WP4
Calorimeter Software
State of art

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MUSE Scientific Board Meeting

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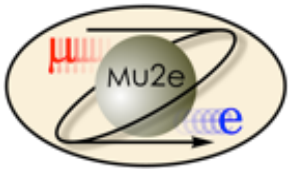

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Calo-software updates

- Geometry: effect of the choice of calorimeter mechanical material
- Calorimeter timing simulation
- Calorimeter trigger

Support material study

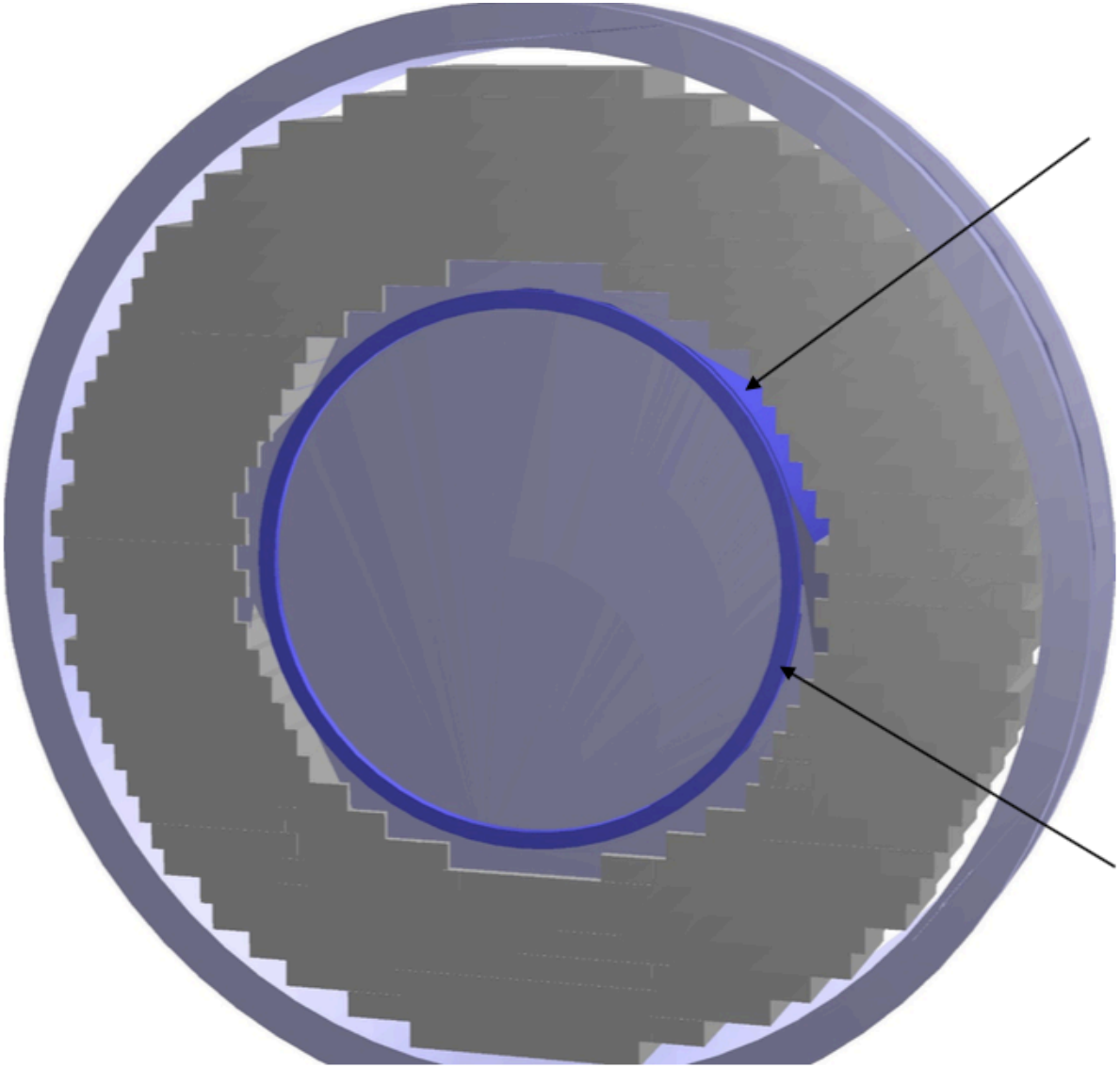
- Study of the effect of the choice of material for the inner support rings and the thickness of the CF skin of the front plate. The material of the inner ring investigated for completeness.
- Simulate 50K Ces with the latest calorimeter geometry for several configurations:

Support ring	Inner ring	CF Front plate thickness
Full CF	Full CF	1.5 mm
Empty CF	Full CF	1.5 mm
Al	Full CF	1.5 mm
Full CF	**Empty CF**	1.5 mm
Full CF	**Al**	1.5 mm
Full CF	Full CF	**1.0 mm**

Full CF = a solid block of CF
Empty CF = an outer CF shell, simulated as completely empty.
Default geom. = Full CF support ring, full CF inner ring, 1.5mm CF front plate.

Examine the energy resolution and efficiency as a function of the cluster energy.

GEANT4 geometry



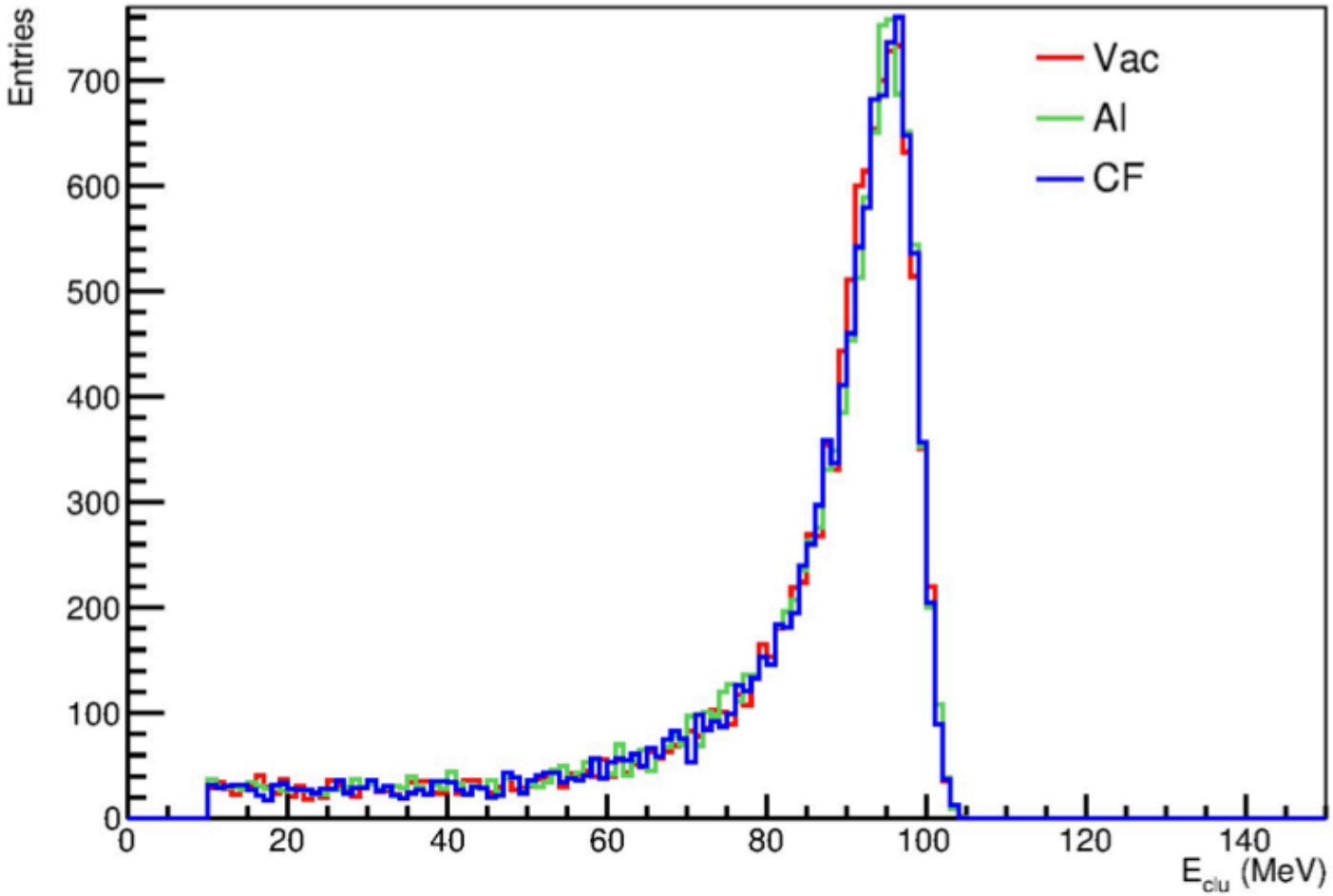
Inner ring along crystals is a single ring of 3x180mm (RxZ).

Support ring at front and back of inner ring.

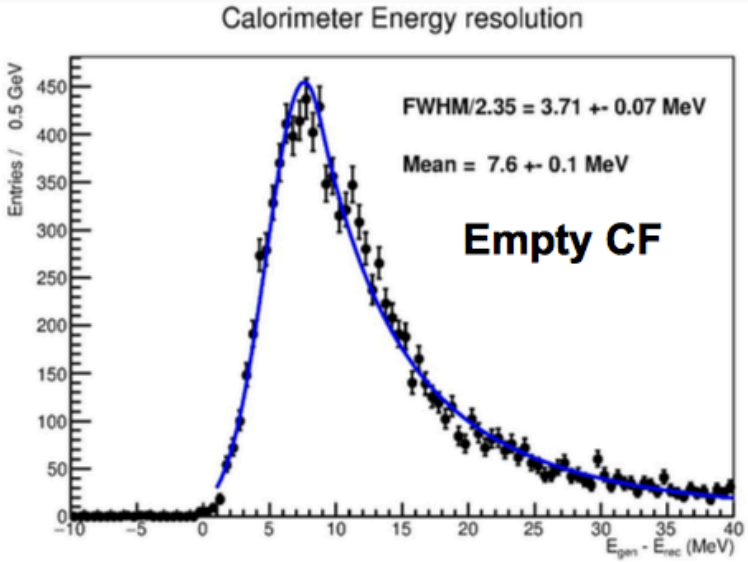
Each ring is 22x15mm (RxZ) in front/back of the inner disk

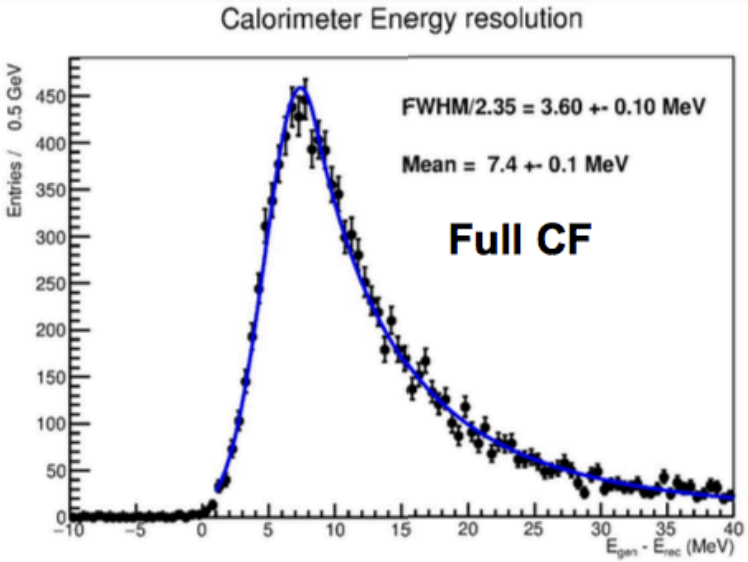
Support ring result

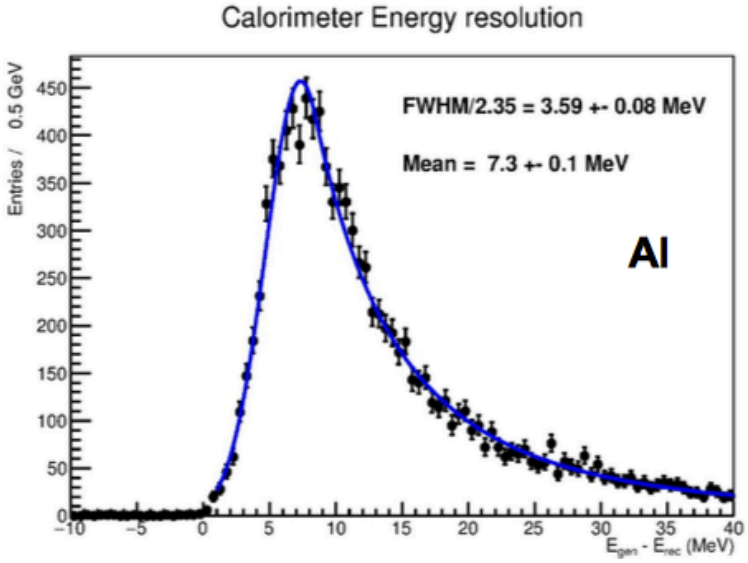
- Cluster energy spectrum for **different support ring material**, default inner ring / front plate.



Support ring result (2)





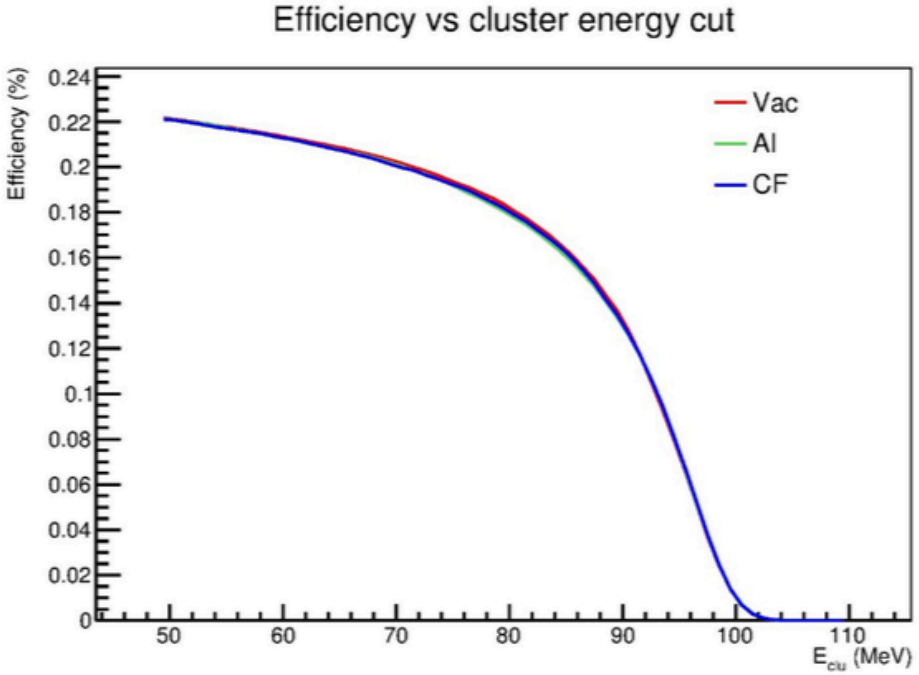


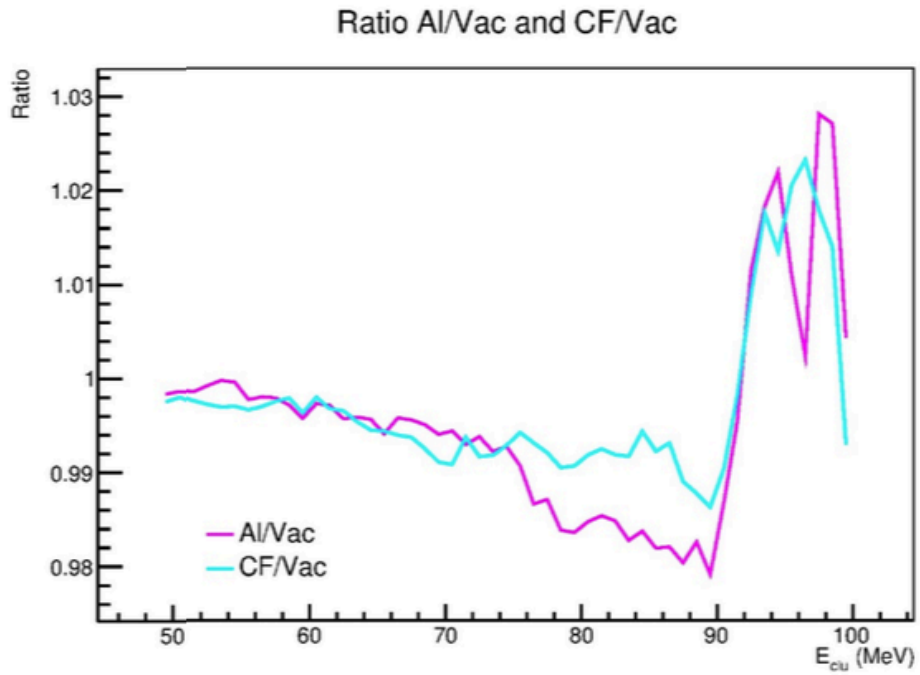
Mean energy loss differs by 0.3 MeV between empty and Al, but systematic uncertainty is large.

Resolution is similar within uncertainty.

Note: changing the fit range can change the central value by 0.2-0.3 MeV.

Support ring result (3)



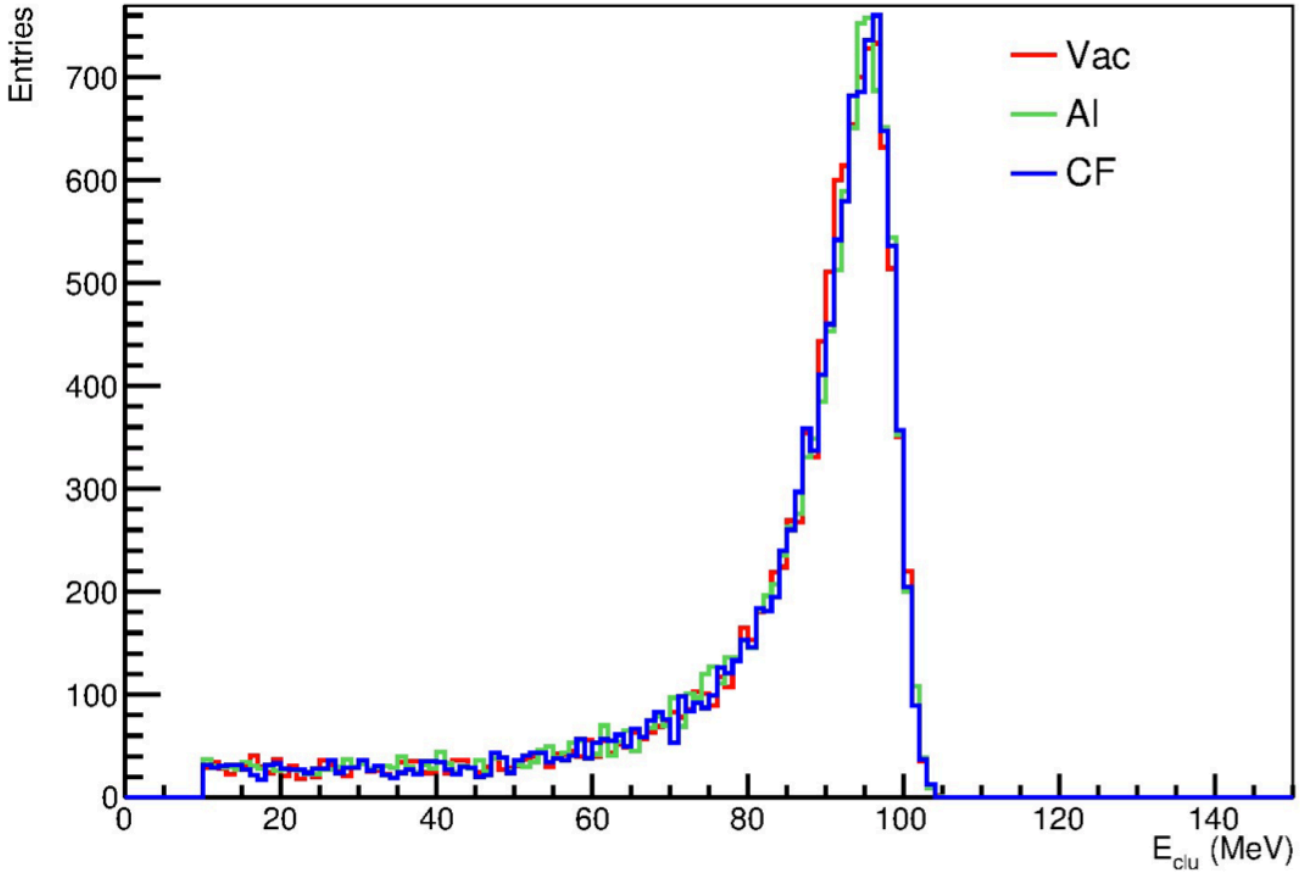


Left: Cumulative efficiency for reconstructing a shower with energy > threshold energy. The denominator is given by the total number of generated CE.

Right: Ratio of efficiency for Al over Empty CF (Full CF / Empty CF). Absolute uncertainty on ratio between 1-2%.

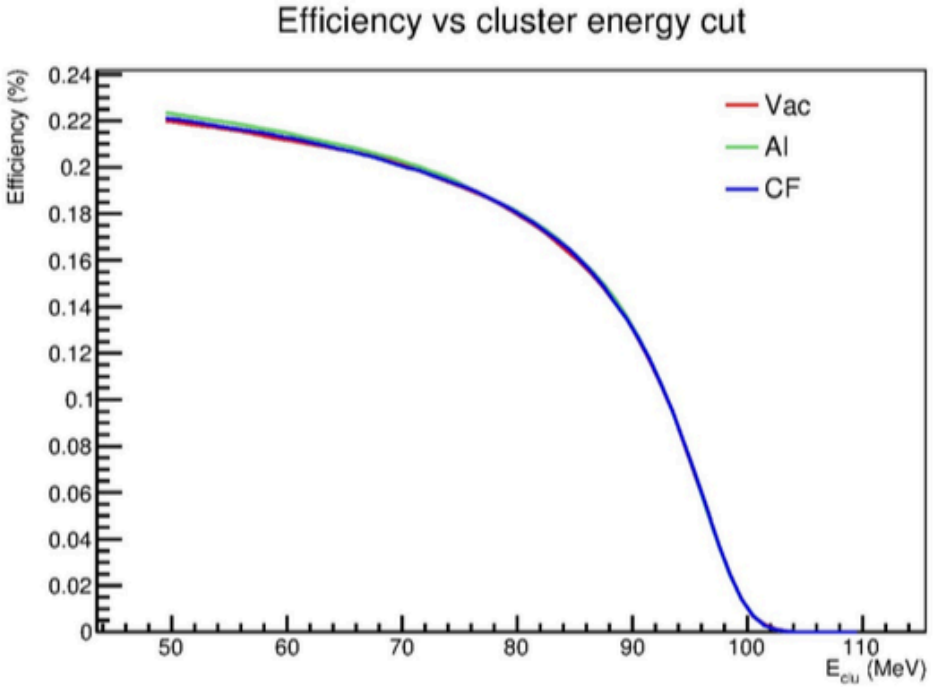
Inner ring result

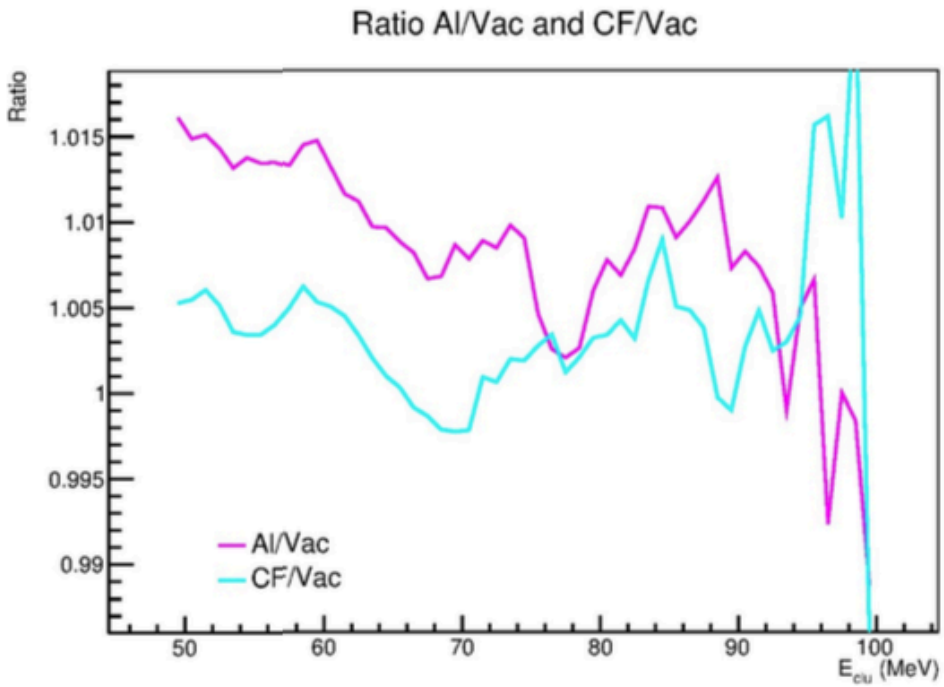
- Cluster energy spectrum for **different inner ring material**, default support ring / front plate.



Mean energy loss differs by 0.1MeV between empty and Al. Resolution similar within uncertainty.

Inner ring result (2)





Left: Cumulative efficiency for reconstructing a shower with energy > threshold energy. The denominator is given by the total number of generated CE.

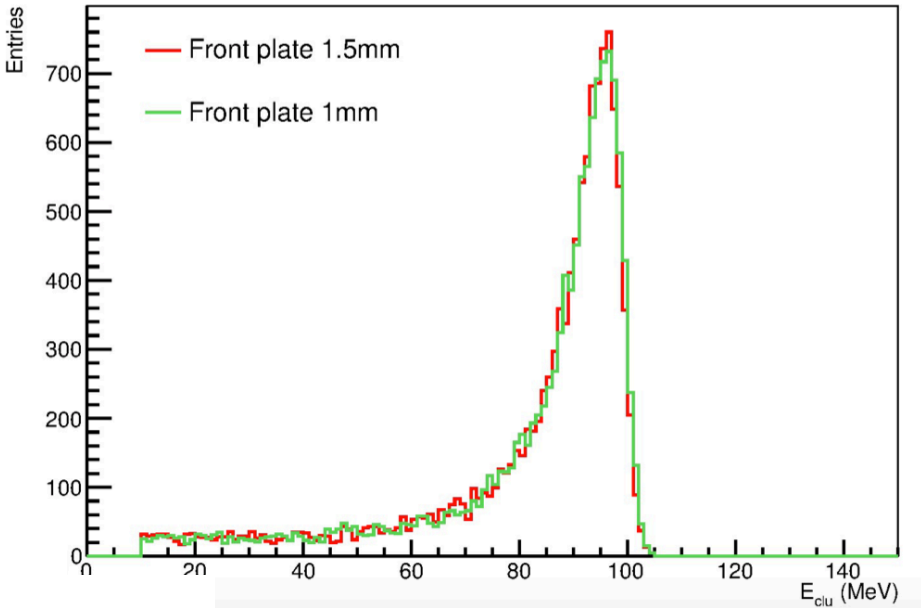
Right: Ratio of efficiency for Al over Empty CF (Full CF / Empty CF). Absolute uncertainty on ratio between 1-2%.

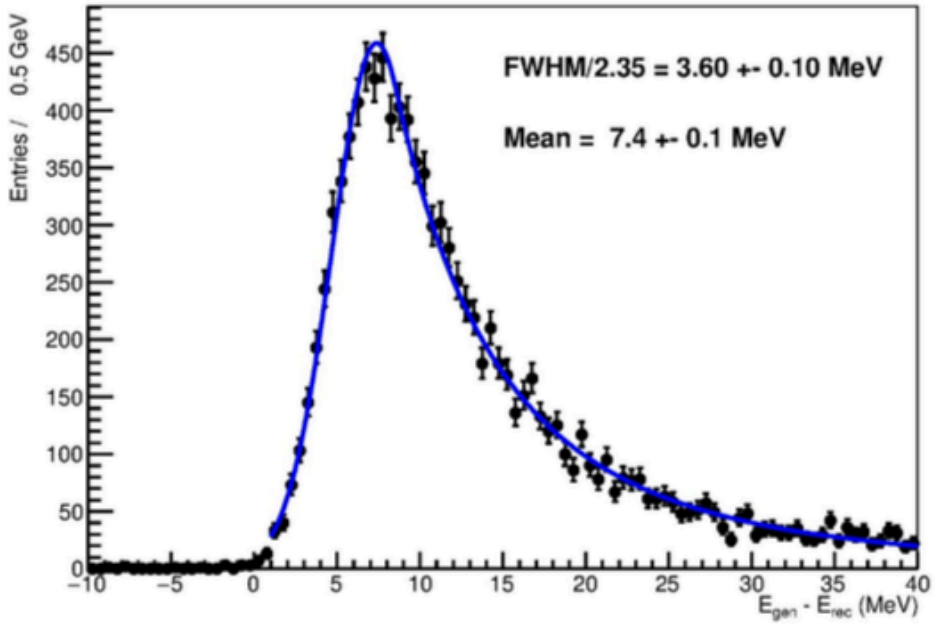
There is essentially no difference between the three choices.

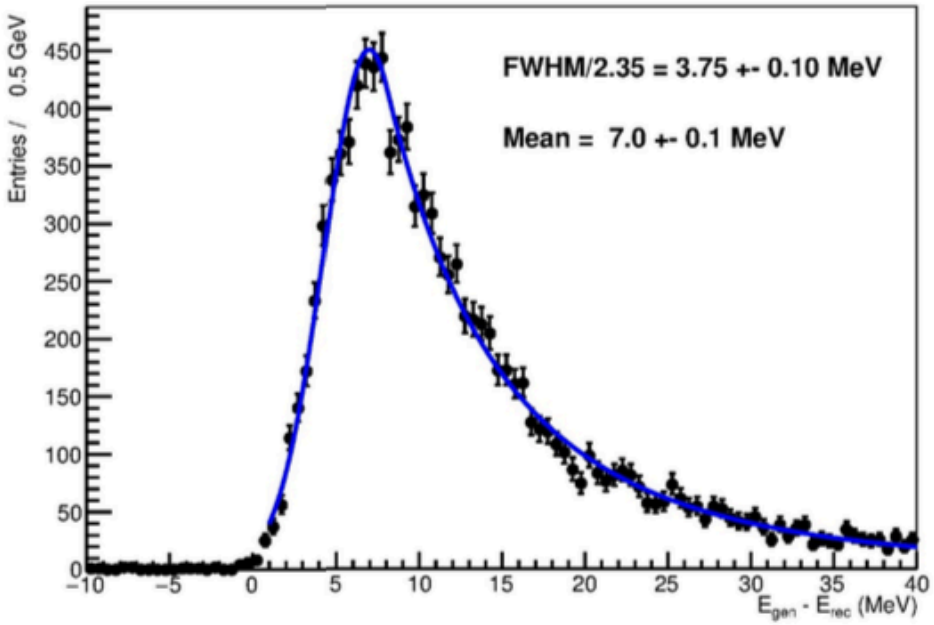
Front plate result

- Cluster energy spectrum for **different CF front plate thickness**, default inner ring / support ring

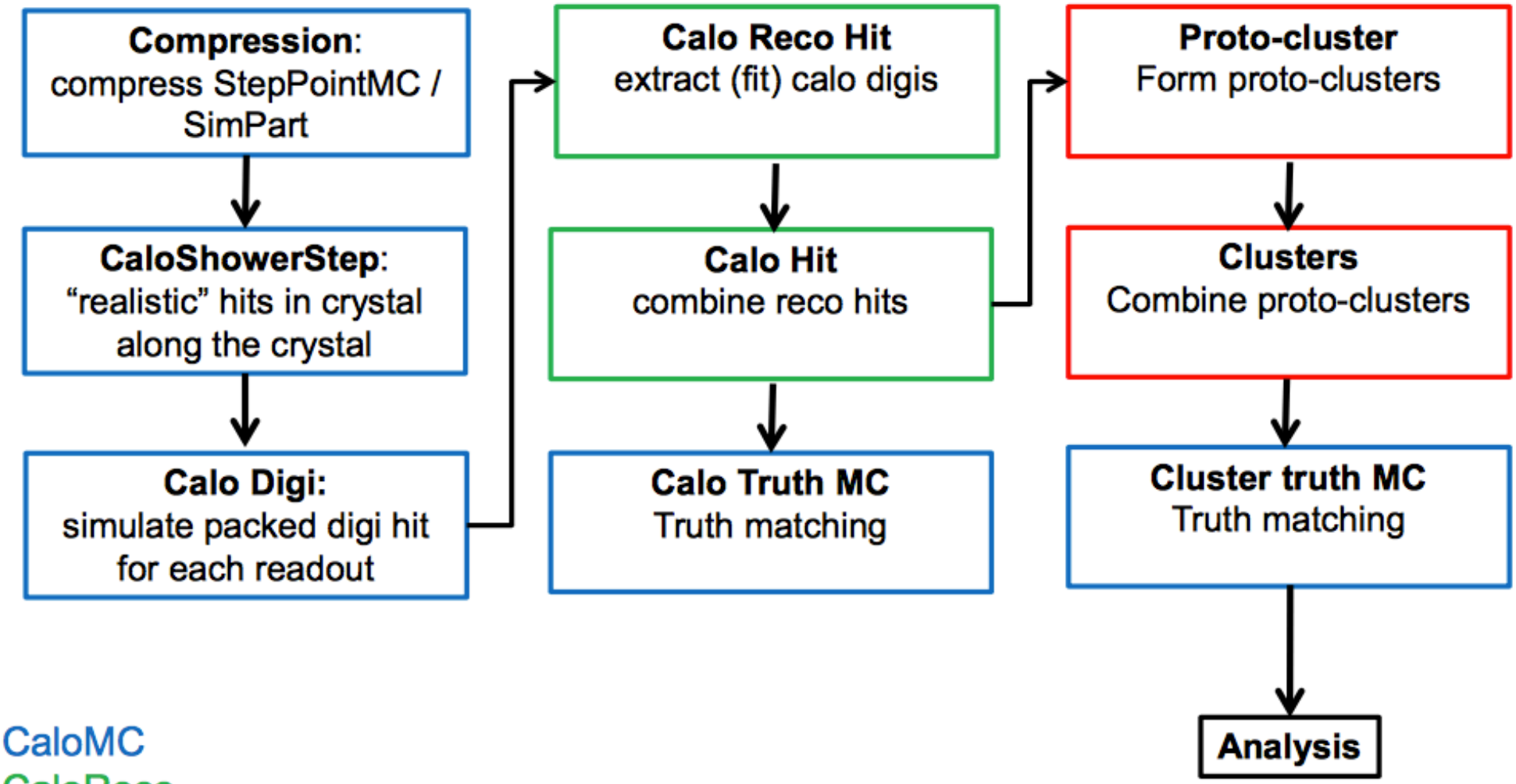
- The energy loss is 0.4 MeV small for 1mm CF front plate than 1.5 mm. The energy resolution is sensibly similar.







Timing simulation
Logic scheme



CaloMC
CaloReco
CaloCluster

Crystal time simulation

We start with SimParticles (particles) and StepPointMCs (energy deposits) produced by Geant4 in each crystal - one SimParticle creates one or more StepPointMCs .

Collect and compress all StepPointMC / SimParticle in crystal slices:

1) For each crystal, collect all StepPoints associated to an incoming SimParticle.

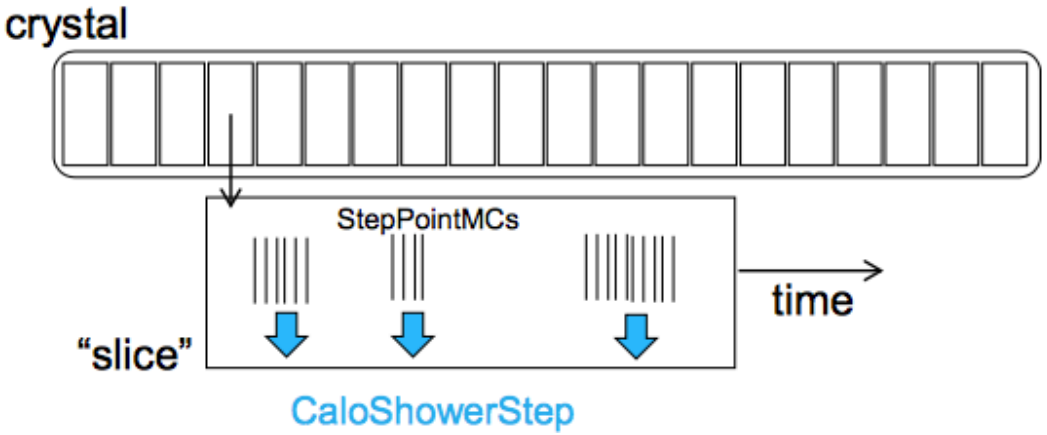
2) Slice the crystal along the longitudinal axis into N slices (N=20 seems a good number).

3) Collect in each slice all the StepPoints within time window t0 + Δt (Δt: fraction of ns).

4) Create *CaloShowerStep* for each slice (record time / total energy / average position / SimParticle), compressing the StepPointMCs for the given incoming SimParticle.

5) Take the first StepPoint after t0 + Δt, set the new t0, and start again.

6) Then repeat for all SimParticles in a crystal and all crystals.



- CaloShowerStep describe the energy deposited by a incoming particle at a given time in a given crystal slice.
- CaloShowerSteps from different incoming particles can overlap in a given crystal slice.
- Can trace back information to all incoming particles.

Readout signal

- Create signal in each crystal readout→3 steps:

1) Transform each CaloShowerSteps (compressed StepPointMC in a slice of a crystal associated to an incoming particle at a given time) into an amount of scintillation light, applying corrections on:

- - LRU
- Additional corrections can be implemented at this stage (e.g. non-linearities in energy deposition)

2) Propagate the scintillation light to the readout and account for propagation time. We assume the light propagates in straight line from the slice to the readout and model the delay as a single number. We can introduce an additional smearing at this stage if needed

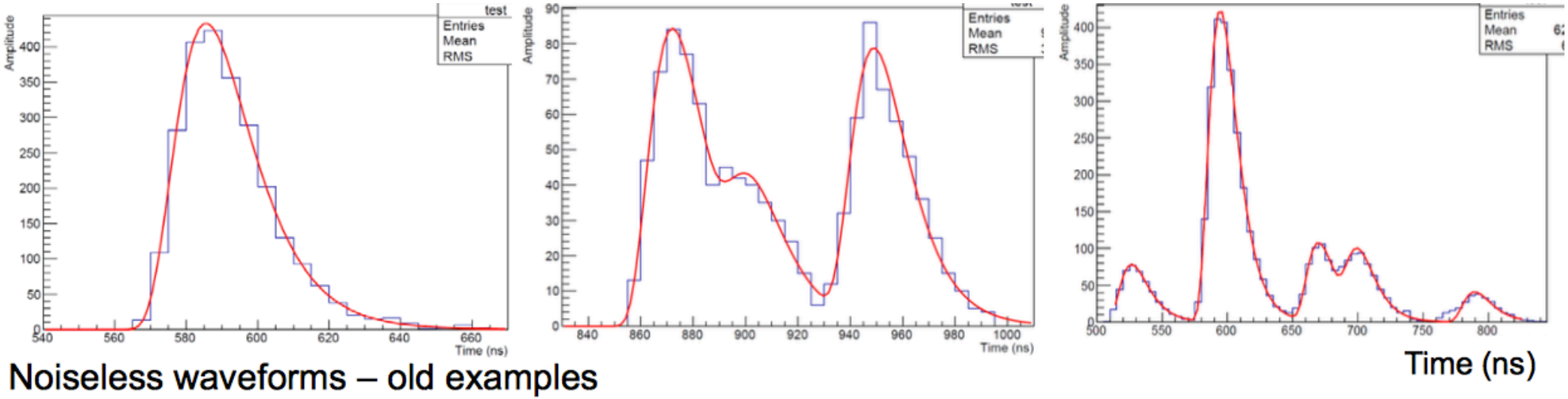
3) Simulate the readout response

- Generate the signal amplitude produced by the scintillation light, including statistical
- fluctuations from the number of p.e./MeV (Poisson distribution)
- Calculate the waveform ADC values from a waveform template (see below)
- Add noise in each readout
- Produce the digitized output - similar to real data.

Readout signal

1) peak finding, scan waveform for local maxima (include scan of residuals).

2) fit waveform



Noiseless waveforms – old examples

To do:

- Update waveform with new FEE output
- Implement the Module-0 TB result

Next steps

Test the code

- Check that the hit extraction is working fine
- Check that the uncertainties are correctly calculated
- Evaluate and check MC timing resolution

Improve the current code

- Update to latest waveform
- Import current “beam test” timing extraction method
- Improve cluster timing

Improve the light propagation model

- Simulate individual PEs
- Measure waveform with point source