Validation of Proton Nozzle

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Outline

1. Proposal
2. Status Report of “BeamNozzle” example
3. Comparison between simulation and measurement
4. Summary

Proposal

❖Goal

EM physics Validation With Proton Beam Simulation & Measurement

1. Development of “BeamNozzle” example
2. G4 MC Simulation for Validation.
3. Measurement of Proton Stopping Range and scattering in Water (on-going)
4. Comparison with monthly updated reference tags. (on-going)

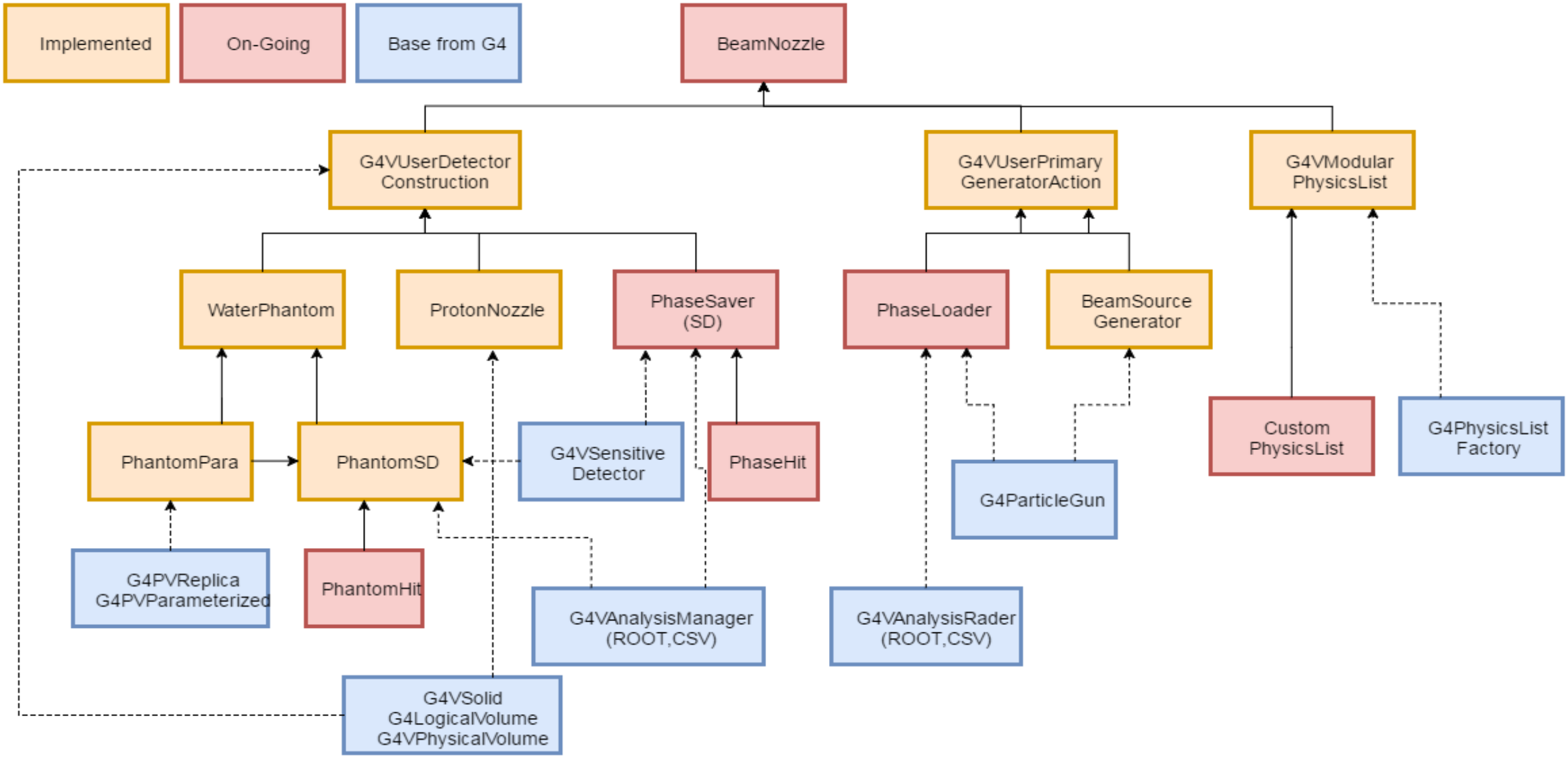
Status Report of "BeamNozzle" example

Since 2014 GEANT Collaboration Meeting (Barcelona,Spain)

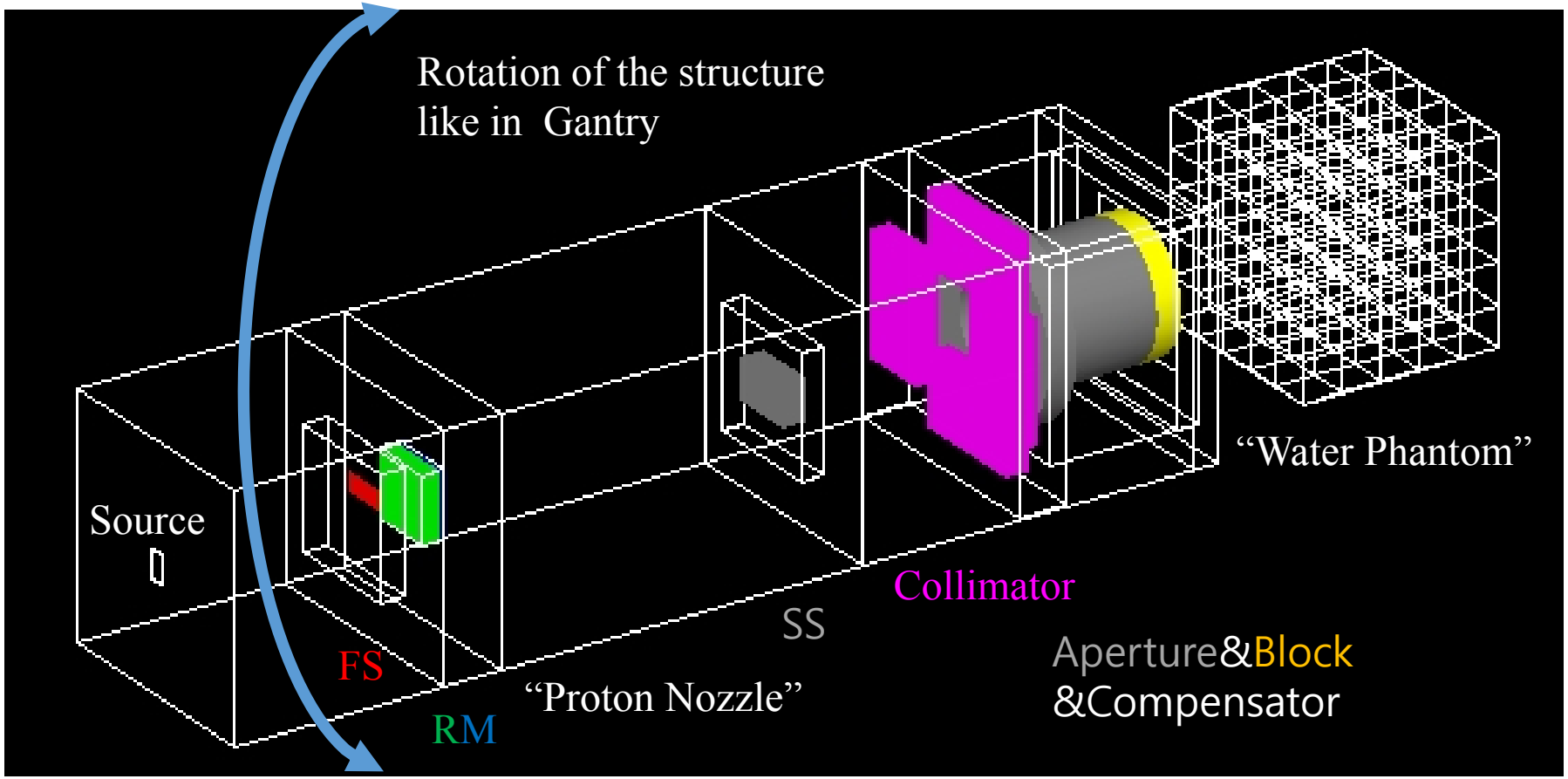
“BeamNozzle” example

- ✓Simplify commercial proton therapy beam nozzle (IBA Proteus235)
- ✓Use minimum information to avoid license of company (Single Scattering, Range Modulation Wheel)
- ✓Components for Proton Therapy beam nozzle simulation (easy-adapt to user’s application)
- ➢Support the validation data with example(on-going)

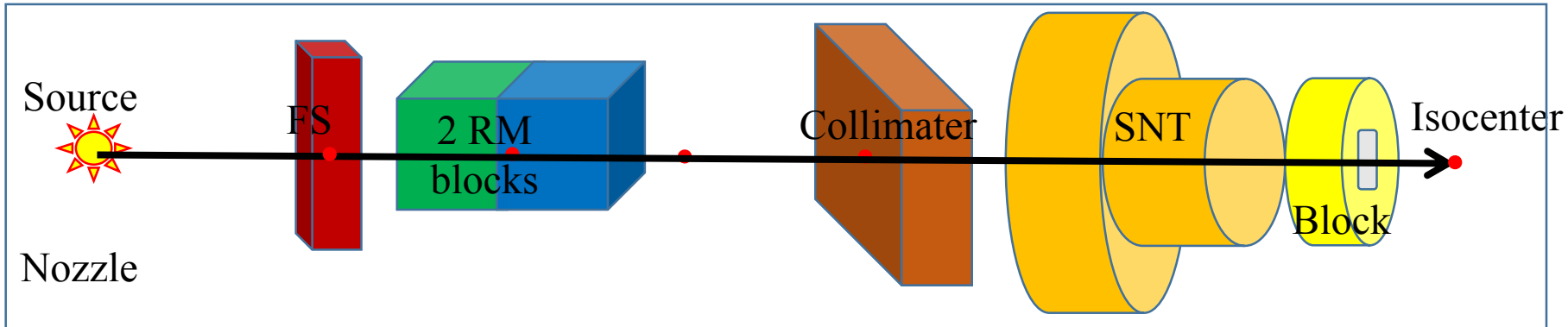
Migration from 9.6 to 10.02 MT-compatible



Detector Construction : Proton Nozzle



- ❖Class "ProtonNozzle"
- Set First Scatter
- Set Range Modulation
- Set Collimator
- Set Airgap
- ....



Detector Construction : Water Phantom

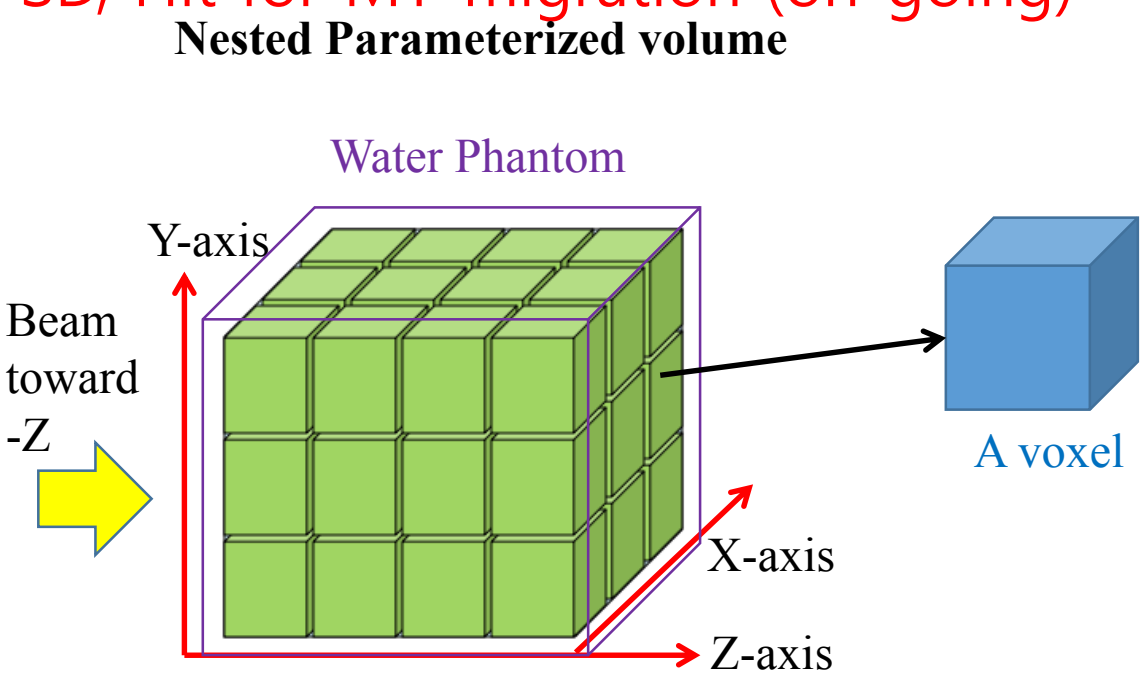
❖Class "WaterPhantom" for 3D-Voxelized Phantom like CT-DICOM

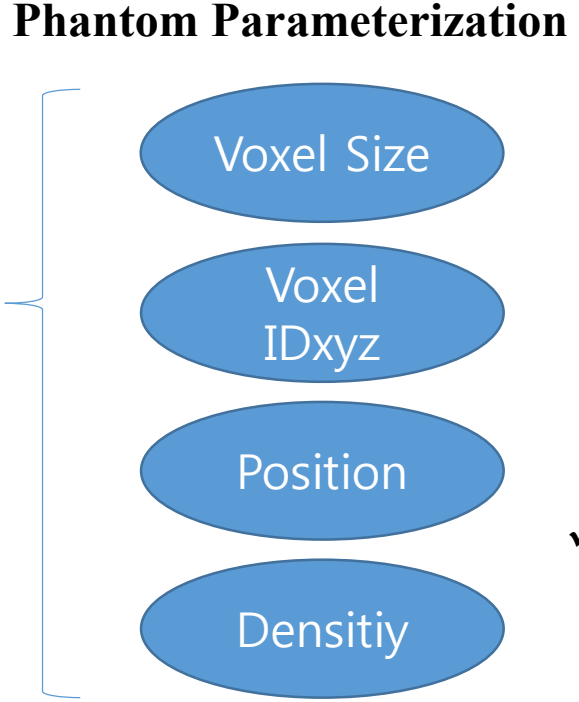
- Set Size of a Water Phantom
- Set Size of a Voxel

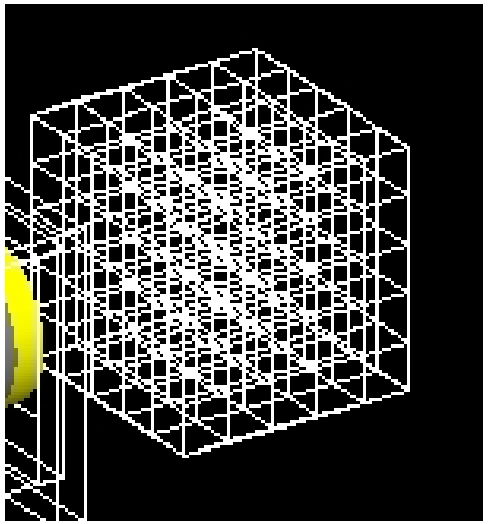
✓Use NestedParameterzation (PhantomPara)

✓Adapted to G4ROOTAnalysisManger

➢SD, Hit for MT-migration (on-going)







✓ Inhomogeneous Volume like human body

Primary Generator Action

- Use classic Primary Generator action with ParticleGun for easy usage

❖Class “BeamSourceGenerator”

✓Set the energy and sigma of source

✓Set the beam size and incident angle(gantry rotation) of source

➢Adapt the characteristics from beam optics (Emittance, Twiss parameter)

❖Class “PhaseLoader”

- Needs for Multi-Field dose calculation (medical physics)

✓Load the beam data(phase space) from independent application (applying PhaseSaver)

➢Remove ROOT-dependency, Adapt AnalysisReader (on-going)

PhysicsList

❖For entry user, the example support “reference physics list”

- combination of Hadronic, Electromagnetic, Extra physics lists
- Ex) QGSP_BIC_EMX, FTFP_BERT_EMV, …

✓Remove macro-based physics list, Adapt “G4PhysicsListFactory”

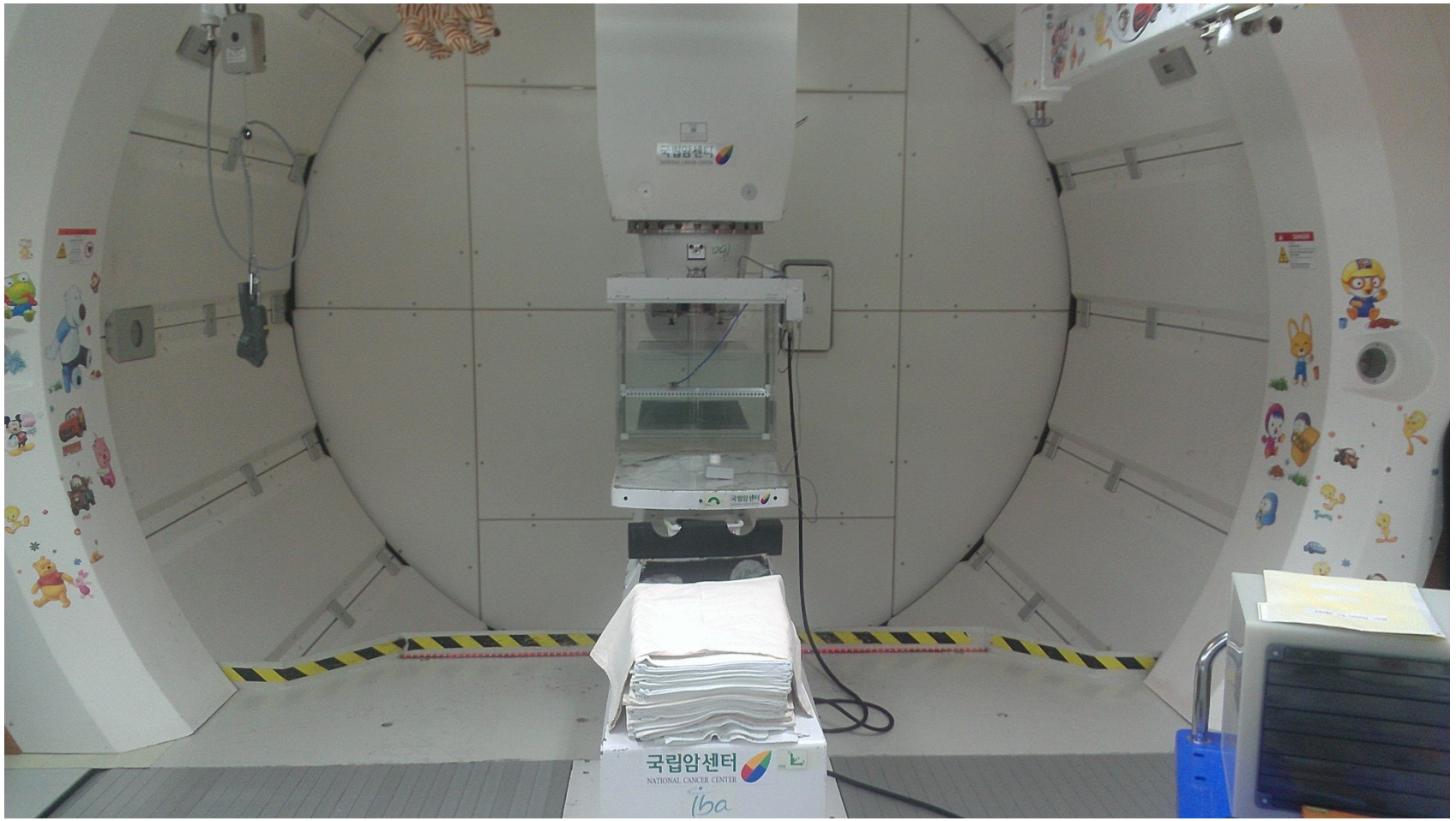
❖Needs for validated, well-explained physics list in medical physics

➢In future implement, custom physics list from papers (H.Paganetti, etc) will support and compare with reference.

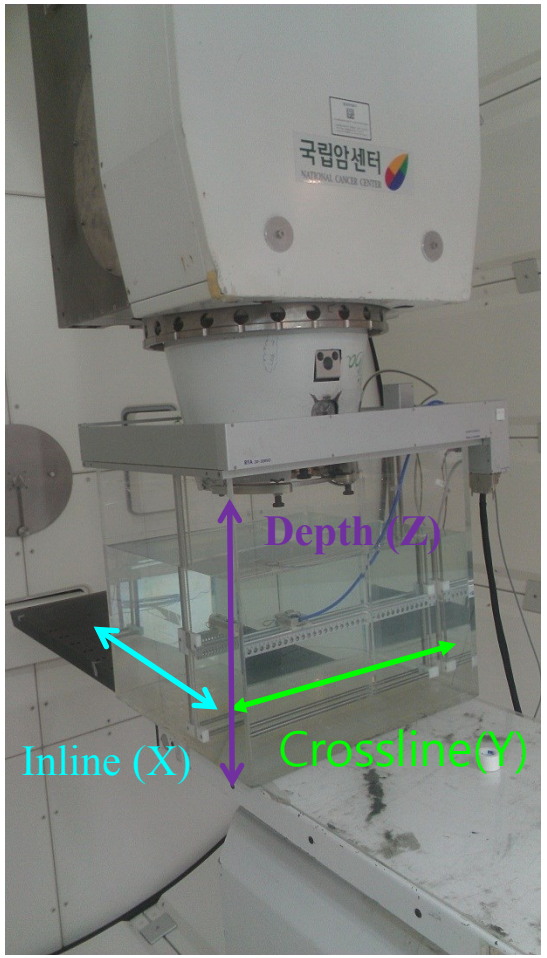
Comparison between simulation and measurement

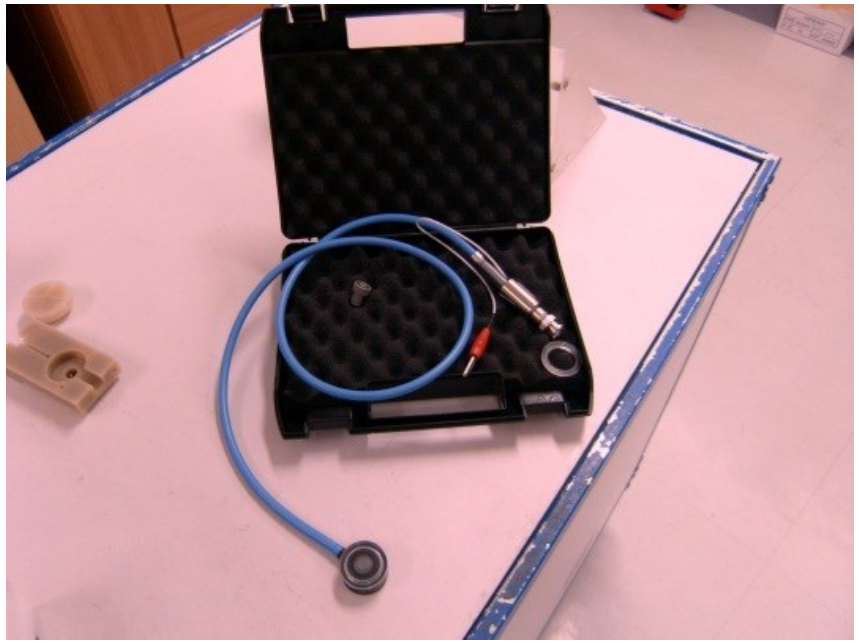
NCC Proton Therapy Center

3D WaterPhantom @ Proton Therapy room



3D moving Ion chamber

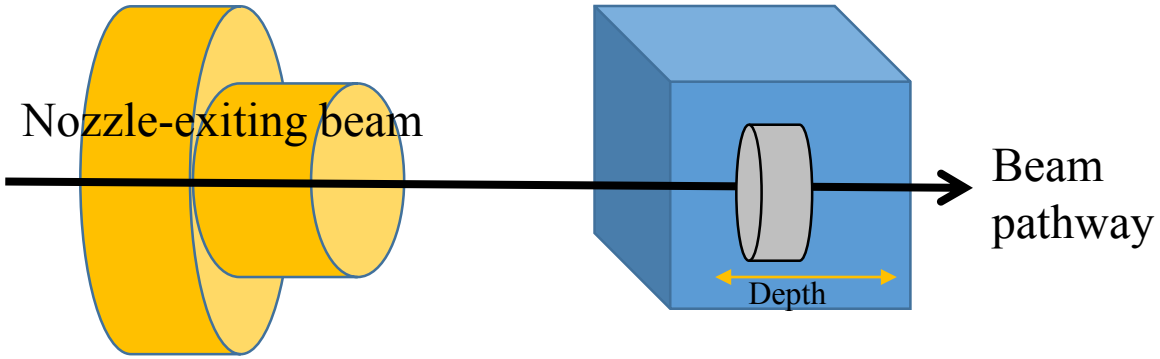




PTW Markus Chamber (23343)

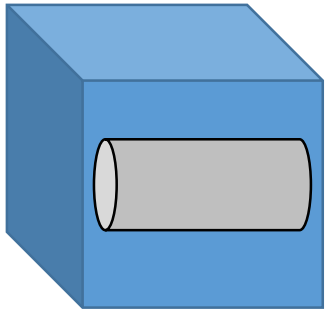
- Sensitive volume
- Radius 2.65mm, depth 2mm

Measurement #1 Bragg Peak

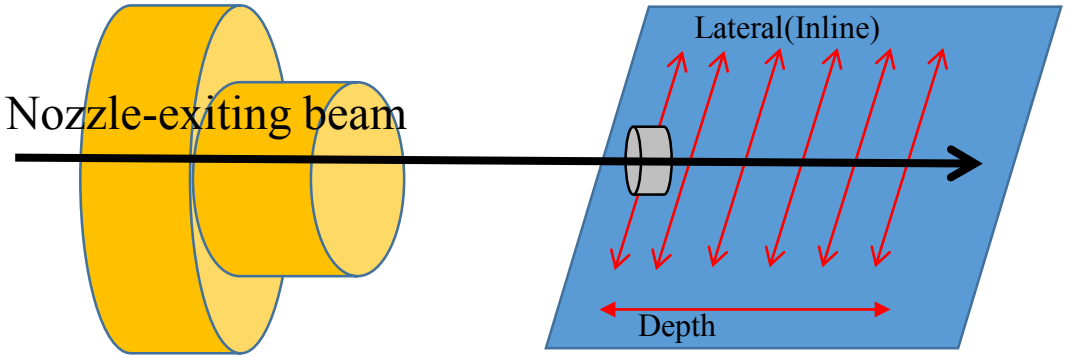


Proton beam nozzle

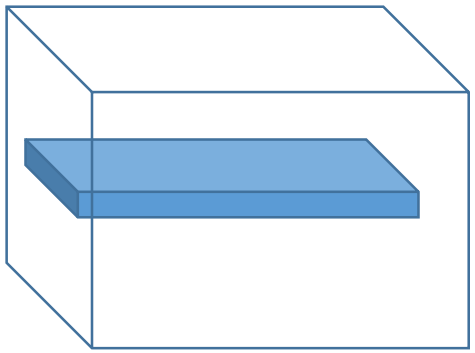
Markus Chamber
(1D moving)



Percent Depth Dose
Detective volume



Markus chamber
(2D moving)



2D dose distribution
Detective volume

System Environment

- CentOS 6.6 64bit (kernel 2.6.32-504.el6.x86_64)
- GCC 4.9.2 (20150212 Red Hat 4.9.2-6) from devtoolset-3
- CMAKE 3.4.3
- GEANT4 10.02.p2

- Version Comparison

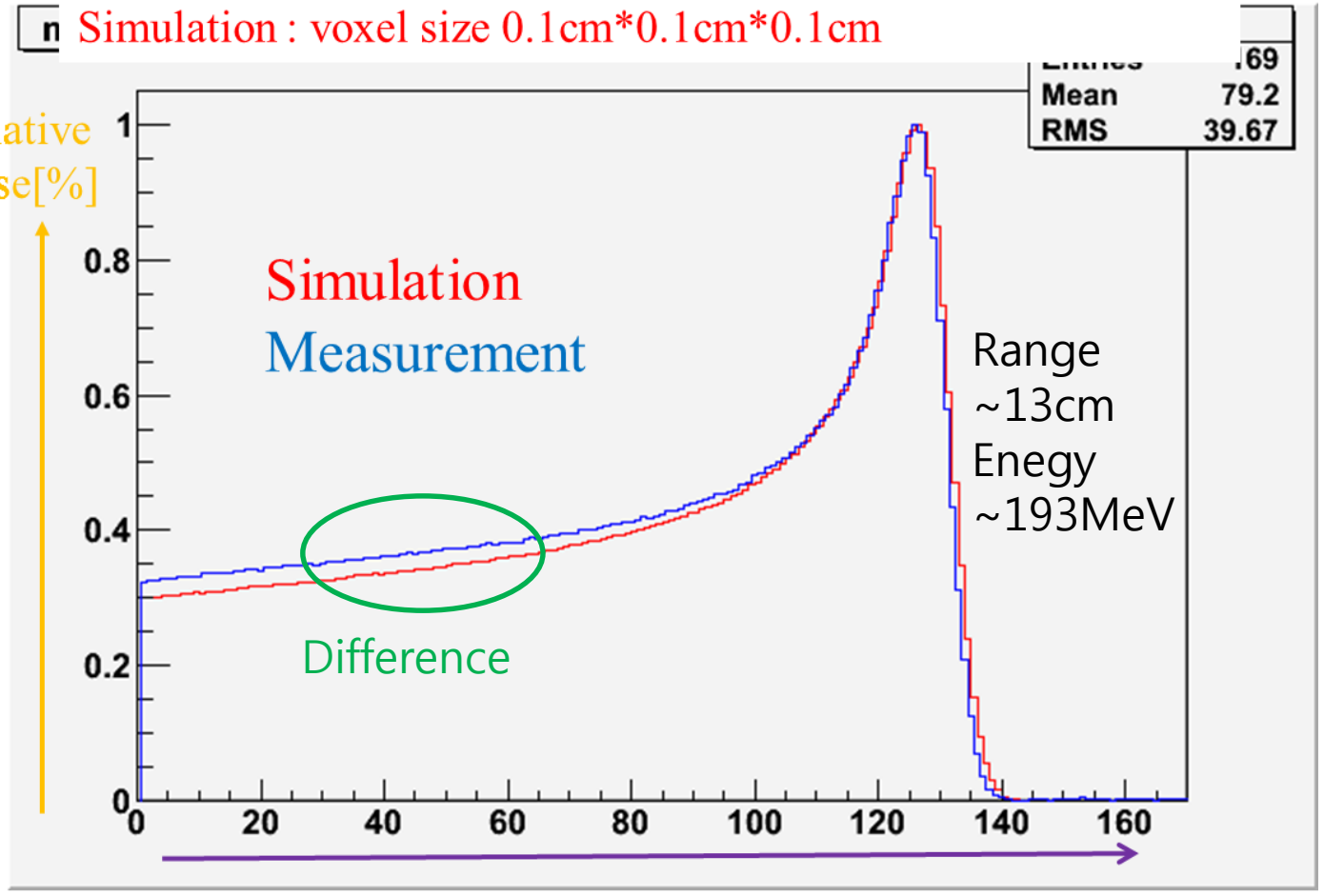
✓GEANT4 10.01.p3 with GCC 4.9

✓GEANT4 10.02.p2 with GCC 4.9

✓GEANT4 10.03.b1 with GCC 4.9

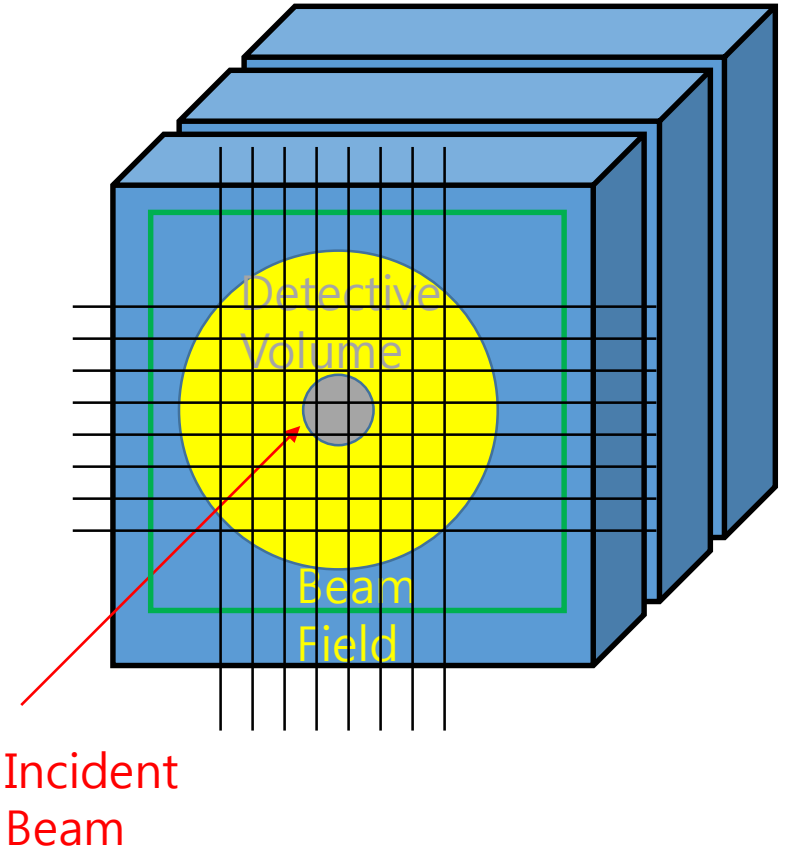
Percent Depth Dose in Water Phantom

Measurement :Depth 0~15cm (increment by 0.1cm)
Simulation : voxel size 0.1cm*0.1cm*0.1cm



Detective Volume

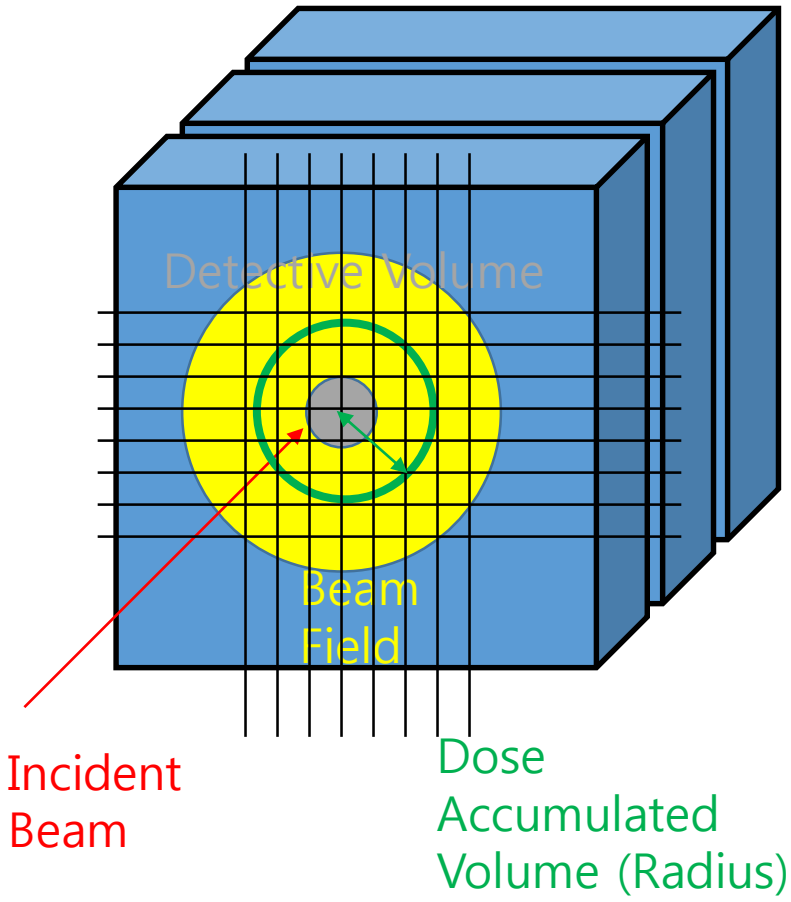
≠,<< Dose Accumulated Volume



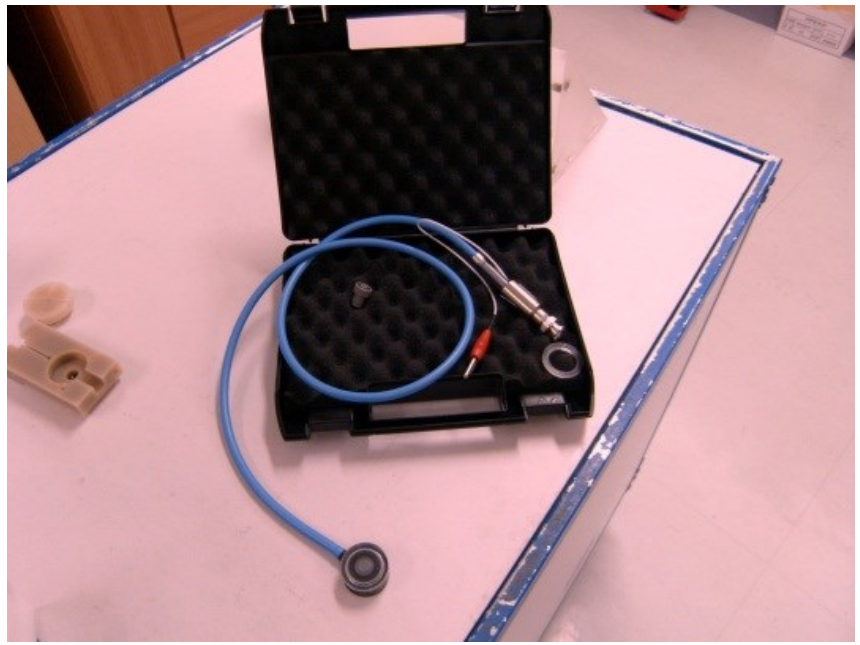
G4CM2014

Rearrange of Detector Volume

Detective Volume
=,~ Dose Accumulated Volume

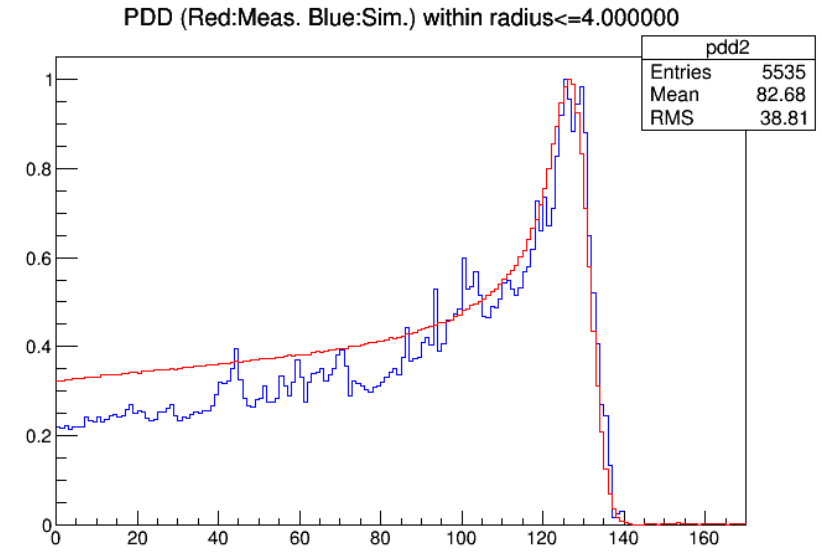


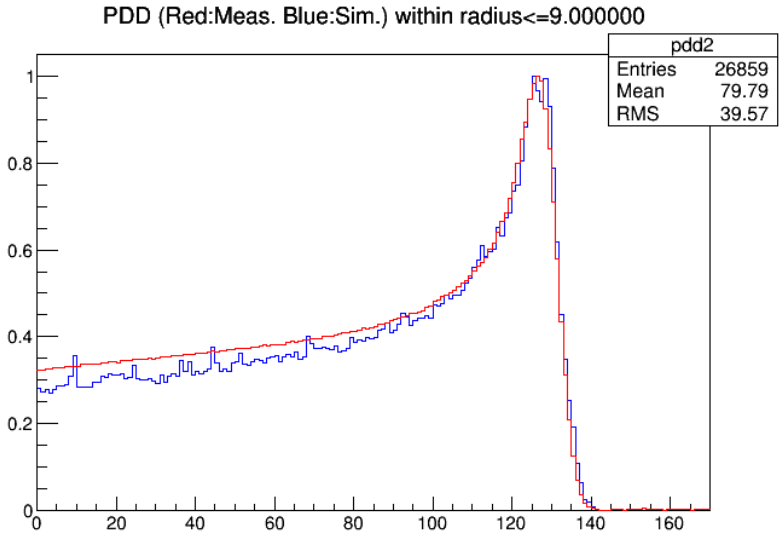
Equipment for measurement

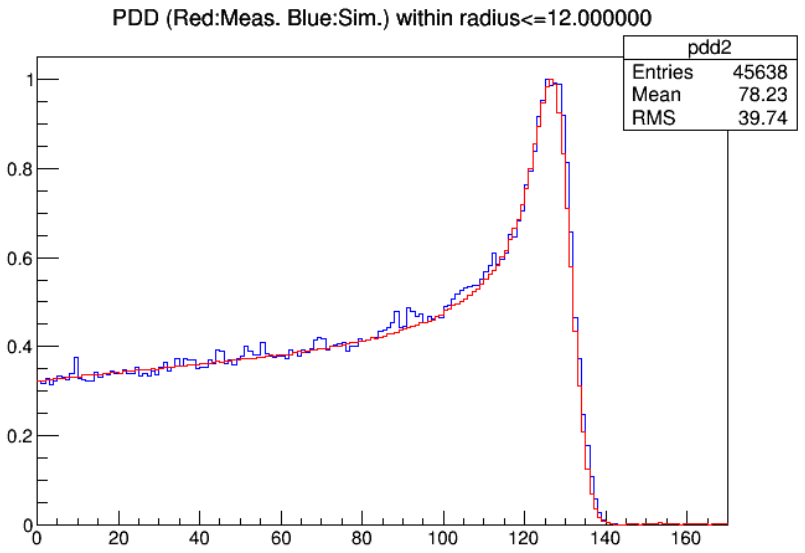


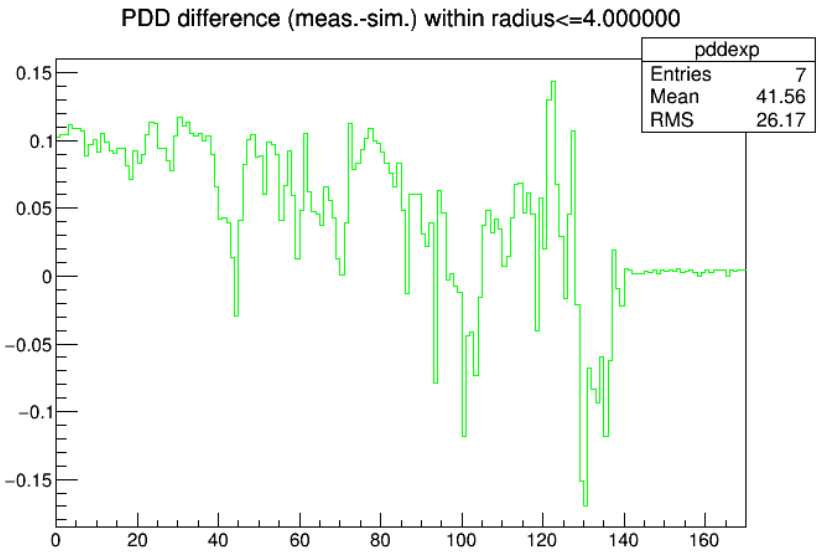
PTW Markus Chamber (23343)
Sensitive volume :
Radius 2.65mm, depth 2mm

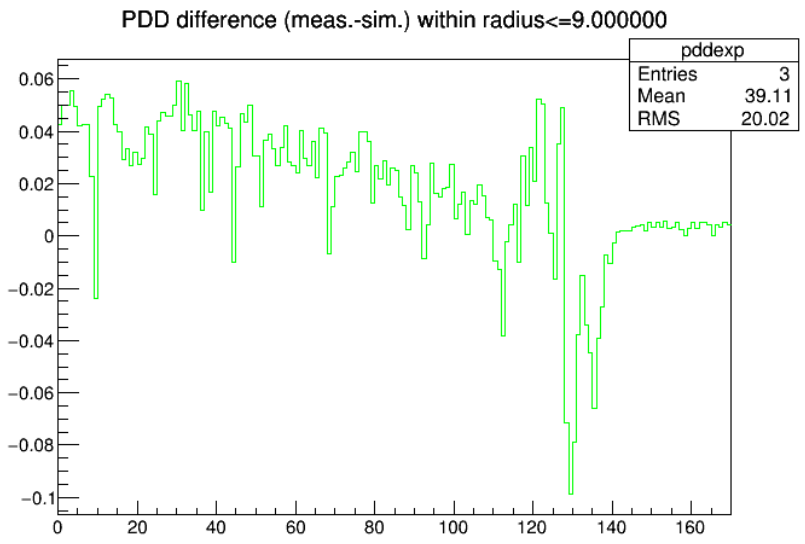
PDD depending on Radius (QGSP_BIC_EMV)

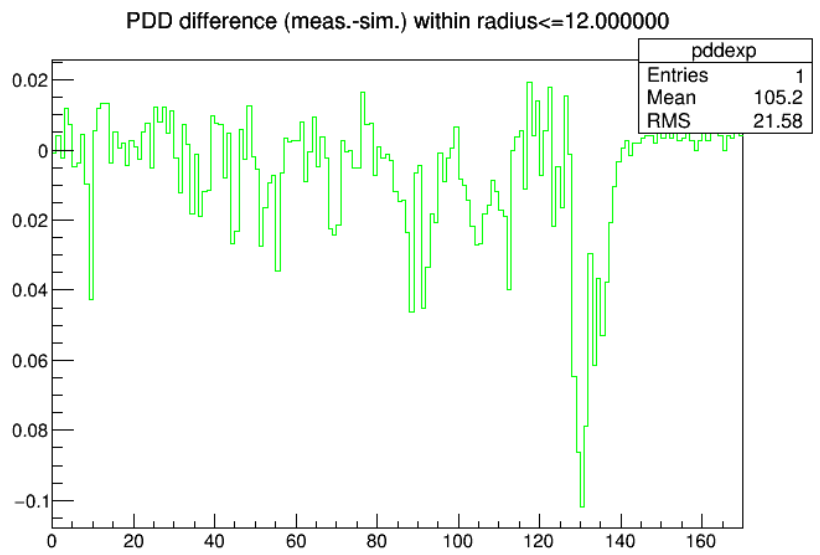




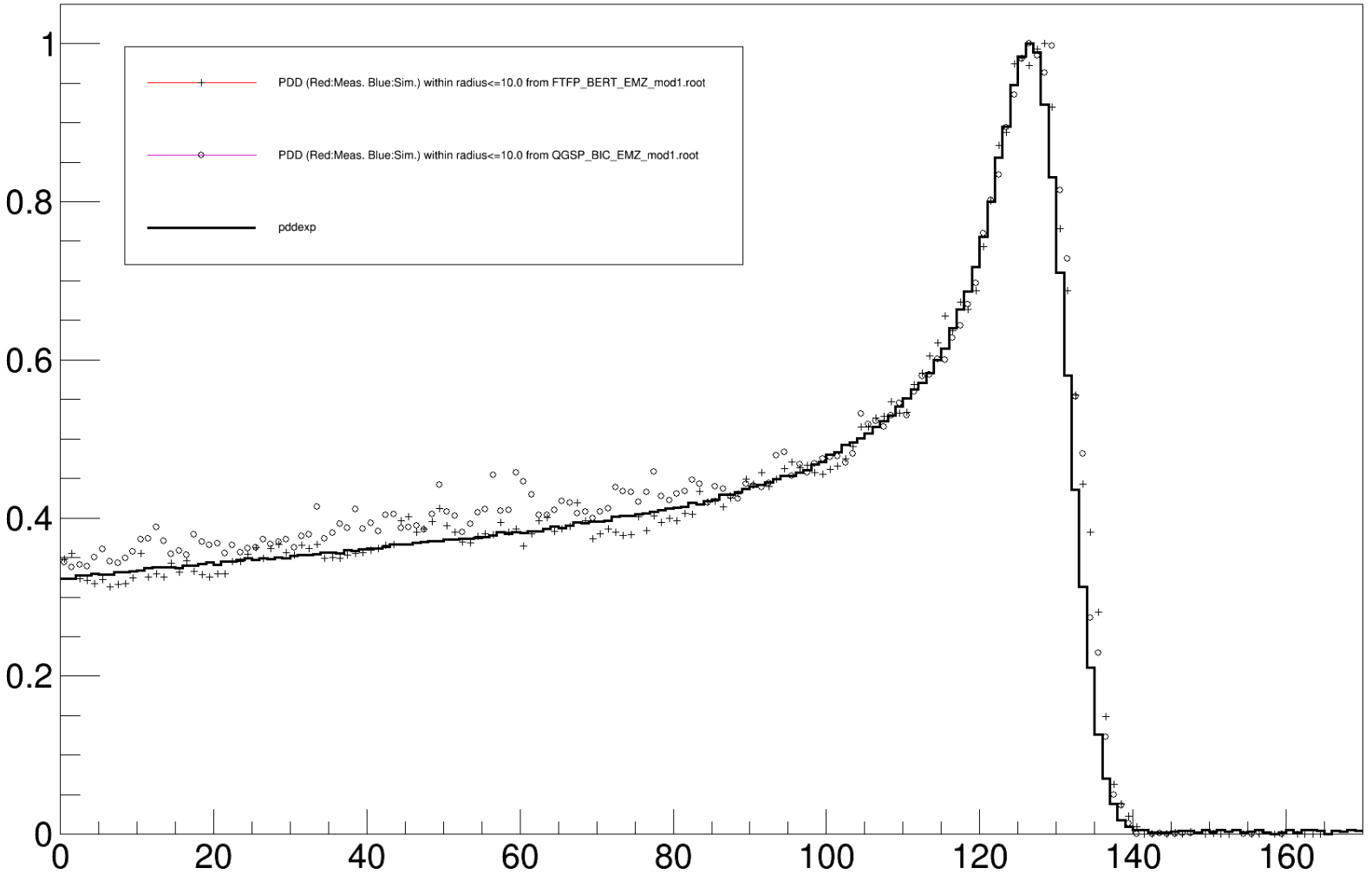




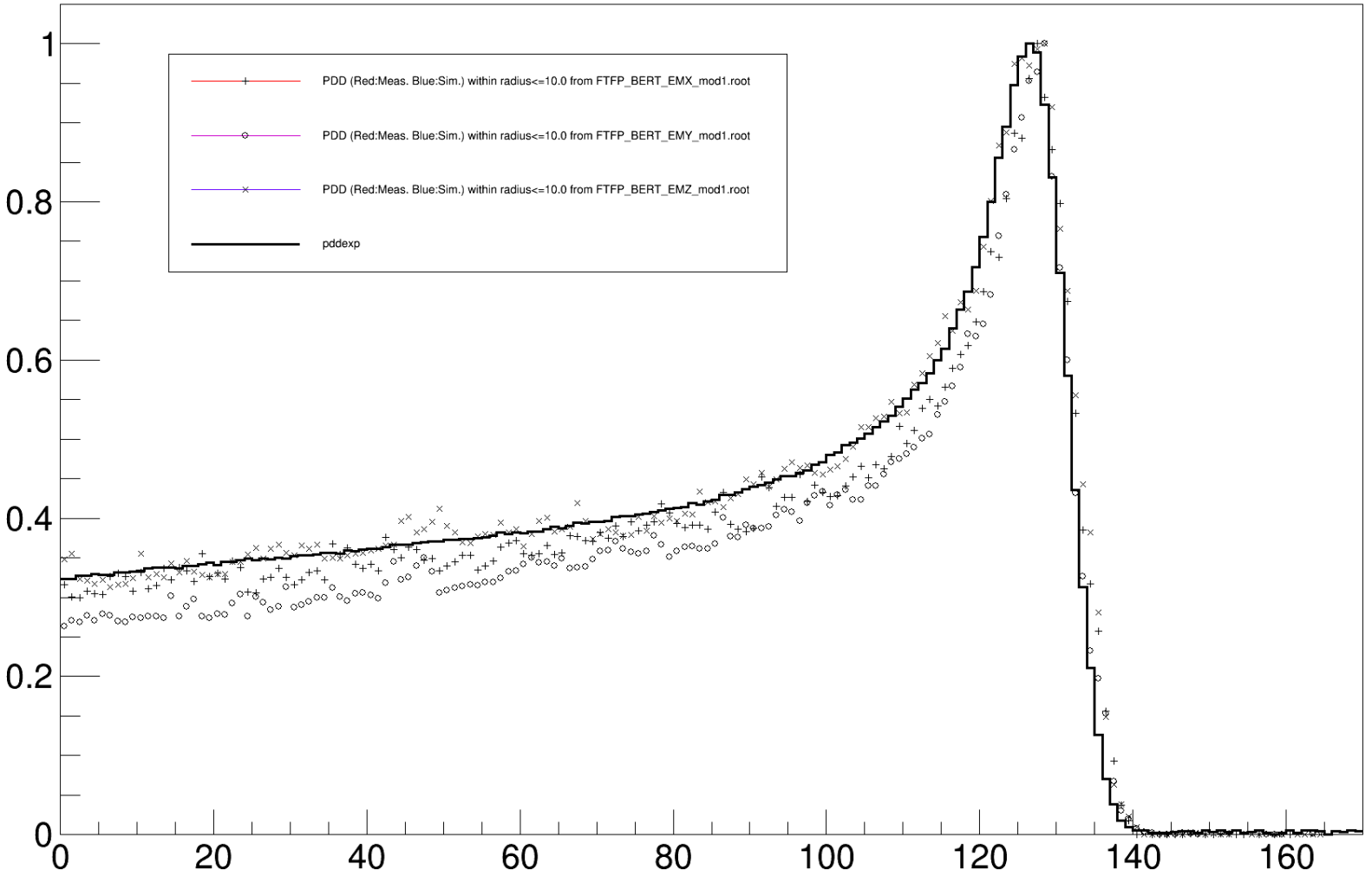




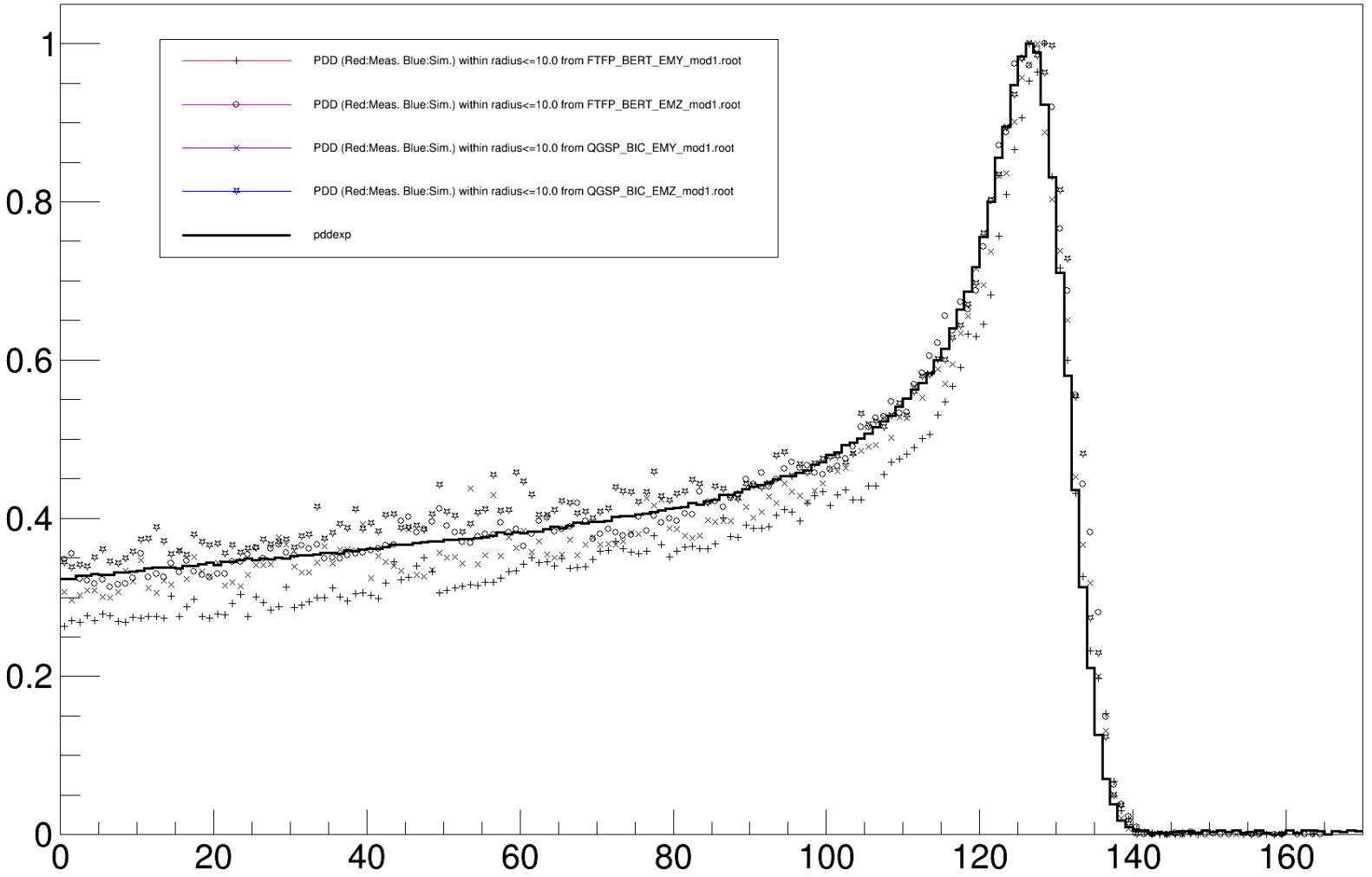
PDD depdning on HadPhysics (10mm Radius)



PDD deepening on EmPhysics (10mm Radius)

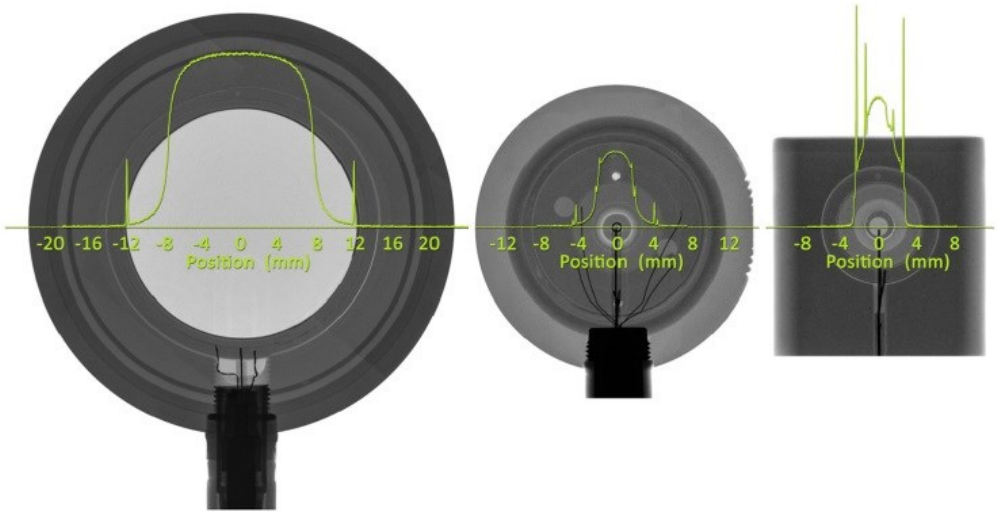


PDD depdning on RefPhysicsList (10mm Radius)

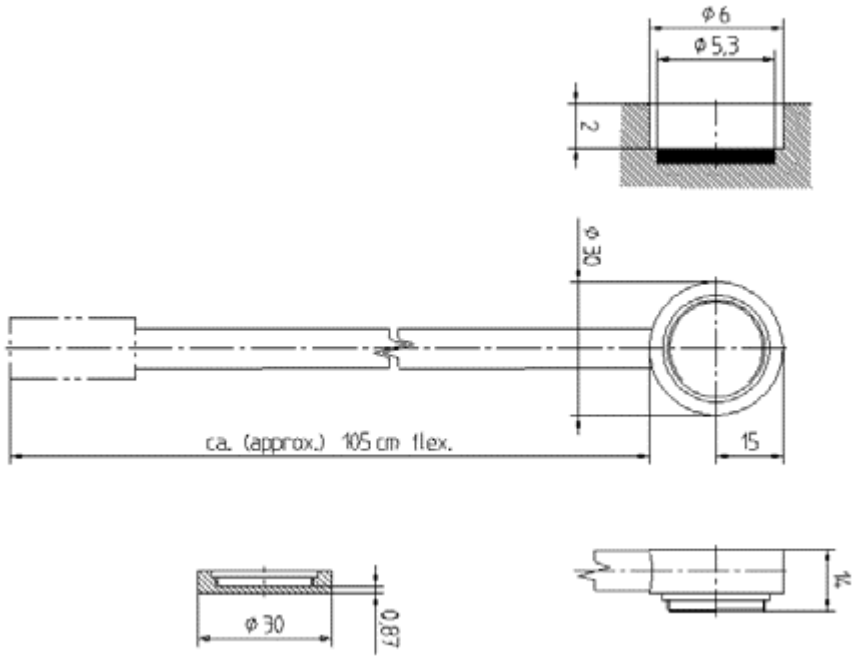


RadialPhantom (under development)

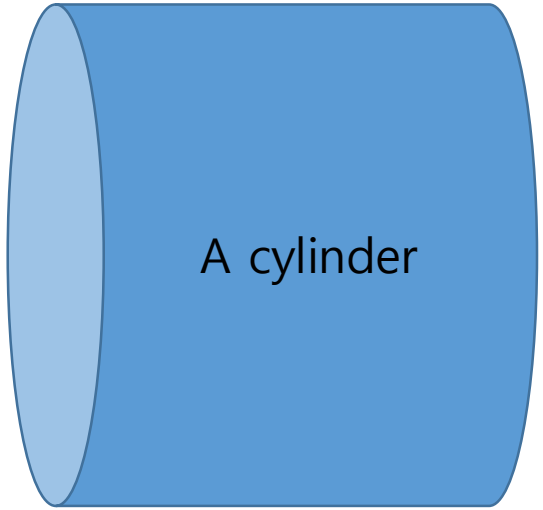
- Farmer, Markus ion chamber-liked geometry
- Parameterized Volumes consisted of various angle, radius, height
- Disk (parameterized along kZAxis)
- Ring (parameterized along kRho)
- Segment (parameterized along kPhi)

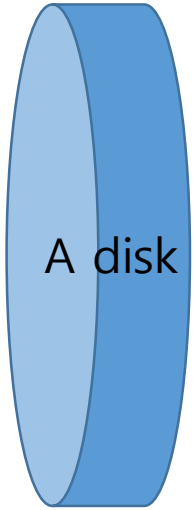


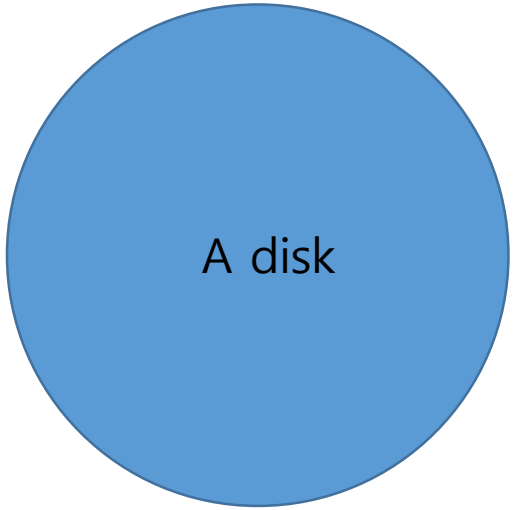
Parallel Plate type Chambers (a Roos chamber, an Advanced Markus chamber and a lowenergy soft Xray chamber)

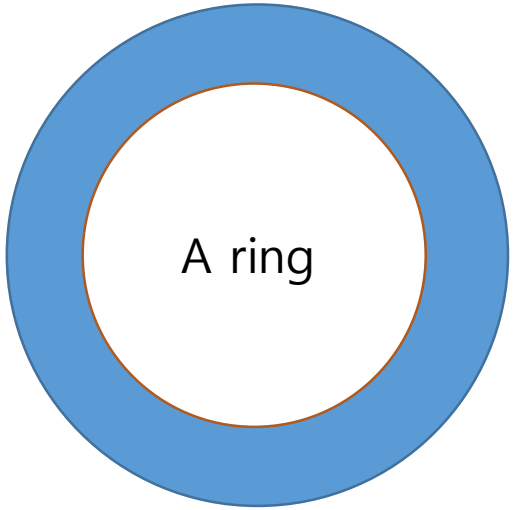


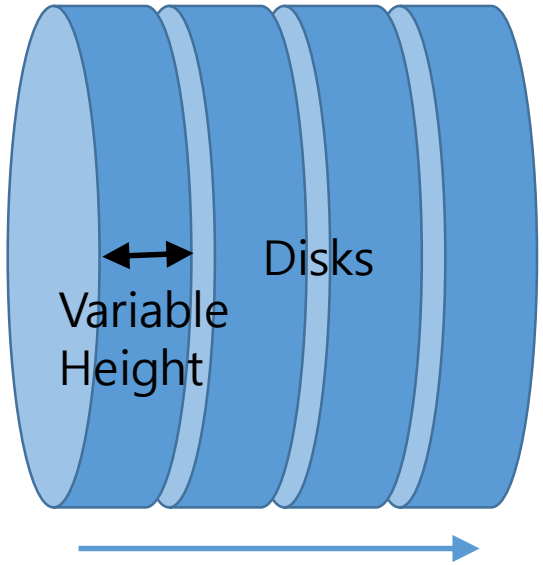
Drawing of PTW Markus chamber



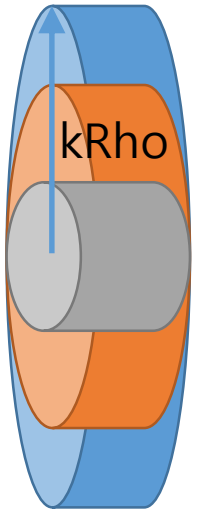




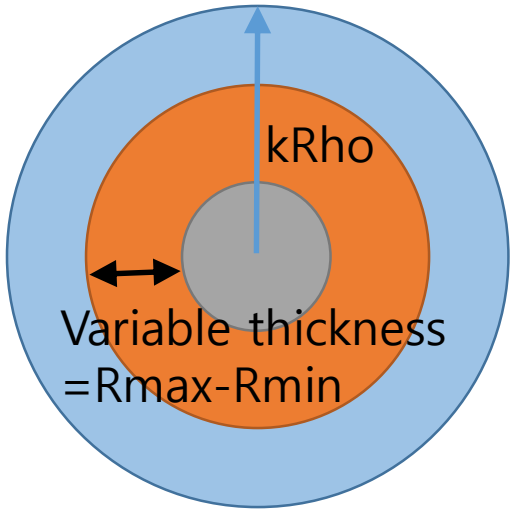




Dividing cylinder by disks with different height along Z-axis

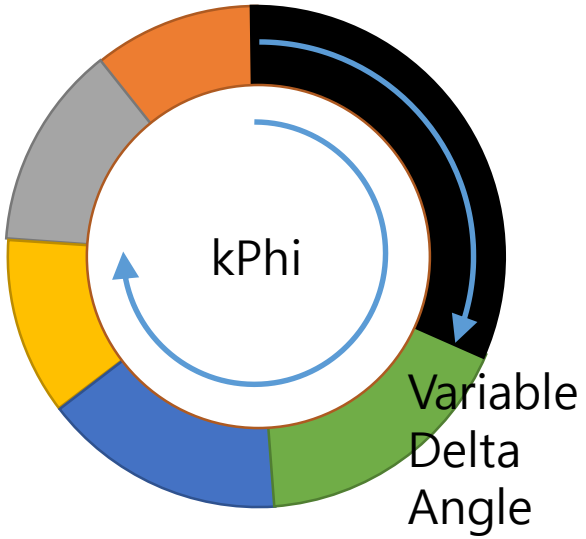


Rings



Rings

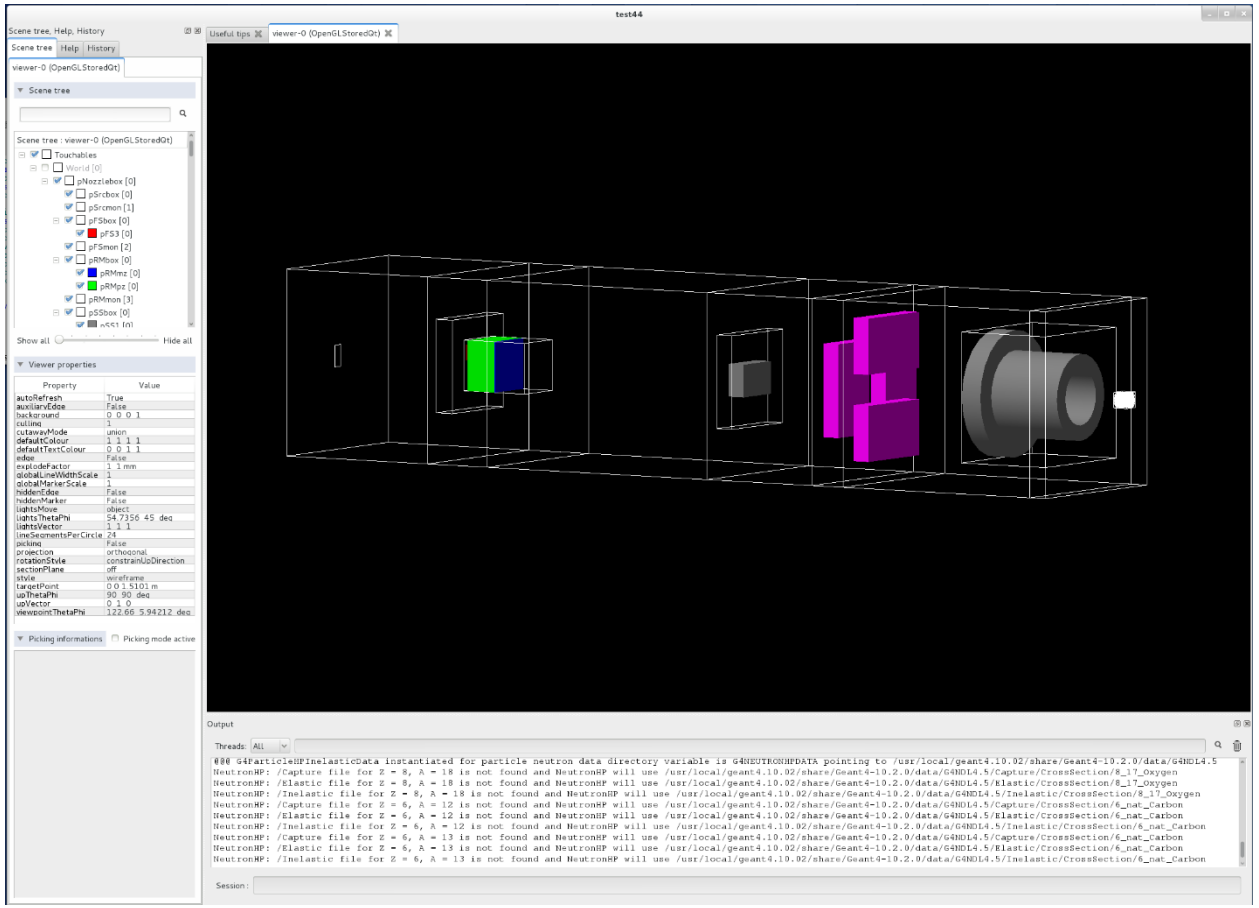
Concentric rings,
Same center, different minimum, maximum radius

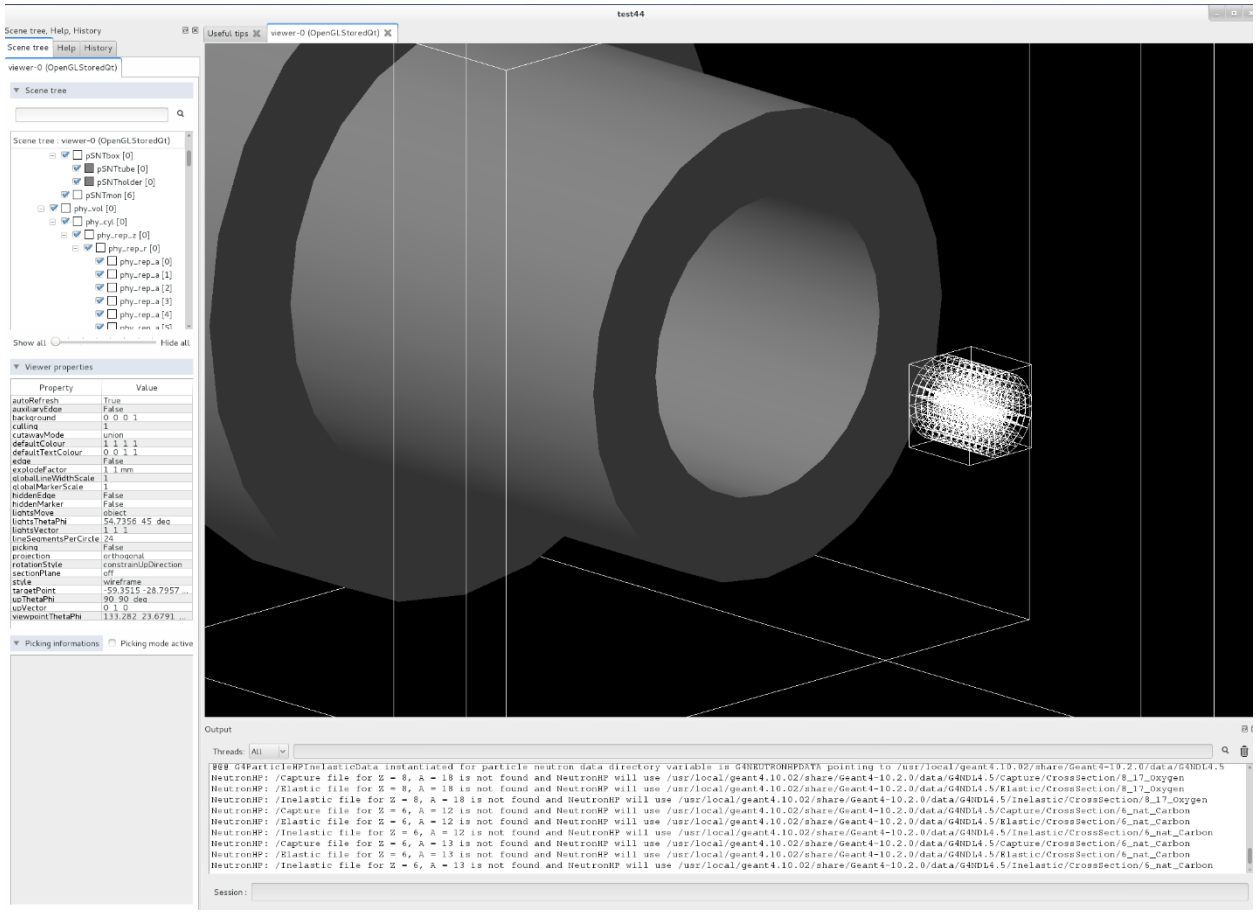


Segments

In a ring, different start angle, delta angle

Visualization of Radial Phantm





Summary

- Now on-going migration to MT compatible
- Relation between Sensitive Volume(G4) and Detector Volume
- Changes depending on EM, Hadron Physics List
- Under developing the Radial Phantom Simulation
- On-going Validation between simulation and measurement about Bragg Peak and SOBP