The Status of Standard EM Physics

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for Electromagnetic Physics Group

Outline

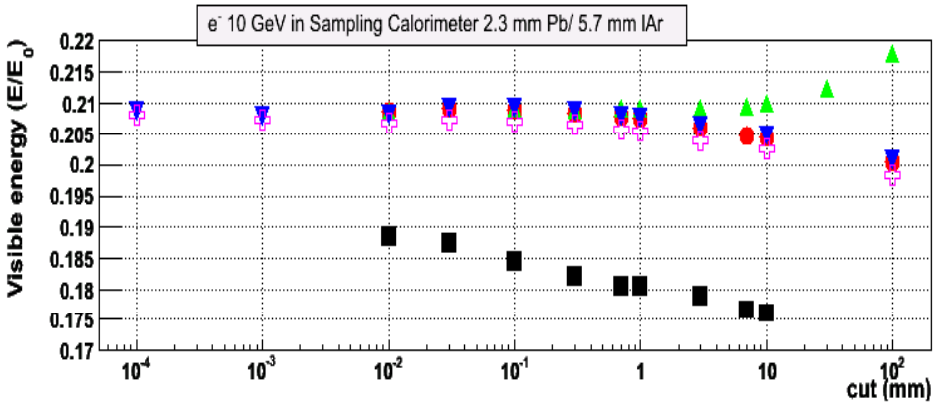
- **Refinement of existing models**
  - **Multiple scattering**
  - **Fluctuation model**
  - **Sub-cutoff option**
  - **Physics Lists**
  - **Polarization library**
- **Interface change for 9.0**
  - **CPU performance**
- **New models**
  - **Single Coulomb scattering**
  - **Monopole ionization**
- **Validation infrastructure update**
  - **Testing suite in production mode**
  - **New tests**
- **Problems and Plans**
- **Summary**

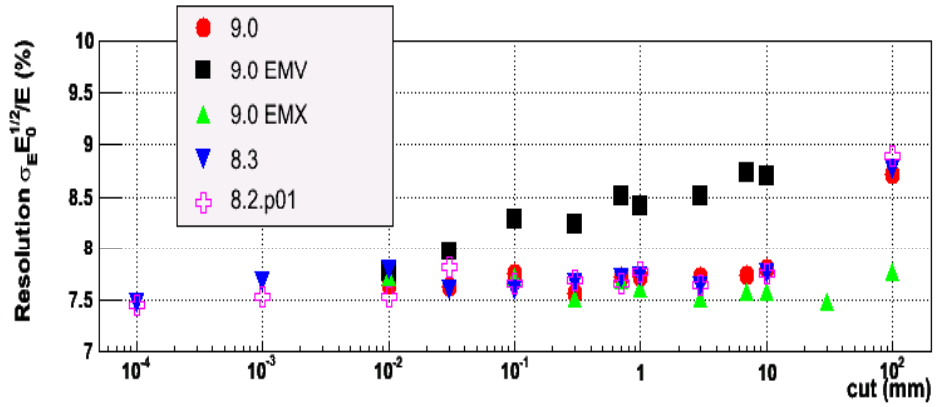
Multiple scattering options in g4 9.0

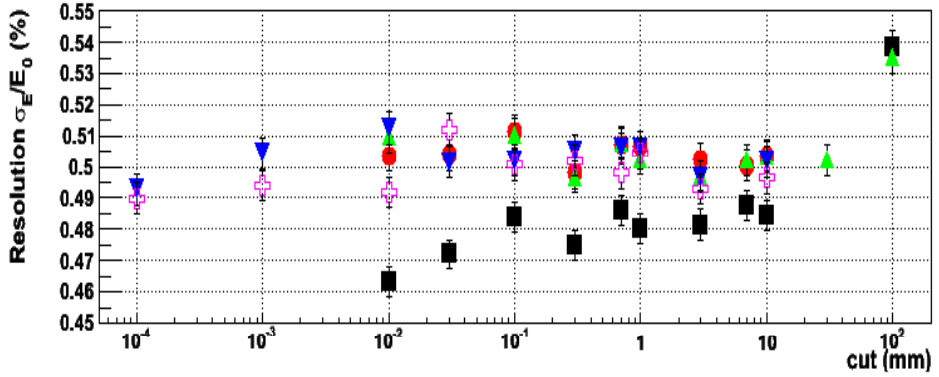
- G4SafetyHelper class have been introduced
- G4MscStepLimitType
  - Minimal - equivalent to the algorithm of Geant4 7.1 and earlier releases (QGSP_EMV Physics Lists)
  - UseSafety - the current default, uses geometrical safety (QGSP and QGSP_EMX Physics Lists)
    - **QGSP_EMX includes sub-cutoff option**
  - 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
- Fluctuations and msc update details in L. Urban talks

Calorimeter tests ATLAS barrel type

- Practically no difference between 8.3 and 9.0
- EMV results are the same as for 7.1p01
- Sub-cutoff option (EMX, cut = 7 mm) was optimized
  - G4SafetyHelper







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

Polarization library

- Mainly fixes
- Details in the talk of A. Schaelicke

Interface change with g4 9.0

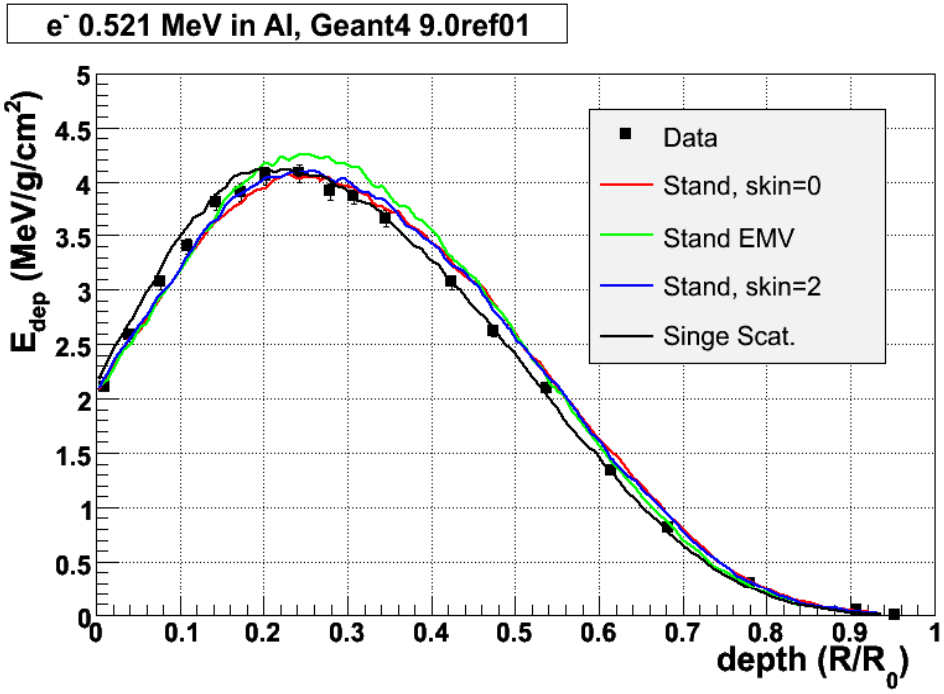
- EM base classes
  - Renamed Physics Lists optional builders
  - Renamed EM standard components in examples
  - Renamed methods of G4EmProcessOptions
  - New UI commands
    - **/process/msc/**
  - Updated interface to G4UrbanMscModel
    - **Parameters can be changed between runs**
  - Use only G4SafetyHelper
    - **not G4Navigator anymore**
  - Removed 52-type processes

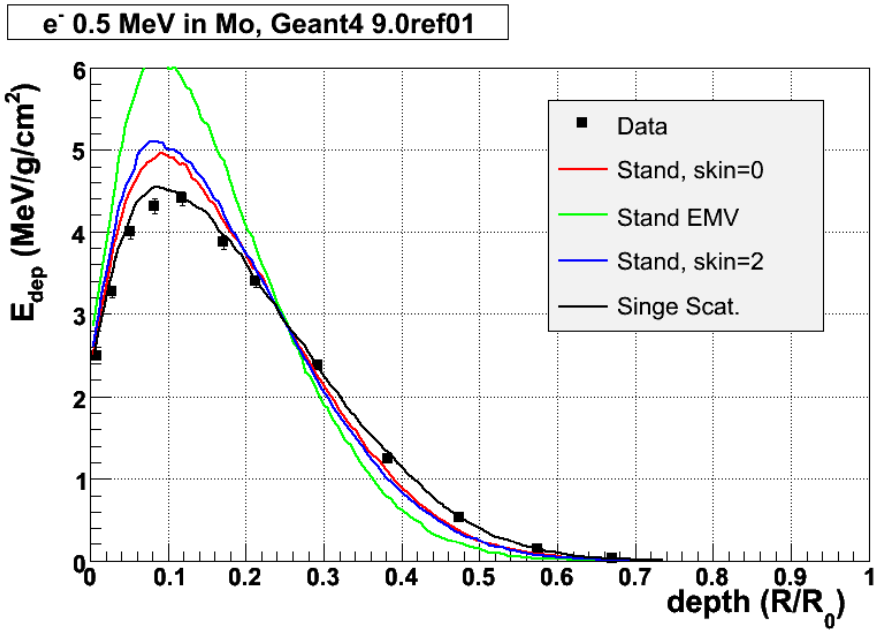
CPU optimization for Geant4 9.0

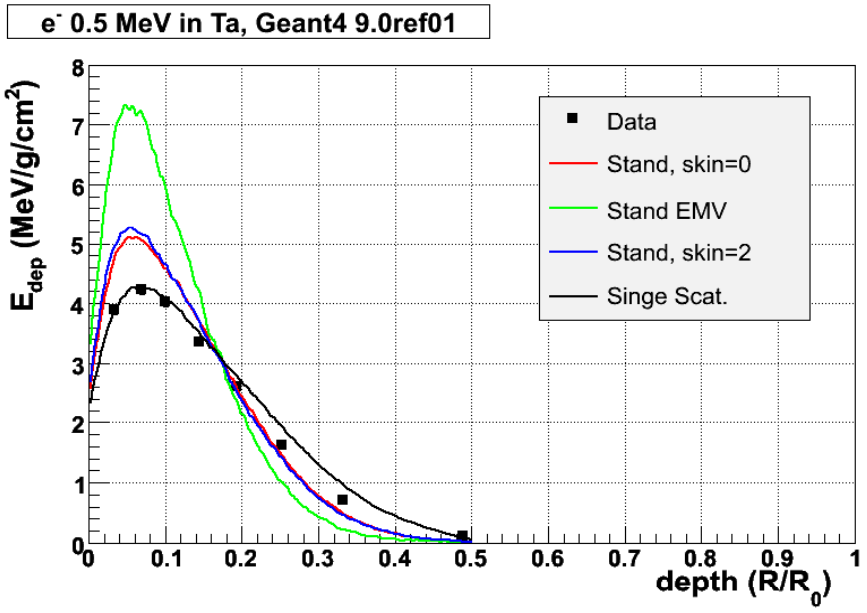
- Task force efforts organized by J. Apostolakis
- The review and optimization of interfaces have been performed
  - **G4VEmModel**
  - **G4VEnergyLossProcess**
  - **G4VEmProcess**
  - **G4VMultipleScattering**
  - **Modifications were provided for all derived classes**
- Reduction of usage of virtual methods
- Reuse stl vectors - reduced calls to *new* and *delete* for intermediate vectors
  - **should be considered for hadronics**
- Minor optimization of G4UrbanMscModel code
- Summary effect about 10% for EM showers

New process G4CoulombScattering

See talks at parallel session



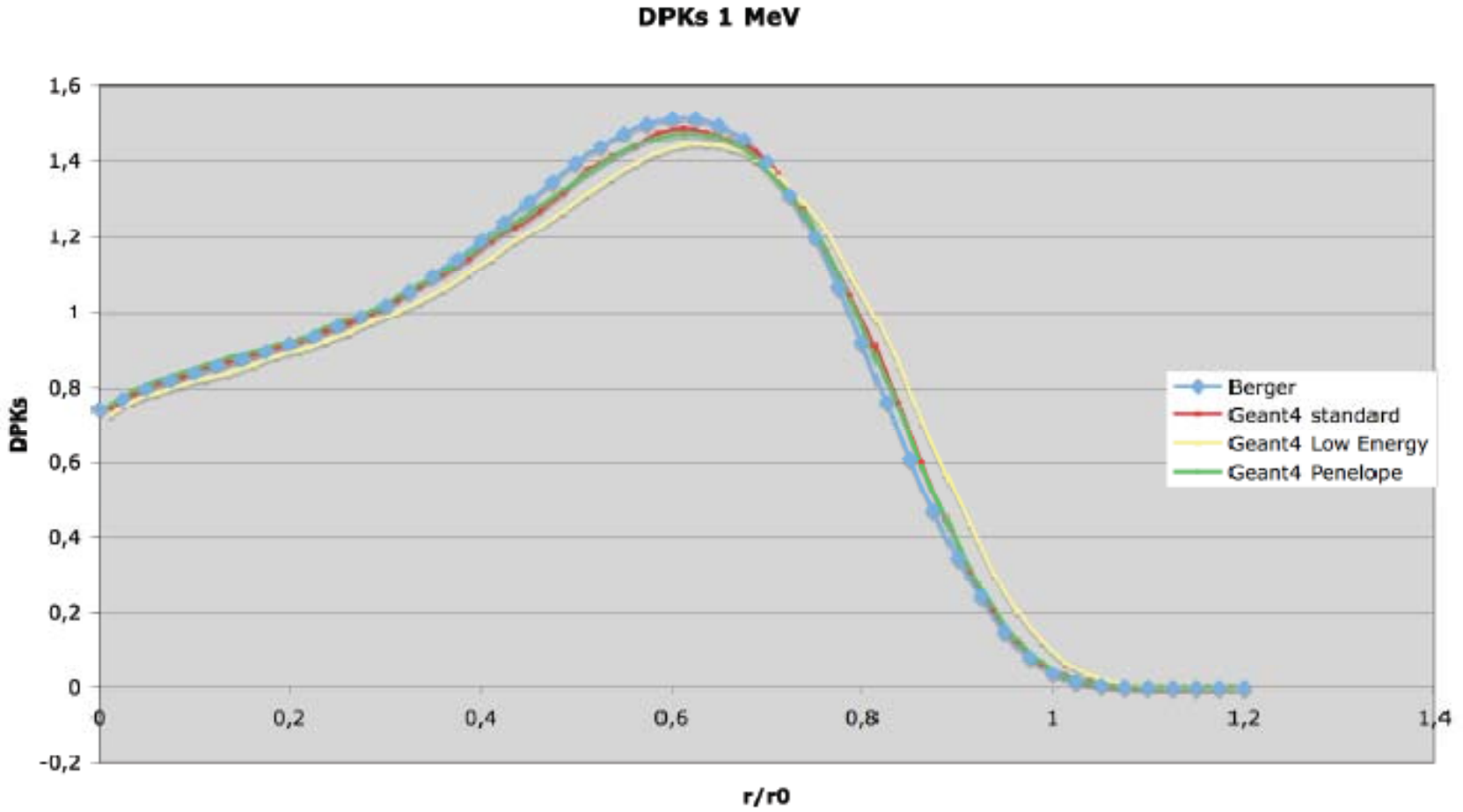




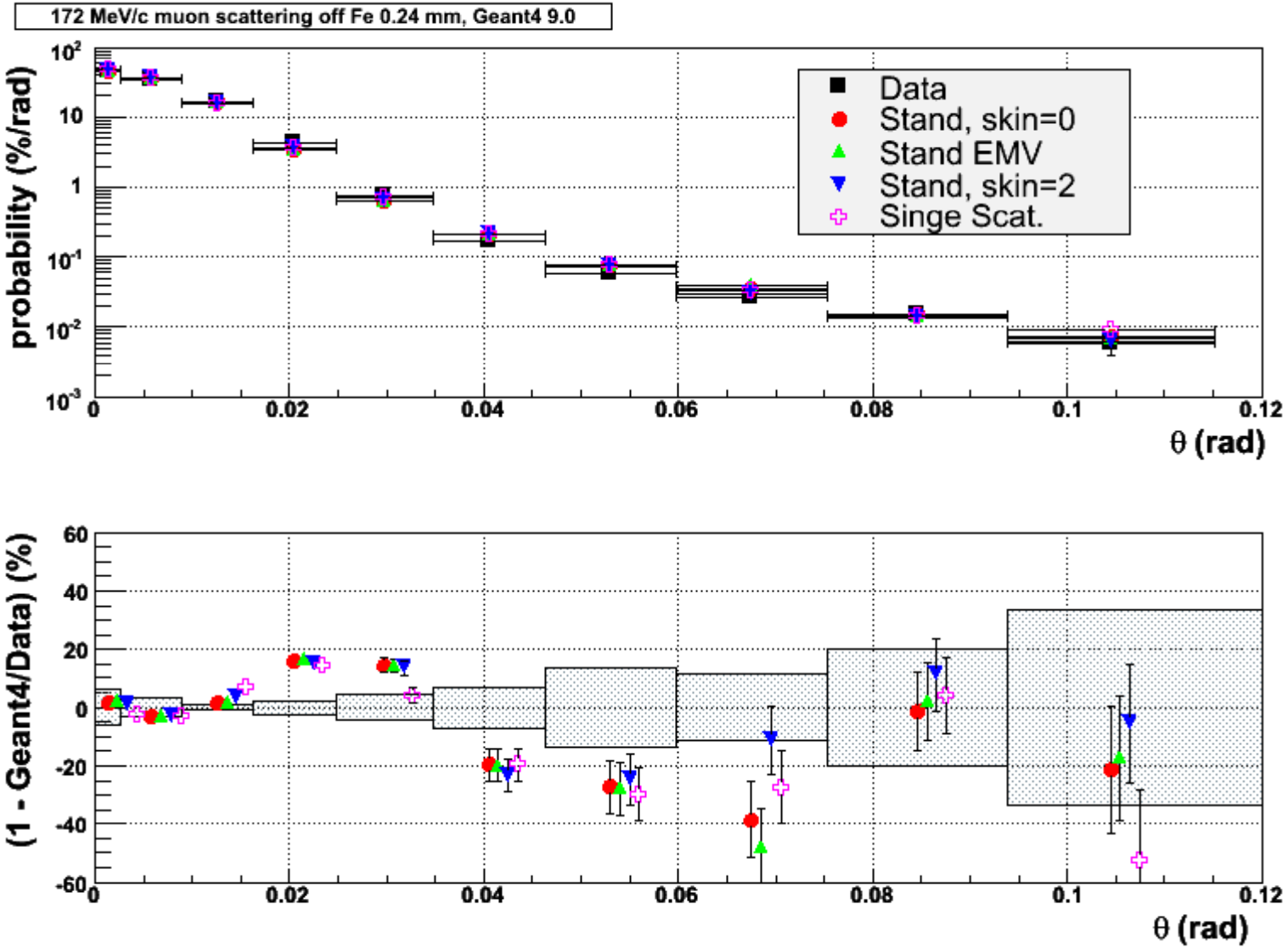
Standard cut 0.7 mm

Similar test versus other MC codes

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



G4 9.0



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

Precise transport parameters

- The problem of precision of dEdx and range simulation was identified by A. Bagulya and detailed study was performed by CERN summer student
- It was shown that for precise simulation one should decrease linLossLimit parameter and increase number of bins in dEdx tables
  - Systematic biases for proton range may be 0.5 mm
- For medical applications we would propose
  - /process/eLoss/linLossLimit 1.e-6
  - /process/eLoss/maxKinEnergy 1 GeV
  - /process/eLoss/binsDEDX 700
- See details in M. Vladymyrov talk at parallel session

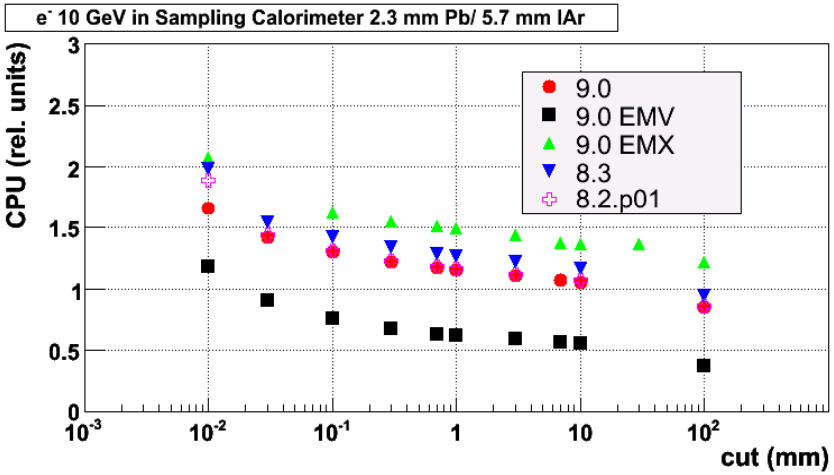
Magnetic monopole ionisation

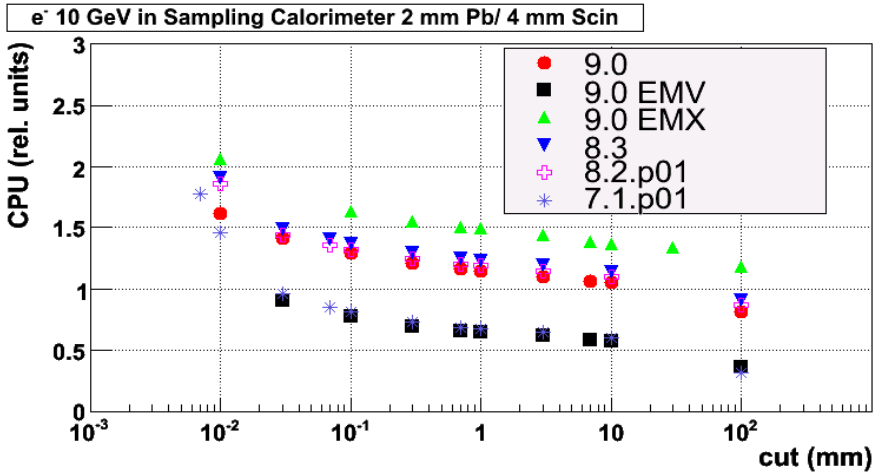
- Have been verified and updated for g4 9.0ref01
- First example of exotic physics is released
  - Examples/extended/exoticphysics/monopole
- See details in M. Vladymyrov talk at parallel session

Validation infrastructure update

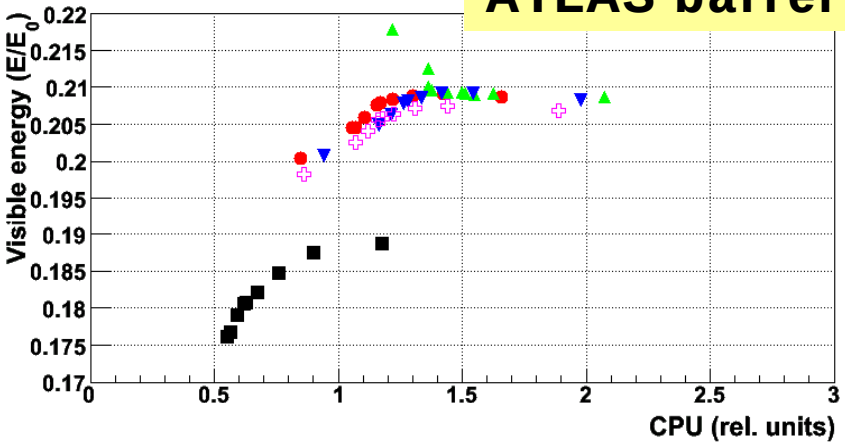
- Production mode for EM testing suite
  - Similar to hadronic testing suite
  - New automatic tests: tests37, test41
    - **ASCII output**
    - **ROOT scripts provide plots in batch**
  - Calorimeter tests
    - **Scripts should be added to get plots in batch**
- Results are visible in the web
  - thanks to G. Folger
  - L. Urban private test results are copied to msc subdirectory and are also available
  - We will try to add all validations in this directory structure
  - Should access to this web be non-restricted?

Visible energy and CPU performance

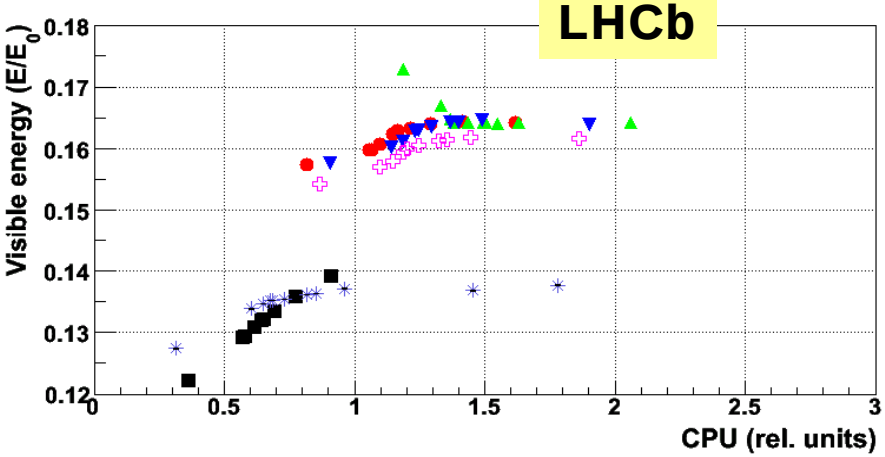




ATLAS barrel



LHCb



CPU benchmark

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 Geant4 CERN afs installation for SLC3 and shared libraries

CPU benchmark upgrade

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

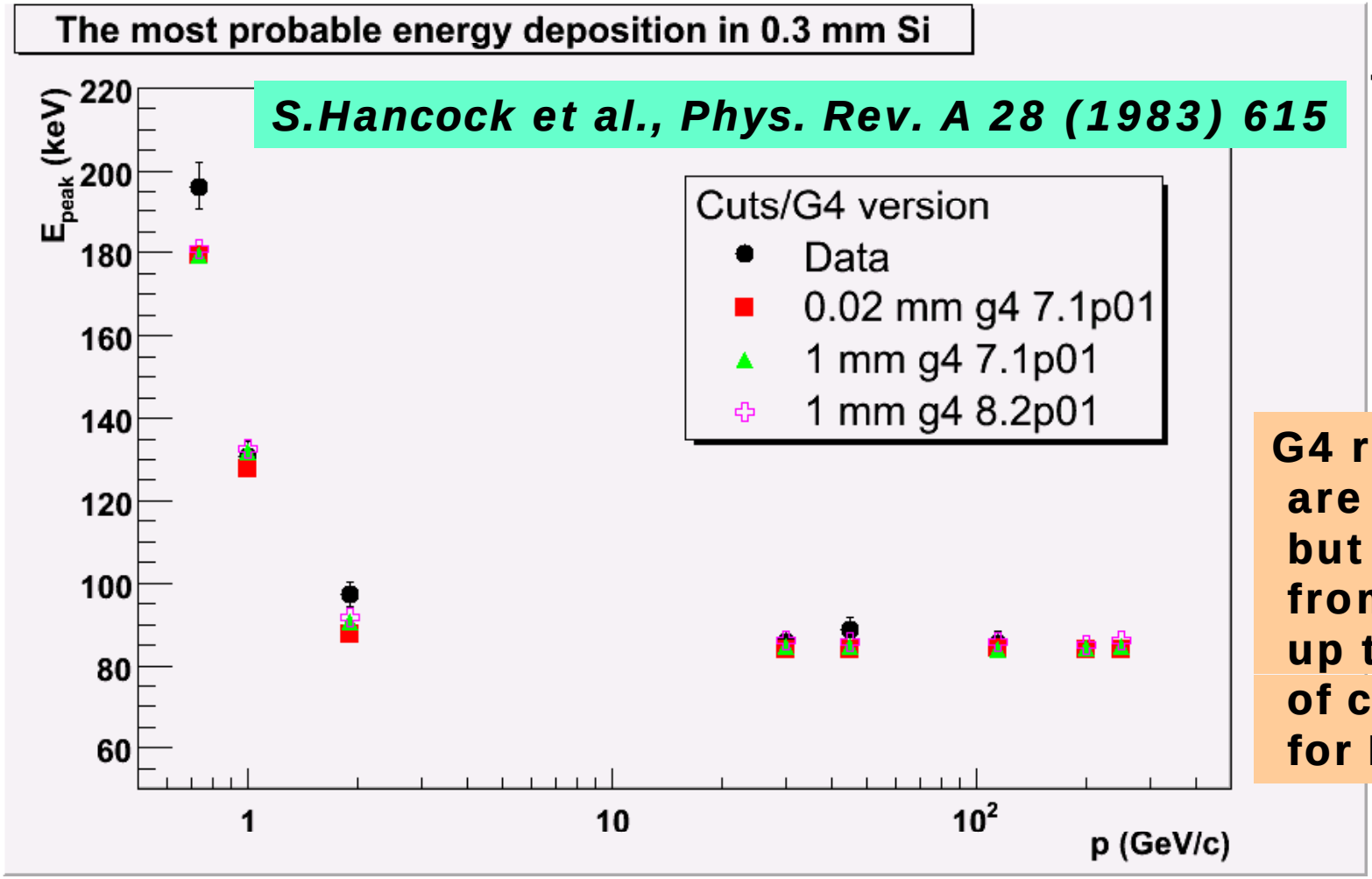
	EM1	EM2	EM3	EM1_EMV	EM2_EMV	EM3_EMV
8.3 SLC4	1.33	2.30	1.84	1.0	1.0	1.0
9.0	1.21	2.05	1.65	0.92	0.93	0.94
9.0ref01	1.17	2.07	1.66	0.91	0.92	0.91

- Possible further CPU improvements:
  - more efficient computation of safety
  - more efficient sub-cutoff sampling
  - reducing of number of steps

Possible issues in 9.0 EM physics: next talks of M. Maire

Some issues for LHC simulation below

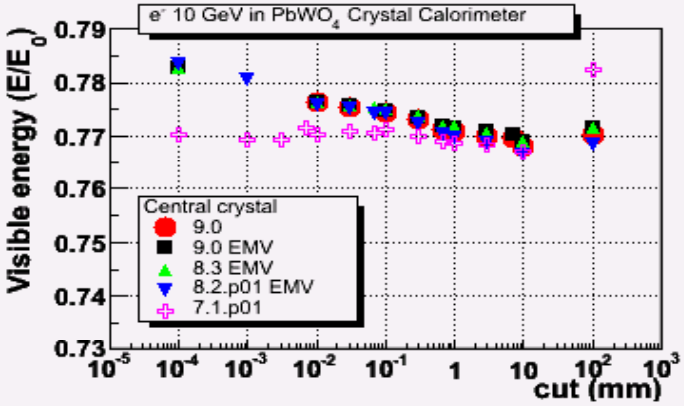
Geant4 simulation and data for signal in a vertex detector – very essential for LHC start

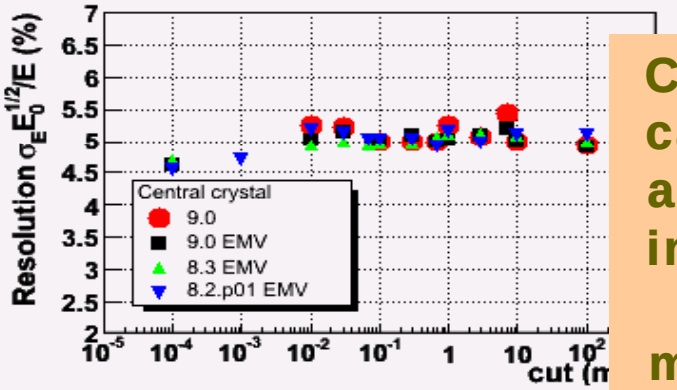


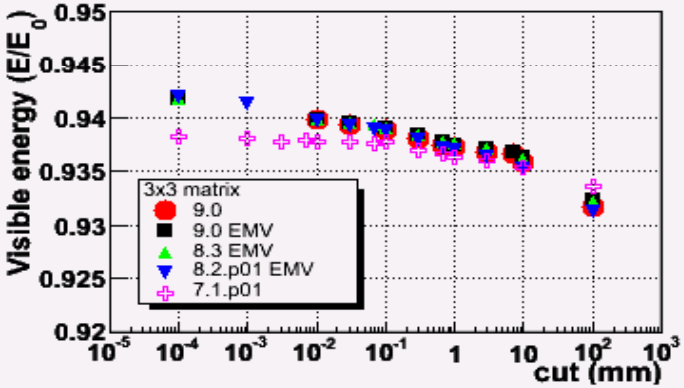
TestEm3

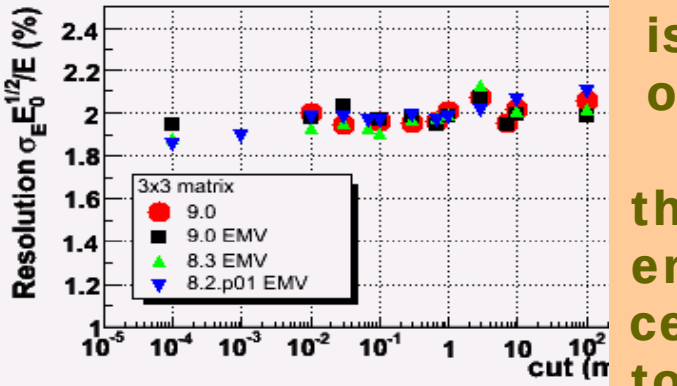
π^+ or p beam

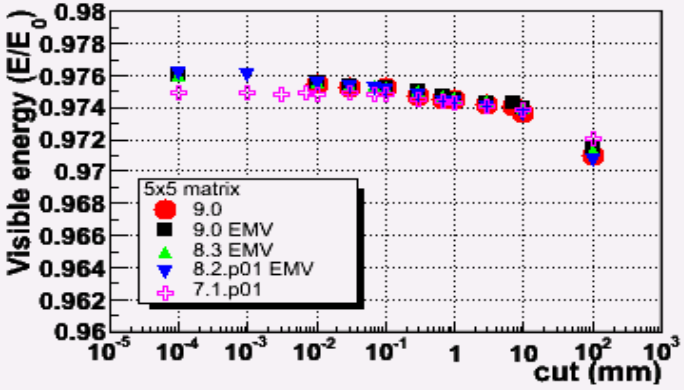
G4 results are stable but biases from the data up to 8 % of concern for LHC

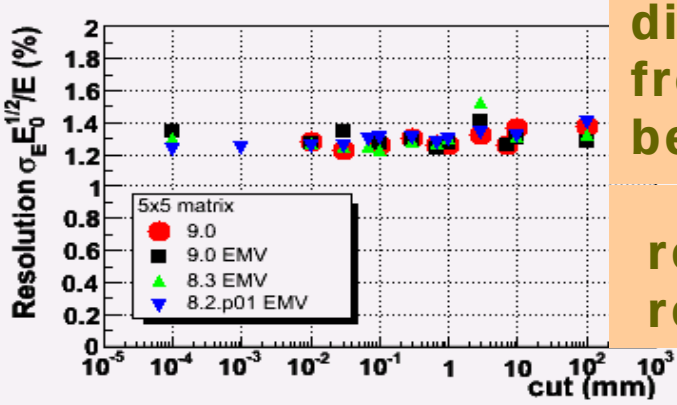












CMS type calorimeter about 0.5% instability

may be msc or bremsstrahlung issue, see talk of J. Perl

the ratio of the energy in central crystal to 5x5 matrix differs for 0.5% from the test-beam data

review is required

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

Short-term list to do

- Further development of scattering models
  - **Specialized model per particle type (V.Grichine talk)**
  - **Nuclear recoil**
- **Bremsstrahlung review**
  - **Hadron incident**
  - **Specialized models for electrons**
- **Ionisation in thin layers review**
  - **PAI model review - SLC4 problem**
- **ICRU'73 ion ionisation implementation**
- **Saturation effects**
  - **Birks**
- Cherenkov process revision
- Polarization library developments
- X-ray emission (K-, L- shells)
- CPU performance optimization

Validation suite

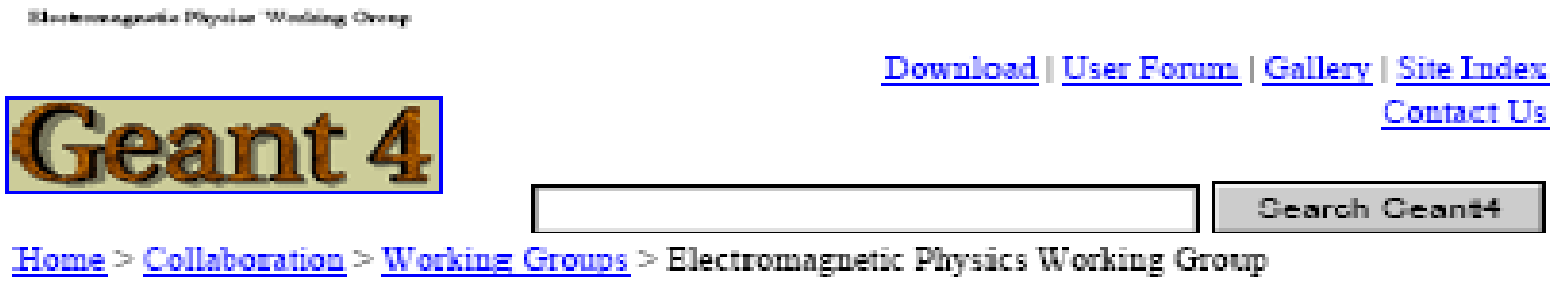
- EM standard physics is well tested and widely used
  - LHC production
- Accuracy is on the level or close to available theory and data
- Minor change of the model within systematic uncertainty of theory/data provides a minor shift of simulation results
- We need to change our minds to increase significantly efforts for independent tests
  - Tests be maximally independent from development
  - Automatisation of tests
  - Regression is necessary

Summary

- With Geant4 8.3 and 9.0 EM standard is capable to provide results on level of accuracy ~2 %
  - EMV Phys List is kept to be the same as default physics of Geant4 7.1p01
- 0.7 mm cut is the today default
  - Lower cuts not needed for LHC calorimeters
  - Lower cuts may be useful for tracking detectors
- Sub-cutoff option (EMX) provides stable results up to cut 10 mm
  - CPU performance of sub-cutoff needs to be upgraded
- There is a visible speed up for Geant4 9.0
- EM (standard) working group page:

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

Please, visit and comment



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