Open and New Requirements for HEP experiments

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ALICE requirements (1/2)

OPEN requirement: Energy Thresholds

- 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
- The time overhead reported at the CM last year (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)) was caused by redundant computation of cuts:
  - Computation happened in a loop over all logical volumes the materials already processed were not taken into account. The issue is understood now and there is **no performance penalty**
- **Problems that remained:**
  - Double conversion Energy => Range => Energy is redundant
  - The final energy threshold does not match exactly the initial value due to the approximations

ALICE requirements (2/2)

- **Updated 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

- **Recently closed 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
  - Available solution as interface to PYTHIA.

- **No new requirements**

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ATLAS requirements (1/3)

- **Quasi-stable particle Simulation requirements:**
  - 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

- **UI commands to set the FTF parameters:**
  - ATLAS has observed a degradation of pion energy resolution of ~20% in Geant4 10.6 w.r.t. Geant4 10.1
  - Lorenzo and Alberto provided a solution by tuning the FTF parameters
    - *Many thanks to both!*
  - **Requirement**: introduce UI commands to tune those parameters

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ATLAS requirements (2/3)

- **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 issues with **monopoles, debugged and solved**:
    - *Thanks to John A. for his help!*
- **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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ATLAS requirements (3/3)

Open Requirement:

- **Radiation Modelling:** Geant4 10.6 and later versions showed more total ionizing dose (TID) and neutron fluence compared to Geant4 10.1.
  - 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
- **Requirement: look at the HP physics lists (in particular at the caching code)**
  - Update: The recent investigation on the hadronic physics list by Lorenzo might have an impact, study is ongoing

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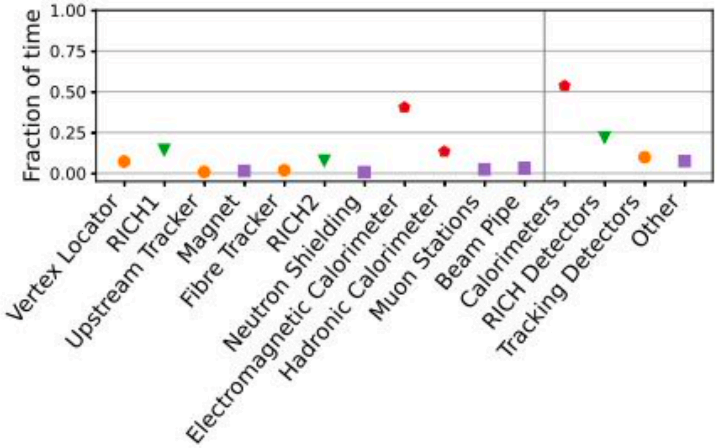
LHCb: Optical photons



- In **LHCb** the **computational resources** for the full simulation based on Geant4 are dominated by the calorimeters and the two Ring Imaging Cherenkov (RICH) detectors
- The LHCb Collaboration is currently investigating **various approaches (fast simulations, hybrid workflow with GPUs etc.)** to improve the computation time in these sub-detectors
- Some **simple optimization strategies** of the optical processes have been adopted in order to reduce the number of optical photons to be propagated
- In particular the `G4Cerenkov` class has been modified in order to limit the volumes where the OP are generated, even if the volumes are made by a material provided with RINDEX
- Indeed there are parts of the RICH volumes where, due to geometrical reasons or to the efficiency of the photon detectors, no usable information can be obtained by OP generated inside those parts
- **If this approach could be of wider interest the switch off of the Cherenkov effect could be controlled by a true/false flag associated to the logical volume**

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LHCb: Particles unknown to Geant4

- Work is in progress to address the problem of **exotic particles**, **excited B and ions**, often produced at generator level, which are not known to Geant4
- The standard Geant4 approach is to create a unique static object derived from the `G4ParticleDefinition` class for each new particle
- Unfortunately to accommodate all the possible cases the creation of hundreds of classes is required
- **A first attempt to create dynamically the "unknown" particles failed** → Must be done at initialization
- The adopted solution is to implement at initialization all the particles known to the LHCb ParticlePropertyService (not creating however a specific class for each particle, just an appropriate instance of `G4ParticleDefinition`)
- The situation is **different for the unknown ions**, in this case an abstract prototype exists, the `G4GenericIon` which is created by default, and has all the processes already attached
- The new, unknown, ion can therefore be dynamically created on top of `G4GenericIon` using the `GetIon` method of the `G4IonTable` class
- **A similar approach with a "`G4GenericParticle`" prototype created by default at initialization time, could be a solution to this problem with the advantage of reducing the size of the `G4ParticleTable`**

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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? Closer collaboration to the experiment highly desirable
- Interest in CPU/memory optimization improvements in Geant4
- Heterogeneous hardware interest is high in all experiment collaborations
  - Intensive R&Ds ongoing in each experiment

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

Thanks for your attention!

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Backup slides

ATLAS requirements

► 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