Towards a Geant4 ATLAS LAr Barrel Validation Test

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About a Geant4 ATLAS LAr barrel test

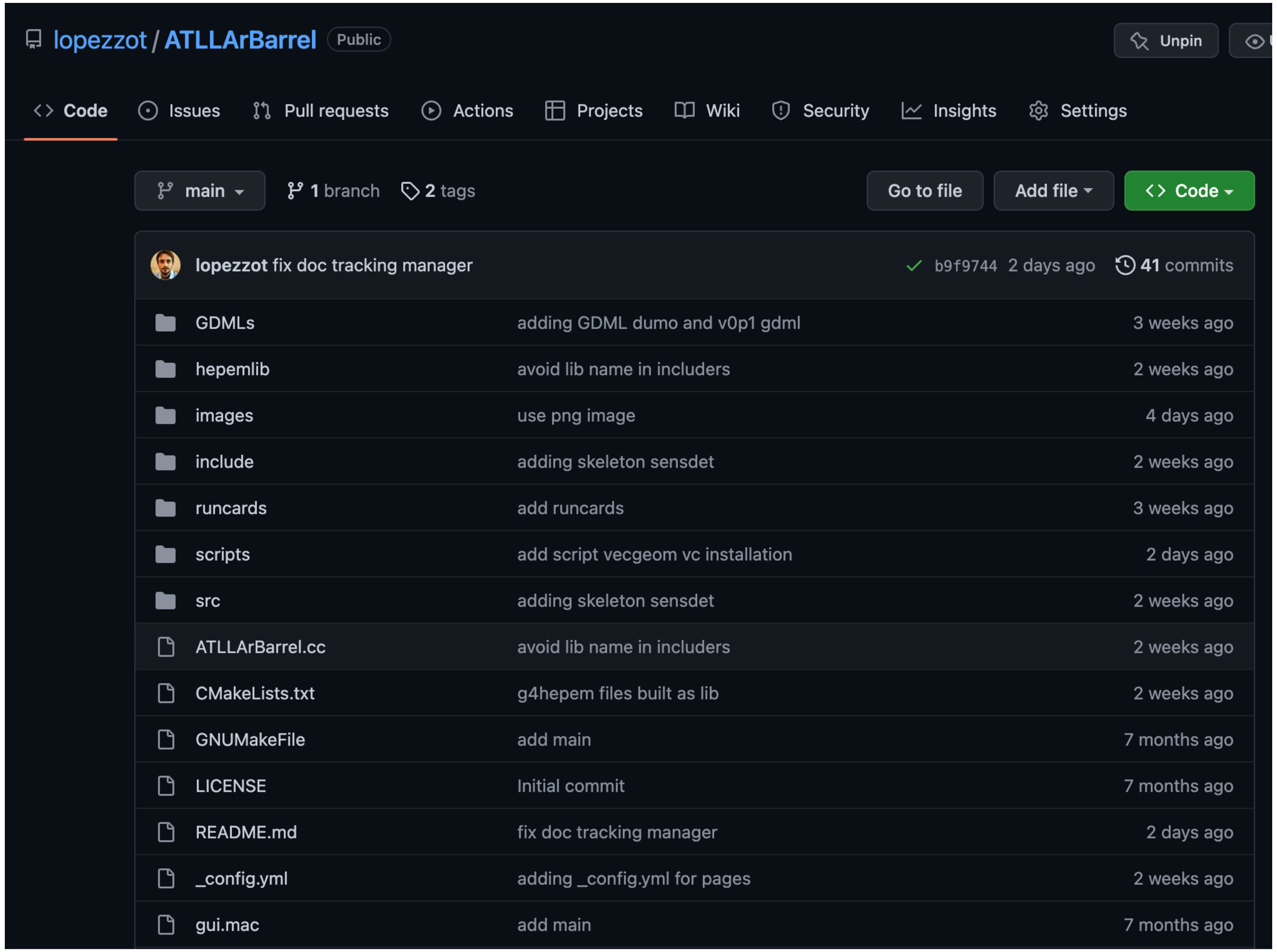
- A JIRA ticket to *create realistic setup for testing of EM showers in ATLAS EM-Barrel geometry* is open on GEANT4-SIM JIRA since 2017.
- The ATLAS LAr test-beam setup is the ideal framework to accomplish it.
- However, as far as I know, ATLAS is no longer using/validating the simulation of the LAr barrel test-beam → little expertise preservation.
- A standalone Geant4 test can only target:
  - Geant4 version control and
  - physics list comparison (EMZ, EMY, …)
- Most EM-shower generation happens in the LAr barrel geometry → there is where we have to speed up the simulation the most.
  - We need a testbed for testing our speeding up solutions.
  - Both Adept and Celeritas expressed their interest for such a test (ATLASAdept-presentation, Celeritas-presentation).

How…

- Start from the ATLAS LAr original code (same code used for the new Geant4 ATLAS HEC validation).
- Isolate the LAr barrel test-beam geometry (by G. Unal *et al.*) from the other detectors.
- Remove GeoModel dependency → use only G4Solids.
- Remove ATLAS Detector Description Database dependency → hardcode numbers.
- Make Geant4 the only **REQUIRED** package
    - Add optional dependencies of interest, *e.g.*
        - G4HepEM
        - VecGeom

ATLLArBarrel

- New Github repo contains our work in progress.
- Currently in pre-release:
  - geometry completed,
  - tested with 10^6 events with no crashes and no warnings,
  - added G4HepEm related files as optional library compiled with
    - `-DWITH_G4HepEm=ON`
    - `-DWITH_G4HepEmTracking=ON`
  - tested with VecGeom with both scalar and vector backend.
- Need guidance from ATLAS for SensitiveDetector implementation.



The geometry

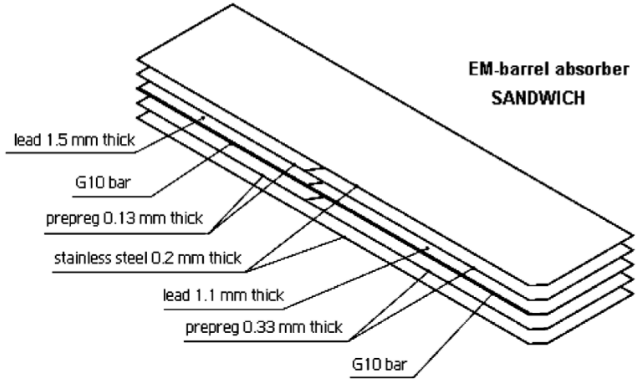
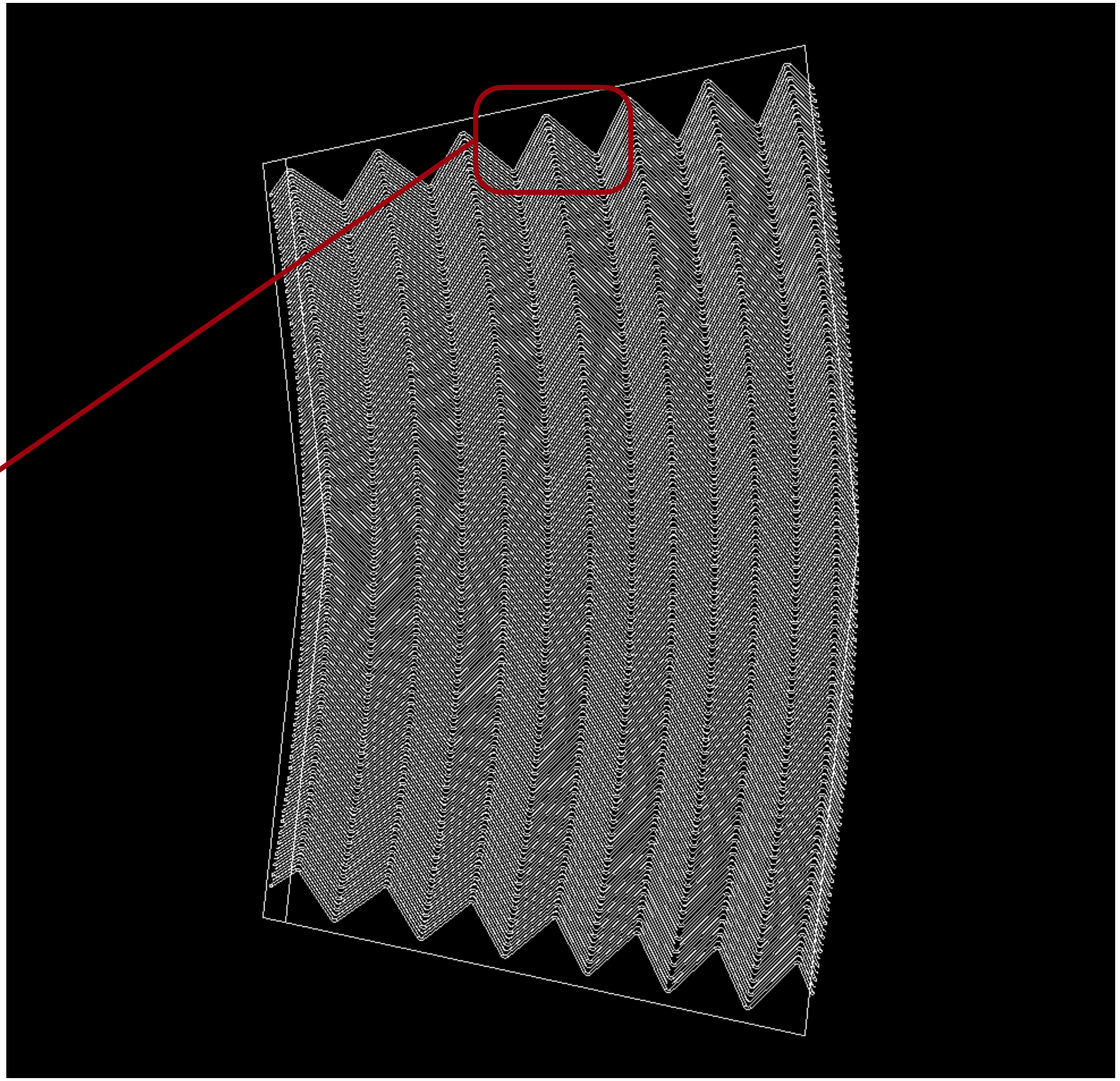
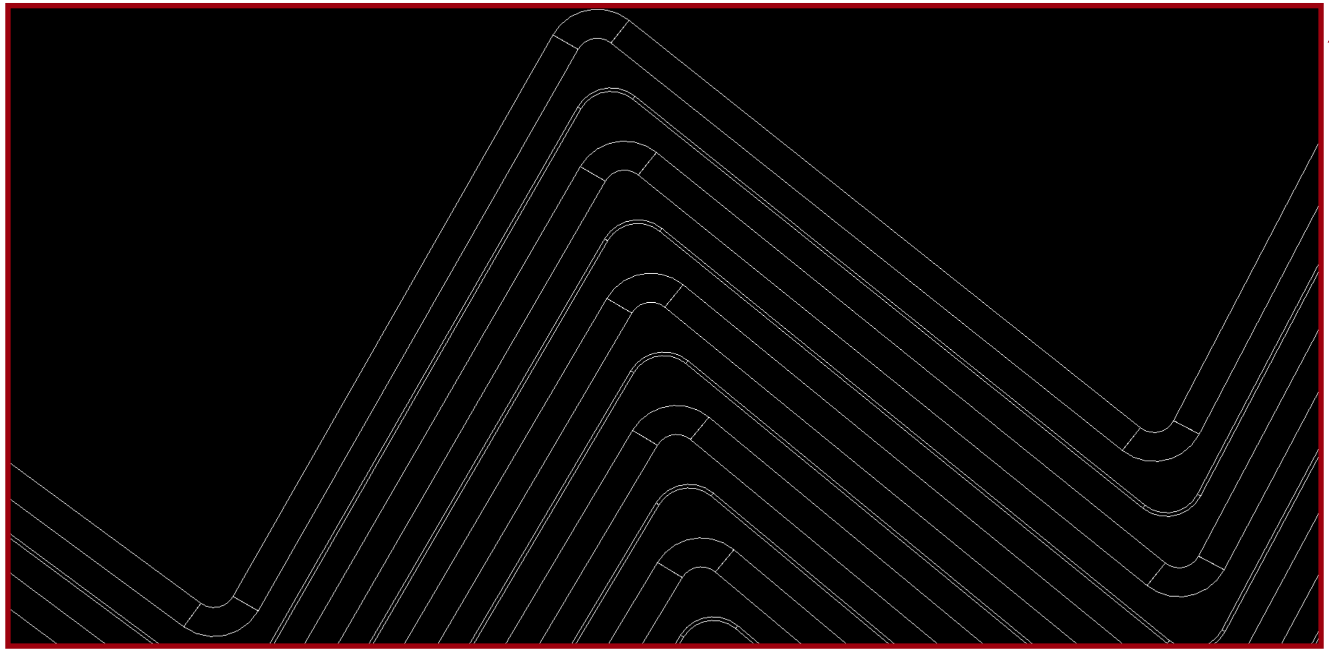


Fig. 3. The upper figure shows the absorber profile and a sketch of a stack of five absorbers. The lower figure shows the piling up of the absorber sandwich with the two lead thicknesses, before folding the absorber in an accordion shape.

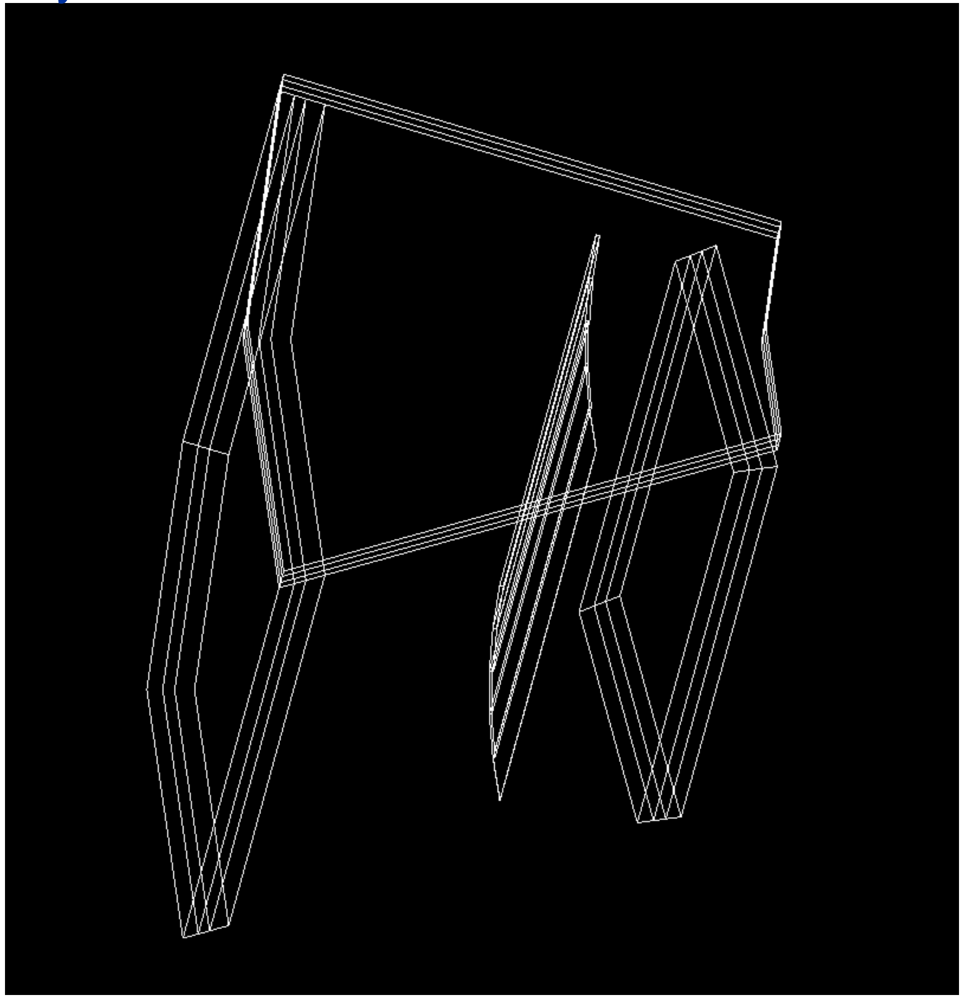
EMB::STAC



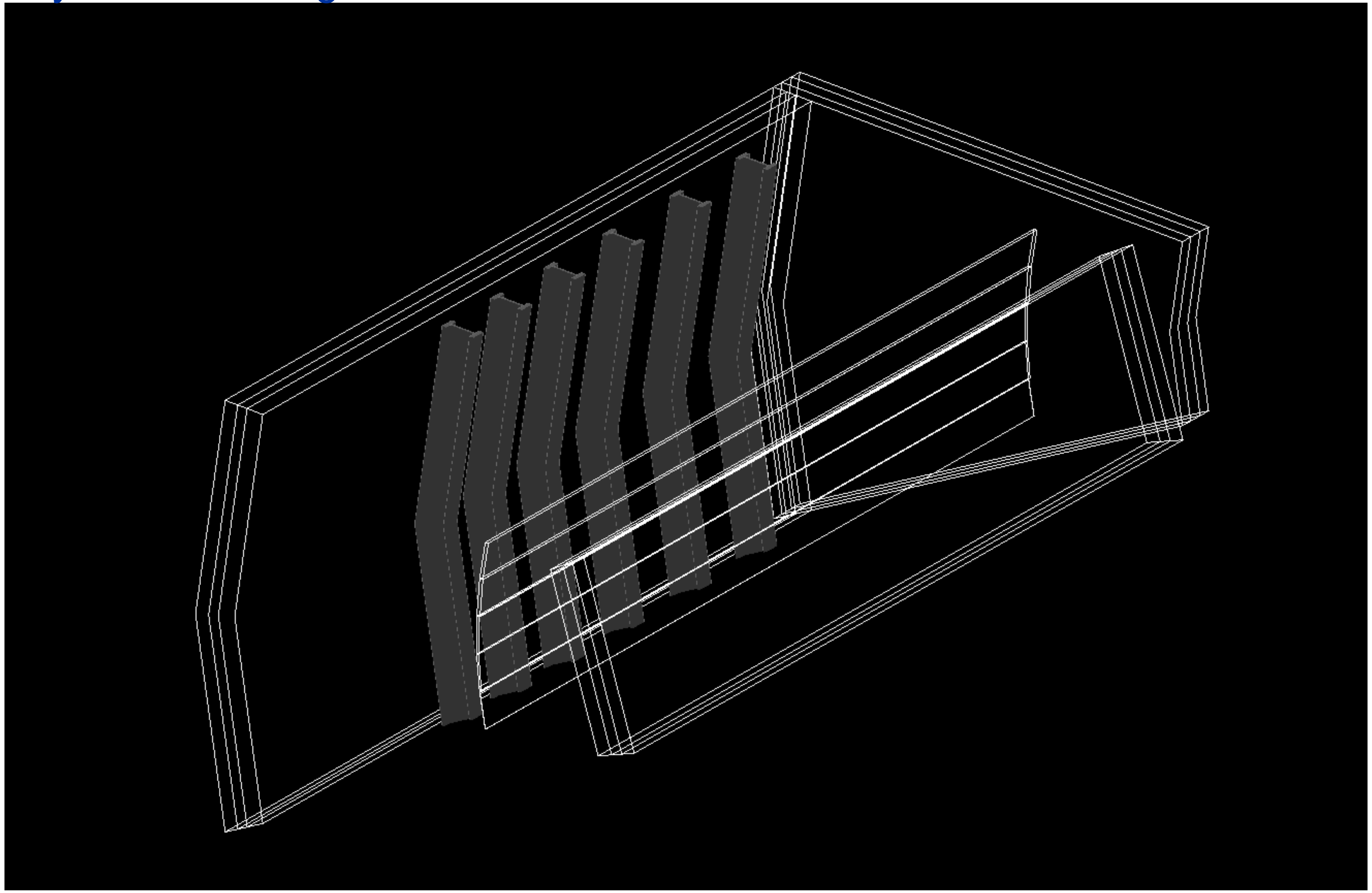


The geometry

Cryostat

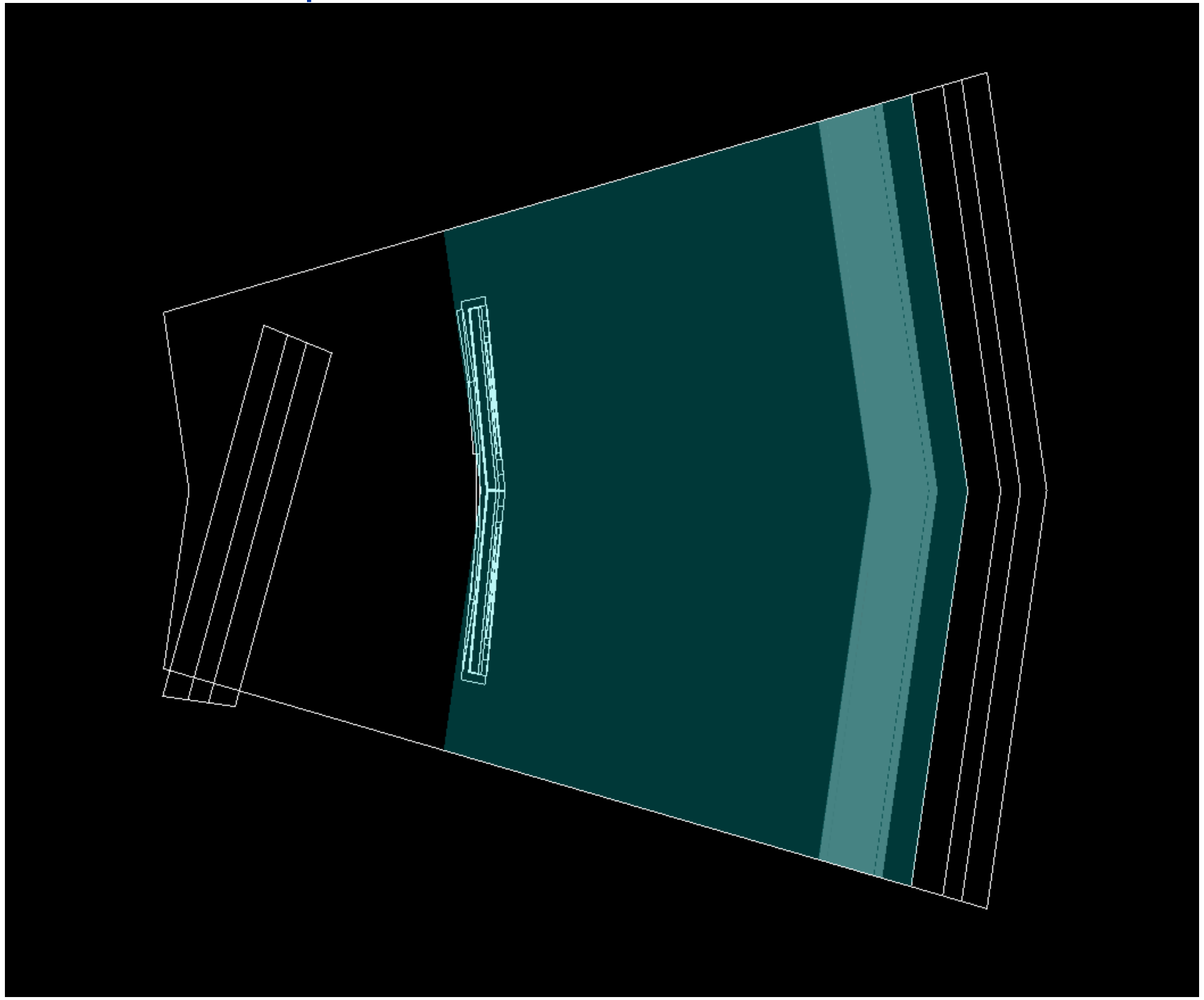


Cryostat + 6 Rings

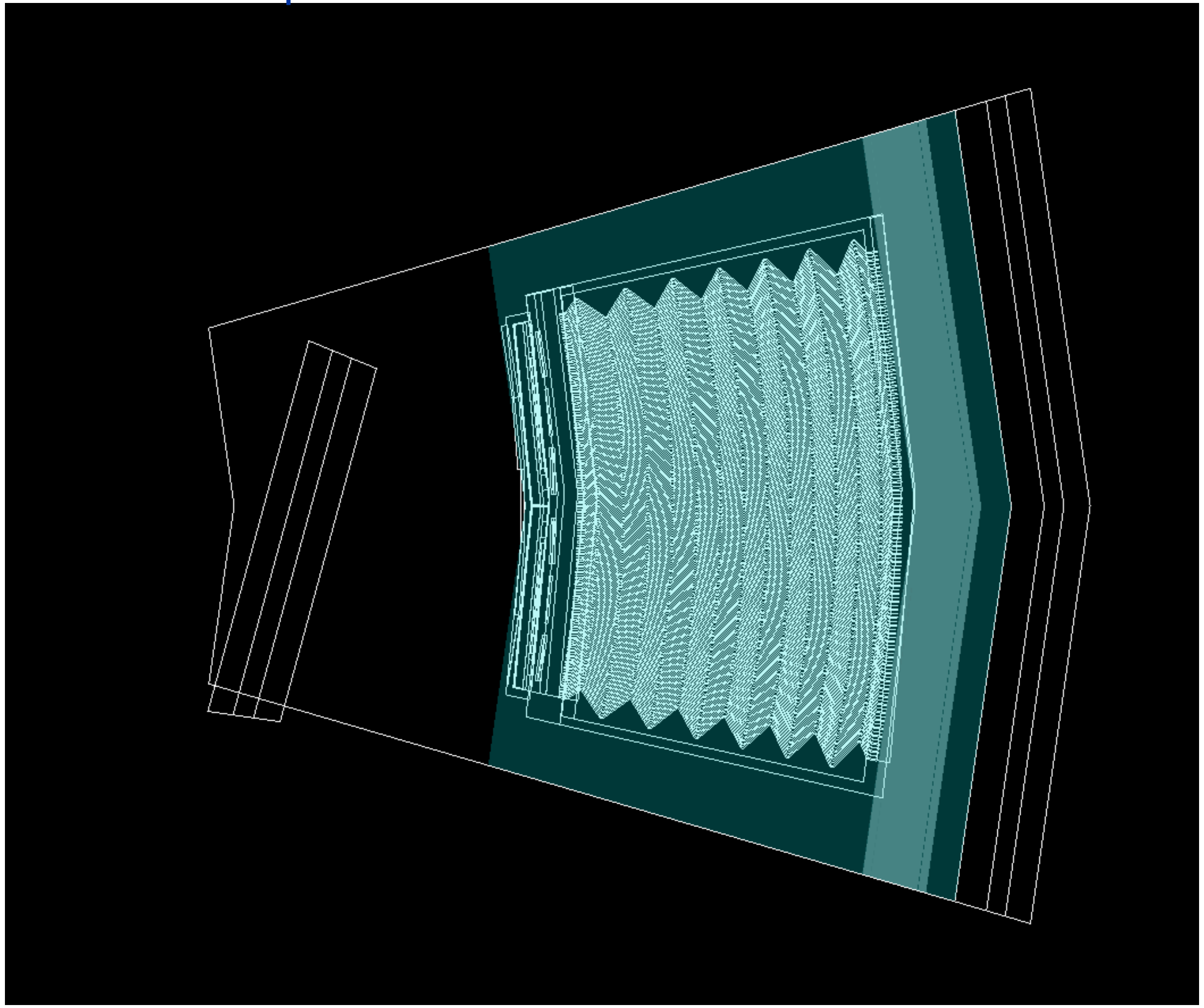


The geometry

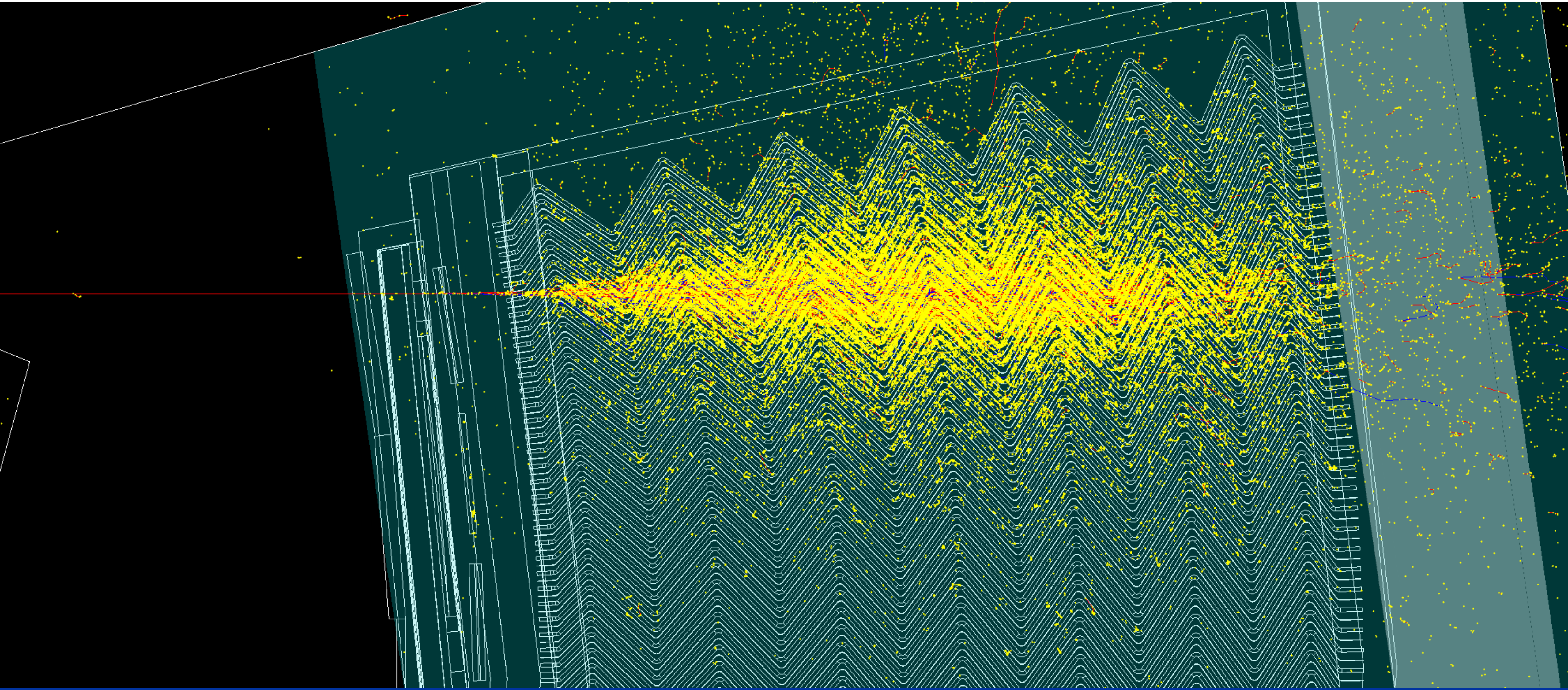
LAr + Presampler



LAr +Presampler + EMB::STAC

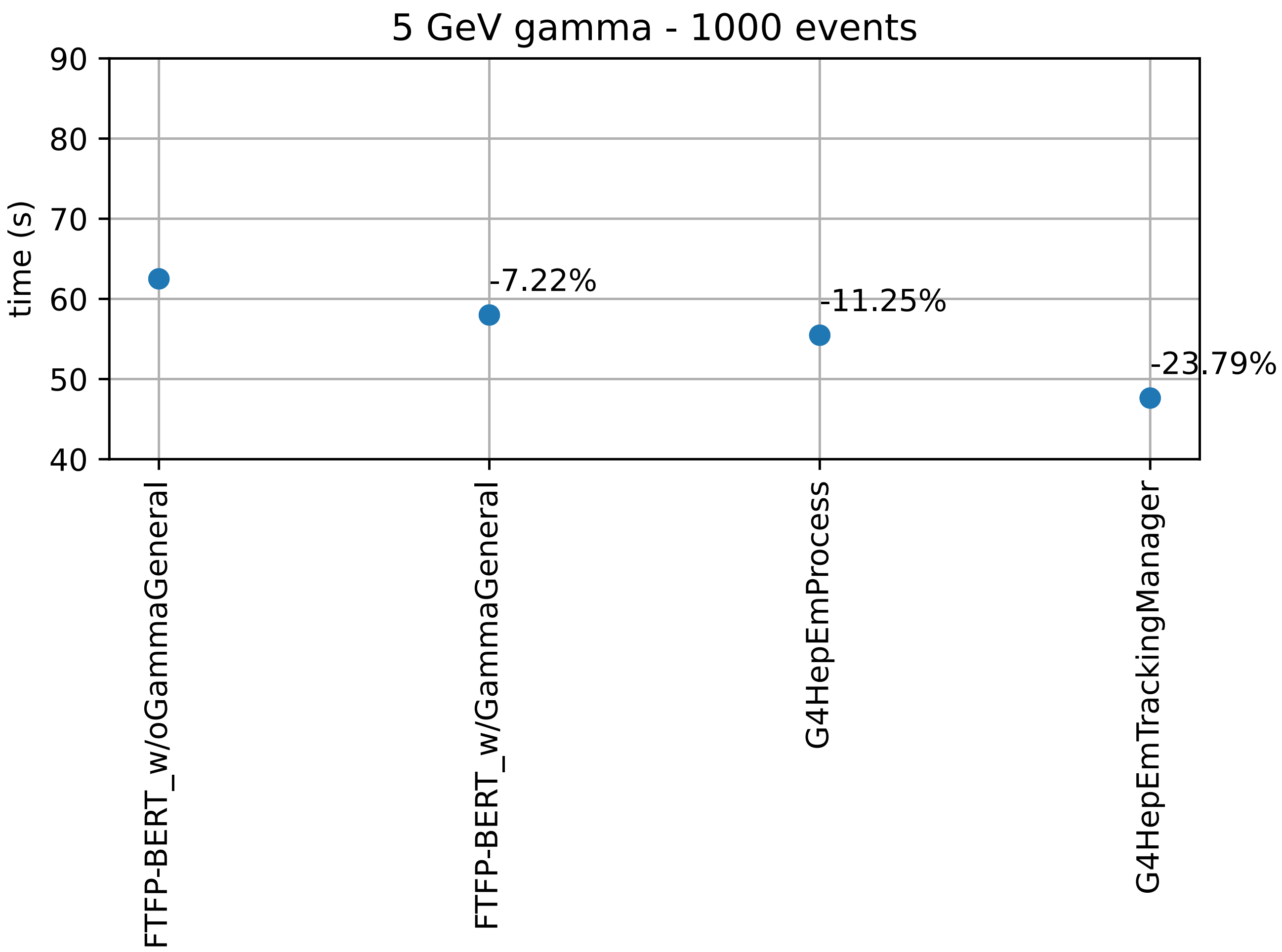


100 GeV e^- event display



Testing speedup solutions - G4HepEm

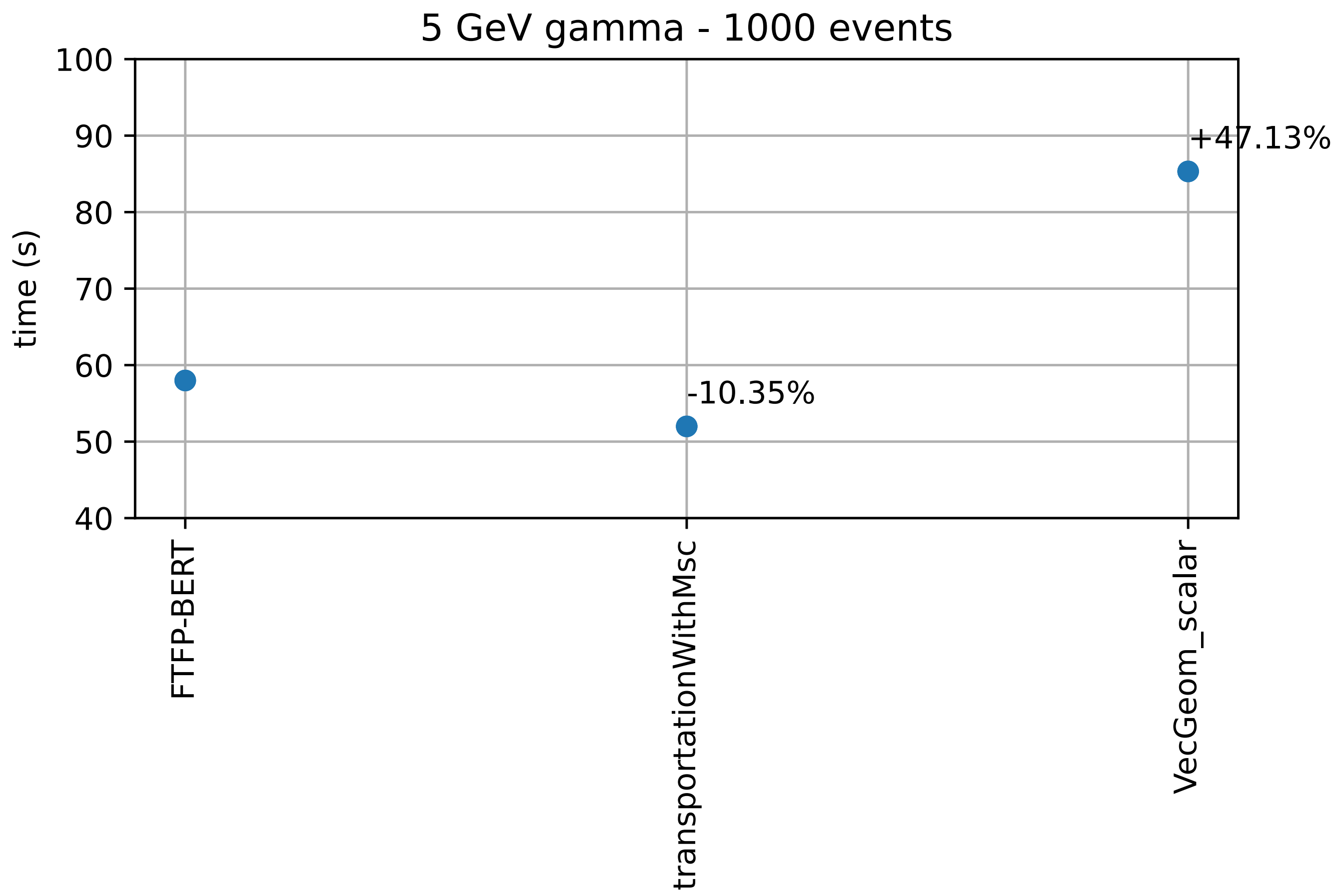
- 1000 events, 5 GeV γ:
  - Using Geant4-11.1
  - Time taken by `G4Timer` between `BeginOfRunAction` and `EndOfRunAction`.
  - CPU: Apple M1 Pro @3.2 GHz, using a single thread.
  - No SensitiveDetector, no hit, no SteppingAction, no EventAction.
  - Note:
    GammaGeneral process is not included in G4HepTrackingManager nor in G4HepEmProcess.



Testing speedup solutions - Others

- 1000 events, 5 GeV γ:
  - Using Geant4-11.1
  - Time taken by `G4Timer` between `BeginOfRunAction` and `EndOfRunAction`.
  - CPU: Apple M1 Pro @3.2 GHz, using a single thread.
  - No SensitiveDetector, no hit, no SteppingAction, no EventAction.
  - Note:
    We found that special cases of `G4Trap` to be less optimized in VecGeom.

    Some of the `G4Trap` can be replaced with `G4Box`, in this optimized geometry VecGeom is 20.06% slower.



Conclusion

- We believe it is possible to include a realistic ATLAS LAr Barrel validation test to geant-val:
  - geometry is done (and partially optimized G4Trap $\rightarrow$ G4Box),
  - need to understand how to implement realistic sensitive detectors and hits.
- We found impressive speed up, up to $\simeq 24\,\%$, using recently developed tools.
- Using VecGeom slows down the simulation, however the relative impact depends on the actual geometry implementation (it ranges from $\simeq 20\,\%$ to $\simeq 50\,\%$).
- The relative speedup/down is:
  - Consistent when executing the simulation on multiple threads, and
  - is crosschecked on an AMD Ryzen 3900 @3.1 GHz cpu.