SDHCAL : reconstruction of ILD model 2

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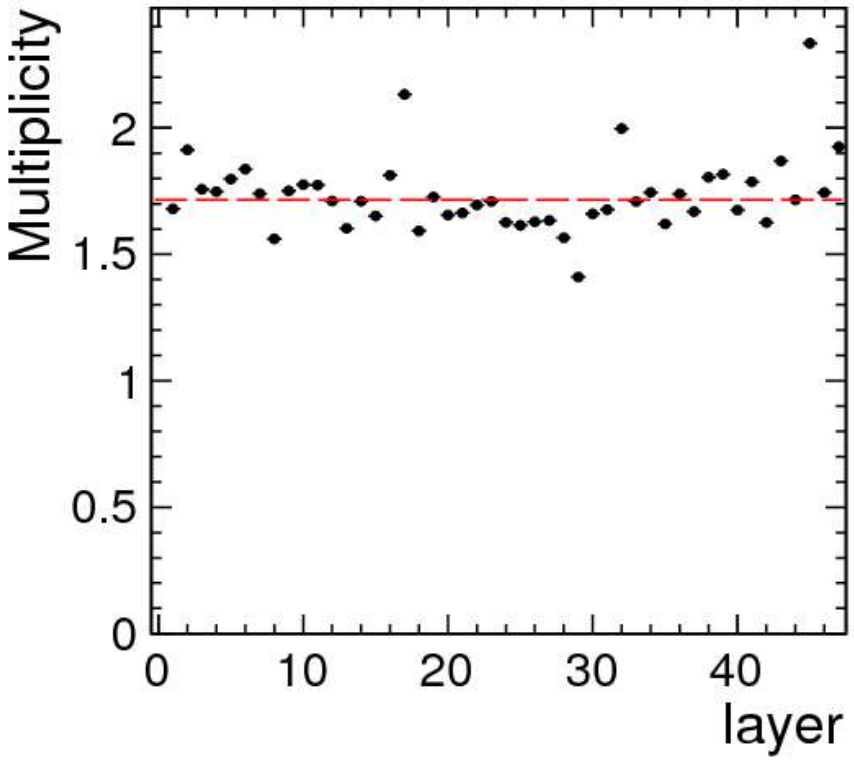
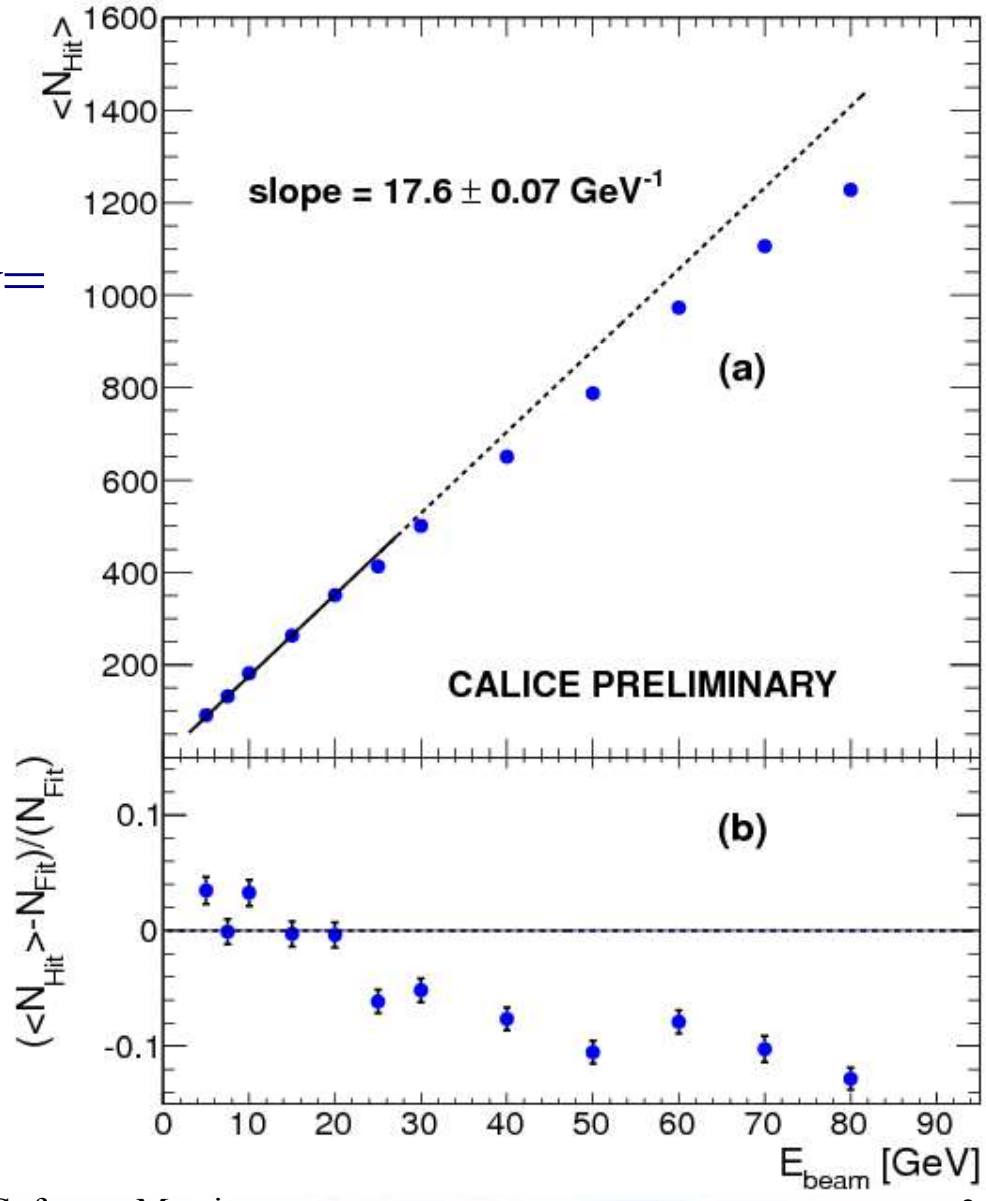
The issue

- Reproduce the number of hits :
  - for muons : multiplicity= average number of hits/MIP/layer



The issue

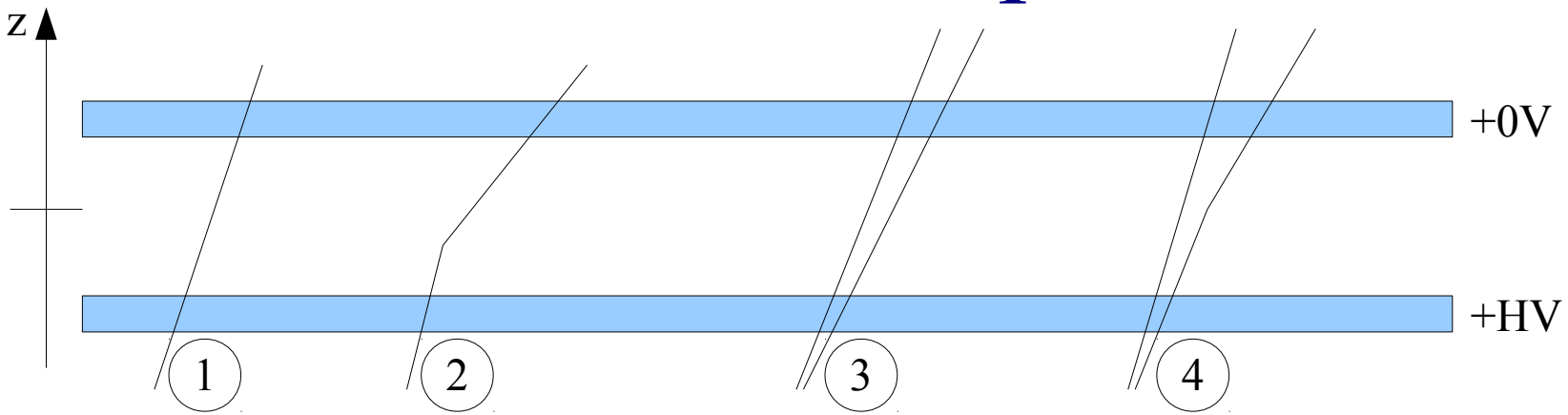
- Reproduce the number of hits :
  - for muons : multiplicity= average number of hits/MIP/layer
  - And for pions.



The SDHCAL digitization logic

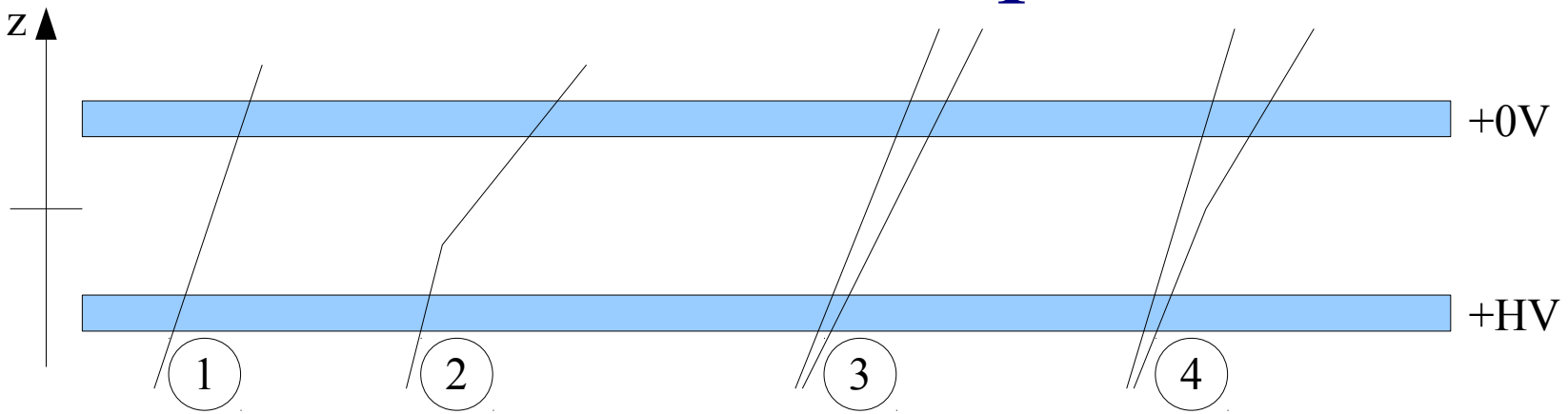
- For each input SimCalorimeterHit
  - Get list of steps position in “cell frame”.
  - Filter out some steps.
  - For each kept step
    - Simulate induced charge.
    - Dispatch the charge on the cell and neighbour cells.
      - If a hit for this cell already exist, add the new charge.
      - Else create the hit and give it the charge.
      - Hits are stored in a std::map[cellID0]=CalorimeterHit
- Remove candidate hits below first threshold.
- Apply thresholds and store hits in output collection

Filter out steps



- Step position from Mokka is the middle of the GEANT4 step
  - 1 : one particle and one step at z=0 (in “cell frame”)
  - 2 : one particle and two steps at z≠0
  - 3 : two particles and two steps at z=0
  - 4 : two particles and 3 steps.

Filter out steps



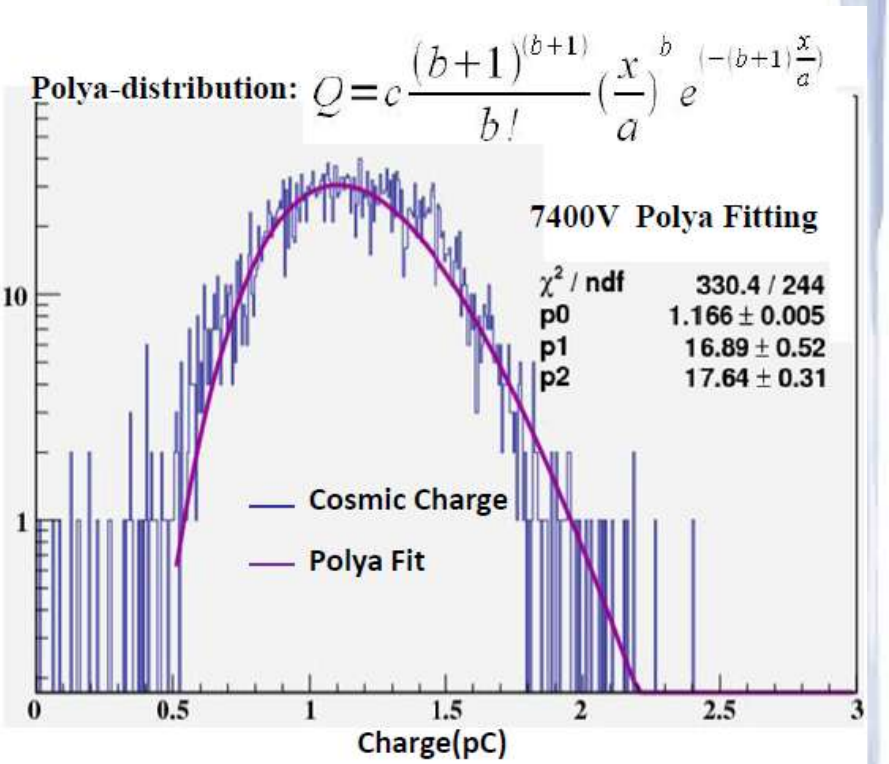
- Processor parameters
  - A="StepCellCenterMaxDistanceLayerDirection"
    - Keep step if abs(z)<A, default=0.0005 mm
    - Ok for case 1 and 3
    - Remove non propagating steps at the RPC entrance
  - B="KeepAtLeastOneStep"
    - Default true : don't remove all steps
    - Retrieve case 2

Filter out steps

- Screening effect
  - Avalanches overlap if ionizing particles too close
    - Typical avanlanche size 1 mm
    - Parameter processor
      - C="StepsMinDistanceRPCplaneDirection"
      - Default=0.5 mm
      - Changed to 0.0001 mm to reproduce pion data
    - If distance projected in the RPC plane between 2 steps is smaller than C, then remove one step.

Simulate induced charge

- Each step produced a random induced charge according to a Polya distribution.
  - Charge measured analogically on a small GRPC cathode
- Processor parameters :
  - "PolyaAverageCharge"
    - Parameter 'a' set to 1.6 pC
  - "PolyaWidthParameter"
    - Parameter 'b' set to 16.3
  - Parameters depend on GAS mixture, HV applied, temperature, ...

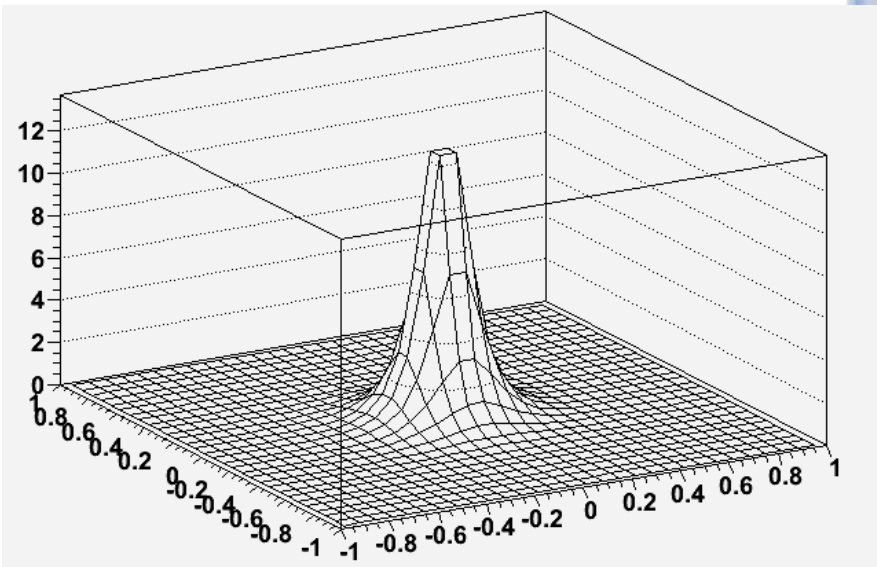


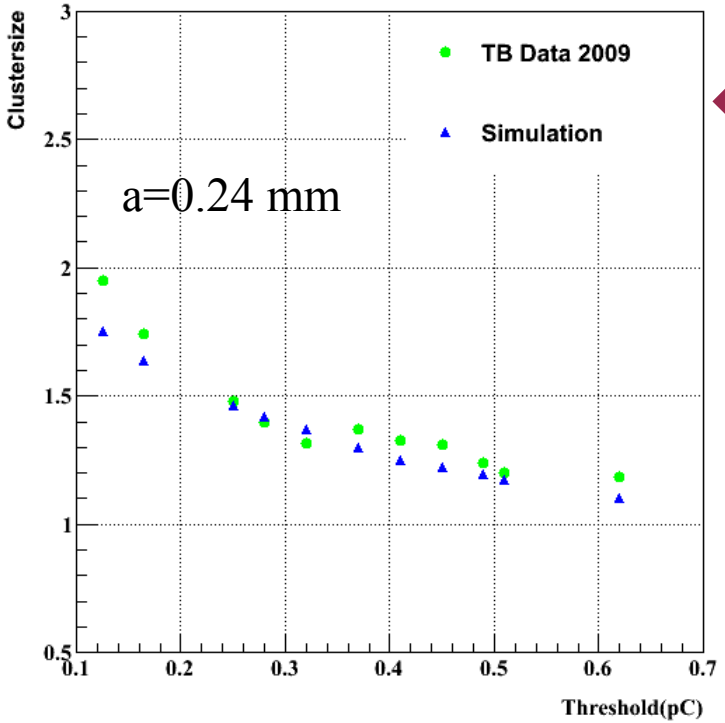
Charge dispatch with function

- **Spread of the induced charge**

KIRK T. MCDONALD's lecture

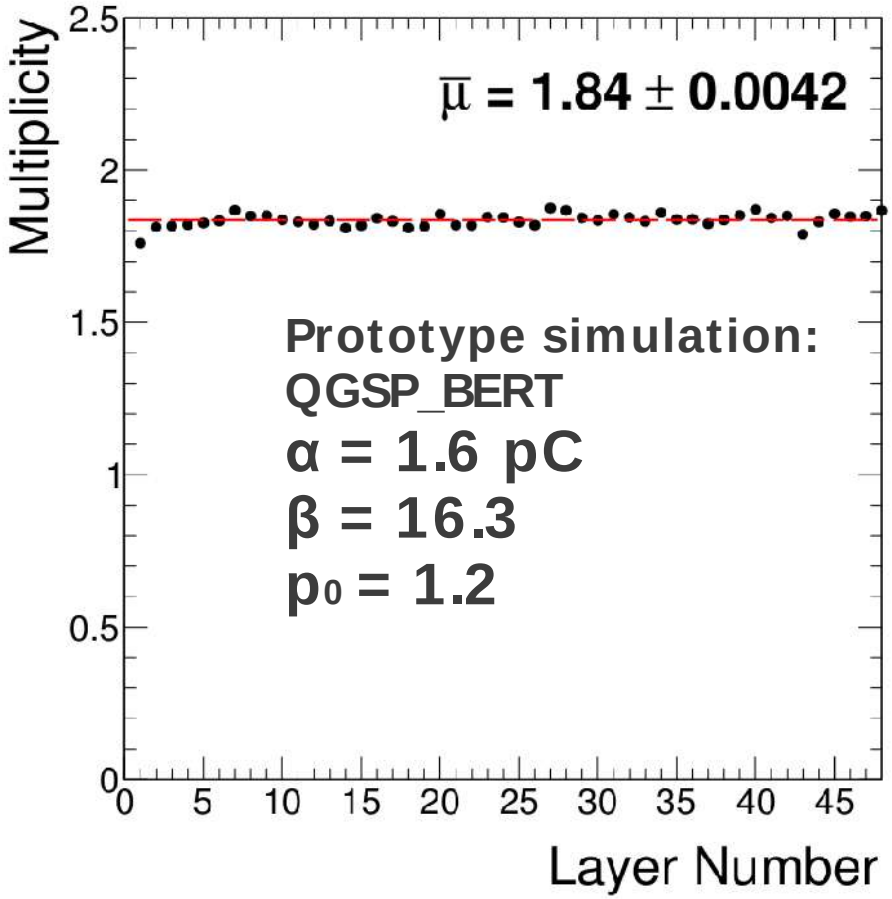
$$\sigma(x,y)=c\frac{-q}{2a}\frac{1}{\cosh\left(\pi\frac{\sqrt{(x-x_0)^2+(y-y_0)^2}}{a}\right)}$$

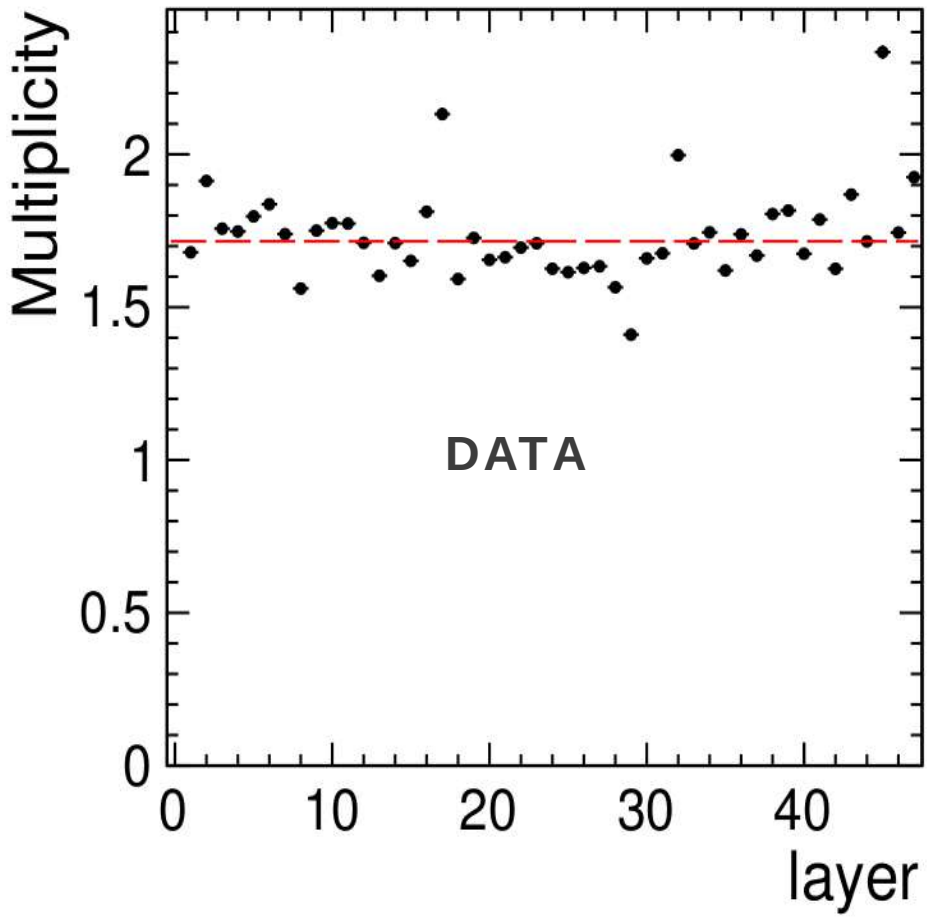




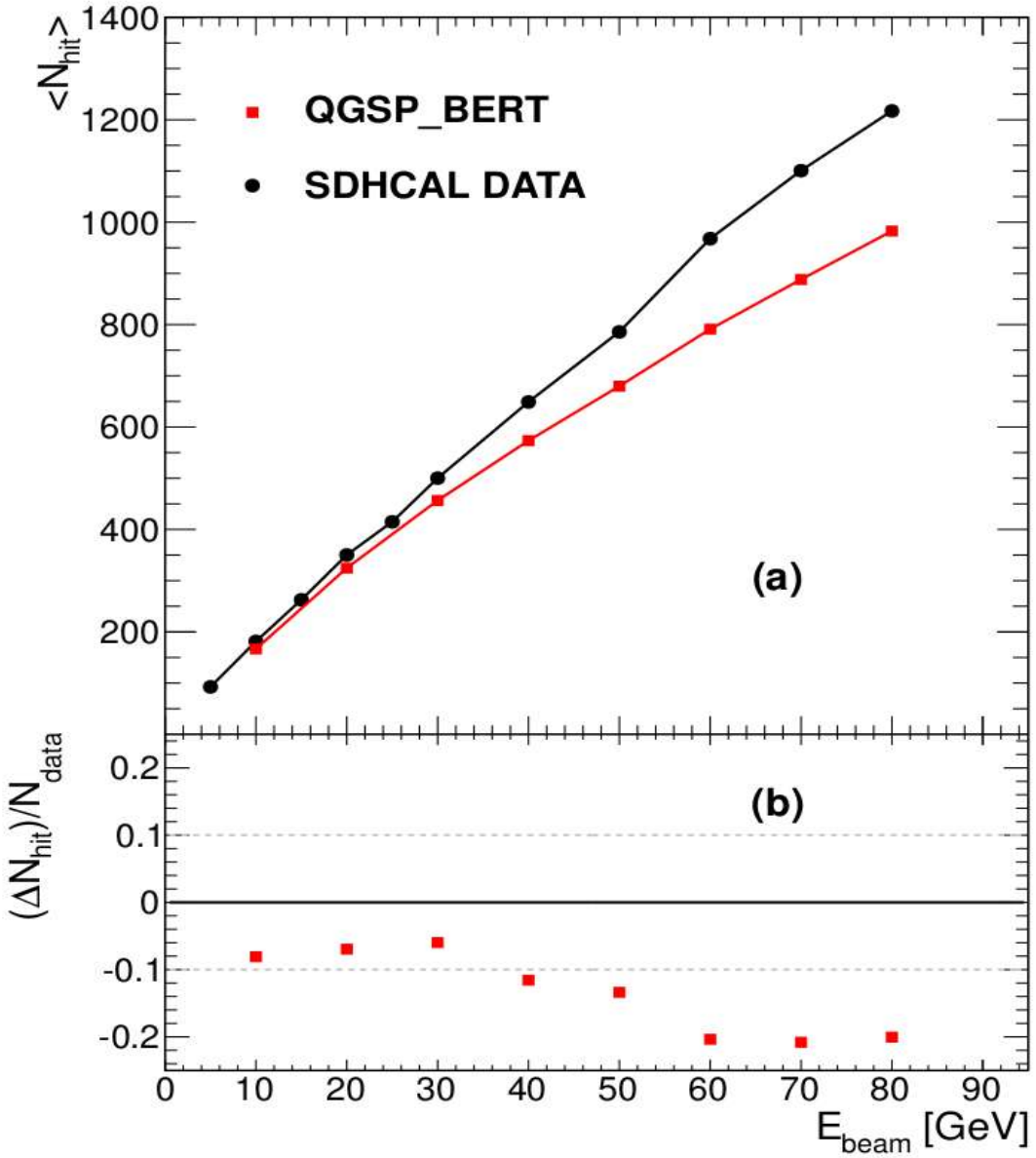
- Processor parameters
  - "functionFormula"
    - ROOT TF2 formula
    - Default = "1/cosh([0]*sqrt(x*x+y*y))"
  - "functionParameters"
    - Vector of parameters for the TF2

This reproduce the multiplicity





But not the pion data



- Impossibility to reproduce both muon and pion data with one dispatch width.

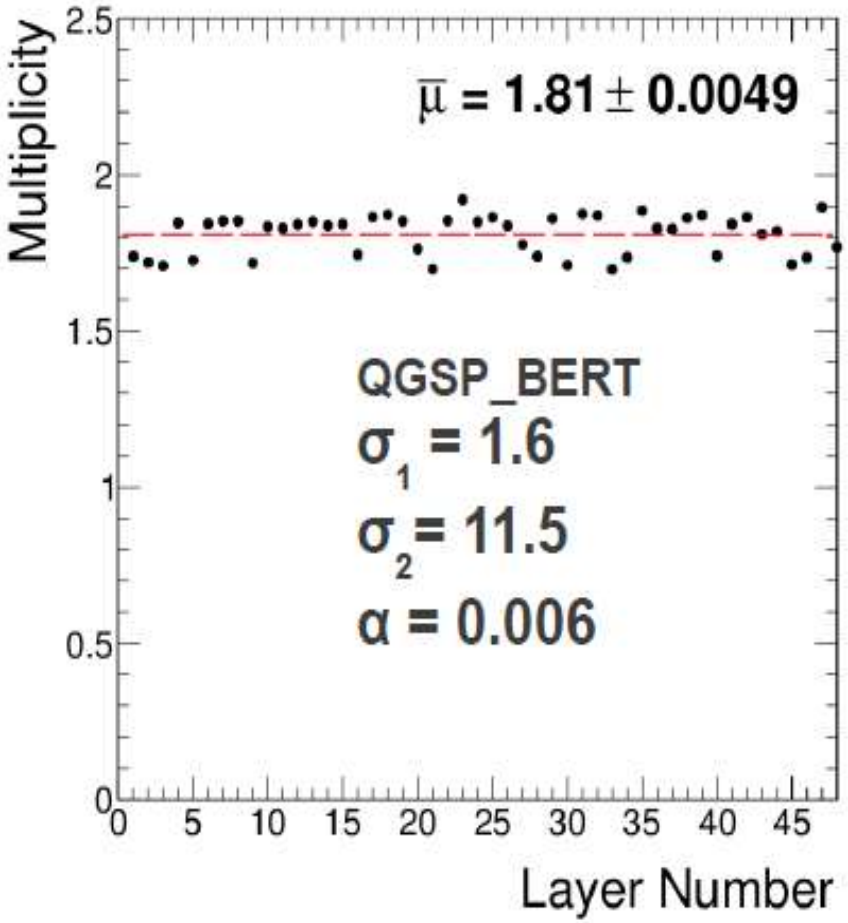
Dispatch with a 2 gaussian function

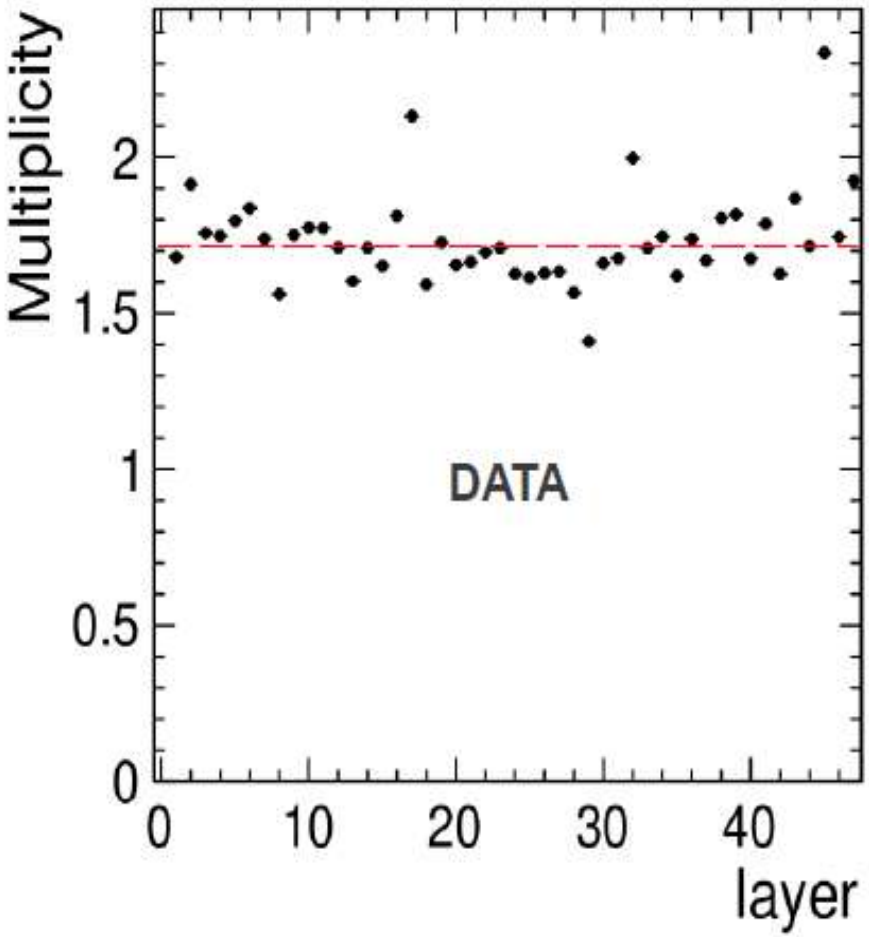
- Sharp gaussian to reproduce muon data and wider gaussian to reproduce pion data.

$$f(x,y) = e^{-\frac{x^2+y^2}{\sigma_1^2}} + \alpha e^{-\frac{x^2+y^2}{\sigma_2^2}}$$

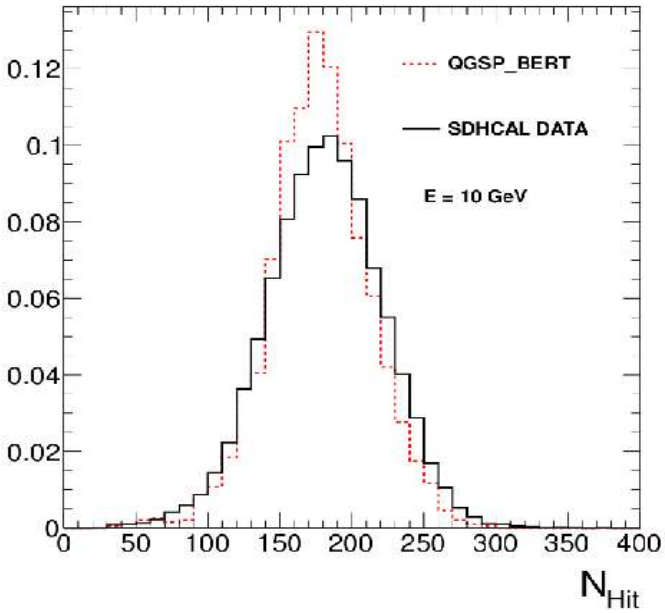
- With $\sigma_1 < \sigma_2$ and $\alpha < 1$
- (x,y)=coordinates in the RPC plane from the step position.

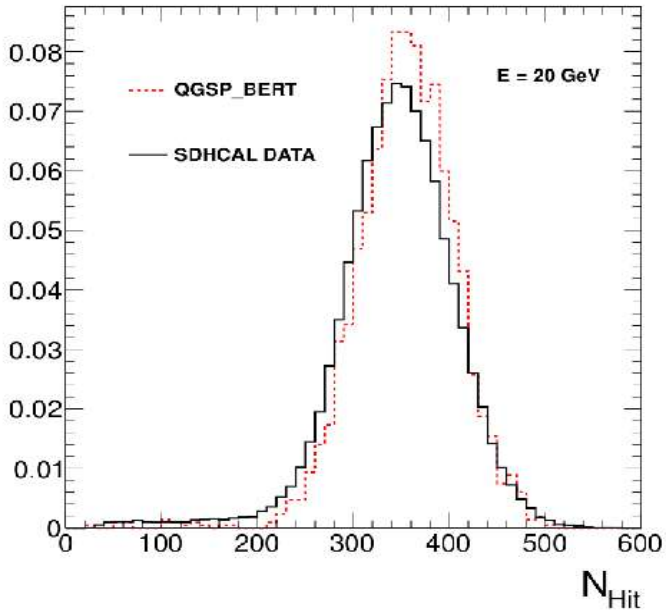
Reproduce muon data

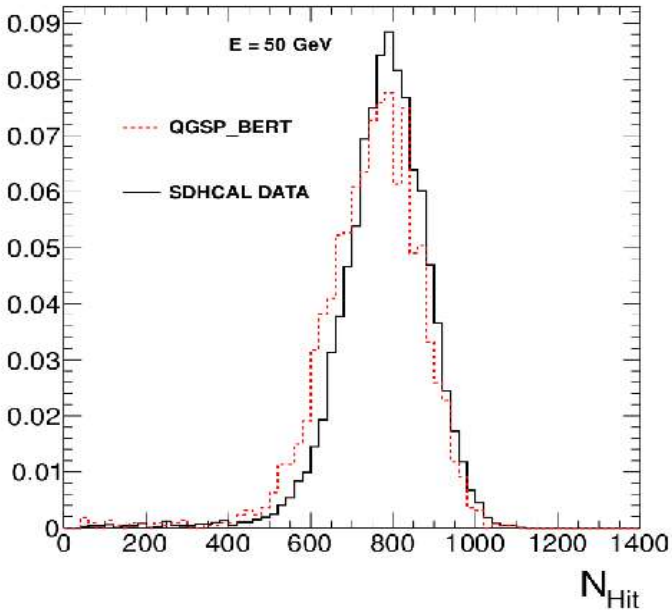


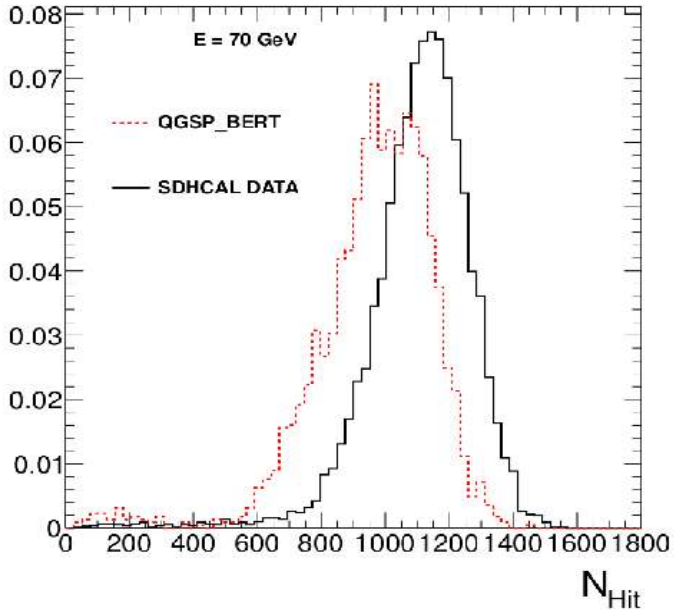


Reproduce better pion data

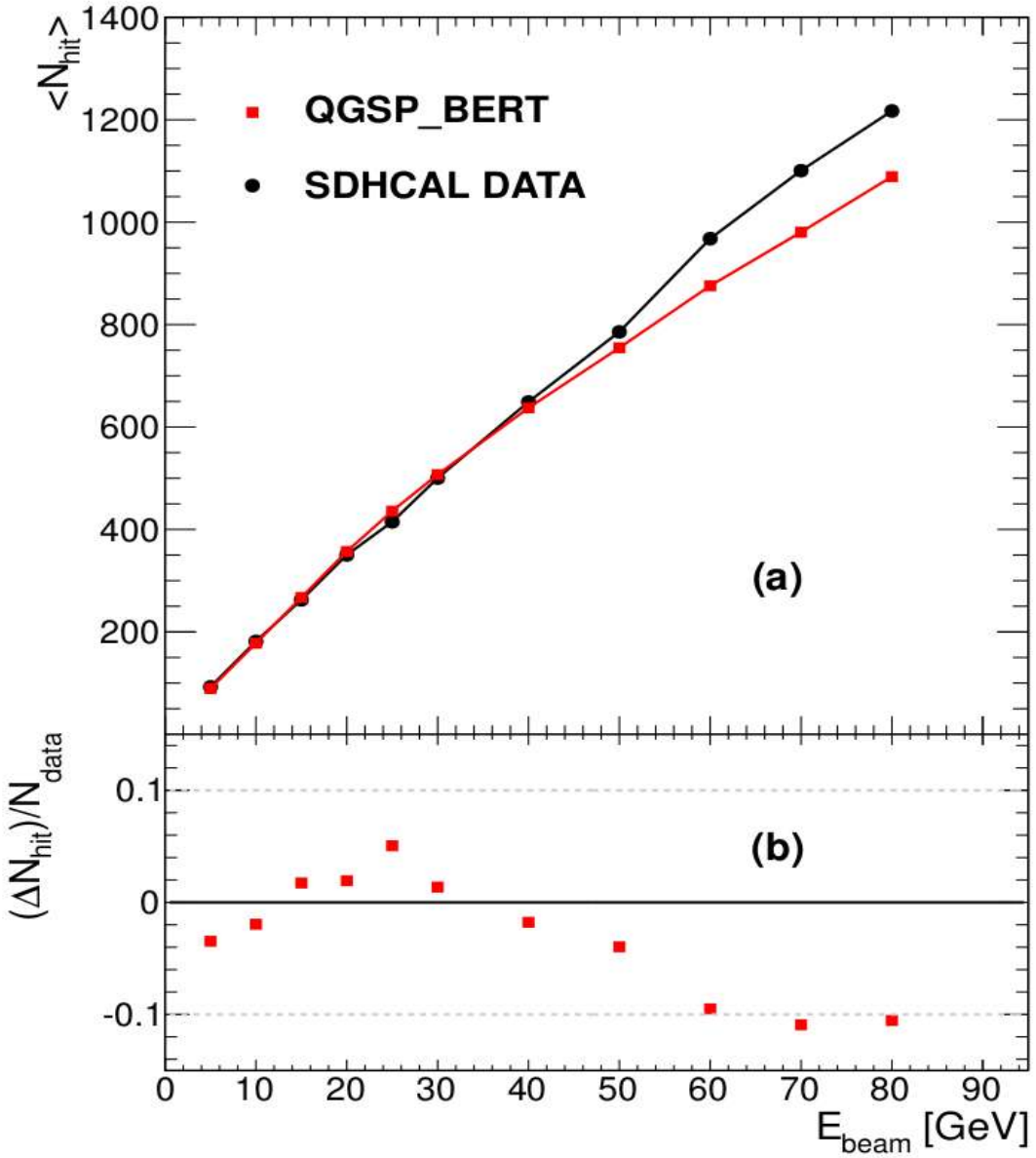








Reproduce better pion data

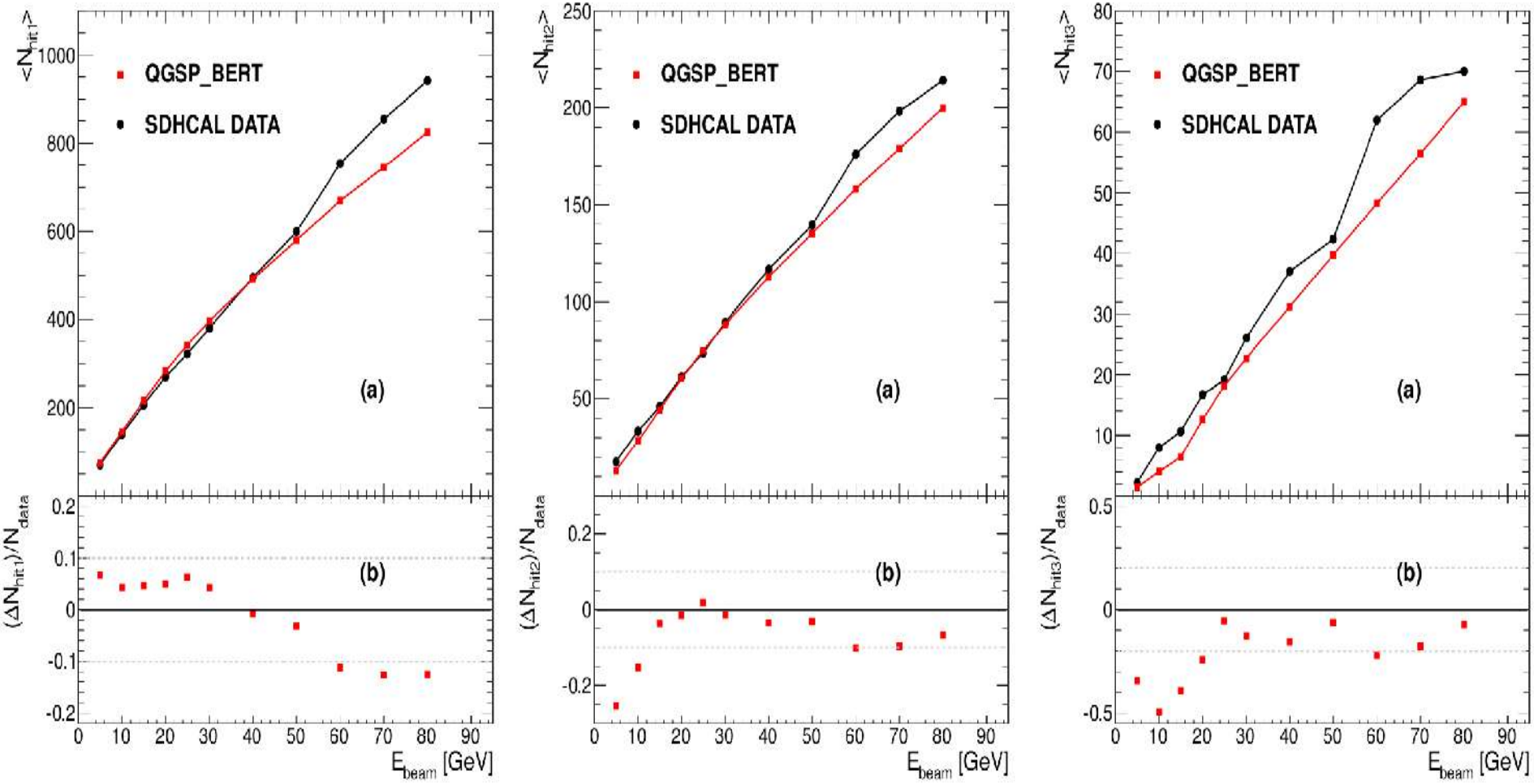


- Good data reproduction up to 50 GeV.
- In a jet, don't expect to have many hadron with energy above 50 GeV

Apply thresholds

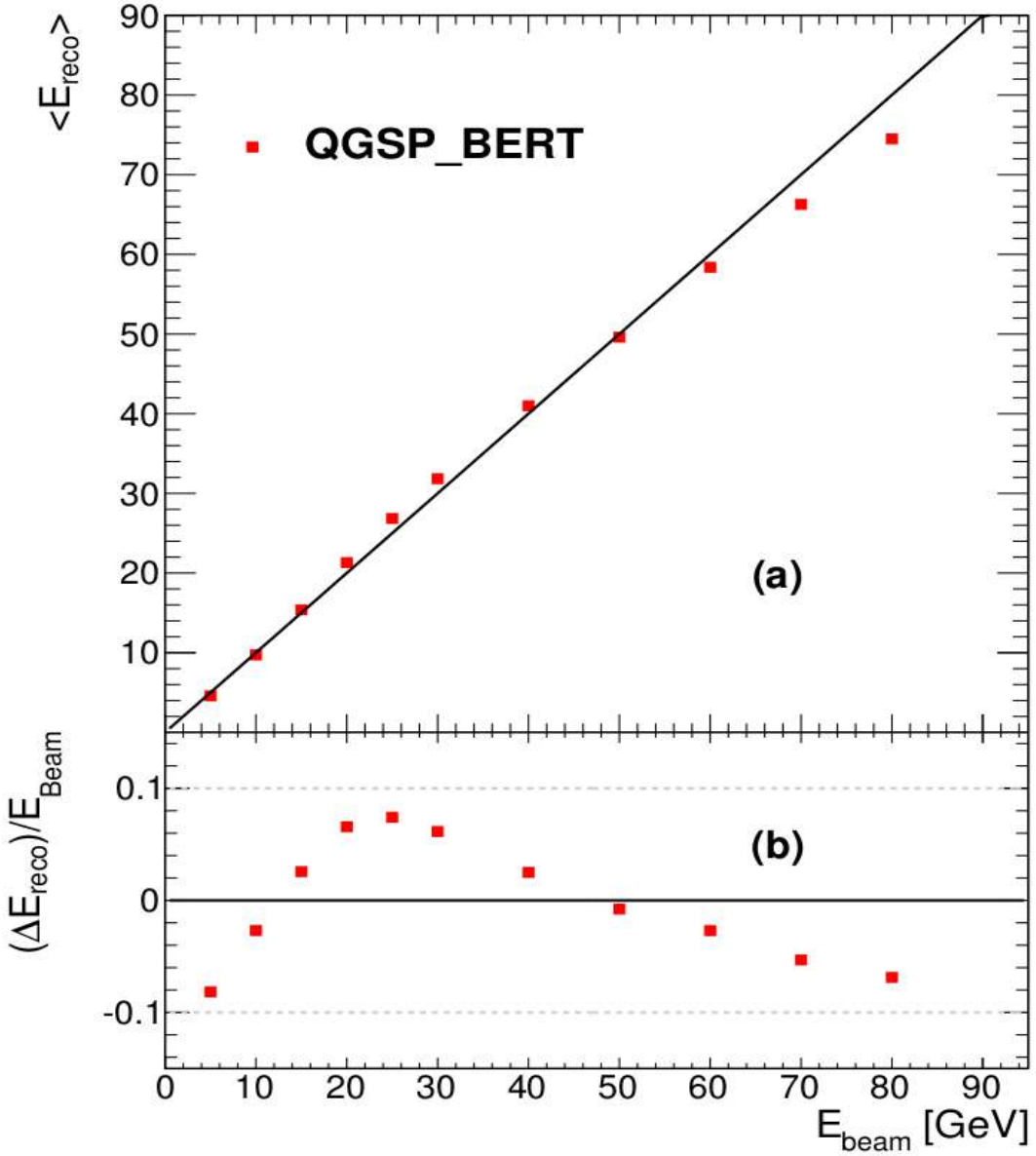
- Processor parameters :
  - "HCALThreshold"
    - Vector of thresholds in pc
  - "CalibrHCAL"
    - Vector of values
  - "doThresholds"
    - Bool flag, if true, replace output hit energy by value given by CalibrHCAL depending on the bigger HCALThrehold they exceed.
    - In any case, hits below the lowest threshold are removed.

Reasonable reconstruction



- Thresholds : 0.114, 1.45, 3.8 pC

Reasonable reconstruction



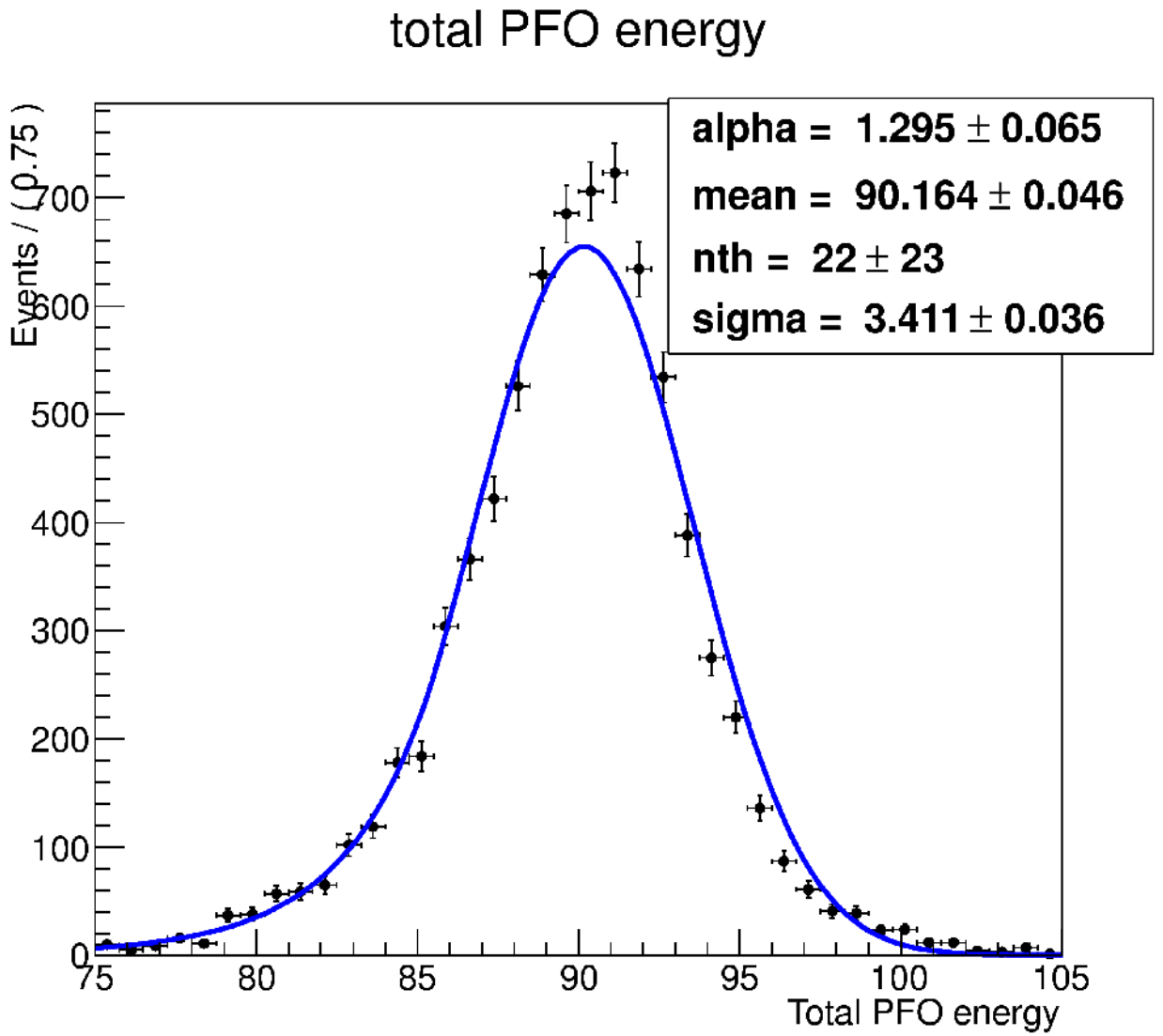
- $E_{reco}=\alpha N1+\beta N2+\gamma N3$
  - $\alpha=0{,}041$ GeV
  - $\beta=0.102$ GeV
  - $\gamma=0.258$ GeV

Test on uds jets

- Reconstruction with ilcsoft v01-16-01
- Use steering file from ILDConfig tag v01-16-p05_500 but
  - Change the digitizer for HCAL
- Use Pandora calibrated for AHCAL but
  - remove the “ScaleHotHadrons” hadronic energy correction.
- Test on standard $Z \rightarrow$ uds MC :
  - 91 GeV, 200 GeV, 360 GeV and 500 GeV

Di-jet reconstruction 91 GeV

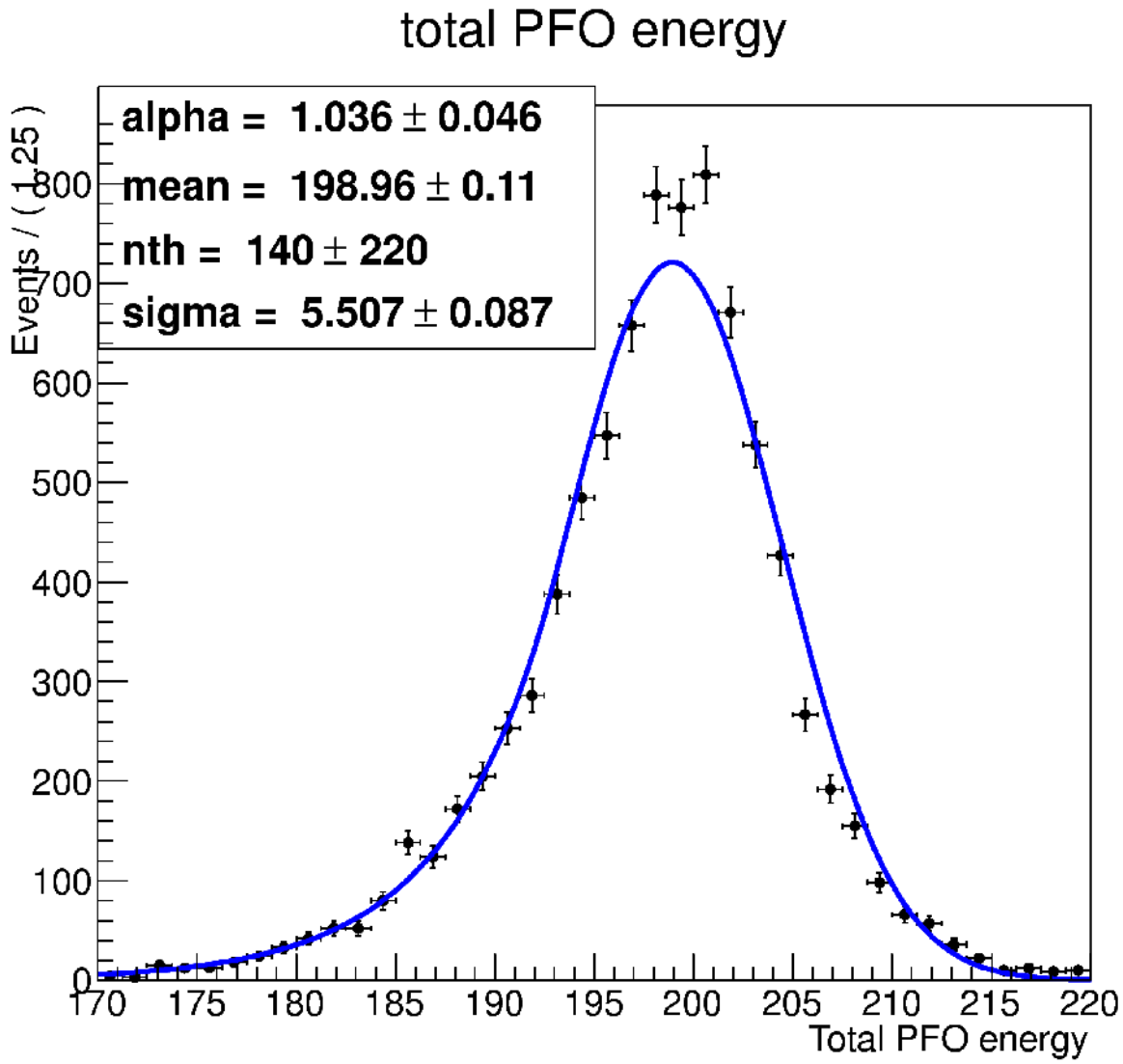
- Crystal Ball Fit
- 7900 events



- **Correct mean energy for SDHCAL though Pandora tuned for AHCAL**

Di-jet reconstruction 200 GeV

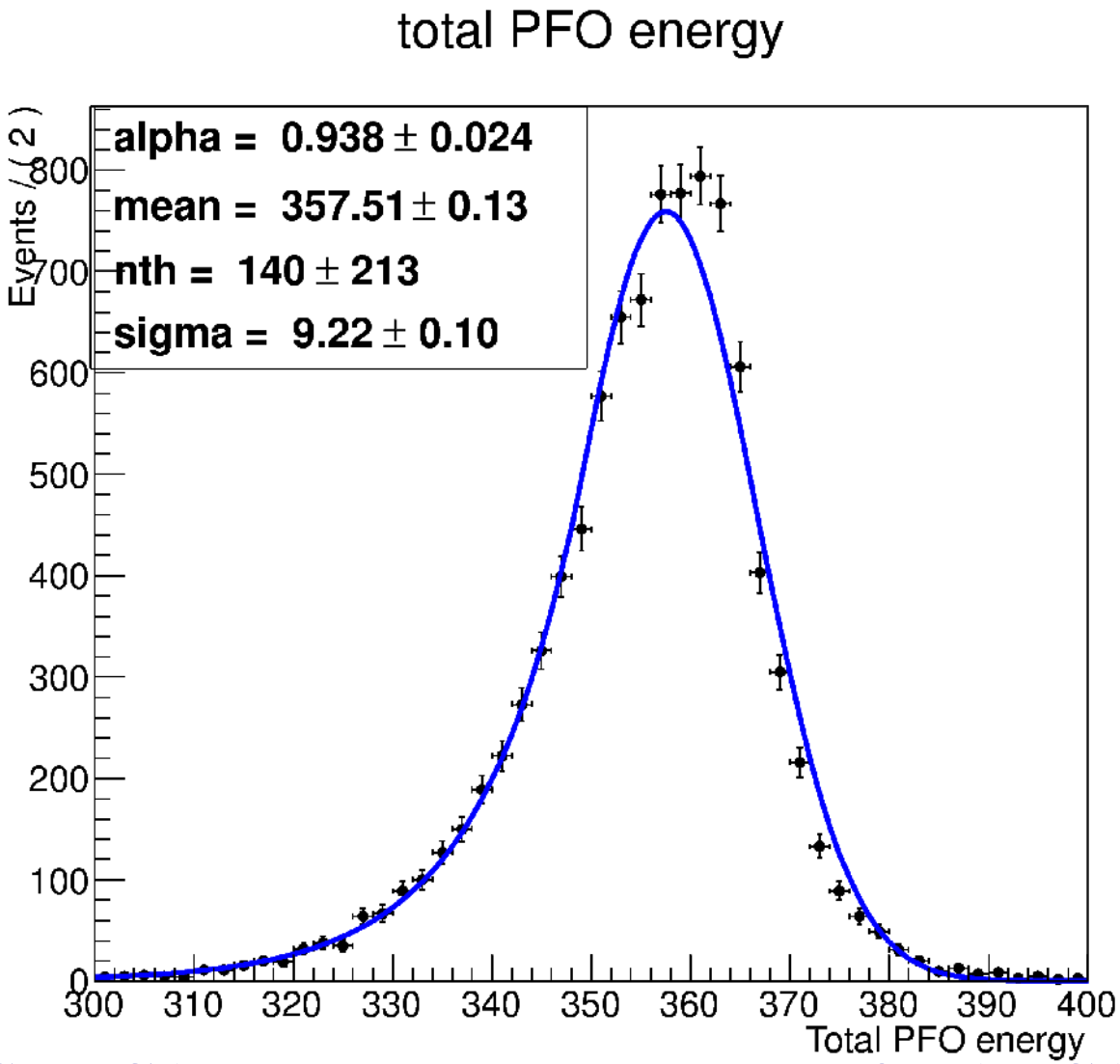
- Crystal Ball Fit
- 8800 events



- **Correct mean energy for SDHCAL though Pandora tuned for AHCAL**

Di-jet reconstruction 360 GeV

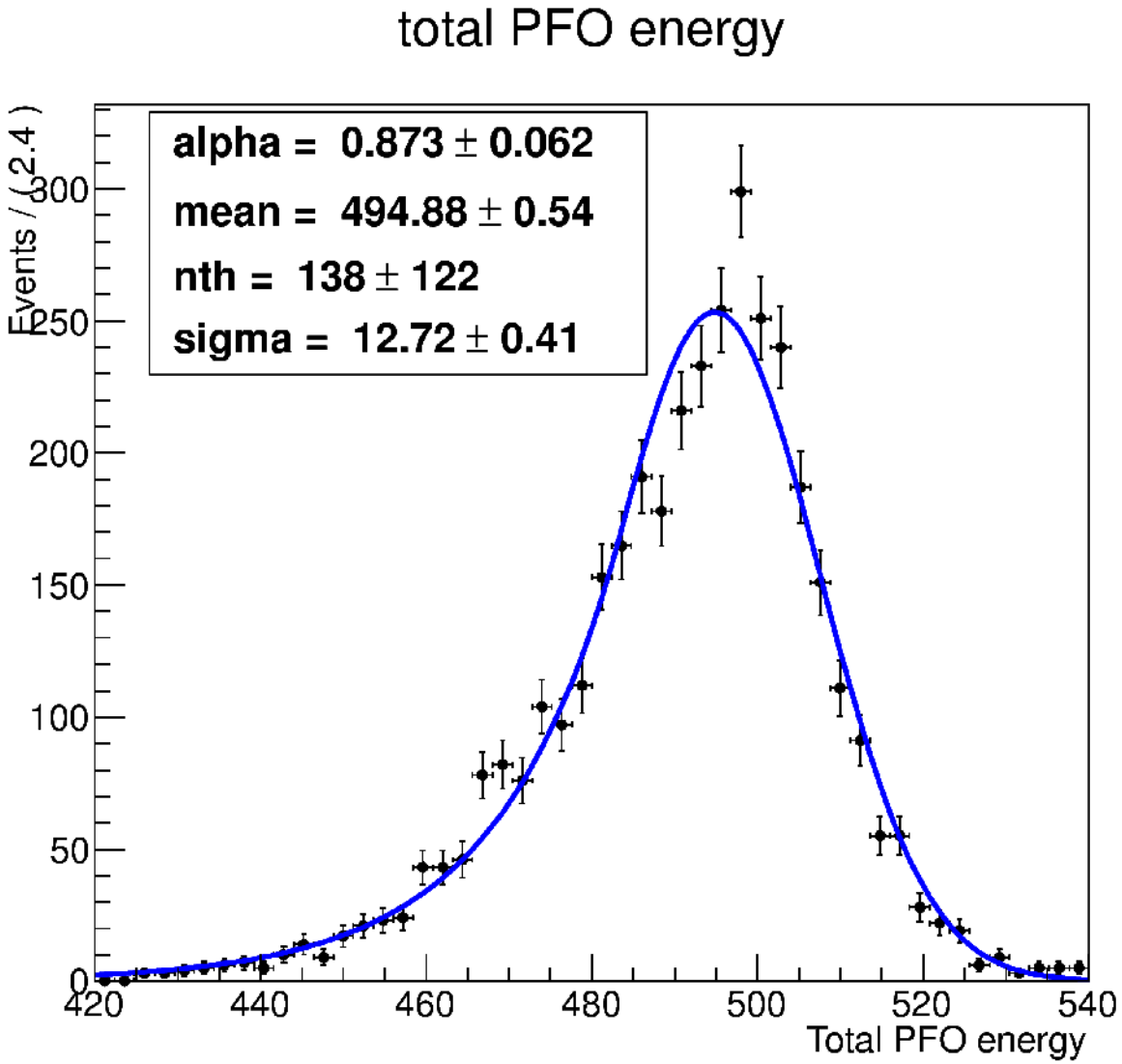
- Crystal Ball Fit
- 10000 events



- **Correct mean energy for SDHCAL though Pandora tuned for AHCAL**

Di-jet reconstruction 500 GeV

- Crystal Ball Fit
- 4000 events



- **Correct mean energy for SDHCAL though Pandora tuned for AHCAL**

Di-jet resolution

- ILD option 2 reconstruction using option 1 tuned PFA

E, GeV	RMS	RMS90*	CB fit	CB Mean	σ_{Ej}/E_j*
91	4.0	2.8	3.4	90.1	4.3%
200	7.1	4.9	5.5	198.9	3.5%
360	12.5	8.5	9.2	357.5	3.4%
500	17.5	12.4	12.7	494.9	3.5%

* computed with PandoraAnalysis v00-04 (ilcsoft v01-16-01)

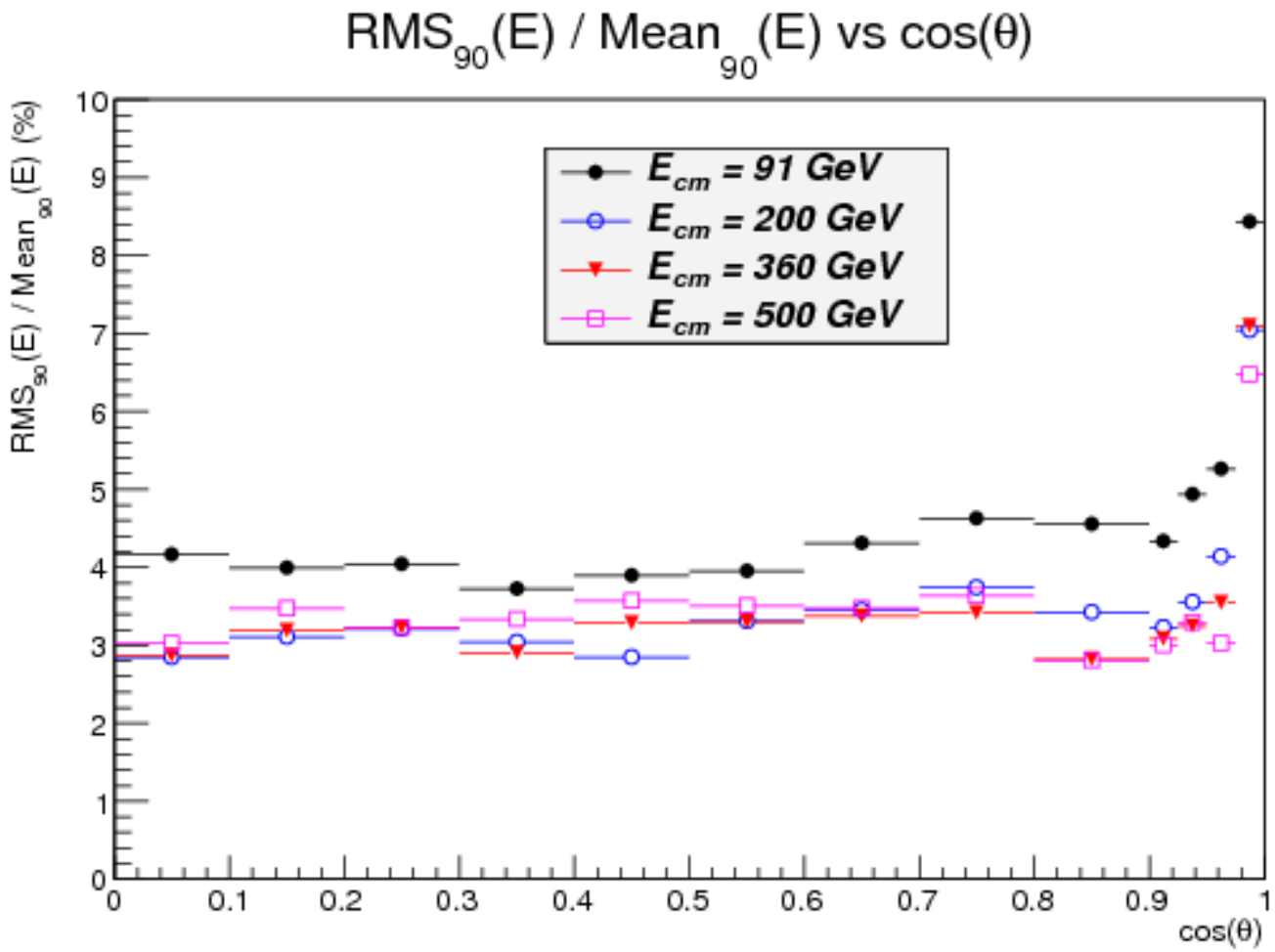
Jet resolution ($\cos\theta < 0.7$)

- ILD option 2 reconstruction using option 1 tuned PFA

E_j, GeV	SDHCAL, σ_{Ej}/E_j	AHCAL, σ_{Ej}/E_j
45	4.0%	3.7%
100	3.1%	2.8%
180	3.2%	2.8%
250	3.3%	2.9%

- AHCAL numbers from DBD,
- SDHCAL meets ILD goal with uncalibrated Pandora PFA

Jet resolution



Conclusion and next steps (I)

- Reconstruction for ILD option 2 available
  - Using ilcsoft version frozen for DBD
  - tth samples reconstructed
  - Reasonnable behaviour for jets reconstruction
- Remarkable results since
  - Pandora is calibrated for ILD option 1
  - SDHCAL energy is reconstructed without the linearity correction algorithms used for data

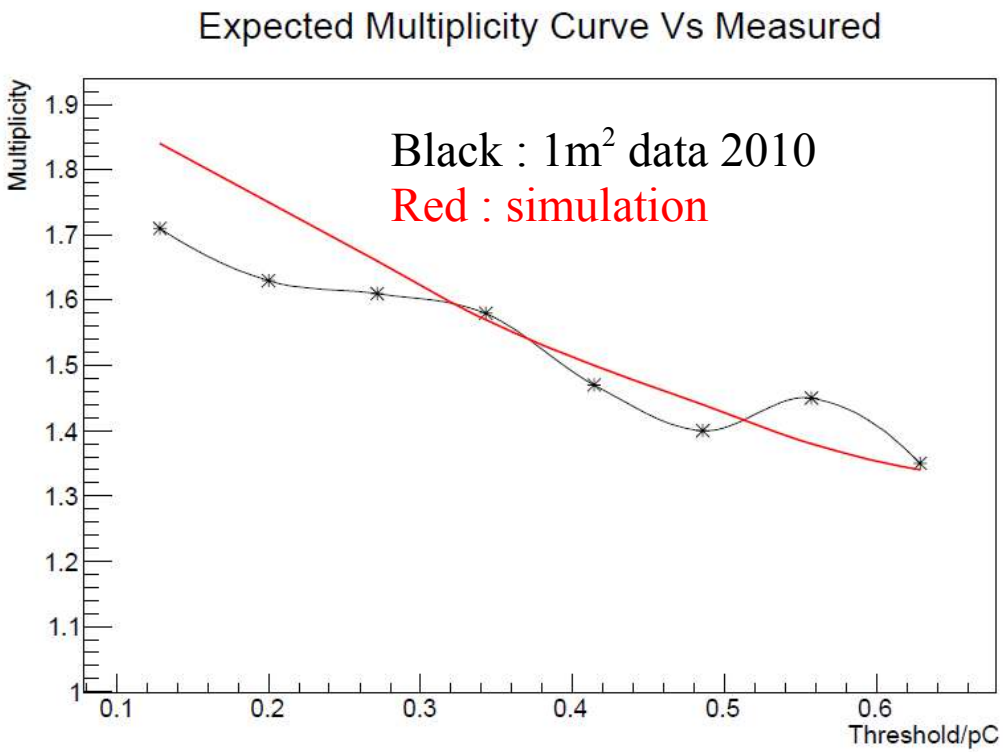
Conclusion and next steps (II)

- Next steps needing time (no ilcsoft code change)
  - Improve testbeam data reconstruction
  - Improve SDHCAL data-MC agreement with a 3 gaussians dispatching function
  - Calibrate Pandora for ILD model 2
- Next steps needing code change
  - Implement non linear energy reconstruction in Pandora
  - Speed up and improve SDHCAL digitizer in MarlinReco

BACKUP

Other digitizer

- Mokka simulation with 1 mm^2 cell size
  - Marlin processor rebuilds 1 cm^2 cells
    - No need of step position.
    - Need Marlin able to cope with varying geometry (cell size).
  - Also tunable to data.



Charge dispatching with function

- f(x,y) is a function describing the induced charge spatial distribution for a step.
  - (x,y) = coordinate in the “cell frame”.
  - Fraction of charge attributed to a cell :

$$\frac{\int_{xmincellBorderPos}^{xmaxcellBorderPos} dx \int_{ymincellBorderPos}^{ymaxcellBorderPos} dy\, f(x,y)}{\int_{-R}^{R} dx \int_{-R}^{R} dy\, f(x,y)}$$

  - Processor parameters :
    - "functionRange" : R above
    - "RPC_PadSeparation" :
      - Simulate interpad by reducing surface of integration per cell.

Add a 3rd gaussian