Update on Advanced Examples: summary

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On behalf of the Geant4 Advanced Examples WG

27 Advanced Examples

Coord.: S. Guatelli (UOW), Dep.: F. Romano (INFN)

air_shower	B. Tomè	Detection system for cosmic ray shower simulation
ams_Ecal	M. Maire	Simulation of an Electromagnetic calorimeter
brachytherapy	S. Guatelli	Dosimetry for endocavitary, interstitial and superficial brachytherapy
composite_calorimeter	A. Ribon	A composite electromagnetic and hadronic calorimeter
ChargeExchangeMC	A. Radkov	Simulation of charge exchange real experiment
doiPET	A. Ahmed , S. Guatelli , M. Safavi	Simulation of a detector system for PET
eRosita	F. Longo	PIXE simulation with Geant4
fastAerosol	A. Knaian, N. MacFadden	Modelling of particle interactions with
gammaknife	F. Romano	A device for Stereotactic Radiosurgery with Co60 sources for treatment of cerebral diseases
gammaray_telescope	F.Longo	A simplified typical gamma-ray telescope with advanced description of the detector response
gorad	M. Asai	Model of a NASA space mission
hadrontherapy	G.A.P.Cirrone	Simulation of a transport beam line for proton and ion therapy
HGCal_testbeam	A. Zaborowska	High-end High Energy Physics test beam setup, for the endcap electromagnetic calorimeter of the CMS detector [CERN-LHCC-2017-023]
human_phantom	S: Guatelli	Dosimetry in analytical anthropomorphic phantoms
ICRP110_HumanPhantoms	S. Guatelli	Dosimetry in the ICRP110 Phantom
Iort_therapy	F. Romano	Simulation of a IORT device
lAr_Calorimeter	A. Dotti	Simulation of the Forward Liquid Argon Calorimeter of the ATLAS Detector at LHC
medical_linac	B. Caccia, G.A.P. Cirrone	A typical LINAC accelerator for IMRT,
microbeam	S. Incerti	Simulation of a cellular irradiation microbeam line using a high resolution cellular phantom
microelectronics	M. Raine	Simulation of tracks of few MeV protons in silicon
nanobeam	S. Incerti	Simulation of a nanobeam line facility
purging_magnet	J. Apostolakis	Electrons travelling through the magnetic field of a purging magnet in a radiotherapy treatment head
radioprotection	S. Guatelli, F. Romano	Microdosimetry with diamonds and silicum detectors for radioprotection in space missions
STCyclotron	F. Poignant, S. Guatelli	Modelling the production of radio-isotopes
underground_physics	A. Howard	A simplified typical dark matter detector (such as the Boulby Mine experiment)
xray_fluerescence	A. Mantero	Elemental composition of material samples through X-ray fluorescence spectra
xray_telescope	G. Santin	A simplified typical X-ray telescope (such as XMM-Newton or Chandra)

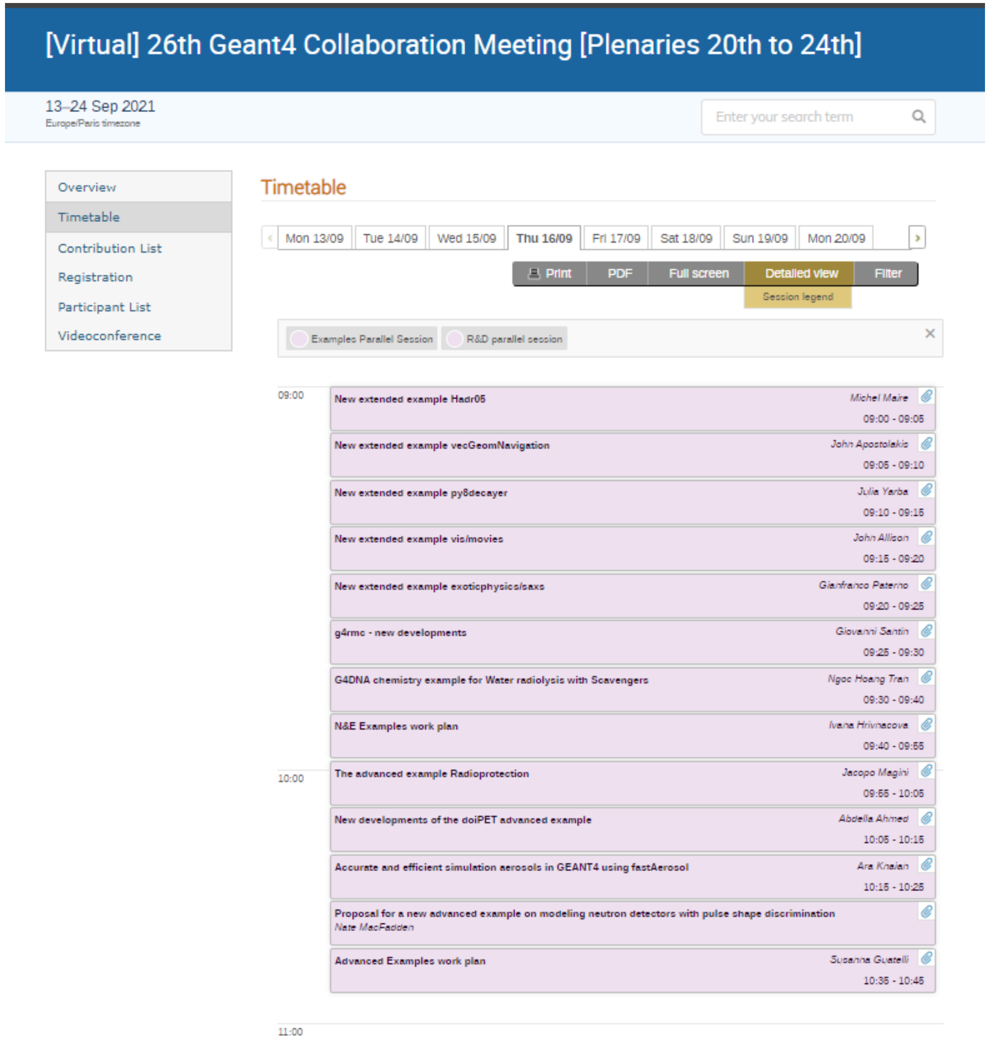
Progress in 2021

Note:

- For detailed progress on the Work Plan, please refer to the talk I had in the parallel session on the Geant4 examples (16th September).

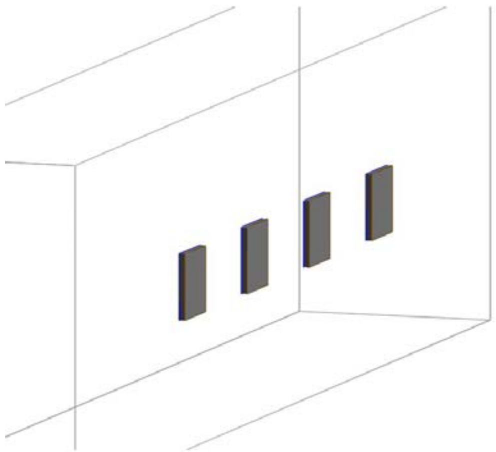
- **Code review and maintenance**
  - Code review done in *ICRP110Phantom*, *brachytherapy* and *microbeam*, on going in *radioprotection* and *eRosita*.
  - Migration to *G4RunManagerFactory* almost completed (to be done in: *ChargeExchangeMC*, *doiPET*, *iort_therapy*, *lAr_calorimeter*, *medical_linac*, *purging_magnet*, *x_rayfluorescence*)
  - Migration to MT: only 3 examples missing (*medical_linac, ChargeExchangeMC , iort_therapy)*

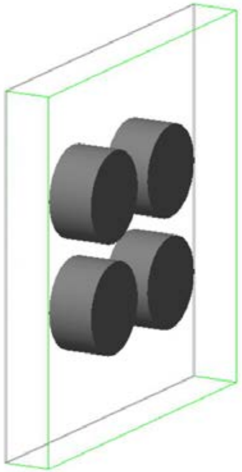
- **Migration to C++11/14/17**
  - In the initial phase
  - Thank you Ivana and Ben for your interactive seminars!

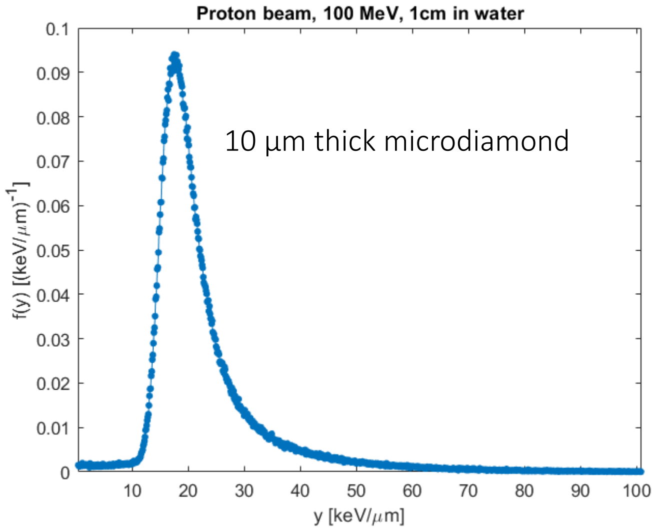


Radioprotection advanced example

- **Responsible developers:** S. Guatelli (University of Wollongong, Australia) and F. Romano (INFN - Catania Division, Italy)
- New implementation of **diamond microdosimeters** (produced by University of Rome "Tor Vergata"): collaboration between INFN-Catania and University of Surrey (J. Magini, G. Parisi, G. Schettino and F. Romano) → **completed**
- Implementation of simple macro commands for easy management of the geometrical configuration from Users:
  - Possibility of changing the different simulated microdosimeters (silicon vs microdiamond) via → **completed**
- Cross-comparison with experimental data → **completed**/**in progress** (data acquired with low energy ion beams)
- Simulation of double-stage microdiamond for particle identification → **in progress**
- Python scripts for microdosimetric spectra and data analysis (first version) → **in progress**


Diamond microdosimeters


Silicon microdosimeters



see talk on the «Radioprotection example»

ICRP110Phantom

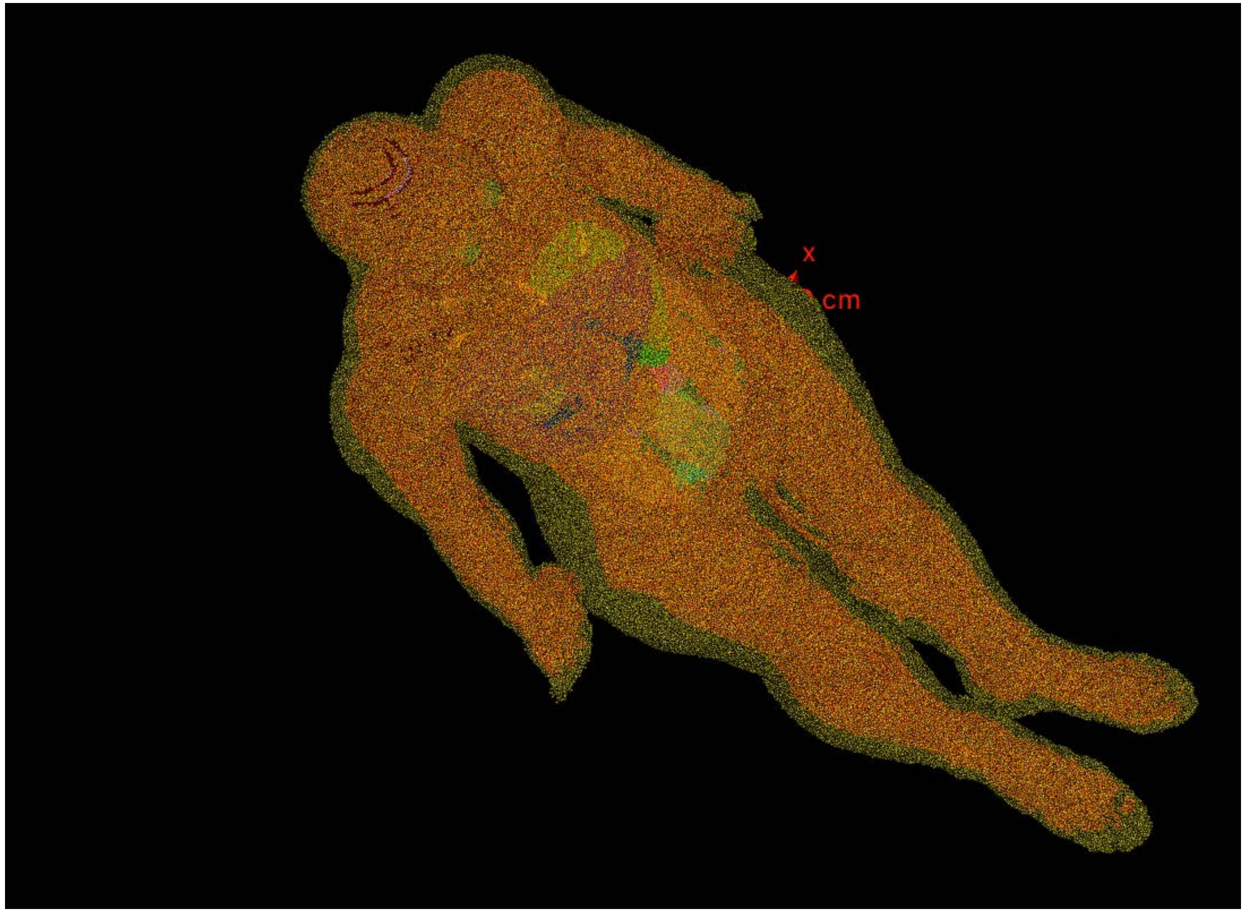
Authors:
- **S. Guatelli, M. Large and A. Malaroda (University of Wollongong, NSW, Australia**
- **John Allison, Geant4 Associates International and University of Manchester, UK.**

In Geant4 v.11:

- The dose can be calculated in entire organs (before in voxels)
- Special vis rendering
  - G4VNestedParameterisation: One dot per mesh point
  - From vis.mac

```
# Draw phantom
/vis/viewer/set/specialMeshRendering
/vis/drawVolume
```

  - Drawing: 100× speed-up
  - Normally that would be 7 million boxes – impossible – but 7 millions dots is OK



Video by J. Allison

Plan for 2021: Hadrontherapy

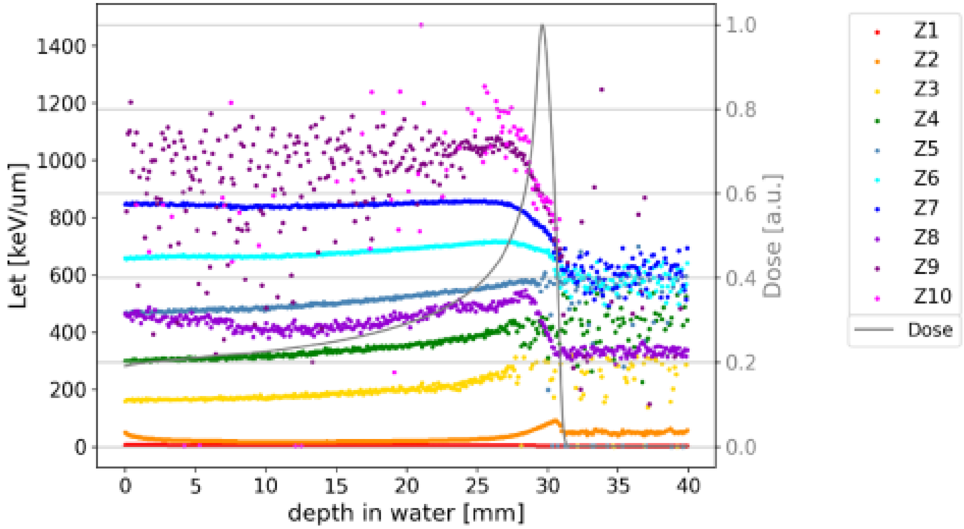
G. Petringa, P. Cirrone, L. Pandola, G. Miluzzo, S. Fattori

New developed algorithms to compute the LET

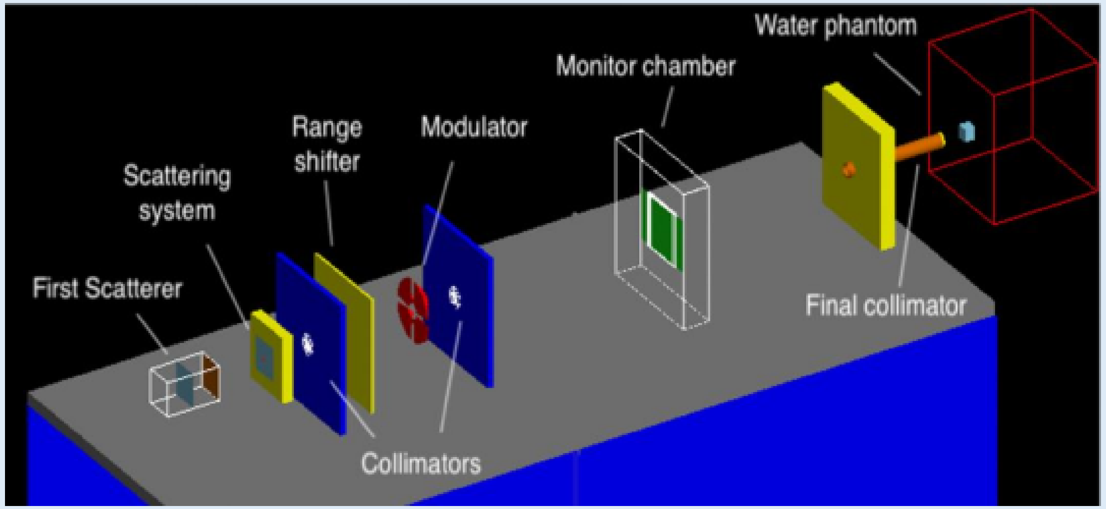
- **Validation done with clinical proton beams:**

G. Petringa et al. “Study and validation of Monte Carlo methods for linear energy transfer calculation in voxelized geometries with clinical proton beams”, PMB, DOI: [10.1088/1361-6560/abaeb9](https://doi.org/10.1088/1361-6560/abaeb9) (2020)

- **On going validation with ions:**



A new geometry : Best-Cyclotron beam line



	Best Cyclotron source parameters
Energy	70MeV
Energy spread (sigma)	300keV
Spot dimension (FWHM of a gaussian distribution)	3mm-5mm (sigma)
Spatial distribution type	Circular
Angular distribution type	Gaussian
Angular divergency	~ 0.16 ° (sigma)

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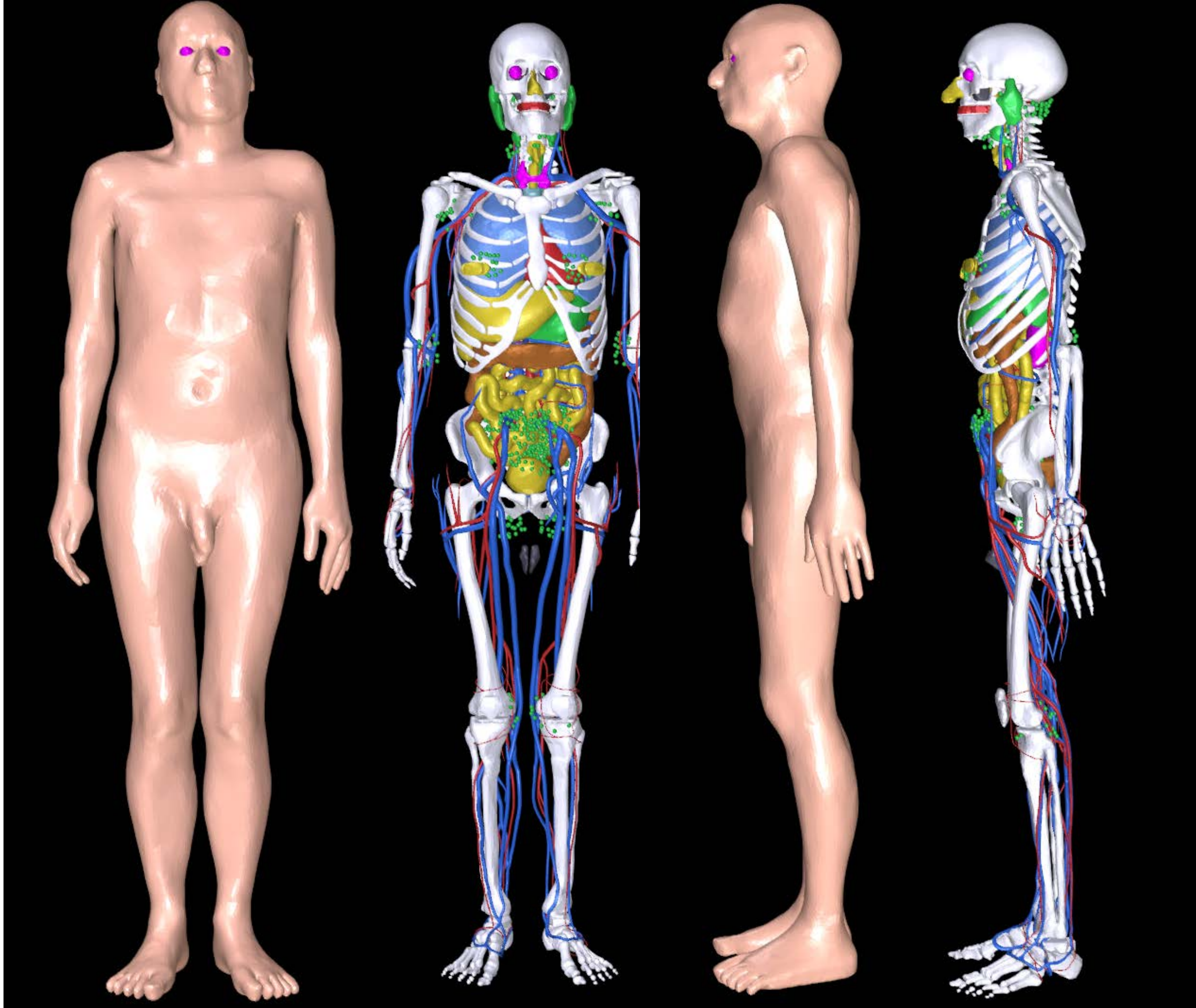
INFN Istituto Nazionale di Fisica Nucleare

New Advanced Examples

New Advanced example: ICRP145Phantom

- ICRP Publication 145 on Adult Mesh-type Reference Computational Phantoms
  - Ann ICRP . 2020 Oct;49(3):13-201. doi: 10.1177/0146645319893605.
- Use of the General Particle Source
- Calculation of the **dose in the organs of the phantoms**
- To be released in Geant4 v. 11, in agreement with the original developers of the models.



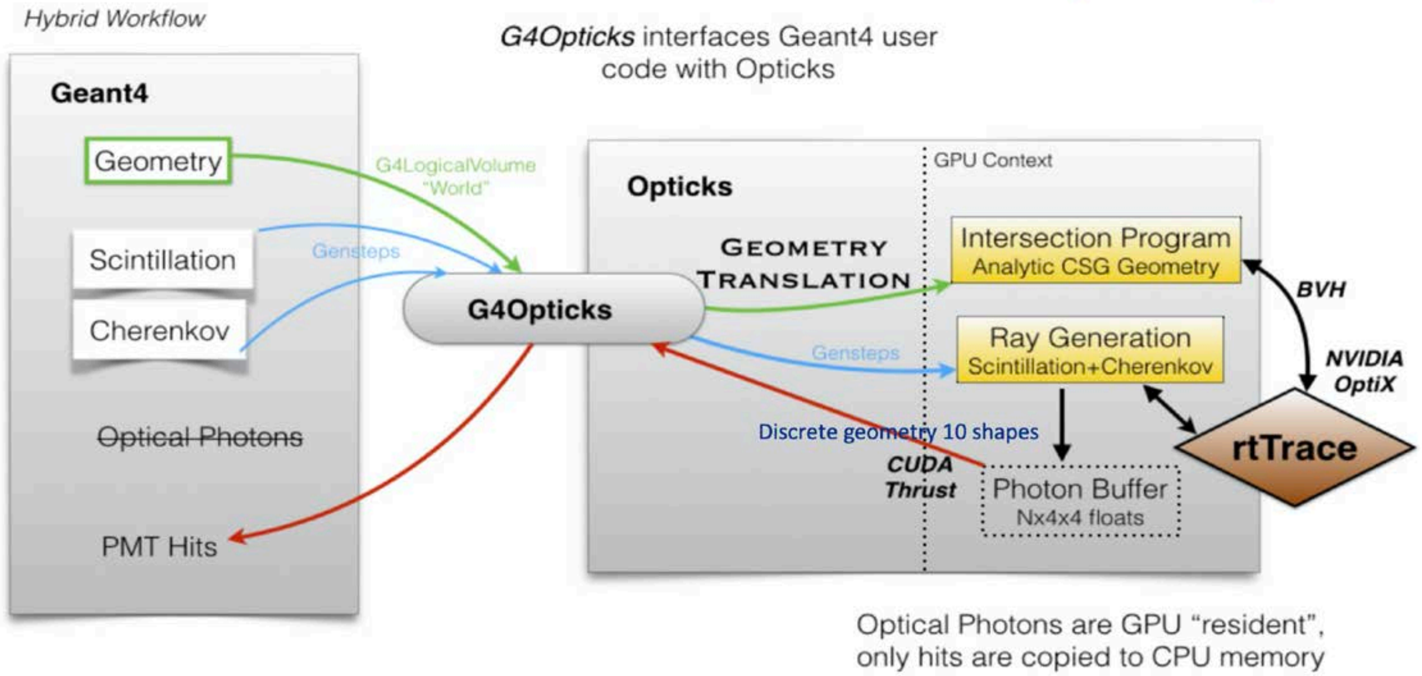
G4Opticks/CaTS: simulation of optical photons on NVIDIA GPUs

G4Opticks (part of Opticks developed by Simon Blyth): interfaces Geant4 user code with Opticks.

- Hybrid workflow where generation and tracing of optical photons is offloaded to Opticks (GPU/device) at stepping level when a certain amount photons is reached. Geant4 (CPU/host) handles all other particles.
- The Geant4 Cerenkov and Scintillation (C/S) processes are only used to calculate the number of optical photons to be generated at a given step and to provide all necessary quantities to generate the photons on the GPU.
- The information collected is the so called GenStep which is different for Cerenkov and Scintillation (C/S).
- Photon Hits are collected at the end of the G4Opticks call and added to the event hits collection.

Authors: Hans Wenzel, Krzysztof Genser, Soon Yung Jun, Alexei Strelchenko (Fermilab) and Simon Blyth ((Institute of High Energy Physics, Chinese Academy of Sciences)

Figure from Simon's presentation

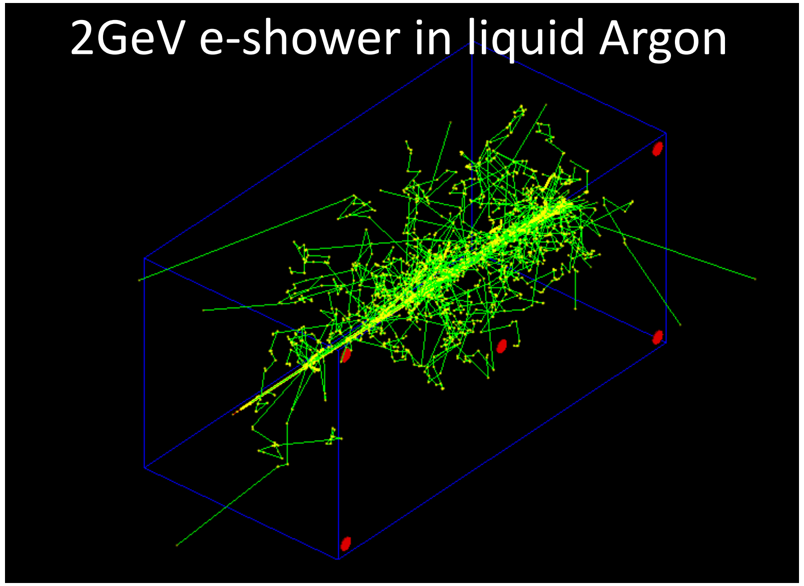


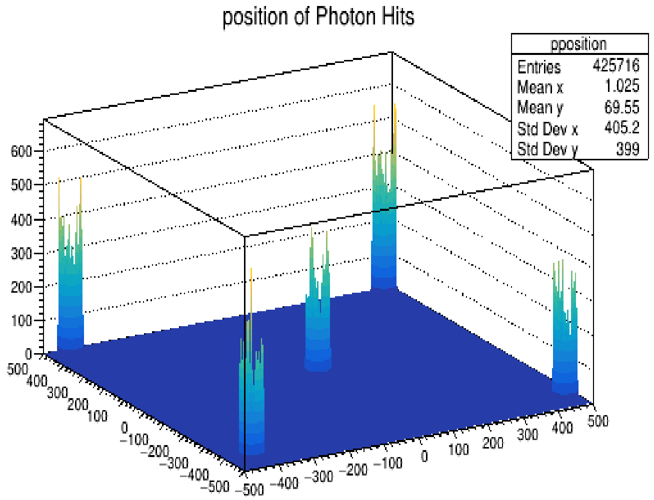
CATS: Geant4 Application that demonstrates the G4Opticks workflow: https://github.com/hanswenzel/CaTS

In the process of making it an advanced example and getting resources at CERN to run it: https://gitlab.cern.ch/wenzel/geant4-dev/-/tree/CaTSv1_0/examples/advanced/CaTS

CaTS Performance:

Hardware:	
CPU	Intel(R) Core i7-9700K 3.6GHz 32 GB memory.
GPU	GeForce RTX 2070 CUDA Driver Version /11.3 CUDA Capability: 7.5 VRAM: 7981 Mbytes Cores: 2304





Timing results (Geant4 10.7.p01):	
Geant4 optical physics	2438 sec/event
G4Opticks, RNGmax[1] 10	6.45 sec/event
G4Opticks RTX enabled, RNGmax[1] 10	2.72 sec/event
G4Opticks, RNGmax[1] 100	6.86 sec/event
G4Opticks RTX enabled, RNGmax[1] 100	2.87 sec/event

1) Memory pre allocated for pre-initialized (at installation) curandState files to load.

Geant4/(Geant4 + Opticks) comparison:
2438/6.45 = 378 (x 2.4 ~ 900 with RTX) x speed up
RTX Ray tracing hardware acceleration is usually not available on HPC platforms

Proposed Advanced Examples

Example to model a realistic scintillator+PMT system

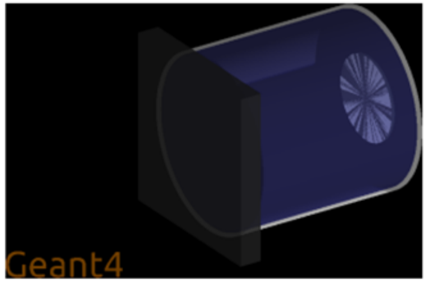
Proposed by Nate MacFadden
NK Labs, LLC, US

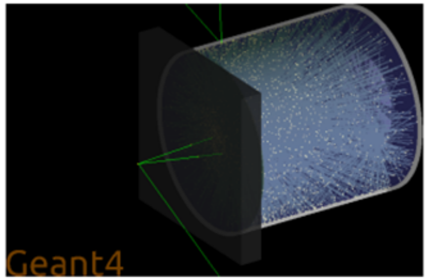
More details in the talk by Nate in the Parallel session dedicated to the Geant4 examples

- Example demonstrating scintillators (G4Scintillation), PMTs, and digitizers (G4VDigitizerModule), in a ‘full experiment’ simulation
- Model of a common scintillators (e.g., EJ301) and PMT to detect and discriminate the signal from gamma rays and neutrons.
  - Neutron-excited scintillation signals decay more slowly than gamma-excited signals -> pulse shape discrimination
  - Model of the PMT (from photon hit to electronic pulse)
    - Based on the model by F. Kaether, C. Langbrandtner , JINST 7 P09002 (2012): arxiv.org/pdf/1207.0378.pdf
  - N. MacFadden and team are now preparing an experiment/beam time at FNAL and PSI
  - Of interest for nuclear and particle physics experiments

Example Specifications

Following ‘3CYL’ cylindrical detector experiment from[1].



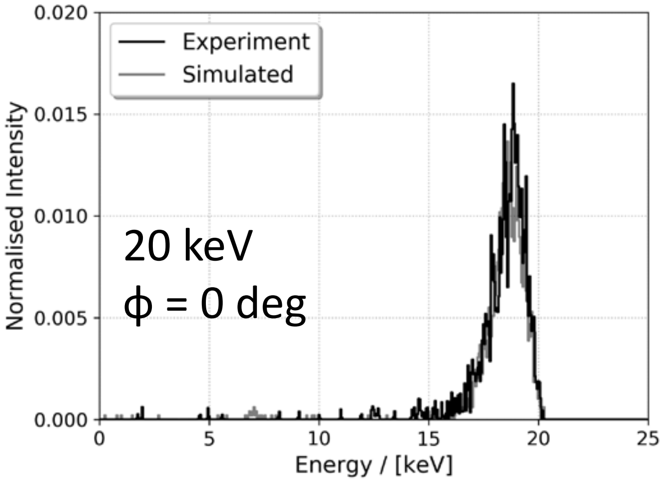


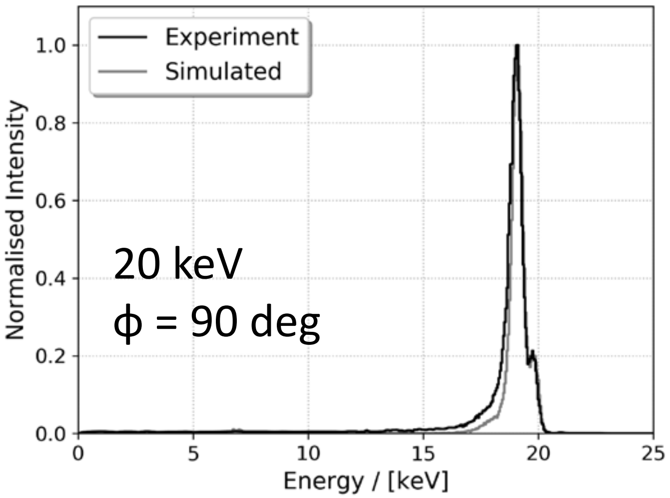
- $r = 38$mm, $h = 76$mm cylinder with 1.5mm Al walls and filled with EJ309,
- Cf252 source (G4fissionEvent + isotropic alpha emission) at one end,
- 50mm Pb shielding[2] between source and detector,
- PMT[3] placed at opposite end from source, connected via quartz window[4],
- and a CAEN-esque digitizer with pole-zero correction and lowpass filtering.

[1](Ellis, Tintori, Schotanus, Duroe, Kendall, Mini ’13)
[2]currently using 10mm thick Pb shielding for easier data
[3]currently using different PMT than from paper
[4]currently using no window for better data

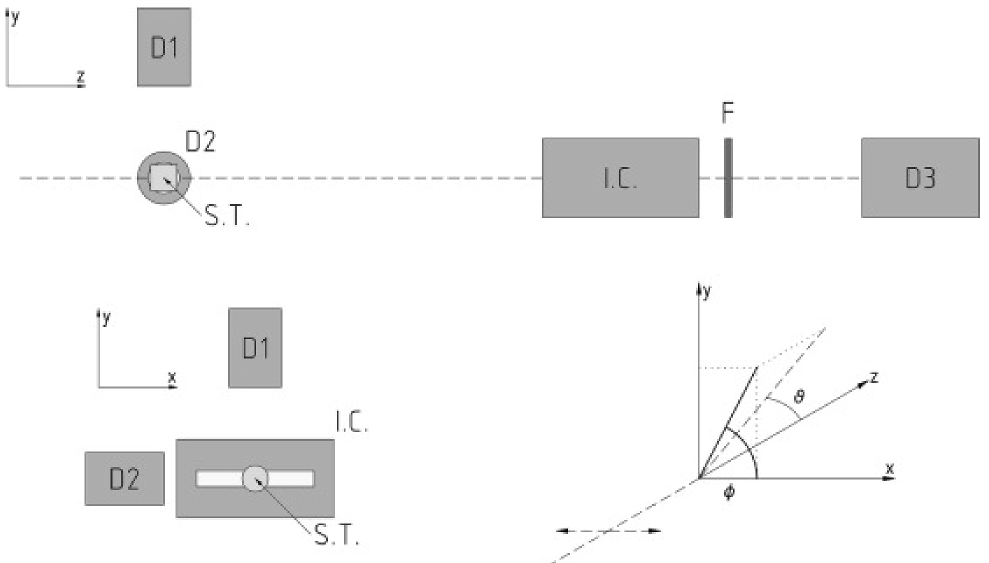
Synchrotron X-ray Polarimetry

- Use of the “G4LowEPPhysics” electromagnetic physics constructor to describe low energy (E < 10 MeV) polarised X-/gamma ray transport in Geant4
  - J. M. C. Brown and M. R. Dimmock, NIM B, 502, 2021, 176-182.
- Experimental validation against Compton X-ray polarimetry measurements of the BL38B1 beamline at the SPring-8 synchrotron (Sayo, Japan)
- Of interest for laser driven polarised x-ray sources, synchrotron physics, and X-ray/Gamma ray astronomy instruments





Proposed by Jeremy Brown, ANSTO, Lucas Heights, NSW, Australia



Experimental set-up. Courtesy of J. M. C. Brown and M. R. Dimmok, NIM B, 502, 2021, 176-182.

X-ray polarimeter: the scattering target (S.T.) and both CdTe detectors (D1 and D2), with respect to the 170 mm long He gas-flow type ionisation chamber (I.C.), set of metal filters (F), and YAP(Ce) scintillator based energy discriminating photon counting detector (D3) locations at the BL38B1 beamline (SPring-8). The dashed line represents the propagation of the 98% horizontally polarised 100 μm by 100 μm collimated mono-energetic X-ray beam along the z-axis.

Final remarks

- There is on-going work to further improve the existing examples
  - Code cleaning
  - Maintenance
  - Extend the existing functionality
- New examples in the pipeline

- That’s all, thank you