

# Update on Requirements

56<sup>th</sup> Geant4 Technical Forum  
March 24<sup>th</sup> 2022  
Virtual Meeting

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On behalf of the Geant4 Collaboration

Requirements Tracking System Page:  
<https://jira-geant4.kek.jp/secure/Dashboard.jspa?selectPageId=10000>

New/analyzed requirements

# Requirements from 2021 Geant4 Collaboration Meeting (CM)

- Requirement sessions during CM are quite productive
  - > 2021 session ended with O(> 50) requirements expressed !
  - > <https://indico.cern.ch/event/1052654/sessions/401937/#20210920>
- Some first level of filter done, but analysis process is on-going
  - > Is requirement new ? Is it relevant to Geant4 ? Does it need clarification ? Etc.
  - > In interaction / iteration with requesters
- Requirement analysis work shared among several volunteers:
  - > HEP : Alberto Ribon
  - > Intensity Frontier : Soon Yung Jun
  - > Nuclear Physics : no new requirements !
  - > Space Science and Engineering : Makoto Asai
  - > Medical and Bio Science : Susanna Guatelli
- Requirements will be added to JIRA as they are validated
- Thank you for your patience !

# Validated requirements (HEP)

Source	Requirement	Responsible
CMS	Extended decay module of Geant4 <ul style="list-style-type: none"><li>• More accurate branching ratios for baryons and mesons</li><li>• Improved final state sampling</li><li>• Addition of detailed tau, c-, and b- particle decays<ul style="list-style-type: none"><li>• Native or via interface to generator packages</li></ul></li></ul>	Alberto Ribon
ATLAS	Quasi-stable particle Simulation : Improved robustness of Geant4 when using pre-defined decay chains from Generators. <ul style="list-style-type: none"><li>• Perhaps implementing some kind of sanity checker for G4Events with predefined decays to spot potential problems. (Unknown particle types, particles with no physics models attached, zero lifetime particles.)</li></ul>	Alberto Ribon
ATLAS	Quasi-stable particle Simulation : Establish conventions on consistency of decay models between G4 and Generators where there are overlaps ? <ul style="list-style-type: none"><li>• Or possibly common work to directly integrate event generators for certain decays and interactions?</li></ul>	Alberto Ribon
ATLAS	Quasi-stable particle Simulation : Dealing with hadronic interactions of oscillating neutral mesons	Alberto Ribon

# Validated requirements (IF)

Source	Requirement	Responsible
DUNE	Propagation of polarized muons and taus in dense media	John Apostolakis & Krzysztof Genser (contact IF)
Mu2e	pbar annihilation process to be improved <ul style="list-style-type: none"><li>including being able to affect the nuclear destruction process at energy below 2GeV</li></ul>	Davide Mancusi
Muon g-2	Muon g-2 is interested in having a symplectic stepper	John Apostolakis (but need manpower)

# Validated requirements (medical)

Source	Requirement	Responsible
Medical	Provide an example of physics list activating both Geant4-DNA and hadronic physics, including radioactive decay	Sébastien Incerti & Susanna Guatelli
Medical	Isotope production from protons: <ul style="list-style-type: none"><li>• IAEA has made an extensive work to cover isotope production for medical applications (<a href="https://www-nds.iaea.org/medical/">https://www-nds.iaea.org/medical/</a>)</li><li>• Put IAEA medical cross section into Geant4 ParticleHP database</li></ul>	Alberto Ribon
Medical	AtRest in Geant4 Biasing framework <ul style="list-style-type: none"><li>• add AtRest in Geant4 Biasing framework</li></ul>	Marc Verderi
Medical	Modelling Radiation damage in Semiconductor devices <ul style="list-style-type: none"><li>• <a href="https://geant4-forum.web.cern.ch/t/modelling-radiation-damage-in-semiconductor-devices/5751">https://geant4-forum.web.cern.ch/t/modelling-radiation-damage-in-semiconductor-devices/5751</a></li><li>• Include a Geant4 example to show how to calculate radiation damage (with G4NIELCalculator and G4NuclearStopping)</li></ul>	Susanna Guatelli & Ivana Hrivnacova

# Open requirements

# 4702 : Inclusion of $\gamma$ polarization effects in the high energy EM models

- ◉ Originator:
  - > CMS
  - > 47th Technical Forum ([link](#))
- ◉ Scope:
  - > Include Linear Polarization into HE  $\gamma$  Models
  - > This has potential usage in the analysis of  $H \rightarrow \gamma \gamma$ 
    - Polarization planes of scalar (pseudo-scalar) particle to  $\gamma$ 's are parallel (perpendicular)
    - Investigate the effect of polarization in the shower shape of photons
      - May give additional handles to distinguish direct  $\gamma$ 's from H decay from BG
- ◉ Responsible:
  - > Vladimir Ivantchenko
- ◉ Status:
  - > In progress, continuing this year.
  - > Open.



# 5002 : Support for "sub-event" parallelism across G4 threads

- ◉ Originator:
  - > ALICE
  - > Page 6 of [Requirements from energy frontier](#)
  - > Declined by ALICE last year, but requirement still considered of interest
- ◉ Scope:
  - ~~ALICE handles~~ For experiments which handle very big events
  - > These would be processed faster if one event could be split into "sub-events" ( = {subset of primary tracks} ) -each processed on one thread- with merging back of sub-events into the event at the end
- ◉ Responsible:
  - > Makoto Asai
- ◉ Status:
  - > This comes along with the tasking model, released with 11.0.
  - > Reproducibility is the main issue
  - > Will be continued this year
  - > Open

# 5005 : Neutron self-shielding effect

- ◉ Originator:
  - > LZ (LUX-ZEPLIN), SuperCDMS
  - > Page 7 of [Requirements from intensity frontier](#)
- ◉ Scope:
  - > Significant reduction of the neutron flux in material when neutron energy is in the resonance region
    - The capture process can reduce the flux at one position in a crystal creating a kind of shadow in which the downstream atoms see a reduced flux (a ~10% effect)
- ◉ Responsible:
  - > Vladimir Ivanchenko
- ◉ Status:
  - > Valid requirement but big work
    - Needs theoretician support as well as manpower.
  - > Collection of publications and references on-going.
  - > Not expected to be concluded in the short term.
  - > Open.

# 5006 : Improve simulation of gamma induced neutron background

- ◉ Originator:
  - > LZ (LUX-ZEPLIN), SuperCDMS
  - > Page 7 of [Requirements from intensity frontier](#)
- ◉ Scope:
  - > Low energy gammas producing neutrons in various materials can generate a significant background
  - > But photo-nuclear process does not model this well below 30 MeV
  - > Point that G4LEND gamma models might resolve the issue
- ◉ Responsible:
  - > Vladimir Grichine
- ◉ Status:
  - > Improved gamma-nuclear cross sections in G4 11.0.
  - > Next step is the final-state; in the work-plan for this year.
  - > Open.

# 5007 : Improve electro-nuclear models

- ◉ Originator:
  - > Markus Diefenthaler (EIC Center, EICUG) for:
    - JLAB 12 GeV Science program
    - Electron-Ion Collider (EIC)
  - > Page 12 of [Requirements from nuclear physics experiments](#)
- ◉ Scope:
  - > Electro-nuclear models rely on Weizsacker-Williams approximation.
  - > Not sufficient for high-intensity and high precision electron scattering.
  - > The full, off-shell electron scattering vertex must be implemented for nucleons within the nuclear target.
- ◉ Responsible:
  - > Vladimir Grichine
- ◉ Status:
  - > Will be continued this year.
  - > New collaborator, Maurizio Ungaro (JLab), involved on this.
  - > Open.

# 5008 : Make EPICS2017 models (electrons, photons) as an alternative to Livermore

- ◉ Originator:
  - > General demand
  - > Page 11 of [Requirements from Medical and bio science](#)
- ◉ Scope:
  - > EPICS2017 : Electron and Photon Interaction Cross Sections
    - Mention : these data supersede all earlier versions of the data libraries EADL, EEDL and EPDL
- ◉ Responsibles:
  - > Sébastien Incerti, Claire Michelet
- ◉ Status:
  - > On-going in framework of thesis of Z. Li (CENBG/LP2I Bordeaux+CERN EM group)
    - Thesis will end in 2023
  - > **Gamma models have been released, in the plan for this year for electrons**
  - > **Open.**

# 5009 : Extend energy and material coverage of G4-DNA beyond DNA and liquid water

- ◉ Originator:
  - > General demand
  - > Page 11 of [Requirements from Medical and bio science](#)
- ◉ Scope:
  - > Develop track structure models for specific materials (beyond liquid water and DNA)
  - > Extend energy coverage of existing models
    - Need to fill the gap from where DNA model stop (~100-500 keV) up to at least ~100 MeV.
- ◉ Responsible:
  - > Sébastien Incerti
- ◉ Status:
  - > Gold G4-DNA model has been included in 11.0 beta release.
  - > Will be continued this year (with, eg, DNA bases + sugar/phosphate).
  - > Open.

# 5010 : Physics models for ions below 1 MeV/u for Boron Neutron Capture

- Originator:
  - > General demand
  - > Page 12 of [Requirements from Medical and bio science](#)
- Scope:
  - > Allows usage of Geant4 in BNC therapy field
- Responsible:
  - > Sébastien Incerti & Jose Ramos-Mendez (University of California, San Francisco)
- Status:
  - > Work taken care by Naoki Domínguez (Ph.D. student at BUAP, México), and José Ramos (UCSF)
  - > In development since 2021, will be continued this year.
  - > Open.

# 5201 : To extend “force collision” biasing to charged particles

- ◉ Originator:
  - > NA62
- ◉ Scope:
  - > A “force collision” biasing scheme exists in Geant4, but is adapted to neutral particles.
  - > NA62 uses a K<sup>+</sup> beam
  - > A biasing with forced collisions for charged particles would allow for generating samples of useful statistics within a reasonable time to study the rare inelastic interactions in thin material in more detail.
  - > Space domain also expresses its interest for this (requirement session CM 2021)
- ◉ Responsible:
  - > Marc Verderi
- ◉ Status:
  - > Will be continued this year.
  - > Open.



# 5202 : Precision versus speed optimized EM physics simulation configuration for ATLAS

- ◉ Originator:
  - > ATLAS, from 2020 LPCC workshop
- ◉ Scope:
  - > The most precise Geant4 (`_EMZ`) EM physics option provides more accurate simulation results in some cases (compared to the standard EM option). However, this precision gain comes at the expense of a significant increase of the simulation time.
  - > The goal is to find the EM physics configuration that provides the optimum in terms of computing time and simulation accuracy.
- ◉ Responsible:
  - > Mihaly Novak
- ◉ Status:
  - > Effort started in 2021, the related studies and optimizations are ongoing together with our ATLAS colleagues.
  - > On-going, complex task. Will continue in 2022
  - > Open.

# 5203 : Improve the inelastic cross sections of $\bar{d}$ and anti\_He3 at low energies (< 1-2 GeV/c).

- ◉ Originator:
  - > ALICE, from 2020 LPCC workshop
- ◉ Scope:
  - > Inelastic cross-section of anti-deuteron and anti\_He3 is too low at low energies
  - > Likely, the same is needed for anti\_triton and anti\_alpha cross sections.
- ◉ Responsible:
  - > Vladimir Uzhinsky
- ◉ Status:
  - > Started in 2021 , will continue in 2022.
  - > Impact of war ?
  - > Open.

# 5301: Model for positronium (aka Ps) creation and annihilation

- ◉ Originator:
  - > David Sarrut and Lydia Maigne, on behalf of GATE community
  - > From CM2020 requirements session
- ◉ Scope:
  - > The  $e^+$  annihilation proceeds in tissue via Ps creation in > 40% cases
  - > Ortho-positronium (o-Ps; triplet spin state :  $s=1$ ;  $m=-1,0,1$ ) formed with 25% probability (in water)
    - Decay via  $2\gamma$  (pickoff) or  **$3\gamma$  (0.5% in tissue, 100% in vacuum)**
    - $\langle\tau\rangle$  o-Ps maybe correlated with metabolic disorders ( $\langle\tau\rangle$  depends on the size of the free volumes between atoms; varies from 142 ns in vacuum, down to below O(few10 ps) in matter).
  - > Feasibility study in Phys. Med. Biol. 64 (2019) 055017 to measure  $\langle\tau\rangle$  using o-Ps  $\rightarrow \gamma\gamma\gamma$  decay.
- ◉ Responsible:
  - > Vladimir Ivanchenko
- ◉ Status:
  - > Some implementation already in 10.7
    - 3- $\gamma$  annihilation is available in G4EmStandardPhysicsWVI Physics List
  - > One person now working on the topic
  - > Open

# 5302 : Extended example to directly retrieve Auger e- E & associated atomic transition

- ◉ Originator:
  - > Alfonso Mantero
  - > From CM2020 requirements session
- ◉ Scope:
  - > Have better/complete “MC truth” information for these emissions
- ◉ Responsible:
  - > Susanna Guatelli
- ◉ Status:
  - > In the work plan for this year to add a model sub-type
    - which will make it easy to identify Auger electrons.
  - > Seeking for a student to work on the topic
  - > Open

# 5303 : GIDI - LEND Models : install new GIDI when ready & validate with updated LEND

- Originator:
  - > From CM2020 requirements session
- Scope:
  - > Future of high precision neutrons looks like it will be GND (Generalized Nuclear Data)
    - New & simpler data format (will replace ENDF) & includes low- to medium-energy nuclear data
    - however, not as complete as ENDF
  - > Current LEND models in Geant4 are based on this
    - GIDI (General Interaction Data Interface) = interface between GND data and LEND physics models
      - Written in C
      - Many bugs uncovered by users and LEND validation effort
    - Livermore is writing a new, redesigned version in C++
  - > Makes this available when ready
- Responsible:
  - > Alberto Ribon
- Status:
  - > Was in the plan of work for 2021, but it is often postponed
  - > Livermore got some grant to work on this year
  - > Open

Requirements pending because  
of “Lack of resources”

# Valid requirements, but no resources to address them

- 5305, "Fix overproduction of n and p near endpoints of reactions at 4.5 GeV"
- 5304, "Beta-delayed Neutrons : develop understanding of highly excited level densities in nucleus and model neutron decay from this region"
- 5005, "Neutron self-shielding effect"
- 4005, "Neutron production in muon showers at the %-level"
- 4001, "Anti-proton production from proton beam (Mu2e request)"
- Contribution/resources welcome to address these requirements !