Forward Beam Monitor for KATRIN's first tritium measurements

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KATRIN experiment source monitoring

The *KArlsruhe TRItium Neutrino* (KATRIN) experiment will measure the neutrino mass with a sensitivity of 0.2 eV (90 % CL) by observing the β-electron spectrum of tritium decay.

In order to accurately measure neutrino mass, the tritium source properties, particularly the activity,

- should be stable over time
- must be known to a high precision
- will undergo measurements from several monitoring systems

The *Forward Beam Monitor* (FBM) is one such monitoring system. Using two independent motion systems, the FBM detector board can be driven throughout the entire cross section of the flux tube.

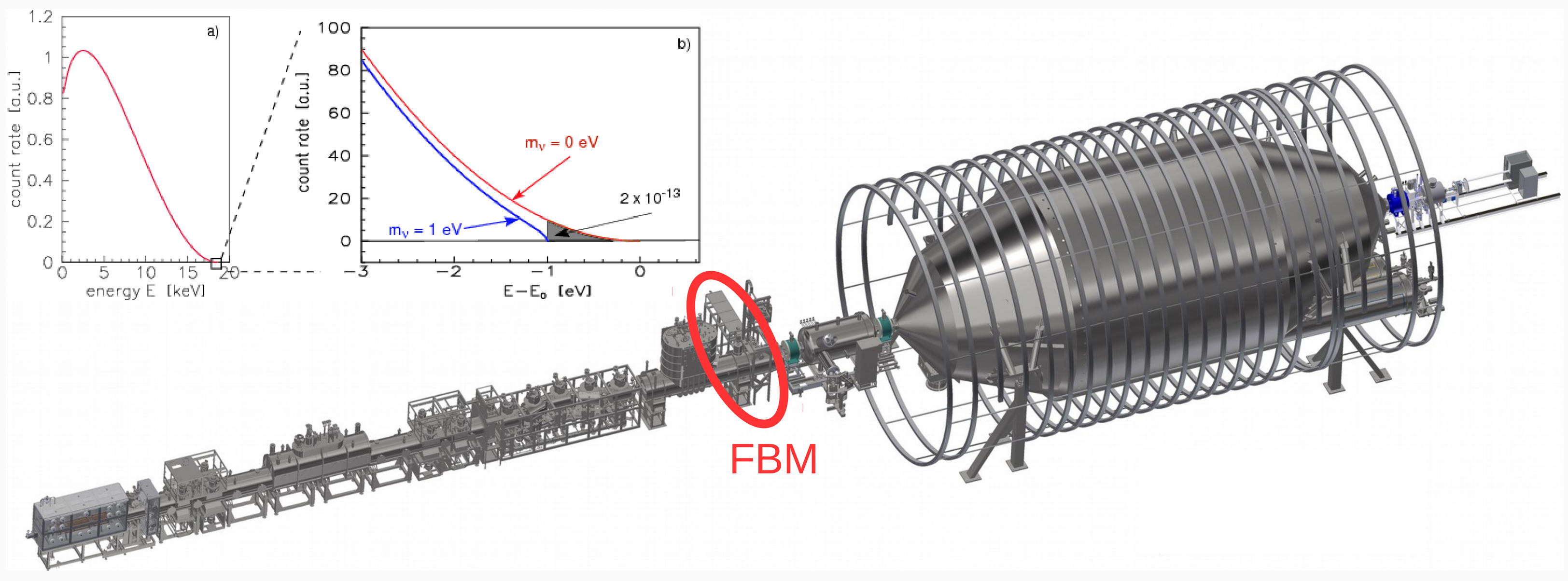

Fig. 1: The KATRIN beamline. β-electrons are guided 70 m from the source to the detector. The expected β-spectrum is shown in the inset. The FBM (circled in red) is located inside the beamline.

Forward Beam Monitor

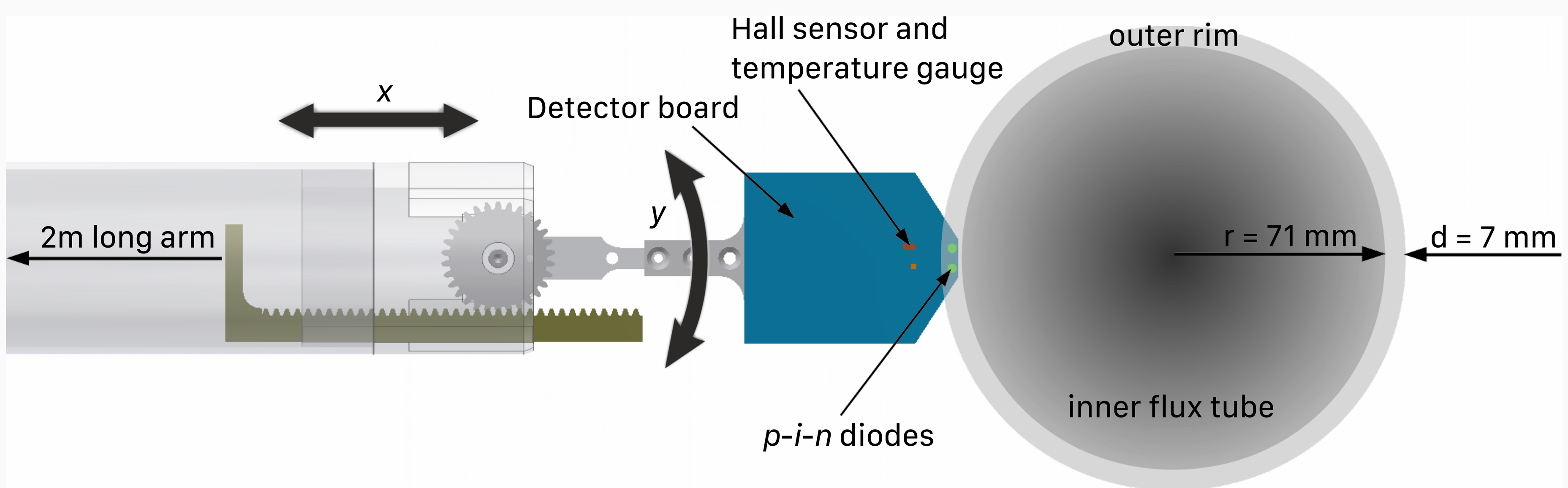

Fig. 2: The FBM detector boards sits at the outer rim of the flux tube in monitoring position. It continuously measures the flux properties without shadowing the FPD. The detector board can also be moved in both *x* and *y* directions to scan across the flux tube during commissioning and calibration measurements.

The FBM detector board contains

- silicon *p-i-n* diodes
- hall sensor
- temperature gauge

and is inserted into the flux tube where the electron flux density is up to $10^6\,\mathrm{s}^{-1}\,\mathrm{mm}^{-2}$.

The FBM monitors the relative intensity of the electron flux and detects β-electrons with a precision of 0.1 % in less than a minute.

Flux tube scanning

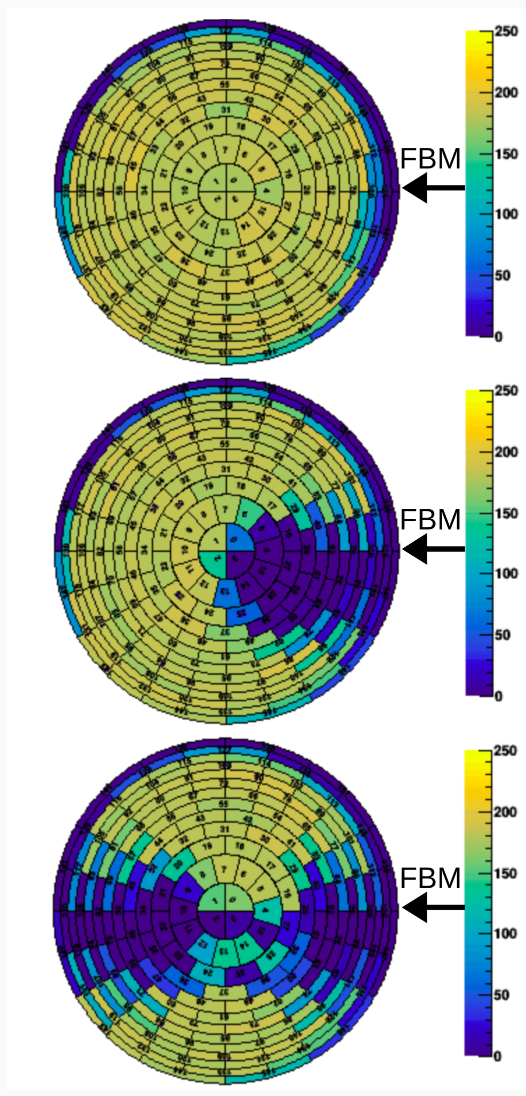

Fig. 5: The FBM shadow as it scans across the flux tube.

The shadow of the FBM can be seen during commissioning and calibration measurements. When tritium is in the source the FBM can detect a rate difference as it scans across the flux tube.

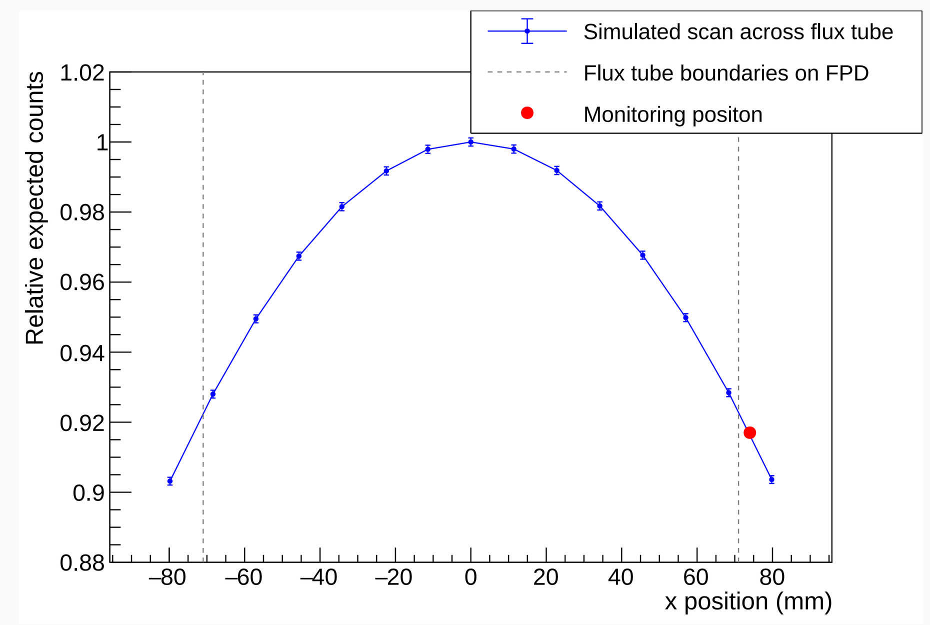

Fig. 6: Simulated relative counts from an FBM horizontal scan across flux tube.

Detector calibration

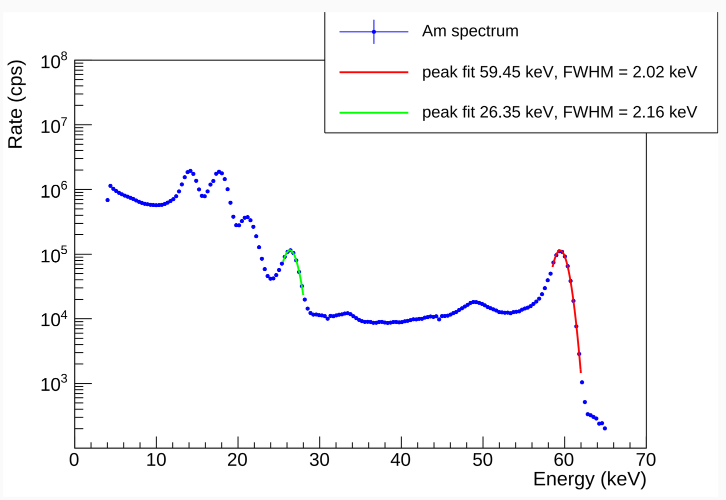

Fig. 3: Americium spectrum used for *p-i-n* diode energy calibration.

The measurement principle and precision of the FBM *p-i-n* diodes was demonstrated using a ^{241}Am calibration source which emits gamma particles.

The energy properties are

- energy resolution, $\sigma_{\mathrm{FWHM}} = 2\,\mathrm{keV}$
- energy threshold, $E_{\mathrm{th}} = 4\,\mathrm{keV}$

Rate stability and spectral shape

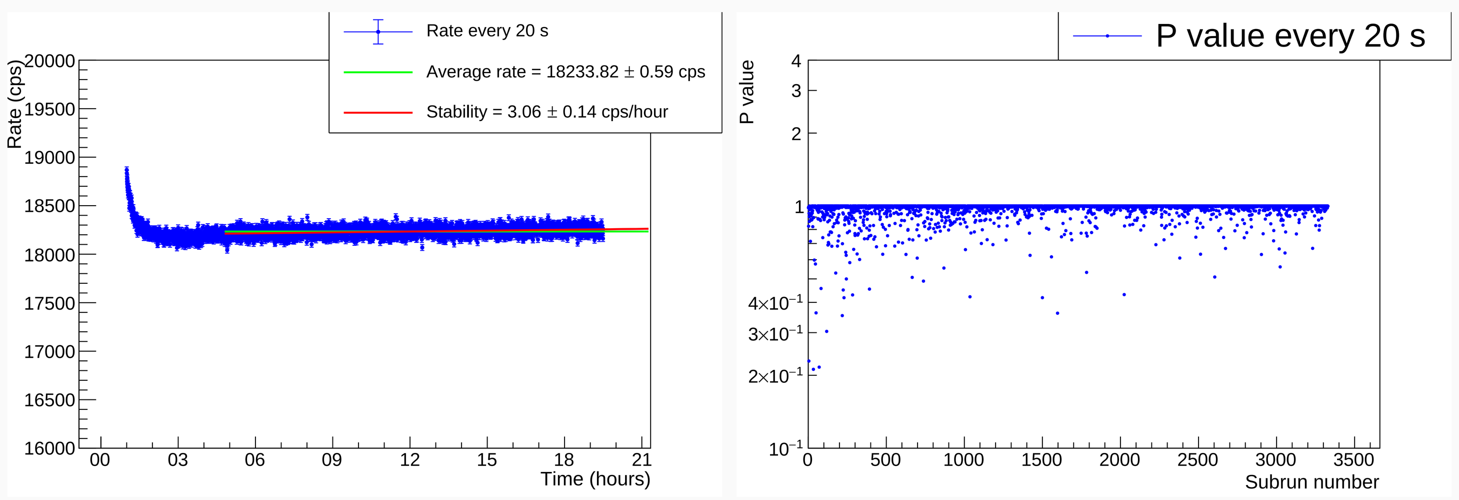

Fig. 4: Rate stability and spectral shape analysis over a 20 hour calibration measurement.

Histograms and rate information are pulled once every 20 s (subrun length) and

- rate stability is plotted
- spectral shape is compared to a reference spectrum using the Kolmogorov-Smirnov test to produce a P value

FBM detector is stable to within approximately 3 cps/hour when temperature conditions have stabilised after inserting into the flux tube.

Setting limits on rate stability and P value from spectral shape comparisons indicates the tritium source stability.

Towards measurement with tritium

KATRIN first measurements with tritium started in May 2018. During this, and in future measurement phases with tritium, the *Forward Beam Monitor* (FBM) will

- monitor the rate stability and spectral shape of the β-electrons from the tritium source
- perform scanning measurements throughout the cross section of the flux tube

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