Recent Validation and Developments for Geant4 Electromagnetic Physics

11th Geant4 Workshop, Hebden Bridge, UK, *Sept.13-19*

V.N. Ivanchenko, CERN, Geneva, Switzerland

for Geant4 Electromagnetic Group

Outline

- Recent upgrades for Geant4 standard EM
  - EM physics and navigation
  - Updates provided with g4 8.3
  - Updates provided with g4 9.0
- Recent validation results for standard EM
  - Electron transport
  - Heavy particle transport
  - Calorimeter response
- Future plans for standard EM
- Recent progress and plans for Low-energy EM
  - Talk L. Pandola (Thursday plenary)
  - Talk S. Inserti (Thursday parallel)

EM physics and Geant4 navigation

- Geant4 7.1p01 have been used in production for ATLAS, CMS, LHCb and other experiments
- Since then multiples scattering models was significantly upgraded
  - reduced dependence of detector response on production cuts for sampling calorimeters
- Sub-cutoff option restored – simulation with lower cuts in vicinity of geometry boundary
- Upgrades require access to geometry information from physics model to get
  - safety radius
  - distance to the next boundary
- Redesign of interfaces to navigator/transportation

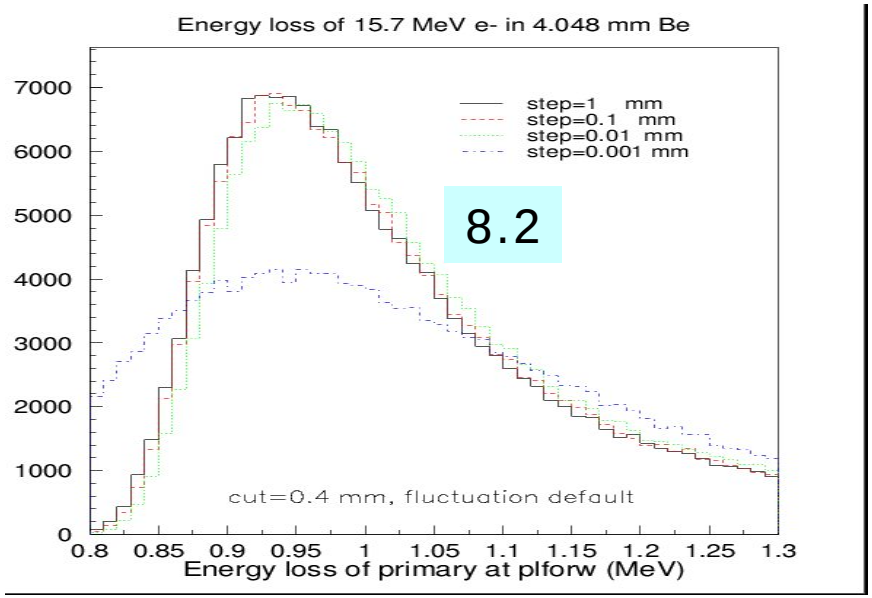
Updates provided with Geant4 8.3

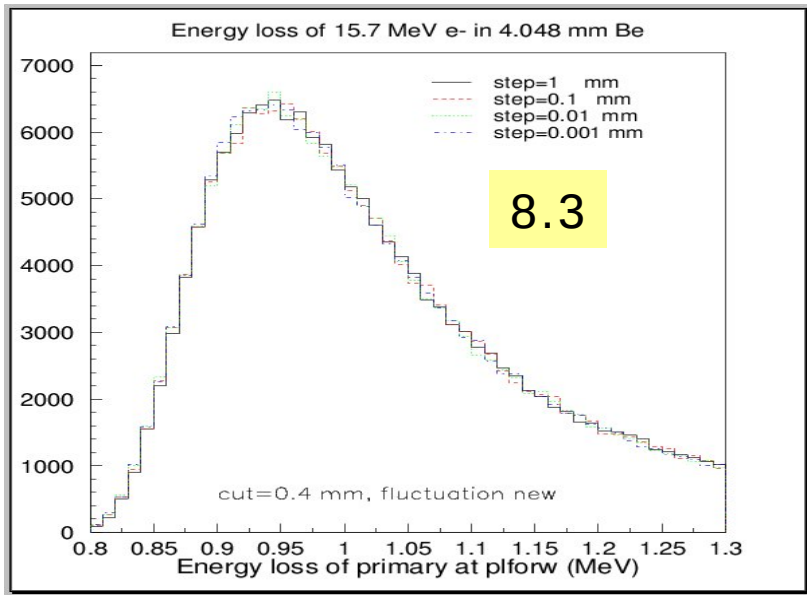
- G4SafetyHelper was introduced
- Single Coulomb scattering mode near geometry boundaries inside G4UrbanMscModel
  - do not use for simulation with strong magnetic field
- Multiple scattering angular distribution improved
  - both central part and tail
- G4hMultipleScattering process for heavy particles
  - the same model with options for faster computations
- Updated model for energy loss fluctuations
- EM (standard) working group page:

http://cern.ch/geant4/collaboration/working_groups/electromagnetic/index.shtml

Sampling of fluctuations in Geant4 8.3

L. Urban





- We cannot use Landau distribution which assumes no δ-rays production
  - Model of fluctuations is cut and material dependent **(L.Urban, NIM A362(1995) 416)**
- The model was improved for small steps or gas

Updates provided with Geant4 9.0

- Updated G4SafetyHelper
  - multiple scattering model
  - sampling of sub-cutoff option
- Provided alternative to continues multiple scattering G4CoulombScattering process
  - pure single scattering
- Optimized general interfaces for EM processes to be more fast (about 10%)
- Infrastructure updated
  - Renamed Physics Lists optional builders
  - Renamed EM standard components in examples
  - Renamed methods of G4EmProcessOptions
  - New UI commands
  - Removed 52-type processes

Multiple scattering options with g4 9.0

- G4MscStepLimitType
  - Minimal - equivalent to the algorithm of Geant4 7.1 and earlier releases (QGSP_EMV Physics Lists)
  - UseSafety - the current default, uses geometrical safety (QGSP and QGSP_EMX Physics Lists)
    - **QGSP_EMX includes sub-cutoff option**
  - UseDistanceToBoundary - the most advanced, recommended for accurate computations in the cases, where no magnetic field is set
    - **also option is recommended: skin = 2**
- Multiple scattering options configurable via UI

Standard EM Physics Lists with g4 9.0

Physics Lists	Builders	Names in UI of examples
QGSP	G4EmStandardPhysics	emstandard
QGSP_EMV	G4EmStandardPhysics_option1	emstandard_opt1
QGSP_EMX	G4EmStandardPhysics_option2	emstandard_opt2
examples	-	standard
examples	-	standardSS
examples	-	standardIG

- If reference Physics Lists are used – nothing needs to be changed

Validation of MeV electron transport using Standard EM packages

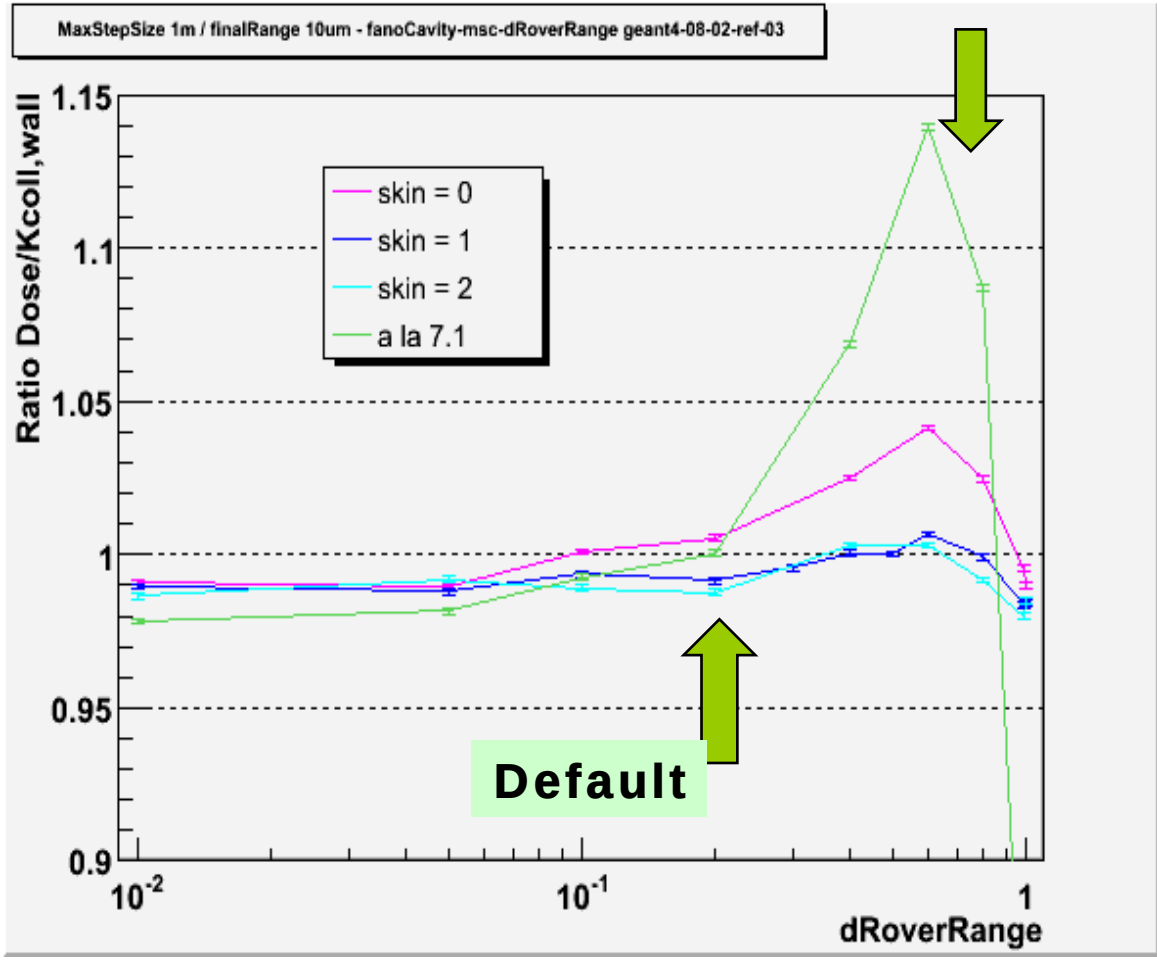
Motivation: A significant part of LHC calorimeter response due to e^- with energy below 1 MeV

Fano Cavity test of e^- transport

S. Elles, M. Maire

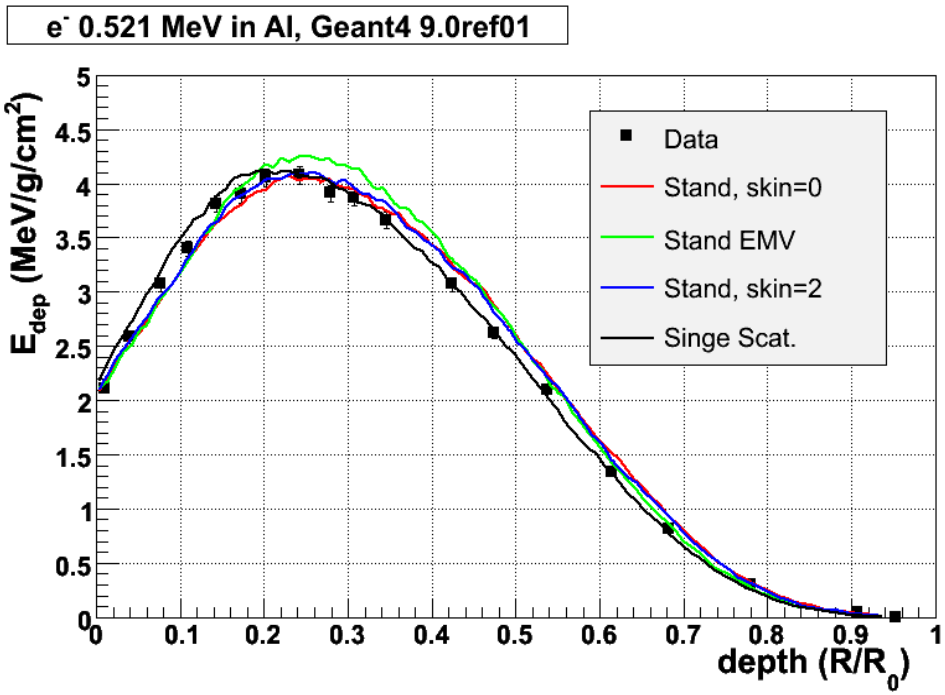
EMV

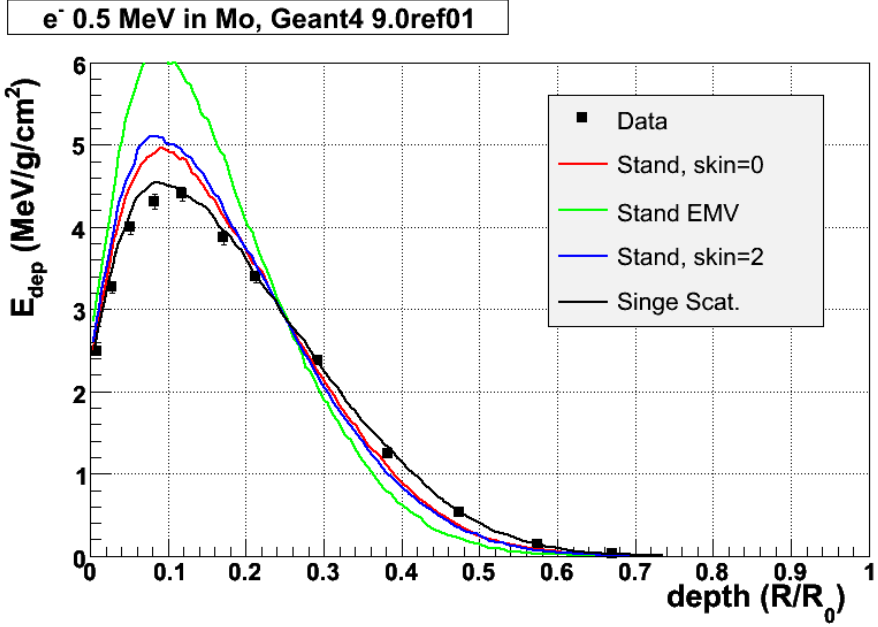
- 1 MeV gamma beam in water with cavity of water-gas
- The absolute prediction of the dose deposition inside the cavity
- Significant deviation for EMV Physics List (g4 7.1p01)

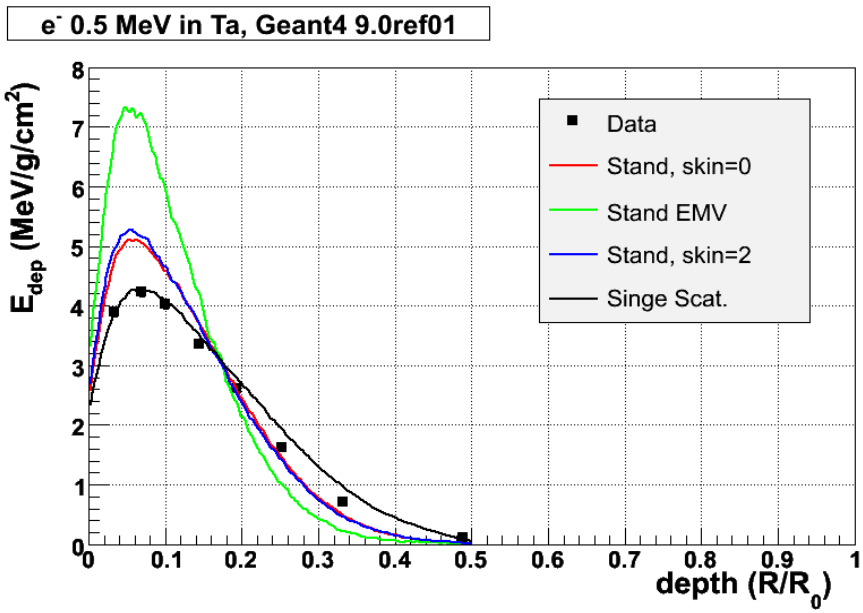


Sandia test of e⁻ transport (NIM B258 (2007) 358)

Integral dose is an important value for LHC – 3 % accuracy



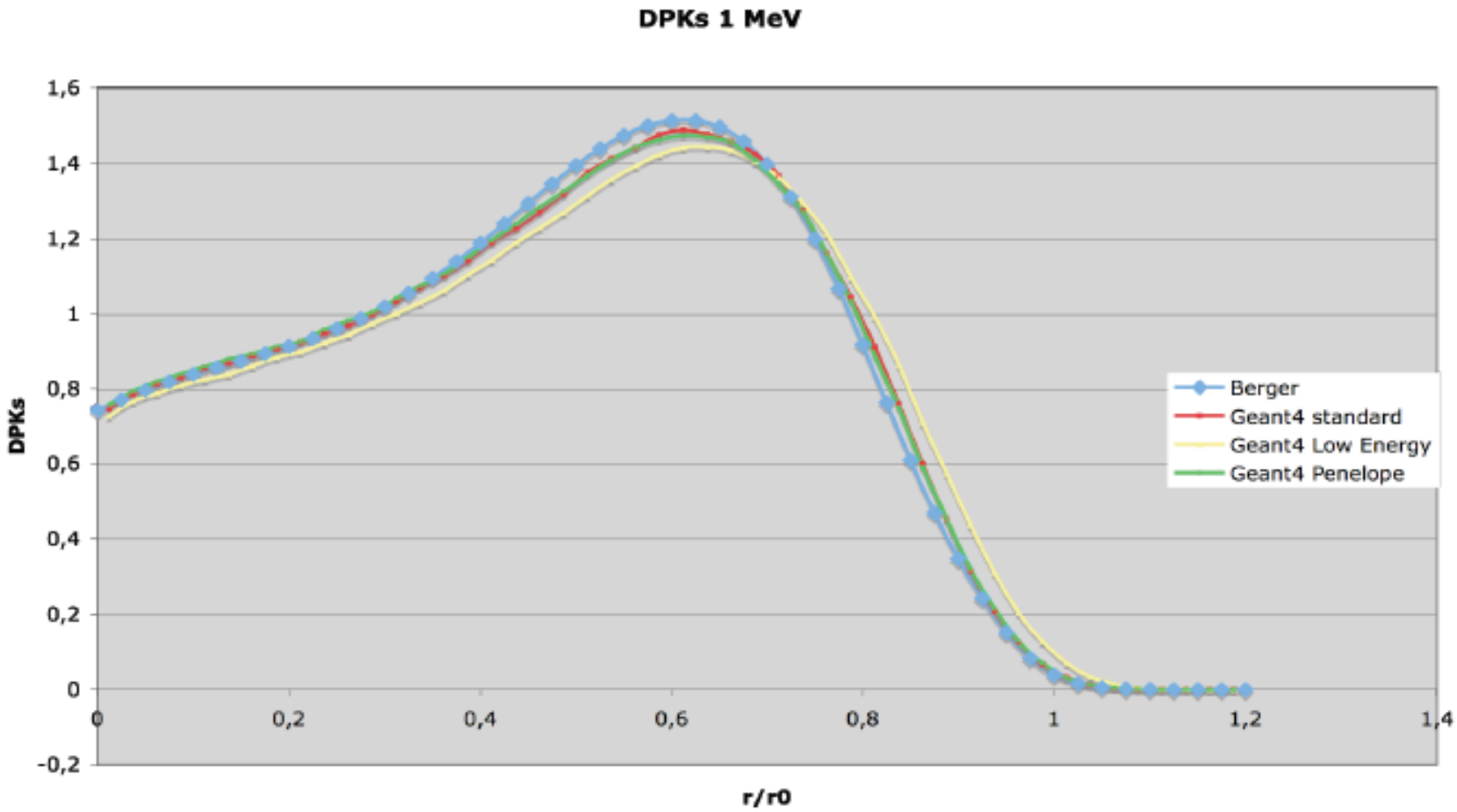




Standard cut 0.7 mm

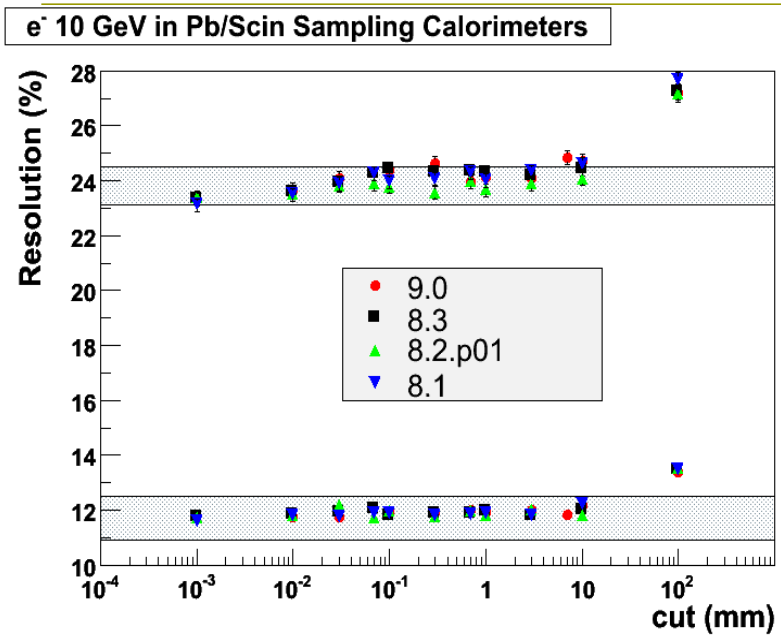
Similar test versus other MC codes

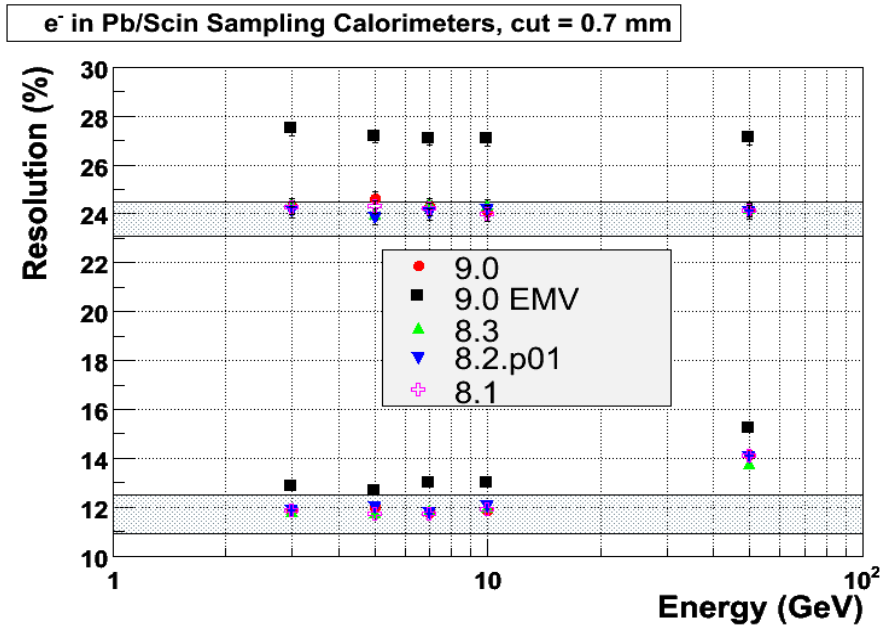
(L. Ferrer et al., Cancer Biotherapy & Radiopharmaceutical, 22 (2007))



Pb/Scintillator sampling calorimeter

(NIM A262 (1987) 229; NIM A274 (1989) 134)

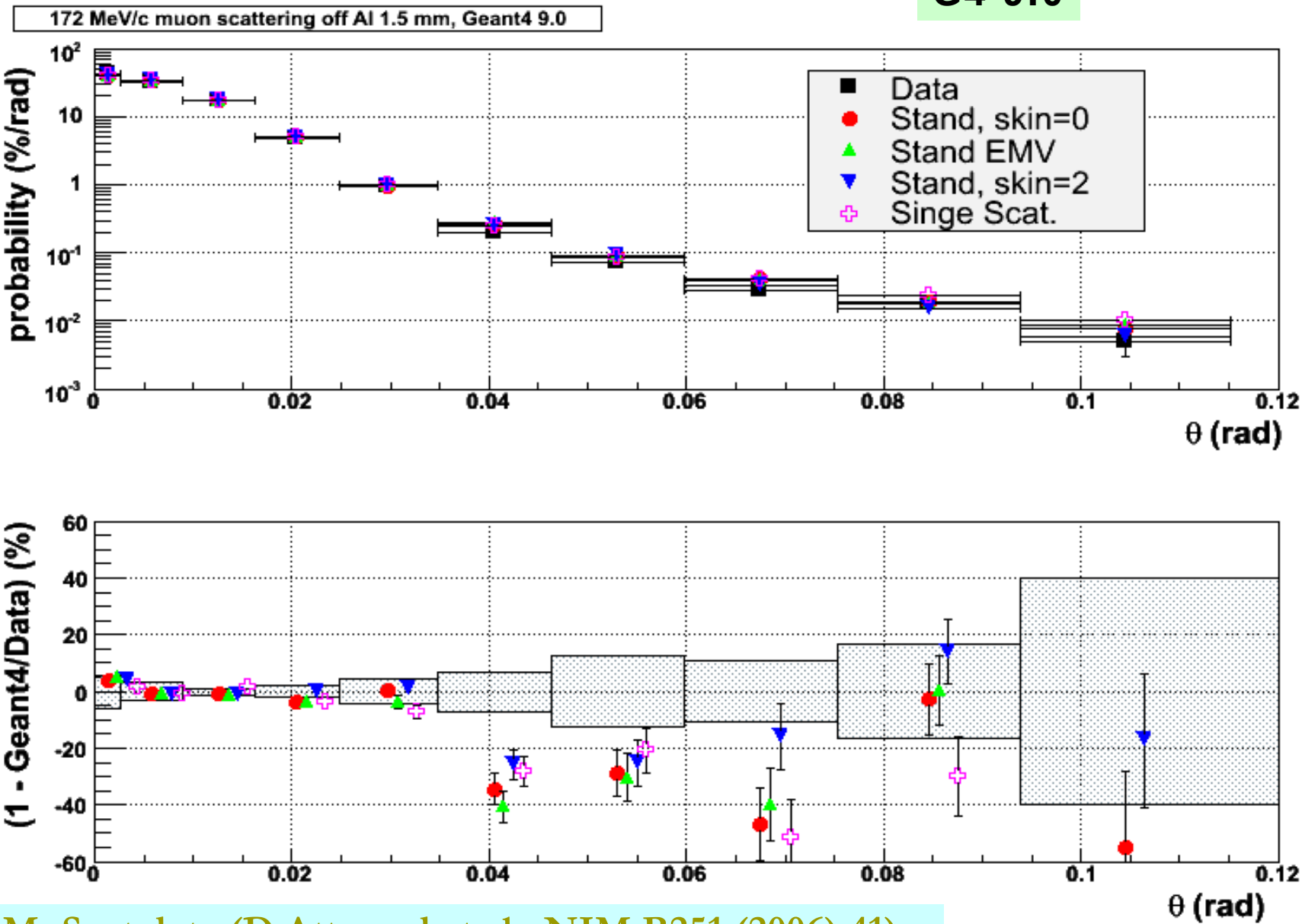




- **Two configurations:**
  - **5 mm Pb / 5 mm Scintillator**
  - **10 mm Pb / 2.5 mm Scintillator**
- **Default Geant4 (QGSP) within experimental uncertainty**
  - **At 50 GeV a special cut was applied for data analysis to reduce leakage**
- **QGSP_EMV version provides biased results**
  - **Less precise for small sampling fraction**

Validation on heavy particle transport using Standard EM packages

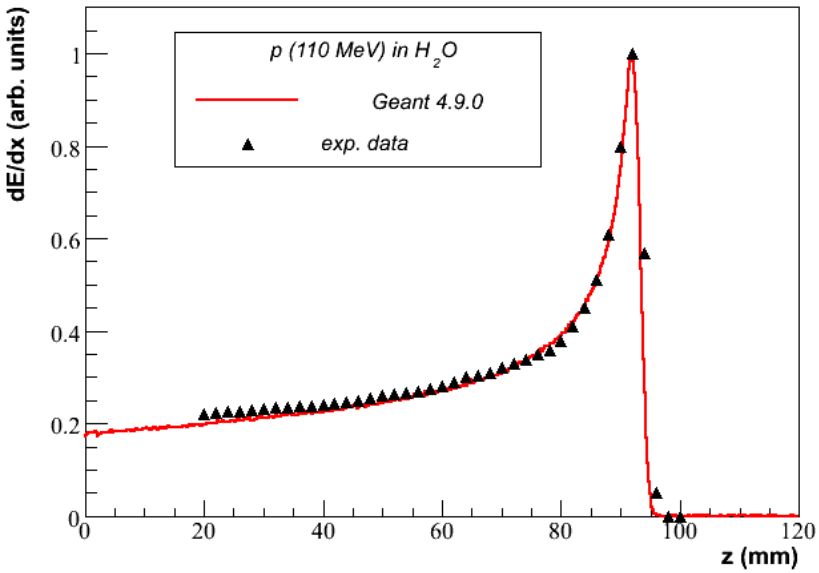
G4 9.0

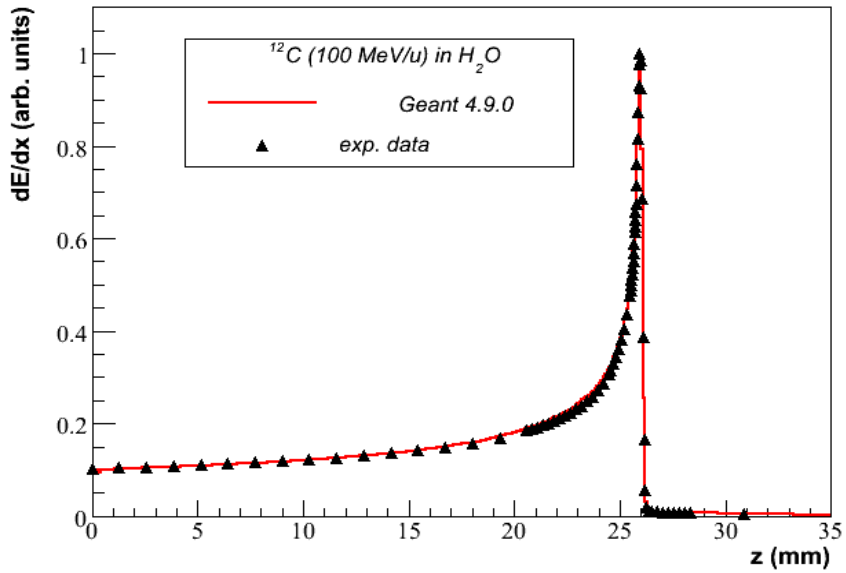


MuScat data (D.Attwood et al., NIM B251 (2006) 41)

Proton and ion stopping in water

(QBBC Physics List, g4 9.0)

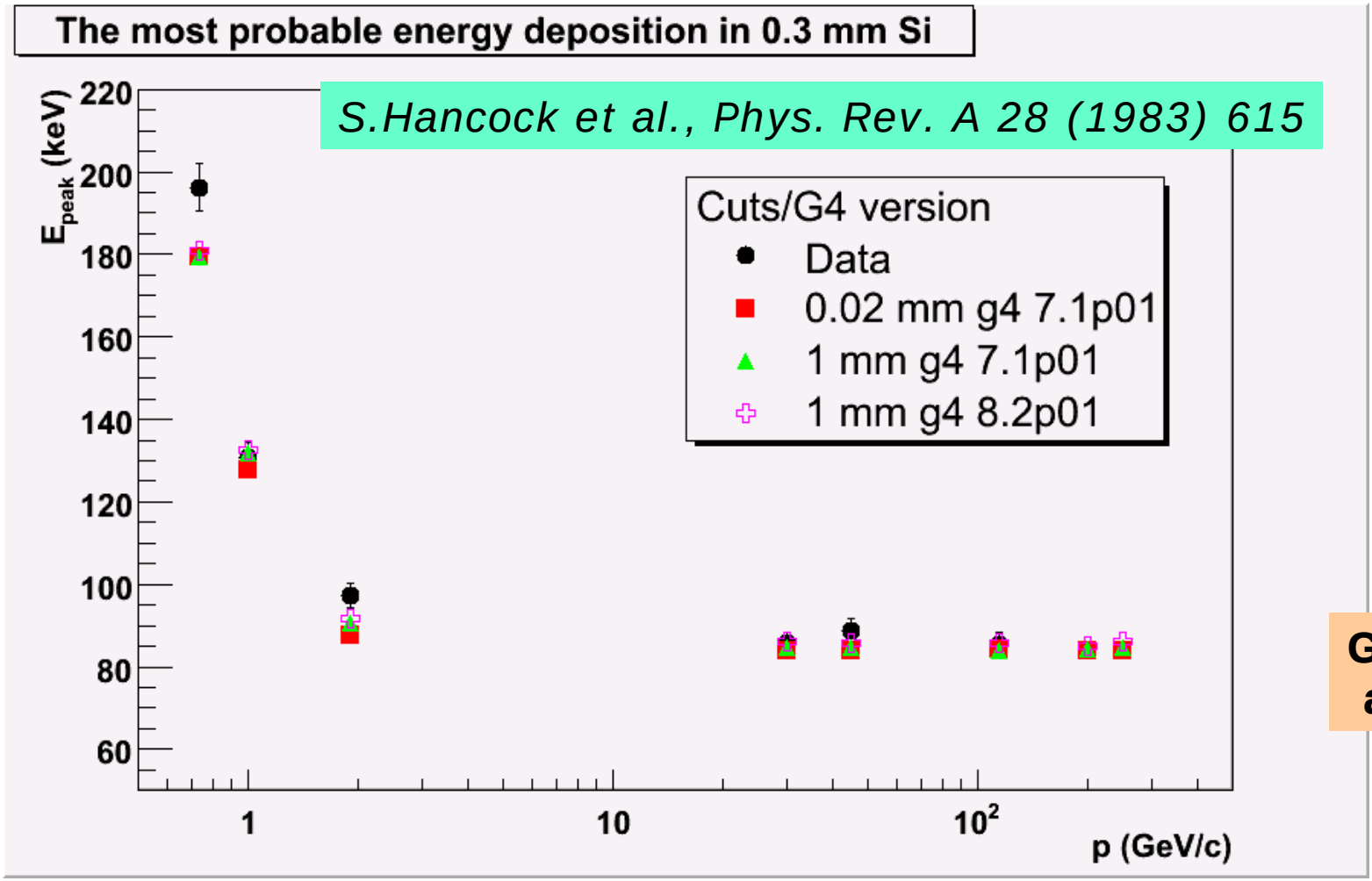




A.Bagulya et al., 11th Geant4 workshop, Lisbon, 2006

- The data for medical proton and carbon-ion beams in water are well reproduced by the Standard package
- Binary Cascade is used for sampling of inelastic interactions
- QElastic model is used for sampling of elastic scattering

Geant4 simulation and data for signal in a vertex detector



TestEm3

π^+ or p beam

G4 results are stable

Updates available with g4 9.0ref01 August, 31

- Materials:
  - NIST elements or materials and man-made elements or materials are completely separated
    - **Allows to have an element with natural abundances and with user defined abundances in the same run**
- G4UrbanMscModel – tuning
- G4CoulombScattering – added nuclear size effect
- New G4ionGasIonisation process for simulation of ion transport in low-density media
- Fixed G4mplIonisation
- New example: G4INSTALL/examples/extended/exoticphysics/monopole

Standard EM group is working on

- Further development of scattering models
  - **Specialized model per particle type**
  - **Nuclear recoil**
- Bremsstrahlung review
  - **Hadron incident**
  - **Specialized models for different energy range**
- Ionisation models tuning
  - **PAI model shows a problem at SLC4**
  - **Ion ionisation tuning**
- Saturation effects
  - **Birks**
- G4Cherenkov process
- Polarisation library extension
- X-ray emission (K-, L- shells)
- CPU performance optimization