Open and New Requirements for HEP experiments

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Many thanks to..

- **ALICE:** Ivana Hrivnacova, Sandro Christian Wenzel
- **CMS:** Vladimir Ivantchenko
- **ATLAS:** John Derek Chapman, Tommaso Lari
- **LHCb:** Gloria Corti

ALICE Requirements (1/3)

- The **detectors cuts & thresholds** in the ALICE framework are defined in **energy per tracking medium** (= material in the context of Geant4)

  - In total: 363 materials, 333 user limits

- These are first **converted into the ranges**, then set to the regions defined according to the materials and then **converted** by Geant4 **into energy**

ALICE Requirements (2/3)

- **Problems:**
  - **Double conversion** Energy => Range => Energy is redundant
    - Geant4 provides only RangeToEnergy converters but not EnergyToRange, so we have to perform time consuming extrapolations to get the resulting energy match with the original one
  - The conversion takes **75%** of the total initialization time
  - 13% of the total simulation time of 100 "pythia8pp" events run time in serial mode and 41% of the total simulation time of the same run in parallel mode (8 cores) => **~ 4 % overhead in the future production (2000 events, 8 cores)**
  - The final energy threshold does not match exactly the initial value due to the approximations

ALICE Requirements (3/3)

- **New requirement:**
  - Have a possibility to define thresholds in energy
    - Either have a method per region & material to **set the cuts in energy**
    - Or have a possibility to **predefine G4ProductionCutsTable** with the energy thresholds that would not be then recomputed
  - Or, if none of the above cannot be done (?), *provide a fast **EnergyToRange** converter* that could replace our own computations

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CMS Requirements

- **Open requirement:**
  - **Extended decay module of Geant4**
    - More accurate branching ratios for baryons and mesons
    - Improved final state sampling
    - Addition of detailed tau, c-, and b- particle decays
      - Native or via interface to generator packages

- **No new requirements**

ATLAS Requirements (1/5)

- **Open Requirements:**
  - **TLS impact reduction:**
    Observed a decrease in performance when switching Athena r21 release from Geant4.10.1 to Geant4.10.6

G4 version	Event time	Slowdown
Geant4 10.1	193.6 +- 7.28	-
Geant4 10.1 MT	200.1 +- 7.525	3,35%
Geant4 10.6	198.6 +- 7.898	2,5%
Geant4 10.6 MT	195.3 +- 7.61	0,87%

- **Quasi-stable particle Simulation:**
  - Improved robustness of Geant4 when using pre-defined decay chains from Generators.
  - Establish conventions on consistency of decay models between G4 and Generators where there are overlaps
  - Dealing with hadronic interactions of oscillating neutral mesons
- **EM and HAD physics lists assignment** as fine grained as possible

- **Exotic particles simulation:**
  Many experiments need to simulate BSM particles. Individual experiments have implemented extensions to Geant4 to add support for additional particles and processes.
- Recently experiencing some issues with **monopoles**:
  - Use specialised equation of motion
  - Use the ClassicalRK4 and not the ATLASRK4
- **New requirement:**
  - Create a centralised repository for such modules that all experiments can benefit from/contribute to.
  - E.g. modules for R-hadrons, monopoles, quirks, etc.

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- **Support varying of detector geometry**
  - Increased use of data to model cavern/beam backgrounds and additional p-p collisions requires the simulation of the hard scatter to adapt event-by-event (or lumiblock-by-lumiblock) to the actual data taking detector conditions: alignment, beam spot, etc. in order to maintain consistency.
- **New requirement:** Support varying detector geometry in G4 and/or fast simulations in a fast enough way to be used in production jobs.

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ATLAS Requirements (4/5)

- **Radiation Modelling:** Geant4 10.6 and later versions showed more total ionizing dose (TID) and neutron fluence compared to Geant4 10.1.
  - TID difference was due to buggy treatment of final states (FS) in neutron capture for HP physics lists:
    - Fixed and patch provided to Geant4 collaboration and included in releases since May2022
  - There is a high discrepancy (~30%) between 10.1 and 10.6 (or 10.7 or 11.0) in terms of neutron spectra in HP physics lists.
    - G4 was already higher in neutron fluence compared to FLUKA for 10.1 and now is even higher
    - Major suspect: the caching code for Particle in the HP physics lists
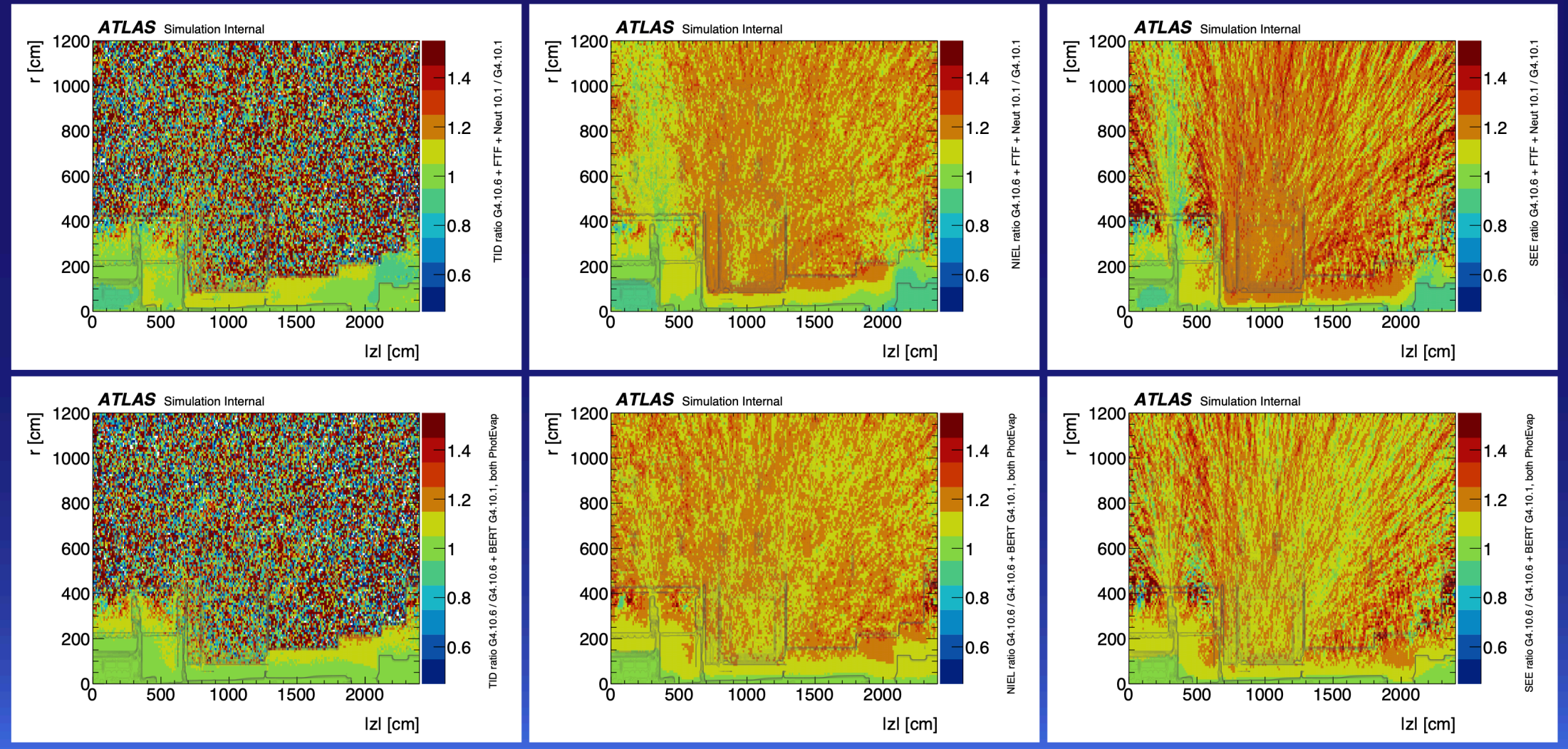- **New requirement: look at the HP physics lists (in particular at the caching code)**

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► 1st row: G4.10.6 over G4.10.1 (Run-2) ► 2nd row: G4.10.6 over G4.10.6 with old BERT (Run-3) – all with PhotEvap to avoid TID bug

LHCb Requirements

- No new requirements

Common Highlights

- Extended decay modules/interface to generators
- BSM physics centralised repository
- Fast simulation support
  - Intensive R&Ds ongoing in each experiment
  - Framework support and generic techniques such as biasing etc.
  - Flexible interfaces/frameworks for fast simulations (e.g. batching),
    - fast simulation engines might be very experiment specific?
- Interest in CPU/memory optimization improvements in Geant4
- Heterogeneous hardware interest is rising in all experiment collaborations
  - Intensive R&Ds ongoing in each experiment

Thanks to the Geant4 experts for the fruitful collaboration and their constant support!

Thanks for your attention.

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Backup slides

CMS Requirements

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- **New requirements:**
  - **Heterogeneous and FastSim features configurable** per detector region and energy range
  - **Specialized geometry and navigation** components (navigation with knowledge of geometry structure)