



PRINCETON
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Status of EM Physics

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Outline

- Updates of EM libraries
 - New developments
 - Remaining work items for 11.2
 - Conclusions
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- *Main development efforts during 2023 we spend to consolidate and provide patches for the previous release 11.1*
 - *11.1.patch02 is the current default for CMS*
 - *New Geant4 11.2 should include*
 - *Consolidation of EM developments for HEP*
 - *Introduction of new features for various domains of EM physics*
 - *Significant improvements for Geant4 DNA*

Some statistics

- Number of merged MRs after December release 11.1:
 - Electromagnetic/utils - 15
 - Electromagnetic/standard - 20
 - Electromagnetic/muons - 3
 - Electromagnetic/highenergy – 2
 - Electromagnetic/lowenergy - 9
 - Electromagnetic/dna - 21
 - Electromagnetic/xrays - 1
 - Optical - 9
 - Physics_lists/constructors/electromagnetic – 9
- New dataset G4EMLOW8.4

General updates of EM libraries

- Format classes using `cling-tidy` and `cling-format`
 - Ben Morgan provided python scripts allowing to use the latest version clang
 - We apply class formats when prepare merge requests, no campaigns this year
 - Please, consider these formats when make merge requests
- Access to `G4LEDATA` environment variable
 - `const G4String& G4EmParameters::GetDirLEDATA();`
 - Environment variable is checked in one place and only once
 - The update is already done in `utils`, `standard`, and few model classes of `lowenergy`, which are used in Option0 EM physics
 - It is needed to do inside `lowenergy` and `dna` sub-libraries

Initialisation of static data

- There was problem report #2546
 - Crash due to data race if user instantiate extra instances of EM models
- The first step for 11.2beta
 - It was understood that not in all cases it is possible to use `G4VEmModel::IsMaster()` to decide to initialize static data, in some model classes (used inheritance) an extra Boolean flag `isFirst` is added
- Recently more clean approach is proposed (like one used in CMSSW)
 - `static std::once_flag applyOnce`
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 - `std::call_once(applyOnce, [this] () { isInitializer = true; });`
- The `isInitializer` flag substitutes `isFirst`
 - This construction defines that given class object is responsible to initialize shared data
 - It is important that model classes migrated to this schema is no more responsible for deletion of data structure

Change in bremsstrahlung

- Problem report #2546 (V. Hewes, S. Hageboeck)
 - Crash when user instantiate model class in the user action
 - Long discussion with M. Novak
- G4SeltzerBergerModel – implemented inheritance from G4VEmModel instead of intermediate G4eBremsstrahlungRelModel
 - Removed LPM flags (which are not used)
 - Some code duplication but clearer initialization
 - Use static `std::once_flag` `applyOnce`
- G4eBremsstrahlungRelModel
 - Use static `std::once_flag` `applyOnce`

G4ElementData

- G4ElementData is used for many years as an effective data structure to keep G4PhysicsVectors and G4Physics2DVector data and fast run time access via Z and A
 - Was using C-arrays with fixed length Zmax=99, was usually static
 - Deleted by the consume class (it is the main problem!)
- Updated version for 11.2 of the class uses std::vector and std::pair
 - Zmax is defined by the consume class
 - Registered in G4ElementDataRegistry
 - Allow extra structures for vector and 2D-vector per isotope
- G4ElementDataRegistry
 - Is responsible for deletion end of job
 - Has access method by the G4ElementData name
 - Now G4ElementData may be shared between threads but be non-static

Ionisation classes

- When ICRU90 were introduced in Geant4 the code become fragile
 - Energy range of different data sets are different
 - Scaled He or proton data were used for ions differently depending on projectile energy
 - T. Toshito and M. Giraldo efforts
- For 11.2beta and 11.2 more clean configuration of the code
 - G4BraggModel – for low energy protons and backup for ions
 - G4BragglonModel – for alpha particles
 - G4LindhardSorensenModel – for all other ions
- Low-energy stopping power data $E \cdot m_p / M < 2 \text{ MeV/u}$
 - For protons - ICRU90 (if available for a material), PSTAR for the rest
 - For alpha - ICRU90 (if available for a material), ASTAR for the rest
 - For other ions ICRU90 (if available for a material), alternatively ICRU73 (if available for a material), for the rest PSTAR and effective charge
 - New stopping power data may be added (even custom data)
- Problem #2531 fixed
 - Spline flags were lost for mu-, pi-, K-
 - Maximal effect of this problem: ~5% bias for ranges for muon of 50 MeV/c

New models developments

- Components of EM physics in crystals are implemented via fast simulation interface (A.Sytov)
 - Processes are released within \$G4INSTALL/parameterisations/channeling
 - See talk at the parallel session Monday
- X-Ray surface reflection process (H.Burkhardt)
 - Needed for many applications in accelerator physics, space science, ...
 - See talk at the parallel session Monday
- MicroElec model and data for (C. Inguibert et al.)
 - New photon model applicable to projectile electrons and ions
 - Elastic and inelastic scattering for extra materials
 - Previously the models were applicable to Silicon only
 - Now Aluminum oxide, Boron nitride, and Silicon dioxide are added
- Significant code evolution inside DNA library
 - Both physics and chemistry
 - See Hoang Tran talk in this session

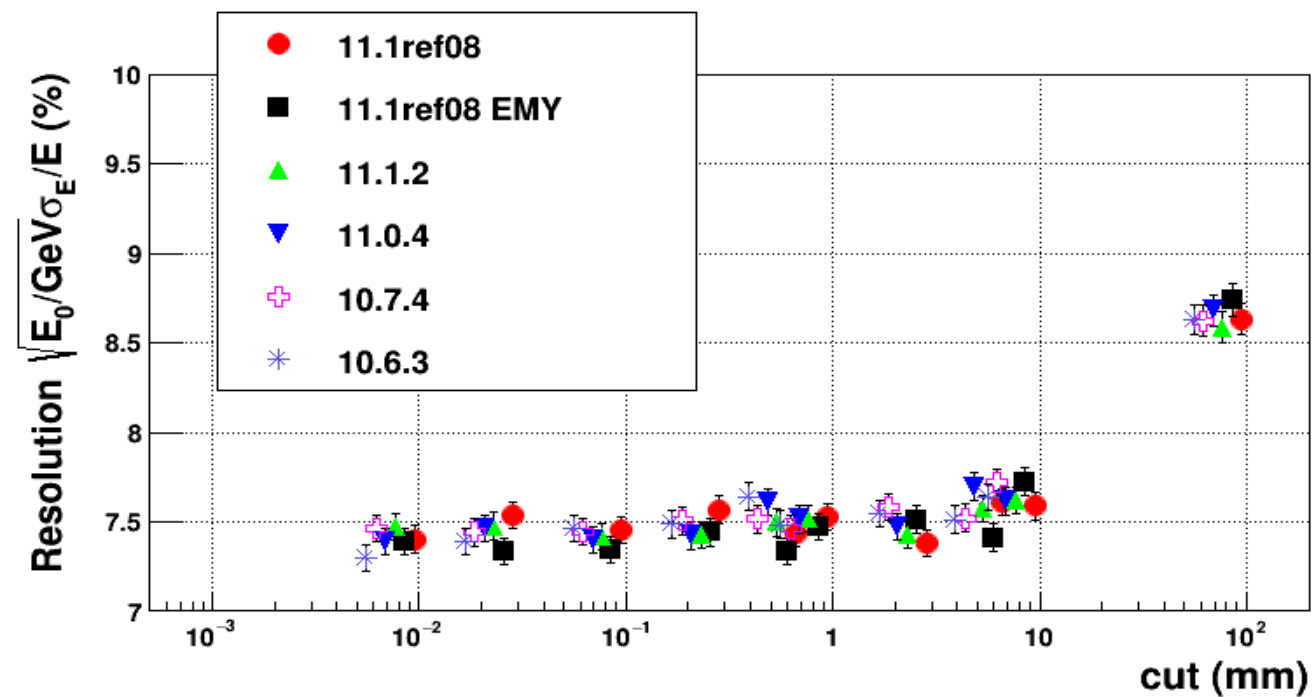
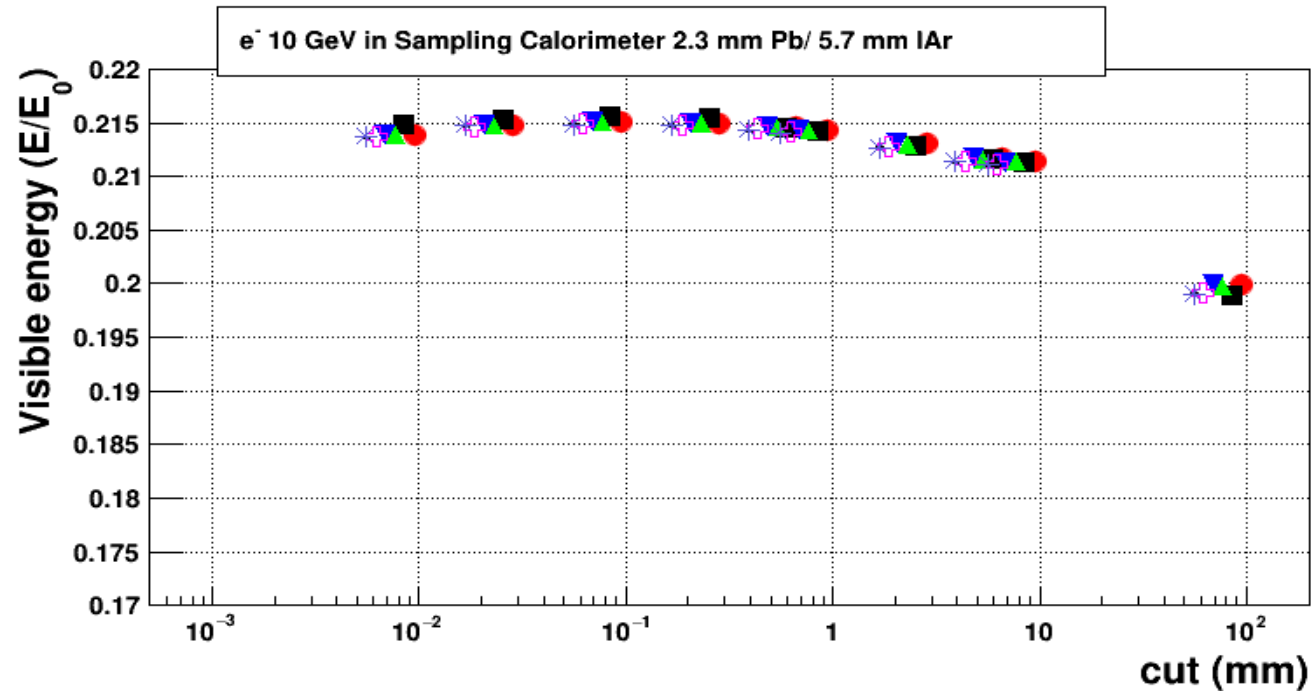
Other developments

- Number of bugs are fixed
 - Bugzilla #2511, #2530, #2531, #2532, #2543, #2546, #2555
 - Git issues: #168,
- Added extra flag
 - MscPositronCorrection – may be used to enable/disable L. Urban positron correction introduced in early Geant4 releases (ATLAS problem)
 - UI command and C++ interface
- Update for quantum entanglement (J. Allison)
 - Allowing definition in G4State_Idle
 - Postpone one of correlated track into waiting stack (see Makoto talk) this allows to keep track on correlations after 1st Compton scattering
- Fixed rare infinite loop in Penelope Compton (L. Pandola & D.Iuso)

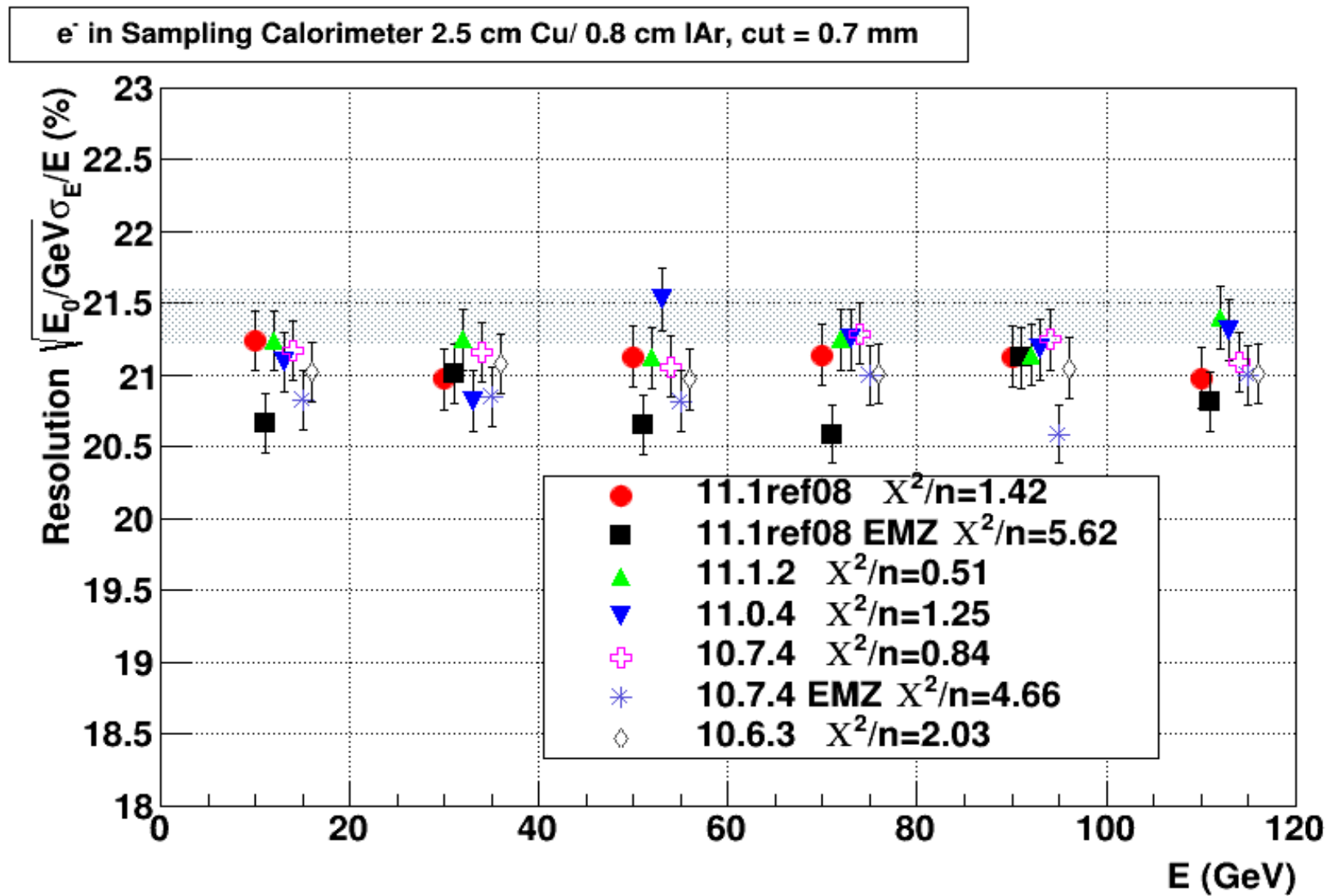
Selected validation results

Confirm stability of main observables

Simplified ATLAS barrel

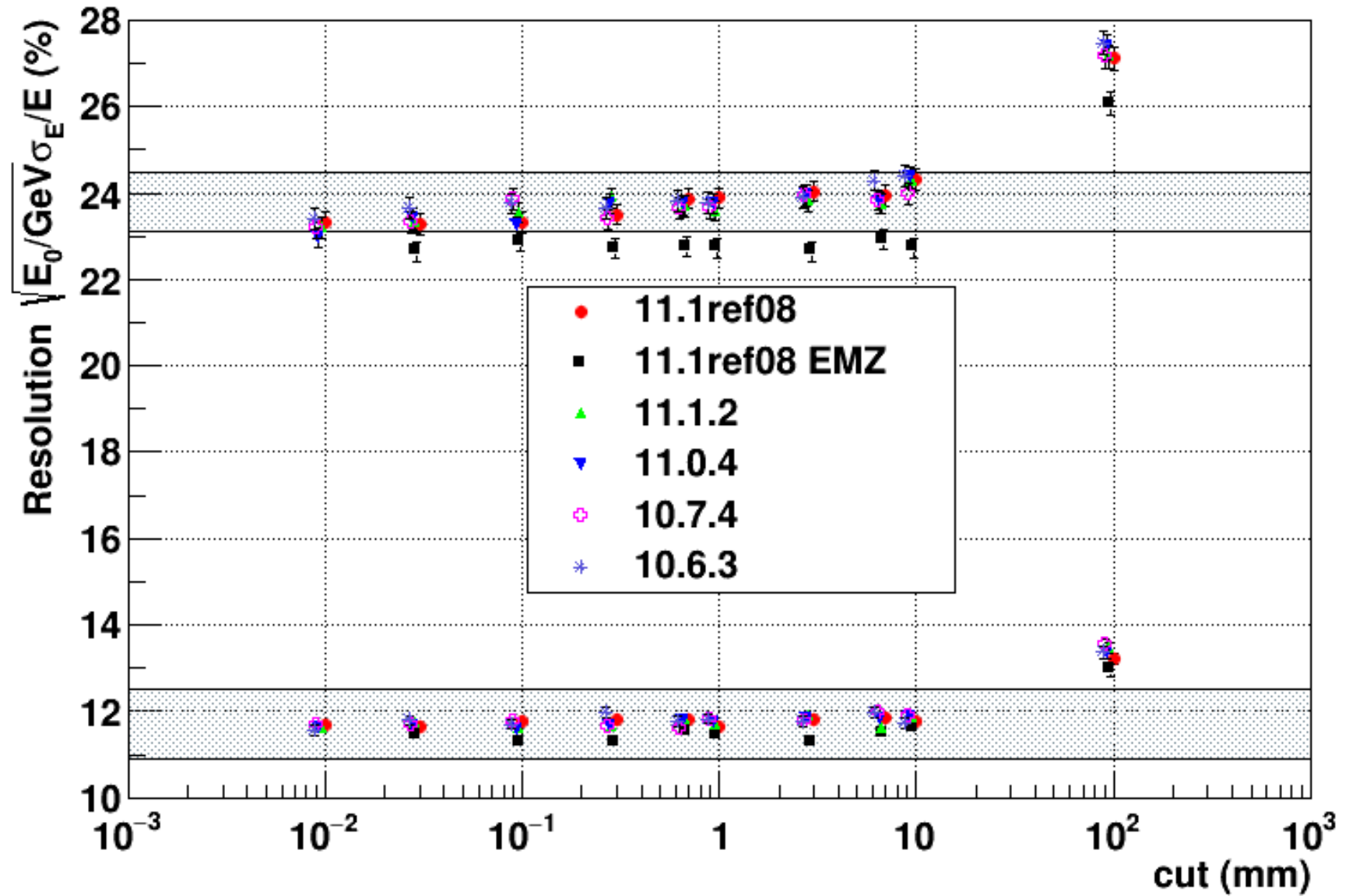


Simplified ATLAS HEC

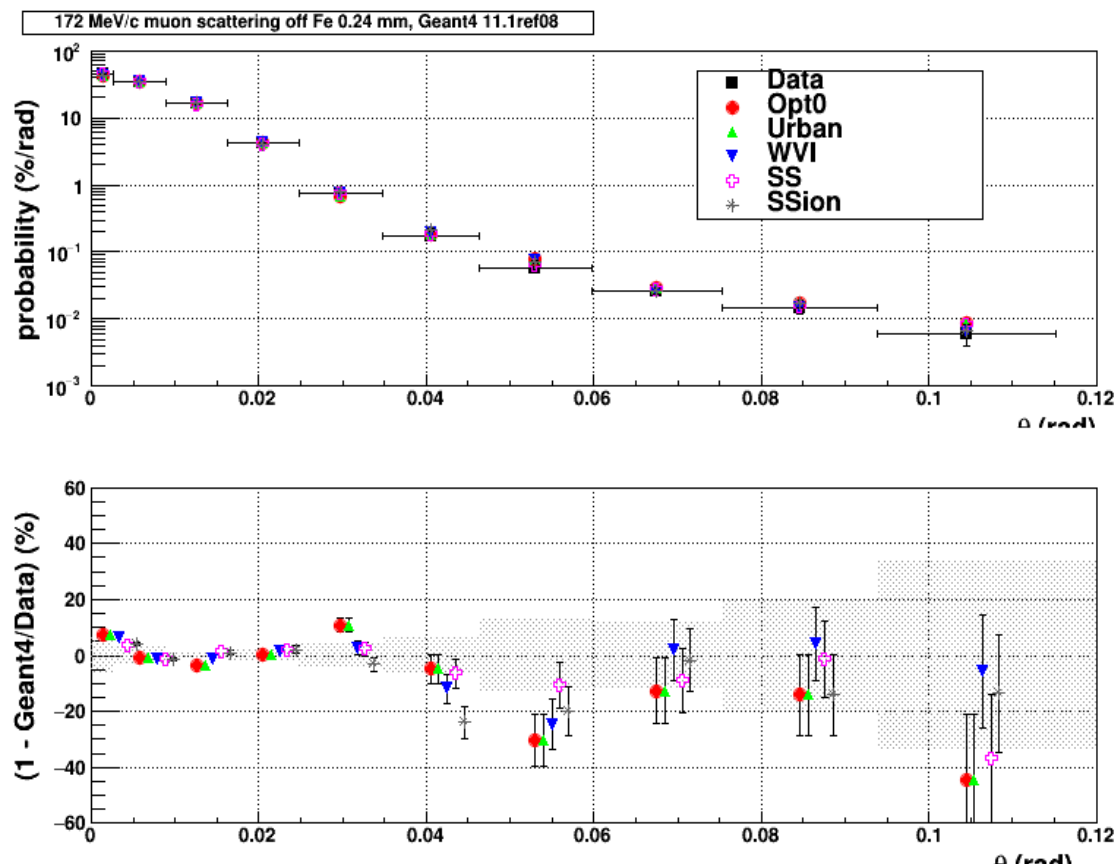


ZEUS test beam

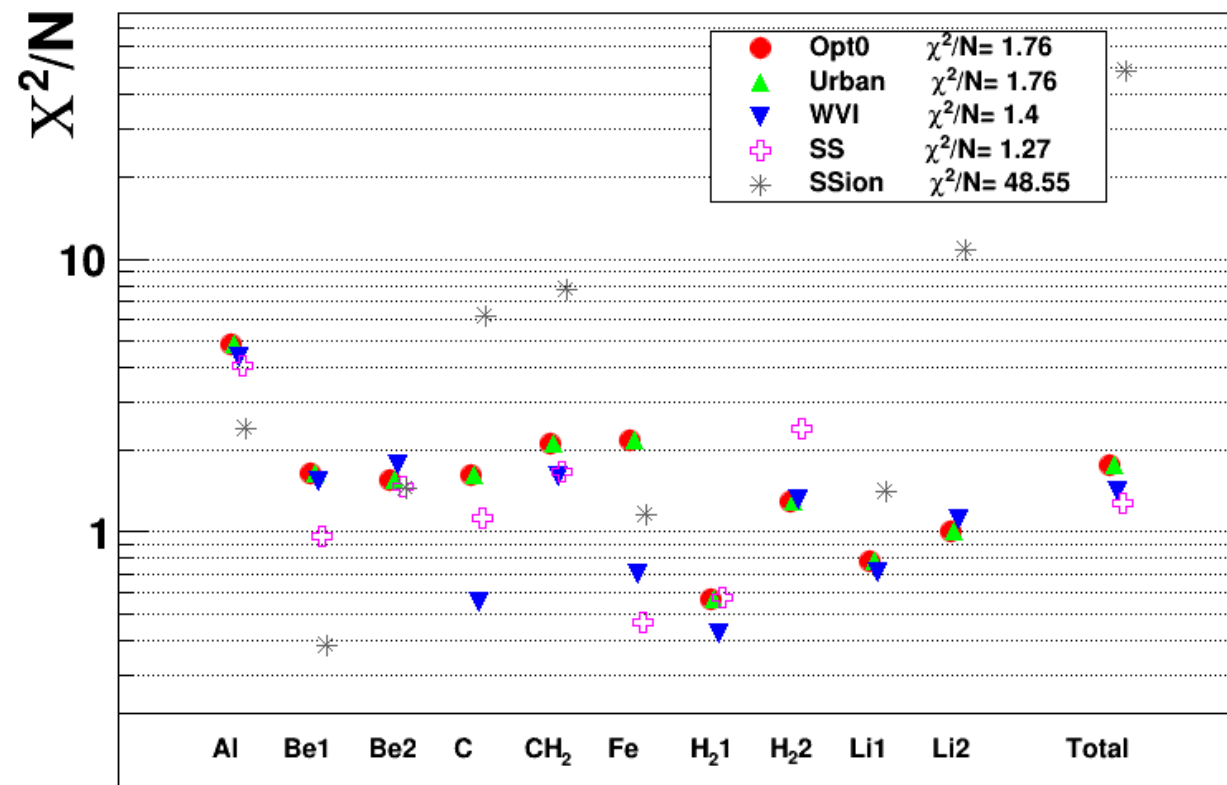
e^- 10 GeV in Pb/Scin Sampling Calorimeters



MuScat benchmark versus data

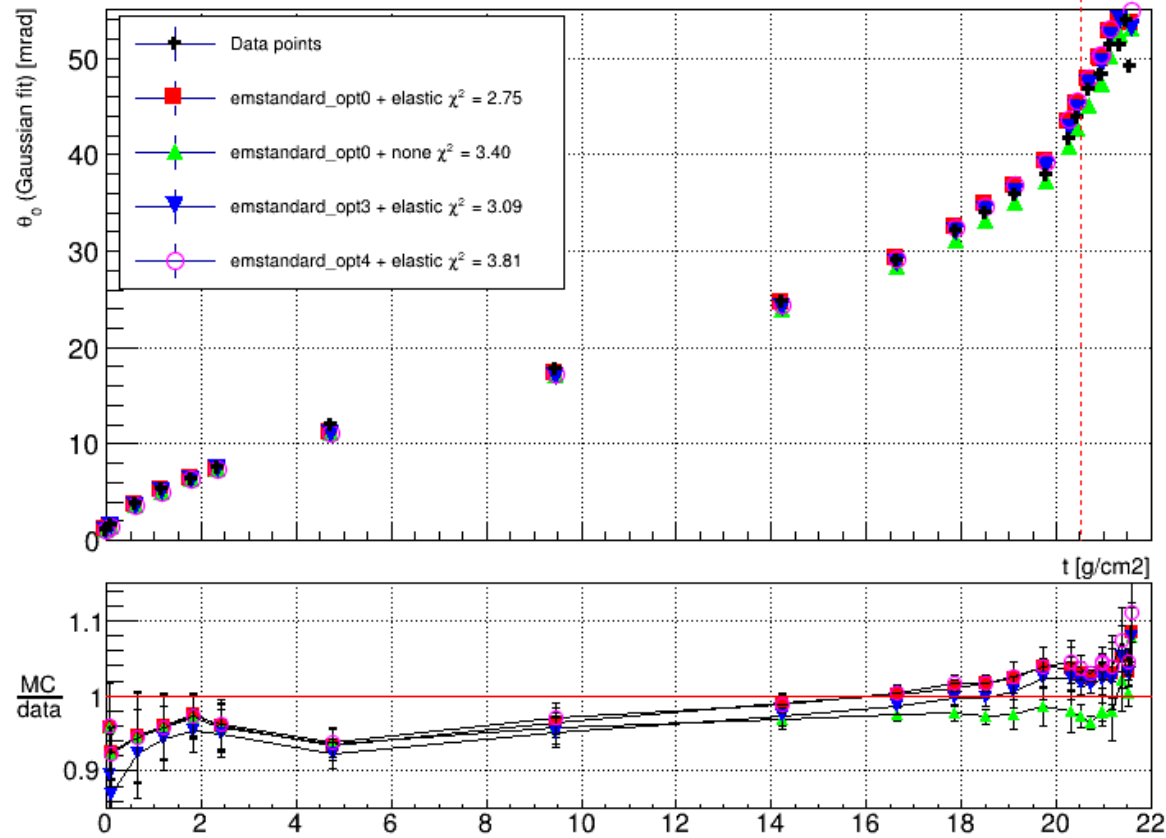


172 MeV/c muon scattering - MuScat, Geant4 11.1ref08

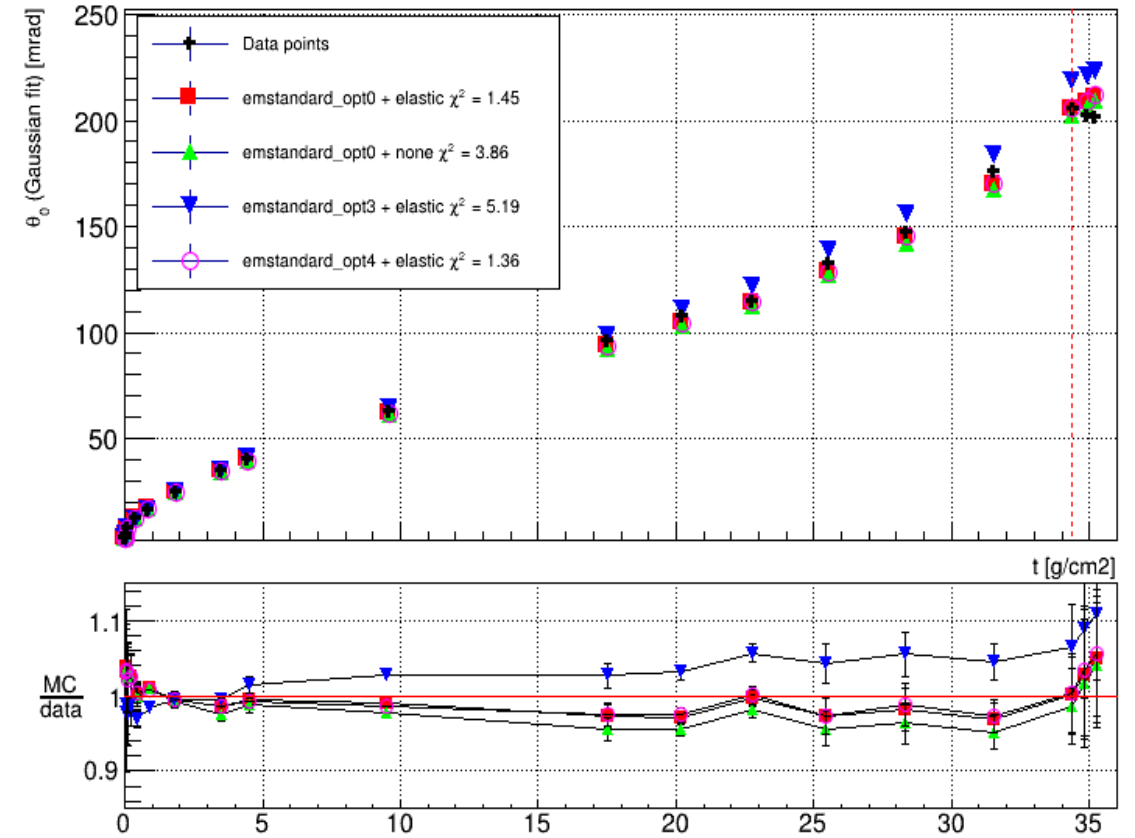


Proton scattering in Be and Pb

Charachteristic Angle Distribution for Beryllium



Charachteristic Angle Distribution for Lead



Remaining work items for 11.2

- Release X-Ray scattering process
 - Merge request pending
 - G4LEDATA required update
- Make muon model initialization free of IsMaster() check
 - Mainly for Geant4e applications
- Check proposed improvements by L.Urban to the G4UrbanMscModel
 - We need critically evaluate the effect
 - If proposed modifications affect results in a significant way, provide a new option to keep the default unchanged
- Finalize configuration for combined standard/DNA physics constructors
- Evaluate ALICE requirement for production cut initialization

Conclusions

- EM physics developments are in a good shape
 - Geant4 11.1.p02 is used by CMS
 - New models are prepared for the release
- Validation of EM physics should be the main efforts before the release
 - Validation results for monthly versions for 11.2 are under control