Status of DHCAL Slice Test Data Analysis

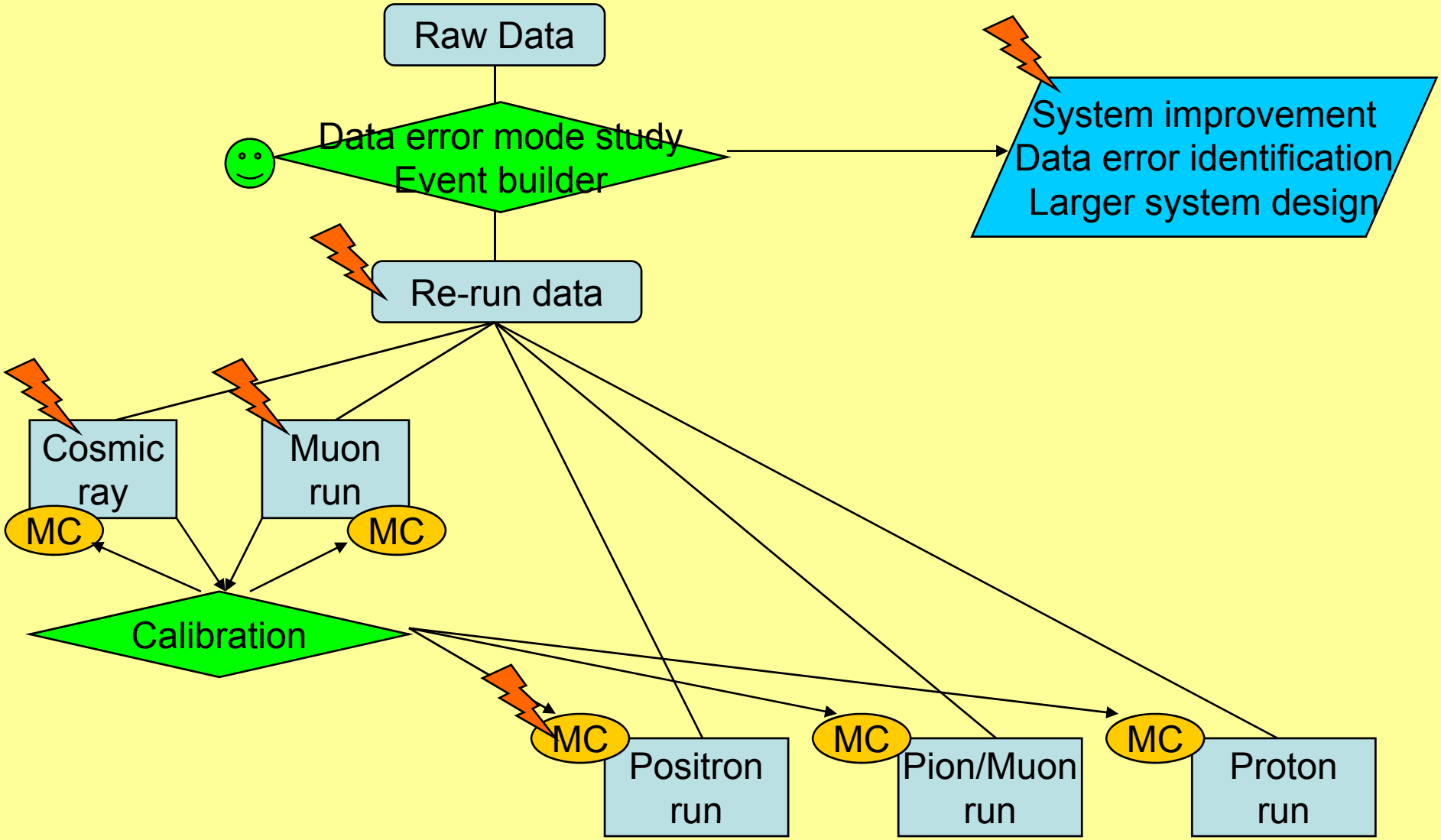
Lei Xia
ANL-HEP

All results preliminary

Data set

- Beam data
  - Muon runs (‘calibration run’, RPC eff/pad multiplicity vs HV/Thr)
    - 120 GeV proton beam hitting beam stop
    - Steel (16mm) + copper (4mm) absorber
  - Positron runs (‘EM shower’)
    - 1,2,4,8,16 GeV/c secondary beam (Čerenkov trigger)
    - Steel (16mm) + copper (4mm) absorber
  - Pion/muon runs (‘hadronic shower/MIP track’)
    - 1,2,4,8,16 GeV/c secondary beam (veto on Čerenkov trigger)
    - With/without additional Fe absorber in front of stack
    - Steel (16mm) + copper (4mm) absorber
  - Proton runs (‘rate measurement’)
    - 120 GeV primary beam
    - Scan beam rate (from lowest possible rate to ~30k/spill)
    - PVC ‘absorber’ plate (17x17cm^2 hole at center == no absorber)
- Cosmic ray data (‘calibration’)
  - Before beam test (ANL lab)
  - Right after beam test (FNAL MTBF)

Analysis plan

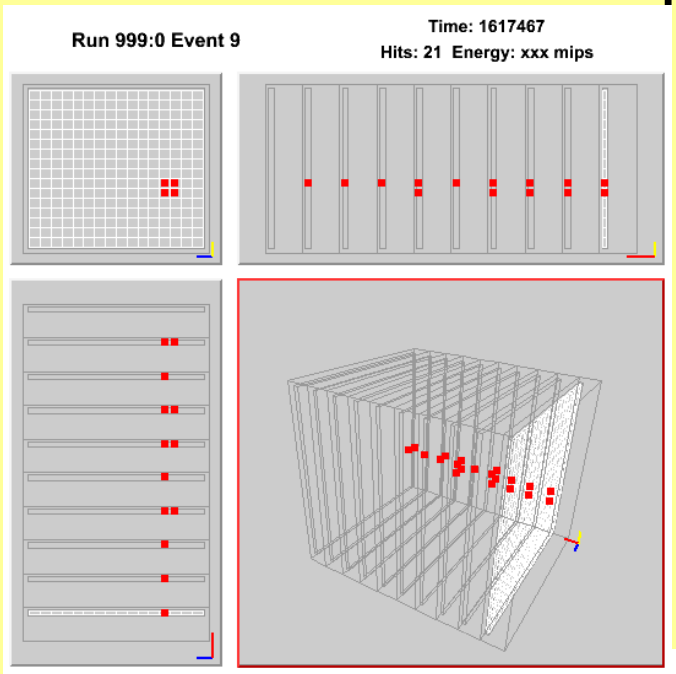


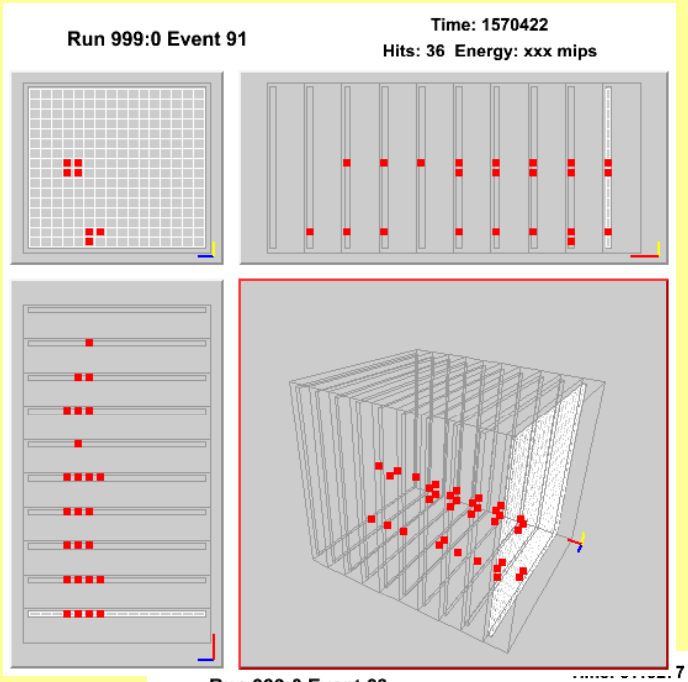
With limited manpower, a lot of analyses are not covered at the moment…

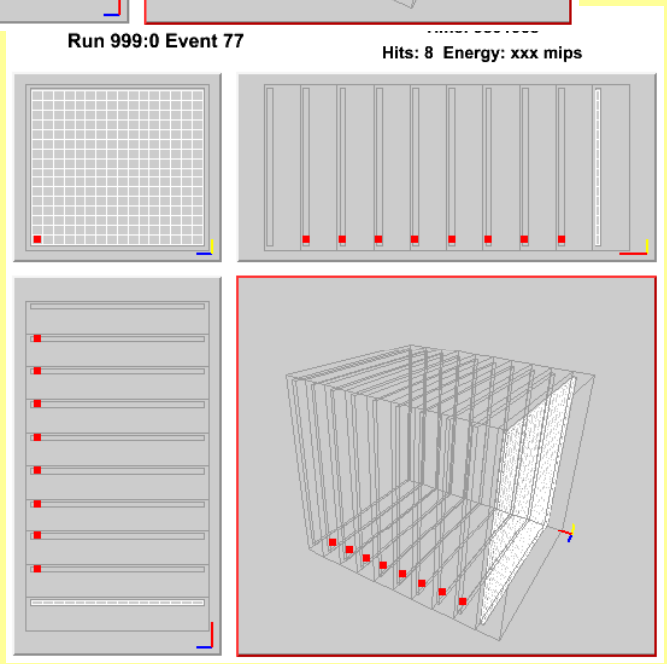
Data error modes

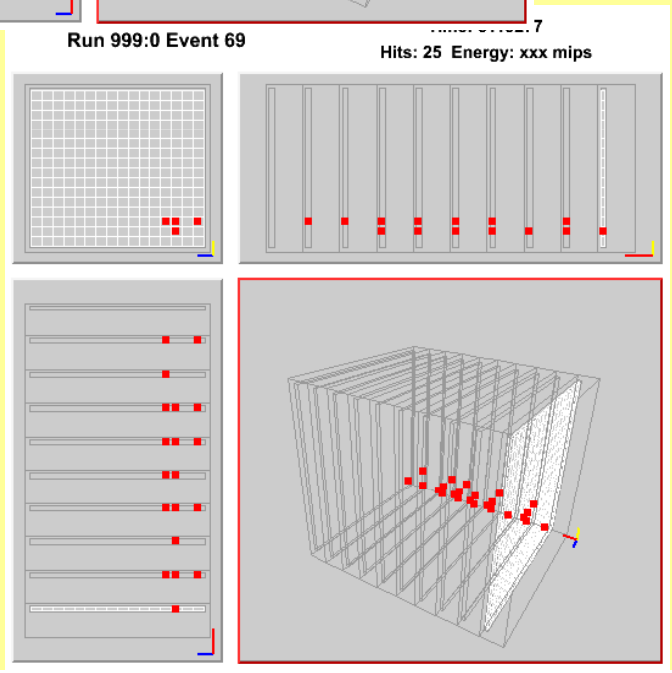
- Slice test data errors
  - Rate of data error is very low, ~0.x% (error package/total package)
  - Need to understand the source, mechanism and scaling properties of these errors
    - Critical for event building and data analysis
    - Helps to find ways to eliminate/identify errors
    - Critical for designing a larger system (1m^3 physics prototype)
- Current status
  - Identified 14 error modes (not all independent)
    - 9 ‘fatal error’ modes: data can NOT be recovered
    - 5 ‘non-fatal error’ modes: data can still be recovered
  - 7 error modes have been eliminated after slice test
  - 4 major errors (2 ‘fatal’+2 ‘non-fatal’) still exist
  - Data re-run just started

Muon data

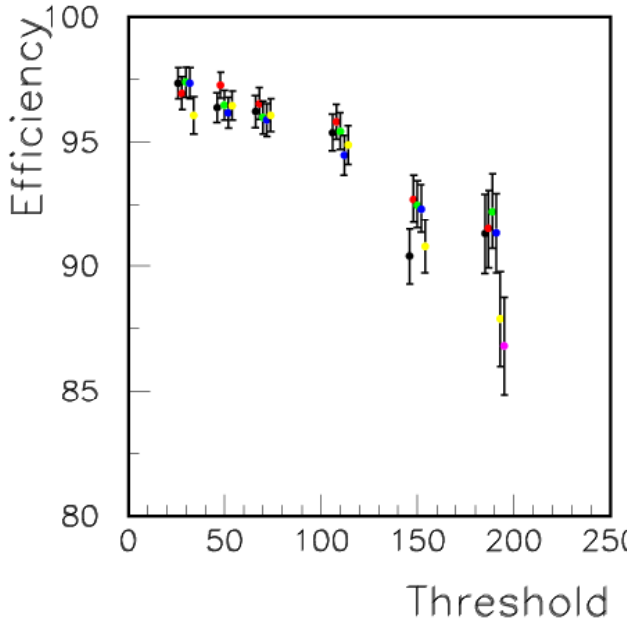

Run 999:0 Event 9
Time: 1617467
Hits: 21 Energy: xxx mips

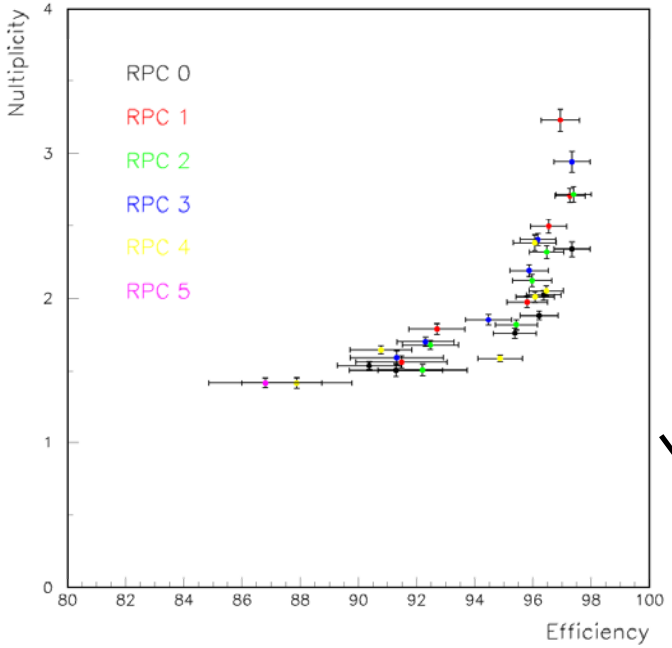

Run 999:0 Event 91
Time: 1570422
Hits: 36 Energy: xxx mips

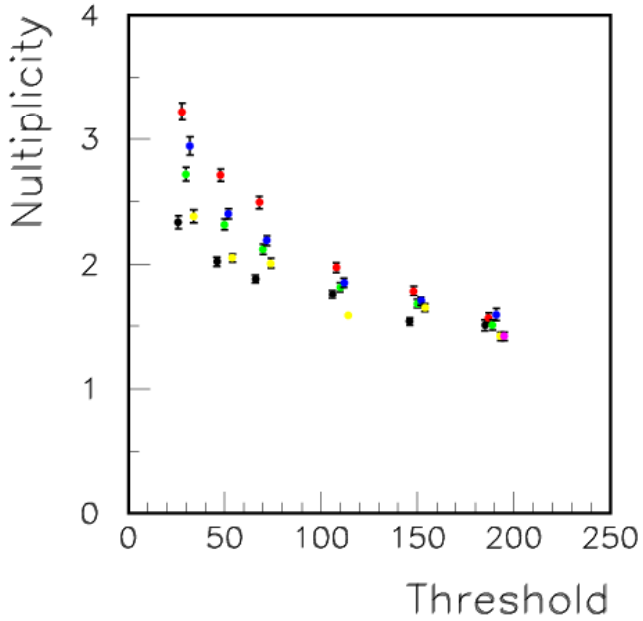

Run 999:0 Event 77
Hits: 8 Energy: xxx mips


Run 999:0 Event 69
Hits: 25 Energy: xxx mips

Muon data: calibration of all runs



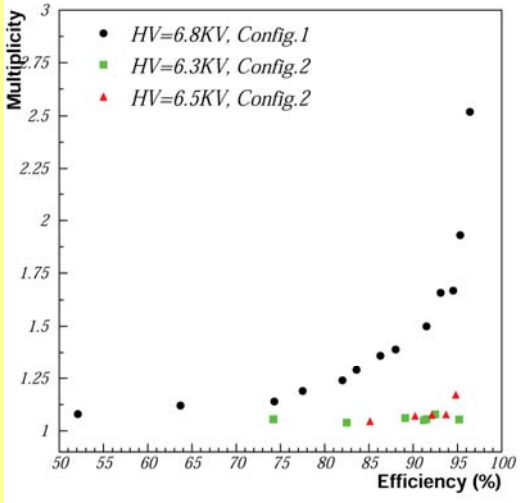




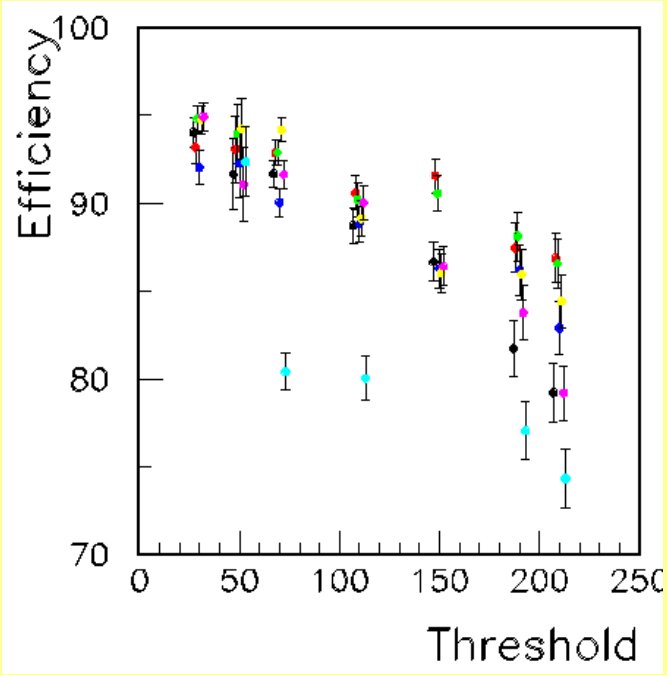
RPC 0
RPC 1
RPC 2
RPC 3
RPC 4
RPC 5

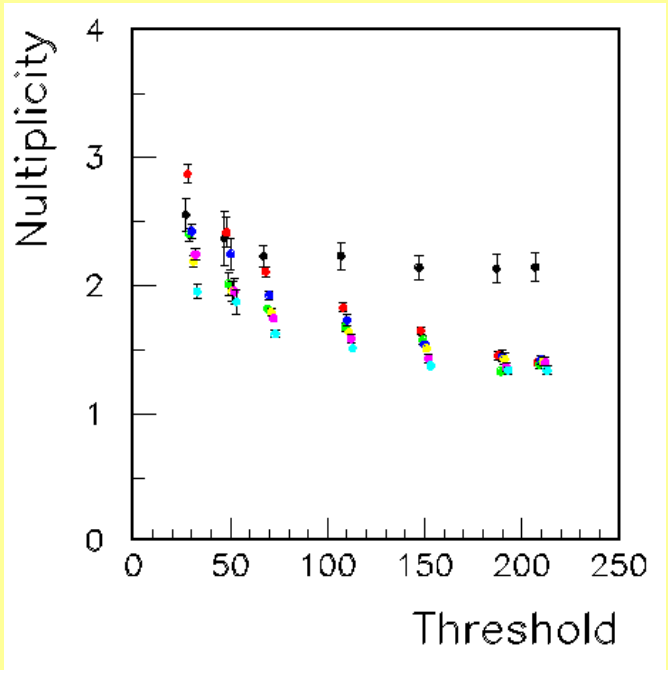
From: Cosmic Ray Runs

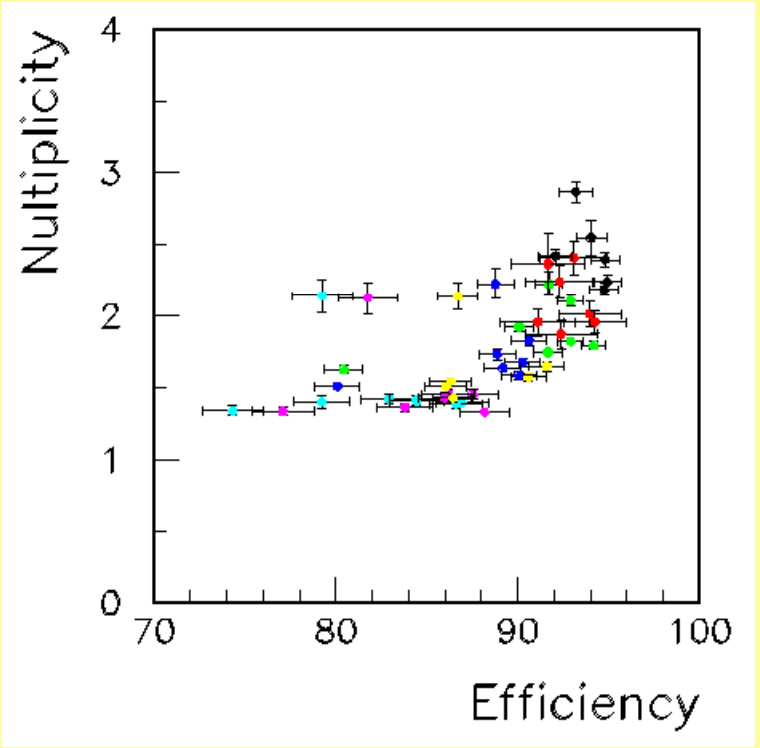
Very similar to results with ‘old’ VME digital readout



Muon data: ‘online results’





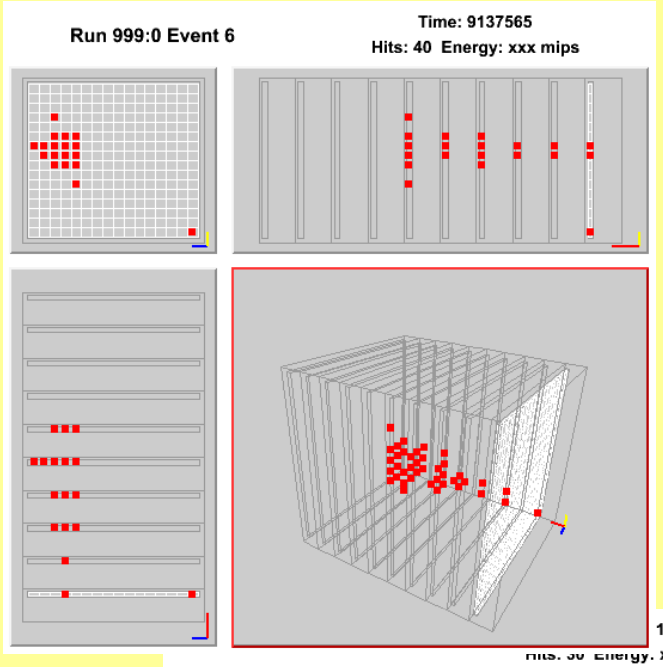


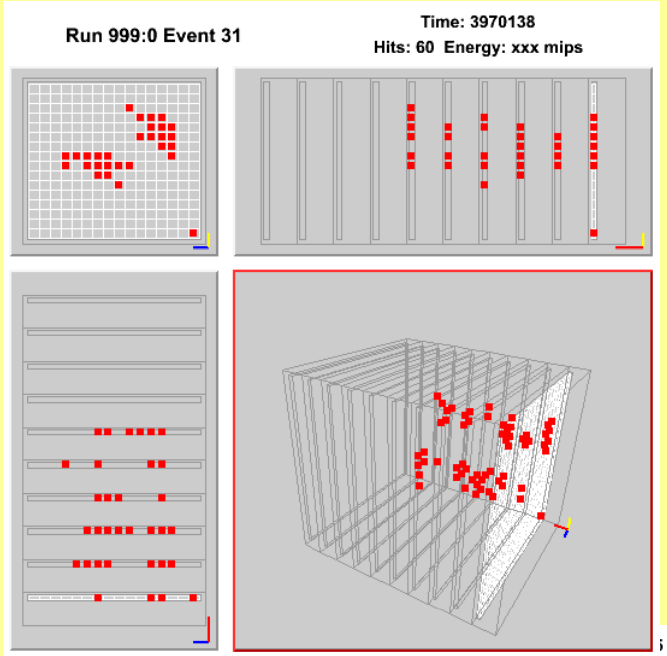
(from muon beam runs)

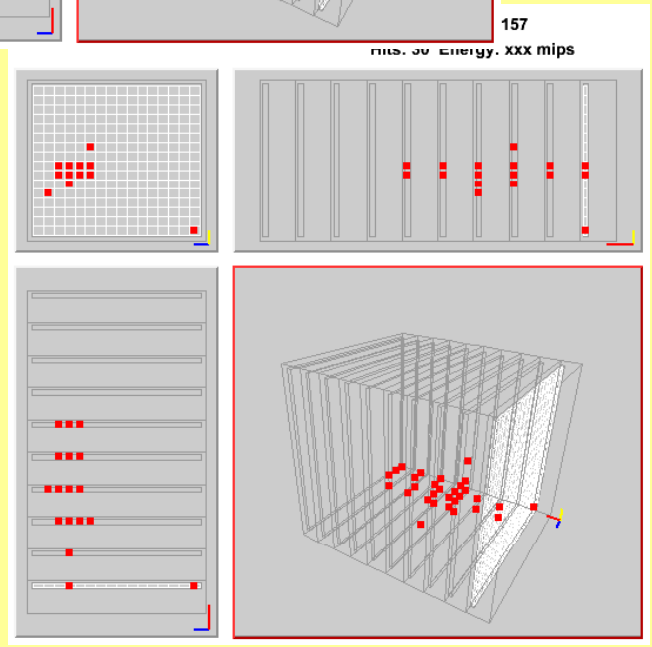
Data still need clean-up…

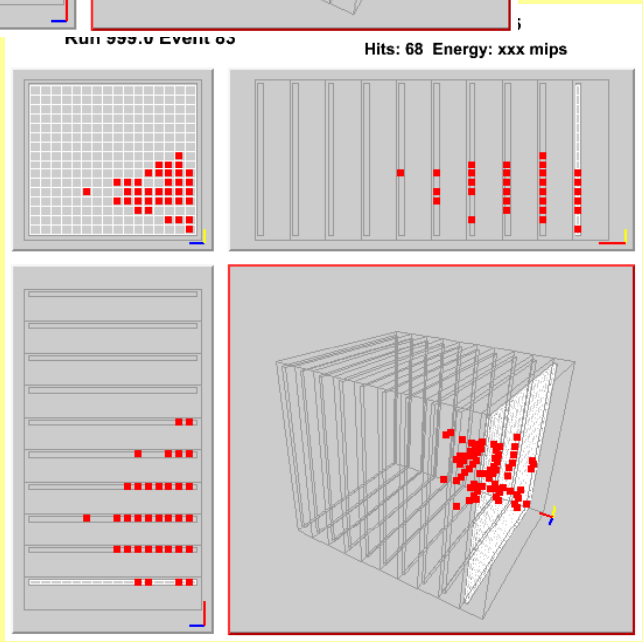
Results will be fed into simulation for all run types

Positron data







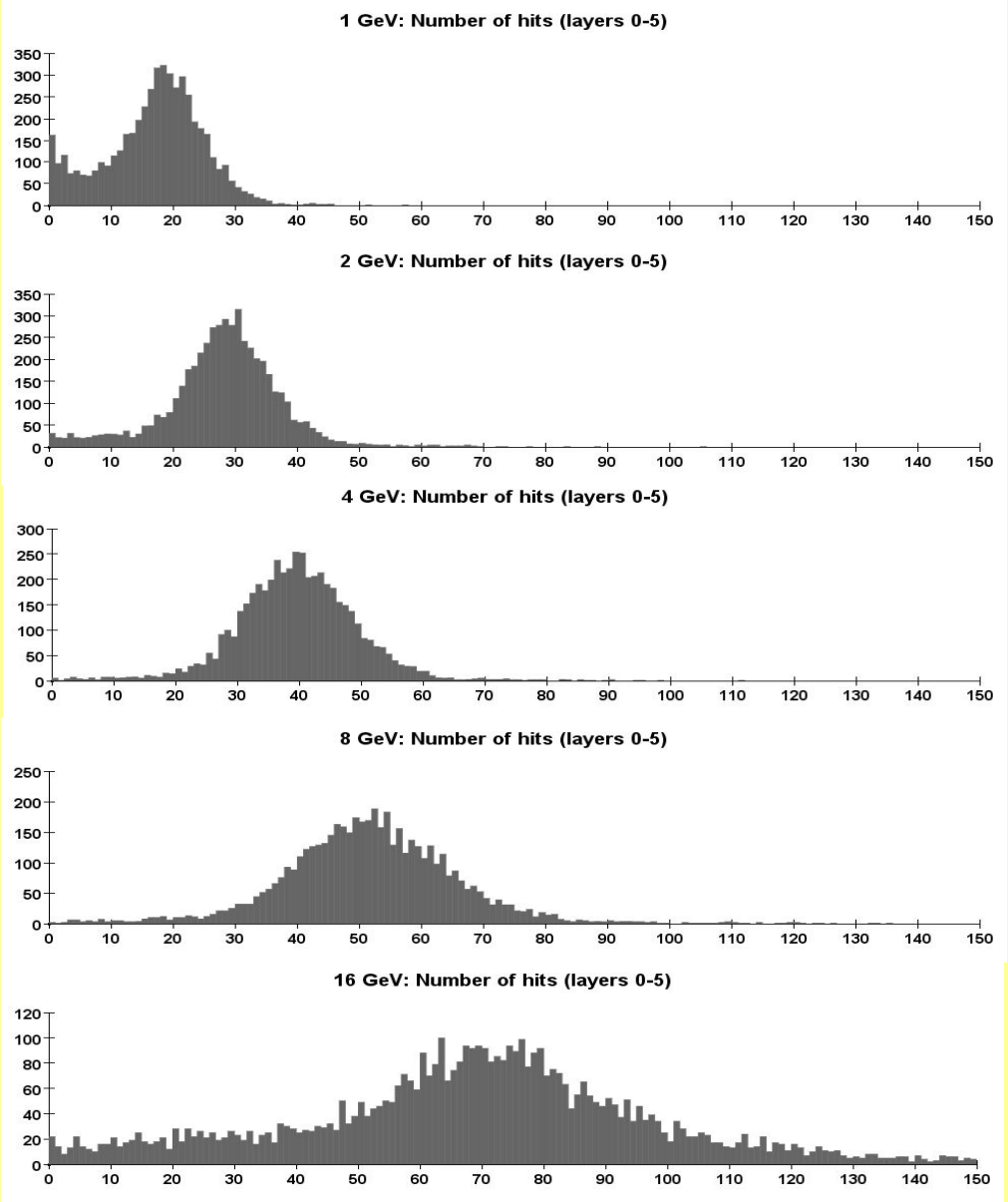


Positron data: ‘online results’

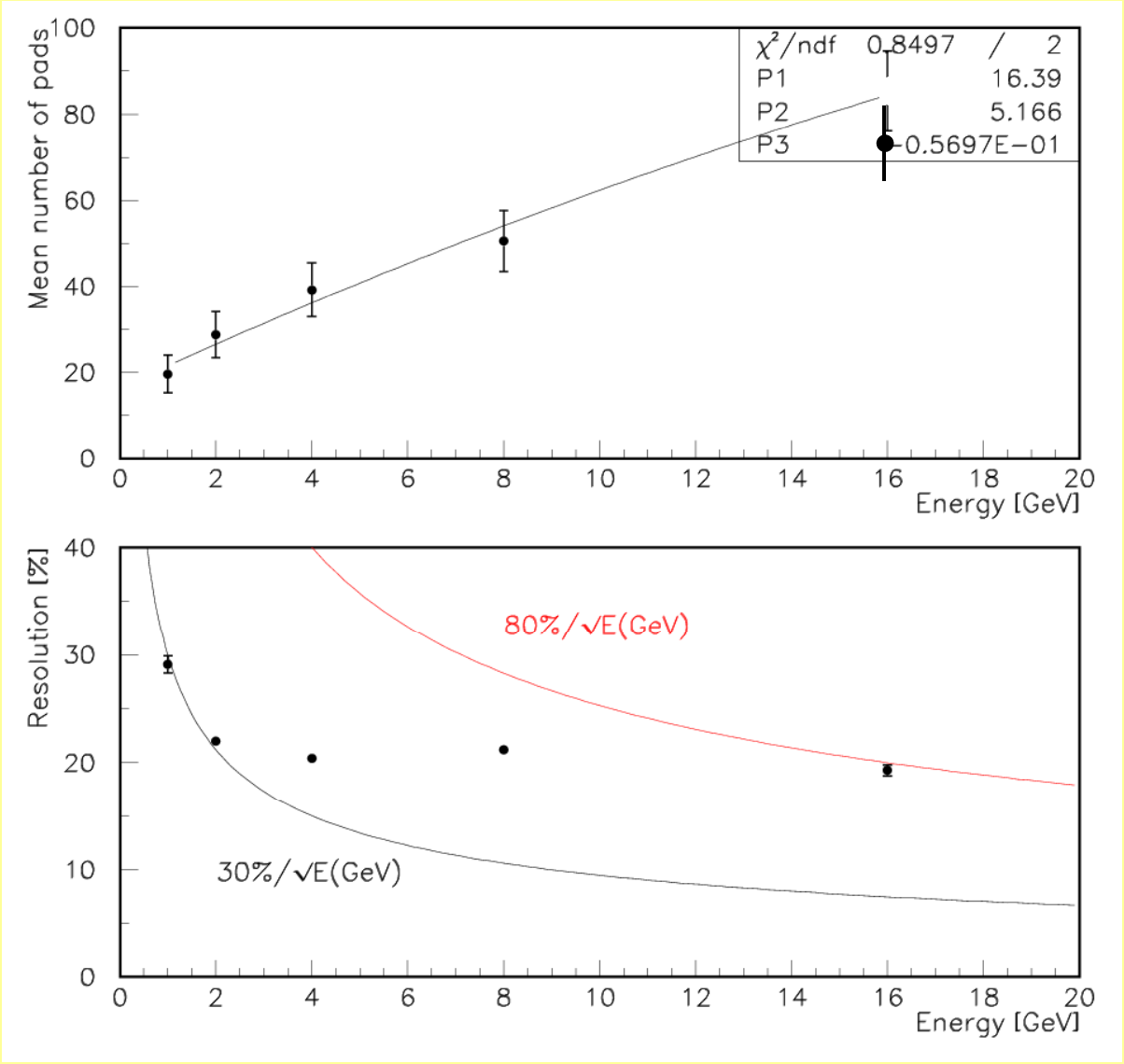
- Number of hits in layer 0-5
  - Positron data @ 1, 2, 4, 8, 16 GeV/c
  - Using Čerenkov signal to selecte positron (very pure)
  - No event selection
    - Particle hitting edge
    - Particle showered upstream
    - Multiple particles
    - …

Remember:

This is an incomplete Digital Hadron Calorimeter



Positron data: ‘online results’



Highly non-linear response

- Largely due to shower leakage
- Also due to digital approach

Surprisingly good energy resolution

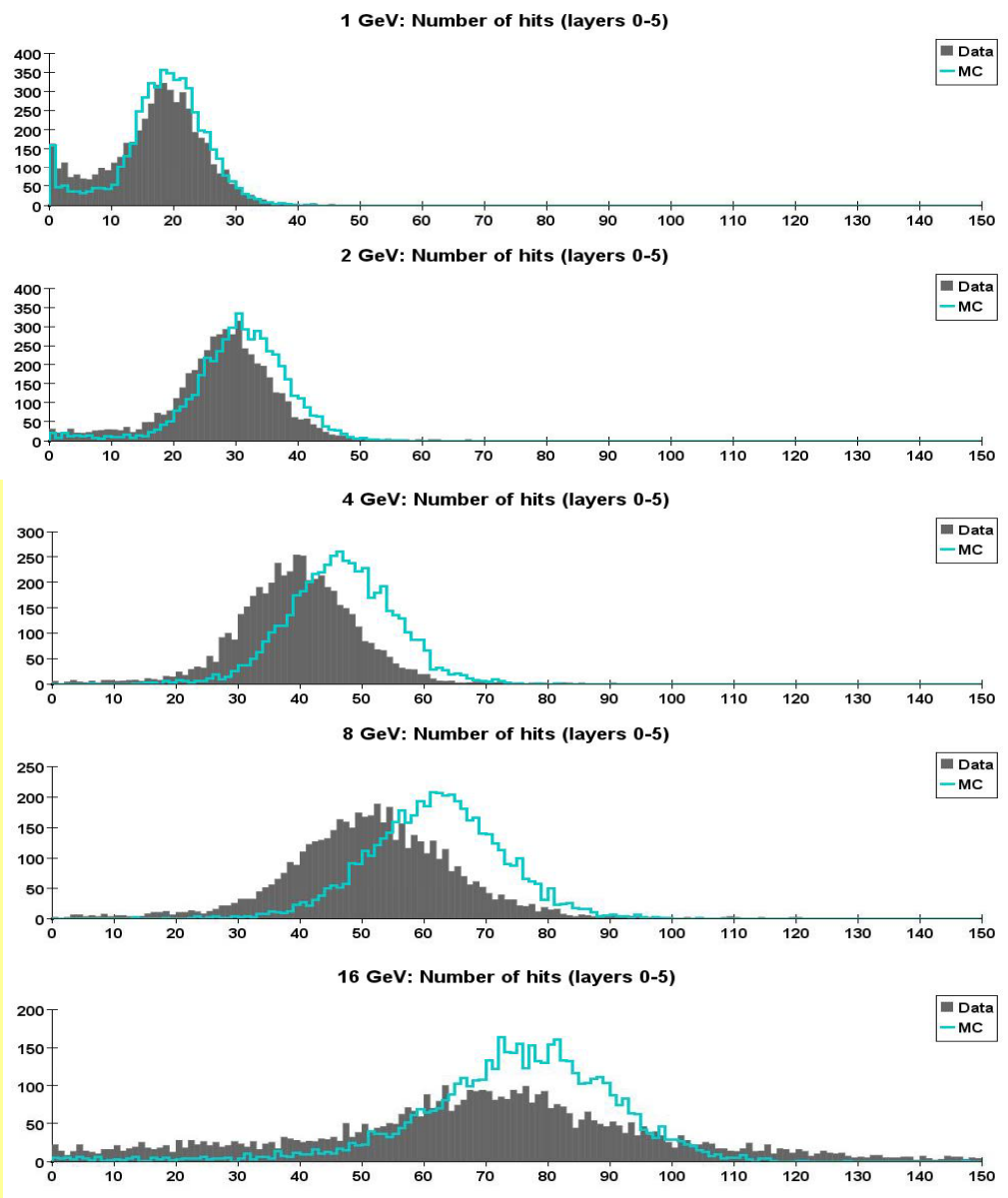
- degrade at high energy due to heavy shower leakage

Positron data: MC simulation

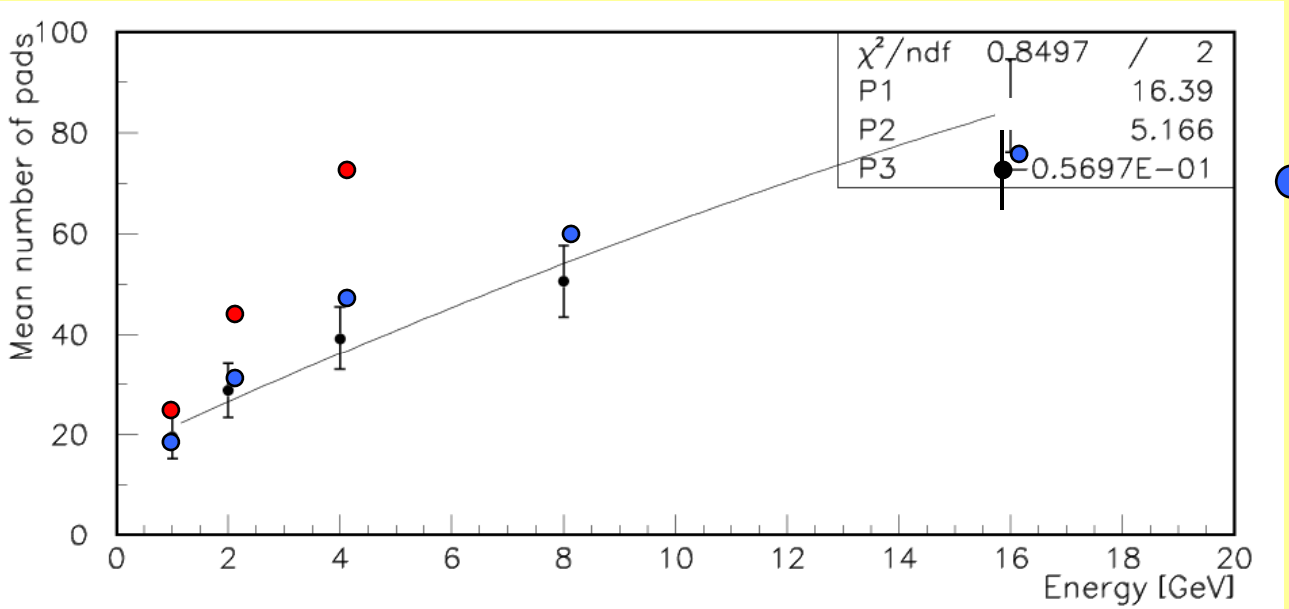
- A crude Geant4 simulation was done, just to have an idea about the detector performance
  - Simulated detector has similar layer structure, but with larger size and much more layers
    - Absorber: 2cm Fe (beam test: 1.6cm Fe, 0.4cm Cu)
    - Gap size: 13.4mm (== beam test setup)
    - Use fiducial cut to get ‘beam test’ hits
  - RPC properties
    - MIP efficiency = 0.90 (beam test: still to be determined)
    - Hit multiplicity = 1.65 (beam test: still to be determined)
      - Implementation not optimal
  - Beam properties
    - Pure positron at 1,2,4,8,16 GeV/c, no upstream material, no multiple beam particles, etc. (data: may have junk in it)
    - Assume Gaussian distribution for beam spot (reality: still to be determined)
      - Gaussian central/width from a crude estimate

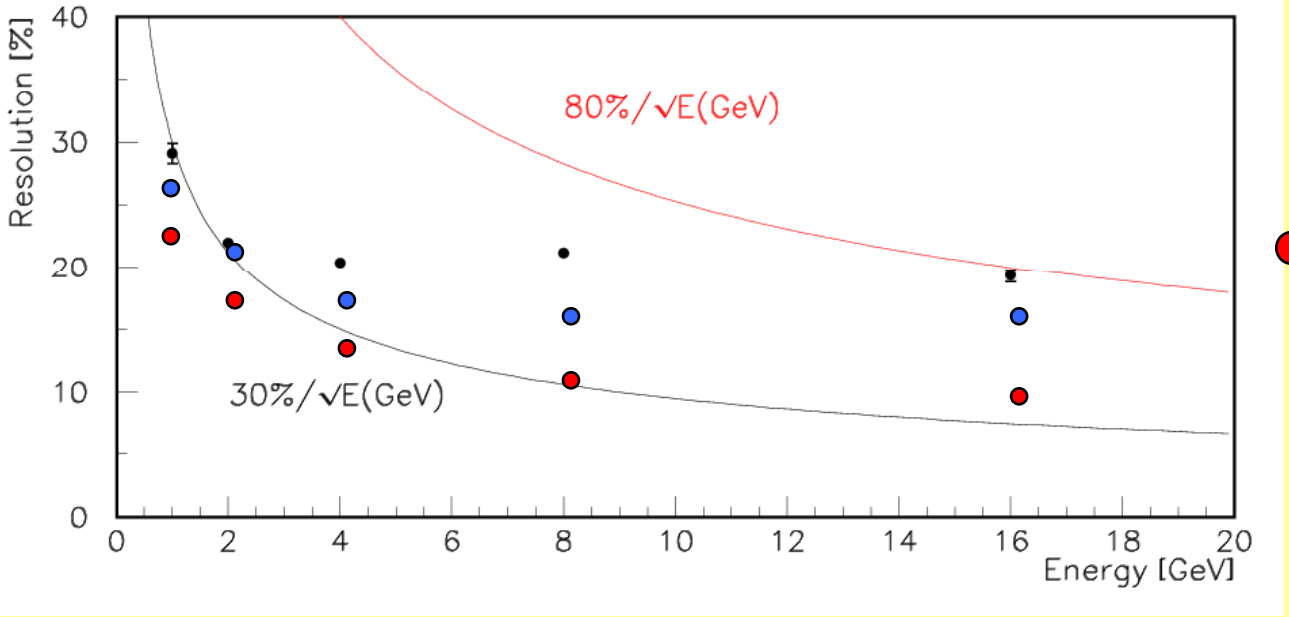
Positron data: compare data/MC

- Agreement is reasonably good
  - Expect significant improvement with careful calibration
- Confirmed that DHCAL works as expected



Positron data: compare data/MC

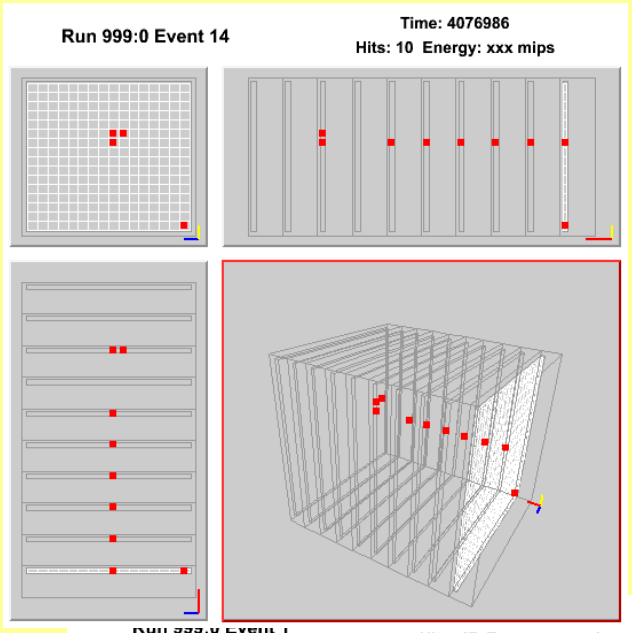


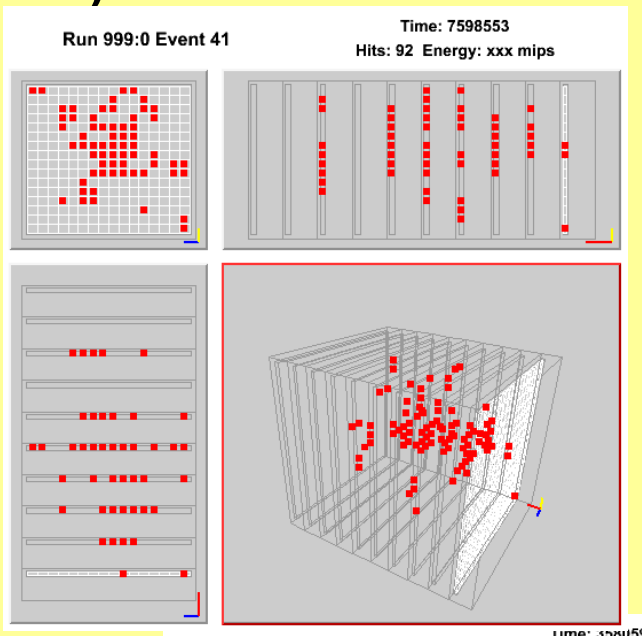


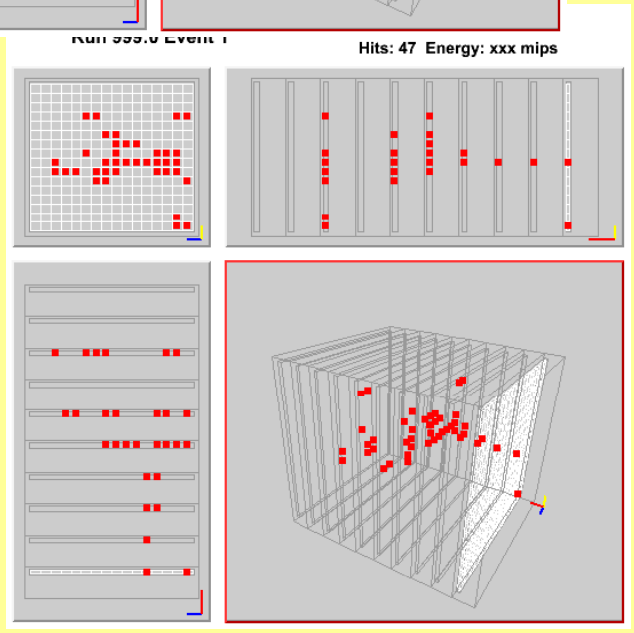
● : simulation: 0-5 layers
agree reasonably well

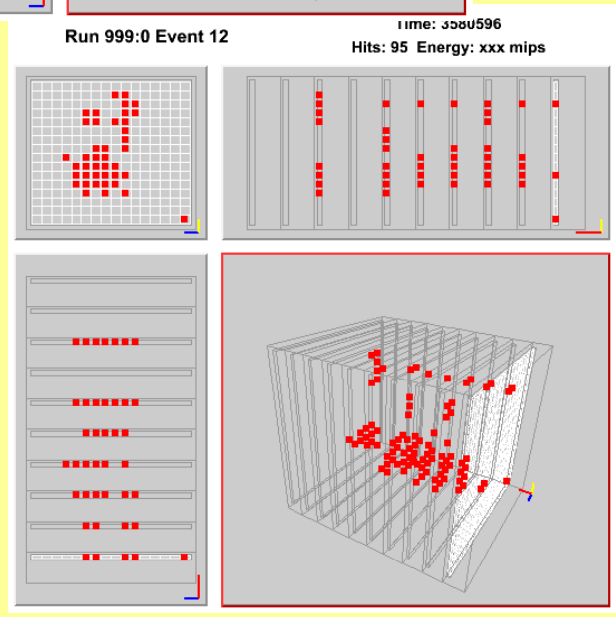
● : simulation: no leakage
linearity: improved
resolution: even better

Pion(/Muon) data





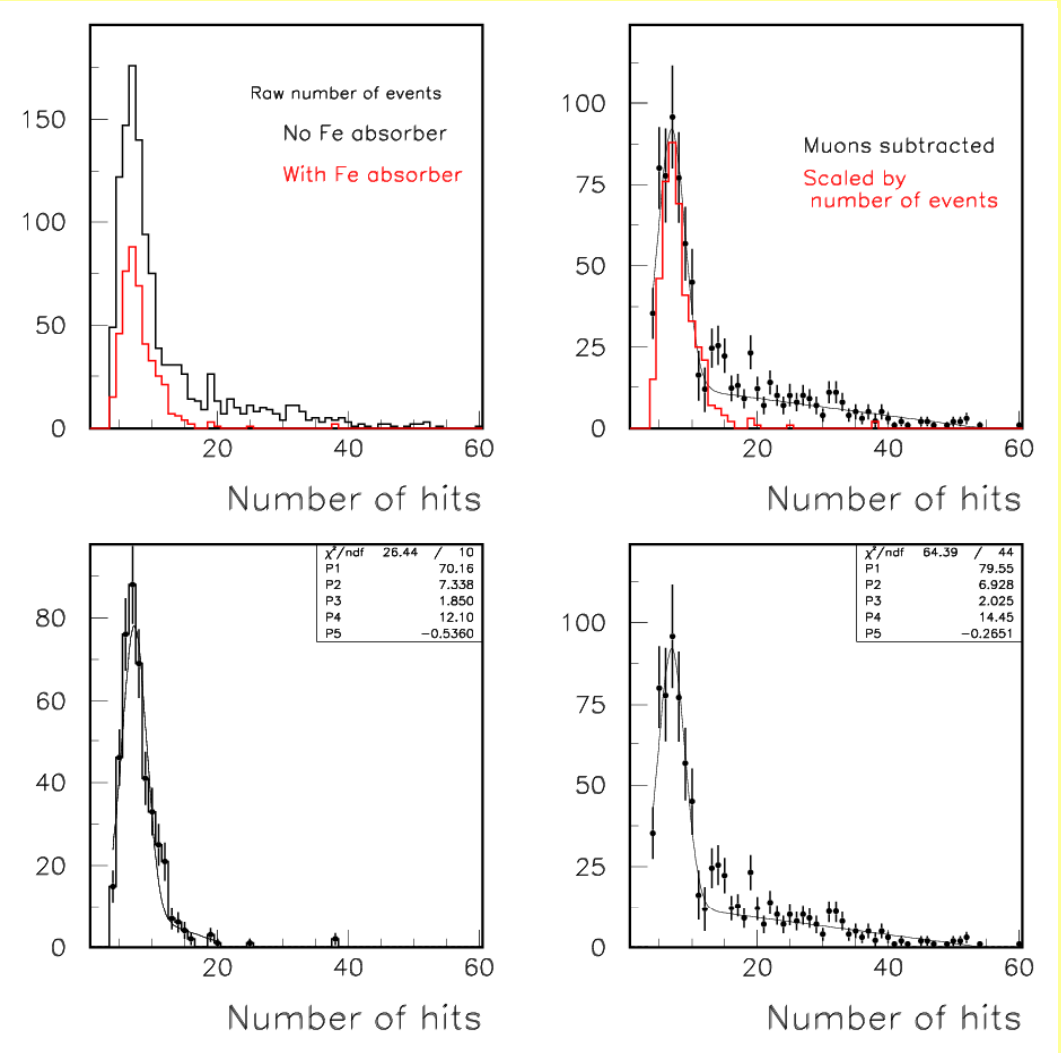




Collected data at (1),2,4,8,16 GeV/c data with Čerenkov veto

Pion(/Muon) data: ‘online results’

Data at 2 GeV taken with/without additional iron absorber



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

Data will be used to compare with Geant4 simulation

Proton data

- No absorber: event looks like MIP tracks
- Data will be used to study RPC rate capability
  - Long time scale effect: decrease of efficiency with overall rate (T ~ sec)
  - Short time scale effect (?): ‘dead time’ after individual event (T ~ ms)

Conclusion

- DHCAL slice test was a great success
- 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
- We are clearly short of manpower – help is very welcomed