Geant4 validation on the CALICE SiW 2008 test beam
(first test, first results)

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Simulation bi-weekly meeting
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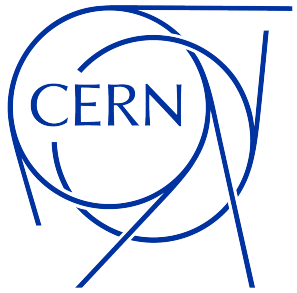


Status of the GEANT4 validation program

- Four/five tests selected:

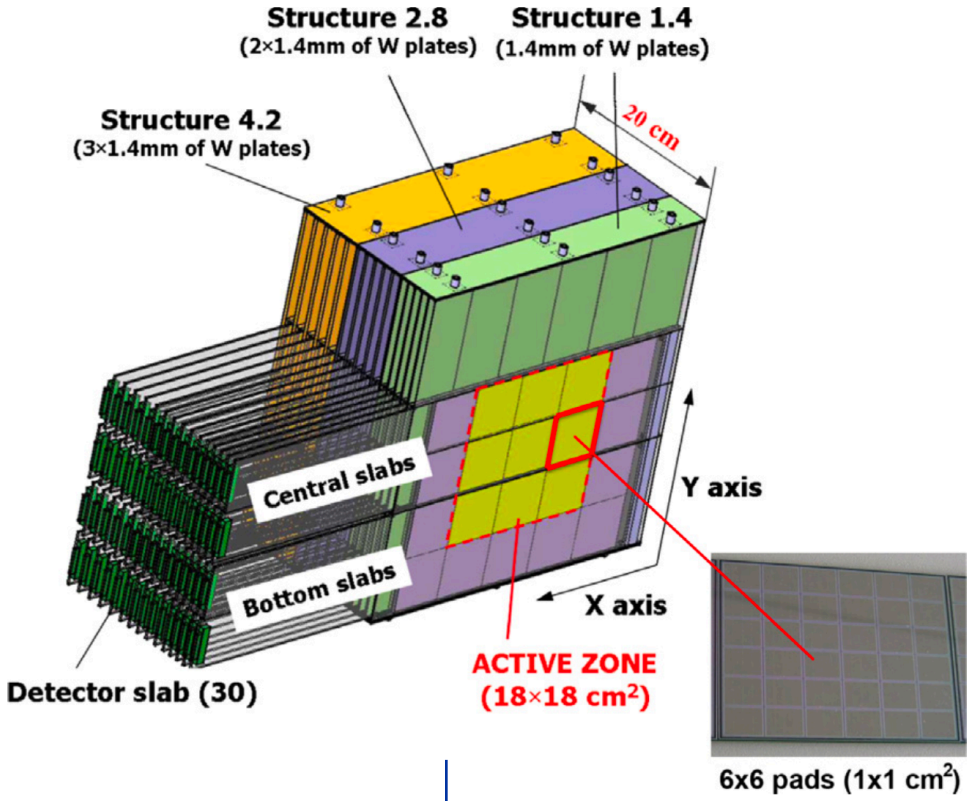
ATLAS Hadronic Endcap Calorimeter (HEC)		Completed.
ATLAS Tile Calorimeter (TileCal)		To be done.
The 2020 Dual-Readout fiber calorimeter (em-sized)		Ongoing. Presented twice at this meeting [link1] [link2].
Calice iron/scintillator hadronic technological prototype		To be done.
Calice silicon/tungsten technological prototype (em-sized)		Started in February 2022, today's topic.

The CALICE SiW 2008 test beam

- Beam tests performed in 2008 at the FNAL beam line, involving 2, 4, 6, 8 and 10 GeV π^-.

- The CALICE SiW prototype is ECAL-sized. It features:
  - 30 longitudinal layers,
  - each layer readout by 36x9 Si cells. Active area is 18x18 cm², thickness is 24 X_0 ($\simeq 1\lambda$).
  - Tungsten slabs used as absorbers with different thicknesses (1.4, 2.8 and 4.2 mm). Sampling fraction decreasing with shower depth.

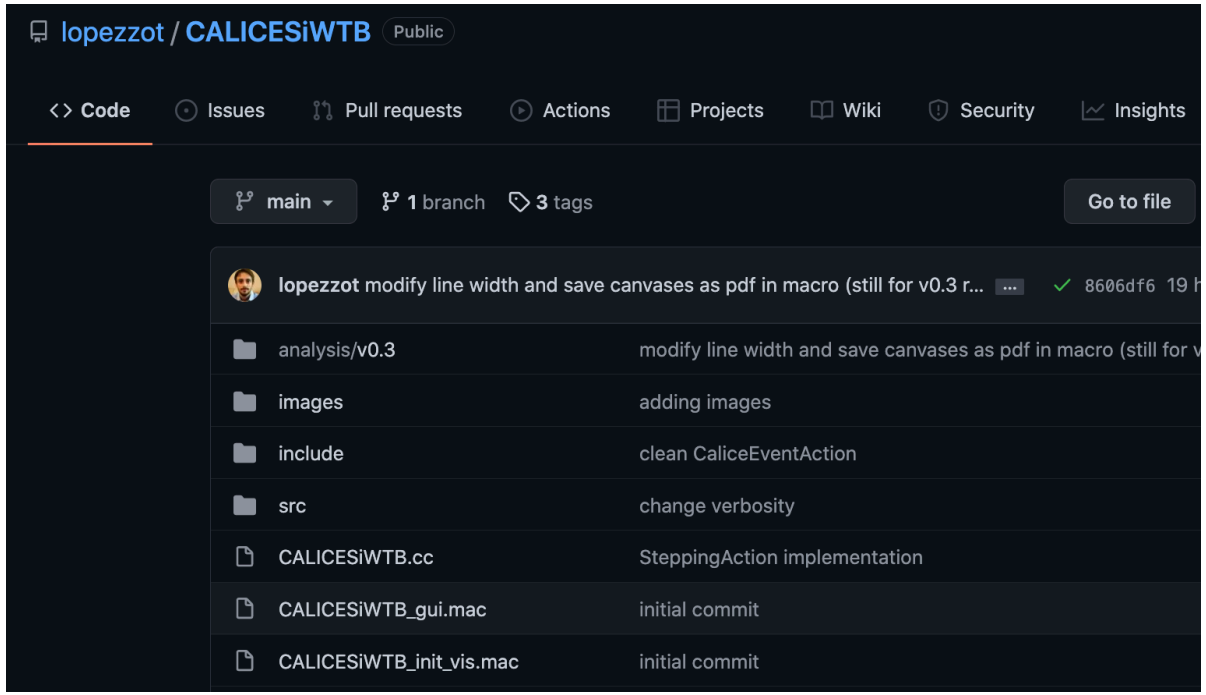
- Reference paper from 2015: NIM A 794 (2015) [link].



9720 sensitive volumes

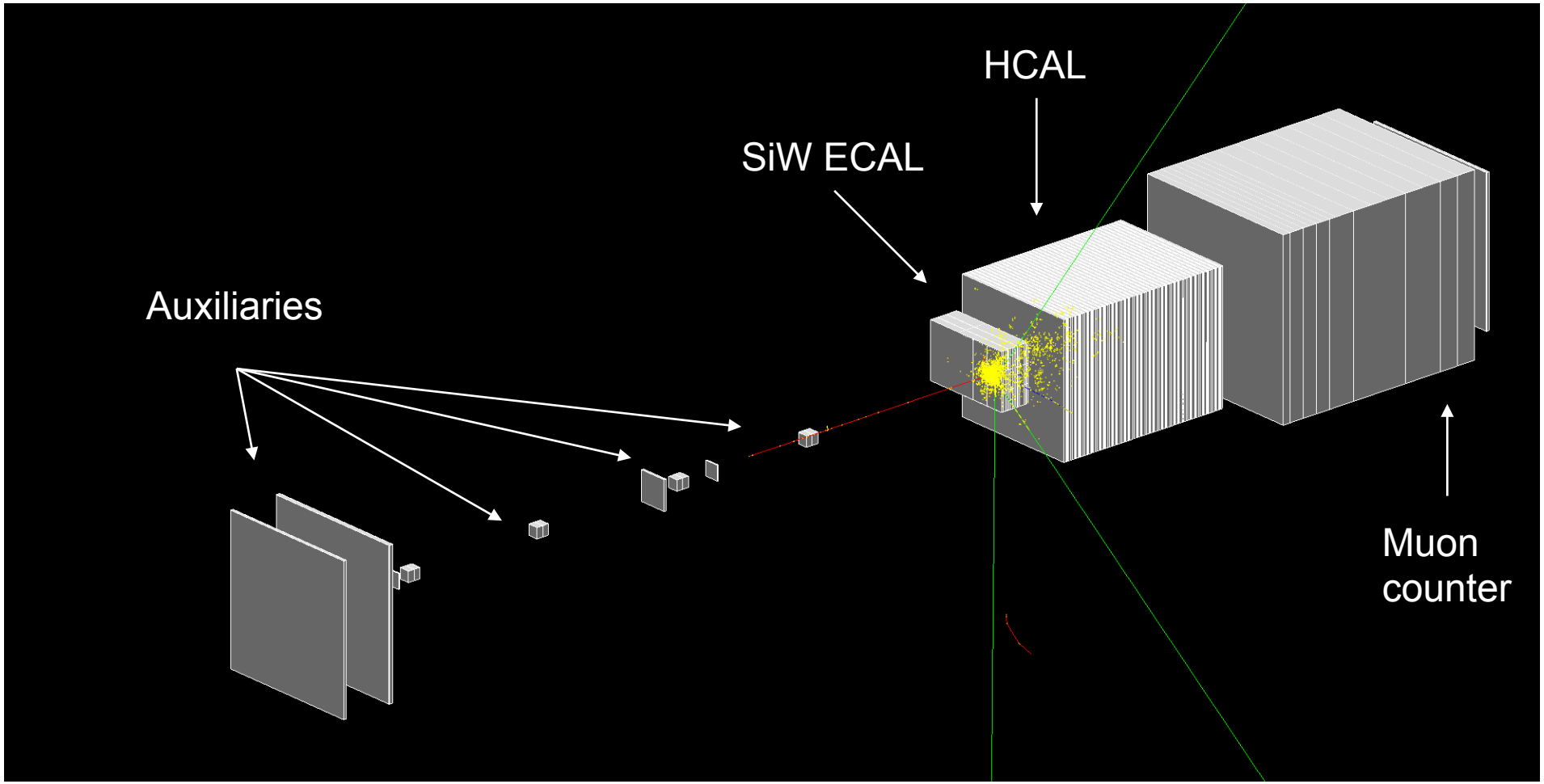
CALICESiWTB - a (revised) Geant4 simulation

- First test to extract a standalone Geant4 simulation from CALICE work was done around 2018 by Katy:
  - [GitLab-link]
  - We reviewed the code and found several dependencies on CALICE mini-frameworks and external libraries (ROOT).
- We migrated to a new GitHub repo [CALICESiWTB]:
  - Removed any dependency, only the Geant4 env is now needed.
  - Extracted only the geometry and sensitive detectors. Remaining parts rewritten as a standalone Geant4 example.
- CALICESiWTB v0.3 used for results in the following.
- Note: *I have never spoken with Katy, nor with the CALICE Collaboration on this, mistakes are quite likely!*



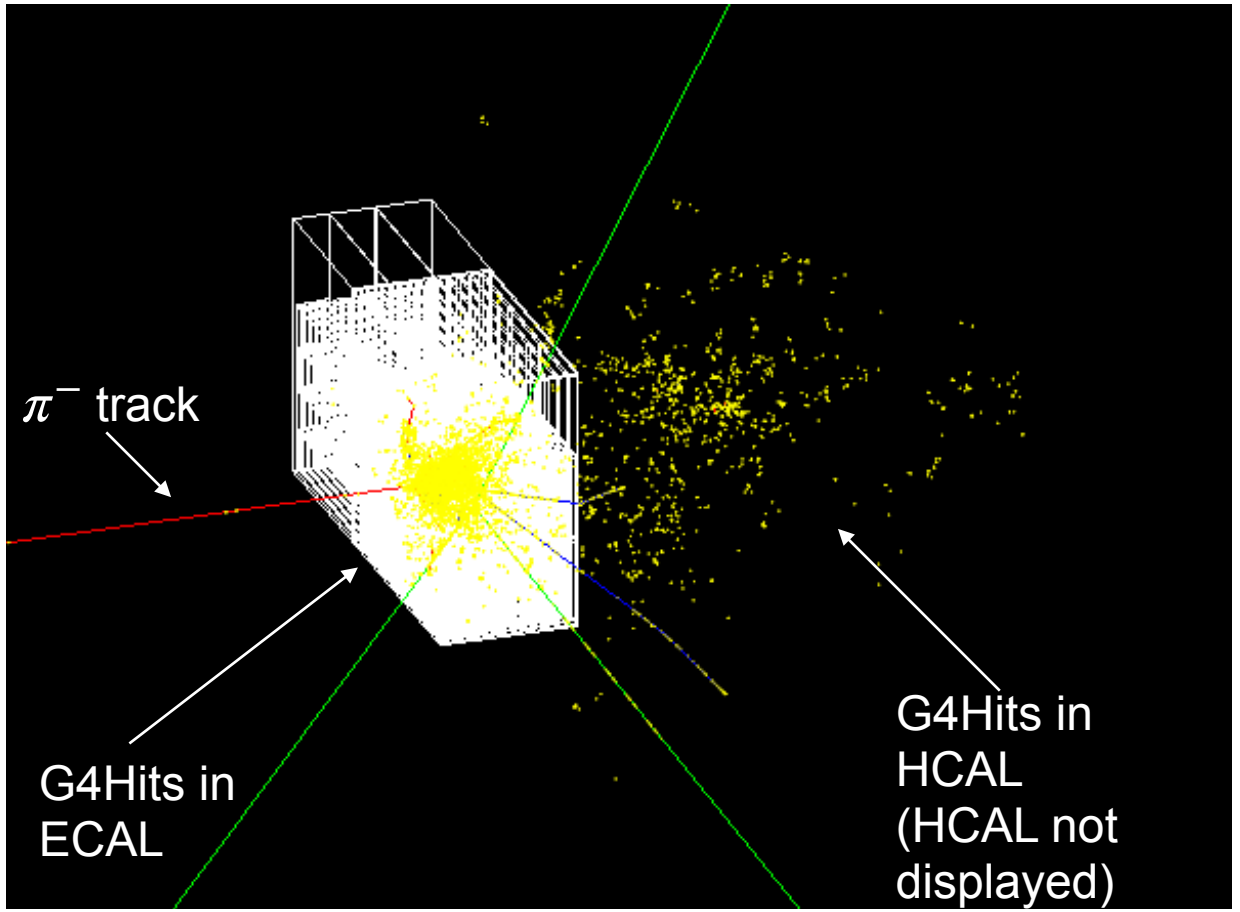
CALICESiWTB - geometry

- Geometry description retrieved from a GDML file [this-file].



CALICESiWTB - selecting events

- Only π^- events with a nuclear breakup are considered in the analysis.
- Any cell is calibrated in MIPs: energy deposits are expressed in MIP units.
- First interaction layer (i) is detected if:
  - Three consecutive layers have an energy > 8 MIPS, or,
  - $$\frac{E_i + E_{i+1}}{E_{i-1} + E_{i-2}} > 6 \text{ and, } \frac{E_{i+1} + E_{i+1}}{E_{i-1} + E_{i-2}} > 6$$
- Setting the interaction layer as layer 0, it is possible to extract the longitudinal energy distribution (in MIPS) as a function of the beam energy, *regardless the depth of the first interaction*.



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Conclusion from CALICE 2015 paper:

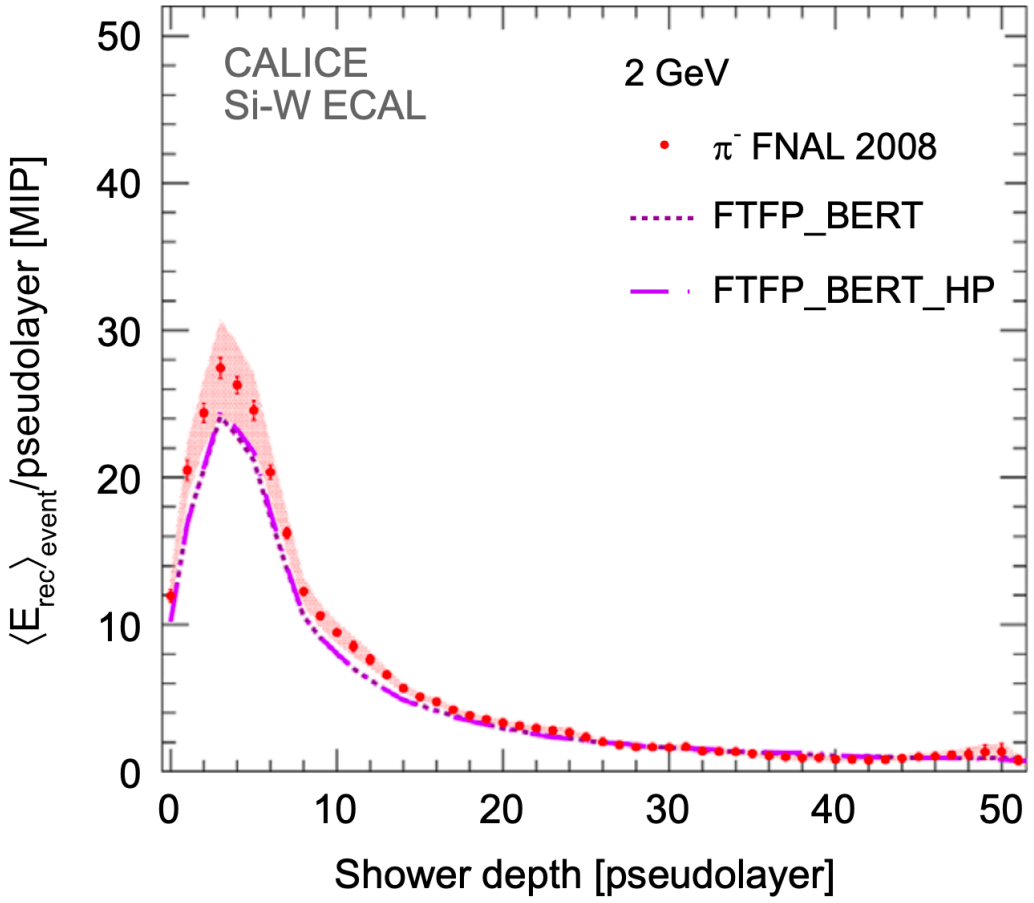
"… the physics observables which take into account the energy deposition are not reproduced well by the Monte Carlo. The reconstructed energy is too low due to a lower number of hits. Combining the longitudinal and radial energy profiles it seems that especially the Fritiof model deposits too much energy near the interaction region."

We tried to reproduce te longitudinal energy deposition profiles with new Geant4 versions. However, I cannot guarantee that Katy's code is the one used for the CALICE publication (probably not the case)…

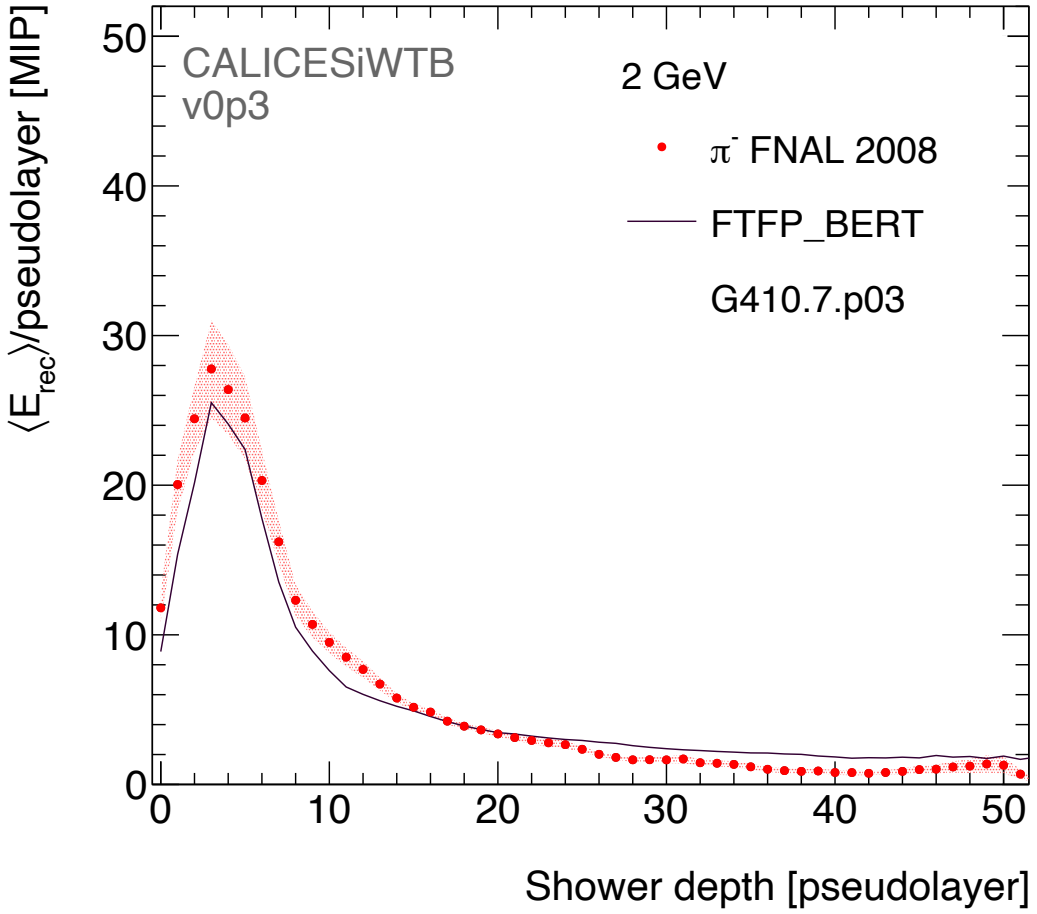
Longitudinal energy distribution - data, CALICE and us

2 GeV π^-

CALICE 2015 - Geant4.9.6 NIMA794



Geant4 Collaboration 2022 - Geant10.7.p03



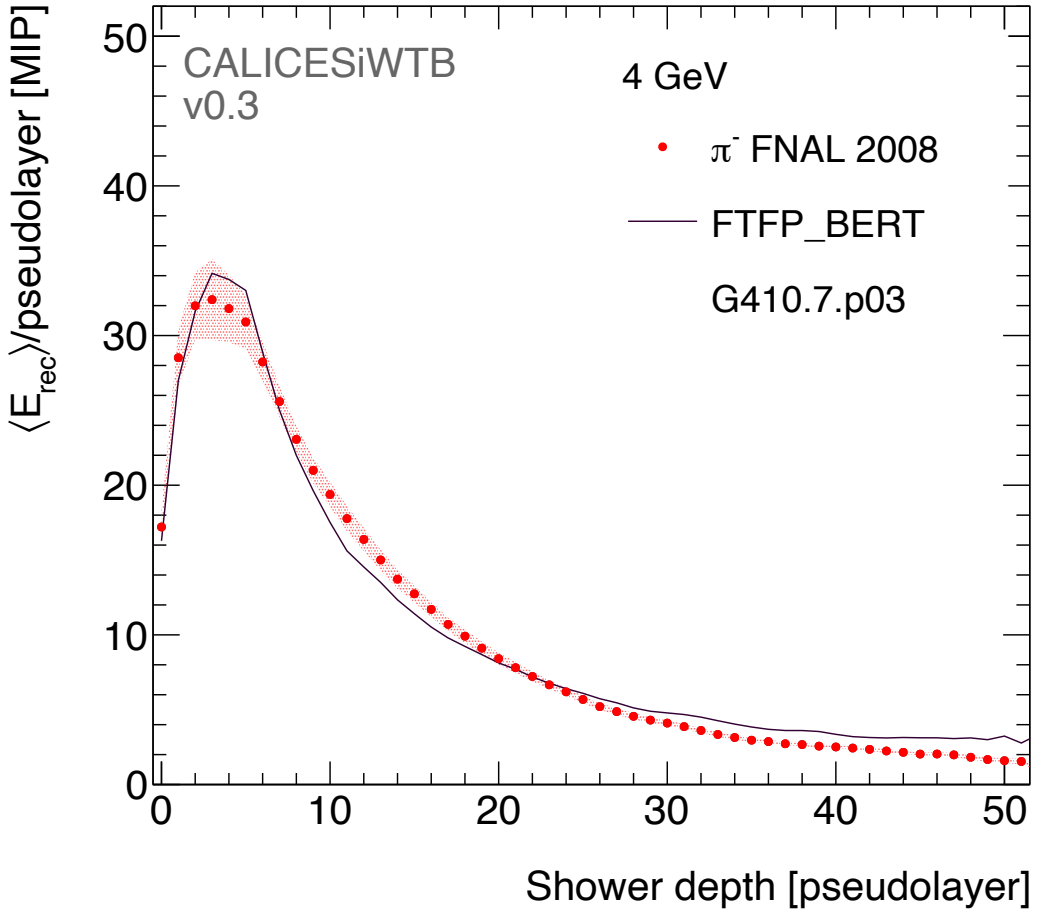
Longitudinal energy distribution - data, CALICE and us

4 GeV π^-

CALICE 2015 - Geant4.9.6 NIMA794

NOT PUBLISHED

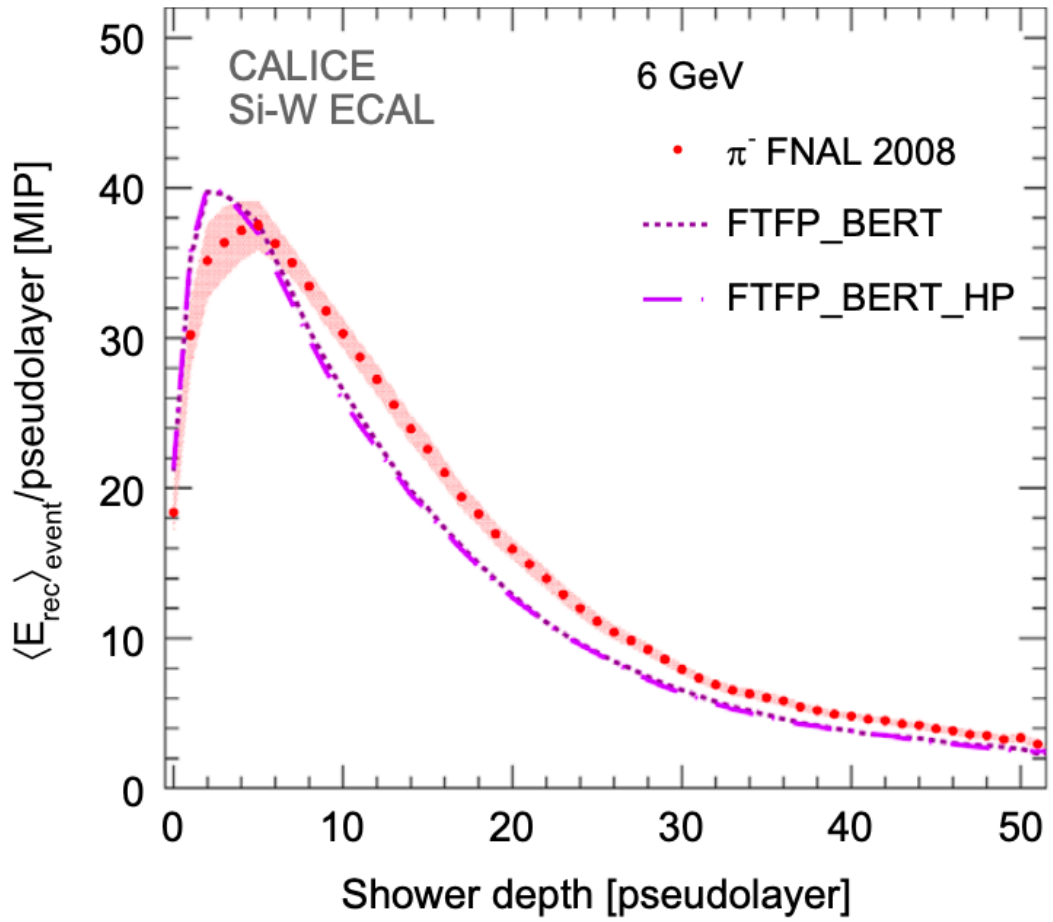
Geant4 Collaboration 2022 - Geant10.7.p03



Longitudinal energy distribution - data, CALICE and us

6 GeV π^-

CALICE 2015 - Geant4.9.6 NIMA794



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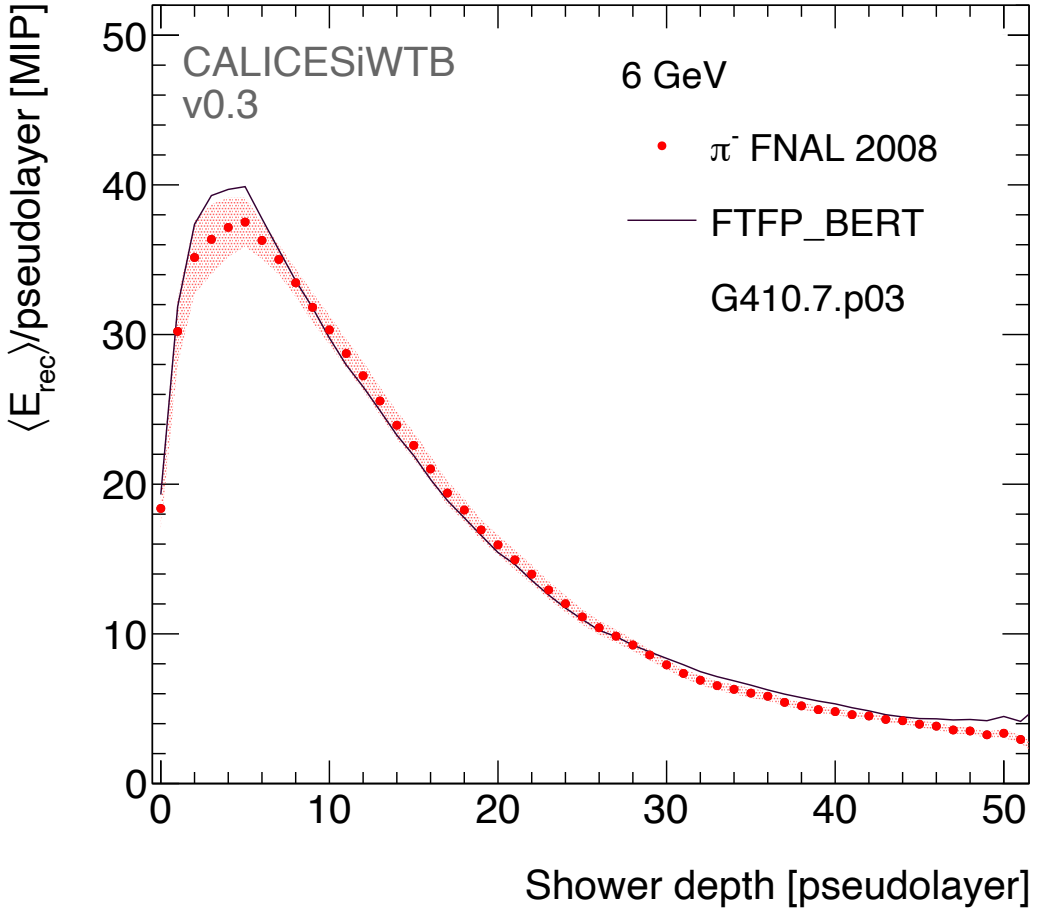


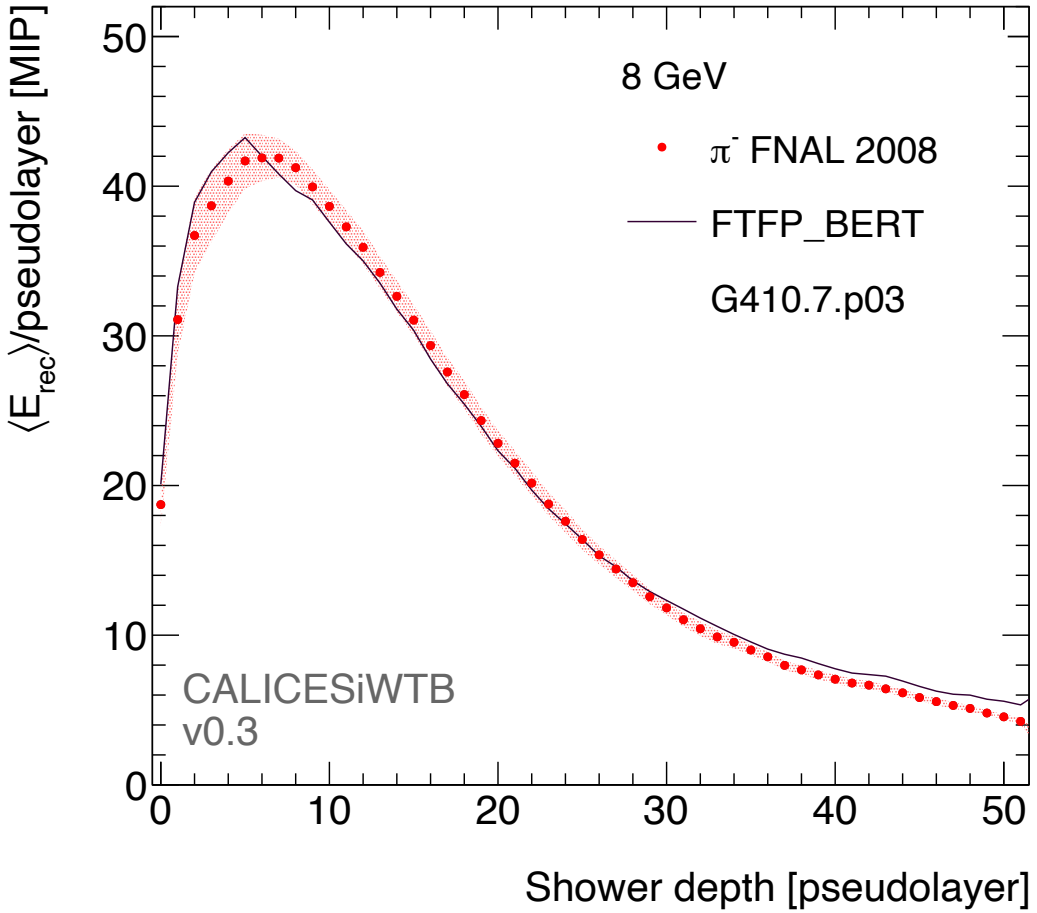
Longitudinal energy distribution - data, CALICE and us

8 GeV π^-

CALICE 2015 - Geant4.9.6 NIMA794

NOT PUBLISHED

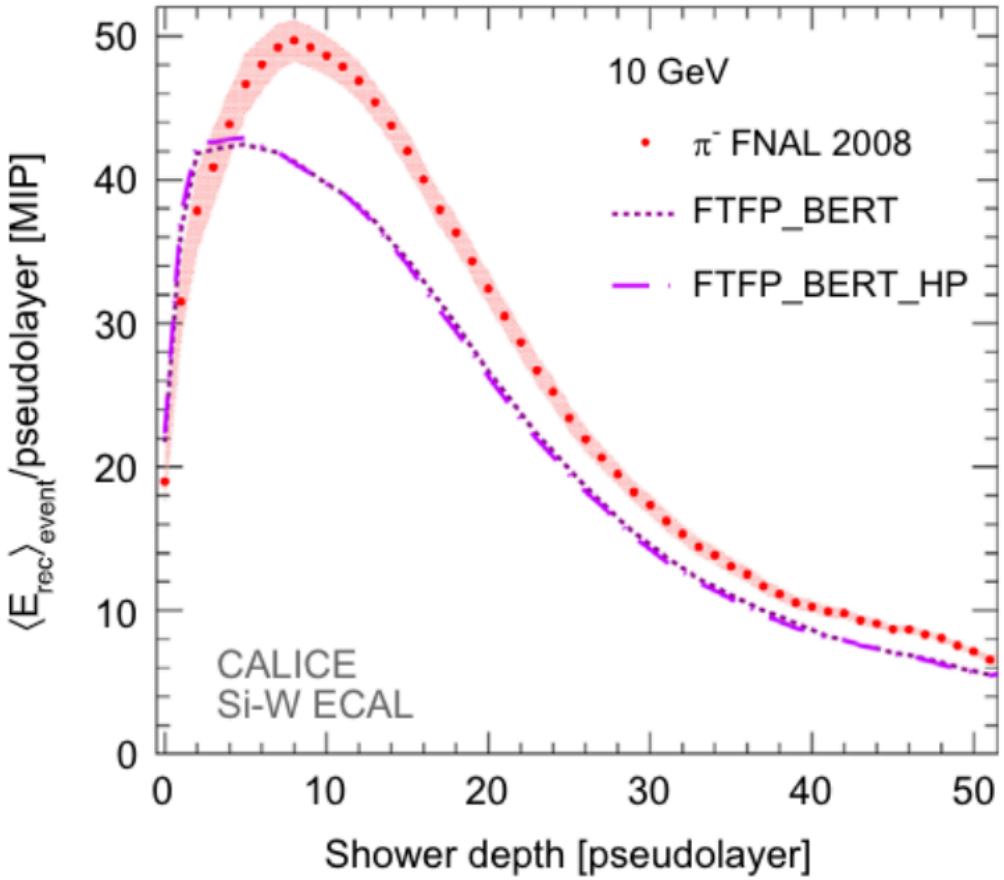
Geant4 Collaboration 2022 - Geant10.7.p03



Longitudinal energy distribution - data, CALICE and us

10 GeV π^-

CALICE 2015 - Geant4.9.6 NIMA794



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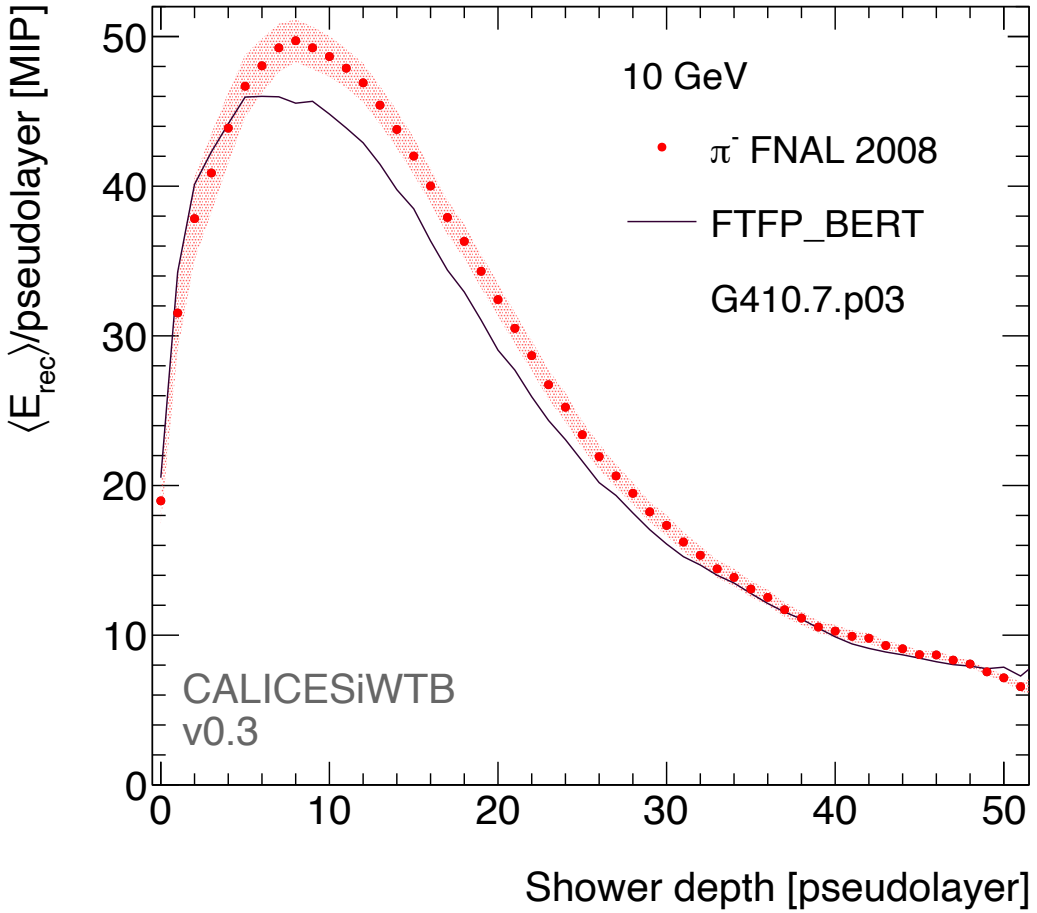

Conclusion and take home

- Software:
  - Reviewed the existing code to validate Geant4 on the CALICE 2008 SiW test beam. Probably extracted from a CALICE (mini)framework.
  - Migrated to a standalone Geant4 application importing sensitive detectors and geometry.
  - Tested on Mac, lxplus and lxplus+HTCondor it works on top of the Geant4 env with no crashes (1 warning related to material redefinition in GDML file, not sure if we should fix it).
- Physics:
  - Tested the energy longitudinal distribution of π^- events giving a single nuclear breakup in tungsten.
  - Sensible improvement in data description when comparing our 2022 results with the 2015 CALICE results.
  - Possible to extend the validation on the radial energy distributions (maybe a good working topic for our next summer student).
- To do:
  - We should contact the CALICE Collaboration for code cross-checking.
  - Possible to port these results into Geant-val.