Carbon Ion depth-dose profile in HIBMC facility

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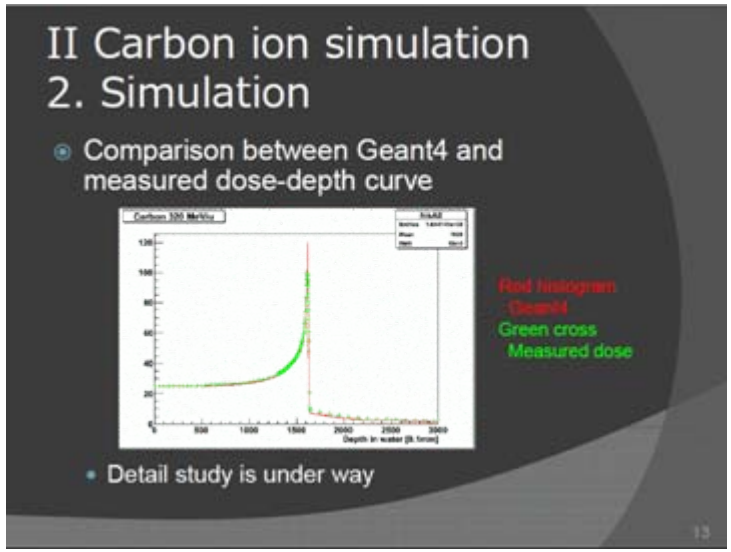
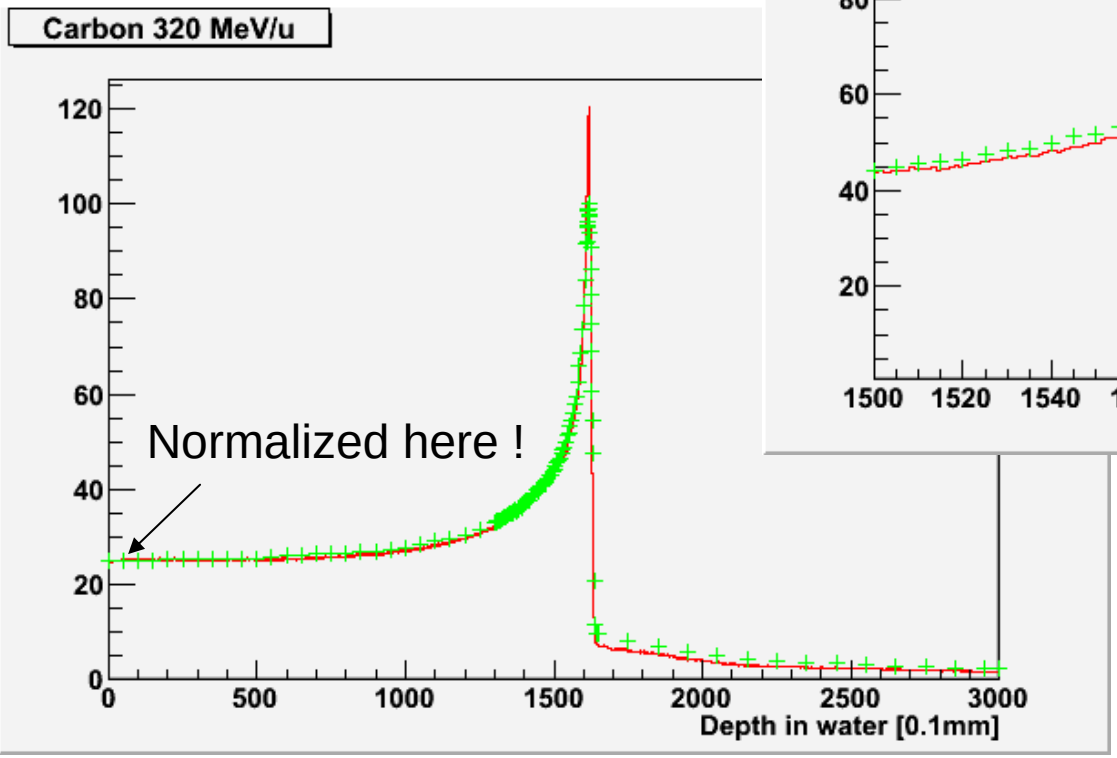
KEK

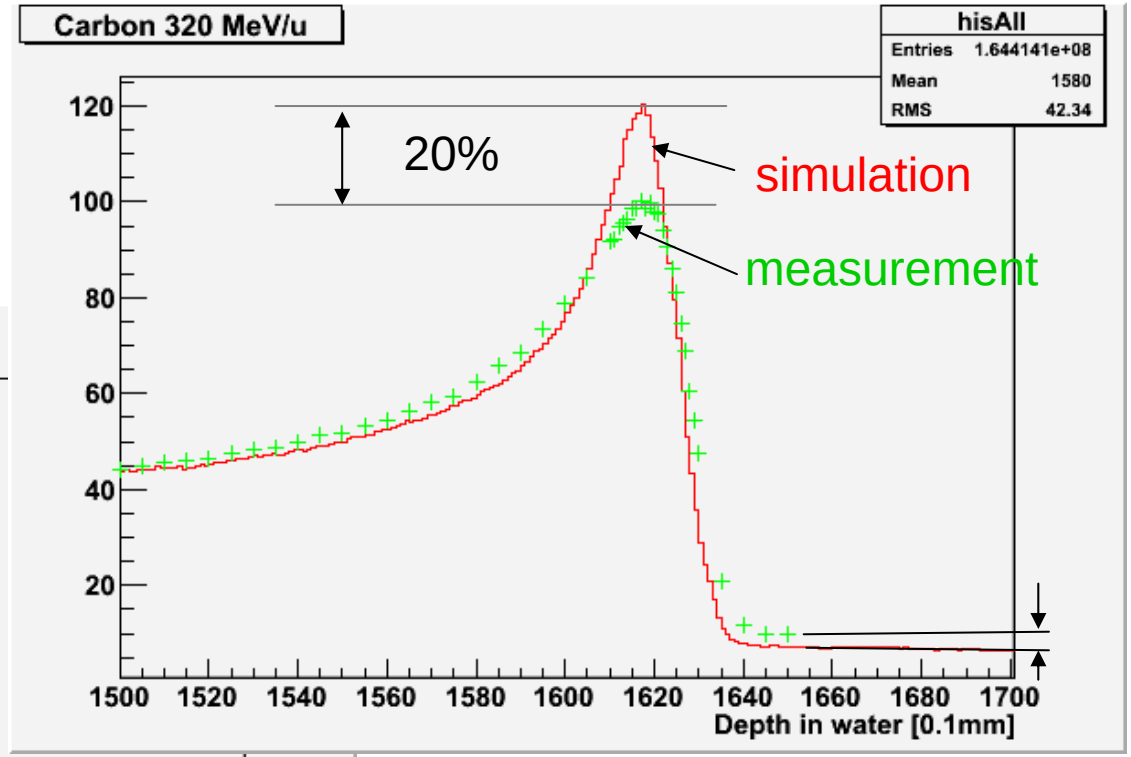
T. Yamashita 13-Sep.
Medical / Gate Applications
Geant4 simulation of HIBMC facility using DICOM
Proton therapy at HIBMC facility
Visualization of CT image and dose in real patients were presented.



Study for Carbon therapy is also underway.
We have realized that to reproduce depth-dose profile for carbon is much more difficult than for proton.

Depth-dose profile





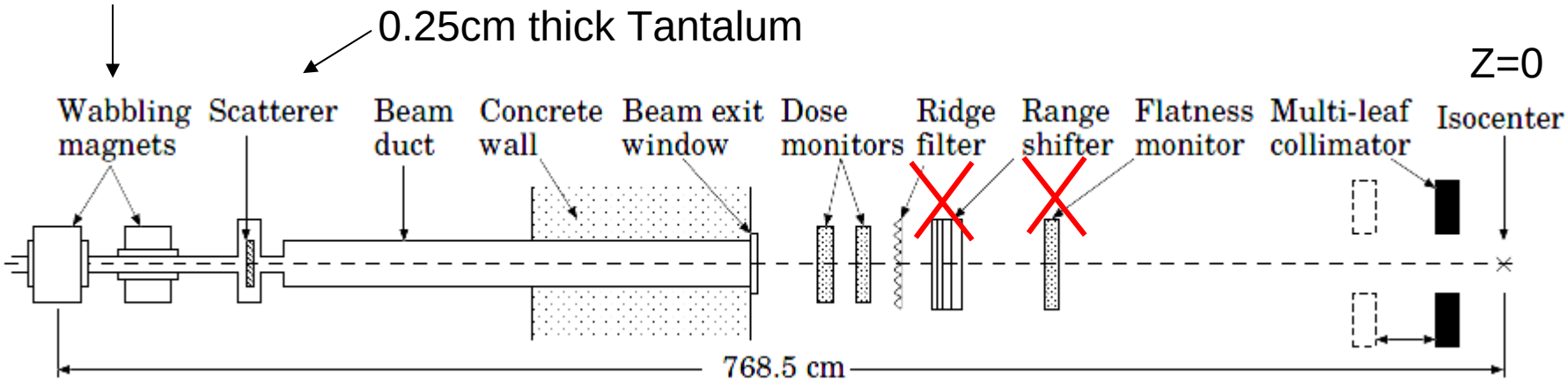
- Width of bragg peak
  EM and hadron physics
- Tail dose
  Hadron physics

4.9.0

Nozzle for carbon at HIBMC facility in Hyogo, Japan

r=10cm at Isocenter

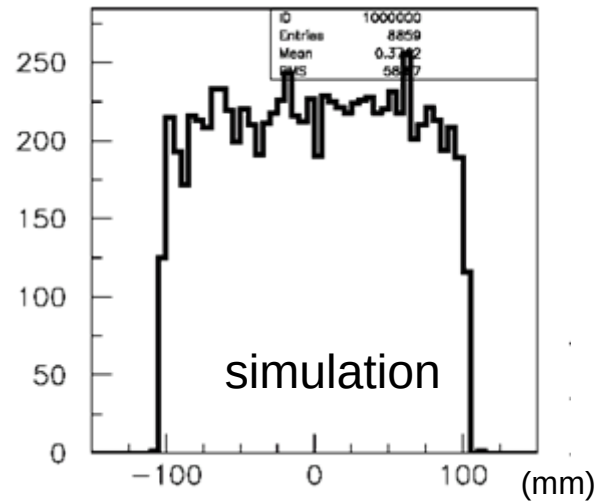
0.25cm thick Tantalum

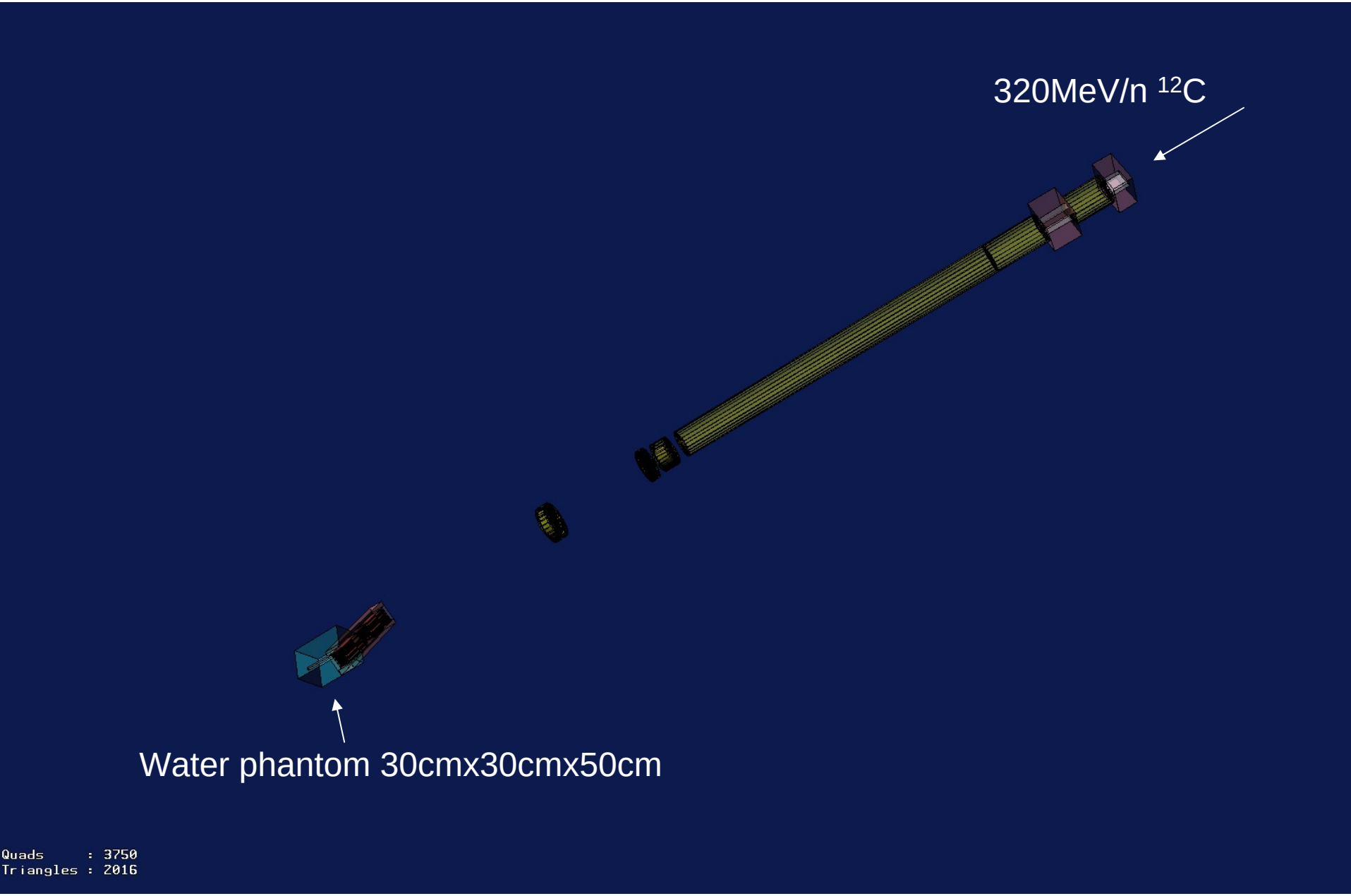


E_{kine}=320MeV/n

$\Delta P/P$=0.1%(FWHM) in simulation

In fact, it is estimated to be±0.02%




320MeV/n ^{12}C
Water phantom 30cmx30cmx50cm
Quads : 3750
Triangles : 2016

Dosimetry

experimental

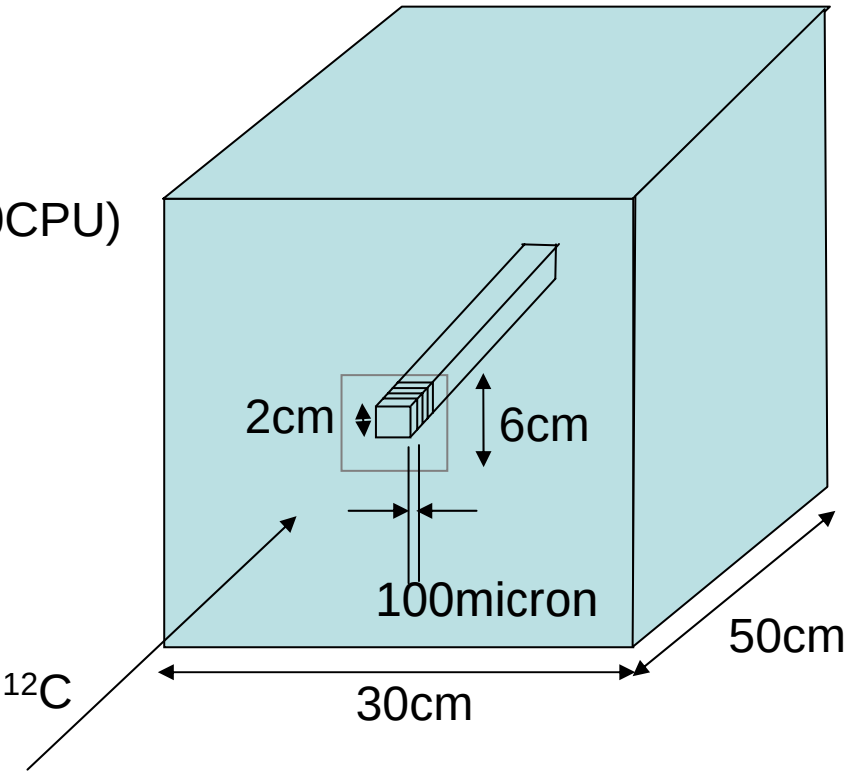
r=0.25cm
depth 0.1cm
vented to air

Moved along beam axis

Simulation

Cross section
- 2cmx2cm for speedup (~6hr with 20CPU)
- 6cmx6cm for further speedup

Thickness
- sensitive detector is sliced into
- 100micron thickness



Configuration

Geant4 version

4.8.2.p01/4.9.0

Physics List

Electromagnetics – LowE G4hLowEnergyionisation

Physics table of dE/dx

SRIM2000p for E<10MeV/n

Physics tables for proton are used for Ions

after scaled by mass and effective charge

```
theProtonIonisation->SetElectronicStoppingPowerModel(G4Proton::Proton(),"SRIM2000p");
theProtonIonisation->SetHighEnergyForProtonParametrisation(10.*MeV);
```

Ion inelastic - Binary cascade with Shen's total cross section

Hadron elastic - G4HadronElasticPhysics("elastic",0,false)

No Ion elastic

Decay $^{8}Be \rightarrow 2alpha$

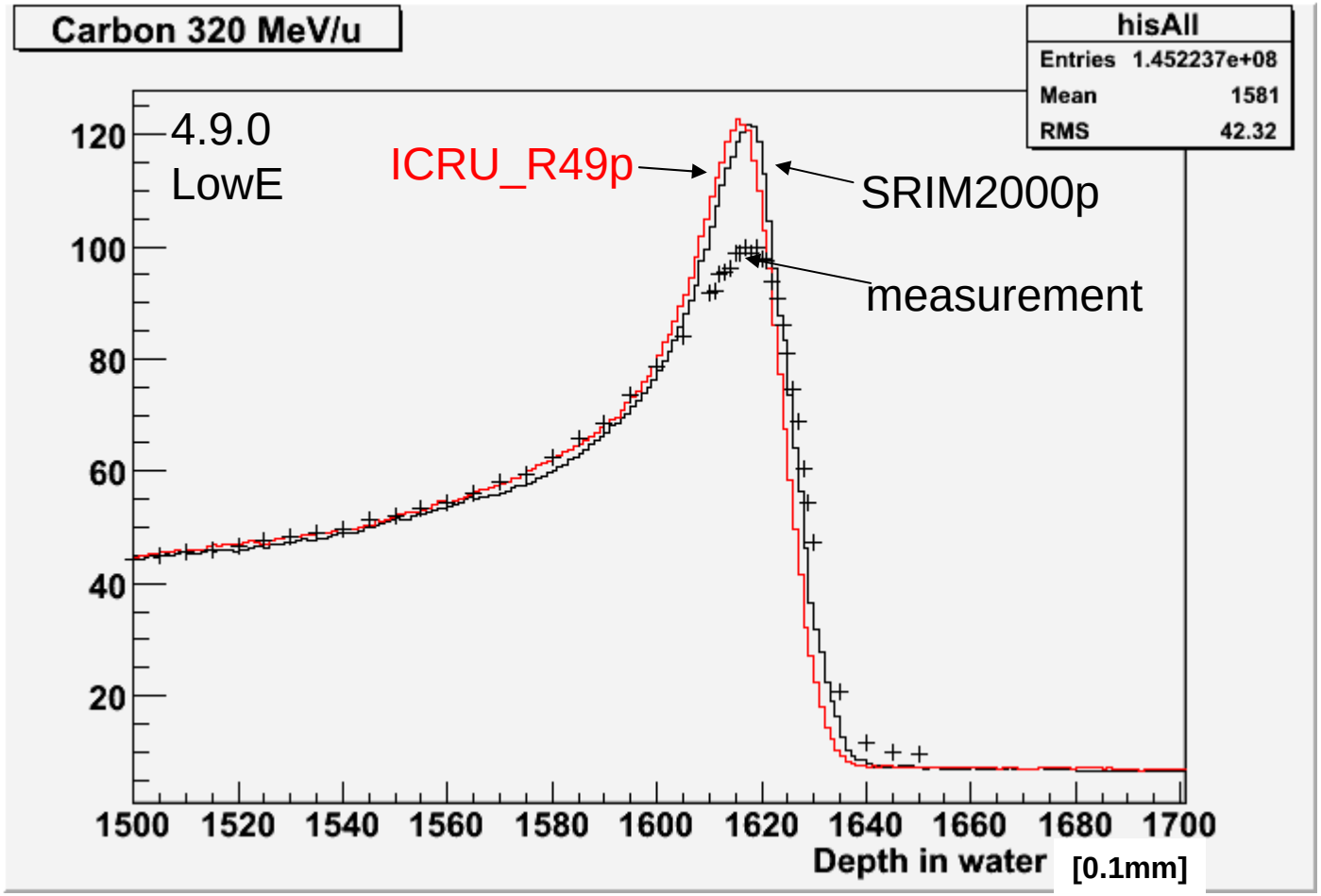
```
G4RADIOACTIVEDATA z4.a8
```

Production cut 1mm (30micron in water phantom)

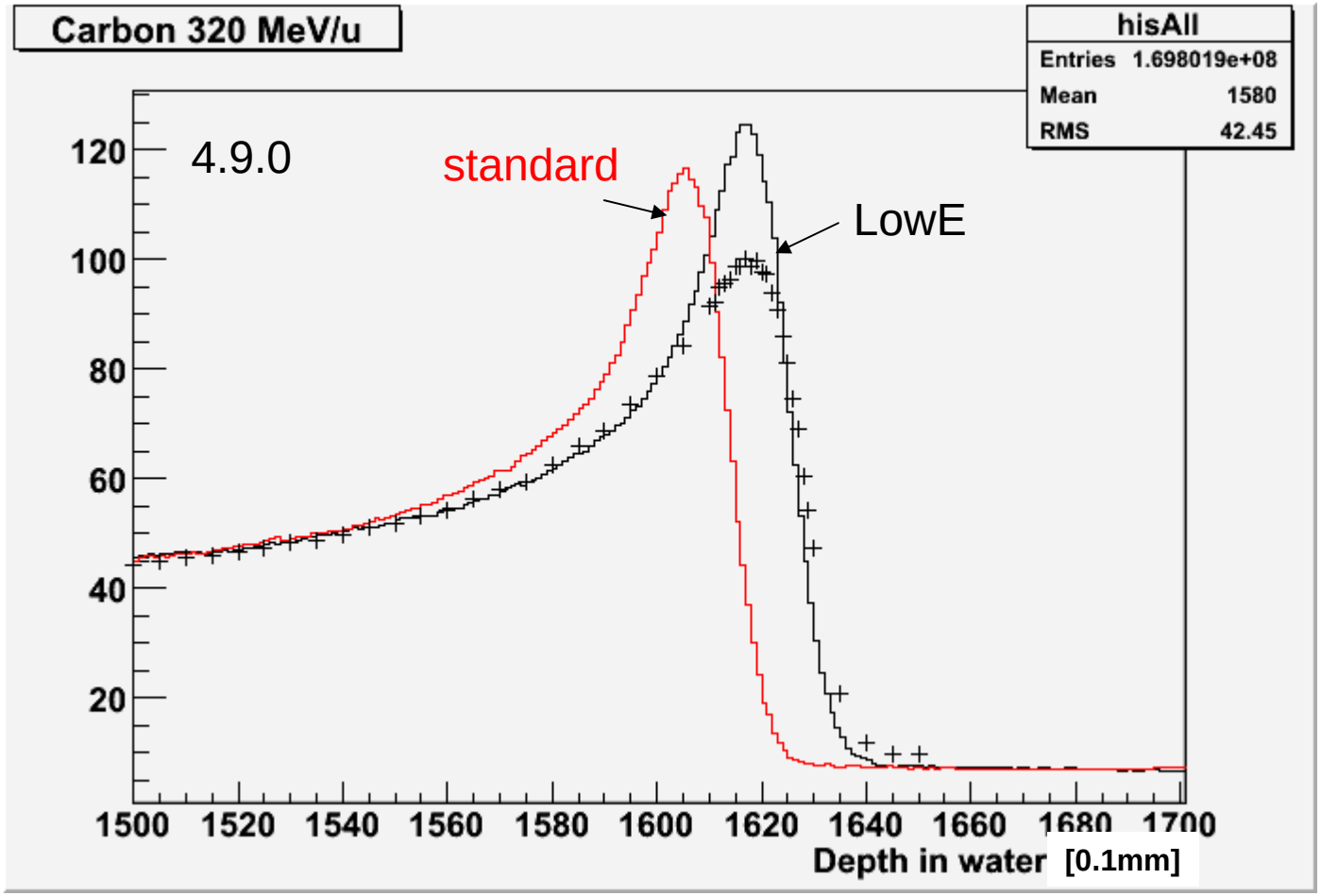
```
/run/setCut 1. mm
/run/SetCutForRegion WaterPhantom 30. micrometer
```

electromagnetics

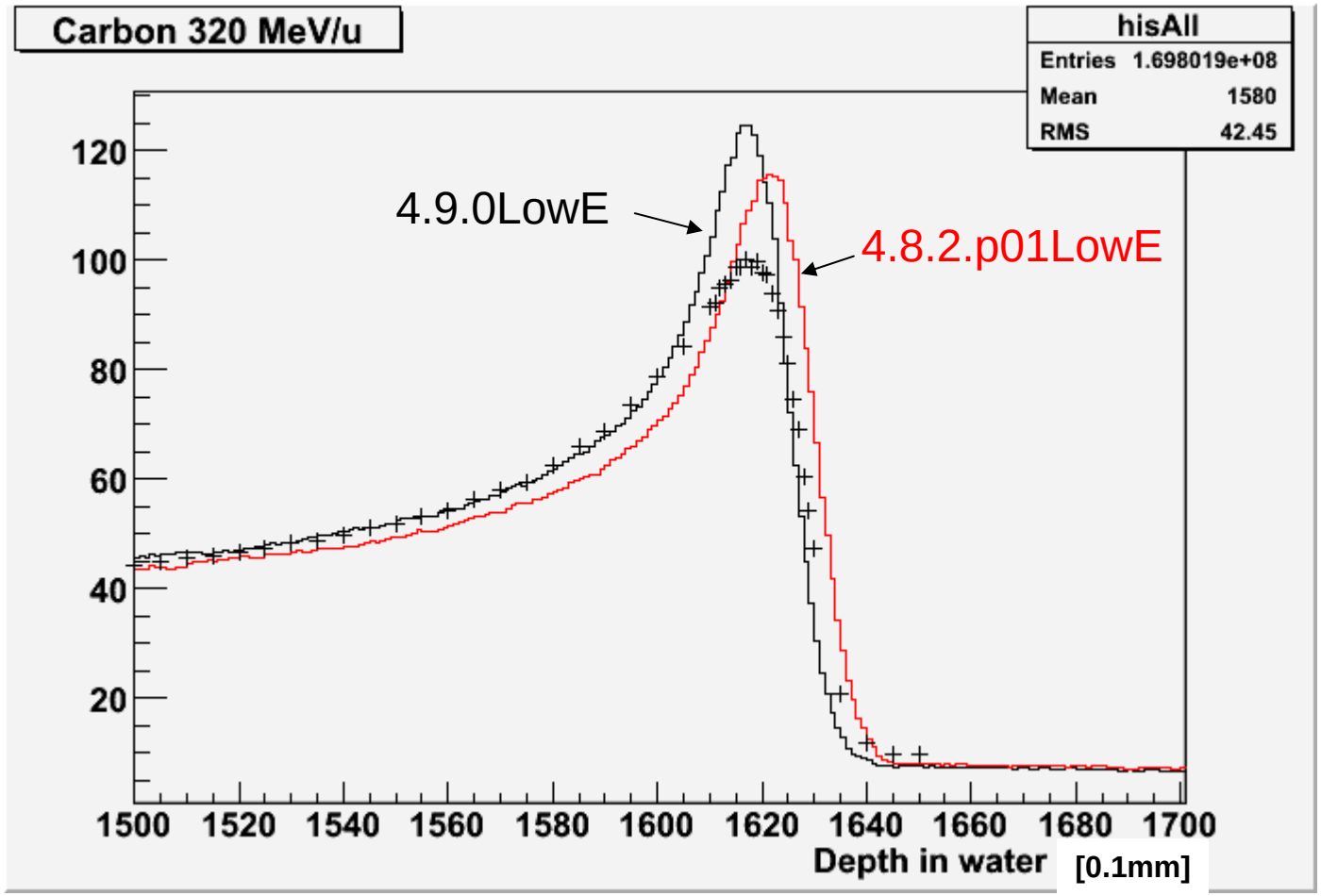
ICRU_R49p for E<2MeV/n
vs. SRIM2000p for E<10MeV/n



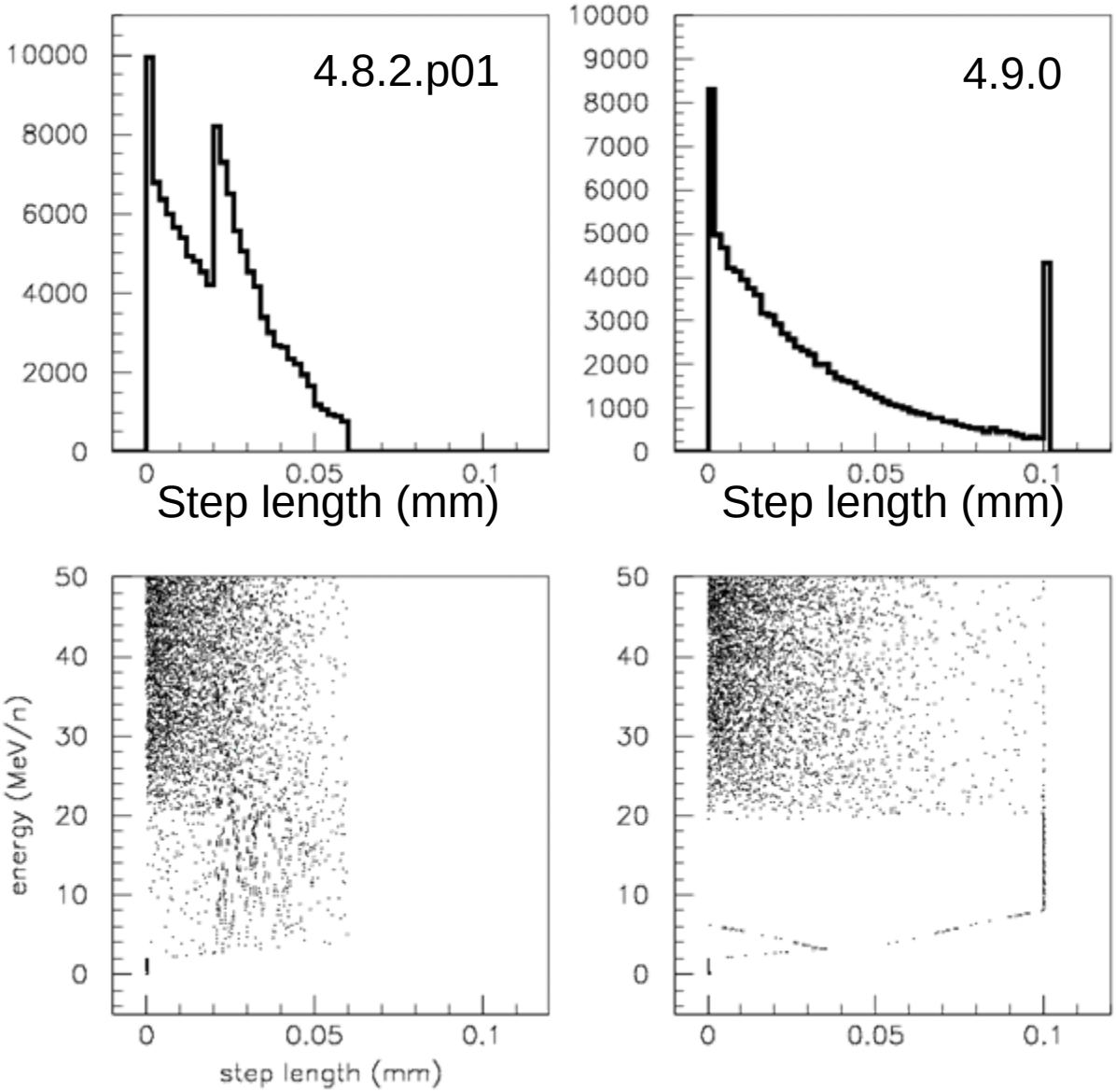
Standard EM vs. LowE



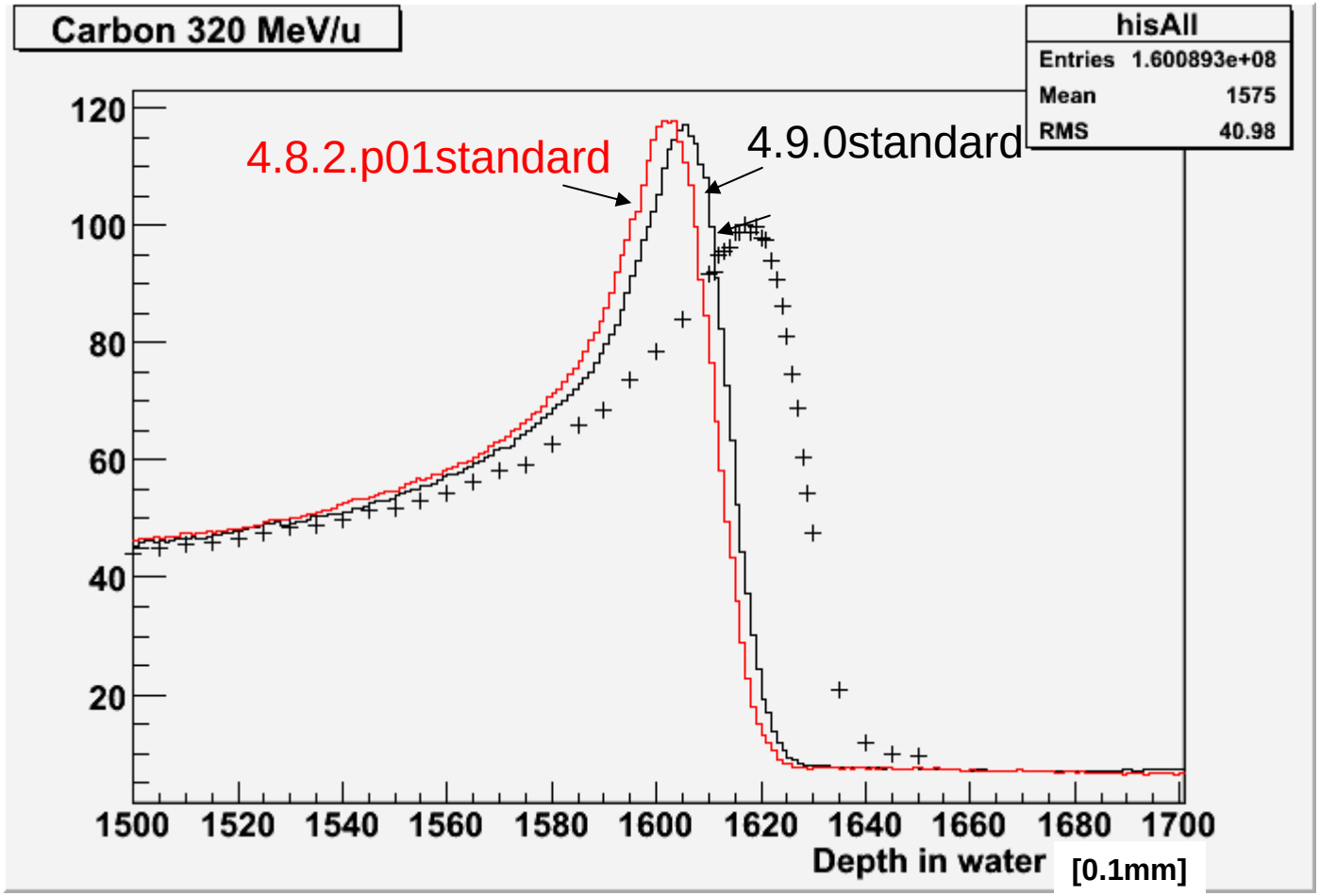
4.8.2.p01 LowE vs. 4.9.0 LowE



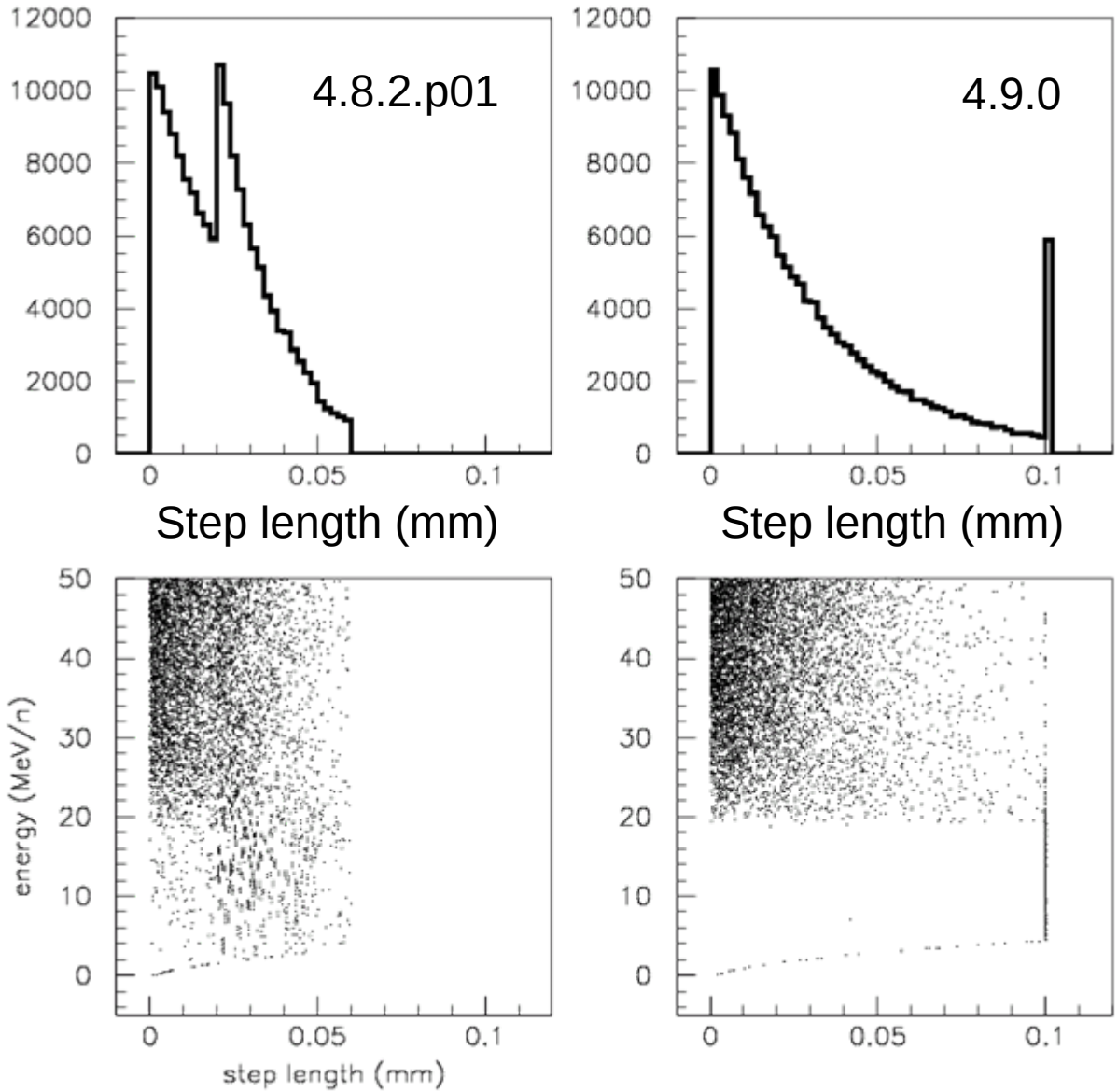
Step length in LowE



4.8.2.p01 Std vs. 4.9.0 Std

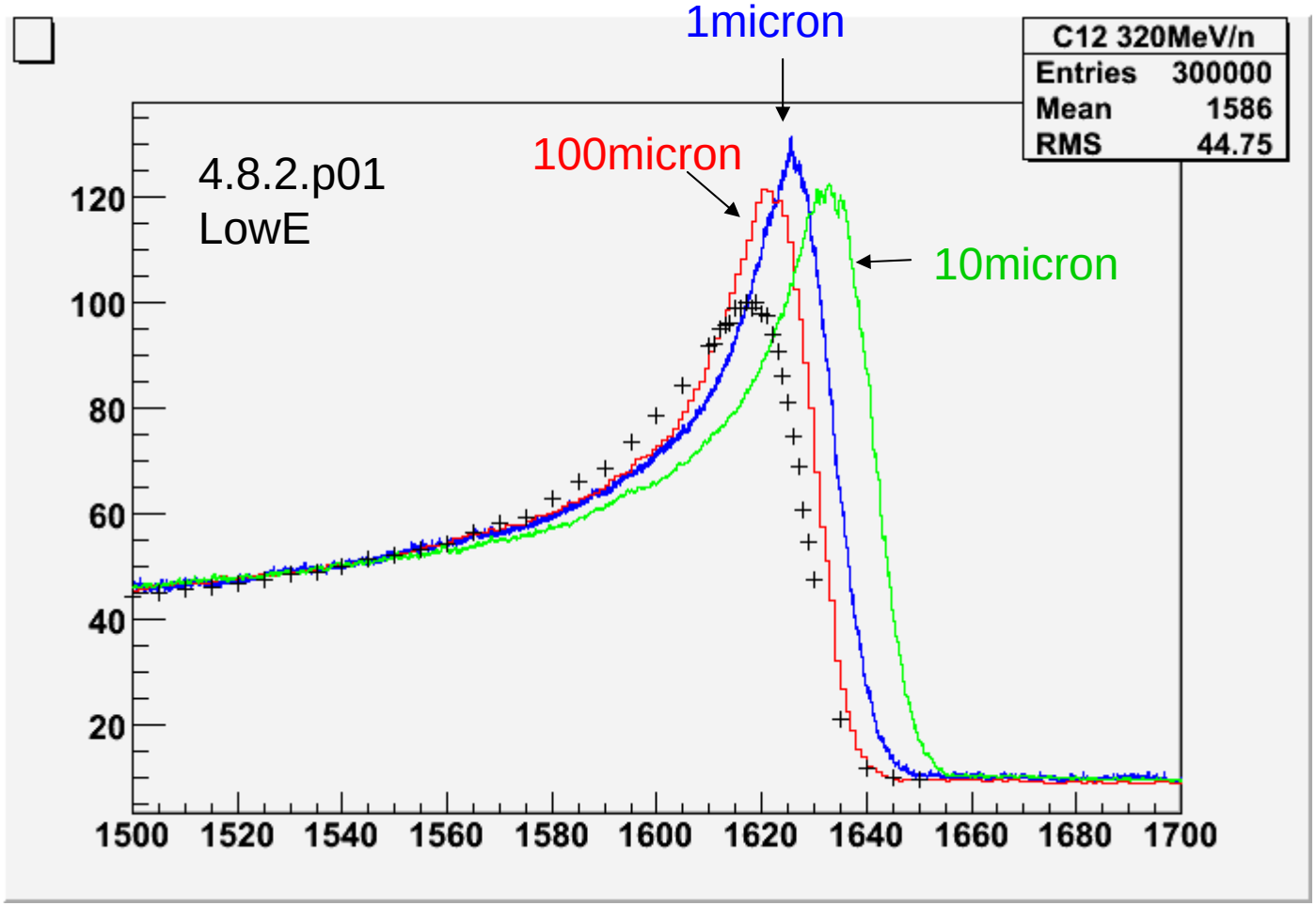


Step length in Standard EM



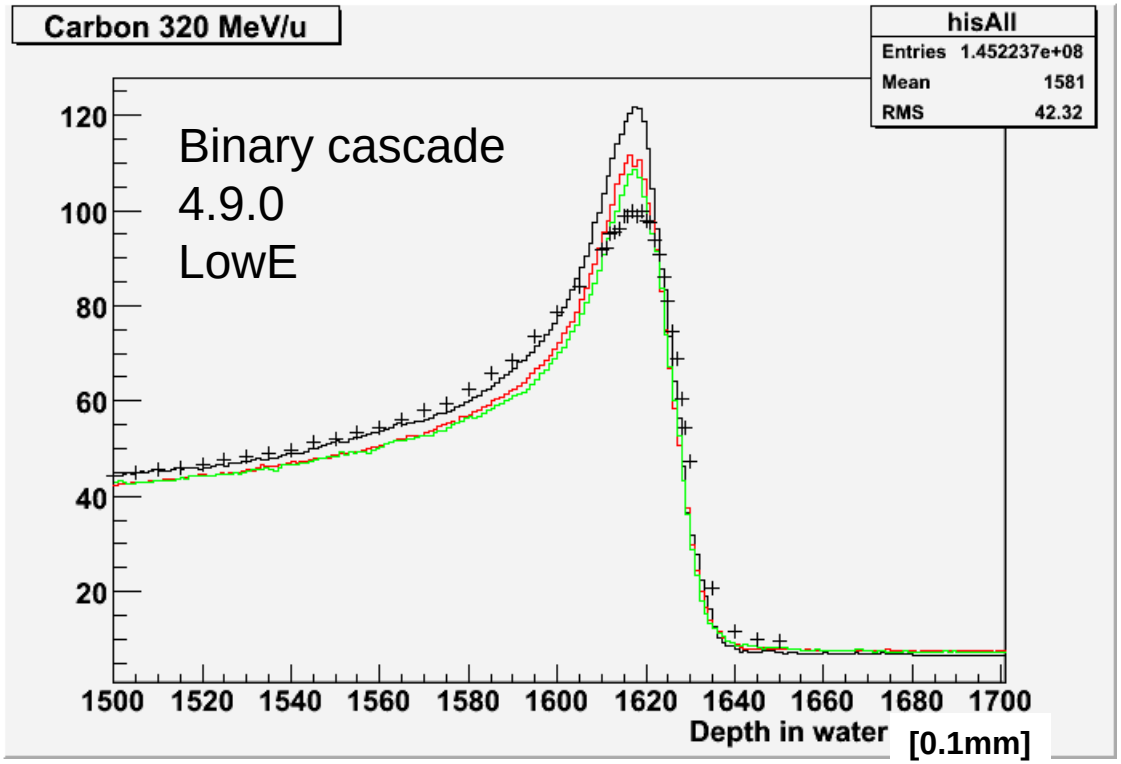
Thickness of slice

Step length is limited by thickness of slice

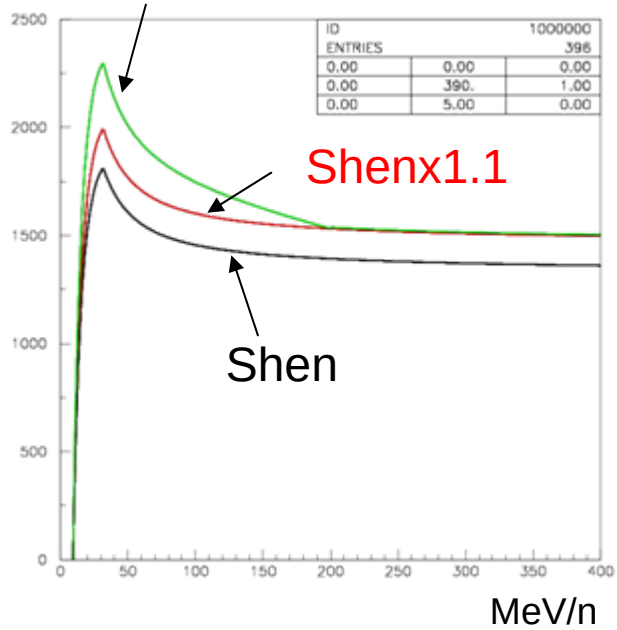


Ion inelastic / elastic

Total cross section

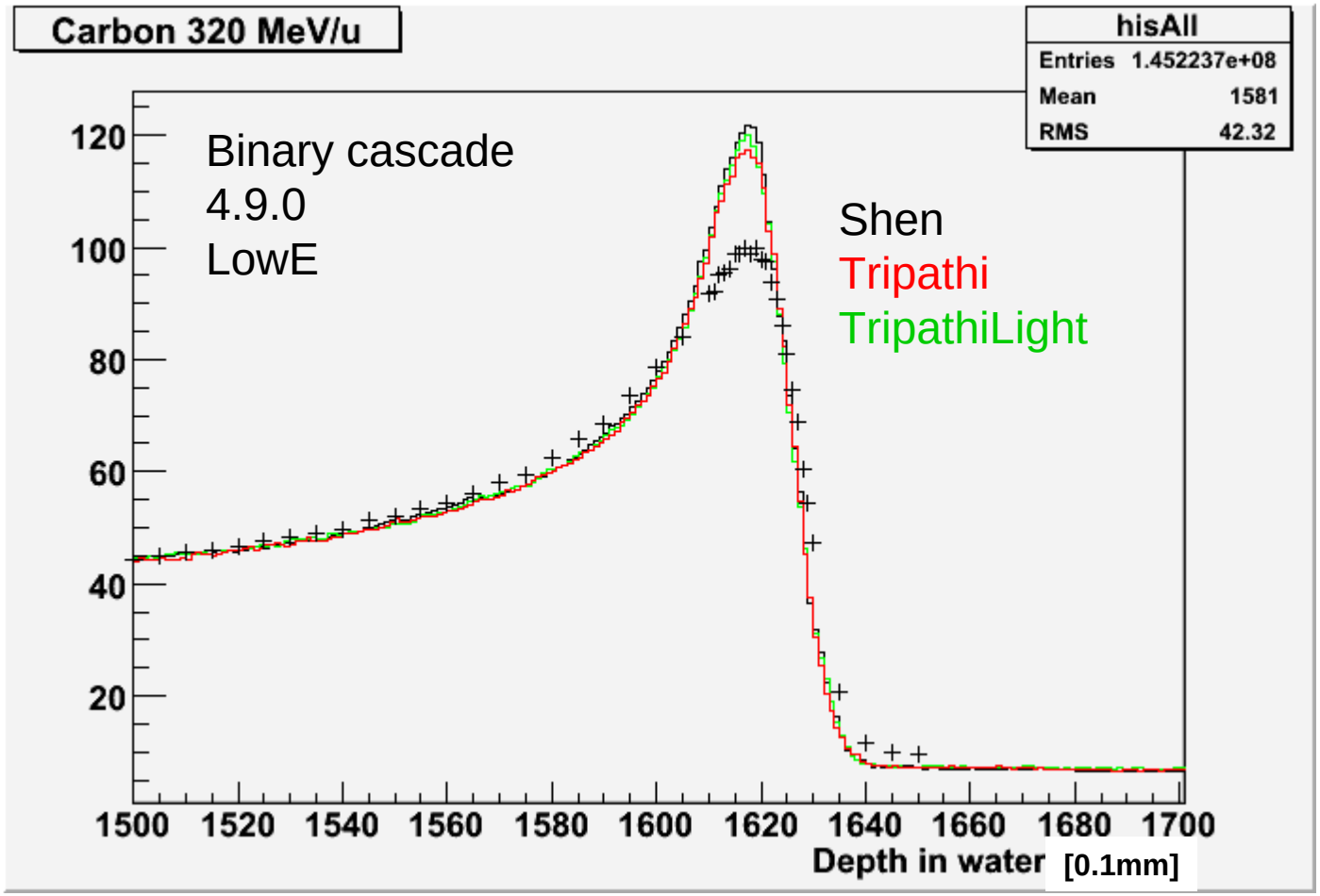


Enhanced at LowE



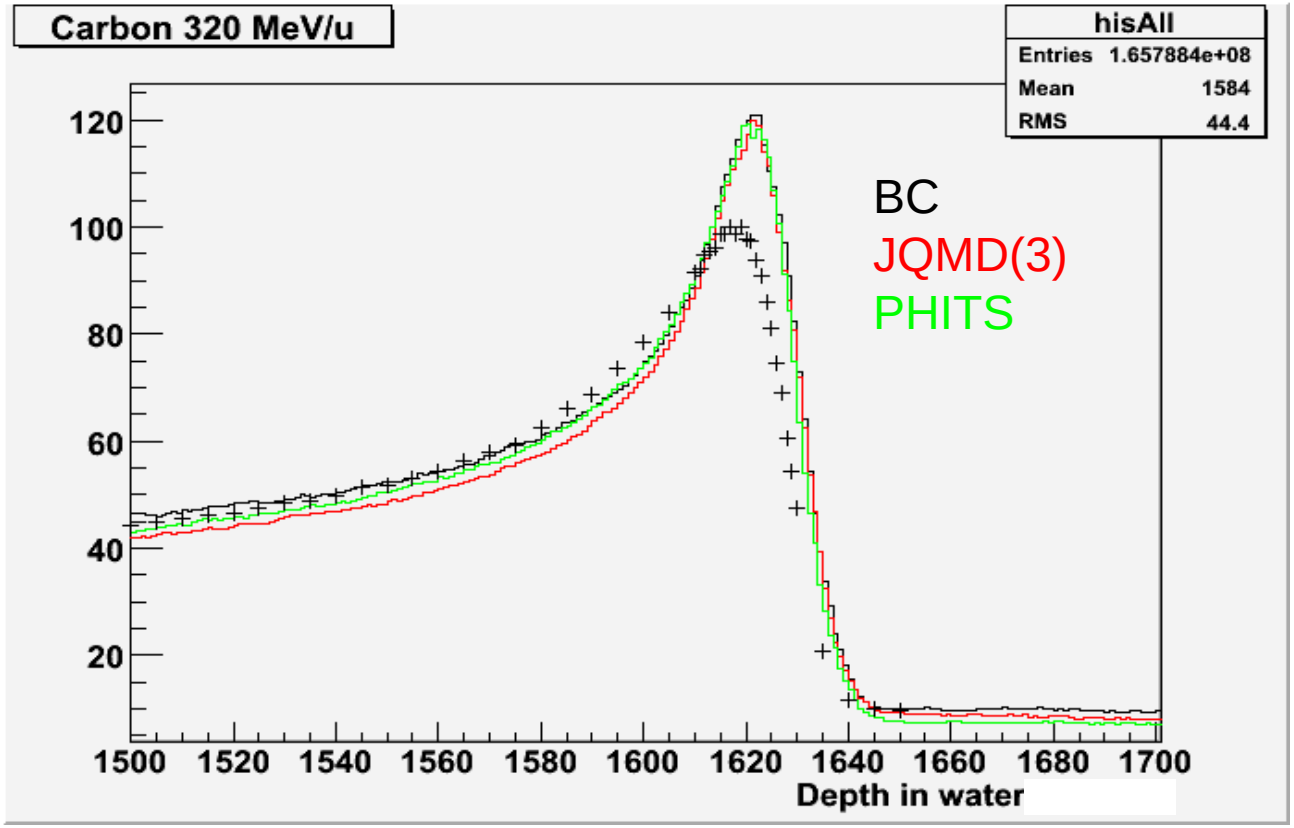
6cmx6cm rightMLCpos 4.9.0

Shen vs. Tripathi vs. TripathiLight



6cmx6cm rightMLCpos 4.9.0

BC vs. JQMD vs. PHITS



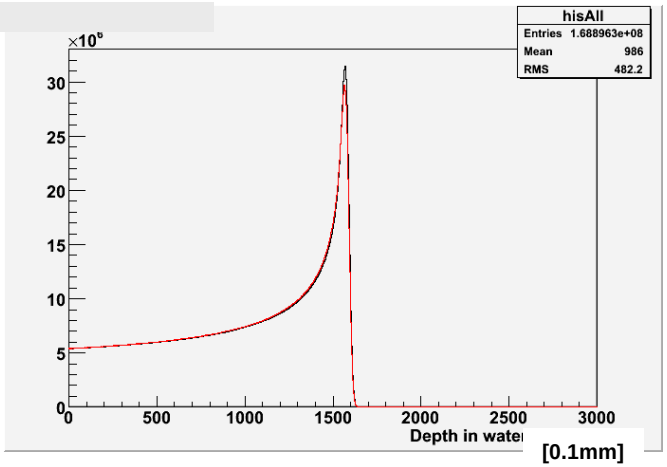
Ion elastic

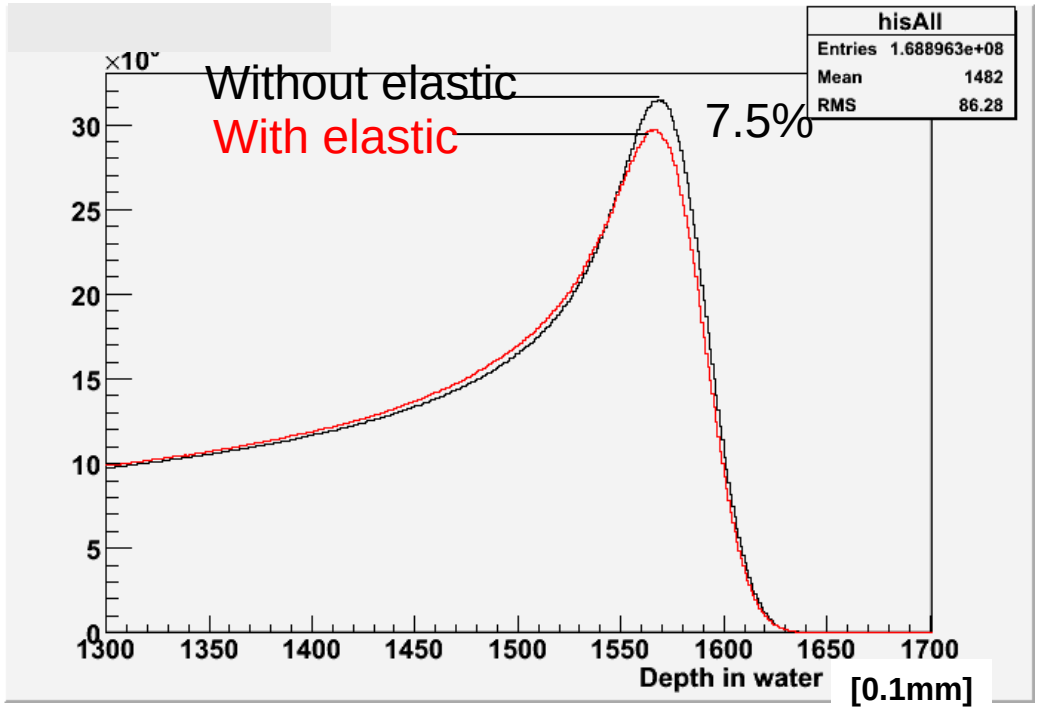
Collaborative work with T.Koi

JQMD can treat elastic process as peripheral collision.
A version to manipulate JQMD to simulate elastic process
was developed by T.Koi and tested.

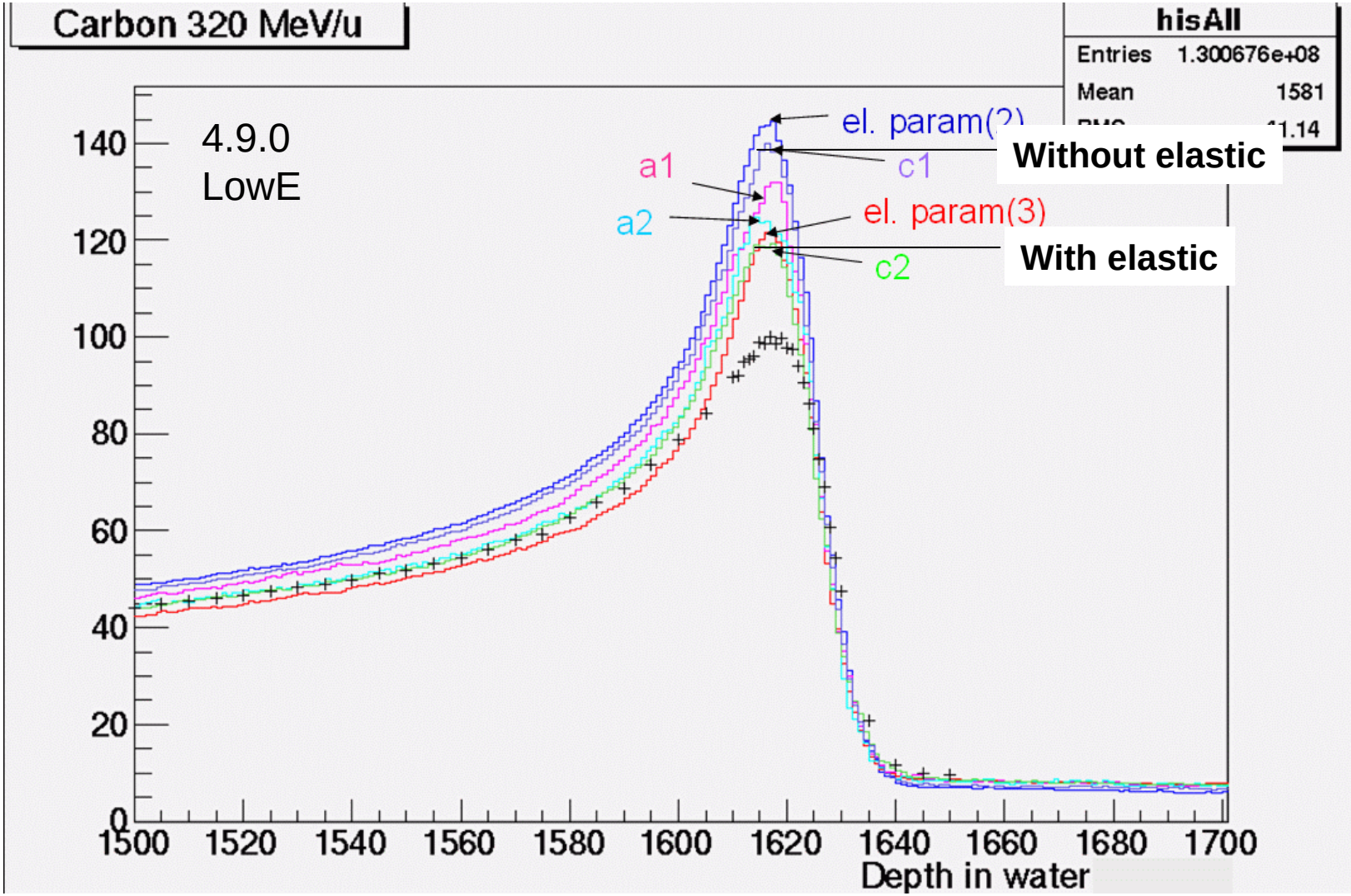
```
JTri->SetEnhanceFactor(1.0);
                    multiplication factor against Tripathi Cross Section
gionInelasticModel->SetSDMEMin(2*MeV);
                    minimum excitation energy treated by statistical process
                                                    1MeV:default
gionInelasticModel->SetPeripheralFactor(1.2);
                    multiplication factor against Tripathi Cross Section to derive
                    maximum of impact parameter
gionInelasticModel->SetElasticParameter (2);
                    region to judge the collision as elastic
                                                    2:default
```

Elastic (150MeV proton)





Ion elastic

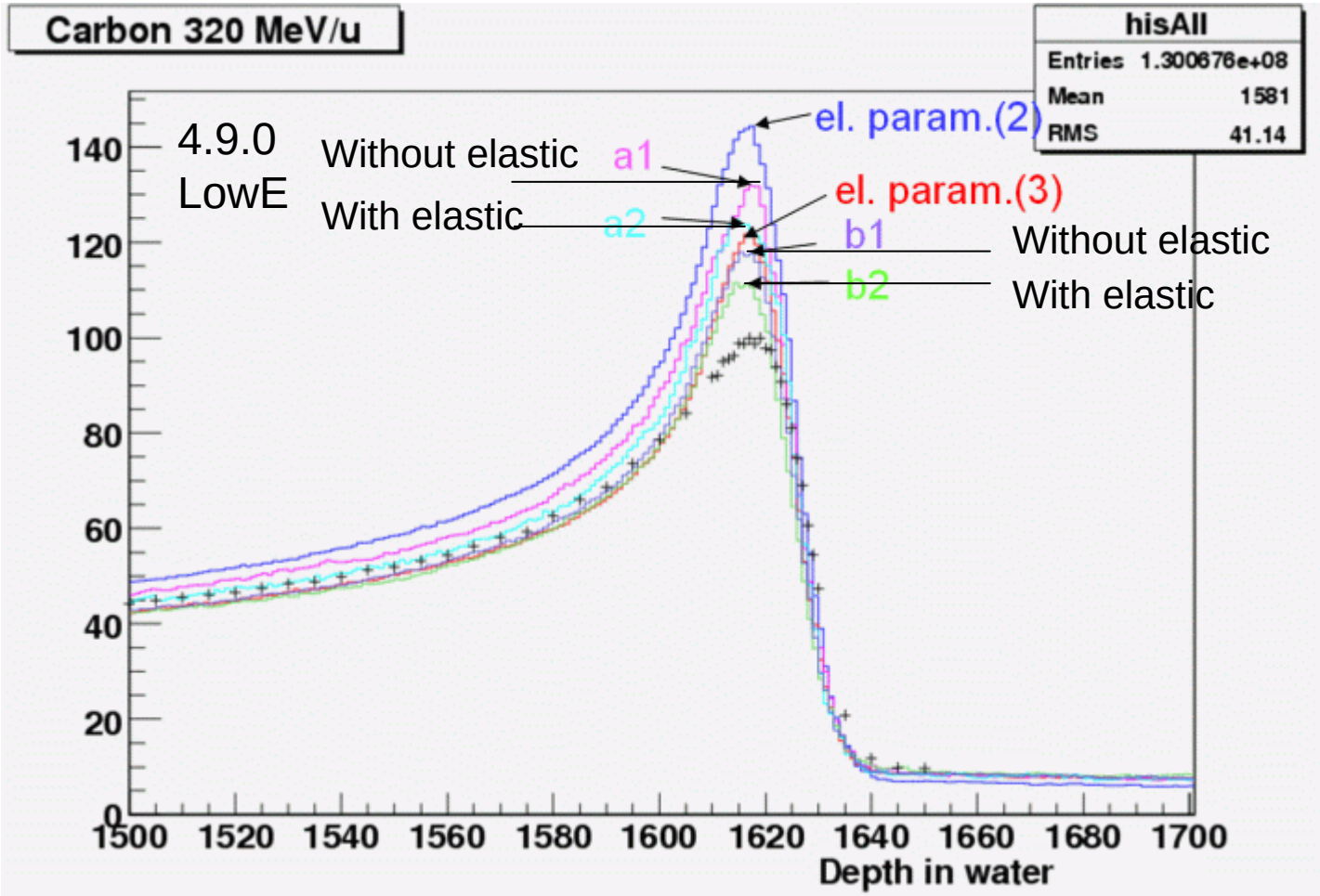

Carbon 320 MeV/u
hisAll
Entries 1.300676e+08
Mean 1581
4.9.0
LowE
el. param(2)
c1
Without elastic
a1
a2
el. param(3)
With elastic
c2
140
120
100
80
60
40
20
0
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
Depth in water

Summary

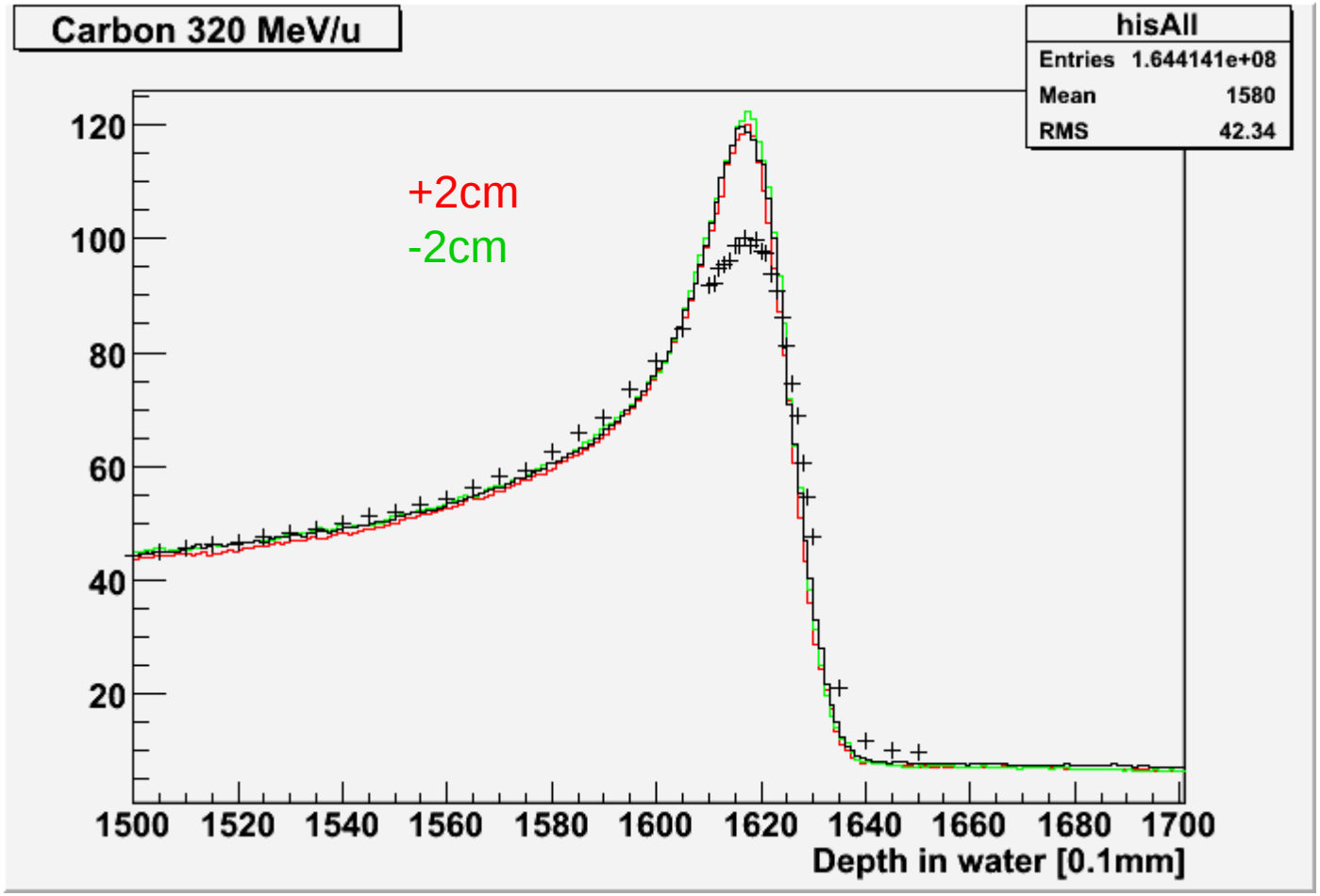
- No configuration to reproduce the height of Bragg peak in HIBMC facility has not been found so far.
- Both electromagnetics and Ion inelastic/elastic process significantly affect the depth-dose profile.
- More systematic study in electromagnetics is needed.
- Ions elastic process will be improved.
- We need more experimental data for cross check.
- I welcome any idea or suggestion.

Ion elastic

Collaborative work with T.Koi

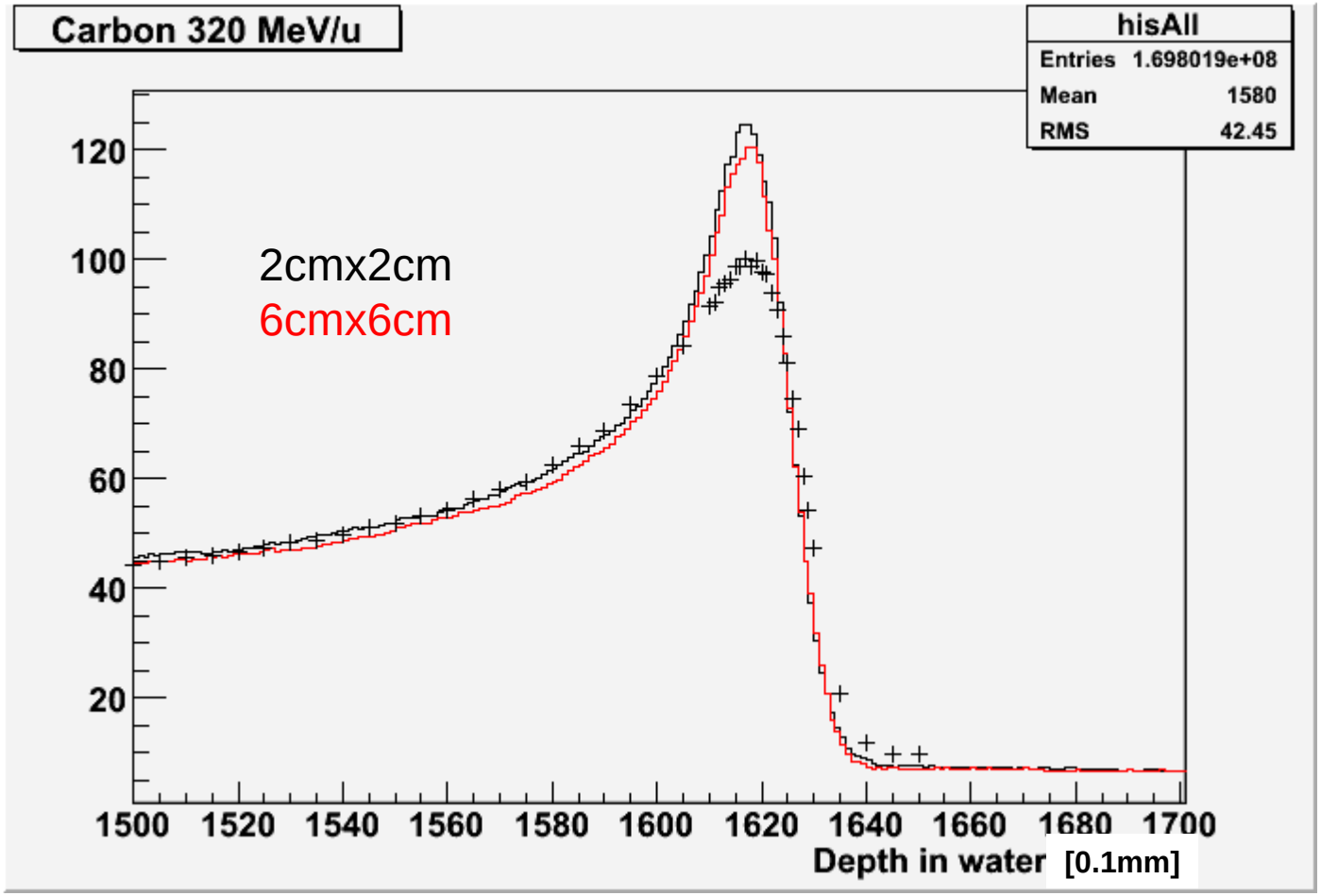


Detector position



2cmx2cm rightMLCpos

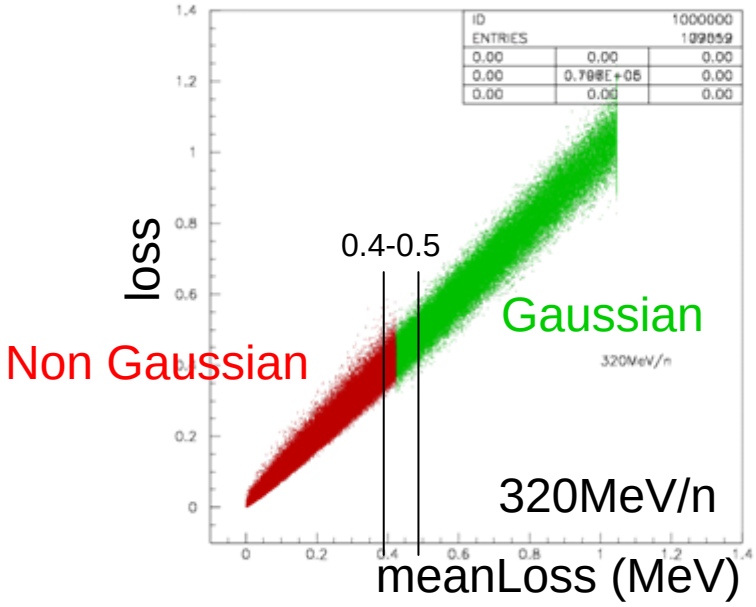
Detector size

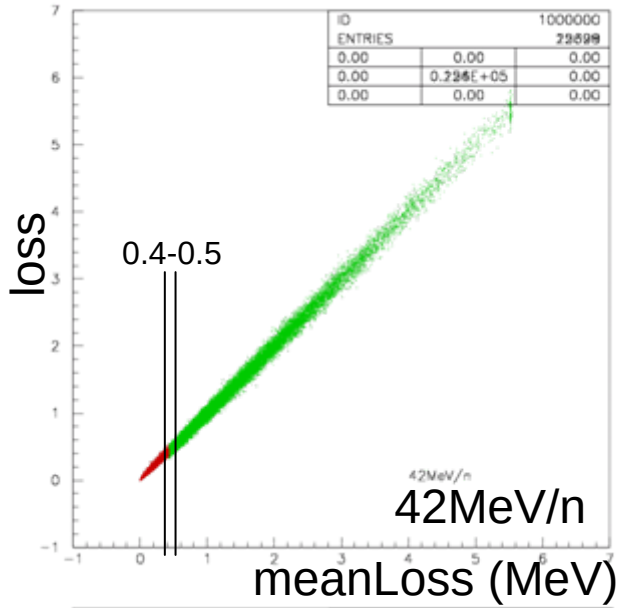


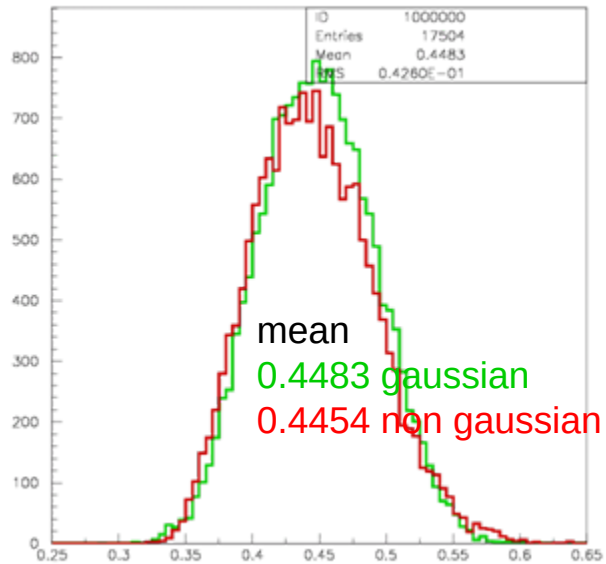
G4hLowEnergyIonisation.cc

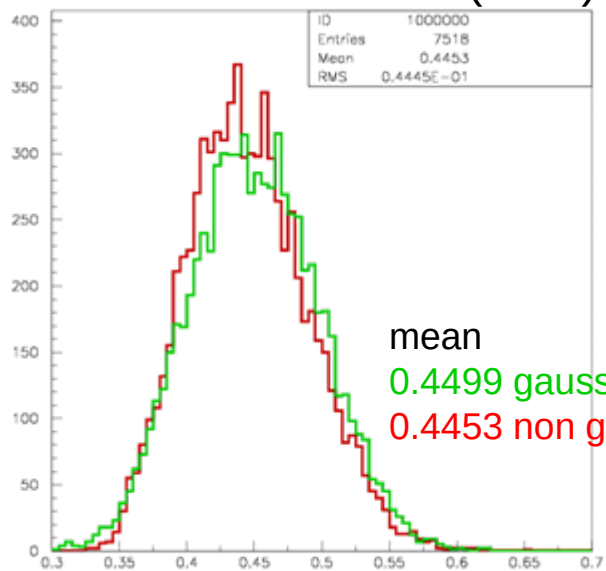
```
G4double G4hLowEnergyIonisation::ElectronicLossFluctuation(
                const G4DynamicParticle* particle,
                const G4MaterialCutsCouple* couple,
                G4double meanLoss,
                G4double step) const
{
……..
……..
……..
// Gaussian fluctuation
if(meanLoss > kappa*tmax || tmax < kappa*ipotFluct )
{
……..
……..
……..
                return loss;
}

// Non Gaussian fluctuation
……..
……..
……..
return loss;
}
```

Energy loss fluctuation

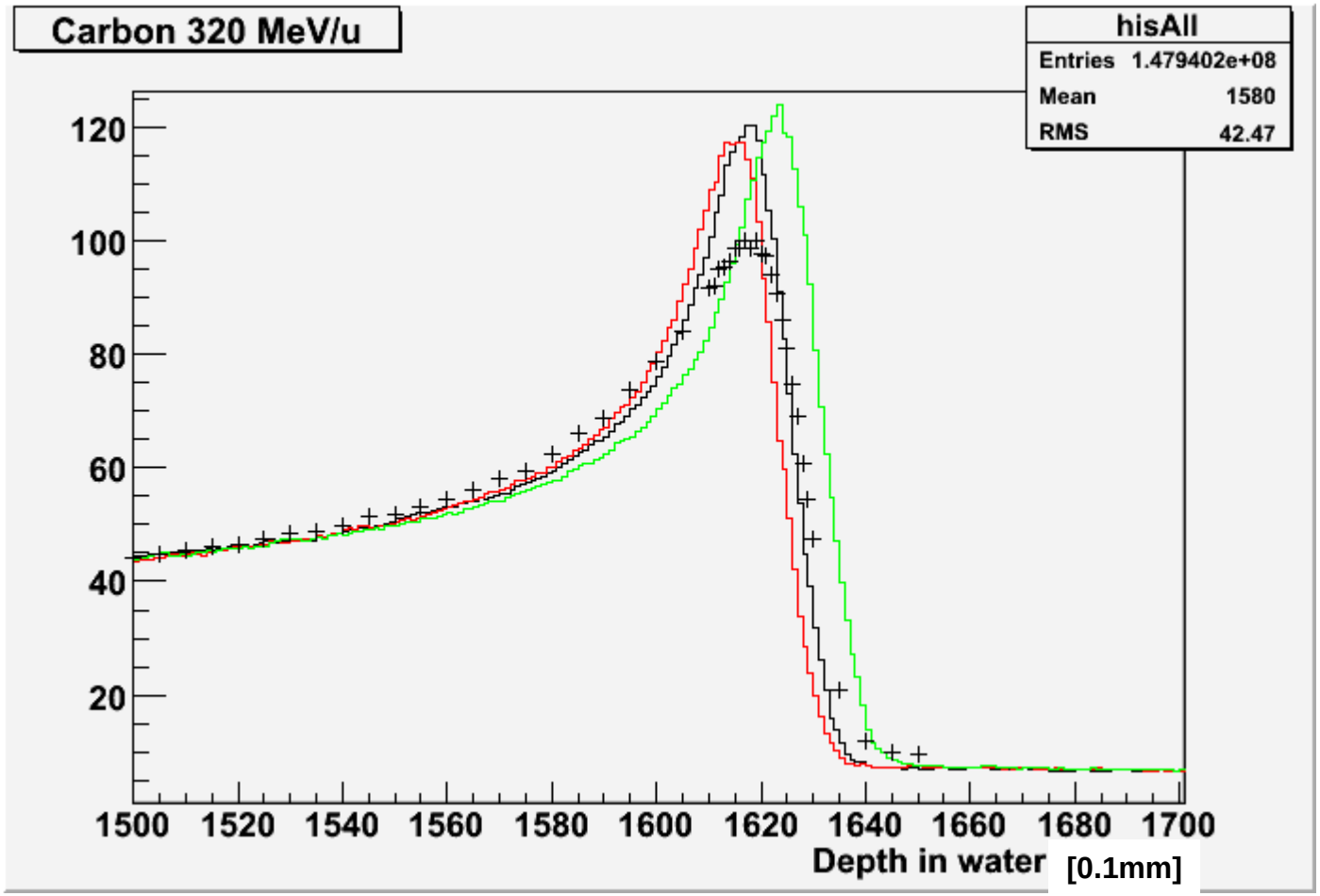




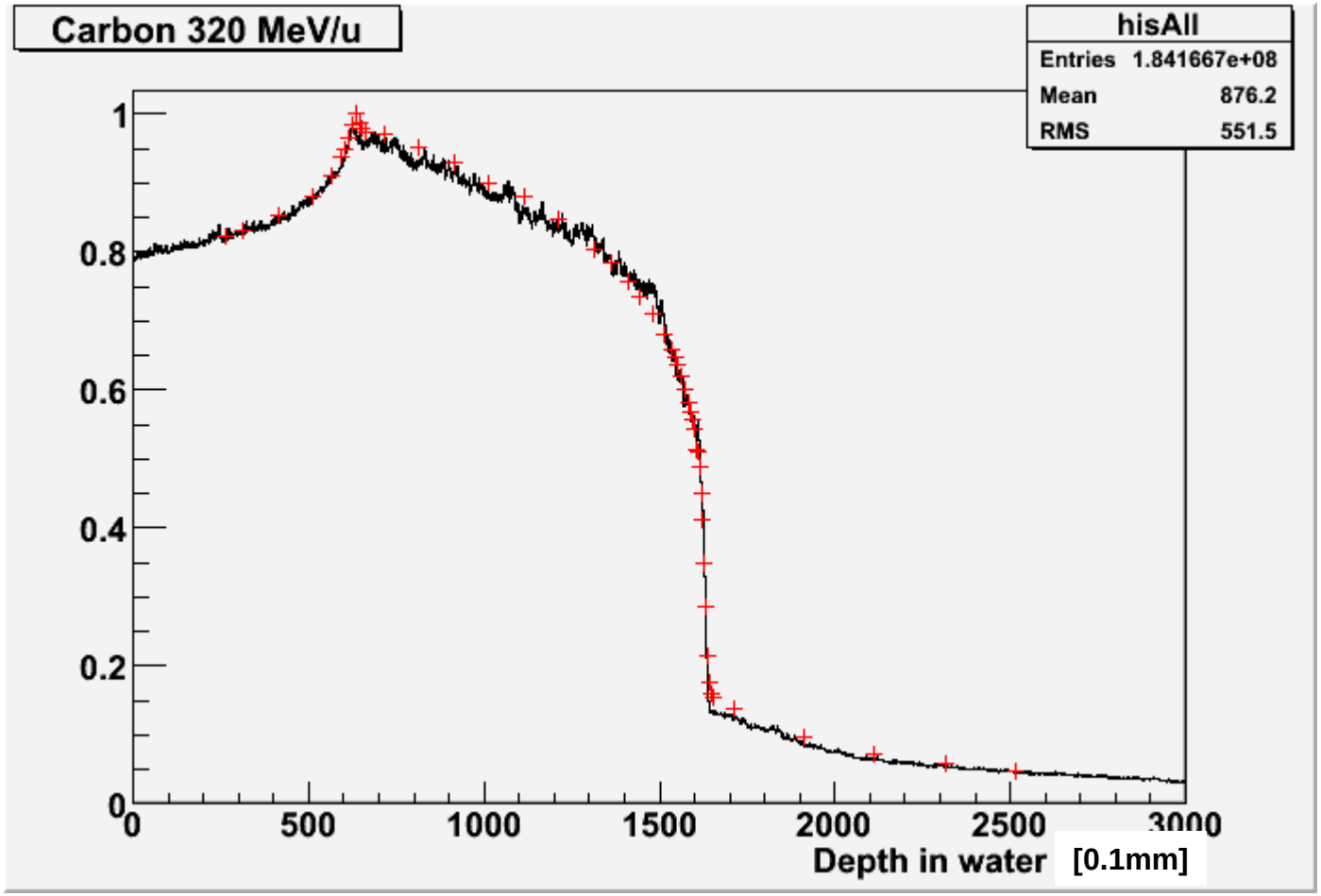




Gauss vs. non-gauss

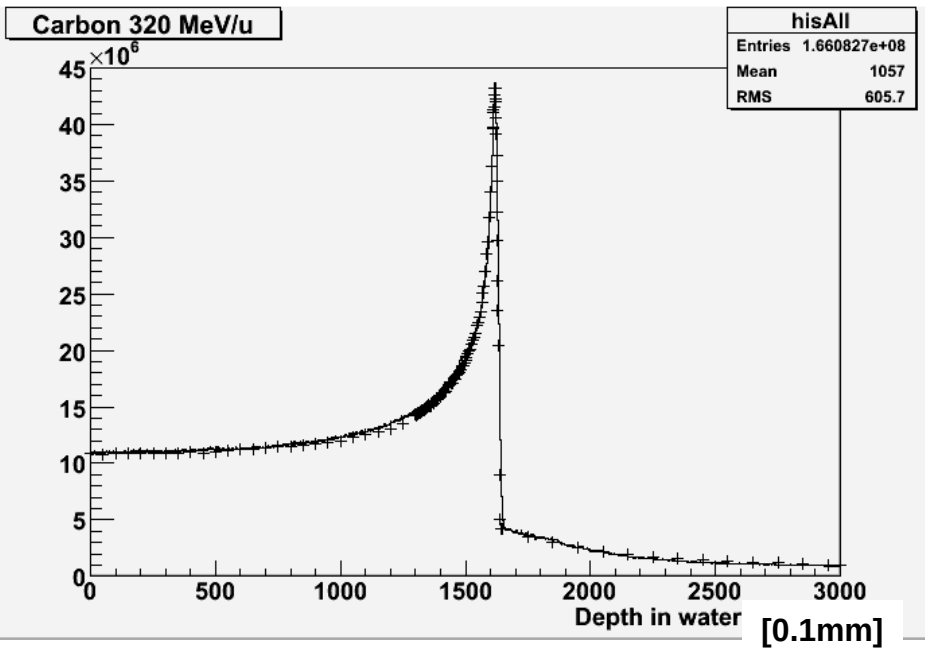


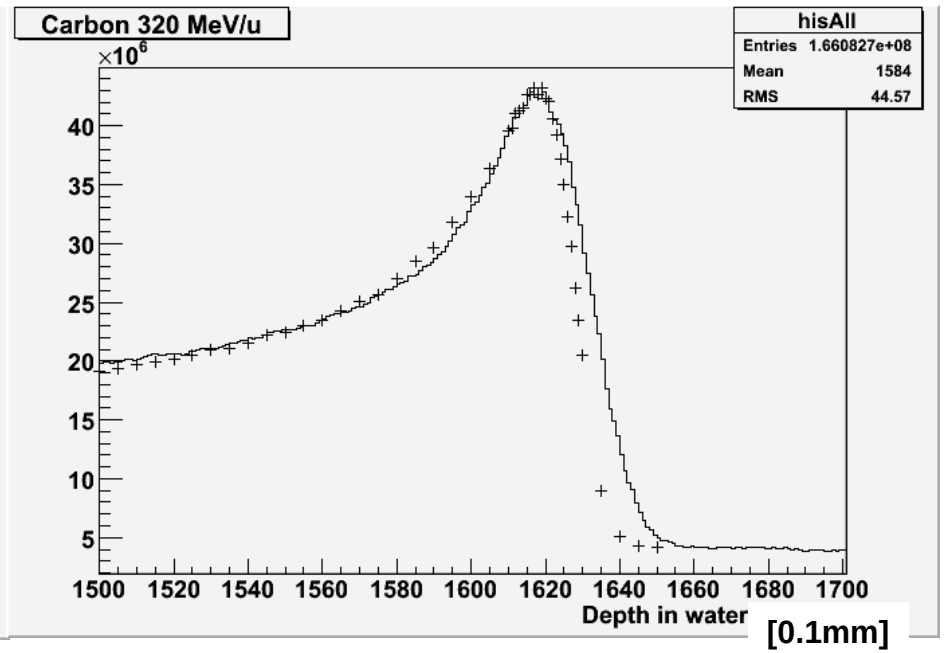
SOBP 10cm


Carbon 320 MeV/u
hisAll
Entries 1.841667e+08
Mean 876.2
RMS 551.5
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
3000
Depth in water [0.1mm]

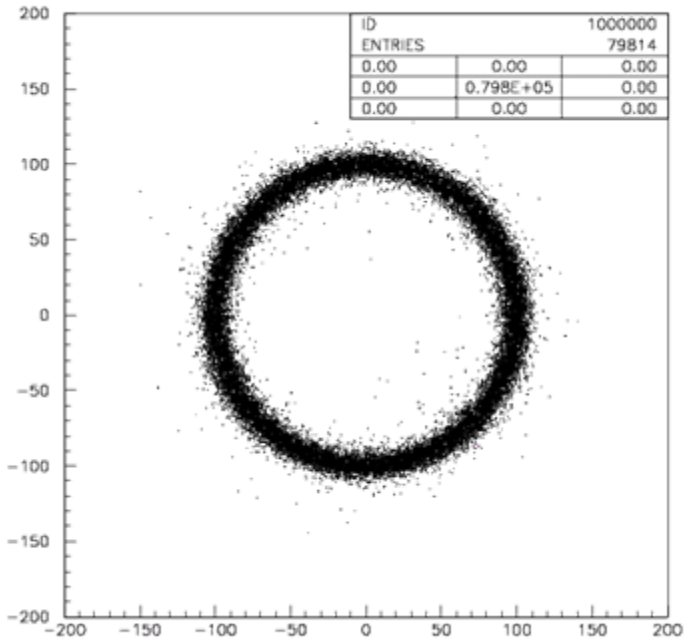
Spread of beam momentum

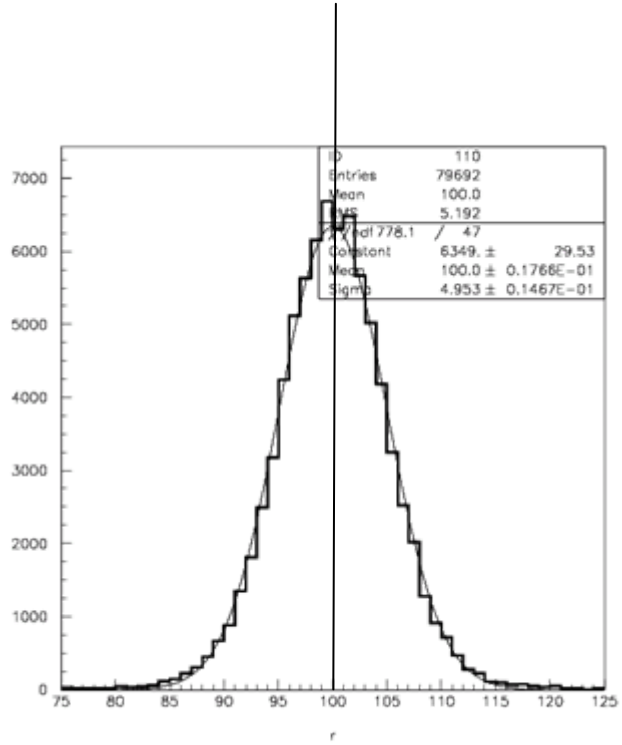
ΔP/P=0.35%(FWHM) : far from realistic





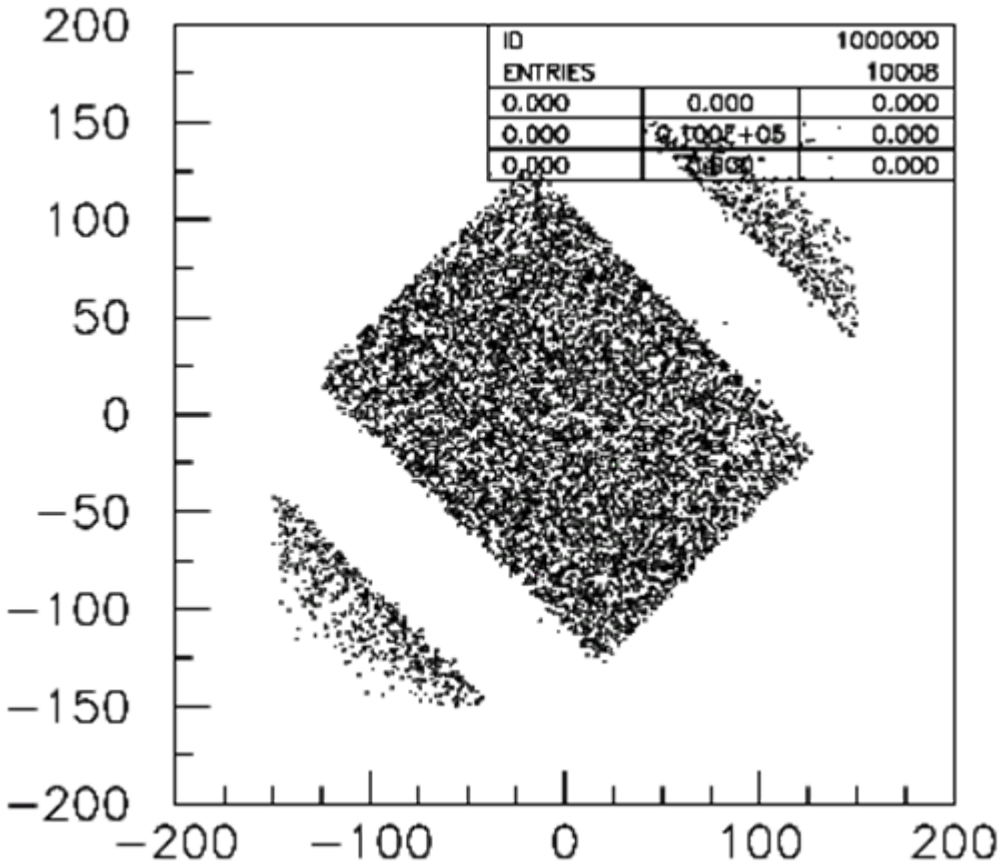
Wobbler

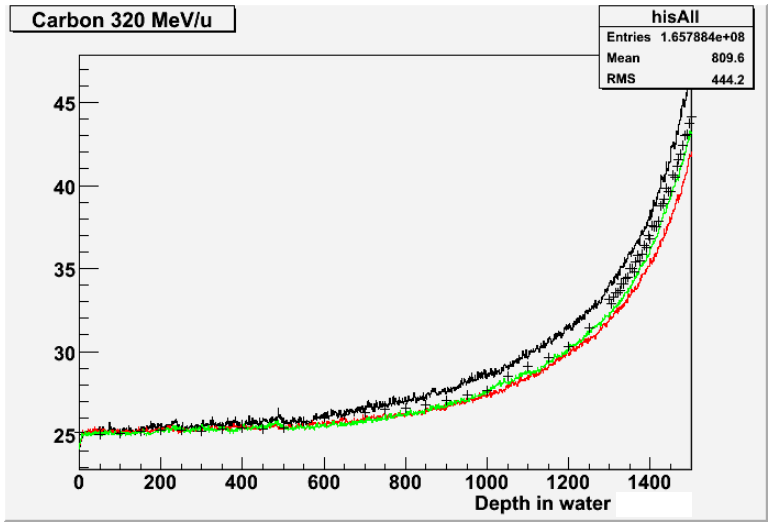


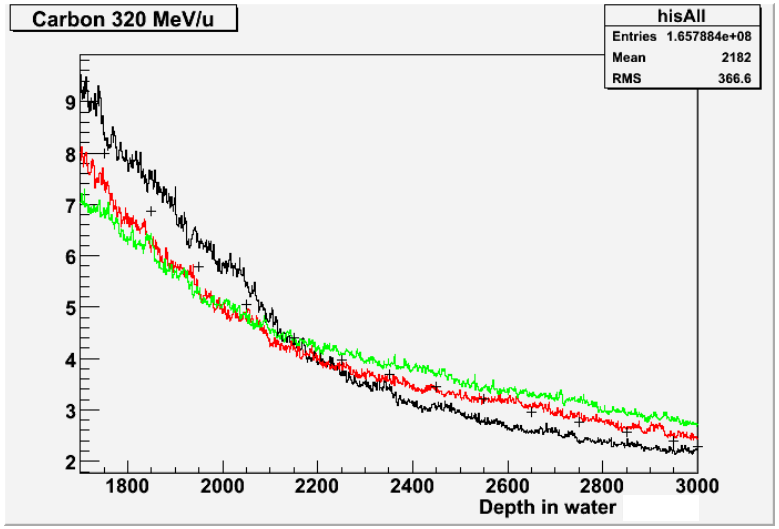


10cm

$r=\sqrt{x^2+y^2}$

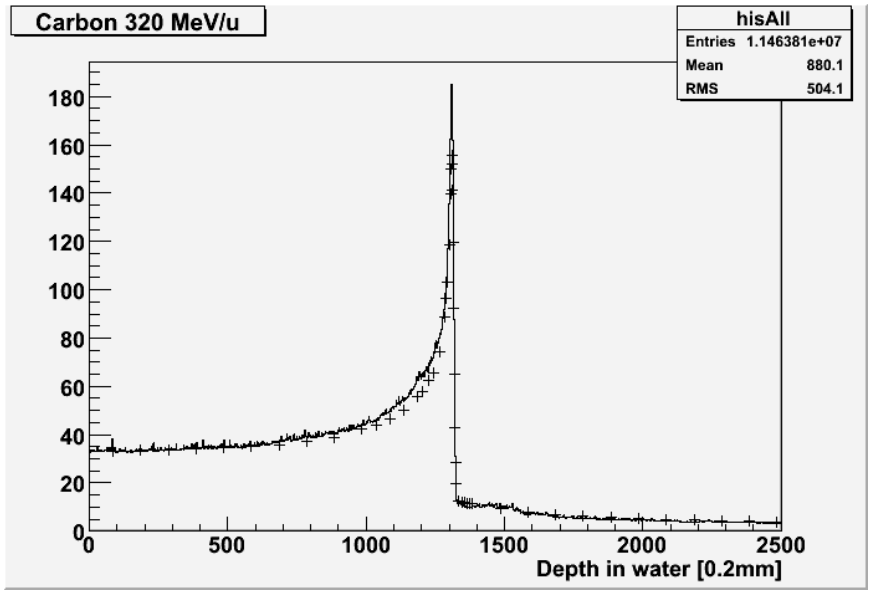

ID 1000000
ENTRIES 10008
0.000 0.000 0.000
0.000 0.000 0.000
0.000 0.000 0.000
200
150
100
50
0
−50
−100
−150
−200
−200 −100 0 100 200

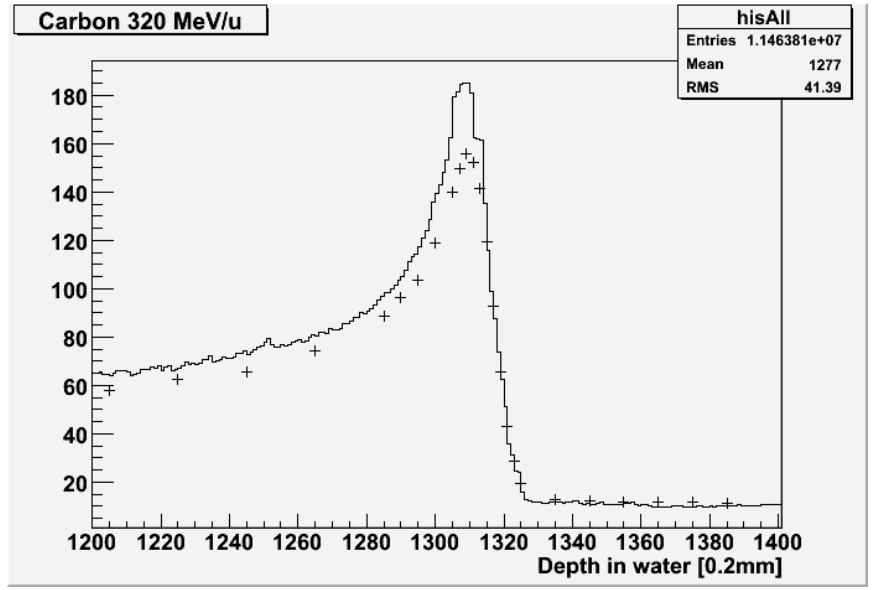

Carbon 320 MeV/u
hisAll
Entries 1.657884e+08
Mean 809.6
RMS 444.2
45
40
35
30
25
0
200
400
600
800
1000
1200
1400
Depth in water


Carbon 320 MeV/u
hisAll
Entries 1.657884e+08
Mean 2182
RMS 366.6
9
8
7
6
5
4
3
2
1800
2000
2200
2400
2600
2800
3000
Depth in water

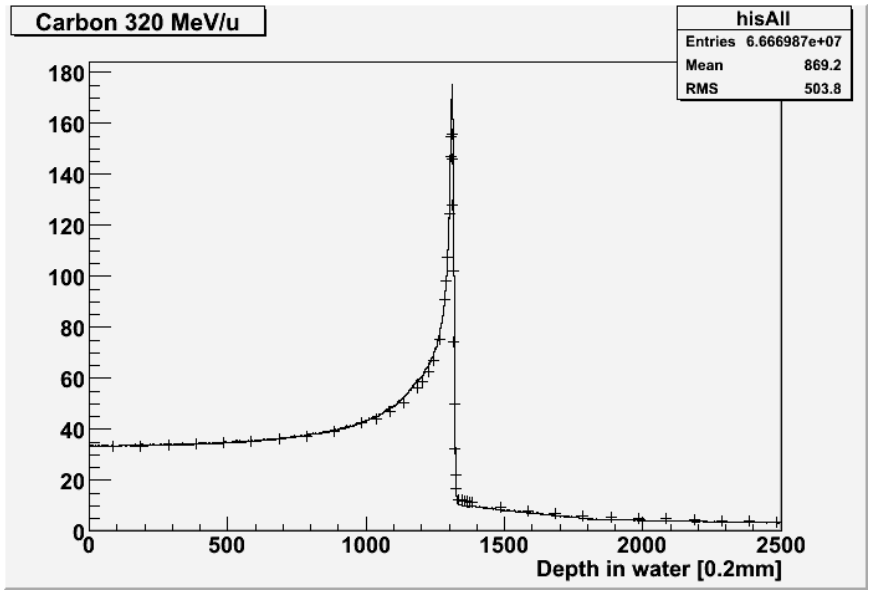
290 2x2

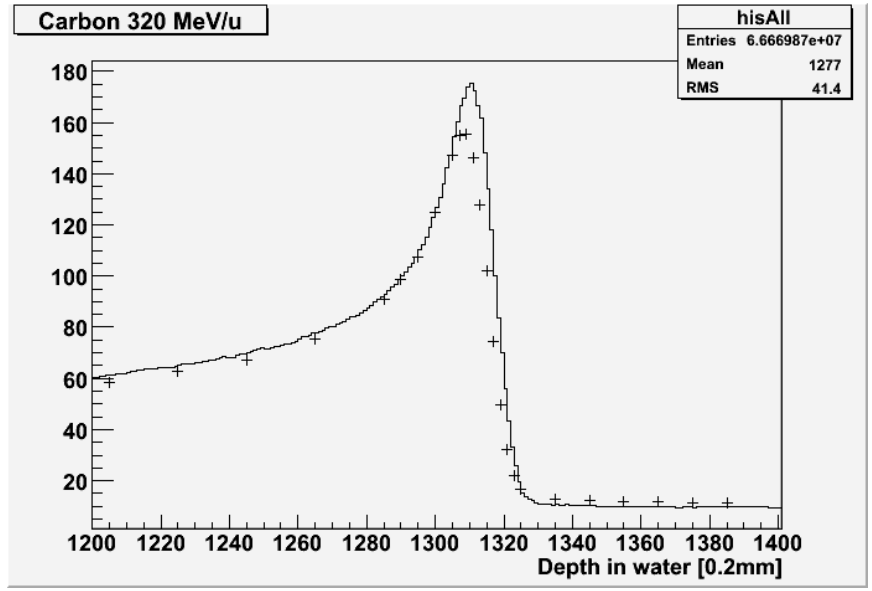
070723



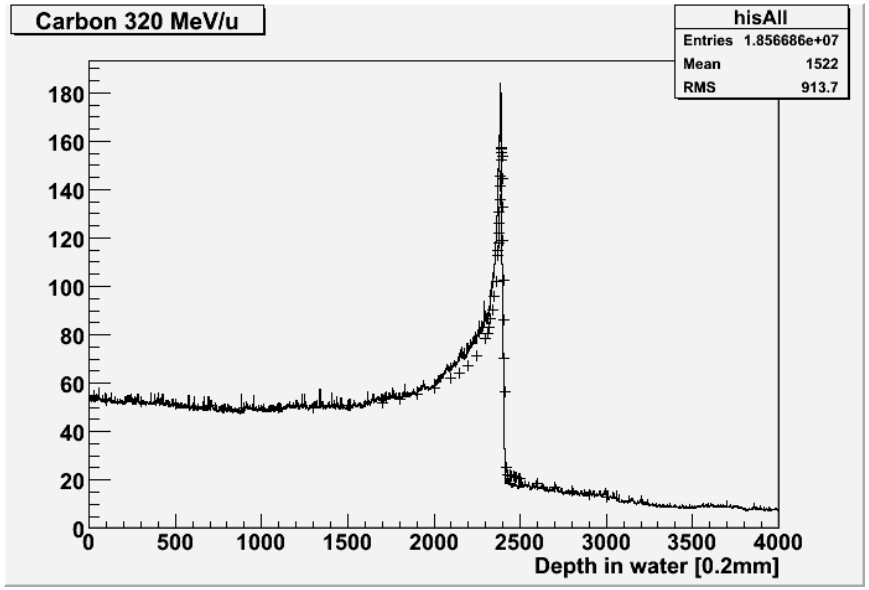


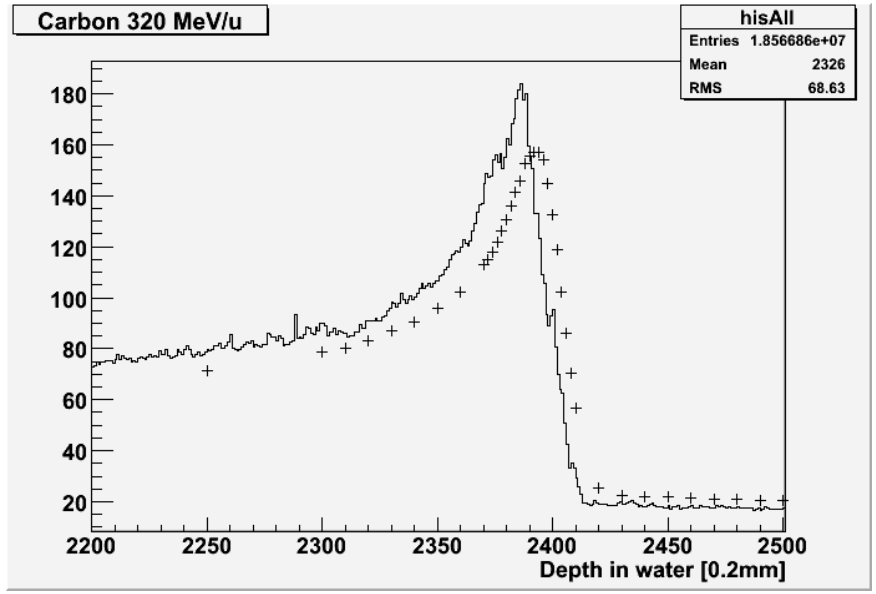
290 2x192



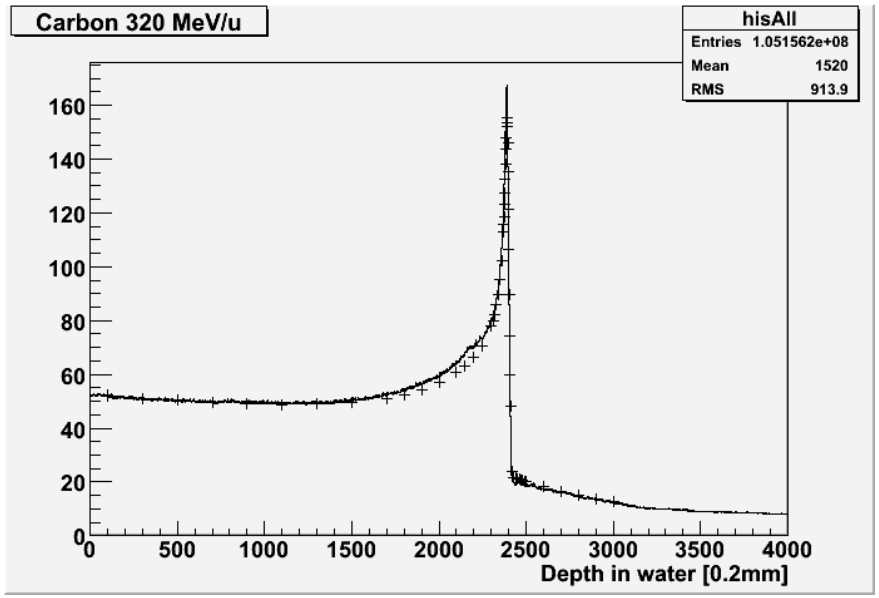


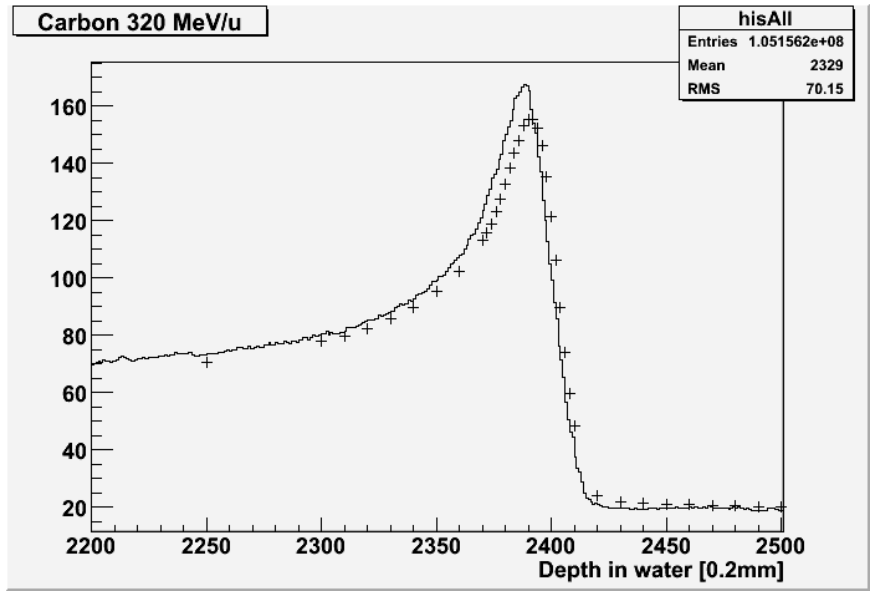
400 2x2



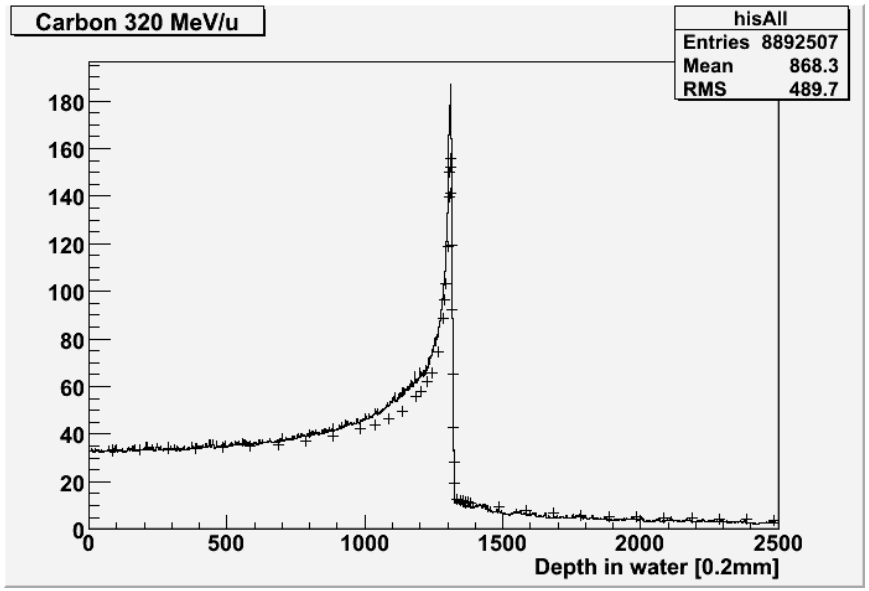


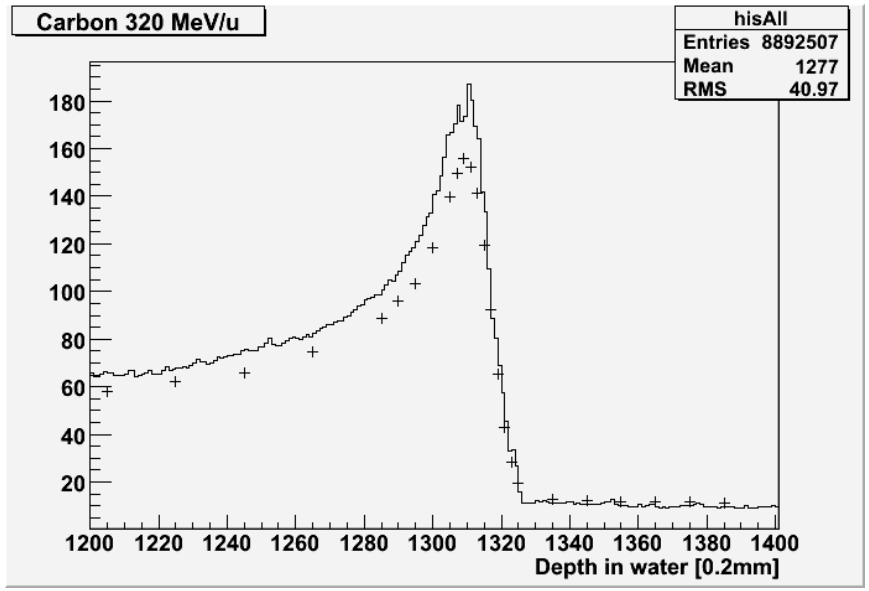
400 2x192



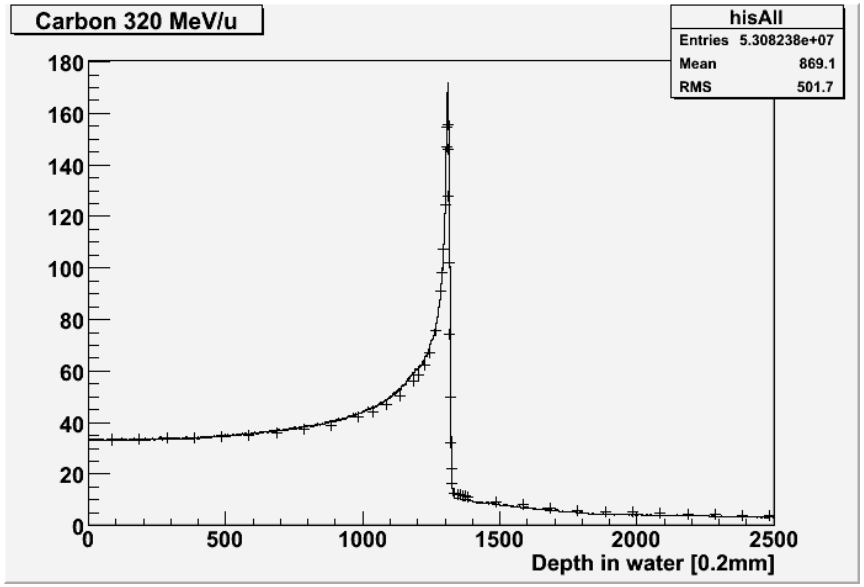


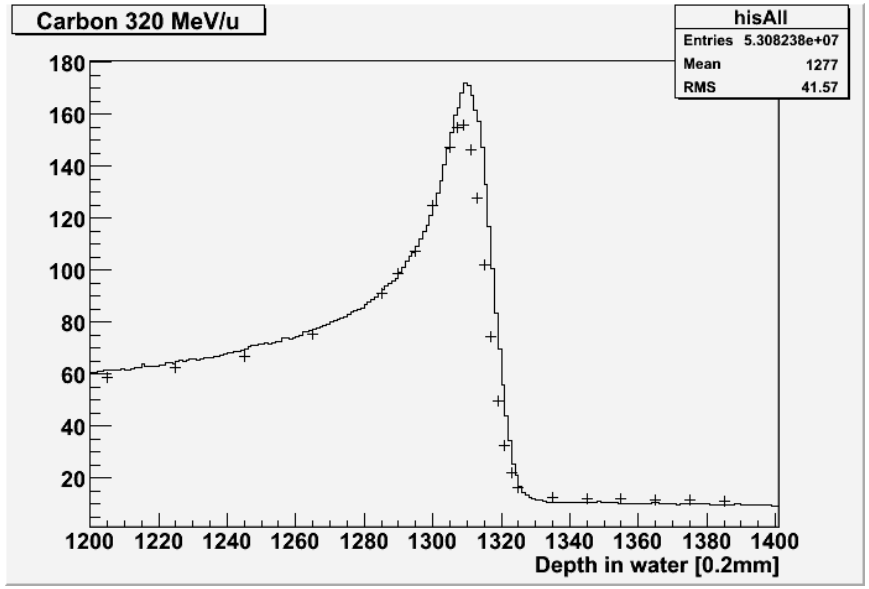
290 2x2 BC



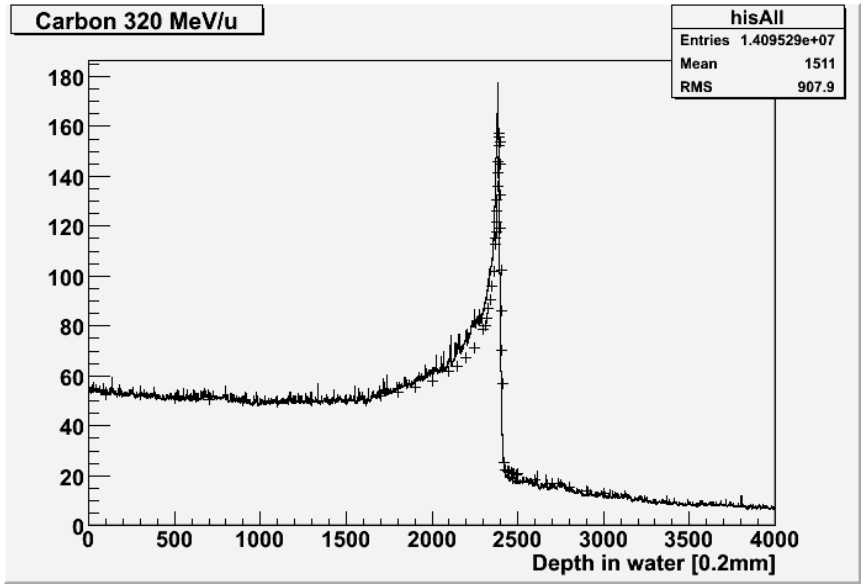


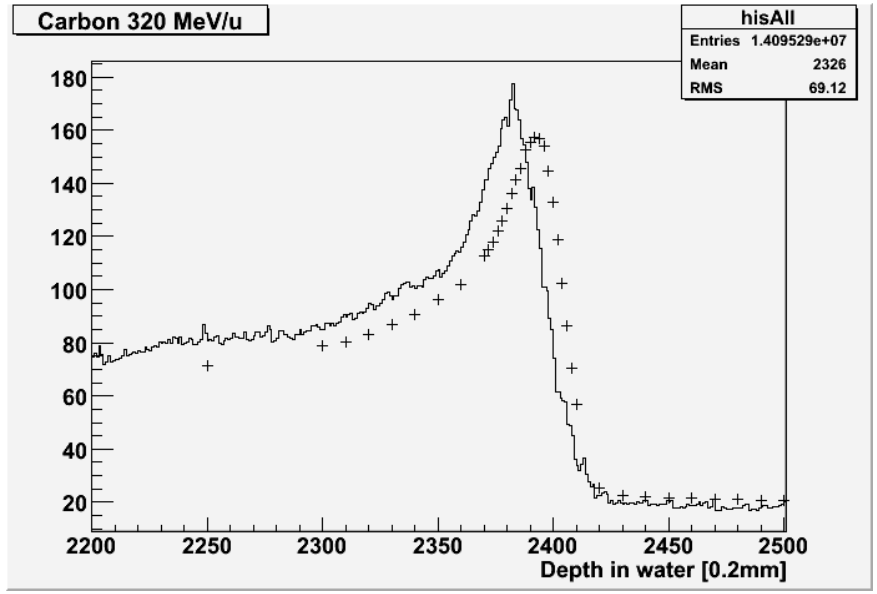
290 2x192 BC





400 2x2 BC





400 2x192 BC