W-DHCAL Digitization

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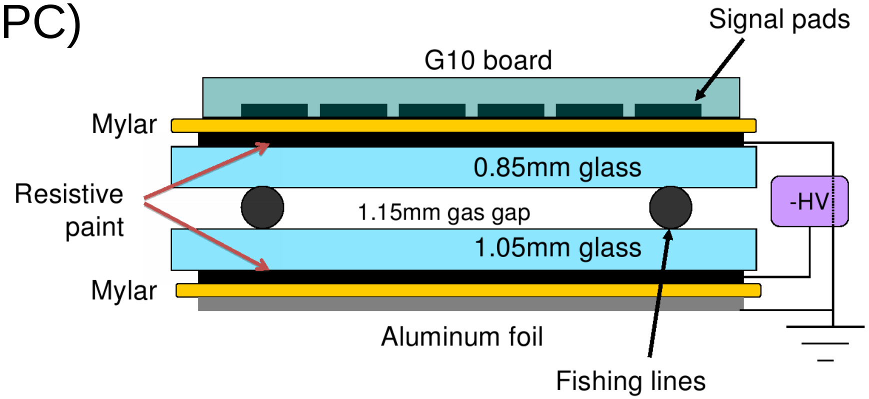
CALICE Collaboration Meeting at Argonne

DHCAL prototype

<u>Active element:</u> Thin Resistive Plate Chambers (RPC)
- Glass as resistive plates (~1 mm)
- single 1.15 mm thick gas gap
- 1x1 cm² pads
- digital readout:
    - 1 bit discriminator per pad/channel
    - Timestamp (100 ns time resolution)



<u>1 layer:</u>
- 3 RPCs (32 x 96 cm²)
    - ⇒ 96x96 pads = 9216 pads

<u>DHCAL:</u> 54 layers
- main stack: 39 layers with tungsten absorber
    - 10 mm thick W plate
- tail catcher:
    - 8 layers with steel absorber (25.4 mm thick)
    - 7 layers with steel absorber (100 mm thick)

⇒ ~500'000 channels

- RPC cassette contents, layout, and sensitive detector description from **steel DHCAL simulation**

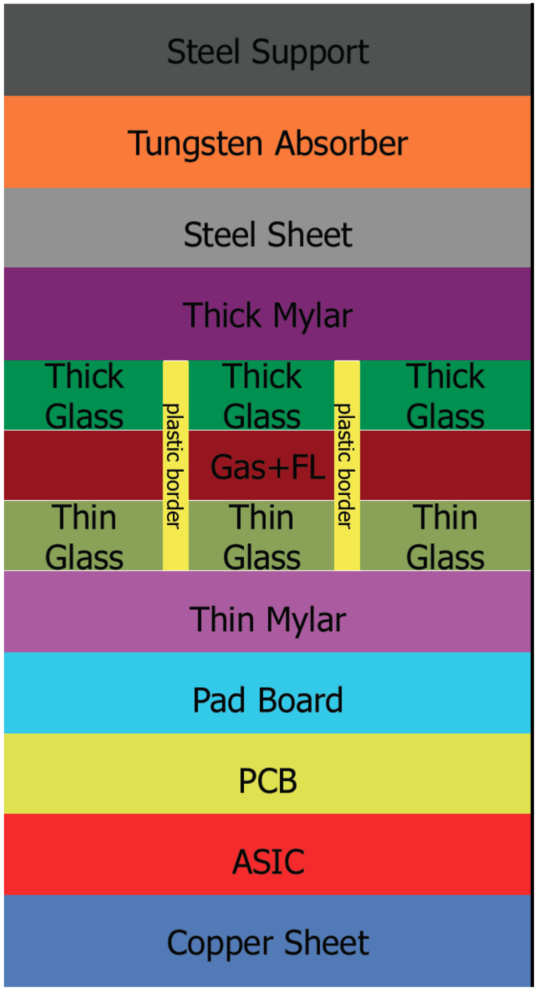
- Octogonal tungsten absorbers + support from **W-AHCAL simulation**

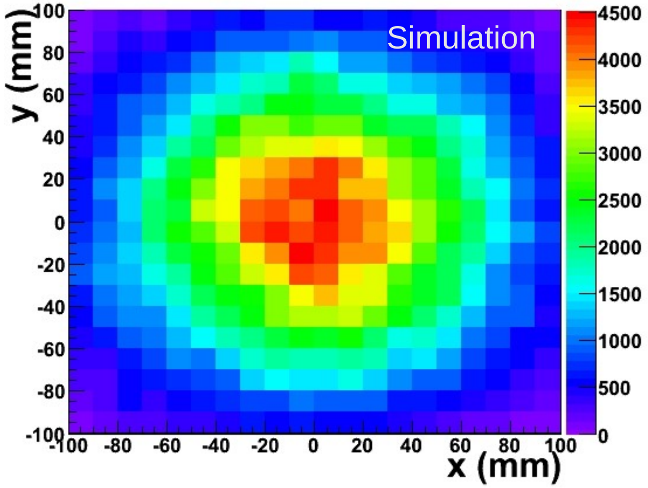
- Beam instrumentation (scintillators, Cerenkov counters, and Wire Chambers) from **W-AHCAL simulation**

- Only the main stack is included in the simulation
  → only 39 layers in the next slides

- Beam profile → 5 cm width Gaussian
  → 30 mrad angular spread

- Secondary particle production cut → 5 μm





Digitization

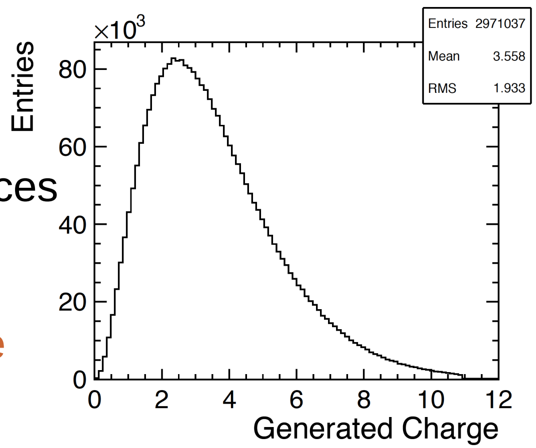
Re-implementation of RPCSim as a Marlin Processor

- Intro : RPCSim
- Strategy for tuning RPCSim
- Event Selection
- Results

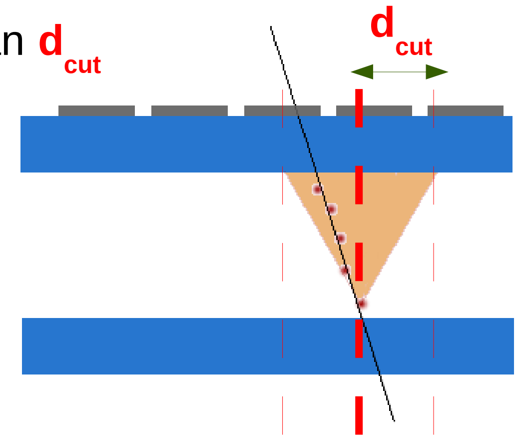
Charge generation

- Collect all energy deposits from Mokka
  → avalanche starting points

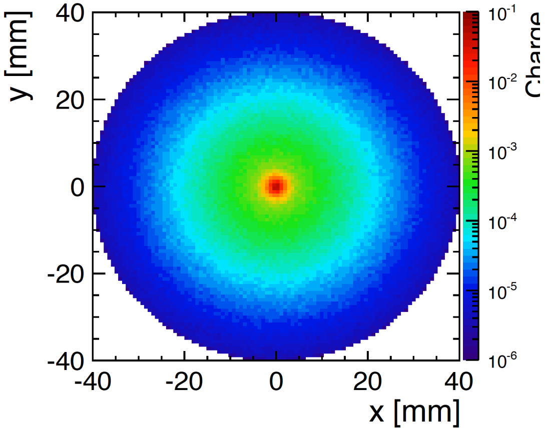
- Charge generation parametrized from data taken with analog RPC
  → The charge is randomly generated from distribution
  → Shift applied to charge distribution to accommodate possible differences in the operating point of RPCs **Q_0 ($Q_e = Q - Q_0$)**
  → Correct in average:
    - Do not take into account the distance of the ionization from anode
    - Ignore higher ionization probabilities of non-MIP particles



- Local inefficiencies
  → avalanche depletes electric field and prevents secondary avalanches within a small radius
  → apply a distance cut **d_{cut}** :
    - One point of a pair of points randomly discarded if closer than **d_{cut}**
    - To be tune with $e^{+/-}$ data



Charge spread



- Charge distributed in the XY plane :
  → Several spread models

$$f(\rho) = (1 - r) \cdot e^{-\frac{\rho}{S_1}} + r \cdot e^{-\frac{\rho}{S_2}}$$

$$f(\rho) = (1 - r) \cdot e^{-\left(\frac{\rho}{\sigma_1}\right)^2} + r \cdot e^{-\left(\frac{\rho}{\sigma_2}\right)^2}$$

→ Need to determine charge integral for each individual pad (MC method)
- Pre-calculated look up table
- Take into account symmetry

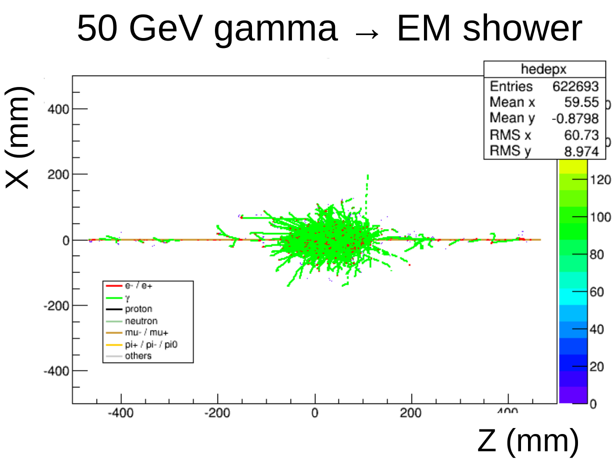
→ Tune spread model parameters with MIPs :
- S_1 : Slope of the exponential decrease of charge induced in the readout plane
- S_2 : Slope of 2nd exponential, to improve the description of the tail
- r : Relative contribution of the 2 exponentials

- Apply trigger threshold

Strategy for tuning RPCSim

1) - Select 'pure' MIPs (muons without secondary EM showers)

- Tune spread and trigger threshold parameters
  → Minimization using 'Nhits per layer' distribution
  → 10'000 events per parameter set (~30 min)
  → Huge parameter space

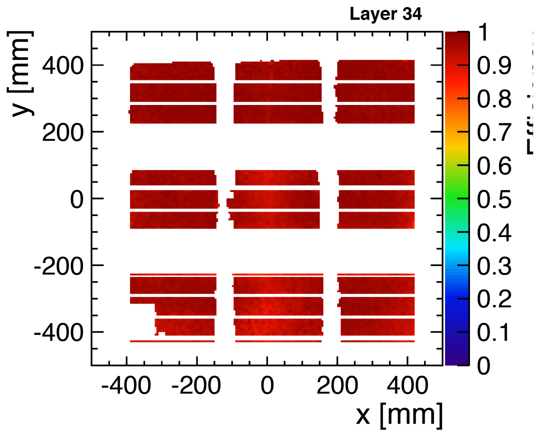


2) - Select all muons

- Tune d_{cut} and Q_0 parameters
  → plan: Q_0 in the previous step, e- for d_{cut}

3) - Check with electron and pions data

To do : Tune parameters in clean regions (see Christian's talk)



Event selection

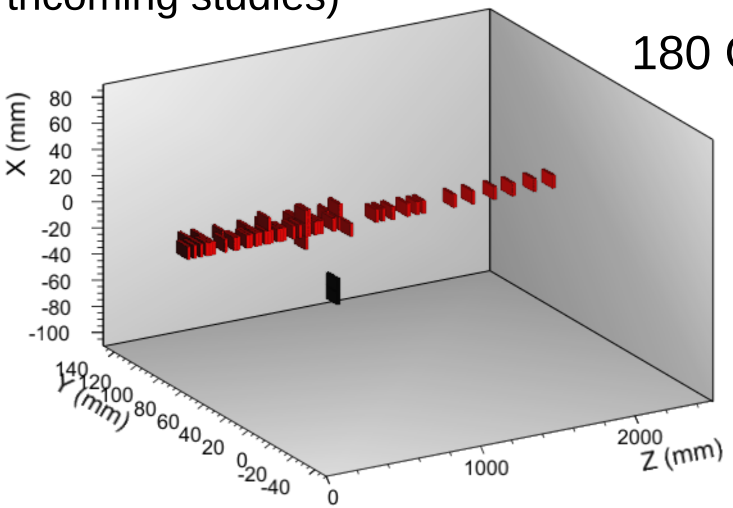
Preselection :

→ Filter box events, dead RPC modules, noisy/dead channels/ASICs
→ Remove duplicate hits (same position, different timestamps)

Reconstruction

→ Remove out-of-time hits: only keep events in a 300 ns window
→ Nearest neighbor clustering of adjacent cells
→ Hough transform based track reconstruction
(not the most efficient in this case but useful for forthcoming studies)

180 GeV μ



Final selection

→ Ntracks = 1
→ Ncluster > 15

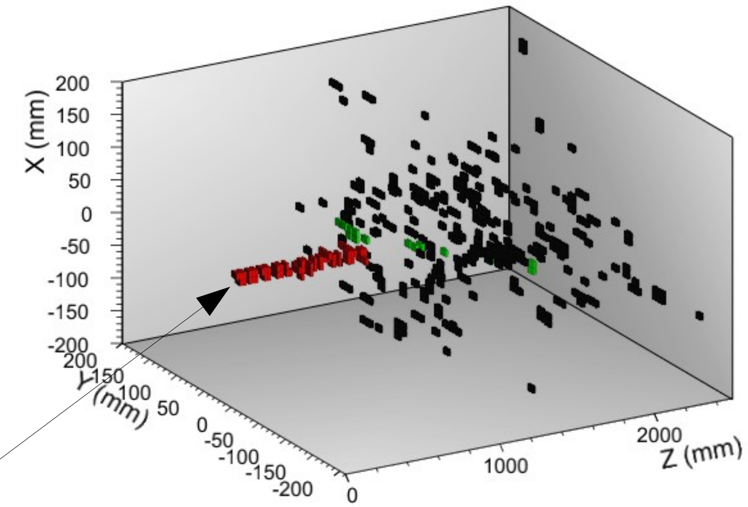
→ pure MIP muons : remove events with 2 consecutive layers with Nhits > 9

<u>To do :</u>
Slope less than 3 degrees

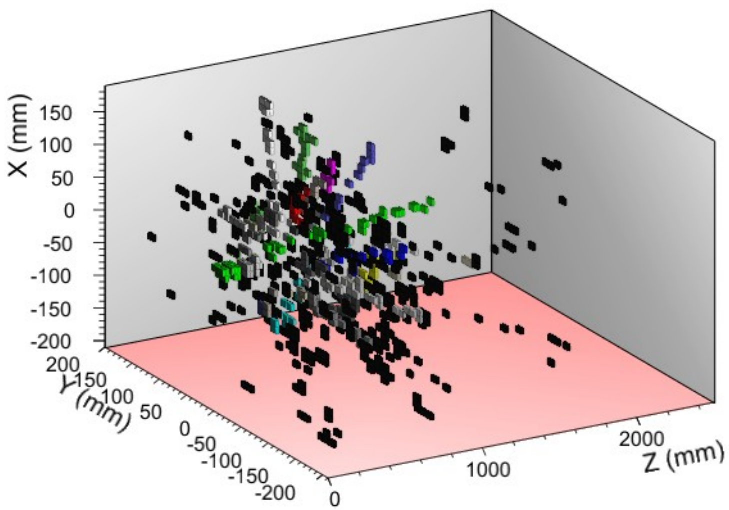
Parenthesis about Hough transform

300 GeV pions

- Black = clusters not linked to a track
- 1 color per track

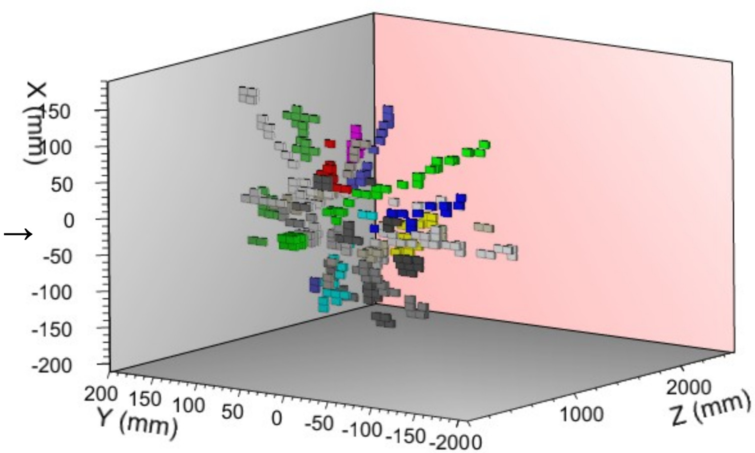


Track of the pion before hadronic interaction



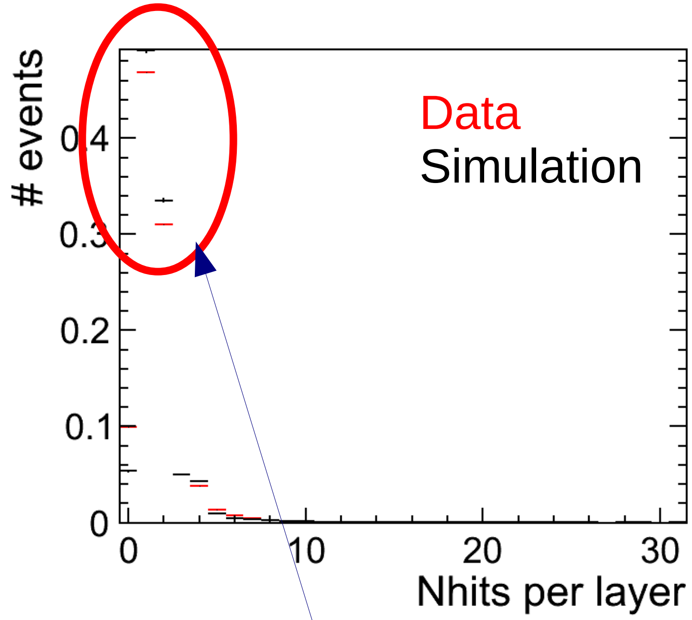
Same event

← all clusters
Only track clusters →

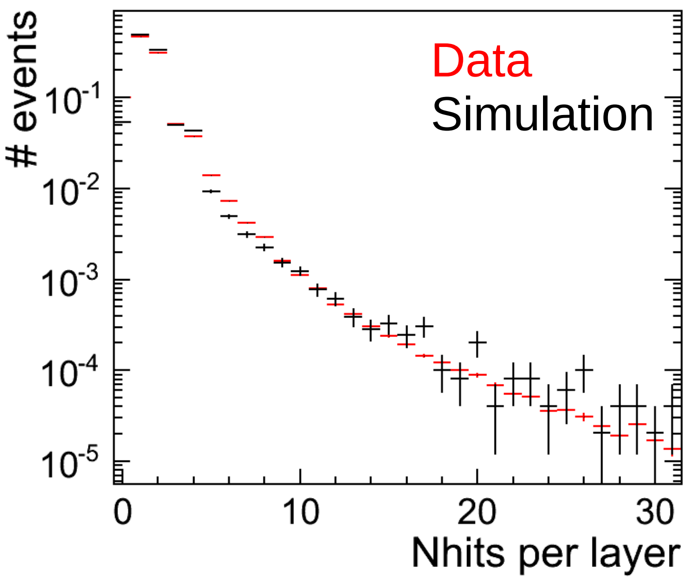


Digitizer tuning with muons

Run 660356 – 180 GeV μ

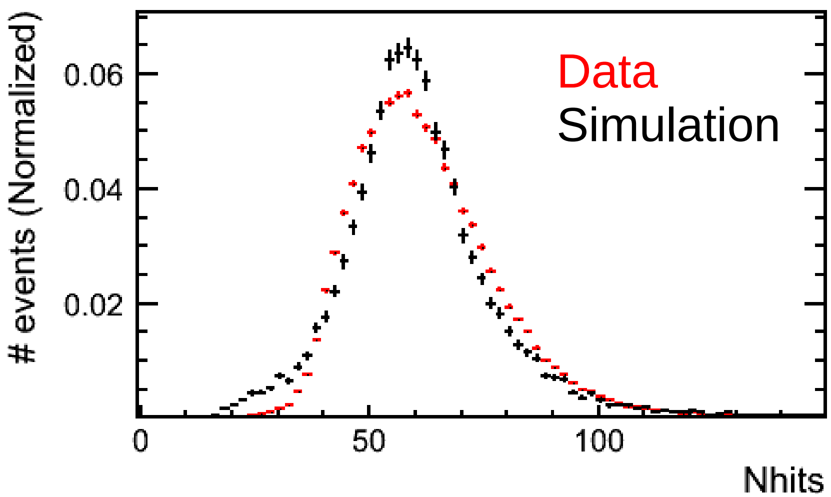


Core is not well reproduced



Tail seems OK

S_1	0.4 mm
S_2	4 mm
r	2%
TT	0.012
d_{cut}	1.8 mm
Q_0	0.2 pC



To do: - needs further improvements
- compare parameter values with Steel-DHCAL digitization

First look at pions

Preselection :

→ Filter box events, dead RPC modules, noisy/dead channels/ASICs
→ Remove duplicate hits (same position, different timestamps)

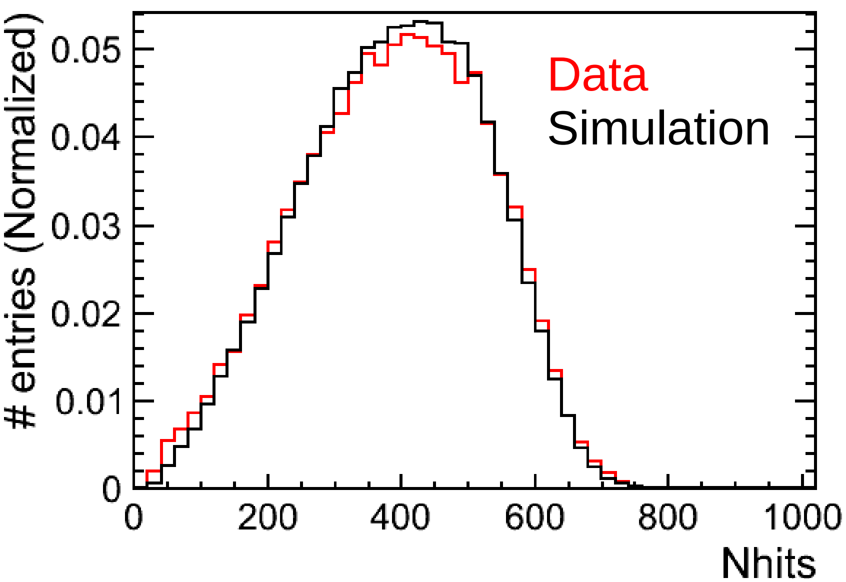
Reconstruction

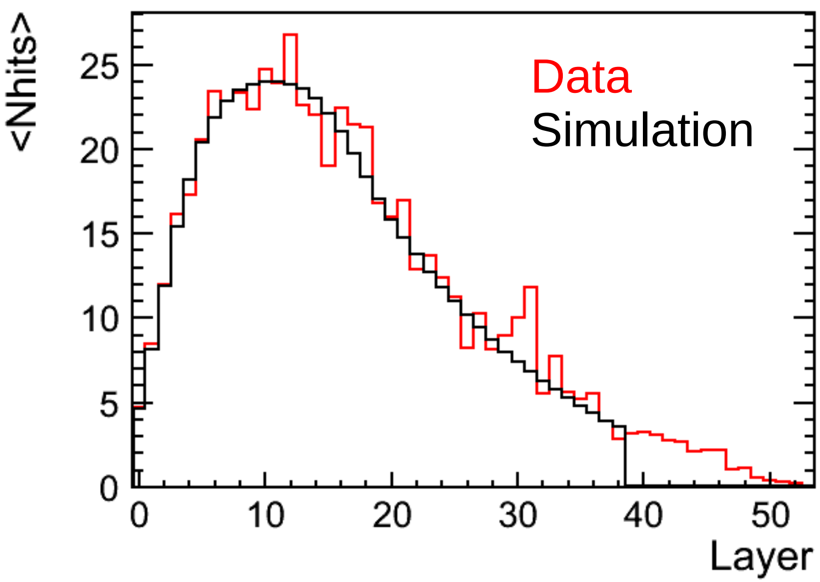
→ Remove out-of-time hits: only keep events in a 300 ns window
→ Nearest neighbor clustering of adjacent cells

Final selection

→ interaction layer < 15
→ nHits > 20
→ hit density > 3
→ at least 20 layers with hits

Run 660259 – 80 GeV π





NOTE : This result seems too good, probably some mistakes are hidden somewhere

Summary and outlook

Re-implementation of RPCSim as Marlin processor

Digitizer parameters are tuned with muons

→ ongoing work

→ prediction for electrons and pions

→ First results look promising

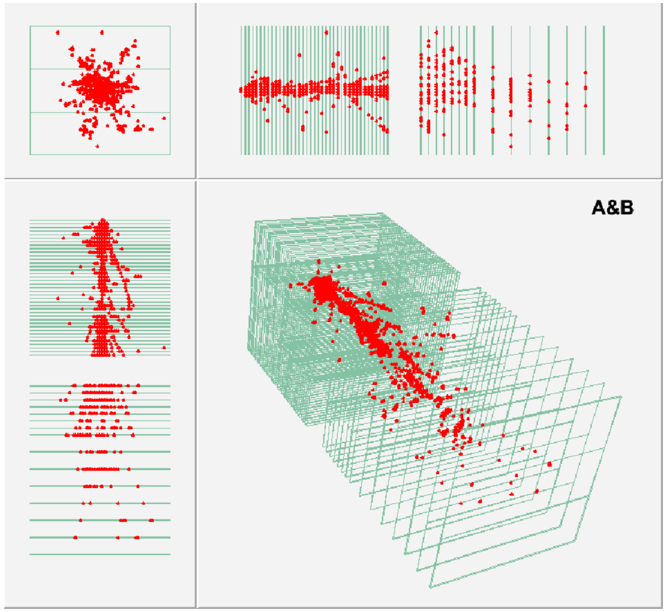
Finalize Mokka model including beam line instrumentation

→ Need to include local effects in simulation / digitization

- effects of fishing lines and borders (already implemented in Mokka)
- local efficiencies are crucial for data–Monte Carlo comparison

Back up

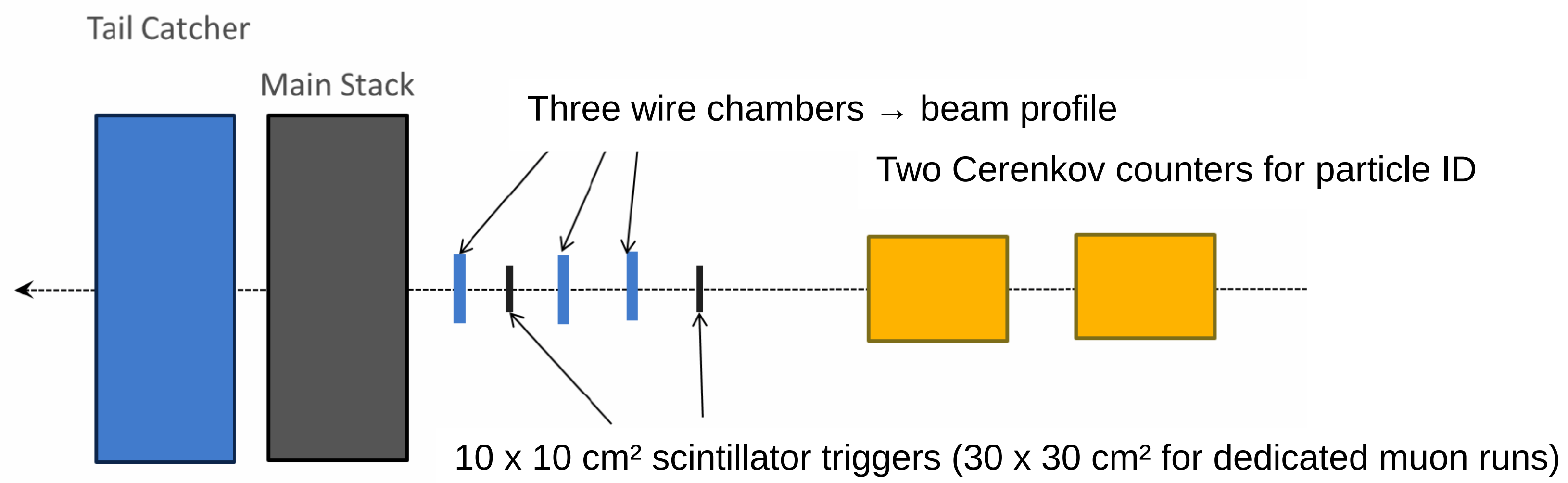
Test beam setup (2012)



PS (2 weeks)
- 1 – 10 GeV/c
- electrons, pions, protons
- RPC rate capability OK
- Data taking with ~500 triggers/spill

SPS (4 weeks)
- 10 – 300 GeV/c
- electrons, pions
- RPC rate capability problem → running with limited rate: 250 – 500 triggers/spill

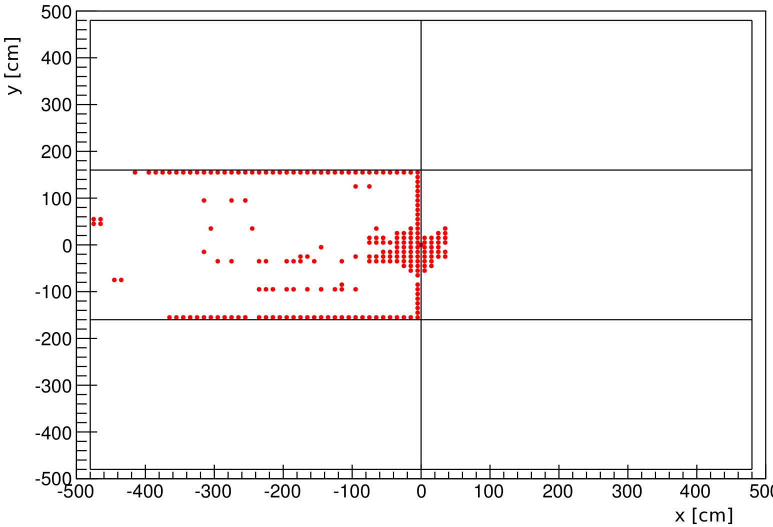
~ 30 million events recorded



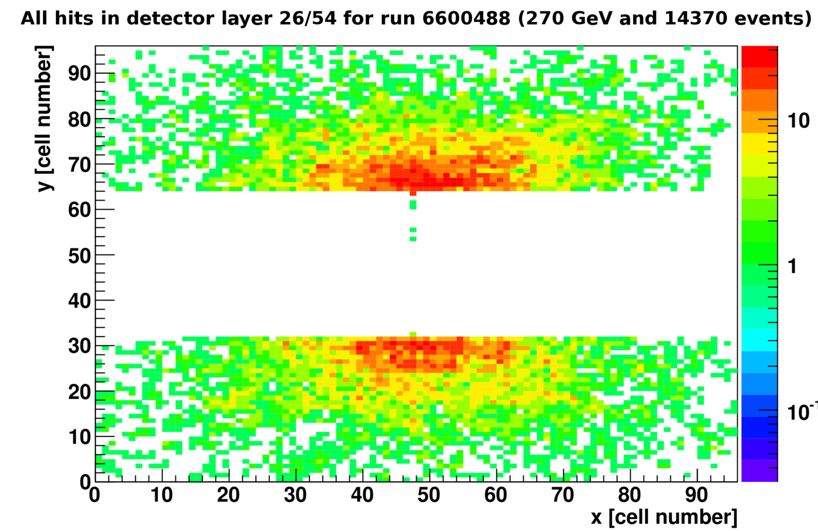
Data quality

H. Holmestad (CERN, University of Oslo)

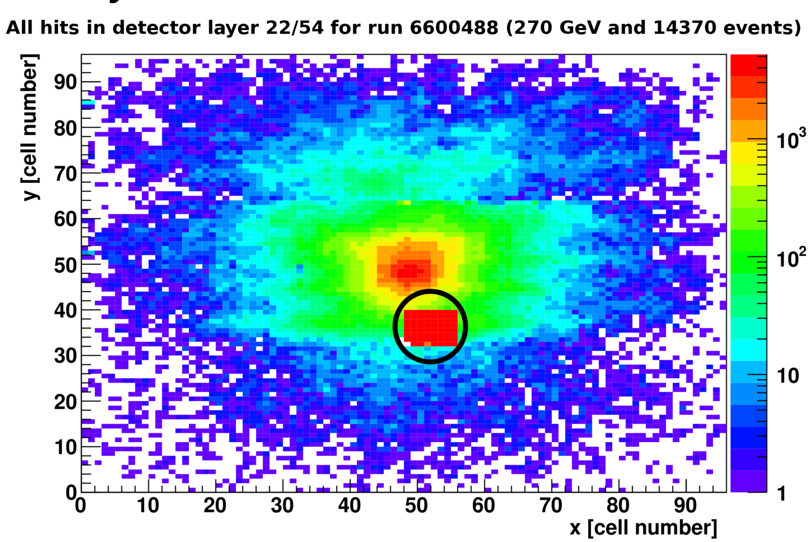
Box events:
- box shaped pattern in individual layers
- hits created along boundary of front end board



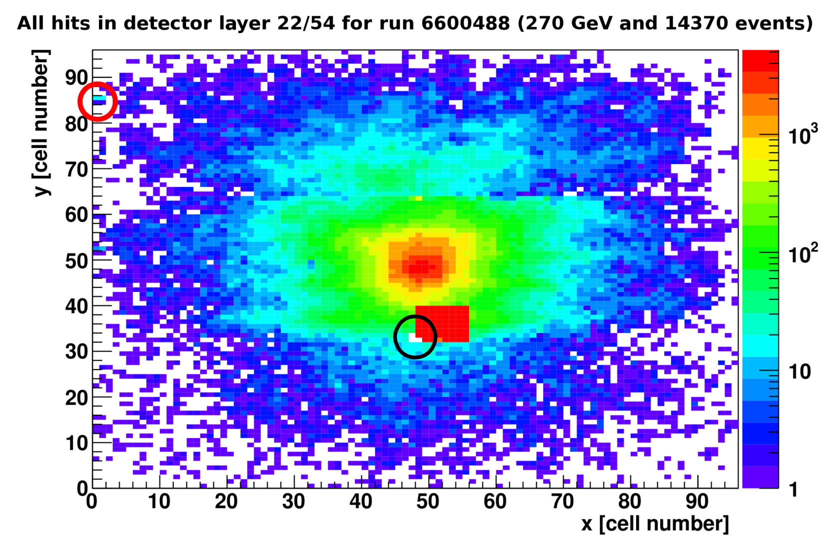
Dead RPC modules:



Noisy and dead ASICs:



Noisy and dead cells:

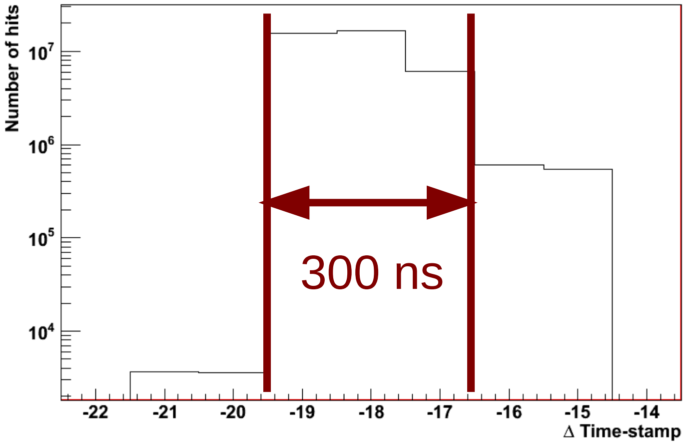


$\Rightarrow$ Taken away from the data

Reconstruction

Remove duplicate hits (same position, different timestamps)

Remove out-of-time hits: only keep events in a 300 ns window



Nearest neighbor clustering of adjacent cells