Updates on EM Physics

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Outline

- Short list of modifications
- Material category
- Updates on standard EM models
- Updates on EM infrastructure
- Summary

We will focus on standard EM developments

Short list of the most important modifications in standard EM

- Based material approach
- EM standard models
  - G4UrbanMscModel95
  - G4SeltzerBergerModel
- Infrastructure
  - Biasing options
  - Option2 (EMX) is oriented to LHCb requirements
  - Configuration of EM options in G4PhysListFactory
  - Initialisation of muon/hadron bremsstrahlung and pair production is improved

Summary of EM low-energy (S.Incerti)

- Development of Low Energy EM Physics is on-going with strong connection with the Standard EM WG
  - For the first time in Geant4 history, coherent approach of modelling of EM interactions in Geant4
  - Situation easier for users, easier for developers
  - Common validation effort

- Main achievements
  - Penelope 2008
  - Common atomic deexcitation interface
  - Extension of Geant4-DNA Physics

- Thank you for your attention
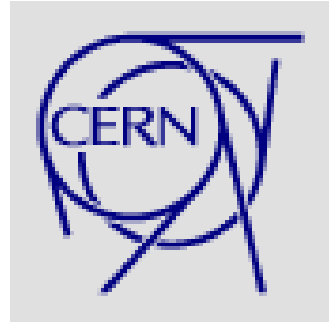
Material category

Base material approach

- Material may be constructed using existing ("based") material
  - Allowing reuse all corrections and data tables of Geant4 NIST materials for any user defined material
- The goal: reducing initialisation time and size of data tables
- Feasible applications
  - Needed for DNA where density of a voxel may be function of geometry definition
  - Medical applications (DICOM)
  - Definition of atmosphere
  - May be useful for HEP and any other complex simulation

Base material approach

▸ New constructor of G4Material:

  G4Material(newName, density, baseMaterialPointer)

▸ Alternatively, new method in G4NistManager:
  BuildMaterialWithNewDensity(newName,baseName, density)

▸ Expect saving of initialisation time and executable size if several materials have the same base material

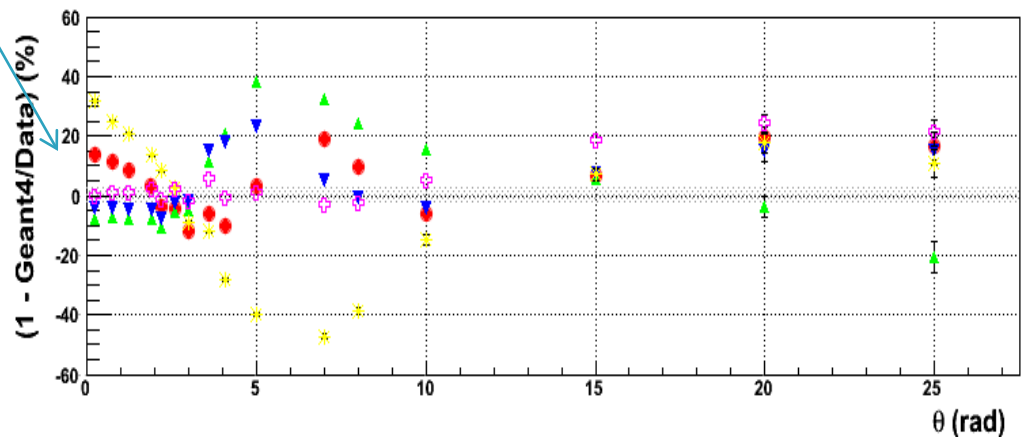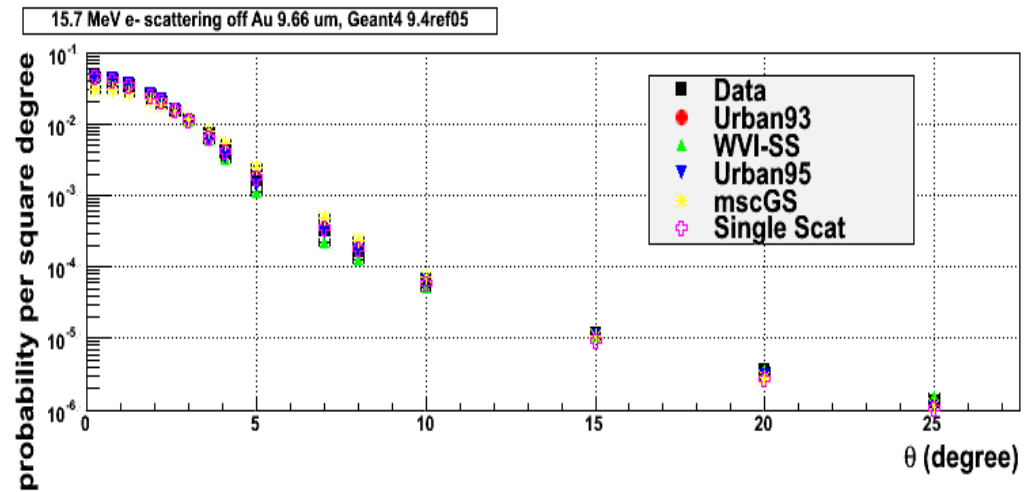# Updates on standard EM models

List of updated standard models

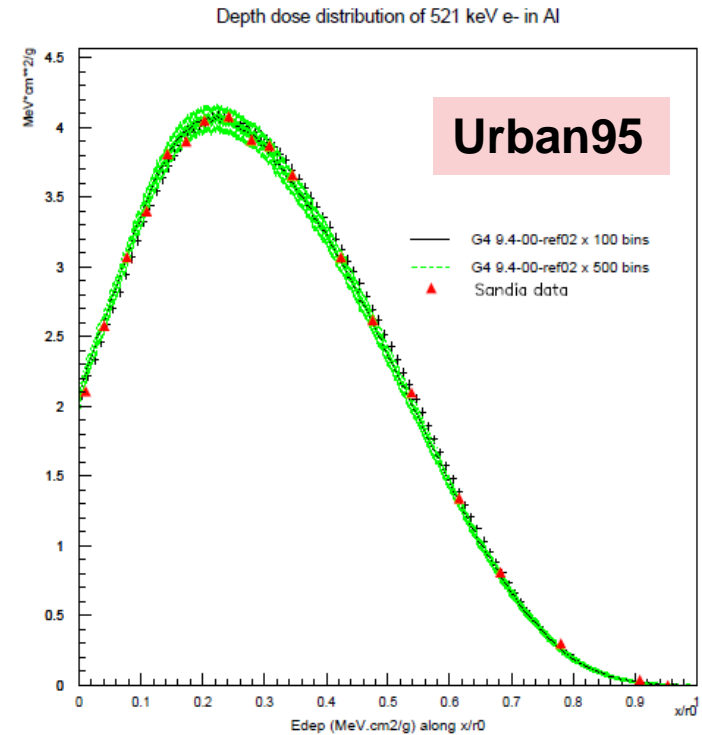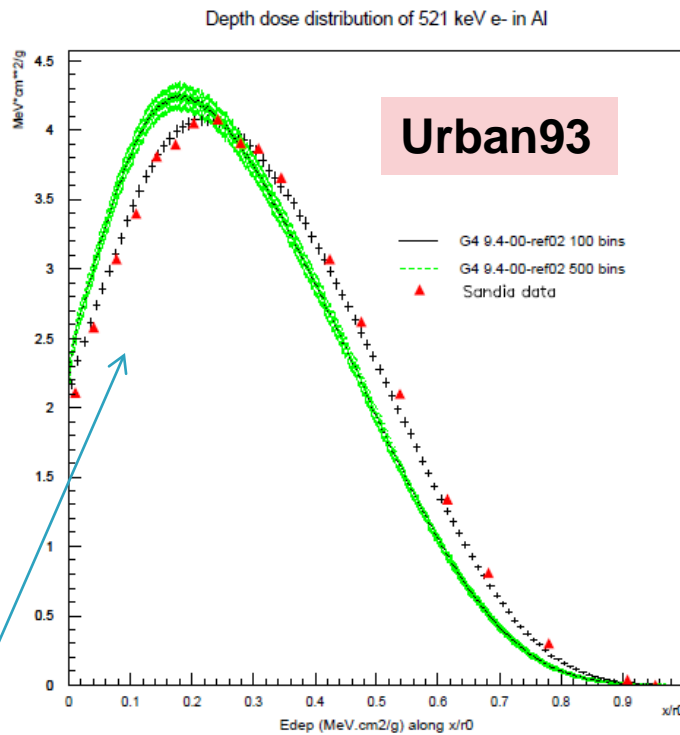|	Model	Status	Phys List
1	G4UrbanMscModel95	tuned	All except Opt2
2	G4SeltzerBergerModel	New bremsstrahlung	Standard and Livermore
3	G4PEEffectFluoModel	Added deexcitation	All standard
4	G4KleinNishinaModel	Added de-excitation and Doppler broading	Opt2, Opt3
5	G4MollerBhabhaModel	Reduced low-limit	All standard
6	G4XrayRayleighModel	Fast model	
7	G4PAIModel	Reduced low-limit	
8	G4eCoulombScatteringModel	Low-limit1 keV	All for muons
9	G4WentzelVIModel	Low-limit 1 keV	All for $\mu^{\pm}$, Opt2, Opt3 for hadrons
10	G4eSingleCoulombScatteringModel	New single scattering	

Upgrade of multiple scattering

- Old default G4UrbanMscModel93 will be kept for backward compatibility
- New G4UrbanMscModel95 becomes default since 9.4ref08 – it is an upgraded version of the Urban model
  - Improved lateral displacement sampling
  - Added sampling along Z-axis
  - Improved tail sampling
- Validation tests show similar or improved results with the new model
- Fixes are made also for alternative models
  - G4GoudsmithSaundersonMscModel
  - G4WentzelVIModel

Electron scattering test for the Hanson data (15.7 MeV e⁻ in Au)

- Single scattering model is the most precise
- Urban95 is better for central part and tail than other msc models
- Goudsmith–Saunderson model has lower precision than Urban

SANDIA data for 0.521 MeV electron transport in Al media with step limitation (L.Urban)

Depth dose distribution of 521 keV e- in Al

Urban93

- G4 9.4-00-ref02 100 bins
- G4 9.4-00-ref02 500 bins
- ▲ Sandia data

Edep (MeV.cm2/g) along x/r0

Depth dose distribution of 521 keV e- in Al

Urban95

- G4 9.4-00-ref02 x 100 bins
- G4 9.4-00-ref02 x 500 bins
- ▲ Sandia data

Edep (MeV.cm2/g) along x/r0

More strict step limit provides biased results

Urban95 is more stable than Urban93

New bremsstrahlung model: motivation

- ATLAS and CALICE reported that EM shower shape agree well in a core but overestimate tails (1-2%)
- CMS reported non-ideal agreement between LHC isolated EM shower and Geant4
- Different option on top of default EM physics were studied:
  - Multiple scattering
  - Step limitation
  - Cuts
  - Bremsstrahlung
  - Compton
  - Polarized processes
- Only extrapolation of relativistic bremsstrahlung down in energy make some effect

Physics validation - Bremstrahlung & Pair production

New relativistc bremsstrahlung model

CHEP`2010, A.Schaelicke

- ▶ Bethe-Heitler formula with corrections
- ▶ complete screening (valid $E > 1$ GeV)
- ▶ includes density and LPM effect
  and consitent combination
  a'la Ter-Mikaelian
- ▶ available since Geant4 version 9.2

New relativistc pair production model

- ▶ includes LPM effect
- ▶ important only for $E > 1 - 10$ TeV
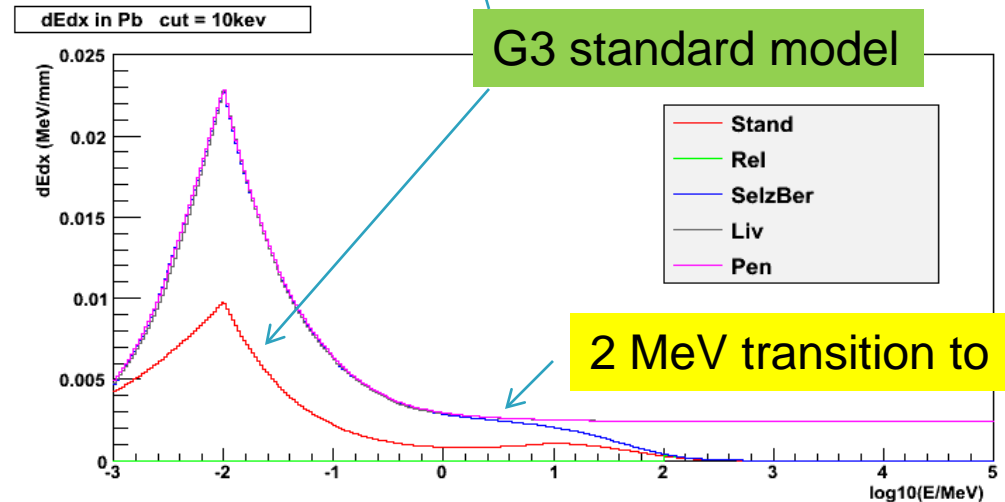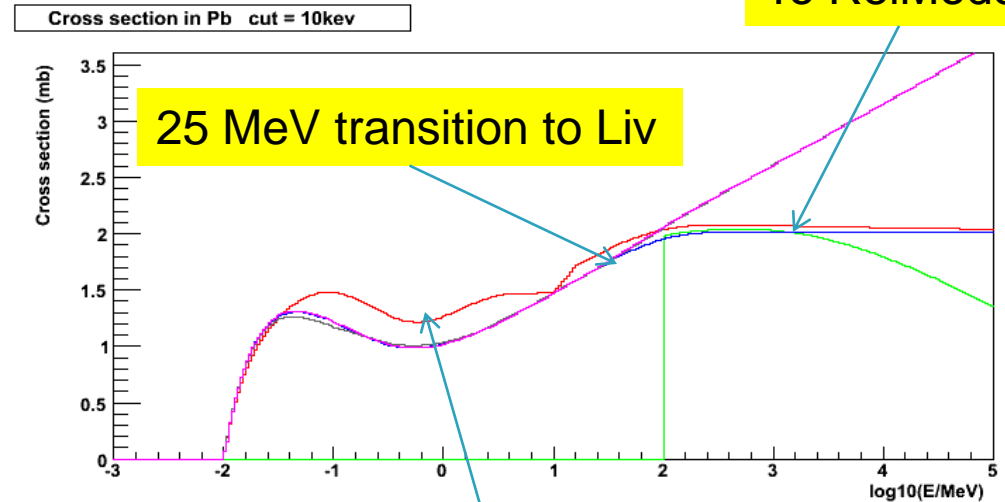- ▶ availble since Geant4 version 9.3
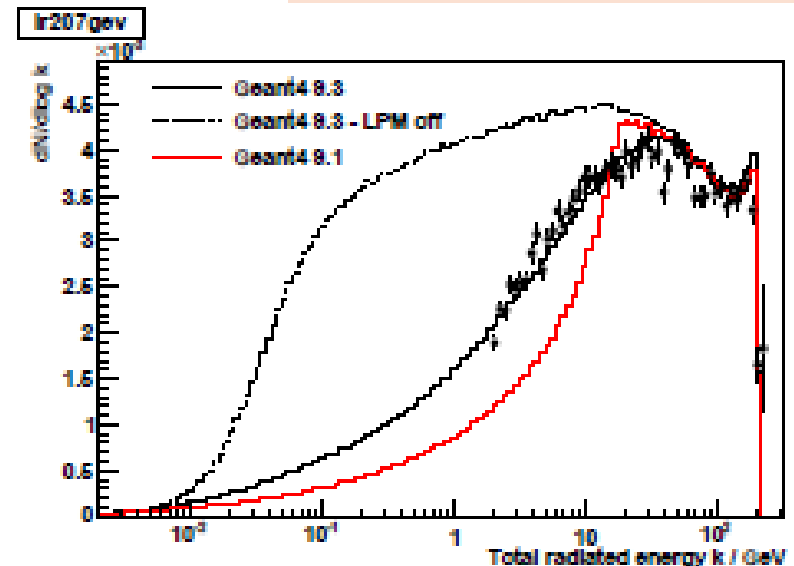
Data: H.D. Hansen et al., Phys.Rev.D 69, 032001 (2004)

New bremsstrahlung model
Fully based on theory

▶ **Seitler-Berger model:**

- Has a smooth transition to the relativistic model at 1 GeV

- Practically coincide with Livermore model below 25 MeV and with Penelope model below 3 MeV

▶ It requires data set G4EMLOW6.23

1 GeV Transition To RelModel

25 MeV transition to Liv

G3 standard model

2 MeV transition to Pen

ATLAS barrel

e⁻ 10 GeV in Sampling Calorimeter 2.3 mm Pb/ 5.7 mm lAr

- Visible energy and resolution are stable within 1 % since Geant4 8.3
- There is no change in the calorimeter response between 9.4 and 9.4p01

Legend:
- 9.5cand
- 9.4p02
- 9.4p02 EMV
- 9.4
- 9.3p01
- 9.2
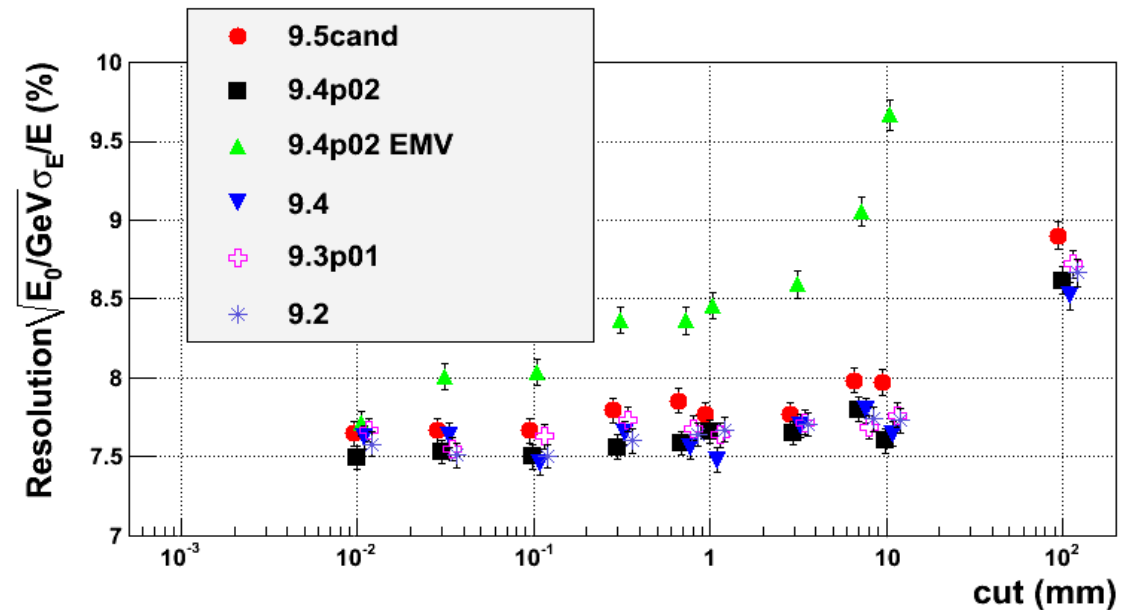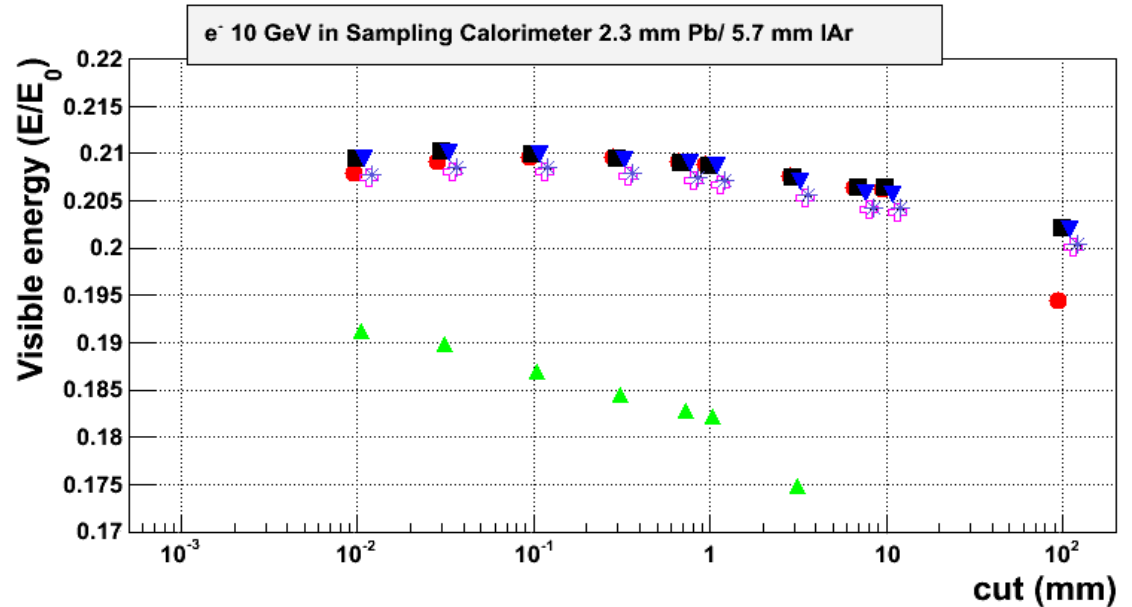
Updates on EM infrastructure

Physics based EM biasing options

- New options are added to EM infrastructure:
  - Cross section biasing
  - Forced interaction of primary
  - Secondary splitting
  - Russian roulette for secondary
- Simple UI commands activate/deactivate biasing options for any EM Physics Lists per process and G4Region
- Motivations:
  - Study of uncertainty effects
  - Speed up simulation

EM Physics List constructors for High Energy Physics

- May be used in any application domain
- From 9.5 G4LEDATA data set become mandatory

Constructor	Components	Comments
G4EmStandardPhysics	Default (QGSP_BERT, FTFP_BERT…)	ATLAS, and other HEP productions, other applications
G4EmStandardPhysics_option1	Fast due to simple step limitations, cuts used by photon processes (_EMV)	Similar to CMS production, good for crystals not good for sampling calorimeters
G4EmStandardPhysics_option2	Fast due to simple step limitations, cuts used by photon processes, msc93, WVI for hadrons (_EMX)	Trying to address LHCb requirements

Combined EM Physics List constructors

- For today focus more to precision than to maximum simulation speed
- Ion stopping model based on the ICRU'73 data
- Strongly recommended for hadron/ion therapy and space applications

Constructor	Components	Comments
G4EmStandardPhysics_option3	Strict step limitation (_EMY)	Any application
G4EmLivermorePhysics	Msc95, strict step limitation, Livermore models for γ below 1 GeV, for e⁻ bremsstrahlung below 25 MeV, ionisation – below 100 keV	Any application, de-excitation module active by default
G4EmPenelopePhysics	UrbanMsc95 model Penelope models for γ, e± below 1 GeV, Standard models above 1 GeV	Any application, de-excitation module active by default

G4PhysListFactory

- With 9.5 we will have the possibility to use all EM options – standard and low-energy with any reference Physics List
  - Simple if G4PhysListFactory is used
- Physics List name is analyzed and if at the end there are 4 characters corresponding to one of EM builders then this builder is used:
  - "_EMV" – standard Opt1
  - "_EMX" – standard Opt2
  - "_EMY" – standard Opt3
  - "_LIV" – Livermore
  - "_PEN" – Penelope
- By default the standard EM builder Opt0 is assumed

Summary

- EM physics (in particular standard) was significantly improved
  - Backward compatibility to 9.4 and 9.3 is provided – old models are frozen and kept
- The most significant model development for the standard EM package:
  - G4UrbanMscModel95
  - G4SeltzerBergerModel
- The most significant changes in user interface:
  - G4LEDATA set is mandatory for all Physics Lists
  - EM builders may be easily selected via Physics List name
  - EM biasing options may be activated via UI