Straw-tracker simulation

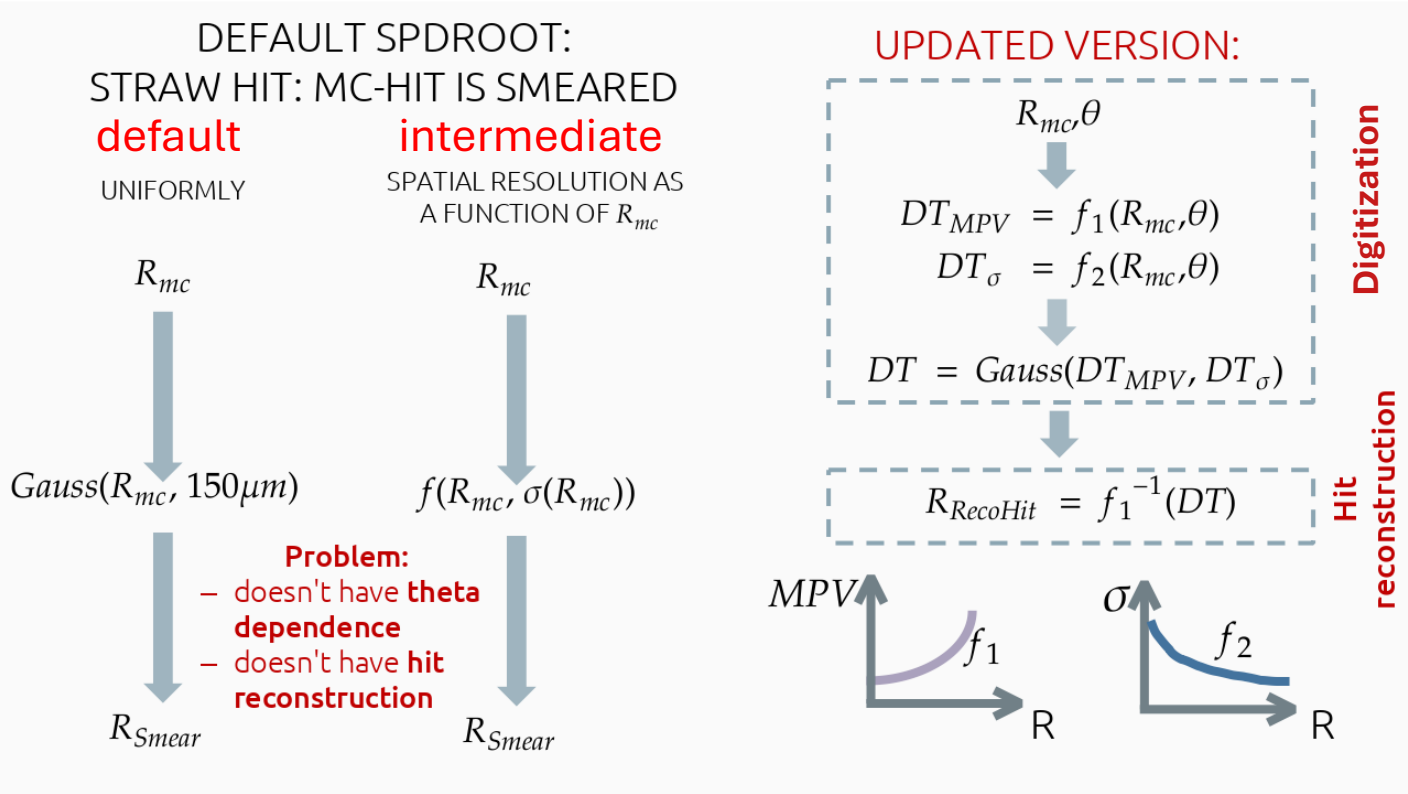
Alexander Lazarev, Katerina Kuznetsova

25 Mar 2026

Outline

- Realistic straw-tracker simulation is done (about a year ago)
- See Ekaterina's report
- General hit reconstruction performance quantities have been studied
- Now we want to study track reconstruction performance
- Need to calculate momentum resolutions
- Firstly need to reproduce previous results (cross-check) obtained with SPDROOT versions without hit reconstruction
- After that compare tracking of master and dev branches to our SPDROOT version with hit reconstruction

Drift time parameterization and hit reconstruction

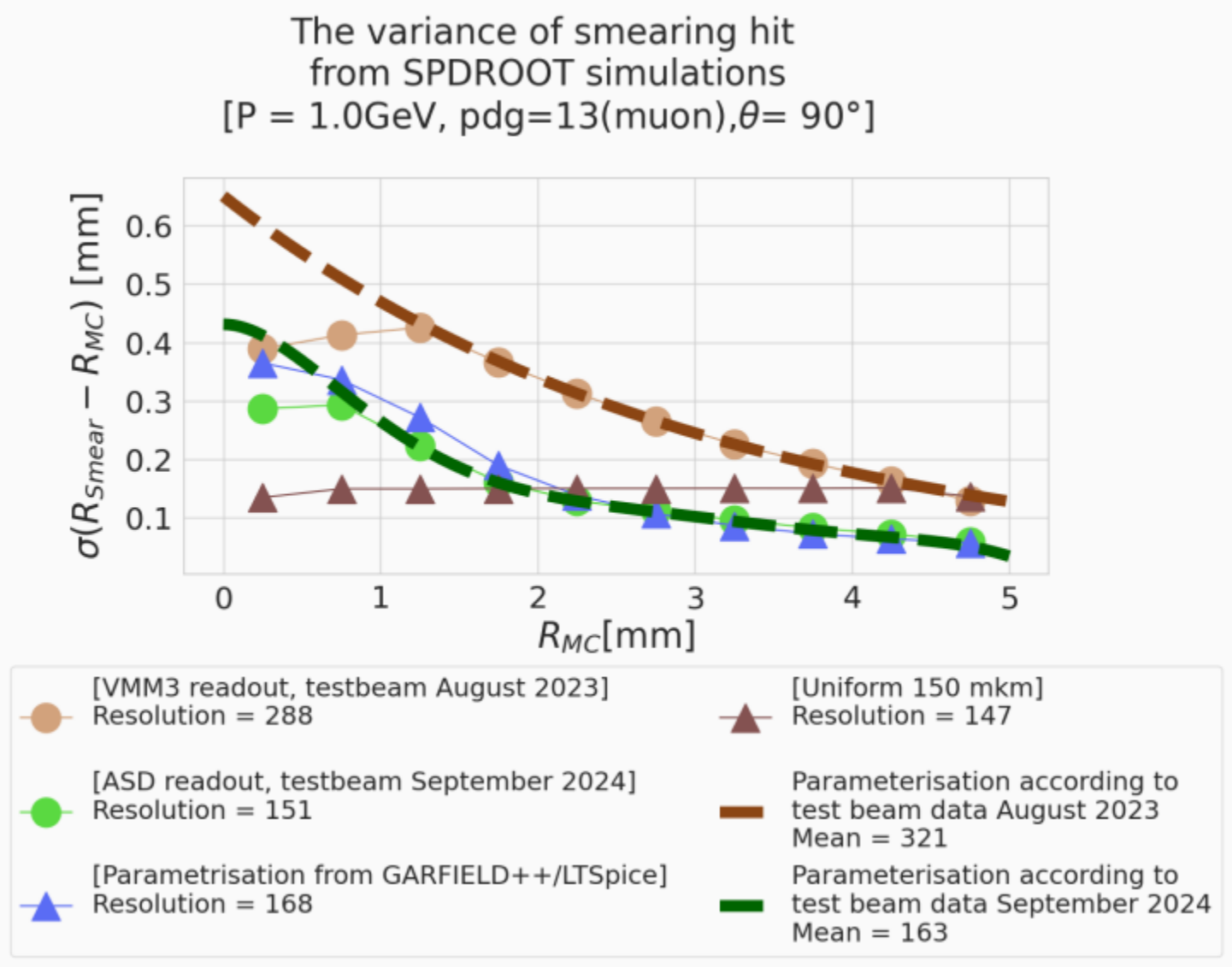


On hit reconstruction in straw.

Source: E. Mosolova et al. Update on Realistic Simulation and Hit Reconstruction for the Straw Tracker; PNPI | IX SPD collaboration meeting; May 15, 2025.

Naming

- Last commit master-version of SPDROOT with R_{hit} smeared by 150 μm with Gauss – **master**
- Last commit development version (6a9837b) with R_{hit} smeared by $\sigma(R) = a_0 \exp(a_1 R)$ with Gauss – **dev** (mean resolution 321 μm)
- Modified **dev** with $\sigma(R) = \sum_{i=0}^{8} a_i R^i$ corresponding to Ekaterina's fit of testbeam data – **2024 version** (mean resolution 163 μm)
- Parameterization with drift time "simulation" and hit reconstruction – **our (or modified) version**



Hit resolutions for different parameterizations.

Source: E. Mosolova et al. Update on Realistic Simulation and Hit Reconstruction for the Straw Tracker; PNPI | IX SPD collaboration meeting; May 15, 2025.

Simulation parameters

- Isotropic generators – one for each run; full ϕ coverage (from 0 to 360)
- Muons (PDG = 13)
- 10000 events for each run
- Straw tilt angle α is fixed and equals 2 degrees (default octant geometry of SPDROOT)
- No vertex at all (neither in simulation, nor in reconstruction), only TS is used
- Cuts from this macro are used + check for primary particles

Two ways to study momentum resolution

We are going to draw $\sigma_p/_p$, $\sigma_{p_T}/_{p_T}$ and $\sigma_{p_z}/_p$

- For comparison to Ruslan's studies (see next slides): take covariation matrix from track fit parameters (works fine for very good fits). $\sigma_{p_z} = \sqrt{\mathrm{cov}(p_z, p_z)}$, while σ_p and σ_{p_T} are calculated using long formulas with $\mathrm{cov}(p_i, p_j)$. These values are filled in histos; needed sigmas are just taken as histograms' mean values, their errors – histograms' mean errors.
- Calculate $\frac{\Delta p}{p} = \frac{p_{MC} - p_{reco}}{p_{MC}}$, fill it in histos, fit them with Gauss – needed sigmas are Gauss sigmas, their errors – fit errors.

Part 1: cross-check

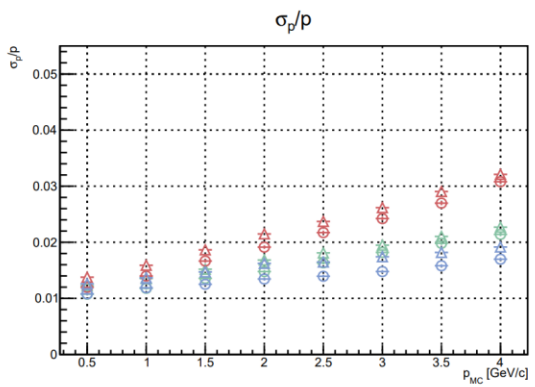
Presentations we cross-check with:

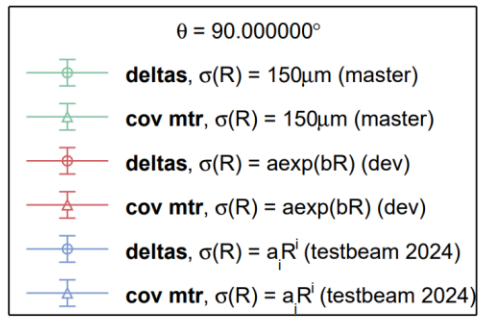
- Ruslan Akhunzyanov. Momentum resolution dependence on straw tube orientation, polar angle, and momentum; JINR, SPD Physics & MC meeting; Nov 10, 2021
- Ruslan Akhunzyanov. Dependence of momentum resolution on straw tracker spatial resolution; JINR, SPD Physics & MC meeting; Jun 19, 2024

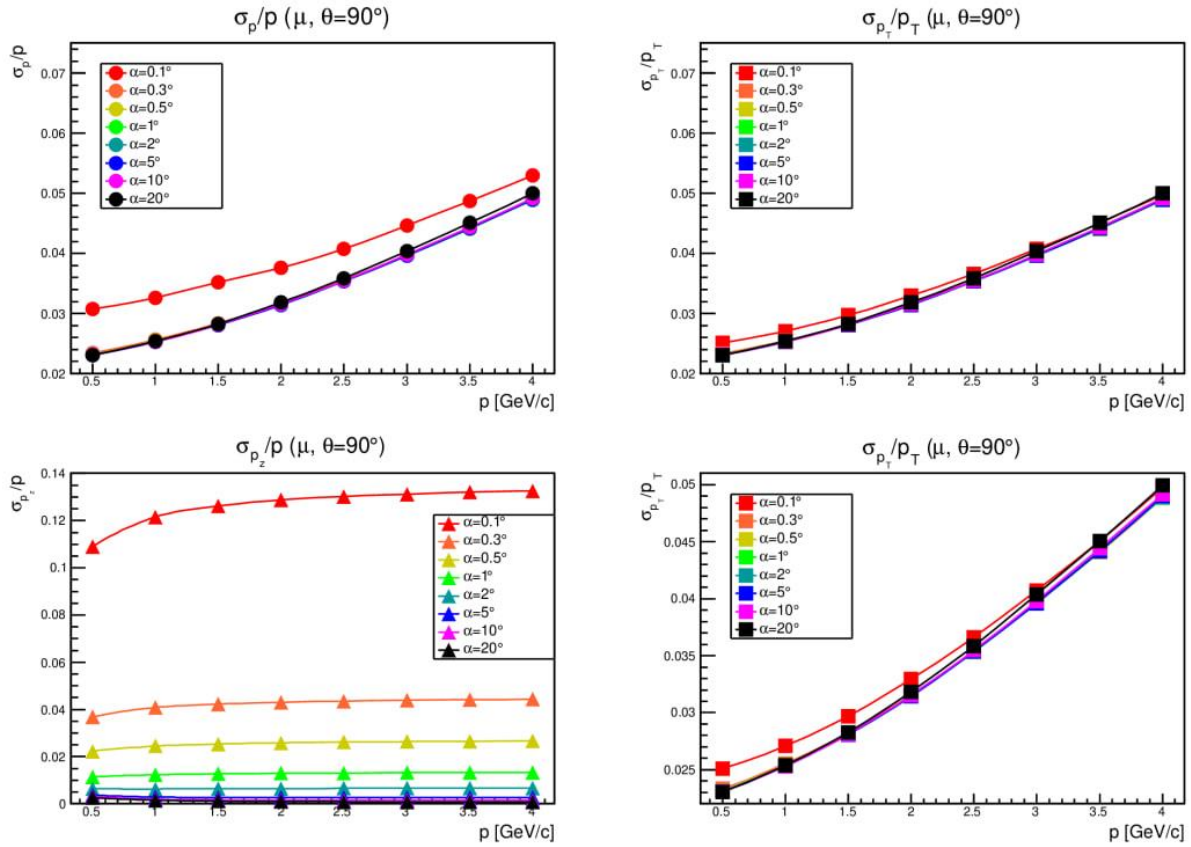
A comment on these presentations

- 2021 presentation has been made using really old SPDROOT version (4.1.1 or older) – lots of changes could be made since these times
- 2024 presentation has been made using protons and pions instead of muons

Comparison with 2021 results

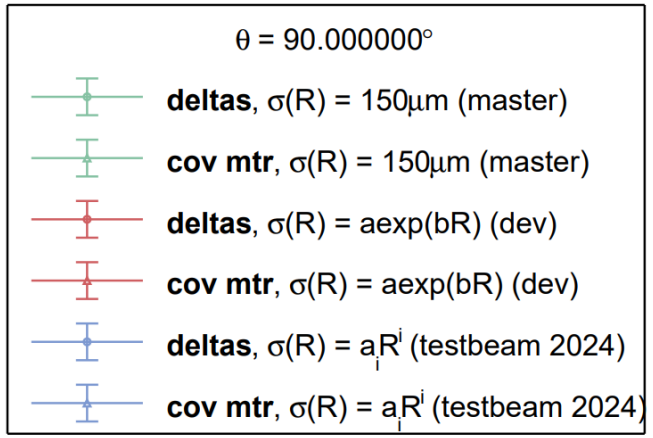


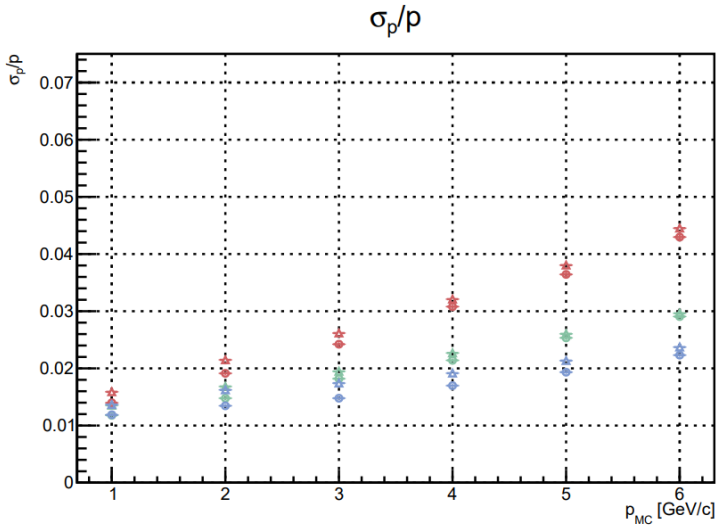


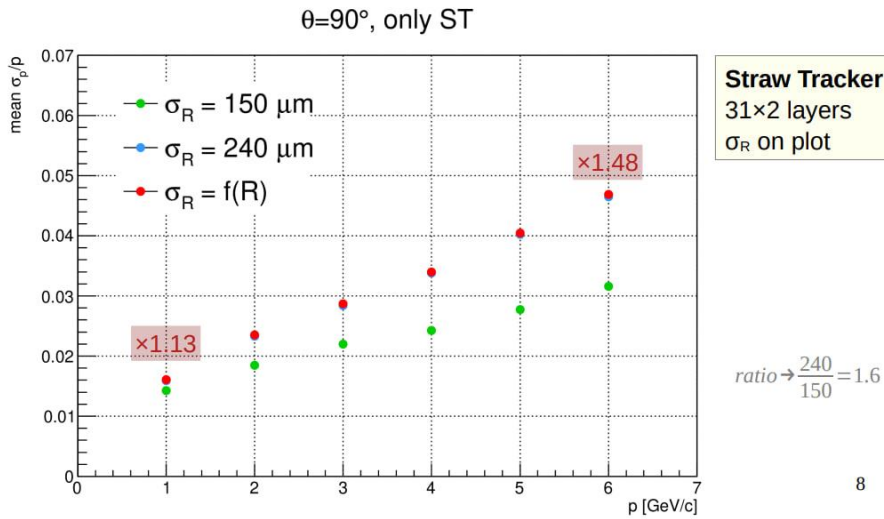


Left: our results. Right: Ruslan's results. Attention on vertical axes ranges. We see difference in 2 times for p and p_T

Comparison with 2024 results

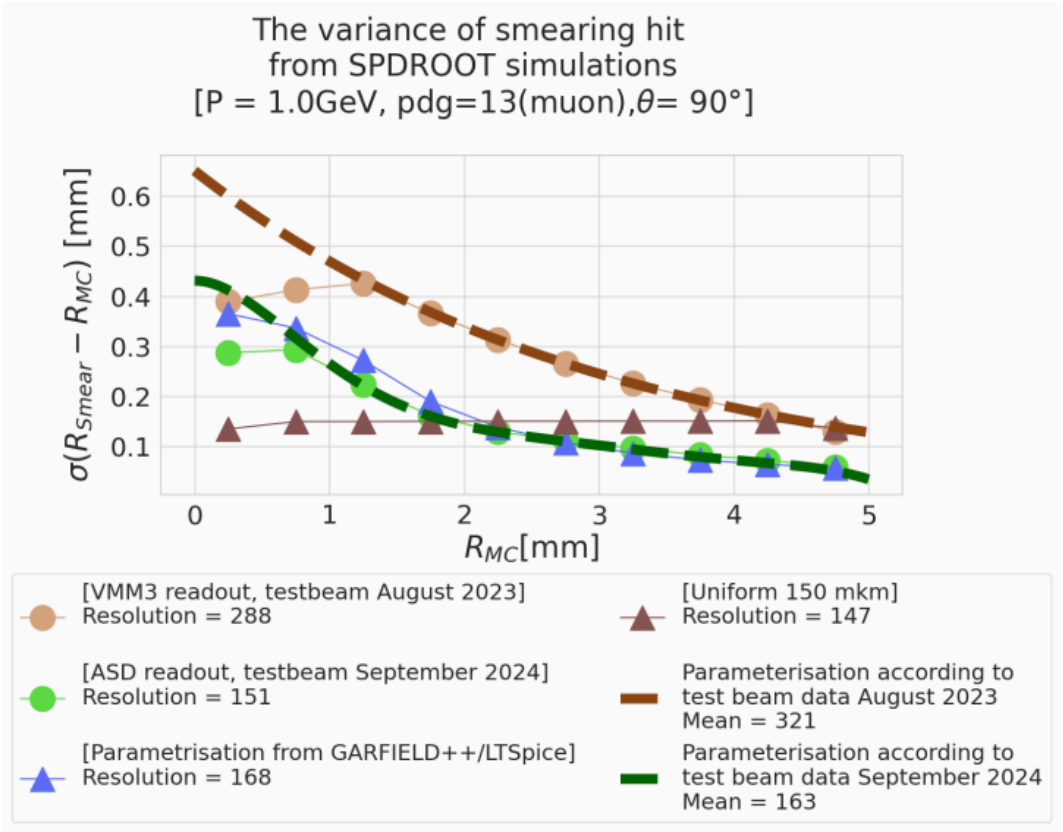


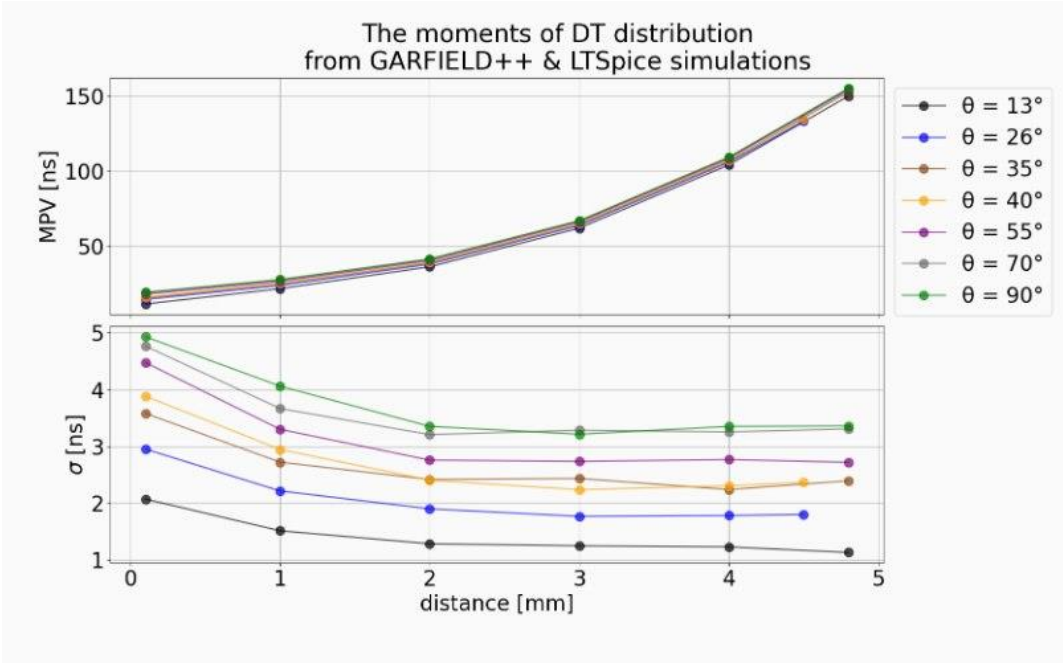


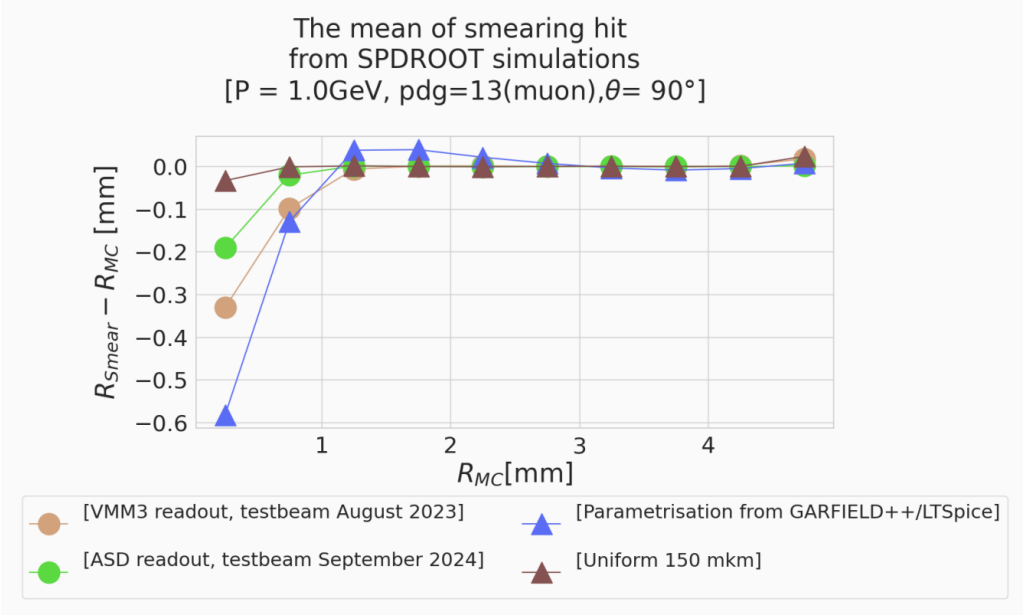


Left: our results. Right: Ruslan's results. Be careful: don't compare blue graphs, they correspond to different parameterizations!

Reminder from Katya's presentation







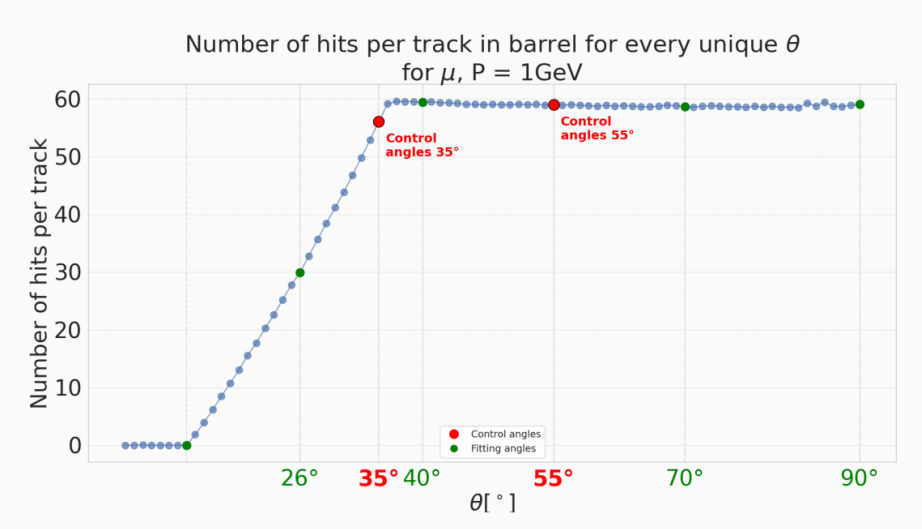
Spatial resolution of realistic simulation + hit reconstruction is in a good agreement with testbeam 2024 data for 90 degrees.

Hit resolutions

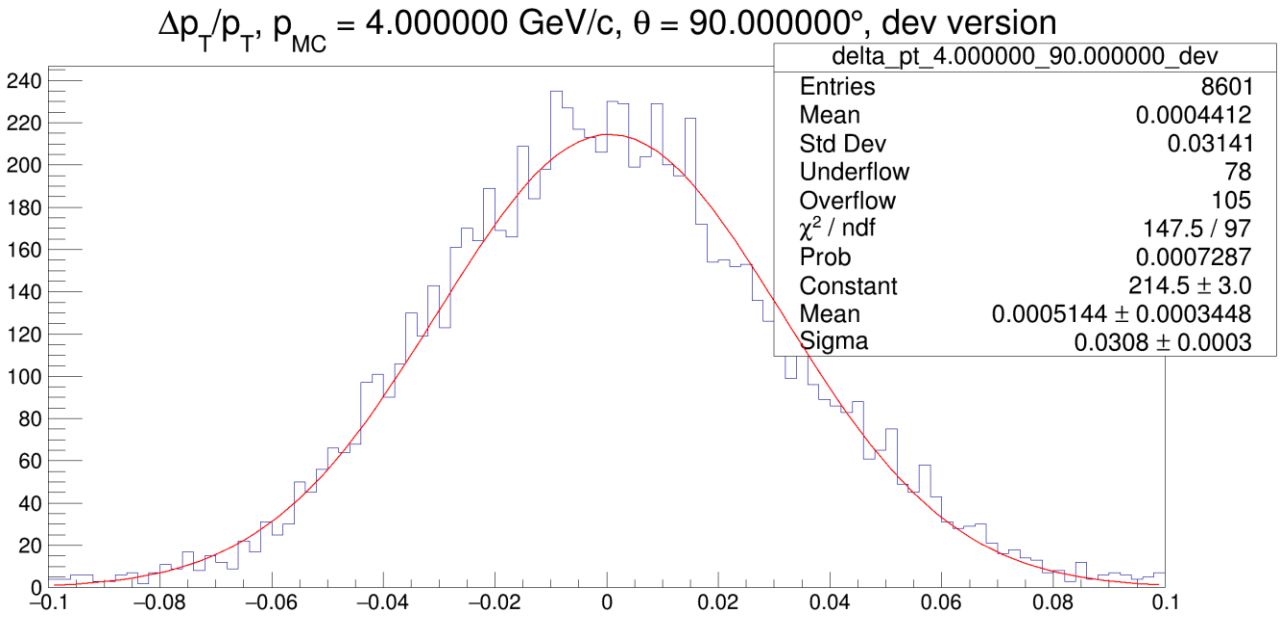
- Two opposite factors, influencing the overall tracking performance:
- Better resolution for smaller θ in realistic simulation
- Our hit reconstruction introduces significant bias near anode wire – the resolutions may become worse, also efficiency suffers

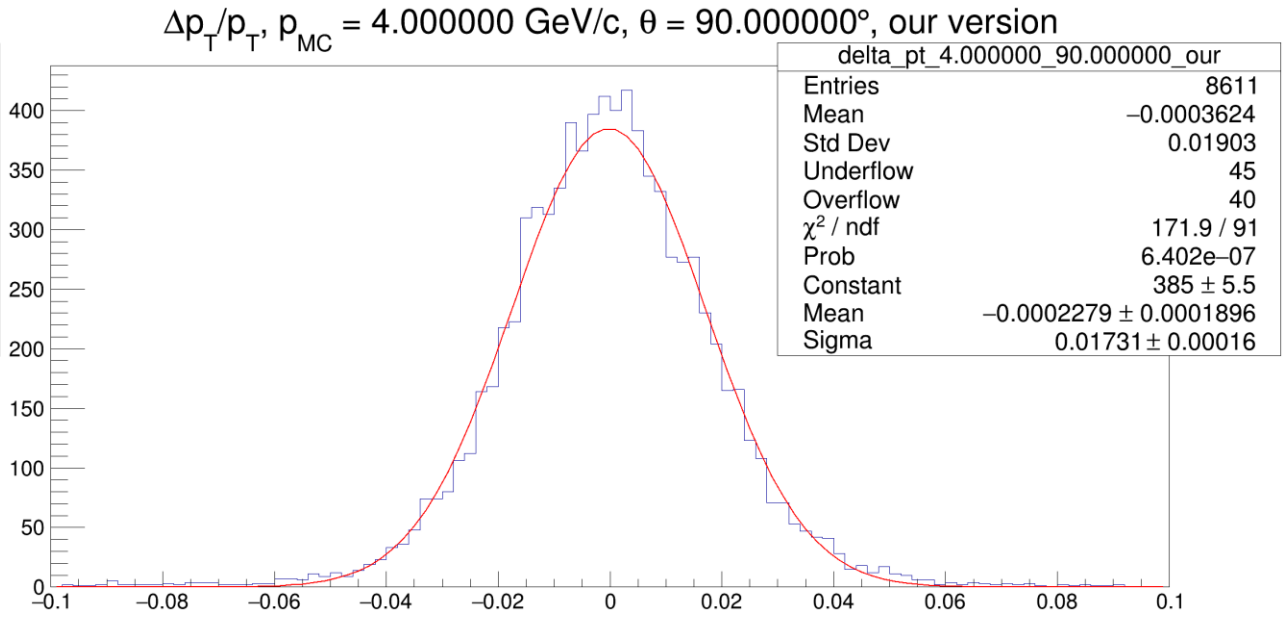
Part 2: tracking studies with the updated SPDROOT version

- Three θ values – 26, 40 and 90 degrees
- Three p_{MC} values – 0.5, 1.0 and 4.0 GeV/c
- Dependencies of momentum resolution on θ for different p_{MC} and on p_{MC} for different θ
- Efficiencies also have been calculated as the number of reconstructed tracks passing the quality cut divided by the number of generated particles – but there are some troubles



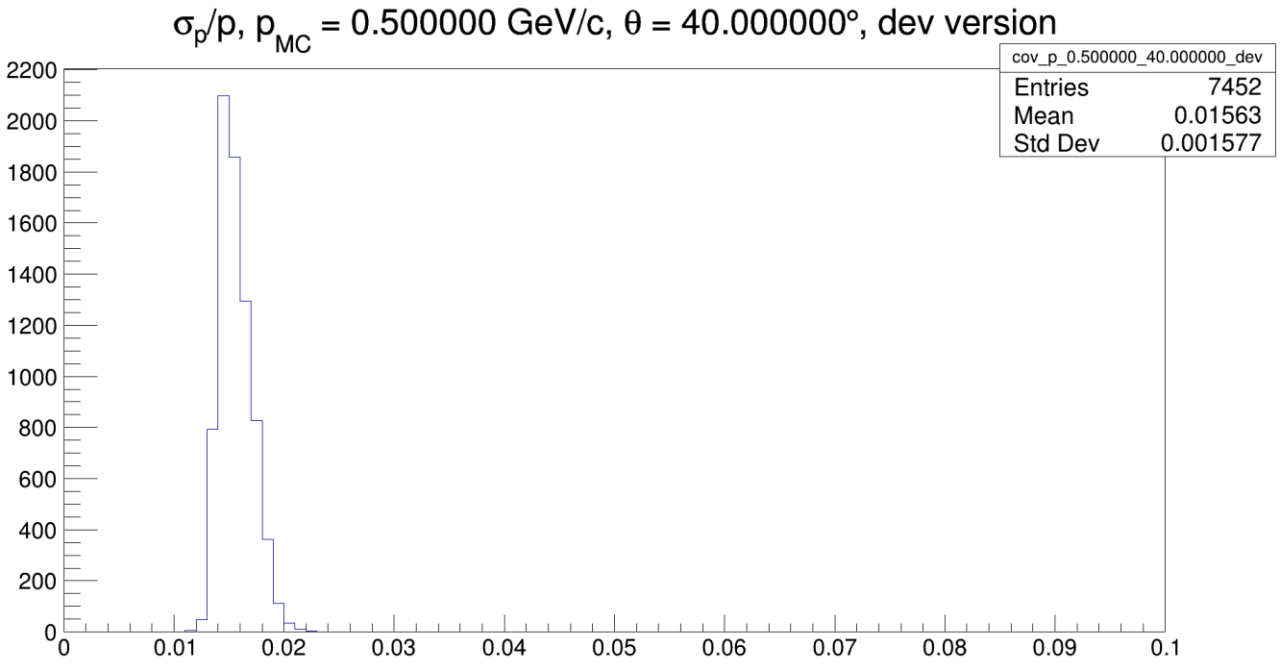
Examples: Δp/p

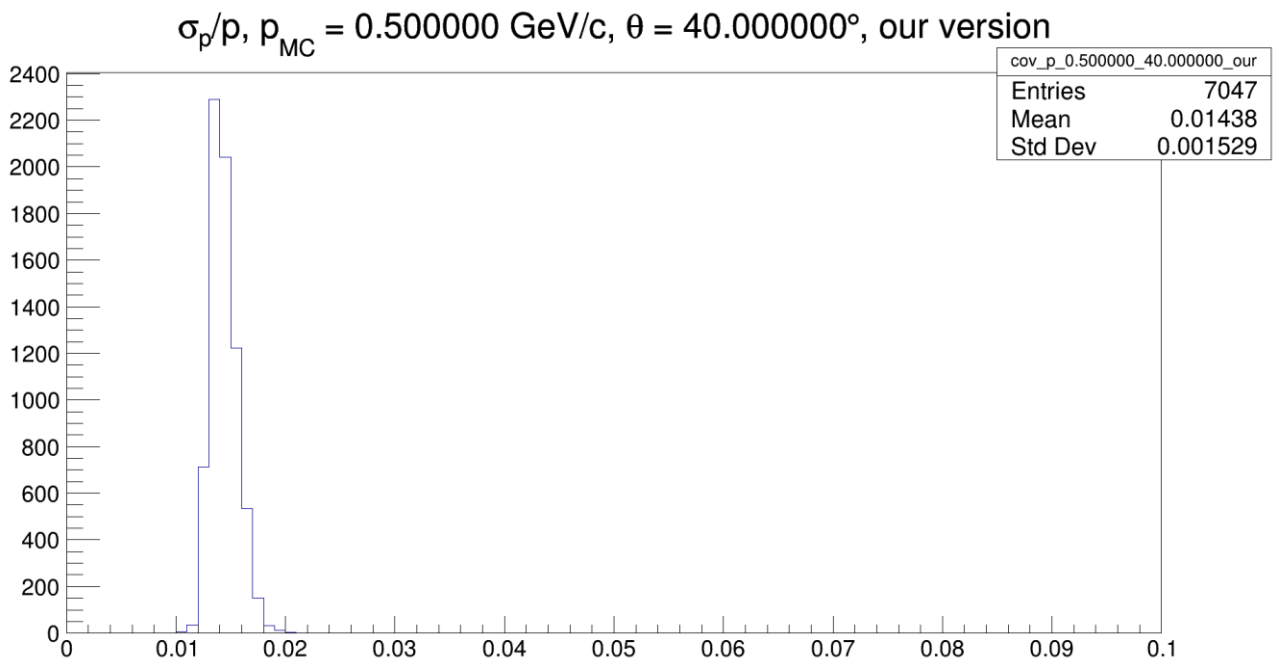




All fits have converged finely. Their sigmas are taken as points for resulting graphs.

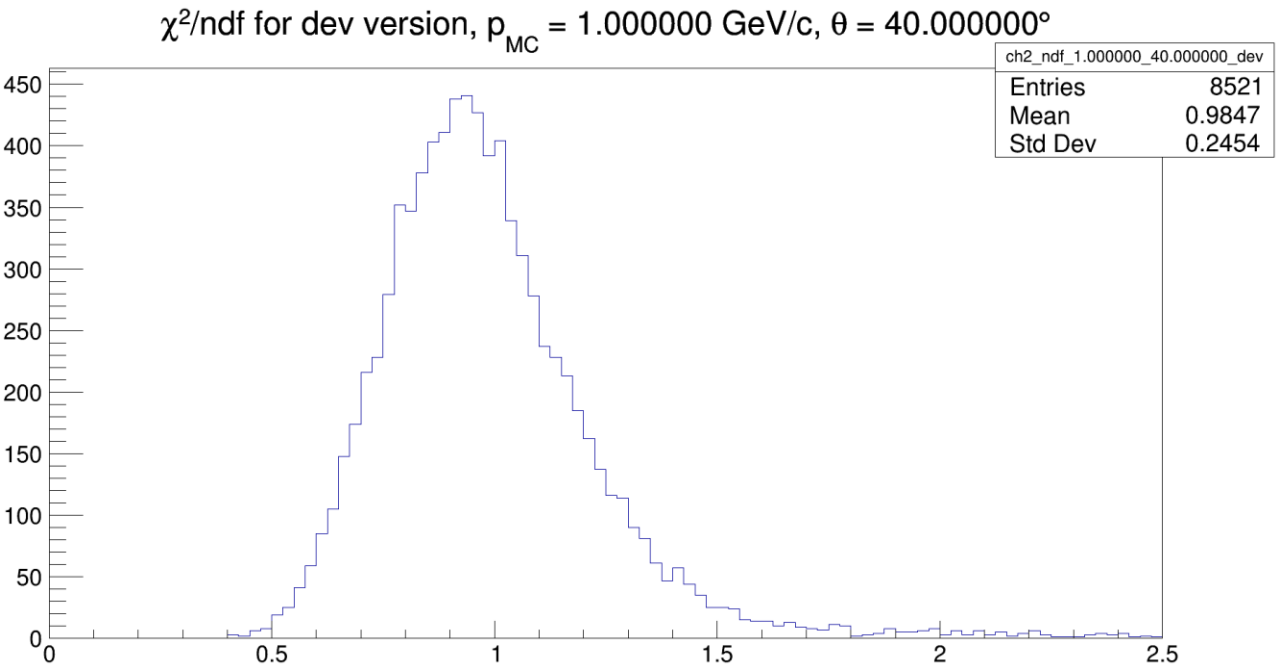
Examples: resolution from covariation matrix

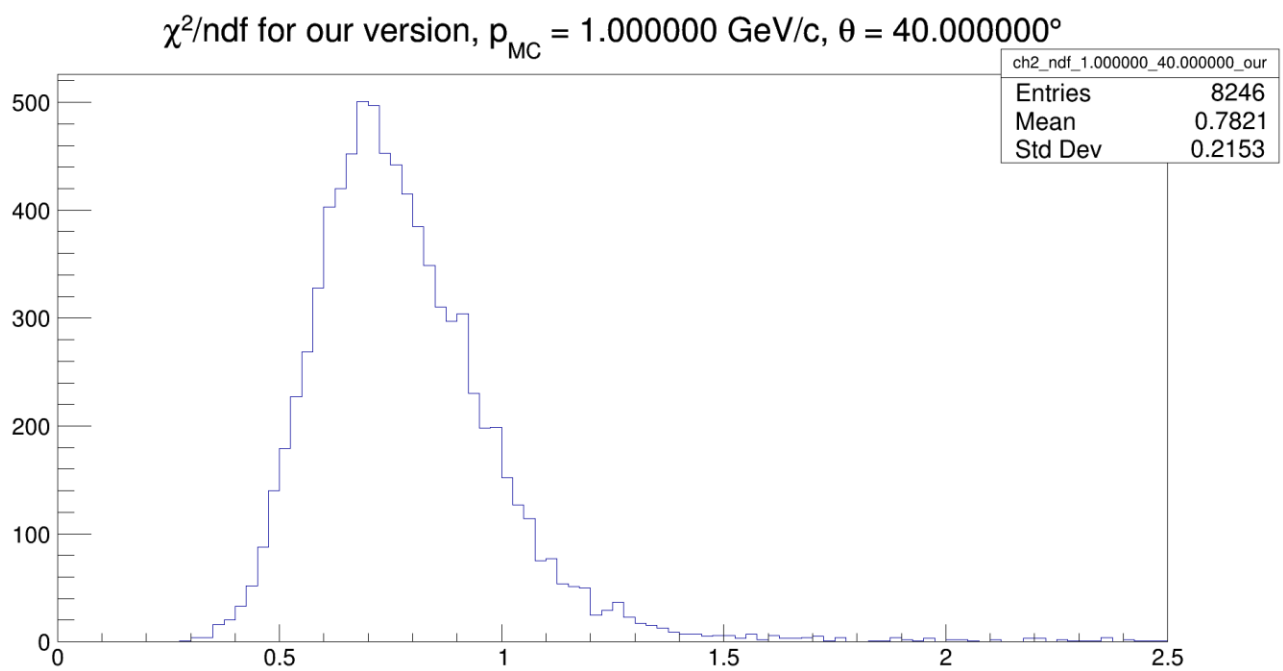




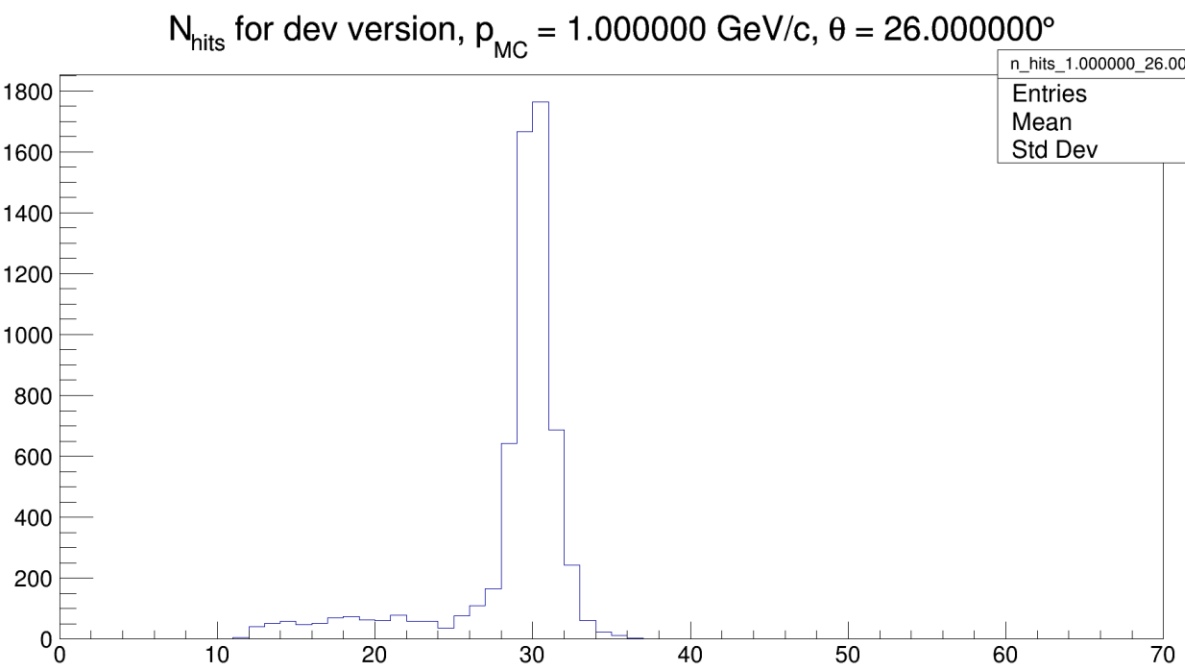
Examples for histograms, built using covariation matrices. Their mean values are taken as points for resulting graphs.

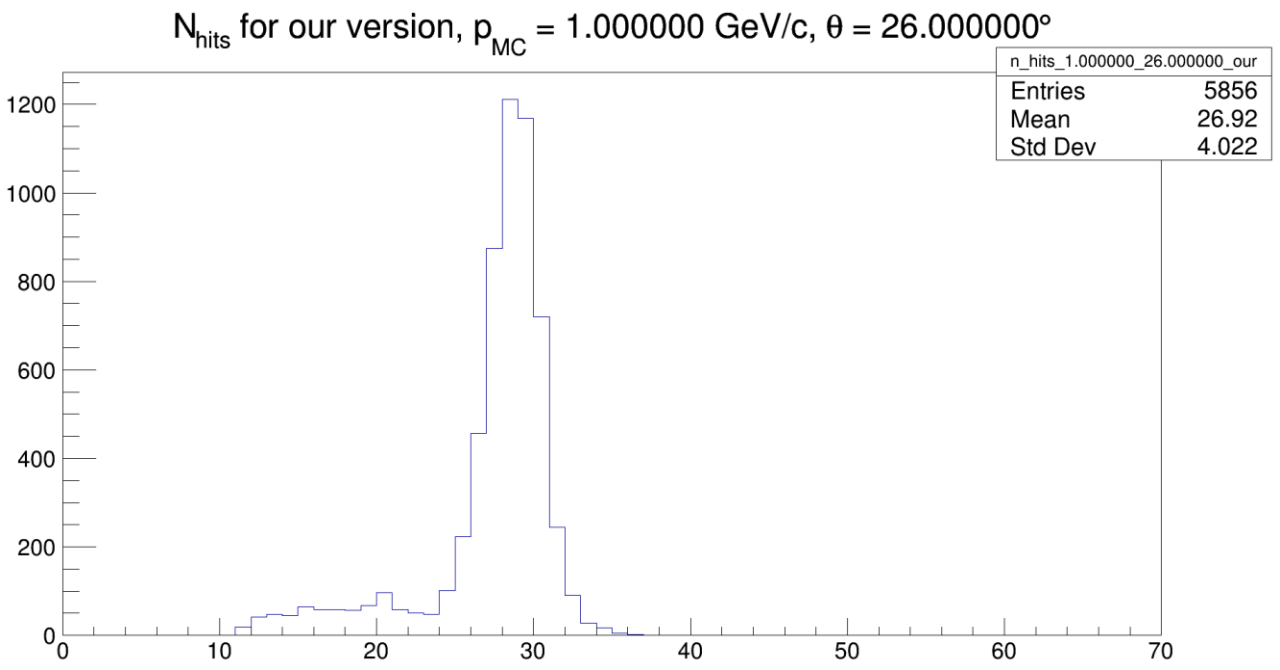
Examples: χ^2/ndf for track fitting





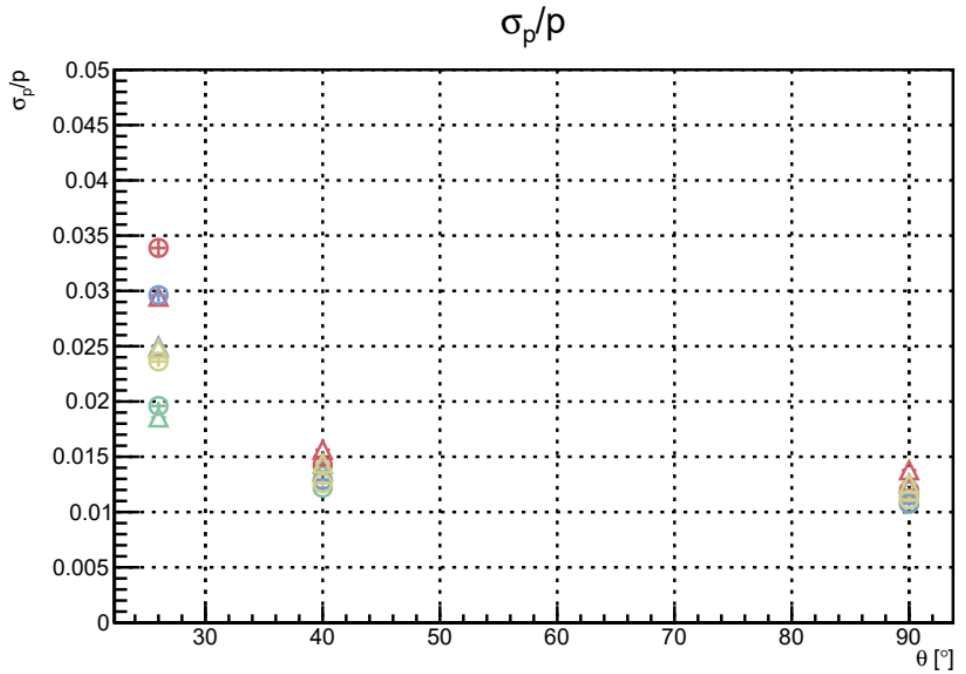
Examples: number of hits per track in barrel



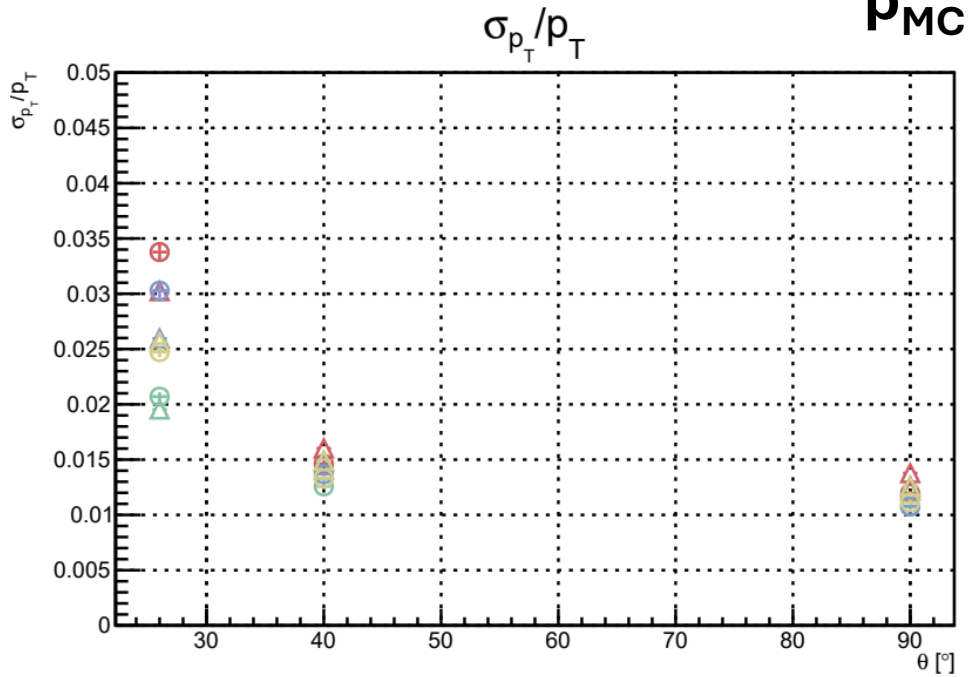


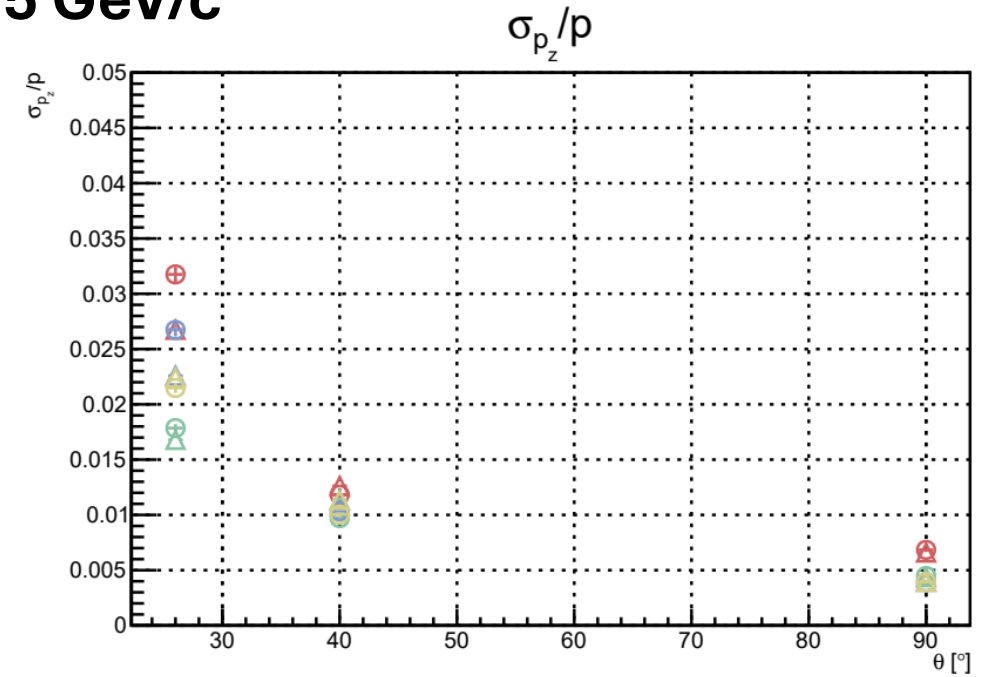
Momentum resolutions obtained with:

- **deltas**, σ(R) = 150μm (master)
- **cov mtr**, σ(R) = 150μm (master)
- **deltas**, σ(R) = aexp(bR) (dev)
- **cov mtr**, σ(R) = aexp(bR) (dev)
- **deltas**, σ(R) = $a_i R^i$ (testbeam 2024)
- **cov mtr**, σ(R) = $a_i R^i$ (testbeam 2024)
- **deltas**, our hit reconstruction
- **cov mtr**, our hit reconstruction



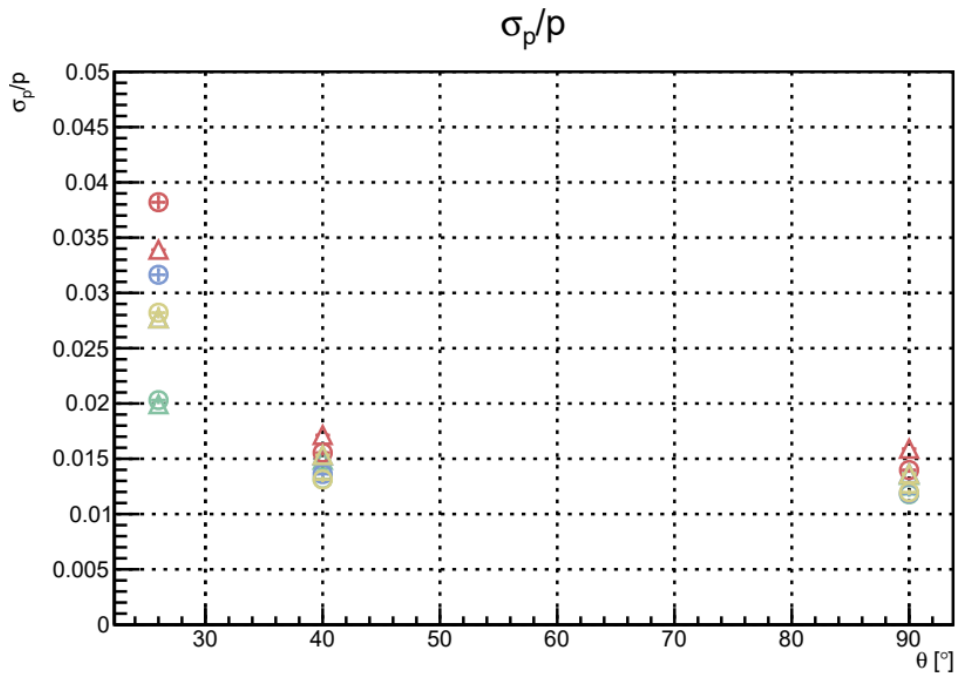
p_{MC} = 0.5 GeV/c



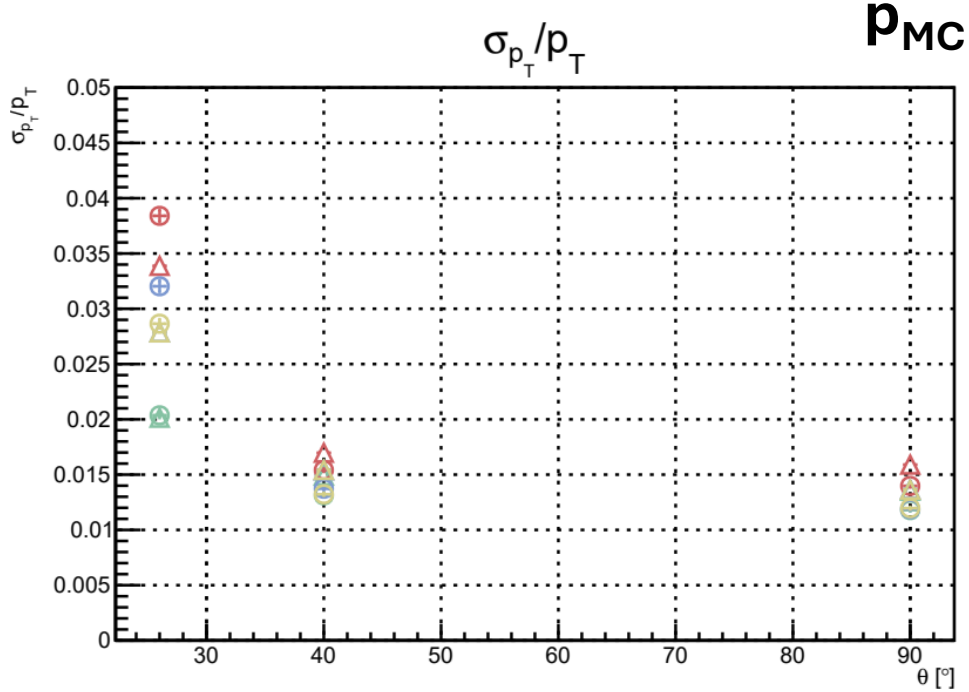


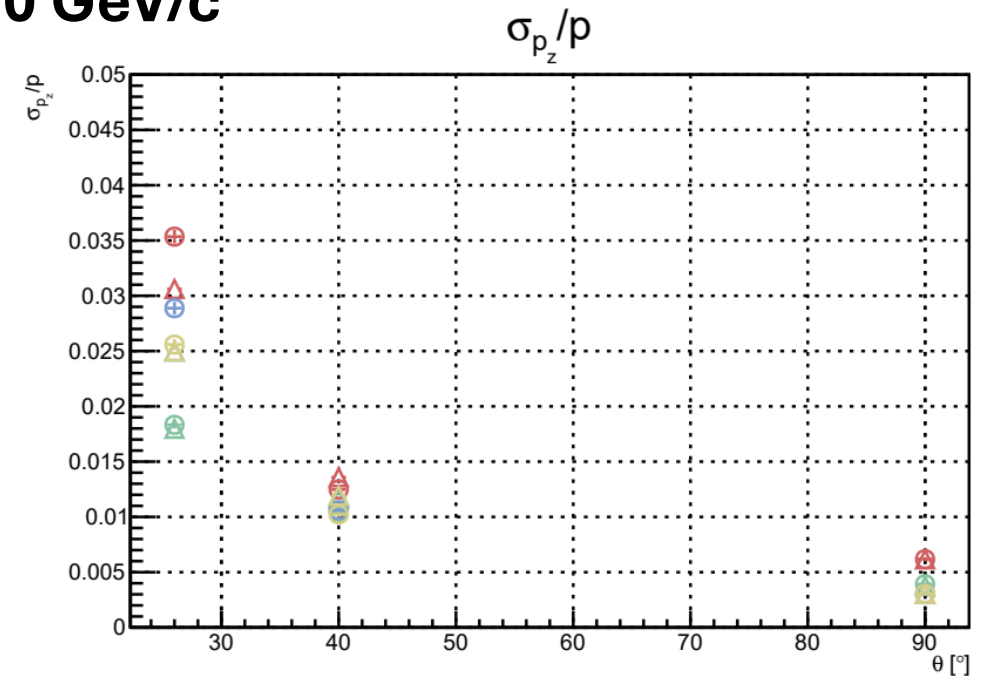
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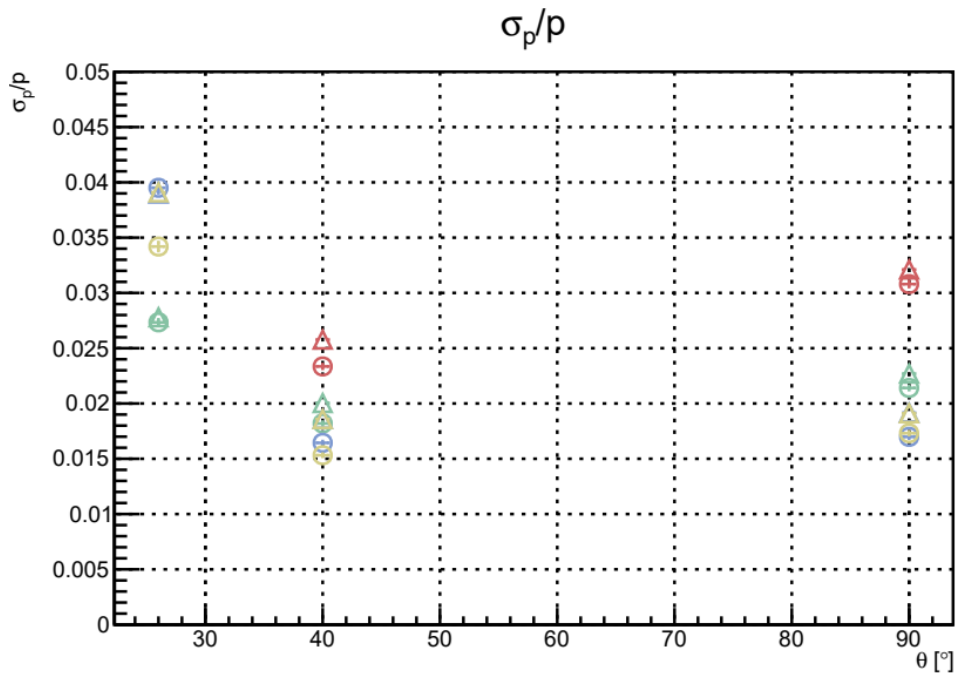
p_{MC} = 1.0 GeV/c



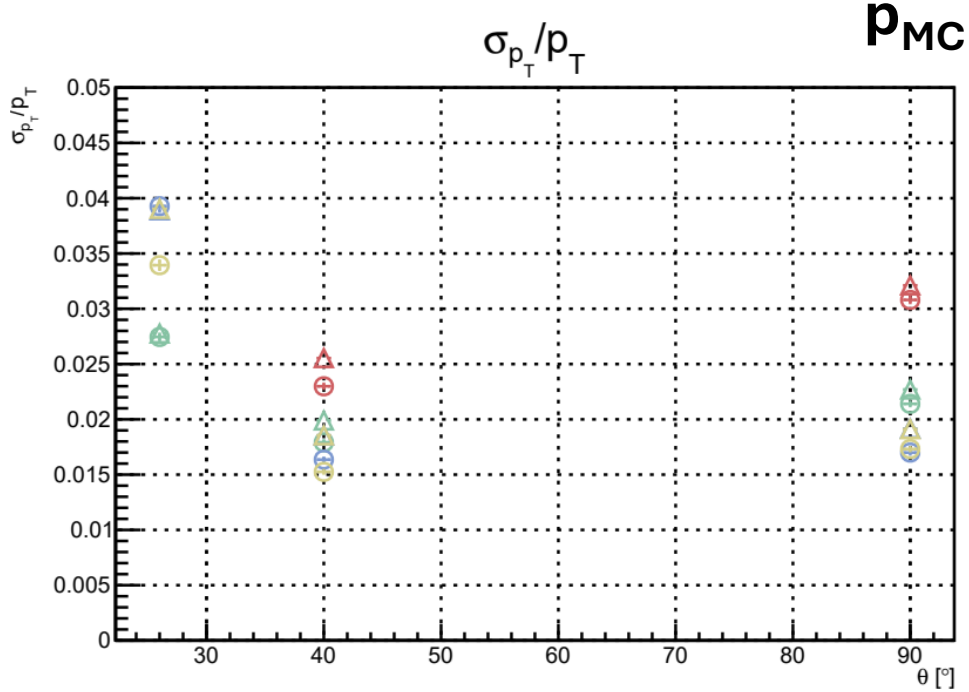


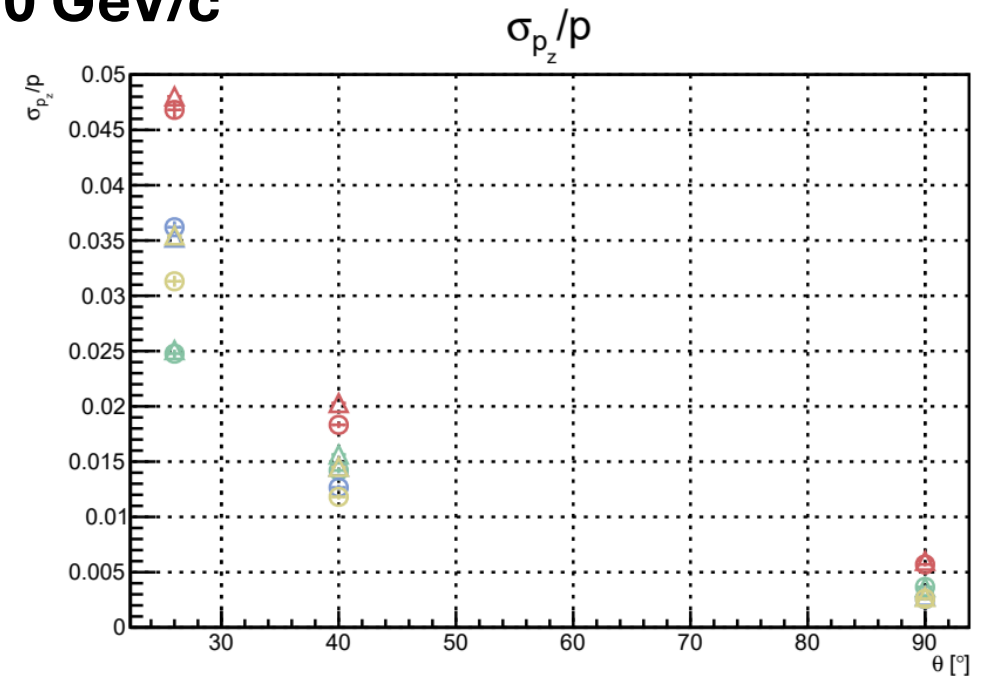
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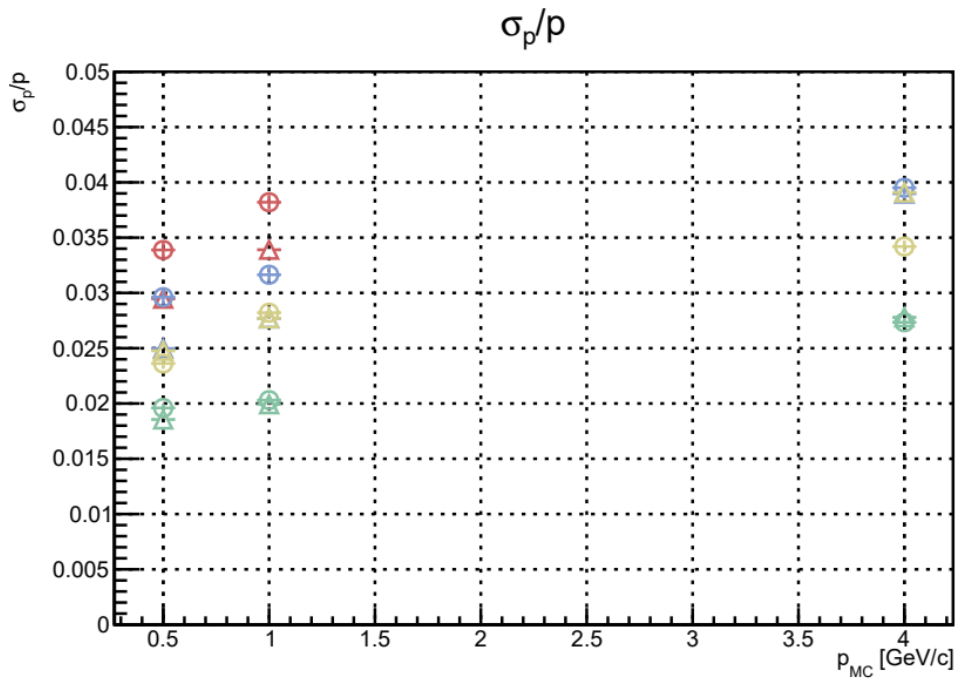
p_{MC} = 4.0 GeV/c



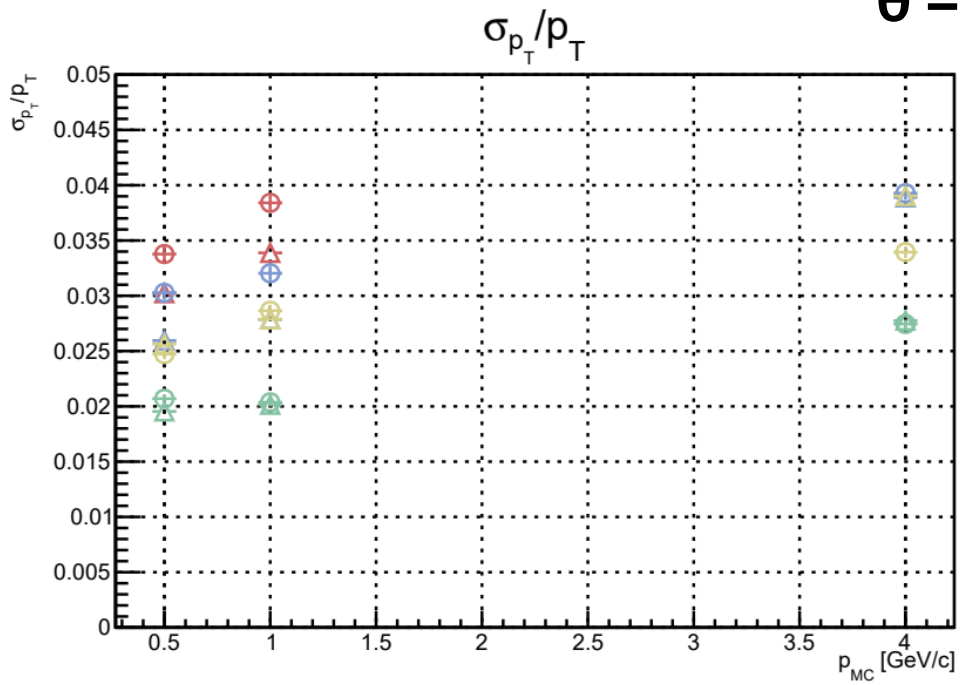


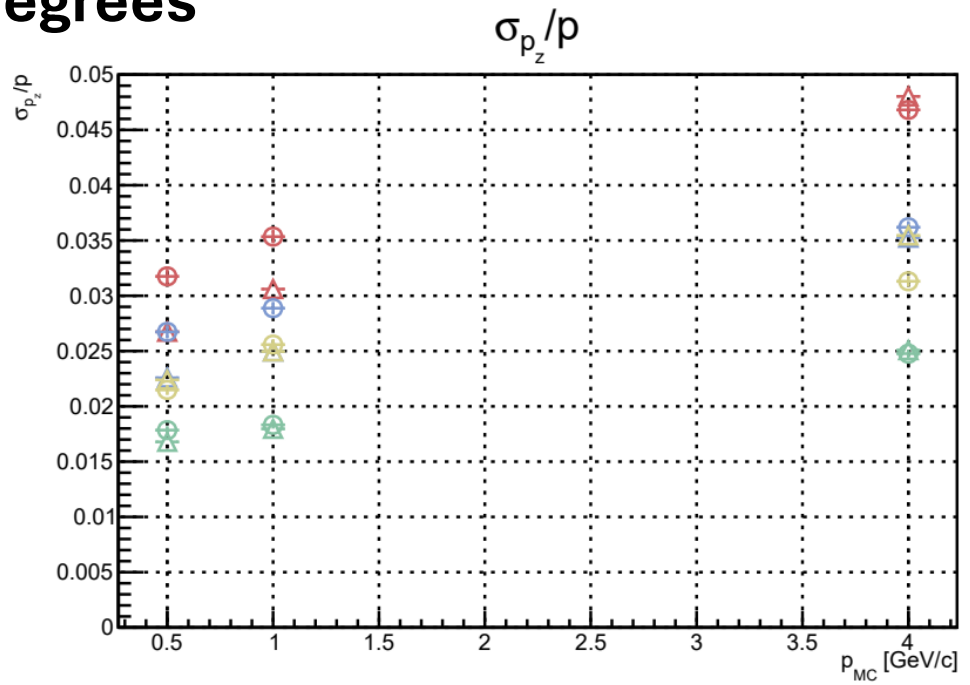
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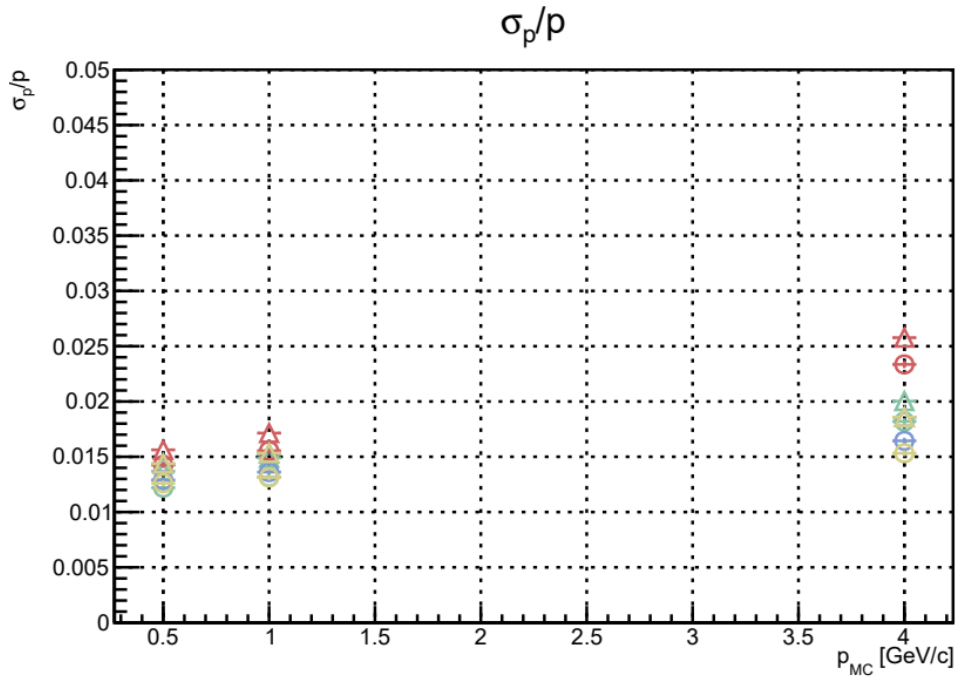
θ = 26 degrees



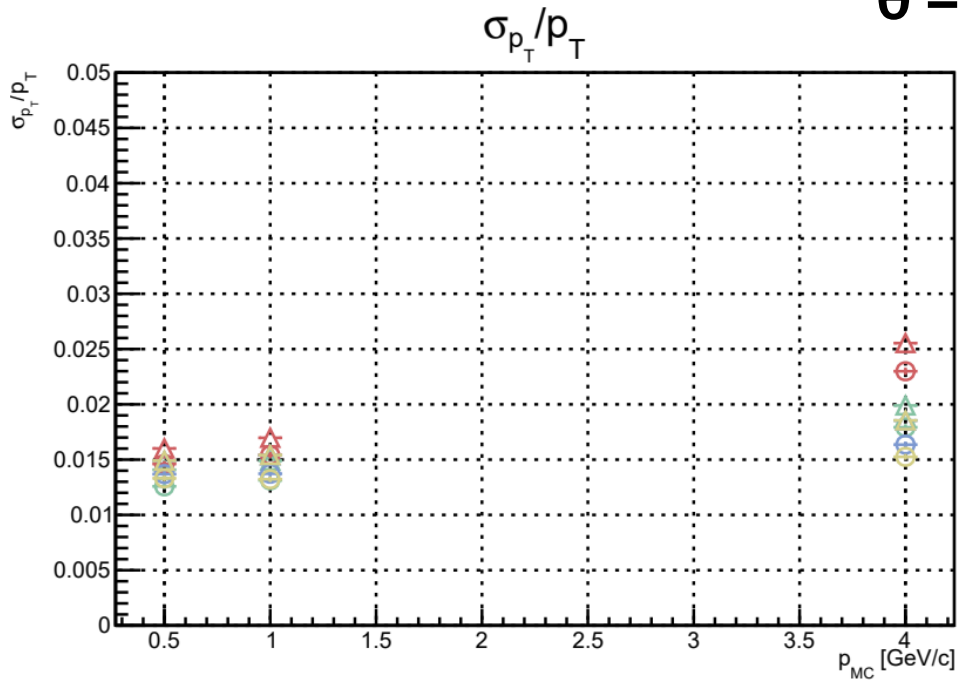


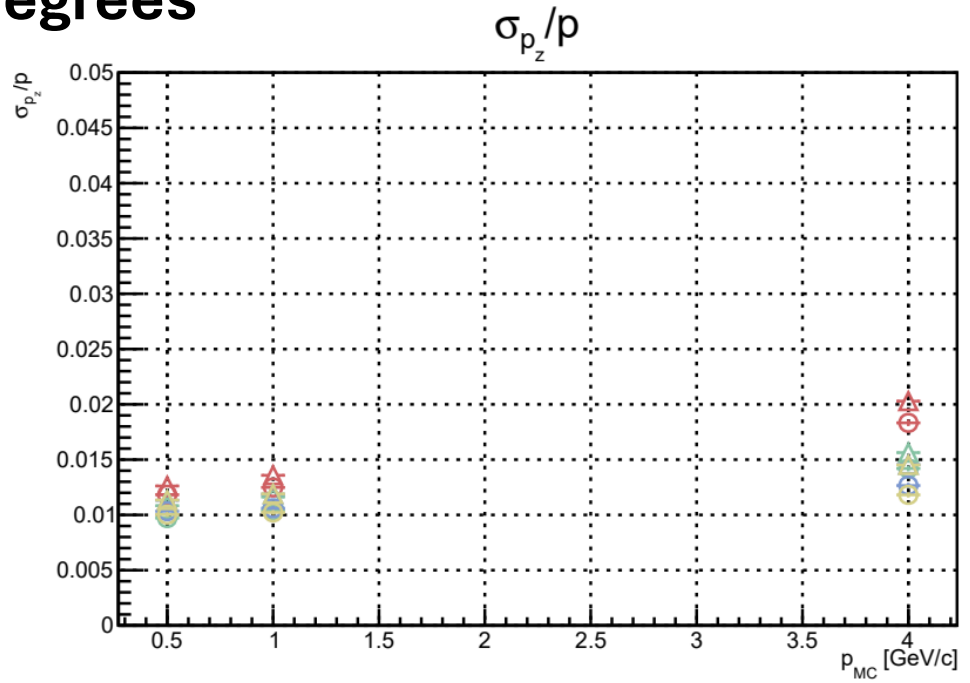
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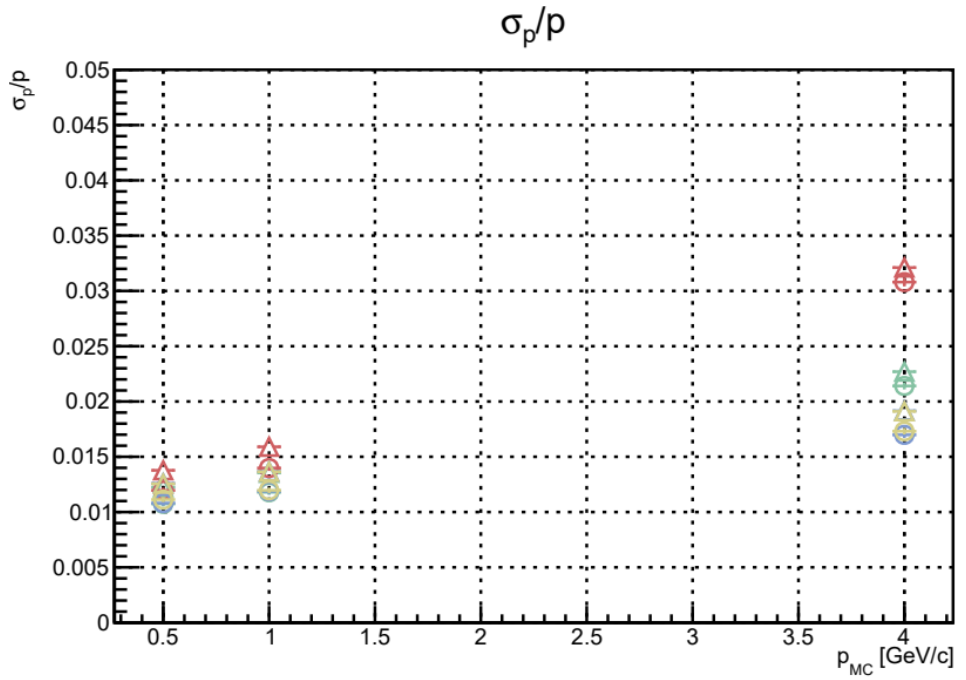
θ = 40 degrees



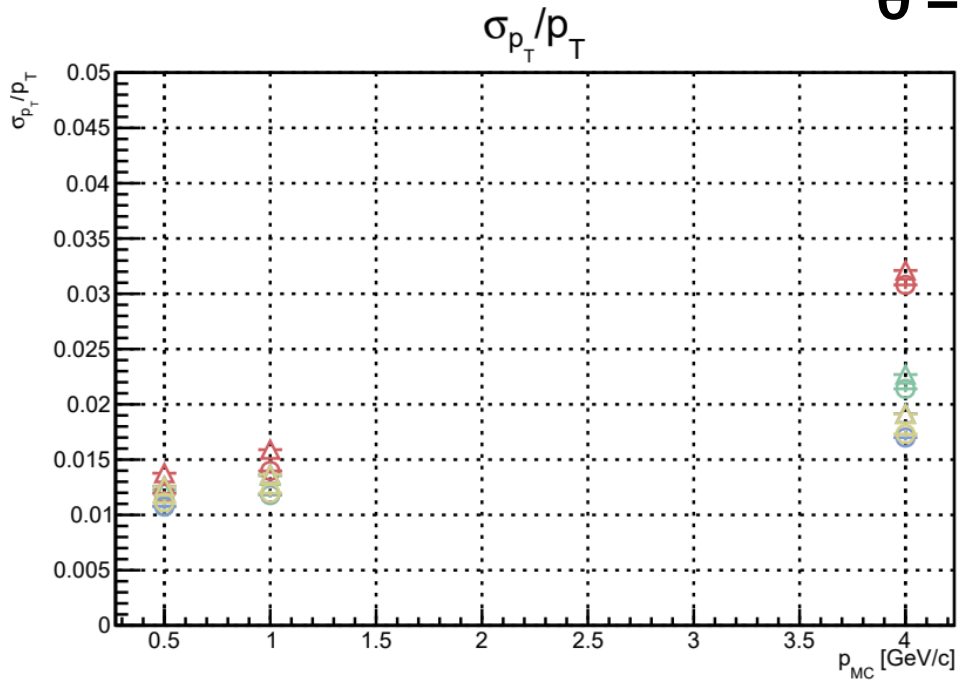


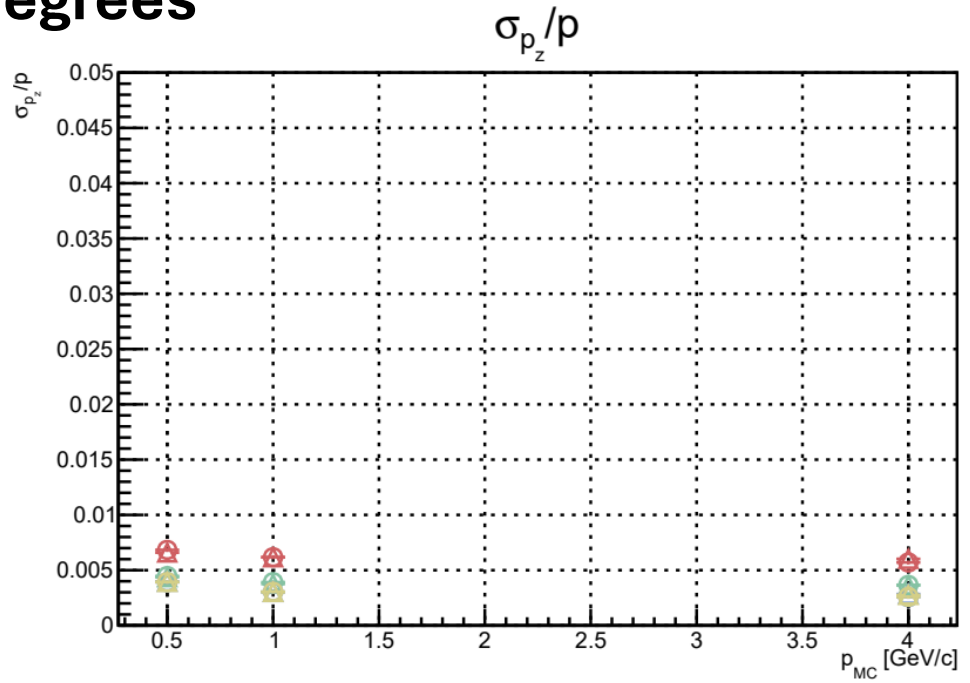
Momentum resolutions obtained with:

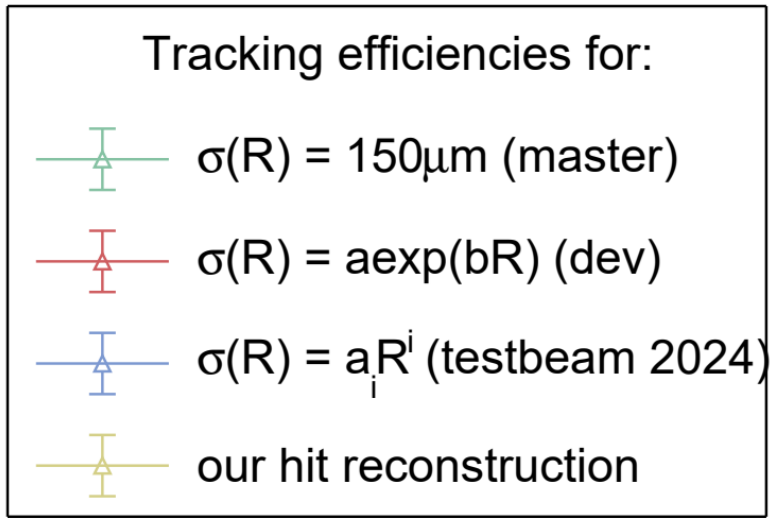
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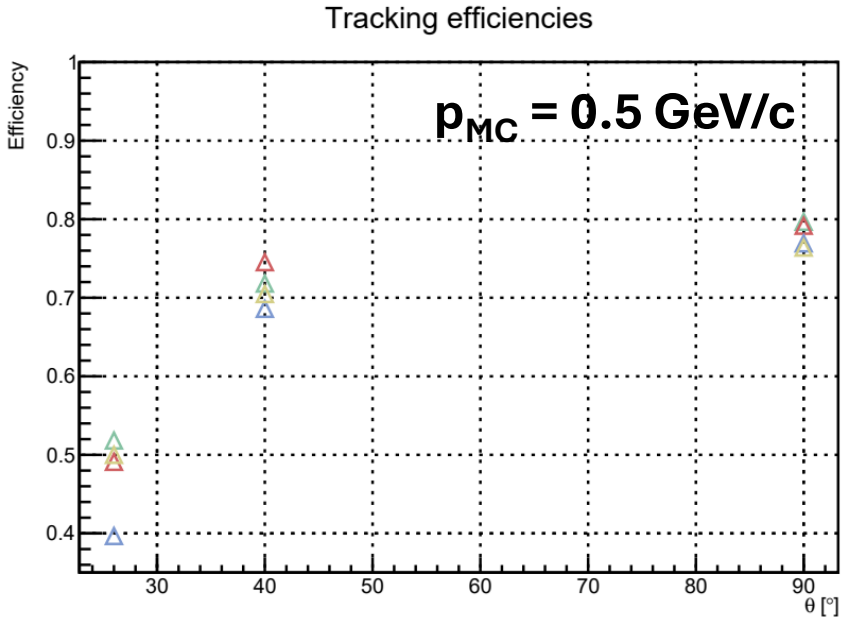


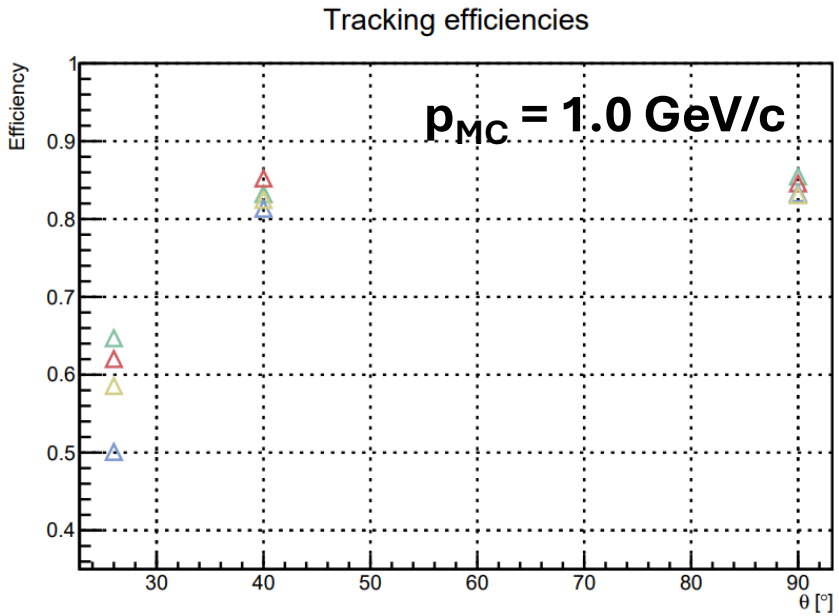
θ = 90 degrees

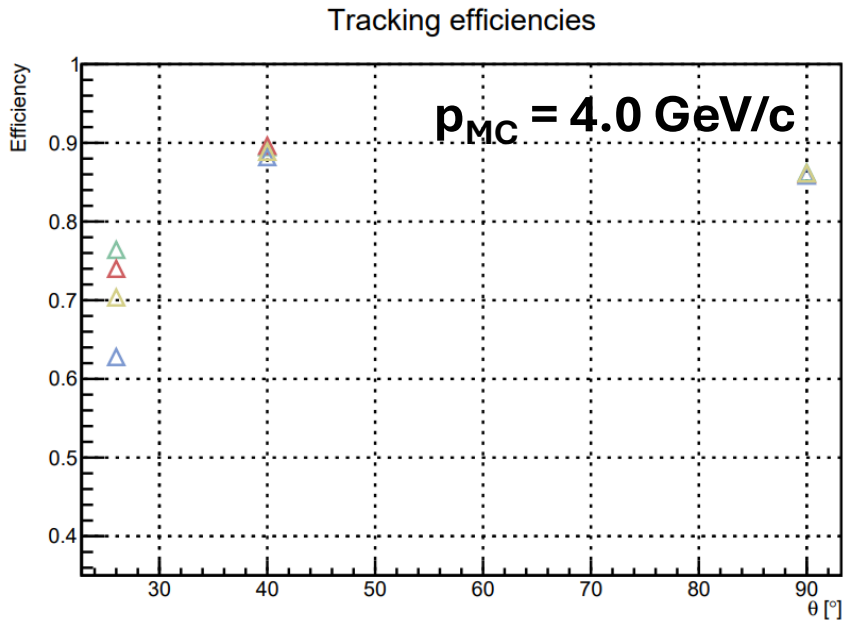





Tracking efficiencies for:
σ(R) = 150μm (master)
σ(R) = aexp(bR) (dev)
σ(R) = a_i R^i (testbeam 2024)
our hit reconstruction

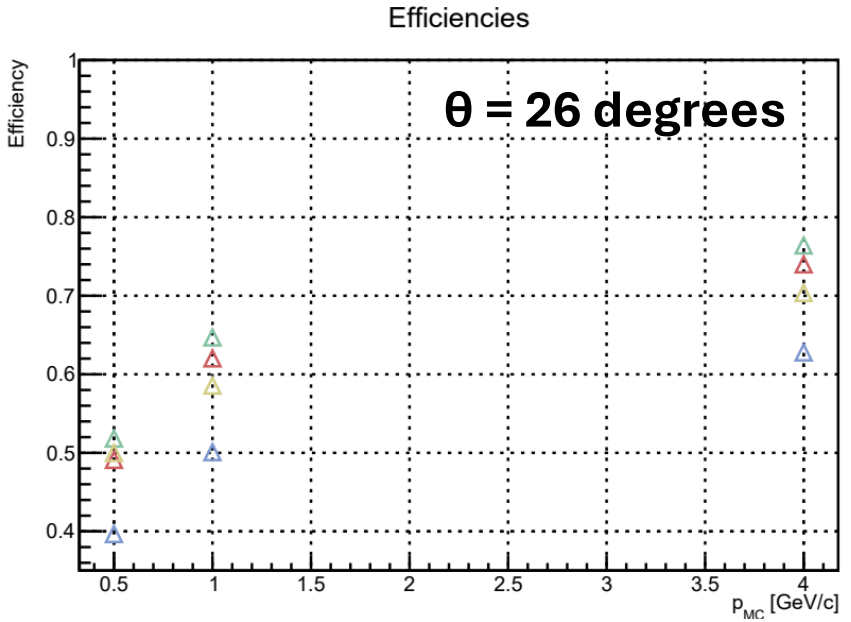

Tracking efficiencies
Efficiency
p_MC = 0.5 GeV/c
θ [°]

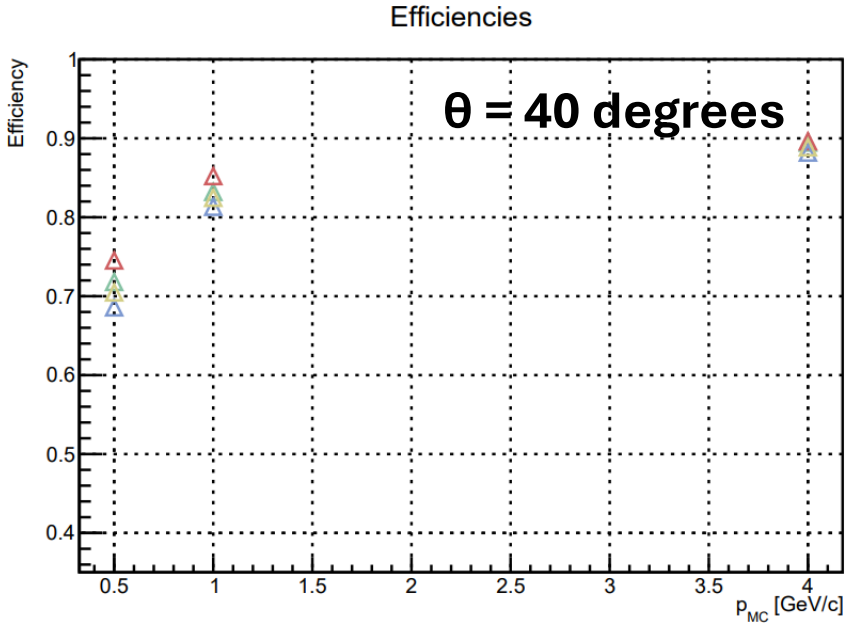

Tracking efficiencies
Efficiency
p_MC = 1.0 GeV/c
θ [°]

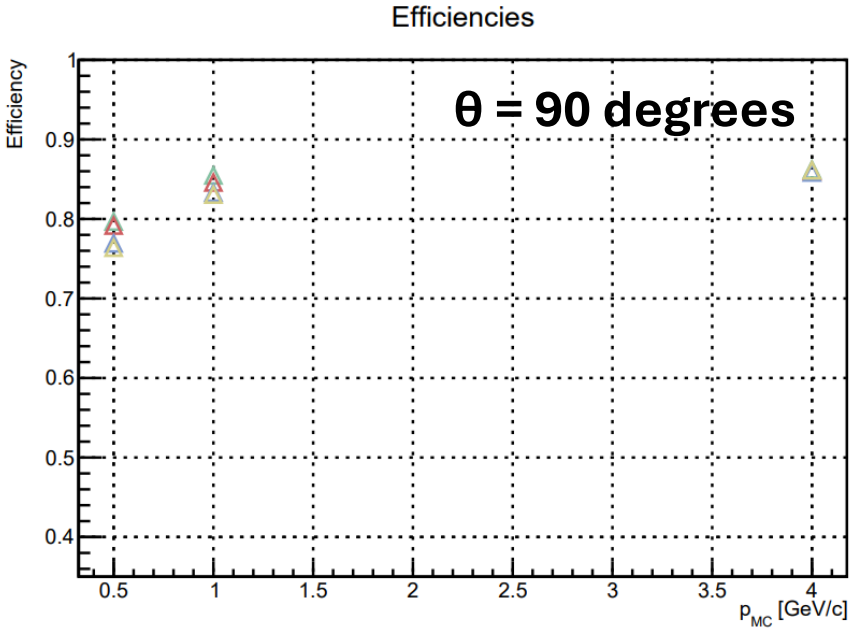

Tracking efficiencies
Efficiency
p_MC = 4.0 GeV/c
θ [°]

Tracking efficiencies for:

- σ(R) = 150μm (master)
- σ(R) = aexp(bR) (dev)
- σ(R) = $a_i R^i$ (testbeam 2024)
- our hit reconstruction







Number of MC-tracks (?)

- There are 10k primary particles generated for each run
- We see a smaller number of MC-tracks (8500-9500 in our case, **5-15% are lost**)
- The loss is significantly reduced if use several isotropic generators in one primary generator (several tracks for event)

p_{MC}, GeV/c	Number of MC-tracks (1st generation)	Number of good fitted tracks	N_{fitted}/N_{MC}	$N_{fitted}/N_{generated}$
1	8822	8547	**0.9688**	**0.8547**
2	8825	8695	**0.9853**	**0.8695**
3	8783	8610	**0.9803**	**0.8610**
4	8759	8622	**0.9844**	**0.8622**
5	8786	8662	**0.9859**	**0.8662**
6	8707	8597	**0.9874**	**0.8597**

Example for previous slide for SPDROOT version from master-branch

Hit weight bug

- Hit weight is not taken into account while doing reconstruction
- Critical for our hit reconstruction – hits below RT-curve have to be rejected before track fitting
- This effect does not have any impact on versions with R-smearing
- **The issue is partly fixed for ST (only hits with zero weights are rejected, any other weights are still ignored) – fix list in backslides**

Conclusions

- Our hit reconstruction has been validated with track reconstruction performance; it works fine
- The track momentum resolution is between values for constant (150 μm) and testbeam 2024 parameterization
- Hit weight bug identified, unclear origin of MC-track object…
- We are ready to work with SAMPO

Thank you for your attention!

Hit weight bug fix

- Header: line **134** (new field fNHitsFailedReco)
- Cxx: line **54** (initialization of new field in constructor), line **240** (array nr now have 5 elements), line **245** (new counter nhrej_failreco), line **348** (cycle for 5 elements), line **376** (hit rejection based on zero weight), lines **420** and **425** (adding to global counters), line **429** (cycle for 5 elements), lines **434**, **440** and **696** (output)
- This is fixed only for Ts track finding (can (and must) be done for Its)

Hit rejection criteria

- Multiple hit (from more than one particle)
- Hit from rejected particle
- Hit with no MC-truth
- Hit not from neither TsB nor TsEC

Introduced criteria: **hit weight equals zero**