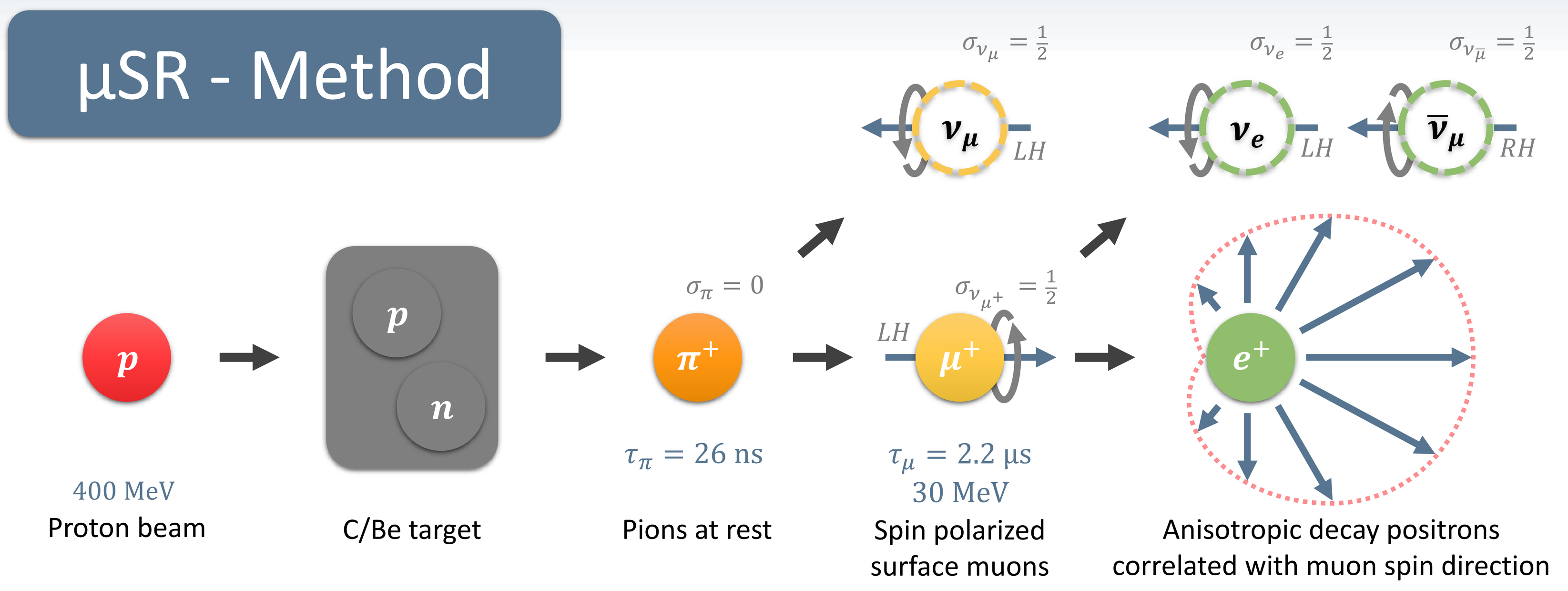
A **Silicon Pixel Tracker** for future **μSR Experiments**

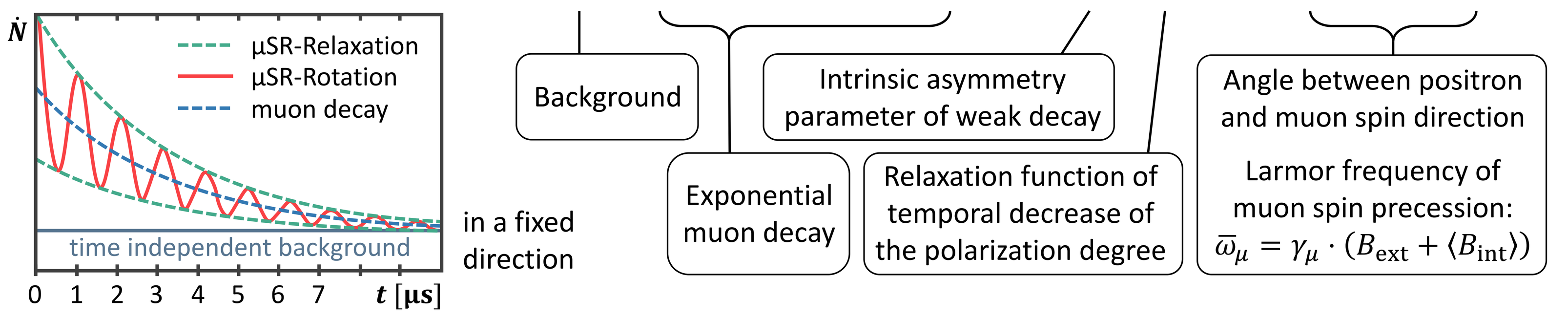
Enabling more precise and efficient investigation of **magnetic** and **superconducting** materials through **vertex reconstruction**

Muon Spin Rotation/Relaxation/Resonance (μSR) is used to measure local magnetic fields within a sample material.
Parity violation in muon decay results in an anisotropic positron emission that correlates with the muon's spin direction.
Magnetic fields present in the material affect the muon's spin precession, which can be quantified by the positron emission rate.

μSR - Method

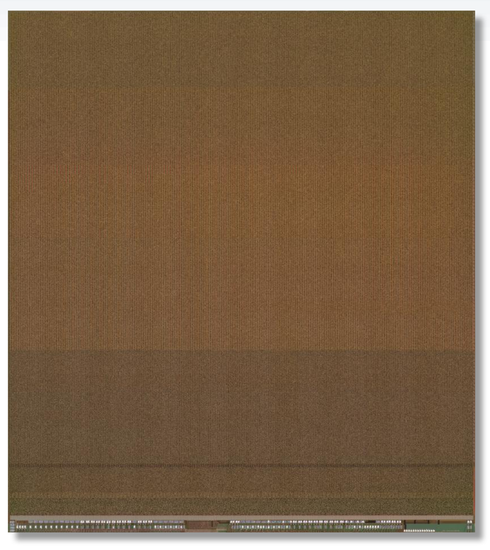


Positron rate: $N(t)/dt = B_0 + N_0 \cdot \exp(-t/\tau_\mu) \cdot [1 + A_0 G_\perp(t) \cos(\bar{\omega}_\mu t + \phi)]$



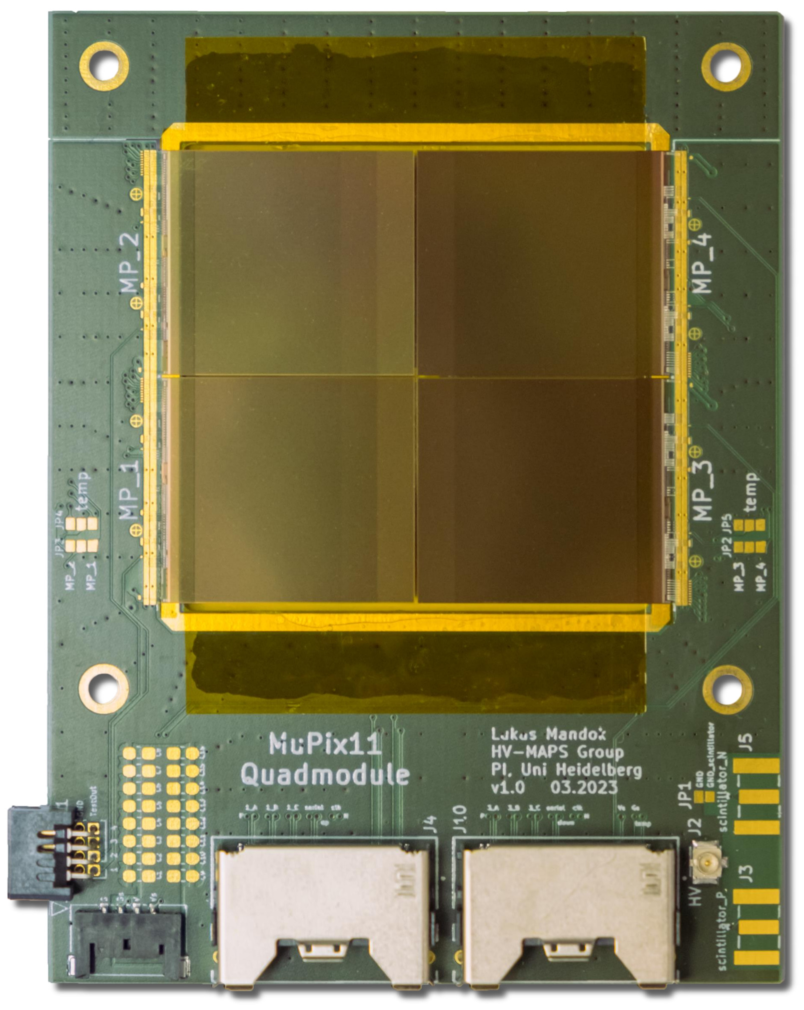
HV-MAPS

- **H**igh-**V**oltage **M**onolithic **A**ctive **P**ixel **S**ensor
- Embedded readout electronics in deep n-wells within substrate
- Reversely biased substrate for fast charge collection via drift



Mupix11 specifications:
- Active area: 20×20 mm^2
- Pixel size: 80×80 μm^2
- Can be thinned down up to 50 μm ($< 7 \times 10^{-4}\ X_0$)
  ⇨ Ideal for low momentum particle tracking

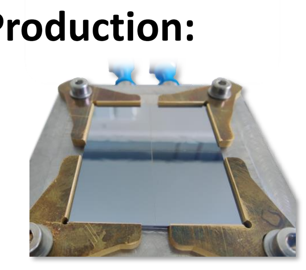
Mupix11 Quad Module

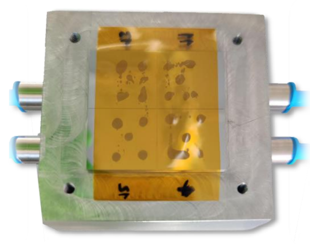


- Module with large active sensor area for beam monitoring and μSR detector prototype

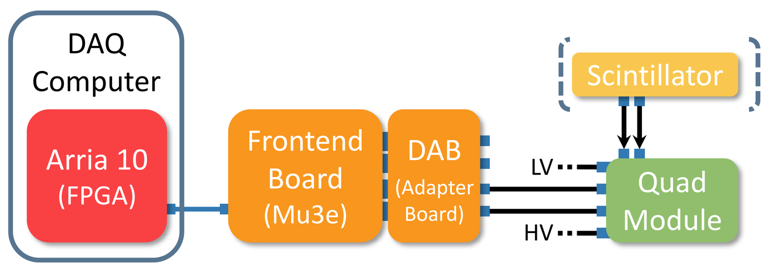
Specifications:
- 2×2 grid of 50 μm **Mupix11** sensors
- 25 μm Kapton foil for structural support
- Active area: 40×40 mm^2
- Sensor spacing: 200 μm

Production:


Sensor alignment


Sensor gluing

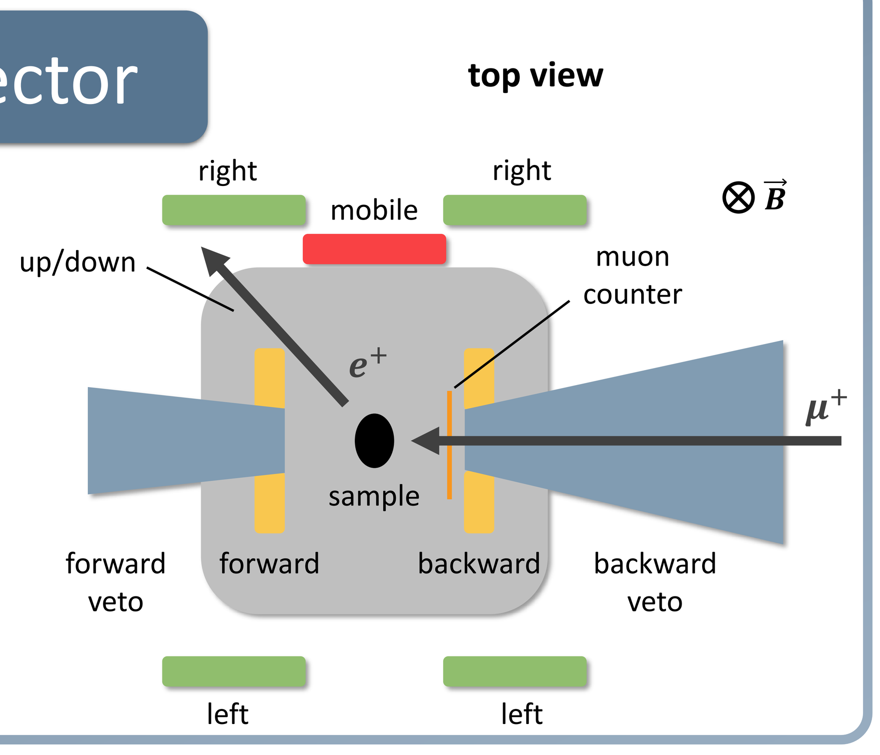
DAQ:
- Minimal, Mu3e compatible DAQ setup
- Optional scintillator input for improved timing



Scintillator-Based Detector

Principle:
- Scintillators measure Time-of-Arrival of incoming muon & emitted positron
  ⇨ temporal evolution of asymmetry between forward and backward signals

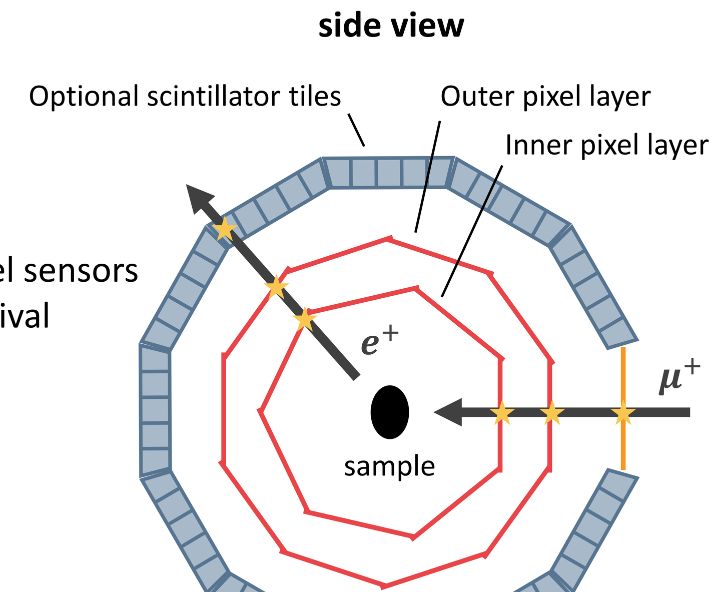
Disadvantages:
- No position information of muon decay
- Maximal 1 muon per time window of 10 μs
  ⇨ veto logic to filter out pile-up and non-decayed muons
  ⇨ limited acceptance rate of ~ 18 kHz

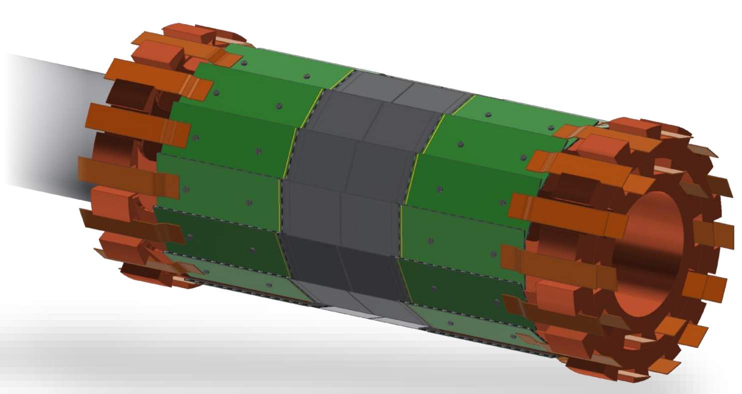


Pixel-Based Detector

Principle:
- Barrel of inner and outer pixel layer
- Incoming muons and outgoing positrons tracked by pixel sensors
  ⇨ Trajectory ⇨ Stopping position ⇨ Time of arrival
- Optional scintillator tiles to improve time resolution

Advantages:
- Vertex reconstruction allows to differentiate between several simultaneous events and their origin
- Expected position uncertainty: Positron ≤ 1 mm
  (for 100 MeV muons) Muon ≤ 0.6 mm
  ⇨ Increased muon rate by 10 – 100 times
  ⇨ Several smaller samples possible at once
  ⇨ Increased observation time of ~ 20 μs

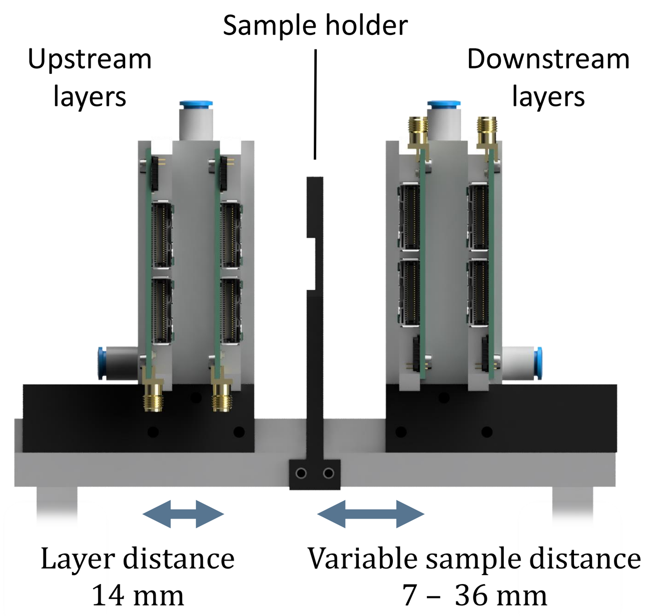


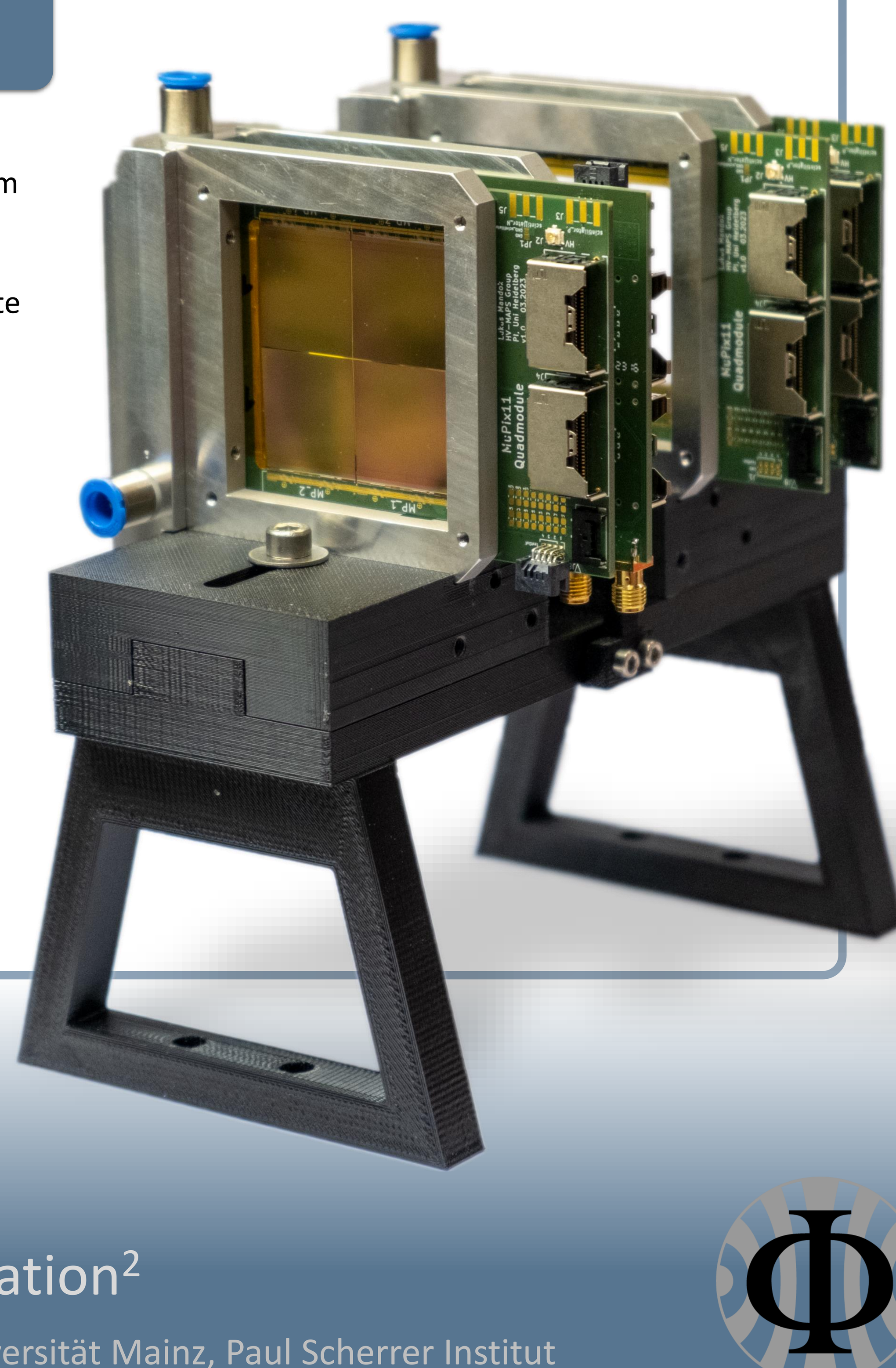


Goals:
- Prove of principle
- Detector characterization & cooling studies
- Resolve 1 mm structures
- Measure upper limit of muon rate increase

Detector Prototype

- 4 Quad Module layers:
  - 2 upstream – sample – 2 downstream
- Sensor cooling options:
  - Air-cooling via fan
  - Water-cooling of frame and backplate heatsinks





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