Standard Electromagnetic Physics in Geant4 9.0

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Outline

- Updates provided with g4 9.0
- New UI commands
- Validation of multiple scattering
- Calorimeter response with g4 9.0
- CPU performance

Updates provided with g4 9.0

- Infrastructure updated
  - Renamed Physics Lists optional builders
  - Renamed EM standard components in examples
  - Renamed methods of G4EmProcessOptions
  - New UI commands
  - Updated interface to multiple scattering
  - Removed 52-type processes
- Updated sampling of fluctuations of energy loss
- Updated simulation of sub-cutoff
- Updated G4CoulombScattering process
- Optimized general interfaces to be more fast

Physics Lists

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

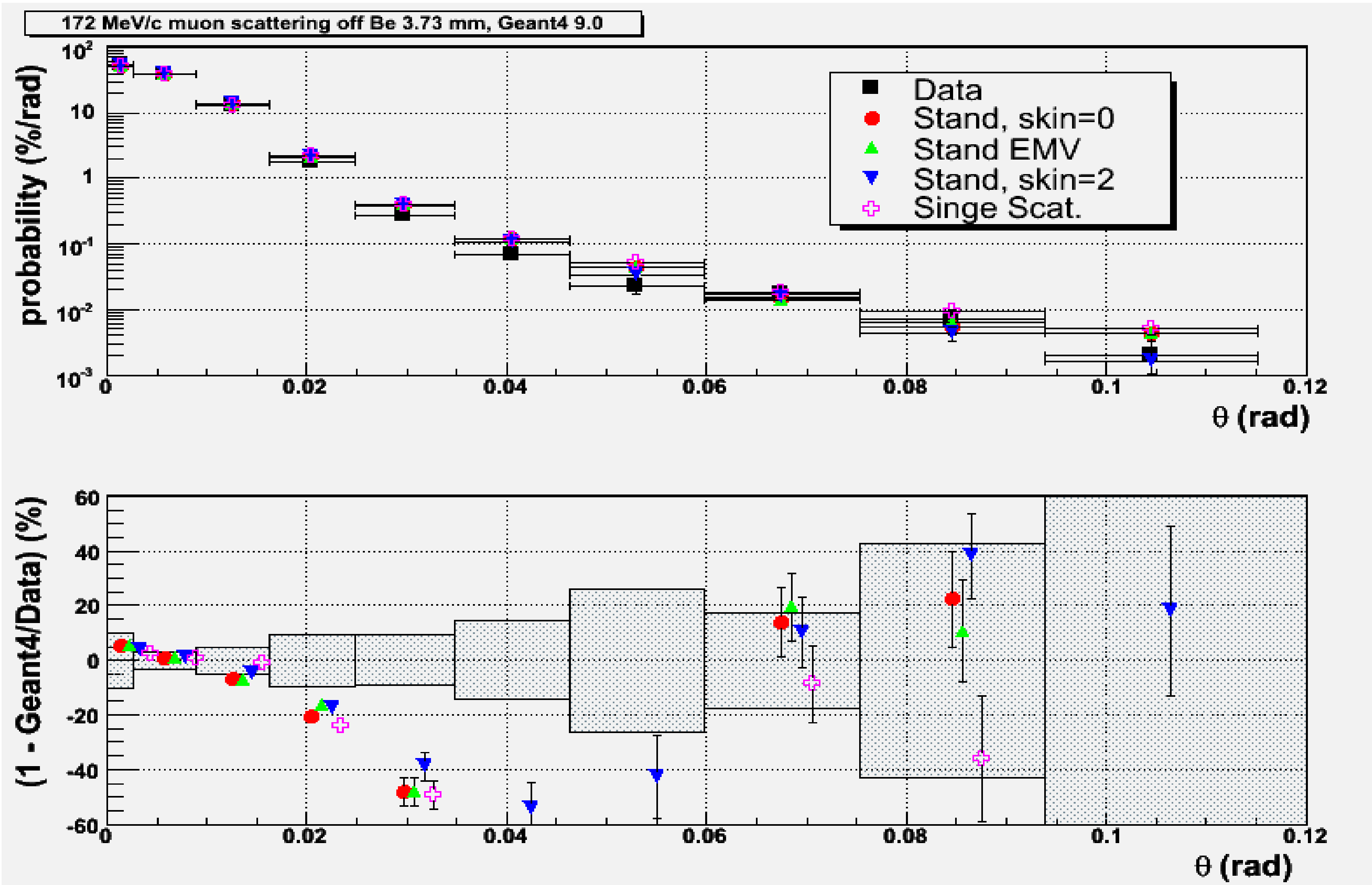
- If predefined Physics Lists are used – nothing needs to be changed

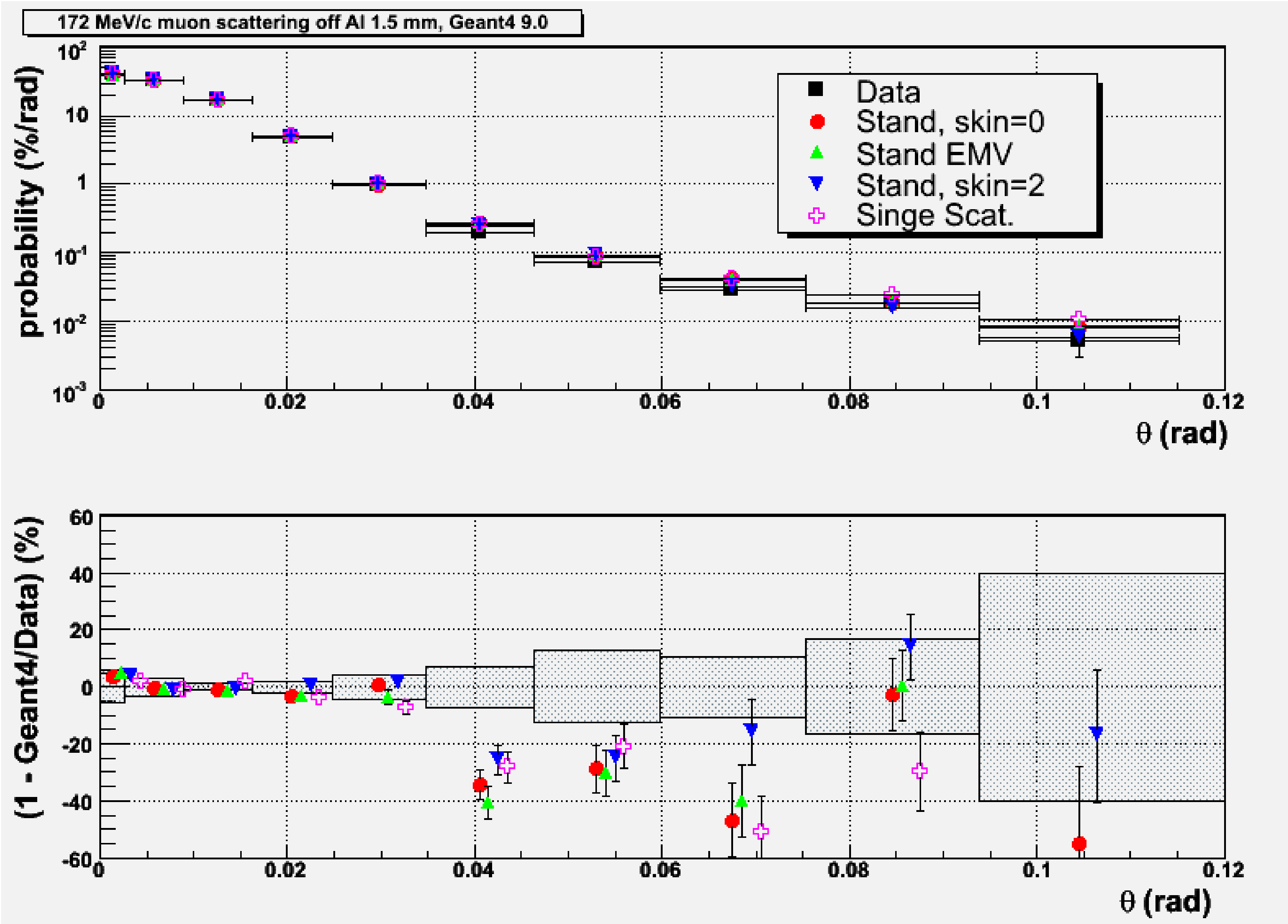
Multiple scattering options

- G4MscStepLimitType
  - Minimal - equivalent to the original algorithm, as implemented in Geant4 7.1 and earlier releases.
  - UseSafety - the current default, which makes use of the geometrical safety
  - UseDistanceToBoundary - the most advanced, recommended for accuracy in the cases where no magnetic field is set
- Multiple scattering configuration

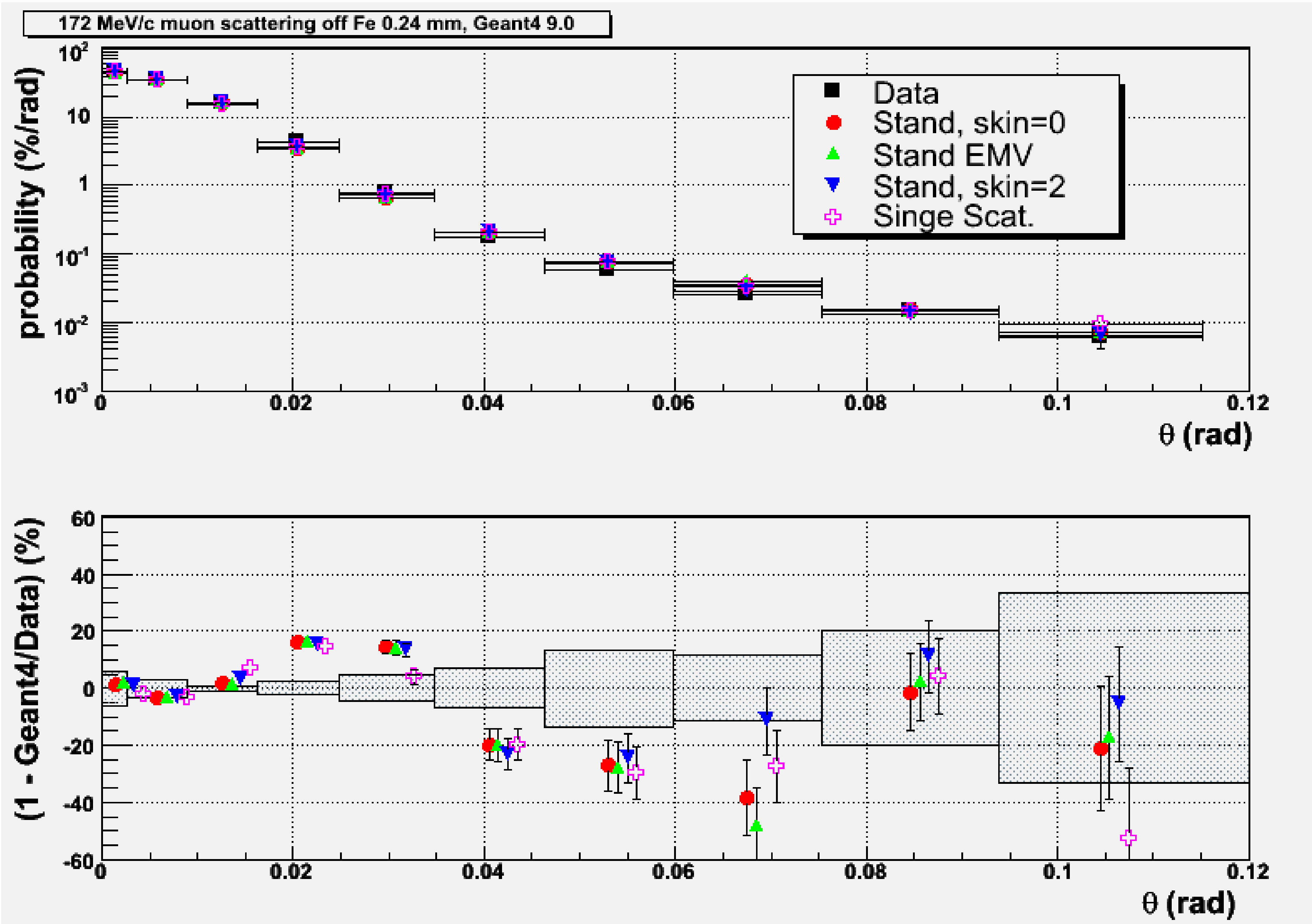
/process/msc/StepLimit	UseDistanseToBoundary
/process/msc/LateralDisplacement	true
/process/msc/RangeFactor	0.02
/process/msc/GeomFactor	3.5
/process/msc/Skin	2

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





172 MeV/c muon scattering off Al 1.5 mm, Geant4 9.0
probability (%/rad)
θ (rad)
Data
Stand, skin=0
Stand EMV
Stand, skin=2
Singe Scat.
(1 - Geant4/Data) (%)
θ (rad)

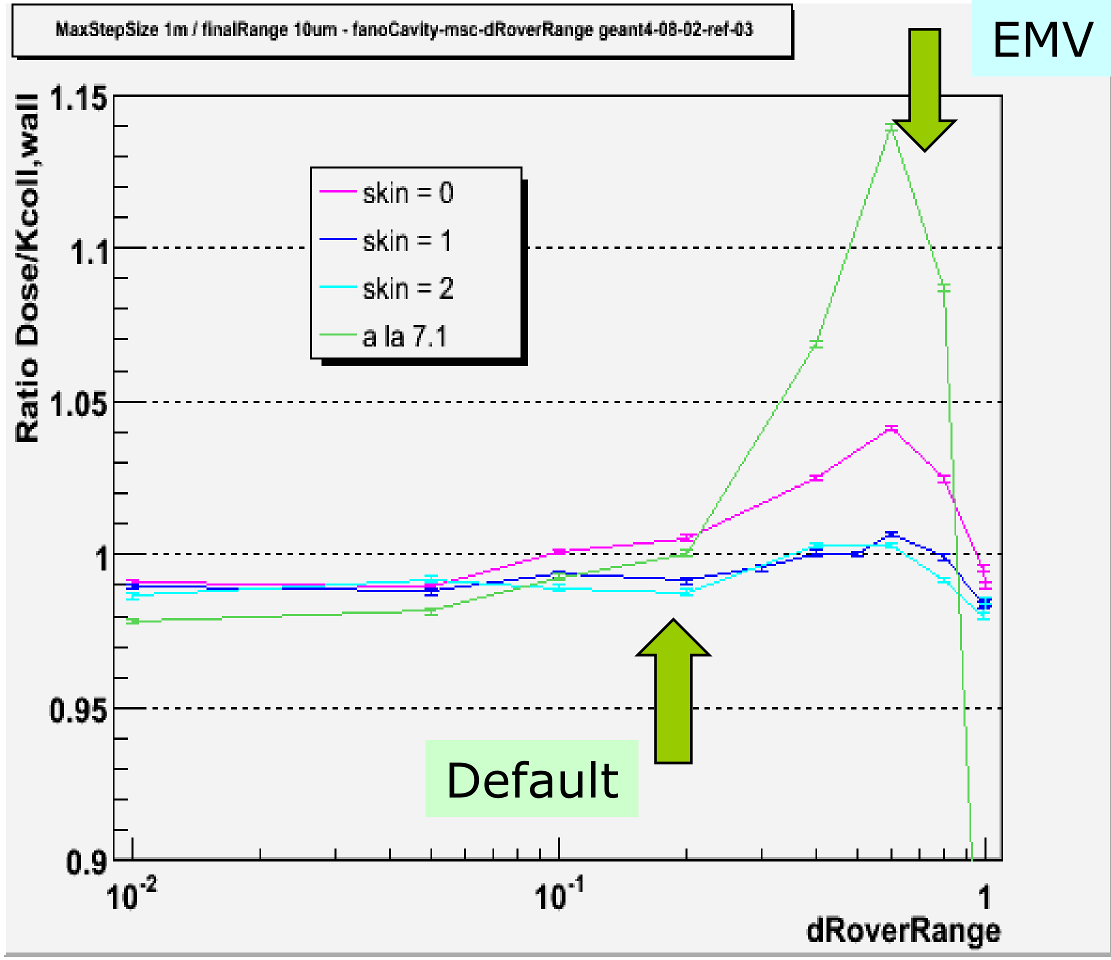

172 MeV/c muon scattering off Fe 0.24 mm, Geant4 9.0
probability (%/rad)
Data
Stand, skin=0
Stand EMV
Stand, skin=2
Singe Scat.
θ (rad)
(1 - Geant4/Data) (%)
θ (rad)

Summary on muon scattering

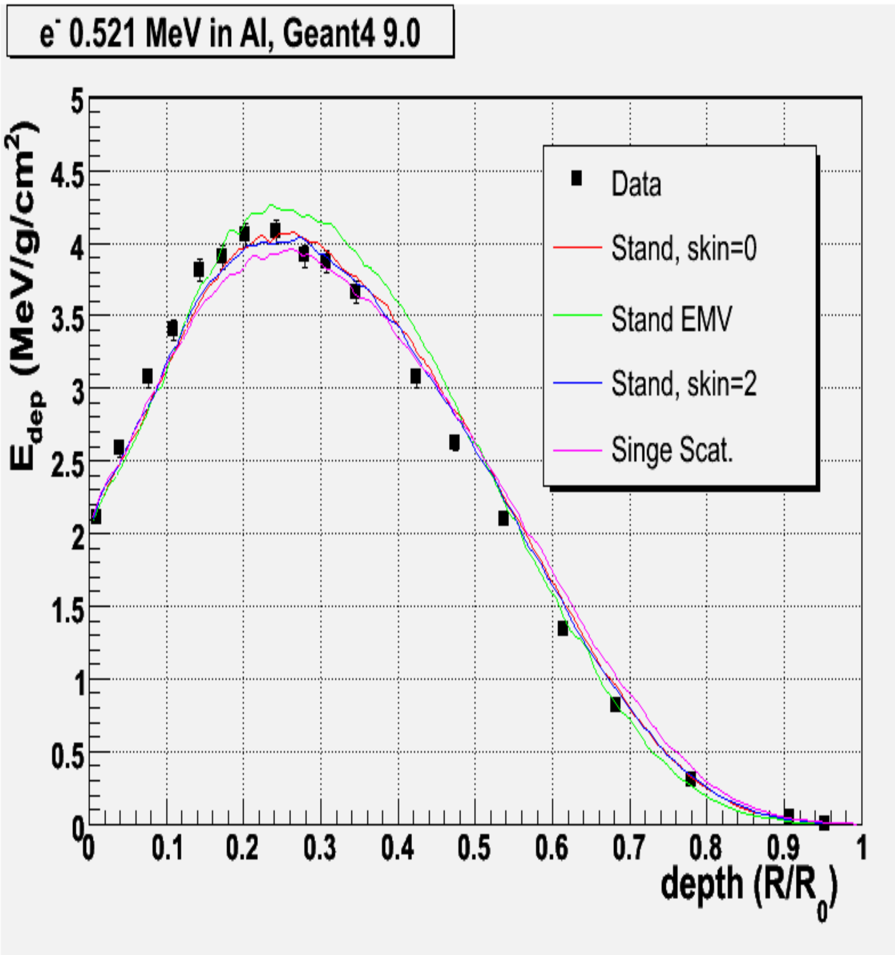
- Muon scattering is in a good agreement with the data for light materials
  - Tested up to Iron
  - Skin=2 little bit more precise than Skin=0
  - EMV provides the same results as Skin=0
  - Single scattering model is working as Skin=2
  - The most significant difference for Iron – up to 4σ for a middle part of a tail

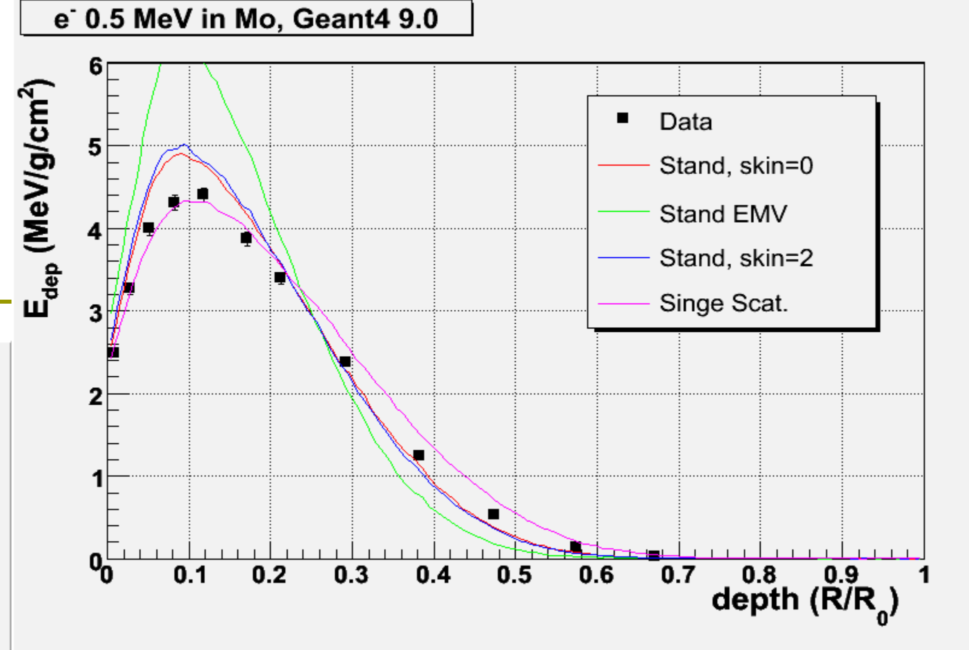
Fano Cavity test (M. Maire, S. Elles)

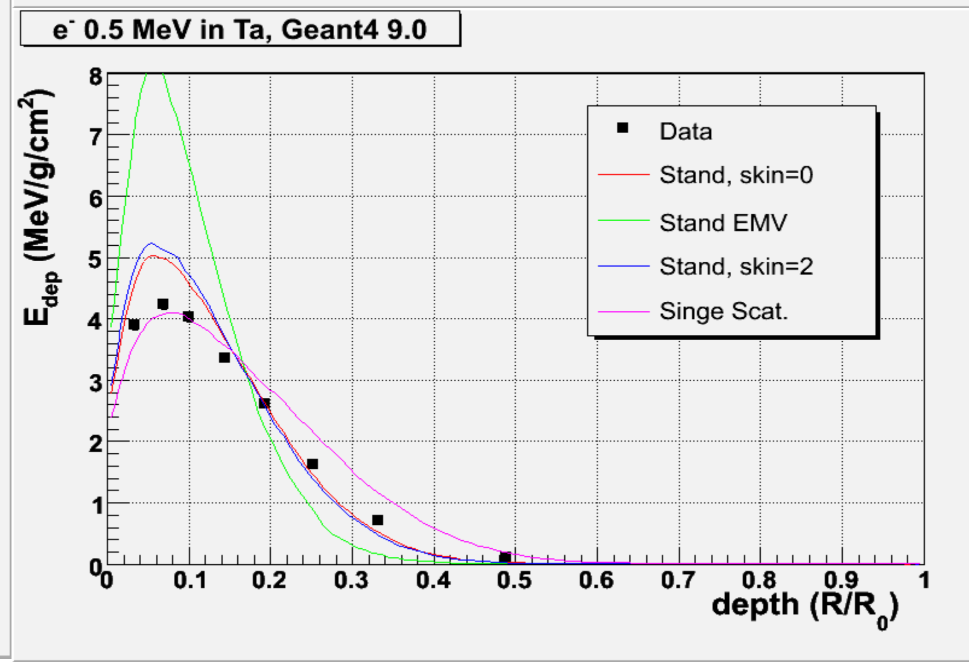
- 1 MeV gamma beam in water with cavity of water-gas
- The absolute prediction of the dose deposition inside the cavity
- Work point of EMV Physics Lists – maximum deviation



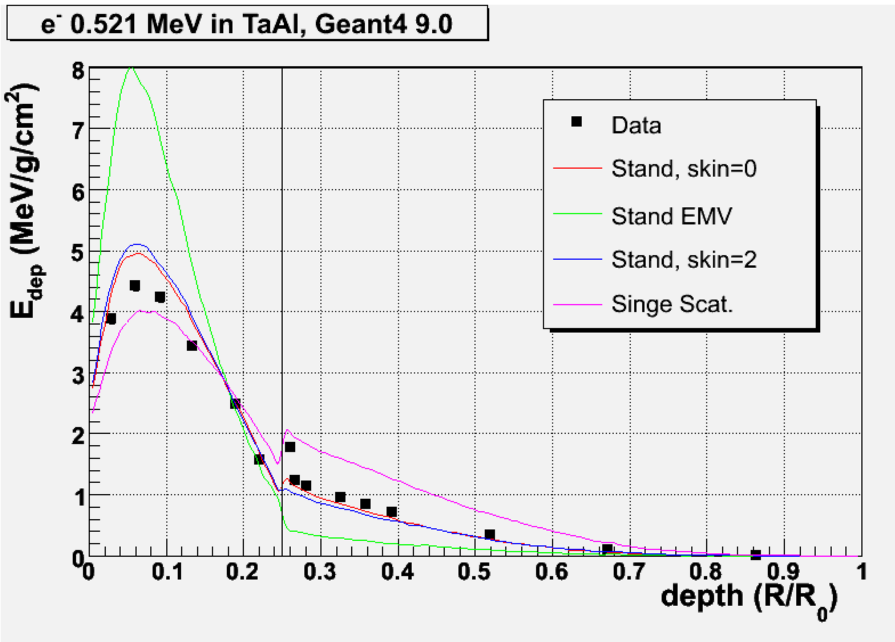
Sandia test for e⁻ beam (O. Kadri)

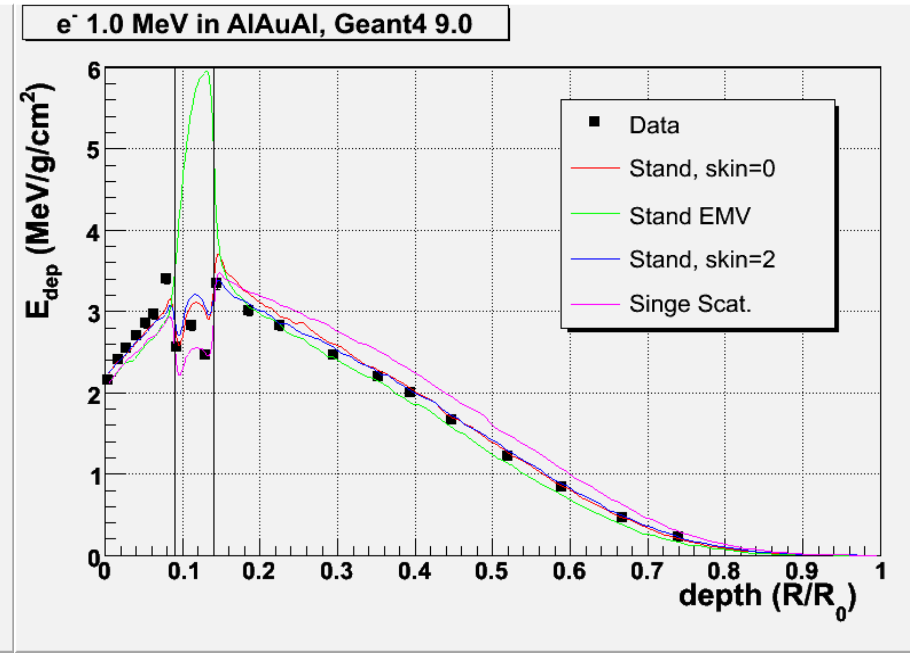






Sandia test for multi-layer configurations

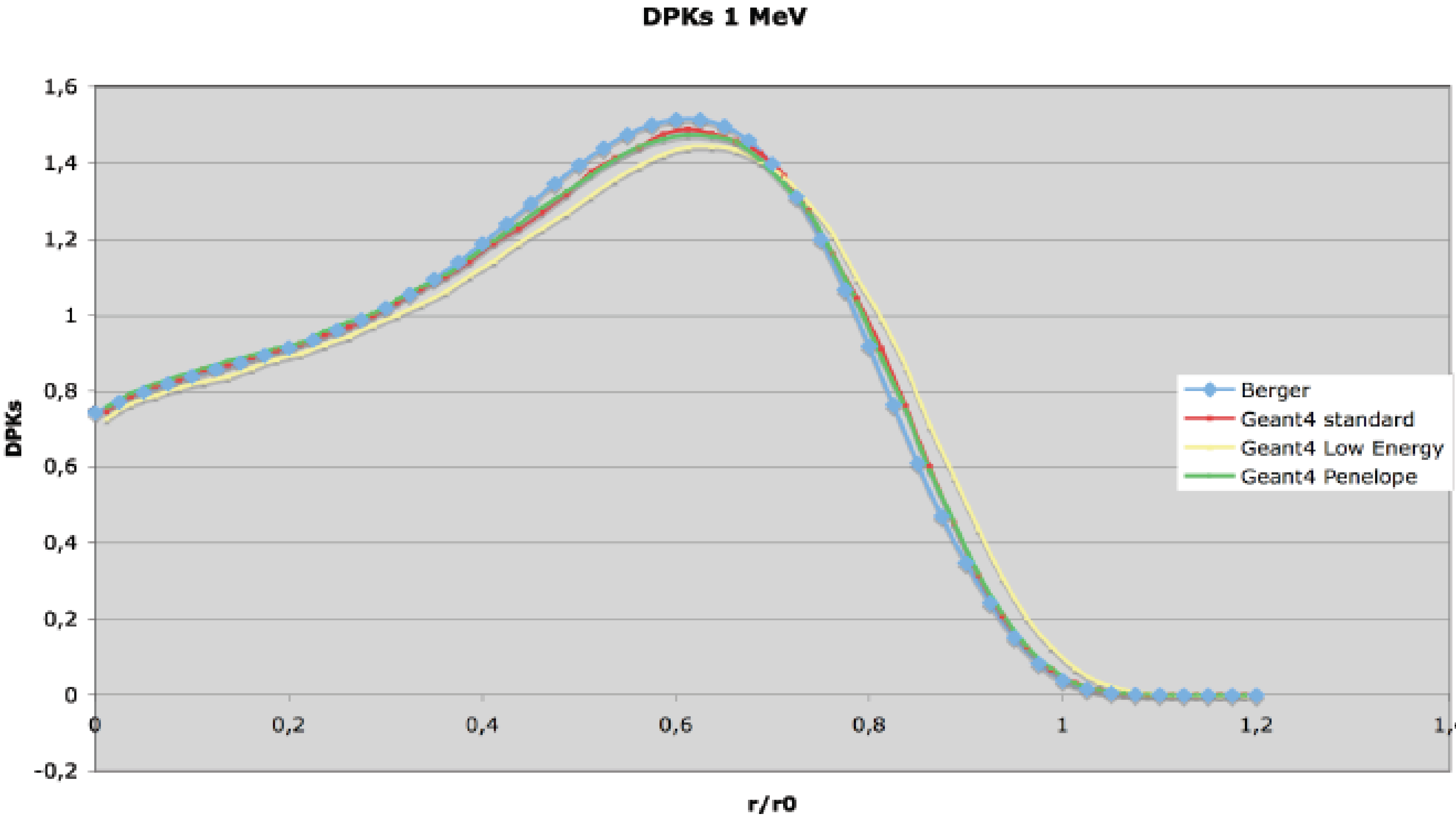




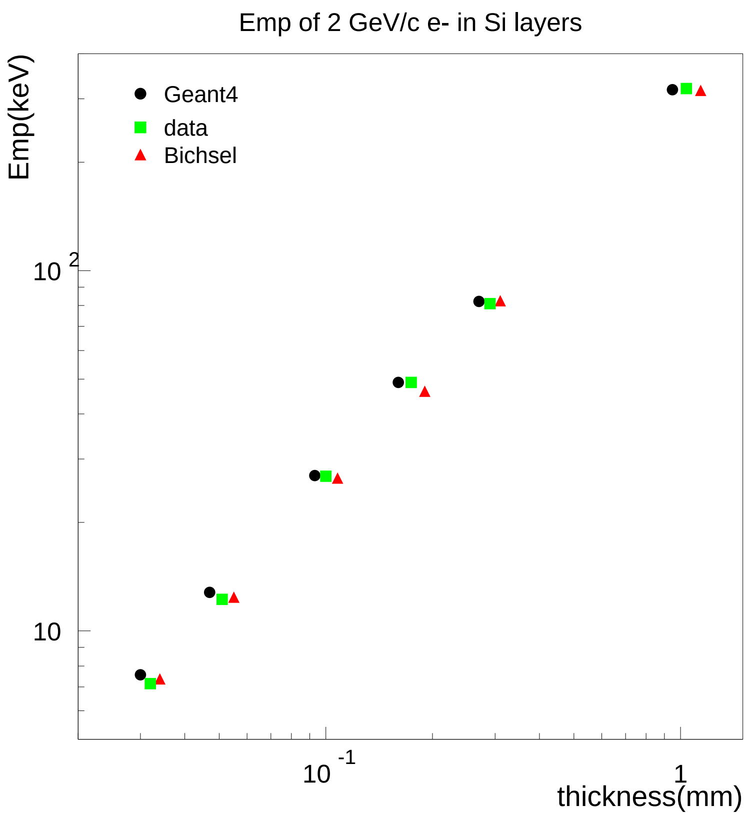
- EMV shows significant deviation from the data
- Single scattering model overestimates dose deposition in the last layer and provide longer distribution in dense media

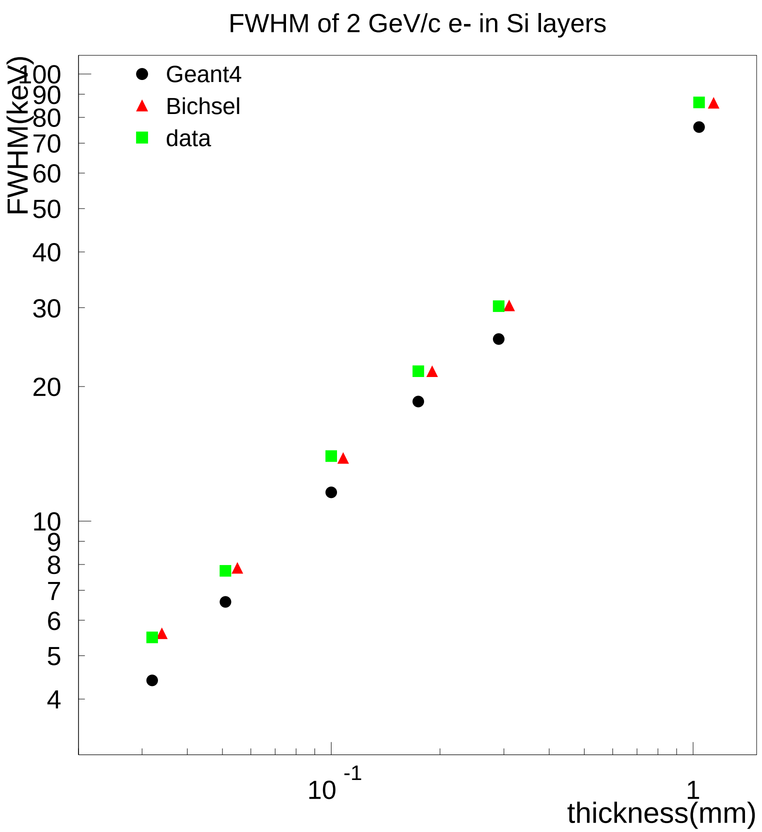
Similar test versus other MC codes

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



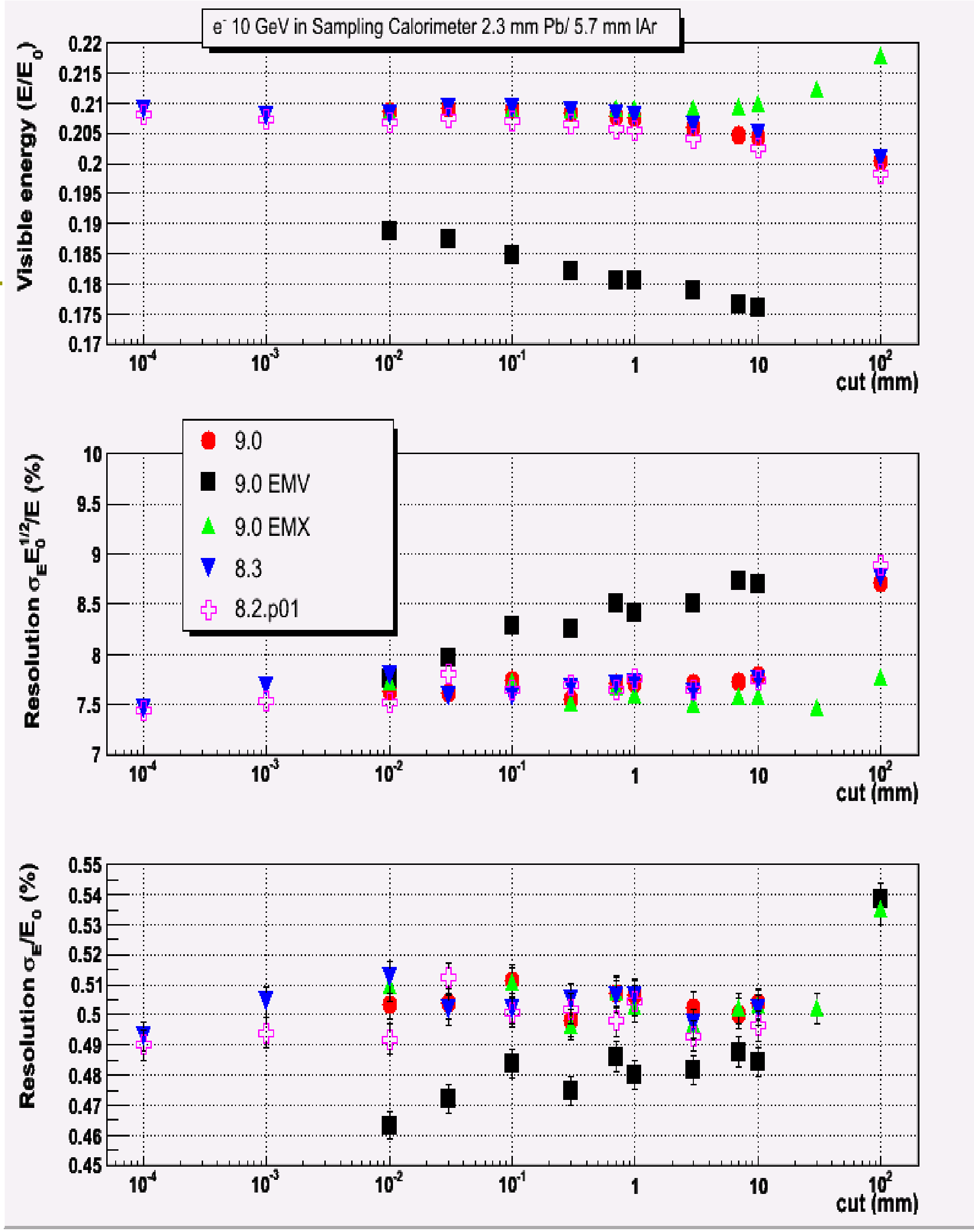
Simulation of fluctuations (L. Urban)



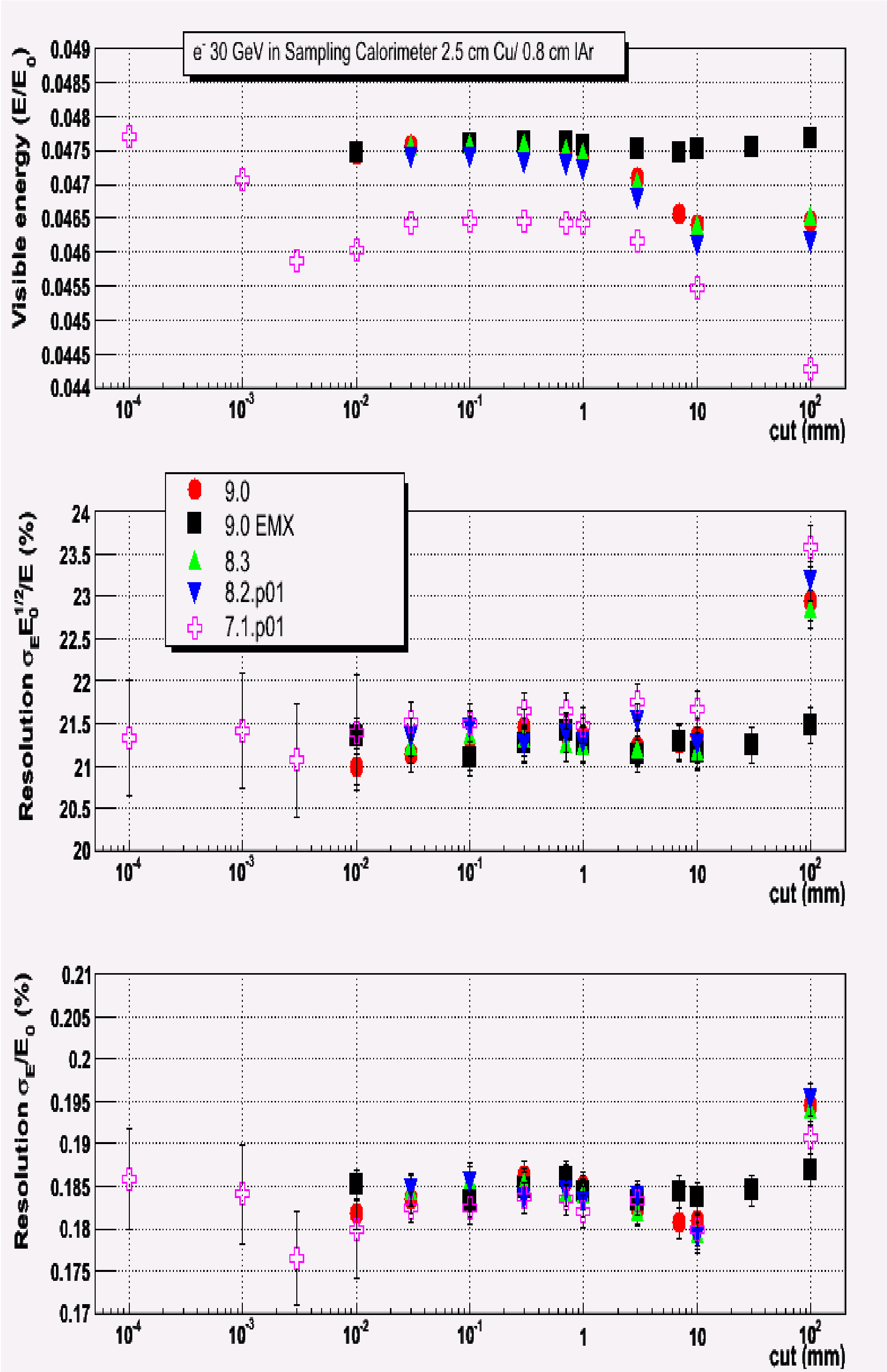


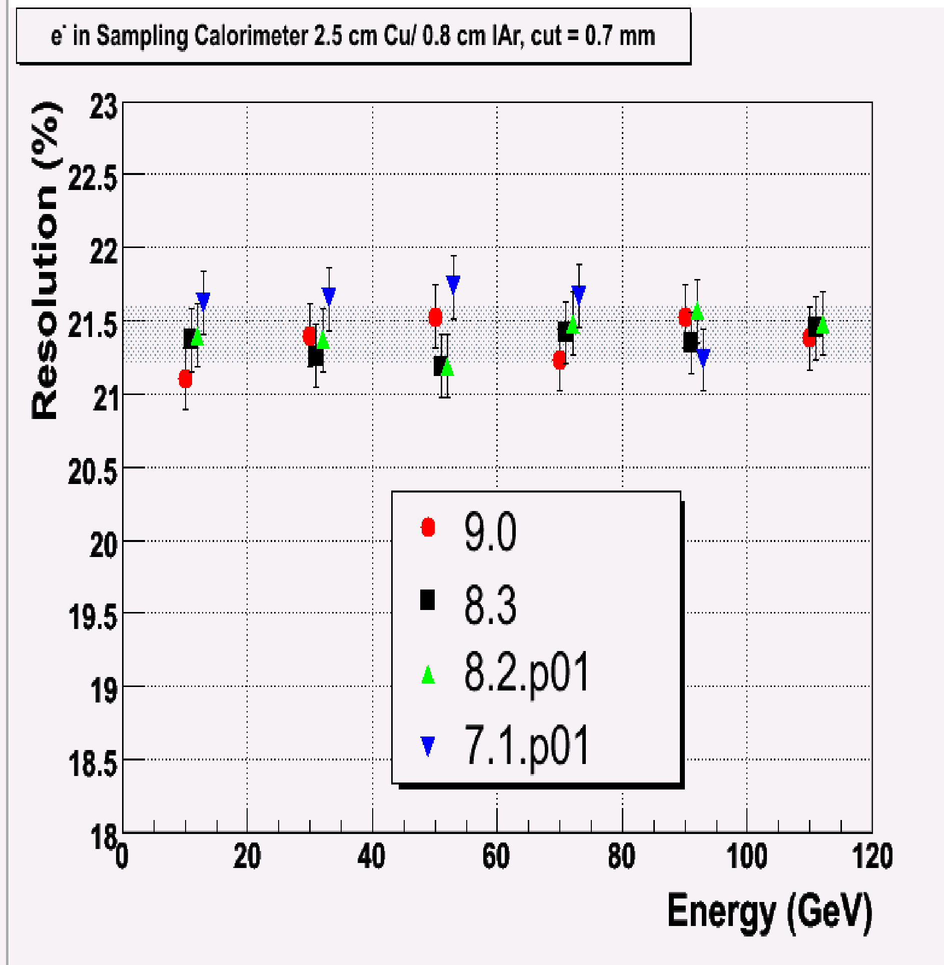
Calorimeter tests ATLAS barrel type

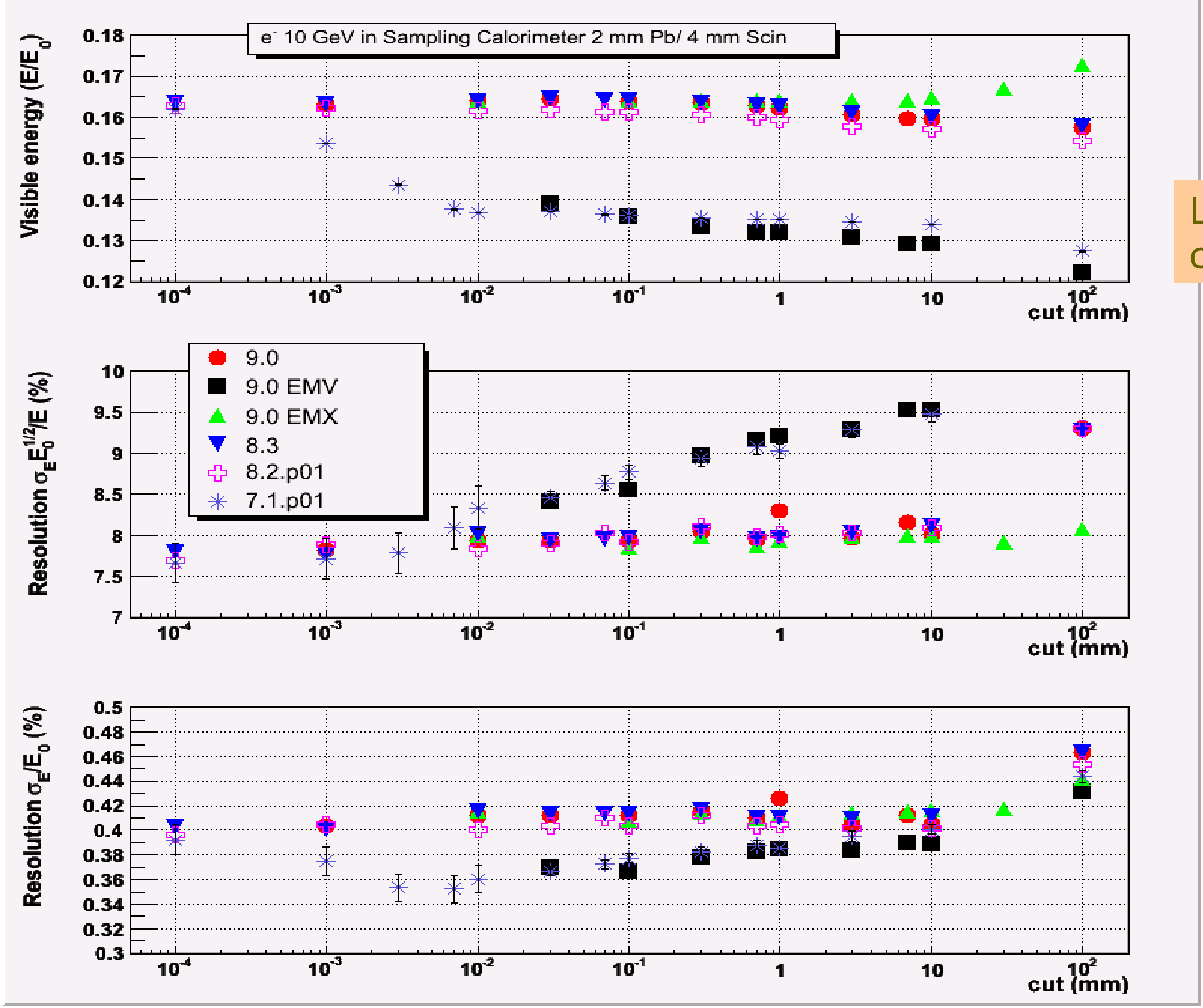
- Practically no difference between 8.3 and 9.0
- EMV results are the same
- Sub-cutoff option (EMX) was optimized



ATLAS HEC type

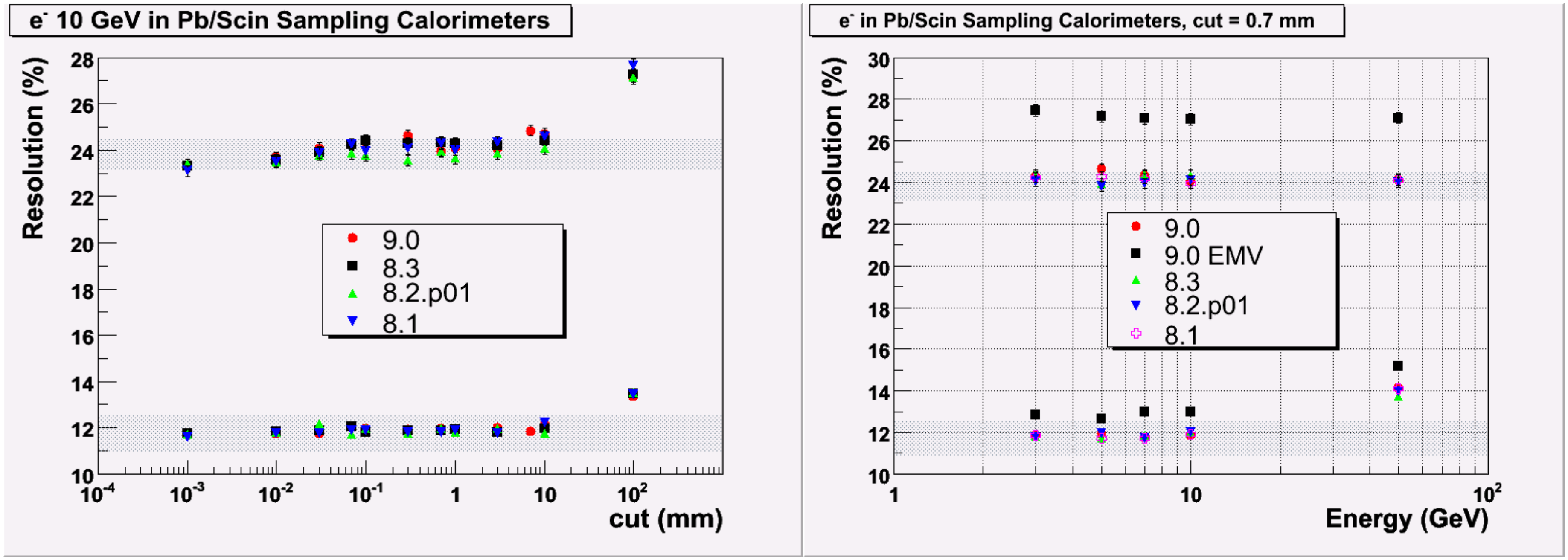




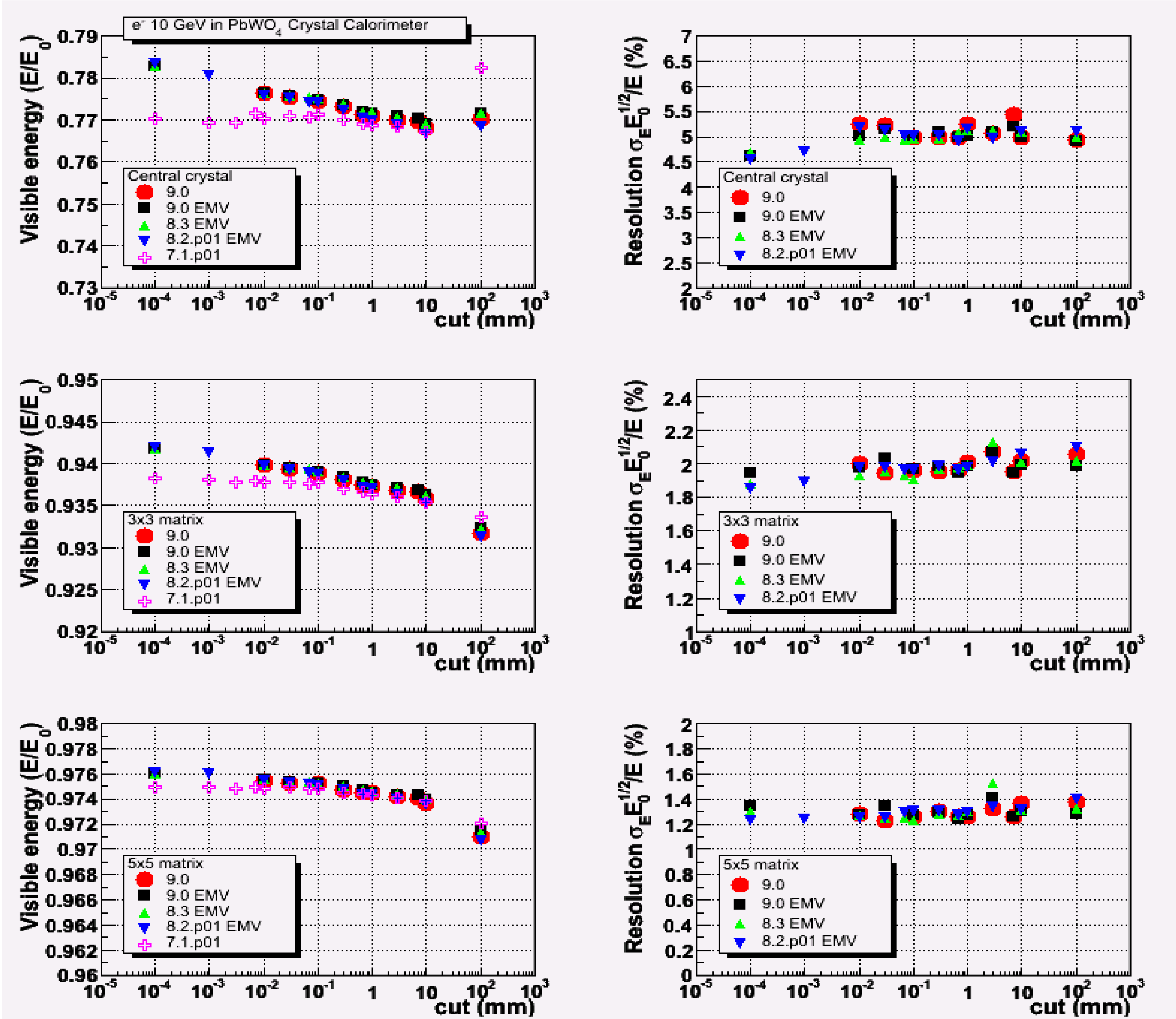


LHCb type calorimeter

Pb/Scintillator sampling calorimeter
(NIM A262 (1987) 229; NIM A274 (1989) 134)

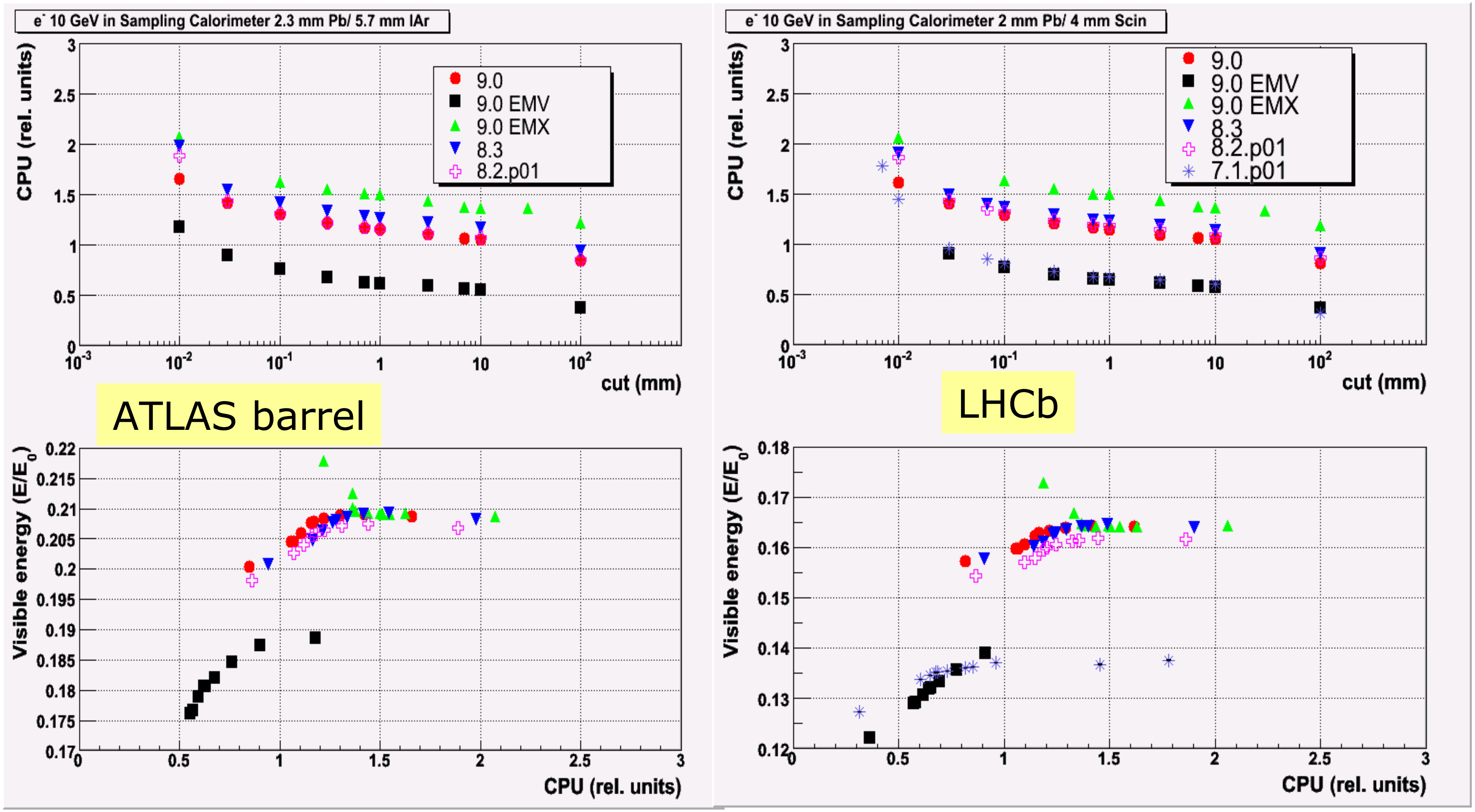


- Two configurations:
  - 5 mm Pb/5 mm Scintillator
  - 10 mm Pb/ 2.5 mm Scintillator
- Default Geant4 (QGSP) within experimental uncertainty
  - At 50 GeV a special cut was applied for data analysis to reduce leakage
- QGSP_EMV version provides biased results
  - Less precise for small sampling fraction



CMS type calorimeter

Visible energy and CPU performance



Summary on calorimeter tests

- EMV Phys List is kept to be the same as default physics of 7.1
  - May be changed by request of experiments
- There are no visible difference between 8.3 and 9.0
- 0.7 mm cut is today optimal for LHC
- Sub-cutoff option (EMX) provides stable results up to cut 10 mm
- Low cuts not needed for LHC calorimeters!
- There is a visible speed up for g4 9.0

CPU optimization for g4 9.0

- The review and optimization of interfaces have been performed
  - G4VEmModel
  - G4VEnergyLossProcess
  - G4VEmProcess
  - G4VMultipleScattering
  - Modifications were provided for all derived classes
- Optimization of usage of virtual methods
- Use prepared stl vectors instead of calling new and delete for intermediate vectors of secondary particles in run time
- Minor optimization of G4UrbanMscModel code

CPU benchmark SLC3 (G4 review)

Electromagnetic physics

EM-1 : 10 GeV e- in matrix 5x5 of PbWO4 crystals (CMS-type);
cut = 0.7 mm, 1000 events.
EM-2 : 10 GeV e- in ATLAS barrel type sampling calorimeter;
cut = 0.7 mm, 1000 events.
EM-3 : 10 GeV e- in ATLAS barrel type sampling calorimeter;
cut = 0.02 mm, 100 events.

	QGSP			QGSP_EMV		
Release	**EM-1**	**EM-2**	**EM-3**	**EM-1**	**EM-2**	**EM-3**
5.2.p02	1.03	0.99	1.59			
6.2.p02	0.89	0.98	0.97			
7.1.p01	1.00	1.00	1.00			
8.0.p01	1.33	2.24	2.26			
8.1.p01	1.37	2.43	2.01	1.06	1.08	1.07
8.2.p01	1.27	2.03	1.73	1.03	1.09	1.06
8.2.ref02	1.29	2.14	1.79	1.03	1.08	1.06
8.2.ref03	1.28	2.08	1.78	1.04	1.04	1.05

All numbers with CERN afs installation for SLC3 and shared libraries

CPU benchmark SLC4

- Static build on dedicated SLC4 PC, no libraries from afs
- SLC3 to SLC4 migration slightly change ratio between CPU of different tests

	EM1	EM2	EM3	EM1_EMV	EM2_EMV	EM3_EMV
8.3 SLC3	693 s	1757 s	216 s	537 s	842 s	133 s
8.3 SLC4	459 s	1139 s	143 s	334 s	495 s	79 s
9.0 SLC4	0.90	0.89	0.91	0.95	0.93	0.93

Conclusion remarks

- With 9.0 EM standard package is capable to provide correct results on level of accuracy ~2 %
- One of our main goals is to keep precision but speed up computations
- Testing suite have been extended
  - Running in production mode at LXBATCH
  - SLC3 and SLC4
  - Automatic mode is available