

Simulation for the SiW ECAL prototype

DESY Test Beam 2022

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Plan

- TB setup - Simulation
 - Generation
 - Digitizer
- Performance
 - Energy resolution methods
 - First look at data-mc

The prototype - test beam

Our SiW ECAL prototype was taken to DESY test beam past November and March

- 15 layers with 1024 cells each.
→ Different ASU types
- Electron beams @ 1 to 6 GeV.
- Runs without Tungsten (aka MIP runs) and with Tungsten



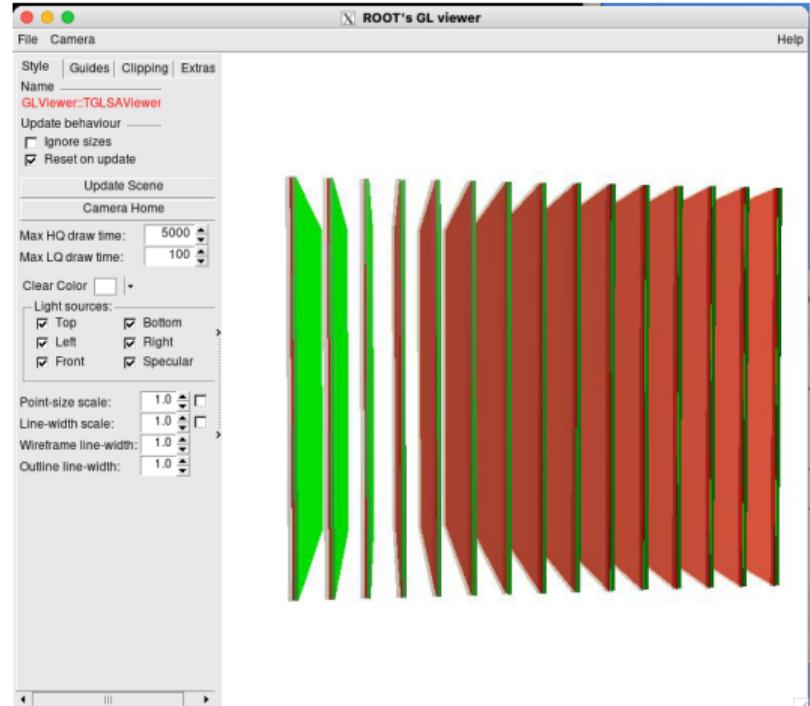
See talks from Roman, Adrián, Jonas and Yuichi earlier this week.

Status of simulation

- Generation of several energies/configurations, covering configs used at DESY TB (2021-22) and prospectives for CERN next June.
- Implementation of a digitizer (conversion+shaping)
- Processor for going from LCIO to “build” format (Jonas’ talk).
- Work in progress for comparison with data.
- Repo: github.com/fabriciojm/SiWECAL-Sim

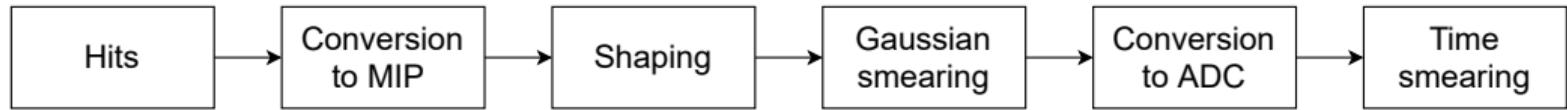
Generation

- Simulation based in DD4hep (GEANT4)
- Easy geometry/setup definition
- MIP runs using e^- at 3 GeV
- Tungsten runs at energies used in DESY TB, from 1 to 6 GeV
- Different incidence angles (3 GeV e^- , w/ and w/o Tungsten)
- Simulation of high-energy, preparing for CERN TB (from 3 to 300 GeV w/ Tungsten).



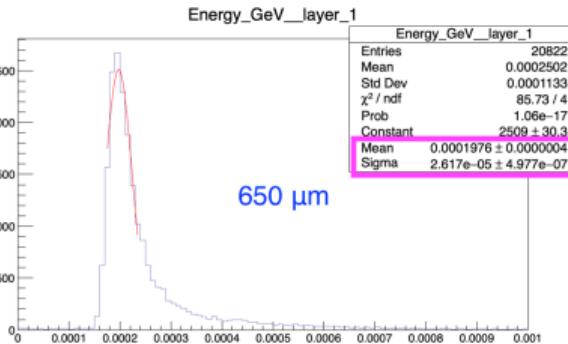
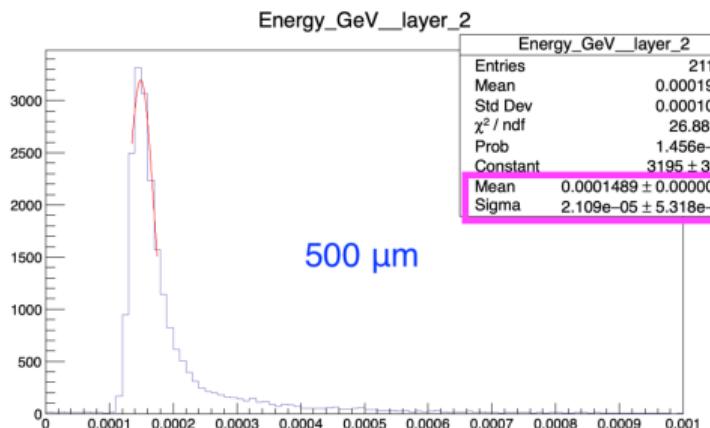
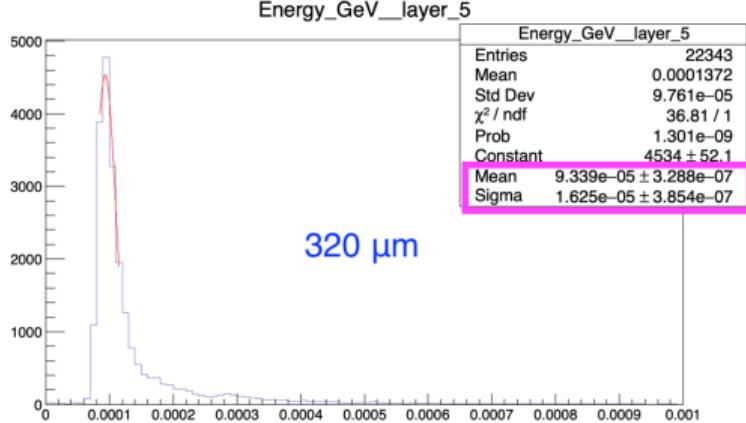
Digitization

Raw simulation \Rightarrow info. resembling detector output, including readout effects



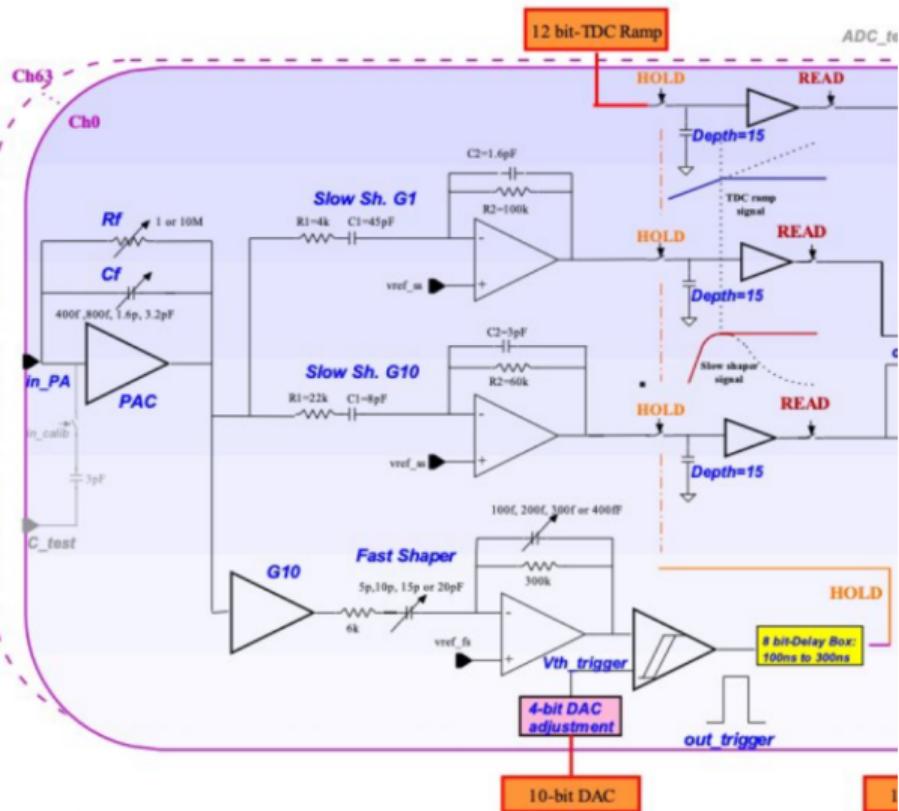
- Hits: starting point from raw simulation.
- Map energy deposited to MIP scale.
- Simulate pulse shaping in the readout electronics + saturation effects.
- Add smearing: noise term in detector cells/readout.
- Conversion to ADC, time smearing

Conversion to MIP scale (electrons @ 3 GeV)



- Conversion per layer (different layers Si thickness)

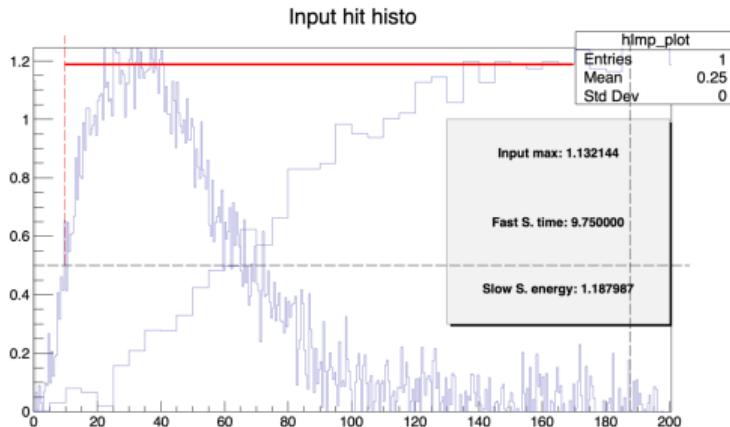
Skiroc2 readout (from datasheet)



Two signal paths after pre-amp:

- One Fast Shaper
→ Trigger threshold
- Two Slow Shapers
→ Measure energy, time

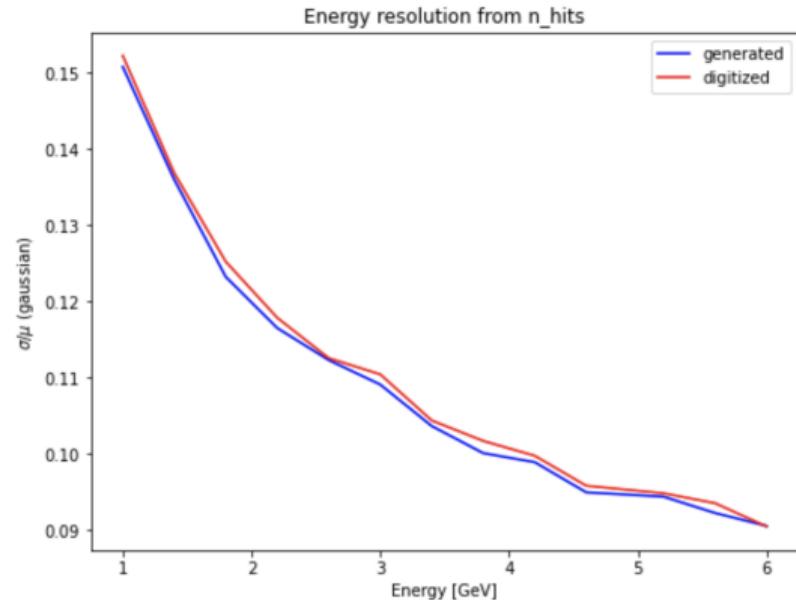
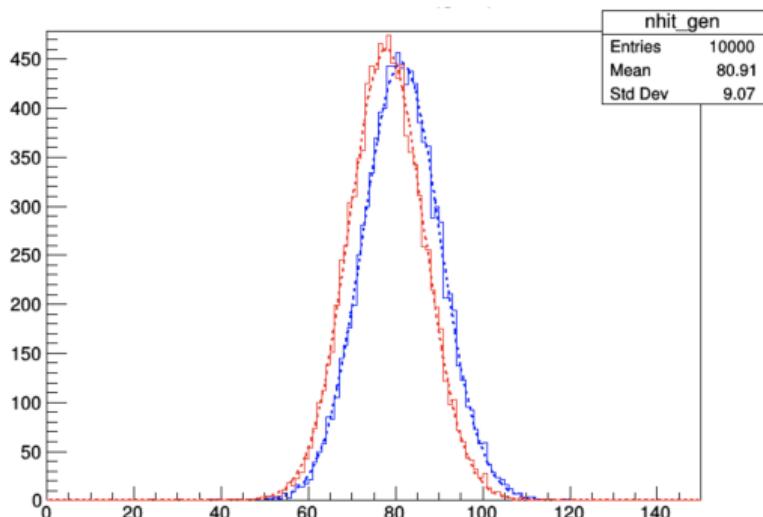
Shaping



- Shaping processor properly implements noise and a realistic time binning
- Example: Threshold 0.5 MIP, delay 180 ns
- Shapers with noise MIP/12 and MIP/20
- TBD: Study the impact of shaper parameters in energy resolution

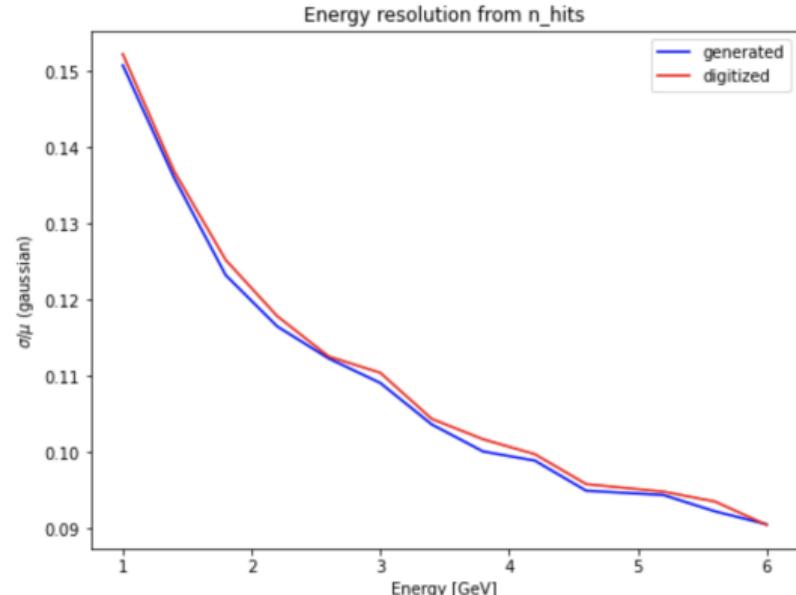
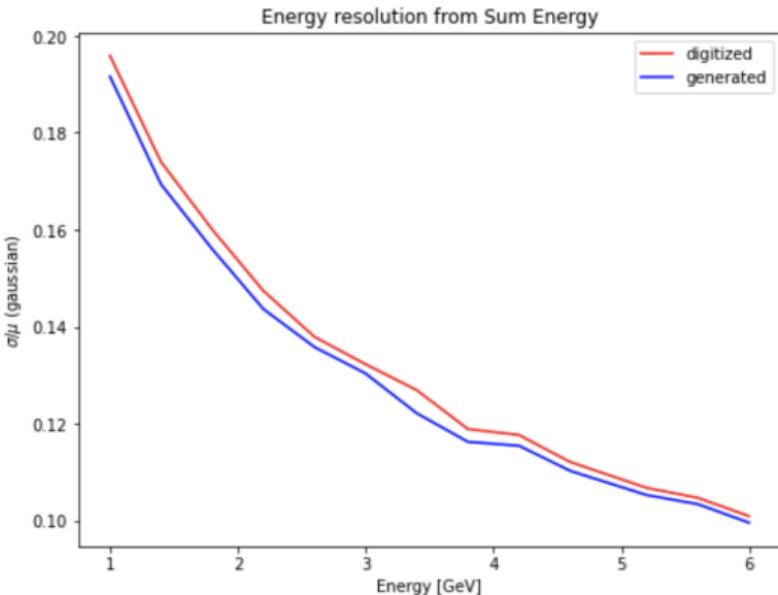
Energy resolution - nhits

Fit a gaussian to number of hits per event as energy prompt
Configuration 1 (with Tungsten)



Energy resolution - sum energy

Number of hits better prompt for energy resolution (at low energies)



Still need to include masking!

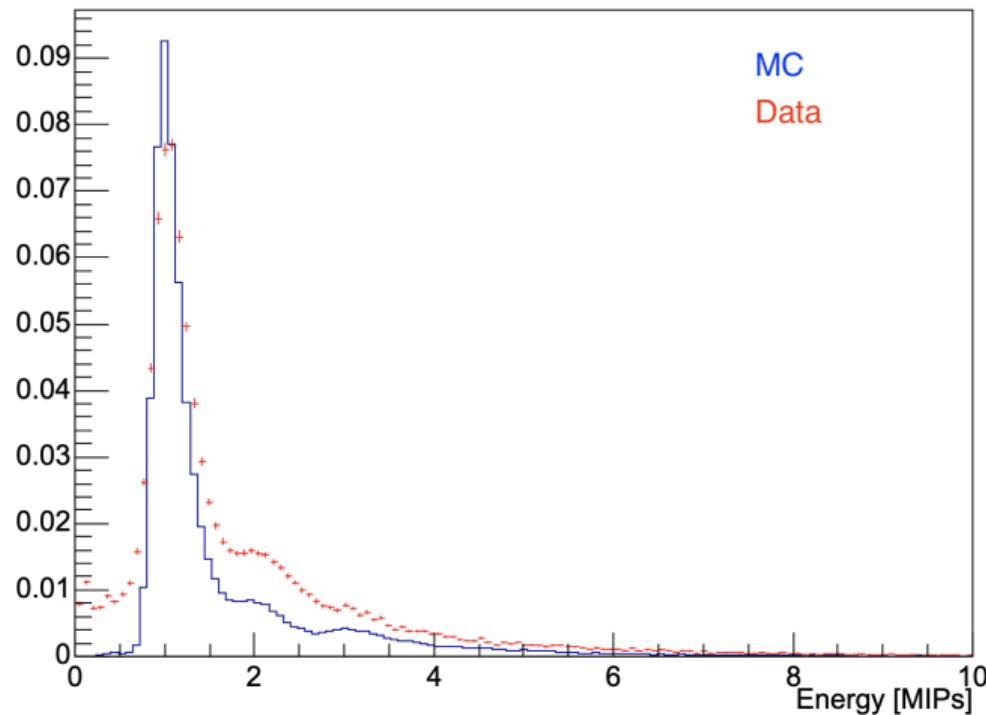
MIP spectrum (no Tungsten)

3 GeV electrons - data built from a MIP run from DESY March TB (all layers)

Hit energy

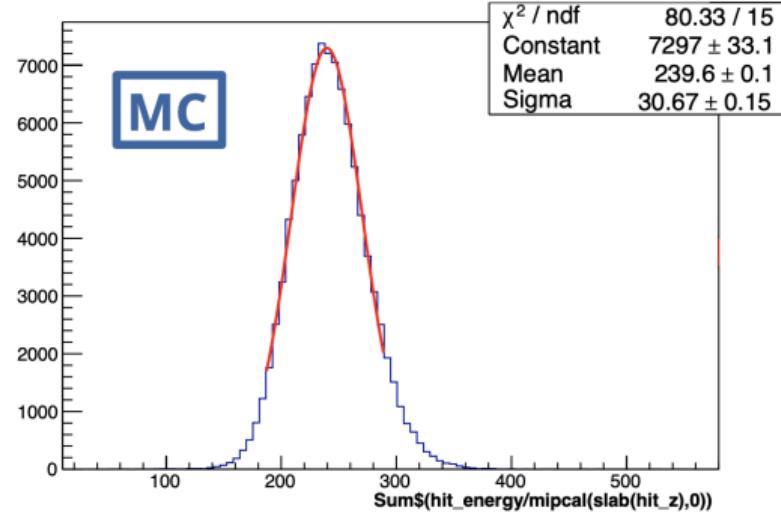
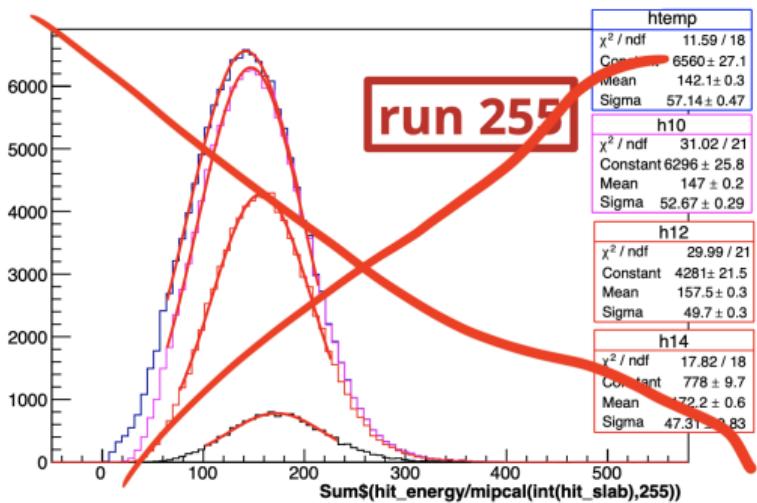
Explore:

- Beginning of the spectrum
- 2 - 3 MIP difference in data-mc
- Effects per layer
- Peak width



Energy resolution (Tungsten)

Resolution using sum hit energy for data ($\sim 27\%$) and simulation ($\sim 13\%$)



(Plots by Vincent Boudry) The plot on the left was shown in the meeting, but it was using the wrong building/calibration. Actual resolution is better. See [Jonas' talk](#)

Final remarks

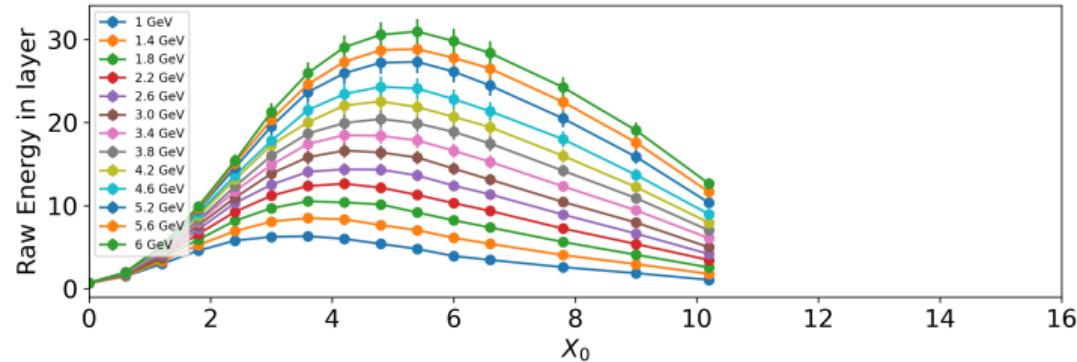
- Simulation software in place for DESY TB2022, including digitizer
- Feedback from and to data taken
- Studies in the near future:
 - Impact of digitizer parameters
 - MIP performance
 - Energy resolution (w/ Tungsten)
→ masking
 - Shower events

Backup

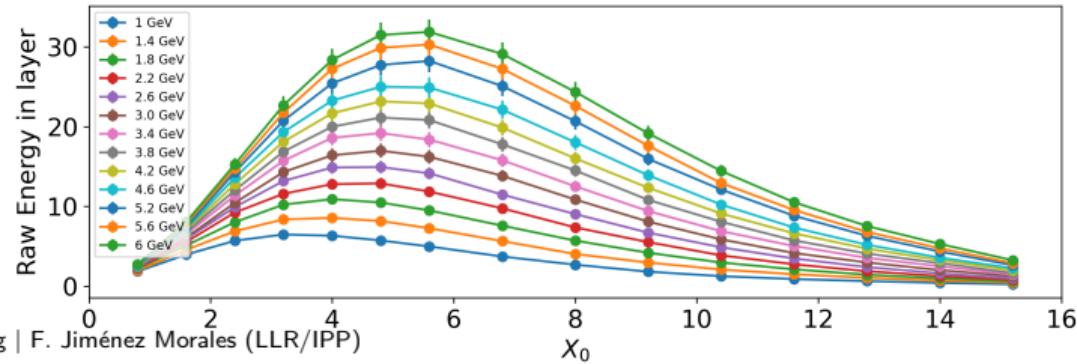
TB2021-11 / TB2022-03

Shower better contained in TB2022 W configuration.

TB2021



TB2022

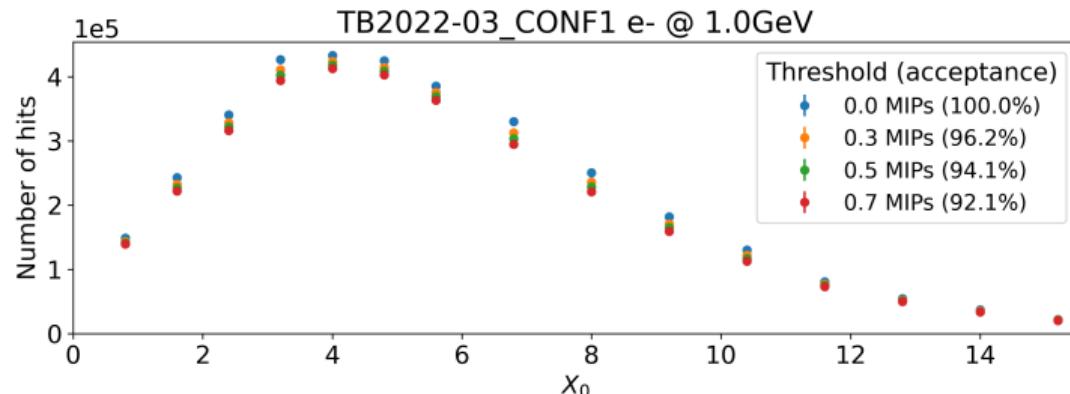
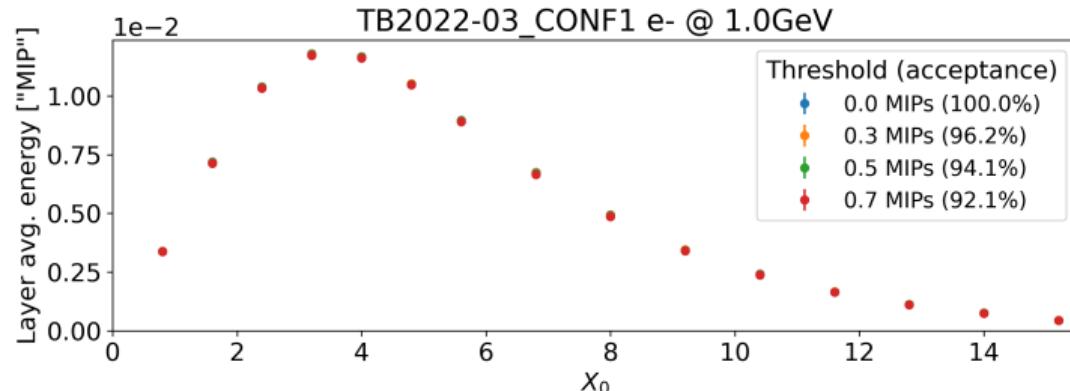


Conversion

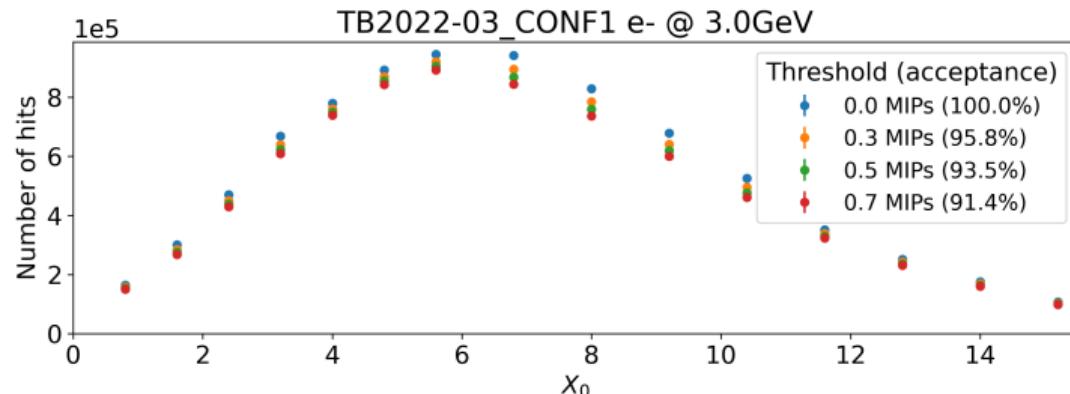
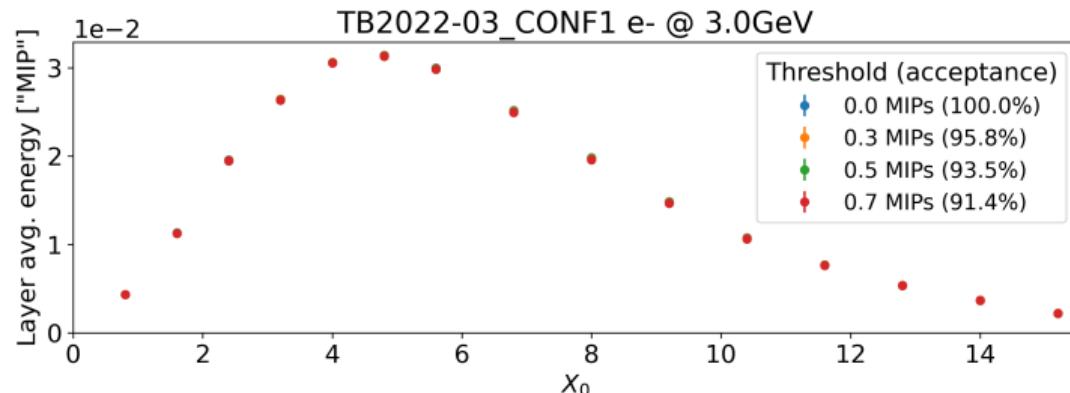
Perform a rough conversion using:

- Factor extracted from previous digitization: 0.0923 MeV/MIP
- The corrected Si thickness (now I've run the simulations with the updated wafer thicknesses).
- “Profiles” with number of hits / energy, with thresholds: 0, 0.3, 0.5, 0.7 MIPs

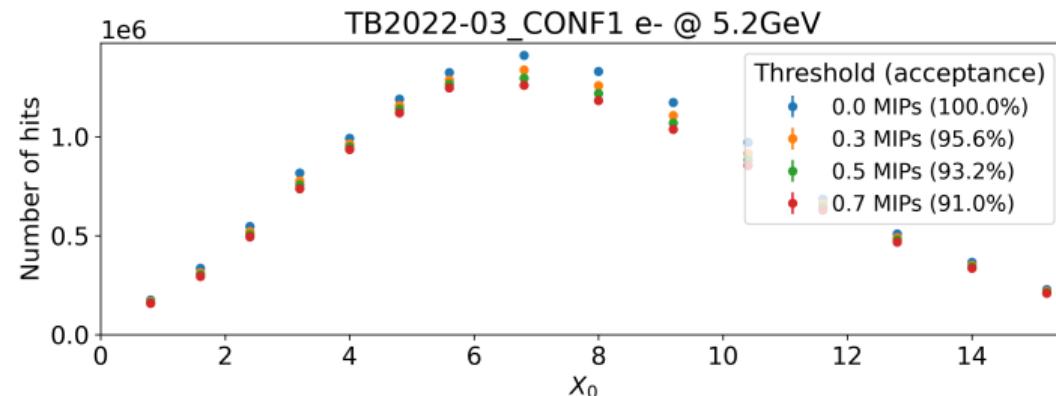
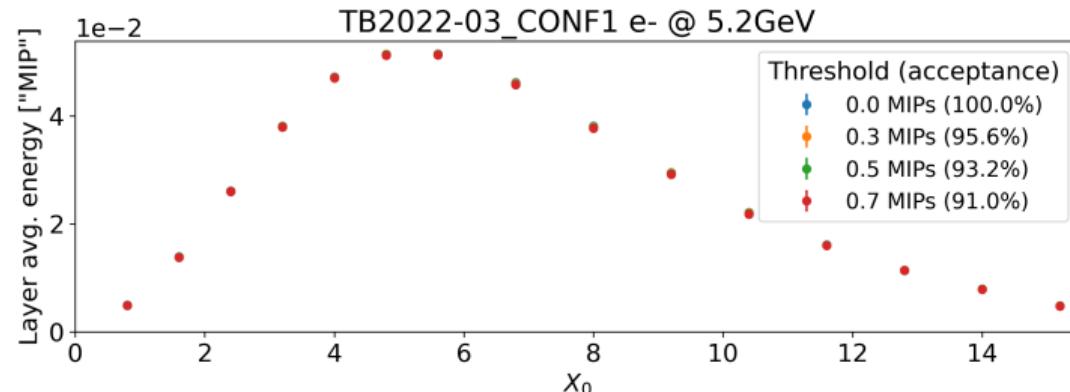
e- @ 1 GeV



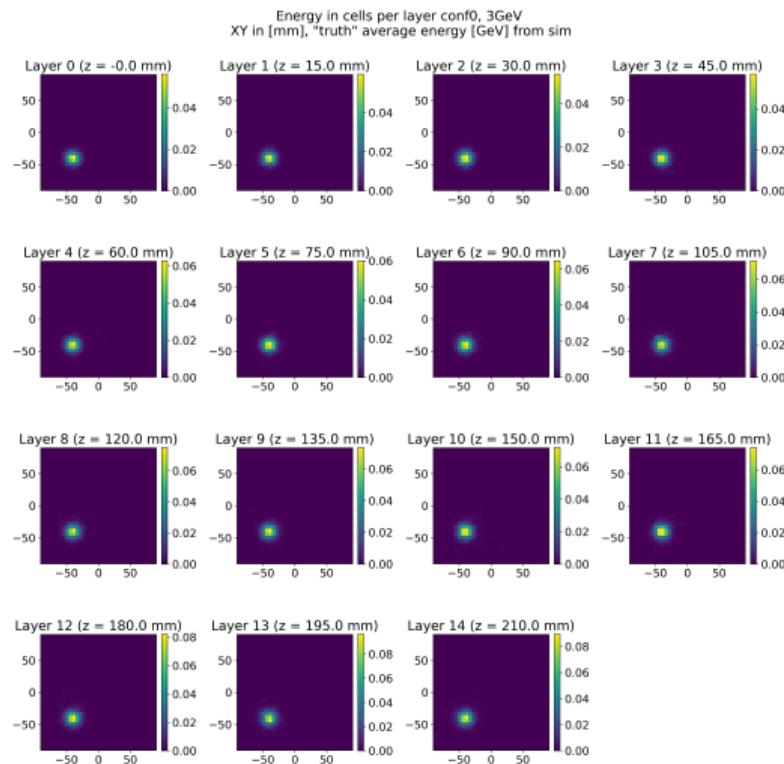
e- @ 3 GeV



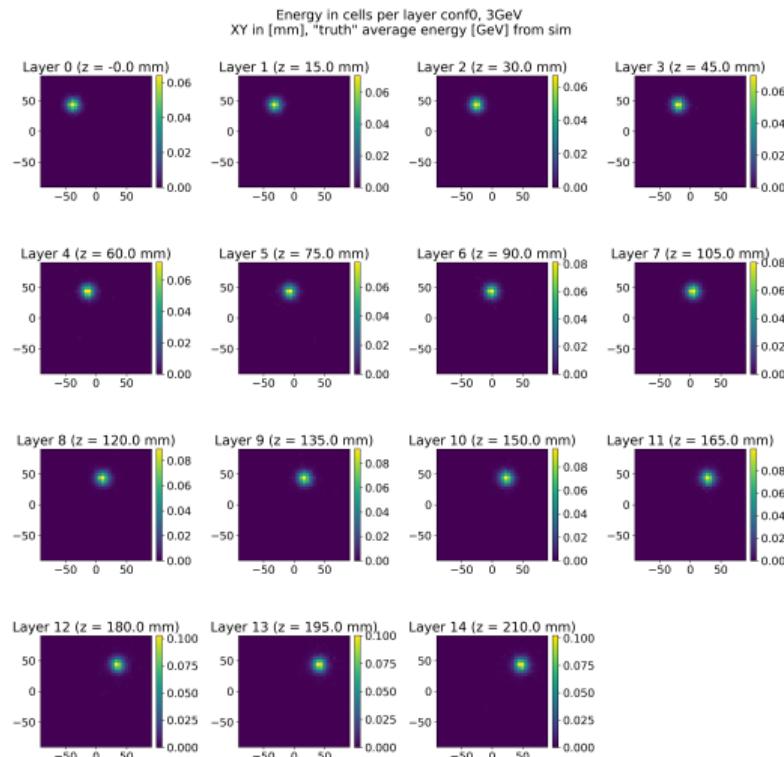
e- @ 5.2 GeV



MIP runs (3 GeV e-), perpendicular

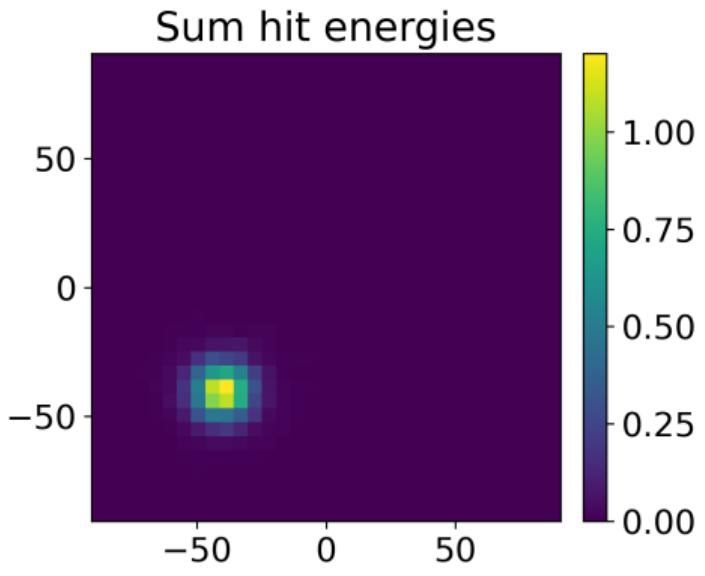


MIP runs (3 GeV e-), 22° angle

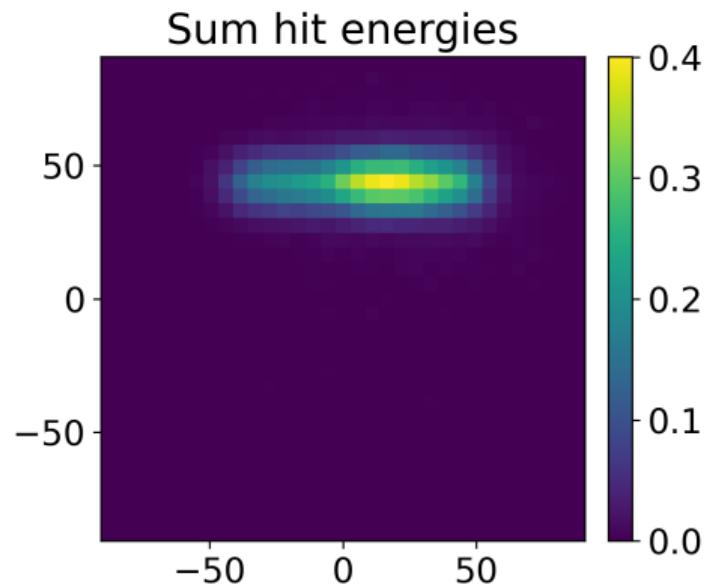


MIP runs (3 GeV e-), average energy (all layers sum)

Perpendicular



22 degrees



TB2021 - TB2022

TB2021:

- $0 + 11 * 2.1 \text{ mm} + 3 * 4.2 \text{ mm}$
- $0 + 11 * 0.6 X_0 + 3 * 1.2 X_0 \rightarrow 10.2 X_0$
- Not absorbing electron shower

TB2022:

- $7 * 2.8 \text{ mm} + 8 * 4.2 \text{ mm}$
- $7 * 0.8 X_0 + 8 * 1.2 X_0 \rightarrow 15.2 X_0$

Next plots: sum of energy cell deposited per layer (average profile).

Simulation of W runs

- Mono-energetic beams: 1, 1.4, 1.8, 2.2, 2.6, 3.0, 3.4, 3.8, 4.2, 4.6, 5.2, 5.6, 6 [GeV]
- Beam spread: measure from data
- Sim repository:
github.com/fabriciojm/SiWECAL-Sim
- A bunch of control plots

```
grid_-40-40_e-[Energy]GeV.mac  
  
/gps/verbose 1  
/gps/particle e-  
/gps/direction 0 0 1  
/gps/pos/type Beam  
/gps/pos/shape Circle  
/gps/pos/centre -40 -40 0 mm  
/gps/pos/sigma_x 7 mm  
/gps/pos/sigma_y 7 mm  
/gps/ang/rot1 0 0 1  
/gps/ang/rot2 0 1 0  
  
/gps/ene/type Mono  
/gps/ene/mono [Energy] GeV  
/run/beamOn 1000
```

Material for simulation

From upstream beam direction:

Material	Thickness [mm]	Notes
Polyethylene + air	2 + 61.8	Only first layer. CHO (0.89 g/cm ³)
Tungsten	0, 2.1 or 4.2	Variable air/Tungsten (19.1 g/cm ³) box
Carbon Frame	1.5	
Kapton	0.1	
Glue	0.1	Using air
Wafer	0.32 or 0.5	
Glue	0.1	Using air
Copper	0.1	
PCB	1.7	D. Jeans: Si O C H Br (1.7 g/cm ³)
Chip	1.2	Inhomogeneous layer to be modeled
Air	Variable	15 mm between consecutive grooves