Update on Standard Electromagnetic Physics

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Menu

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- Evolution of physics models
- EM standard for FCC
- Summary
- Validations of EM physics

- Standard EM developments are traditionally focused on LHC applications but by product are relevant to wide range of different simulation tasks

List of recent developments

ANTIPASTO

Modifications in materials for 10.3

- G4NistMaterialBuilder, G4NistManager
  - added a lock when build new material
  - added new const methods to access existing materials and elements in rn time in MT mode
- G4MaterialPropertyTable (A.Dotti)
  - fixed data race for optical physics
- All asserts are substituted by G4Exception which are checked now only if G4VERBOSE flag is enabled
- G4AtomicShell_EADL (L.G.Sarmiento)
  - a new alternative class which require further evalution before will be default, data are from recent review
- Fixed density effect parameterisation for compounds (M.Novak)
- Added C++ keywords

Modifications in EM utils

- G4EmParameters
  - moved all remaning parameters from G4EmProcessOptions class (this class become obsolete);
  - Changed logic – allow initialisation only from master thread and only in PreInit and Idle states;
  - Extend default upper upper energy limit from 10 TeV to 100 TeV (FCC simulation)
- G4VEmModel
  - Added a flag allowing to «lock» model parameters
    - This is needed in order to configure custom set of a parameters for energy range and/or region
- G4VAtomDeexcitation
  - fixed initialisation per region and data race
- G4EmSaturation (Birks effect)
  - make this helper class thread safe and reuse it between threads in run time
  - updated Birks constants using ATLAS and CMS values
- G4EmCalculator
  - fixed dEdx computations for He3 and He4
- C++11 keywords and constructions are added (D.Sawkey)

Modifications in standard EM for 10.3

- Data for ionisation models from ASTAR, ESTAR PSTAR, NIST DBs are transformed from G4double to G4float
- G4UniversalFluctuations (L.Urban)
  - fixed assymetry in Gaussian sampling
- G4UrbanMscModel (L.Urban)
  - Fixed randomisation of step limit
  - Applied improved lateral displacement for Opt3 and Opt4 Physics Lists only
  - Fixed step limitation when gun is at geometry boundary (M.Novak)
- G4GoudsmithSaundersonModel (M. Novak)
  - Fixedstep limitation when gun is at geometry boundary
- G4WentzelVIModel
  - Added several alternative EM formfactor parameterisations
- G4eSingleCoulombScatteringModel (P.G. Rancoita and M.Tacconi)
  - Revised and updated
- G4eBremsstrahlungRelModel (M.Novak)
  - Fixed LPM constant and LPM function computation (M.Novak)
- G4SeltzerBergerModel
  - fixed data handling for Z > 92
- Added C++ keywards and optimized constants definitions

Modifications in other standard EM sub-libraries

- G4ePairProduction
  - New process for e+e- pair production by electron or positron
- Polarisation library was reviewed by D. Sawkey and an outstanding problem was to compute mean free path for circular polarised beam was addressed
  - Was pending for a long time
- TransitionRadiation processes have now correct process sub-type
- G4Scintillation (P.Gumplinger)
  - It is possible to by user demind to add G4ScintillationTrackingInformation
- Added C++ keywards and some other constructions (D.Sawkey)

Technical modifications

PASTA

Electromagnetic parameters

- In previous versions of Geant4 EM parameters were defined via UI commands and C++ interface G4EmProcessOptions
  - Via this class each EM process was accessed one by one in order to set parameter value
- After Geant4 10.0 we face some limitation in MT mode and switch to G4EmParameters class
  - EM process or model at initialization read these parameters
    - This class is kept for backward compatibility but will be removed later (may be in 10.3)
  - Now UI command order become not so important as before
    - Commands should be issued in PreInit and/or Idle states from master thread
  - Information on set of parameters is available via Dump method
- Now parameter configuration is working fine in general but we may be provide too much freedom for customisation?

Atomic de-excitation for radioactive decay

- Sinse 10.3beta EM physics and pre-compound/de-excitation allowing to change parameters before the run
  - At G4PreInit_State any parameter may be safely changed
  - At G4Idle_State change of EM parameters will have an effect only for the next run
  - During the initialisation (before G4Idla_State) situation is not fully under control
    - There are public interfaces allowing change EM or DeexPreco parameters «on-fly»
    - This change cannot be controlled
    - To reduce possible damage changes are enabled only in the master thread
- Minimal constrains which we may require (from EM physics point of view):
  - Any G4 process should not create new materials
    - EM physics infrastructure assuming fixed list of materials
  - Any process/model should not change common parameters during construction or inside Initilise() methods
- Just in release time of 10.3beta a problem of the radioactive decay appeares when the radioactive decay enable initialisation of atomic de-excitation
  - The issue has been fixed in the last moment before the beta-release

- Without gentelmen agreements between developers we cannot gurantee stable initialisation of hadronic and EM physics if we allow modification of parameters via C++ interface or UI commands

Migration to c++11 and code clean-up

- We make a campain to migrate standard sub-libraries to c++11
  - Use nullptr
  - Use keywards: explicit, delete, override, final
  - Use auto in few places
- All places where const expressions are used
  - «static const G4double» or «static const G4float»
  - Placed locally just before places where const is used
- G4VMultipleScattering – remaining code is PostStepDoIt is moved to AlognStepDoIt
  - The migration to msc computations was moved to AlongStep two years ago
  - At PostStep only fill of G4ParticleChange remains
  - By this we reduce number of calls to virtual methods at each step of charged particle
- Ionisation data is moved from G4double to G4float
  - They are known for an accuracy of few digit only
- The results of these efforts is NULL for CPU and library size but
  - The code become more uniform and transparent
  - We have improved comments and removed unused variables and methods

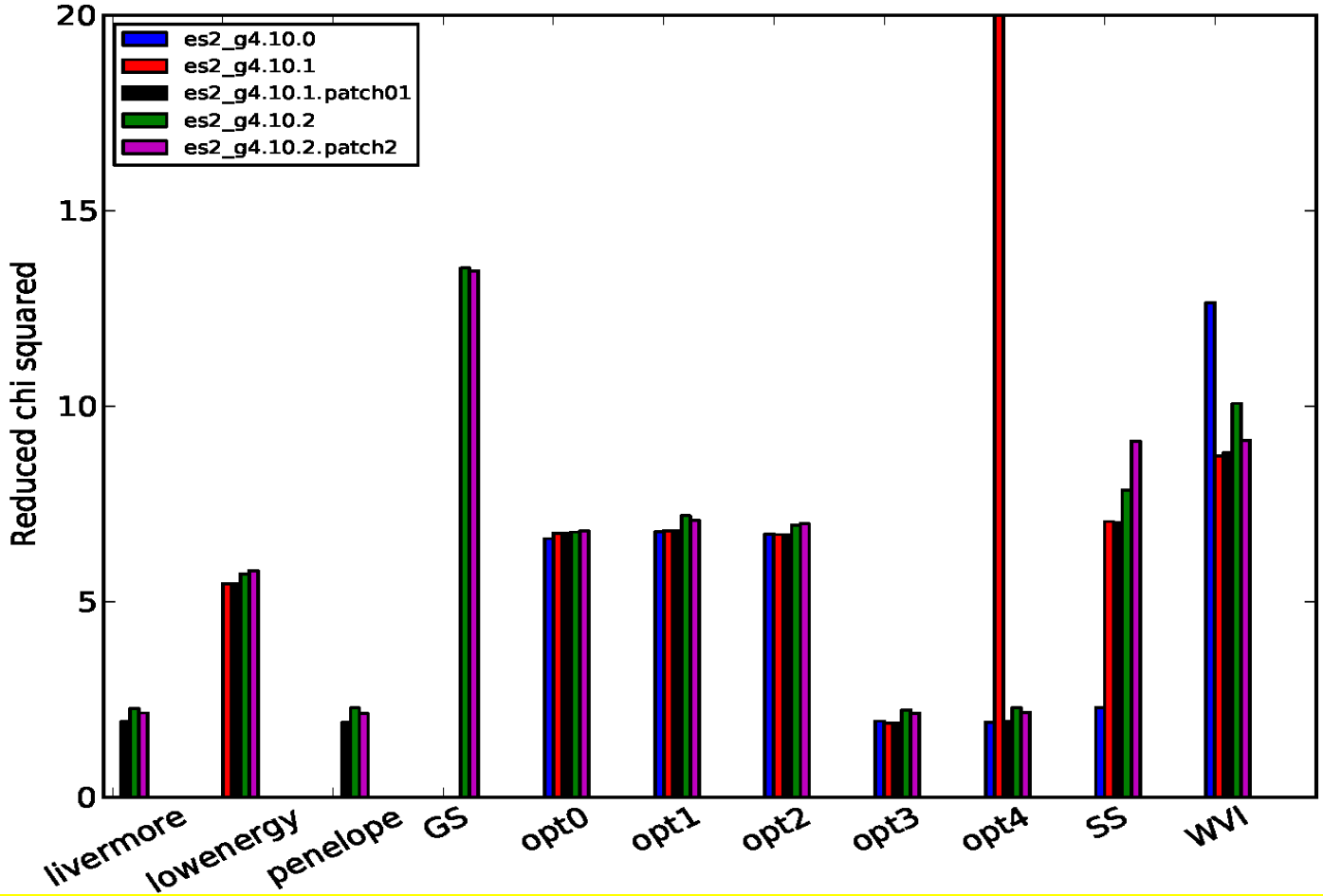
EM physics configuration

- Until Geant4 10.2 we had a limitation Geant4 EM physics should be customised by a user for any special needs:
  - Different models for G4Region
  - Different model options for G4Region
  - Standard/DNA models
- This customisation can be done properly only by an expert user and make problems even for top experts
- For 10.2 we provide new UI commands:
  - /process/em/AddPAIREgion all myregion PAI
  - /process/em/AddMicroElecRegion myregion
  - /process/em/AddDNARegion myregion DNA_Opt0
- For 10.3 we provide new UI command:
  - /process/em/AddEmRegion myregion G4EmStandard_Opt3
- This is not PhysicsList per G4Region but EM physics configuration per G4Region
  - By this new command we do not fully emulate Opt0, Opt1.. But mainly msc models and atom de-excitation

Evolution of physics models

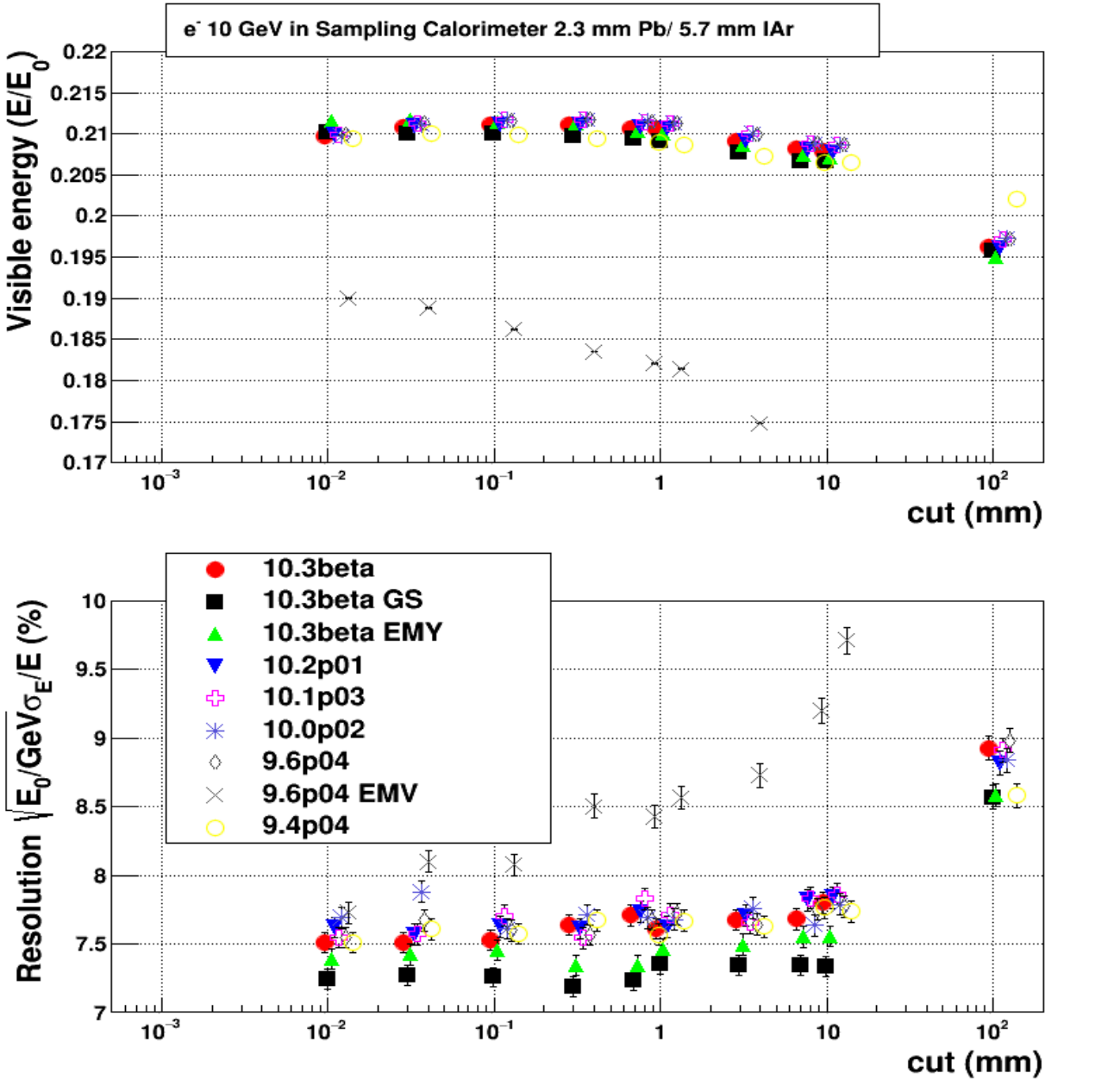
MAIN FISH

Electron scattering benchmark (Daren Sawkey)



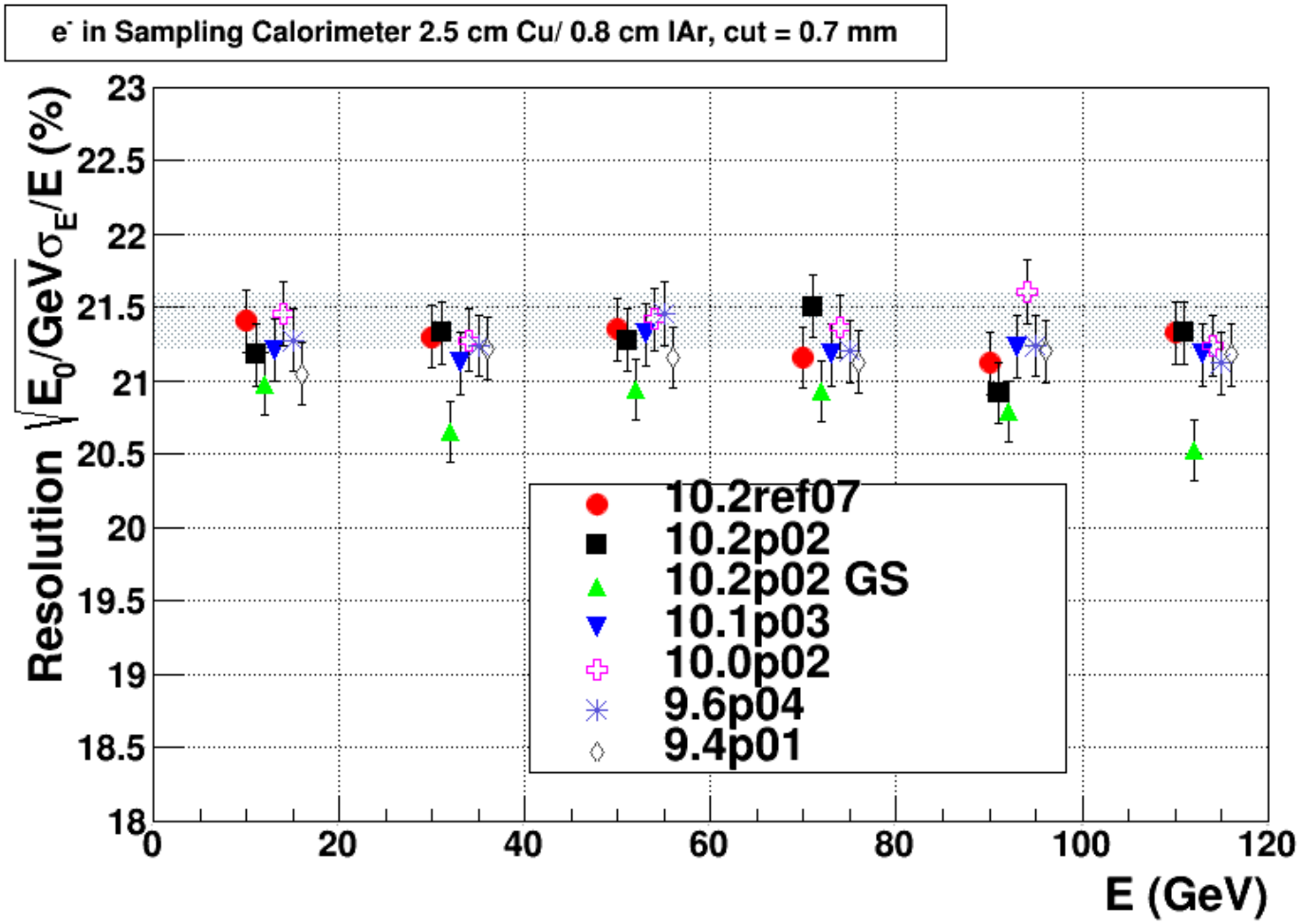
- For 13 and 20 MeV forward scattering all models are OK
- Urban with a strong step limtation is the most accurate

ATLAS barrel type simplified calorimeter results



Improved lateral displacement sampling in Urban model significantly change calorimeter response, it become closer to GS

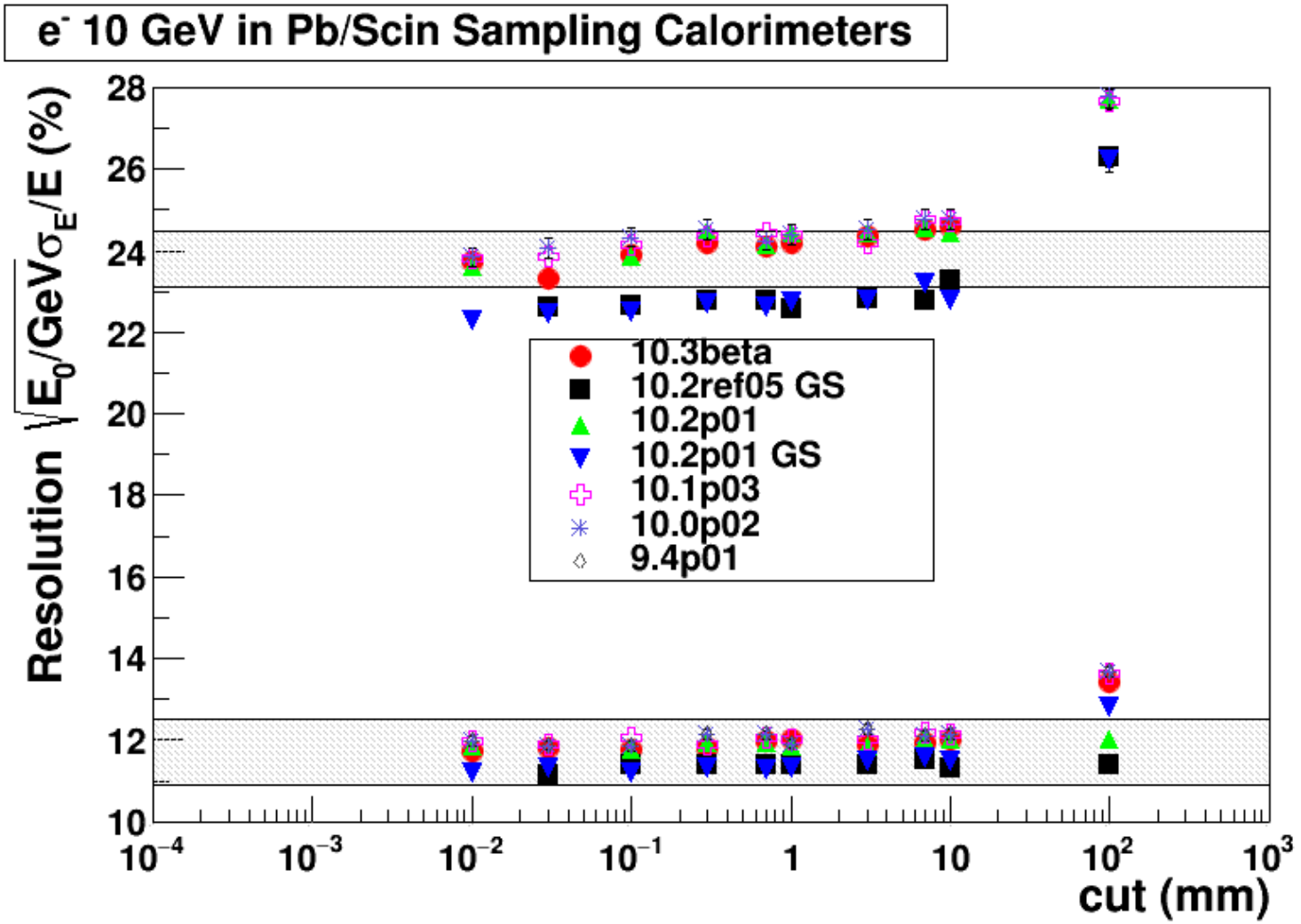
Resolution of simplified ATLAS HEC calorimeter versus test beam data



Data ± 1 RMS

Both GS and improved Urban model underestimate resolution

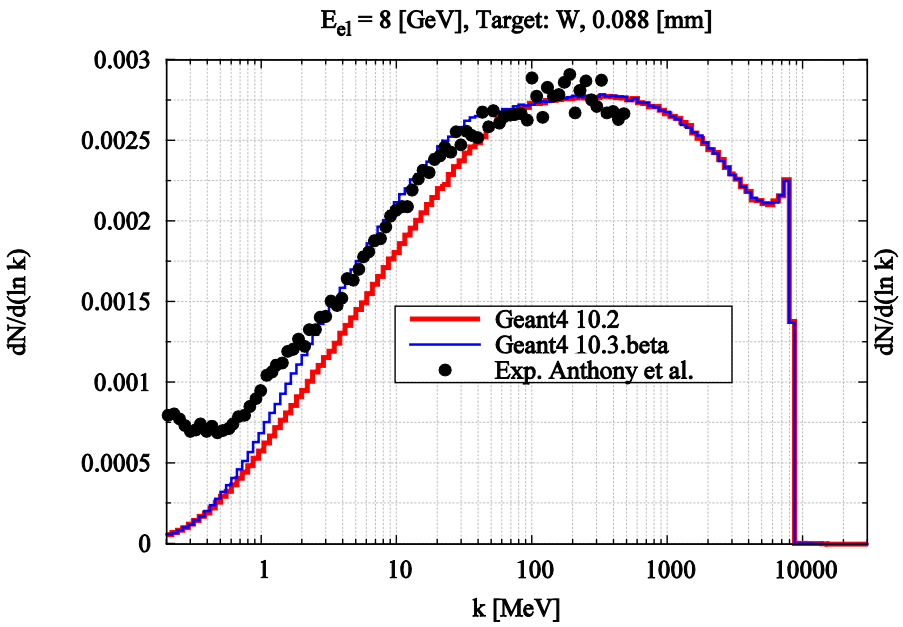
ZEUS test-beam calorimeters

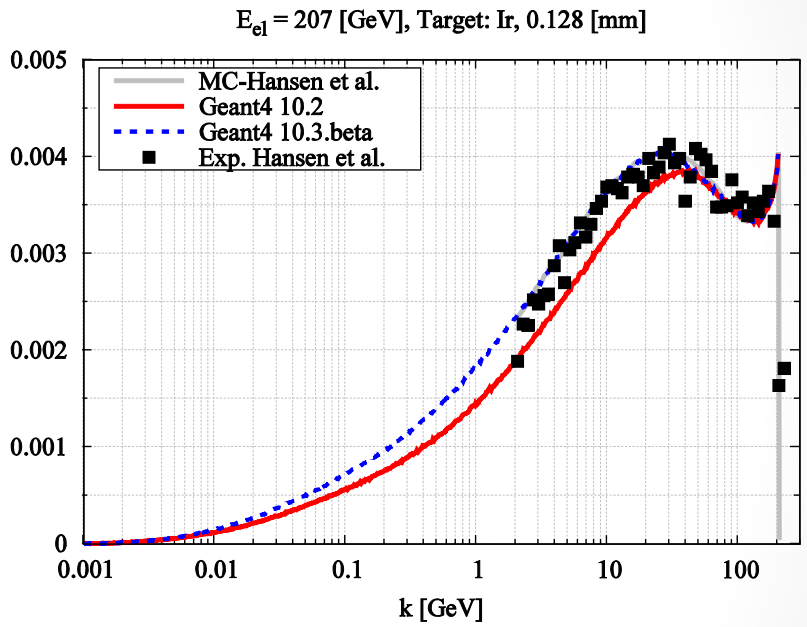


The problem of the sampling calorimeter response

- Both Urban and GS models of multiple scattering were improved recently and provide very good agreement versus thin target data
- Default msc configuration of the Urban model with the old (less accurate) lateral displacement sampling better agree with calorimeter test-beam data
- We commit significant efforts to understand the issue
  - Code review
  - A new process of e+e- pair production by electron and positron was added
  - New tests were added:
    - ATLAS tilecal
    - ALICE TRD
  - Laszlo Urban
    - proposed improvements for the fluctuation model
    - study cut/step size dependence of the fluctuation model
    - tried to use PAI model for calorimeter simulation
  - Birks and gamma-nuclear effects on the EM shower were studied
  - LPM for bremsstrahlung was reviewed
- Problem remains unresolved up to now

LPM supression fixed (M.Novak)





A classical formula for LPM effect description has been restored

Shape of distribution is described now with better accuracy

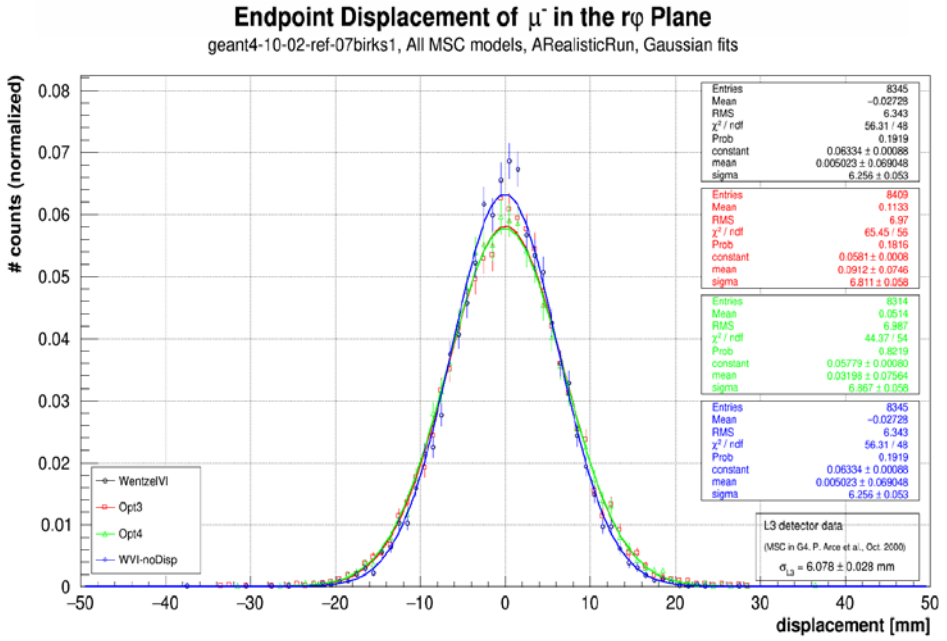
We do not observe a visible effect of this fix on HEP calorimtry response

Electron scattering with Mott corrections (P.G. Rancoita and M. Tacconi)

- They are working recent years on several aspects of Single Event Effect simulation
- A new tool was developed: screened relativistic nuclear stopping calculator: http://www.sr-niel.org/index.php/niel-dose-calculator-for-spectral-fluence-of-electrons-protons-ions
- They pointed out that there are various parameterisations of electromagnetic form-factors of atomic nuclei:
  - Exponential - old defaults
  - Gaussian
  - Flat
- These options are now implemented inside WentzelVI models of single and multiple scattering

Effect of modification of EM form-factor parameterisation on L3 data (P. Arce et all)

Introduction of the Gaussian form-factor parameterisation improving agreement data/MC



Model	RMS (mm) of displacement
L3 data	6.078 ± 0.028
Urban (Opt3)	6.649 ± 0.079
WentzelVI Exponential	6.254 ± 0.075
WentzelVI Gaussian	6.147 ± 0.073

EM standard for FCC

DESERT

Summary and EM Validation

GRAPPA

Summary

- Progress for EM standard libraries for 10.3:
  - EM physics is c++11 aware
  - We complete migration to G4EmParameters
  - We have set of UI commands to configure EM physics per region
  - LPM effect for bremsstrahlung is fixed
  - New process of e+e- pair production by electrons and positrons is added
  - WentzelVI model uses various form-factor parameterisations
  - Upper limit is extended from 10 TeV to 100 TeV
- We have list of problems which needs to be resolved
  - Resolution of sampling calorimeters
  - Use EM form-factors by other EM processes at high energy
  - New benchmark for CMS high granular calorimeter
- EM validation
  - A.Bagilya developed a web application allowing easy access to EM benchmarks:
    - https://geant4-tools.web.cern.ch/geant4-tools/emtesting/