Status Report for the PANDA GEM-Tracker Simulation

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Motivations

- **Comparison between track reconstruction using PndSttMvdGemTracking class and PndBarrelTrackFinding class**
- **Momentum resolution and track finding efficiency**
- **To check and compare the PANDA GEM-tracker acceptance using full geometry with one or three stations**
- **Invariant mass reconstruction for the antip + p ⟶ ∧0 + anti∧0 as a important hyperonic channel**

Small Summary from the previous presentations and its'Results

Part One :

As Reminder

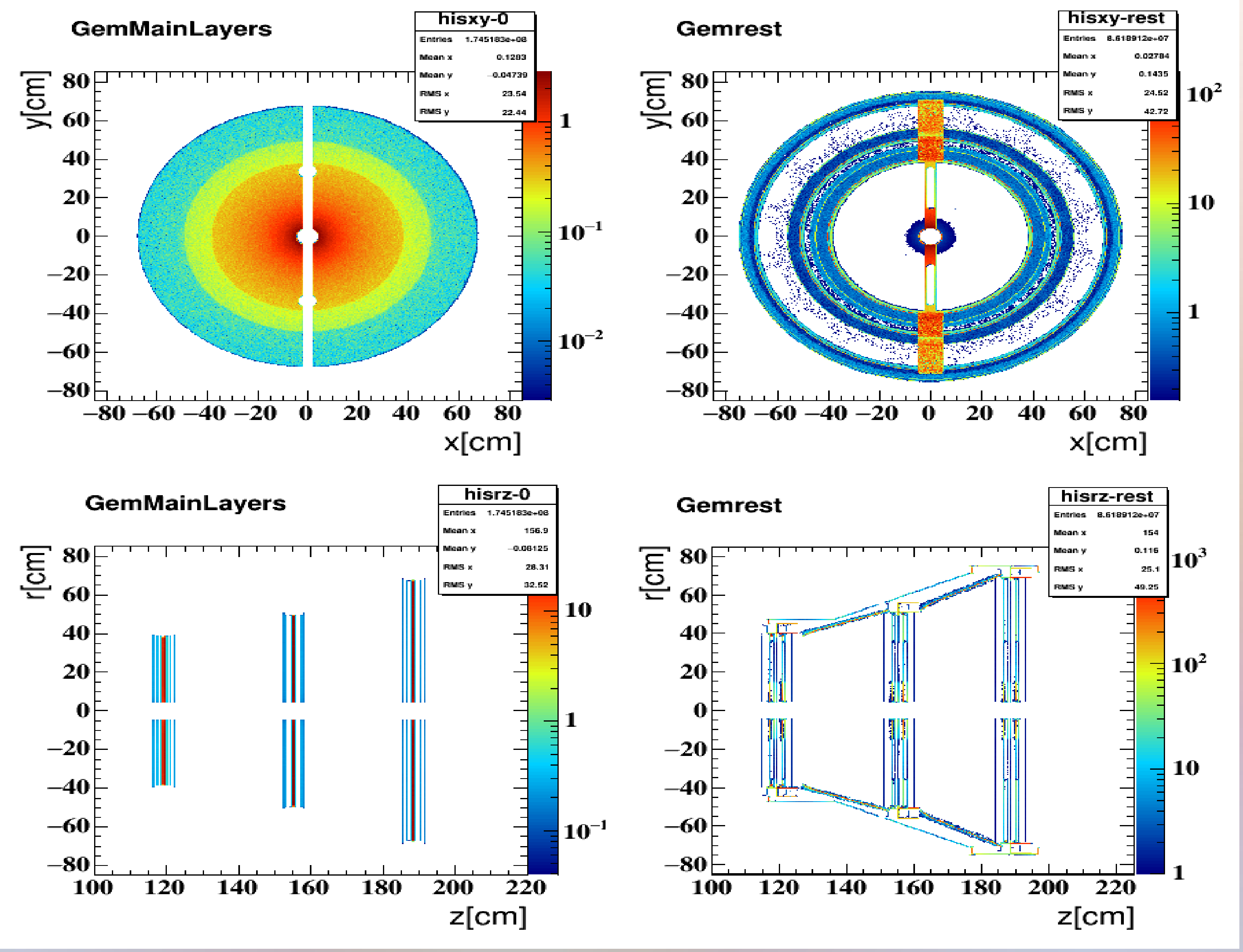
Details Reminding about the PANDA GEM-tracker Geometry on the Simulation

3 GEM Stations

MC Points, xy view

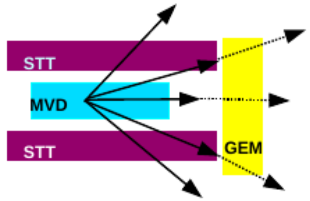
3 GEM Stations

MC Points, rz view



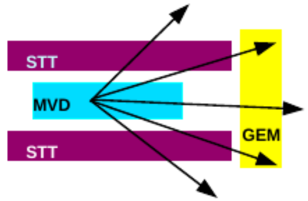
gem_3Stations_realistic_v1.root
gem_3Stations_realistic_v1.digi.par

Reminding Studies results about the GEM influence to improve track reconstruction



PndSttMvdGemTracking

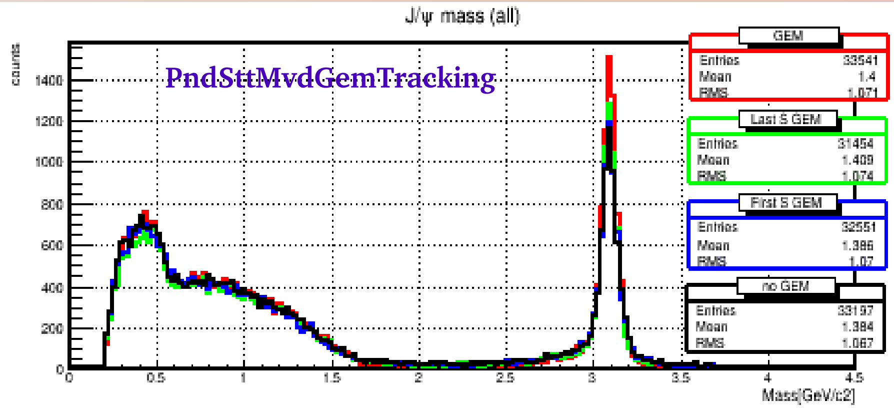
- Current tracking class in the framework is PndSttMvdGemTracking
  - Tracking procedure always uses hits in STT and MVD
  - GEM hits are used for track improving when they exist
  - Contributions with STT+MVD & GEM coincidence is not large

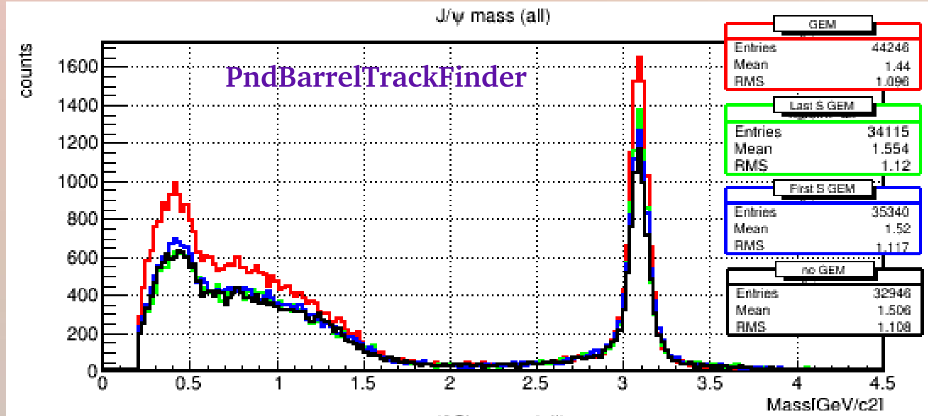


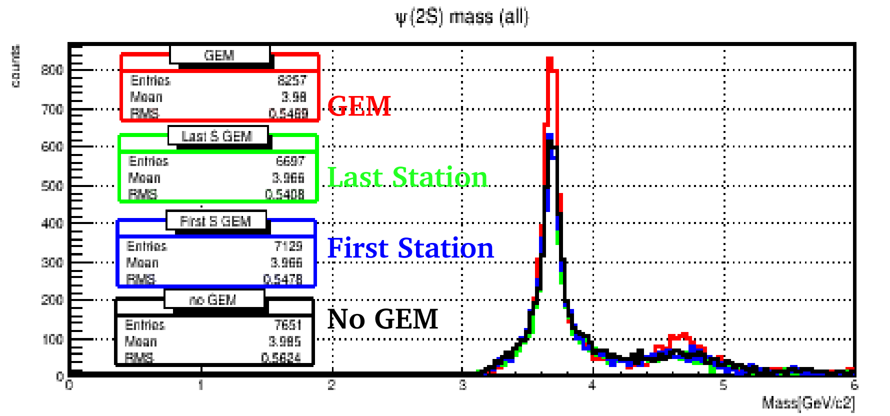
PndBarrelTrackFinder

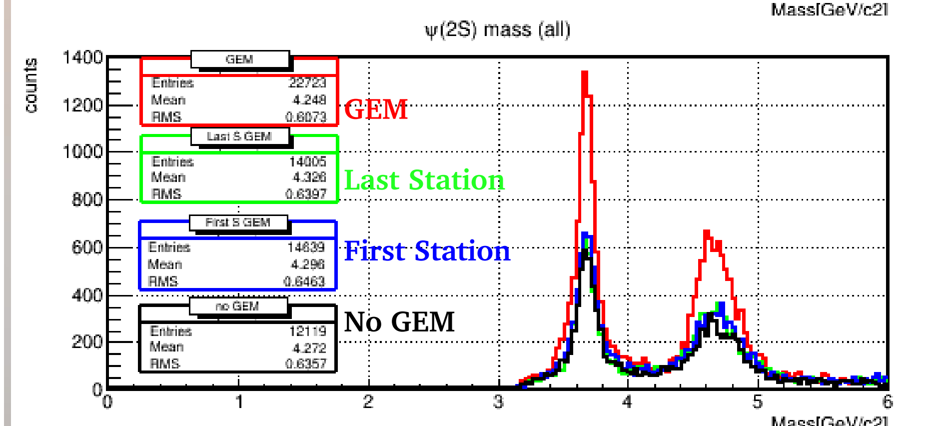
- Another tracking class in the framework is PndBarrelTrackFinder
  - Tracking procedure always uses any hits in STT and MVD and GEM
  - GEM hits are counted for track finding simultaneously
  - Contributions with STT+MVD & GEM coincidence is good

- **The PndBarrelTrackFinder gives better results than the PndSttMvdGemTracking in the Psi channel since there are low momentum pions going in the forward directions using GEM with 3 stations.**

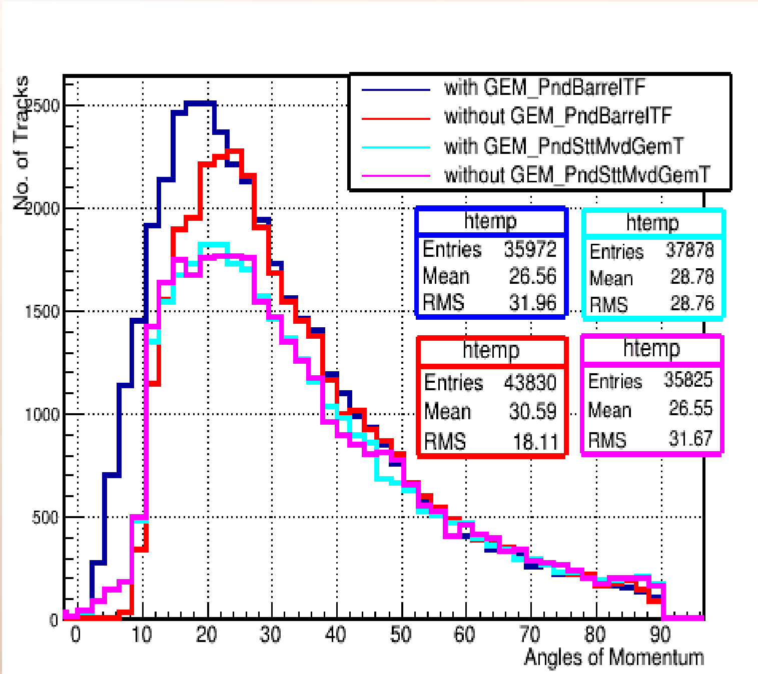


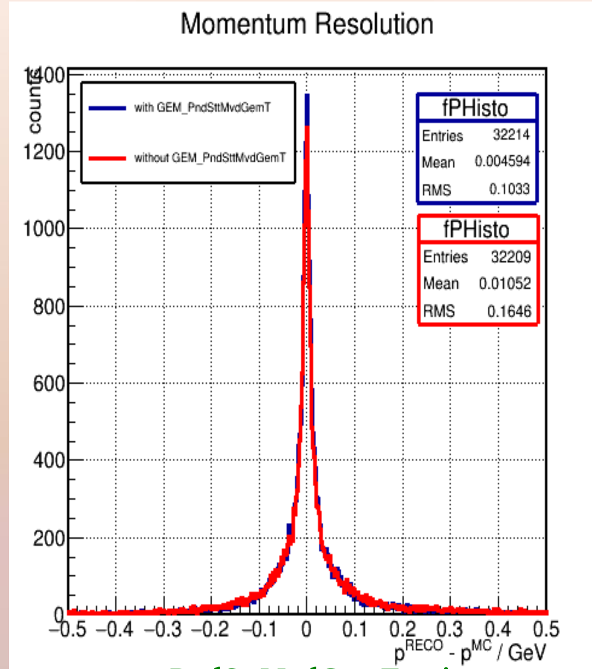




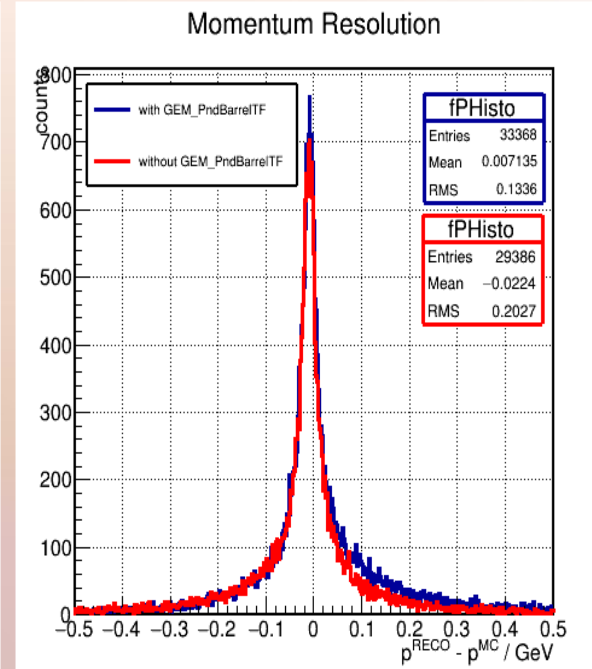


Reminding about the Investigation of Track Finding Efficiency & Momentum Resolution





PndSttMvdGemTracing



PndBarrelTrackFinder

- Although momentum resolution doesn't improve too much by using PndBarrelTrackFinder class, it could be useful to reconstruct tracks in forward directions (GEM region).
- How about the quality of track finding by using PndBarrelTrackFinder track reconstruction class and influence of GEM to improve momentum resolution?
- By mentioning to these points : To need to continue our study in all of aspects !

Part Two :

Single Particle Study

Single Particle Study

- We need to understand the behavior of these two classes at different momenta and angles.

- In this study , the simulation condition:
  No. of Events=10000,   SimEngine =TGeant4,   Event generator=BoxGenerator,
  Particles=Pions (211),   Phi range=0 to 360 [degree],

  Theta range =2, 4, 8, ..., 22, 25, 30, ..., 45 [degree]
  Particles Momentum= 0.1, 0.2, 0.5, 1, 2, 5 [GeV/c]
  (We need to study about low momentum pions for hyperon channel)

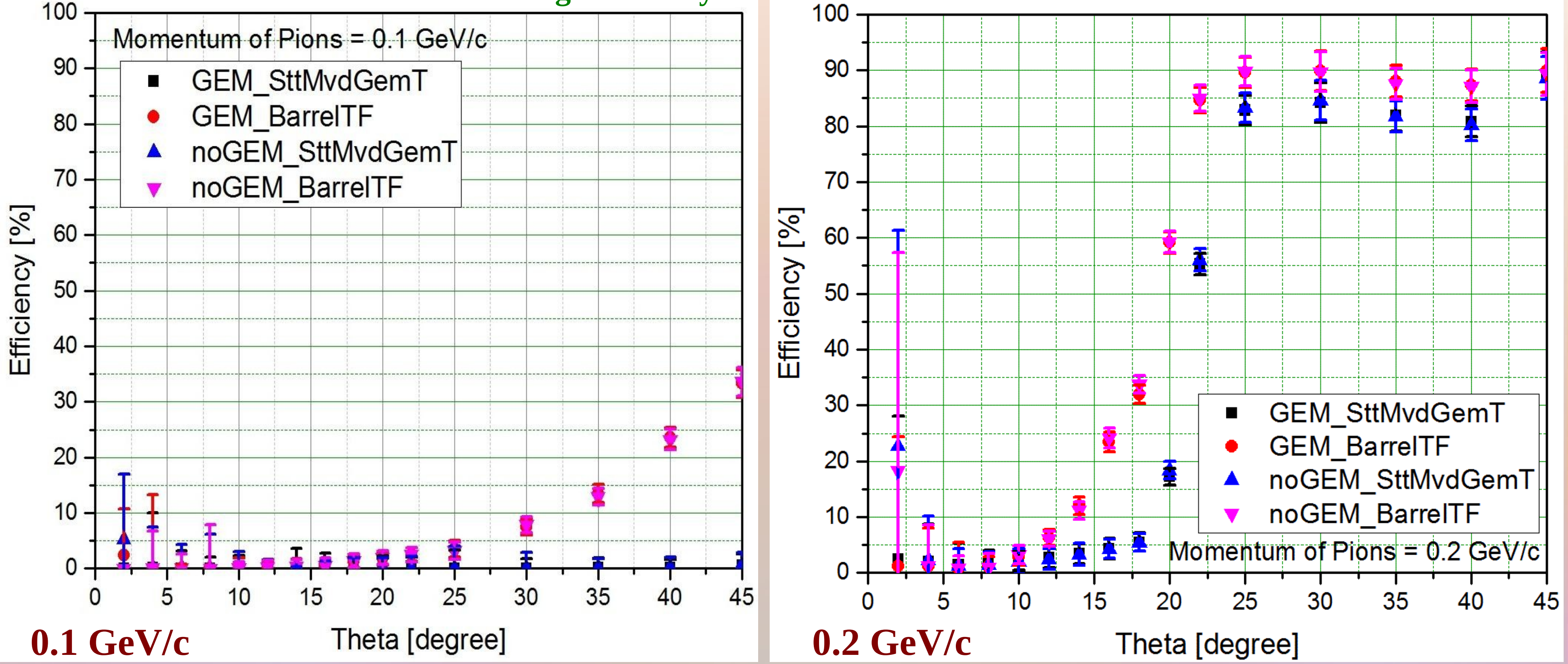
- For each theta and Momentum we did the simulation separately in several cases:
  without and with GEM (full geometry(3stations) – its' covering polar angle= 2° to 20°)
  using PndSttMvdGemTracking & PndBarrelTrackFinder

- Macros in used for each theta and momentum:
  Gem_simBox.C
  Gem_digBox.C
  Gem_recBox.C
  Gem_recoqaBox.C
  Gem_recBox_bar.C
  Gem_recoqaBox_bar.C

- Using Revision: 29377 of PandaRoot

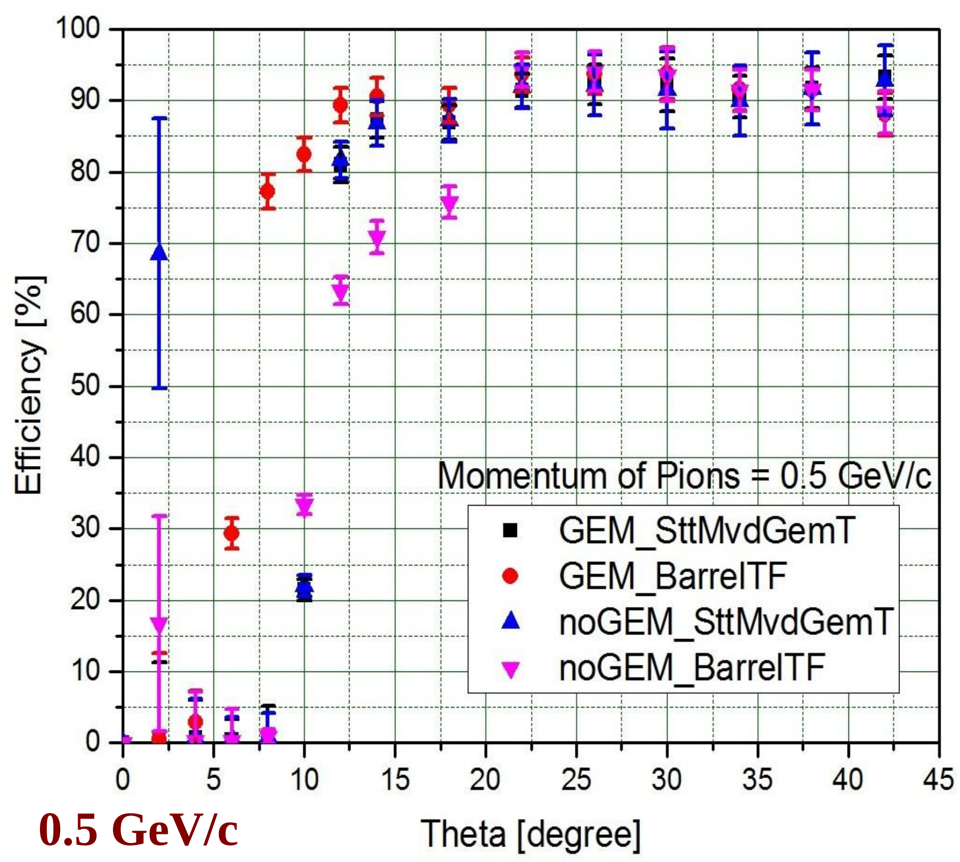
Quality of Track Finding Efficiency Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder

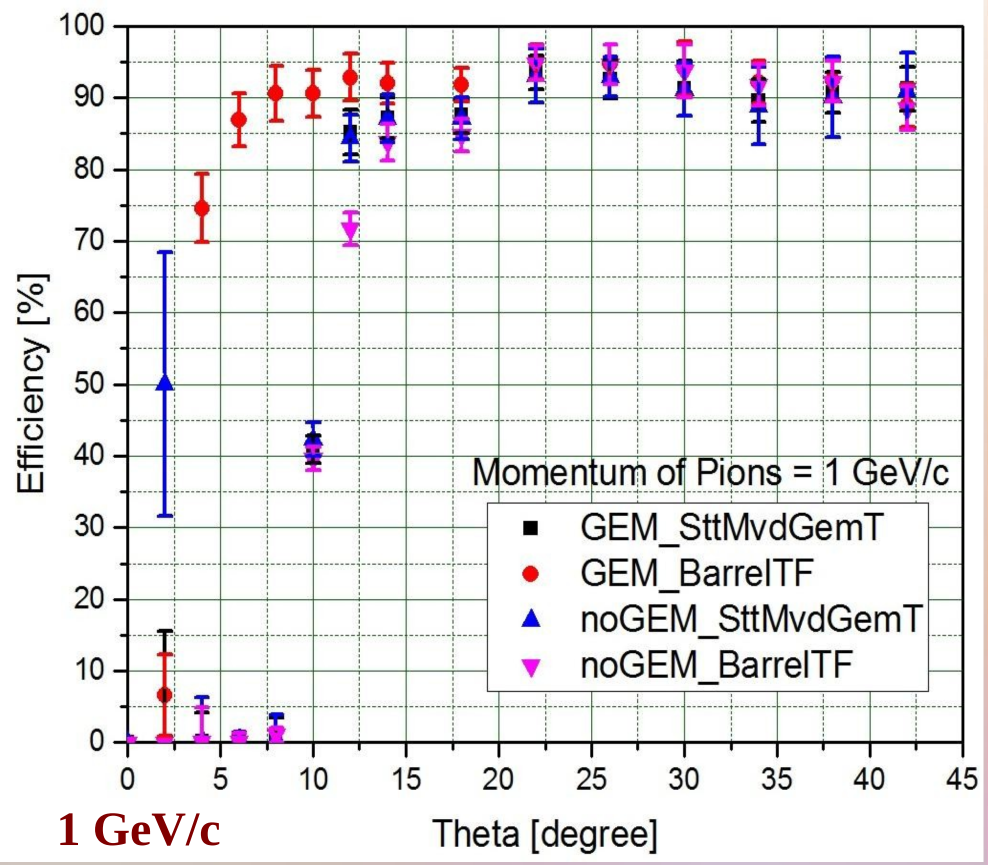
Track Finding Efficiency versus Theta for Pion = 0.1 & 0.2 GeV/c



- Quality of Track Finding Efficiency is not good for low momentum tracks

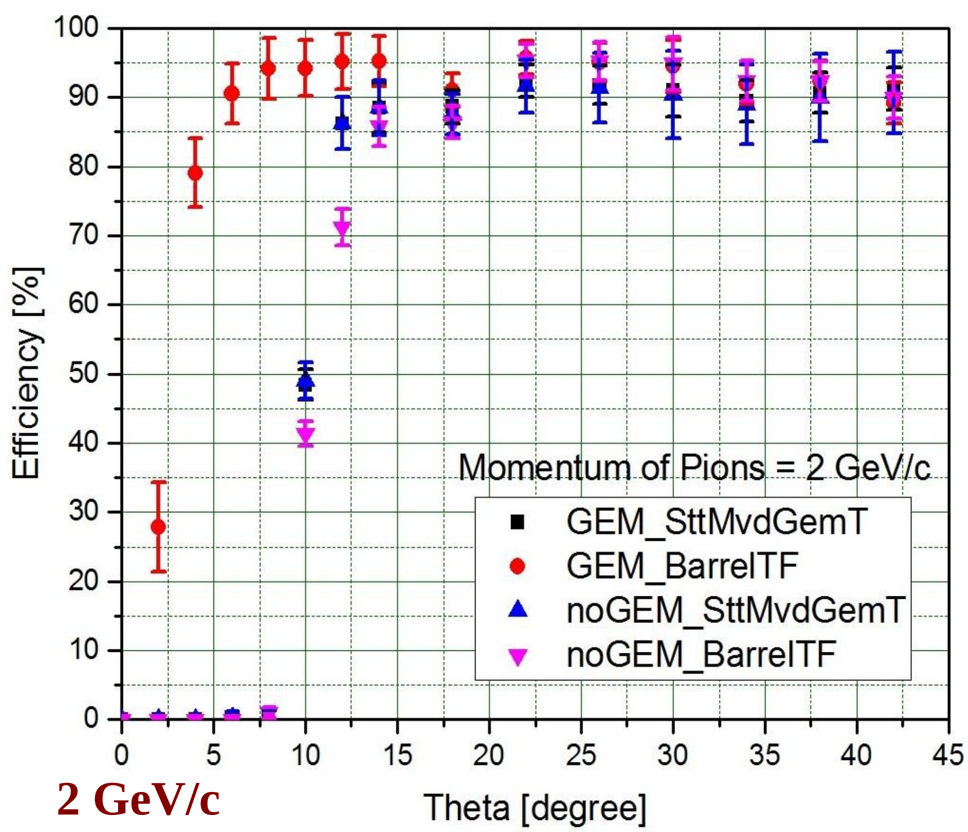
Track Finding Efficiency versus Theta for Pion = 0.5 & 1 GeV/c

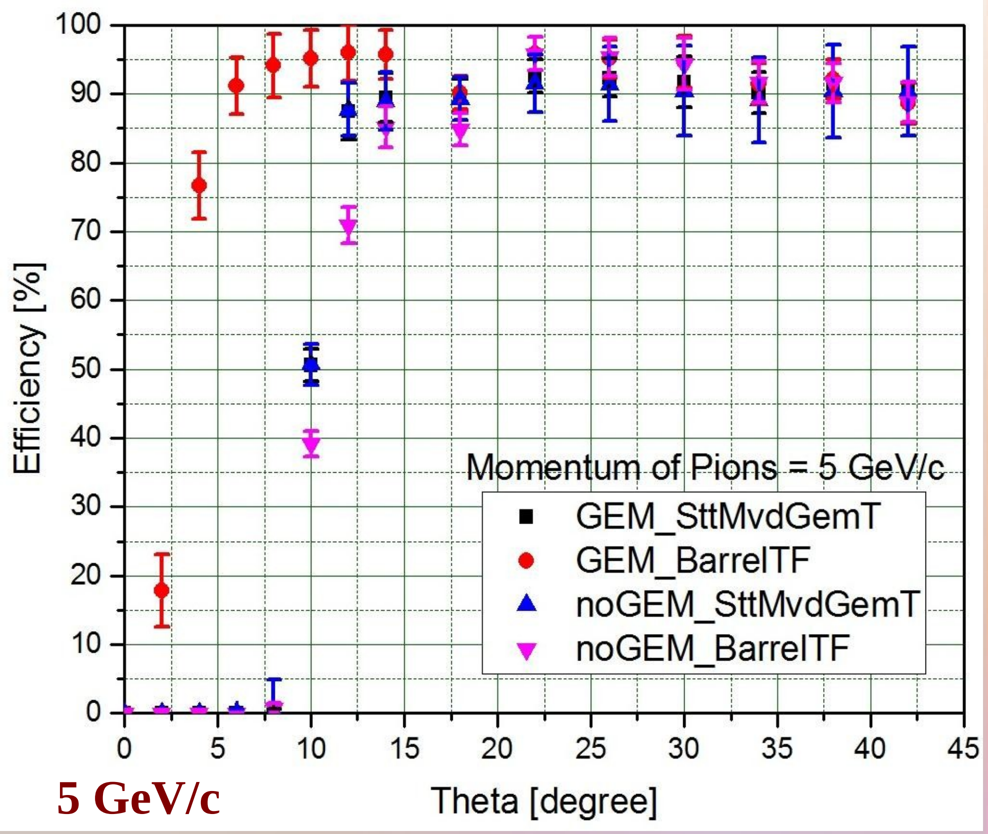




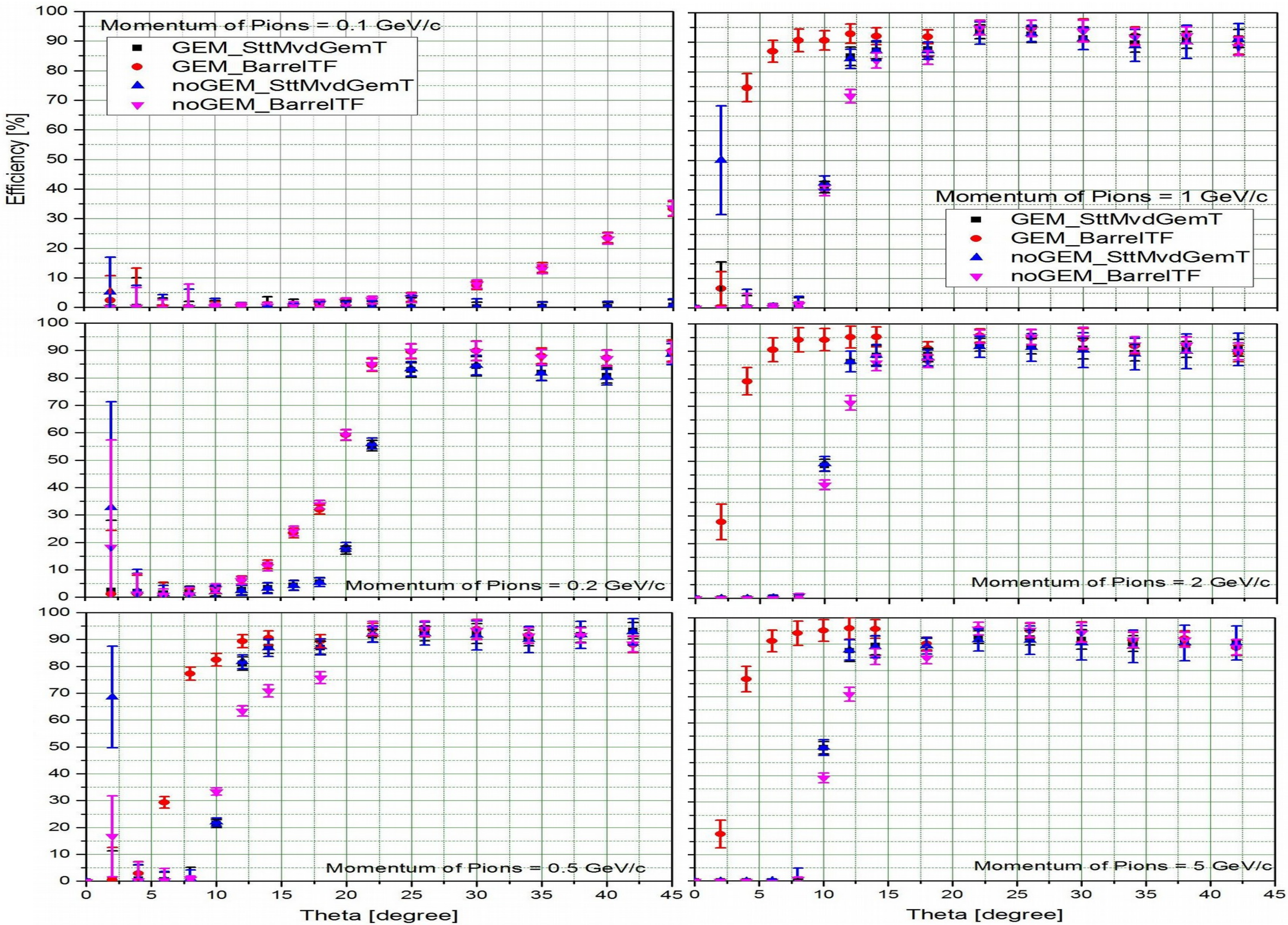
- Quality of Track Finding Efficiency is getting higher by increasing the momentum of particles
- The performance of the GEM is coming to appear clearly

Track Finding Efficiency versus Theta for Pion = 2 & 5 GeV/c



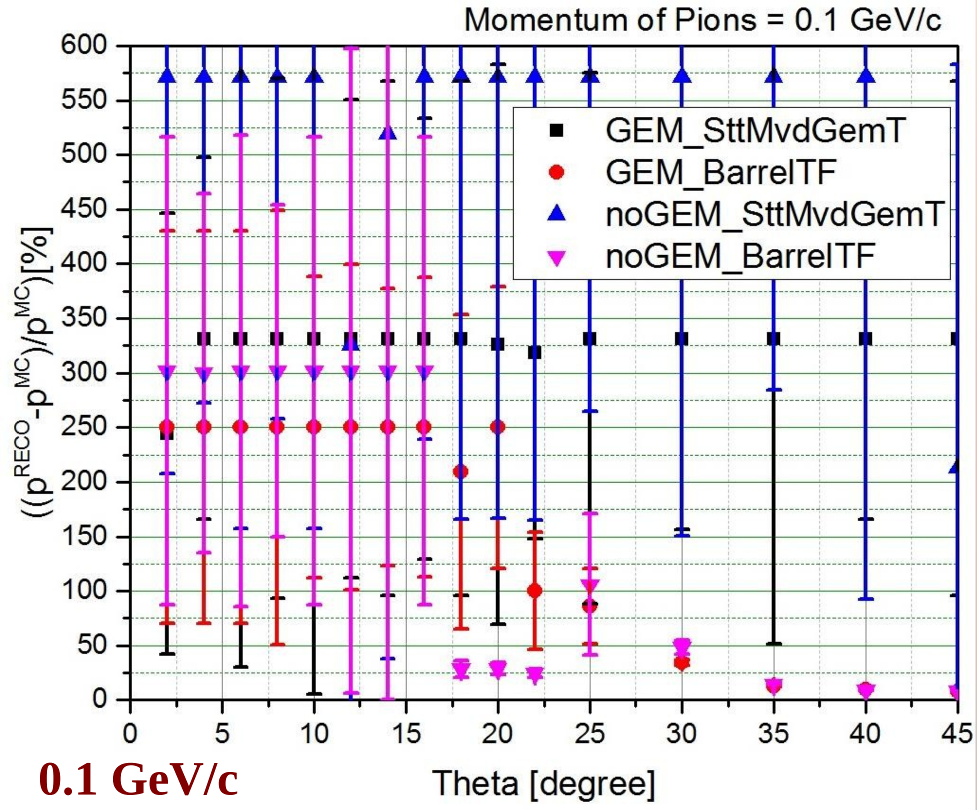


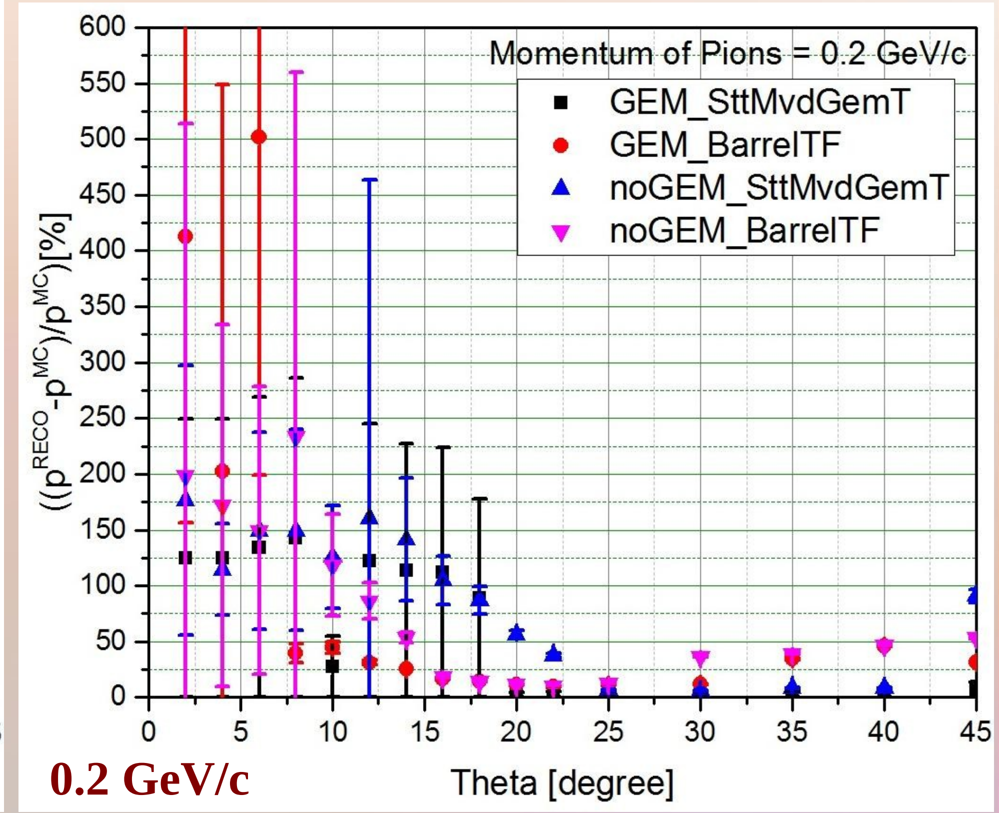
- **The performance of the GEM is good to improve the quality of Track Finding Efficiency**
  - **There is big changes for the GEM and in case of using PndBarrelTrackFinder**


Momentum of Pions = 0.1 GeV/c
GEM_SttMvdGemT
GEM_BarrelTF
noGEM_SttMvdGemT
noGEM_BarrelTF
Efficiency [%]
Momentum of Pions = 1 GeV/c
Momentum of Pions = 0.2 GeV/c
Momentum of Pions = 2 GeV/c
Momentum of Pions = 0.5 GeV/c
Momentum of Pions = 5 GeV/c
Theta [degree]
Theta [degree]

Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder

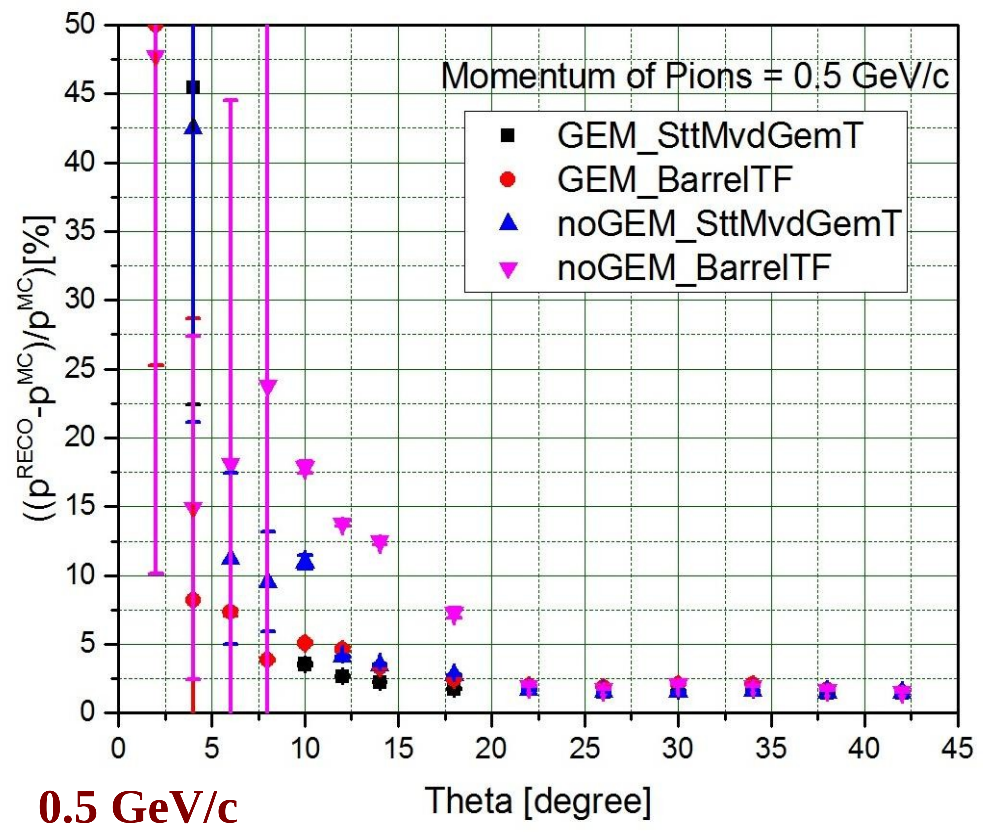
Momentum Resolution versus Theta for Pion = 0.1 & 0.2 GeV/c

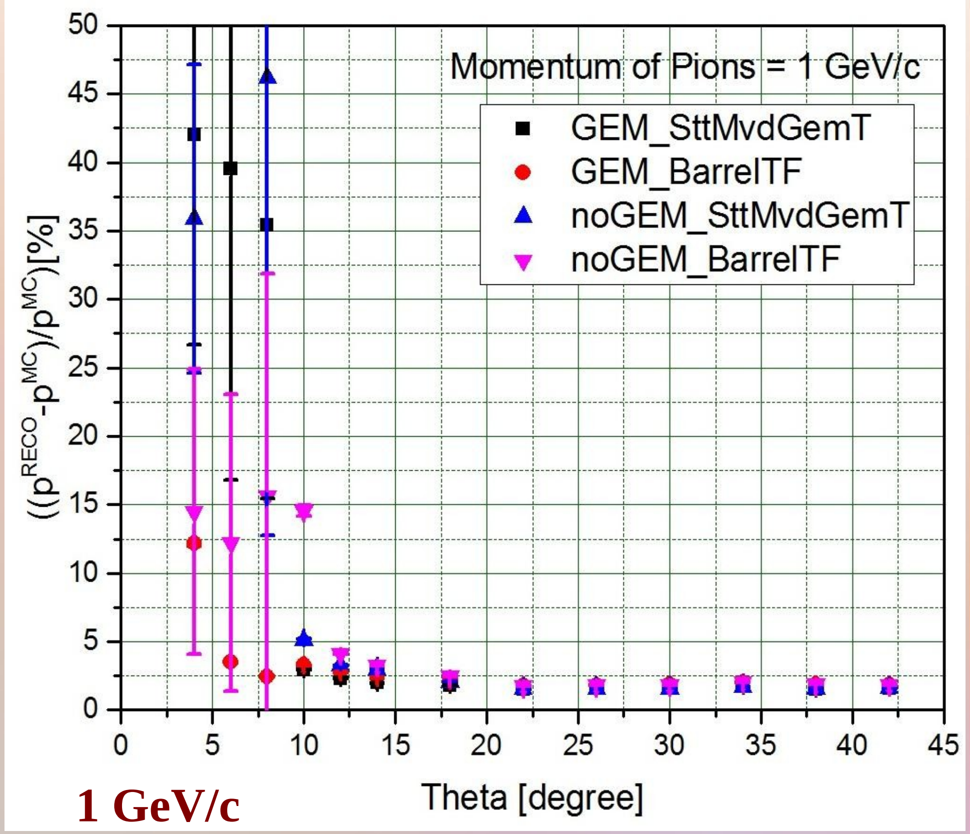




- **Momentum Resolution is not good for low momentum tracks**

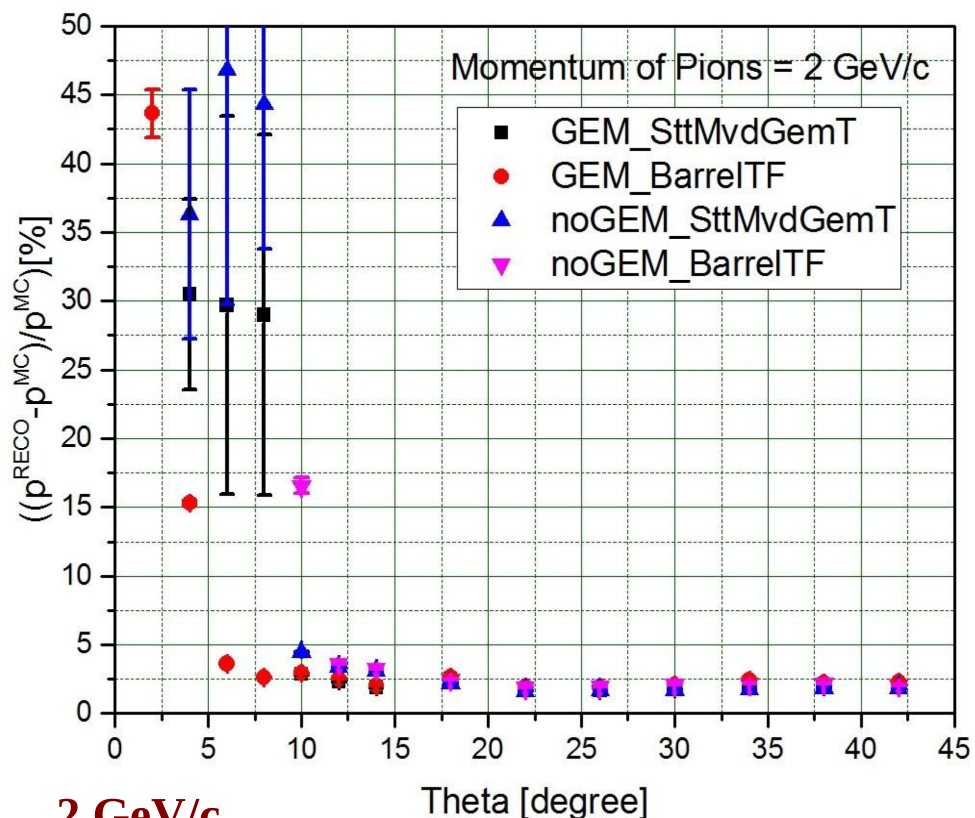
Momentum Resolution versus Theta for Pion = 0.5 & 1 GeV/c



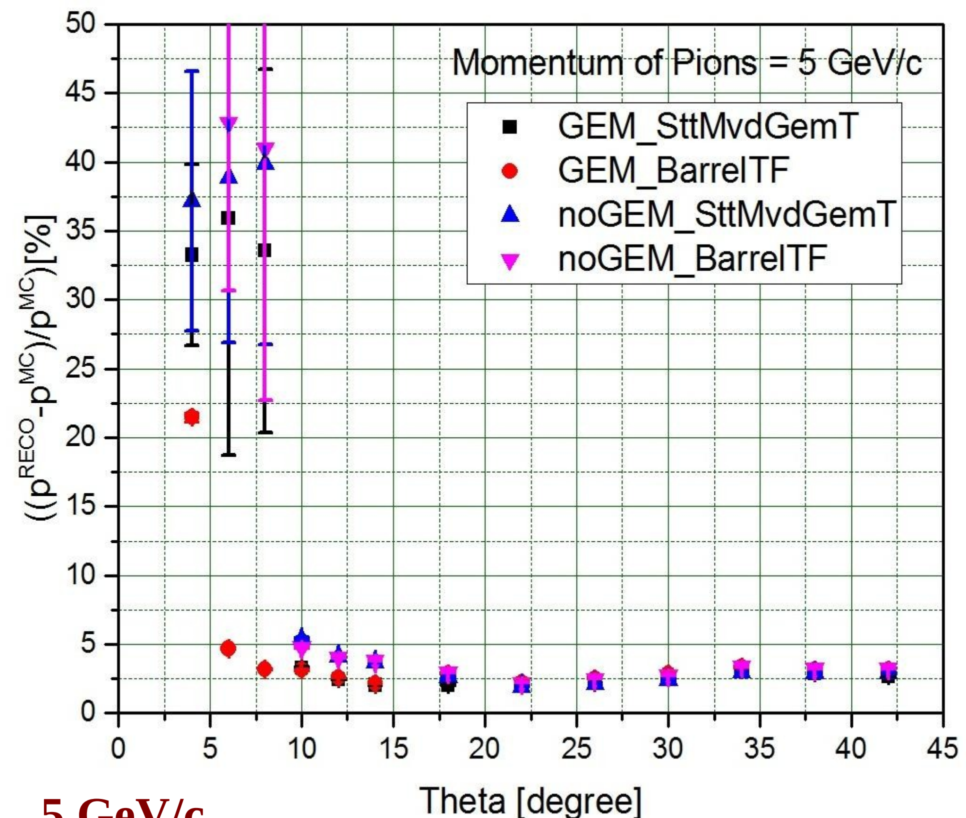


- **Momentum Resolution is getting better by increasing the momentum of particles**
- **Momentum Resolution is not good below 10°**
- **The performance of the GEM is coming to appear clearly**

Momentum Resolution versus Theta for Pion = 2 & 5 GeV/c

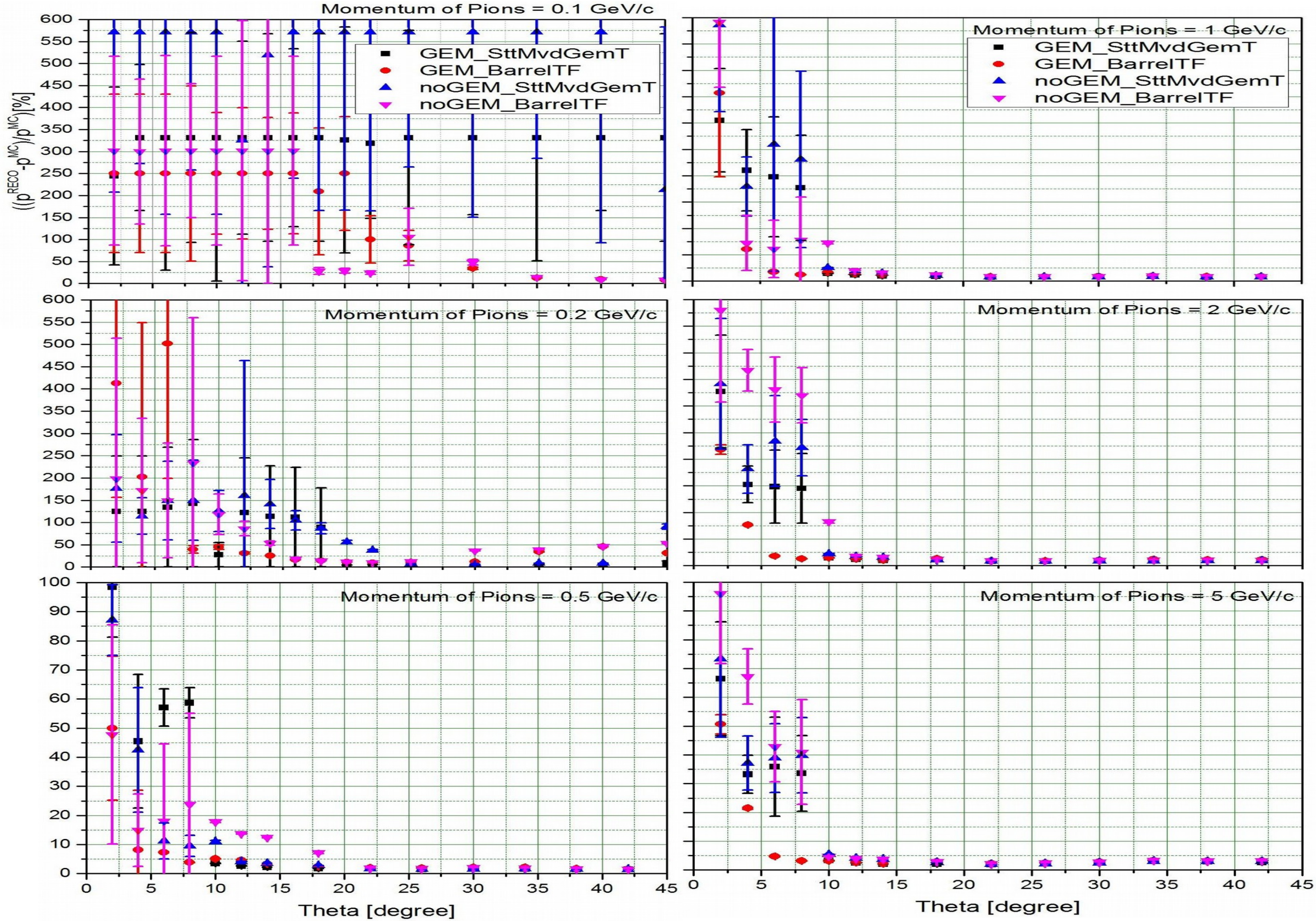


2 GeV/c

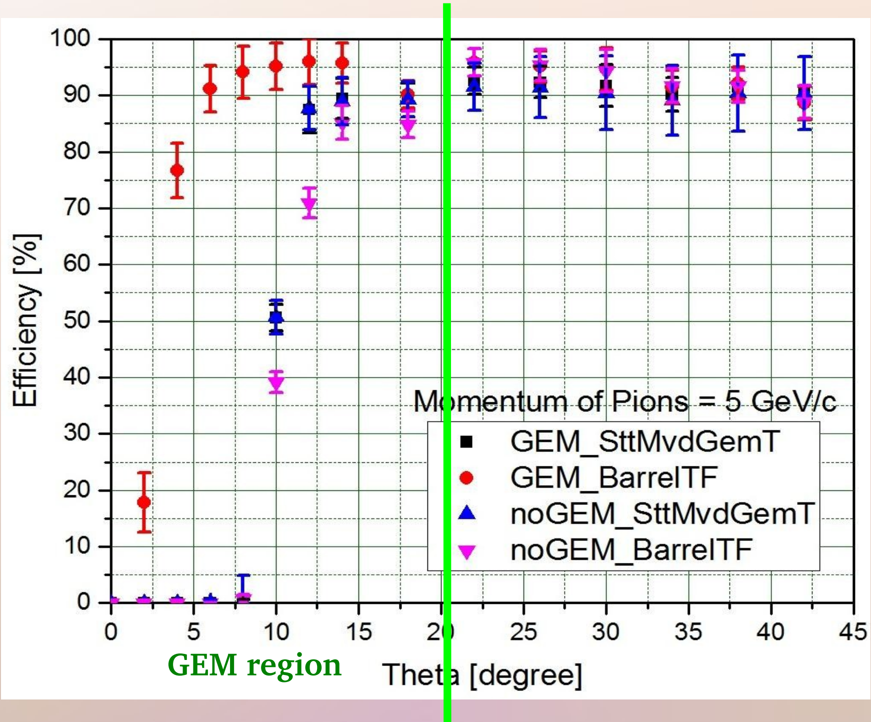


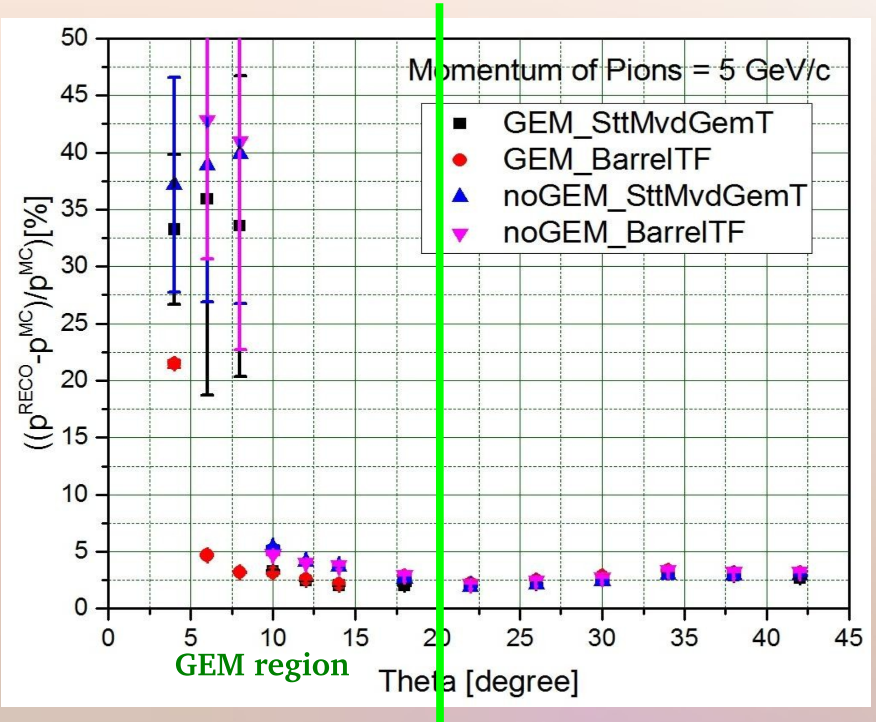
5 GeV/c

- The performance of the GEM is good to improve the momentum resolution by PndBarrelTrackFinder
- There is impressive changes for the GEM and in case of using PndBarrelTrackFinder



Momentum of Pions = 0.1 GeV/c
Momentum of Pions = 1 GeV/c
Momentum of Pions = 0.2 GeV/c
Momentum of Pions = 2 GeV/c
Momentum of Pions = 0.5 GeV/c
Momentum of Pions = 5 GeV/c
GEM_SttMvdGemT
GEM_BarrelTF
noGEM_SttMvdGemT
noGEM_BarrelTF
((p^RECO-p^MC)/p^MC)[%]
Theta [degree]



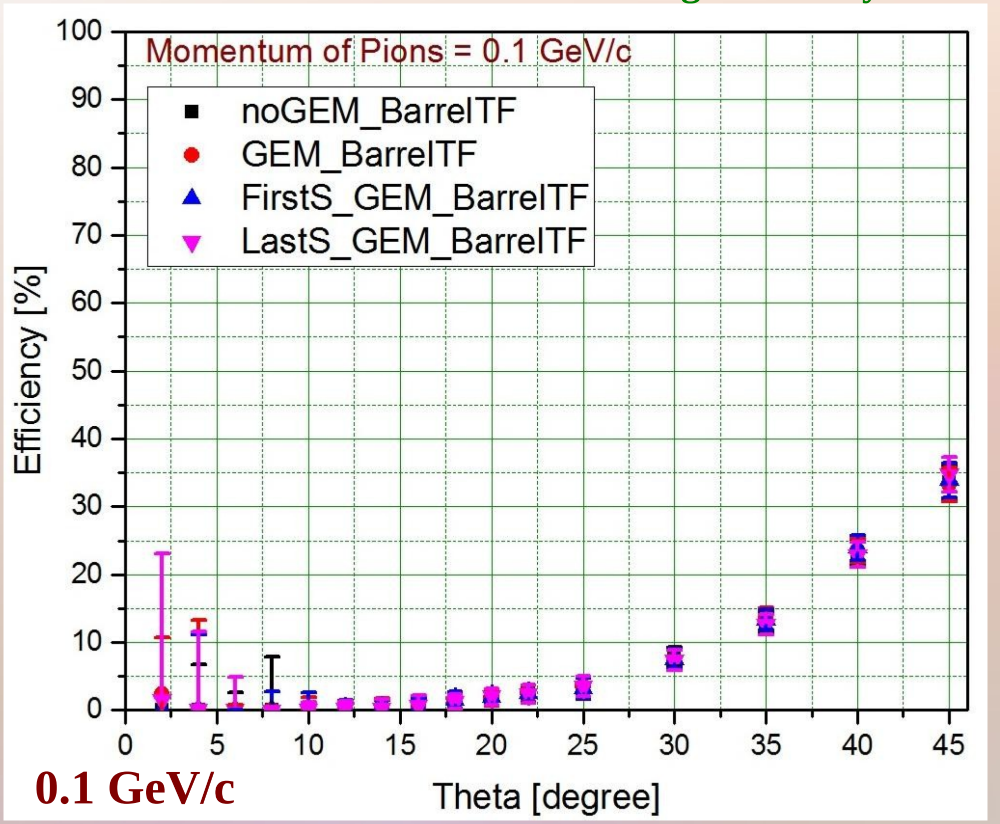


- The behavior of the PndSttMvdGemTracking & PndBarrelTrackFinding is more understandable at different momenta and angles now

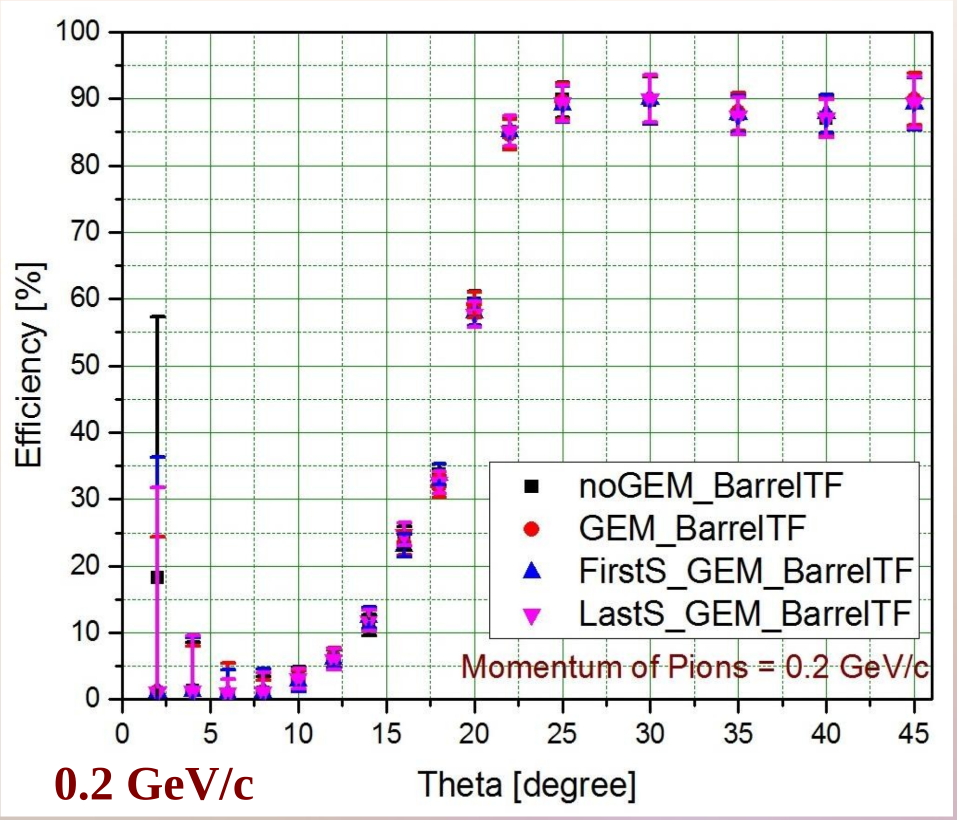
- Using PndBarrelTrackFinding class is more beneficial to see the influence of the GEM tracker to improve quality of track finding efficiency and momentum resolution in the GEM region below 22°

Investigation of Track Finding Efficiency without, with 3 stations & single station GEM

Track Finding Efficiency versus Theta for Pion = 0.1 & 0.2 GeV/c



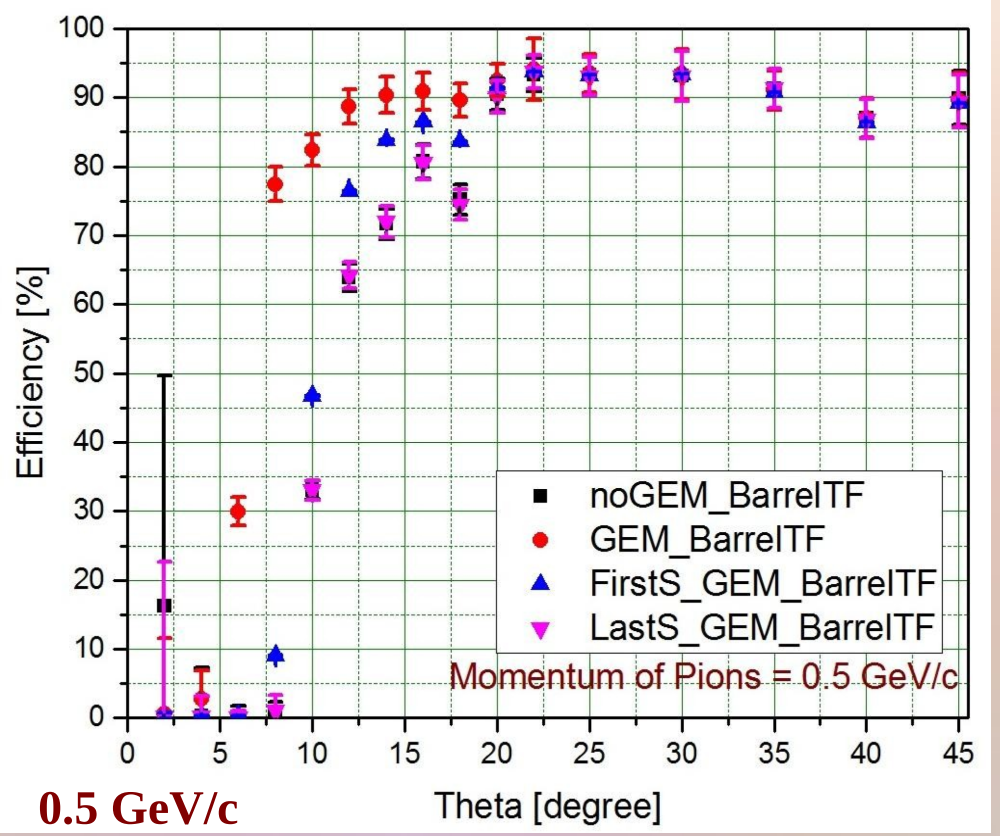
0.1 GeV/c

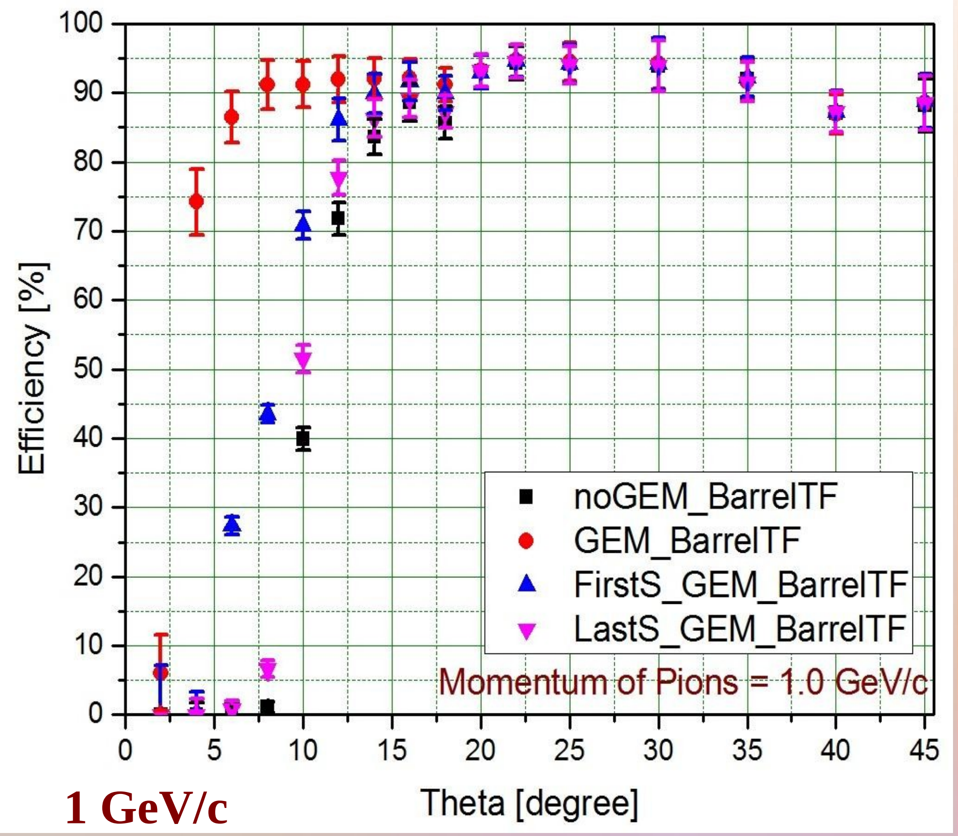


0.2 GeV/c

- Bad track finding efficiency for low momentum tracks
- No any differences with GEM and without GEM

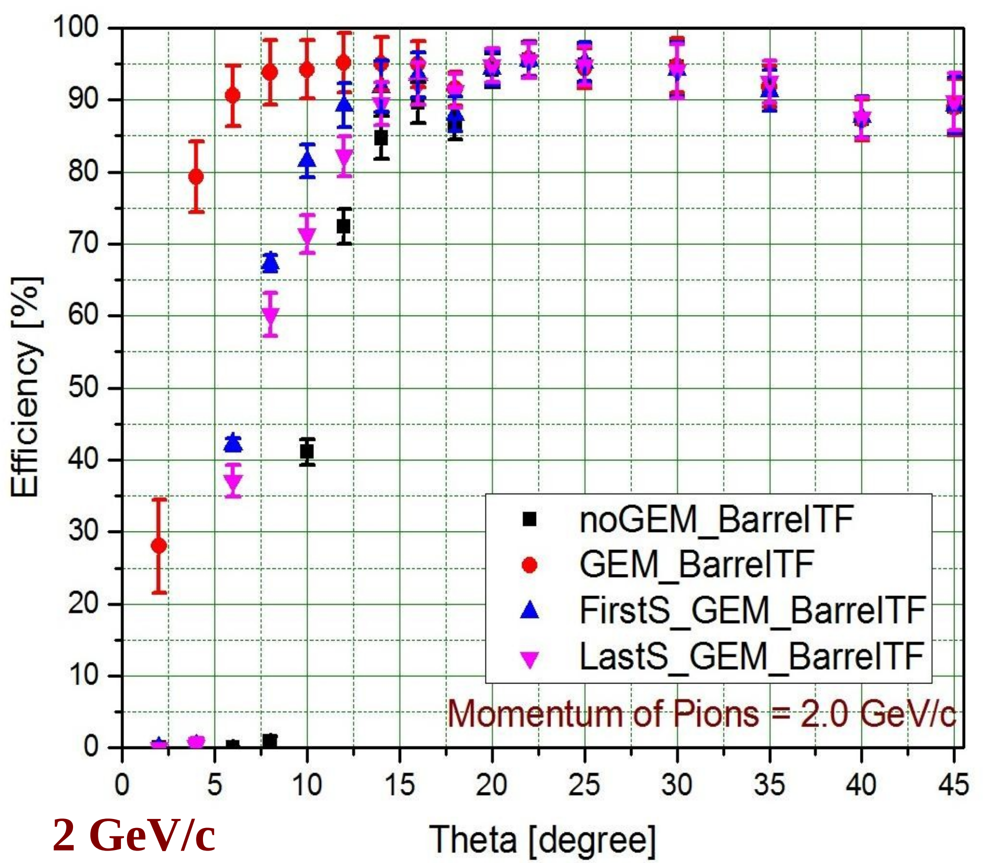
Track Finding Efficiency versus Theta for Pion = 0.5 & 1 GeV/c



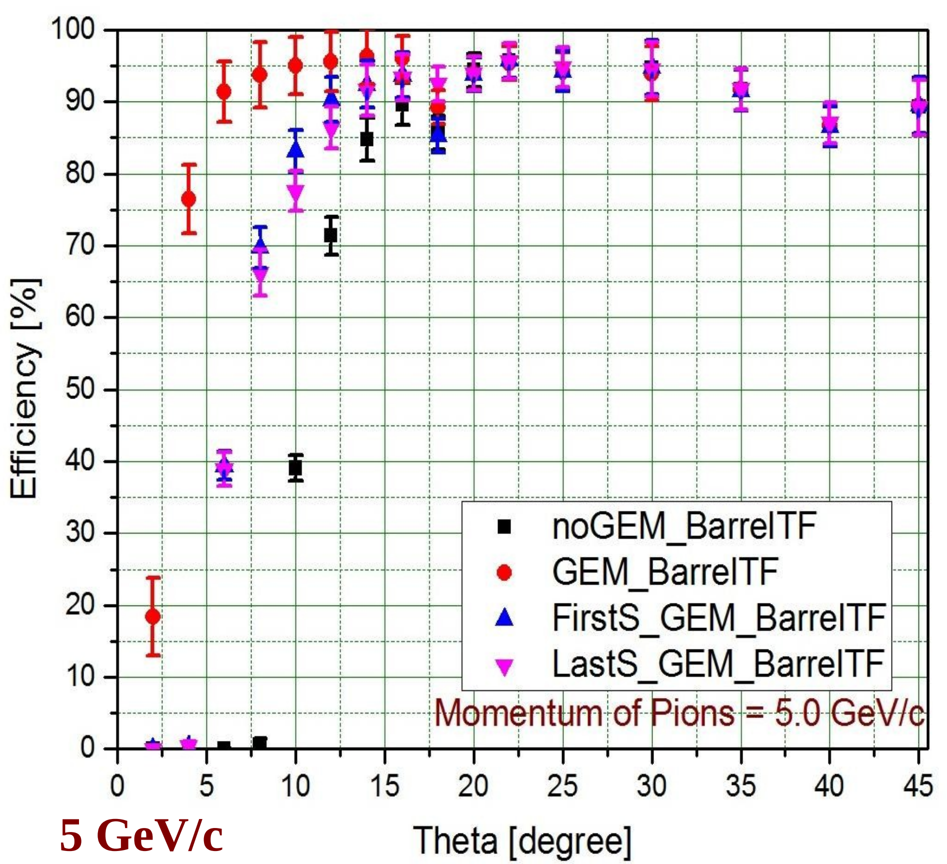


- Good track finding efficiency by increasing the momentum of particles
- The performance of the GEM with 3stations is coming to appear clearly

Track Finding Efficiency versus Theta for Pion = 2 & 5 GeV/c

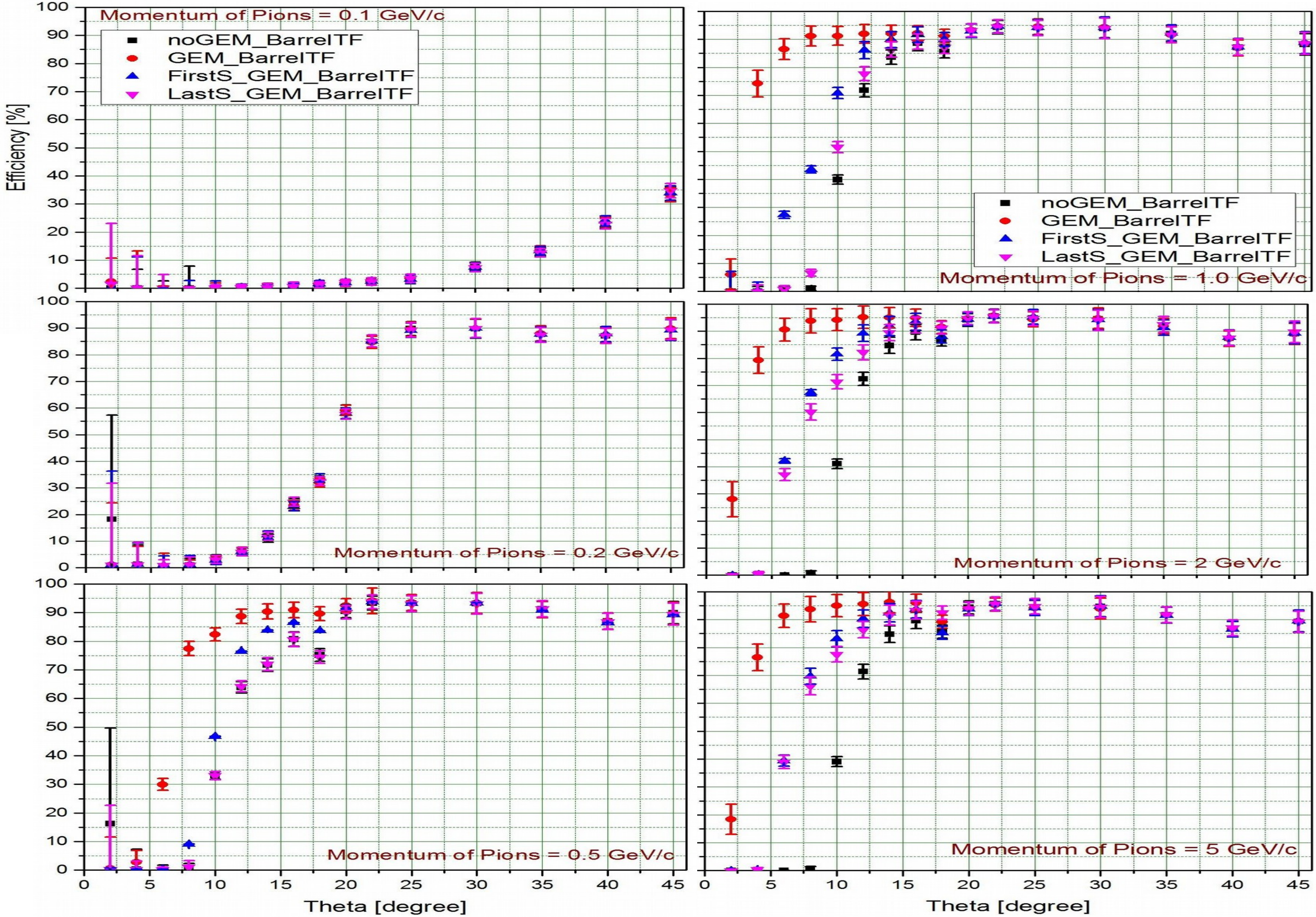


2 GeV/c



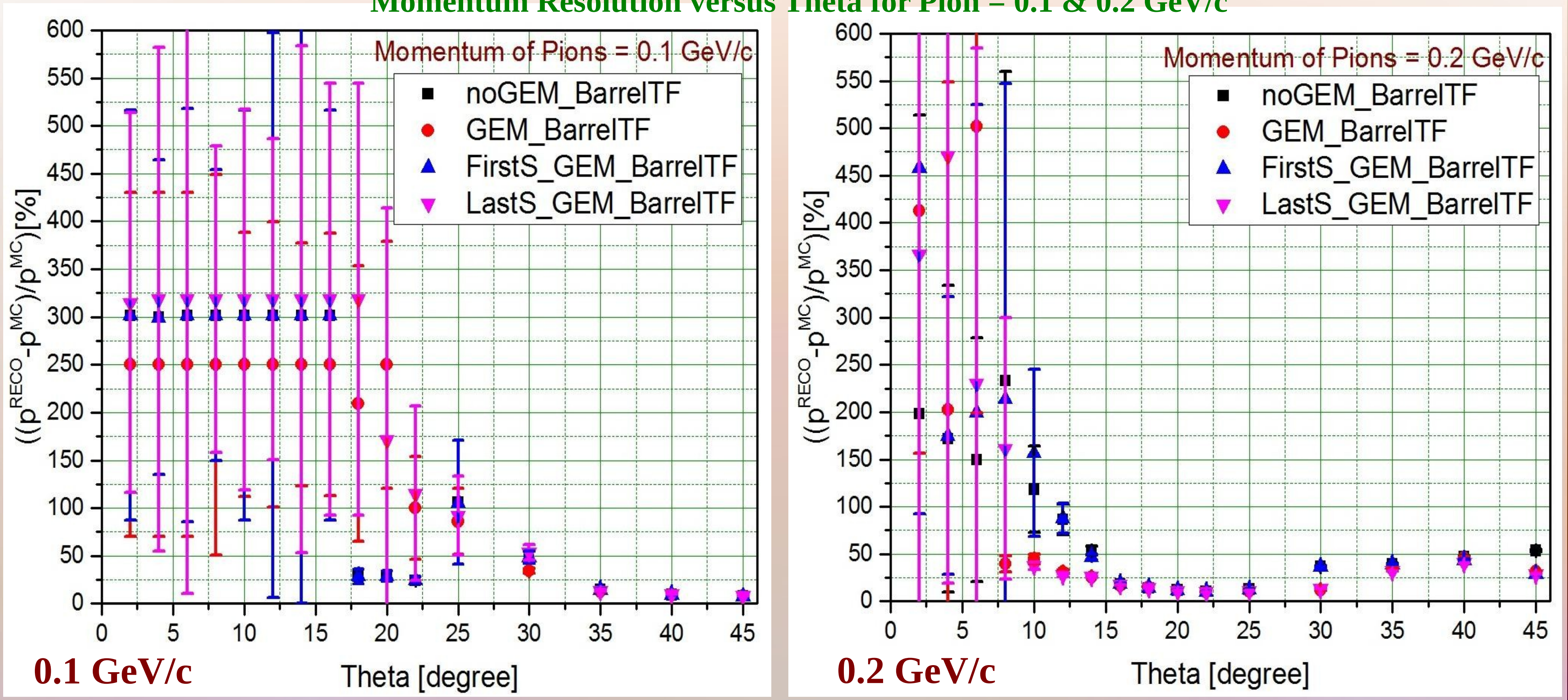
5 GeV/c

- The performance of the GEM with 3stations is good to improve track finding efficiency
- There is impressive shifts for the GEM with 3 stations geometry in comparison with the other cases


Momentum of Pions = 0.1 GeV/c
noGEM_BarrelTF
GEM_BarrelTF
FirstS_GEM_BarrelTF
LastS_GEM_BarrelTF
Efficiency [%]
Momentum of Pions = 1.0 GeV/c
Momentum of Pions = 0.2 GeV/c
Momentum of Pions = 2 GeV/c
Momentum of Pions = 0.5 GeV/c
Momentum of Pions = 5 GeV/c
Theta [degree]
Theta [degree]

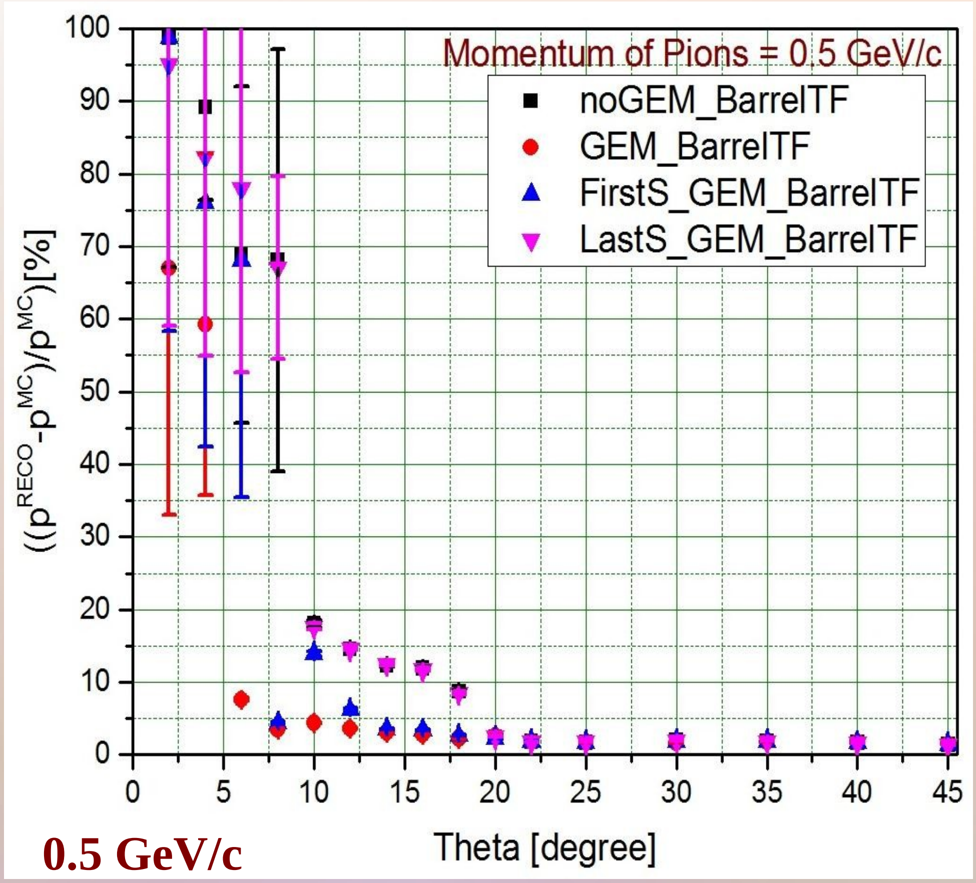
Investigation of Momentum Resolution without, with 3 stations & single station GEM

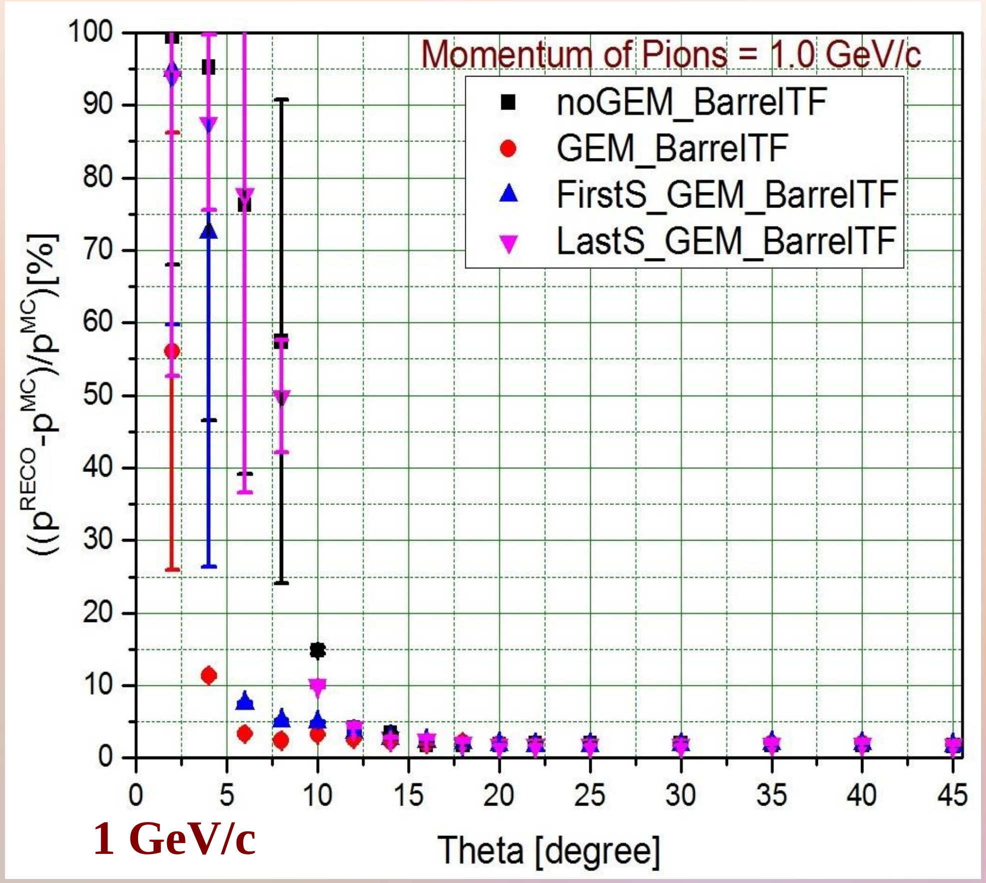
Momentum Resolution versus Theta for Pion = 0.1 & 0.2 GeV/c



- Momentum Resolution is not good for low momentum tracks
- At least, GEM with 3 stations geometry is better than the others

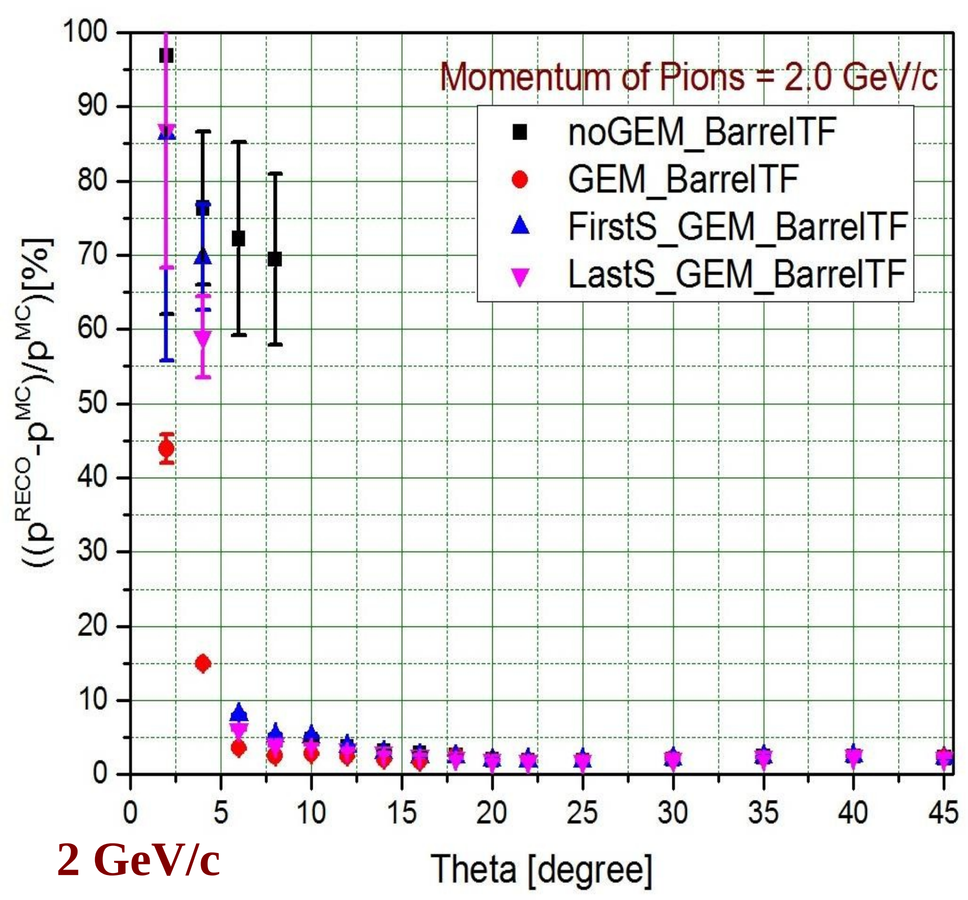
Momentum Resolution versus Theta for Pion = 0.5 & 1 GeV/c

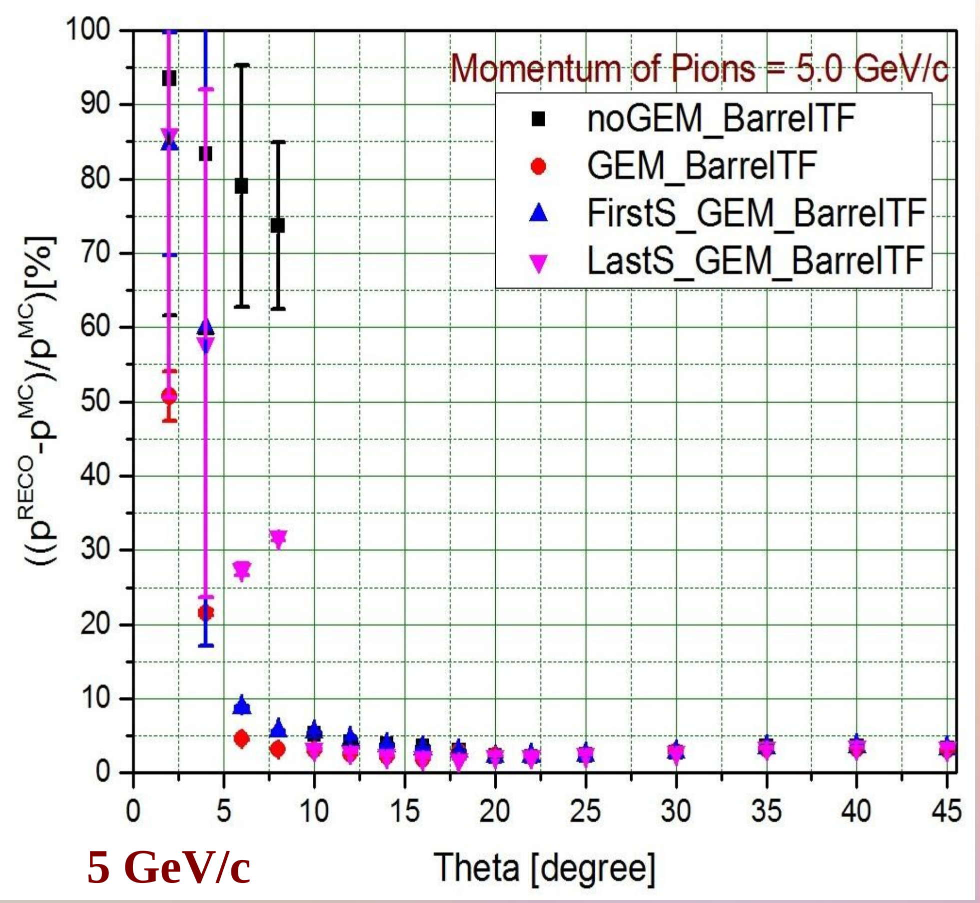




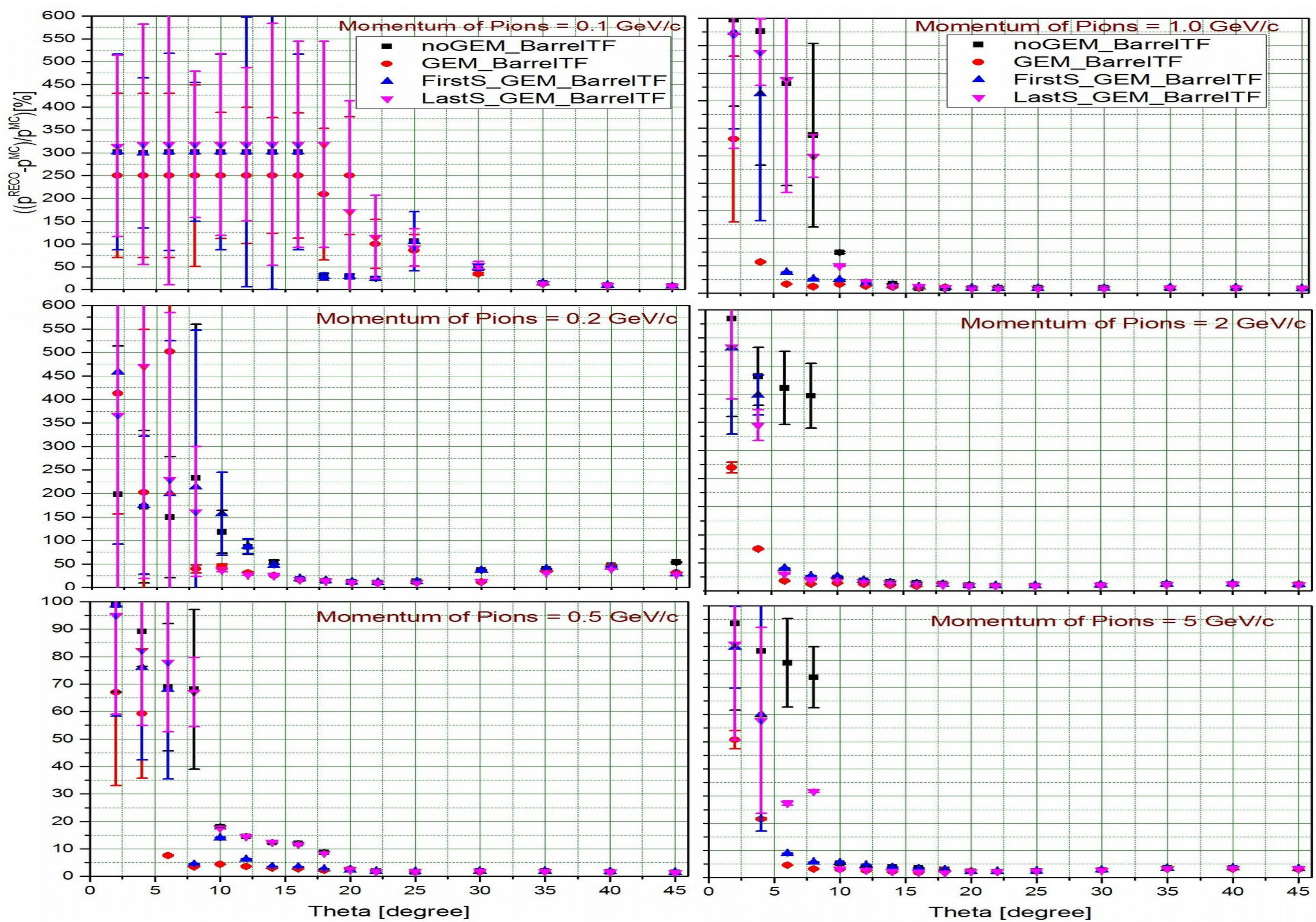
- Momentum Resolution is not good for small angles
- The performance of the GEM with 3 stations geometry is coming to appear clearly

Momentum Resolution versus Theta for Pion = 2 & 5 GeV/c

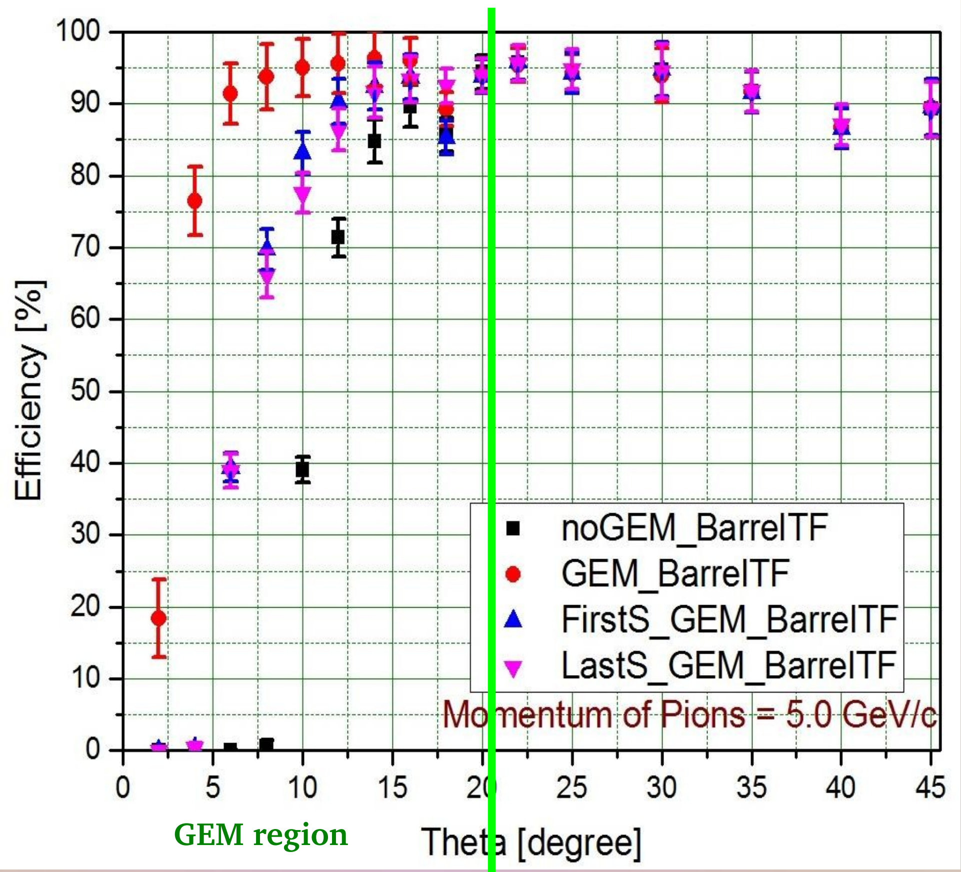


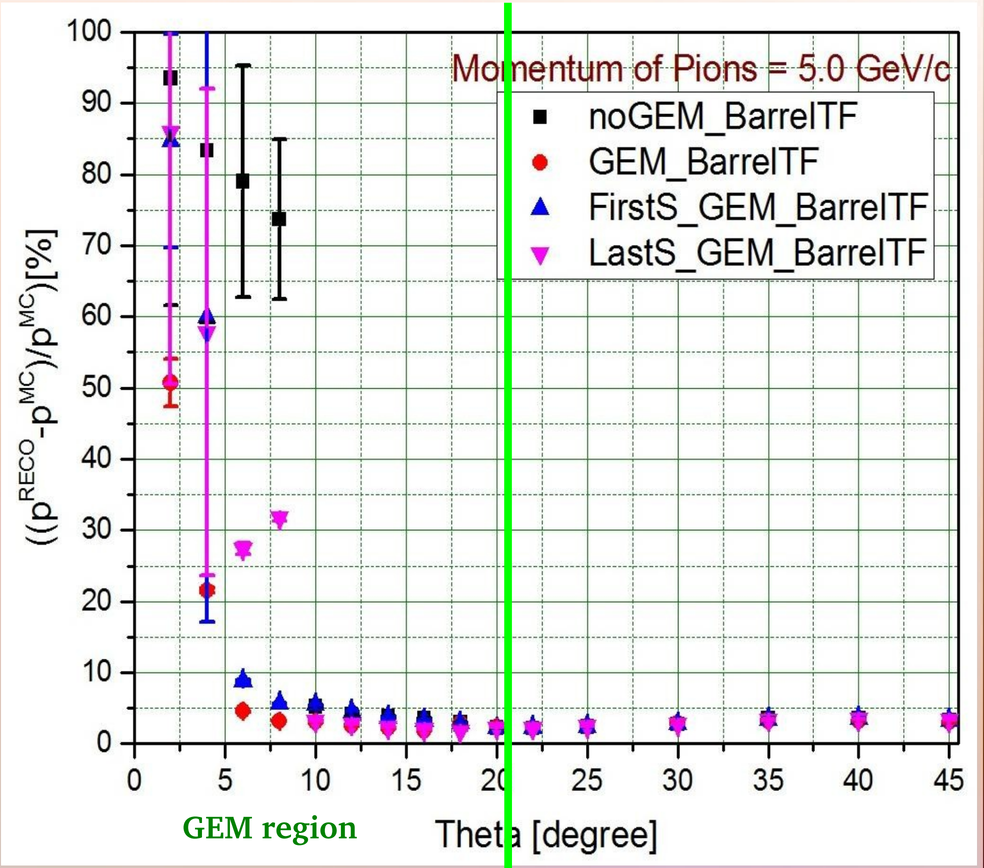


- **Momentum resolution is almost the same in case of GEM with single station and without GEM**



Momentum of Pions = 0.1 GeV/c
Momentum of Pions = 1.0 GeV/c
Momentum of Pions = 0.2 GeV/c
Momentum of Pions = 2 GeV/c
Momentum of Pions = 0.5 GeV/c
Momentum of Pions = 5 GeV/c
noGEM_BarrelTF
GEM_BarrelTF
FirstS_GEM_BarrelTF
LastS_GEM_BarrelTF
$((p^{RECO}-p^{MC})/p^{MC})[\%]$
Theta [degree]





- **GEM tracker with 3 stations can improve momentum resolution and track finding efficiency better than the others**

Part Three :

Lambda-Lambda Bar Mass Reconstruction Study

Investigation of Lambda – Anti Lambda Invariant Mass Reconstruction

Benchmark channel including : antip + p → Λ0 + antiΛ0

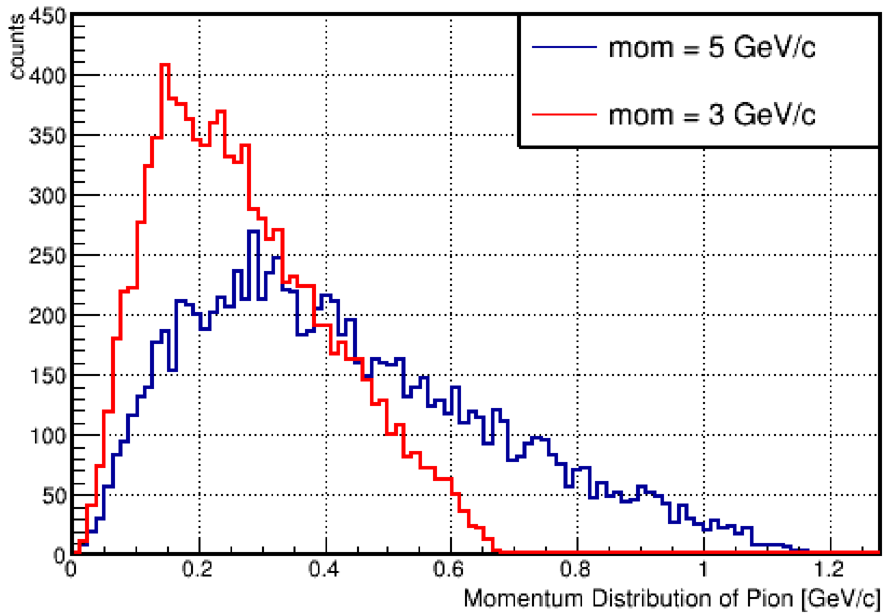
→ Λ0 → p+ & π–

→ AntiΛ0 → p- & π+

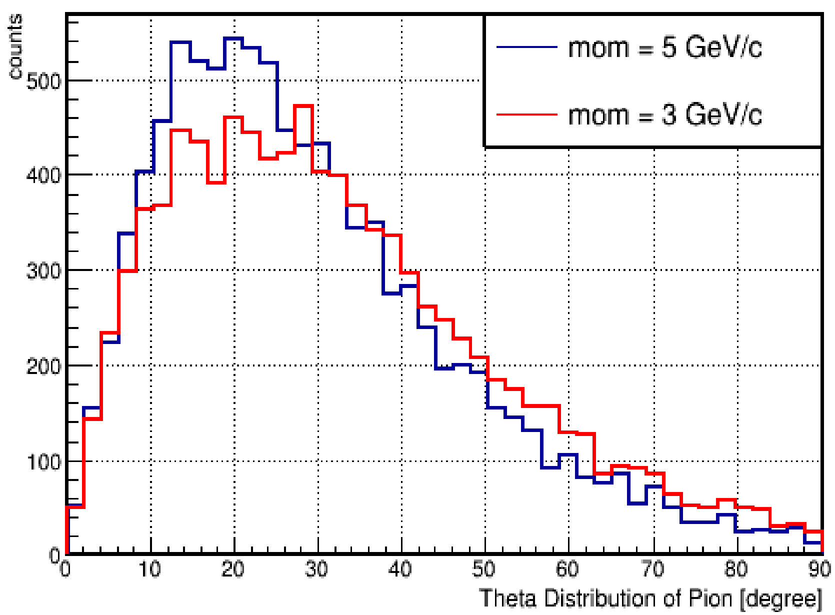
The exact mass value of the Λ0 and antiΛ0 :
1115.683±0.006MeV/c²

- **In this study , the simulation condition:**
- No. of Events=10000, SimEngine =TGeant4, Event generator=EvtGen,
- Momentum= 5 [GeV/c]
- without and with GEM (full geometry and single station geometry)
- Using PndBarrelTrackFinder class
- Using Revision: 29377 of PandaRoot

Momentum Distribution Plot of Pi+

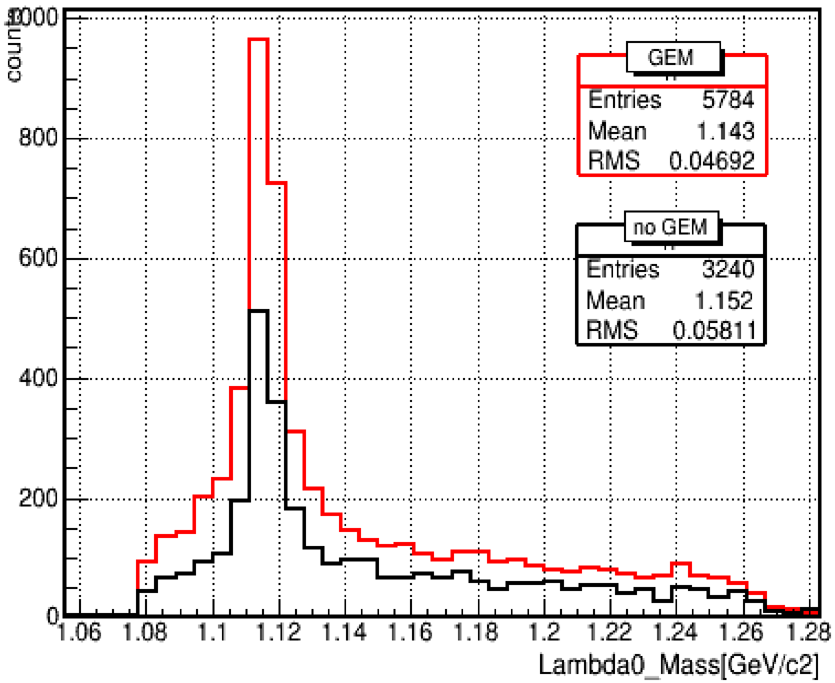


Theta Distribution Plot of Pi+

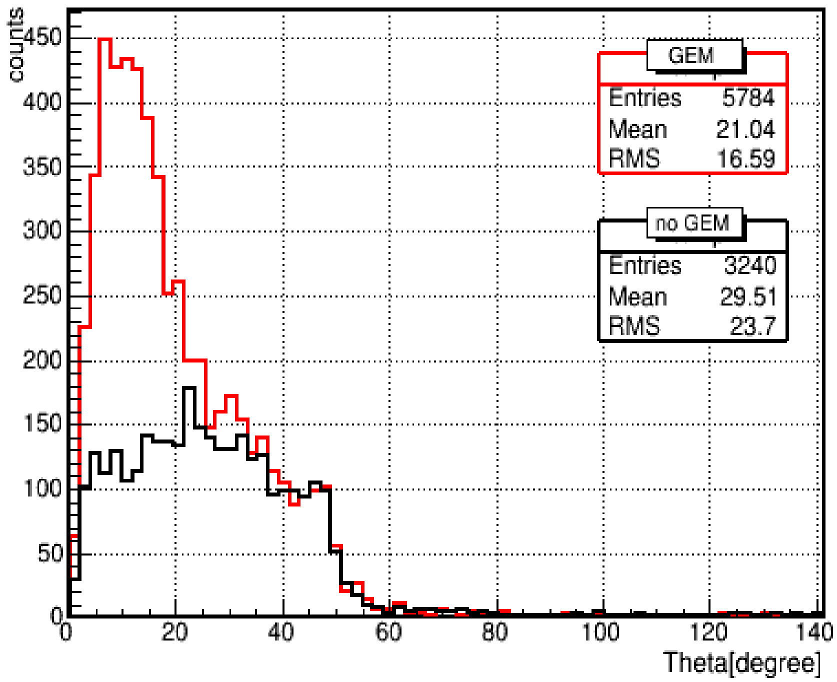


Lambda0 Invariant Mass Reconstruction with and without GEM

Lambda Invariant Mass Plot



Lambda Theta Distribution Plot



The values of Gaussian fitting on the peak :

with GEM

Mean value of the peak=(1.116±0.000013)GeV/c²

Sigma = 0.003162±0.000176

No. of counts under peak = 3115

The values of Gaussian fitting on the peak :

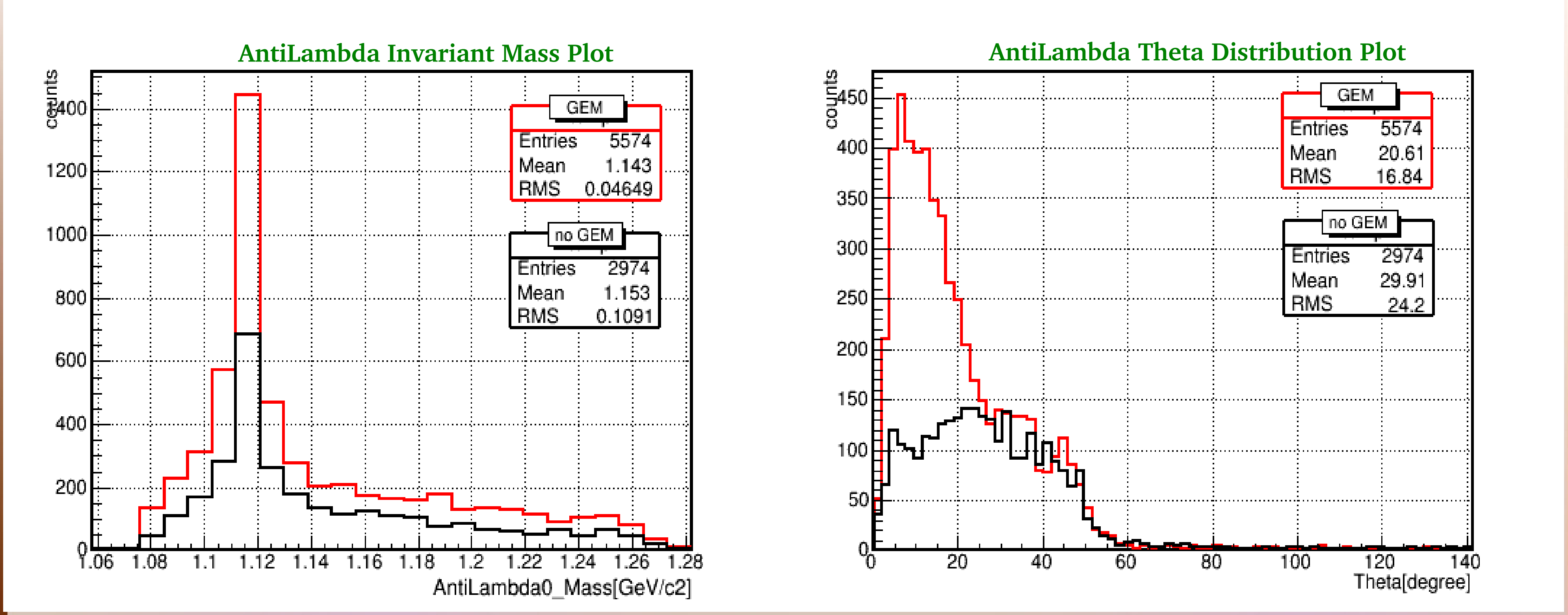
without GEM

Mean value of the peak=(1.116±0.000022)GeV/c²

Sigma = 0.004109±0.000219

No. of counts under peak = 1649

AntiLambda0 Invariant Mass Reconstruction with and without GEM



The values of Gaussian fitting on the peak :

with GEM

Mean value of the peak=(1.116±0.000015)GeV/c²

Sigma = 0.003581±0.000207

No. of counts under peak = 2962

The values of Gaussian fitting on the peak :

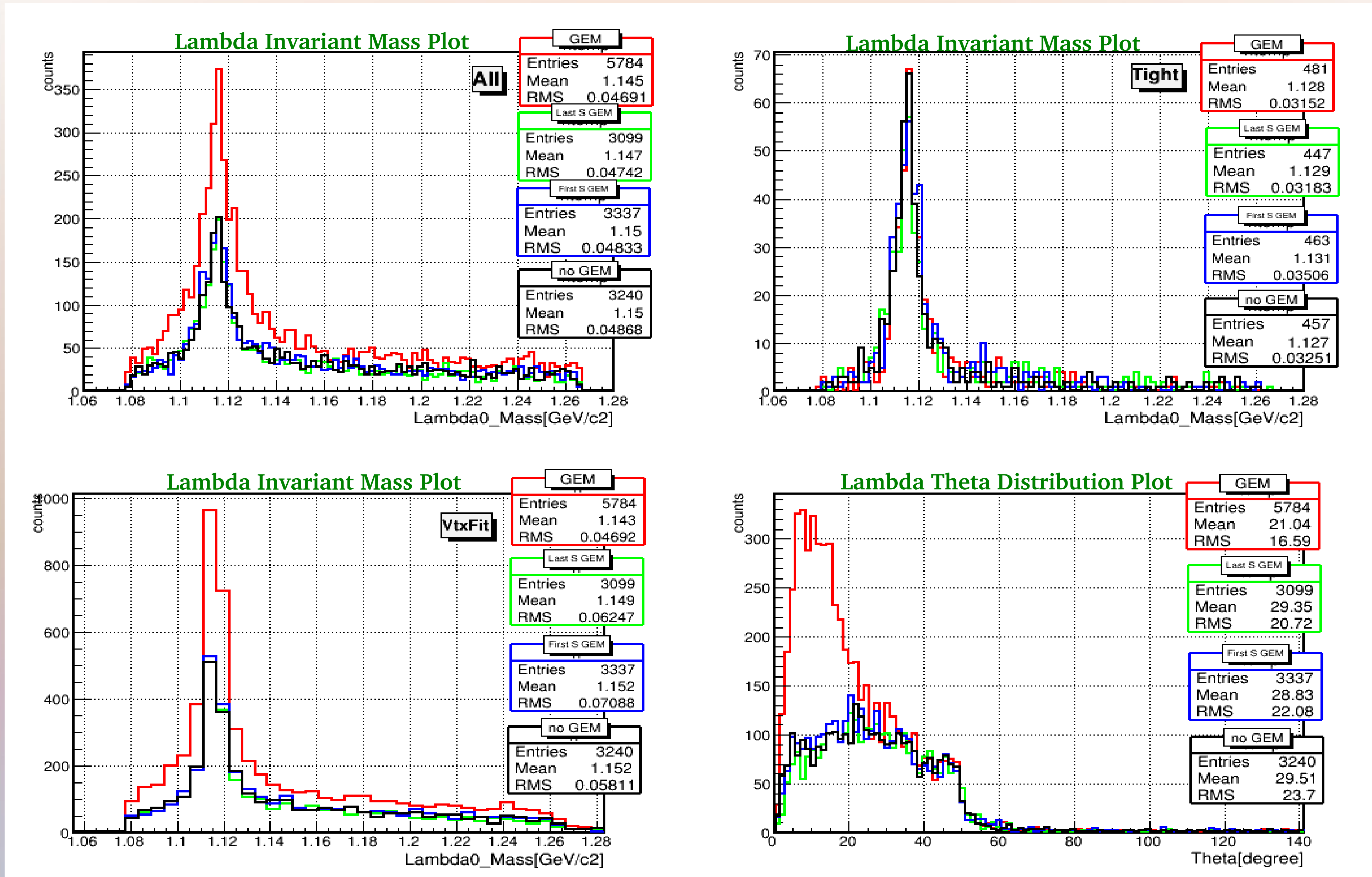
without GEM

Mean value of the peak=(1.116±0.000029)GeV/c²

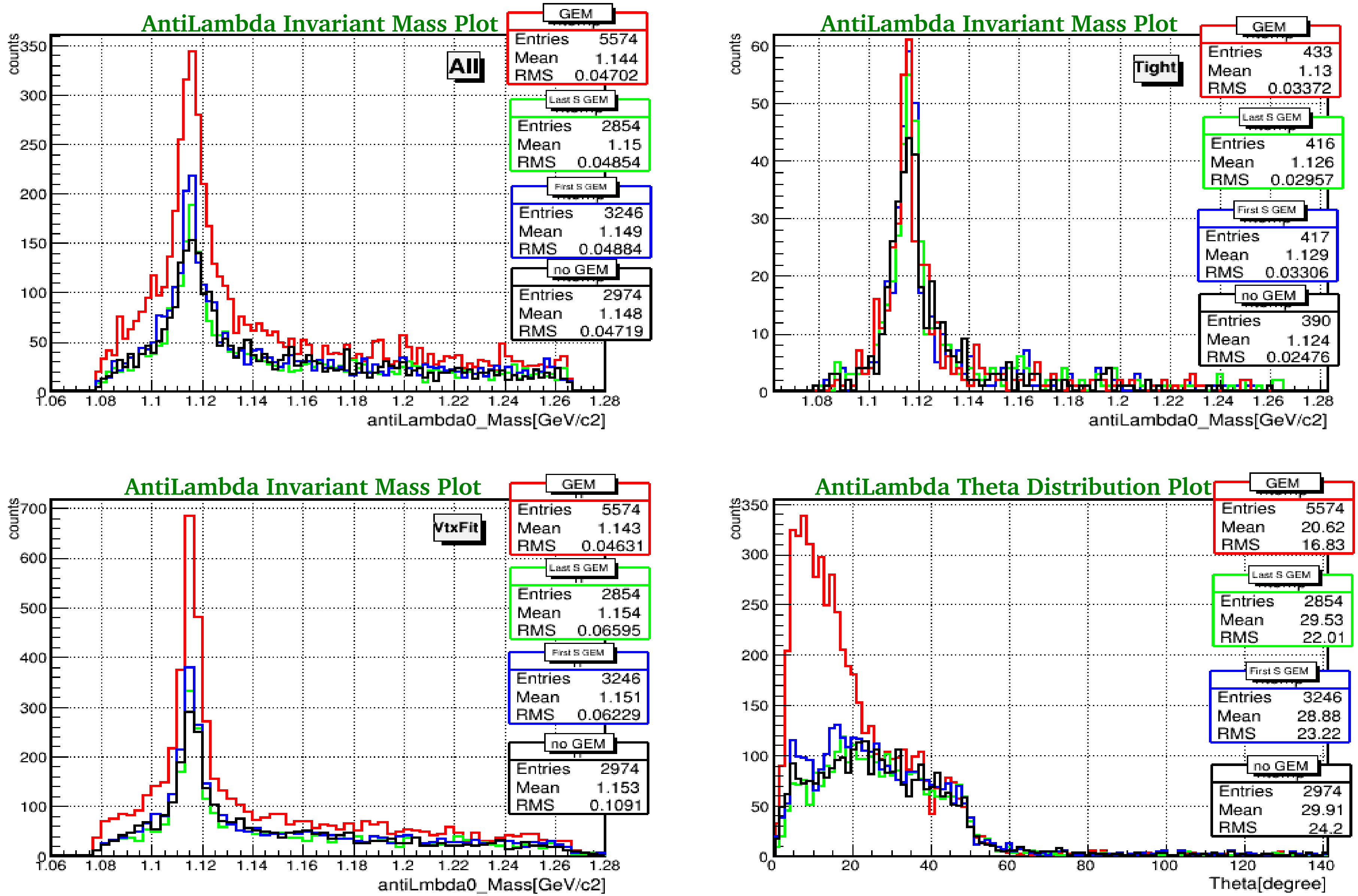
Sigma = 0.004314±0.000328

No. of counts under peak = 1516

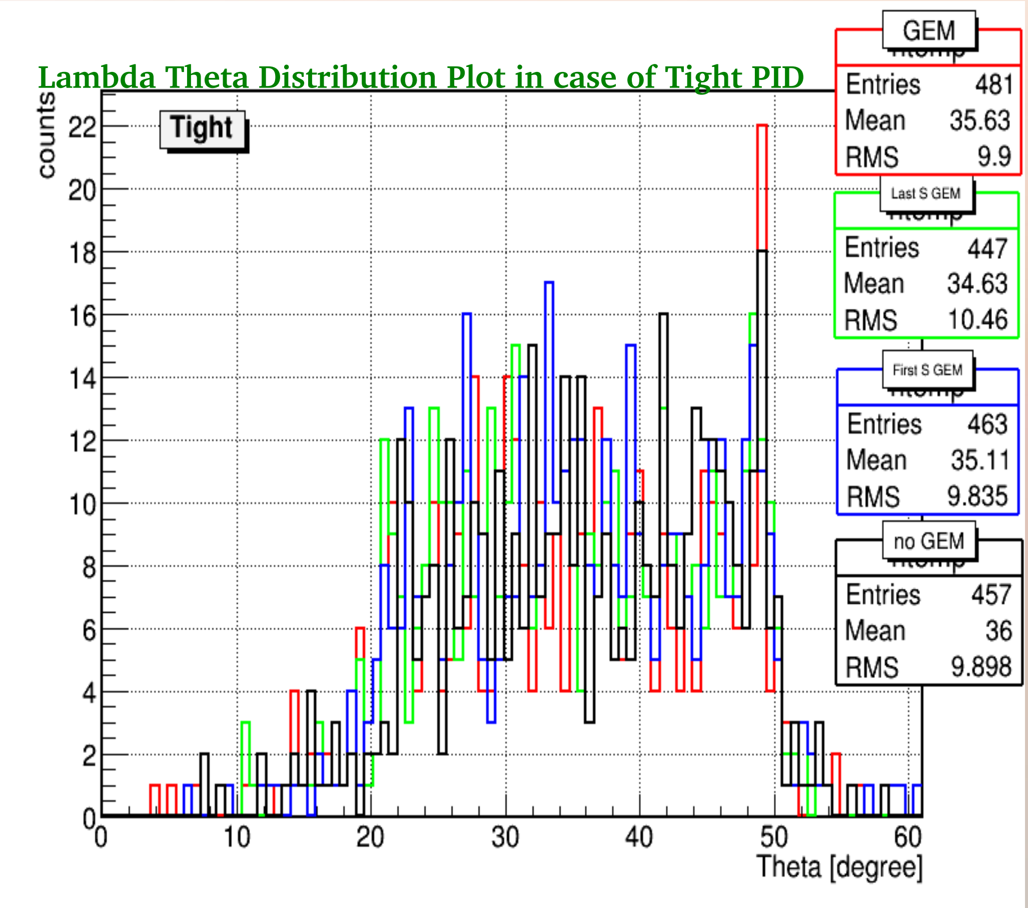
Investigation of Lambda0 Invariant Mass Reconstruction in Comparison without, with Three Stations & Single Station GEM



Investigation of AntiLambda0 Invariant Mass Reconstruction in Comparison without, with Three Stations & Single Station GEM



Important Point



It seems there is not a good Particle Identification below 20° yet !

Conclusion

- **Invariant mass reconstruction for Lambda0-antiLambda0 has been implemented.**
- **we can clearly see the positive influence of the GEM to improve track finding efficiency and momentum resolution in the forward directions (using PndBarrelTrackFinder).**
- **It seems to improve PANDA experiment mass resolution, using only GEM with one single station is not sufficient.**
- **With 1 station GEM geometry, mass resolution and tracking acceptance:**

  - are almost similar to those without GEM.
  - are worse than those with 3 stations GEM.

Many Thanks For Your Attention

Part Four :

Investigation of the Radiation Length

Investigation of Radiation Length for the Materials of the GEM Detector

In physics, the radiation length is a characteristic of a material, related to the energy loss of high energy particles. The characteristic amount of matter traversed for the related interactions is called the radiation length X0,

$$X_0 = \frac{716.4 \cdot A}{Z(Z+1)\ln\frac{287}{\sqrt{Z}}}\ \mathrm{g}\cdot\mathrm{cm}^{-2} = \frac{1432.8 \cdot A}{Z(Z+1)(11.319 - \ln Z)}\ \mathrm{g}\cdot\mathrm{cm}^{-2}$$

The impact of the introduced material can be quantitatively described by a resulting fractional radiation length, X/X0 , which adds up in all traversed volumes j:

$$X/X_0 = \sum_j \frac{\rho_j \cdot L_j}{X_{0_j}}$$

where X0j and **ρ**j are the specific radiation length and the density of the material defined for the volume j, respectively, and Lj corresponds to the traversed path length therein.

In this study , the simulation condition :

- For the extraction of the GEM material map, muon particles were propagated through the detector.
- Also, virtual particles ("geantinos") were propagated through the detector . The fictitious "geantino" particle undergoes no physical interactions but flags boundary crossings along its straight trajectory.
- Five million events were simulated starting from the origin with an isotropic emission over the polar angle, **θ**, and the azimuthal angle **φ**.
- Simulation Engine =TGeant4, Event generator=BoxGen, Theta Range(0.0001, 45), Phi Range(0., 360.) , Momentum Range (0.05, 10.0) , Beam Momentum= 15 [GeV/c]
- with full geometry of GEM detector

Investigation of Radiation Length for the Materials of the GEM Detector

GEM Materials On the Simulation	Carbon Density=2.265 g/cm3	Copper Density=8.96 g/cm3	Aluminum Density=2.7 g/cm3	Kapton Density=1.42 g/cm3	Glass Fiber Density=2.77 g/cm3
Station 1	2.440568 kg	31.9322189 kg	5.43217268 kg	0.21899042 kg	7.0290712 kg
Station 2	3.610685 kg	66.7585211 kg	5.81343111 kg	0.36925732 kg	9.5082353 kg
Station 3	5.537874 kg	68.0850433 kg	6.46993688 kg	0.690296 kg	13.6113037 kg
And totally :	Gem_Disk1_Volume has 81.4294 kg Gem_Disk2_Volume has 86.1164 kg Gem_Disk3_Volume has 94.4239 kg GEM_Riddle_Volume has 18.6689 kg GEM_Copperbar_Volume for cables has 28.52864 kg Gem_Disks has 308.968 kg				

Investigation of Radiation Length for the Materials of the GEM Detector

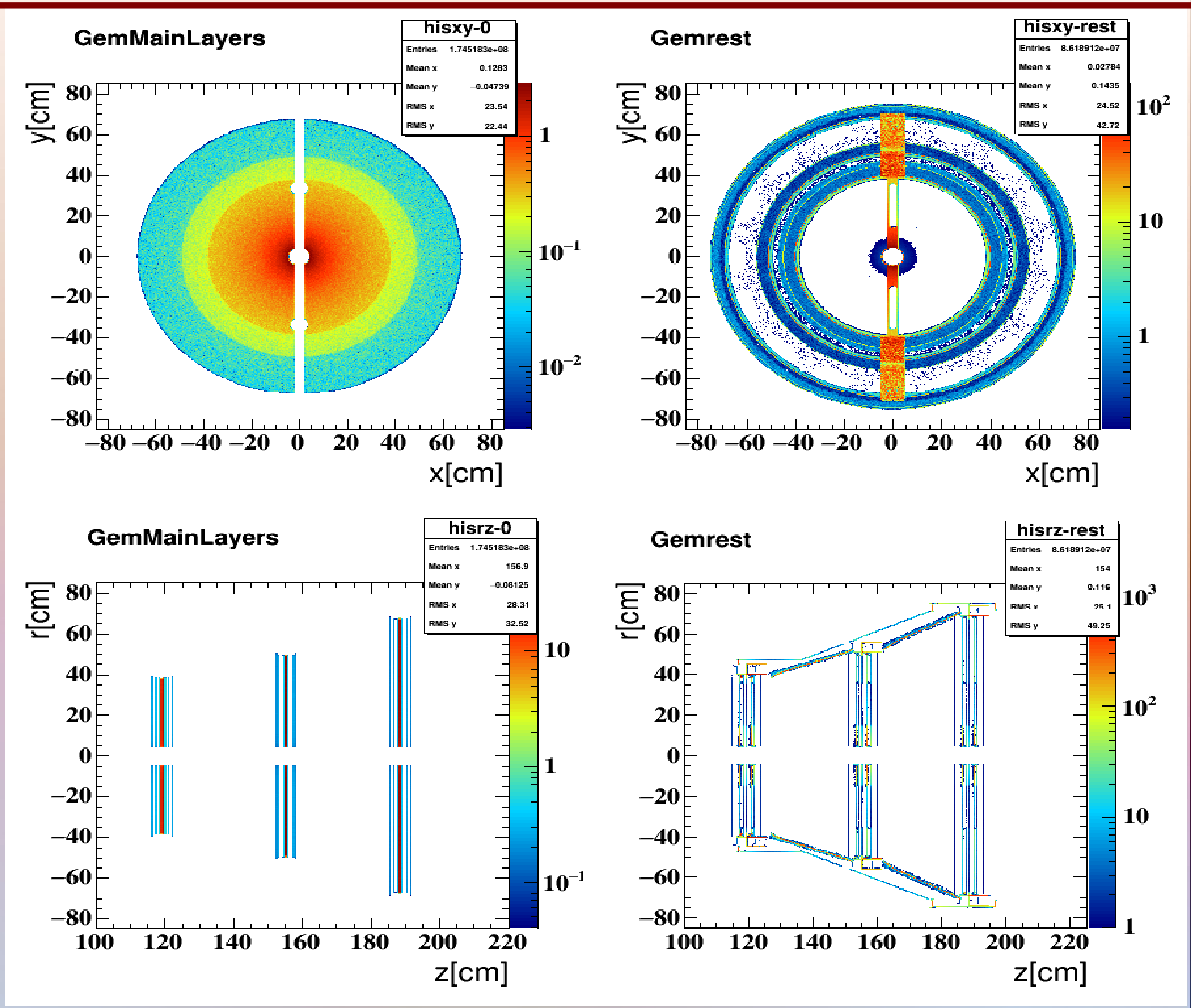
For Muon particles

3 GEM Stations

MC Points, xy view

3 GEM Stations

MC Points, rz view



Investigation of Radiation Length for the Materials of the GEM Detector

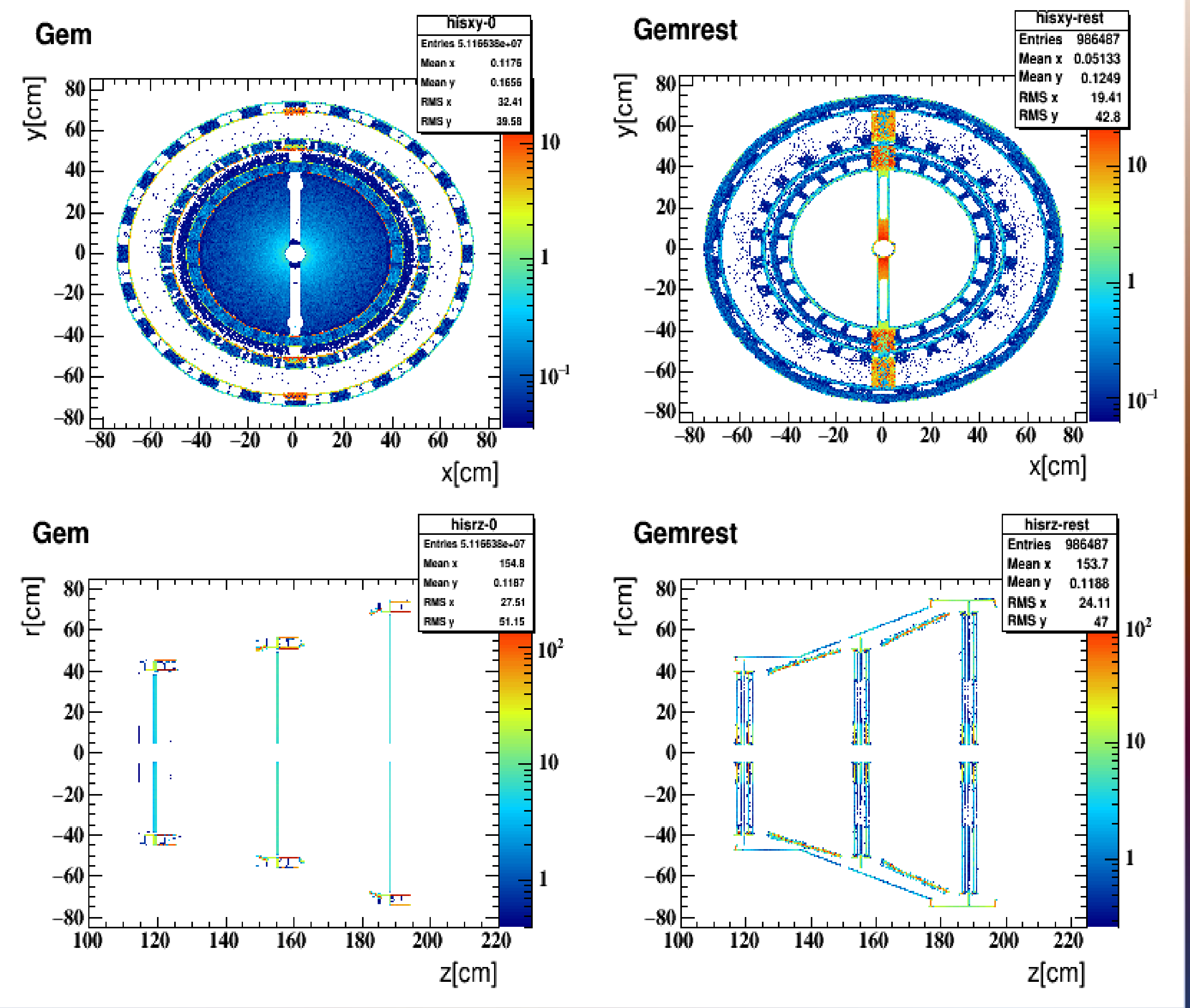
For Muon particles

3 GEM Stations

MC Points, xy view

3 GEM Stations

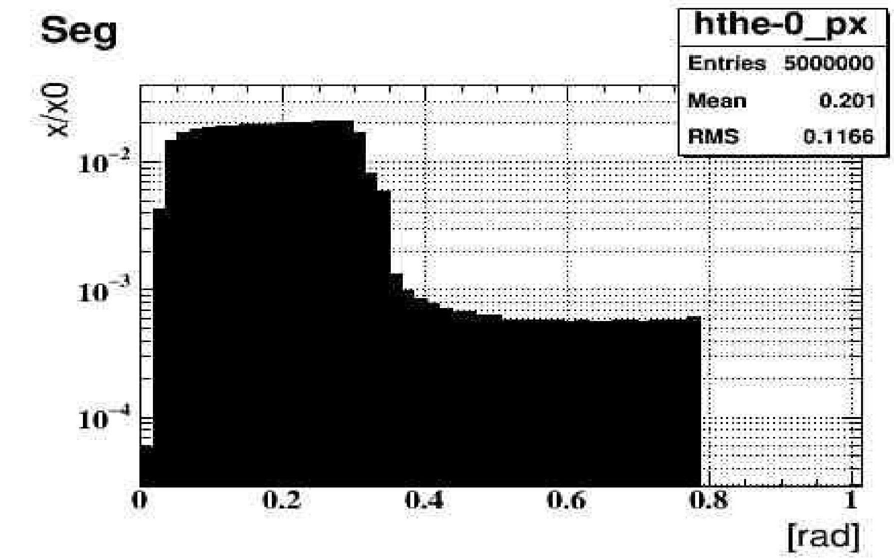
MC Points, rz view



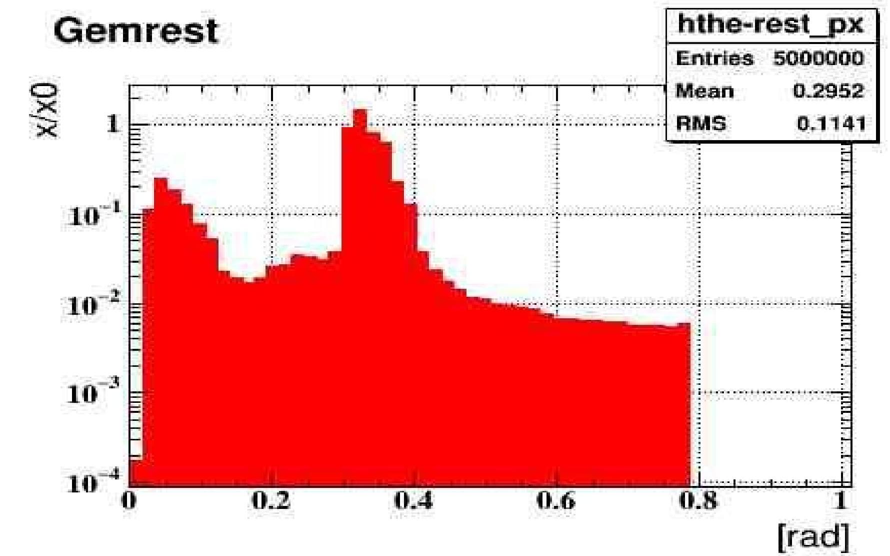
Investigation of Radiation Length for the Materials of the GEM Detector

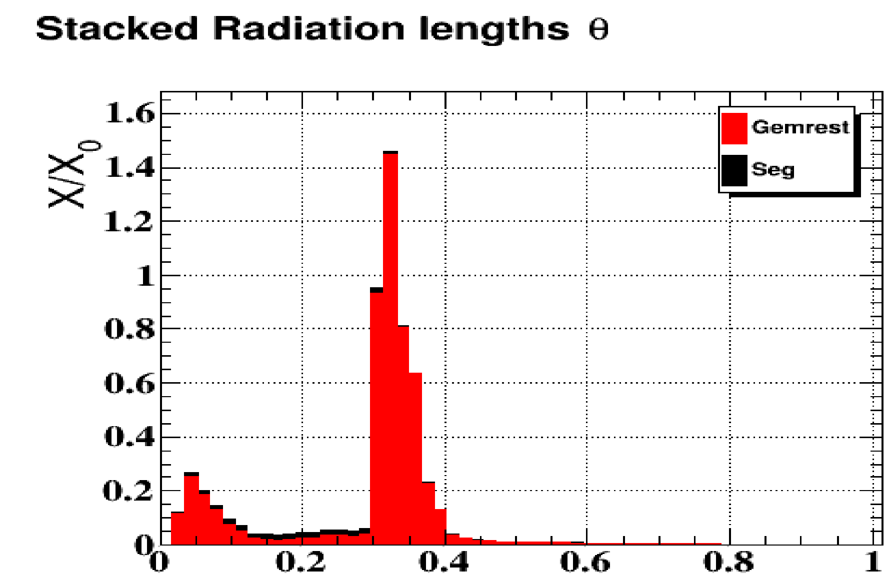
For Muon particles

Polar distribution of fractional radiation length, X/X0, for GEM main layers materials

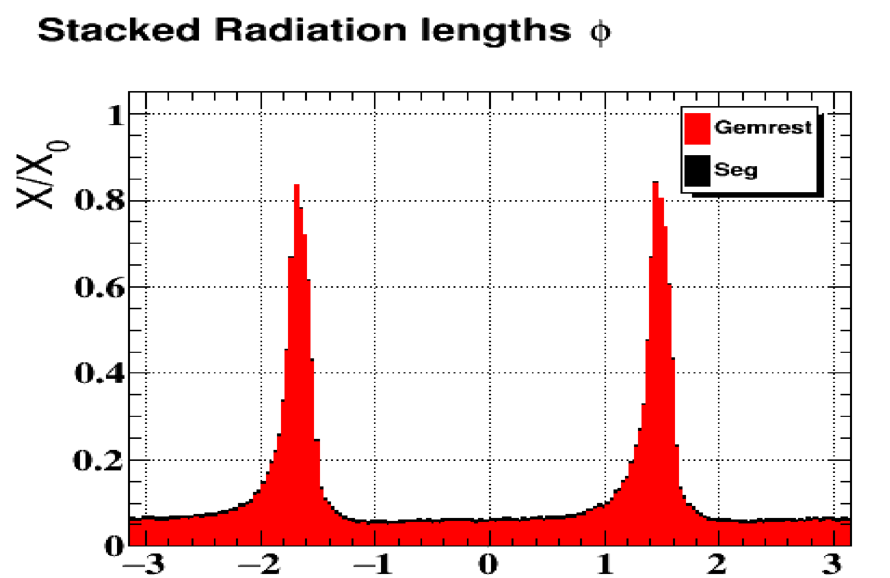


Polar distribution of fractional radiation length, X/X0, for GEM holding structures layers materials



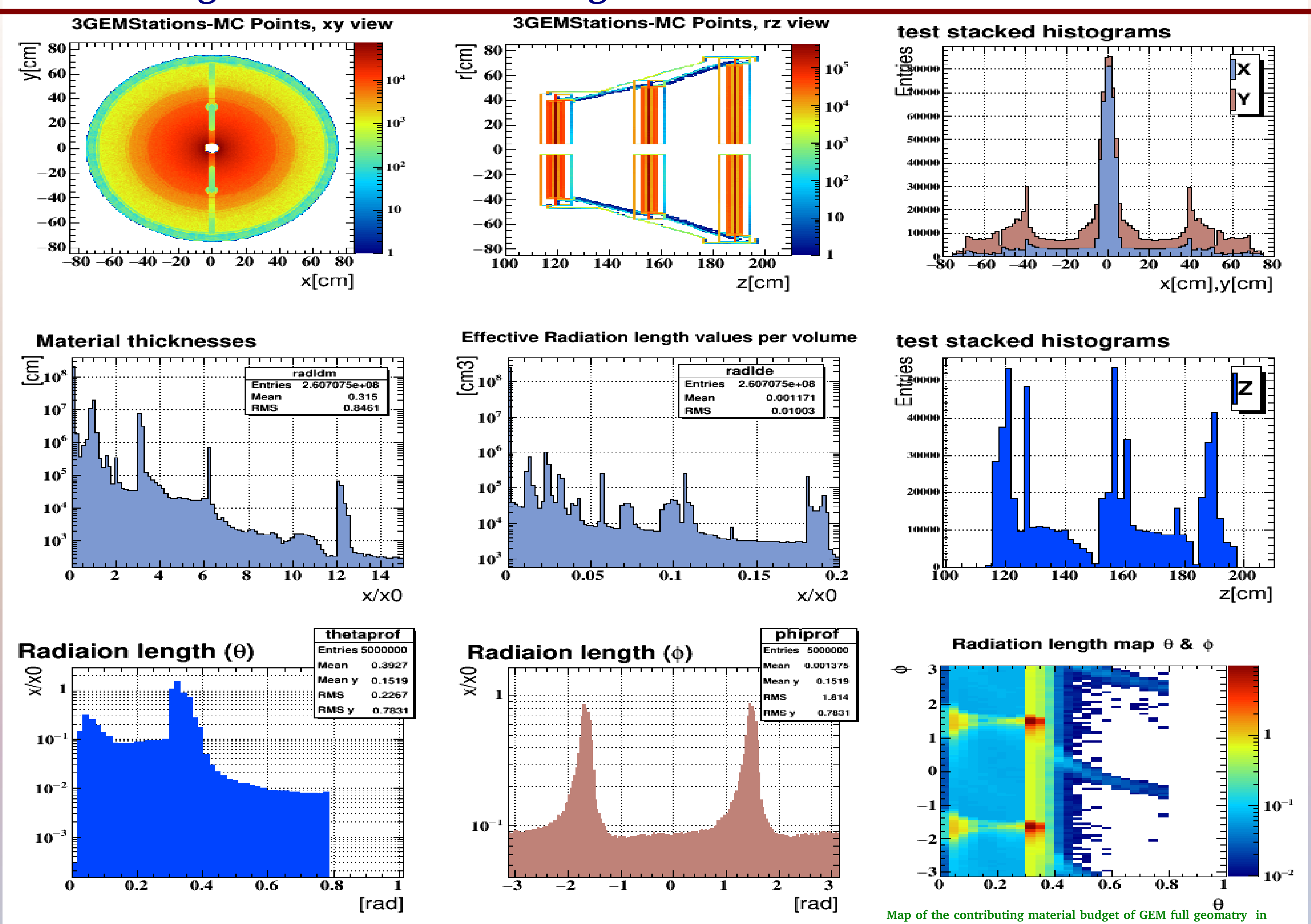


Polar distribution of fractional radiation length, X/X0, for materials of GEM full geomatry



Fractional radiation length, X/X0, versus phi[rad] for materials of GEM full geomatry

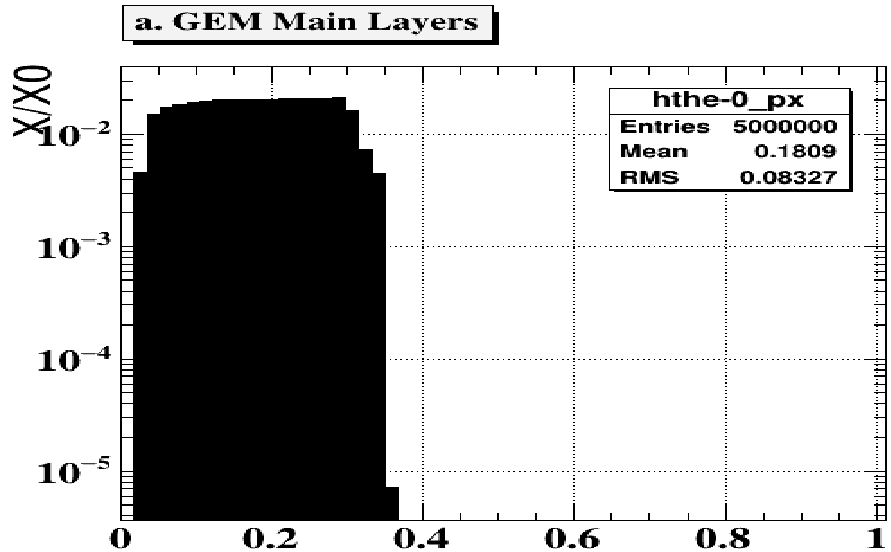
Investigation of Radiation Length for the Materials of the GEM Detector



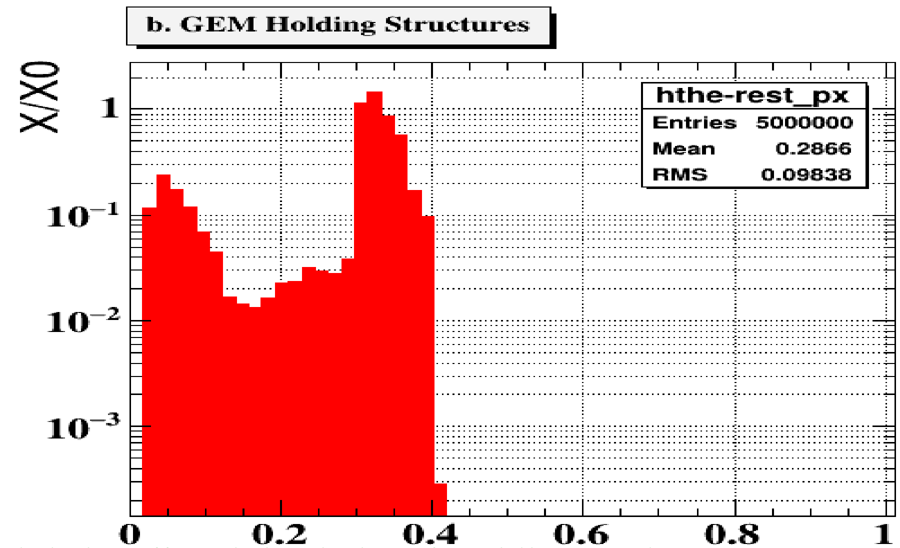
Map of the contributing material budget of GEM full geometry in terms of fractional radiation length, X/X0

For Muon particles

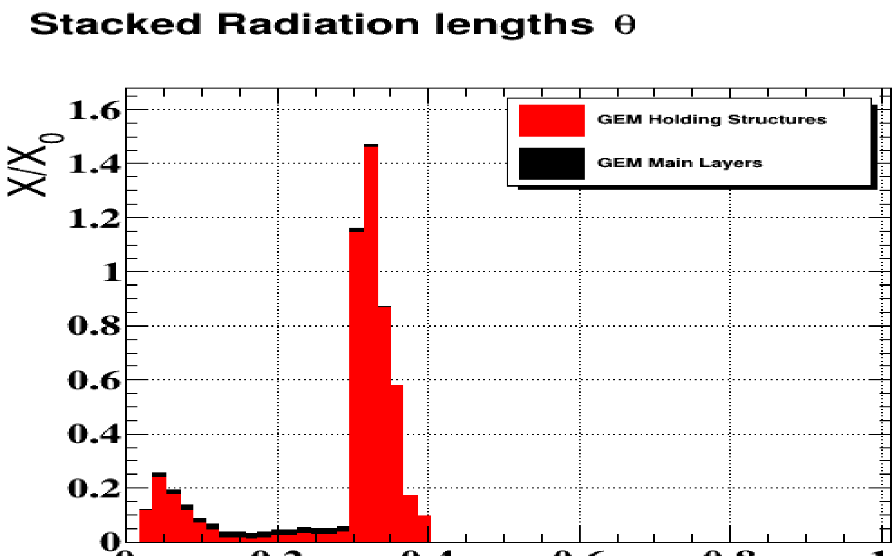
Investigation of Radiation Length for the Materials of the GEM Detector



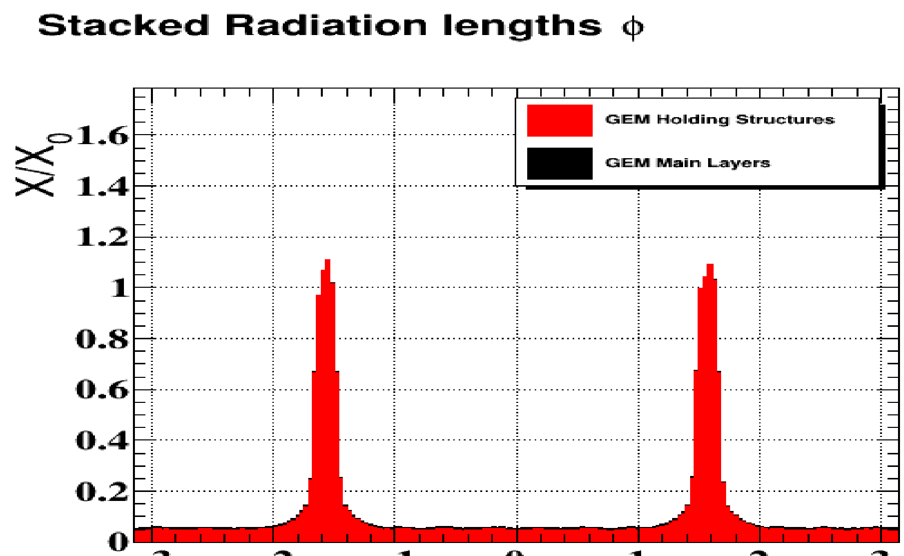
Polar distribution of fractional radiation length, X/X0, for GEM main layers materials



Polar distribution of fractional radiation length, X/X0, for GEM holding structures layers materials



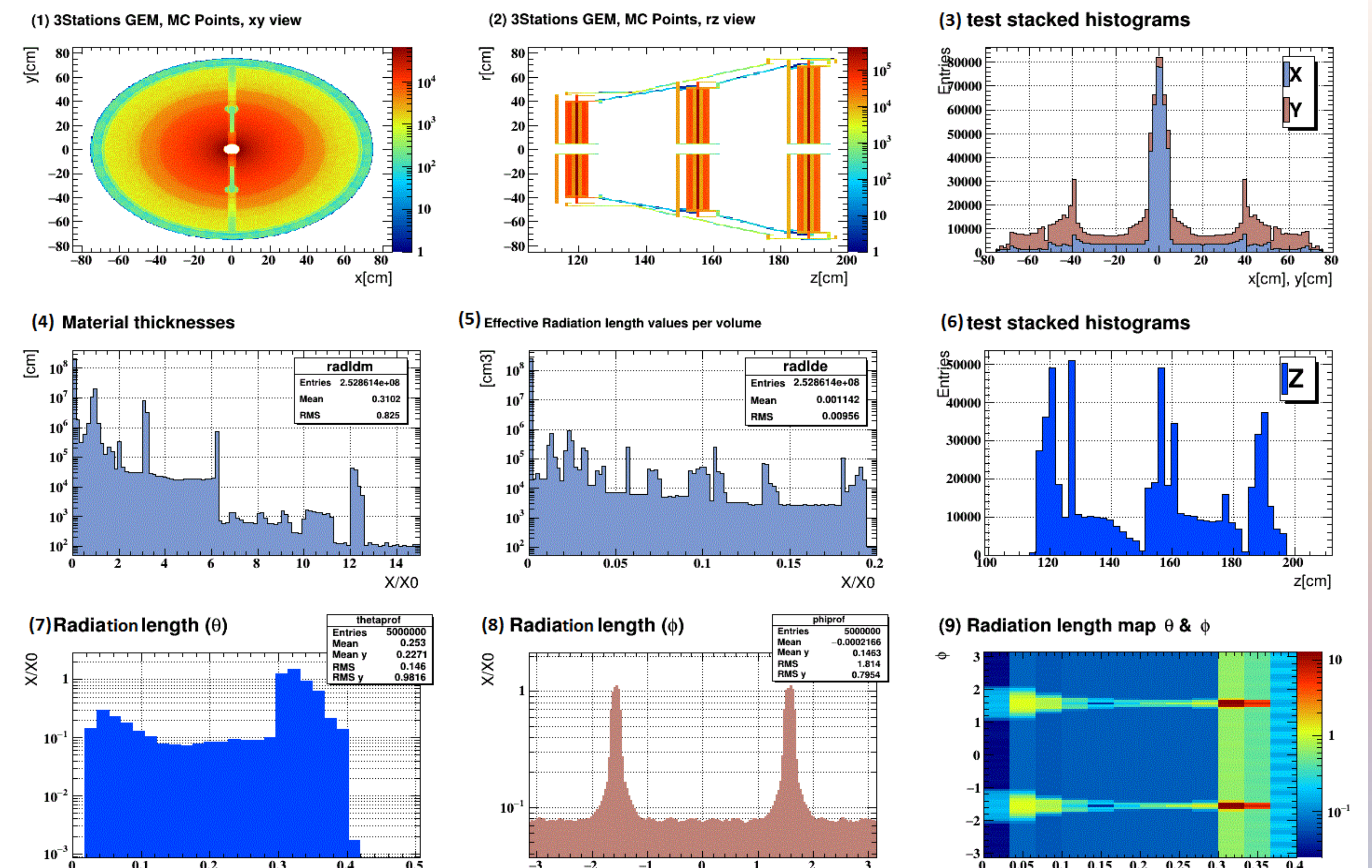
Polar distribution of fractional radiation length, X/X0, for materials of GEM full geomatry



Fractional radiation length, X/X0, versus phi[rad] for materials of GEM full geomatry

For Geantino particles

Investigation of Radiation Length for the Materials of the GEM Detector



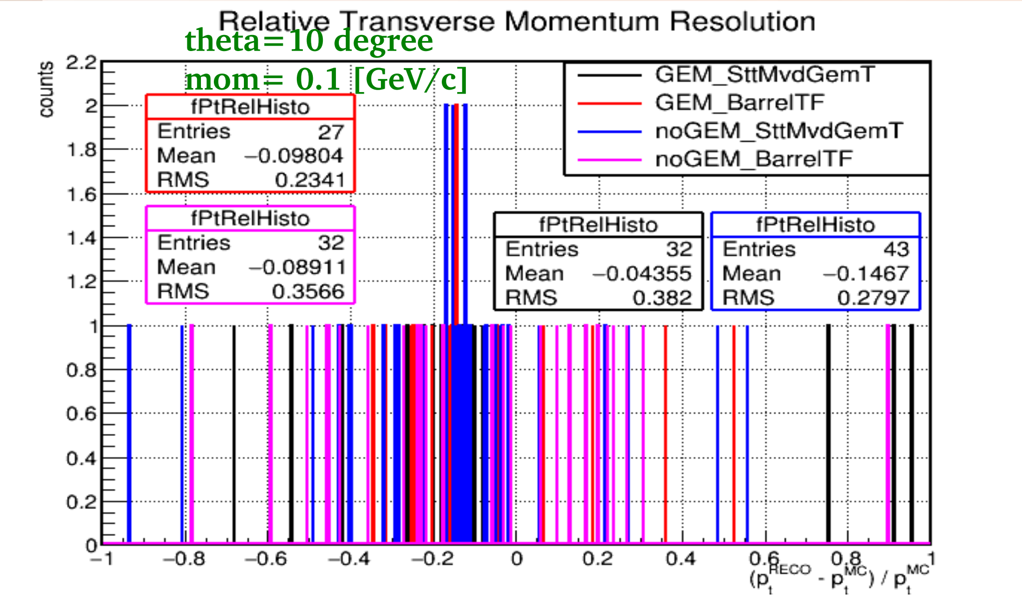
Map of the contributing material budget of GEM full geomatry in terms of fractional radiation length, X/X0

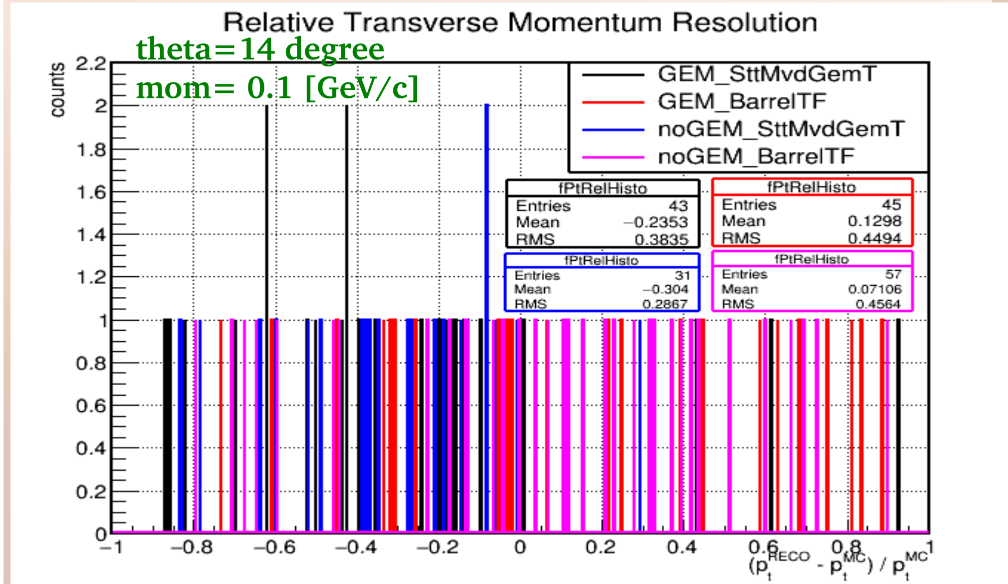
For Geantino particles

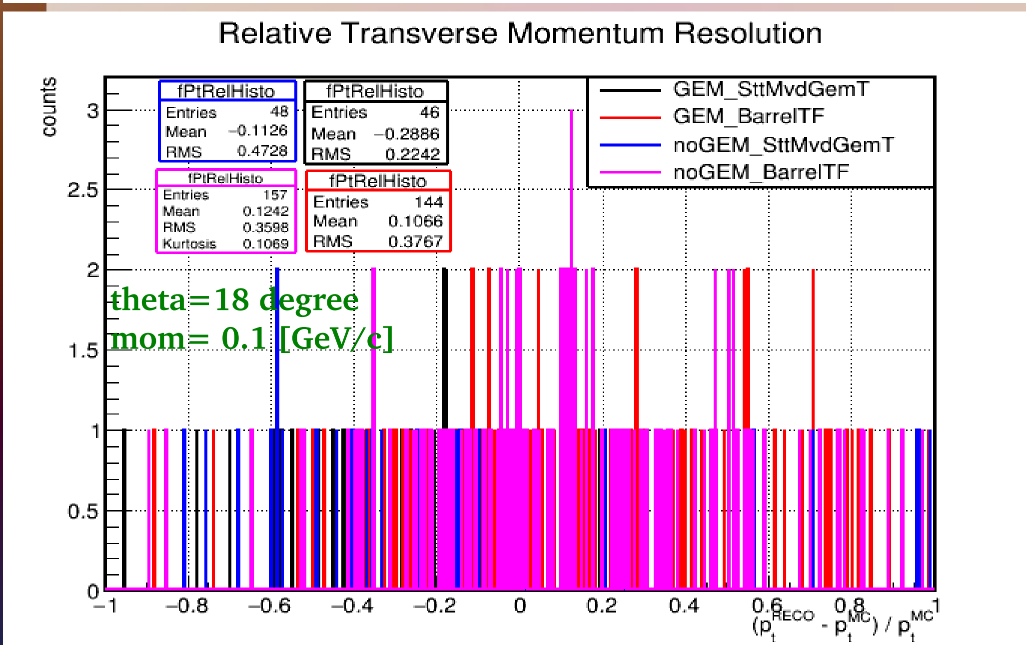
Part Five :

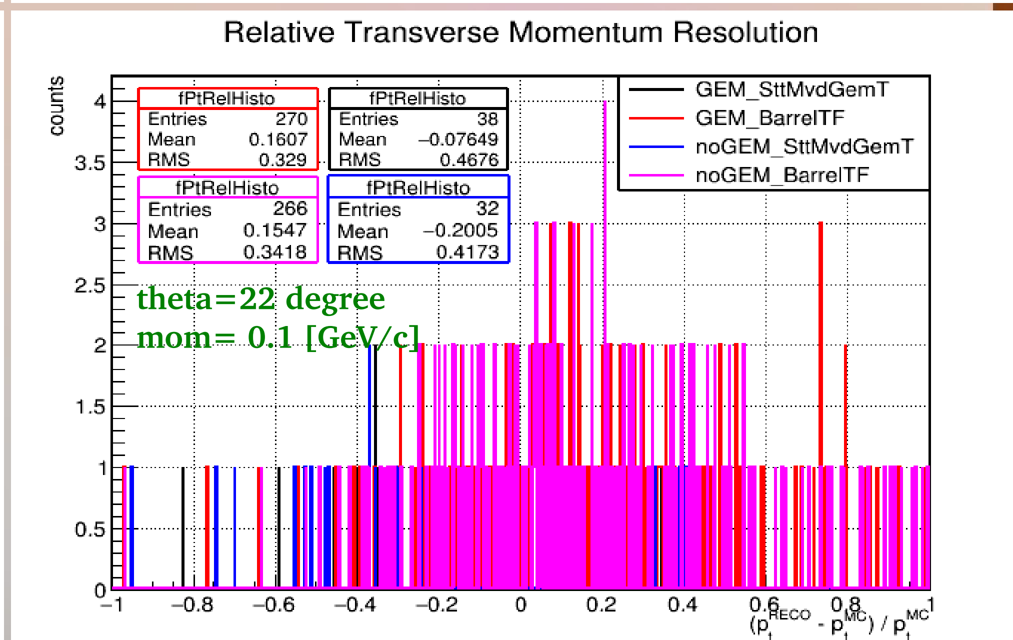
More Results & Extra Information

Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder

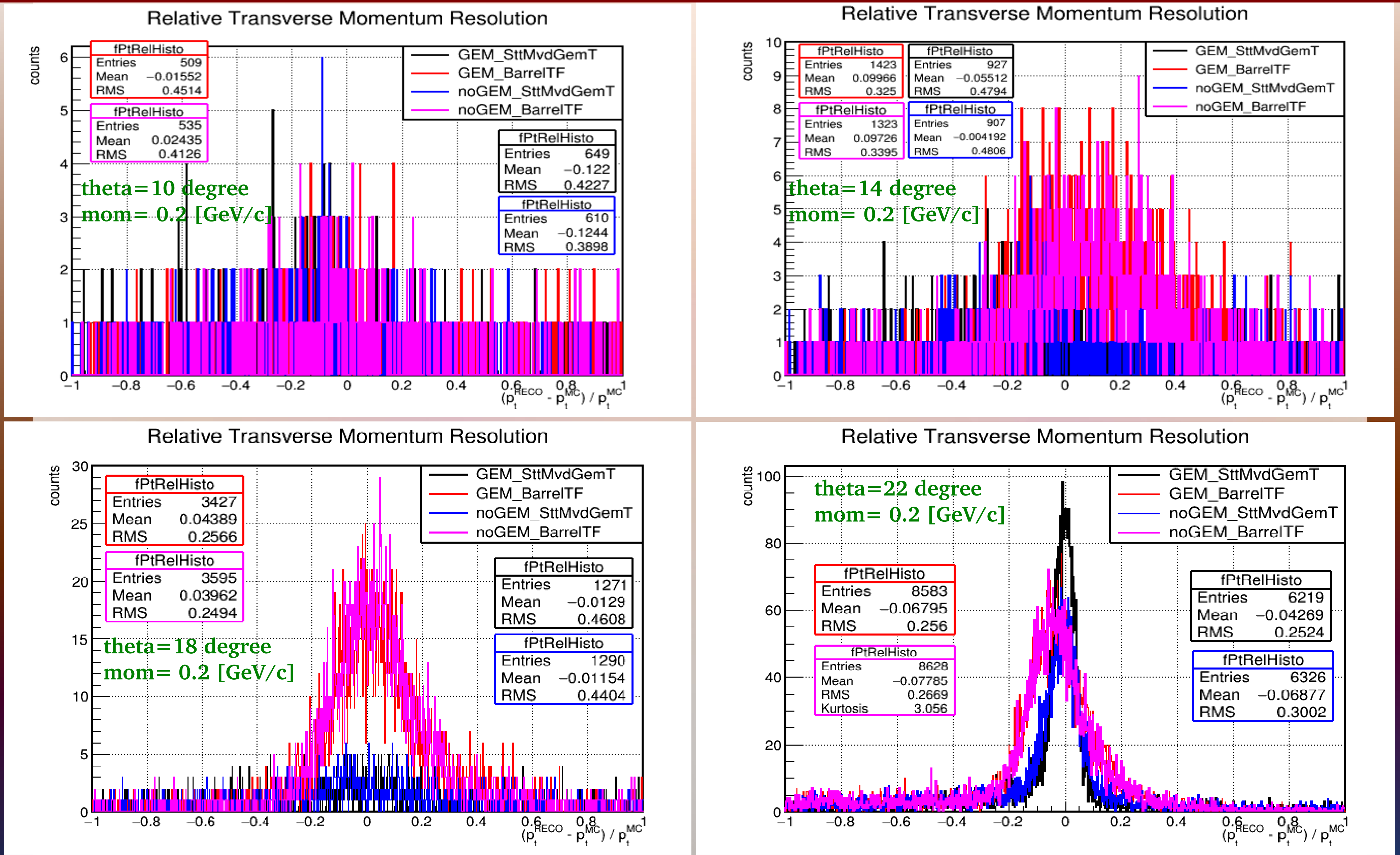








Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder



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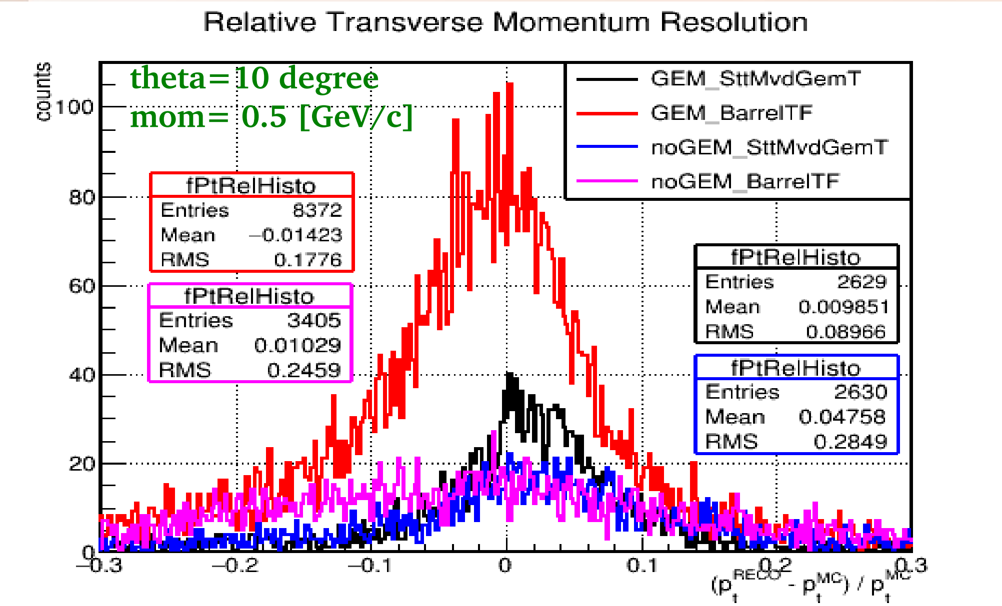
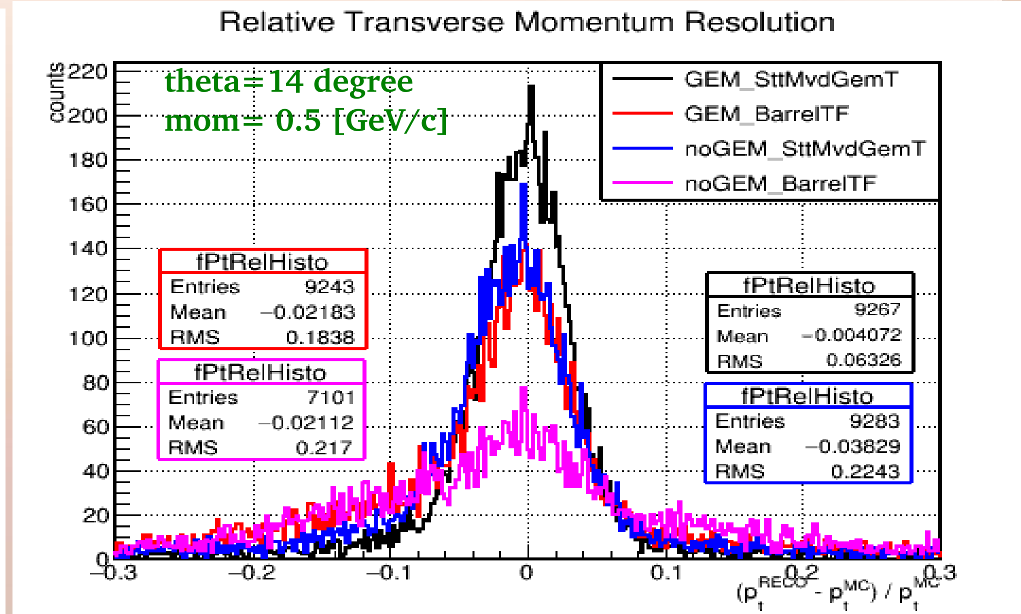
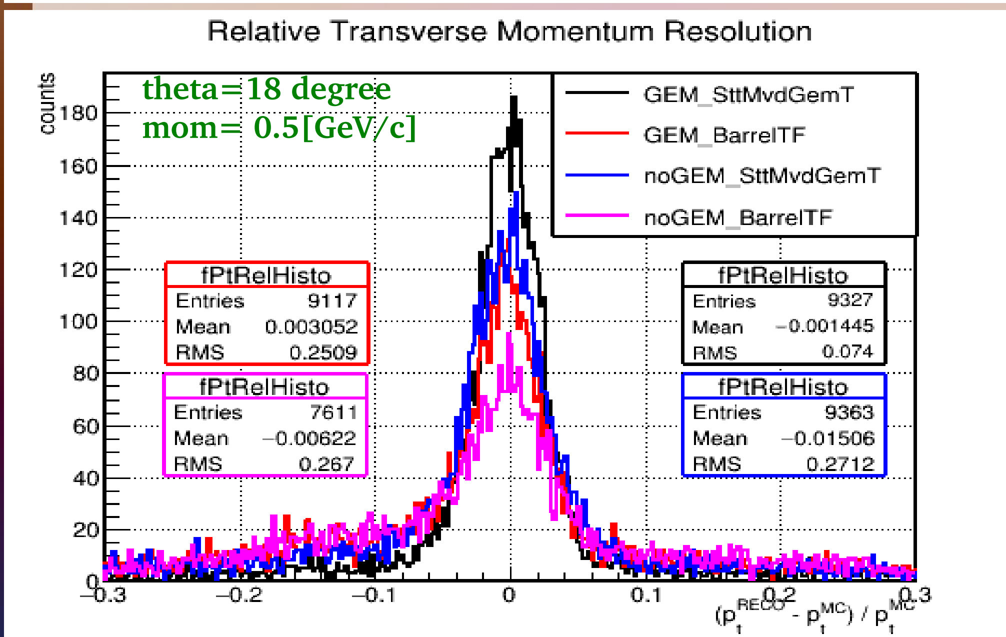
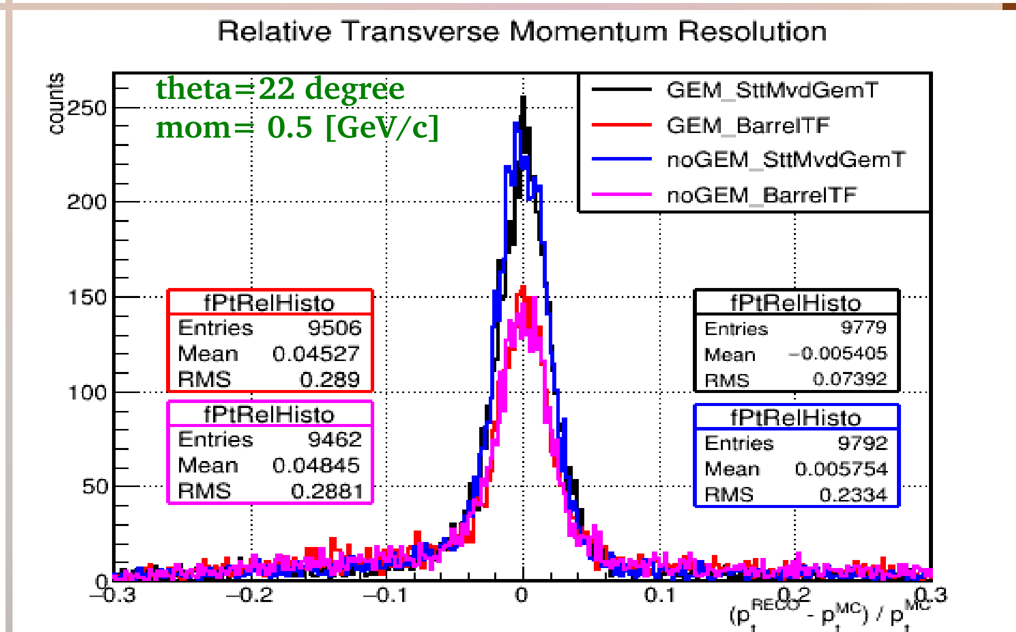
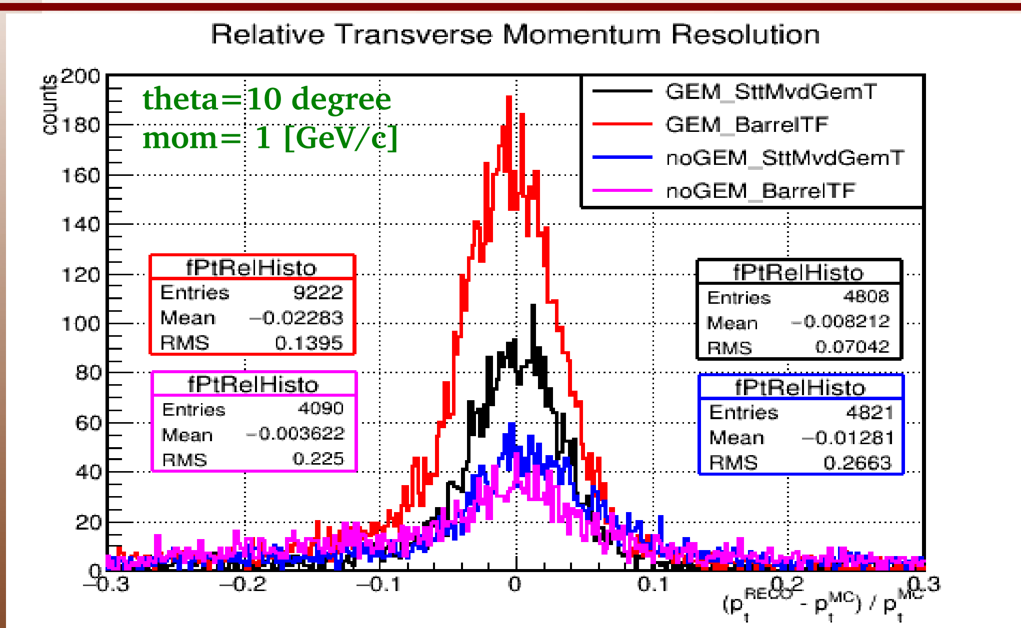


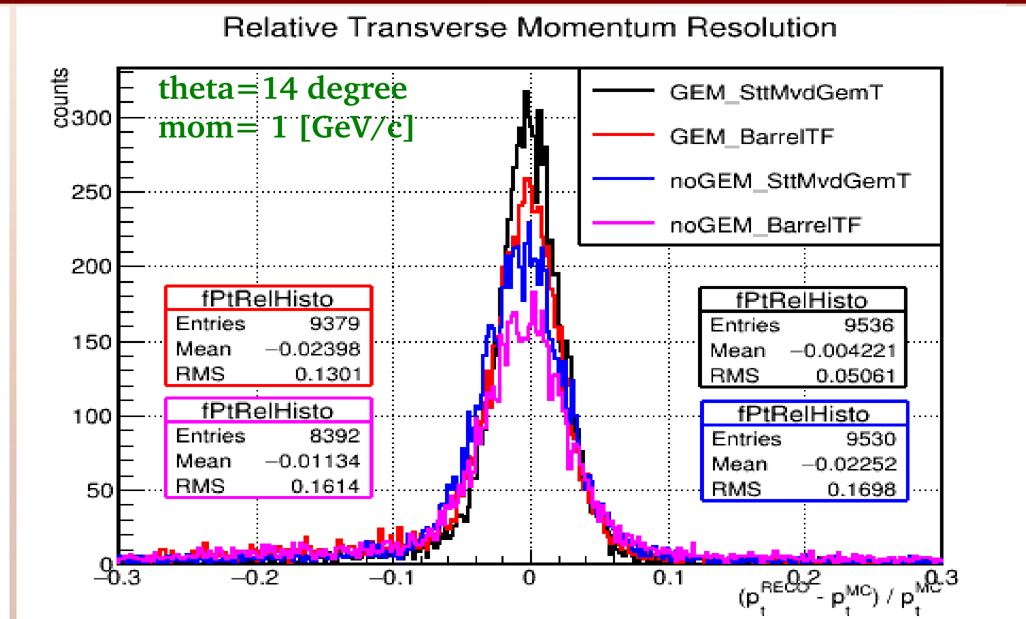


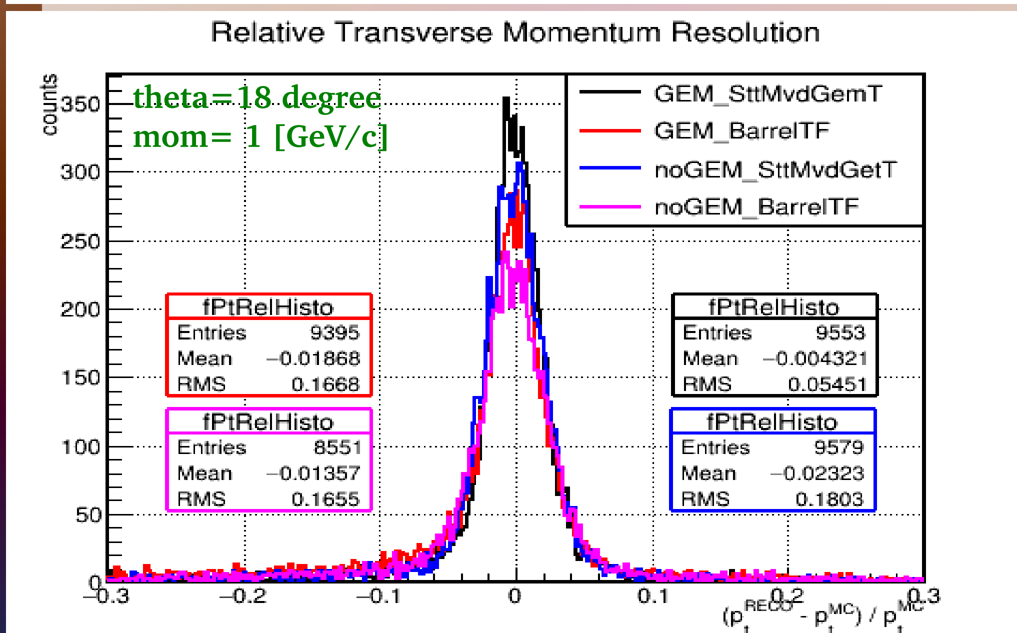


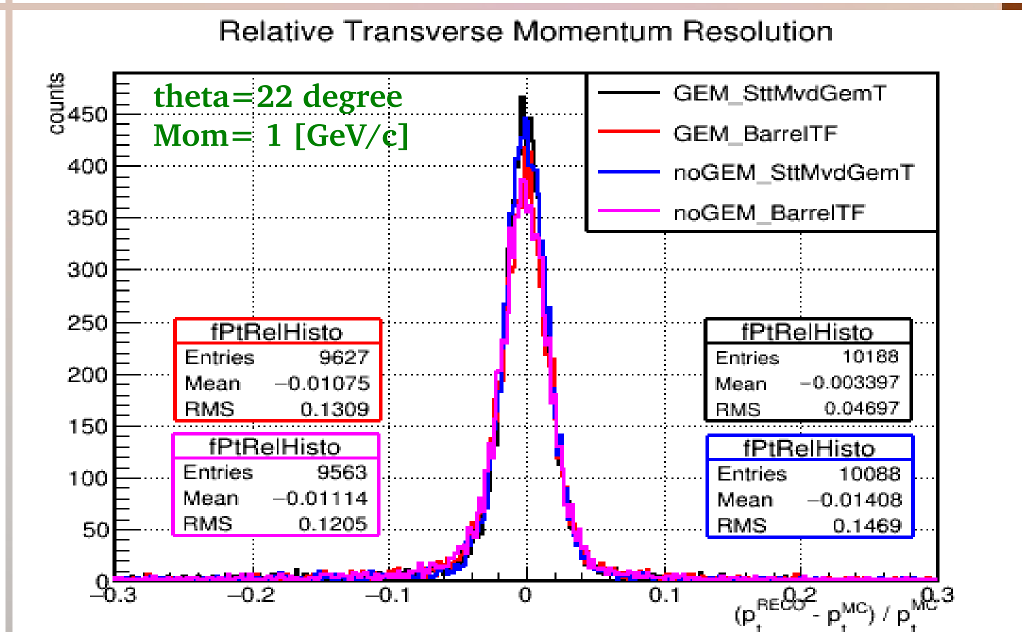


Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder

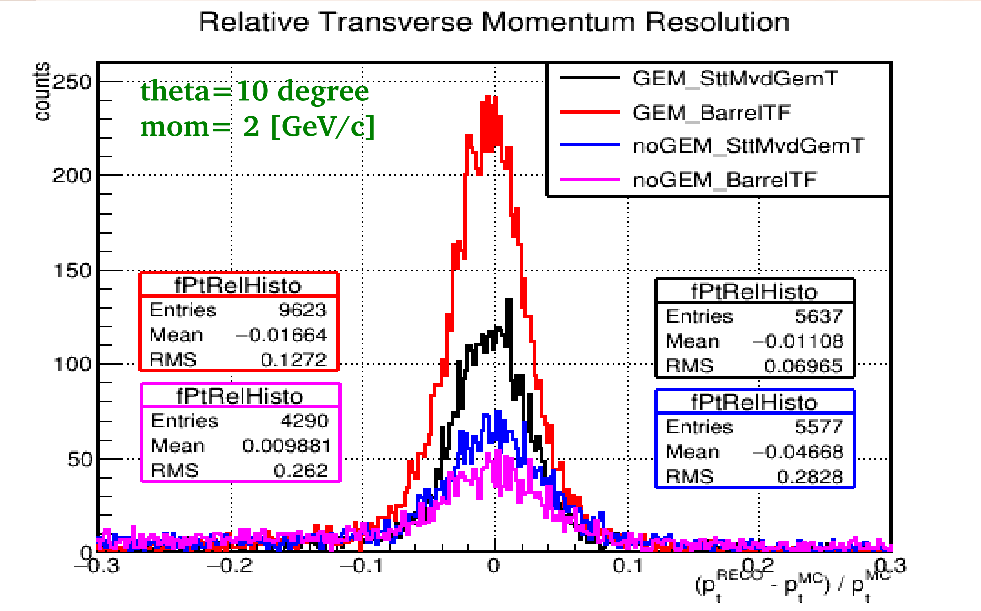


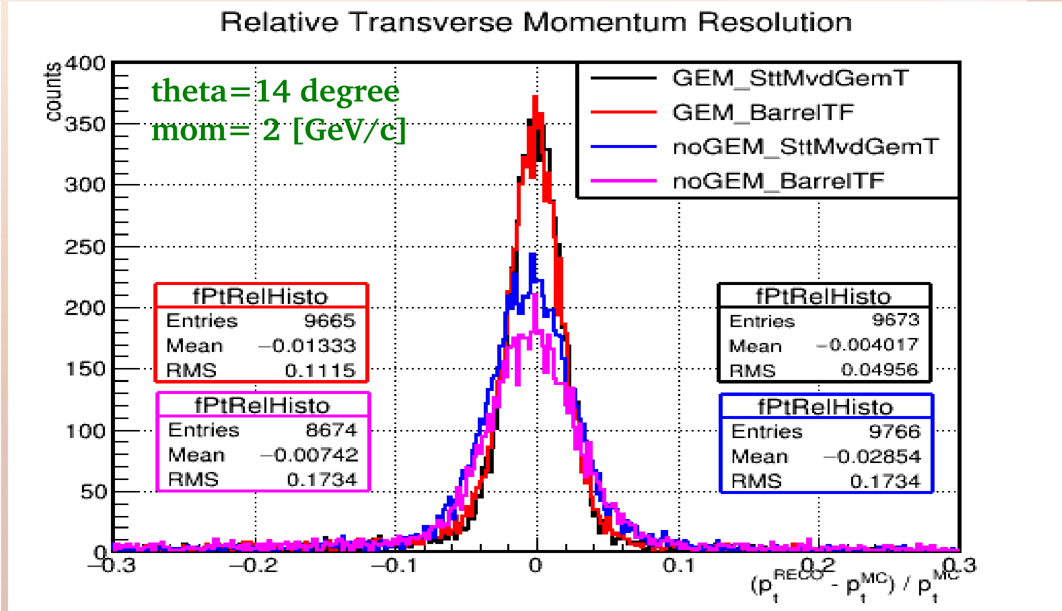


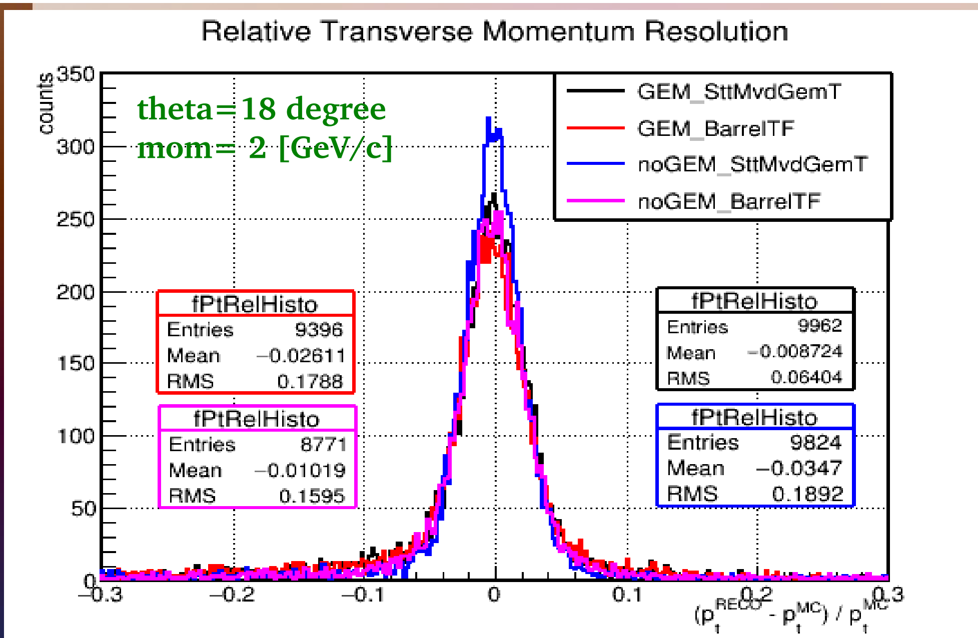


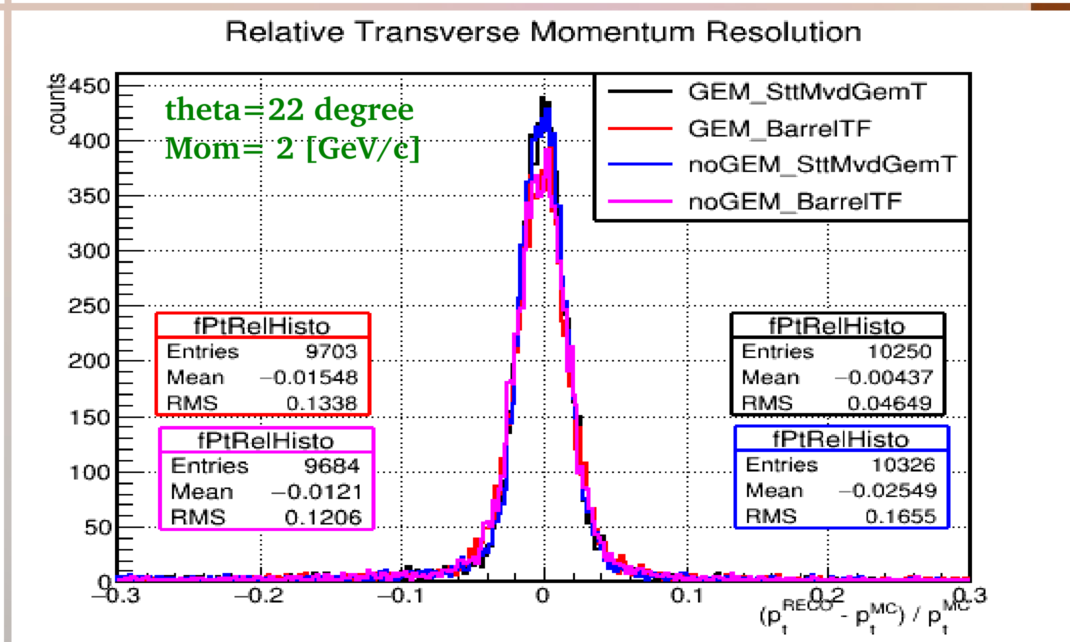


Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder

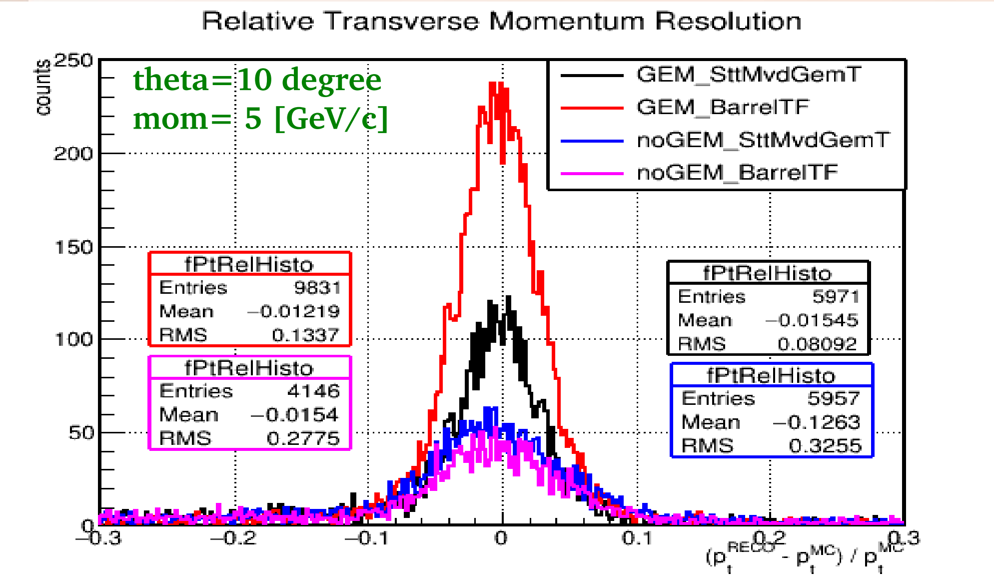


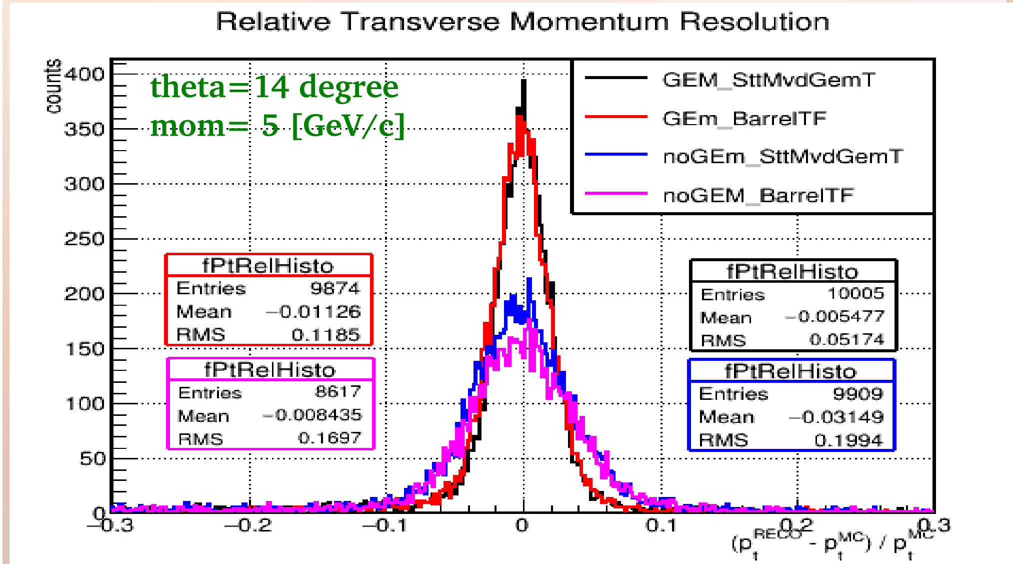


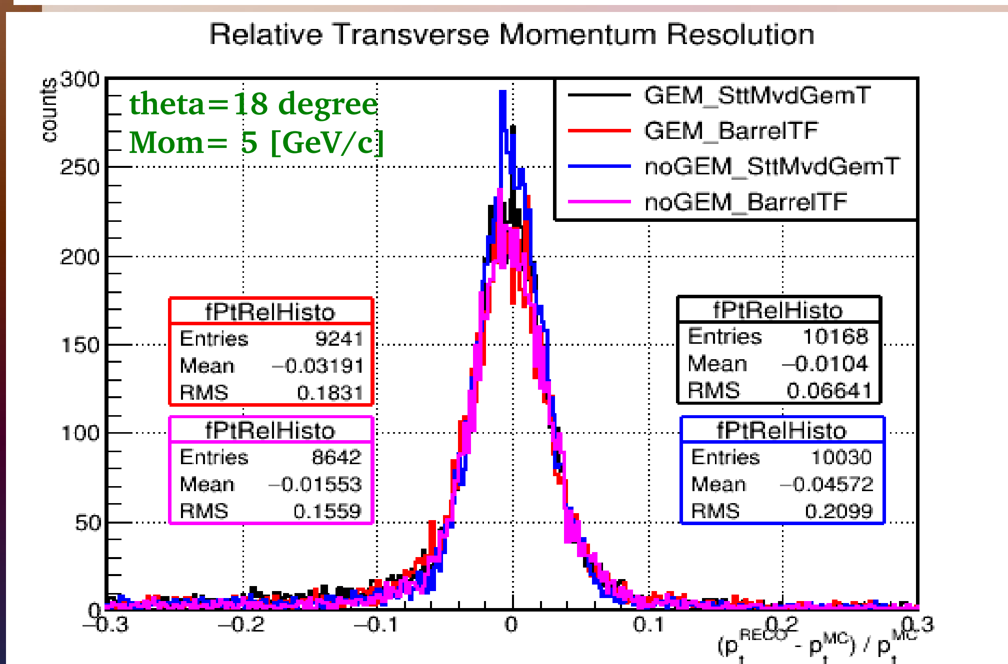


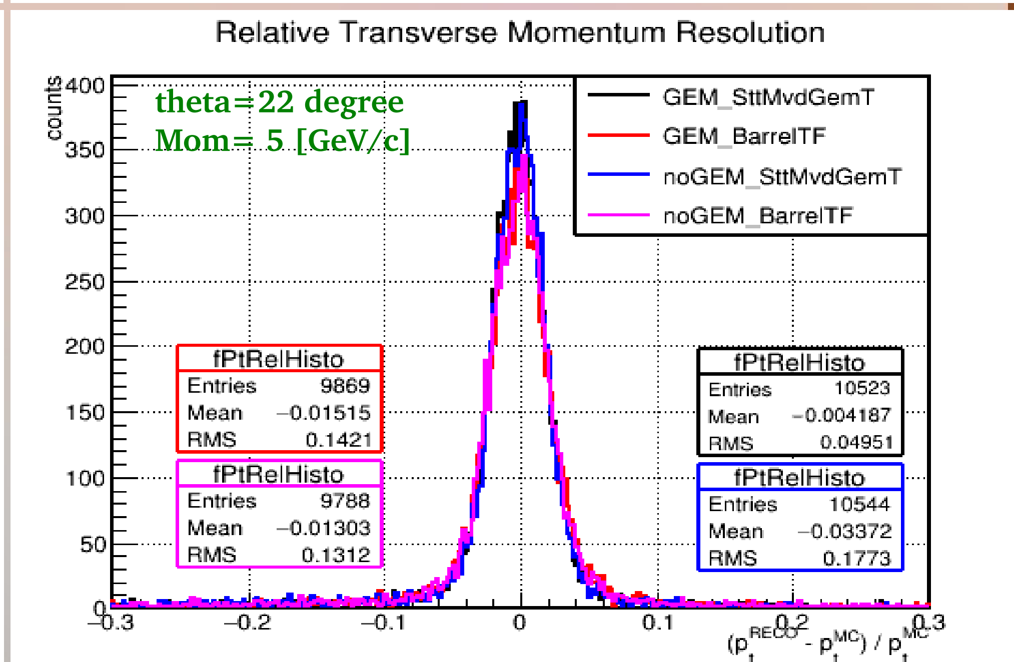


Momentum Resolution Study with and without GEM In Comparison between using two Track Reconstruction Classes : PndSttMvdGemTracking & PndBarrelTrackFinder



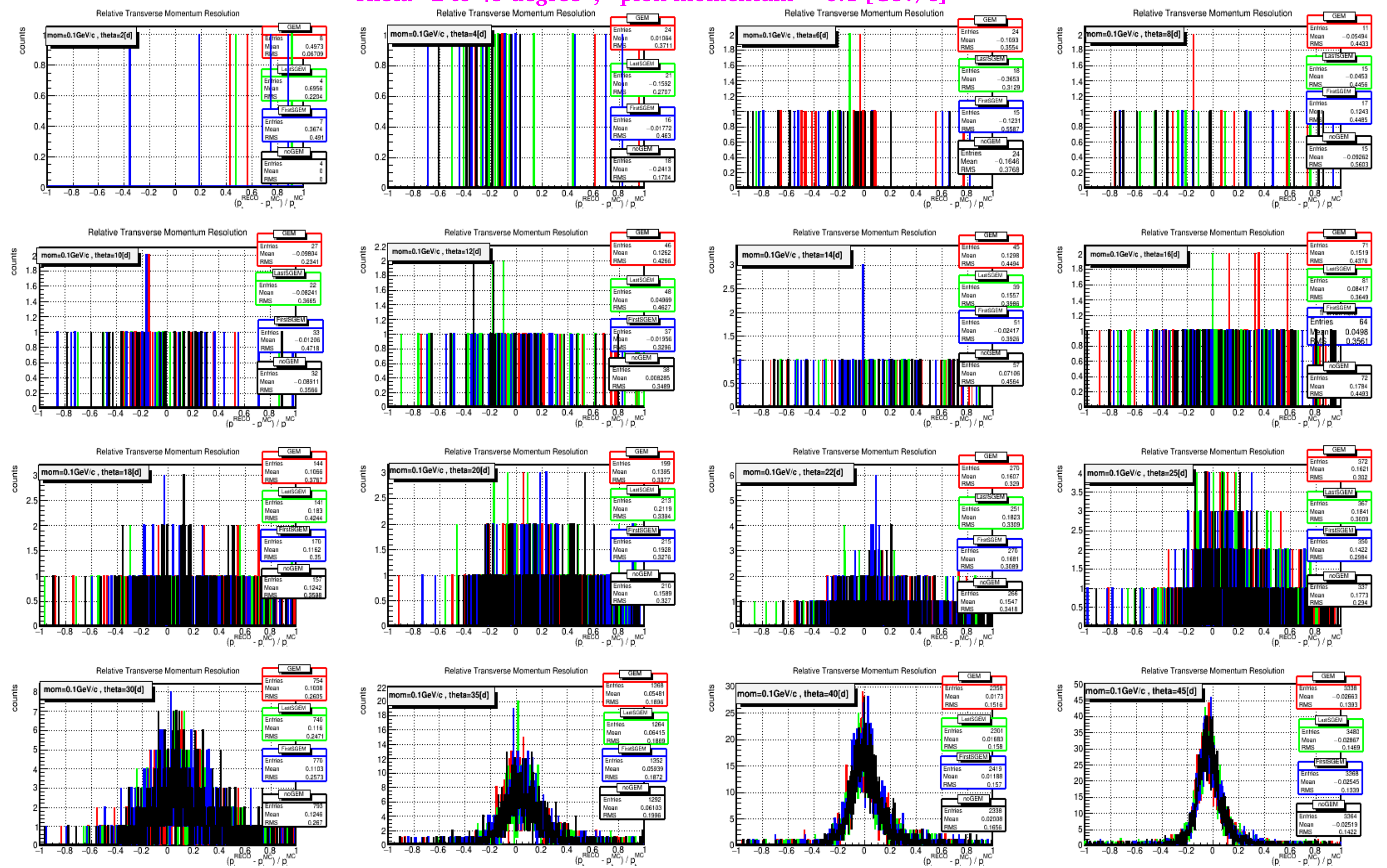






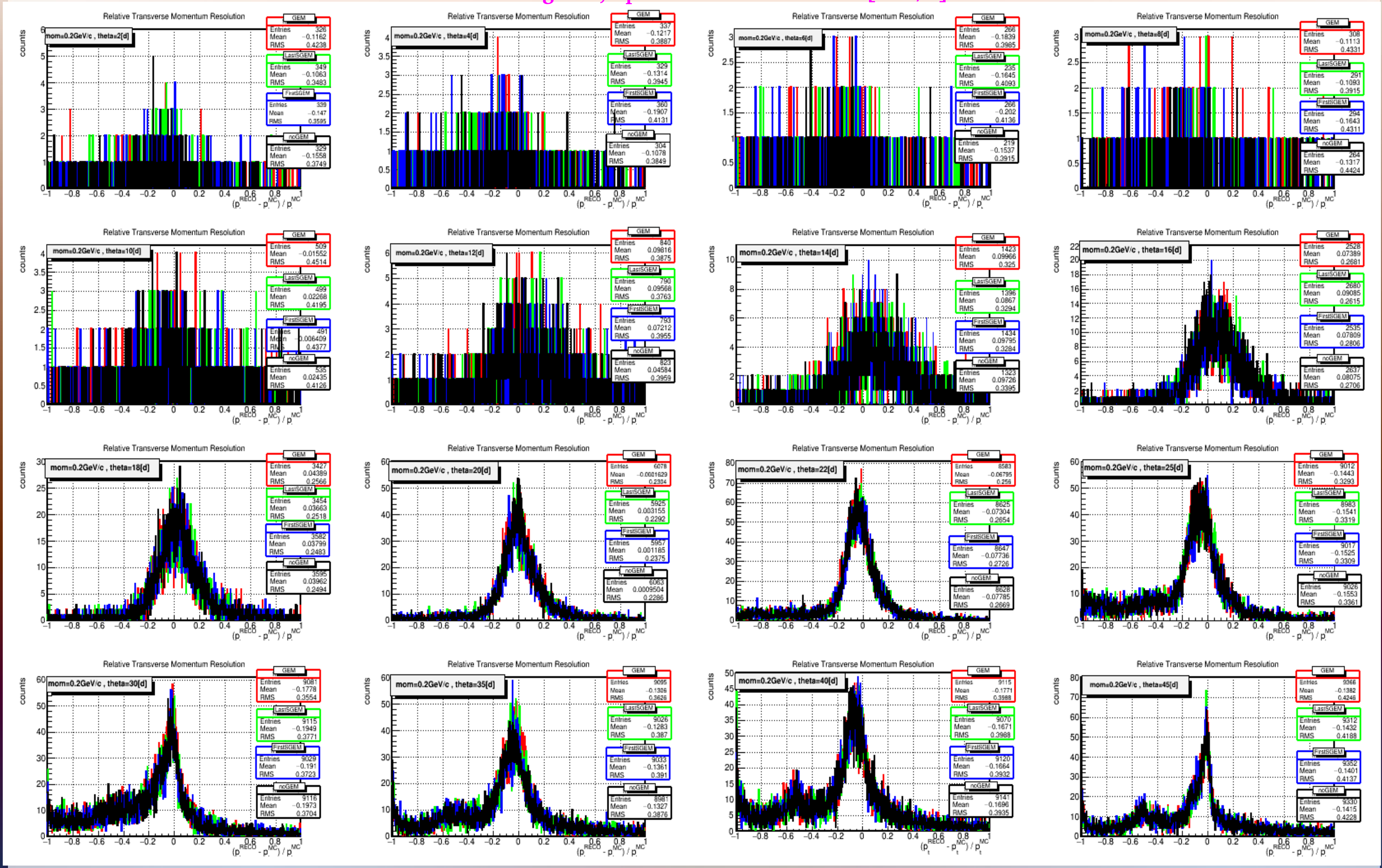
Investigation of Momentum Resolution without, with 3 stations & single station GEM

Theta=2 to 45 degree , pion momentum = 0.1 [GeV/c]



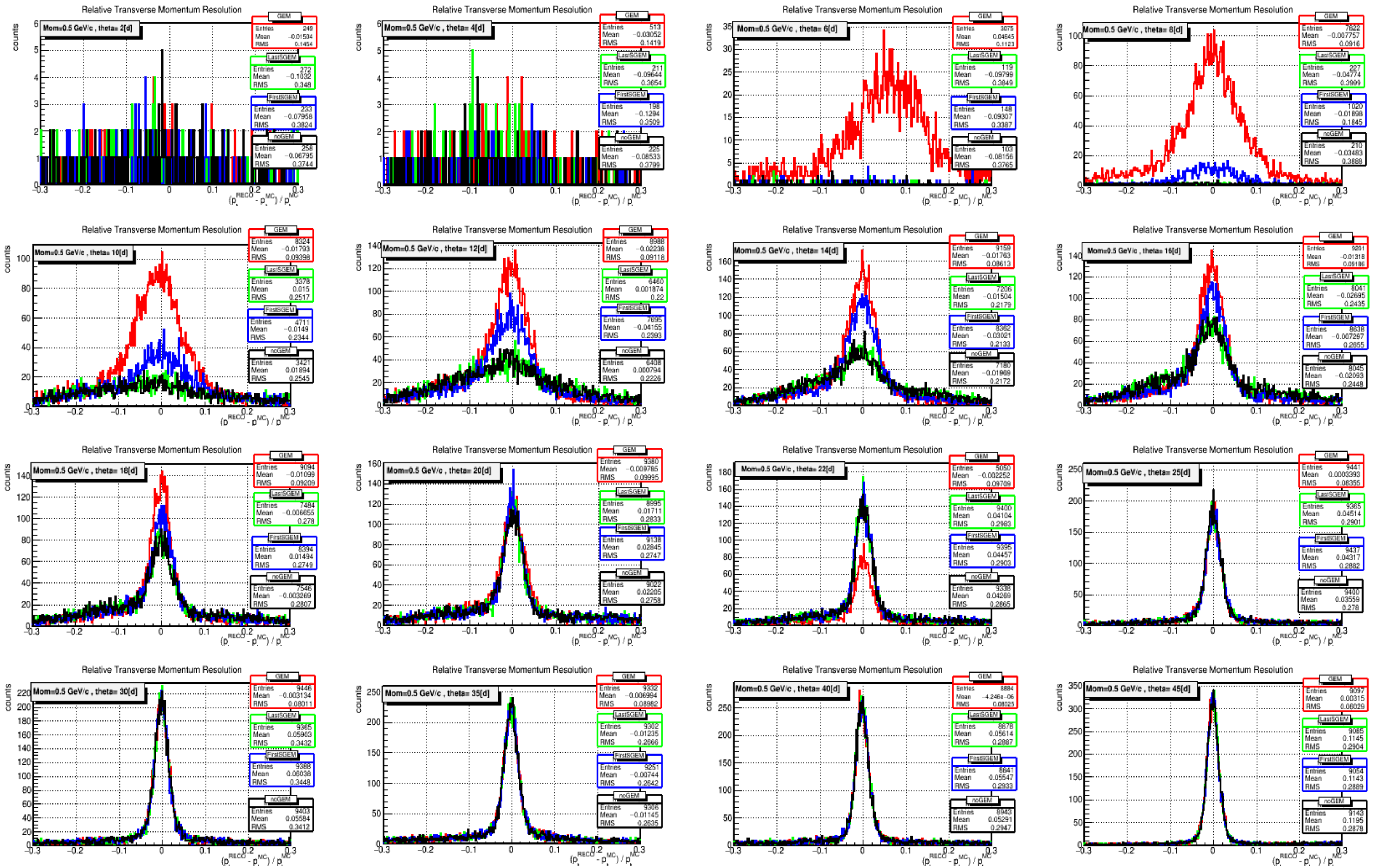
Investigation of Momentum Resolution without, with 3 stations & single station GEM

Theta=2 to 45 degree , pion momentum = 0.2 [GeV/c]



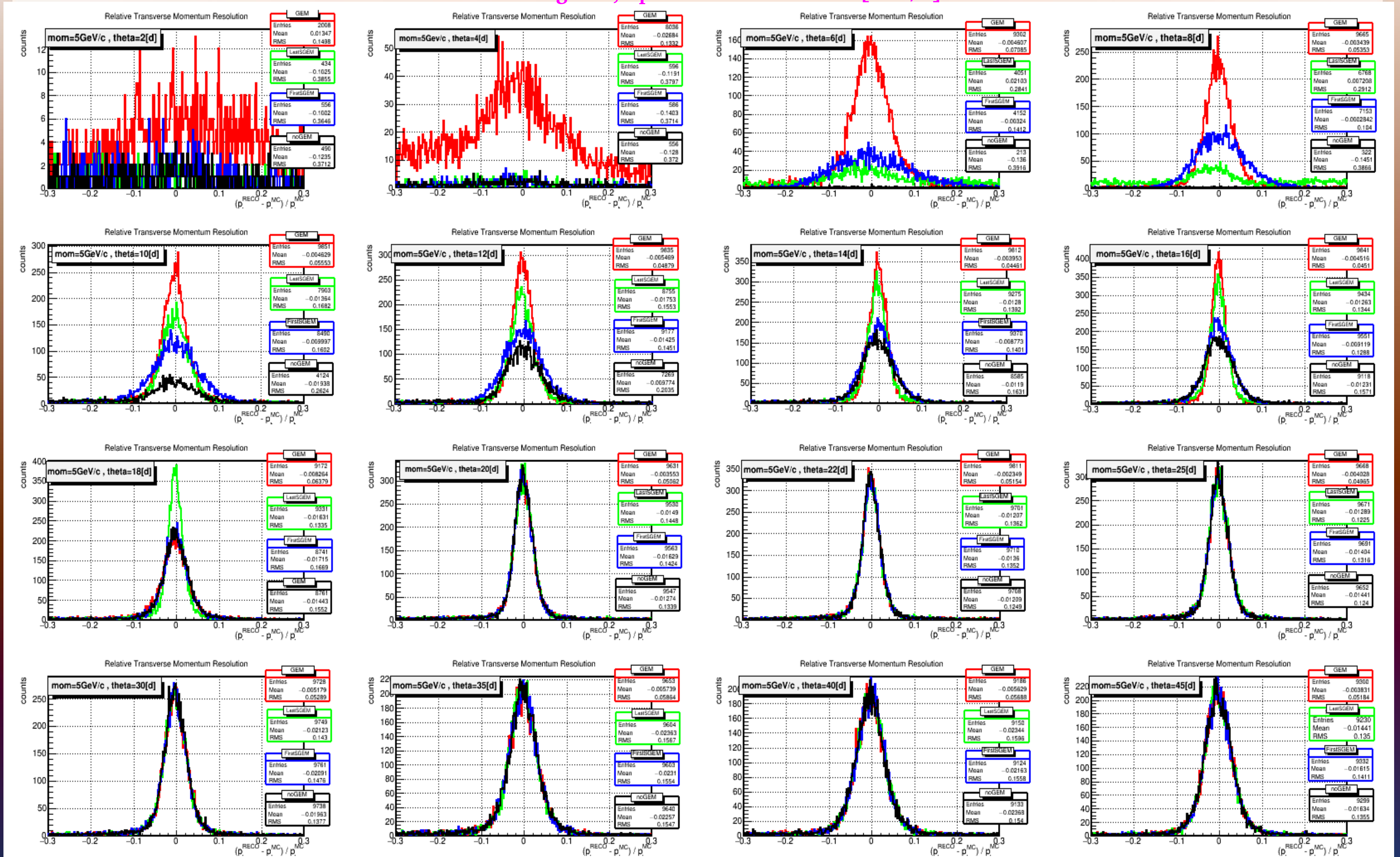
Investigation of Momentum Resolution without, with 3 stations & single station GEM

Theta=2 to 45 degree , pion momentum = 0.5 [GeV/c]

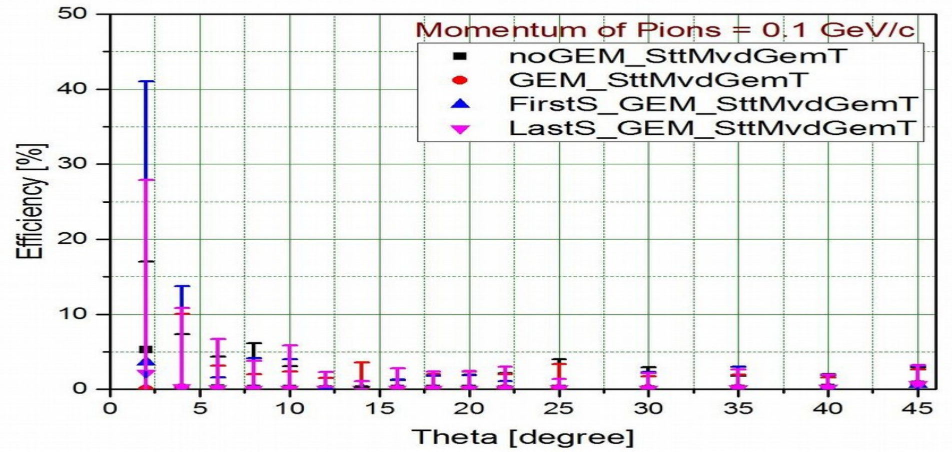


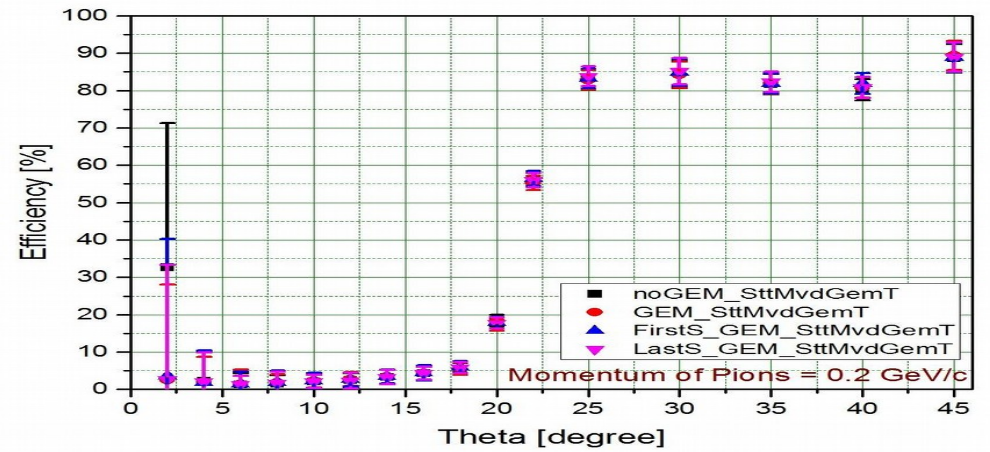
Investigation of Momentum Resolution without, with 3 stations & single station GEM

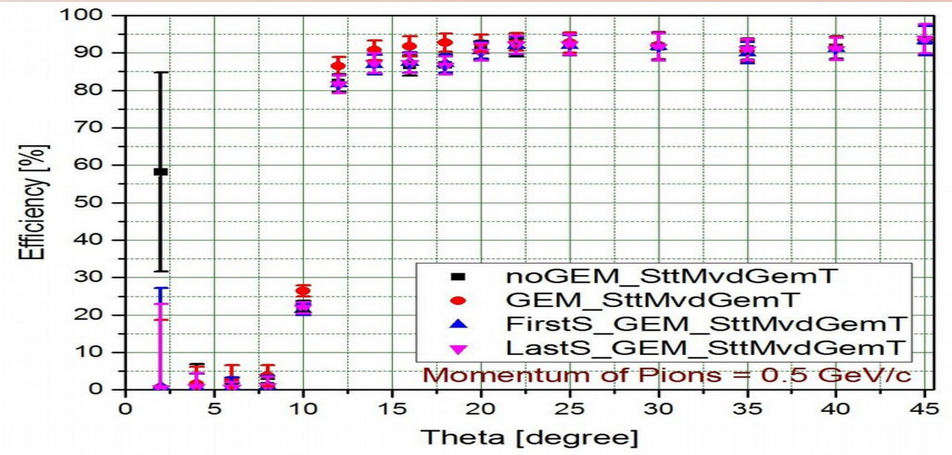
Theta=2 to 45 degree , pion momentum = 5 [GeV/c]

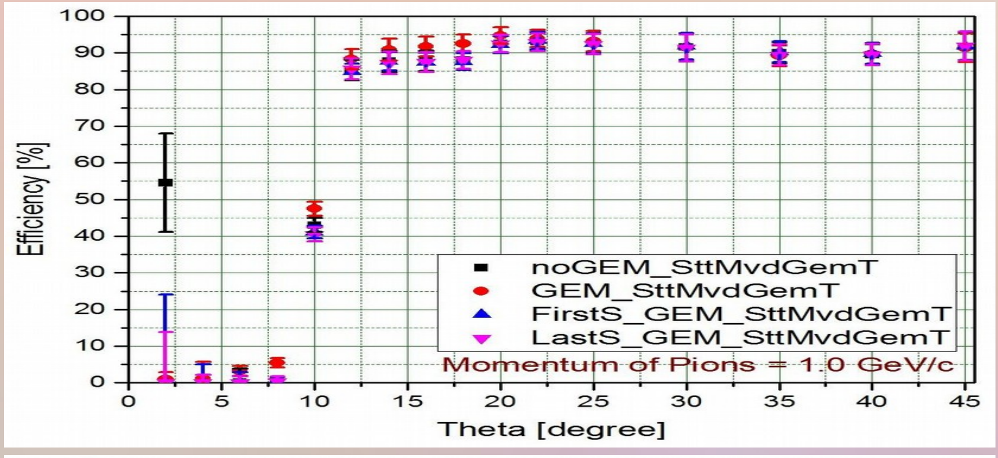


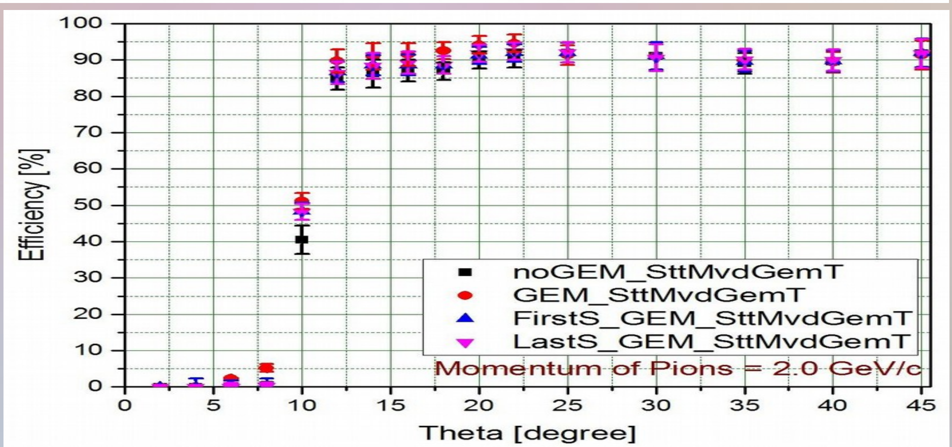
Backup Slide : Investigation of Track Finding Efficiency without, with 3 stations & 1 station GEM using PndSttMvdGemTracking class

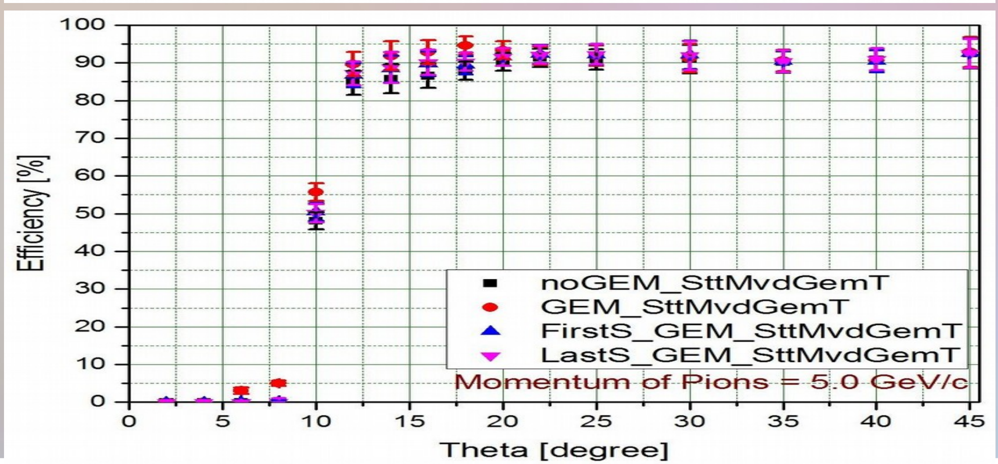




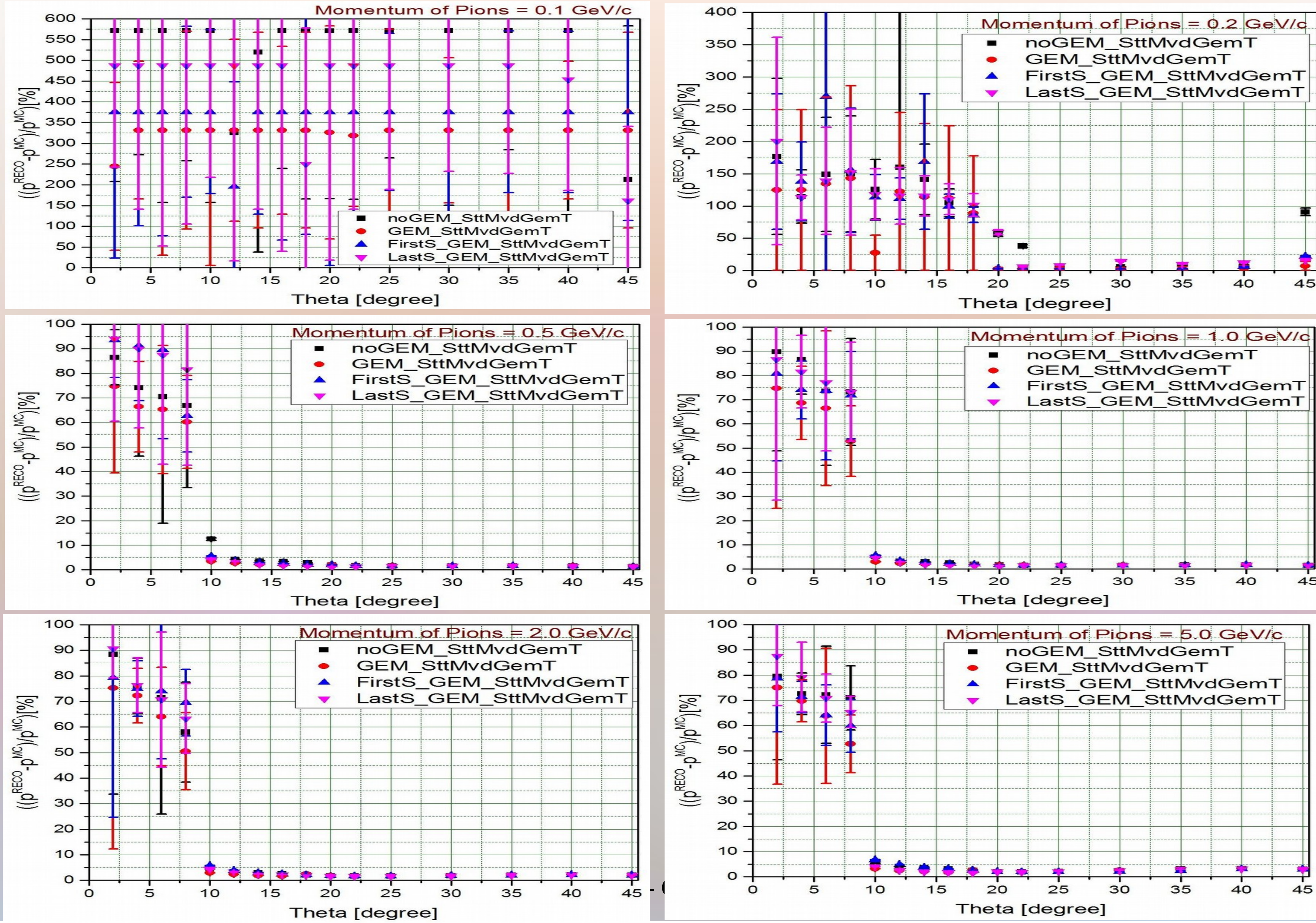






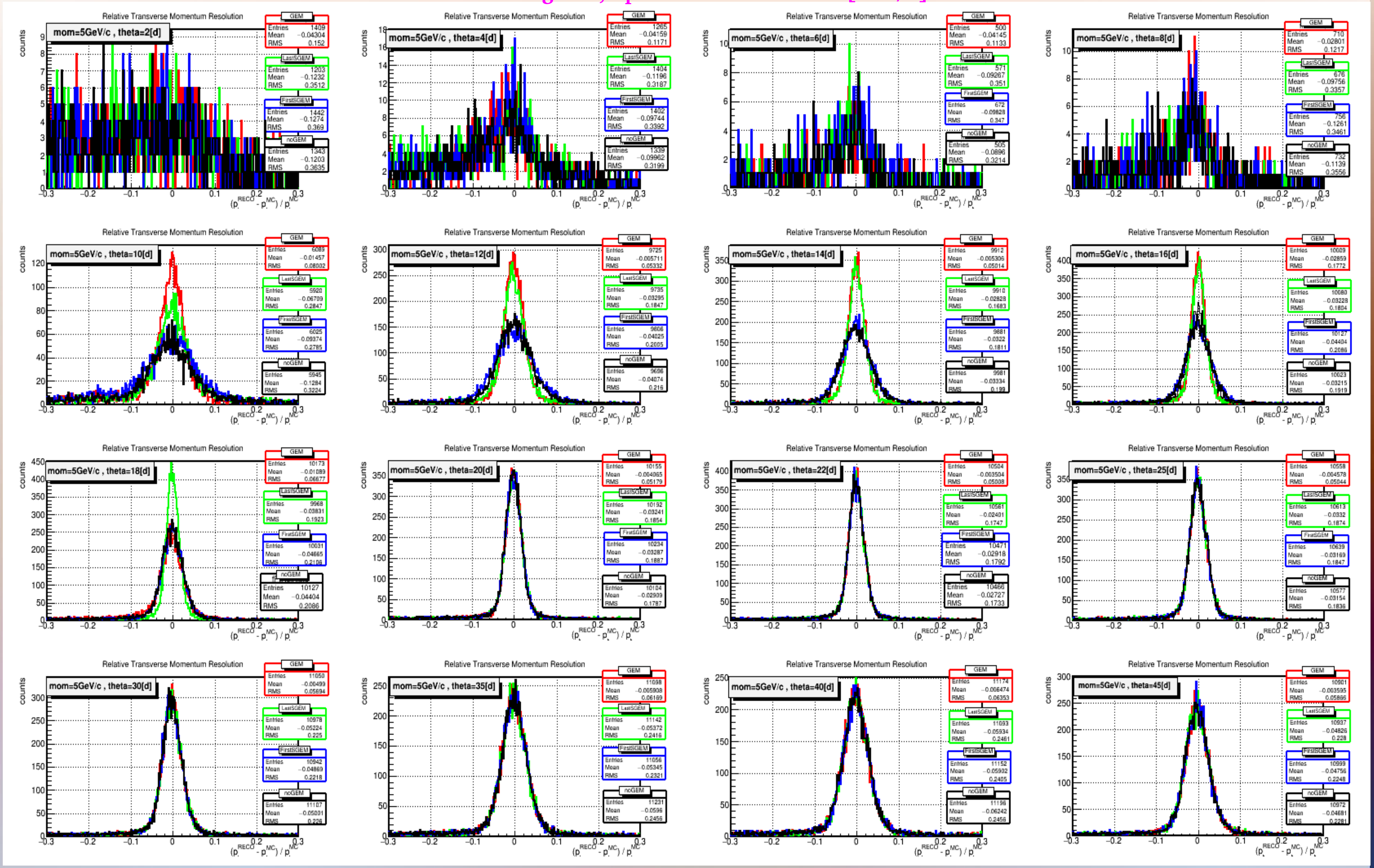


Backup Slide : Investigation of Momentum Resolution without, with 3 stations & 1 station GEM using PndSttMvdGemTracking class



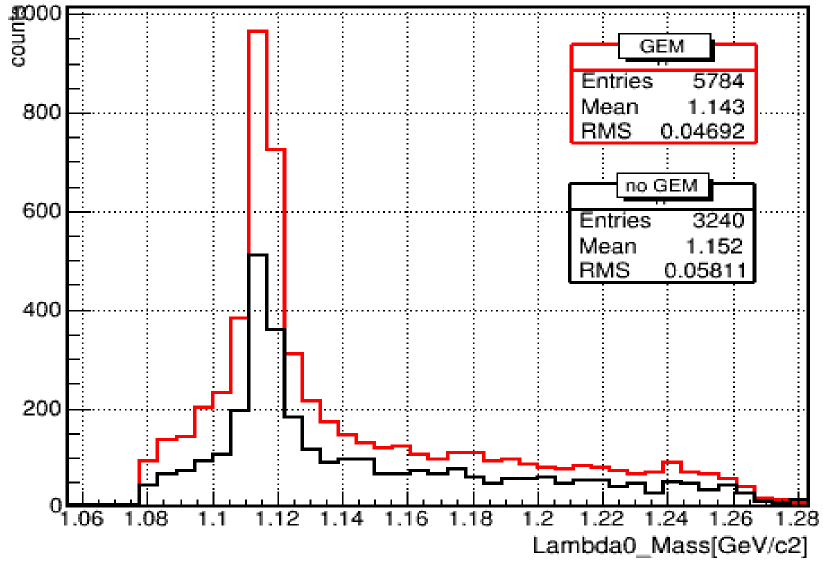
Backup Slide : Investigation of Momentum Resolution without, with 3 stations & 1 station GEM using PndSttMvdGemTracking class

Theta=2 to 45 degree , pion momentum = 5 [GeV/c]

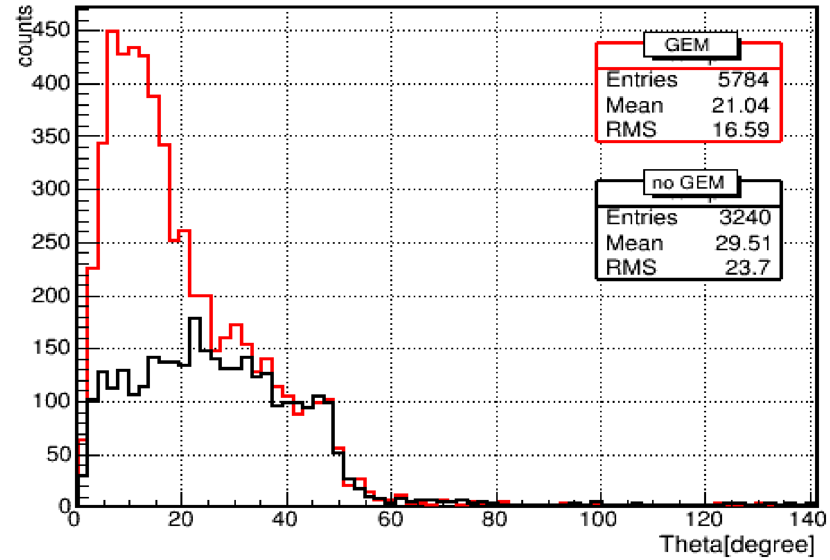


Investigation of Lambda – Anti Lambda Invariant Mass Reconstruction with and without GEM

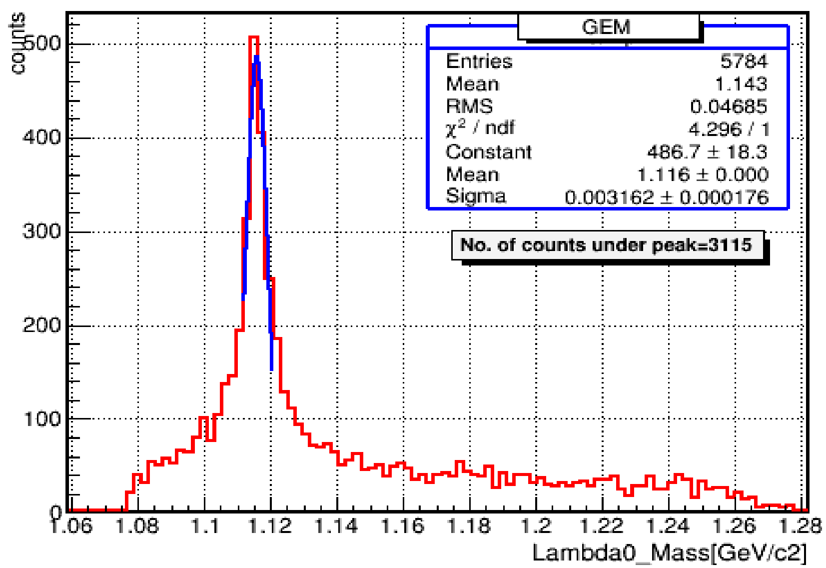
Lambda Invariant Mass Plot



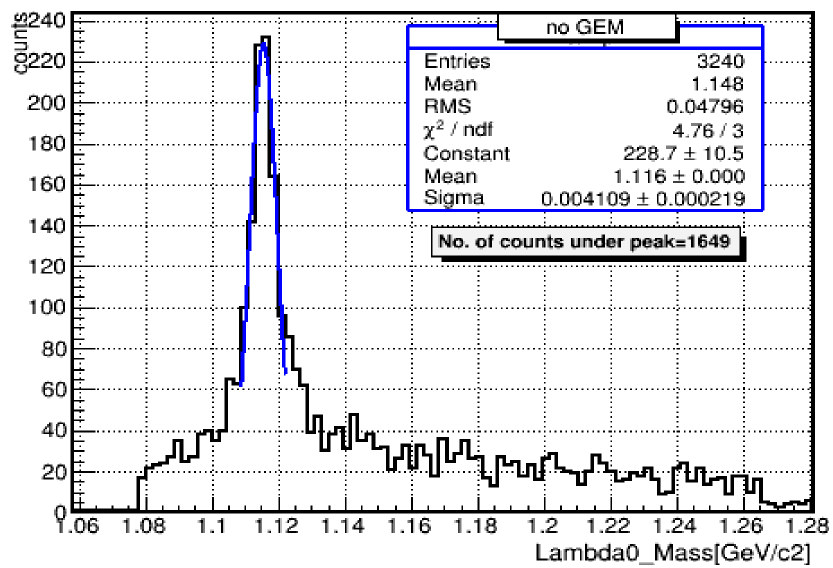
Lambda Theta Distribution Plot



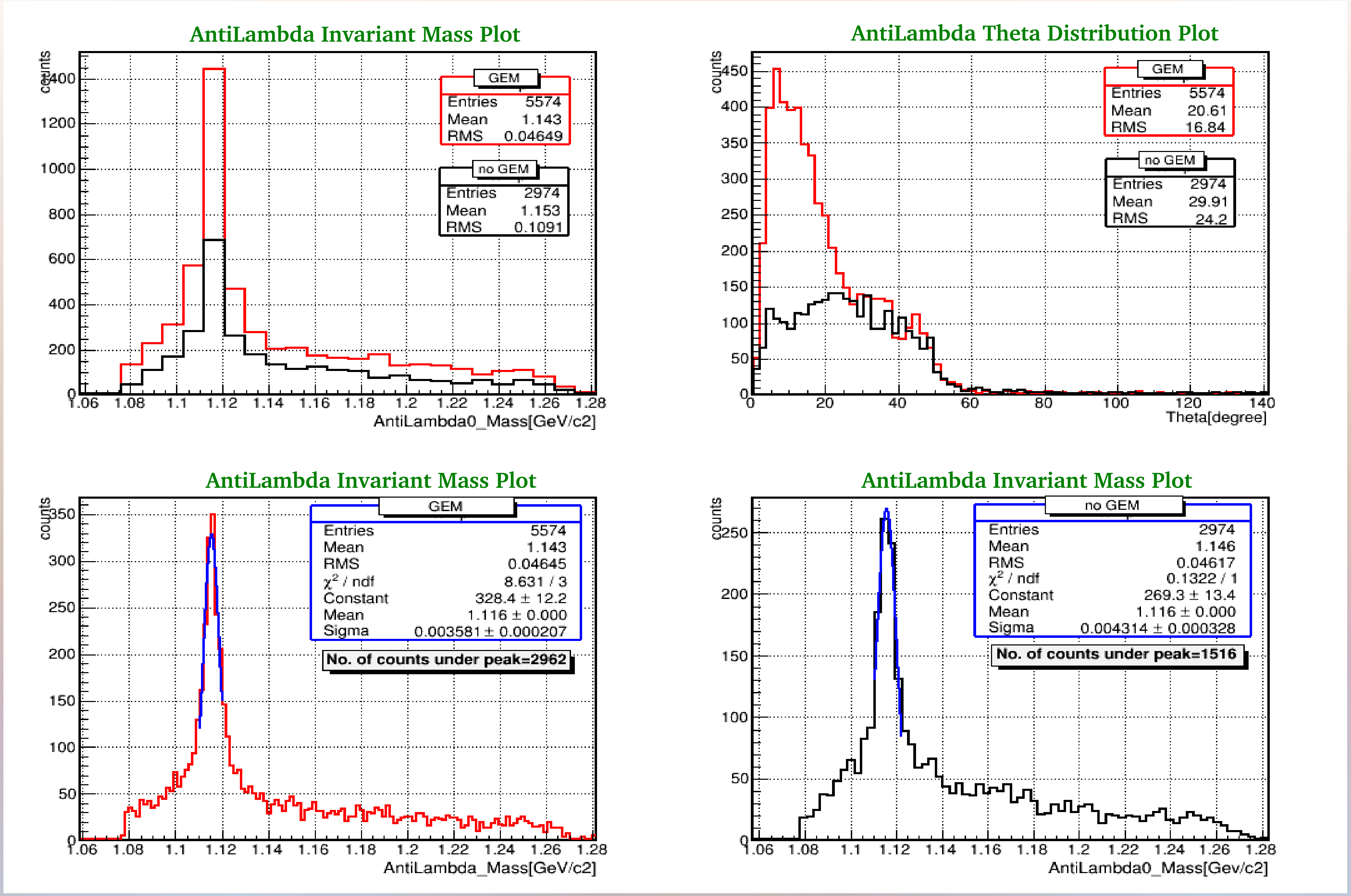
Lambda Invariant Mass Plot



Lambda Invariant Mass Plot

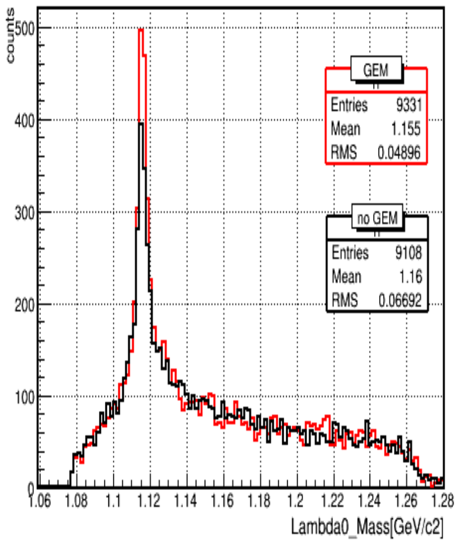


Investigation of Lambda – Anti Lambda Invariant Mass Reconstruction with and without GEM

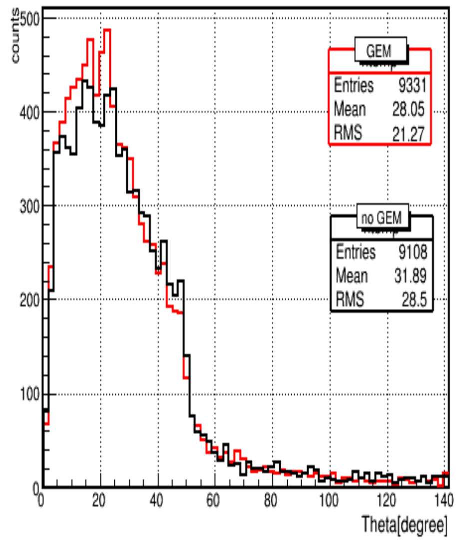


Backup Slide : Investigation Lambda-AntiLambda Mass Reconstruction without, and with GEM using PndSttMvdGemTracking class

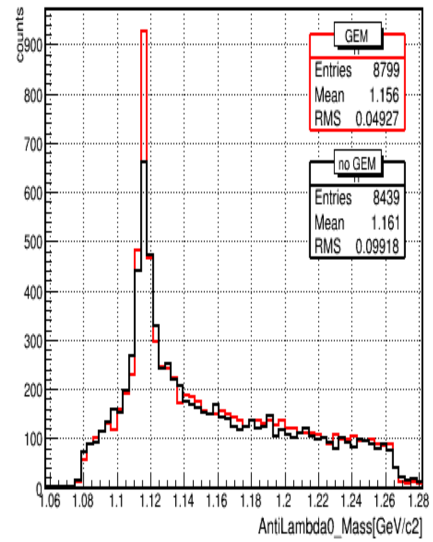
Lambda Invariant Mass Plot



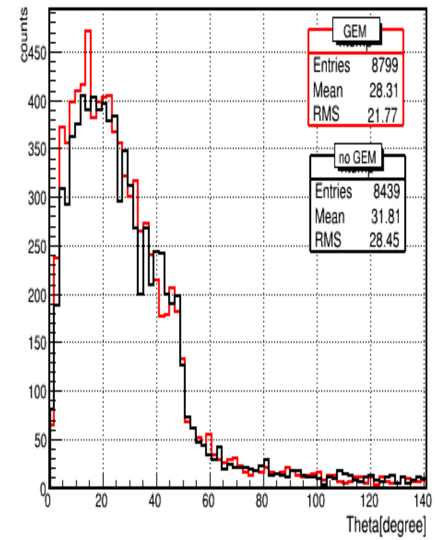
Lambda Theta Distribution Plot



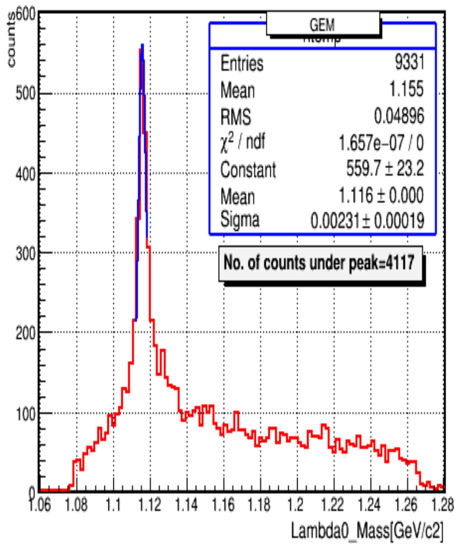
AntiLambda Invariant Mass Plot



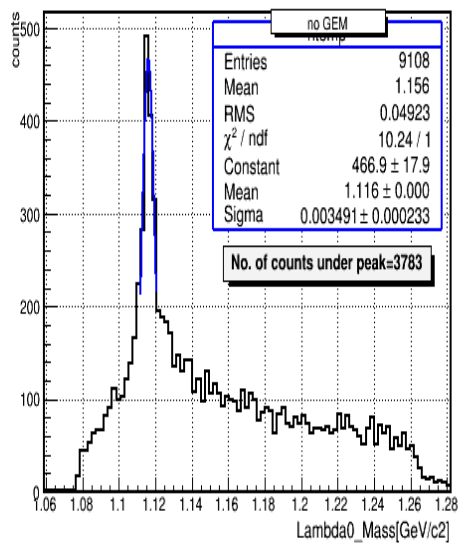
AntiLambda Theta Distribution Plot



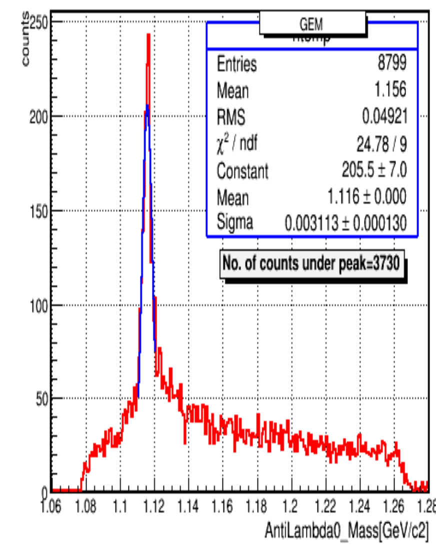
Lambda Invariant Mass Plot



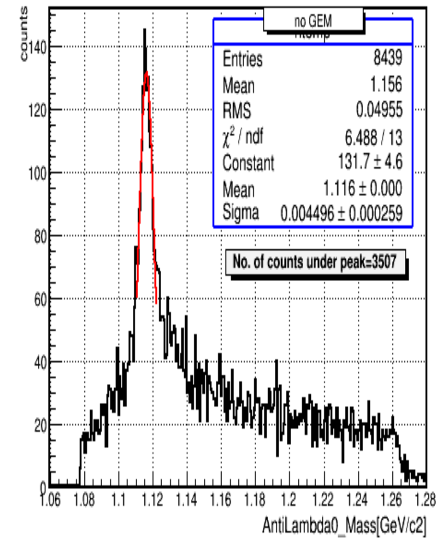
Lambda Invariant Mass Plot



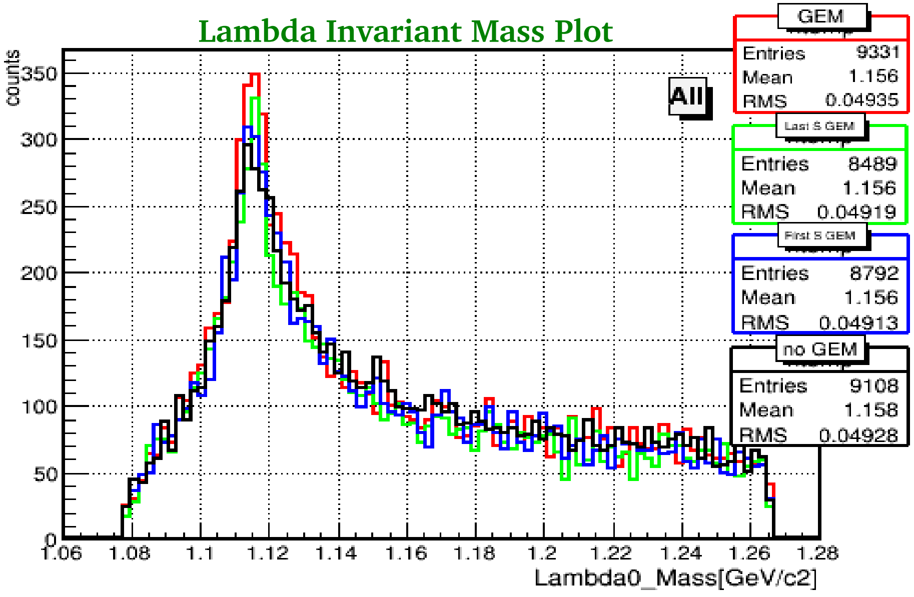
AntiLambda Invariant Mass Plot

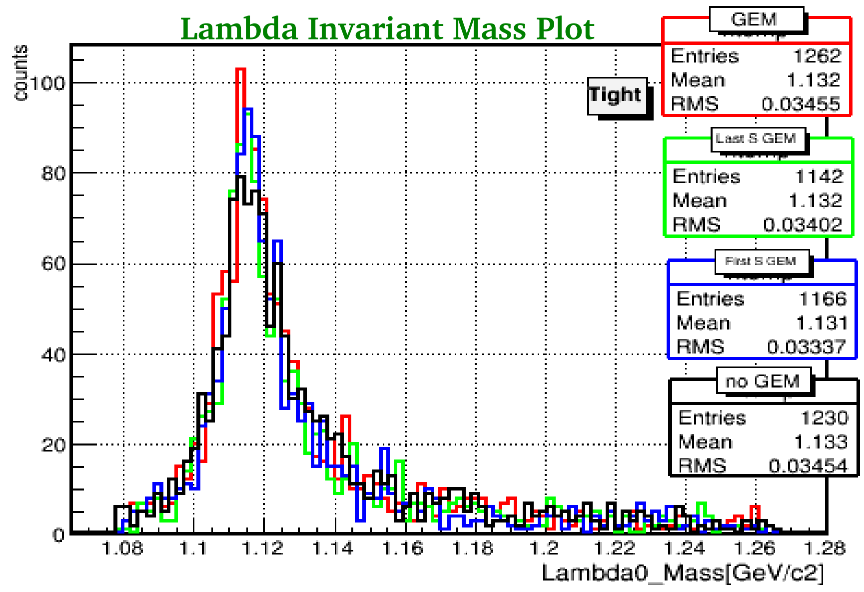


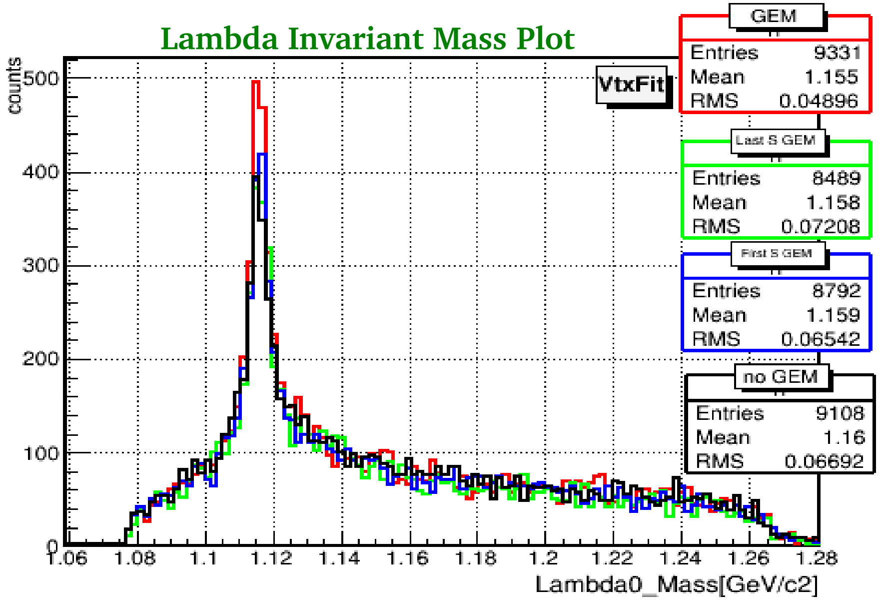
AntiLambda Invariant Mass Plot

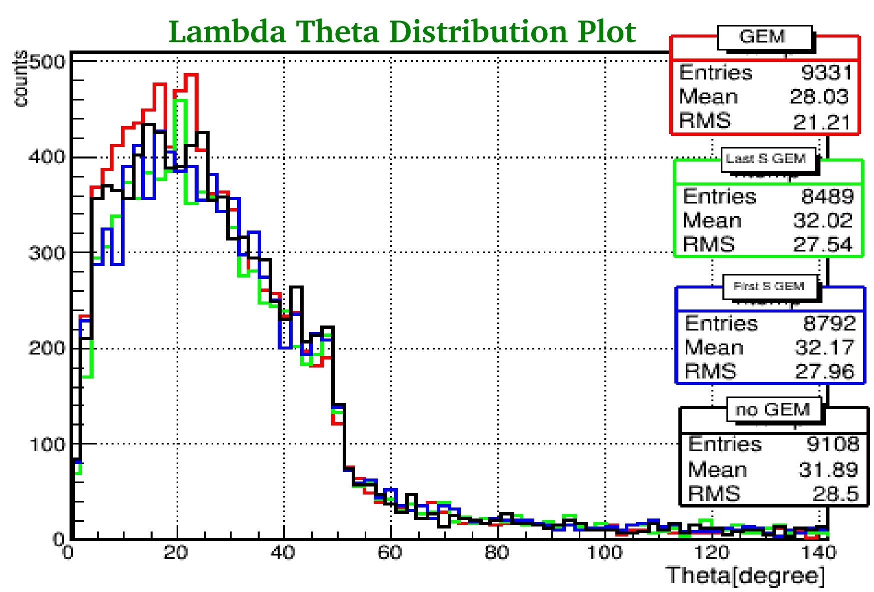


Backup Slide: Investigation of Lambda – Anti Lambda Invariant Mass Reconstruction in Comparison without, with Three Stations & Single Station GEM using PndSttMvdGemTracking class

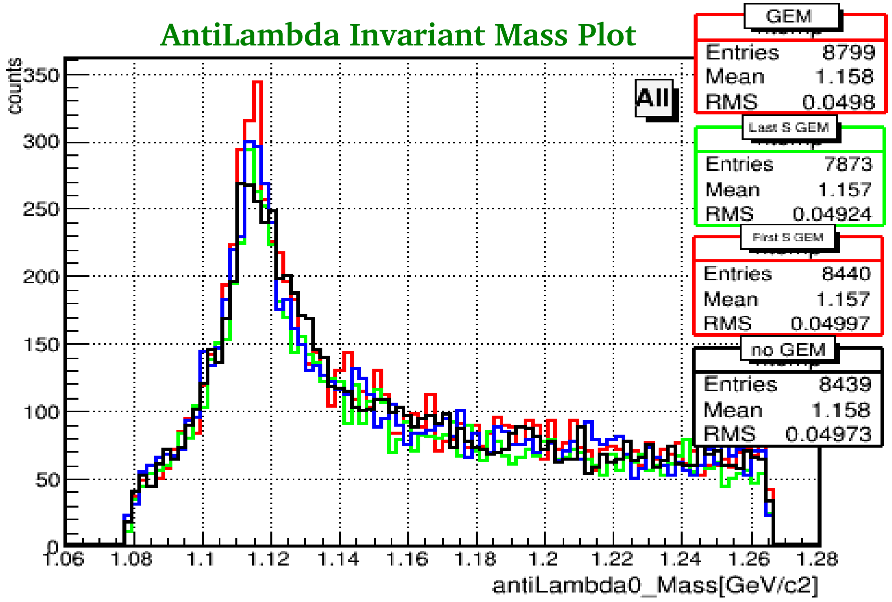


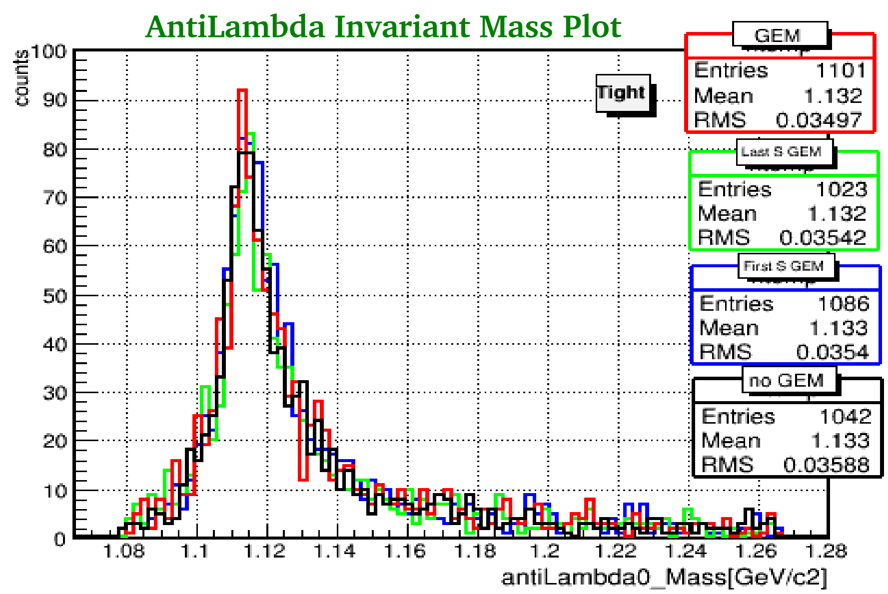


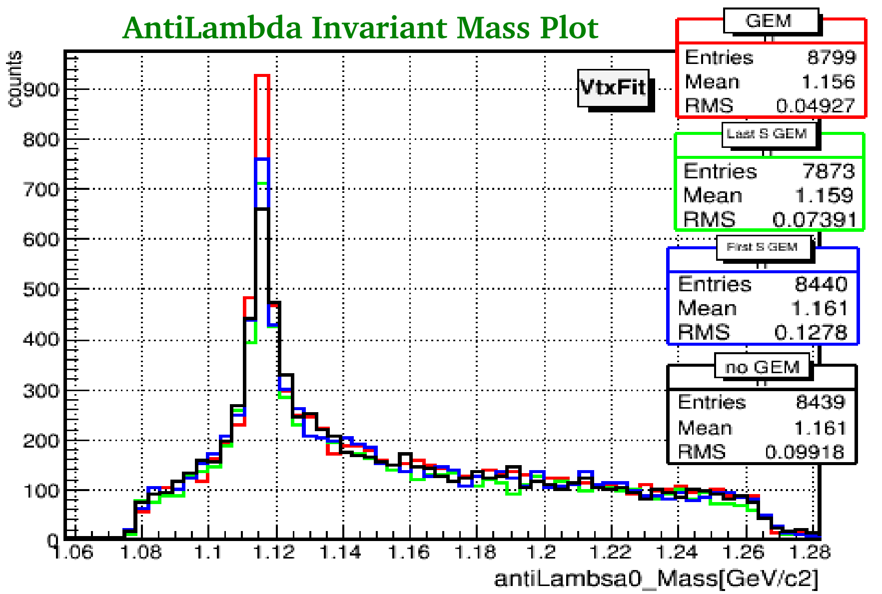


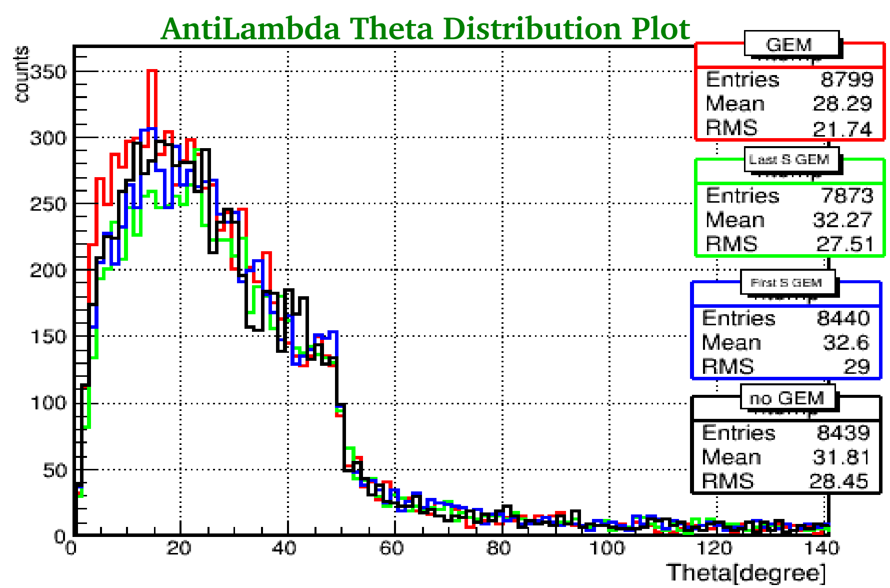


Backup Slide: Investigation of Lambda – Anti Lambda Invariant Mass Reconstruction in Comparison without, with Three Stations & Single Station GEM using PndSttMvdGemTracking class

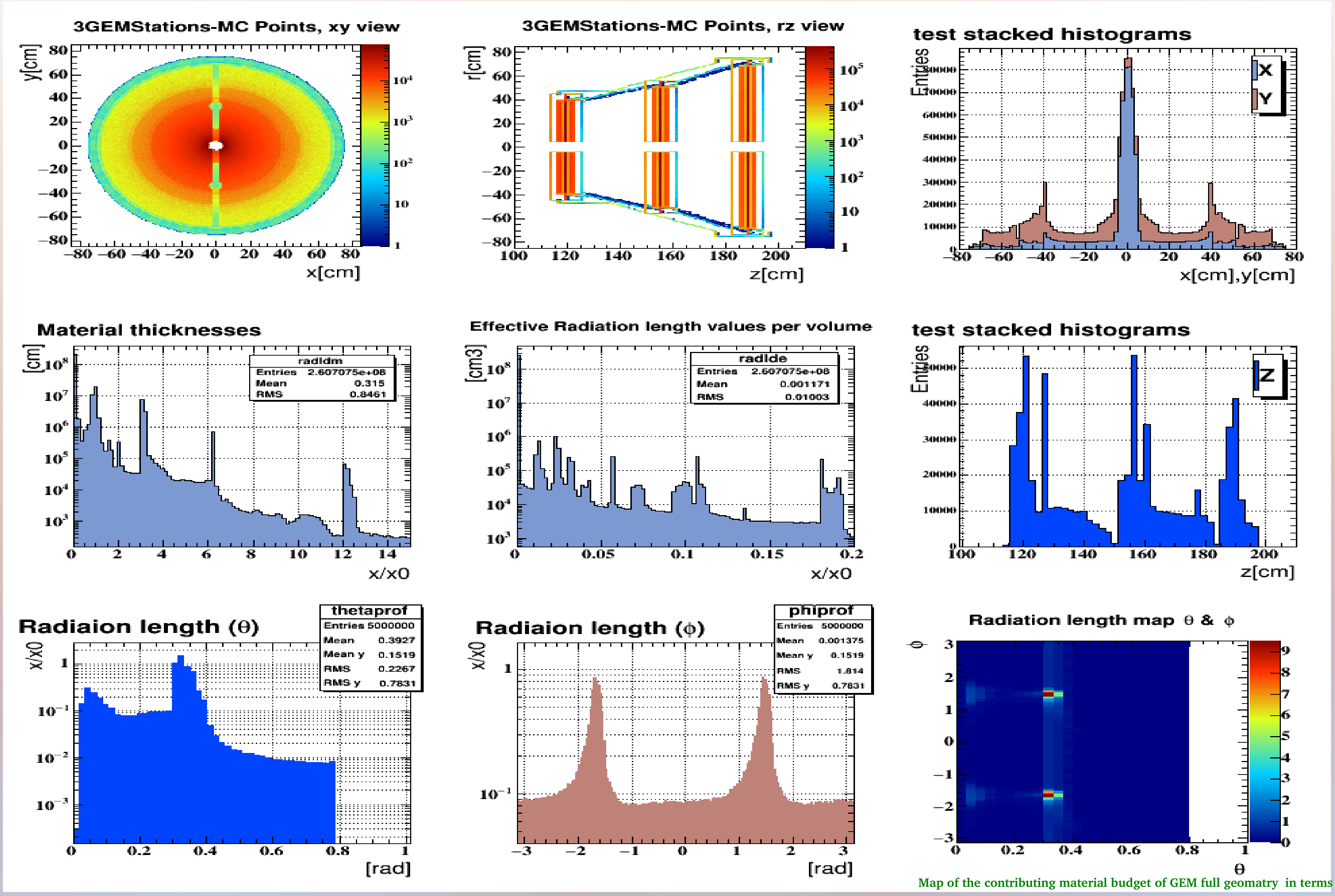








Backup Slide: Investigation of Radiation Length for the Materials of the GEM Detector



Map of the contributing material budget of GEM full geometry in terms of fractional radiation length, X/X0

For Muon particles

3 GEM Stations

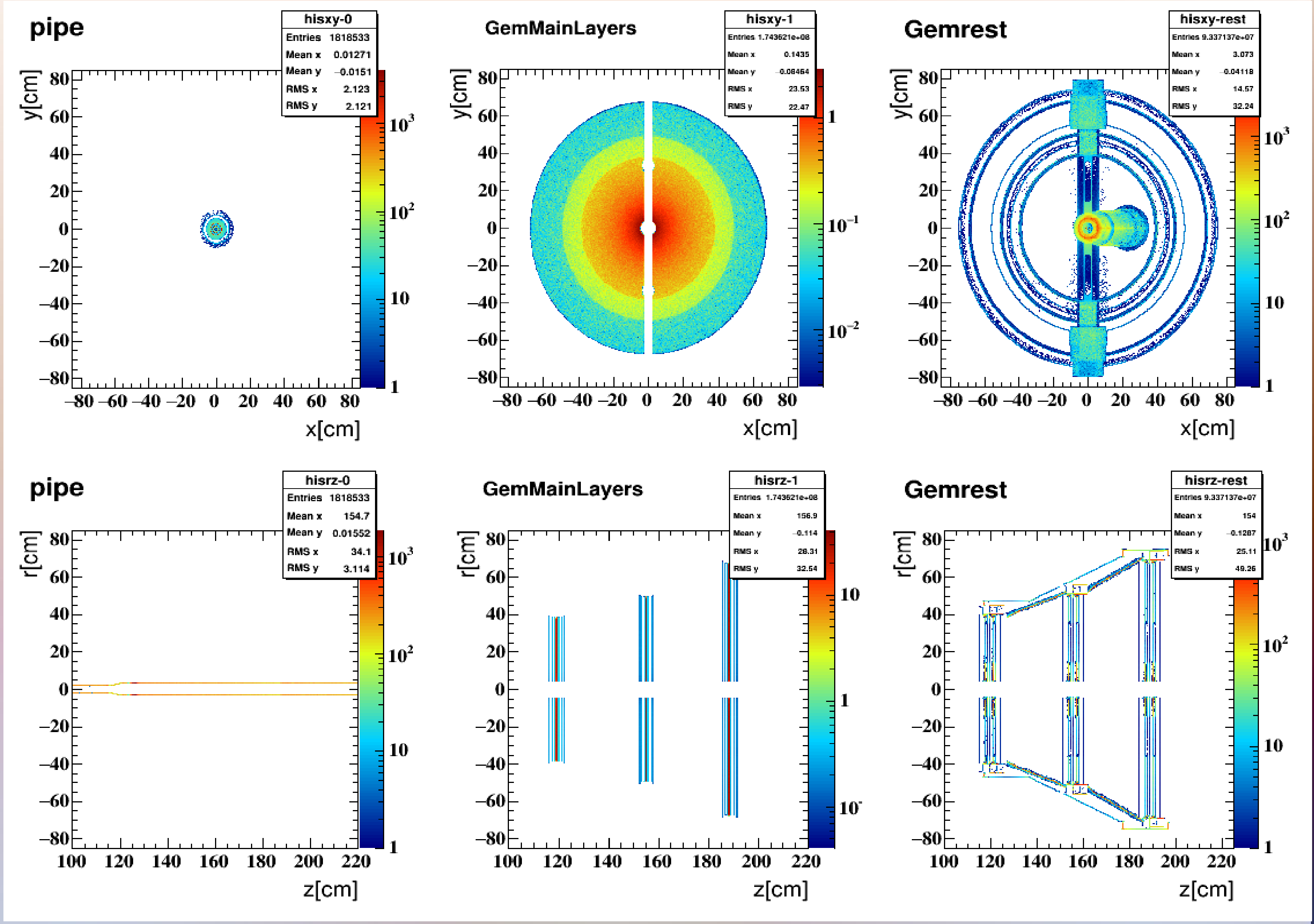
& Pipe MC Points,

xy view

3 GEM Stations

& Pipe MC Points,

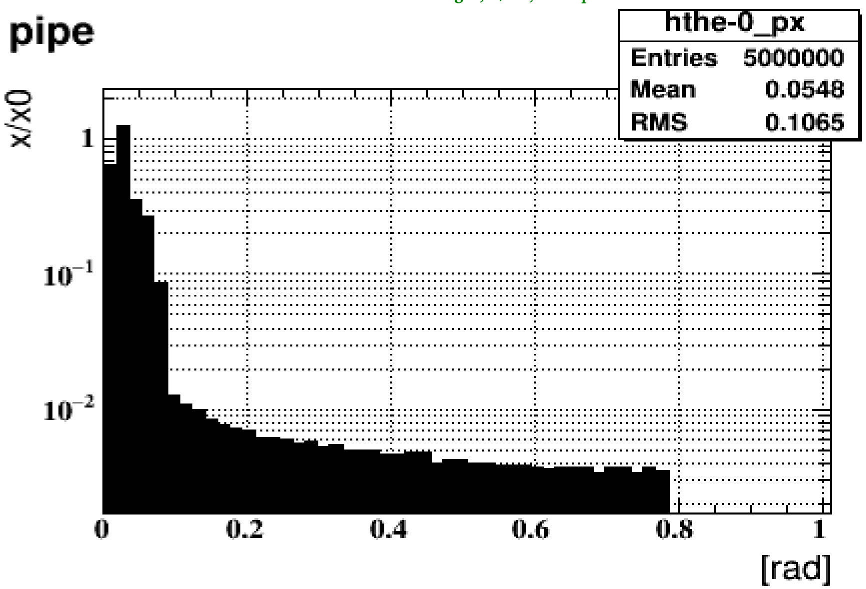
rz view



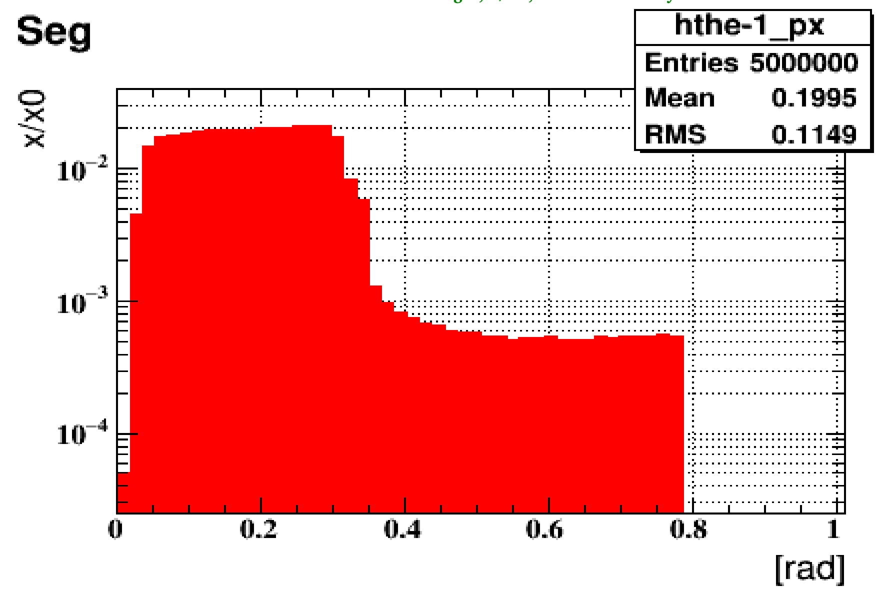
For Muon particles

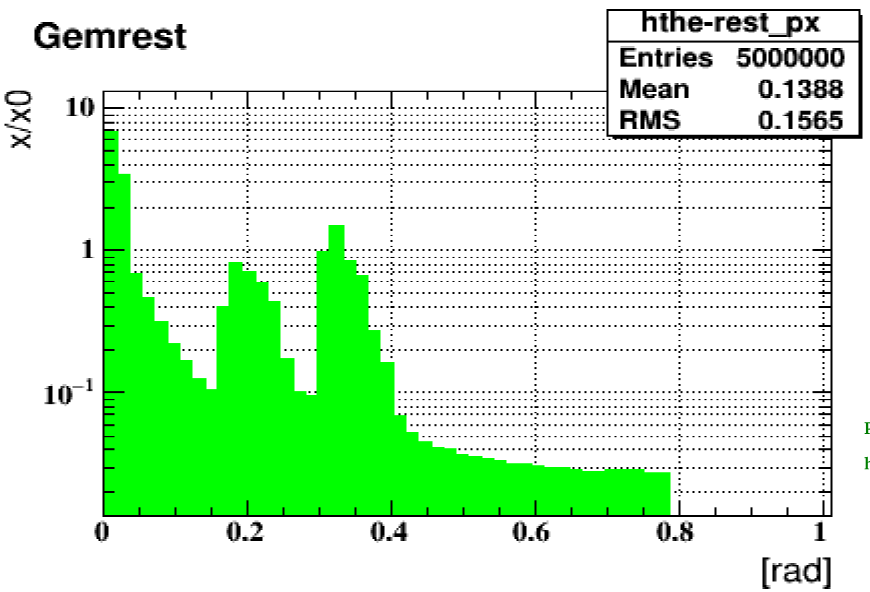
Backup Slide: Investigation of Radiation Length for the Materials of the GEM Detector and Pipe

Polar distribution of fractional radiation length, X/X0, for Pipe materials



Polar distribution of fractional radiation length, X/X0, for GEM main layers materials

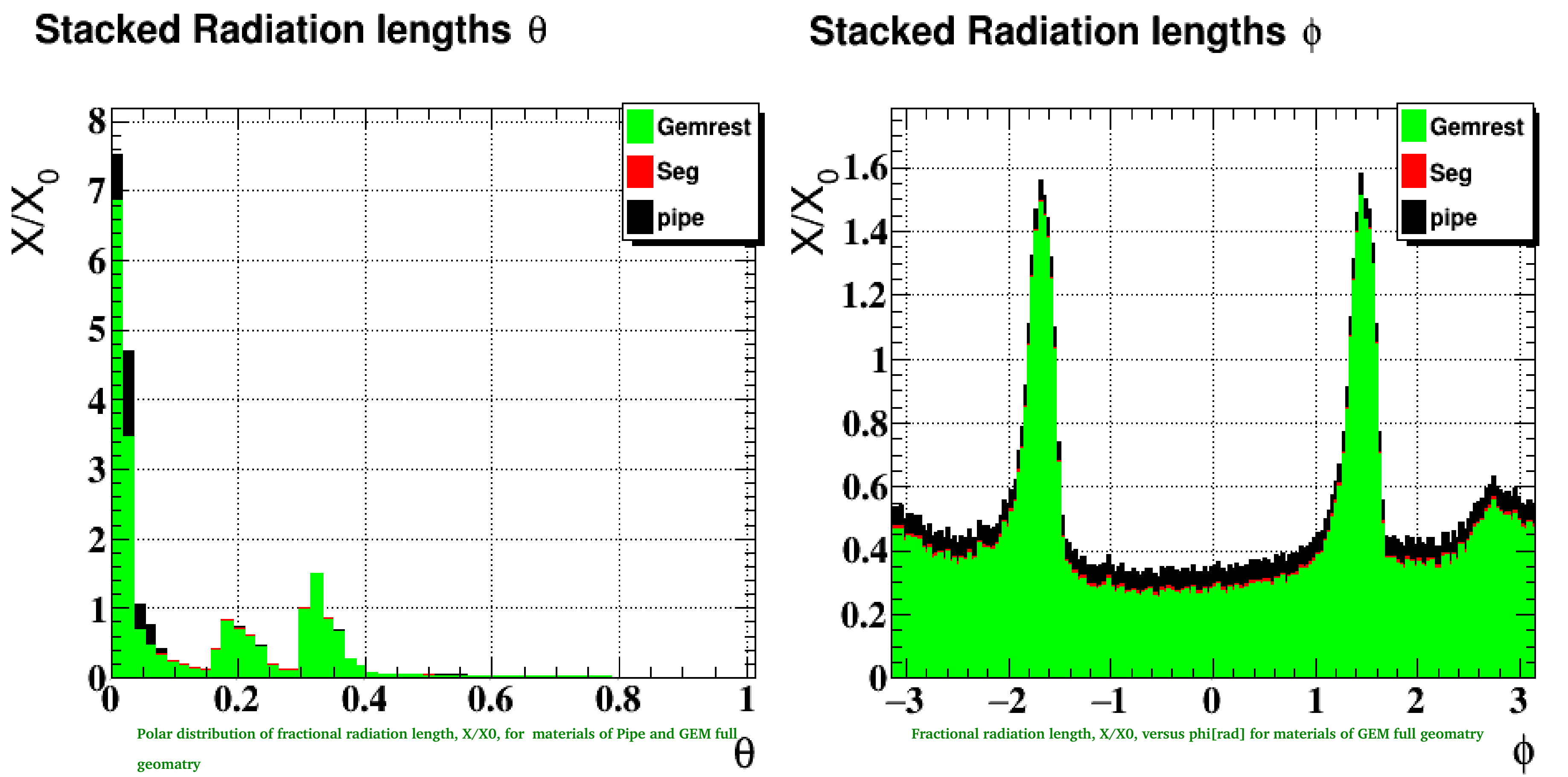




Polar distribution of fractional radiation length, X/X0, for remaining volumes of Pipe and GEM holding structures layers materials

For Muon particles

Backup Slide: Investigation of Radiation Length for the Materials of the GEM Detector and Pipe

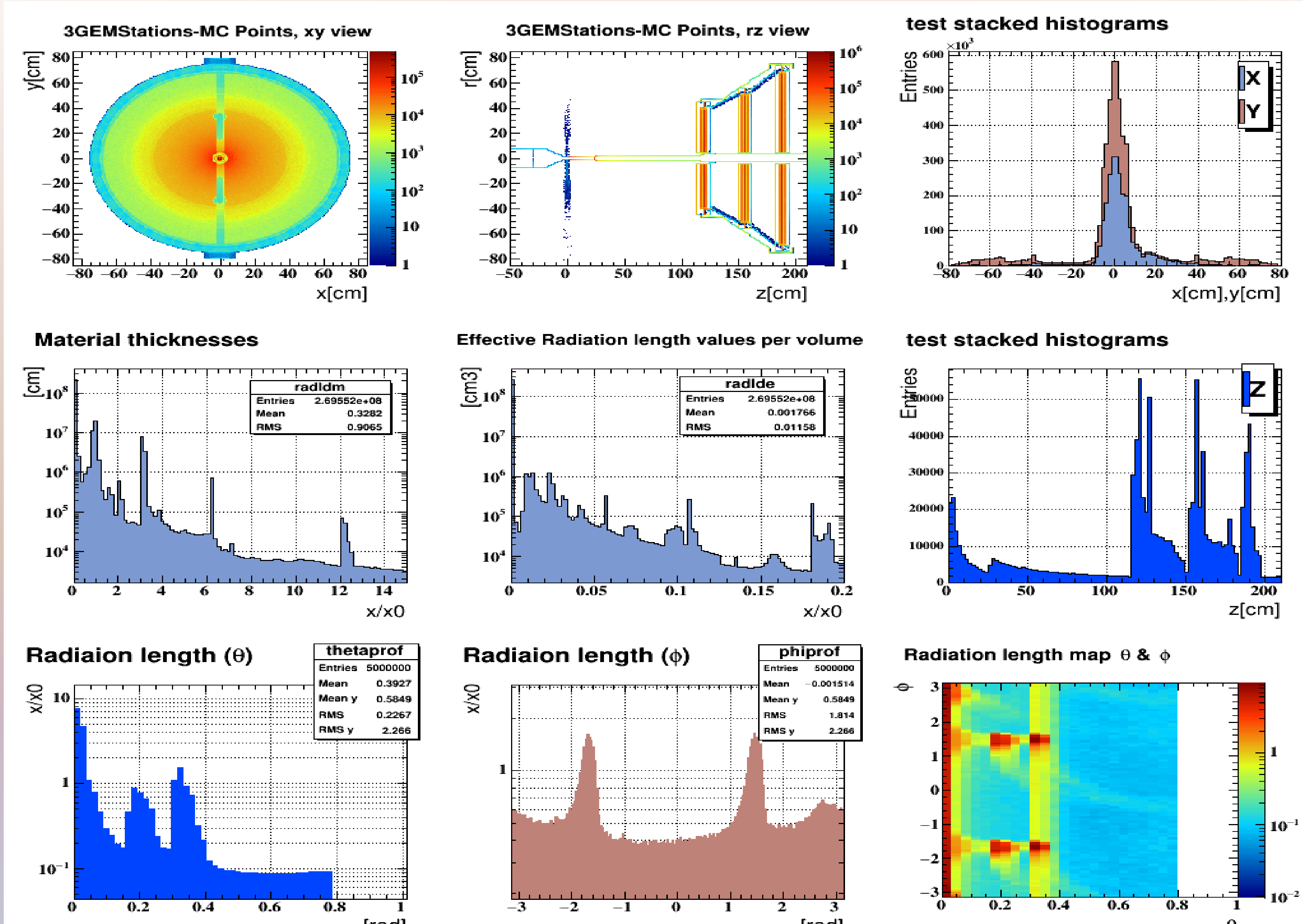


Polar distribution of fractional radiation length, X/X0, for materials of Pipe and GEM full geomatry

Fractional radiation length, X/X0, versus phi[rad] for materials of GEM full geomatry

For Muon particles

Backup Slide: Investigation of Radiation Length for the Materials of the GEM Detector and Pipe



Map of the contributing material budget of pipe & GEM full geomatry in terms of fractional radiation length, X/X0

For Muon particles