



# Cluster Reconstruction against Pile-up effect

Calorimeter Upgrade Meeting Dec. 11, 2013

**LAL, Orsay**

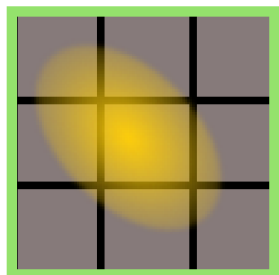
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# Outline

- Why do we want to reduce the cluster size?
- How do we compare the actual clusters and the new ones?
- Does the new cluster shape reduce the pile-up effect?
- Does smaller cluster lead to higher energy leakage?
  - Can we correct this energy leakage?
- Is the resolution degraded with smaller cluster?

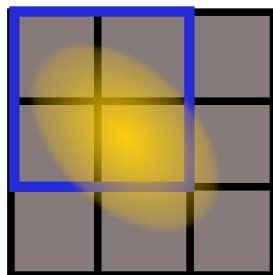
# Reducing the cluster size

Current Cluster

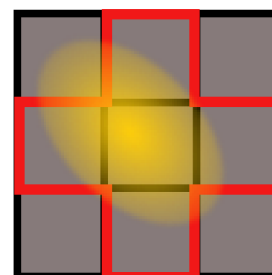


3x3

New Clusters Studied



2x2



cross

Molière radius in LHCb:  $R_{\text{molière}} = 3.5 \text{ cm}$

Calorimeter cells sizes:

inner area	4x4 cm <sup>2</sup>
middle area	16x16 cm <sup>2</sup>
outer area	32x32 cm <sup>2</sup>

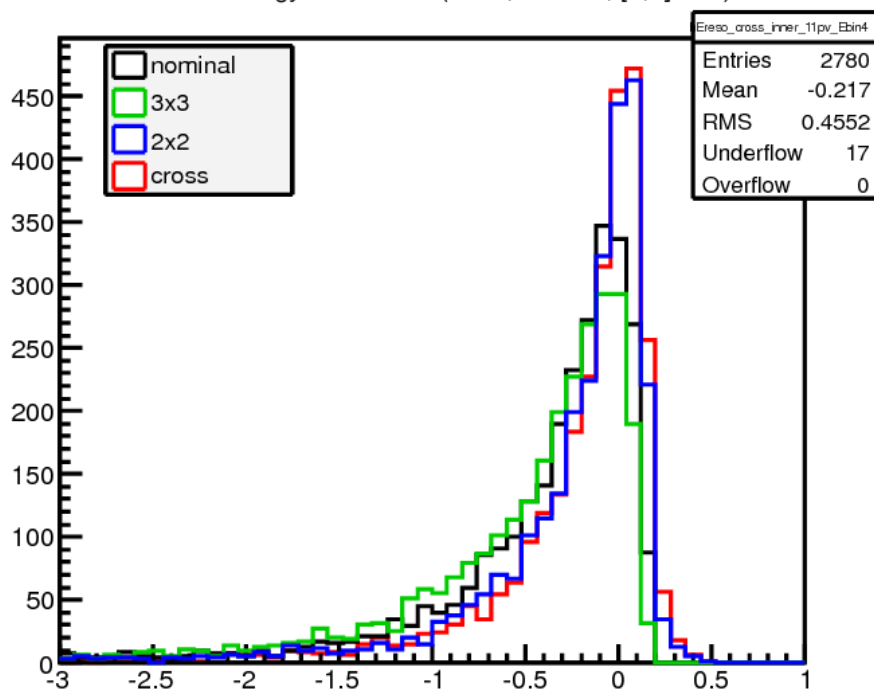
- Upgrade => Higher instantaneous luminosity.
- Overlap of showers in calorimeter.
- Degradation of Energy and Position measurement.
- Reducing the cluster size = reducing the overlap probabilities, so the pile-up effect on the resolutions.

# Samples used for the study

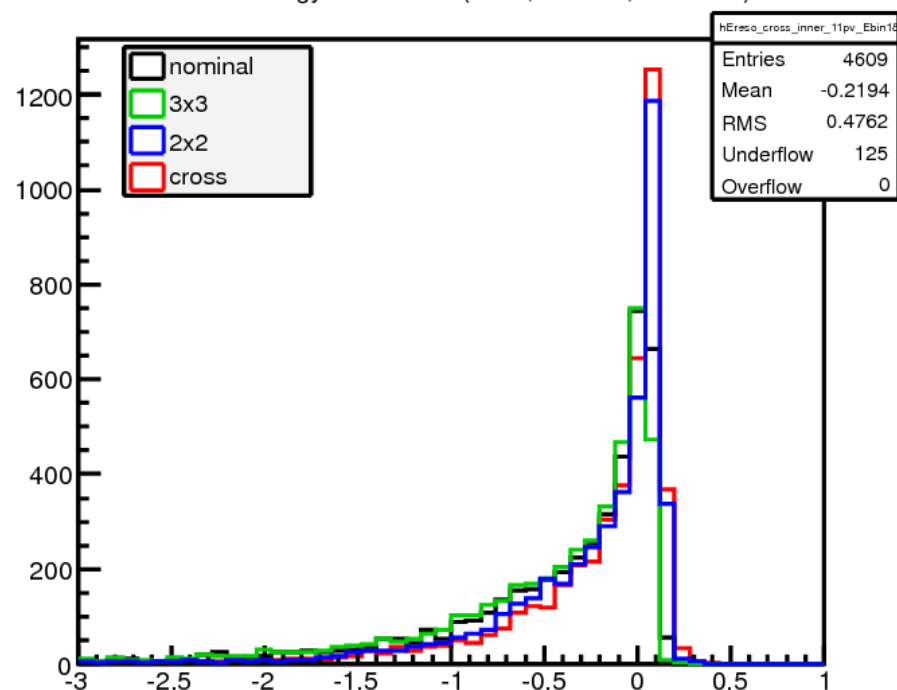
- Mixed 3 Upgrade MC samples of  $B_s \rightarrow \Phi \gamma$  :
  - $v = 3.8, 7.6$  and  $11.4$  ( $L = 1.10^{33}, 2.10^{33}$  and  $3.10^{33} \text{ cm}^2\text{s}^{-1}$ )
- Photon selection:
  - $P_T > 250 \text{ MeV}$
  - No conversion before the calorimeter
  - Physical origin ( $\Delta r < 10\text{mm}$  and  $\Delta z < 150\text{mm}$  wrt IP)
  - Association MCTruth/RecPhoton
- Cells at the border between 2 areas are masked
- Categories in calo region, in 18 Energy Bins, in nPV.

# Shape of the resolution

Photon Energy Resolution (Inner,  $\geq 11$  PV, [3,4]GeV)



Photon Energy Resolution (Inner,  $\geq 11$  PV,  $\geq 30$ GeV)



- Fit the resolution with a CB:

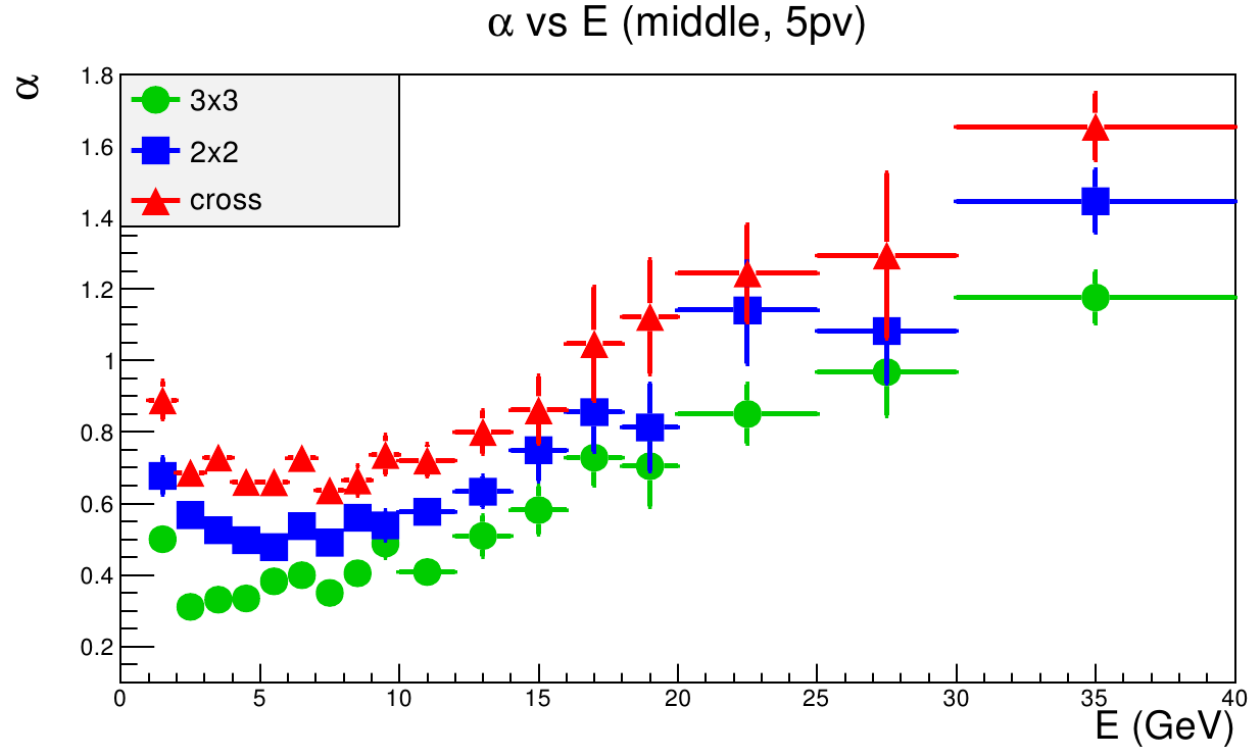
$$f(x; \alpha, n, \mu, \sigma) = N \cdot \begin{cases} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right), & \text{for } \frac{x-\mu}{\sigma} > -\alpha \\ A \cdot \left(B - \frac{x-\mu}{\sigma}\right)^{-n}, & \text{for } \frac{x-\mu}{\sigma} \leq -\alpha \end{cases}$$

Amplitude of the tail

Energy bias

Gaussian resolution

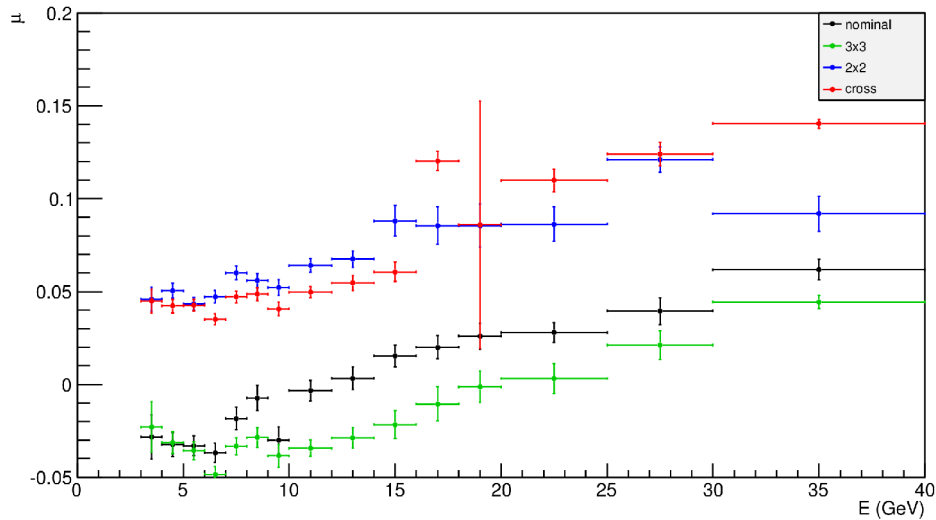
# $\alpha$ vs E



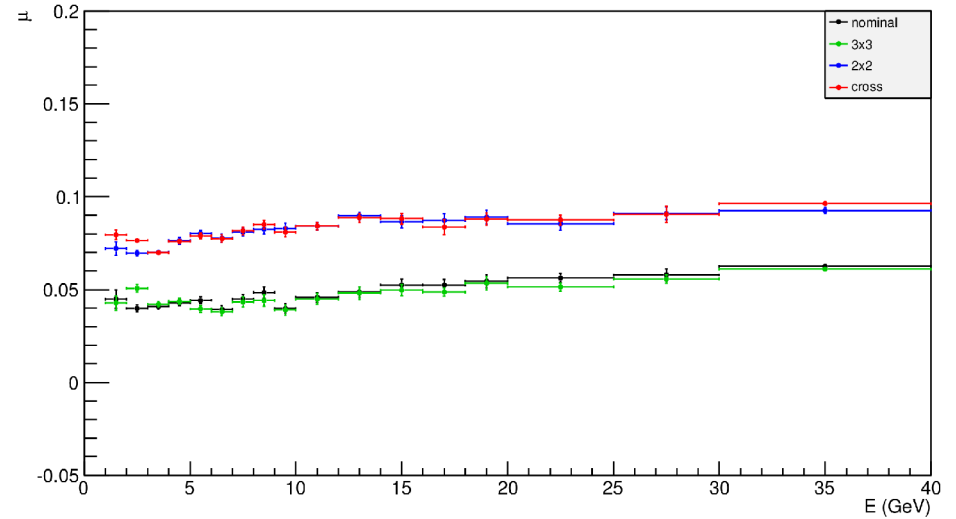
- With smaller clusters, higher  $\alpha$ :
  - Smaller tails
  - Pile-up effect reduced

# Energy Bias

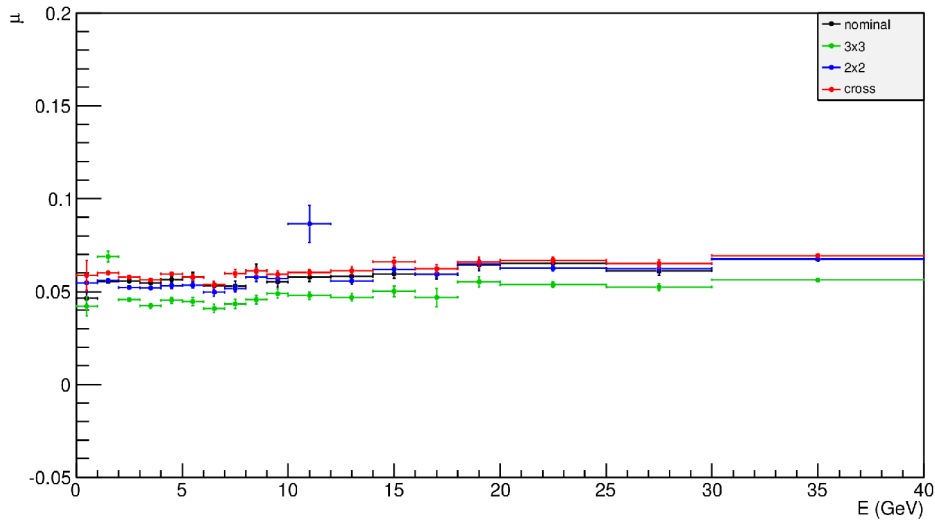
$\mu$  vs E (inner, 11pv)



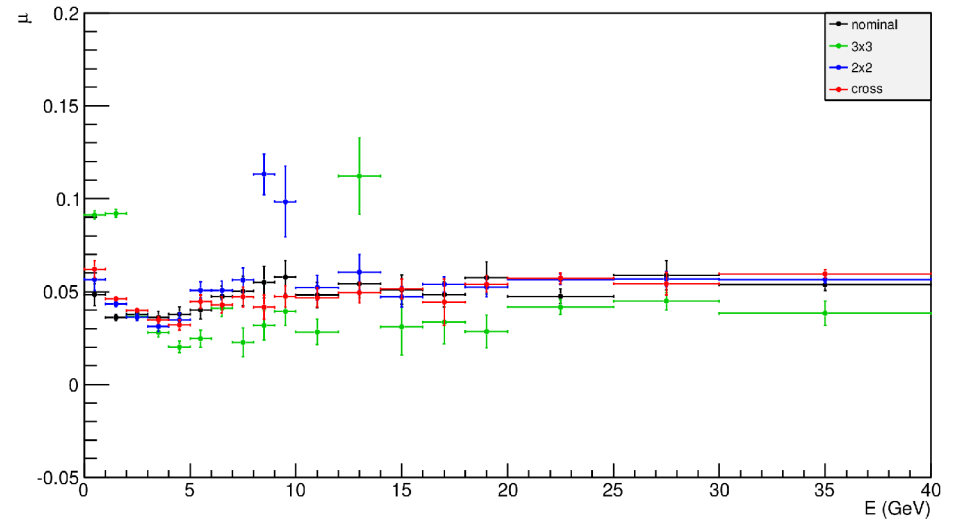
$\mu$  vs E (middle, 5pv)



$\mu$  vs E (outer, 2pv)



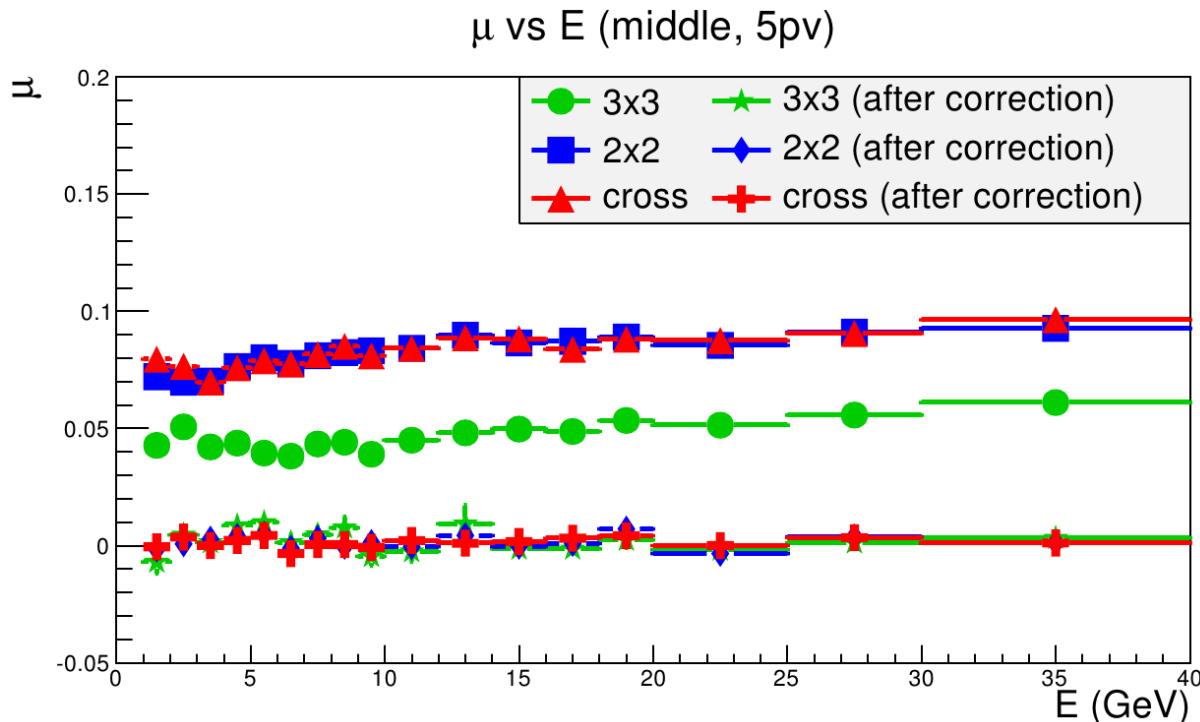
$\mu$  vs E (outer, 11pv)



With smaller clusters : bigger energy bias.

# Energy Bias Correction

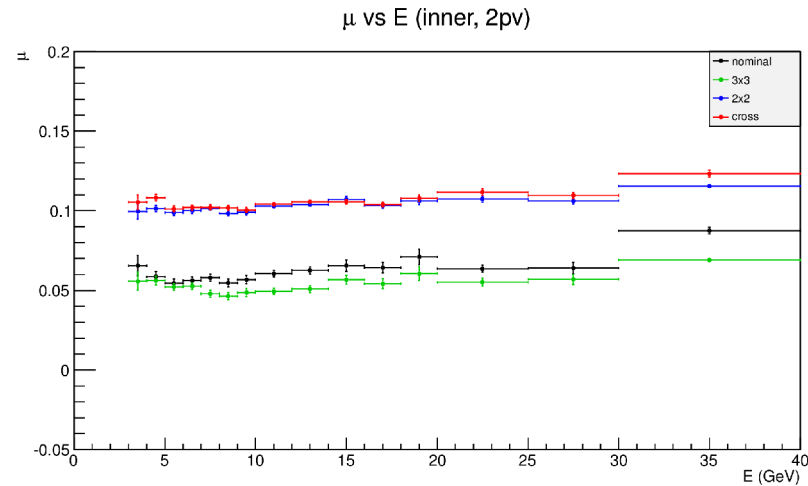
- First attempt to correct the energy leakage:  $e_{\text{cluster}}^{\text{corr}} = e_{\text{cluster}} (1 + \beta_{\text{cluster}})$
- We want  $(e_{\text{true}} - e^{\text{corr}}) / e_{\text{true}} \sim 0$
- We take  $\beta_{\text{cluster}} = \mu_{\text{cluster}} / (1 - \mu_{\text{cluster}})$
- $\beta_{\text{cluster}}$  is obtained for each calo region, each energy bin, and averaging over nPV



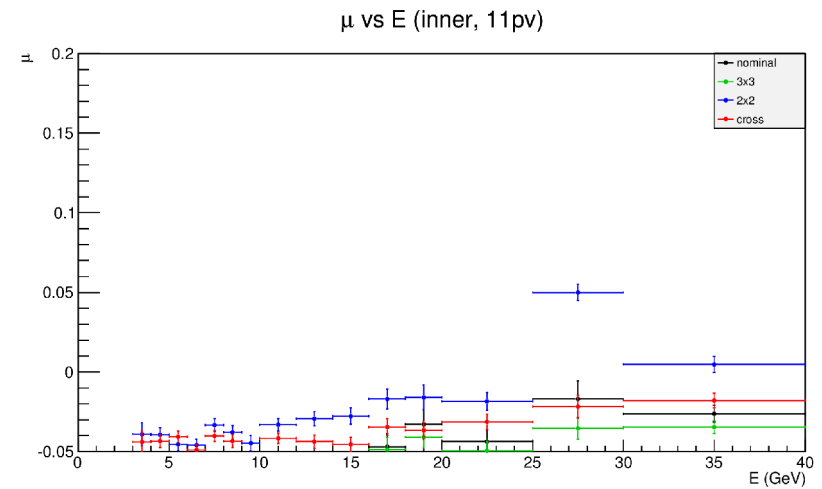
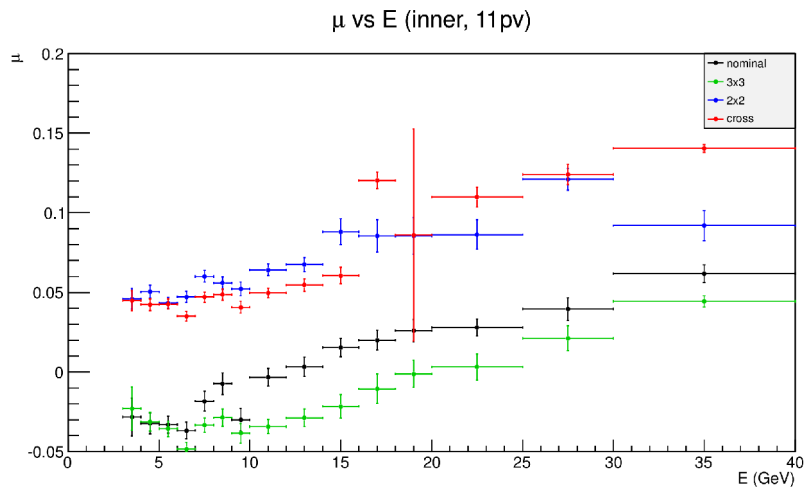
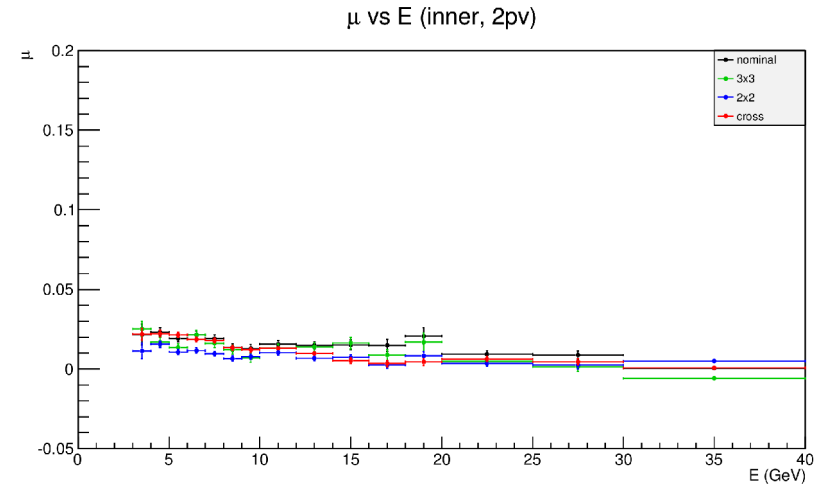


# Correction not yet optimal

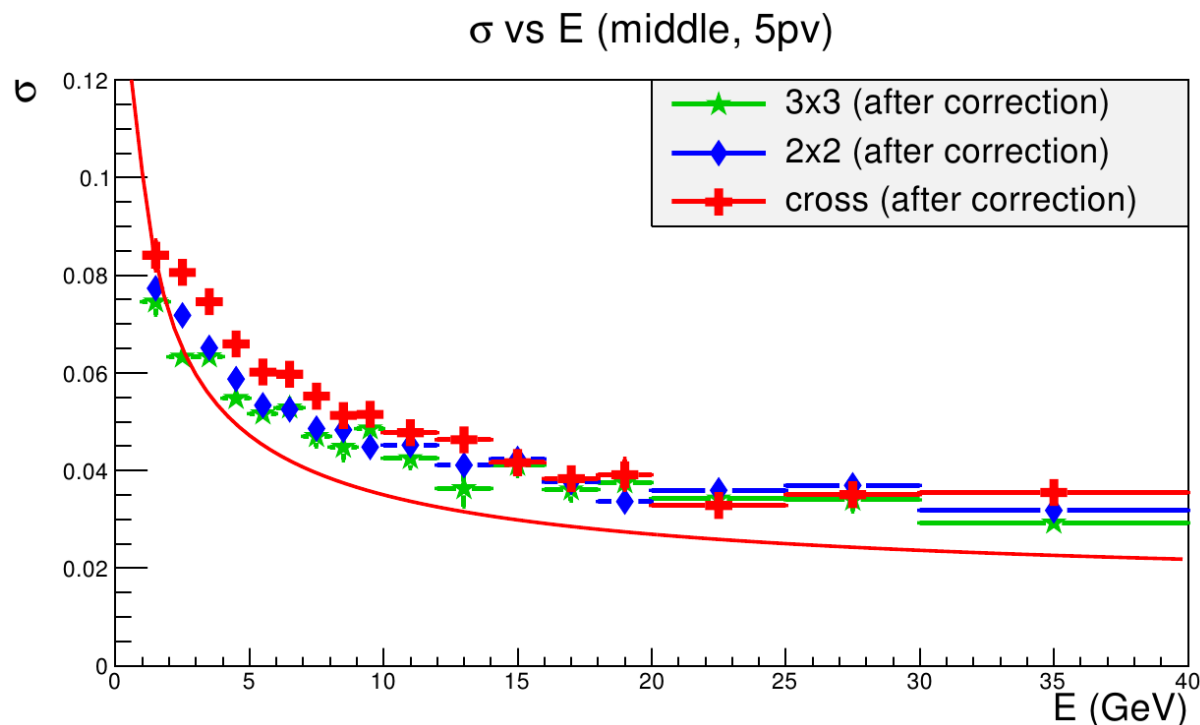
## Before correction



## After correction



# Resolution after Energy Correction



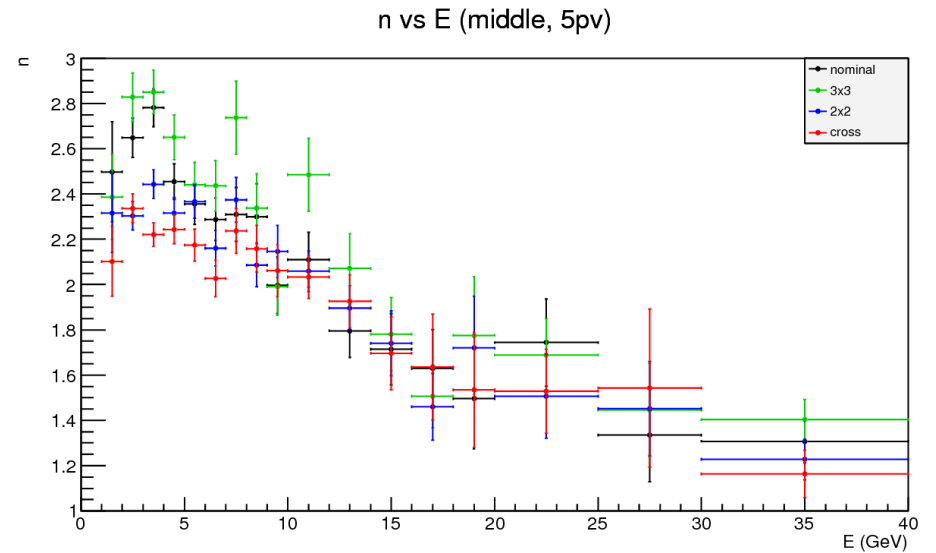
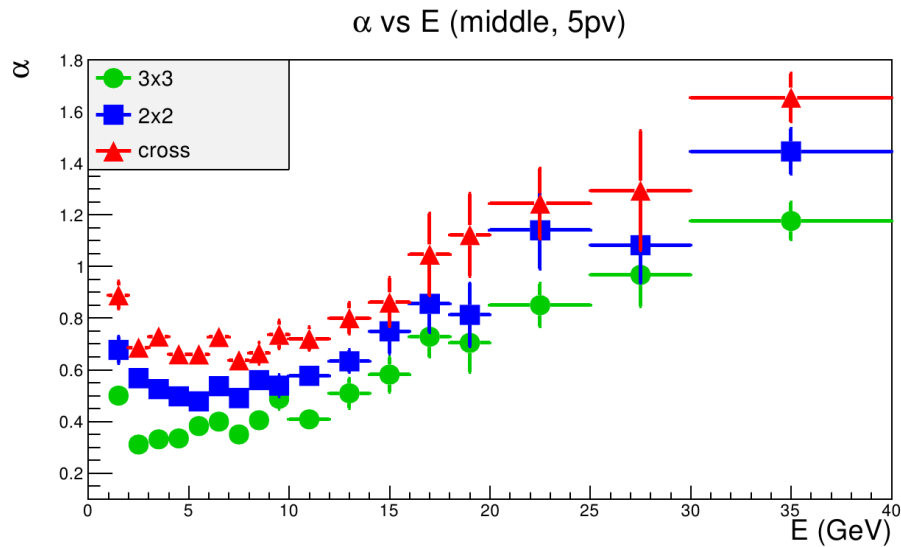
- 2x2 clusters are better:
  - Reduction of the tail due to the pile-up.
  - The energy leakage correction does not alter significantly the resolution.

# Conclusion

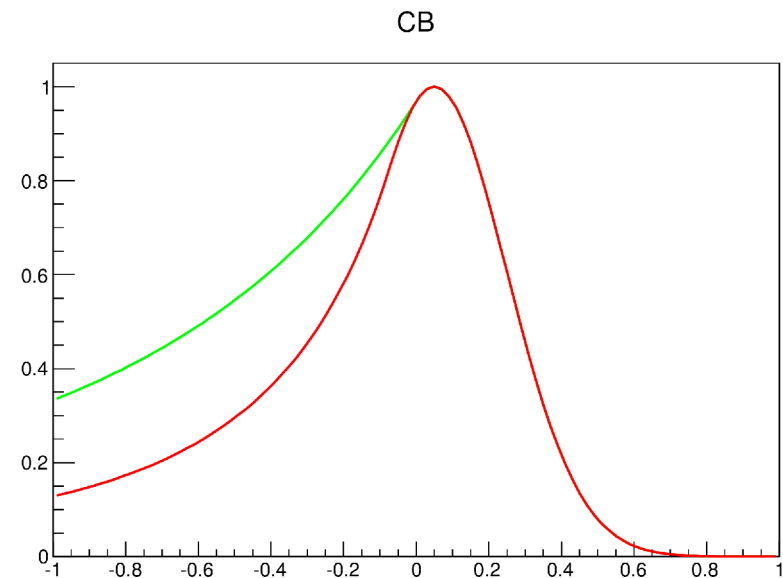
- 2x2 clusters reduce the pile-up effect with a similar resolution.
- Work planned:
  - Make unbinned fit of the resolution.
  - Refine the energy binning.
  - Compute calibration factors w/o averaging on nPV.
  - Implement 2x2 clusters in reconstruction.
  - Look at position measurement.
  - Look at real Data.

# BACKUP

# n vs E

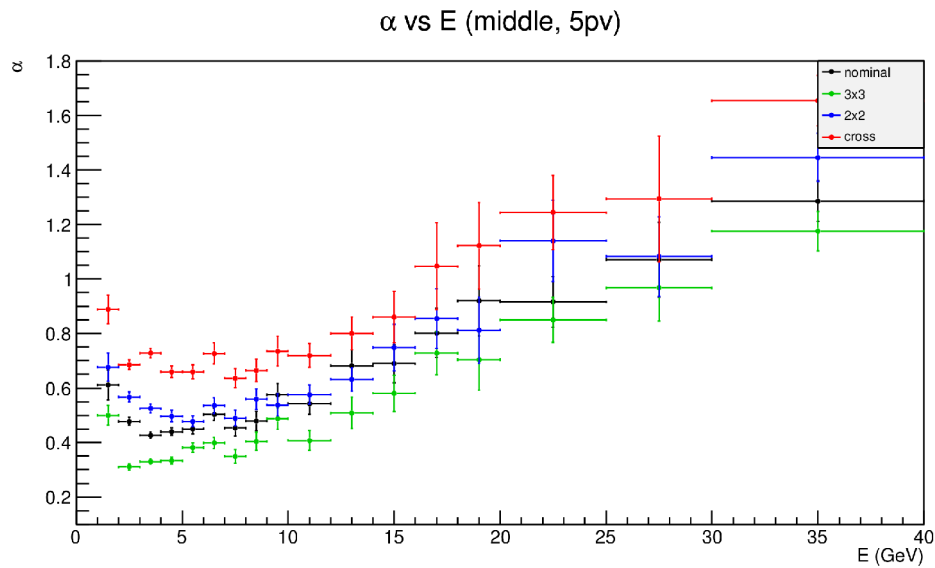


- Green  $n=3.5$   $\alpha=0.25$
- Red  $n=2.5$   $\alpha=0.6$



# $\alpha$ after Energy Correction

Before correction



After correction

