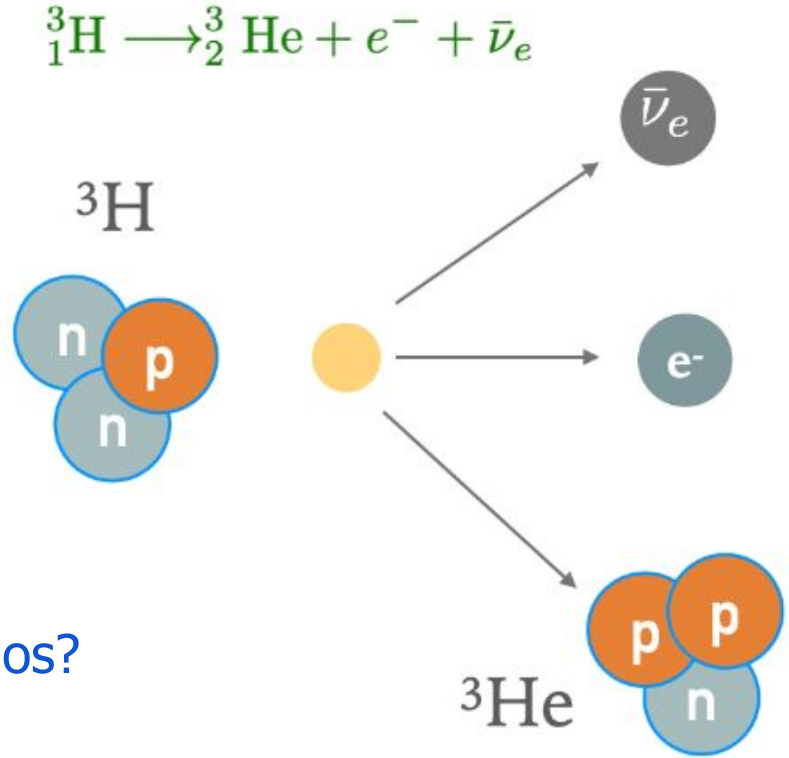
Search for sterile keV neutrino with first KATRIN data

Sterile neutrinos

- Right-handed neutrinos
- Mixing with SM neutrinos
- Promising dark matter candidate

KATRIN uses tritium β-decays to measure neutrino mass

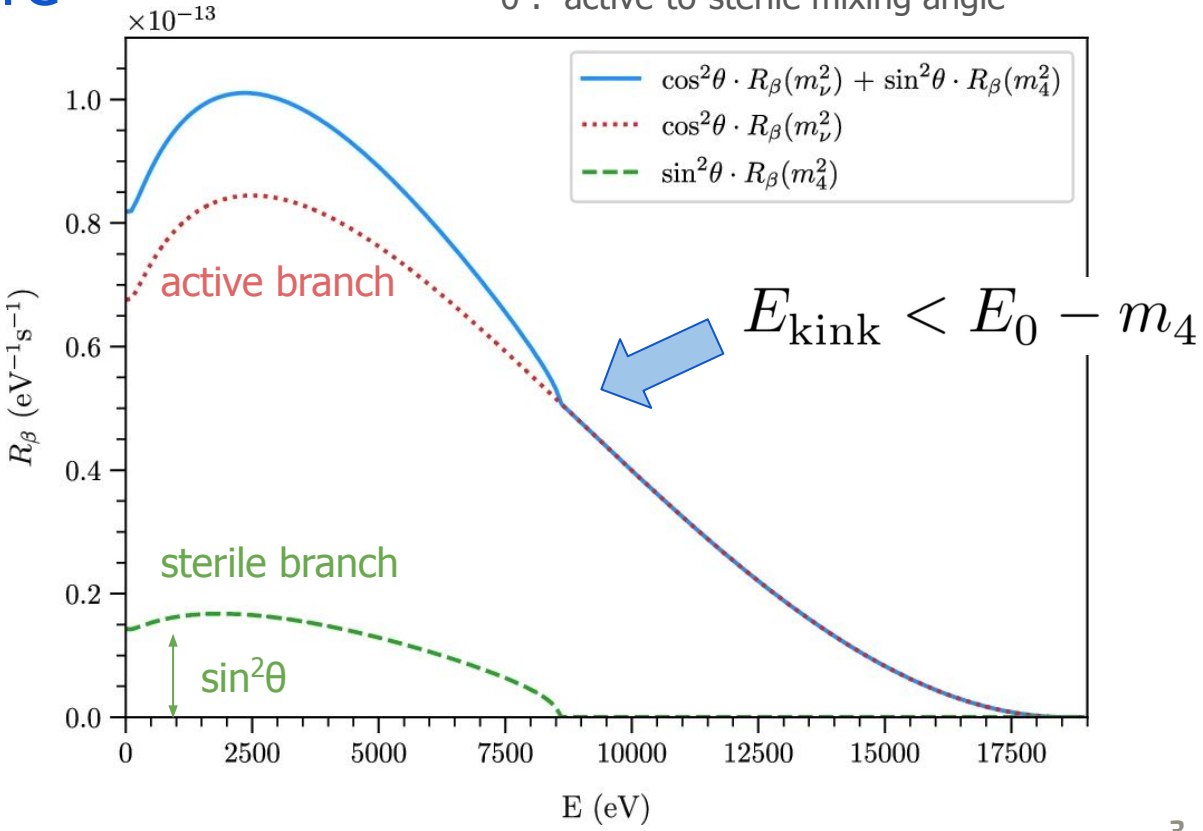


Can they search for keV sterile neutrinos?

Expected signature

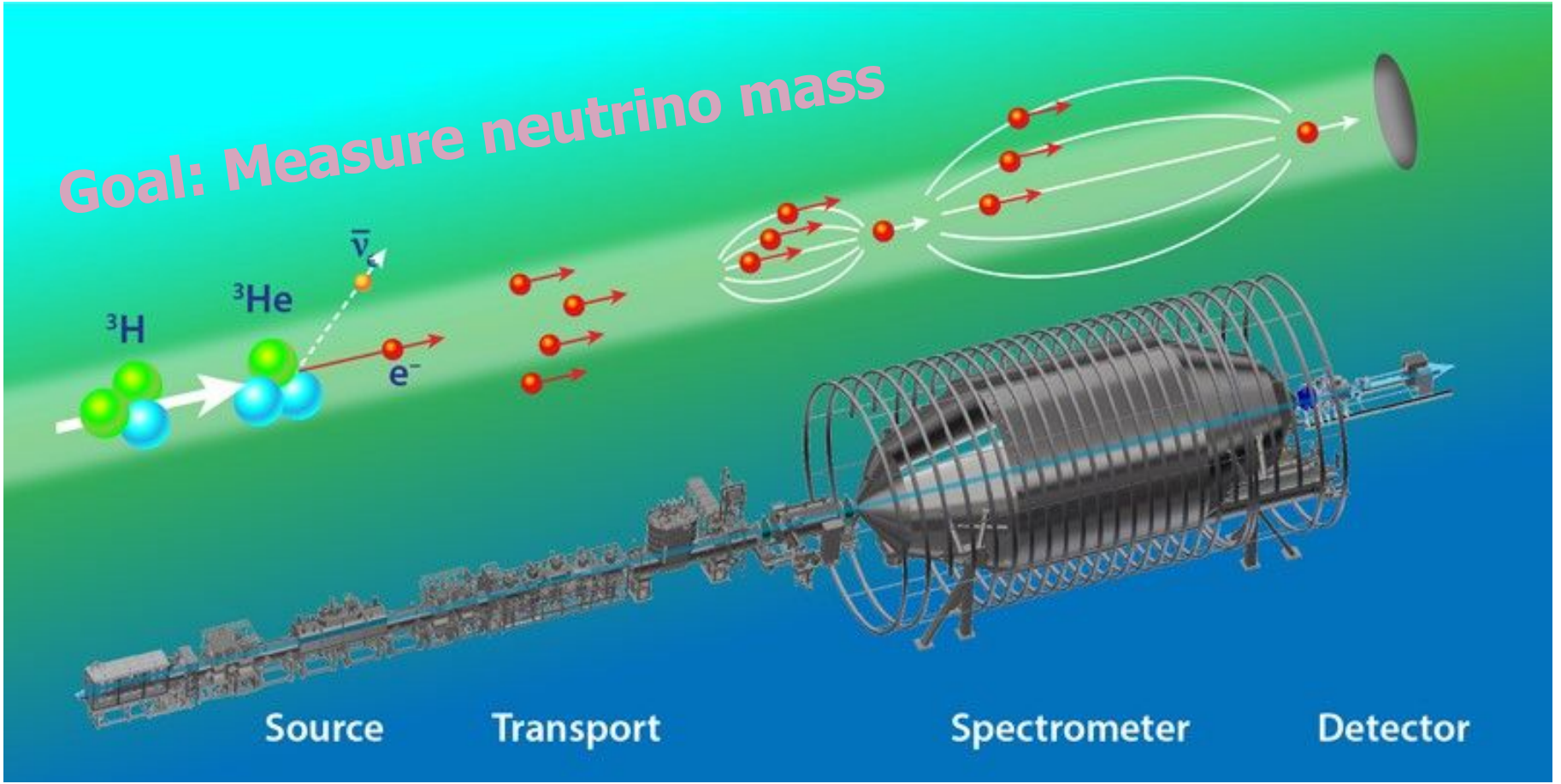
E_0: 18.6 keV (kinematic endpoint)
θ : active-to-sterile mixing angle

Adding 4th neutrino mass leads to kink in total β-decay spectrum $R_\beta(E)$



Search for keV sterile neutrinos
arXiv:2207.06337

KATRIN experiment



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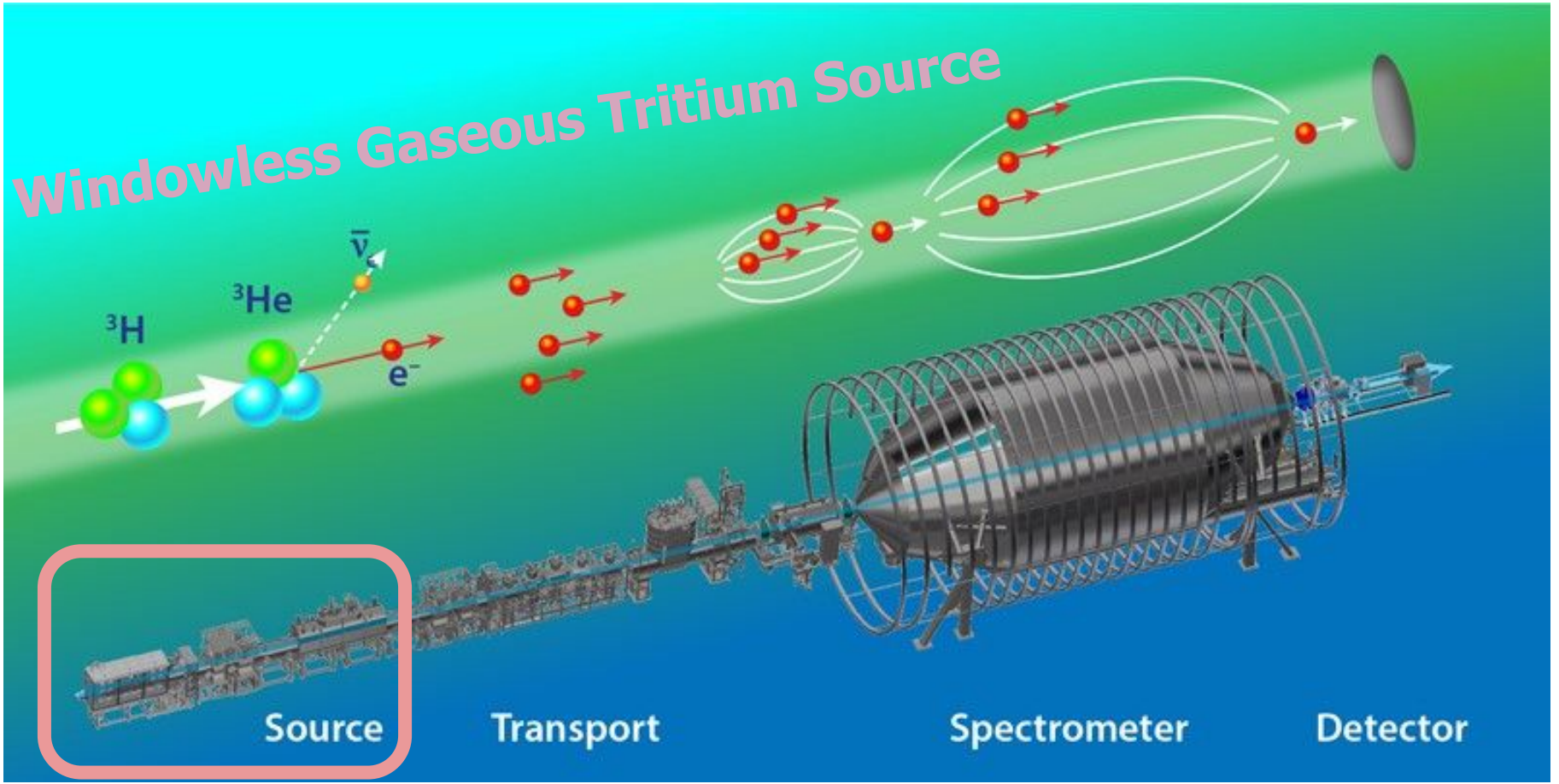

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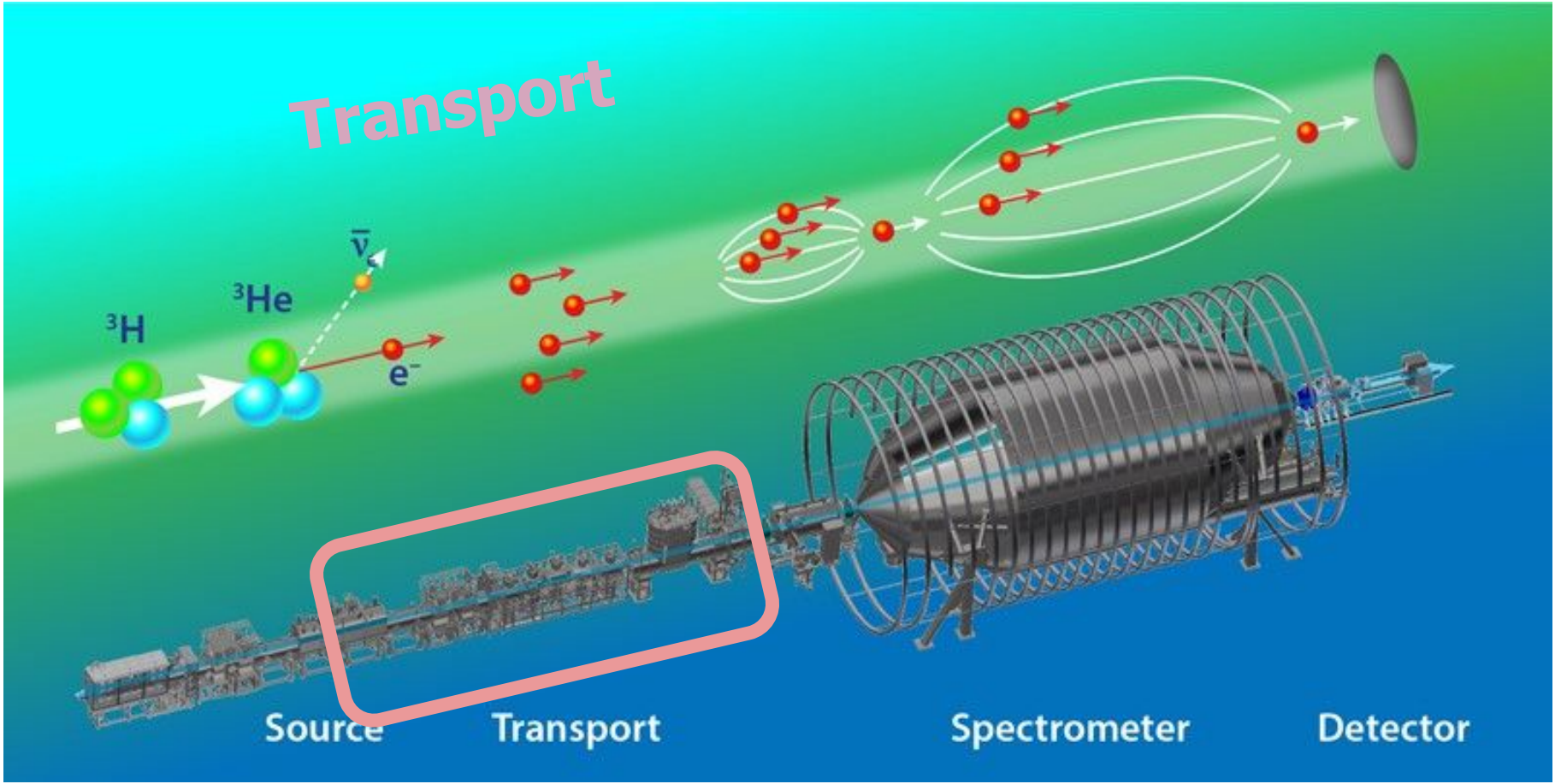
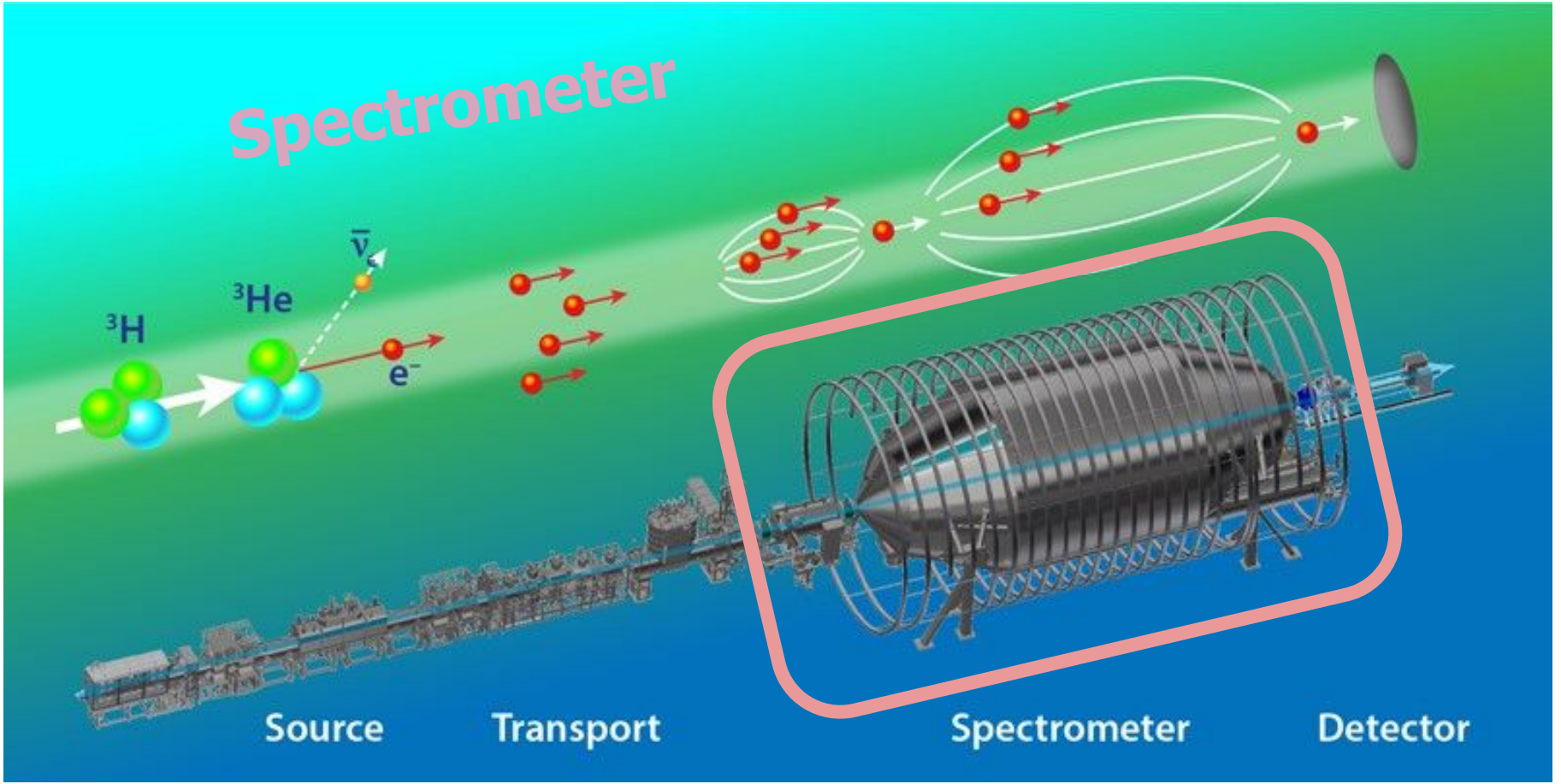

Transport
^{3}H
^{3}He
$\bar{\nu}_e$
e$^-$
Source
Transport
Spectrometer
Detector



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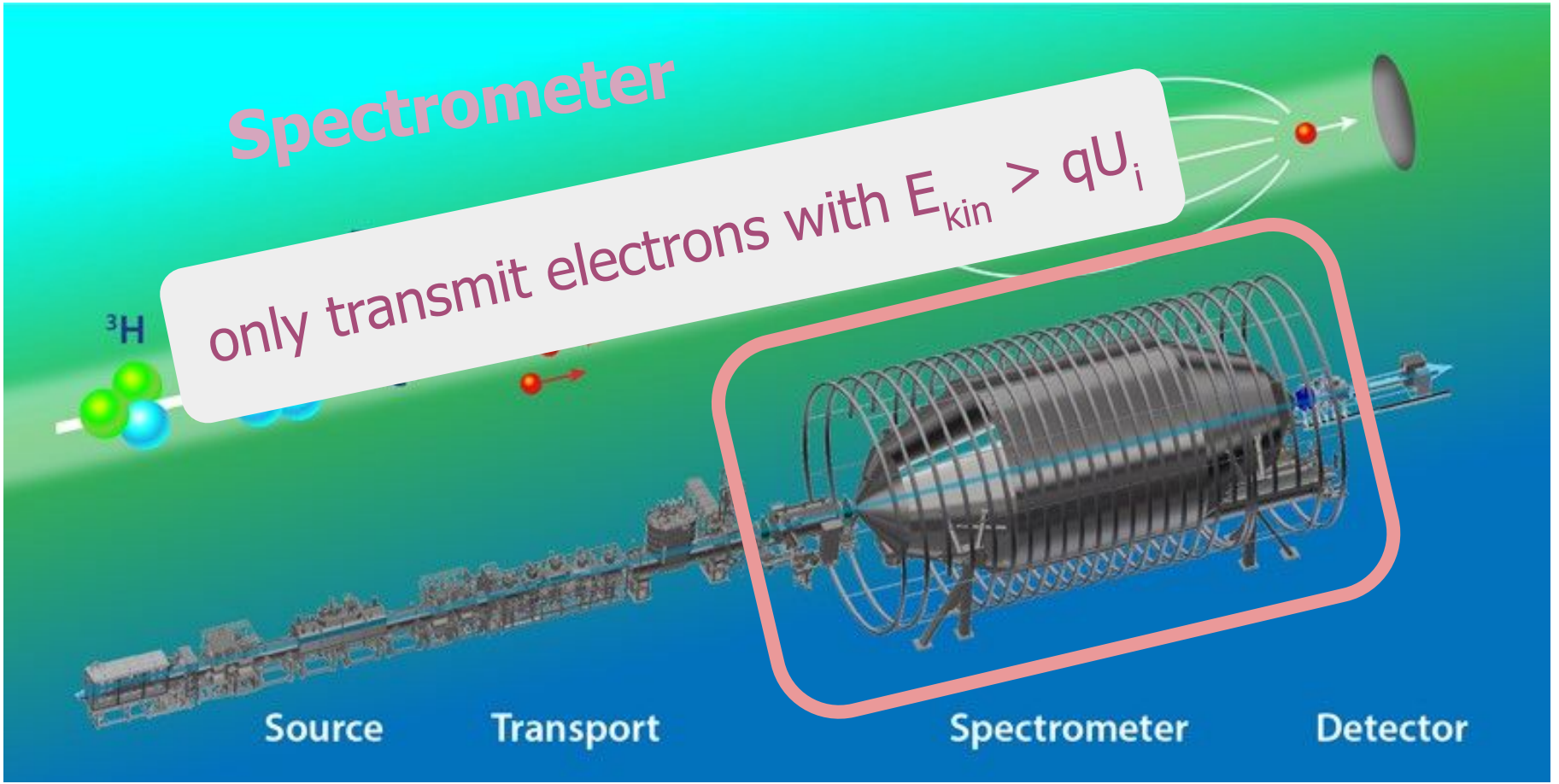
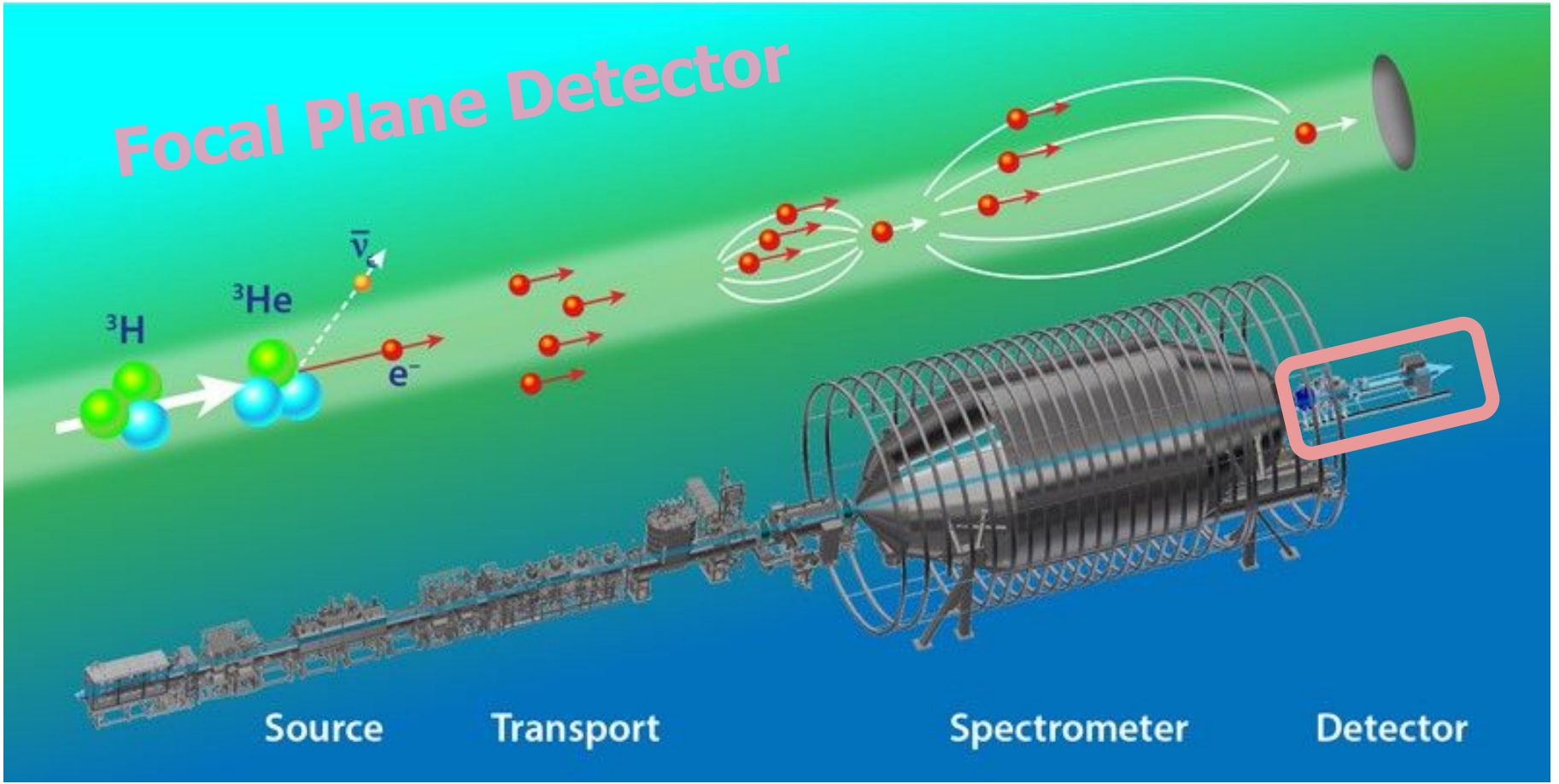

Spectrometer
only transmit electrons with $E_{kin} > qU_i$
^3H
Source
Transport
Spectrometer
Detector



Search for keV sterile neutrinos
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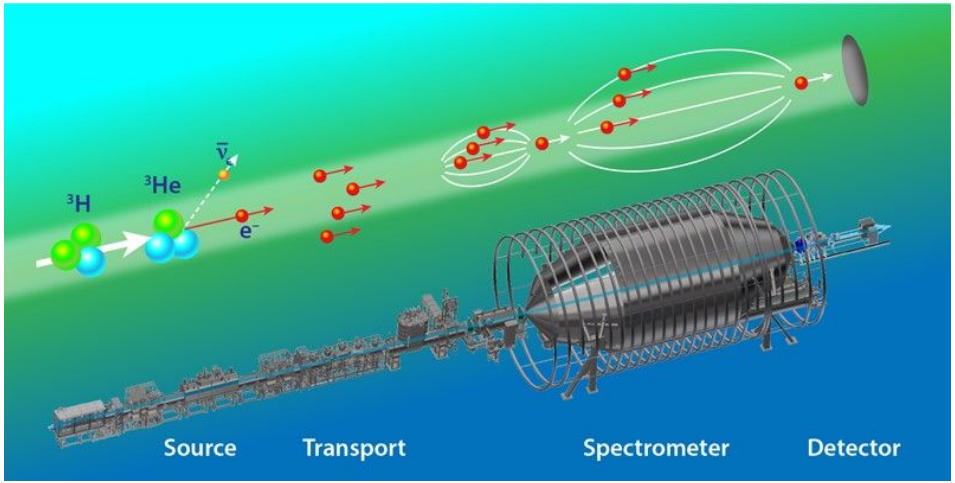
KATRIN experiment

Obtain β-decay spectrum by varying qU_i → Count no. of transmitted electrons

Measurement interval needs to be extended for keV sterile neutrino search

→ Reduced source activity (0.5% of nominal)



Integrated β-decay spectrum R_{calc}

1. Beta spectrum $R_\beta(E)$

   v-mass eigenstates + heavy sterile ν distortion

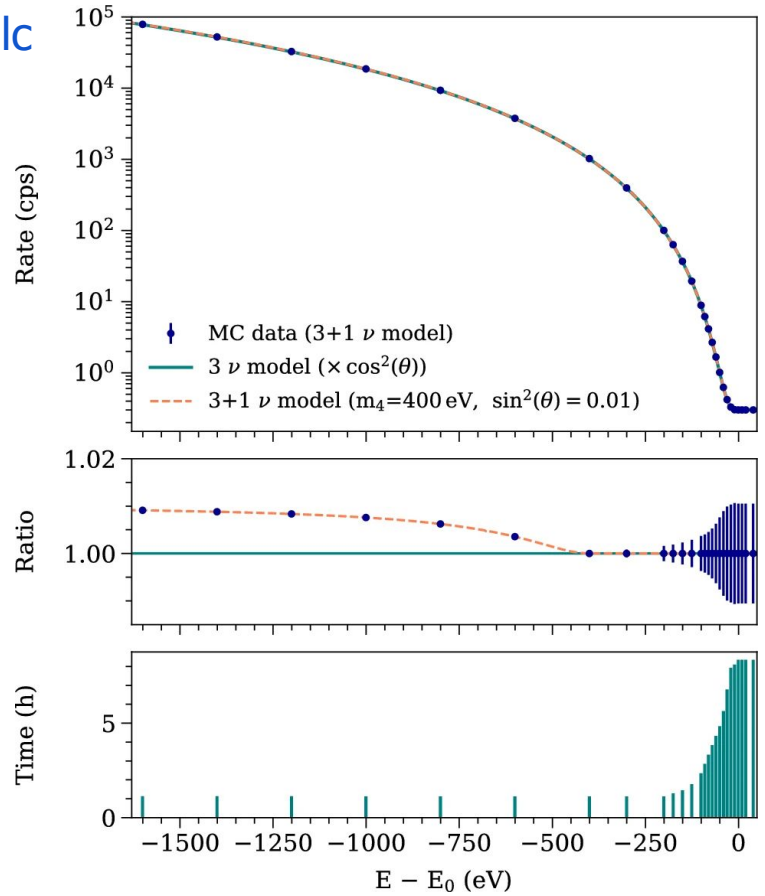
2. Response function $f_{calc}(E, qU_i)$

   Probability e reaches the detector

$$R_{\mathrm{calc}}(qU_i) = A_{\mathrm{s}} N_{\mathrm{T}} \int_{qU_i}^{E_0} R_\beta(E) f_{\mathrm{calc}}(E, qU_i)\,\mathrm{d}E + R_{\mathrm{bg}}$$

→ Vary retarding energies

$$E_0 - 1600\,\mathrm{eV} \leq qU_i \leq E_0 + 30\,\mathrm{eV}$$



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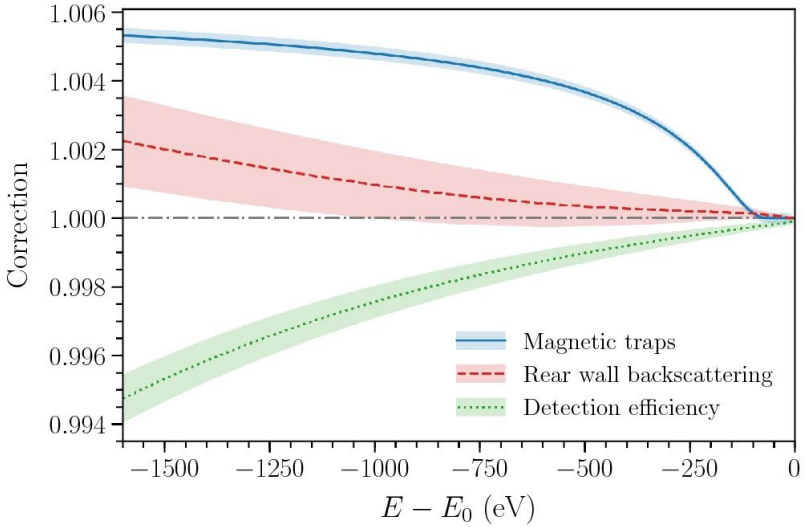
Wide interval corrections

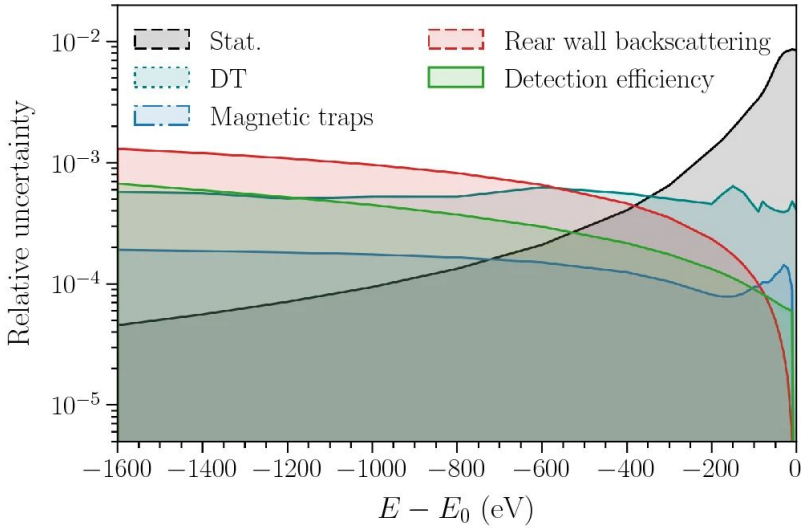
Effects relevant at energies further away from endpoint

Pileup, backscattering, ROI coverage

Fake electrons from backscattering reaching detector

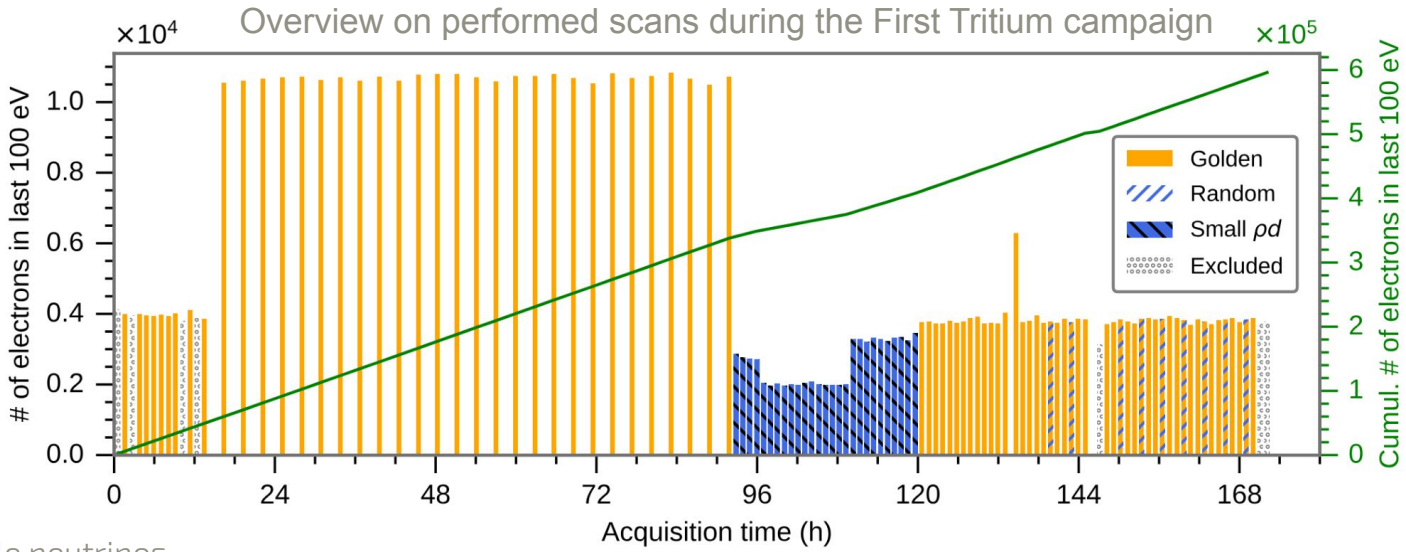
Gaps of magnetic fields from beamline introducing fake electrons





Data selection and combination

- Integral Tritium spectrum: 122 scans, 82 selected
- Focal-Plane Detector Pixel: 148 independent pixel, 119 good pixel selected



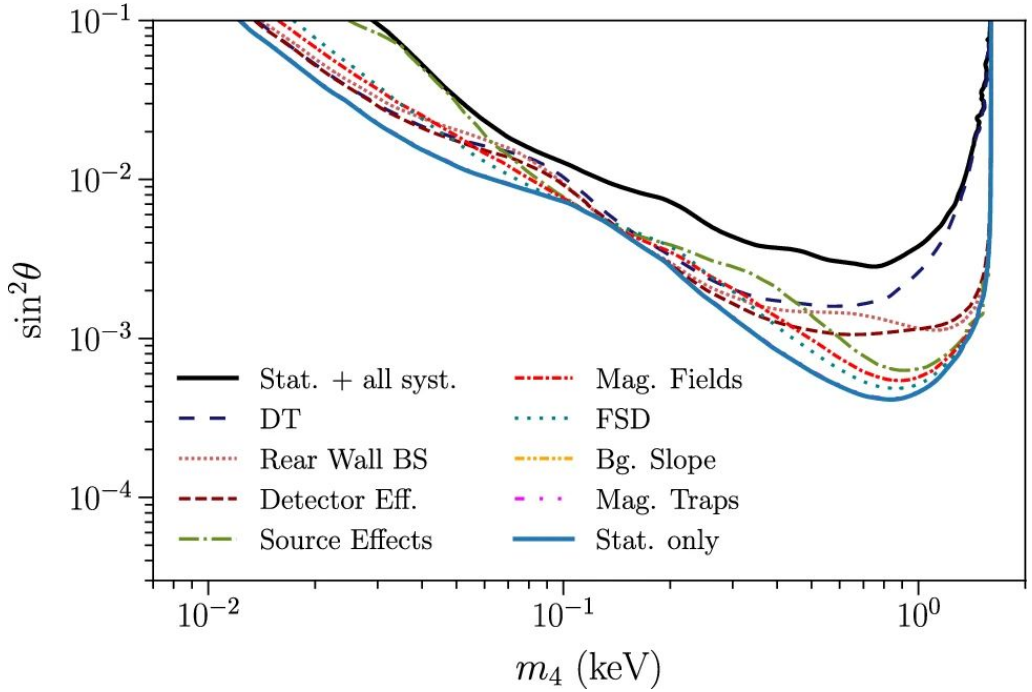
Systematic uncertainties on 95% CL exclusion limit

Activity fluctuation

Rear-wall backscattering

Retarding-potential-dependant detector efficiency

Et cetera …



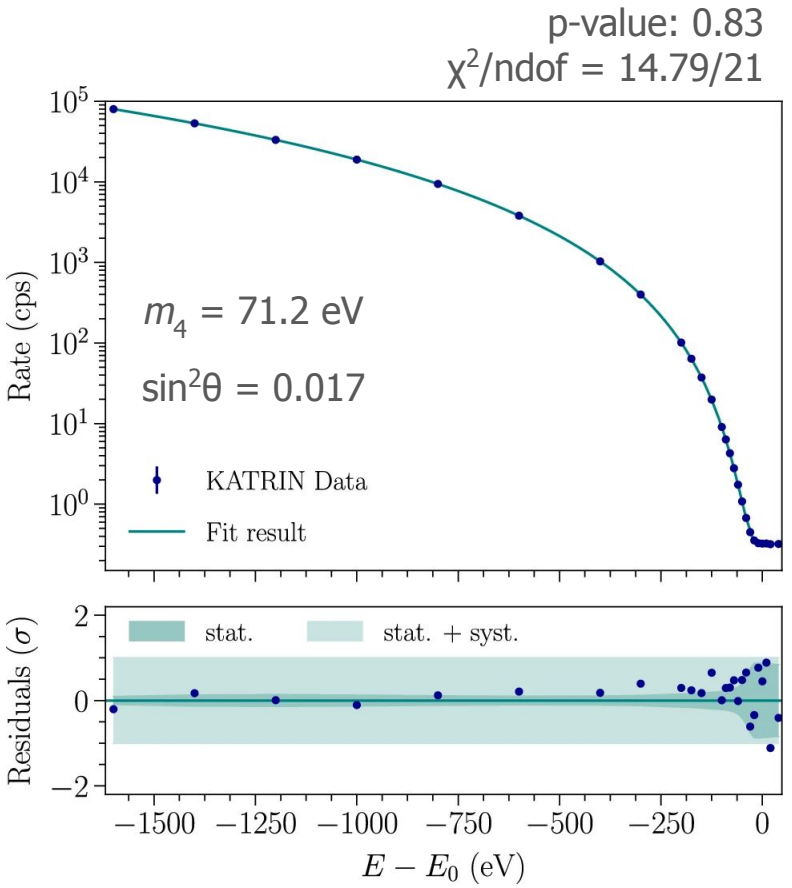
Spectrum fit

$1.2 \cdot 10^9$ β-electrons in dataset

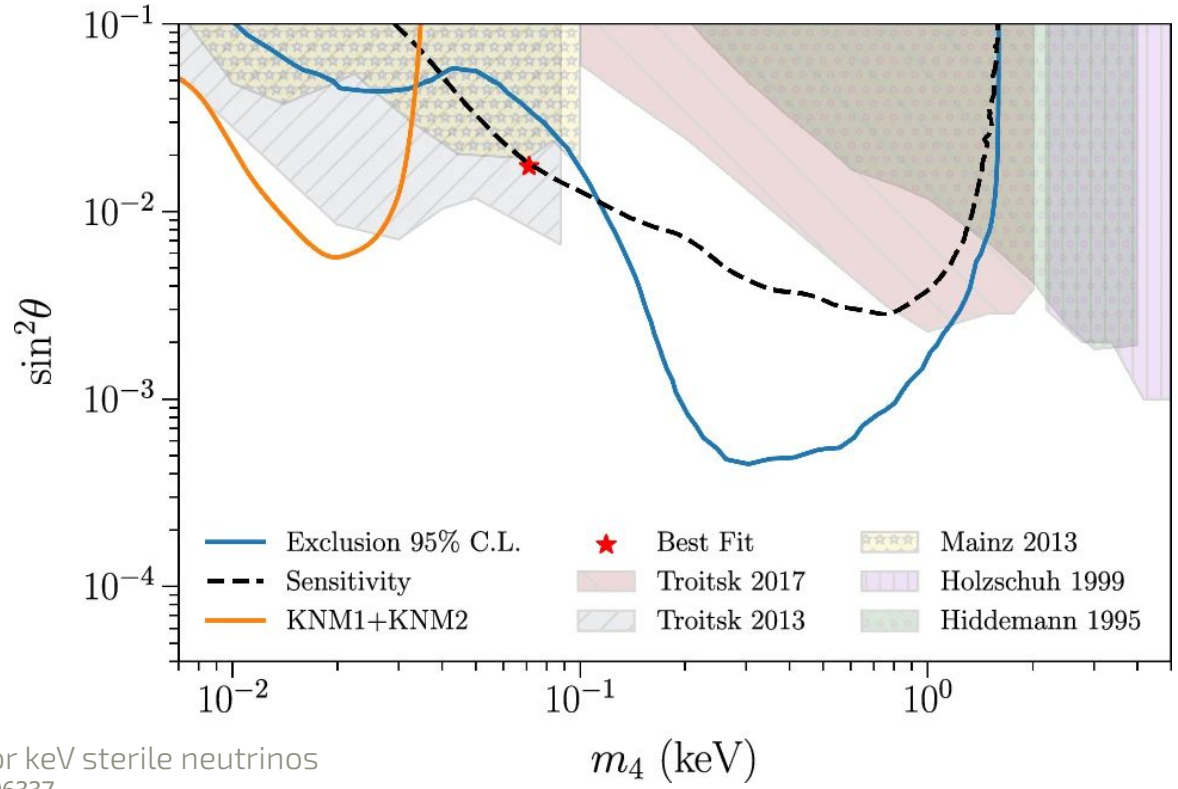
Construct frequentist confidence interval according to Neyman procedure

Scan (m_4, $\sin^2\theta$) and determine minimal χ^2

Deviation of 2.26 σ at best fit



Exclusion limit



LS method

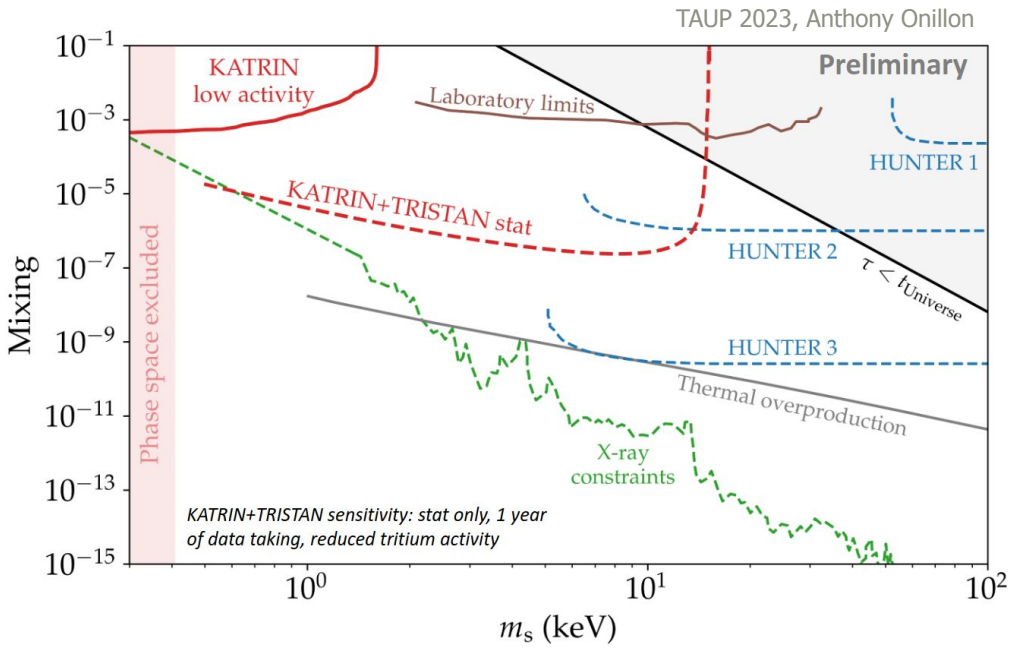
No signal observed

Summary & Outlook

No keV sterile neutrino observed

Improved limits in mass range of 0.1 keV < m_4 < 1.0 keV

Feasibility of study demonstrated



Several order of magnitude improvement of current limits expected with TRISTAN