THE DOSE PROFILER TRACKING STUDY *ET AL.*

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Introduction

- **We want to study the DP resolution on the reconstructed tracks:**

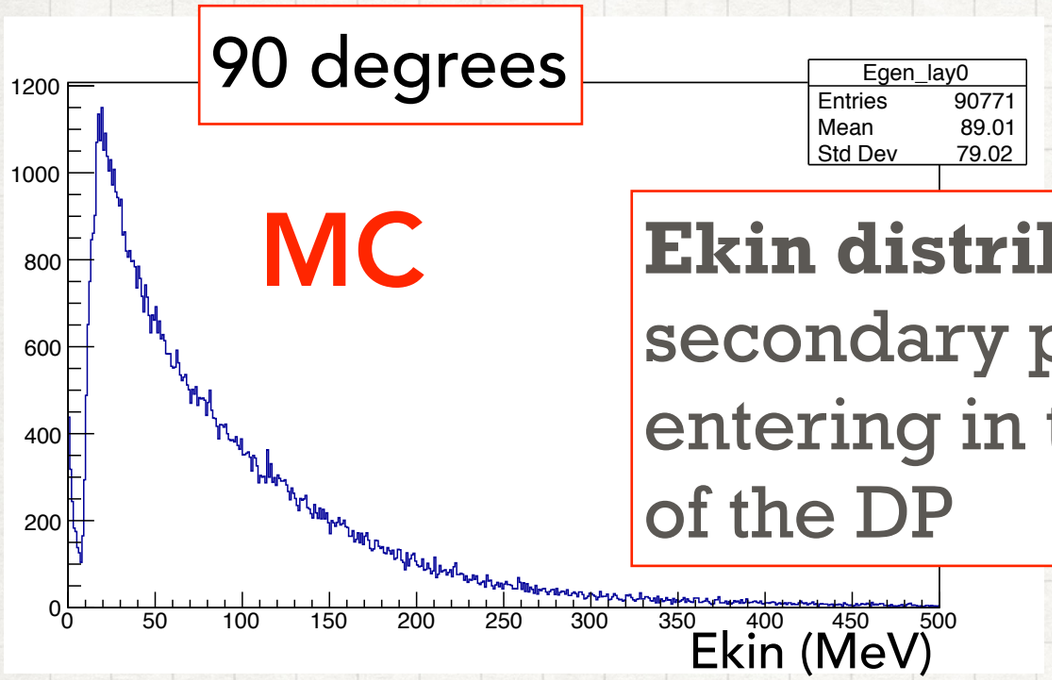
  1) CNAO Panduit run: at CNAO (July 2017) we irradiated a panduit 1.1 mm thick with a 220 MeV/u 12C ion beam
  => reconstructing the tracks in the beam axis plane, we expect to obtain a gaussian peak with ~ 1.1 mm sigma

  2) we want to compare the CNAO panduit result to the DP resolution obtained at Trento (July 2017), where a 70 MeV/u proton beam (sigma 7mm) was directed towards the DP

- **Once we have a reliable result, we can trust our reconstruction software and go through the analysis of the RANDO runs (Energy Scan, GridXY, Dose Cube)**

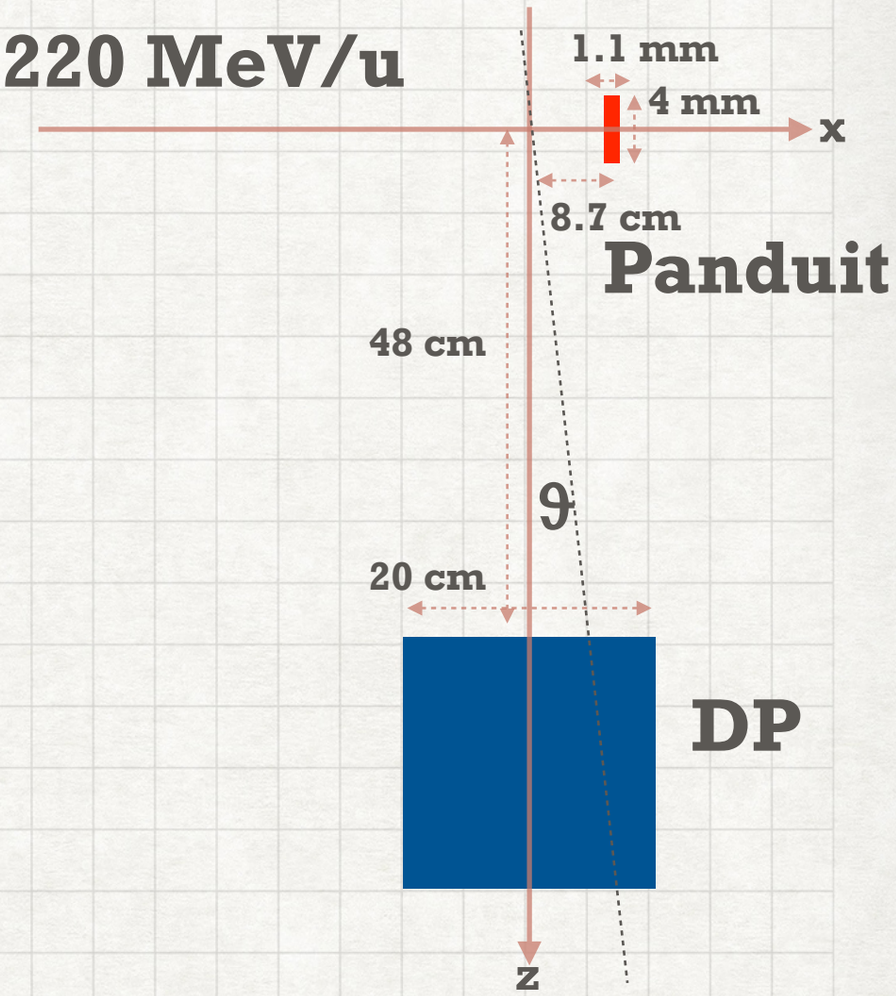
MC Study of the Panduit Run

90 degrees

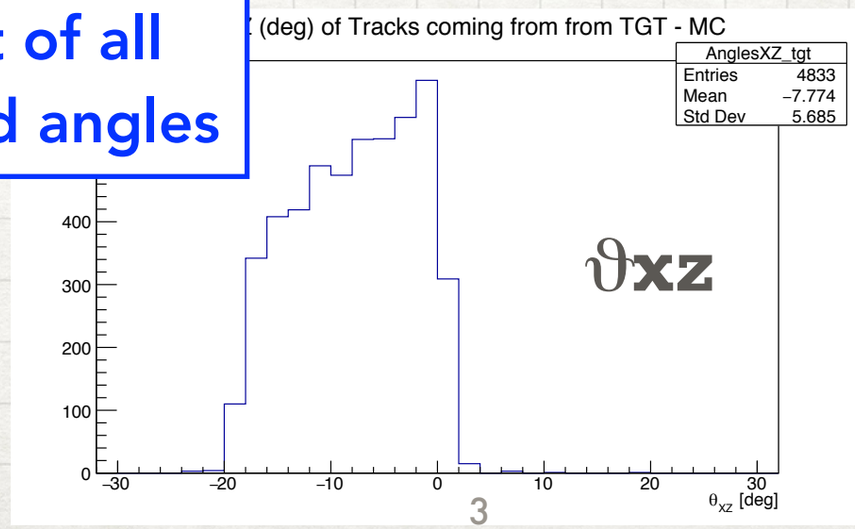


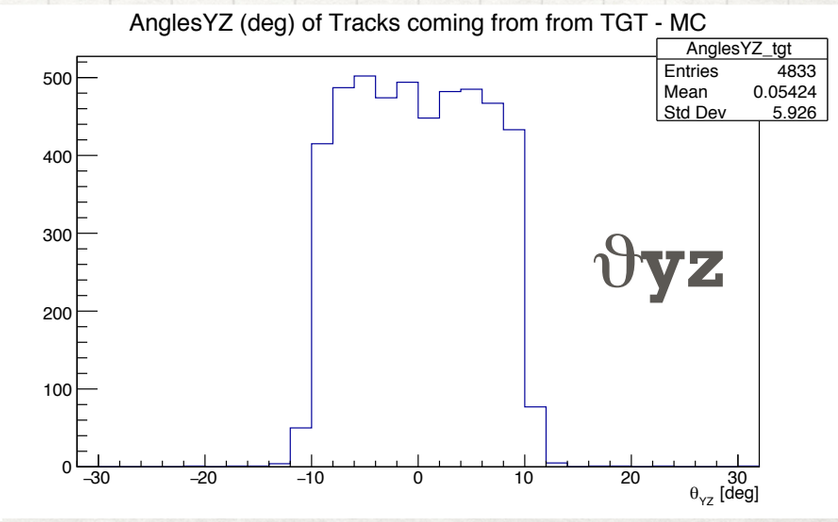
Ekin distribution of secondary protons entering in the first layer of the DP

Ekin Peak ~ 20-30 MeV



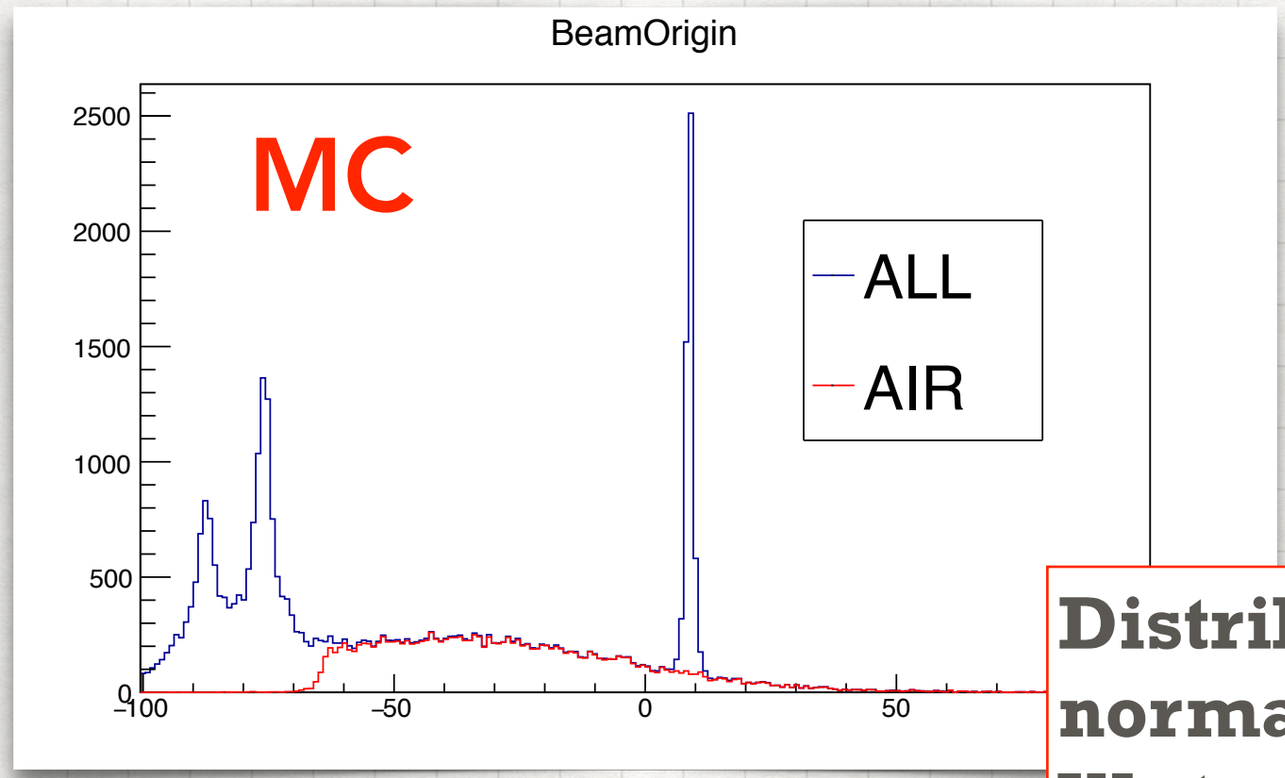
The reconstructed XZ tracks from TGT are most of all emitted at backward angles



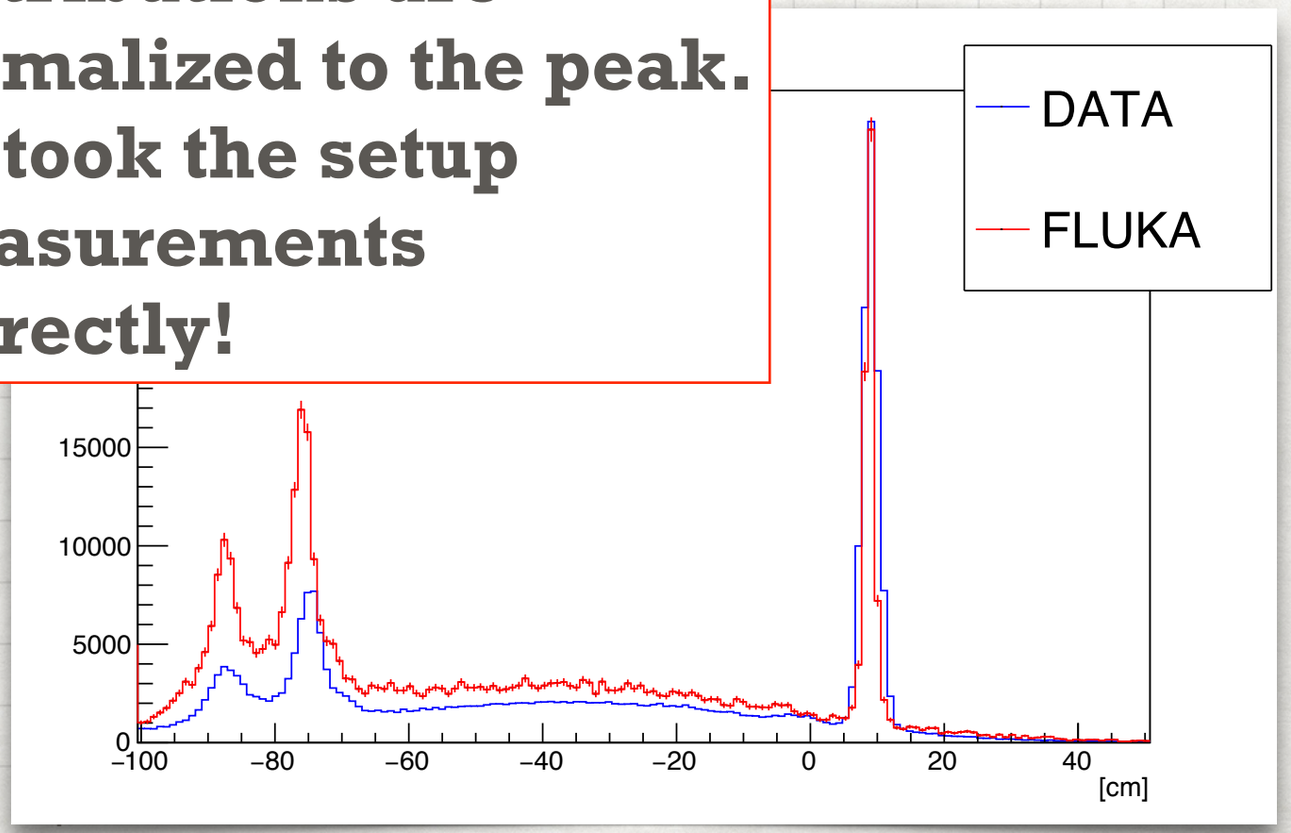


Study of the Panduit Run

Beam Spot XZ distribution



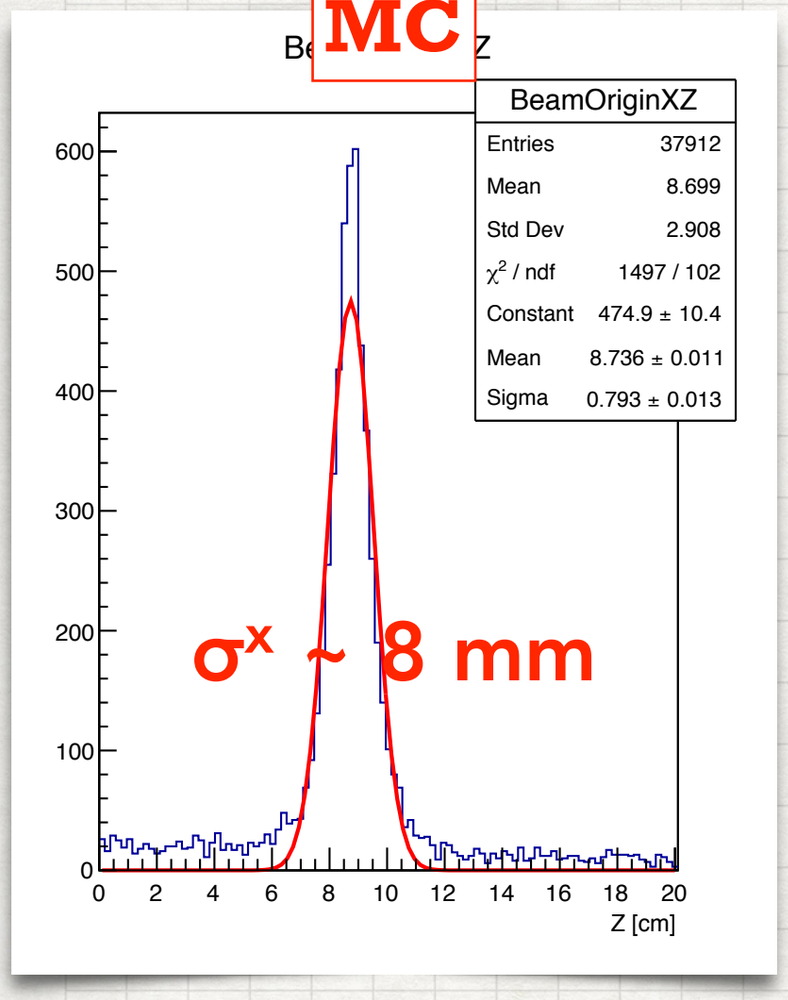
Distributions are normalized to the peak. We took the setup measurements correctly!



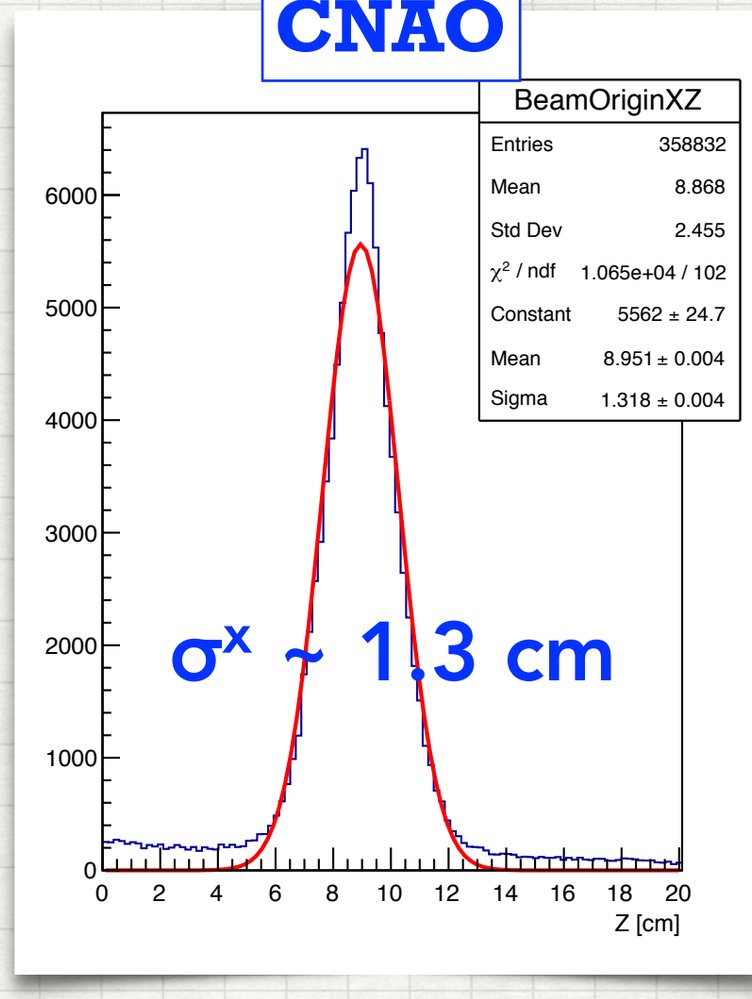
Study of the Panduit Run

Beam Spot XZ distribution

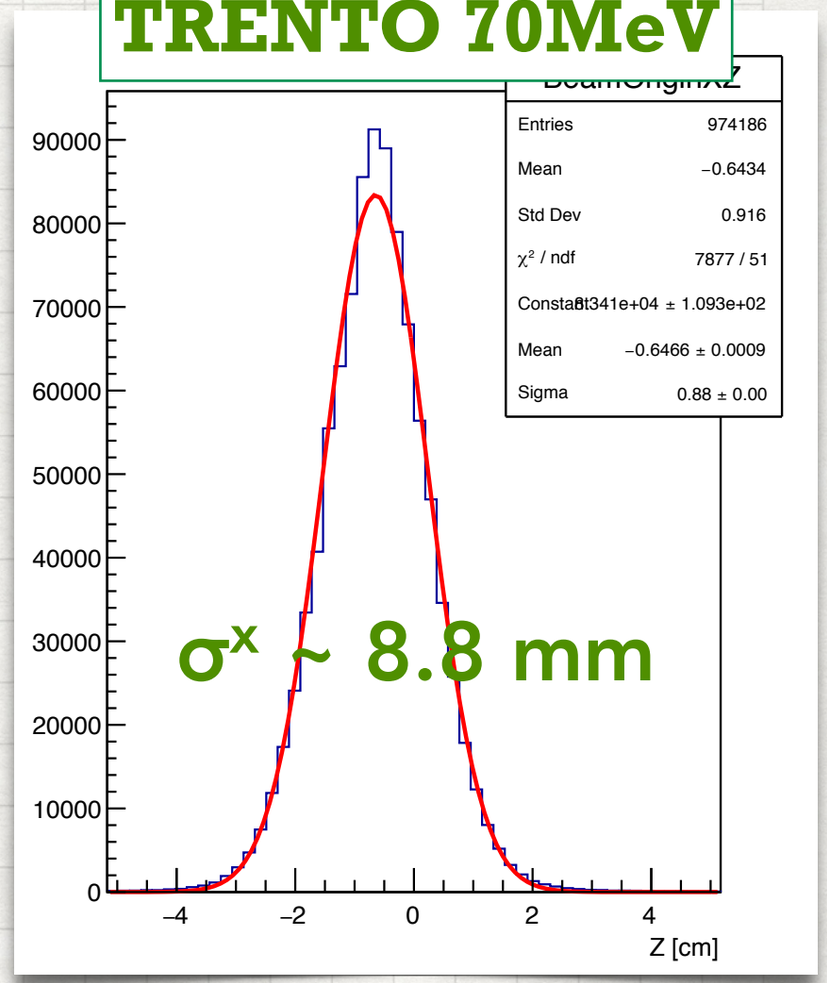
MC



CNAO



TRENTO 70MeV



YES CLUSTER SIZE IN MC

Resolution Study

FitTracks2D Legend

HE = High Energy selection:
the track has arrived to the end of the DP

ang = Theta ≤ 1° selection (cutting also some stuff from the TGT):
straight tracks

	σ^X	σ^X_{HE}	σ^X_{ang}
MC	8mm	4.5mm	5.4mm
CNAO	1.3cm	1.1cm	7.6mm
TRENTO70	8.8mm	8.8mm	8.4mm
TRENTO70 no Beam	5.3mm	5.3mm	4.6mm
MC TRENTO70 no Beam	5.45mm	5.45mm	4.5mm

Trento 70@iso $\sigma^{X,Y}$ = 7 mm

MC Trento 70@iso σ^X = 7.9 mm

Multiple Scattering

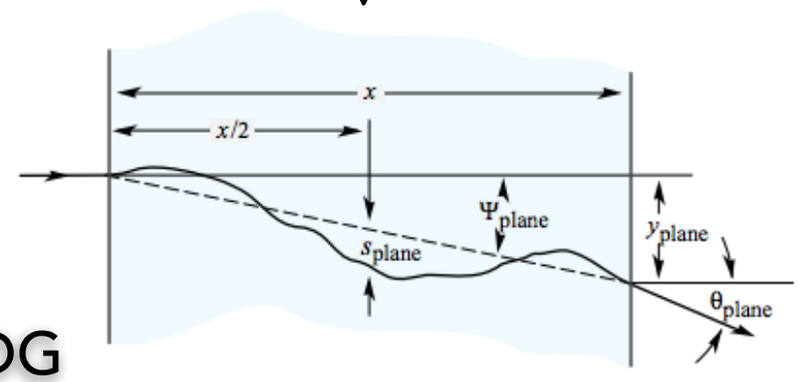
Multiple Scattering evaluation (MC truth)

Mtgt = pz/px @ TGT exit face

Mdp0 = pz/px @ LAY0

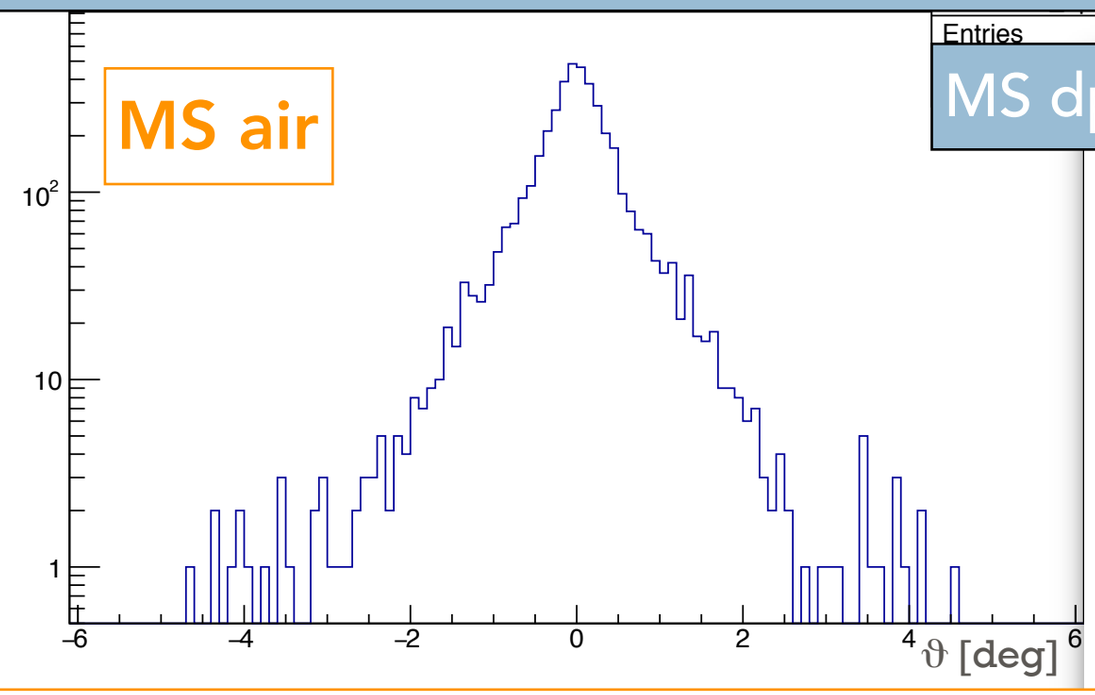
Mdp5 = pz/px @ LAY5

$$y^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}}\, x\, \theta^{\text{rms}}_{\text{plane}}$$



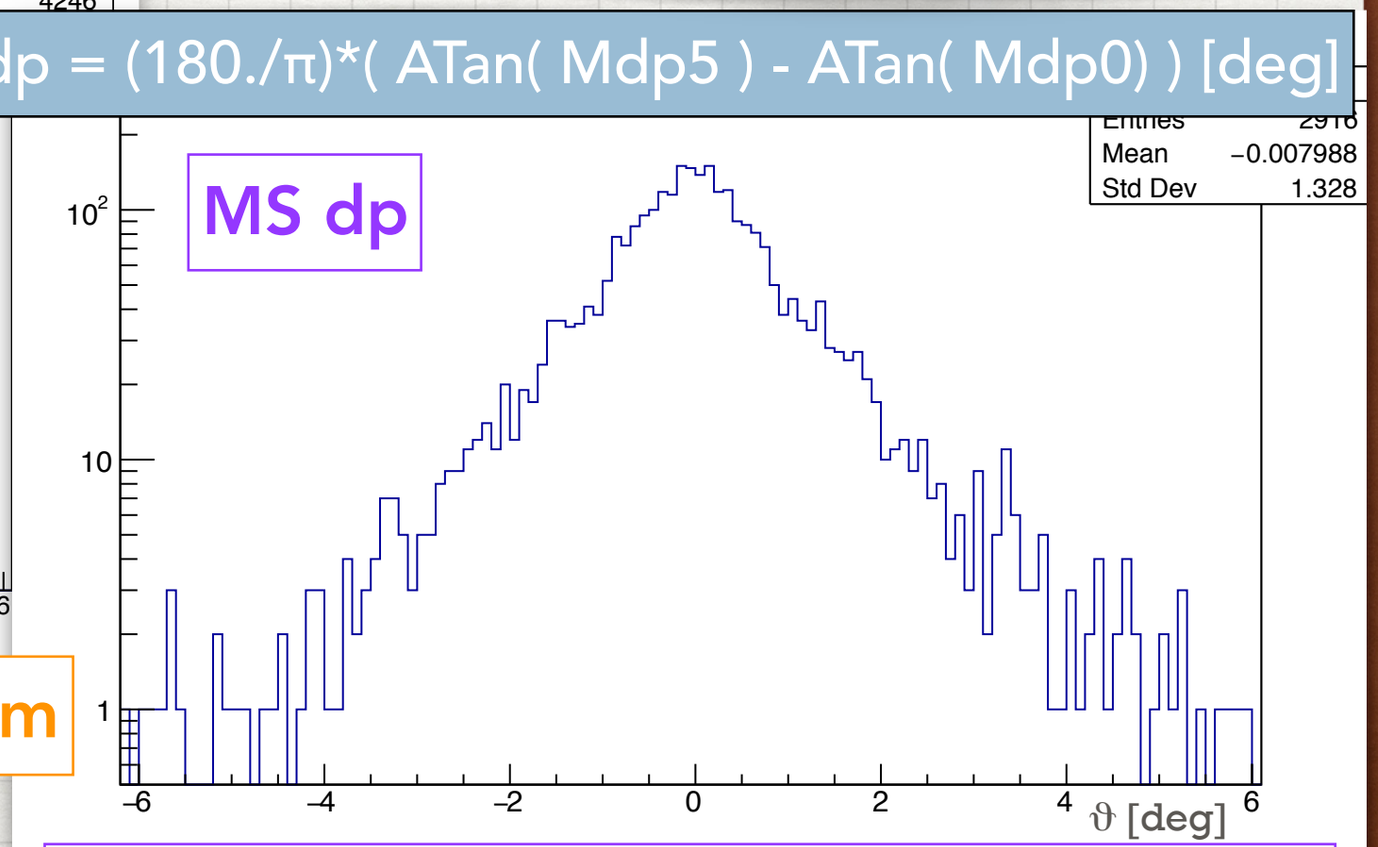
PDG

MS air = (180./π)*(ATan(Mdp0) - ATan(Mtgt)) [deg]



STD DEV = 0.7° ->@48cm ~ 3.4mm

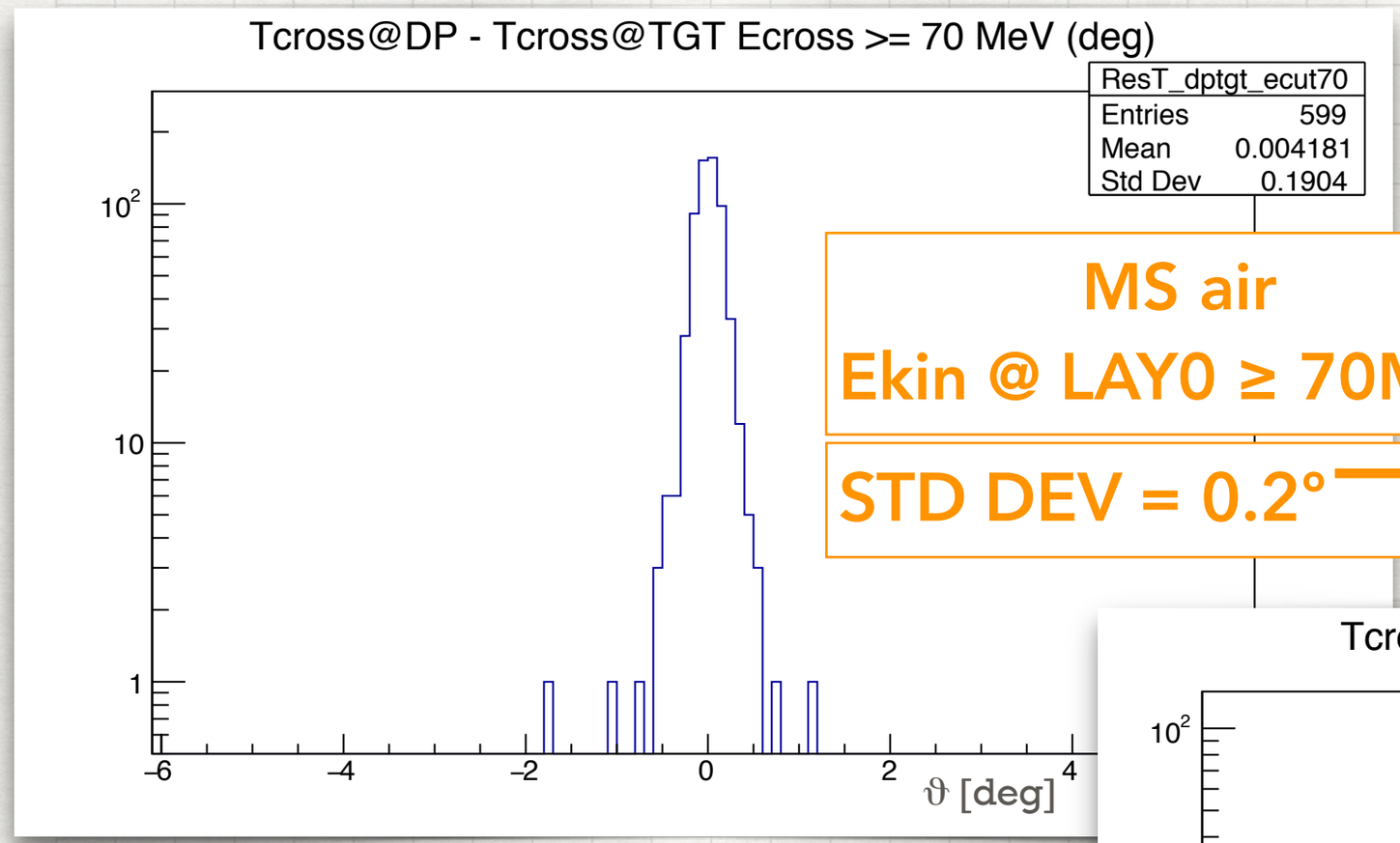
MS dp = (180./π)*(ATan(Mdp5) - ATan(Mdp0)) [deg]



STD DEV = 1.3° -> @10.66cm ~ 1.4mm

Multiple Scattering with Ekin cut

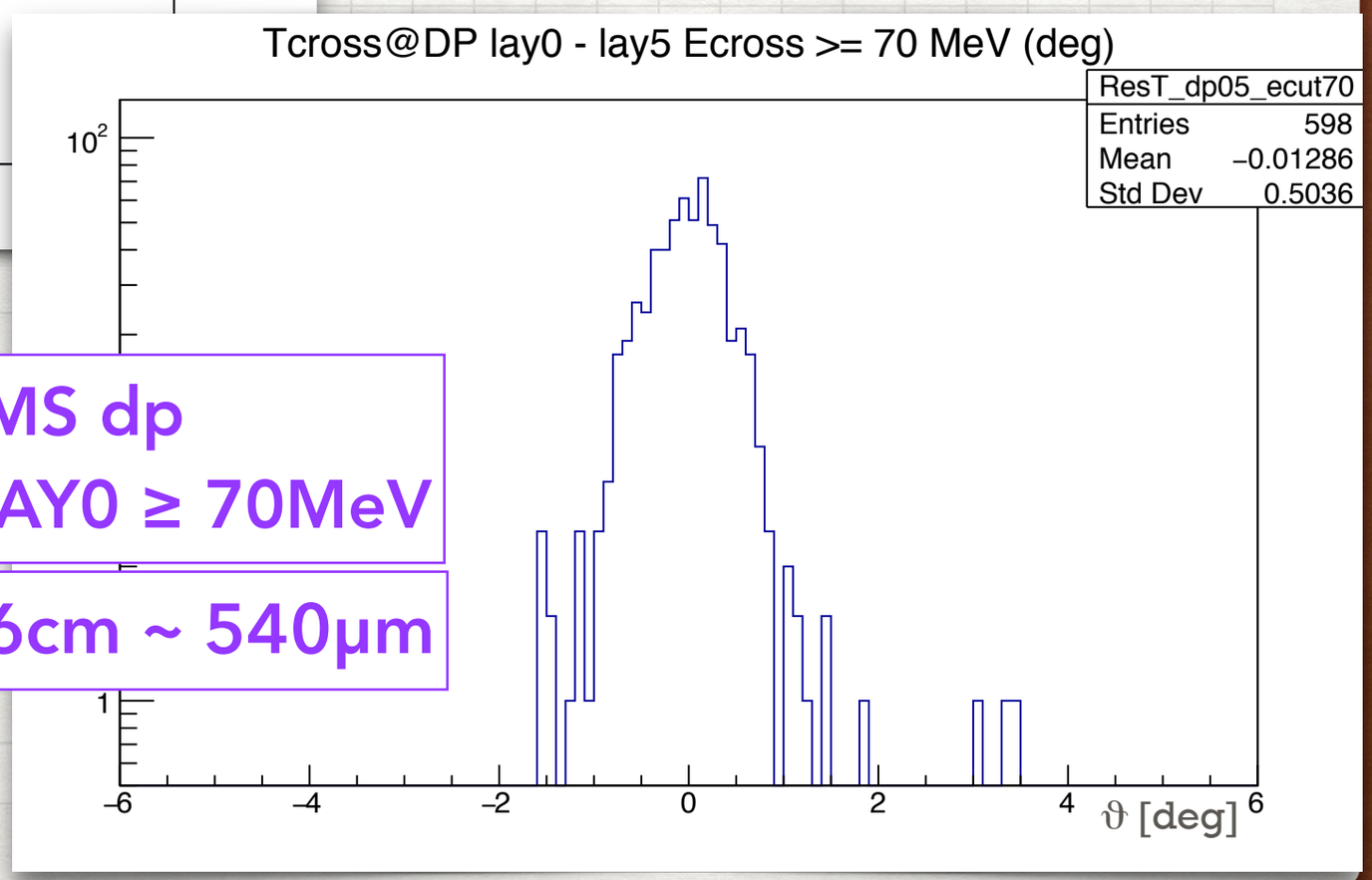
Multiple Scattering evaluation (MC truth)



MS air

Ekin @ LAY0 ≥ 70MeV

STD DEV = 0.2° → @48cm ~ 1mm



MS dp

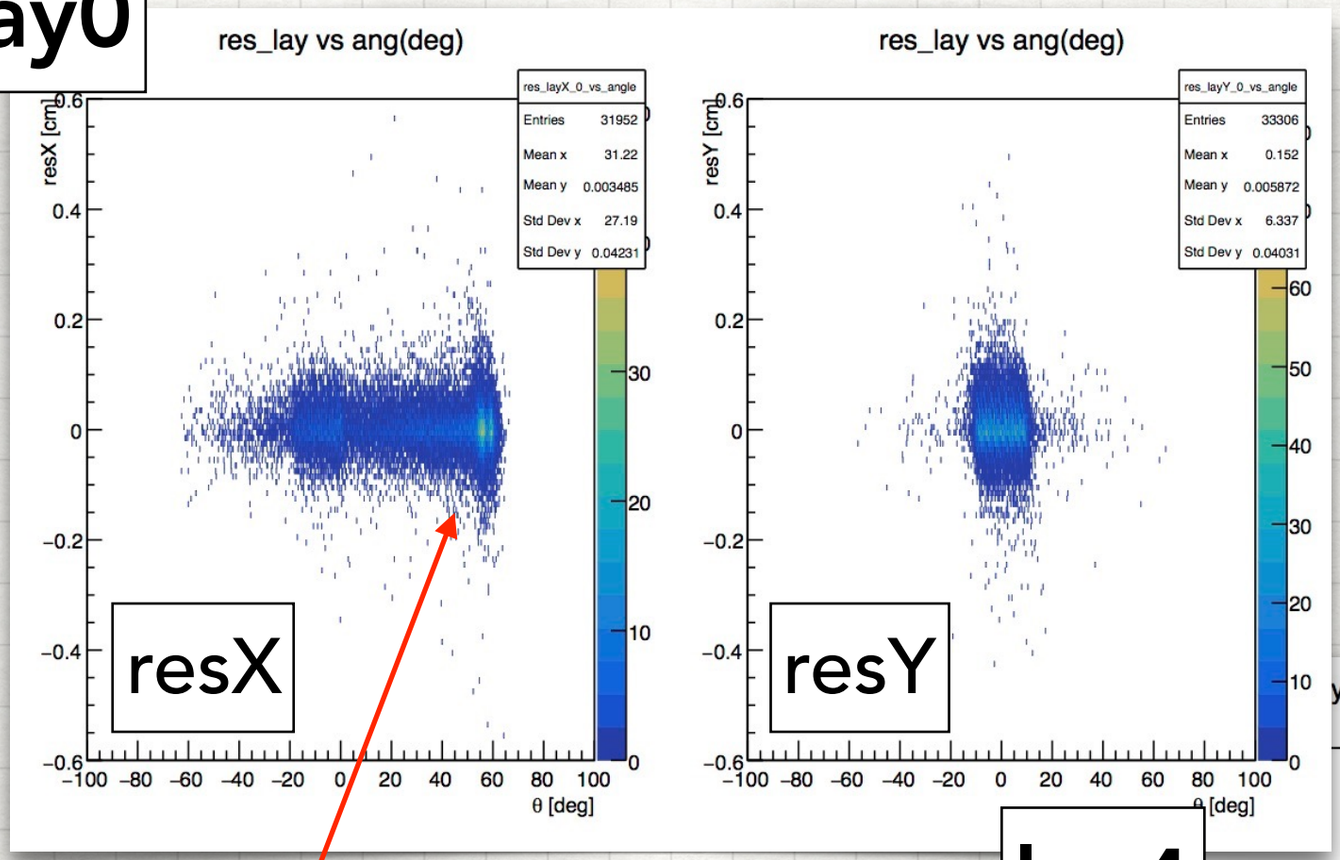
Ekin @ LAY0 ≥ 70MeV

STD DEV = 0.5° → @10.66cm ~ 540μm

MC

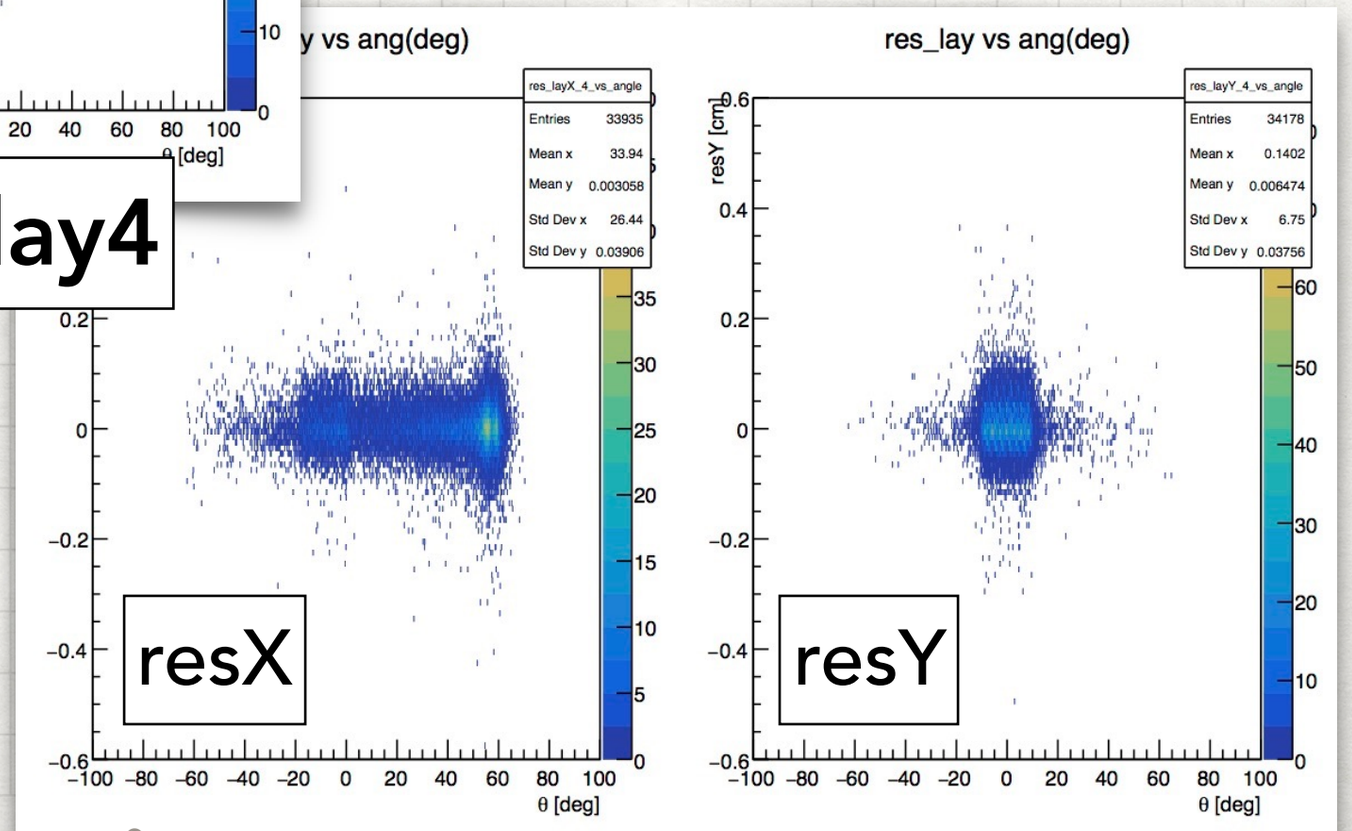
Residuals vs Angle

lay0



Beam monitor chambers!

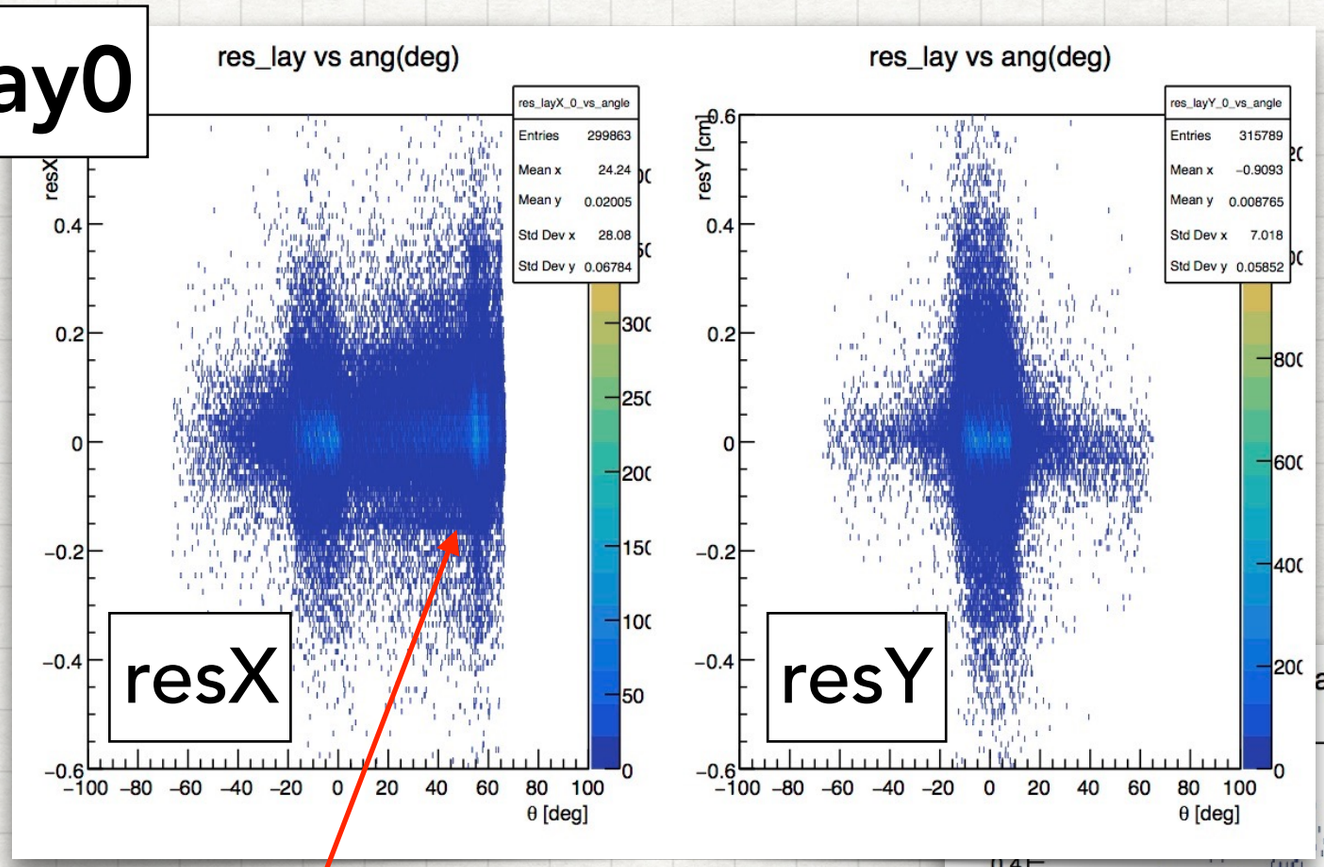
lay4



CNAO

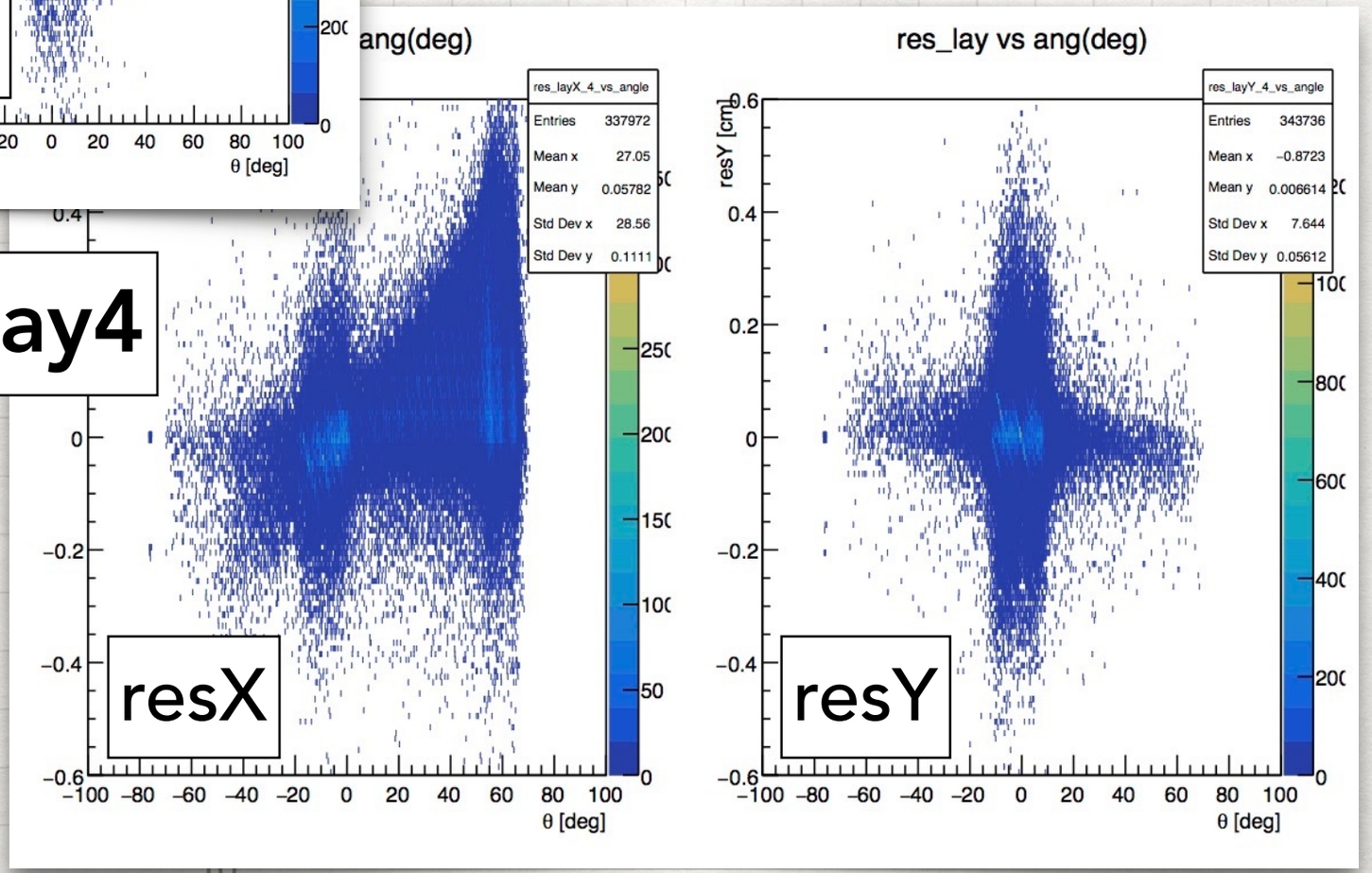
Residuals vs Angle

lay0



Beam monitor chambers!

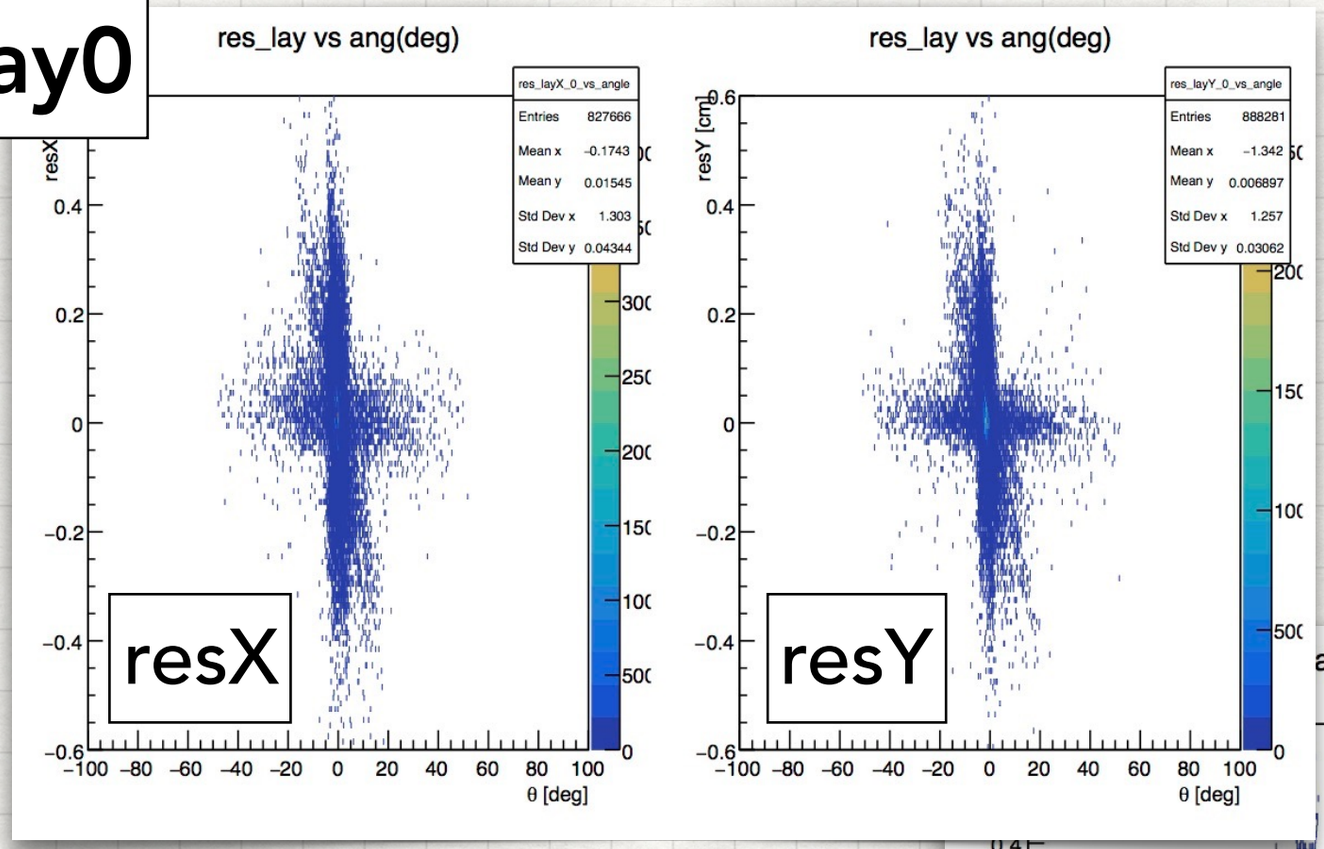
lay4



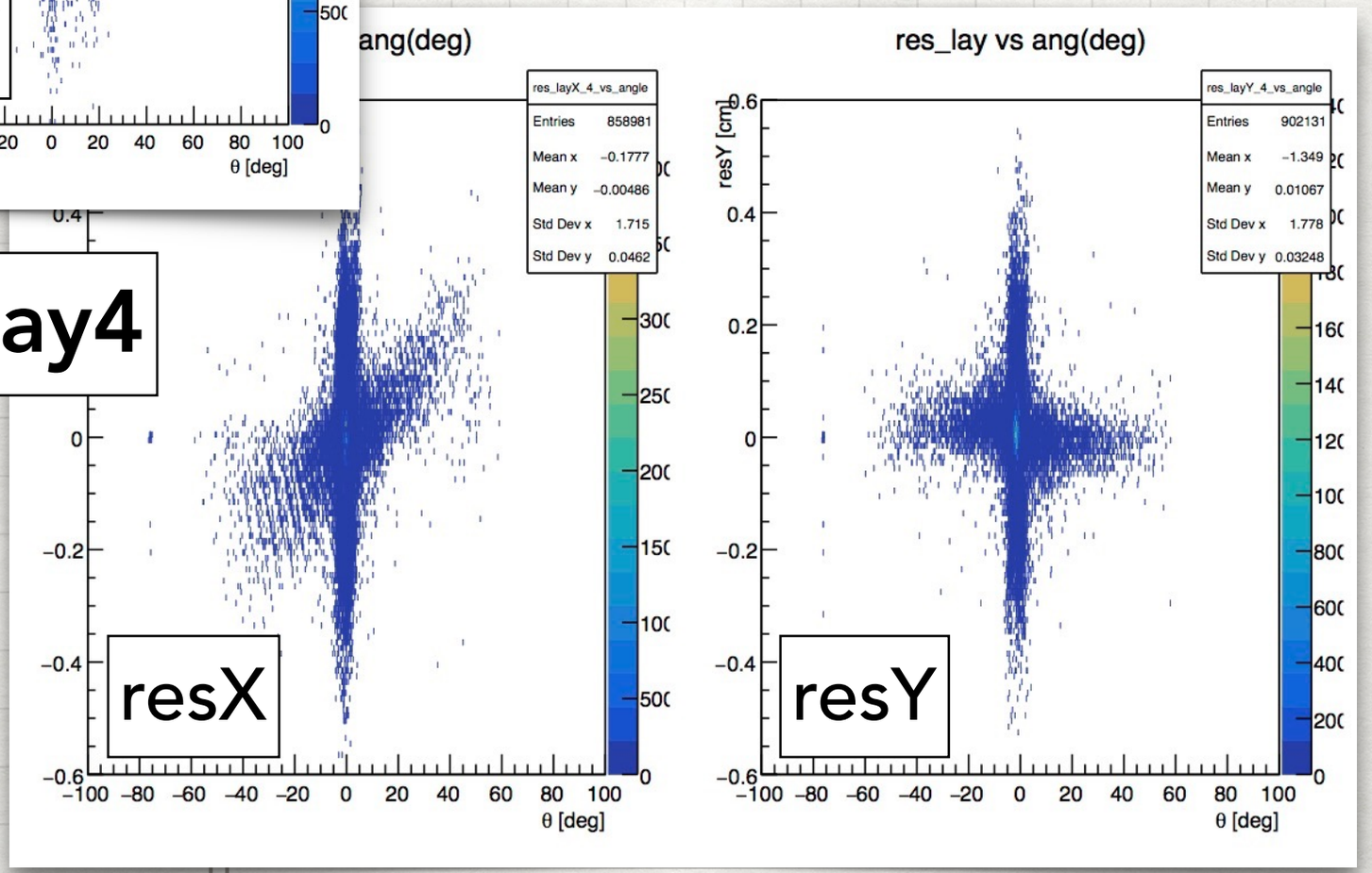
TRENTO

Residuals vs Angle

lay0

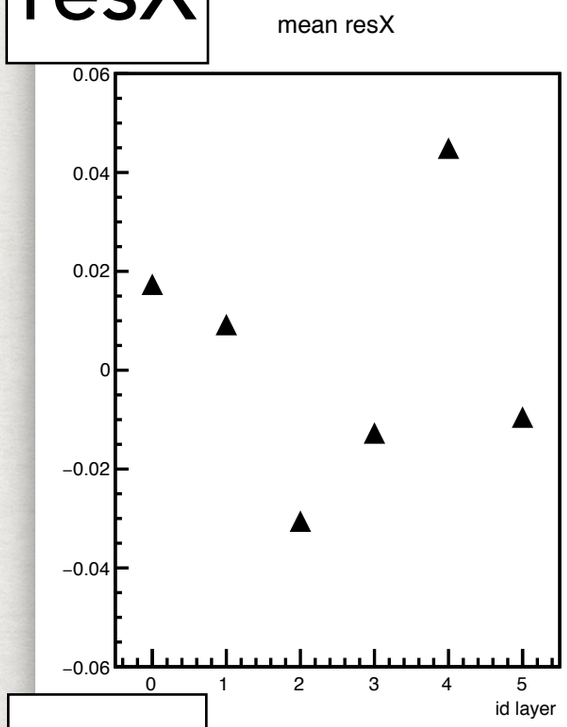


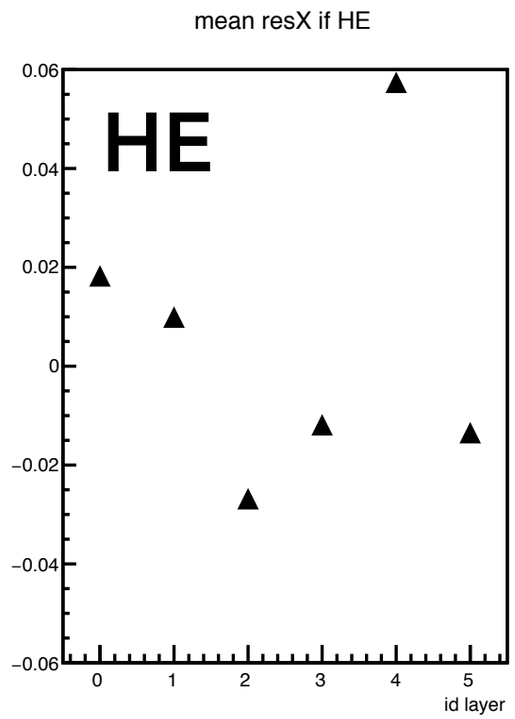
lay4

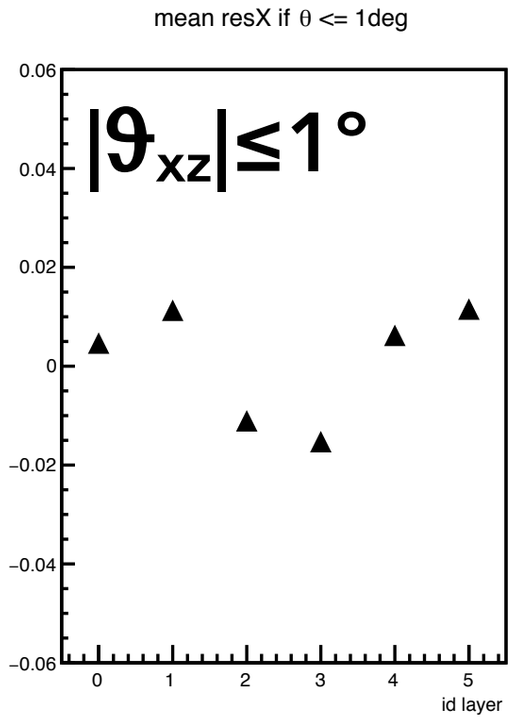


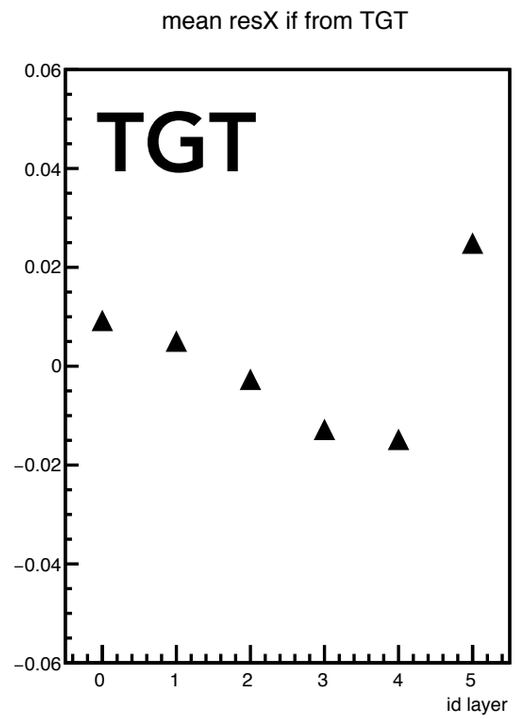
CNAO ean of Residuals (cm) vs IDLay

resX

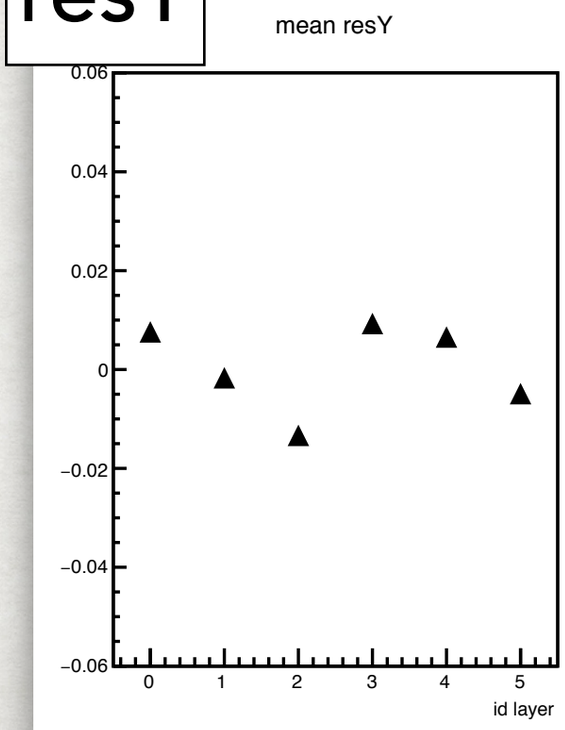


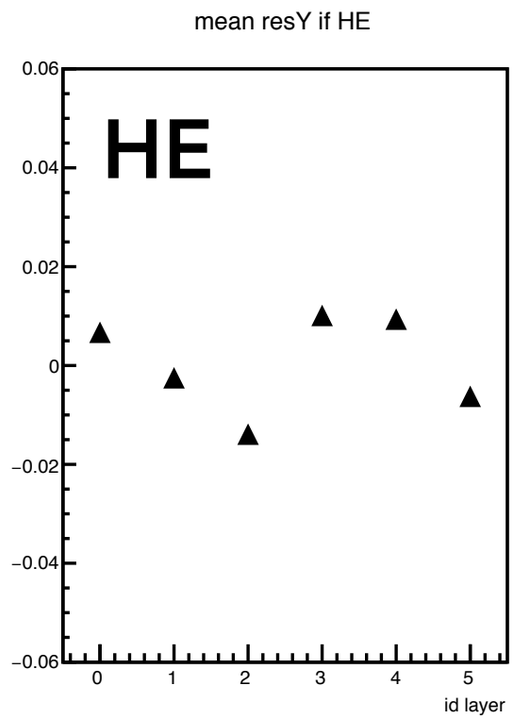


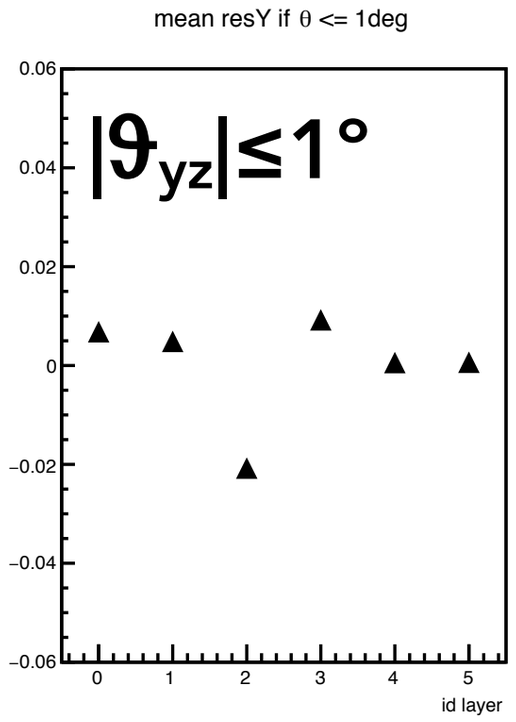


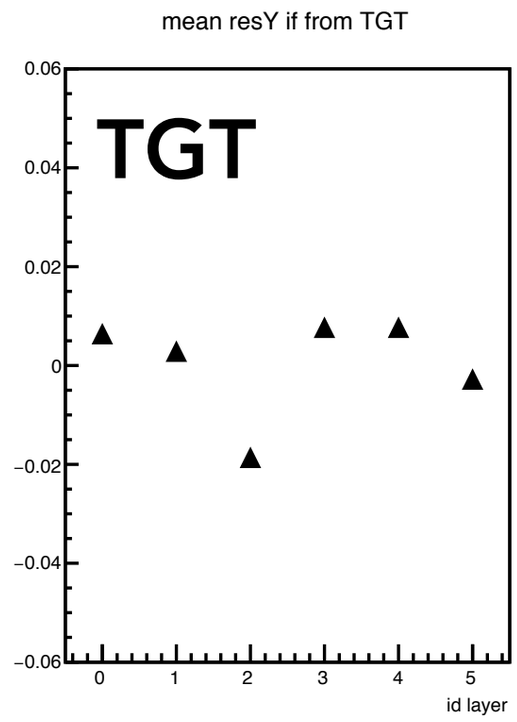


resY





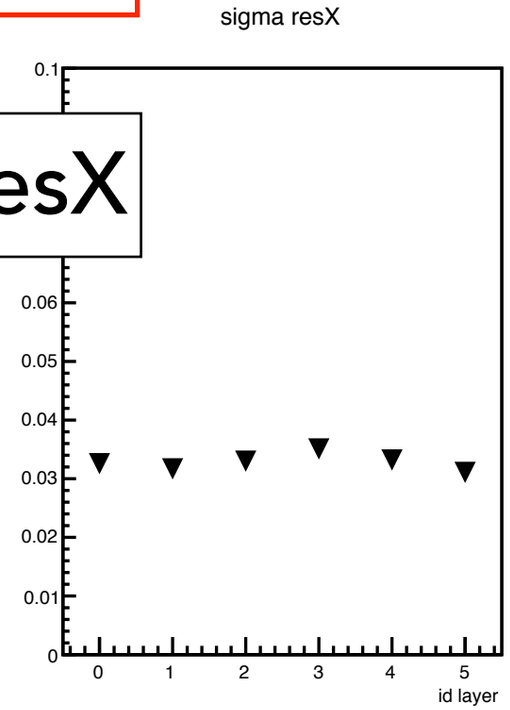


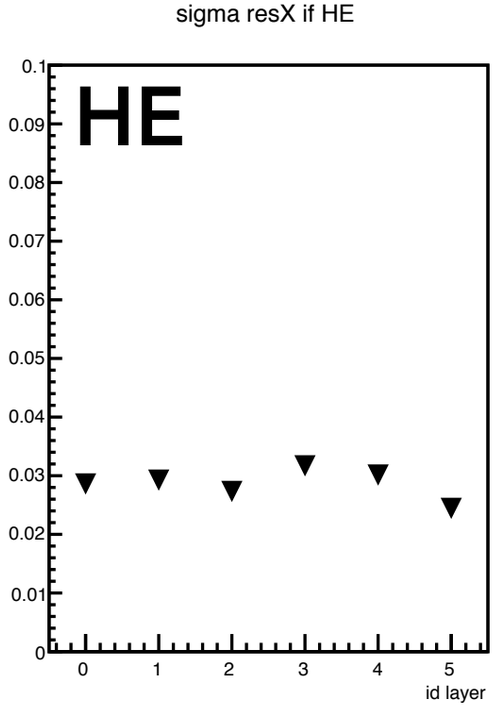


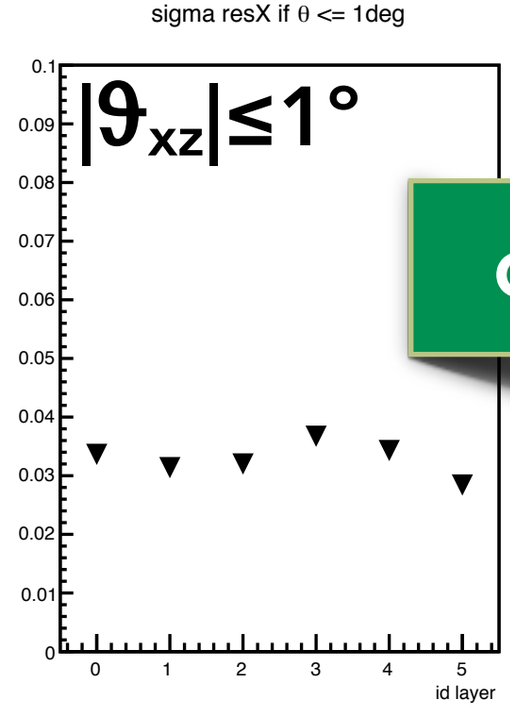
Sigma of Residuals (cm) vs IDLay

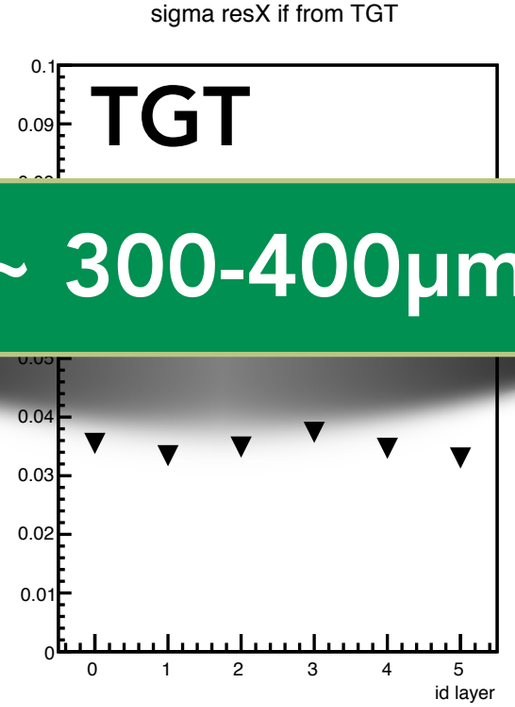
MC

resX



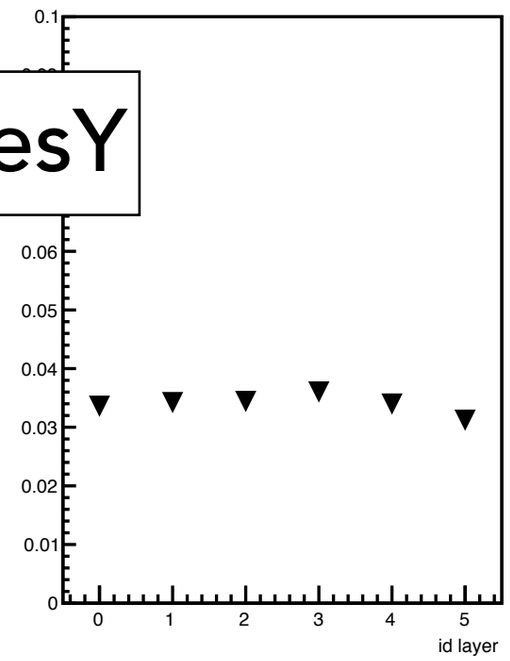


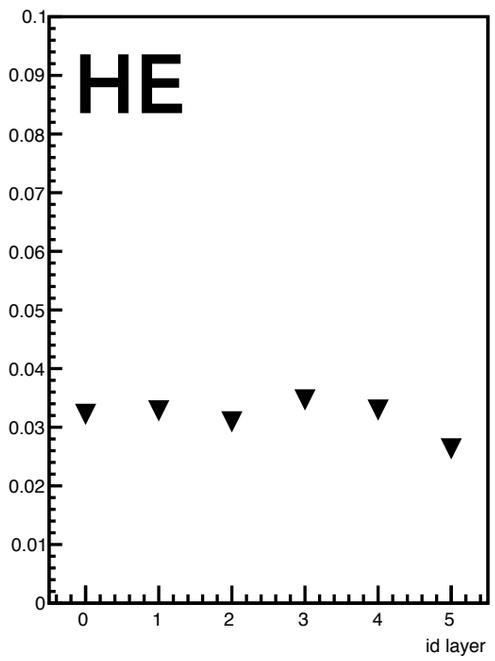


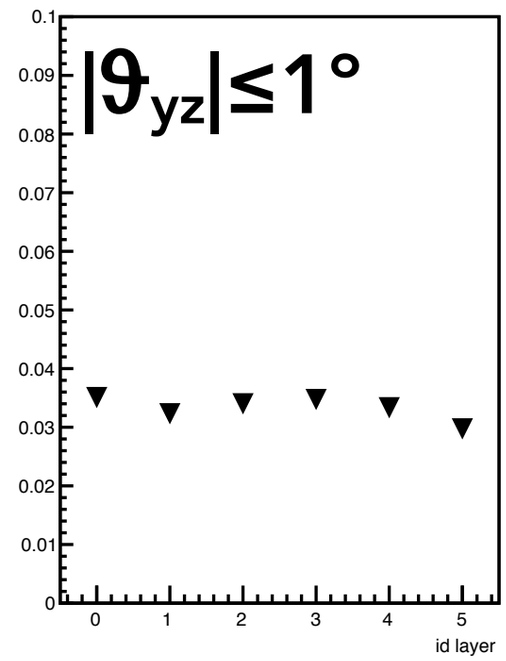


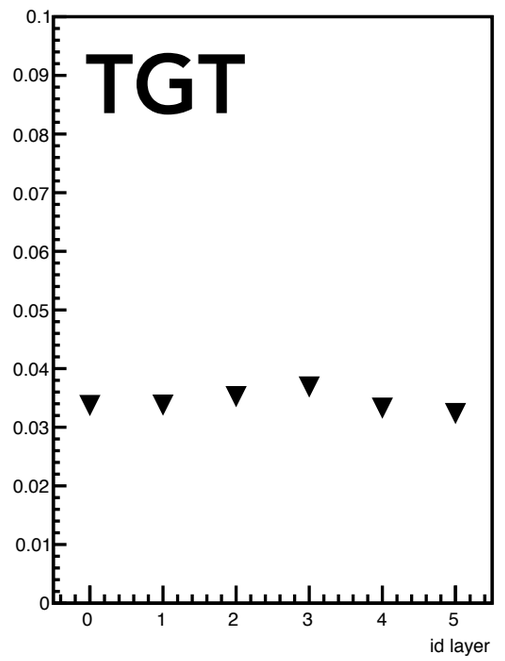
σ ~ 300-400μm

resY





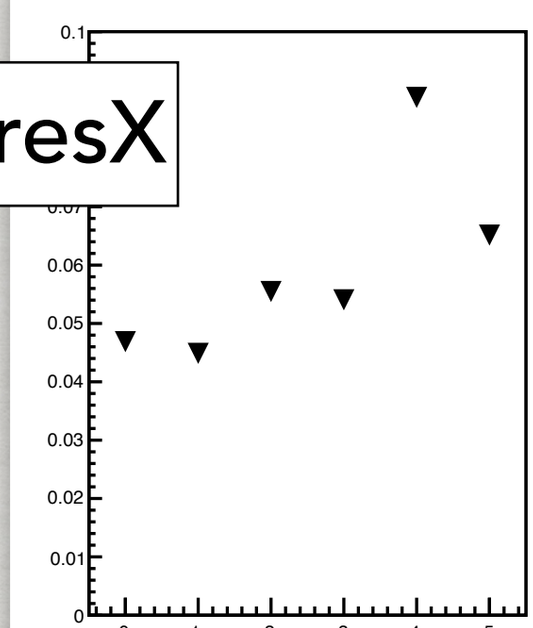


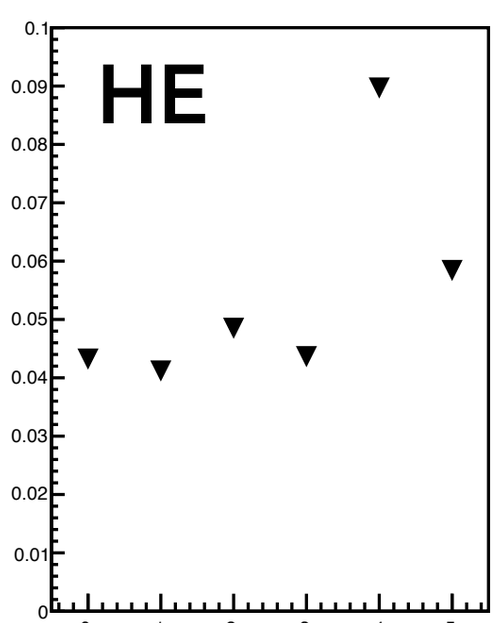


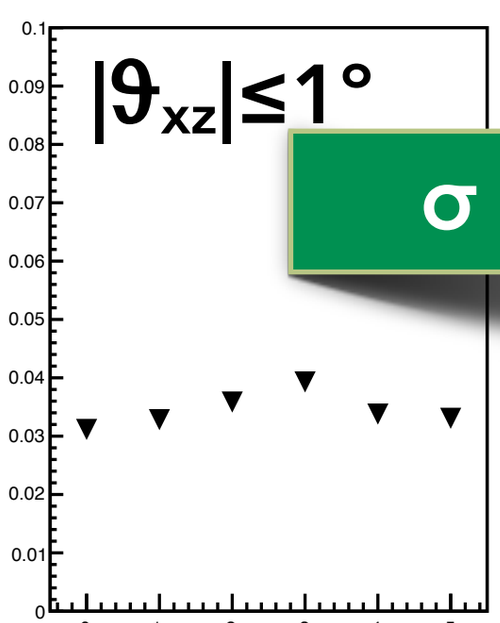
Sigma of Residuals (cm) vs IDLay

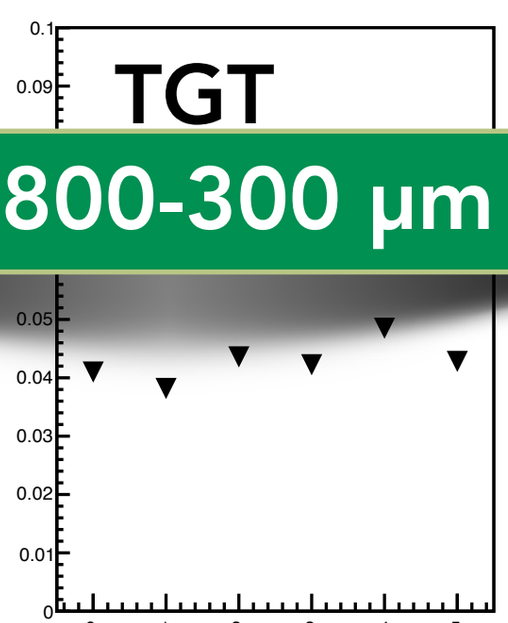
CNAO

resX



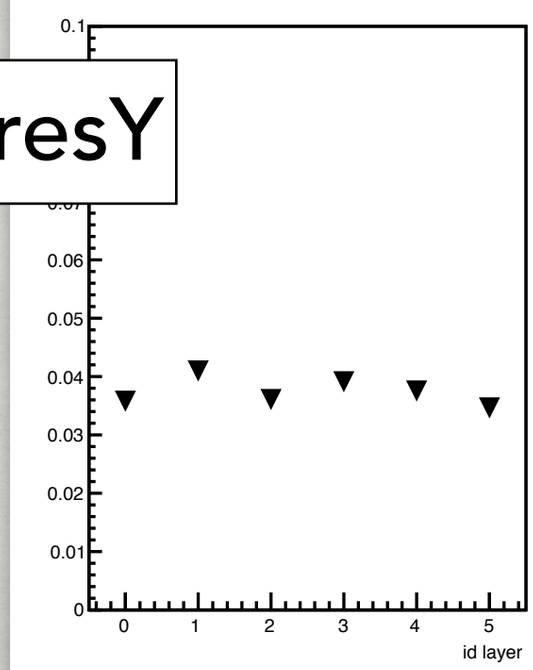


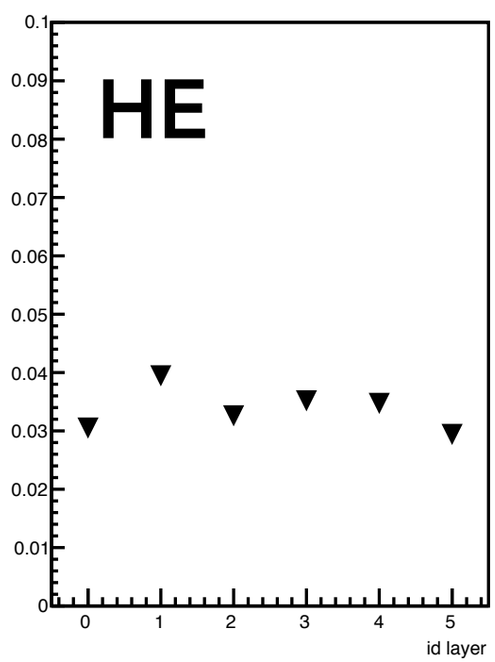


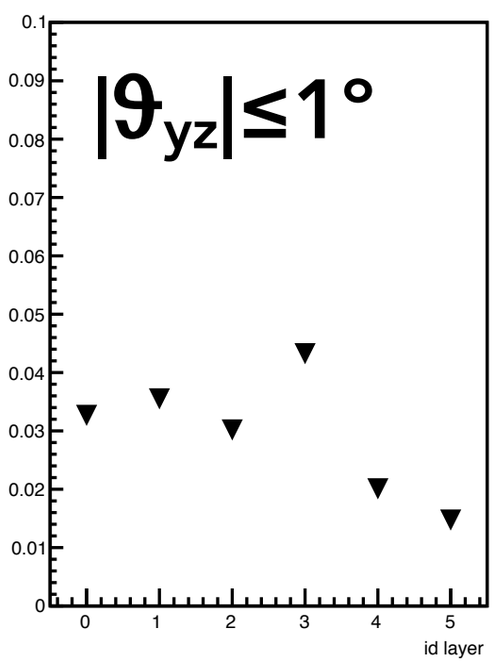


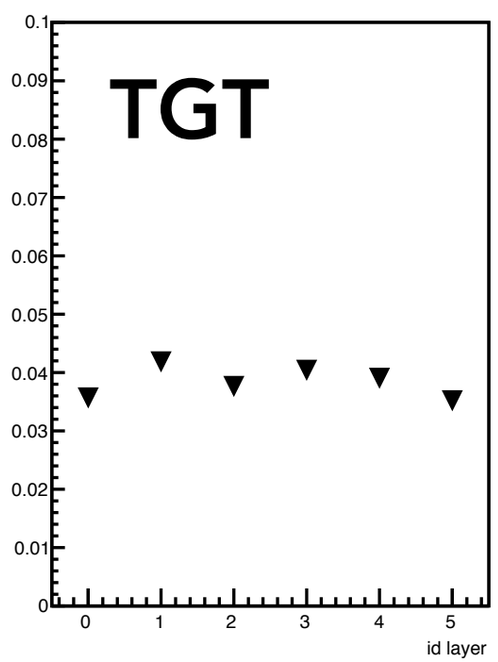
σ ~ 800-300 μm

resY





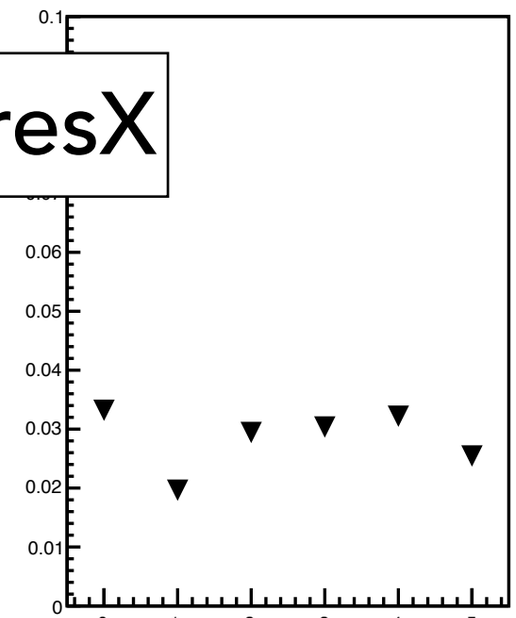




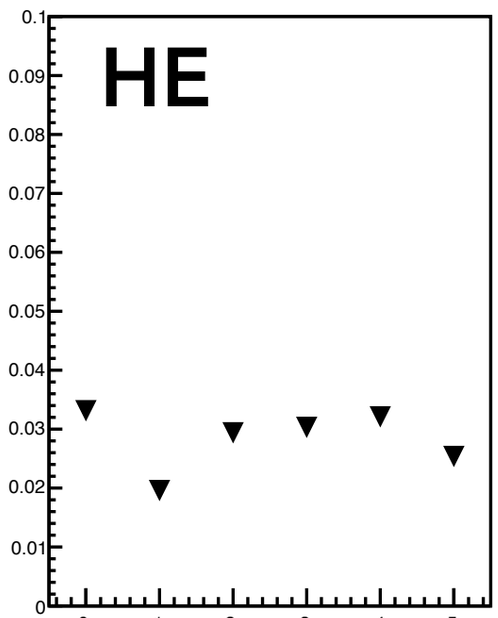
Sigma of Residuals (cm) vs IDLay

TRENTO

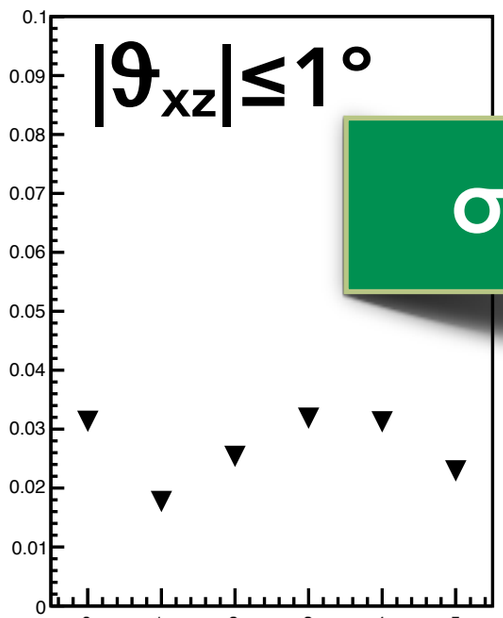
resX



sigma resX if HE



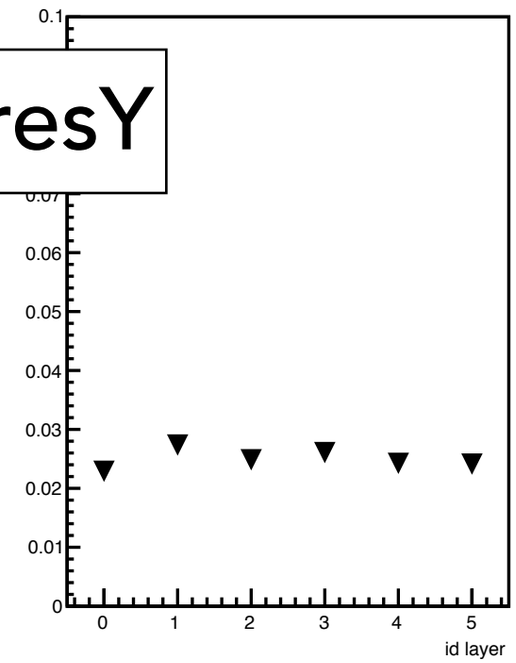
sigma resX if θ <= 1deg



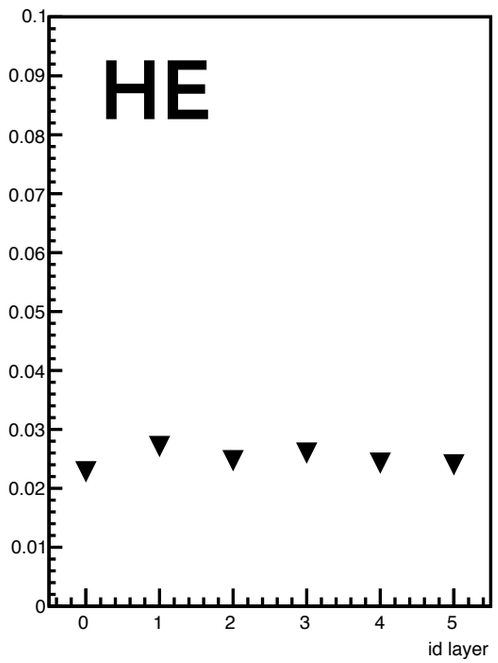
σ ~ 200-300 μm

sigma resY

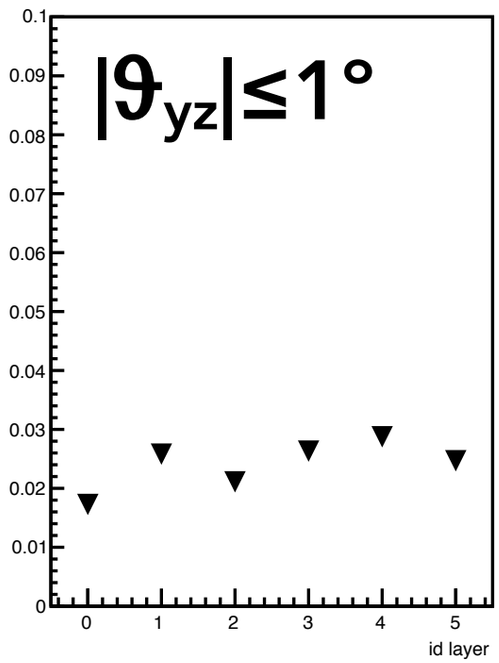
resY



sigma resY if HE

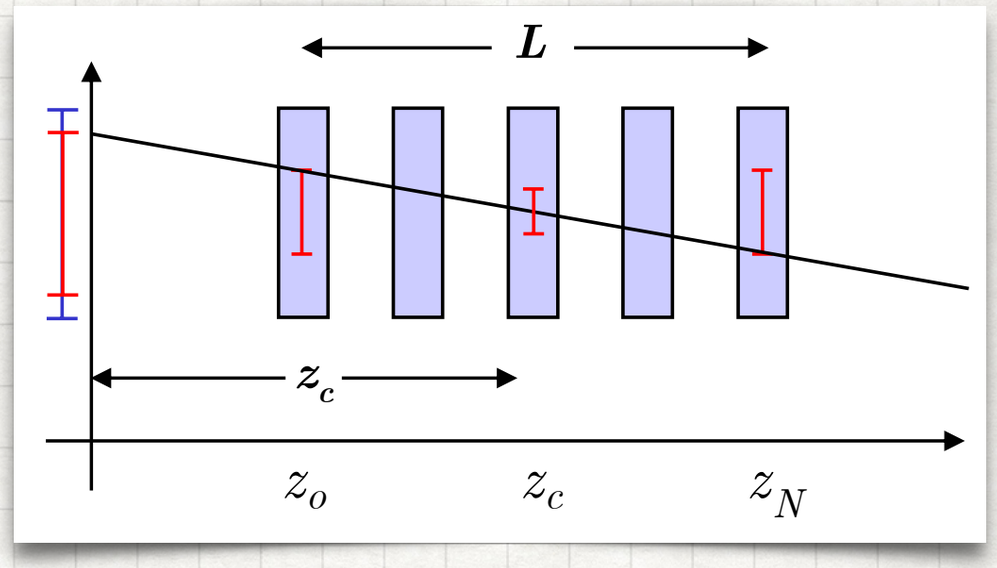


sigma resY if θ <= 1deg



DP Analytic Resolution

$$\sigma_{dp@D} = \frac{\sigma}{\sqrt{N}} \sqrt{1 + 12 \frac{N-1}{N+1} \frac{z_c^2}{L^2}}$$

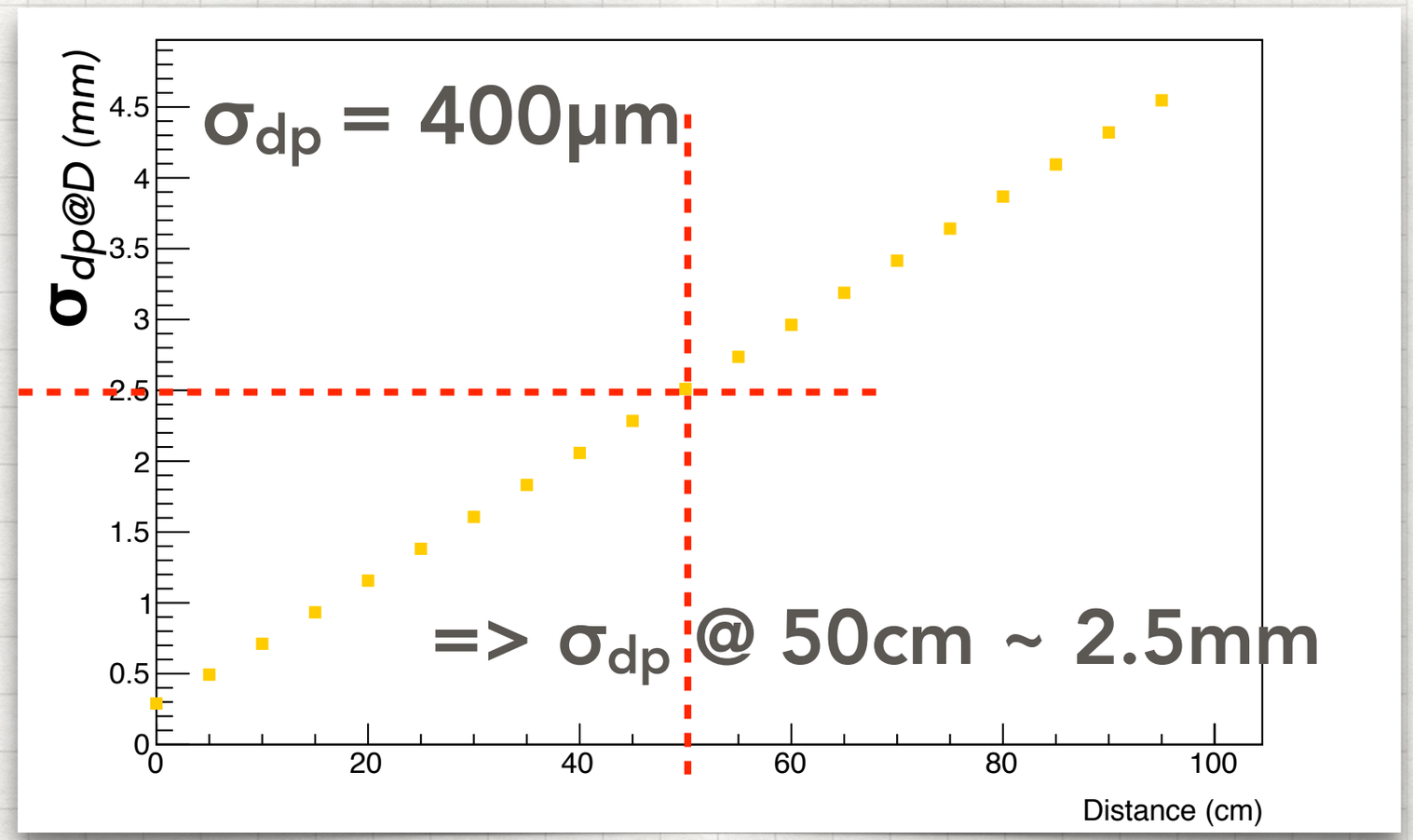


. z_c = (z0+zN)/2 + distance

. N = 6 (n detector)

. L = 10.55 cm

. $\sigma = \sigma_{dp}$ (σ residuals)



Resolution Study

	σ^X	σ^X_{HE}	σ^X_{ang}	σ^X_{angHE}
MC	8mm	4.5mm	5.4mm	4.3mm
CNAO	1.3cm	1.1cm	7.6mm	7.1mm
TRENTO70	8.8mm	8.8mm	8.4mm	8.4mm

σ_{MSdpHE} ~ 540 μm

$\sigma_{MSairHE}$ ~ 1mm

$\sigma_{TgtThick}$ = 1.1 mm

$\sigma_{dp(400\mu m)}$@50 cm ~ 2.5mm

$\sigma_{dp(300\mu m)}$@50 cm ~ 2mm

$\sigma_{beam(70MeV)}$@50 cm ~ 7mm

Considering the same reconstructed tracks scenario:

$$\sigma_{meas@50cm} = \mathrm{sqrt}(\sigma_{fit} + \sigma_{MSdpHE} + \sigma_{MSairHE} + \sigma_{dp@50cm} + \sigma_{beam})$$

$$\text{TRENTO70} :: (\sigma_{fit})@50cm = \mathrm{sqrt}(8.4^2 - (0.54^2 + 1^2 + 2^2 + 7^2)) \sim 4 \text{ mm}$$

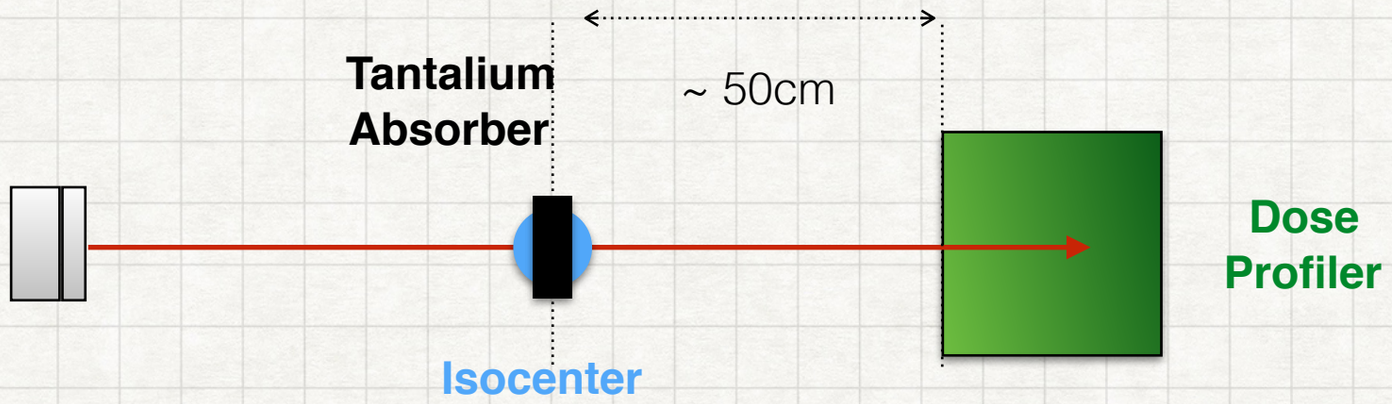
$$\sigma_{meas@50cm} = \mathrm{sqrt}(\sigma_{fit} + \sigma_{MSdpHE} + \sigma_{MSairHE} + \sigma_{TgtThick} + \sigma_{dp@50cm})$$

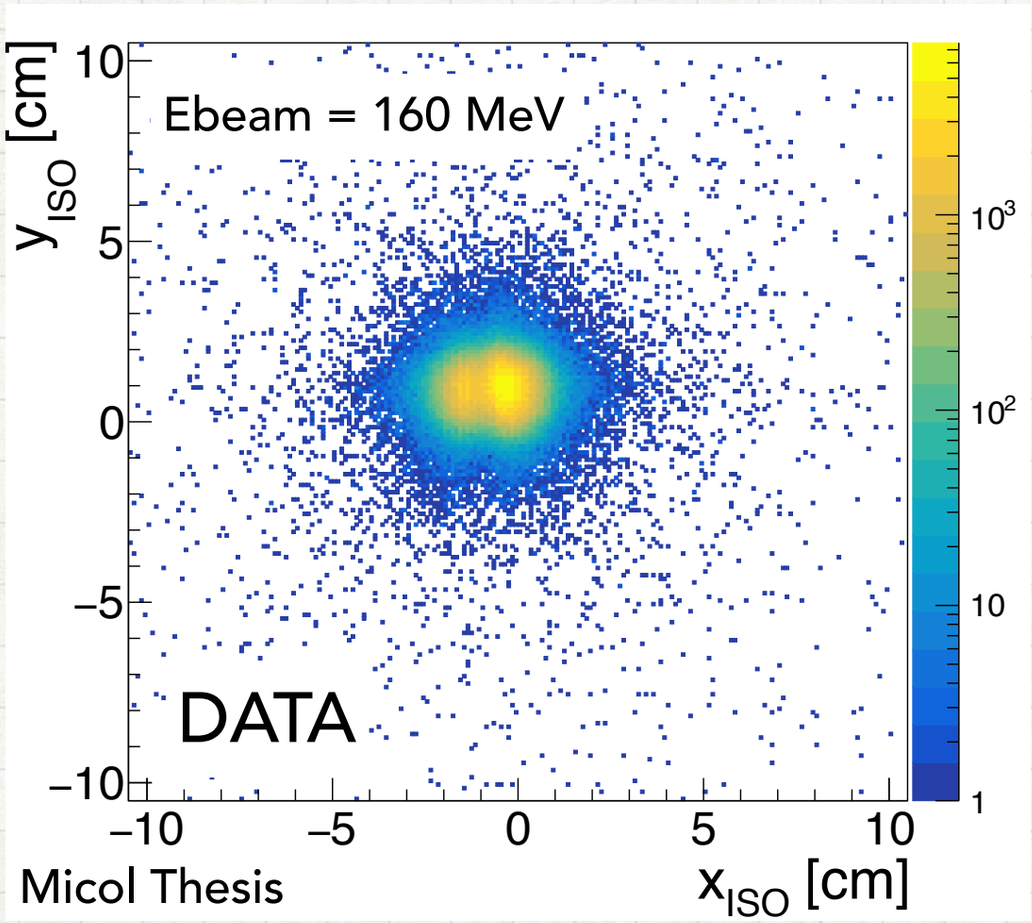
$$\text{CNAO} :: (\sigma_{fit})@50cm = \mathrm{sqrt}(7.1^2 - (0.54^2 + 1^2 + 1.1^2 + 2.5^2)) \sim 6.5 \text{ mm}$$

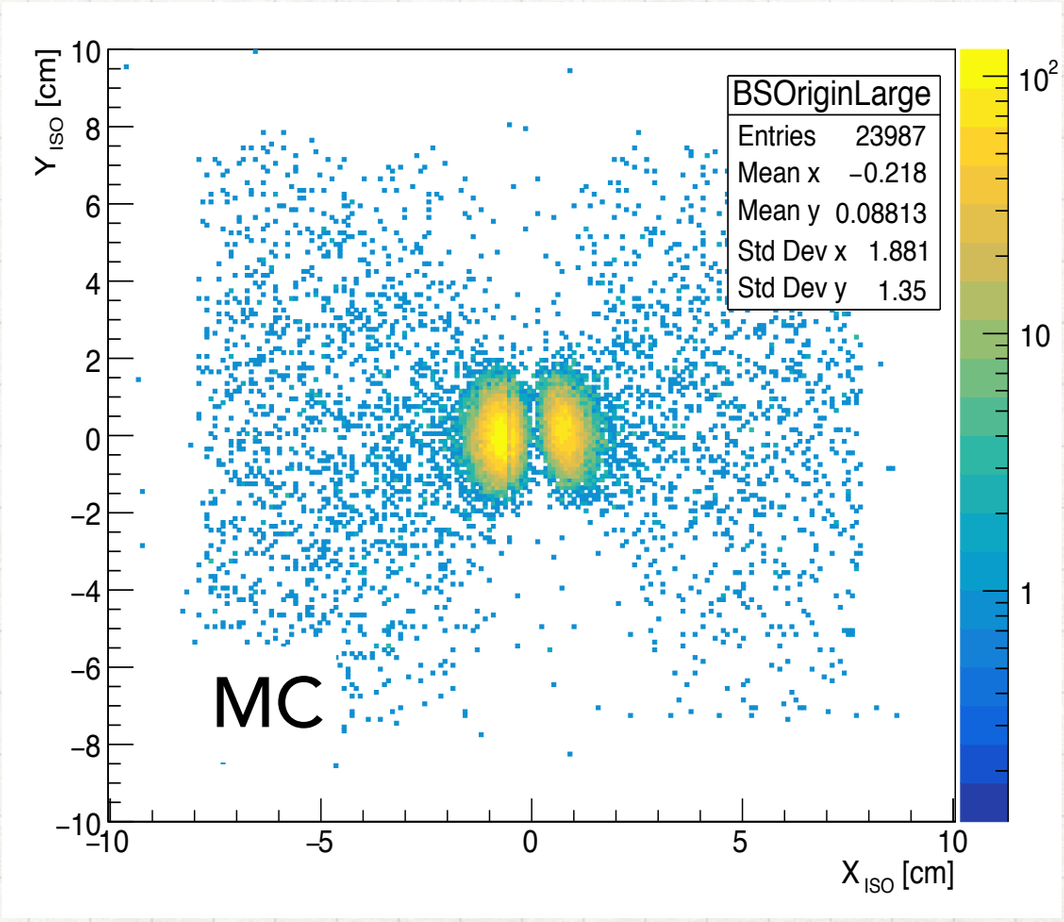
$$\text{MC} :: (\sigma_{fit})@50cm = \mathrm{sqrt}(4.3^2 - (0.54^2 + 1^2 + 1.1^2 + 2.5^2)) \sim 3 \text{ mm}$$

- **CNAO gets closer to TRENTO**
- **we still have a factor ~ 2 btw CNAO and MC**

About The Wedge Run at Trento…







Conclusions

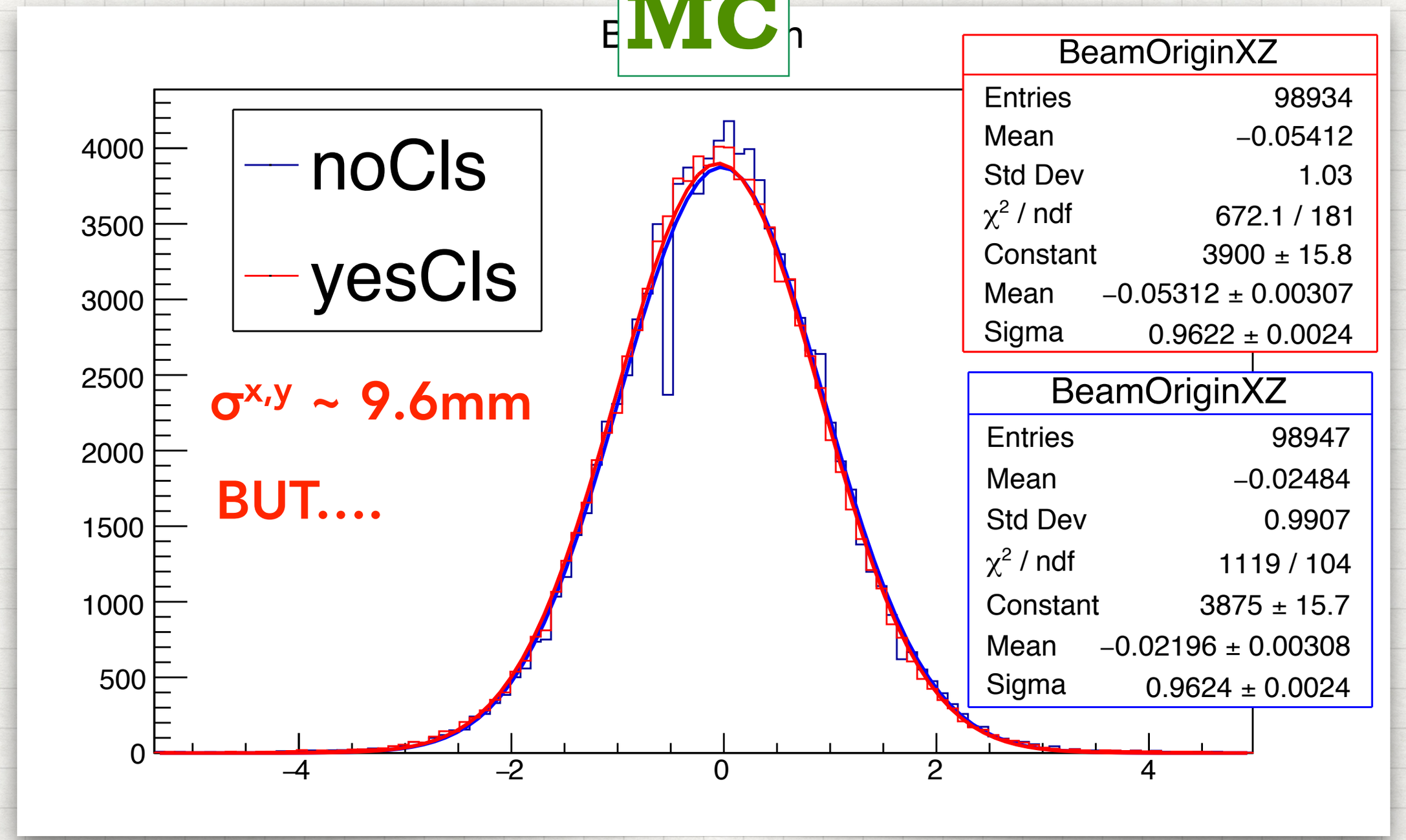
- **We are making the effort to have a MC in agreement with CNAO Panduit run: we are on the good way, but some more work has to be done**
- **We just started the resolution study for the YZ view**
- **We are implementing the charge center of gravity method to assess the clusters position for the track fitting**
- **We are refining the method to assign the cluster size in MC**
- **We are improving the 2D track fit:**
  - recover the tracks with more than one track candidate
  - assignment of cluster error along z coordinate (140μm)
  - perform the fit with HITS not clustered
- **…**

SPARES

Study of Trento 70MeV Run

Beam Spot XZ distribution

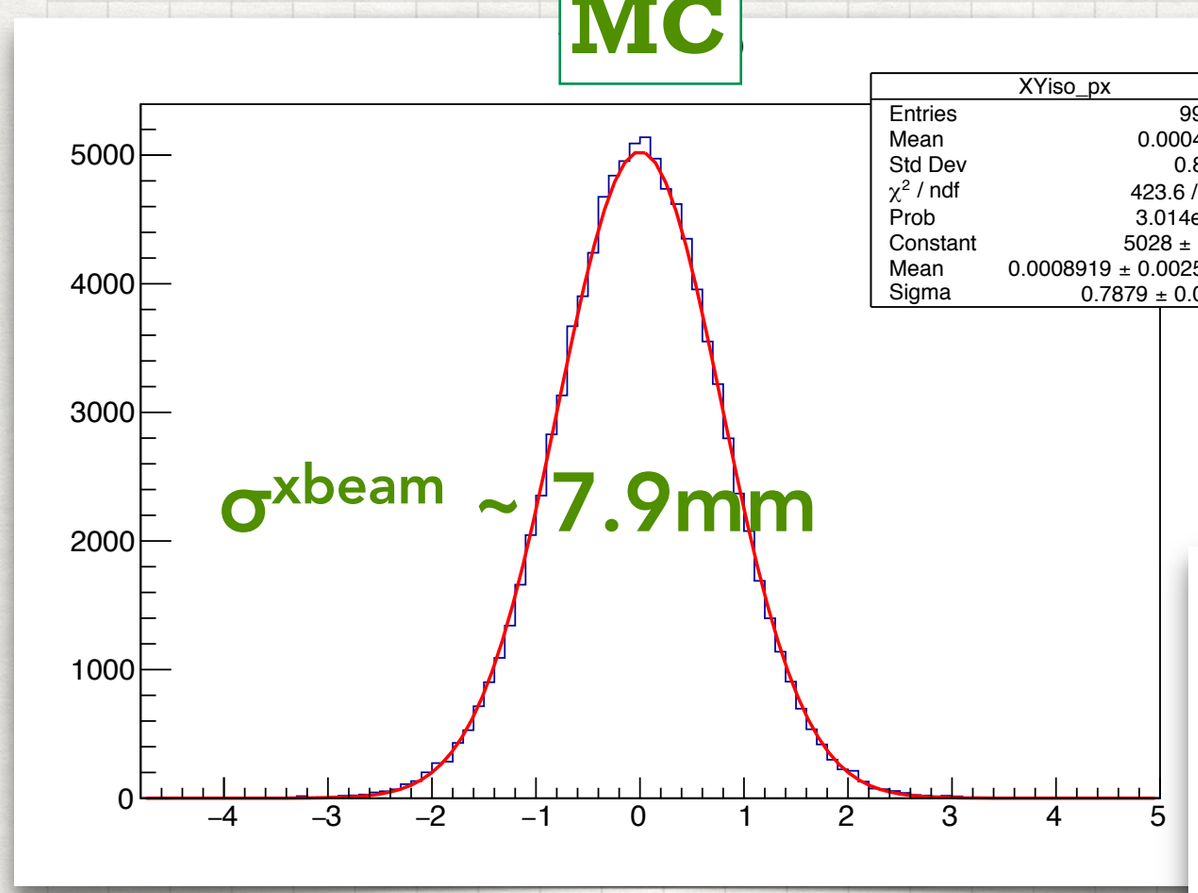
MC



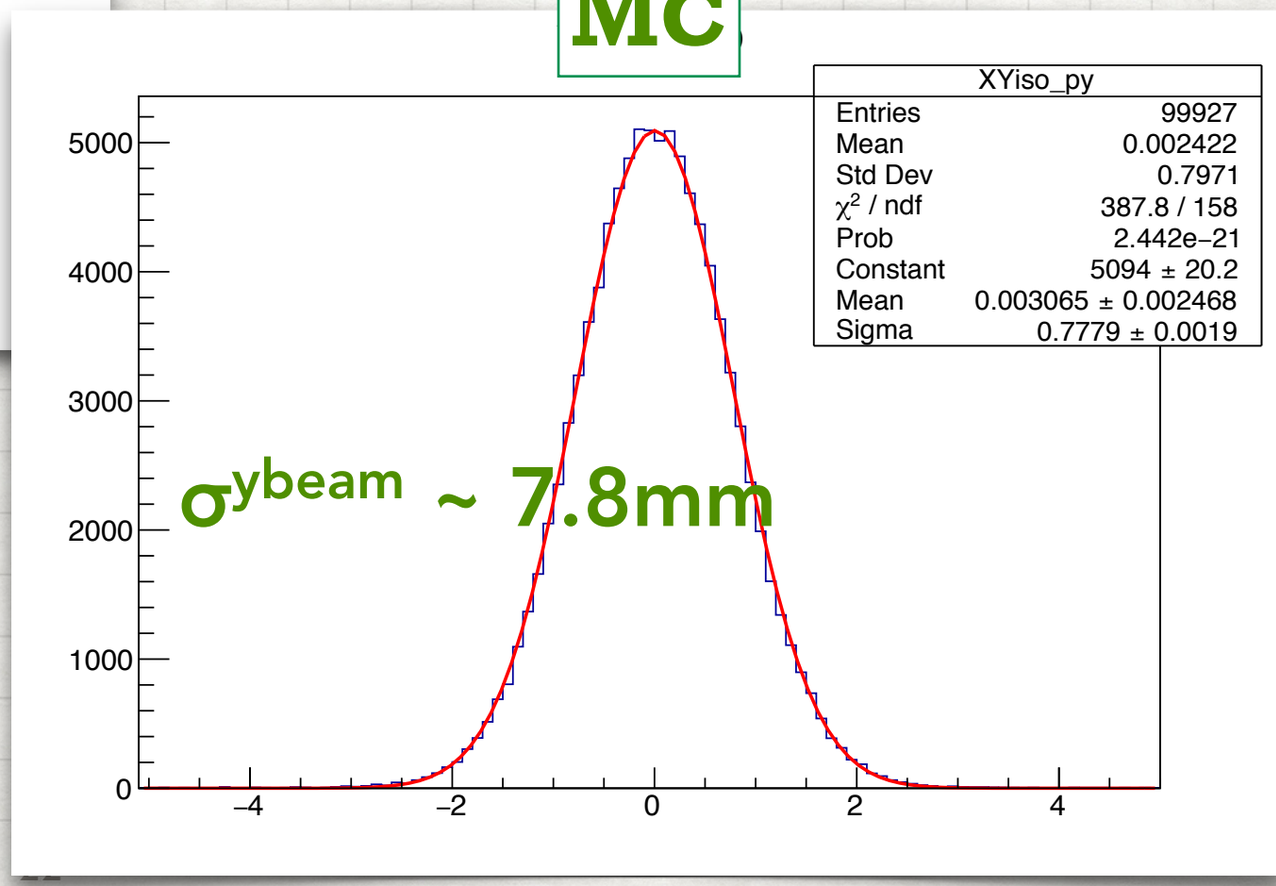
Study of Trento 70MeV Run

Monte Carlo Beam Spot at ISOCENTER

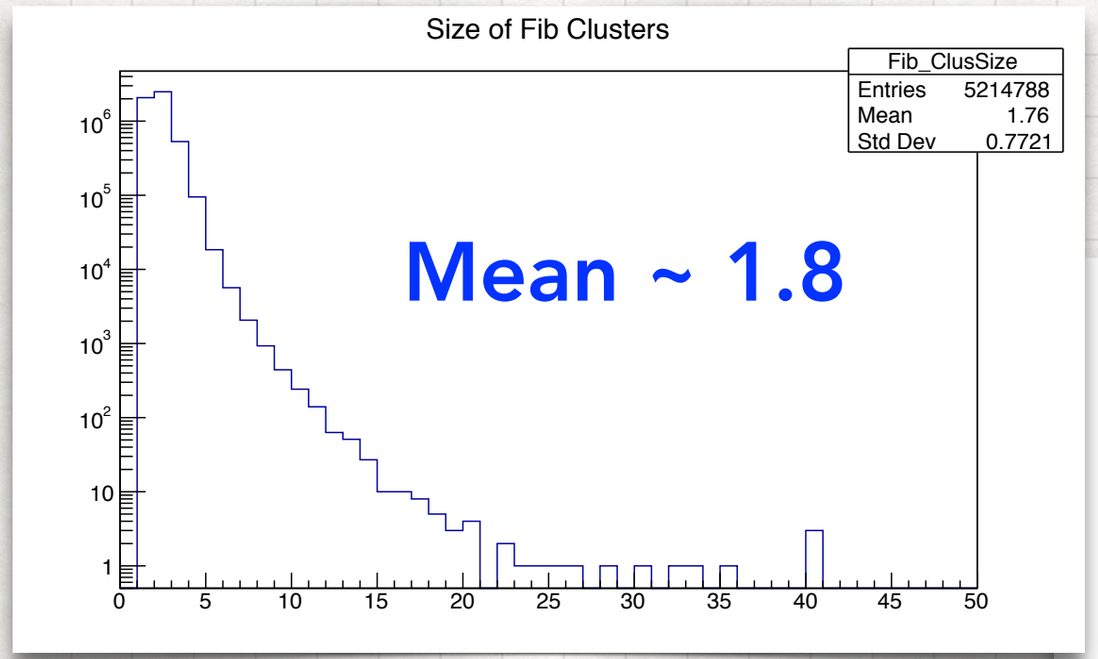
MC

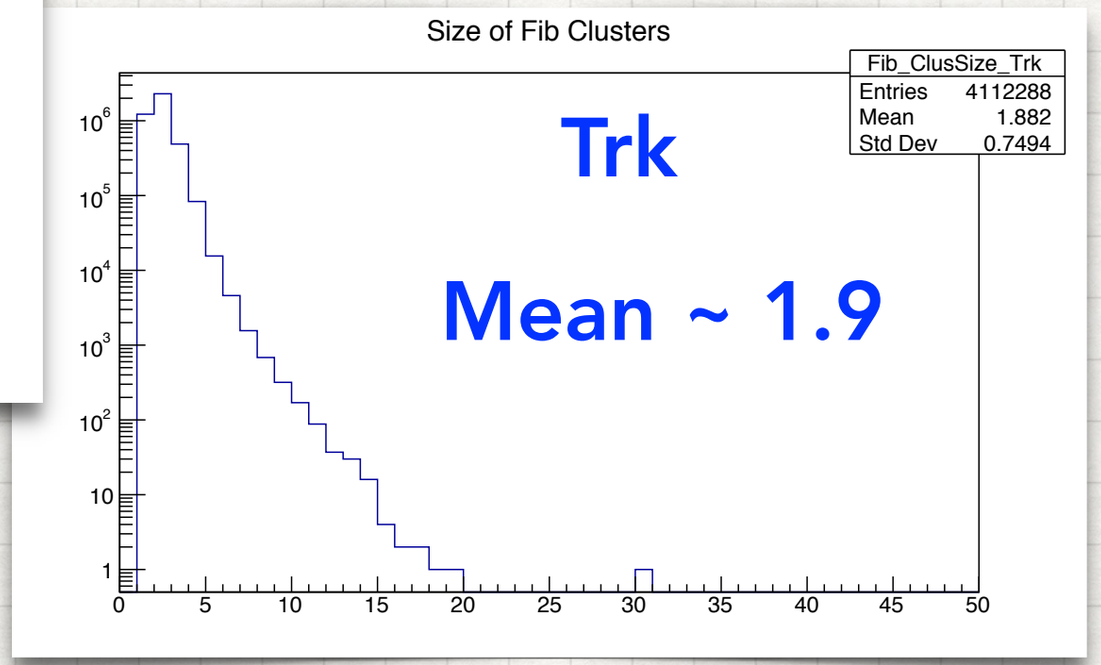


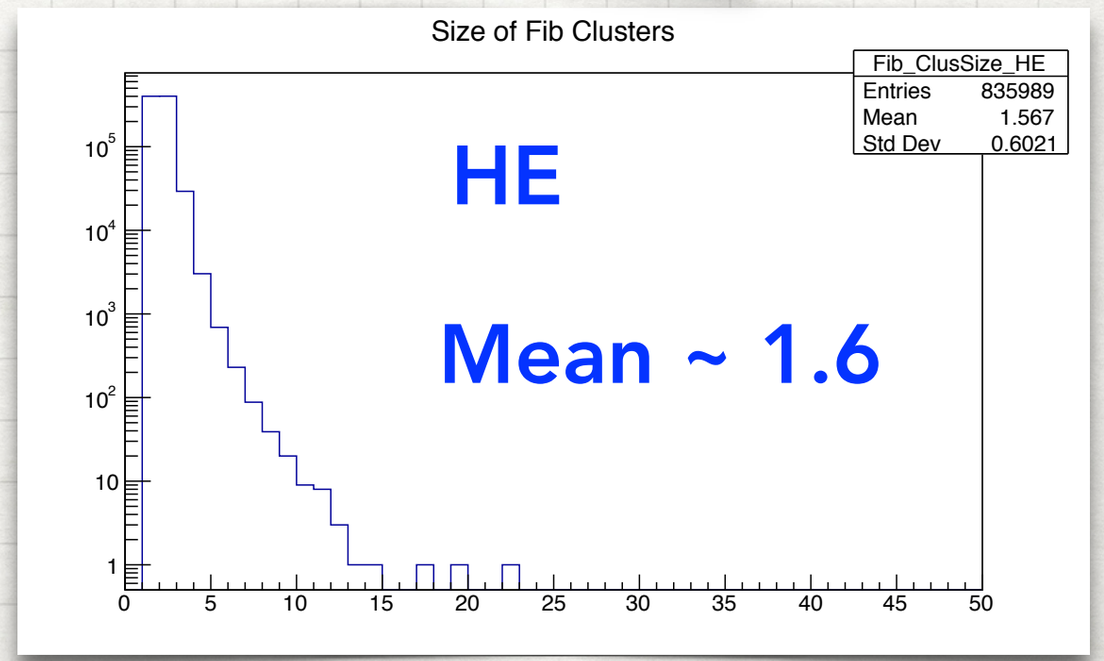
MC



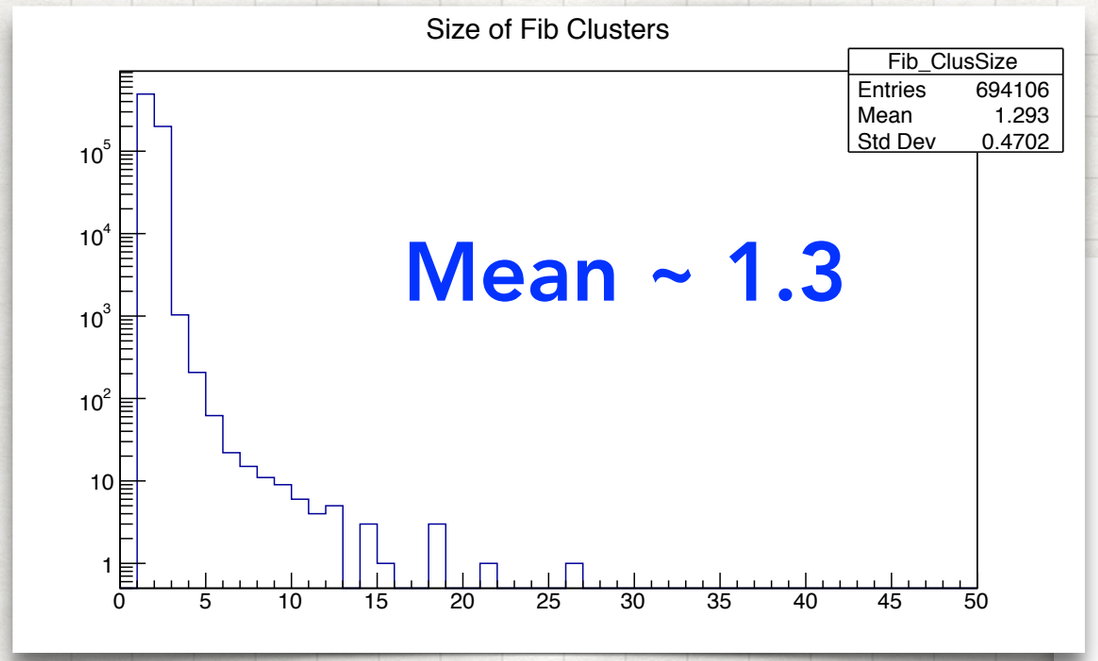
CNAO Cluster Size

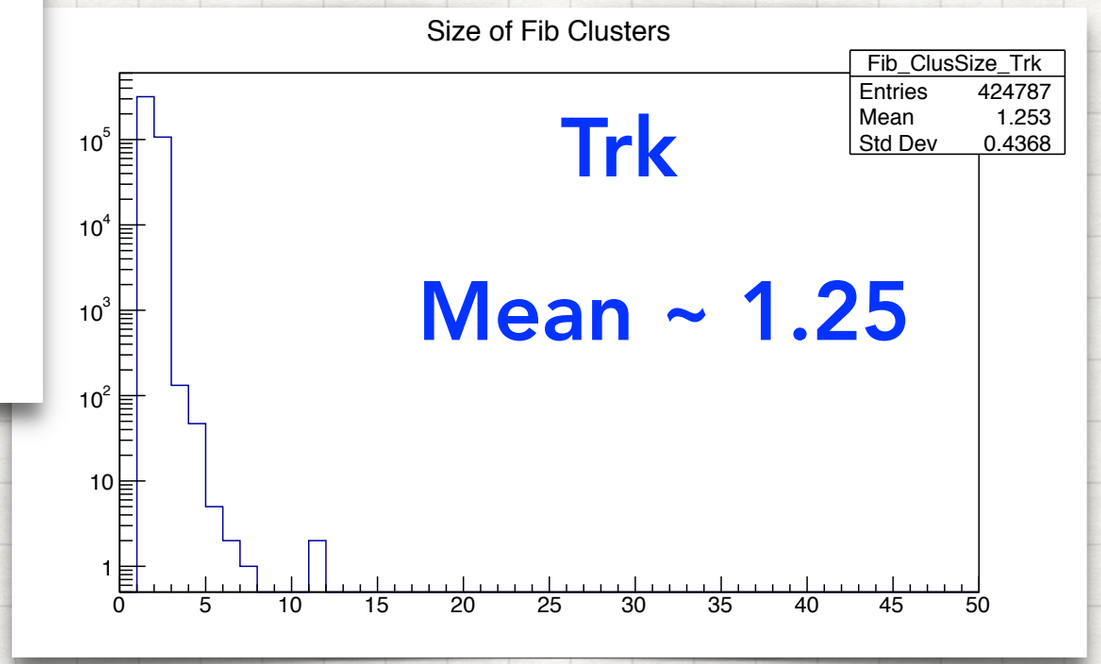


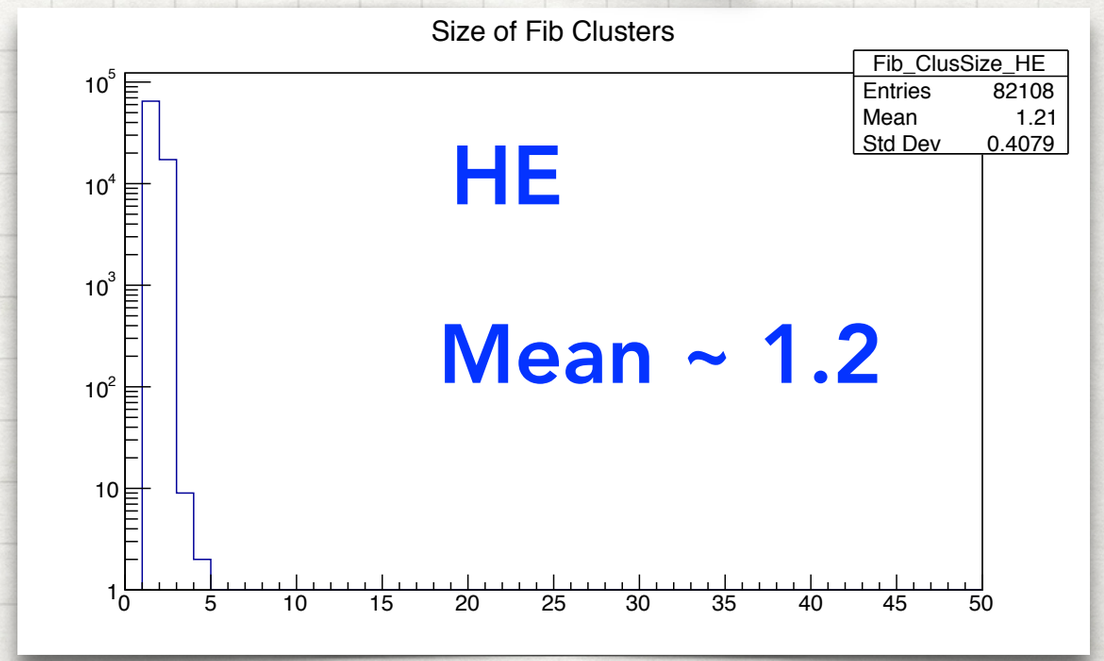




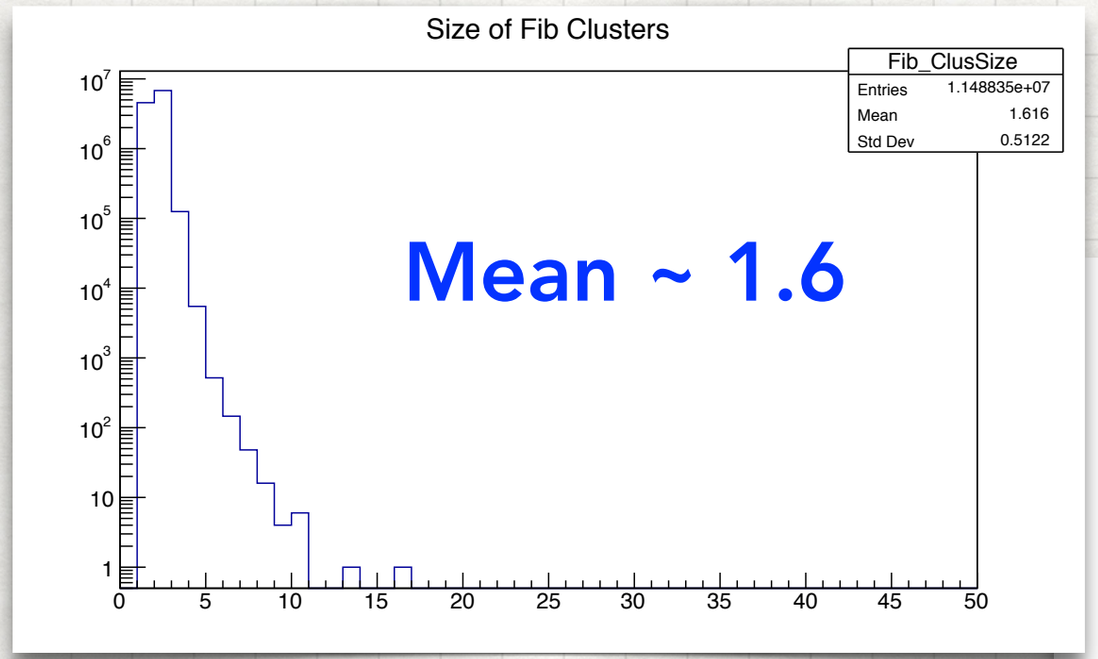
FLUKA Cluster Size (no tuning)

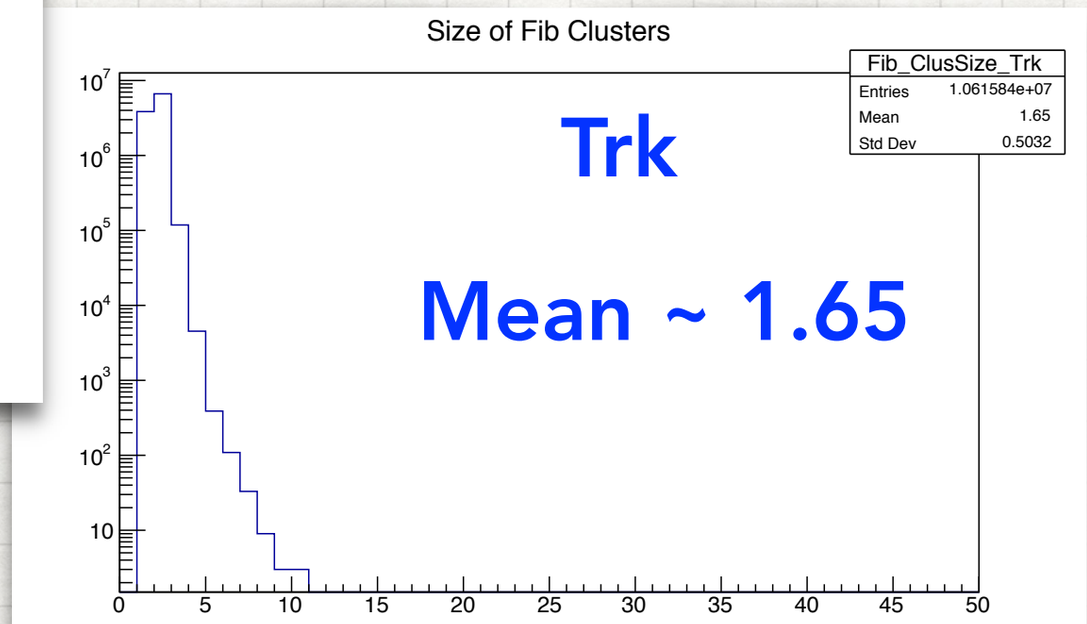


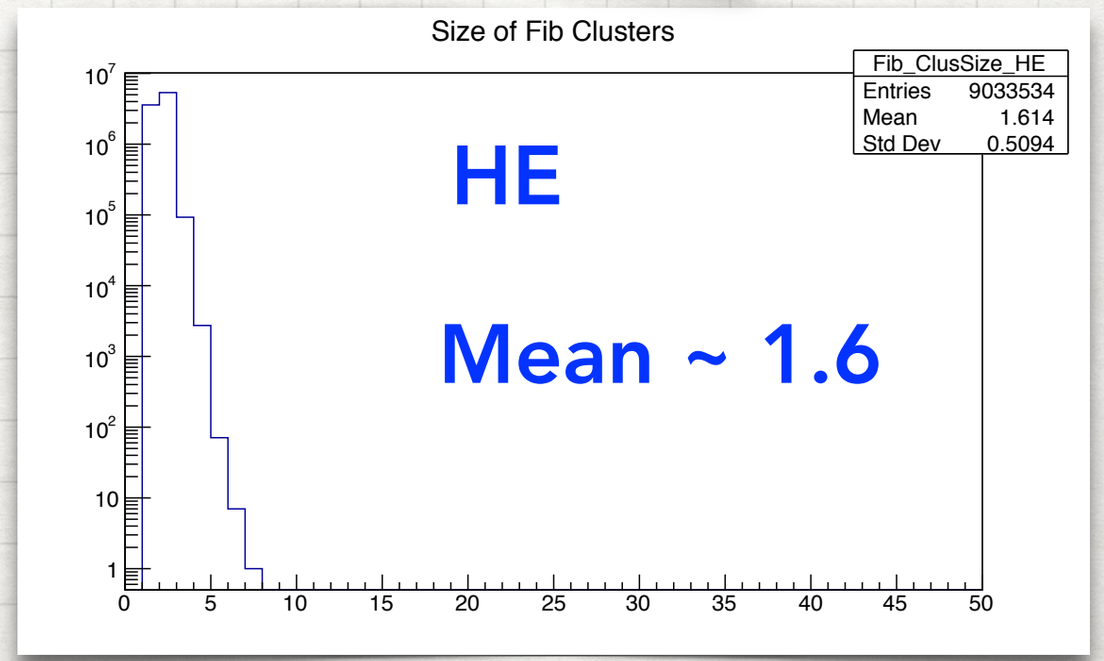




TRENTO Cluster Size

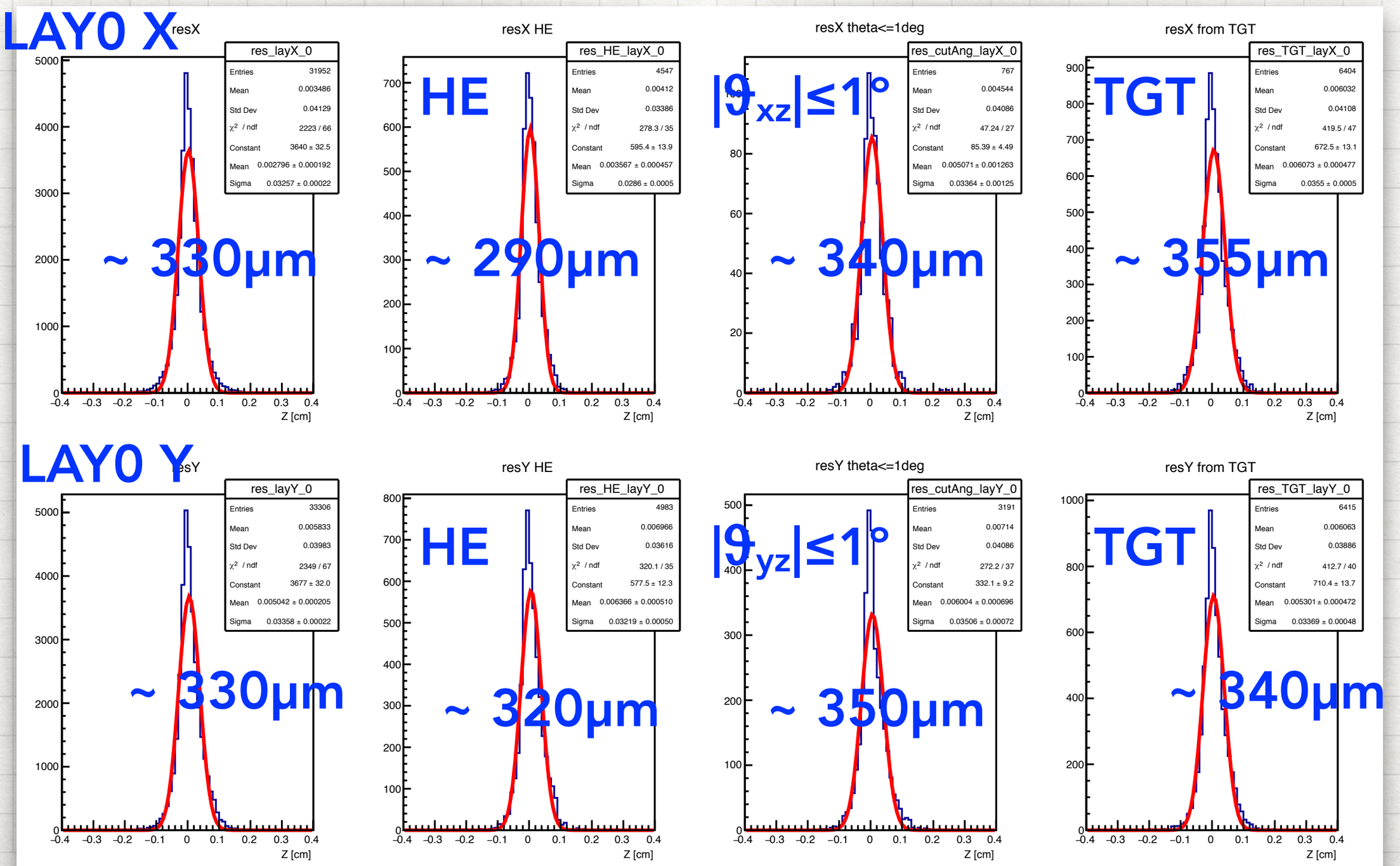






FLUKA Residuals

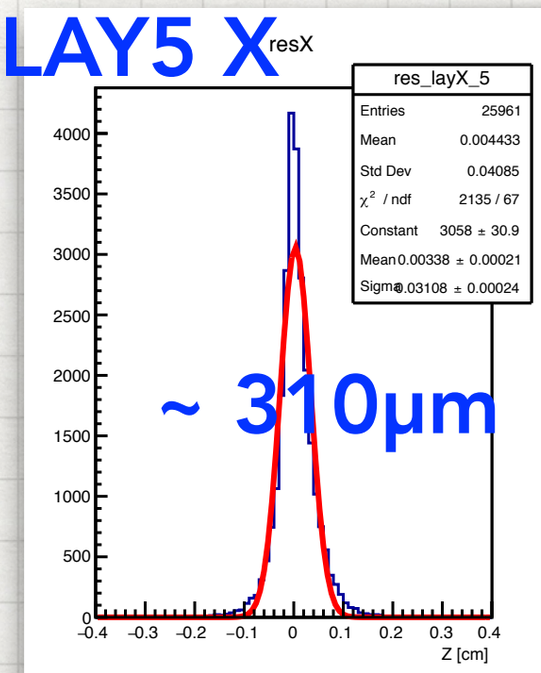
XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)

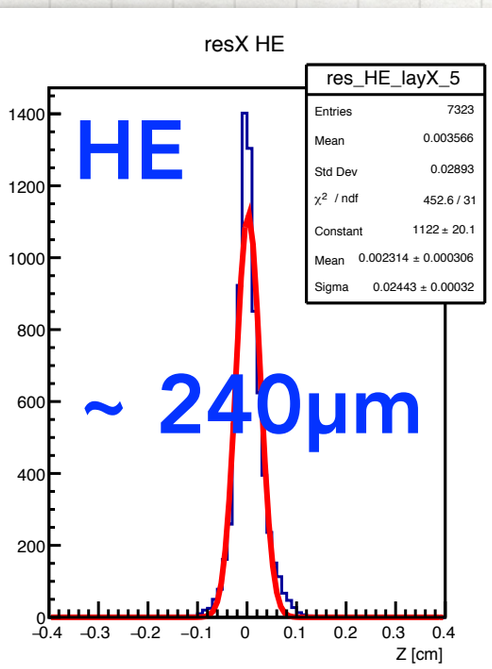


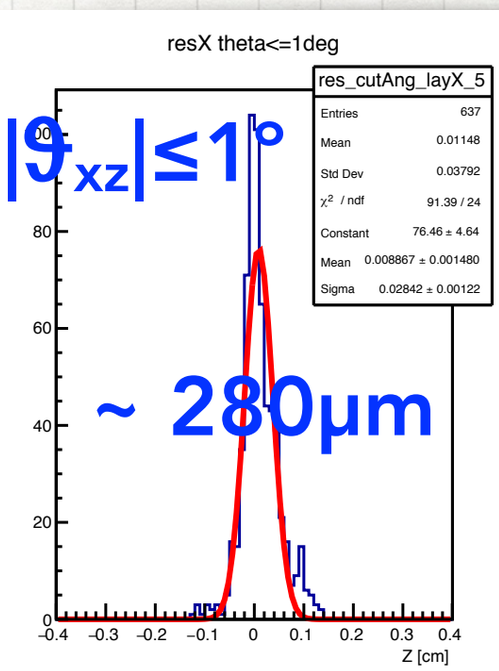
FLUKA Residuals

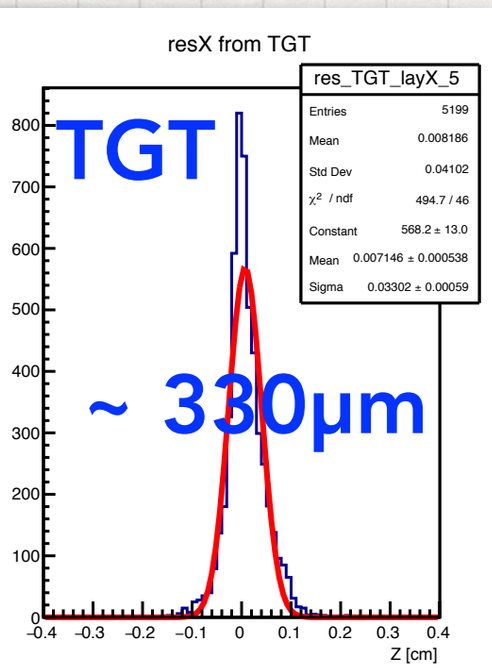
XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)

LAY5 X

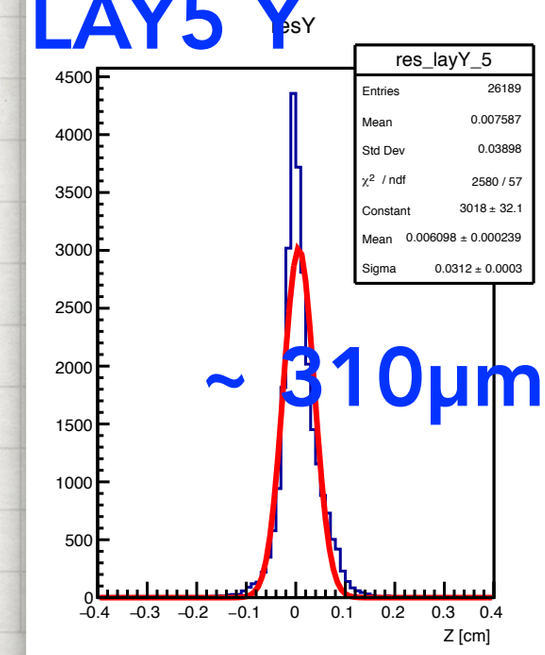


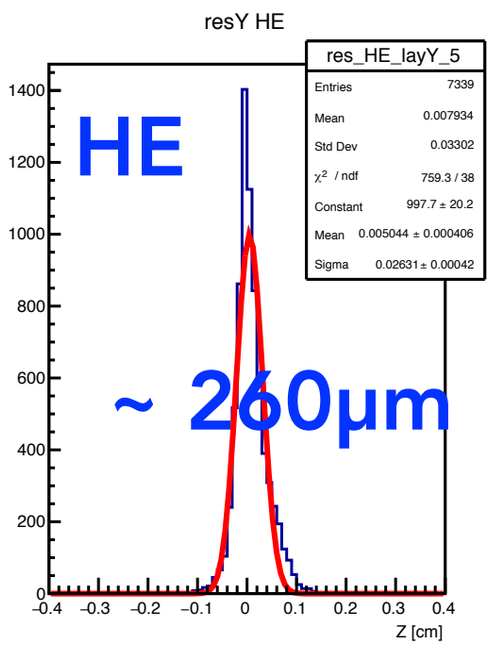


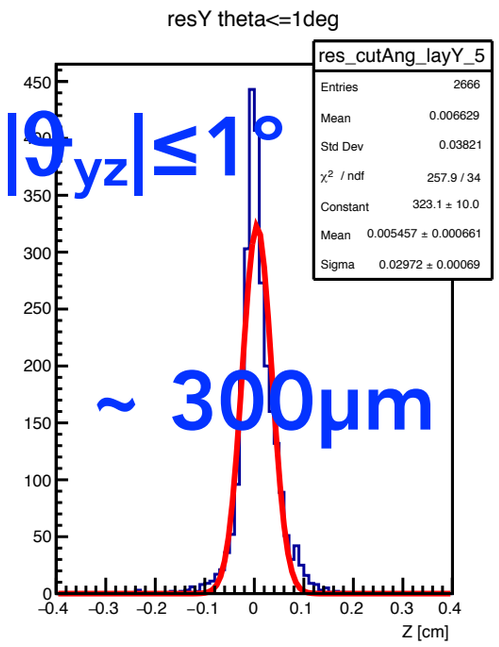


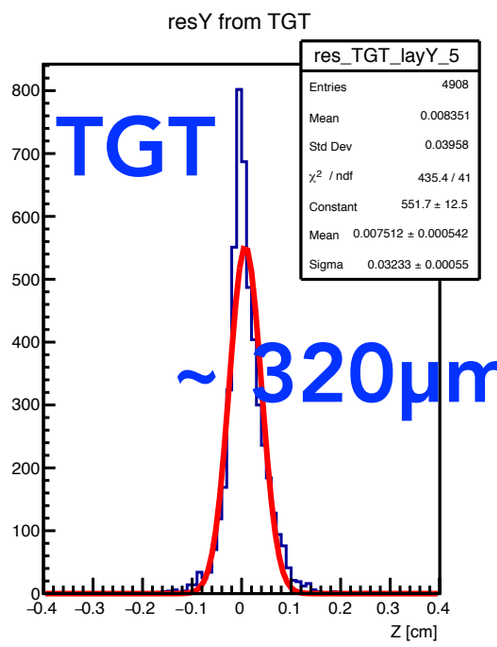


LAY5 Y



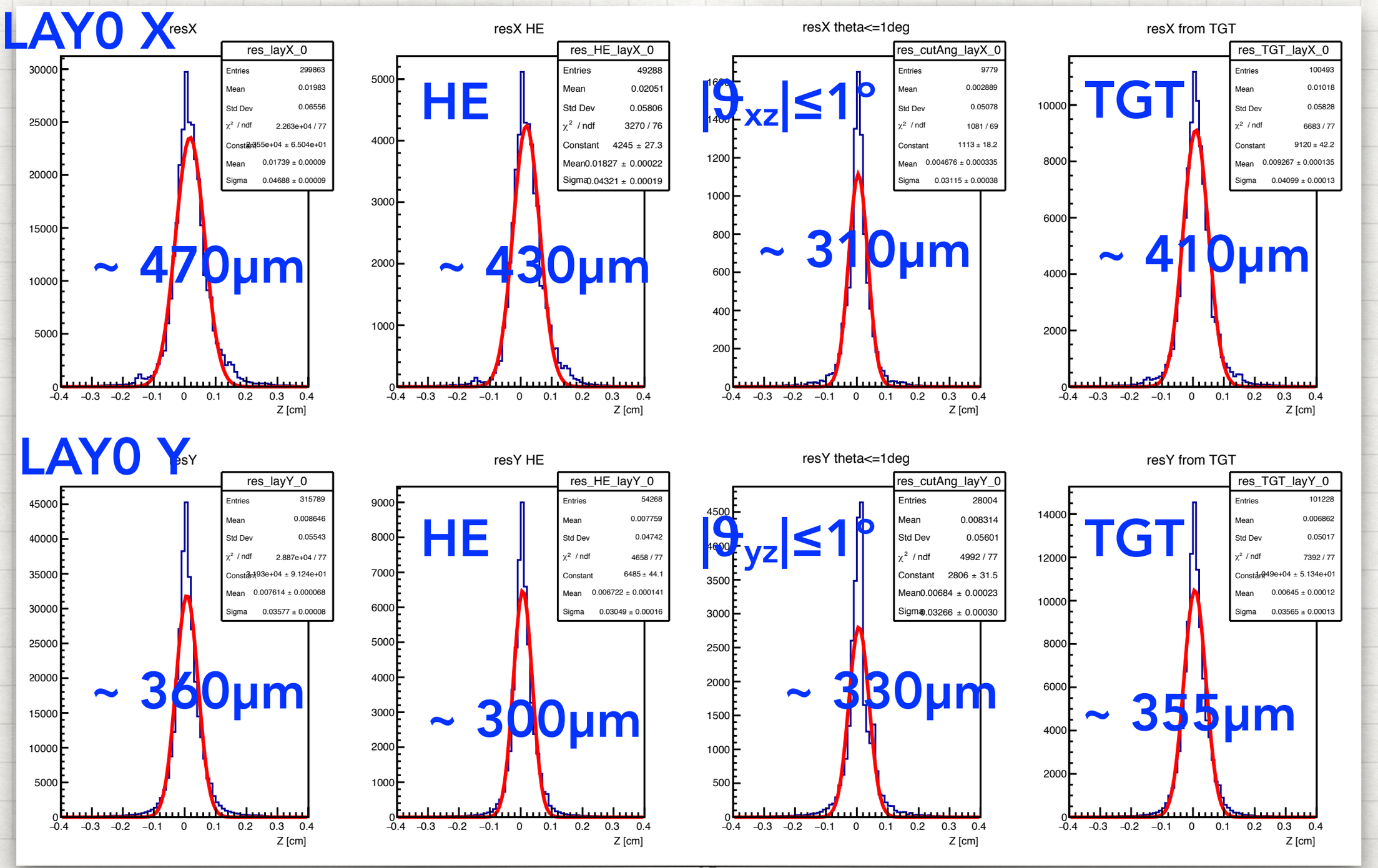






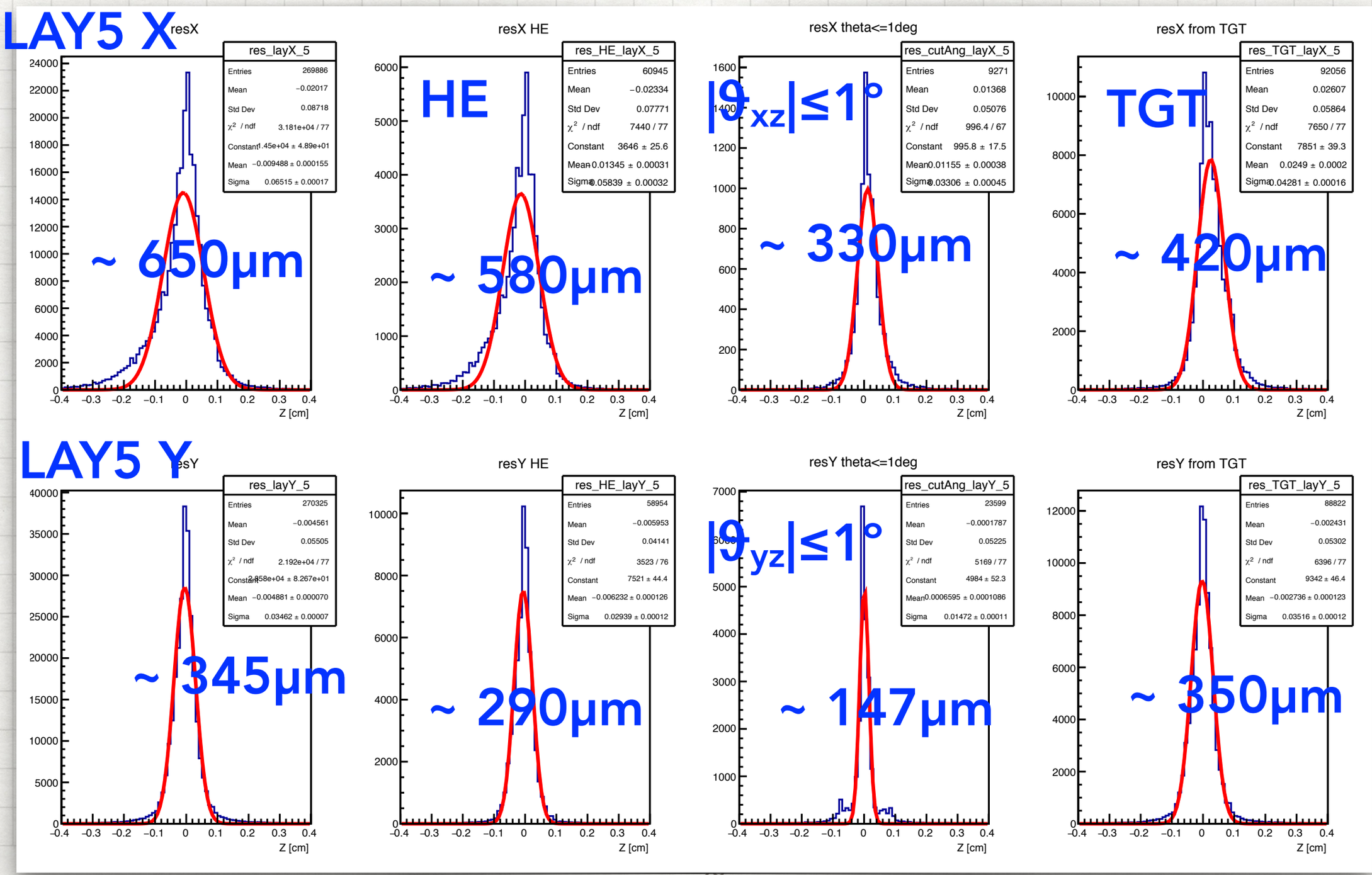
CNAO Residuals

XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)



CNAO Residuals

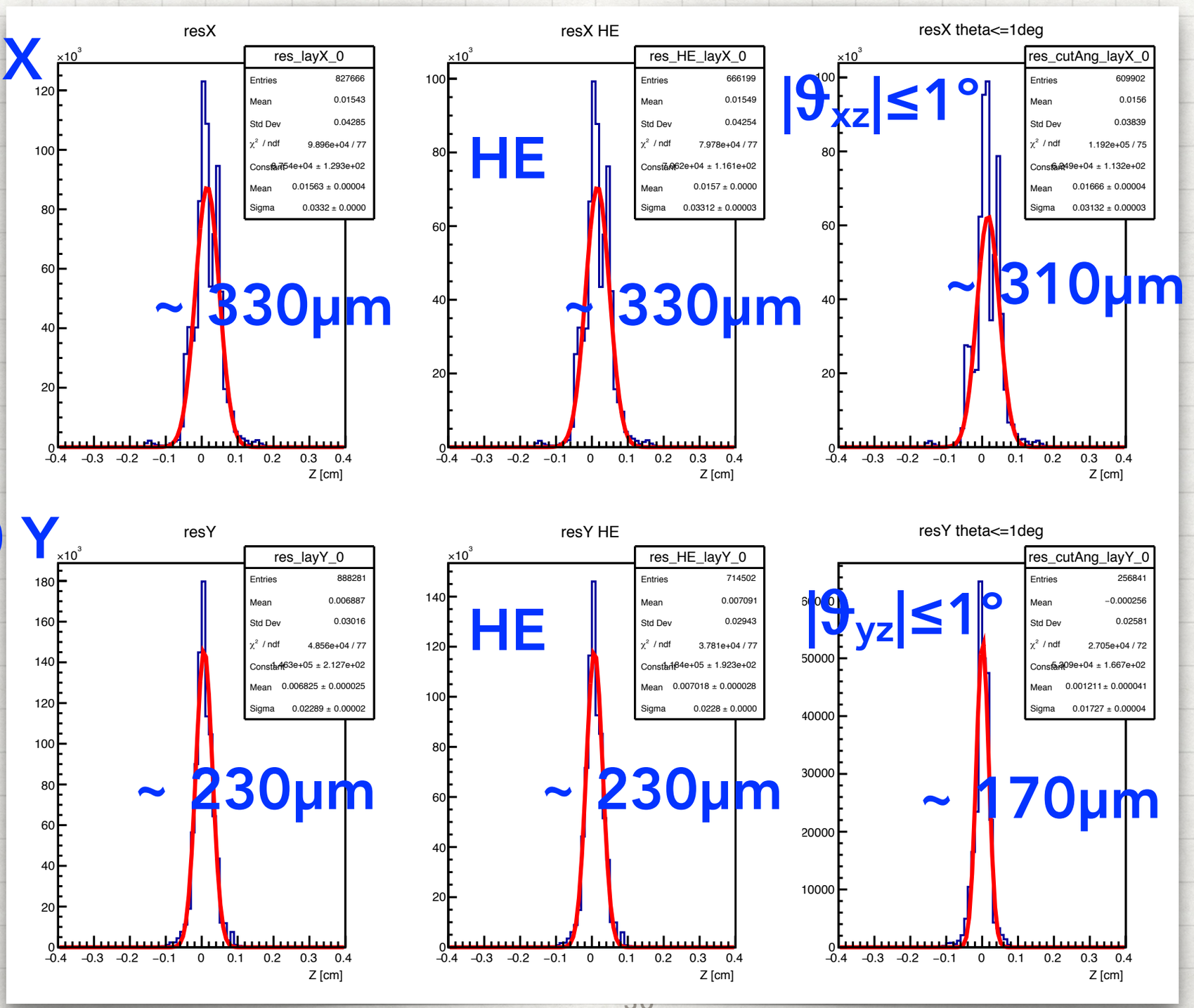
XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)



Trento Residuals

XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)

LAY0 X

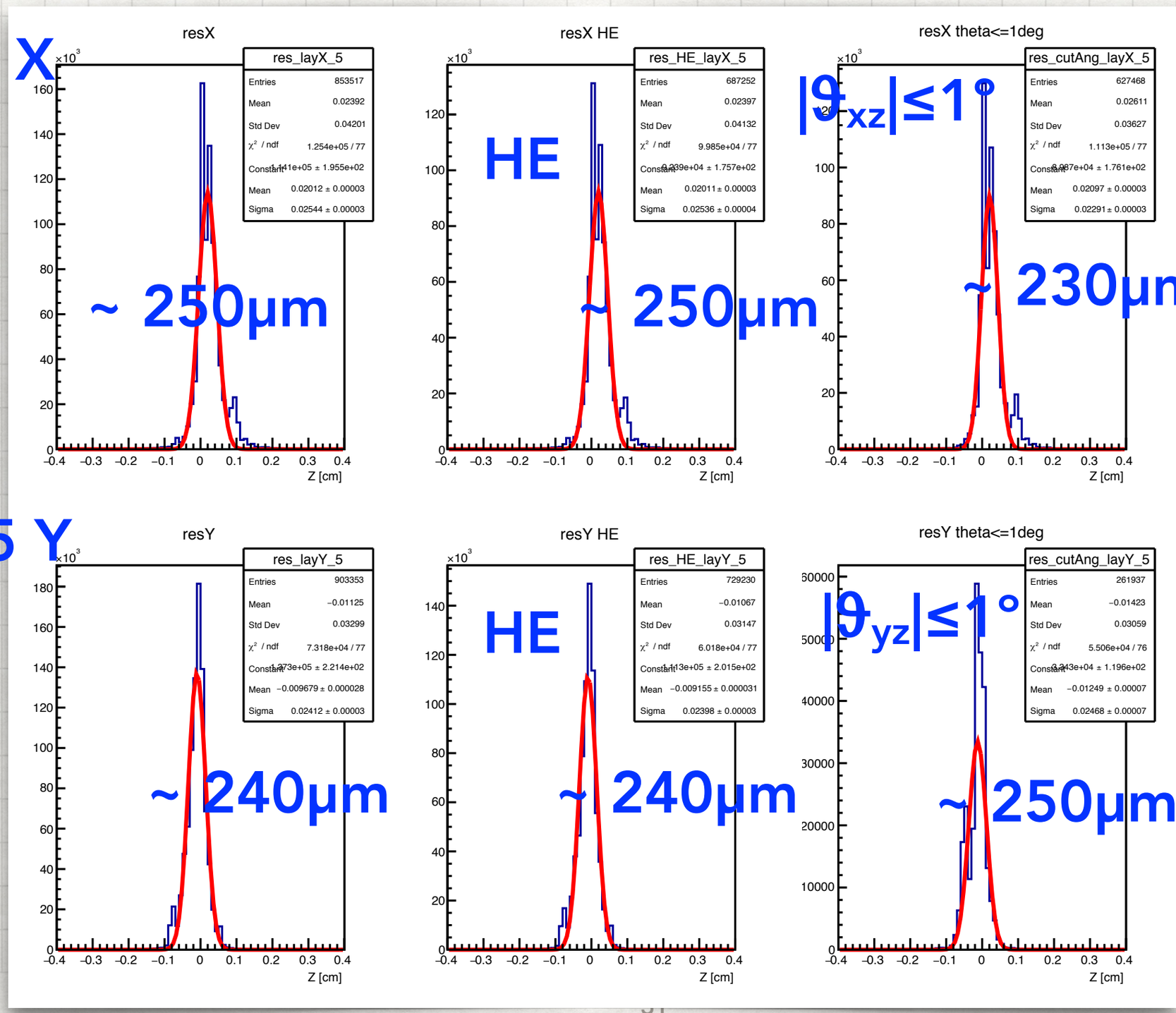


LAY0 Y

Trento Residuals

XClusterMeas - XClusterFit (= ZClusterMeas * Axz + Bxz)

LAY5 X



LAY5 Y

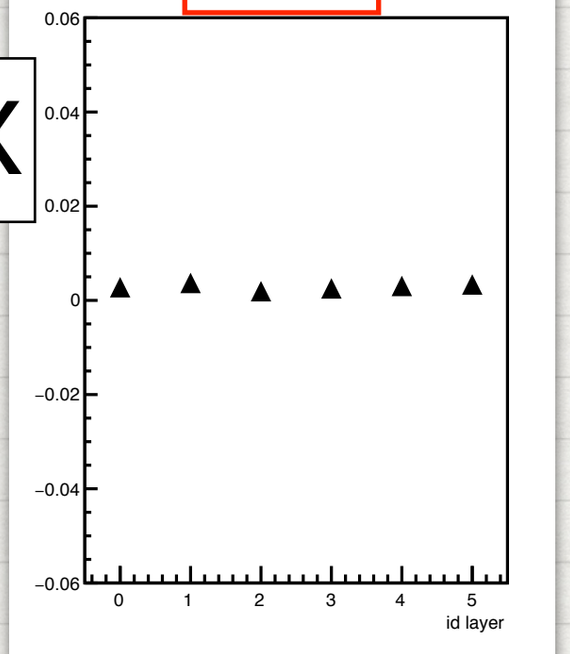
Mean of Residuals (cm) vs IDLay

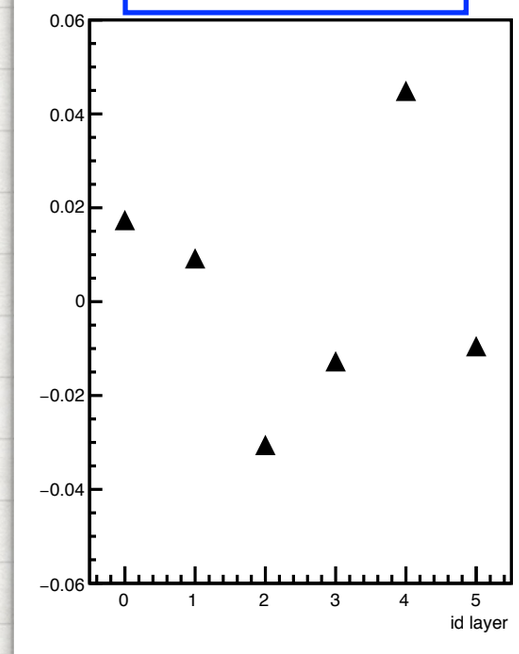
MC

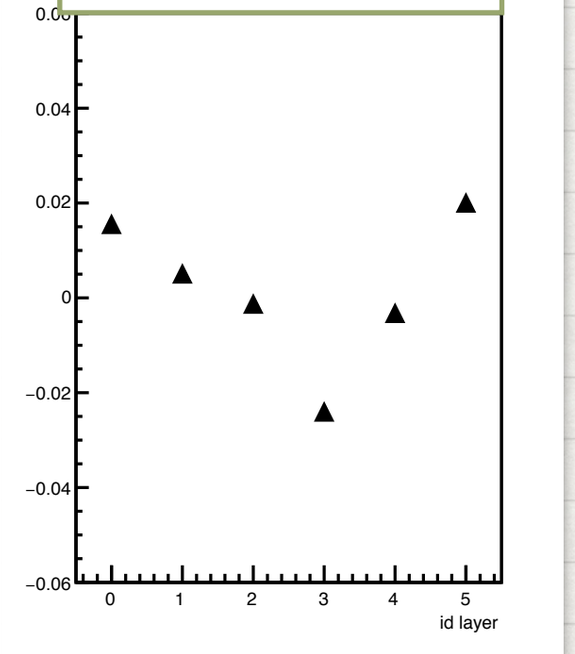
CNAO

TRENTO

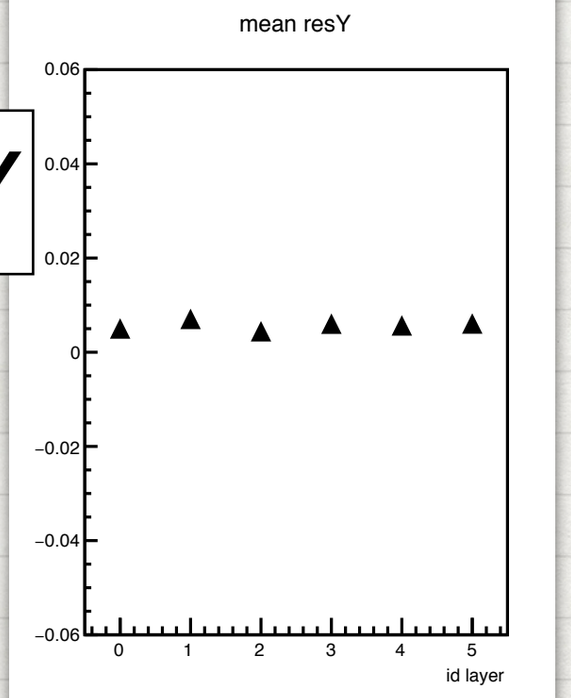
resX

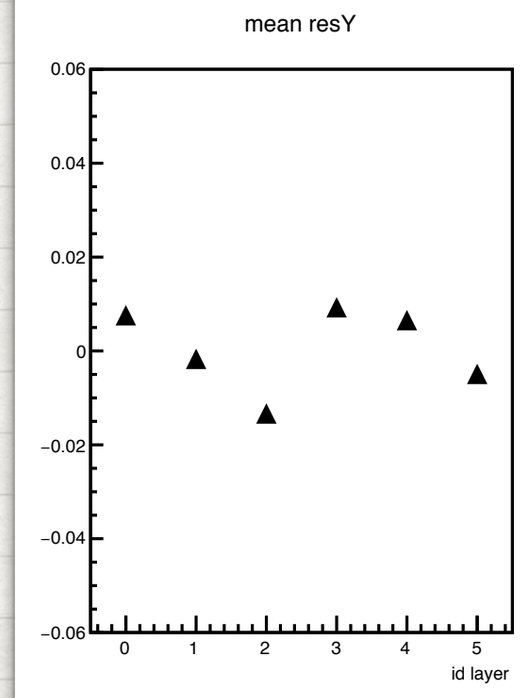


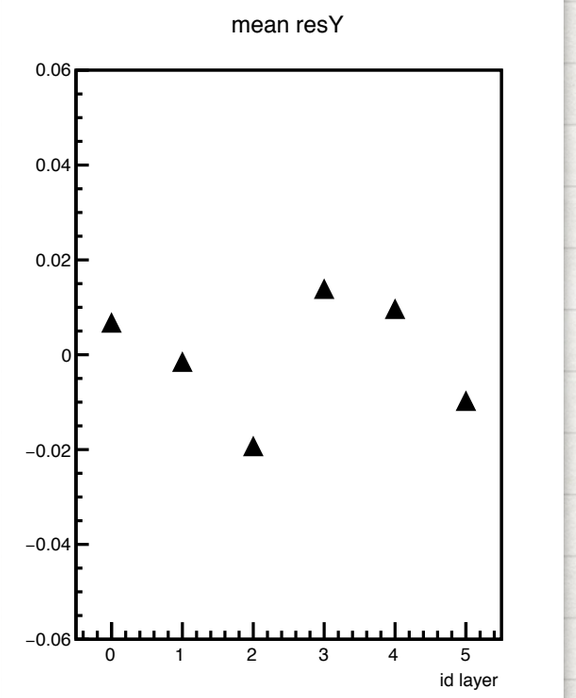




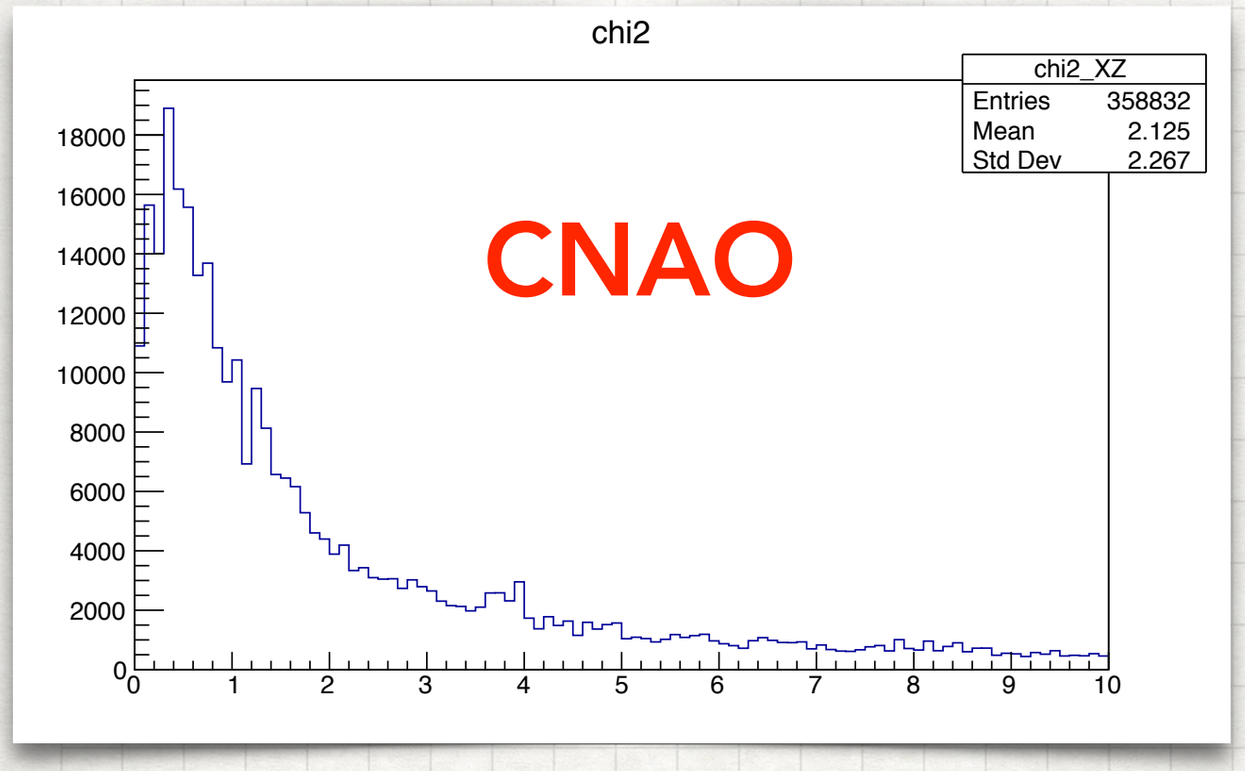
resY

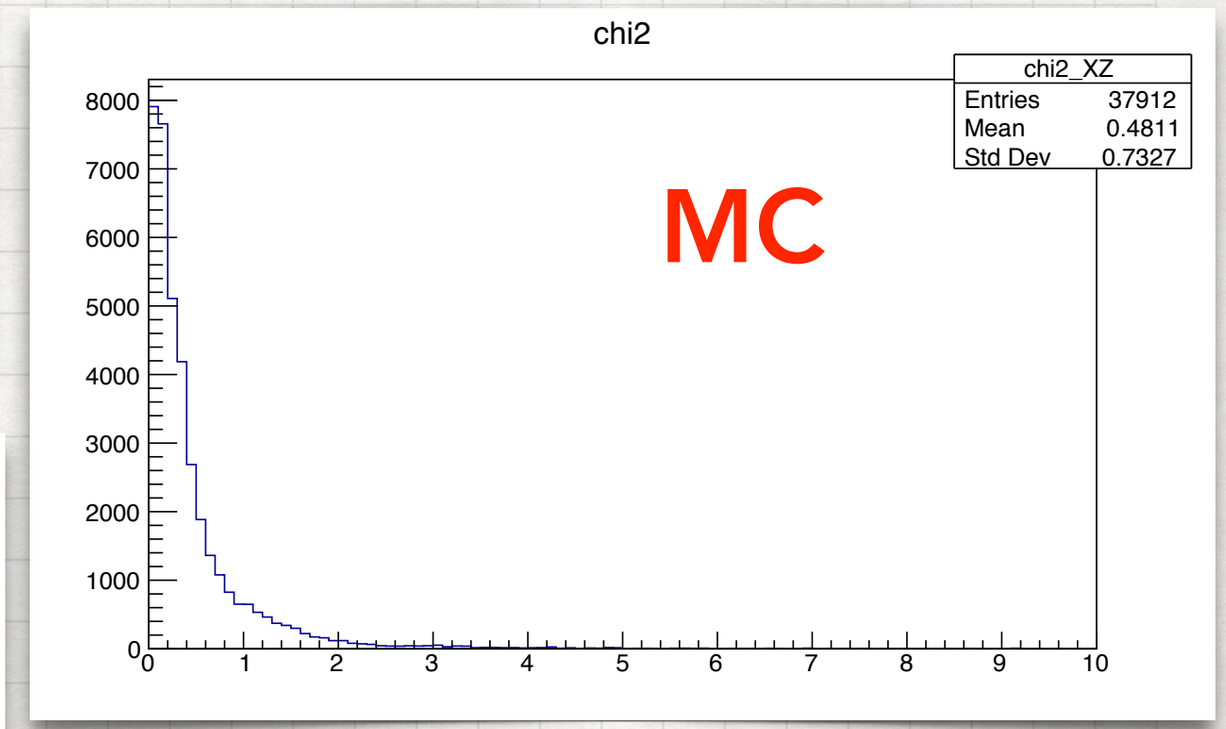


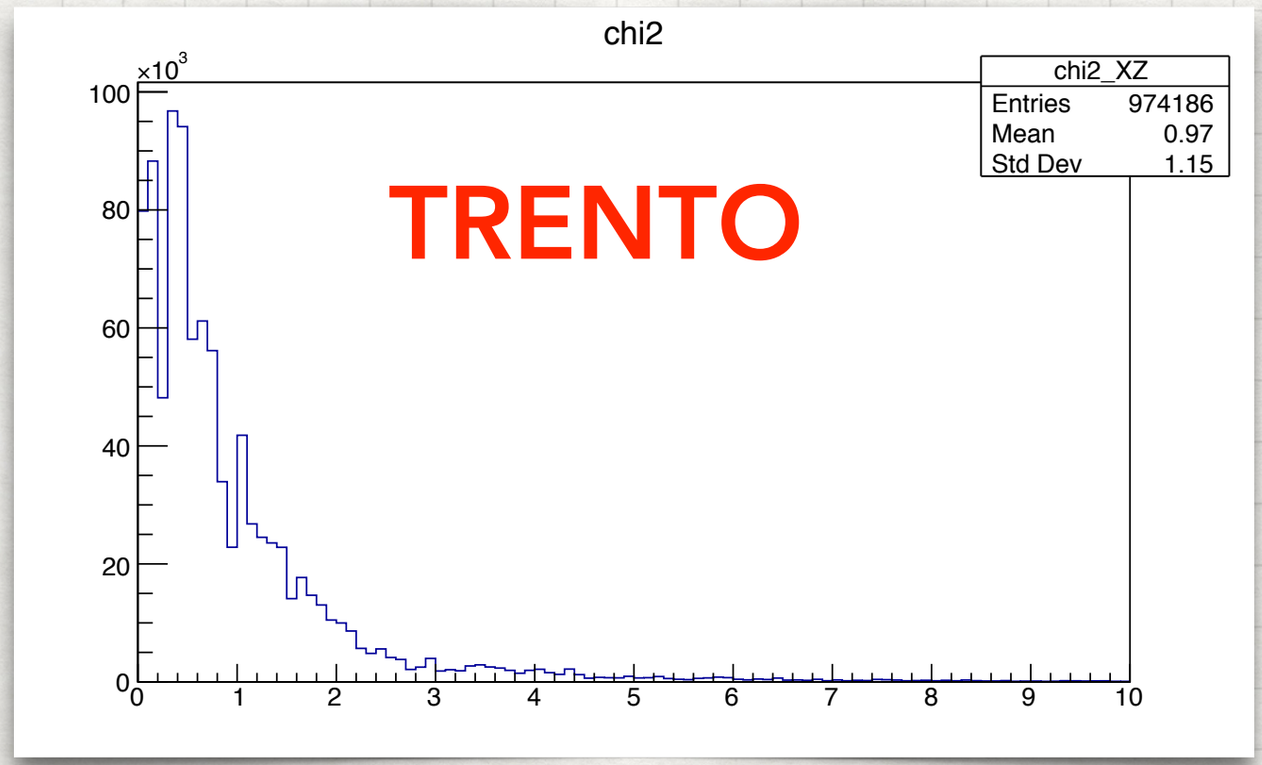




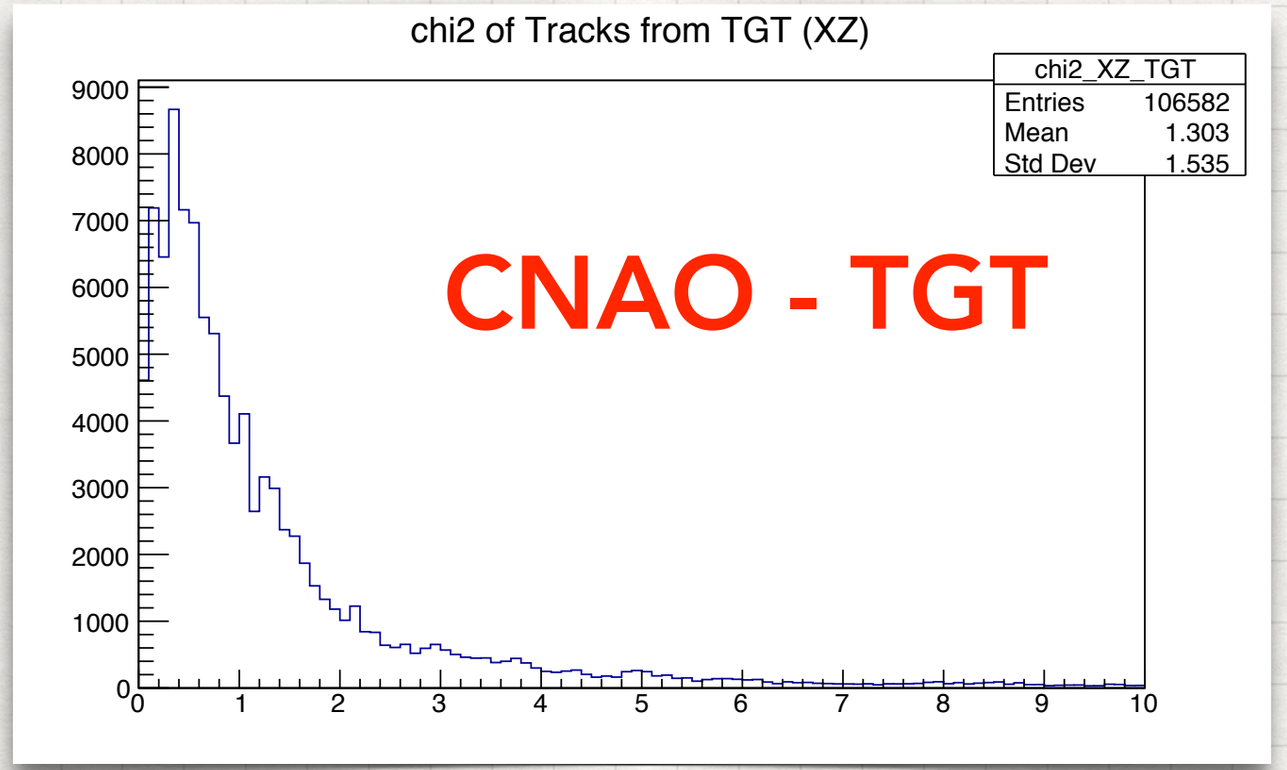
Chi2 XZ VIEW

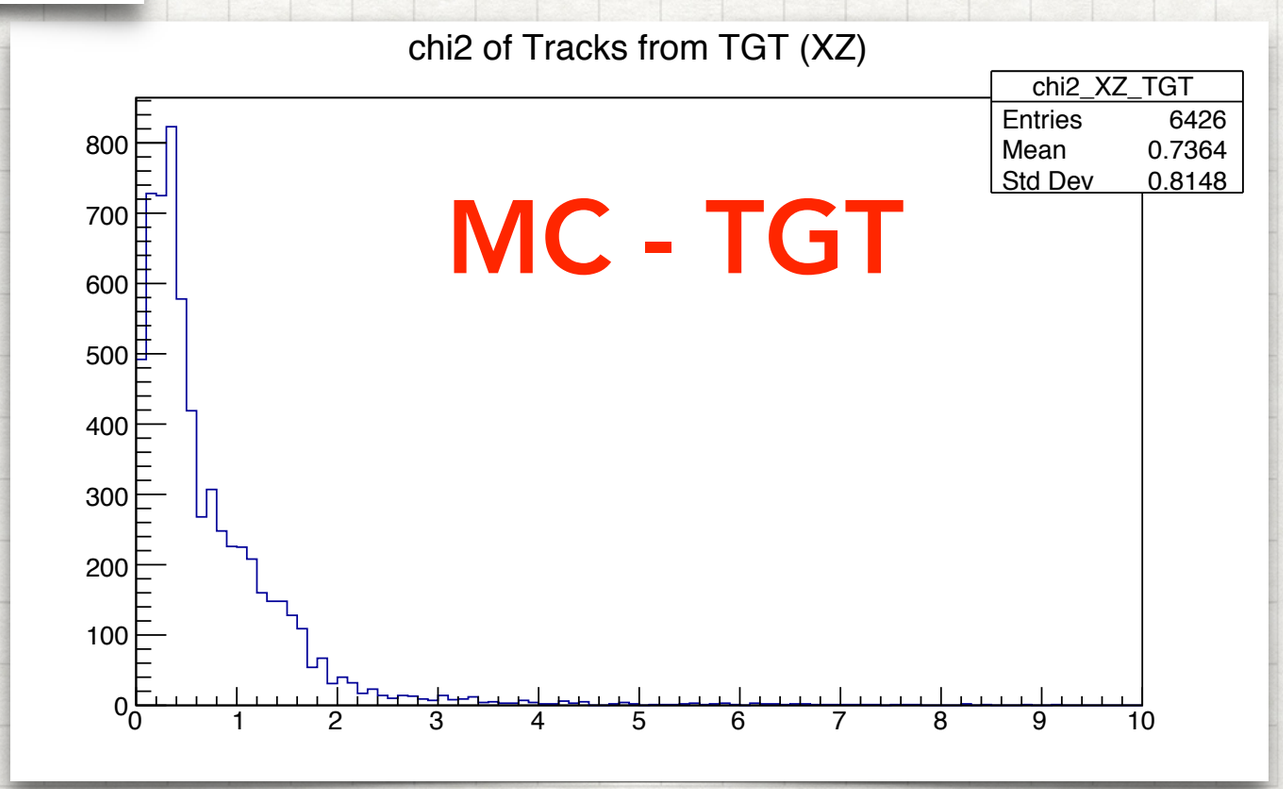

chi2
chi2_XZ
Entries 358832
Mean 2.125
Std Dev 2.267
CNAO


chi2
chi2_XZ
Entries 37912
Mean 0.4811
Std Dev 0.7327
MC

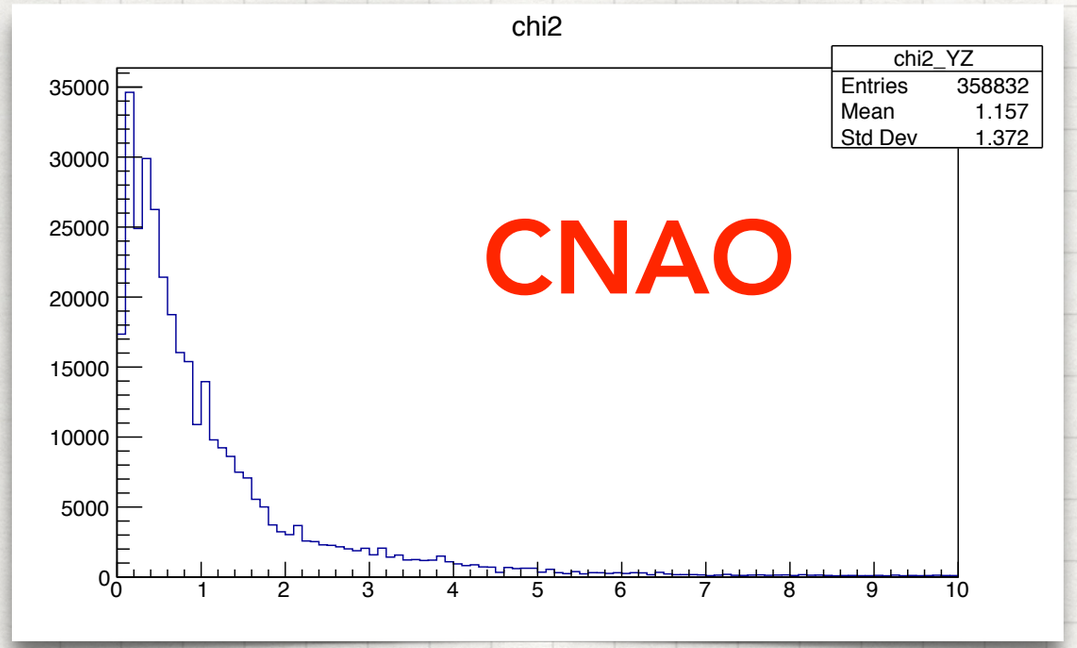

chi2
chi2_XZ
Entries 974186
Mean 0.97
Std Dev 1.15
TRENTO

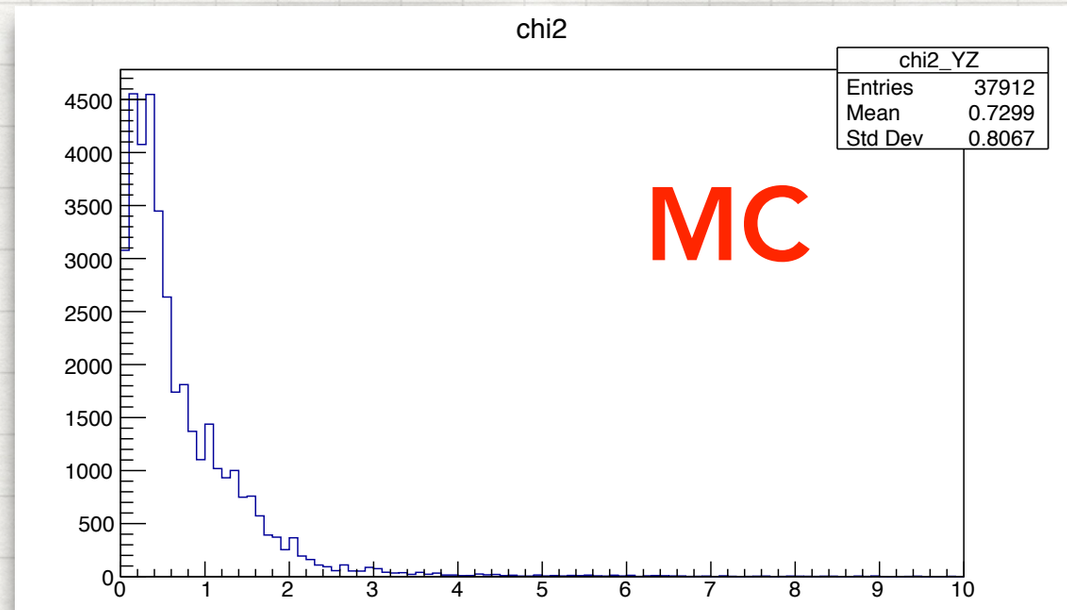
Chi2 XZ VIEW

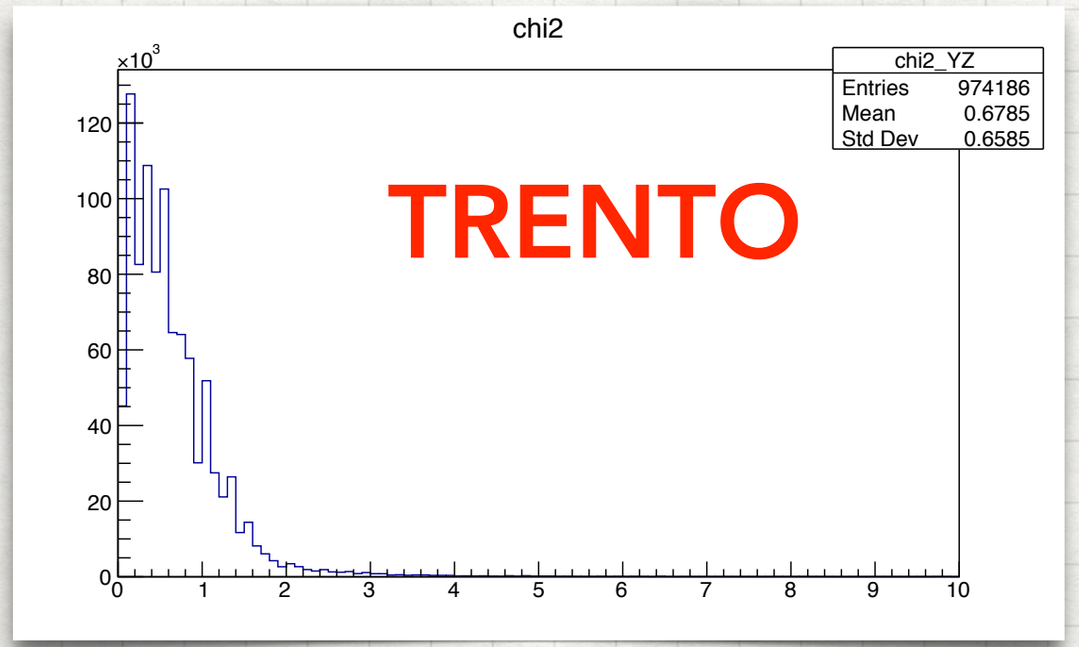

chi2 of Tracks from TGT (XZ)
chi2_XZ_TGT
Entries 106582
Mean 1.303
Std Dev 1.535
CNAO - TGT
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10


chi2 of Tracks from TGT (XZ)
chi2_XZ_TGT
Entries 6426
Mean 0.7364
Std Dev 0.8148
MC - TGT
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10

Chi2 YZ VIEW


chi2
chi2_YZ
Entries 358832
Mean 1.157
Std Dev 1.372
CNAO


chi2
chi2_YZ
Entries 37912
Mean 0.7299
Std Dev 0.8067
MC


chi2
chi2_YZ
Entries 974186
Mean 0.6785
Std Dev 0.6585
TRENTO

cluster vs layer