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## EM Physics: Geant4-11.1.p02 and status

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# Outline

- [EM physics modifications in Geant4-11.01-patch-02](#)
- Updates and new developments toward Geant4-11.2

# Modifications in EM 11.1.2 on top of 11.1.1 (1/2)

- **Electromagnetic/utils:**
  - **G4TransportationWithMsc:** Protect code for multiple scattering; fix type of particle change
  - **G4LossTableManager** - improved debug printout and removed unused lines of code
  - **G4VEnergyLossProcess** - fixed static analyzer warning
  - **G4EmTableUtil** - fixed verbose output and class comments
  - **G4EmExtraParameters** - fixed AddPAIModel(...) method and improved comments
  - **G4EmExtraParametersMessenger** - fixed broadcasting; Allow /process/em/QuantumEntanglement in G4State\_Idle
- **Electromagnetic/standard:**
  - **G4LindhardSorensenIonModel** - updated effective charge of an ion at each step of simulation or at each call to G4EmCalculator, added extra protection and improved debug printout
  - **G4WentzelOKandVlxSection** - fix numeric instability for the extreme case of very small kinetic energy (< 1 eV); fix #2530 – single scattering per G4Region; improved comments

# Modifications in EM 11.1.2 on top of 11.1.1 (2/2)

- Electromagnetic/: muons
  - **G4MuBremsstrahlung, G4MuPairProduction** - fix problem #2531 (spline flag was lost for mu-, pi-, K-, and pbar dEdx and range tables, the max observed problem was for mu- with momentum  $\sim 50$  MeV/c,  $\sim 5$  % biased range)
  - **G4MuBetheBlochModel** - enable option to use angular generator for sampling of delta-electron direction
  - **G4Mulonisation** - implement full schema of selection of the model of energy loss fluctuation
- Electromagnetic/highenergy:
  - **G4GammaConversionToMuons** - fixed FPE exception in compound, when selected element and address issue of cross section factor reported in #2543
    - sampling of muon pair with energy transfer from threshold  $2*m_e$  to  $4*m_e$  – low-energy limit of the model

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# 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
- 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

# Change in bremsstrahlung

- Problem reported by Stephan Hageboeck
  - Crash due to complicated inheritance and configuration settings
- 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`
- Only technical modifications no change expected

# 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 cleaner configuration of the code
  - G4BraggModel – for low energy protons and backup for ions
  - G4BraggIonModel – 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)

# New model developments

- Components of EM physics in crystals are implemented via fast simulation interface (A.Sytov)
  - Processes are released within \$G4INSTALL/parameterisations/channeling
- X-Ray surface reflection process (H.Burkhardt)
  - Needed for many applications in accelerator physics, space science, ...
- MicroElec model and data for (C. Inguibert et al.)
  - Elastic and inelastic scattering for extra materials
    - Previously the models were applicable to Silicon only
    - Now Aluminium oxide, Boron nitride, and Silicon dioxide are added

# Other developments

- 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 this allows to keep track on correlations after 1<sup>st</sup> Compton scattering
- Fixed rare infinite loop in Penelope Compton (L. Pandola & D.Iuso)