Monte Carlo Simulation for the PANDA GEM-Tracking Detector

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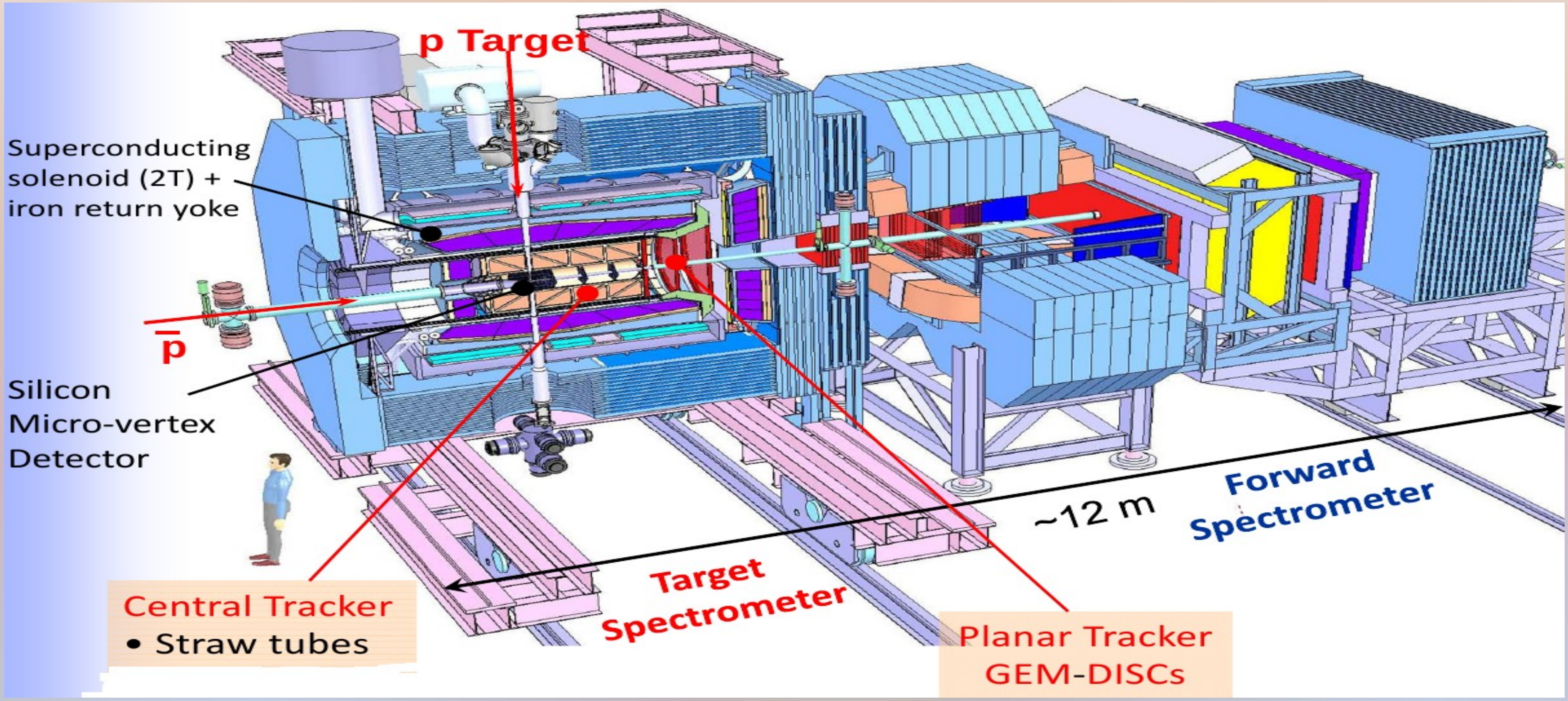
Motivations

- **Update the GEM geometry including the realistic one by technical design**
- **Investigation and performance studies with some of the physics benchmark channels within the current tracking framework**

Introduction

- To provide measurement of charged particle trajectories with high resolution over the complete solid angle, one of the inner tracking system is a GEM detector
- A gas electron multiplier is a type of gaseous ionization detector which will be used as a first forward tracking detector after the central tracker in PANDA setup

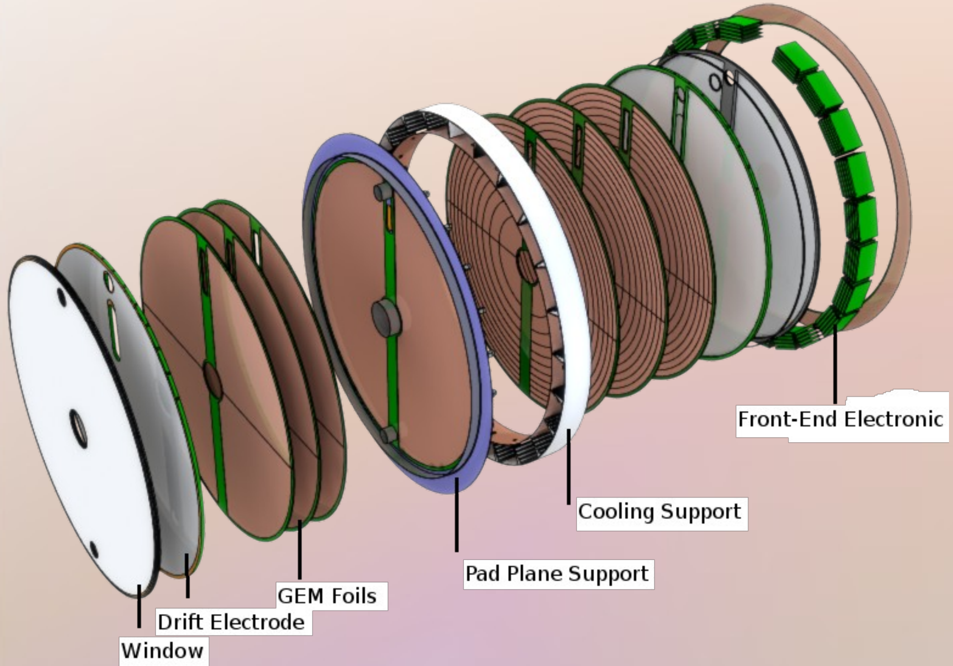


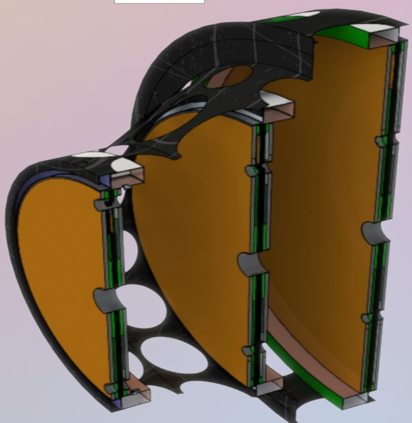
Brief Review of the PANDA GEM-Tracking Detector Project Up to Now

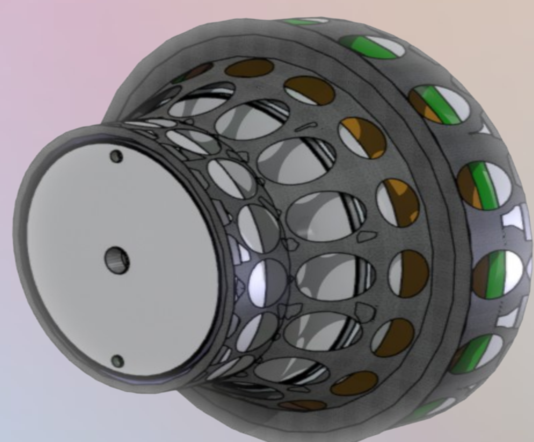
- **2008:** Starting design studies for 3 or 4 detectors stations based on large-area planar Gaseous Electron Multipliers
- **2009:** Study of track finding for the GEM tracker in the PandaRoot
- **2010:** Study of the GEM-Disks parameters , positions and dimensions for good resolution
- **2011:** Study of the mechanical GEM tracker structures for GEM foils and riddle shell, geometry and combinations
- **2012:** Improve GEM tracker software status in the PandaRoot
- **2013:** Study of GEM prototype and the quality assurance for GEM foils and pad plane design as an experimental works
- **2014:** Continue to study all of the aspects of GEM tracker simulation and experimental parts
- **2015:** Start to update the GEM geometry in the PandaRoot

My participation since May

GEM Geometry on the CAD and GEM Details



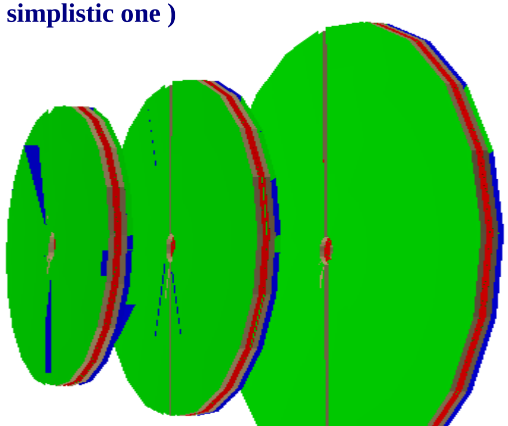




- A set of 3 stations of planar Gaseous Electron Multipliers as a first forward detector after central tracker
- To be mounted approximately 1m behind the target along the beam axis in a solenoid magnetic field, at 119, 155 and 188 [cm]
- Cover polar angles from 5 to 20 degrees
- Each station consists of detector windows, cathodes, GEM foils, sensitive pad planes, $ArCO_2$ gas containers, cooling support and electronic devices
- The double-sided read-out
- Providing strip information on crossing particles in 4 directions: radial and circular (front), horizontal and vertical (back)
- Riddle shell with rigid and light-weight support structures

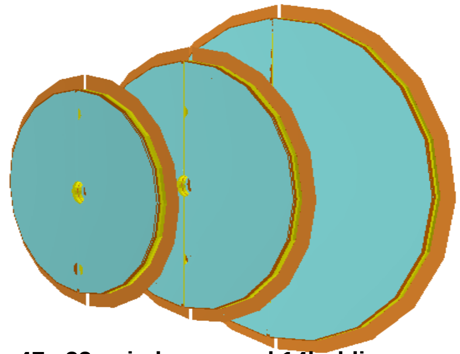
GEM Detector Geometry in the Simulation

(simplistic one)



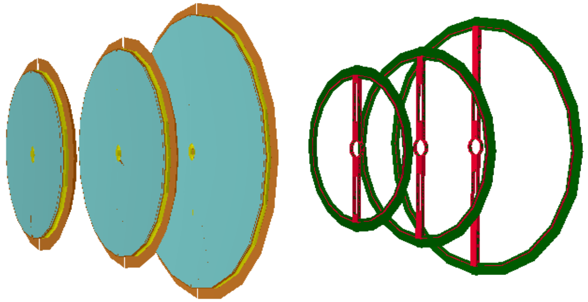
NofLayers = 39
DiskInnerRadius = { 4.52, 4.52, 4.52 }cm
DiskOuterRadius = { 37.92, 46.4, 64.4 }cm
DiskZPosition= { 119.6, 143.1, 175.6 }cm

(realistic one: main layers)



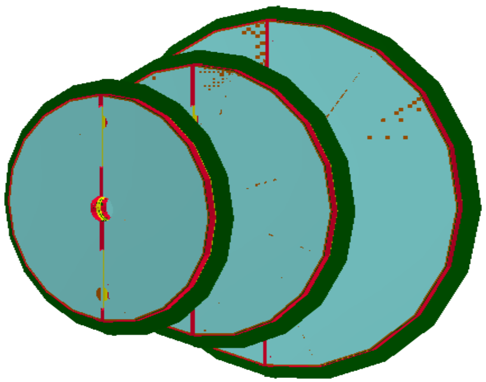
NofLayers = 47 , 33main layers and 14holding structure layers
DiskInnerRadius= { 4.50, 4.50, 4.50 }cm
DiskOuterRadius= { 45.00, 56.00, 74.0 }cm
DiskZPosition= { 119.40, 155.40, 188.50 }cm

(realistic one: holding structure layers)



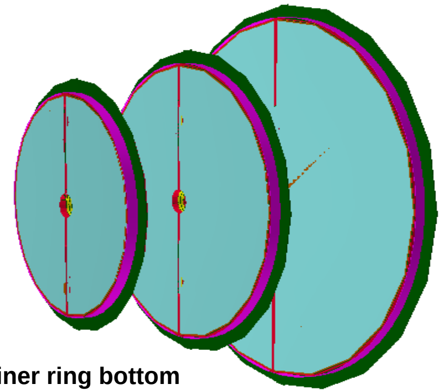
NofLayers = 14
As holding structure layers

(realistic one: all layers with different sizes and thicknesses)



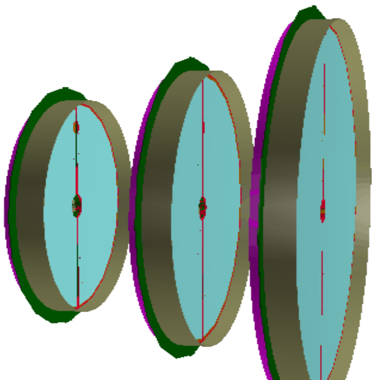
NofLayers = 47
Main and holding structure layers together

(realistic one: with details)



Gas container ring bottom
carbonRingInnerRadius= { 40.0, 51.0, 69.0 }cm
carbonRingOuterRadius= { 40.2, 51.2, 69.2 }cm
carbonRingHalfThickness = 1.5cm

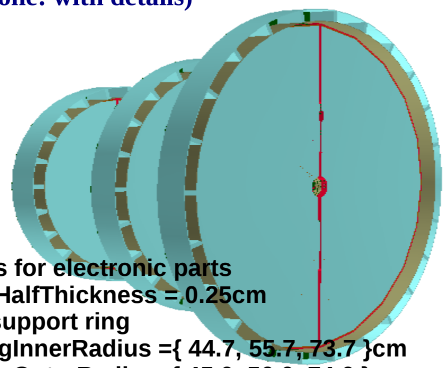
(realistic one: with details)



Gas container ring top
copperRingInnerRadius= { 39.9, 50.9, 68.9 }cm
copperRingOuterRadius= { 40.1, 51.1, 69.1 }cm
copperRingHalfThickness = 3.75cm

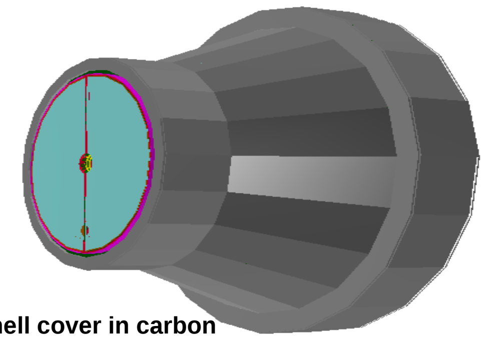
GEM Geometry Simulation and GEM Points Plots

(realistic one: with details)



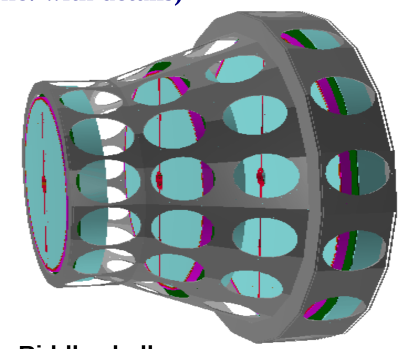
Segments for electronic parts
SegmentHalfThickness =,0.25cm
Cooling support ring
AlumiRingInnerRadius ={ 44.7, 55.7, 73.7 }cm
AlumiRingOuterRadius={ 45.0, 56.0, 74.0 }cm
AlumiRingHalfThickness =3.75cm

(realistic one: with details)

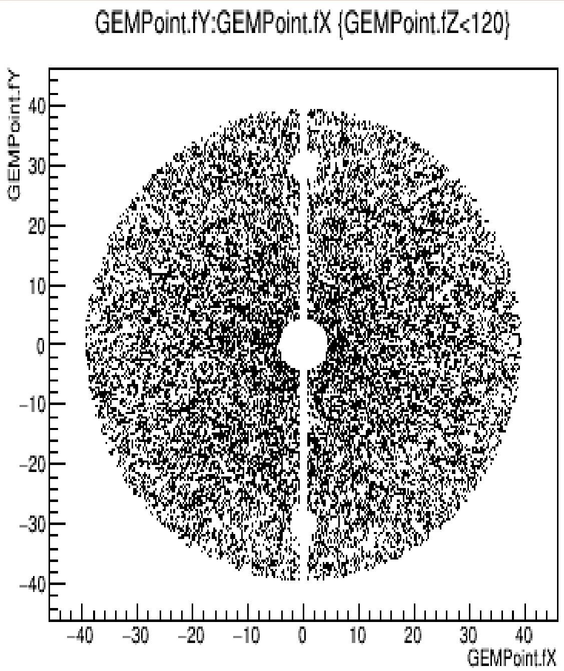


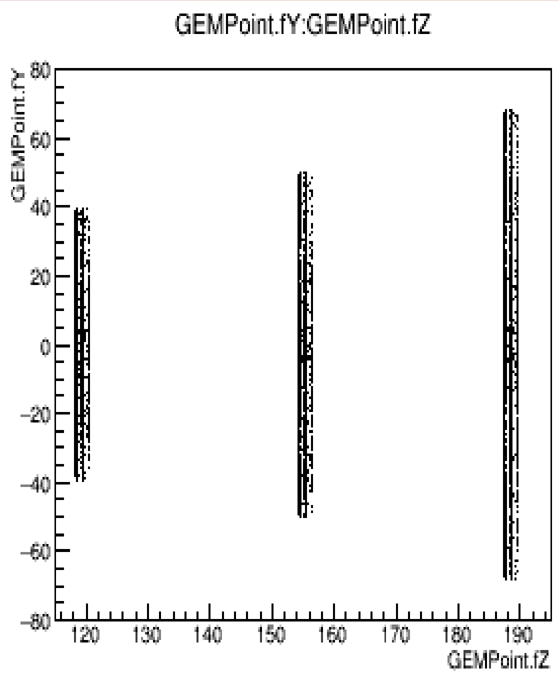
Riddle shell cover in carbon
Small radious=47cm , big radious=78cm
Thickness = 0.5 cm

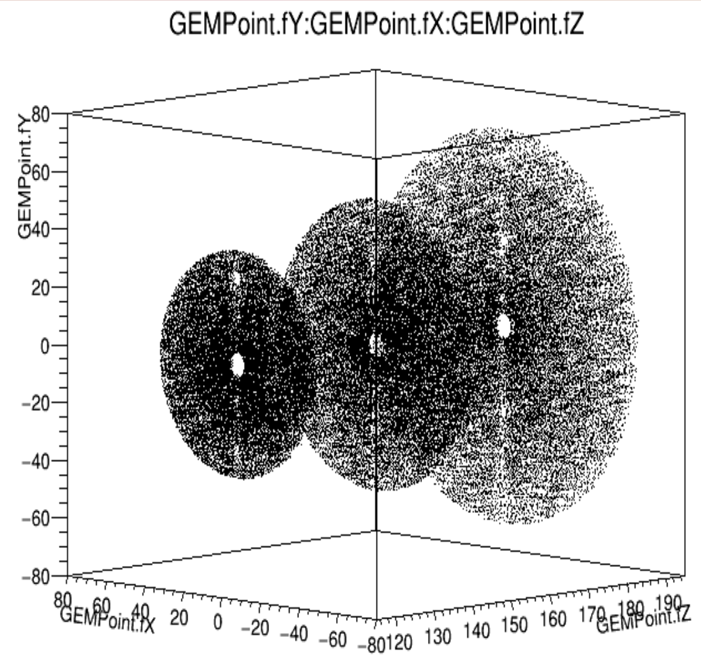
(realistic one: with details)



Holes on the Riddle shell cover
Nofholes=16 on 4 rows

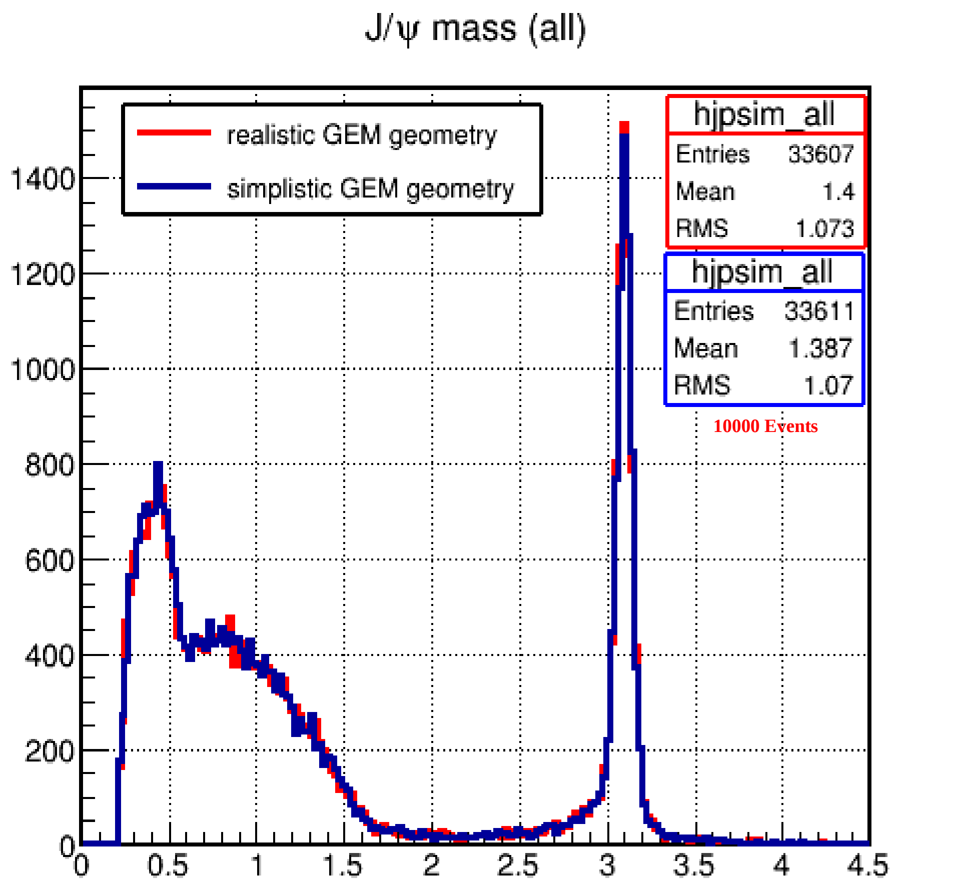


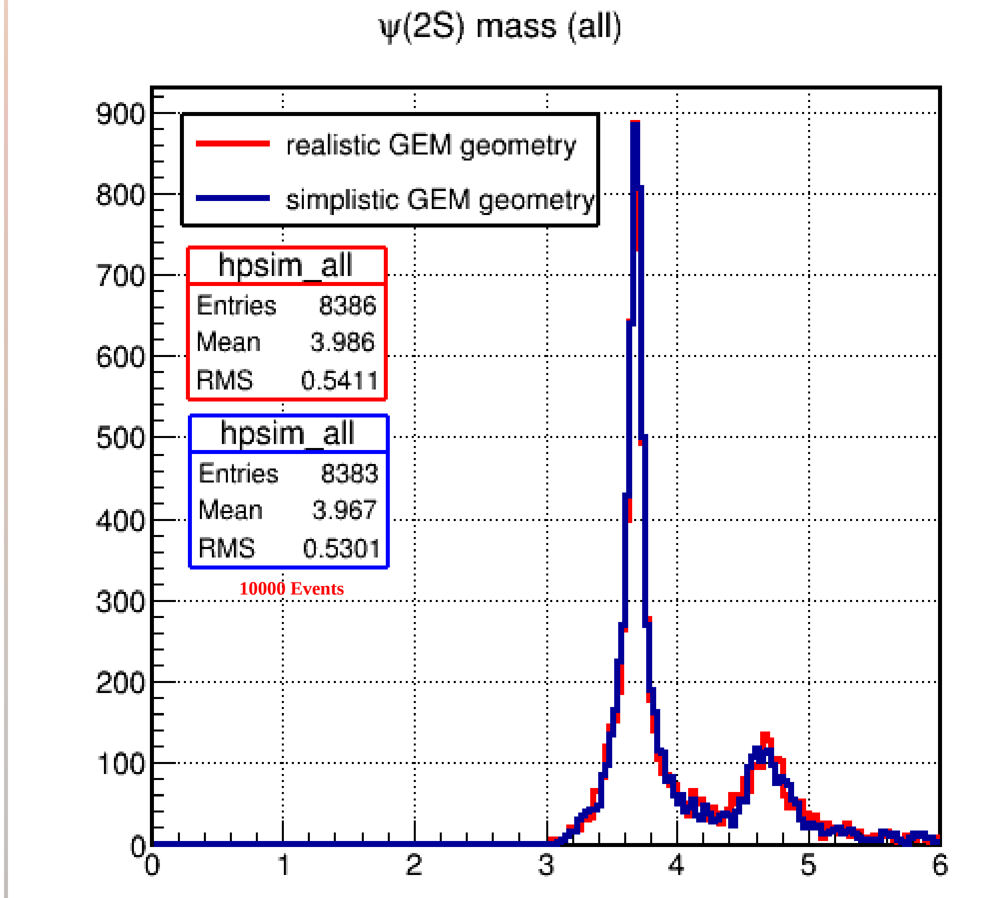




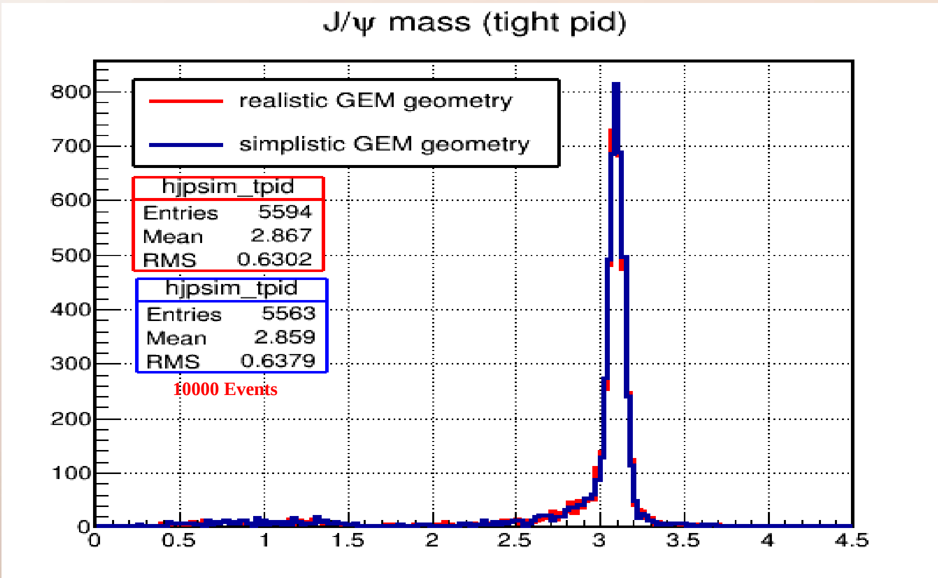
Investigation of Invariant Mass Reconstruction

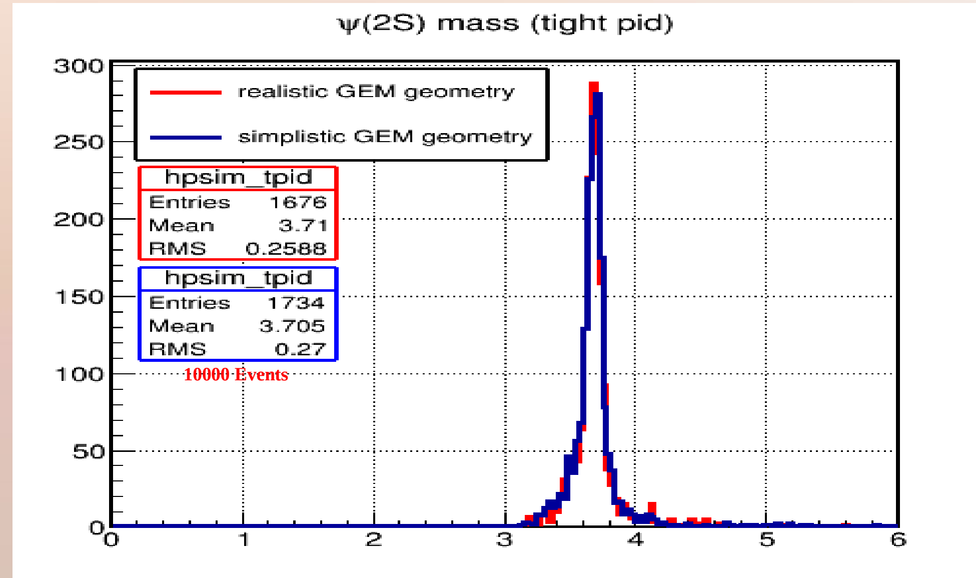
Benchmark channel including antip+p→ψ(2S)→J/ψ(1S)π+π–, then J/ψ into μ+ and μ- (muonic decay).The mass of the ψ(2S) and J/ψ(1S) are respectively 3686.109±0.012MeV/c² , 3096.916±0.011MeV/c² .

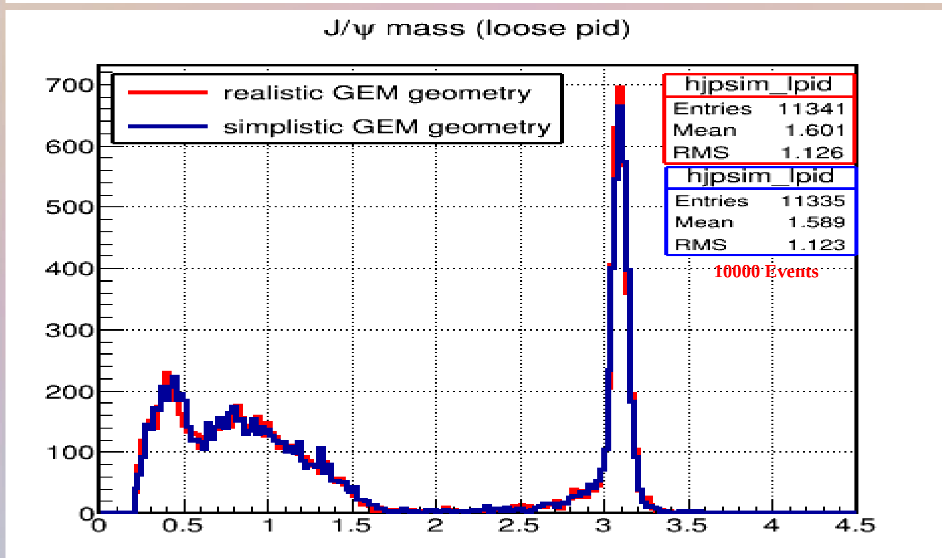


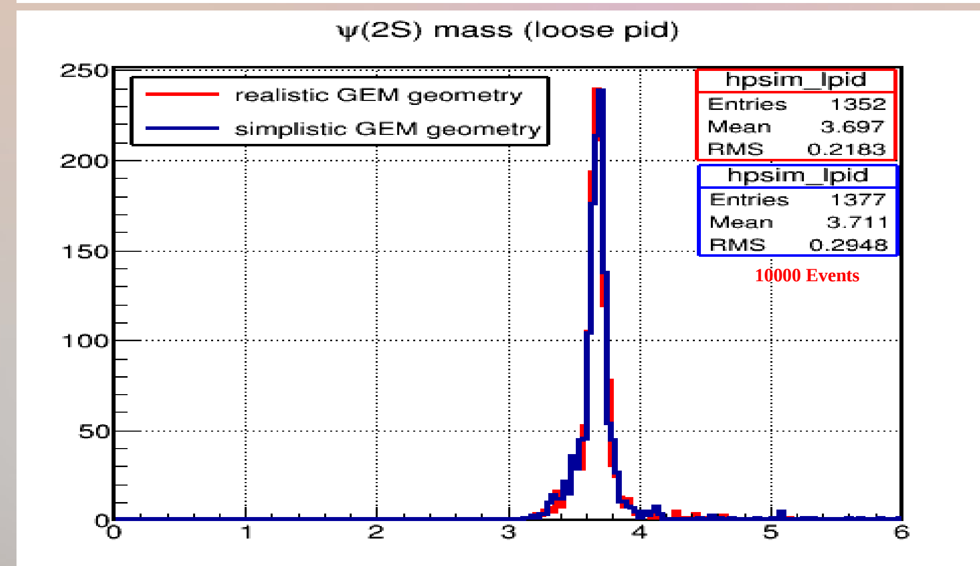


Invariant Mass Reconstruction: with tight and loose PID for Muons







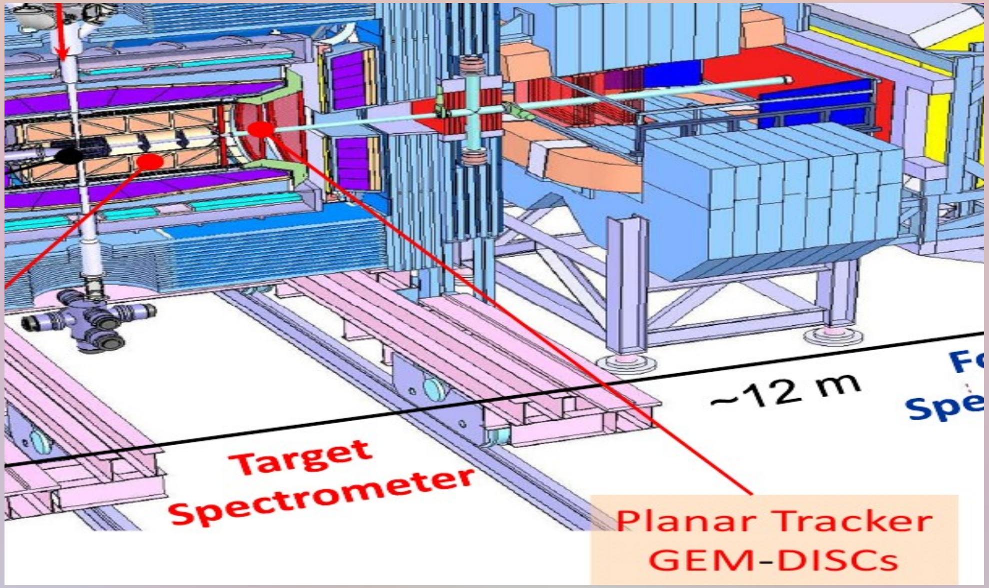


Comparison between two cases: PANDA setup without GEM and with GEM

- **Benchmark channel including antip+p→ψ(2S)→J/ψ(1S)π+π–, then J/ψ into μ+ and μ- (muonic decay).**
- **Current tracking framework in PndSttMvdGemTracking**

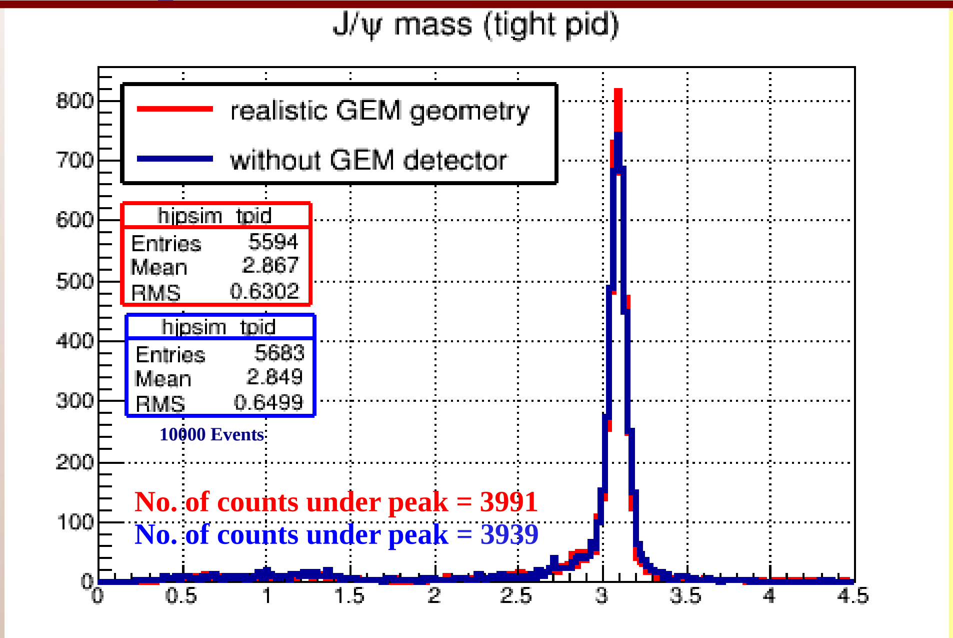
  - Tracking procedure always requires hits in STT and MVD

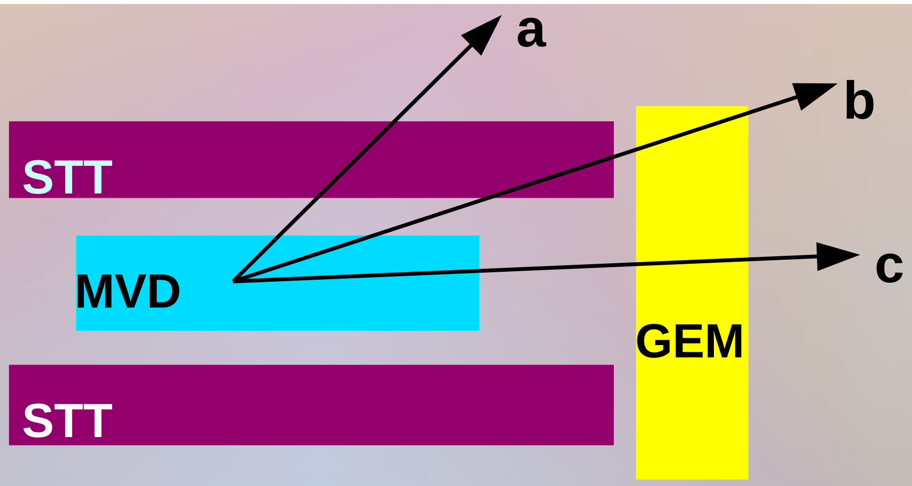
  - GEM hits are used for track fitting when they exist



- **Contributions with STT+MVD+Gem coincidence is not large**
- **Implementation for tracking only with MVD+GEM is foreseen**

Comparison between two cases: PANDA setup without GEM and with GEM





Two kind of track candidates

- Tracks *a*; hitting MVD and STT
- Tracks *b*; hitting MVD, STT and GEM

Without GEM

X = *a*(MVD+STT) + *b*(MVD+STT)

With GEM

Y = *a*(MVD+STT) + *b*(MVD+STT+GEM)

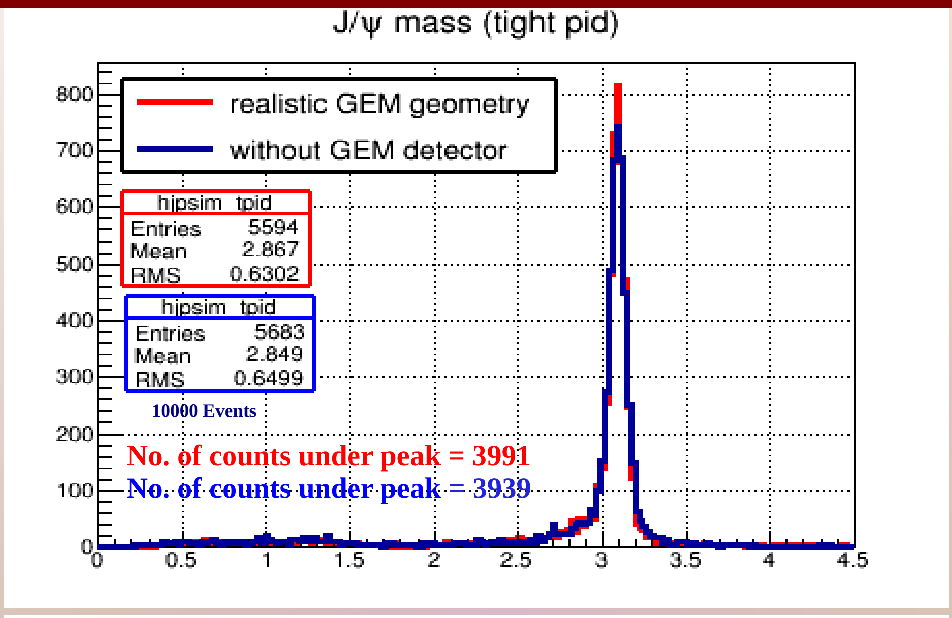
Considering only the GEM efficiency, eff<100%;
b(MVD+STT) > *b*(MVD+STT+GEM)

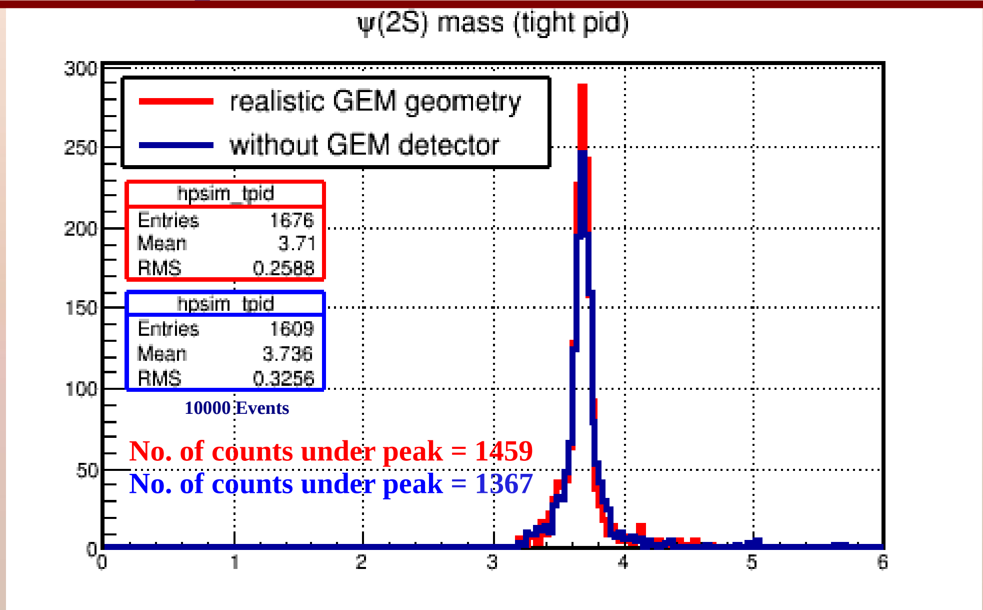
Thus, should be
X>Y

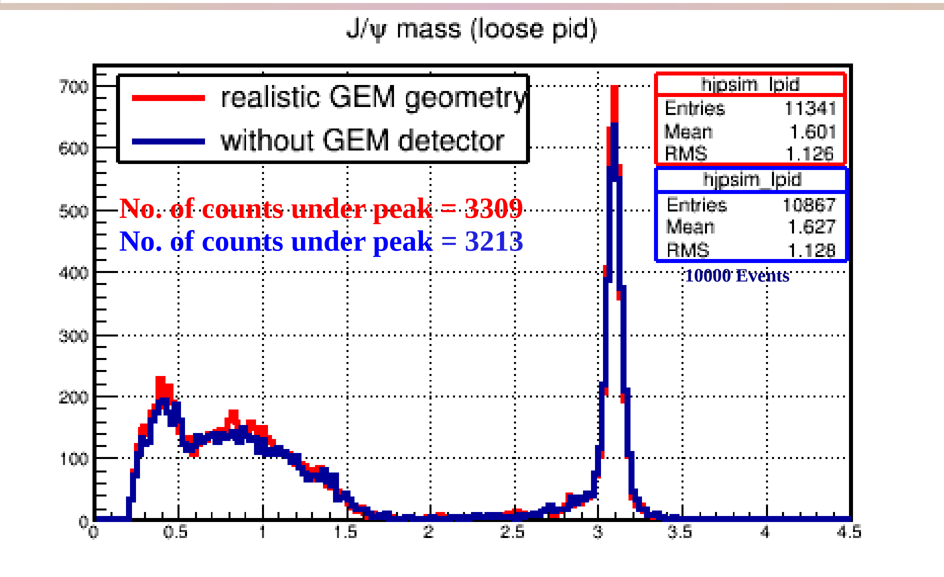
However,
X<Y in results because tracking *b* became better by using GEM in the track fitting procedures

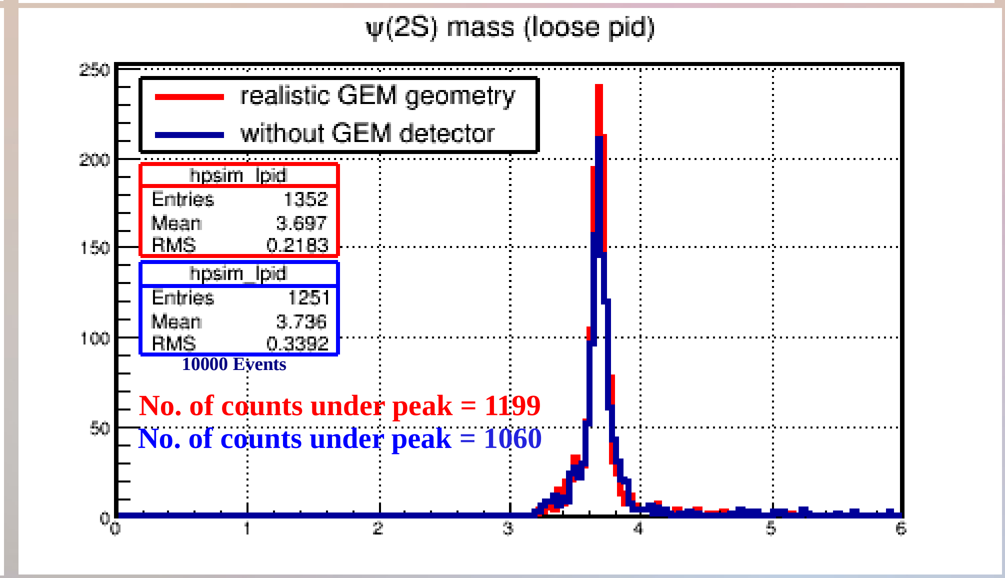
Track *c*; hitting only MVD and GEM
Not used in the current work yet, it should be foreseen

Comparison between two cases: PANDA setup without GEM and with GEM









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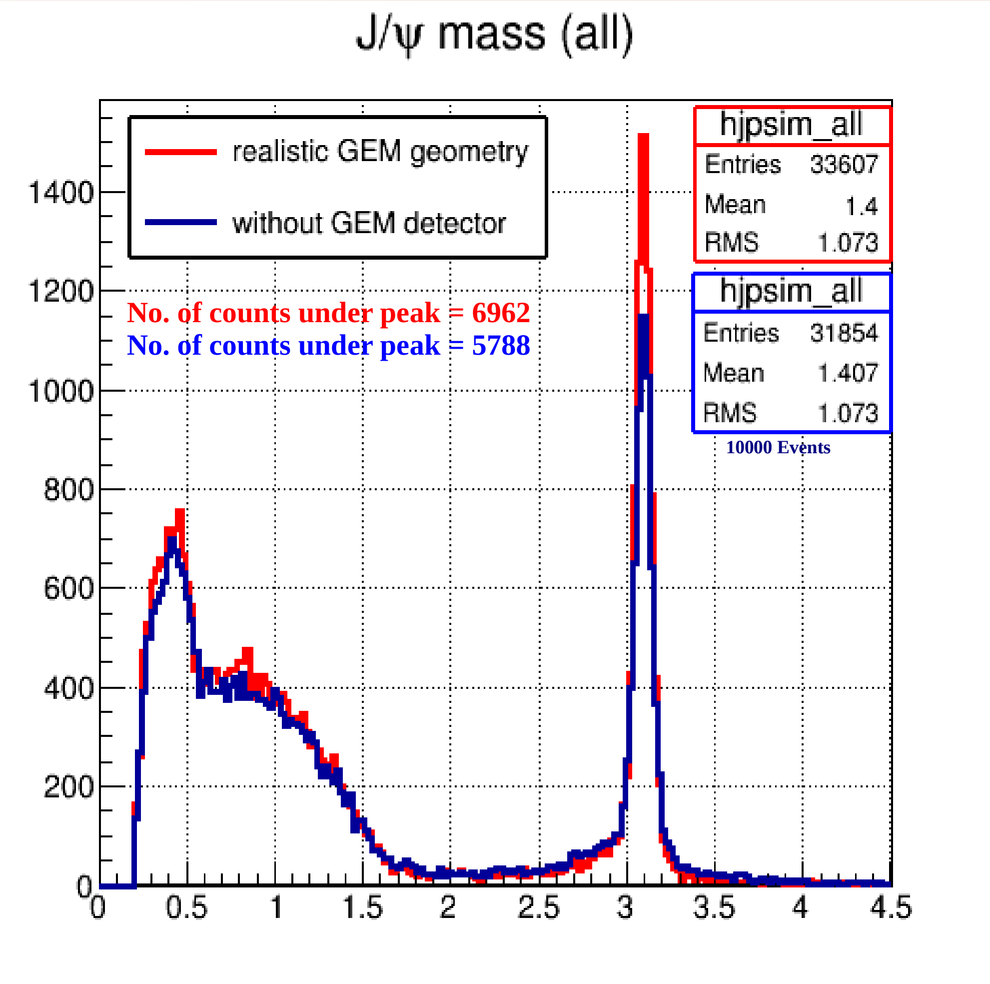
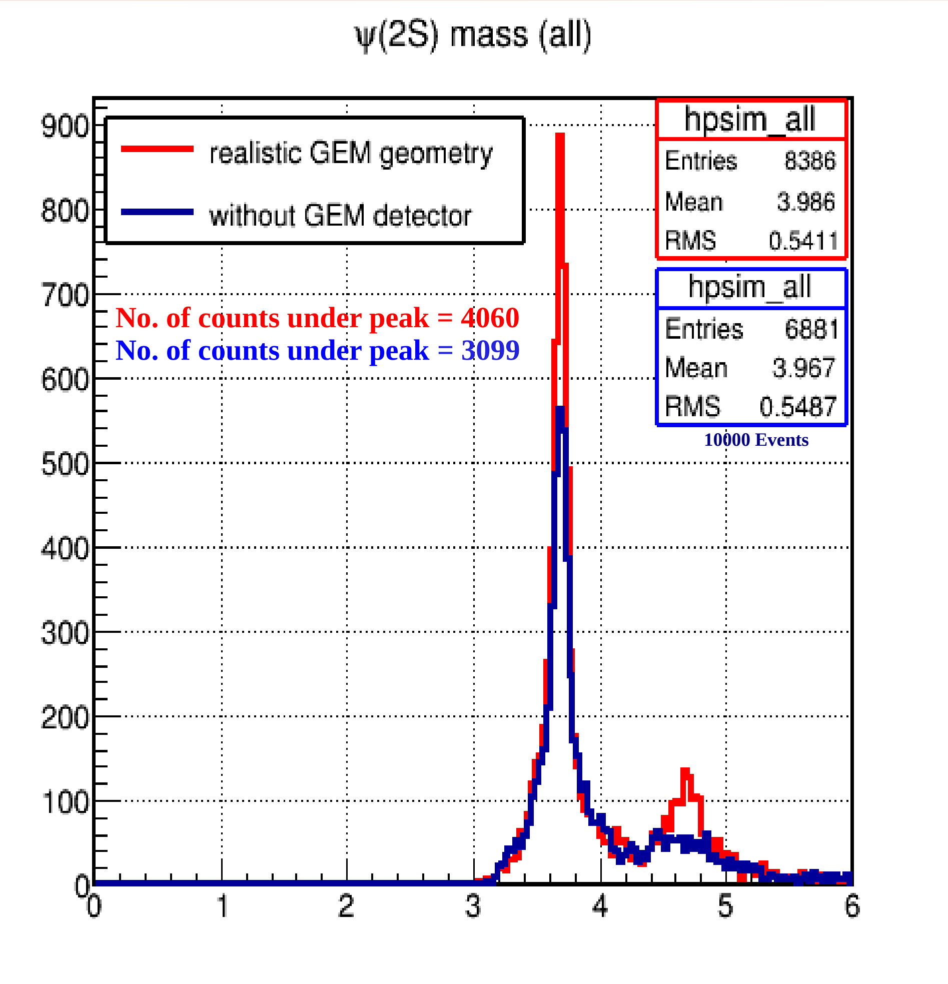
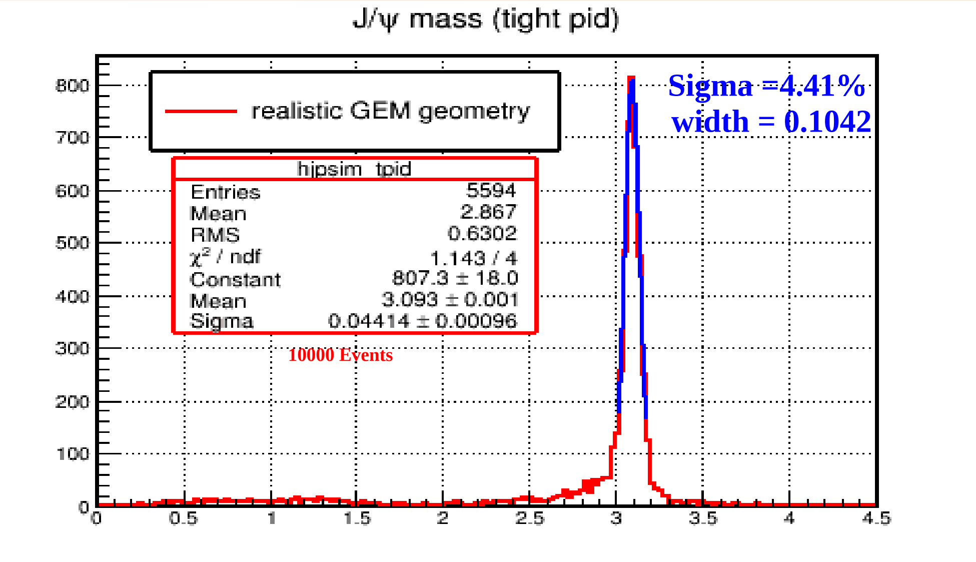
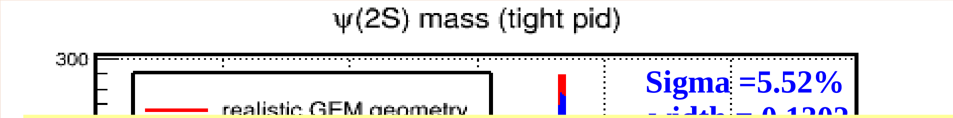




PANDA setup without GEM and with GEM





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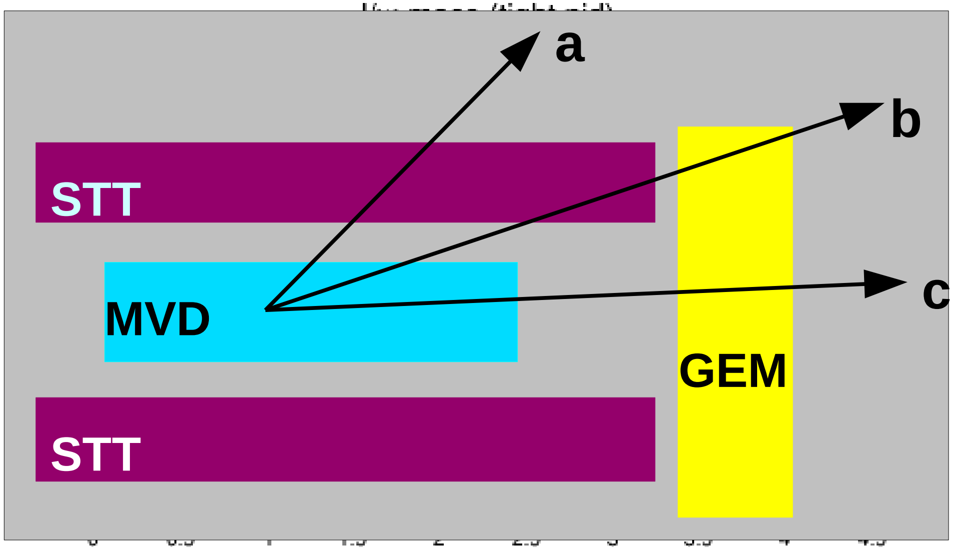
X = *a*(MVD+STT) + *b*(MVD+STT)

With GEM

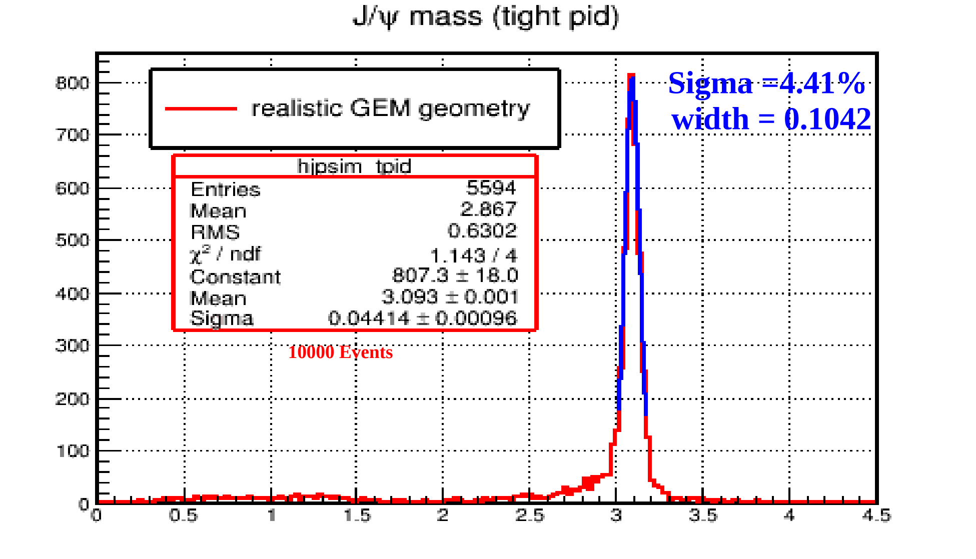
Y = *a*(MVD+STT) + *b*(MVD+STT+GEM)

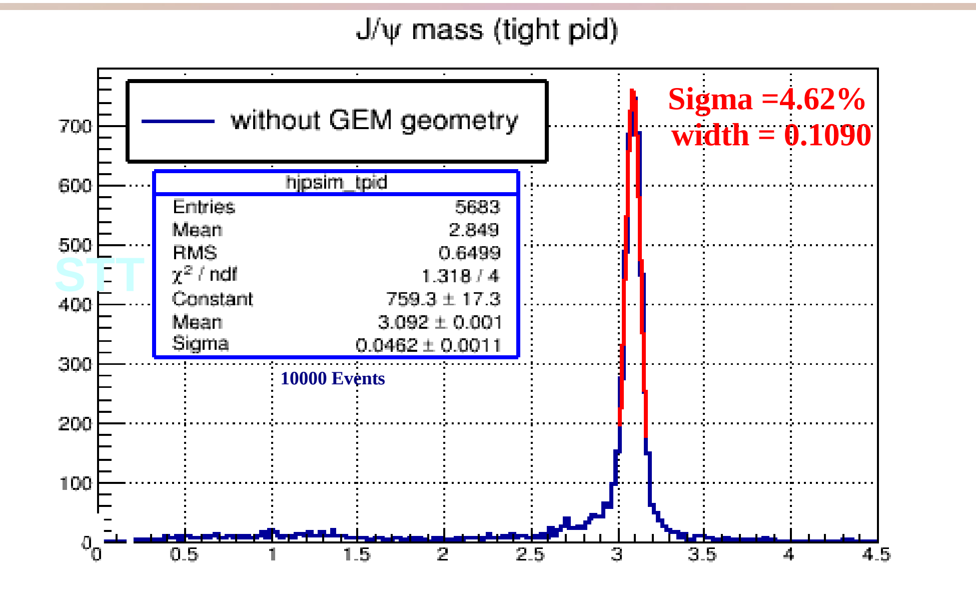
We have to see the resolution improvement from *b*(MVD+STT) to *b*(MVD+STT+GEM), it should be done soon



Track *c*; hitting only MVD and GEM
Not used in the current work yet, it should be foreseen

PANDA setup without GEM and with GEM





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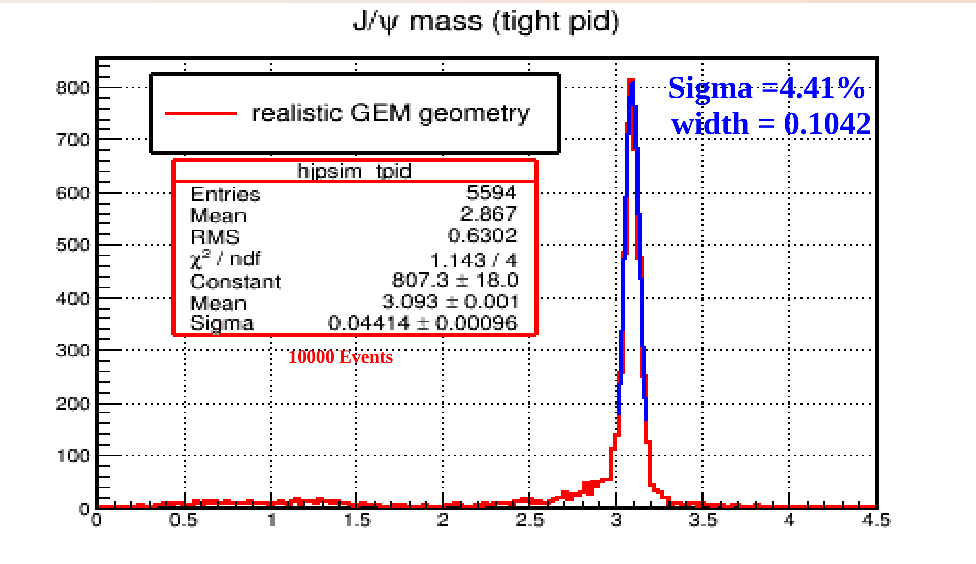
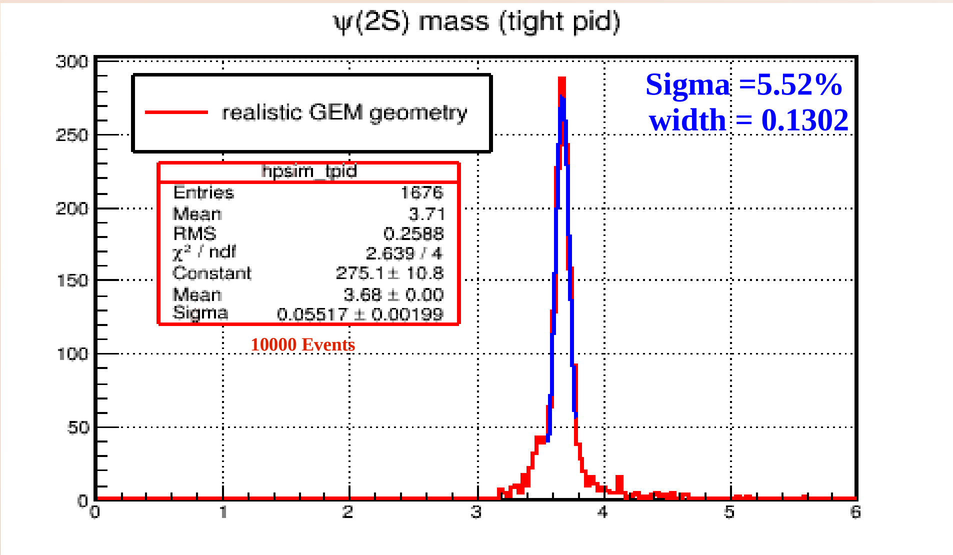
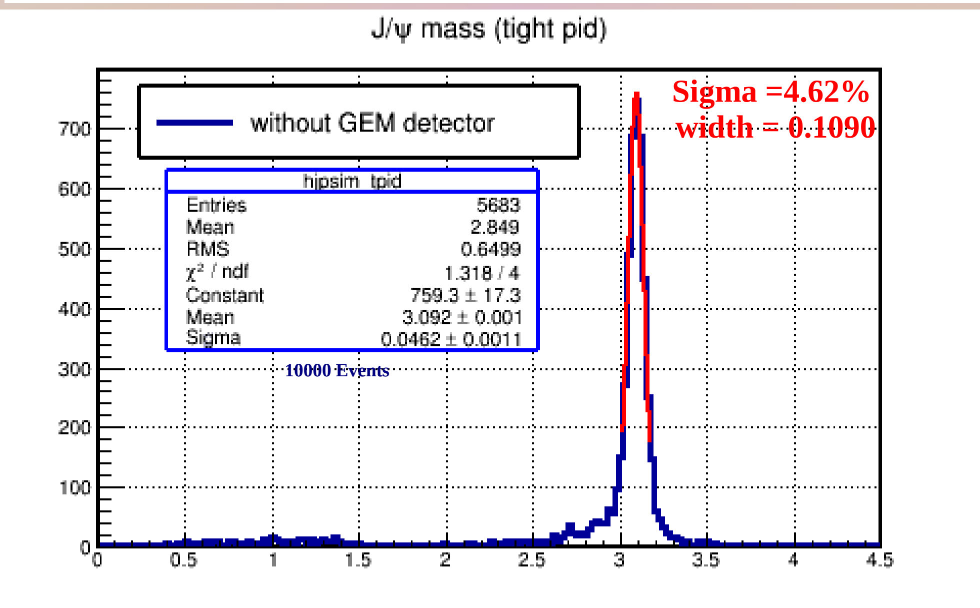
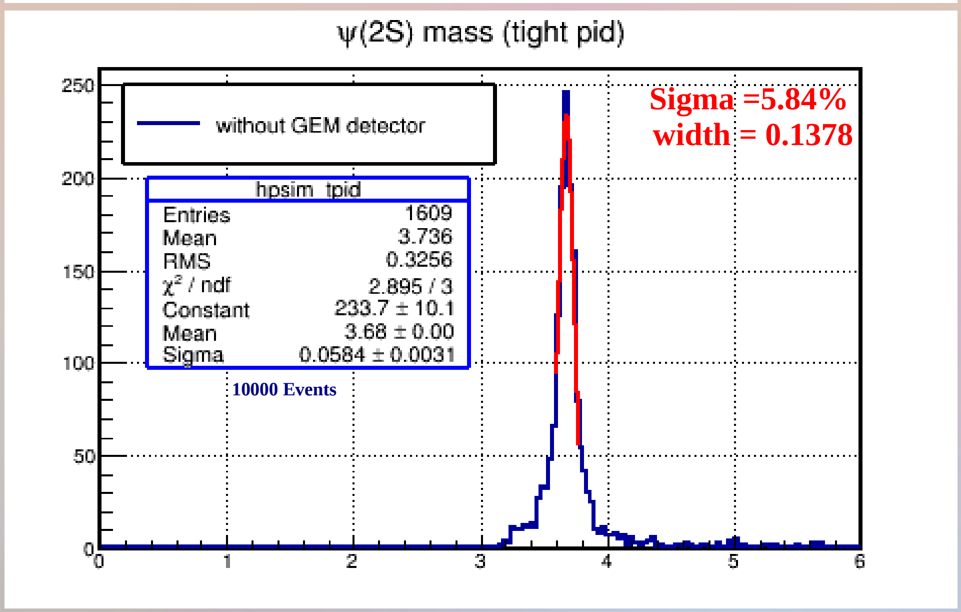
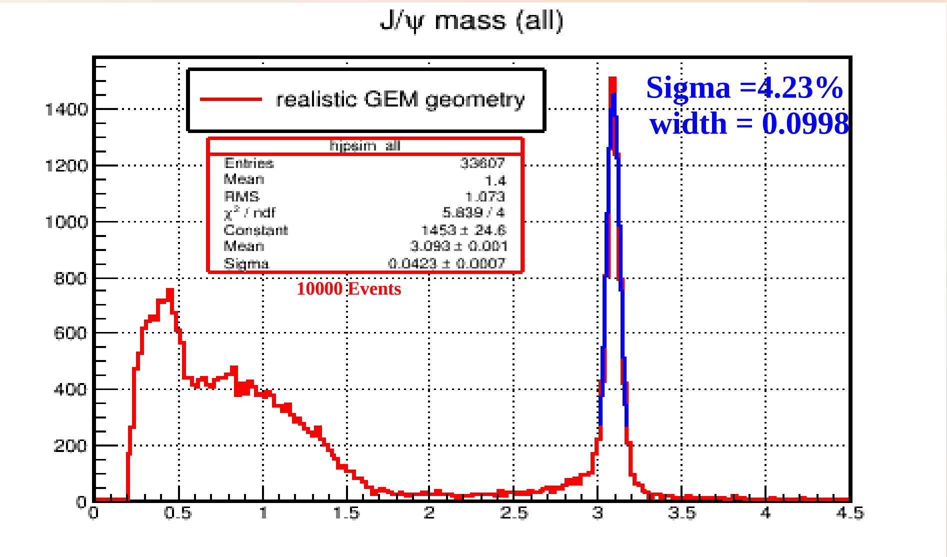


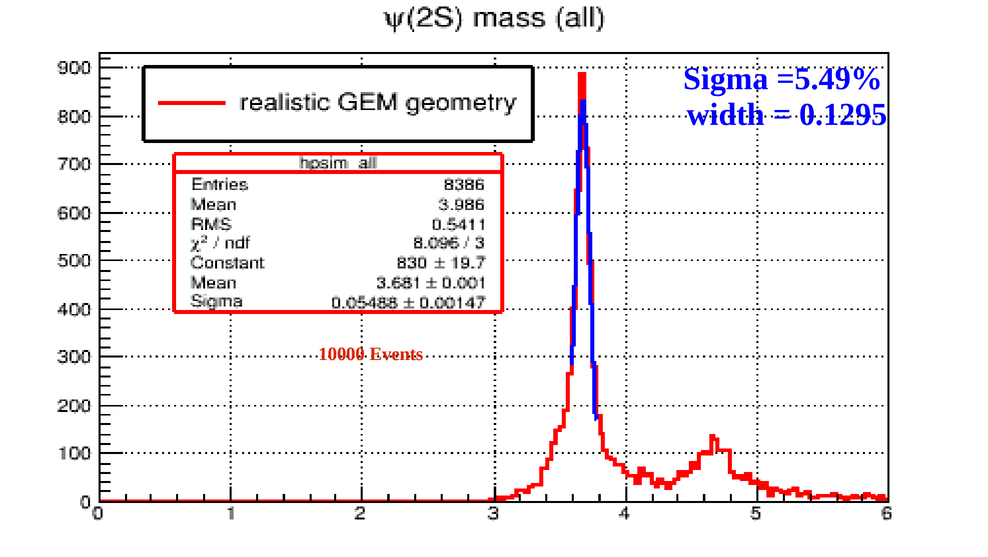


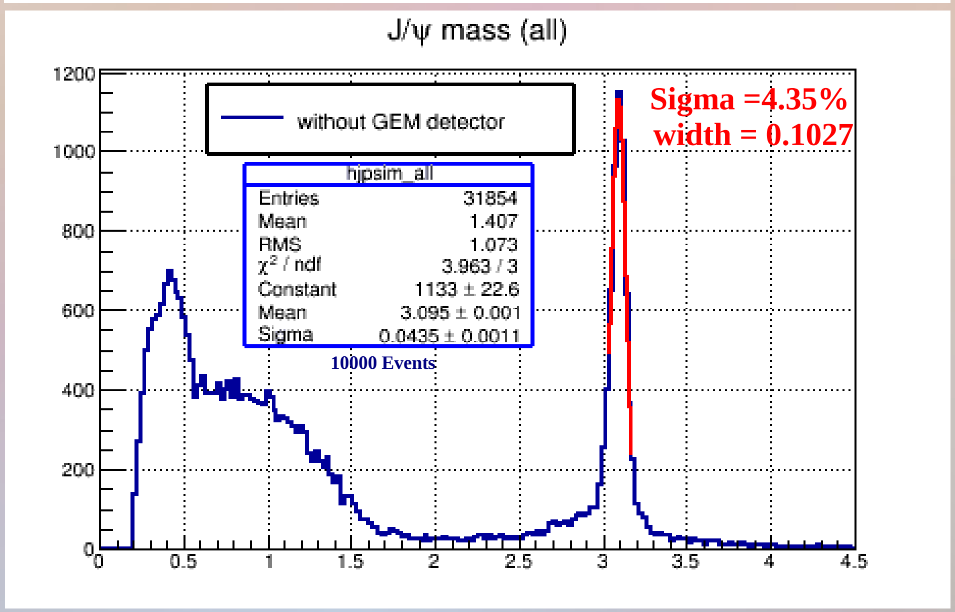


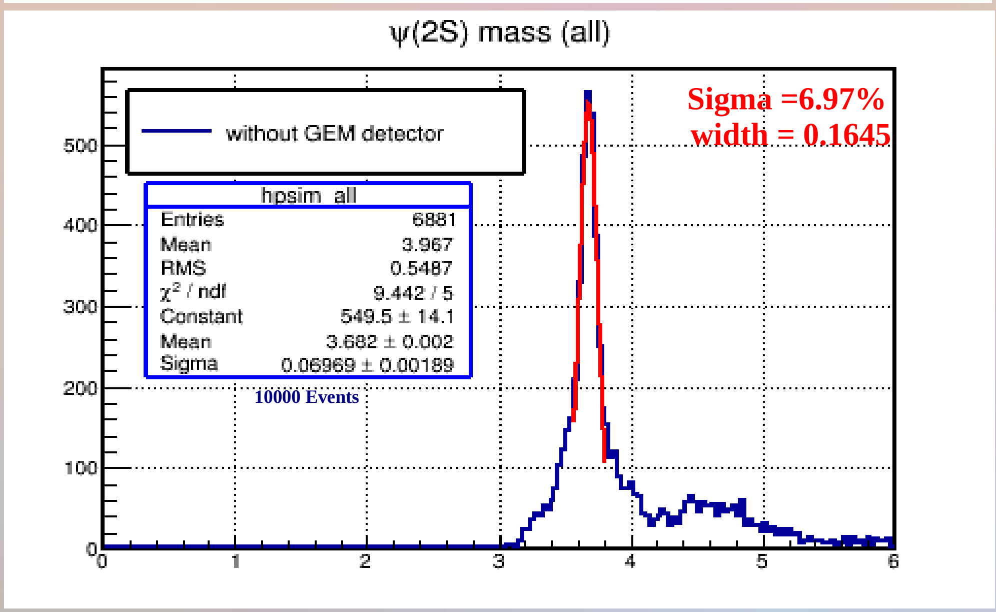


PANDA setup without GEM and with GEM







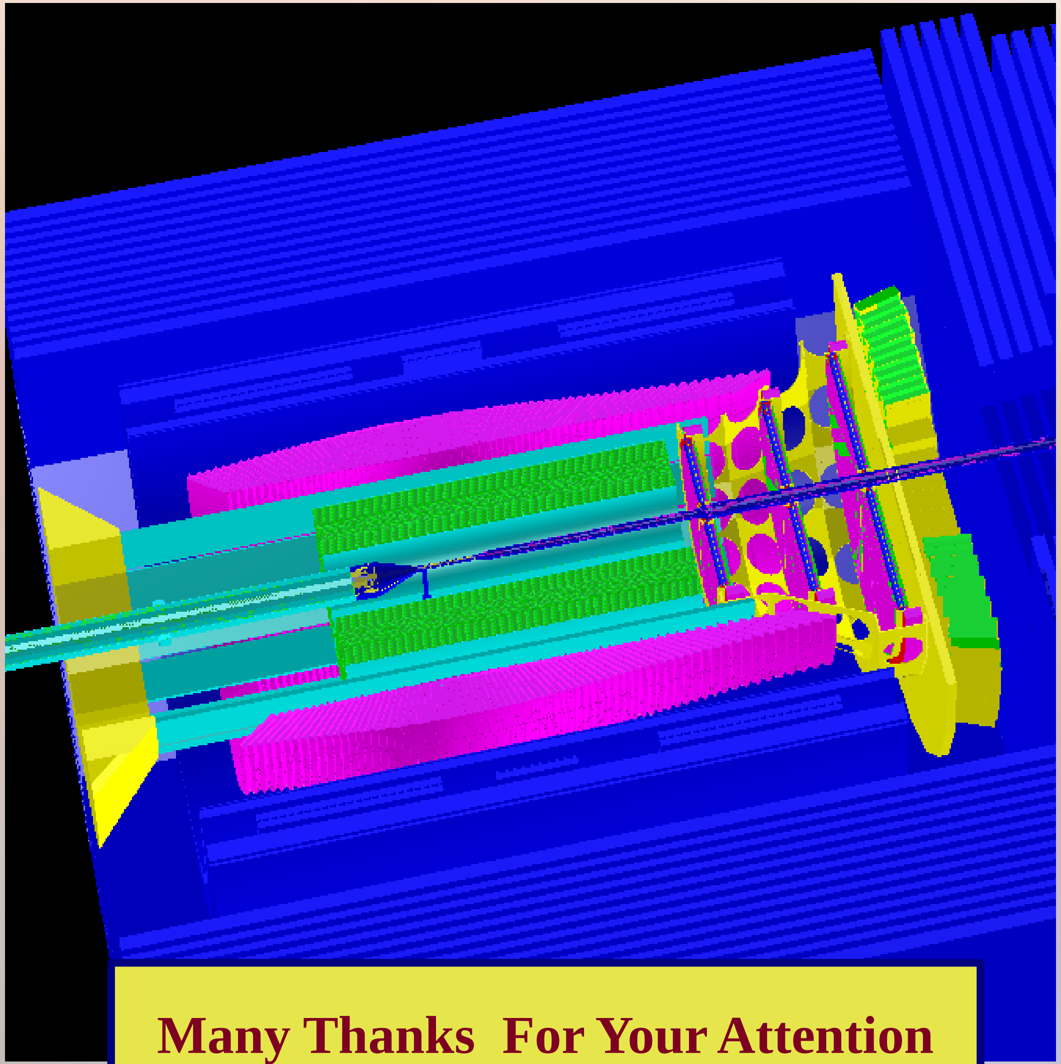


Conclusion

- **The geometry in the MC simulation has been implemented successfully**
- **Additional materials in the GEM geometry do not disturb the invariant mass reconstruction**
- **With realistic GEM geometry, mass resolution and tracking efficiency are better than those without GEM**
- **However, in the current tracking procedure PndSttMvdGemTracking;**
  - **Always requiring STT+MVD**
  - **Improvement by adding GEM should be separated from the other contributions**
  - **Implementing tracking procedures with only MVD+GEM is also the next task**

Future Tasks

- Separate contributions by GEM from the other contributions
- Implement MVD+GEM tracking
- Investigate the invariant mass reconstruction for the other physics benchmark channels
- Implement more realistic geometries such as electronics modules, cables and connectors
- Check extrusions and overlaps once again for inner GEM parts and between GEM and its neighbors
- Upload the realistic GEM geometry to the repository of the PandaROOT framework



Many Thanks For Your Attention

Back up slides

using the mar15 release of PANDARoot Package

```
ndivaniv@lxg0480:/data.local1/Nazila/PandaRoot/mar15/release2/tutorials/rho$ svn info
Path: .
URL: https://subversion.gsi.de/fairroot/pandaroot/release/mar15/tutorials/rho
Repository Root: https://subversion.gsi.de/fairroot
Repository UUID: 0381ead4-6506-0410-b988-94b70fbc4730
Revision: 28659
Node Kind: directory
Schedule: normal
Last Changed Author: kgoetzen
Last Changed Rev: 27159
Last Changed Date: 2015-03-05 09:36:14 +0100 (Thu, 05 Mar 2015)
```

GEM stations materials:

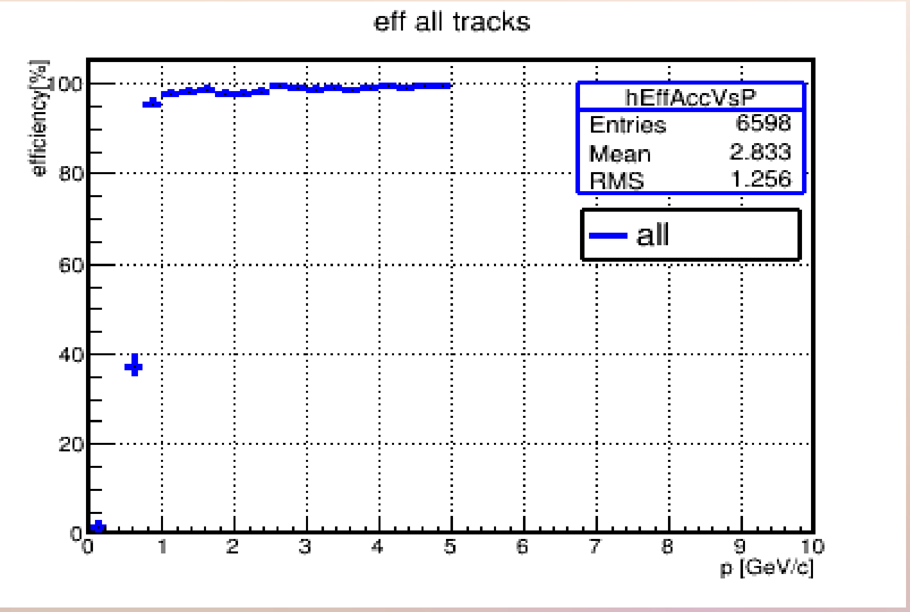
- The stations are in form of circular planes (Disk shape) → HalfStationThickness = 7.4 cm
- The stations are full of $ArCO_2$ gas
- Separately , each station has 2 Gem_Sensor_GEMmixture ($ArCO_2$ gas) that each one has 1.0020 cm thickness
- The total thickness of each station only for layers is 5.8864 cm

each station includes: 0.0338 cm of kapton, 0.0006 cm of aluminium, 0.008 cm of copper (for main layers)

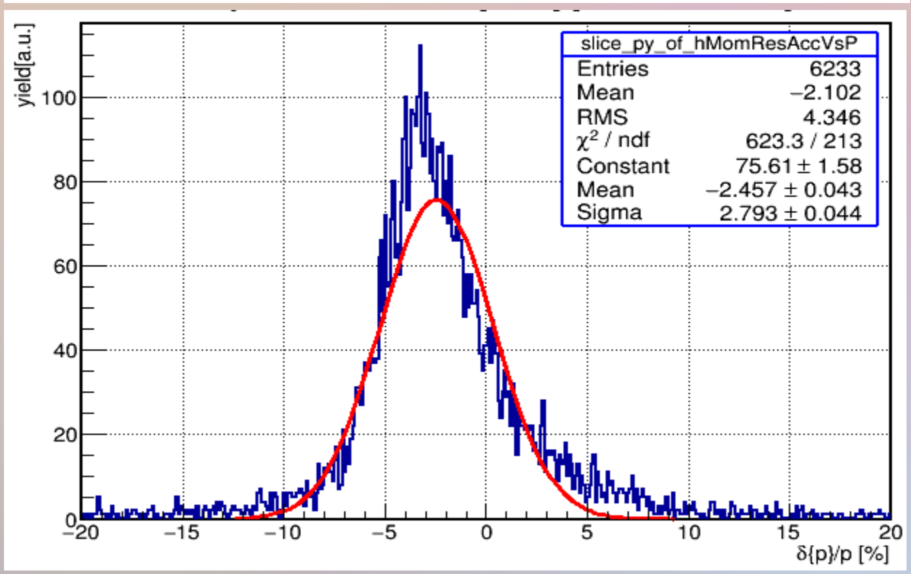
1.84 cm of glass fiber , 2 cm of carbon (for holding structure layers)

GEM Track Efficiency and Track Momentum Resolution

---------------- GEM Digitizer : Summary-----------------------
Events: 10000
MC Points: 45424 (4.5424 per event)
Digis: 90767 (9.0767 per event)
--> (1.51278 per sensor)
--> (0.0186744% occupancy)
--> (2 x 0.999108 per point)
---------------- GEM Hit Finder : Summary --------------------
Events: 10000
Digis: 90767 (9.0767 per event)
HitsTemp: 48975 (4.8975 per event)
Hits: 47659 (4.7659 per event)
--> (0.794317 per sensor)
--> (0.52507 per digi)
---------------- PndGemFindTracks : Summary --------------
Events: 10000
Tracks: 6403 (0.6403 per event)
Time: 0.253427 (2.53427e-05 per event)
(3.95793e-05 per track)
---------------- PndGemTrackFinderQA : Summary ---------
Events: 10000
MC Tracks: 8633
reconstruable:6791
reconstructed: 6392 >>>> 94.1246%
primaries: 6708
reconstructed: 6392 >>>> 95.2892%
reference: 5556
reconstructed: 5299 >>>> 95.3744%
secondaries: 83
reconstructed: 0 >>>> 0%
Ghosts: 1 >>>0.0001 per event >>>
0.000115835 per MC Track
clones: 16 >>>0.0016 per event>>>
0.00185335 per MC Track



track efficiency vs momentum



track momentum resolution

PANDA setup without GEM and with GEM