Software Updates

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BESIII Italia Meeting, Perugia 27-28/02/2023

Monte Carlo

Experimental data

Tuning

Monte Carlo

Updates since last BESIII Italy

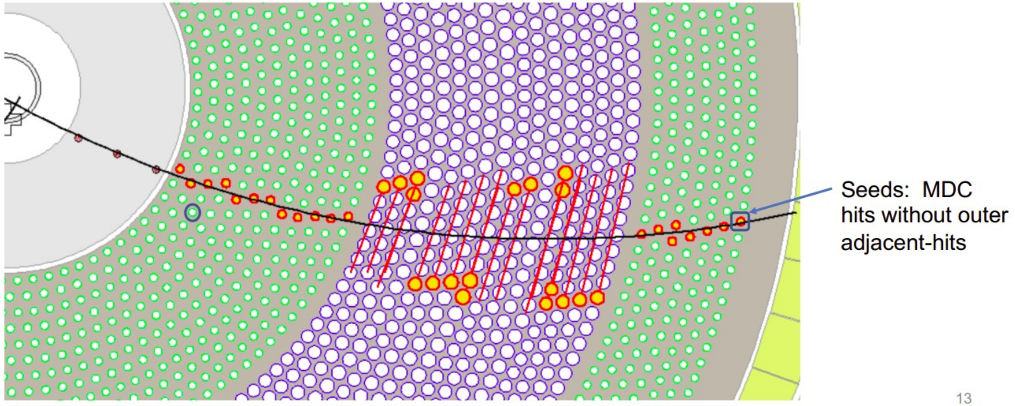
- Track follower track finder
- Tracking Quality Assurance

Track Follower - Track Finder

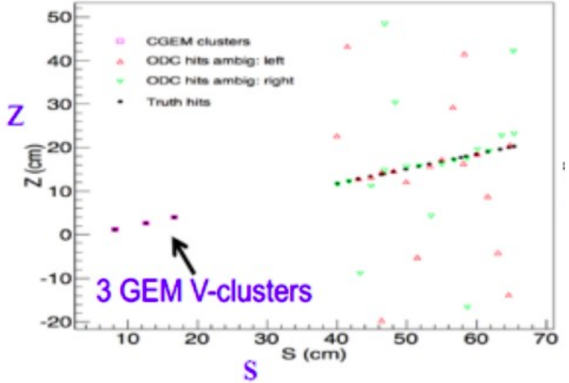
Hough Transform assumes tracks stemming from interaction point
→ not usable for **displaced vertices** from charged tracks decaying from long-living neutral particles (Λ, K°)

New track finding procedure based on track following (road-finding) technique

axial tubes/strips
1) Start from the most external MDC axial layer
2) Associate neighboring MDC tubes → compile a track candidate
3) First fit in xy (*)
4) Extrapolate the circle to CGEM planes
5) Associate x clusters closest to the extrapolated circle
6) Second fit in xy (*)



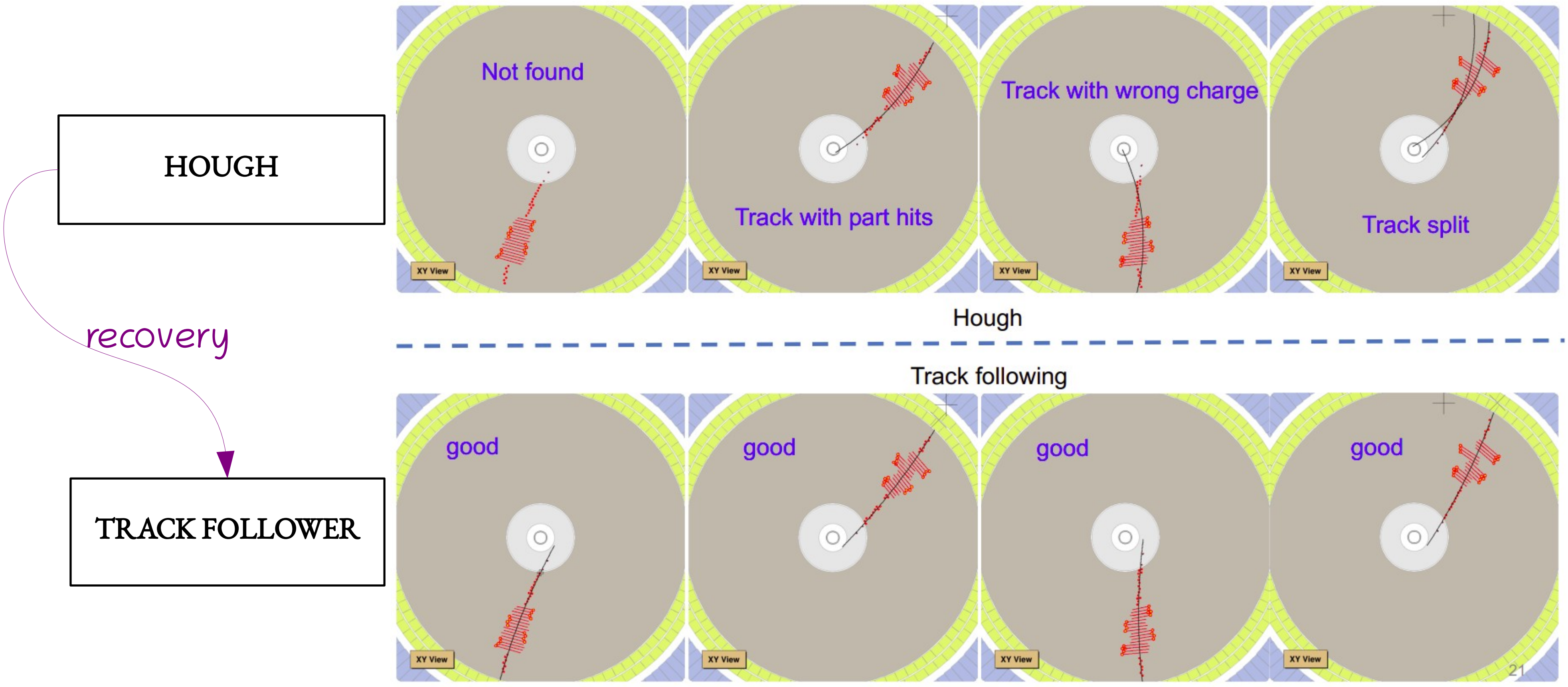
stereo tubes/strips
7) Plot on the s-z plane and associate the stereo MDC and GEM clusters (Hough)
8) Fit with a straight line



(*) Taubin fit (fast, stable, no initial circle parameters needed, no error matrix)

Track Follower - Track Finder

A systematic test is not yet available (maybe for next software meeting), but results are promising for secondary vertices from display

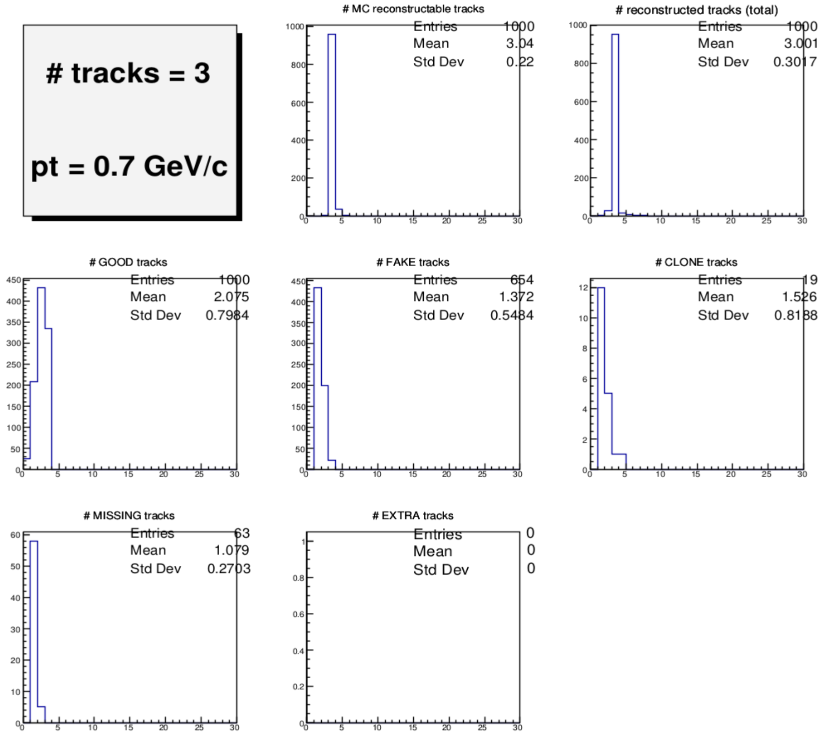


Quality Assurance

- to assess the quality of tracks from track finding and fitting a QA procedure is available (**INFN milestone for 2022 completed**)
- efficiency/purity can/must be evaluated vs (transverse) momentum, angle …

Package uploaded to CVS in /CgemBossCvs/Reconstruction/TrackingQA

File ▾
- Parent Directory
- TrackingQASvc.h →
  - service class
  - associate MC ↔ reco data
  - MDC & CGEM
- TrackingQA.h →
  - algorithm class
  - uses the TrackingQASvc
  - QA histogram filling
- ITrackingQASvc.h



- Delivered an additional macro that:
  - reads the output files
  - plots all the histograms
  - saves a PDF file for consultation

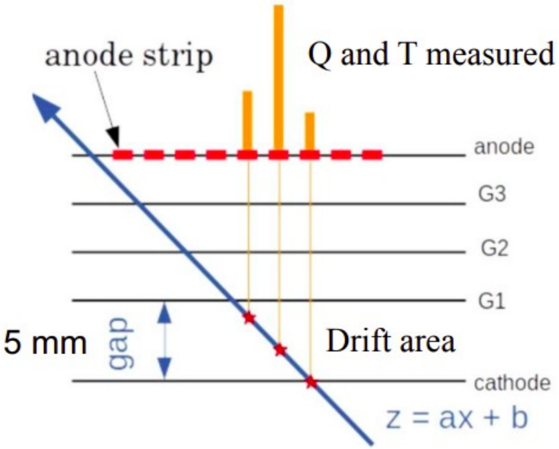
- Usable to compare different track finding approaches

Experimental data

Updates since last BESIII Italy

- Progress on micro-TPC reconstruction
- Machine Learning

Micro-TPC corrections

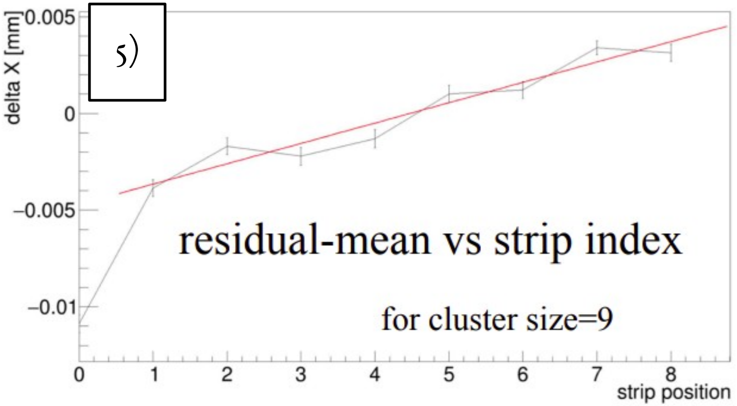


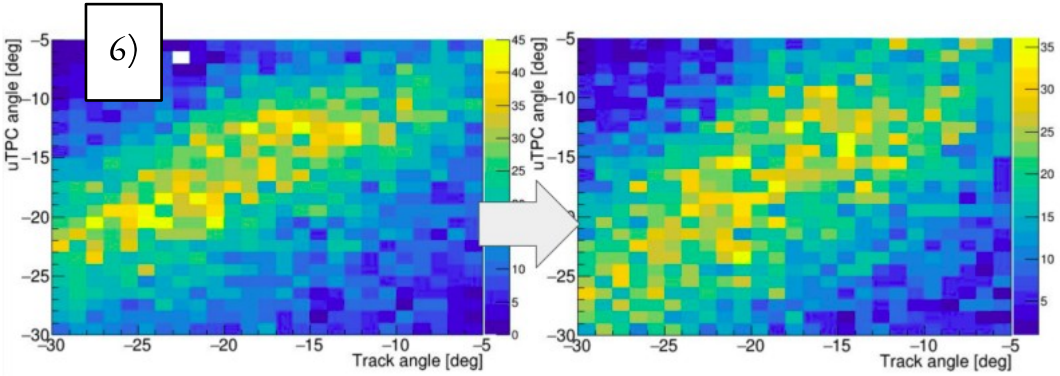
Several tests and corrections to the calculation of micro-TPC position to improve the resolution

1) Time walk + time reference corrections (already shown)
2) Additional time shift to set z_{TPC} in the range [0,5]mm
3) Wider clusterization (allowed up to 2 missing strips)
4) Fixed error of xTPC in cgemboss

$$dx_{tpc} = \sqrt{\left(\frac{pitch}{\sqrt{12}}\right)^2 + \left(\frac{pitch}{\sqrt{12}} \cdot \frac{Q_{cluster}}{N_{hit} \cdot Q_{hit}}\right)^2}$$

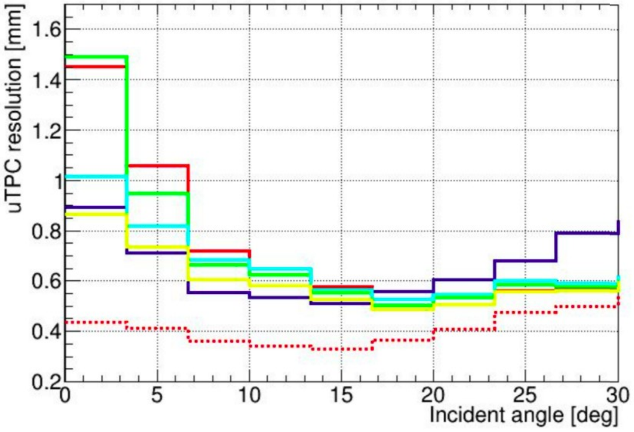
5) Correction of x_{TPC} from the residual x_{TPC} – x_from_fit vs strip-in-cluster (line)
6) Rotation of x_{TPC} to have angle TPC = angle from track fit





Updates of μTPC corrections for cosmic-ray data

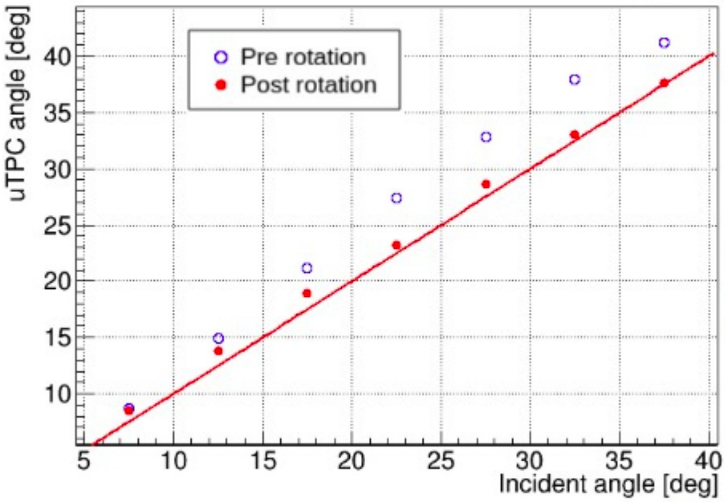
Red	=	No correction
Blue	+=	Revised drift velocity
Green	+=	Time-walk & time-reference
Lblue	+=	Error-association in line fit
Yellow	+=	Residual-mean correction
Dred	+=	μTPC angle rotation



✓ μTPC resolution 350~400 μm reached with this approach

● Extensive study on the corrections and approach needed

Tracking contribution not yet removed!



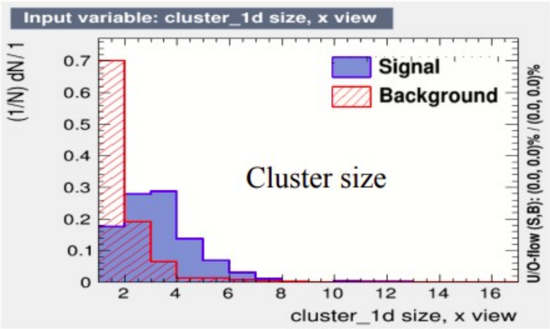
- uTPC angle = from uTPC linear fit
- Incident angle = from track fitting

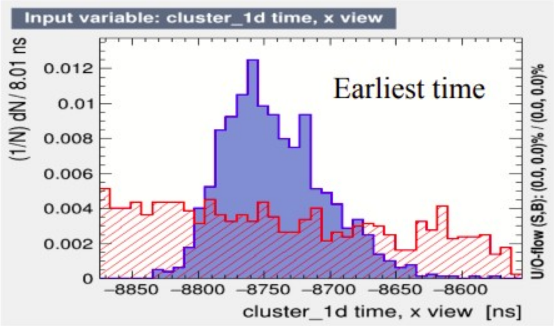
Code committed to CVS in:

- CgemRecEvent, tag 19
- CgemClusterCreate, tag 38
- CgemLineFit, tag 32

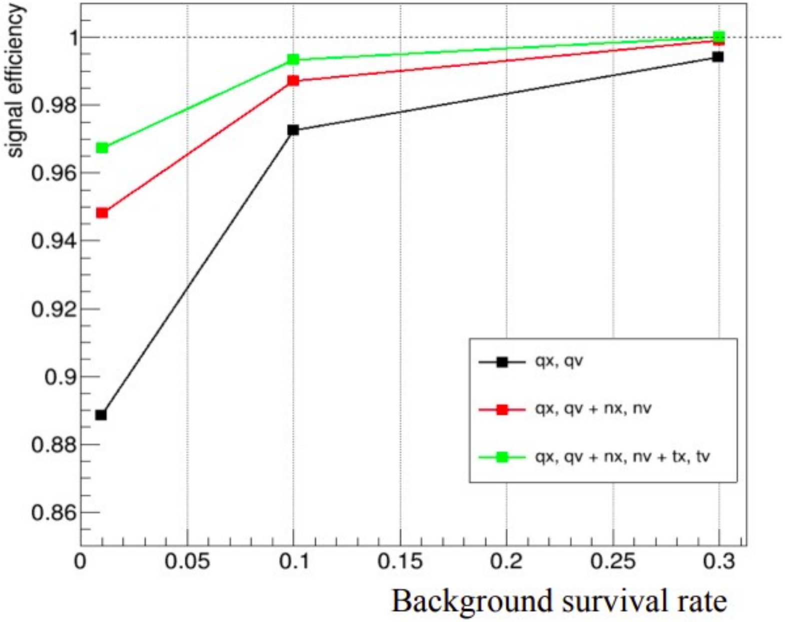
Machine Learning

- Machine Learning to separate signal from noise at hit/cluster level (classification)
- Use TMVA, Boosted Decition Tree
- No big development from last time, only added more variables:
  - Cluster 1d Charge x, v (starting point)
    + cluster 1d size x, y
    + fastest hit in cluster 1d x, y





→ improvement



Tuning

Updates since last BESIII Italy

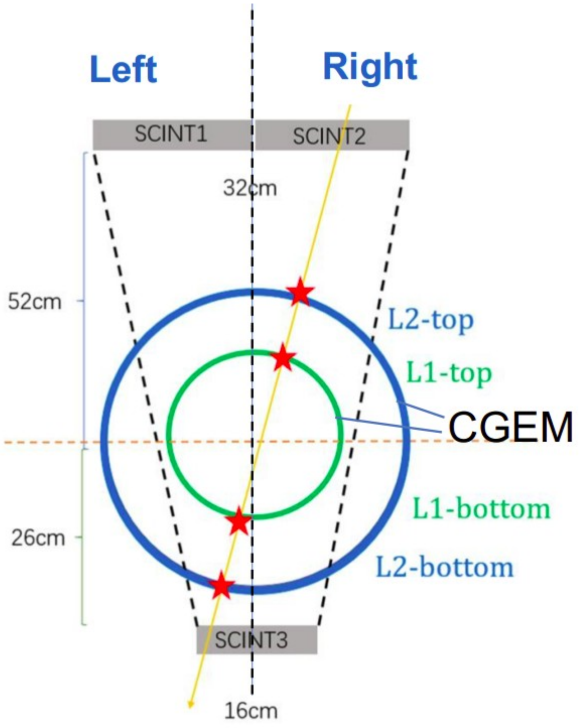
- Tuning on charge sharing
- Tuning on diffusion
- Asymmetries in data

Digitization in CgemBoss

Ongoing tuning on cosmic ray data (run 17)

In the **MC simulation** there are:

- Geometry of the setup:
  - cylinders
  - scintillators
  - pole is not inserted
- Microsectors
- Channel-dependent thresholds, both TIGER branches
- Dead channels
- Correction for the loss of "one-out-of-64 hits" as in real data (firmware fixed, old data probl
- MC weighted to match different area efficiency from data (acceptance)
- gap-allowed clustering



Problem

- There are un-explained (so far) asymmetries in data, not reproduced in MC
- → anomalous areas removed from tuning

Tuned quantities

- Mean gain
- Charge sharing/spread
- Spatial diffusion

Digitization in CgemBoss

Gain

- Mean value, G_0 in the Polya

$$P(G) = C_0 \frac{(1+\theta)^{1+\theta}}{\Gamma(1+\theta)} \left(\frac{G}{G_0}\right)^{\theta} exp\left[-(1+\theta)\frac{G}{G_0}\right]$$

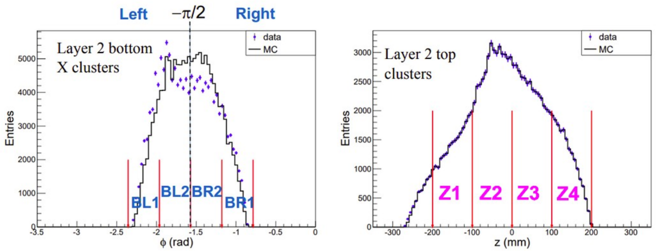
- $G_0 \sim 1.6$

Charge sharing/spread

- Qv/Qx

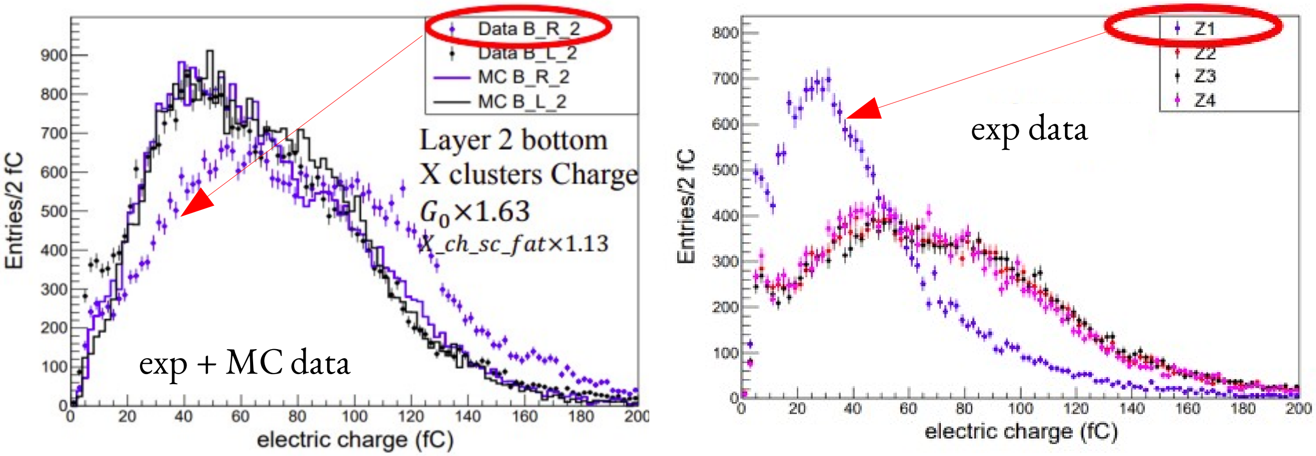
Some anomalies show up when dividing the cylinder in "geometric sectors":

- left/right
- front/back



BL1: Bottom Left part 1
BR1: Bottom Right part 1

LAYER2, cluster 1d, x charge - **not all the "geometric sectors" behave the same**



Digitization in CgemBoss

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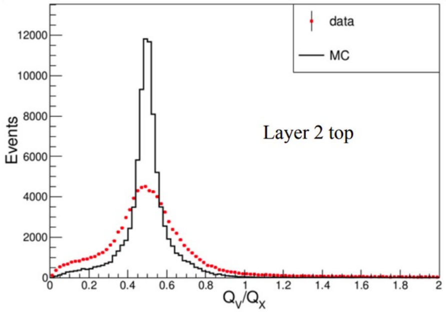
- G_0 ~ 1.6

Charge sharing/spread

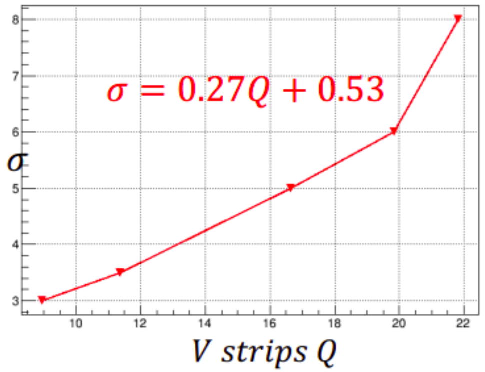
- Qv/Qx
  + additional smearing on Qx

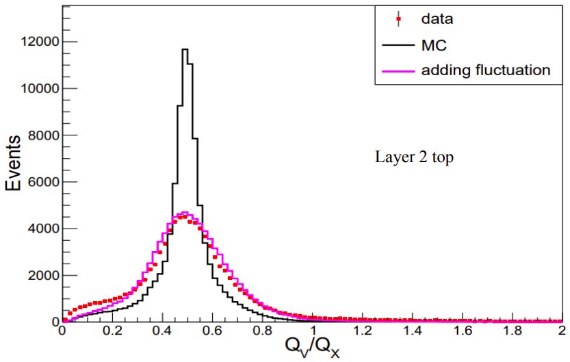
Simulated charge sharing **too peaked → need additional smearing**



- Tried:

1) sampling charge sharing ratios and current (Garfield++) → no impact
2) additional time fluctuation (13 ns) in T-Branch digitization → no impact
3) cluster 1d, x charge distribution is divided into 5 intervals and in each interval, additional spread in charge for MC is added w.r.t the v charge → good match





Digitization in CgemBoss

Gain
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$$P(G)=C_0\frac{(1+\theta)^{1+\theta}}{\Gamma(1+\theta)}\left(\frac{G}{G_0}\right)^{\theta}exp\left[-(1+\theta)\frac{G}{G_0}\right]$$

- G_0 ~ 1.6

Charge sharing/spread
- Qv/Qx
  + additional smearing on Qx

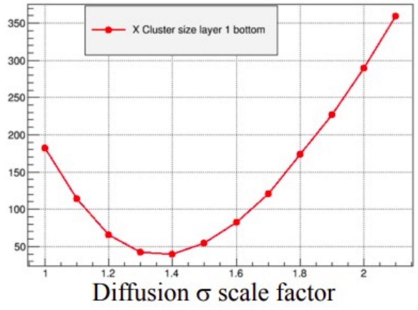
Spatial diffusion
- Sigma from Garfield++ multiplied by a factor

Scan the multiplication factor

Layer 1 top, x view
Layer 1 top, v view
Layer 1 bot, x view

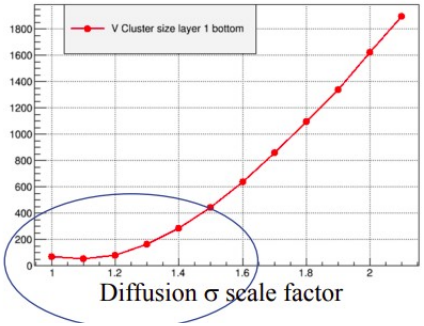
Layer 2 top, x view
Layer 2 top, v view
Layer 2 bot, x view
Layer 2 bot, v view

All behave like this



Only Layer 1 bottom, v view

Behaves like this



Digitization in CgemBoss

Gain

- Mean value, G_0 in the Polya

$$P(G) = C_0 \frac{(1+\theta)^{1+\theta}}{\Gamma(1+\theta)} \left(\frac{G}{G_0}\right)^{\theta} exp\left[-(1+\theta)\frac{G}{G_0}\right]$$

- $G_0 \sim 1.6$

Charge sharing/spread

- Qv/Qx
  + additional smearing on Qx

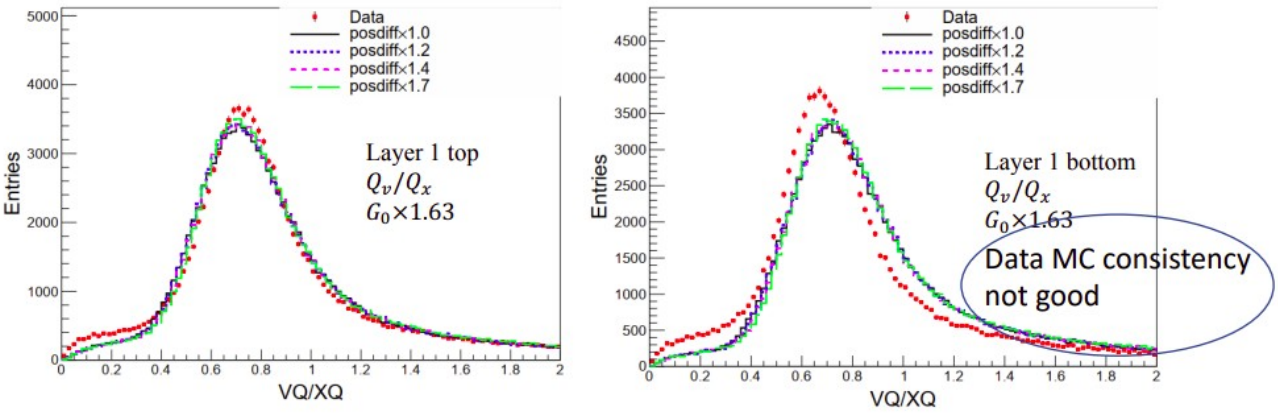
Spatial diffusion

- Sigma from Garfield++ multiplied by a factor

Final result, so far

Charge sharing – LAYER1

Top Bottom



Charge sharing is different in top and bottom of LAYER 1

BUT LAYER1 is just one sheet!

(for now, applied a different charge sharing ratio tuning in digitization)

Software Papers

Track-based alignment for the BESIII CGEM detector in the cosmic-ray test

A. Q. Guo, L. H. Wu, L. L. Wang, R. E. Mitchell, A. Amoroso, R. Baldini Ferroli, I. Balossino, M. Bertani, D. Bettoni, F. Bianchi, A. Bortone, G. Cibinetto, A. Cotta Ramusino, F. Cossio, M. Y. Dong, M. Da Rocha Rolo, F. De Mori, M. Destefanis, J. Dong, F. Evangelisti, R. Farinelli, L. Fava, G. Felici, I. Garzia, M. Gatta, G. Giraudo, S. Gramigna, S. Garbolino, M. Greco, Z. Huang, Y. R. Hou, W. Imoehl, L. Lavezzi, X. L. Lu, M. Maggiora, F. M. Melendi, R. Malaguti, A. Mangoni, S. Marcello, M. Melchiorri, G. Mezzadri, Q. Ouyang, S. Pacetti, P. Patteri, A. Rivetti, R. S. Shi, M. Scodeggio, S. Sosio, S. Spataro, B. L. Wang, H. P. Wang, J. Y. Zhao

The Beijing Electron Spectrometer III (BESIII) is a multipurpose detector operating on the Beijing Electron Positron Collider II (BEPCII). After more than ten year's operation, the efficiency of the inner layers of the Main Drift Chamber (MDC) decreased significantly. To solve this issue, the BESIII collaboration is planning to replace the inner part of the MDC with three layers of Cylindrical triple Gas Electron Multipliers (CGEM). The transverse plane spatial resolution of CGEM is required to be 120 μm or better. To meet this goal, a careful calibration of the detector is necessary to fully exploit the potential of the CGEM detector. In all the calibrations, the detector alignment plays an important role to improve the detector precision. The track-based alignment for the CGEM detector with the Millepede algorithm is implemented to reduce the uncertainties of the hit position measurement. Using the cosmic-ray data taken in 2020 with the two layers setup, the displacement and rotation of the outer layer with respect to the inner layer is determined by a simultaneous fit applied to more than 160000 tracks. A good alignment precision has been achieved that guarantees the design request could be satisfied in the future. A further alignment is going to be performed using the combined information of tracks from cosmic-ray and collisions after the CGEM is installed into the BESIII detector.

Subjects: **High Energy Physics - Experiment (hep-ex)**; Instrumentation and Detectors (physics.ins-det)
Cite as: arXiv:2211.01101 **[hep-ex]**

Submitted

PARSIFAL: a toolkit for triple-GEM parametrized simulation

A. Amoroso, R. Baldini Ferroli, I. Balossino, M. Bertani, D. Bettoni, F. Bianchi, A. Bortone, A. Calcaterra, S. Cerioni, W. Cheng, G. Cibinetto, A. Cotta Ramusino, F. Cossio, M. Da Rocha Rolo, F. De Mori, M. Destefanis, J. Dong, F. Evangelisti, R. Farinelli, L. Fava, G. Felici, I. Garzia, M. Gatta, G. Giraudo, S. Gramigna, M. Greco, L. Lavezzi, M. Maggiora, R. Malaguti, A. Mangoni, S. Marcello, M. Melchiorri, G. Mezzadri, E. Pace, S. Pacetti, P. Patteri, J. Pellegrino, A. Rivetti, M. Scodeggio, S. Sosio, S. Spataro

PARSIFAL (PARametrized SImulation) is a fast and reliable software tool that reproduces the complete response of a triple-GEM detector to the passage of a charged particle, taking into account the main physical effects. Starting from the detector configuration and the particle information, PARSIFAL reproduces ionization, spatial and temporal diffusion, effect of magnetic field, if present, and GEM amplification to provide the dependable triple-GEM detector response. In the design and pptimization stages of this kind of detectors, simulations play an important role. Accurate and robust software programs, such as GARFIELD++, can simulate the transport of electrons and ions in a gas medium and their interaction with the electric field, but they are CPU-time consuming. The necessity to reduce the processing time while maintaining the precision of a full simulation is the main driver of this work. For a given set of geometrical and electrical settings, GARFIELD++ is run once-and-for-all to provide the input parameters for PARSIFAL. Once PARSIFAL is initialized and run, it produces the detector output, including the signal induction and the output of the electronics. The results of the analysis of the simulated data obtained with PARSIFAL are compared with the results of the experimental data collected during a testbeam: some tuning factors are applied to the simulation to improve the agreement. This paper describes the structure of the code and the methodology used to match the output to the experimental data.

Comments: to be submitted to Computer Physics Communications, CPiC
Subjects: **Instrumentation and Detectors (physics.ins-det)**
Cite as: arXiv:2005.04452 **[physics.ins-det]**
(or arXiv:2005.04452v3 **[physics.ins-det]** for this version)
https://doi.org/10.48550/arXiv.2005.04452

Submitted to Computer Physics Communications

THANK YOU