Geant Val integration of the Geant4 ATLAS HEC simulation

<u>Lorenzo Pezzotti</u>, Alberto Ribon, Dmitri Kostantinov
CERN, EP-SFT

Simulation bi-weekly meeting
19/10/2021

Geant4 validation using ATLAS HEC beam tests

The project aims to validate Geant4 using the ATLAS Hadronic End-cap Calorimeter (HEC) test-beam data.
Started in May 2021.

Three main tasks identified:

- Porting the official ATLAS HEC simulation into a new standalone Geant4 simulation.
- Perform Geant4 validation against ATLAS HEC test-beam data.
- Integrate the application into the Geant Val testing suite.

Geant4 validation using ATLAS HEC beam tests

The project is to validate Geant4 using the ATLAS Hadronic End-cap Calorimeter (HEC) test-beam data.
Started in May 2021.

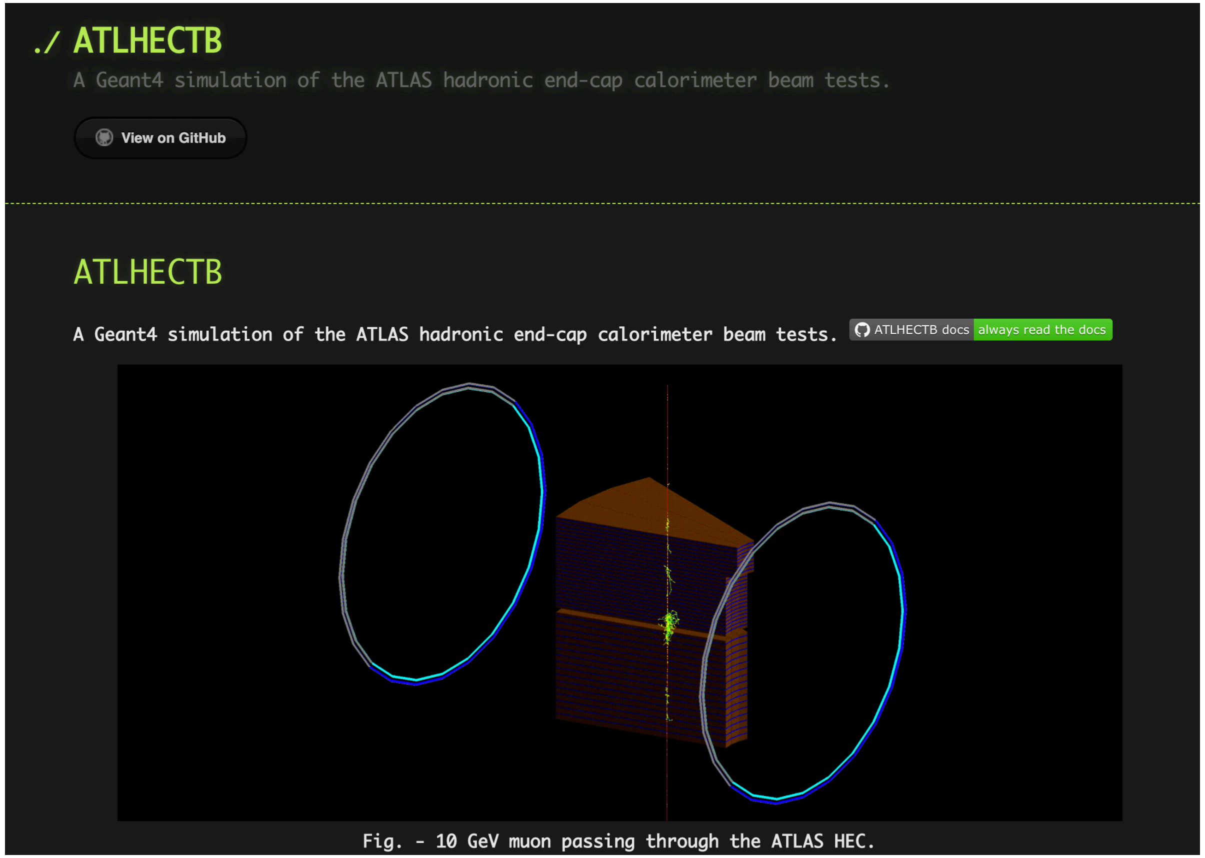
Three main tasks identified:

- Porting the official ATLAS HEC simulation into a new standalone Geant4 simulation.
  - Completed in June 2021, presented at this meeting [presentation].
- Perform Geant4 validation against ATLAS HEC test-beam data.
  - First results presented in July 2021 at this meeting [presentation],
  - and at the ATLAS Simulation Group Meeting [presentation].
  - Updated results to be presented today.
- Integrate the application into the Geant Val testing suite.
  - To be presented today.

ATLHECTB

A Geant4 Simulation of the ATLAS hadronic end-cap calorimeter beam tests.

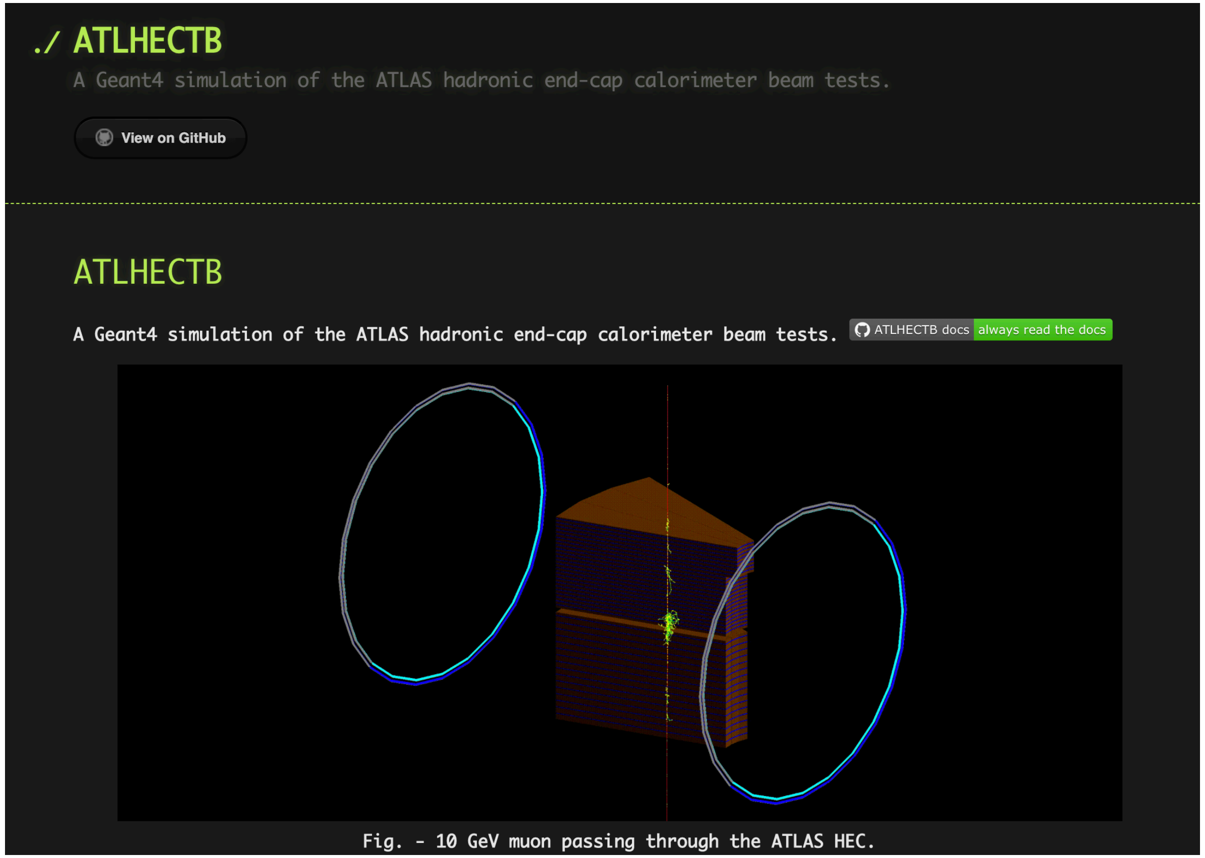
- GitHub-link
- New static website with documentation [link]



ATLHECTB

A Geant4 Simulation of the ATLAS hadronic end-cap calorimeter beam tests.

- GitHub-link
- New static website with documentation [link].
- Updates since last presentation (*v1.1-v1.7*):
  - A new timing scheme for signal readout mimicking the HEC electronics.
  - New beam alignment.
  - New materials definition (not retrieved from NIST manager, consistent with ATLAS).
  - /run/setCut 1.0 mm
  - Birks' law now taken directly from the ATHENA implementation.

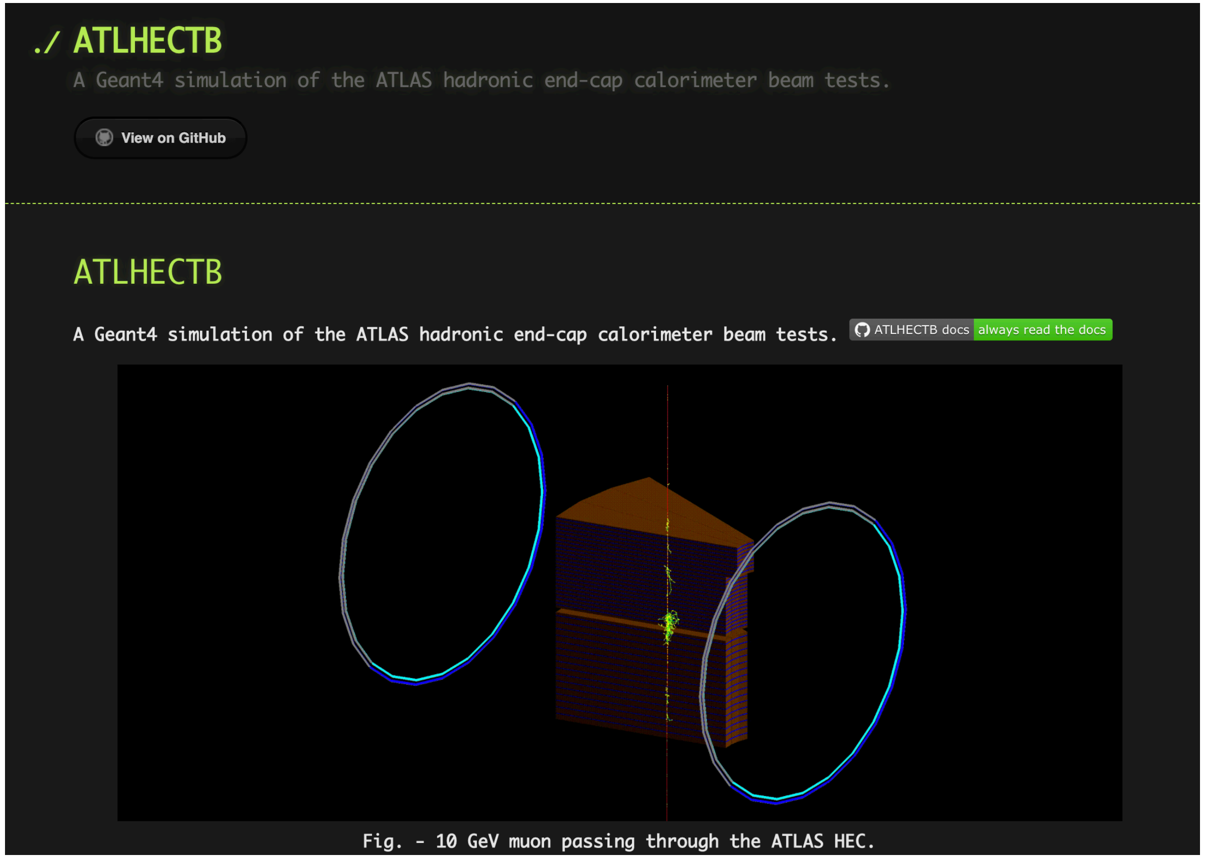


ATLHECTB

A Geant4 Simulation of the ATLAS hadronic end-cap calorimeter beam tests.

- GitHub-link
- New static website with documentation [link]

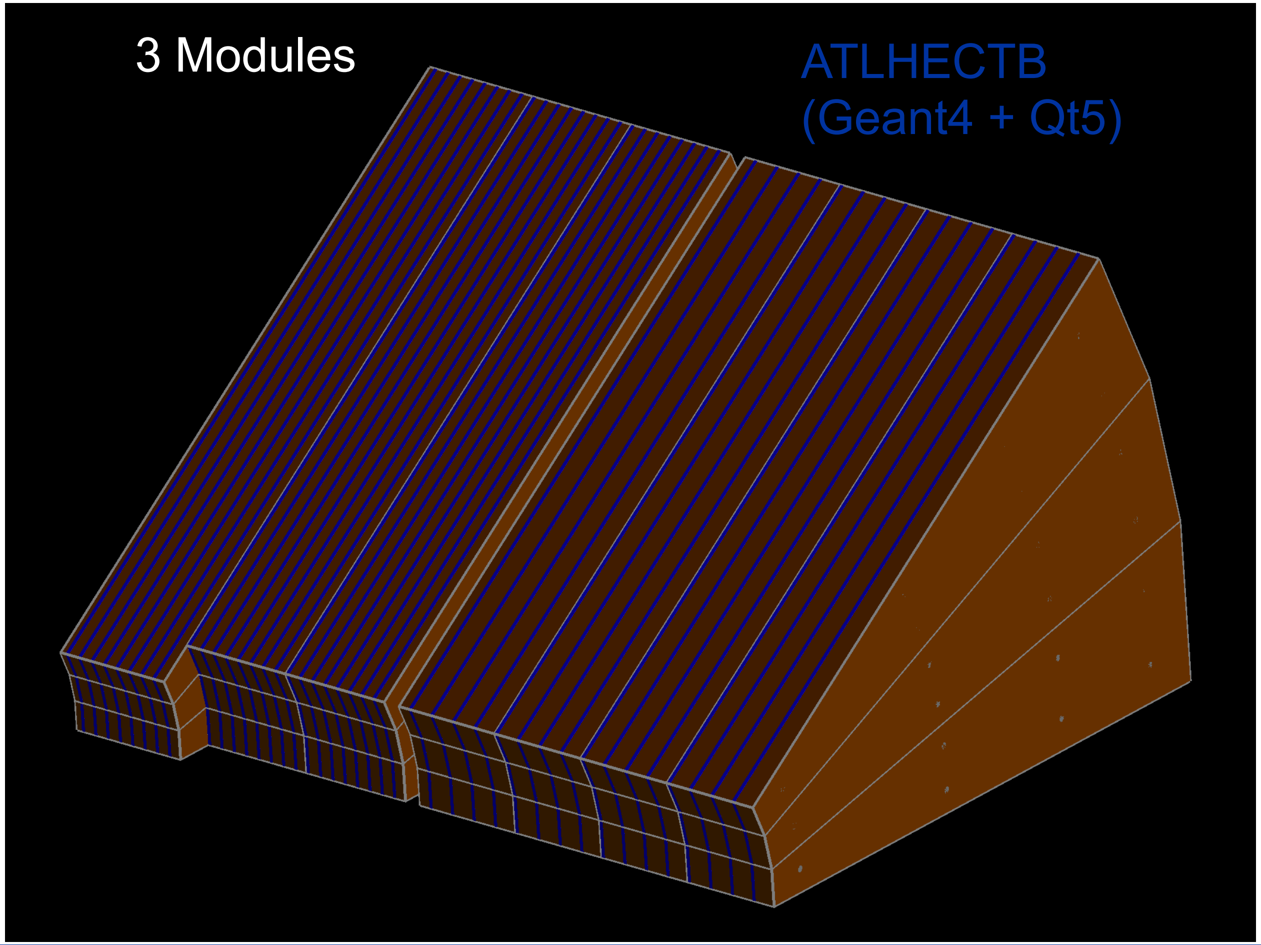
- From *v2.0* on, it is available to be used within Geant Val, for automatic:
  - Multiple macros creation for,
  - Multiple jobs submission with HTCondor, and
  - Multiple output files analysis.



Geometry

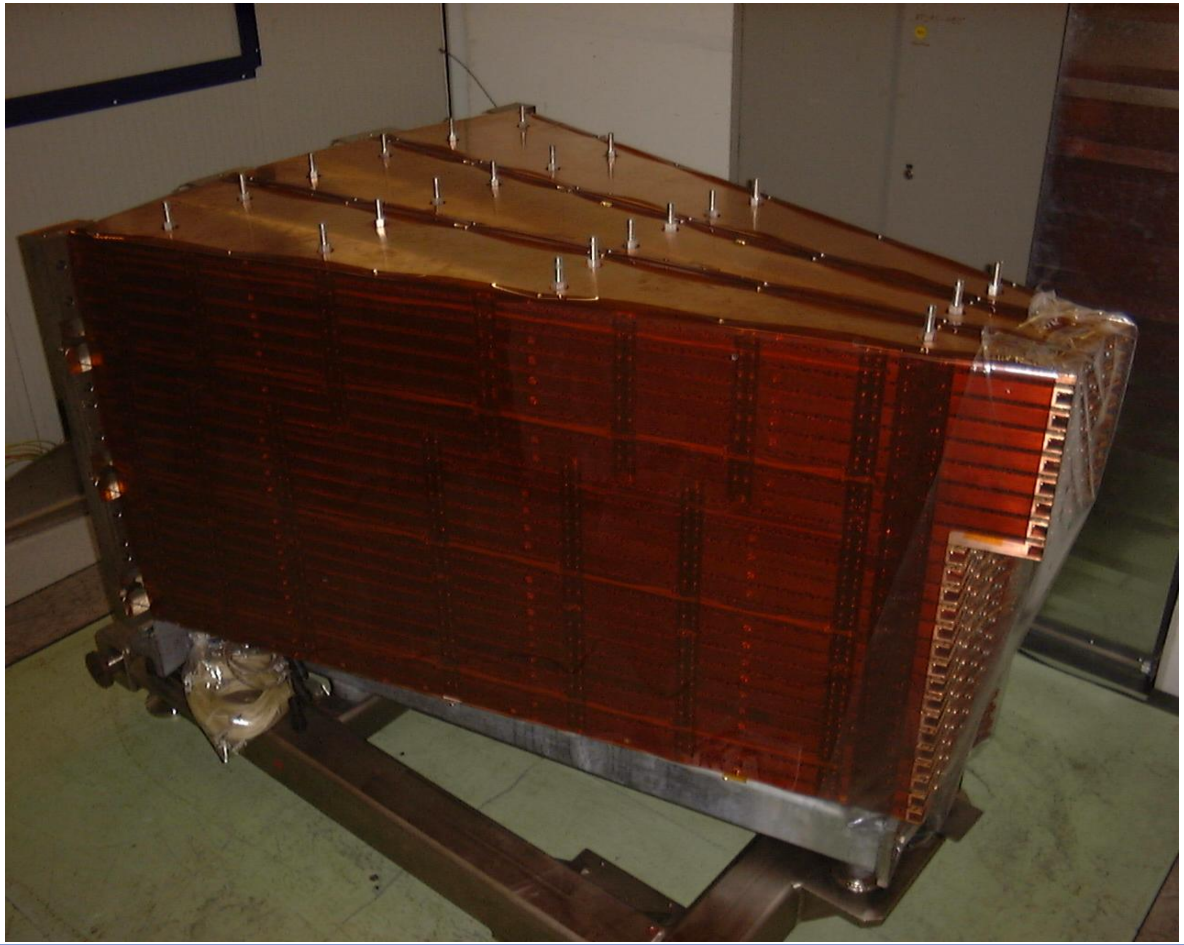
Default ATLHECTB geometry.

Detailed geometry description [presentation].



Picture from ATLAS HEC test beam (2000/2001).

Some pictures from ATLAS [link].

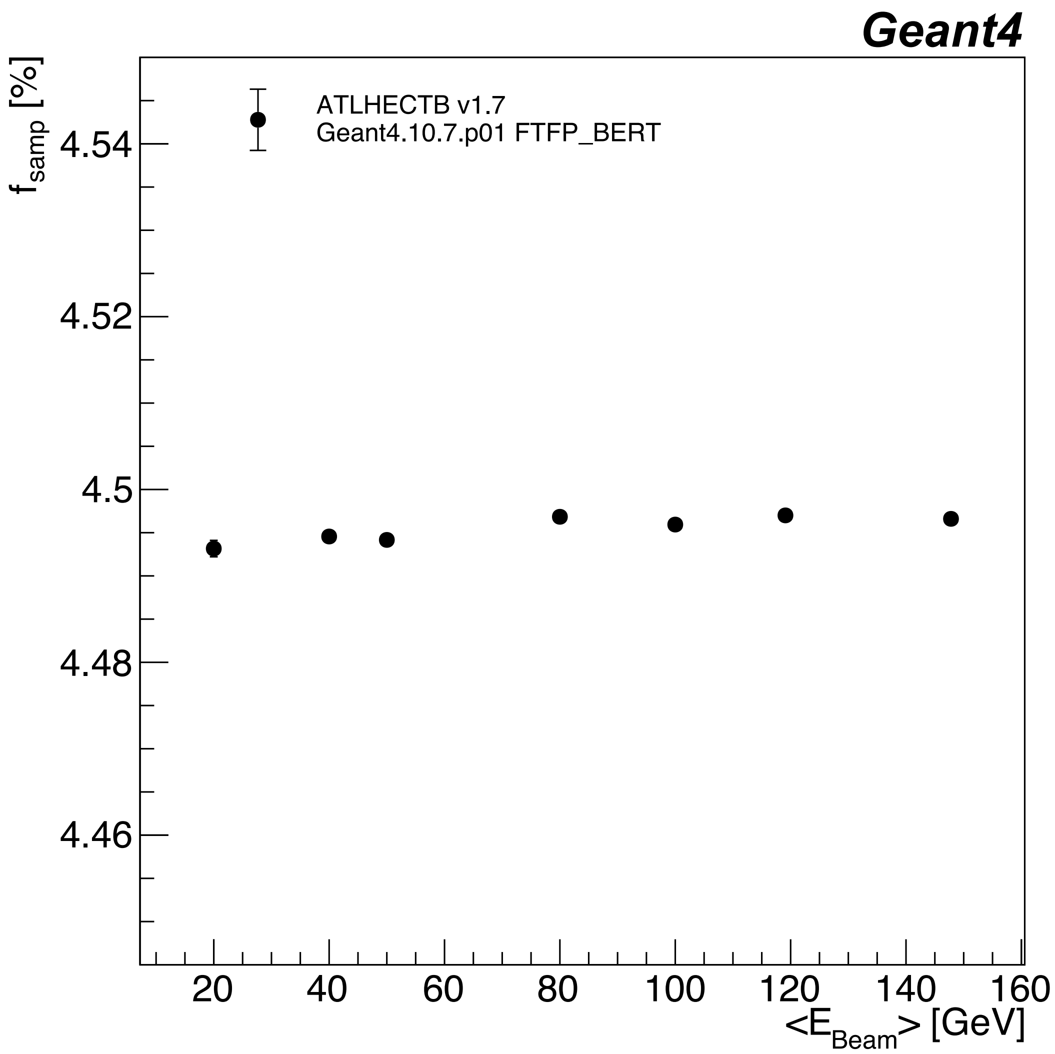


Updated results from v1.7

Sampling fraction (e^-)

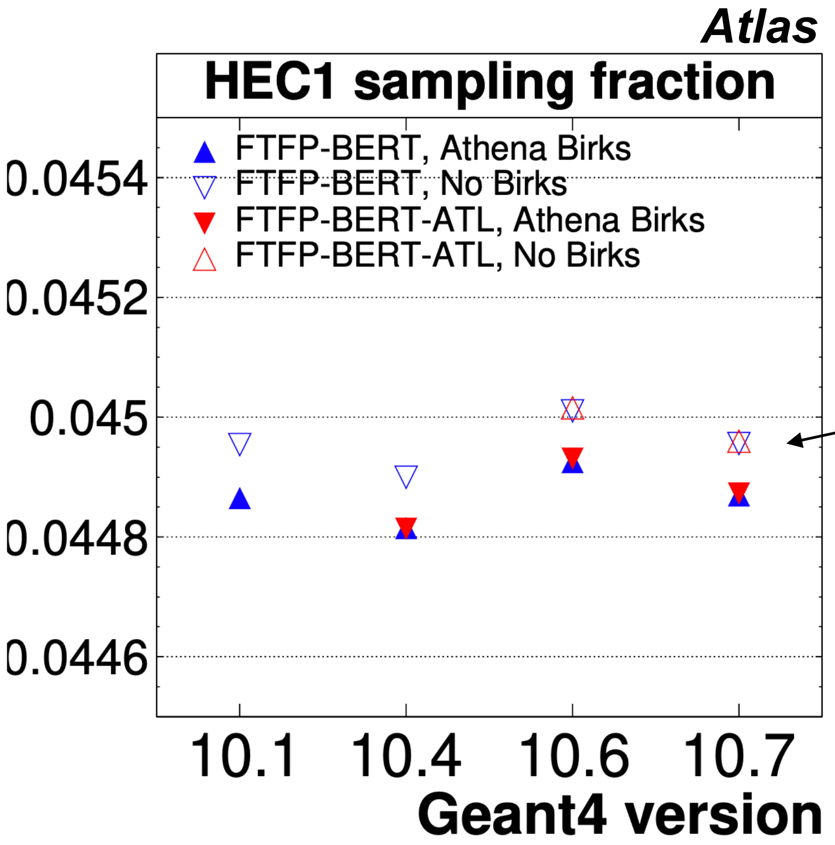
Sampling fraction for e^- estimated as Birks quenched energy in liquid argon divided by beam energy.

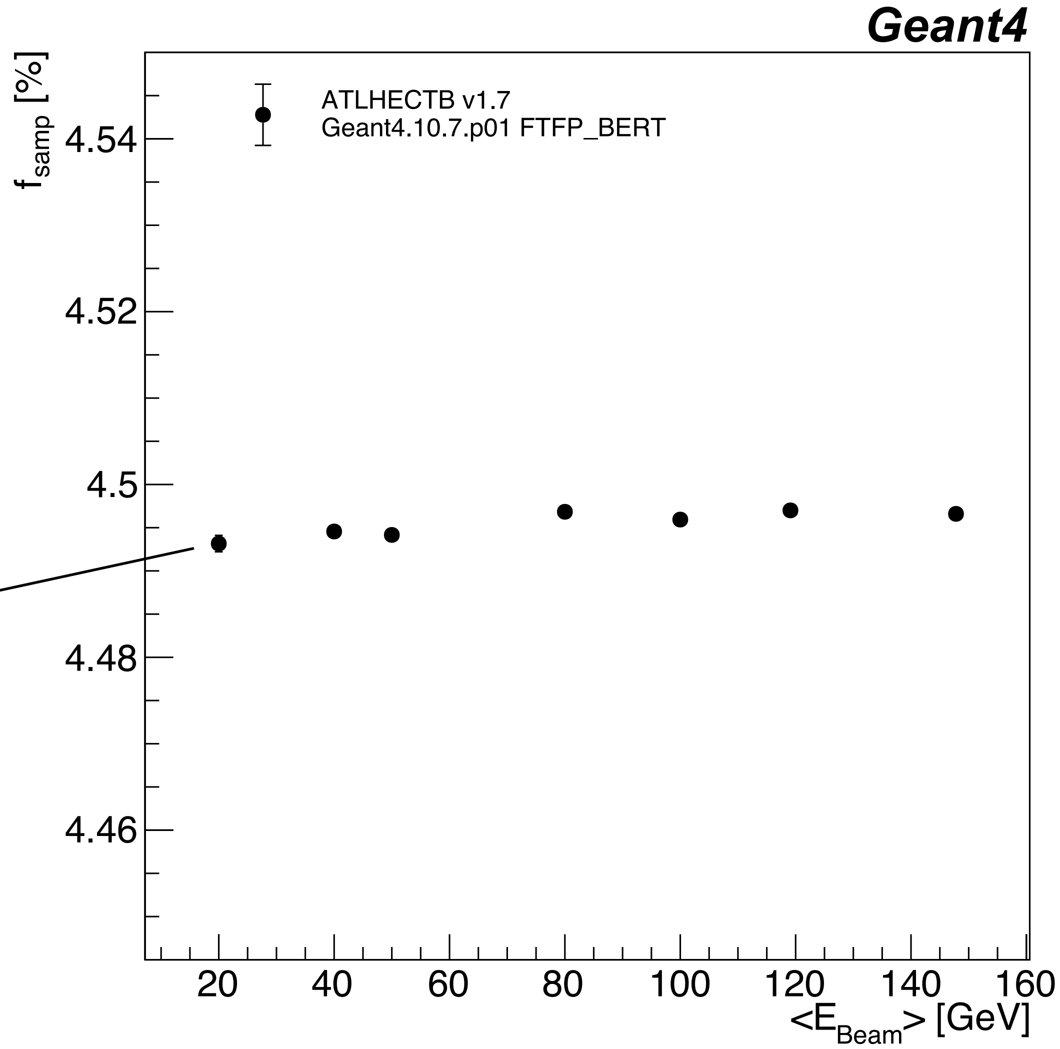
- Constant over the beam energy range 20-150 GeV.



Sampling fraction (e^-)

Almost identical to the one quoted by the ATLAS Simulation Group [link].



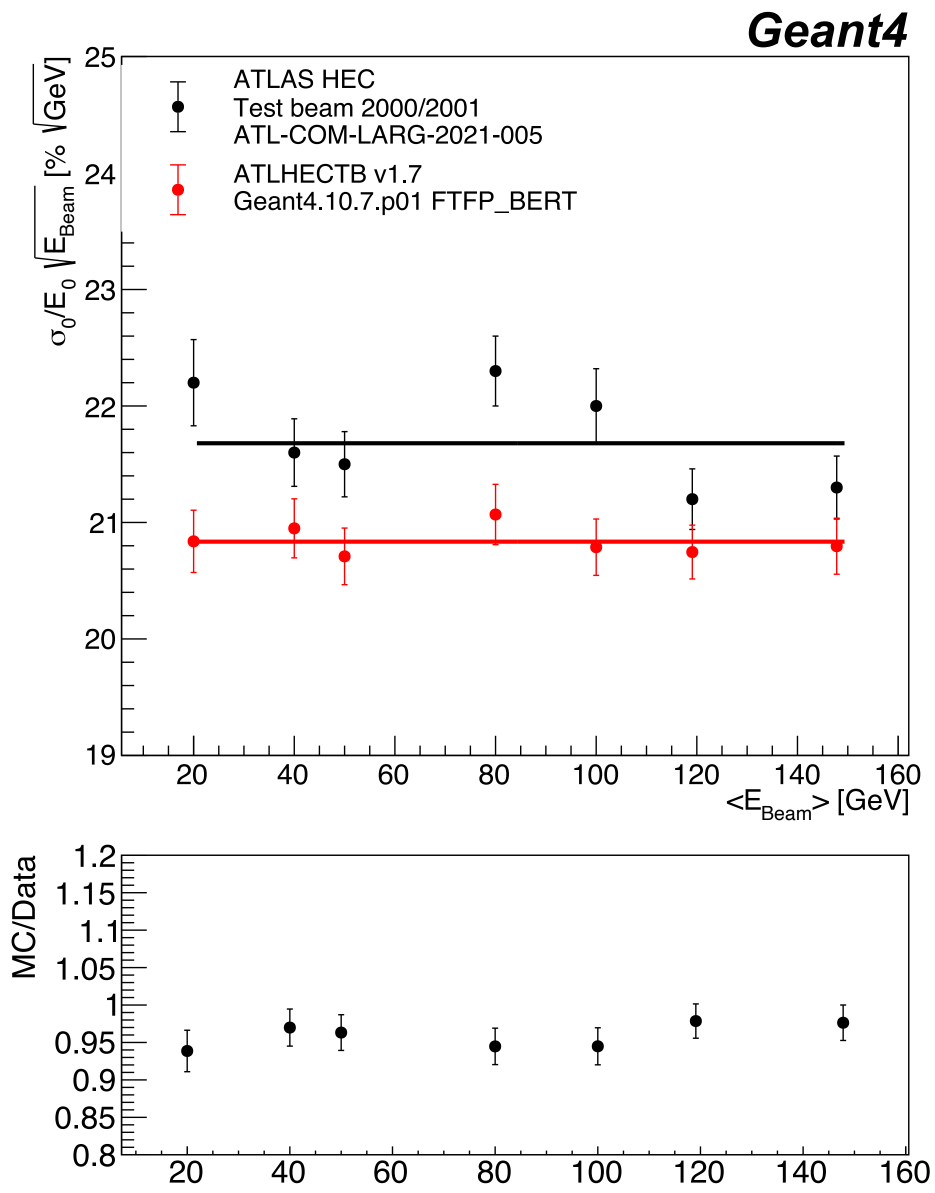


Energy resolution (e^-)

Using the average sampling fraction the beam energy was reconstructed and the energy resolution extracted from a Gaussian fit.

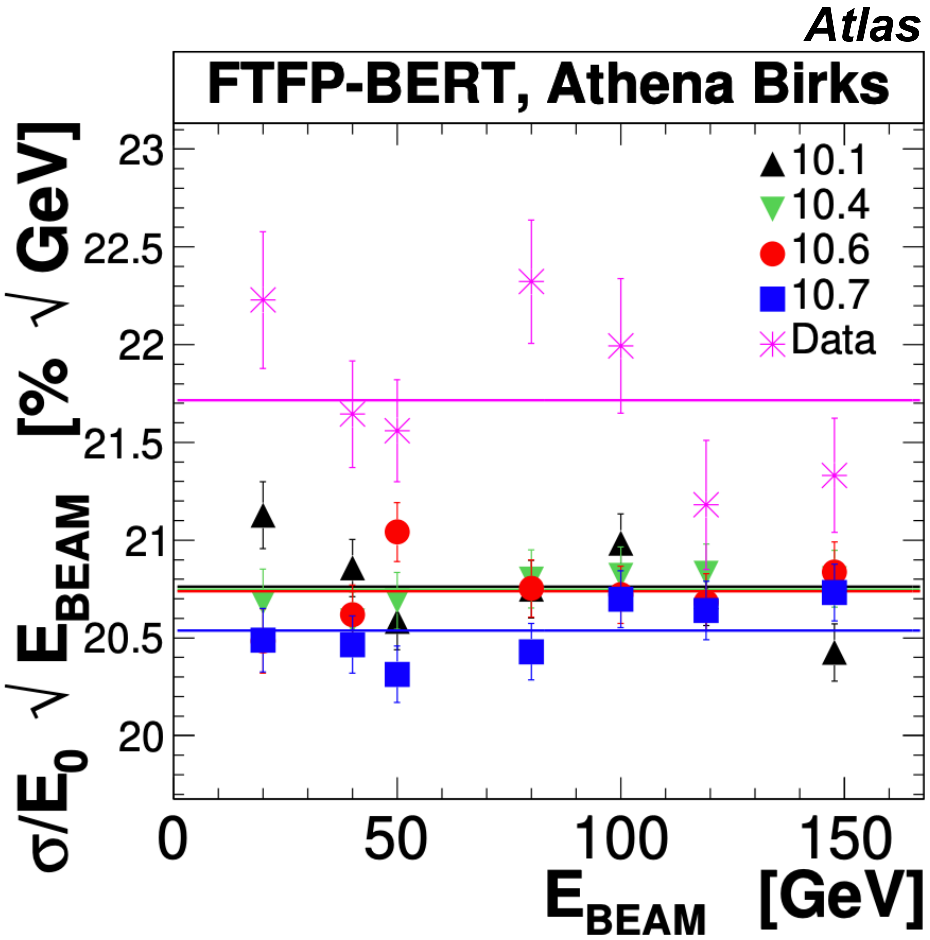
- Can be directly compared to test beam results (ATL-COM-LARG-2021-005) as ATLAS quotes

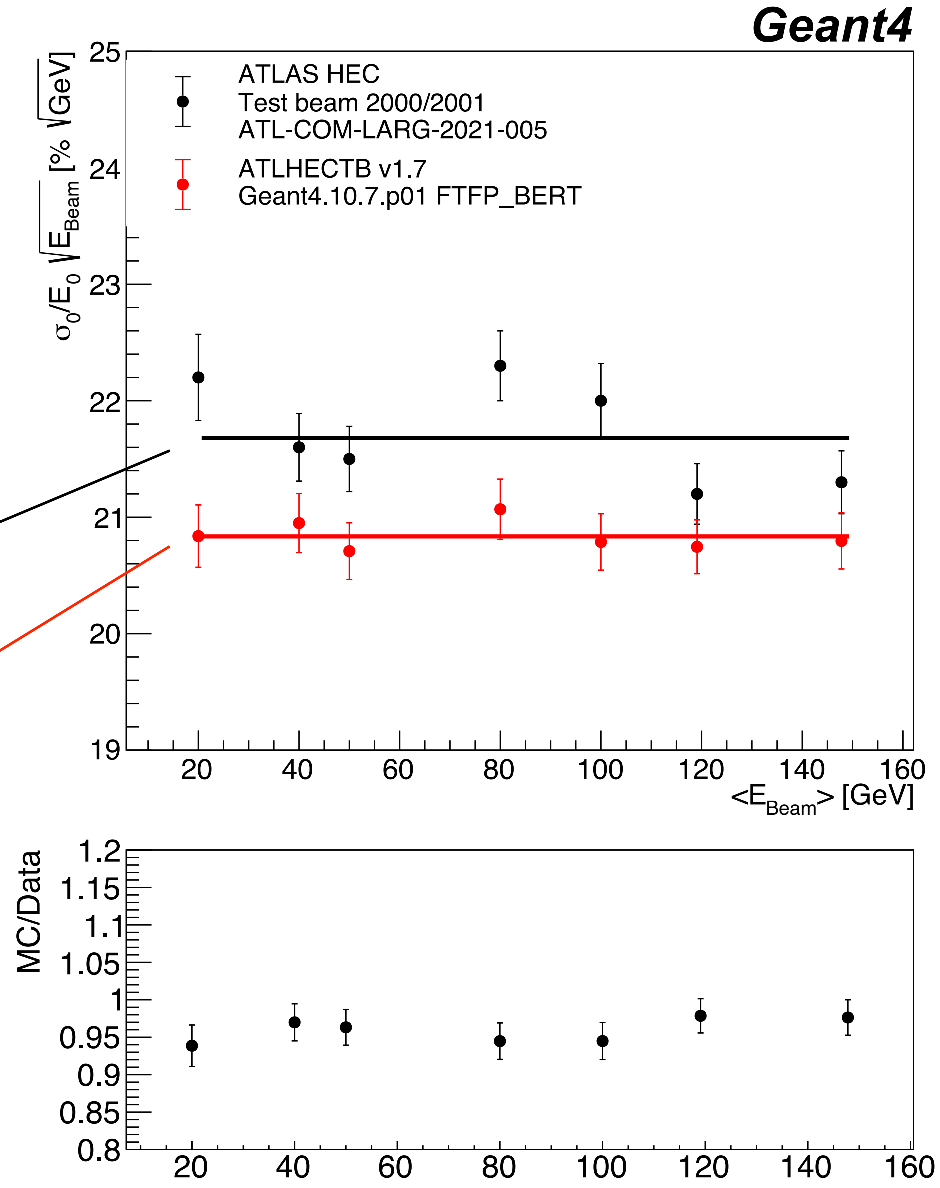
$$\sigma_0 = \sqrt{\sigma_E^2 - \sigma_{noise}^2}$$



Energy resolution (e^-)

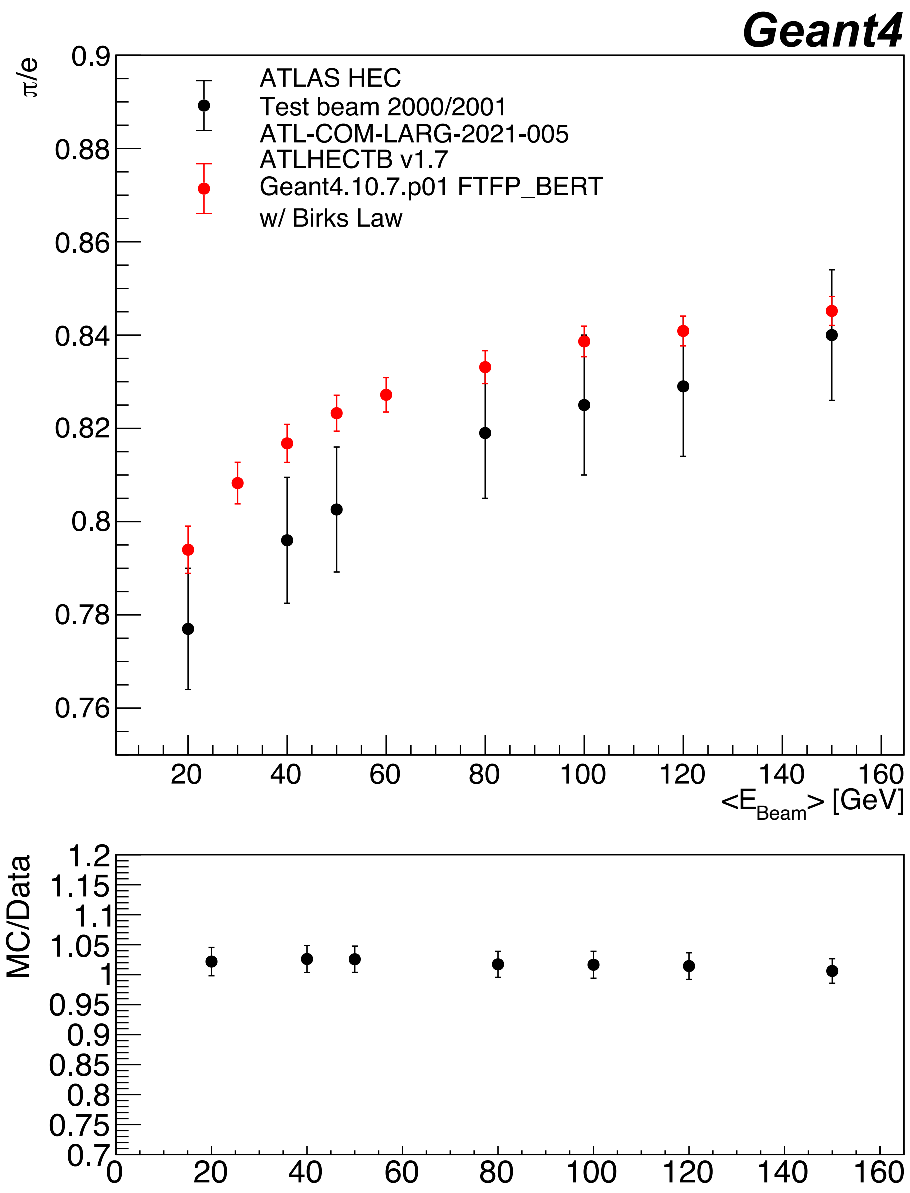
Very close to the ATLAS Simulation results [link].





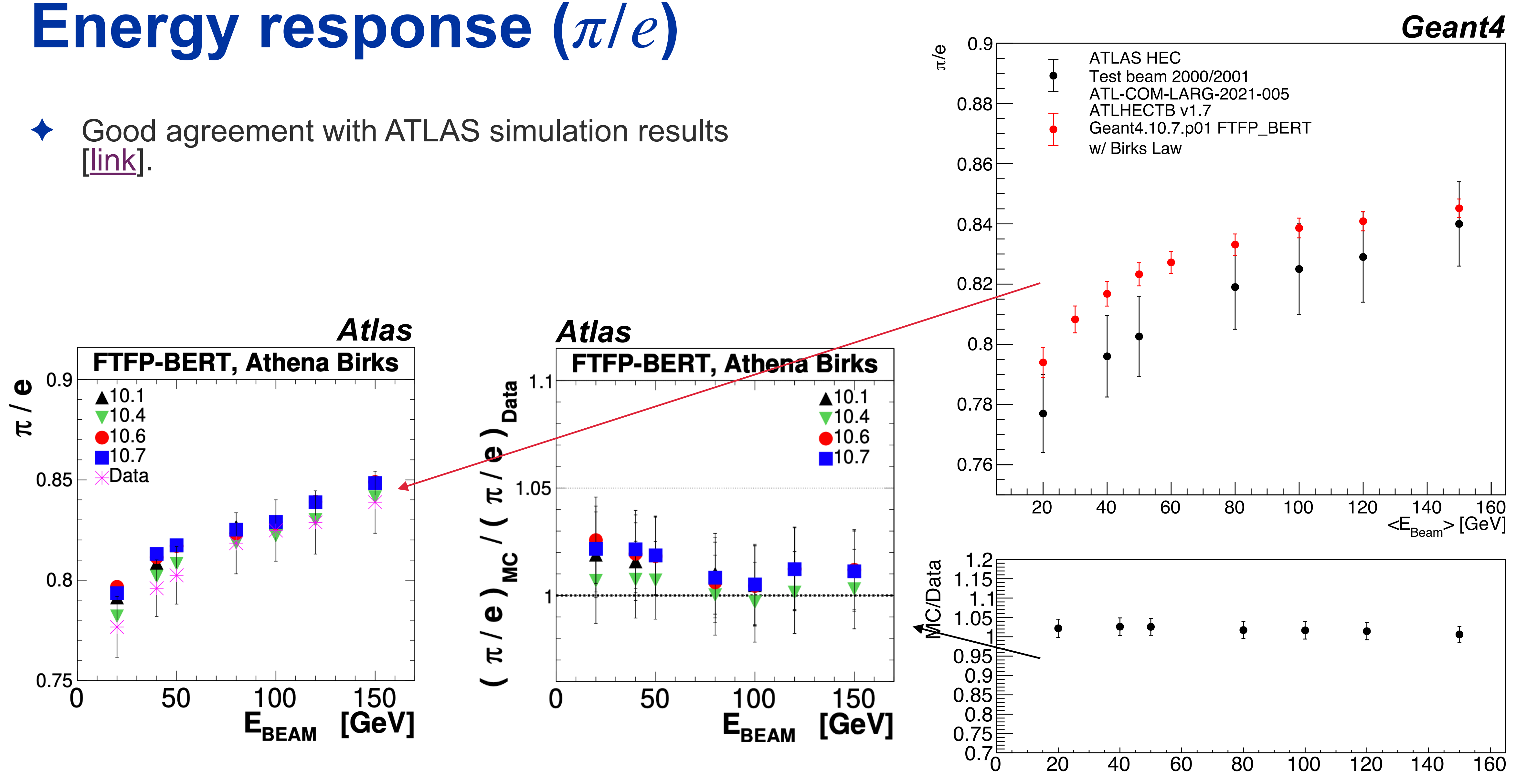
Energy response (π/e)

- π/e is extracted from the average π^- reconstructed energy, using the calibration at the electromagnetic scale, divided by the beam energy.
- In the range 20-150 GeV Geant4 it is in $\sim 2\,\%$ agreement with test-beam data (using ATLHECTB v1.7, Geant4.10.7.p01, FTFP_BERT).



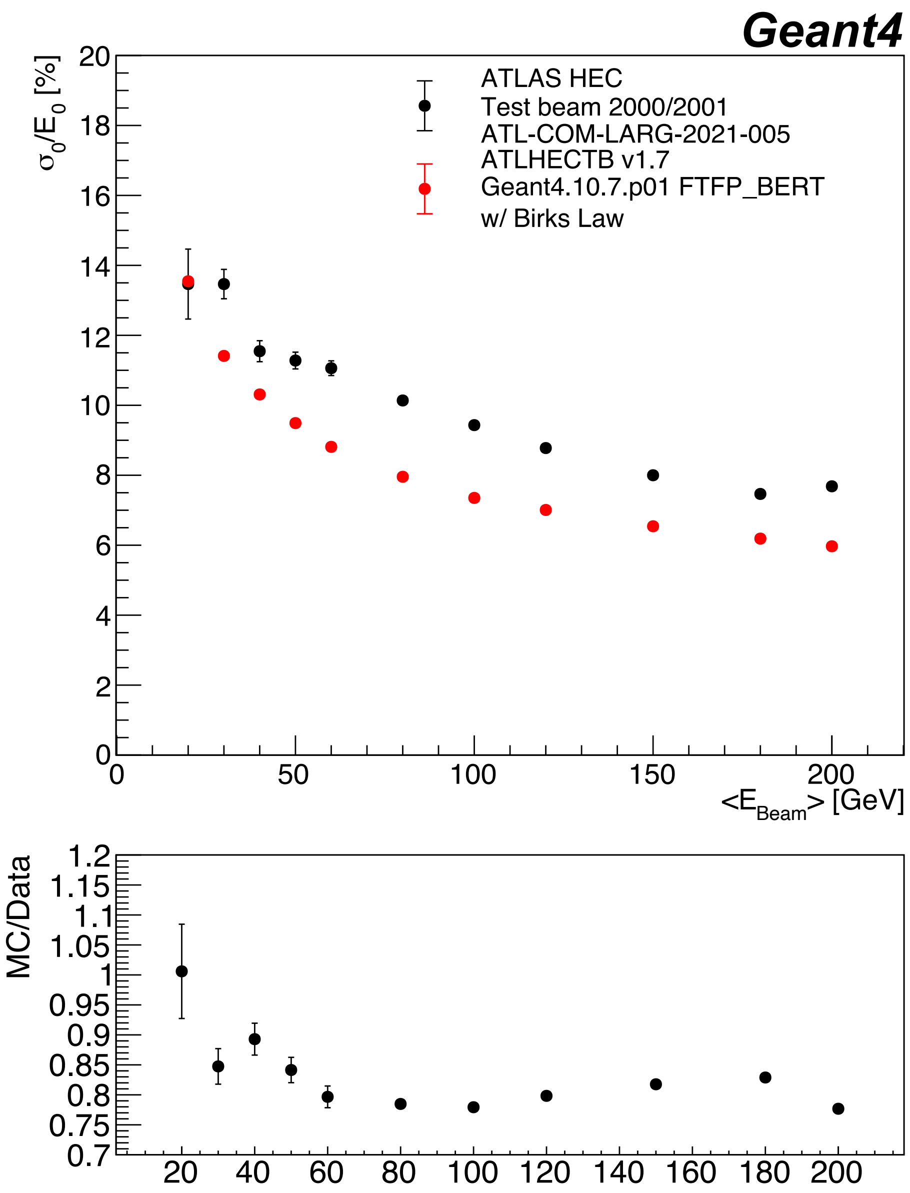
Energy response (π/e)

- Good agreement with ATLAS simulation results [link].



Energy resolution (π^-)

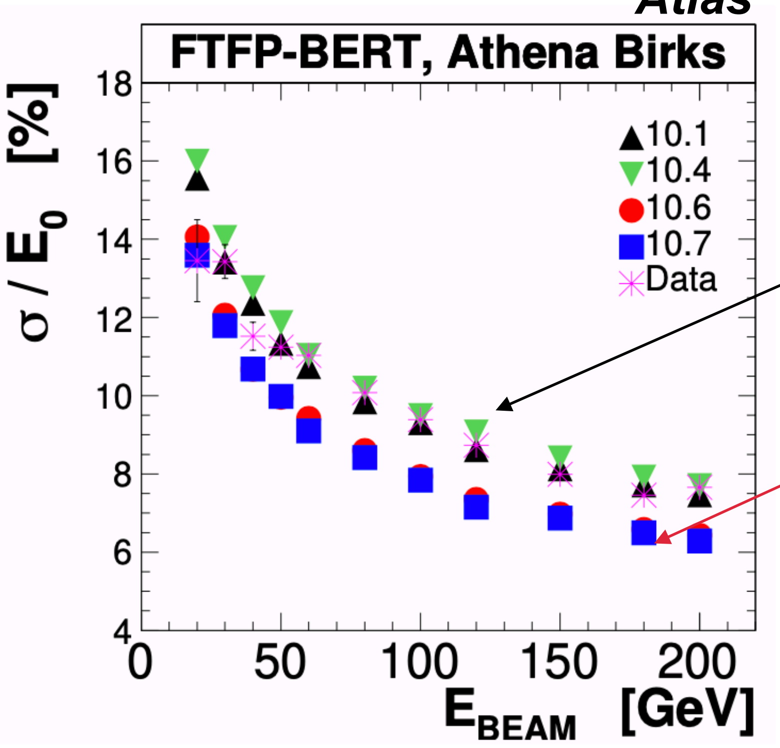
- Energy resolution is obtained from a Gaussian fit to the asymmetric π^-energy distributions (the HEC is a non compensating calorimeter).



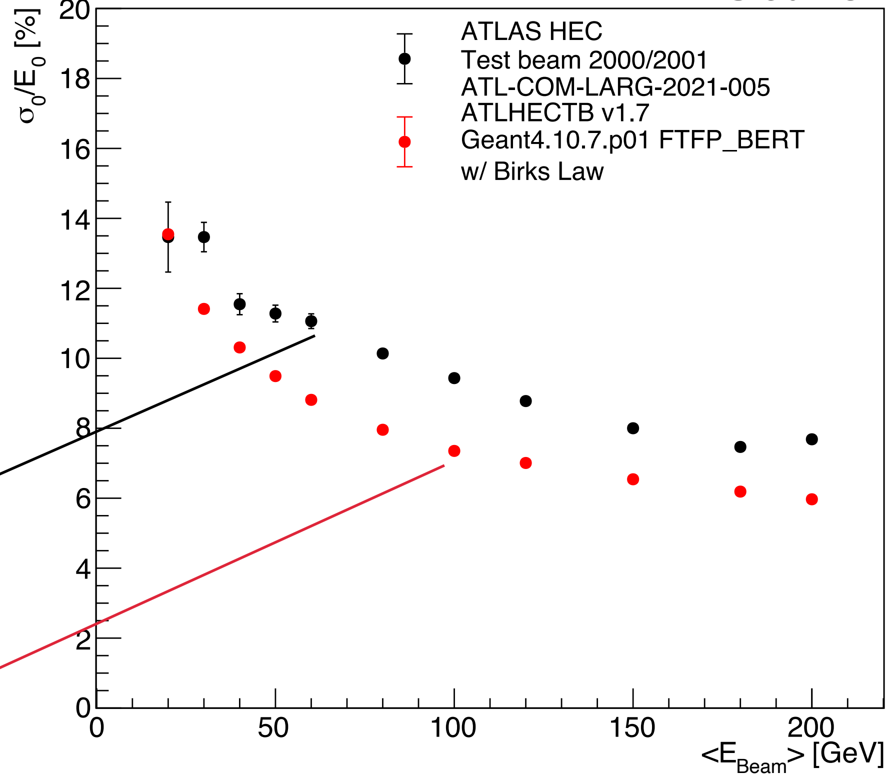
Energy resolution (π^-)

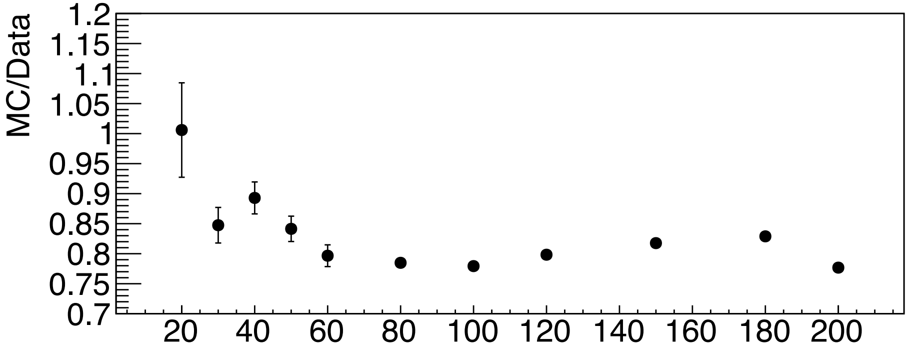
- Both Geant4 and ATLAS simulations are $\sim 20\,\%$ off w.r.t. test-beam data.
  ATLAS simulation suggests this only happens in Geant4.10.7 and Geant4.10.6 [link].

Atlas



Geant4

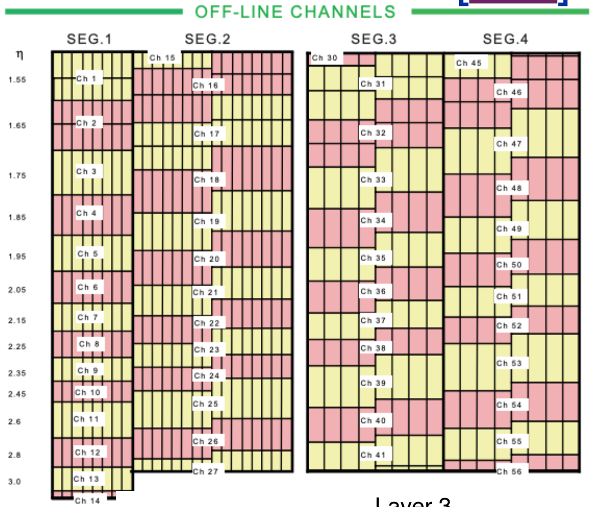




Shower shape (π^-)

- Possible to study the fraction of energy (signal) deposited in each layer: $F_i = \langle E_i \rangle / E_{sum},\ E_{sum} = \Sigma \langle E_i \rangle$
- and the the F_i dependence with E_{beam}.

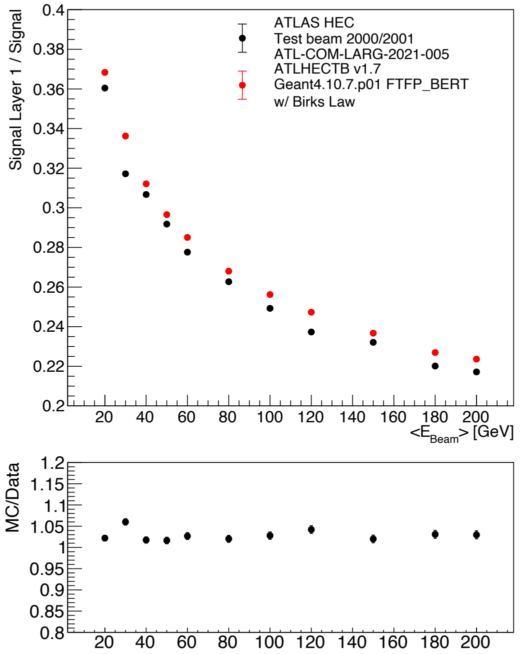
Found at [Link]



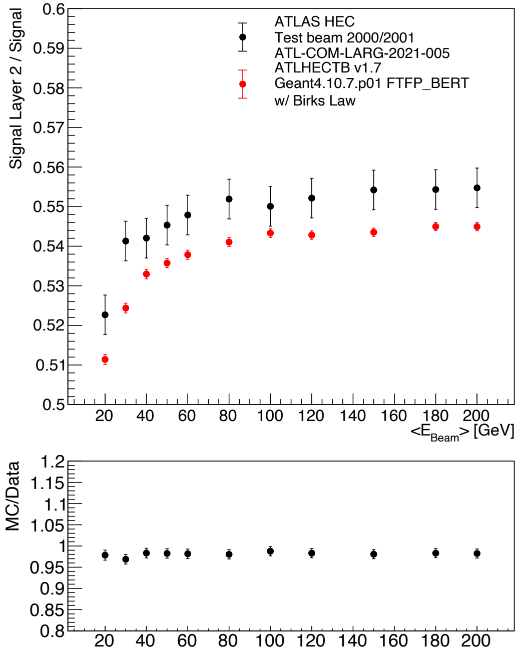
HEC longitudinal structure

HEC layer	Number of LAr gaps	HEC length	
		[cm]	[λ_{int}]
1	8	28.05	1.45
2	16	53.60	2.75
3	8	53.35	2.87
4	8	46.80	2.66

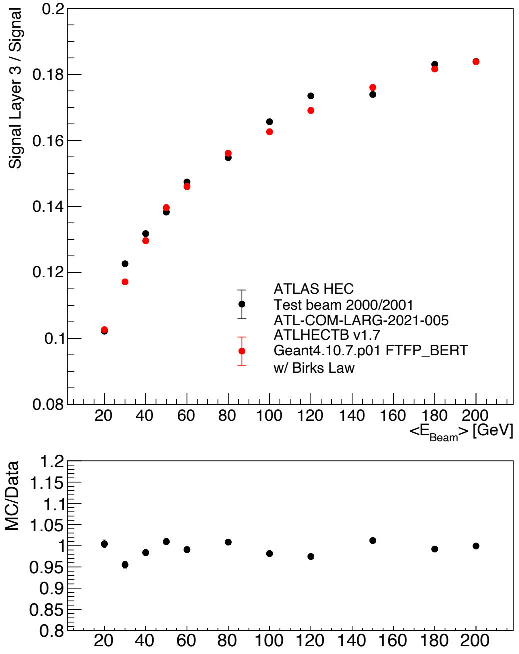
Layer 1



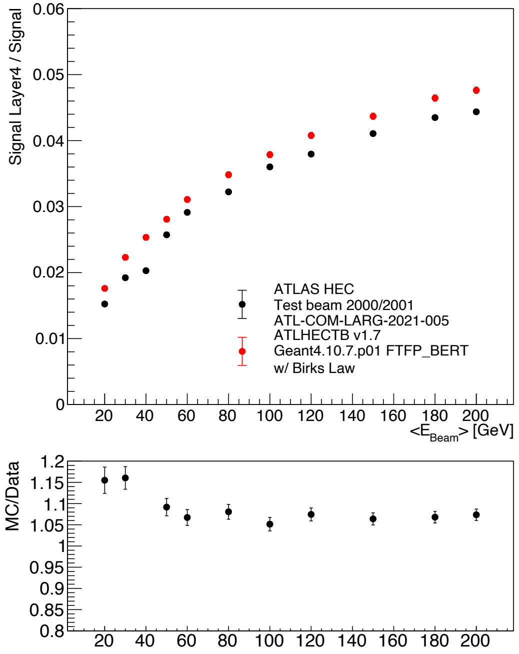
Layer 2



Layer 3

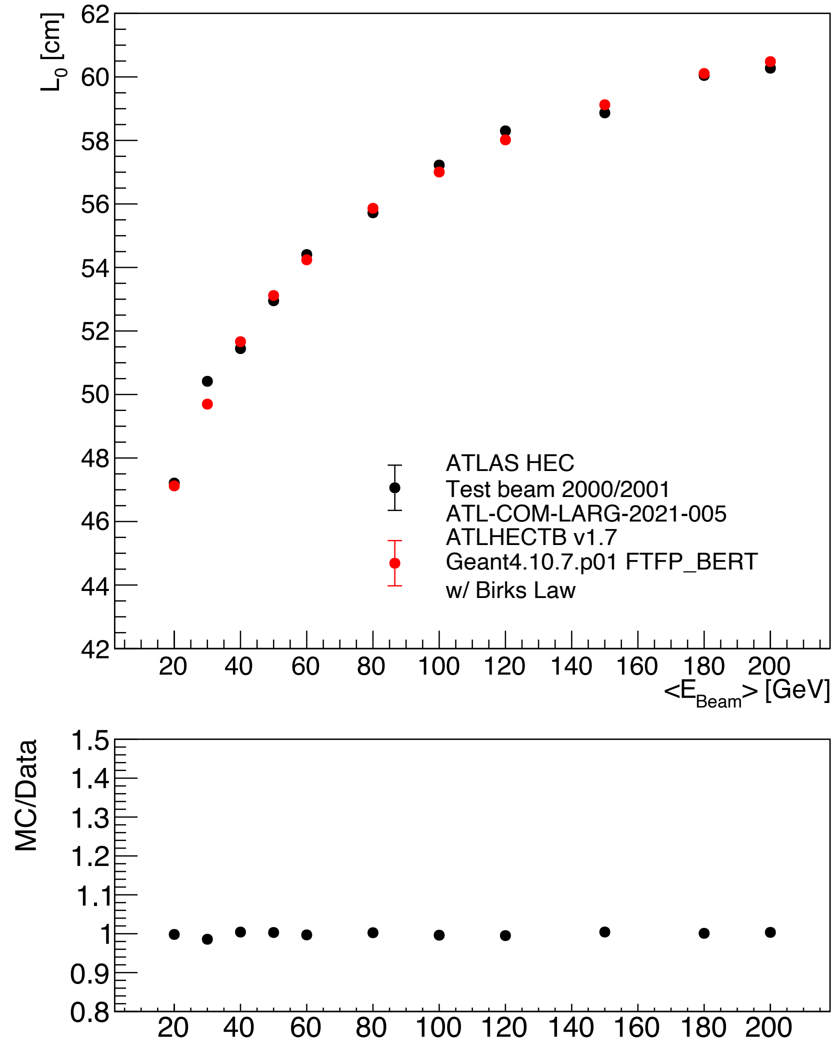


Layer 4



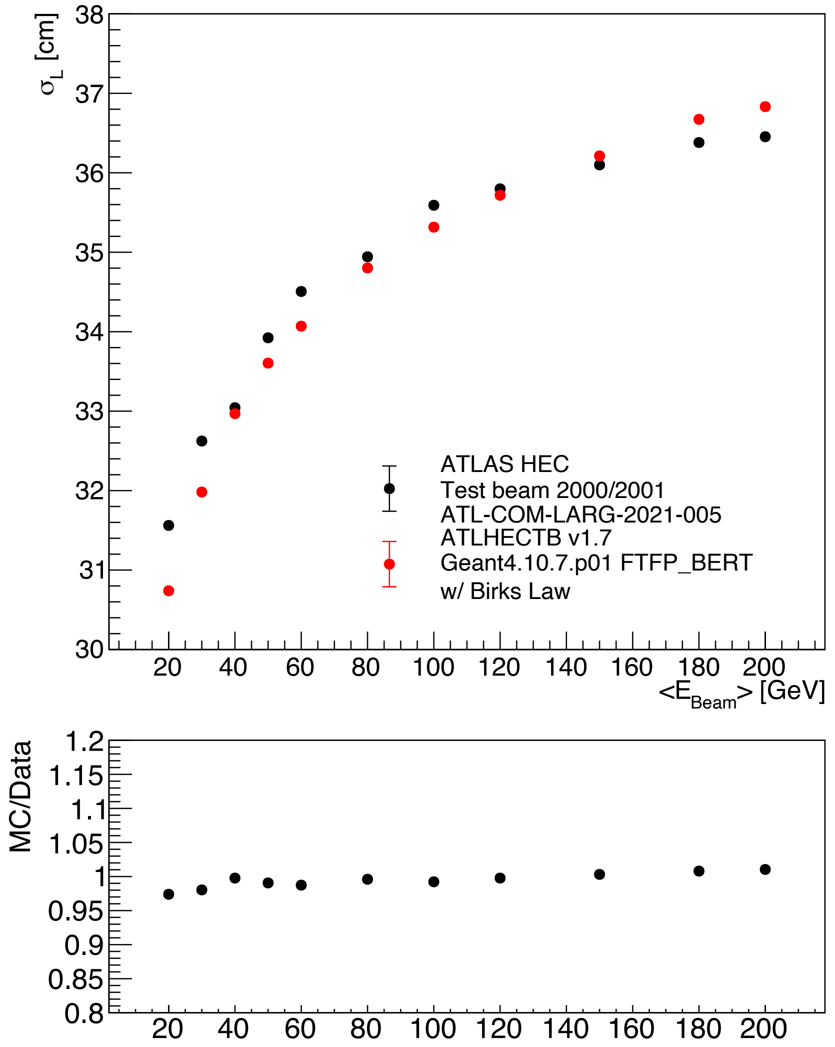
Longitudinal shower barycenter (π^-)

- Hadronic showers longitudinal profiles are calculated from the fraction of energy (signal) in each layer, as a function of the layer longitudinal position.
  - Mean of the profile (L_0): is a direct measurement of the hadronic shower average depth.
    - Excellent description provided by Geant4.10.7.p01 and FTFP_BERT (ATLHECTB v1.7).



Shower length (π^-)

- Hadronic showers longitudinal profiles are calculated from the fraction of energy (signal) in each layer, as a function of the layer longitudinal position.
  - Mean of the profile (L_0): is a direct measurement of the hadronic shower average depth.
    - Excellent description provided by Geant4.10.7.p01 and FTFP_BERT (ATLHECTB v1.7).
  - RMS of the profile (σ_L): is an indirect measurement of the hadronic shower length.
    - Within $\pm 2\,\%$ agreement w.r.t. test-beam data.



Geant Val integration

ATLHECTB Geant Val integration

From *v2.0* on, ATLHECTB is fully compatible with the Geant Val workflow.

- <u>Many thanks to Dmitri Kostantinov for the mentorship on the topic.</u>
- Instructions for Geant Val usage at [Geant-Val-Intregration].

ATLHECTB Geant Val integration

From *v2.0* on, ATLHECTB is fully compatible with the Geant Val workflow.

- Many thanks to Dmitri Kostantinov for the mentorship on the topic.
- Instructions for Geant Val usage at [Geant-Val-Intregration].

params.conf

```
!PHYSLIST=FTFP_BERT, QGSP_BERT
!CONST:ENERGY_UNIT=GeV
PARTICLE | ENERGY | PHYSLIST | NEVENTS
pi- | 20. | PHYSLIST | 50000
pi- | 30. | PHYSLIST | 50000
pi- | 40. | PHYSLIST | 50000
pi- | 50. | PHYSLIST | 50000
pi- | 60. | PHYSLIST | 50000
pi- | 80. | PHYSLIST | 50000
pi- | 100. | PHYSLIST | 50000
pi- | 120. | PHYSLIST | 50000
pi- | 150. | PHYSLIST | 50000
pi- | 180. | PHYSLIST | 50000
pi- | 200. | PHYSLIST | 50000
e- | 20. | PHYSLIST | 50000
e- | 40. | PHYSLIST | 50000
e- | 50. | PHYSLIST | 50000
e- | 80. | PHYSLIST | 50000
e- | 100. | PHYSLIST | 50000
e- | 119.1 | PHYSLIST | 50000
e- | 147.8 | PHYSLIST | 50000
```

template.conf

```
/run/initialize
/gun/position -9 172 0 cm
/gun/direction 0 0 1
/gun/particle %PARTICLE%
/gun/energy %ENERGY% %ENERGY_UNIT%
/run/setCut 1.0 mm
/run/beamOn %NEVENTS%
```

run.sh

```
#!/bin/bash

# Environment variables
export PHYSLIST="%PHYSLIST%"

# Execute
ATLHECTB -m ATLHECTB.mac -pl %PHYSLIST%
-t 2
```

In a nutshell:

1. Create config files, JSON files (with metadata), and submit jobs on HTCondor

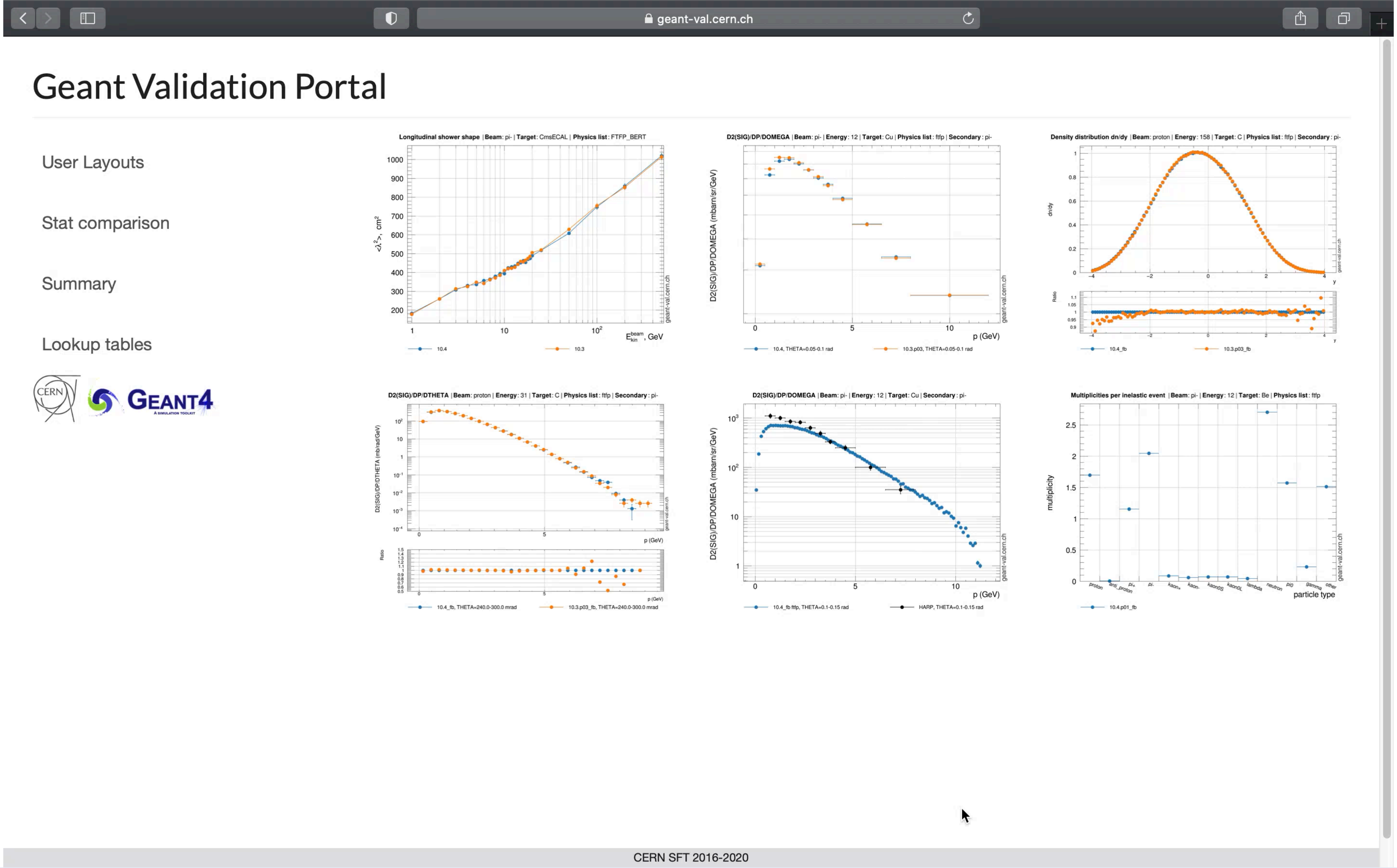
```
python mc-config-generator.py submit -t ATLHECTB -d OUTPUT -v 10.7.p01 -q "testmatch" -r
```

2. Run analysis: `python mc-config-generator.py parse -t ATLHECTB -d OUTPUT`

3. Deploy JSONS on Geant Val database:

```
find . -name '*.json' | while read i; do curl -H "Content-Type: application/json"
-H "token: askauthor" --data @$i https://geant-val.cern.ch/upload; echo; done
```

For .pdf usage, this is a video!



Physics lists comparison using Geant4.10.7.p01

Physics lists comparisons with Geant Val

- Energy response (π/e): $\sim 2\ \%$ for FTFP_BERT, $\sim 3\ \%$ QGSP_BERT, $\sim 5\% - 6\ \%$ FTFP_INCLXX (all overestimating)
- Longitudinal shower barycenter (π^-): $\sim 0.1\ \%$ for FTFP_BERT and FTFP_INCLXX, $3\% - 4\ \%$ for QGSP_BERT (overestimating)
- Shower length (π^-): $\pm 2\ \%$ for FTFP_BERT and FTFP_INCLXX (underestimating at low energies and overestimating at high energies), $\sim 3\ \%$ QGSP_BERT (overestimating).