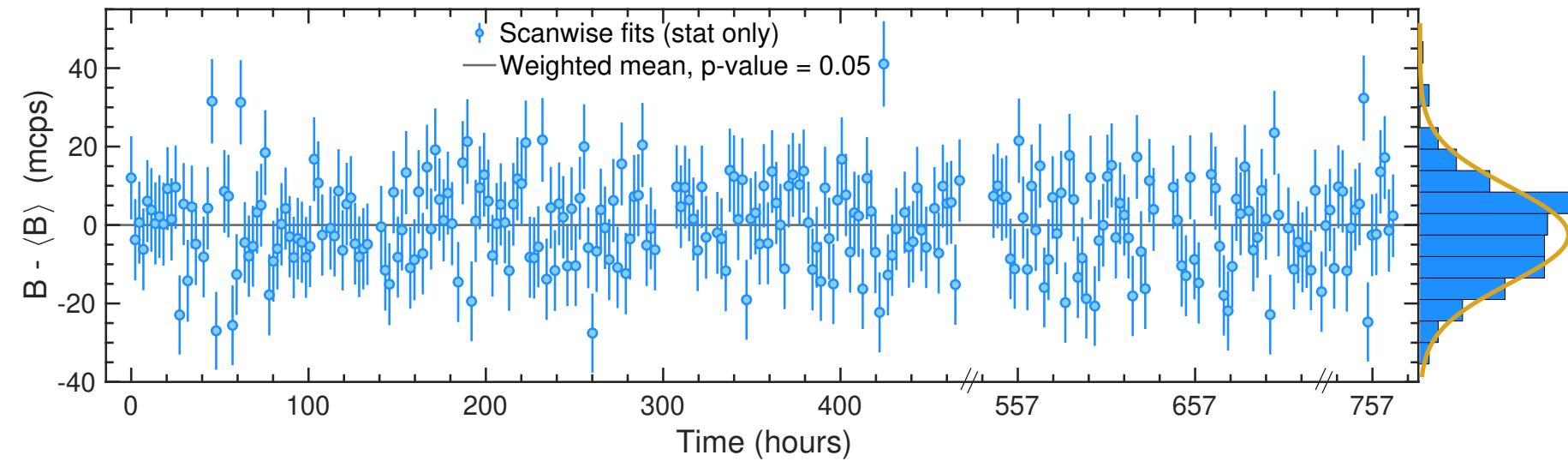
- A single 2h β -scan
- m_ν fixed to 0
- 3 parameter fit
 - Tritium Activity, A_s
 - Endpoint, E_0
 - Background, R_{bg}
- High quality data

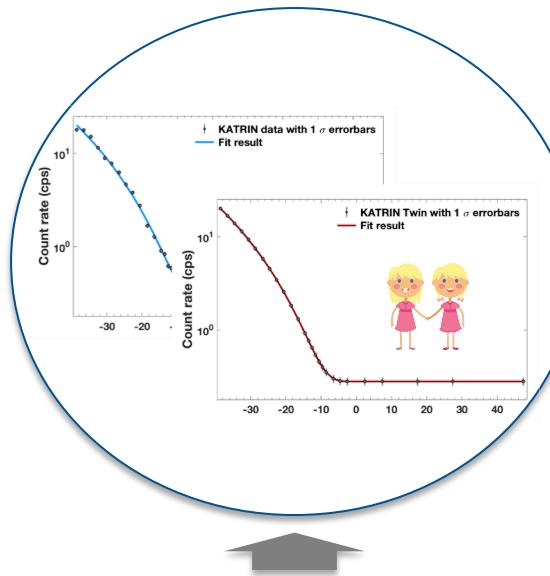
β -scan Fit Parameters Stability over 780 hours (Data)

274 single
 β -scan fits

Stable
Background

Stable
Endpoint

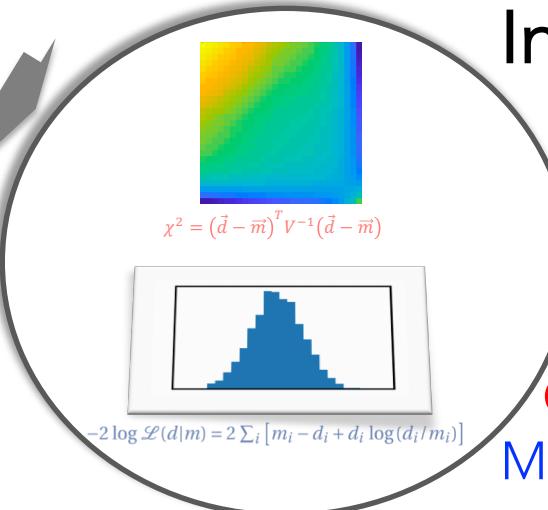
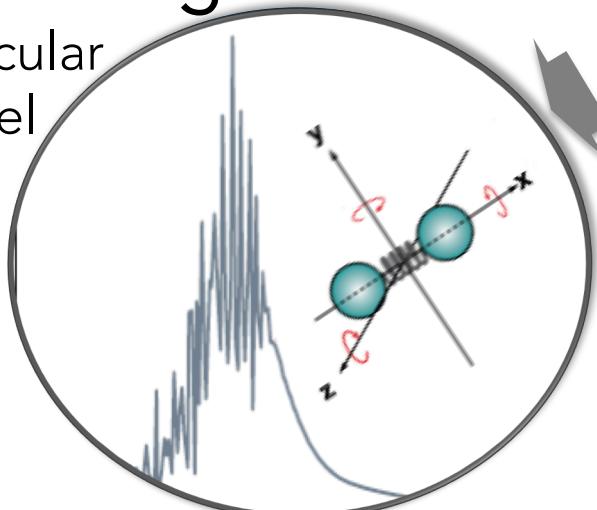




Analysis on fake data
implement & freeze analysis
using fake data mimicking
actual 1st science run

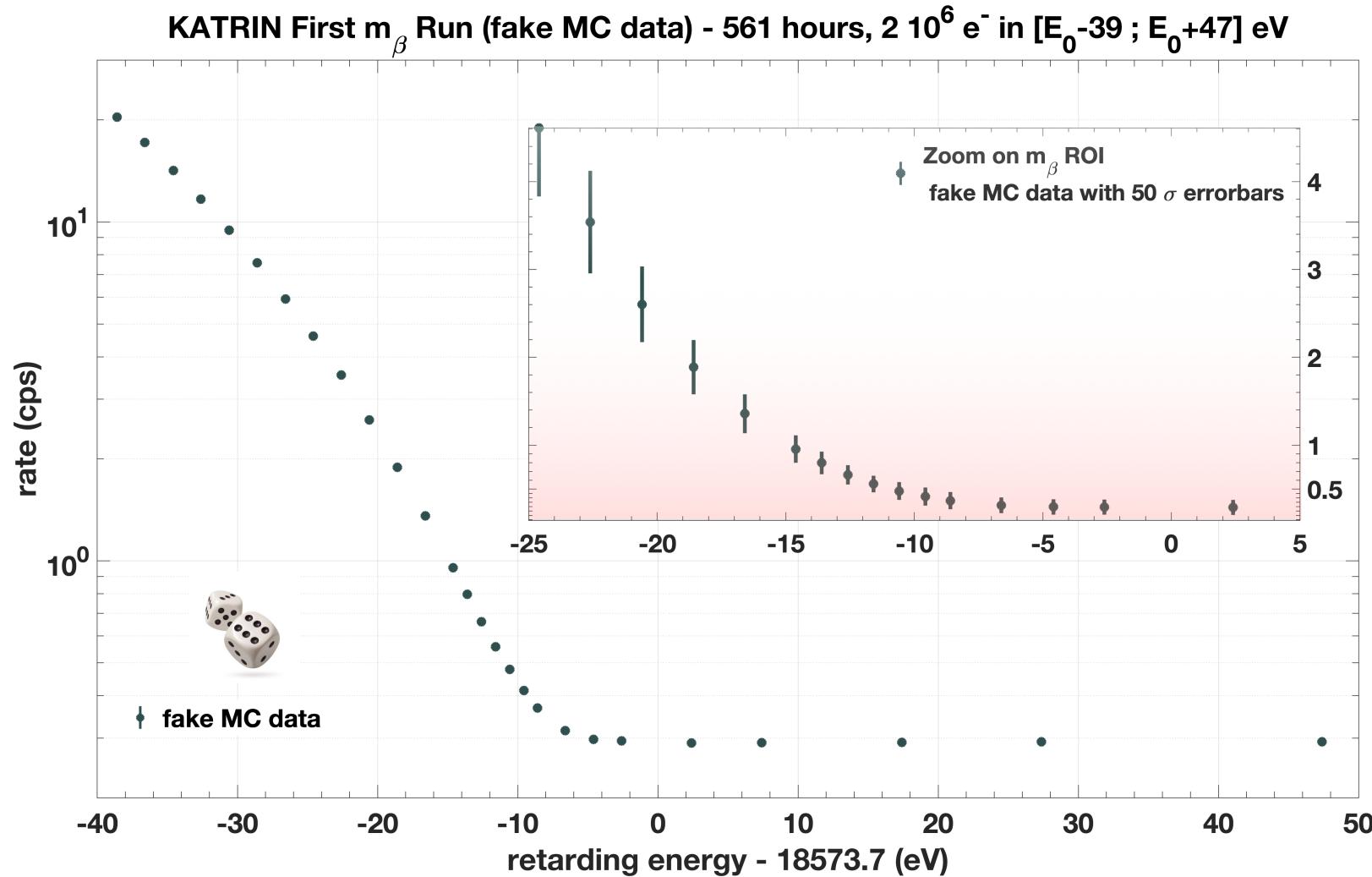
Bias Free Analysis Strategy

Model blinding
modified molecular
physics model
veiling m_ν^2 only

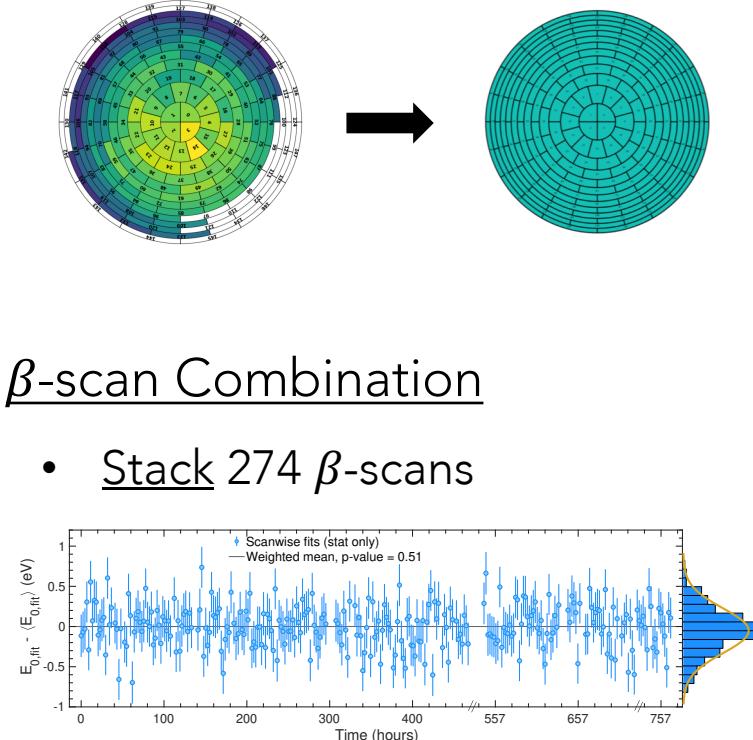


**Independence &
Complementarity**
2 independent
approaches to
assess systematics
Covariance matrix
Monte Carlo propagation

Integral tritium β -decay spectrum: Fake Data

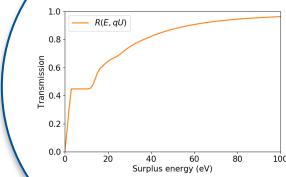


- Pixel Combination
 - Sum all pixel counts
- β -scan Combination
 - Stack 274 β -scans



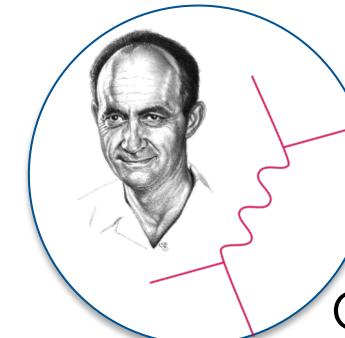
Full analysis chains developed with simulated fake data, before turning to real data

Instrumental Response Function
Magnetic fields
Inelastic scattering energy loss
(Multi-) scattering



Systematic uncertainties

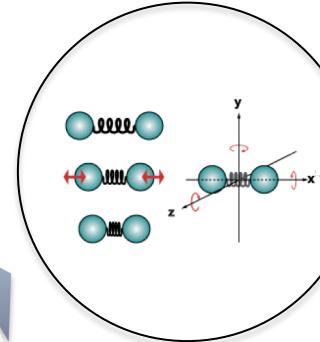
Background:
Non-Poisson Rate
HV-dependent
Shape



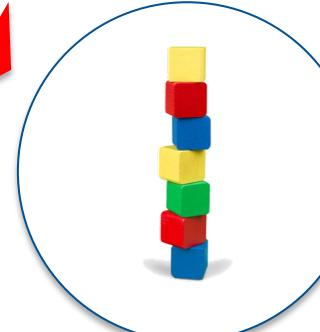
Theoretical Corrections



Tritium Activity Fluctuations
within a single β -scan



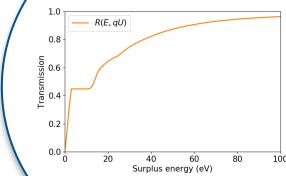
Molecular Physics Calculations



274 β -scan Combination

Data driven

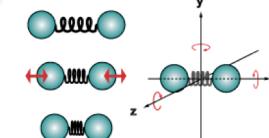
Instrumental Response Function
Magnetic fields
Inelastic scattering energy loss
(Multi-) scattering



Tritium Activity Fluctuations
within a single β -scan



Molecular Physics Calculations

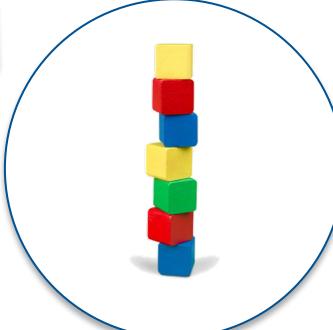


Systematic uncertainties

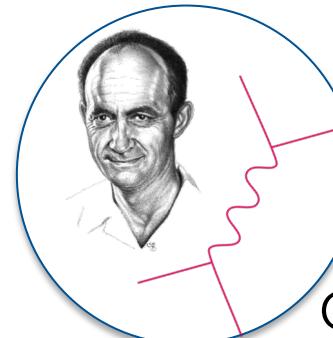
Background:
Non-Poisson Rate
HV-dependent
Shape



274 β -scan
Combination

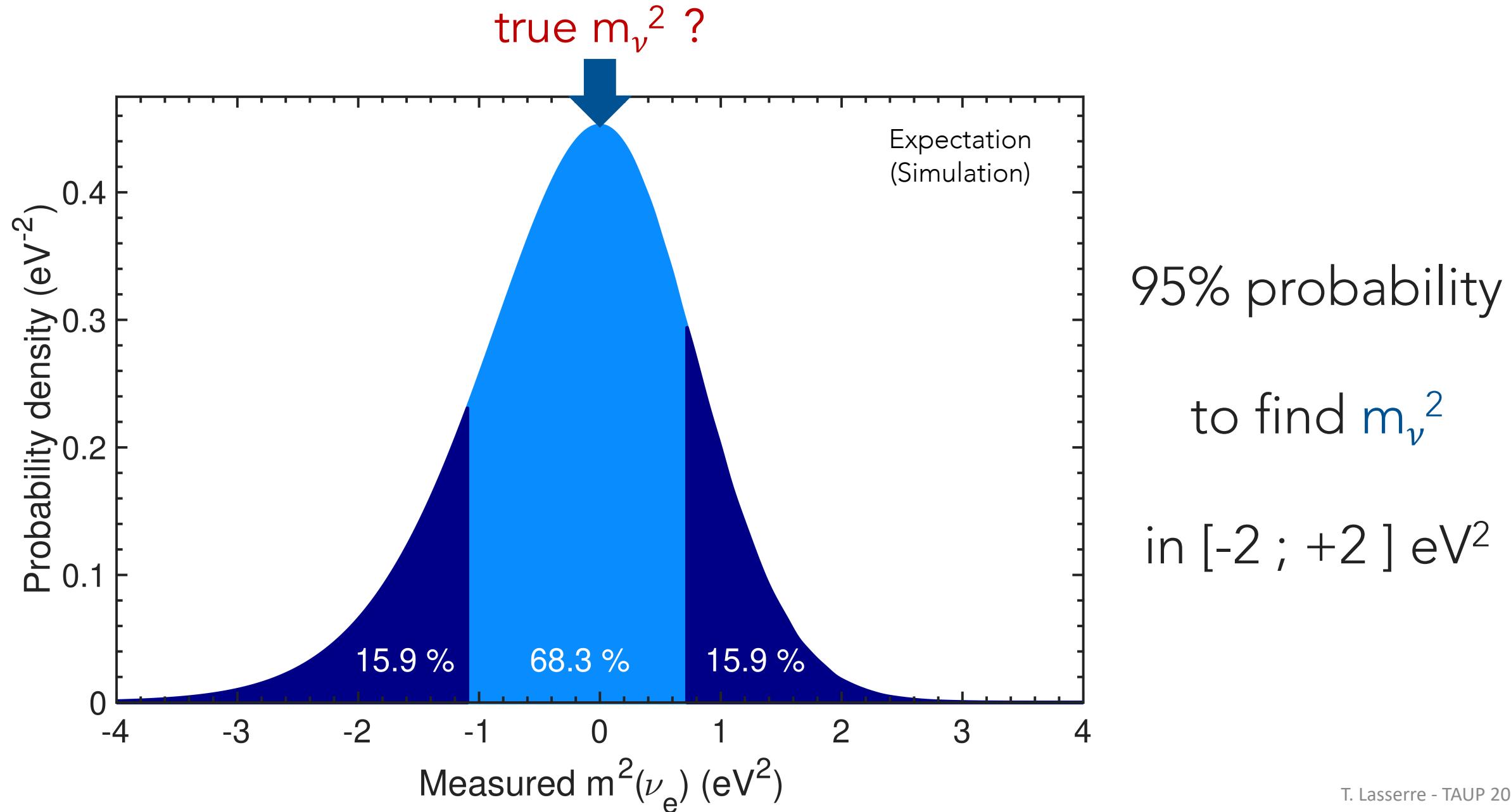


Theoretical Corrections

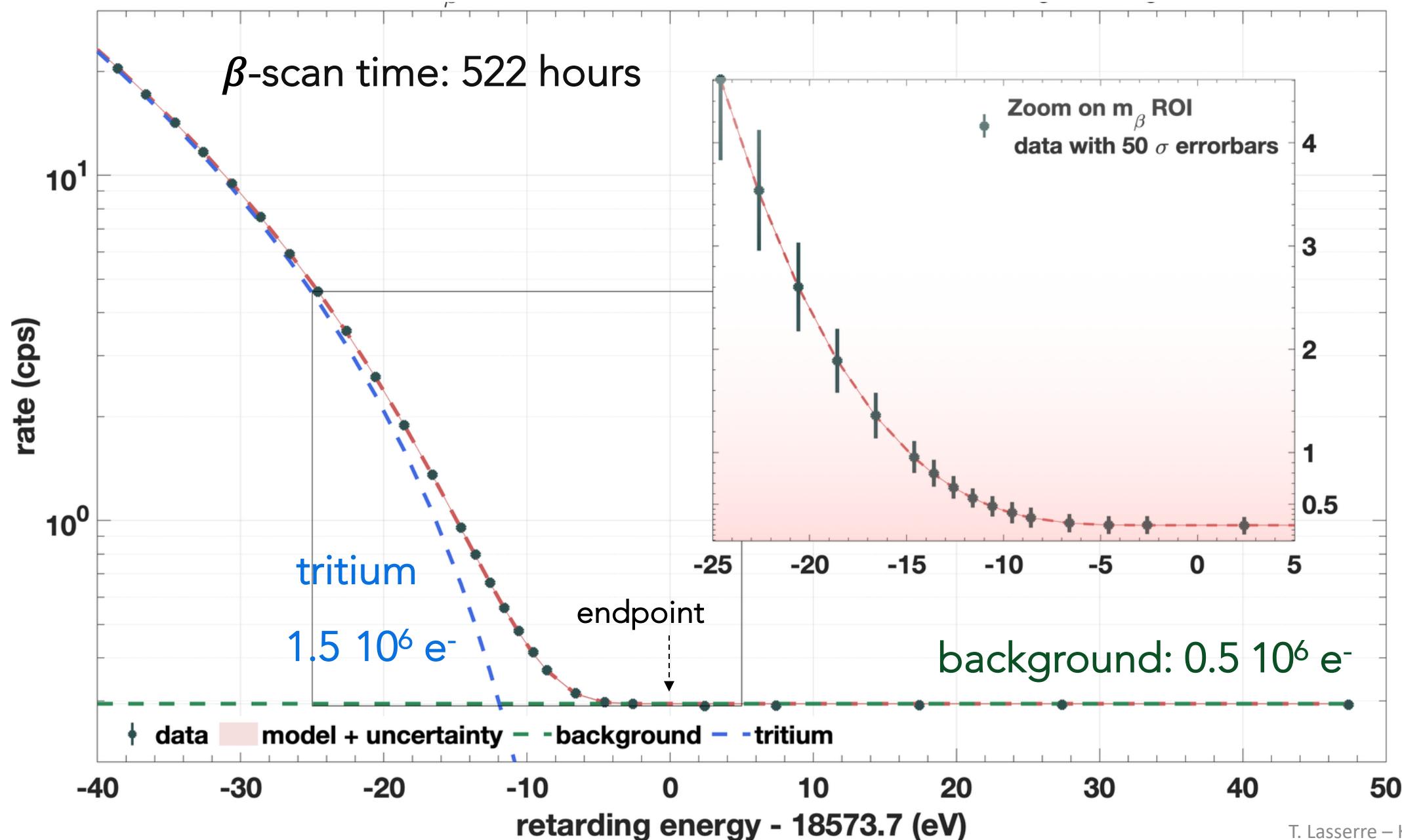


Data driven

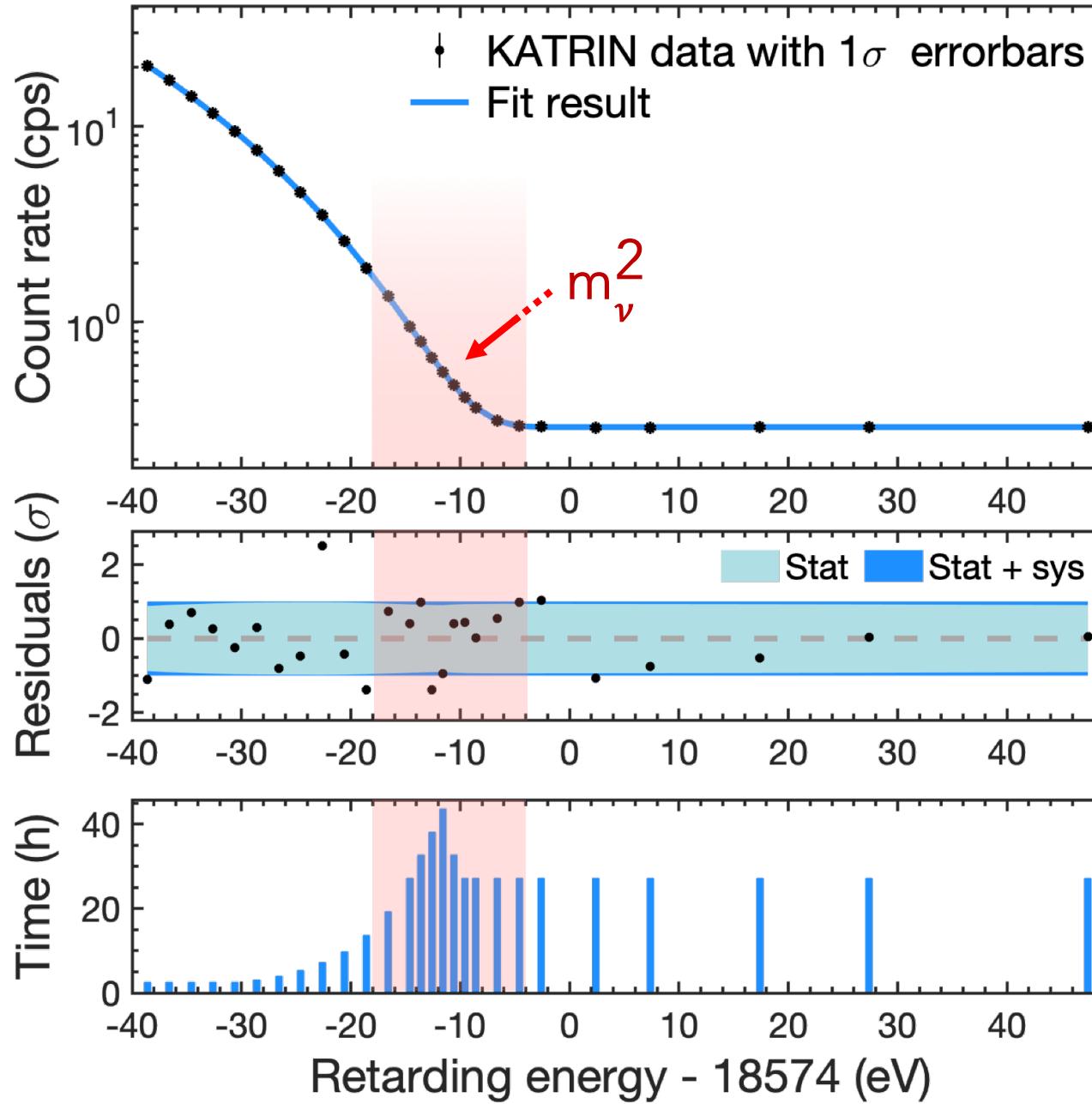
Expected Result Based on Simulation



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

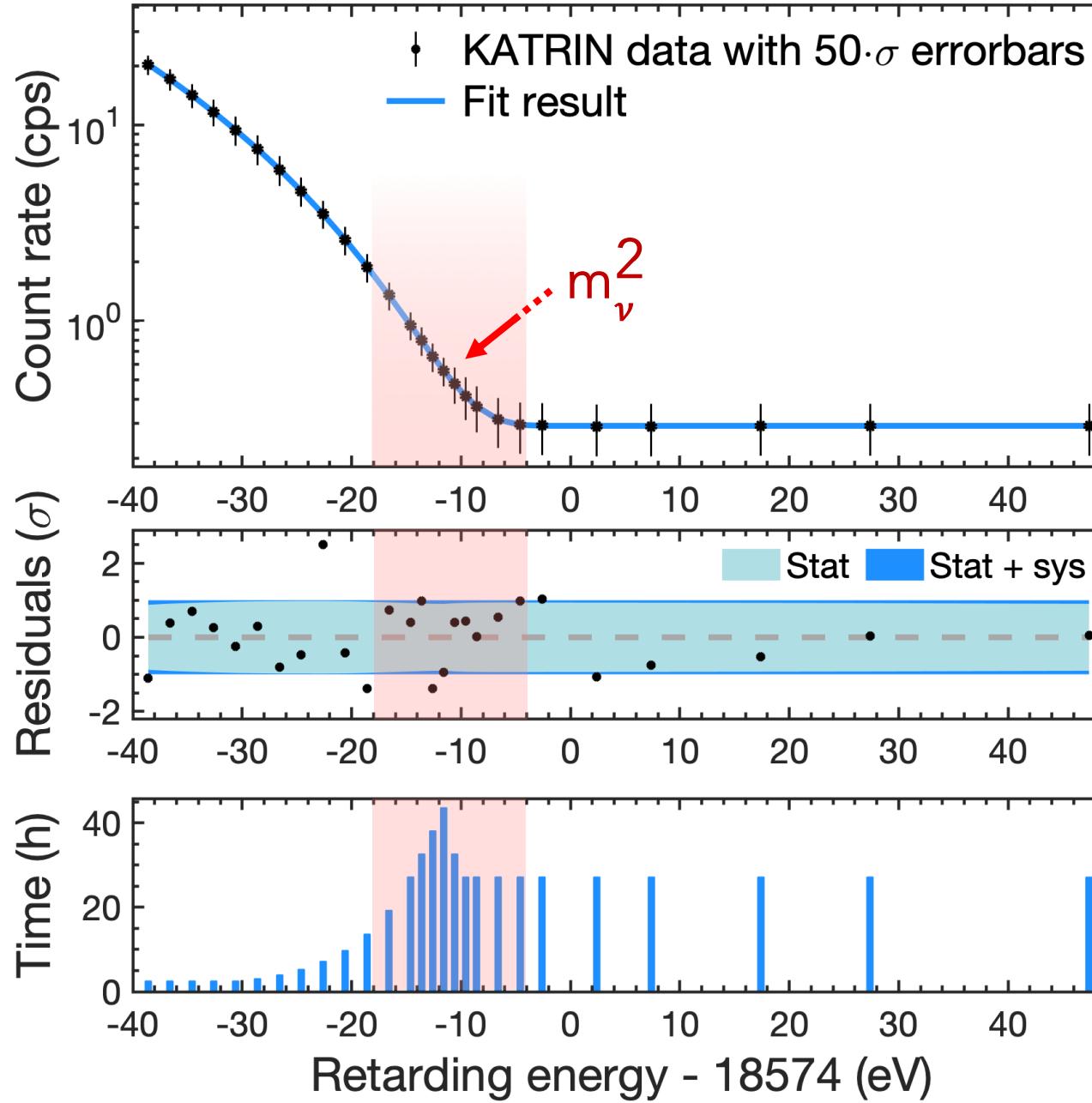
- excellent goodness-of-fit:
p-value = 0.56

- Neutrino mass best fit

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

- Uncertainties dominated by statistical fluctuations (0.97 eV²)

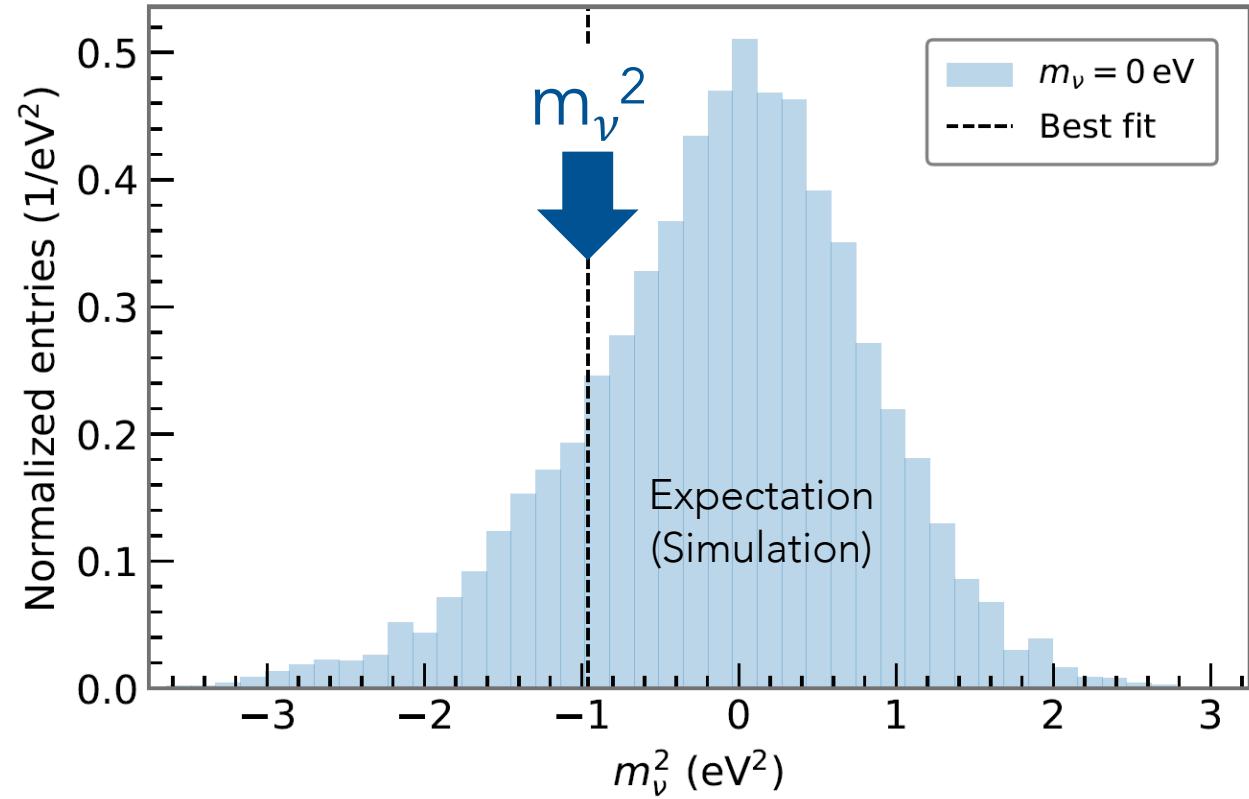
Neutrino Mass Inference



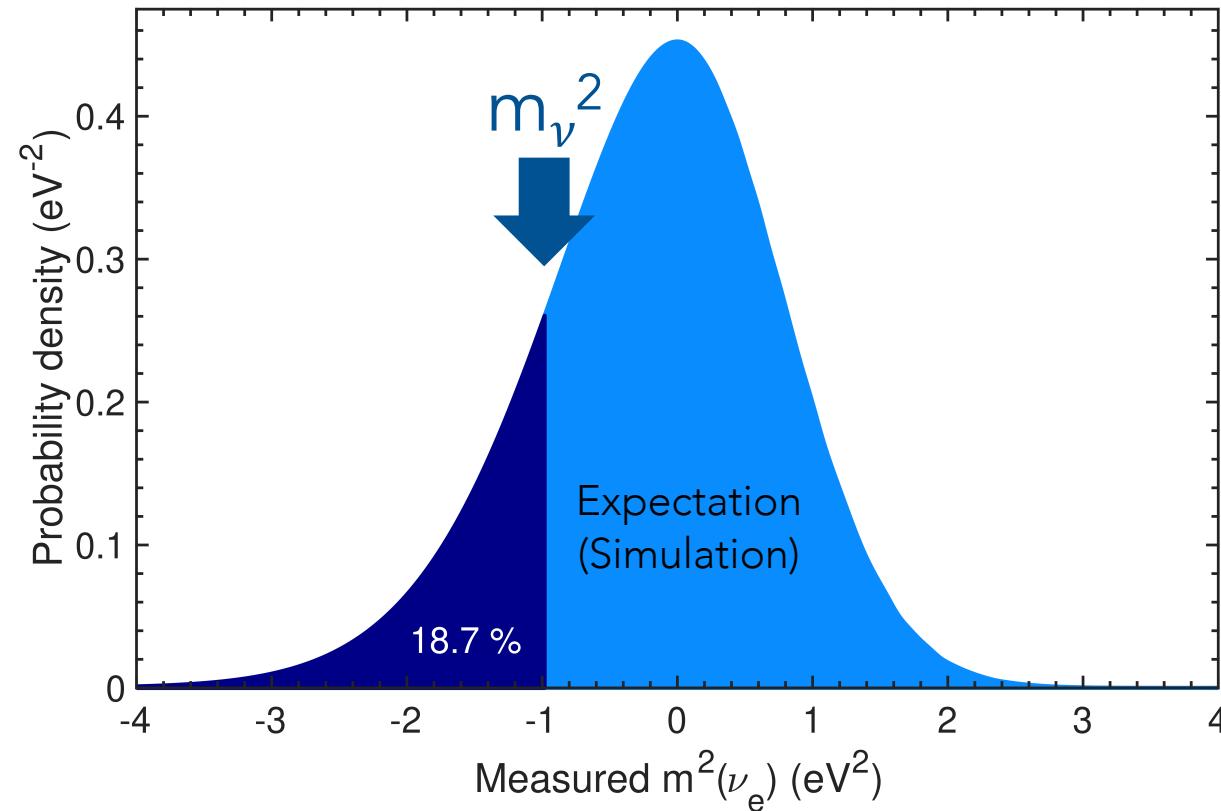
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- $$m_\nu^2 = -1.0^{+0.9}_{-1.1} \text{ eV}^2$$
- Uncertainties dominated by statistical fluctuations (0.97 eV²)

Actual Result Compared to Expectation

MC-Propagation Method

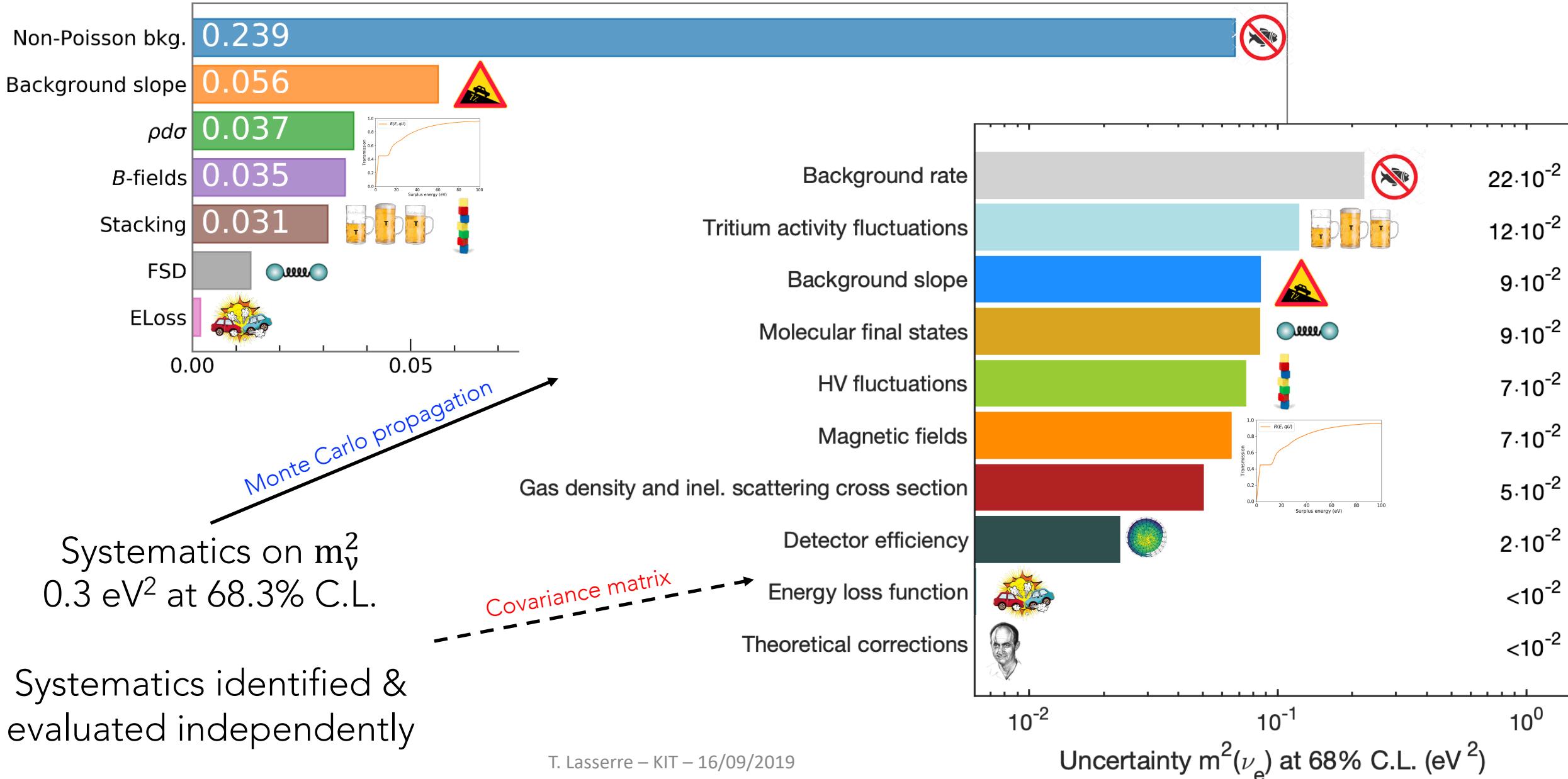


Covariance Matrix Method

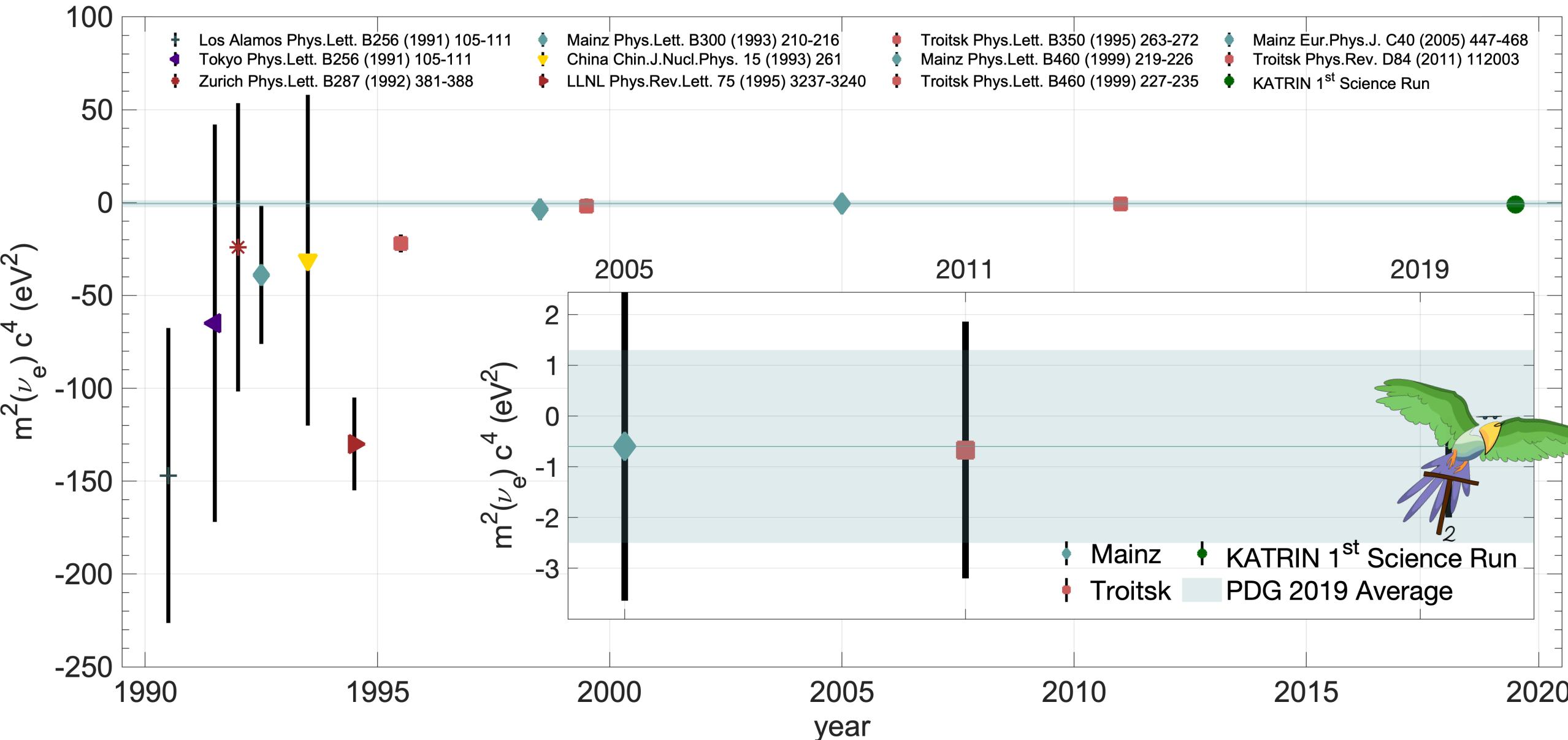


Best-fit m_{ν}^2 is fully consistent with our expectations
(1σ statistical fluctuation)

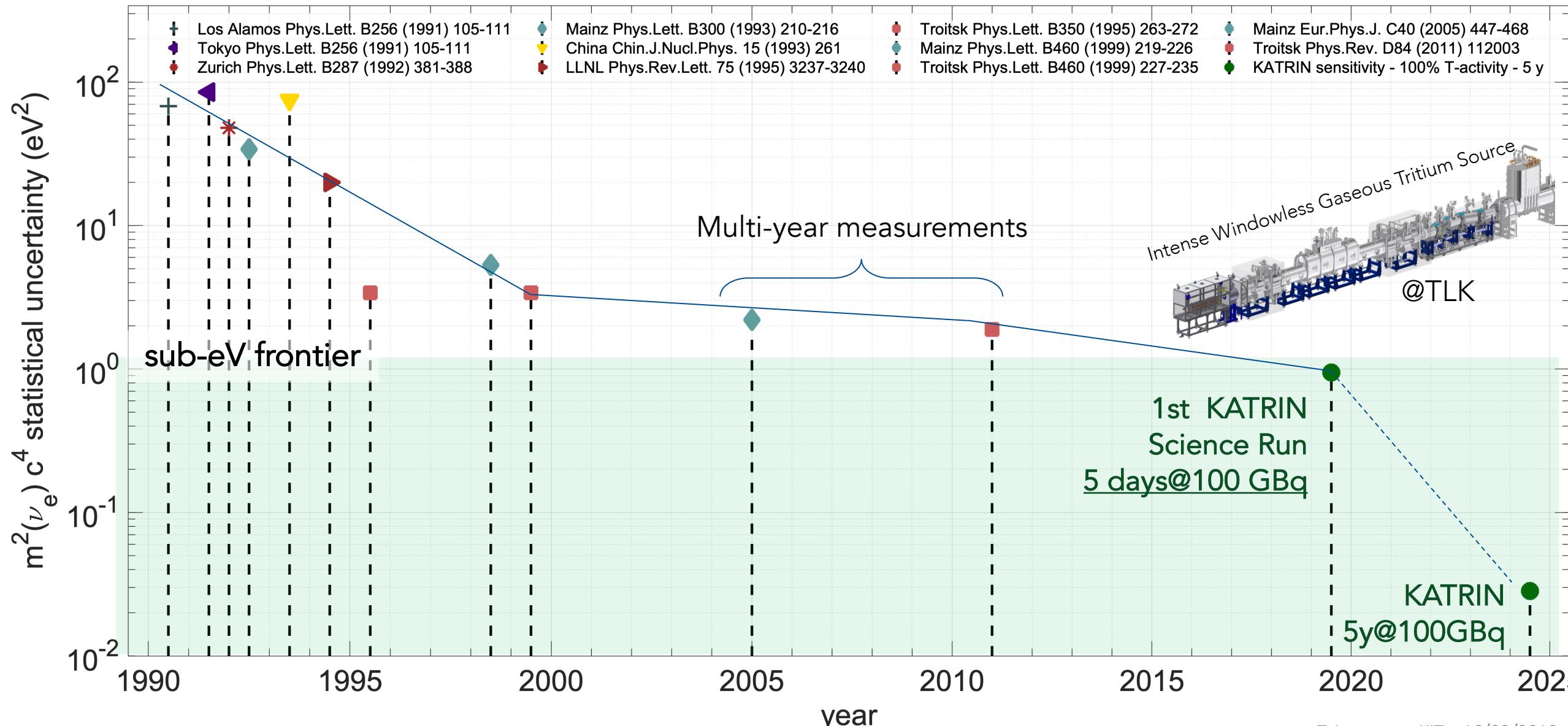
Systematic Uncertainties Breakdown



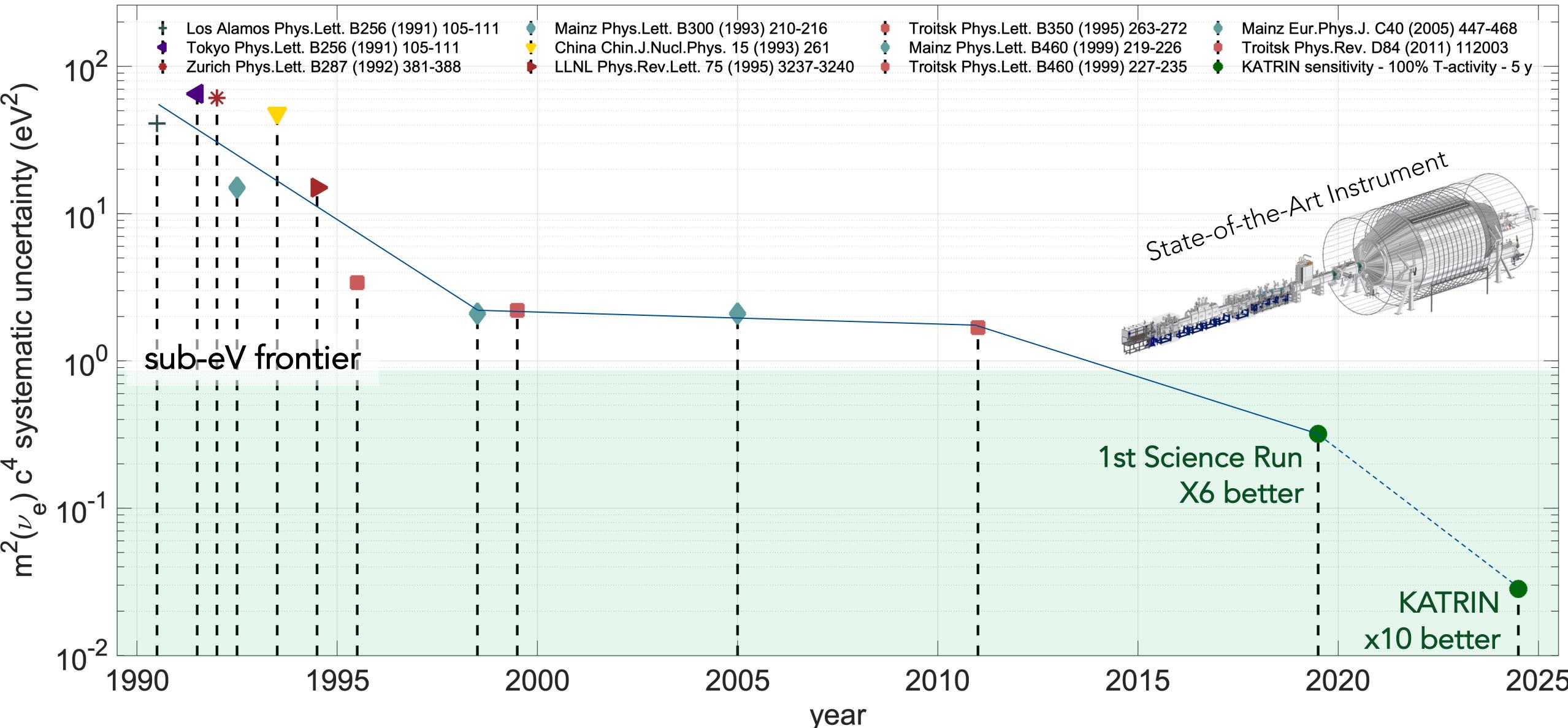
1st Science Run the light of previous results



Improvement of Statistics

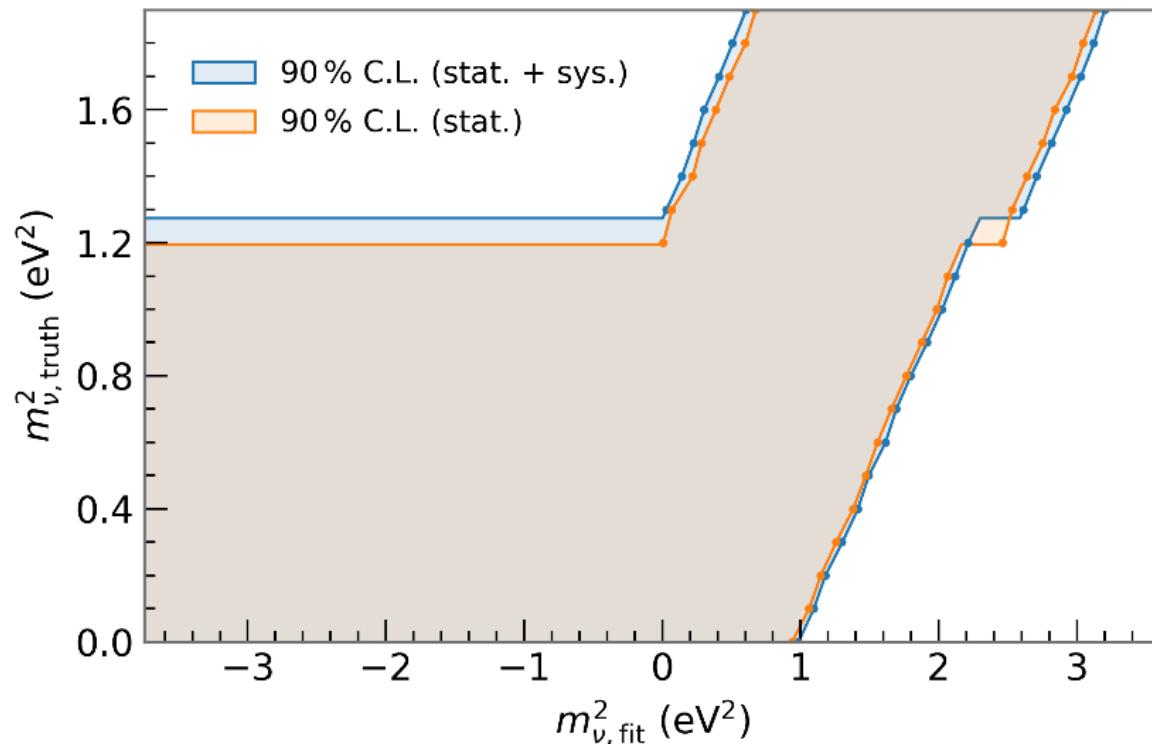


Improvement of Systematics

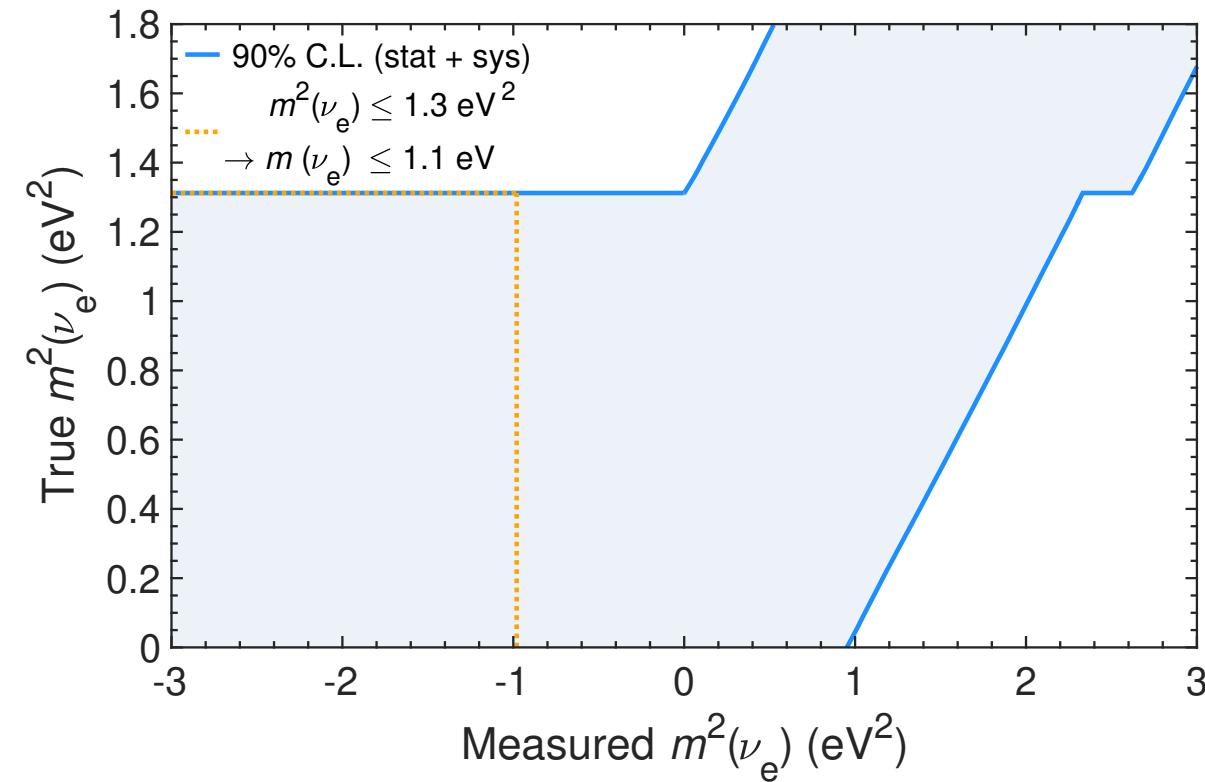


Conservative Upper Limit on the Neutrino Mass

MC-Propagation Method

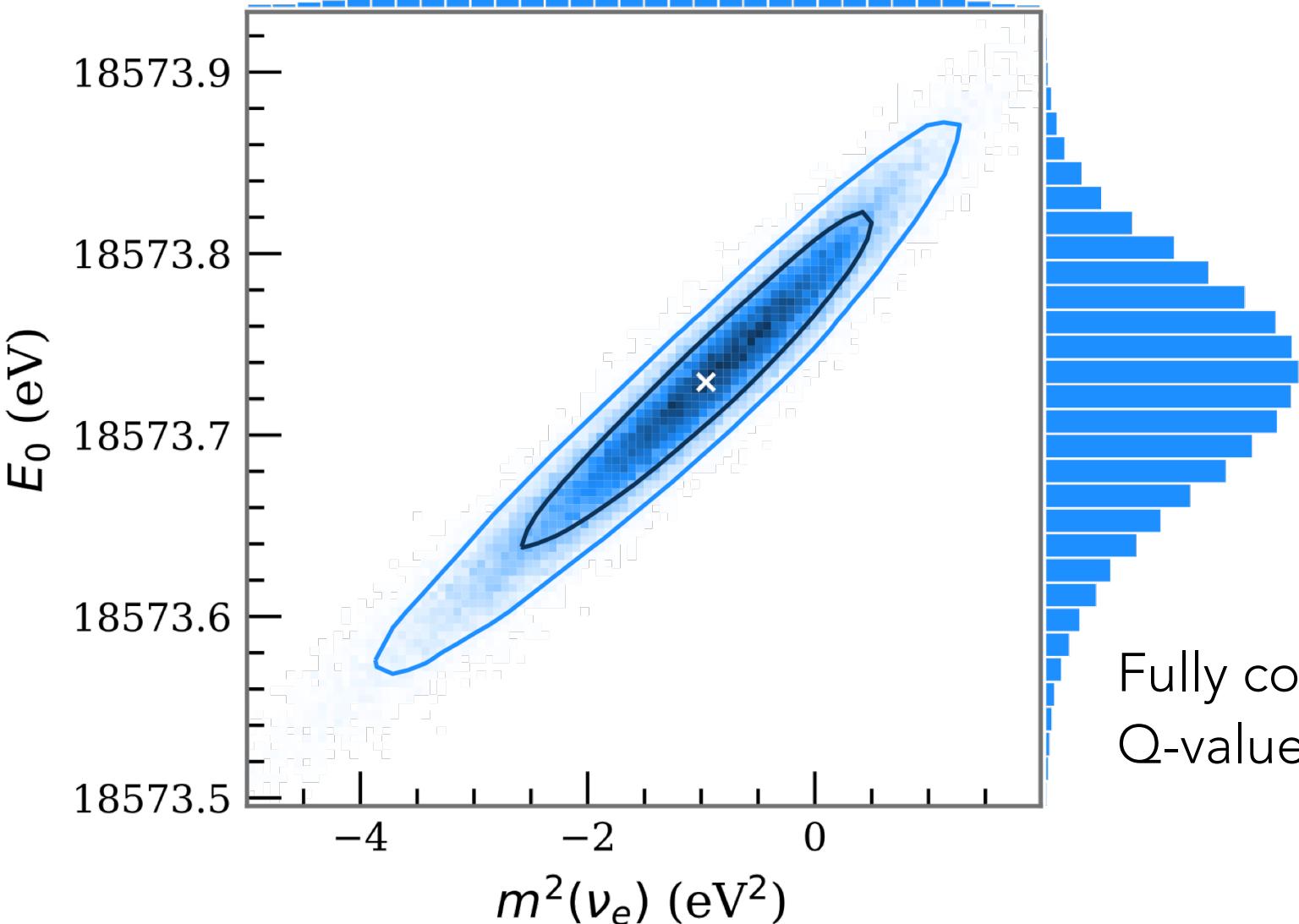


Covariance Matrix Method



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

Endpoint Measurement



Maximum electron energy in tritium decay

$$E_0 = (18573.7 \pm 0.1) \text{ eV}$$

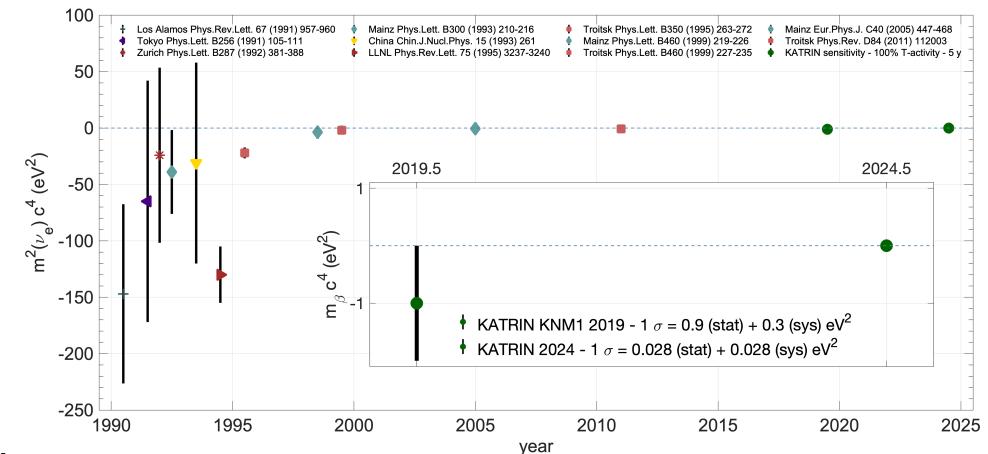
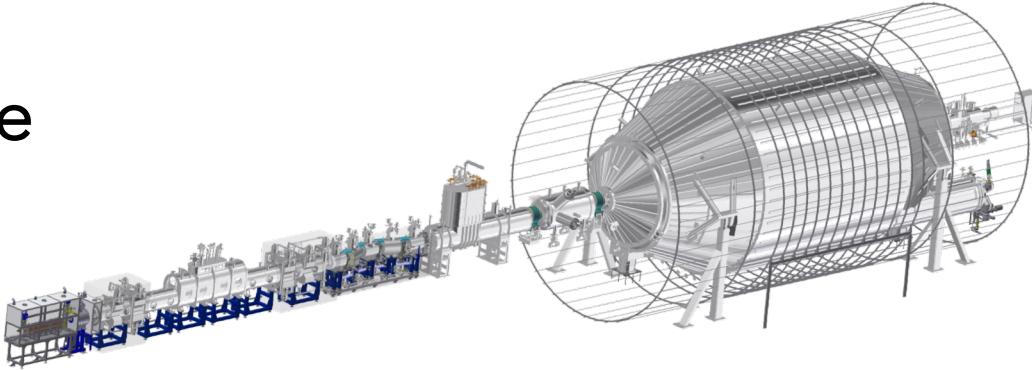
$$\Rightarrow Q\text{-value} = (18575.2 \pm 0.5) \text{ eV}$$

Mass ${}^3\text{H}$ – Mass ${}^3\text{He}$

Fully consistent with the prediction:
 $Q\text{-value} = (18575.72 \pm 0.07) \text{ eV}$

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: $m_\nu < 1.1 \text{ eV}$ (90% C.L.)
 - Statistics improved by a factor 2
 - Systematics uncertainties reduced by a factor 6
 - <http://arxiv.org/abs/1909.06048>
- Expected sensitivity $m_\nu < 0.2 \text{ eV}$ (90% CL) within 5y



A black and white photograph of a large group of people, identified as the Analysis Team, gathered in what appears to be a control room or monitoring station. They are seated at long desks, each equipped with multiple computer monitors displaying various data or video feeds. The room is filled with rows of these workstations, and the people are dressed in casual attire, some wearing jackets and others shirts. The overall atmosphere suggests a busy, technical environment.

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