BIC Reconstruction Overview and Recent Updates

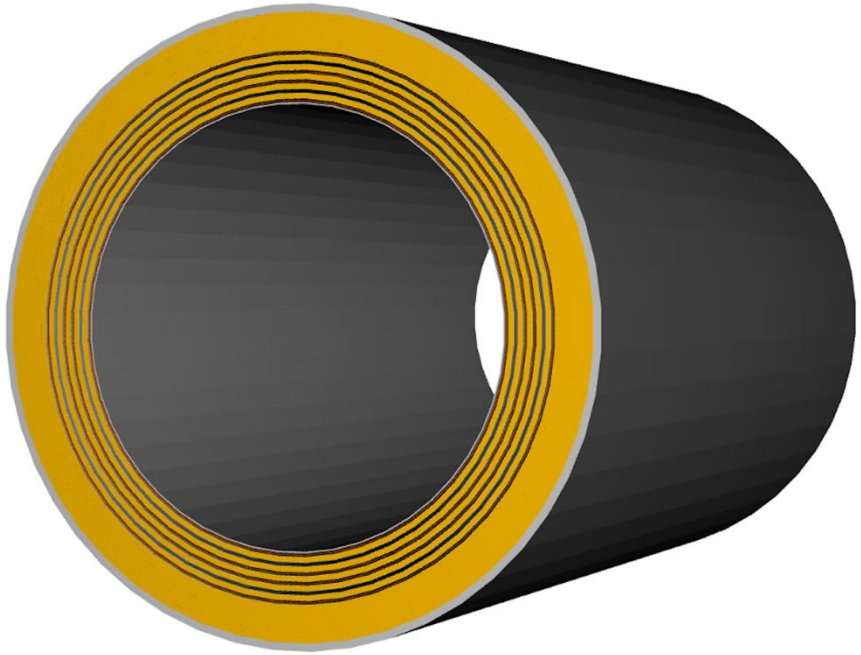
Minho Kim
Argonne National Laboratory

4th BIC In-person Workshop
April 9, 2025

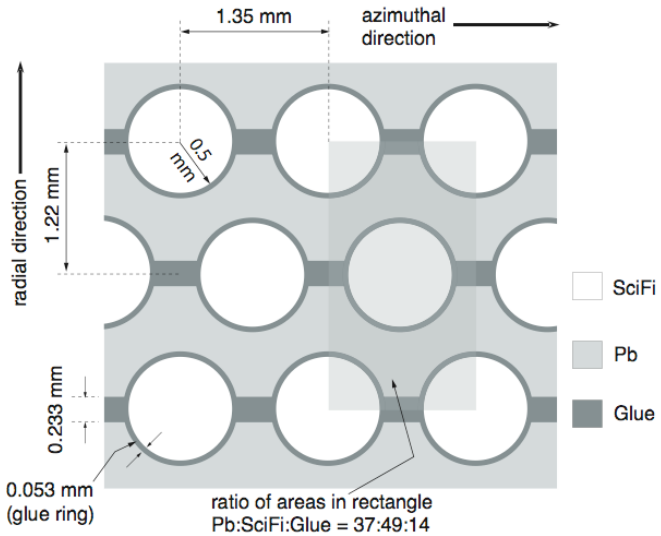
Argonne NATIONAL LABORATORY

BIC geometry in ePIC simulation

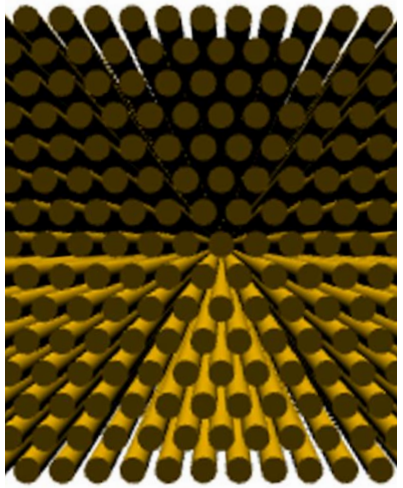
Barrel Imaging Calorimeter



ScFi/Pb



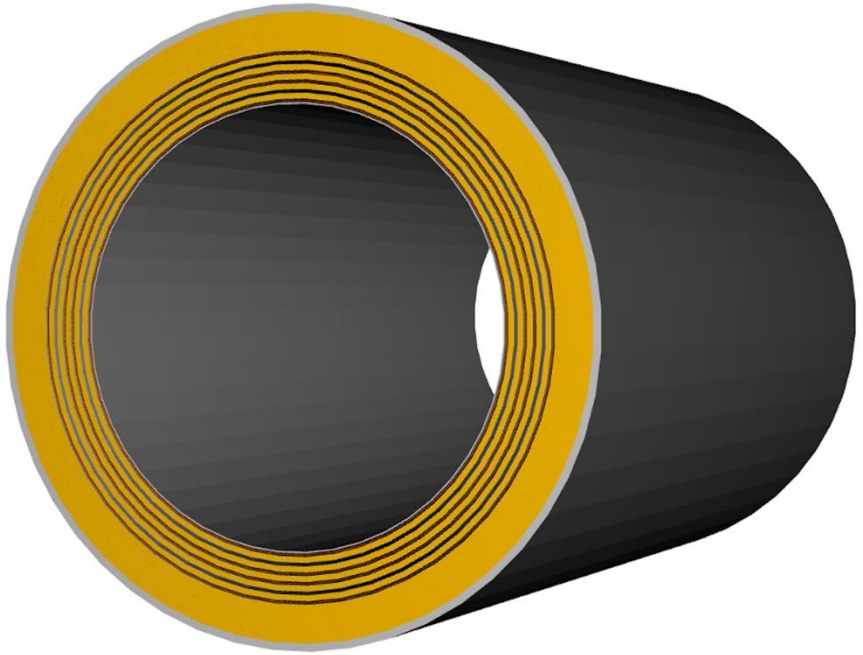
ScFis



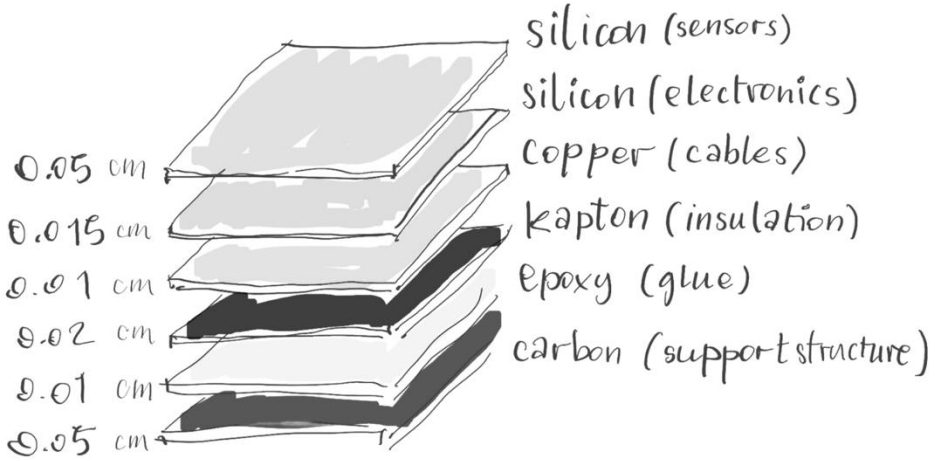
- To study the BIC performance in detail, realistic BIC geometry has been implemented into the ePIC simulation package.
  - In ScFi layers, the ScFis are embedded in the Pb matrix.
  - In AstroPix layers, each AstroPix sensor forms a stave.

BIC geometry in ePIC simulation

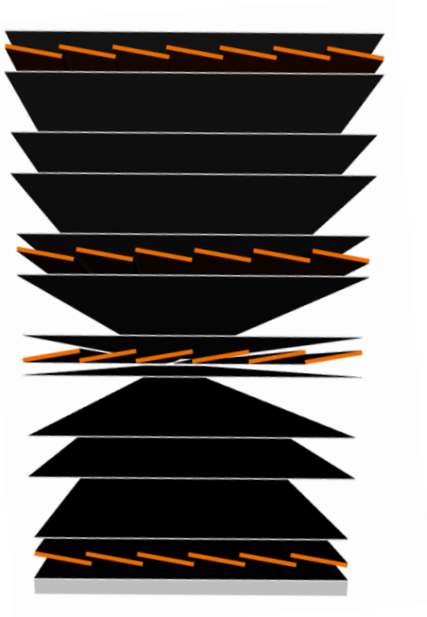
Barrel Imaging Calorimeter



AstroPix staves



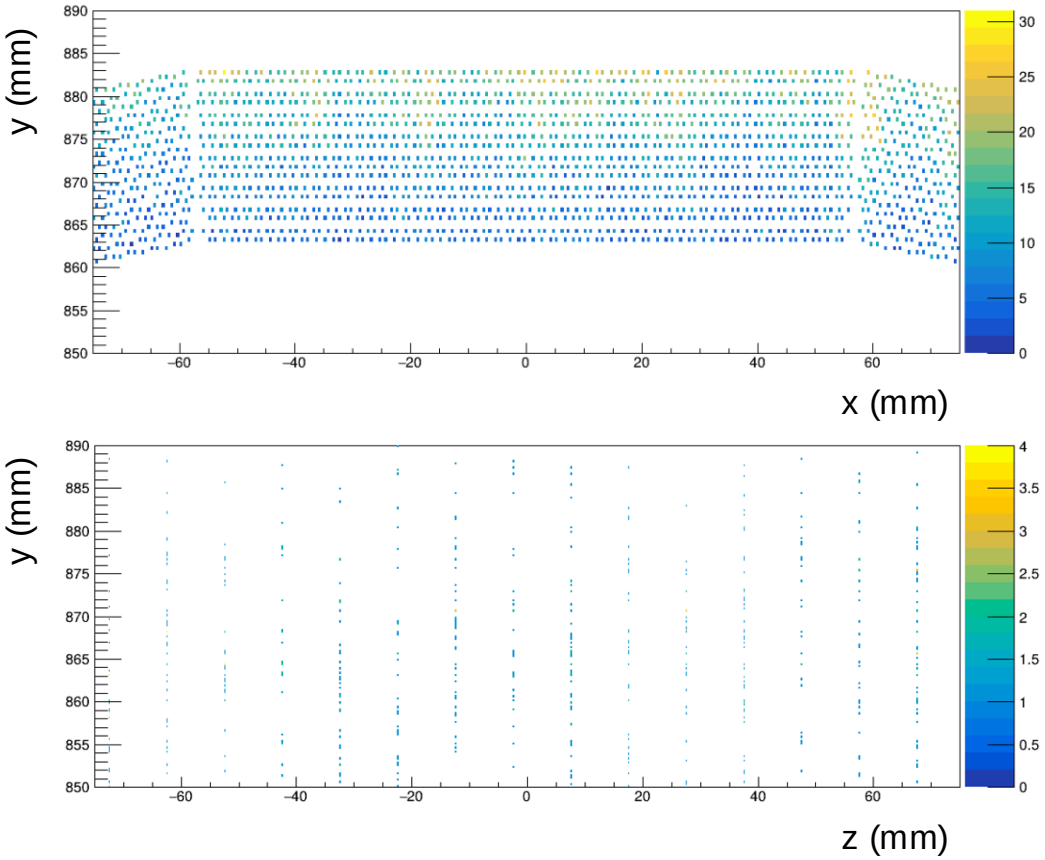
Imaging layers



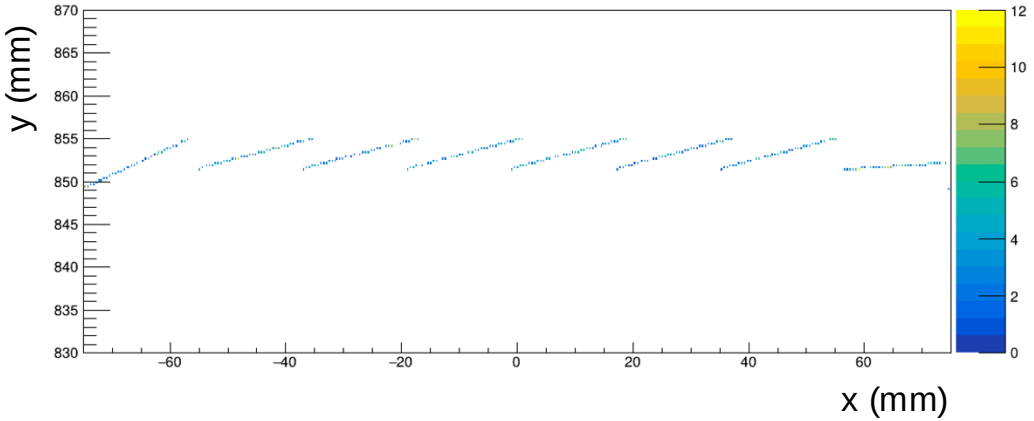
- To study the BIC performance in detail, realistic BIC geometry has been implemented into the ePIC simulation package.
  - In ScFi layers, the ScFis are embedded in the Pb matrix.
  - In imaging layers, each AstroPix sensor forms a stave.

Raw hits

ScFi



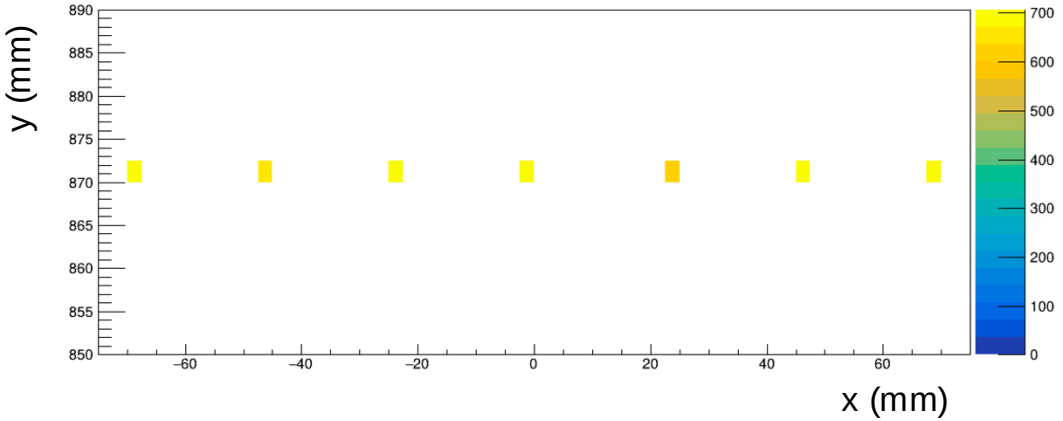
AstroPix



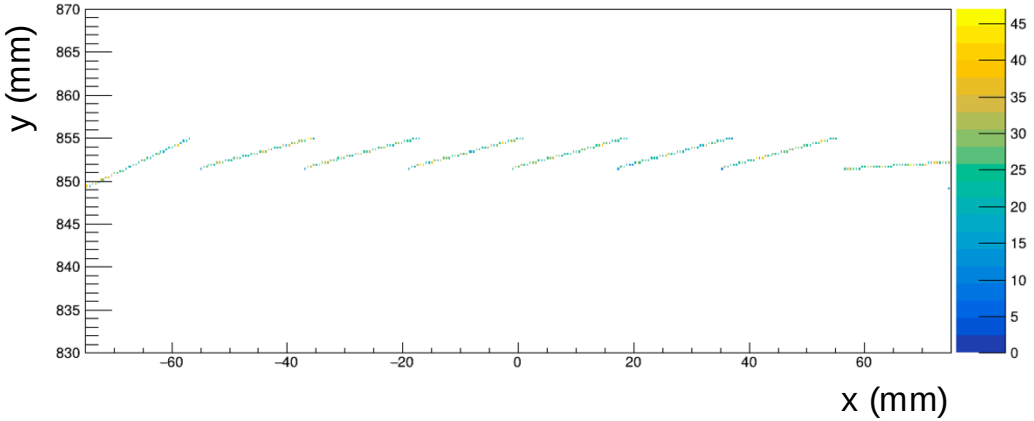
- Once a particle shower is generated in the detector, we have energy deposits in each
  - ScFi and z-segmentation.
  - AstroPix sensor.

Reconstructed hits

ScFi



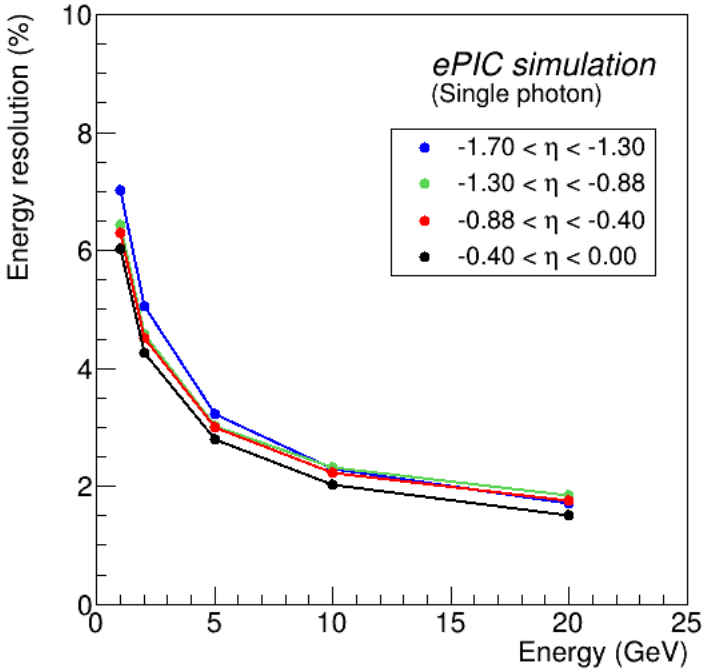
AstroPix



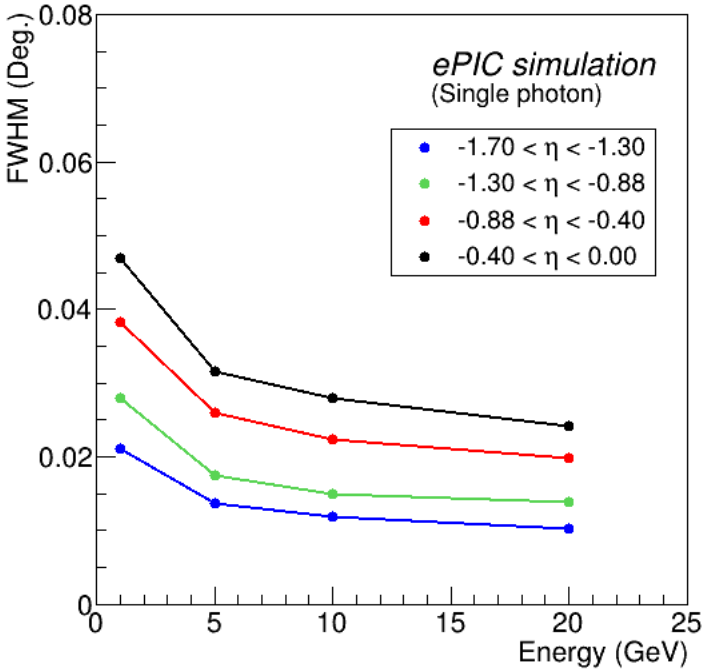
- Energy deposits are added up and multiplied by sampling fraction. This process is done
  - for each SiPM in the case of ScFi layer.
  - for each AstroPix sensor in the case of imaging layer.

BIC performances

Energy resolution



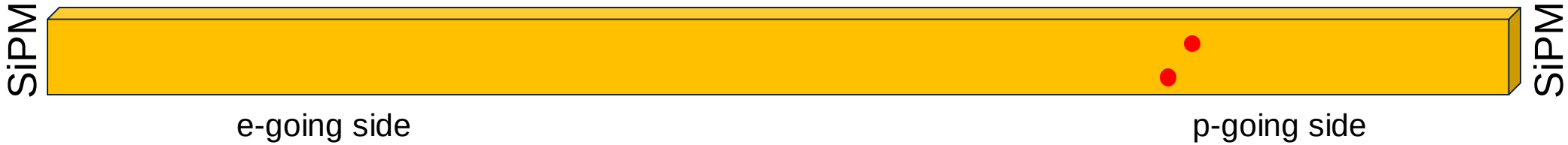
θ resolution



- θ was reconstructed by the most energetic hits on the layer where the EM shower started to develop. → Reconstruction on the first layer gives the best resolution.
- Higher η range shows better θ resolution because particle experiences more X_0 at higher η and it makes probability of the first layer reconstruction higher.

More realistic energy reconstruction

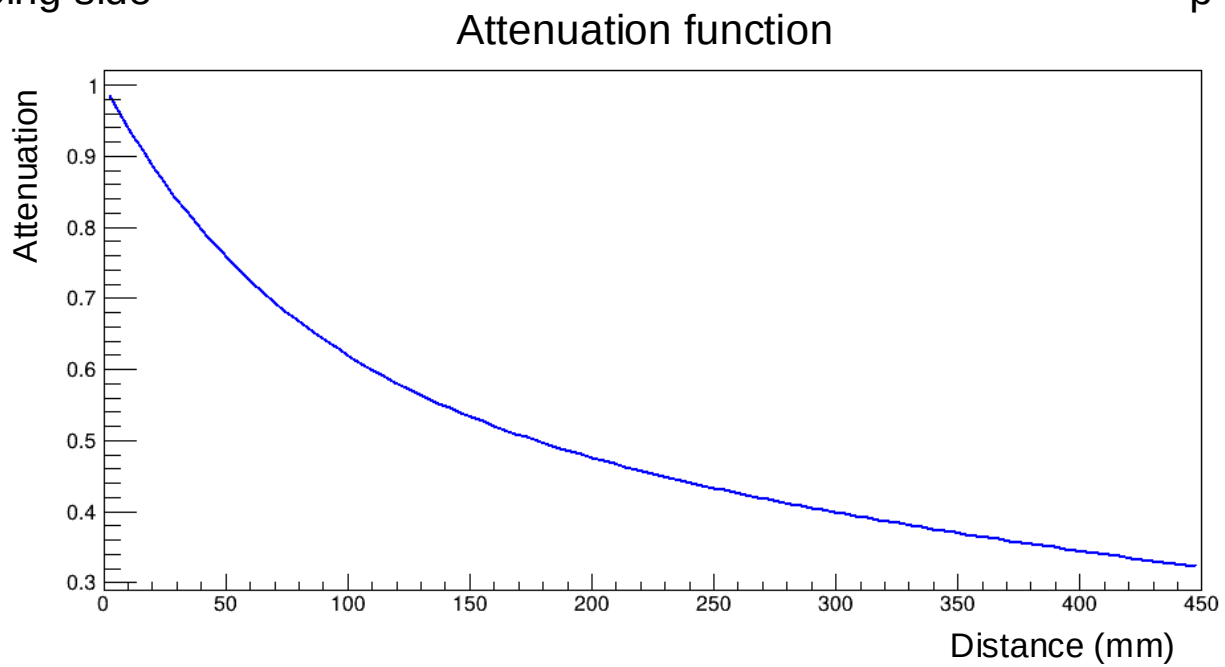
Energy deposits



- Current BIC reconstruction uses the energy deposits of the shower particles as they are.

Attenuation

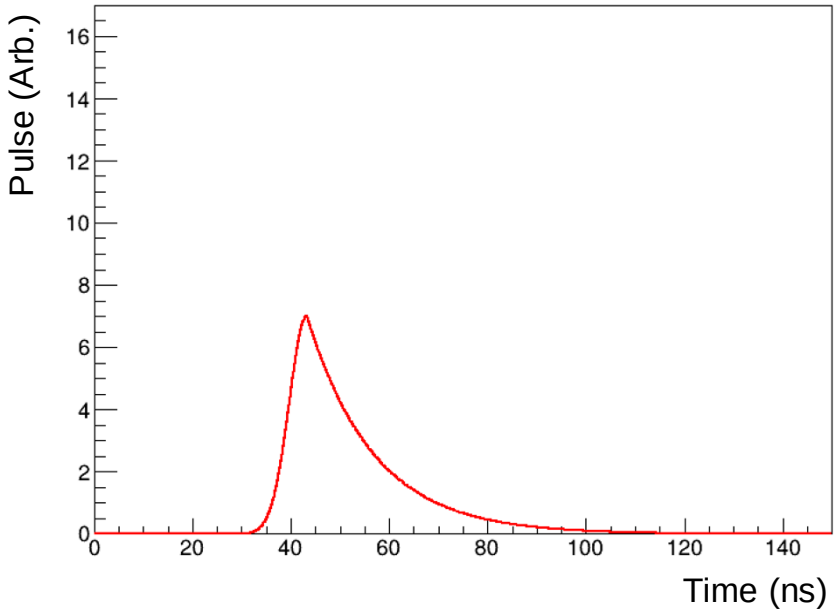
e-going side p-going side



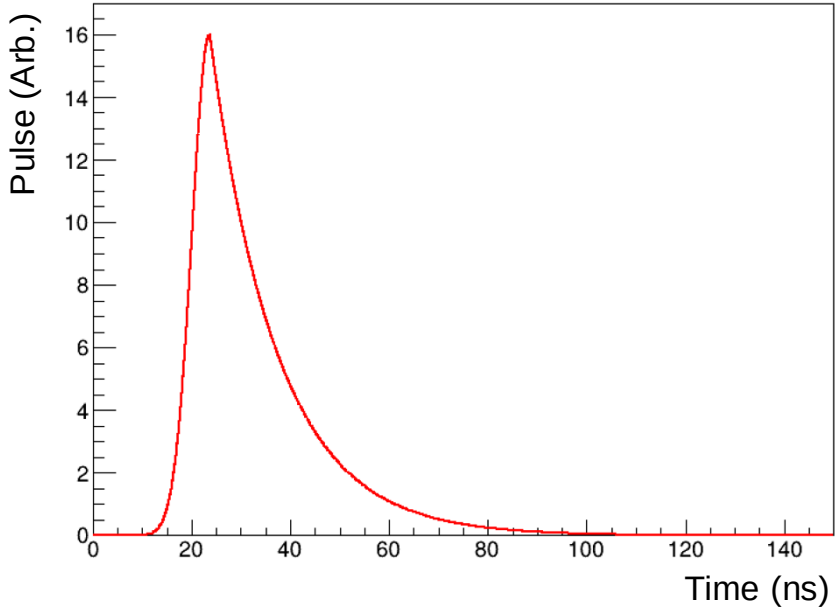
- Each energy deposit is attenuated before they hit the SiPM.
- The attenuated energy deposits (scintillation lights) hit the SiPM and photoelectrons are generated.

Pulse implementation

e-going side

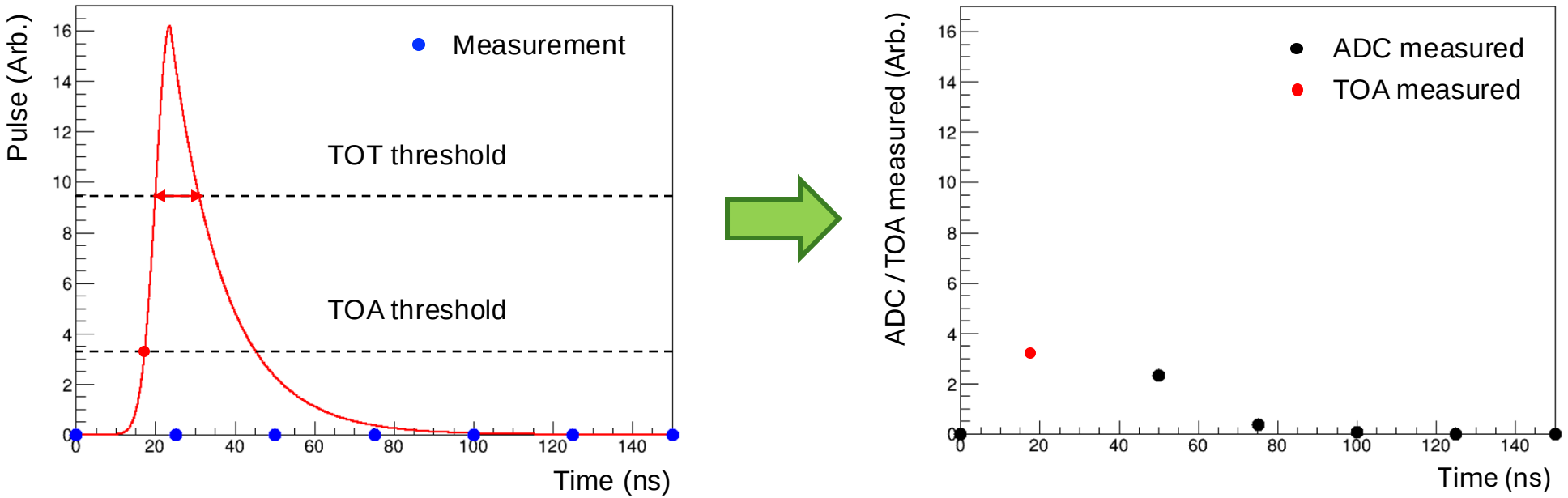


p-going side



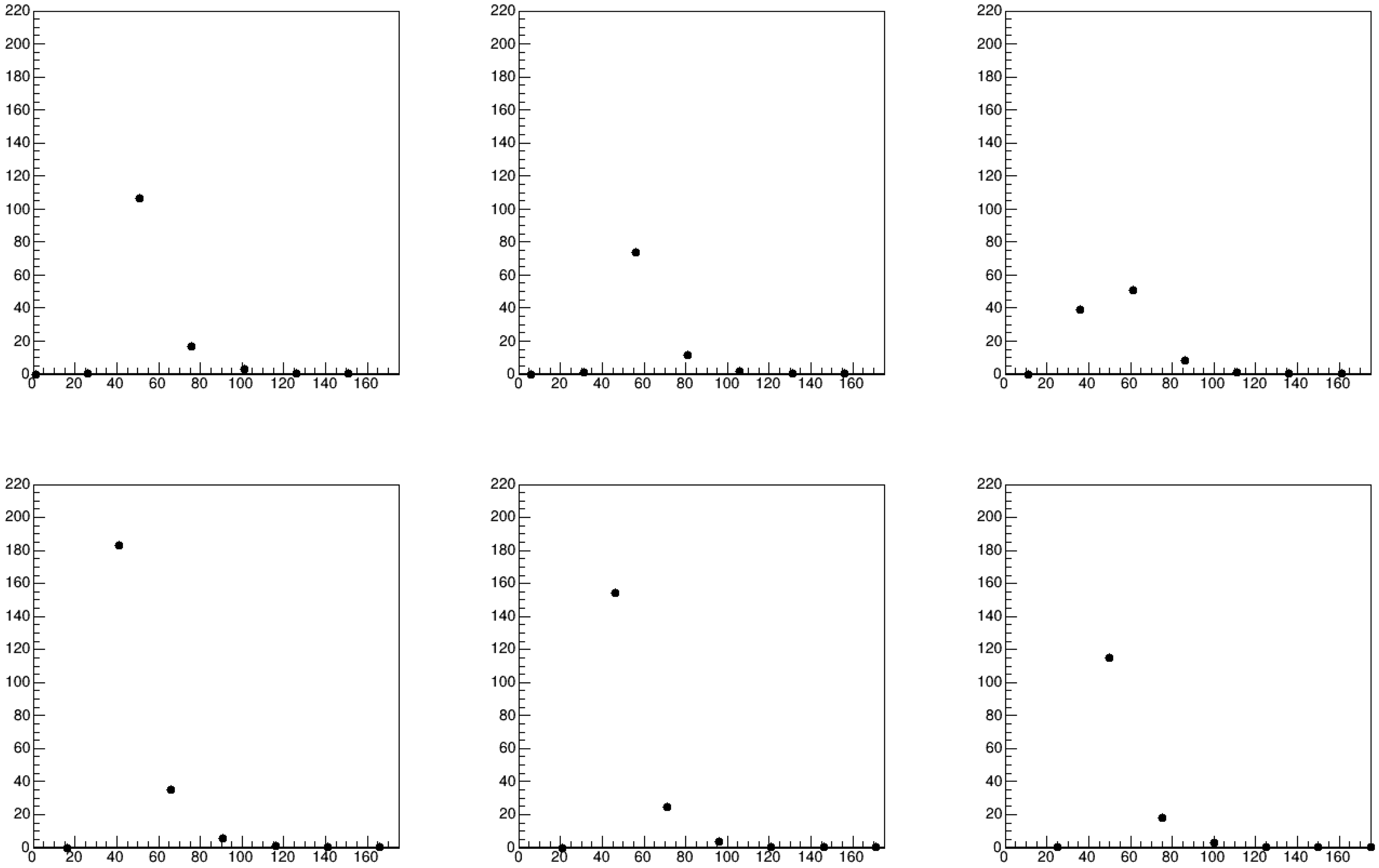
- SiPM pulses are generated by the photoelectrons and amplified.

ADC, TOA, and TOT measurements

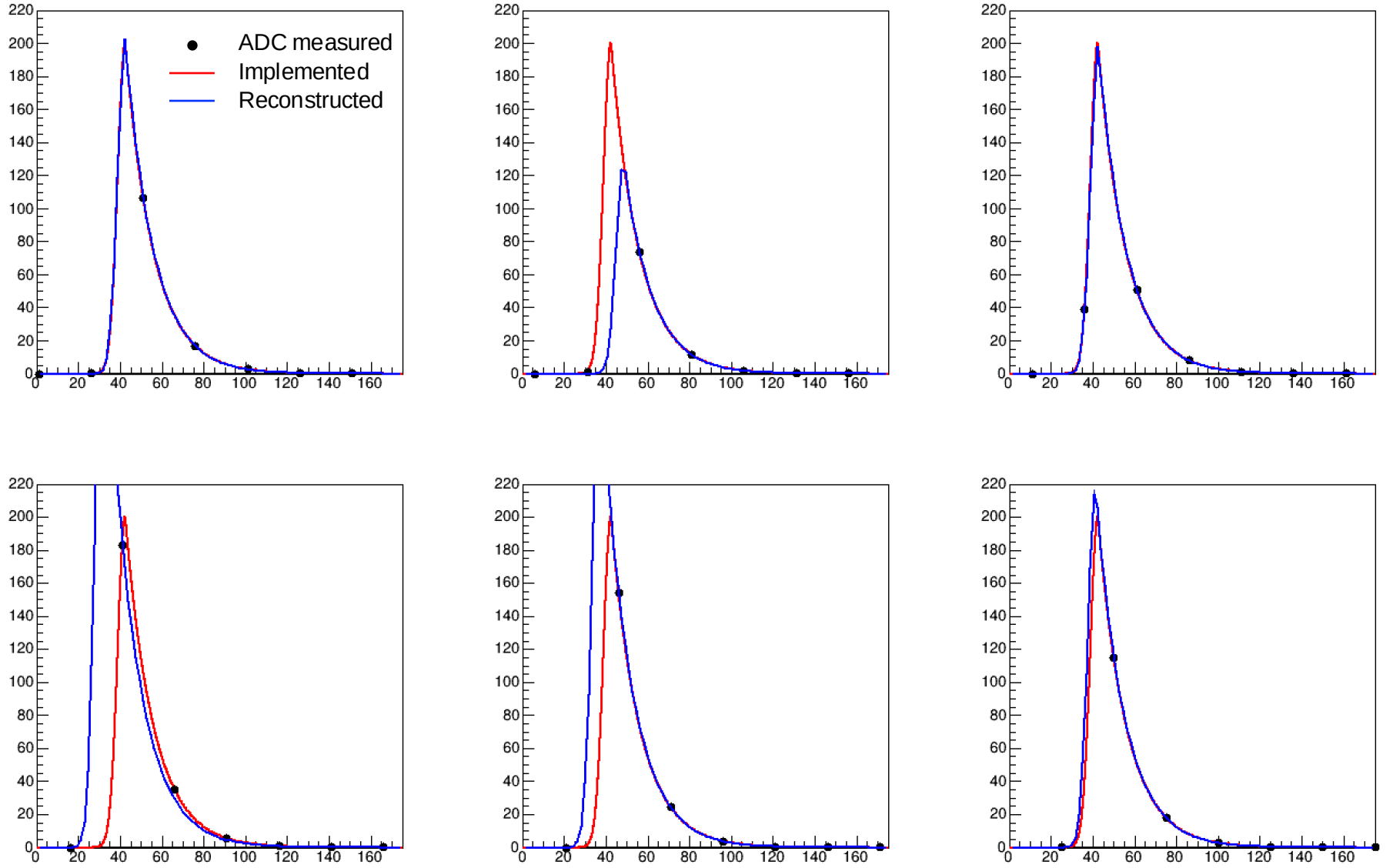


- ADC, TOA, and TOT values are measured by H2GCROC depending on the pulse height with respect to the TOA and TOT thresholds.
- To reconstruct the particle energy, we should reconstruct the pulse height using the measured data points.

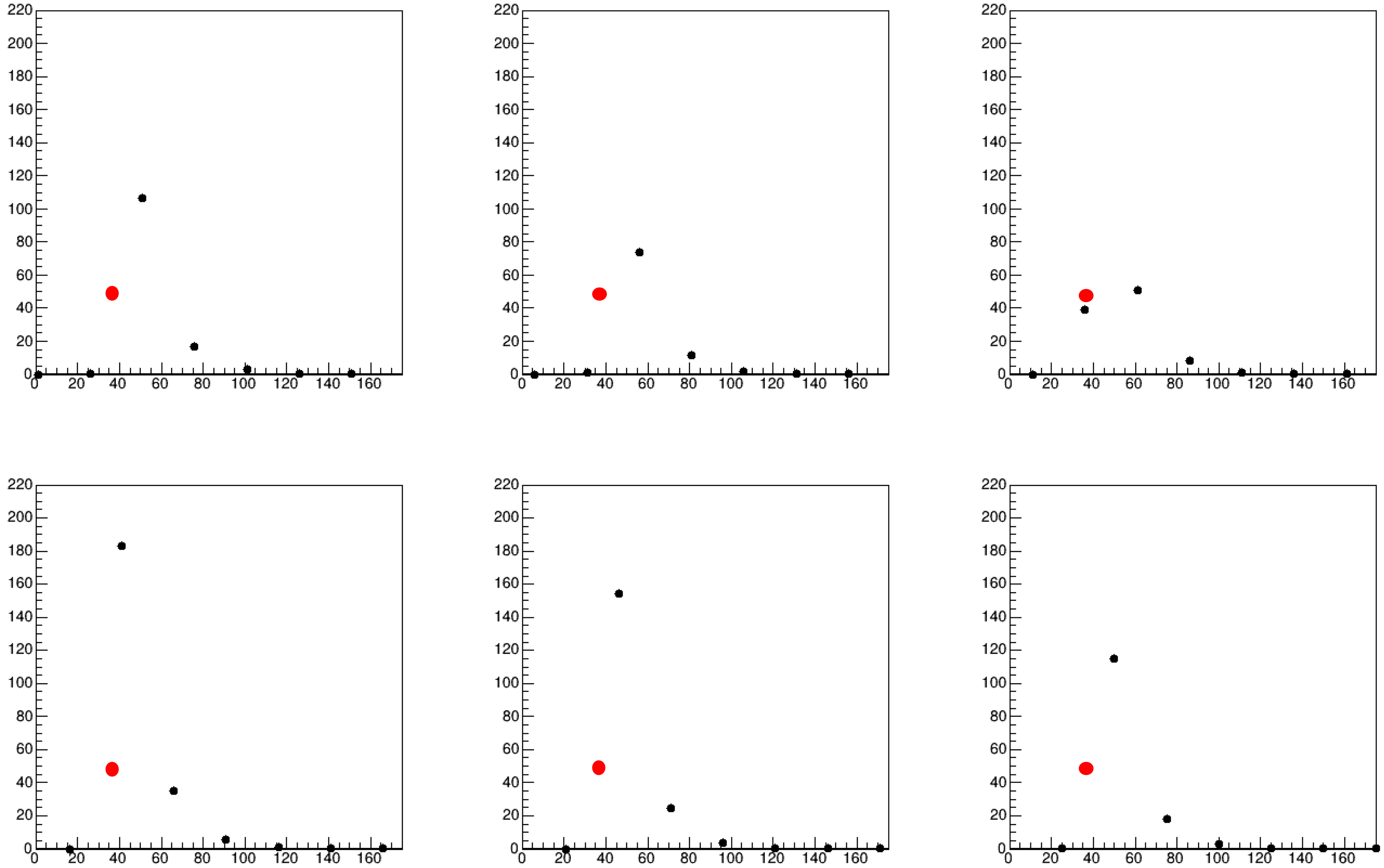
Pulse height reconstruction (h $\leq$ Thr$_{TOA}$)



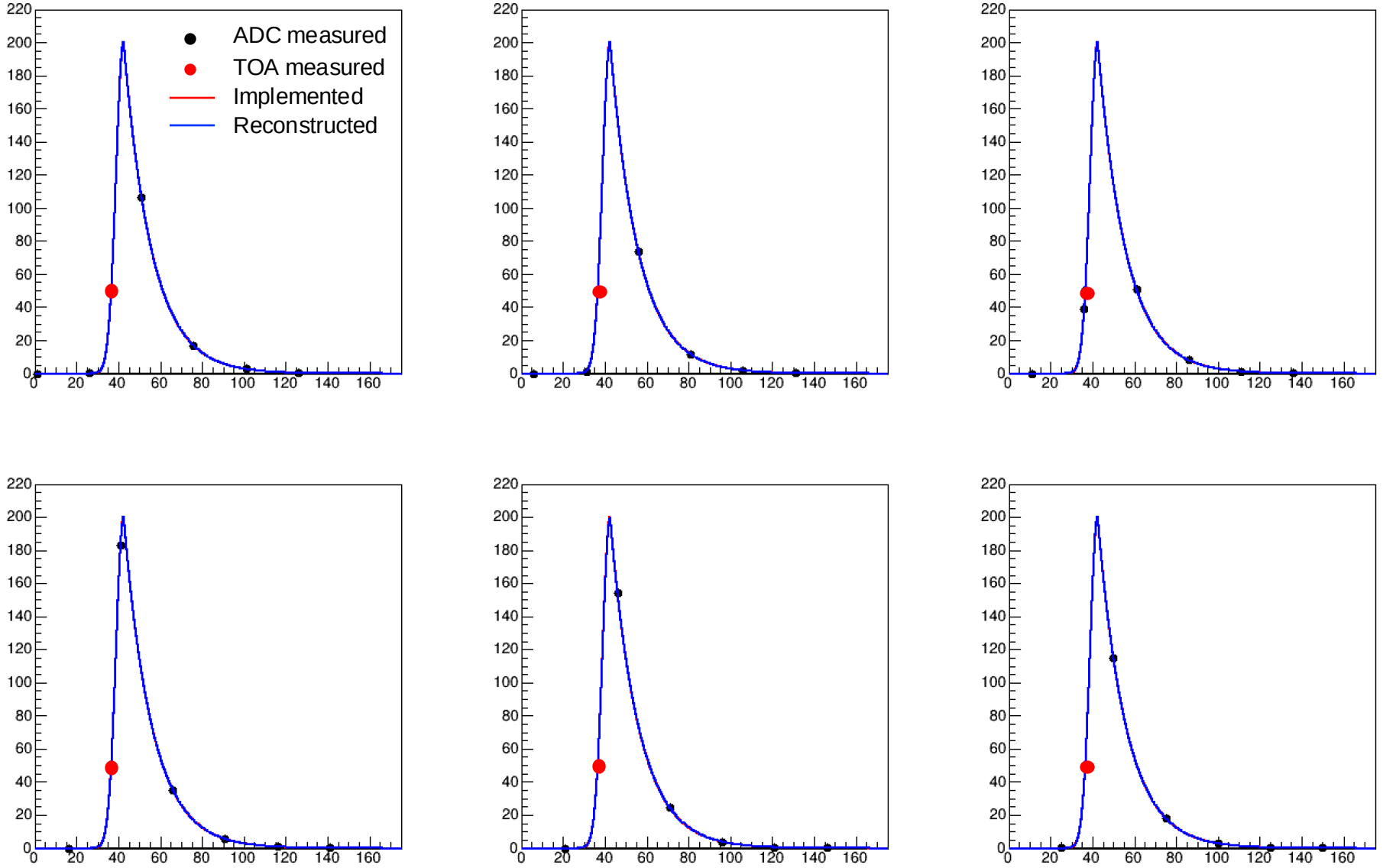
Pulse height reconstruction ($h \leq Thr_{TOA}$)



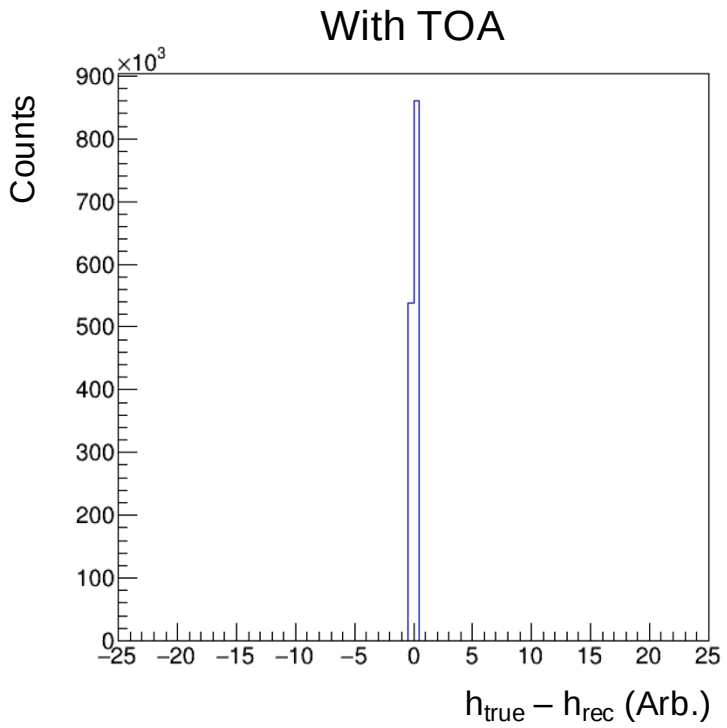
Pulse height reconstruction ($Thr_{TOA} < h \leq Thr_{TOT}$)

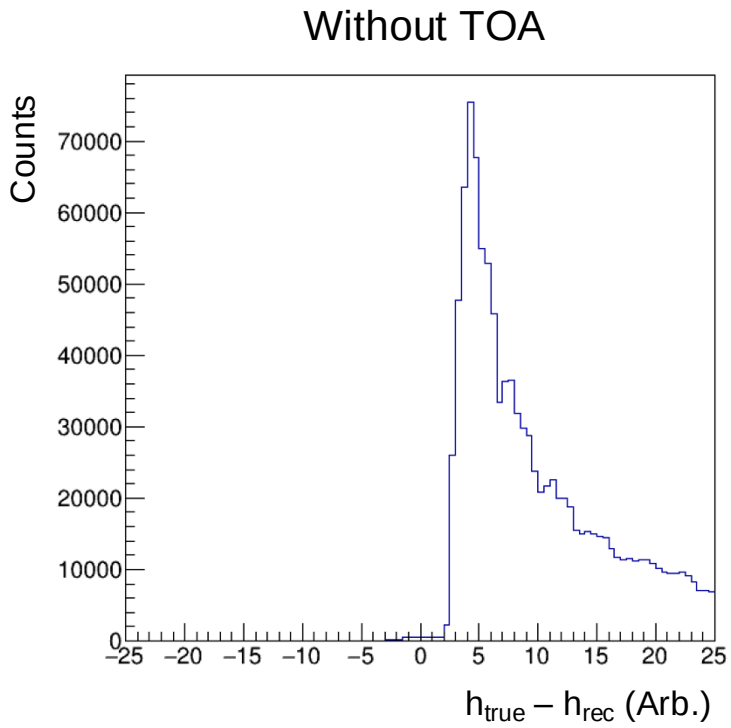


Pulse height reconstruction ($Thr_{TOA} < h \leq Thr_{TOT}$)



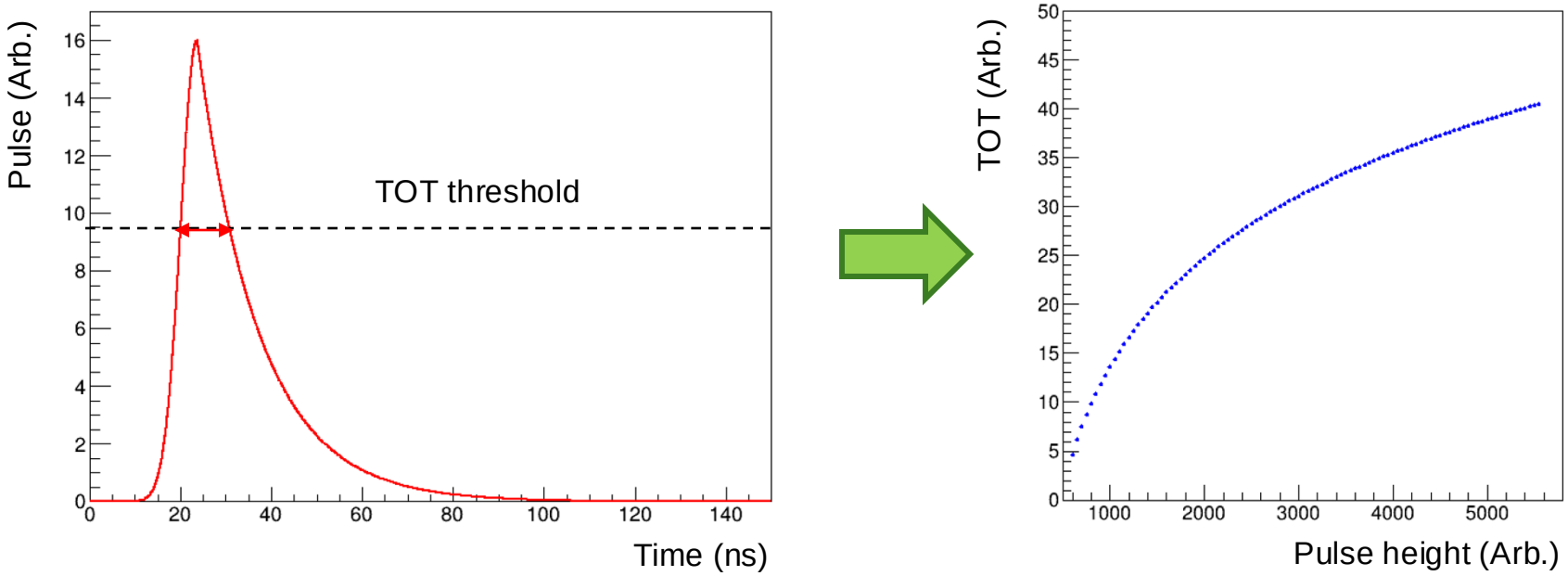
Pulse height reconstruction ($Thr_{TOA} < h \leq Thr_{TOT}$)





- We expect much better reconstruction performance when we have the TOA value.
- We need to set the TOA threshold as low as possible to make as many channels as possible have the TOA value.

Pulse height reconstruction ($Thr_{TOT} < h$)



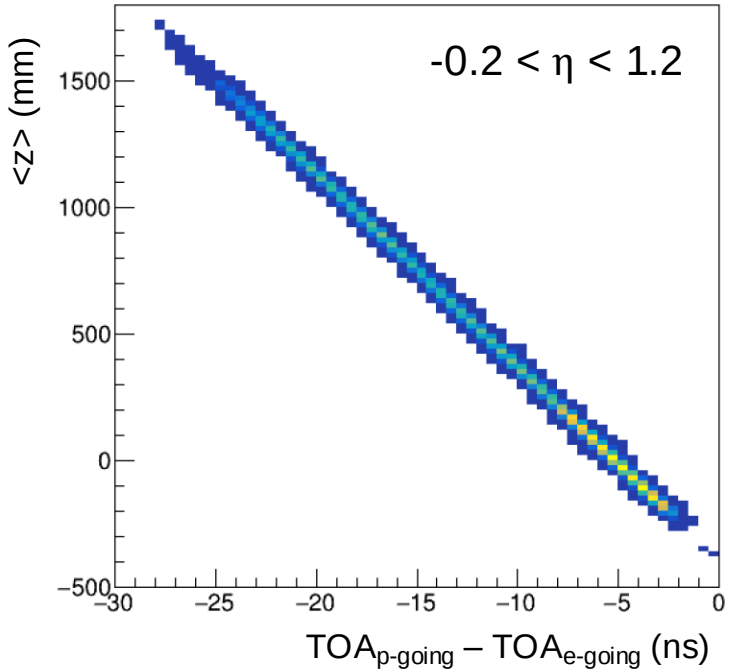
- The TOT value can be 1 vs. 1 matched to the pulse height, thereby the pulse height can be reconstructed precisely.

Attenuation correction

e-going side

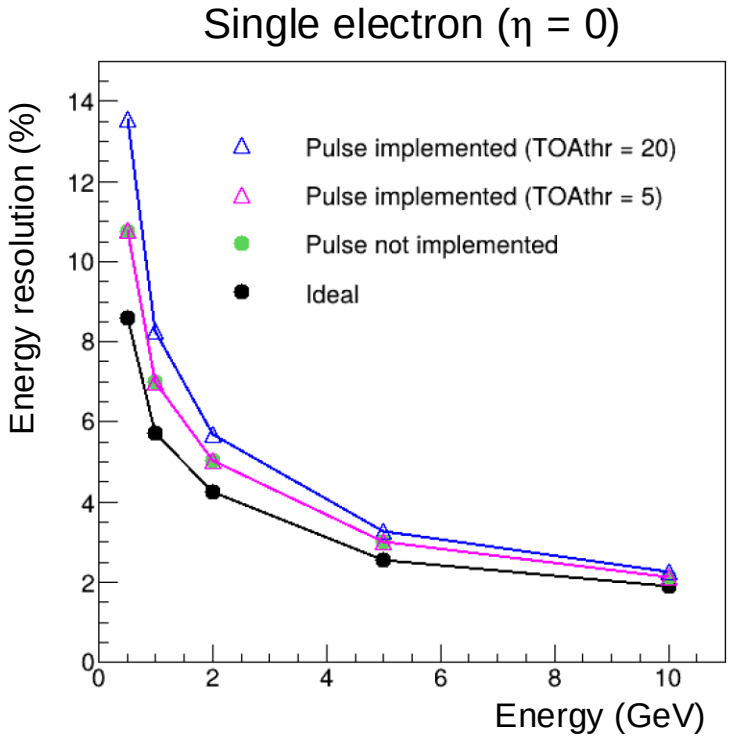
p-going side

5 GeV single electron



- The attenuation correction was done using the TOA difference between p-going and e-going sides.
- If the TOA was not measured on either side, average value of the TOA was used.

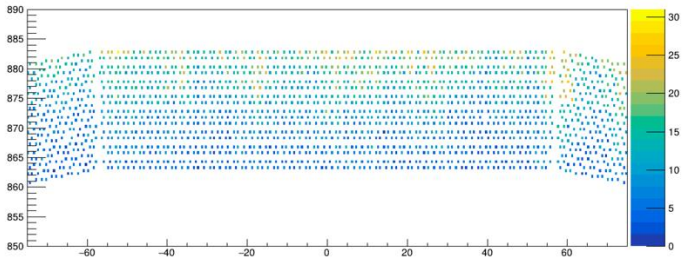
Energy resolution comparison



- A threshold of 5 Npe was applied to each SiPM.
- When Thr_{TOA} is 5 Npe, the resolution is almost the same with the “Pulse not implemented”. This means the pulses have been implemented and reconstructed well in the simulation.

Implementation into the ePIC simulation package

Implementation plan



edm4hep::
SimCalorimterHit

1. Regroup
2. Attenuation
(left & right)

edm4hep::
SimCalorimterHit

E → Npe for
each SiPM

edm4hep::
SimCalorimeterPulse

Combining
pulses

edm4hep::
SimCalorimeterPulse

Adding noises

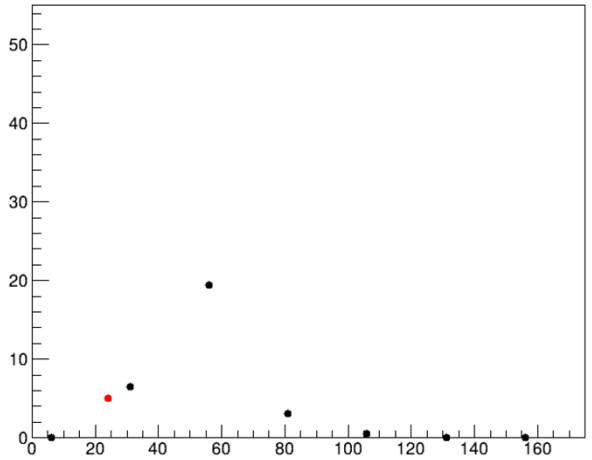
edm4hep::
SimCalorimeterPulse

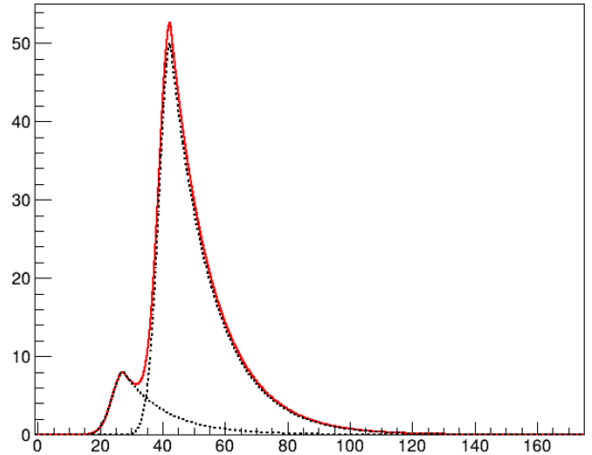
Digitization

edm4eic::
RawHGCROCHit

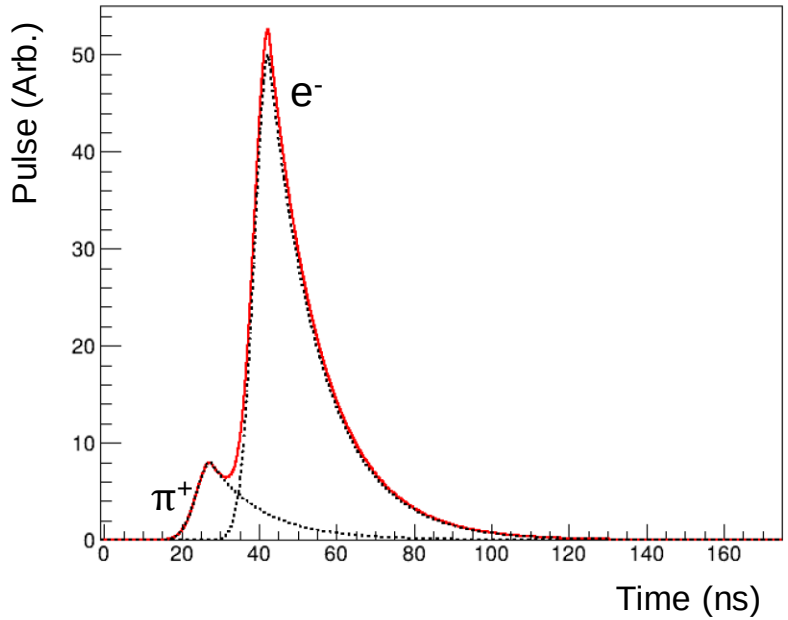
Reconstruction

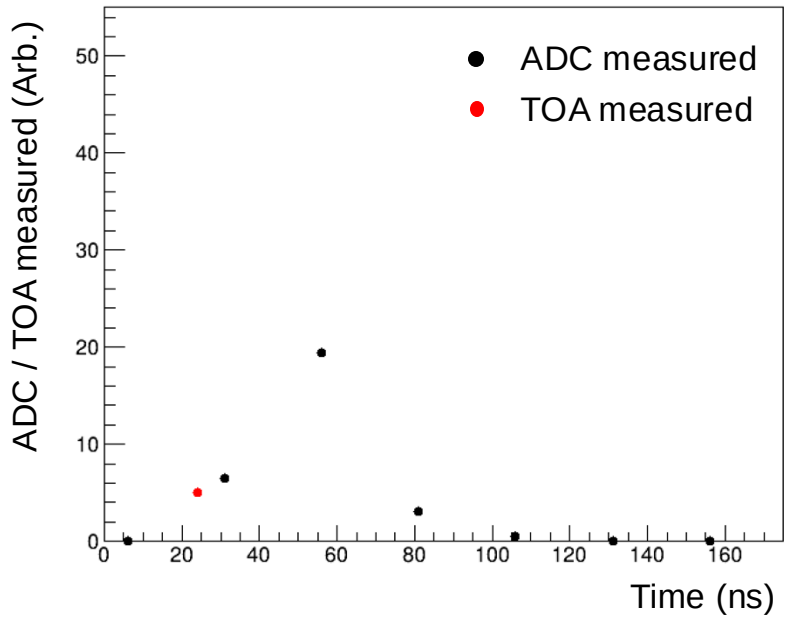
edm4eic::
CalorimeterHit





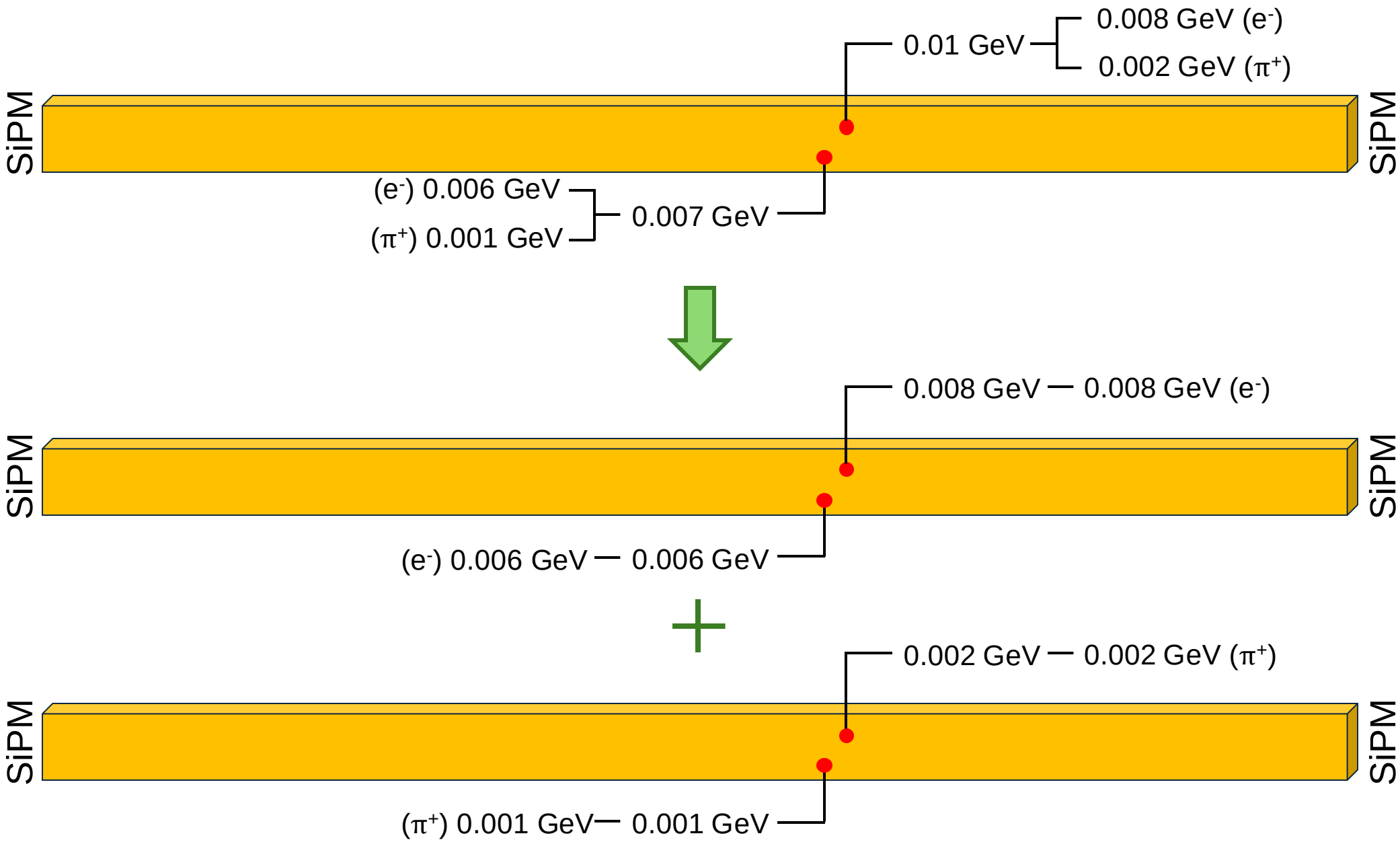
Energy splitting



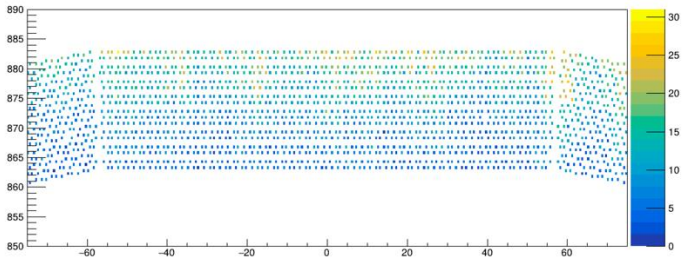


- One of our target is studying the energy splitting because the BIC could measure two particles together.
- To study the energy splitting, we need pulse information classified by particle.

Regrouping


0.008 GeV (e-)
0.01 GeV
0.002 GeV (π+)
SiPM
SiPM
(e-) 0.006 GeV
(π+) 0.001 GeV
0.007 GeV
0.008 GeV
0.008 GeV (e-)
SiPM
SiPM
(e-) 0.006 GeV
0.006 GeV
0.002 GeV
0.002 GeV (π+)
SiPM
SiPM
(π+) 0.001 GeV
0.001 GeV

Implementation plan



edm4hep::
SimCalorimterHit

1. Regroup
2. Attenuation

edm4hep::
SimCalorimterHit

E → Npe for each SiPM

edm4hep::
SimCalorimeterPulse

Combining pulses

edm4hep::
SimCalorimeterPulse

Adding noises

edm4hep::
SimCalorimeterPulse

Digitization

edm4eic::
RawHGCROCHit

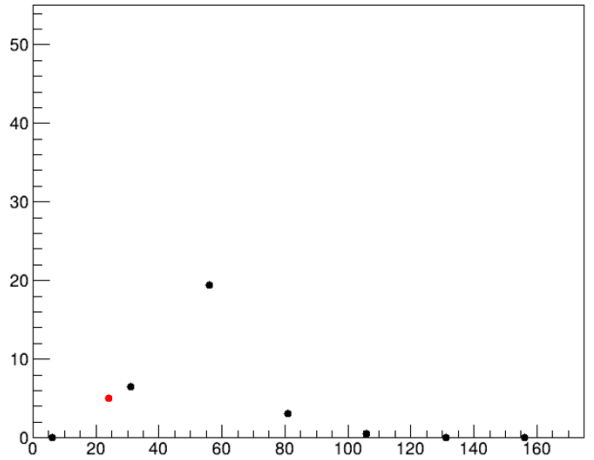
Reconstruction

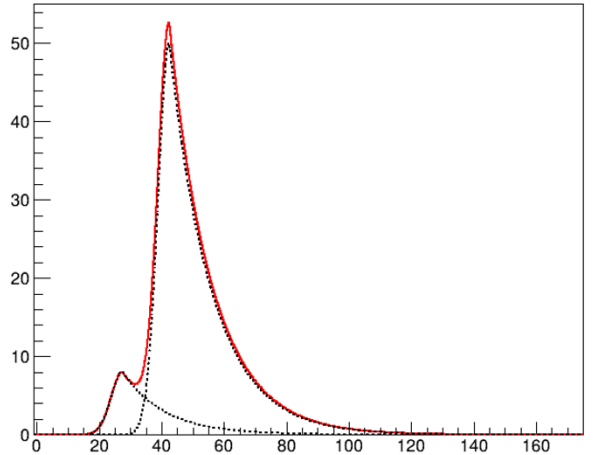
edm4eic::
CalorimeterHit

Target date:
End of April

Target date:
End of May

Target date:
End of June





Current status

edm4hep::
SimCalorimterHit

1. Regroup
2. Attenuation

edm4hep::
SimCalorimterHit

E → Npe for each SiPM

edm4hep::
SimCalorimeterPulse

Pull request

1776 implementation of the bic attenuated hits #1783

Open mhkim-anl wants to merge 34 commits into `main` from `1776-implementation-of-the-bic-attenuated-hits`

mhkim-anl commented 2 days ago — Member

Briefly, what does this PR introduce?

This PR adds new factory, output, plugin, algorithm for attenuating ScFi hits of the BIC. The followings were added or updated.

- `src/factories/calorimetry/CalorimeterHitAttenuation_factory.h`
- `src/services/io/podio/JEventProcessorPODIO.cc` `EcalBarrelScFiPAttenuatedHits` (readout at p-going side) and `EcalBarrelScFiNAttenuatedHits` (readout at e-going side) were added.
- `src/detectors/BEMC/BEMC.cc`

Pull request

Add `SimCalorimeterPulse` data type for storing simulated calorimeter pulses pre-digitization #106

Open sly2j wants to merge 3 commits into `main` from `feat-add-simcalorimeterpulse`

sly2j commented last week • edited — Member

Briefly, what does this PR introduce?

This PR adds a new data type, `edm4eic::SimCalorimeterPulse`, to represent simulated calorimeter pulses before digitization.

The new structure is modeled consistently with `edm4hep::SimCalorimeterHit` and aligns with existing waveform structures such as `edm4hep::RawTimeSeries` (generic digitization output) and `edm4hep::TimeSeries` (generic measured time series).

`SimCalorimeterPulse` defines three one-to-many relations relations: