Fast Simulation in Geant4

EICUG Software Working Group Meeting

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Overview

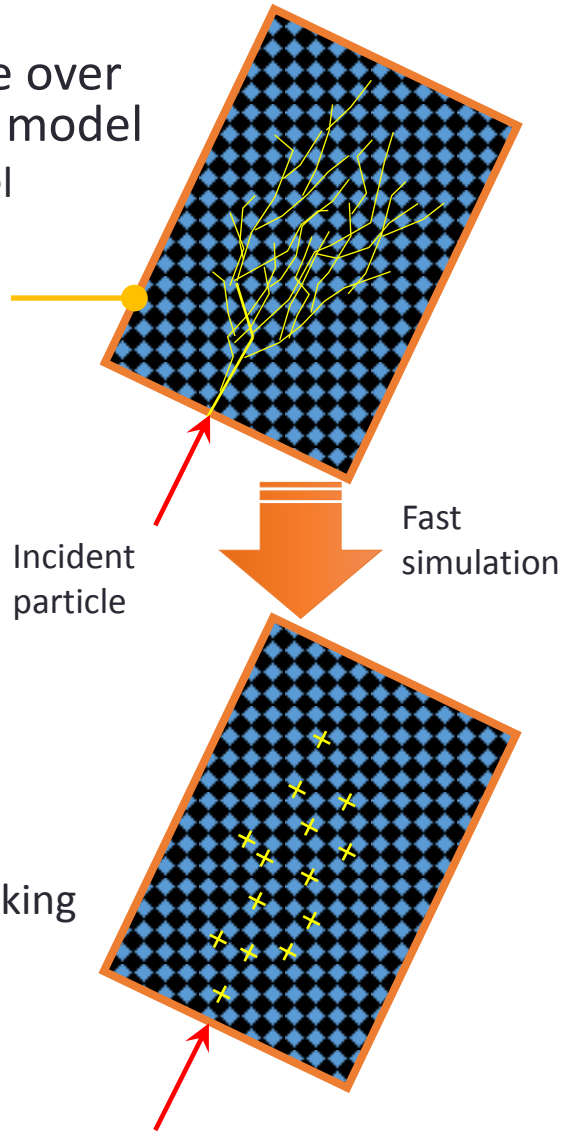
- Base classes in Geant4
- The GFlash model reimplementation

Base classes in Geant4

Geant4 Fast Simulation in an nutshell

- Fast simulation in Geant4 gives the user the ability to take over the tracking to let him/her develop whatever fast physics model
  - The user takes full responsibility for the correctness of the model

- The basic concepts are:
  - **The envelope (a G4Region object)**
    - This is typically the "mother" volume of a large sub-system :
      - The calorimeter volume, of the volume of a calorimeter module
    - In Geant4 these envelopes are G4Region objects (see later)
    - They can live also in "parallel geometries"
  - **Fast simulation model (a G4VFastSimulationModel)**
    - An object which knows:
      - For what particle type it is valid
      - Under what conditions it can take over the tracking
      - What to do when it takes over the tracking
    - A model is attached to an envelope (G4Region)
    - Several models can be attached to a same envelope (G4Region)
  - **A "special process"** that provides the interface between the tracking and the fast simulation classes
    - The user does not need to know the details of it
    - But has to take some action to equip the "physics list" with this process



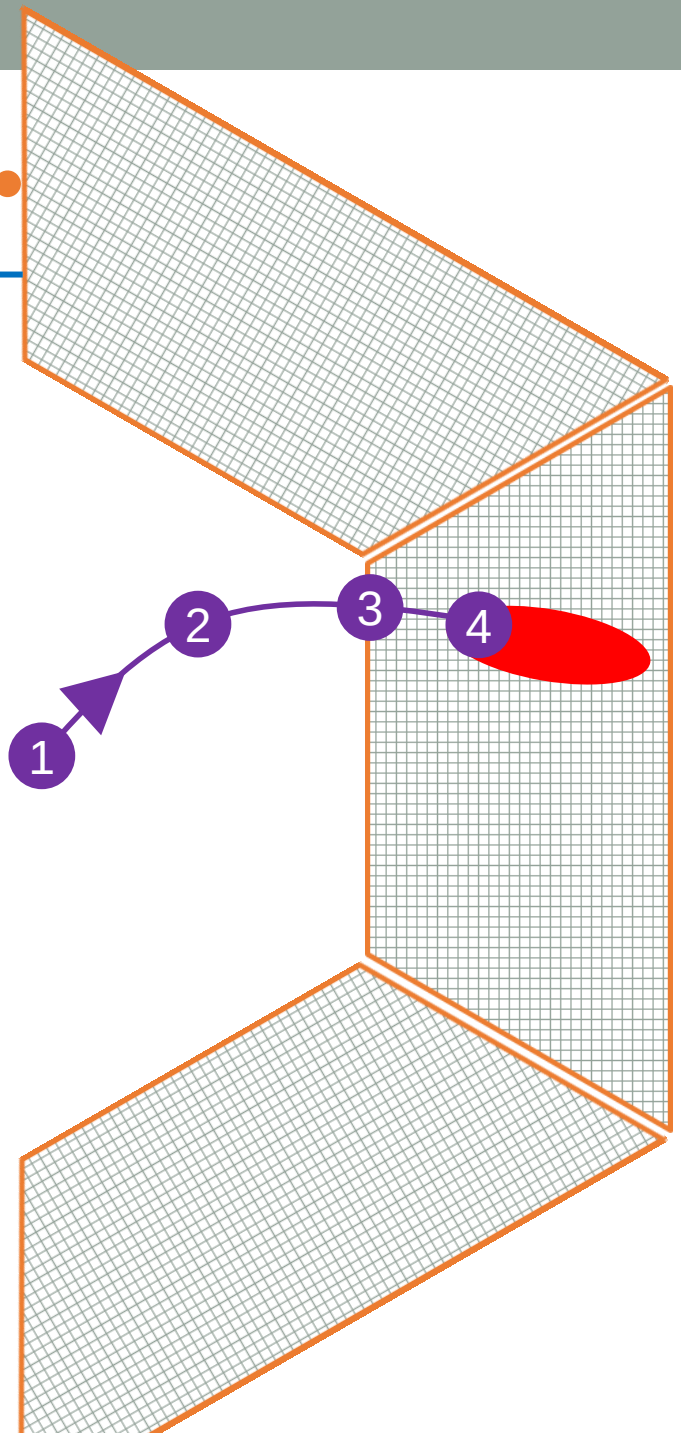
G4Region “calorimeter module”, with multiple placements.

G4FastSimulationManager

MyElectronModel

MyPionModel

G4VFastSimulationModel
G4bool IsApplicable(…)
Tell if the model can handle the current particle type
G4bool ModelTrigger(…)
Tell if the model wants to trigger the fast simulation
void DoIt(…)
Do the fast simulation



The Gflash model reimplementation

Existing model in Geant4 : GFlash

- Reimplementation of the electromagnetic shower gflash model developed by G. Grindhammer and S. Peters
  - arXiv:hep-ex/0001020
  - Parametrisation as a function of particle energy;
  - Parametrisation able to work in any material (Z-dependent)
  - And able to treat any calorimeter
    - Homogeneous
    - Sampling calorimeter (based on average material);
- Homogeneous version in decent shape
  - Used in CMS
  - With further evolution in CMS compared to the G4 code
- A sampling calorimeter version also exists
  - But was unused
  - And is under serious revision

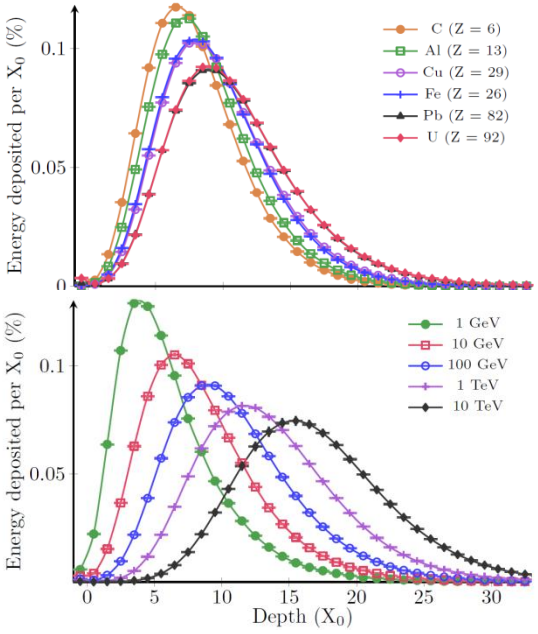
- Note these models are being refreshed/revised/modernized this year
- Much of materials after from Anna Zaborowska (CERN)

Longitudinal & transverse profiles

- Longitudinal profile:
  - Expressed as gamma function:

$$f(t) = \left\langle \frac{1}{E}\frac{dE(t)}{dt} \right\rangle = \frac{(\beta t)^{\alpha-1}\beta e^{-\beta t}}{\Gamma(\alpha)}$$

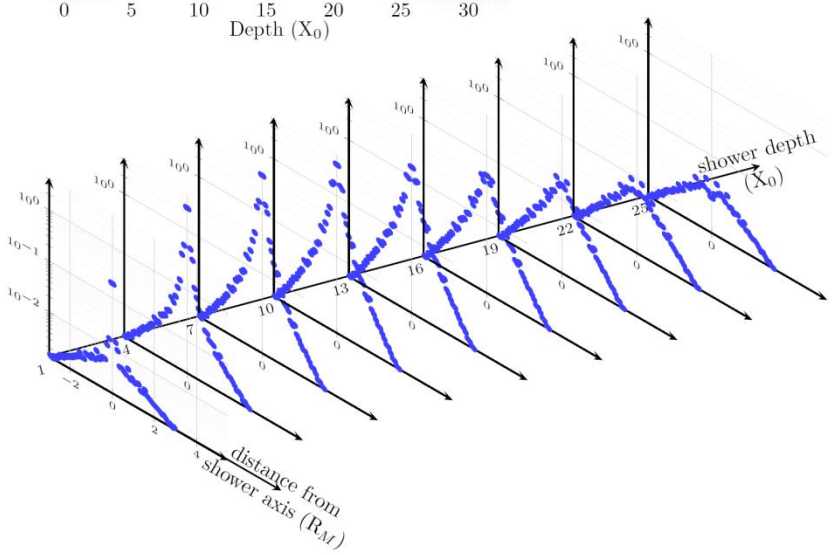
  - With energy expressed in units of critical energy $y = \frac{E}{E_c}$
  - Shower maximum is at $T = \frac{\alpha-1}{\beta}$



- Transverse profile:

$$f(r) = \left\langle \frac{1}{dE(t)}\frac{dE(t,r)}{dr} \right\rangle = pf_{\text{core}}(r) + (1-p)f_{\text{tail}}(r)$$

$$= p\frac{2rR_{\text{core}}^2}{\left(r^2 + R_{\text{core}}^2\right)^2} + (1-p)\frac{2rR_{\text{tail}}^2}{\left(r^2 + R_{\text{tail}}^2\right)^2}$$

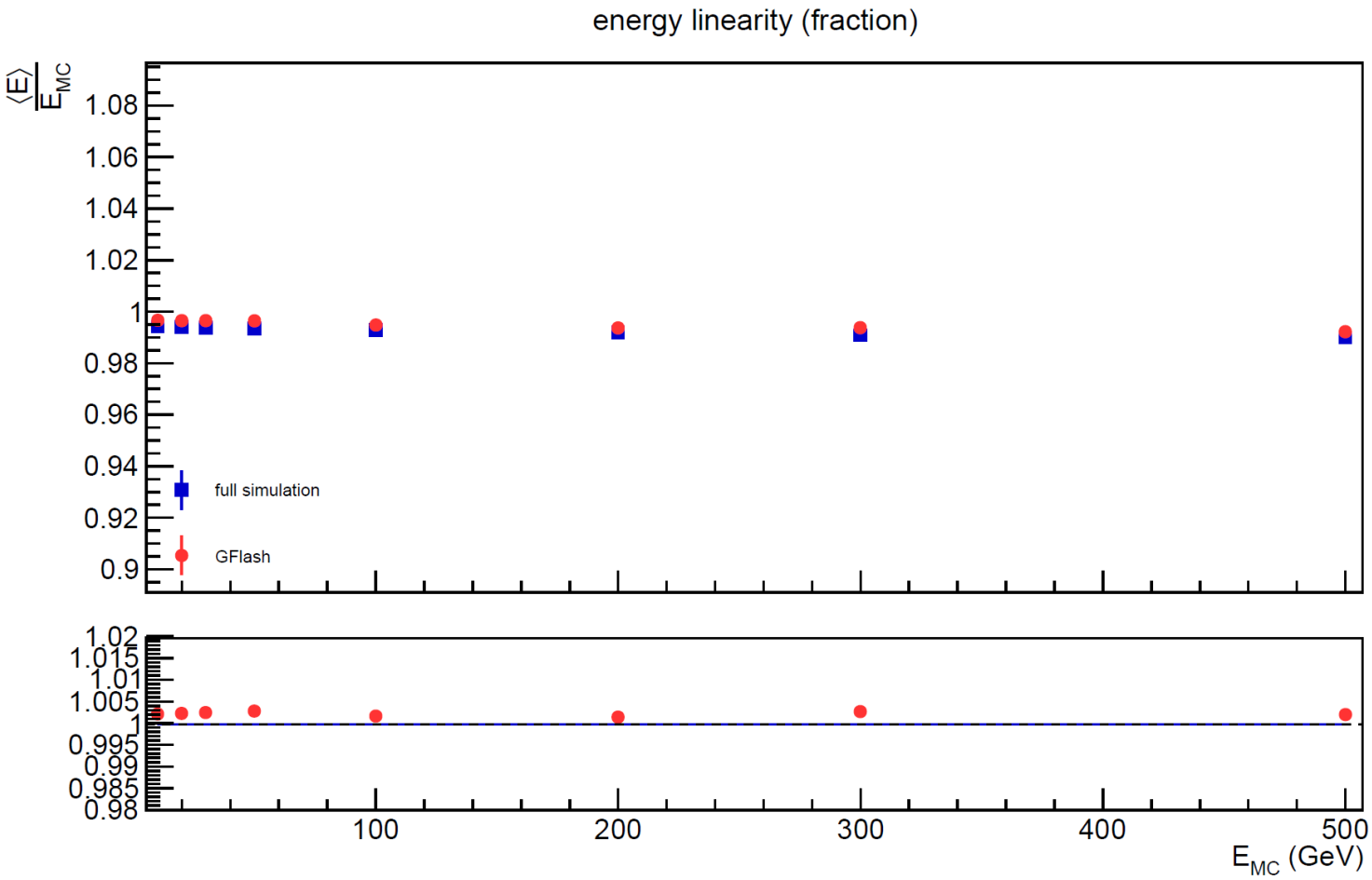


GFlash model implementation

- Triggers if:
  - Incident particle is electron/positron
  - Average containment good enough (90%)
- If triggered, applies the shower model:
  - Deposit energy in slices along incident particle direction
    - In slices of 1 X_0
  - Get energy from longitudinal profile E_{slice} (integrated over slice)
  - Get number of spots/deposits N (integrated over slice)
  - Shoot radial angle from flat distribution
  - Create deposits: E_{slice}/N according to radial profile
  - Locate volume, check if SD, add to hit collection

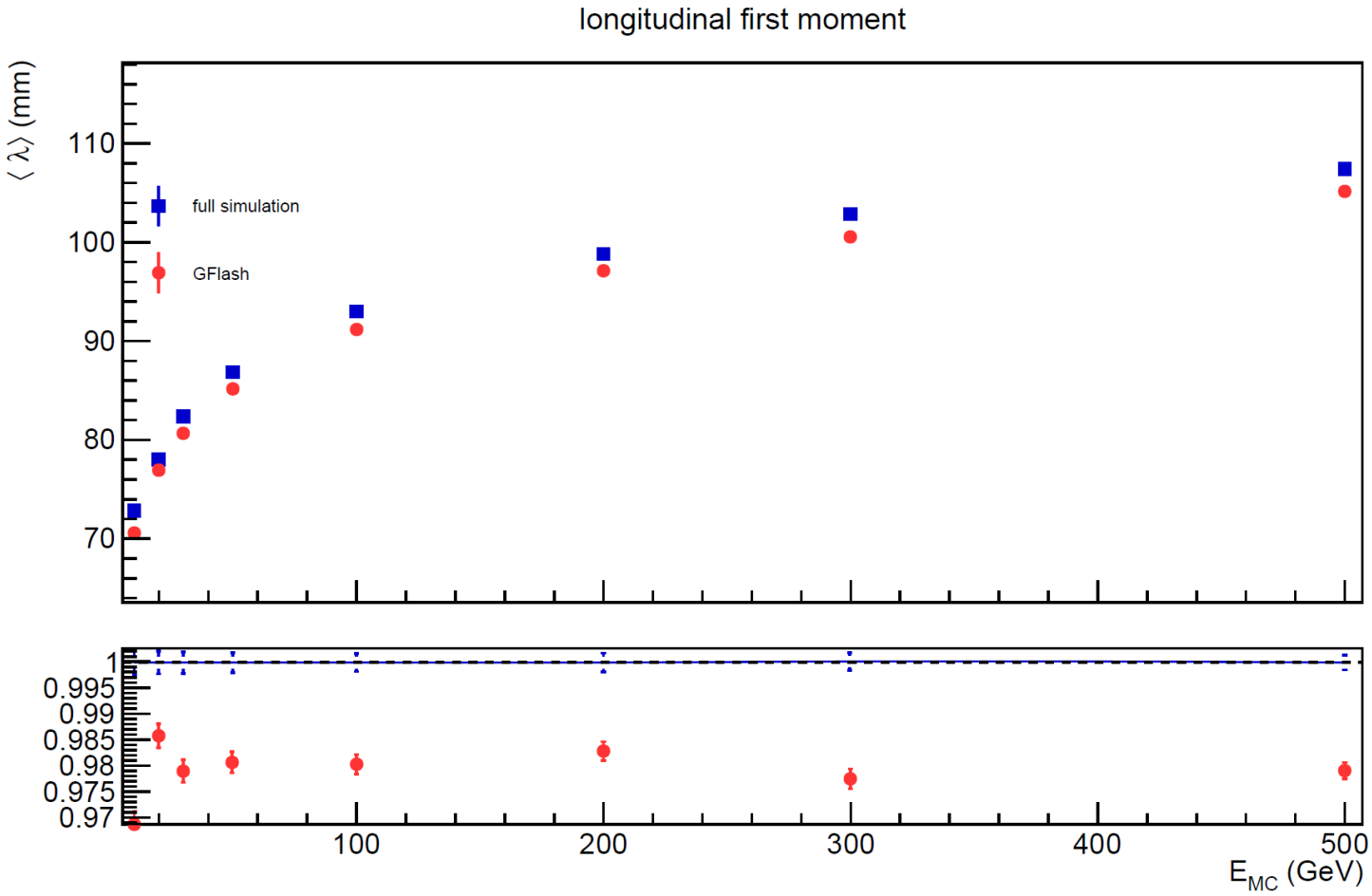
- Illustrates performances after with:
  - $PbWO_4$ homogeneous calorimeter
  - 25 × 25 × 25 10 mm cells
  - 5k electrons per energy

Fraction of energy collected



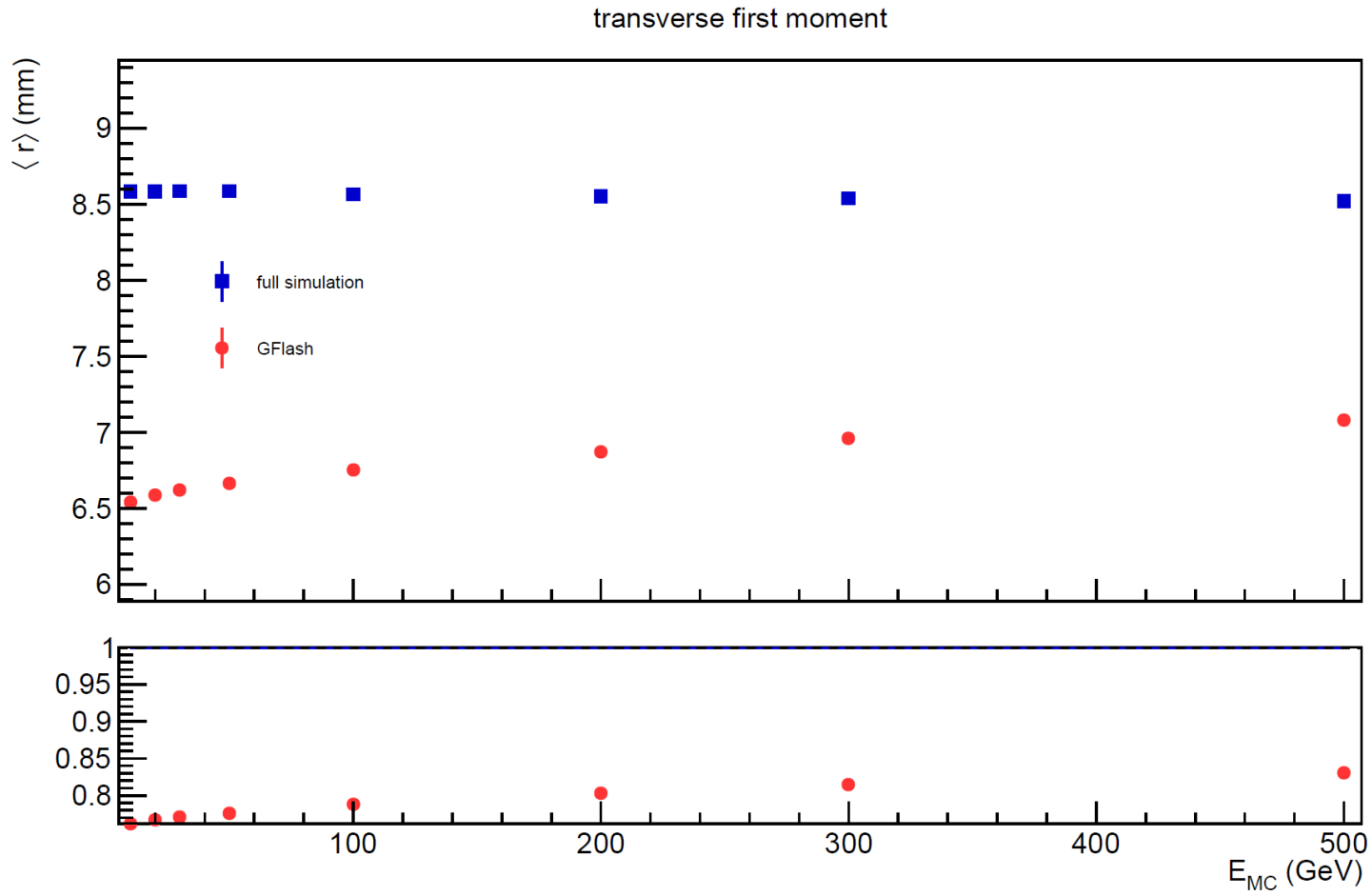
- Fast sim. & full sim. with few %

Longitudinal first moment



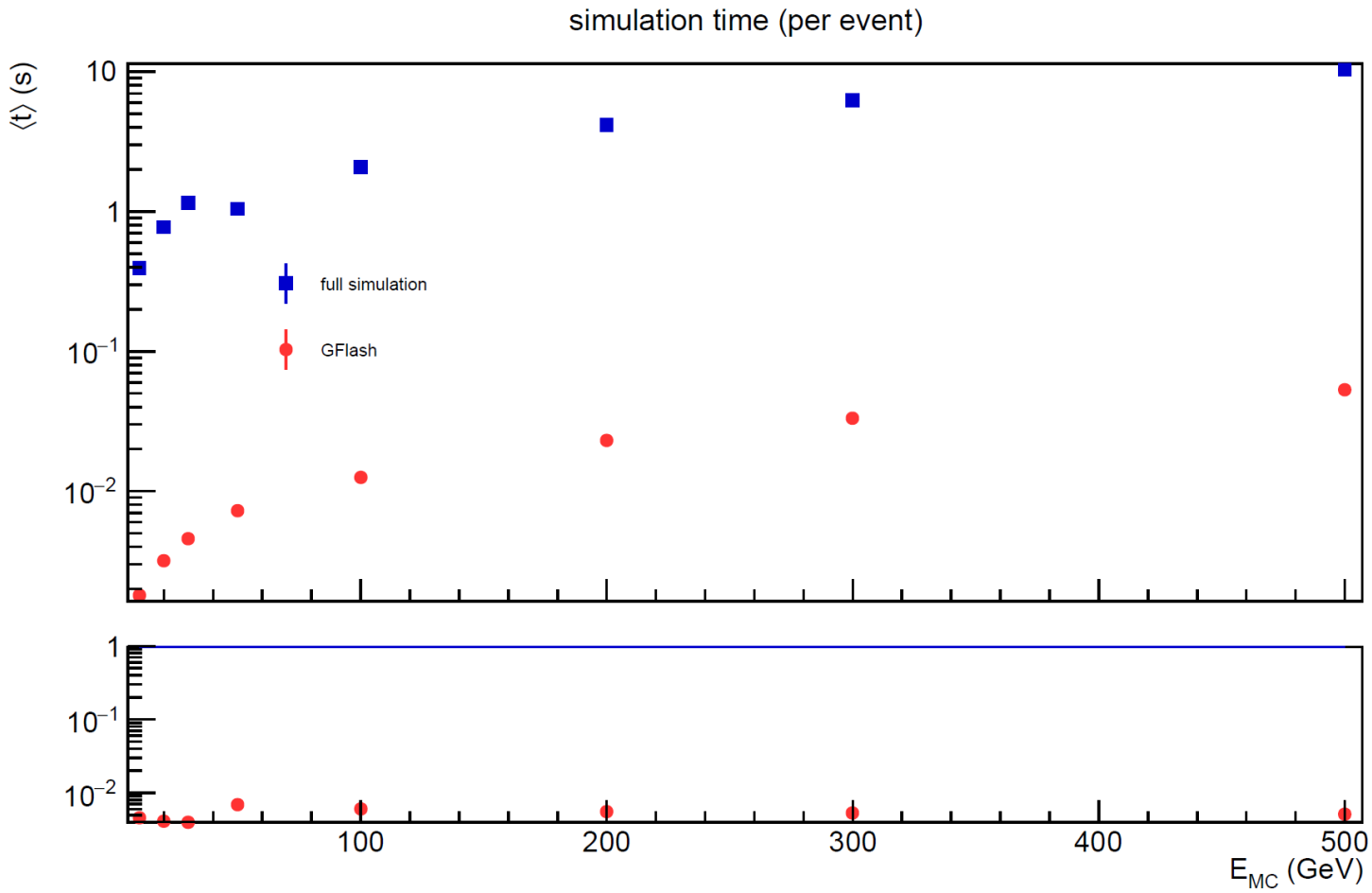
- Fast sim. & full sim. with few %

Transverse first moment



- Fast sim. & full sim. with ~20 %

Simulation time



- Speed-up independent of energy
- Time mostly spent in locating cells → increases with geometry complexity !

Summary

- Generic framework for fast simulation
  - Envelope (G4Region) that defines the subsystem under fast simulation
  - Decision on each step for triggering (or not) the fast simulation while travelling inside the envelope
  - Examples provided examples/extended/parameterisations
- Existing shower model exist
  - Reimplementation of Gflash
  - Decent shape for homogeneous
  - Sampling calorimeter model unused → under correction now
- Please note that models under revision this year:
  - Tuning of parameters
    - On more granular detectors (more modern ones)
  - Ability to change these by users to adapt to specific calorimeter
  - If not in a hurry, the revised models will be much recommended !