Highlights on version 10.4: EM physics

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Materials for EM and Optical physics

- New interfaces to the density effect parameterisations:
  - User may add custom density effect parameterisation per material
    - G4Material::GetIonisation()>SetDensityEffectParameters(
      G4double cd, G4double md, G4double ad, G4double x0, G4double x1, G4double x2);
  - User may scale density effect parameterisation from based material
    - G4Material::GetIonisation()->SetDensityEffectParameters(
      const G4Material* base_mat);

- Material property table:
  - Added new interfaces to G4MaterialPropertyTable (S.J.Yun et al.)
    - In run time use enumerator instead of string as a key to a property
    - Use new interface for optical boundary process
    - Keep old interfaces for backward compatibility
    - Make this table thread safe
  - Added M.Stockhoff DAVIS model for boundary processes (P.Gumplinger)

EM infrastructure updates

- Extended user interface to EM physics
  - Added extra UI commands and C++ interface to EM parameters and fixed some problems
    - Mainly added protections against usage of commands in a wrong application state
  - Added dump methods allowing print information on EM physics configuration or direct it to an output stream
    - Allowing online documentation for used EM processes and models
    - Improved dump of EM parameters
- Added an new interface to G4VEmModel allowing enabling triplet production
  - Useful for gamma conversion, bremsstrahlung, positron annihilation
  - Different model is used for sampling of final states when a primary particle interacts with atomic electrons
- Fixed mechanism of model enumeration for EM physics
  - User may identify production model for gamma and electrons
- EM web documentation are reviewed and updated (A.Howard, D.Sawkey)
- EM testing suite significantly updated (A.Bagulya, S.Elles)
- New example for dark matter particles simulation (V.Grichine)

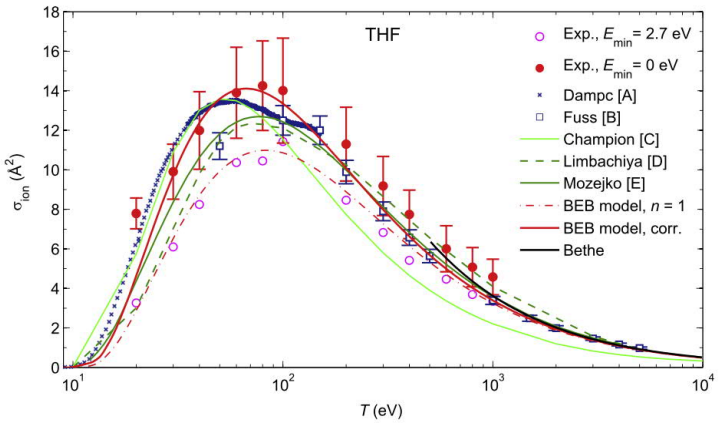
Standard models updates

- Models of fluctuation of energy loss updated
  - Urban model of fluctuations and the PAI model (L.Urban)
  - Fixed low-energy hadron transport
  - Nuclear stopping fixed
  - Low limit for cut in PAI model is set to 12.5 eV (D. Pfeiffer)
    - Needed for gaseous detector simulations
- Models of single and multiple scattering for e+-
  - Added Mott corrections to GS model and to single scattering (M.Novak)
    - Providing “error free” mechanism of tracking near geometry boundary
  - Updated relativistic scattering model
- Gamma models
  - Fixed inconsistency in LPM correction computation (F.Hariri, M.Novak)
  - Improved sampling of e- angles for photo-effect (M. Bandieramonte)

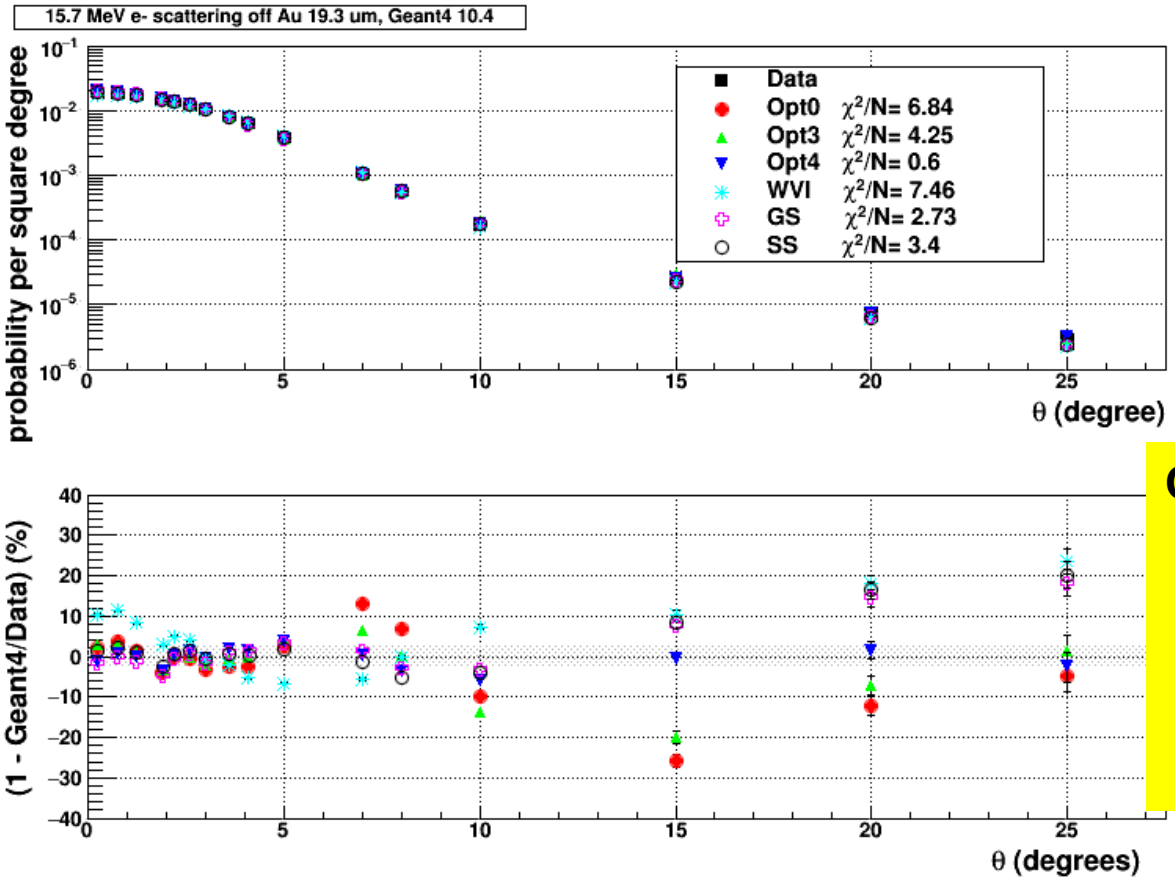
Low Energy EM Physics

- Livermore photo-electric model (M. Bandieramonte)
  - EPICS2014 data for shell cross sections
  - Improved parameterisations of cross sections
- Atomic de-excitation
  - updated set of shell ionisation cross sections for protons from calculations by M. Reis et al.
- Geant4-DNA
  - new cross sections
    - CPA100 for electrons in liquid water
    - Semi-empirical models for electrons in biomaterials
  - new G4DNAElectronSolvation process for the handling of sub-excitation electrons in all constructors
  - new examples: mfp (mean free path), microyz (micro-dosimetry), neuron (network of neuron cells), slowing (slowing down spectra), spower (stopping power), chem4 with ROOT interface (radiochemical yields)
  - tagging of Geant4-DNA de-excitation products
    - illustration in TestEm5
  - all Geant4-DNA constructors available in all extended Geant4-DNA examples

Eg. total electron ionisation cross sections in THF



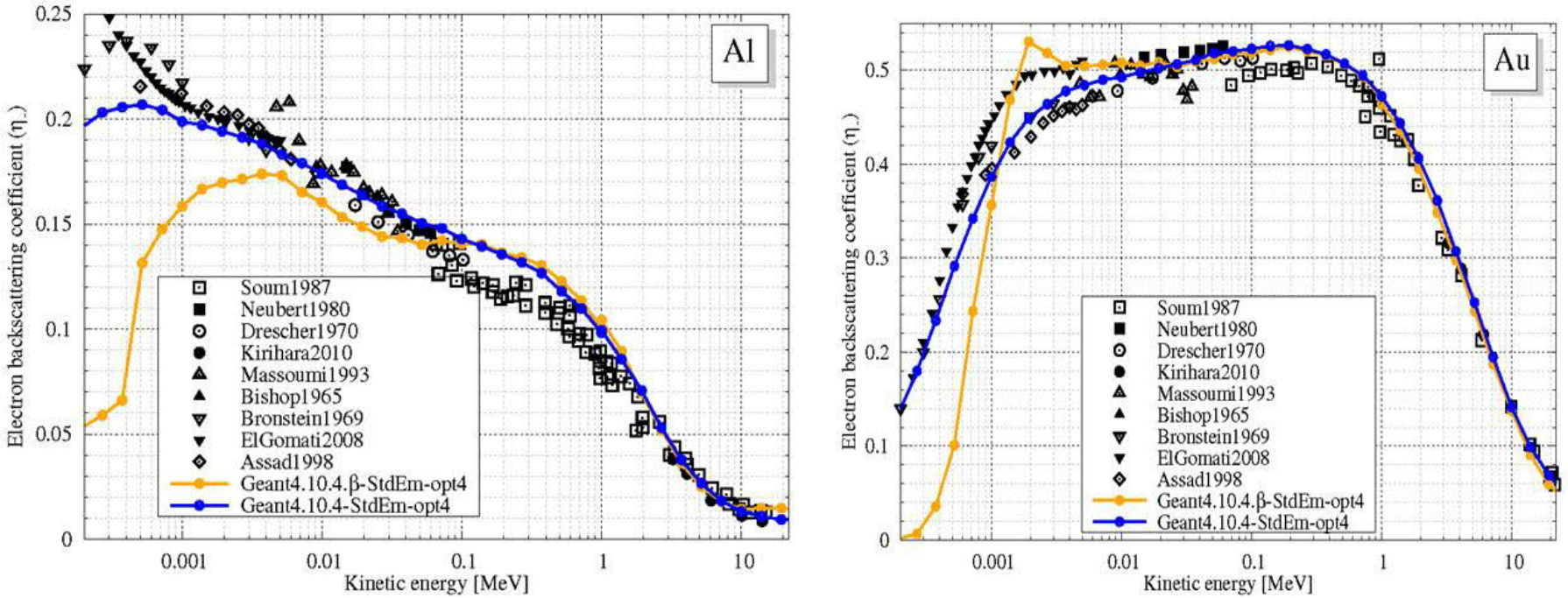
Hanson data for electron scattering off Gold target (Phys. Rev. 84, 634-637, 1951)



Opt4 Physics List uses the GS model with Mott corrections

Significant improvements for forward scattering

Backscattering validation results



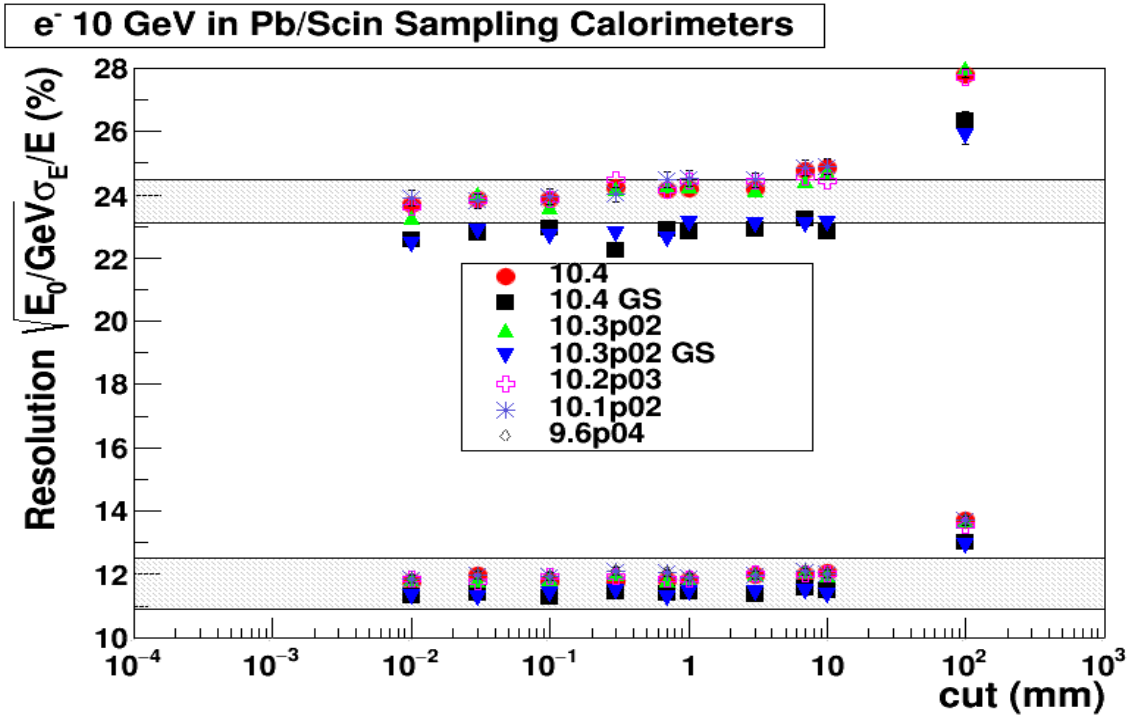
- Simulation of electron backscattering from Al (left) and Au (right) targets versus data from different experiments.
- Opt4 EM configuration is with the Urban model (yellow) and the GS model with "error-free" stepping (blue)

EM Physics Lists configurations

- Several EM physics constructors (Physics List components) are provided, main modifications are in
  - G4EmStandardPhysics – default
    - Includes Livermore photo-electric model and Rayleigh scattering
    - No performance degradation for HEP benchmarks due to code optimisations
  - G4EmStandardPhysics_option4 (EMZ) – a combination of the most accurate EM models
    - Includes the GS model with Mott corrections and error free stepping
  - G4EmStandardPhysicsGS – alternative multiple scattering
  - G4EmStandardPhysicsSS – single scattering
    - very CPU demanding
- Since Geant4 10.3 a new possibility to customize EM configuration per detector region is available, which was improved for Geant4 10.4
  - Alternative Physics Lists per region
    - /process/em/AddEmRegion myregion G4EmStandard_Opt4
  - PAI ionisation model per particle and region
    - /process/em/AddPAIRegion all myregion PAI
  - MicroDosimetry models per region below 100 MeV
    - /process/em/AddMicroElecRegion myregion
    - Single elastic and inelastic scattering in Silicon (very slow)
  - DNA models per region
    - /process/em/AddDNARegion myregion DNA_Opt0

Resolution of Pb/Sc calorimeters

Bernardi E. et al. 1987 Nucl. Instrum. Meth. A **262**, 229



- A classical benchmark (ZEUS test-beam) for two sampling calorimeters with different sampling fractions
  - The same simulation conditions for two setups
- Geant4 results are stable between previous releases and 10.4
  - The GS model of multiple scattering is slightly shifted compared with the default Urban model
  - We propose to use GS models in various configurations and feedback us results

Migration in user applications

- New data files are mandatory for Geant4 10.4 G4EMLOW7.3
  - The GS model data
  - The photo-electric data
  - The DNA model data
- Custom user PhysicsList
  - Revised method: SetEmModel(G4VEmModel*, G4int index)
    - Started from index=0
    - Default models does not instantiated if this method is called by user code