Muon Selection Studies for Rel 16

Data/MC comparison for release 16 reprocessing

Investigations of pT tails & increased eta acceptance

→ active studies within dilepton exotics group

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Proposed studies for Exotics dilepton group

Validating muon selection:

D.Fortin & S.W.

Use baseline selection in all studies below. Baseline described at bottom.

0. chi^2 match from Z->mumu and W->mu nu candidates in data and MC

1. chi^2/dof matching probability distribution from Z->mumu and W->mu nu candidates in data and MC.

2. Plot the (pMS - pID) / pID distribution for muons from Z->mumu candidates and W->mu nu candidates in data and MC

3. Plot the pT distribution of the muons from data for the Z->mumu candidates and W->mu nu and compare with MC truth and MC reco. Repeat for the following eta bins:
   a) |eta| < 1.05
   b) 1.05 < |eta| < 1.4
   c) 1.4 < |eta| < 1.7
   d) 1.7 < |eta| < 2.0
   e) 2.0 < |eta| < 2.4

4. From W->mu nu and Z->mumu samples, bin the pT as: 50-100 GeV; 100-200 GeV; >200 GeV and plot for each pT bin:
   a) # of stations with at least 3 precision hits
   b) # of stations with at least one phi hit
   c) Match chi2
   d) [pMS - pID] / pID
   e) | eta |
   f) 2-D plot of eta-phi.

5. Invariant mass of Z->mumu candidates using in the Barrel-Barrel, Barrel-Endcap, Endcap-Endcap
   a) With 2 stations
   b) With 3 stations
   Can check result using pT from combined muon and MS only

Muon Selection

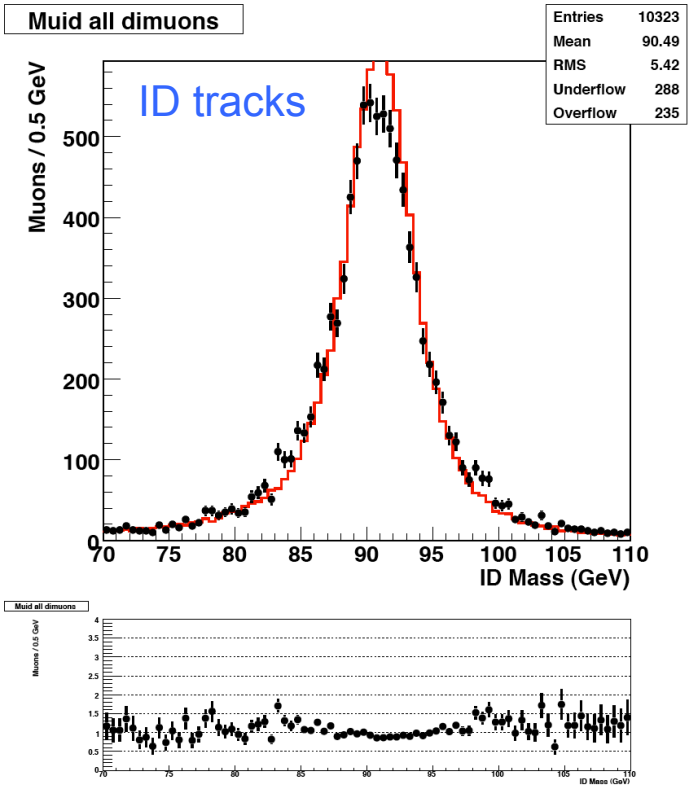
- **Base selection for release 16**
  - MUID combined author == 12
  - # pixel hits > 0 && # SCT hits > 5
  - # TRT hit cuts applied following MCP Rel.15 recommendation
  - |eta| < 2.4
  - pT_combined > 25 GeV
  - |z0 w.r.t. PV| < 1 mm
  - |d0 w.r.t. PV| < 0.2 mm
  - Sum (pT cone 0.3) / pT_combined < 0.05
  - # MS phi hits > 0
  - # MS precision hits in inner, middle, outer > 2 in at least 2 of the 3 layers
  - Remove track if BEE hits present (no cuts yet on BIS7/8)

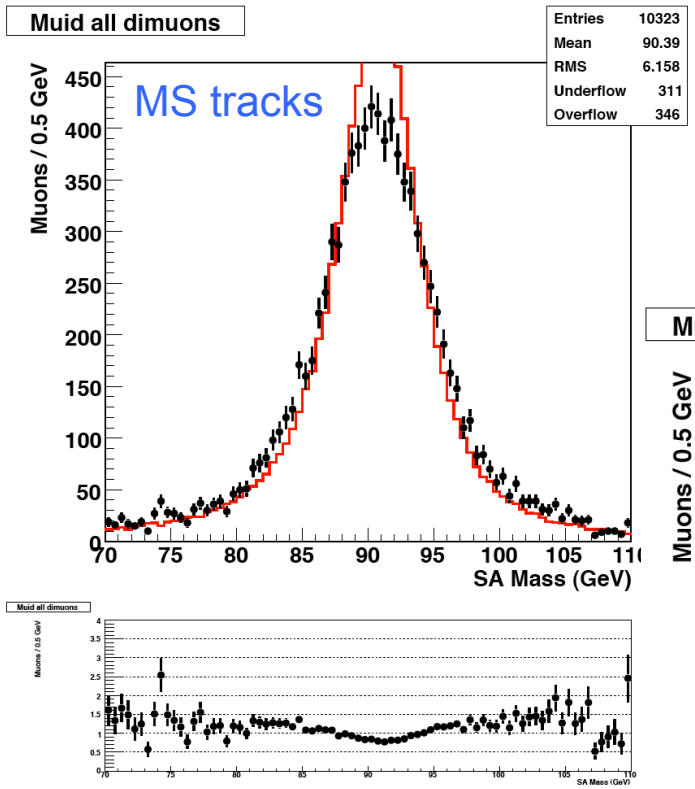
Select events with at least 2 combined muons passing these basic requirements
+ *require event passes Zmumu GRL*

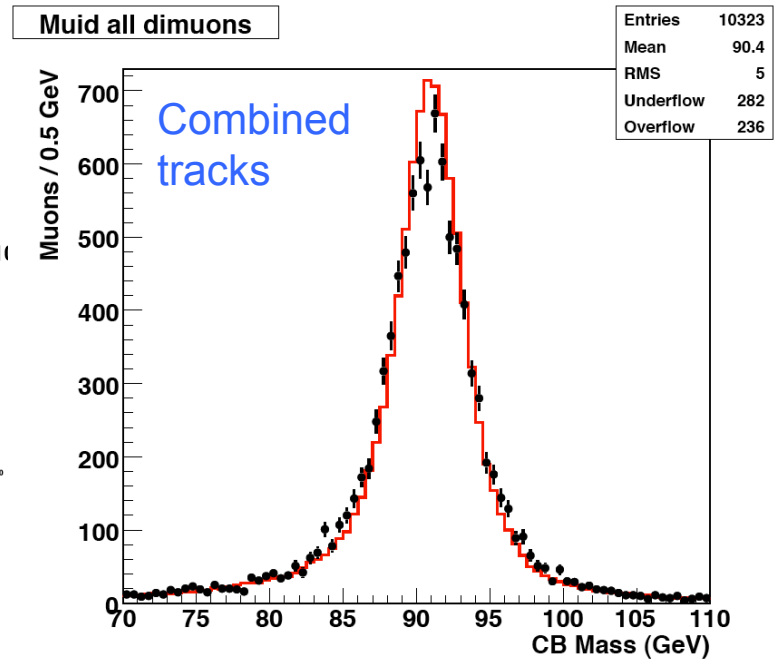
- **Samples**
  - **Data single muon skim periods G, H, I**
    - data10_7TeV.periodG.physics_Muons.PhysCont.DESD_SGLMU.repro05_v02
  - **Zmumu MC (0.5 M events)**
    - mc10_7TeV.106047.PythiaZmumu_no_filter.merge.AOD.e574_s933_s946_r1652_r1700
- **Analysis**
  - **AOD/ESD-based muon performance ntuple maker (Niels, Egge et al.)**

Dimuon mass around Z peak

- **Resolution near Z peak much improved over rel 15**





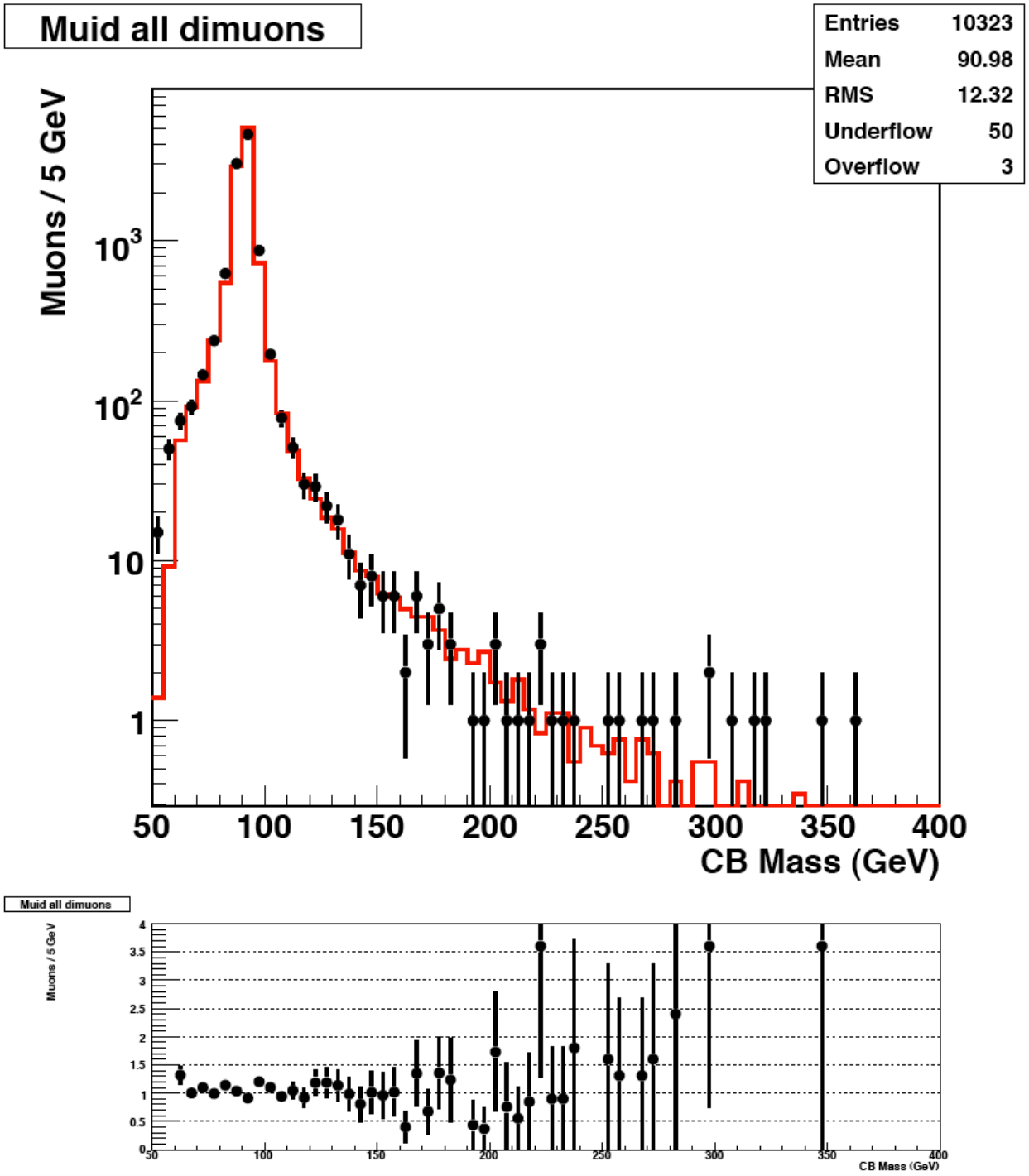


Data: points

MC: red histograms
(normalized to data area inside histo)

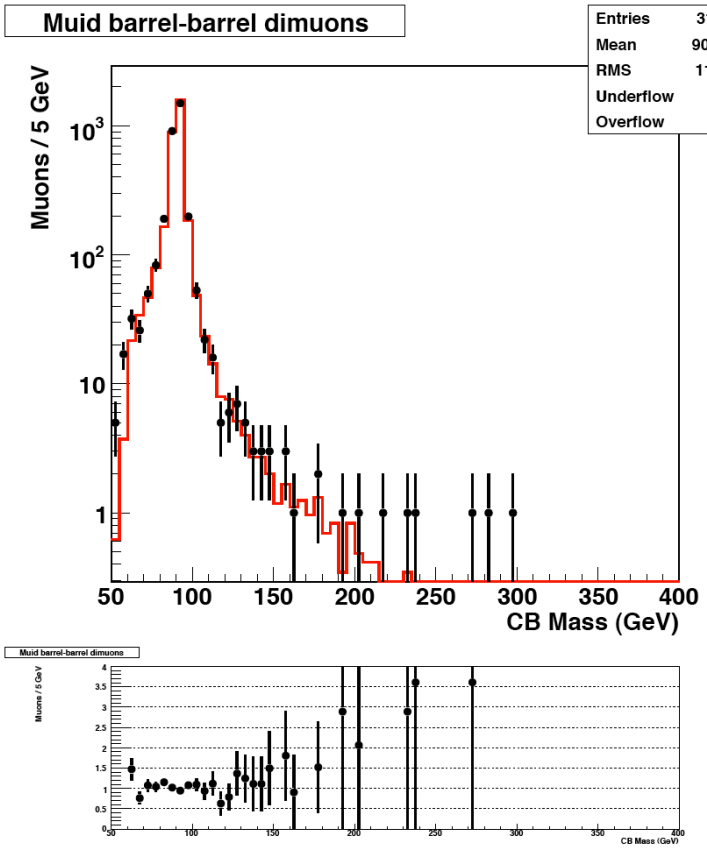
Dimuon mass tails

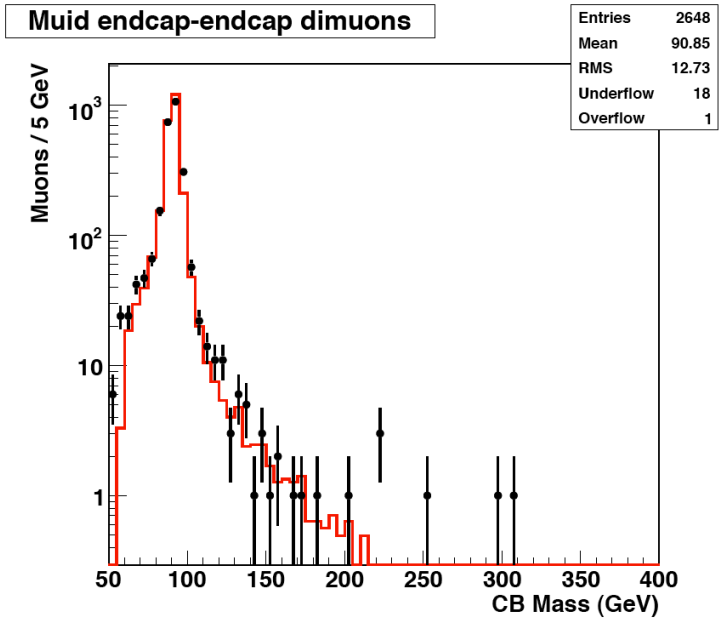
- Good data / MC agreement up to ~250 GeV
- Need to study the long tail however

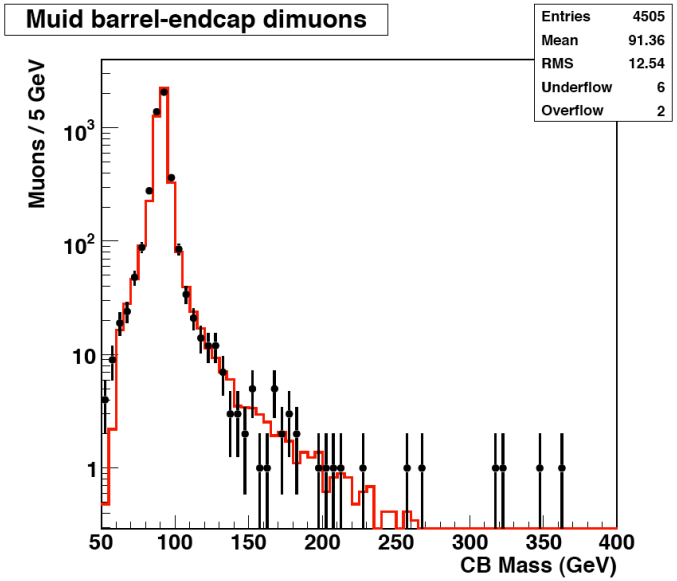


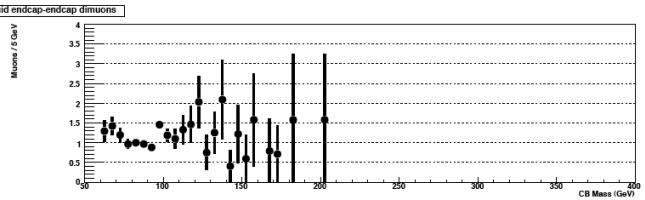
Dimuon mass tails

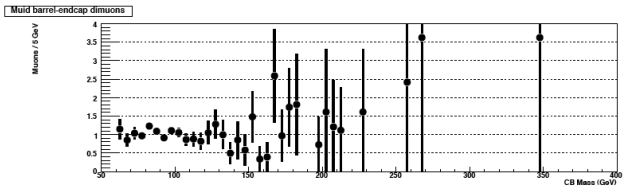
- Data high-mass events not confined to just barrel or endcap





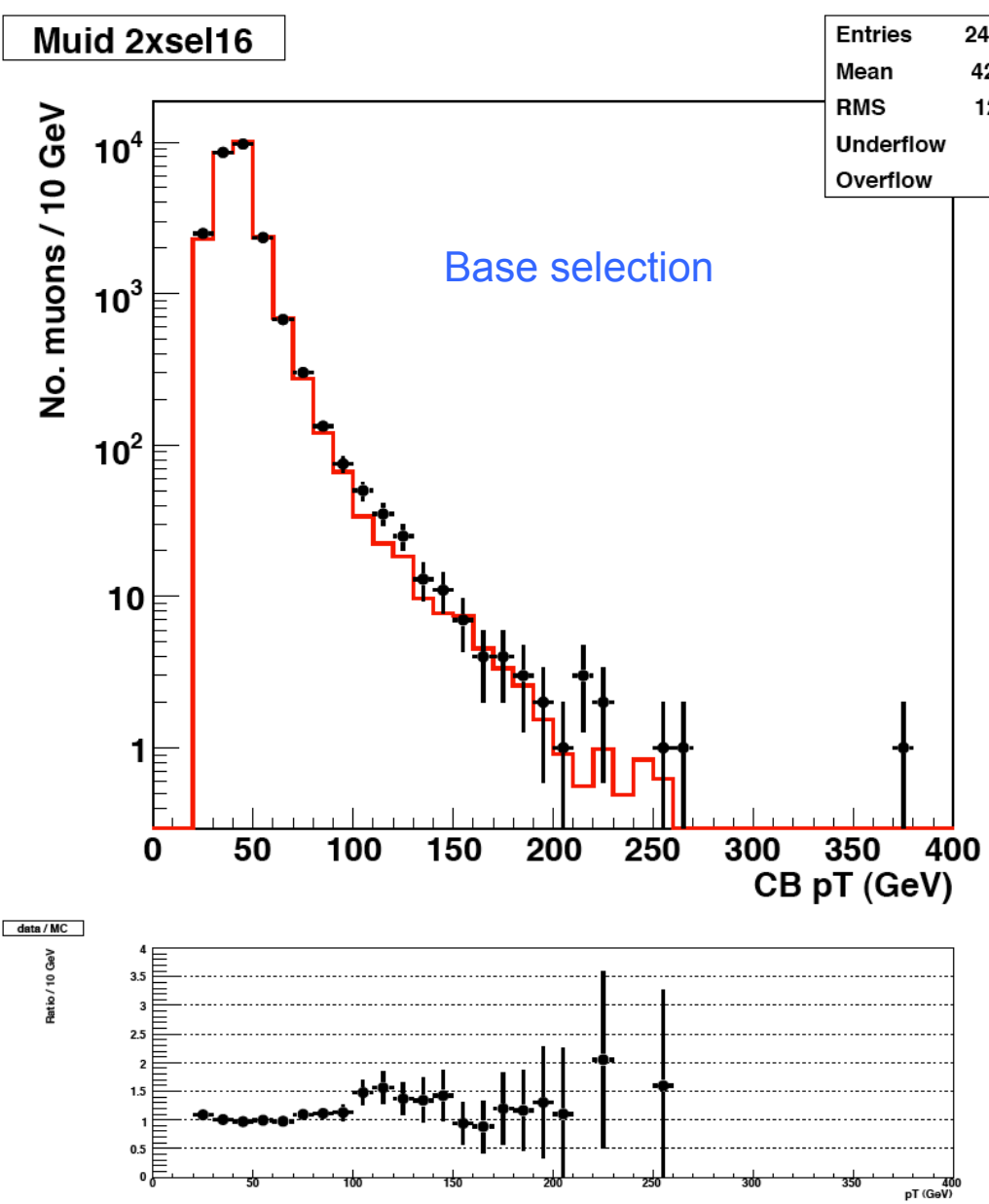


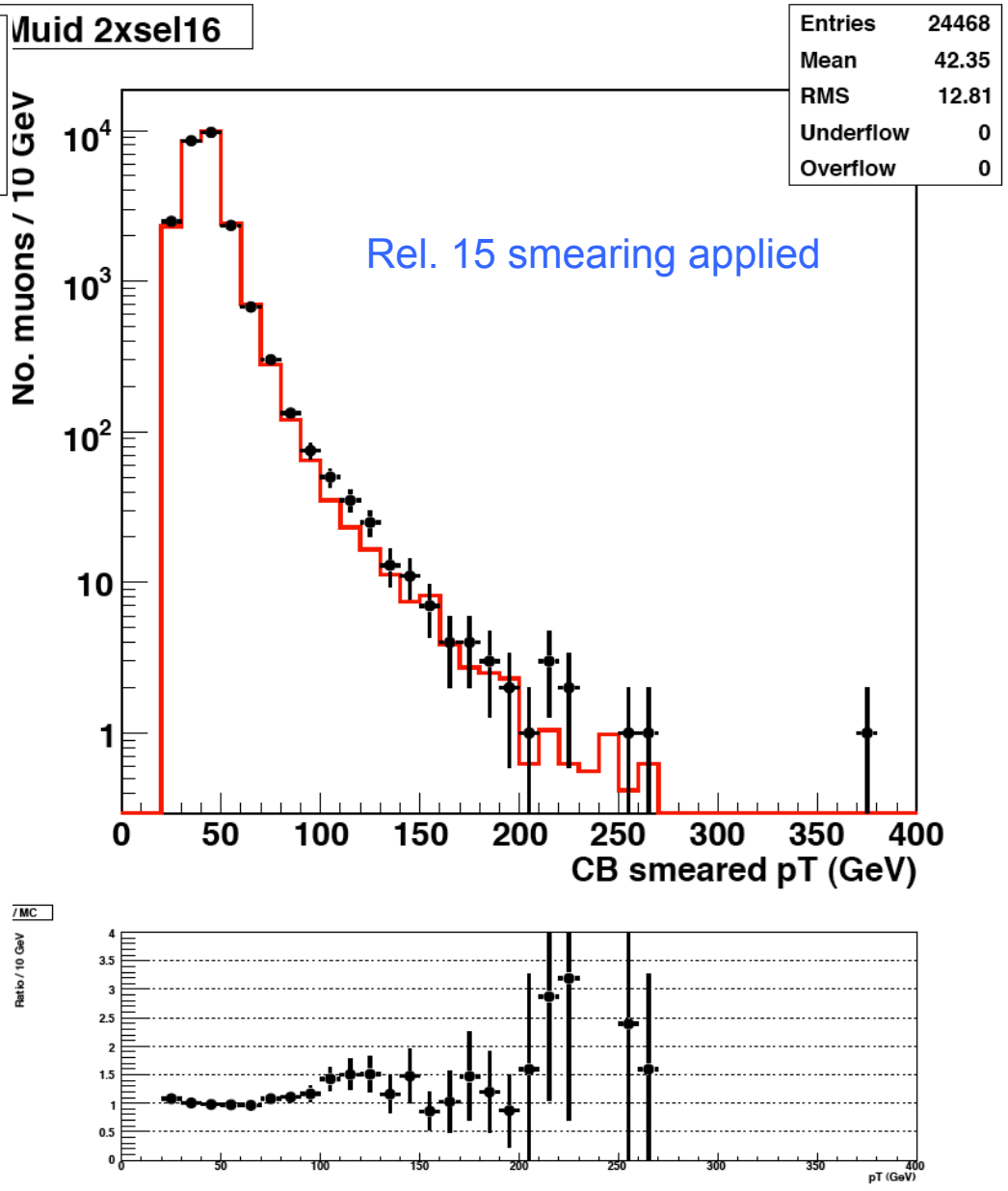




Single-muon Momentum Spectrum

- Slight data excess for pT > 100 GeV
- Slightly improved data/MC agreement with momentum smearing turned on



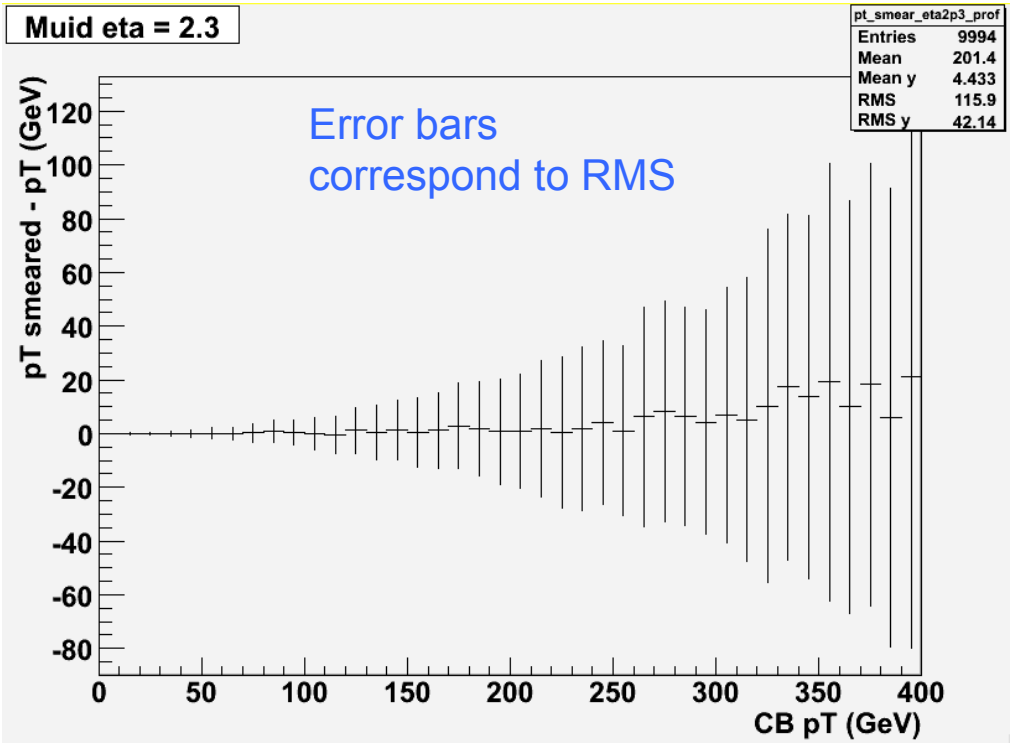


Momentum Smearing

- **Smearing applied to MC, derived from release 15 performance studies (similar to what is applied to W' analysis — D.Adams)**

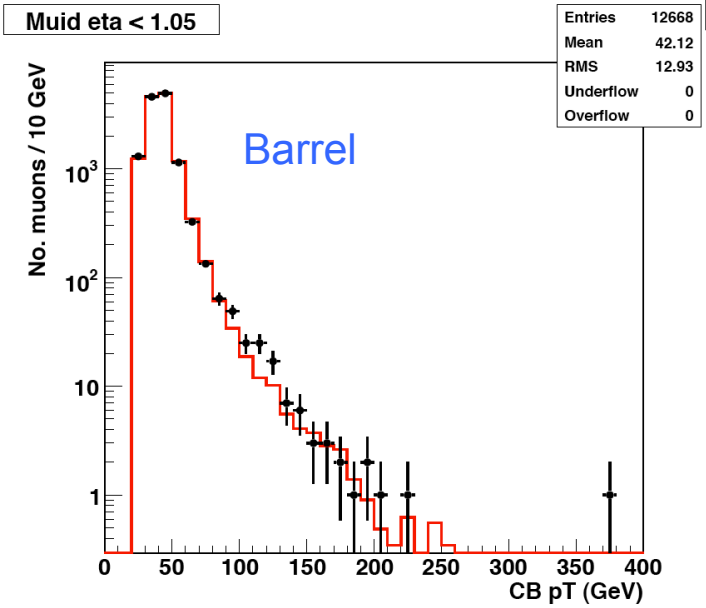
  → ***This addresses average resolution NOT tails***

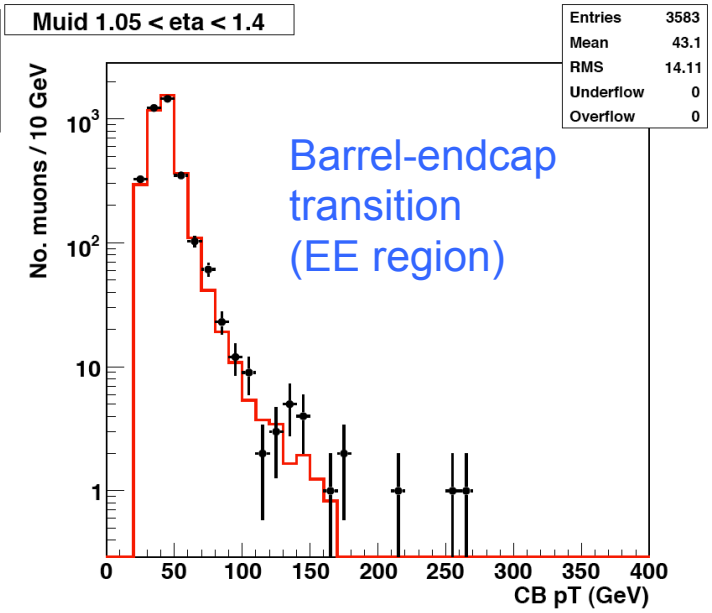
- **Multiple scattering term**
  - **q / pt += q / pt * smear1 * ran.Gaus(0.0,1.0);**
  - **smear1 = 0.02**
- **Single-point spatial resolution term**
  - **q / pt += smear2 * ran.Gaus(0.0,1.0);**
  - **smear2 = 0.18 / TeV (for |eta| < 2)**
  - **smear2 = 0.5 / TeV (for |eta| > 2)**
    → 10% uncertainty at pT = 200 GeV

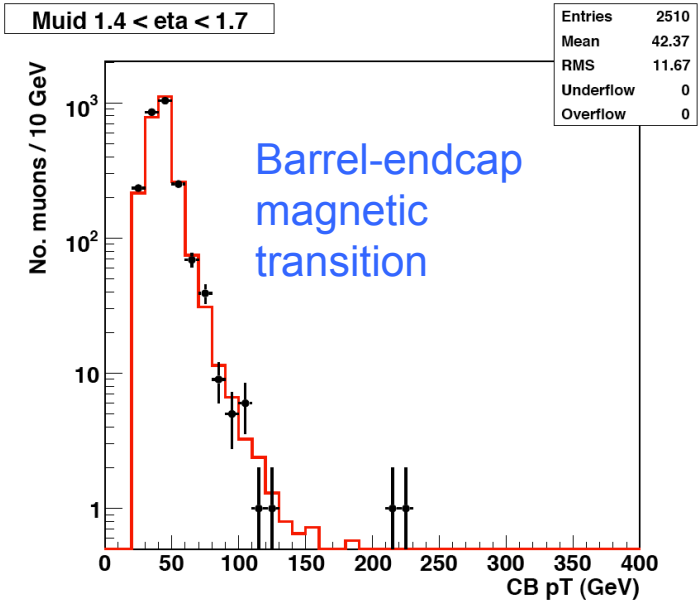


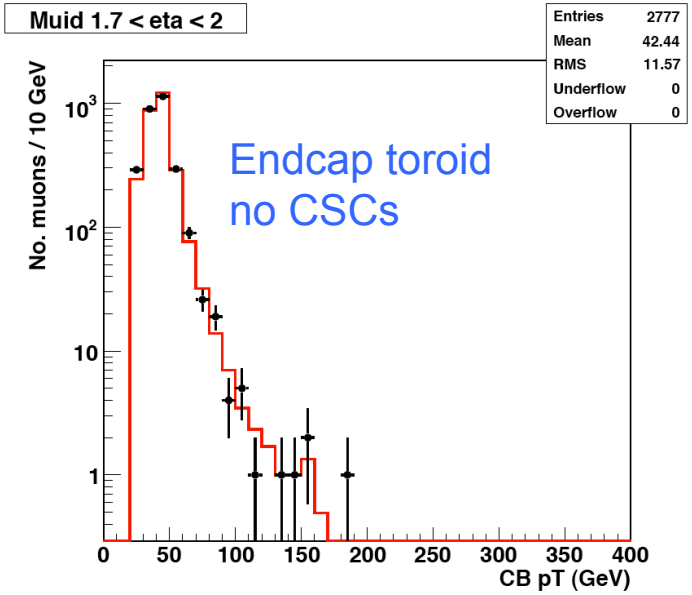
Momentum Spectrum vs. eta ranges

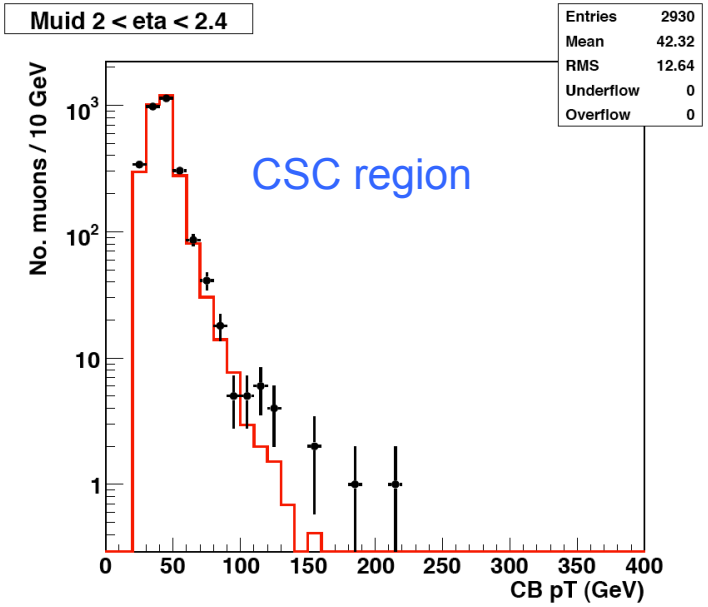
- **Largest deviations for |eta| ranges [1.05 - 1.4] and [2.0 - 2.4]**





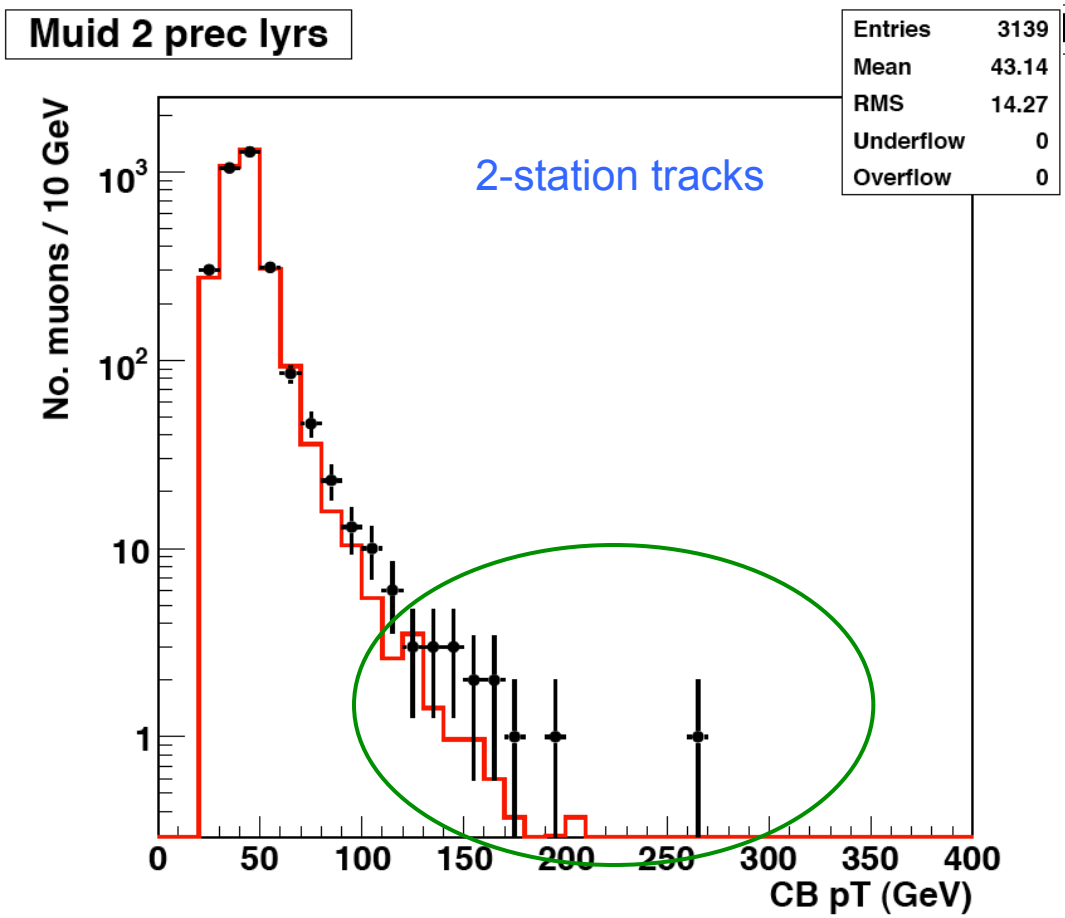


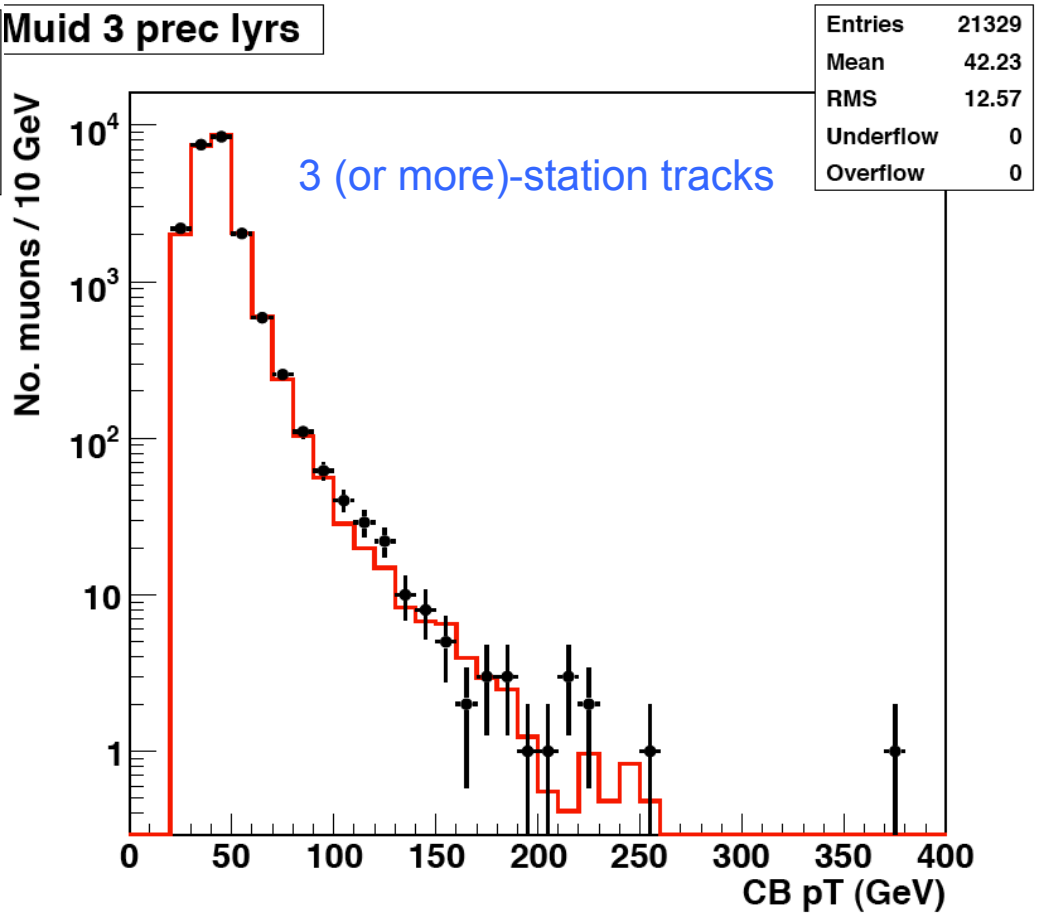




Momentum Spectrum vs. # precision layers

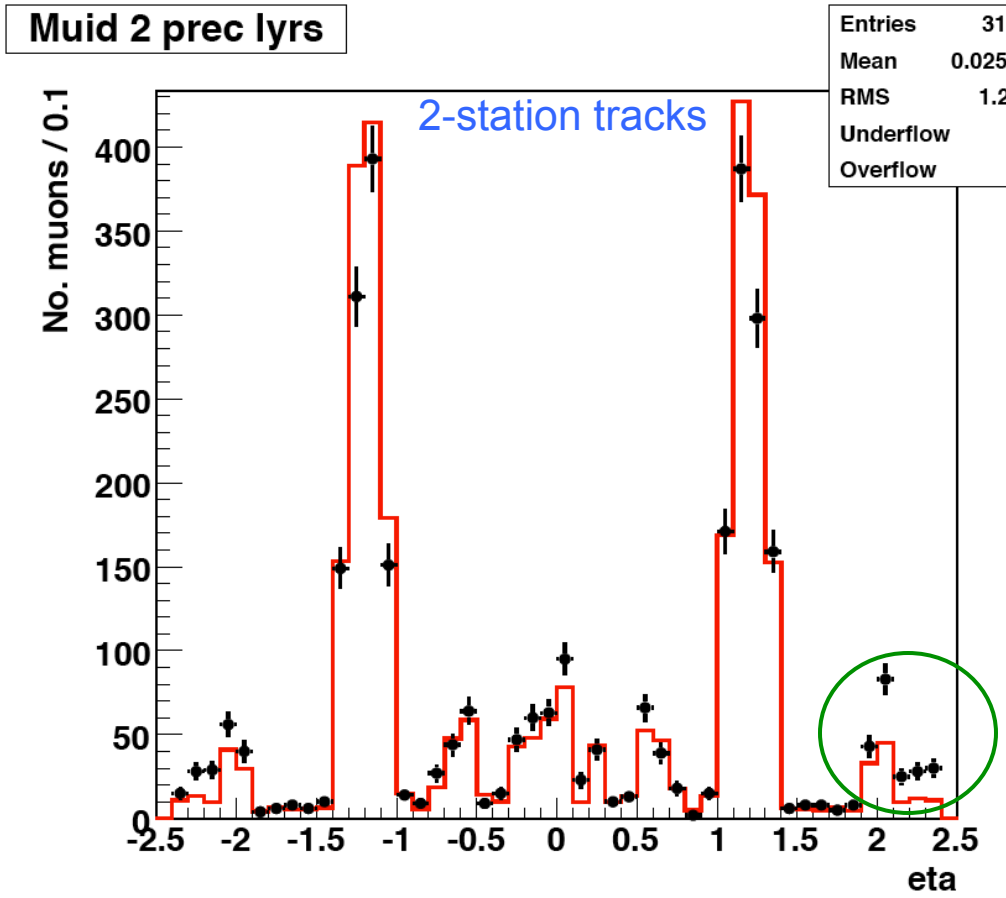
- **Largest deviations when only 2 MS precision layers on the track**

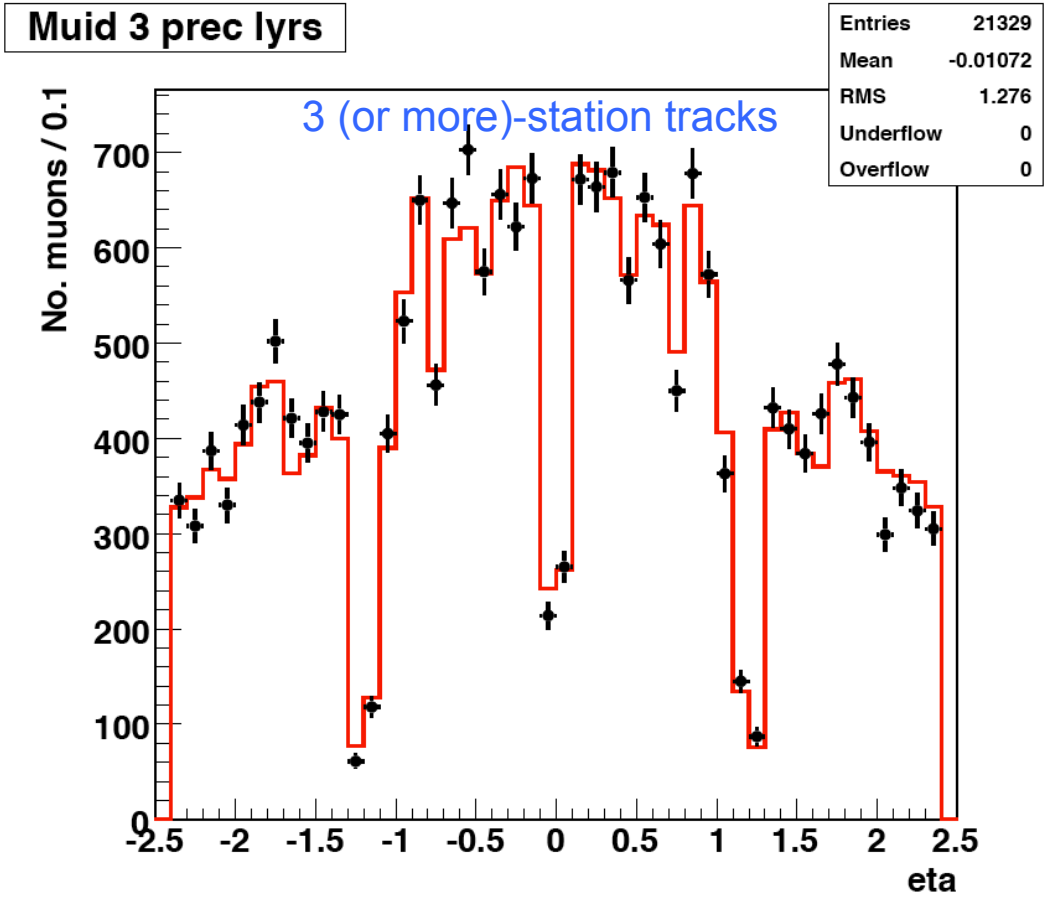


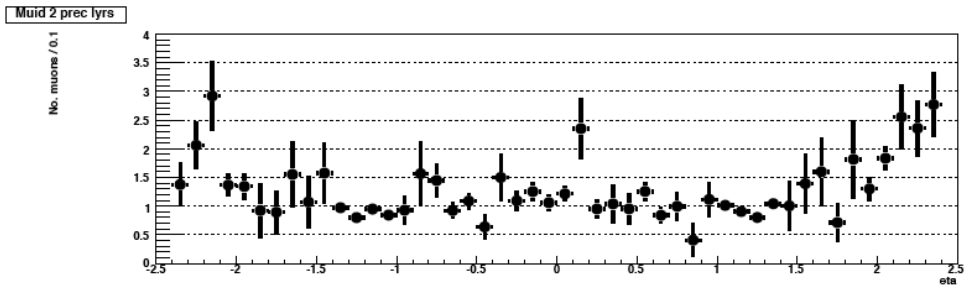


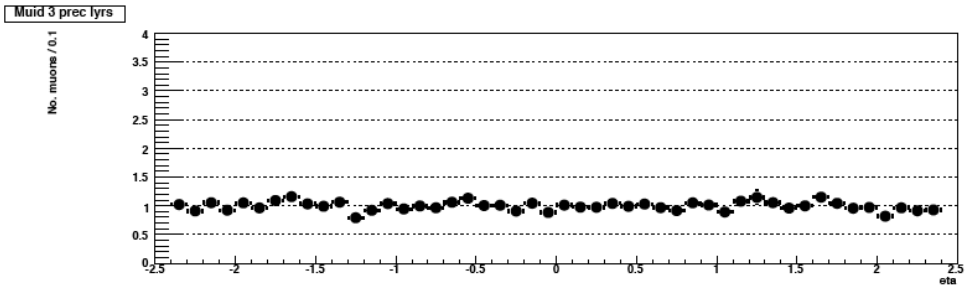
Eta distribution vs. # precision layers

- Good data/MC agreement for 3 or more prec layers (right plot)
- Not quite as good for exactly 2 precision layers on track (left plot)



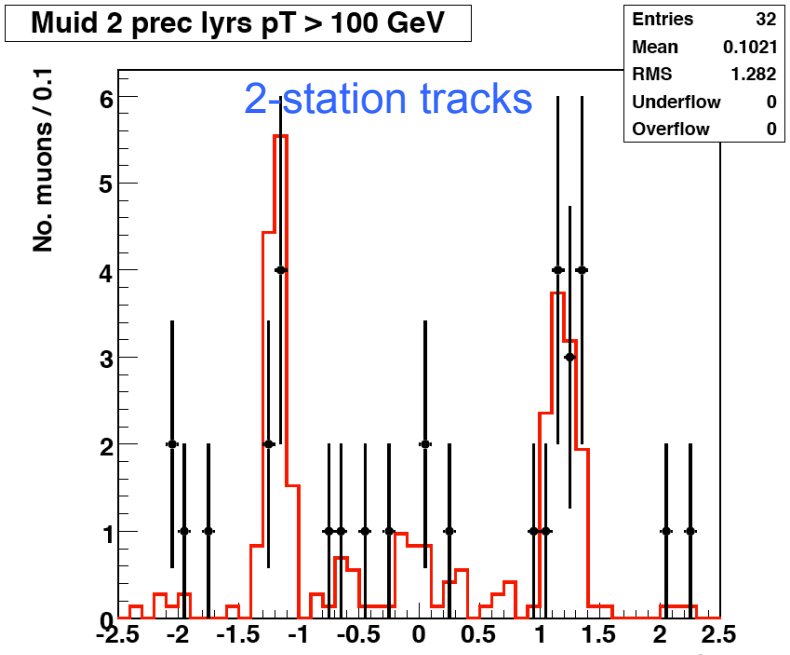


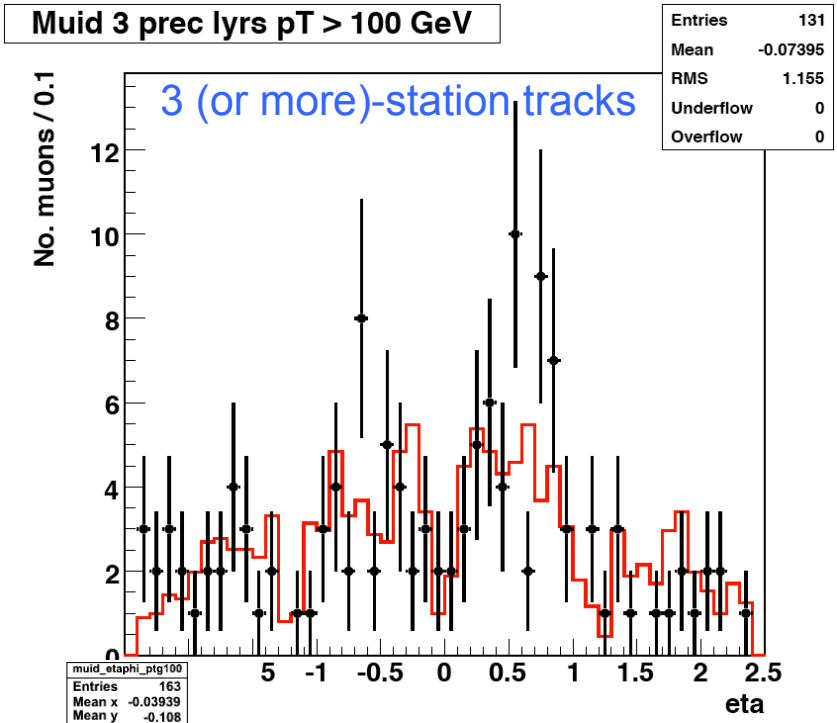


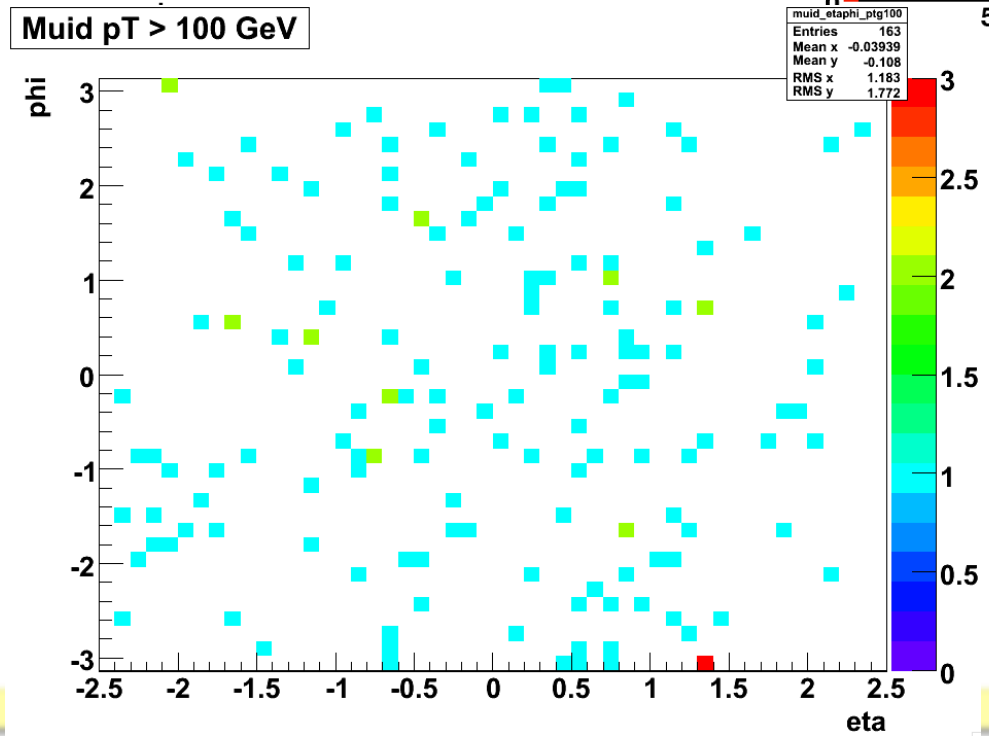


Where are the high-pT muons?

- No special eta values at which data at pT > 100 GeV clusters anomalously

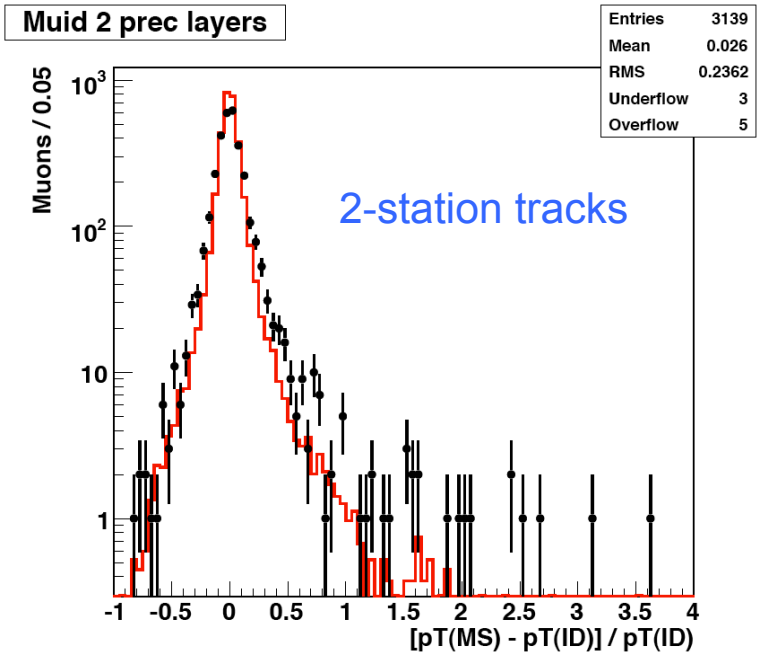


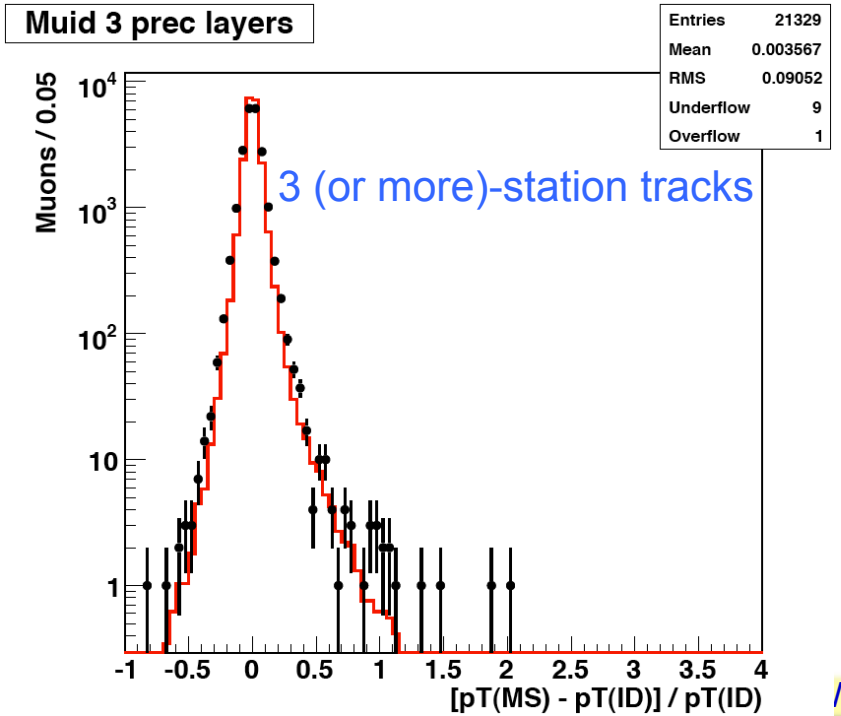


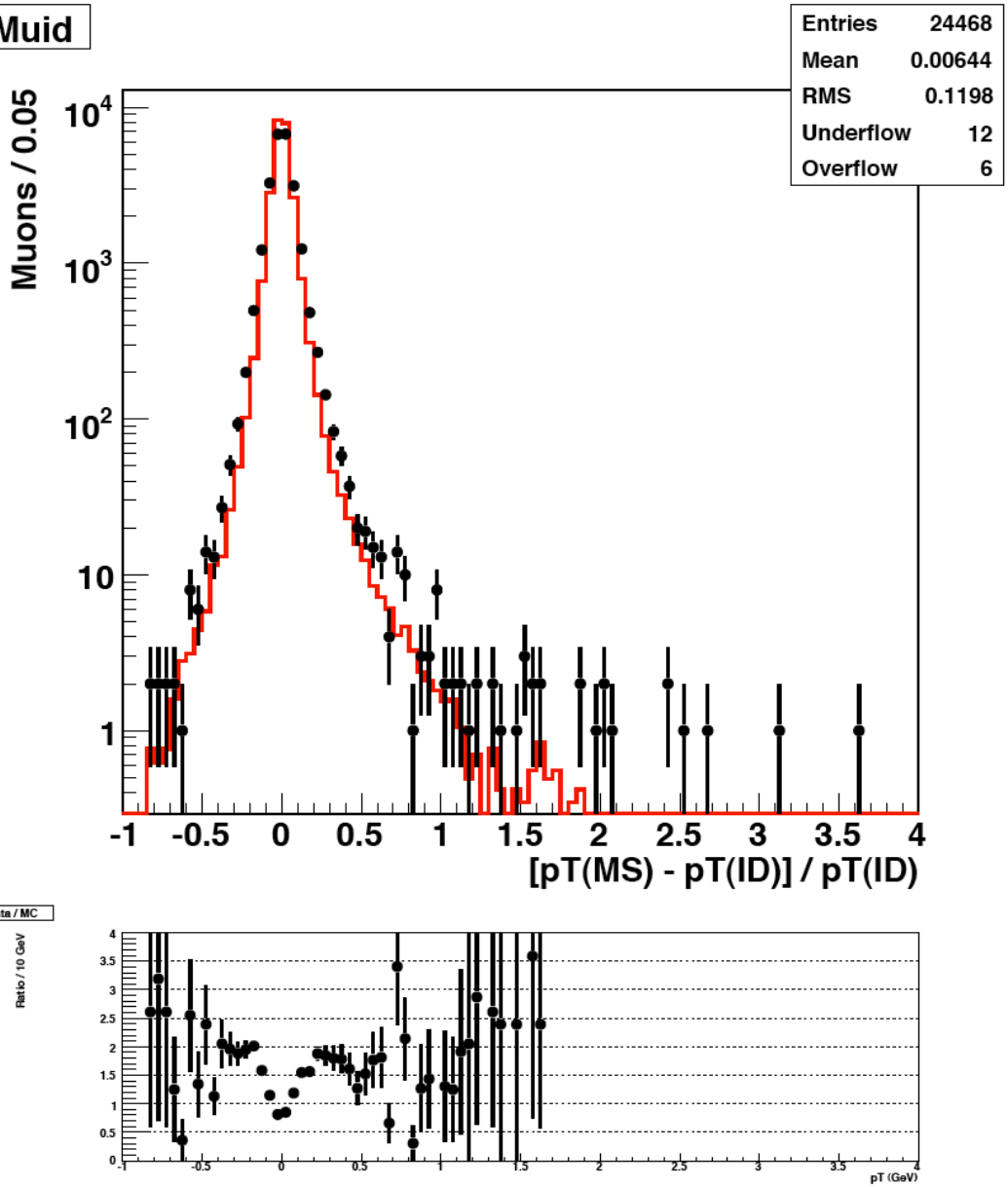


pT difference MS vs. ID

- **Clear data tail toward higher pT(MS)**

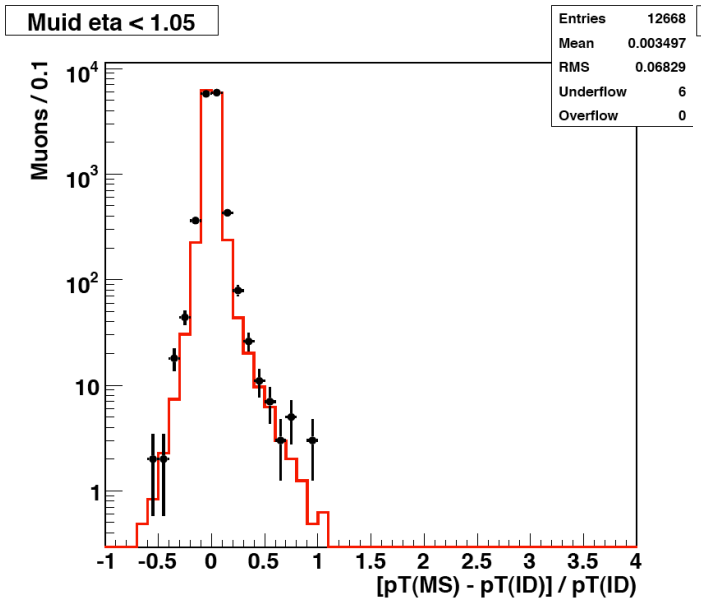


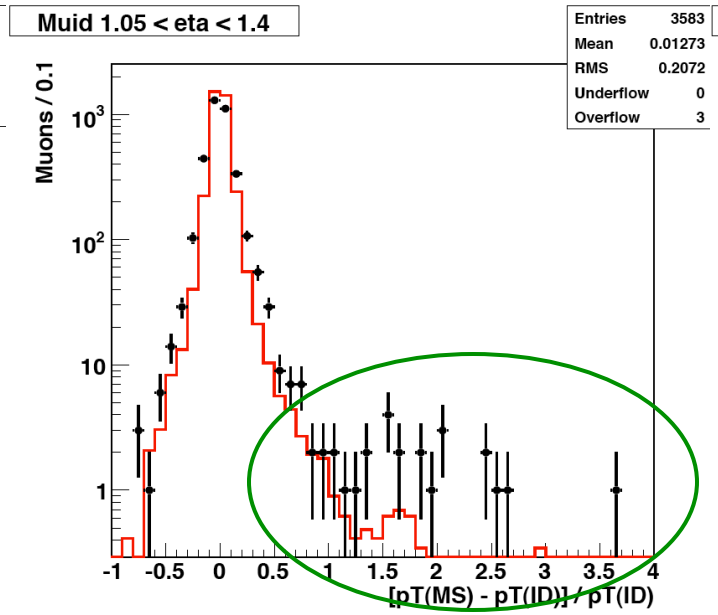


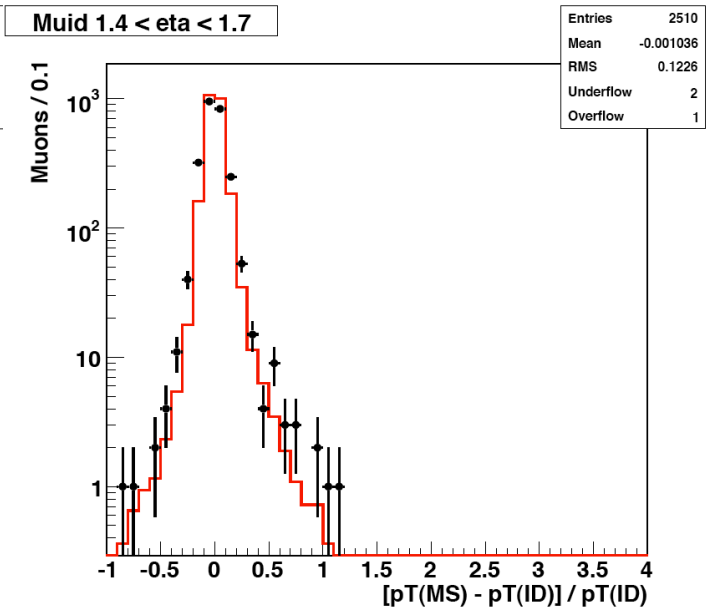


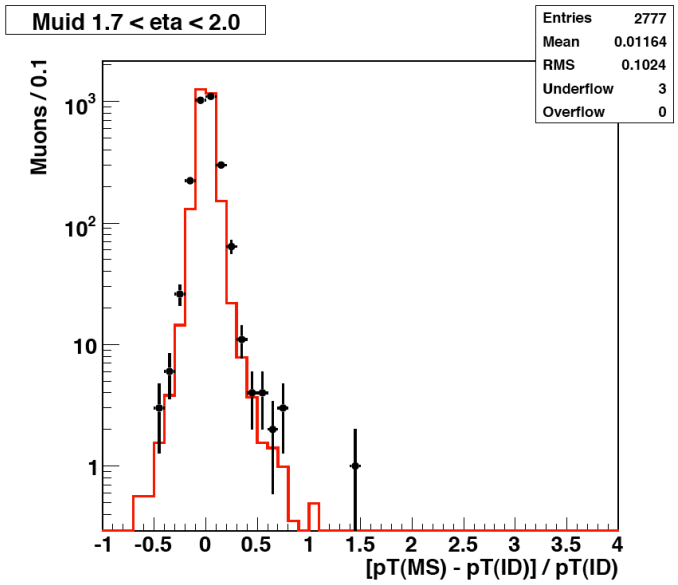
pT difference MS vs. ID

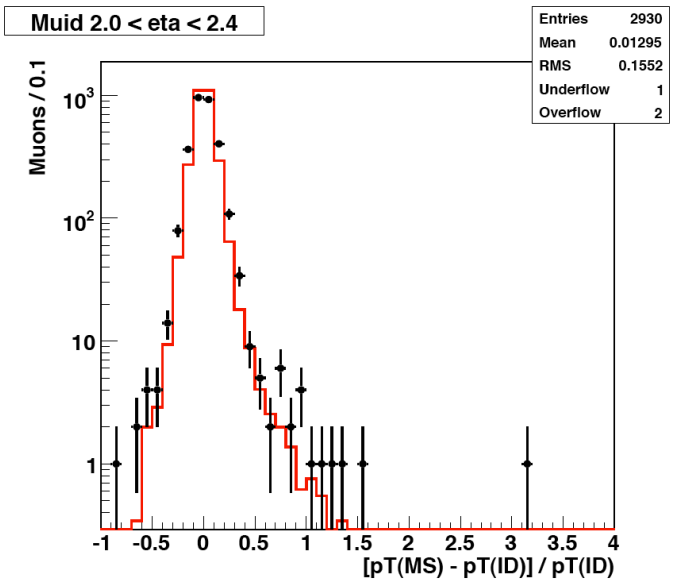
- **Largest deviations for |eta| ranges [1.05 - 1.4] and [2.0 - 2.4]**





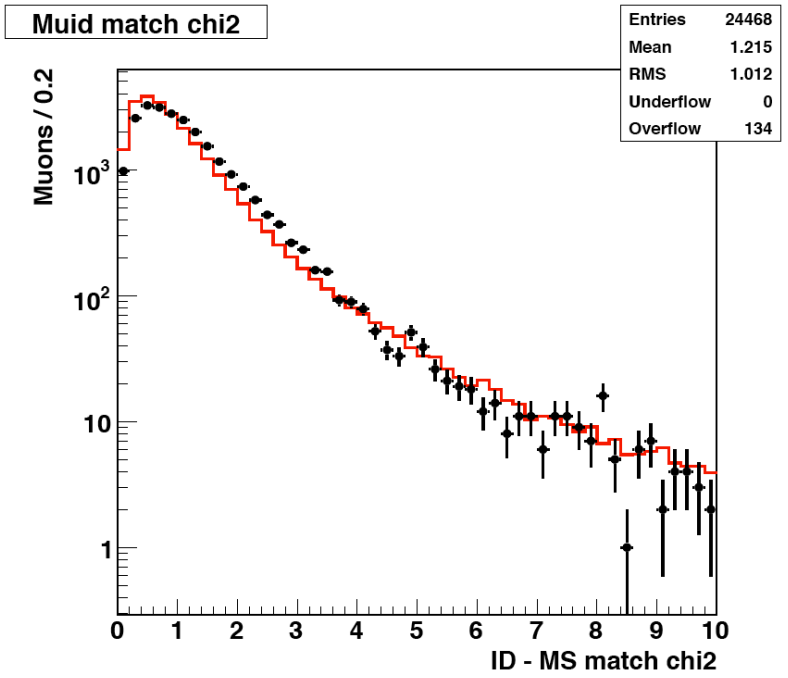


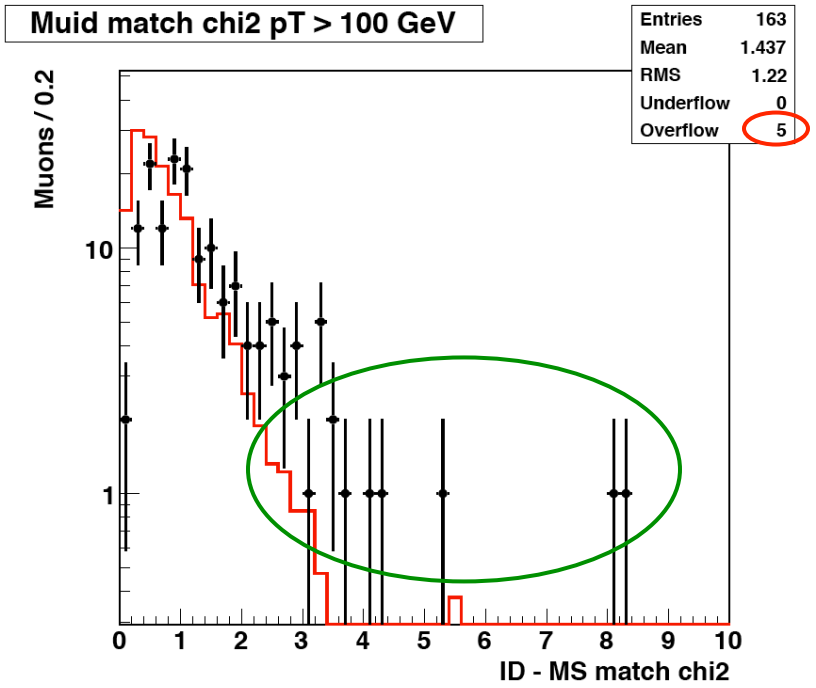


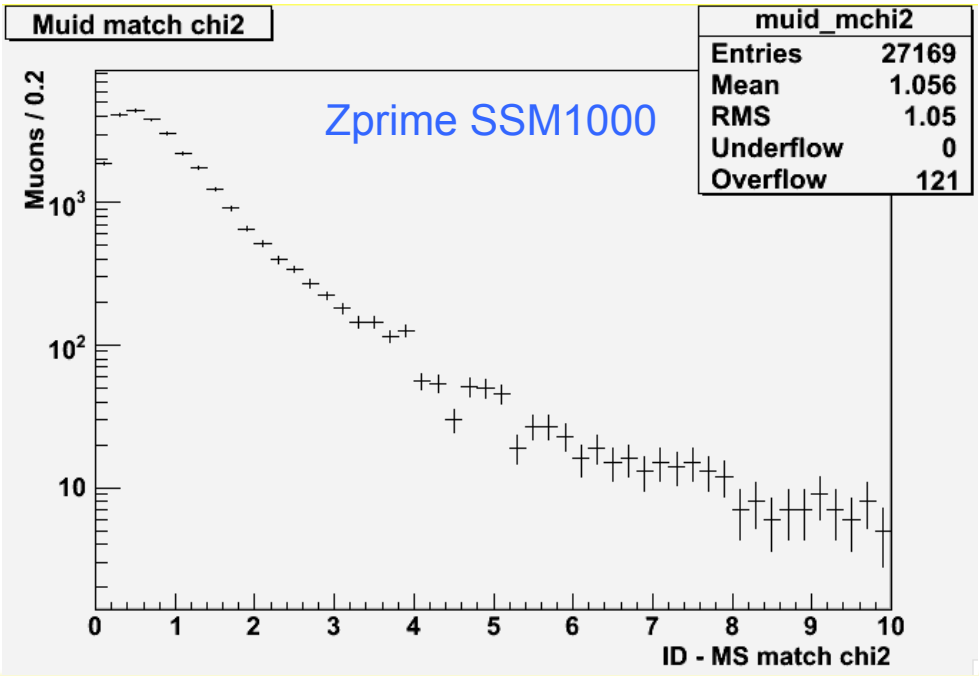


ID-MS match chi2 / dof (dof = 5)

- Data deviates clearly at high mchi2 for pT > 100 GeV





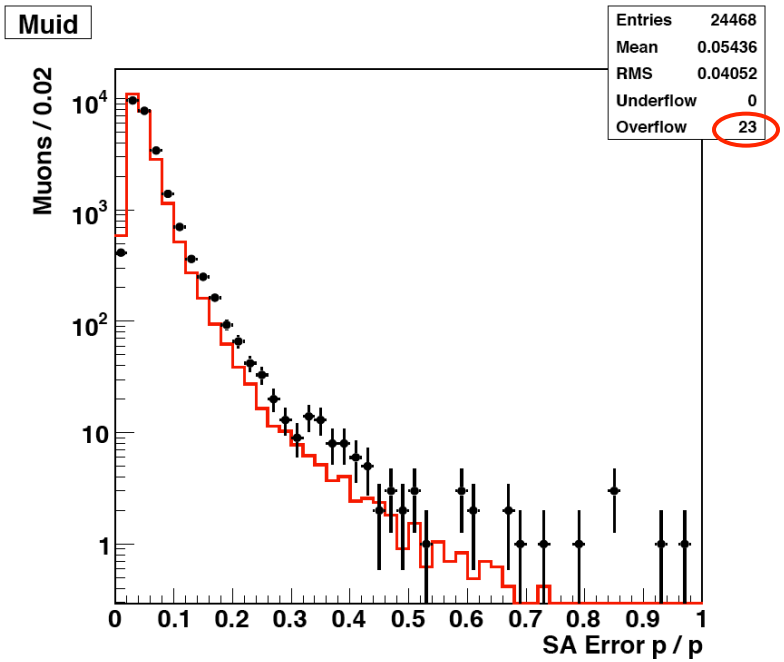


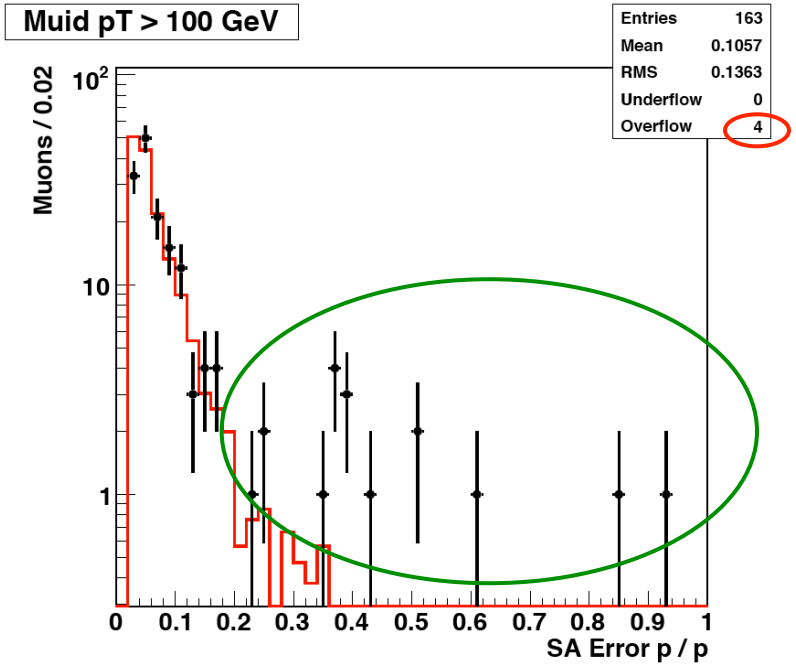
mchi2 < 5 removes
480 single-muons (1.8%)

in Z' MC

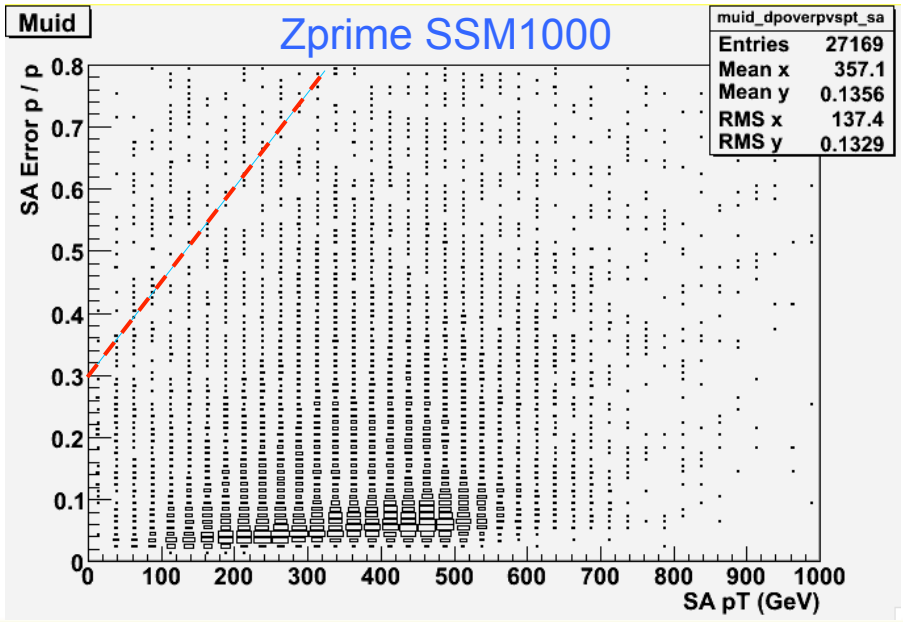
MS extrapolated relative error Dp/p

- Data deviates clearly at high Dp/p for pT > 100 GeV





- pT-dependent cut could be applied to minimize bias at high pT

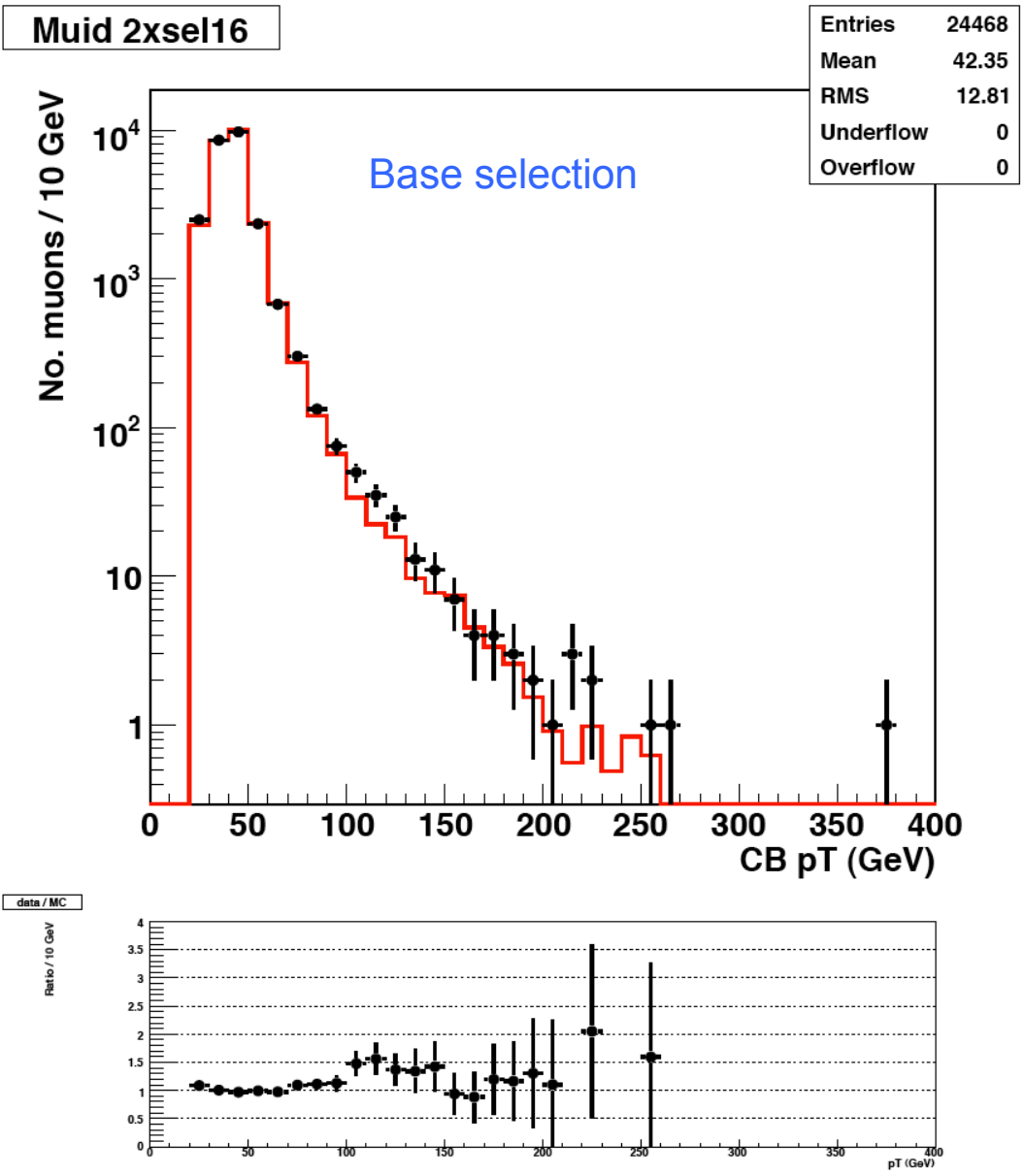


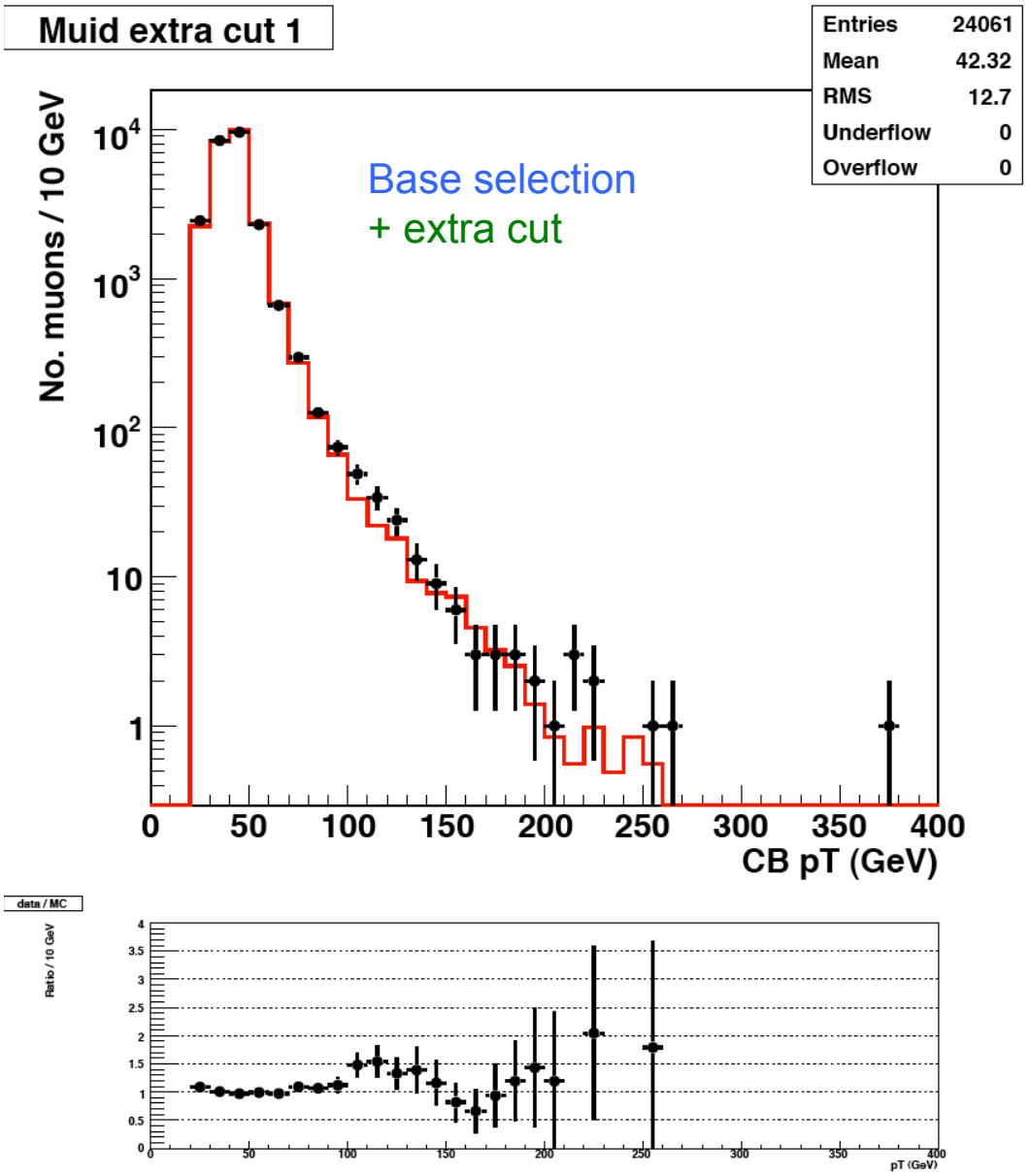
Dp / p < (0.3 + 0.0015 x pT)

Using MS extrap. parameters
(pT in GeV)

Momentum Spectrum with extra cuts

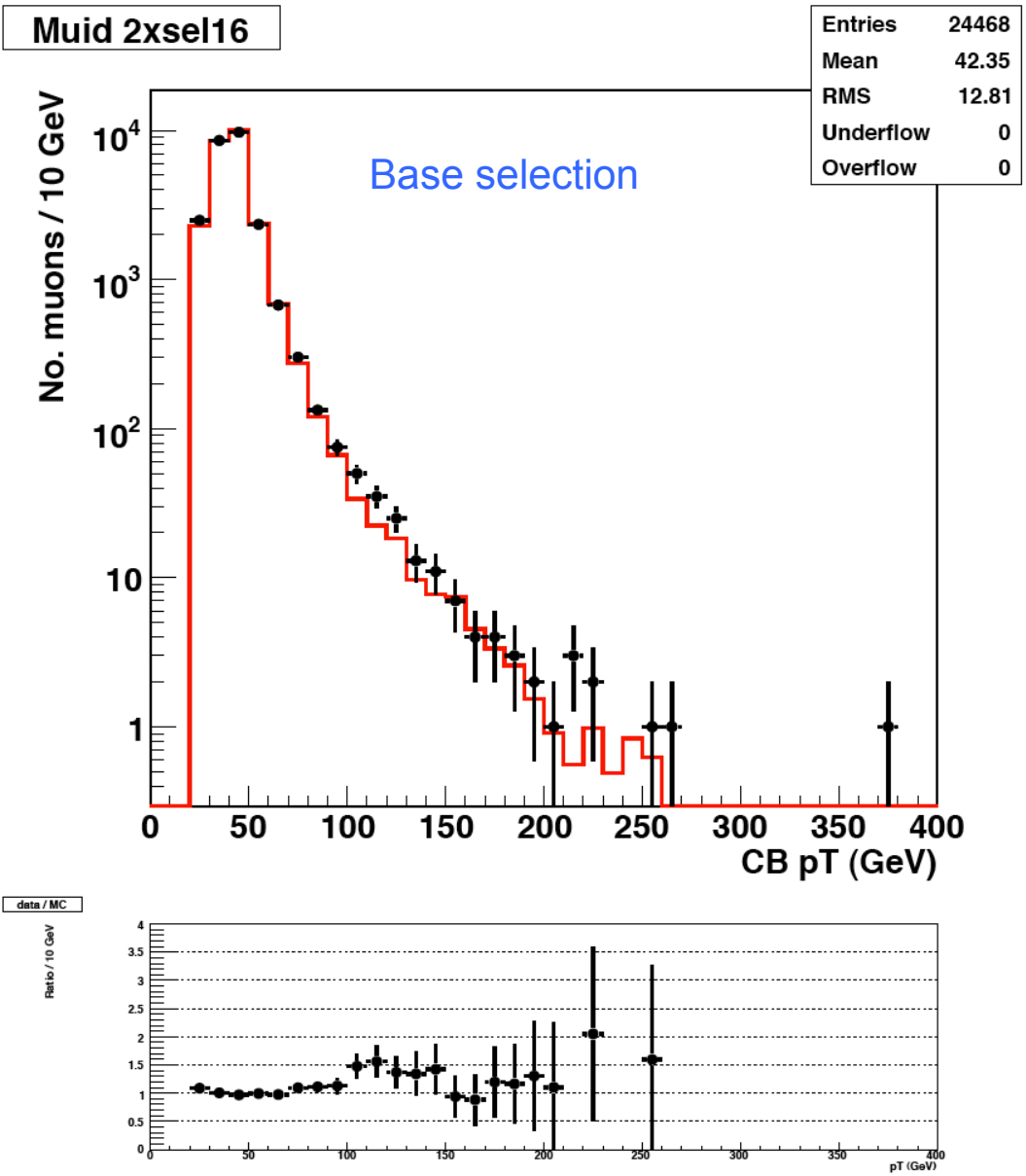
- **Sel16 + match chi2 < 5**
- ***Slightly reduced data excess (around pT of 150 GeV) little drop in efficiency***

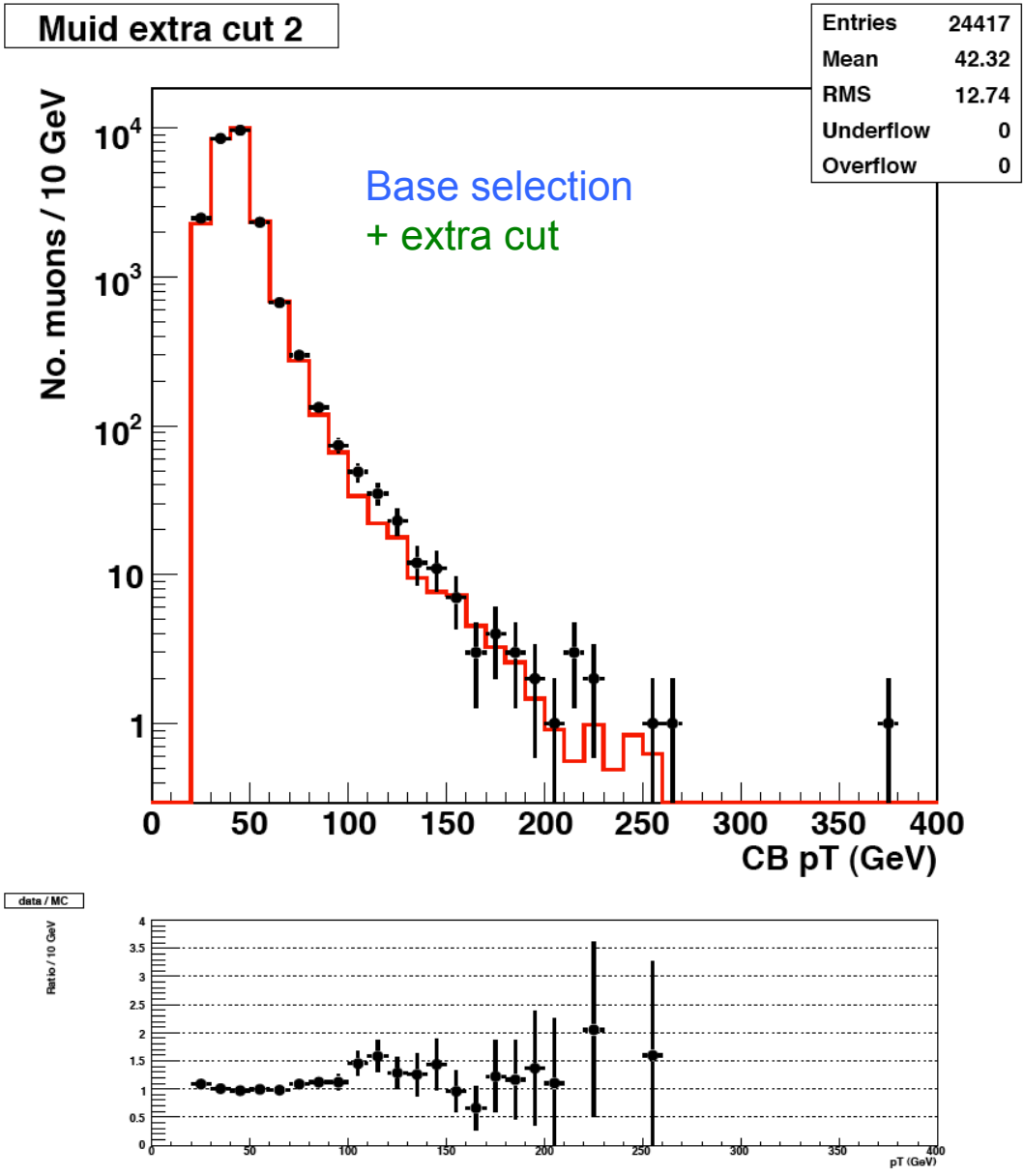




Momentum Spectrum with extra cuts

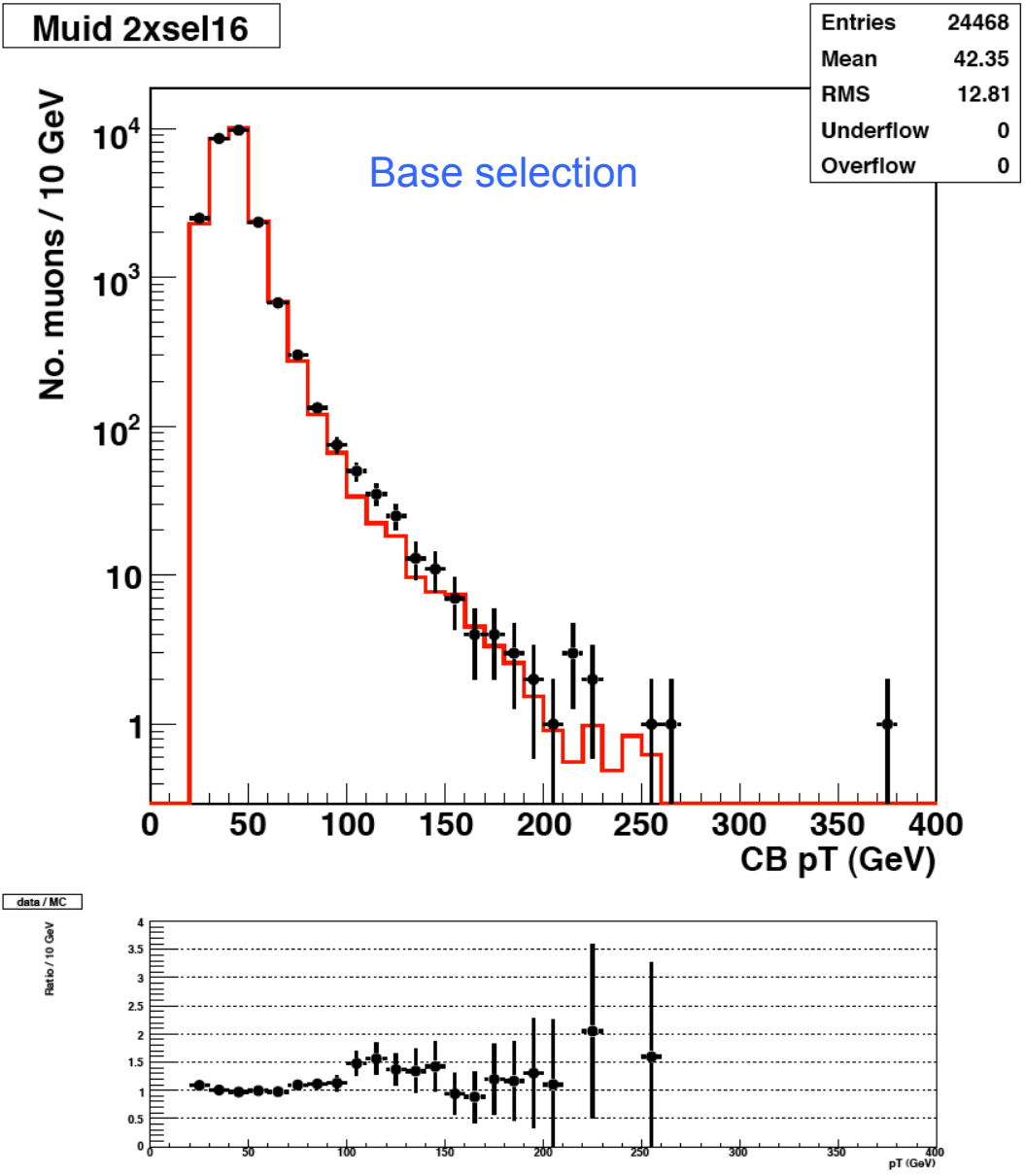
- **Sel16 + MS extrap track exists && MS extrap Dp/p cut**
- ***Slightly reduced tail with little drop in efficiency***

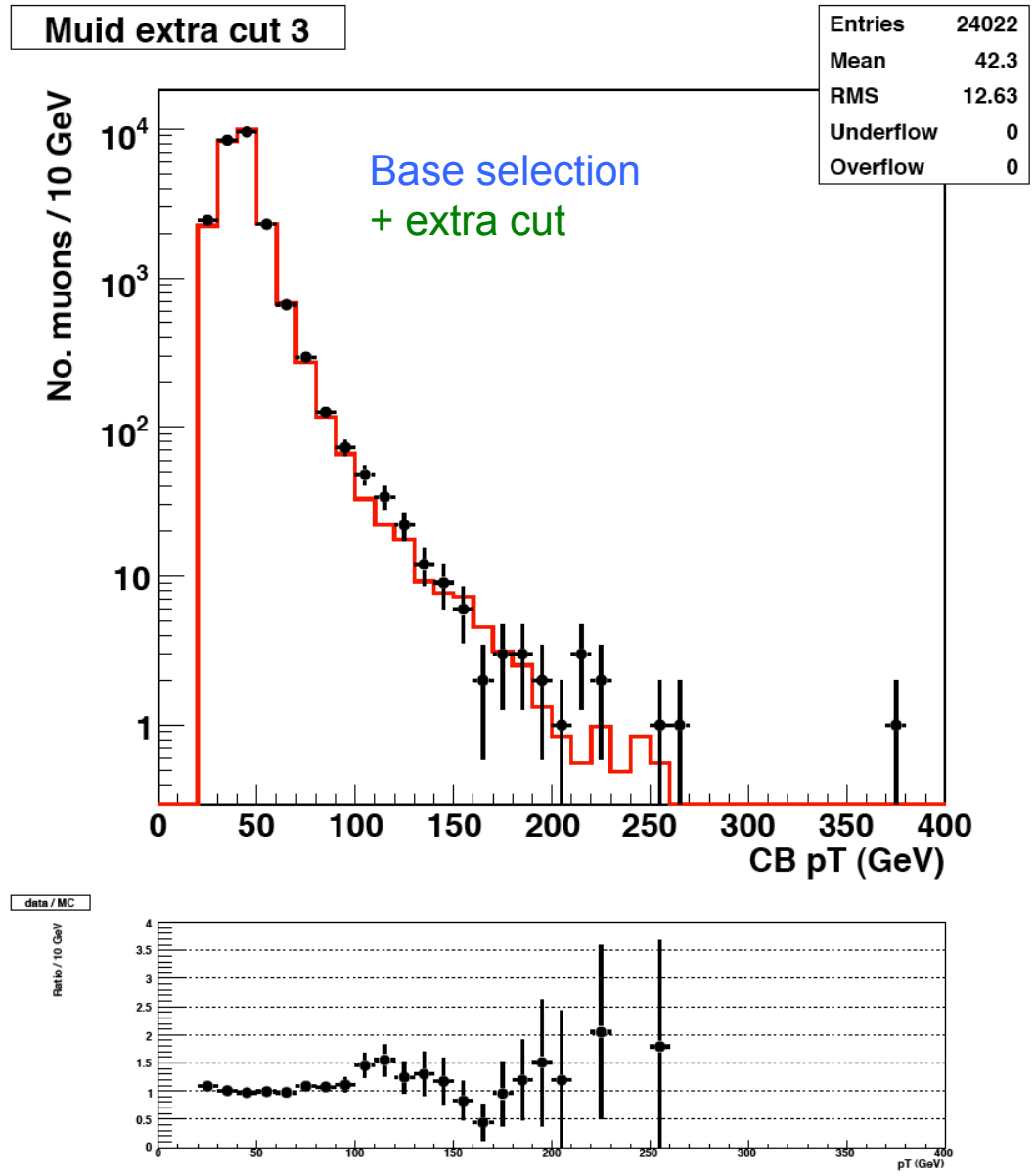




Momentum Spectrum with extra cuts

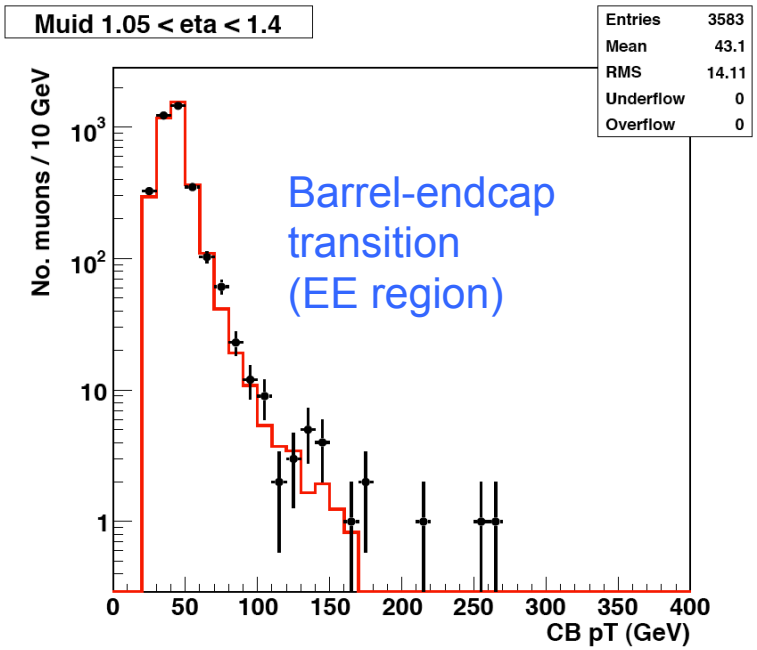
- **Sel16 + MS extrap track exists && MS extrap Dp/p cut && match chi2 < 5**
- ***Slightly reduced data excess for pT = 120-170 GeV little drop in efficiency***

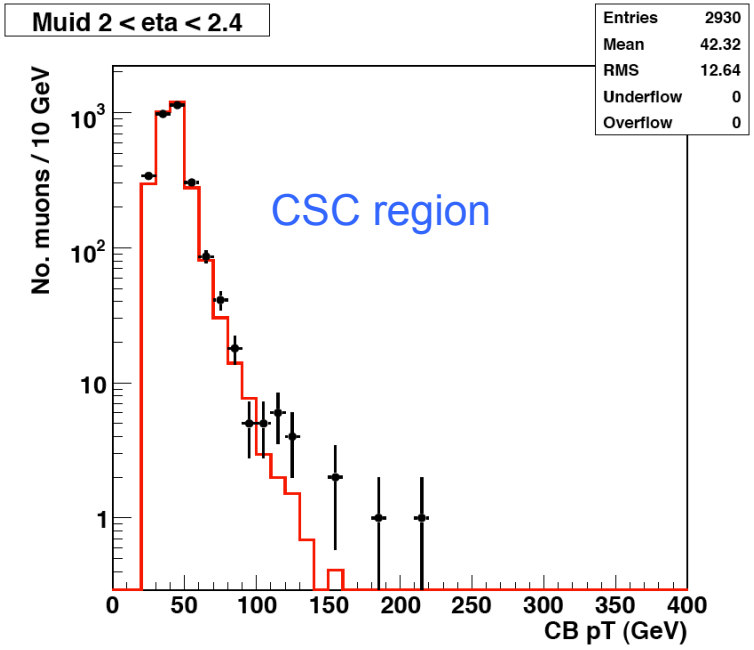


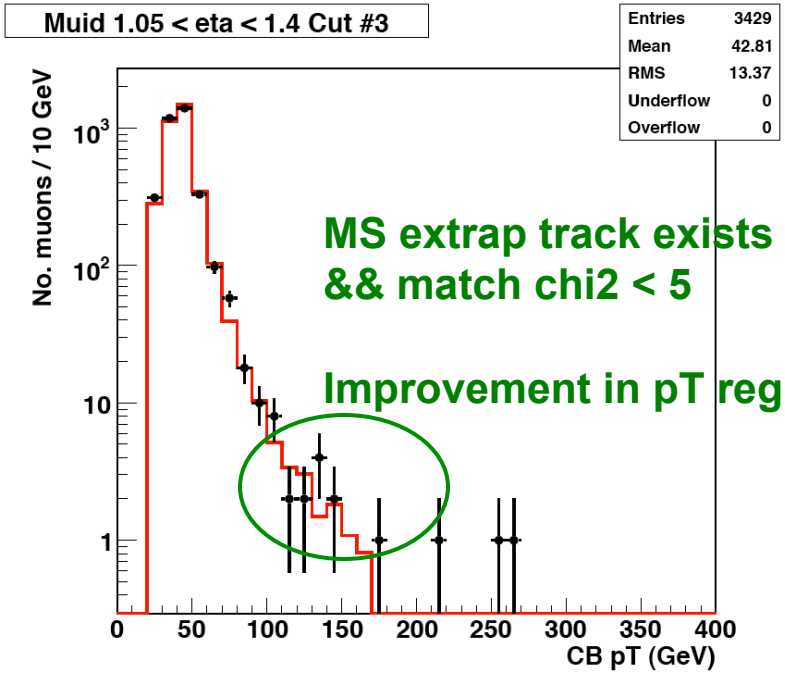


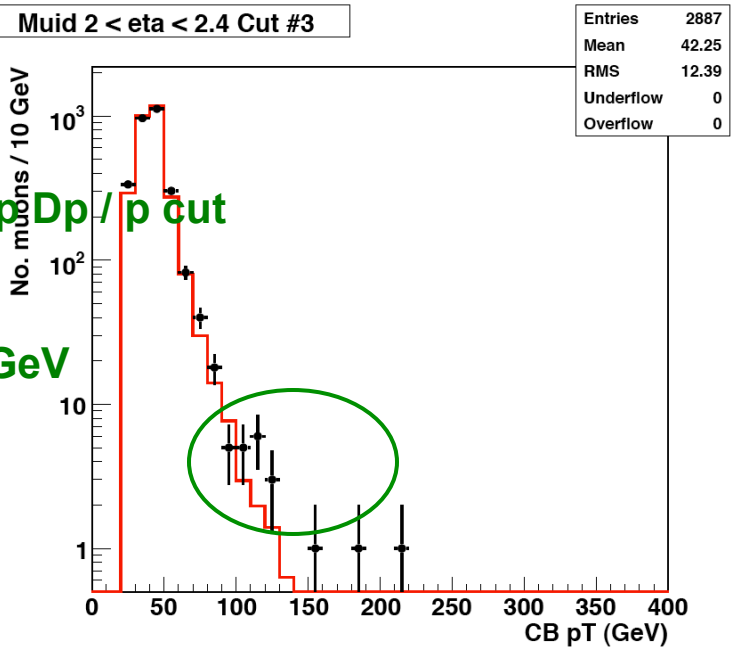
Momentum Spectrum vs. eta ranges

- **Modest improvement at high pT with additional cuts**









MS extrap track exists && MS extrap Dp / p cut && match chi2 < 5

Improvement in pT region 120-170 GeV

Track info for muons with Muid CB pT > 250 GeV

```
Run 167844 Event 49505132 Muid track

  CB: q 1  pT 372.673  eta 0.808   phi 0.229   d0 -0.013  z0 0.000  mainSector 1  nSectors 2
      dp/p 0.056    dtheta 0.0001 dphi 0.0000 dd0  0.005 dz0 0.026  chi2 0.772  mchi2 1.246
  ID: q 1  pT 366.436  eta 0.808   phi 0.229   d0 -0.013  z0 0.000
      dp/p 0.160    dtheta 0.0003 dphi 0.0001 dd0  0.009 dz0 0.050  chi2 0.815
  SA: q 1  pT 372.915  eta 0.809   phi 0.228   d0  1.362  z0 37.710
      dp/p 0.062    dtheta 0.0004 dphi 0.0005 dd0  1.919 dz0 1.909  chi2 0.476

  No. hits  MDT 44  CSCeta  0  CSCphi  0        precLayers  3  phiLayers  3  precOutliers  1
  No. holes MDT  0  CSCeta  0  etatriglayers  0  preclayers  0  philayers  0
  No. MDT hits     inner 21  ee  0  middle 11  outer 12
  No. MDT outliers inner  0  ee  0  middle  1  outer  0
  No. MDT holes    inner  0  ee  0  middle  0  outer  0
  No. MDT close h. inner  1  ee  0  middle 31  outer 18
```

Shower in middle & outer stations

```
Run 167776 Event 80637220 Muid track

  CB: q 1  pT 254.351  eta 1.383  phi -0.698  d0 0.008  z0 0.047  mainSector 15  nSectors 1
  dp/p 0.070  dtheta 0.0001  dphi 0.0001  dd0 0.007  dz0 0.042  chi2 0.784  mchi2 1.899
  ID: q 1  pT 242.215  eta 1.382  phi -0.698  d0 0.008  z0 0.047
  dp/p 0.101  dtheta 0.0002  dphi 0.0001  dd0 0.015  dz0 0.087  chi2 0.695
  SA: q 1  pT 224.157  eta 1.382  phi -0.700  d0 6.942  z0 109.178
  dp/p 0.092  dtheta 0.0004  dphi 0.0015  dd0 8.571  dz0 4.732  chi2 0.310

  No. hits  MDT 22  CSCeta  0  CSCphi  0        precLayers  3  phiLayers  4  precOutliers  0
  No. holes MDT  0  CSCeta  0  etatriglayers  0  preclayers  0  philayers  0
  No. MDT hits     inner  8  ee  0  middle  8  outer  6
  No. MDT outliers inner  0  ee  0  middle  0  outer  0
  No. MDT holes    inner  0  ee  0  middle  0  outer  0
  No. MDT close h. inner  0  ee  0  middle  0  outer  0
```

Nothing outstanding
Apparently well measured

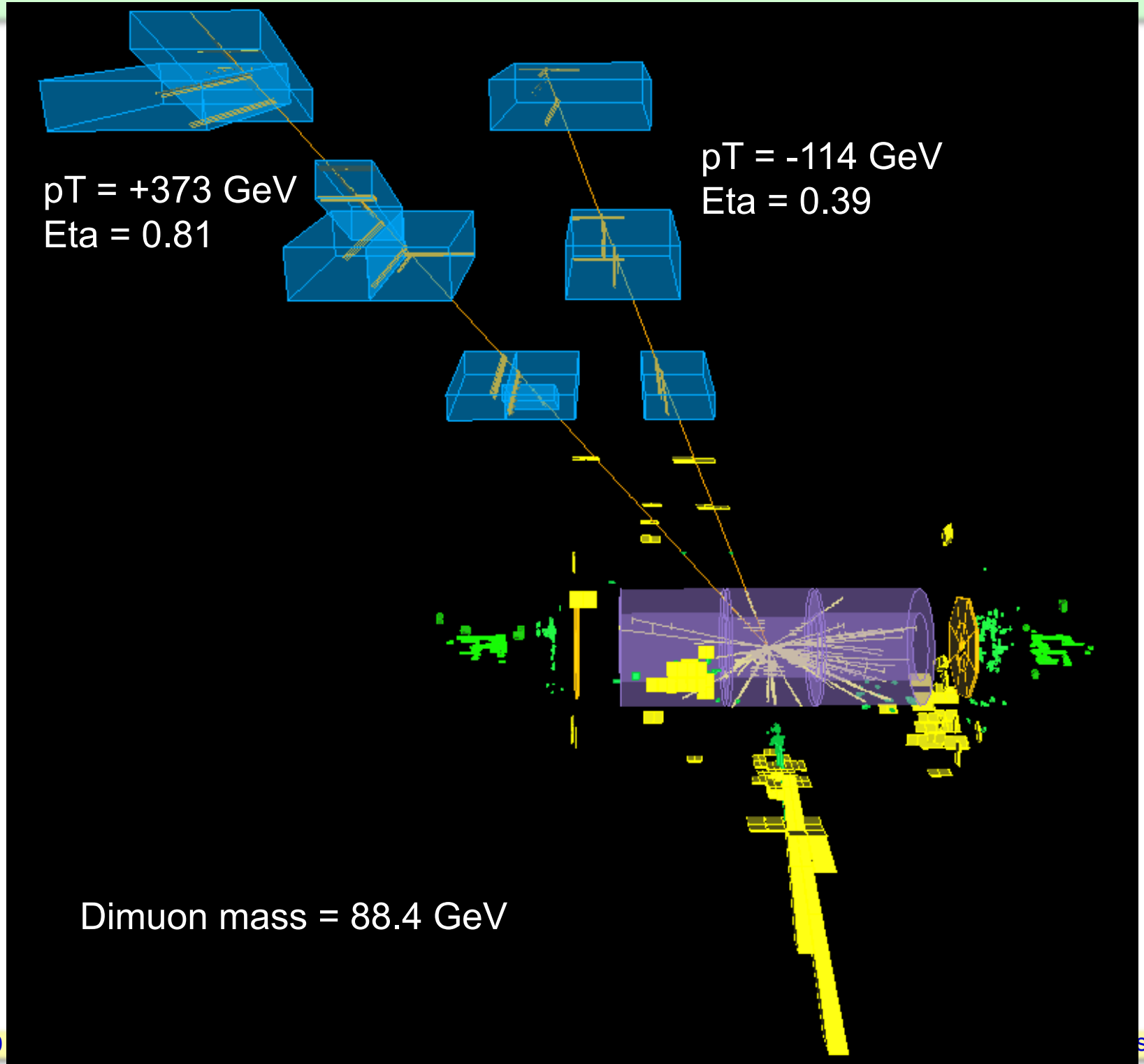
Track info for muons with Muid CB pT > 250 GeV

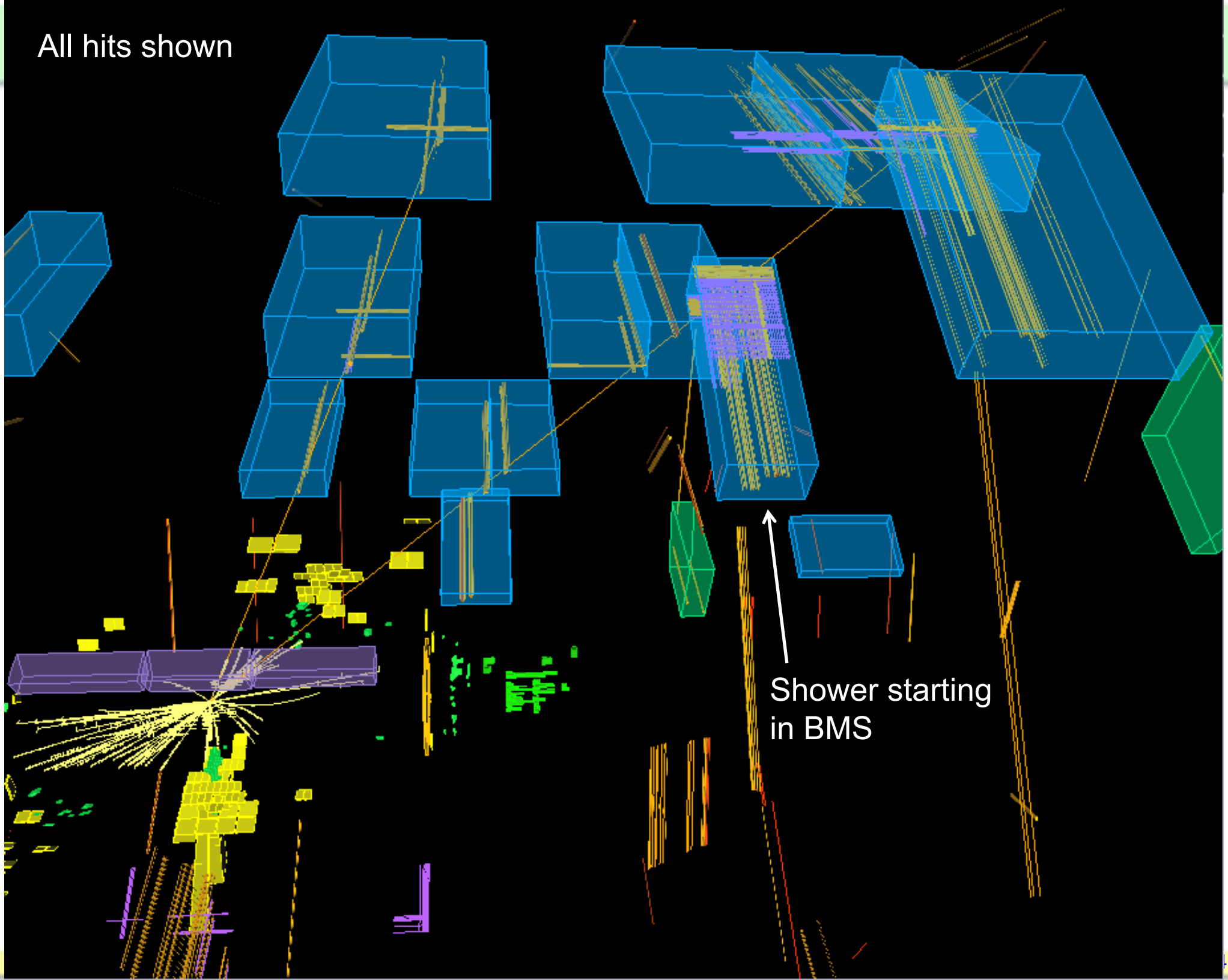
```
Run 166097 Event 14582720 Muid track

  CB: q -1  pT 261.131  eta 1.187   phi 0.724    d0 0.007  z0  0.032  mainSector 3  nSectors 1
      dp/p 0.083    dtheta 0.0001 dphi 0.0001   dd0 0.007 dz0  0.036  chi2 0.741  mchi2 1.615
  ID: q -1  pT 240.811  eta 1.187   phi 0.723    d0 0.007  z0  0.032
      dp/p 0.081    dtheta 0.0002 dphi 0.0001   dd0 0.009 dz0  0.061  chi2 0.748
  SA: q -1  pT 183.644  eta 1.191   phi 0.725  d0 -16.310  z0 -13.618
      dp/p 0.367    dtheta 0.0010 dphi 0.0047  dd0 42.980 dz0  13.266 chi2 0.134

  No. hits  MDT 17  CSCeta  0  CSCphi  0        precLayers  2  phiLayers  4  precOutliers  0
  No. holes MDT  8  CSCeta  0  etatriglayers  0  preclayers  0  philayers  0
  No. MDT hits     inner 11  ee  0  middle  6  outer  0
  No. MDT outliers inner  0  ee  0  middle  0  outer  0
  No. MDT holes    inner  0  ee  8  middle  0  outer  0
  No. MDT close h. inner  0  ee  0  middle  0  outer  0
```

No outer station due to eta = 1.2

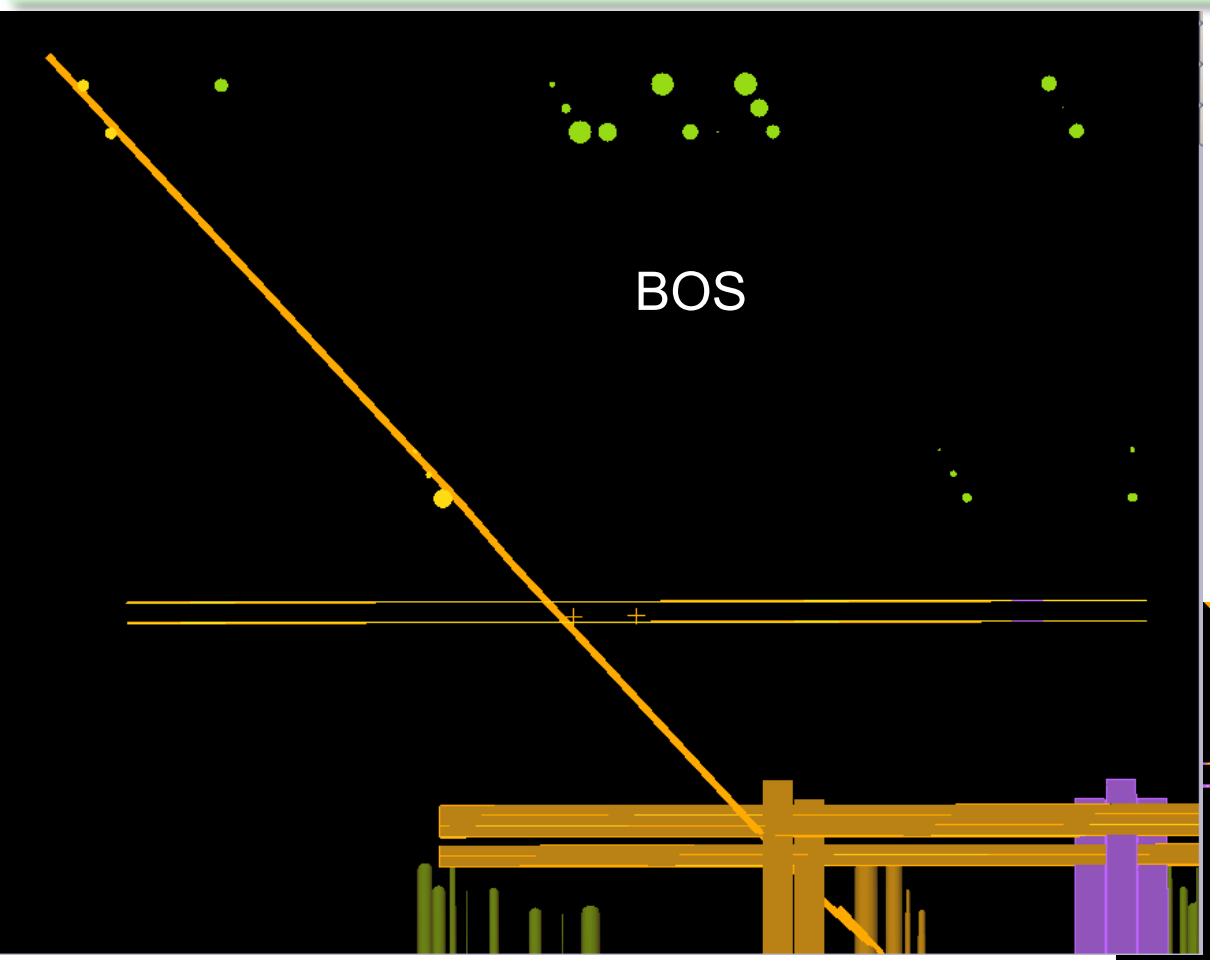
EE not installed yet

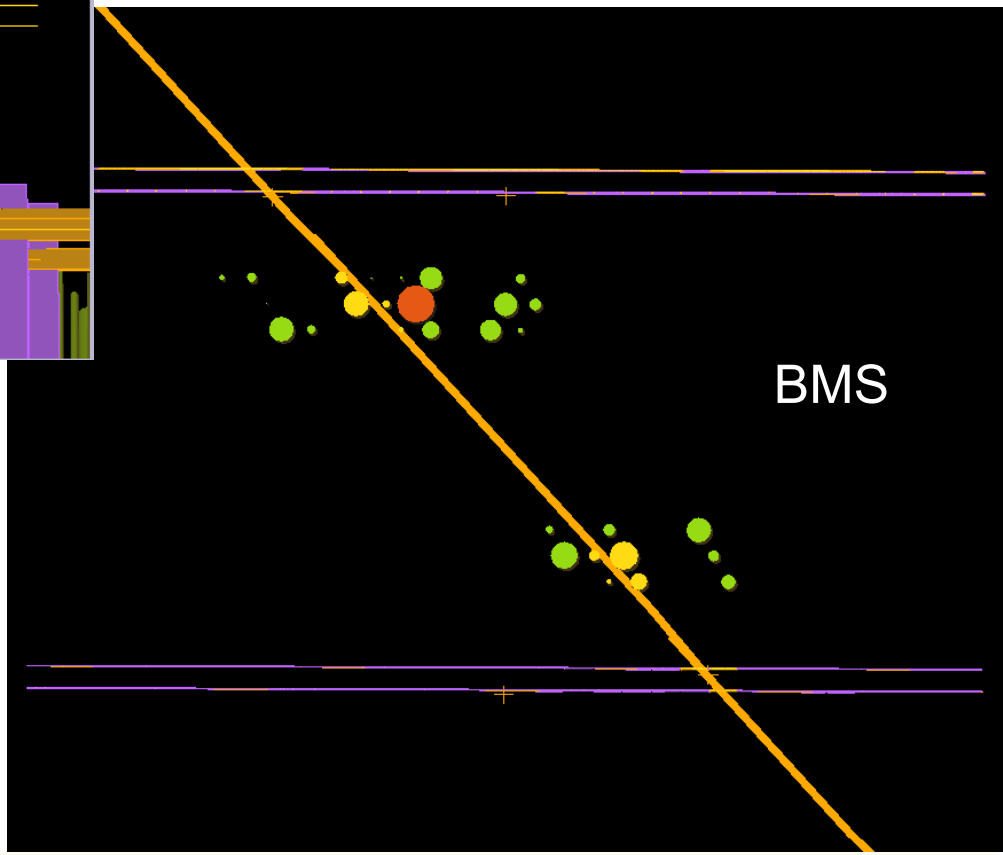
Run 167844 Event 49505132



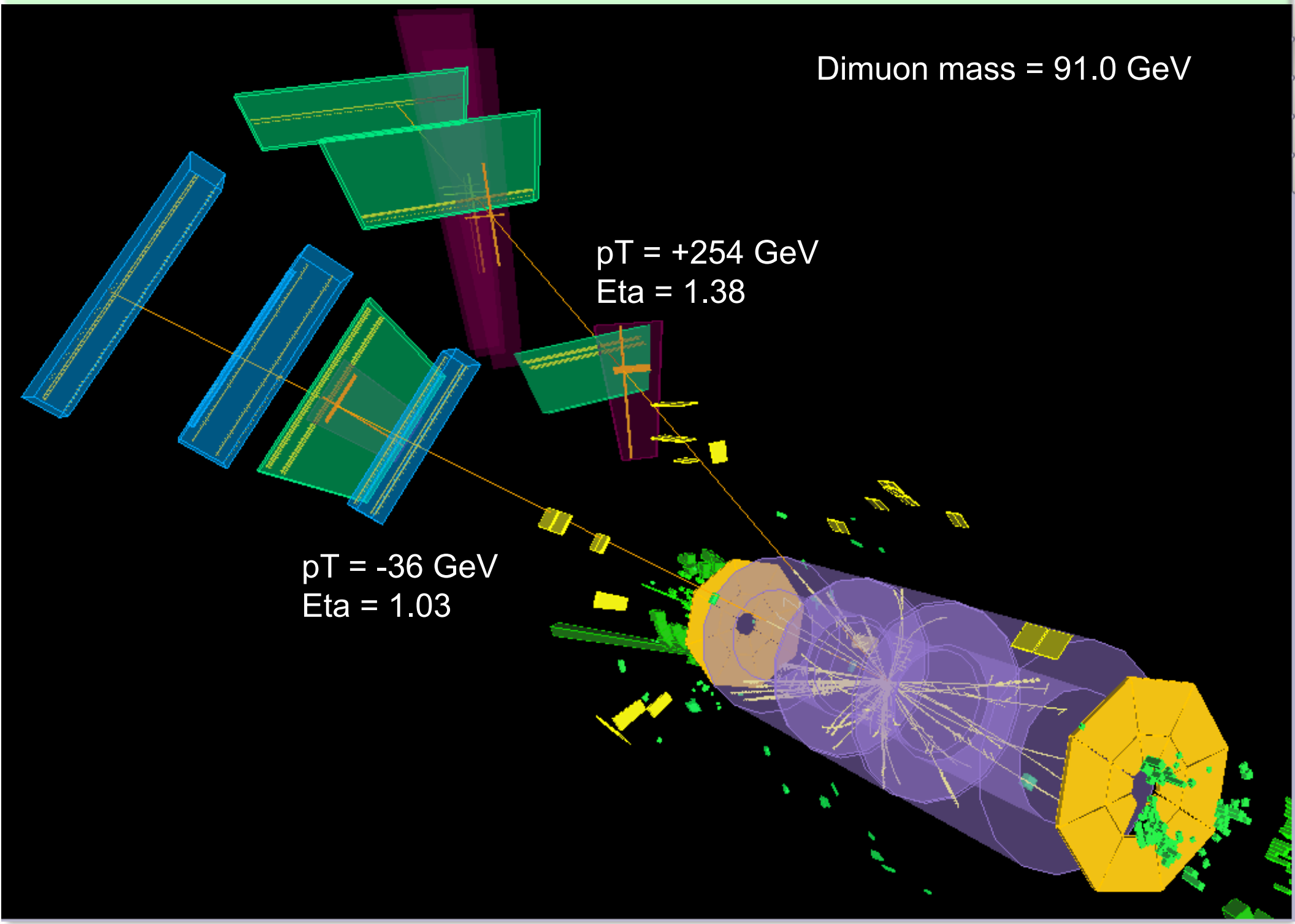

All hits shown
Shower starting
in BMS

Run 167844 Event 49505132

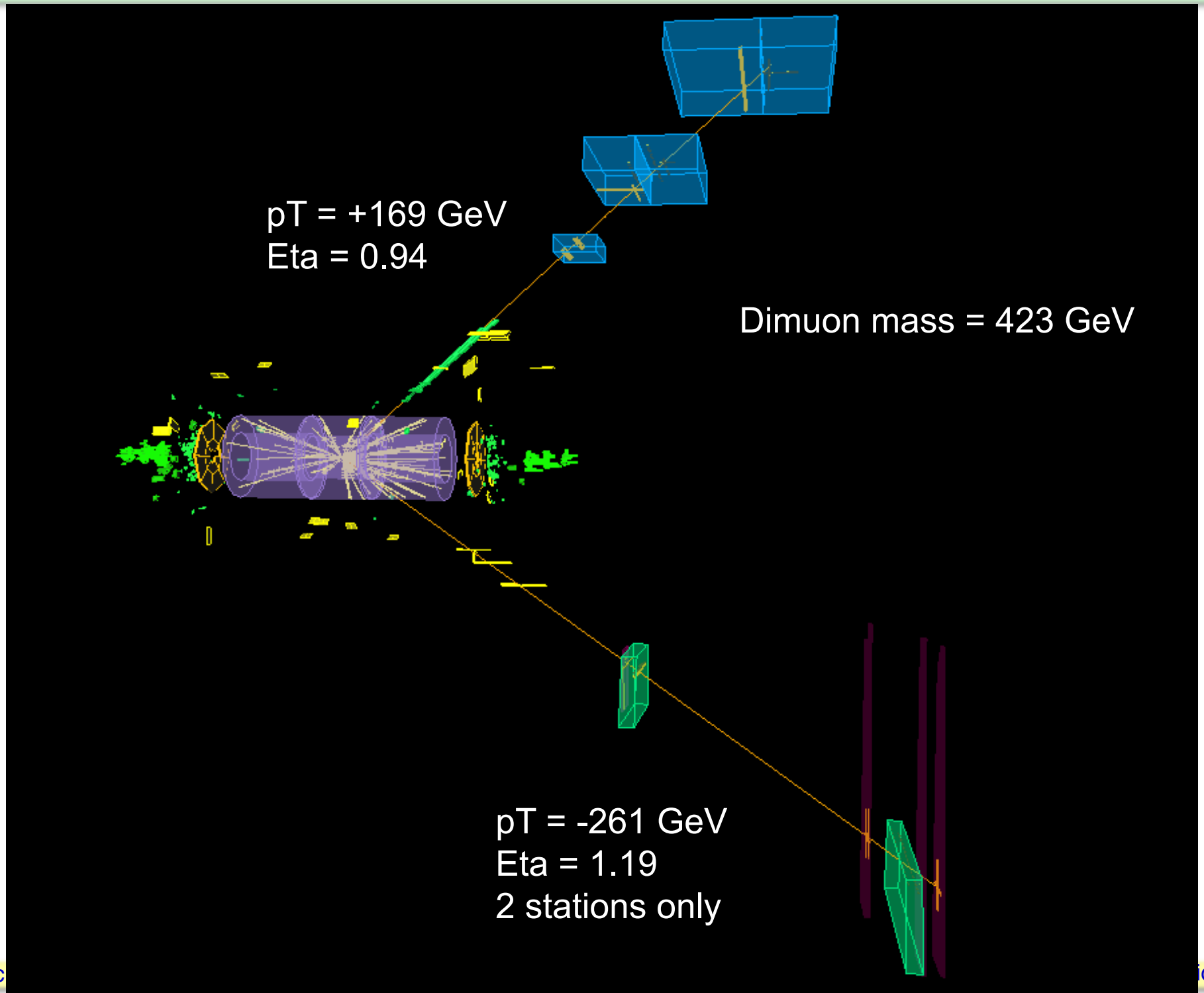




Run 167776 Event 80637220



Run 166097 Event 14582720



What next?

- **Release 16:**
  - Extended coverage can be used with *combined* muons
  - Extra data muons at high pT, as compared with MC
  - Data/MC agreement clearly better for tracks with 3 or more stations + fewer high-pT tails
    → but significant impact on efficiency for dimuon analyses (~15% reduction per muon with pT > 300 GeV in Z' SSM1000 MC)
- **If we keep 2-station tracks need to apply additional requirements on**
  - MS extrap track exists and has reasonable Dp/p (use momentum-dependent maximum value)
  - ID-MS track match chi2/dof (< 5)
  - Modest improvement in data/MC match at high pT (120-170 GeV range) with those additional requirements

    → these cuts mostly affect 2-station tracks
    → impact of additional requirements on Z' SSM1000 MC is ~5% reduction per muon at pT > 300 GeV
  - ***Is this enough?***