Simulation for the SiW ECAL prototype

Fabricio Jiménez Morales
Laboratoire Leprince-Ringuet (CNRS/IPP)

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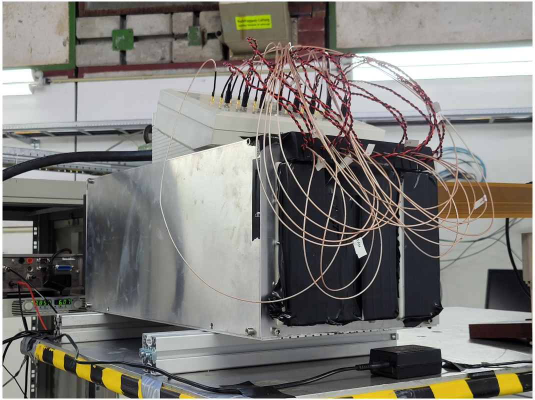
The prototype - beam tests

SiW ECAL prototype under Beam Test at DESY (March) and CERN (June)

- 1024 (5.5 mm)^2 Si cells x 15 layers
  $\rightarrow$ Different thicknesses, ASU types
- Beams: DESY e^- @ 1-6 GeV, CERN up to 150 GeV
- Runs w/ and w/o Tungsten (DESY: 15 X_0, CERN 20 X_0)

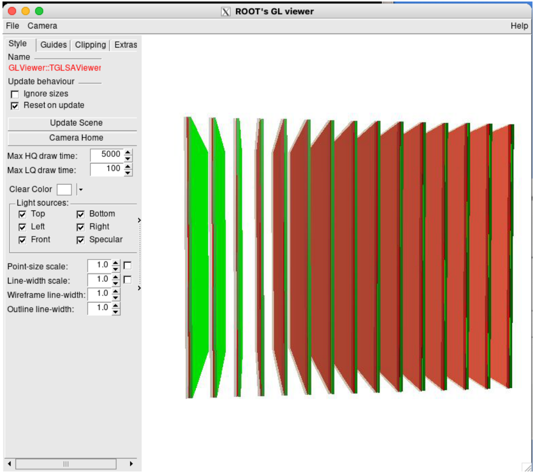


Status of simulation

- Geometry written for $\sim$all configs used in BTs
- Implementation of a digitizer (conversion+shaping+noise).
- Mapping and masking included.
- Processor for going from LCIO to "build" format.
- Repo: github.com/fabriciojm/SiWECAL-Sim

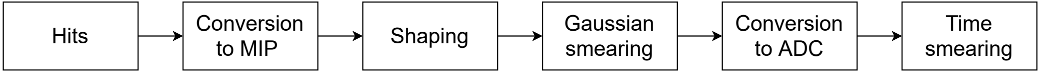
Generation

- Simulation based in DD4hep (GEANT4)
- Easy geometry/setup definition & vis
- MIP runs and W runs for different energies
- Software: lots of tools for easily add and run new configs



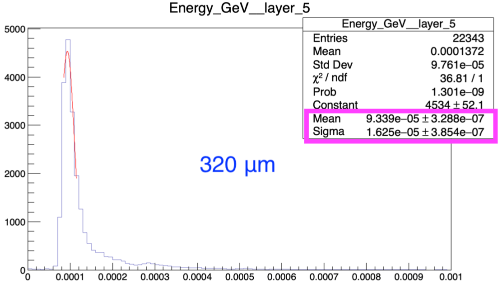
Digitization

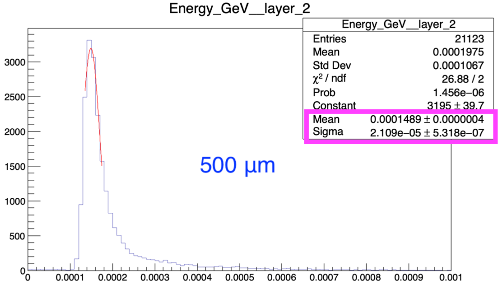
Raw simulation ⇒ info. resembling detector output, including readout effects

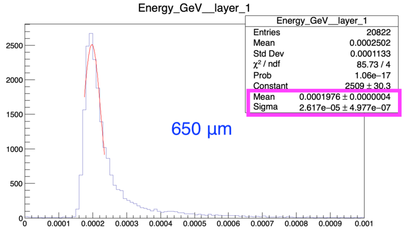


- Hits: starting point from raw simulation.
- Map energy deposited to MIP scale.
- Simulate pulse shaping in the readout electronics + saturation effects.
- Add smearing: noise term in detector cells/readout.
- Conversion to ADC, time smearing (tbd)
- (Masking at any point.)

Conversion to MIP scale (electrons @ 3 GeV)

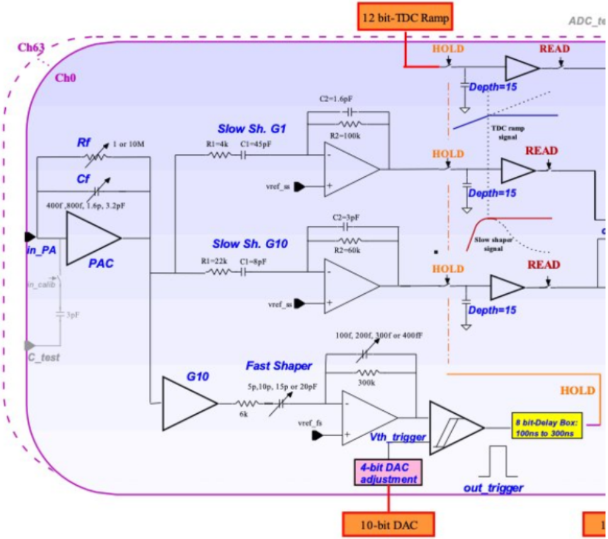






- Conversion per layer (different layers Si thickness)

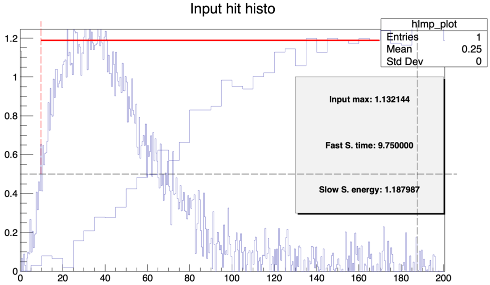
Skiroc2 readout (from datasheet)



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/optimize shaper parameters in energy resolution

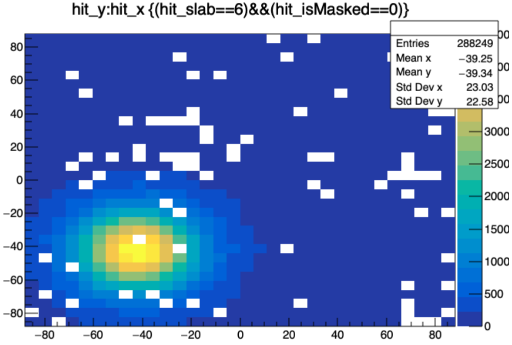
Impact of masking in resolution

Used 1-150 GeV e- hitting on the lower left of the detector (CERN BT)

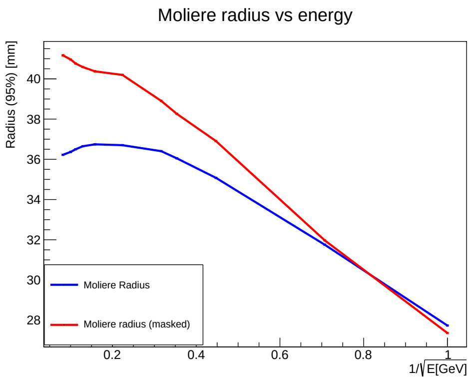
- Conversion to mip using sim muons @ 100 GeV
- Masking from run 90474
- In example: 1488 masked chans (<10%)

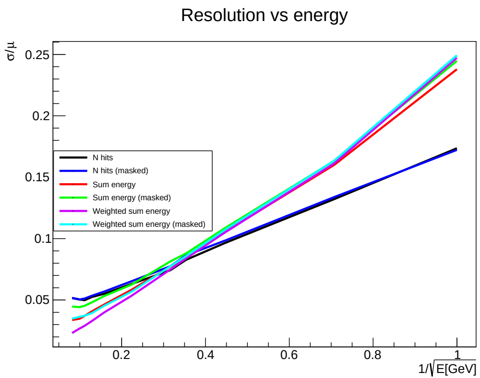
Resolution methods:

- Hit counting
- ΣE (w/ and w/o W sampling fr.)



Moliere radius and resolution vs Energy (no digi)





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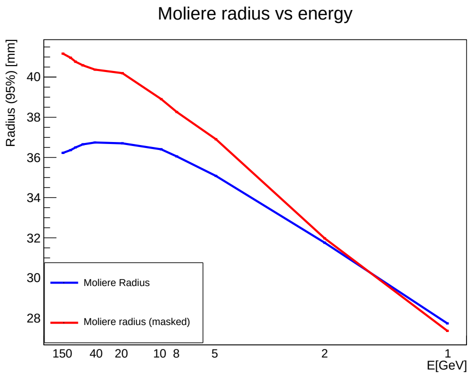
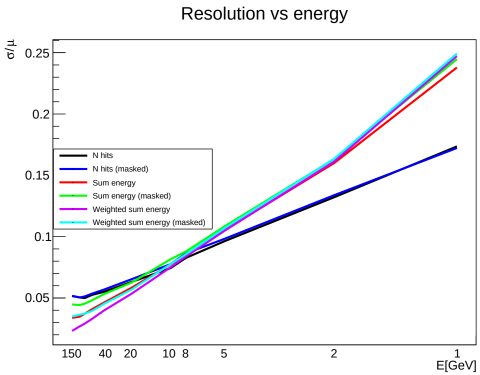
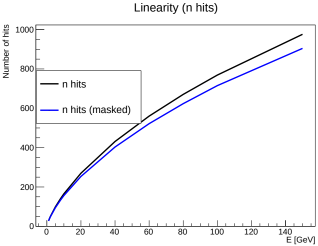
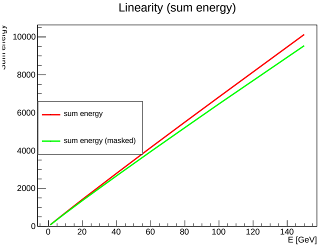


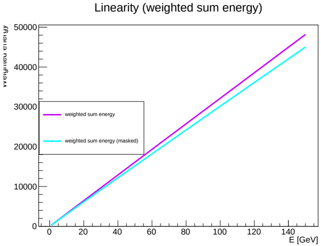


How to optimally combine resolution information?

Linearity (no digi)







N hits saturates $\sim$ 10 GeV (need to correct for it)

Impact of digitization (preliminary)

The case of 3 GeV electrons @ DESY (run 050282, see Jonas' talk)

- 30k events
- Masking taken from run

Method	Before digi	After digi
N hits	11.06 %	11.15 %
ΣE	13.76 %	13.78 %
ΣE_W	13.17 %	13.10 % (?)

Need to check, but so far, impact in resolution of digitization as implemented is very small

Final remarks

- Simulation software:
  - Generation + digitizer
  - Mapping and masking included in output files
  -
- Future studies:
  - Follow up in resolution studies / E containment
  - Optimal resolution method?
  - Impact of digitization and digitizer parameters

Backup

TB2021 - TB2022

TB2021:

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

TB2022 (DESY):

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

TB2022 (CERN):

- 8 * 4.2 mm + 7 * 5.6 mm
- 8 * 1.2 X_0 + 7 * 1.6 X_0 $\rightarrow$ 20.8 X_0

Simulation of W runs

- Mono-energetic beams [GeV]
- Beam spread: from data
- Angles in progress

Sample G4 macro file

```
/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