The DHCAL Data Analysis

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Data Samples

I) Cosmic ray data

Taken in June – July
1 – 6 RPCs in stack (as becoming available)
Runs typically 14 hours → ~ 1000 events

II) FNAL test beam data

Taken in July – August
4 – 9 RPCs in stack (as being operational)
Runs typically 5,000 – 10,000 events

Beams of protons, pions, electrons and muons

Many more details in my talk to-morrow

All results preliminary

I) Cosmic Ray Data

Trigger

Coincidence of 4 scintillation counters
Small fake rate (< 1%)
~ 3 x 5 cm^2 acceptance

RPCs

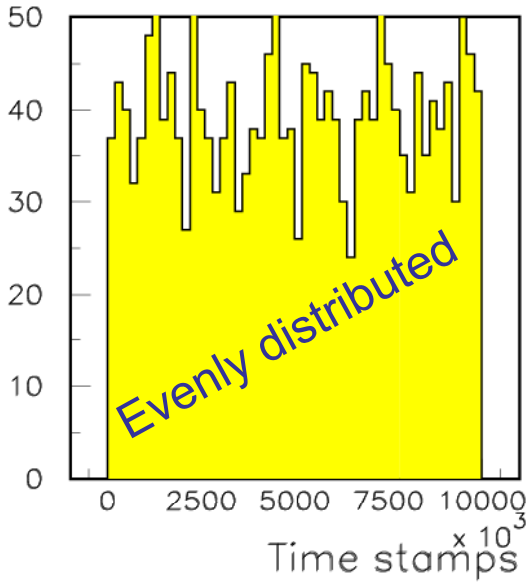
Horizontal: up to 6
Each 20 x 20 cm^2 area

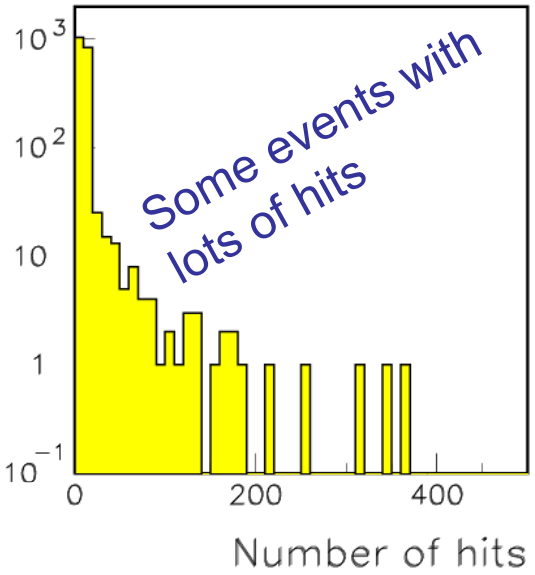
Same readout as for test beam

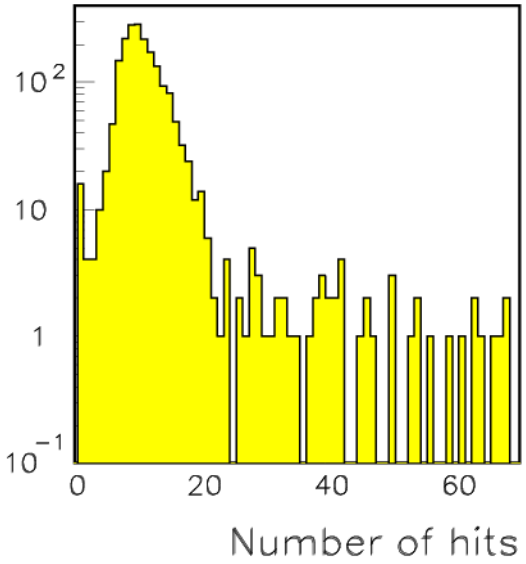
Pad-, FE-boards with DCAL chips
→ 16 x 16 cm^2 = 256 channels
Data concentrators
Data collector
Time and trigger module

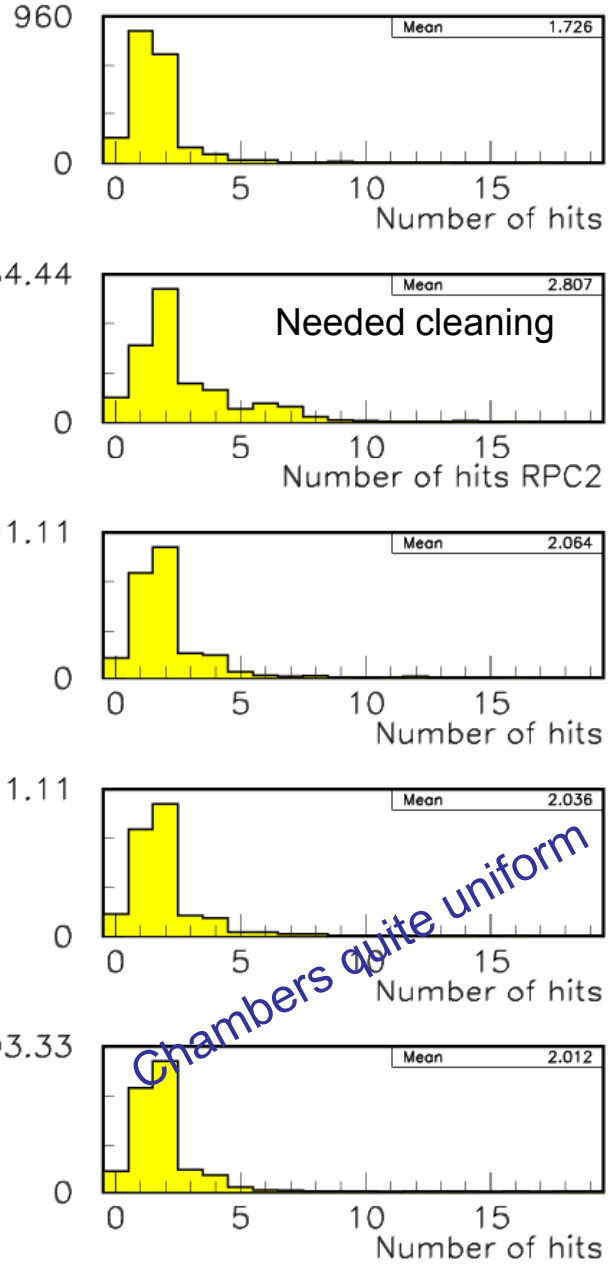
Runs with HV ~ 7.0 kV

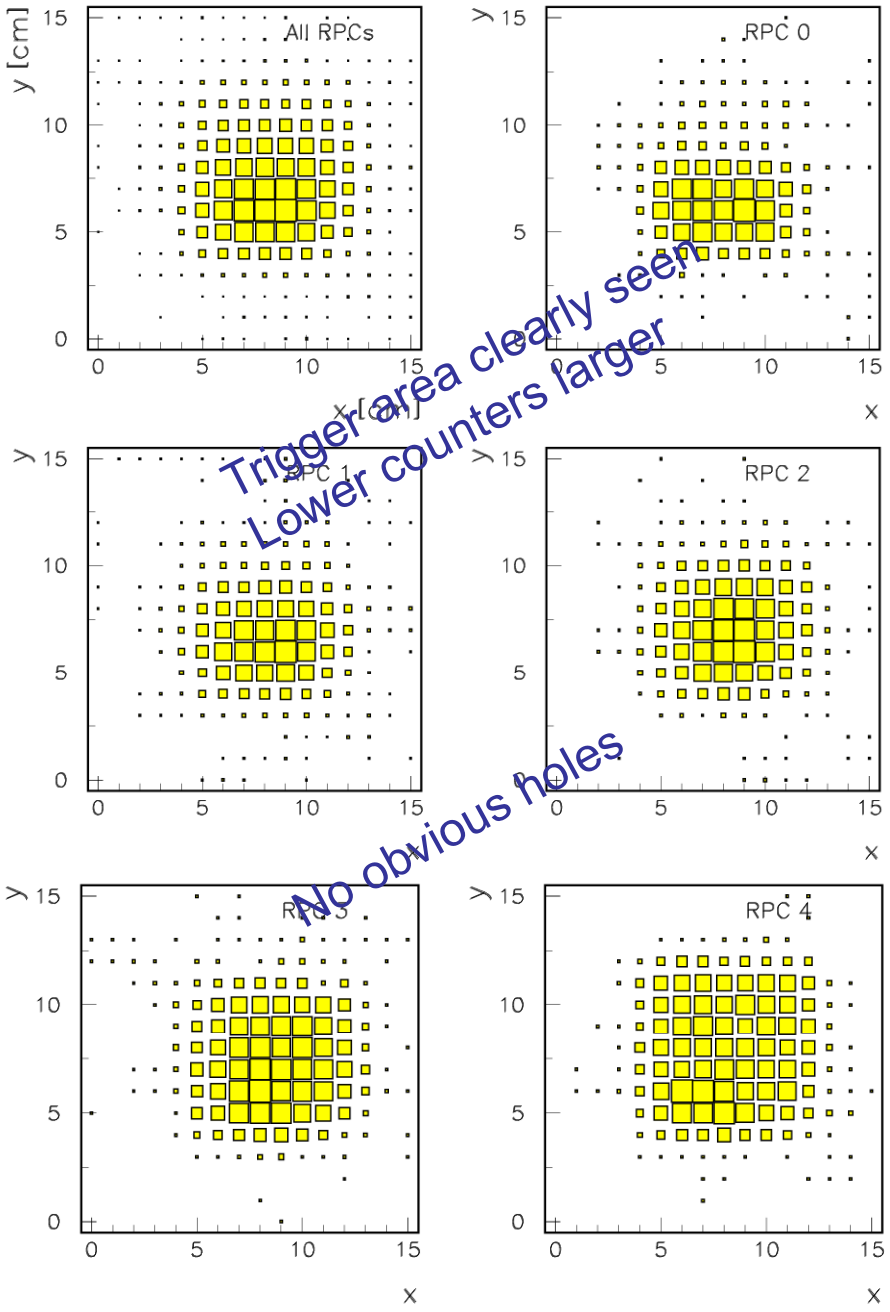
Example: Run 59 with
THR = 200



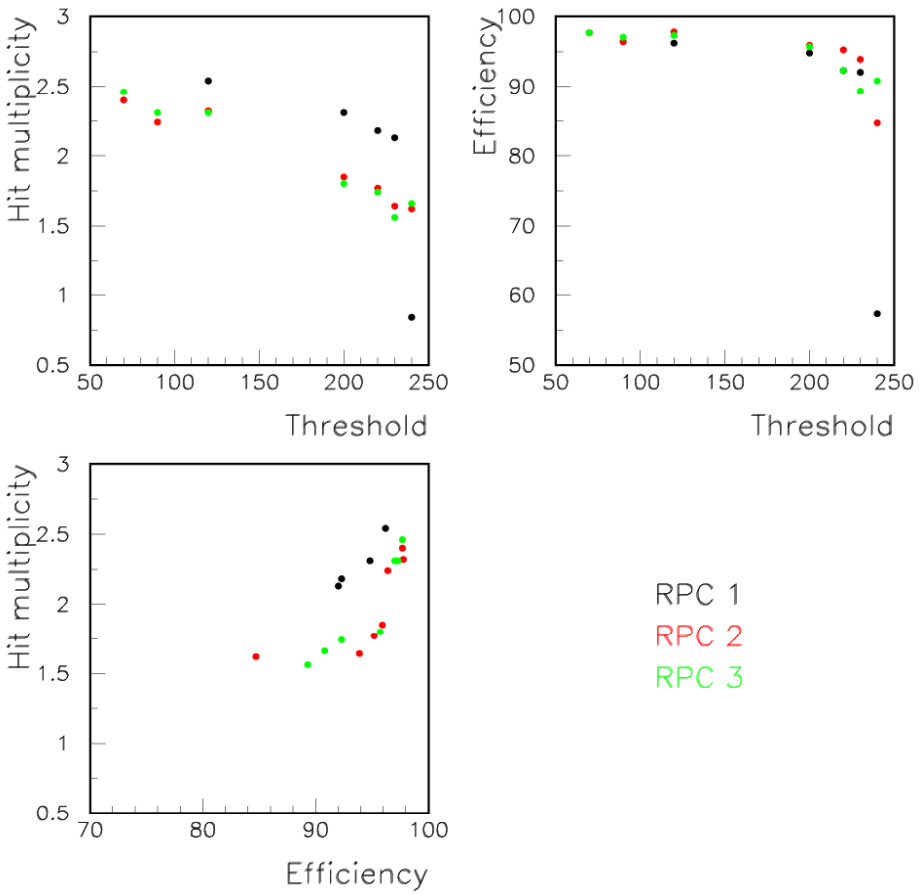








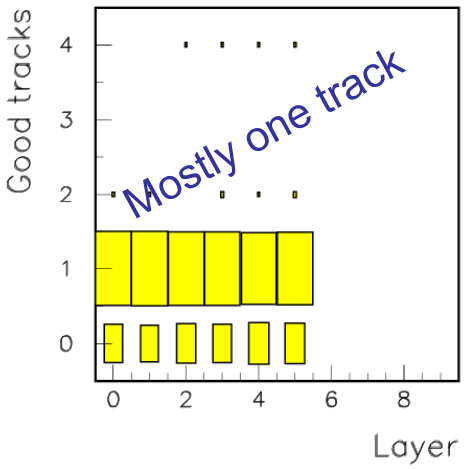
Use chambers 0 & 4 to track

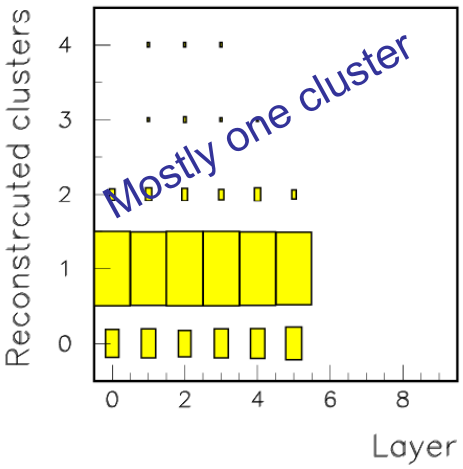


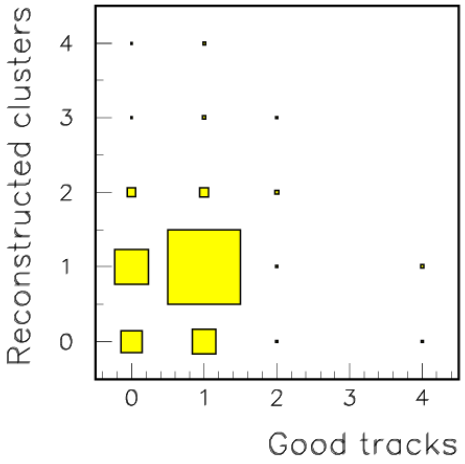
Need to operate at lower voltage

Runs with HV = 6.3 kV

With calibrated HV supplies





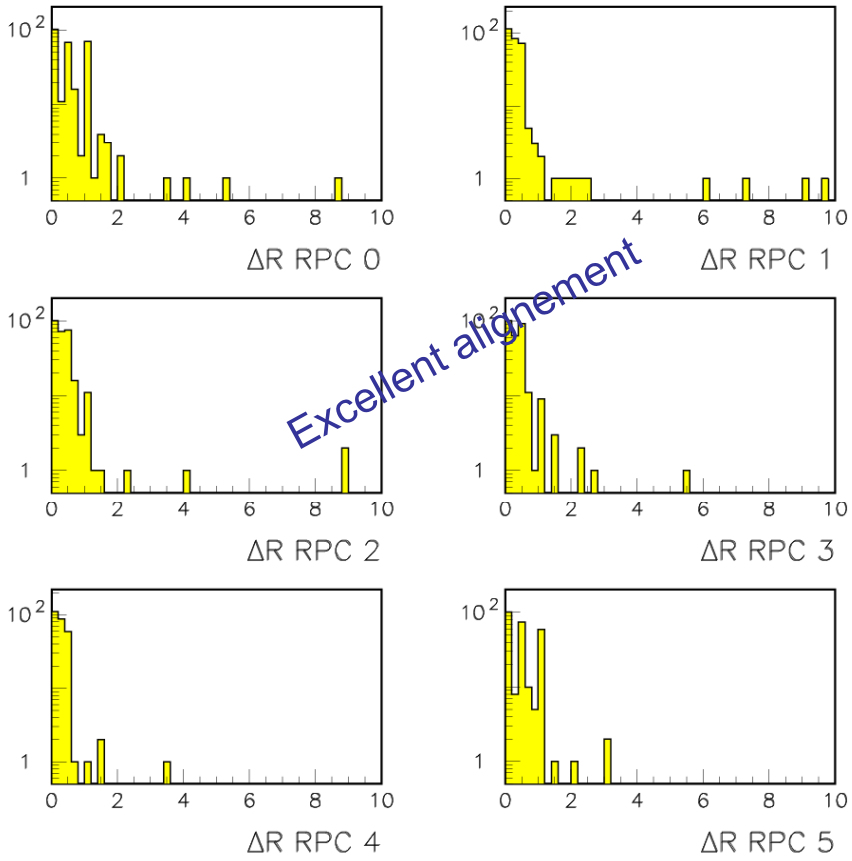


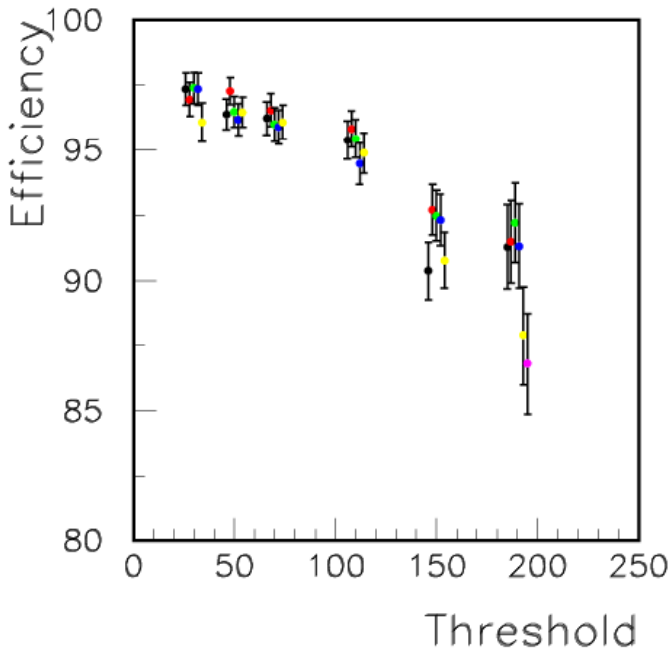
Cluster hits in each layer
(cells touching each other)

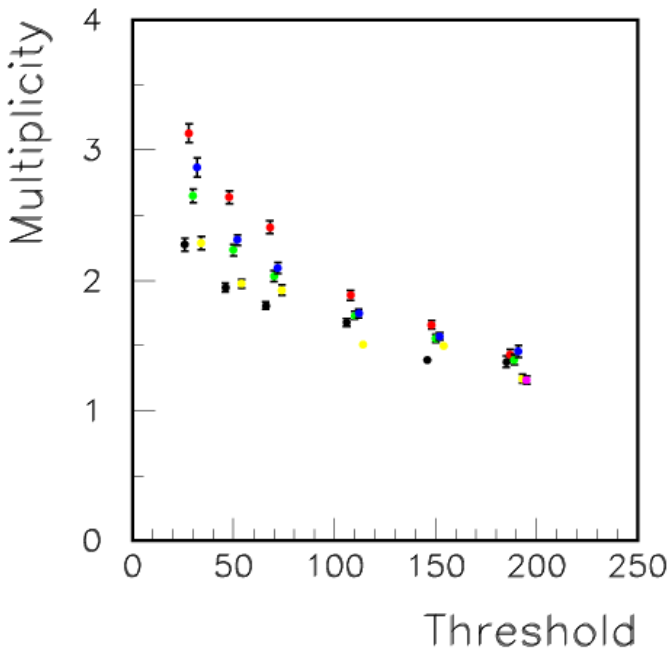
Use surrounding
layers to define track
(layer 0 uses 1 & 2
layer 1 uses 0 %2 etc.)

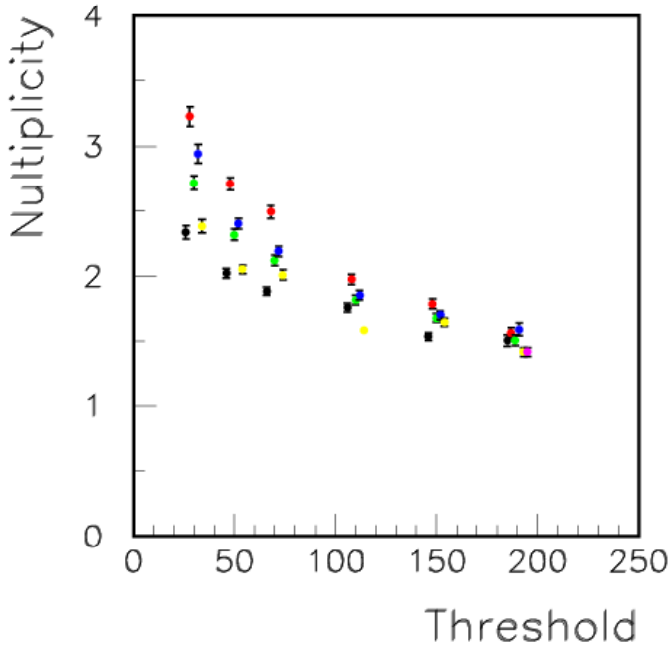
Look for aligned clusters

Look for closest cluster to
extrapolated track







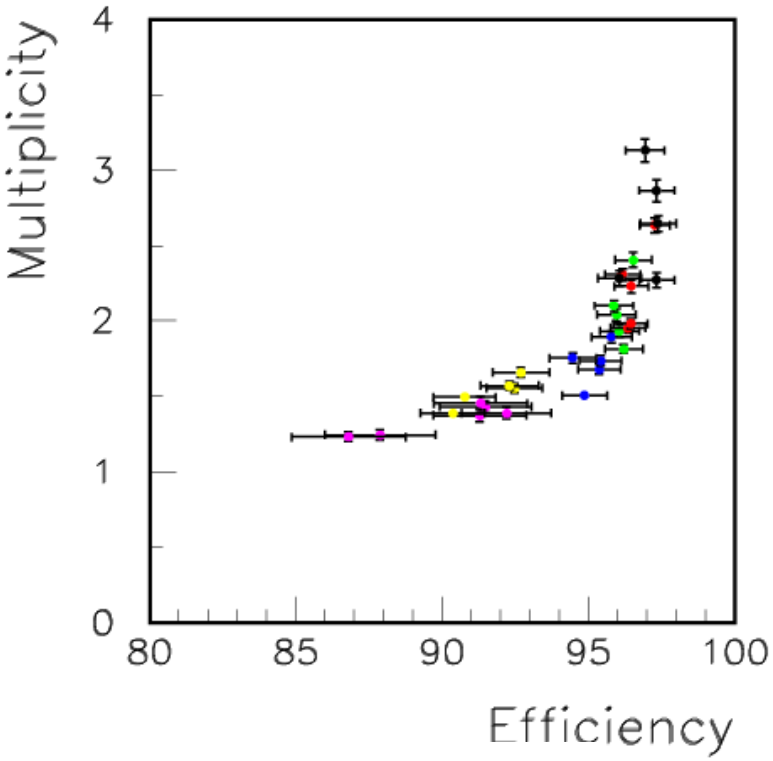


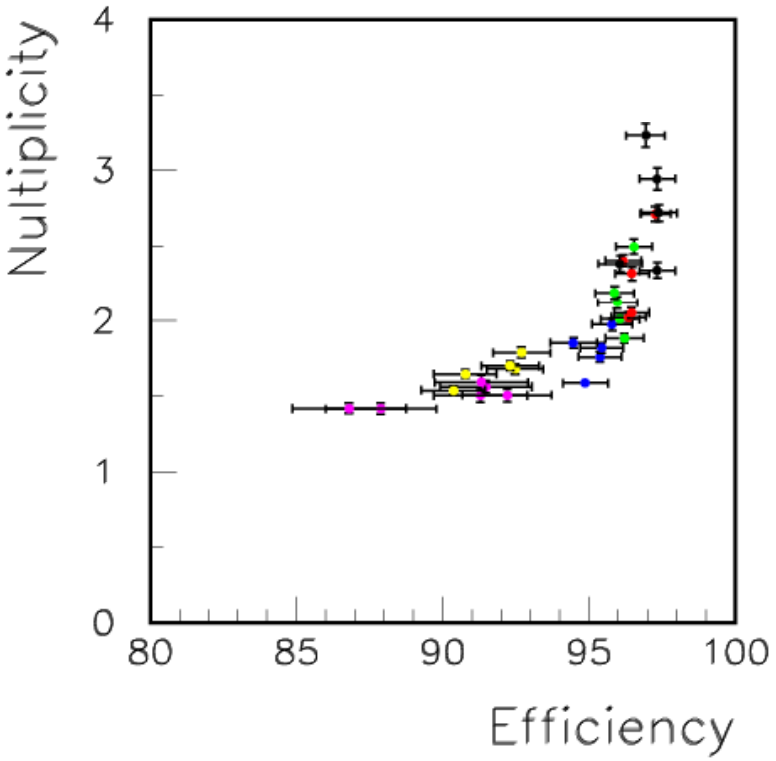
RPC 0
RPC 1
RPC 2
RPC 3
RPC 4
RPC 5

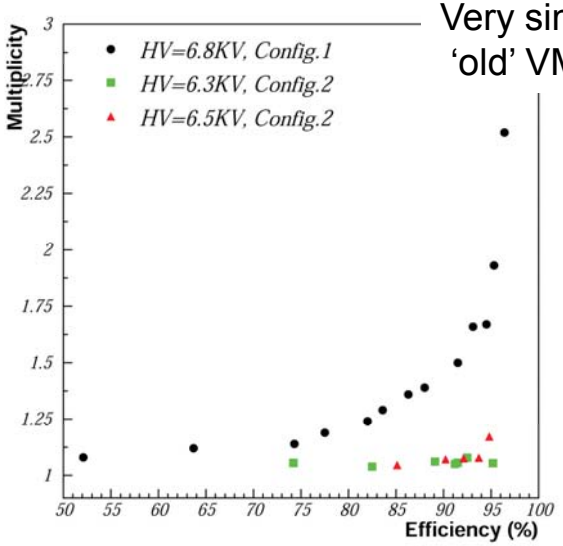
Multiplicity includes ‘zeros’
Nultiplicity excludes ‘zeros’

Errors on efficiency
→ binomial

Errors on m(n)ultiplicities
→ RMS/√N







Very similar to results with 'old' VME digital readout

Threshold = 30

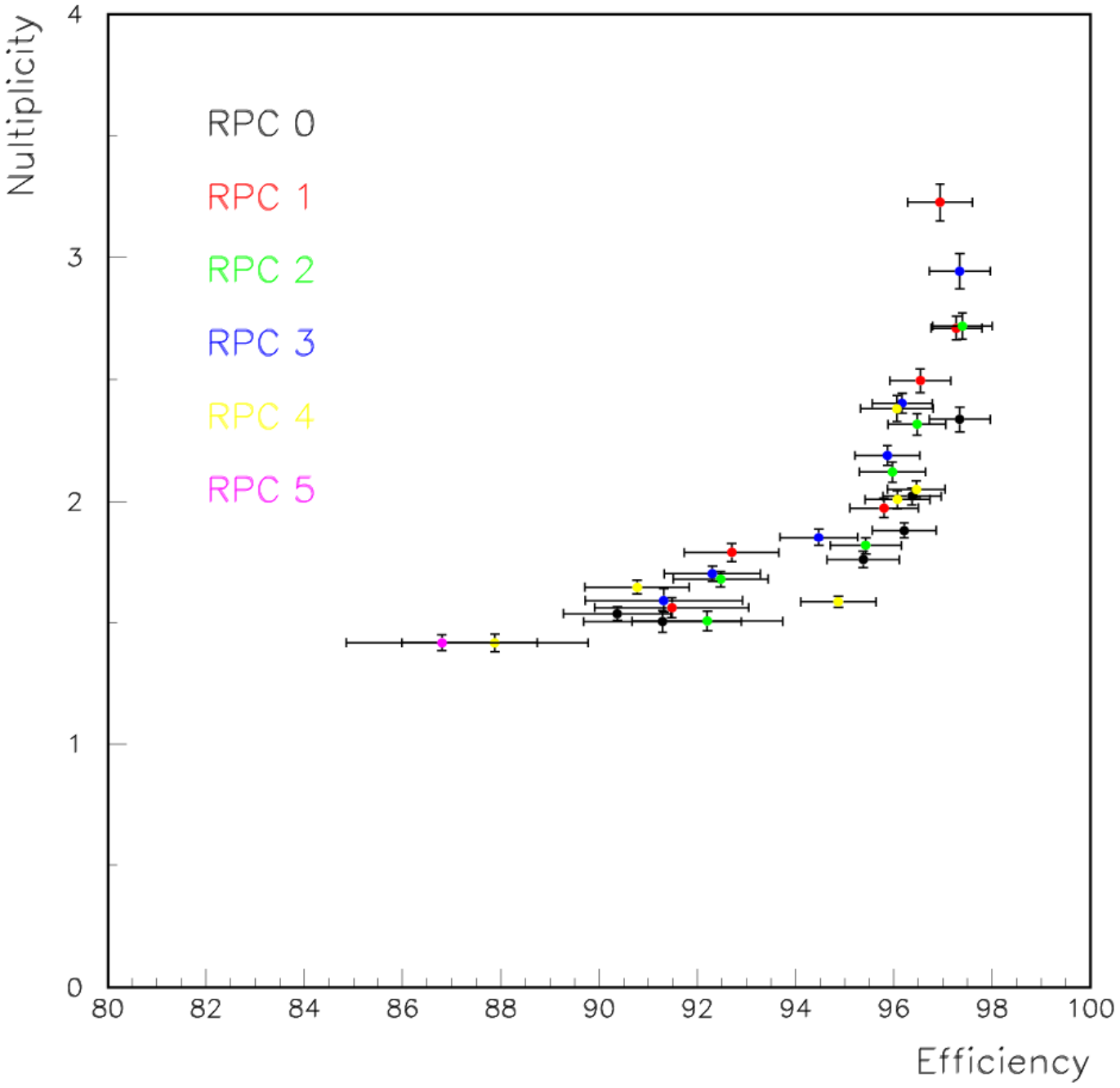
Threshold = 50

Threshold = 70

Threshold = 110

Threshold = 150

Threshold = 190



Some differences between chambers

Still needs to be studied in detail

II) FNAL Test Beam Data

Trigger

Coincidence of 2 scintillation counters (19 x 19 cm^2)
Significant rate of fakes

RPCs

Vertical: up to 9
Each 20 x 20 cm^2 area

Analysis

All results obtained during data taking
Very preliminary!!!

Publications

Aim at writing 5 papers

Data Taking

A) Muon runs

120 GeV protons
Beam blocker in (1 meter of Fe)
Steel+copper absorber plates

Chamber efficiency/pad multiplicity
as function of HV and threshold

B) Pion/positron/muon runs

1,2,4,8,16 GeV/c secondary beam
Included Čerenkov in trigger

Requiring Čerenkov signal (positrons)
Vetoing on Čerenkov signal (pions/muons)
Additional Fe-absorber (muons)

Steel+copper absorber plates

EM and hadronic showers

C) Proton runs

120 GeV protons
No beam blocker
Variable rates
PVC absorber plates

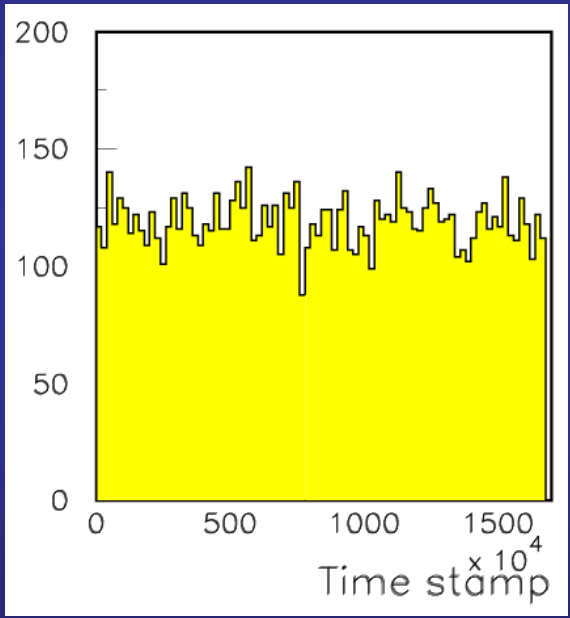
Rate capability measurement

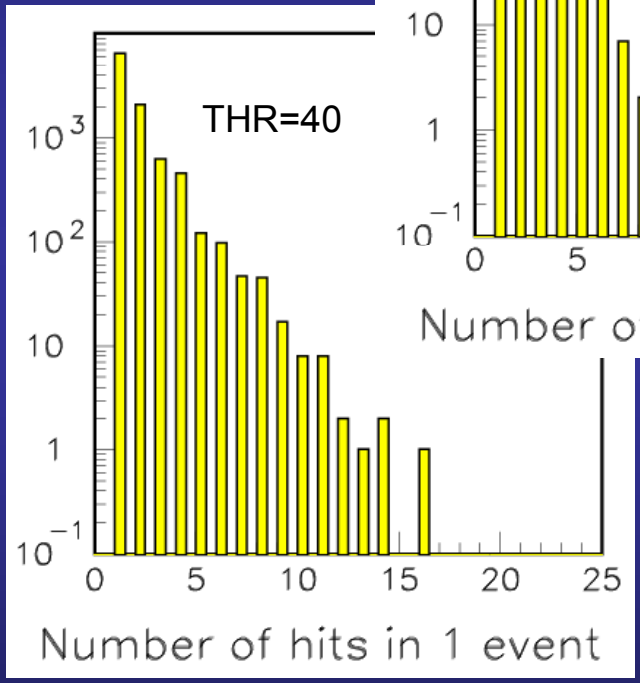
I) System description

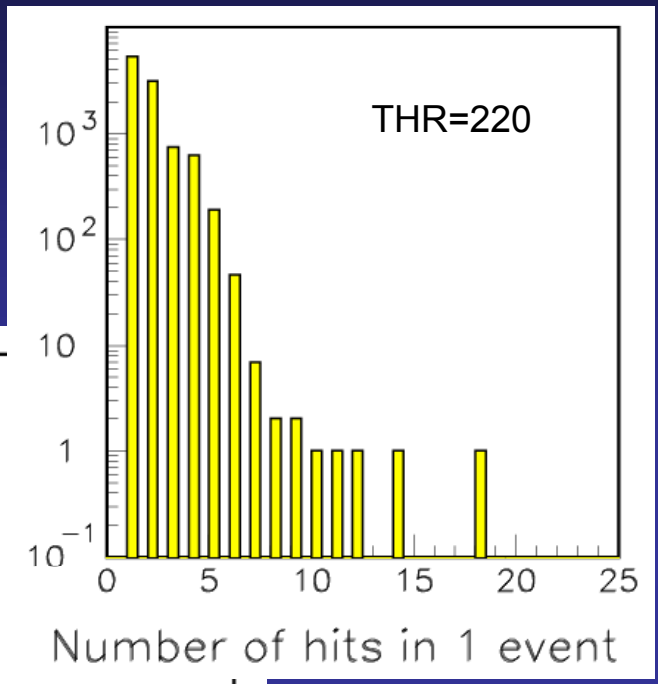
Description of DCAL, Pad-, Front-end board, DCON, DCOL, TTM

Self triggered data: Noise studies

Under different conditions
As function of threshold



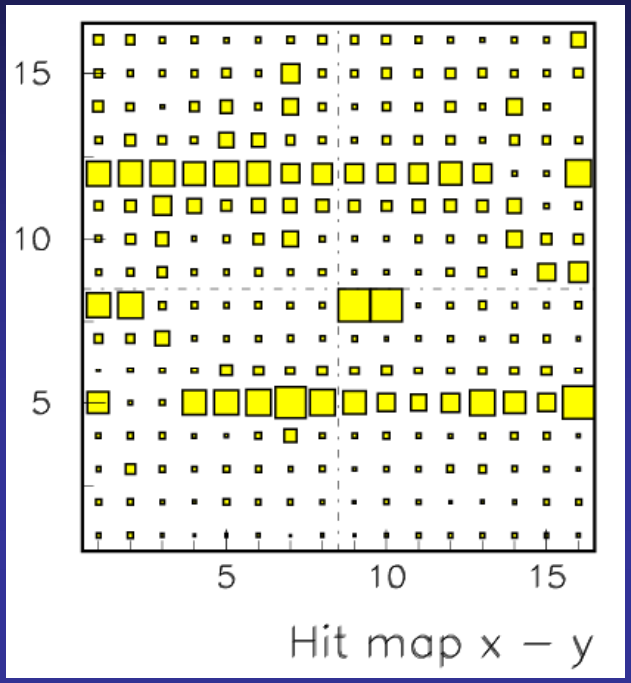




Time stamps evenly distributed

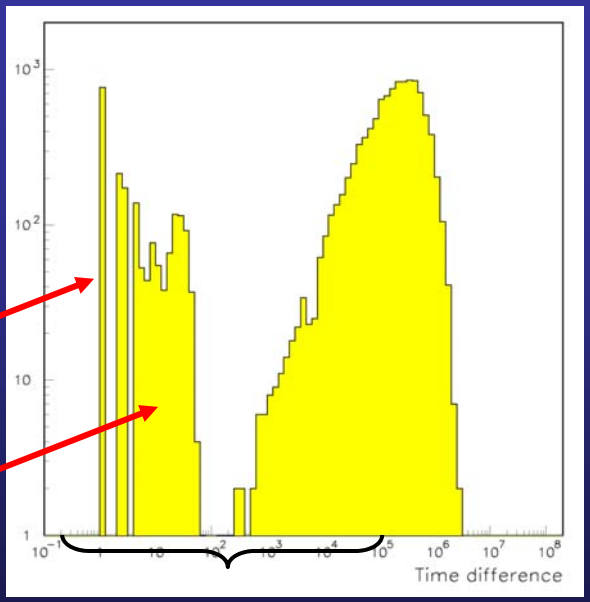
Up to 17 hits/event
Lower multiplicity with higher threshold

Self triggered data: Noise studies



Hits along fishing lines!

Time difference between hits in different ASICs



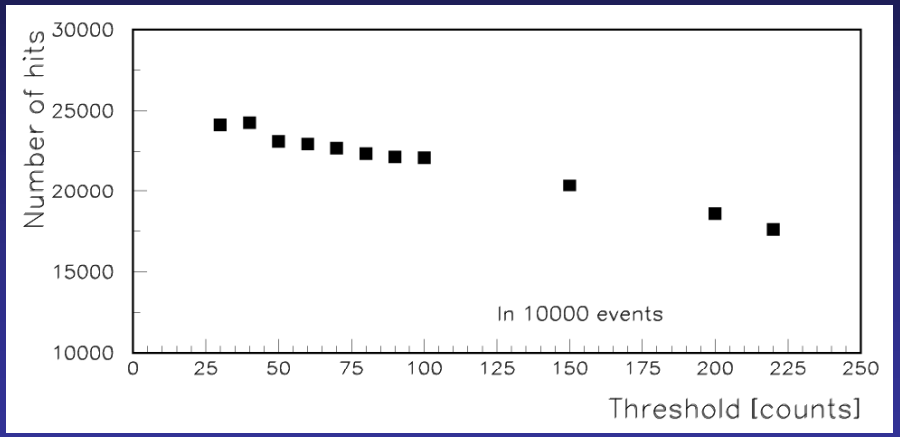
Coherent noise

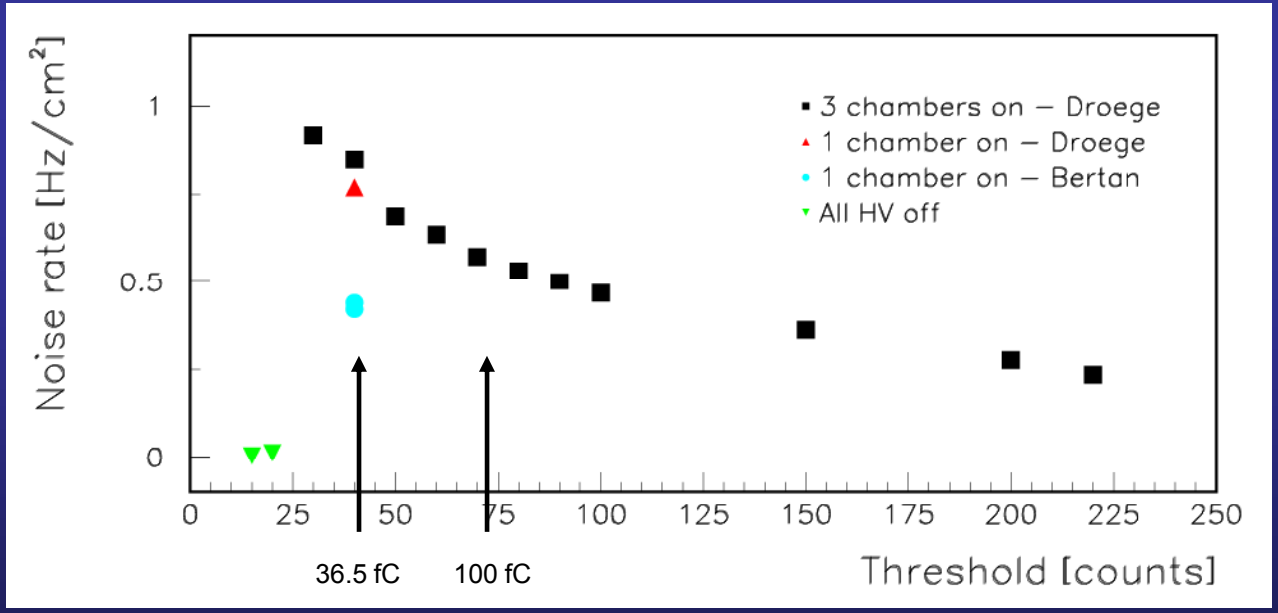
Software glitch (gone now?)

As expected

Self triggered data: Noise studies

Multiplicity decreases with higher threshold





Noise rate of electronics ~ 0
Noise rate < 1 Hz/cm²

Compare SiPMs: Noise rate ~ 1 MHz ~ 100 kHz/cm²
Noise rate in 1 m³ prototype section: $2 \cdot 10^{-2}$ hits/100 ns

II) RPC Calibration

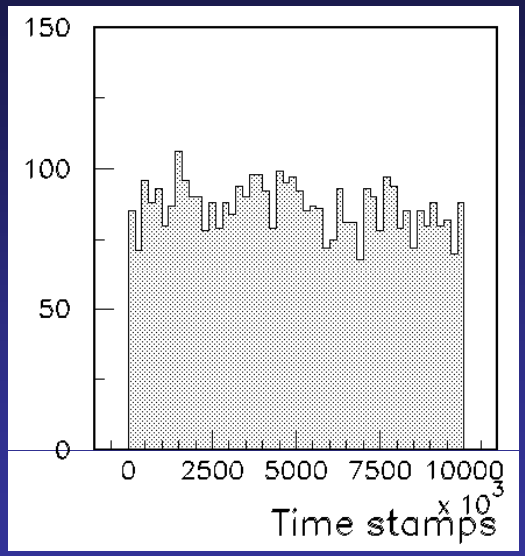
Analysis of Muon data

Example

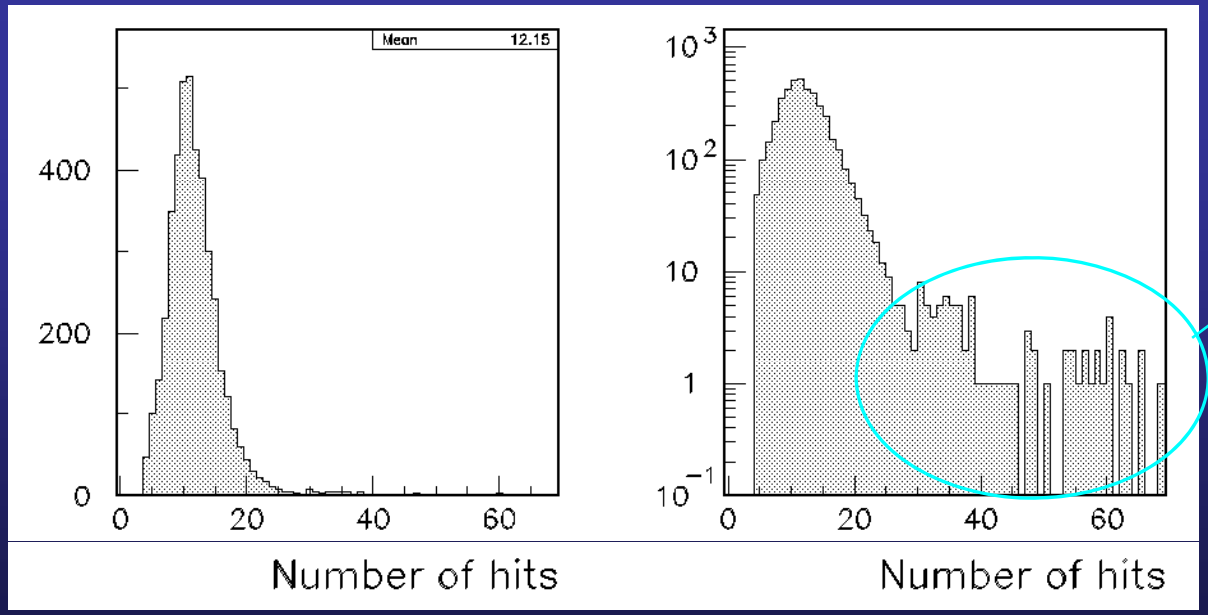
HV = 6.3/6.0
THR = 110 (DAC counts)

Minimal cuts

At least 4/9 layers with hits
At most one cluster in first layer



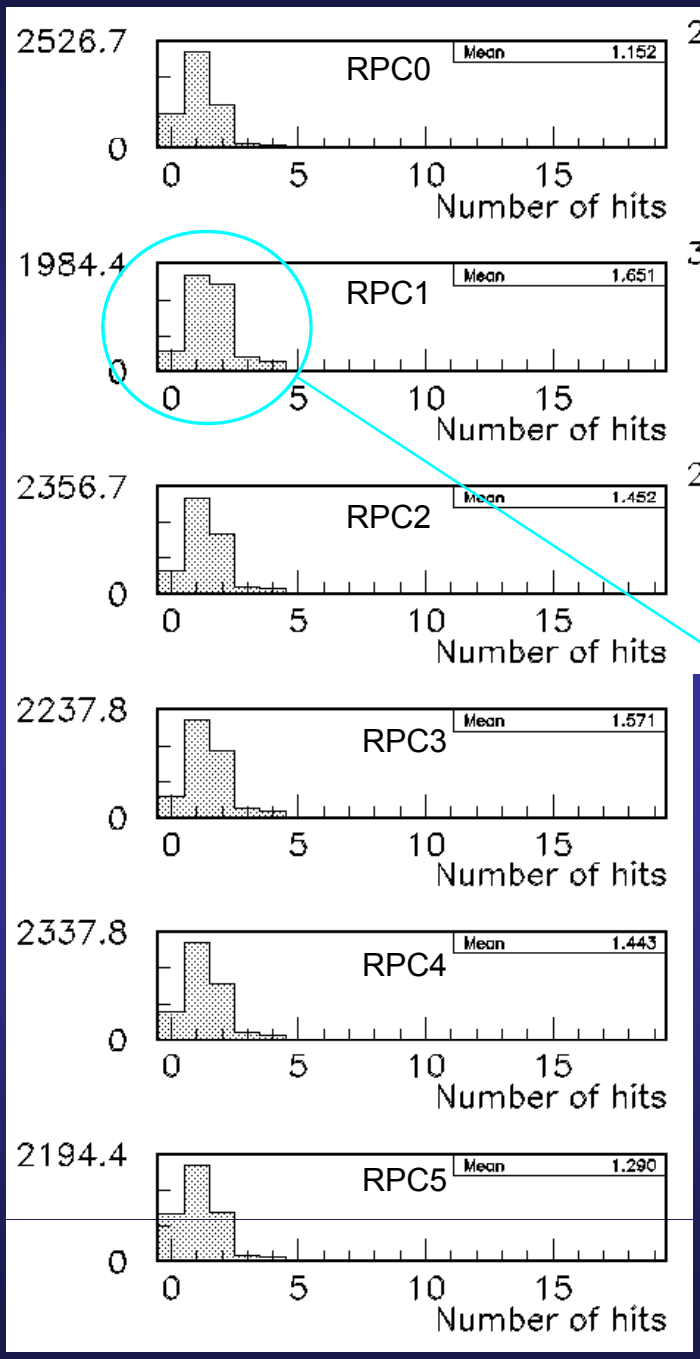
Time-stamps evenly distributed

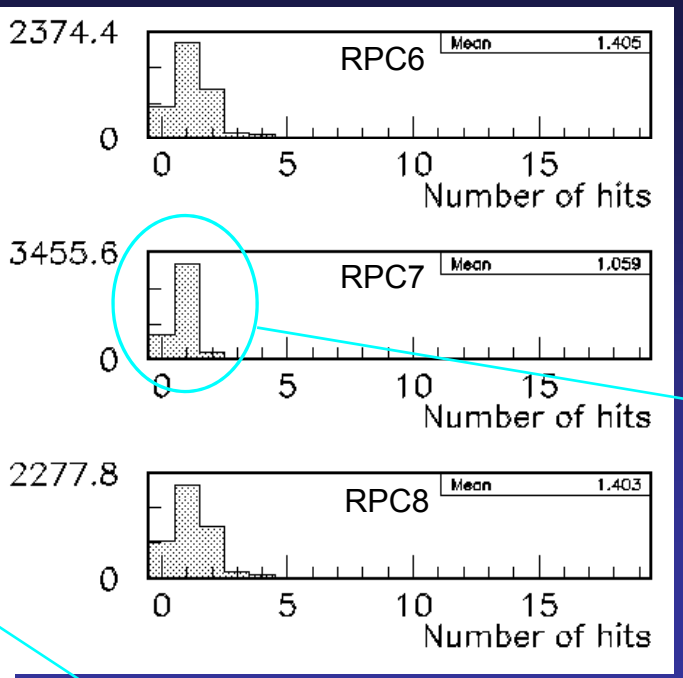


Multiple particles?
Coherent noise?

Summed over all layers (0 – 8)

As expected

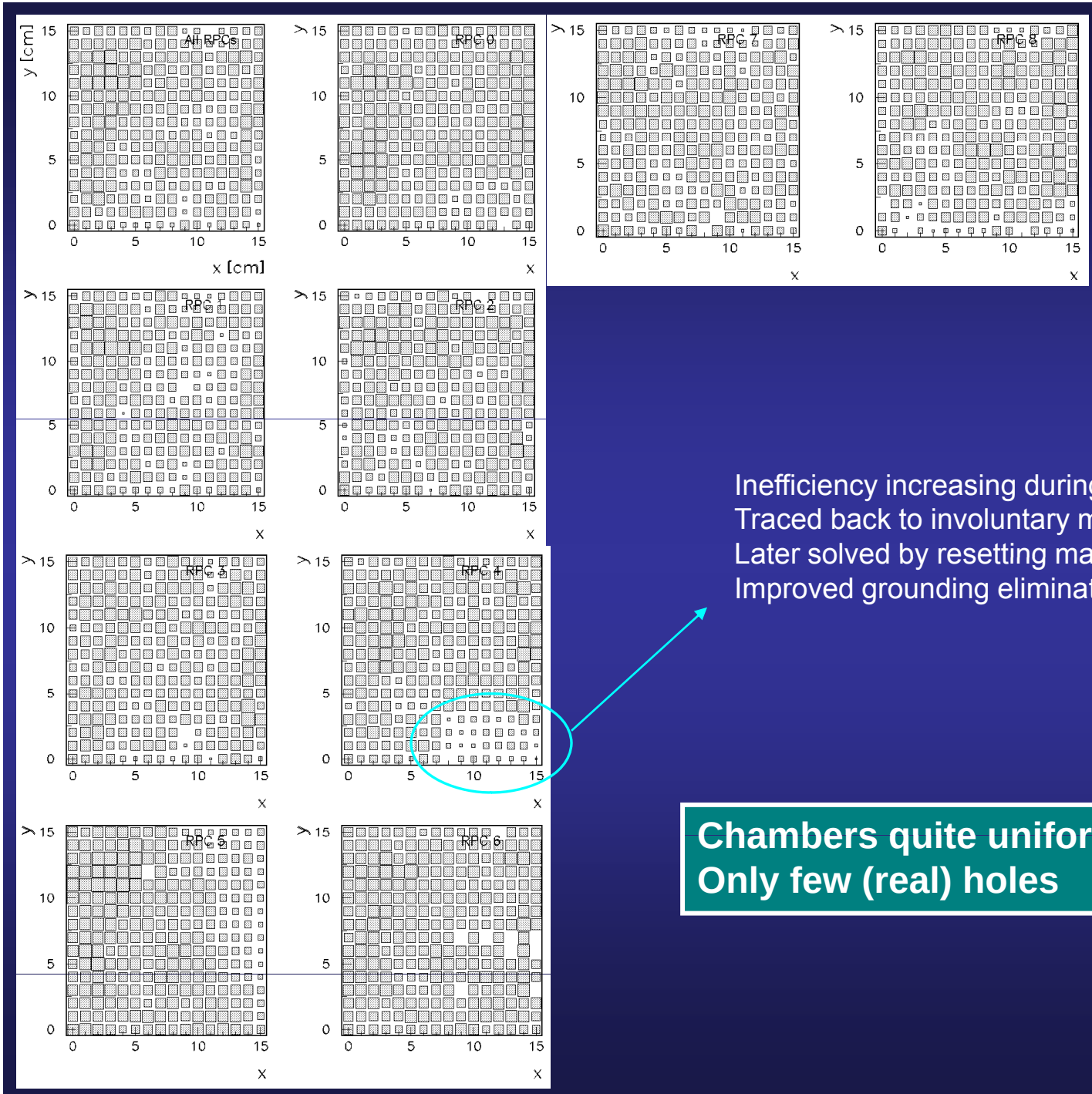




Exotic chamber
(one glass RPC)

Needed cleaning
(humidity?)
Behaved better afterwards

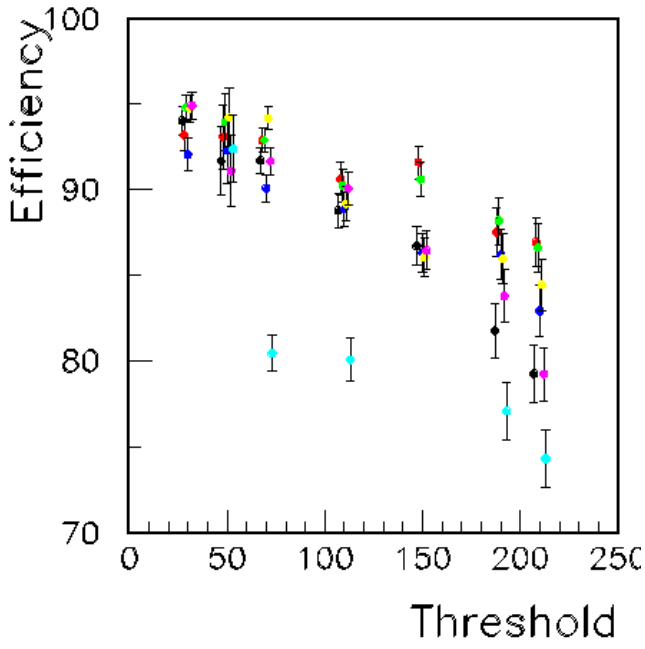
Chambers surprisingly uniform
Exotic chamber has lower multiplicity

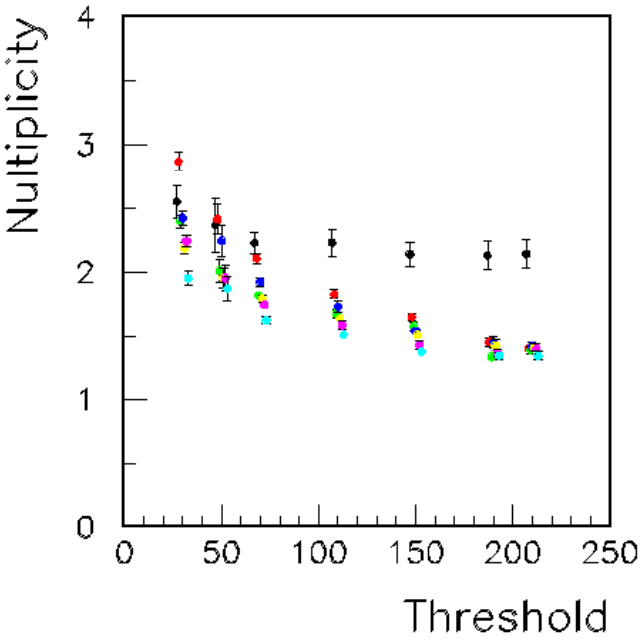


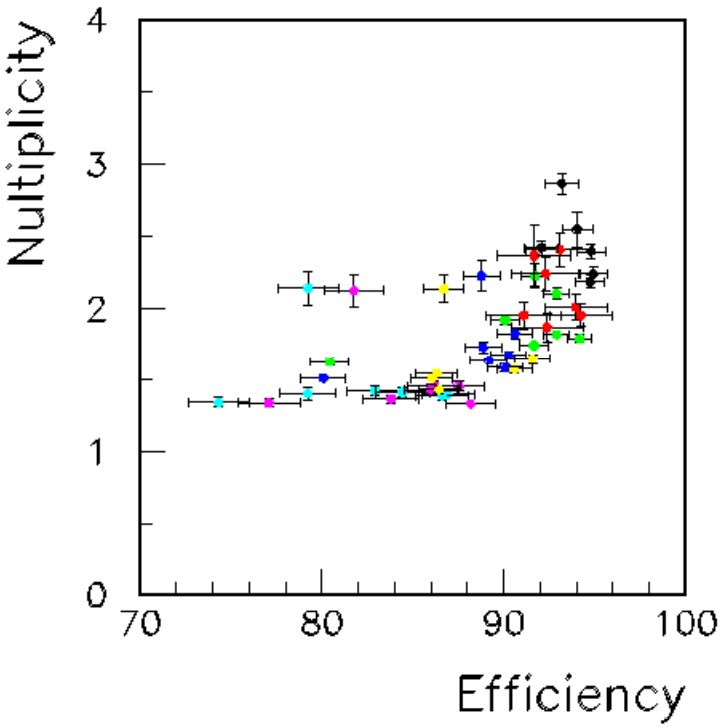
Inefficiency increasing during run
Traced back to involuntary masking off in FE
Later solved by resetting masks every 30 seconds
Improved grounding eliminated the problem

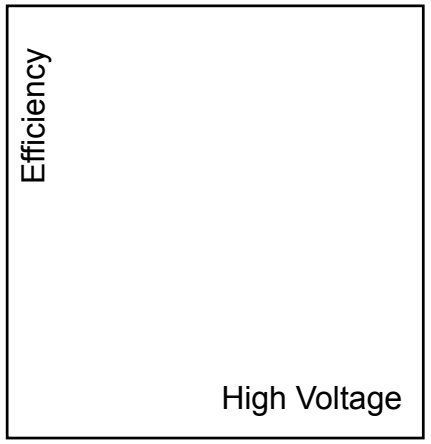
Chambers quite uniformly illuminated
Only few (real) holes

‘Online’ results needs cleaning up….









etc…

III) Positron data

Analysis of 1, 2, 4, 8, 16 GeV data with Čerenkov requirement

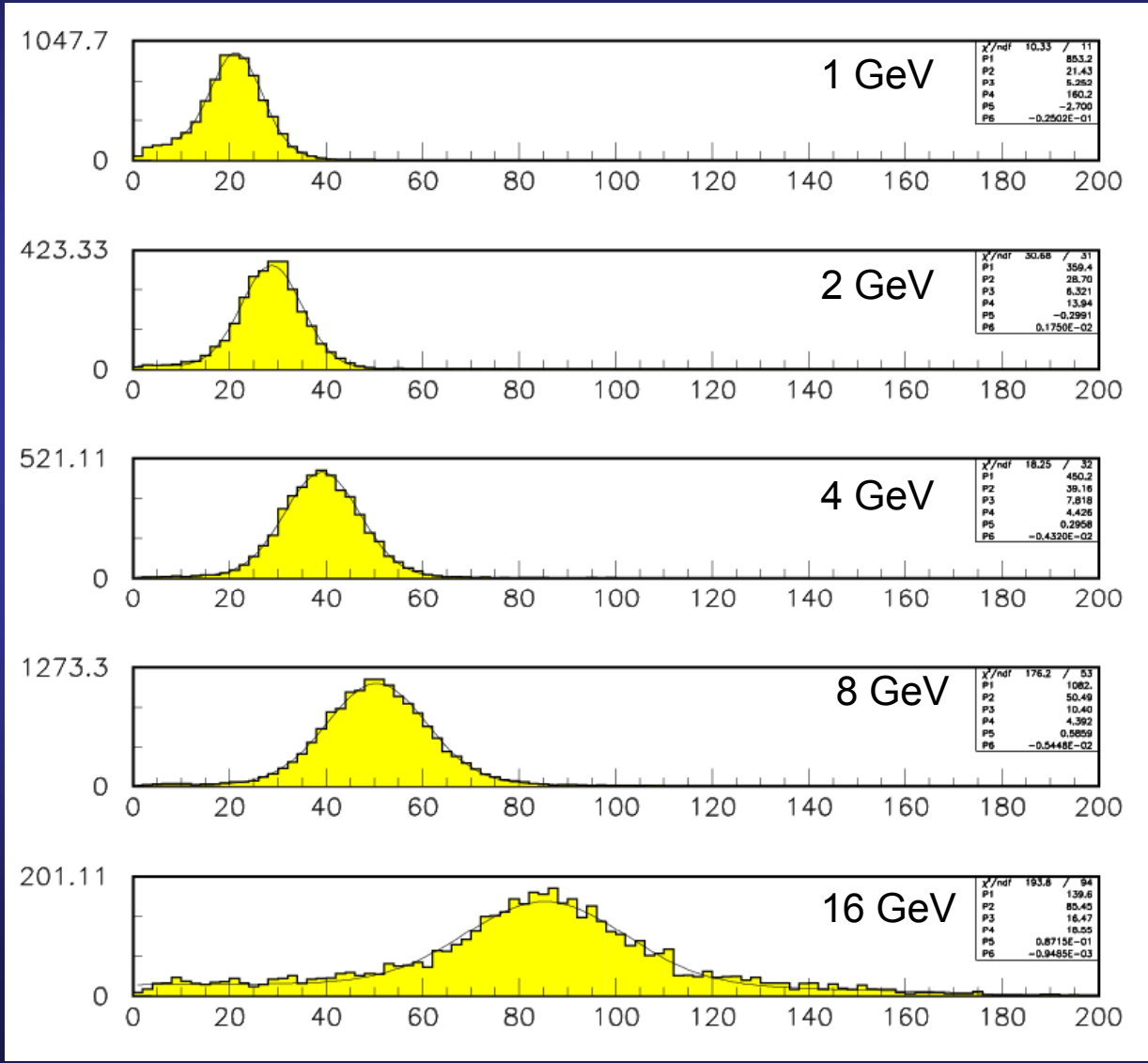
Čerenkov appears to be very pure

Only using RPC 0 – 5

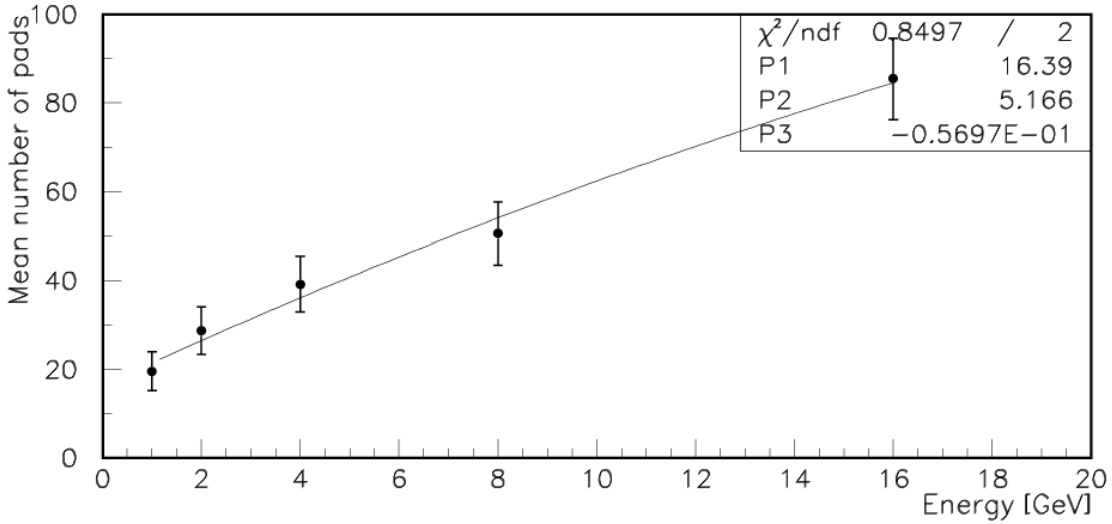
Large leakage

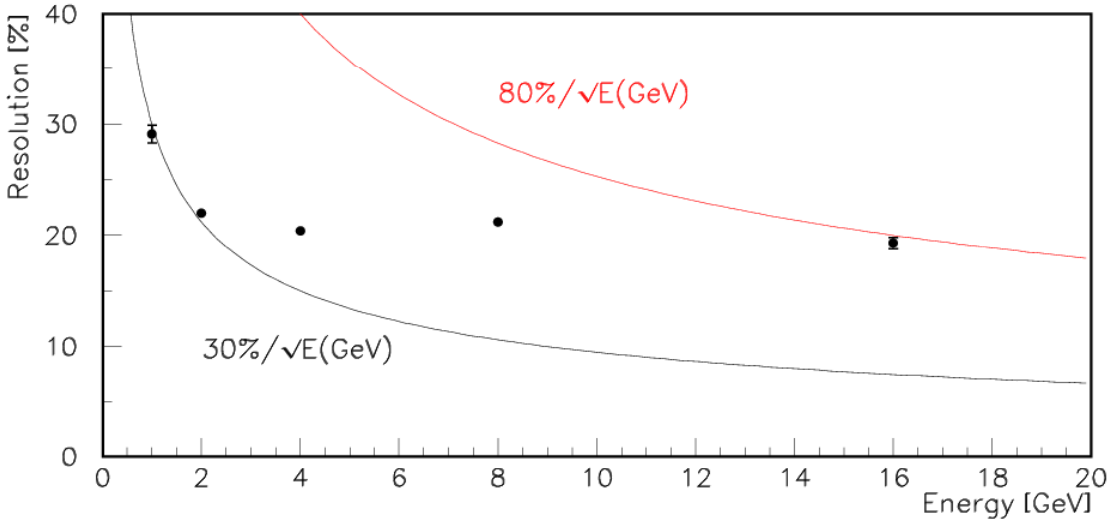
Remember:

This is an incomplete Digital Hadron Calorimeter



‘Online’ results…
needs calibration, comparison to GEANT4





Highly non-linear (as expected)

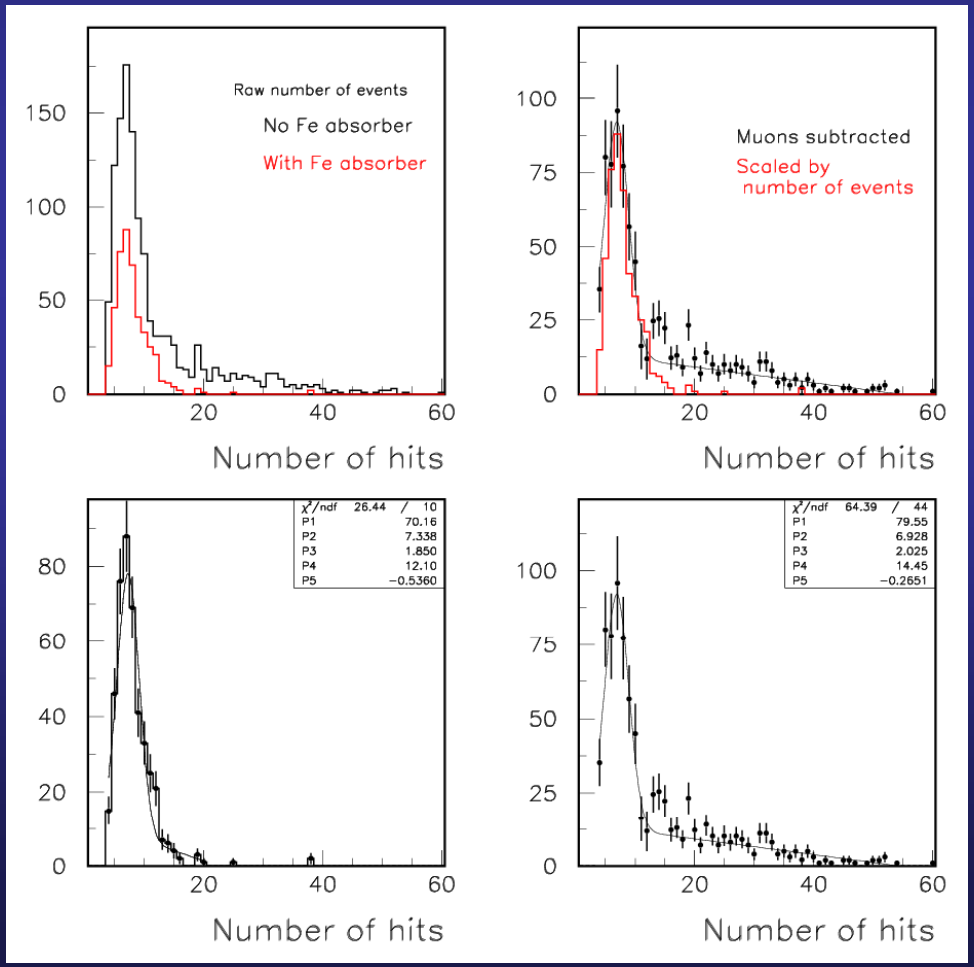
Surprisingly good resolution

IV) Pion data

Collected data at (1),2,4,8,16 GeV data with Čerenkov veto

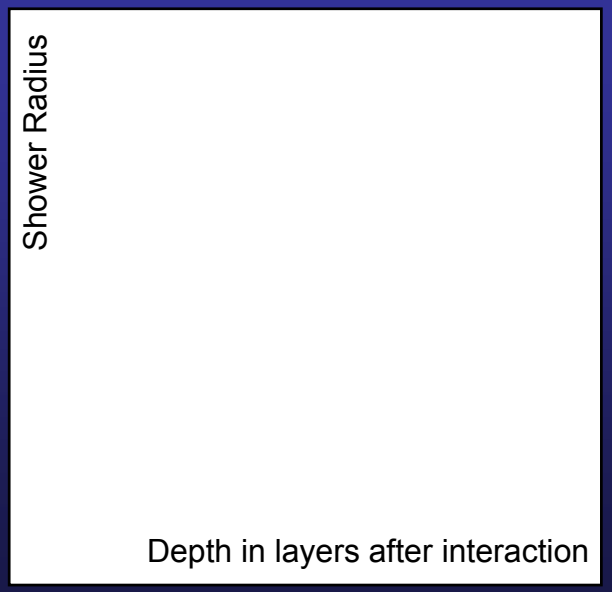
Čerenkov appears to be highly efficient

Data at 2 GeV taken with/without additional iron absorber



'Online' results…
needs calibration
comparison to GEANT4

Clear evidence for π^+ at 2 GeV
(~ 57% π^+ and ~ 43% μ^+)



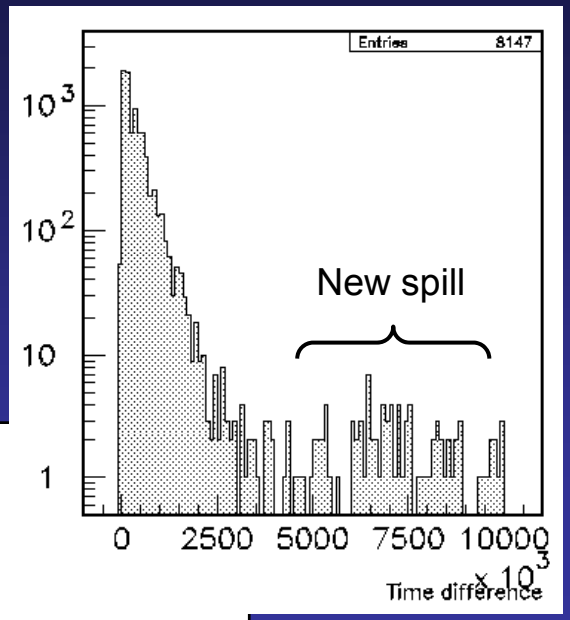
V) Rate capability

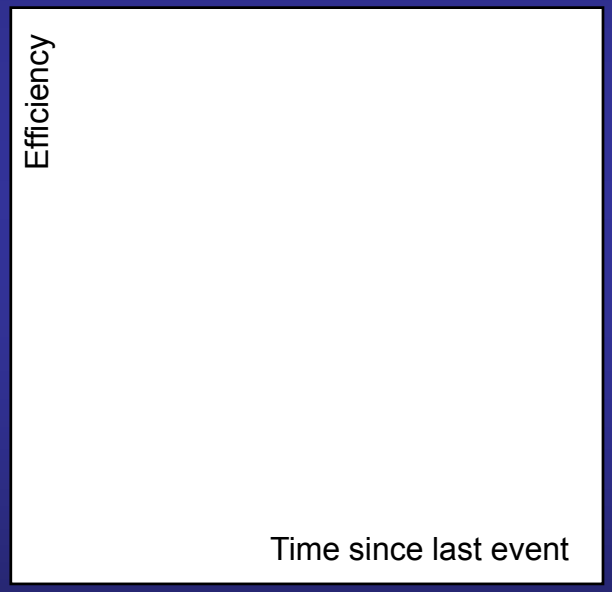
Analysis of 120 GeV proton data with PVC absorber

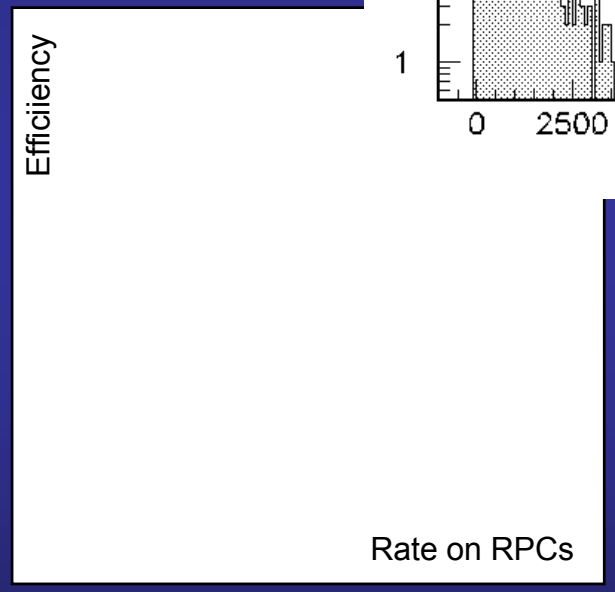
Short term effects: dead time after individual events

Long term effect: decrease of efficiency with overall rate

Time difference between consecutive events







Very challenging,
but all data available for precise measurement

Conclusion

The Vertical Slice Test was entirely succesful

We collected large, high quality data sets

The analysis has begun, but a lot remains to be done

We plan on producing 4 – 5 papers

Manpower

Timely publication of results important (funding, visibility…)

People

George Mavromanolakis
José Repond
Lei Xia
(University of Iowa)

} Could use additional help!

Possibilities for additional help

- Graduate students

Analyse VST data
Help build Prototype Section
Participate in Fermilab data taking
Analyse Prototype Section data

} Nice thesis!

- Undergraduate students

Need to work full time for at least 6 months

- Postdocs

Need funds