

PAUL SCHERRER INSTITUT



Michael Heiss :: MIXE :: Paul Scherrer Institute

GEM-TPC for low energy muon tracking: Introduction and Simulation Results

Monthly Tracker Meeting, 09.02.2023

MIXE: Muon Induced X-ray Emission

Archeological artifacts

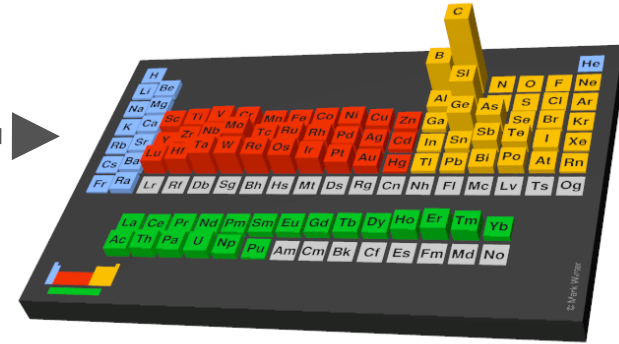
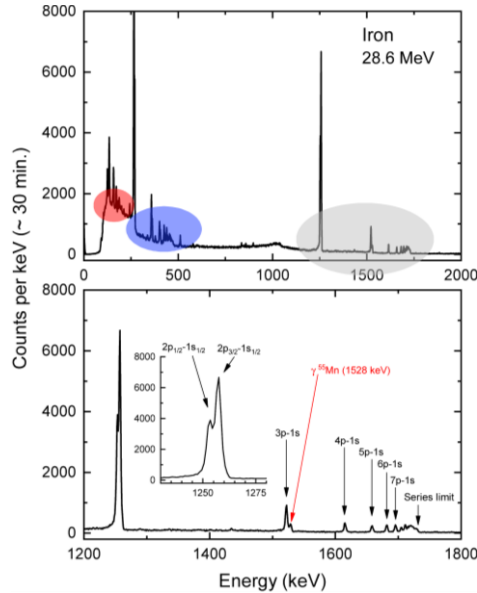


μ^-

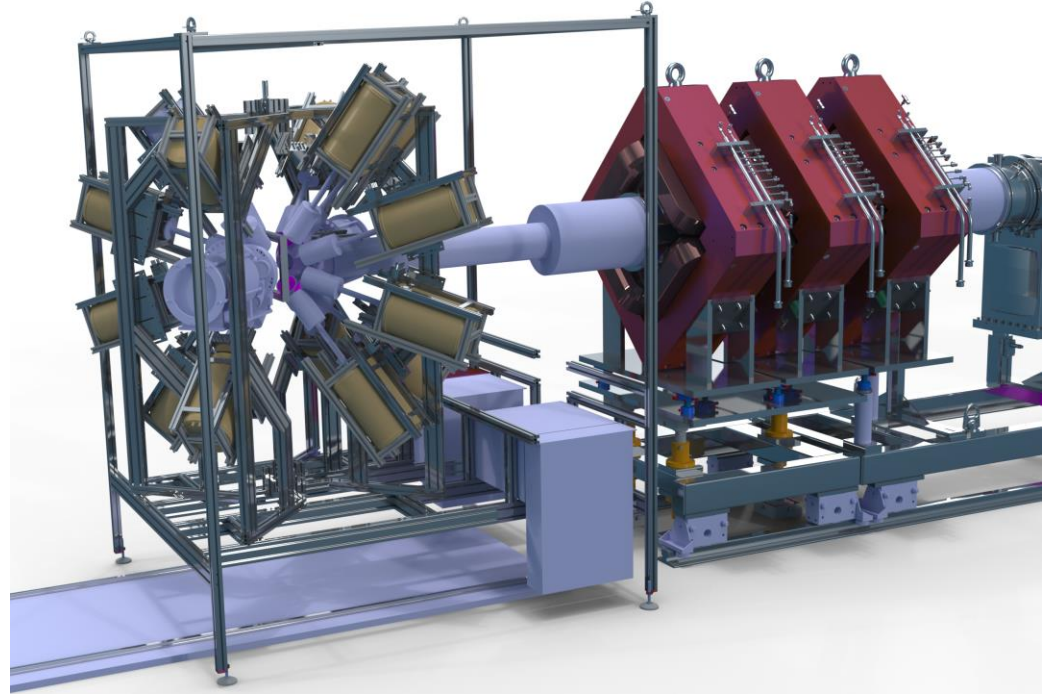
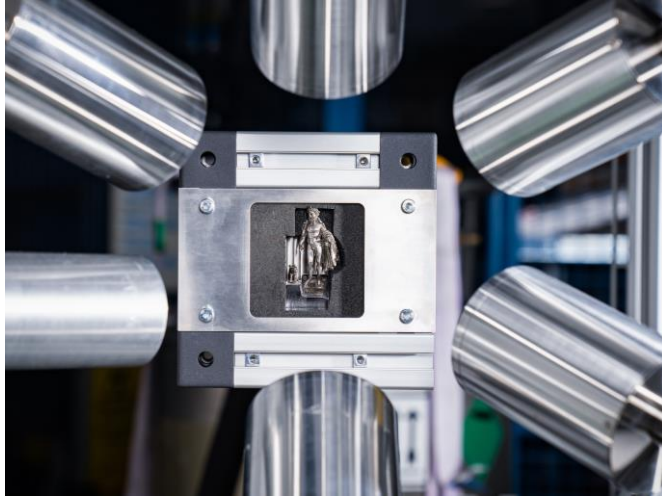
Meteorites

Batteries

and many more!



The GIANT setup



GIANT

Germanium Array for Non-destructive Testing

Beamline piE1.2 – Beamspot for MIXE

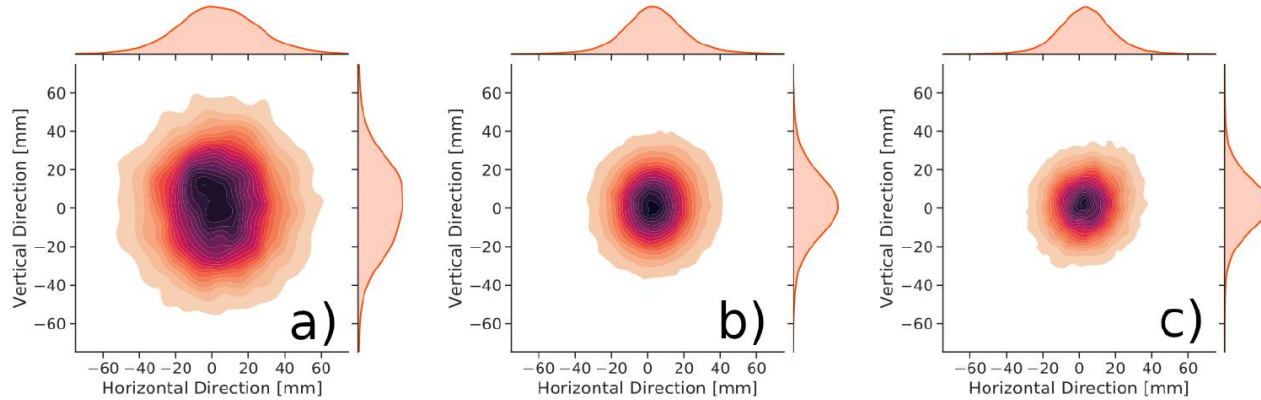
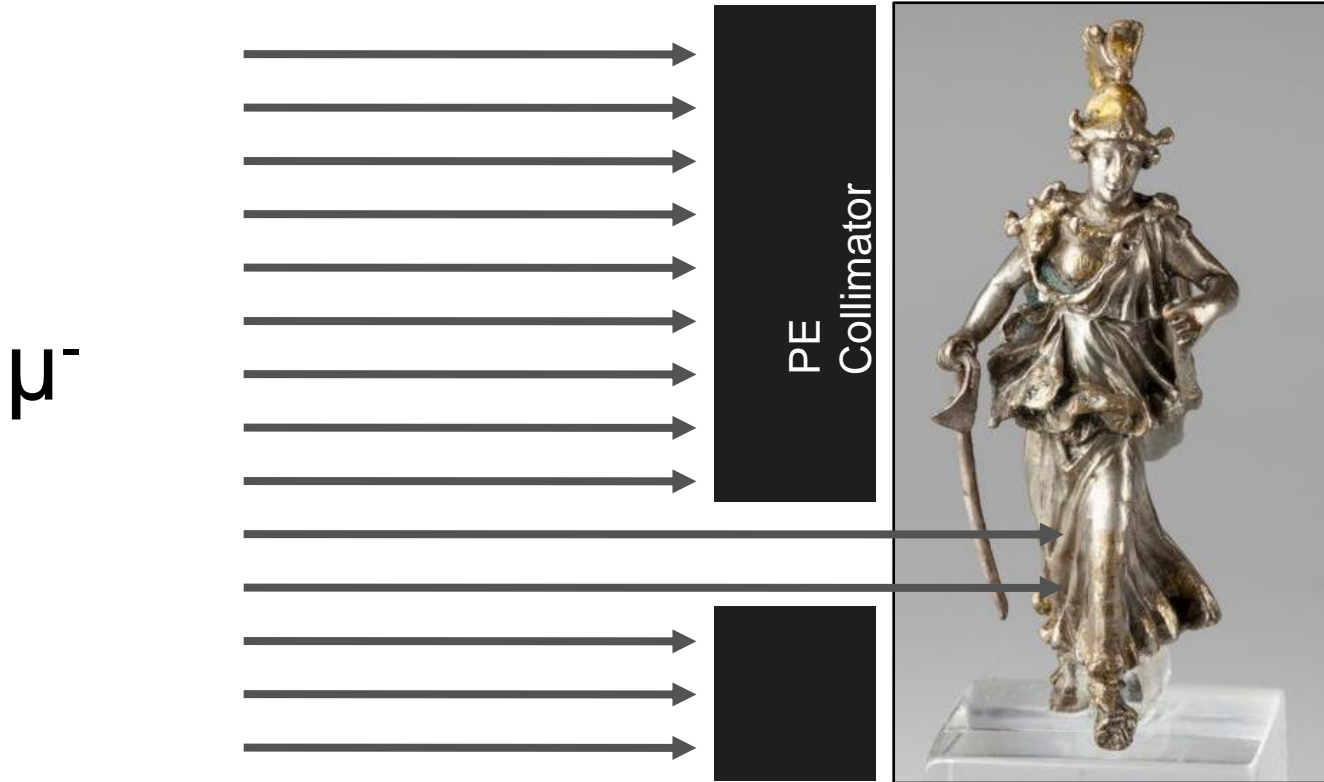


Figure 5: Beam spots on target during the MIXE campaign in 2022 May in $\pi E1$ for different momenta: (a) 25 MeV/c, (b) 35 MeV/c and (c) 45 MeV/c .

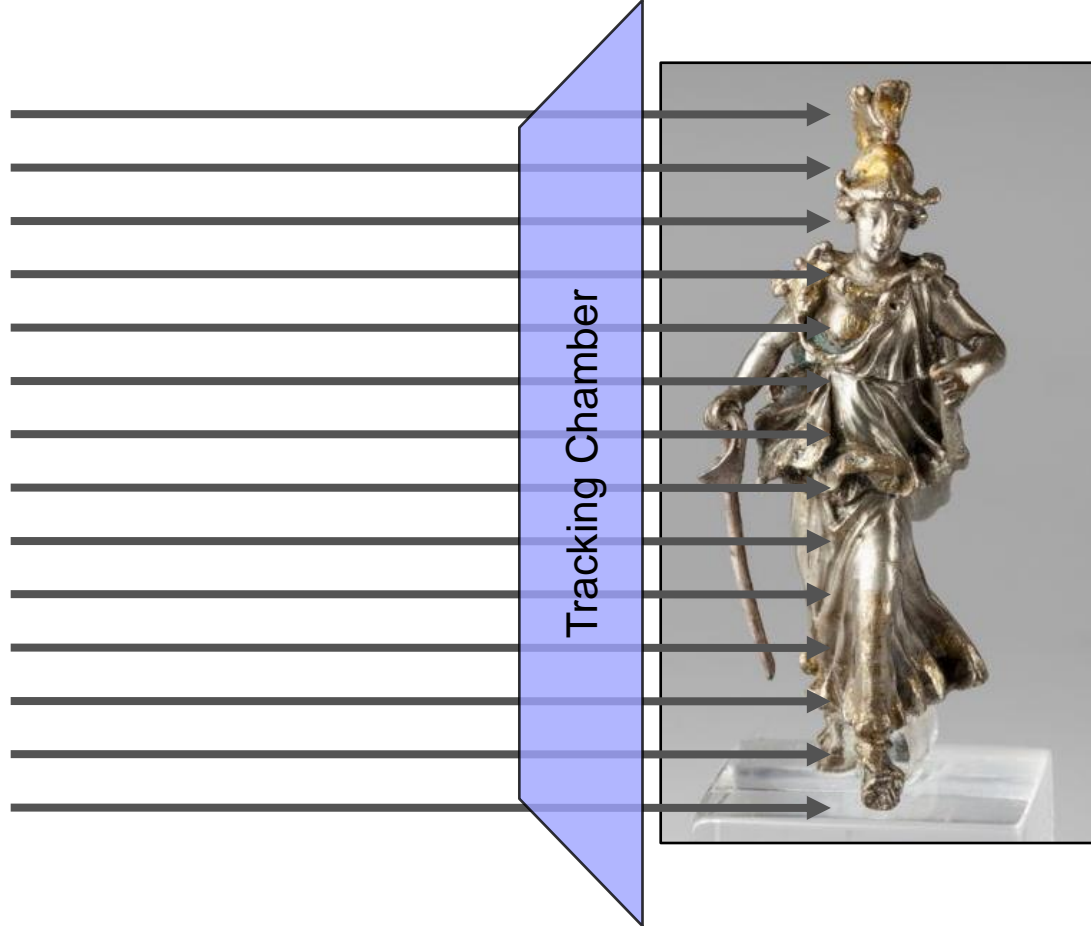
Momentum (MeV/c)	σ_x (mm)	σ_y (mm)
25	22.06(18)	23.54(18)
33	17.52(3)	18.07(3)
35	16.55(3)	17.24(3)
45	14.45(6)	14.34(6)

Small resolution details – Collimation



Small resolution details – Tracking

μ



Small resolution details – Tomography



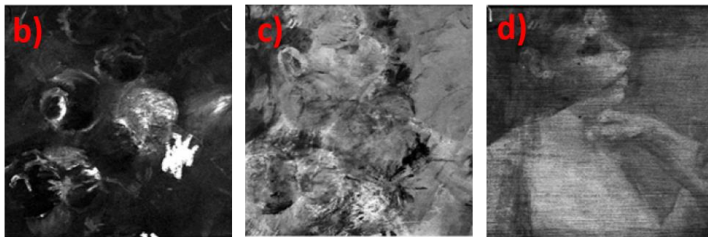
a) Vincent van Gogh's Flower Still Life with Meadow Flowers and Roses, summer 1886 (Kröller-Müller Museum, Otterlo, the Netherlands), rotated for illustration purposes.

b) Hg fluorescence signal of the area in the red box, flowers are visible.

c) Zn fluorescence signal of the same area, hints of a human face visible.

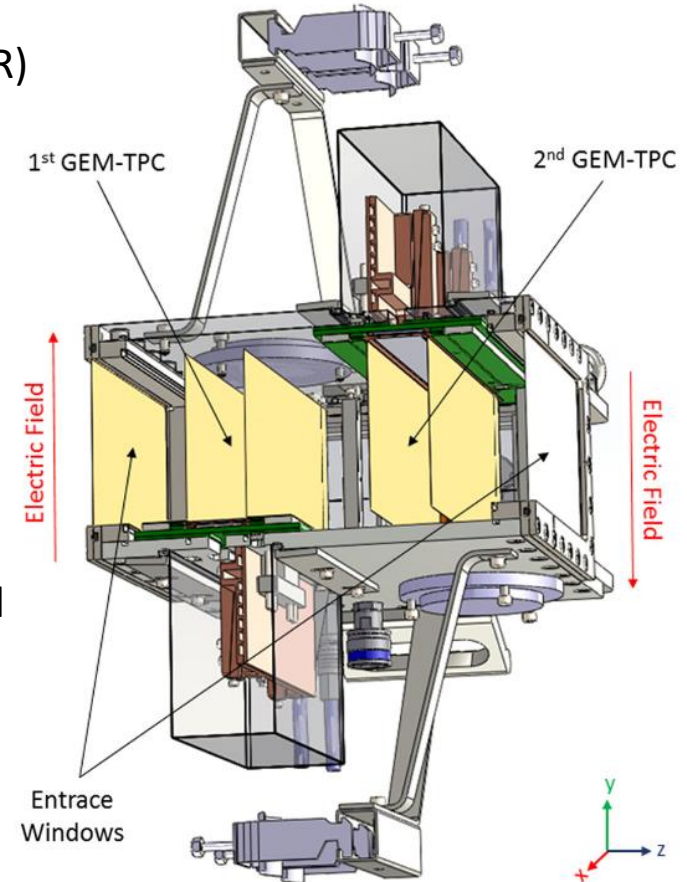
d) Zn fluorescence measured from the back of the painting with less absorption, revealing the human face as part of an overpainted wrestling scene..

M. Alfeld and J. A. C. Broekaert, Spectrochimica Acta Part B 88, 211- 230 (2013)



Twin GEM-TPC Tracking chamber

- Prototype for heavy ion tracking @ Super-FRS (FAIR)
 - Twin Time-Projection-Chamber
 - GEM stack amplification stage
 - 1D strip readout
 - 4th iteration prototype – great performance
- Still some general work remains to be done
 - Need to build calibration detector (fiber grid)
 - Setup of test bench after move to CERN
 - DAQ needs to be migrated to VMM3
 - Readout/Analysis software development needed
- Modifications for MIXE?
 - Low density gas?
 - Single chamber?
 - Underpressure?



Low Momentum Muon Tracking – Geant4 MC

- Multiple scattering over 10cm of gas at atmospheric pressure ($p \approx 25 \text{ MeV}/c$)
 - Air: $\sigma \approx 1.9 \text{ mm}$
 - ArCO₂ (90/10): $\sigma \approx 3.4 \text{ mm}$
 - HeCO₂ (90/10): $\sigma \approx 0.6 \text{ mm}$
- Multiple scattering considering complete detector setup + 10cm air
 - Original setup incl. twin GEM-TPC (HeCO₂):
 - $\sigma \approx 19 \text{ mm} (p \approx 25 \text{ MeV}/c)$ $\sigma \approx 7 \text{ mm} (p \approx 45 \text{ MeV}/c)$
 - Modified (slightly) setup incl. single GEM-TPC (HeCO₂):
 - $\sigma \approx 9 \text{ mm} (p \approx 25 \text{ MeV}/c)$ $\sigma \approx 3 \text{ mm} (p \approx 45 \text{ MeV}/c)$
- Tracker resolution on test target (1mm distance from tracker)
 - Original setup incl. twin GEM-TPC (HeCO₂):
 - $\sigma \approx 3 \text{ mm} (p \approx 25 \text{ MeV}/c)$ $\sigma \approx 0.9 \text{ mm} (p \approx 45 \text{ MeV}/c)$
 - Modified (slightly) setup incl. single GEM-TPC (HeCO₂):
 - $\sigma \approx 4 \text{ mm} (p \approx 25 \text{ MeV}/c)$ $\sigma \approx 1.3 \text{ mm} (p \approx 45 \text{ MeV}/c)$

Conclusions from simulation

- Multiple scattering in the gas is a serious concern
 - We need low density mixture, e.g. HeCO₂ (90/10) for reasonable performance
 - Underpressure (say 0.1atm) would solve this issue completely
- For test samples (masks, *to be produced!*) we expect the best tracking resolution with unmodified twin setup (allows to resolve angle!)
- Moderate modifications (single setup, gas vessel, tagging detector, etc.) will not suffice to meaningfully improve MIXE measurements
- **On a more positive note:** GEM-TPC is very promising solution with specialized design
 - smaller volume (e.g. 3x3x1 cm³)
 - single TPC, but with angular resolution (e.g. Timepix readout instead of 1D strips)
 - Underpressure
 - Optimized integration (single entrance window, low pressure extension to target, ...)

Planning: Next steps

- Calibration detector
 - Design?
 - Parts?
 - Production?
- Twin GEM-TPC @ CERN (possible from mid of March)
 - Testbench setup – *What infrastructure do we need?*
 - Gas tests
 - VMM3 integration
 - Readout/Analysis
- In-beam test with low energy muons at PSI (possibility from mid May to end of May)
 - Transport
 - Setup (Mounting, Electronics, etc.)