Work-plan for the EM physics and Geant4 10.7patch01

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for the Geant4 Collaboration

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Outline

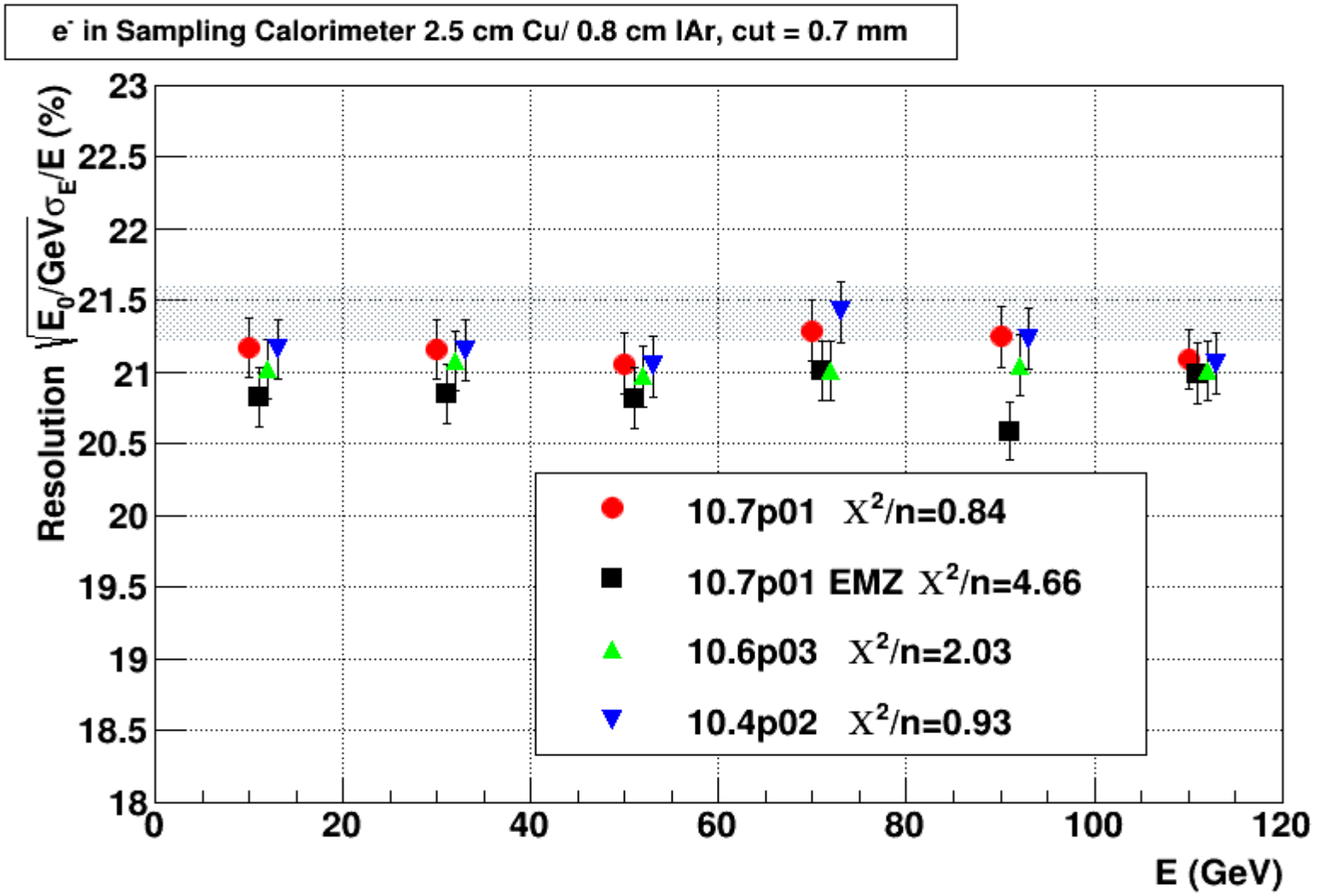
- List of modifications for EM physics in Geant4 10.7p01
- Plan for EM physics developments in 2021

- We expect delivery in 2021 of the major release 11.0
- It is an opportunity of
  - Removal of obsolete classes/methods
  - Clean-up of EM sub-libraries
  - Improve user interfaces
  - Fresh look on EM physics simulation

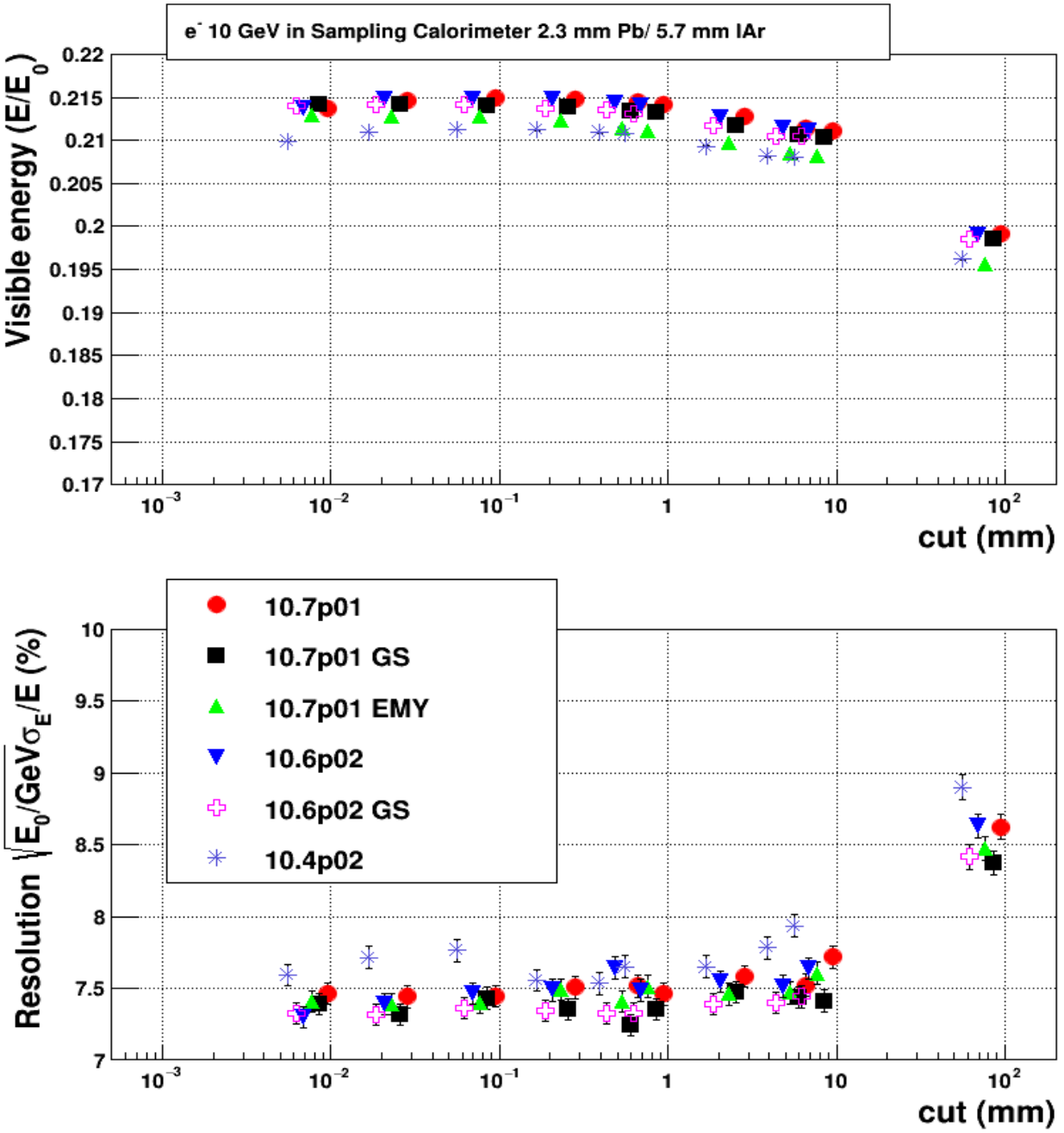
Updates included into the patch-01 for 10.7

- G4MicroElecSurface, G4MicroElecLOPhononModel
  - fixed Coverity defects.
- G4BetheBlochModel, G4LindhardSorensenIonModel
  - restore computation of maximum energy transfer as in Geant4 version 10.4; affecting only ultra-relativistic ions. Addressing problem report #2312.
- G4EmCorrections
  - fixed 2-D interpolation of shell corrections, which provides minor change of ranges of charge particles (< 0.1 mm). Addressing problem report #2308.
- G4VEnergyLossProcess, G4VEmProcess, G4EmExtraParameters and G4EmExtraParametersMessenger
  - improved printout. Addressing problem report #2292.
- OrderingParameterTable
  - added forgotten processes (general positron, surface reflection, DNA) coherently with G4PhysicsListHelper.
- G4GammaGeneralProcess
  - changed 1st energy limit from 50 keV to 150 keV to guarantee K-shell energy for any element to be within 1st energy area.
  - Changed logic for selection of a concrete process. Maximally reduced use of 'if' statements; reduced number of 'return' in run time methods; removed shadowing of base class methods. Addressing problem report #2309.

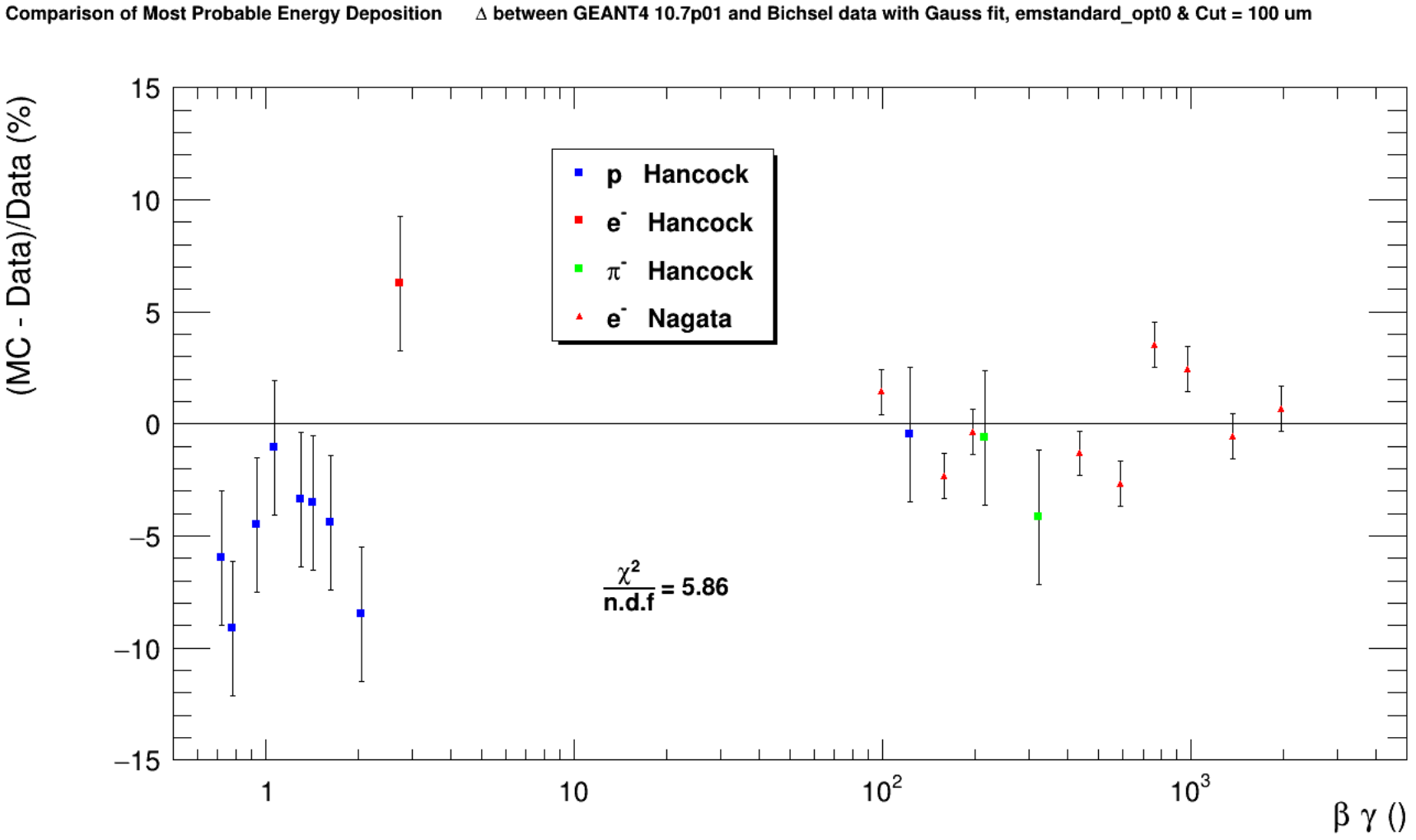
Simplified ATLAS HEC



Simplified ATLAS barrel



Silicon detector response



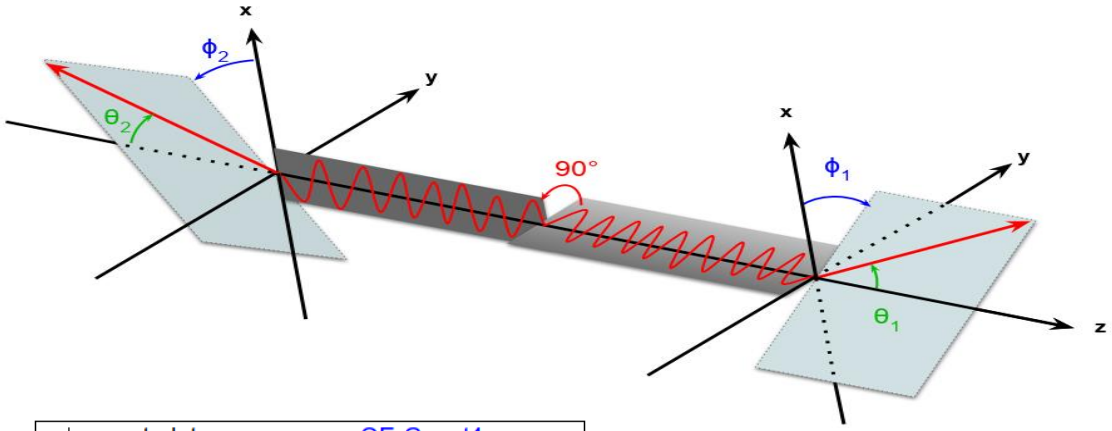
Plan for EM physics developments in 2021

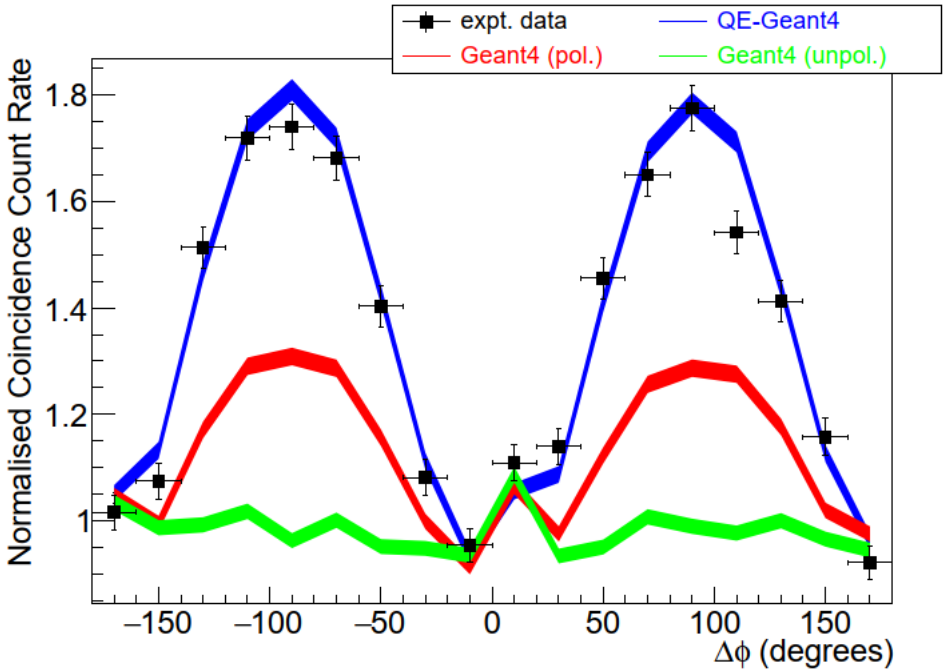
Infrastructure

- Exploit C++17 features in EM libraries where advantageous - (1)
  - C++11 features are already used in many places
- Removal of obsolete interfaces and classes, improved public interfaces - (1)
  - G4EmProcessOption is already removed – users should migrate to G4EmParameters
  - In custom EM physics constructors SetEmModel(G4VEmModel*) should be used
  - Many other small modifications
- Introduction of gamma linear polarisation option for HEP and low-energy EM physics configuration - (1)/(2)
  - G4EmLivermorePolarizedPhysics will be removed
  - Gamma linear polarization transport will be enabled on top of any EM physics constructor
  - Quantum entanglement may be enabled on top of any EM physics constructor

Quantum entanglement in positron annihilation

(arXiv: 2012.04939v1)





- There is angular correlation for Compton scattering of two photons in PET device
- Geant4 method how simulate quantum effects has been developed by J. Allison
- The developed method may be potentially used in HEP

EM physics for HEP

- Improvement to Urban model of fluctuations - (1)
  - Reduce step size dependence of results
- Review of model for sampling fluctuations of e+- and considering an alternative - (1)/(2)
  - Based on theory
- Extension to energy limit for positron annihilation to hadrons - (1)/(2)
  - FCC simulation support
- Evaluation of new ion ionisation models for moderate and high energies, providing ICRU73 and ICRU90 data driven model at low energy and a smooth transition to the Linhard-Sorensen model at high energy - (2)
  - Evaluation of new ion energy fluctuations model - (2)
- Introduction of Bremsstrahlung on atomic electrons at high and moderate energies with triplet production - (2)
  - Dark matter search experiments
- Addition of tau pair production by positrons - (2)
  - FCC simulation support

EM physics for medical and other low-energy applications

- Introduction of discrete Gold ionisation models - (1)
  - Nanoparticle therapy
- Introduction of ANSTO data libraries and cross-sections - (1)/(2)
  - Auger electron emission
- Validation of PIXE cross-sections versus data for protons, alpha, and carbon ions - (1)/(2)
  - Extend energy range of parameterisation
- Review and extension of MicroElec models - (1)/(2)
  - More materials, improved software
- Introduction of full set of models based on EPICS2017 - (2)
  - Livermore and Standard models
- New model of the 3-gamma annihilation - (2)
  - PET simulations
- New very low-energy photo-electric effect model - (2)
  - Use data on photon absorption in various materials

Simulation of Optical Photons

- Caching of material property values in optical processes - (1)
  - CPU performance
- Clean-up of user interface to material property tables - (1)
  - Make it more robust
- Inclusion of a selection of optical material properties - (2)
  - Extension of Geant4 internal DB

DNA Physics and Chemistry

- Validation of CPA100 models for adenine, guanine, cytasine, thymine - (1)
- Electron CPA100 models for dexoribose and phosphate - (2)
- Extension of relativistic electron ionisation model up to 10 MeV - (2)
- Extension of proton ionisation model above 100 MeV - (1)/(2)
- Implementation of N2 and C3H8 gas cross-sections for electrons down to 10 eV - (2)
- Development of transport of chemical ions in magnetic field - (1)/(2)
- Clean-up DNA physics model - (1)/(2)
- Pre-chemical stage and DNA damage chain - (1)/(2)
- Extension of Geant4-DNA to FLASH radiotherapy, including novel chemistry approach - (1)/(2)
- Development of family of Gillespie models - (2)

R&D

- Evaluation and extension of General process approach - (1)
  - G4GammaGeneralProcess is available in 10.7 and bring few % speed-up for HEP simulation
  - Electron and positron processes will follow
- Evaluation of G4HepEm project for integration in Geant4; addition of multiple-scattering and gamma processes; support for R&D targeting GPU - (1)/(2)
  - Next talk of Mihaly Novak
- Extensions to dark matter particle interactions - (1)/(2)
  - Mainly examples
- Integration of Opticks package on GPUs with new extended example - (2)
  - The package is working in real experiment
  - Attempt to make an advanced example which will show how to use this external library

Validation & testing

- Regular validation of EM physics (1)/(2)
- Integration of DNA physics-lists in some geant-val tests - (1)
- Extended validation of HGCal example and integration in geant-val - (1)/(2)
- Introduction of new tests in geant-val for radioactive decay, nuclear medicine and x-ray radiotherapy - (1)/(2)

Thank you for your attention!