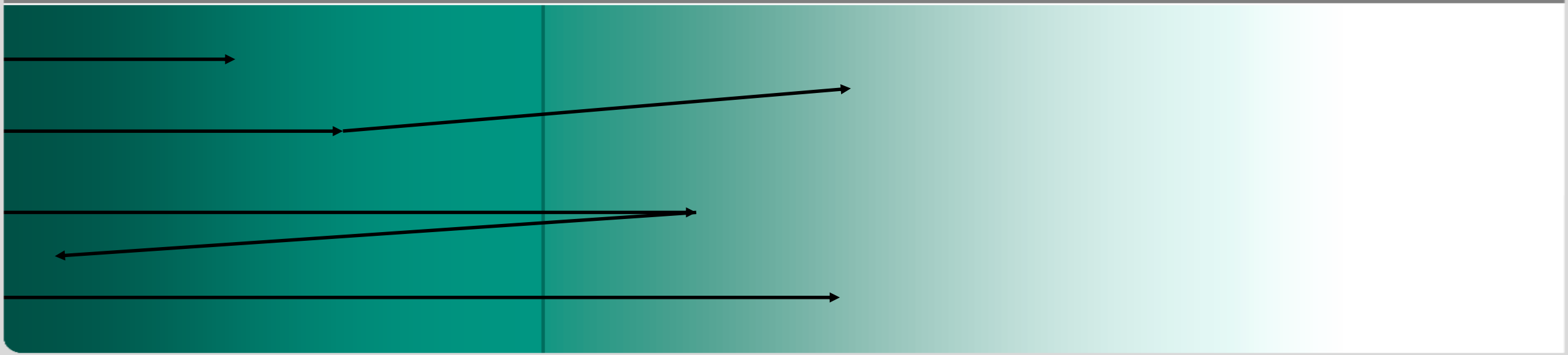
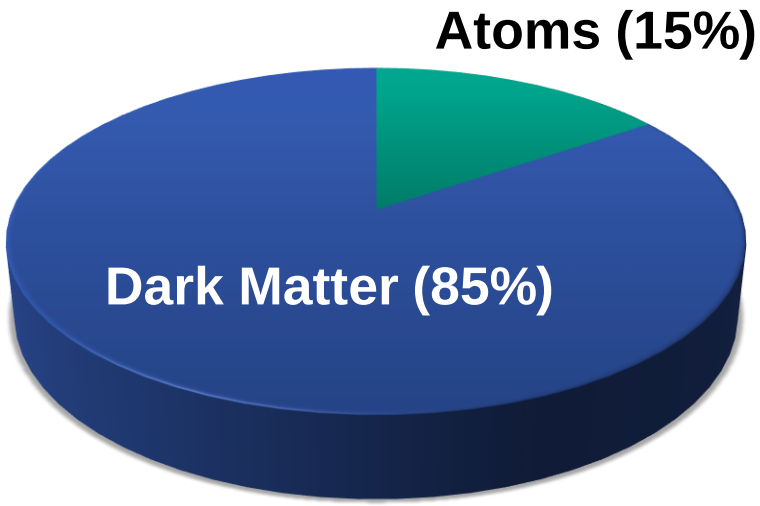
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Characterization of the detector dead layer for a sterile neutrino search with KATRIN

Tim Brunst, IMPRS Young Scientist Workshop at Ringberg Castle, July 18th 2017

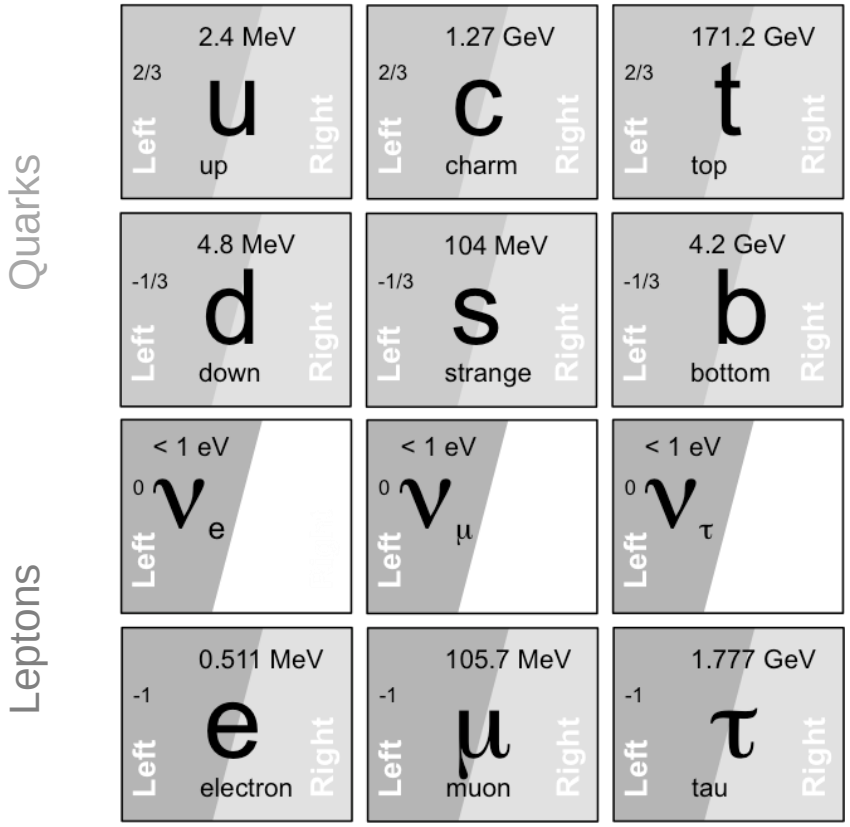


Sterile neutrinos in cosmology



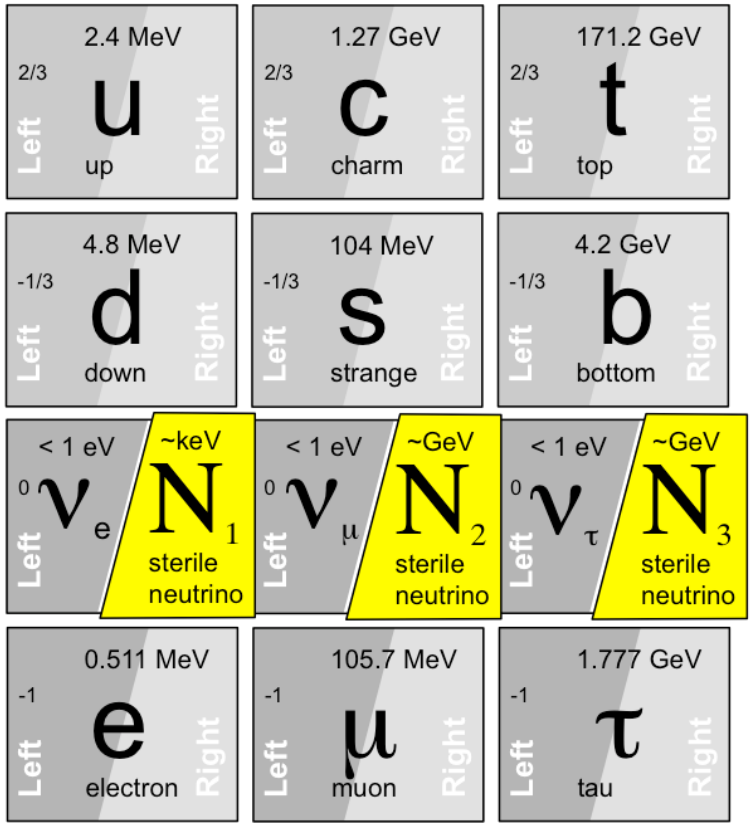
- Discovery of neutrino oscillations proofs that $m_\nu \neq 0$
- Sterile neutrinos in the keV mass range are a prime candidate for Dark Matter

Sterile neutrinos in particle physics



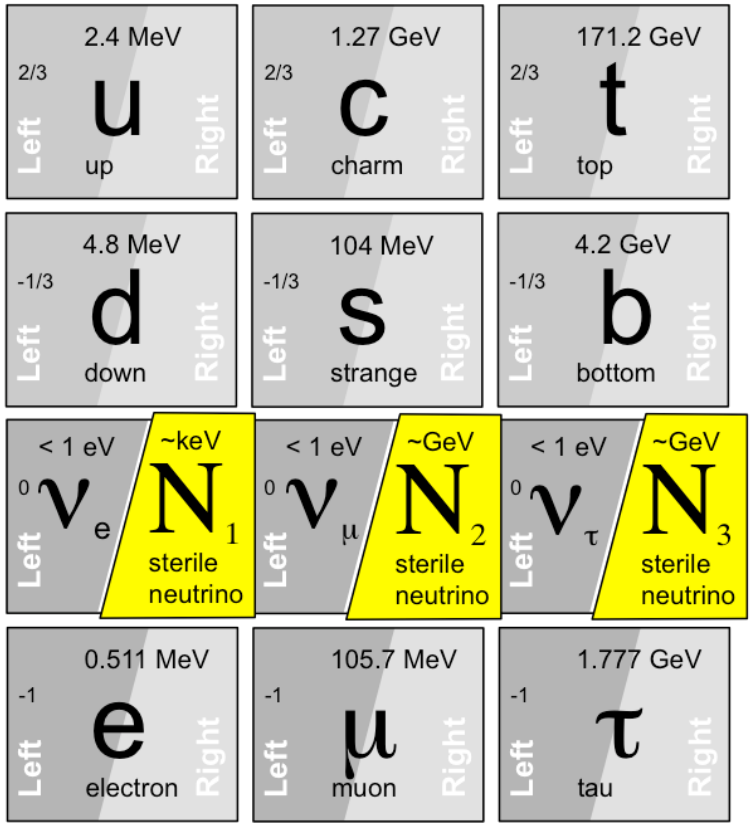
- No right-handed neutrinos in the SM

Sterile neutrinos in particle physics

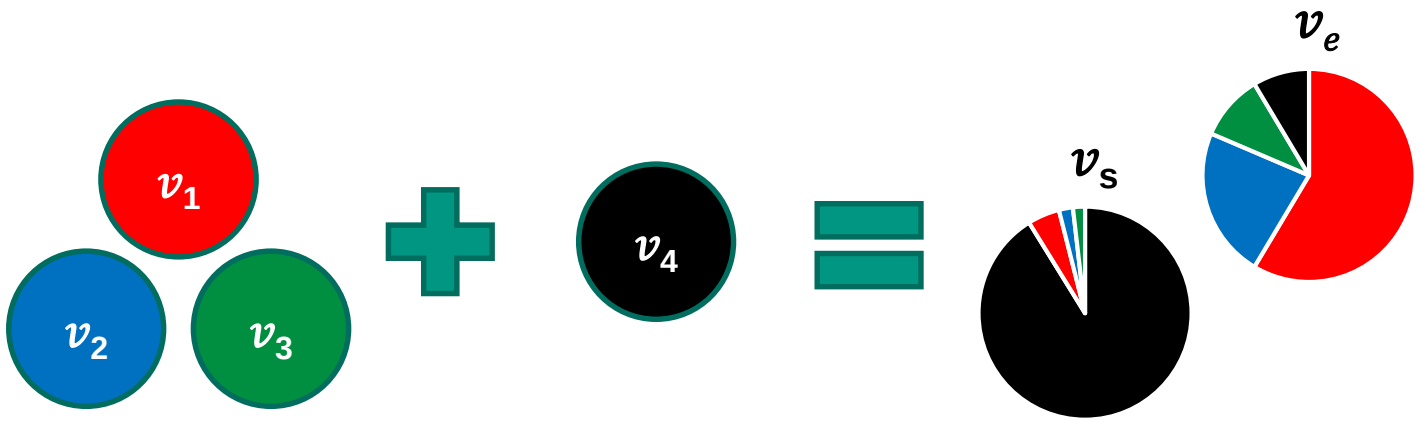


- No right-handed neutrinos in the SM
- Or: right-handed neutrinos are sterile

Sterile neutrinos in particle physics



- No right-handed neutrinos in the SM
- Or: right-handed neutrinos are sterile
- ... but mix with the active neutrinos

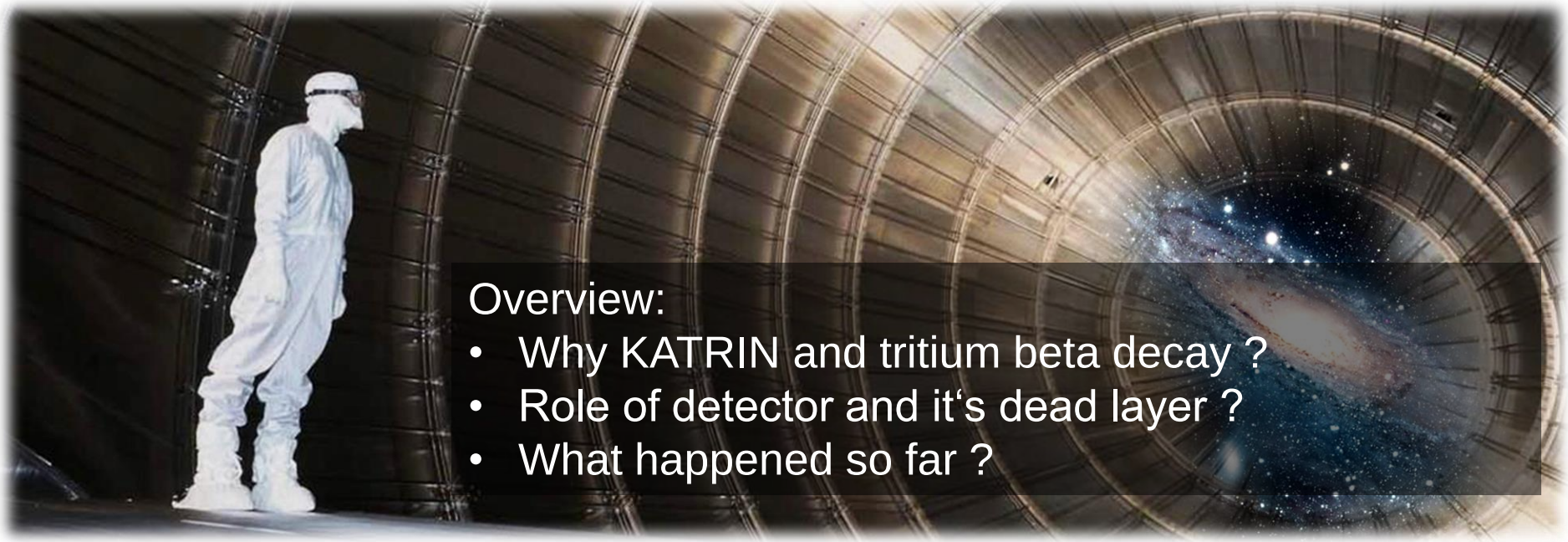


Mass eigenstates

Flavour eigenstates

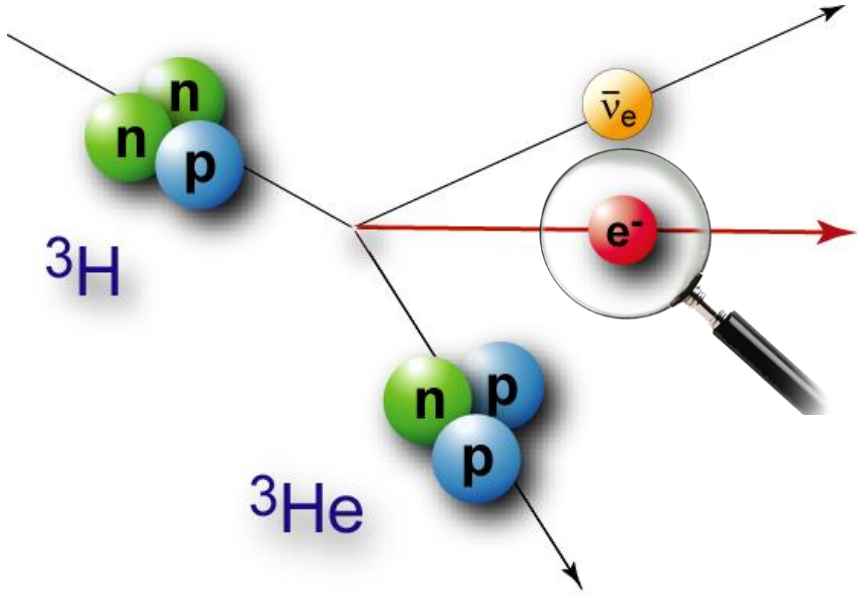
Objective of TRISTAN

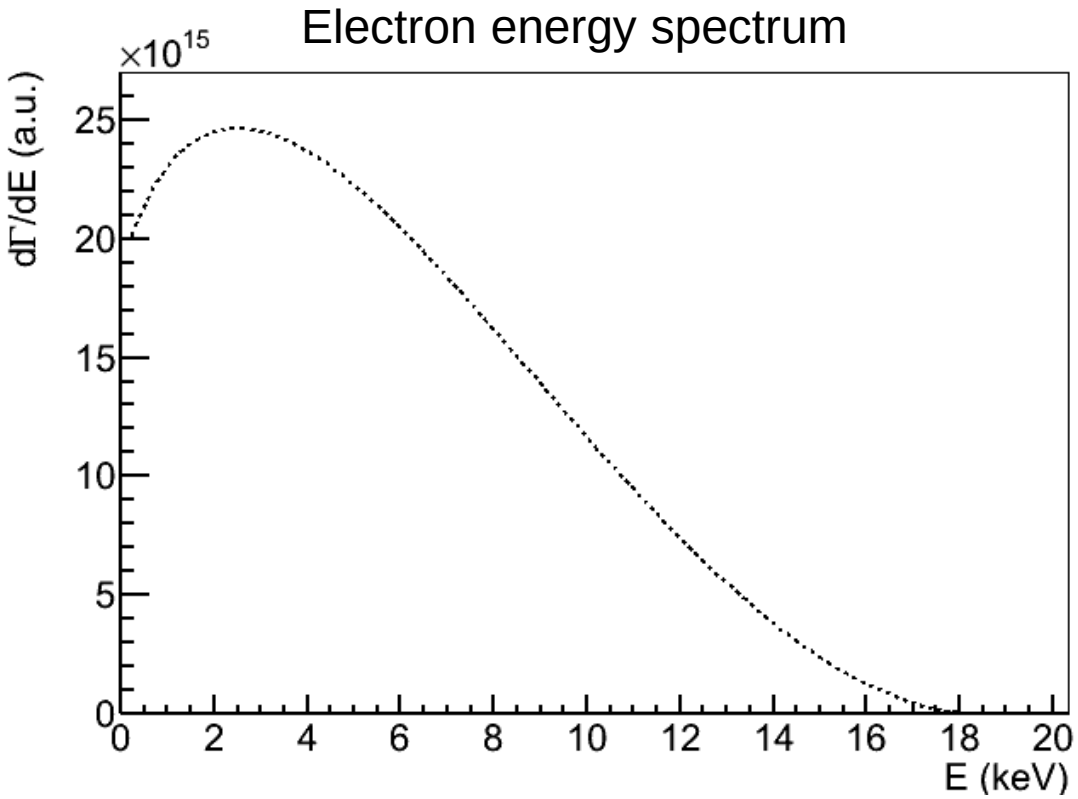
- Search for **Sterile Neutrinos** in the **Model-Independent** laboratory experiment **KATRIN**



Tritium beta decay

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}E} \propto C\, F(Z,E)\, p(E+m_e)(E_0-E)\sqrt{(E_0-E)^2-m^2(\nu_e)}$$





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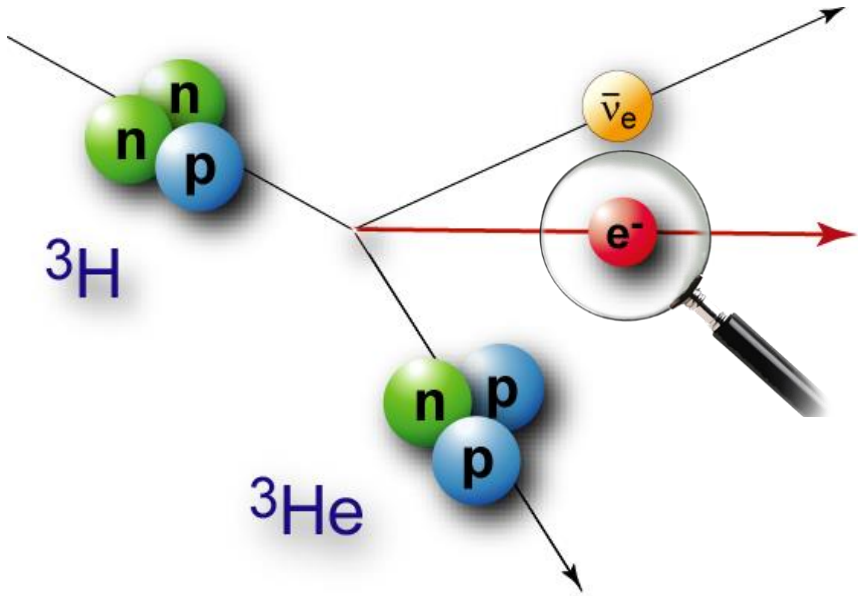
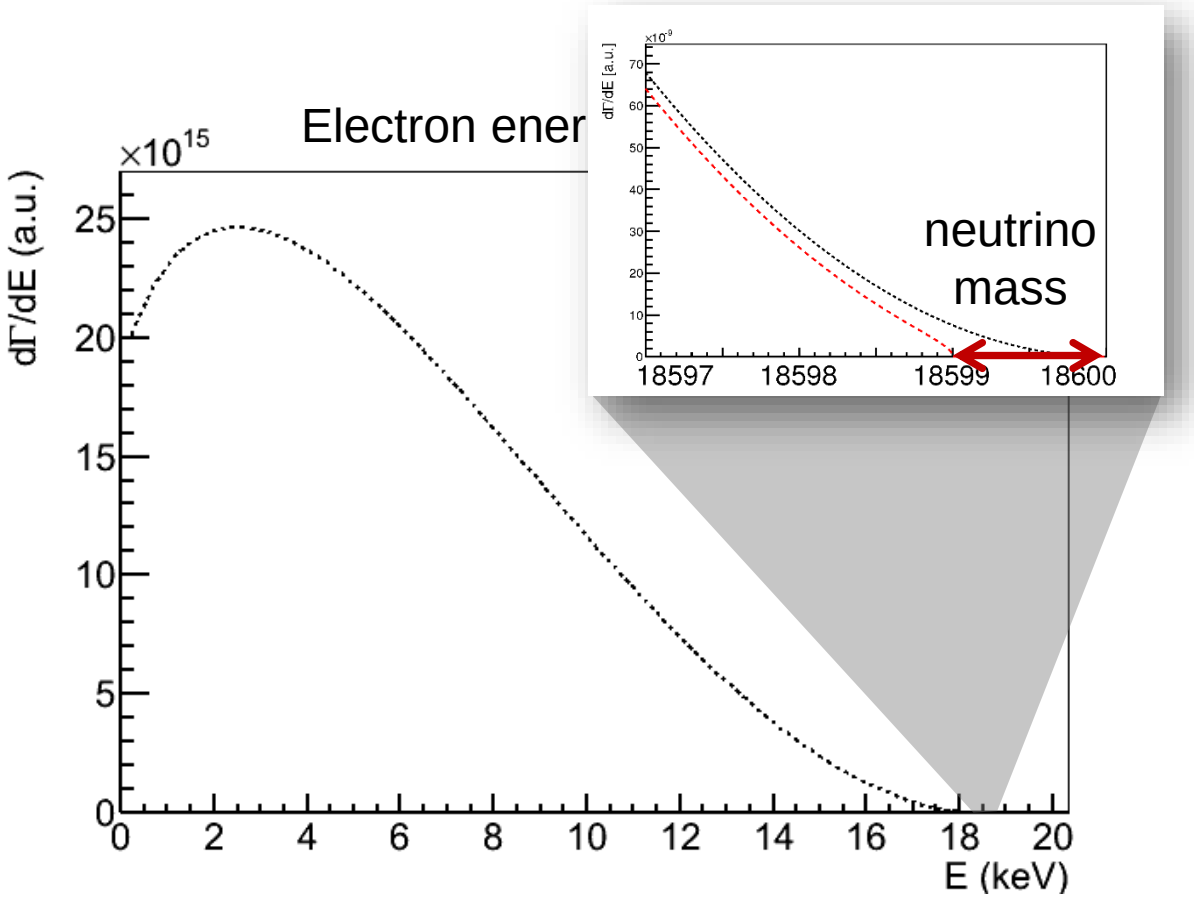
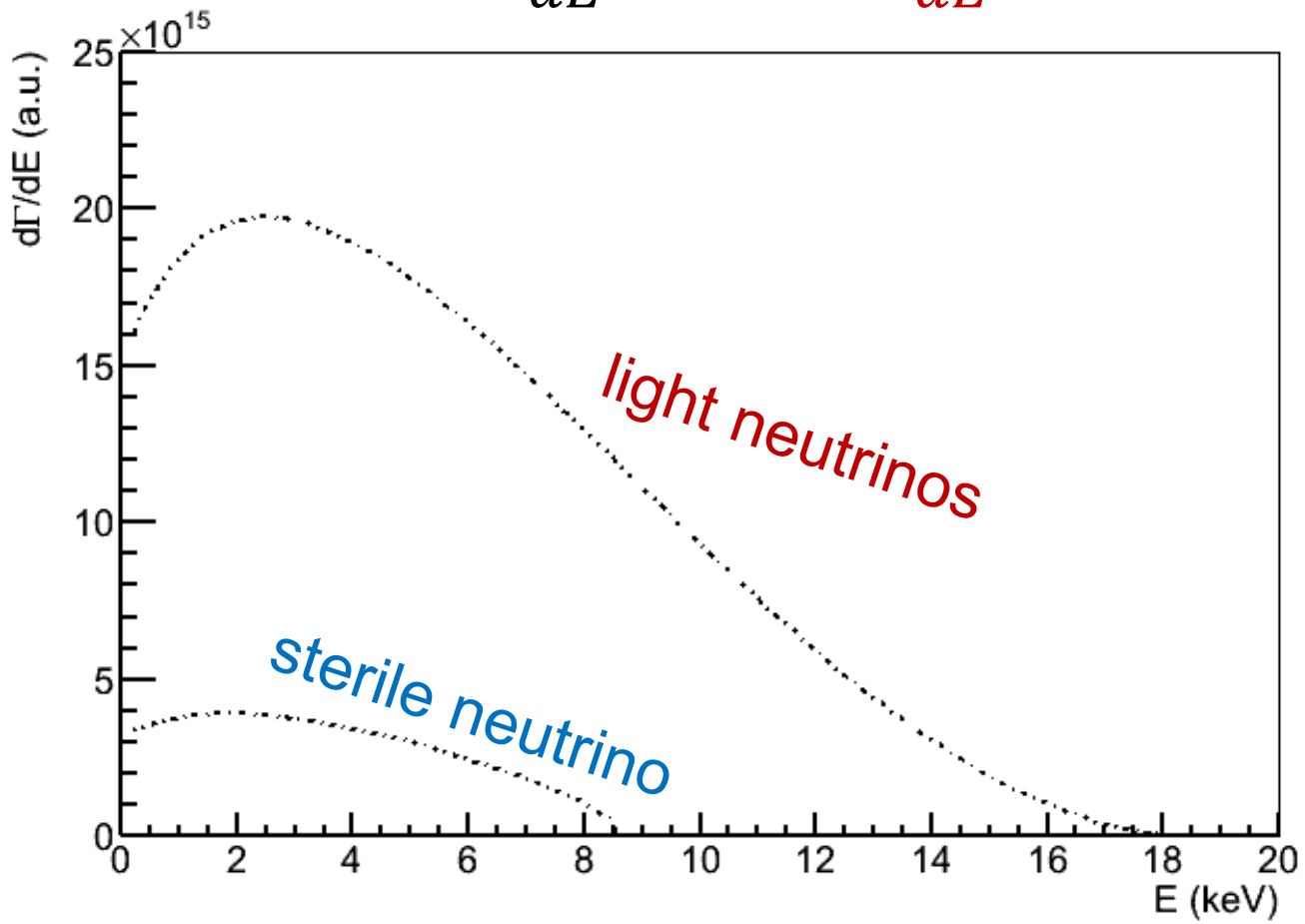
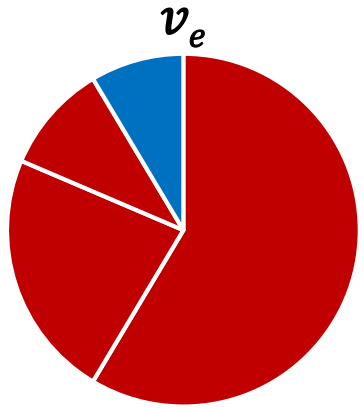




Imprint of sterile ν‘s on ß-spectrum

$$\frac{d\Gamma}{dE} = \cos^2(\theta)\frac{d\Gamma}{dE}(m_\beta) + \sin^2(\theta)\frac{d\Gamma}{dE}(m_s)$$





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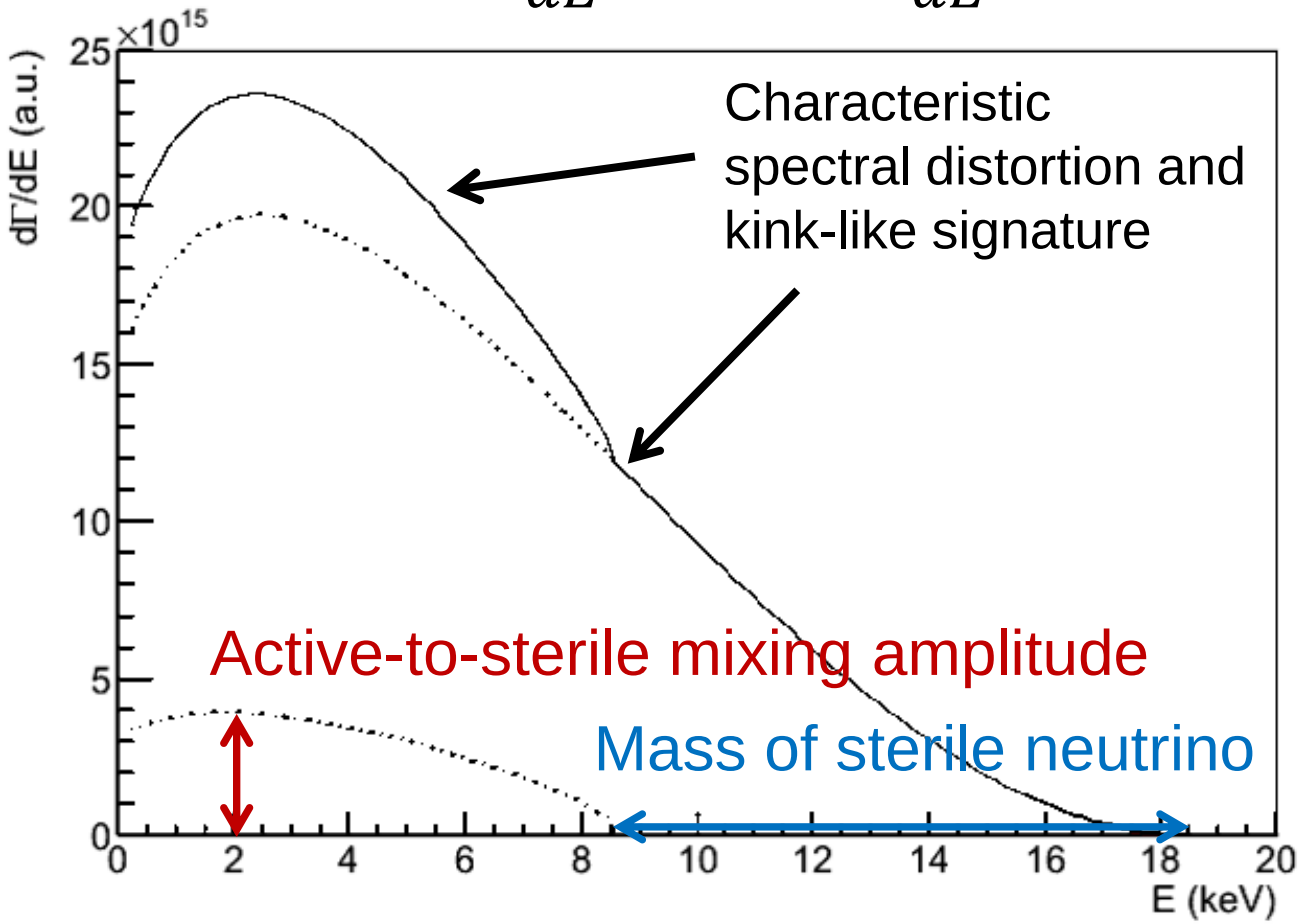
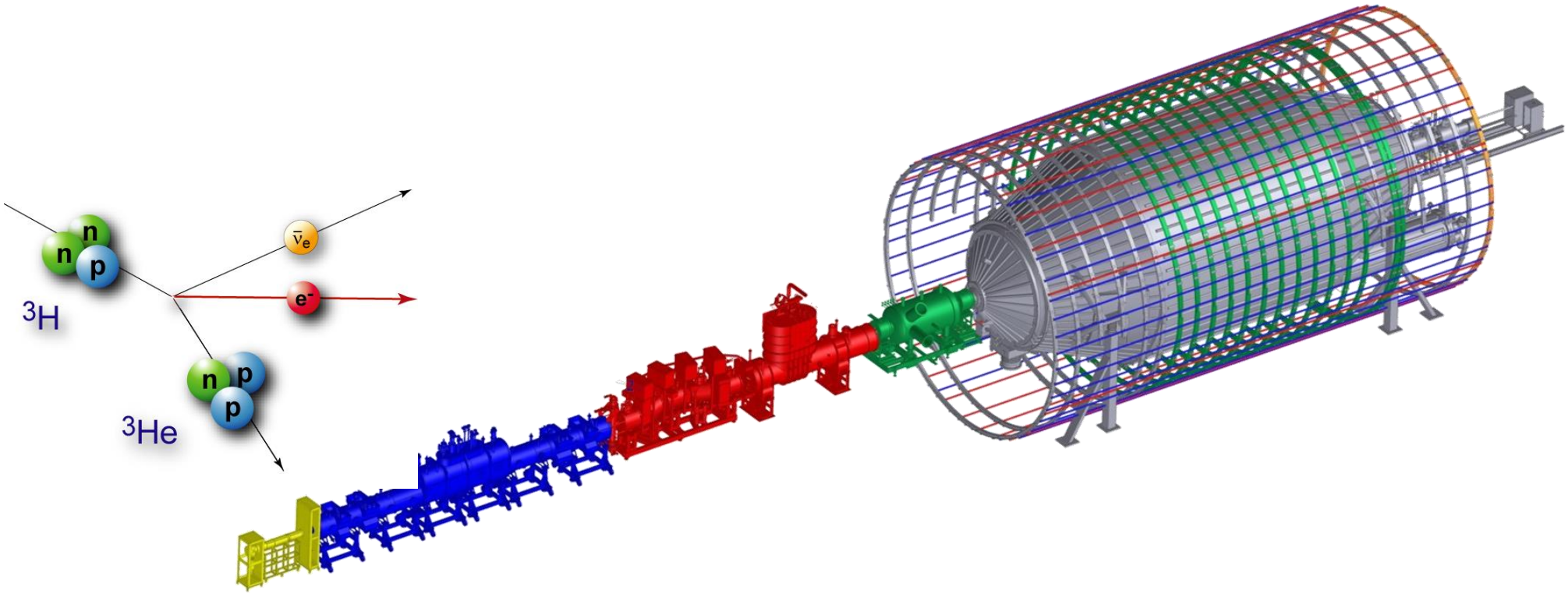


KATRIN (KArlsruhe TRItium Neutrino) experiment

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

KATRIN overview

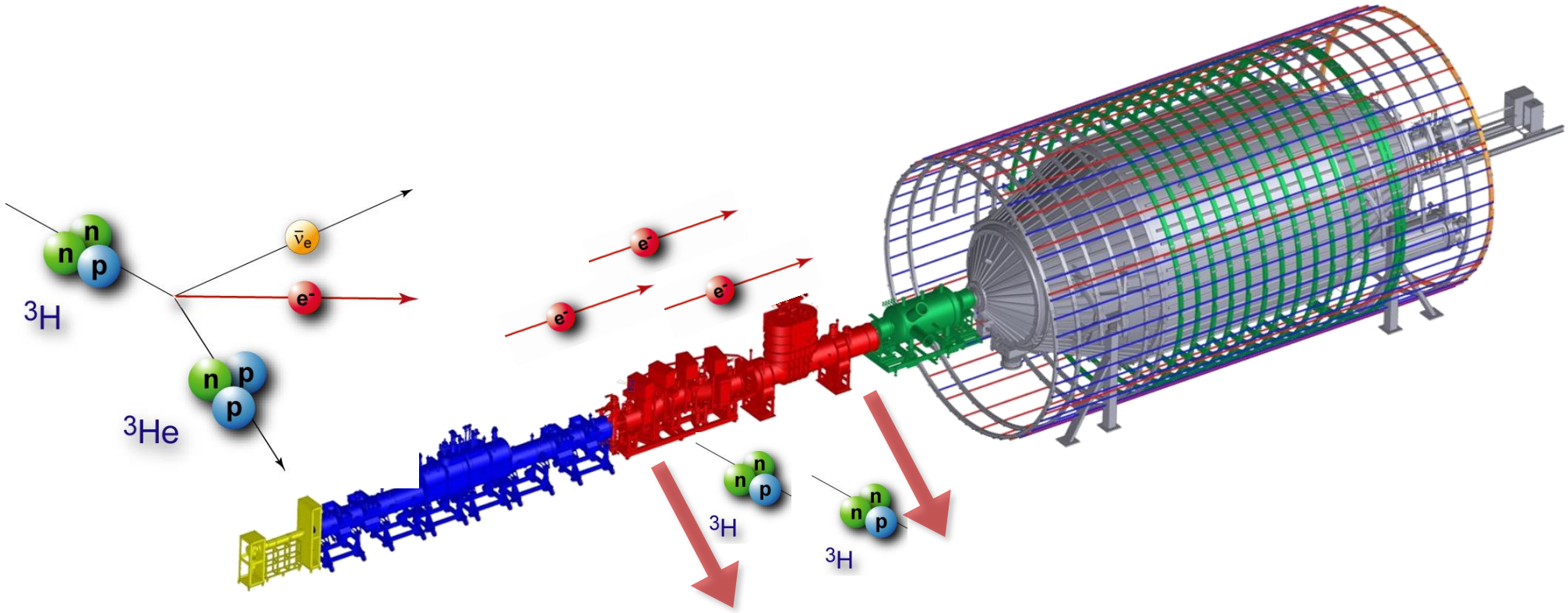
Windowless Gaseous Tritium Source



KATRIN overview

Windowless Gaseous Tritium Source

Transport and Pumping Section



KATRIN overview

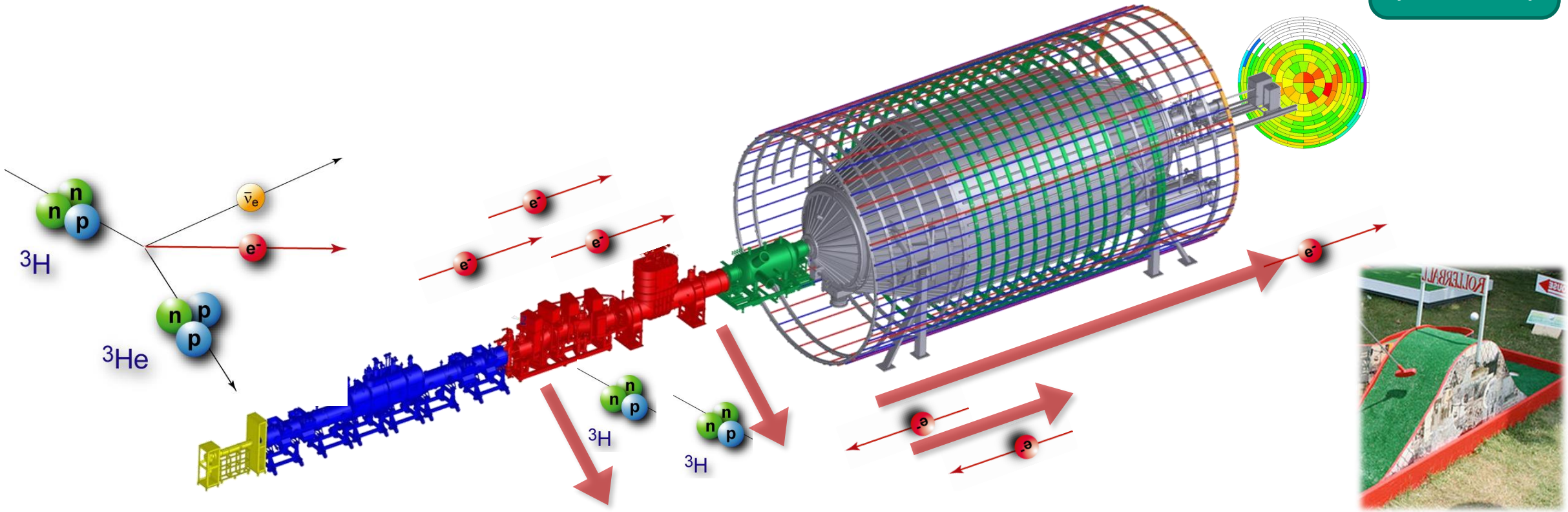
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Windowless Gaseous Tritium Source

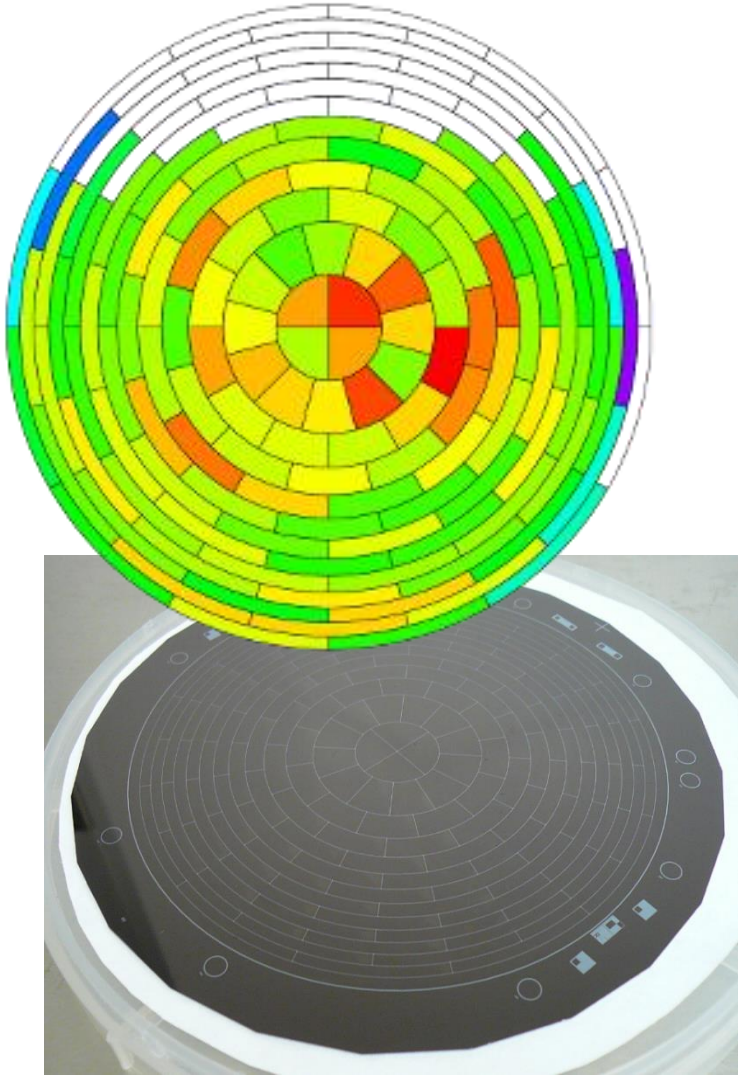
Transport and Pumping Section

Spectrometer and Detector Section

200 meV
(90% C.L.)

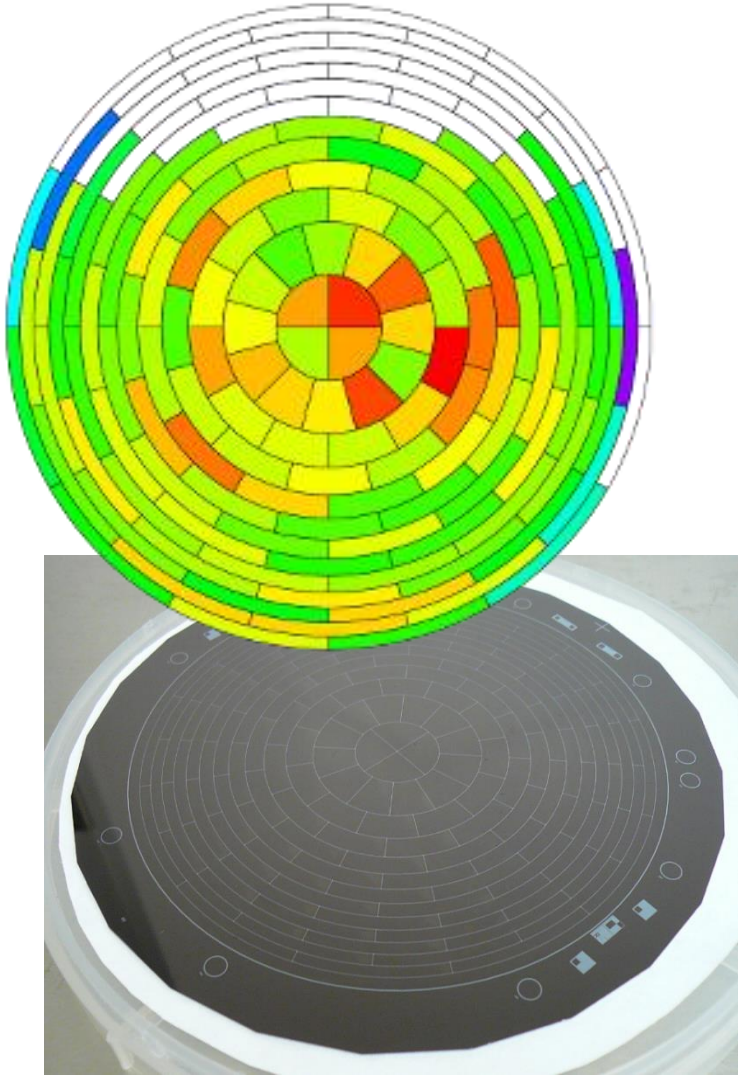


KATRIN detector



- Silicon PIN-diode array with 148 pixels
- Energy resolution ~ 1.4 keV
- Pile-up ~ 1 % at 1 kHz

KATRIN detector



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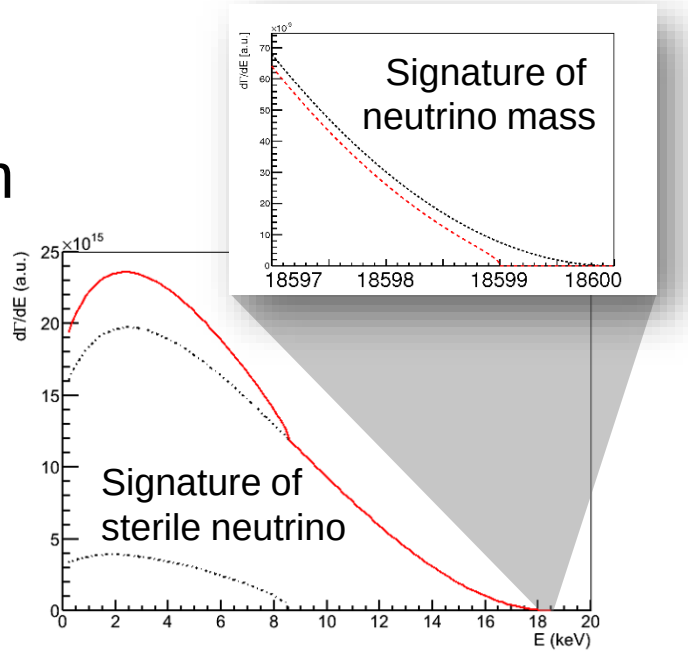
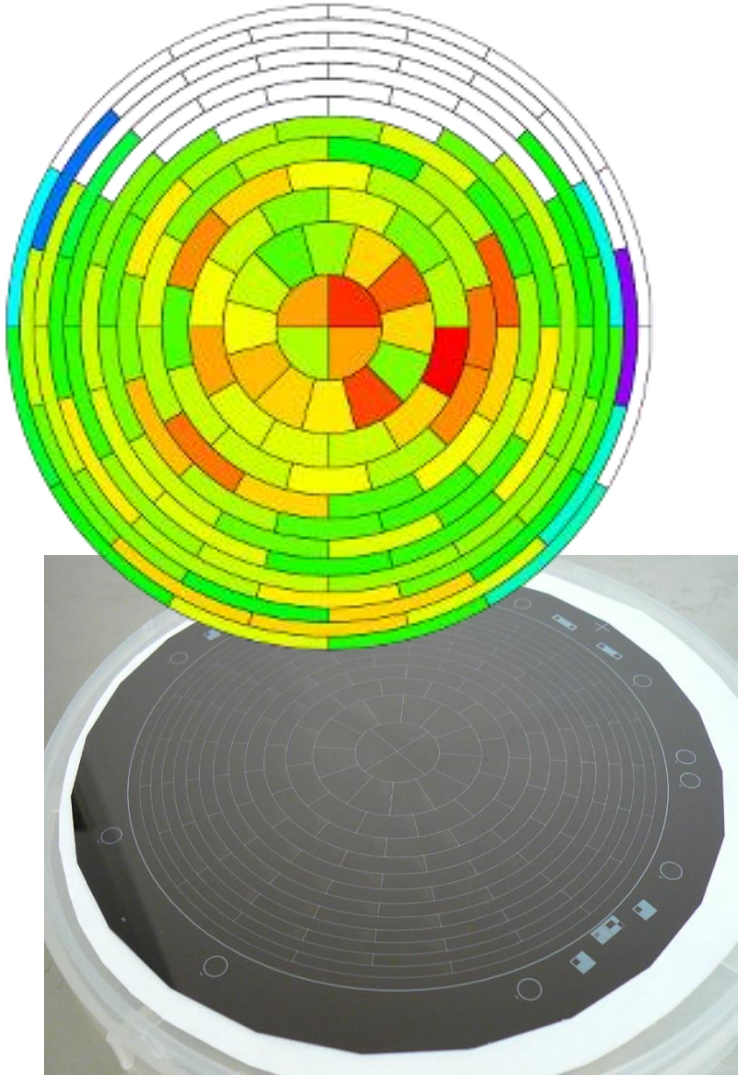
- Neutrino mass: last 50 eV
  - ➢ rate ~ 1 Hz
- Sterile neutrino: entire spectrum
  - ➢ rate ~ 10^8 – 10^{10} Hz



KATRIN detector



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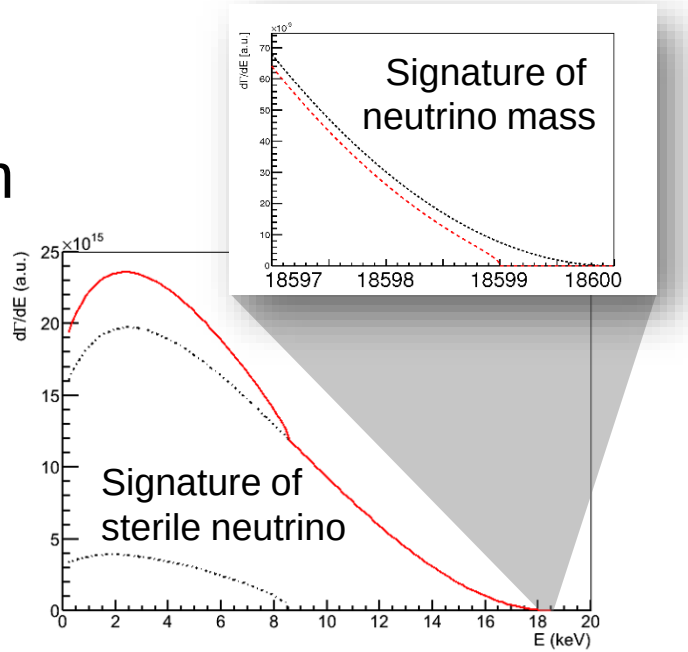
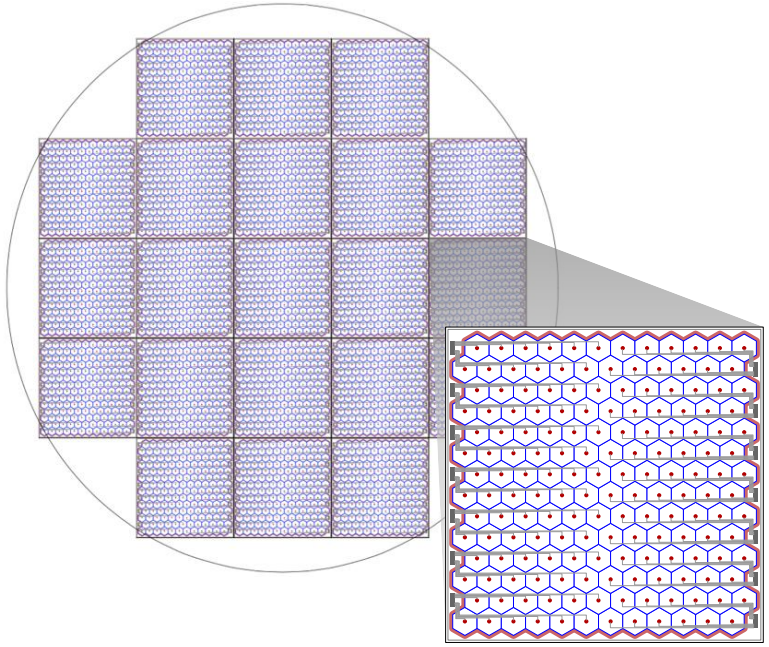
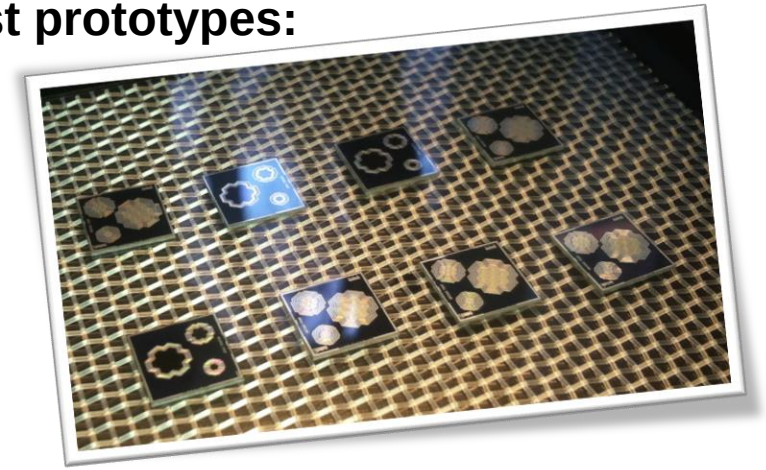
Does not meet requirements for a sterile neutrino search



TRISTAN detector



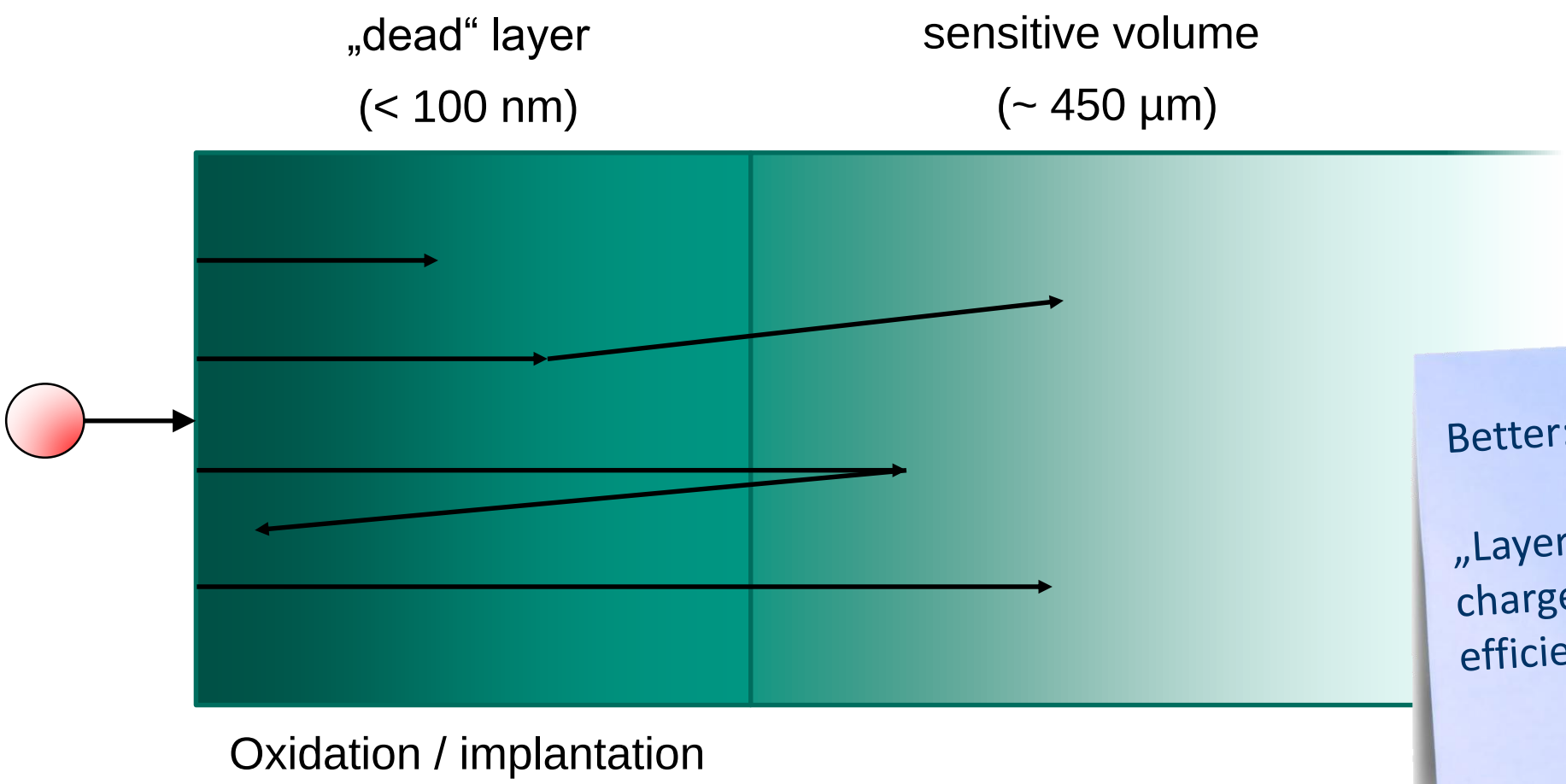
First prototypes:



Develop novel multi pixel detector system:

- Handling of high rates (>10^9 Hz)
  - ➢ 3000 - 4000 pixels
- Large area coverage (20 cm diameter), small capacitance
  - ➢ Multi-drift ring design (SDD)
- Good energy resolution (300 eV @ 20 keV), low threshold (1 keV)
  - ➢ **Thin dead layer** (< 100 nm)

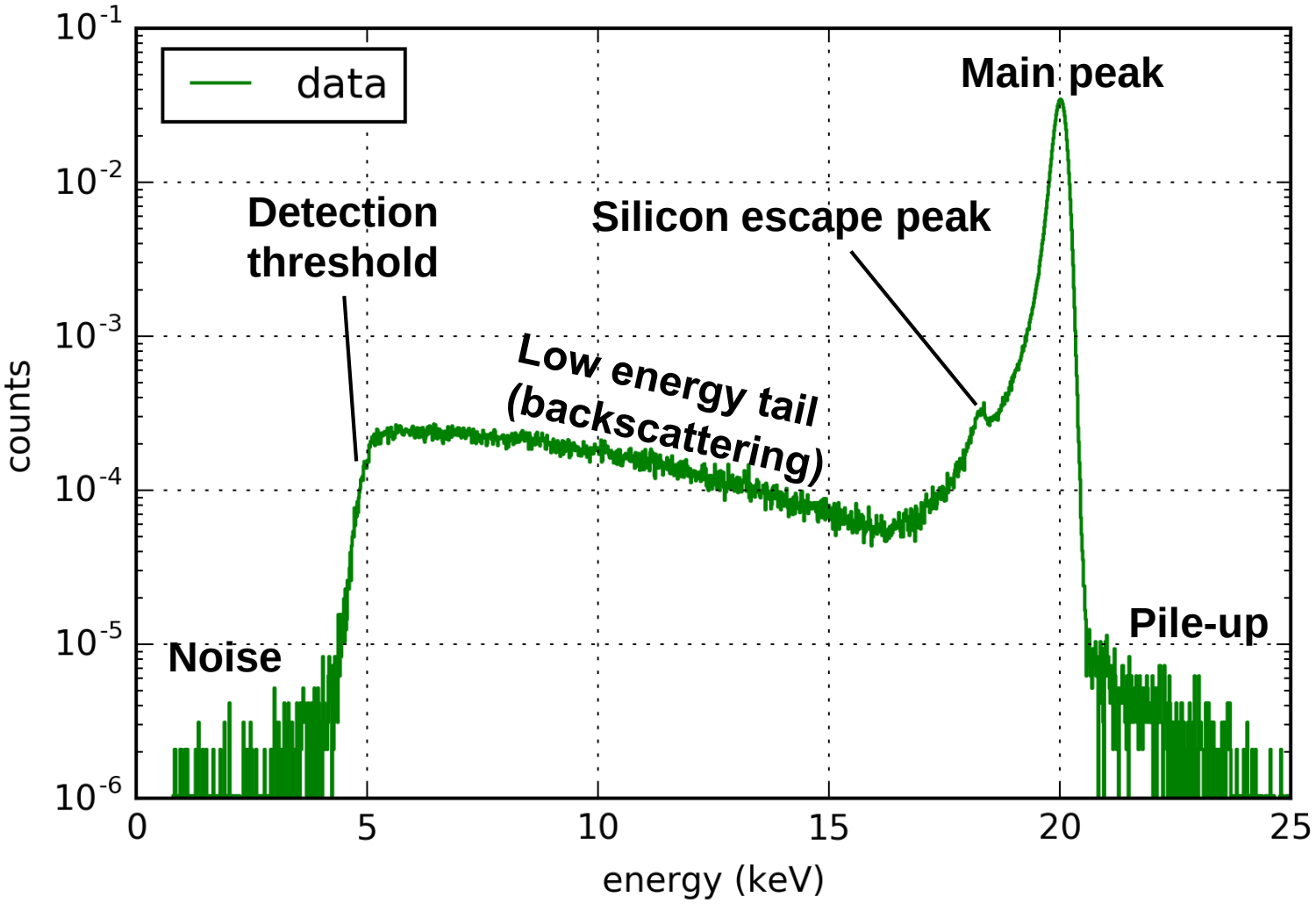
What is a dead layer?



Better:

„Layer of incomplete charge collection efficiency“

Dead layer effect

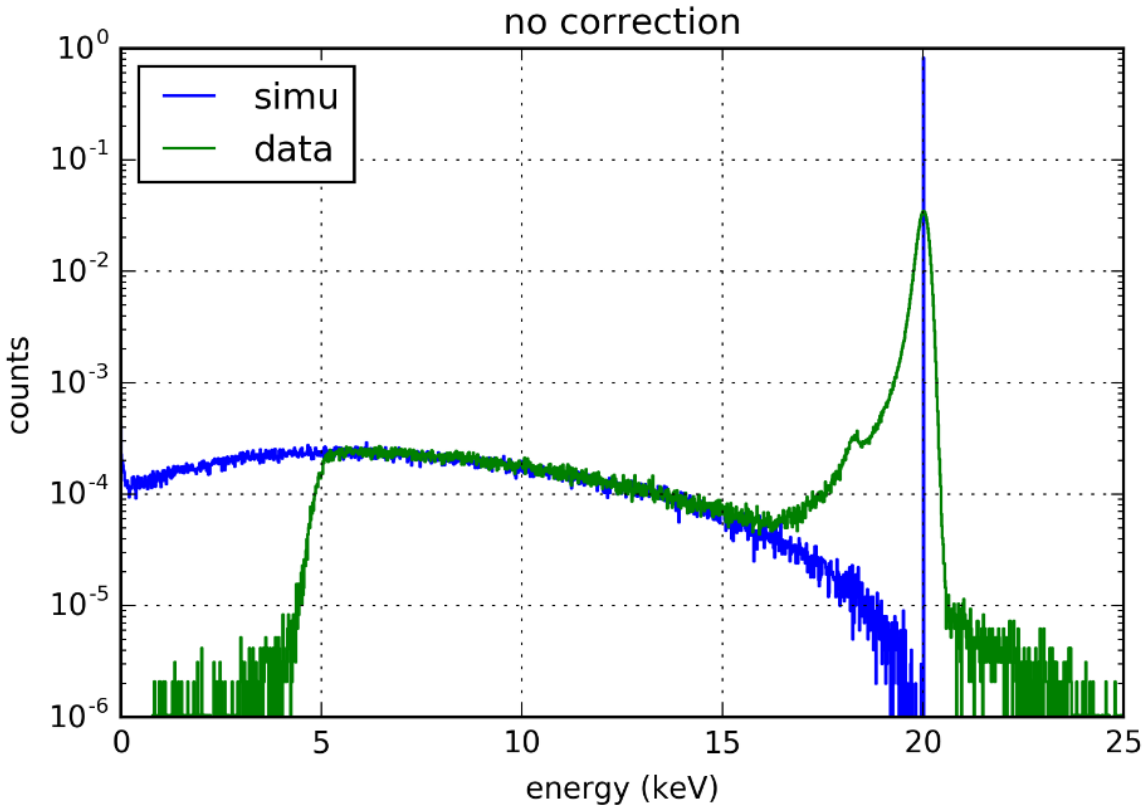


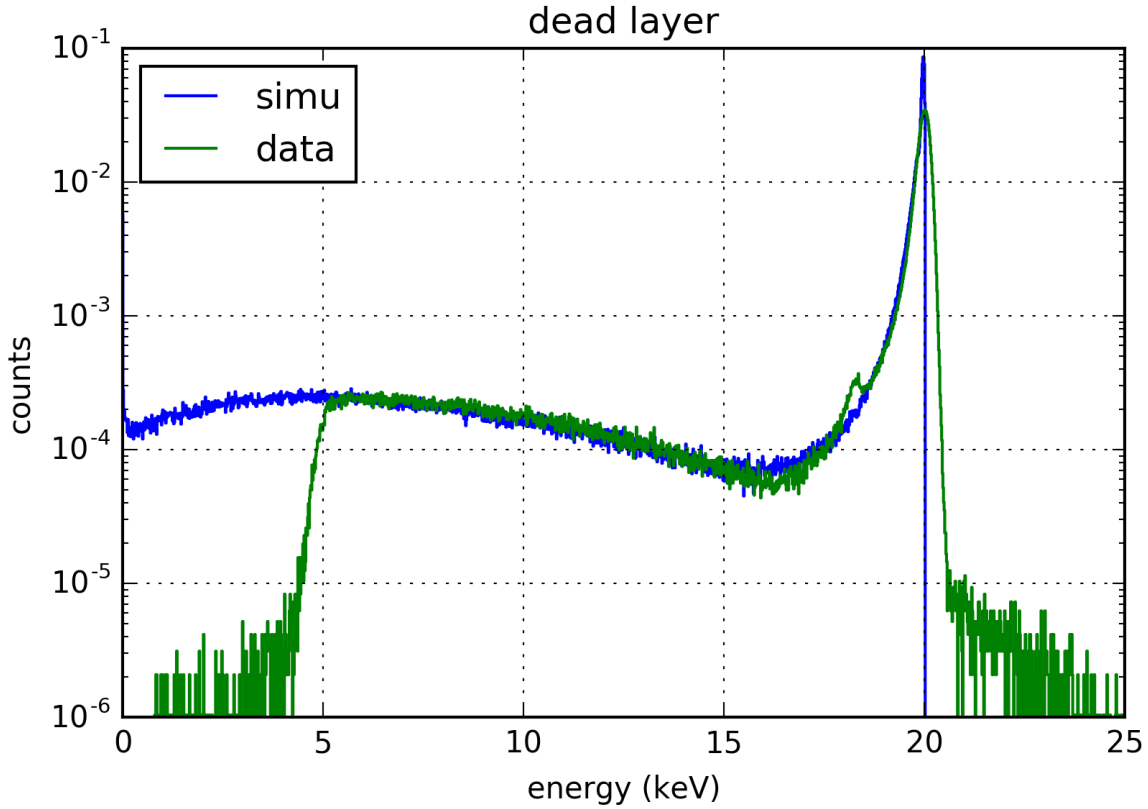
Measurement @ HLL:

- 20 keV electrons
- ~ 10 kHz on one pixel

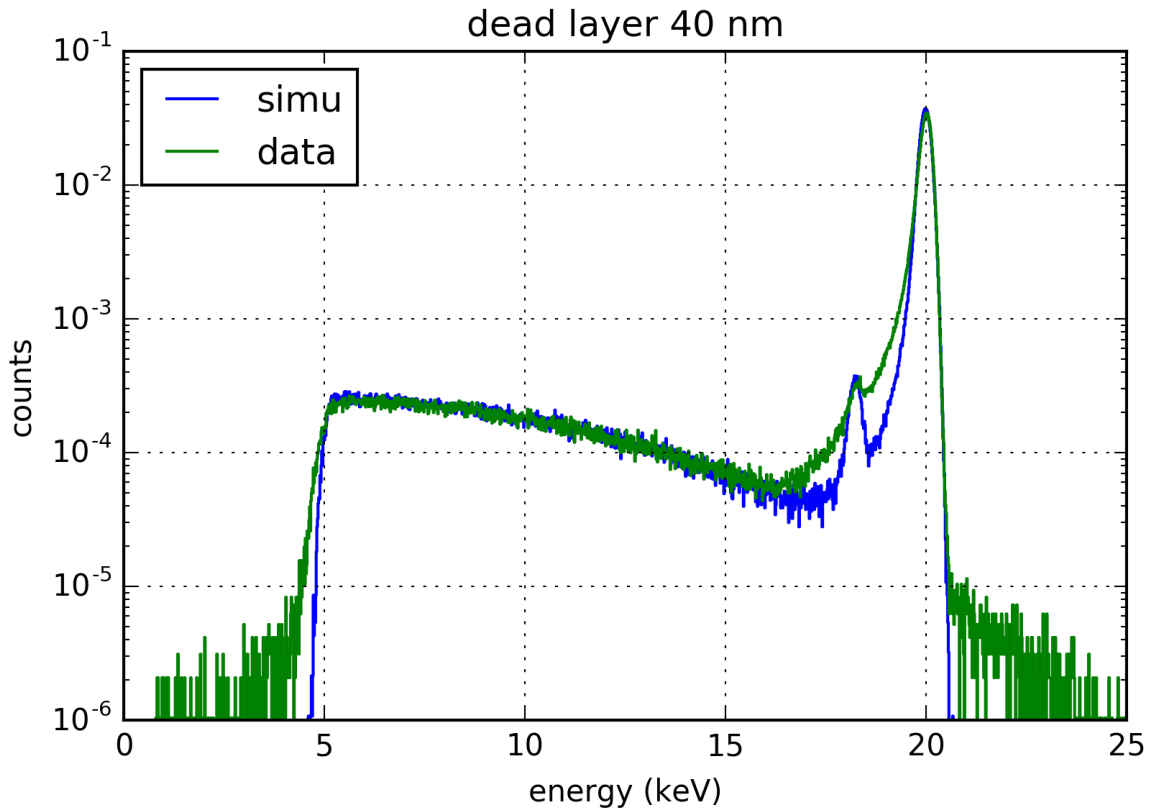
JEOL JSM-IT300

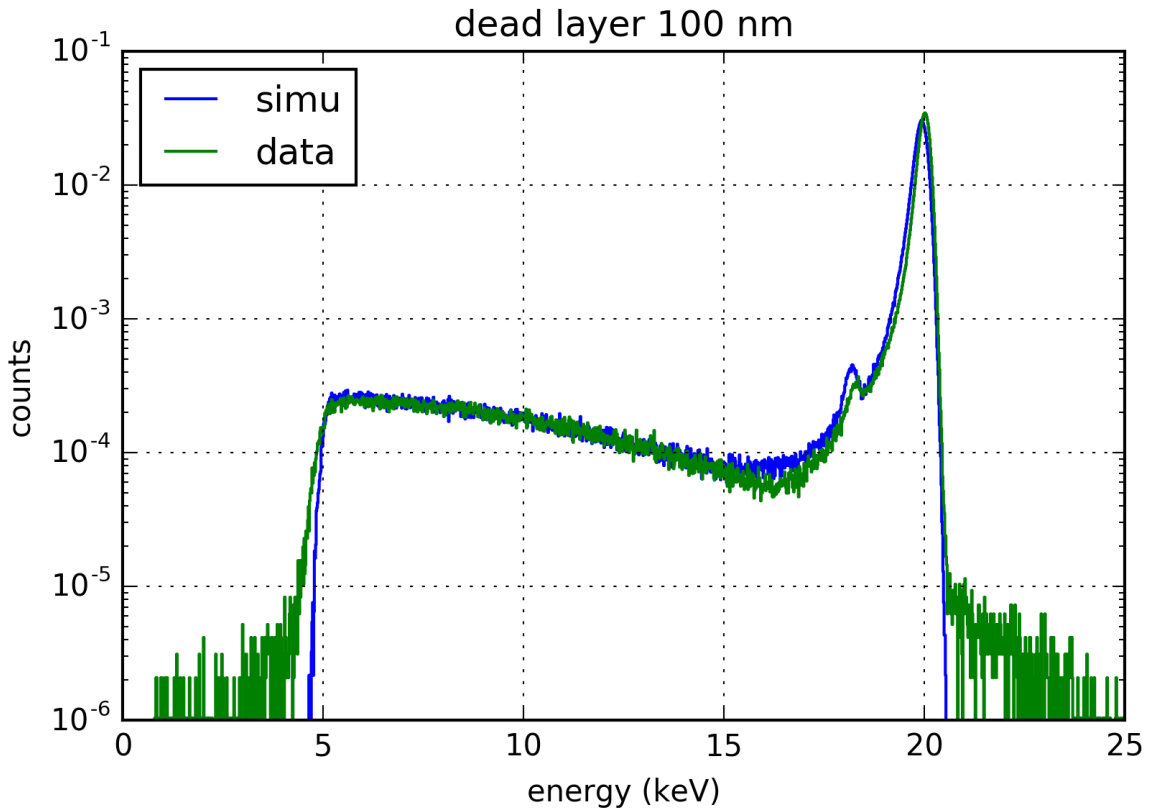
Dead layer effect





Dead layer effect





Measure low energy shoulder, compare with simulations

What is a dead layer… and why do we have to correct for it?

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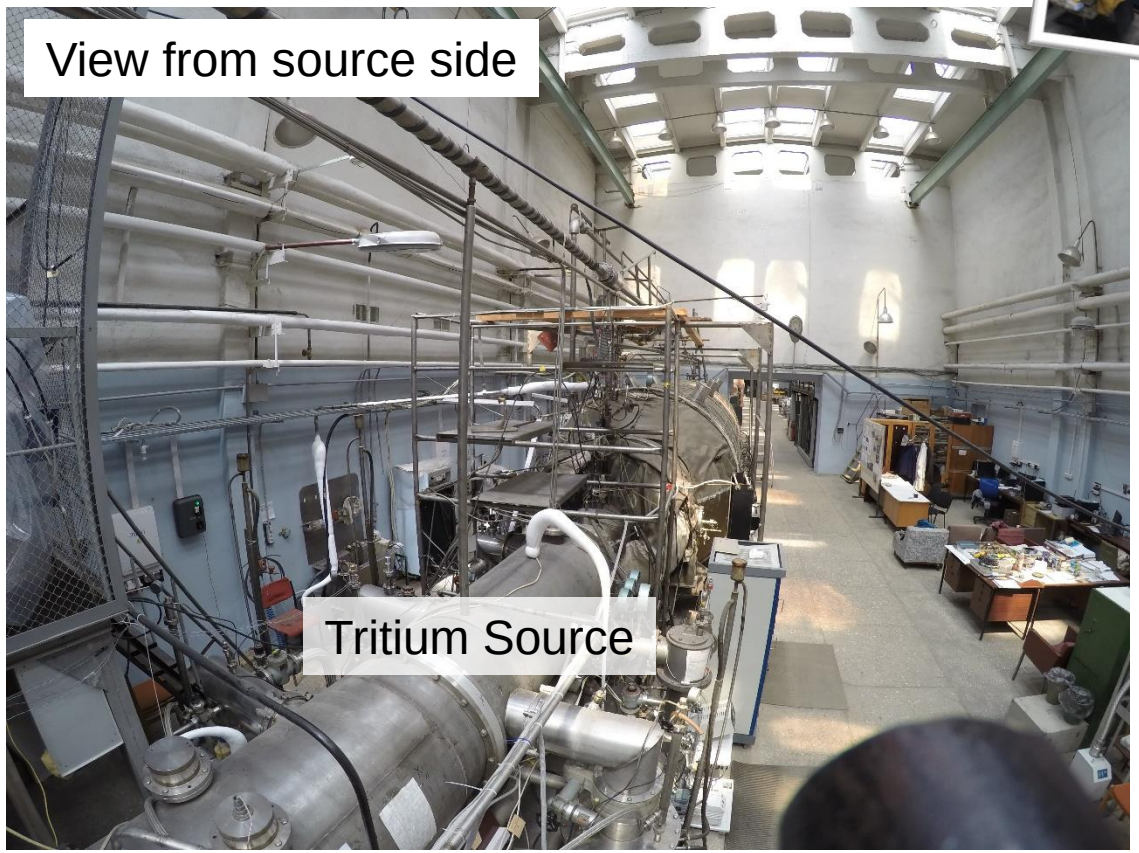
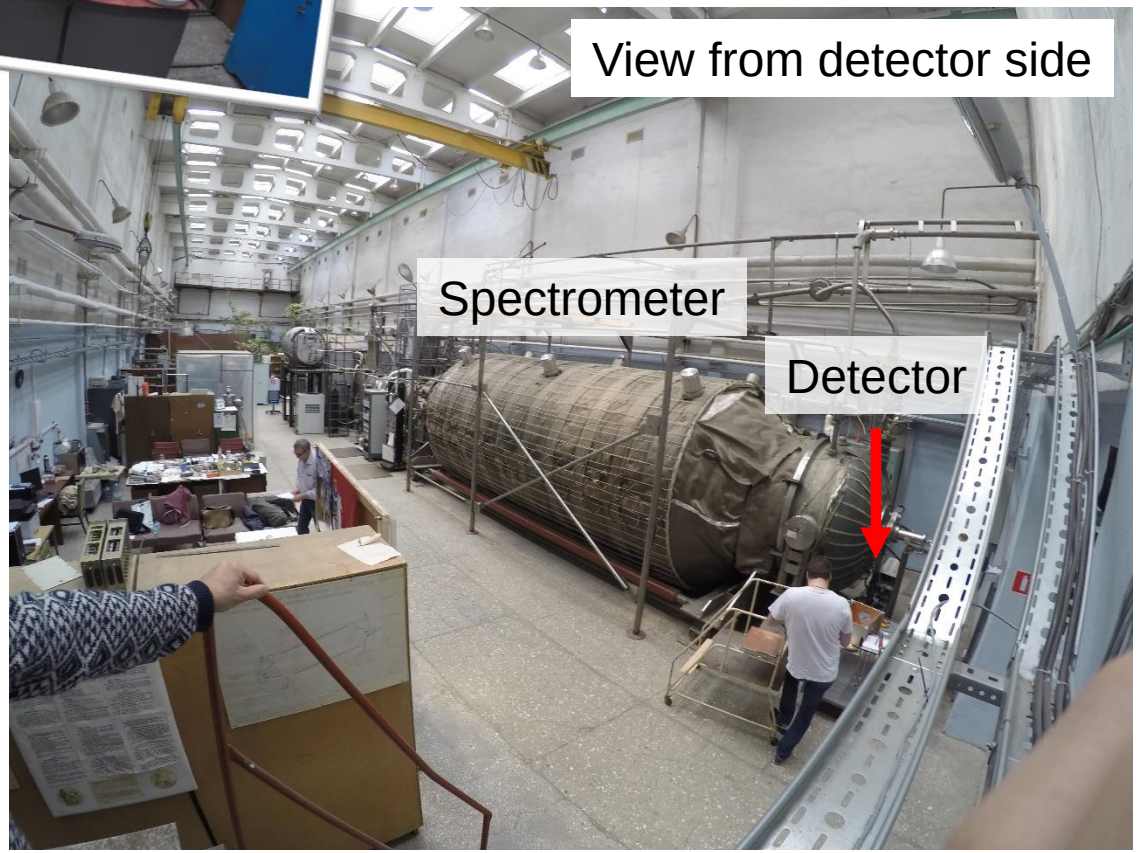
- Large effect for low incident electron energy
  - ➢ Backscattered electrons can pass dead layer several times due to magnetic reflection
- Systematic uncertainty in continuous spectrum
  - ➢ Wash out of sterile neutrino signature

TRISTAN in Troitsk

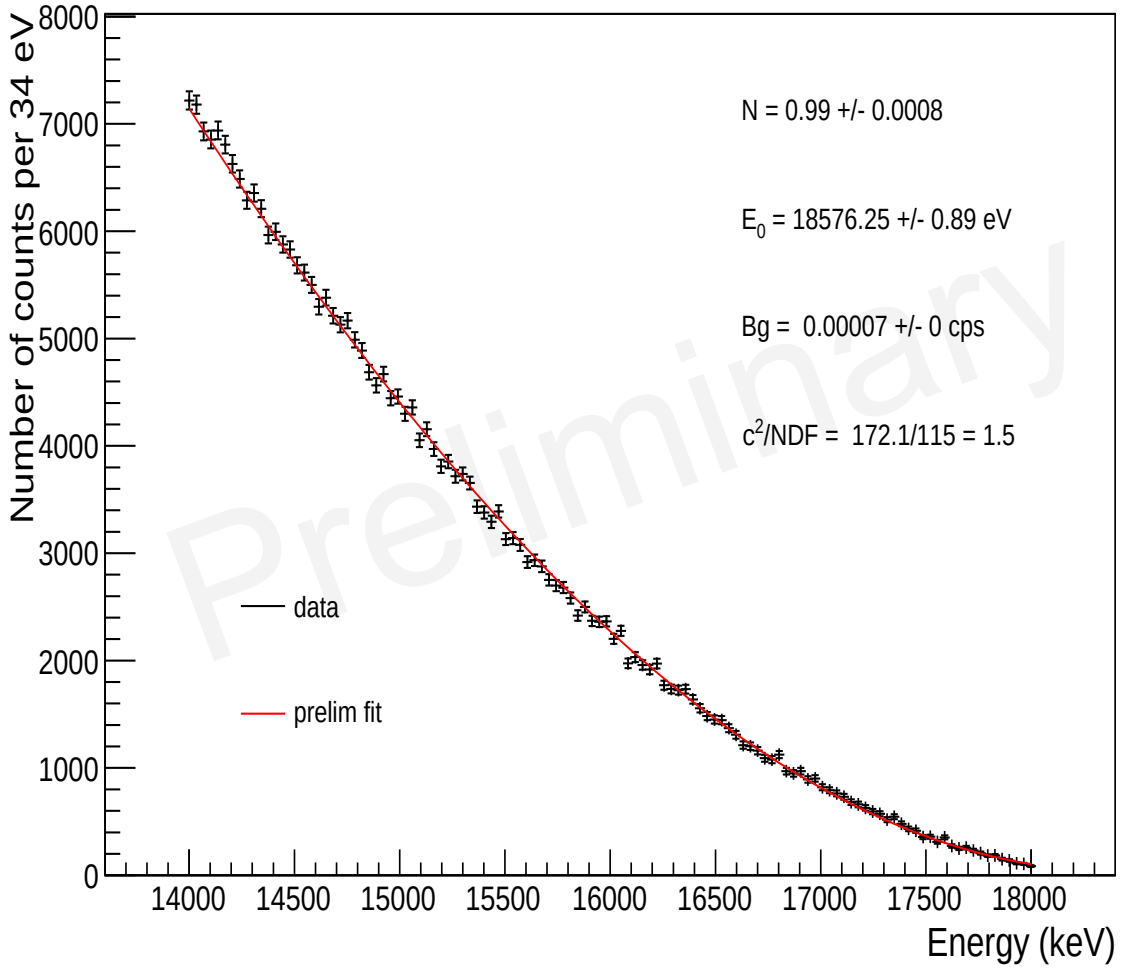
- May 25th – June 4th 2017





TRISTAN in Troitsk

- 1mm 7-pixel TRISTAN detector
- Measurement of electrons from
  - Spectrometer walls
  - Electron gun
  - Tritium
- Data analysis is ongoing,
  first glance at data looks promising



TRISTAN in Troitsk

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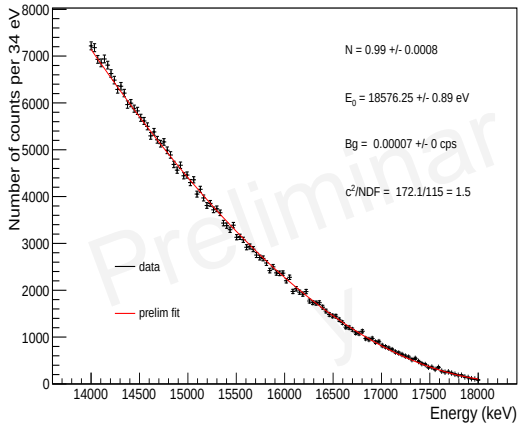
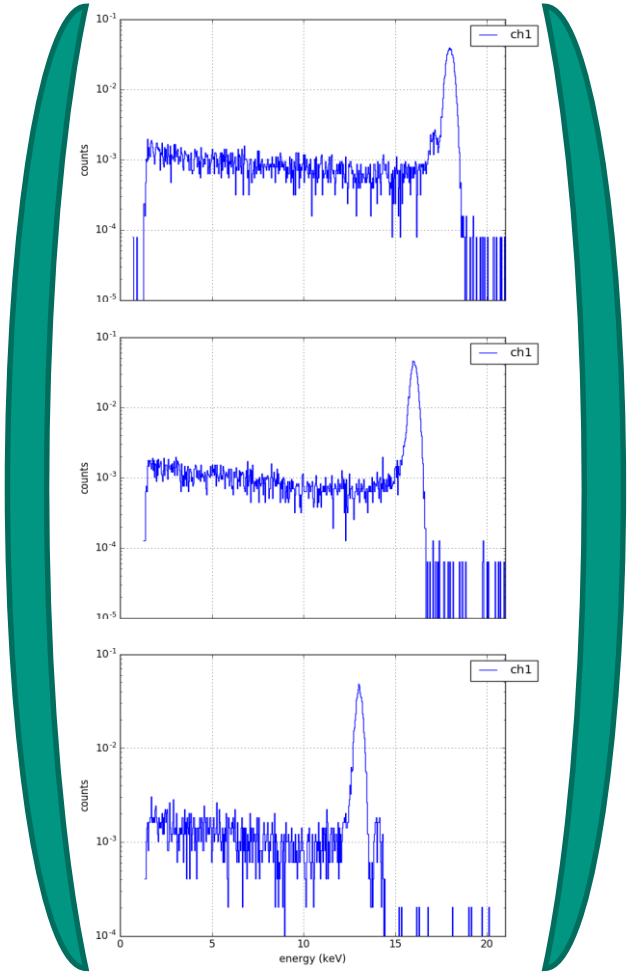
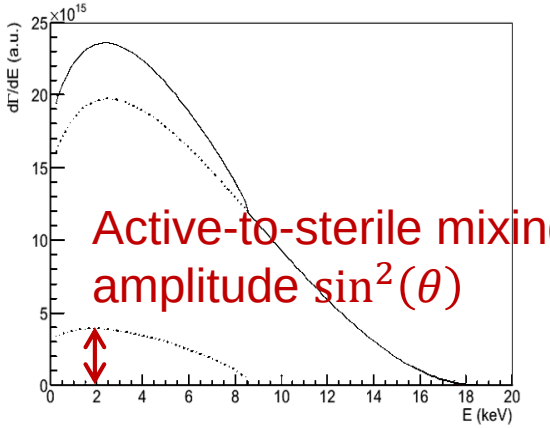
Measured tritium spectrum



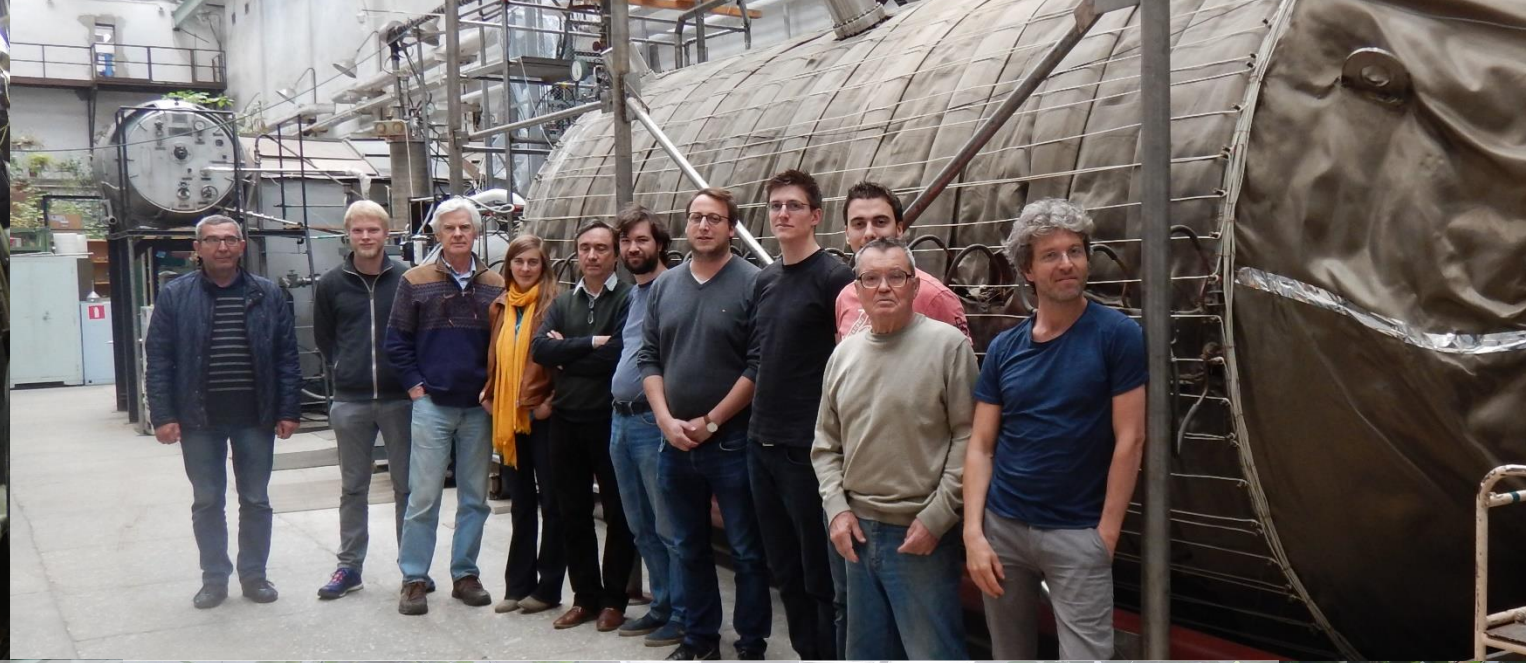
Detector response at different energies



Corrected tritium spectrum



Upper limit on mixing angle



Next visit planned for November 2017