CALICE Si-W ECAL Calorimeter Preliminary Testbeam Results

Cristina Cârloganu

Clermont Ferrand

On behalf of the CALICE collaboration

Outline

Calorimeter for ILC

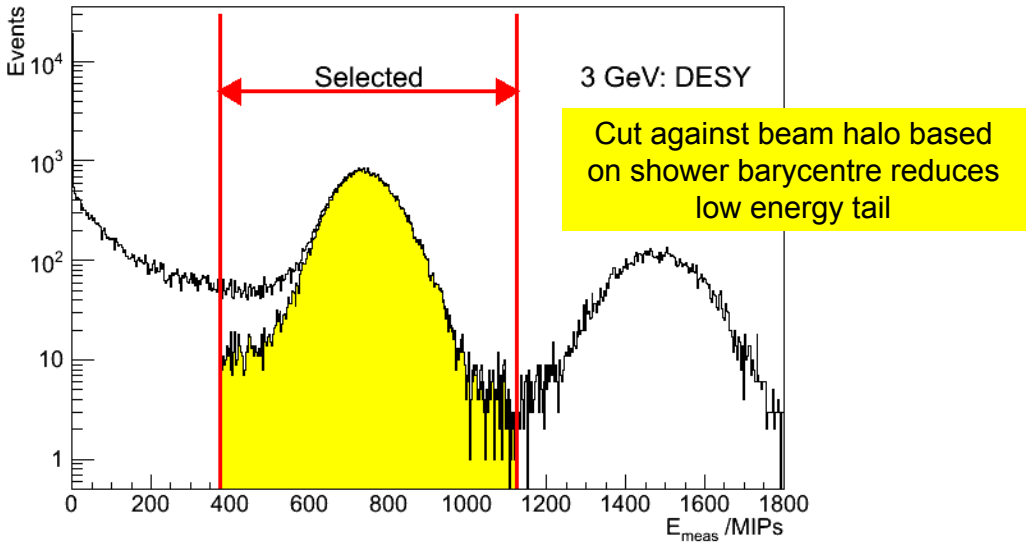
ECAL resolution and linearity

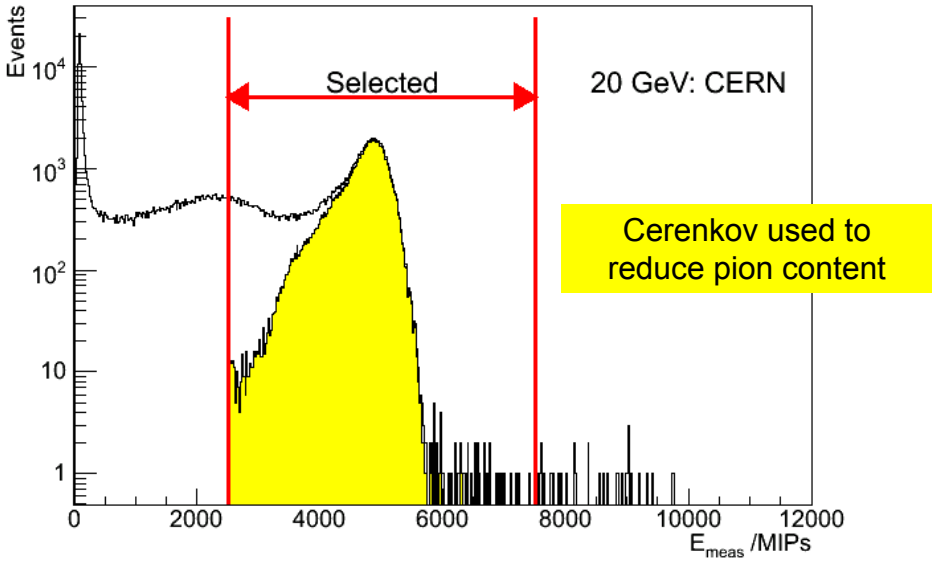
Inter-wafer gaps correction

Longitudinal and transversal shower development

Spatial resolution at normal incidence

Electron selection





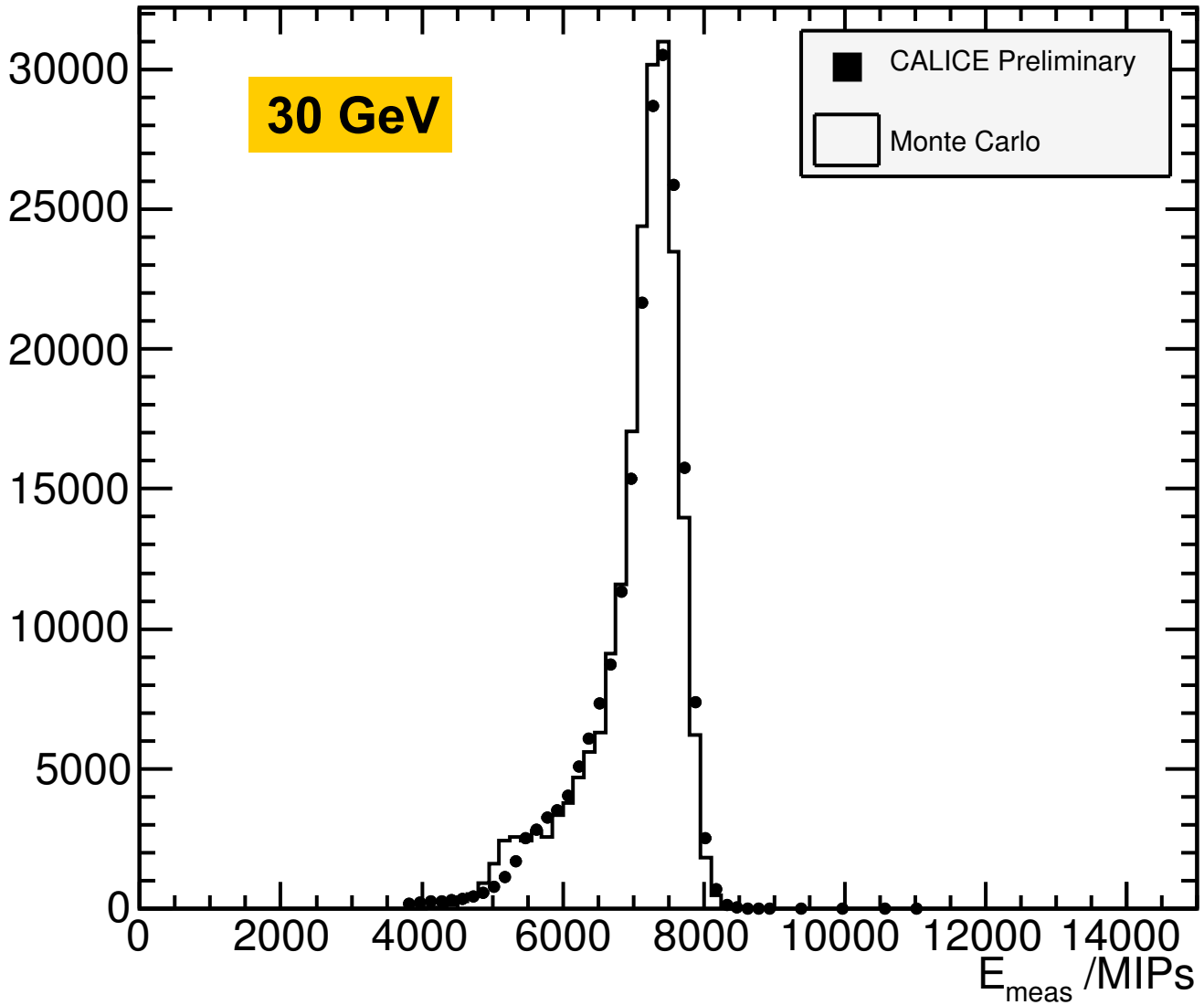
Triggering : coincidence of 3 scintillators along the beam line.

Signal threshold: 0.6 MIP

Selection of single electron events:

$$125 \times E_{beam} < E_{raw} / \text{MIP} < 375 \times E_{beam}$$

"Raw" energy spectrum for electrons



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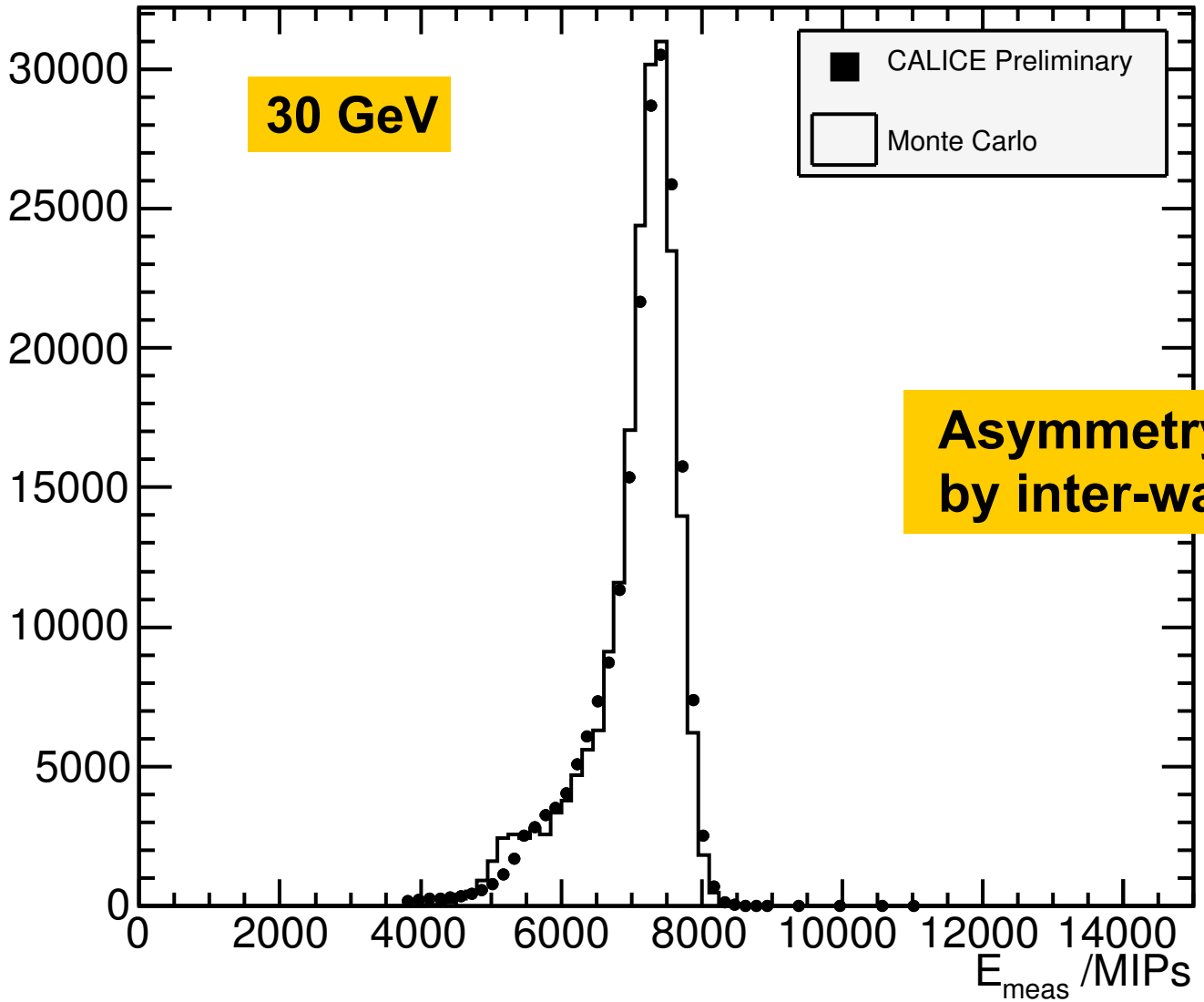
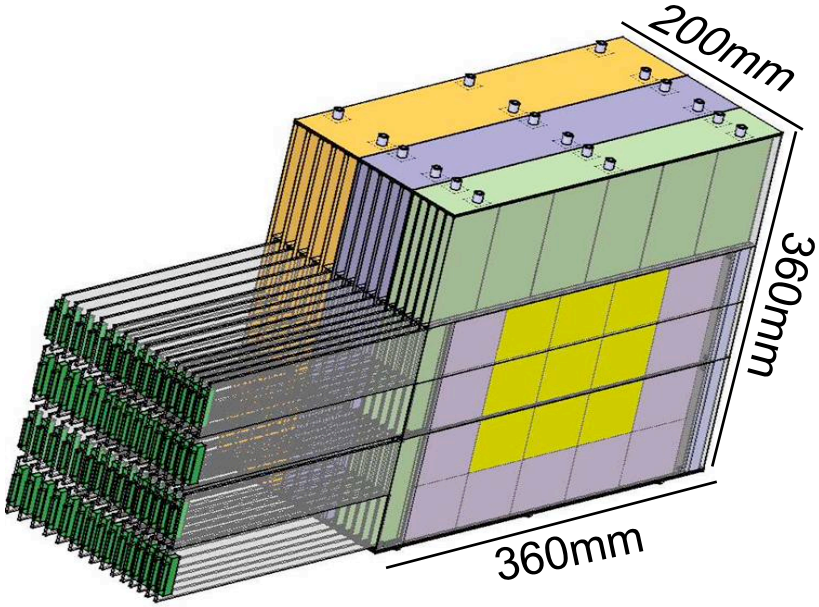


Asymmetry caused by inter-wafer gaps

Ecal geometrical scan



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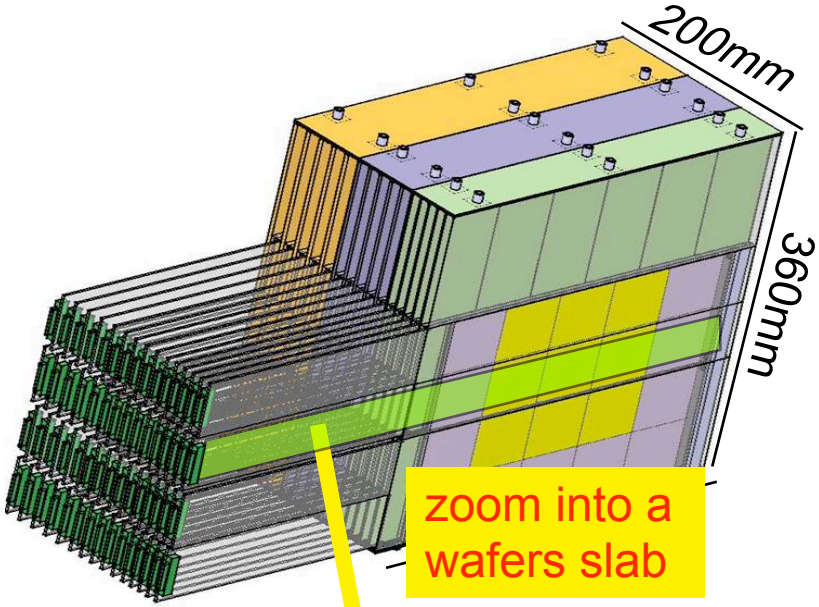

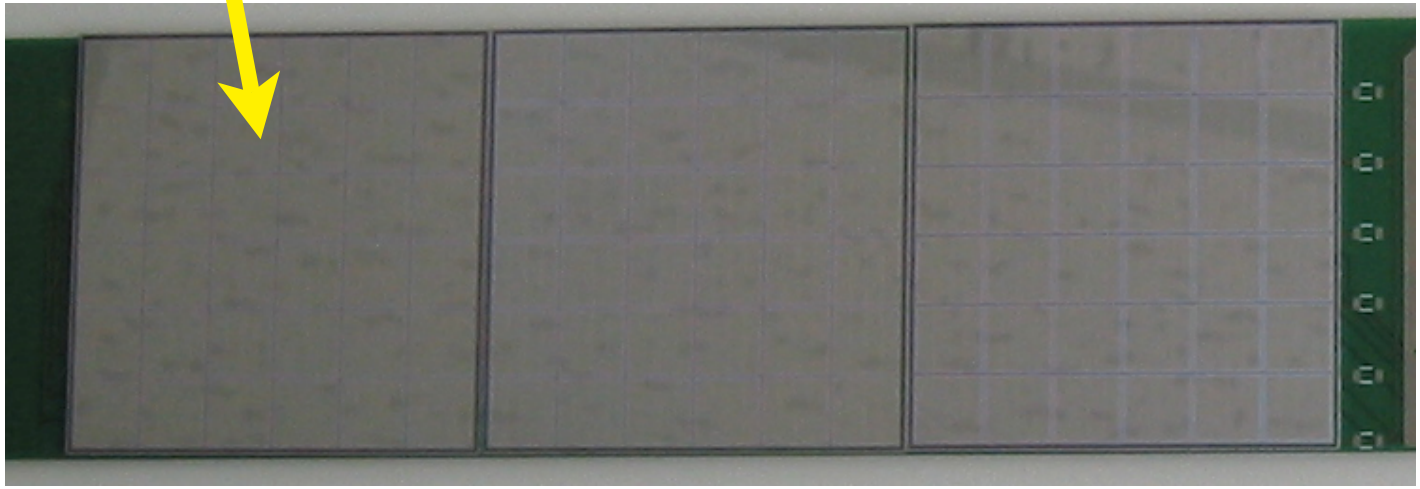

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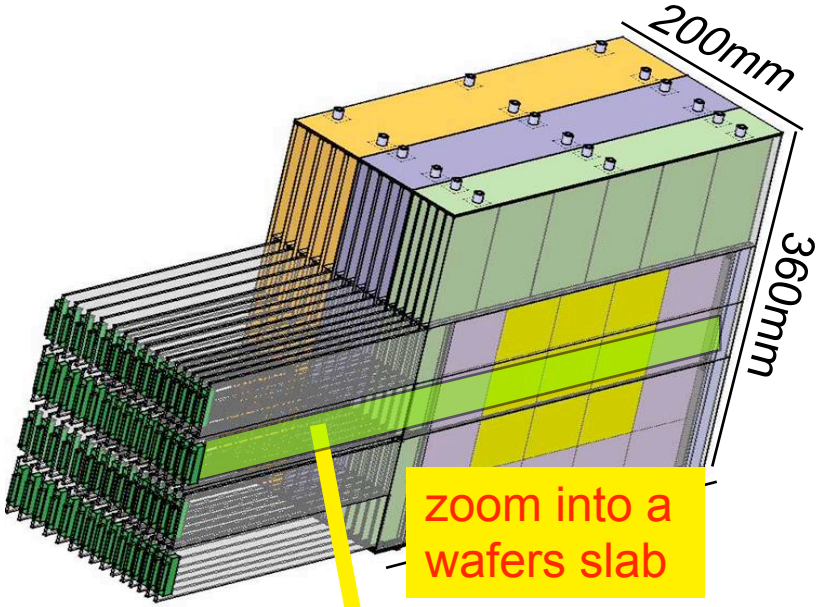

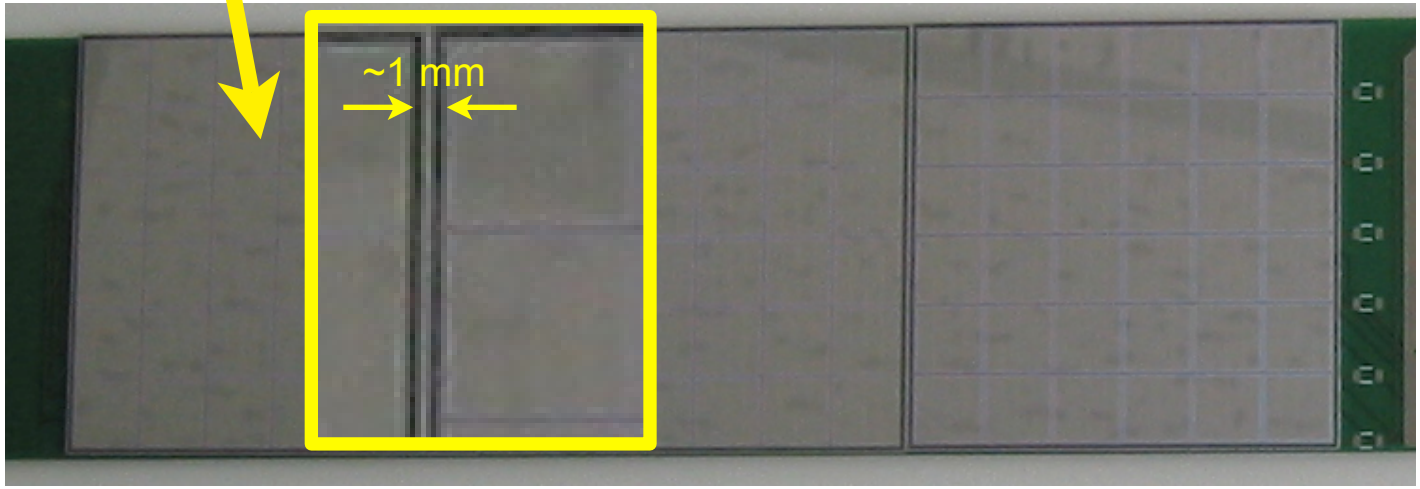

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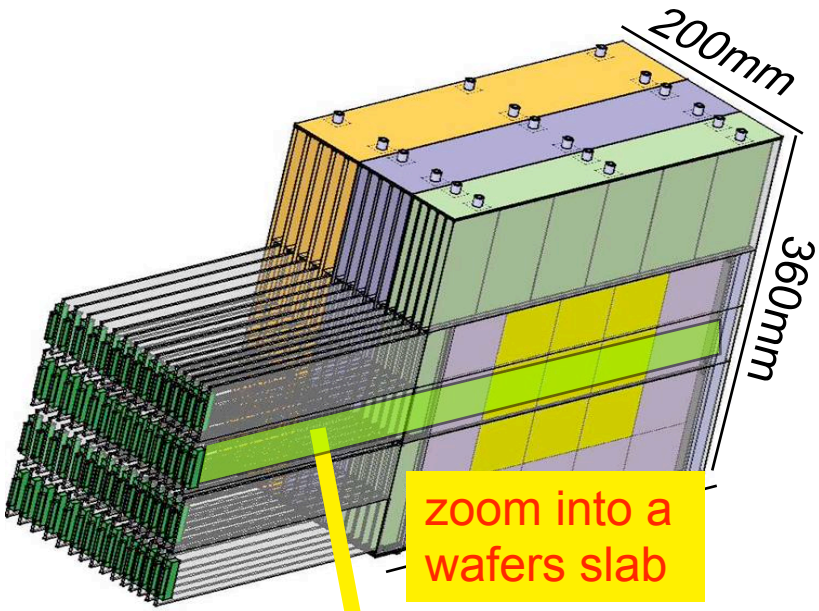
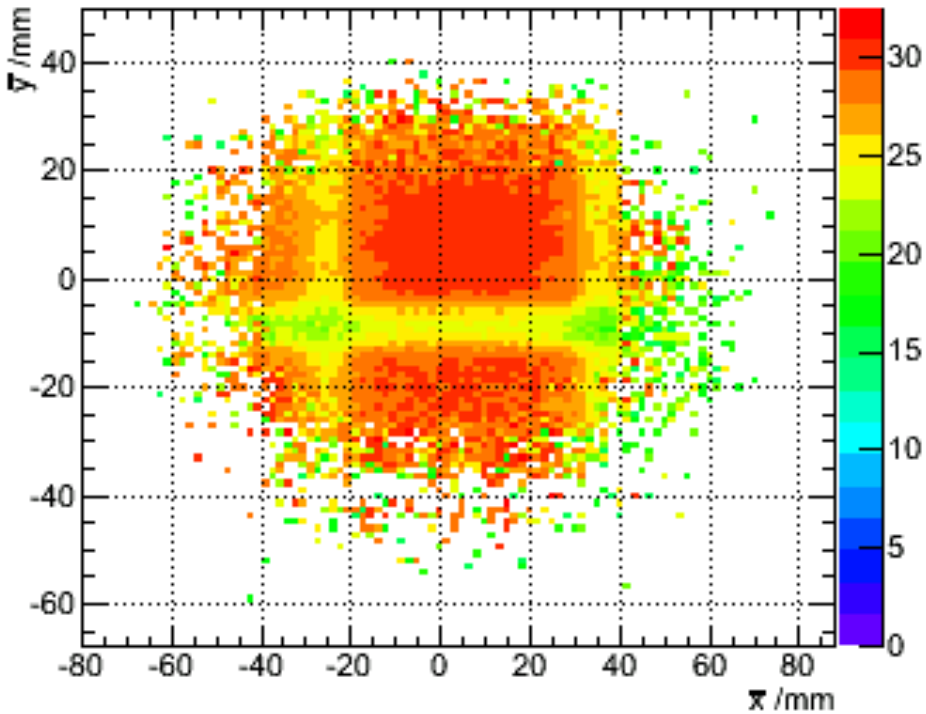
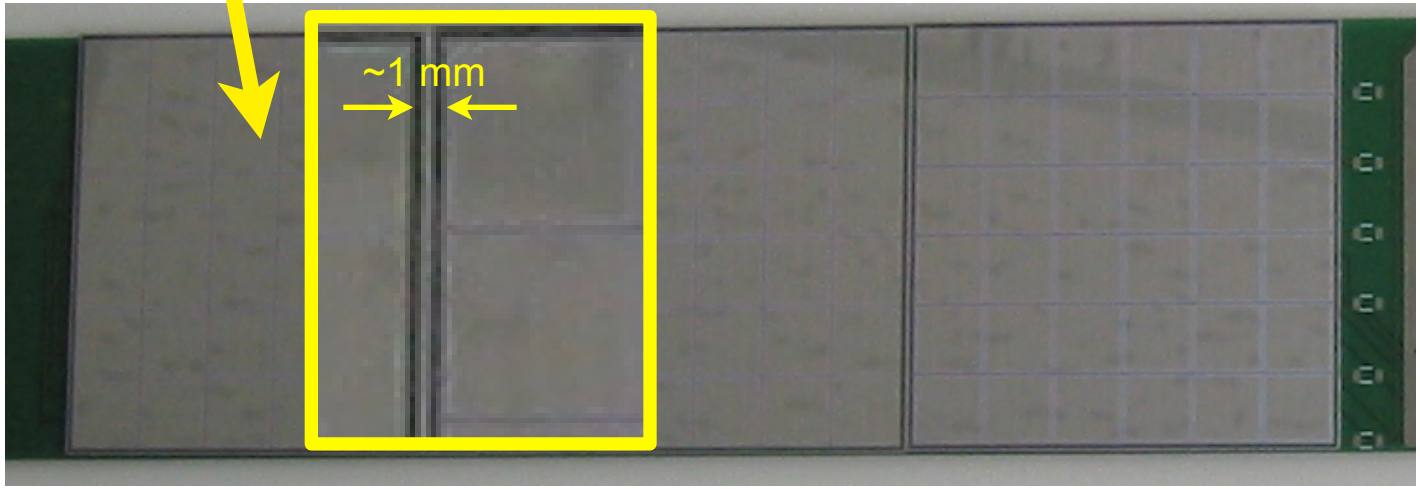


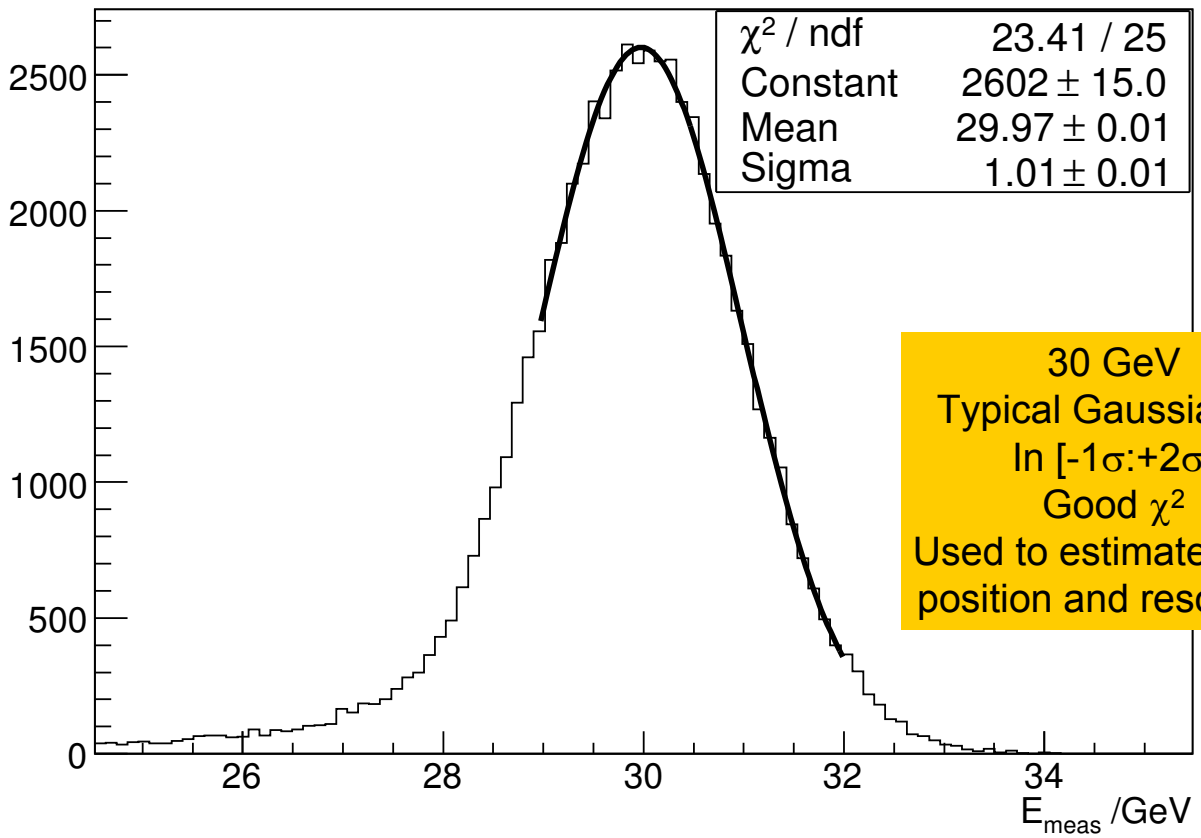




ECAL resolution outside gaps

$$E_{meas} = (\alpha_1 E(1\text{-}10) + \alpha_2 E(10\text{-}20) + \alpha_3 E(21\text{-}30)) / \beta$$

$(\alpha_1, \alpha_2, \alpha_3) = (1, 2, 3)$ $\beta=250$



30 GeV
Typical Gaussian fit
In [-1σ:+2σ]
Good χ^2
Used to estimate peak position and resolution

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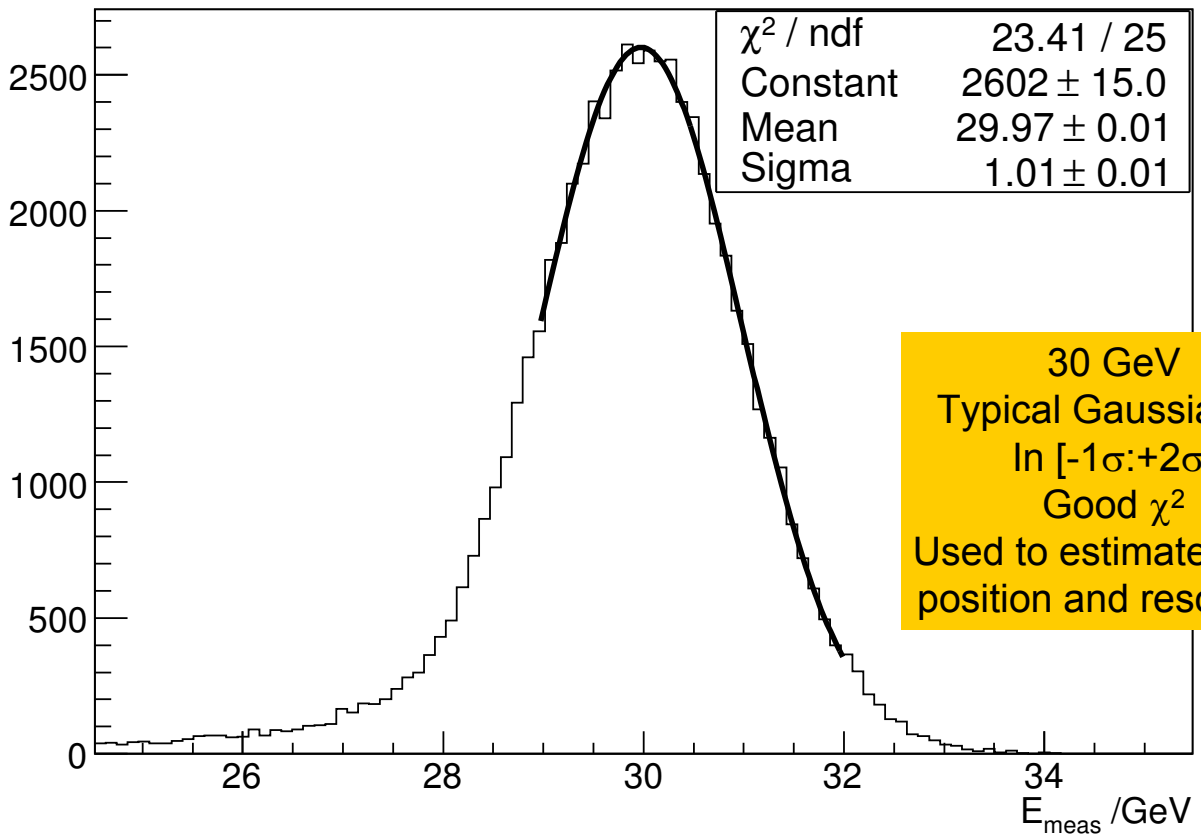
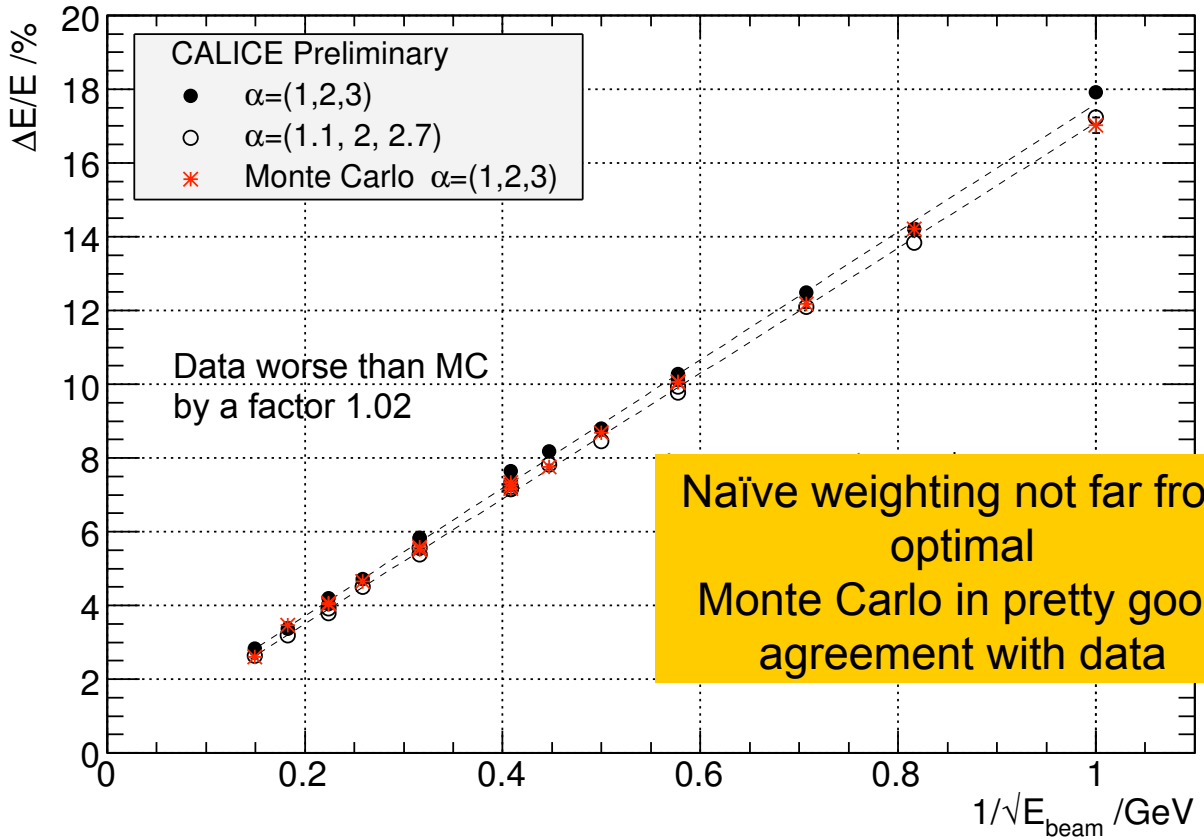


30 GeV
Typical Gaussian fit
In [-1σ:+2σ]
Good χ^2
Used to estimate peak position and resolution

Optimised weights for resolution: $(\alpha_1, \alpha_2, \alpha_3) = (1.1, 2, 2.7)$

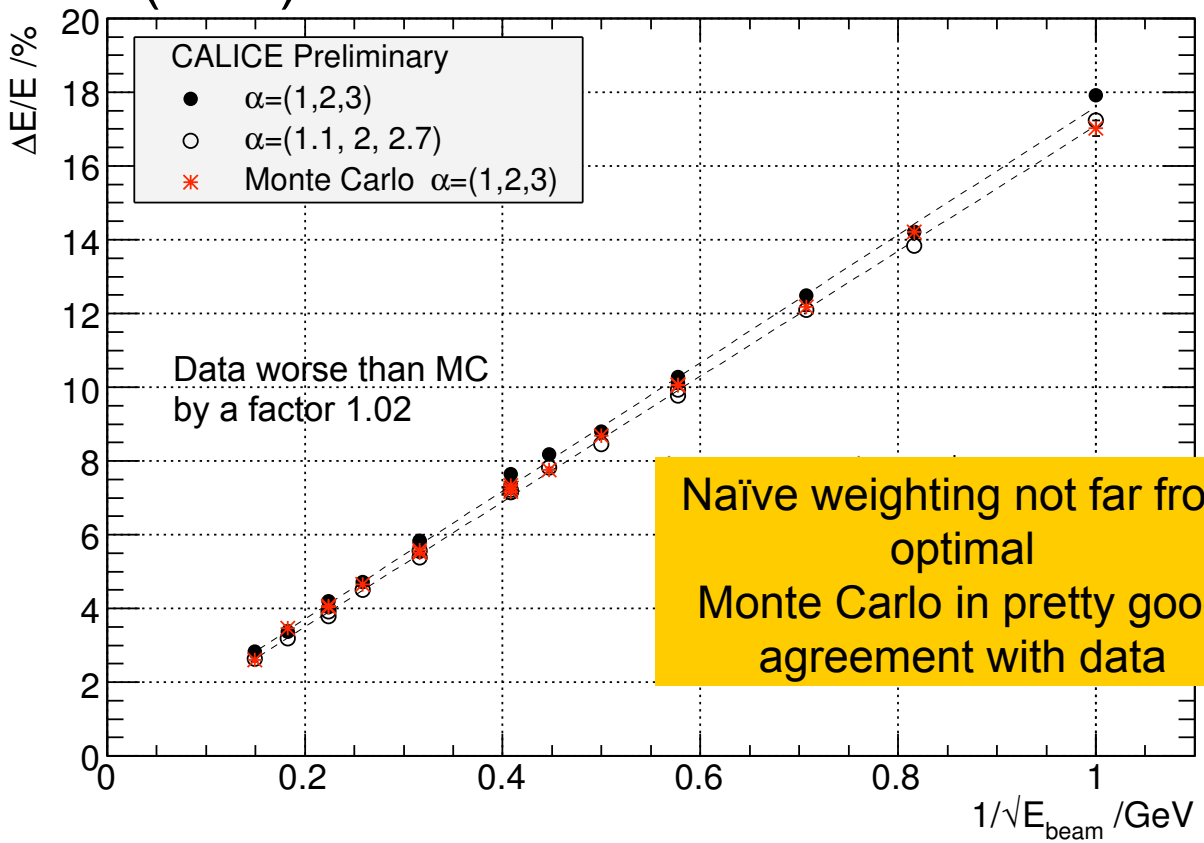
Resolution (outside gaps)



Naïve weighting not far from optimal
Monte Carlo in pretty good agreement with data

Resolution (outside gaps)

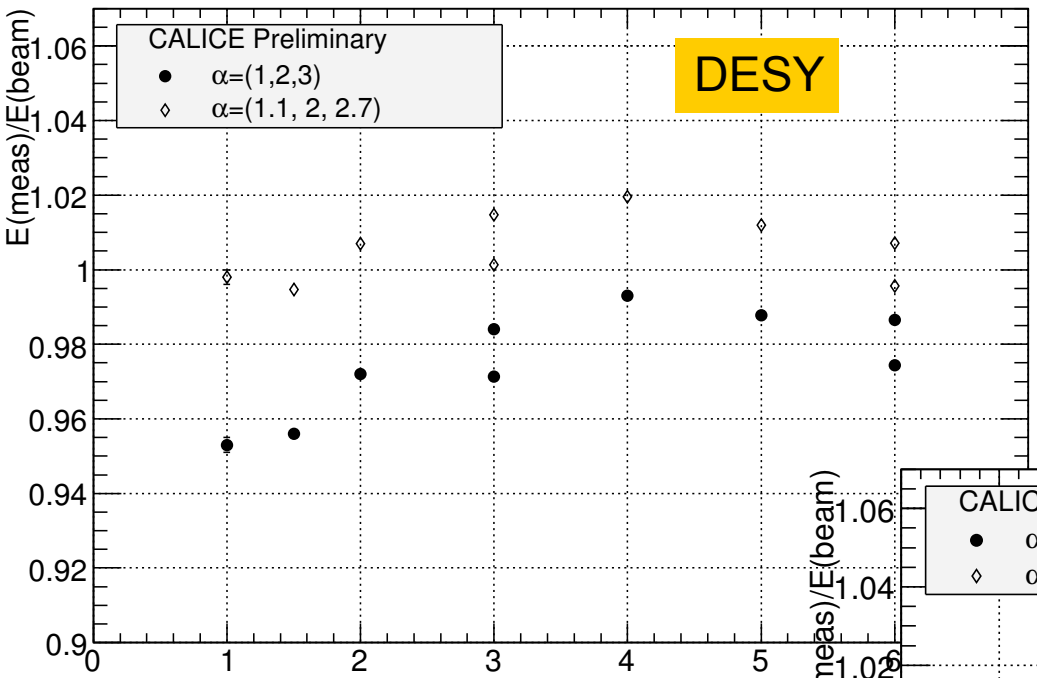
$$\frac{\Delta E}{E}(\%) = \frac{17.7 \pm 0.07}{\sqrt{E\,(\mathrm{GeV})}} \oplus (1.1 \pm 0.08) \qquad (\alpha_1, \alpha_2, \alpha_3) = (1, 2, 3)$$

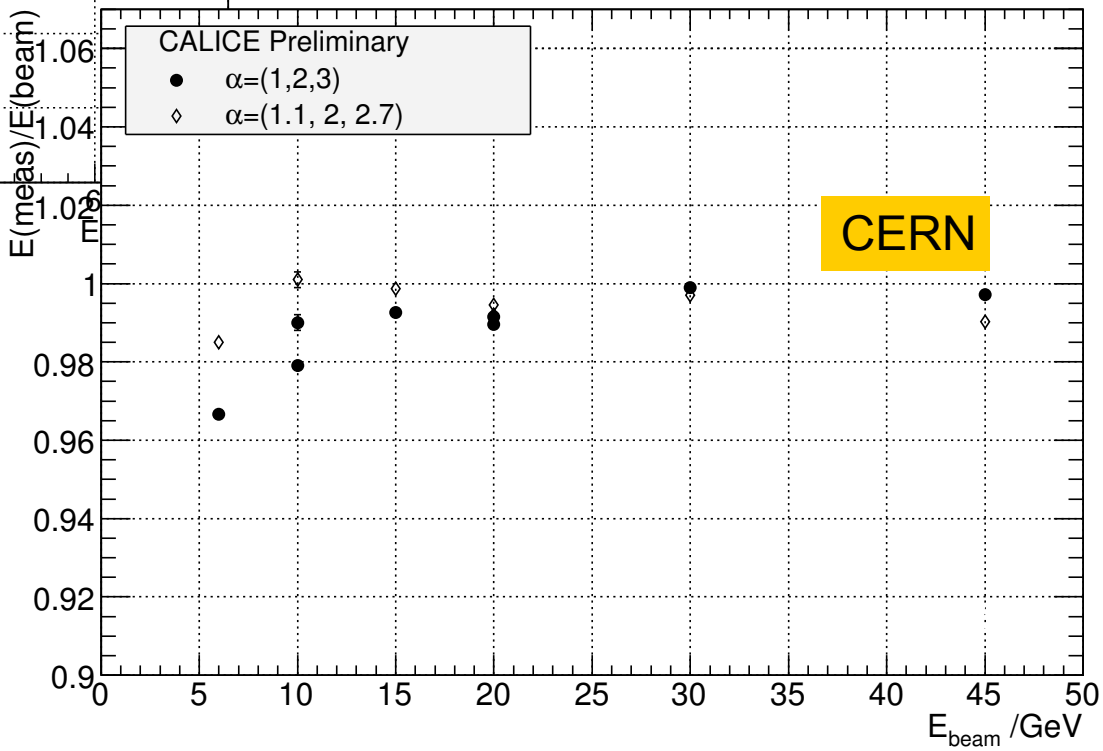


Naïve weighting not far from optimal
Monte Carlo in pretty good agreement with data

$$\frac{\Delta E}{E}(\%) = \frac{17.1 \pm 0.07}{\sqrt{E\,(\mathrm{GeV})}} \oplus (0.5 \pm 0.15) \qquad (\alpha_1, \alpha_2, \alpha_3) = (1.1, 2, 2.7)$$

Linearity (outside gaps)





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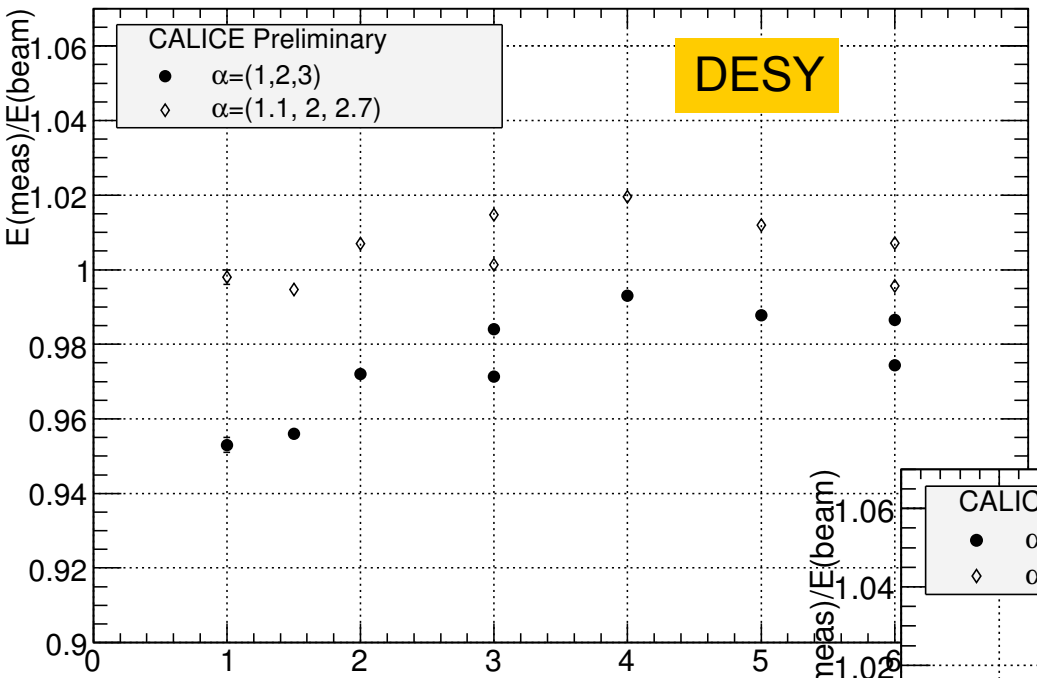
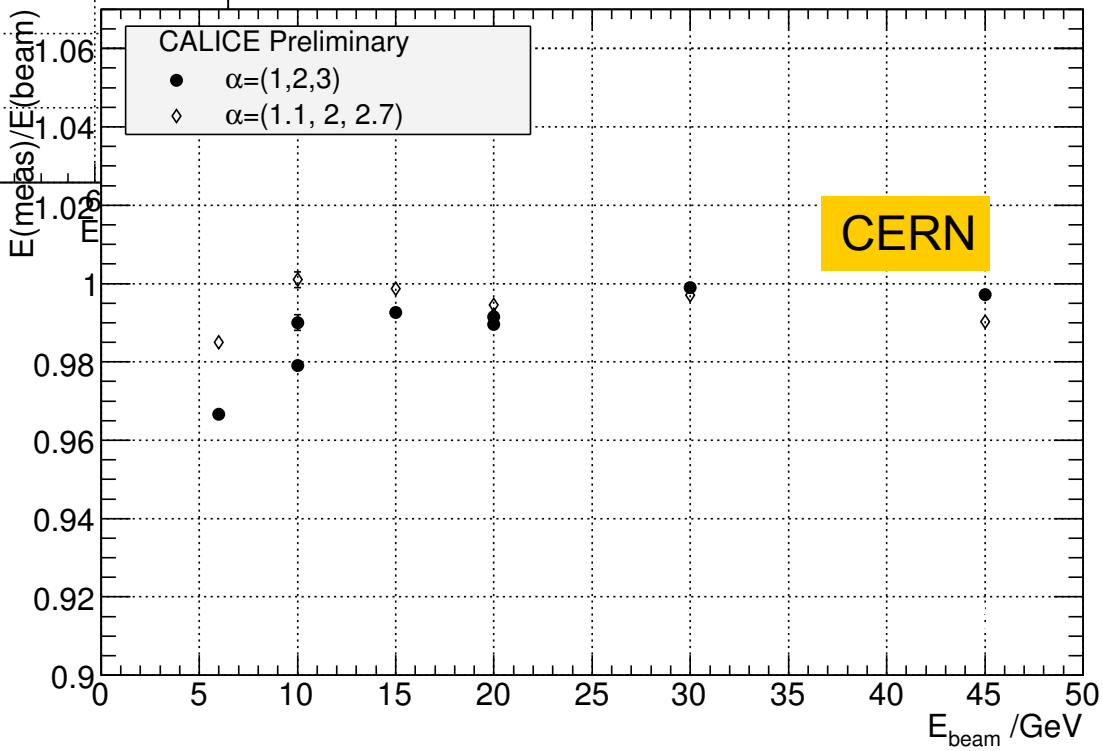


Non-linearities at few % level



Inter-wafer gap correction

Only calorimeter information

- get the mean response as function of shower position
- apply corrective factors per event basis according to the mean response
- corrections can be either energy independent or have a rough energy dependance

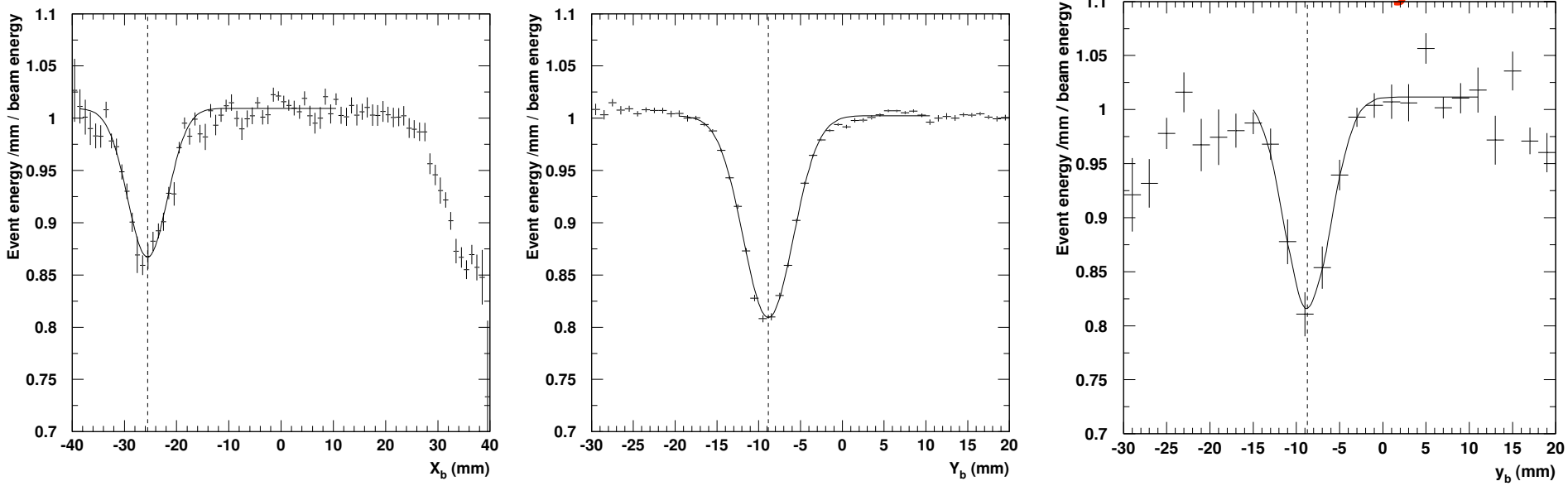
Tracking available

- calculate the shower position within the wafers
- estimate the crossed non-active area based on the mean shower shape
- correction is (total) energy independent

Inter-wafer gap correction (1)

Global barycentre correction

Barycentre correction in each layer



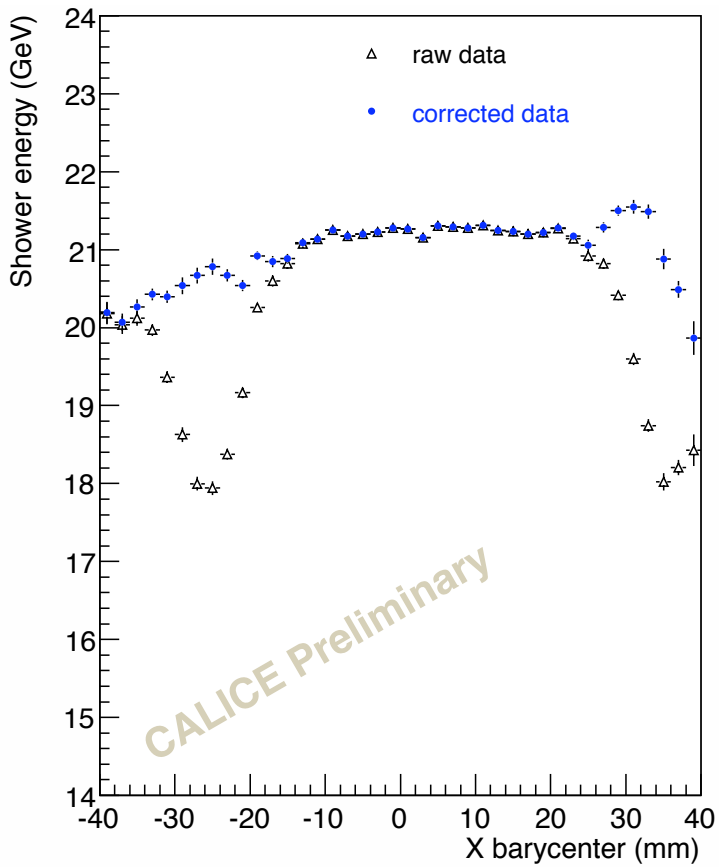
$$\left(1 - a_x \exp\frac{-(x_b - x_{gap})^2}{2\sigma_x^2}\right) \times \left(1 - a_y \exp\frac{-(y_b - y_{gap})^2}{2\sigma_y^2}\right)$$

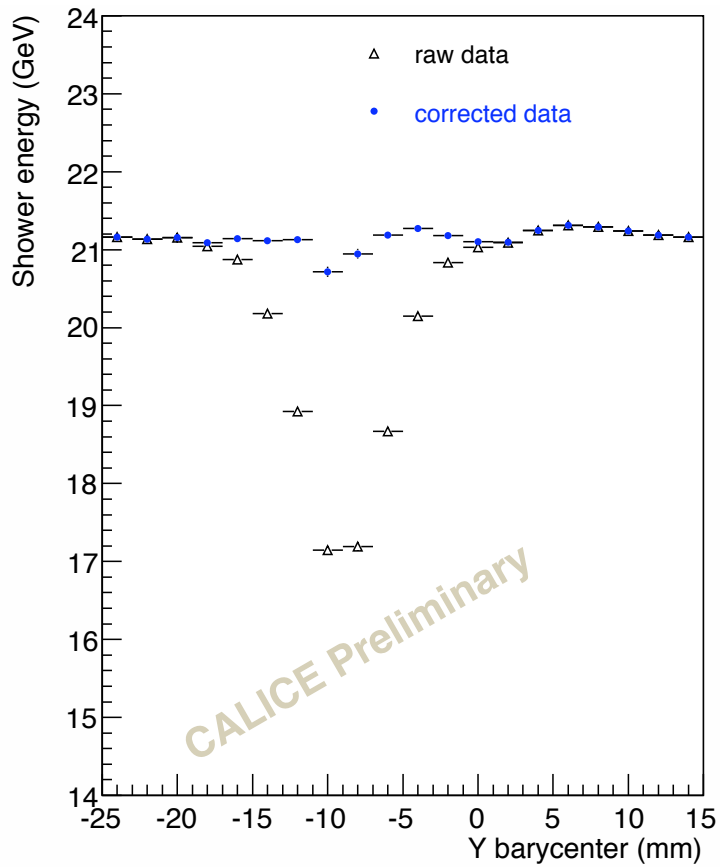
	x_{gap}, y_{gap} (mm)	σ_x, σ_y (mm)	a_x, a_y
x direction	-25.56	3.8	0.14
y direction	-8.8	3.01	0.19

Fit results for the global barycentre approach

Inter-wafer gap correction (1)

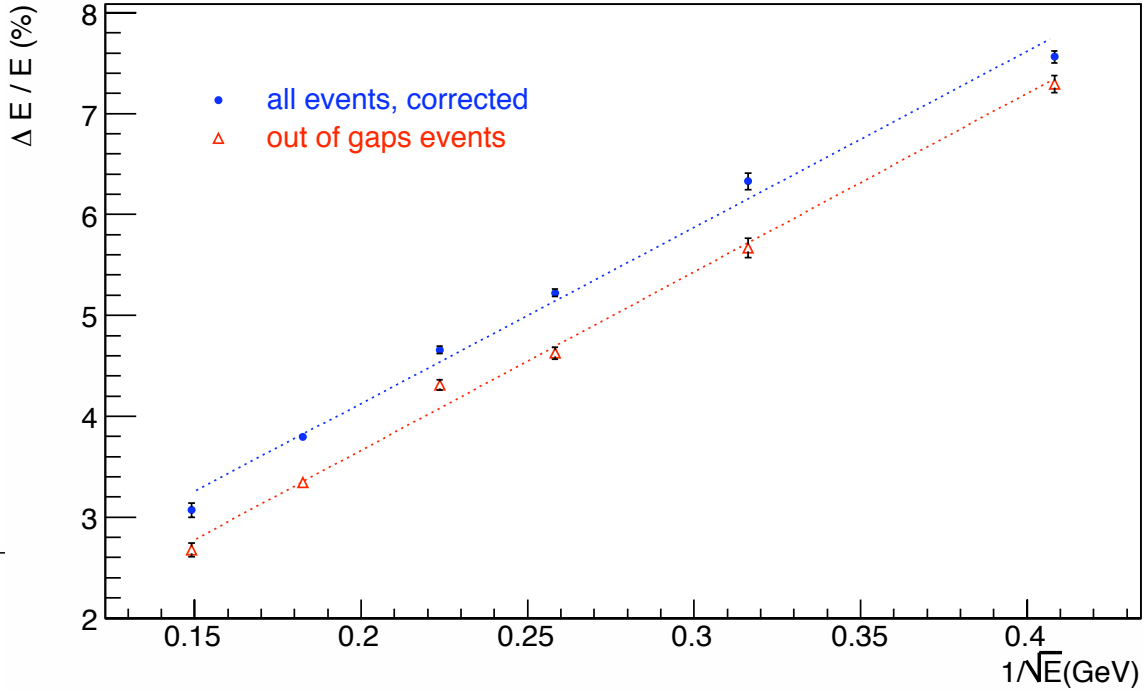
20 GeV electrons, global barycentre

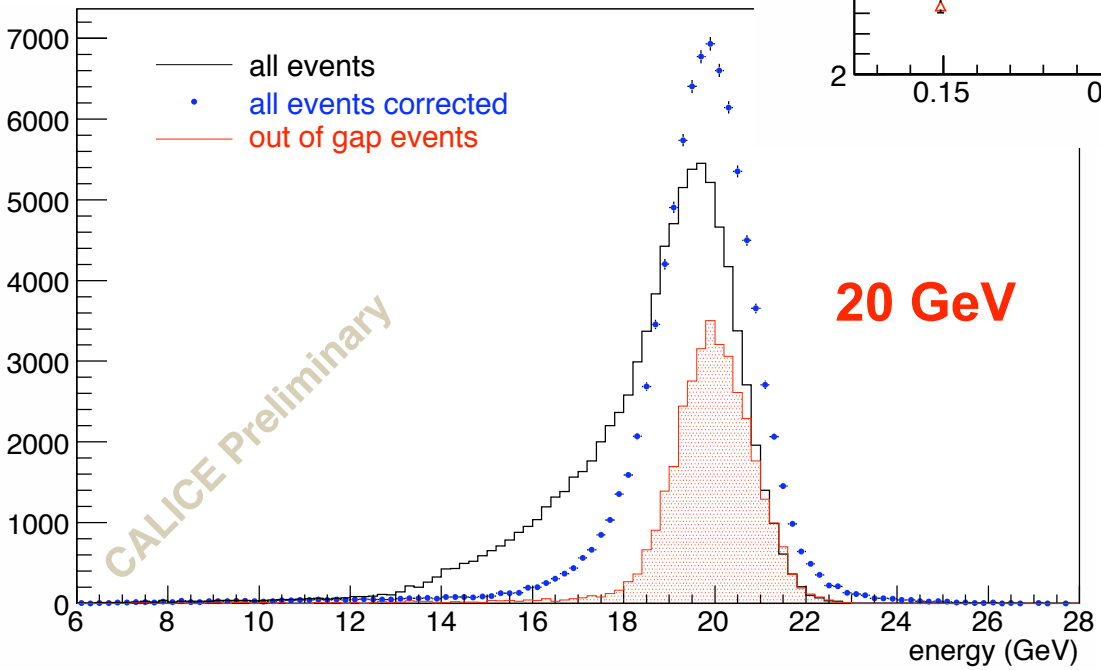




Inter-wafer gap correction (1)

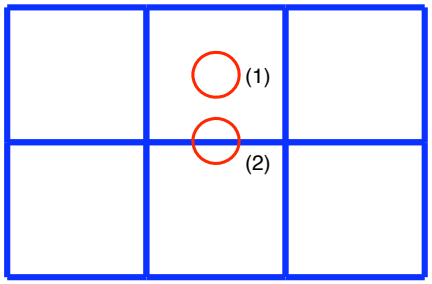
global barycentre method





20 GeV

Inter-wafer gap correction (2)

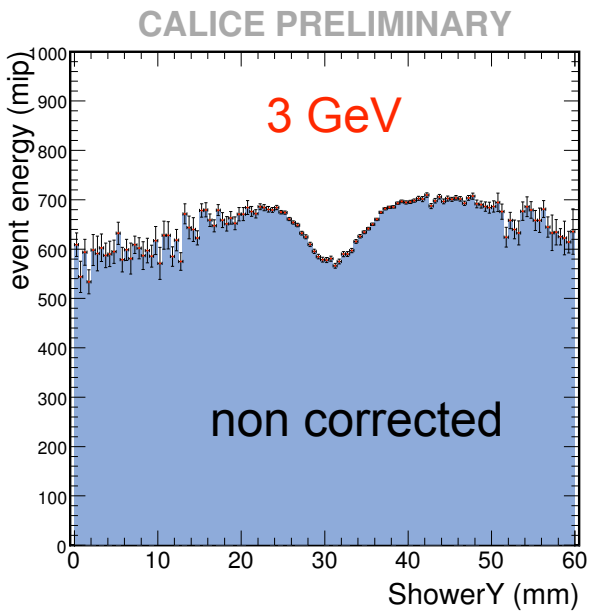


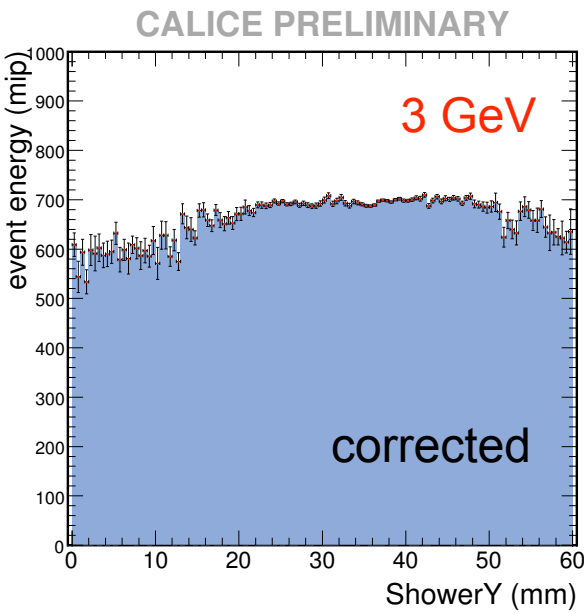
(1) signal $\propto \pi R^2$

(2) signal $\propto \pi R^2 - 2Rd_{gap}$

R = shower spread in the layer

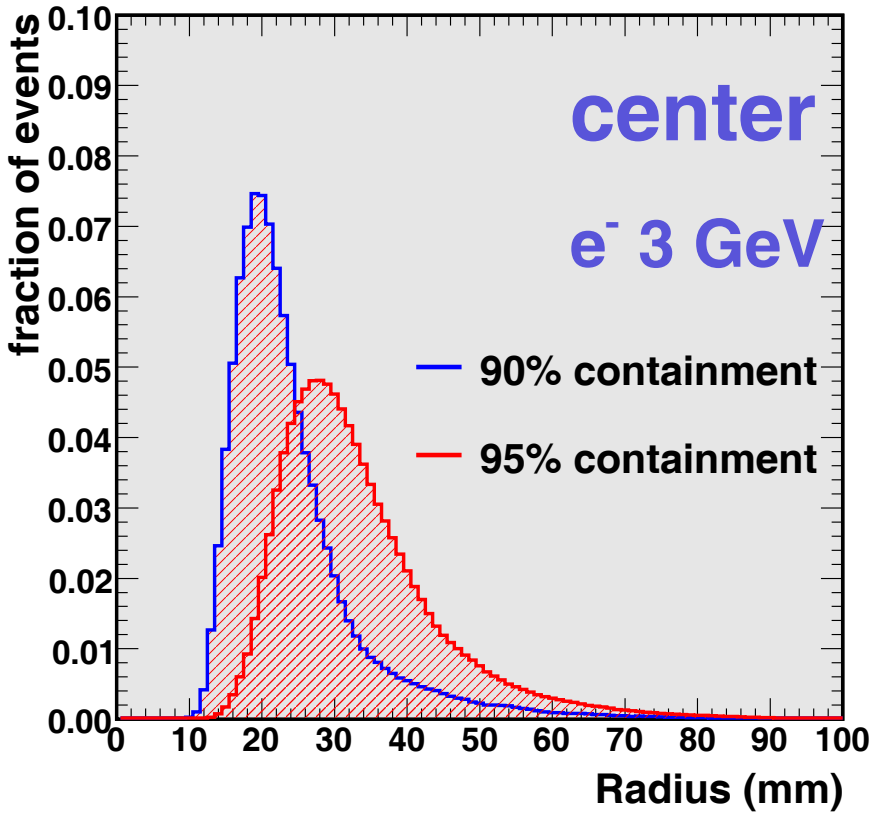
$$\text{correction factor} = \frac{LayerEnergyCorrect}{LayerEnergyReadout}$$

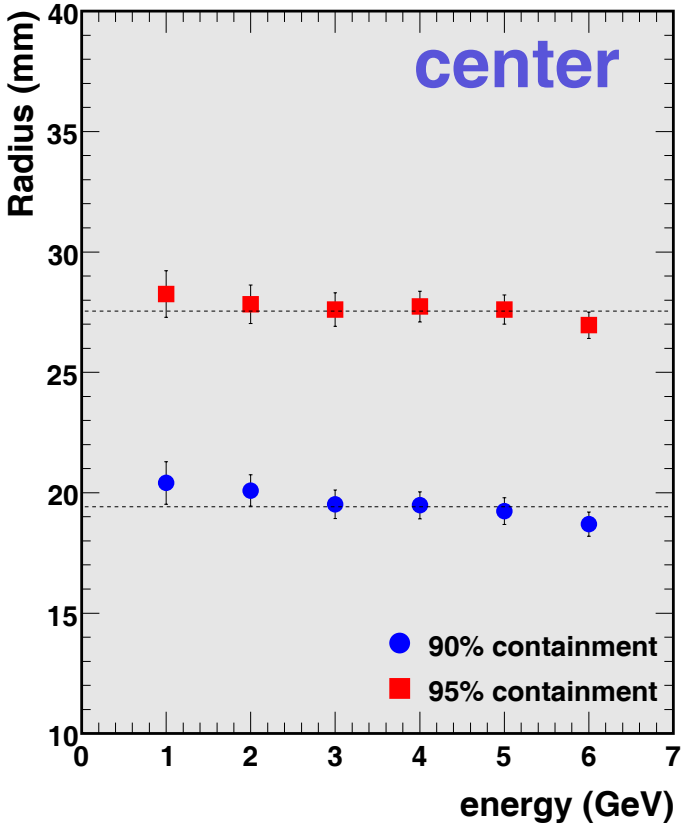




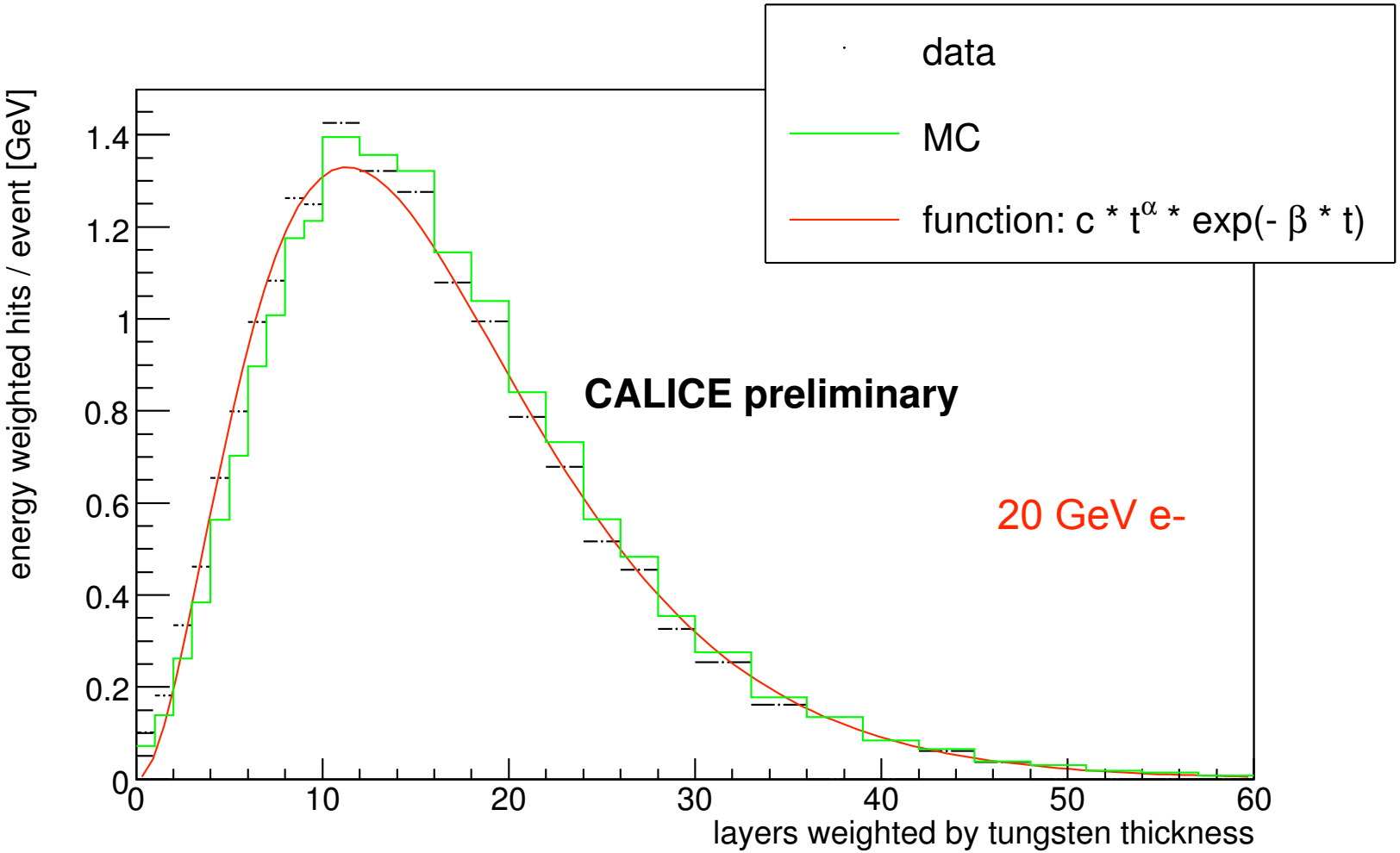
- **on an event-by-event basis do**
  - : for all layers and events set $\sigma_x = \sigma_y =$ 5 mm, $d_{gap} =$ 2 mm
  - : get position of gaps X_{gap}, Y_{gap} per layer (construction/engineering data)
  - : get shower position X,Y per layer relative to gaps (tracking)
  - : approximate R with the energy weighted RMS of X,Y of shower hits in layer
  - : apply correction formula per layer

Radial development of the shower





Longitudinal development of the shower



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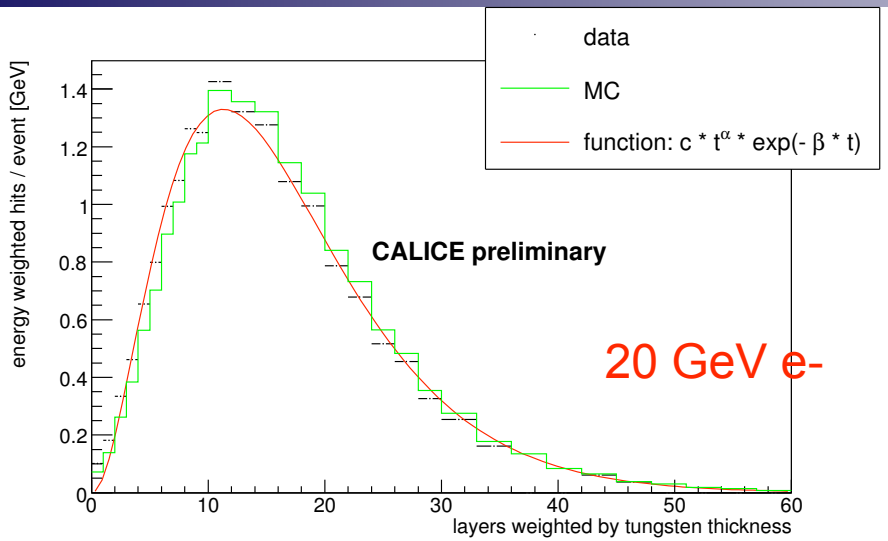

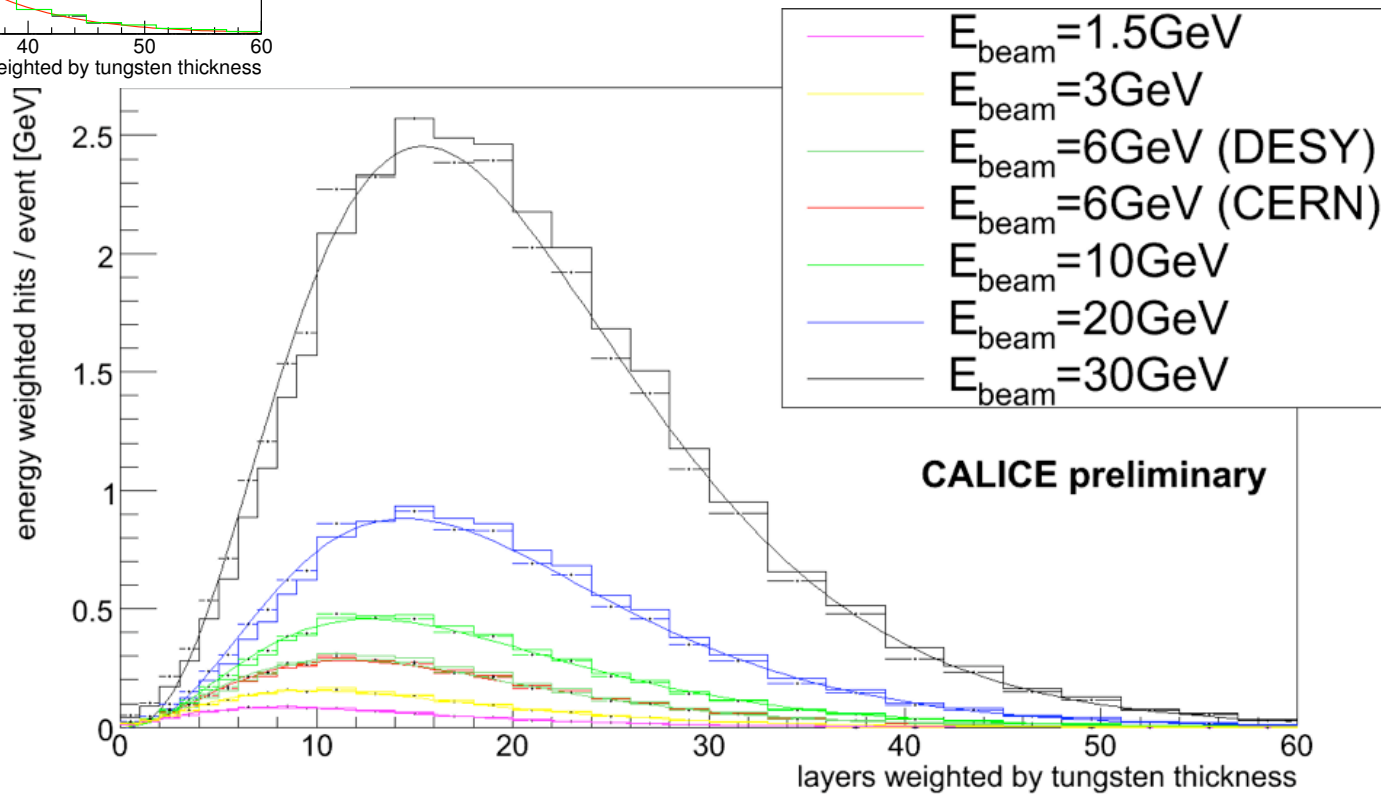

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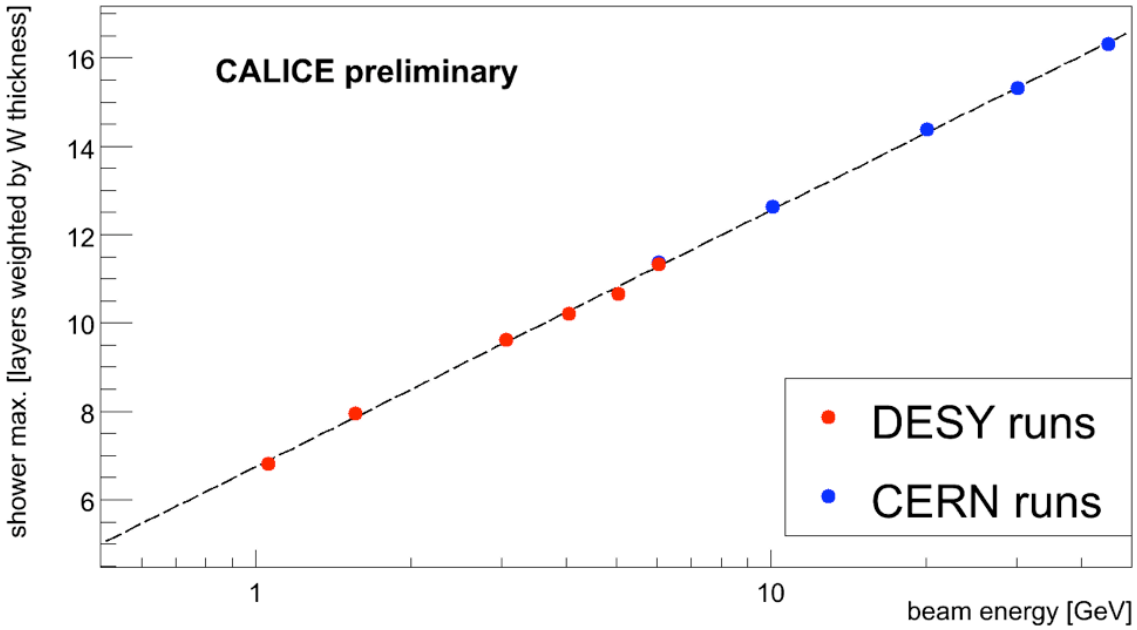
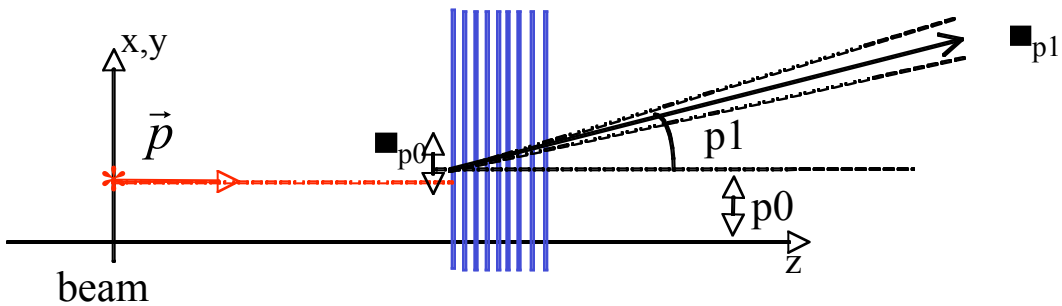


Spatial resolution (@normal incidence)



- Linear fit: $$\chi^2 = \sum_{i,j} (x_{meas} - x_{th})_i W_{ij} (x_{meas} - x_{th})_j$$

$$x_{th} = p_{0x} + p_{1x} \times z$$

$$x_{meas} = \frac{\sum_i E_i x_i}{\sum_i E_i}$$

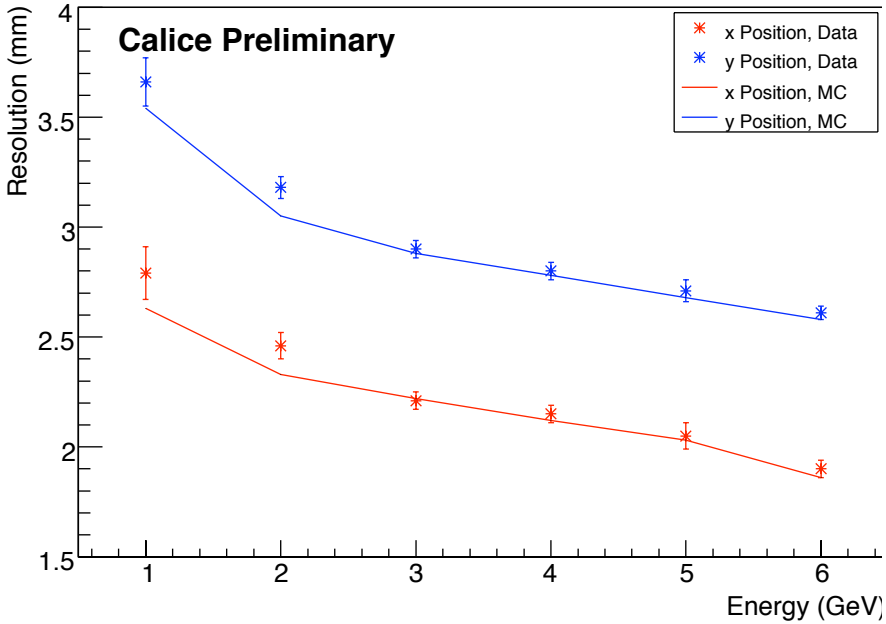
i = hits in layer L.

- Error matrices extracted from the simulation (per energy)
  - x and y uncorrelated
  - two error matrices W_{ij}
  - two independent fits

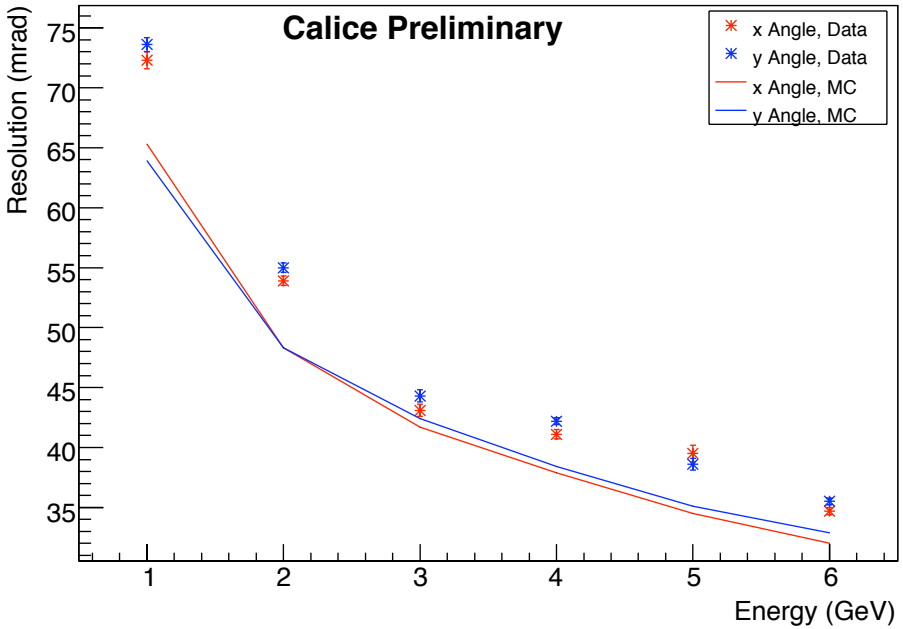
- Minimize χ^2 with respect of p_{0x}, p_{1x}

Spatial resolution (@normal incidence)

Position Resolution



Angular Resolution



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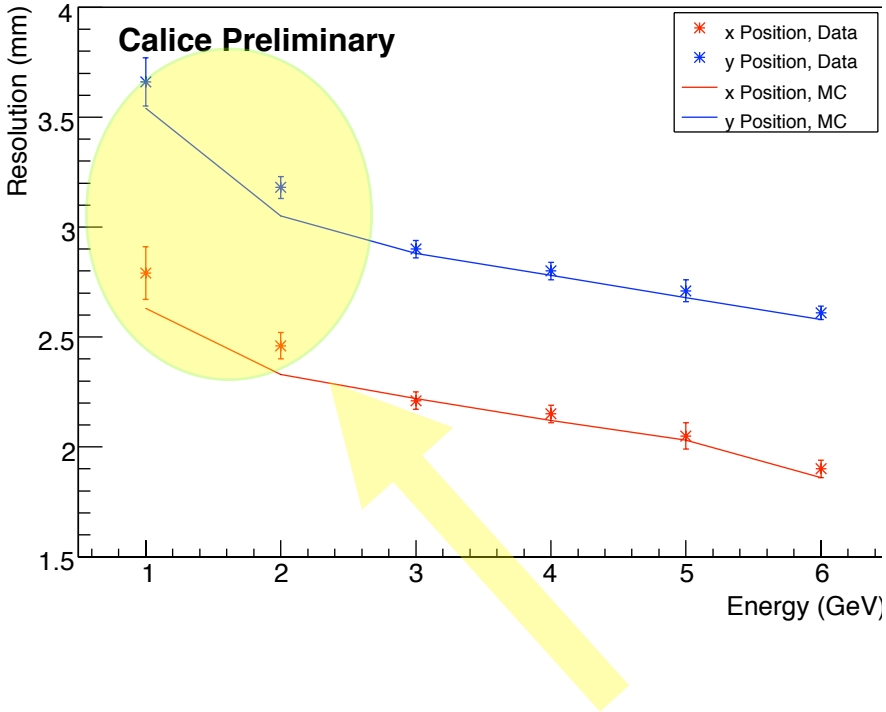

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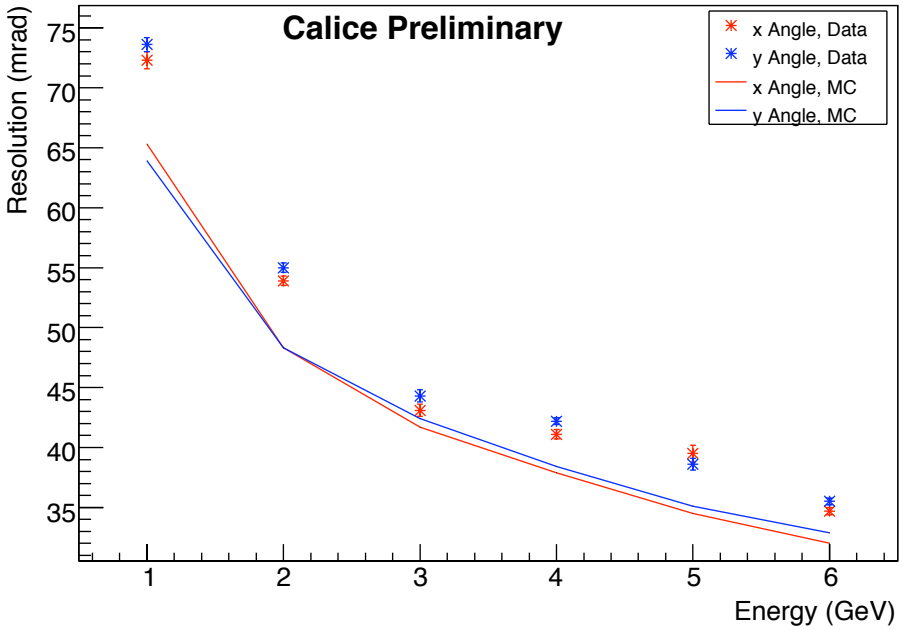

Low energy: $\sigma_{data} > \sigma_{MC}$ likely due to inadequate material description in front of ECAL (missing about 20%)

Conclusion

A ~6500 channels calorimeter operated successfully.

It took time to develop the tools for a proper data processing, reconstruction, analysis...

Interesting physics results, with the prototype, used almost in standalone mode (tracking, HCAL not yet fully integrated in data analysis).

Do expect detailed MC / data comparisons in the close future

We work with a real detector (non-uniformities, detection cells inter-calibration) : it improves and refines the detector description which is one of the key points to evaluate the PFA performance.