

Noise and Cosmics in the DHCAL



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Construction of the DHCAL

Description of the DHCAL

40 planes of RPCs to be inserted into the AHCAL structure
Each plane $96 \times 96 \text{ cm}^2$ and subdivided into 3 RPCs ($32 \times 96 \text{ cm}^2$)
Readout with $1 \times 1 \text{ cm}^2$ pads
Each pad read with 1 – bit (digital) resolution
Total of ~350,000 readout channels

Status of the construction

Almost complete
Tests and measurements at every step in the construction process

Details → talk in the DHCAL session

Setup for noise and cosmic ray measurements

Test stand

Up to 9 RPCs tested at once
RPCs in horizontal position

Operation of RPCs

High voltage set at 6.5 kV (default is 6.3 kV)
High voltage scans from 5.8 to 6.8 kV
Gas premixed (by us)

Data taking

Trigger-less mode: noise and cosmics
Triggered mode: noise and cosmics



Analysis effort

DAQ software

← Jim Schlereth

Event building

← Lei Xia (JAVA based)

← Jacob Smith (C++ code)

Noise analysis

← Lei Xia (using binary files, C++)

← Kurt Francis (using ASCII files, C++)

← José Repond (using ASCII files, F77)

Cosmic ray analysis

← Daniel Trojand (trigger-less data, C++)

← Jacob Smith (triggered data, C++)

← José Repond (trigger-less data, F77)

Event building

Data format

Time-stamp (with 100 ns resolution), chip address, hit pattern

Task

Build events from list of unsorted time-stamps
(somewhat tricky)

Programs

JAVA – based (limited to 1 VME crate - out phased)
C++(no limits)

Output

Binary file
ASCII file
Split into noise data and cosmic ray events with at least 3 layers with hits

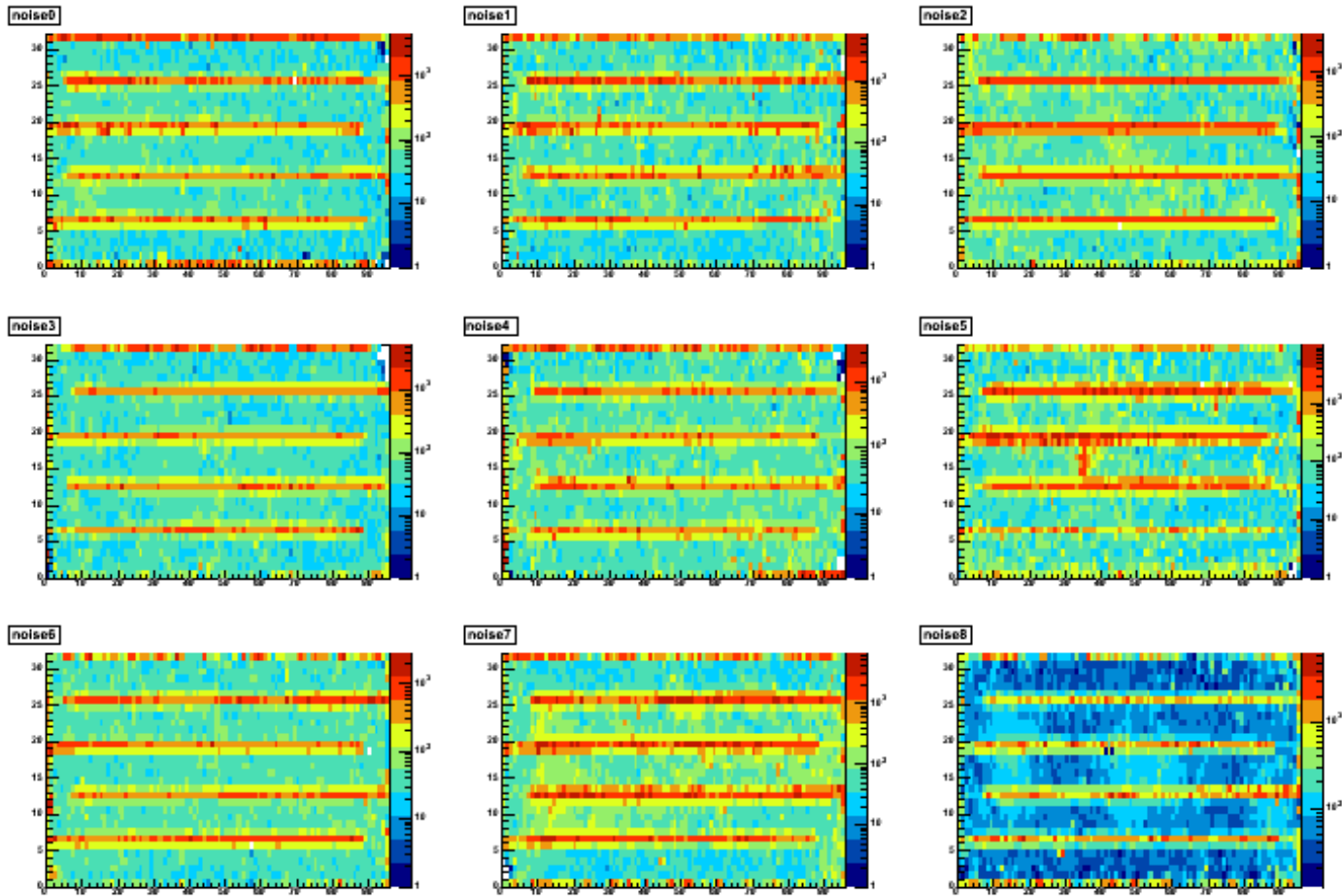
Status

Complete, apart from possible need for event recovery

```
t -1 -1 -1  
t x y z  
t x y z  
t x y z  
t x y z  
....  
t -1 -1 -1  
t x y z  
t x y z  
.....
```

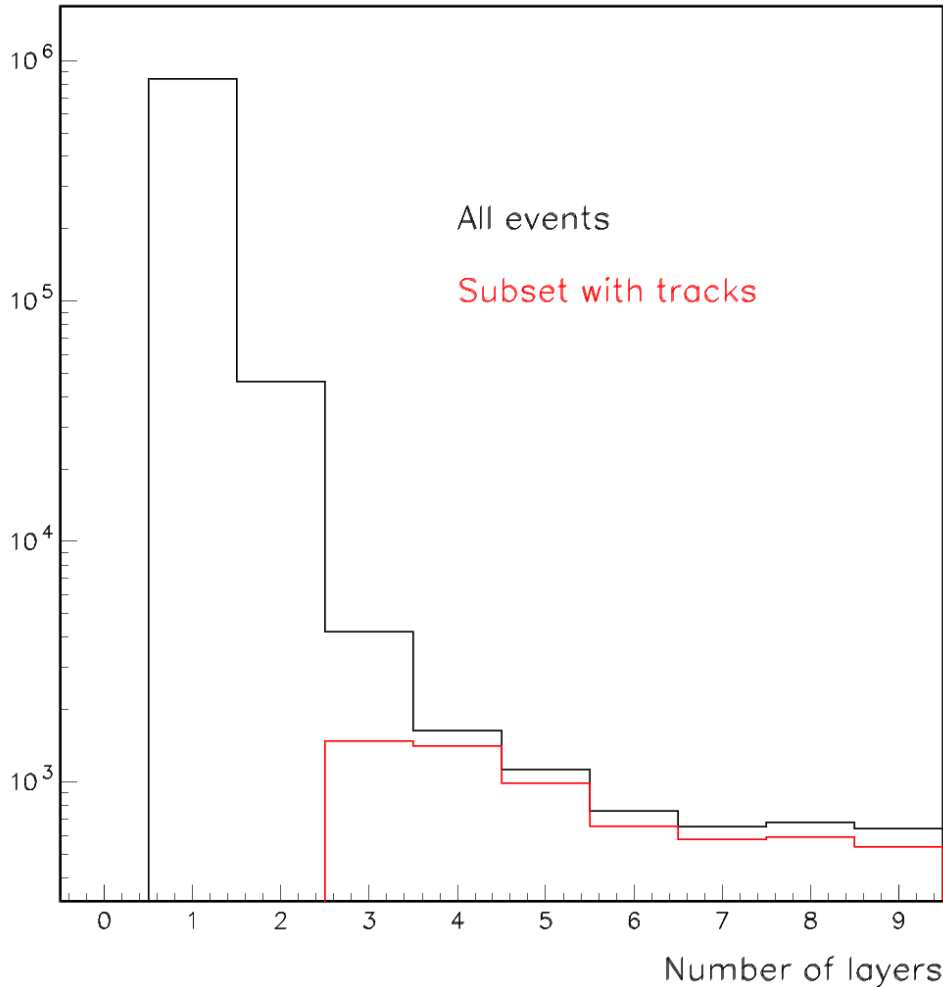
Analysis of trigger-less noise data

Typical run lasts 5 minutes



Fishing lines clearly visible

Number of layers with hits



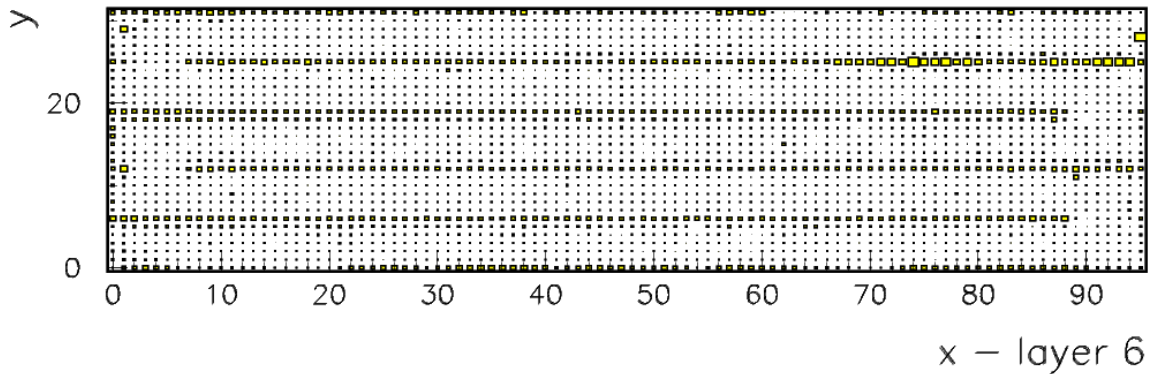
Events with $N_{\text{hits}} > 300$ removed

Tracks defined with a minimum length of 3 layers
 $\chi^2/\text{DOF} < 1.0$ (high quality tracks)

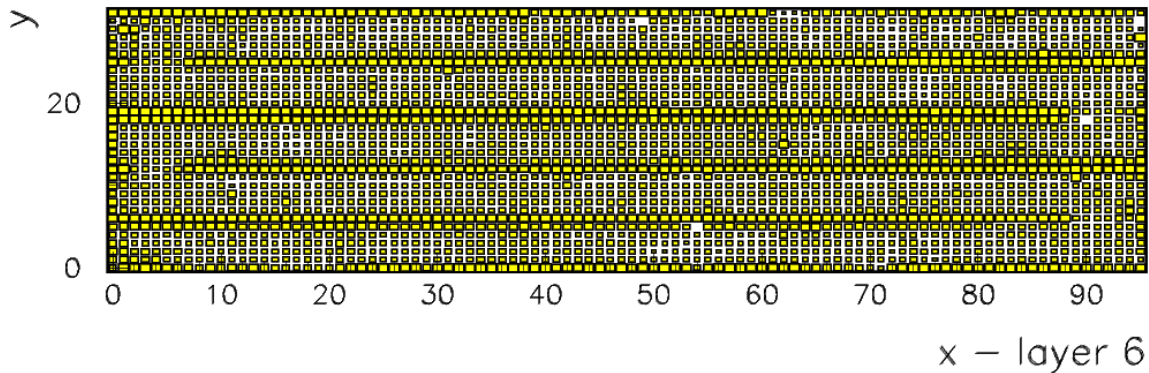
Most events with > 3 layers have tracks

Some events without high quality tracks and with > 3 layers:
showers?
(let's not worry about them)

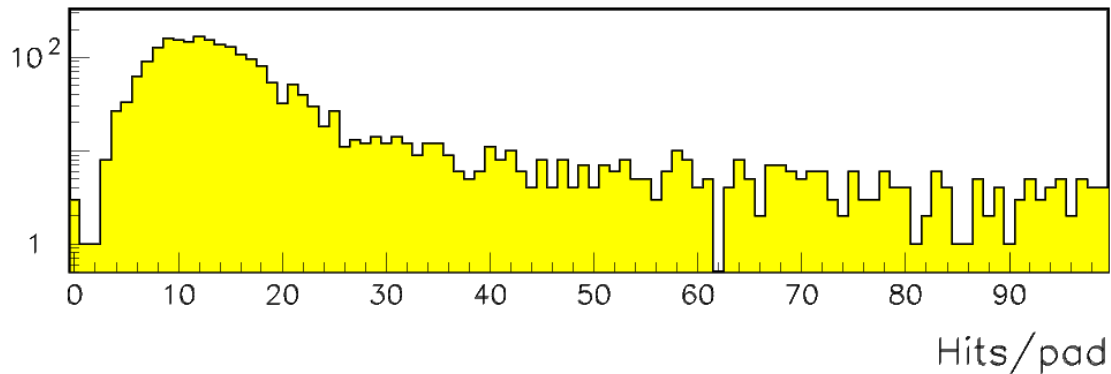
Cosmics removed: Detailed look at a specific layer (307,377 events)



Linear z scale



Logarithmic z scale



$$P(0) = e^{-\mu} \\ = 4.54 \times 10^{-5} \\ \text{(with } \mu = 10)$$

Probability of one
of the 3072 pads is
zero =

$$3072 \times P(0) = 14\%$$

Fishing lines clearly visible
Some dead channels

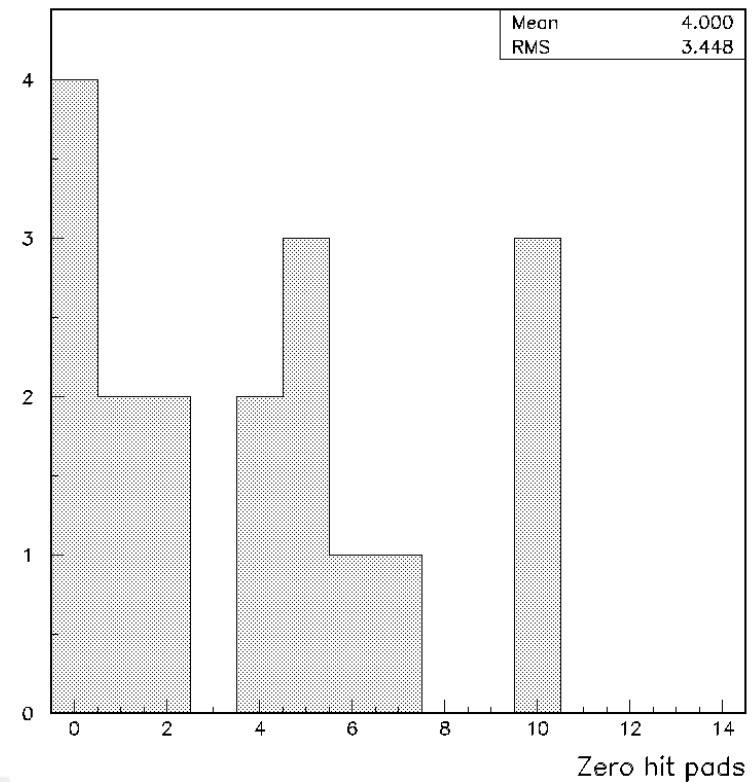
Summary at 6.5 kV

Layer	Total hits	Rate = N/300/2 /1536	Number of zero hit pads (left)	Number of zero hit pads (right)
0	356623	0.39	5	10
1	379405	0.41	5	2
2	328092	0.36	1	7
3	269035	0.29	2	6
4	322551	0.35	1	10
5	586540	0.64	0	10
6	307377	0.33	0	4
7	480360	0.52	5	0
8	368437	0.40	4	0

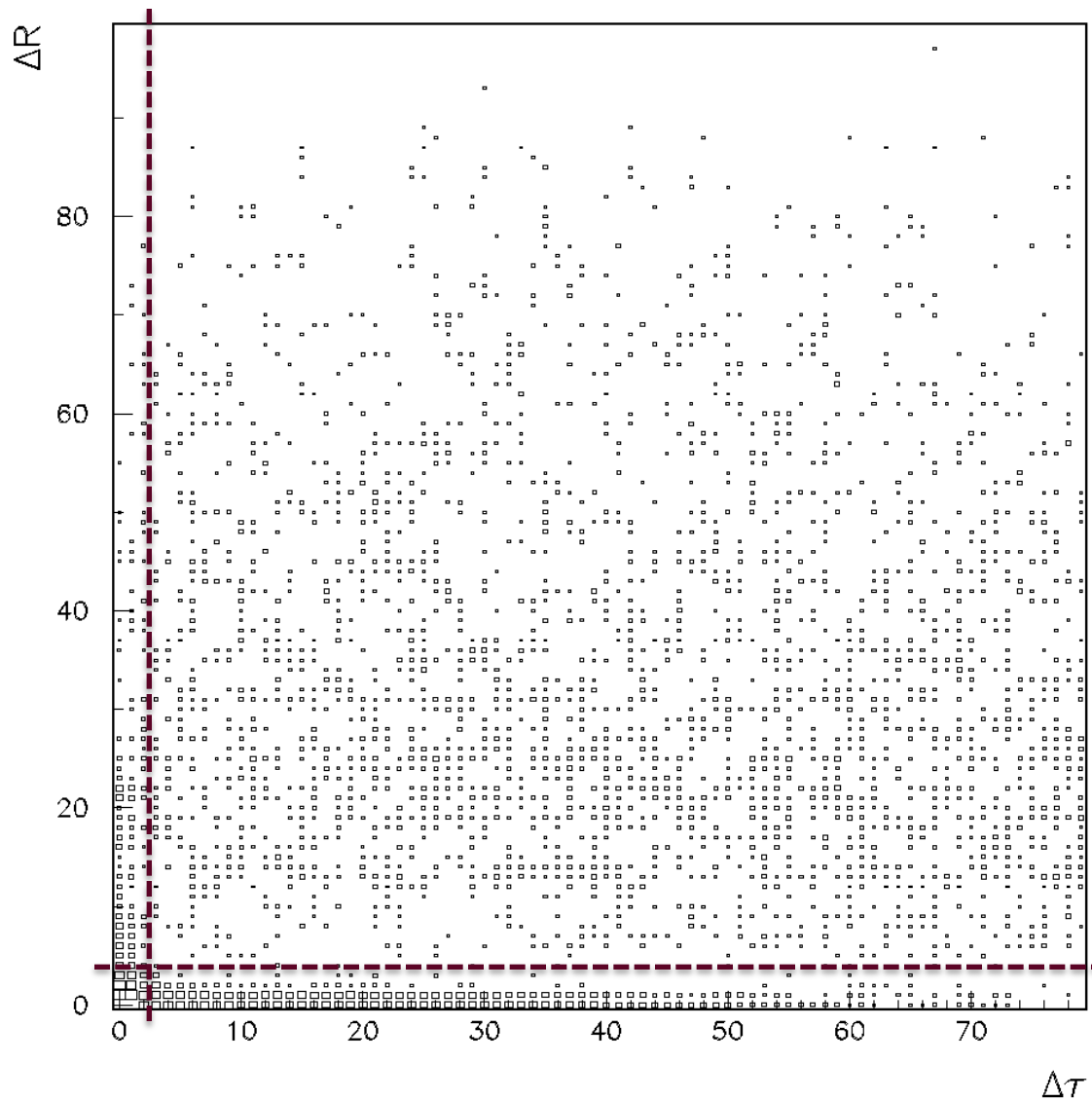


Noise rate in Hz/cm²

Dead channels/board



Single layer and low hit number analysis



Selection

$$N_{hit} = 2, 3, 4$$

Plot

ΔR ... distance between hits
 $\Delta \tau$... time bins between hits
Logarithmic z scale

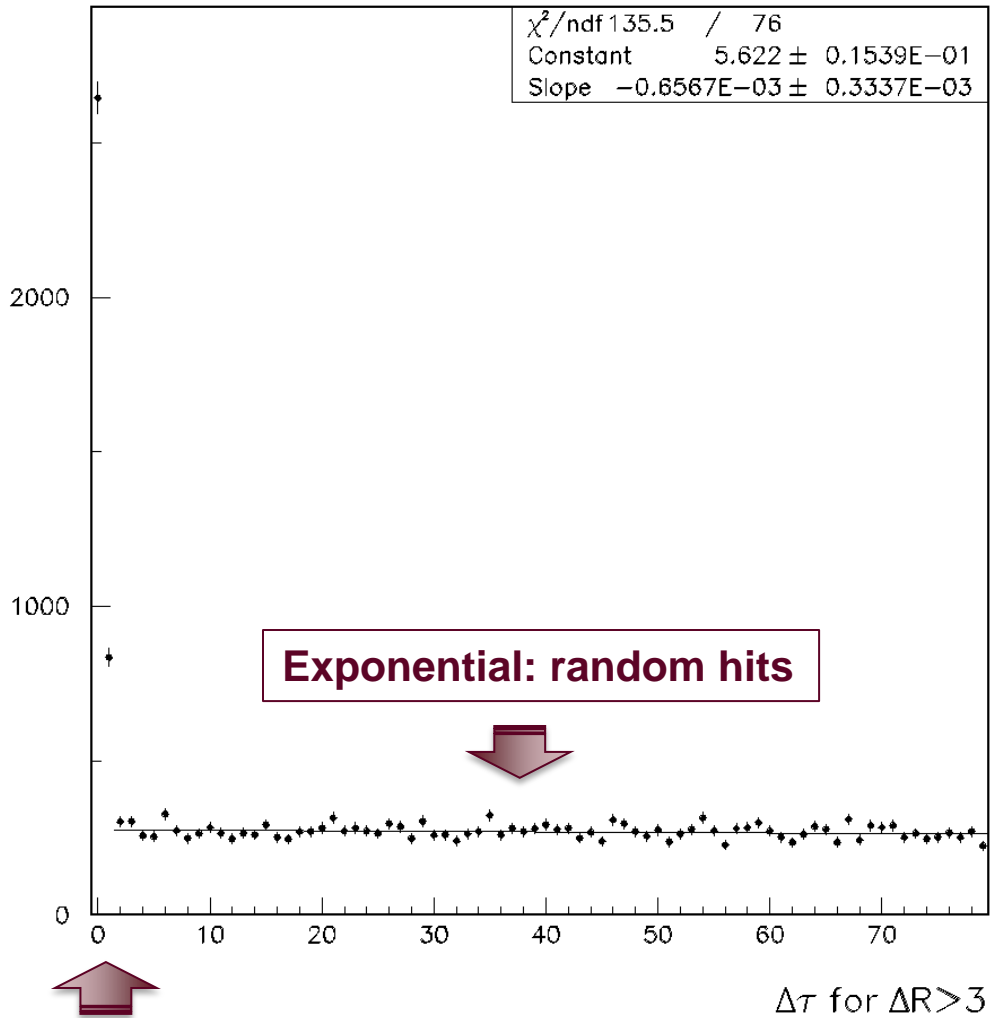
3 regions

I $\Delta R < 4$

II $\Delta \tau < 4$

III Remainder

Large distances



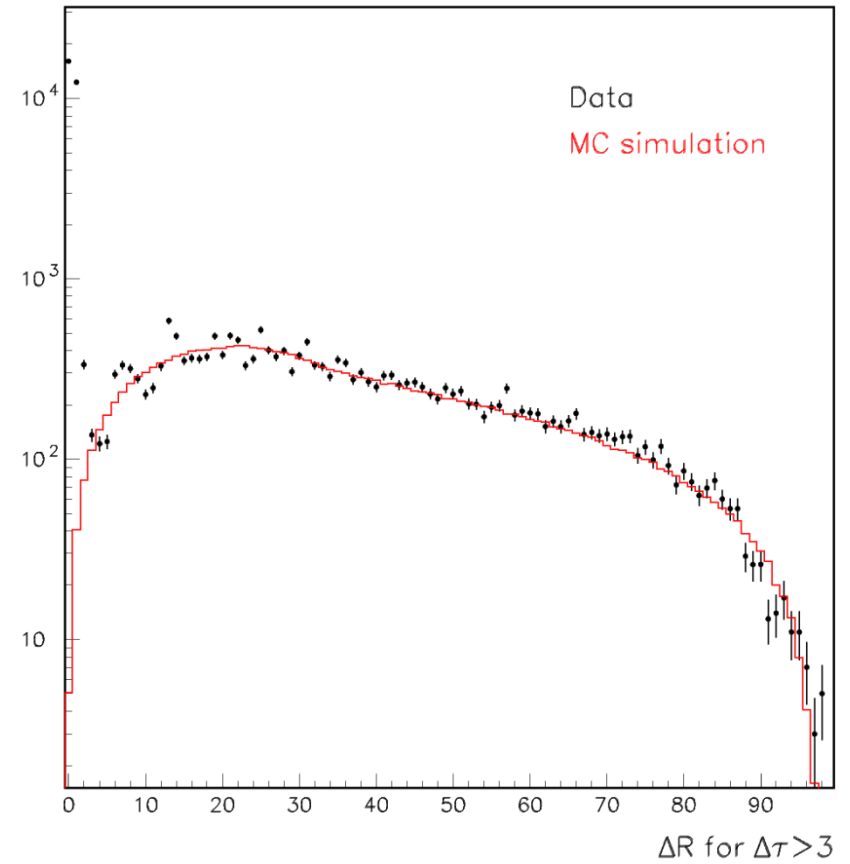
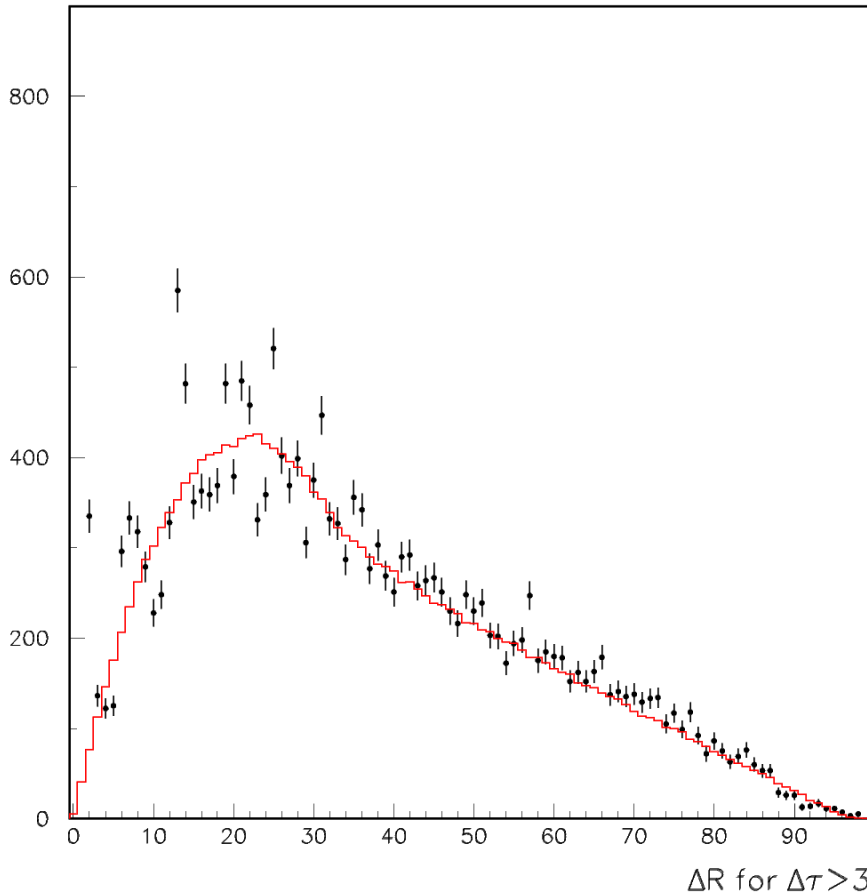
Average time between hits =
 $1/\text{slope} = 1522 \times 10^{-7} = 1.5 \times 10^{-4} \text{ s}$

Noise rate = slope =
 $6.6 \times 10^{-4} \times 10^7 / (18 \text{ boards} \times 1536) =$
 $0.24 \pm 0.12 \text{ Hz/cm}^2$

Large time differences

MC simulation

No correlation between hits
Pad structure not implemented



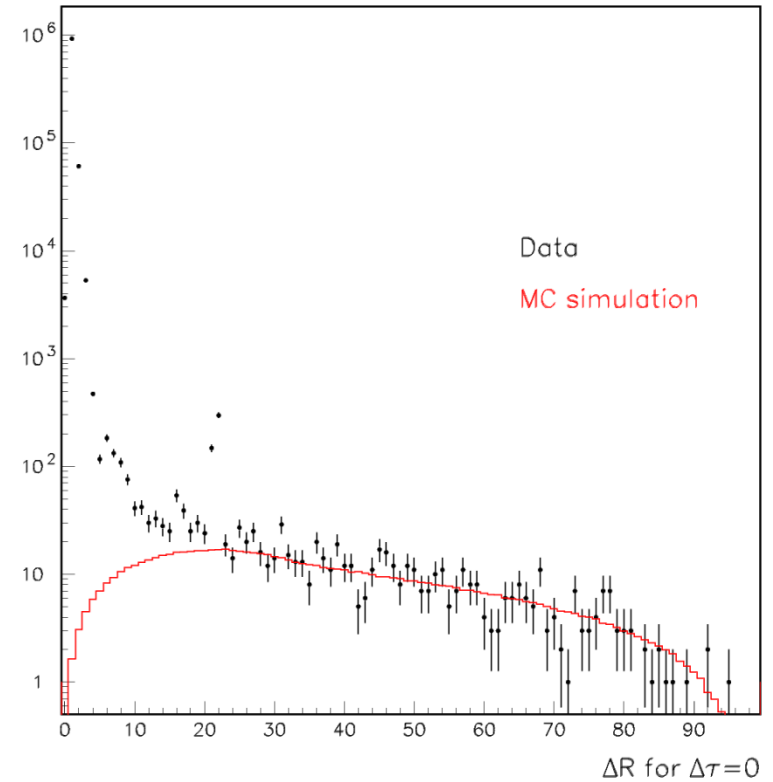
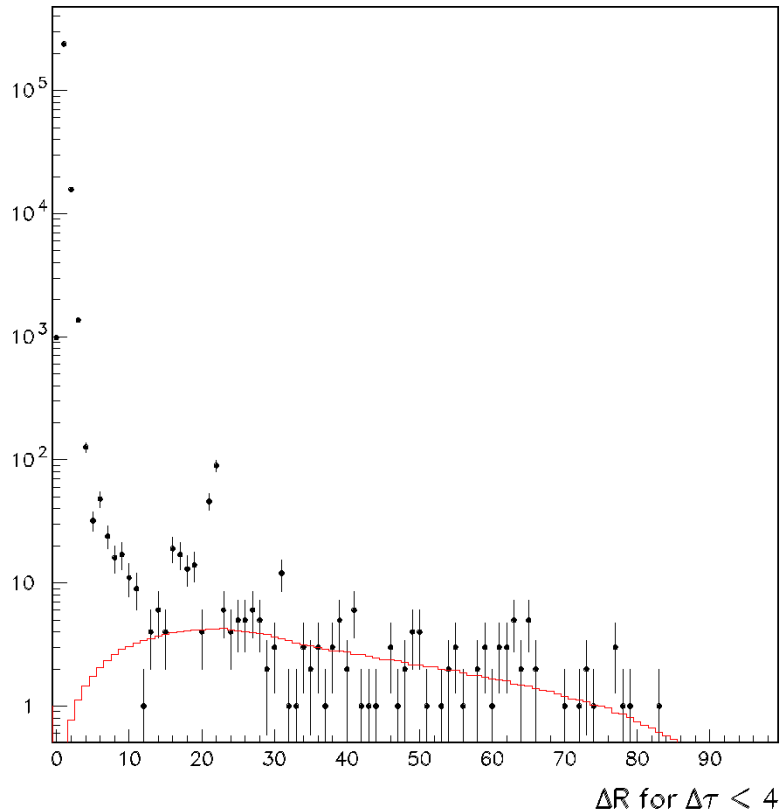
Hits obviously random
→ no correlations

Fluctuations in linear plot most likely due to binning effects

Small time differences

MC simulation

No correlation between hits
Pad structure not implemented



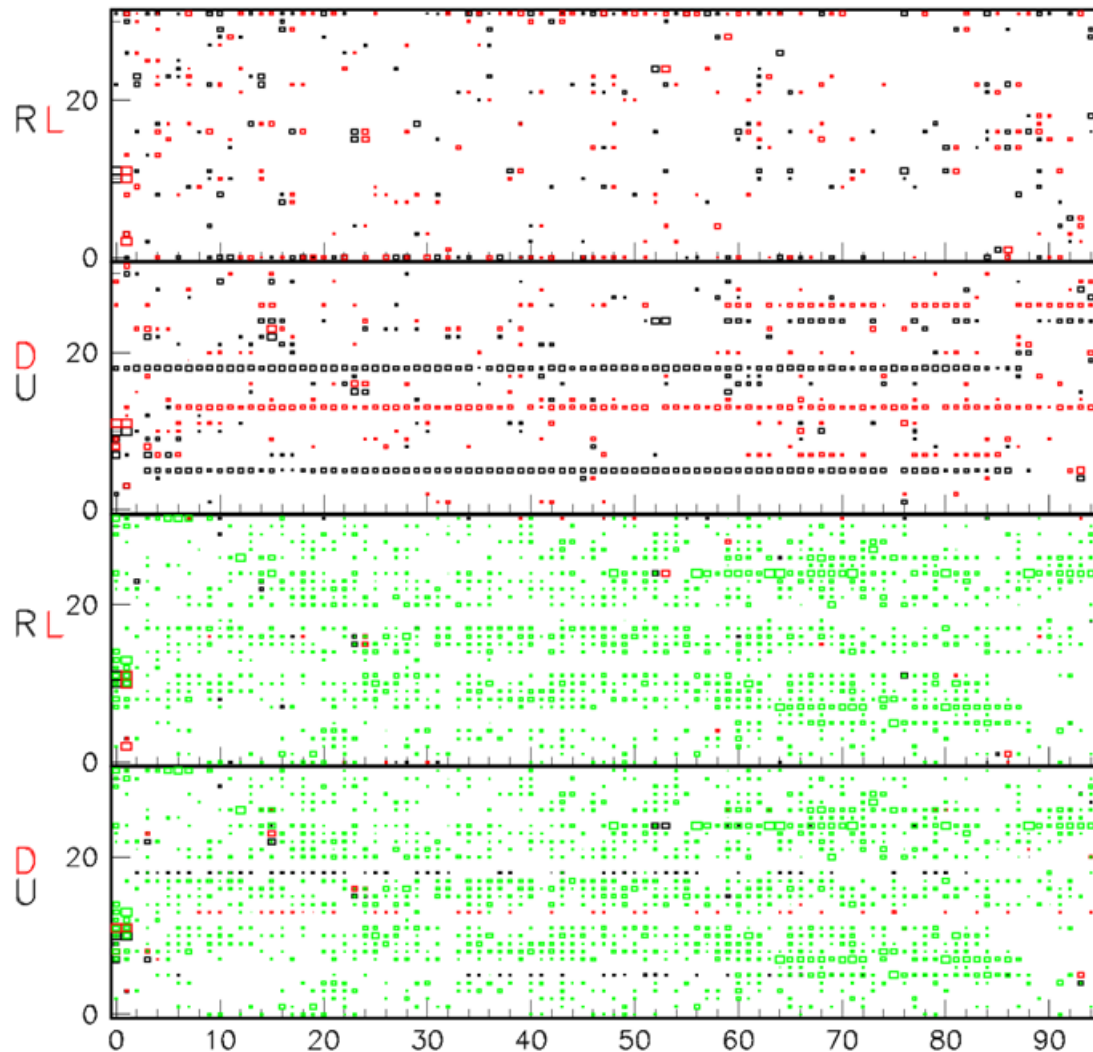
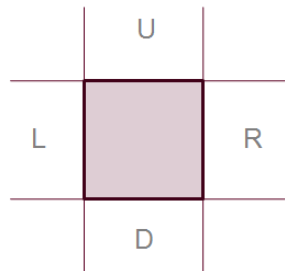
Hits at large ΔR obviously random
→ no correlations

Peak at 1 from pad multiplicity > 1

Peak at 20
→ faulty ground connections
(has been corrected)

Correlations between pads

(possibly due to problems with pad- and front-end board gluing)



Hits with neighbors
normalized by 'all hits'

Minimum $z = 0.5$

Hits with neighbors
normalized by 'all hits'

Minimum $z = 0.9$

Single hits normalized
by 'all hits'

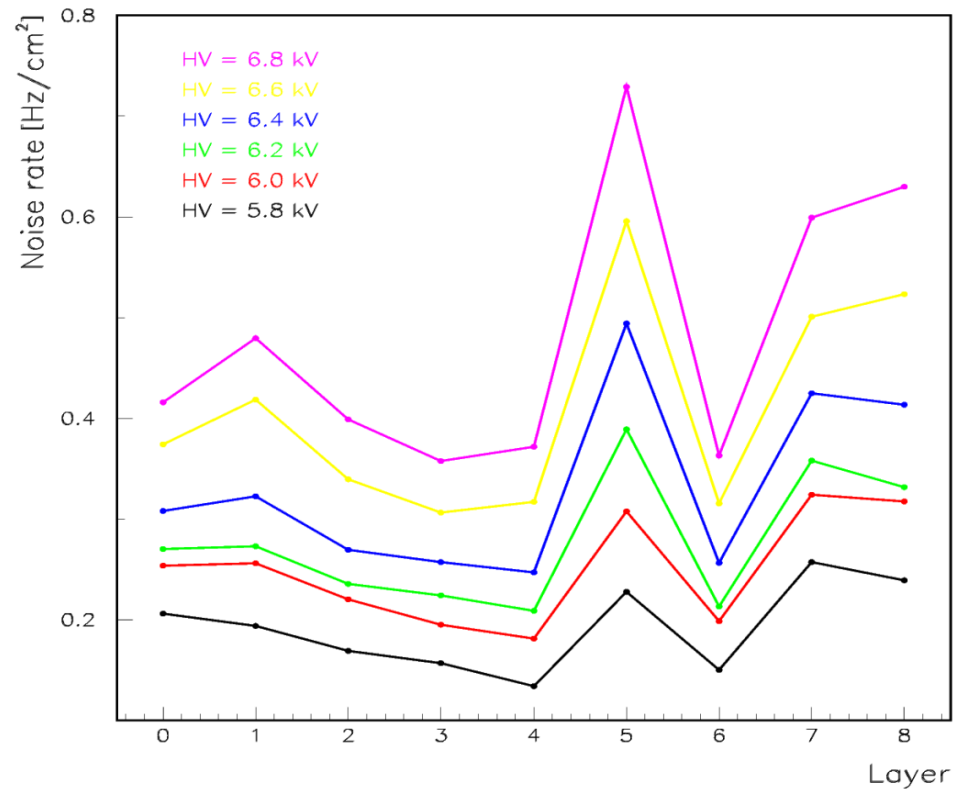
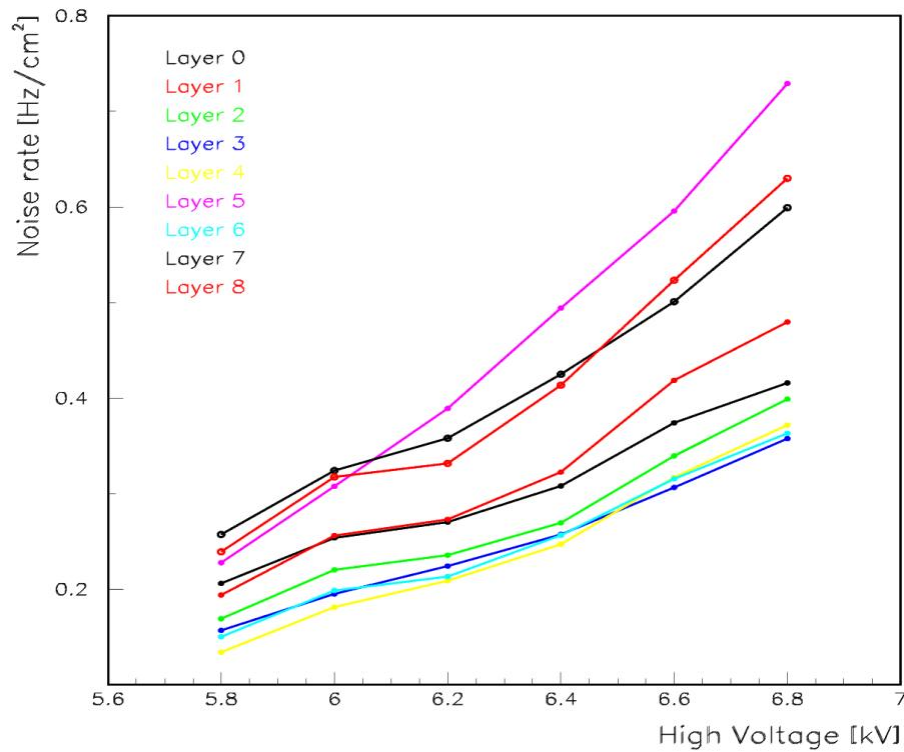
Minimum $z = 0.2$

Look for **RL** or **DU** pairs
without **singles**

No evidence for correlations



Study of the HV dependence



**Results as expected
(higher noise rates due to
poor grounding?)**



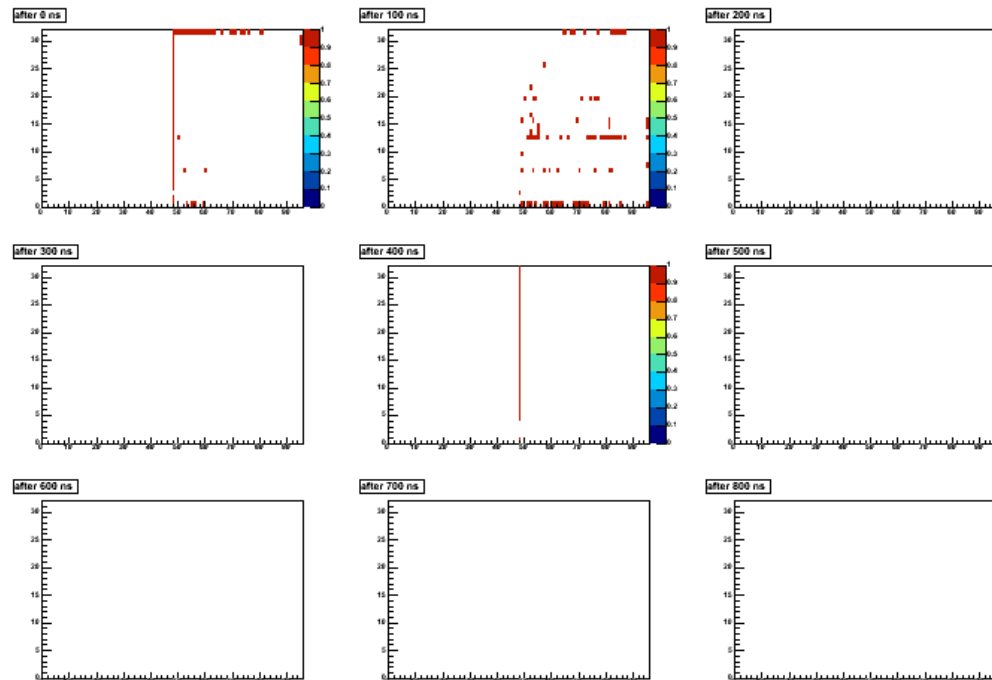
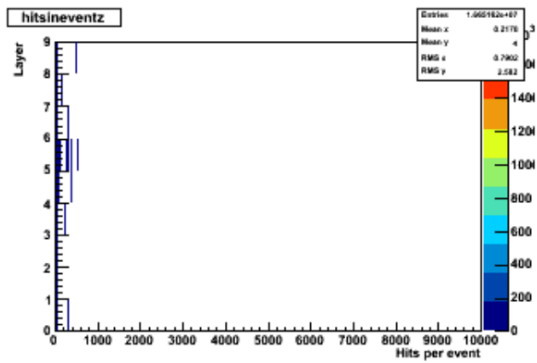
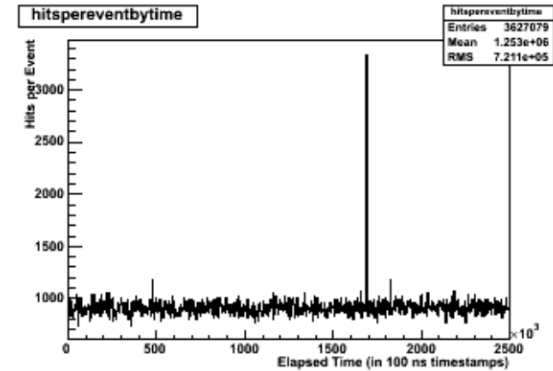
Problems: events with > 300 hits

These events are rare (a handful in 5 minutes)

They spill over several time bins

Their rate and their characteristics depend on the grounding scheme

These events will be studied further within the cubic meter structure



Grounding scheme to be finalized with cubic meter

Hits in bins of 200 ns



Analysis of triggered noise data

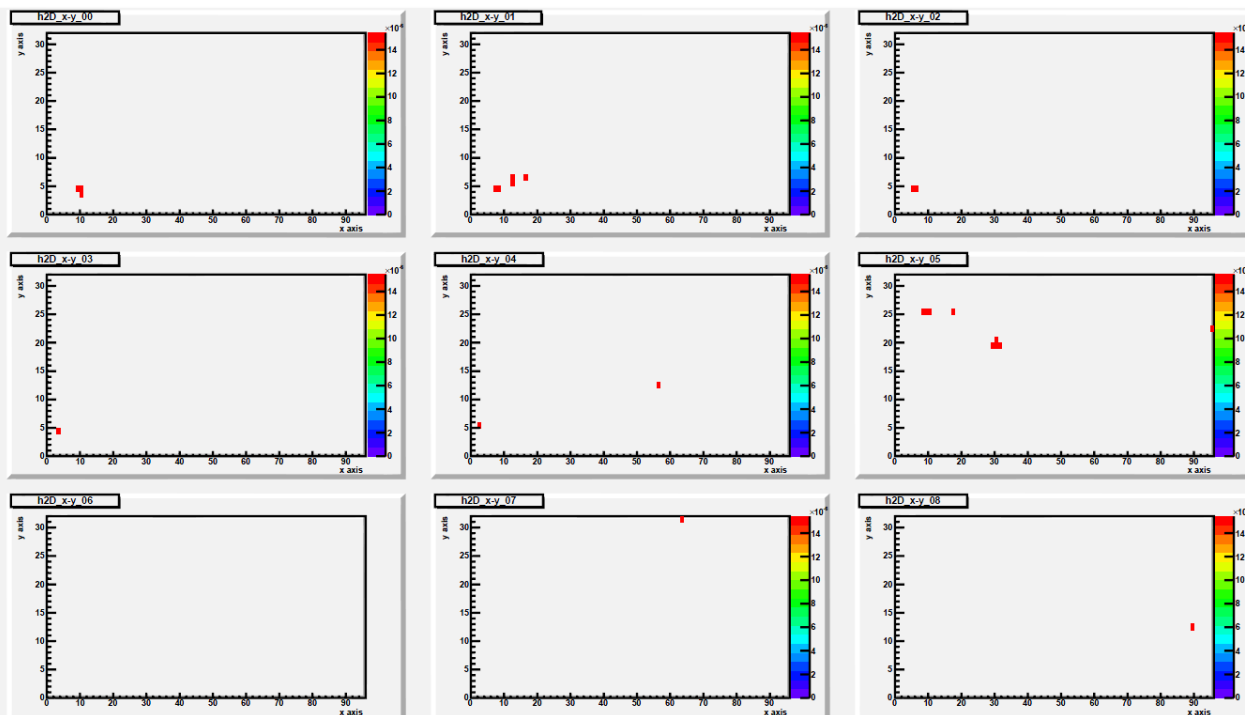
Data collected with random triggers at a rate of 500 Hz

9 RPCs with a total of 27,648 readout channels (8% of the cubic meter)

MIP detection efficiency $\sim 95\%$

Collected 31,906 events in 60 seconds \rightarrow **Not a single hit**

Collected 1,010,494 events in 3 x 10 minutes \rightarrow **24 hits in 10 events**



Analysis of trigger-less cosmic rays

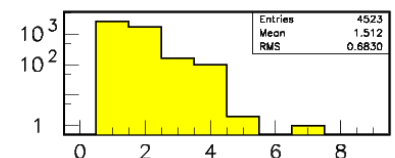
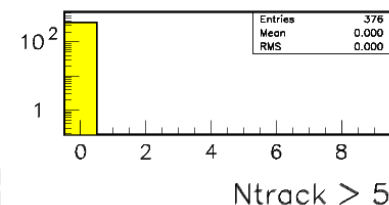
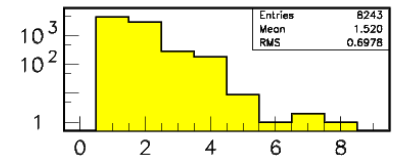
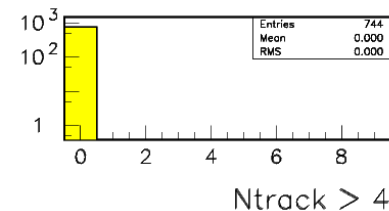
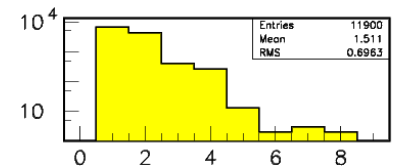
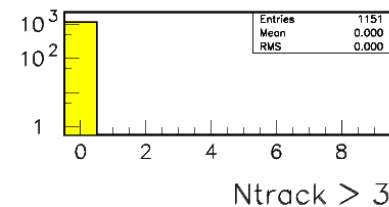
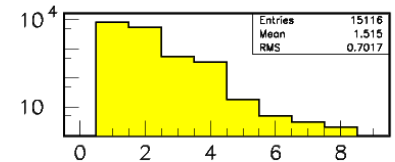
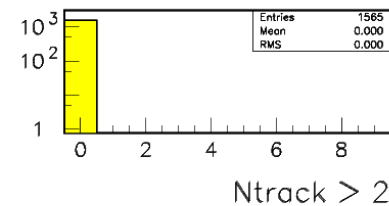
Data selection

Select events among noise data requiring at least 2 layers with hits
(Obviously, no hardener of cosmic rays implemented)
(Top and bottom layer will show systematic differences)

Procedure for layer i

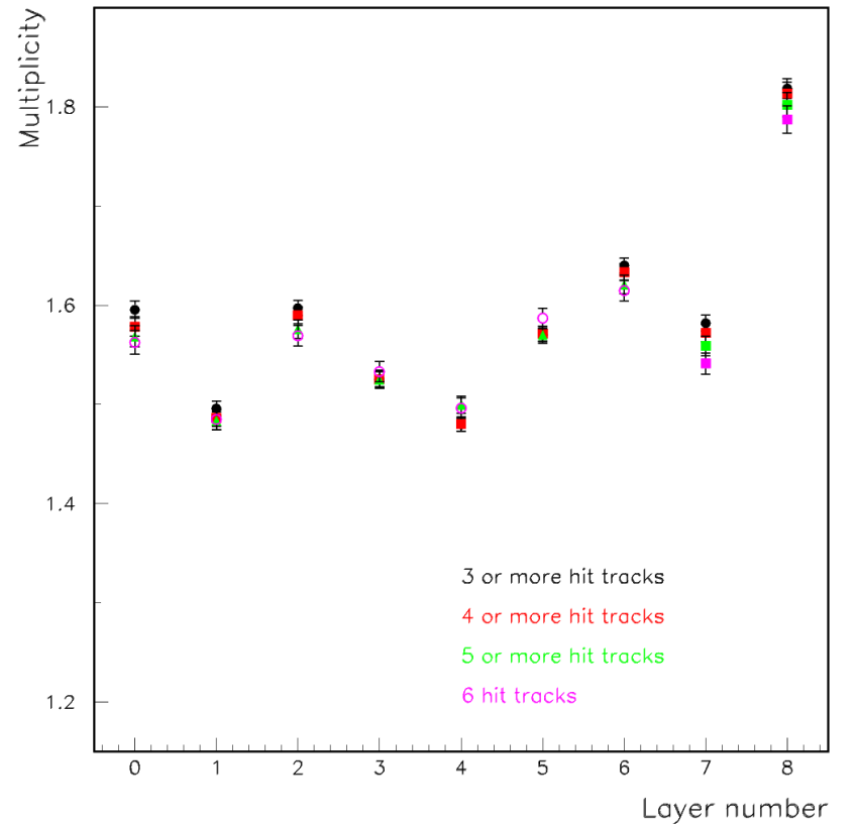
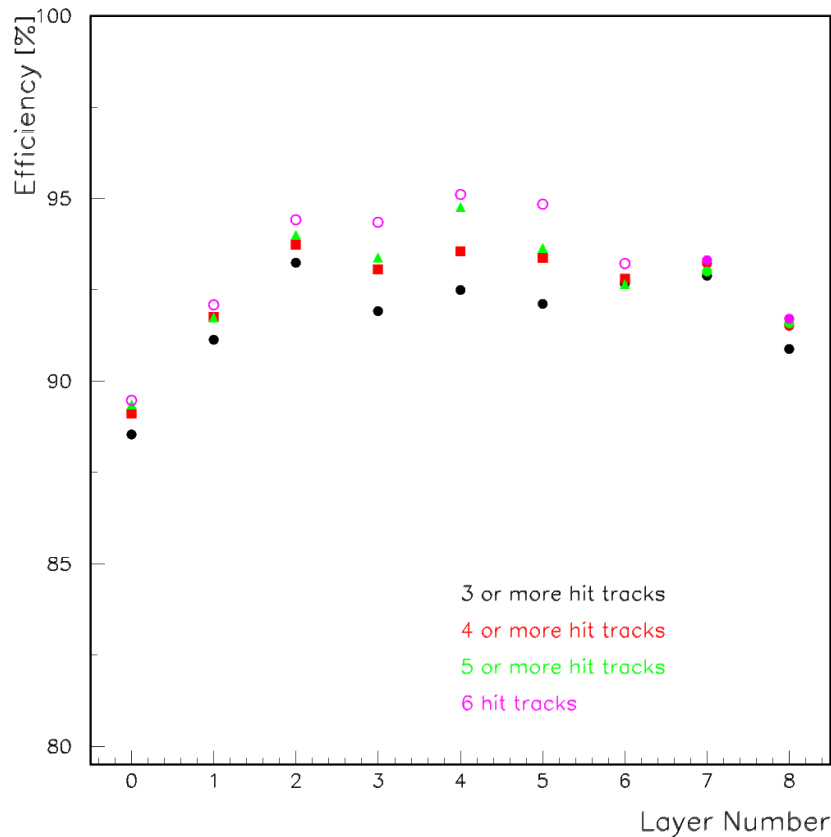
Cluster hits in layers individually
Request only 1 cluster in any layer but layer i
Fit track to clusters in any layer but layer i
Extra- or interpolate track to layer i
Reject tracks with $\chi^2 > 1.0$
(calculated with $\sigma_{\text{cluster}} = 1.0$ cm)
Declare a match if cluster in layer i
within $R = 2.5$ cm
Calculate efficiency and pad multiplicity

Layer 2



Efficiency and pad multiplicity

9 layers à 3072 channels = 27648 channels

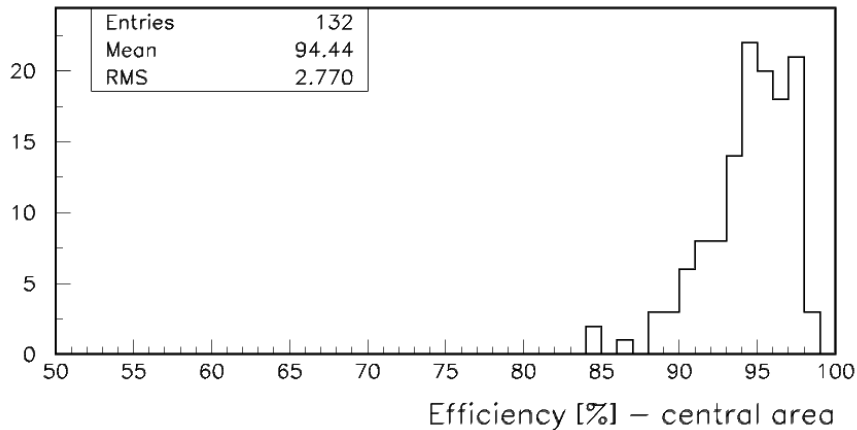
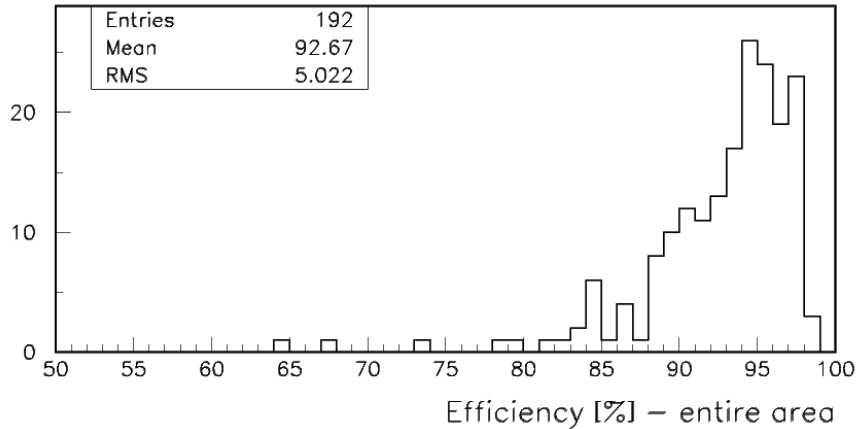


Clear systematic dependence on track quality
High multiplicity of top layer most likely systematic effect

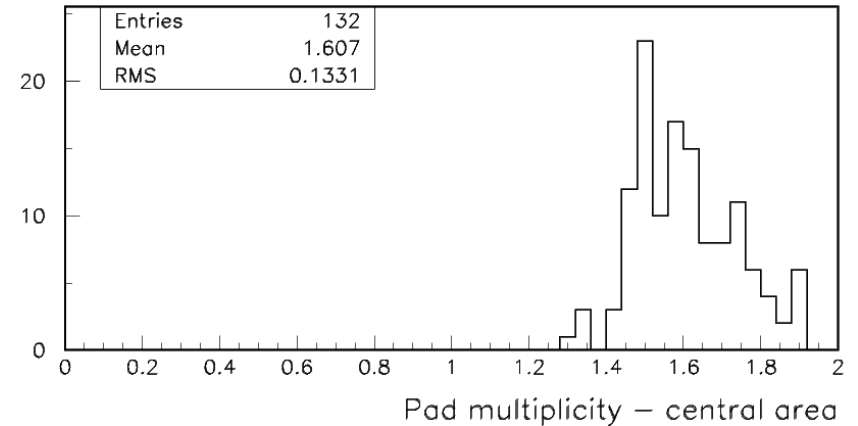
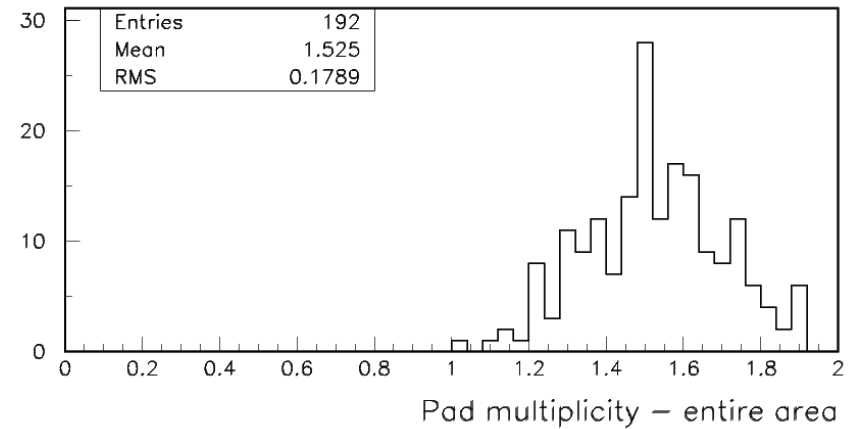
Distributions of ε , μ

For statistical reasons added binned in $4 \times 4 \text{ cm}^2$ areas

Layer 7



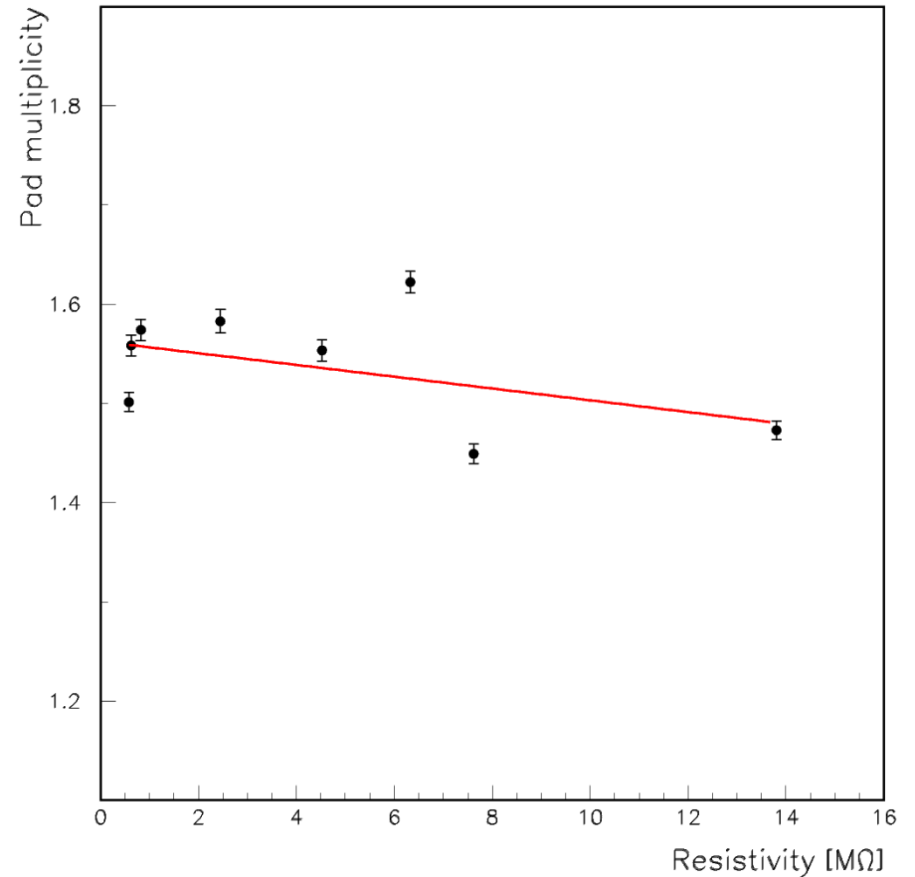
Layer 7



Some smearing: due to statistic and angle of incidence
Some edge effects: in part due to the chambers
In general looks OK

Correlation with Resistivity

Layer #	Chamber #	Glass #	Resistivity
0	31	107	2.45
1	33	92	7.62
2	18	50	0.58
3	15	48	0.82
4	30	113	13.81
5	17	49	0.62
6	26	84	6.33
7	12	46	4.52
8	25	?	?



No obvious correlation
 $\chi^2/\text{DOF} - 29.5/(8-2) = 4.9$

Angle of cosmic rays

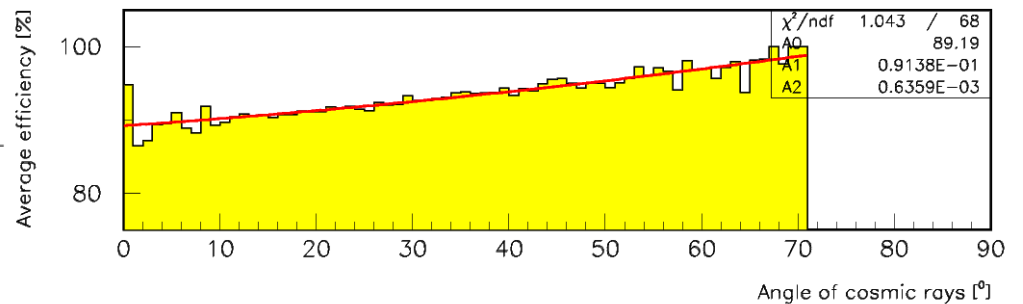
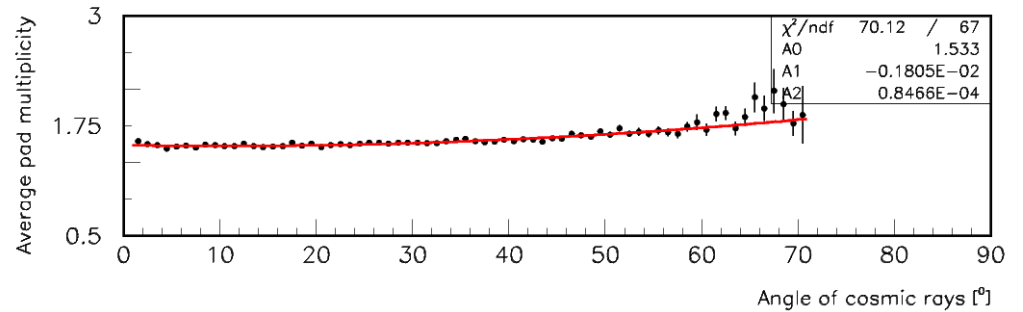
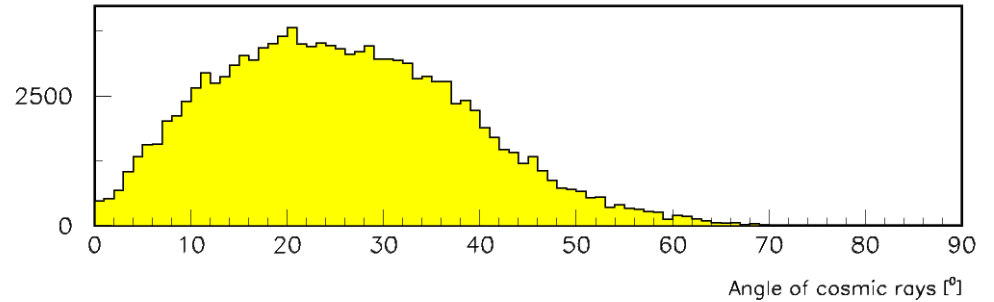
Cuts

- At most 1 cluster/tracking layer
- $\chi^2/\text{DOF} < 1.0$
- $N_{\text{track}} > 3$
- x_{int} within $0.0 \div 95.0$
- y_{int} within $0.0 \div 31.0$

1.533 \div 1.831 or +19.4%

89.3 \div 98.9 % or +10.8%

136.9 \div 181.1 or 32.3%

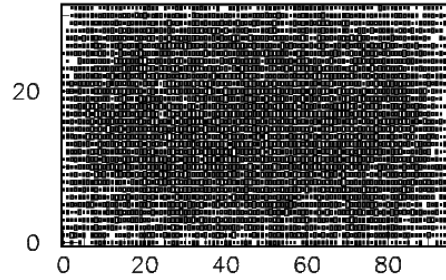


This effect has not (yet) been implemented into the RPC response simulation

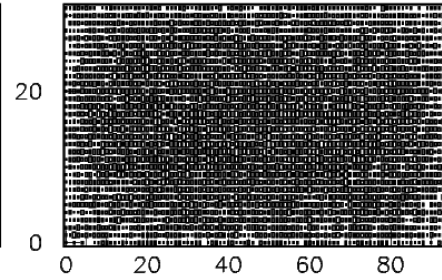
Efficiency maps

Layer 2

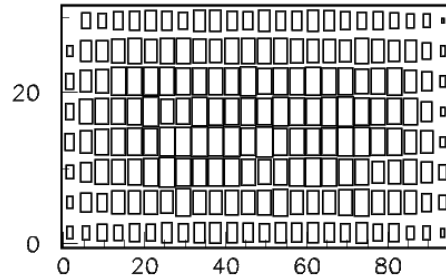
Hits
(Pad binning)



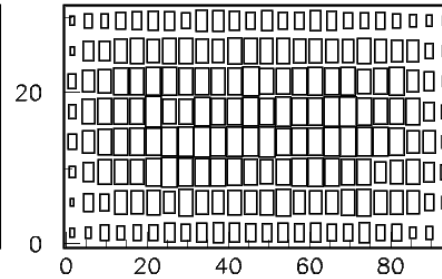
All tracks
(Pad binning)



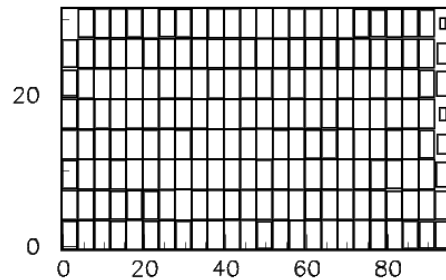
Hits
(2 x 2 pad binning)



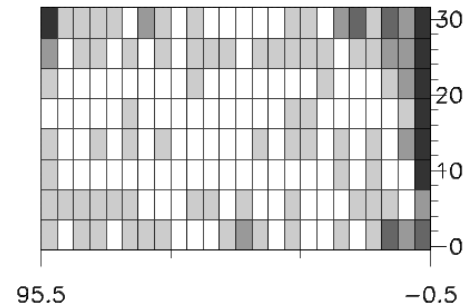
All tracks
(2 x 2 pad binning)



Efficiency
0 – 100%



Efficiency
75 – 100%

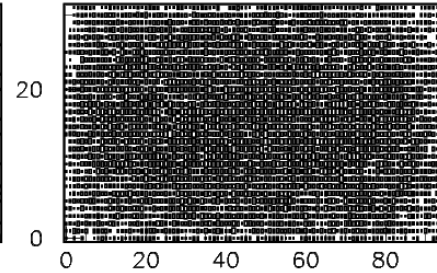
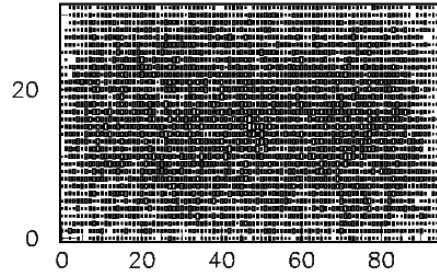


Reasonably uniform, edges difficult to measure

Pad multiplicity maps

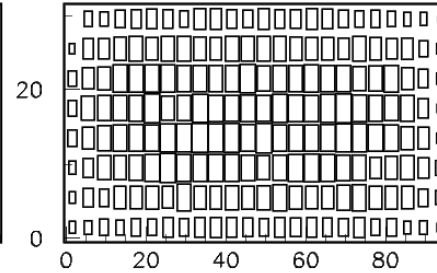
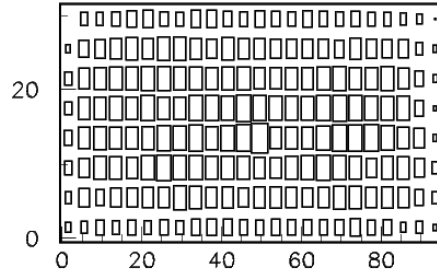
Layer 2

Multiplicity weighted matches (1 pad binning)



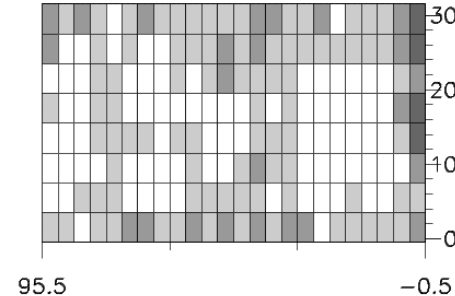
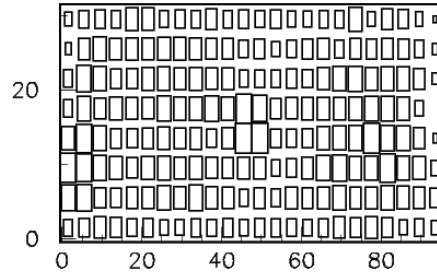
Matches (1 pad binning)

Multiplicity weighted matches (2 x 2 pad binning)



Matches (2 x 2 pad binning)

Average multiplicity Scale 0 - max (2 x 2 pad binning)



Average multiplicity Scale 0.8 – 1.8 (2 x 2 pad binning)

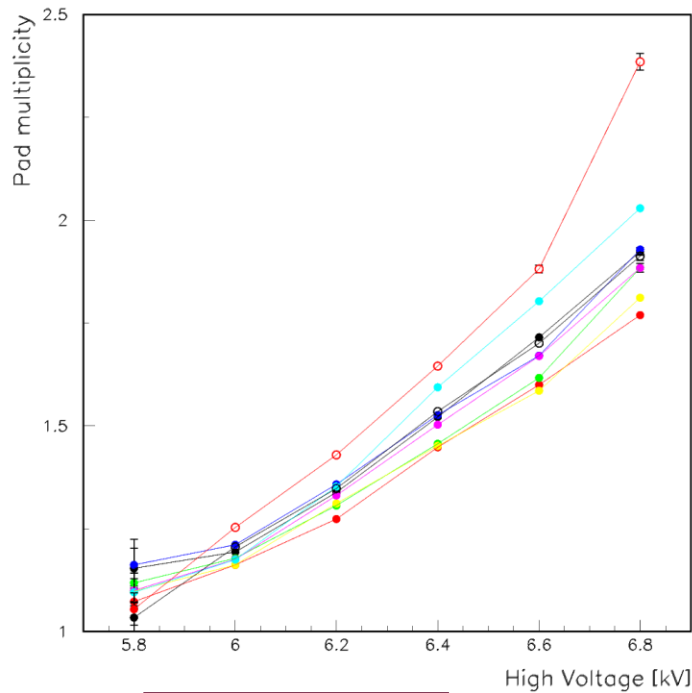
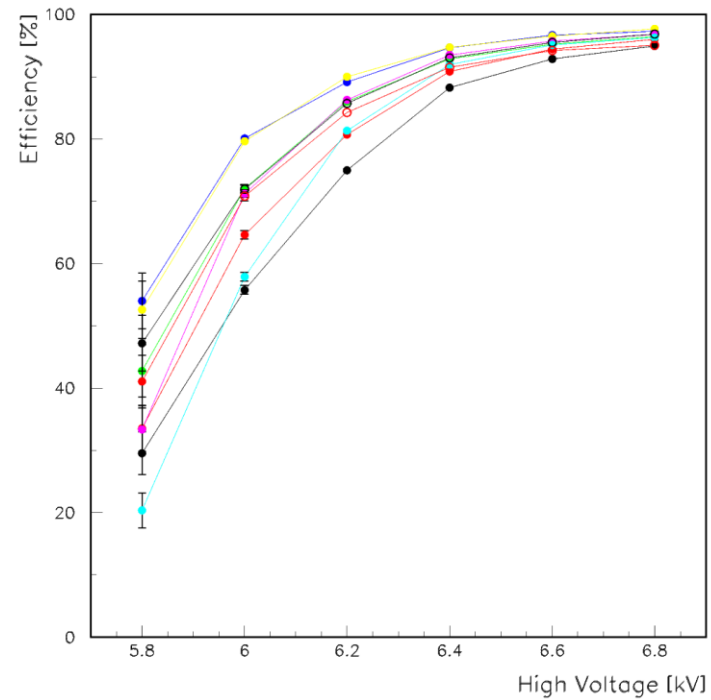
Reasonably uniform, edges difficult to measure



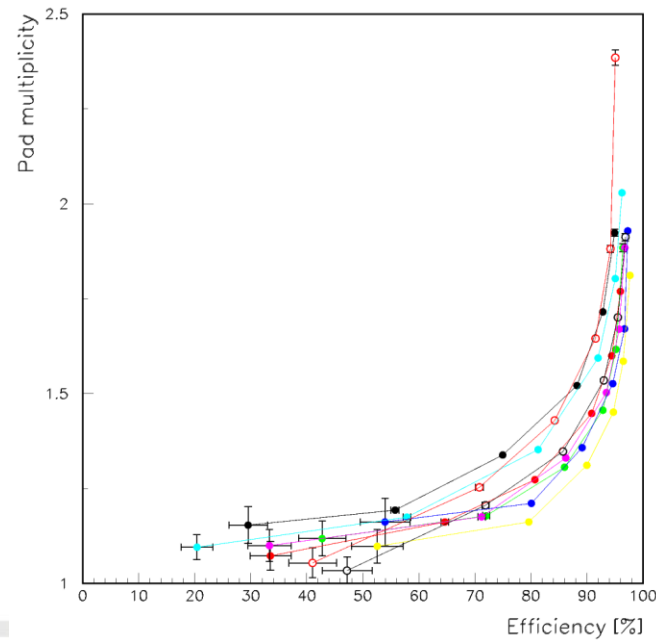
Dependence on high voltage

Cuts

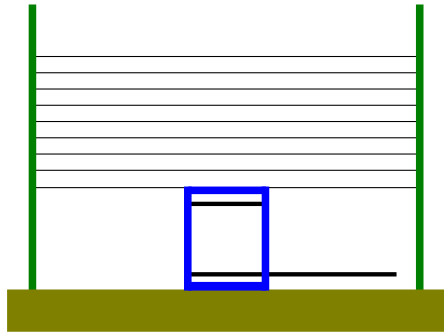
- At most 1 cluster/tracking layer
- $\chi^2/\text{DOF} < 1.0$
- $N_{\text{track}} > 5$
- x_{int} within $0.0 \div 95.0$
- y_{int} within $0.0 \div 31.0$



As expected



Analysis of triggered cosmic rays



2 Scintillator counters at bottom

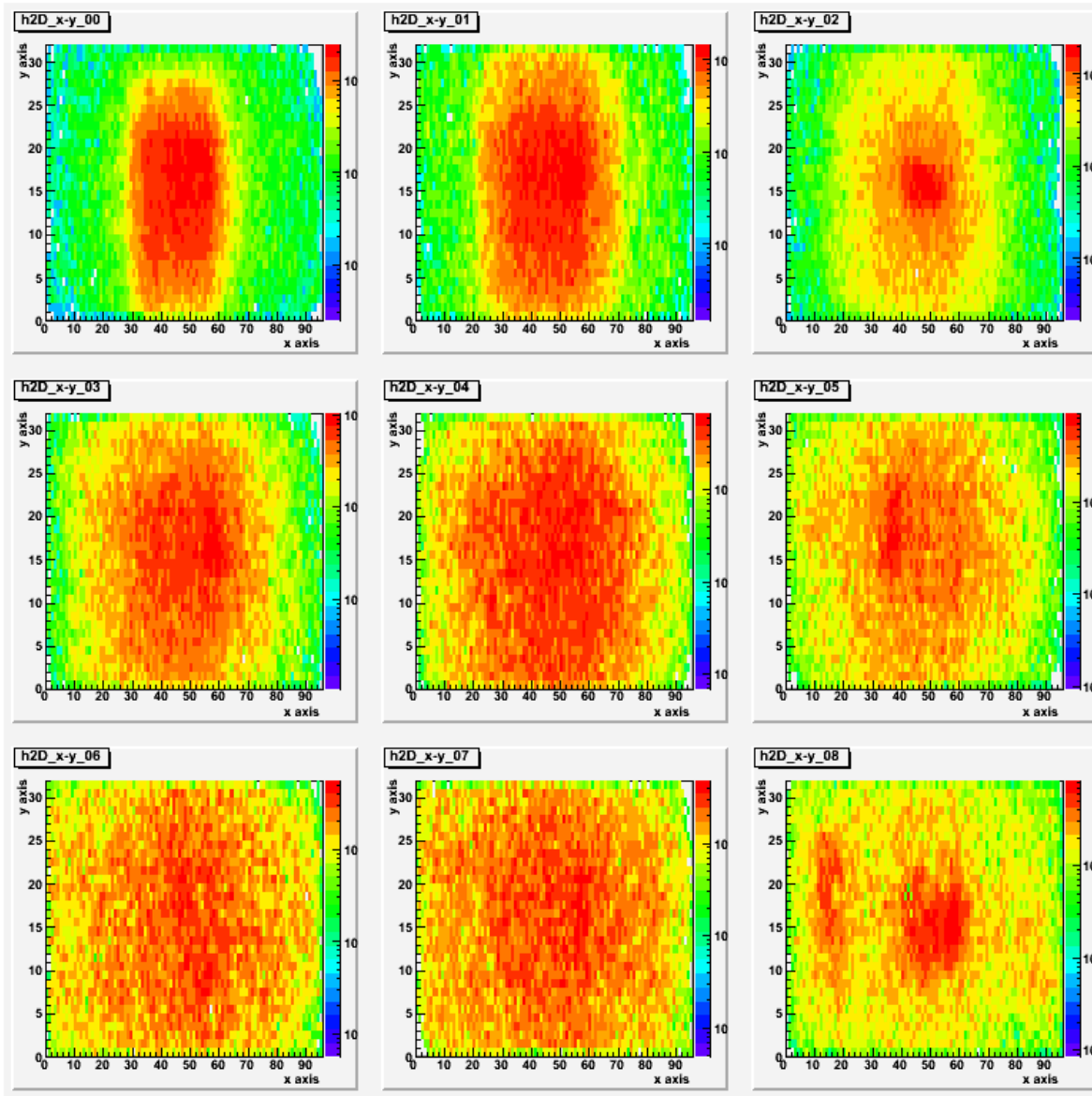
3 sets of runs with different grounding schemes
(grounding in the cubic meter will be different)

Setting	Duration [hours]	Events	Grounding events	Grounding events [%]
I	60	54,475	239	0.44
II	18	16,842	152	0.90
III	36	33,824	291	0.86



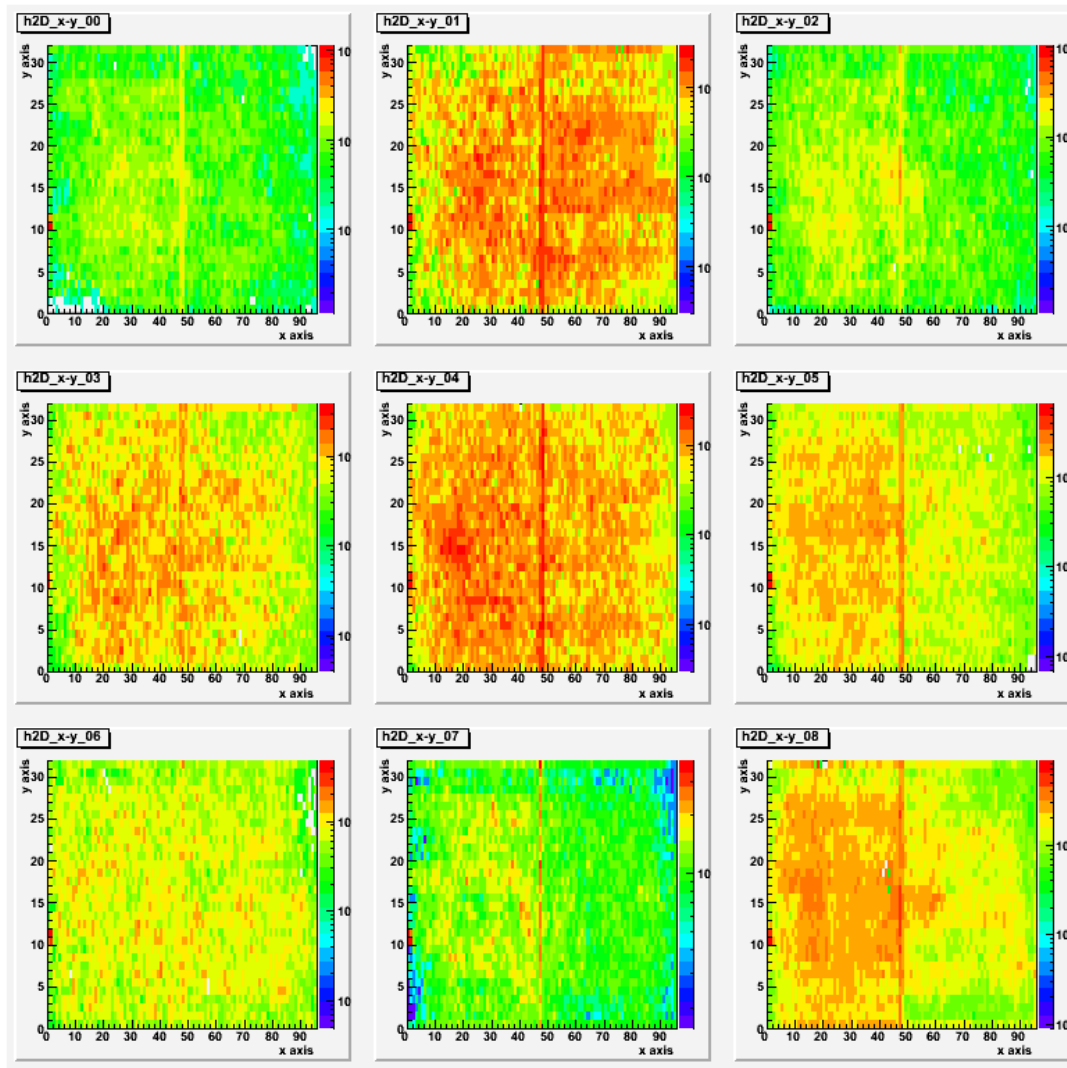
Identified through cluster of hits close to the grounding of the anode

Triggered cosmic rays in the 9 layers



Area grows with layer number due to increased distance from trigger counters

Grounding events in the 9 layers



Note high rate at $(x,y) = (0,11)$ = grounding

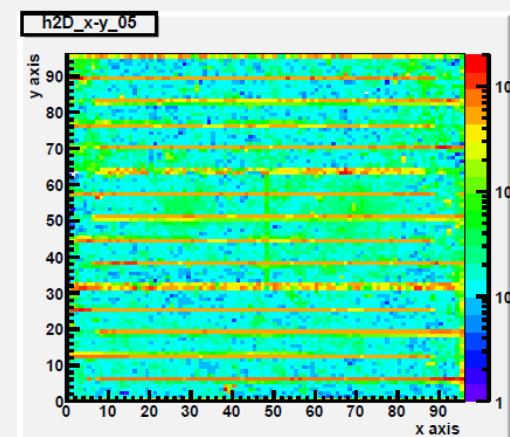
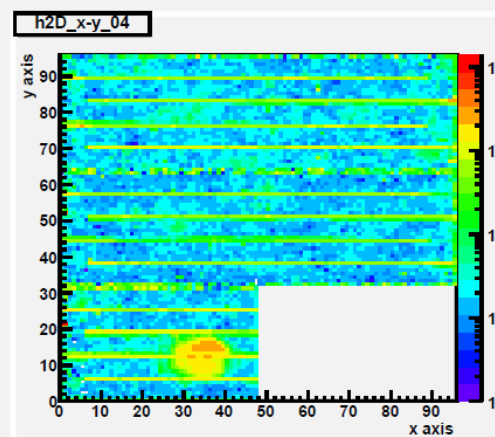
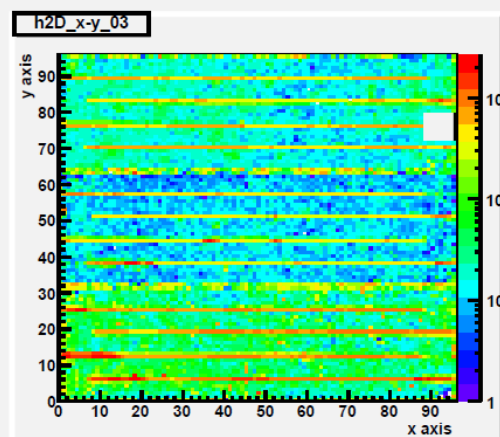
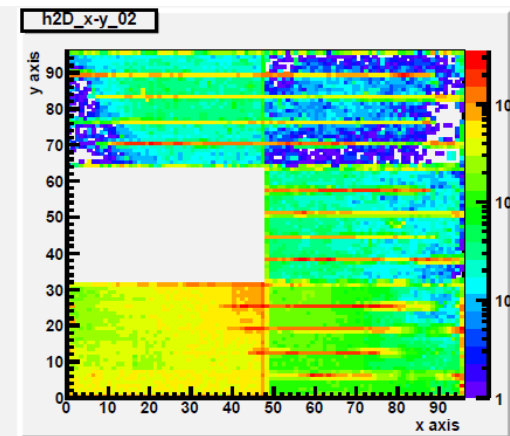
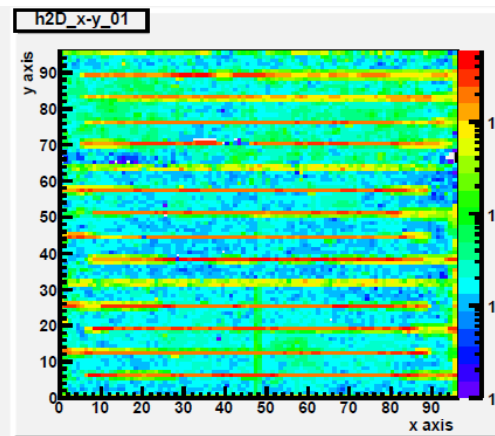
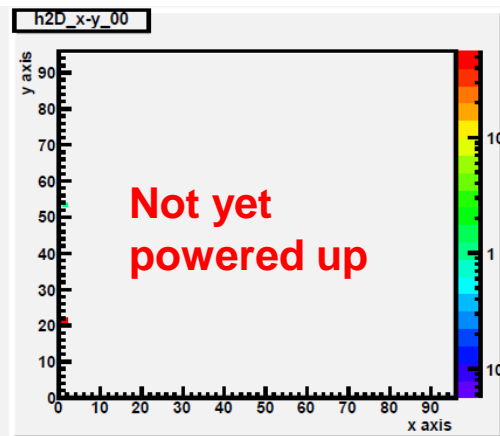
Line at $x = 49$ is the boundary Between the 2 Readout boards

This problem will be sorted out with the grounding of the cubic meter

(suspicion of problems with the trigger counters)

Powering up completed cassettes

First try at powering up complete cassettes



Summary

9 RPCs with 27,648 readout channels thoroughly tested

Noise rate low and as expected

Efficiencies/pad multiplicities OK

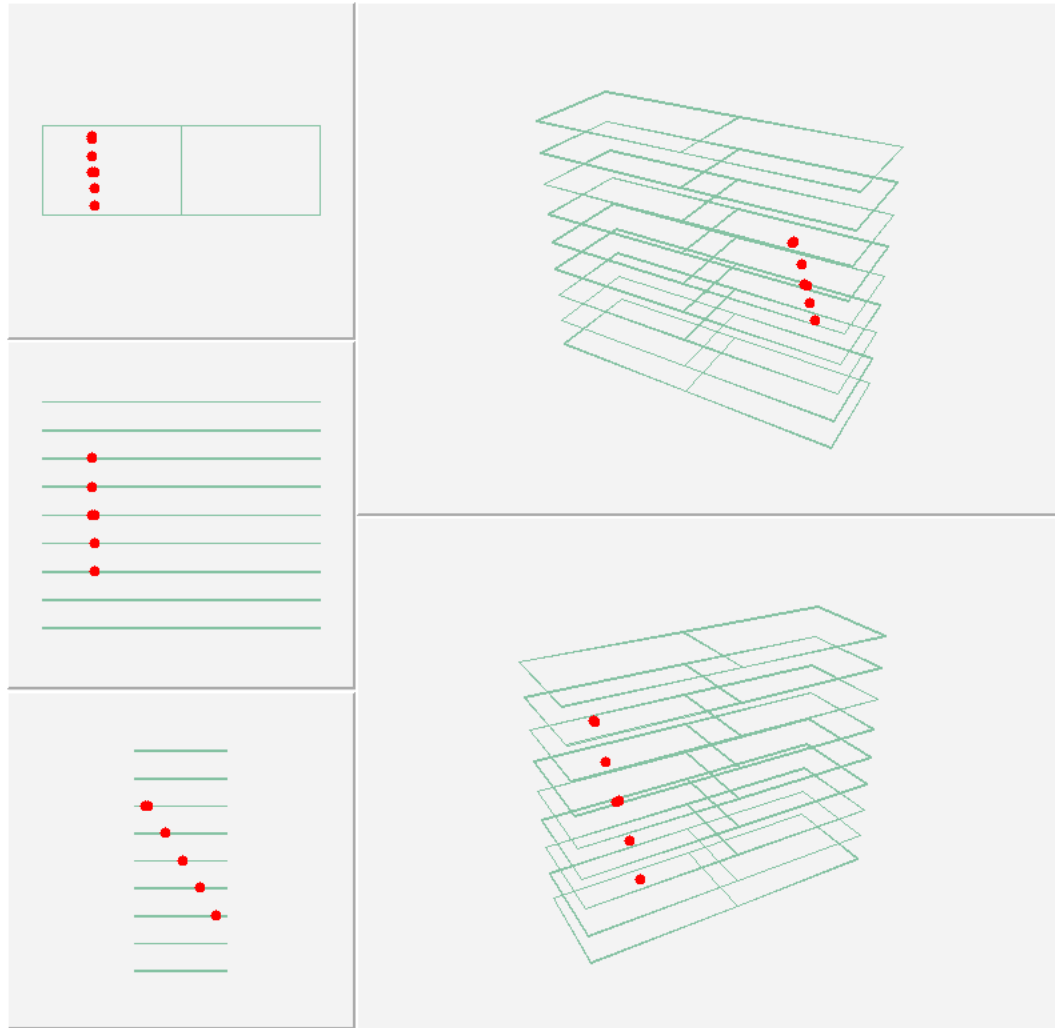
Final grounding still to be established

Cassettes being powered up...



Trigger-less noise data with requirement of hits in > 2 layers (no other tricks!!!!)

Look
for
Noise
Hits



Actual
rate
a
factor
 ~ 10
faster