Update on Outer Tracker detector studies

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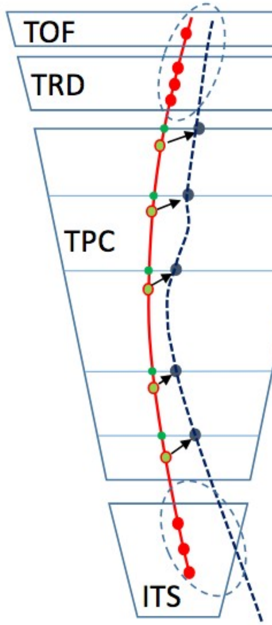
Reminder: monitoring space charge distortions using tracks



From ALICE

Use detectors outside of the TPC to define trajectories

Compared interpolated positions in the TPC to that provided by the TPC to derive space charge distortions

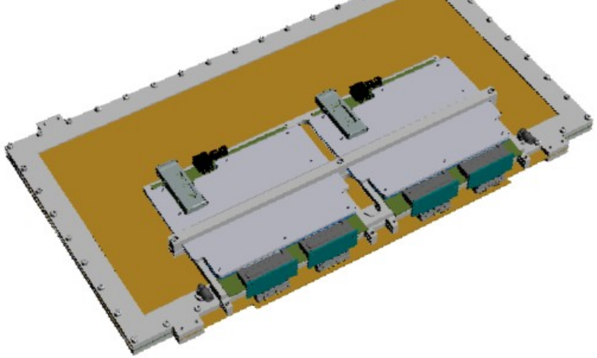
For ALICE: rely on ITS (inside) and TRD+TOF (outside)

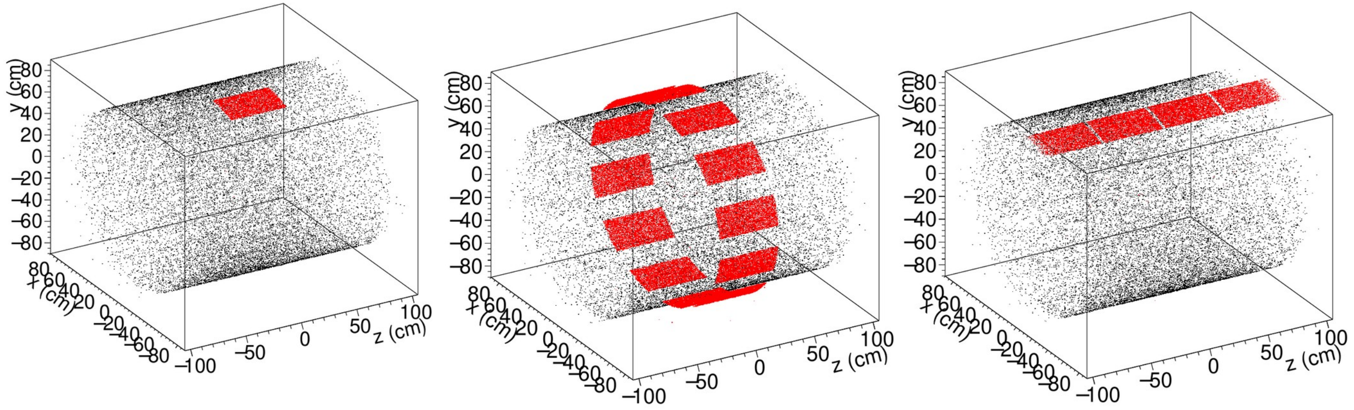
For SPHENIX: rely on MAPS and INTT (inside) + Outer Tracker (?)

Accuracy of the correction in a given volume element depends on

- accuracy of the extrapolation (available detectors)
- (square root of) number of available tracks per unit of time and volume element

The more precise the extrapolation, the less tracks (and time) you need to reach the desired accuracy





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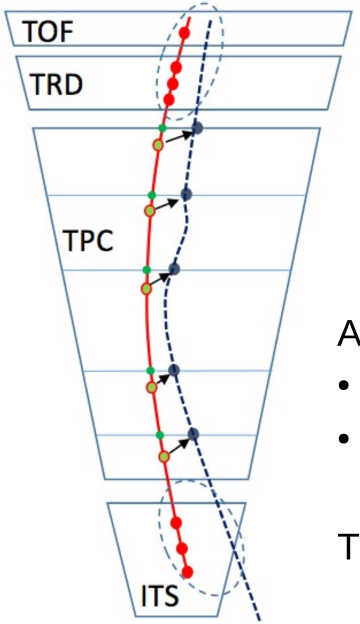

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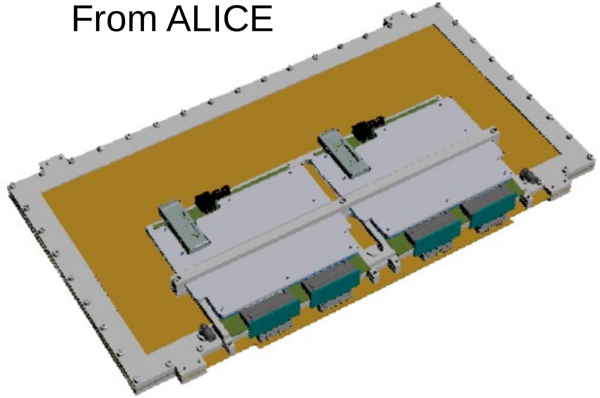

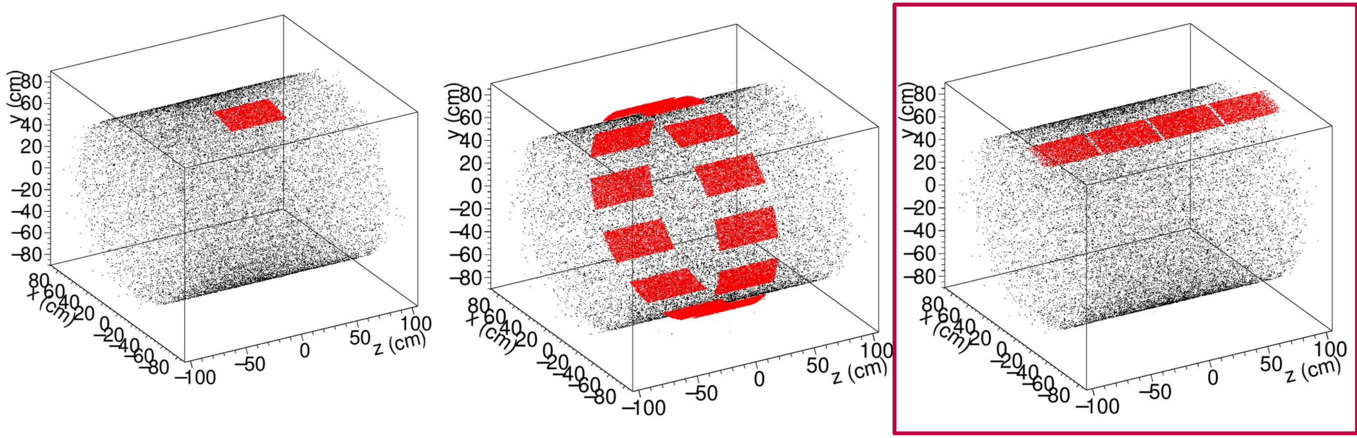

Tasks, milestones, deadline

Task	Output	Manpower	Deadline	status
Hijing production	G4Hits	Chris	Week 28 (early Jul.)	done
Realistic reconstruction chain	Realistic detector resolution, occupancy, noise, ...	Maxence R., Hugo	Week 28 (early Jul.)	done
Occupancy studies	Constraints on detector segmentation	Maxence R., Hugo	Week 30 (end Jul.)	done
Study tracking with MVTX+INTT+ MICROMEGAS	Get expected interpolation accuracy in the TPC, optimal eta coverage, etc.	Maxence R., Hugo, Tony, Joe	Week 34 (mid Aug.)	ongoing
Apply realistic SC distortions	How precise can the setup measure them, with which granularity, and over which timescale	Need coordination with Ross and SC TF.	Week 34 (mid Aug.)	ongoing
Combine with other SC monitoring methods (laser, currents)	Complete strategy for SC calibration	Need coordination with Ross and SC TF.	Week 36 and beyond (end Aug.)	not started
Coordinate detector design and integration in sPHENIX	Ensure integration is possible, no conflict with other detectors (ECAL, TPC)	Klaus, Stephan, Maxence V., R. Takao, Irakli (for DAQ part)	Week 36 (end Aug.)	ongoing
Make recommendations for optimal design (number of tiles, position, segmentation) and cost and HR estimate	Technical note on recommended detector design	Everybody from the TF	Week 36 (end Aug.)	not started

Today: week 34

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Outline

- Effect of space charge distortions on momentum and mass resolution
  https://indico.bnl.gov/event/9302/contributions/40993/attachments/30182/47168/talk.pdf
- Ability to reconstruct the input SC distortions
- Ability to apply the corrections to the reconstruction chain
  https://indico.bnl.gov/event/9399/contributions/41425/attachments/30407/47645/talk.pdf

Setup and limitations

Space charge distortions:

- SC distortion map from Ross
  This is an old one. Uses ideal magnetic field.
  Had some issues with radial (r) distortions (~5x too small)
  but azimuthal (rΦ) distortion has the right magnitude
  no longitudinal distortion

  Should redo with updated maps, however not sure how relevant it is regarding O(1cm) static distortions mentioned in Ross presentation
- Same distortion map is used for all events → no time fluctuations

Implementation:

distortions added to the TPC electron drift code, together with diffusion code from Henry Klest

Simulation setup:

Single particle simulations of either

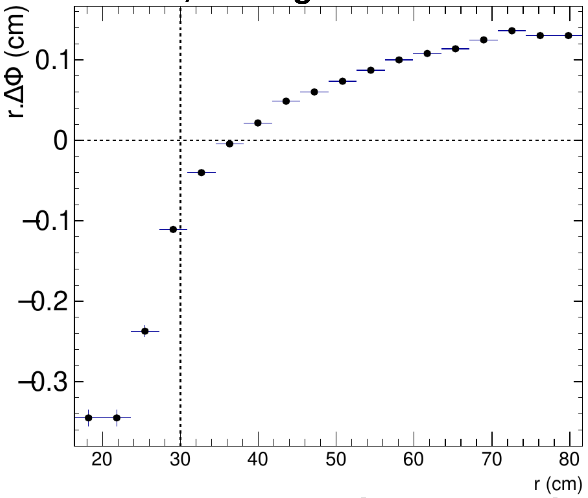
- pions with p_T flat in 0.5 - 20 GeV/c
- upsilons

HIJING simulations consisting of

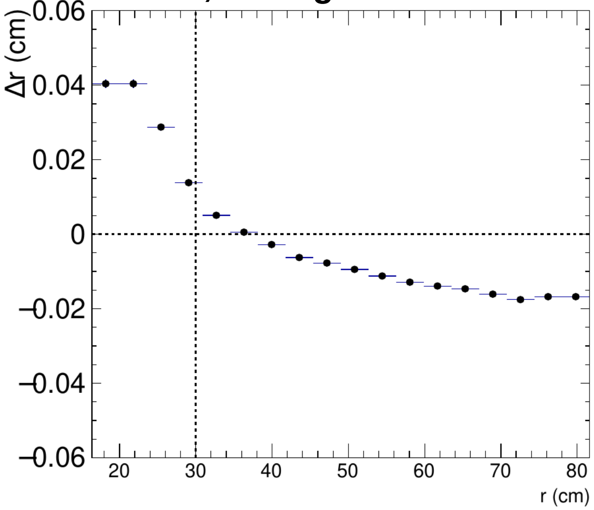
7000 reconstructed HIJING + 50kHz pile-up events

corresponding to 0.5s of data taking

rΔΦ vs r, averaged over Φ and z

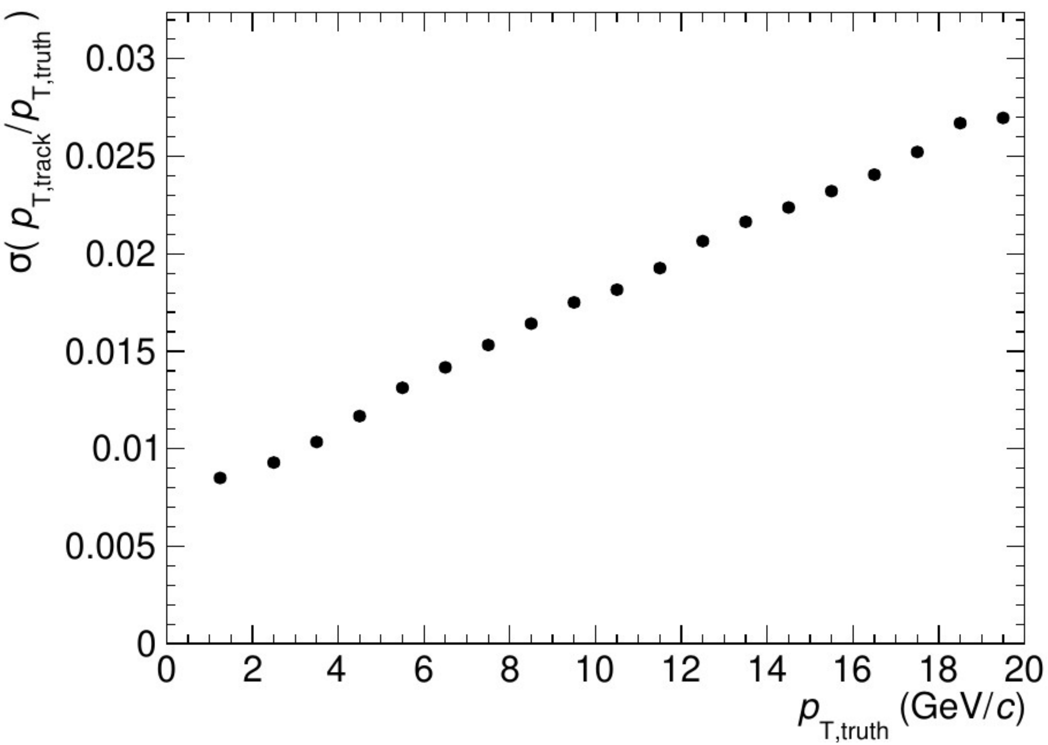


Δr vs r, averaged over Φ and z

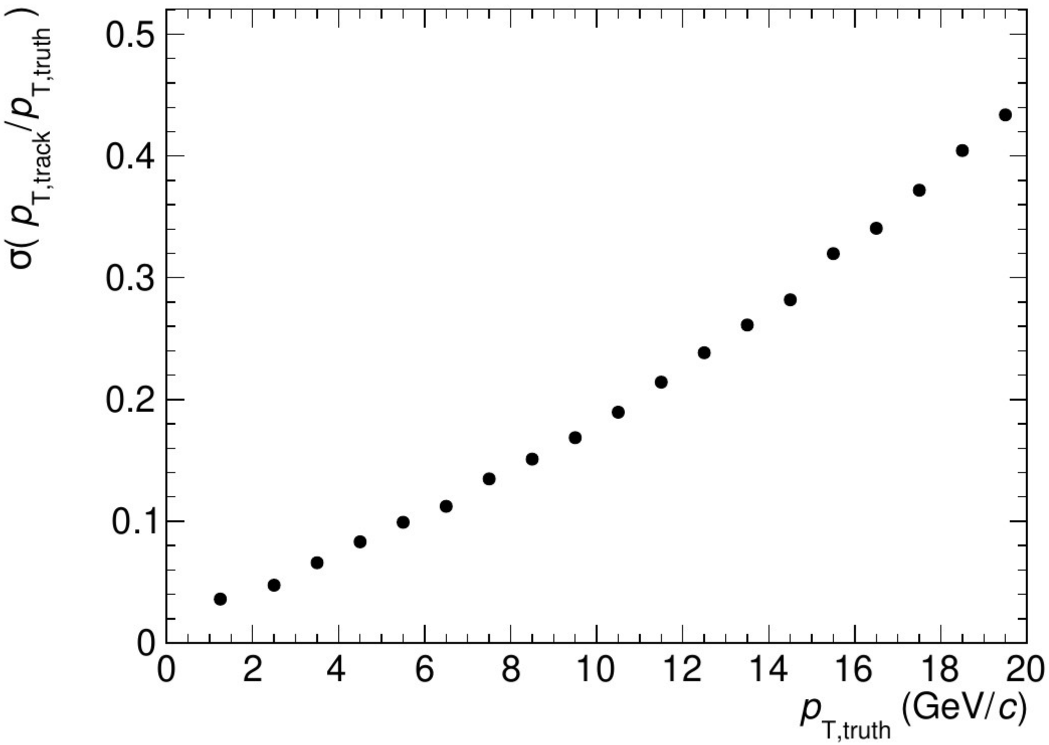


Impact on momentum resolution

Without distortions



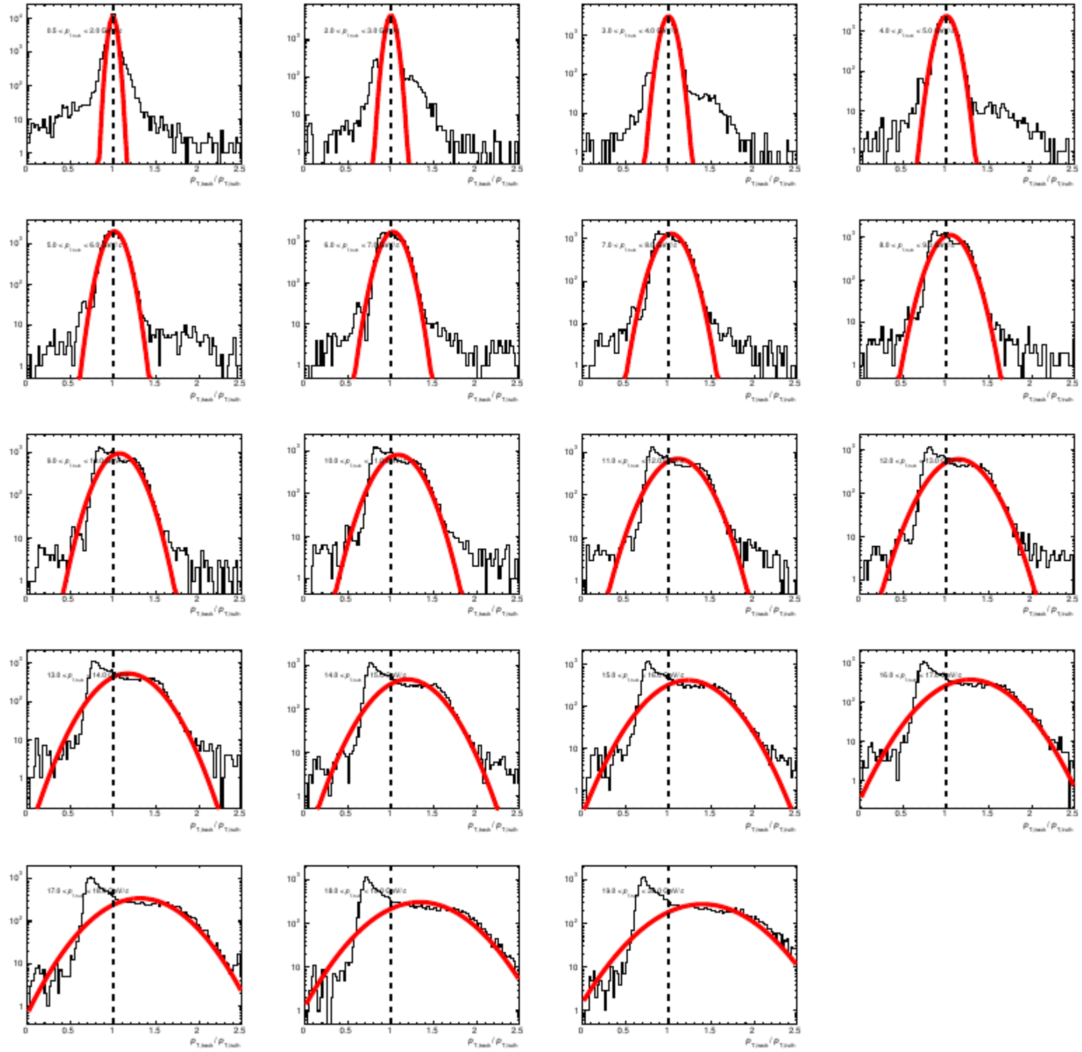
With distortions



The effect on single particle momentum is dramatic (x10 increase in momentum resolution).

At high p_T, (>10GeV/c), the distributions are not Gaussian at all, and the fit makes no sense. (see next slide)

Impact on momentum resolution (cont.)

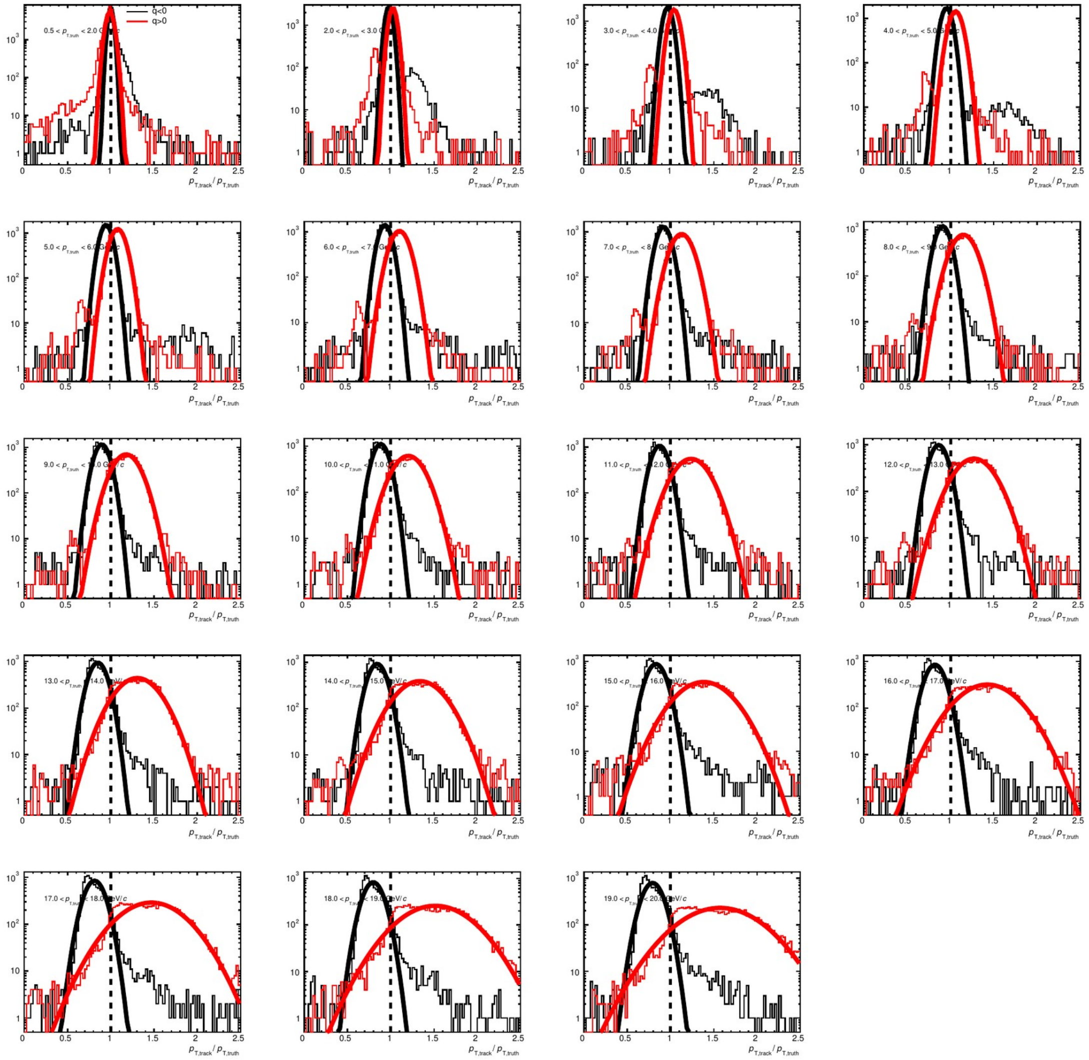


at High p_T large bias between truth and reconstructed p_T

It is charge dependent (see next slide).

Consequence of Φ distortions

Impact on momentum resolution (cont.)



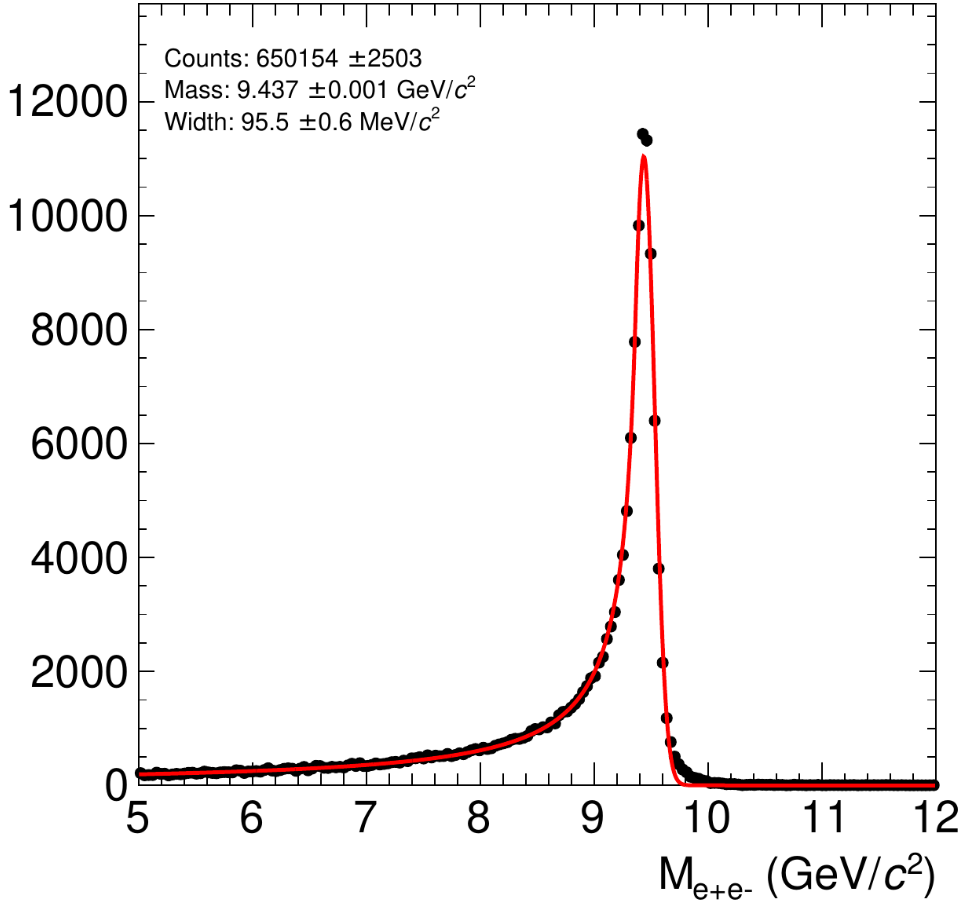
Momentum resolution vs momentum, for positive (red) and negative (black) charges

Not only are the distribution wider but the momentum is shifted, in opposite directions for opposite charges

Impact on Upsilon mass resolution

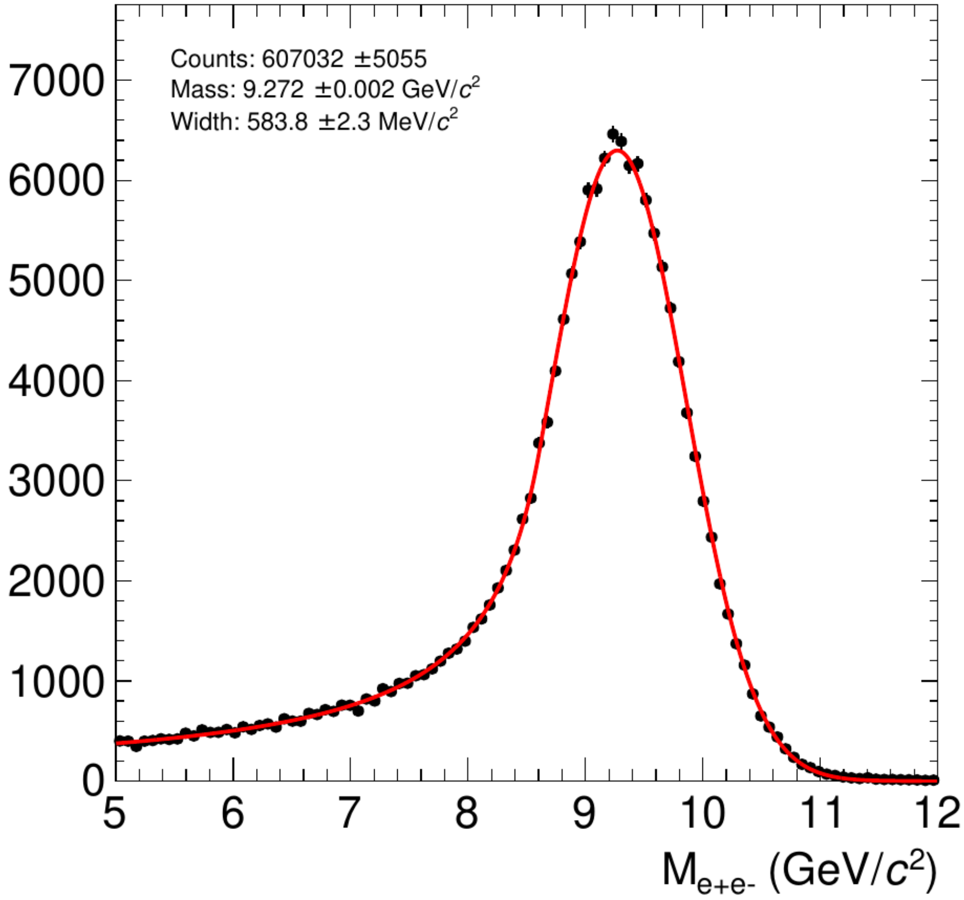
Without distortions

Width = 95 MeV/c^2



With distortions

Width = 580 MeV/c^2



Reconstructing the SC distortions

We use following χ^2 to evaluate the distortions from the residuals:

$$\chi^2 = \sum_{clusters} \frac{\left[r\,\Delta\phi - \left(r\,\delta\phi_0 + \delta r_{0.} \tan(\alpha) \right) \right]^2}{\sigma_{r\phi}^2} + \frac{\left[\Delta z - \left(\delta z_0 + \delta r_{0.} \tan(\beta) \right) \right]^2}{\sigma_z^2}$$

With $r\Delta\Phi$ and Δz the residuals in the TPC in a given cell, $\delta\Phi_0$, δr_0 and δz_0 the actual distortions and α, β the local track angles in (Φ,r) and (z,r) planes

For now focus only on the first term ($\delta r\Phi_0$, δr_0)

For the residuals one can use either

- $\Delta r\Phi = r\Phi_{cluster} - r\Phi_{truth}$ (independently of available detectors)
- $\Delta r\Phi = r\Phi_{cluster} - r\Phi_{track}$ (obtained by disabling the TPC from the track fit)

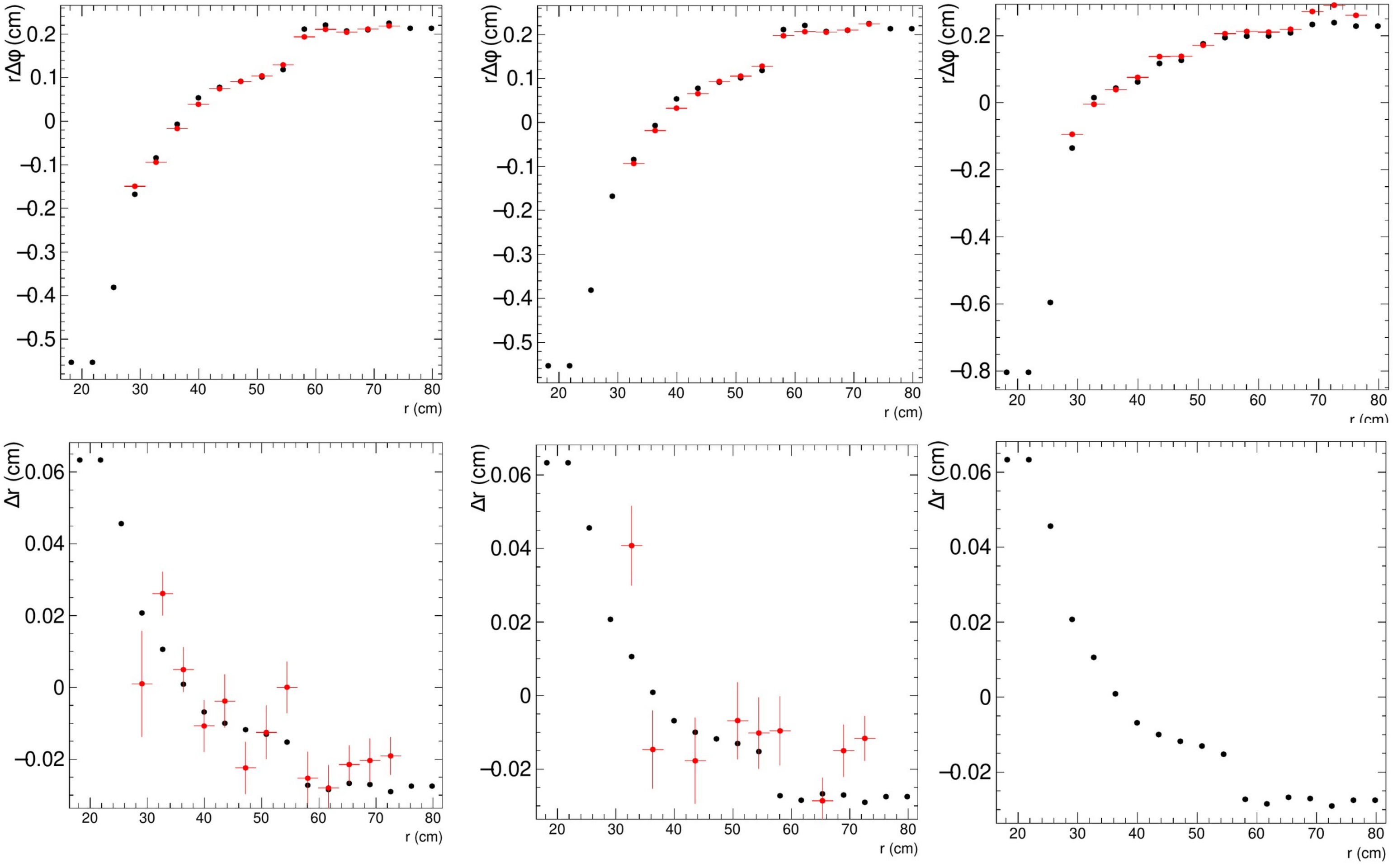
Simulation setup

Use 7000 reconstructed HIJING + 50kHz pile-up events

Corresponds to 0.5s of data

Results

using truth track info | using MVTX + INTT + MM | using MVTX + INTT



Using **truth info**, reasonable agreement between input and reconstructed

> validates the method

MVTX+INTT+MM

- good agreement for rΔΦ
- some bins are missing for r

> need better QA

Also: applies only to a fraction of the acceptance

MVTX+INTT

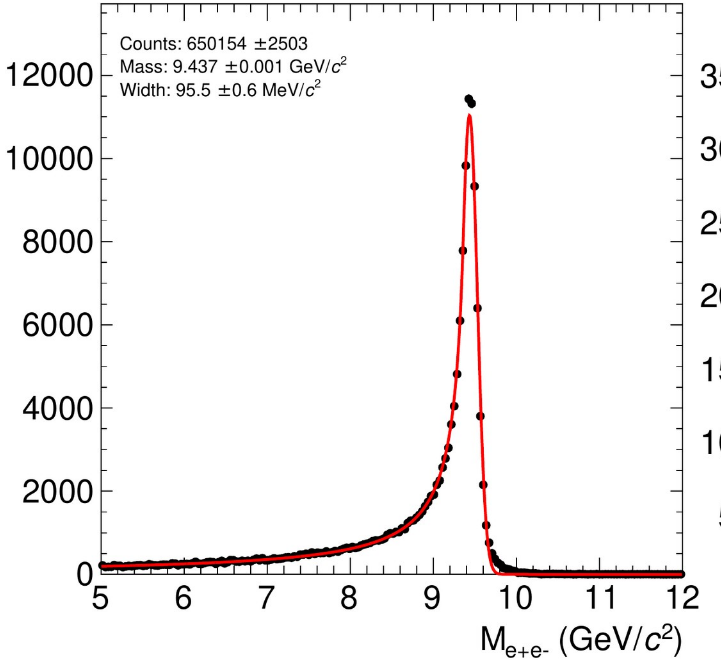
- applies to full acceptance
- reasonable agreement for rΔΦ, but larger fluctuations
- all bins are missing for r due to bias of O(1mm) in the procedure

Ability to apply the corrections to the reconstruction chain

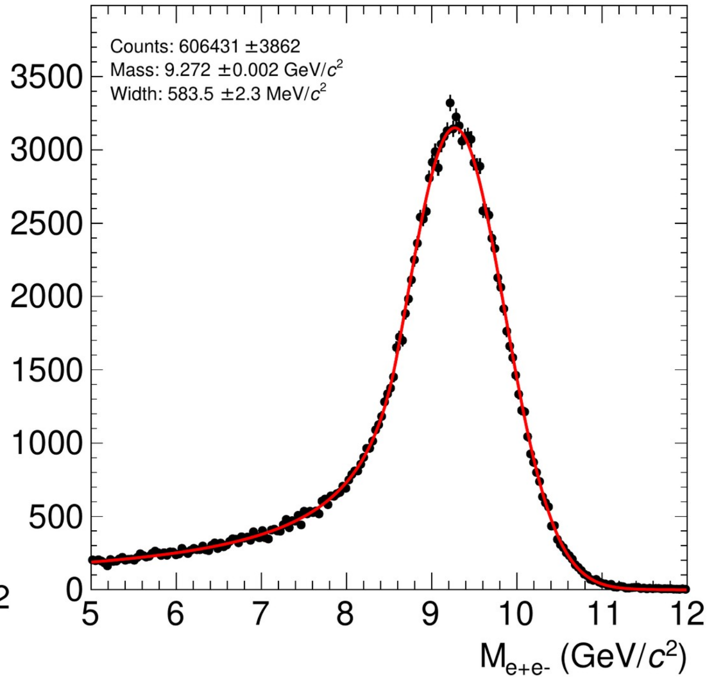
Essentially apply the corrections from previous slides to the clusters, before track fit.

Closure test: if one applies the input distortion as corrections (with a minus sign), one gets back nominal momentum

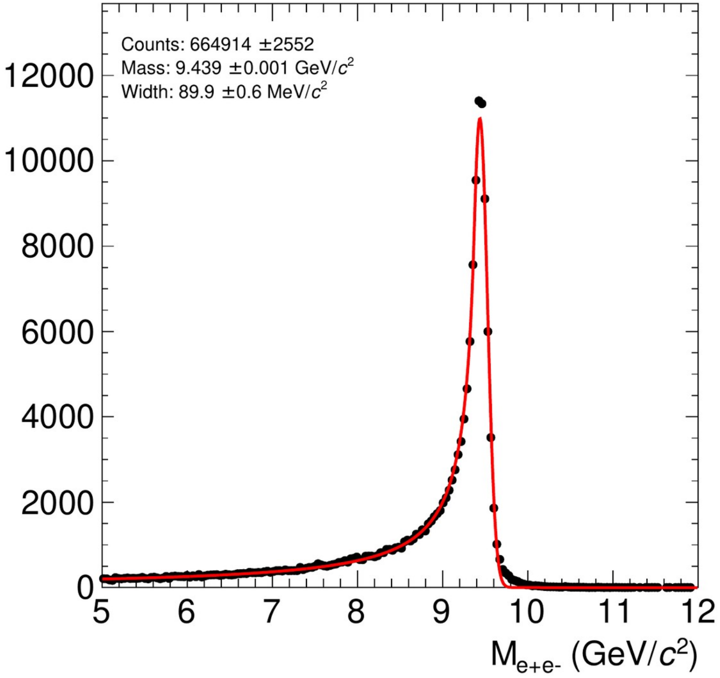
no distortion



distortion

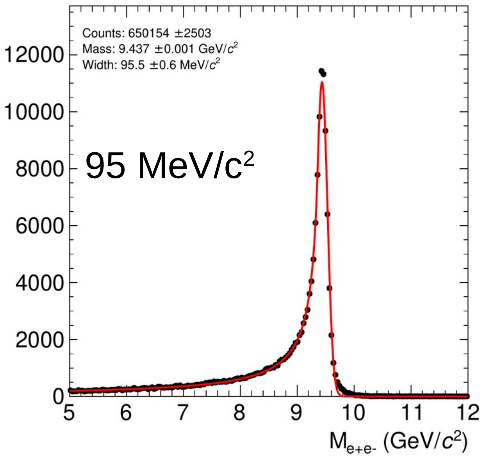


distortion + correction (ideal)

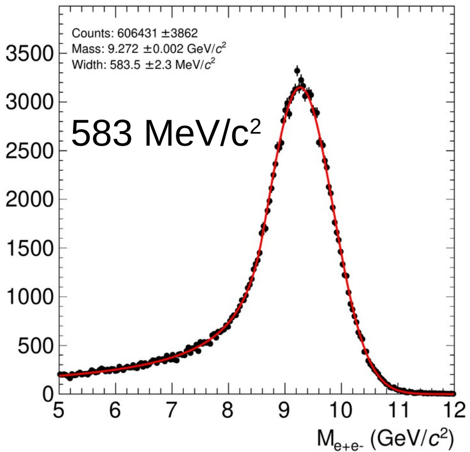


Results (mass resolution)

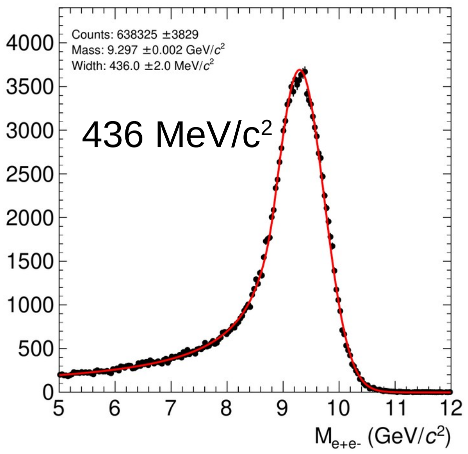
no distortion



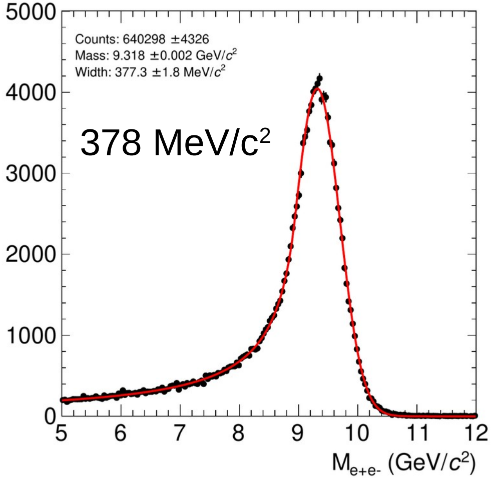
distortion



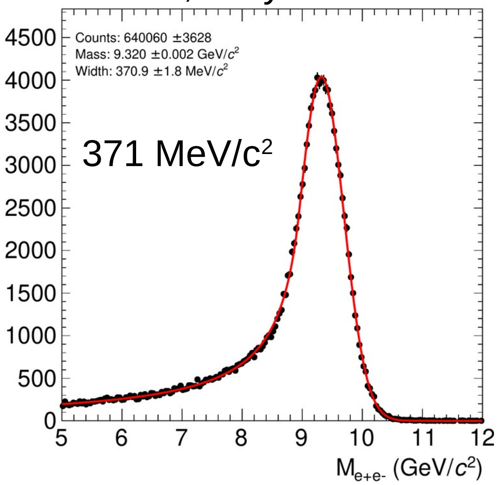
MVTX + INTT + MM Φ sym.



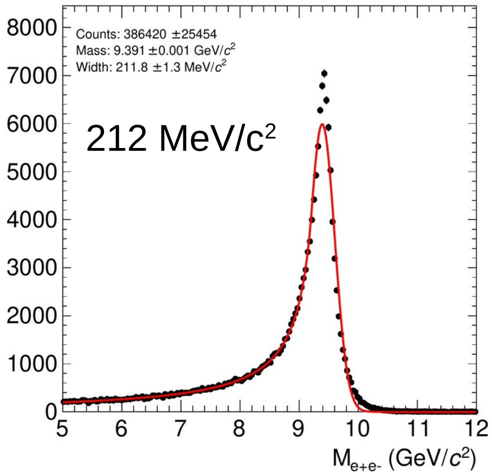
MVTX + INTT full acc.



ideal, Φ sym



using truth track info



Results (mass resolution)

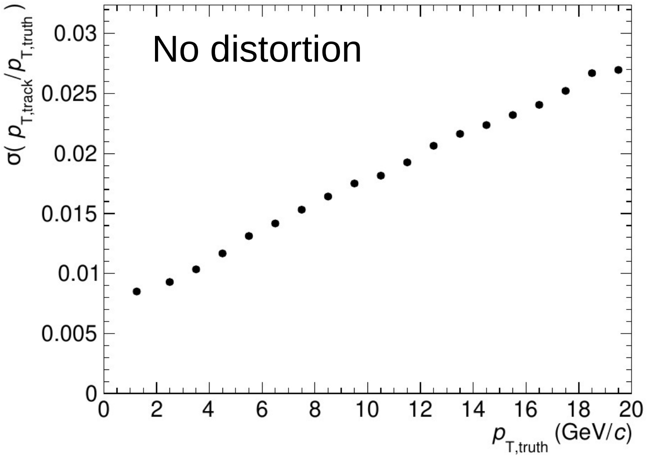
Configuration	Mass resolutions
1/ w/o distortion	95 MeV/c^2
2/ w distortions	583 MeV/c^2
3/ distortions + corrections using truth track info	212 MeV/c^2
4/ distortions + corrections using input averaged over Φ	371 MeV/c^2
5/ distortion + correction, using MVTX + INTT + MM, averaged over Φ	436 MeV/c^2
6/ distortion + correction using MVTX+INTT	378 MeV/c^2

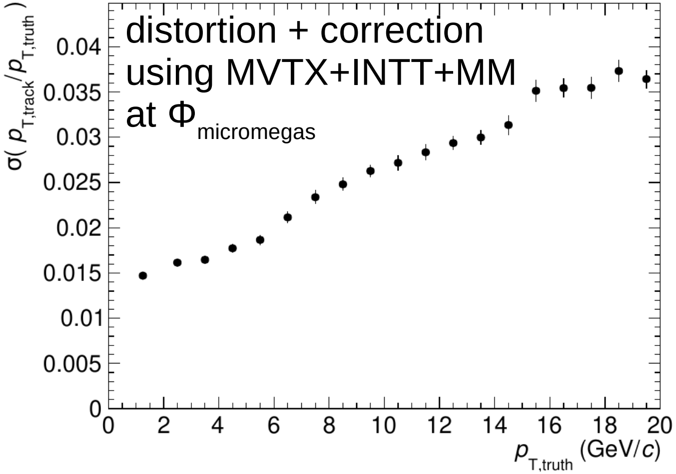
Observations, discussion:

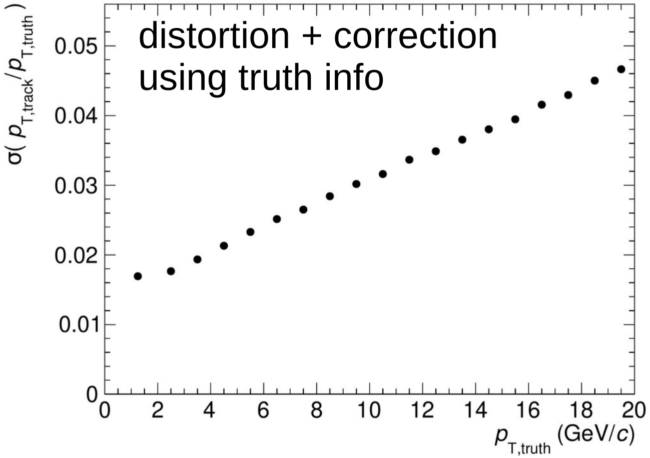
None of the tested corrections allows to recover the initial resolution

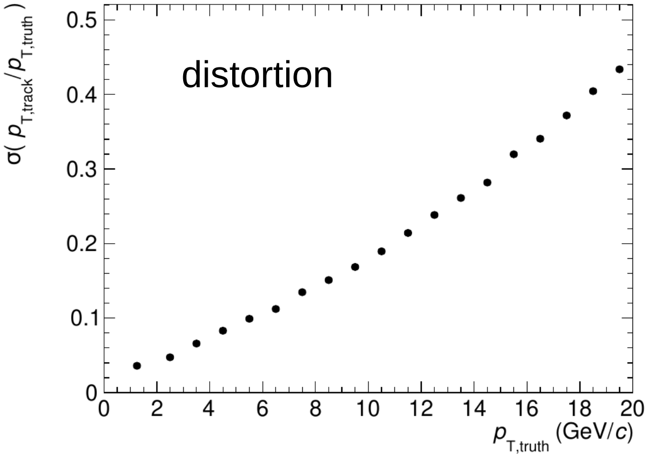
- need to understand why using truth info (3) does not recover original inv. mass resolution (1): finite cluster resolution? bias in the method ?
- (4) gives an idea of the impact of sector-to-sector variations (gain, IBF, collisions topology)
- sector to sector variations also enter (5). However need to understand increase from (4) to (5)
- (6) is still very far from (1): is it only a question of statistics or a bias in the method ?

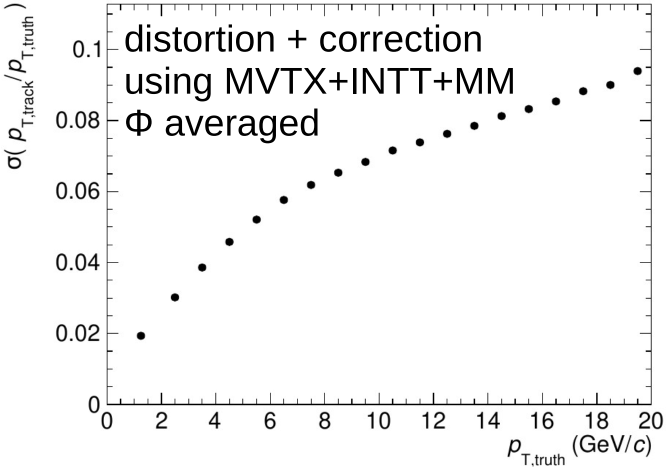
Results (momentum resolution)

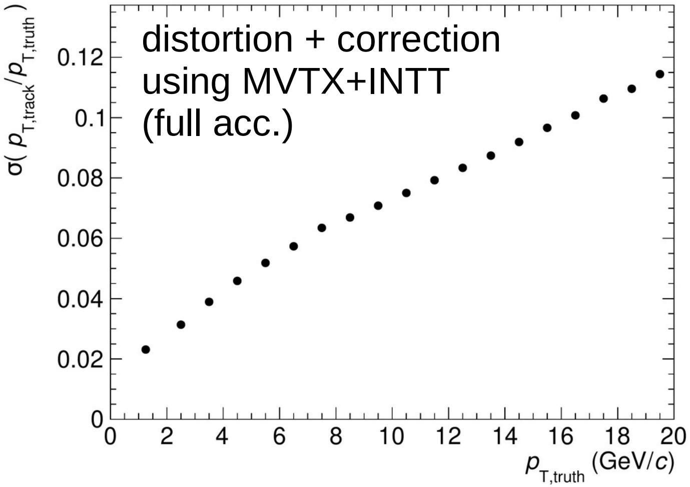












Results (momentum resolution)

Configuration	Momentum resolution at 20 GeV/c
1/ w/o distortion	2.5%
2/ w distortions	50%
3/ distortions + corrections using truth track info	4.2%
4/ distortion + correction, using MVTX + INTT + MM, in Φ_{MM}	~ 4%
5/ distortion + correction, using MVTX + INTT + MM, averaged over Φ	10%
6/ distortion + correction using MVTX+INTT (full acceptance)	12%

Observations, discussion:

None of the tested corrections allows to recover the initial resolution

- need to understand why using truth info (3) does not recover original momentum resolution (1): finite cluster resolution? bias in the method ?
- using truth info (3). or tracks + MM (4) give similar resolution in the MM acceptance
- difference between (4) and (5) gives an idea of the impact of sector-to-sector variations (gain, IBF, collisions topology)
- (6) is still very far from (1): is it only a question of statistics or a bias in the method ?

Conclusion and outlook

All the steps are in place to implement/reconstruct/correct for space charge distortions in the tracking chain but:

- some items are still missing, in particular
  - event-by-event distortion map to implement time-fluctuations
  - z distortions and reconstruction thereof
- there is a lot to understand and consolidate, in particular:
  - why using truth track information does not allow to recover mass and momentum resolution ?
  - is the difference between tracks w/ w/o micromegas just due to different interpolation accuracy ?
  - why can't we reconstruct radial distortions with MVTX+INTT alone ?
  - is there a way to constrain radial distortions from rΦ distortions (both are a consequence of the same radial electric field) ?

Selected todo list

- redo with latest and greatest distortion maps from Ross
- look at the impact of event-by-event fluctuations alone on momentum/mass resolution, assuming time-averaged distortions are perfectly reconstructed
- double-check the uncertainties on SC corrections w/ vs w/o Micromegas and consistancy with extrapolation accuracy
- redo with Micromegas detectors covering the full acceptance