Track Fitting algorithm 1 and performance

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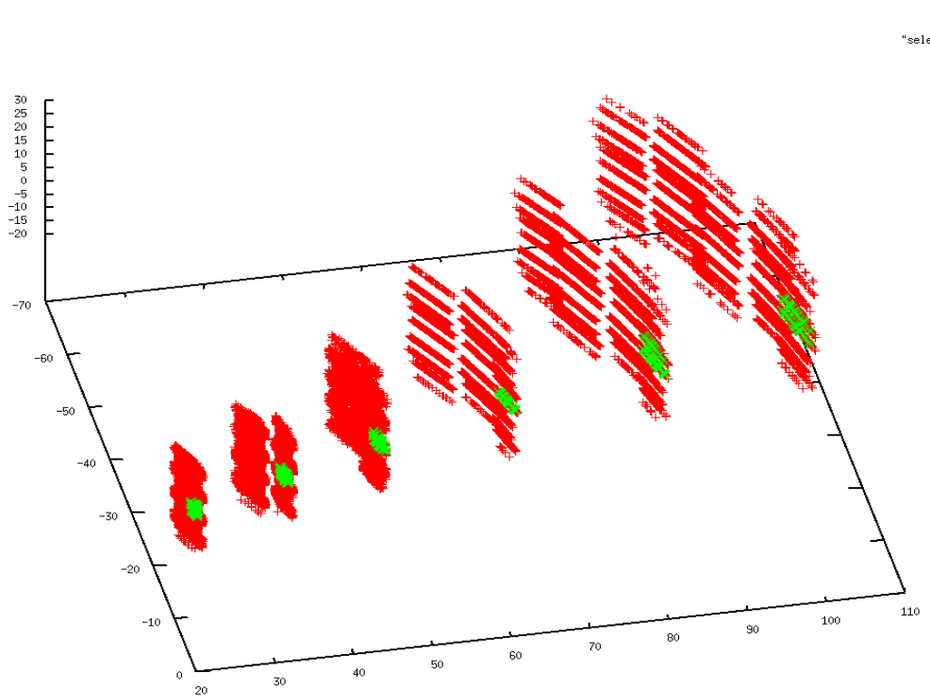
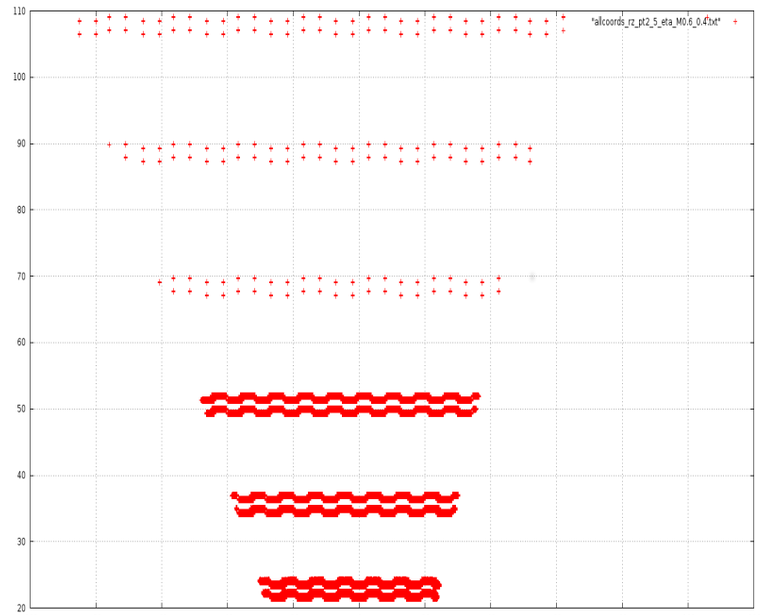
PCA problem

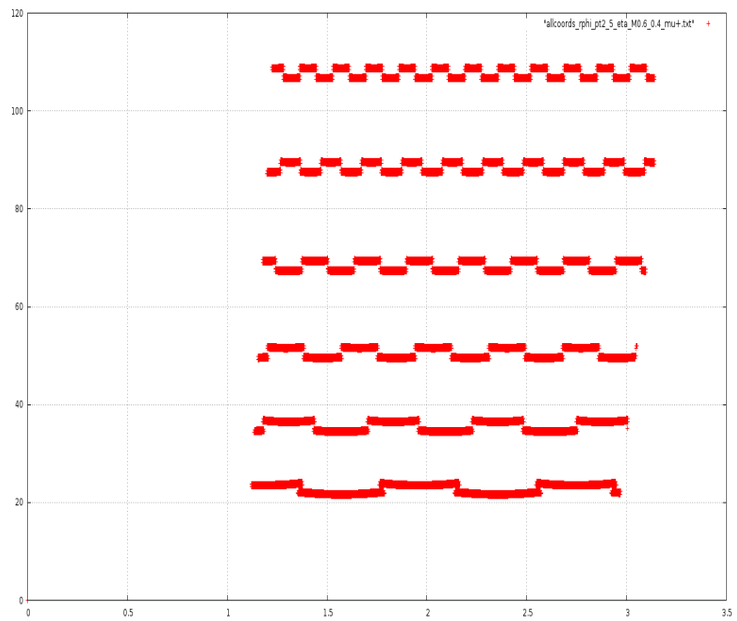


r-Φ plane



- The problem is divided now in two subproblems:
  1. **plane r-z** ➙ from (r_i, z_i), where i is the referred to the stubs, we find the two parameters of the track: **z_0 and η ($\cot(\theta)$)**
  2. **plane r-ϕ** ➙ from (r_i, ϕ_i), where i is the referred to the stubs, we find the two parameters of the track: **c/p_T and ϕ**, where c is the charge
- For **plane r-ϕ**, there are 12 coordinates = 2 coordinates x 6 layers ➙ **12 stub coordinates and 2 track parameters**
- For **plane r-z**, there are 6 coordinates = 2 coordinates x 3 layers ➙ **6 stub coordinates and 2 track parameters (only PS-modules are used)**

r-z plane



Generation and code

- The generation has been performed using the following framework: http://sviret.web.cern.ch/sviret/Welcome.php?n=CMS.HLLHCTuto620.
- The **code for the PCA method that we are developing** can be found here: https://github.com/lstorchi/pca_fit (moved from the original bitbucket repo) there is also a wiki page with the fundamental instructions to compile and use the code.

1. generatepca_split : to generate the needed PCA constant set (fitting and chi2)
2. fitpca_split : to perform the fitting (testing purpose)
3. CMSSW PCA fitter: the fitter has been integrated snd tested within CMSSW_6_2_0_SLHC27 branch
4. Full set of PCA constant for the whole barrel towers both 6 out of 6 and 5 out of 6.

$$p_i \sim \sum_j A_{ij} x_j + q_i$$

i is the index of the parameters,
i= 1,2

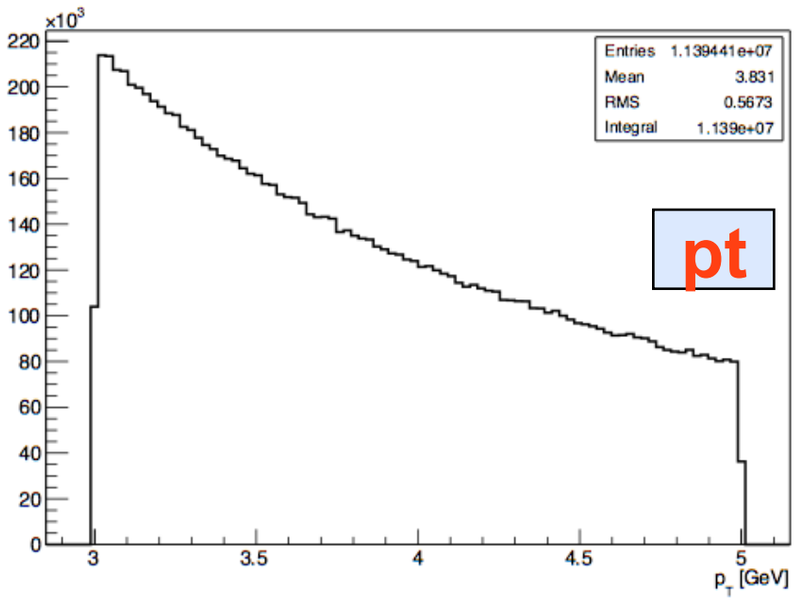
j is the index of the stub coordinates,
j= 1,2,...,12

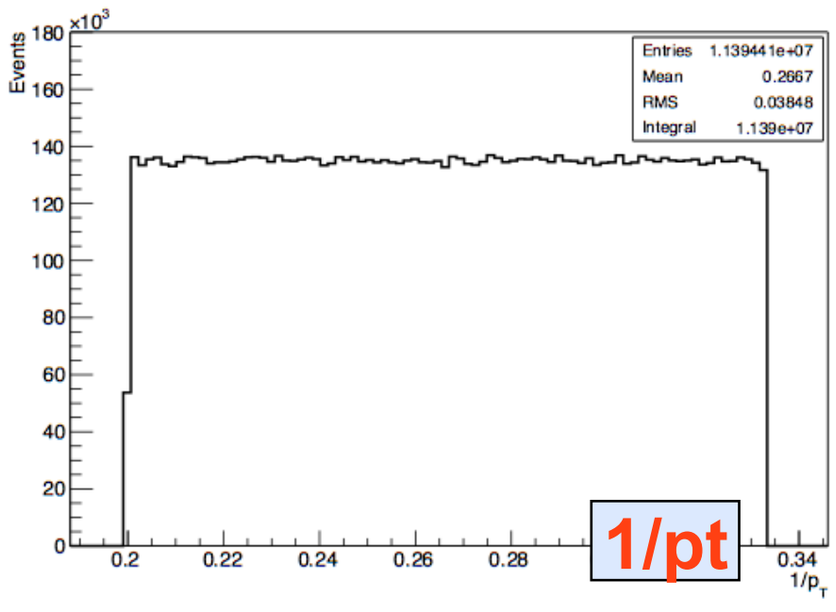
Results Barrel Towers

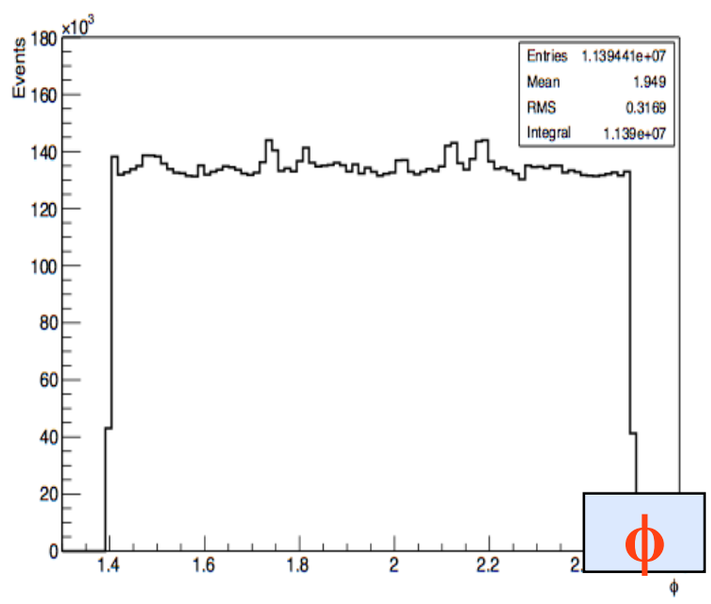
Generation

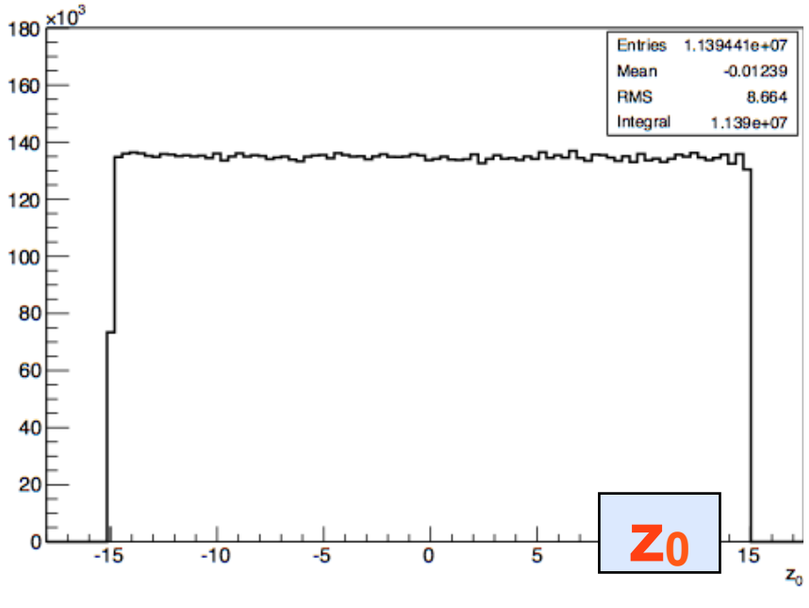
1 dataset for each Tower has been generated:

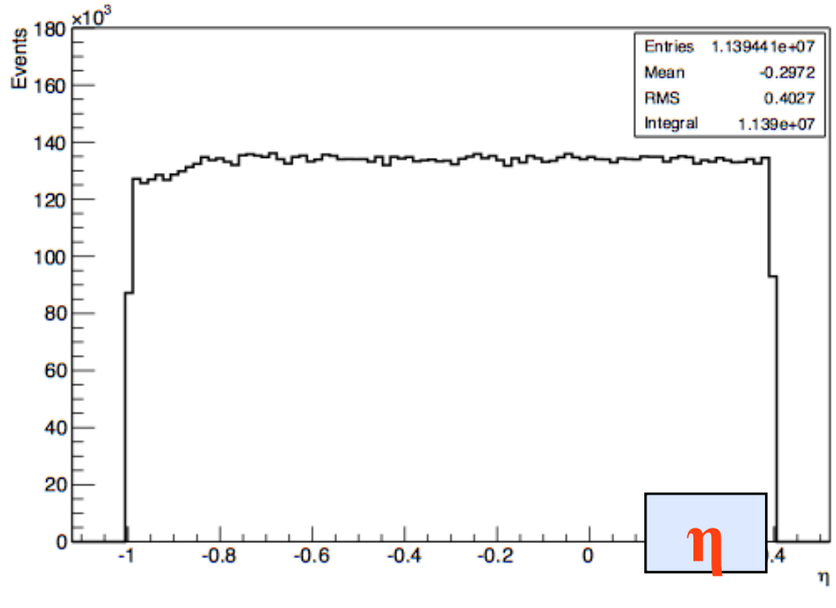
- ~20M of events per sample
- **pt** → {2, 200} GeV

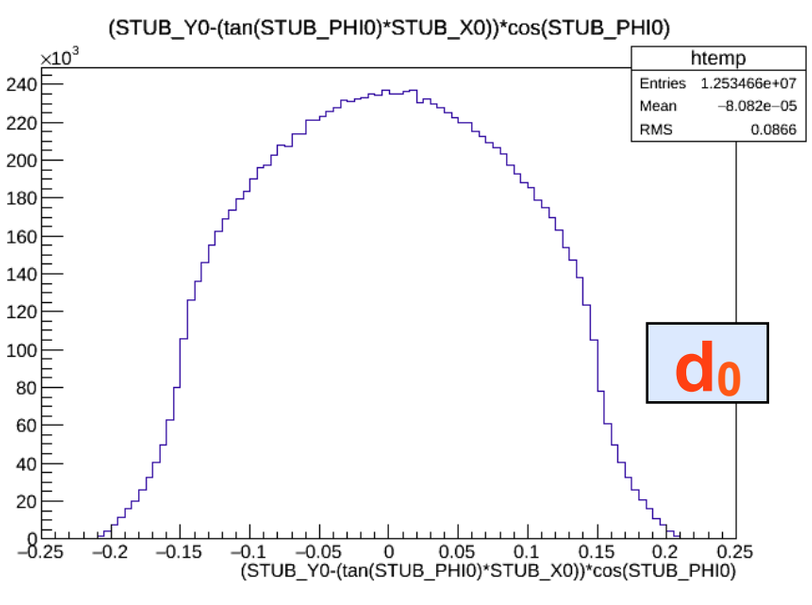












Trigger Towers

48 towers configuration, we are reporting results only for the **16 barrel towers** (6 layers)

Tower ID	η min	η mx	ϕ min	ϕ max
16	-0.6	0.4	-0.5	1.3
17	-0.6	0.4	0.3	2.1
18	-0.6	0.4	1.1	2.9
19	-0.6	0.4	1.9	3.7
20	-0.6	0.4	2.7	4.5
21	-0.6	0.4	-2.9	-1.1
22	-0.6	0.4	-2.1	-0.3
23	-0.6	0.4	-1.3	0.5
24	-0.4	0.6	-0.5	1.3
25	-0.4	0.6	0.3	2.1
26	-0.4	0.6	1.1	2.9
27	-0.4	0.6	1.9	3.7
28	-0.4	0.6	2.7	4.5
29	-0.4	0.6	-2.9	-1.1
30	-0.4	0.6	-2.1	-0.3
31	e-0.4	0.6	-1.3	0.5

Plane rz

In the plane rz, we are using the following configuration:

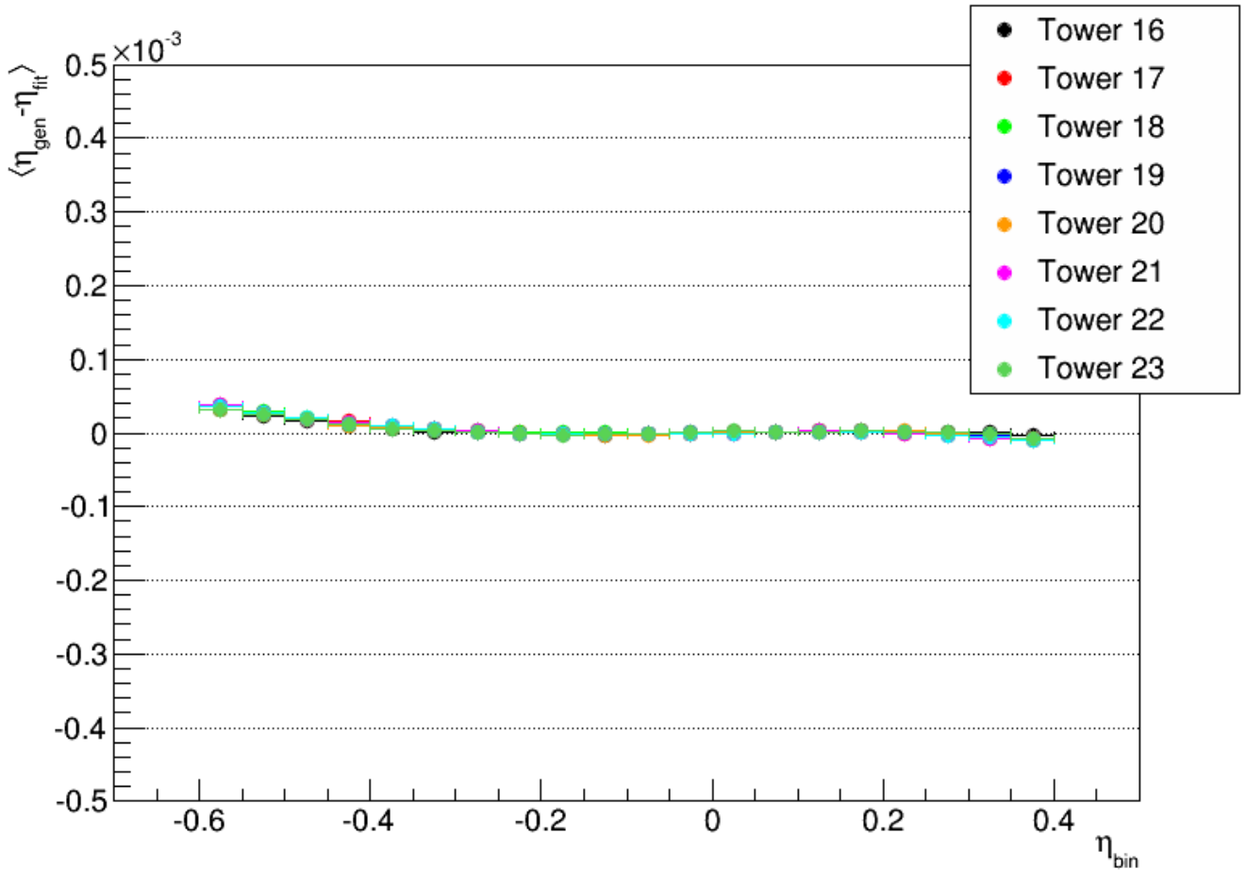
- **1 bin in pt**: [2, 200] GeV
- **20 bins in eta**: bins of **0.05**
- **1 bin in phi**
- The **2S-modules are excluded**, so that only the first three layers are considered (we are considering only 6 coordinates)

At the end, we have 20 sets of constants for each tower. 80 sets including also the 5 out of 6

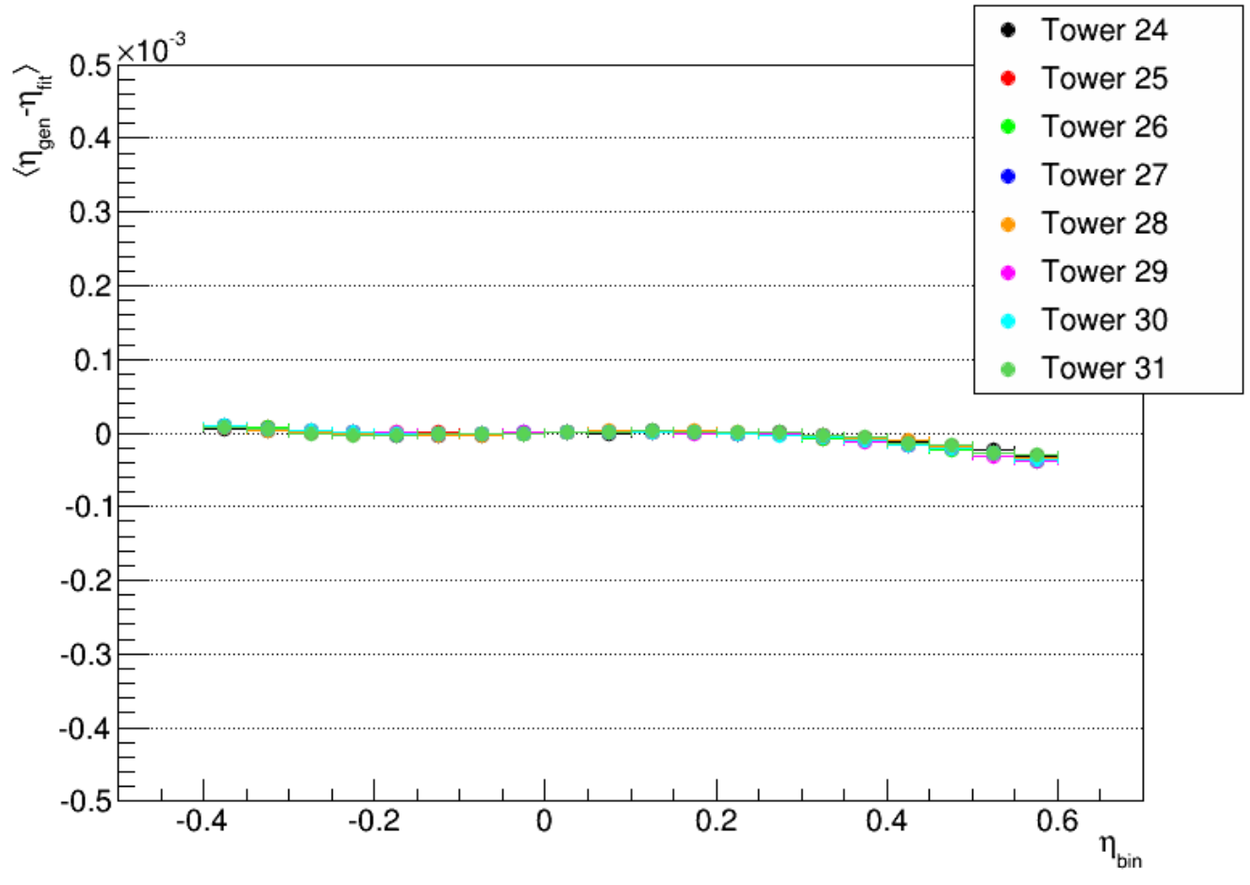
η results 6 out of 6: bias

- We have plotted the following variable: **[η(generated) - η(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** as a function of η for each tower (from 16 to 31)

η bias, **Tower from 16 to 23**



η bias, **Tower from 24 to 31**



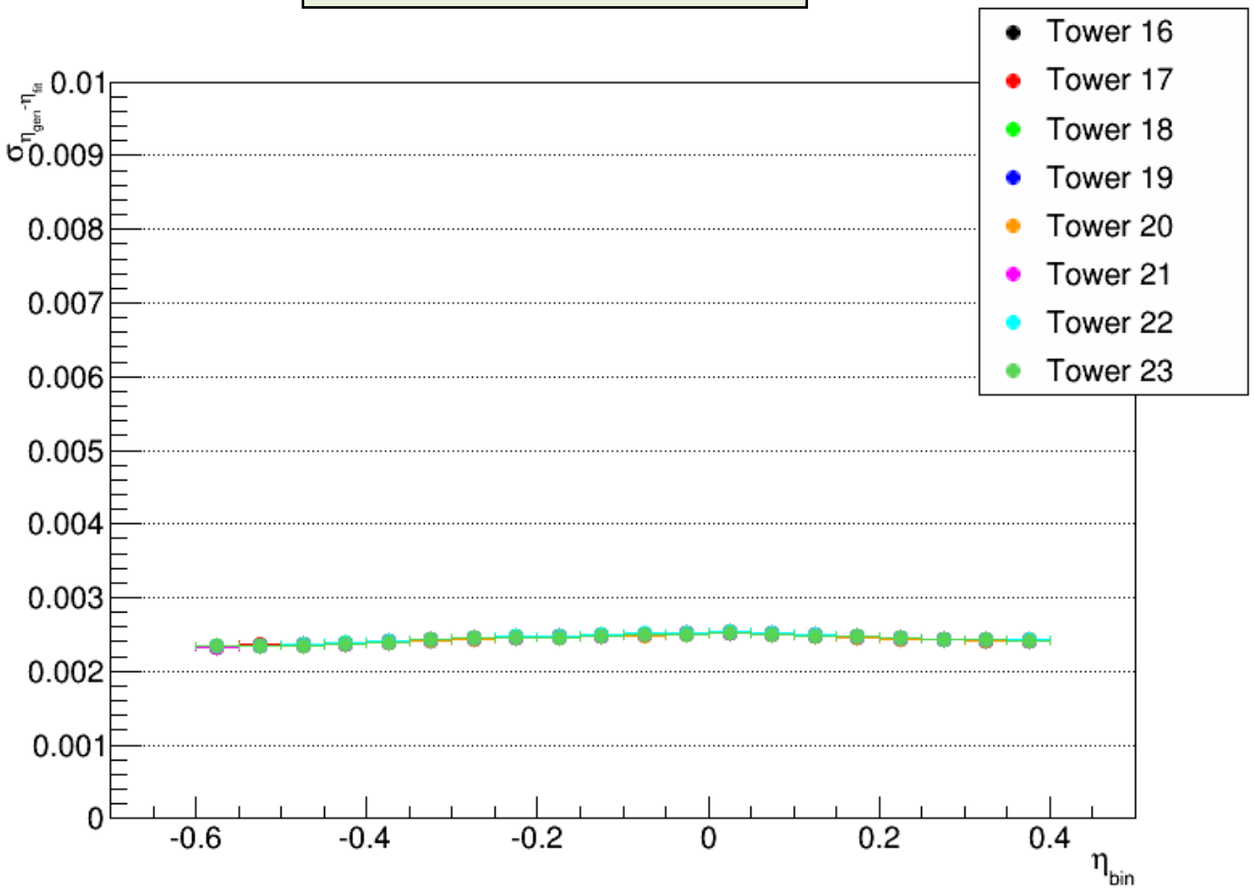
η results 6 out of 6: resolution

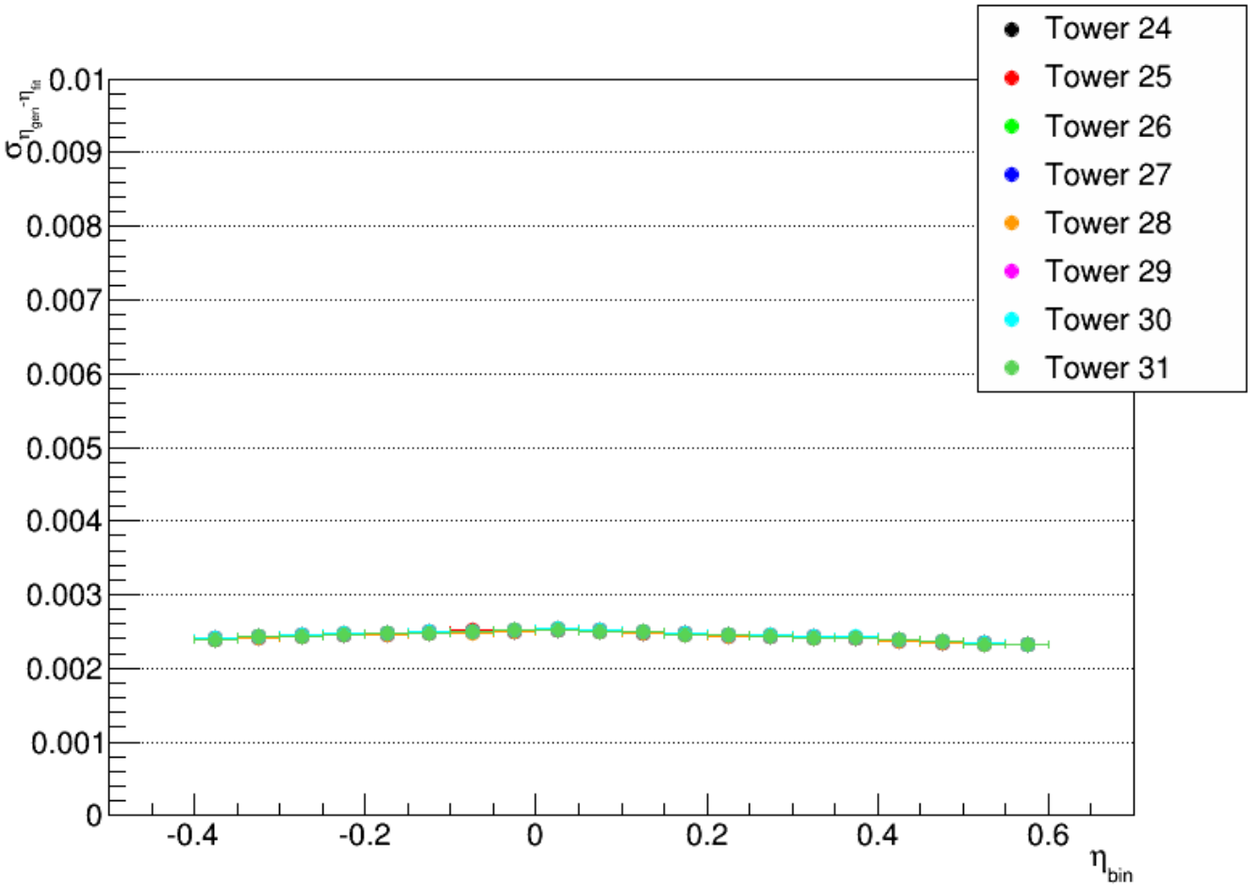
- We have plotted the following variable: **[η(generated) - η(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** as a function of η for each tower (from 16 to 31)

η resolution, **Tower from 16 to 23**

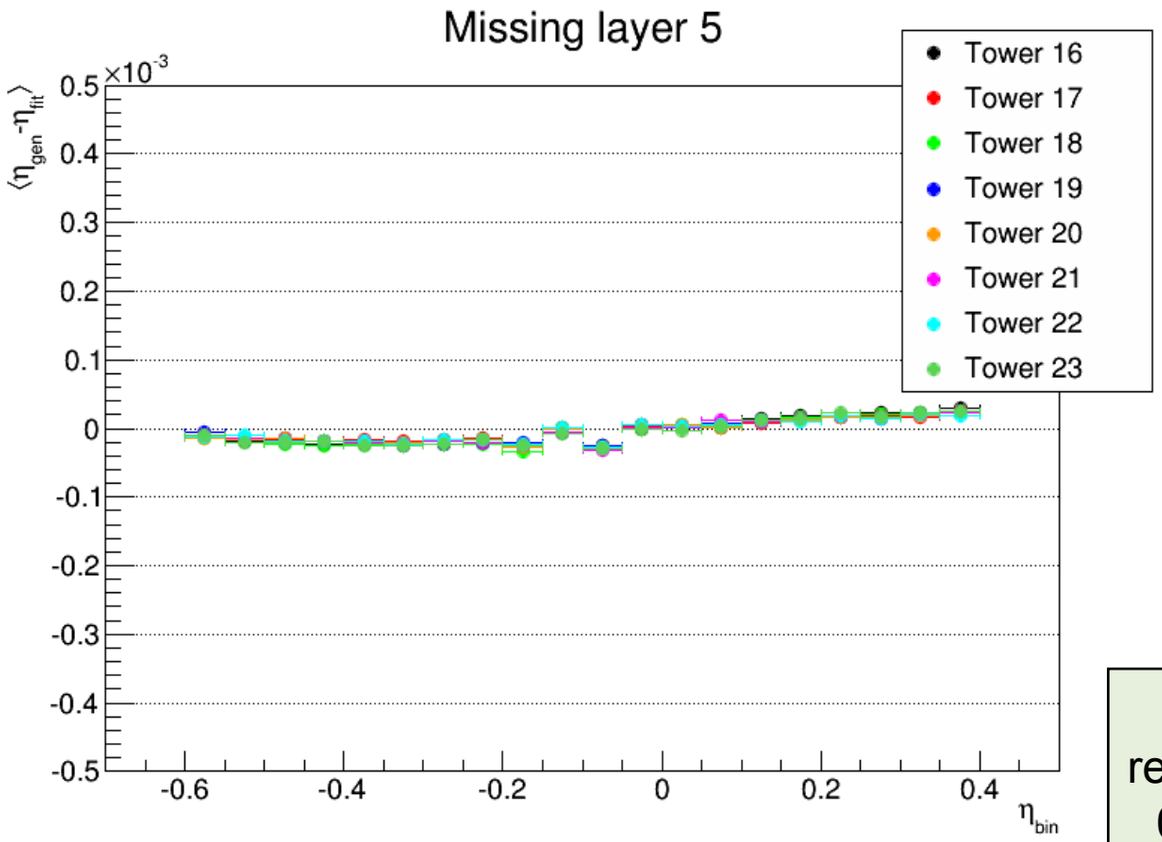
η resolution **0.0024**

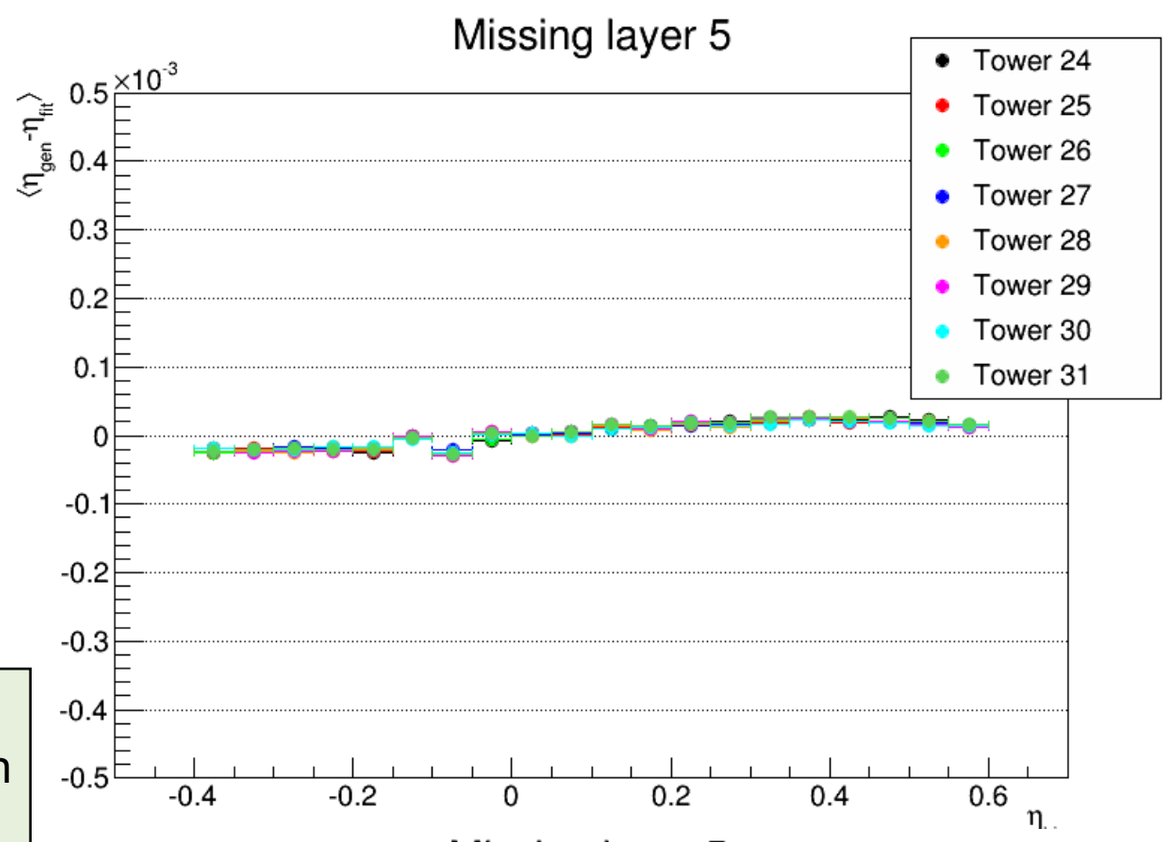
η resolution. **Tower from** 24 **to** 31



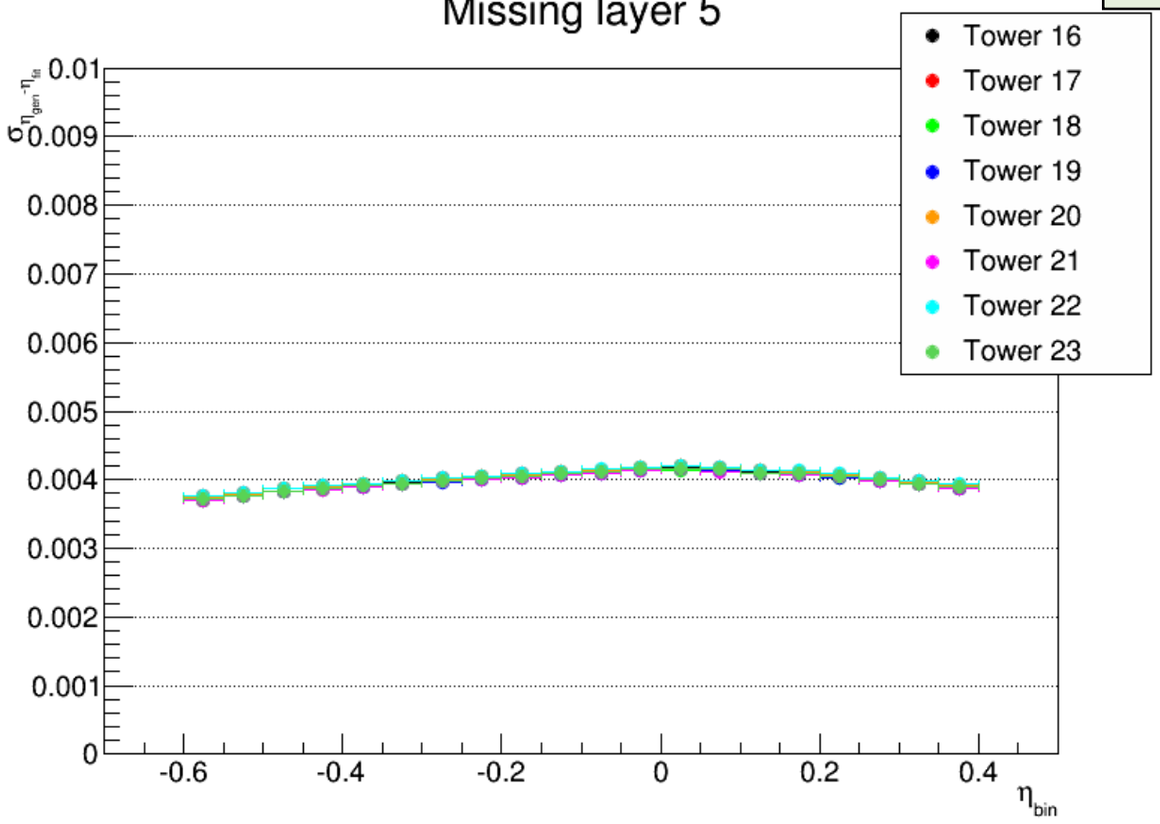


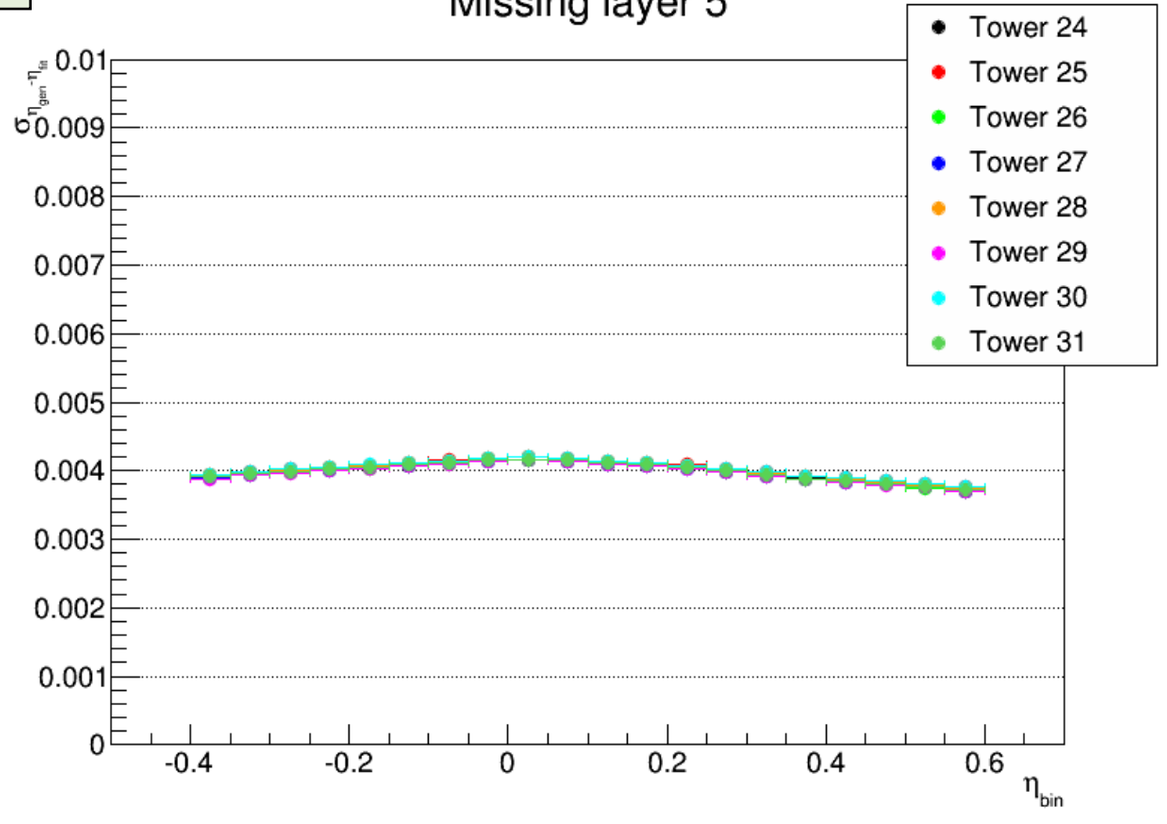
η results 5 out of 6



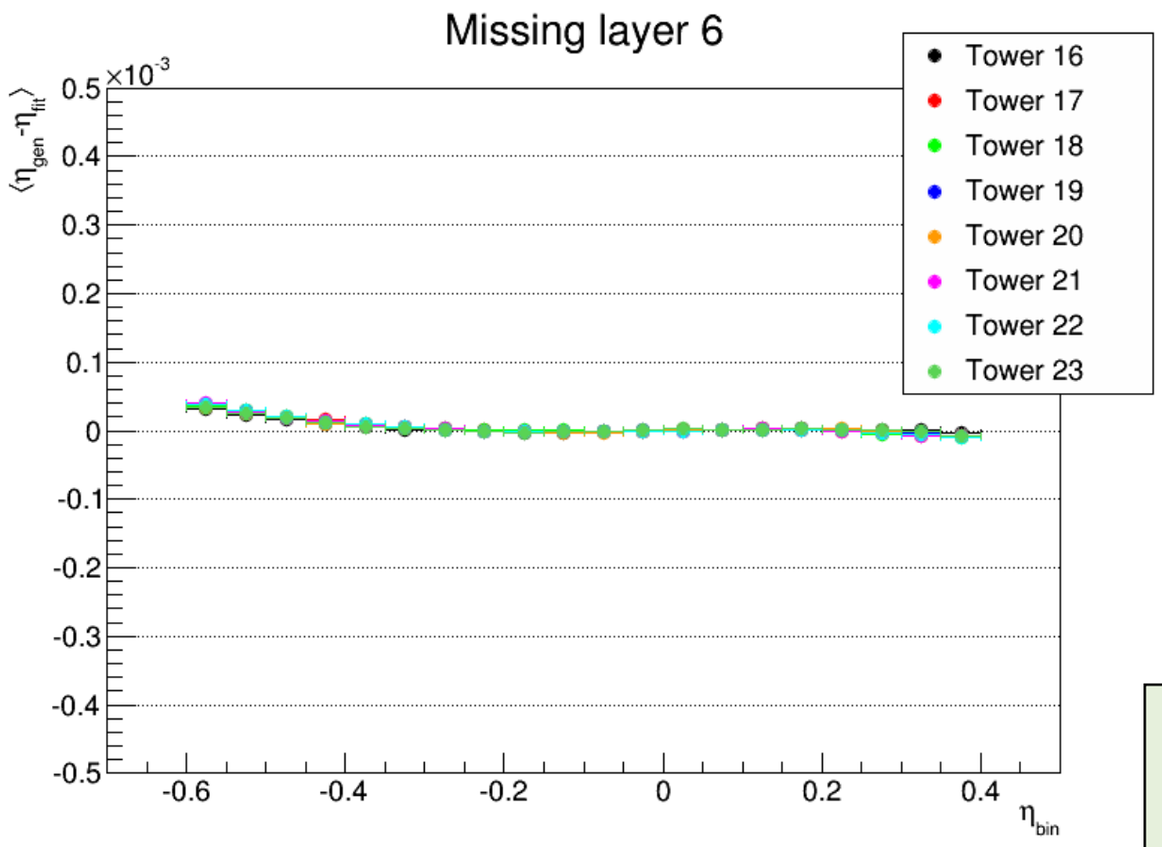


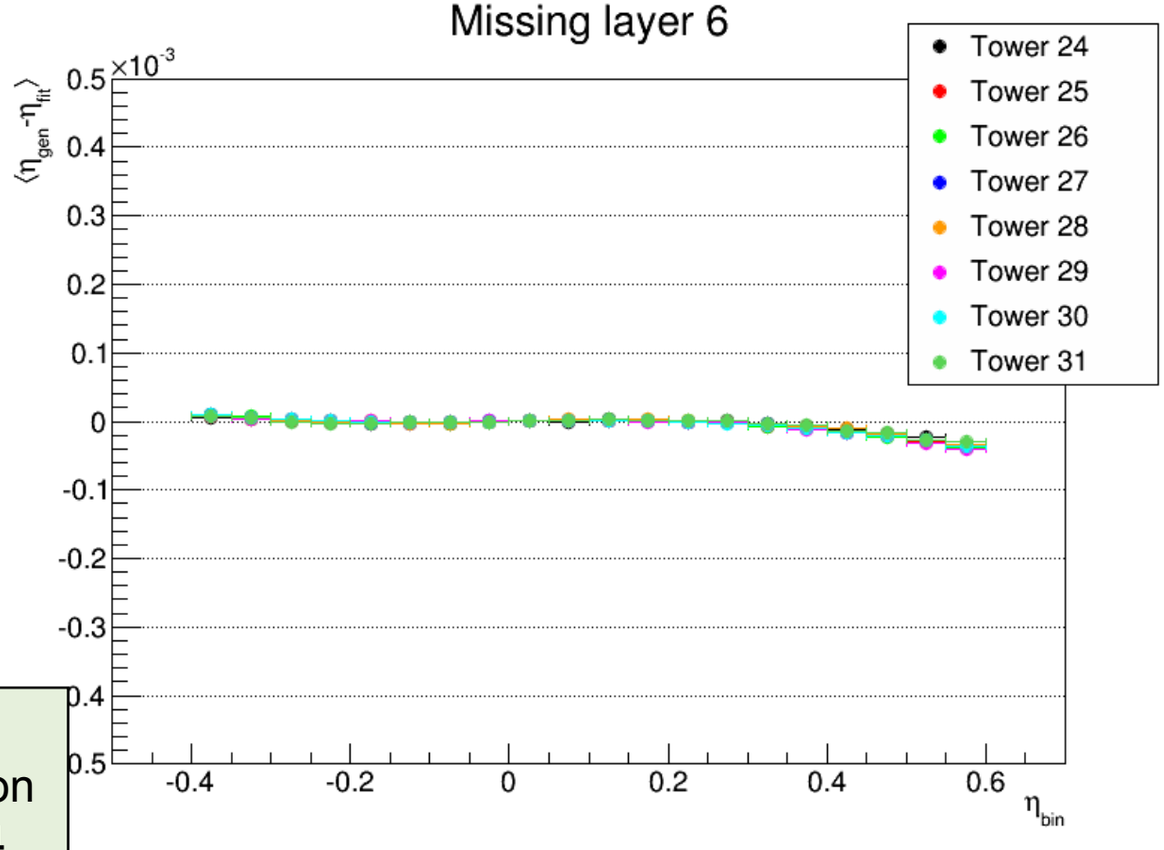
η resolution 0.0040



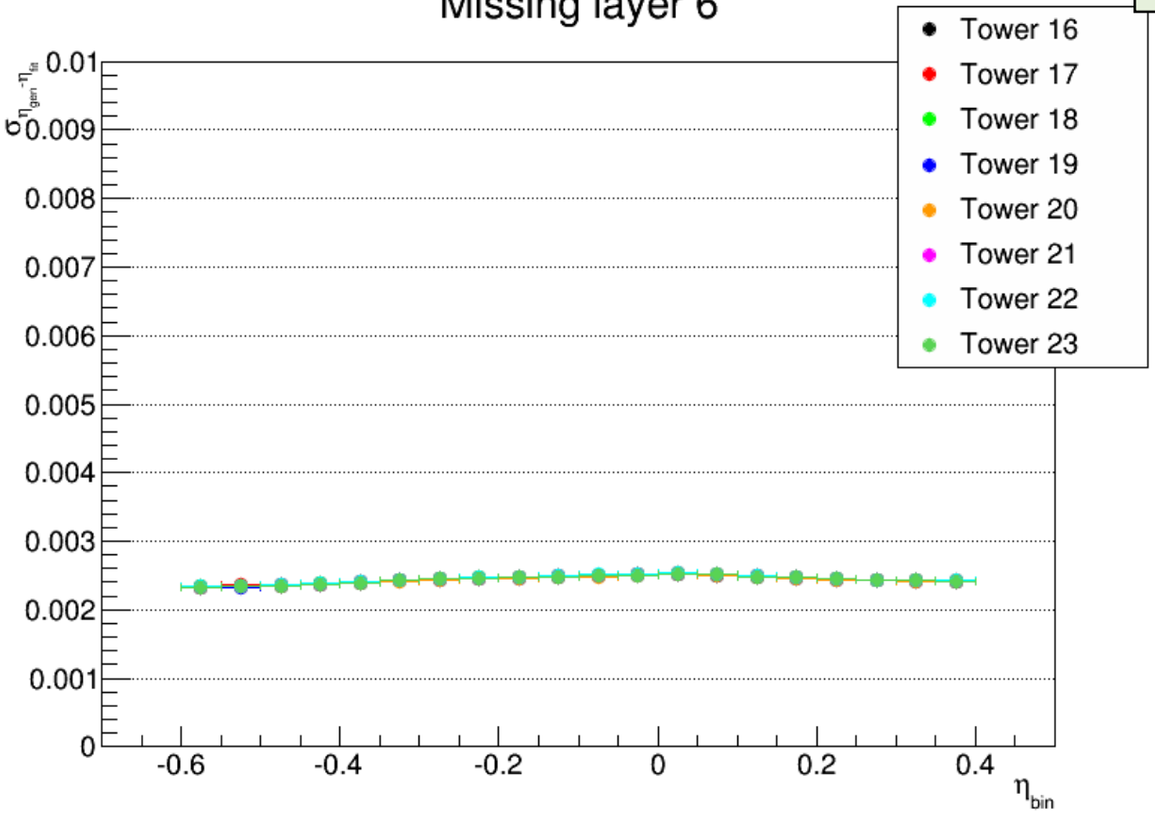


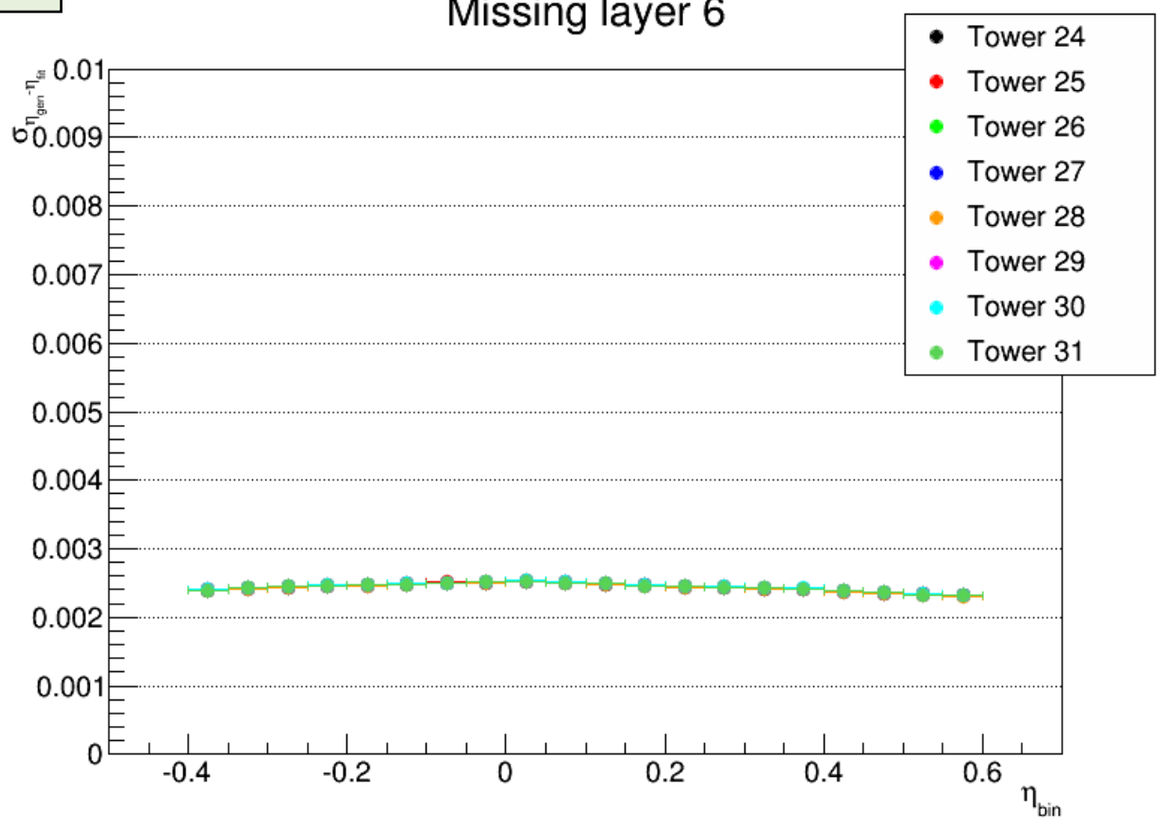
η results 5 out of 6



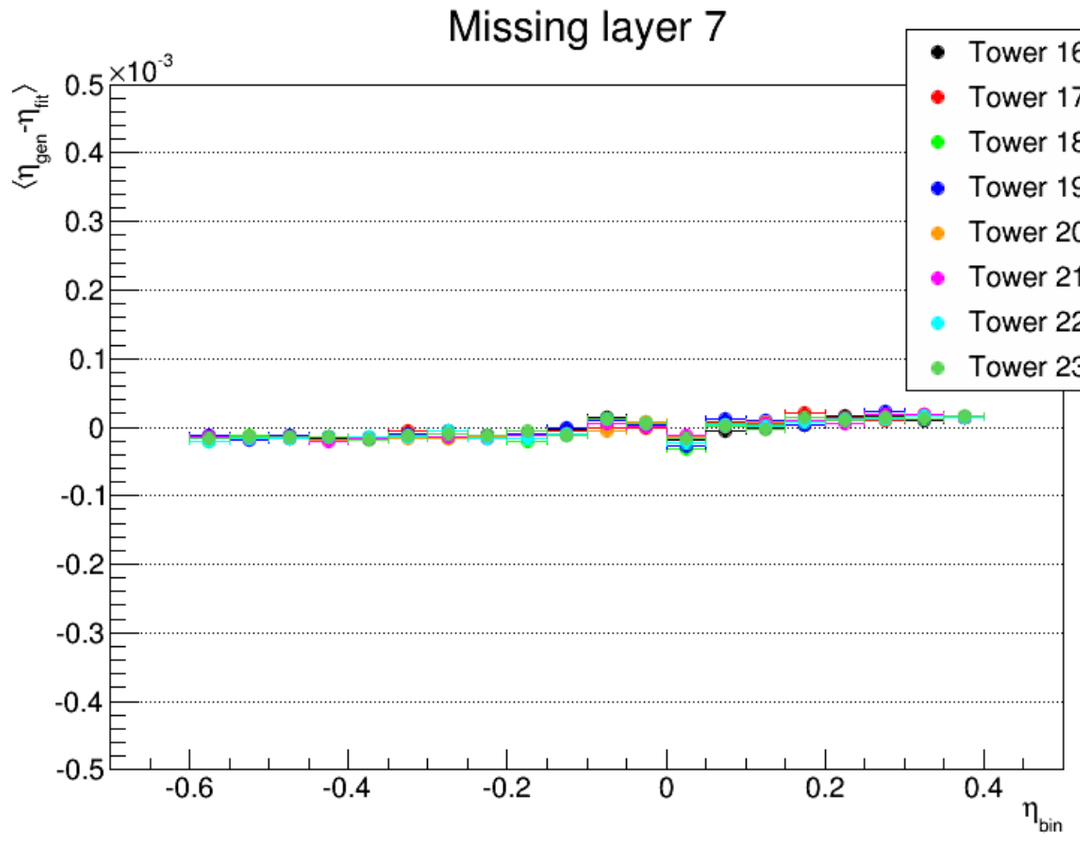


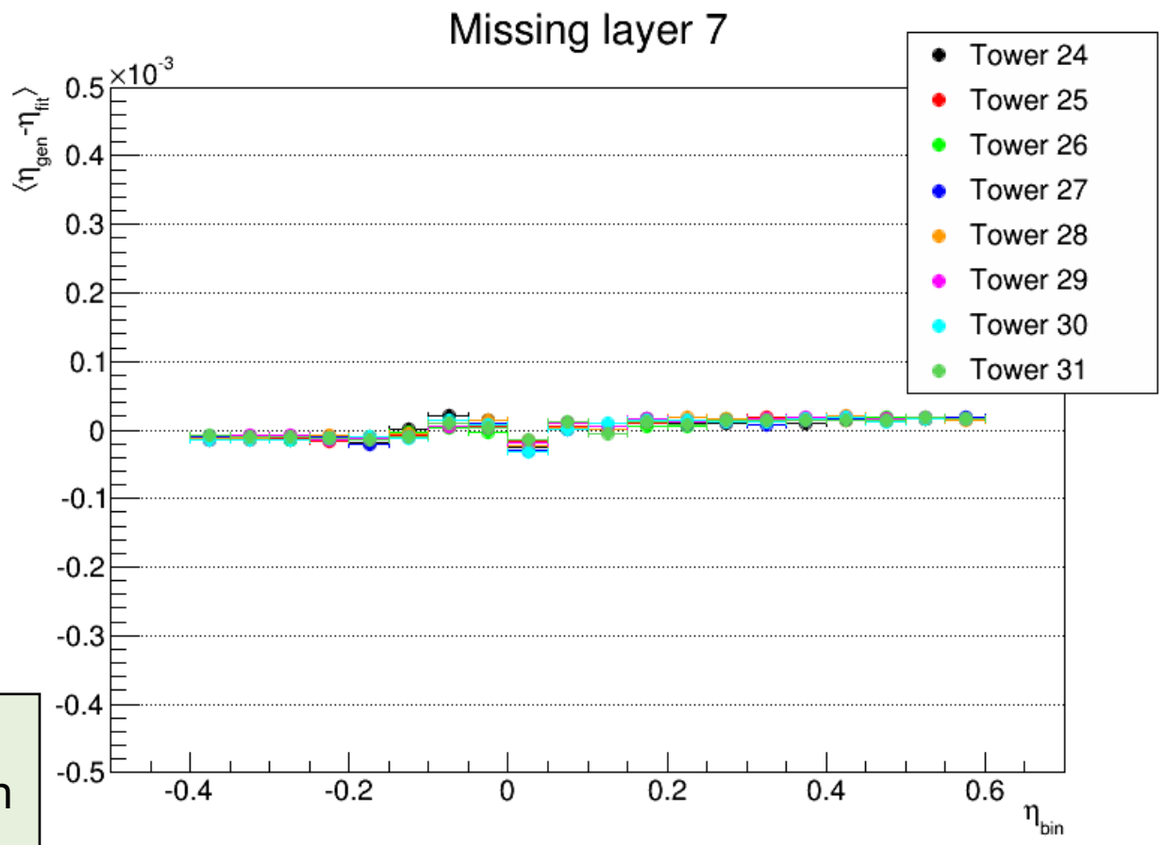
η resolution 0.0024



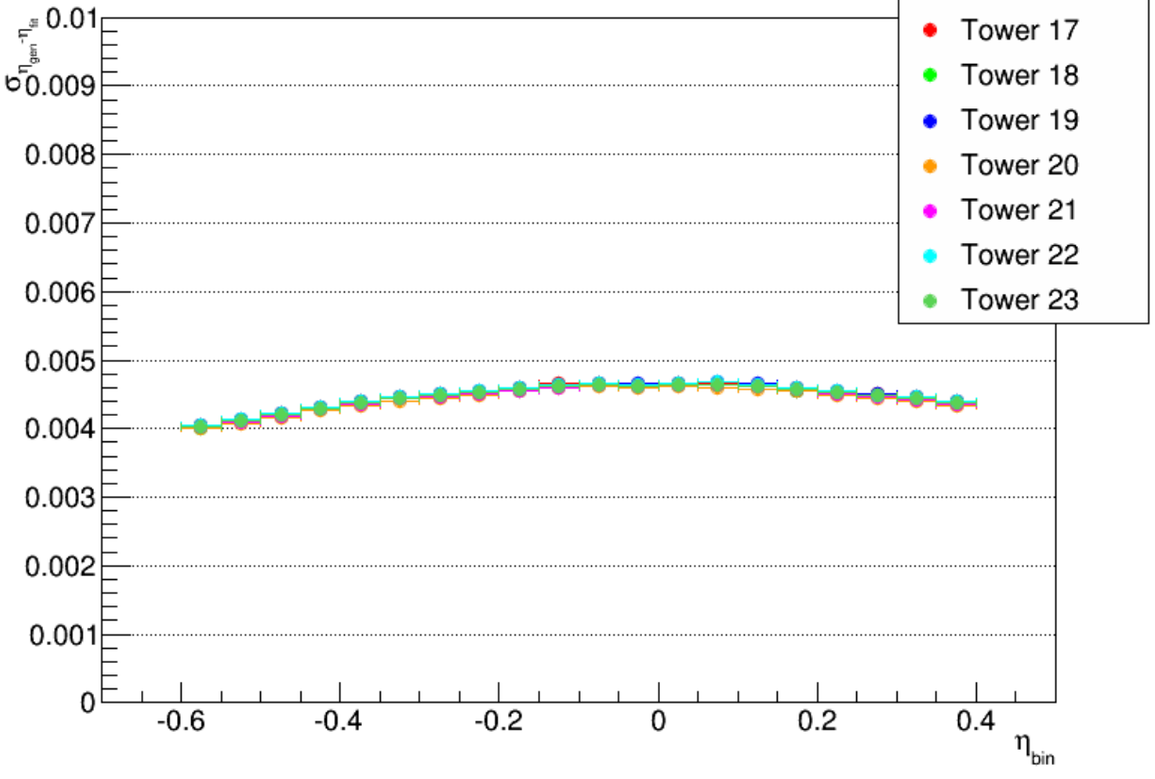


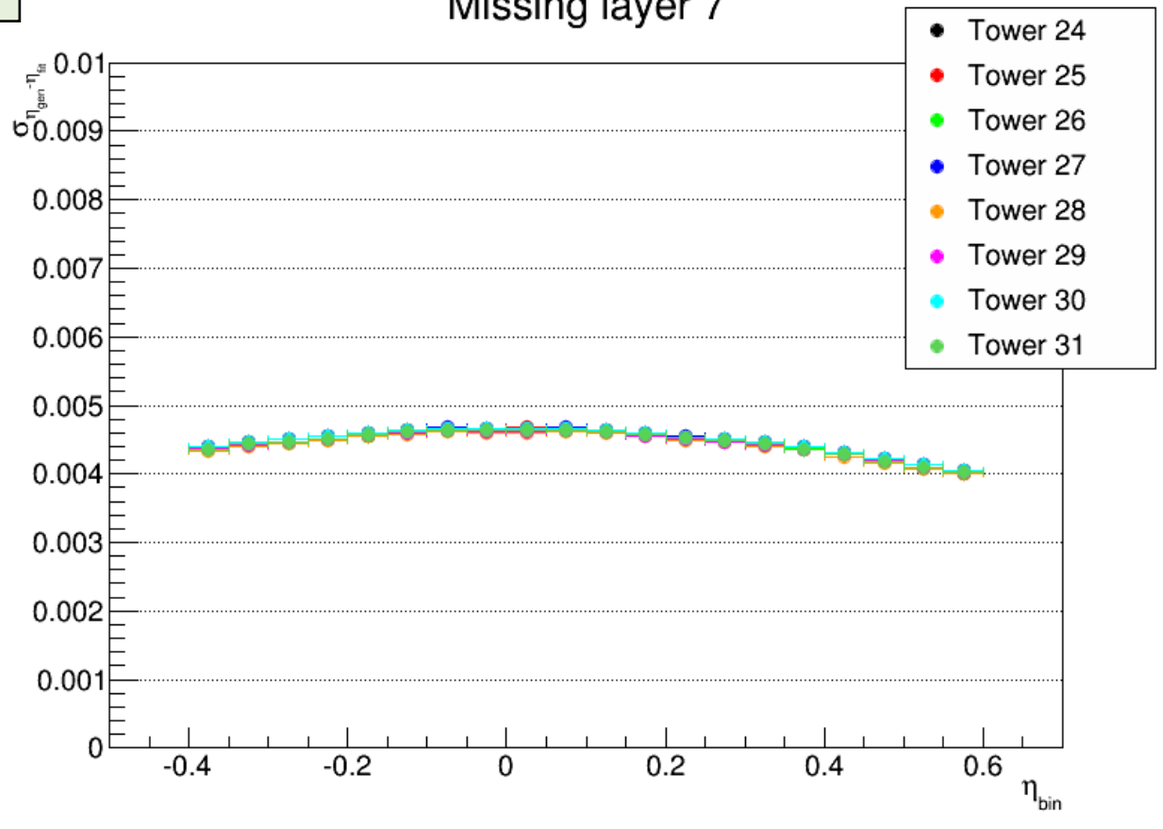
η results 5 out of 6





η resolution 0.0045

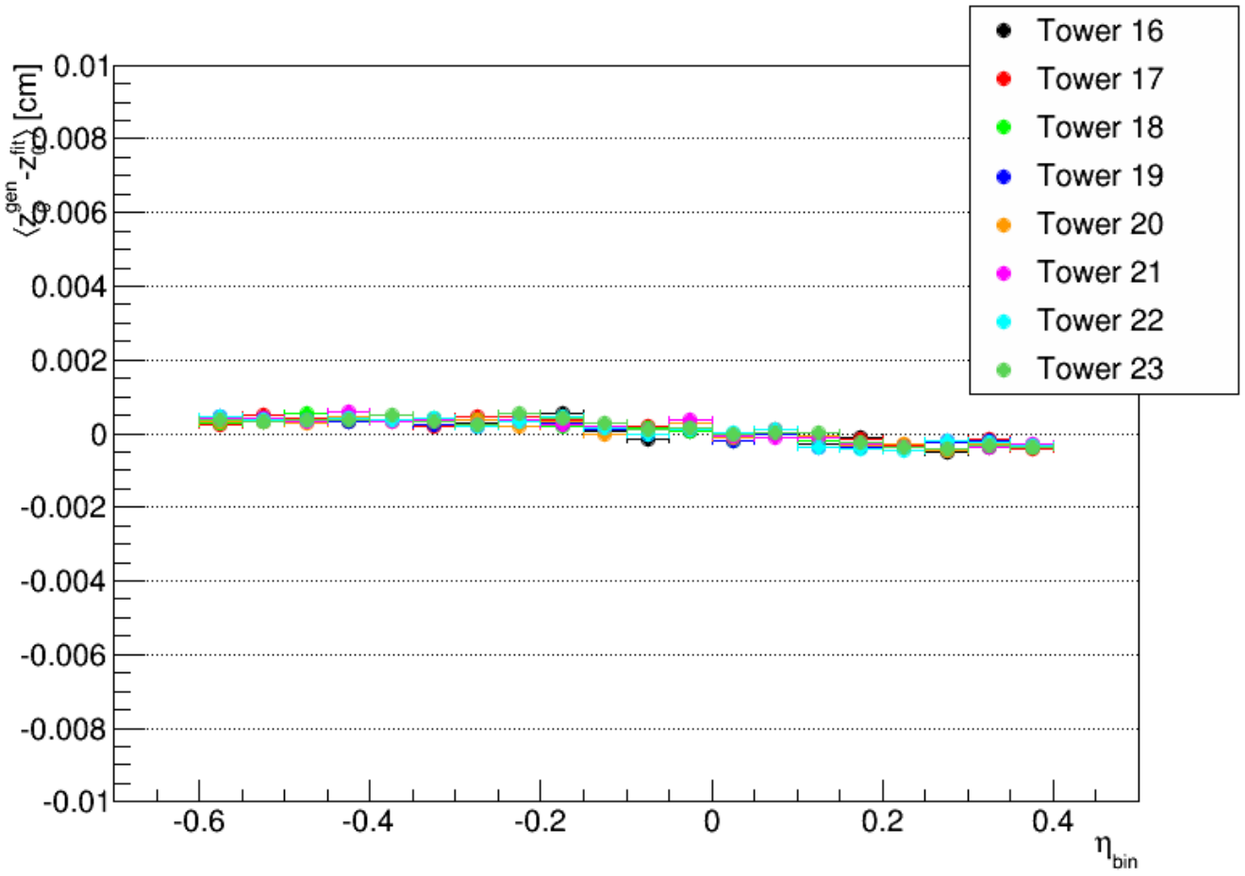




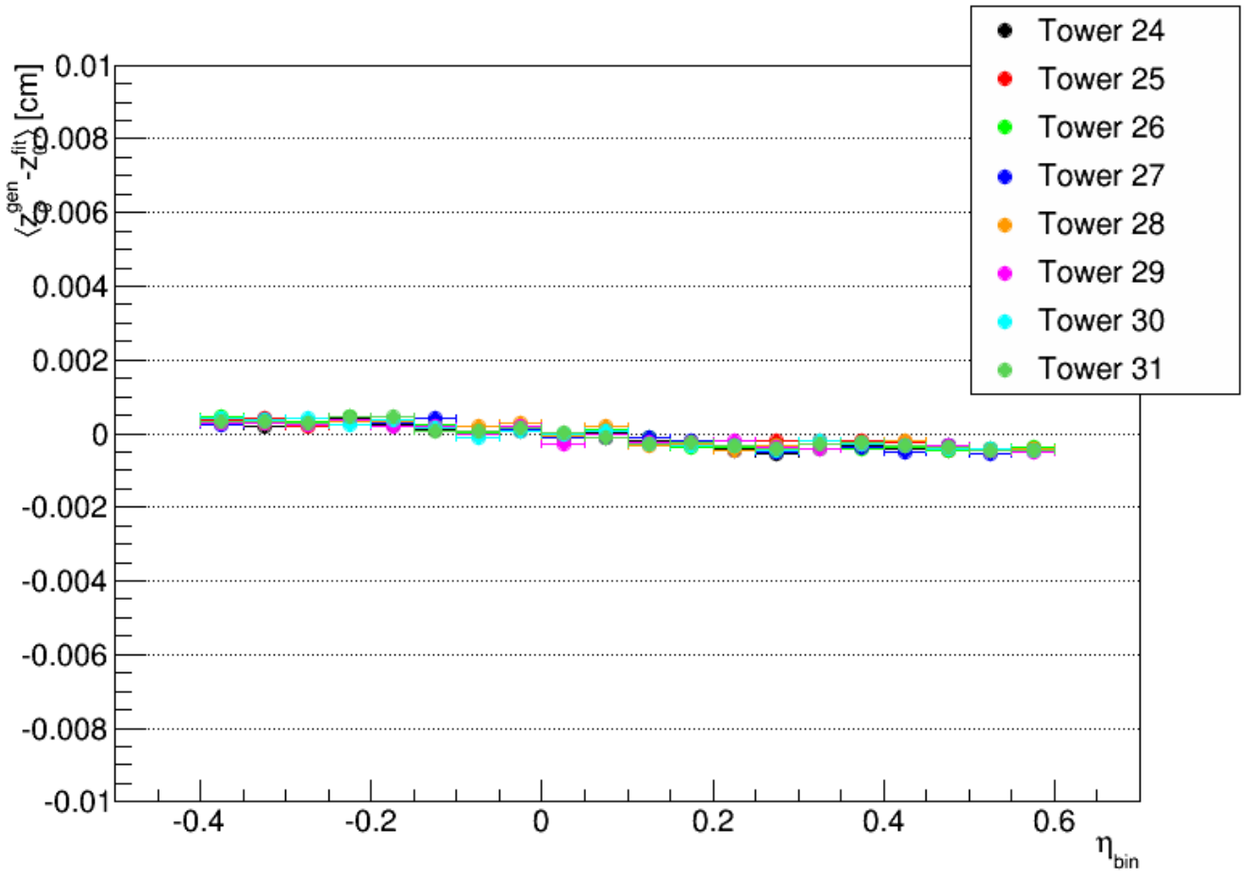
z_0 results 6 out of 6: bias

- We have plotted the following variable: **[z_0(generated) - z_0(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** as a function of η for each tower (from 16 to 31)

z_0 bias, **Tower from 16 to 23**



z_0 bias, **Tower from 24 to 31**



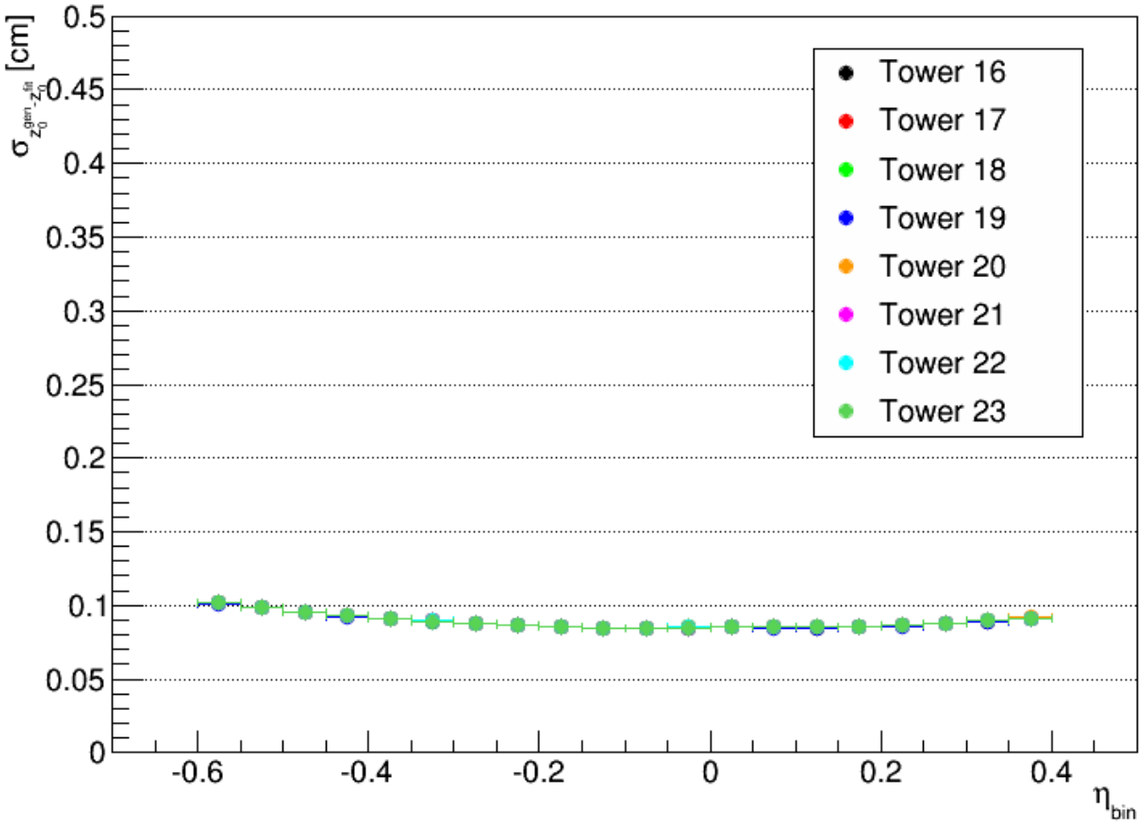
z_0 results 6 out of 6: resolution

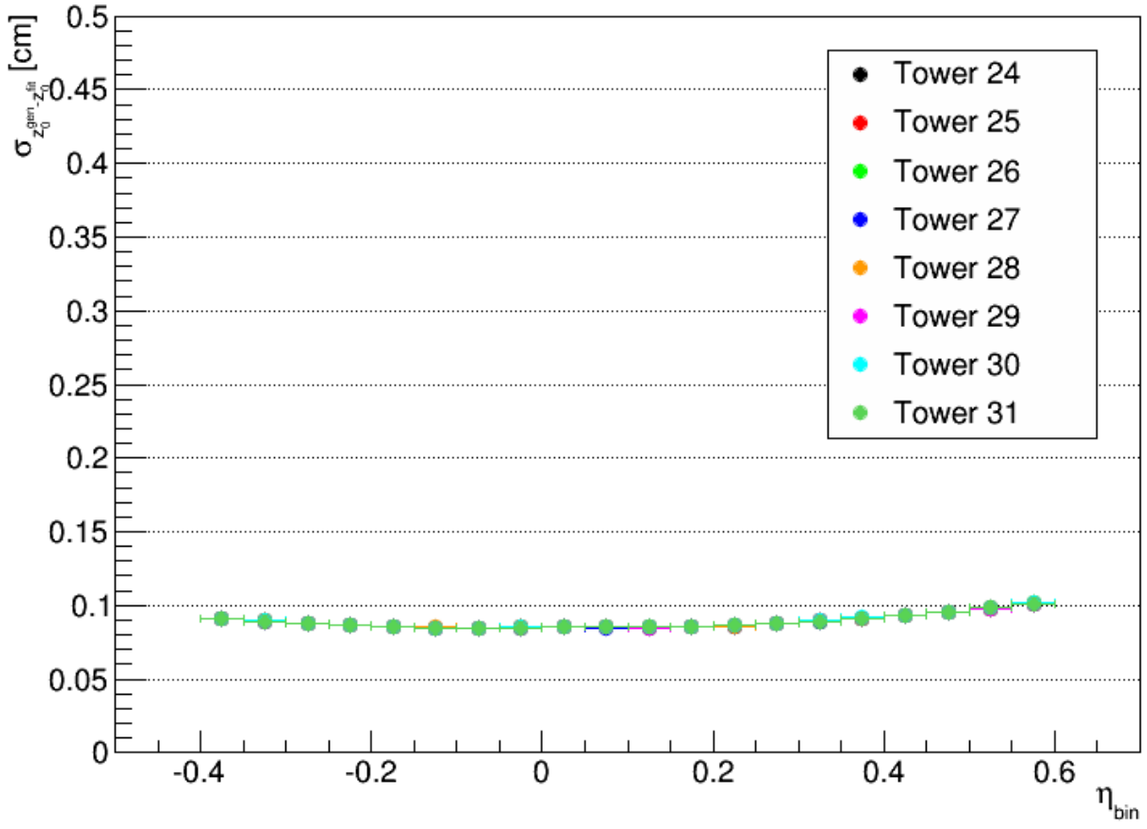
- We have plotted the following variable: **[z_0(generated) - z_0(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** as a function of η for each tower (from 16 to 31)

z_0 resolution, **Tower from 16 to 23**

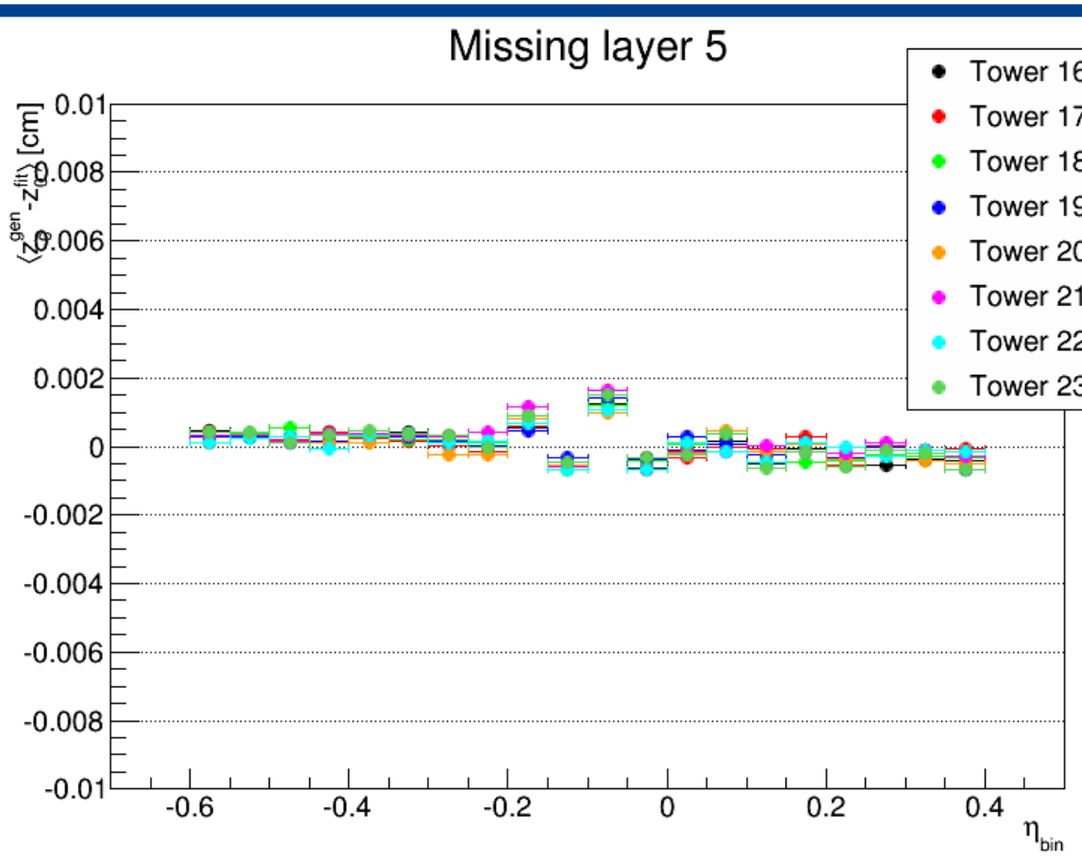
z_0 **resolution 0.089 cm**

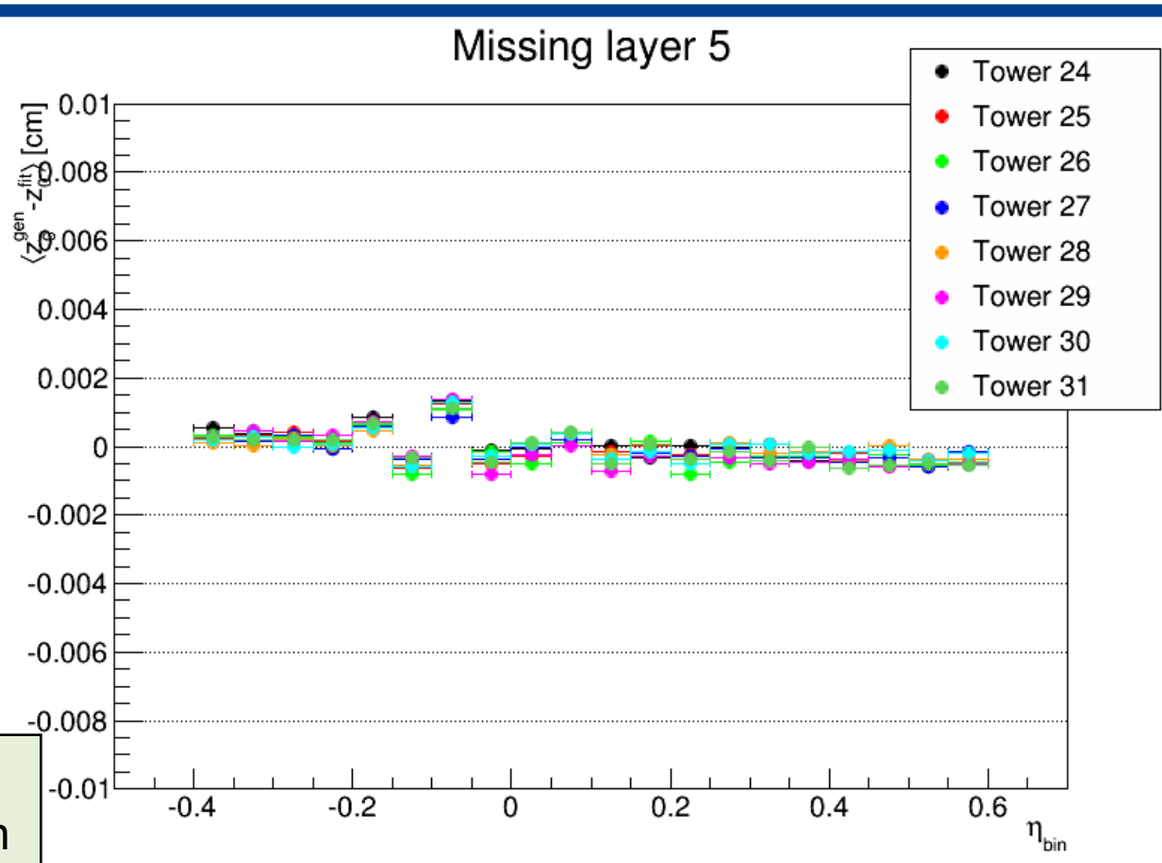
z_0 resolution, **Tower from 24 to 31**



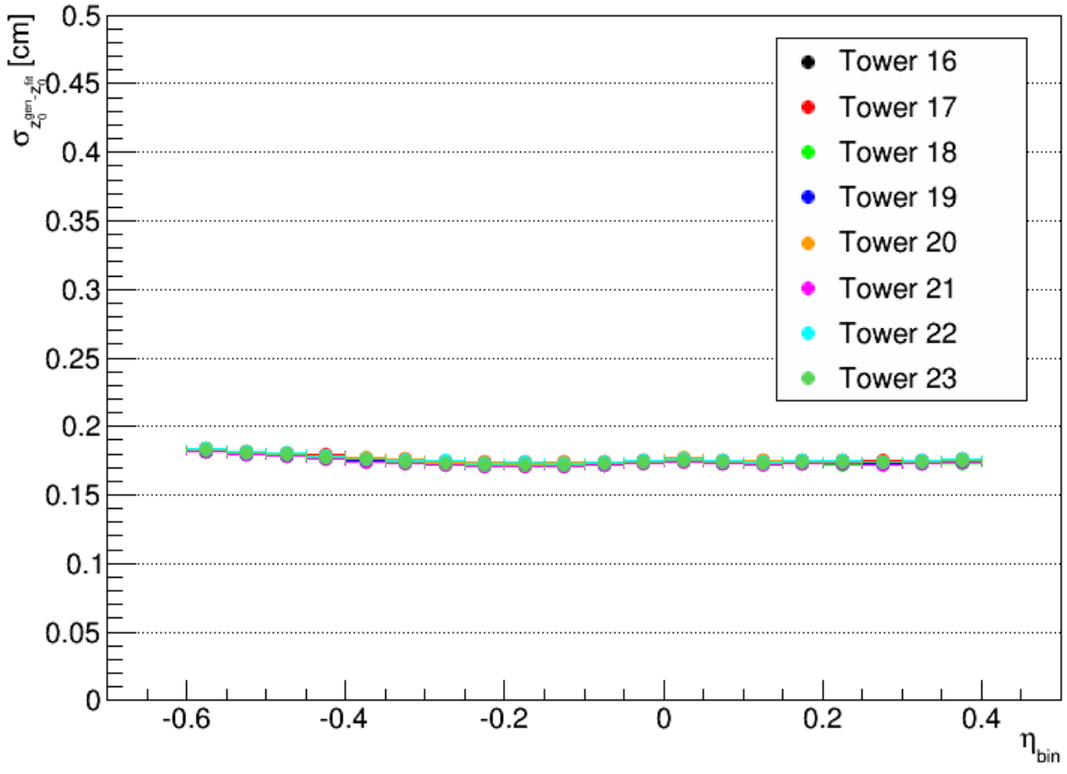


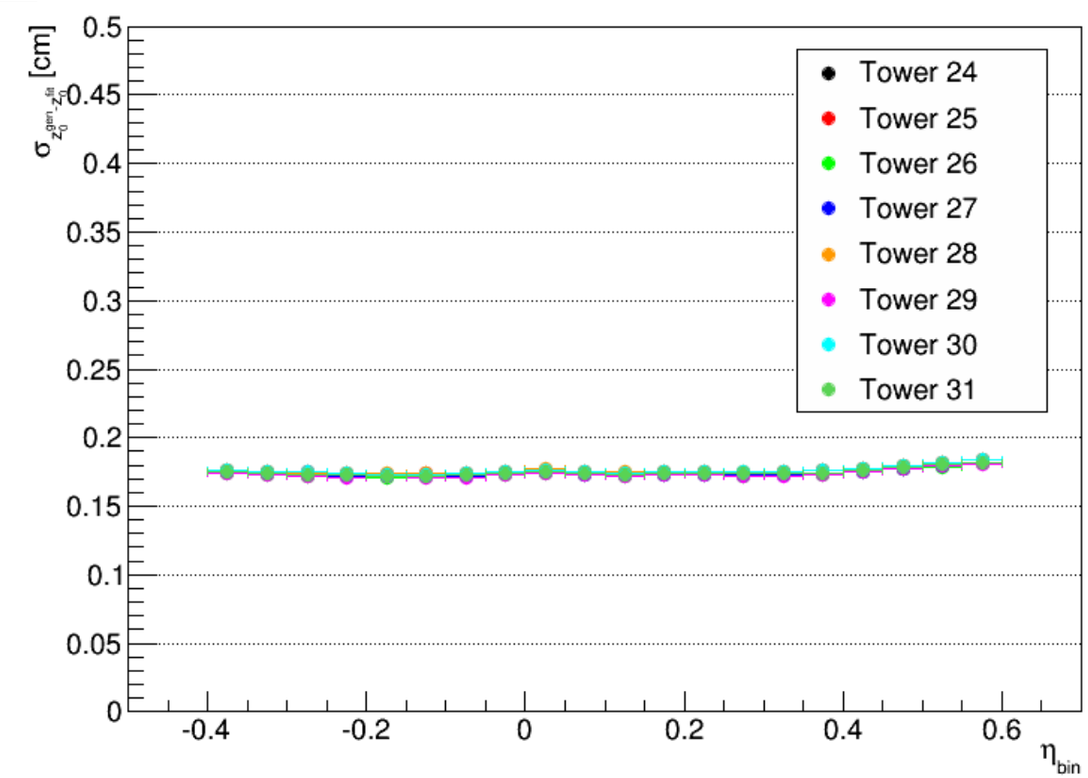
z_0 results 5 out of 6



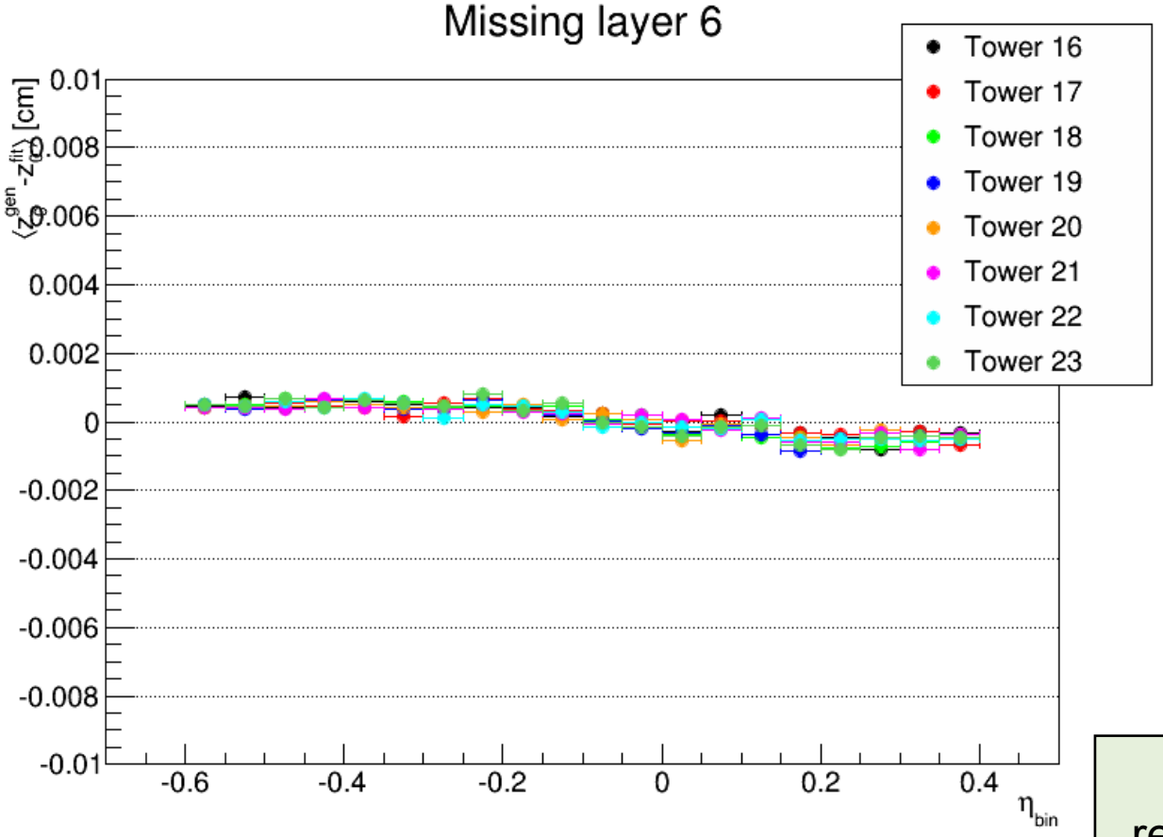


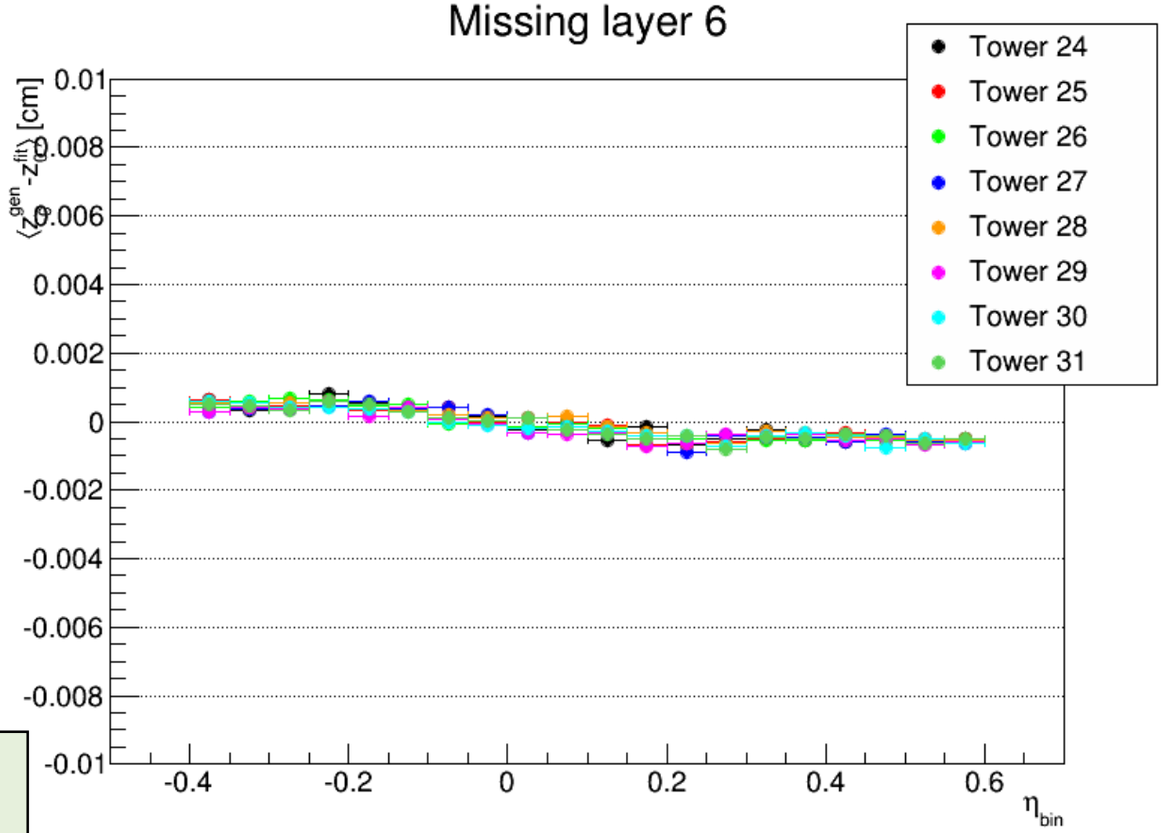
z_0 resolution 0.17 cm



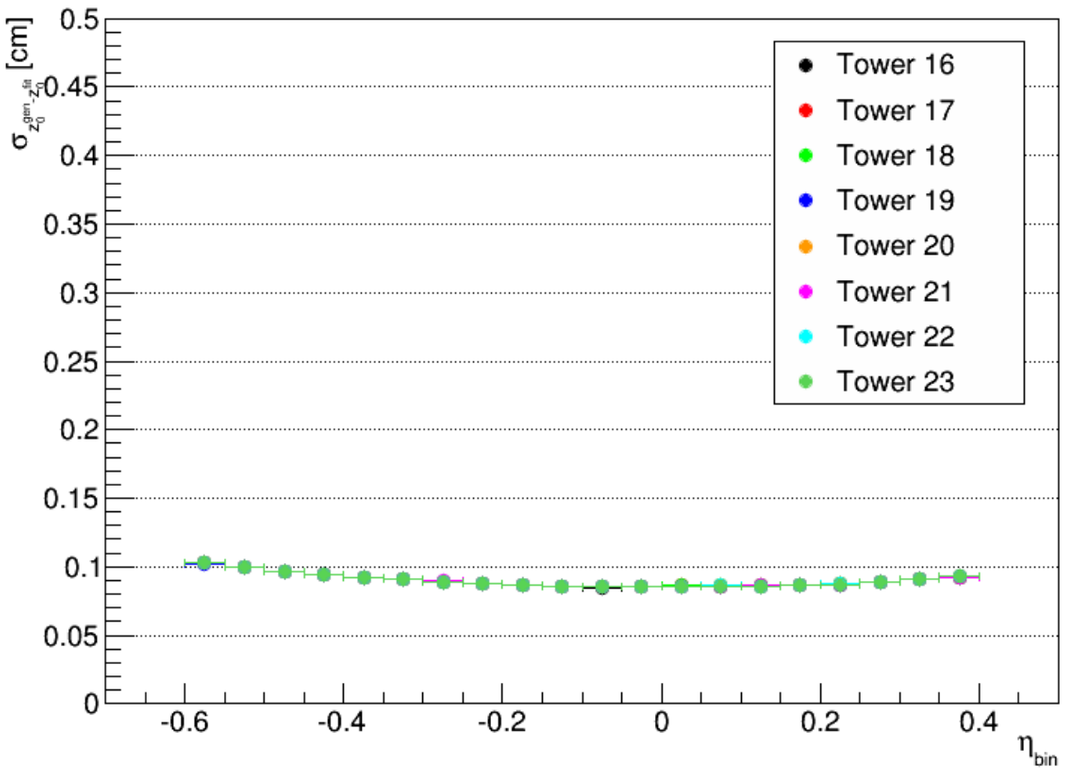


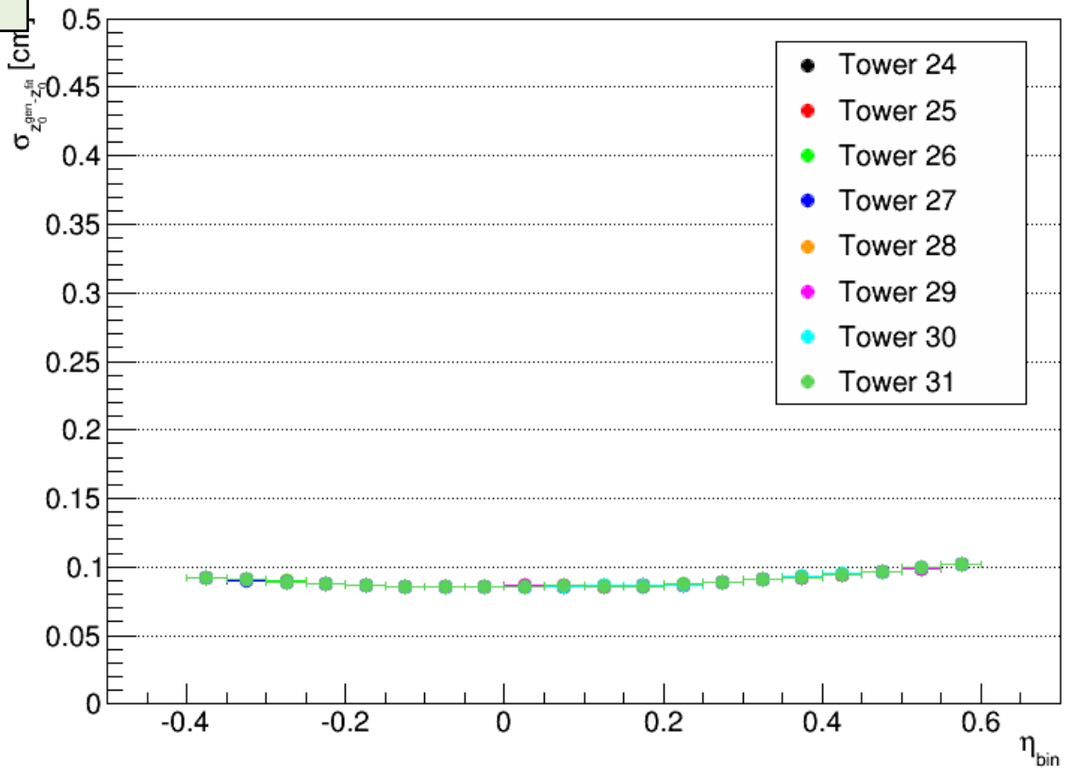
z_0 results 5 out of 6



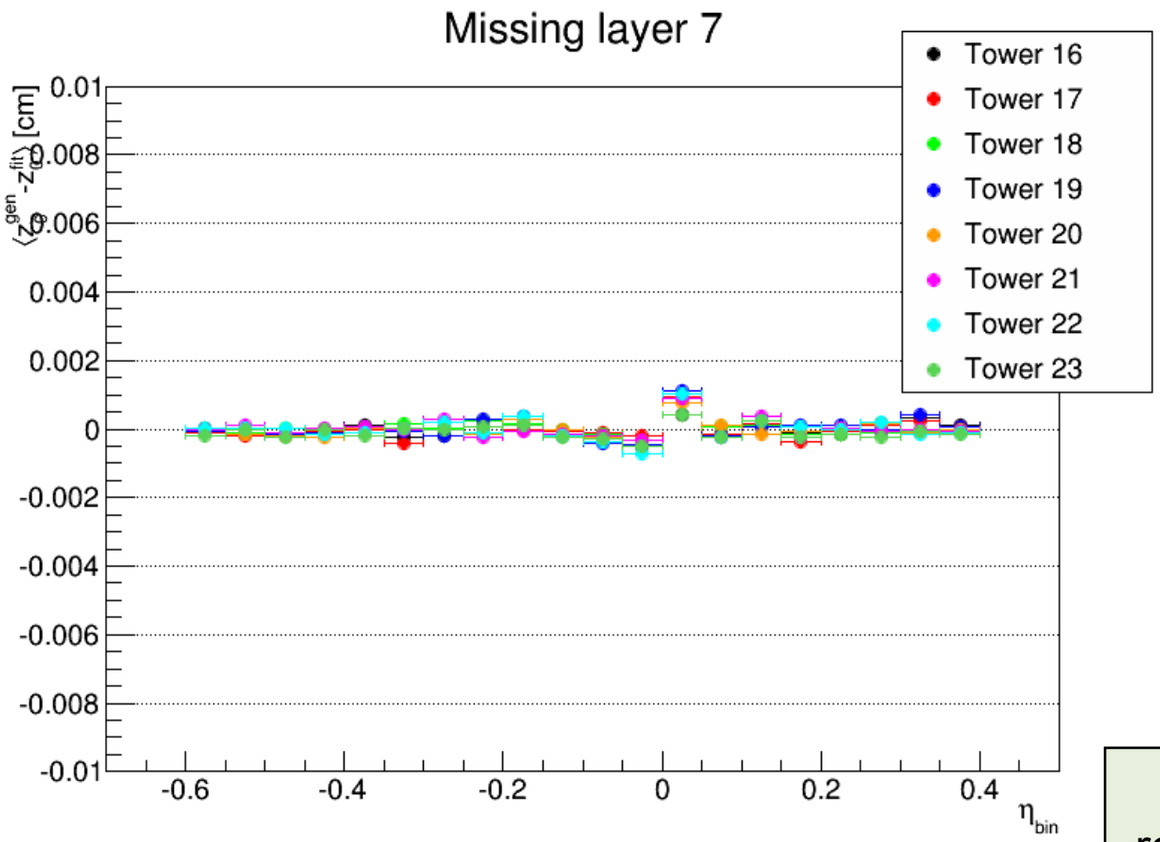


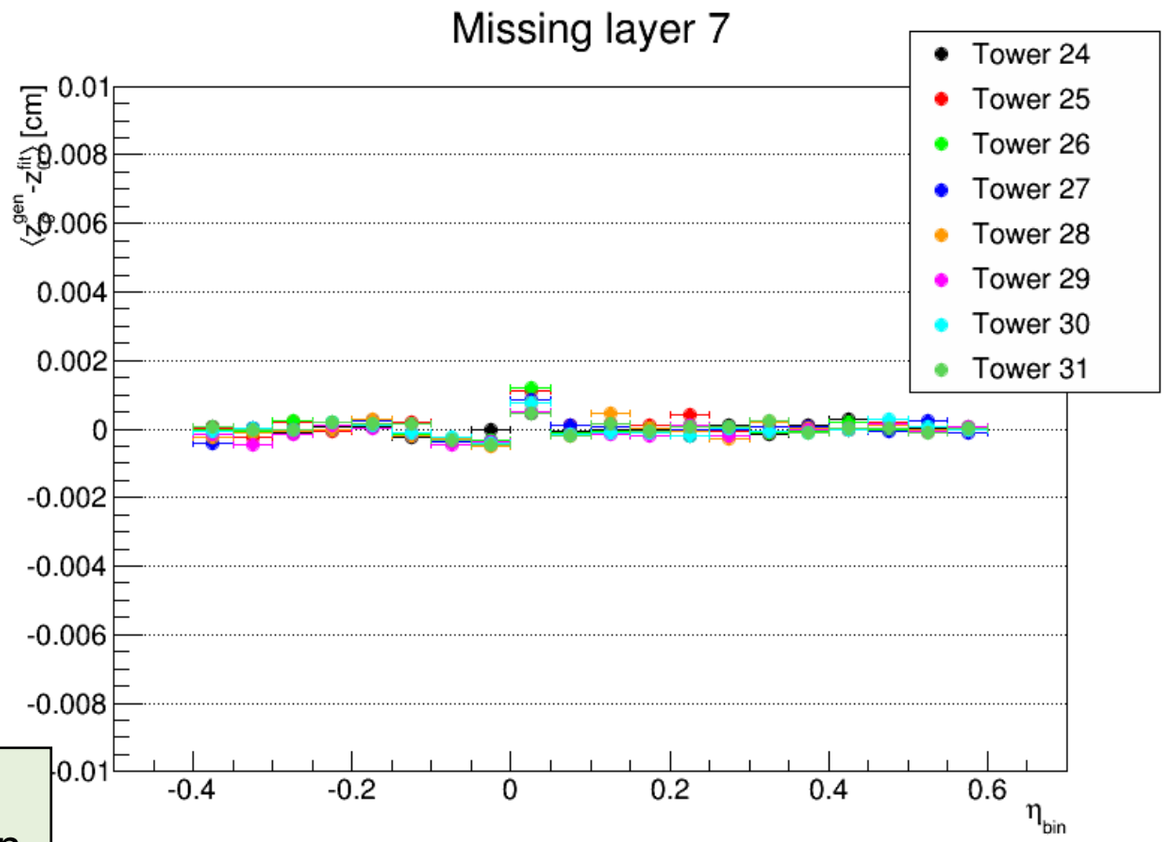
z_0 resolution 0.090 cm



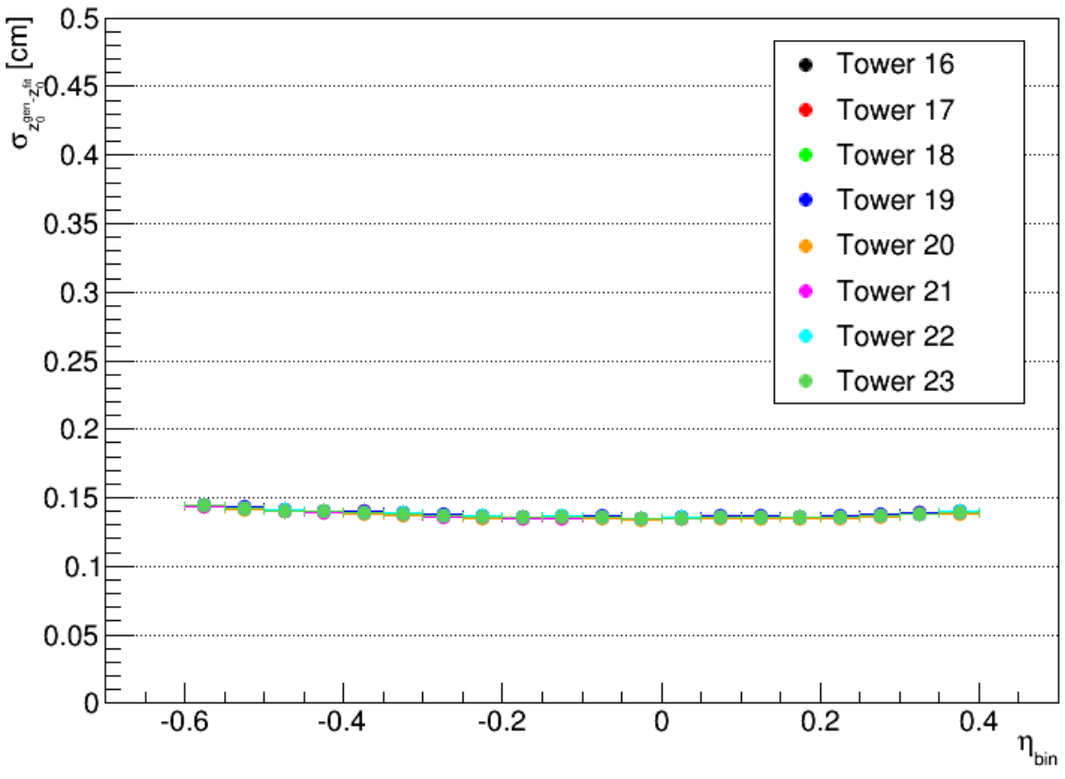


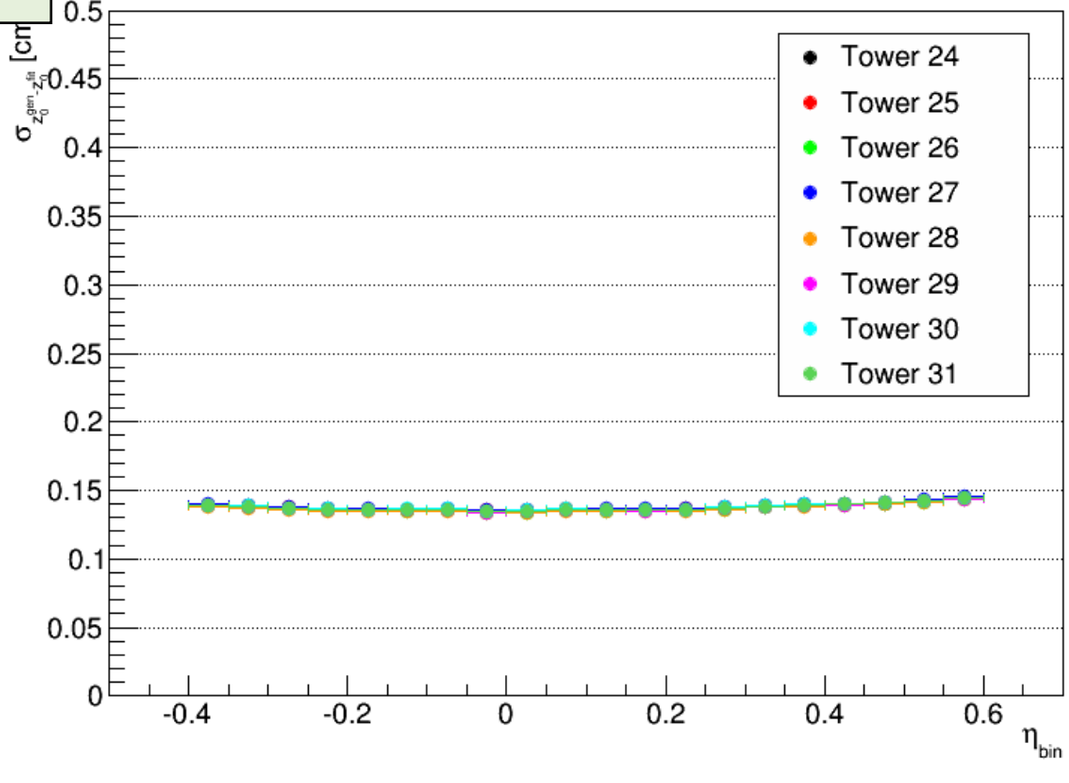
z_0 results 5 out of 6





z_0 resolution 0.14 cm





Plane rϕ

In the plane rϕ, we are using the following configuration:

- **seven bins in pt**: {3, 7, 12, 18, 25, 50, 100, 200} GeV (motivated also by the TC Builder). Because a larger set of constants can fit in the "mezzanine", we are now testing new binning to improve the resolution
- **one bin in eta**
- **one bin in phi**
- the computation of the constants and the fit is done **separately for positive and negative muons**

At the end, we have 14 sets of constants for each tower. 98 including also the 5 out of 6

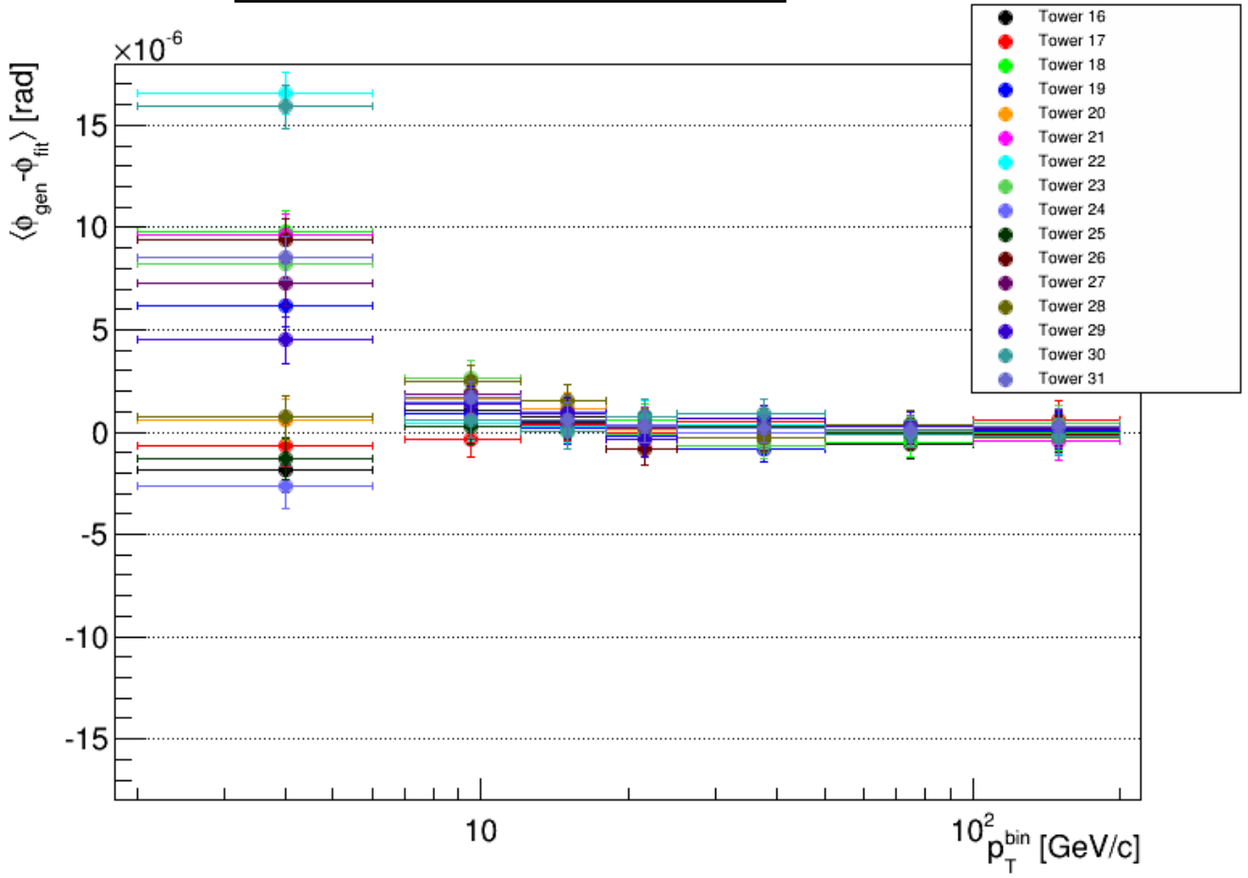
ϕ results 6 out of 6

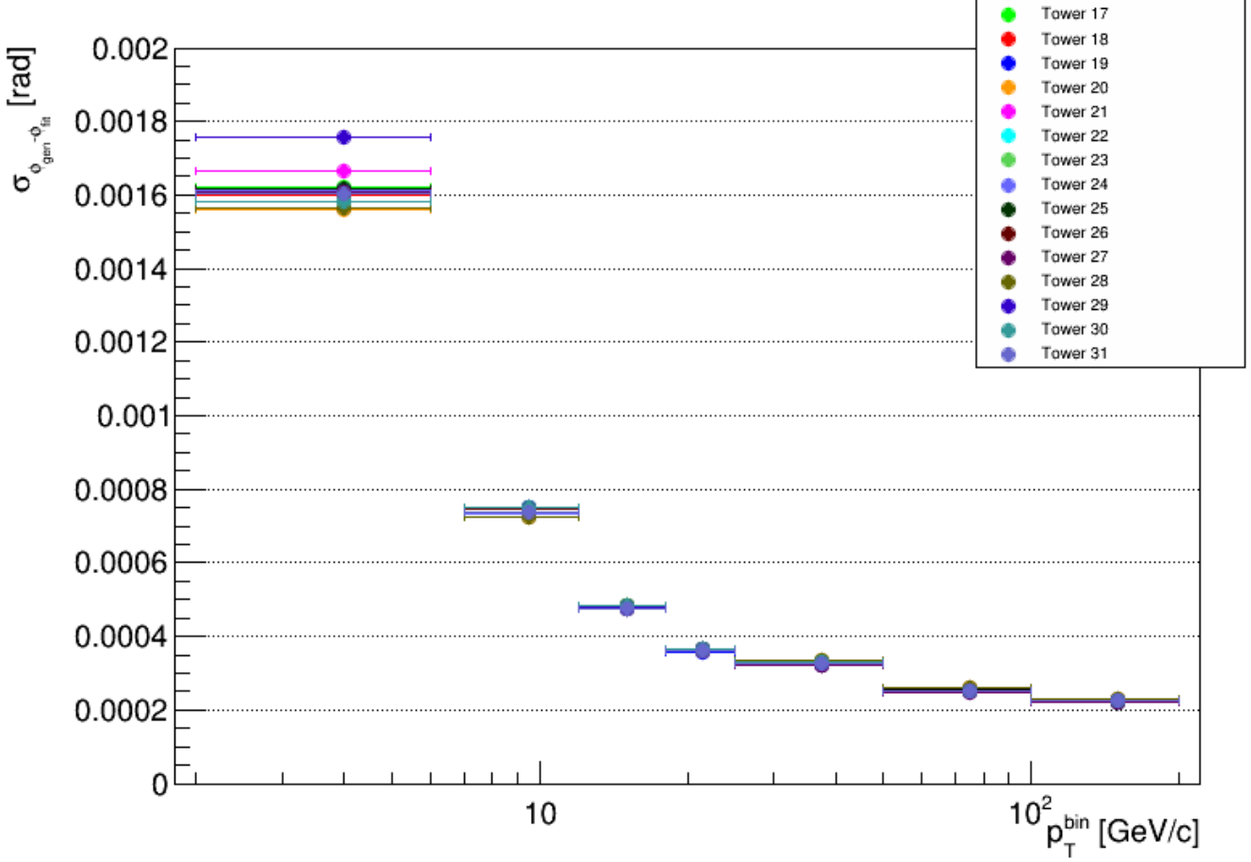
- We have plotted the following variable **[ϕ(generated) - ϕ(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for each tower from 16 to 31

ϕ bias (we are reporting here only only μ+)

ϕ resolution (both μ+ and μ-) from 0.0002 to 0.0017 rad

ϕ resolution (we are reporting here only μ+)





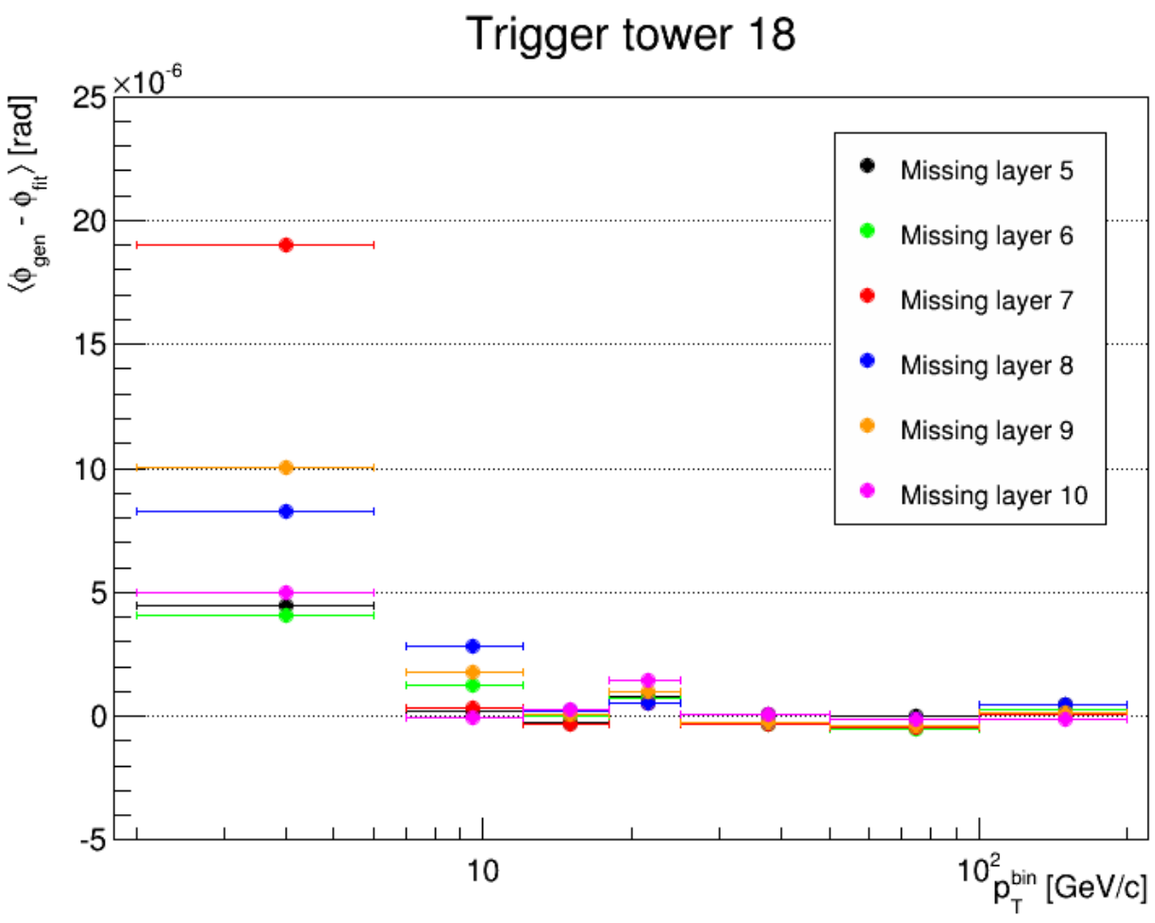
ϕ results 5 out of 6

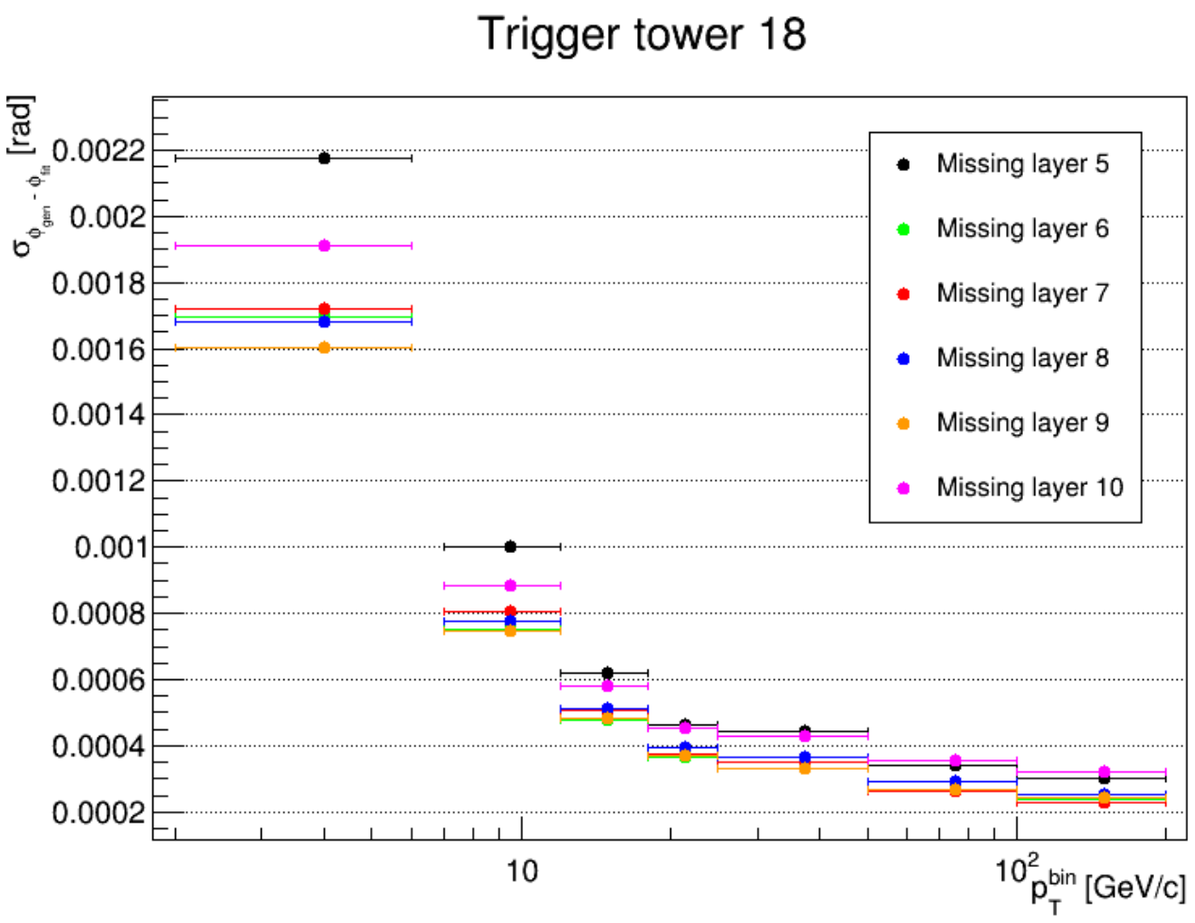
- We have plotted the following variable **[ϕ(generated) - ϕ(fit)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for a single tower

ϕ bias (we are reporting here only only μ+ and only a single trigger tower)

The ϕ resolution is comparable to the 6 out of 6 case for all the towers

ϕ resolution (we are reporting here only μ+ and only a single trigger tower)

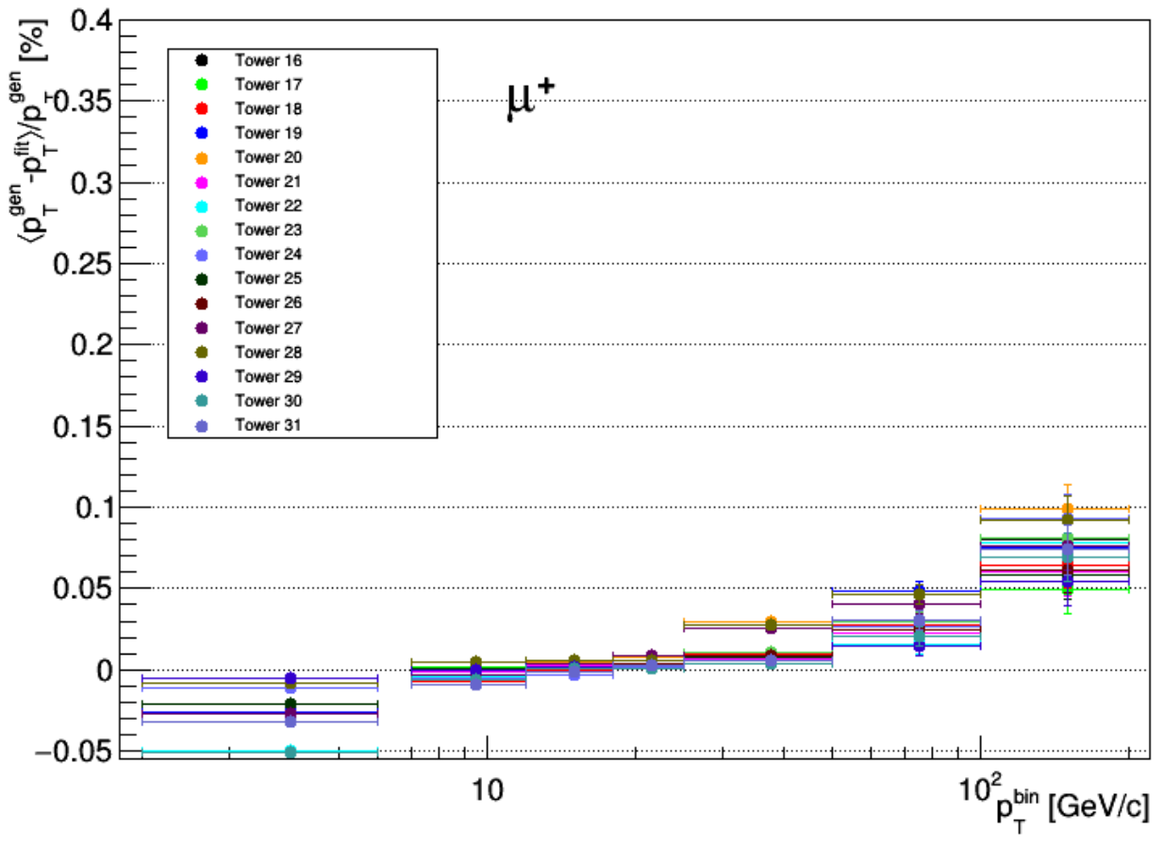


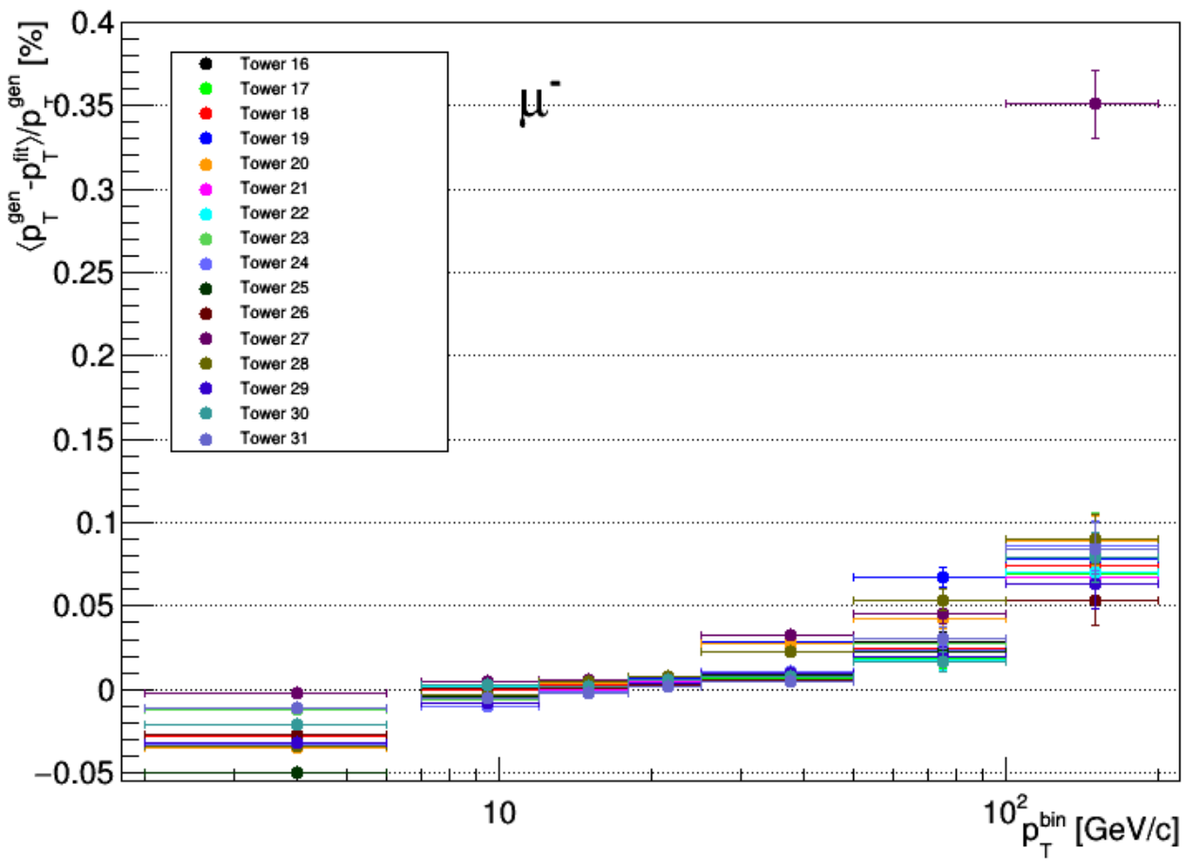


c/p_T results 6 out of 6: bias

- We have plotted the following variable **[c/p_T(generated) - c/p_T(fit)]/[c/p_T(generated)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for each tower from 16 to 31

c/pt bias for both positive and negative muons

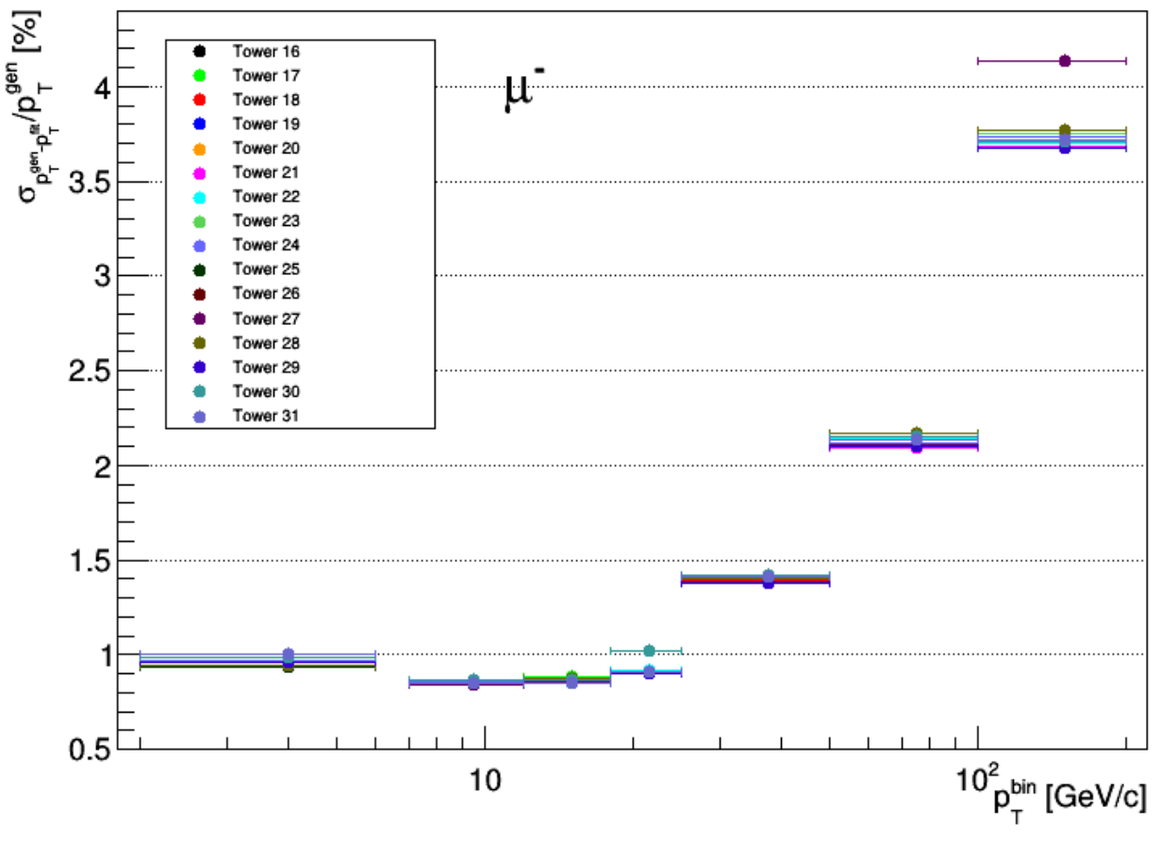


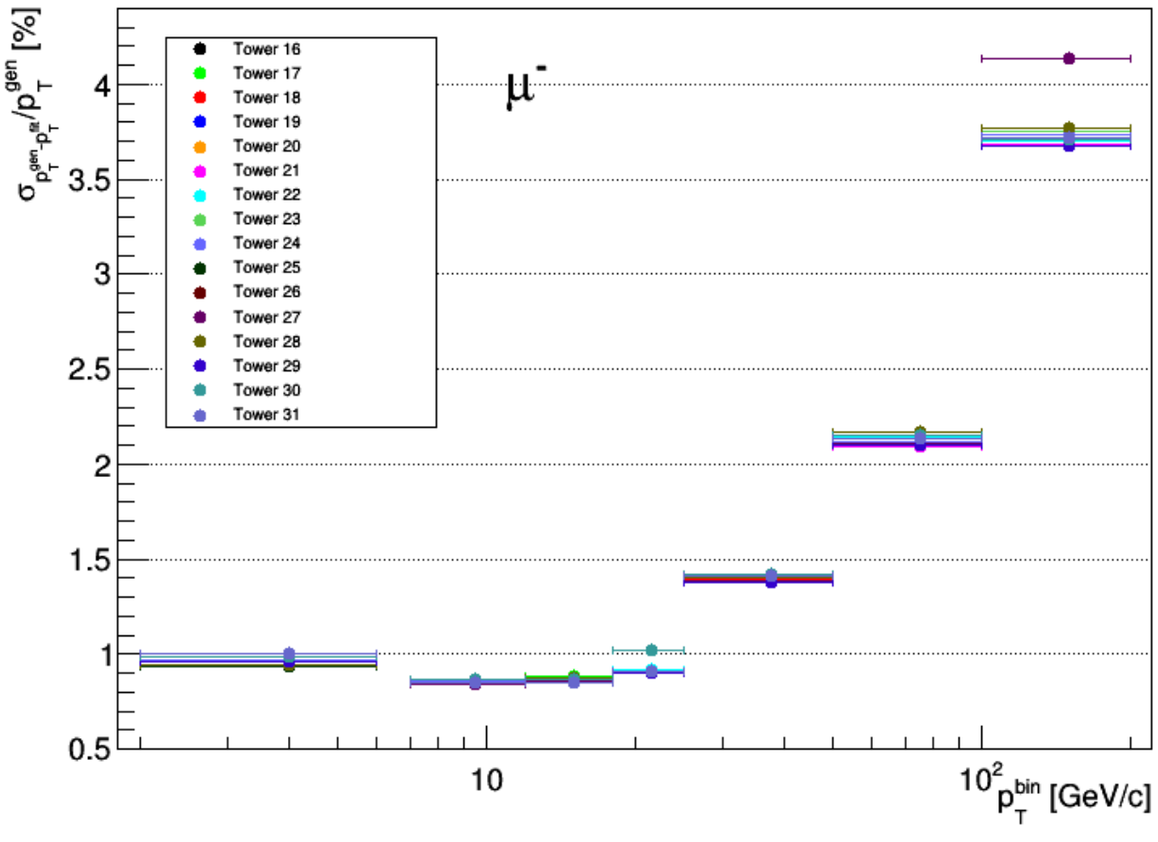


c/p_T results 6 out of 6: resolution

- We have plotted the following variable **[c/p_T(generated) - c/p_T(fit)]/[c/p_T(generated)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for each tower from 16 to 31

c/pt resolution (for both positive and negative muons) from 0.8% to < 4.0% , only for a single tower we have resolution of 4.1% for high pt

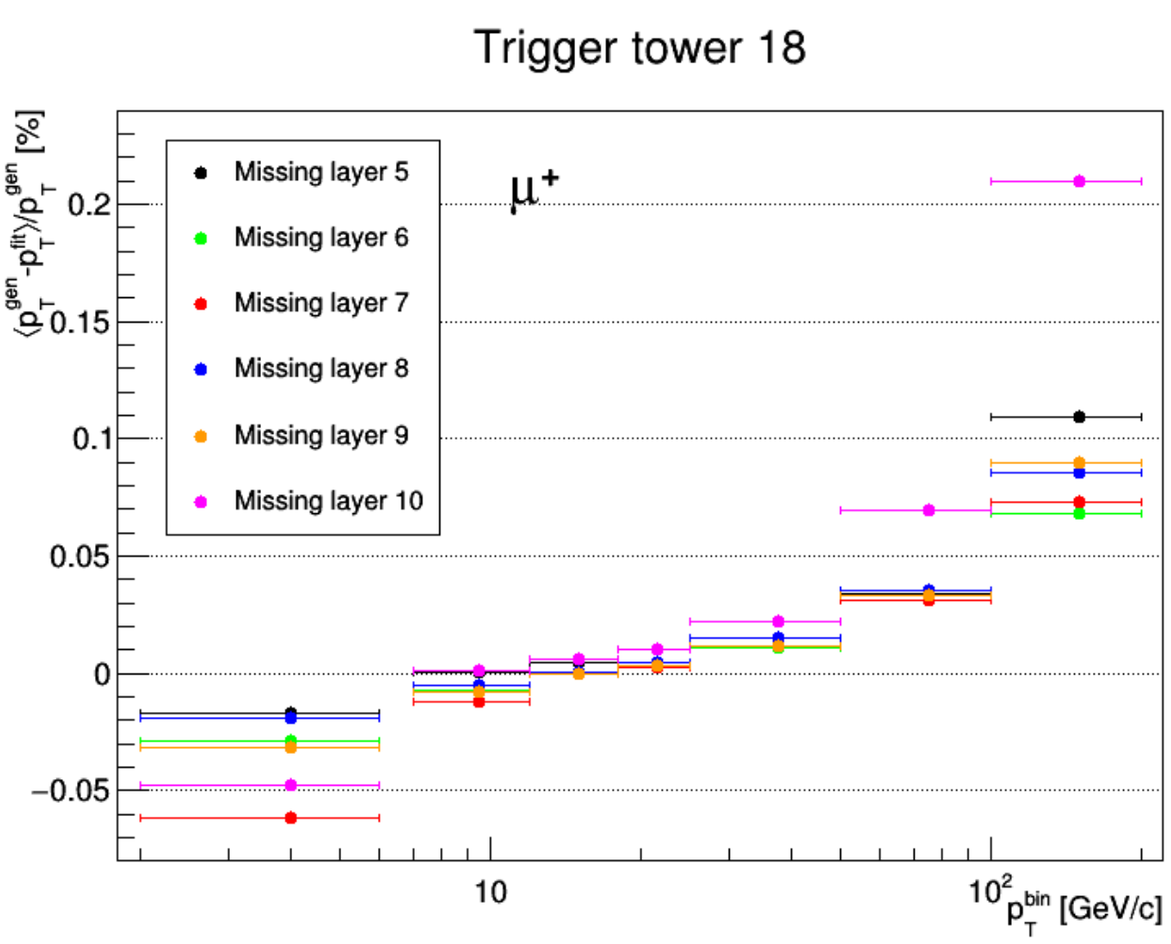


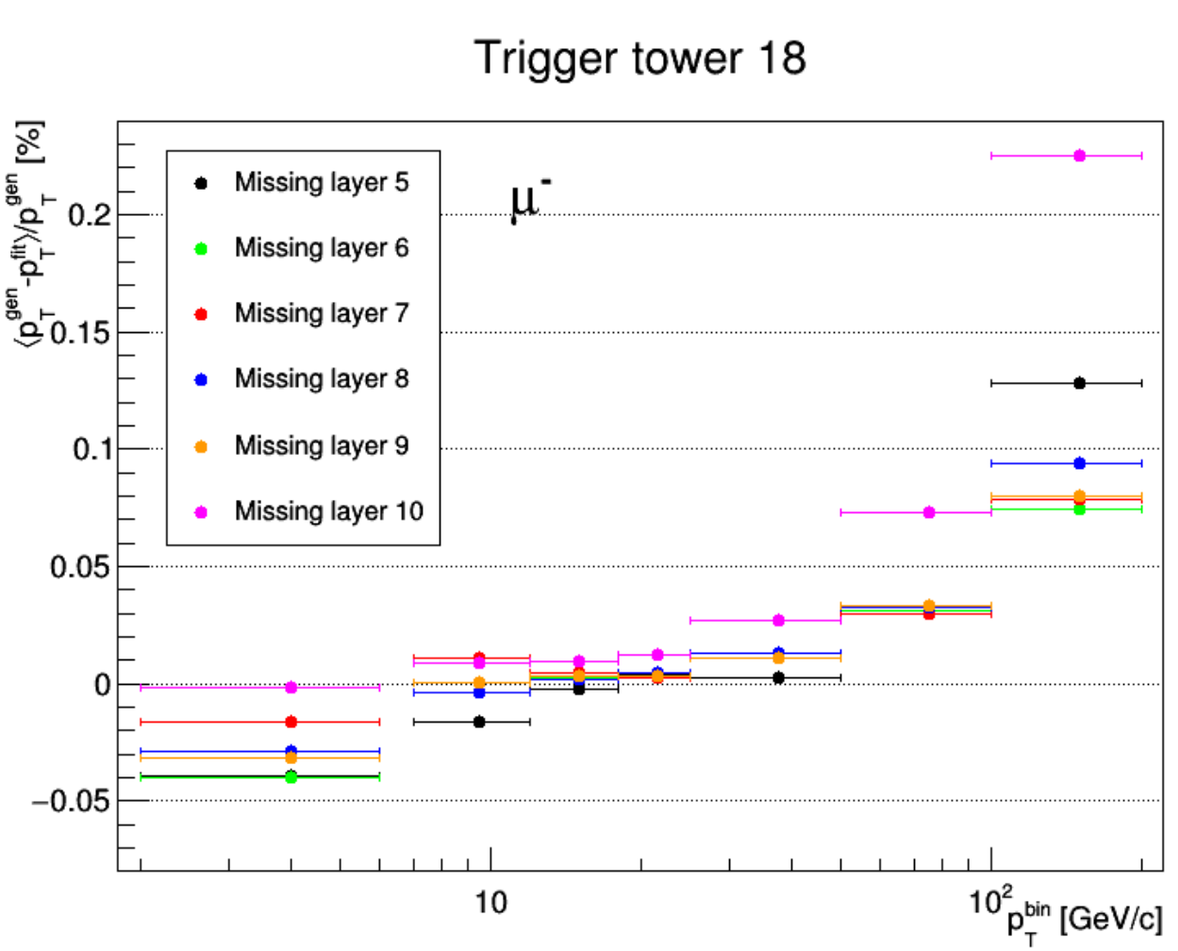


c/p_T results 5 out of 6: bias

- We have plotted the following variable **[c/p_T(generated) - c/p_T(fit)]/[c/p_T(generated)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for a single tower

pt bias, we are reporting the results only for Tower 16, we obtained similar results for all the other barrel towers

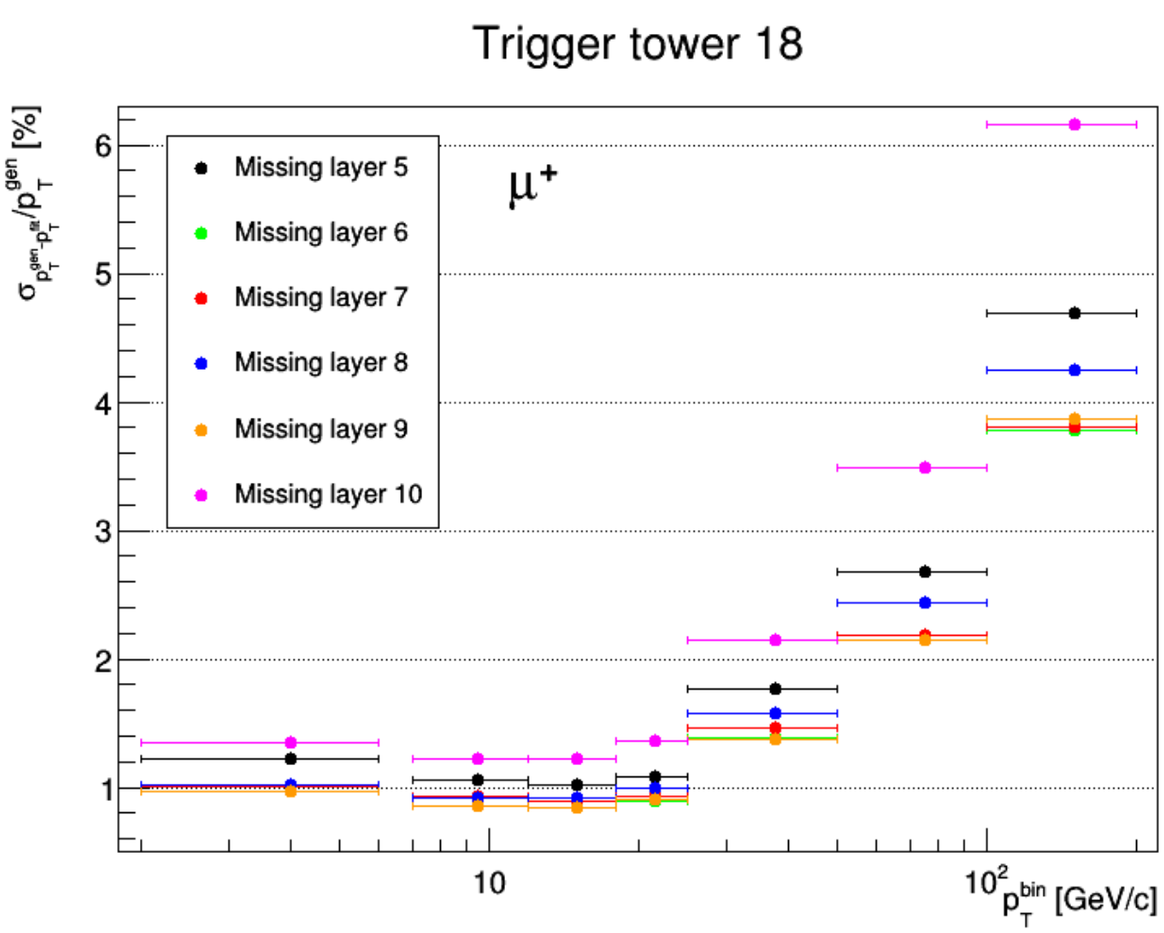


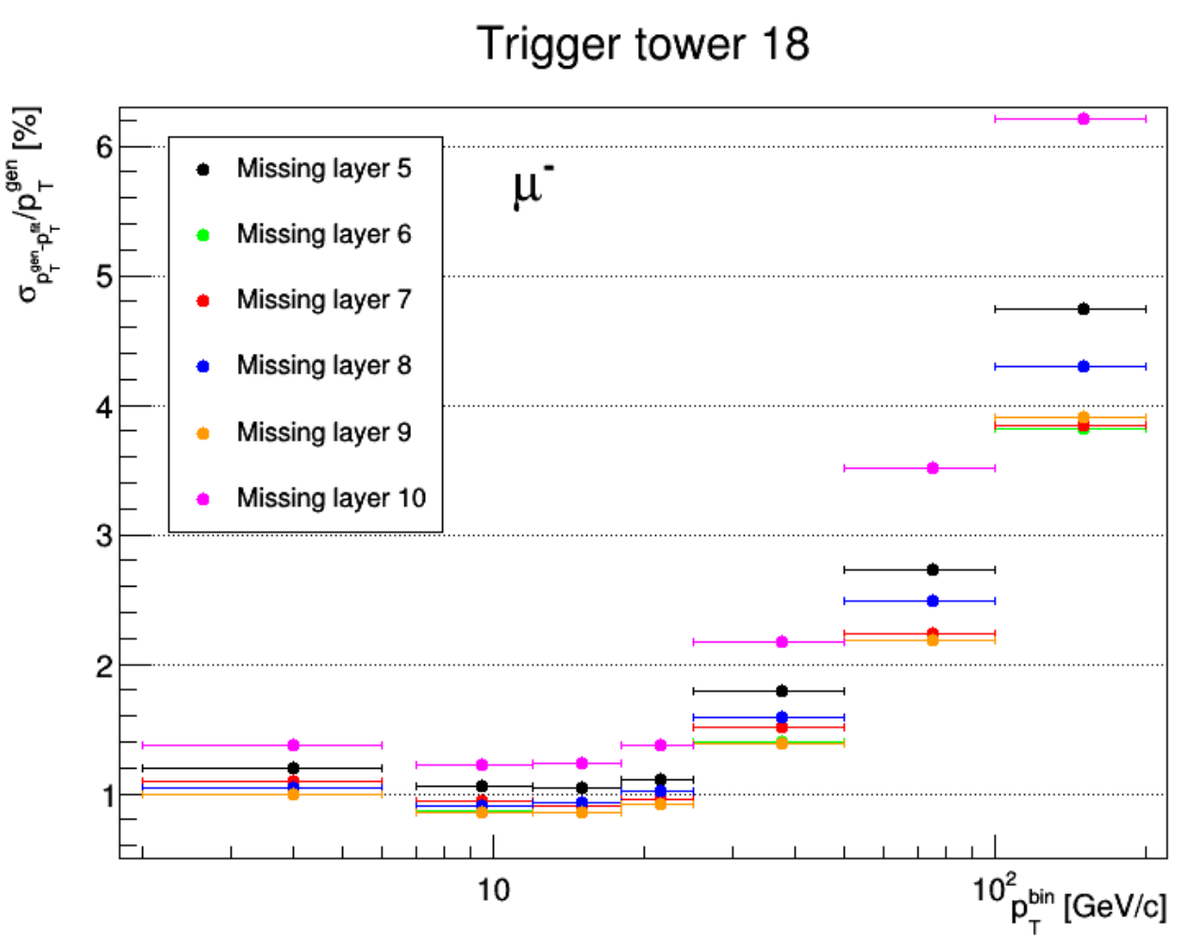


c/p_T results 5 out of 6: resolution

- We have plotted the following variable **[c/p_T(generated) - c/p_T(fit)]/[c/p_T(generated)]**
- We have fitted with a gaussian
- We have plotted the **mean** and the **sigma** of the fit as a function of pt for a single tower

c/pt resolution from 0.8% - 0.9% to 4.2% - 4.9% . When the 10-th layer is missed, resolution from 1.2% to 6.4 %





Conclusion

- The resolutions for the barrel towers are:

rz plane 6/6	
	20 bins in η
Δη	0.0024
Δz_0 cm	0.089
rϕ plane 6/6	
	7 bins in pT
Δϕ rad	0.00022 to 0.0018
Δc/pT	0.8% to 4.1% 0.8% to 3.7% (without tower 27)

rz plane 5/6	
	20 bins in η
Δη	0.0024 (6) to 0.0045 (7)
Δz_0 cm	0.090 (6) to 0.17 (5)
rϕ plane 5/6	
	7 bins in pT
Δϕ rad	0.00024 to 0.0018 (9) 0.00031 to 0.0019 (10)
Δc/pT	0.8% to 4.2% (9) 1.2% to 6.4% (10)

The sets of constants needed are 34 for each barrel tower. To include also 5 out of 6 we need 178 sets

Results Integer representation

Integer Representation

Both PLANES

- 1 datasets have been generated:
  - ~10M of events
  - pt ➙ {2, 200} GeV
  - Using the same configuration as for the floating point

Master Equation:

$$[p\ (\text{parameter})]_{2x1} = [A\ (\text{constant})]_{2x12} * [X\ (\text{coordinates})]_{12x1} + [q\ (\text{constant})]_{2x1}$$

We already know the set of constants “A” and “q”. For a set of Stub Coordinates “X”, we want to compute “p”

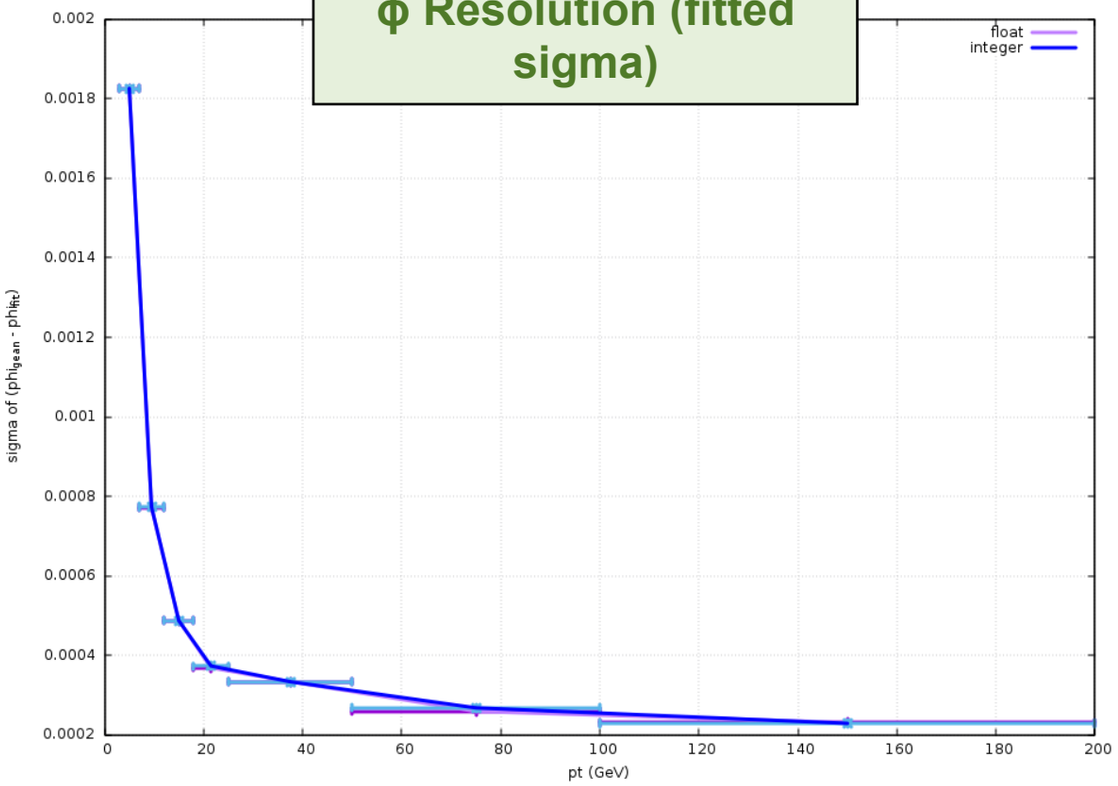
Required bit size in fixed point representation:

- We have assigned 25 bits for the constants, both 'A' and 'q’
- Coordinates are represented by 18 bits
- 25*18 bit multiplication operations are supported by DSP's

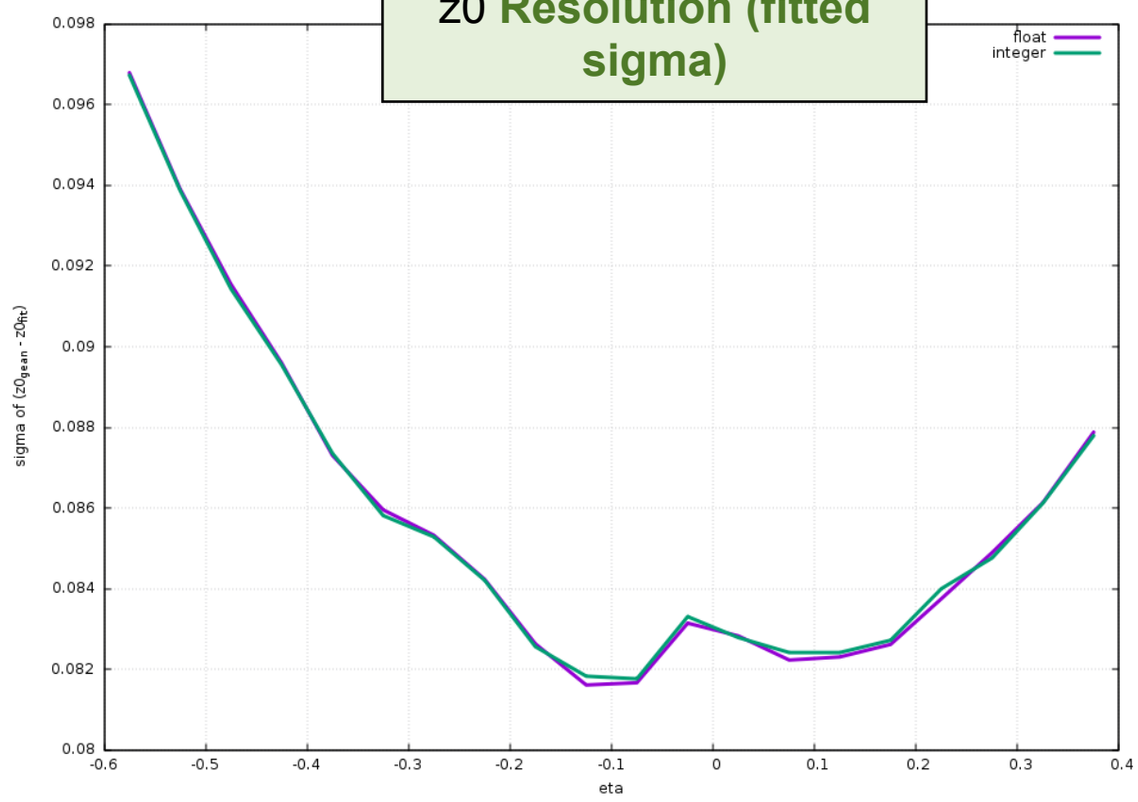
Input precision for stub coordinates:
r-z Plane: r & z 10 μm; r-phi Plane: r 10 μm & ϕ 0.1 mrad

Plane rϕ, rz (6 out of 6)

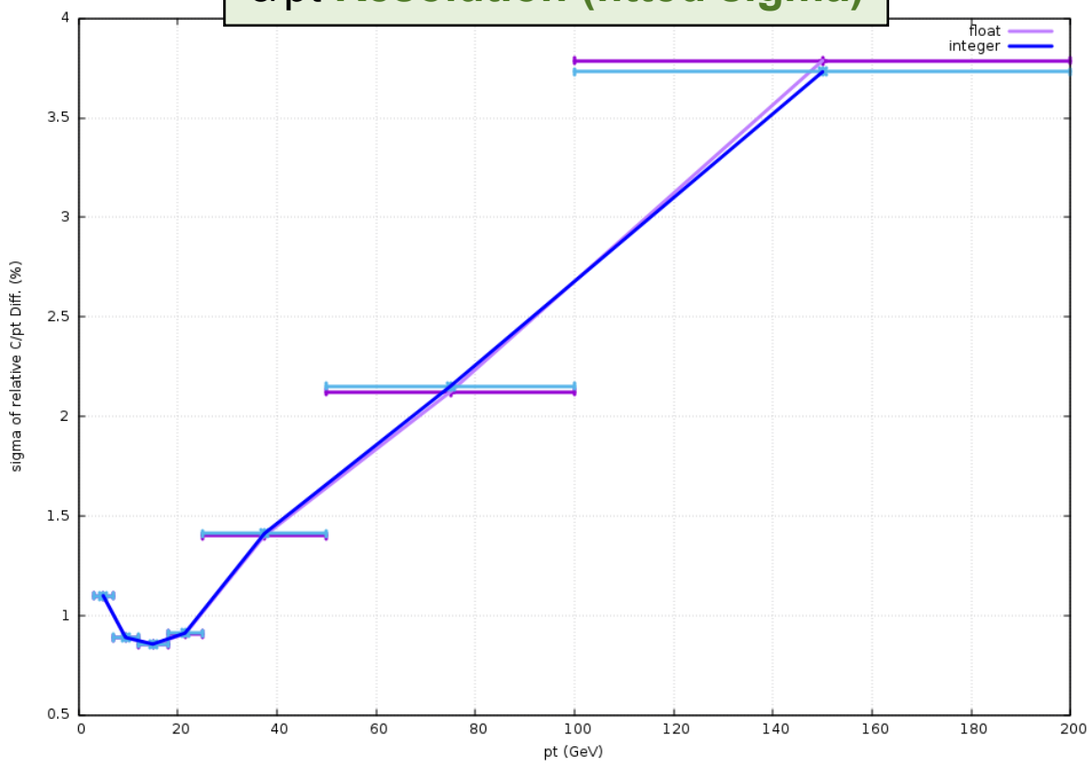
ϕ Resolution (fitted sigma)



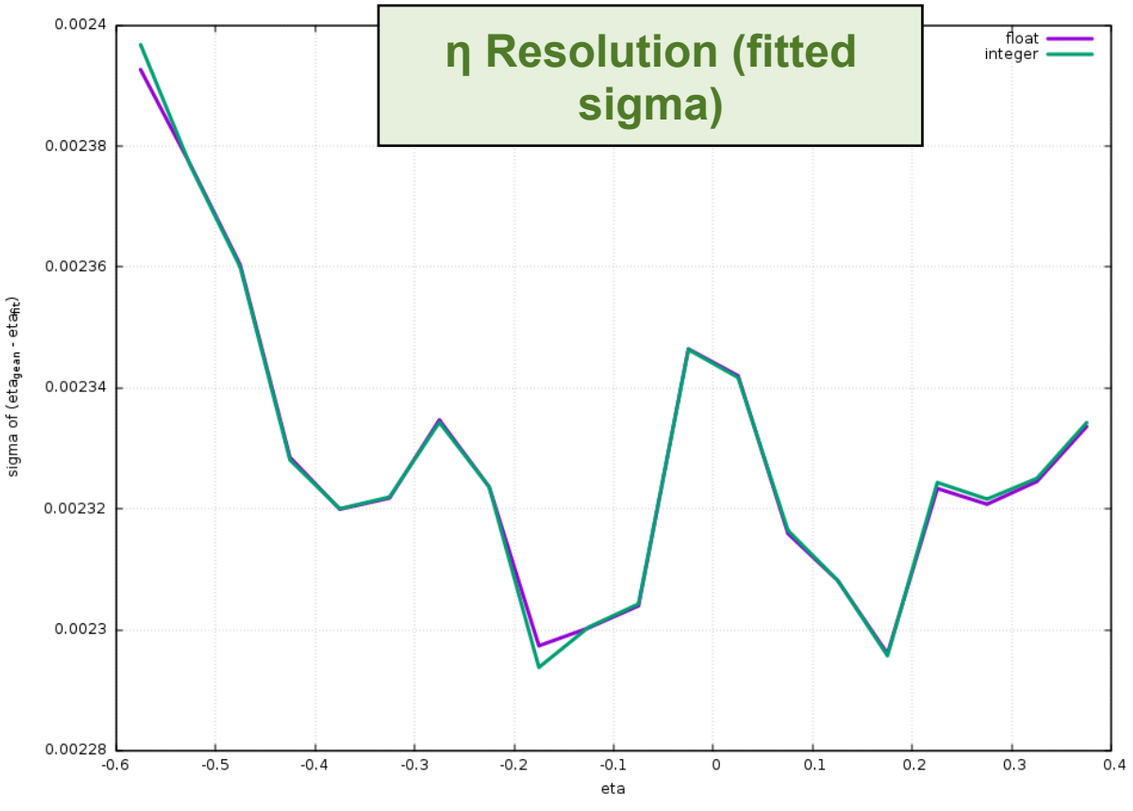
z0 Resolution (fitted sigma)



c/pt Resolution (fitted sigma)



η Resolution (fitted sigma)



Preliminary Results

CMSSW 6/6 and 5/6

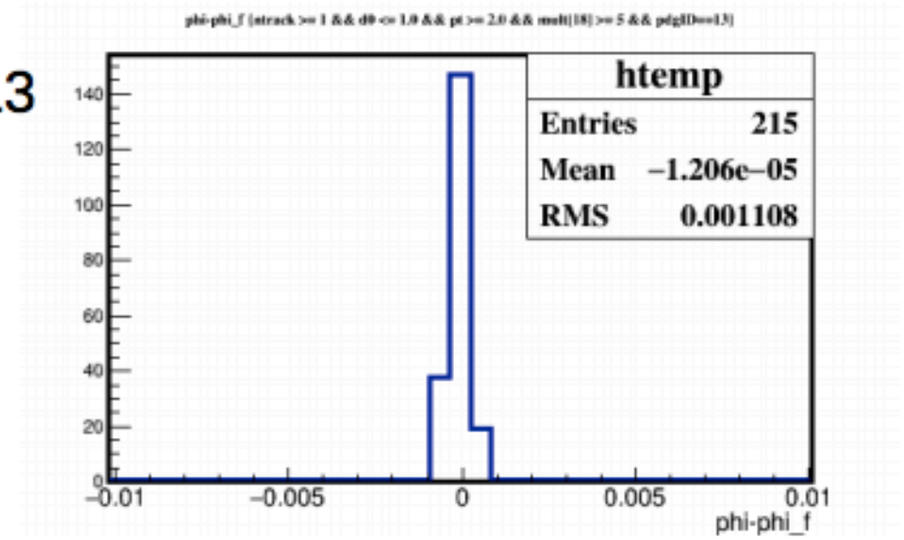
Preliminary results Tow18

- Used Muon Pt 100 GeV + 140 PU sample
- There are two scenarios of mathcing: 5/6 and 6/6
- Processed full sample: ~ 9k events in 48 sector
- we used one of the sectors (18), low statistics

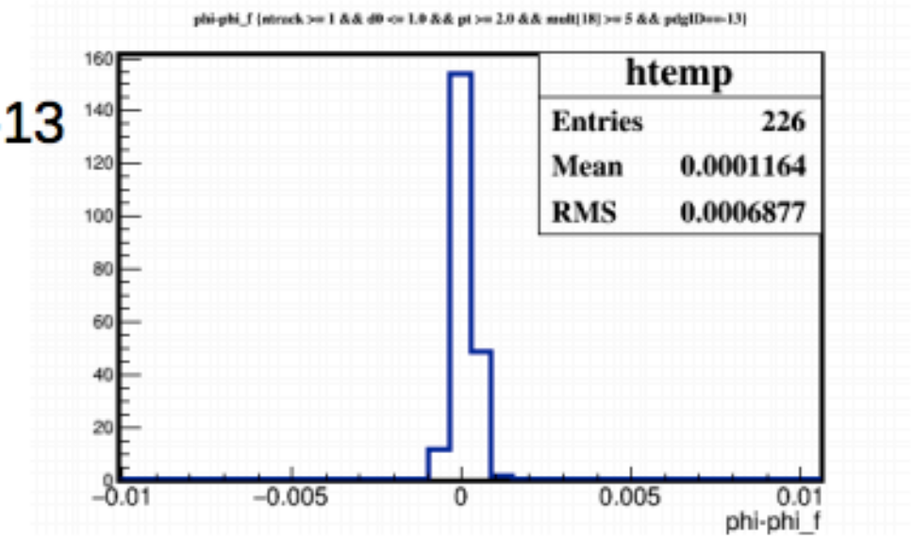
ϕ resolution

Matching secnario:(5/6 || 6/6) together

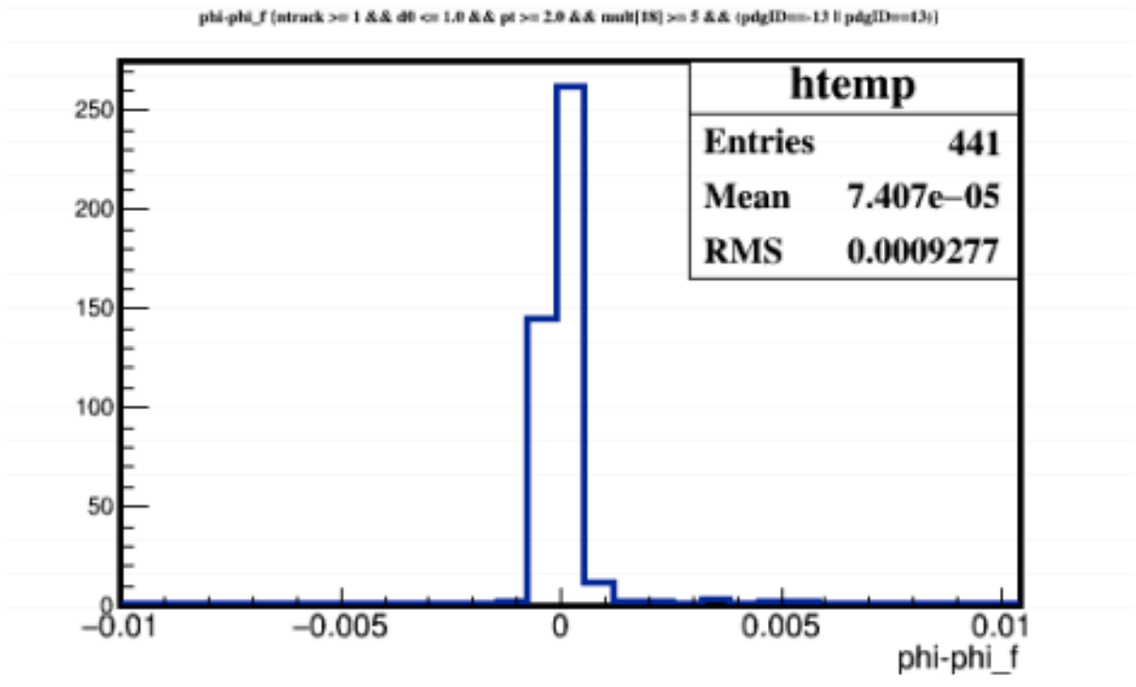
PDG:13



PDG:-13



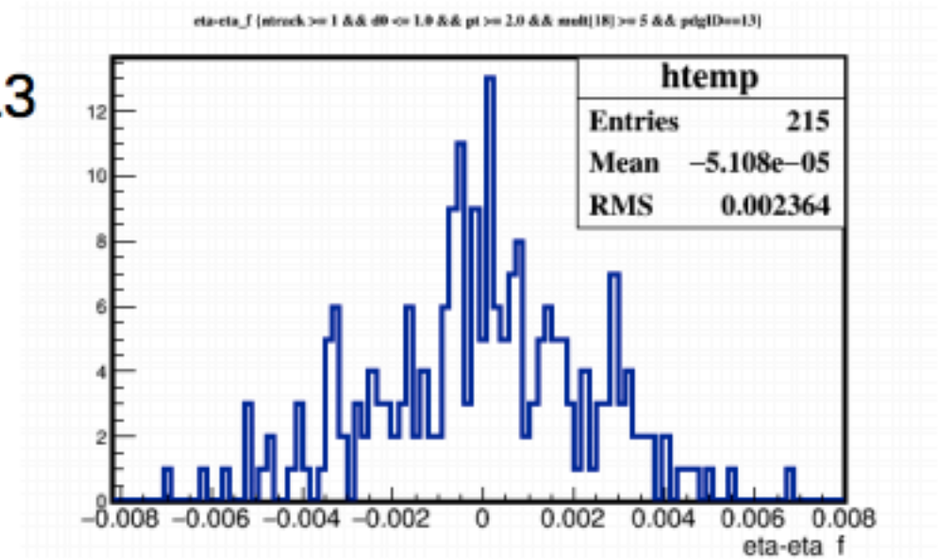
PDG: ±13



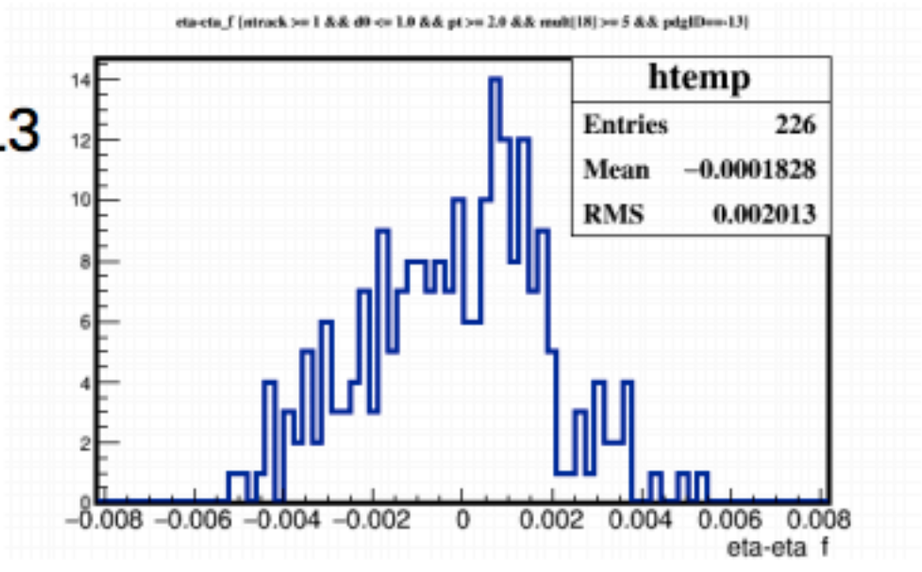
η resolution

Matching secnario:(5/6 || 6/6) together

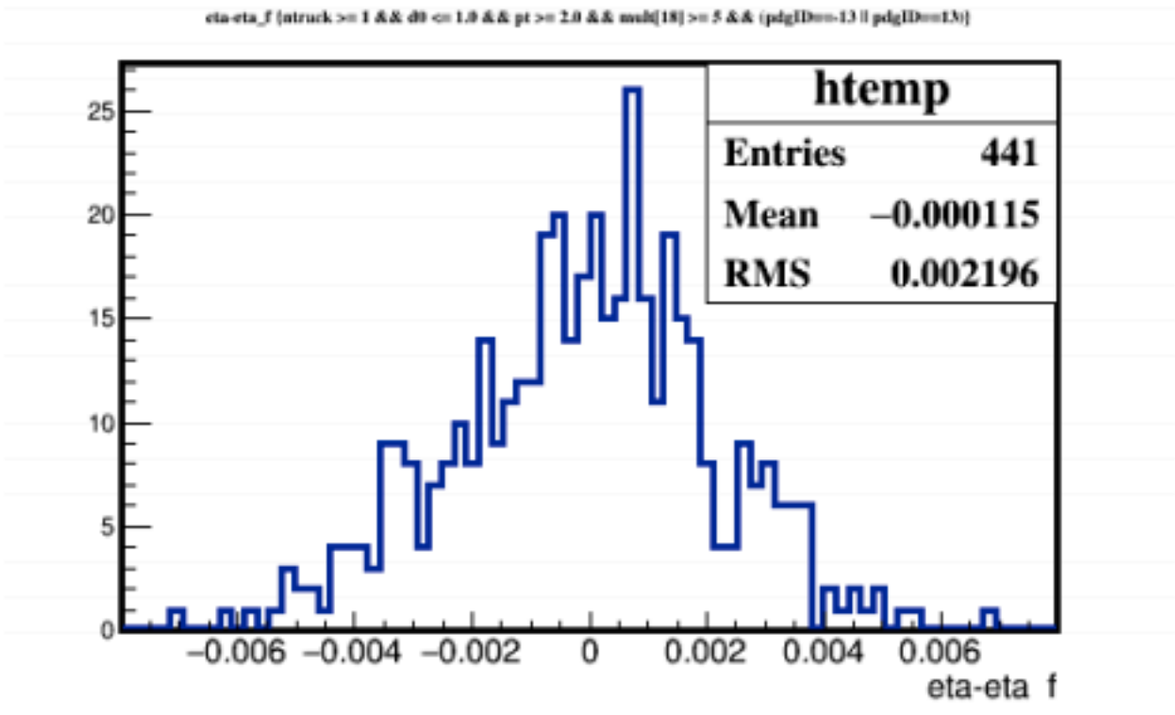
PDG:13



PDG:-13



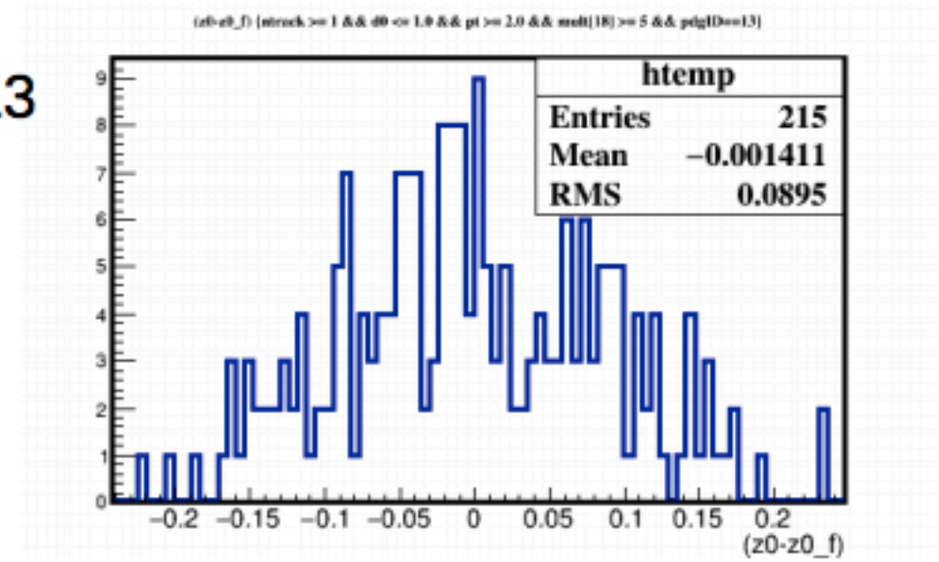
PDG: ±13



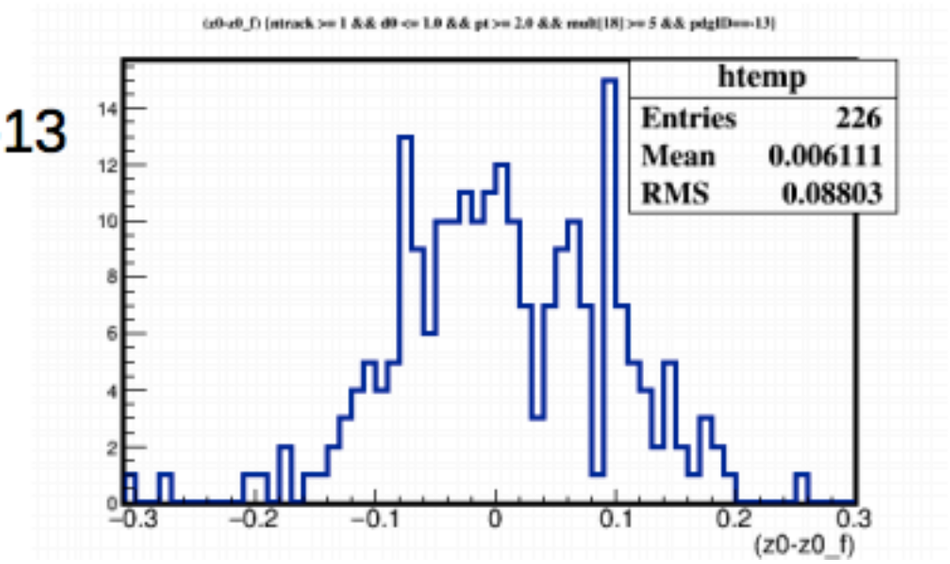
z0 resolution

Matching secnario:(5/6 || 6/6) together

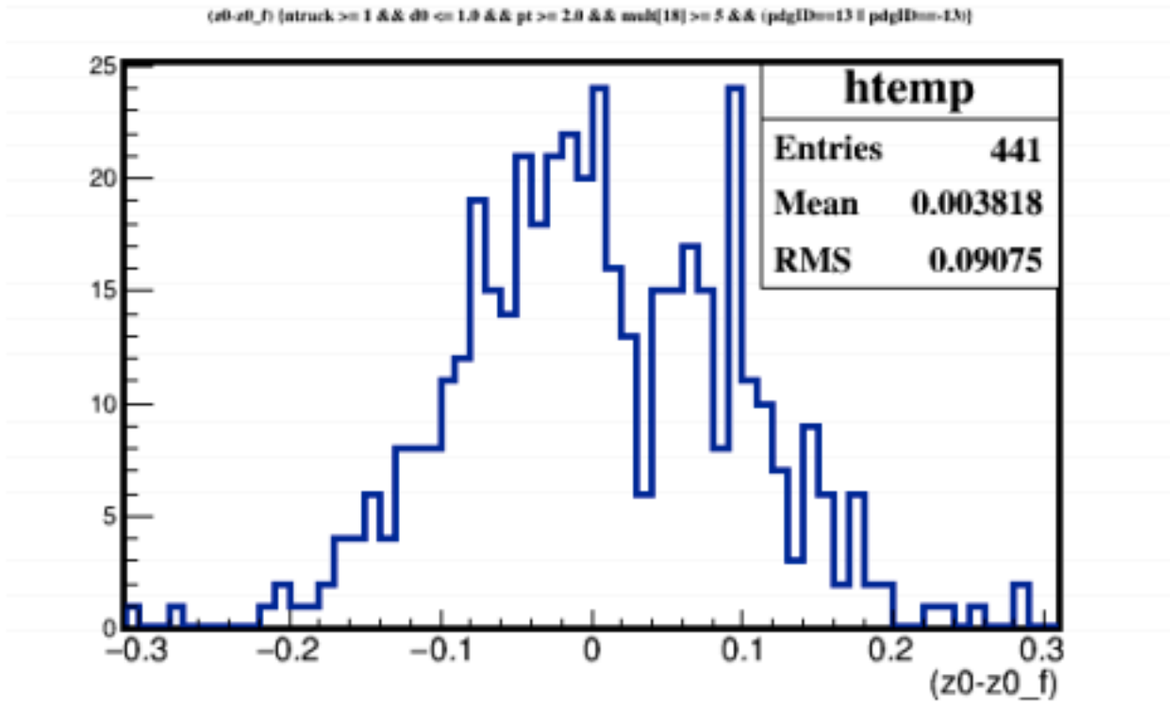
PDG:13



PDG:-13



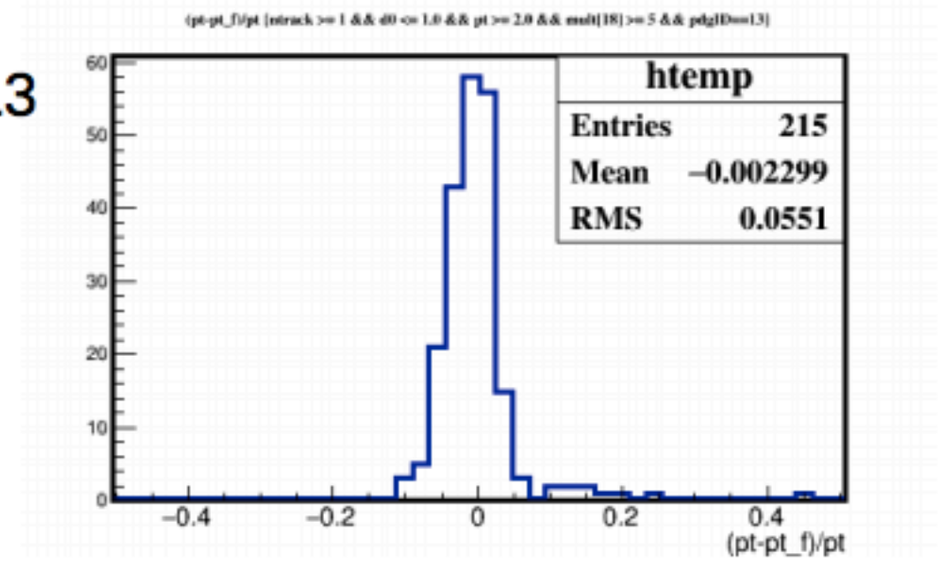
PDG: ±13



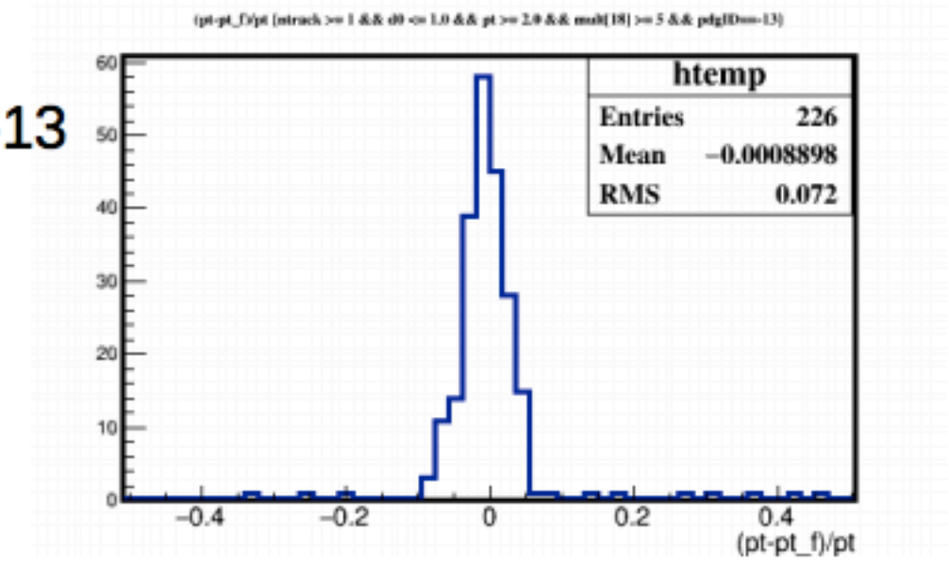
pt resolution

Matching secnario:(5/6 || 6/6) together

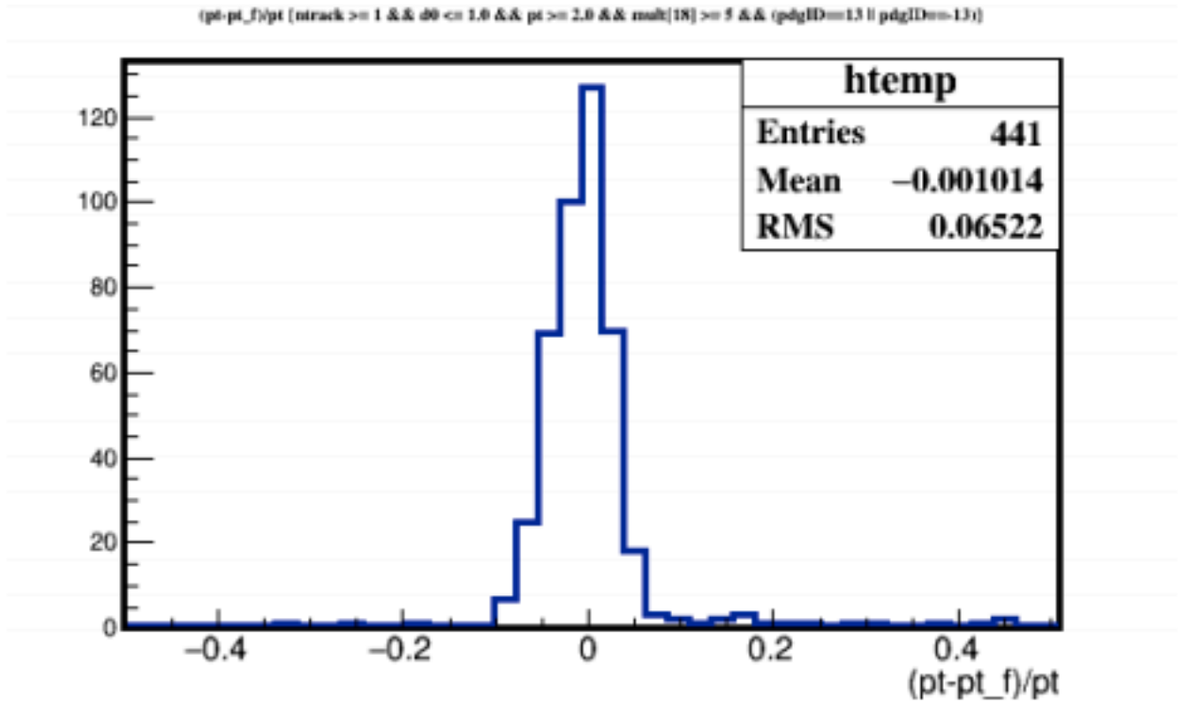
PDG:13



PDG:-13



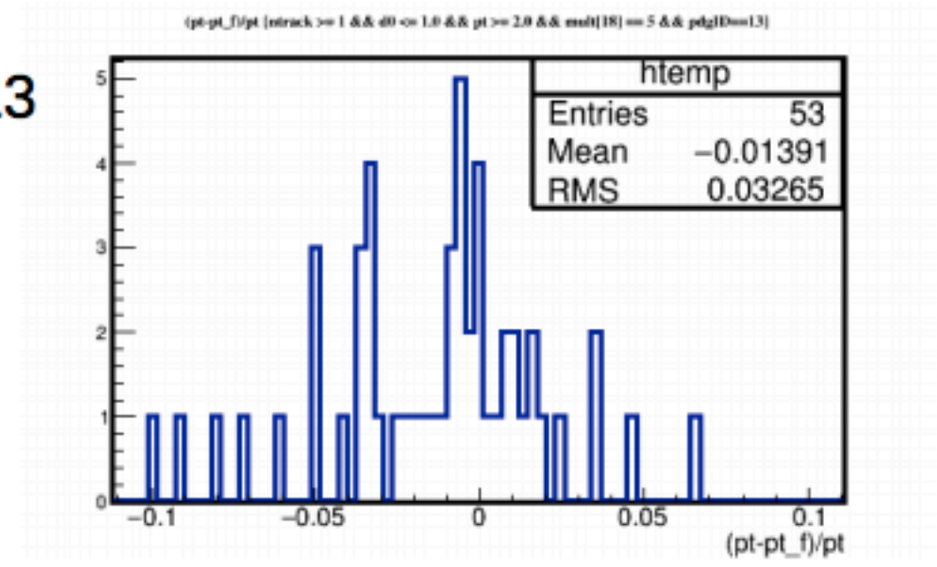
PDG: ±13



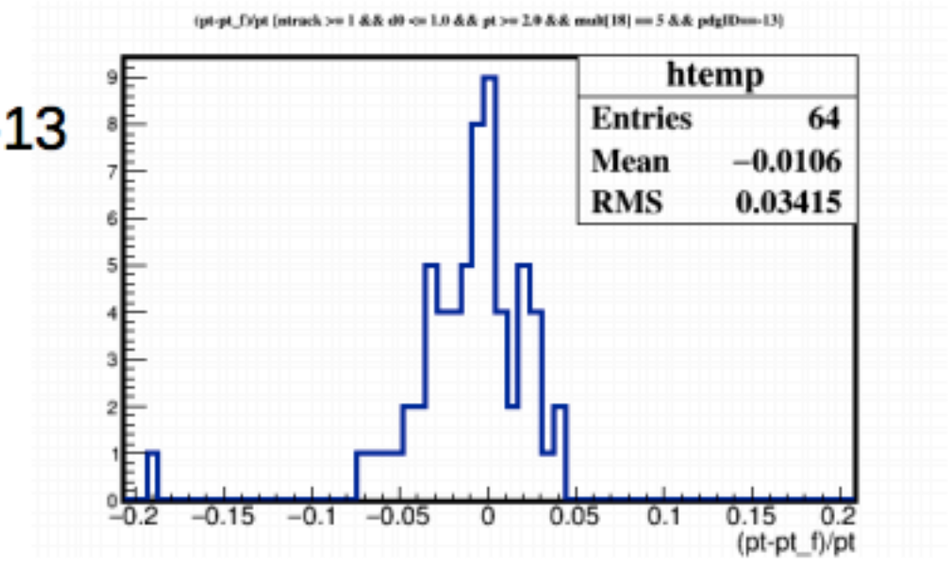
pt resolution

Matching secnario: 5/6 only

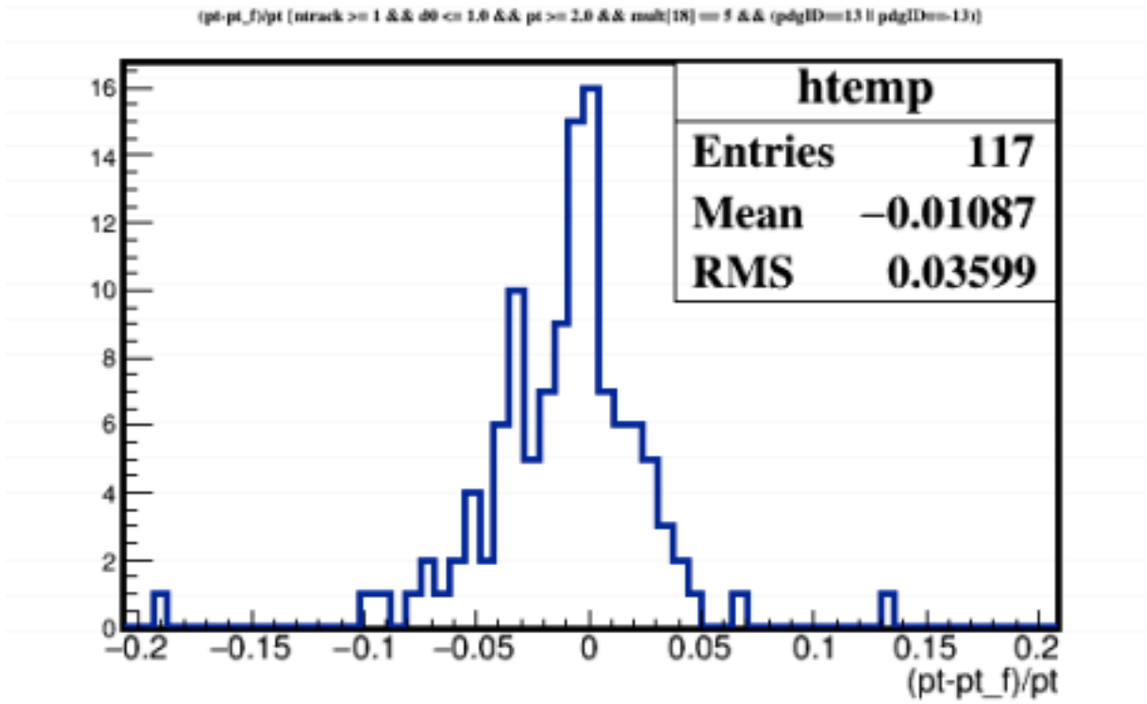
PDG:13



PDG:-13



PDG: ±13



Conclusion

- The resolutions in the barrel for the fixed point are the same as for the floating point

The sets of constants needed are 34 for each barrel tower. To include also 5 out of 6 we need 178 sets. If we include also the chi2 we will need 356 sets (712 matrices / vectors) for each barrel tower

- We prepared a full set of PCA constants (including also Chi2) for the whole barrel region. (only floating point)
- Need to fully validate the set of constant within CMSSW
- Test different pt bin to increase the resolution in the r-phi plane
- Fixed point version for the full barrel is almost ready
- Extend the PCA approach also to hybrid and endcap sectors