

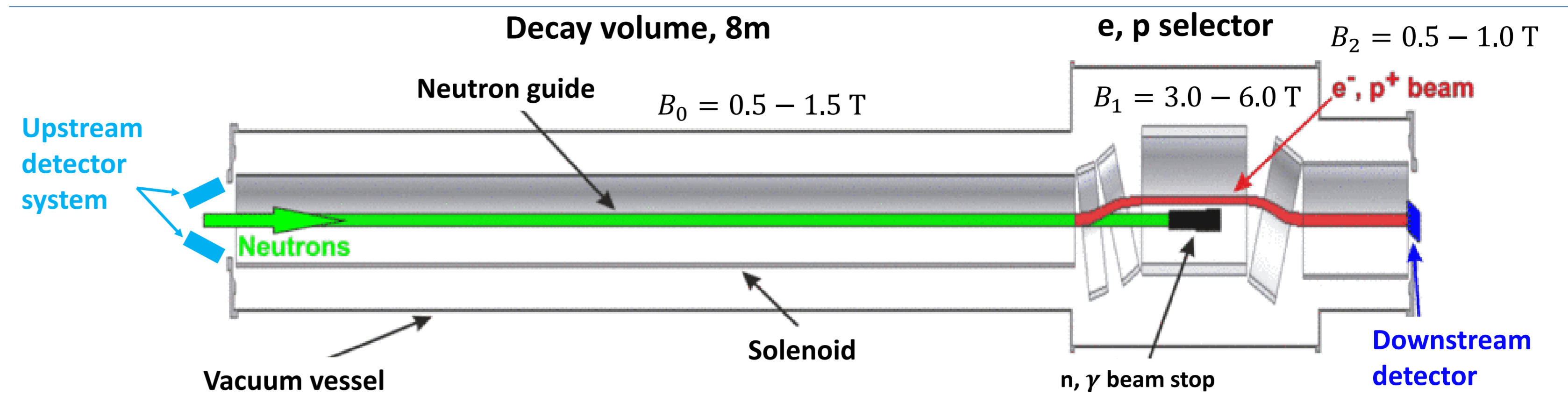
Abstract

The PERC facility is currently under construction at the FRM II in Garching, Germany. It will serve as an intense and clean source of electrons and protons from free neutron beta decay for precision studies. It aims to improve the measurements of the properties of weak interaction by one order of magnitude [1] and to search for new physics via new effective couplings.

The downstream detector and the two upstream backscattering detectors will initially be scintillation detectors with (silicon) photomultiplier readout. In a later upgrade, the downstream detector will be replaced by a pixelated silicon detector.

We present the current design status of this silicon detector prototype.

PERC Schematic



- Neutron decay spectrometer to determine several correlation coefficients (A, b, C, a) [2]
- Electrons are guided by magnetic field towards one of the detectors
- Magnetic filter allows phase space selection and suppresses backscattering
- Downstream detector is the main detector for spectroscopy
- Upstream detector system as active particle dump to veto backscatter events

For details on PERC: see talk of B. Märkisch Thursday 12 pm
For details on upstream detector: see poster of K. Bernert

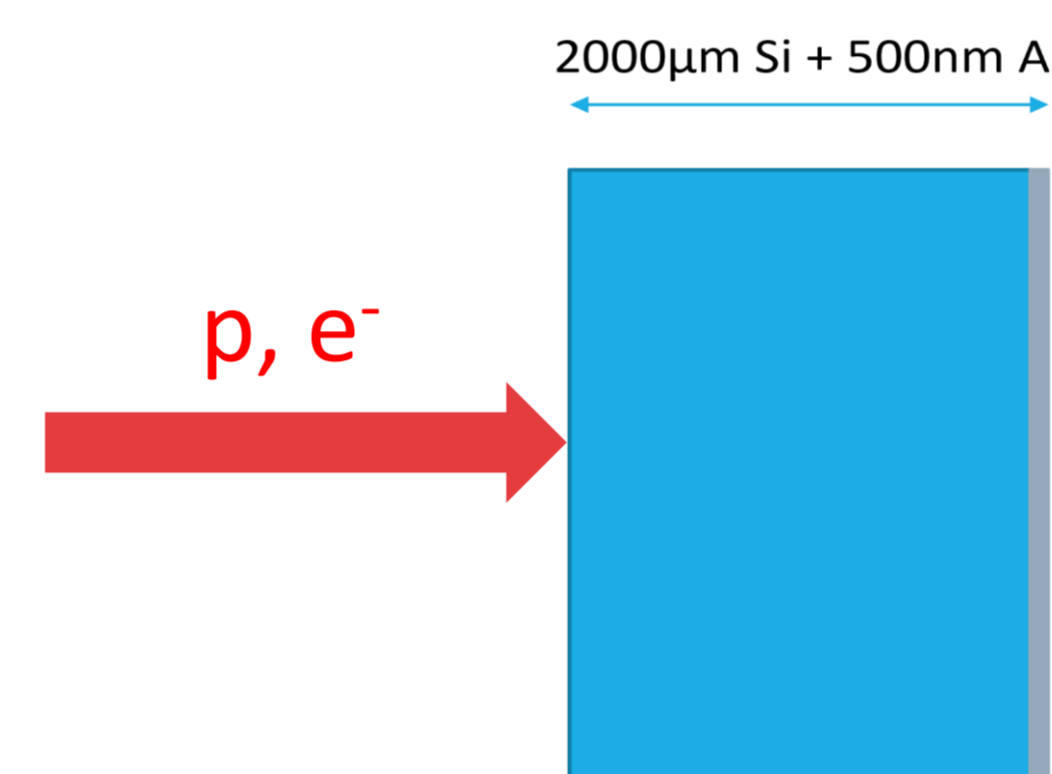
Downstream Detector Characteristics

- This is the main detector for energy spectroscopy.
- In an initial step a plastic scintillator with photomultiplier readout will be used as detector.
- Requirements to achieve the precision goal of PERC :
 - Handle particle rates of up to $\approx 10^5 \text{ s}^{-1}$
 - Area of about $12 \times 12 \text{ cm}^2$ with $\mathcal{O}(1 \frac{\text{cm}^2}{\text{pixel}})$
 - Resolve the calibration peak of ^{207}Bi at $\approx 975 \text{ keV}$
 - Trigger time resolution $< 10 \text{ ns}$ for coincidence measurements
 - Thin dead layer $\mathcal{O}(100 \text{ nm})$
 - Low non-linearities
 - Energy resolution of $\mathcal{O}(1\%)$

Possible Detector Designs

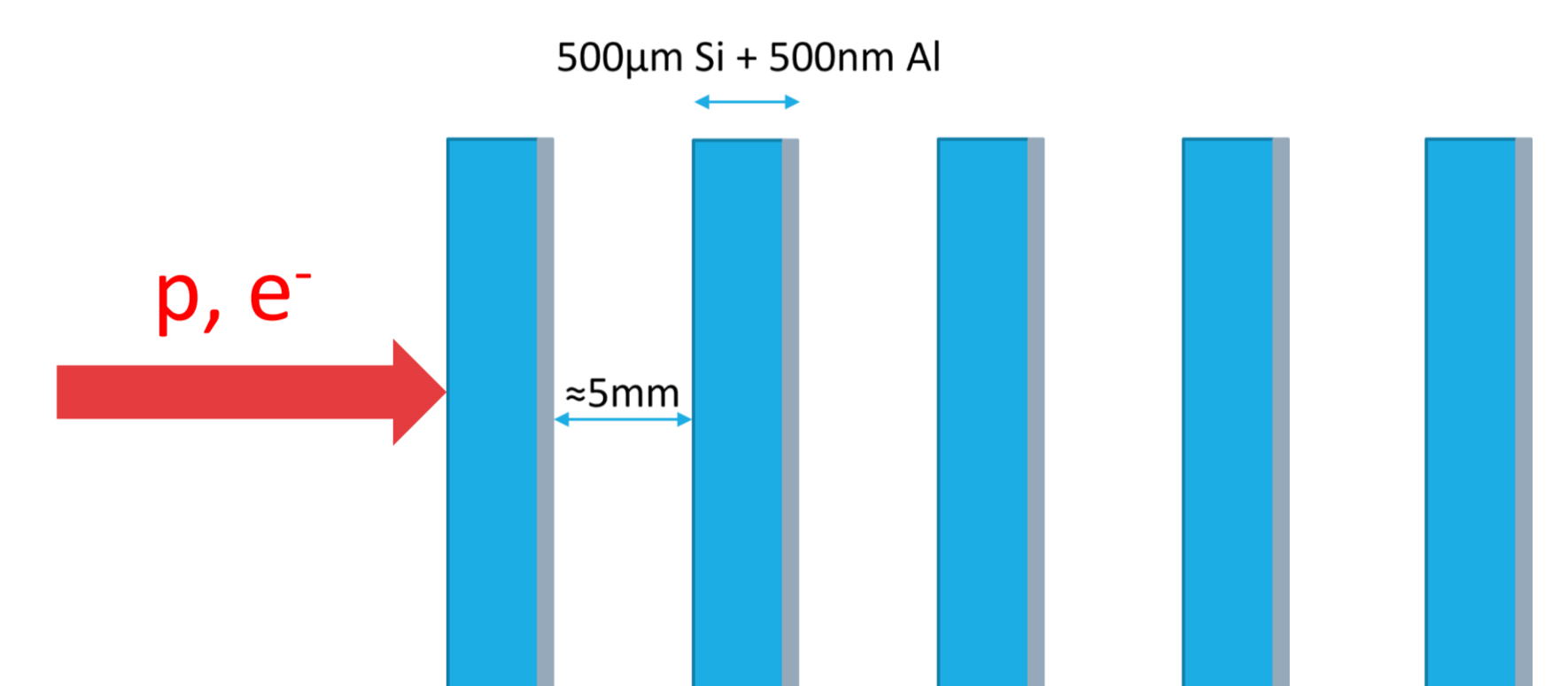
Single 2000 μm thick Si detector

- + One detector with readout electronics \rightarrow Easier analysis
- + No additional dead layers \rightarrow Better energy resolution
- Difficult to manufacture
- High voltages needed
- Triggering is most likely too slow



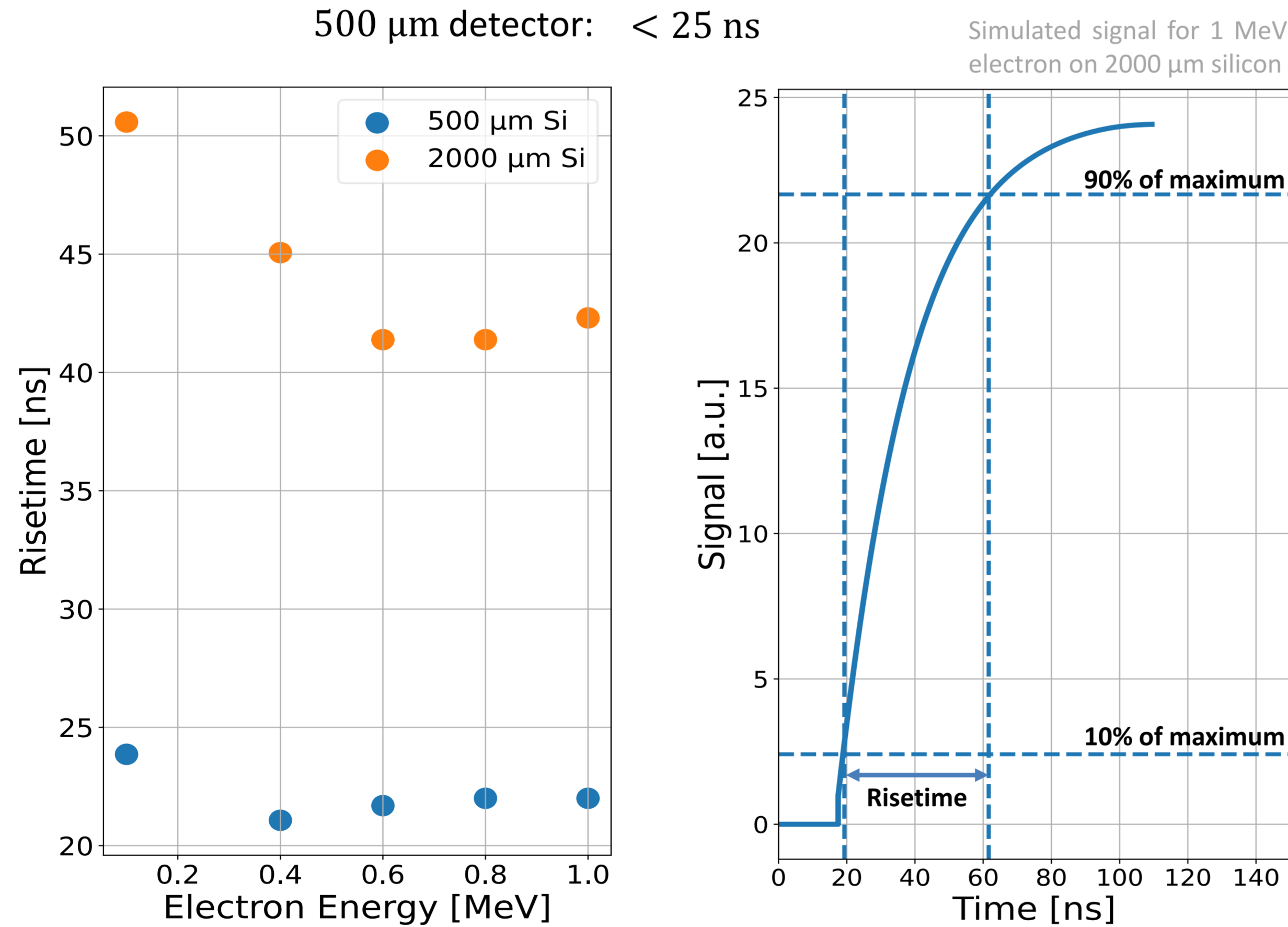
Stack of five 500 μm Si detectors

- + Faster signal formation
- + Easier to manufacture
- + Background suppression
- Five times the readout electronics
- More dead layers \rightarrow Additional non-linearity \rightarrow Worse energy resolution
- Complicated calibration



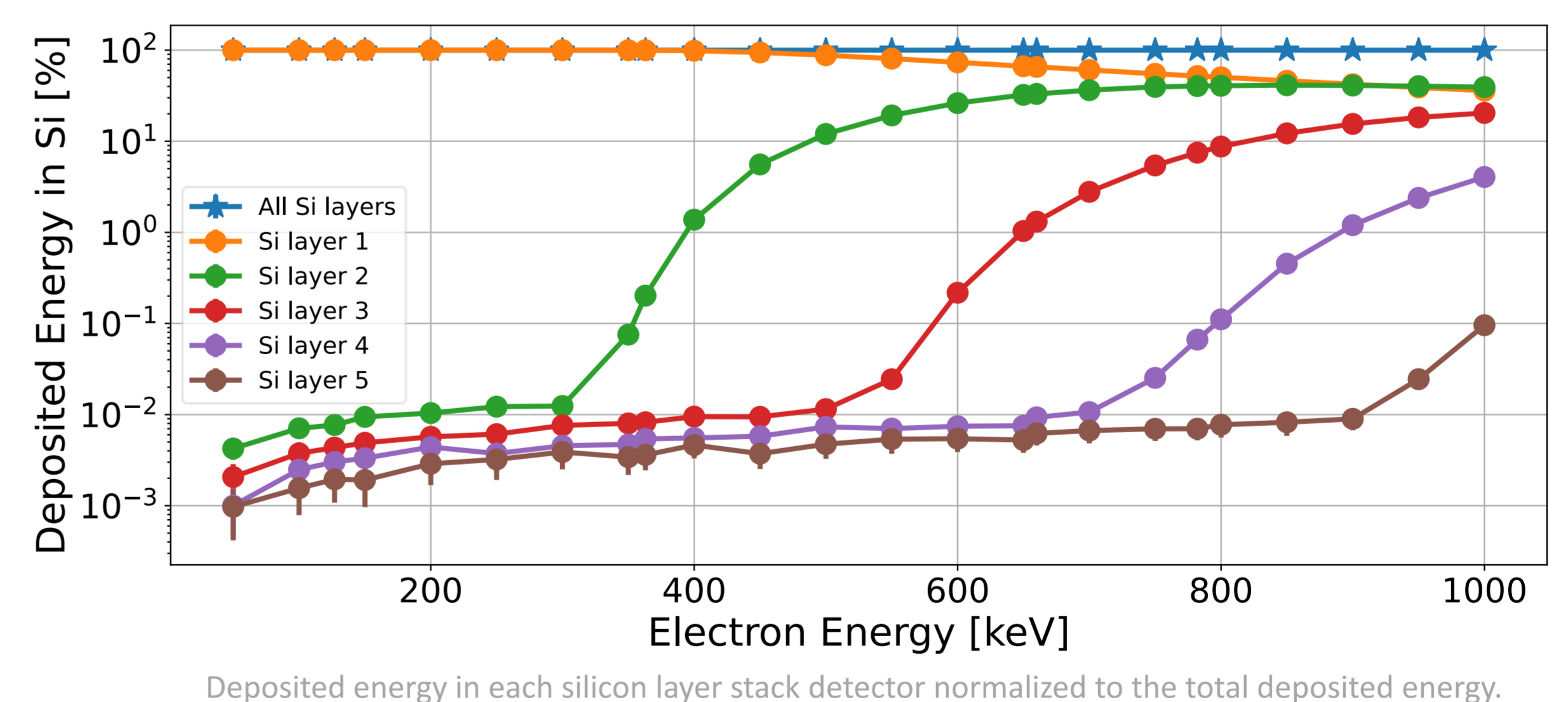
Risetime Simulations

- Short risetime of the detector signal needed for ToF coincidence measurements with upstream detector to identify backscatter events.
- Energy deposition of electrons in silicon simulated with PENELOPE [3].
- Signal formation calculated following [4, 5, 6].
- **Risetime results:** 2000 μm detector: $\lesssim 50 \text{ ns}$
500 μm detector: $< 25 \text{ ns}$



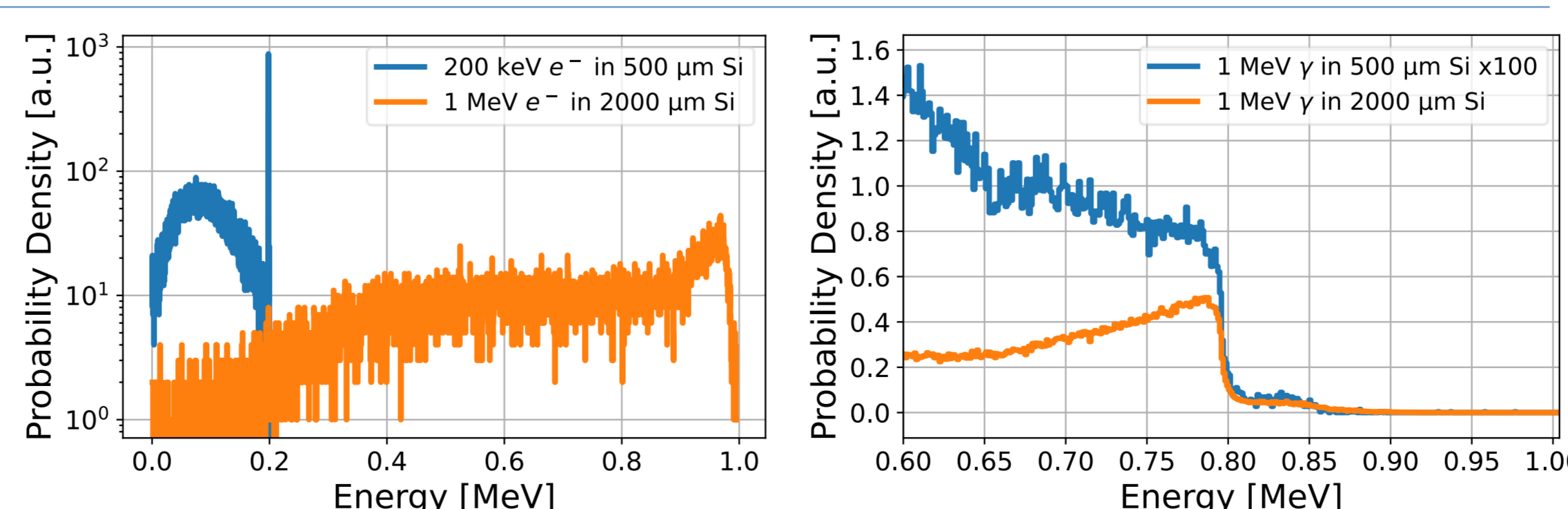
Energy Deposition Simulations

- Energy deposition simulated with PENELOPE [3] without magnetic field (still including backscattering of electrons which will be suppressed by the magnetic filter or detected by the upstream detector).
- **Results:**
 - In the single 2000 μm detector only a negligible amount of energy is lost in the aluminium layer and only at energies around 1 MeV.
 - In the stack detector $\approx 0.1\%$ of the deposited energy at 1 MeV is lost in the aluminium layers.
 - \rightarrow Thin dead layers have only a small effect at these energies.
 - \rightarrow Calibration peak of ^{207}Bi can be measured with both detectors.



Calibration Concept

- Using Compton edge of high energy photons for calibration.
- The single 2000 μm or one 500 μm detector can use monoenergetic conversion electrons.
- Stack can be calibrated separately and checked after assembly with Compton edge.



Next Steps

- How to read out up to 5x144 channels?
- Manufacturing of stack detector feasible?
- Investigate backscattering effect on detector performance.

Acknowledgements

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References

- [1] R.L. Workman et al. (Particle Data Group), Prog. Theor. Exp. Phys., 2022
- [2] Jackson, J. D.; et al.: Possible Tests of Time Reversal Invariance in Beta Decay, 1957
- [3] NEA, PENELOPE 2018: A code system for Monte Carlo simulation of electron and photon transport, 2019.
- [4] Knoll, G. F.: Radiation detection and measurement, 2010.
- [5] Spieler, H.: Semiconductor Detector Systems, 2005.
- [6] Li, Z.; Kraner, H. W.: Modeling and simulation of charge collection properties for neutron irradiated silicon detectors, 1993.