GPU Acceleration in Geant4 Simulations

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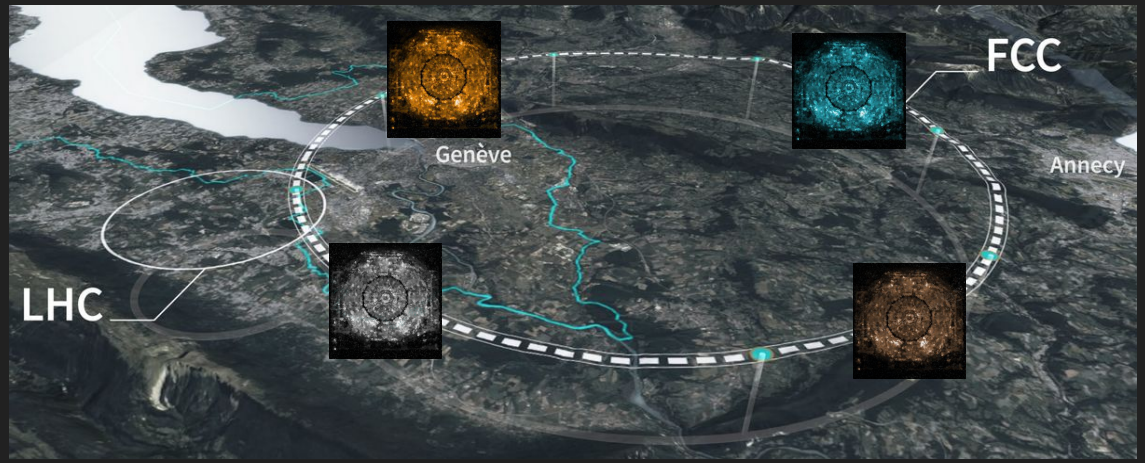
Detector R&D

Tools such as Geant4 enable high energy physics and related fields to optimize detector technologies for scientific reach, cost and performance, and to evaluate the significance of experimental measurements.

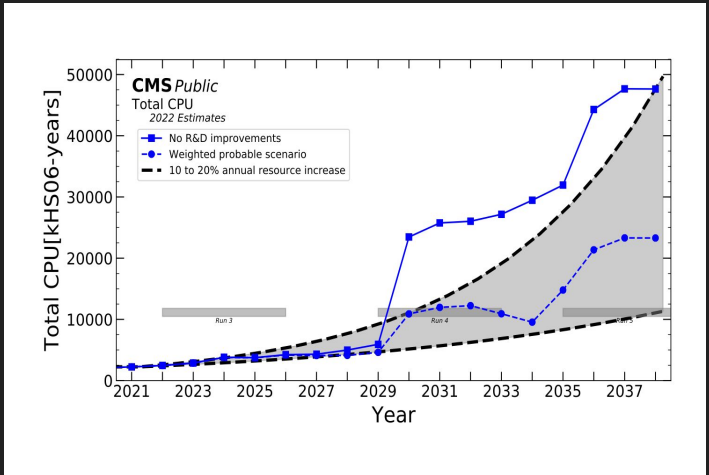


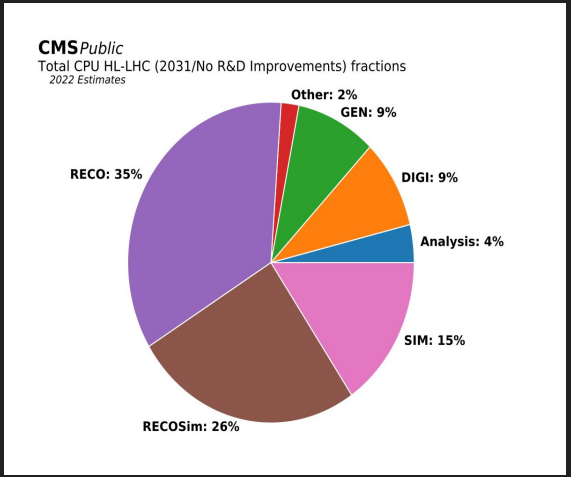
Future detectors for FCC-ee will require the development of new, high precision detectors to maximize the impact of measurements in the electroweak sector.

For example among the four complimentary detectors planned, the IDEA dual-readout calorimeter will seek to achieve unprecedented precision in jet measurements.

Improvements in optical simulation and modeling of hadronic interactions directly benefit its design and physics performance studies. However, simulations are resource intensive!

Forecasting Computing Budgets Case Study: CMS





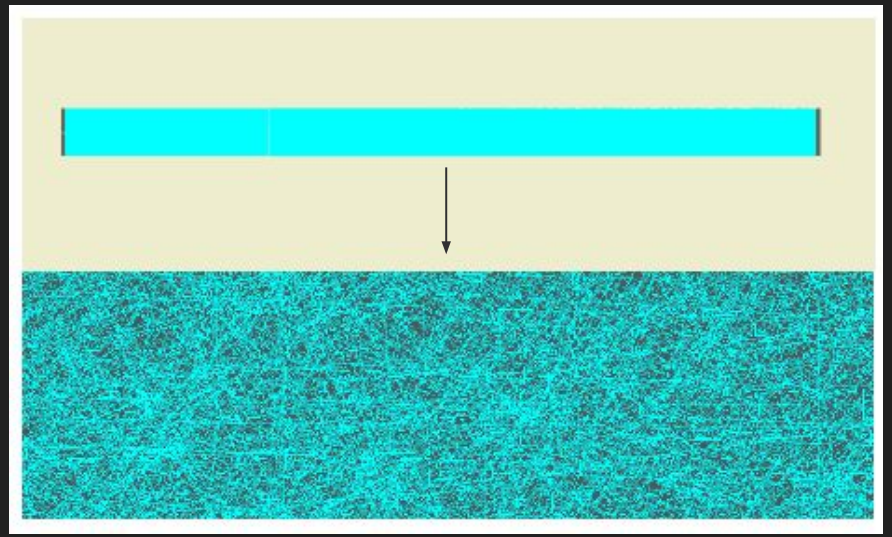
https://cds.cern.ch/record/2815292

As experiments scale, computational requirements also grow.

CMS predicts that more hardware alone won't be enough: R&D is necessary to meet data demands! Multiple domains need to be targeted, including simulation, reconstruction, and analysis.

Example of challenges: Optical Photon Simulations in Geant4

- State of the art resolution calorimetry for both e/γ and jets is possible utilizing dual-read of scintillation and Cherenkov light in a homogeneous ECAL + fiber HCAL detector [arXiv:2203.04312]
- Effects of design choices on light collection must be well understood and modeled



1 GeV muon in lead tungstate

~21,000 Cerenkov photons

~120,000 Scintillation photons

→ Lots of computing power required!

GPU Acceleration: Celeritas

Utilize existing specialized hardware to speed up computations by offloading tracks to GPUs:

- Expand Geant4 simulation capabilities in a hardware independent manner
- Development team spans ANL, BNL, FNAL, and ORNL
- Currently supports high energy EM processes
- Optical photon transport under development
- Future goals include hadronic transport and processes

https://celeritas.ornl.gov

Needs for New Developers

To meet computation goals, young researchers need new skills:

- High performance computing (HPC)
- GPU development

Benefits:

- The US should maintain expertise and a leadership role in future developments and keep up with international progress (AdePT at CERN)
- Universities can partner with national labs and supercomputing computing facilities to address both the physics models and technical aspects of improving and accelerating the performance of the code base.
- Unique training ground for young physicists to focus in HPC and the physics of detectors