Muon/ID combined studies using cosmic data
data/MC comparisons

María Moreno Llácer (IFIC-Valencia)
María J. Costa Mezquita (IFIC-Valencia)

Contents

- Samples analyzed and reconstruction software used
- Event selection and track quality cuts
- Standalone tracking performance (ID and MOORE tracks)
- ID-MOORE tracks comparisons
- Performance of the Combined tracking
- Measurement of muon charge ratio with combined tracks
- E loss studies

Samples and software used

SIMULATION

DATA

ESDs, filtered in ID volume, B ON
valid2.108867.CosSimIDVolSolOnTorOn.
recon.ESD.s533_d167_r676/

DPDs ID COMM, Spring 09 re-processing
data08_cosmag.00091890.physics_IDCosmic.
merge.DPD_IDCOMM.o4_r653_p26/

Release 14.5.2.4,
Re-running *:
-Muon extrapolation (CaloTrkGeo On)

Release 14.5.2.4,
Re-running*:
-Muon extrapolation (CaloTrkGeo On)
- ID reco with new alignment
constants: 'InDet_Cosmic_2008_03'
'TRT_Cosmic_2008_06'
- Combined reco

Trk Validation &
CBNT ntuples

Trk Validation &
CBNT ntuples

ROOT

* on the Grid using Ganga.

3

Note: Non-readout sector in MS are not masked in MC.

Event selection & track quality cuts

	DATA	MC
Initial	130k events	320k events
After Event selection: 1 ID; 1 or 2 MS & 1 Combined tracks + + RPC trigger (data) or 3 RPC phi hits on tracks (MC)	**94k events** (72%)	**80k events** (25%)
After ID quality track (MEDIUM) cuts	21k tracks (22%)	14.5k tracks (18%)
After MOORE quality track cuts (3 RPC phi hits)	49k tracks (29%)	120k tracks (85%)

• ID quality track (MEDIUM) cuts:
- >= 10 Silicon hits, >= 20 TRT hits, d_0 < 250 mm, pT> 1 GeV, 5ns <EP< 30 ns (not yet applied)
- All cuts on #hits are barrel only

• MOORE quality track cuts:
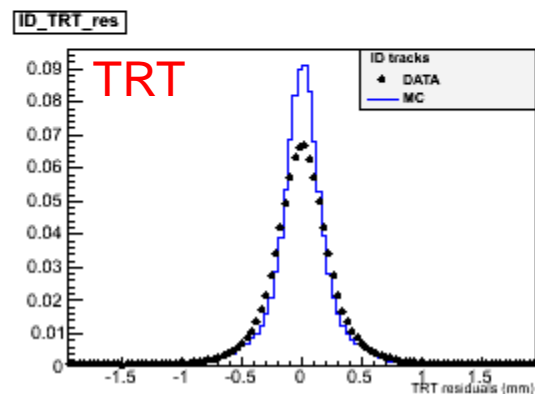- >= 3 RPC ϕ hits

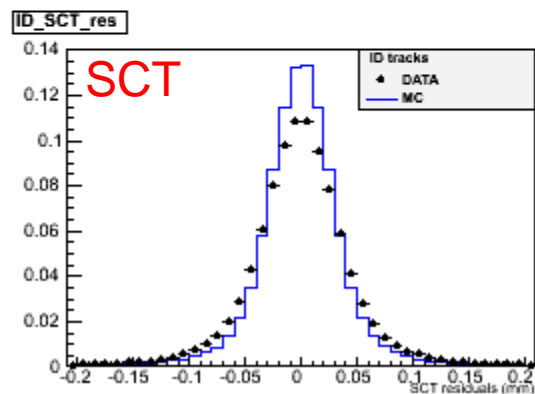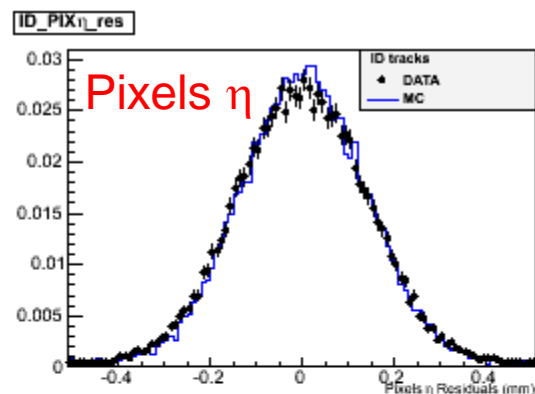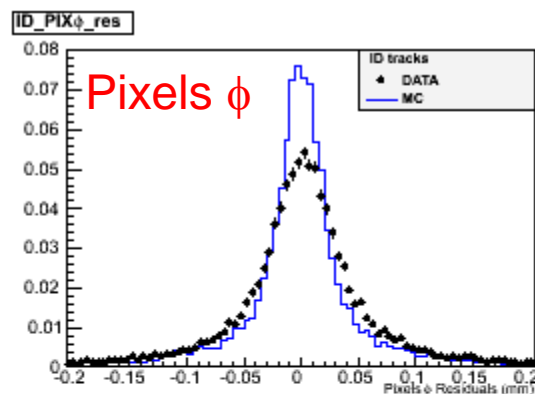# Standalone tracking:

- Inner Detector
- Muon Spectrometer

Standalone tracking: ID

Hits on tracks

Pixels

SCT

TRT
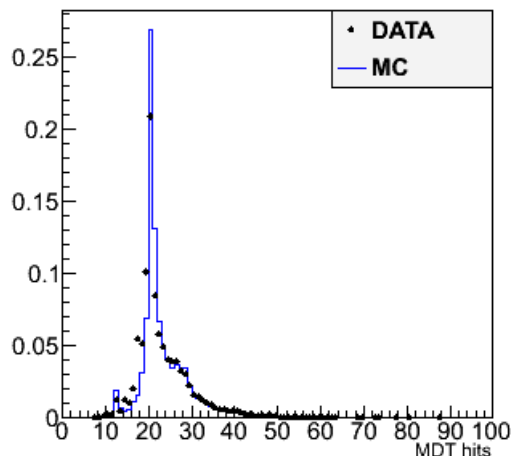

Residuals

Pixels φ

Pixels η

SCT

TRT
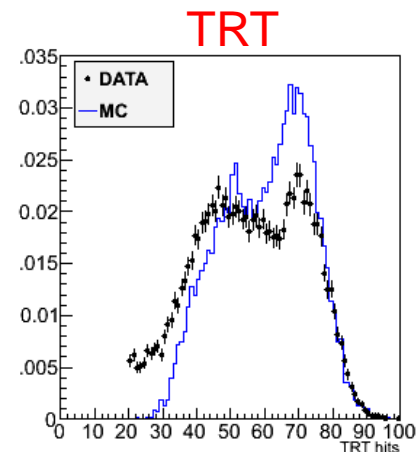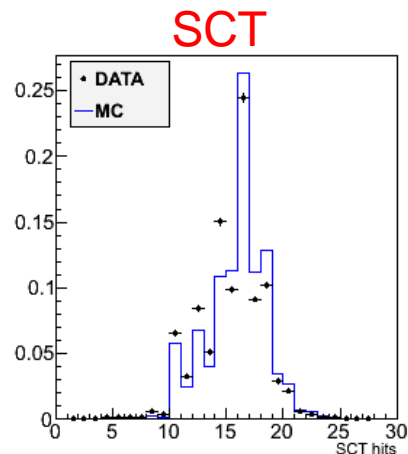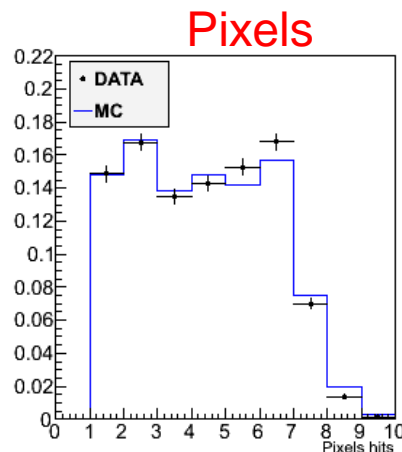
• Less hits on tracks for data.
• Pixels φ, SCT and TRT residuals slightly better than in previous studies (for both data/MC).

Standalone tracking: Moore
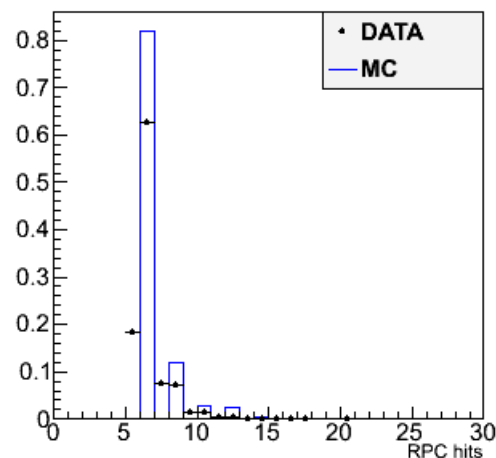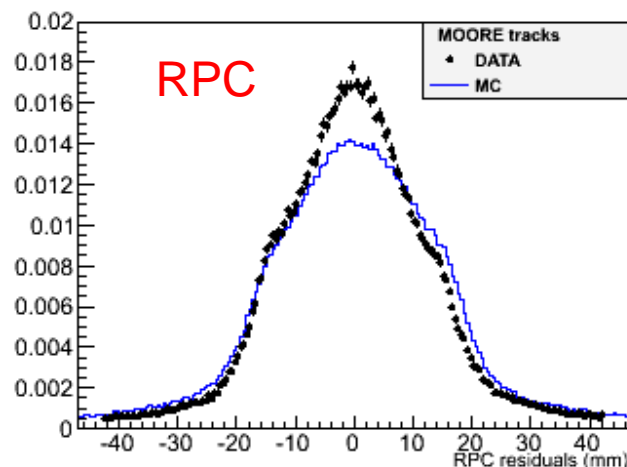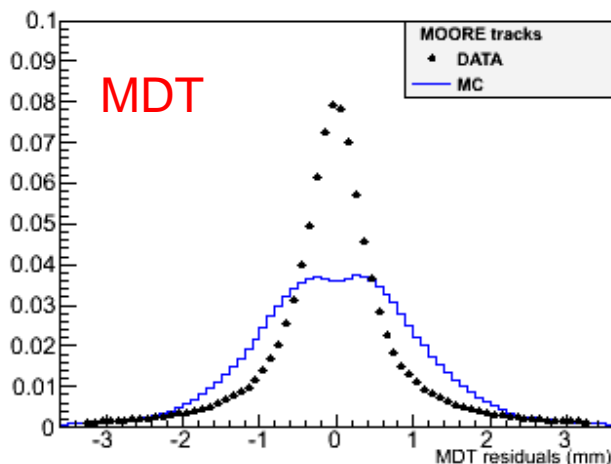
MDT RPC

Hits on tracks

Residuals

MDT RPC

- MDT residuals for data have improved with respect to previous re-processing.
- For MC, it seems that t0 refit was not applied (would like to re-run the Muon reco with: ToolSvc.MdtDriftCircleOnTrackCreator. DoFixedError=False
  - muonRecFlags.useTGCPriorNextBC=True
  - muonRecFlags.doSegmentT0Fit=True).

Track parameters
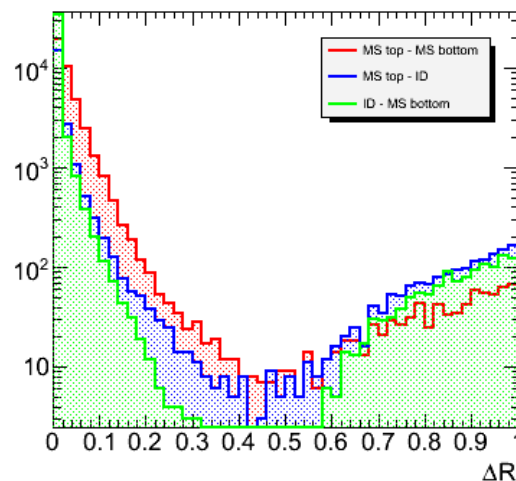
ID tracks

MOORE tracks

p/q

d$_0$

p/q

p/q
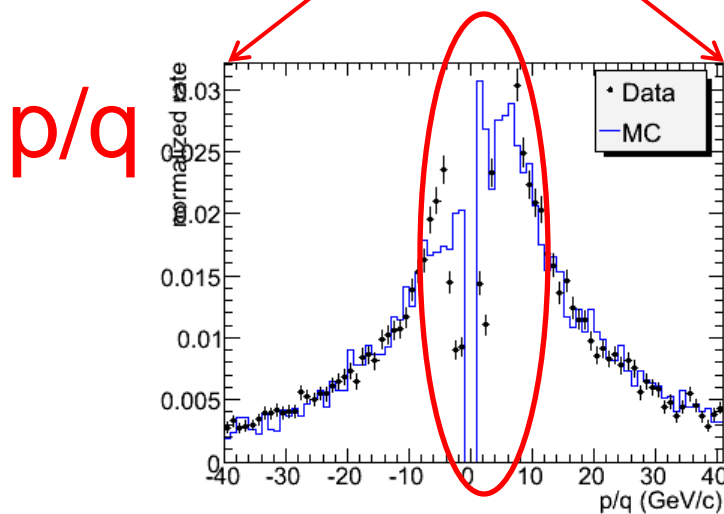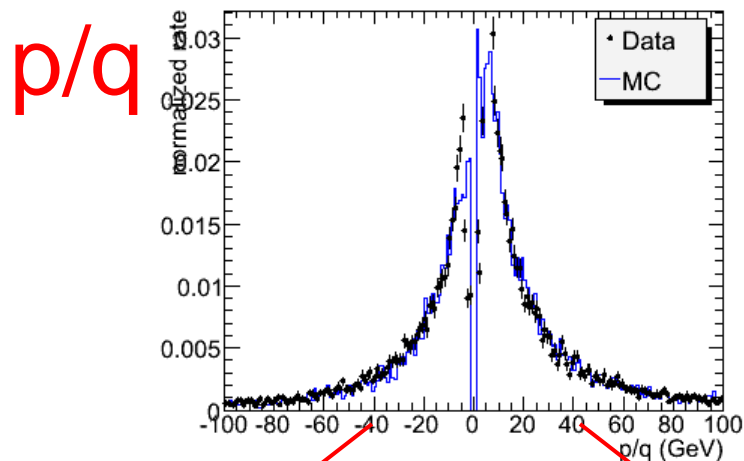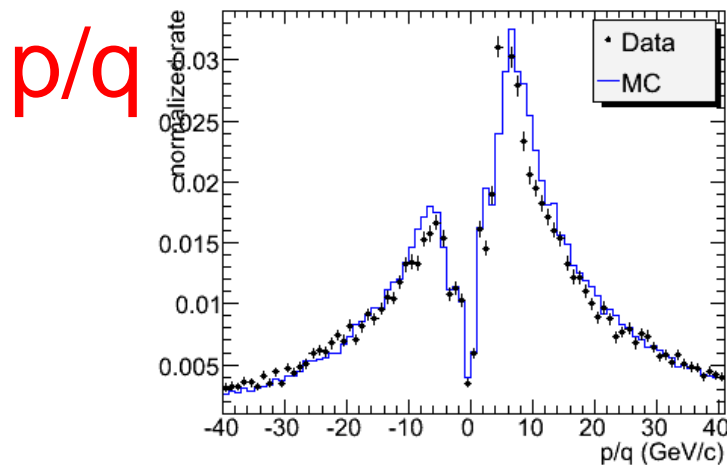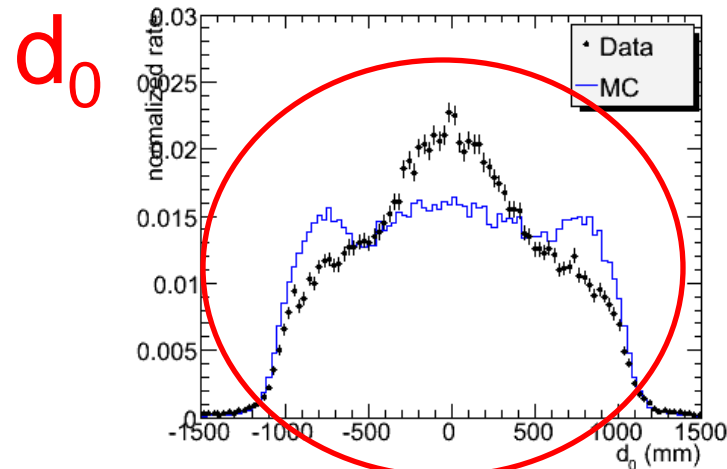
- ID: cosmic MC spectrum has two peaks? (study spectrum @ generation level).
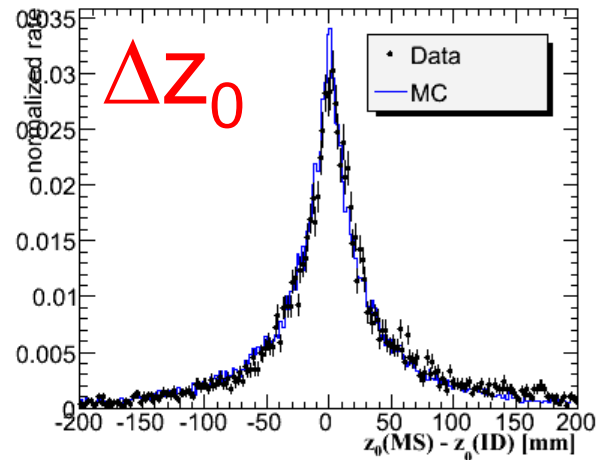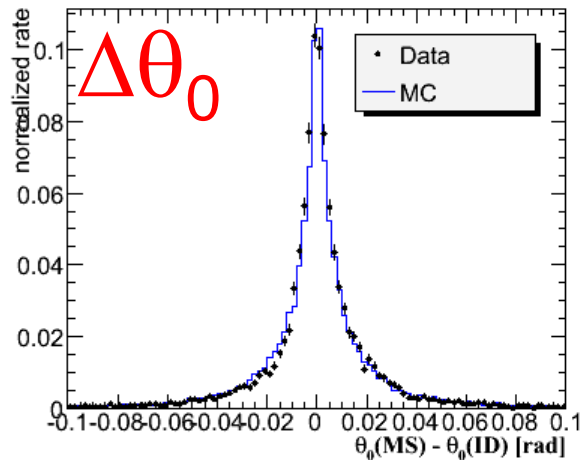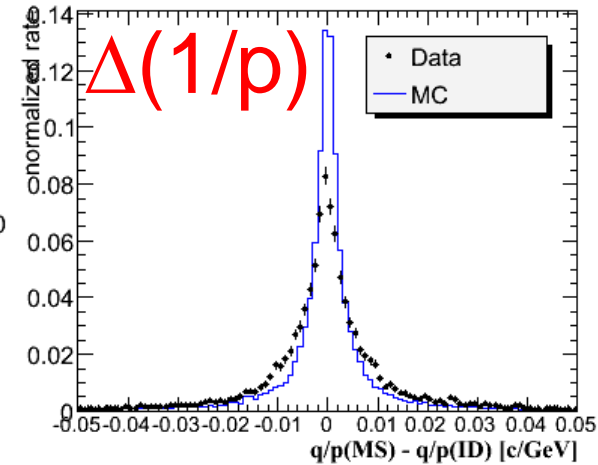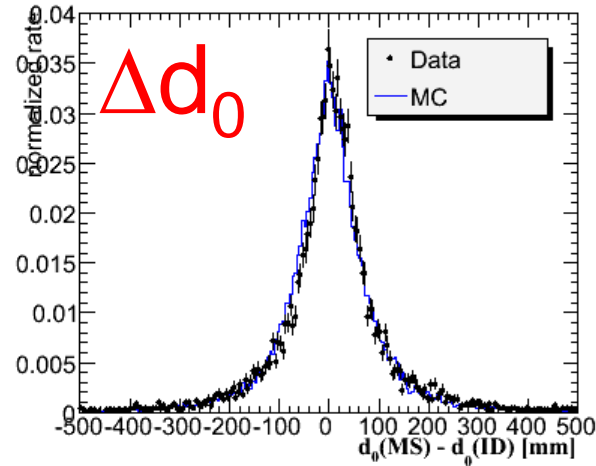- Moore: data/MC agreement not good for d0 distribution (trigger effects?).
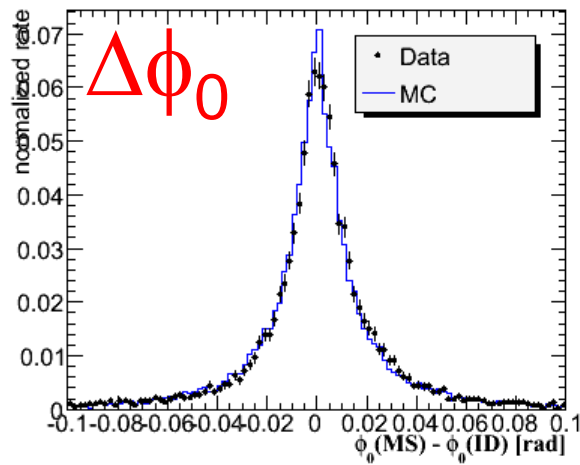
Inner Detector & Muon Spectrometer tracks comparisons

• Matching criteria (ID-MS): distance on the cylinder $\Delta R = \sqrt{\Delta\phi^2 + \Delta\cos\theta^2} < 0.25$ same criteria used in other studies:

(http://indico.cern.ch/getFile.py/access?contribId=6&resId=2&materialId=slides&confId=57453)
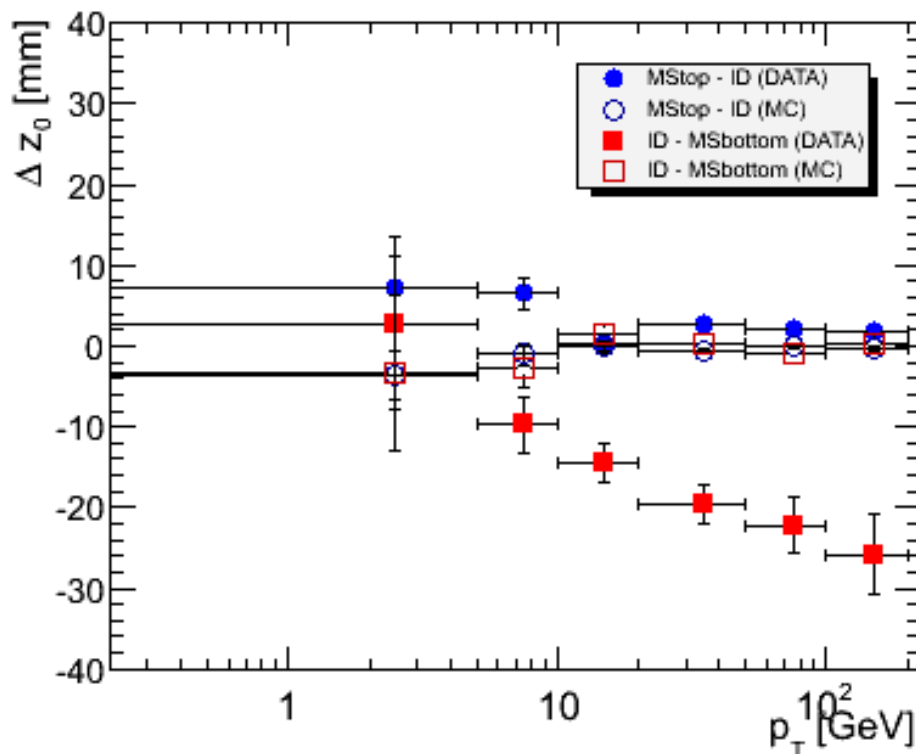
Track parameters: difference ID-Muon

$\Delta\phi_0$

Δd_0

$\Delta(1/p)$

$\Delta\theta_0$

Δz_0

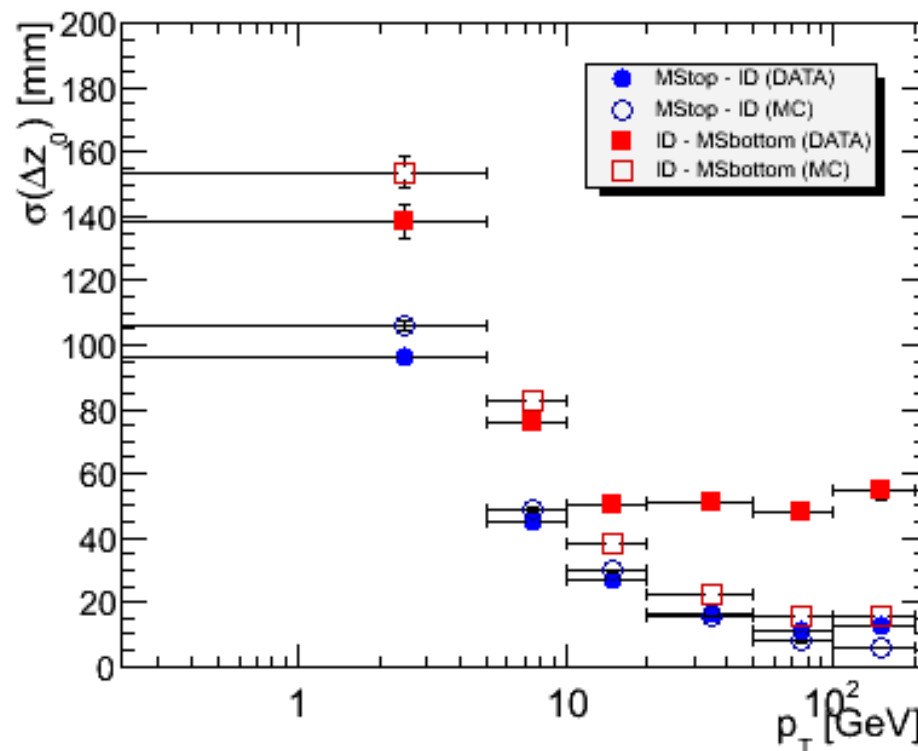• The data/MC agreement for all track parameters is fairly good; slightly worse for q/p.

Track parameters: difference ID-MS
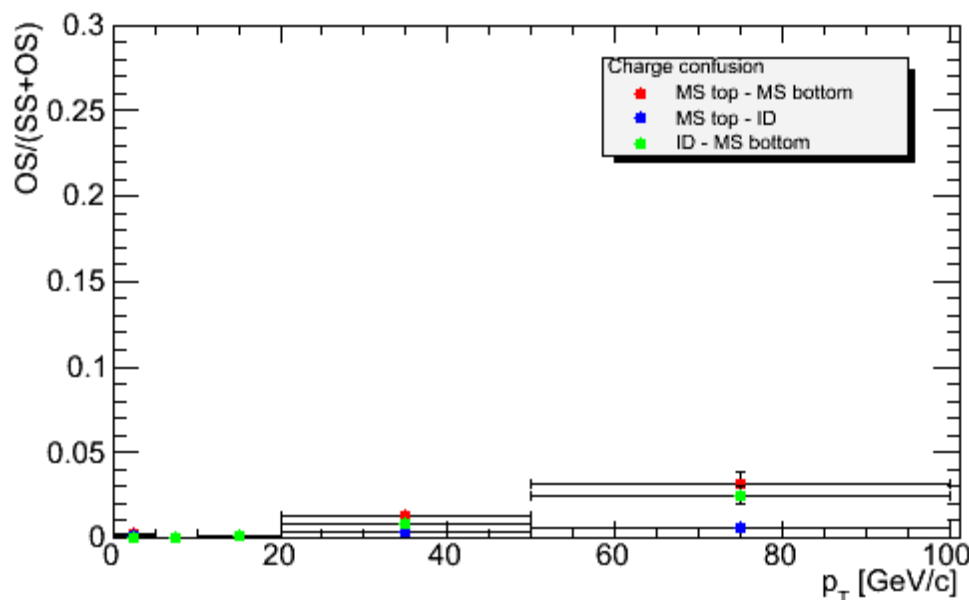
Offset in z0 Vs pT   Resolution in z0 Vs pT

• No bias on ID-MS parameters for MC. However, it seems that there is an offset in the difference ID & MS bottom track parameters for data.
• z0 resolution improves for higher momentum and it is worse for bottom tracks for data.
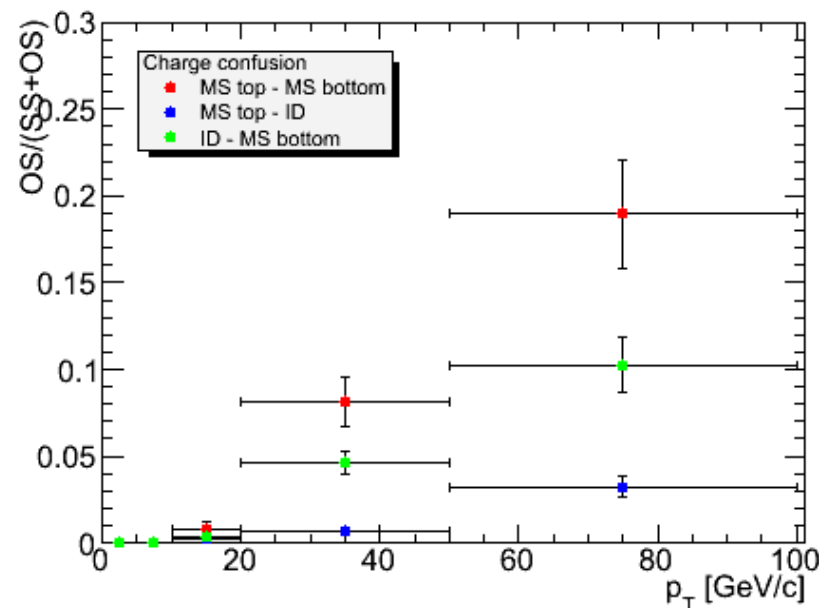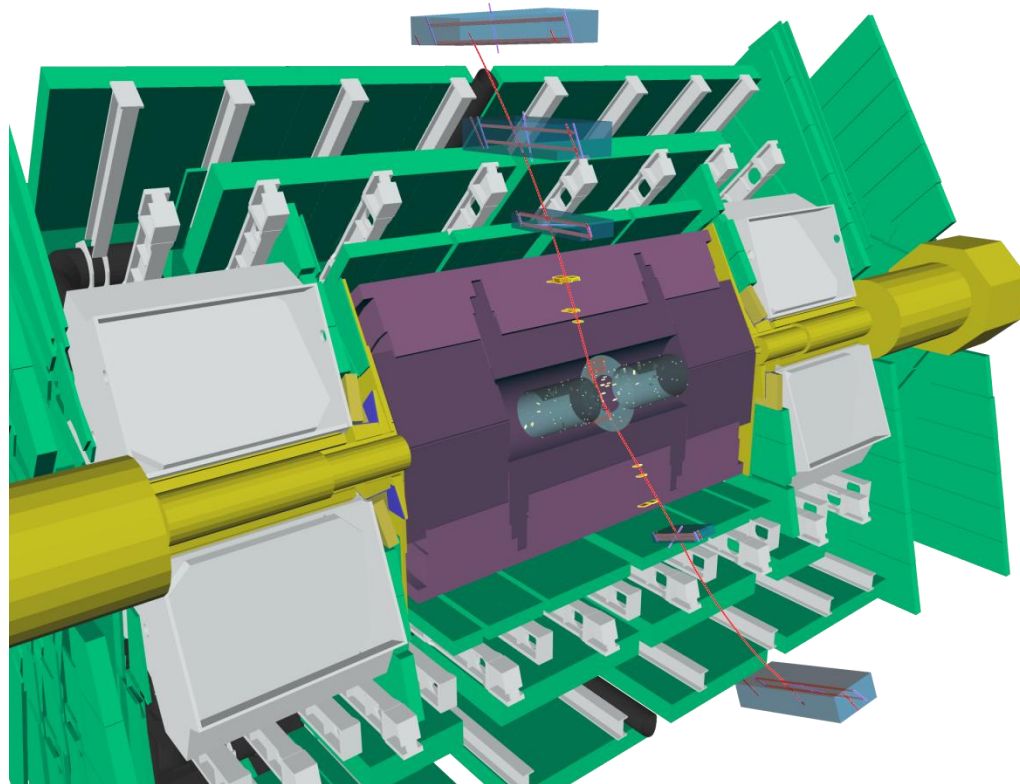
11

Charge confusion

MC

DATA

- The fraction of tracks that have opposite sign increases with momentum (and it is higher for data).
- This fraction is decreased if tight cuts are applied to ID tracks.
- Binomial errors on a fraction strictly less than 1, sqrt(r*(1-r)/N)

12

Performance of the COMBINED TRACKING
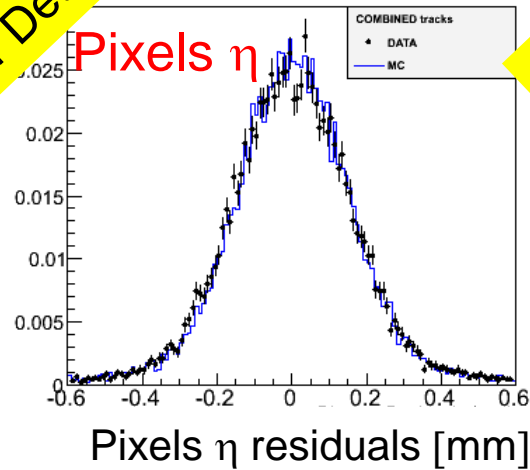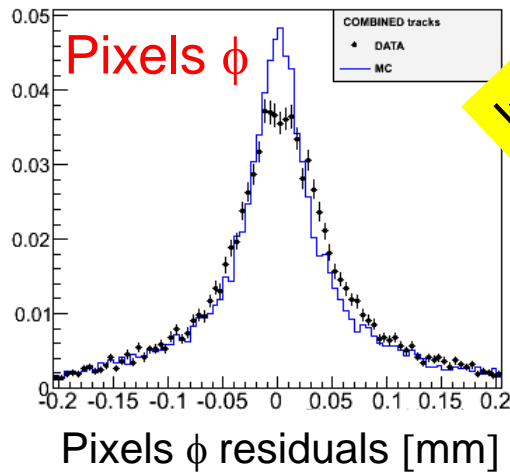## (Inner Detector + Muon Spectrometer)

Hits on combined tracks

Pixel hits   SCT hits   TRT hits

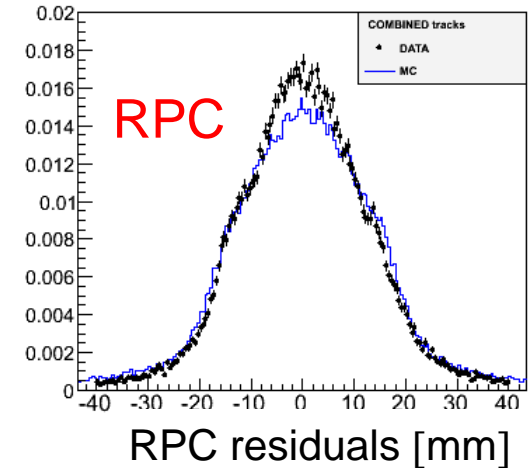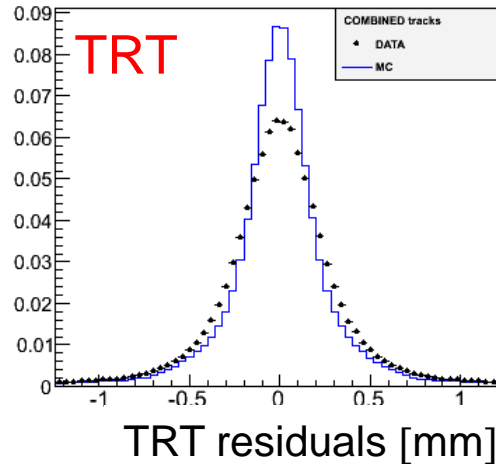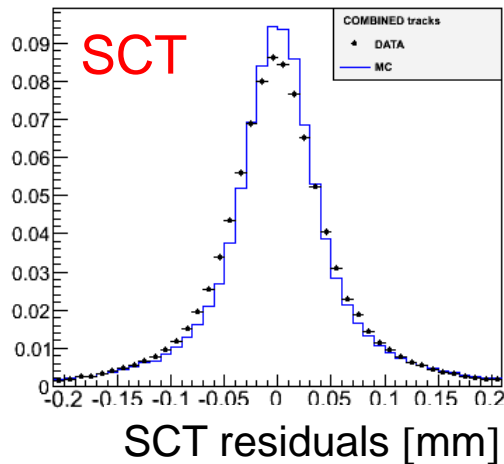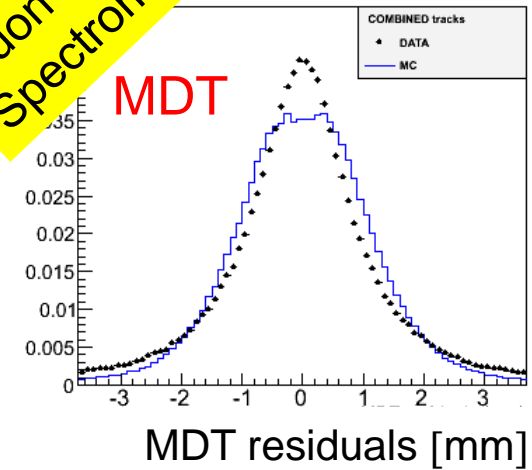tracks that cross top and bottom parts

MDT hits   RPC hits
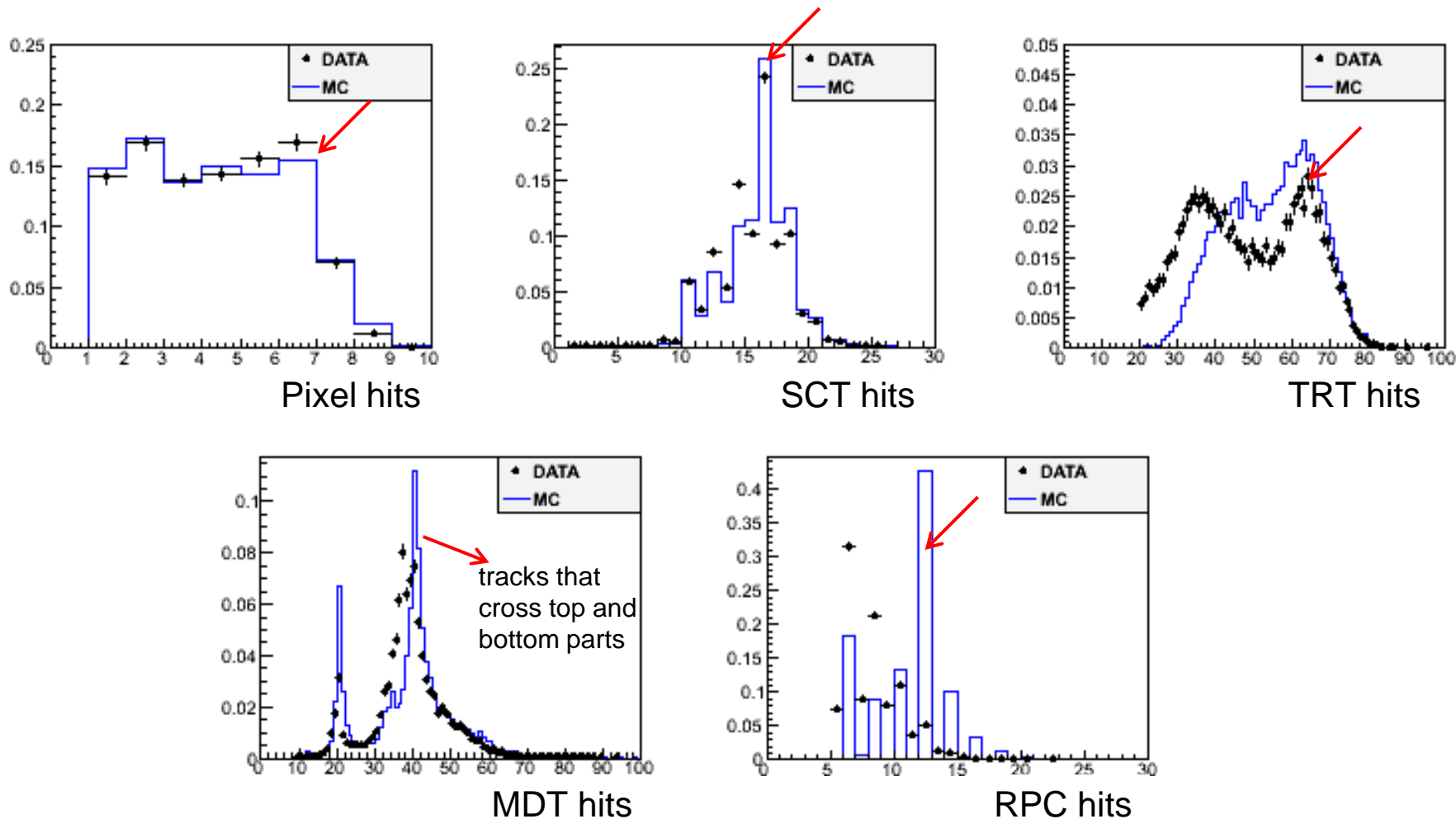
• Slightly more associated hits in simulation than in data.
• For RPC, there are much less hits associated for data due to the non readout elements or the ones operating at lower voltages (discrepancies also shown in previous studies).

Residuals

Pixels φ

Inner Detector

Pixels η

Muon Spectrometer

MDT

Pixels φ residuals [mm]

Pixels η residuals [mm]

MDT residuals [mm]

SCT

TRT

RPC

SCT residuals [mm]

TRT residuals [mm]

RPC residuals [mm]
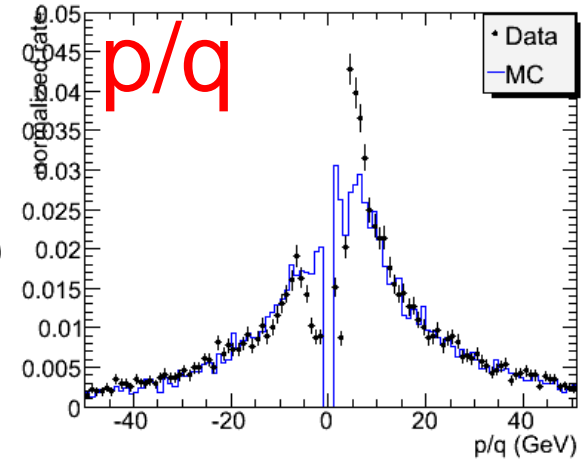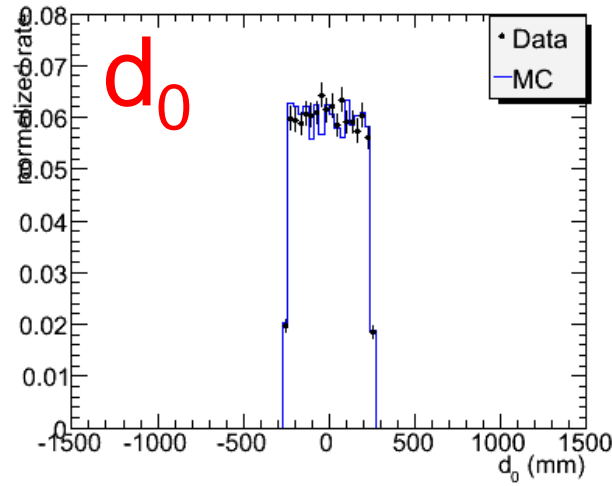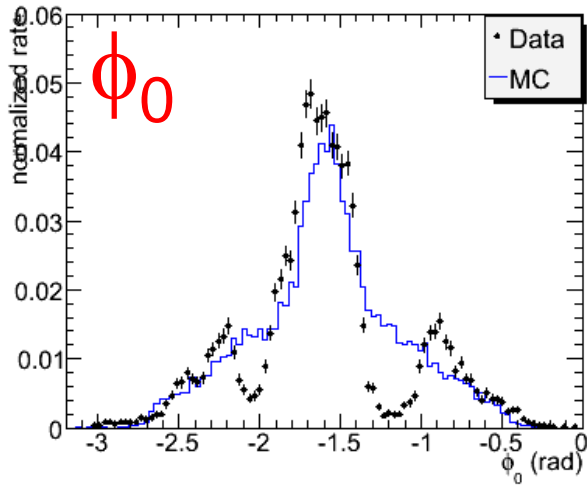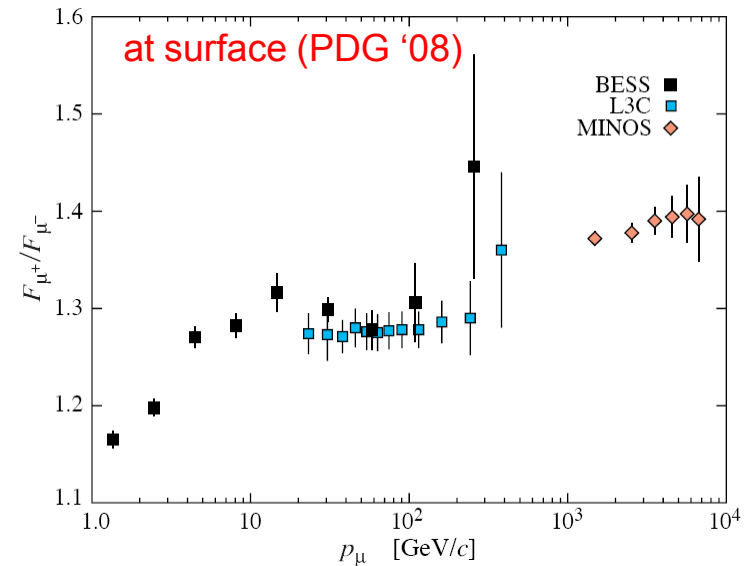
• Distributions are wider than for standalone tracks and now the agreement data/MC is better.

15

Combined Track parameters
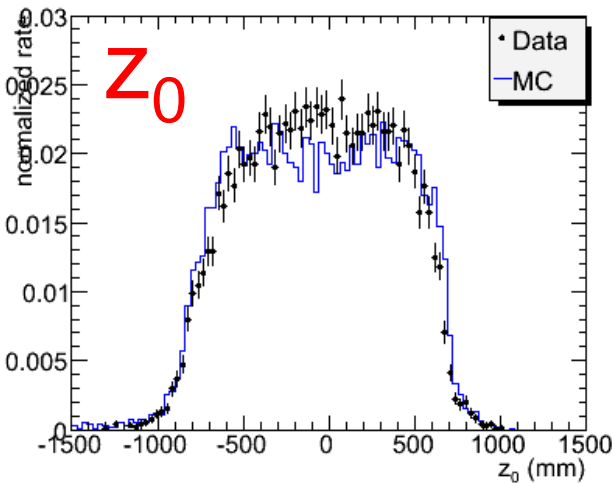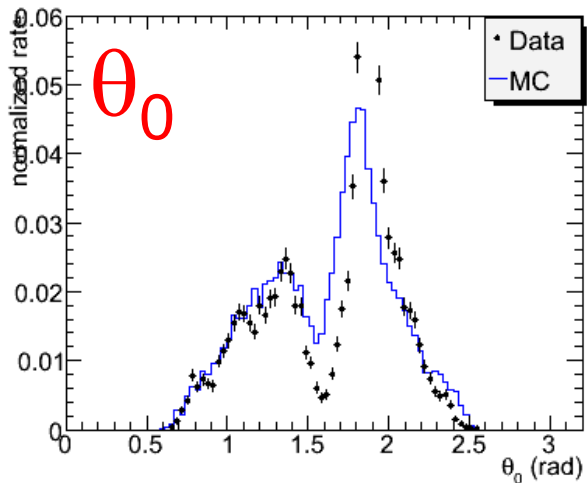
- Relatively good agreement data/MC.
- Discrepancies observed specially in ϕ and θ distributions (due to discrepancies in the readout and trigger conditions).

Measurement of $N\mu^+/N\mu^-$ (with combined tracks)

at surface (PDG '08)

- Studies performed in collaboration with LBNL group
and following their proposed strategy:
http://indico.cern.ch/getFile.py/access?contribId=16&resId=1&materialId=slides&confId=52750

→ track parameters resolution (splitting combined tracks in upper and lower halves)
→ charge miss-identification
→ charge dependent acceptance and effciency

Measurement Strategy

 # tracks measured as positive

 # tracks measured as negative

- Raw Ratio, Center of ATLAS
  - P'/N' (versus p')
- Corrected Ratio, Center of Detector
  - P/N (versus p') = $\varepsilon^- / \varepsilon^+ \cdot f(P', N', c)$
- "Unsmeared" Ratio, Center of Detector
  - p' $\rightarrow$ p
- Ratio at sea level

wrong charge probability

- "Analytical" correction for
  - Efficiency + Acceptance
    - geometrical
    - track selection
    - detectors
    - trigger
  - Charge miss-measurement
- MC with resolution smeared to match data (tbd)
  - correcting p_T bin migration, other resolution effects,
  - extrapolation to surface

must measure
wrong-charge probability c
resolution of track parameters
efficiency ratio $\varepsilon^- / \varepsilon^+$ (tracking)
efficiency ratio $\varepsilon^- / \varepsilon^+$ (trigger)
acceptance ratio $\varepsilon^- / \varepsilon^+$
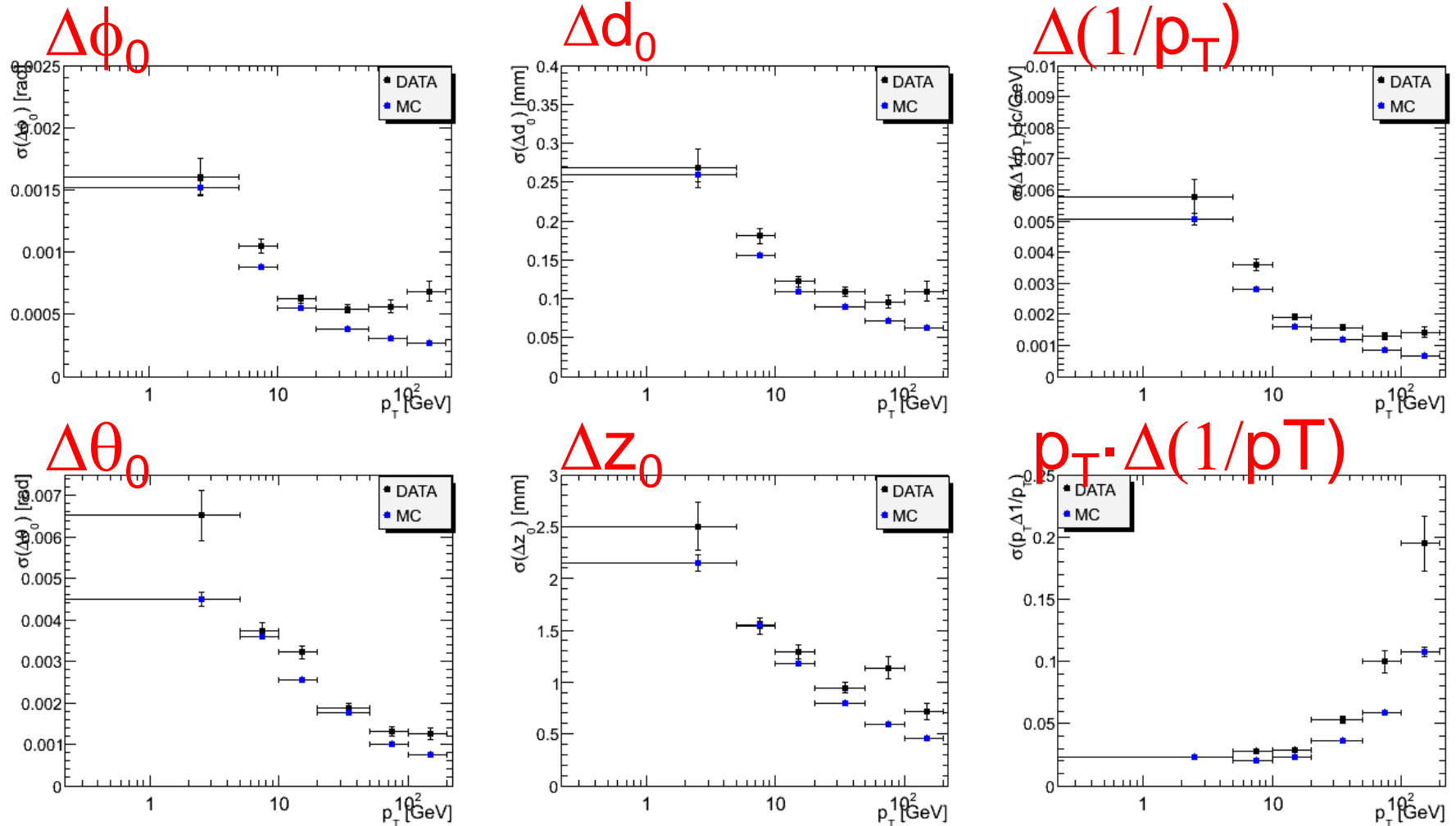
Only efficiency/acceptance *ratios* matter

18

Bias of track parameters (Vs. p_T)

$\Delta\phi_0$

Δd_0

$\Delta(1/p_T)$

$\Delta\theta_0$

Δz_0

$p_T \cdot \Delta(1/pT)$
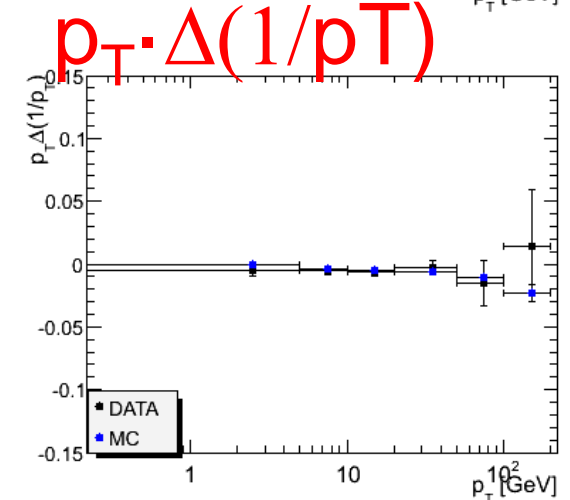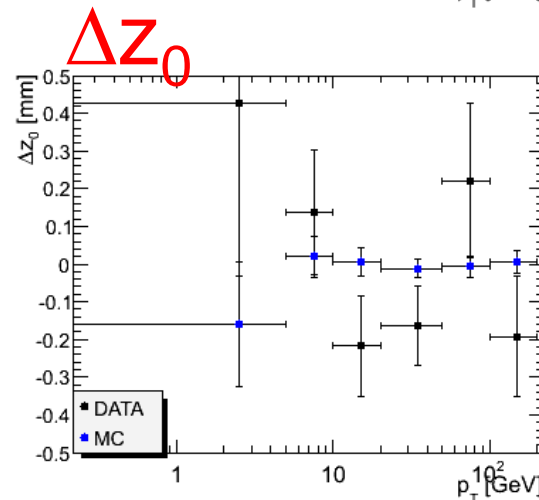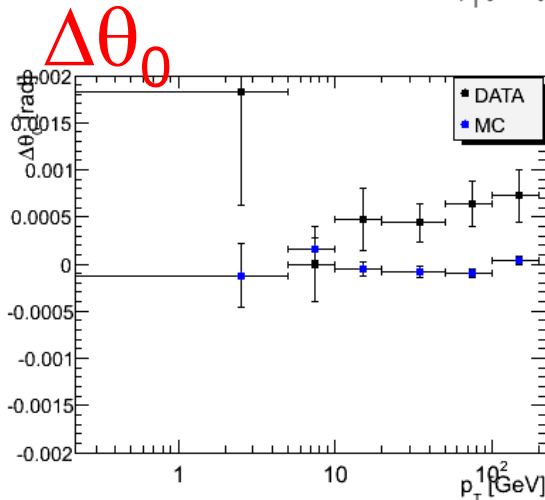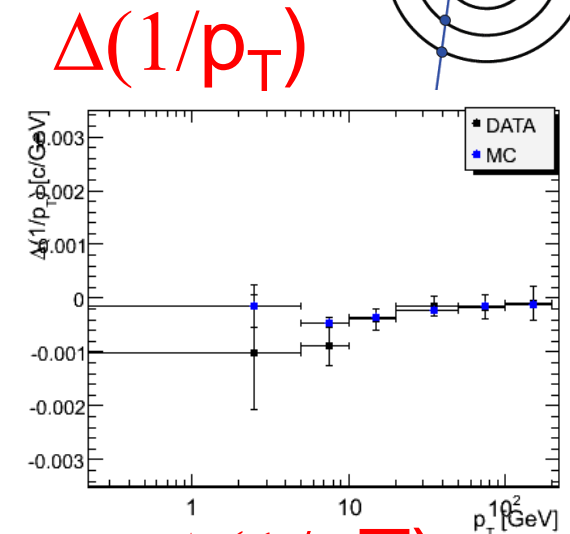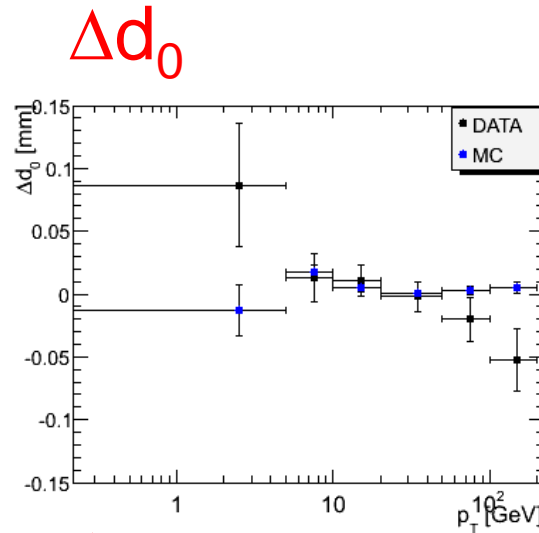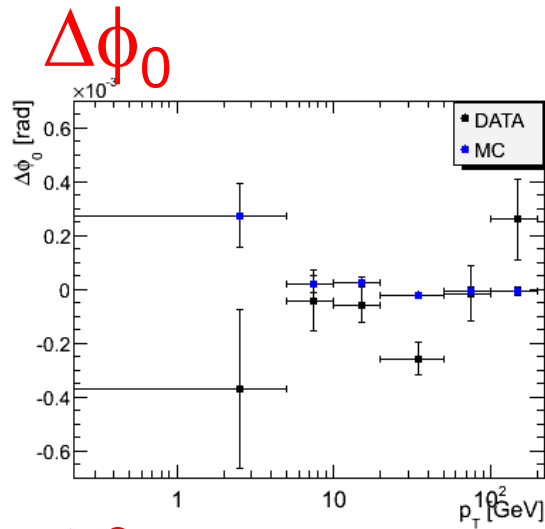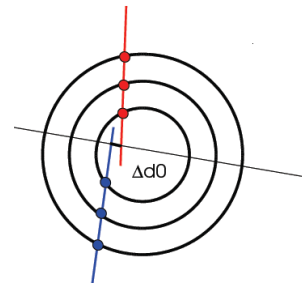
• No offset observed for MC track parameters.

Track parameters resolution (Vs. p_T)

$\Delta\phi_0$ Δd_0 $\Delta(1/p_T)$

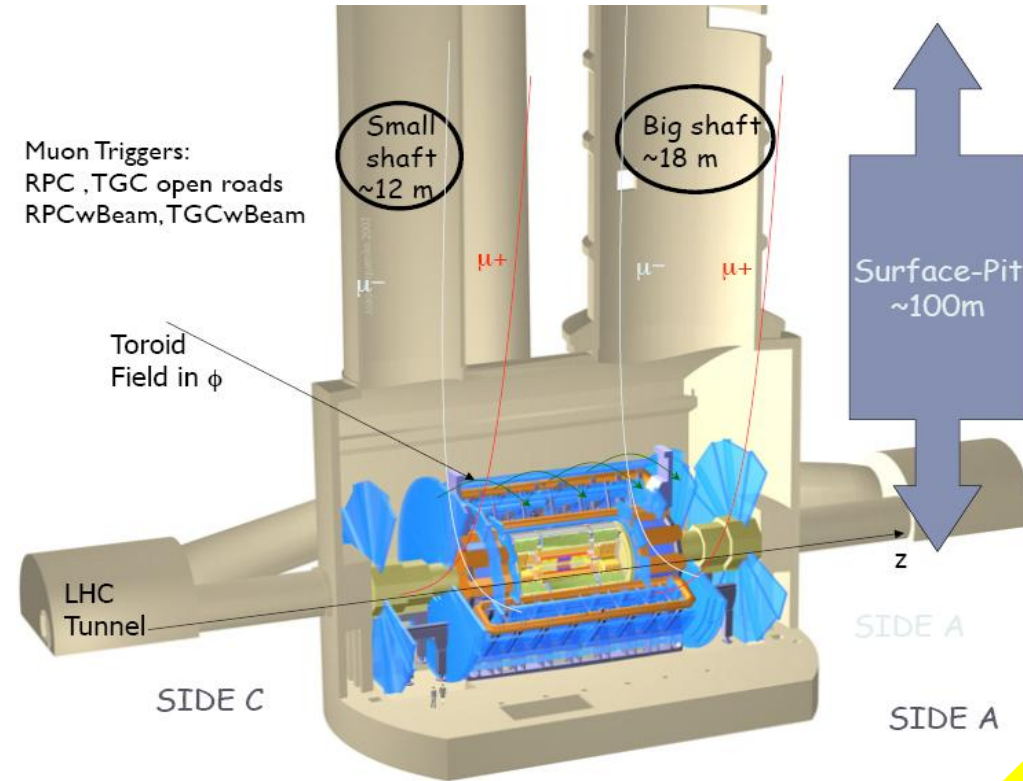$\Delta\theta_0$ Δz_0 $p_T \cdot \Delta(1/pT)$

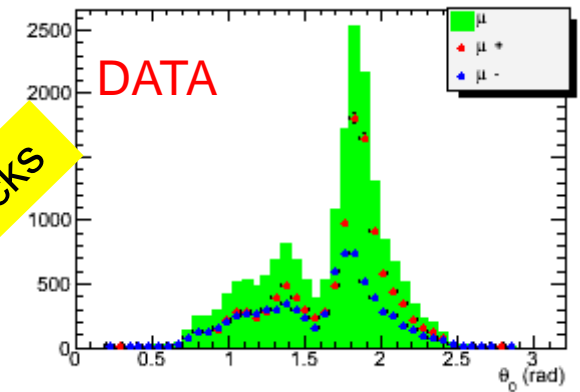- Better resolution observed for MC.

Charge miss-identification
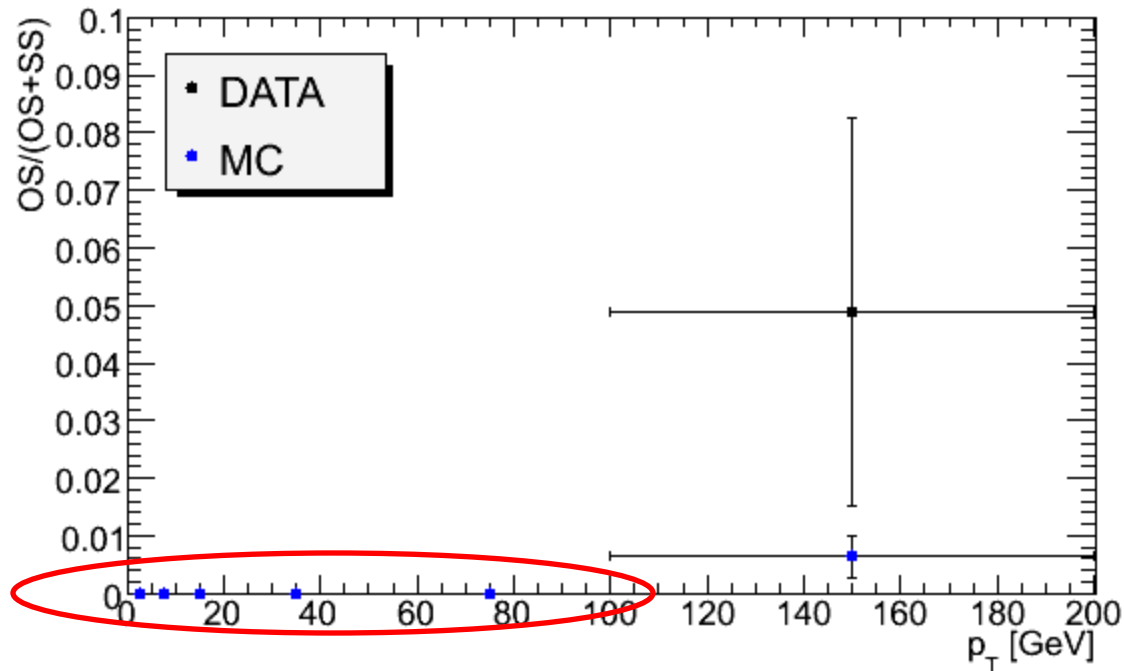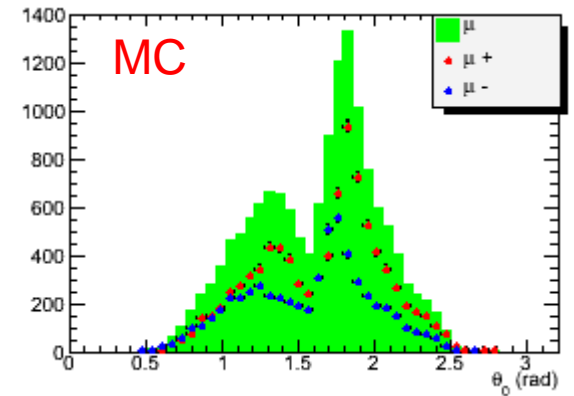

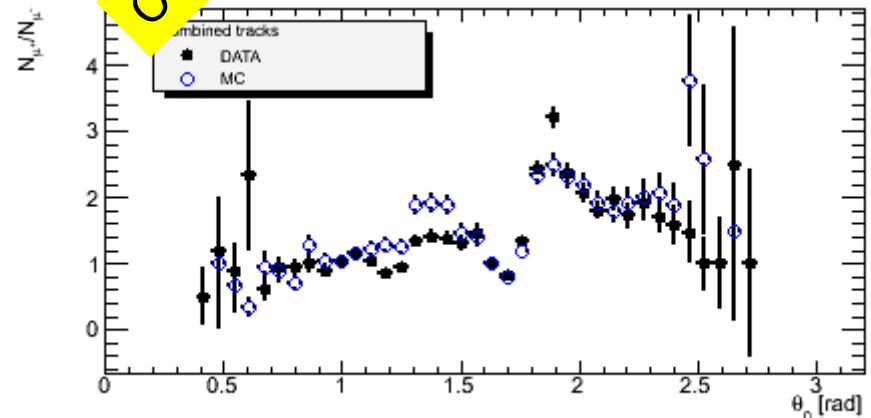• Low momentum splitted tracks have the same sign (both for data and MC).

Charge dependent acceptance

Muon Triggers:
RPC ,TGC open roads
RPCwBeam,TGCwBeam

Small shaft ~12 m

Big shaft ~18 m

Toroid Field in ϕ

$\mu+$ $\mu-$ $\mu+$ $\mu-$

Surface-Pit ~100m
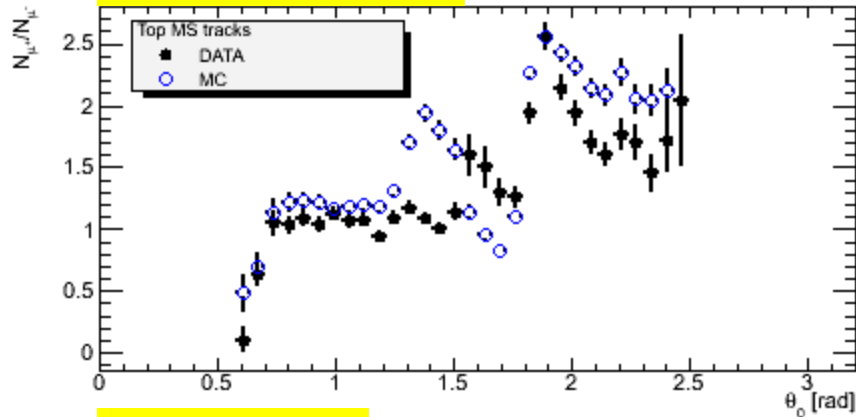
z

LHC Tunnel
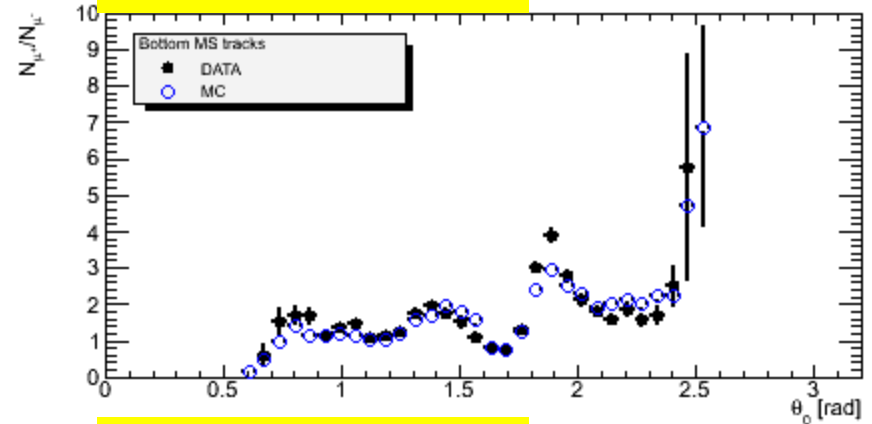
SIDE C

SIDE A

SIDE A

Vs θ_0

MC

DATA

COMBINED tracks

• Muons are bend out of ATLAS depending on its charge and position → charged bias acceptance.
• Large impact on asymmetry measurement.

03/06/2009

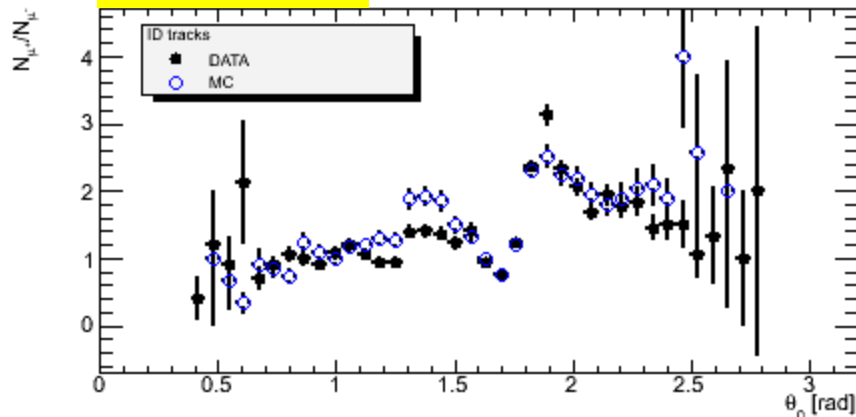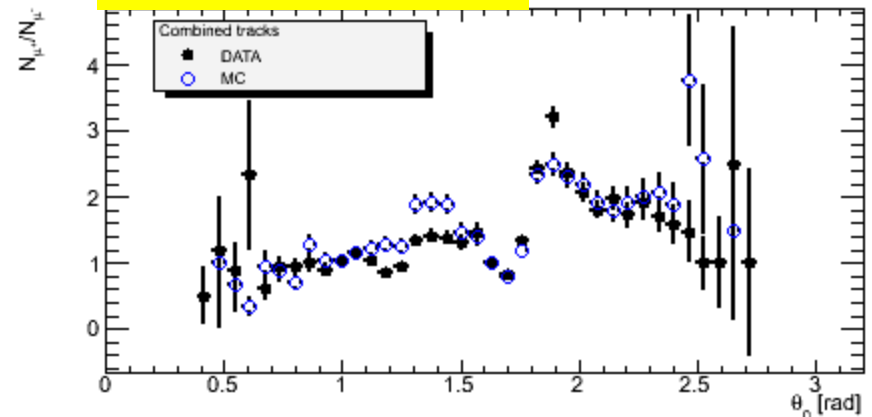22

Charge dependent acceptance

Top MS tracks

Bottom MS tracks

ID tracks

Combined tracks

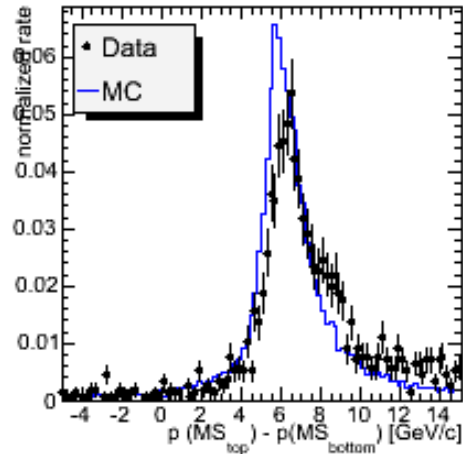- Data/MC agreement increases in low part of the detector.

E loss studies

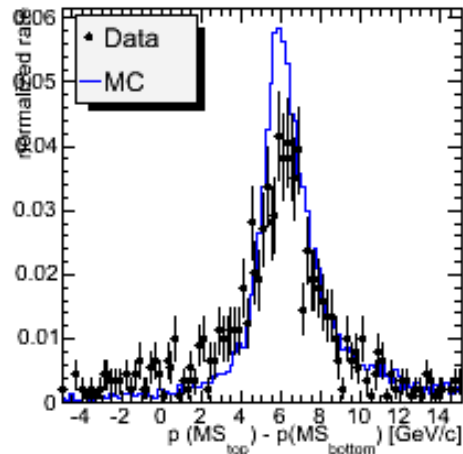- For this study, it is required that muon tracks have the same charge.

Energy loss & momentum difference ID-MS

$\Delta P(MS_{top} - Ms_{bottom}) \sim 6$ GeV

μ^+

μ^-

TOP tracks
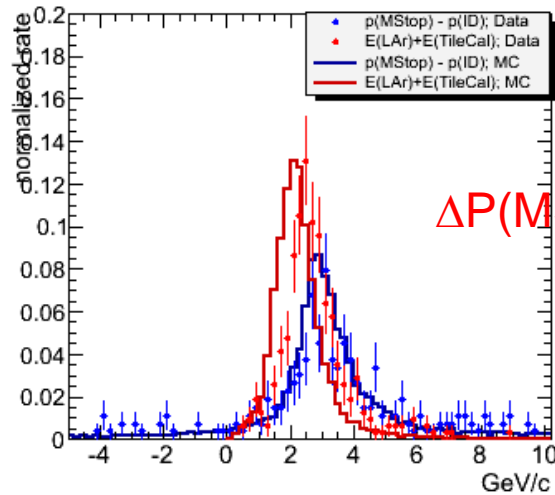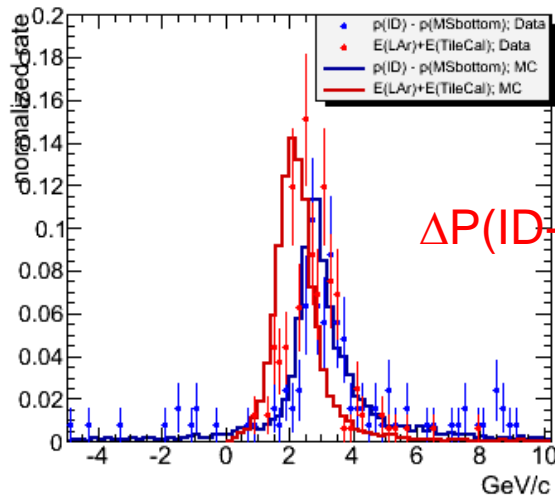
$\Delta P(MS_{top} - ID) \sim 3$ GeV

BOTTOM tracks

$\Delta P(ID - MS_{bottom}) \sim 3$ GeV

• The energy deposited in the calorimeters is smaller than the ID-MS momentum difference (for both data & MC; observed in previous studies).
• The momentum difference between ID and MS tracks is wider for tracks in the top MS hemisphere. This could be due to the known problem in material in top MS.

Energy loss & momentum difference ID-MS

BOTTOM tracks — MC

Slope= 0.75±0.13

TOP tracks — DATA

Vs p_T

Vs θ_0
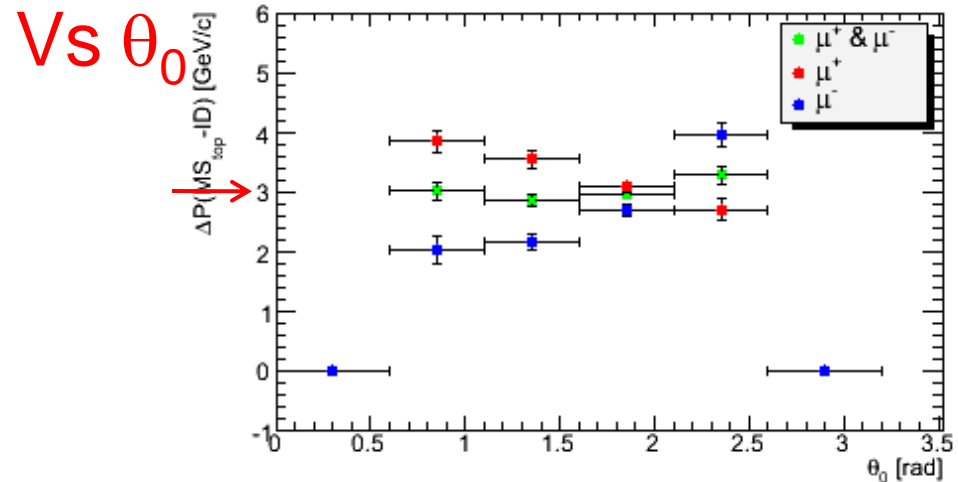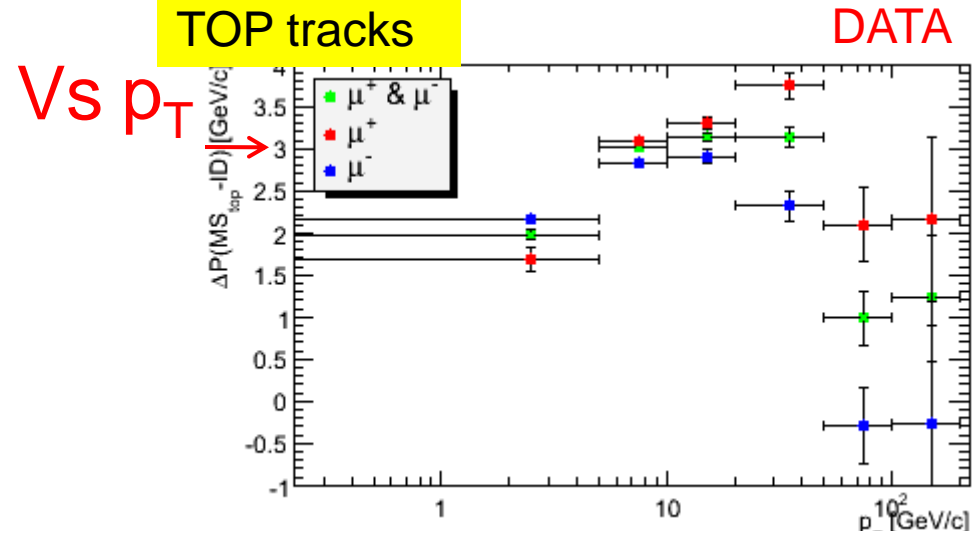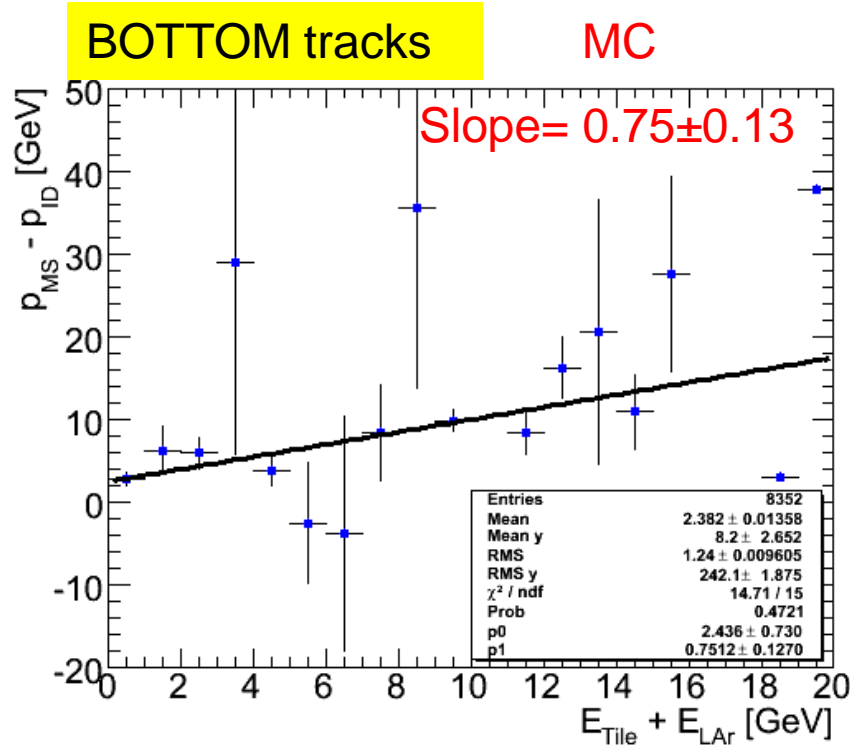
- Not a clear correlation observed between this momentum difference and the energy in the calos (requires more statistics).
- Momentum difference Vs. θ depends the muon charge (only observed in data, real?).

Conclusions

- Cosmic data from the last re-processing has been used to study:
    - the performance of the ID and Muon standalone and
    - combined tracking
    - energy loss in the calorimeters
    - studies towards a first measurement of muon charge ratio with combined tracks

- A validation of the simulation has been done by performing data/MC comparisons
→problem in the official Moore reconstruction detected.

- Future plans:
    - for MC, re-run Moore reconstruction with the following options:
        - ToolSvc.MdtDriftCircleOnTrackCreator. DoFixedError=False
        - muonRecFlags.useTGCPriorNextBC=True
        - muonRecFlags.doSegmentT0Fit=True
    - Moore fix for material in the top part of MS (for both data & MC)
    - use other cosmic 08 golden runs: 91885, 91888, (91890) & 91890 (solved Grid problems!)