



Open and New Requirements for HEP experiments

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Many thanks to..



- **ALICE:** Ivana Hrivnacova, Sandro Christian Wenzel, Andreas Morsch
- **CMS:** Vladimir Ivantchenko
- **ATLAS:** John Derek Chapman, Michael Duehrssen

ALICE Requirements



- Proposal to close the pending requirement from ALICE for the support for "sub-event" parallelism across G4 threads, as not needed WITHIN Geant4
 - Production system managing sub-events outside of the transport engines.
 - Nevertheless the functionality would be very useful for other experiments
- No new requirements

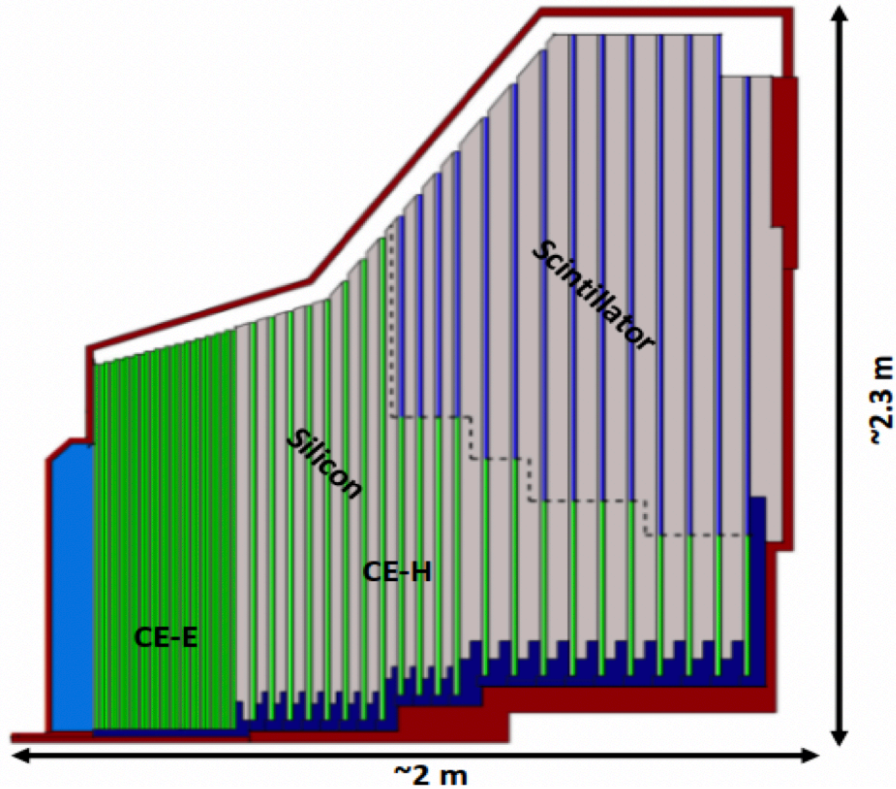
CMS Requirements (1/3)



CMS Phase-2 Upgrade

- Include new detectors with higher resolutions and better radiation hardness
 - Phase-2 Tracker
 - Time of flight (MTD) detector
 - Endcap calorimeter (HGCAL)
 - Muon detectors (GEM)
- Current FullSim for Phase-2 CMS is about 2-3 times slower than simulation for Run-3
 - CMS requires more performant Geant4
 - CMS requires adequate quality of physics for the simulation of the new detectors responses

CMS Requirements (2/3)



Electromagnetic calorimeter (CE-E):

Si/CuW/Pb absorbers 28 layers, $25.5 X_0$, 1.7λ

Hadronic calorimeter (CE-H):

Si & scintillator, steel absorbers, 22 layers, 9.5λ

HGCal - Phase-2 CMS Endcap Calorimeter

- For HL-LHC a new endcap calorimeter is under design and development
- Will provide higher resolution w.r.t the existing CMS calorimeters
- Will provide a possibility of high-quality particle flow analysis
- Simulation precision must meet the mark for new, high performing detector
 - Improved simulation of high and medium energy hadron/nuclei interactions for HGCal materials
 - Maximally explore high granularity for the particle flow analysis and pattern recognition

CMS Requirements (3/3)



Geant4 improvements for CMS

- Heterogenous and FastSim features should be configurable per detector region and energy range
 - Geometry, navigation, physics
- Specialized geometry and navigation components (navigation with knowledge of geometry structure)
 - Phase-2 CMS has ~2 times more physical volumes and ~1.5 more logical volumes mainly due to HGAL
- 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

ATLAS Requirements (1/5)



- **TLS impact reduction:**

Observed a decrease in performance when switching Athena r21 release from Geant4.10.1 to Geant4.10.6

- Geant4.10.1 compiled with MT support OFF, Geant4 10.6 compiled with MT support ON
- Test on a dedicated machine with turboboost and hyper-threading turned off
 - 100 tt-bar events in Athena r21

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%

- **More Generally:**

Speedup observed with *FullSimLight* (full ATLAS Geometry + MagField) and other simplified setups, is not visible in Athena (i.e. G4.10.6 vs G4.10.7)

- Ideas on possible reasons/investigations?

ATLAS Requirements (2/5)



- **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.

- **Suggestion:**

- Create a centralised repository for such modules that all experiments can benefit from/contribute to.
- E.g. modules for R-hadrons, monopoles, quirks, etc.

ATLAS Requirements (3/5)



- **Quasi-stable particle Simulation**

Working definition for Run 2 and Run 3: Particles considered unstable by the Generator, but which propagate through at least one sensitive detector layer.

Requirements:

- **Improved robustness of Geant4 when using pre-defined decay chains from Generators.**
 - Perhaps implementing some kind of sanity checker for G4Events with pre-defined decays to spot potential problems. (Unknown particle types, particles with no physics models attached, zero lifetime particles.)
- Establish conventions on consistency of decay models between G4 and Generators where there are overlaps?
 - Or possibly common work to directly integrate event generators for certain decays and interactions?
- Dealing with hadronic interactions of oscillating neutral mesons

ATLAS Requirements (4/5)



- **Support varying of detector geometry**
 - **Conservative R&D:** ATLAS would overlay simulated interactions on zero-bias Heavy Ion data events to capture the underlying event.
 - **Aggressive R&D:** ATLAS could overlay hard-scatter MC events on zero-bias p-p data events to include the effects of pile-up.
 - **Request:** Support varying detector geometry in G4 and/or fast simulations in a fast enough way to be used in production jobs.
 - 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.

ATLAS Requirements (5/5)



EM physics tuning:

- Very good interaction with the G4 experts (**many thanks!**) on the EM tuning study
- Very good feedback there and definitely want to continue these investigations
- Might need to tune the physics processes depending on different detectors and regions
 - Possible for EM physics processes, what about HAD?
- **Suggestion/Request:**
 - The more fine grained the EM and HAD physics lists can be assigned, the better for the future

Interest in testing/integrating G4HepEM library in FullSimLight/Athena

Common Highlights



- 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 developers for their constant support and precious help!

Thanks for your attention.

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Backup slides
