W-DHCAL Analysis: Status and Plans

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CERN LCD

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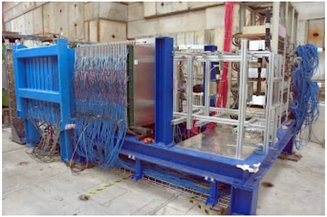
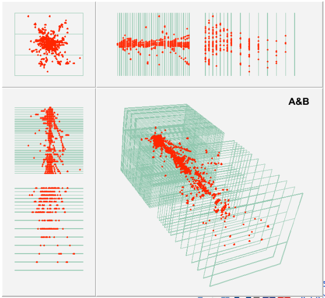
Outline

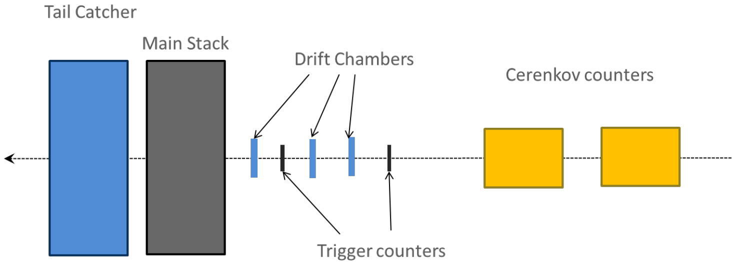
Data Taking at CERN (2012)

- 54 RPC layers:
  39 with tungsten absorber (main stack),
  15 with steel absorber (tail catcher)
- Each layer instrumented with 96×96 $1 \times 1\,\mathrm{cm}^2$ pads $\Rightarrow \sim 500000$ channels
- PS (1–10 GeV): 1 run period of 2 weeks
- SPS (10–300 GeV): 2 + 1 + 1 weeks
- Dedicated μ and high rate runs
- In total ∼ 30 million events recorded





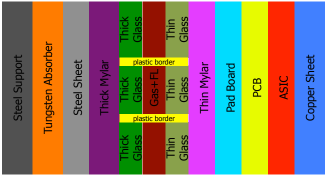
Data Taking at CERN (2012)

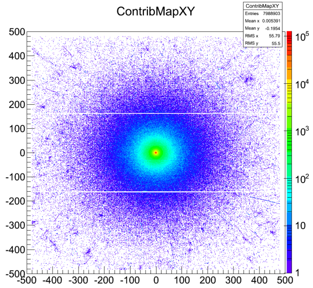


- 39 layers W-DHCAL + 15 layers Fe-DHCAL
- $10 \times 10\,\mathrm{cm}^2$ scintillator triggers ($30 \times 30\,\mathrm{cm}^2$ for dedicated muon runs)
- Three wire chambers
- Two Cerenkov counters

Geant4 Detector Model

- Absorber geometry taken from W-AHCAL geometry (octagonal tungsten plates)
- RPC cassette geometry from Fe-DHCAL
- Sensitive layer definition from Fe-DHCAL
- Write LCIO output including step positions of all hit contributions (required in digitization)
- Individual Mokka drivers for main stack (done), tail catcher and beam line
- Available in our Mokka DB: `dbod-lcdmokka.cern.ch:5500`
- Release to default DB once fully validated





Digitization of Simulation Data

- Re-implemented RPCSim as Marlin processor
- Smearing of primary energy depositions using two exponentials (6 parameters): minimum distance, charge scaling, two slopes, ratio of two slopes, threshold
- Fully configurable via XML
- Want to understand underlying parametrization:
  ⇒needs some knowledge transfer
- Afterwards: thorough validation by comparing with test beam data

S. Arfaoui (CERN)

Raw Data Conversion

- Convert raw DHCAL data into LCIO format
- 2 CalorimeterHit collections: main stack and tail catcher hits:
  Cell IDs: i, j and layer
- Wire chamber data in ns as TrackerRawData collection
- Run information stored as LCParameter with RunHeader:
  momentum, polarity, temperature, Cerenkov pressures, etc.
- Cerenkov trigger values stored as LCParameter with event
- Format of digitization output and raw data conversion is consistent

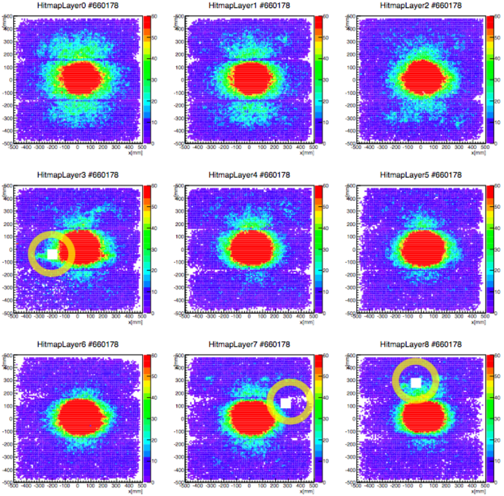
Wire Chamber Data

- Form tracker hits from TrackerRawData: all possible combinations of vertical and horizontal signals in each layer
- Apply calibration: ns $\rightarrow$ mm
- Straight line fit of all possible combinations of hits in 3 layers
- Select best fit to determine position and direction of incoming particle: $\Rightarrow$ determine beam profile for simulation and shower start in x-y

W. Nash (U. Boston)

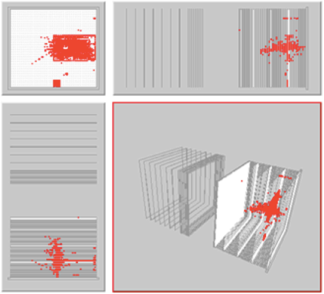
Noisy and Dead Cells

- Need to mask dead cells in simulation and noisy cells in data
  ⇒ same response in simulation and data
- Identified by looking at cell occupancies in each run
  ⇒ list of dead and noisy regions by run and layer
- Information not yet used in analysis

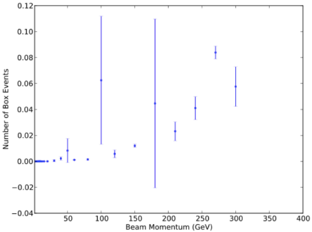


K. Motohashi (Tokyo Institute of Technology)

Box Events



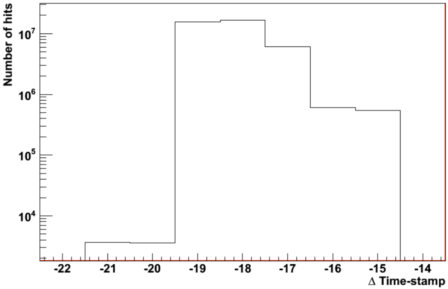
- Some events experience box shaped patterns in individual layers
- Hits created along boundary of individual front end board
- Identify box events by comparing number of hits along these boundaries and number of hits within the box
- Identified events are vetoed:
  $\Rightarrow$ recover by interpolation from surrounding layers?
- Need to understand from simulation if event selection introduces bias



J. Strube (CERN)

Event Reconstruction

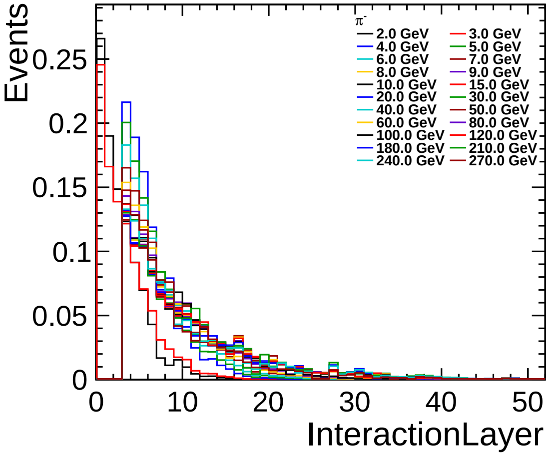
- Remove duplicate hits (same position, different time stamp)
- Remove out-of-time hits: only keep 3 most relevant time bins ($3 \times 100\,\mathrm{ns}$)
- Nearest neighbor clustering with a maximum distance of 1 cell
- ROOT tree containing all relevant event variables:
  $\Rightarrow$ do particle identification, plotting, etc. on ROOT files



Particle Identification

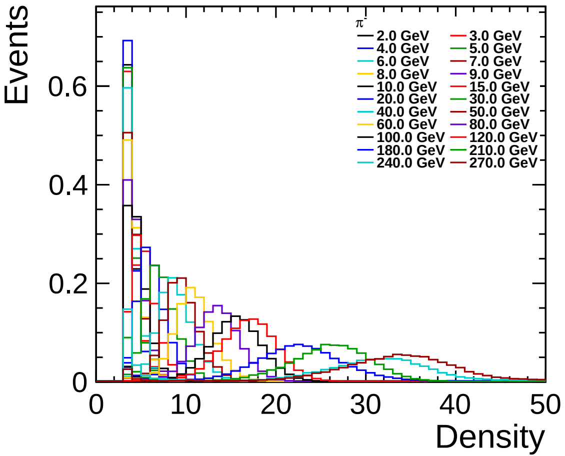
- See backup for details
- Used observables
  - Two Cerenkov counters
  - Interaction layer
  - Hit density
  - Barycenter (layer)
  - Activity in first layer and last layers

Interaction Layer



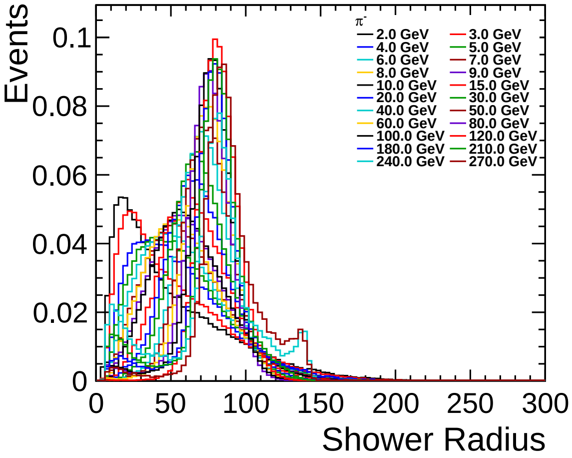
- Interaction layer: first two consecutive layers with nHits > 3

Shower Density



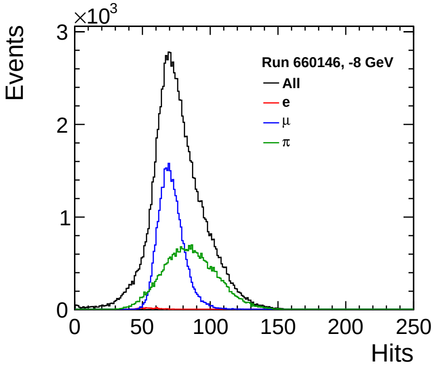
- Hit density: nHits/nActiveLayers

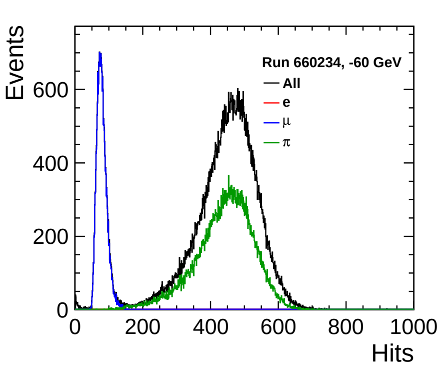
Shower Radius



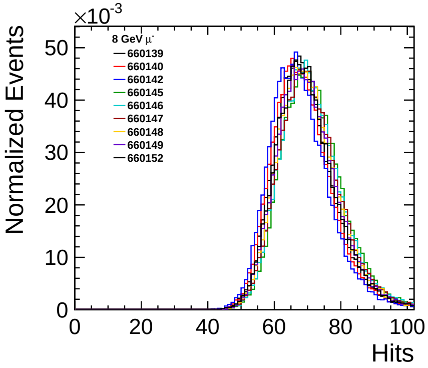
- Shower radius: standard deviation of *x*-*y* hit positions

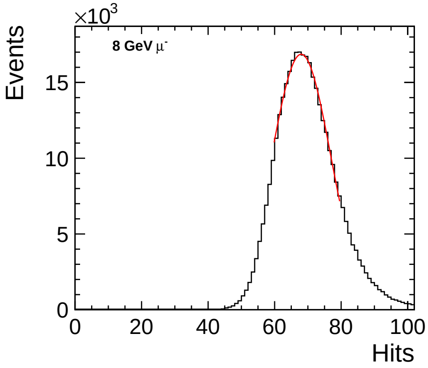
Muons


Events
×10^3
Run 660146, -8 GeV
All
e
μ
π
Hits
0
50
100
150
200
250
0
1
2
3

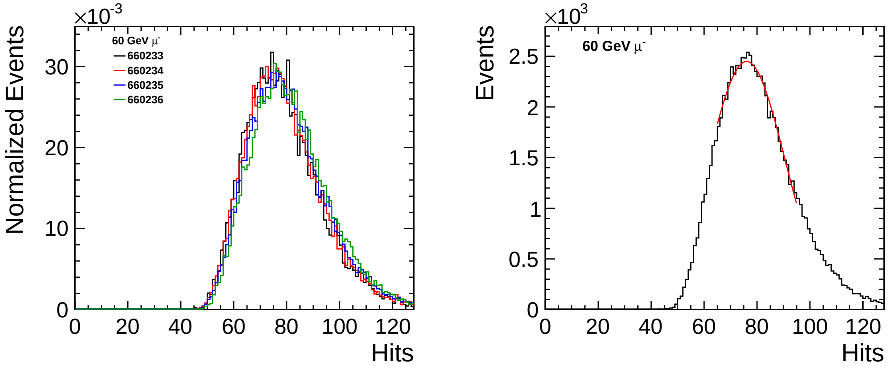

Events
Run 660234, -60 GeV
All
e
μ
π
Hits
0
200
400
600
800
1000
0
200
400
600

Muons

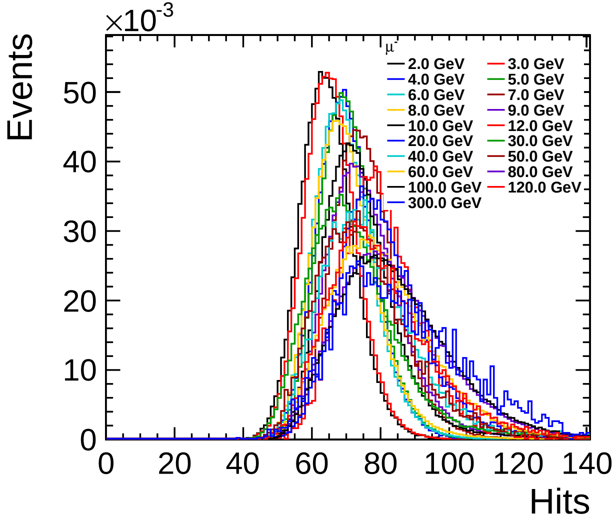

×10-3
8 GeV μ-
660139
660140
660142
660145
660146
660147
660148
660149
660152
Normalized Events
0
10
20
30
40
50
0
20
40
60
80
100
Hits


×10³
8 GeV μ-
Events
0
5
10
15
0
20
40
60
80
100
Hits

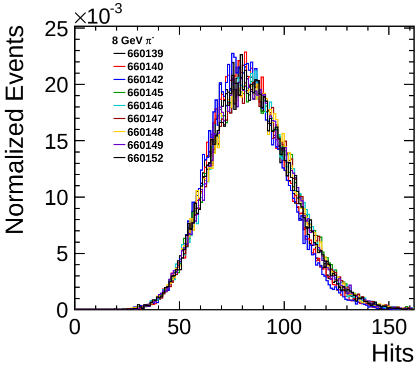
Muons

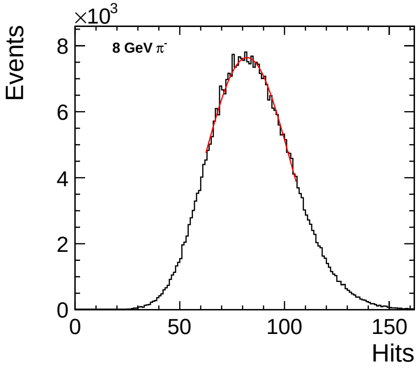

×10-3
Normalized Events
60 GeV μ-
660233
660234
660235
660236
0
10
20
30
0
20
40
60
80
100
120
Hits
×10³
Events
60 GeV μ-
0
0.5
1
1.5
2
2.5
Hits

Muons

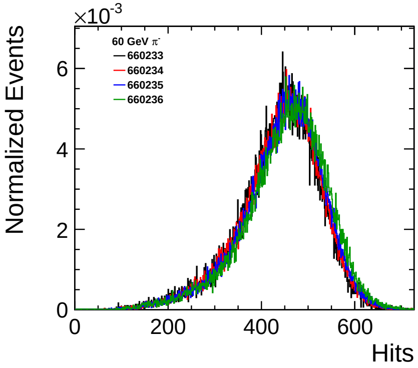

$\times 10^{-3}$
Events
Hits
μ⁻
2.0 GeV
3.0 GeV
4.0 GeV
5.0 GeV
6.0 GeV
7.0 GeV
8.0 GeV
9.0 GeV
10.0 GeV
12.0 GeV
20.0 GeV
30.0 GeV
40.0 GeV
50.0 GeV
60.0 GeV
80.0 GeV
100.0 GeV
120.0 GeV
300.0 GeV
0
10
20
30
40
50
0
20
40
60
80
100
120
140

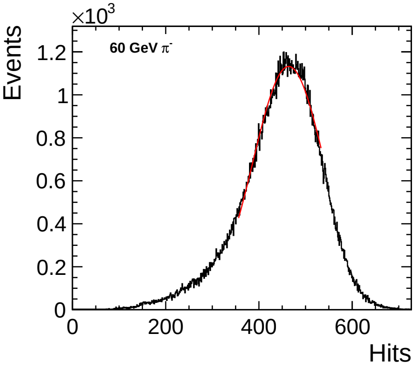
Pions


×10^-3
Normalized Events
8 GeV π-
660139
660140
660142
660145
660146
660147
660148
660149
660152
0
5
10
15
20
25
0
50
100
150
Hits

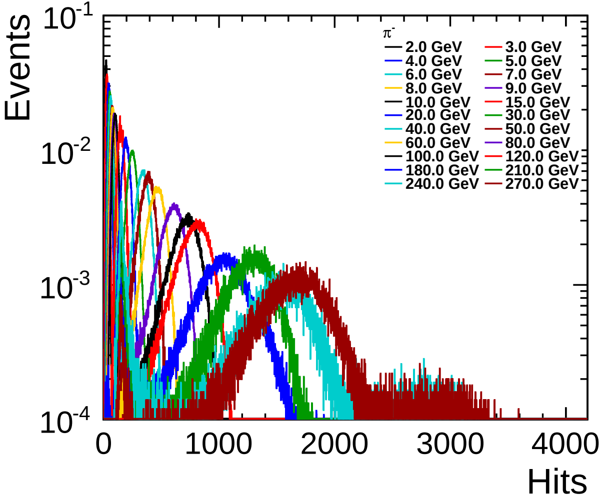

×10^3
Events
8 GeV π-
0
2
4
6
8
0
50
100
150
Hits

Pions

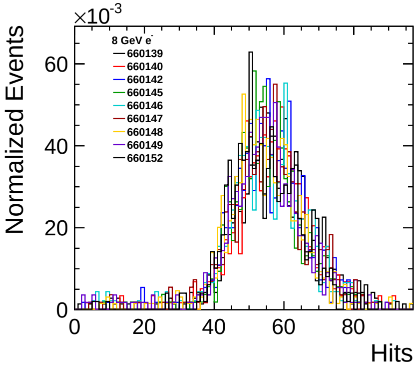

×10^-3
Normalized Events
60 GeV π-
660233
660234
660235
660236
0
2
4
6
0
200
400
600
Hits

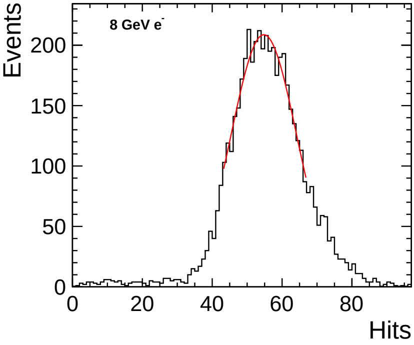

×10^3
Events
60 GeV π-
0
0.2
0.4
0.6
0.8
1
1.2
0
200
400
600
Hits

Pions

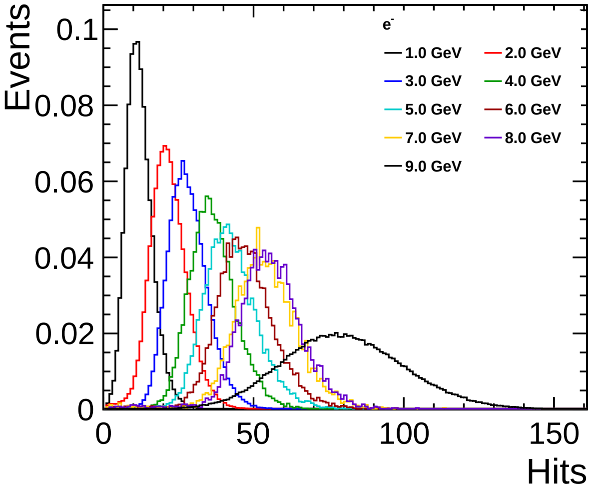

Events
Hits
π^-
2.0 GeV
3.0 GeV
4.0 GeV
5.0 GeV
6.0 GeV
7.0 GeV
8.0 GeV
9.0 GeV
10.0 GeV
15.0 GeV
20.0 GeV
30.0 GeV
40.0 GeV
50.0 GeV
60.0 GeV
80.0 GeV
100.0 GeV
120.0 GeV
180.0 GeV
210.0 GeV
240.0 GeV
270.0 GeV
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
1000
2000
3000
4000

Electrons

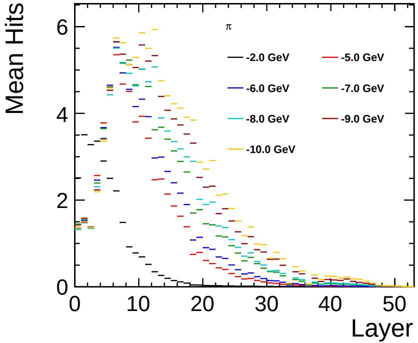

×10^-3
Normalized Events
8 GeV e^-
660139
660140
660142
660145
660146
660147
660148
660149
660152
0
20
40
60
0
20
40
60
80
Hits

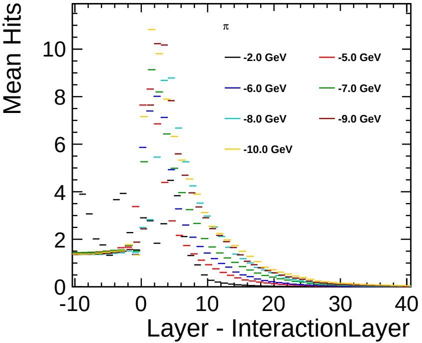

Events
8 GeV e^-
0
50
100
150
200
0
20
40
60
80
Hits

Electrons

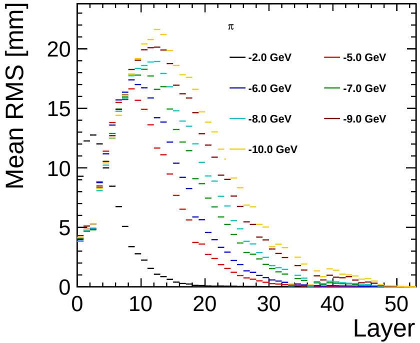

Events
0.1
0.08
0.06
0.04
0.02
0
50
100
150
Hits
e⁻
1.0 GeV
2.0 GeV
3.0 GeV
4.0 GeV
5.0 GeV
6.0 GeV
7.0 GeV
8.0 GeV
9.0 GeV

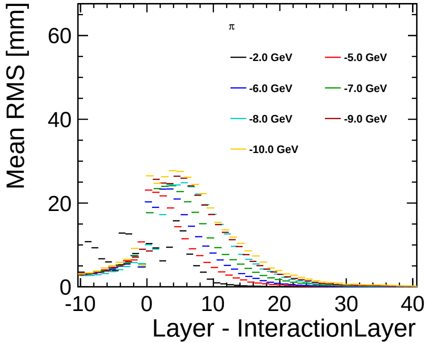
Shower Profiles





Shower Profiles





Summary

- Successful data taking at CERN PS and SPS in 2012
- Implementation of Mokka model for W-DHCAL main stack
- Digitization available in Marlin
- First iteration of reconstruction chain available
  - Event cleaning: hit times, double hits, box events
  - (Simple) particle identification
- Very first look at shower observables
- Code (world readable with CERN account):
  `svn+ssh://svn.cern.ch/reps/clicdet/trunk/DHCalAnalysis`

Outlook

- Implement (and release) complete Mokka model: main stack, tail catcher and beam line
- Validate hit digitization and calibrate with data
- Remove dead and noisy cells
- Improve particle identification $\Rightarrow$ requires simulation
- Calibrate tail catcher hits (steel absorber)
- Normalize runs at same beam momenta:
  $\Rightarrow$ remove temperature and pressure dependence, correct for varying layer efficiencies
- Compare shower observables with simulation

Backup

$e^{\pm}$ Selection

- Cerenkov A $= 1$
- Cerenkov B $= 1$
- Barycenter (layer) < 8
- nHits in first layer > 4 (if $p > 12\,\mathrm{GeV}$)
- Density > 4 (if $p > 12\,\mathrm{GeV}$)

$\mu^{\pm}$ Selection

- Barycenter (layer) > 20
- Density < 3
- nHits > 10
- nHits (last 4 layers) > 0

π^- Selection

- Cerenkov A $= 0$
- Cerenkov B $= 0$
- Interaction layer > 2 (if $p > 3\,\text{GeV}$)
- Density > 2 (should increase with beam momentum)

π^+ Selection

- Cerenkov A $= 1$
- Cerenkov B $= 0$ ($= 1$ if $p > 10\,\mathrm{GeV}$)
- Interaction layer > 2 (if $p > 3\,\mathrm{GeV}$)
- Density > 2 (should increase with beam momentum)

p Selection

- Cerenkov A = 0
- Cerenkov B = 0
- Density > 2 (should increase with beam momentum)