Update on fast simulation

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SFT simulation R&D

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First step

Development of Geant application for fast-sim studies.

Fast simulation in general needs full simulation:

$\Rightarrow$ to extract parametrisation / train NN / save shower libraries

$\Rightarrow$ to validate, assess accuracy / speed-up
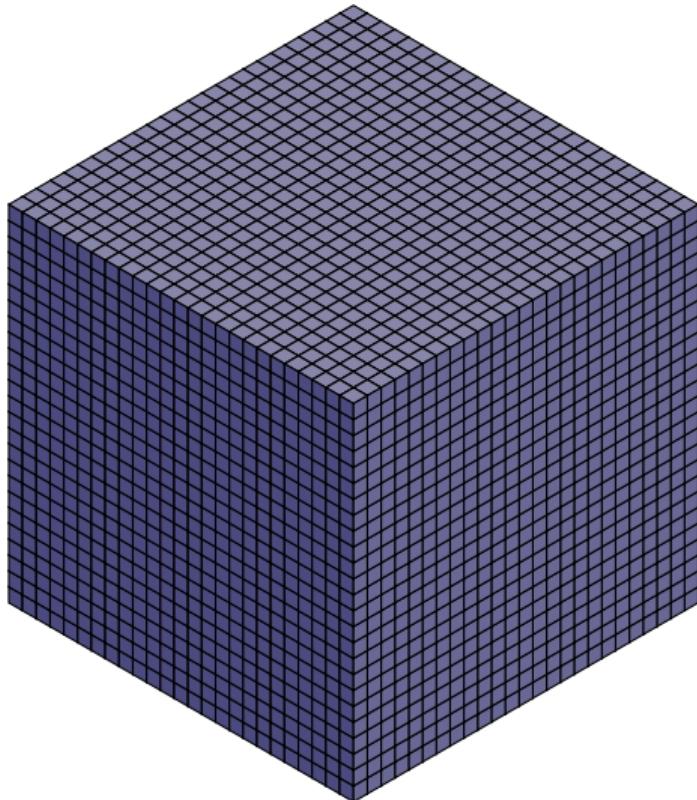
Detector

- ▶ net of $N \times N \times M$ cells
    - ▶ N in xy plane, M along z axis
    - ▶ $25 \times 25 \times 25$ for ML studies
- ▶ each cell can be build of K absorbers (TestEm3 inspired)
    - ▶ $K = 1$ for homogeneous calorimeters, e.g.. PbWO$_4$
    - ▶ other geometries: Pb/LAr, Pb/Sci, W/Si (SimplifiedCalorimeter inspired)
- ▶ using detector messenger to set size, number of cell, materials, sensitivity
- ▶ current cell size: $\sim 1 X_0$ in z and $\sim 0.5 R_M$ in xy

Particle generator
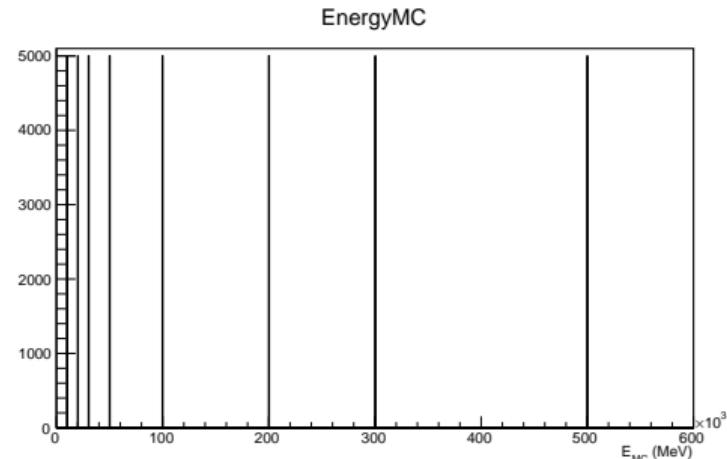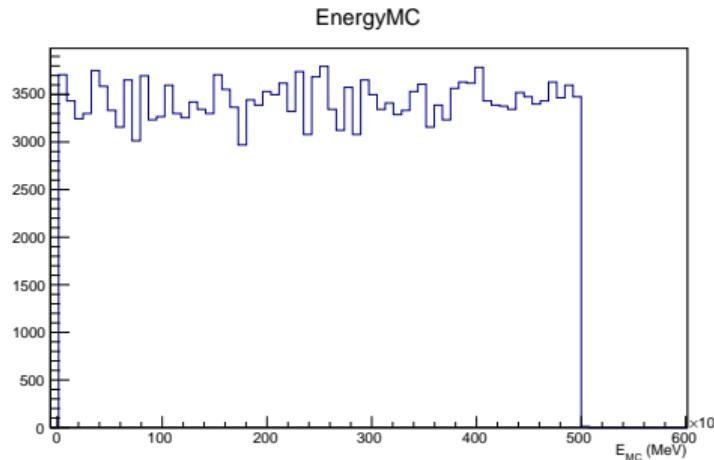
EnergyMC

EnergyMC

- ▶ flat energy spectrum (1–500 GeV) of particle gun along *z* axis
- ▶ for ML training

- ▶ single energy particle gun along *z* axis
- ▶ for validation/ analysis/ comparison

Next step: varied angle (both for training and validation)

Simulation type

▶ full simulation (FTFP_BERT, easy to change if needed)

▶ GFlash parametrisation:
  ▶ using existing implementation (parameters)
  ▶ implemented in G4 for e^-, e^+, not for γs

Output

- ▶ creating ntuples using G4AnalysisManager
- ▶ stored in ROOT files
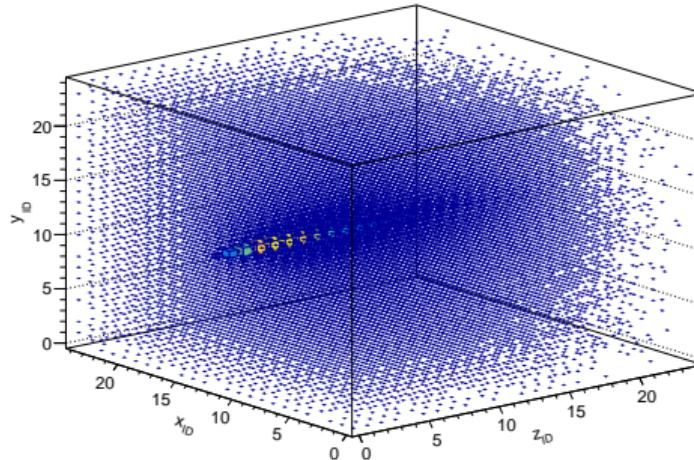
- ▶ for ML studies: created simple tools for ROOT↔H5 translation of cell energy map
  - ▶ HDF5 stores datasets – multidimensional arrays of a homogeneous type
  - ▶ quick to read in python for ML training (as numpy arrays)

Validation

Set of general validation histograms is created:

- ▶ MC energy
- ▶ deposited energy
- ▶ number of cells above threshold (currently $E_{\mathrm{cell}} > 0.1$ MeV)
- ▶ cell energy distribution
- ▶ longitudinal and transverse profiles (and first/second moments)
- ▶ energy distribution layer-wise
- ▶ transverse profile layer-wise
- ▶ simulation time

Gaussian distributions (deposited energy, shower moments) can be additionally fitted and plotted as a function of MC energy.

Validation full sim vs. GFlash

- ▶ for PbWO$_4$ homogeneous calorimeter
- ▶ $25 \times 25 \times 25$ 10 mm cells
- ▶ 5k electrons per energy

Validation full sim vs. GFlash
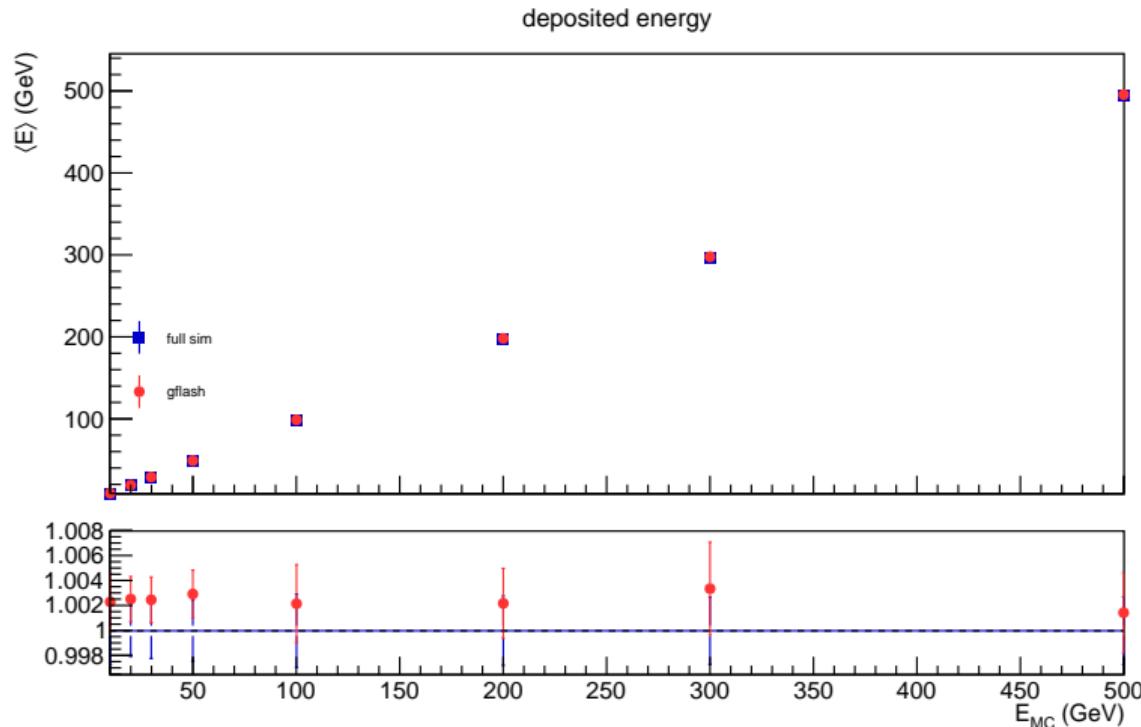
deposited energy

Validation full sim vs. GFlash

100 GeV, cell energy distribution

Validation full sim vs. GFlash

number of cells above threshold

Update on fast simulation
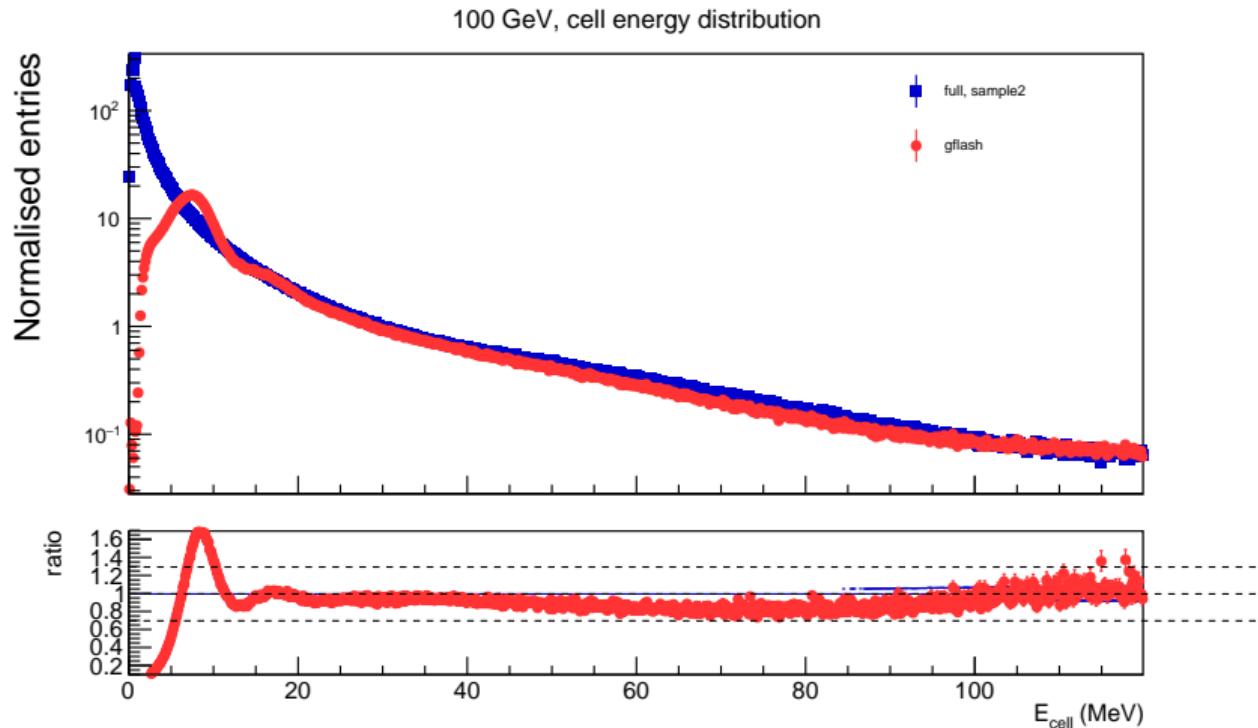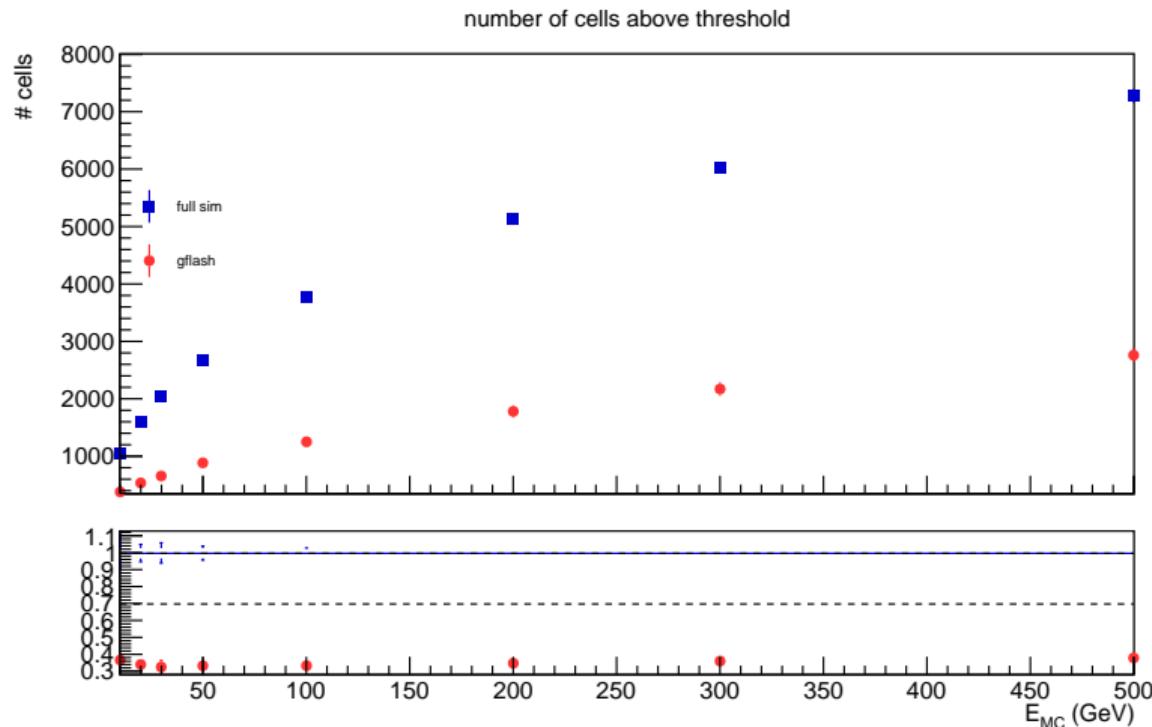
Validation full sim vs. GFlash

longitudinal first moment
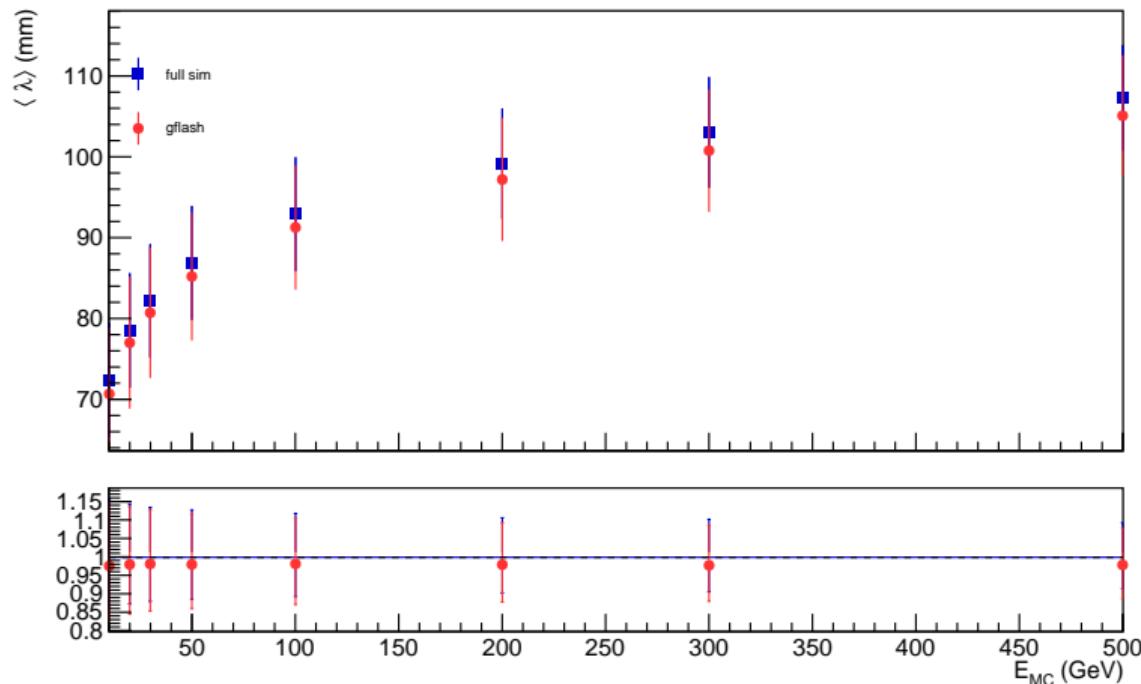
Validation full sim vs. GFlash
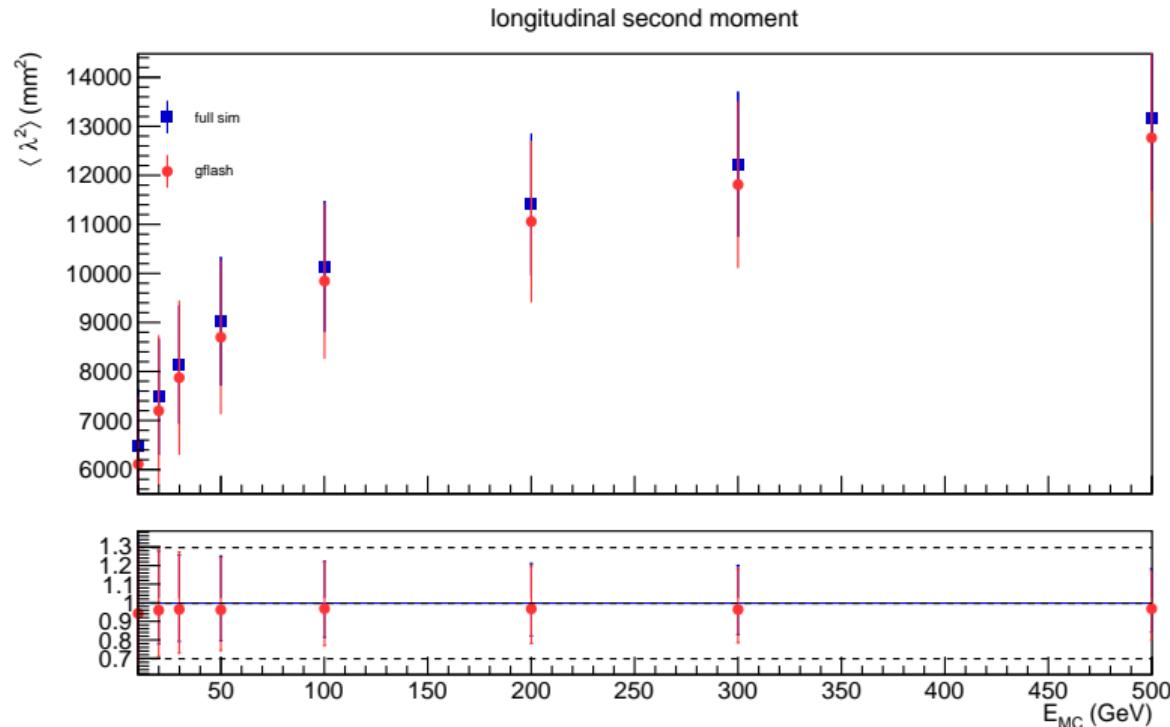
longitudinal second moment

Validation full sim vs. GFlash

transverse first moment

transverse second moment

Validation full sim vs. GFlash

simulation time (per event)
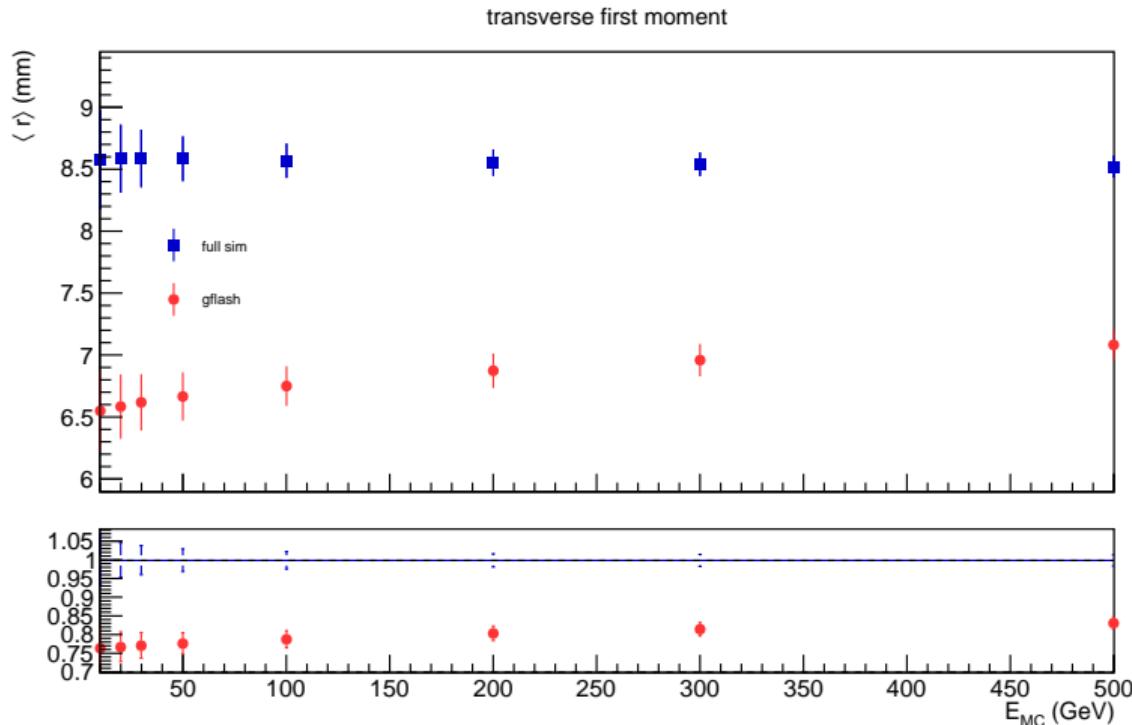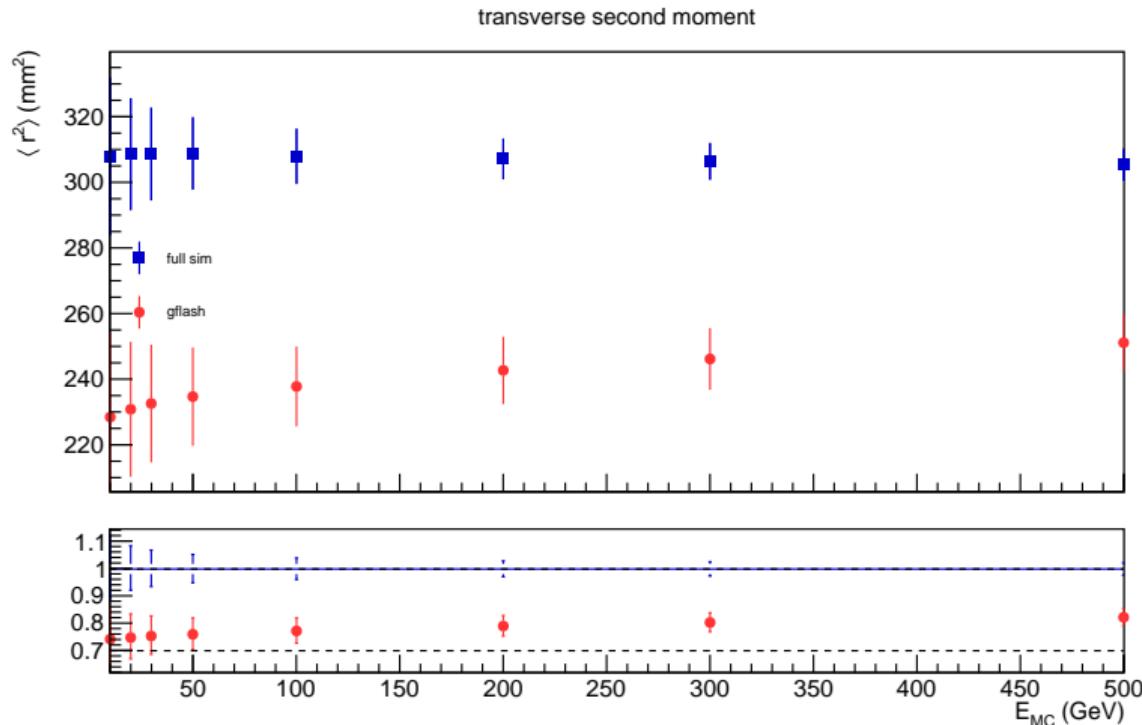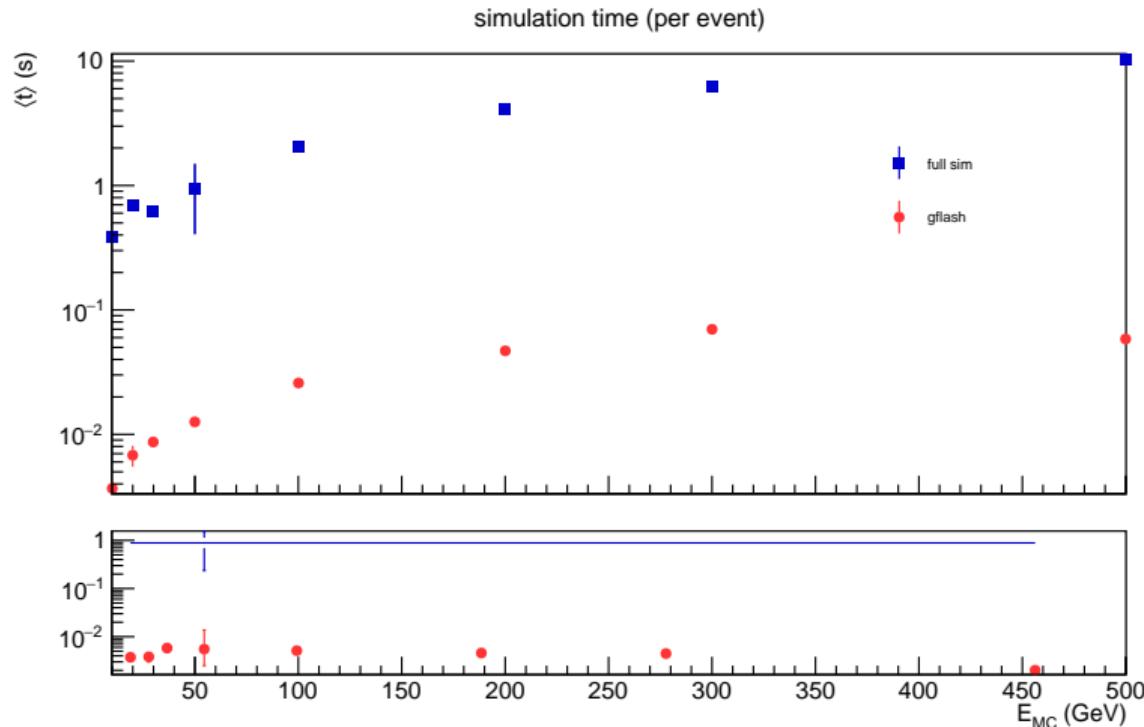
Summary

- ▶ current setup can test performance of GFlash on few sample geometries

- ▶ easy to extend and add any new parametrisation

- ▶ configurable via messengers (detector, generator, fast simulation)

- ▶ machine learning: validation run at training (every few epochs), allows to get some preview

- ▶ next steps:
    - ▶ generate data for different geometries
    - ▶ and for different incident angles