

First results of modular drift chamber design based hodoscopes

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Muography Workshop 2026 in Budapest (1. - 5. June 2026)



Outline

- Motivation
- Detector Developments
- Results and Measurements
- Summary & Conclusion



02.06. | 11:35 => Johann Wolf , An algorithm to localize position indicators using atmospheric muons

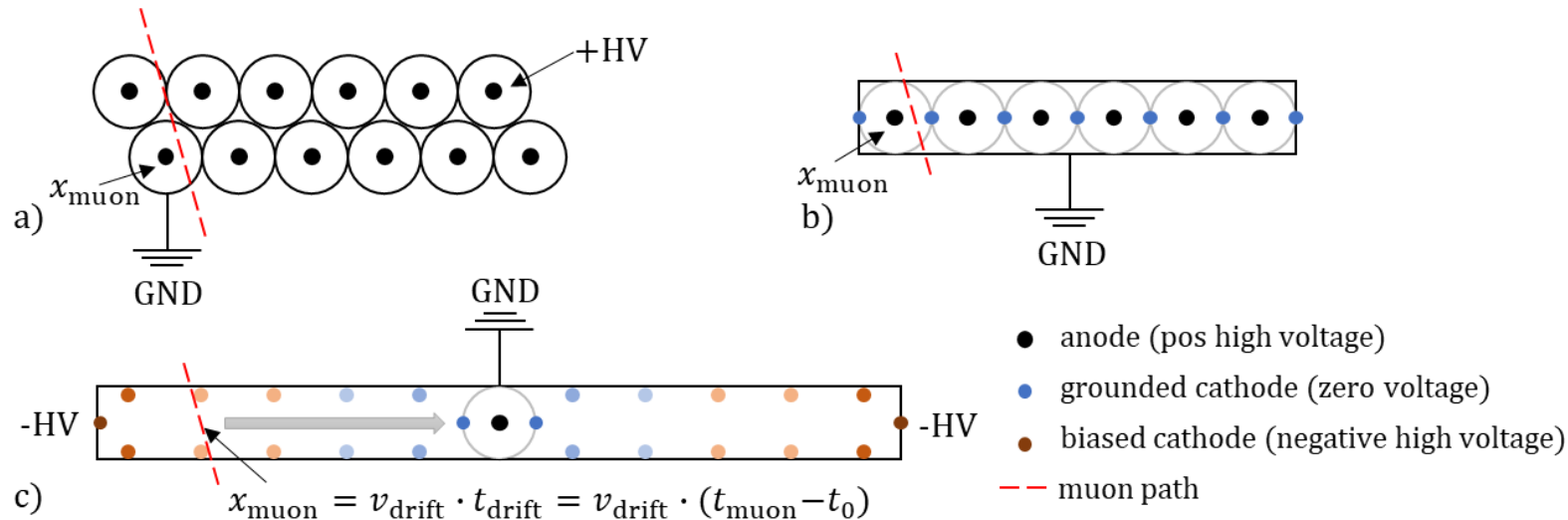


04.06. | 11:50 => Suzanne Eisenhofer, Methodical and Experimental muon imaging for monitoring of industrial facilities

Detector Developments

Detector Selection

a) Single-wire gas tubes, b) Multi-wire gas chamber, c) Single-wire drift chamber



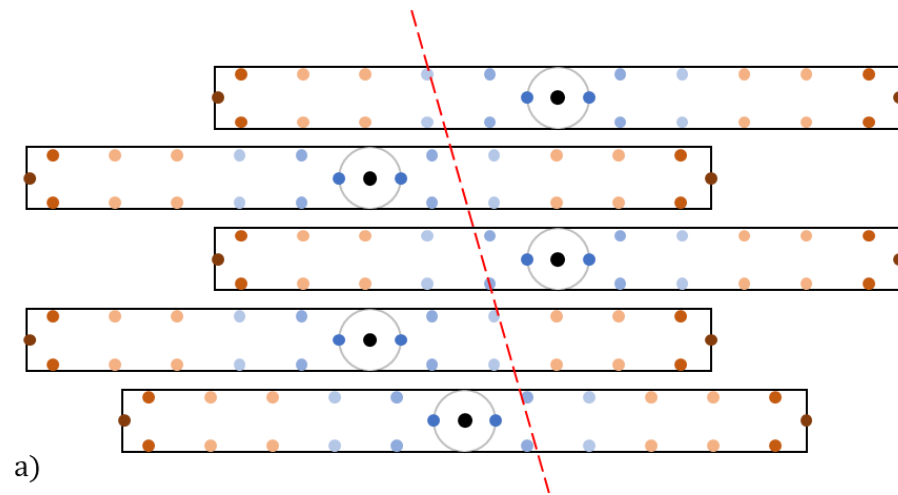
Requirements to a hodoscope:

- ✓ Muon track angle accuracy: $< 1^\circ$
- ✓ Spatial resolution: < 1 mm
- ✓ Low(est) Power Consumption
- ✓ Low(est) Costs
- ✓ Low(est) Weight
- ✓ High Robustness / Low Fragileness
- ✓ Weatherproof (Rain, Sun, Cold, Hot, etc.)
- ✓ Easy Handling
- ✓ Modular / High flexible application

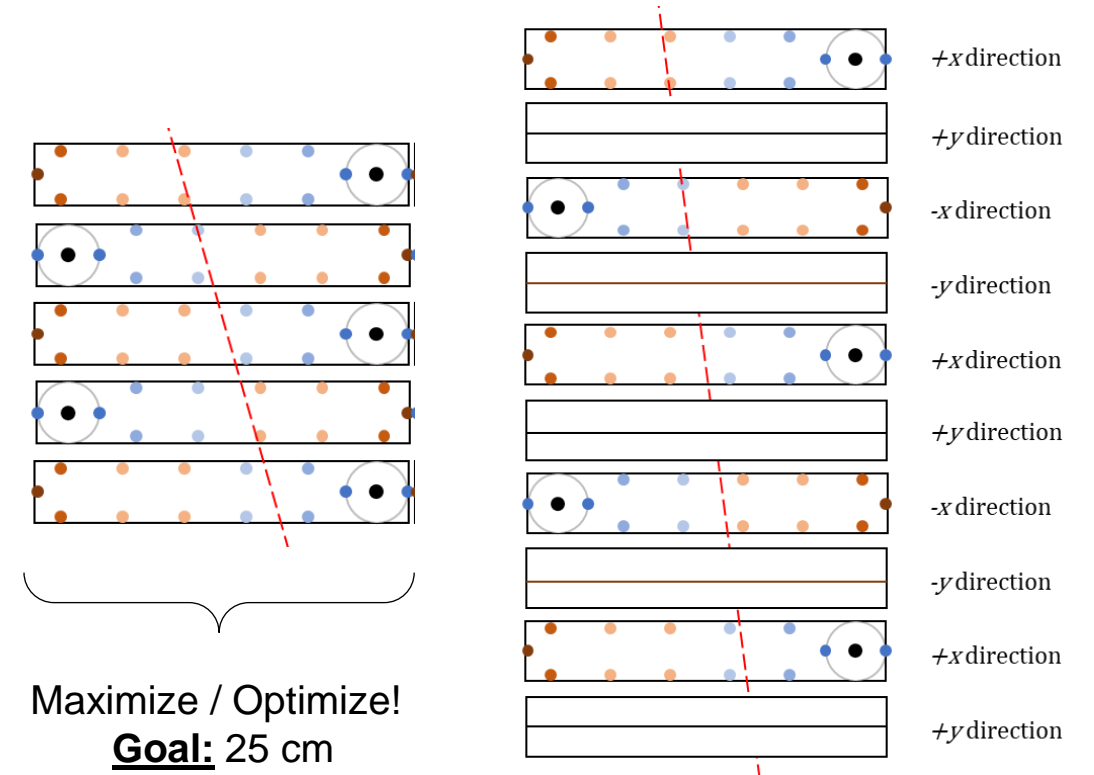
Detector Developments

Detector Design

Hodoscope using symmetric drift chambers



Hodoscope using single-ended drift chambers



=> 16 pcs / m² × 2 × 4 = 128 channels

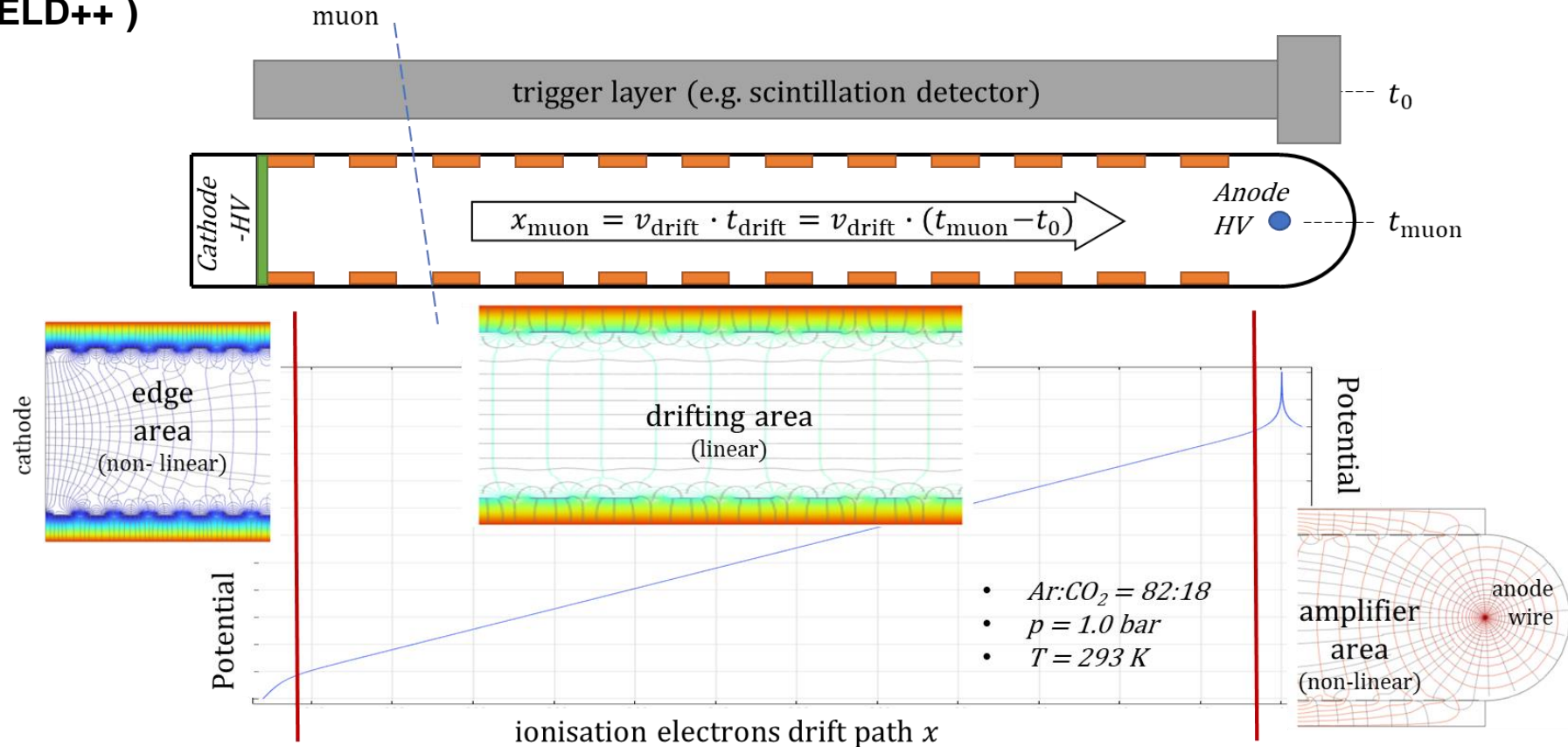
+1 channel (trigger)

Bieberle, A. et al, Nucl. Inst. Meth. Phys Res A 1087 (2026) 171425

Detector Developments

Detector Optimization

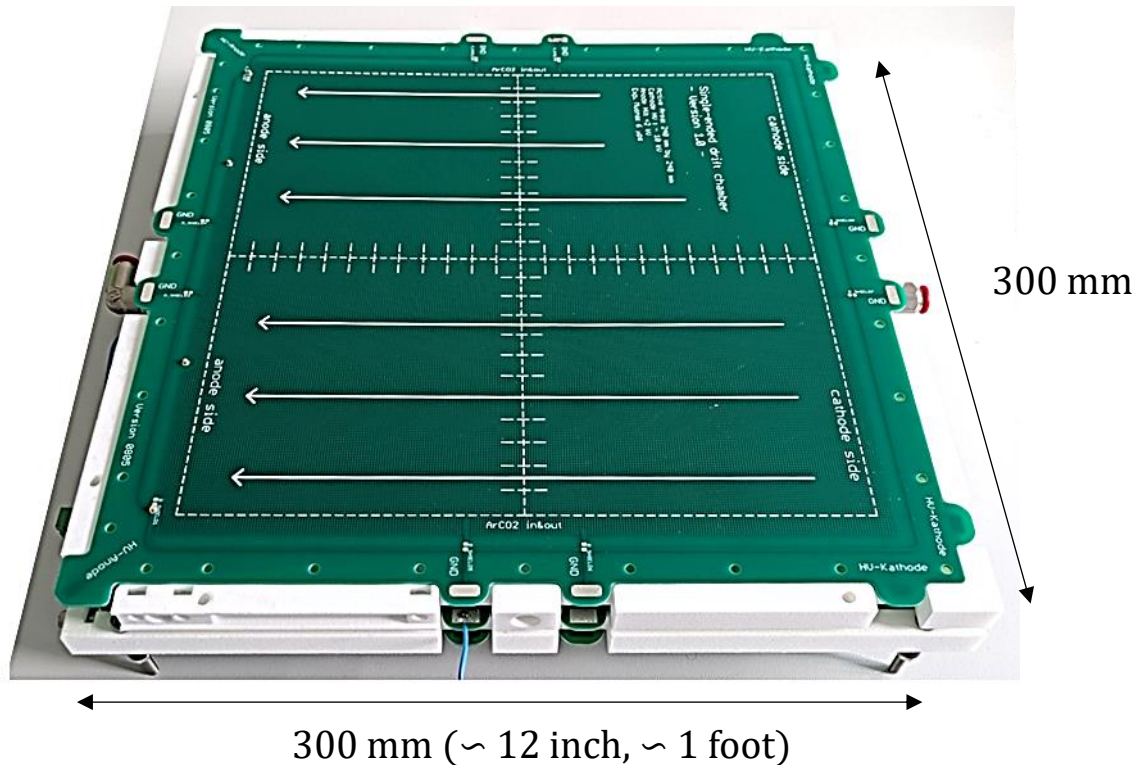
(COMSOL, GARFIELD++)



Bieberle, A. et al, Nucl. Inst. Meth. Phys Res A 1087 (2026) 171425

Detector Developments

Detector Manufacturing



Main Properties

- Geometric Size: $304 \times 304 \times 13 \text{ mm}^3$
- Active Volume: $250 \times 250 \times 10 \text{ mm}^3$ (625 min^{-1})
- High Voltages: +2 kV (anode), -10 kV (cathode)
- Drift Field: 0.4 kV / cm
- **Drift Length: 250 mm**
- Drift Velocity: 1.6 cm/us ($15 \text{ us @ } 250 \text{ mm}$)
- Gas Mixture: Ar:CO₂ (82:18)
- Clock frequency: 125 MHz (8 ns)
- Resolution: 0.16 mm (Sampling)
- Signal Rise Time: analog: 100 ns (0 ... 2 V)
digital: 10 ns (0 ... $\pm 2 \text{ V}$)
- Consumption: 80 mW (HV) + 130 mW (signal)
- Weight: 0.8 kg (... still reducing ...)
- Stackable: $N \times 90^\circ$
- Efficiency: $> 95\%$

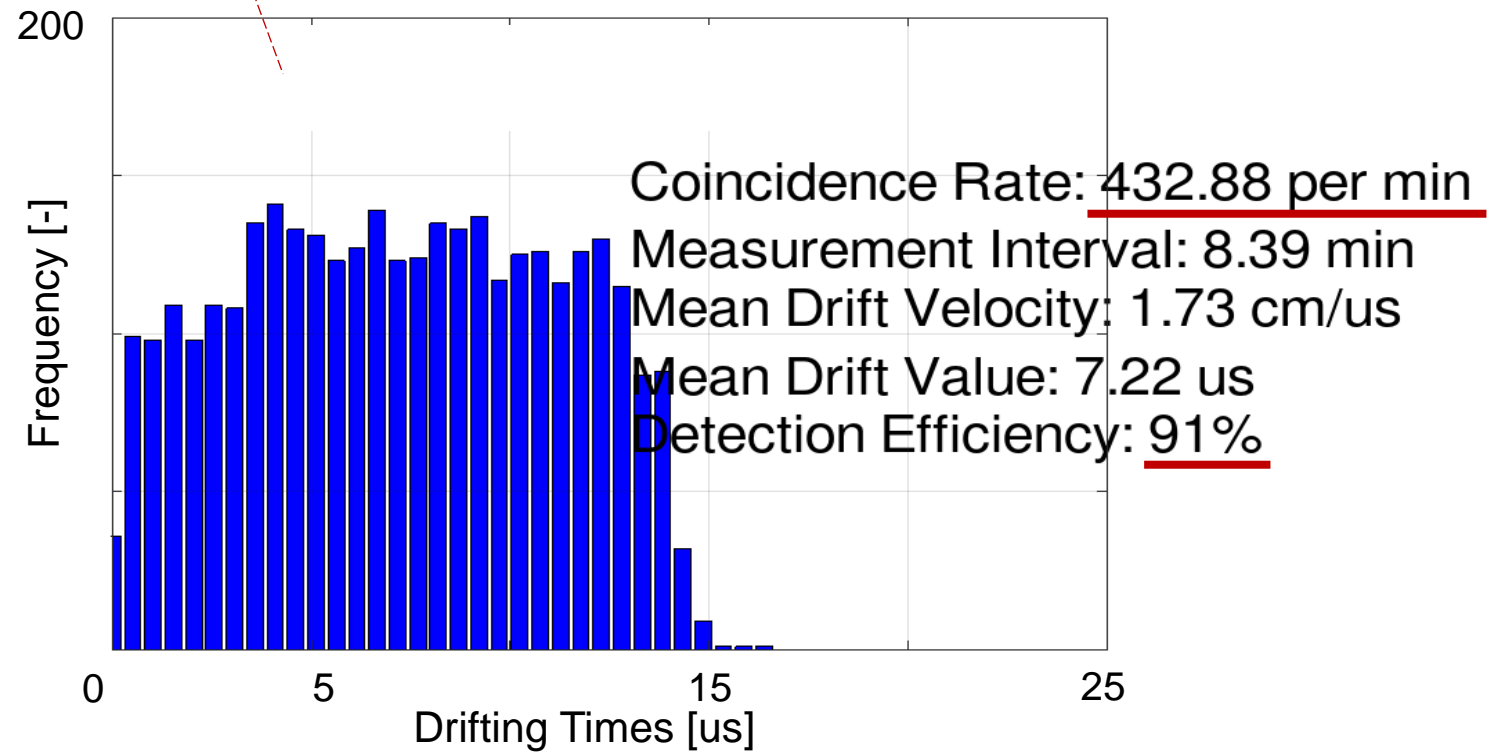
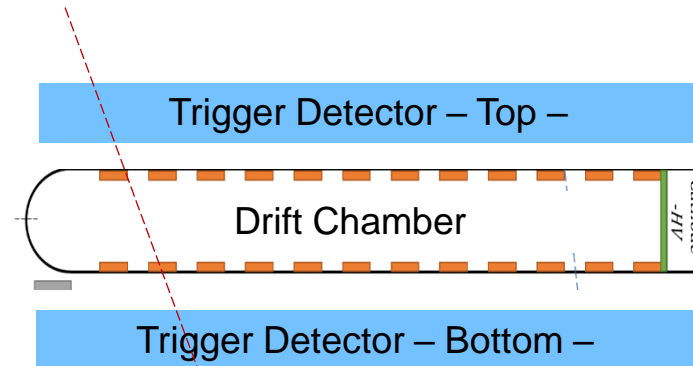
Detector Developments

Detector Evaluation I

Testing conditions

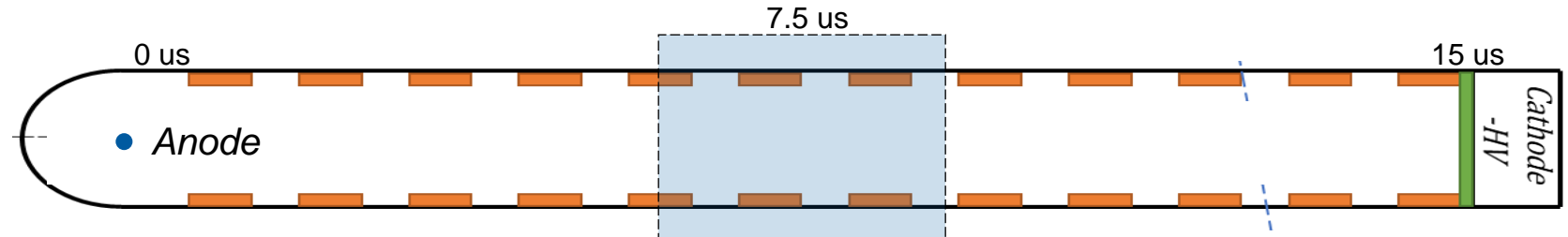
- Using two trigger detector of same active area in coincidence mode
- Distances to the drift chamber is 20 mm
- Measuring interval 10k events
- Resolution: 125 MHz
16 Bit (2048 mV)
- Sampling interval: 25 us (3125 samples)

Rao, G. et al., (2025), *J. Applied Phys*, 138(11).



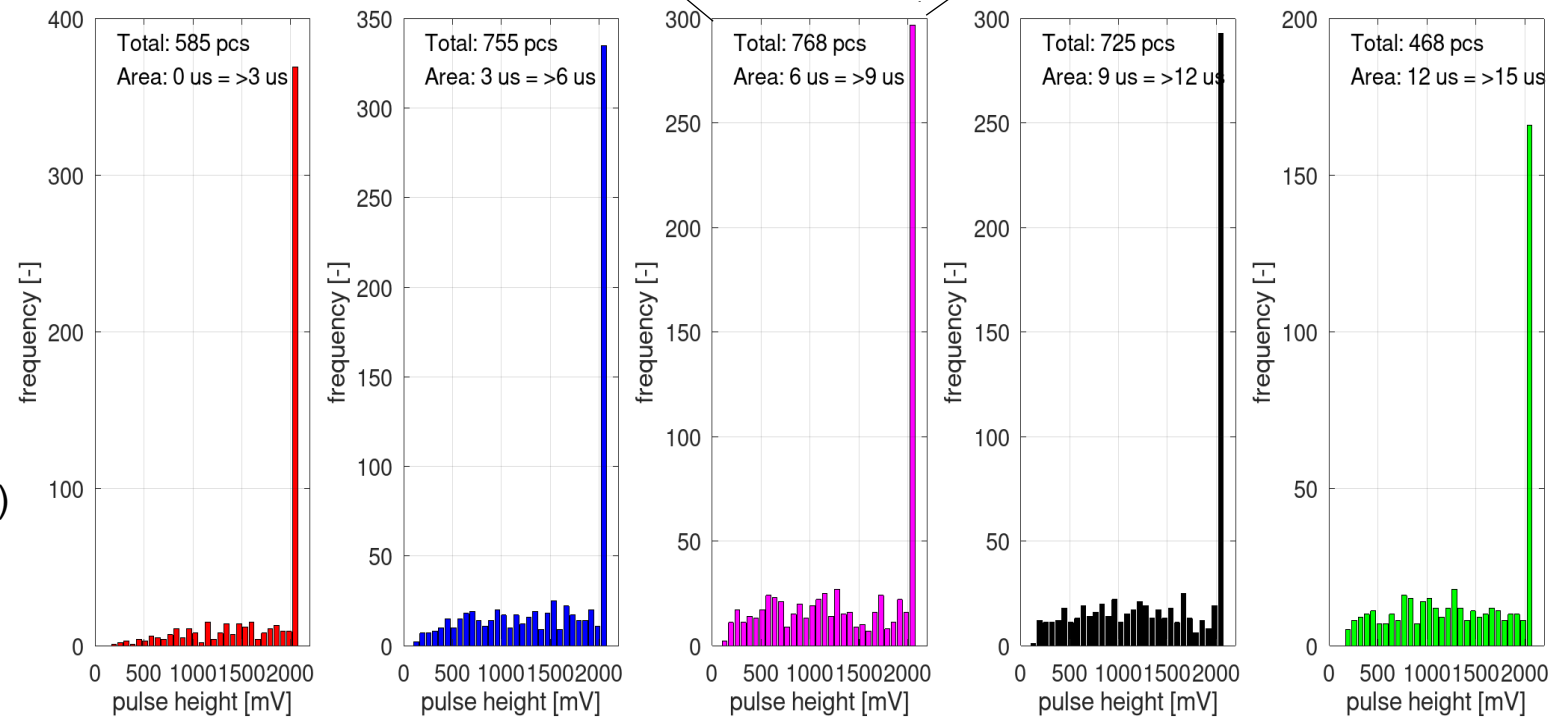
Detector Developments

Detector Evaluation II



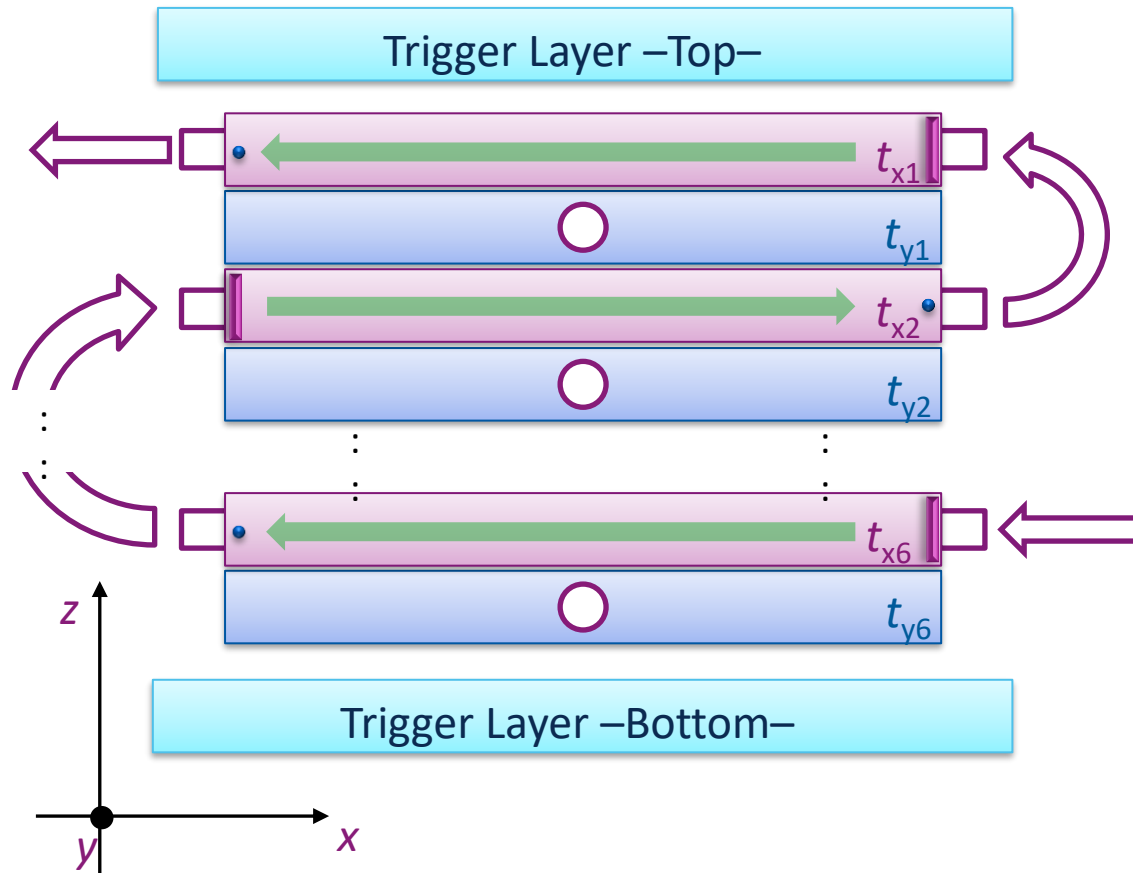
Testing conditions

- Using two trigger detector of same active area in coincidence mode
- Distances to the drift chamber is 20 mm
- Measuring interval 10k events
- Resolution: 125 MHz
16 Bit (2048 mV)
- Sampling interval: 25 us (3125 samples)



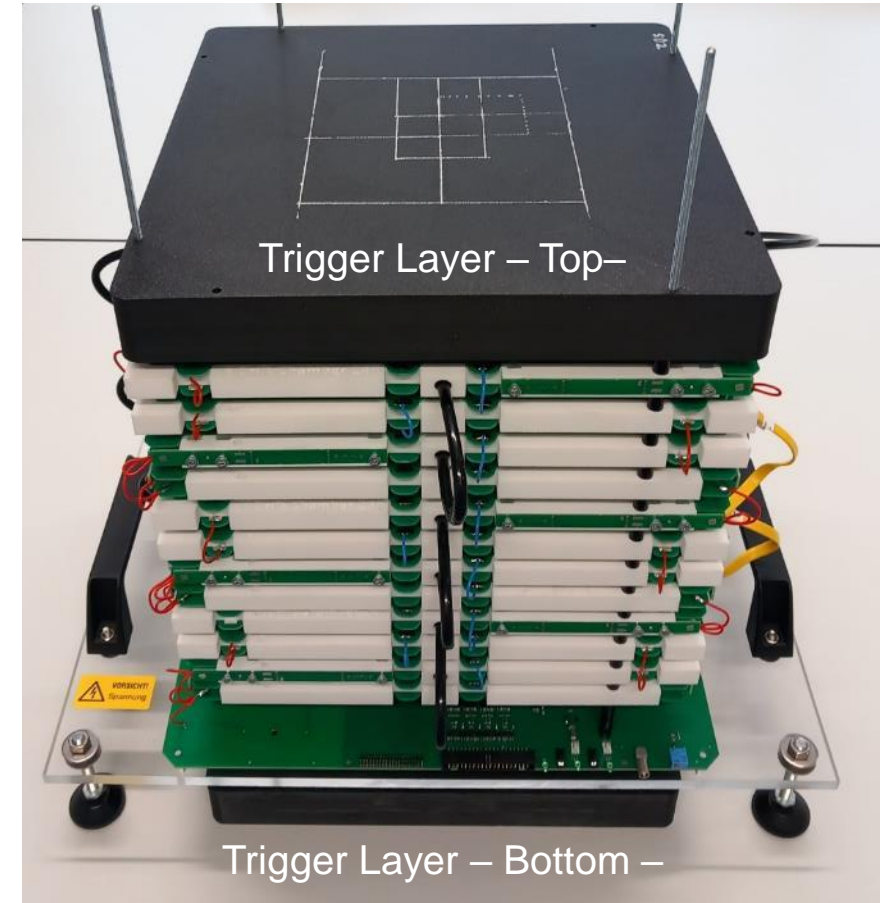
Detector Developments

Building a XY-hodoscope



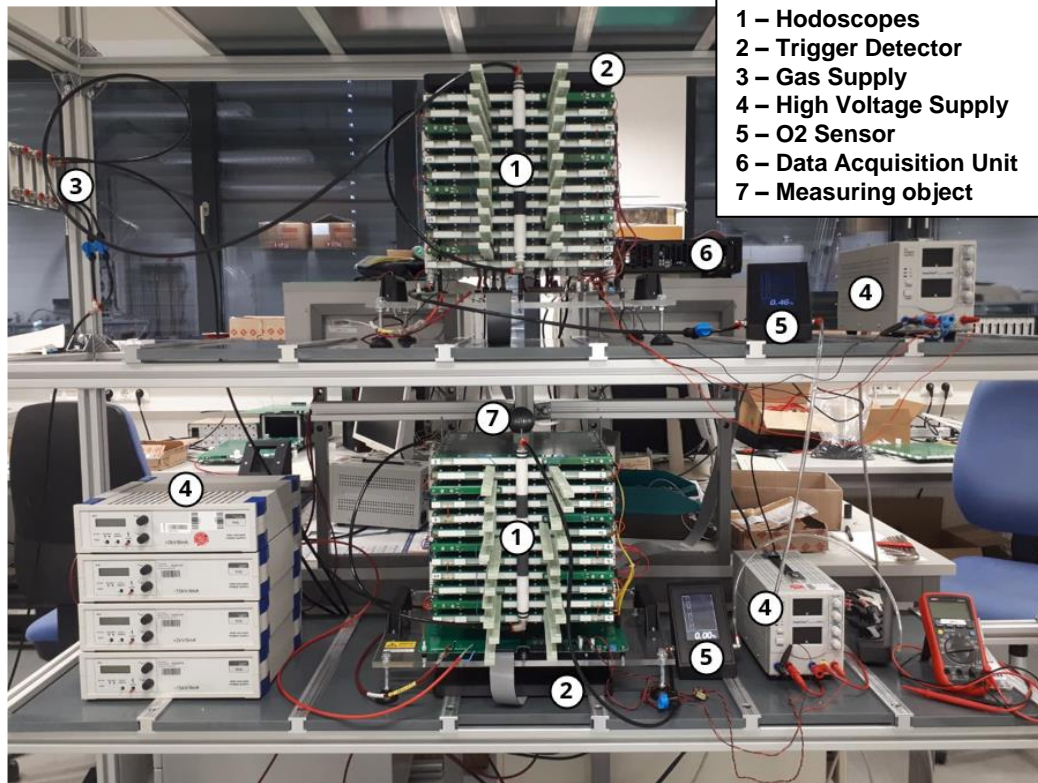
2 stacks of 6 drift chambers each
+ 2 scintillation based trigger detectors

= **Muon Hodoscope**

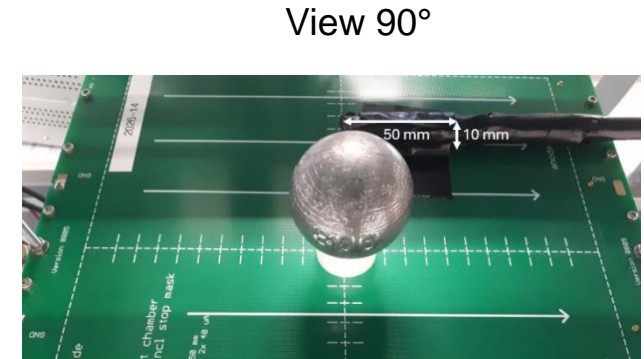
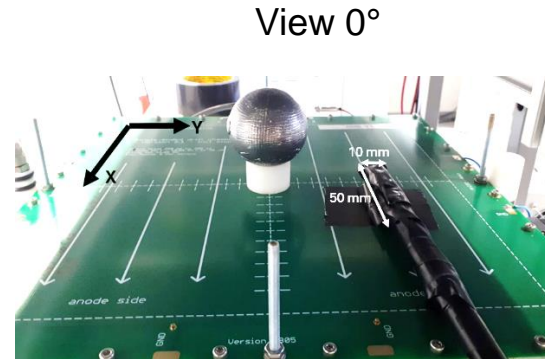


Results & Measurements

Investigations on imaging quality using a scintillation detector of 10 by 50 mm²

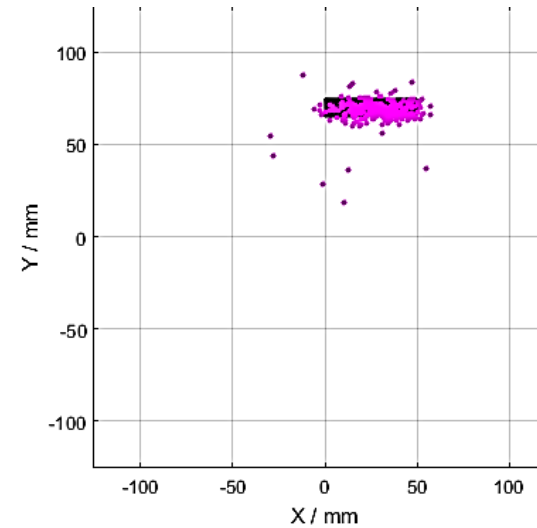


- 1 – Hodoscopes
- 2 – Trigger Detector
- 3 – Gas Supply
- 4 – High Voltage Supply
- 5 – O2 Sensor
- 6 – Data Acquisition Unit
- 7 – Measuring object

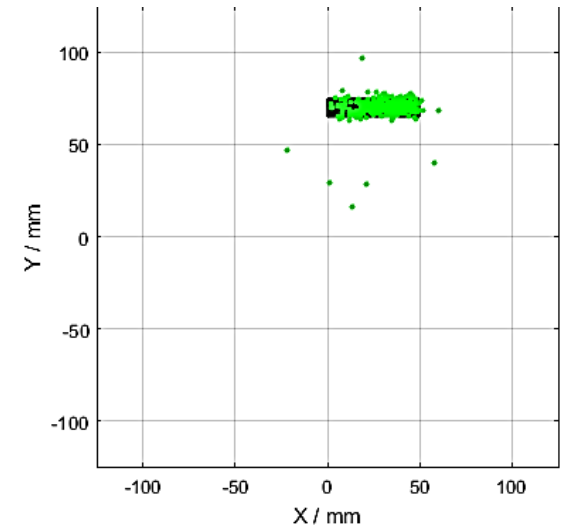


Obtained muon tracks from

Upper hodoscope

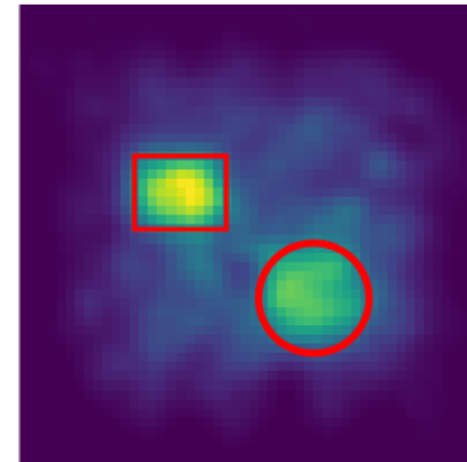
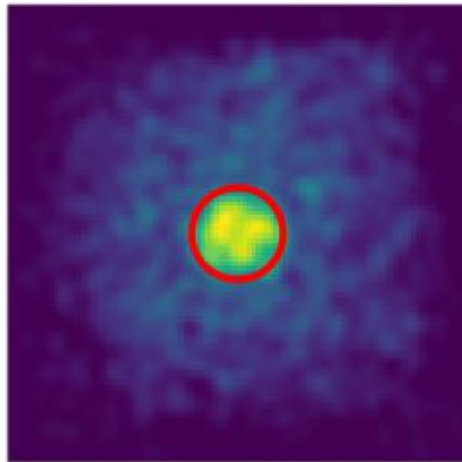
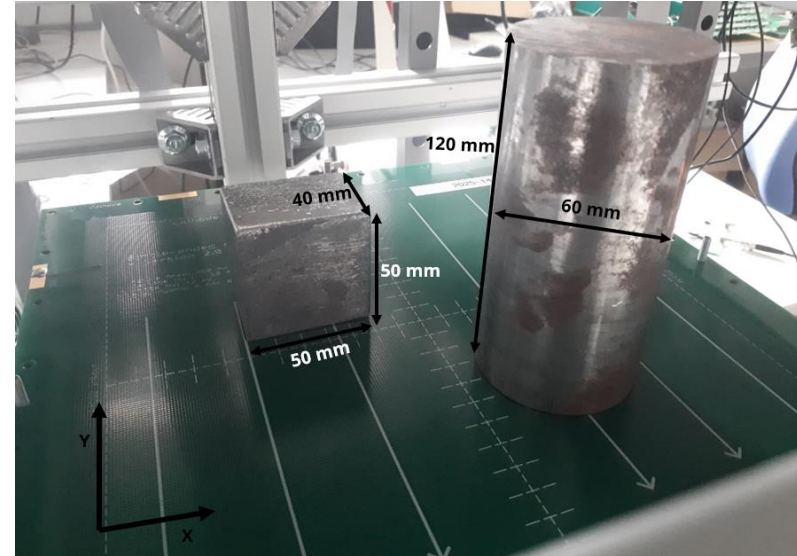
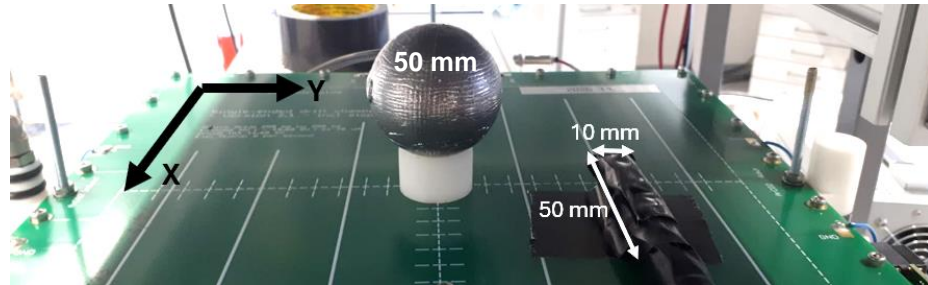


Lower hodoscope



Results & Measurements

Investigations on a
led sphere, led cube and steel bar



Wagner, M. et al, (2025). *J. Applied Phys.*, 138(1).

Results & Measurements

Investigations on a concrete sample



ODD ANDERSEN/AFP

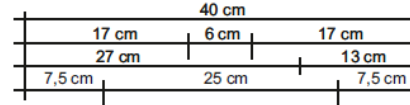
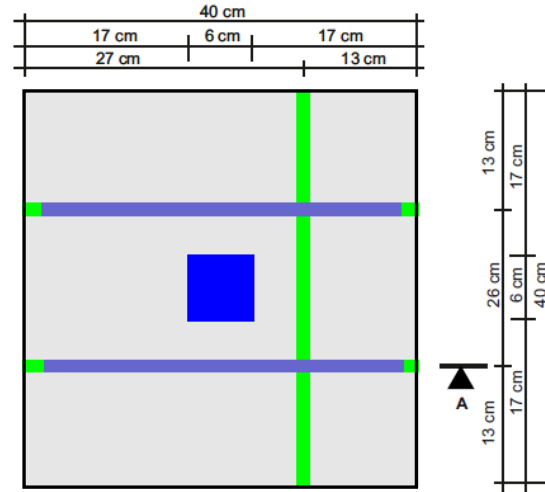
Can Muon Imaging be used for Structural Health Monitoring of buildings and bridges?

Project godparent:

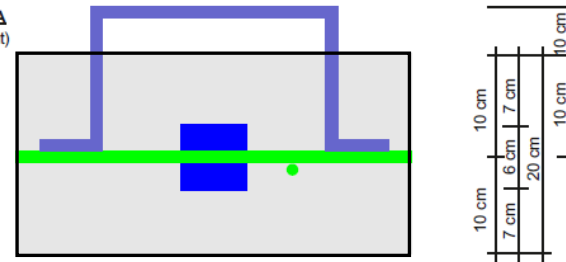


Bundesanstalt für
Materialforschung
und -prüfung

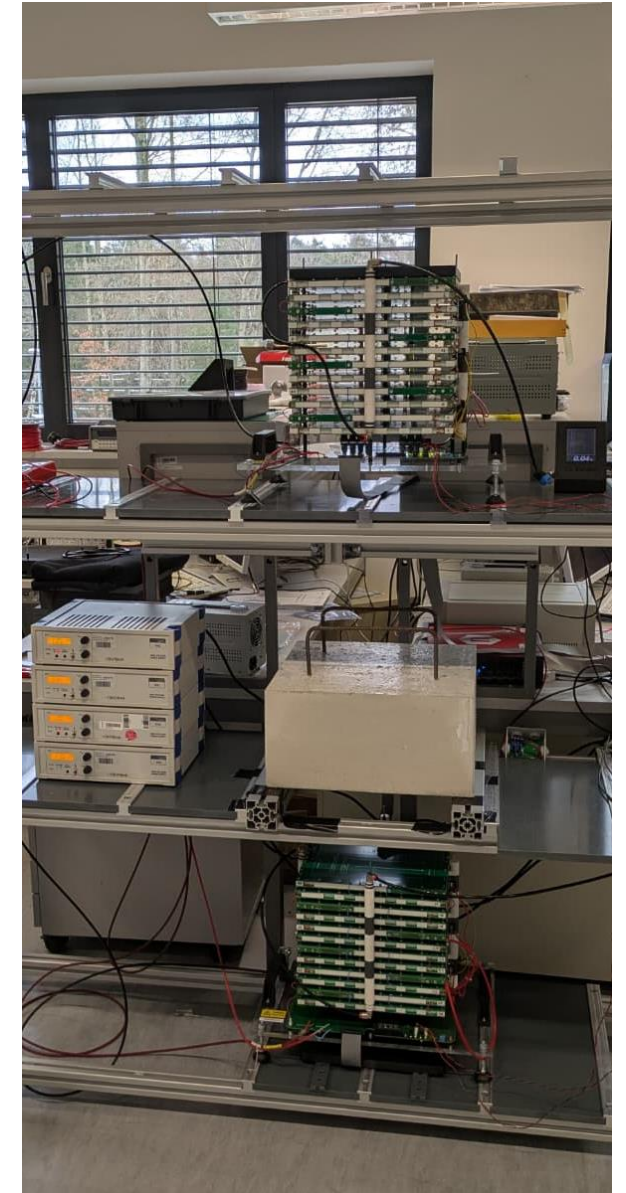
Draufsicht



Schnitt A-A
(Seitenansicht)



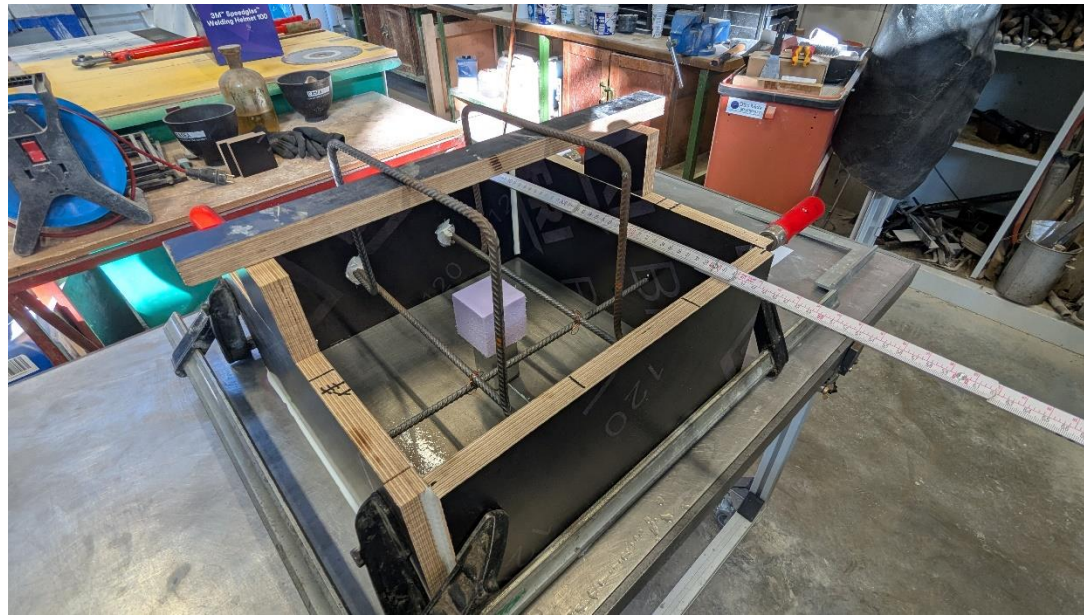
- Styropor o.ä., 6 x 6 x 6 cm³
- Baustahl (Durchm. > 8 mm)
Länge 40 cm, 3 Stk.
- Griff aus Baustahl (Durchm. > 8 mm)
Länge rd. 75 cm
- Beton (Güte egal), rd. 32 Liter



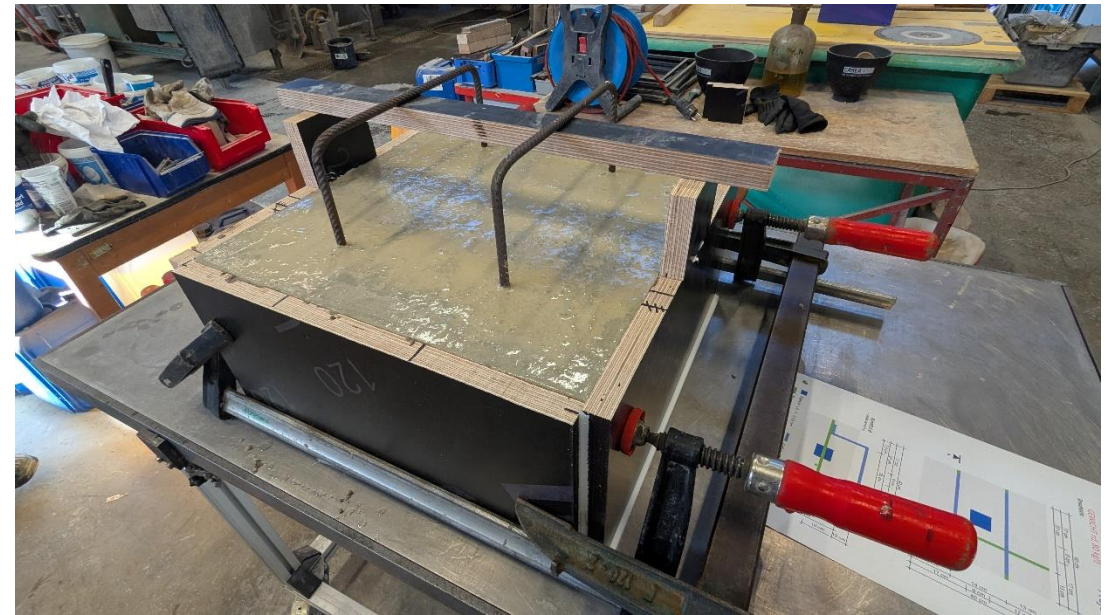
Results & Measurements

Investigations on a concrete sample

Before flooding with concrete



After flooding with concrete



Results & Measurements

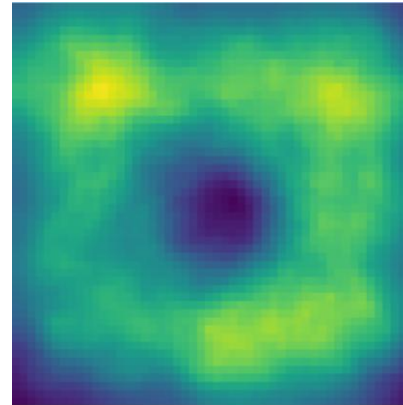
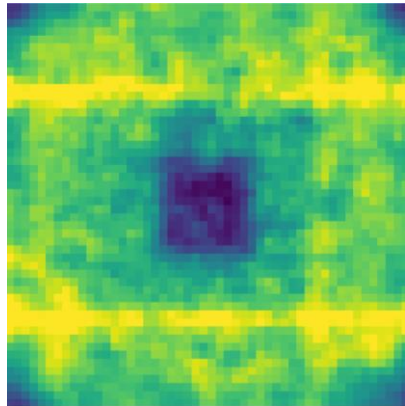
Investigations on a concrete sample

Simulation

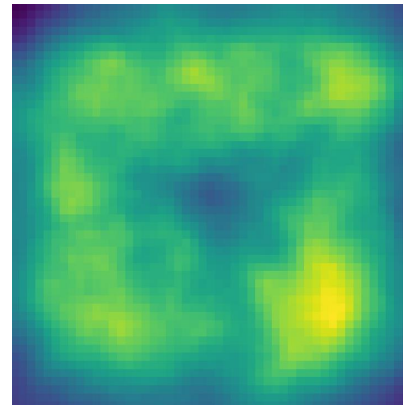
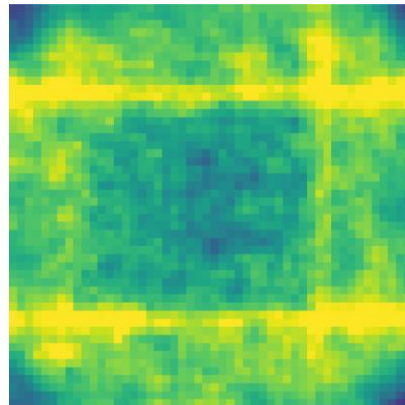
10^6 muons

7×10^4 muons

with styrofoam

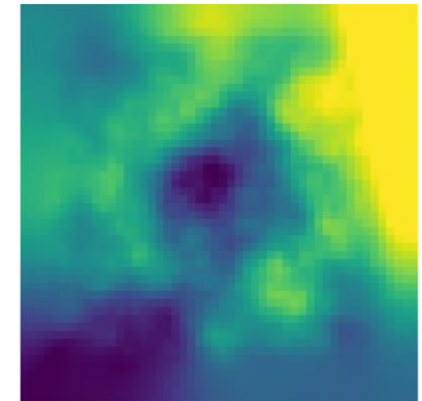


without styrofoam



Measurement

7×10^4 muons



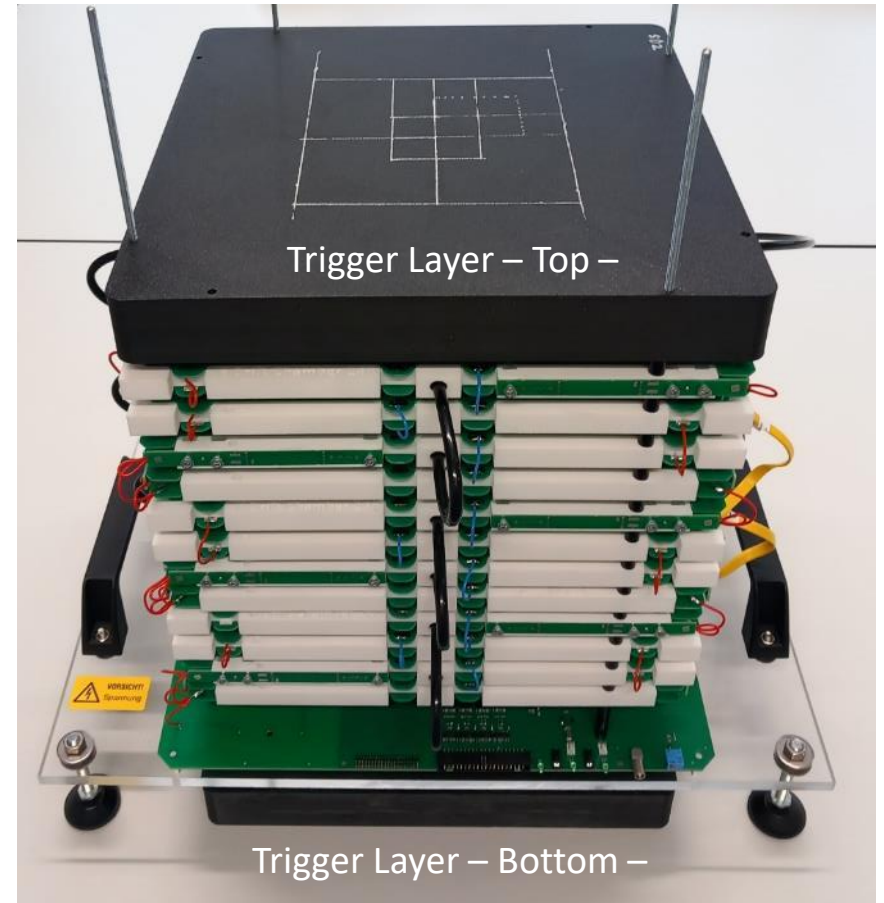
Summary / Conclusion

Conclusion

- Successful evaluation of modular drift chamber detector being suitable as key component in a muon detection measurement system for modular and flexible application
- Build up first muon hodoscope prototypes
- Successful measurements of simple object
- (Successful) measurements of a realistic object

Prospective

- Further geometry optimization of the drift chamber design
- Applying hodoscope(s) on heavy objects, such as CASTOR casks, bridges and kilns



Thanks for your attention

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HELMHOLTZ

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Wagner, M., Eisenhofer, S., Bieberle, A., & Hampel, U. (2025).

Algebraic image reconstruction for muon scattering computed tomography without tracing.
Journal of Applied Physics, 138(1).

<https://doi.org/10.1063/5.0273571>

Rao, G., Bieberle, A., Hampel, U., & Wagner, M. (2025).

Design studies on large muon trigger detectors using silicon photomultiplier devices.
Journal of Applied Physics, 138(11).

<https://doi.org/10.1063/5.0288270>

Bieberle, A., Wolf, J., Eisenhofer, S., Hampel, U., & Wagner, M. (2026).

Design optimization of a single-wire drift chamber for modular muon imaging applications.
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 171425.

<https://doi.org/10.1016/j.nima.2026.171425>

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