Tracking within hadronic showers in the SDHCAL prototype using Hough Transform technique

International Workshop on Linear Colliders LCWS2014 - Belgrade

Arnaud Steen
On behalf of the CALICE Collaboration

IPNL / Université Claude Bernard Lyon 1

6-10 October 2014

Outline

Introduction

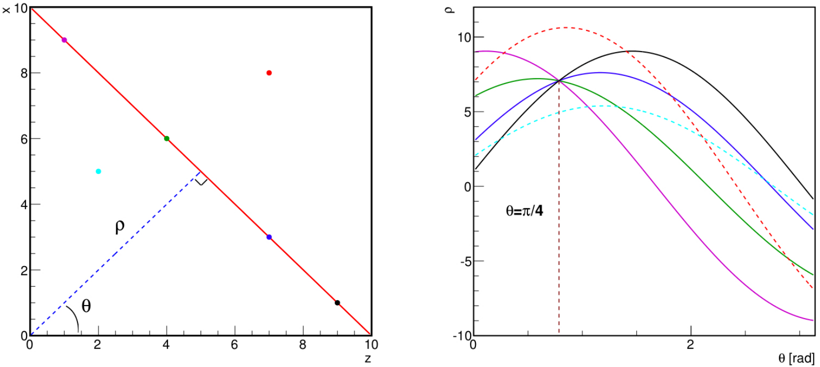
- Hough Transform method invented by P.V.C Hough in 1962 for detecting subatomic particle tracks in buble chambers (*"Method and means for recognizing complex paterns, United State patent US3069654"*)
- The method has been generalized to detect arbitray shapes in 1972 (Duda, R. O. and P. E. Hart, *" Use of the Hough Transformation to Detect Lines and Curves in Pictures"* Comm. ACM, Vol. 15, pp. 11-15 (January, 1972))
- The main idea of the Hough Transform is to increase the number of dimensions of a problem to solve it. Points are transformed into curves, circles...
- Hough Transform allows to detect complex shapes in very noisy environnements like hadronic showers

Hough Transform method

- Each point of coordinates (z,x) is replaced by a curve (ρ,θ) using :

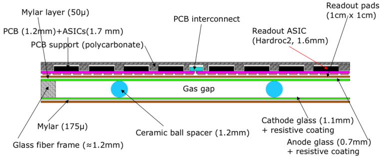
$$\rho = zcos(\theta) + xsin(\theta) \quad (1)$$

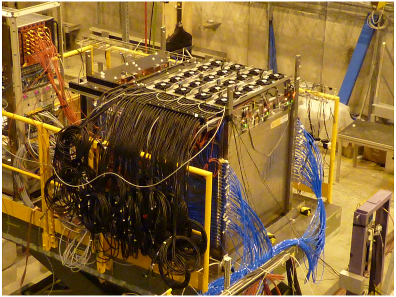
- The intersection of the curves defines the line parameters



SDHCAL prototype

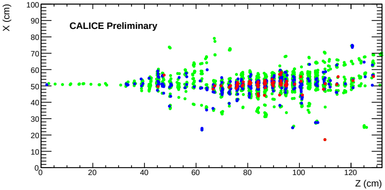
- Sampling calorimeter
- Size : 51 stainless steel plates + 50 active layers $\rightarrow$ $1 \times 1 \times 1.3m^3$
- Active layer :
  - Gaseous detector : GRPC (Glass Resistive Plate Chamber) of $1m^2$
  - Gas mixture : $93\% TFE$; $5\% CO_2$; $2\% SF_6$
  - HV : $\sim 6.9kV$ in avalanche mode
- Readout :
  - 96×96 pads of 1 cm^2 per layer $\Rightarrow$ more than $460k$ channels for the whole prototype
  - Semi-digital readout : 3 thresholds on the induced charge to have a better idea on the deposited energy
- Radiator :
  - $50 \times 20mm$ stainless steel $\Rightarrow \sim 6\lambda_I$

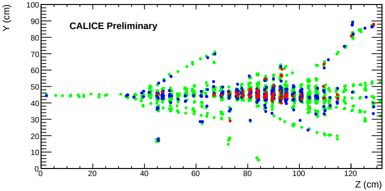




Hough Transform purposes

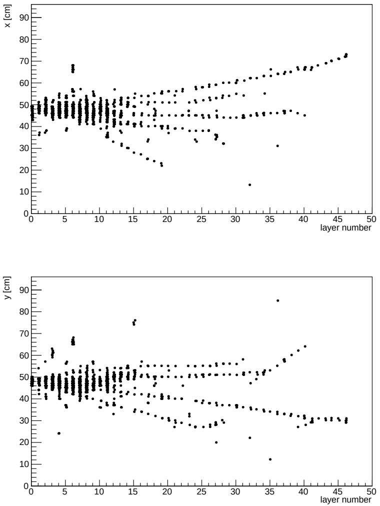
- Use HT tracks within hadronic showers to control efficiency and pad multiplicity *in situ*
- Improve the reconstructed energy calibration by applying special traitement to hits belonging to tracks (see presentation of Alexey Petrukhin)
- Study hadronic shower models
- Use the tracks to improve PFA by connecting tracks and clusters





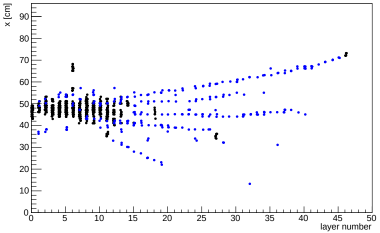
Algorithm steps

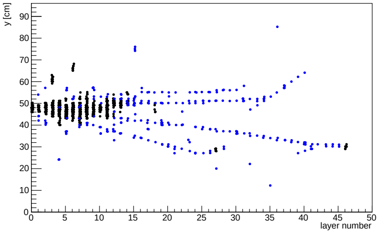
- Gather hits from the same layer into clusters if they share an edge in order to reduce CPU consumption. Find cluster barycenter.



Algorithm steps

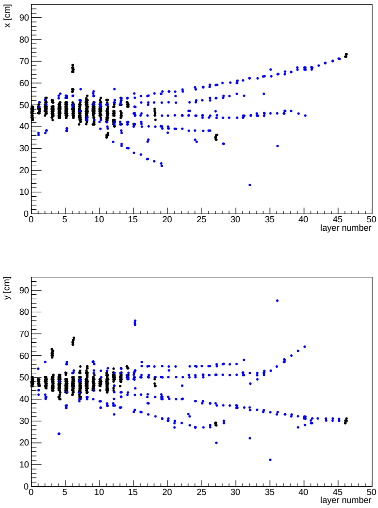
- Gather hits from the same layer into clusters if they share an edge in order to reduce CPU consumption. Find cluster barycenter.
- Keep only non dense part of the shower : clusters with more than 4 hits or with more than 2 neighbouring clusters in 10×10 cm^2 around are removed





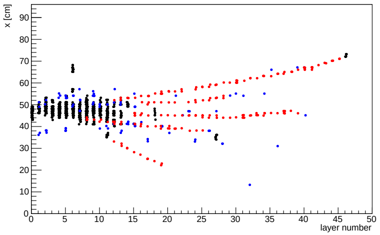
Algorithm steps

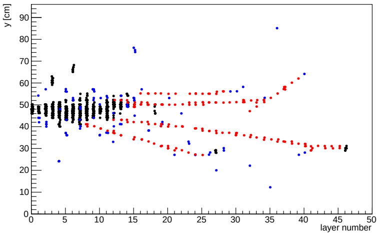
- Gather hits from the same layer into clusters if they share an edge in order to reduce CPU consumption. Find cluster barycenter.
- Keep only non dense part of the shower : clusters with more than 4 hits or with more than 2 neighbouring clusters in $10 \times 10\ cm^2$ around are removed
- Apply Hough Transform method to remaining clusters :
  - a) Using (z,x) coordinates to build HT histogram (ρ_1,θ_1). Sort the bins according to the number of cluster inside and keep only bins with more than 5 clusters
  - b) For each selected bin, a 2^{nd} HT histogram (ρ_2,θ_2) is built using (z,y) coordinates. Select the bin with the maximum number of clusters (and with $N_{clusters} > 5$).
  - c) Remove isolated ones from these clusters (no neighbouring clusters in $18 \times 18 \times 18\ cm^3$ volume).
  - d) Build a track with selected clusters
  - e) Repeat the procedure for all bins selected in a)



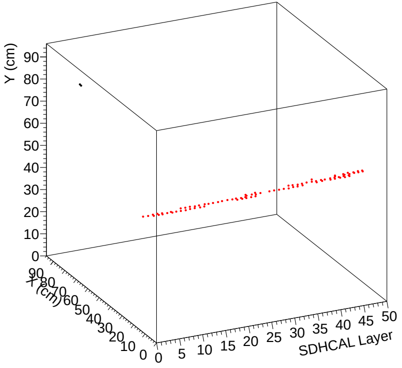
Algorithm steps

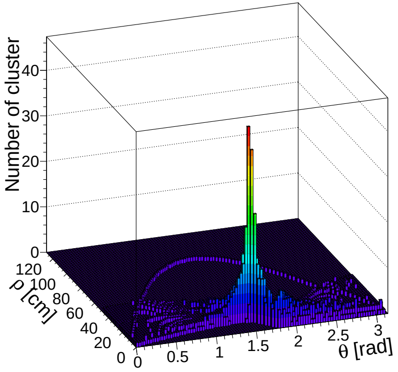
- Gather hits from the same layer into clusters if they share an edge in order to reduce CPU consumption. Find cluster barycenter.
- Keep only non dense part of the shower : clusters with more than 4 hits or with more than 2 neighbouring clusters in $10 \times 10\ cm^2$ around are removed
- Apply Hough Transform method to remaining clusters :
  - a) Using (z,x) coordinates to build HT histogram (ρ_1,θ_1). Sort the bins according to the number of cluster inside and keep only bins with more than 5 clusters
  - b) For each selected bin, a 2^{nd} HT histogram (ρ_2,θ_2) is built using (z,y) coordinates. Select the bin with the maximum number of clusters (and with $N_{clusters} > 5$).
  - c) Remove isolated ones from these clusters (no neighbouring clusters in $18 \times 18 \times 18\ cm^3$ volume).
  - d) Build a track with selected clusters
  - e) Repeat the procedure for all bins selected in a)



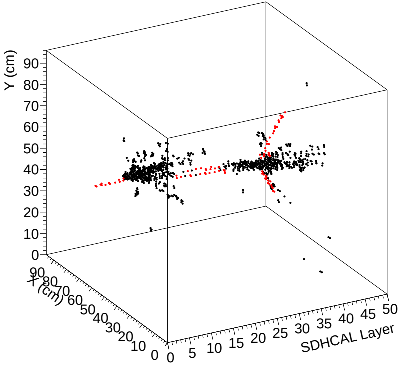


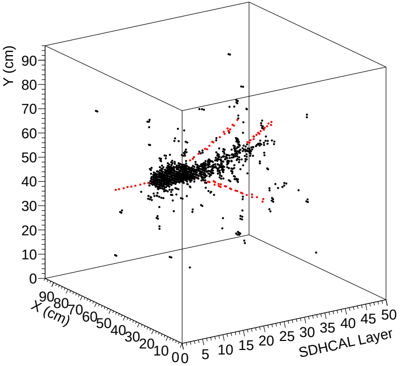
Event displays





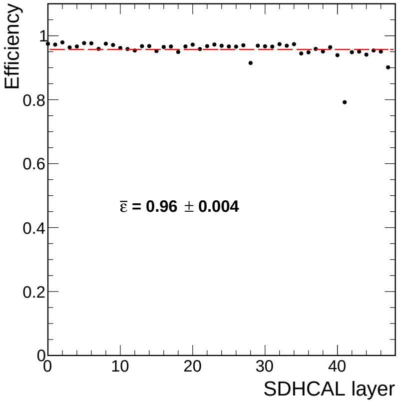
Event displays



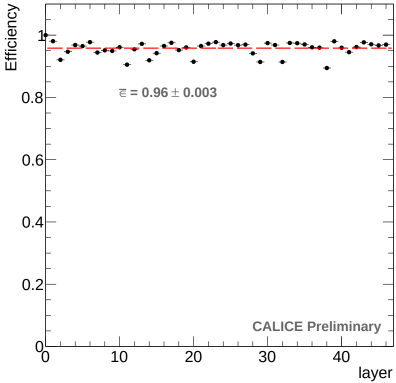


SDHCAL performance using Hough Transform tracks (SPS H6 data)

Efficiency estimated with beam muons

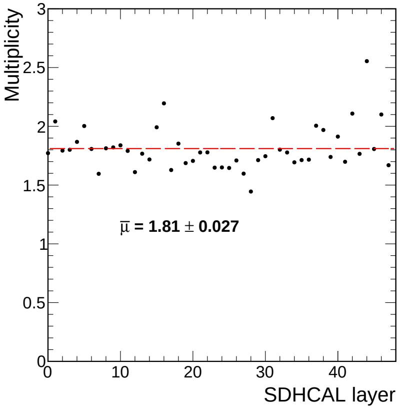


Efficiency estimated with HT tracks

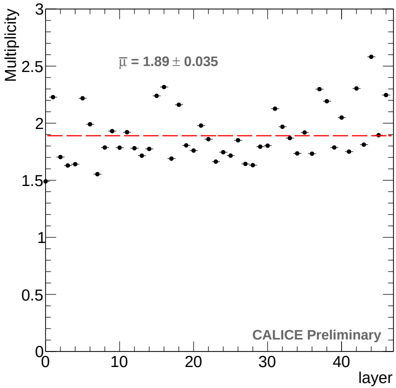


SDHCAL performance using Hough Transform tracks (SPS H6 data)

Multiplicity estimated with beam muons

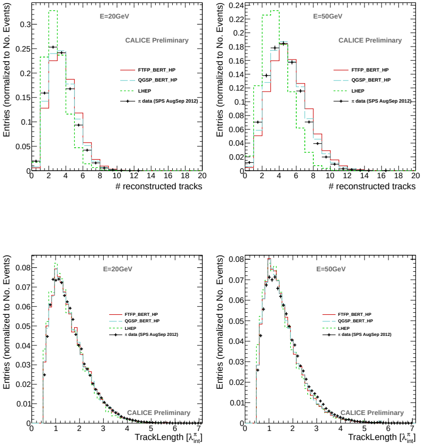


Multiplicity estimated with HT tracks

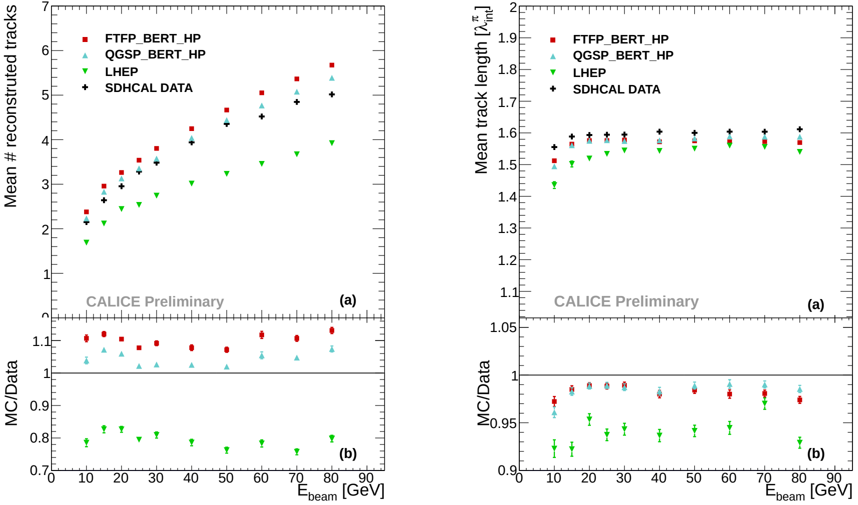


Using Hough Transform to study hadronic shower models

- HT tracks can be used to distinguish between different hadronic shower models.
- A digitizer based on results obtained with muons and hadrons was developed
- A new digitizer based on electrons instead of hadrons is under development



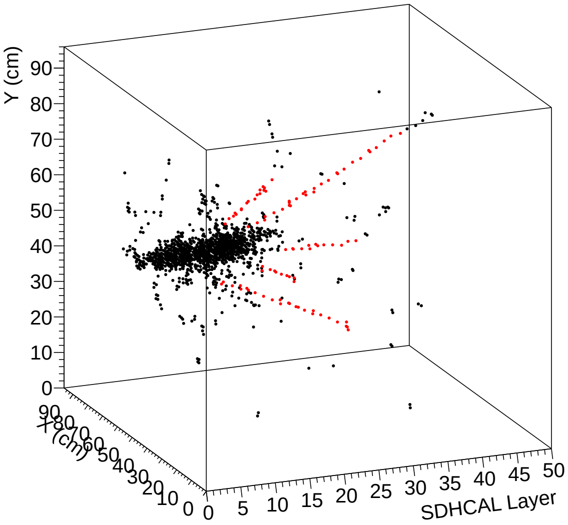
Using Hough Transform to study hadronic shower models



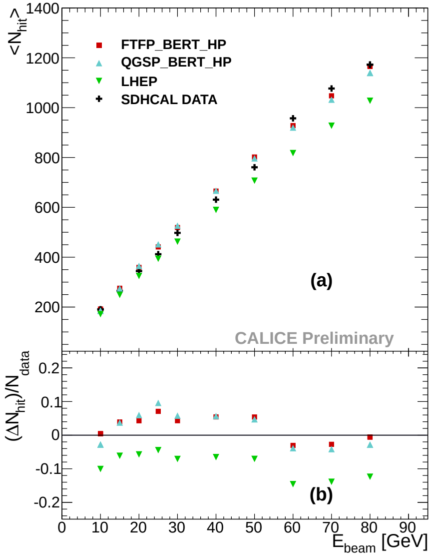
Conclusion

- Hough Transform method has been successfully applied to hadronic showers
- Tracks found with hough transform can be used to monitor the active layer behaviour *in situ*
- Tracks found with hough transform are used to improve on SDHCAL energy resolution (see presentation of Alexey Petrukhin)
- Tracking in hadronic showers seems to be a good tool to discriminate hadronic shower models even if this study must be done with better digitizer

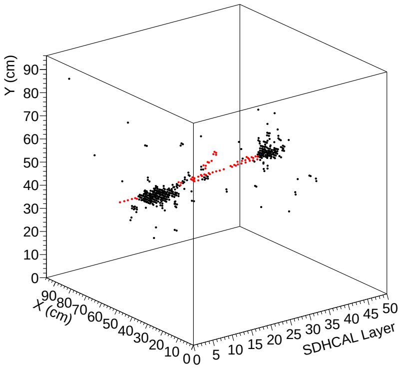
Back-Up

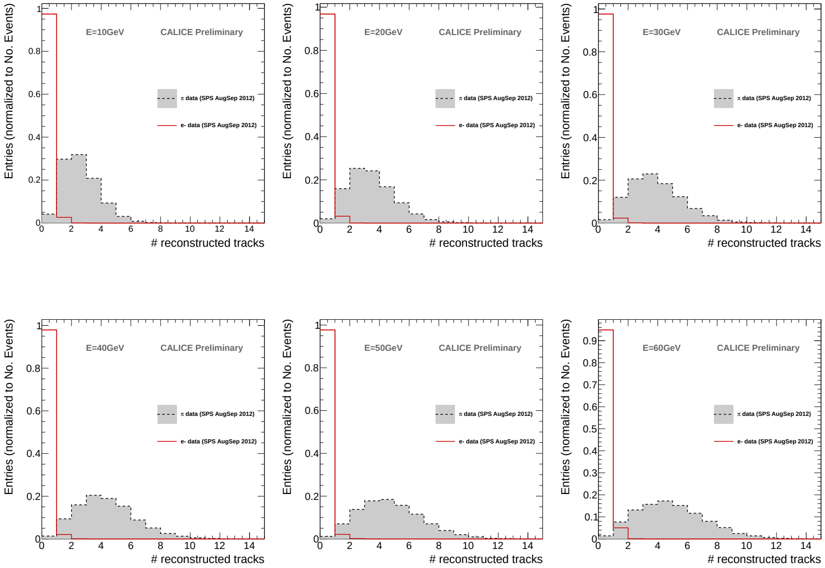


Y (cm)
90
80
70
60
50
40
30
20
10
0
X (cm)
90 80 70 60 50 40 30 20 10 0
0 5 10 15 20 25 30 35 40 45 50
SDHCAL Layer



FTFP_BERT_HP
QGSP_BERT_HP
LHEP
SDHCAL DATA
(a)
CALICE Preliminary
(b)
$<N_{hit}>$
$(\Delta N_{hit})/N_{data}$
E_{beam} [GeV]
1400
1200
1000
800
600
400
200
0.2
0.1
0
-0.1
-0.2
0
10
20
30
40
50
60
70
80
90


Y (cm)
X (cm)
SDHCAL Layer
Y (cm)
X (cm)
SDHCAL Layer


E=10GeV
E=20GeV
E=30GeV
E=40GeV
E=50GeV
E=60GeV
CALICE Preliminary
π data (SPS AugSep 2012)
e- data (SPS AugSep 2012)
Entries (normalized to No. Events)
reconstructed tracks