Beam Position Dependence of Energy Resolution in Simulation

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Introduction

From Giacomos slides (18/01/22):

These studies:
- Investigate contributions to asymmetric shape
- Get an idea about the best possible resolution in case of impact point dependence

From first round of analyses:
- SiPM scintillator distributions non-gaussian, ~gaussian for Cerenkov → can get gaussian response summing the two, but mediocre resolution
- Large impact of preshower on calo response: because of large distance from calo, broad shower already before calo face, approximately measured from preshower sign
  - Additional resolution term from lateral leakage
- Possible dependence of response on impact point washed out an more difficult to correct for
Simulation Layout

- 50,000 e+ per positions
- 20 GeV
- Pencil-like beam
- Once with and without Preshower
No Preshower: Energy Distribution

- Plotted data is intercalibrated ‘NofCherDet’/‘NofScinDet’
  - average response over all positions corresponds to 20 GeV * 0.94 containment
No Preshower: Mean vs Position

- Plotted data is intercalibrated ‘NofCherDet’/‘NofScinDet’
  - average response over all positions corresponds to 20 GeV * 0.94 containment
- 3 GeV oscillation for Cherenkov
- 5 GeV oscillation for Scintillation
No Preshower: Distribution & Fit

- Plotted data is intercalibrated ‘NofCherDet’/‘NofScinDet’
  - average response over all positions corresponds to 20 GeV * 0.94 containment
No Preshower: Resolution

- Strong position dependence for the resolution
- Scintillation resolution seems to be best when hitting Cherenkov fibre…
No Preshower: Combined Channel

- Combine data from both channels according to equation below
  - weighted average of responses where weight is the width of distribution for corresponding position
- Doing this for each event of each position yields 19 new distributions with 50,000 entries each

\[
E_{comb} = \left( \frac{E_C}{\sigma_C^2} + \frac{E_S}{\sigma_S^2} \right) \left( \frac{1}{\sigma_C^2} + \frac{1}{\sigma_S^2} \right)
\]

\[\sigma_C = 1.03 \text{ GeV}\]
\[\sigma_S = 0.98 \text{ GeV}\]
\[\mu = 18.31 \text{ GeV}\]
\[\sigma = 0.63 \text{ GeV}\]
Still position dependent oscillation present
- Dominated by Scintillation channel
  - Might indicate non-optimal calibration
- Reduced to 1 GeV oscillation
No Preshower: Position Dependence of Mean and Resolution

- Still position dependent oscillation present
- Dominated by Scintillation channel
  - Might indicate non-optimal calibration
- Reduced to 1 GeV oscillation
- Position dependence not completely rid off
- Combination improves achievable resolution to around 3.5%
No Preshower: Position Dependence of Mean and Resolution

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\[
\frac{\sigma}{\mu} \sim \frac{\alpha}{\sqrt{E}}
\]

\[\Rightarrow \alpha \approx 15.65\%\]
So now...

... with Preshower
With Preshower: Energy Distribution

- Oscillating behaviour washed out
- Asymmetry introduced in Scintillation Channel
- Plots include cut on Preshower for 1 MIP
With Preshower: Mean vs Position

- Oscillation not completely gone
- Reduced to below 1 GeV variation
- (Preshower energy loss not re-added)
With Preshower: Distribution & Fit

- Cherenkov channel only slight asymmetry
- Asymmetry reduced in combined channel
  - weight of Scintillation skewed due to non-Gaussianity
With Preshower: Resolution

- Preshower seems to deflect e+ strong enough to wash out impact point
- Relative deterioration in resolution by ~15%
No Preshower, but 5mm Beam Radius (1 Simulation)

- Larger asymmetry
  - likely due to imbalance in material
    (more tube area than C/S-fibre area)
- Asymmetry not removed in combined channel
Conclusion

- Qualitatively the dependence of the calorimeter response on the impact point reproduced in simulation
- Dependence does not disappear in combined channel
- Combined Channel enables to achieve better resolution than individual channels
  - best achievable resolution for calorimeter in simulation: $a \simeq 15.65\%$
- Preshower washes out dependence & introduces asymmetry (mainly Scintillation channel)
  - due to opening of the beam
- Asymmetry appears (to larger extent) in simulation with 5mm beam
Backup-Slides