PROTON BRAGG PEAK AND SCATTERING VALIDATION

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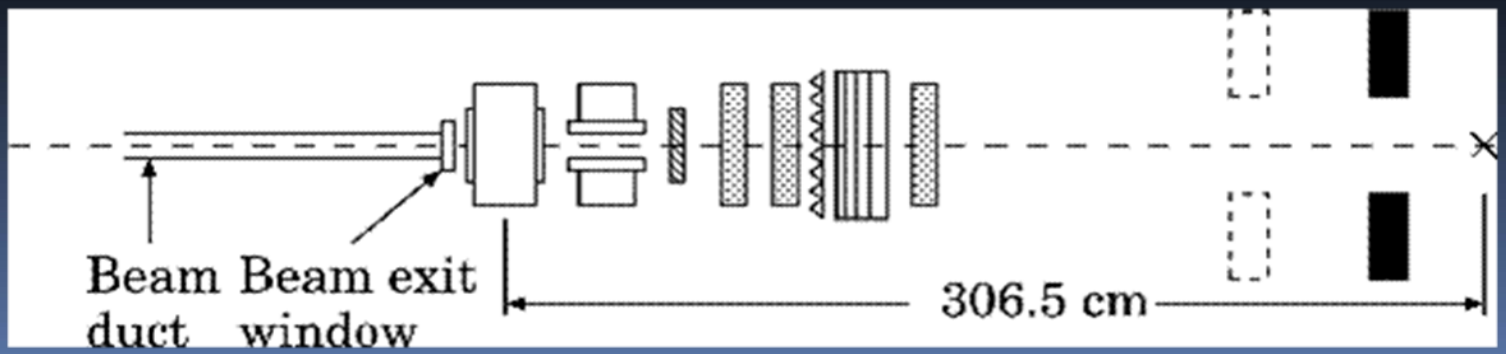
Outline

I. Proton Bragg peak
II. Scattering validation
    I. Comparison between MSC and NR within G4
    II. Comparison with measurement at HIBMC
III. Summary

I Proton Bragg peak
1. Setup(1)

- Beam delivery system (nozzle) at HIBMC
  - Lateral beam spreading devices
    - Wobbler magnets
    - Scatterer
      - Lead for proton
  - ~~Range modulator and degrader~~
    - Not used for this Bragg peak measurements
- Dose was measured in water phantom

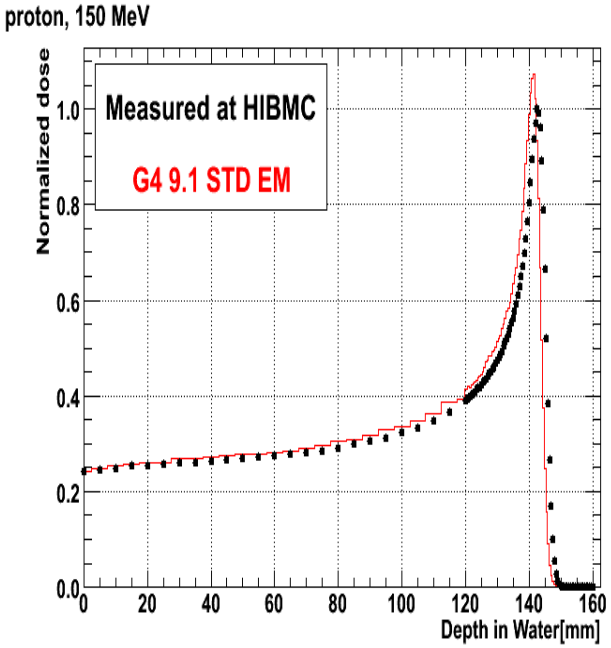


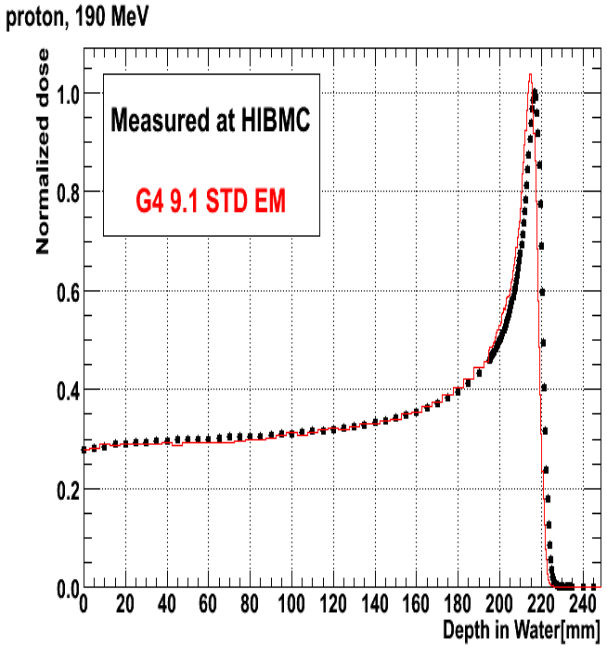
I Proton Bragg peak
1. Setup(2)

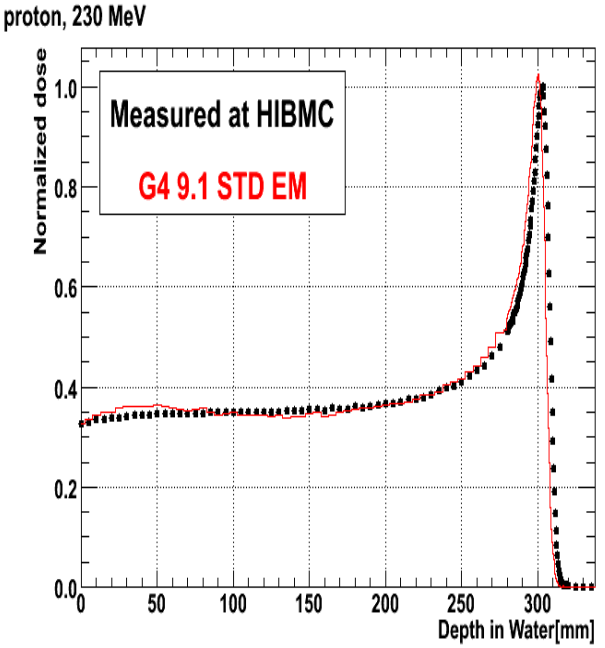
- Geant4 simulation
  - Version : 9.1
  - Standard EM
  - No step limit applied but water phantom was subdived by thin slices of 0.1 mm thickness
  - Range cut in the phantom : 10 micron
  - G4HadronElastic, G4LEProtonInelastic, G4HEProtonInelastic and G4PreCompoundModel were used

I Proton Bragg peak
2. Comparison

- Comparison between G4.9.1 and measurement at HIBMC

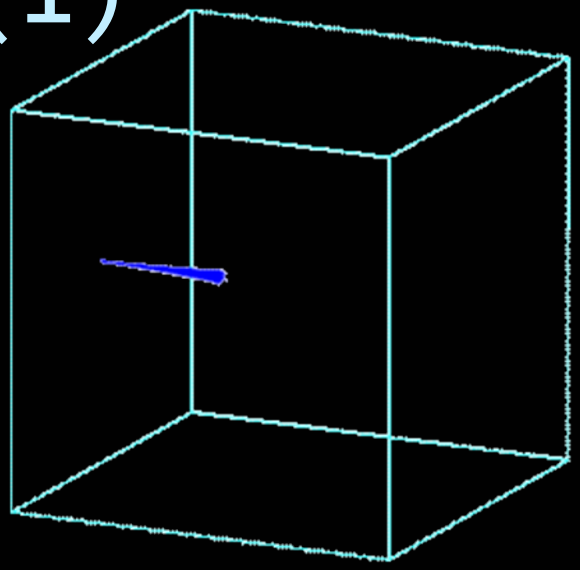


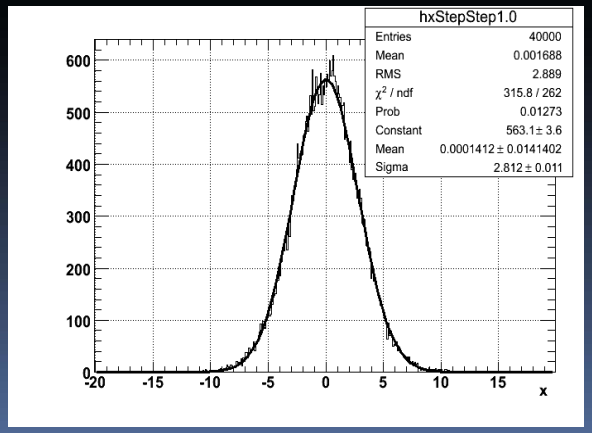




II Scattering validation
1. MSC/NR within G4(1)

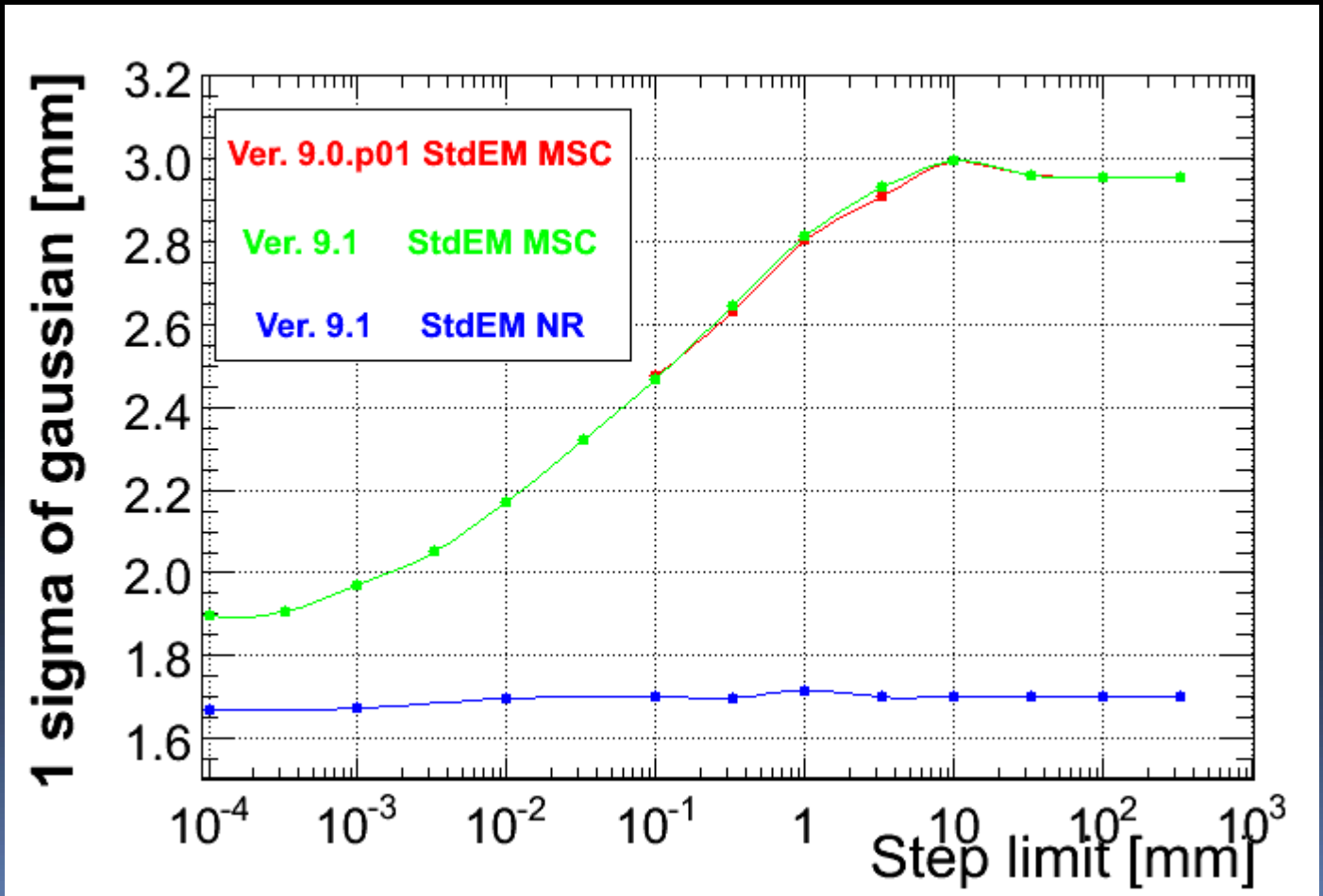
- Setup
  - Simple cubic filled with water
  - Version 9.1
  - 150 MeV proton beam starts from the water surface
  - Standard EM
    - No Hadronic
    - Secondary particles are suppressed
- Beam position is measured on the plane which is 15 cm from the surface
- Compared lateral spread between MSC/NR





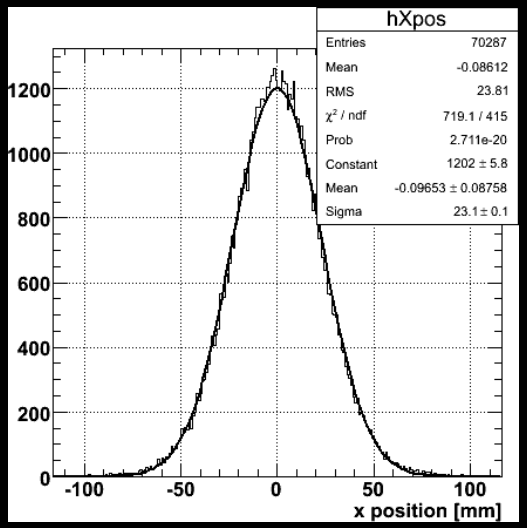
II Scattering validation
1. MSC/NR within G4(2)

- Lateral spread size as a function of step limit



II Scattering validation
2. Comparison with measurement at HIBMC(1)

- Either Lead (1 or 2 or 3 mm thickness) or Polyethylene (2 or 6 or 10 cm) is placed on the beam line
- There are monitors and a window which are fixed
- 150 MeV proton
- Beam position is measured and fitted
- Varied step limit in lead or polyethylene



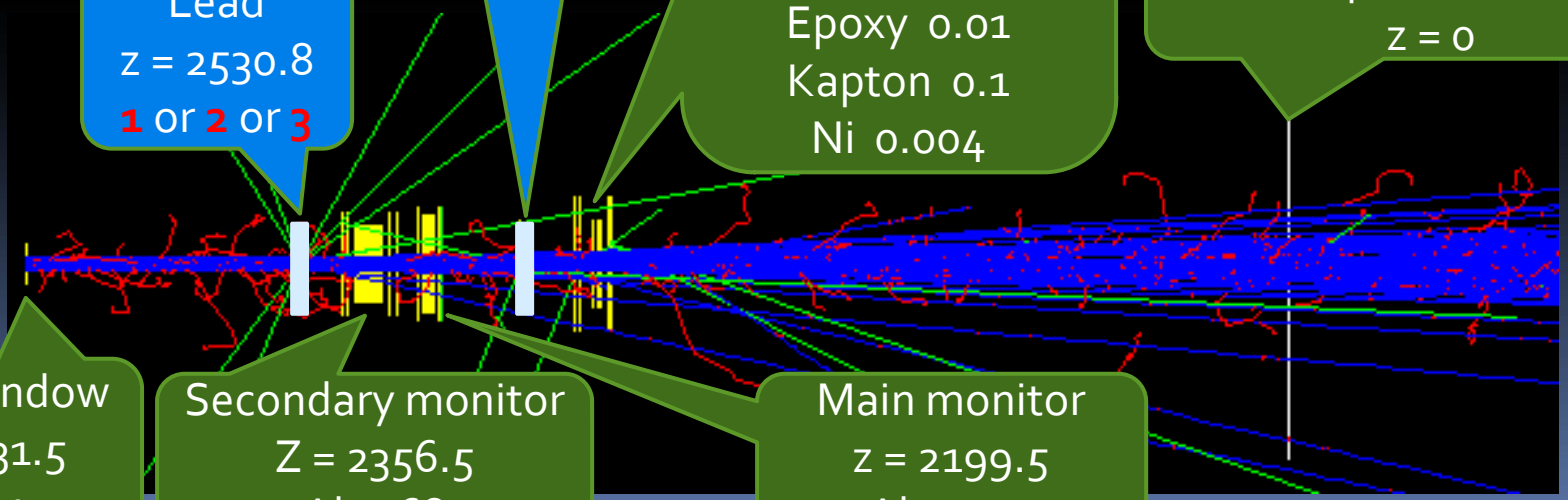
Name
Position[mm]
Thickness[mm]

Polyethylene
z = 1958
20 or 60 or 100

Flatness monitor
z = 1781
Al 0.06
Au 0.002
Cu 0.07
Epoxy 0.01
Kapton 0.1
Ni 0.004

Beam position measured on this plane and fitted
z = 0

Lead
z = 2530.8
1 or 2 or 3



Beam window
Z = 3231.5
Ti 0.1

Secondary monitor
Z = 2356.5
Al 1.68

Main monitor
z = 2199.5
Al 0.105

II Scattering validation

2. Comparison with measurement at HIBMC(2)

- For initial beam lateral beam size at σ_{ini} in the simulation, a value was chosen so that lateral beam sizes w/out lead nor polyethylene matches between G4 and measurement

$$\sigma_{ini}^2 = \sigma_{HIBMC}^2 - \sigma_{G4}^2$$

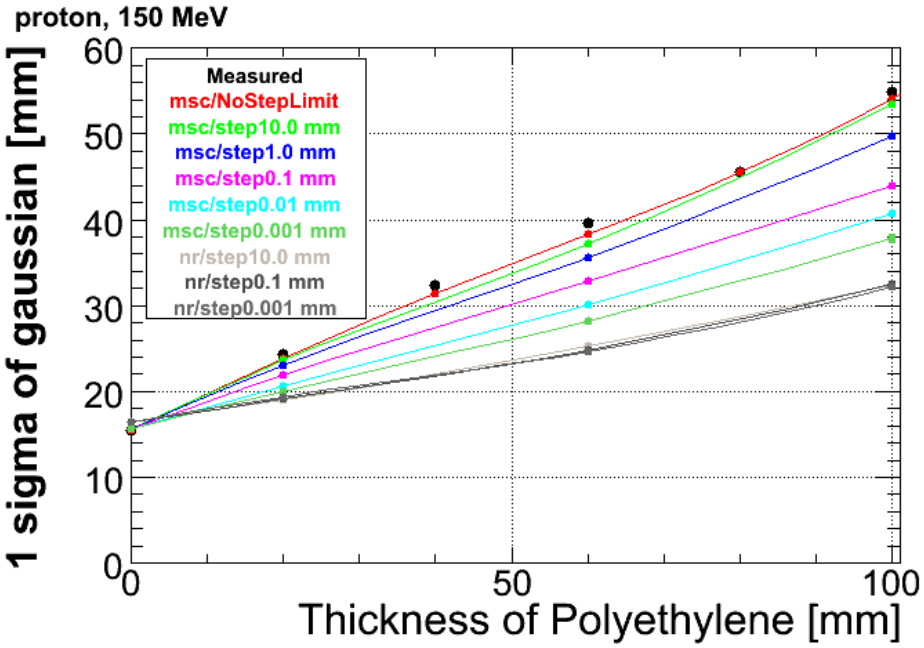
where

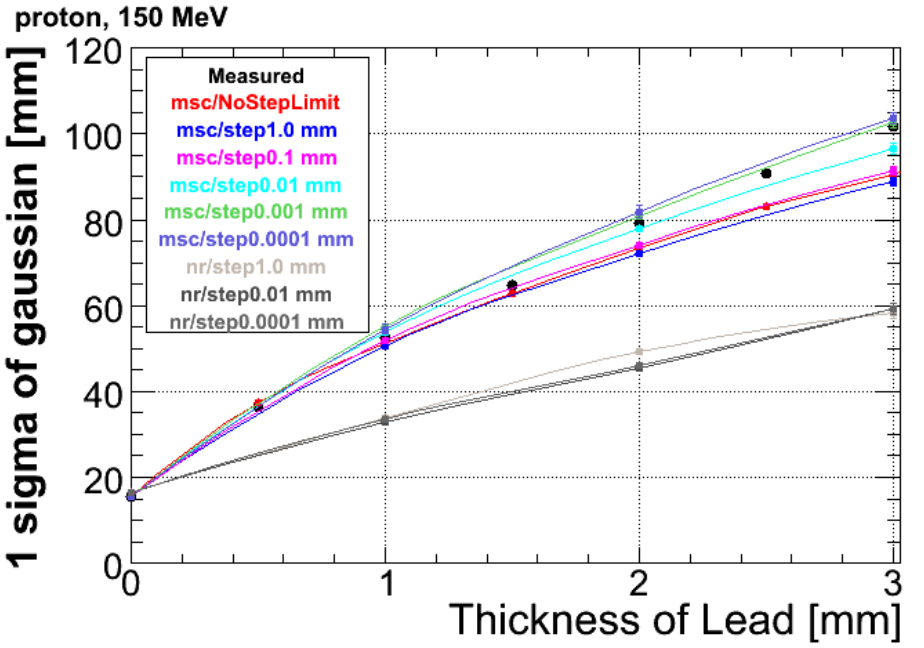
  - σ_{HIBMC} : Lateral beam size measured at HIBMC w/out lead nor polyethylene
  - σ_{G4} : Lateral beam size estimated by G4 w/out lead nor polyethylene

II Scattering validation

2. Comparison with measurement at HIBMC(3)

- Polyethylene and lead show different tendency
  - In polyethylene,
    - MSC with big steps show better agreement with measurement
    - MSC with smaller steps show smaller spread
    - NR is constant against step limit, and gives smaller size of spread
  - In lead
    - Spread sizes less depend on step limit
    - NR is constant against step limit, and gives smaller size of spread





III. Summary

- Bragg peaks by G4 show a little shorter range than measurement at HIBMC for 150, 190 and 230 MeV proton
- Peak/Plateau ratios by G4 are higher than the measurement at HIBMC
- Lateral spread size by MSC depends on step limit
- MSC in polyethylene, big steps agree better than small steps, for 150 MeV proton
- MSC in lead, lateral spread less depends on step limit and small steps show better agreement
- NR is independent of step limit but shows smaller lateral spread for 150 MeV proton