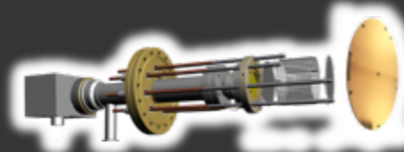
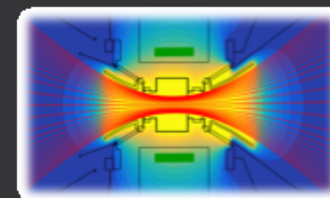
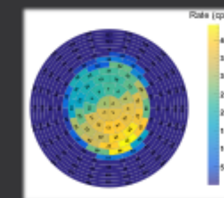
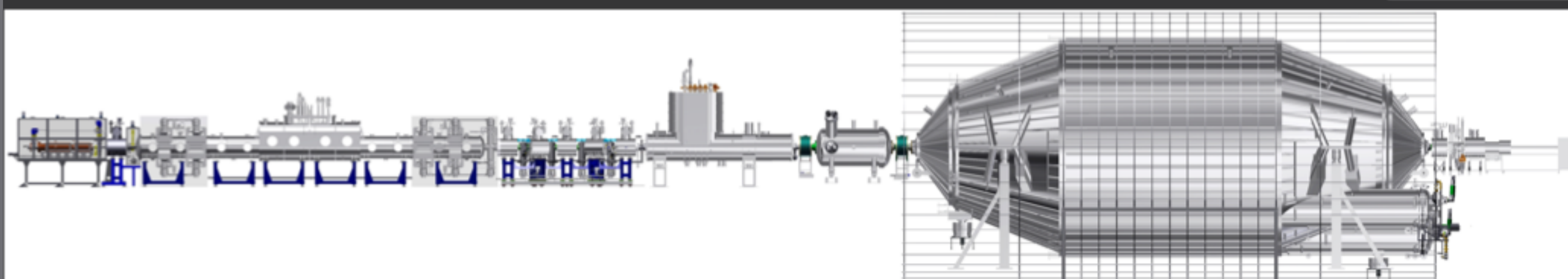
Status of the KATRIN experiment









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Lake Louise Winter Institute

February 22, 2018

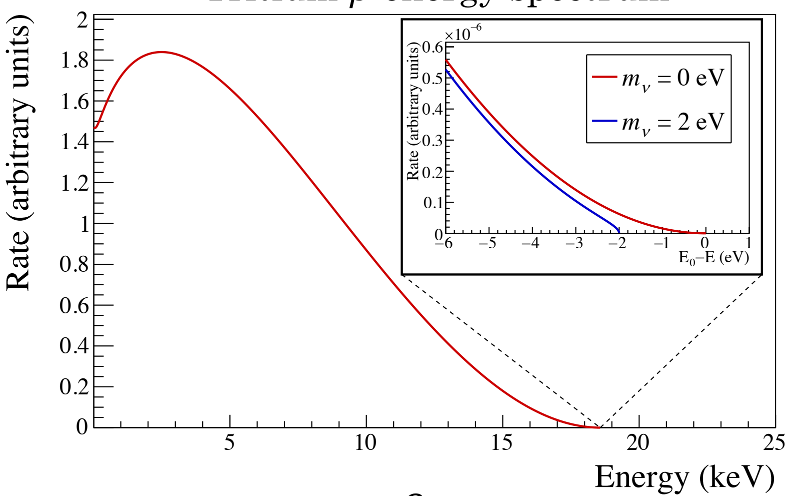
Outline

- KATRIN overview
- Measurement campaigns
  - First Light
  - Krypton
  - Background studies
- Summary and outlook

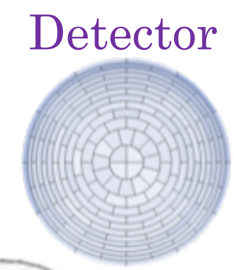
photo source: Karlsruhe Institute of Technology, www.katrin.kit.edu

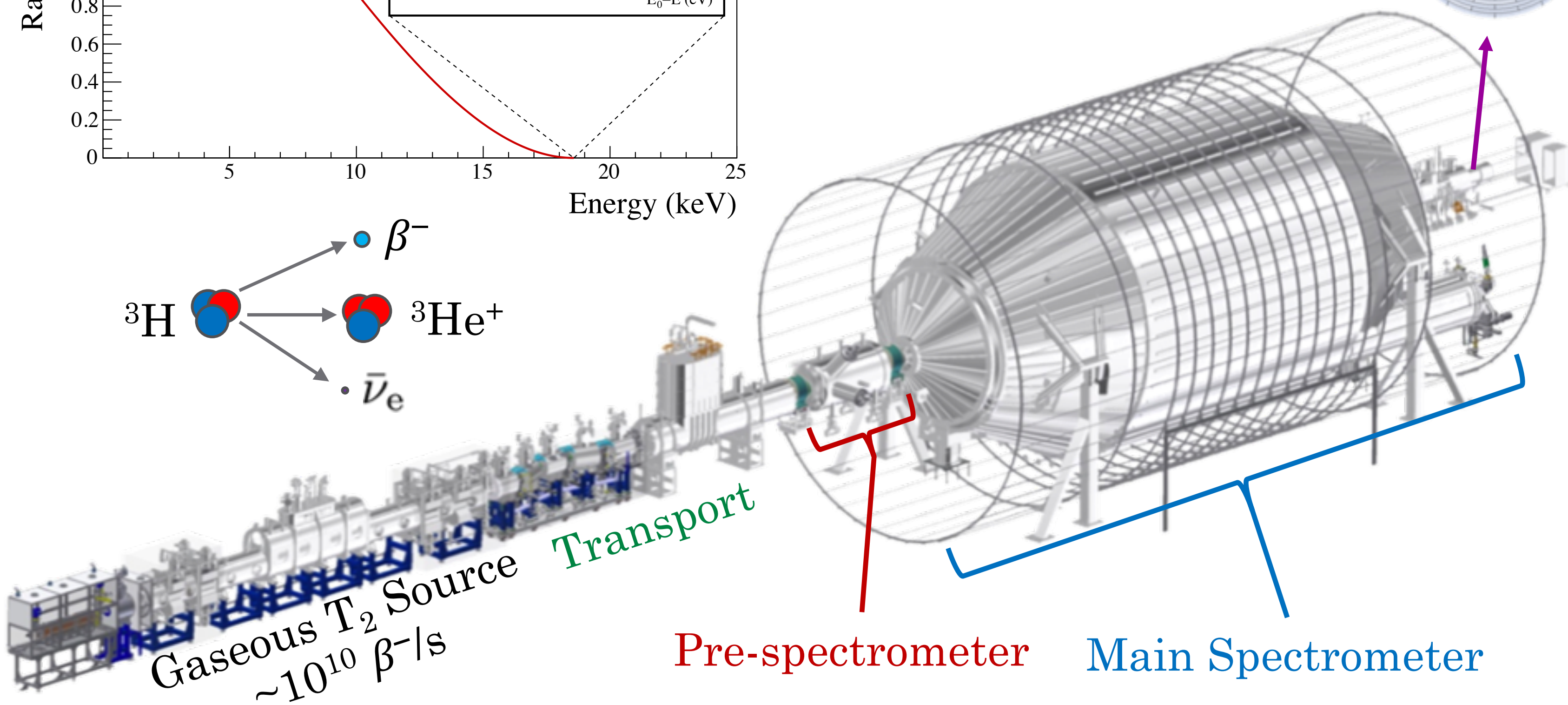
The Karlsruhe Tritium Neutrino Experiment

Tritium β energy spectrum

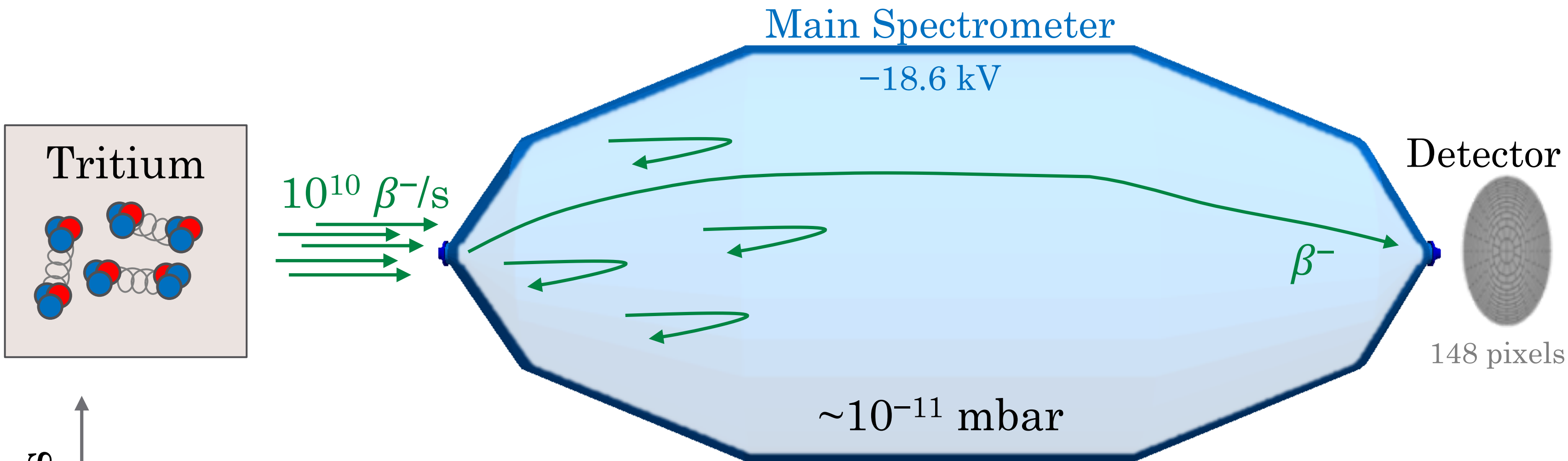


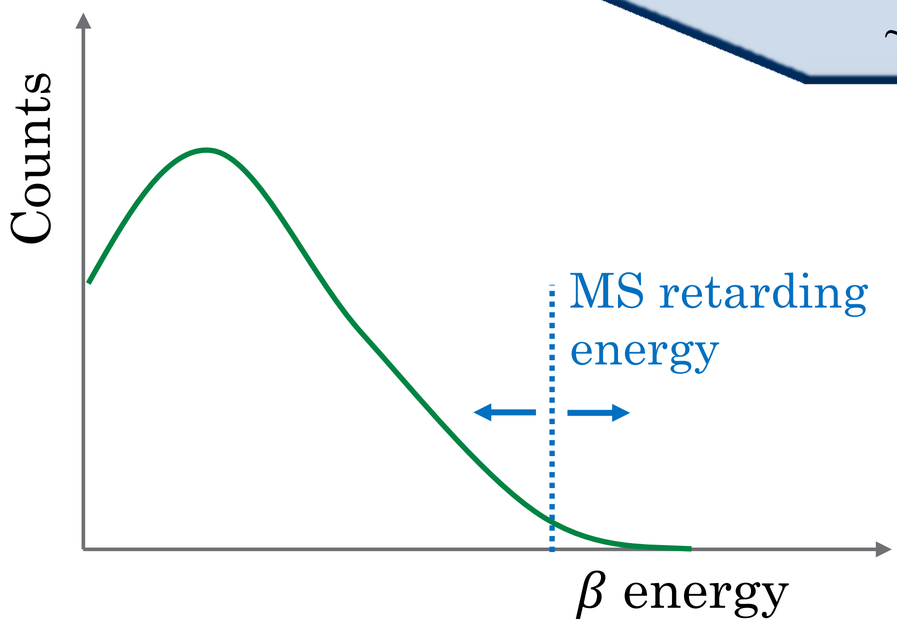
Goal:
Measure effective neutrino mass with sensitivity of 0.2 eV/c² (90% CL)





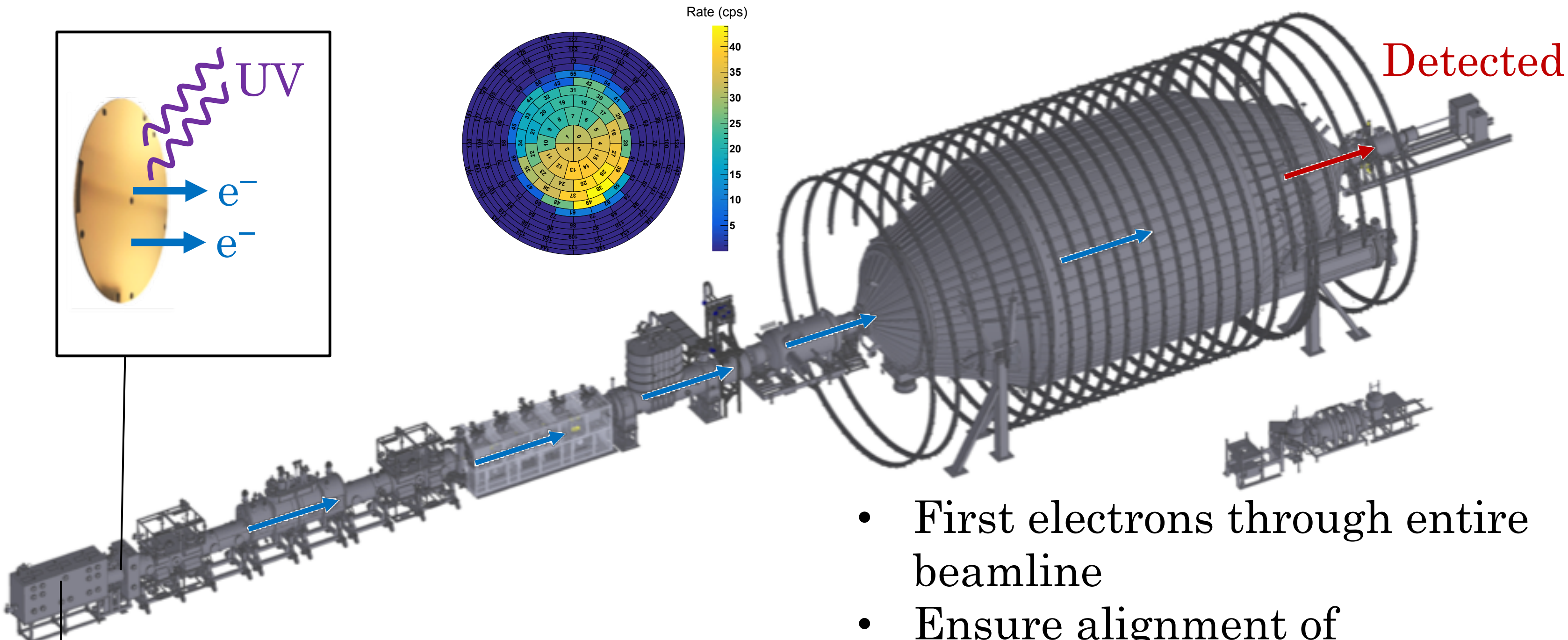
Spectrometer operation

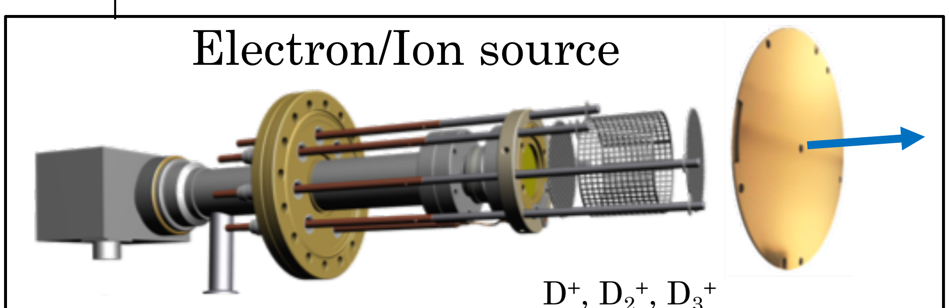




- MAC-E filter with energy resolution of ~1 eV
- Measure integral rate for different retarding energies
- Fit the integral spectrum to obtain the neutrino mass

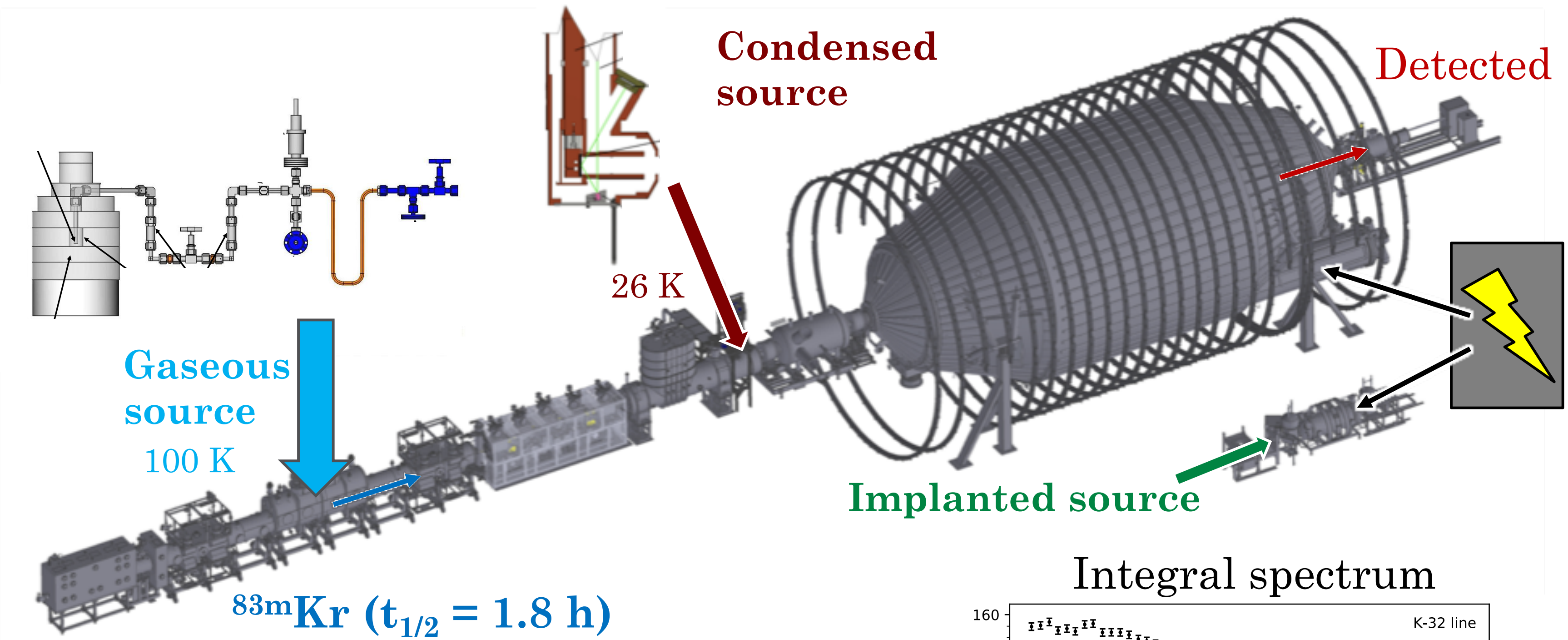
First Light: Autumn 2016





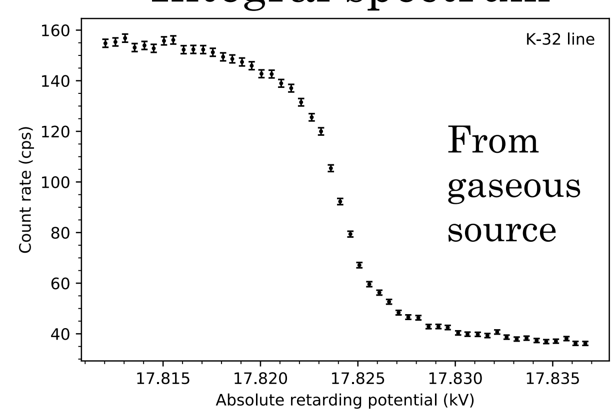
- First electrons through entire beamline
- Ensure alignment of components and magnets
- Test methods for ion blocking and ion removal
- Technical paper:
  - arXiv:1802.04167

Krypton campaign: July 2017



- Mono-energetic electron source, including K32 line (E = 17.8 keV)
- Can calibrate near tritium endpoint (E_0 = 18.6 keV)
- Measure line position and shape using the main spectrometer

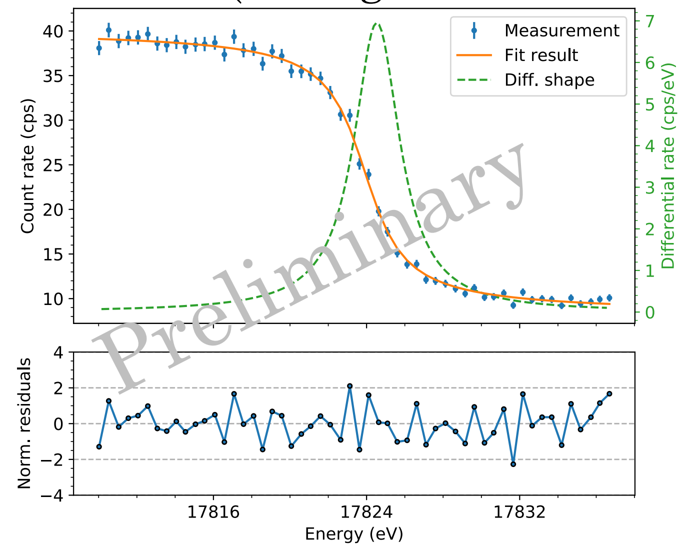
Integral spectrum



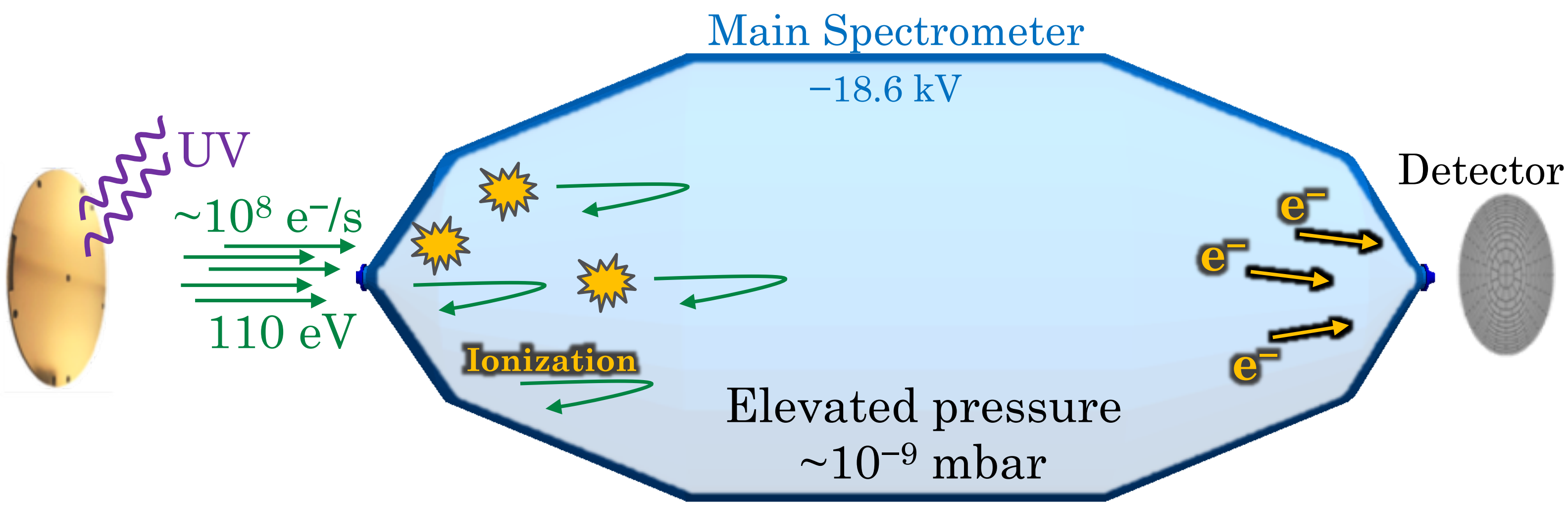
Krypton campaign: July 2017

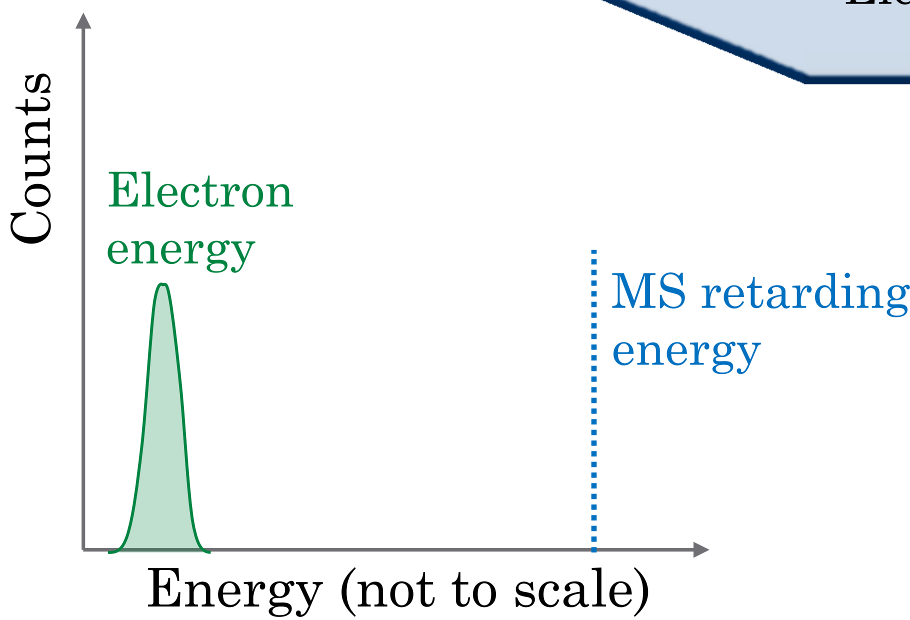
- Commissioning of ^{83m}Kr sources
  - Test stability of source temperature (gaseous source)
- High voltage stability
  - Sub-ppm level
  - Paper: arXiv:1802.05227
- Characterize Main Spectrometer performance
  - Scan of ^{83m}Kr lines
  - Publication forthcoming →
- Preparation for tritium operation
  - System performance meets/surpasses specifications
- Technical paper
  - "First Light" and Krypton overview
  - arXiv:1802.04167

K-32 Line (from gaseous source)



Background from ionization



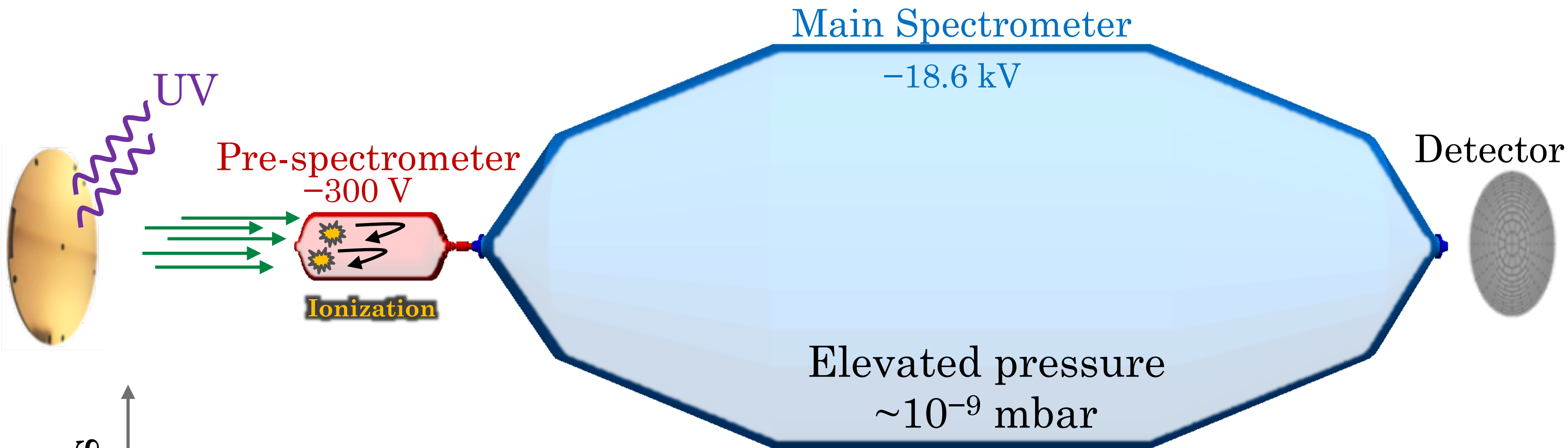


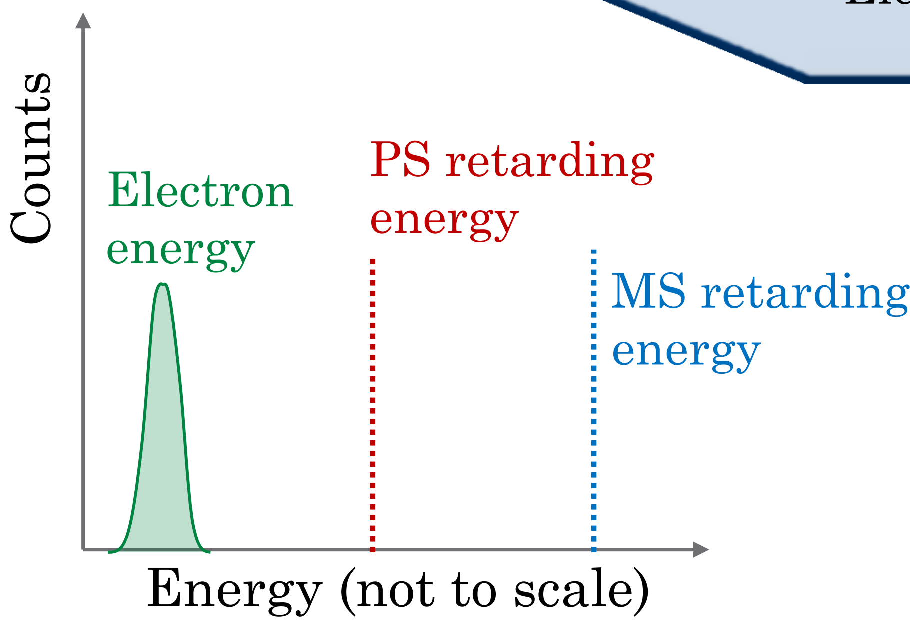
First Light: arXiv:1802.04167

Electron rate (e^-/s)	Detector rate (cps)
~0	0.6
~10^8	2.5

Elevated rate due to ionization

Pre-filtering electron beam



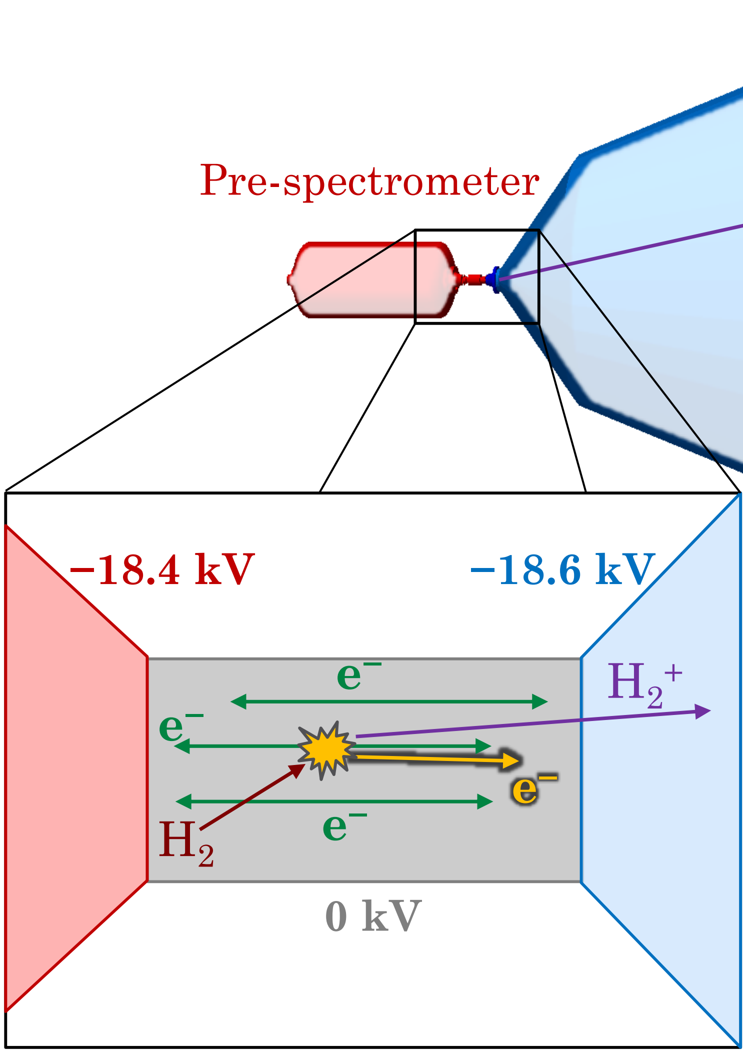


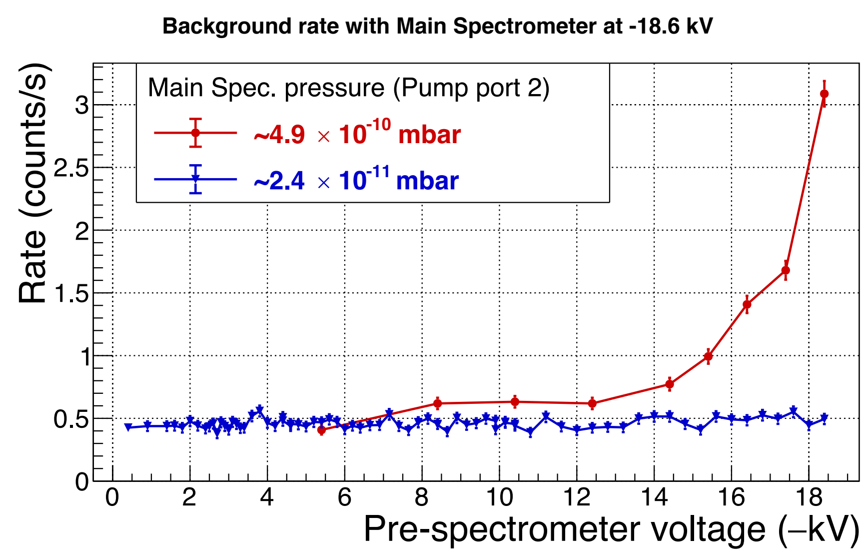
First Light: arXiv:1802.04167

Electron rate (e^-/s)	ΔU_{PS} (V)	Detector rate (cps)
~0	0	0.6
~10^8	0	2.5
~10^8	−300	0.6

Rate remains at reference value

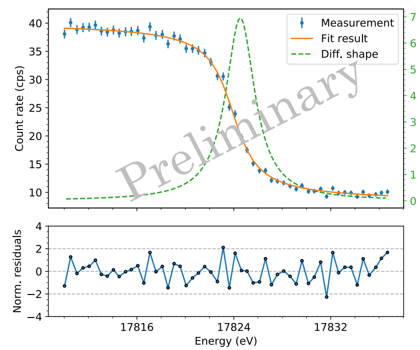
Penning trap background



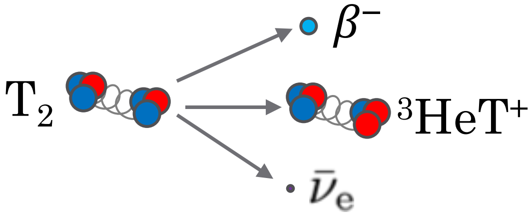


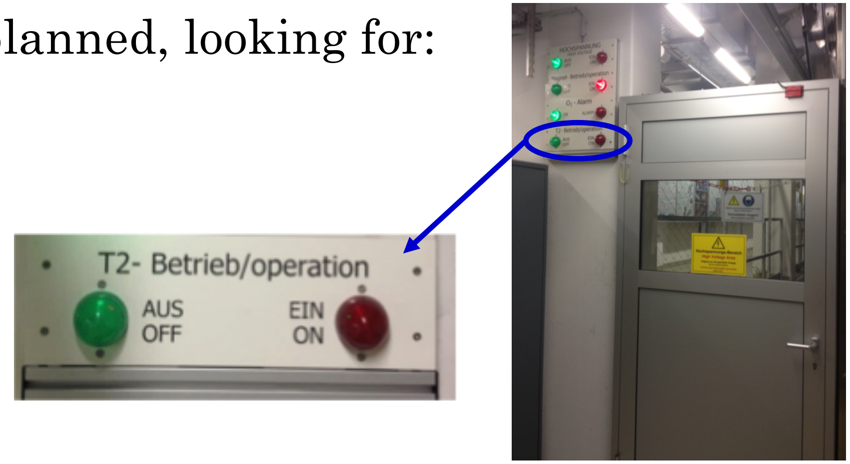
Summary and Outlook

- Very successful measurement campaigns
  - First electrons through entire beamline
  - Spectral scanning with ^{83m}Kr
  - Background studies



- First tritium
  - Final preparations for commissioning are underway
  - Official inauguration of the KATRIN beamline: June 11, 2018
- 5 years of measurements planned, looking for:
  - Effective neutrino mass
  - Sterile neutrinos
  - BSM physics





Photos courtesy of Martin Mark, KIT

Thank you

KATRIN funded by:

Germany
- Helmholtz Association (HGF)
- Ministry for Education and Research BMBF
- Helmholtz Alliance for Astroparticle Physics (HAP)
- Helmholtz Young Investigator Group

Czech Republic
- Ministry of Education, Youth and Sport
- Cooperation with the JINR Dubna

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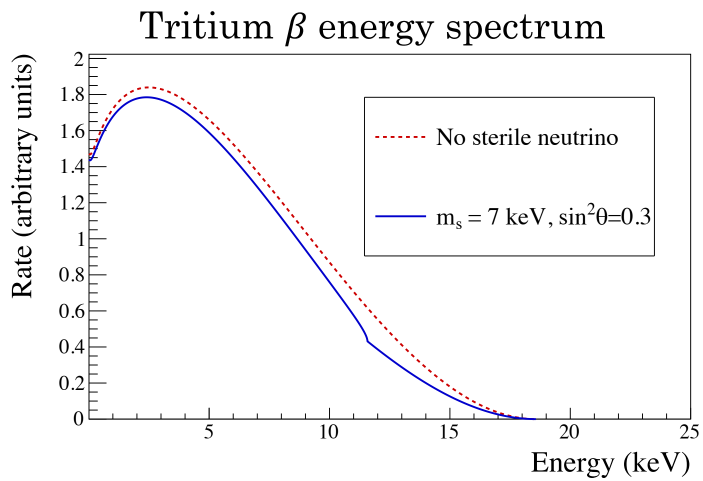
- Karlsruhe Institute of Technology
- Lawrence Berkeley National Laboratory
- Max Planck Institut für Kernphysik, Heidelberg
- The Massachusetts Institute of Technology
- University of Applied Science, Fulda
- University of Bonn
- University of Münster
- University of North Carolina
- Complutense University of Madrid
- University of Washington
- University of Wuppertal
- Max Planck Institute for Physics, Munich
- Technical University of Munich
- Humboldt University of Berlin
- Case Western Reserve University
- Carnegie Mellon University
- The Czech Academy of Science, Újf Prague
- French Alternative Energies and Atomic Commission, Paris

Sterile neutrinos and BSM physics

Sterile neutrinos result in a "kink" in the beta decay spectrum

- Search at the keV-scale and also eV-scale



New physics can be probed by looking for distortions near the endpoint in the beta spectrum

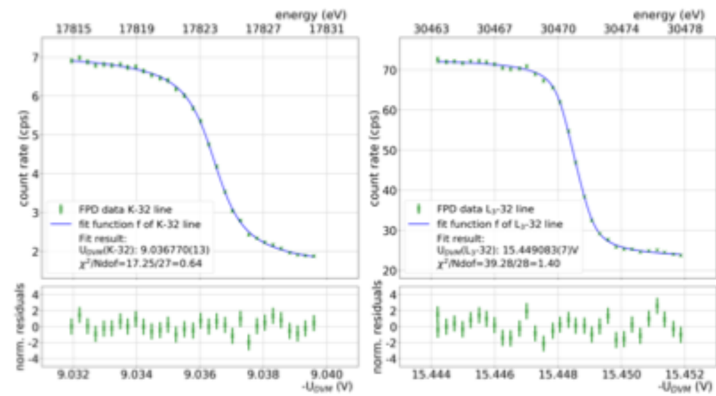
- Non V−A contributions
- Violations of Lorentz invariance
- Tachyonic neutrinos

See:

- KATRIN Design Report 2004, FZKA scientific report 7090.
- Mertens et al. JCAP02(2015)020
- Steinbrink et al. JCAP06(2017)015

High voltage stability

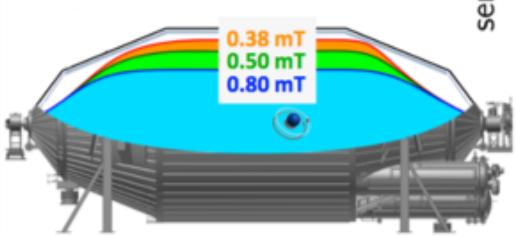
- Measure the voltage difference between two ^{83m}Kr lines
- HV divider scale factor
  - 2017 krypton value = 1972.449(10)
  - 2013 value = 1972.4531(20)
  - $\Delta M/M = -2(5)$ ppm over four years

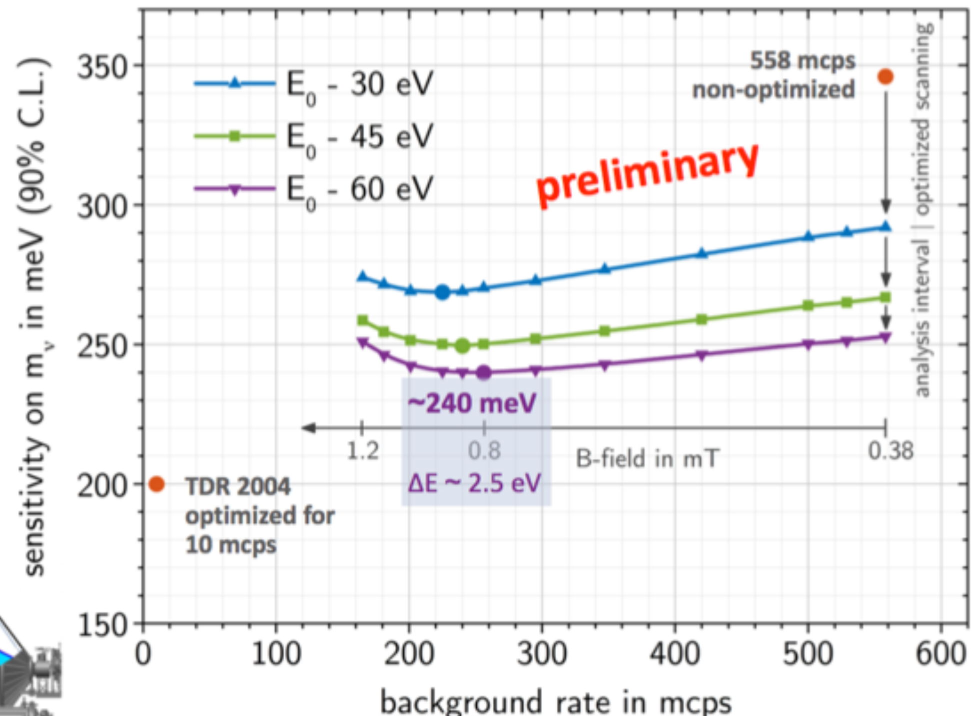


- HV is stable at the <u>sub-ppm</u> level over 2 months (assuming constant drift), which is the planned measurement interval for KATRIN
- Compare with 3 ppm requirement from KATRIN Design Report 2004
- For details see the recent publication: arXiv:1802.05227

Sensitivity and background

- Further **background reduction measures** being studied
- In addition: **several mitigation strategies** currently under investigation:
  - optimized scanning
  - range of spectral analysis
  - flux tube compression by increasing B





Taken from presentation by Kathrin Valerius (KIT) for NEUTRINO 2016, entitled "Direct probes of neutrino mass"

Magnetic Adiabatic Collimation with an Electrostatic Filter

- Smoothly change magnetic field → magnetic moment will be conserved
  - Decrease B, decrease $E_\perp$
  - Convert $E_\perp$ into $E_\parallel$

$$\mu = \frac{E_\perp}{B}$$

- Good energy resolution requires a large spectrometer!

$$\frac{\Delta E}{E} = \frac{B_{\text{min}}}{B_{\text{max}}}$$

$$\Phi = \int \vec{B} \cdot d\vec{A}$$

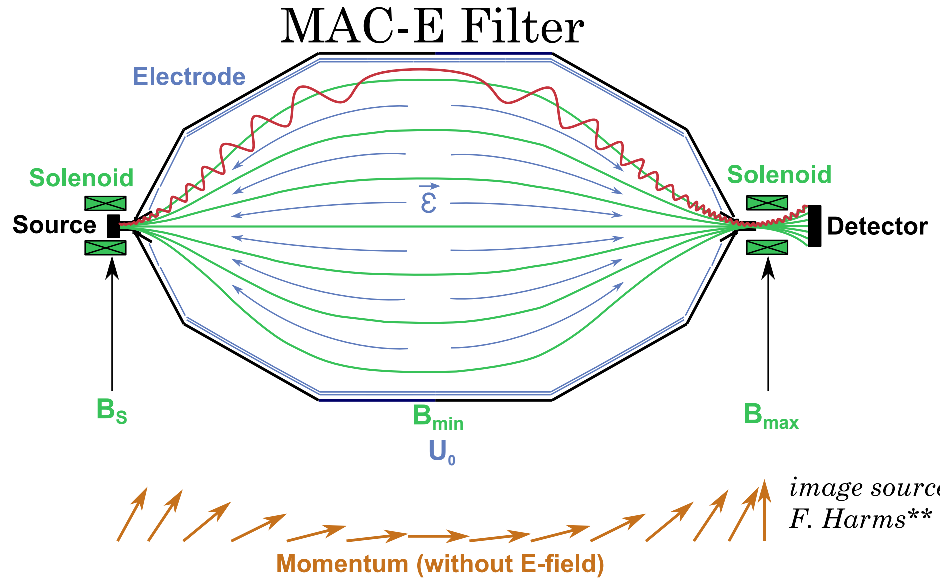


*image source: F. Harms***

**F. Harms. PhD thesis, Karlsruhe Institute of Technology, 2015.*