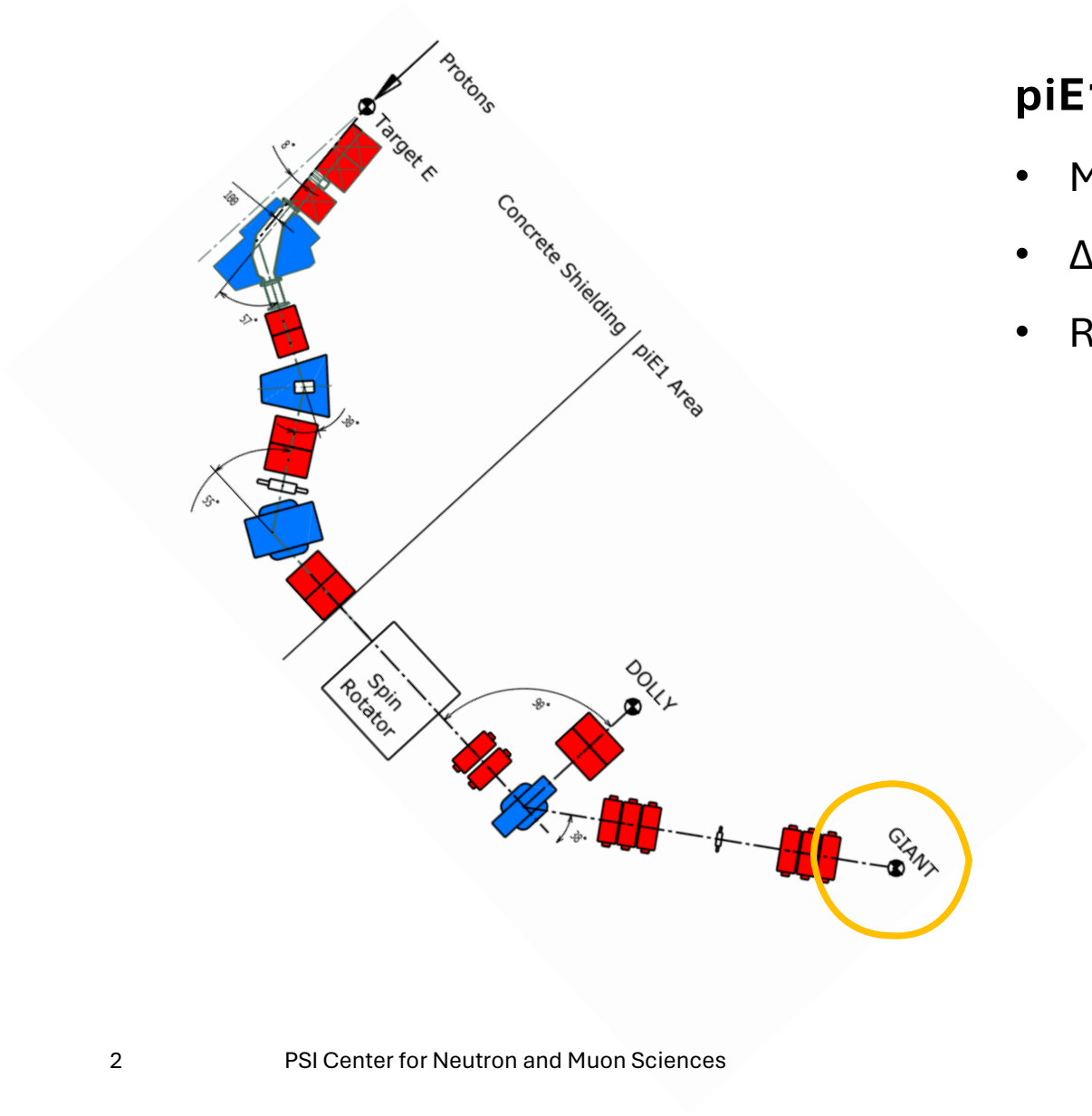
PSI Center for Corporate Services

Twin-GEM TPC for Low-Momentum Muon Beam Monitoring in MIXE

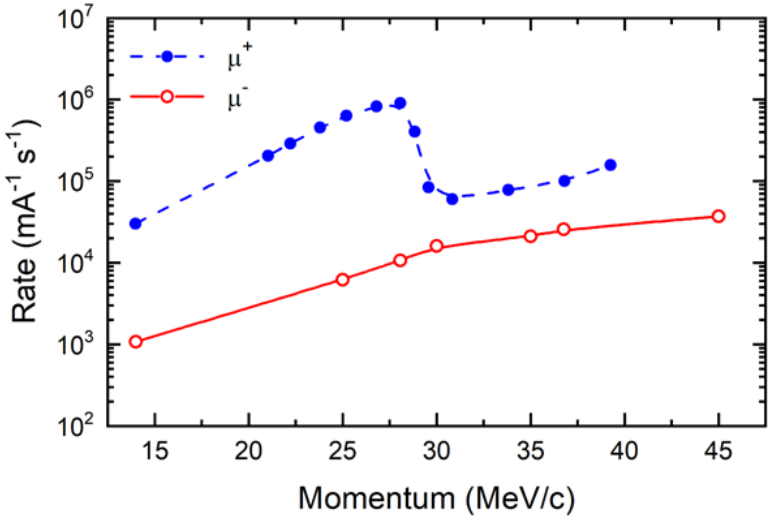
Xiao Zhao
30 Jan 2026

MIXE location



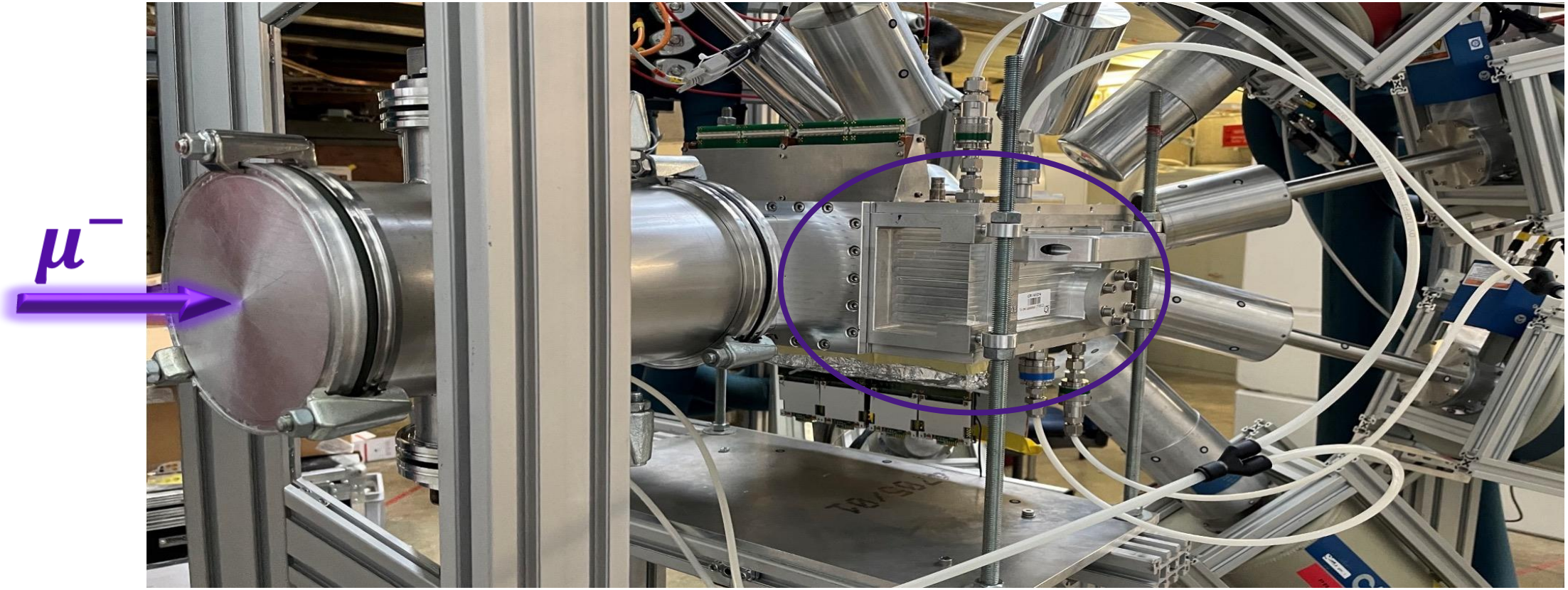
piE1 (host all past MIXE campaigns)

- Momenta: 15-60 MeV/c μ^-
- $\Delta p/p$: 1 ~ 8 % FWHM
- Rates: 10^3 up to 10^5 μ^-/s on target



Beam Monitor

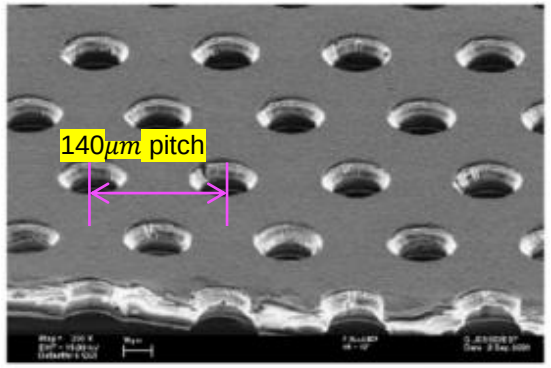
- Beam position and profile stability are critical for precision experiments
- Online beam diagnostics enable fast tuning and stable long-term operation
- For low-momentum muon beams (piE1), material budget and multiple scattering are dominant limitations

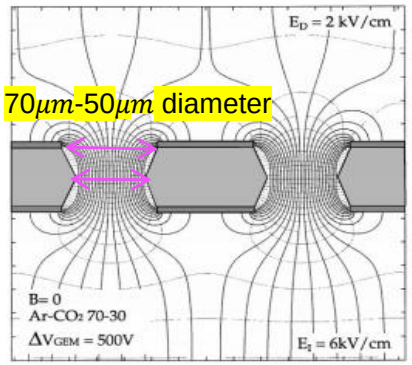


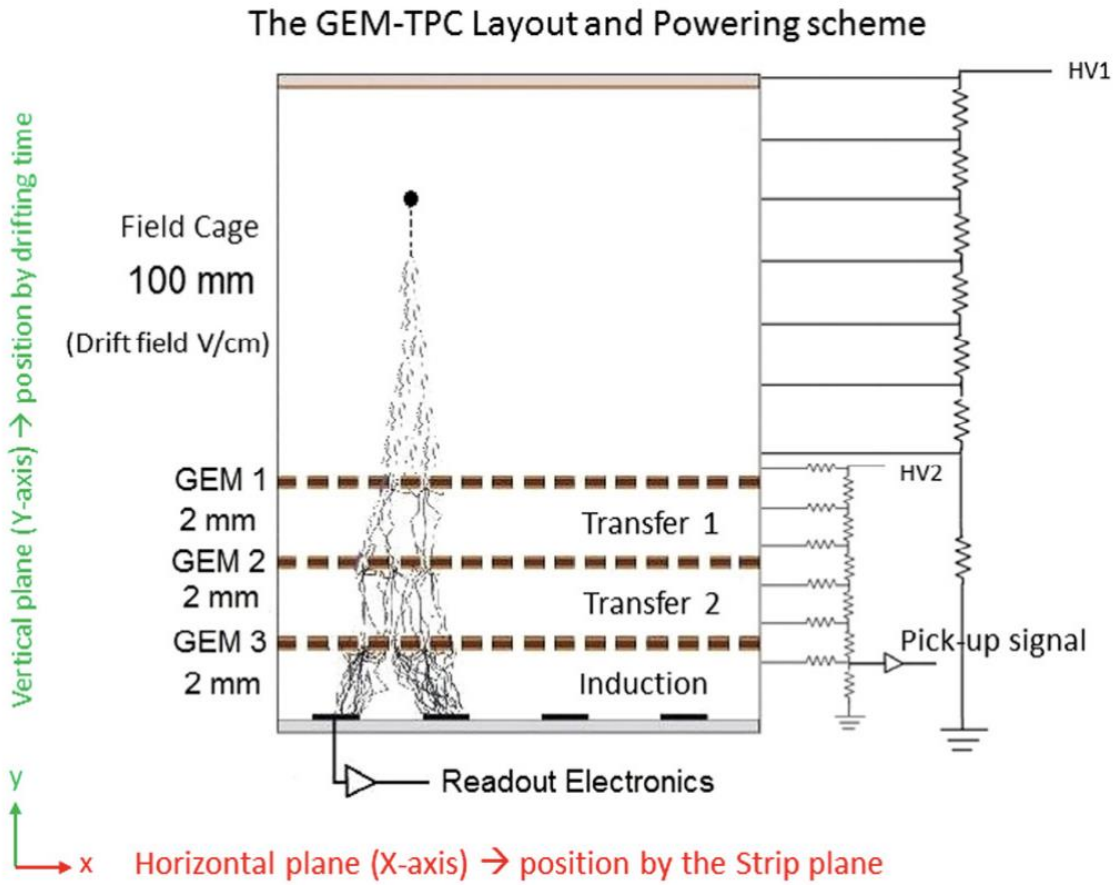
GEM detector

Gas Electron Multiplier detector

- Good spatial resolution
- High gain, low ion backflow (IBF)
- Low cost, easy installation
- Robust, stable, widely used



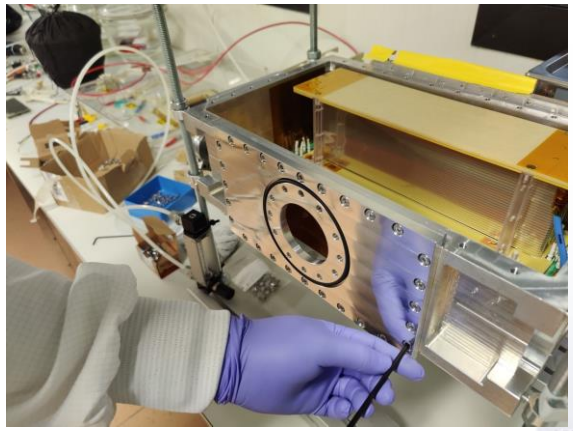


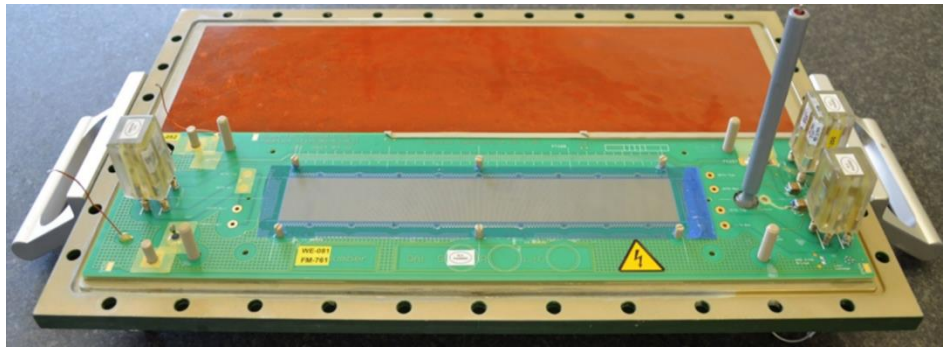


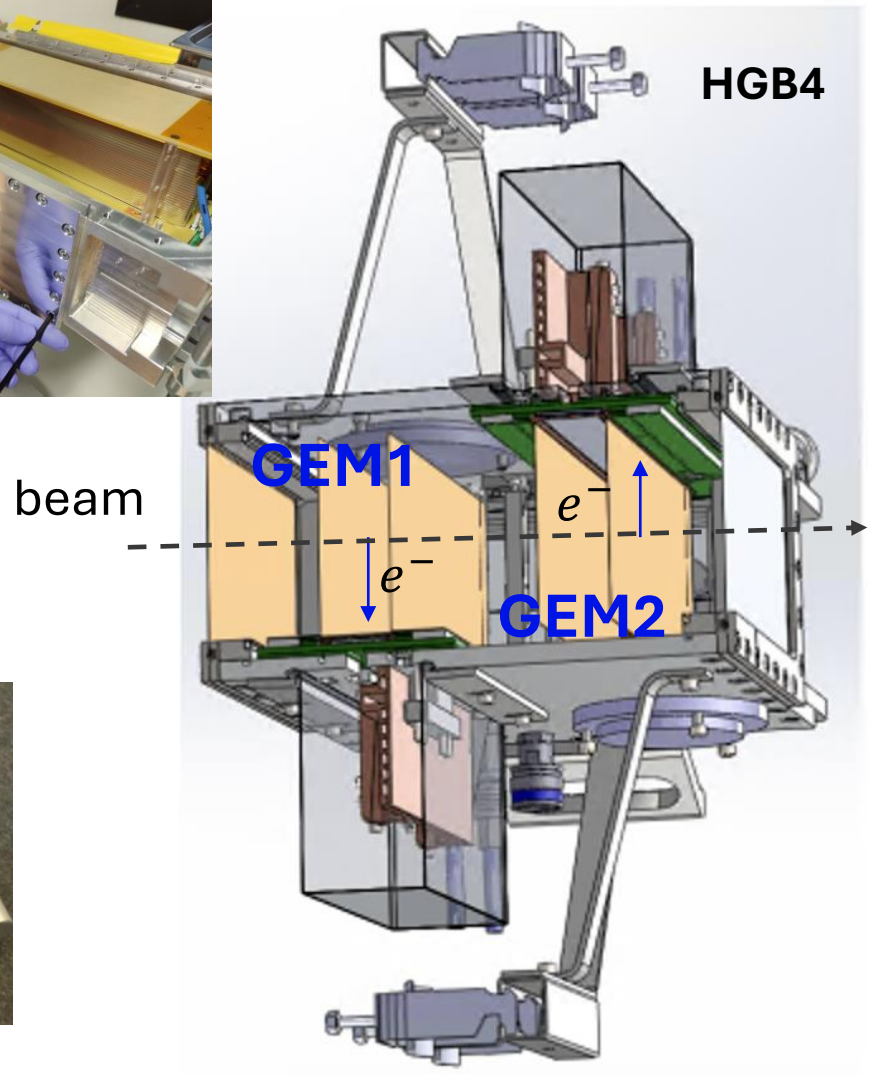
Garcia, F., et al. "The Super-FRS GEM-TPC prototype development-TDR." *arXiv preprint arXiv:1612.05045* (2016).

Twin GEM-TPC Tracking chamber

- Active Area ~20x10 cm^2
- Triple GEM stack amplification stage
- 1D strip readout , 1024 ch in total , 0.4 mm pitch
- X position given by the projection of cluster on strips
- Y position given by drift time(s)







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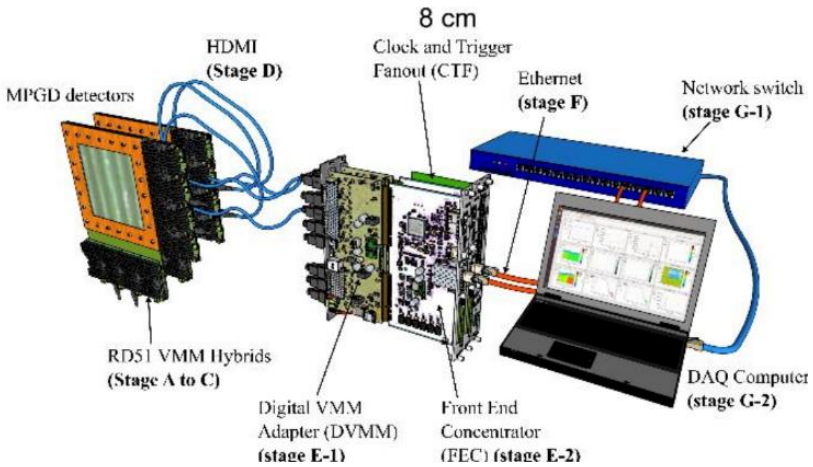
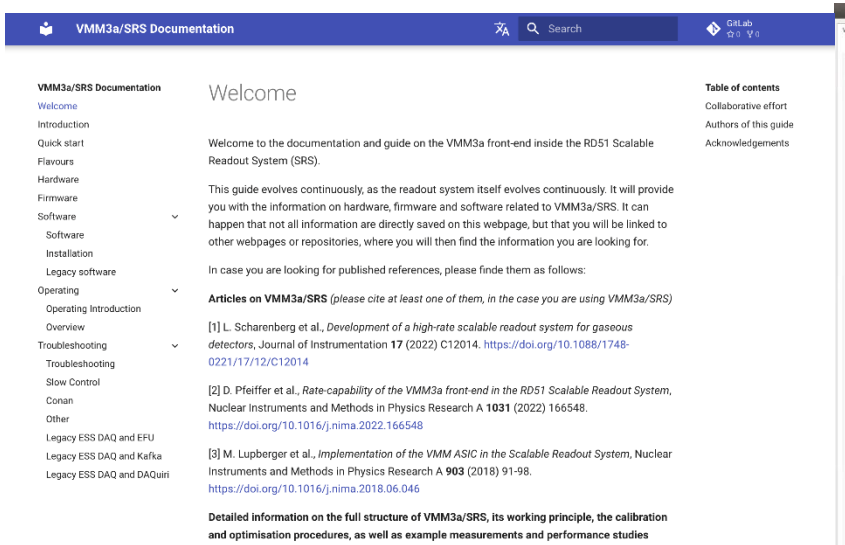
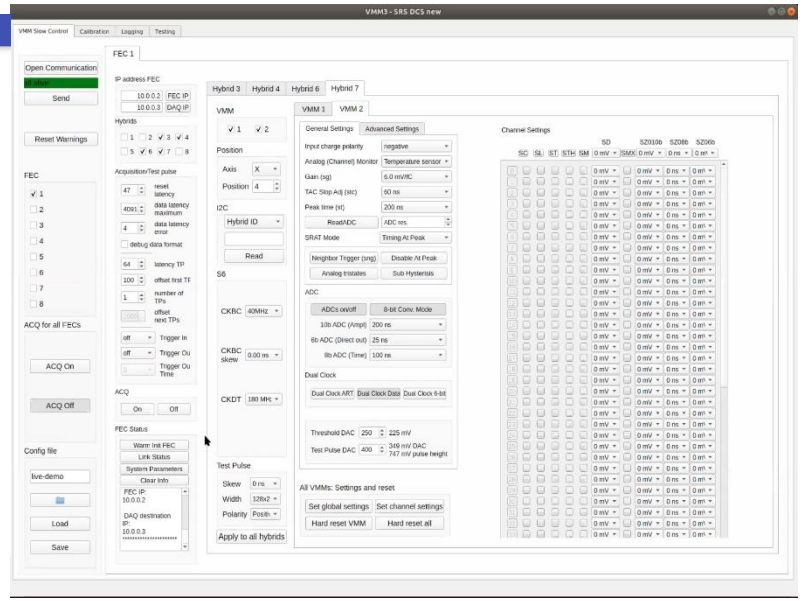
VMM3a/SRS

- Standardized SRS-FEC / VMM3a readout
- 64 readout channels with fast readout ~4 MHz per VMM3a

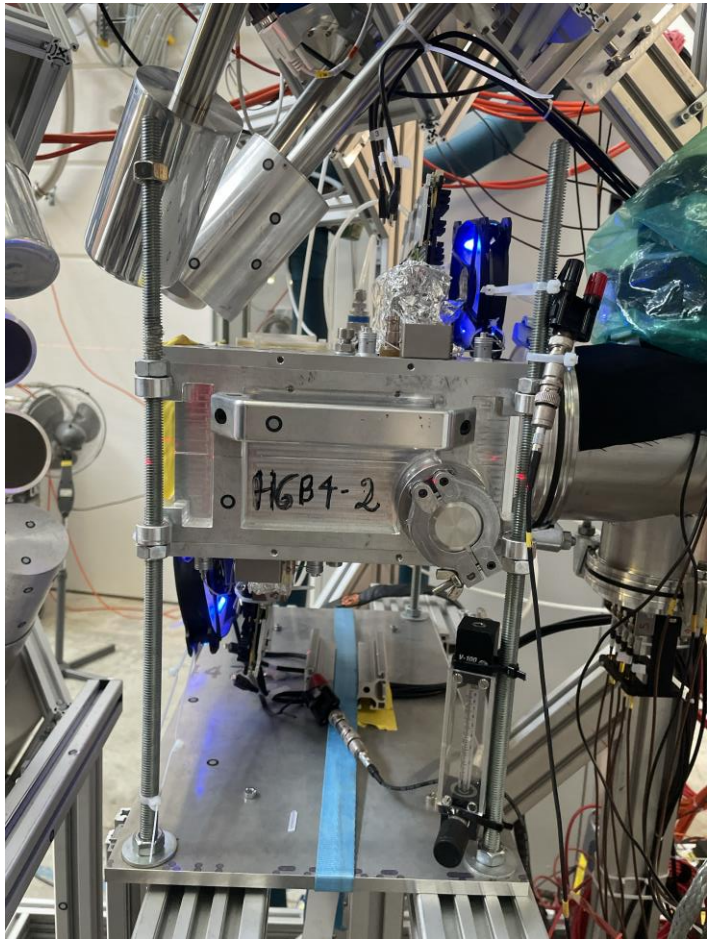






https://vmm-srs.docs.cern.ch/

HGB4 for low momentum beam tracking

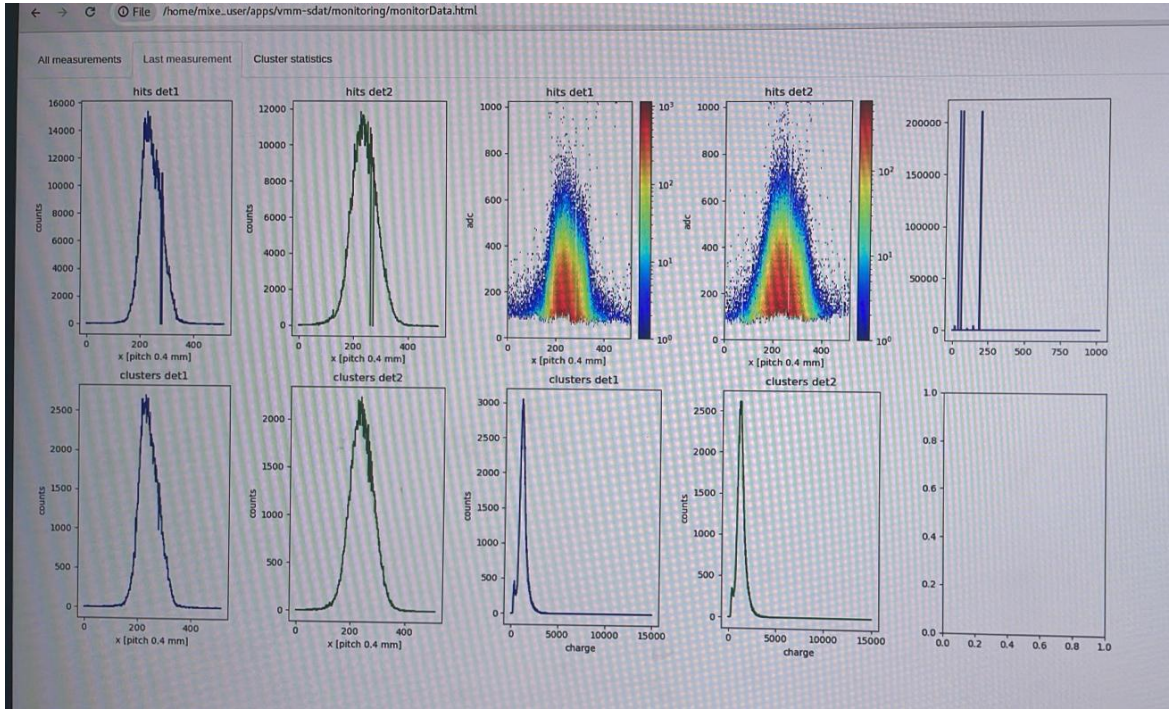


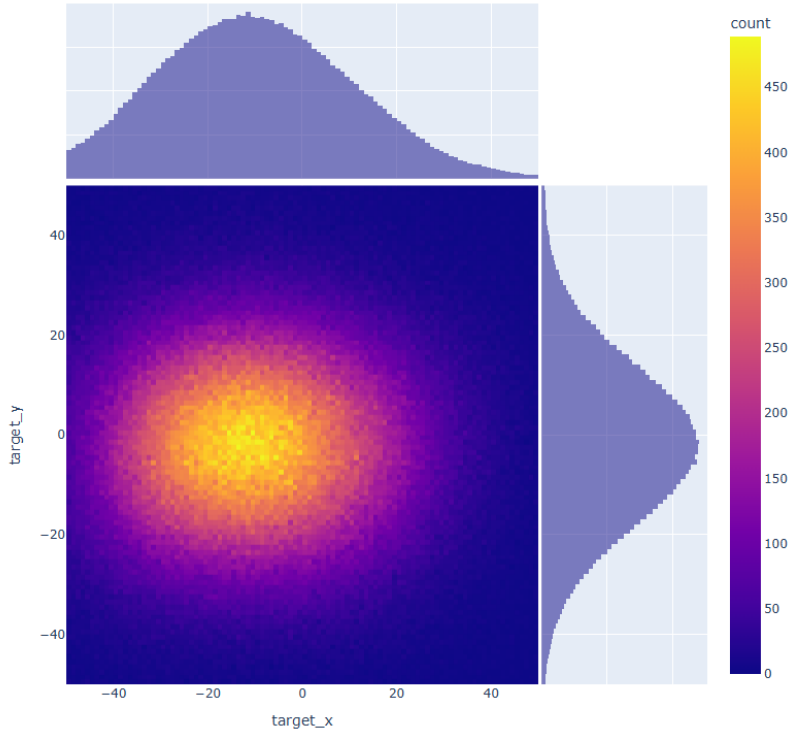
Ultra low material budget for low momentum beam

- He/CO_2 90:10 gas mixture
- Low effective radiation length (2.81E-3 X/X_0)
- Minimized multiple scattering
- Reduced energy loss and beam distortion
- Even lower material budget gas mixtures under study (He/CO_2 95:5, 97:3) to further reduce multiple scattering
- Stable operation using He/CO_2 97:3 in lab test at CERN

HGB4 for low momentum beam tracking

- Data acquisition via SRS/VMM3a (RD51 CERN)
- Online monitoring and quick-look displays with python-based website
- Support beam alignment and beam tuning
- Stable long-term running during beamtime



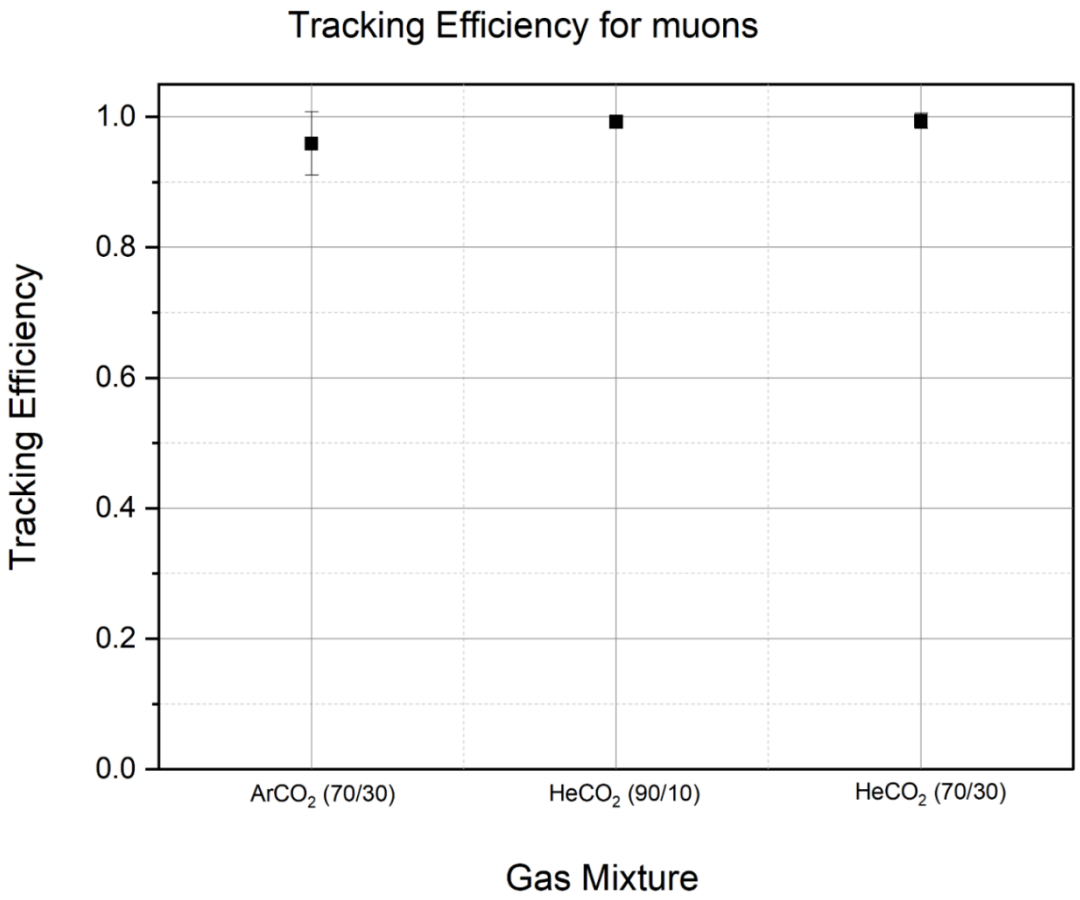


Measured at different facilities

SPS H4

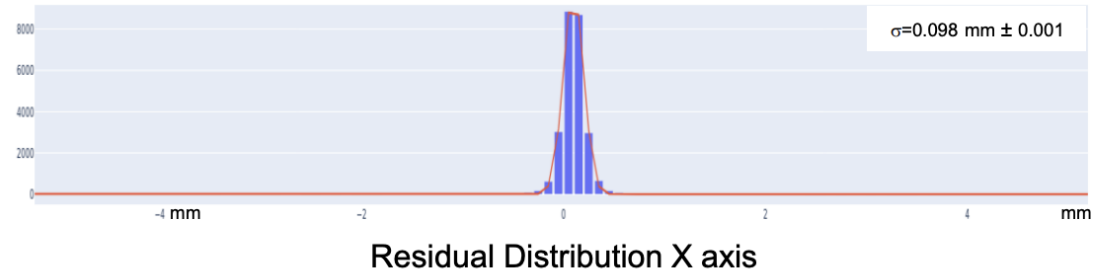
- Particles: μ and π at 180 GeV/c
- Beam spot: μ 10cm in X and Y
  π 6 mm in X and Y
- Intensity: μ → 80k/spill
  π → 80k - 10M/spill
- Different gas mixture: Ar/CO_2 70:30
  He/CO_2 70:30 He/CO_2 90:10
- Spatial resolution He/CO_2 90:10 : ~100µm in X
  ~140µm in Y

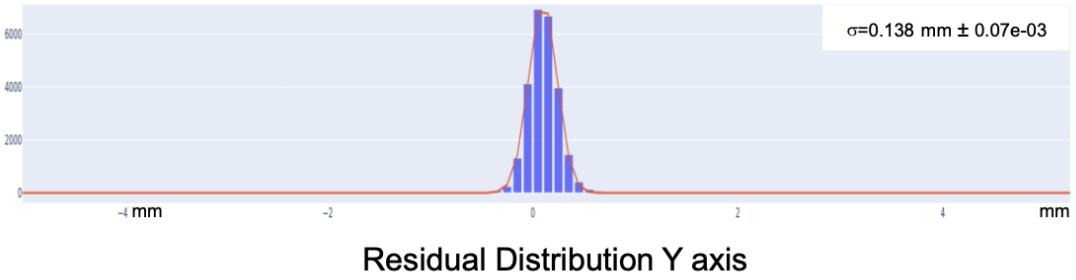
Garcia, F., *The UltraLow Material Budget GEM based TPC used for Tracking*, MPGD2024

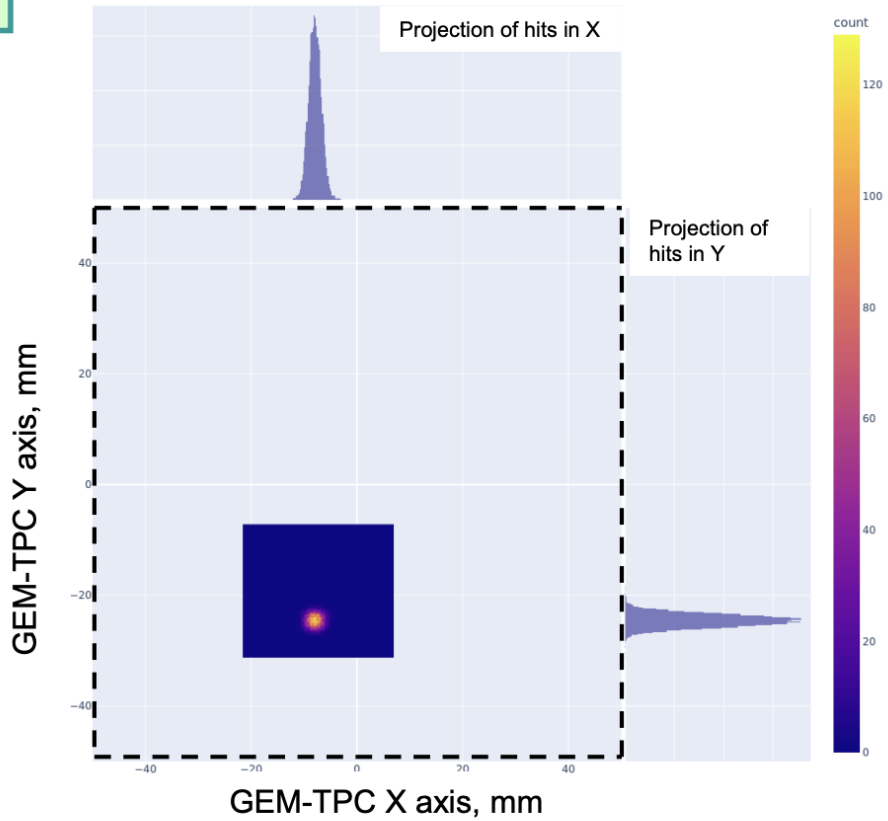


Measured at different facilities

The hit map, residuals and the control sum for pions .







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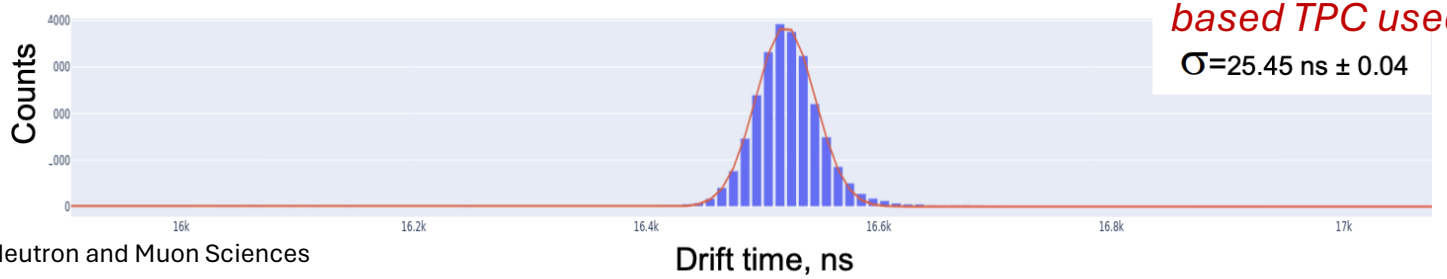


Measured at different facilities

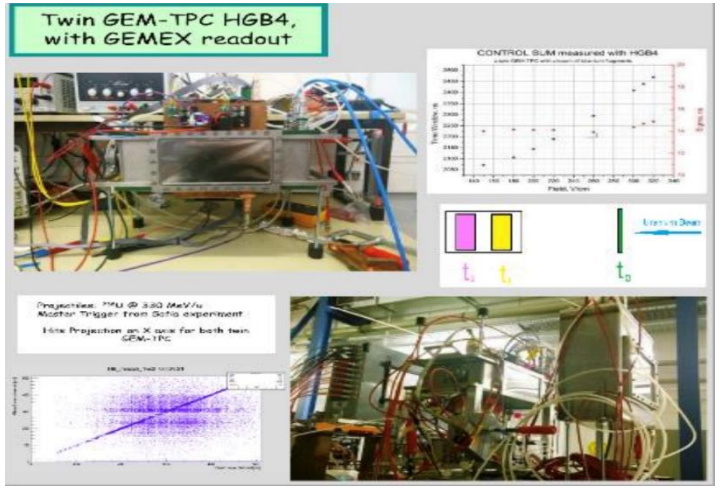
FRS-GSI

- Elements p – U
- Energy up to 1.5 GeV/u
- Intensity up to 10^{12} /spill

Performance with P10 (ArCH4 90/10) gas

- Tracking efficiency >95%
- Test using heavy-ion beams

Garcia, F., *The UltraLow Material Budget GEM based TPC used for Tracking*, MPGD2024
Garcia, F., *A GEM-TPC in twin configuration for the Super-FRS tracking of heavy ions at FAIR*, NIMA



Ion beam	Year	Facility / Location	Spatial resolution
^{64}Ni	2010	FRS S4 (GSI)	125µm (X), 150µm (Y)
^{197}Au	2012	FRS S4 (GSI)	300µm (X)
Xe, C	2016	FRS S4 (GSI)	188µm (X), 147µm (Y)
U	2019	FRS S4 (GSI)	740µm (X)

HGB4 as general beam monitor

Key Advantages & Performance

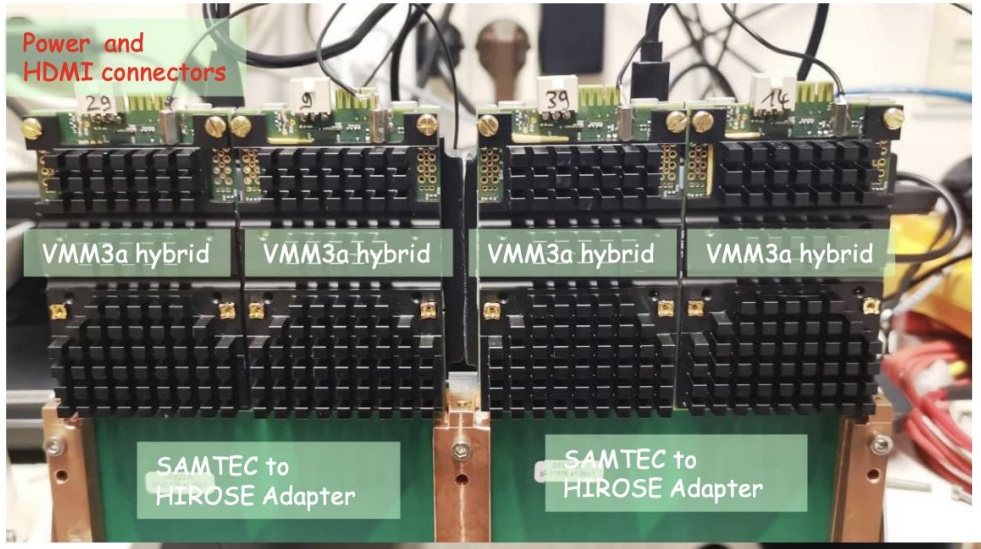
- Validated under different beam conditions (GSI, SPS/CERN, PSI)
- Continuous and stable operation under high-rate condition (up to 1MHz)
- Configurable gas mixtures, lower material budget for minimal beam perturbation
- Good spatial resolution (~100μm in X/Y when using He/CO2 90:10)
- High tracking efficiency close to 100%
- Standardized SRS-FEC/VMM3a readout with large dynamic range
- Cost-effective and robust for long-term beamline operation

New prototype

- Optimized for low-momentum muon beam diagnostics
- Even lower-density gas mixtures He/CO_2 97:3
- Single-GEM design with pixel-based readout
- Reduced detector size (half of the current one) to further minimize multiple scattering
- Modular design for easy installation and integration
- Cost: ∼8kCHF for each detector
- Beamline testing of the new prototype planned within this year
- Develop a more user friendly web-based online monitoring interface

Thank you for your attention!

VMM3a INTEGRATION to the GEM-TPC in TWIN



Create + SRS-FEC + DVM card

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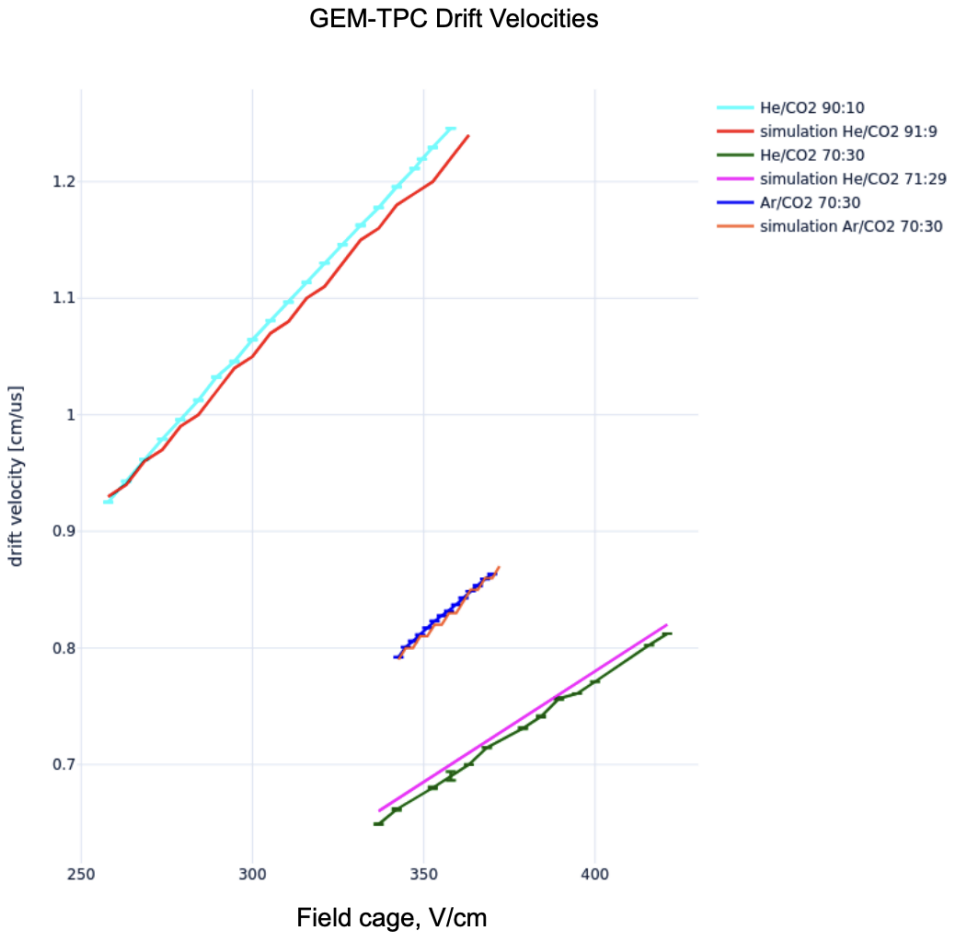
TEST BEAM at the SPS – H4 Beamline

Drift Velocity Calibration

- By the use of scintillation grid detector:

- By the correlation of the hits from the tracker:
  - Prealigment.
  - Selection straight tracks (small χ^2).
  - Fine alignment.
  - Correlation of the GEM-TPC clusters to the first reference tracker plane in X and Y.



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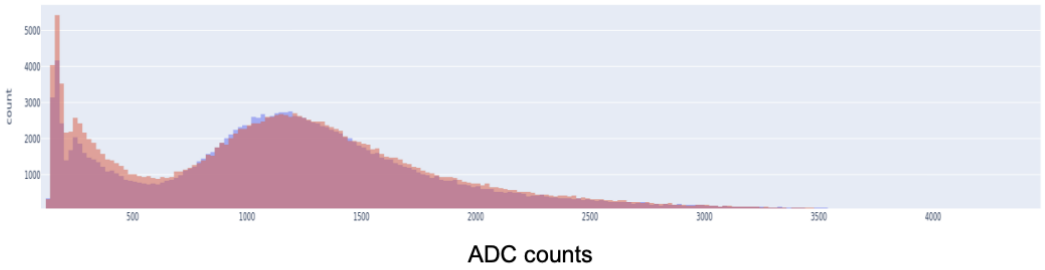
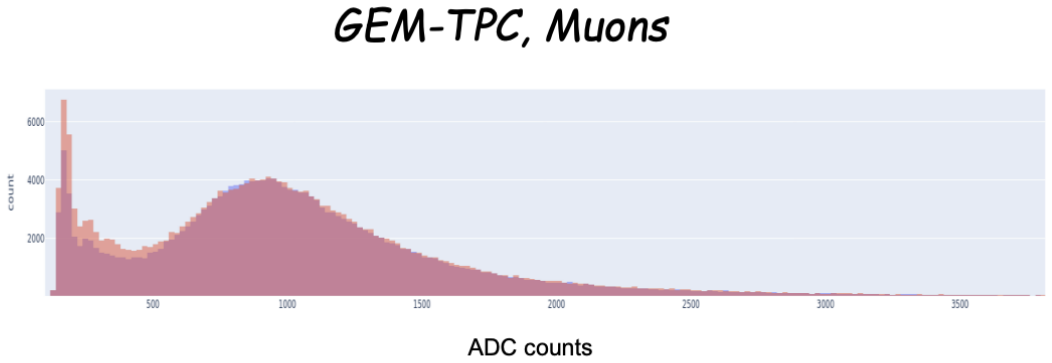
Cluster Charge Distribution

$ArCO_2$ (70/30)



$HeCO_2$ (90/10)



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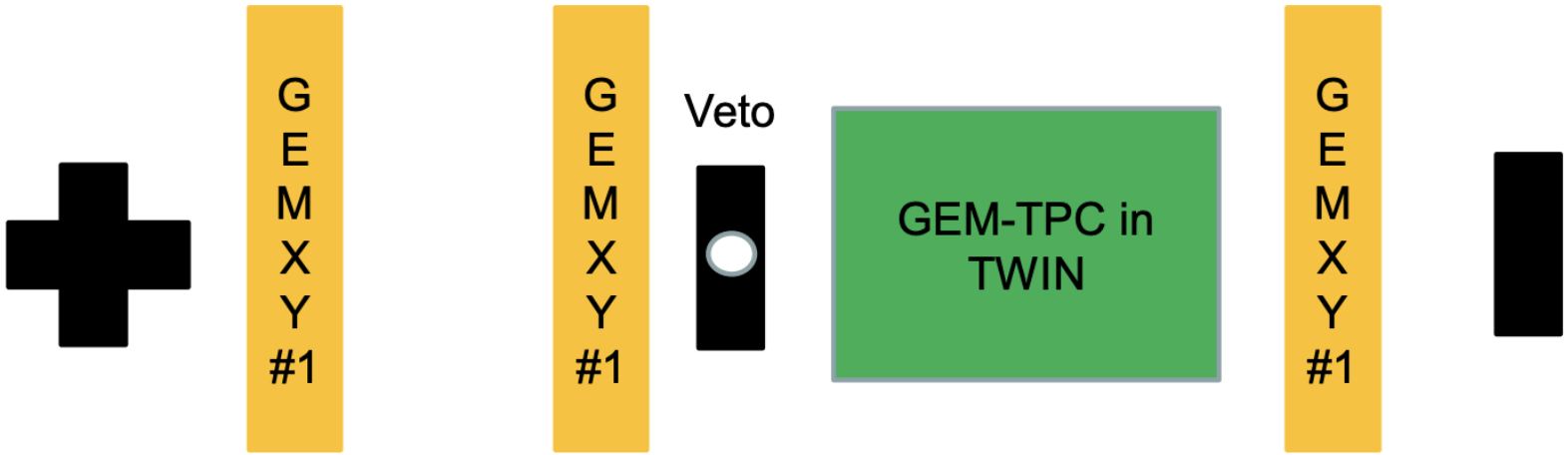
SETUP in the BEAM



Projectiles:
μ and π
(parallel beam)

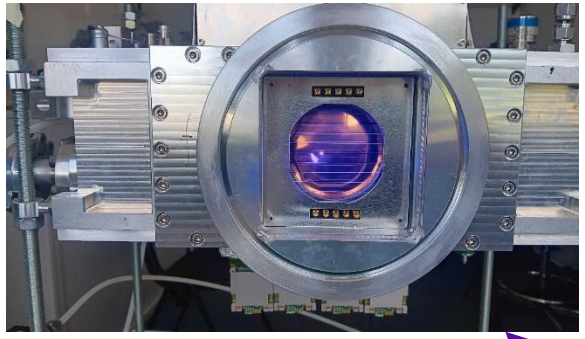
Gas mixture:
$ArCO_2$ (70/30)
5 l/h

Powering:
Veto: 1kV
GEM-TPC: 8kV
3 kV
VMM3a: DVM

Electronics:
VMM3a - SRS

DAQ:
ESS based DAQ
(Virtual Machine)

HGB4 at PSI PiE1



Segmented Tagger Detector

- 10 independent strips
- **67x 67mm** entrance window
- High repetition rate
- Provide t0 for the system
- Support for time-based filtering and pileup handling