



NCC proton therapy validation activities

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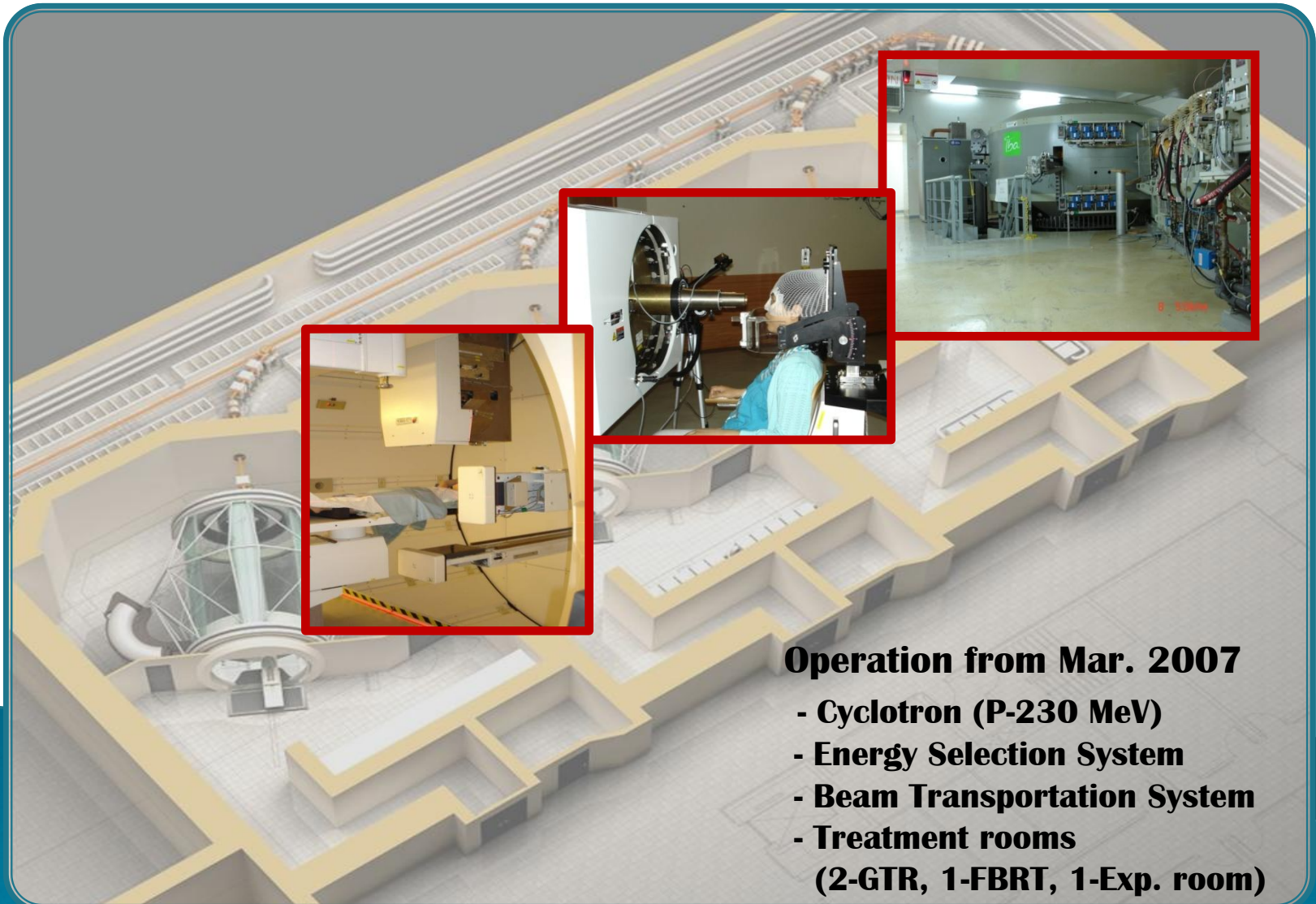
*17th Geant4 Collaboration Meeting Maison Saint-Yves
Parallel session 2A : New EM validation results on 10th of Sep. 2012*

Proton Therapy Facility in NCC

- 2005. 2.15 IBA Proteus 235 installation start**
- 2005. 10.21 First Beam Production**
- 2005. 9.~ 2006. 2. Beam tuning (Cyclotron & Beam line)**
- 2006. 6.~ 2006.12. Passive mode beam calibration & acceptance test
(1 Fixed Beam & 2 Gantry)**
- 2007. 1.~ 2007.2. GTR2 Commissioning & Beam data taking**
- 2007. 3.19. First Proton treatment start**
- ~ 2011.12. 810 patients treated in Proton Therapy Facility**



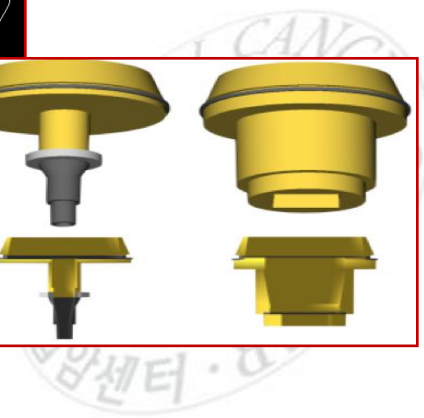
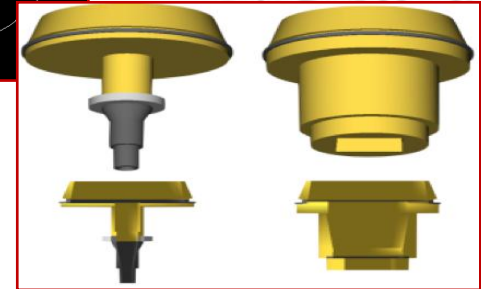
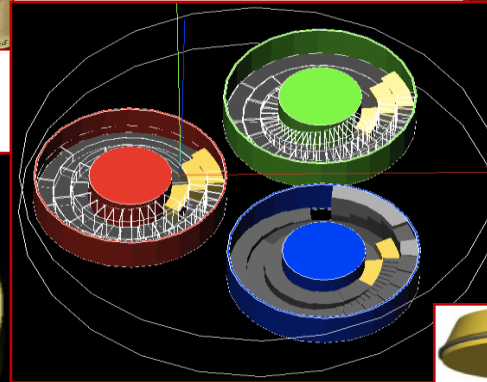
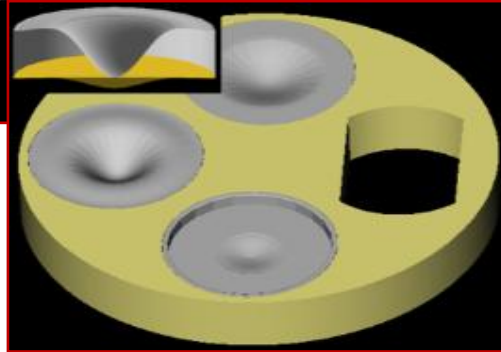
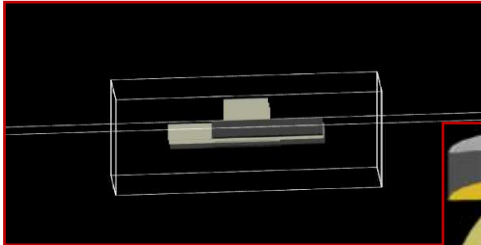
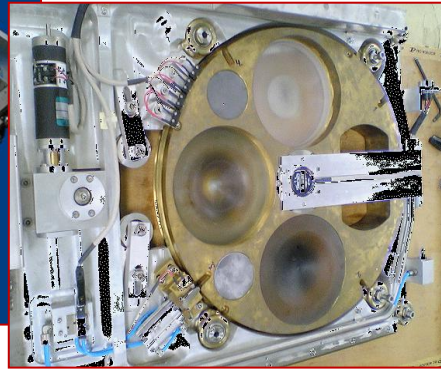
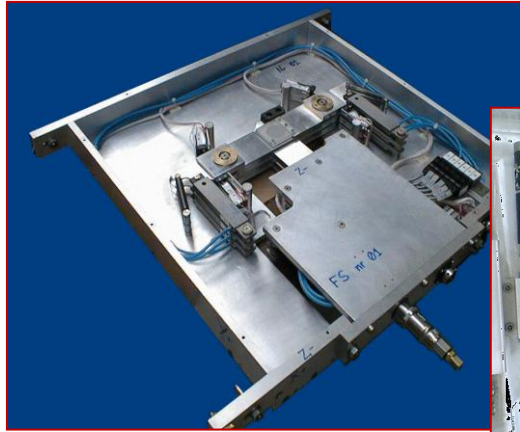
Proton Therapy Facility in National Cancer Center



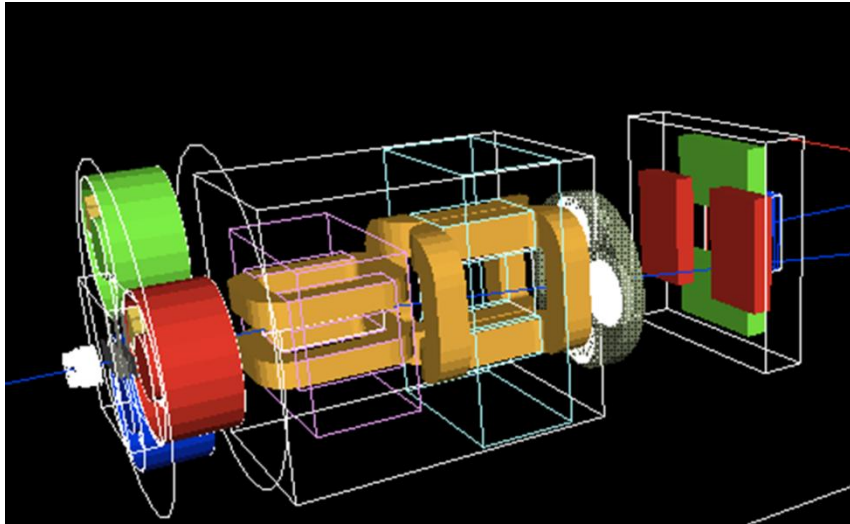
Operation from Mar. 2007

- Cyclotron (P-230 MeV)
- Energy Selection System
- Beam Transportation System
- Treatment rooms
(2-GTR, 1-FBRT, 1-Exp. room)

1st & 2nd Scatterers, Range modulator and Snouts Modeling



Proton Beam Treatment IBA Nozzle Simulation



Current & Past Geant4 Researchers in NCC

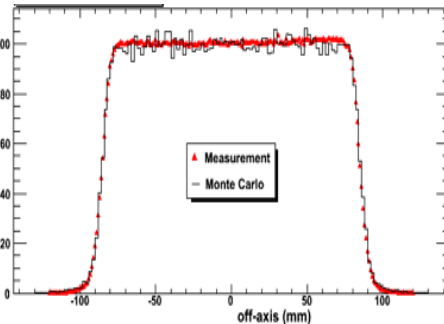
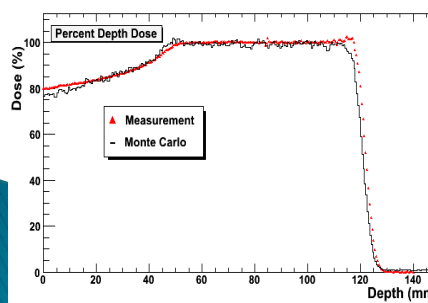
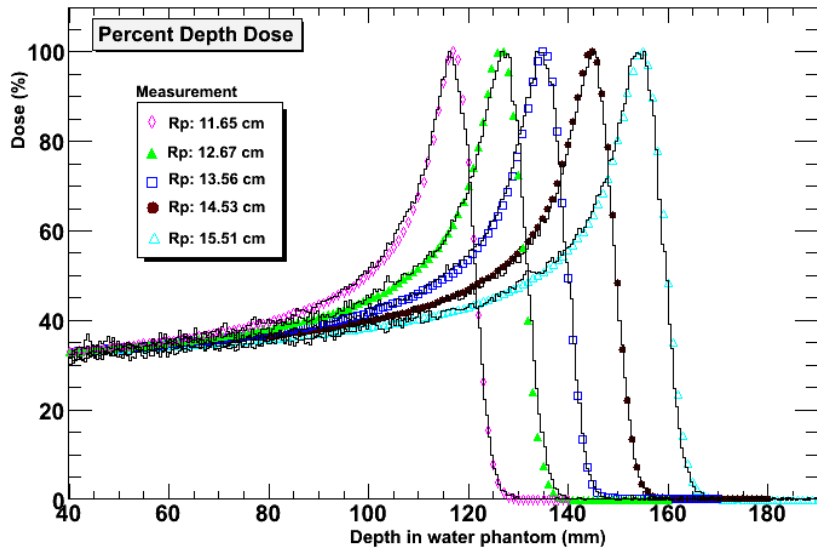
- Dr. Jungwook Shin
TOPAS Collaboration in USA
- Mr. Dae Hyun Kim
Catholic University of Korea
- Mr. Sey-Joon Park
NCC Korea
- Mr. Jae Ik Shin
NCC Korea
- Etc..

Nozzle Simulation

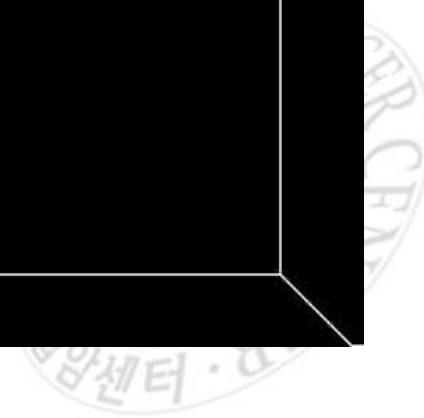
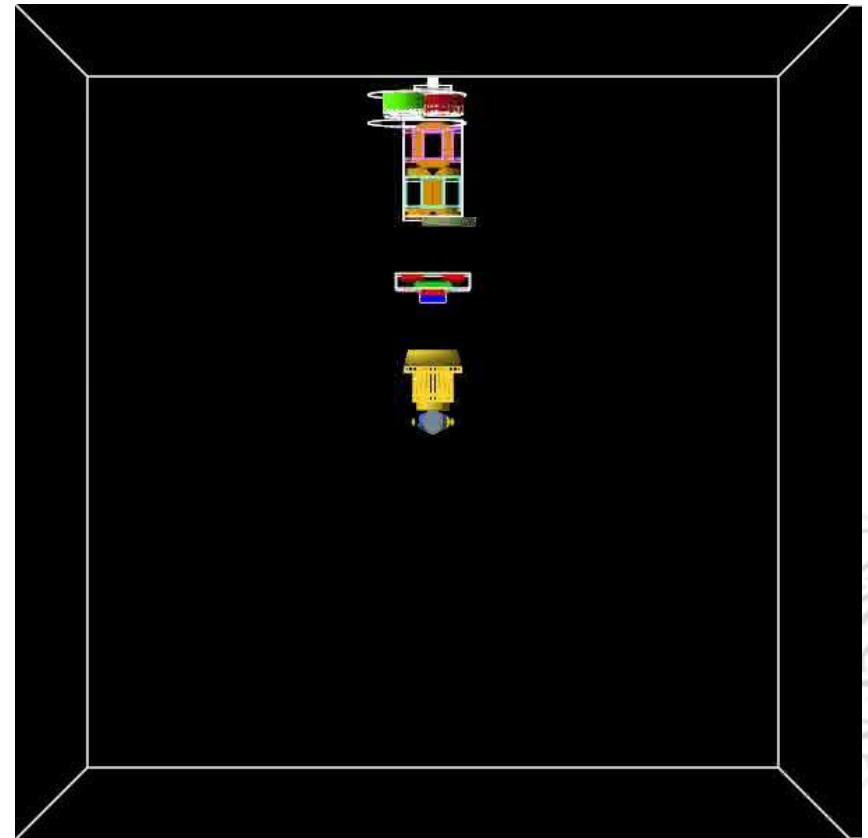
Geant4 version: 8.2.p01

- EM model : G4hlonization with ICRU49 parameterized table
- Hadronic : LHEP_PRECO_HP (precompound model)

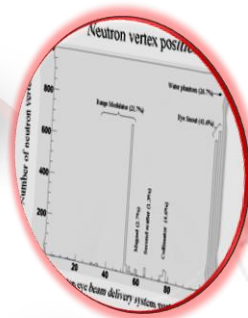
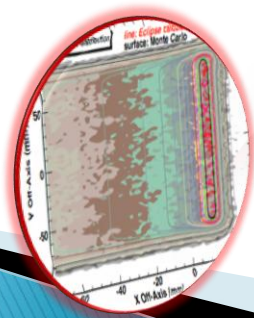
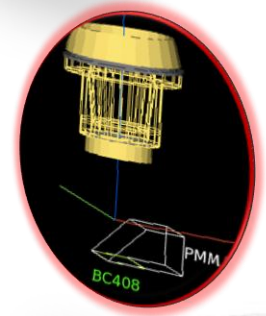
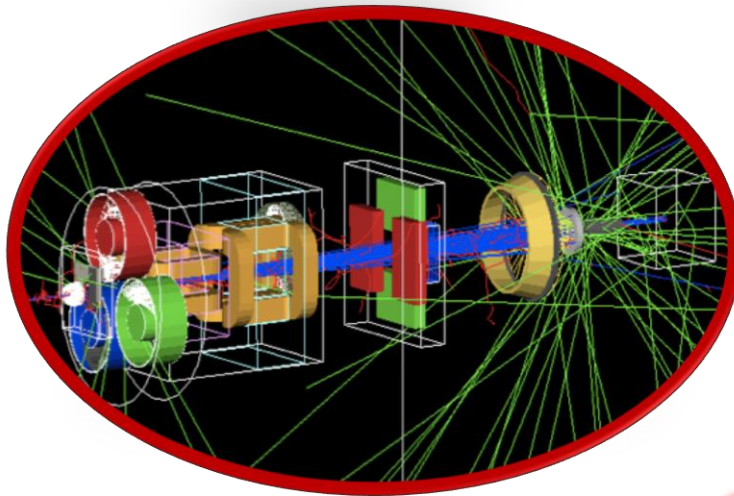
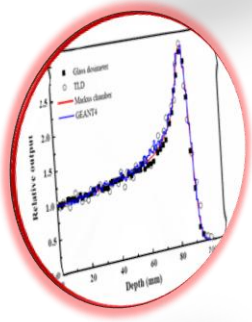
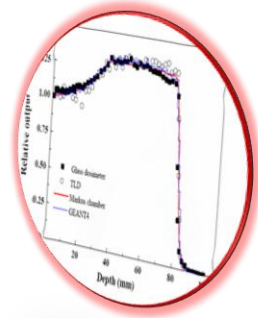
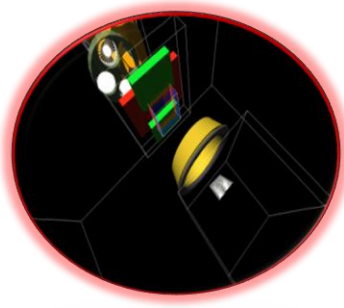
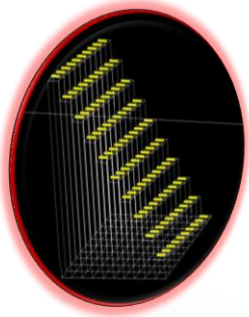
MC Simulation validation Test



NCC Proton Beam Delivery MC Simulation



Application



Geant4 Use in the NCC Research & Clinic

- ▶ Proton Beam Dosimetry
 - Scintillator-CCD system development
 - Glass dosimetry
 - Gold Maker for Patient Setup
- ▶ Radiation Safety
 - Secondary Neutron dose evaluation
- ▶ Patient Treatment Planning
 - **Dose Calculation Accuracy of Commercial PTS**
 - Geant4-DNA



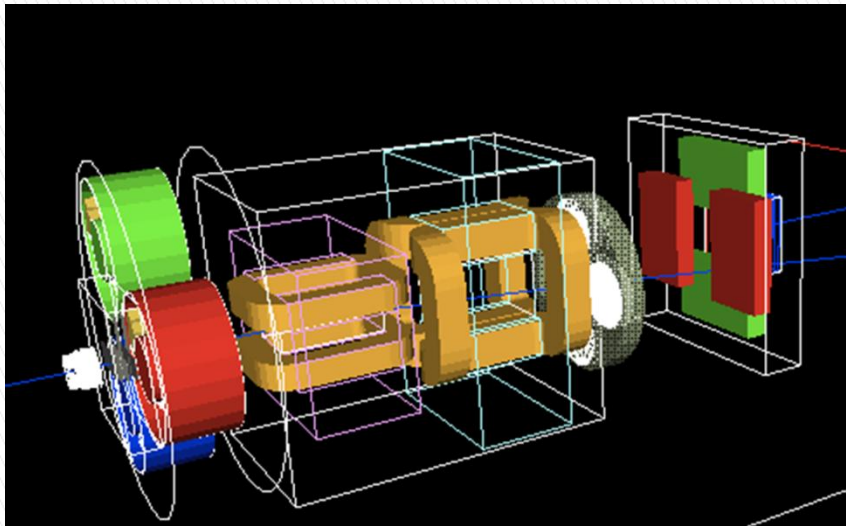
Standard EM Validation 1

Therapeutic Proton Beam Dosimetry

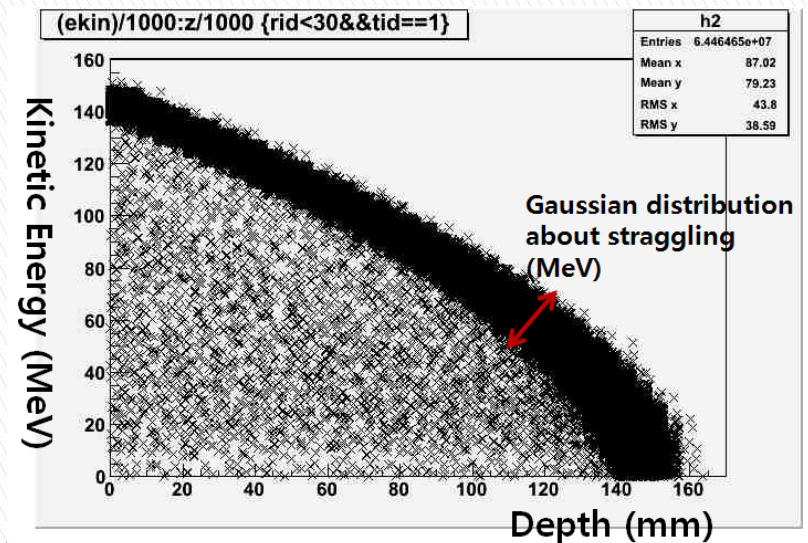


NCC Proton Beam Simulation

- Pristine Bragg-peak Beam Measurement with Markus Chamber in 3D water phantom
- Geant4 MC simulation with a new Standard EM physics list and Comparison with measurement data periodically.



NCC nozzle simulation



Primary Proton Energy
in Water from NCC nozzle exit

Water Phantom

- ▶ Dimension : 50*50*50cm
- ▶ Material : G4_Water
- ▶ Position : Nozzle Isocenter(0,0,0)~50cm
- ▶ No Parameterisation
- ▶ Generate about 2×10^6 Protons



Physics List in 4.8.2

- ▶ G4HadronElasticPhysics
- ▶ HadronPhysicsLHEP_PRECO_HP
- ▶ **Customizing Low EM Physics**
- ▶ G4EmExtraPhysics, G4DecayPhysics
- ▶ G4QStoppingPhysics, G4IonPhysics

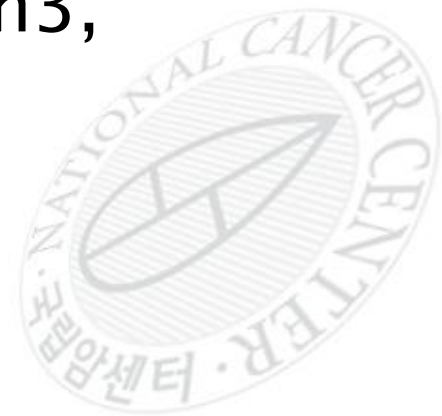
- ▶ **Customizing Low EM Physics**
: mixed “LowEnergy”Process & Penelope



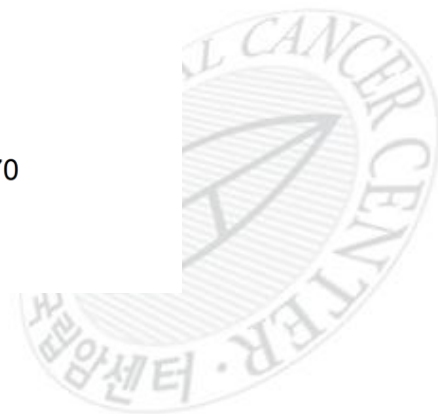
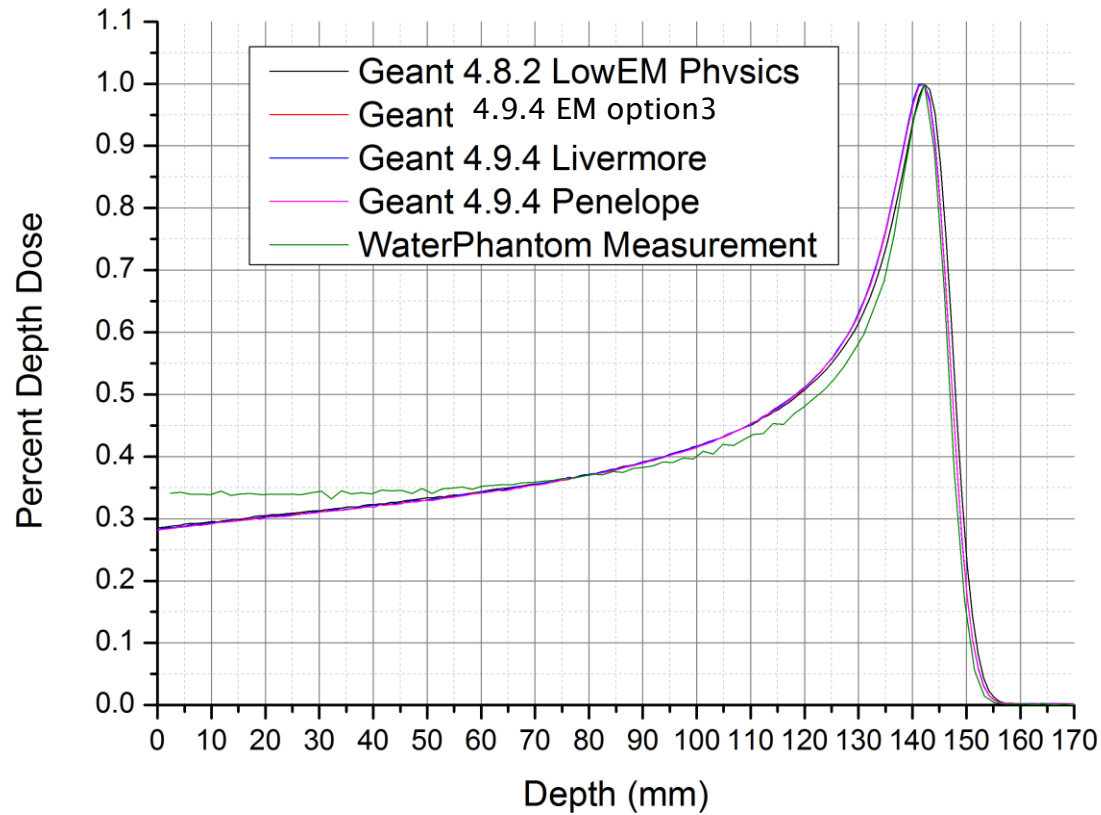
Physics List in 4.9.4

- ▶ G4HadronElasticPhysics
- ▶ HadronPhysicsQGSP_BIC_HP
- ▶ **PreBuilt LowEM Physics**
- ▶ G4EmExtraPhysics, G4DecayPhysics
- ▶ G4QStoppingPhysics, G4IonPhysics

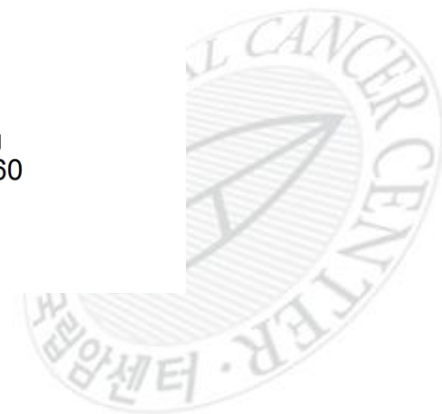
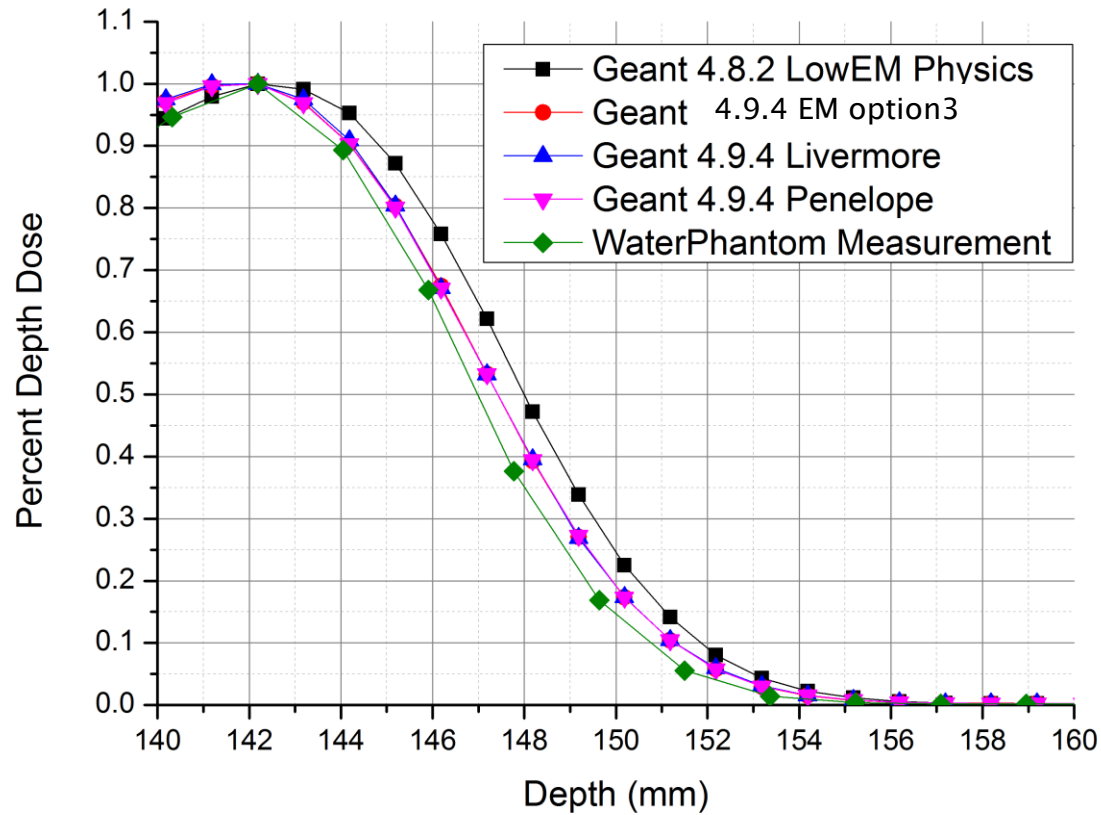
- ▶ **PreBuilt Low EM Physics** : one of Low EM Physics Options (EM Standard Option3, Livermore, Penelope)



Bragg Curve Range 14.4g/cm²(140.9MeV)



Distal fall-off



Standard EM Validation 2

Microdosimetry Study with Nuclear Emulsion



Measurement LET(dE/dx) of Proton using Nuclear Emulsion

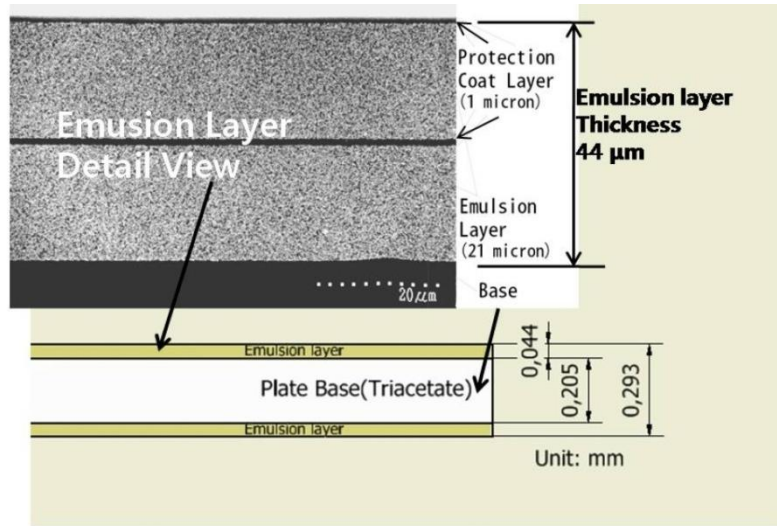


Fig. 1. Schematic drawing of cross section in the emulsion plate

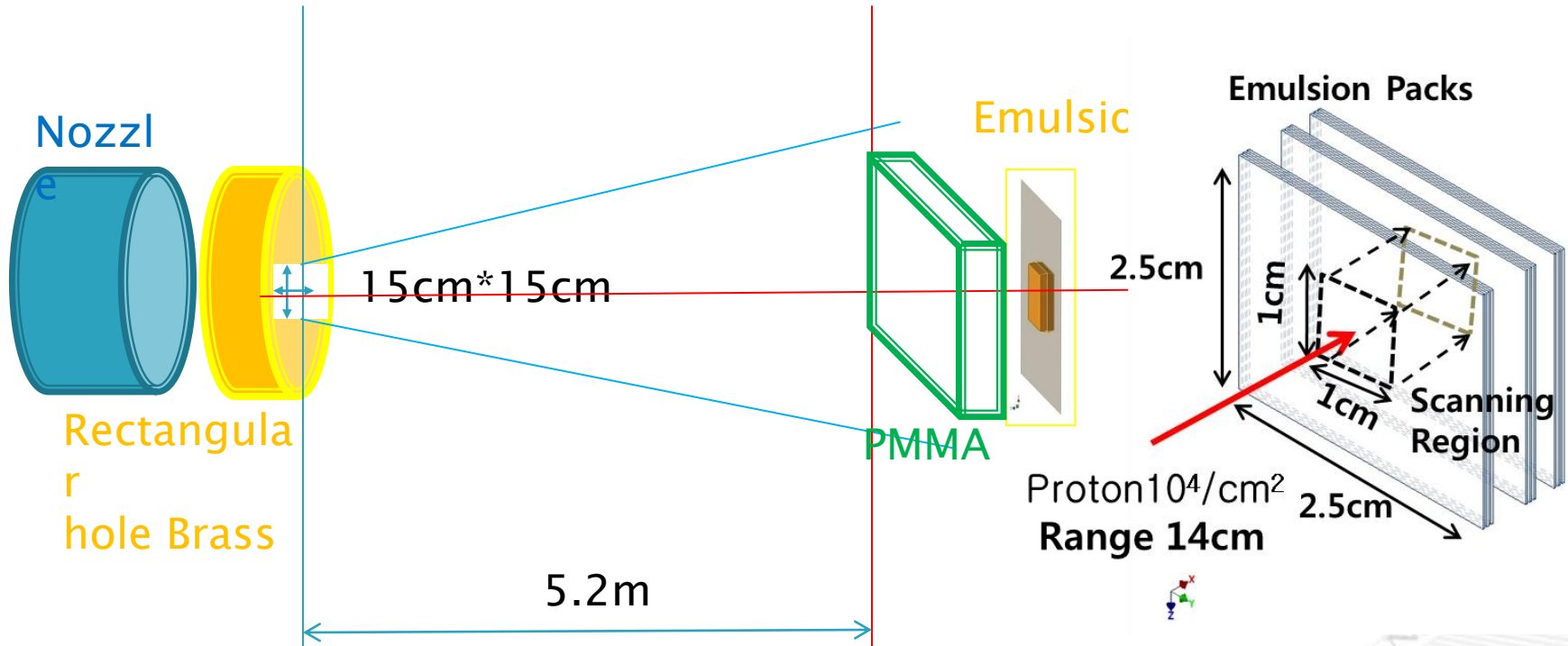
Table 1. Gel parameters. The diameter and the divergence were measured on the images taken by an electron microscope

	Fuji ET7B	OPERA film
Average diameter of the crystal	0.240 μm	0.200 μm
Divergence of the diameter	0.078 μm	0.016 μm
Volume occupancy of AgBr	0.50	0.31
Number of crystals per 100 μm	262	230
Grain density for MIP (/ μm)	38	36
Detection efficiency per crystal	0.14	0.17
Machine-coating possibility	X	O

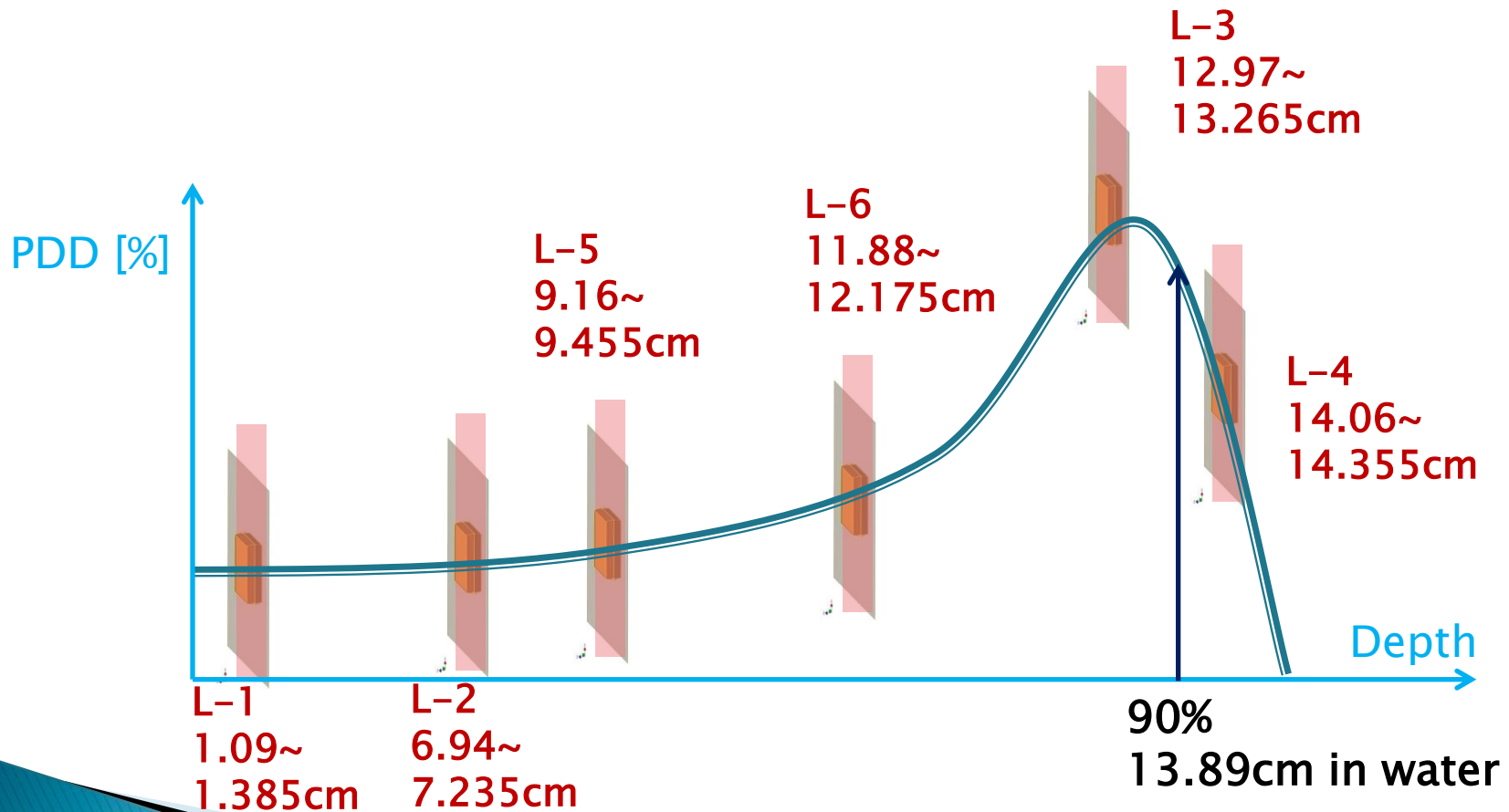
Collaboration :
 Se Byeong Lee, Jae-ik Shin^(a),
 Sung Hyun Kim^(b),
 Kunihiro Morishima^(c)

- (a) Proton Therapy Center, National Cancer Center
- (b) Department of Physics, Pusan National University
- (c) Department of physics, Nagoya University

Experiment Setup

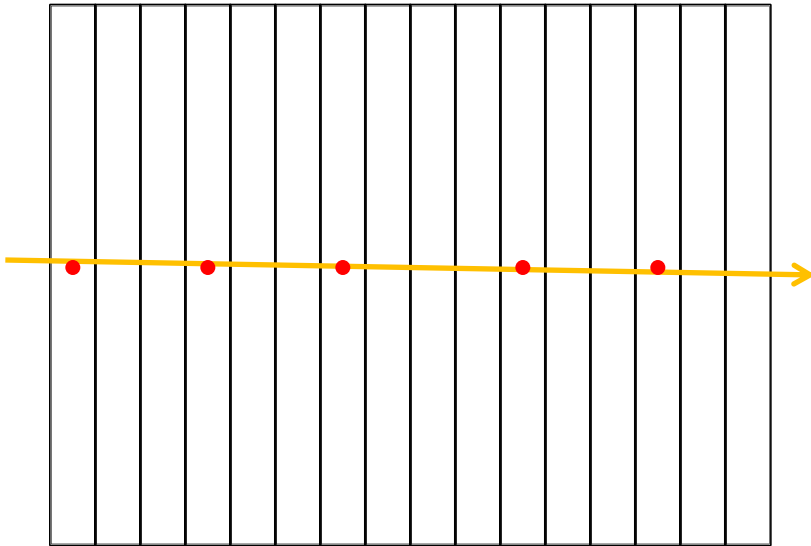


Emulsion Pack (thickness 0.295cm) Position In Proton Beam Bragg-peak with Range 13.89 g/cm² (137.9 MeV)



Meaning of PH & VPH

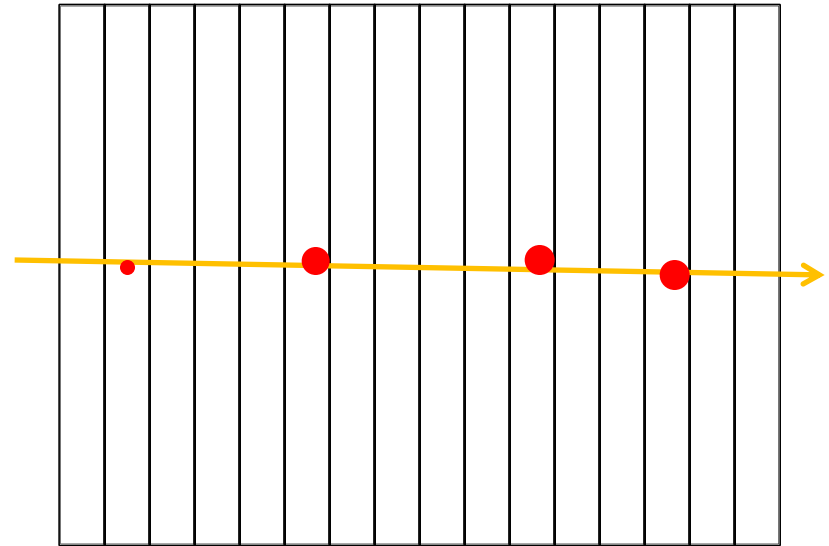
A EMULSION film



In a Emulsion film, Scanning layer = 1~16

Pulse Height = a Number of marks of a track between two emulsion film connected by reconstruction (2~32)

A EMULSION film



Volume Pulse Height
= Intensity of Interaction in Emulsion by a Track
(Information related Bragg Curve)

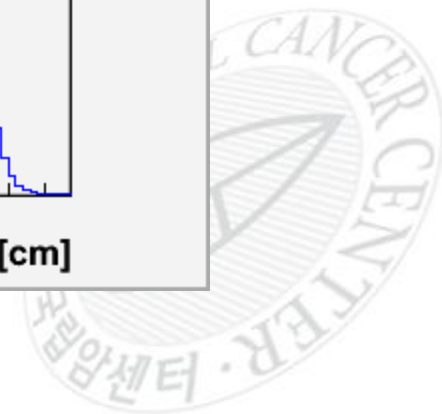
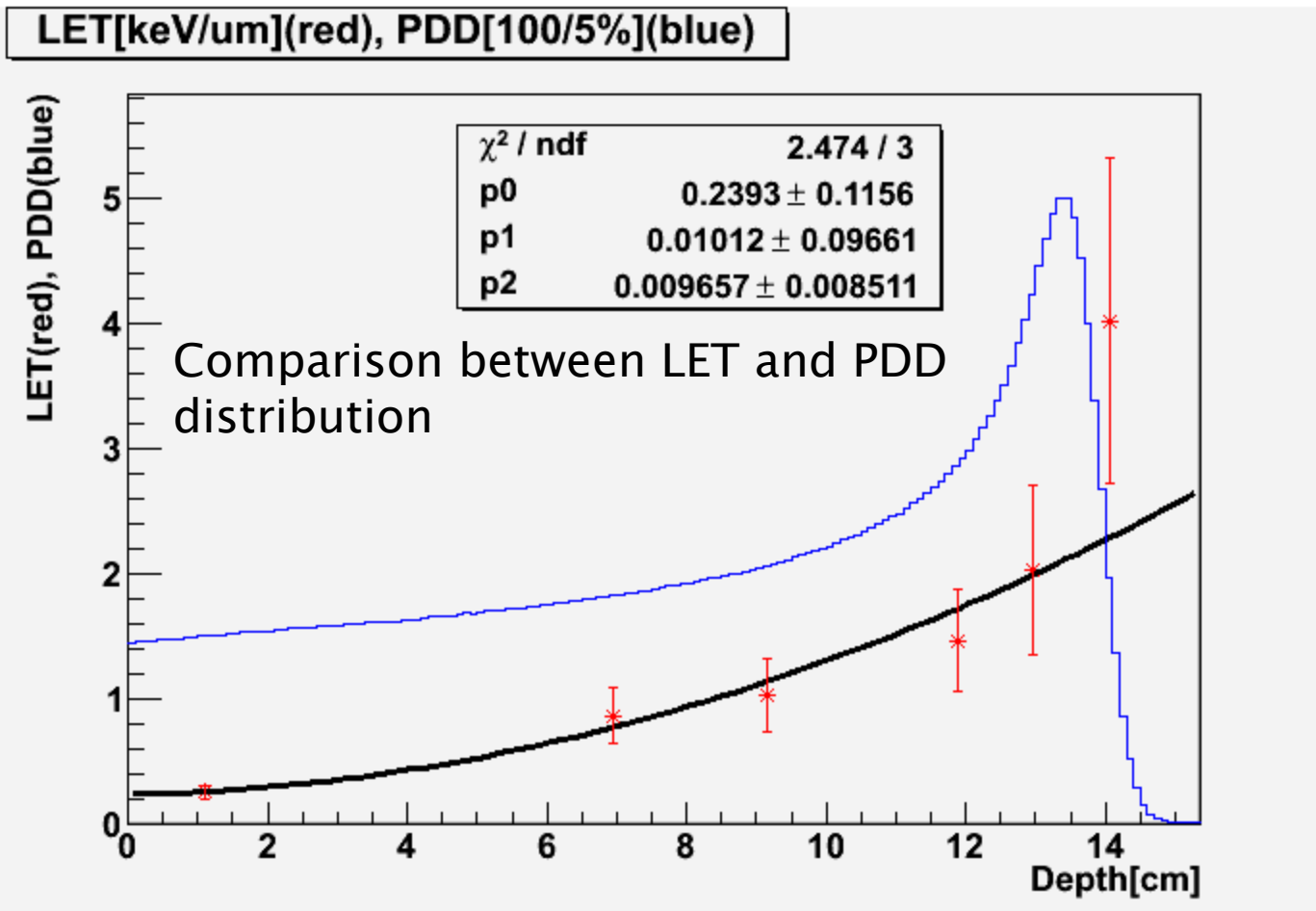
Physics List

Version : Geant4.9.4

- Elastic Scattering: G4HadronElasticPhysics
- Inelastic Scattering: QGSP_BIC
- EM: EM standard Option3 physics,
G4EmExtraPhysics, G4DecayPhysics
- etc: G4QStoppingPhysics, G4IonPhysics

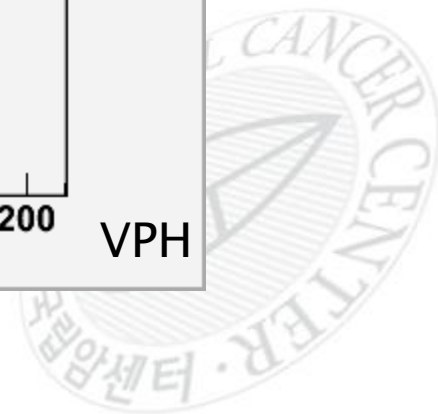
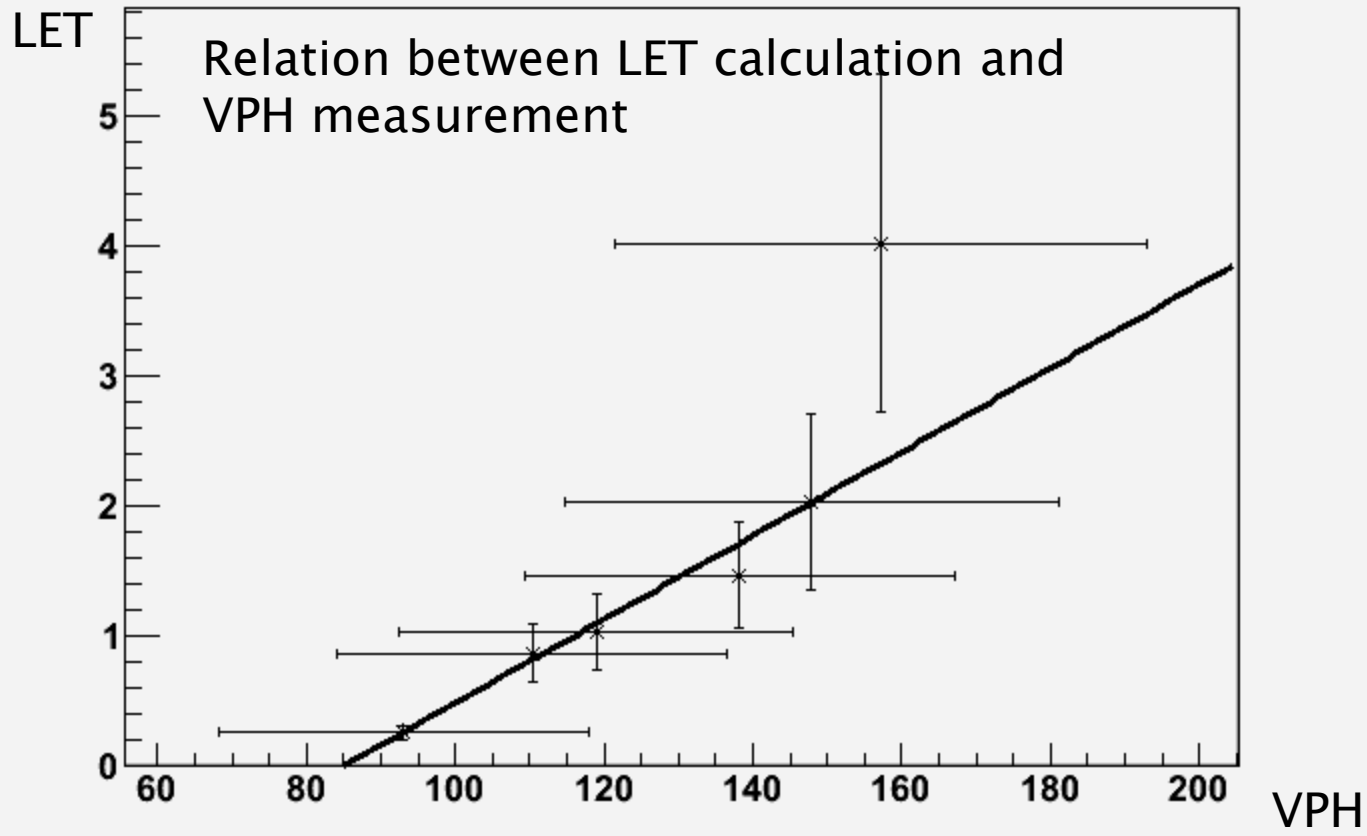


PDD&LET(MC) per Depth



LET(from MC) vs VPH(from Data) in each depth

Graph



Summary

- ◆ We have several research programs for proton dosimetry using Geant4 MC simulation.
(Treatment Beam validation, Microdosimetry, Geant4-DNA study, etc.)
- ◆ For an Accurate Simulation Result and low energy MC simulation application, we want to try physics list optimization and need a collaboration with geant4 EM working Group.
- ◆ NCC team could be a beta tester for new version of G4 code and will provide a proton beam simulation result for validation of it in the Standard EM working group.



Thank you!



Proton Therapy Center

