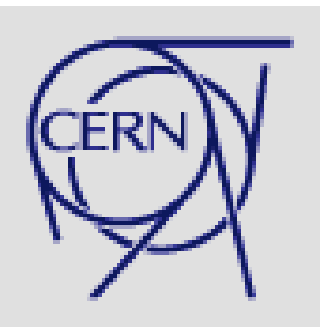
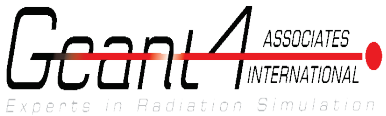




Status and Progress in Standard EM

V. Ivanchenko for EM standard working group

CERN & Tomsk State University, Tomsk, Russia

22th Geant4 Collaboration workshop

UOW Campus, Wollongong, Australia

25-29 September 2017

Outline

- List of main developments/fixes for 10.4
  - Materials
  - Standard EM
  - Livermore model extensions for HEP applications
  - EM physics lists
  - EM infrastructure
- Highlight on fluctuations of energy loss
  - PAI and Urban models
- Mott corrections to e+- elastic scattering
  - GS model update
- Developments for dark matter seach experiments
- Summary

MAIN DEVELOPMENTS/FIXES FOR 10.4

Materials update for EM physics

- Thread safe creation of NIST materials
  - G4Material, G4Element, G4Isotope are shared between threads
  - Normally should be created in master thread at G4State_PreInit
  - There are use cases when a material is created by worker thread
    - Various tests
    - Usage of Geant4 sub-libraries without G4MTRunManager
- Locks are included to avoid data race in the MT mode
  - G4NistManager, G4Material, G4IonisParamMat
  - Does not really affect “normal” users
- Optimisation of G4MaterialPropertyTable (Soon Yung Jun)
  - Additionally to manipulation with strings added enumerators of properties
    - Substantial speed up for optical photon simulation
  - We preserve old slow interface but will remove it in the next release
- New interfaces are added in ref-08 allowing user defined density effect parameterisation (Jira requirement SIM-695)
  - Should be defined together with geometry
  - G4Material::GetIonisation()>SetDensityEffectParameters(
    G4double cd, G4double md, G4double ad, G4double x0, G4double x1, G4double x2);
  - G4Material::GetIonisation()->SetDensityEffectParameters(
    const G4Material* base_mat);

Standard EM update

- Improved version of Urban msc model (L.Urban)
  - Including fix for low-energy antiproton transport (H. Holmestad)
- Mott corrections to the GS model of multiple scattering (M.Novak)
- Updated implementation of Mott corrections to single scattering model (M.Tacconi)
- Restored functionality of G4WentzelVIRelModel (V.Ivanchenko)
- New interface to triplet production for bremsstrahlung (A.Bagulya), gamma conversion, positron annihilation (V.Ivanchenko)
- Nuclear stopping fixed (HyperNews #1595) (V.Ivanchneko)
- Fixed gamma conversion sampling below 50 MeV (V.Ivanchenko)
- Low-energy limit for cut for PAI models for precise simulation of gaseous detectors (D.Pfeiffer)
  - We know better now the limitations of the PAI model
- Review and update of gamma->mumu process (A.Sokolov)
- Fixed LPM effect parameterization for pair production (M.Novak, F.Hariri)

Livermore model extensions for HEP applications

- G4LivermorePhotoeffectModel was revised (M.Bandieramonte)
  - It is the most accurate Geant4 photoeffect model
  - The goal of this work is to use updated data, try to speedup the model keeping accuracy
    - Data structure and sampling algorithm are improved
    - Angular generator is optimized
    - Optimization took ~6 months
  - This allows to use this model in the default (Opt0) Physics List
    - A small CPU penalty for LHC applications (< 1%)
- Triplet production in gamma conversion was firstly developed by F.Longo and G.Depaolo
  - We use this model as a prototype to develop a general scheme of triplet production for all EM sub-libraries
- There is ATLAS request to implement polarized gamma conversion for detailed Higgs physics study
  - The request is not yet well justified
  - We already extended technical upper limit of Livermore polarization models to 100 TeV
  - We need common efforts between standard and low-energy working group in 2018 to improve polarized EM physics
- At previous week User Workshop D.Bernard reported comparisons between HELAS and EGS FORTRAN models versus Geant4 models
  - We have fixed few trivial issues in standard and Livermore gamma conversion
  - Improved sampling of final state should be a development goal in 2018

EM Physics Lists

- Continue developments of combined physics lists configuration
  - Completely split out DNA configuration by adding G4EmDNAPhysicsActivator
  - G4EmModelActivator has not anymore anything from DNA
  - Introduced SS physics per region
- Adding Rayleigh scattering and Livermore photo-effect model into the default (Opt0) physics
  - Soon about 1 % CPU degradation for Higgs sample with the old Livermore model
  - In ref-09 we will switch to the updated Livermore model
- Adding GS e+- scattering model to Opt4 below 100 MeV
  - It is important for many (including HEP) applications
- Extended Livermore polarized models applicability to 100 TeV (ATLAS requirement)
  - This is only technical extension, physics must be verified
  - Switch to polarized physics should be implemented via in 2018
    - First for Livermore physics

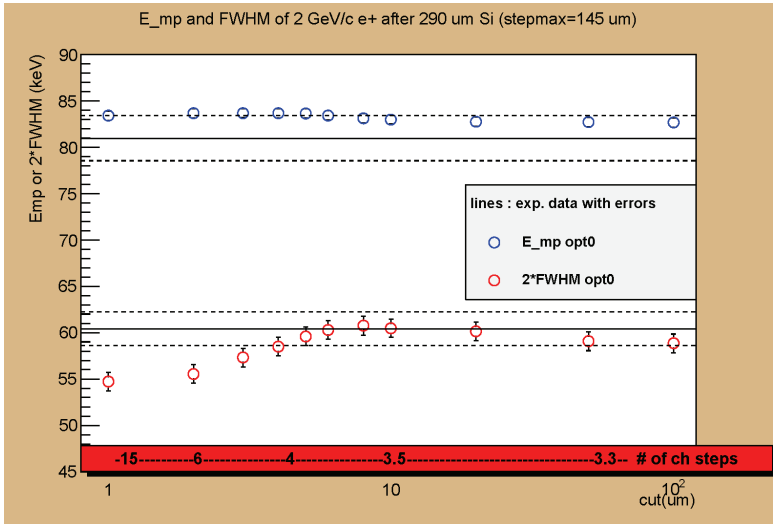
EM infrastructure updates

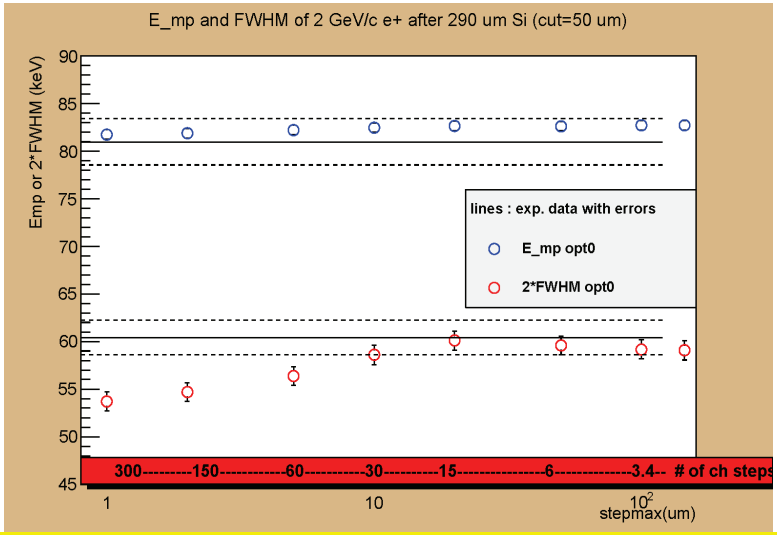
- Added protected interfaces to muon/hadron bremsstrahlung and pair production models
  - allowing usage of inheritance for easy creation dark matter particle interactions
- Extended list of G4EmParameters and corresponding UI commands
  - Mott corrections may be enabled via UI
- S. Elles has cleaned up and migrated to MT several examples and tests:
  - GammaTherapy, FanoCavity, FanoCavity2, test53, test54, test55, test56, monopole
- A.Bagulya has performed migrations of EM testing suite
  - Build with cmake instead of gmake
  - Tests from verification are included in CDASH for nightly and CVMFS
  - Many scripts changed from C-shell to python
  - Checked migration from ROOT5 to ROOT6
    - Few tests yet left to be fixed in 2018
    - Web access and data storage to be migrated from afs in 2018
- V.Grichine has added dmparticle extended example
- A new dataset G4EMLOW7.1 is prepared for 10.4
  - Is not backward compatible for GS and the Livermore photo-effect

FLUCTUATIONS OF ENERGY LOSS

Where is a problem?

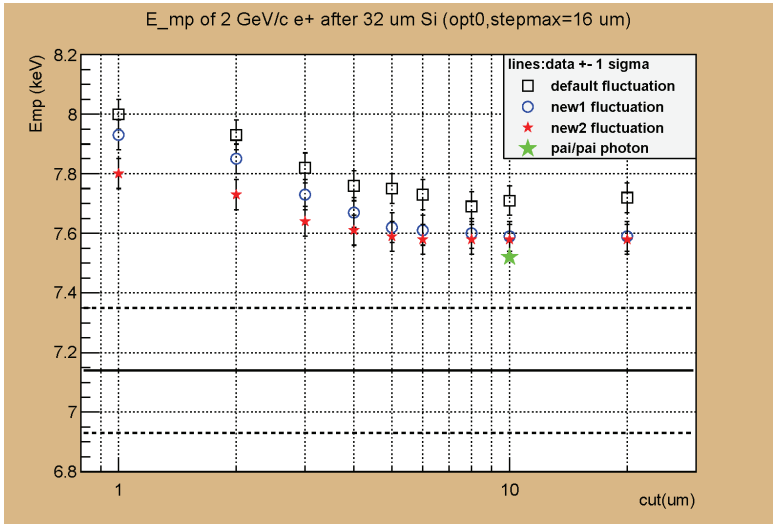
- Many use cases when tiny steps of charged particles are used
  - CMS upgrade EE and FH calorimeters will use thin Silicon detectors
  - Calice examine various variants of high granular calorimeters
  - Some users tries out SS models in order to have accurate tracking
  - GS model with error free stepping
- Simulation results should be stable versus cut or step limit change
  - These plots demonstrate problems of Urban model
- L.Urban was working in 2017 to improve his model of fluctuations
  - We tried several variants of improved parameterizations on top of 10.3
  - These days a new version of tuning committed after ref-08 is under testing
  - Today a new tag with a “final” variant for 10.4 is proposed

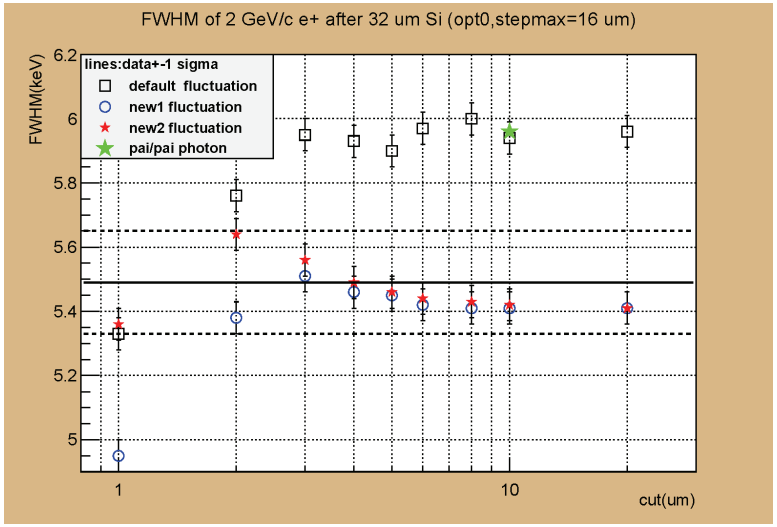


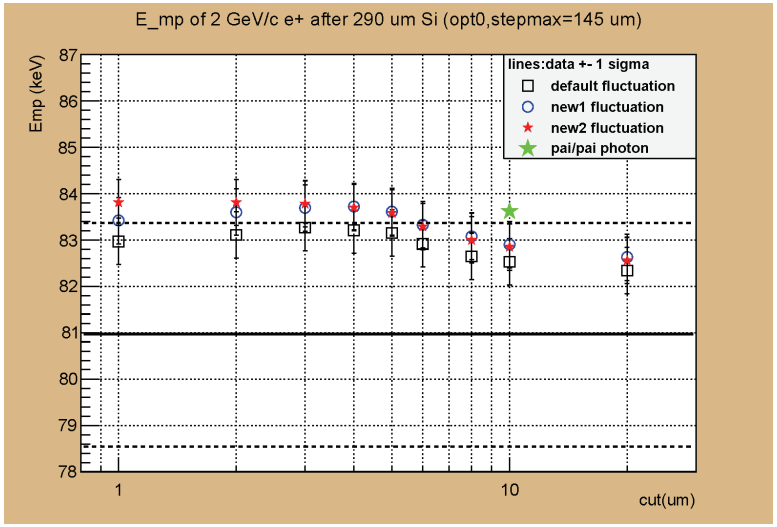


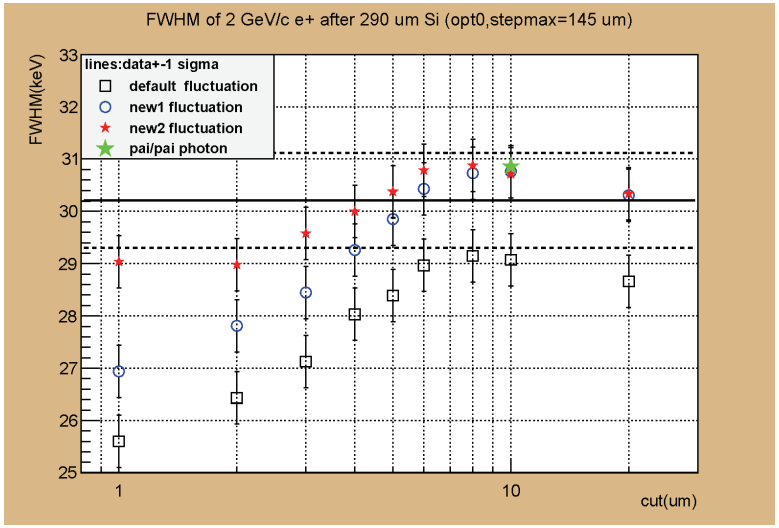
L. Urban plots for cut/step dependence of the 10.3 model

Recent tuning by L.Urban



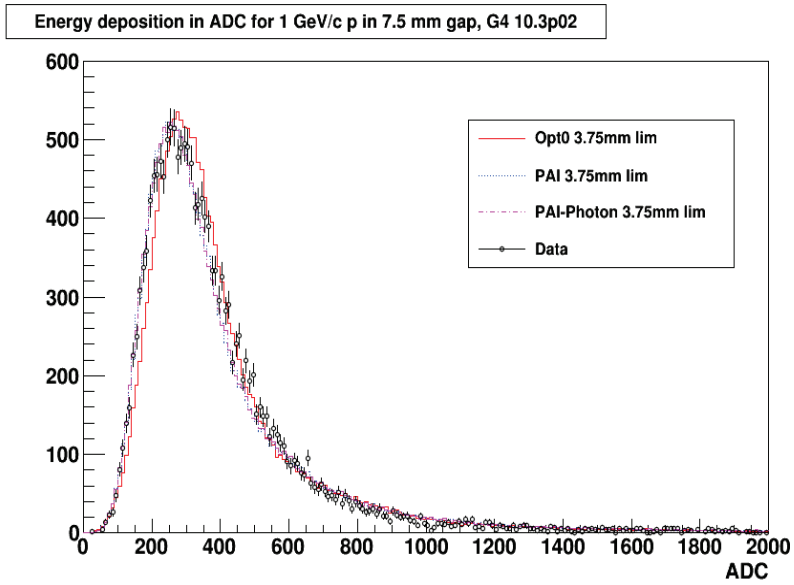




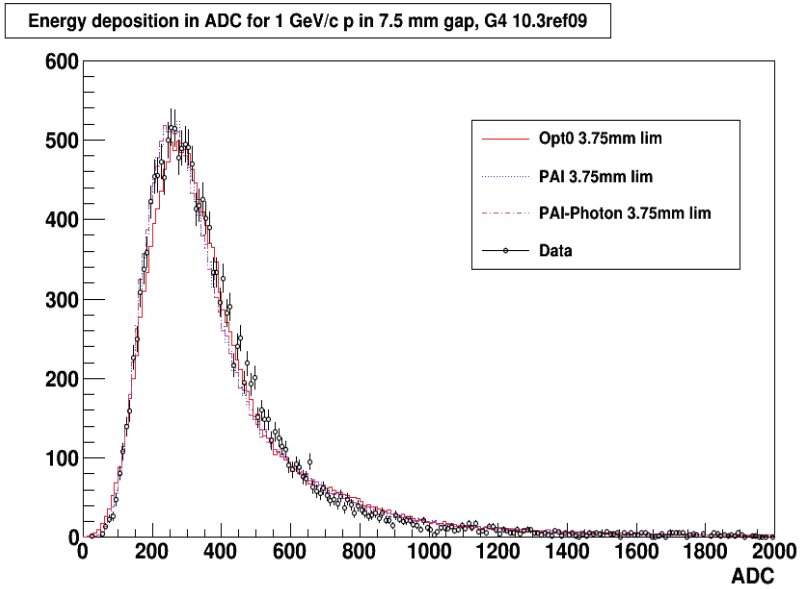


ALICE TPC benchmark

10.3p02



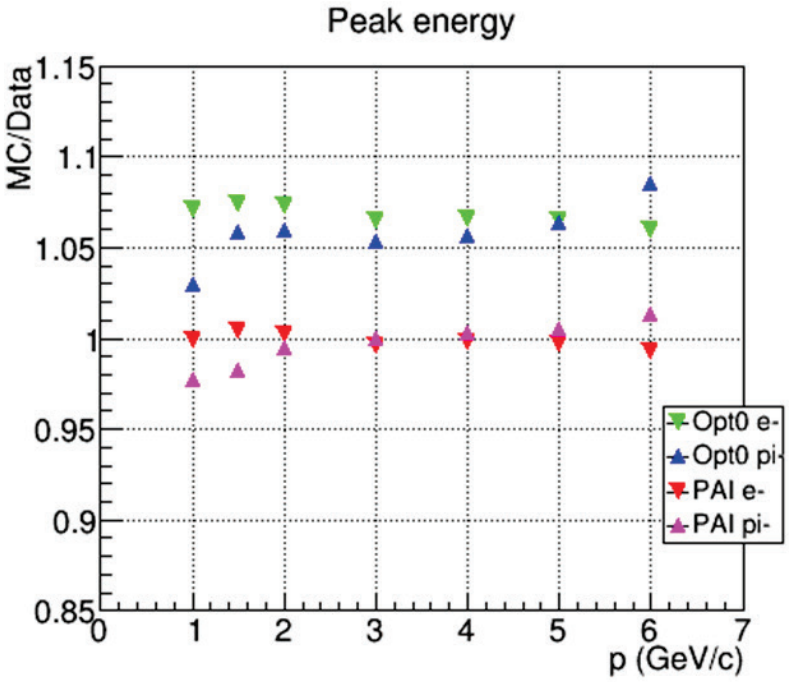
10.3ref08+

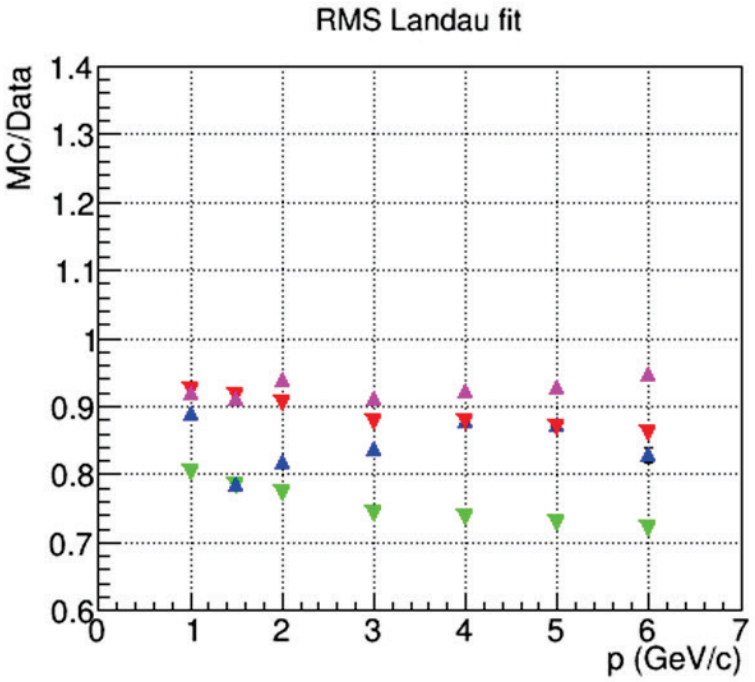


- Light TPC gas Ne + CO_2
- The updated model reproduce results well

ALICE TRD benchmark for 10.3ref08+

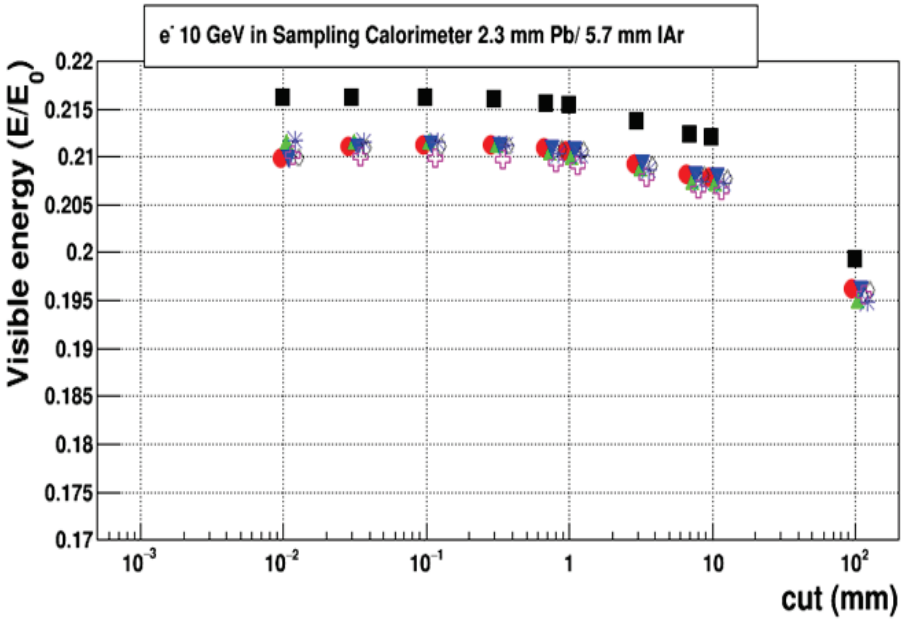
- "Heavy" gaseous mixture based on Xe
- Normalization of PAI model peak at one point
  - PAI peak fit the data within 2%
  - Urban model overestimates the peak for 6%
  - No momentum dependence
- There is an extra factor for width not predicted by simulation
  - Detector response may provide extra smearing factor
  - PAI model underestimate the width for 10%
  - Urban model is less stable and is below in general
- Results with updated Urban model are compatible with 10.3

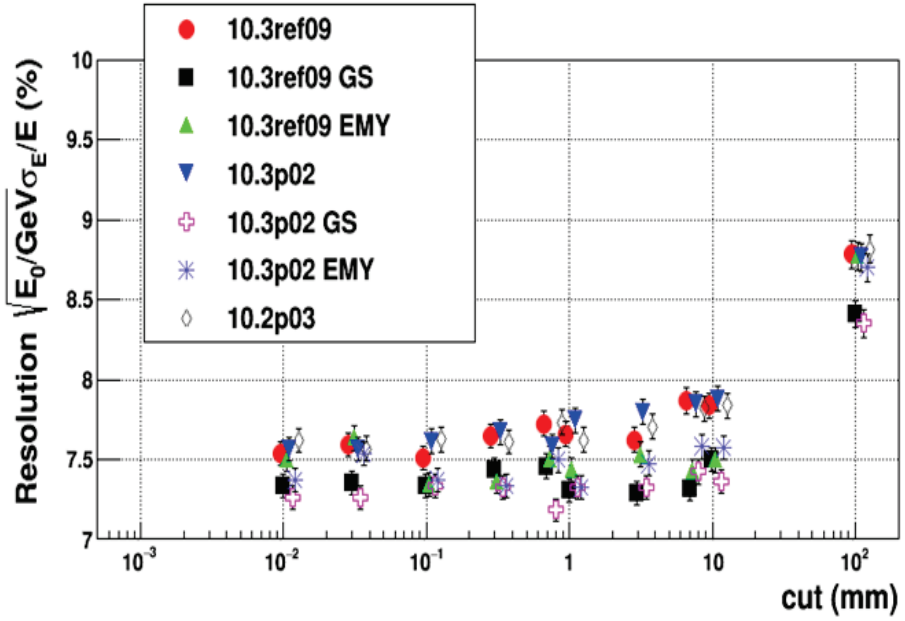




Simplified ATLAS barrel calorimeter

- Results with 10.3ref08+ of the Urban fluctuation model
  - Today “last” tuning is committed
- Visible energy is stable for Urban msc model
- For new GS visible energy overestimated
- Resolution for EMY and GS is slightly improved
  - Is more close to Opt0 results which are acceptable for LHC detectors





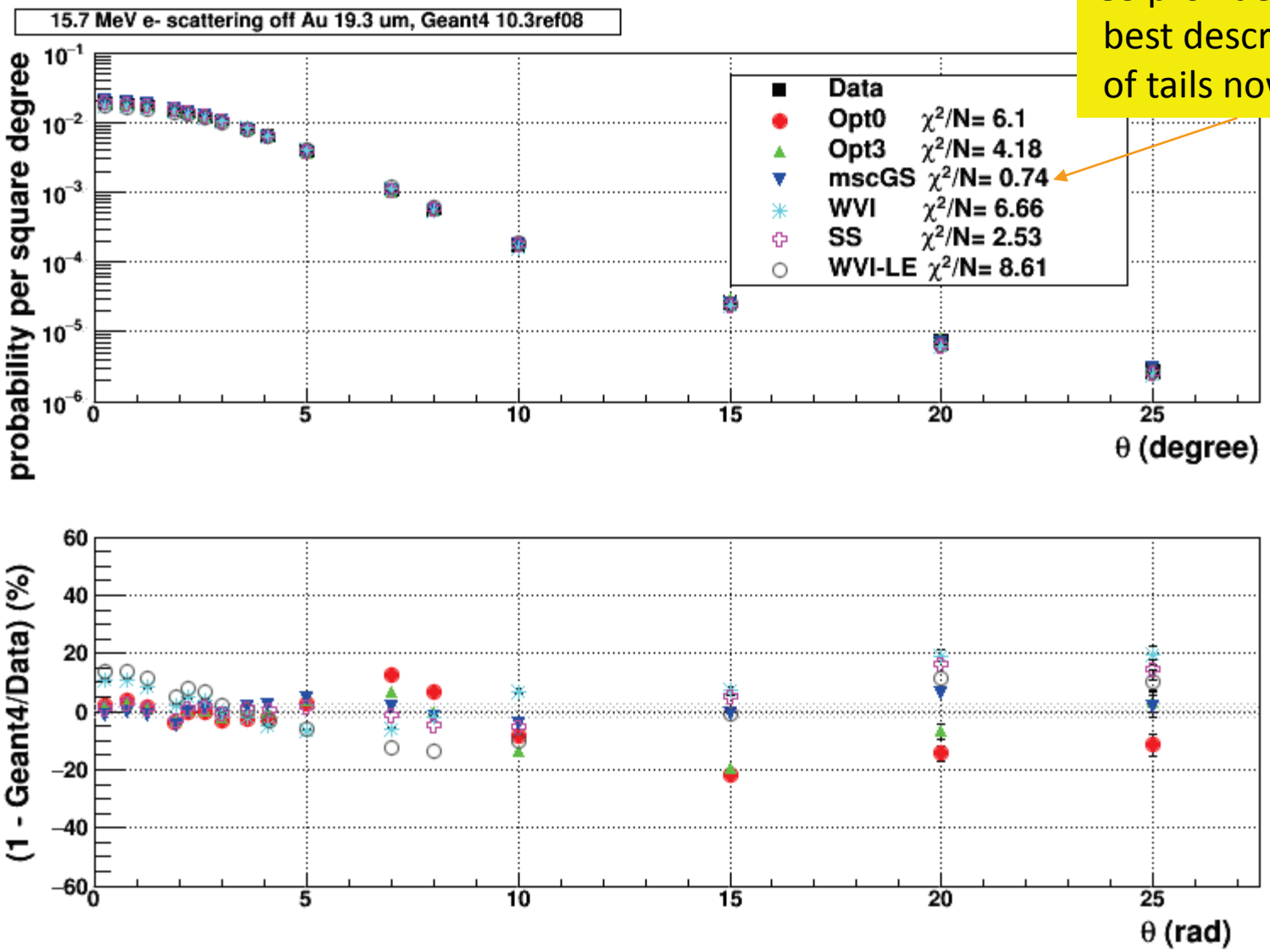
MOTT CORRECTIONS TO E+- ELASTIC SCATTERING

Mott corrections to electron/positron scattering

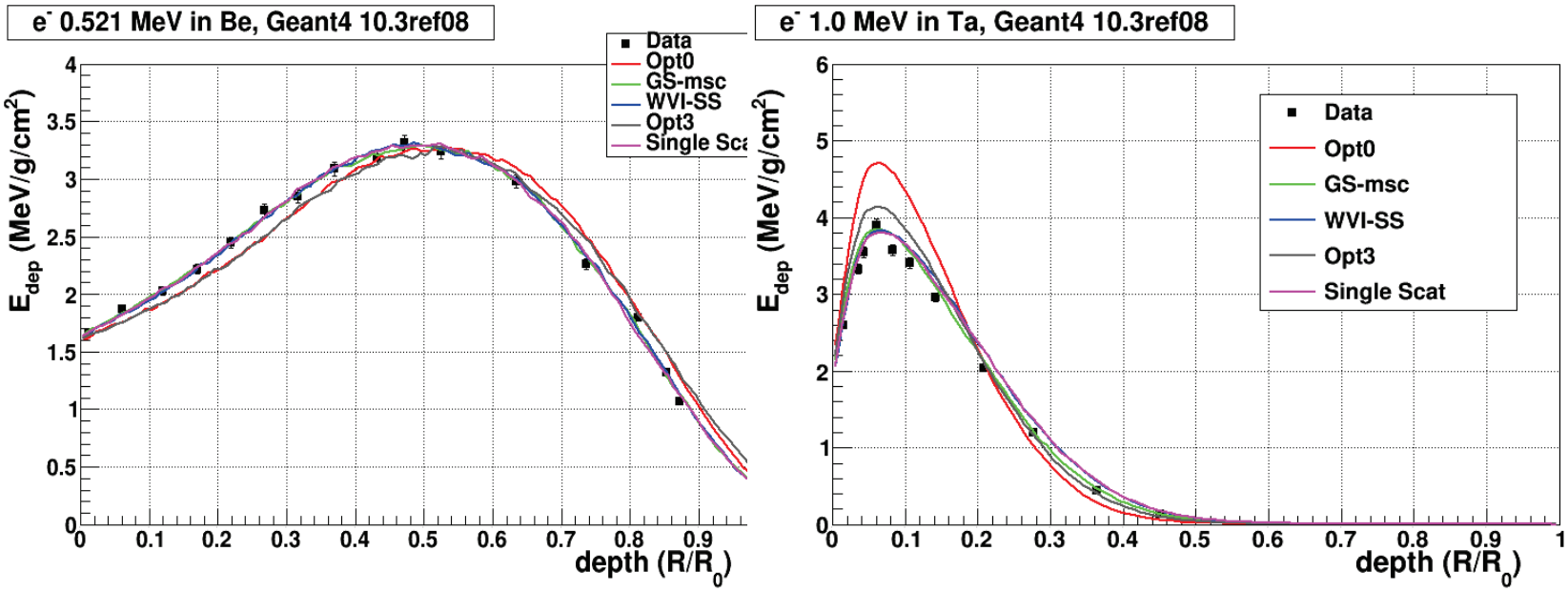
- Mauro Tacconi was working on single scattering model for several years in the framework of NIEL computations for space applications
  - The version of the model with Mott corrections was 100 times slower than standard single scattering in 10.3
  - For ref-08 he has added more sophisticated algorithm of sampling and now this model has compatible speed with the standard model
- Mihaly Novak has developed the new version of the GS model for ref-08 (see talk at the parallel session)
  - See details in the Mihaly talk at parallel session
  - Difficulty to introduce Mott correction into the multiple scattering are more serious than that for a single scattering model
  - He has resolved problems by addition of extra data
    - G4EMLOW7.1 is larger for ~20 M
    - Extra data for Mott corrections are in zip format
- In the next reference tag the updated GS model will be used in Opt4 EM physics

Hanson data for electron scattering off Gold target

GS provides the best description of tails now



Energy deposition in semi-infinite media (Sandia data)

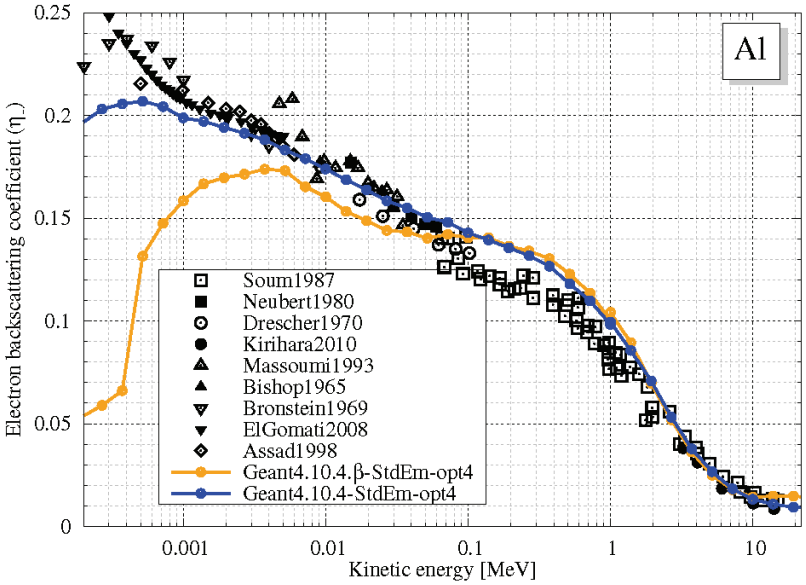


- GS model describe now data for both low-density and high density data as WVI and SS models
  - This test directly couples with the problem of accurate simulation of electron transport in sampling calorimeters

Backscattering test (M.Novak)

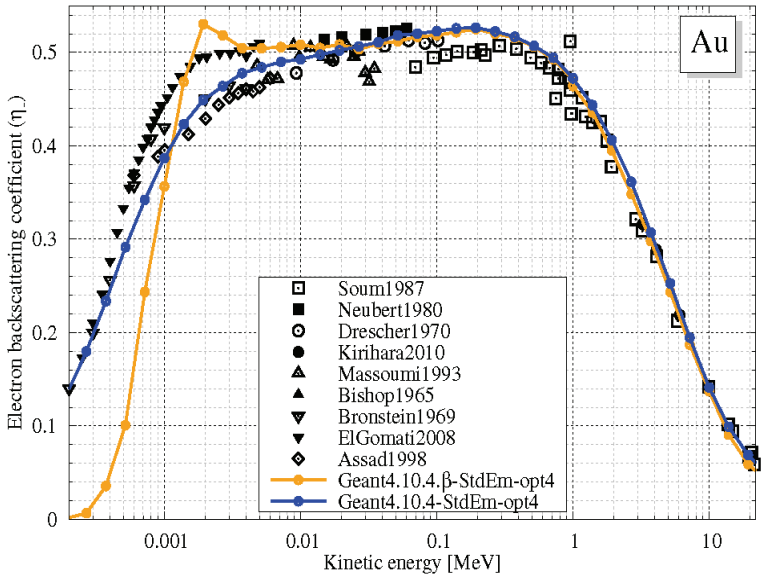
10.4beta – Urban model in Opt4

10.3ref09 – GS model in Opt4



10.4beta – Urban model in Opt4

10.3ref09 – GS model in Opt4



Backscattering description below 10 keV is improved significantly
This is essential for many applications including HEP (high granular calorimeters)

Few remarks

- For many years experts were saying that the golden standard for electron/positron MC simulation are EGS and Penelope
  - The work made by Mihaly and reported at the parallel session also demonstrate that EGS and Penelope high quality results are obtained in specific conditions with special options enabled
    - Very small steps and detailed algorithms of scattering
    - These regimes are far from the default and needs huge CPU
- Long ago we started Opt4 as a configuration which «the most accurate EM physics»
  - With the recent Mihaly result we can start to speak about Geant4 «golden standard» simulation
- Few words about history:
  - GS work has been introduced by Omrane Kadri for Geant4 9.3 and published in 2009
  - Mihaly completely revised the model for 10.2
  - Now Mihaly provides this new update for 10.4
  - GS needs to be tuned not only for «most accurate» simulation but also for HEP users
    - This should be a part of 2018 work plan
- One can see that Geant4 is mature enough and any real improvement of physics requires big efforts, accumulation of expertise and time
  - We need to have this in mind when plan our activity
  - We need explain this fact to management (finding agencies)
  - This is valid not only for EM but also for other physics

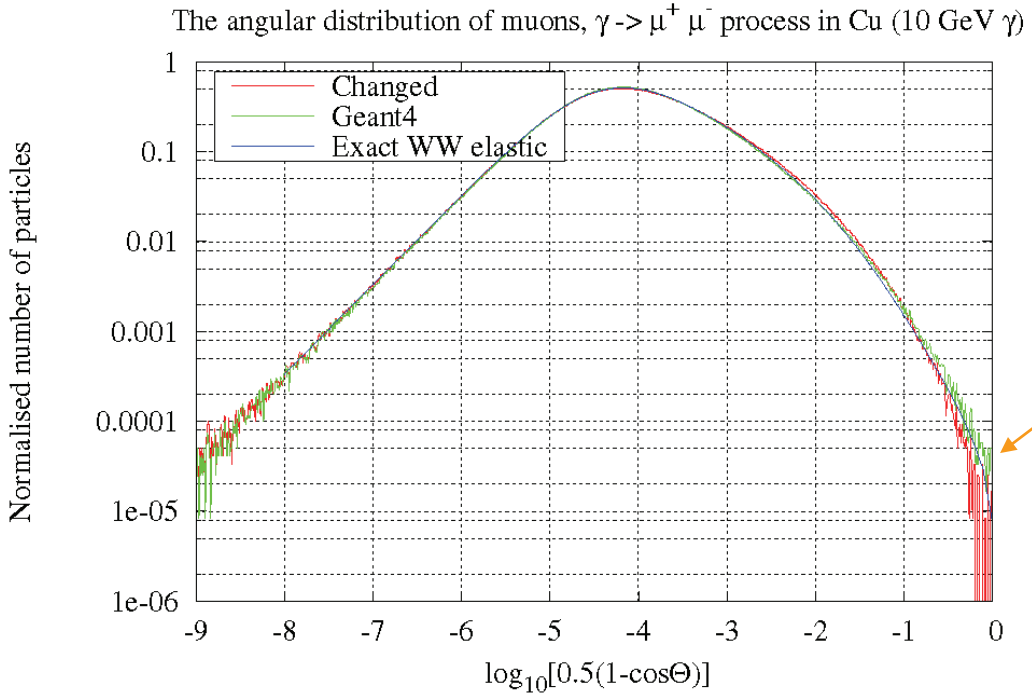
DEVELOPMENTS FOR DARK MATTER SEACH EXPERIMENTS

Requirements for EM physics by new dark matter search experiments

- After Higgs discovery there are intensive discussion on possible experiments for dark matter search
- Currently, several fix target experiments are under consideration or are already started
  - For example, new experiment at CERN SPS Ship
- These new fix target experiments are focused on search of light objects which have very weak interaction with normal particles
  - Geant4 is used for designing new facilities
- EM physics is an important component
  - Diagrams for production and interaction of light dark matter particles are similar to normal EM diagrams
  - EM processes are responsible for background in these searches

Validation of process γ→μ+μ-

CERN summer student project (A.Sokolov)



Large angle muons may be a background matter particles

important for Ship experiment design

- Total cross section were verified using numerical integration and accuracy was confirmed within 3%
- Improved expression for the elastic form-factor was introduced
  - There are no differences at high energies ~100 GeV
  - Some differences at ~10 GeV

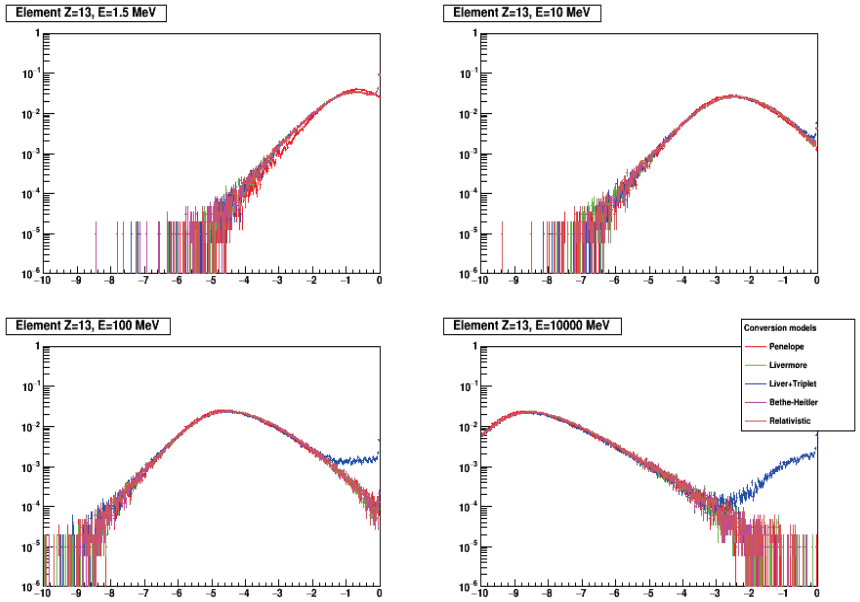
Triplet production interface

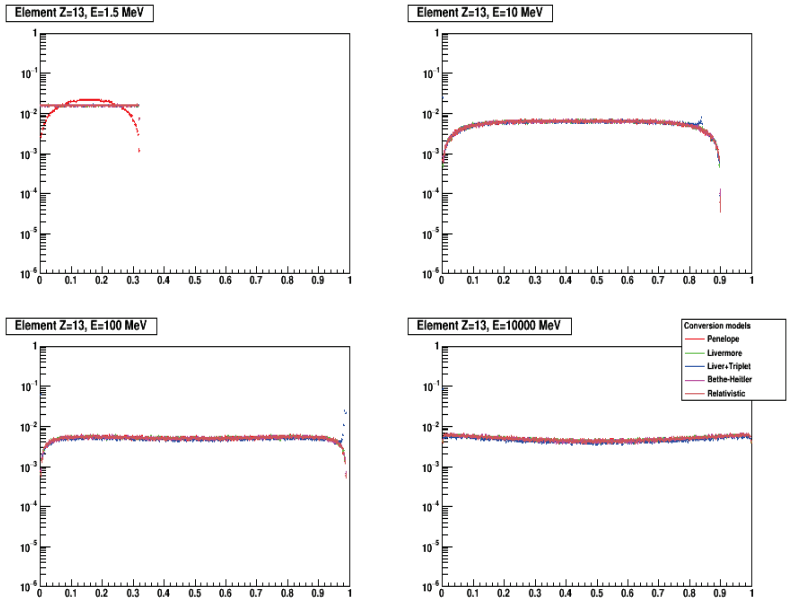
- Triplets production is a background:
  - Bremsstrahlung e- -> e-e- γ
  - Gamma conversion γ -> e+e-e-
  - Positron annihilation e+e- -> 3γ
- G4VEmModel::SetTripletModel(G4VEmModel*)
  - Can be called in Physics List
- G4VEmModel* G4VEmModel::GetTripletModel()
  - Can be used in run time
- G4BoldyshevTripletModel (G. Depaola) is the only existing model
  - It was used to validate general scheme

Test of G4BoldyshevTripletModel

Angular distribution of main e+,e-

Energy spectra of main e+-





Triplet interface is working fine but
The sampling algorithm should be checked and verified
We need verify and improve sub-models

Summary

- Planned developments for 10.4 is completed in general, main improvements:
  - GS model
  - Photo-effect model
  - Urban model of fluctuations
  - New triplet interface
  - Extended interface to define physics versus G4Region
  - Density effect parameterization extended
- Problems for 2018
  - Triplet production model
  - Polarization models
  - Fluctuation of energy loss for tiny steps