New EM validation session 2B

V.Ivanchenko

17th Geant4 Workshop

10-14 September 2012

Chartres, France

Multiple Scattering of HE Muons in Geant4

A Summer Students Project

Michael Schenk
supervised by V. Ivanchenko

LHEP
University of Berne, CH

10. September 2012

Introduction

Objectives

1. Develop an **automated validation tool** for the simulation of **MSC of μ** resulting from $Z \rightarrow \mu^+\mu^-$ using a simplified representation of the former **L3 detector** at LEP, CERN.

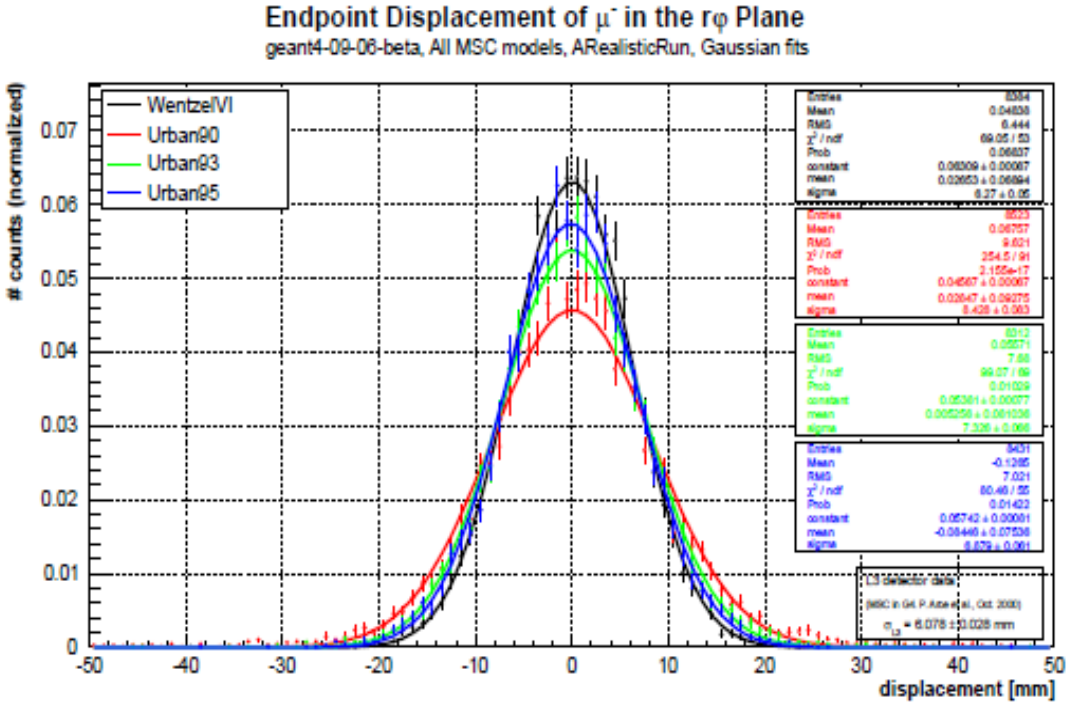
2. Enable **comparisons between different MSC models** and **Geant4 releases** in order to uncover possible differences.

3. **Compare the latest MSC models** with results published by **P. Arce et al.** in

   Multiple Scattering in GEANT4. A Comparison with Molière Theory and L3 Detector Data. (October 2000)

Results

Comparison of WentzelVI and Urban MSC Models



Distribution widths

- **WVI:** 6.27 ± 0.05 mm
- **U90:** 8.43 ± 0.09 mm
- **U93:** 7.33 ± 0.07 mm
- **U95:** 6.88 ± 0.07 mm
- **L3 data:** $\mathbf{6.08 \pm 0.03}$ **mm**

American Association of Physicists in Medicine (AAPM) Task Group on Monte Carlo Validation Sets: Geant4 Related Findings

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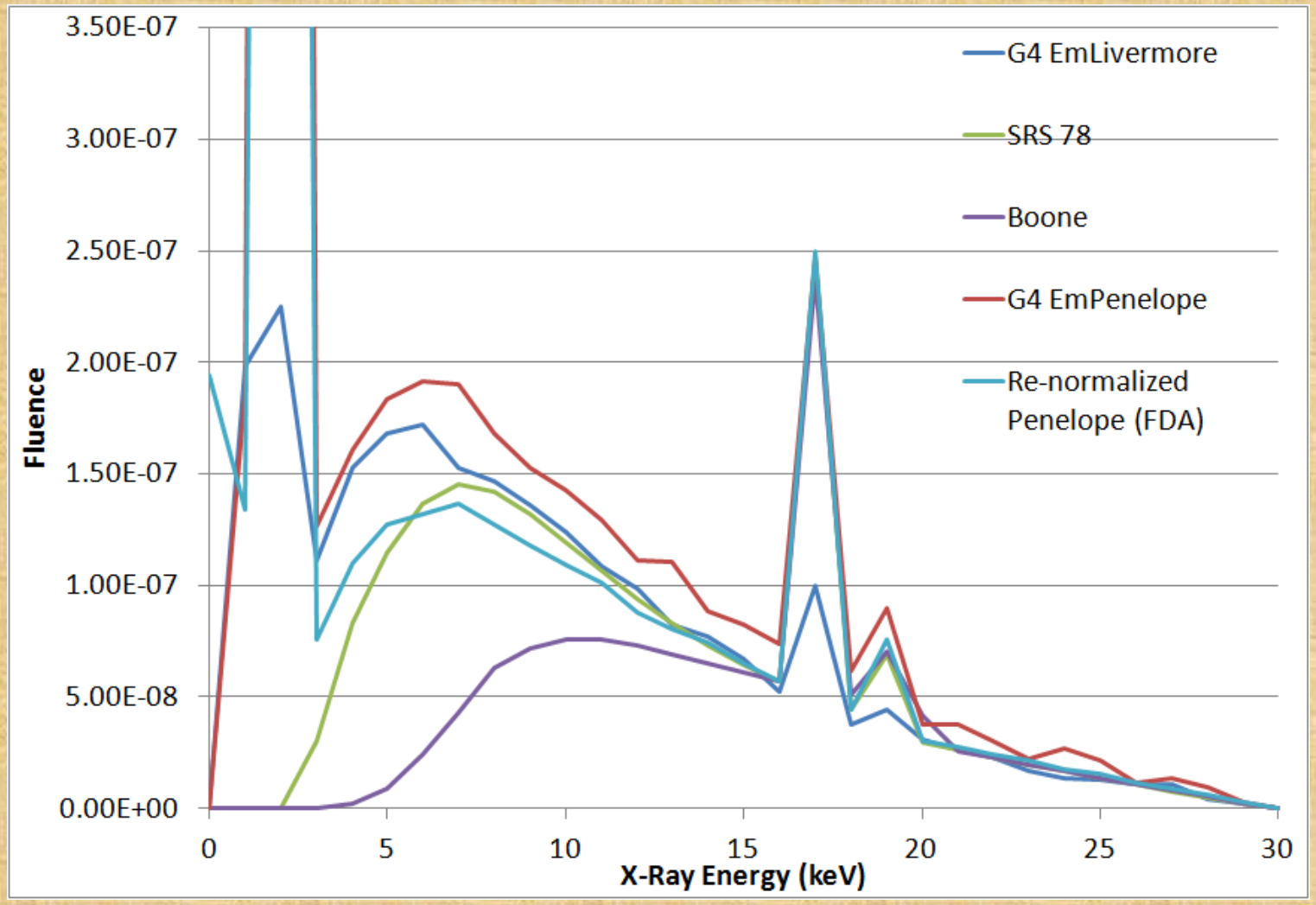
Geant4 / Penelope validation started fall 2011

Summary:	Primary Only	Total
30 keV		
HVL:	1.00	1.00
QVL:	1.02	1.02
100 keV		
HVL:	1.00	1.00
QVL:	0.99	0.99
30 kVp		
HVL:	1.03	1.03
QVL:	1.05	1.05
100 kVp		
HVL:	1.01	1.01
QVL:	1.01	1.01

Geant4 and Penelope match well in simple simulations of photon absorption with simple geometries

Results from other MC codes are coming.

Production of X-Rays
Mo Target, 30 keV electrons



Problems encountered in other simulations

- Simple and voxelized CT
  - Still investigating
- X-ray generation
  - Problems with:
    - G4EmLivermorePhysics (pending)
    - Bremsstrahlung splitting (fixed 9.6beta)
- Feedback from Ioannis is very useful for ongoing developemnts

Geant4 ASSOCIATES INTERNATIONAL
Experts in Radiation Simulation

Validation of gamma processes

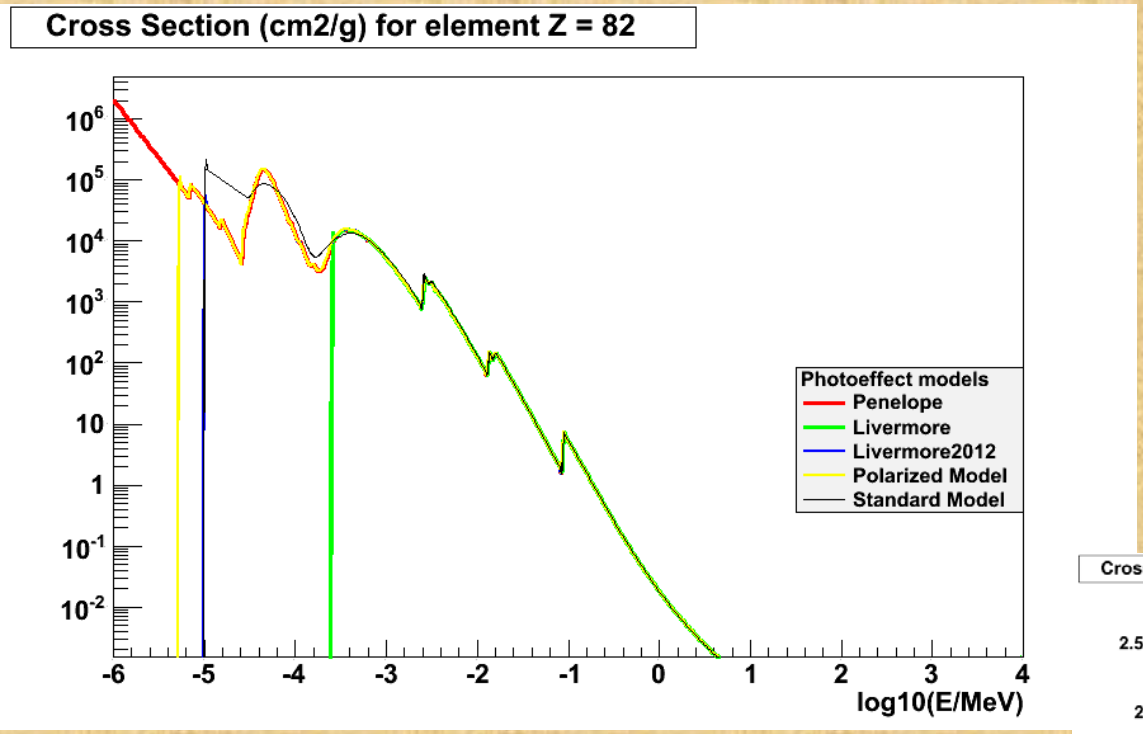
A.Ivantchenko

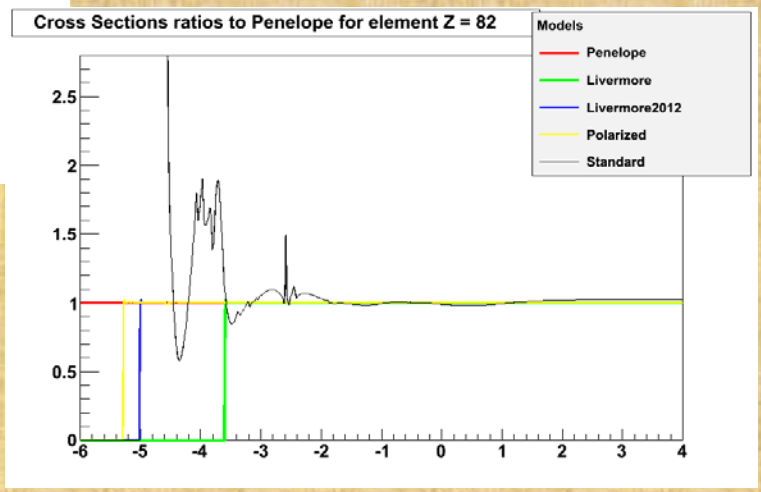
Under ESA technology research programm
Support G4AI and University of Bordeuax I

Goals of the work

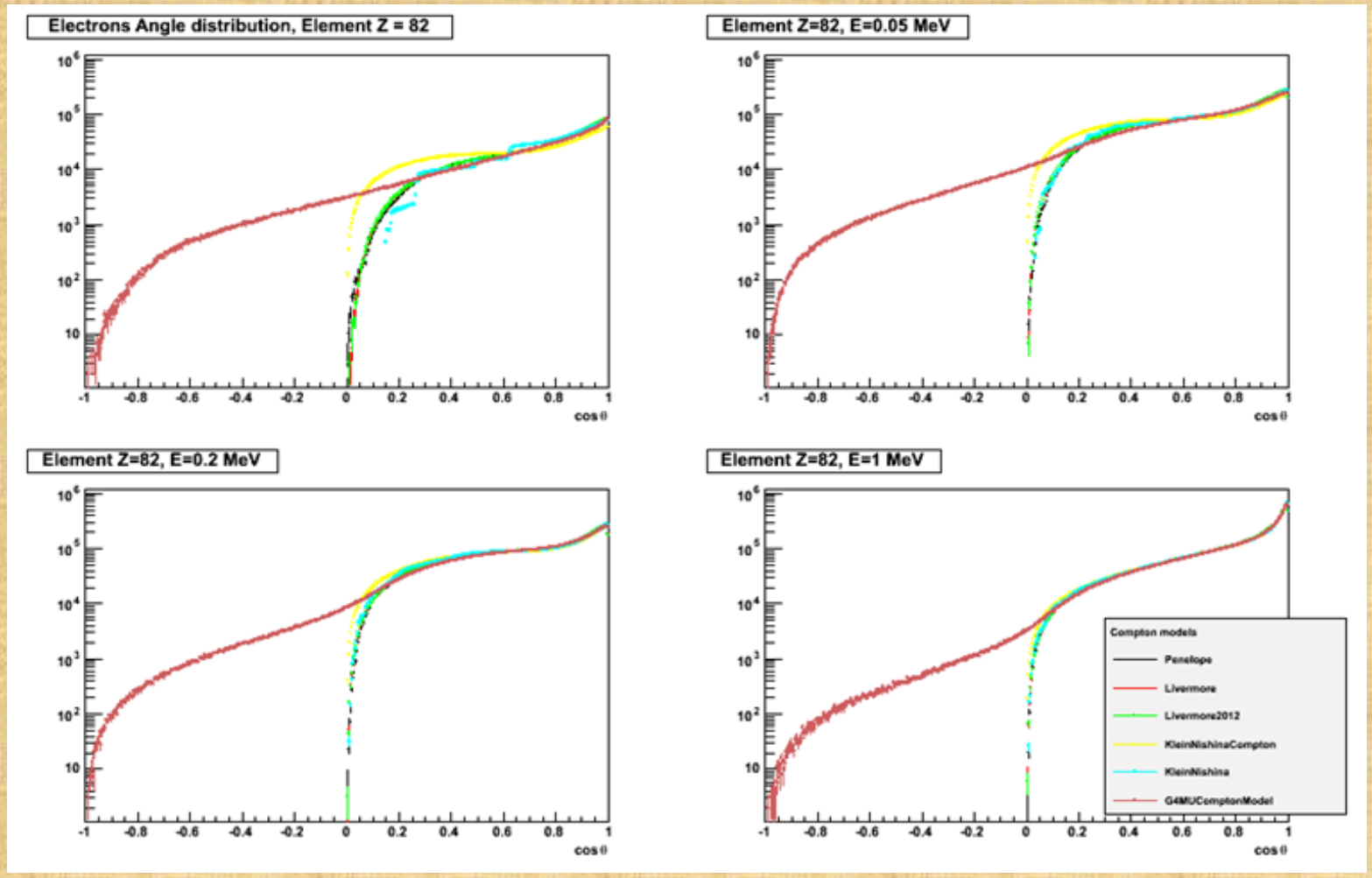
- New tests were created for 4 main gamma processes
  - Tests of all Geant4 models at all energies and elements
  - Cross sections, secondary energy spectra and angular distributions
  - *http://www.cern.ch/antoni/results*
- Creation of new Livermore gamma models
  - Based on G4PhysicsVector data handling
    - Goal for Geant4 X
  - Use optimal algorithms of sampling of final state
  - Download data only for elements used in geometry
- Results are collected for g4.9.5.ref07 (August 2012)

Cross sections for photoelectric





Compton: angle distribution of outgoing electrons, Pb (10, 50, 200, 1000 keV)



CPU comparison for Rayleigh (Pb, 250 keV, 20000 events)

Model	CPU (s)
Penelope	0.03
Livermore	0.03
Livermore-OLD	6.48
V.Grishine	0.01

- Conclusions:
  - New Livermore model provides identical results with Penelope and old Livermore models
  - Old Livermore model is extremely slow
  - V.Grichine model is under development

국립암센터
NATIONAL CANCER CENTER

NCC proton therapy validation activities

Collaborators: Se Byeong Lee, Ph.D., Medical Physicist and
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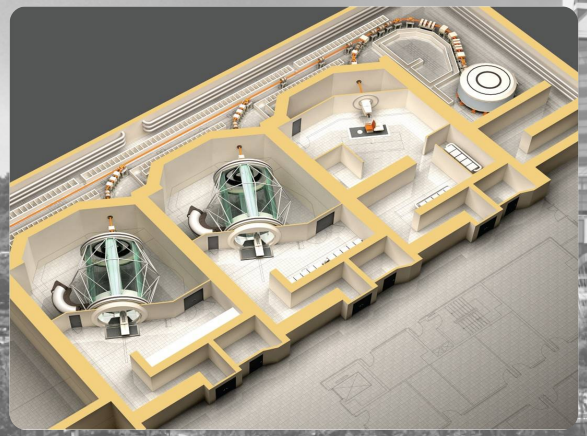
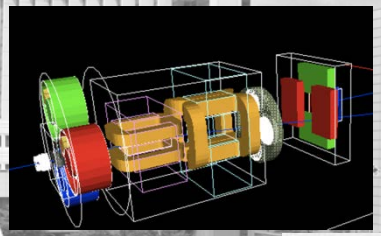
Proton Therapy Center in NCC, Korea,
Sebastien Incerti, Prof, Ph.D.
CENBG, Universite Bordeaux, IN2P3/CNRS

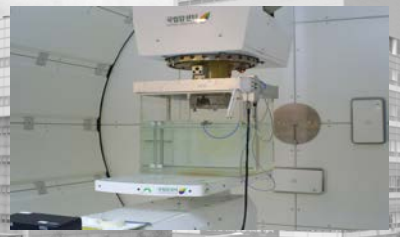
Proton Therapy Facility

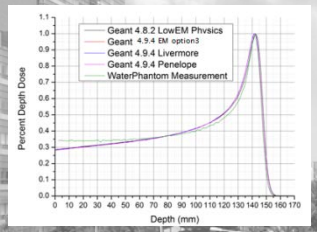


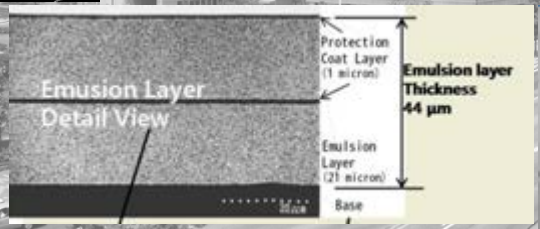
Nozzle modeling & Simulation

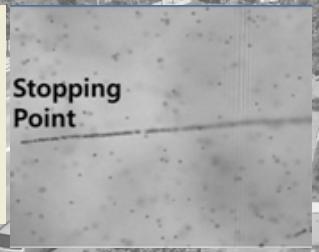


Beam Measurement



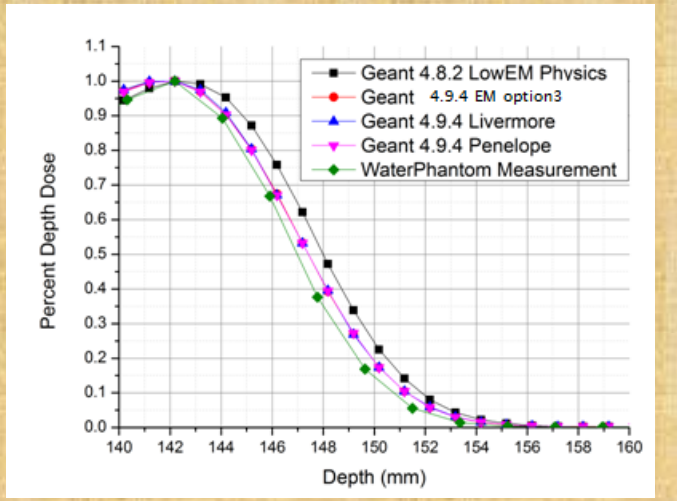




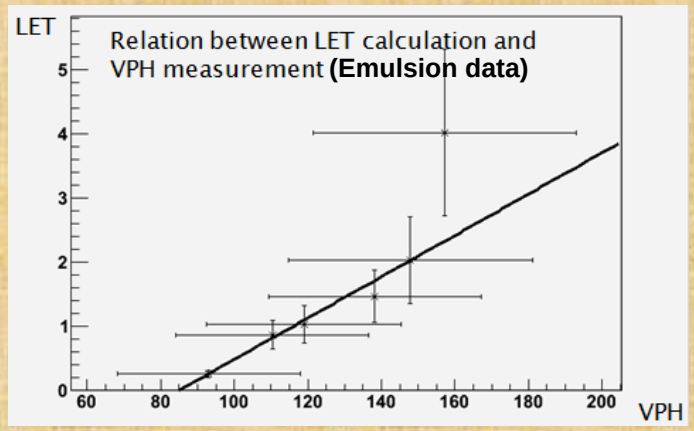


Proposed Standard EM Validation based on Proton Beam Measurement in NCC, Korea

- **Validation 1**: Geant4 MC simulation with a new Standard EM physics list and Comparison with Proton Bragg-peak measurement data periodically.



- **Validation 2:** Micro-dosimetry Study with a Nuclear Emulsion Experiment and the EM physics list



17th Geant4 Collaboration Meeting

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RBE computations in Geant4 medical applications

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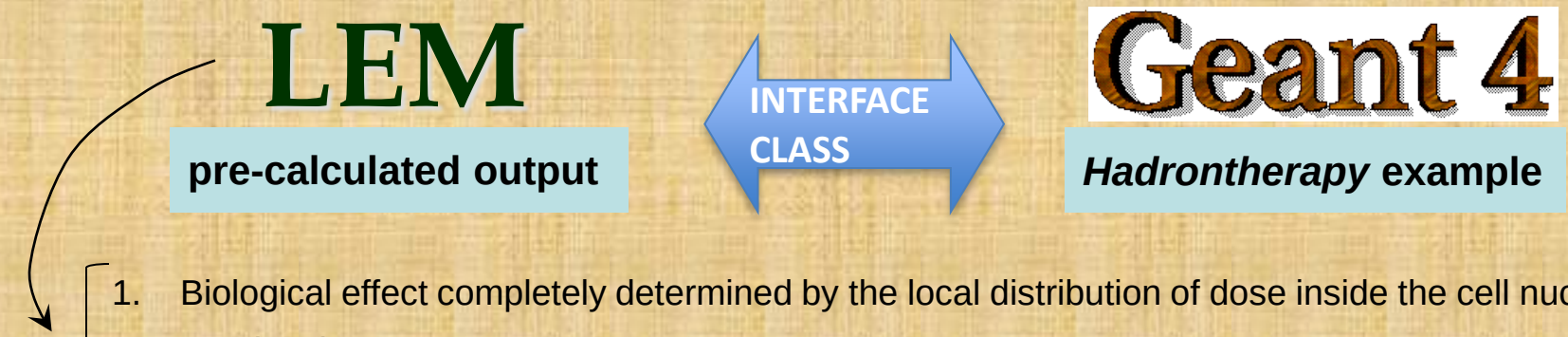
RBE computations in Geant4

- RBE (Relative Biological Effectiveness) is crucial for the prescription of dose in hadrontherapy with ion beams
- It sensibly depends not linearly on physical parameters (dose level, kinetic energy, atomic number, LET) and biological ones (tissue type, oxygenation, endpoint)
- It can be obtained with radiobiology experiments in specific simple configurations, fixing all the mentioned parameters (few data) …
- … but it is difficult to calculate in an accurate (and fast!) way for realistic clinical cases (→ mixing of the mentioned parameters)

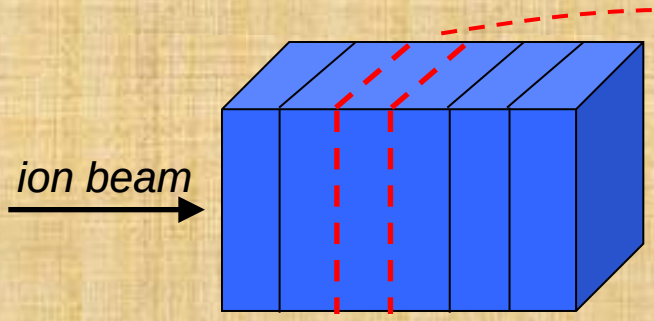
A module for RBE computation has been developed, coupling pre-calculated Local Effect Model (LEM) outputs with Hadrontherapy (in collaboration with the INFN section of Turin)

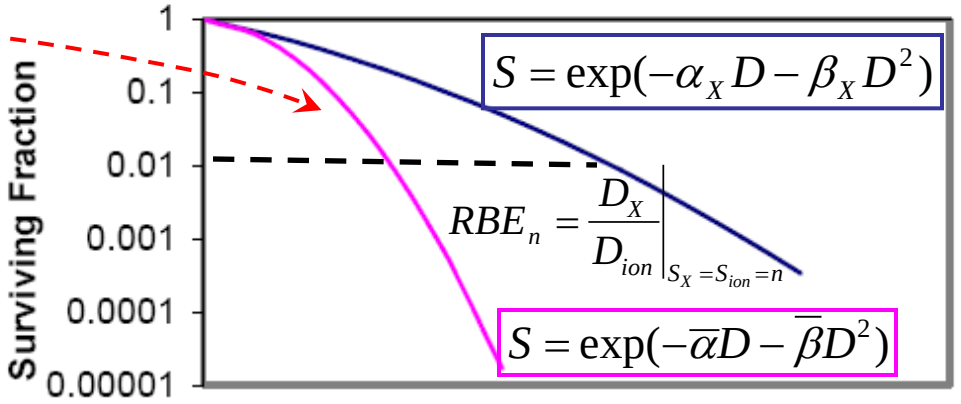


1. Biological effect completely determined by the local distribution of dose inside the cell nucleus
2. The *local* (at cell level) energy deposition of any single track, has a radial symmetry respect to the track itself and an inverse square radial slope
3. Locally, the effect of ions can be evaluated using the X-ray Linear Quadratic (LQ) model

RBE computations in Geant4

- Ion beam impinging on water cubic phantom divided in slices of 100 um
- Table with *pre-calculated* α and β (with *LEM I*) for specific ion/energy/LET is called run-time
- *Step-by-step* particle parameters are retrieved and α and β are obtained with interpolation
- According to the TRDA (*theory of dual radiation action*) a *weighted average* α and β is calculated for each step *i* and updated at the end of each event
- A the end of the run final values of average α and β are stored in each voxel (including secondary contributions) and *RBE* is calculated





Future developments:

- **General interface**: implementation of other **LEM** versions (**II**, **III**, **IV**) and of **MKM** model (Microdosimetric Kinetic Model)
- Different **cell lines** to be implemented and further **comparisons** with published data (few for ion irradiation) and experiments performed @ LNS-INFN
- Future release in the **public version** of *Hadrontherapy*

Discussion on EM Builders in 9.6

- Main modifications affecting different users:
  - WentzelVI msc for electrons above 100 MeV
  - Livermore Rayleigh
  - Relativistice pair production above 80 GeV
  - V.Grichine angular generator for bremsstrahlung
- EM Physics builders for 9.6:
  - Opt0 default (used by ATLAS) no Rayleigh
  - Opt1 coherent with CMS EM builder
  - Opt2 coherent with LHCb EM builder
  - Opt3 – standard, step limits +Rayleigh from Livermore
  - Opt4 (new) – the best combined standard/lowenergy
  - Livermore: mainly Livermore + best standard models
  - Penelope: Penelope + high standard energy models
  - DNA – demonstration of DNA models