Open requirements
for space science and engineering

Giovanni Santin [1]*

[1]ESA/ESTEC *RHEA System

Based also on input from:

Christophe Inguimbert

Christos Papadimitropoulos

Denis Bernard

Fan Lei

Mark Looper

Nigel Bannister

Requirements on

Physics

CAD geometry

Primary generator: GPS

Data persistency

Biasing

Physics:
list / model choice and documentation

Mark Looper (Aerospace Corporation)

- Is Shielding_EMZ the correct choice for

  – ions < a few GeV/nuc

  – e- < some hundreds of MeVs ?

- Related request: some **updates of the webpages** describing the reference physics lists to tell us what range of projectiles and targets each list addresses best, so that I would have something to back up my decision

Status: ongoing documentation work, maybe to be improved?

- Recommendations for a physics list

  – **neutrons** up to a few GeV as well as for charged particles

- Use case:

  – For protons kicked out of hydrogen-bearing parts of the lunar surface by GCR secondary neutrons

European Space Agency

Physics:
validation for High-Energy, High-Z (HZE) ions

ESA (human exploration programmes)

- GCR dominate the biological dose for long duration interplanetary flights

- Cross section measurements are needed

  - but require dedicated, complex experiment set up

- More moderate resource investment:

  - Bragg peak measurement, or fragmentation from thick shielding (GSI, BNL)

  - Comparisons to other codes (PHITS,…)

- Some earlier Geant4 disagreements against data (^{56}Fe in HDPE @963MeV/nuc) still unexplained

Status: ongoing, some new measurements will be taken under ESA ROSSINI 3 contract

Stopping power for HZE ions

From ESA

- Stopping power for high energy heavy ions

- 40 GeV/nuc Xe ion beam test at CERN SPS North area

    – Si PIN diode give ~300 MeV energy deposit (~4.3 MeV cm2 mg-1)

    – Geant4 (MULASSIS and GRAS) simulations at ESA 7% off: 320 MeV (~4.6 MeV cm2 mg-1)

    (FLUKA simulations correctly reproduced the energy deposition)

    – Some improvements in the latest release reported by Vladimir Ivantchenko, not tried yet

Status: work in progress, under discussion with Vladimir (implement Linhard and Sorensen model, PhysRev A 1996?)

European Space Agency

Geant4-DNA: physics / geometry / …

From ESA, but not only

- Improvements in the understanding of the detailed interaction of ionizing radiation with the human body at DNA and cellular level

    - Improve/augment current physics models

    - Improve chemistry extension

    - Improve DNA / cell geometries

    - Include damage / repair response functions

    - Complement higher level macroscopic damage models

- Ultimate goal from ESA side: (indirectly) support risk models for European astronauts

Status: open, in progress. Would need additional resources

European Space Agency

Physics: very low-energy processes for e-, p, ions for effects in microelectronics ("microelec")

From Christophe Inguimbert

Application use cases

- Secondary Electron Emission (SEY)

    - charging, plasma thruster

- SEEs in new technologies

    - e- induced SEE

    - SEE from protons direct ionization

    - Dose structure in nanoscale volumes

- Surface analysis methods

    - Electronic microscopy …

Requirements

- Cross section database extension

    - SiO2, W, BN, C, O…

    XS DB for Al, Cu done by ONERA/CEA but not in G4 yet

- p, ions: new energy loss function treatment

    - Diel. th. (Drude) model not valid for heavy particles

    - Charge transfer for stopping power at low energy (~keV for heavy ions)

- Quantum reflection at material I/F (important for SEY)

- Development of a G4 example

Status: open, slow progress (lack of resources)

European Space Agency

Physics: gamma conversion
for gamma ray space telescopes

From Denis Bernard (LLR, Ecole Polytechnique & CNRS/IN2P3)

- new physics model of gamma-ray conversion to e+e- pairs,

- Sampling the full, that is, five-dimensional, differential cross section

- needed to appropriately simulate the high-performance telescopes and polarimeters that are in preparation these days (e.g. HARPO gas TPC detector for gamma-ray astronomy)

Status: under development, see talk in session Parallel 1A

Geometry: CAD interfaces

- Christos Papadimitropoulos: GATE v8.0 can directly transform CAD files (e.g. STL) into G4Tessellated objects. We would like to see commercial CAD import developed in GEANT4.

- Mark Looper (Aerospace Corporation): Looking for inexpensive or open-source tool to convert these files to GDML; commercial tools (e.g. FASTRAD, NOVICE) very expensive. If Geant4 could either import STEP files or provide a conversion tool to translate them to GDML in one step, that would be a big help.

- Fan Lei: i) G4 endorsed STEP -> GDML convertor

    ii) easy-to-use utility for importing meshed geometry

    iii) Geant4 geometry manager allowing model construction (combination of) from

    – GDML or meshed files

    – G4 ASCII geometry file

    – plug-in for G4 c++ geometries

Status (CAD): quite a few (partially overlapping) independent developments in the past few years

Many use OpenCascade (OCC) libs, a few looking at FreeCAD framework

European Space Agency

Data output persistency

Christos Papadimitropoulos: *Direct interface to external databases*

- In Monte Carlo analysis in GEANT4, a large set of simulated data are usually produced. These data could be handled more effectively if there was a direct link to an external database, a feature that lacks of GEANT4 (it can be done, though, via ROOT).

ESA: *G4Analysis*

- "Parallel" output (of different information) to multiple data formats

Primary generation: GPS

UR origin: ESA

- Review the GPS spectrum differentiation/integration algorithms
    - Current strategy introduces unneeded computational inaccuracies

- Introduce user energy unit choice for GPS spectra
    - Currently: implicit, fixed MeV unit

- Introduce distinction flux/fluence and (mission) time?
    - Currently no absolute intensity concept, delegated to applications

- Improve ease of use for common use cases (spectrum, position)
    - Sensible spectrum sampling options
    - Irradiation from above only, etc.

Status: resources may become available via ESA contract (TO: M. Vuolo)

European Space Agency

Biasing

Reverse (Adjoint) Monte Carlo

- Improvement to e- and p RMC algorithms
- Recent comparisons to forward MC + other codes indicate
  - e-: general good agreement for TID and spectra after shielding (thank you Laurent)
  - ESA: still some deviations at high energy / thick shielding
  - p: significant disagreement reported by Mark Looper (Aerospace Corporation). ESA: OK with cut 1 mm, progressively degrading (higher doses) when lowering cuts to 100 – 10 – 1 um

Status: in progress (Laurent Desorgher), anybody is welcome

Generic Biasing framework

- ESA: needed for investigation of small XS processes (e.g. e- nuclear interactions, but also all hadronic reactions, in microelectronics)
- Extremely promising, not much used yet
- Single Event Effect analysis in biased simulations not trivial (as opposed to total dose tallying). Geant4 example would be useful

Thank you

Giovanni Santin [1]*
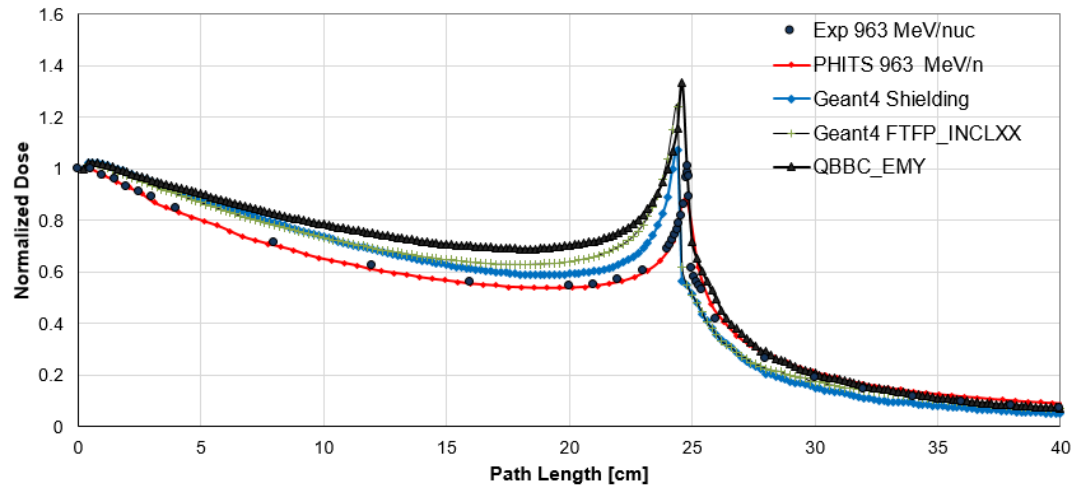
[1]ESA/ESTEC *RHEA System

Lund, August 27-31, 2018

Chicago, 2015

+ ## Comparisons against BNL data

^{56}Fe in HDPE, 963 MeV/nuc

PHITS, Geant4 vs NSRL Experimental Data
^{56}Fe in HDPE

Legend:
- Exp 963 MeV/nuc
- PHITS 963 MeV/n
- Geant4 Shielding
- Geant4 FTFP_INCLXX
- QBBC_EMY

Discrepancy with simulations for high energy iron particles still under investigation