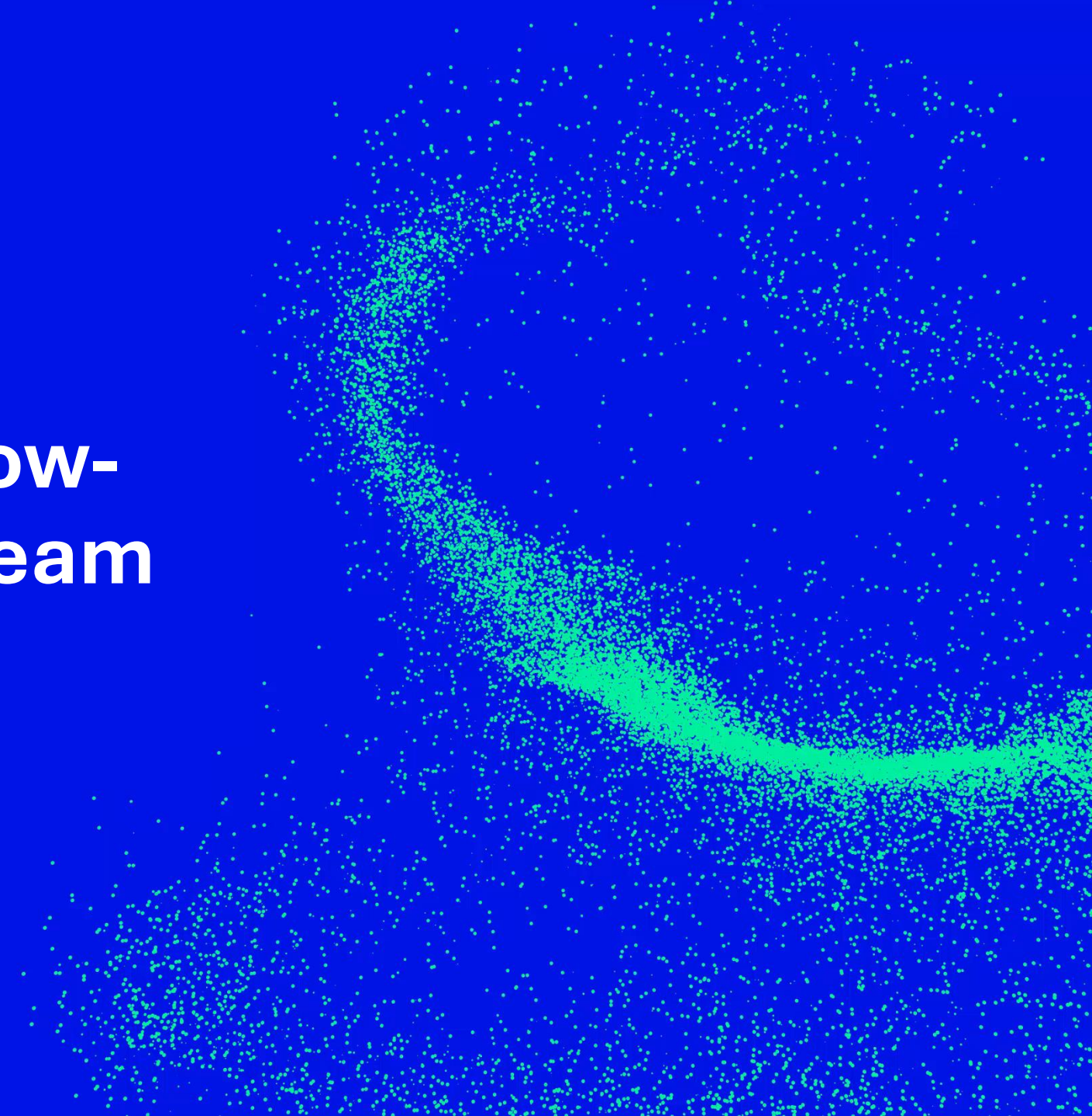
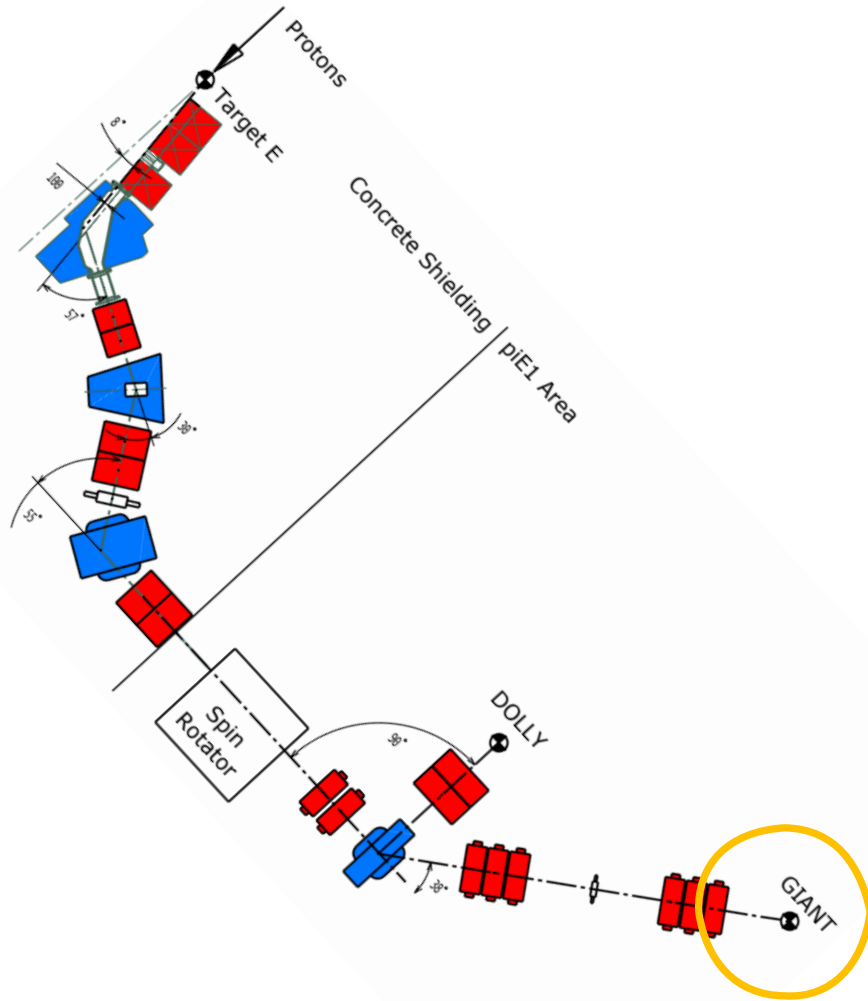


PSI Center for
Corporate Services

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

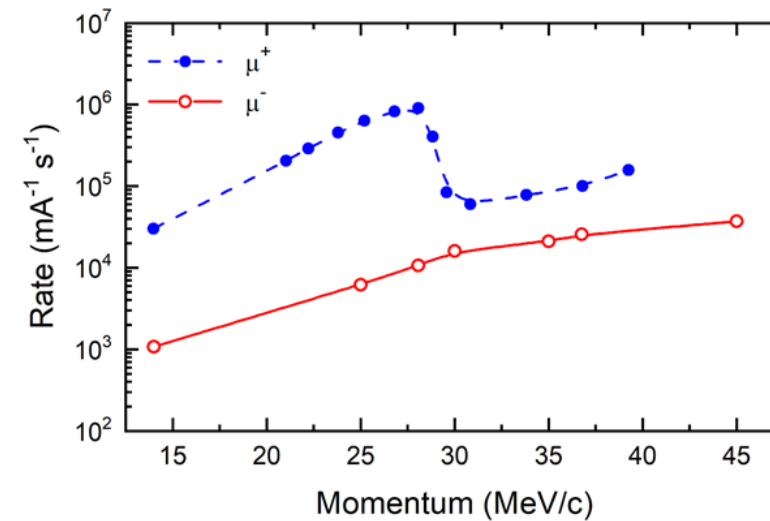
Xiao Zhao
30 Jan 2026





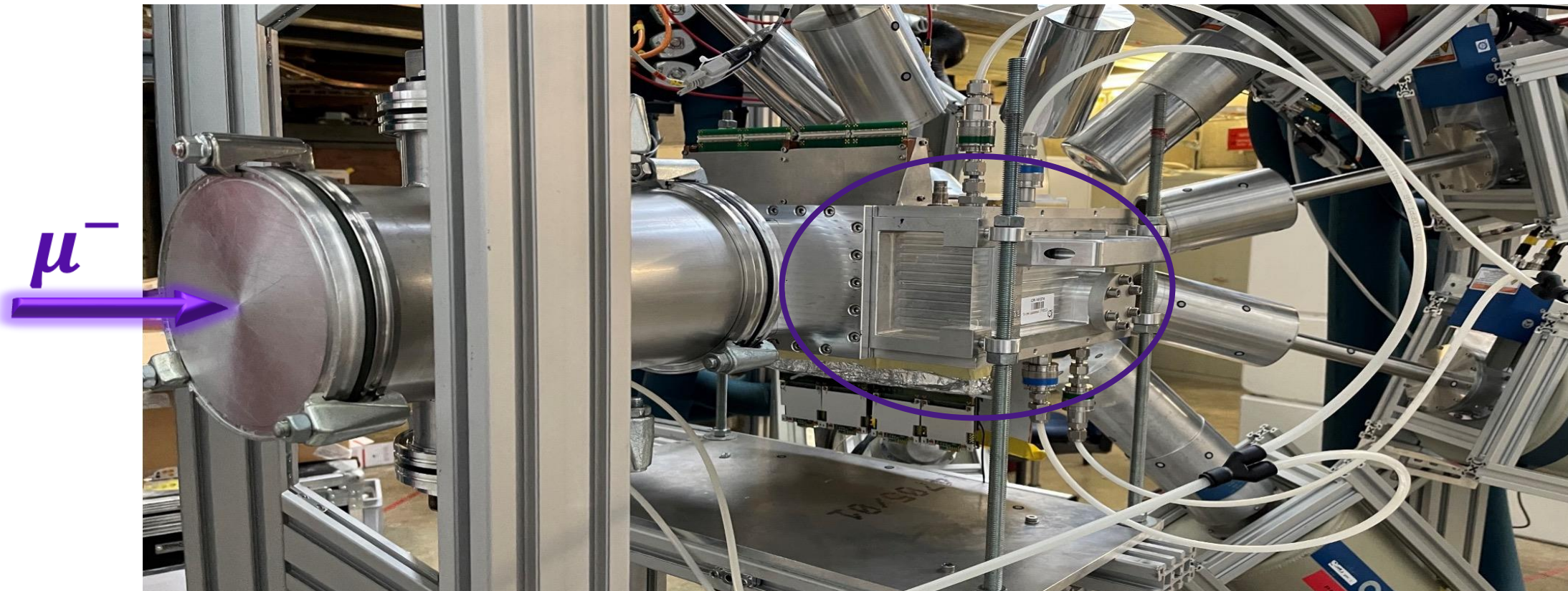
piE1 (host all past MIXE campaigns)

- 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

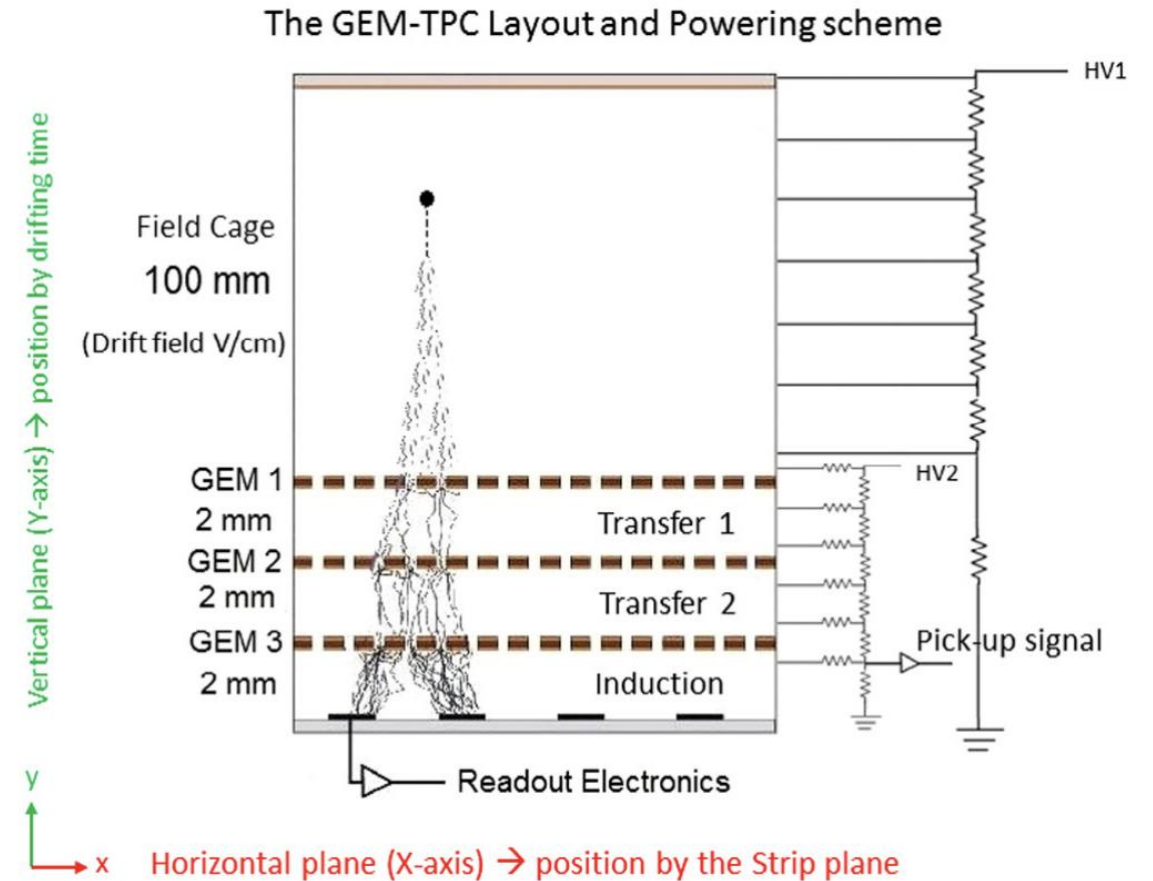
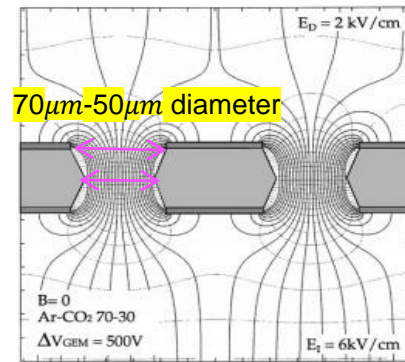
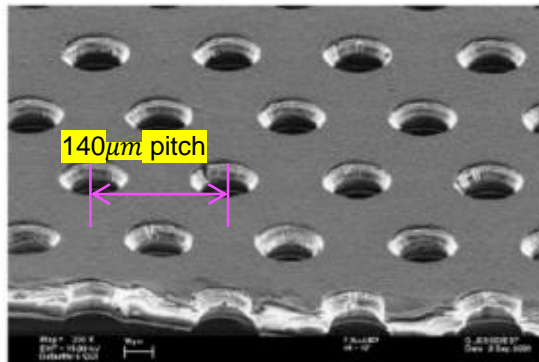
- Beam position and profile stability are critical for precision experiments
- Online beam diagnostics enable fast tuning and stable long-term operation
- For low-momentum muon beams (piE1), material budget and multiple scattering are dominant limitations



GEM detector

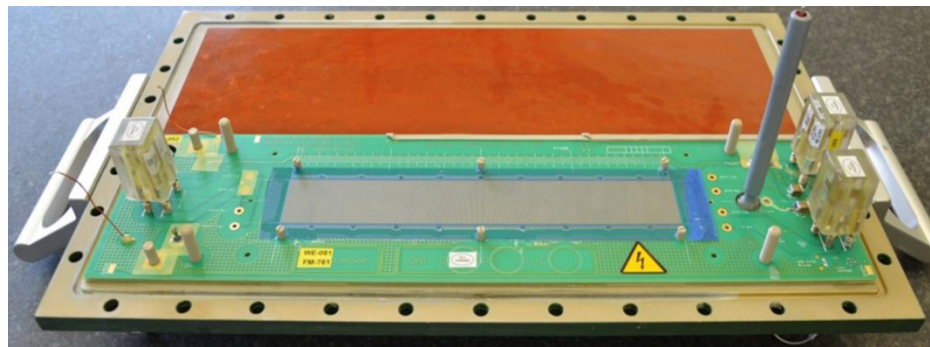
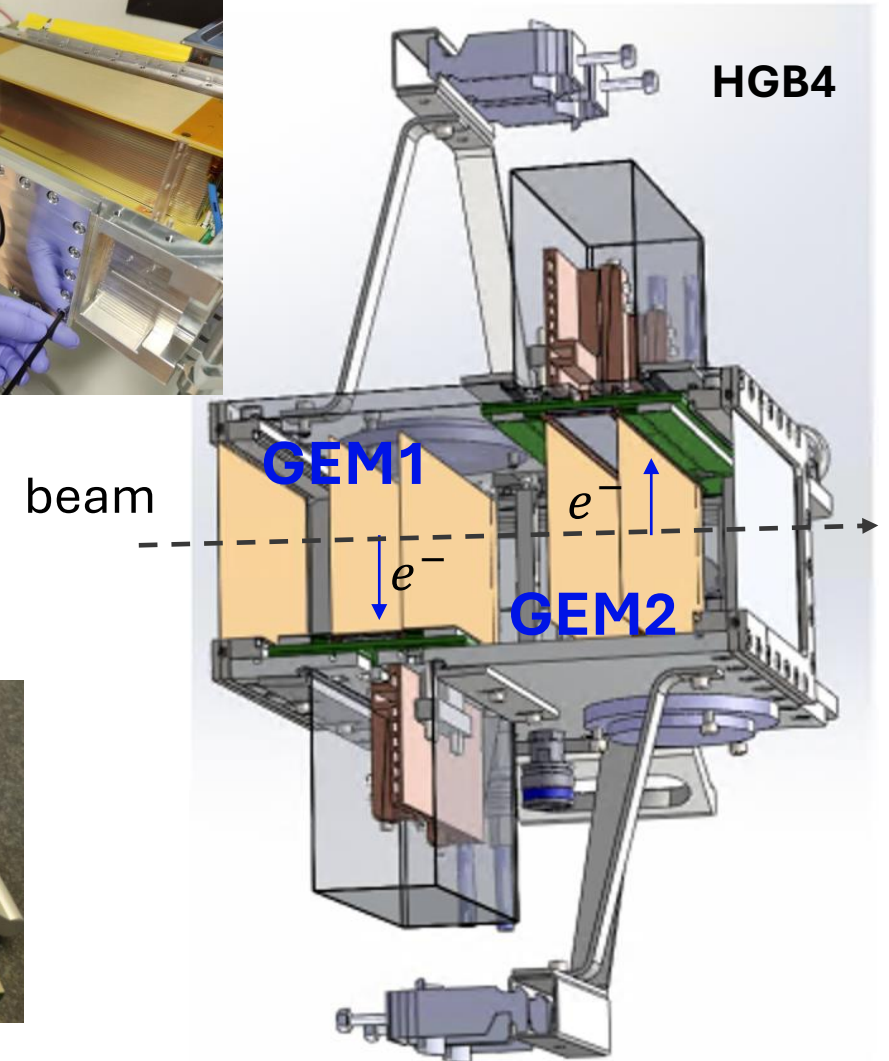
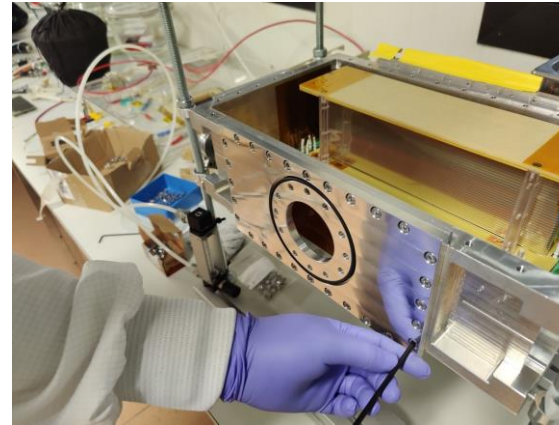
Gas Electron Multiplier detector

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



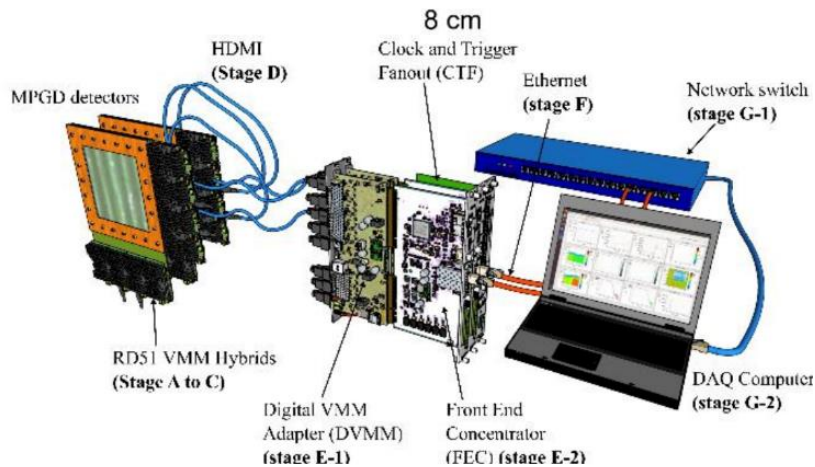
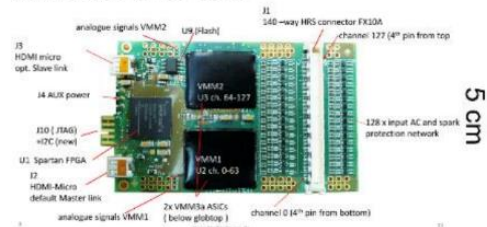
Twin GEM-TPC Tracking chamber

- Active Area $\sim 20 \times 10 \text{ cm}^2$
- 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)



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

VMM hybrid (V4.0 2020)



VMM3a/SRS Documentation

Open Communication

Search

G4 Lab

VMM3a/SRS Documentation

Welcome

Welcome to the documentation and guide on the VMM3a front-end inside the RD51 Scalable Readout System (SRS).

This guide evolves continuously, as the readout system itself evolves continuously. It will provide you with the information on hardware, firmware and software related to VMM3a/SRS. It can happen that not all information are directly saved on this webpage, but that you will be linked to other webpages or repositories, where you will then find the information you are looking for.

In case you are looking for published references, please find them as follows:

Articles on VMM3a/SRS (please cite at least one of them, in the case you are using VMM3a/SRS)

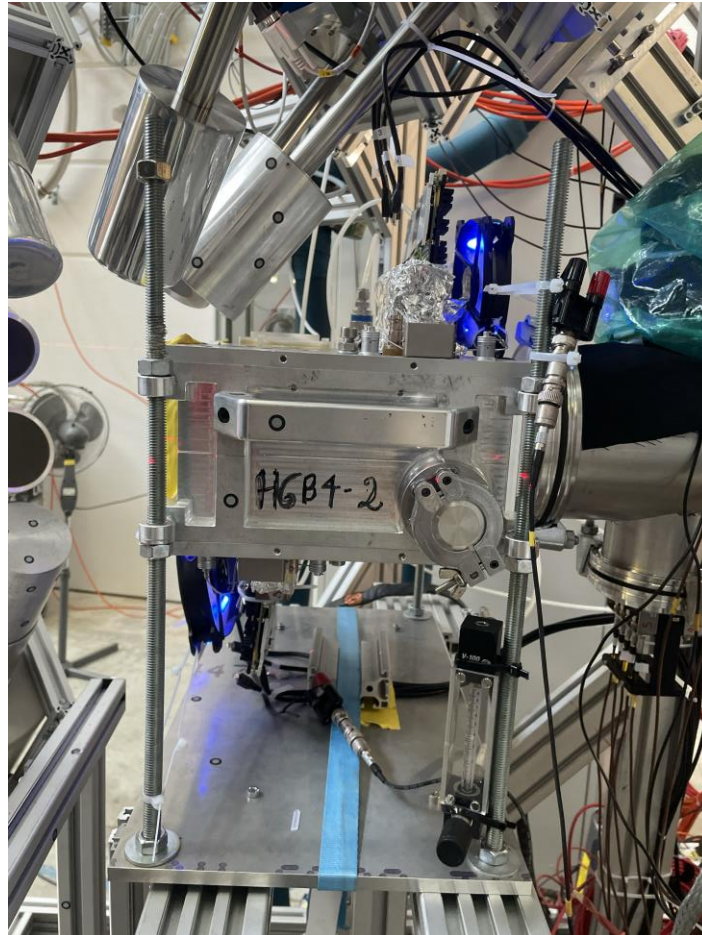
[1] L. Scharenberg et al., *Development of a high-rate scalable readout system for gaseous detectors*, Journal of Instrumentation 17 (2022) C12014. <https://doi.org/10.1088/1748-0221/17/12/C12014>

[2] D. Pfeiffer et al., *Rate-capability of the VMM3a front-end in the RD51 Scalable Readout System*, Nuclear Instruments and Methods in Physics Research A 1031 (2021) 166548. <https://doi.org/10.1016/j.nima.2022.166548>

[3] M. Lupberger et al., *Implementation of the VMM ASIC in the Scalable Readout System*, Nuclear Instruments and Methods in Physics Research A 903 (2018) 91-98. <https://doi.org/10.1016/j.nima.2018.06.046>

Detailed information on the full structure of VMM3a/SRS, its working principle, the calibration and optimisation procedures, as well as example measurements and performance studies

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

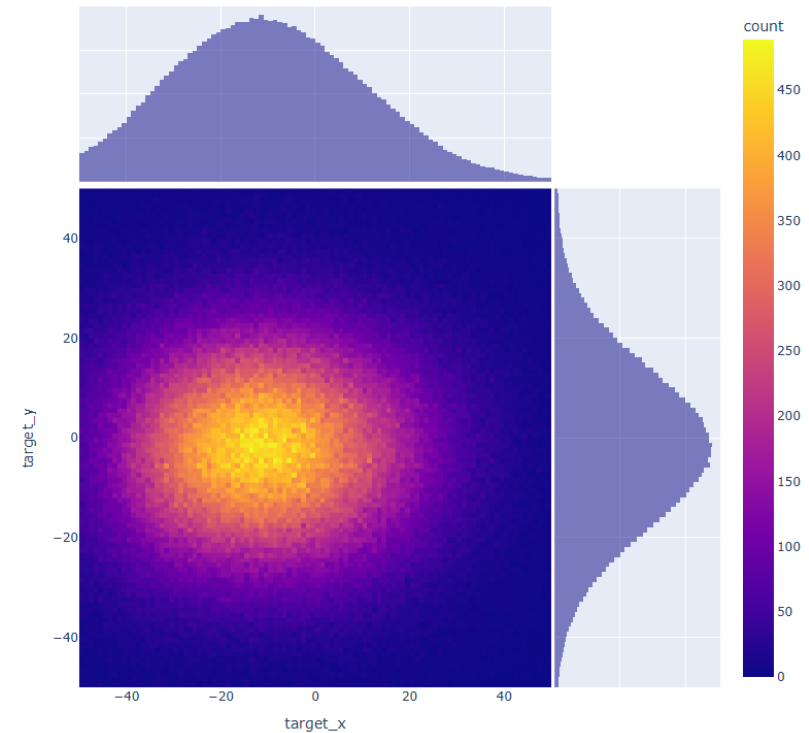
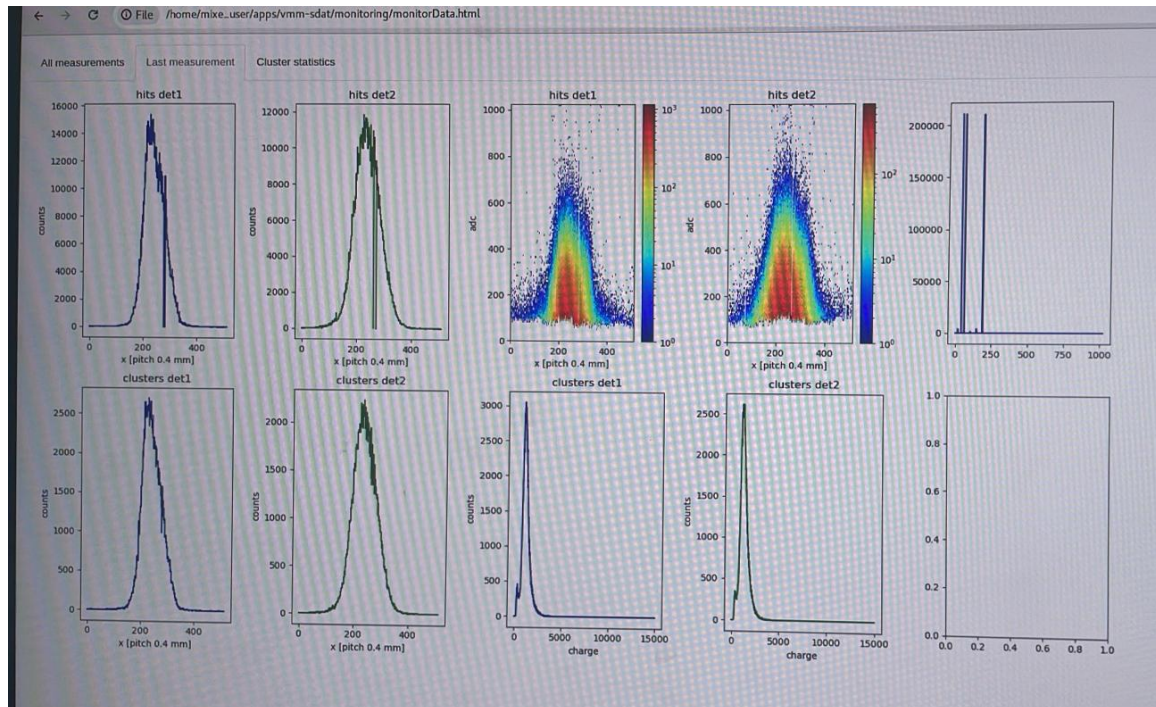


Ultra low material budget for low momentum beam

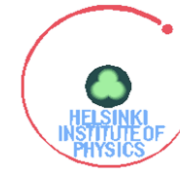
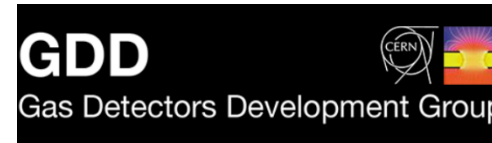
- He/CO₂ 90:10 gas mixture
- Low effective radiation length ($2.81E-3 X/X_0$)
- Minimized multiple scattering
- Reduced energy loss and beam distortion
- Even lower material budget gas mixtures under study (He/CO₂ 95:5, 97:3) to further reduce multiple scattering
- Stable operation using He/CO₂ 97:3 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



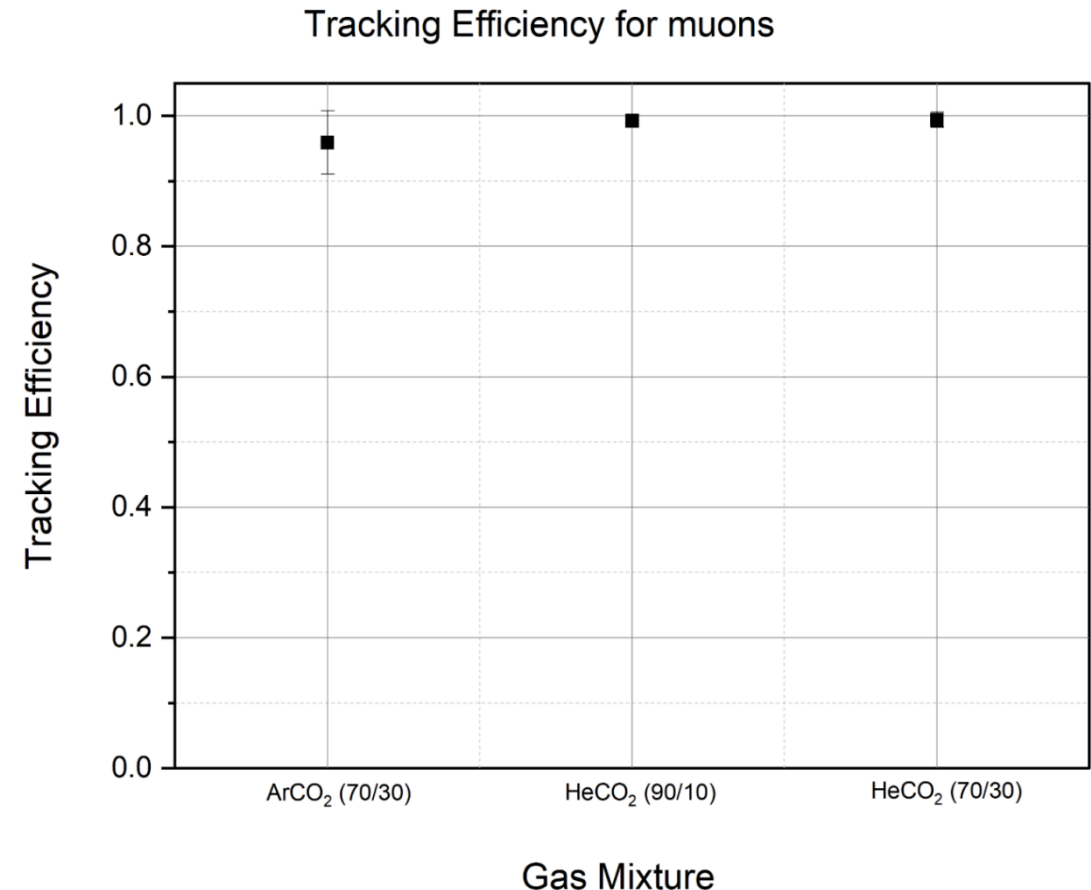
Measured at different facilities



SPS H4

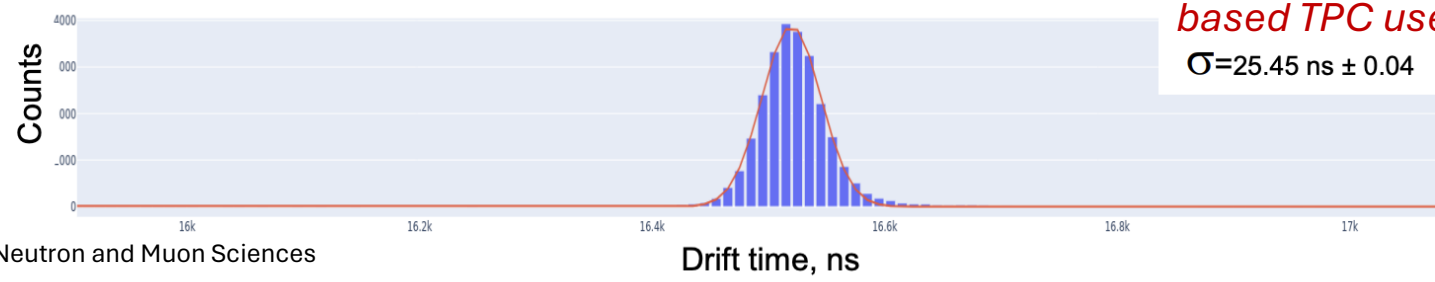
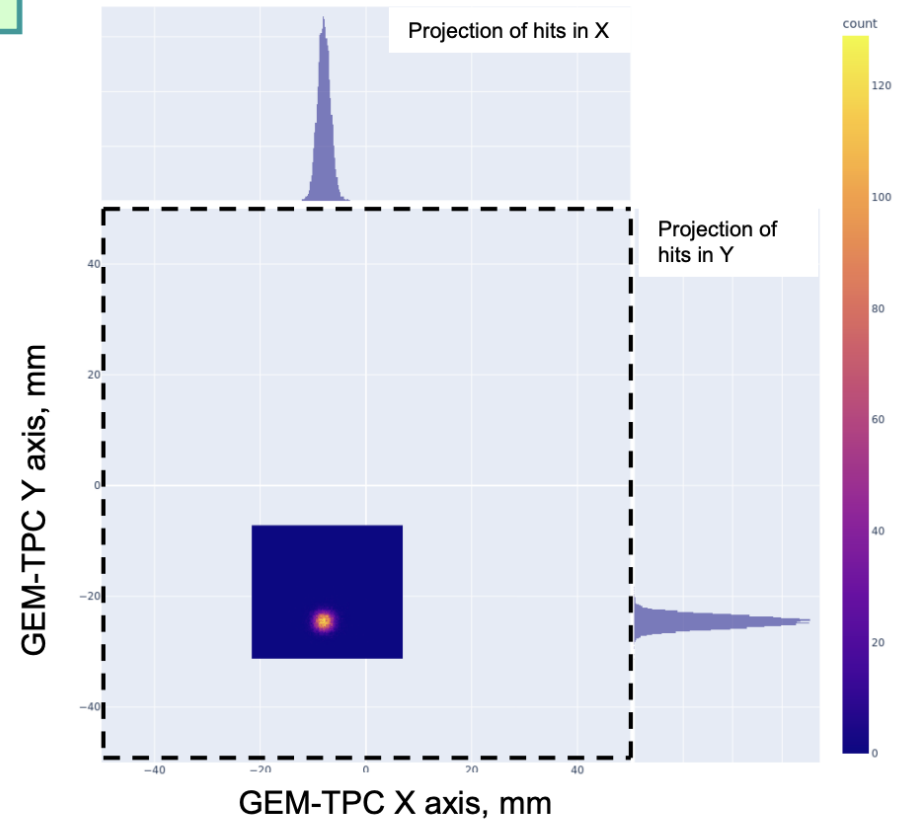
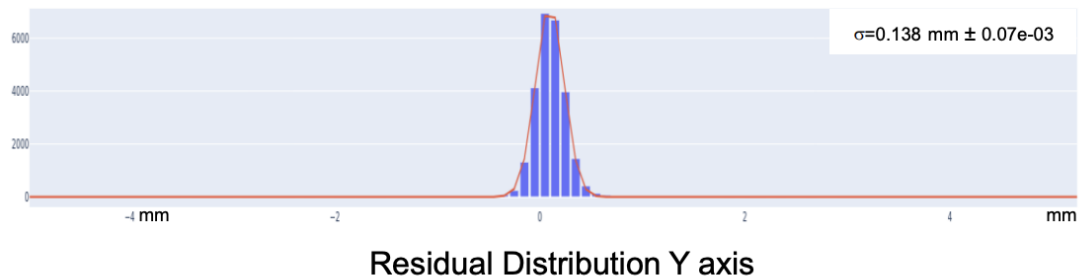
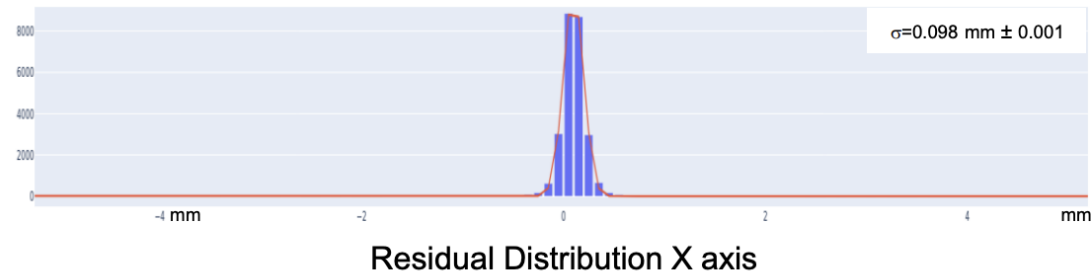
- Particles: μ and π at 180 GeV/c
- Beam spot: μ 10cm in X and Y
 π 6 mm in X and Y
- Intensity: $\mu \rightarrow 80\text{k/spill}$
 $\pi \rightarrow 80\text{k} - 10\text{M/spill}$
- Different gas mixture: Ar/CO₂ 70:30
He/CO₂ 70:30 He/CO₂ 90:10
- Spatial resolution He/CO₂ 90:10 : $\sim 100\mu\text{m}$ in X
 $\sim 140\mu\text{m}$ in Y

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



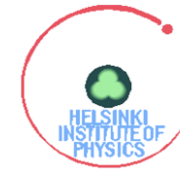
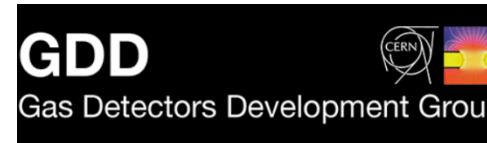
Measured at different facilities

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



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

Measured at different facilities



FRS-GSI

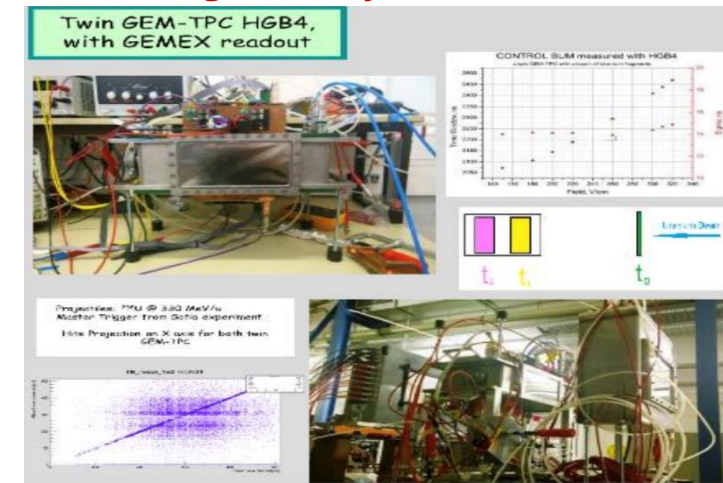
- Elements p – U
- Energy up to 1.5 GeV/u
- Intensity up to 10^{12} /spill

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)	125 μm (X), 150 μm (Y)
^{197}Au	2012	FRS S4 (GSI)	300 μm (X)
Xe, C	2016	FRS S4 (GSI)	188 μm (X), 147 μm (Y)
U	2019	FRS S4 (GSI)	740 μm (X)

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 ($\sim 100\mu\text{m}$ 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/CO₂ 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

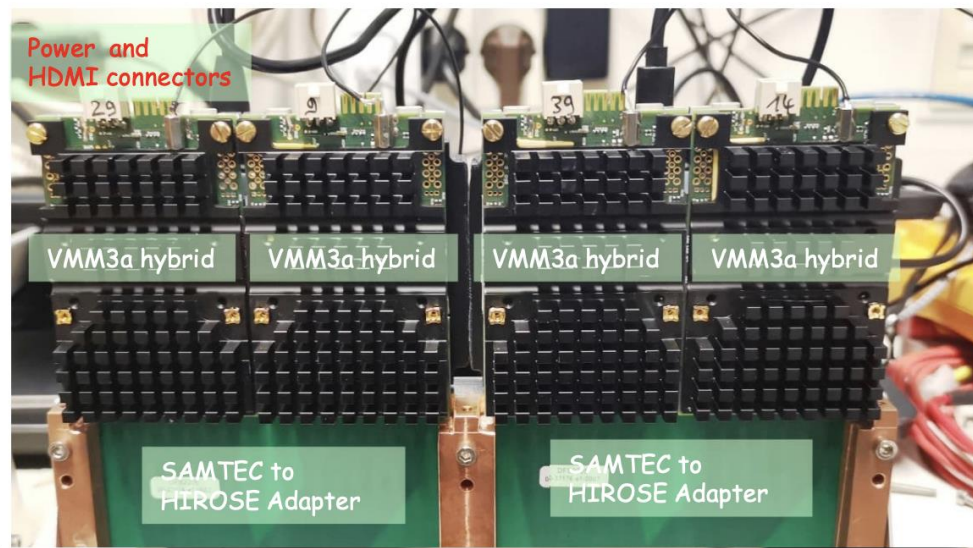
Thank you for your attention!



WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

VMM3a INTEGRATION to the GEM-TPC in TWIN

Create + SRS-FEC + DVM card



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

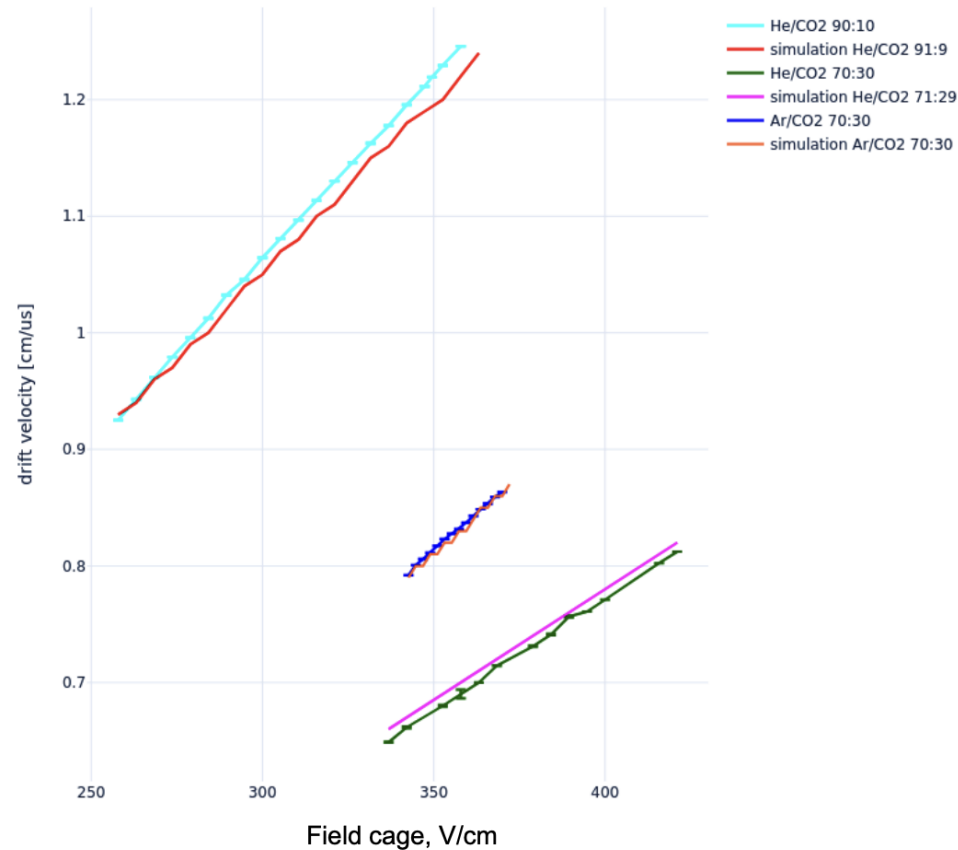
TEST BEAM at the SPS - H4 Beamline

Drift Velocity Calibration

- By the use of scintillation grid detector:

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

GEM-TPC Drift Velocities

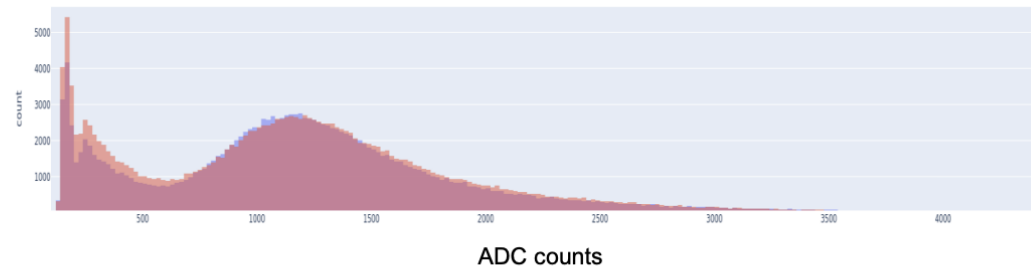


Garcia, F., *The UltraLow Material Budget GEM based TPC used for Tracking, MPGD2024*

Cluster Charge Distribution

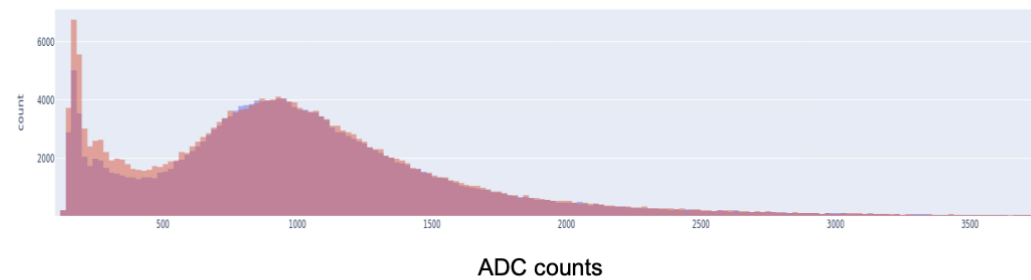
GEM-TPC, Muons

ArCO₂ (70/30)

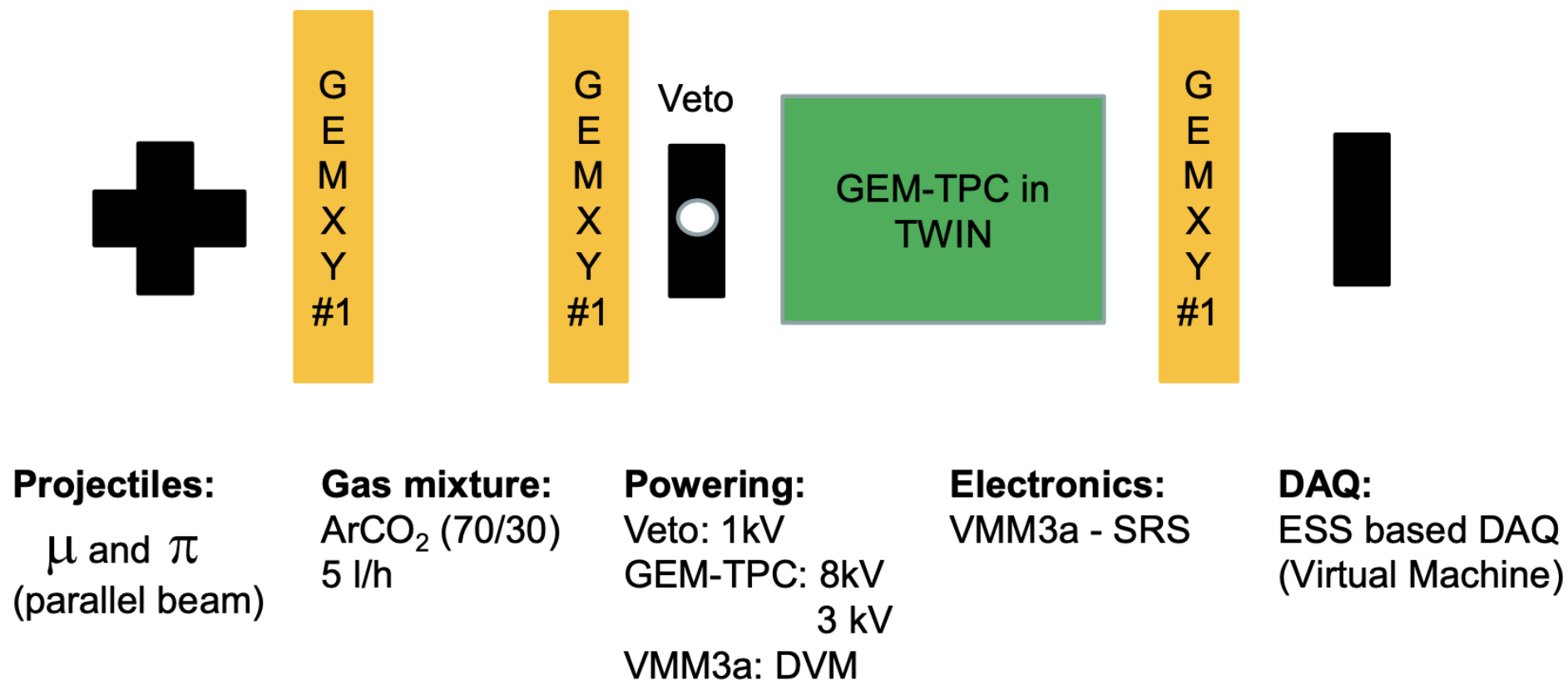


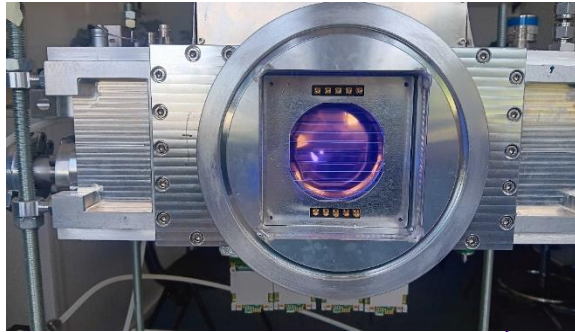
GEM-TPC, Muons

HeCO₂ (90/10)



SETUP in the BEAM





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

