# “Status of the KATRIN project”

**- Florian Fränkle for the KATRIN collaboration -**

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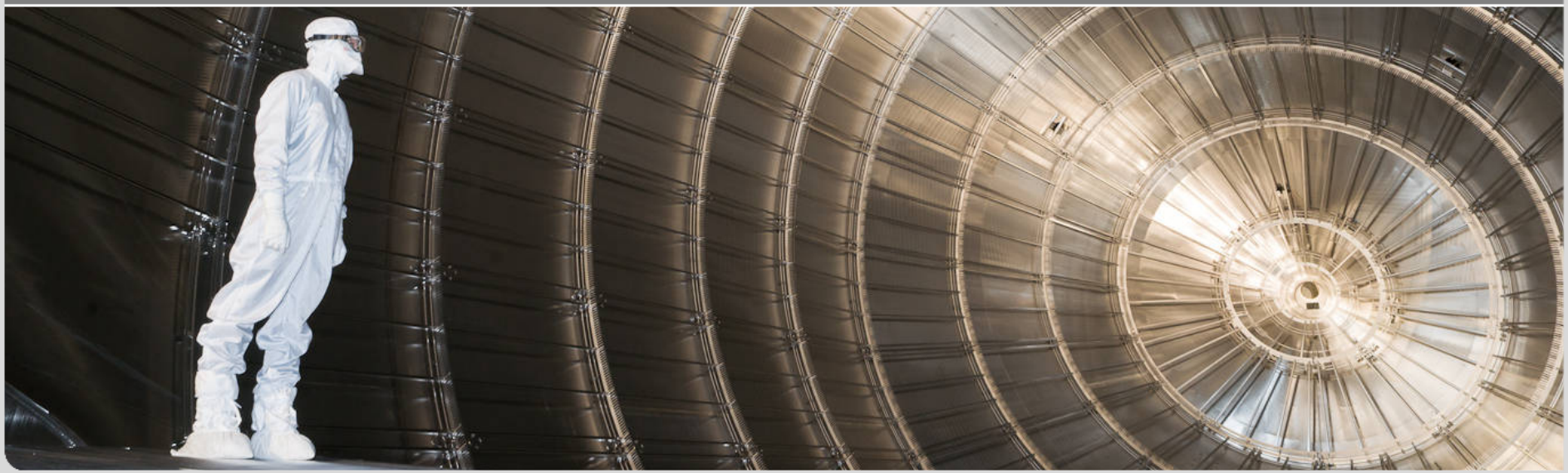


# Outline

- Neutrino mass & single β-decay
- The KATRIN experiment
- Spectrometer transmission characteristics
- Summary & outlook

# Neutrino mass and single β-decay

- β-decay: $n \rightarrow p + e^- + \overline{\nu}_e$
- Neutrino mass influences energy spectrum of β-decay electrons
- Neutrino mass determination via precise measurement of the spectral shape close to the endpoint
- Model independent method

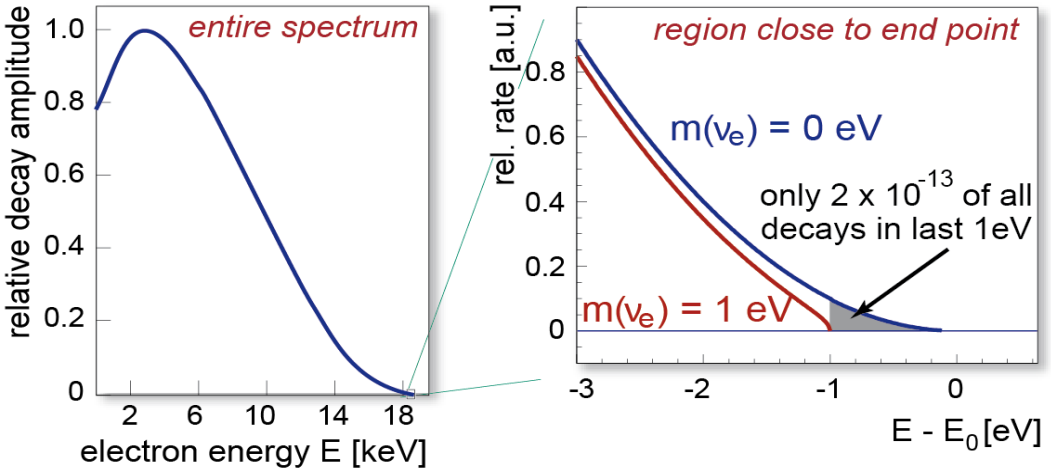
Fermi theory of β-decay:

$$\frac{dN}{dE} = C \cdot F(E,Z) \cdot p(E + m_e) \cdot (E_0 - E) \cdot \sqrt{(E_0 - E)^2 - m_\nu^2}$$

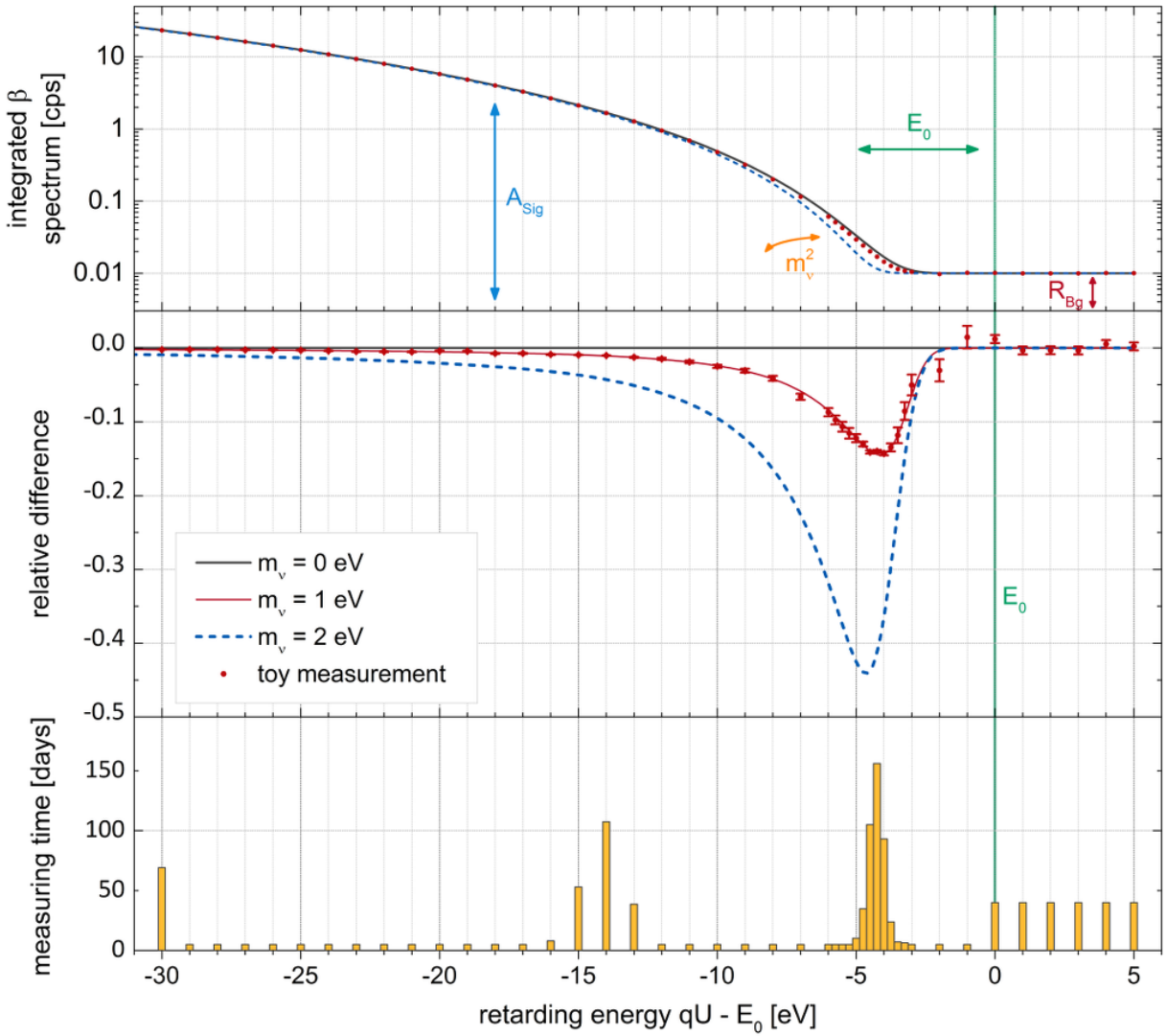
observable:

$$m_{\nu_e}^2 = \sum_{i=1}^{3} |U_{ei}|^2 m_i^2$$

β-spectrum for tritium ($E_0$ = 18.6 keV, $T_{1/2}$ = 12.3 y):



# KATRIN measurement




- KATRIN will measure the integrated β-spectrum close to the $T_2$ endpoint $E_0$
- The influence of $m_\nu$ is most pronounced a few eV below $E_0$
- Optimized measurement time distribution to increase sensitivity

# KATRIN physics goals

## Primary

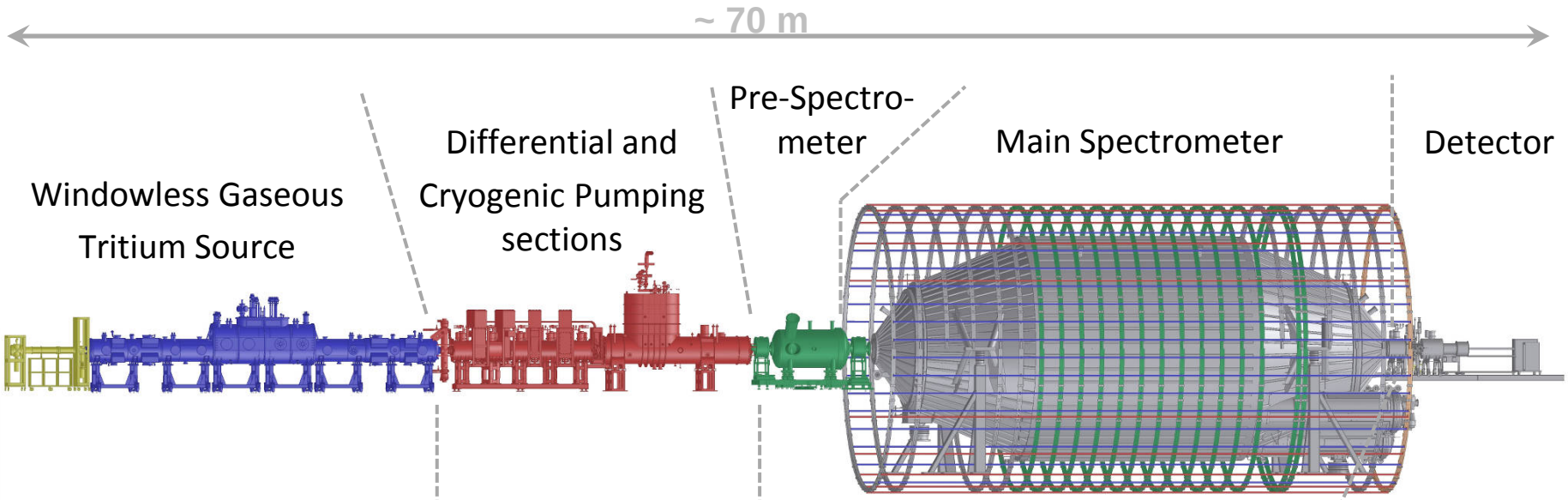
- Measure neutrino mass with a sensitivity of 200 meV (90% C.L.)

## Additional

- Search for sterile neutrinos eV-scale
- Search for relic neutrinos
- Check for Lorentz violation (sidereal variation of endpoint)
- Search for sterile neutrinos keV-scale (detector upgrade)

# The KATRIN experiment

- **KA**rlsruhe **TRI**tium **N**eutrino experiment
- Four major beamline sections, many auxiliary systems




- tritium β-decay
- decay rate: $10^{11}$ 1/s
- $T_2$ pressure: $10^{-3}$ to $10^{-6}$ mbar

- β-electron transport
- tritium retention (factor > $10^{12}$)

- energy analysis of β-electrons
- resolution 0.93 eV @ 18.6 keV
- pressure < $10^{-10}$ mbar

- counting of transmitted β-electrons

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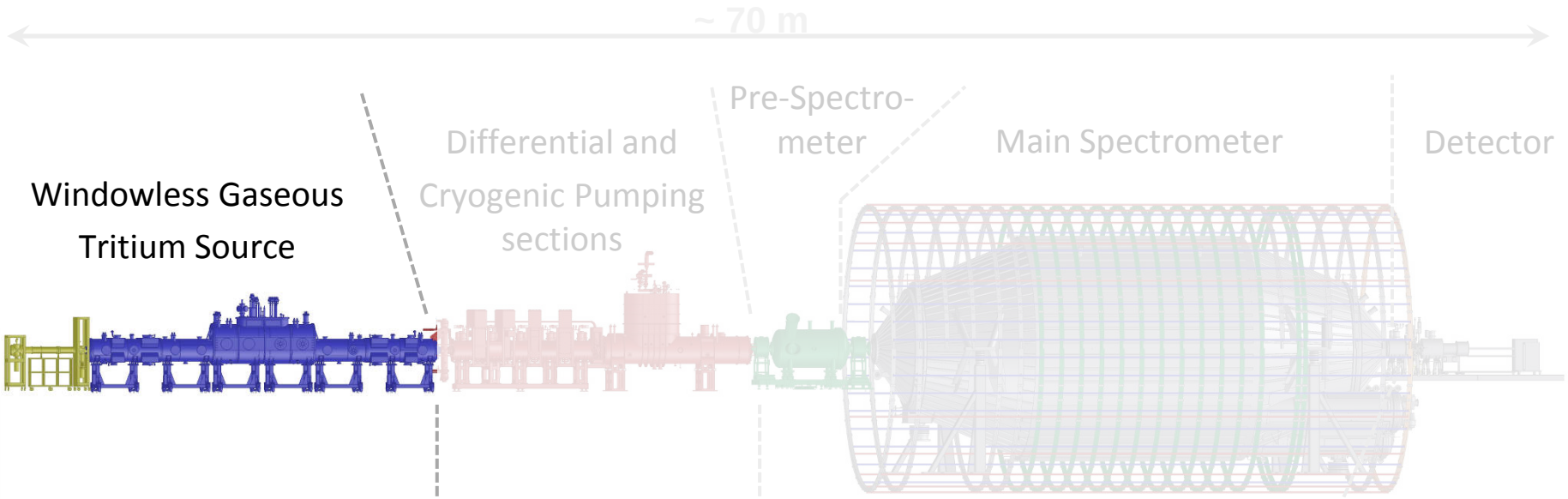


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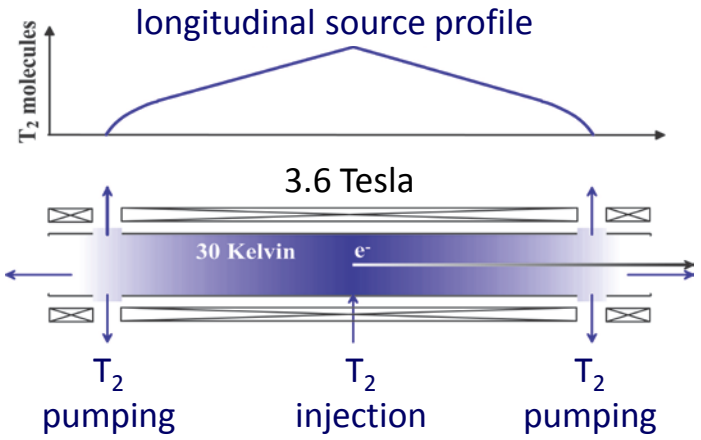
# Windowless Gaseous Tritium Source

**purpose**: delivery of $10^{11}$ β-decay electrons per second





**requirements:**

- stability of $T_2$ density profile of **$10^{-3}$** (function of: injection rate, purity, beam tube temperature $T_B$, pump rate)
- $T_B$ homogeneity ±30 mK
- $T_B$ stability ±30 mK / h

**properties:**

- beam tube: 10 m length, 90 mm diameter, absolute temperature 30 K
- windowless gaseous tritium source
- tritium loop: 40 g $T_2$ / day

**status:**

- demonstrator temperature stability **10x** better than specified
- delivered to KIT in **September 2015**
- integration into beamline ongoing

# The KATRIN experiment

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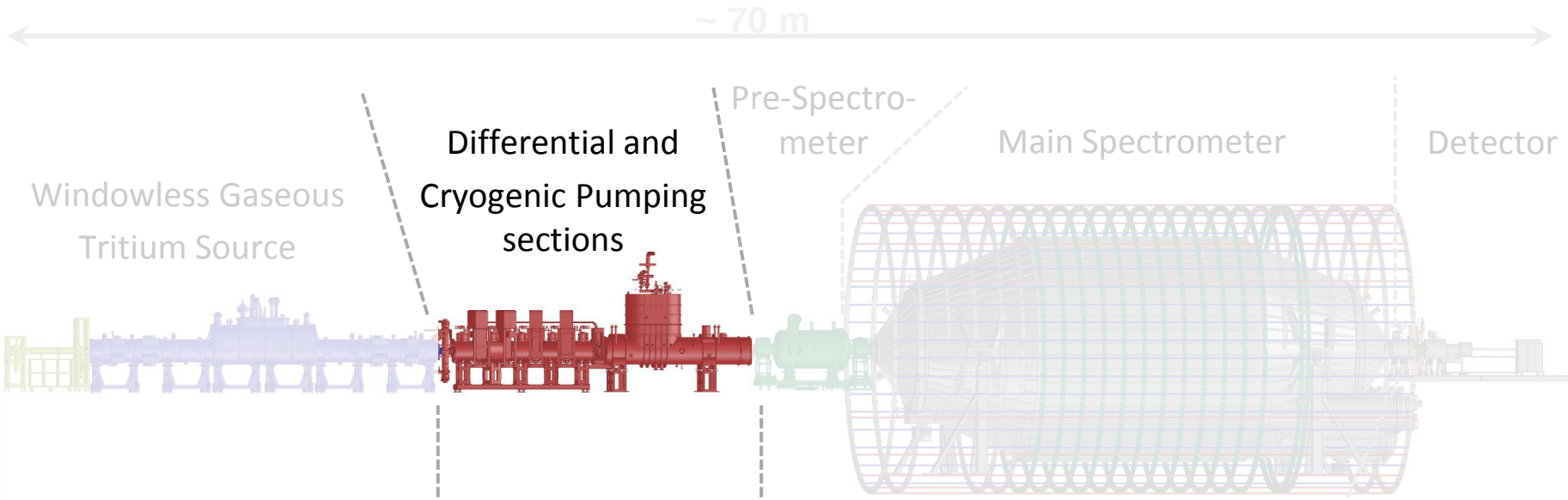


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# Differential Pumping Section

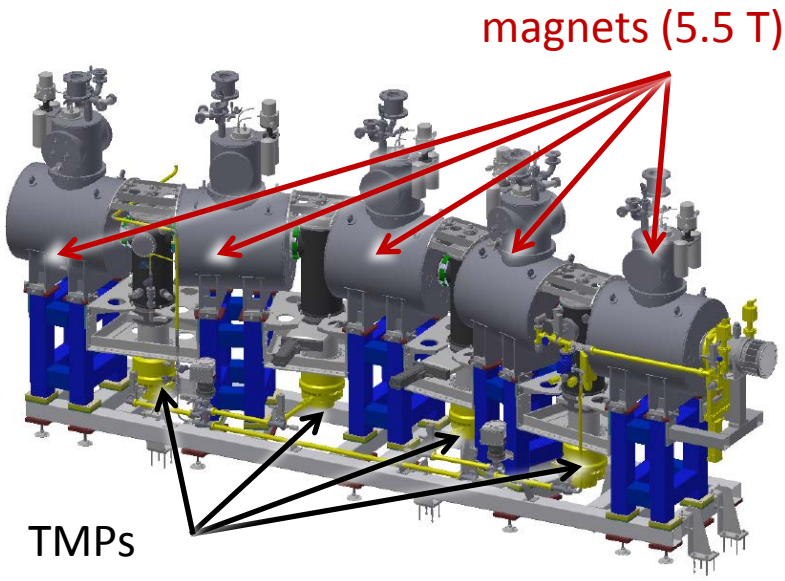
**purpose**: reduce $T_2$ flux and magnetically guide β-decay electrons

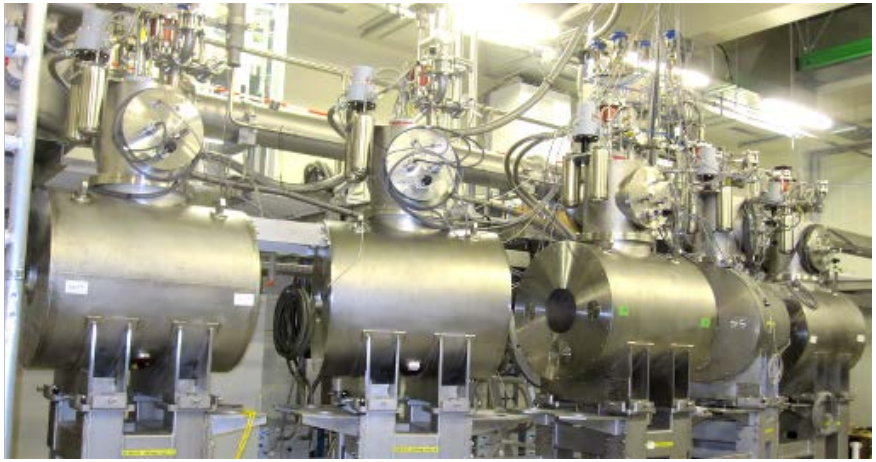
**properties:**

- $T_2$ partial pressure reduction ($10^5$) via differential pumping by turbomolecular pumps (TMPs)
- magnetic guiding of β-electrons via superconducting solenoids
- electric dipole electrodes for removal of positive ions

**status:**

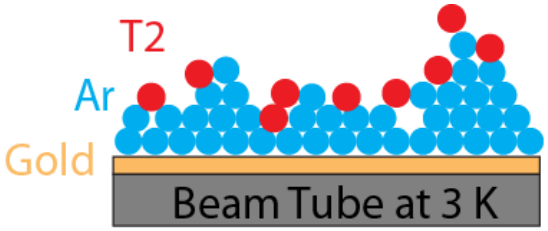
- magnet system successfully tested
- installation of beam tube ongoing



# Cryogenic Pumping Section

**purpose**: reduce $T_2$ flux and magnetically guide β-decay electrons




**properties:**

- $T_2$ partial pressure reduction ($10^7$) via cryosorption of $T_2$ on argon frost
- concept successfully tested

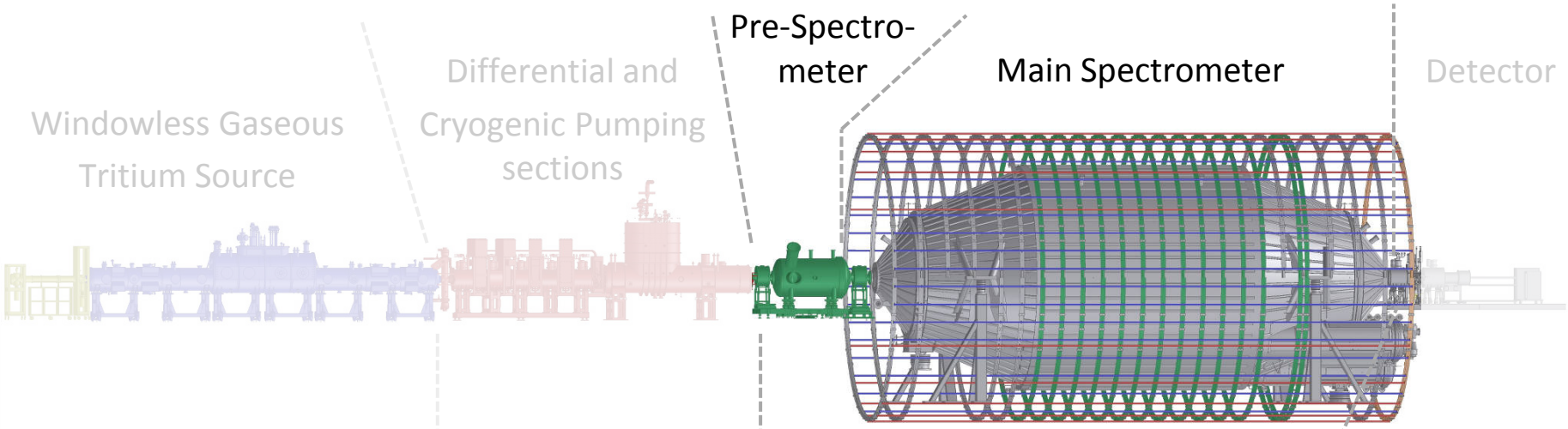
**status:**

- CPS delivered to KIT on July 30th, 2015
- installation and site acceptance tests are ongoing

# The KATRIN experiment

- **KA**rlsruhe **TRI**tium **N**eutrino experiment
- Four major beamline sections, many auxiliary systems

~ 70 m

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# Main Spectrometer

**purpose**: energy analysis

**properties:**

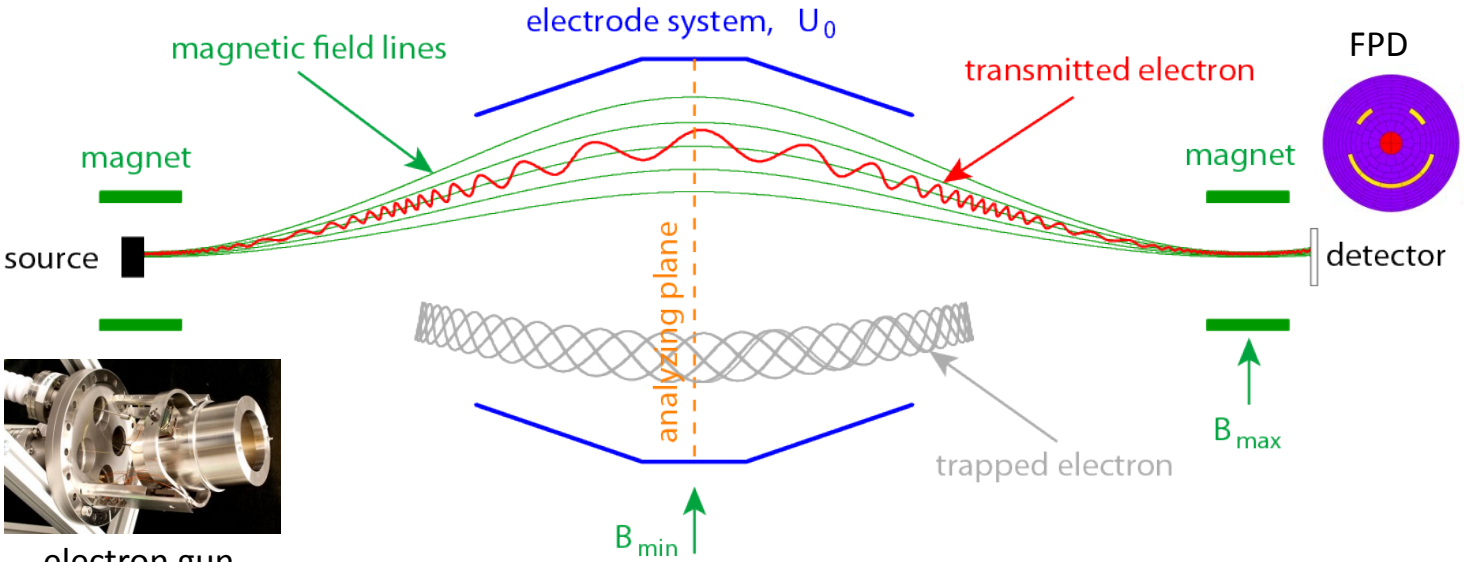
- MAC-E filter (integrating high pass filter)
- energy resolution 0.93 eV @ 18.6 keV
- stable HV system (1 ppm @ -18.6 kV)
- volume: 1240 m³, surface: 689.6 m²
- inner wire electrode system
- variable voltage to scan $E_0$ region
- pressure ~ $10^{-10}$ mbar (one active NEG pump)

**status:**

- 2nd commissioning measurement phase completed
- Preparations for final commissioning phase ongoing

# MAC-E filter

- **M**agnetic **A**diabatic **C**ollimation combined with an **E**lectrostatic Filter





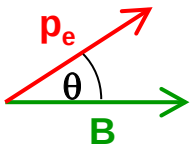

electron gun

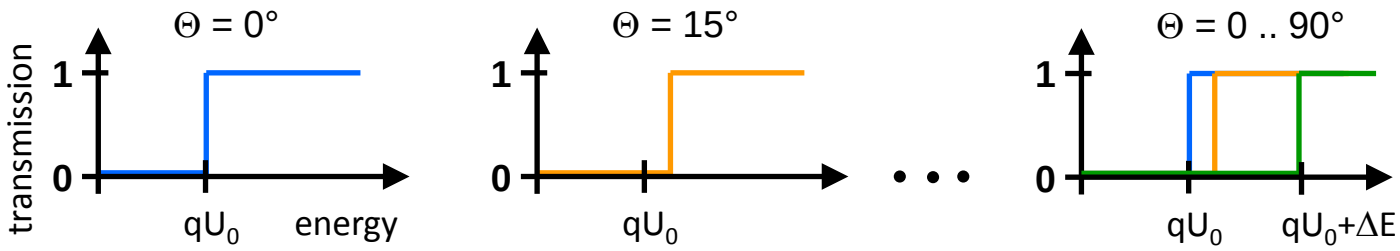
magnetic moment:

$$\mu = \frac{E_t}{B} = const$$

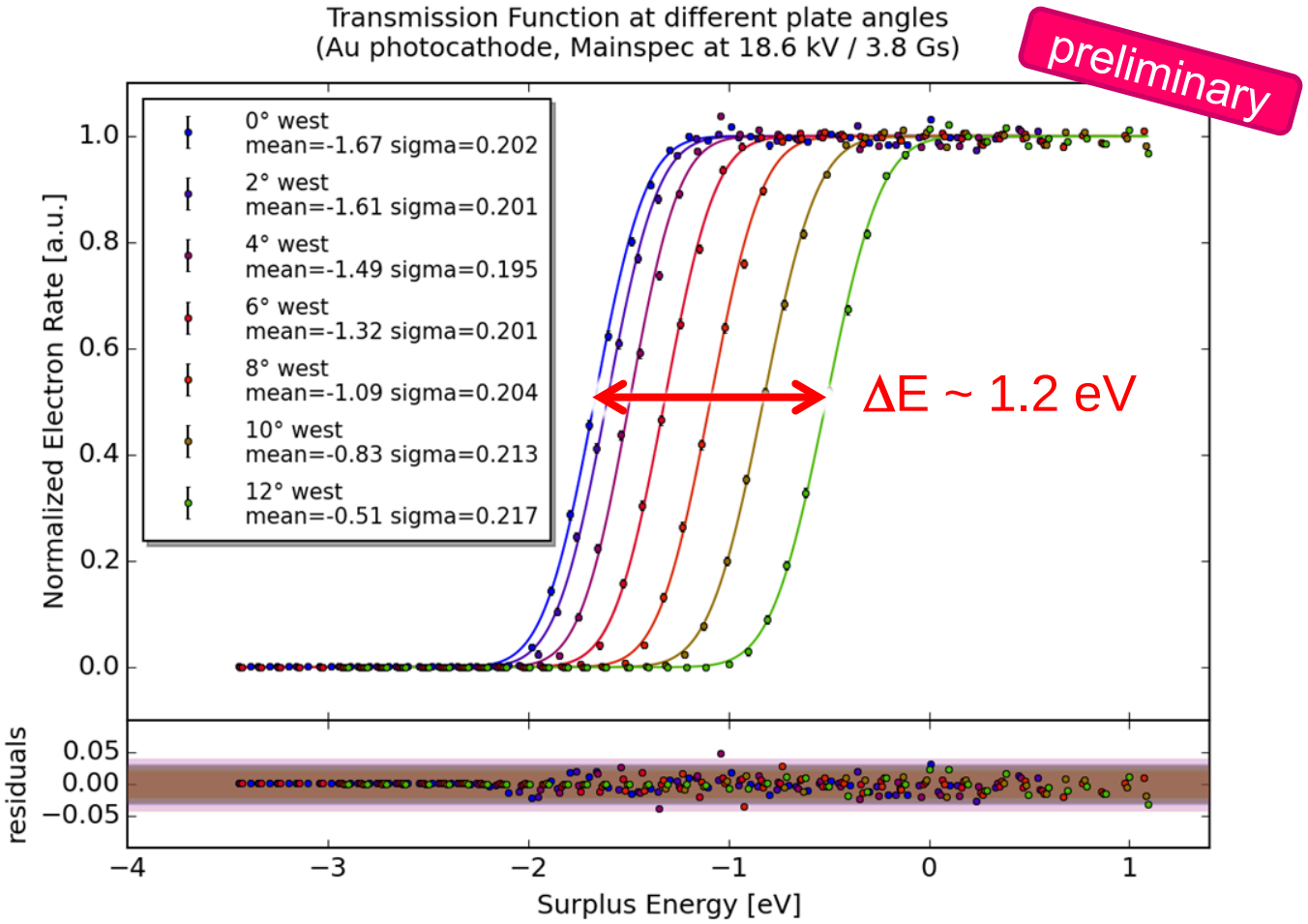
energy resolution:

$$\Delta E = \frac{B_A}{B_{max}} E_t$$



# Transmission function




- Main spectrometer works as high-resolution MAC-E filter!

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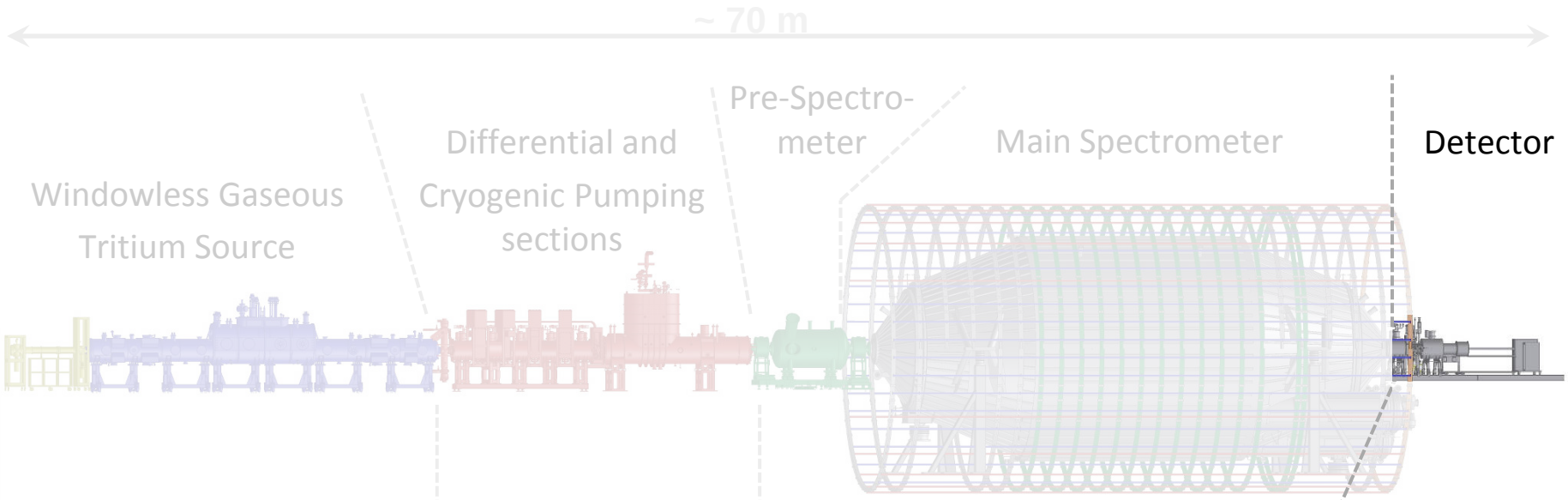


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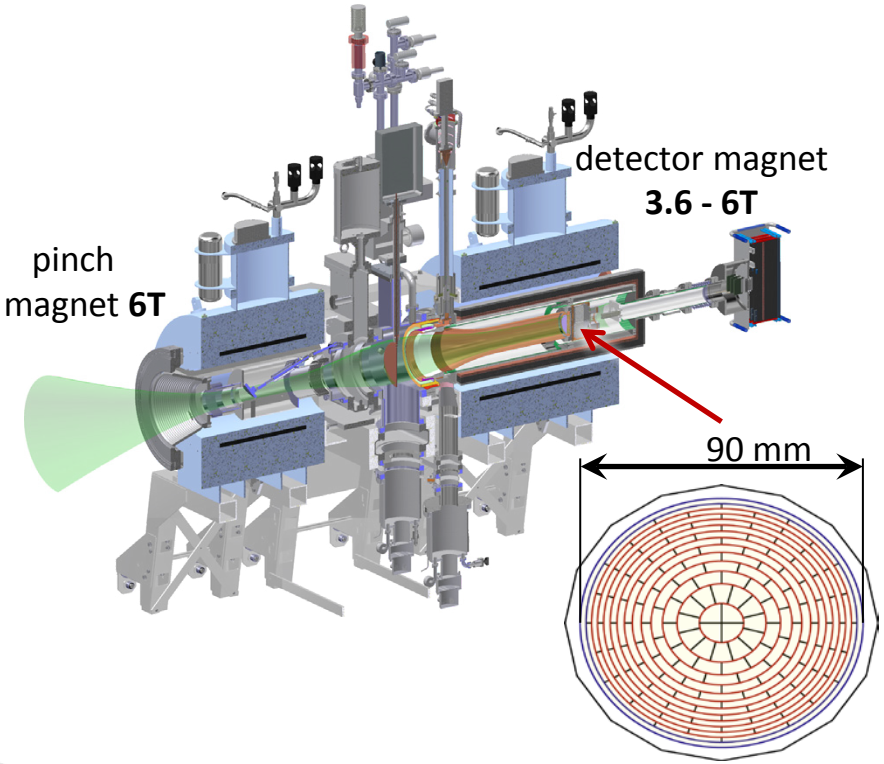
# Detector System




**purpose**: counting transmitted β-decay electrons

**properties:**

- segmented monolithic Silicon PIN Diode
- 148 pixels, area ~ 50 mm² each
- dead layer ~ 100 nm
- post acceleration (up to +10 kV)
- muon veto system
- energy resolution 1.4 keV (FWHM)
- intrinsic background 1.2 mcps / keV

**status:**

- system successfully commissioned
- maintenance phase ongoing

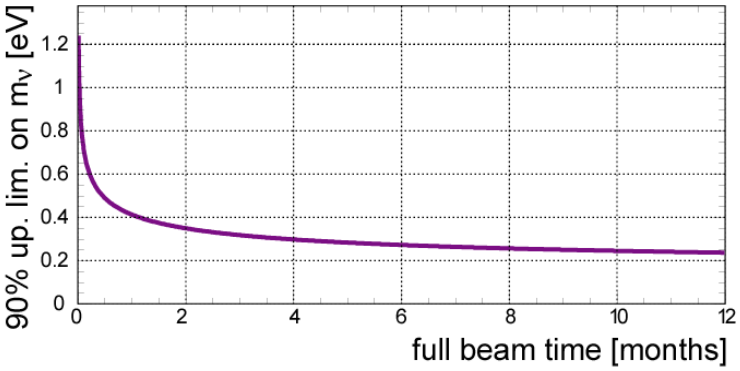
# Summary & outlook

## summary

- KATRIN aims to measure the neutrino mass with 200 meV sensitivity
- All major components are on site
- The main spectrometer works as high resolution MAC-E filter

## outlook

- Commissioning of beamline in 2016
- First tritium runs end of 2016



# KATRIN collaboration


Karlsruhe Institute of Technology

Westfälische Wilhelms-Universität Münster

Johannes Gutenberg Universität Mainz

Bergische Universität Wuppertal

University of Washington

The University of North Carolina at Chapel Hill

UCSB

MIT

Berkeley Lab

Hochschule Fulda
University of Applied Sciences

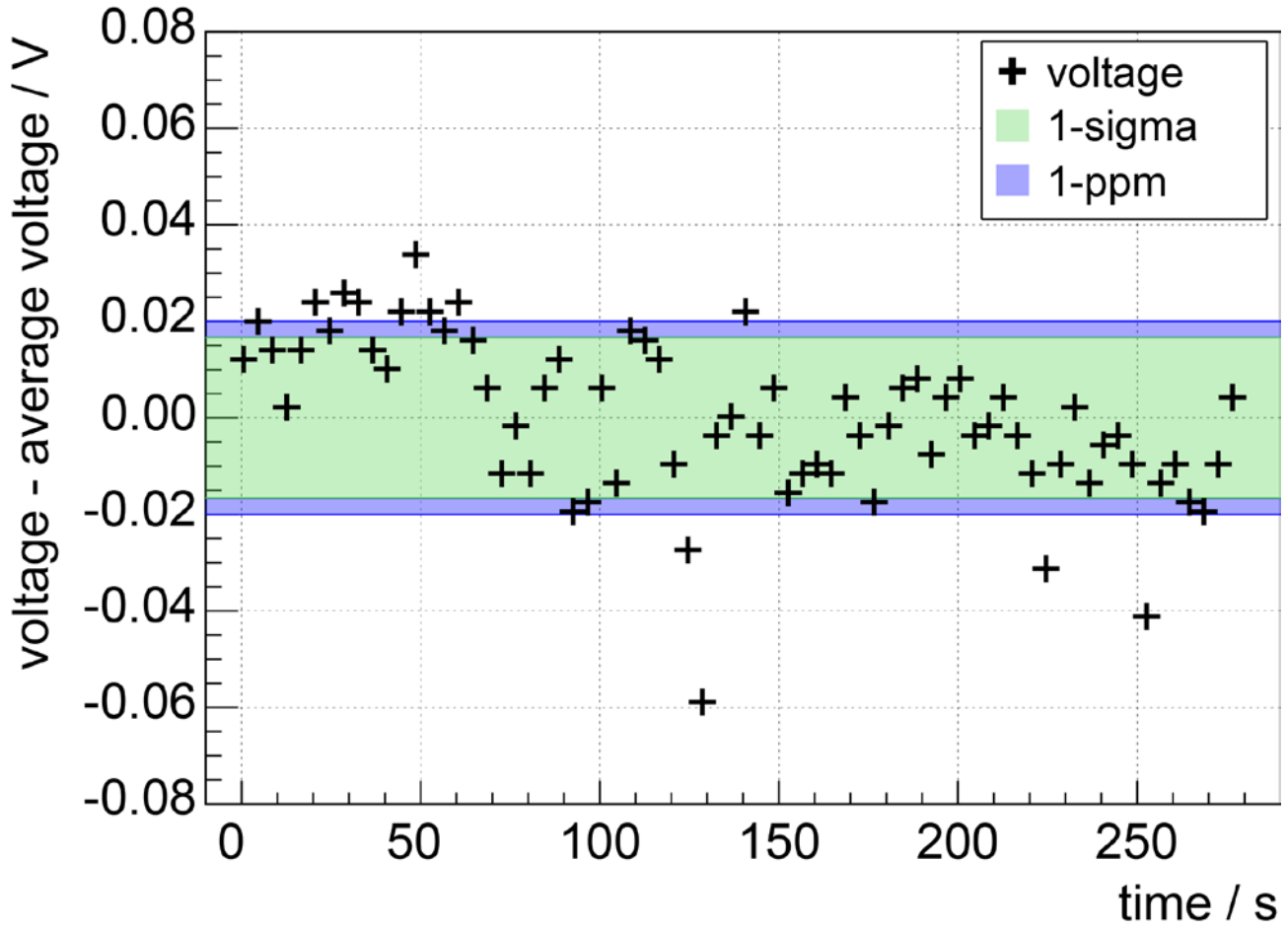
Max-Planck-Institut für Kernphysik

Uni Bonn
Rheinische Friedrich-Wilhelms-Universität

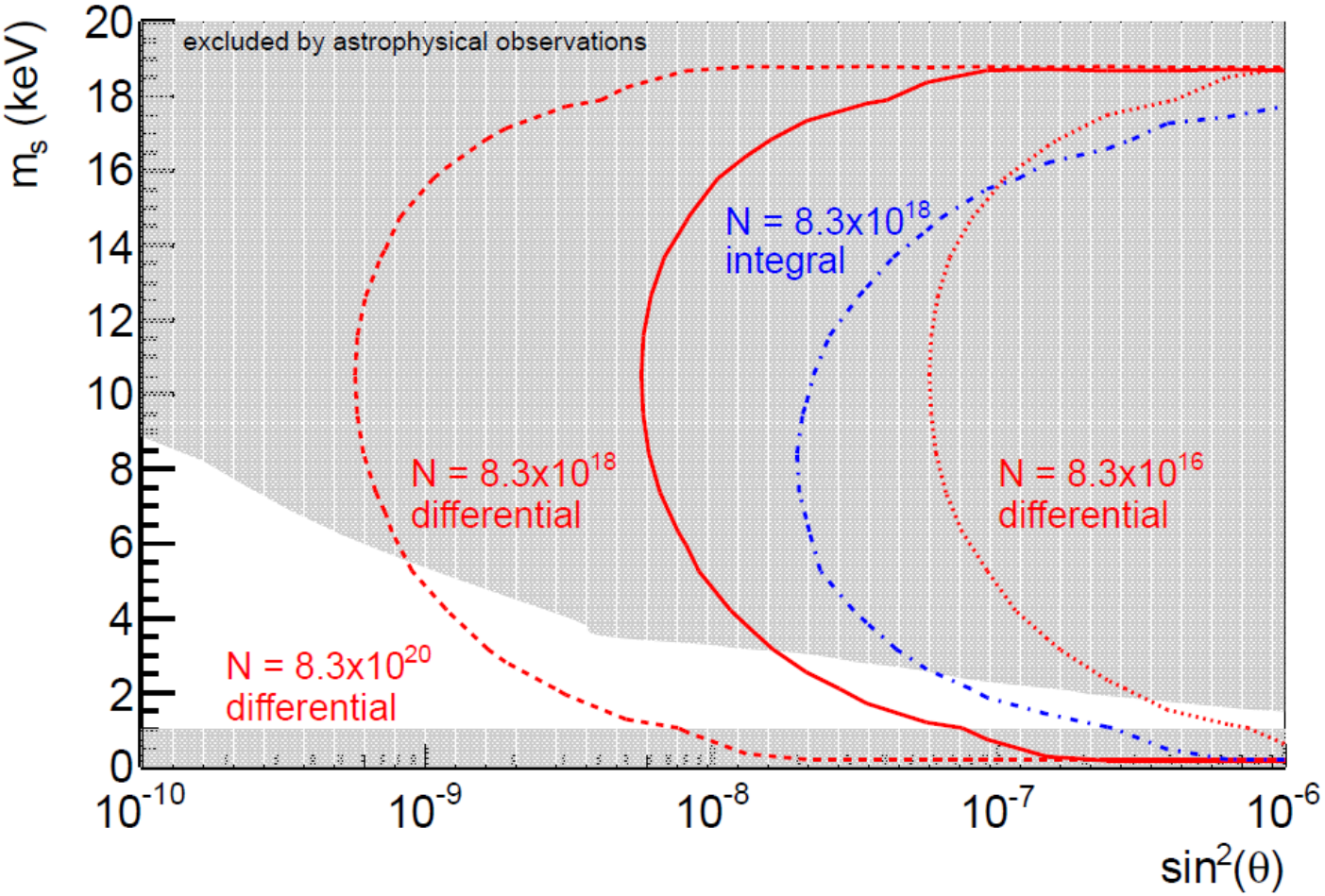
Swansea University
Prifysgol Abertawe

# Backup

# HV stability



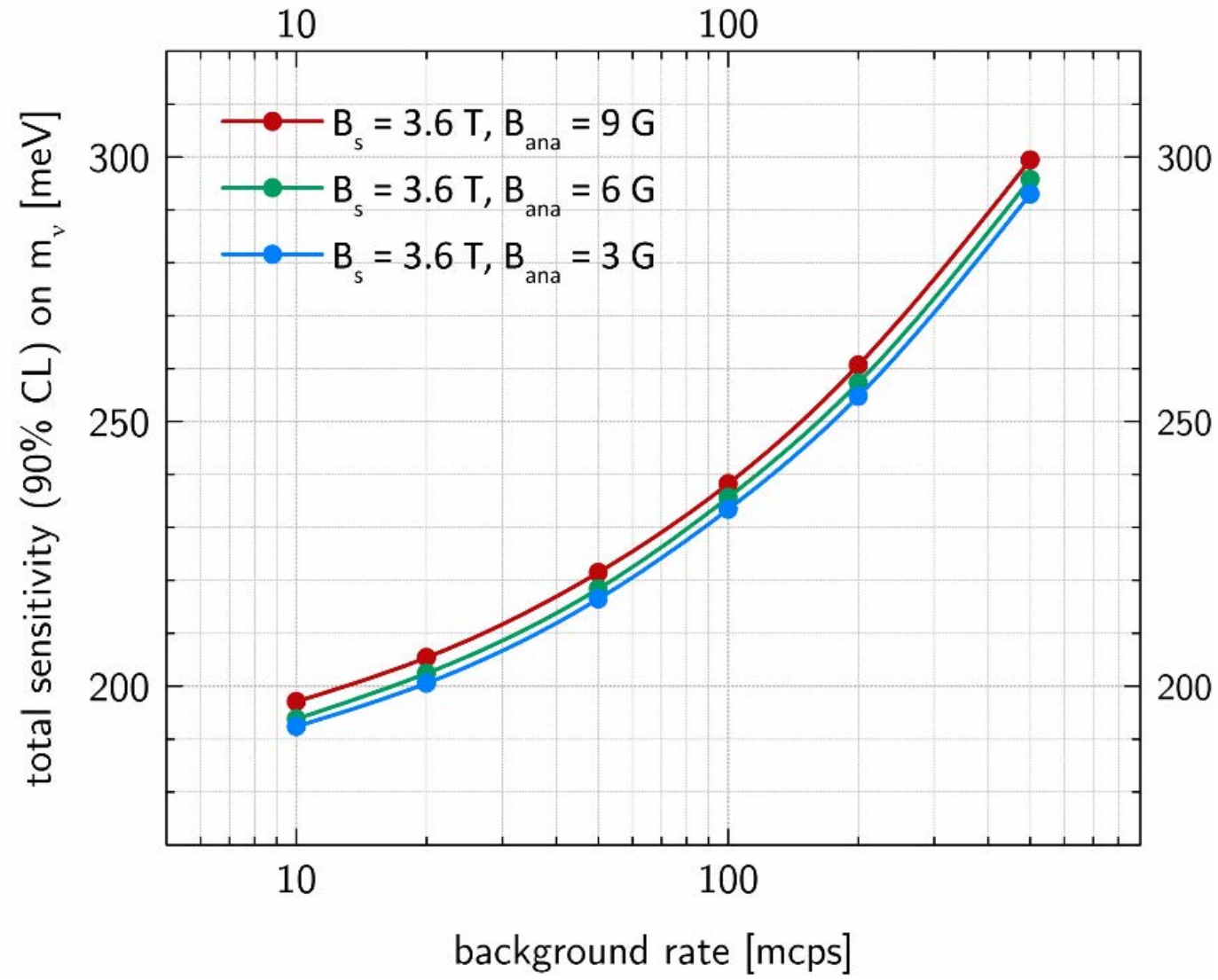
# Sensitivity sterile neutrinos




S. Mertens et al. "Sensitivity of next-generation tritium beta-decay experiments for keV-scale sterile neutrinos", JCAP02(2015)020

doi:10.1088/1475-7516/2015/02/020

# KATRIN sensitivity vs. background



# WGTS temperature stability