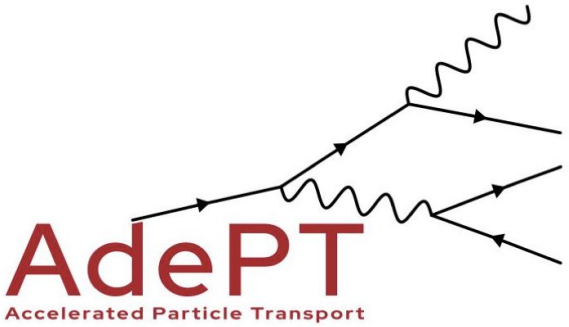


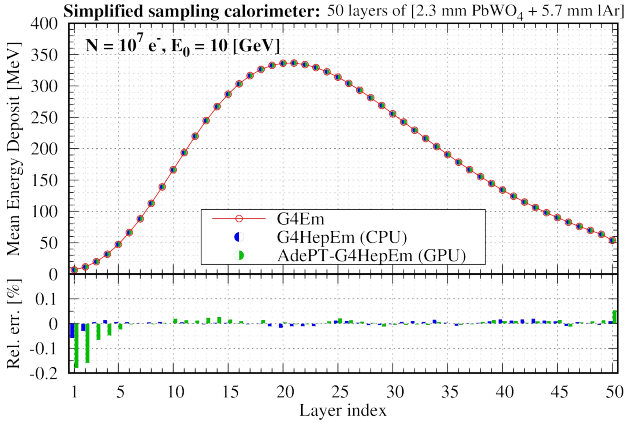
AdePT status report

Jonas Hahnfeld for the AdePT team

28.09.2023

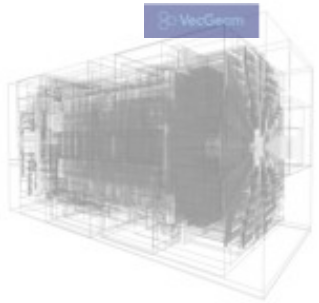
28th Geant4 Collaboration Meeting

AdePT project overview



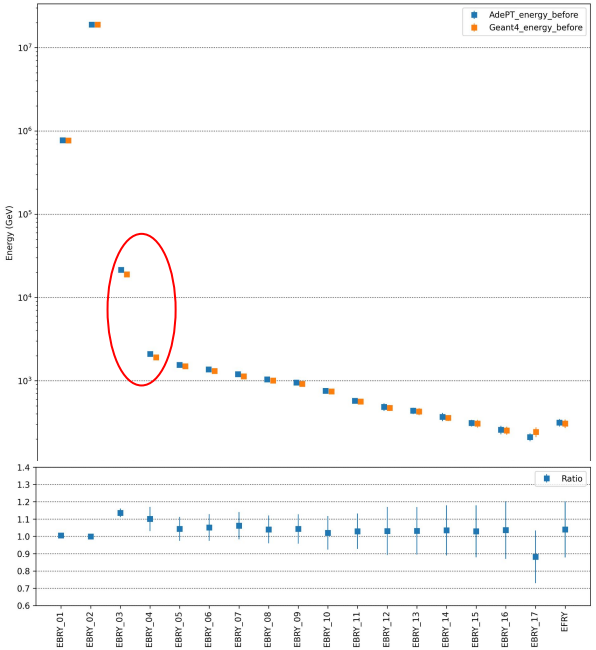
- Project targets:
  - Demonstrate EM shower simulation on GPUs
  - Integrate in a hybrid CPU-GPU Geant4 workflow (using Geant4 fast simulation hooks)
- GPU workflow very different than Geant4 on CPUs:
  - Step all active tracks at the same time
  - One “big” kernel per particle type (electron, positron, gamma)
  - RNG state per track to ensure reproducibility
- Validation against Geant4 and G4HepEm on CPU is essential
  - Previously done for simple geometry setups

Work on GPU geometry

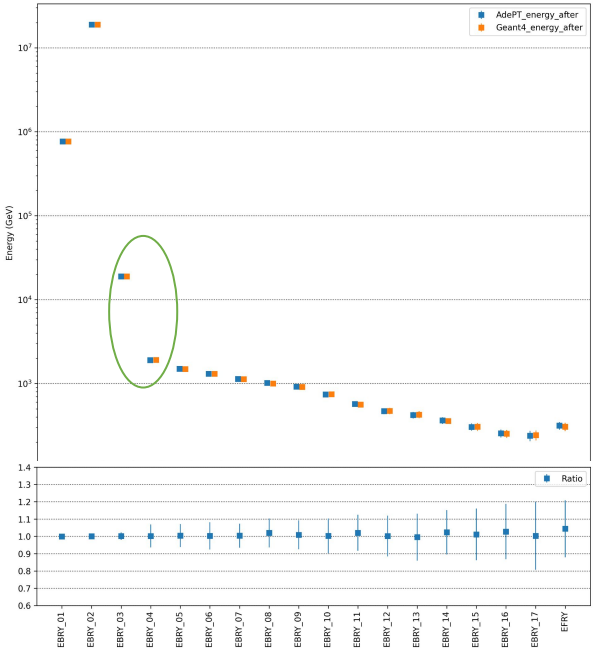


- GPU port of VecGeom to model detector geometry
  - Critical for complexity level of LHC experiments
  - Solid implementation used by both AdePT and Celeritas projects
  - Allowed benchmarking setups as complex as CMS or LHCb
  - Major source of inefficiency and thread divergence on GPU
- Continuous work for bug fixing and improvement
  - Recently solved bugs in Boolean solids (rotations, extent calculations)
    - Contributed to discrepancy of energy deposit in CMS integration example
  - Fixing these allowed validating the current version of AdePT integration

Fix of long standing CMS bug

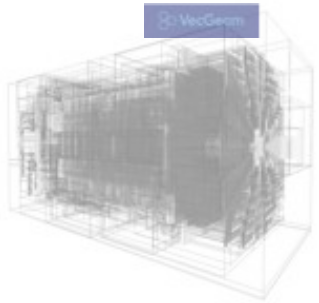


Energy deposits before the fix



Energy deposits after the fix

New surface model

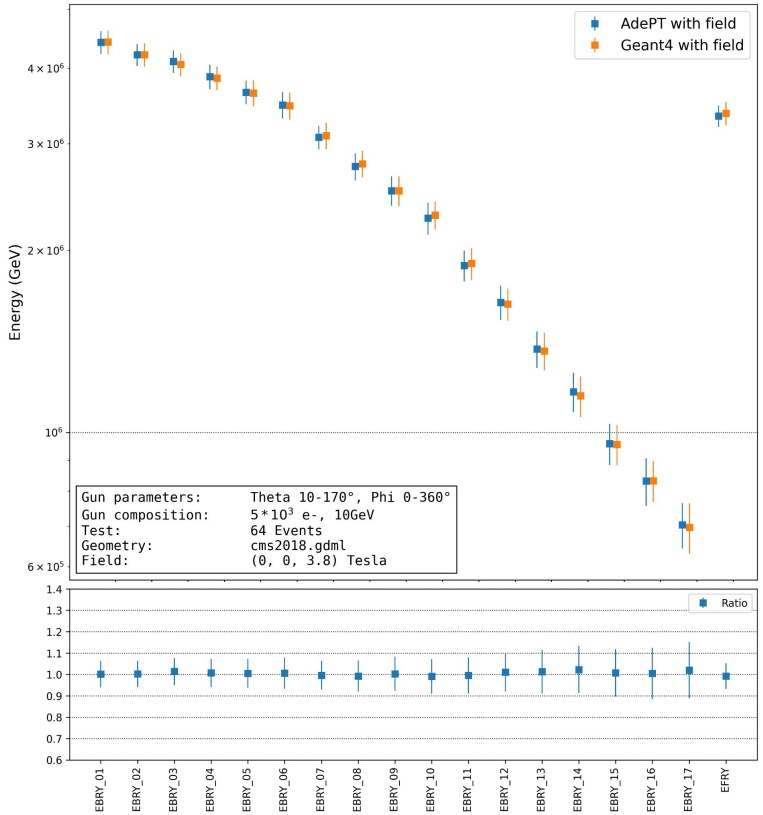


- Started >1 year ago a new surface model
  - Based on bounded surfaces (see also geometry session)
  - Combine successful features from graphics and Geant4:
    - Decompose 3D objects into accurate bounded surface types
    - Preserve hierarchic constraints of Geant4
- Header library implementation for GPU performance & portability
  - Eliminated recursions and virtual calls
  - Faster relocation, better scaling features and work balancing
  - Set of supported 3D solids increasing:
    - box, simple and general trapezoids, parallelepipede, tube, cone, polyhedron
    - Working on extruded, polycone
- Targeting a realistic complex setup test by the end of the year

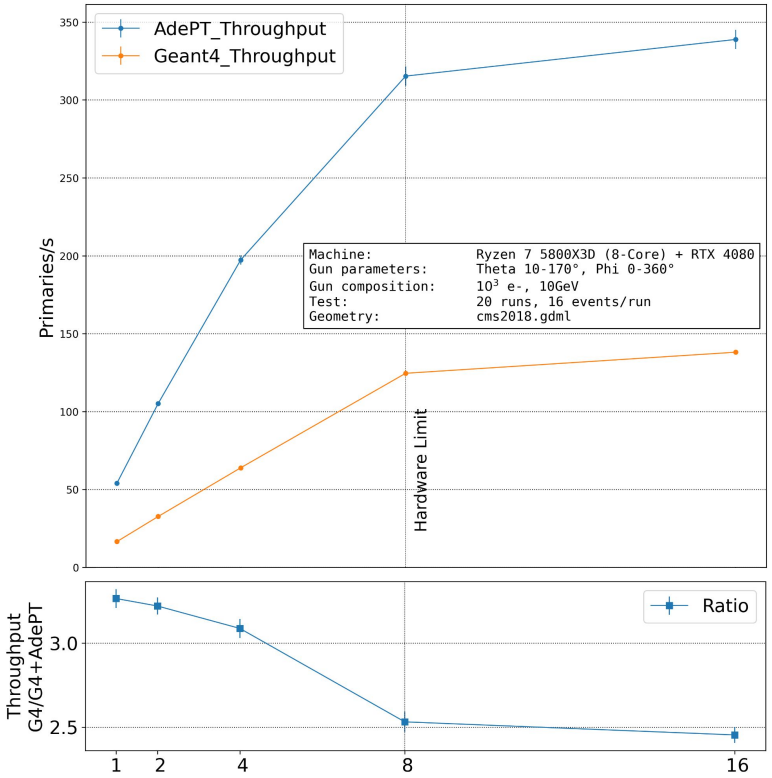
New test tools

- Tools for benchmarking and validation
  - Timers, accumulators, export of results
  - Adapted to the needs found for AdePT
- Implemented in one of the integration examples
  - Easier extraction of in-detail data for further analysis
  - For example time spent simulating leptons inside the CMS ECAL
- Python scripts for automated testing and validation
  - JSON test configurations for easy setup and sharing
  - Automatic plotting of the results

Validation with constant magnetic field



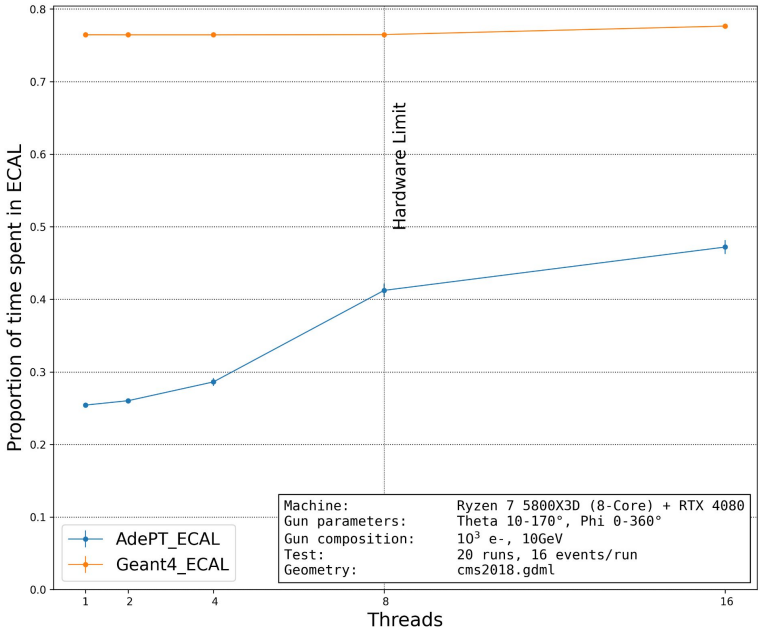
Some benchmarking results



Geant4/AdePT throughput

Some benchmarking results

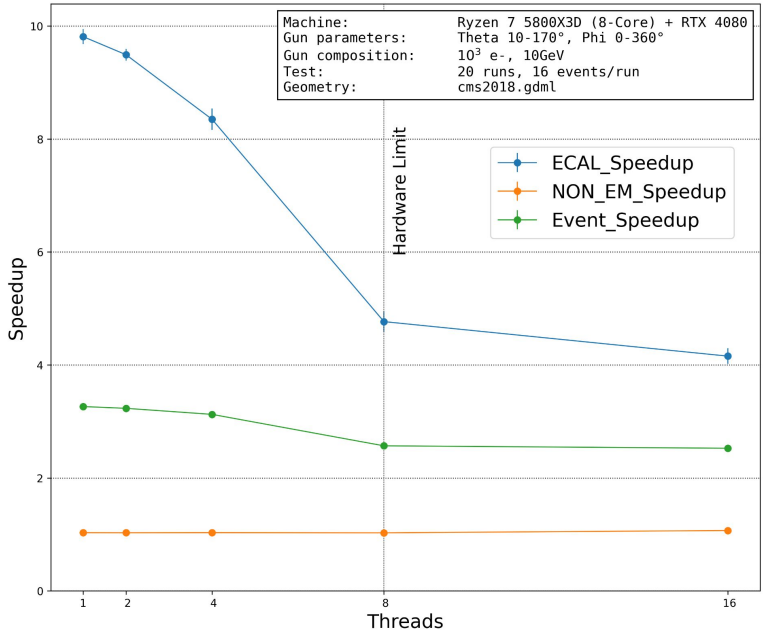
- Measure fraction of time spent simulating leptons in the ECAL
- Compare original fraction with Geant4 with improvement by AdePT



Proportion of time spent simulating leptons in the ECAL

Some benchmarking results

- Speedup of the ECAL simulation and overall event speedup
  - AdePT does not affect the rest of the simulation, 1:1 ratio in the time spent outside the ECAL
- Vary number of Geant4 worker threads
  - Decreasing AdePT speedup as the GPU becomes more saturated



Speedup of the ECAL simulation and overall per-event speedup

Integration with experiments – Motivation

- Identify problems and challenges related to the consolidation of the different components
  - Libraries incompatibilities, linking problems, etc
- Test AdePT in more complex setups
  - Geometry, particles input/output, etc
- Study the requirements for realistic sensitive detectors
  - Challenge and a limiting factor for the performance

ATLAS TileCal test beam

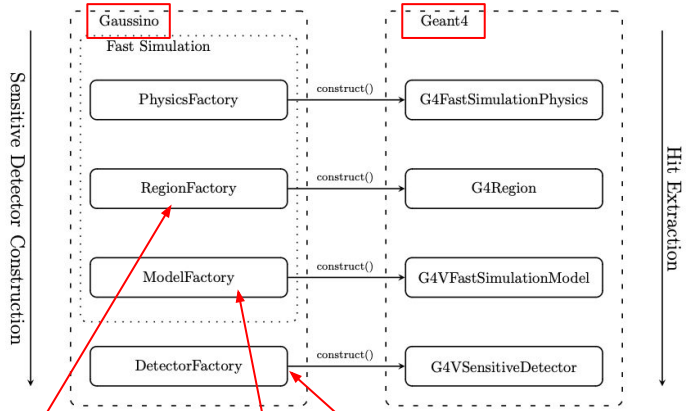
- Standalone Geant4 simulation by Stephan Lachnit, Lorenzo Pezzotti
  - https://github.com/lopezzot/ATLTileCalTB, see also talk in hadr. plenary
- “Trying out AdePT with ATLAS geometries” by Davide Constanzo
  - See https://indico.cern.ch/event/1215829/contributions/5306569/
- First experiments with sensitive detector / scoring code
  - Comparing total energy deposit per module depending on gun placement
  - Started looking into lookup tables for cell ID
- Recent push to also implement as FullSimLight plugin (cf. Celeritas)

Integration with CMSSW

- G4HepEm on CPU integrated since October/November 2022
  - Available as special physics list using the G4HepEmProcess
  - Now also implemented as option with custom tracking managers
    - Only replace electron/positron tracking below 100 MeV
    - Reason: can ignore leptonuclear process
  - Sensitive detector code works, gets all necessary data
  - Pending MSC configuration per region and more complete validation
- Ongoing discussions on required simulation output in HGCal
  - Good: no detailed per information needed for EM particles

LHCb Gaussino integration

- Combine AdePT Example17 with Gauss-on-Gaussino machinery
- Fill AdePT pipeline with particles entering the LHCb calorimeter region
- Generate Gauss hits from AdePT
  - Should be equivalent to plain Geant4
- Working with LHCb doctoral student Juan Bernardo Benavides



Define region for AdePT

Plug in AdePT

Implement a special 'sensitive detector' to create Gauss hits

Ongoing and future work

- GPU geometry model
  - Taking most of the development effort
  - Larger collaboration would accelerate reaching the common goals
- Validation and optimization for non-constant field implementation
- Integration with experiment frameworks and validation
  - Still in a very early stage, hoping to get more momentum soon

Summary

- Work focused on simulation robustness, validation, benchmarking
  - Validation of EM shower in complex CMS geometry now complete
  - Getting better understanding of performance in the current approach
- Most of the development effort spent on new surface model
  - On the way to providing complete functionality and better solid coverage
  - See details in the geometry session
- Geant4 review of GPU activities in December
  - A forum for discussions on technical topics and finding common grounds
  - Hopefully converging towards a single GPU project