Status of EM Physics

V. Ivanchenko for EM working group

CERN & Tomsk State University

22 September 2021

Outline

- Main developments for EM
- Revisions of sub-librares
- Physics model revisions
- Some validation plots
- Physics model catalog
- Summary and plans

Main developments for EM in 2021

- Coming new major release 11.0 allows performing review and update of EM sub-libraries
  - interface change is possible
  - obsolete classes may be removed
  - physics results are preserved
  - involved (V. Ivanchenko, L. Pandola, D. Sawkey)
- Parallel R&D development of G4EmHep library and prototype of the G4EmHep/Geant4 plugin
  - see talk of M. Novak
  - involved (M. Novak, J. Hahnfeld)
- Performance improvements
  - involved (G. Amadio, J. Hahnfeld, V. Ivanchenko)
- Model developments – mainly optical and low-energy in 2021

Revision on sub-librares

- General review of EM libraries and examples
  - improvements are included in 11.0beta
  - ~70 merge requests
- Removal of obsolete classes and interfaces
  - the most important is removal of G4EmProcessOptions
- Use C++11 keyword uniformly over EM sub-libraries
  - “virtual” keyword in base classes methods
  - “override” or “final” in derived class methods
  - where possible use advance loop pattern
  - moved initialisation of pointers, Boolean, and simple numbers to headers
  - use “const” variables where possible
  - removed unused variables and headers
  - check interfaces – improve where needed and possible
- Trying common formatting of all classes
  - not completed
  - needs first protection of data from re-formatting
  - personally like the procedure and the format of CMS

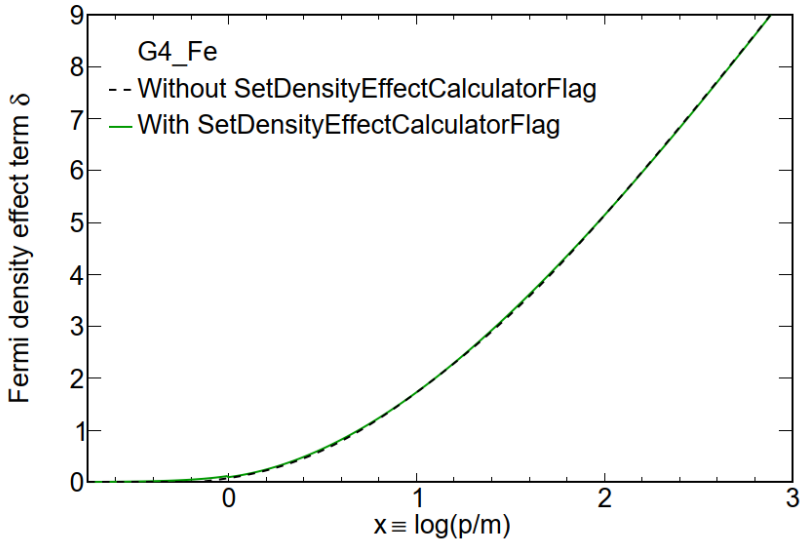
G4PhysicsVector

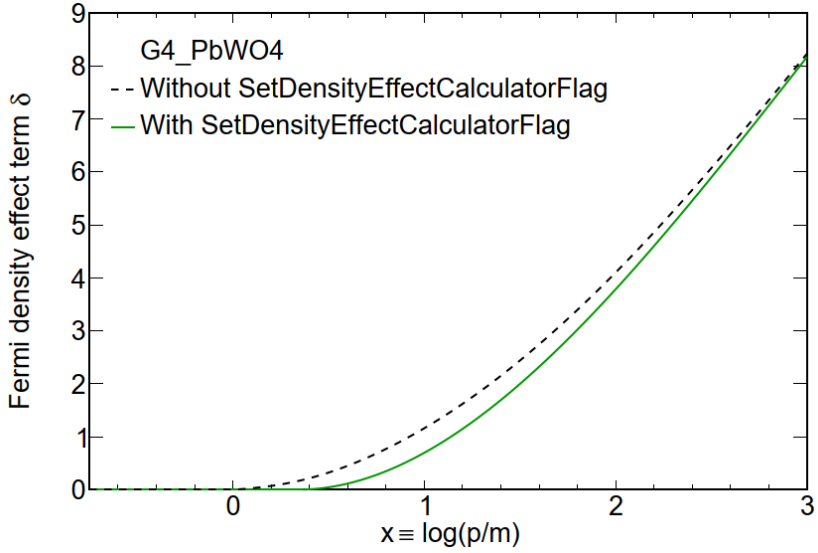
- Only 3 type of vectors remain
  - G4PhysicsLogVector
  - G4PhysicsLinearVector
  - G4PhysicsFreeVector
  - In any constructor a Boolean flag of spline may be added
  - Revised checks on physics vector input
  - Spline flag is not anymore part of G4EmParameters
    - Should be defined by the consumer code, which creates a vector
- Tree types of spline
  - G4SplineType::Simple
  - G4SplineType::Base // default
  - G4SplineType::FixedEdges
  - G4PhysicsVector::FillSecondDerivatives(const SplineType) // when the vector is filled
  - Added check if energy vector can be used for spline
- Optimized run time methods
  - G4PhysicsVector::Value(const G4double e, size_t& idx) // cache index
  - G4PhysicsVector::Value(const G4double e) // compute index from scratch
  - G4PhysicsVector::LogVectorValue(const G4double e, const G4double loge)

Selected physics models revision

G4DensityEffectCalculator

- Matthew Strait proposed improvement of the algorithm
  - He is an original author of the on-fly computation of the density effect in 10.7
  - Version of 10.7 was done at last minute
  - He proposed this update via GitHub and Bugzilla





G4VEnergyLossProcess

- Ionisation processes and models was reviewed and updated
  - Spline and integral options belong now to each process and not centrally defined via G4EmParameters
  - G4CrossSectionType is introduced instead of Boolean flag
    - fEmNoIntegral
    - fEmIncreasing
    - fEmDecreasing
    - fEmOnePeak
    - fEmTwoPeacks
  - Subcut delta-electron production option is removed
    - G4VSubcutProcessor (user hook) interface is available
  - CorrectionAlongStep(..) method is optimized in all ion ionization models
- Number of bins in physics vectors are not anymore part of G4EmParameters but are computed via number of bins per decade

Other developments

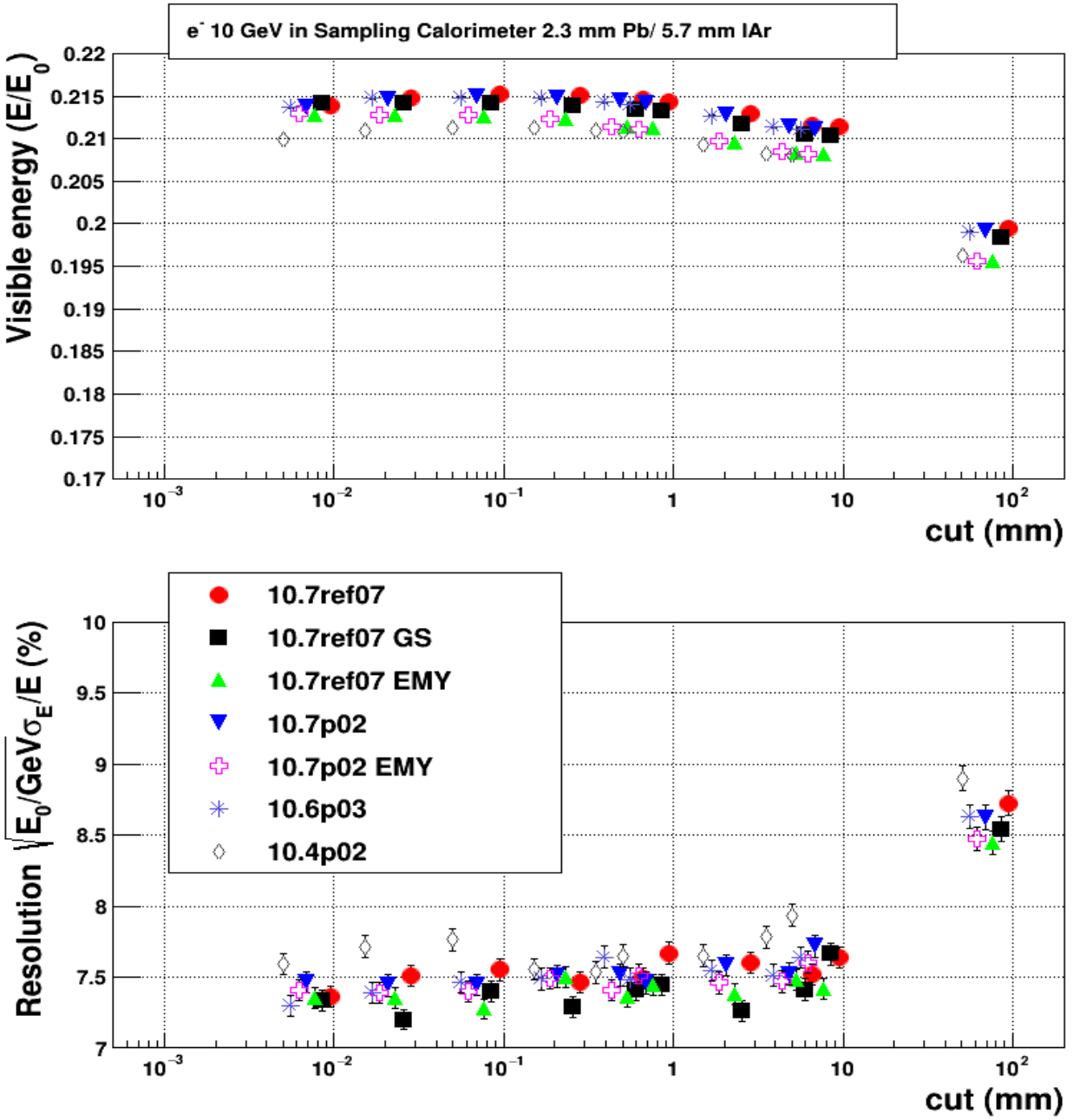
- G4EmHep R&D project
  - See talk of M. Novak
- Low-energy and DNA
  - See talk of L. Pandola
- Optical photon physics
  - See talk of D. Sawkey
- Quantum entanglement may be enabled for positron tomography
  - J. Allison
- Linear polarization may be enabled on top of EM physics constructors
  - Opt0, Opt3, Opt4, Livermore, Penelope, LE

Validation plots for 10.7ref07

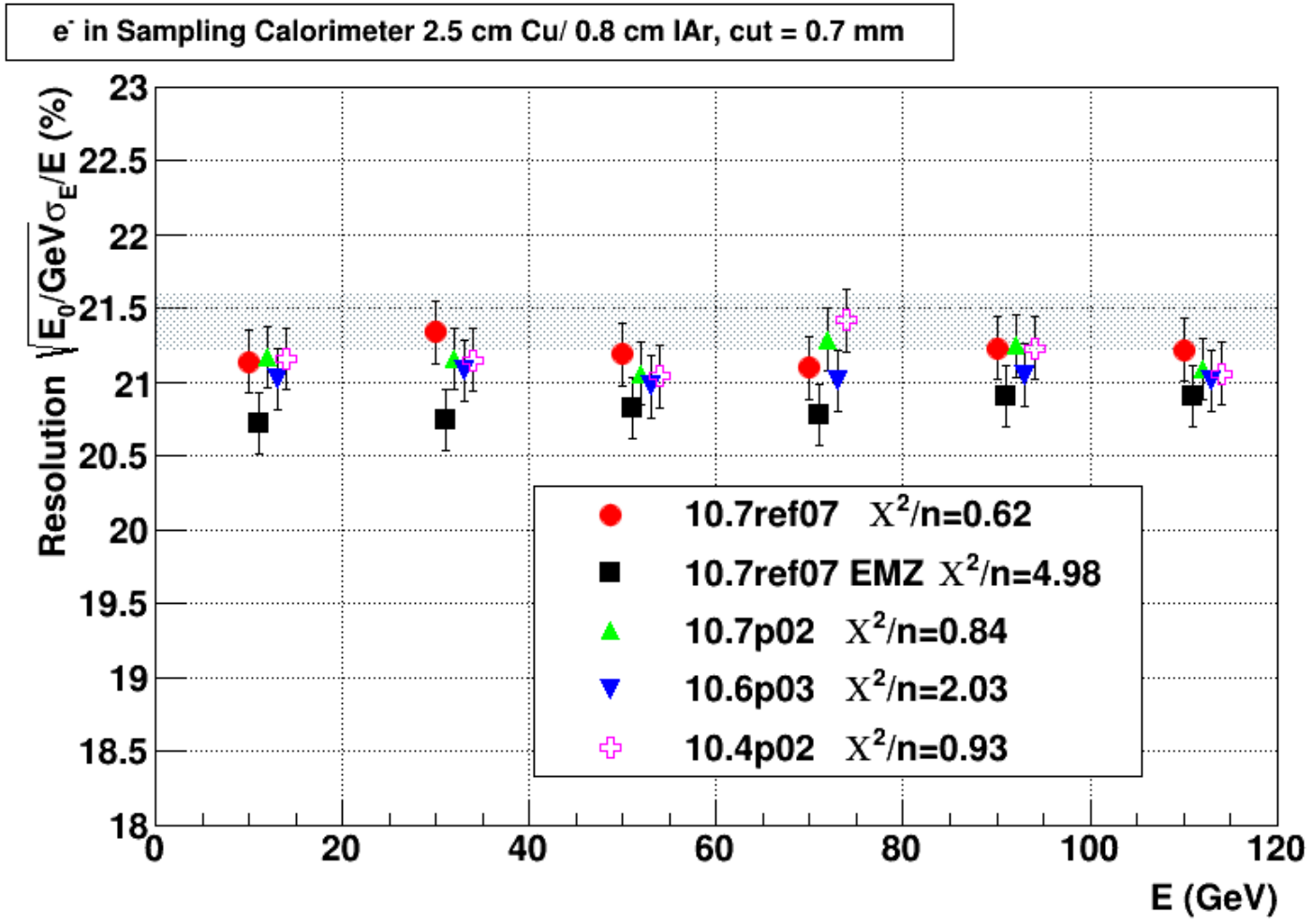
Test Results for 10.7ref07

- Testing results are available:
  - https://test-geant4-tools.web.cern.ch/test-geant4-tools/emtesting/
  - All results are in statistical agreement with Geant4 10.7p01 and 10.7p02

Simplified ATLAS Barrel



Simpified ATLAS HEC



Physics model catalog

Motivations

- Since 2008 we have process subtype (G4VProcess::GetSubType())
  - Simple enumerator G4EmProcessSubType.hh ID = 1-25
  - Optical processes G4OpProcessSubType.hh ID = 31-36
  - G4DNAModelSubType.hh ID = 0-5
  - Stable ID for each process
  - Separate enumerators for EM, DNA, and hadronics models without overlaps
  - Used independently for different applications
- There is a need to identify model type
  - In the same process different sub-models are responsible for secondaries
  - There is a working implementation of A. Makoto which is dynamic
    - in different applications IDs may be different
    - the same IDs may be in EM and hadronics
    - Was working in TestEm5 and other applications
- After 11.0beta A. Ribon introduced new system (see previous talk)
  - We propose to change numbering scheme according to EM needs
  - All new interfaces remain unchanged
  - For 11.0 we define only indexes which are needed today
  - Later we may add extra

EM model indexes proposal

- 10000 EMunknown // any EM model

- 10010 DeltaElectron // ionisation
- 10011 DeltaEBelowCut // sub-cutoff production
- 10012 TripletElectron //
- 10013 AugerElectron // from any process

- 10020 Bremmstrahlung
- 10021 SplittedBrem
- 10022 TripletGamma // from any process
- 10023 Fluorescence // from any process

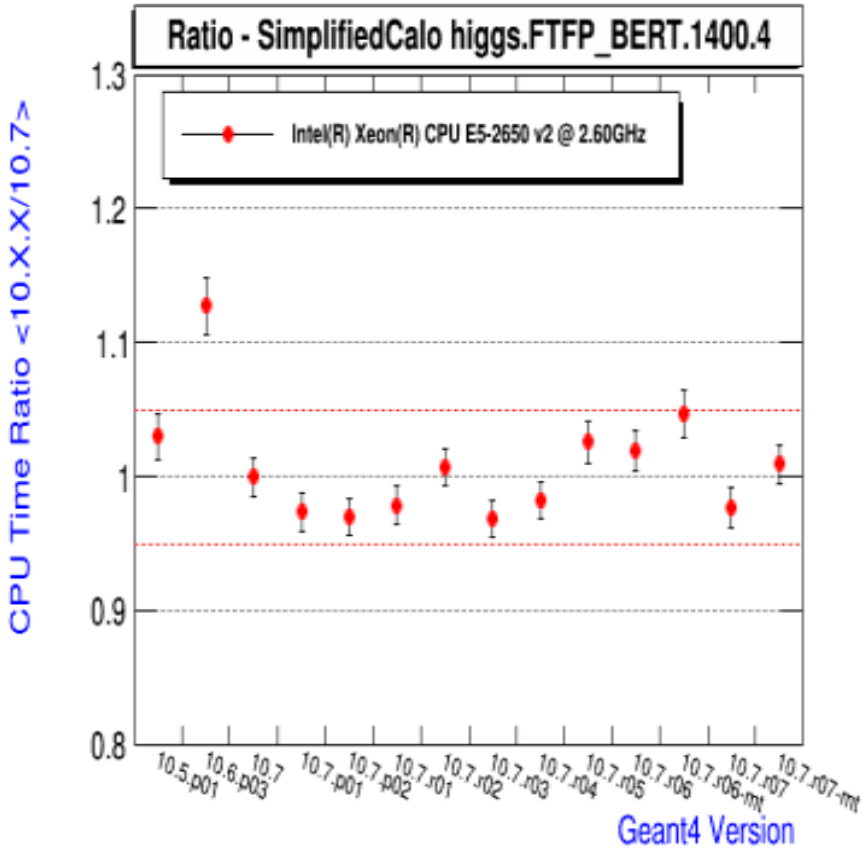
- 11000 DNAModel // any DNA model
- 11001 Ritchie1994eSolvation
- ..... 5 more DMA models

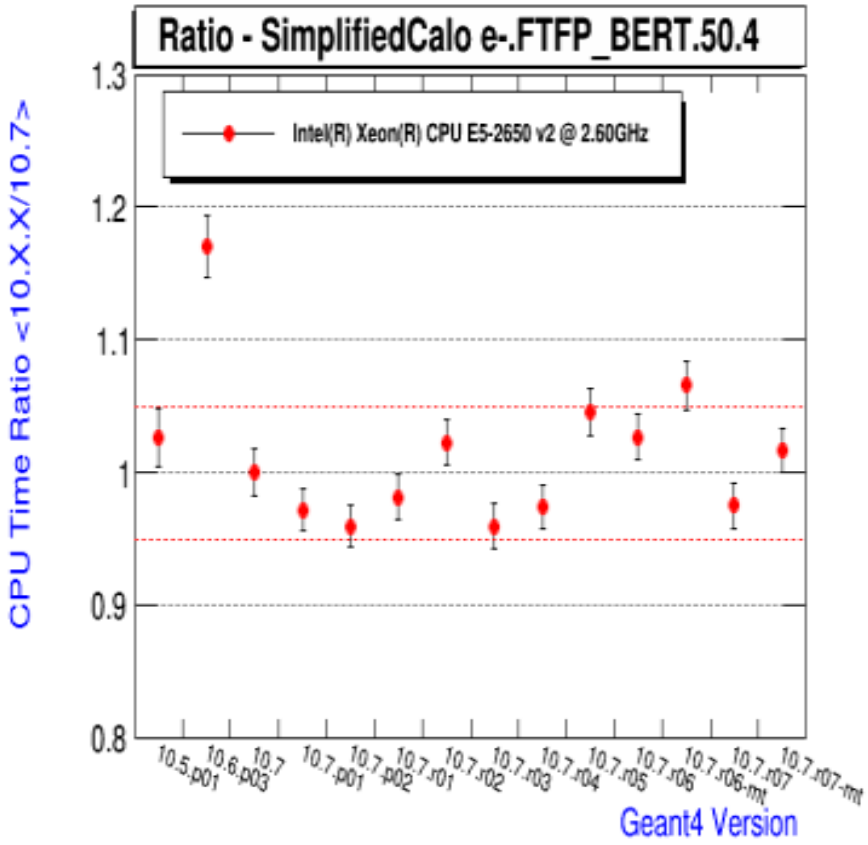
Summary and plans

Summary

- General clean-up of EM physics for 11.0 is done
  - Unified class view
  - Minor revision of method signatures
  - Unified handling of G4PhysicsVector
- Performance improvement is achieved
- Physics results are compatible with 10.7
- For the first time we have introduced
  - Quantum entanglement may be enabled for positron tomography
  - Linear polarization on top of EM physics constructors
- The R&D G4EmHep project looks promising
- New and/or revised low-energy models are added

Results from J. Yarba (FNAL)





Plans for 11.0

- Limited time left (~1 month)
  - We do not expect any big developments
  - We need consolidate what is already done
- G4PhysicsModelCatalog to be converged
  - Define indexes check that example are working
- Add EM interactions for few hypernuclei
  - Optionally in all HEP physics constructors
- There is a proposal of Michel Maire to improve printouts
  - Cannot even think for full implementation for 11.0
  - We may propose two simple improvements:
    - Printout of Parameters always before printout on process/model
    - Only one printout of parameters and processes/models in the case of many runs in one session
- Bugzilla bug reports and Coverity warnings to be addressed
- Recheck examples
- Because of many technical modifications bugs are not excluded
  - We invite all collaborators to run their applications and feedback problems

Beyond 11.0 – list is incomplete

- There are number of physics model developments which cannot be ready for 11.0
  - Should be inside plan for 2022
- New high energy processes
  - Muon pair production by muons (ATLAS request)
  - Other requests may come
- Continue adiabatic improvements of the code
  - Implement Guilherme recommendations (see Tuesday talk)
  - Other improvements which do not change physics
- G4EmHep may become a part of Geant4 ?
  - We need converge with plugin definition
  - The project may stay standalone but some sub-libraries to be included into the Geant4 tree
- We will consider also other R&D proposals
  - As part of Geant4 tree or as an external library

Thank you!