



ECHEP Simulation Update

Ben Morgan and Adam Davis

Overview of ECHEP Activities

- Meetings held on Simulation:
 - *May 1 - Summary of Full/Fast Simulation efforts*
(<https://indico.cern.ch/event/914053/>)
 - *May 22 - Towards a fast simulation of light detection in LAr TPCs with deep learning*
(<https://indico.cern.ch/event/919221/>)
- ECHEP Area Leader Meetings
- Summary document in progress on information collected through above and other discussions
- Presentations today on UK/International work on simulation topics

International Context

- Simulation and Event Generators the two major consumers of offline CPU
- In Simulation, performance improvement studies are taking place along three broad lines
 - *Development of core Geant4 toolkit, ongoing optimization plus internal architecture review/updates for better CPU usage, compatibility with Accelerators*
 - *Offloading of most computationally expensive physics/tracks/regions to “Fast” methods*
 - *R&D on algorithms/methods for particle transport on Accelerators*
- Important to note these work together: e.g. feedback useful R&D outcomes to Geant4 (such as VecGeom)

Where does UK effort fit in?

- Contributions to Geant4 development
 - *2 non-fulltime STFC researchers, ~3 medical/space*
- Development and integration of Fast Simulations for specific experiments
 - *Wide range of methods and integrations with their Full Sim*
- R&D on/use of accelerators for full simulation
 - *Excalibur-HEP work package on EM Physics on GPU*
 - *Edinburgh/NVidia/VecGeom project on tessellated geometry for ATLAS LAr Calorimeter*
 - *Both linked in with Geant4 R&D Task Force, HEP Software Foundation Sim WG, and US Exascale Project (ORNL/FNAL)*
 - *Use of Opticks for photon transport in LHCb*

Full Simulations

- **Critical points here:** no silver bullet, and no accurate numbers on achievable speedups from Accelerators
- Highly geometry/physics domain dependent
 - *E.g. CMS gains ~10% using VecGeom, ATLAS ~3%*
 - *Neutral particles/Lower energy EM/simpler geometries more amenable (e.g. Nuclear/Medical)*
- Speedups from SIMD/GPU can be negated by:
 - *Data transfer bottlenecks (organizing computation)*
 - *Thread divergence from branches in physics models*
- ***Focus of R&D is thus on small prototypes to explore and profile, not solve everything at once, or by ourselves***
- ***Geant4 needs core effort to identify, develop, and profile new features and architectural changes***

“Hybrid” Simulations

- Fancy term for a Full+Fast Simulation where the “Fast” component is **offload of specific particles/regions to GPU for full particle transport** rather than a parameterized model.
 - *E.g. $e^+/e^-/g$ in an EM calorimeter*
- Appears to be the direction/approach of most R&D efforts as easier starting point, and easier to deploy if successful
- Commonalities with parameterized Fast Sim
 - *Both require Geant4 code/documentation to ensure easy offload of particles, onload of results*
 - *Both may trade precision for speed - how to quantify what is acceptable?*

Hybrid Example - OptiX/Opticks

- Optical photons highly amenable to GPU transport
- Opticks package originally developed for Juno
 - *Offloads photon-generating steps to GPU*
 - *Photon generation, transport, scoring of PMT hits on GPU*
 - *PMT hits transferred back to CPU*
- Used/under investigation by other experiments
 - *See talk by Sajan on LHCb use*
 - *DUNE also investigating*
- **Feedback from Opticks on its future**
 - *Currently lacks manpower for further support/development*
 - *Short term goal would be to have Geant4 example demonstrating integration*

Fast Simulations

- Full/Fast simulation dichotomy is a false one
 - *Full sim data to tune/train Fast Sim (Hybrids can help?)*
 - *Active area for a long time, with a variety of techniques:*

Table 1: Summary of Fast Simulation Techniques by experiment in HEP.

Experiment	Fast Simulation Technique						
	GAN	Neural Networks	VAE	Library	Partial Parametrization	Full Parametrization	Multithreading
ATLAS	[9, 10]		[9, 10]		[10]		
CMS					[11]		
LHCb	[12]			[13]		[14, 15]	[16]
ALICE					[17]		
LZ				[6]			
DarkSide	In Devel.						
DUNE				[18]			

- No one method - common requirement is method agnostic hooks/tools in Geant4 for training/inference
- See talk by Stephen on implementations for Dark Matter detection

Future Outlook

- UK contributing at low level to core Geant4 development and R&D efforts on Full Sim for GPU
 - *Excalibur-HEP work proposed to continue and/or through Swift-HEP, build on links with Geant4 R&D/HSF/US Exascale*
- Opticks use in HEP/Other, could UK actively contribute more back through Geant4 contribution?
 - *Useful “Hybrid” system, Ray Tracing for charged particles?*
- Wide range of experience in Fast Sim methods, but quite experiment specific
 - *Main common area is with integration with, and tooling for training/development, Full Sim through hooks*