



Status of Geant4 EM physics

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Outline

- ❖ **Summary on EM progress in 2024**
 - ❖ *Code and data evolution*
 - ❖ *New features*
- ❖ **Selected developments**
 - ❖ *EM data handling*
 - ❖ *3-gamma annihilation and positronium*
 - ❖ *EPICS-2017 data*
- ❖ **Pending work items for 11.3**
- ❖ **Vision for 2025**

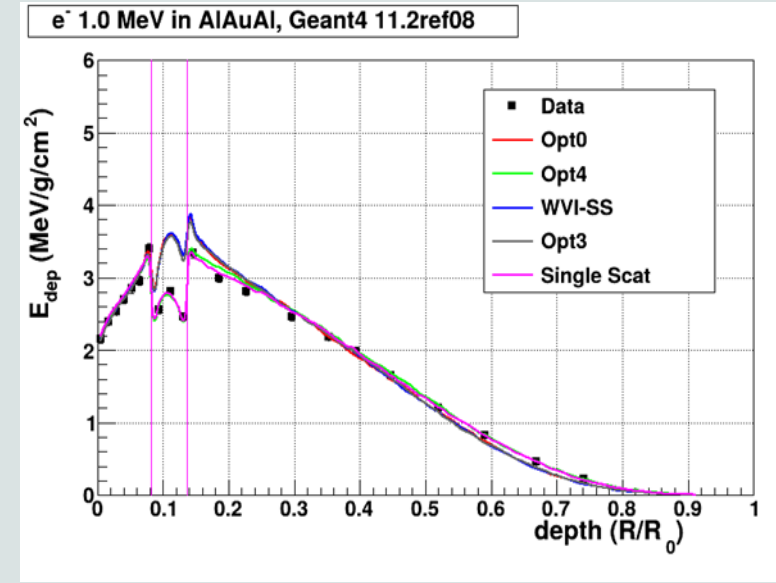
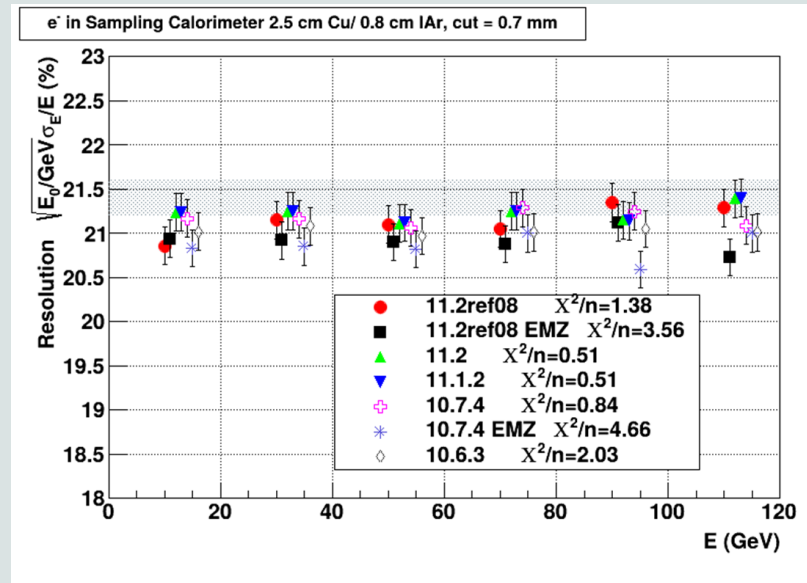
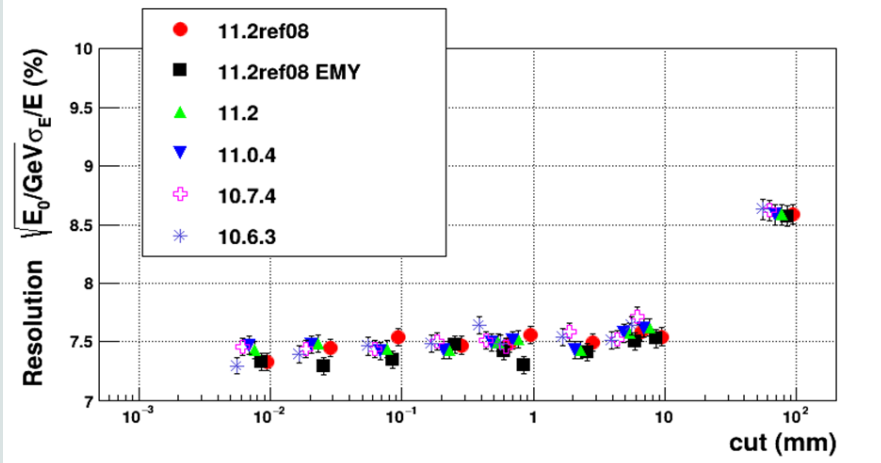
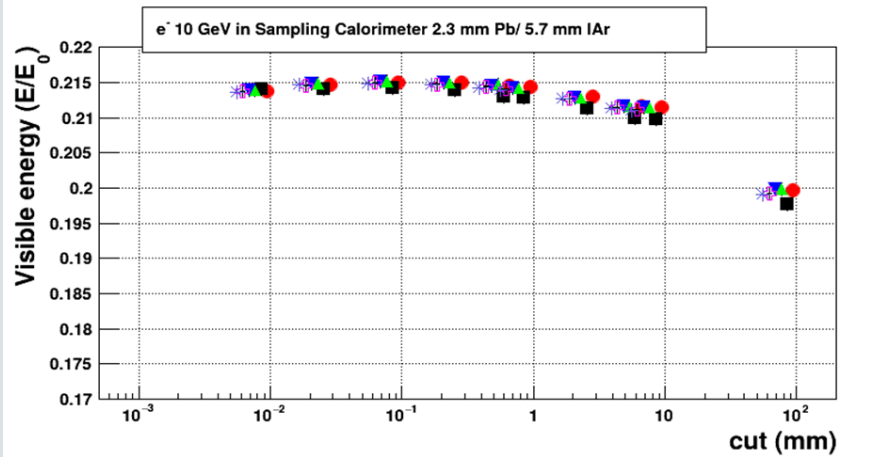


Some statistics

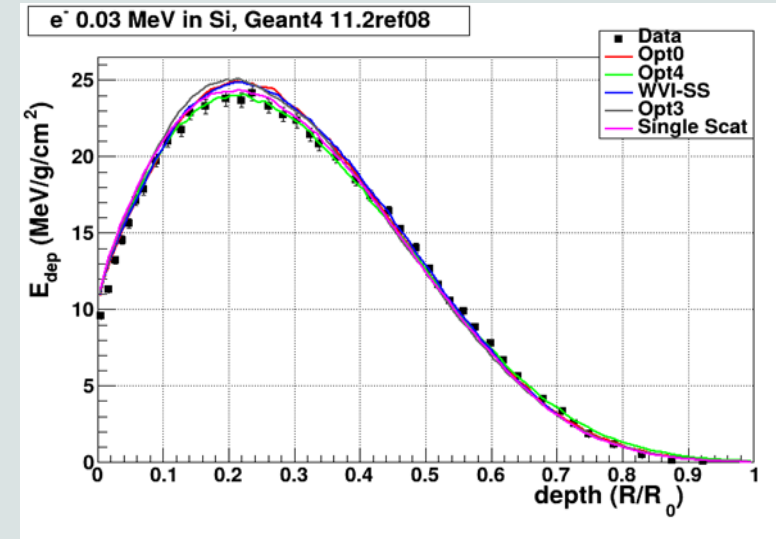
- ❖ **Number of merged MRs after December release 11.1: 104**
- ❖ **Number of merged MRs after December release 11.1: 84 (Oct 5)**
 - ❖ *Materials - 6*
 - ❖ *Electromagnetic/utils - 16*
 - ❖ *Electromagnetic/standard - 17*
 - ❖ *Electromagnetic/muons - 4*
 - ❖ *Electromagnetic/highenergy - 2*
 - ❖ *Electromagnetic/lowenergy - 6*
 - ❖ *Electromagnetic/dna - 16*
 - ❖ *Electromagnetic/xrays - 5*
 - ❖ *Optical - 2*
 - ❖ *Physics_lists/constructors/electromagnetic - 10*
- ❖ **New dataset G4EMLOW8.6.1**
 - ❖ *Updated MicroElec data*
 - ❖ *Fixed X-Ray reflection data*
 - ❖ *Added multi-ionization DNA data*



Recent validation results



- ❖ There is stability in general for EM calorimetry response simulation from 10.6 to 11.3
- ❖ The only known unstable EM physics is EMY, which was fixed in 11.2.2



New features prepared for 11.3

- ❖ Initializations of EM tables and data structures are thread safe.
- ❖ Full implementation of 3-gamma annihilation and positronium production and decay (talk of D. Bernard)
- ❖ Full implementation of X-Ray scattering and examples
- ❖ Alternative EM processes for exotic particles
- ❖ Extension of models and examples for channeling (talk of A. Sytov)
- ❖ DNA developments (talk of Tran Hoang)

Main infrastructure change in 2024

- ❖ In 2023 we were struggled with the problem of initialization and destroy of shared data in EM models
- ❖ **Lessons learned:**
 - ❖ *static data is a very delicate approach - should not be used if possible*
 - ❖ *Instead of deletion of static data in model or process classes we should use register mechanism allowing to keep shared data until the end of the job*
 - ❖ **The work was started for 11.2 using G4ElementData structure**
 - ❖ Data may be accessed via name
 - ❖ Data will be deleted end of job by the dedicated register classes
 - ❖ If a dataset accessed via the register class, then this dataset should not be static

EM data handling for 11.3

❖ Existing G4ElementDataRegistry

❖ Keep *G4ElementData* for EM models

❖ G4LossTableManager define master thread in constructor

❖ It may be the first working thread

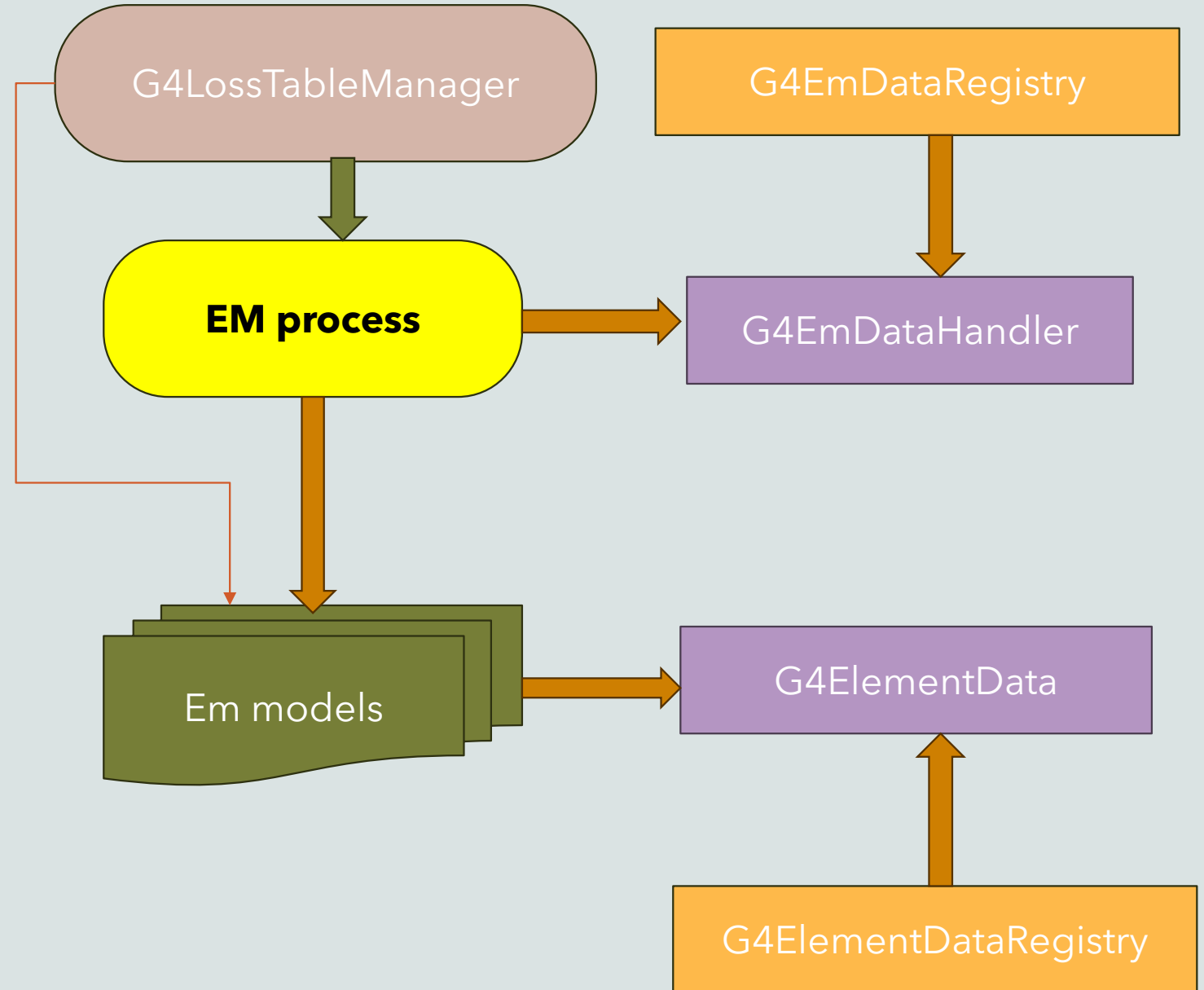
❖ New class G4EmDataRegistry

❖ singleton to keep shared data from EM processes

❖ Physics tables

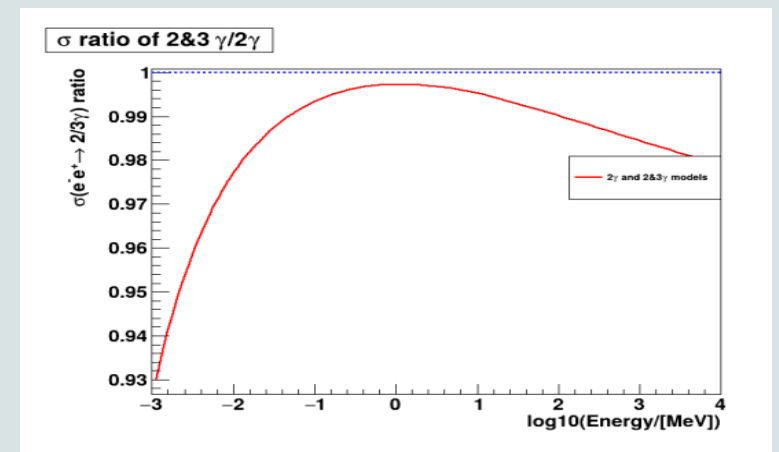
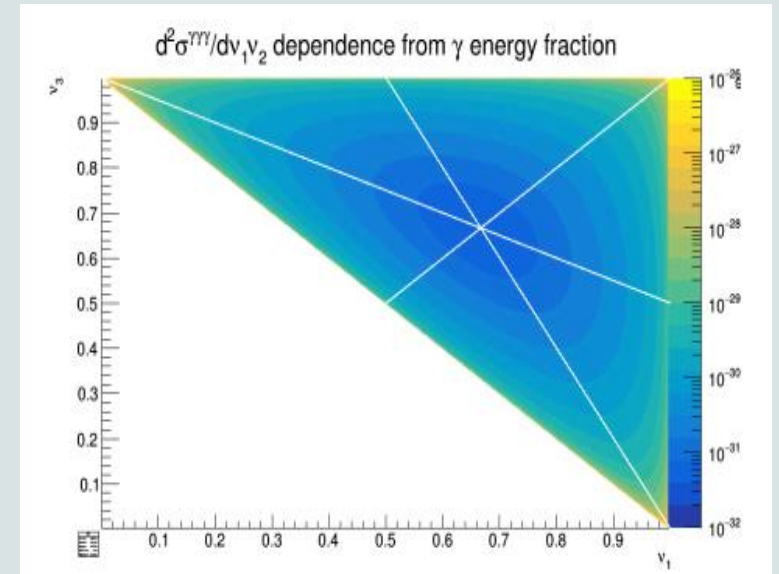
❖ EM cross section shape data

❖ this class is responsible for deletion of *G4EmDataHandlers*



Positron 3- gamma annihilation on fly

- ❖ Pending project for many years
 - ❖ *problems in sampling of final state when a positron become low-energy*
- ❖ Positron 3-gamma annihilation was developed in the framework of CERM summer school projects
 - ❖ *Andrei Alkin (2018)*
 - ❖ *HUNG Tsz Hong (2024)*
- ❖ Design iteration for 11.3 - simulation on fly and at rest are fully independent now
 - ❖ *3-gamma annihilation on fly concerns mainly HEP applications - shower shape may be affected on per mile level*
 - ❖ `/process/em/lowestTripletEnergy 10 MeV`



Positron annihilation at rest

- ❖ Creation of positronium at rest concerns mainly medical applications
 - ❖ *Thanks to contribution from J.Allison, D. Bernard, and I. Semeniouk there is a significant progress in 2024*
- ❖ A choice of model for sampling of final state is provided via enumerator
 - ❖ `G4PositronAtRestModelType`
 - ❖ `fSimplePositronium`
 - ❖ `fAllisonPositronium`
 - ❖ `fOrePowel`
 - ❖ `fOrePowelPolar`
- ❖ Selection of positronium model
 - ❖ `/process/em/setPositronAtRestModel Allison` - variant of selection
 - ❖ *Simple is the current default - annihilation at rest into 2 gamma*
 - ❖ *Allison uses only two gamma Allison model but considers Doppler broadening*
 - ❖ *OrePowell for 2 gamma uses Allison, for 3 gamma - OrePowell model (D. Bernard)*
 - ❖ *Quantum entanglement is applied only on 2 first gamma*
- ❖ Probability of para-/orto-positronium creation and decay defined by `G4Material` property
 - ❖ `/material/g4/ortoPositroniumFraction G4WATER 0.05`



Other new developments

- ❖ EPICS2017 data
 - ❖ *Since 11.2 these data for Livermore gamma models*
 - ❖ *Livermore photo-electric model and Rayleigh scattering models are the default in EM Opt0 physics*
 - ❖ *EPICS2017 cross section for gamma conversion is included into G4BetheHeitler model as an option*
 - ❖ *This model now is not used in any physics configurations but only in tests*
- ❖ New EM models for exotic particle transport
 - ❖ *G4DynamicParticleIonisation*
 - ❖ *G4DynamicParticleMSC*
 - ❖ *G4DynamicParticleFluctuation*
 - ❖ *G4ParticleDefinition is not used in these models, only G4DynamicParticle data*
 - ❖ *All computation on fly - no tables stored*
 - ❖ *G4ChargedUnknownPhysics - builder to be added on top of any Physics List*

Pending work for 11.3

- ❖ For data structure handling check destruction to exclude possible memory leak or double destructions
- ❖ Introduce a new EM parameter and UI command
`/process/em/positron3GammaAnnihilation true`
 - ❖ *should be true for Opt4*
 - ❖ *what about others?*
- ❖ There is a request from Laszlo Urban to change Urban MSC model
- ❖ Address Bugzilla bug reports for EM and problems discussed in the Forum
- ❖ Outstanding request to introduce alternative Cerenkov process



Vision for 2025 physics

- ❖ It is possible to complete development for parallel initialization of EM physics in 2025
 - ❖ *EM physics should be independent on existence/non-existence of the master thread*
- ❖ We may introduce a new option on top of any physics configuration to enable triplet processes and other next to leading order corrections
 - ❖ *This is may be an important addition for precise studies at LHC*
 - ❖ *This would configure 3-gamma annihilation and other advanced options on top of any EM physics configuration*
 - ❖ Users already can add extra options one by one
 - ❖ Alternatively, we may provide flags making easy to study EM shower shape on per mile level for HEP
 - ❖ EPICS2017 cross section is one of such options
- ❖ We should not increase number of EM physics configurations beyond Opt4

Vision for 2025 CPU performance improvement

- ❖ In recent Geant4 releases we do not see significant speed-up of simulation due to EM physics developments
 - ❖ *For standard EM we may speed-up for ~1% due to code optimization*
 - ❖ *Combined processes may improve CPU ~2%*
 - ❖ *DNA and MicroElec code may be improved much more*
 - ❖ *G4HepEm would be a good alternative and should be better integrated with Geant4*
- ❖ New hardware or compiler bring more benefits than our efforts to polish the code
 - ❖ *EL8/EL9 already provide 10% out of the box*
 - ❖ *Risk OS may do factor 2*
- ❖ My personal point of view on 2025 work plan:
 - ❖ *Inside Geant4 EM we should be more concern about accuracy of models and develop G4HepEm further*
 - ❖ *Speed-up is a problem of an application and is the responsibility of users*
 - ❖ we should provide them handles, for example, add a possibility to switch of fluctuations per region

Thank you

