Validation of EM Standard Physics

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Outline

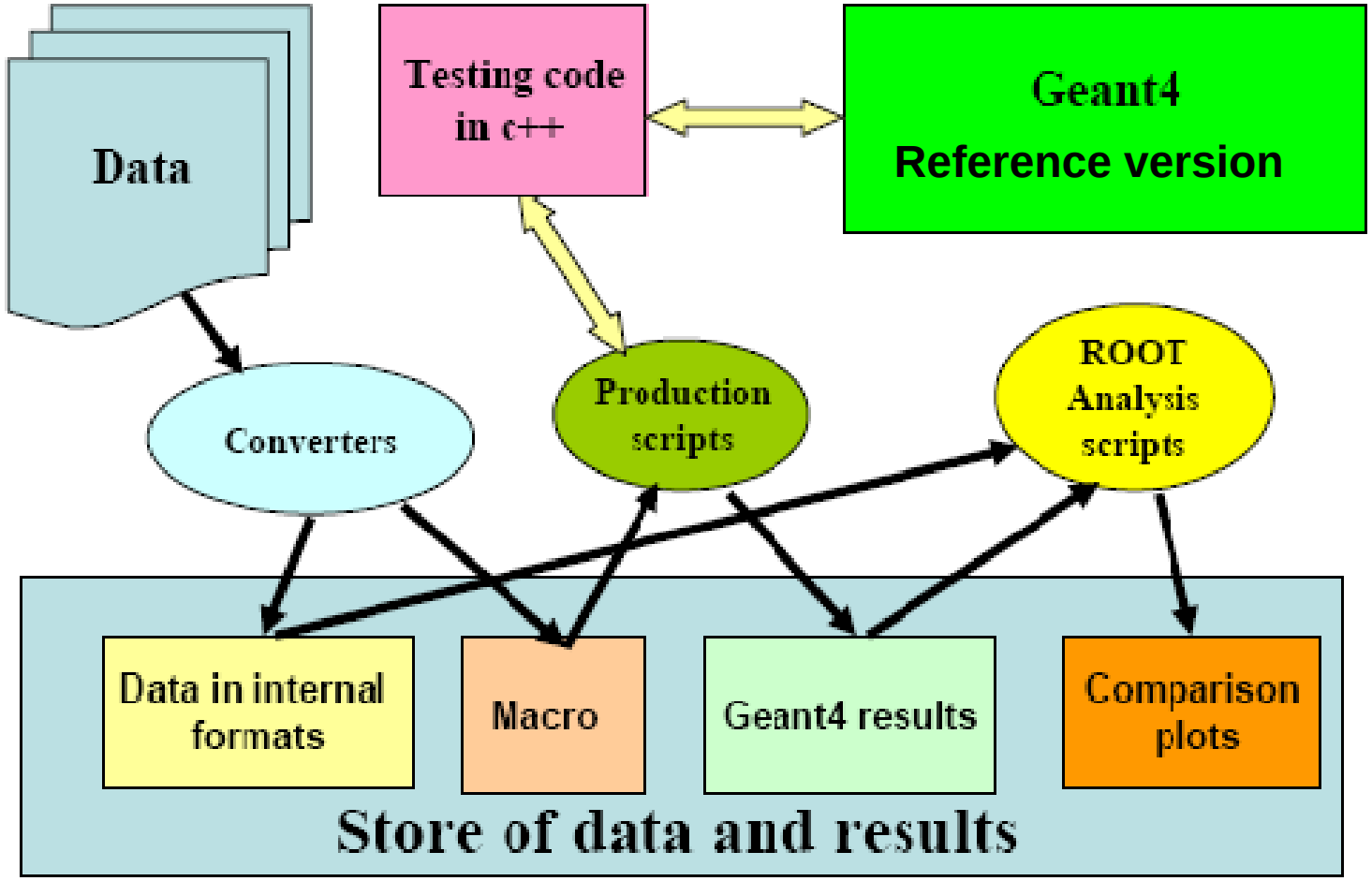
- Validation of EM physics
  - Validation sequences
  - Software infrastructure
- Highlights on new developments for g4 9.2
- Detailed responses to review recommendations #18, #19
- EM response to recommendations #21, #22
- Conclusion remarks

Validation of EM physics

Geant4 approach for validation

- Validation sequence:
  - Developer private tests
  - Low and medium statistic tests with control of basic numbers
  - High statistic tests by EM group
  - User validation
- Reference Physics Lists are required for regular validation
- Main efforts of EM groups in validation
  - versus specific data and evaluated data sets
  - regression tests versus previous version of Geant4
- Long process required manpower

General scheme of validation software



Validation of EM Standard physics

- All processes and models are exercised by integration tests
  http://spreadsheets.google.com/ccc?key=pVWTkls9xs0juh3Wqm-B3LQ
  - 23 tests specialized for Standard EM processes, in other tests EM Standard also are used
    - Regression control of physics output
    - Acceptance tests of important output variables
    - Used by Geant4 system testing team
- Testing suite for EM Standard for high statistic tests
  http://spreadsheets.google.com/pub?key=pw2-SY7kU6F6T0bLY9OIiNw
  - Regular runs in batch mode (CERN, LAPP, KEK)
  - Scripts for running and analysis
  - Results are available in the web
  - Regression tests to compare Geant4 releases
  - The most number of tests versus data

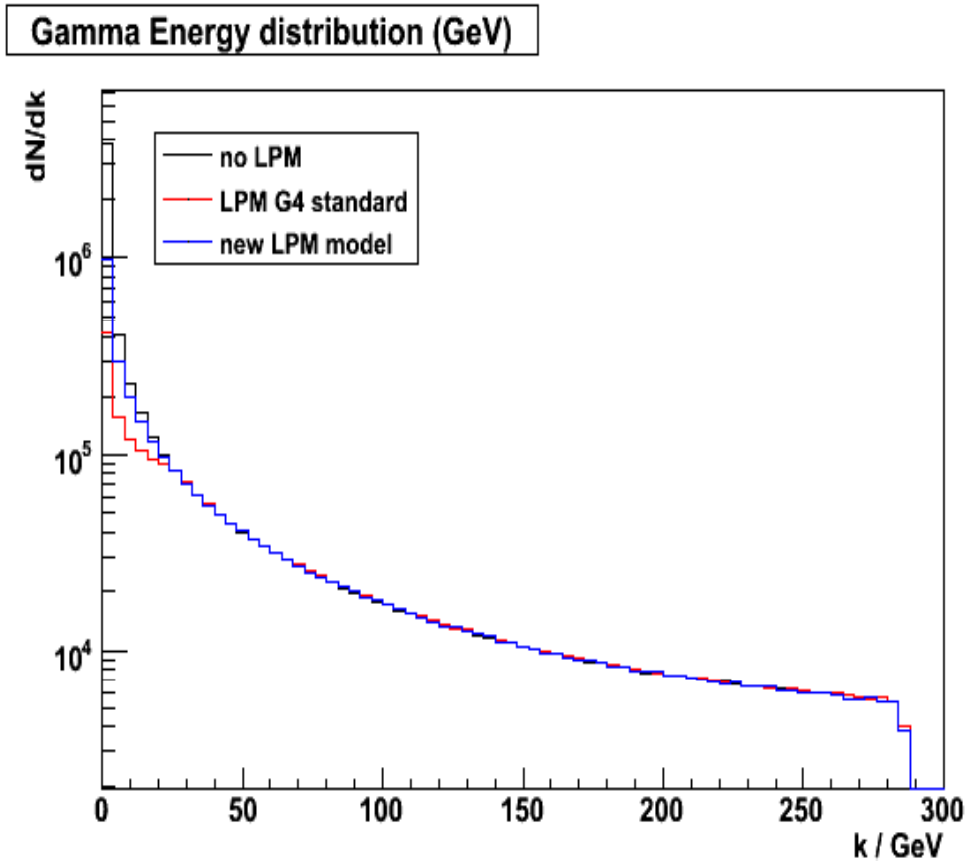
Highlights on new developments available with Geant4 9.2:

results obtained with validation suite

Bremsstrahlung

287 GeV e^- at Ta target ($4\%X_0$)

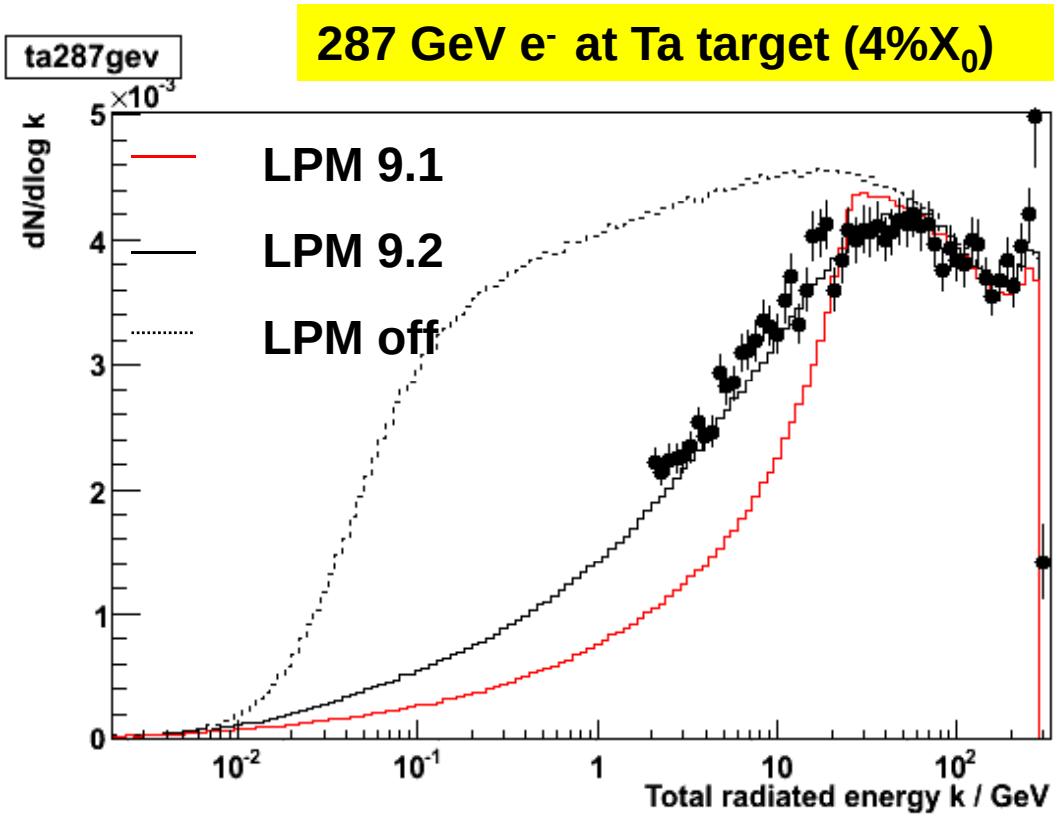
- Added new relativistic model bremsstrahlung model for $e^{\pm}$
  - Updated density and LPM effects
  - Applied above 1 GeV
- Added new model for hadron bremsstrahlung and e^+e^- pair production
  - In reference Physics Lists for $\pi^{\pm}$ and protons



New relativistic bremsstrahlung model

A.Schaelicke, IEEE NSS, 2008

- Bethe-Heitler formula with corrections
- Complete screening with Coulomb correction
  - Valid for E > 1 GeV
- **Density & LPM-Effect**
  - **consistent combination a'la Ter-Mikaelian**



Data from the CERN experiment: H.D.Hansen et al, PR D 69, 032001 (2004)

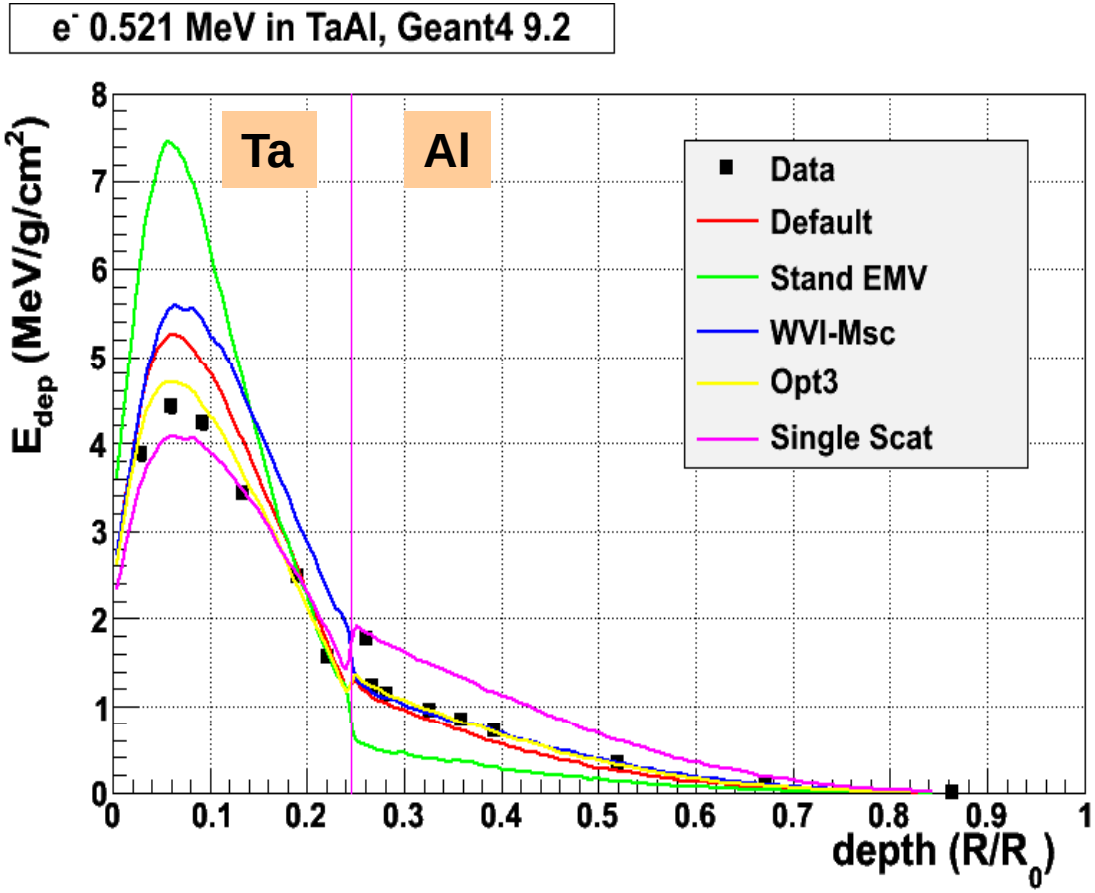
Updated multiple scattering

- Old model G4UrbanMscModel used for 9.1 is frozen for backward compatibility
- New specialized process for $e^{\pm}$ G4eMultipleScattering
  - Uses G4UrbanMscModel2 tuned for electron data
  - F_R = 0.04 (was 0.02 before – number of simulation steps is reduced)
    - $1/F_R$ defines number of steps of e- in vicinity of geometry boundary
- Validation versus data and alternative models in order to control accuracy
  - G4WentzelVIModel (combined msc and single scattering)
  - G4CoulombScattering (single scattering)

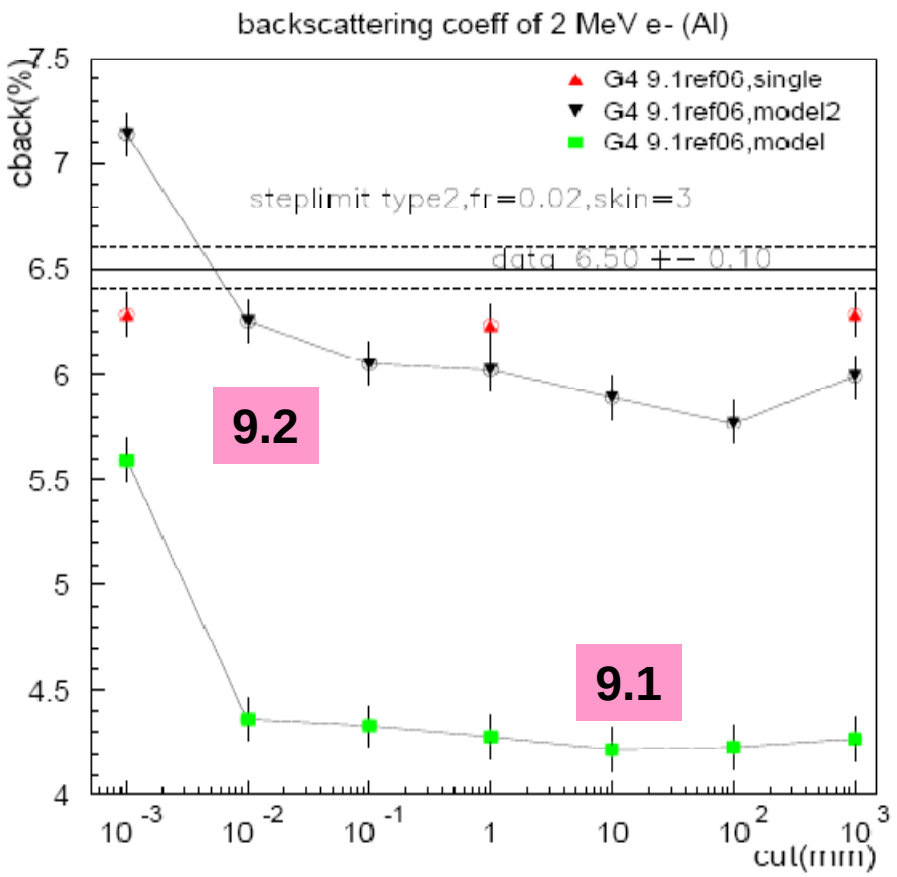
Test of e⁻ transport versus Sandia data

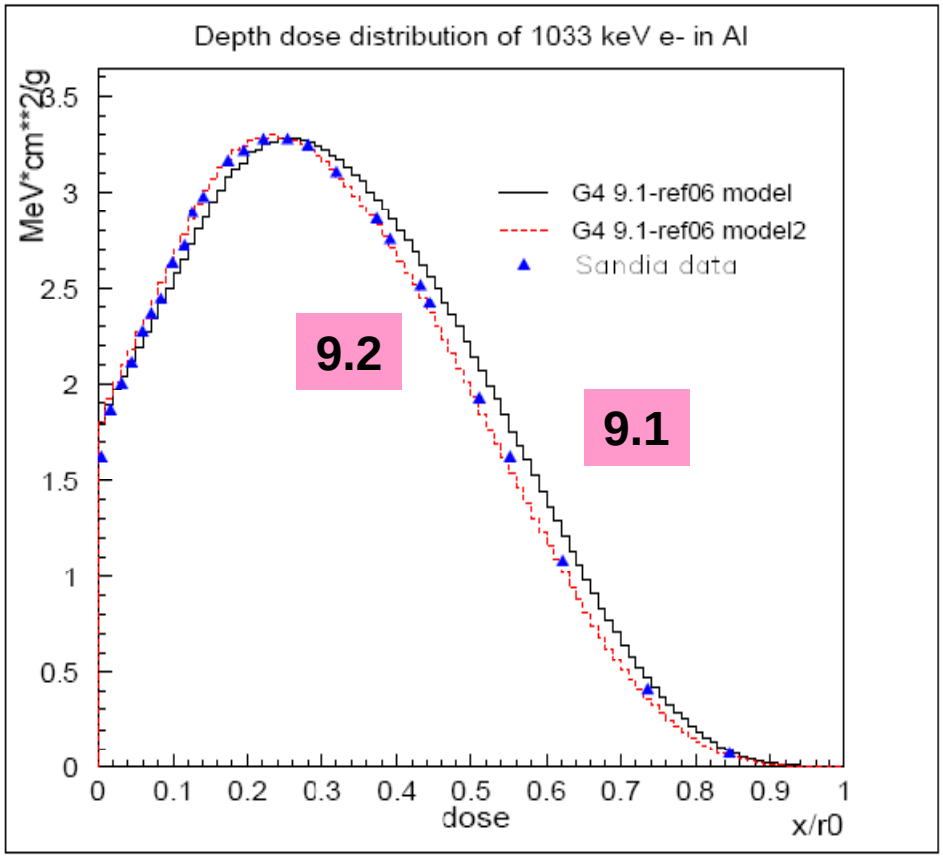
(details in O.Kadri et al, NIM B258 (2007) 358)

- Sensitive to multiple scattering
- Directly connected with LHC calorimeters results
- Tuned Urban's msc model#2
  - Opt3 is best in describing data



Upgrade of multiple scattering model



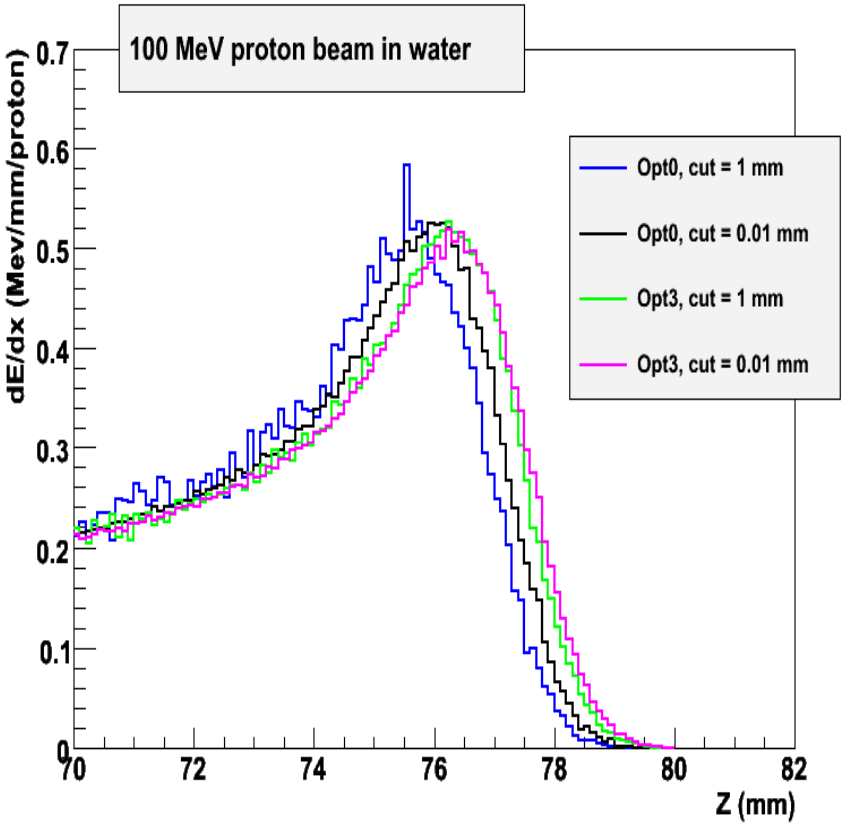


Old msc default version will be kept for backward compatibility

Spline option for Physics Tables

- **Spline interpolation of dEdx, range and other tables**
  - **Previously – linear interpolation**
  - **To achieve precision number of bins in tables should be significantly increased**
- **Opt0 - without spline**
  - strong cut dependence
  - Non-statistical numerical instability
- **Opt3 - spline is activated**
  - Stable result
- Spline option have been validated in different applications
  - Is enabled by default for 9.2

Zoomed Bragg peak

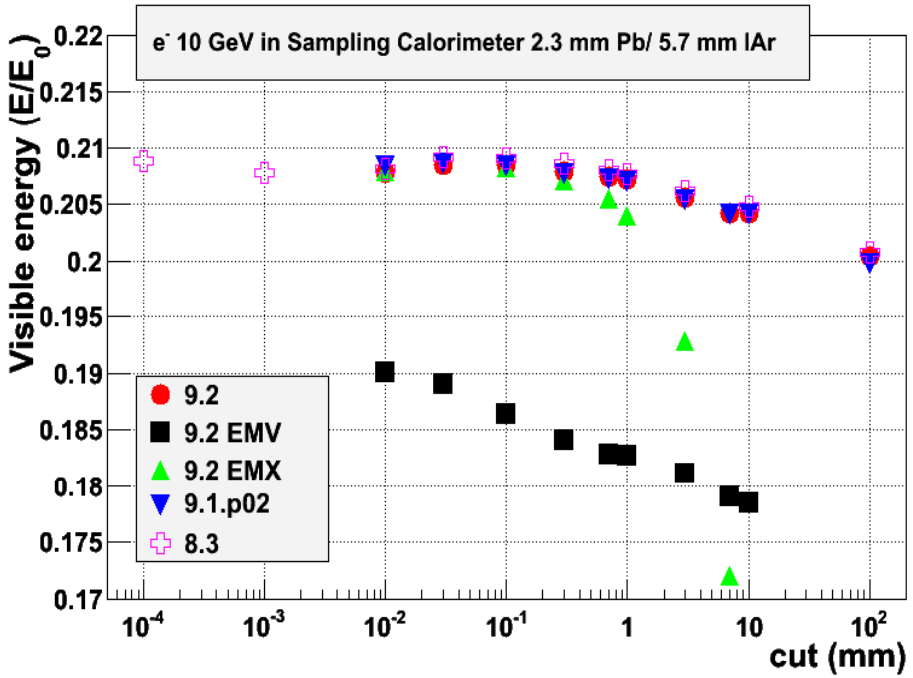


"ApplyCuts" option

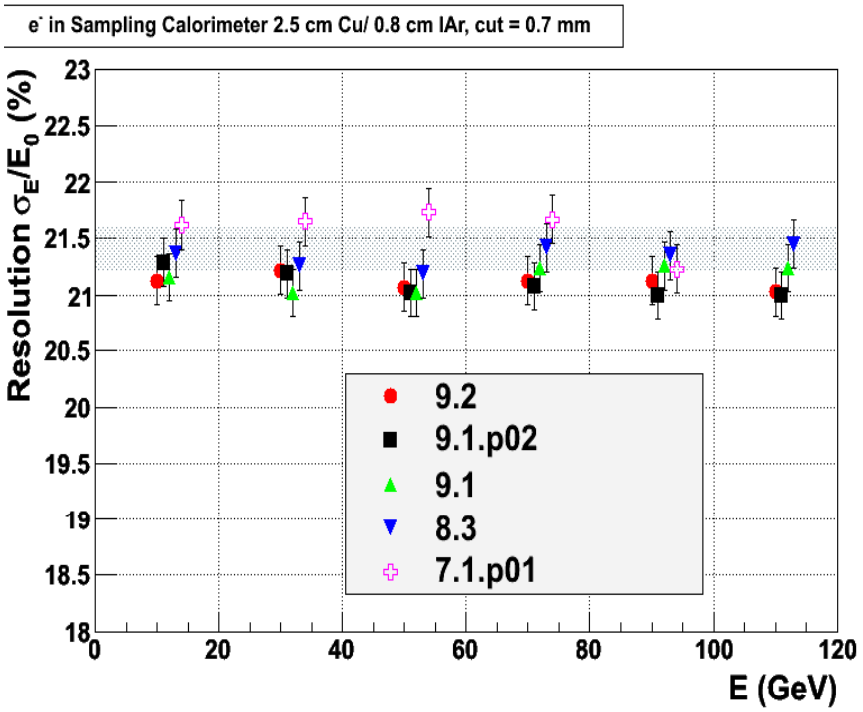
- By default production thresholds in Geant4 are active only for ionisation and bremsstrahlung
- "ApplyCuts" option activates production thresholds for all EM processes
  - Was inside EM standard packages for a long time
  - Secondary particles below threshold are killed
  - Using EM testing suite effects of "ApplyCuts" option were investigated for the release 9.2
- Provides faster simulation but may bias results if cuts are high (above 1 mm)
  - Should be used after validation for the particular application

ATLAS type calorimeters

ATLAS barrel type



ATLAS HEC type



Visible energy is stable within 0.3%

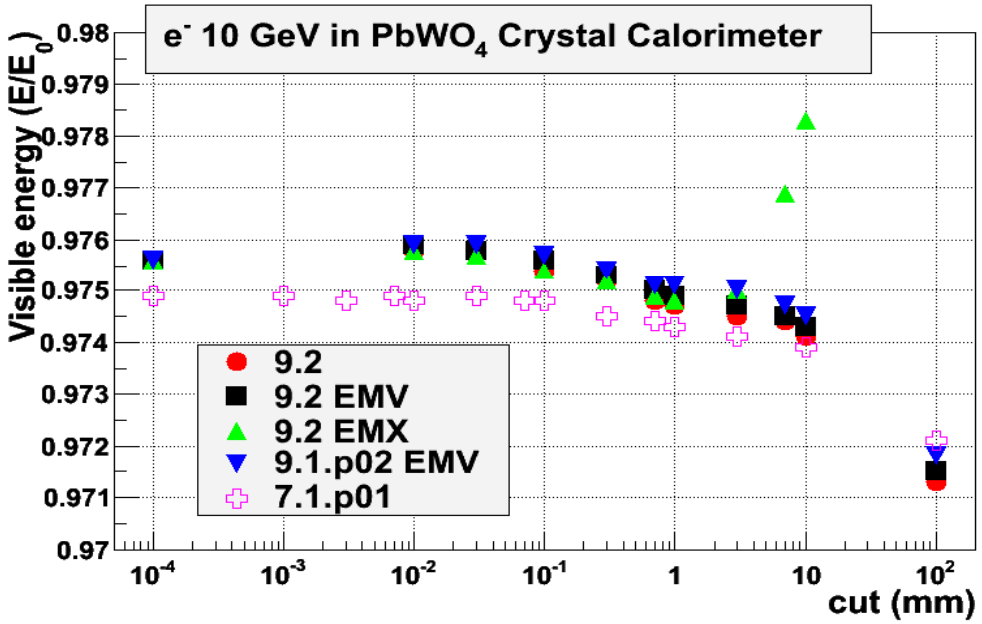
for 8.3, 9.1, 9.2 releases

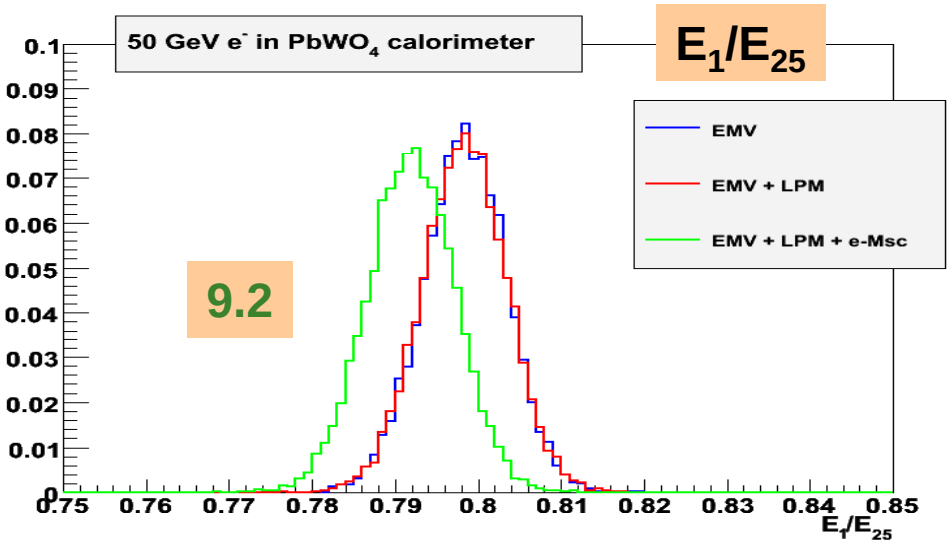
Visible energy increased by 0.5%

Main contribution – msc model

CMS ECAL type calorimeter

- 5x5 matrix of $PW0_4$ crystals
- Reduced (~0.5%) energy deposition in central crystal
  - Result of upgrade of Urban MSC model
  - Better agreement with CMS test-beam





CPU benchmarking for LHC calorimeters

- Static build on dedicated SLC4 PC
  - no libraries from afs

	EM1	EM2	EM3	EM1_EMV	EM2_EMV	EM3_EMV
8.3	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
9.1p02	1.16	2.05	1.64	0.92	0.94	0.93
9.2 (ApplyCuts for EMV)	1.11	1.84	1.49	0.72	0.81	0.87

- CPU gain with 9.0 mainly due to c++ software cleanup
- CPU gain with 9.2 due to optimization of physics
  - step limitation by multiple scattering
  - energy threshold for gamma processes

Responses to review recommendations

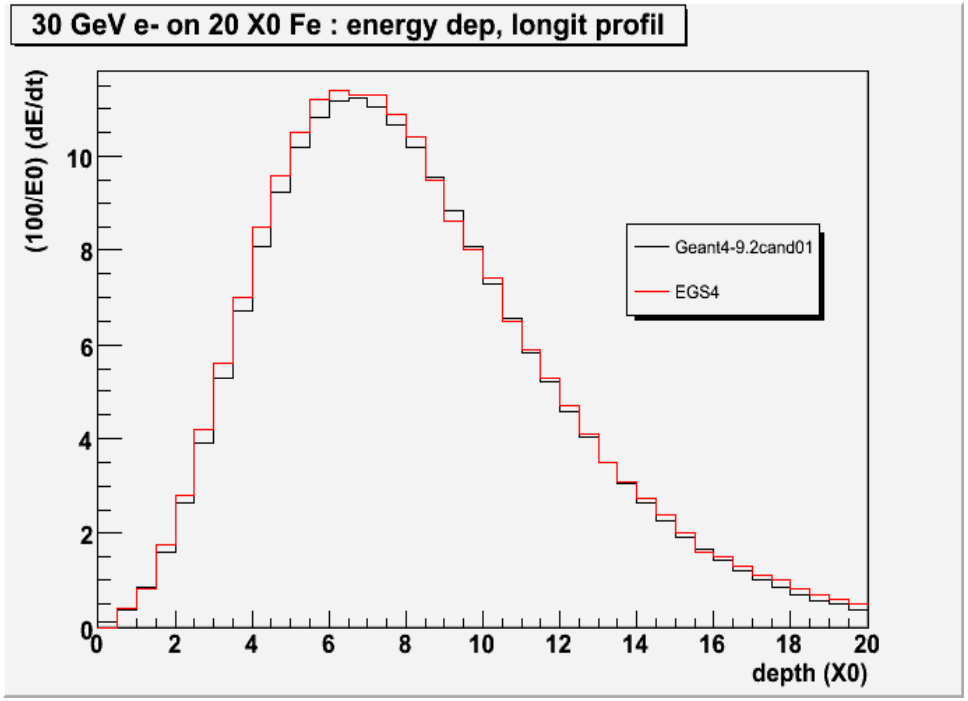
Recommendation 18

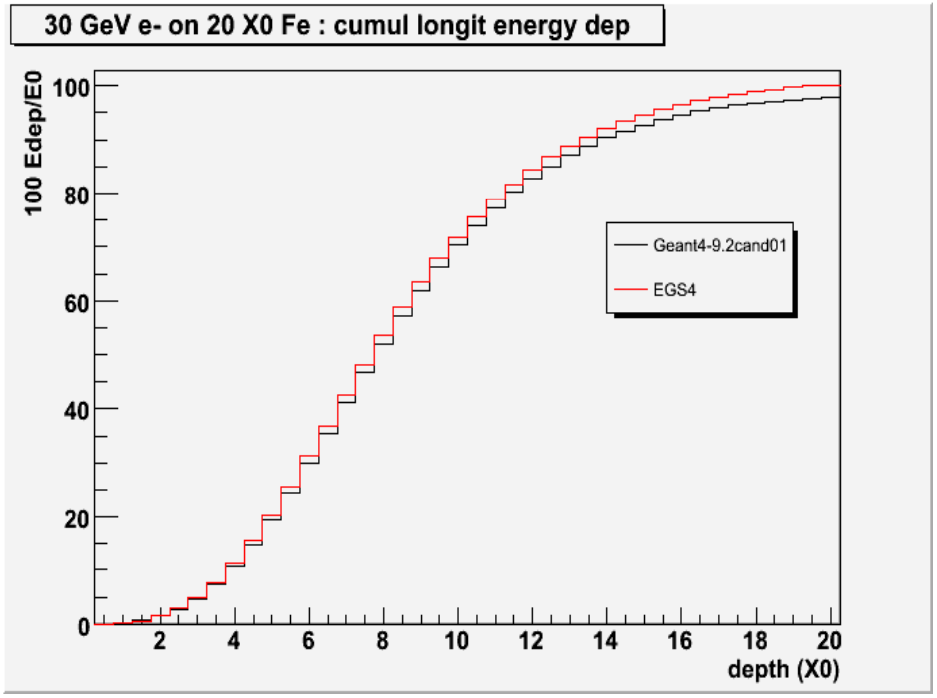
- We recommend aggressively populating the [proposed] **database** with **all relevant experimental data**, as well as validation results provided by others
- Geant4 response:
  - *Number of validations and data sets added has grown in the last few years*
  - *Validation results for electromagnetic physics are accessible via the main EM validation page:* *https://twiki.cern.ch/twiki/bin/view/Geant4/EMValidation*
  - This page includes links to all validation results, publications, manuals, which are references to data sources
    - *Optimal solution, because formats of data are very different*

Recommendation 19

- We recommend continuously and systematically **benchmarking against other Monte Carlo transport codes**
- Geant4 response:
  - *At the beginning of Geant4 EM physics was systematically compared with Geant3*
    - *Corresponding macro files are kept with EM examples*
    - *Currently this comparison is not actual*
  - *Current priority is in benchmarking against concrete data and evaluated database data*
    - *References to publication are available in EM web*
    - *Example: https://twiki.cern.ch/twiki/bin/view/Geant4/EMJournalPublications#EmJpInter*
  - *Validation versus EGS is frequently performed by users*

Testing suite result for shower profile Geant4 versus EGS4





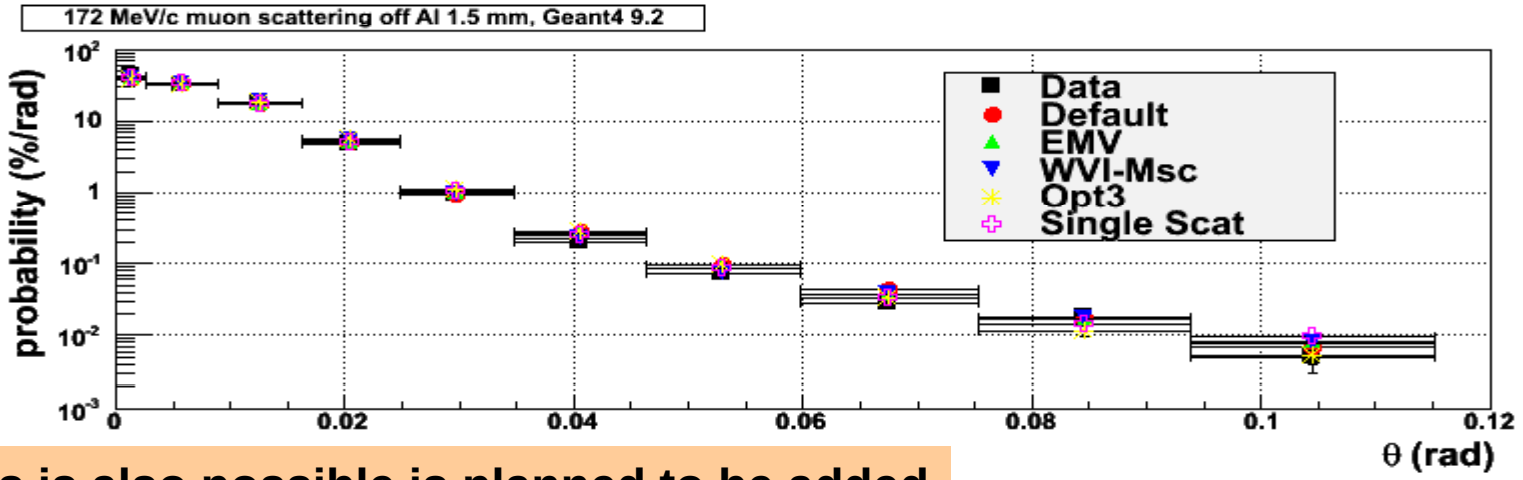
- Small difference in normalizations: EGS4 normalized to total energy deposition, so shower leak is excluded

Recommendation 21

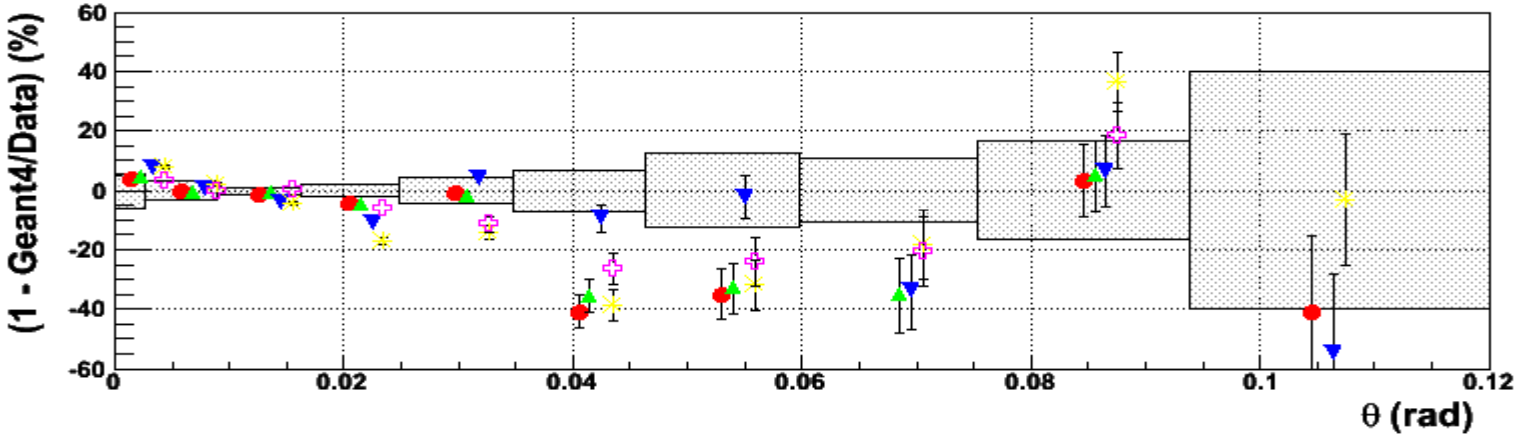
- We recommend defining **quantitative metrics for validation** results
- Geant4 EM response:
  - *Examples of usage of quantitative metrics are available in EM publication page:*

    https://twiki.cern.ch/twiki/bin/view/Geant4/EMJournalPublications#EmJpInter
  - *Extension of usage of different metrics is a part of the working plan for 2009 and beyond*
    - *MC/data is the most frequently used*
    - *Chi-squared and other statistical estimators are useful in some cases*

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

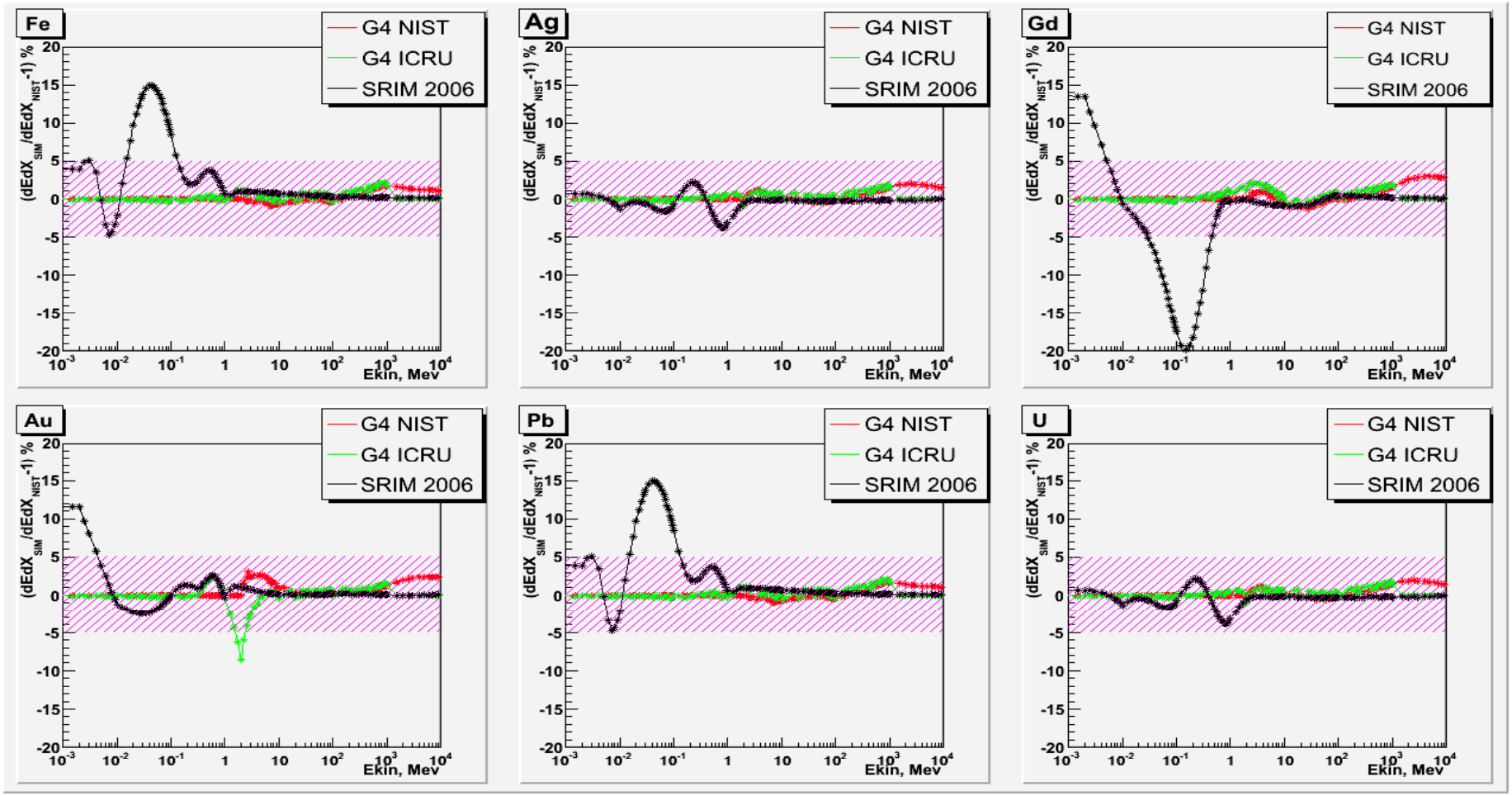


χ^2 analysis is also possible is planned to be added



Proton stopping power comparison:

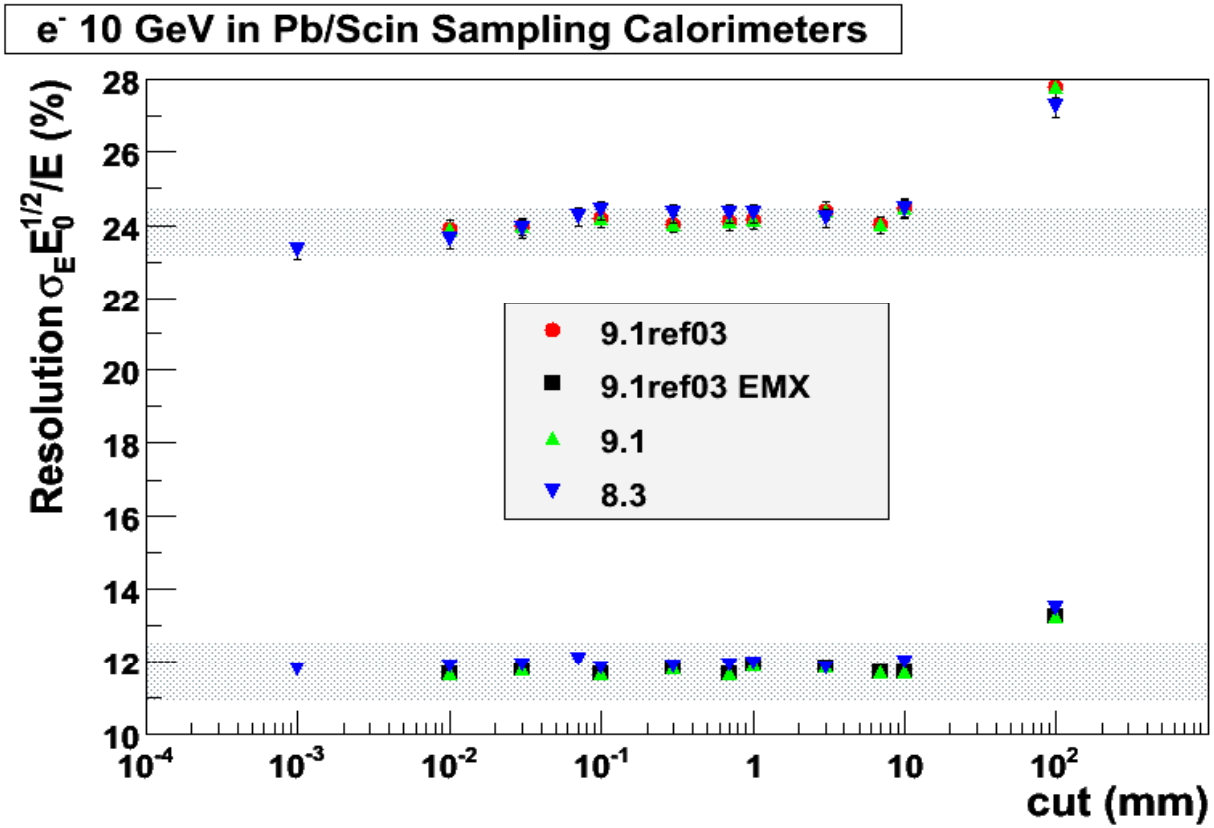
G4 NIST/ G4 ICRU/ SRIM-06/ NIST data



Pb/Scintillator sampling calorimeter

ZEUS test-beam: NIM A262 (1987) 229; NIM A274 (1989) 134)

- Two configurations:
  - **5 mm Pb/5 mm Scintillator**
  - **10 mm Pb/ 2.5 mm Scintillator**
  - **No dead material**
  - **Detector effects are excluded**
- X^2 comparison is possible but not informative



Recommendation 22

- We recommend that ***all validation results***, both the quantitative metrics and the underlying distributions, be **made easily accessible** to the user
- Geant4 EM response:
  - *Corresponding documentation is provided with EM web page*
    https://twiki.cern.ch/twiki/bin/view/Geant4/EMValidation
  - *Extension of this documentation is a part of the working plan for 2009 and beyond*

Conclusion remarks

- Validations for Geant4 EM physics have been significantly developed since 2007
  - Software infrastructure
  - Documentation and web
- Further extensions of EM validation are part of plan for 2009 and beyond requires
  - close collaboration between Standard and LowEnergy working groups
  - high quality validation software and documentation
  - significant manpower