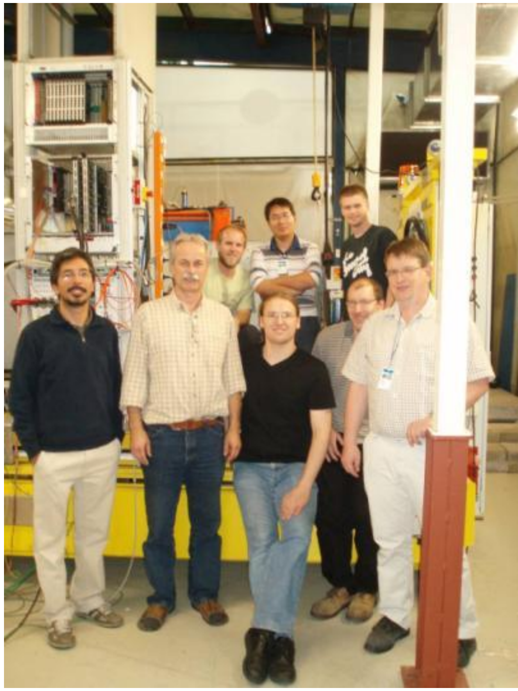
Study of RPC-based HCAL

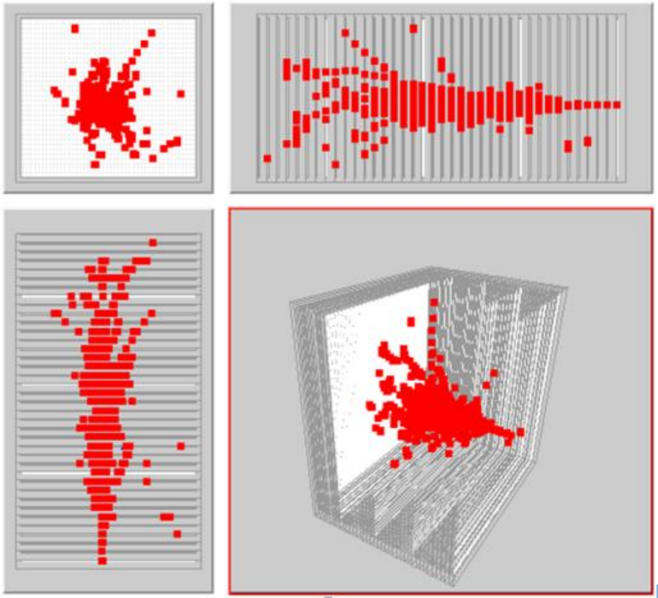
DHCAL results & status

H.Weerts
Argonne National Lab
For DHCAL group

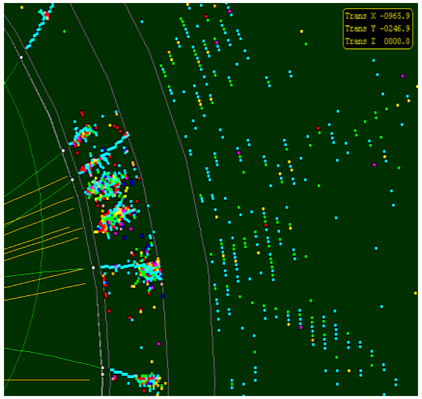


Lei Xia missing

IWLC2010, Geneva, CH
18 – 22 October 2010



Novel approach to the measurement of jets at future lepton colliders



Finely segmented readout
Located inside the coil
Short radiation/interaction length

Particle Flow Algorithms require Imaging Calorimeters

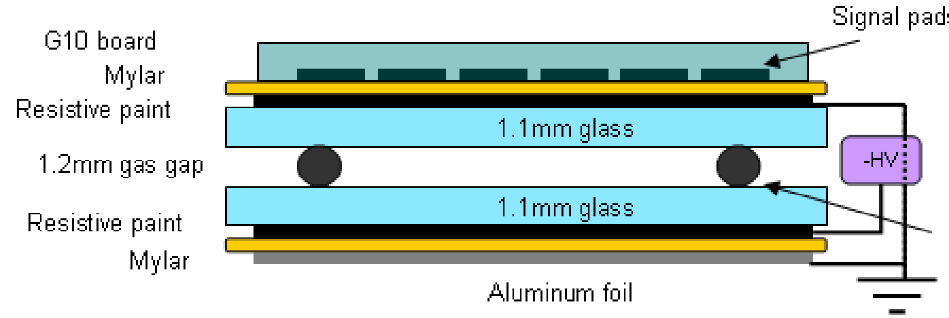
Measure each particle in a jet individually

Use
- tracker for charged particle
- electromagnetic calorimeter for γ's
- entire calorimeter for neutral hadrons

Factor ~2 improvement in resolution over previous experiments

One approach is RPC gas based Digital Hadron Calorimeter

This is approach we have taken, one of many approaches



Collaborative effort of

Argonne, Boston University, FNAL, IHEP (Beijing), University of Iowa, McGill University, Northwestern University, University of Texas at Arlington

Sandwich calorimeter with

Absorber – 20 mm thick steel plates
Active elements – Resistive Plate Chambers (RPCs)

Based on simple design
Robust and reliable (yes!)
Large signals
Can be made to be thin
Allows for segmented readout

Readout

Longitudinally – every layer individually
Laterally – 1 x 1 cm^2 pads

Resolution

1 bit/pad

ILC detector concepts

RPC-DHCAL = Baseline of SiD
RPC-DHCAL = Alternative option of ILD

Staged Approach--- it took a long time, lot of work

2005- 2006

R&D – RPCs
Measurement of basic performance criteria
Development of specific designs

R&D – Electronic readout
Development of front-end ASIC (DCAL chip)
Development of digital readout system

2007

2008

Vertical Slice Test
Test of concept with small scale calorimeter

0.4 m^2
2560 channels

2009

R&D – RPCs
Design of larger chambers
Gas mixing rack

R&D – Electronic readout
Next iteration of DCAL chip
Improved front-end boards

2010

Construct/test
40 m^2
350,000 channels

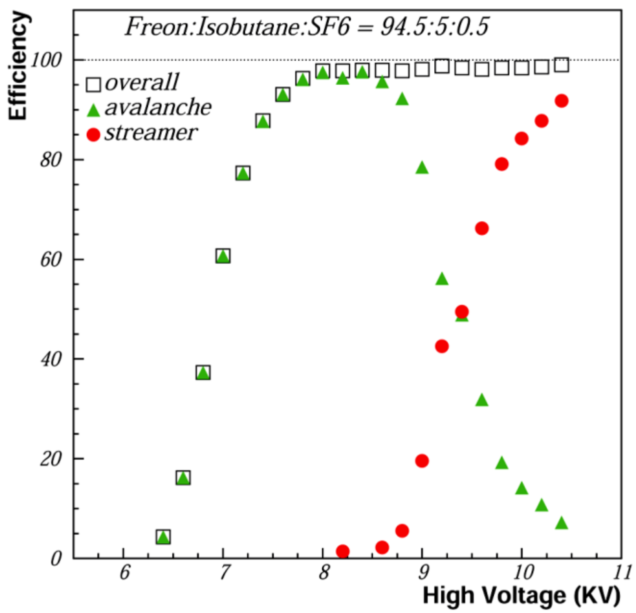
Physics prototype
Proof of DHCAL concept
Measurement of hadronic showers

Current activity

Past Achievements

Detailed studies of RPCs with analog readout

G.Drake et al., Nucl. Inst. Meth **A578**, 88 (2007)



Development of a digital readout system

Tests with a VME based DAQ system
Design of a front-end ASIC (the DCAL chip)
Tests of various front-end boards

Vertical Slice Test

20 x 20 cm^2 RPCs (based on two different designs)
1 x 1 cm^2 readout pads
Up to 10 chambers → 2560 readout channels
Complete readout chain as for larger system

Detailed tests with cosmic rays at Argonne
and in Fermilab test beam
(μ, 120 GeV p, 1 – 16 GeV π^+, e^+)

Very successful → extrapolation to large system

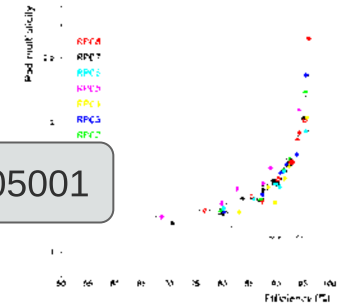
DHCAL

Papers from Vertical Slice Test

Calibration of a Digital Hadron Calorimeter with Muons

Measurement of the noise rate
Measurement of the efficiency and pad multiplicity
under different operating conditions

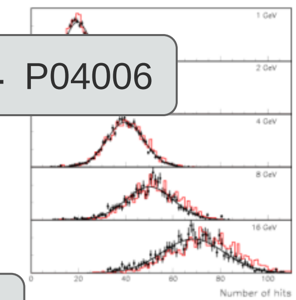
B.Bilki et al., 2008 JINST **3** P05001



Measurement of Positron Showers with a Digital Hadron Calorimeter

Measurement of positron showers (response and shape)
Tuned simulation to reproduce measurement

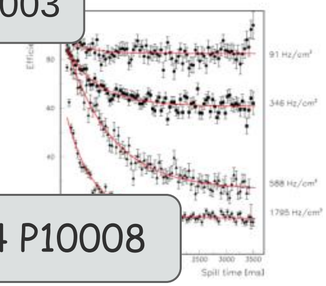
B.Bilki et al., 2009 JINST **4** P04006



Measurement of the Rate Capability of Resistive Plate Chambers

Measurement of short term effect (not observed)
Measurement of rate dependence
New model to calculate RPC response
(contribution to the understanding of RPCs)

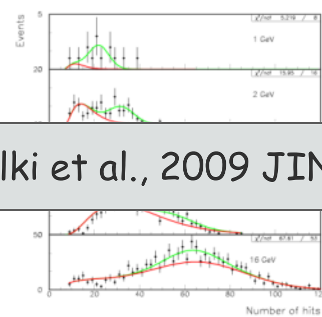
B.Bilki et al., 2009 JINST **4** P06003



Hadron Showers in a Digital Hadron Calorimeter

Measurements with very small calorimeter (leakage)
Absolute prediction from simulation (no tuning!)
Including simulation of response of 1 m^3 prototype

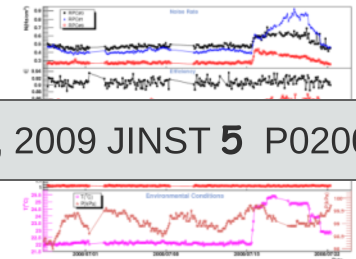
B.Bilki et al., 2009 JINST 4 P10008



Environmental Dependence of the Performance of Resistive Plate Chambers

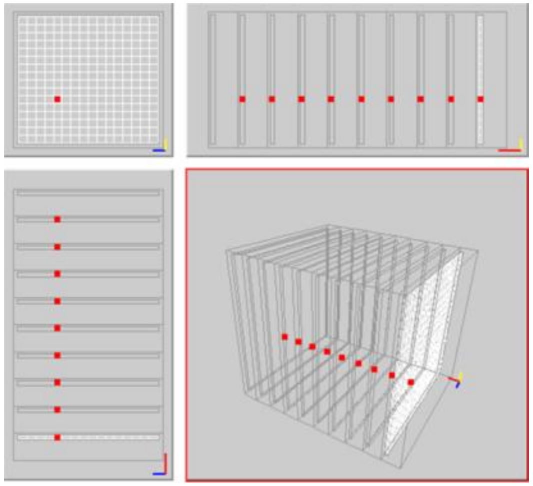
Measurement of the efficiency, pad multiplicity and noise rate as function of ambient pressure, temperature, air humidity and gas flow
(contribution to the understanding of RPCs)

Q.Zhang et al., 2009 JINST **5** P02007

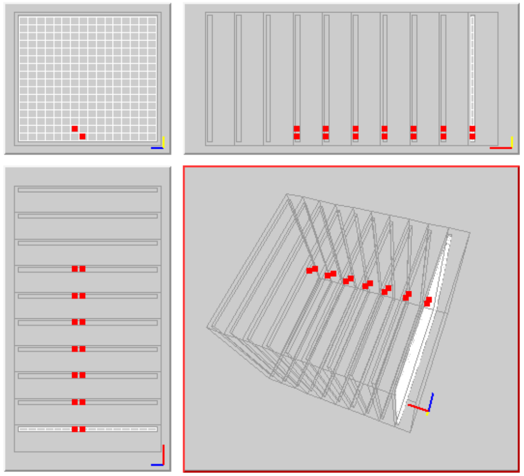


A few nice events from the testbeam….

A perfect μ

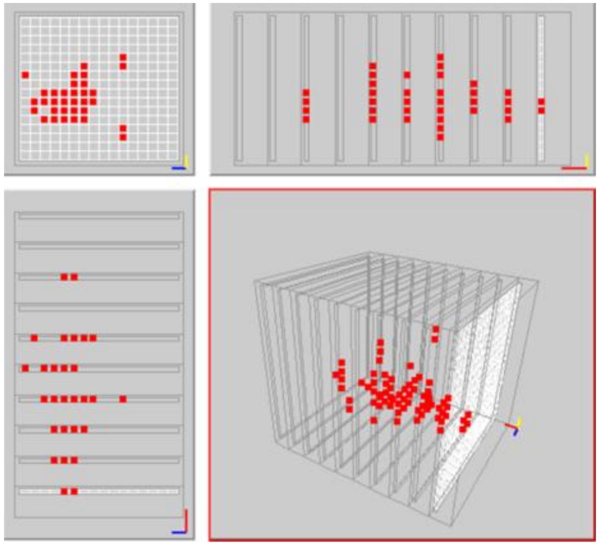


2 perfect μ's

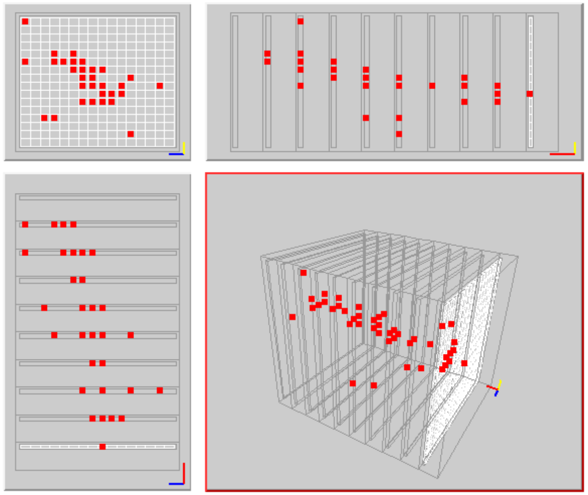


With the small slice test calorimeter

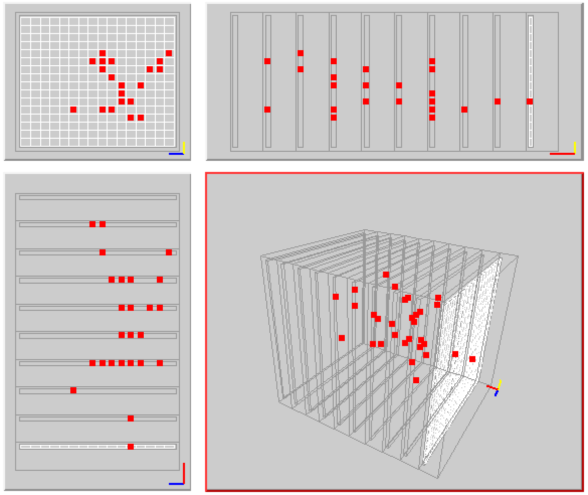
e^+ shower



Based on results confident to build a 1m^3 hadron calorimeter



π^+ showers



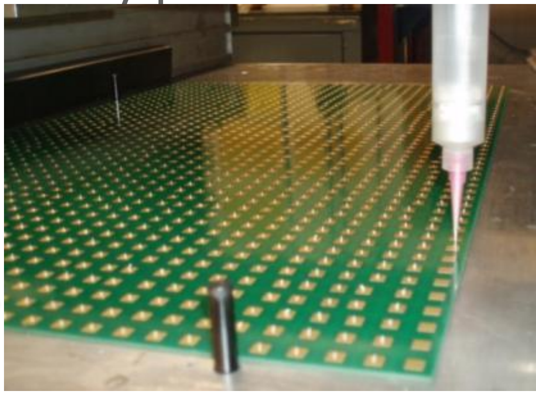
DHCAL Physics Prototype: $1m^3$

Started preparations/construction ~ one year ago~ Fall 2009.

Many problems solved

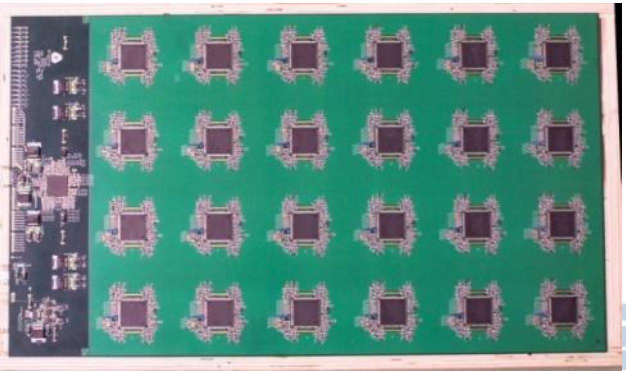
150/114 RPCs built & tested (90cmx30cm)

DCAL III Front-end ASIC designed, produced and tested
~9,000 good parts in hand
Pad-, front-end boards designed, fabricated and assembled
Pad- and front-end boards glued (1536 glue dots)
276/228 boards glued and tested



35/20 Data collectors designed, produced and tested (Boston University)
6/3 Timing and trigger modules designed (FNAL), produced and tested

HV system complete (University of Iowa)
LV system: 7/5 power supplies in hand
7/5 distribution boxes designed and assembled
Gas system: Gas mixer designed, built, tested and used (Iowa)
Gas distribution rack designed, built, tested and used (Iowa)



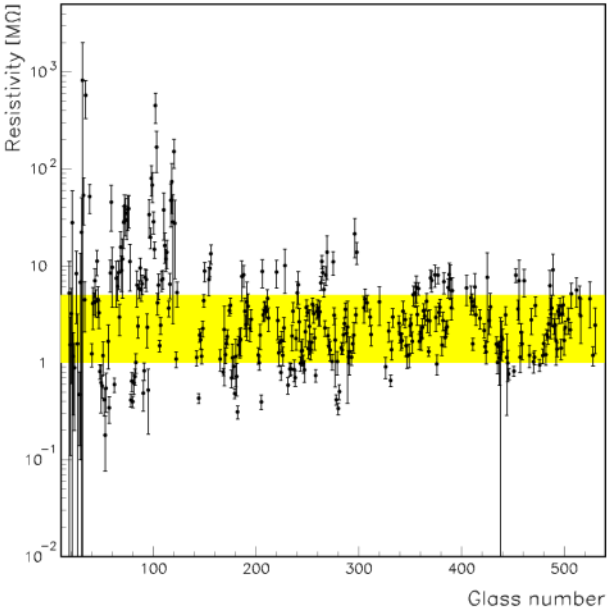
DHCAL Collaboration	Heads
Engineers/Technicians	22
Students/Postdocs	8
Physicists	9
Total	**39**

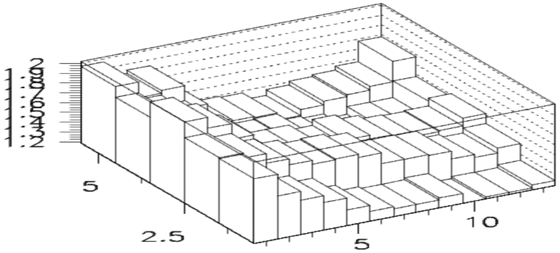
Glass Spraying

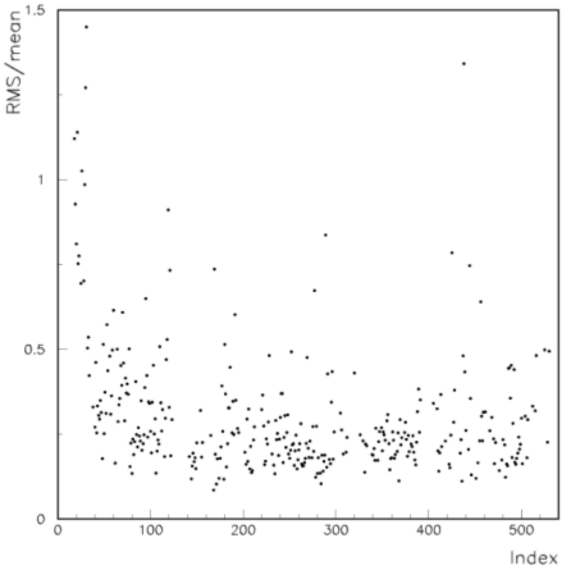
Need to coat anode glass with resistive paint with R□ = 1 – 5 MΩ
R□ of cathode glass not as important

Built automatic spraying booth

- 1 button operation
- fumes (non toxic) vented outside of building
- 1 glass/2 minutes, but long set-up times
- Standard operation: 8 glass/day
- Total production needed ~250 pieces







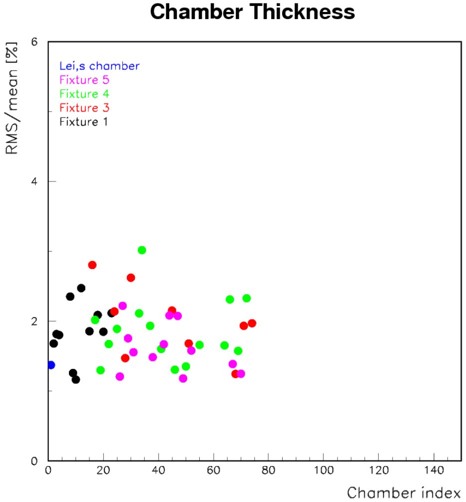
Production completed
Never gained complete control over R□
RMS actually rather good

RPC Assembly

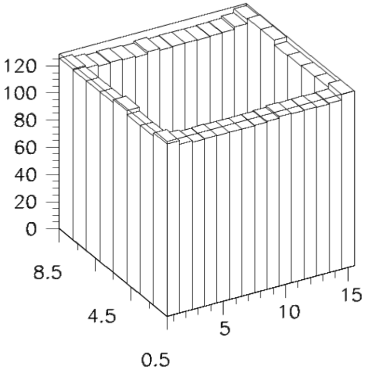
Each chamber 32 x 96 cm^2
Important to maintain gas gap size constant
Need 114 chambers to equip cubic meter

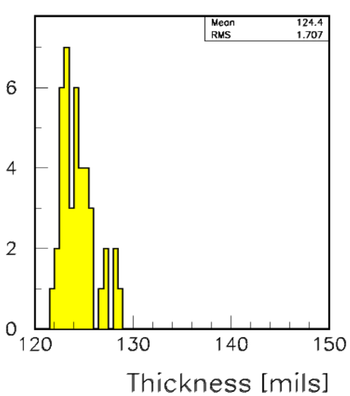
Built precision fixtures for assembly

- 1 frame cutting fixture
- 3 RPC assembly fixtures
- Assembly of 1 RPC/technician/day
- Produced a total of 159 chambers



RPC 001   1 mil = 25 μm





Production completed with 159/114 chambers
Thickness variation on rim acceptable
(not all chambers measured)
All chambers passed leak test at 0.3" of H_2O

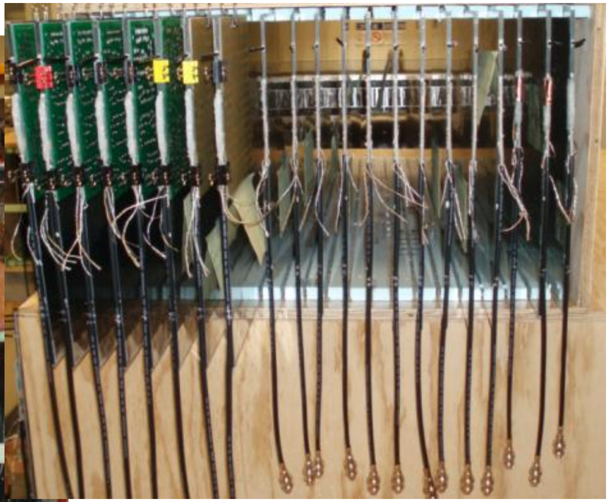
HV Connection

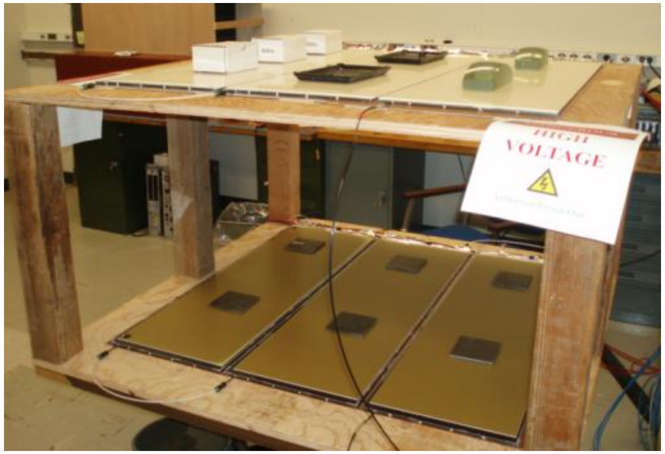
3 steps: 1) attach connector
2) cover chamber in Mylar sheets
3) protect connector with RTV

Nominal voltage 6.3 kV

Built test stand

- 6 chambers tested simultaneously
- Tests performed at 7.0 kV
- Monitoring of (dark) currents

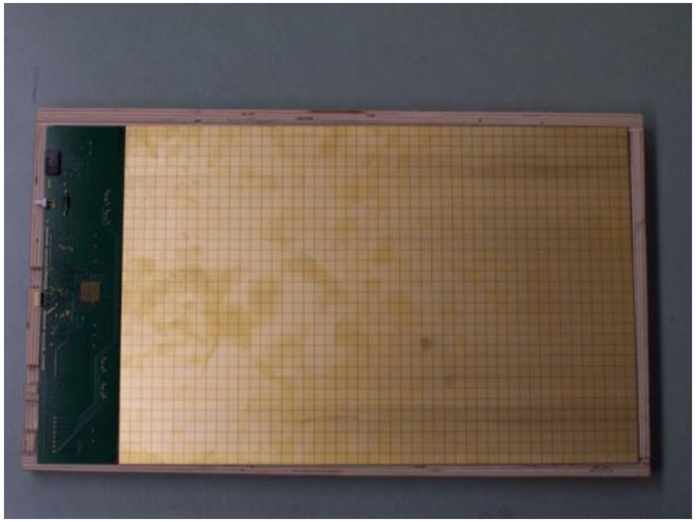




~127/114 chamber successfully tested at 7.0 kV
Currents ~ 0.25 μA/chamber

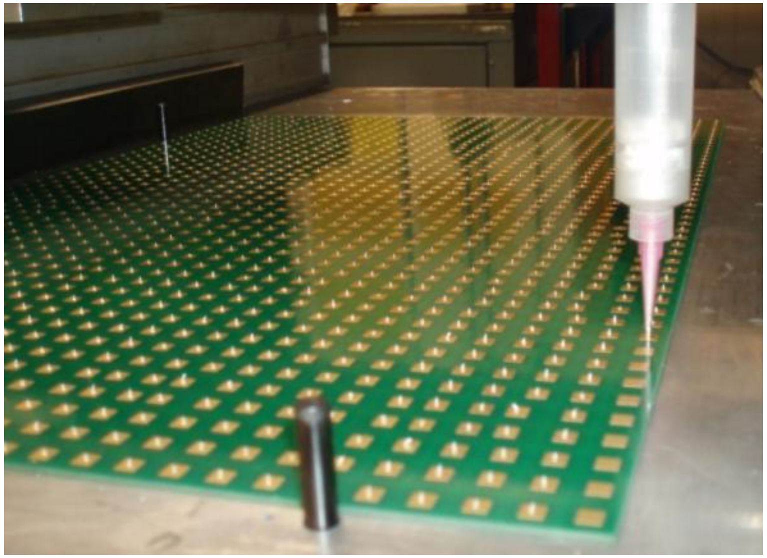
Pad- and FE-board Gluing

Each board contains 1536 channels which need to be connected with conductive glue
The glue dries in 3 hours



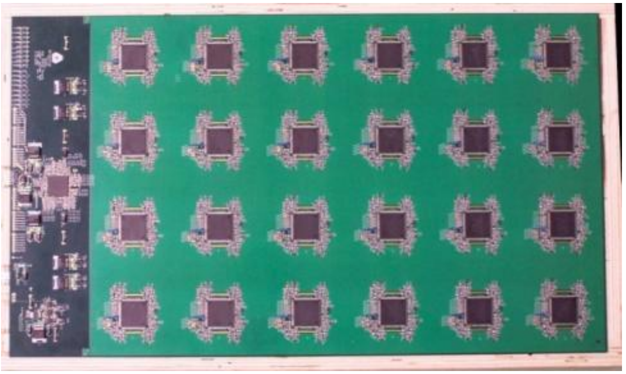
Built a gluing fixture

- Dispenses glue on gluing dots
- Takes only 25 minutes/board
- Glued 10 boards/day
- Glue is cured in oven at 70 C^0



Gluing complete
276/228 glued boards in hand

Front-end Boards



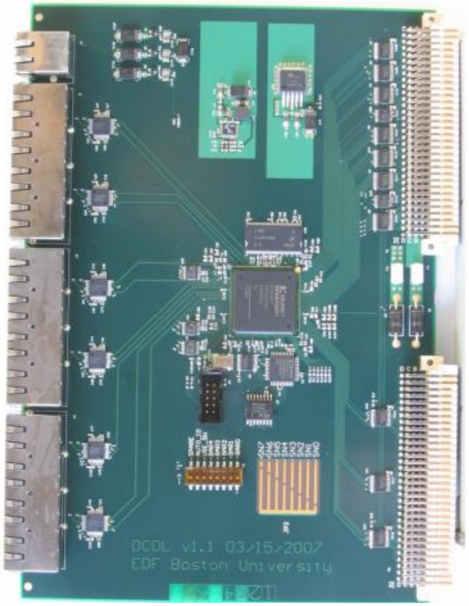
Each board contains 1536 channels and 24 ASICs
The data concentrator is implemented into the same board
2 boards are needed per RPC

Built 3 computer controlled test stations

- Extensive tests (S-curves, noise rates…)
- 3 – 6 hours/board
- Accepted boards with less than 4/1536 dead channels

Testing complete
276/228 boards tested successfully

Data Collector Modules



1 Data Collector Module per 12 front-end boards
Need 19 for cubic meter

Built test station at Boston

BOSTON UNIVERSITY

Production complete
30/20 boards delivered to Argonne

Timing and Triggering Module

Fermilab

Provide control to up to 24 Data Collectors
Need 1 Master and 2 Slaves for cubic meter

Designed and debugged at FNAL

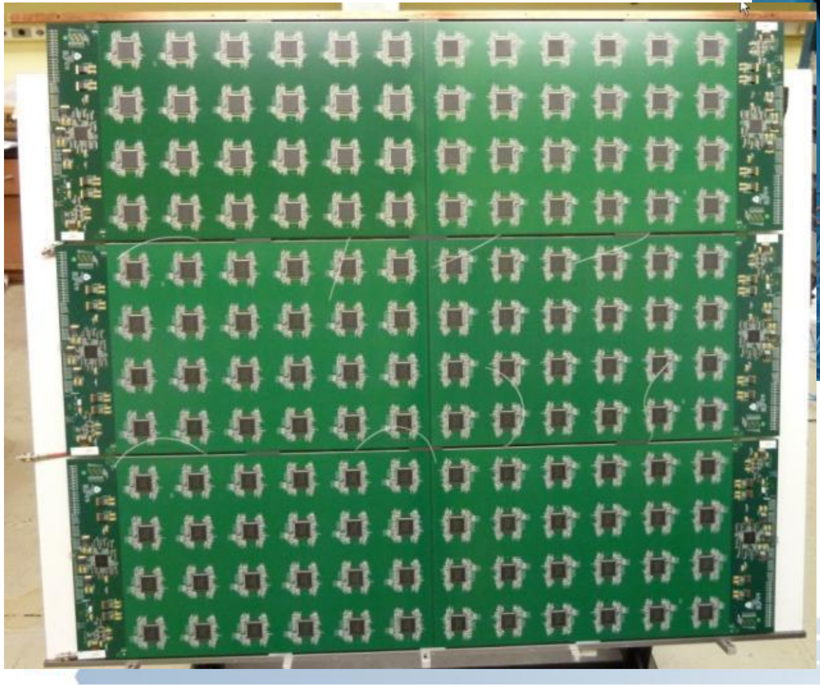
12 boards produced
6/3 assembled so far

Cassette Assembly

3 RPCs assembled into a cassette
Front-plate is copper (for cooling of ASICs) and back plane is steel
Cassette is compressed horizontally with a set of 4 (Badminton) strings
Strings are tensioned to ~ 20 lbs

Assembly

- Not very difficult
- Best timing so far:
  45 minutes/cassette

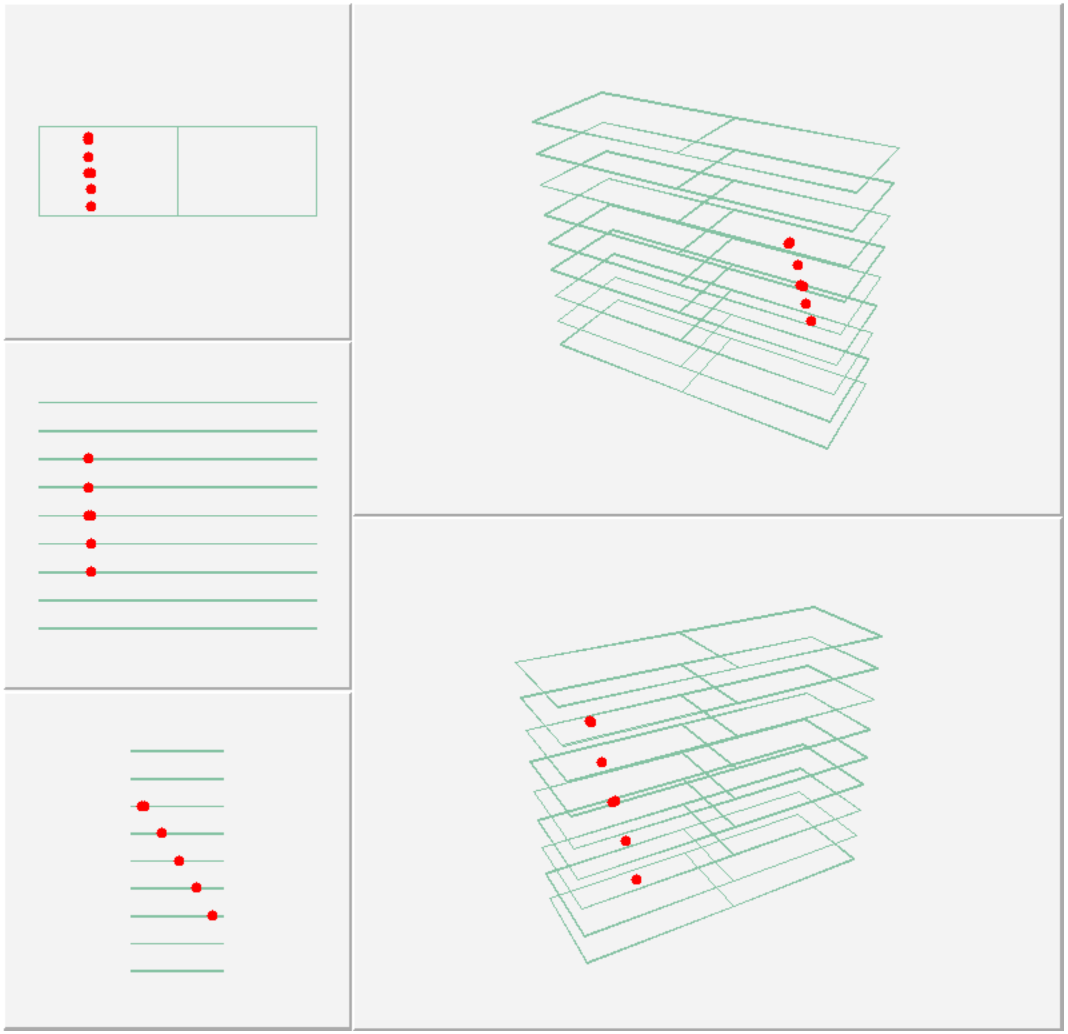


40/38 cassettes assembled

Nine layers of production RPC chambers (30x 90 cm), with 1x1cm pad readout. **Self** triggering and requiring hits in > two planes for trigger. Total ~ 25000 channels.

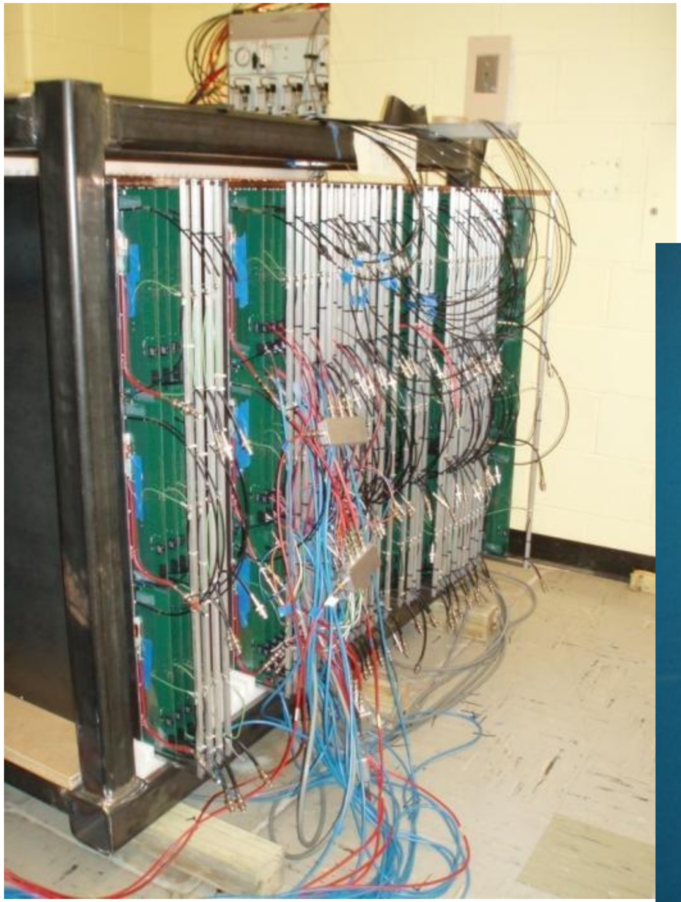
Trigger-less noise data with requirement of hits in > 2 layers
(no other tricks!!!!)

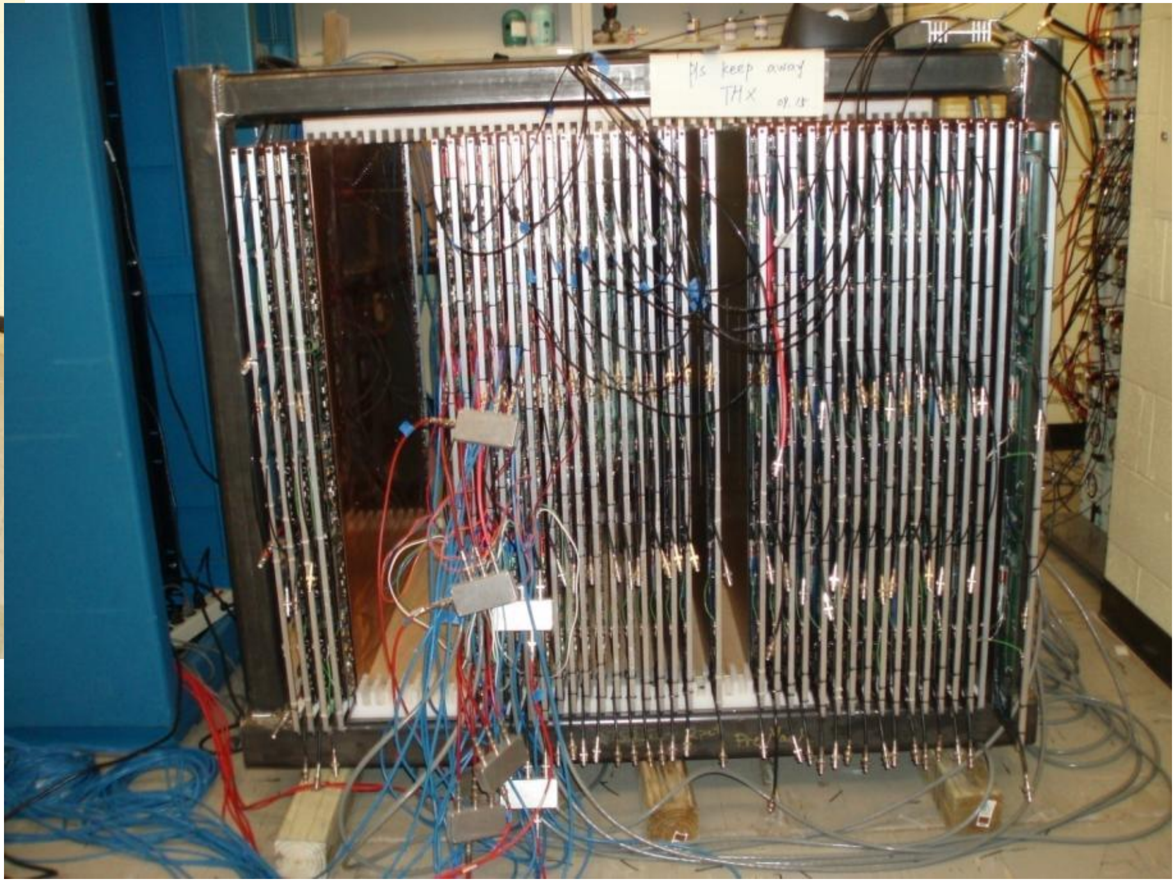
Look for Noise Hits



Actual rate a factor ~10 faster

Completed cassettes at Argonne





Peripherals

Low Voltage Power Supply

Need power to 228 front-end boards (+5V)
Acquired 7 Wiener power supplies
Built 7 power distribution boxes
All fully operational

High Voltage Power supply

Need 6.3 kV to 38 layers (3 RPCs powered by 1 line)
Borrowed 3 LeCroy 4032 power supplies
Borrowed 2 sets of controllers
Developed computer control program
All fully tested

Gas Supply

Need 19 lines (2 layers or 6 RPCs per line)
Built mixing rack for 3 gases
Built distribution rack
All fully operational

All complete

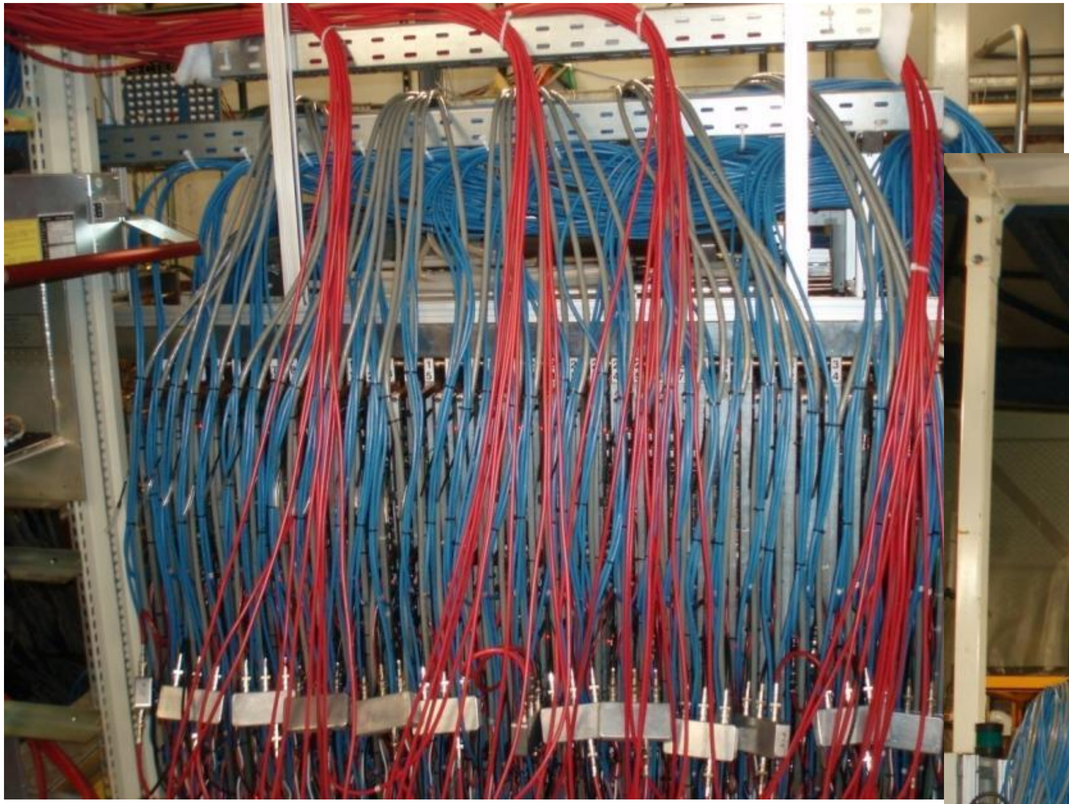
Transportation to FNAL and installation

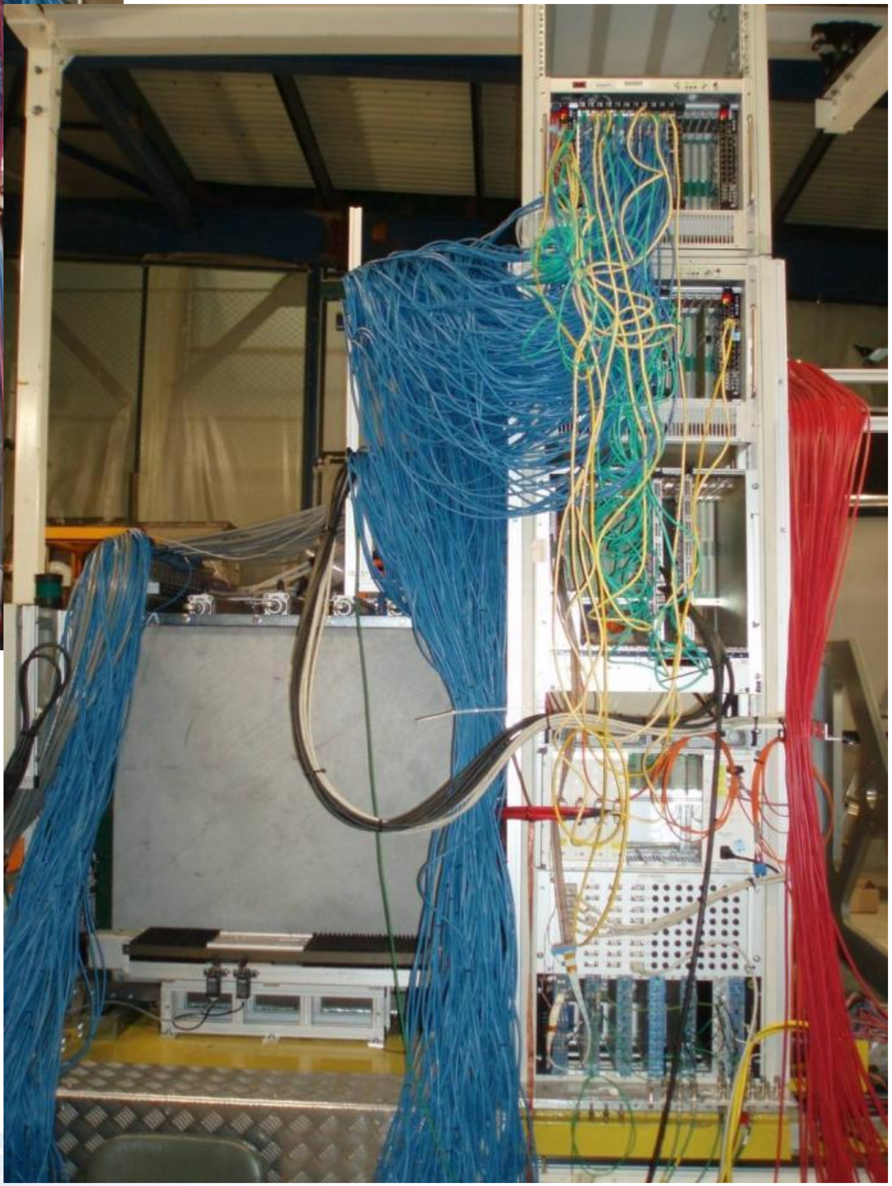
Installation complete

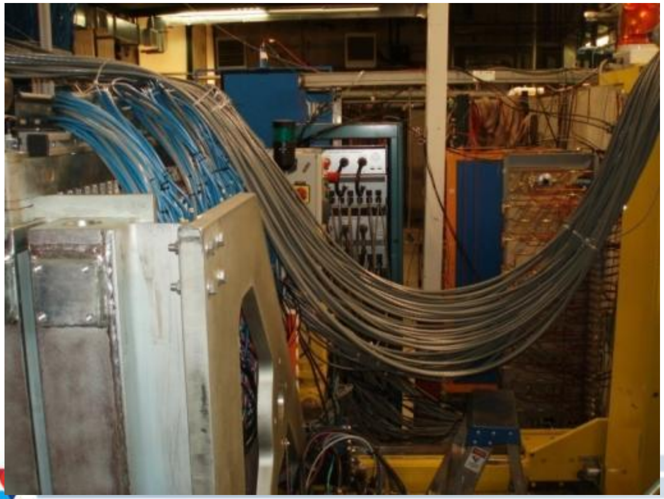
Cabling up

12 hours of hard work
(350,000 readout channels)

Cabling done







Summary

40/38 layers built and checked out successfully

40 layers transported to FTBF

CALICE HCAL structure and stage ready

Thanks to Karsten, Beni and Sven

38 layers installed into CALICE HCAL structure

Cabling done

224 data cables
76 low voltage cables
38 high voltage cables
19 x 2 gas lines

Trigger Scintillators installed and cabled up

Thanks to Beni, Sven, Karsten

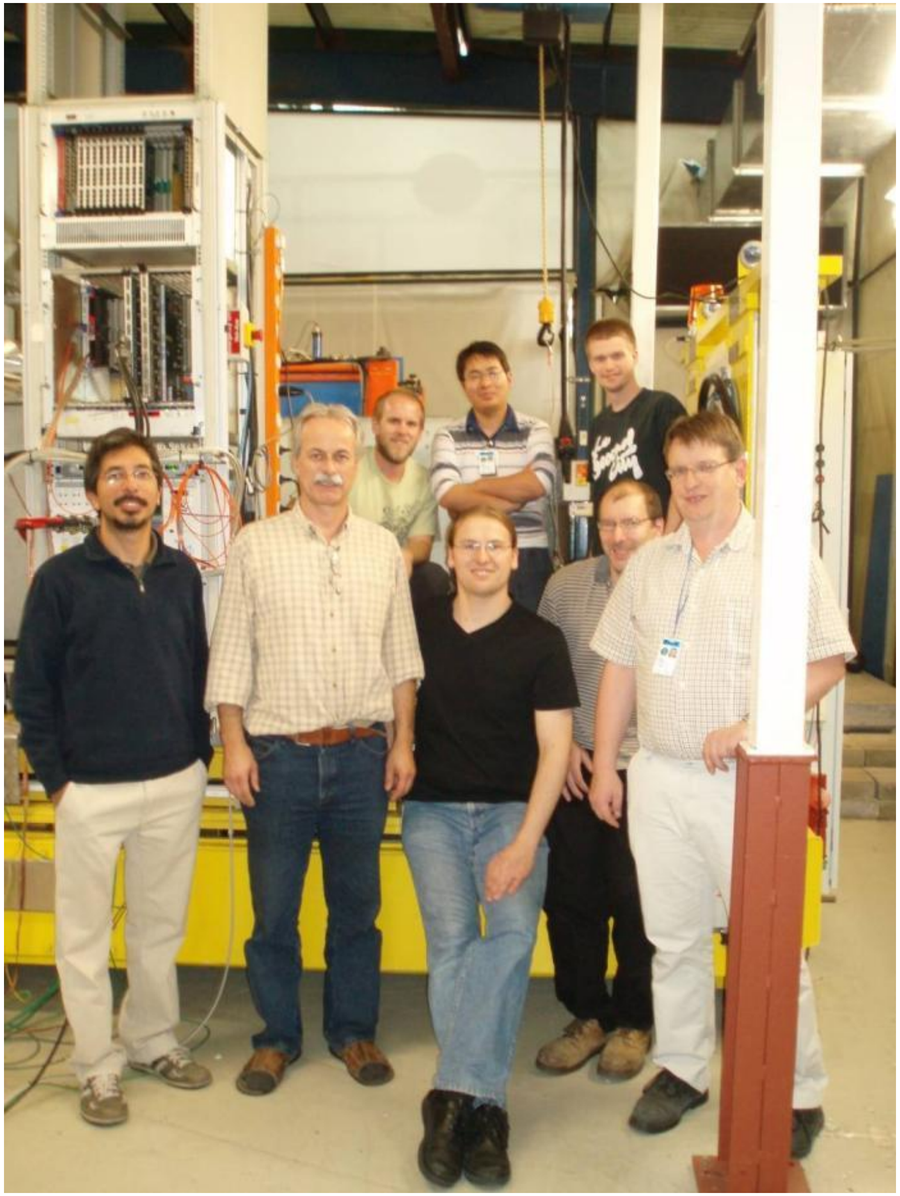
TCMT cabled up and ready

Thanks to Eric Johnson

Safety review passed

Gas
Electrical
Mechanical

Beam imminent


Lei Xia missing

Schedule:

4 October start moving hardware to Fermilab

8 October RPCs installed, hook up gas, HV, get permits, start cabling

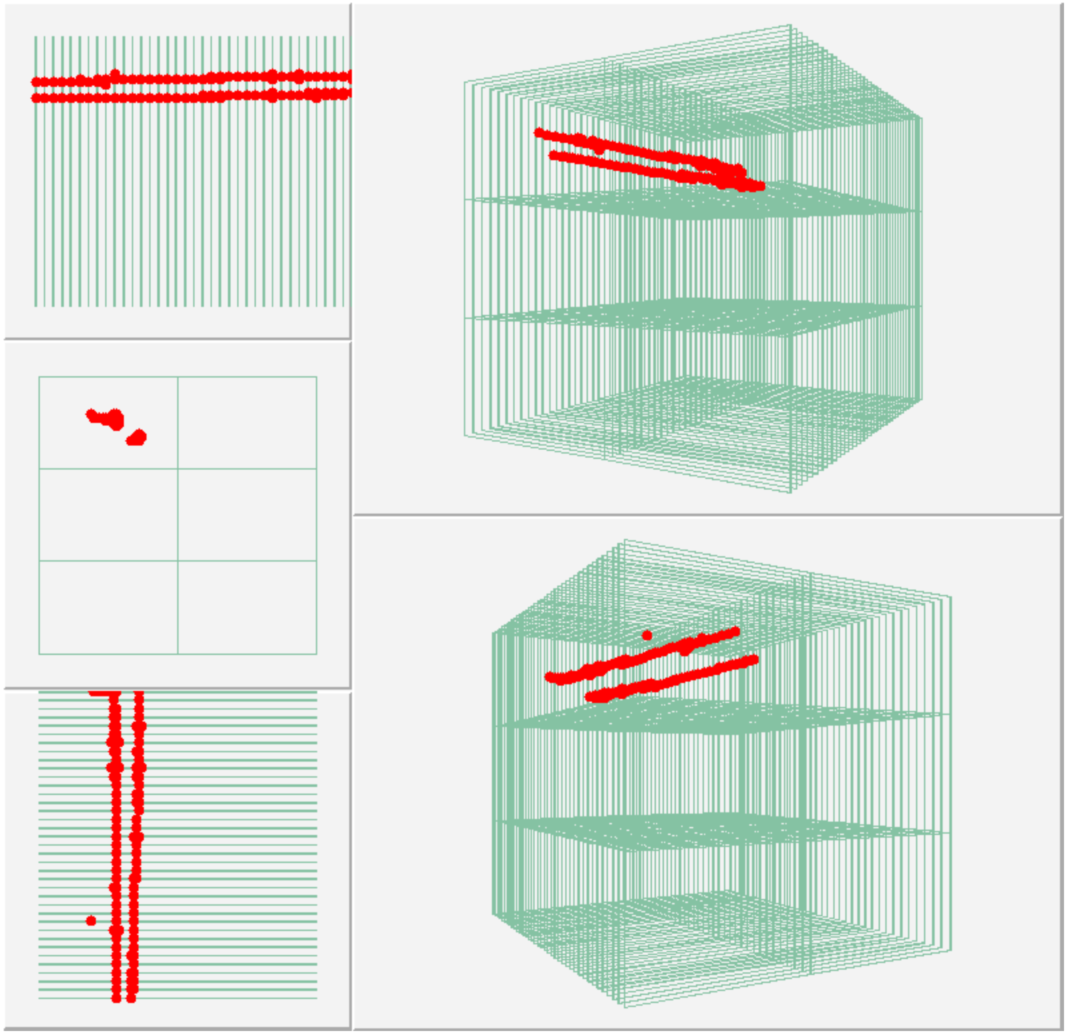
15 October all cabled up, ready for beam

16 October first noise runs and muons from beam

20 October (today) waiting for hadrons

First indications so far ➔

32 GeV secondary beam with 3 m beam blocker = muons
NO event selection



Occasional noise hits

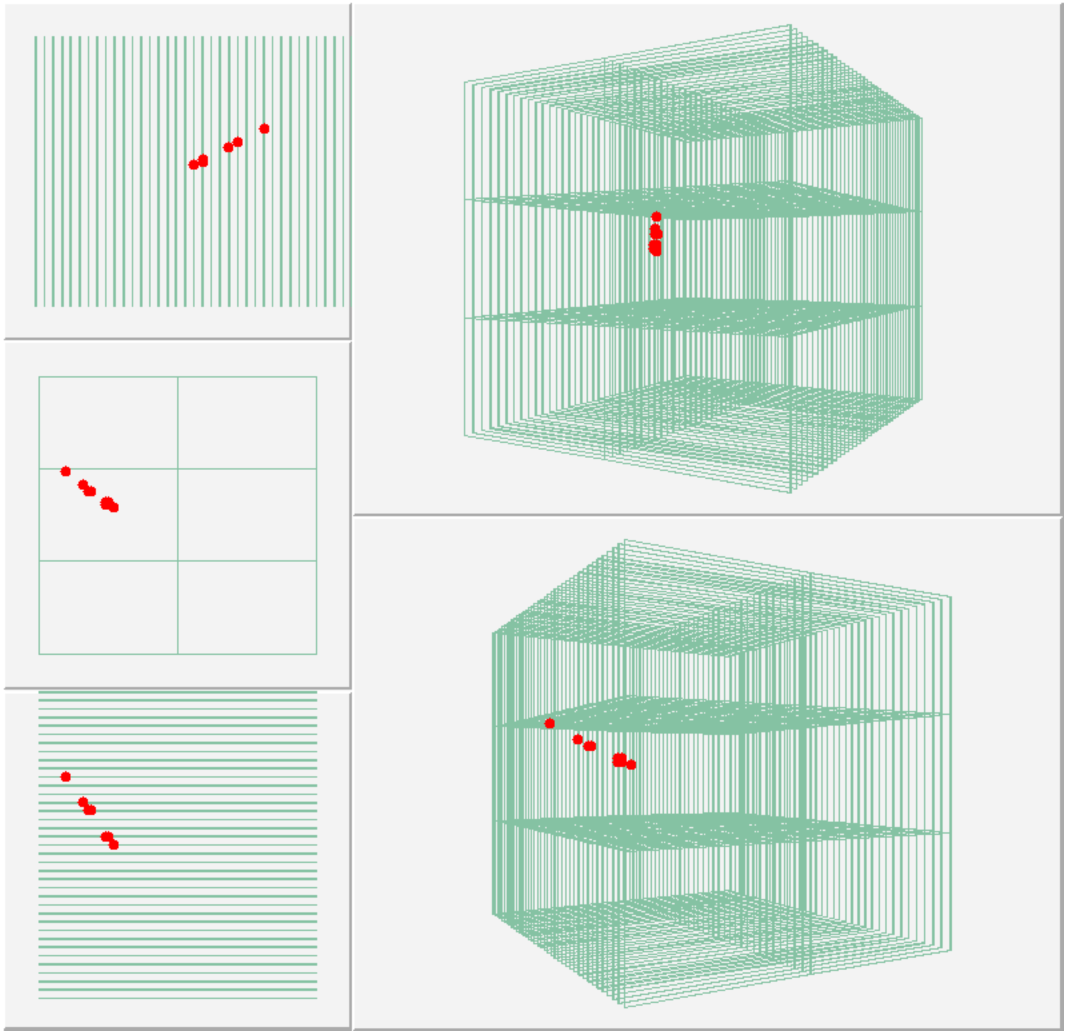
Chambers operated at higher temperature than usually

→ Higher efficiency
→ Much higher noise rate
→ higher pad multiplicity

Noise run

Event selection requesting at least 5 different layers with hits

Due to high data rates, only selection of layers read out



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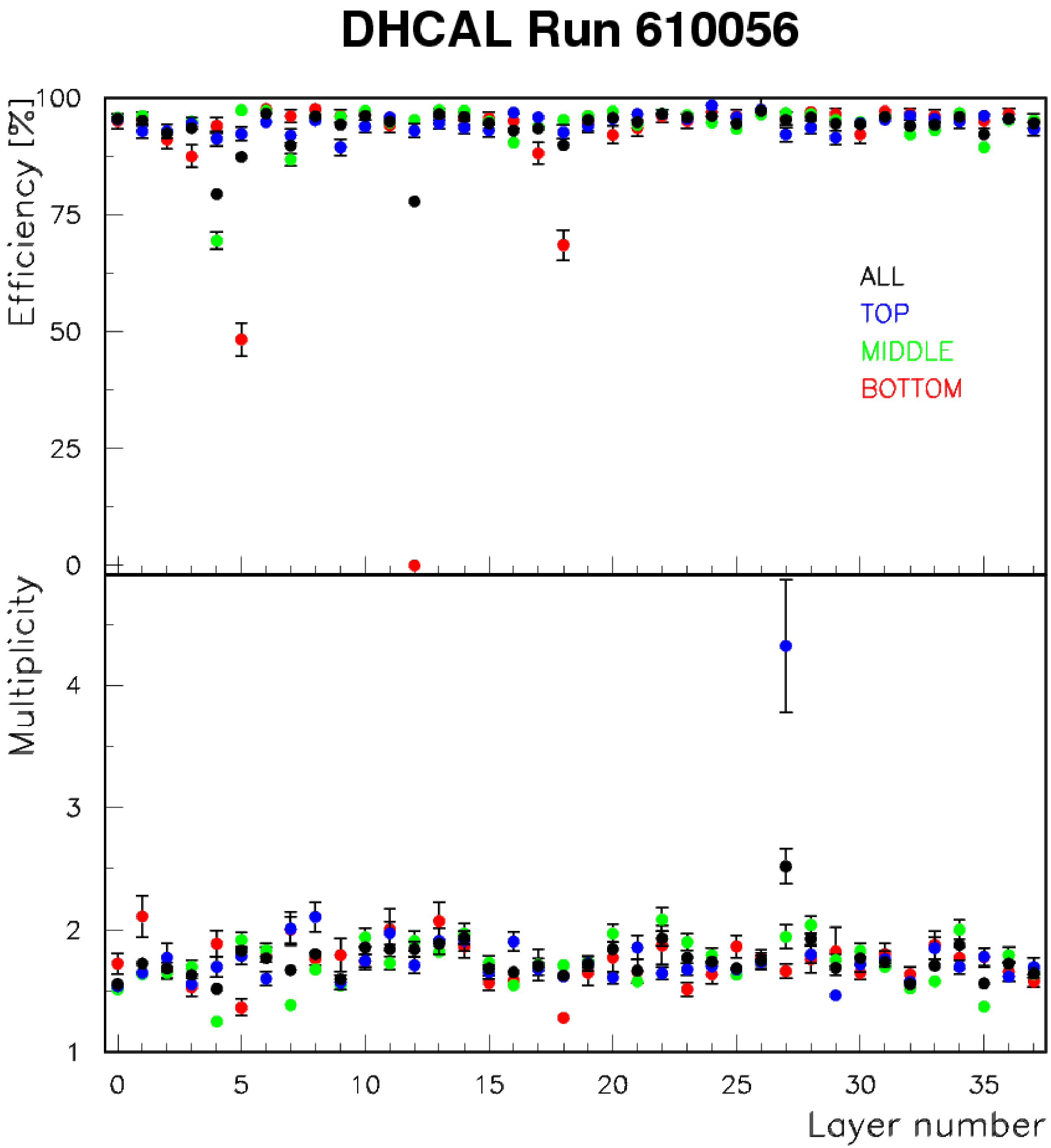
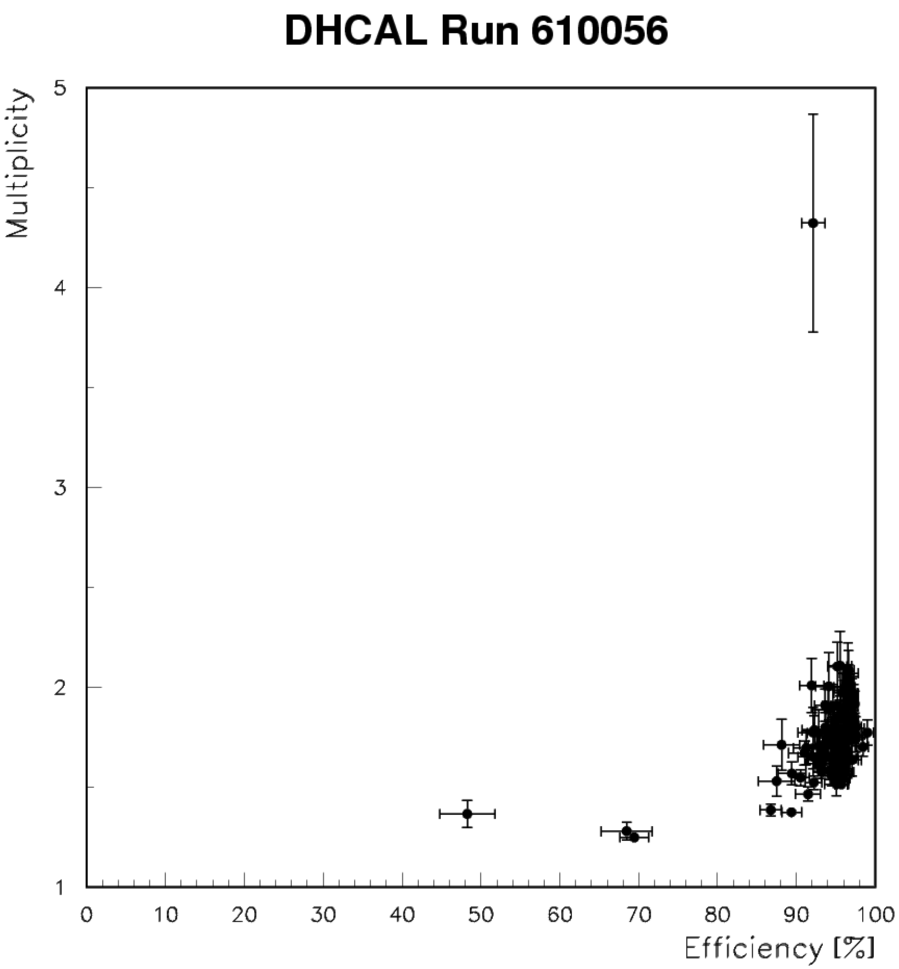
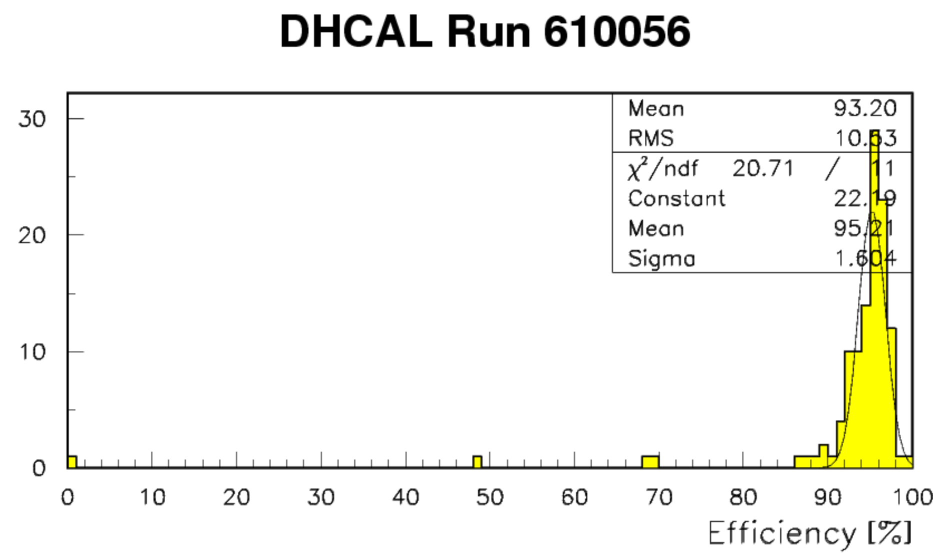
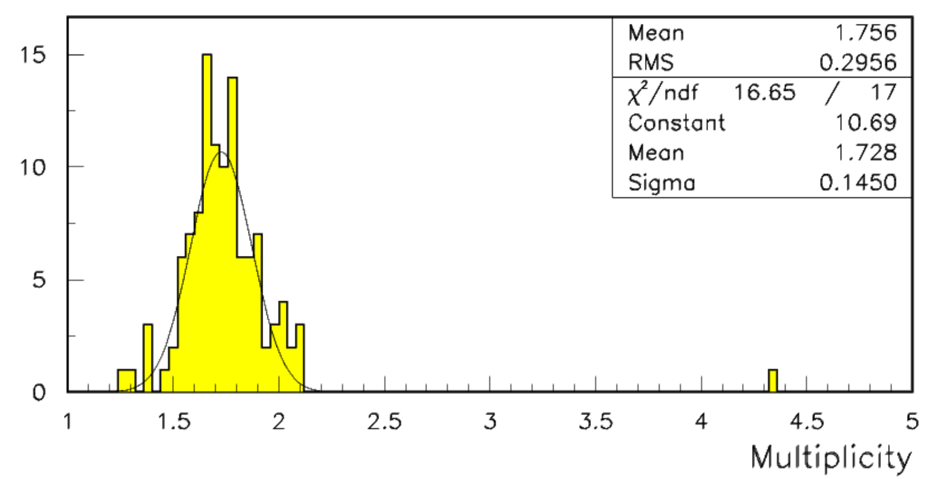


Very preliminary from testbeam: muons

Very preliminary from testbeam: muons







Testbeam plans

Broadband muons for calibration

Calorimeter not rotated
Move calorimeter around to expose entire volume (probably not needed)
Trigger with 1 x 1 m^2 Scintillator paddles
Adjust timing of Scintillator coincidence, TCMT DAQ, and Cerenkov signals
Most likely for one week, depending on statistics and width of beam
(rough calculation: (100/pad)*(9216 pads)/(350 muons/spill) = 2,600 spills = 44 hours)

Energy scans (separation of positrons and pions offline using Cerenkov)

Calorimeter not rotated
Into center of calorimeter
Trigger with coincidence of 20 x 20 cm^2 Scintillator counter and 1 x 1 m^2 Scintillator paddle
1,2,4,8,12,16,20,24,32,40,48,60 GeV
(rough calculation: 100,000 events/energy /(300 particles/spill)*(12 energies)= 4,000 spills = 67 hours)

Test beam ends November 2

Next test beam January 2011 (DHCAL + RPC-TCMT)

3^{rd} test beam April 2011 (ECAL + DHCAL + RPC-TCMT)

4^{th} test beam ? 2011 (DHCAL + RPC-TCMT)

Summary

CALICE now has at least two HCAL modules in testbeam one at FNAL & one at CERN (Fe and W).

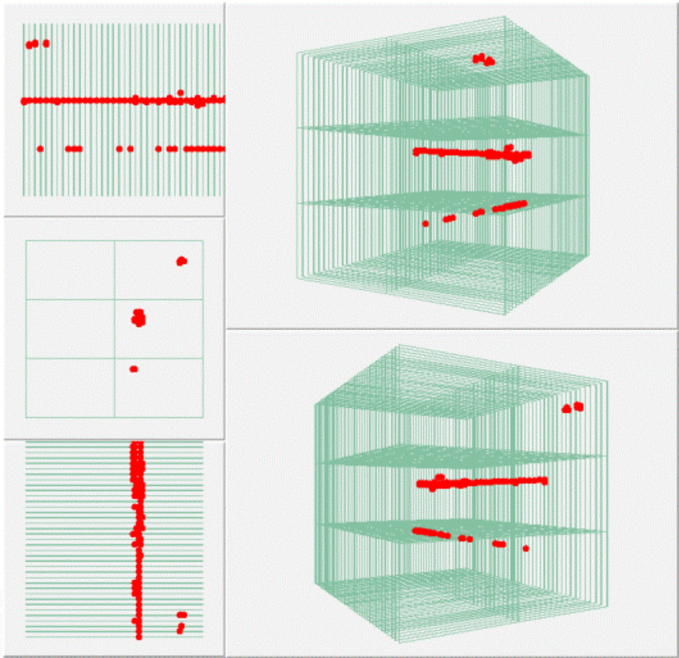
Thanks to FNAL for making it easy

Thorough testing, commissioning and calibration of first digital RPC based HCAL with Fe in next few months. Exciting next few months.

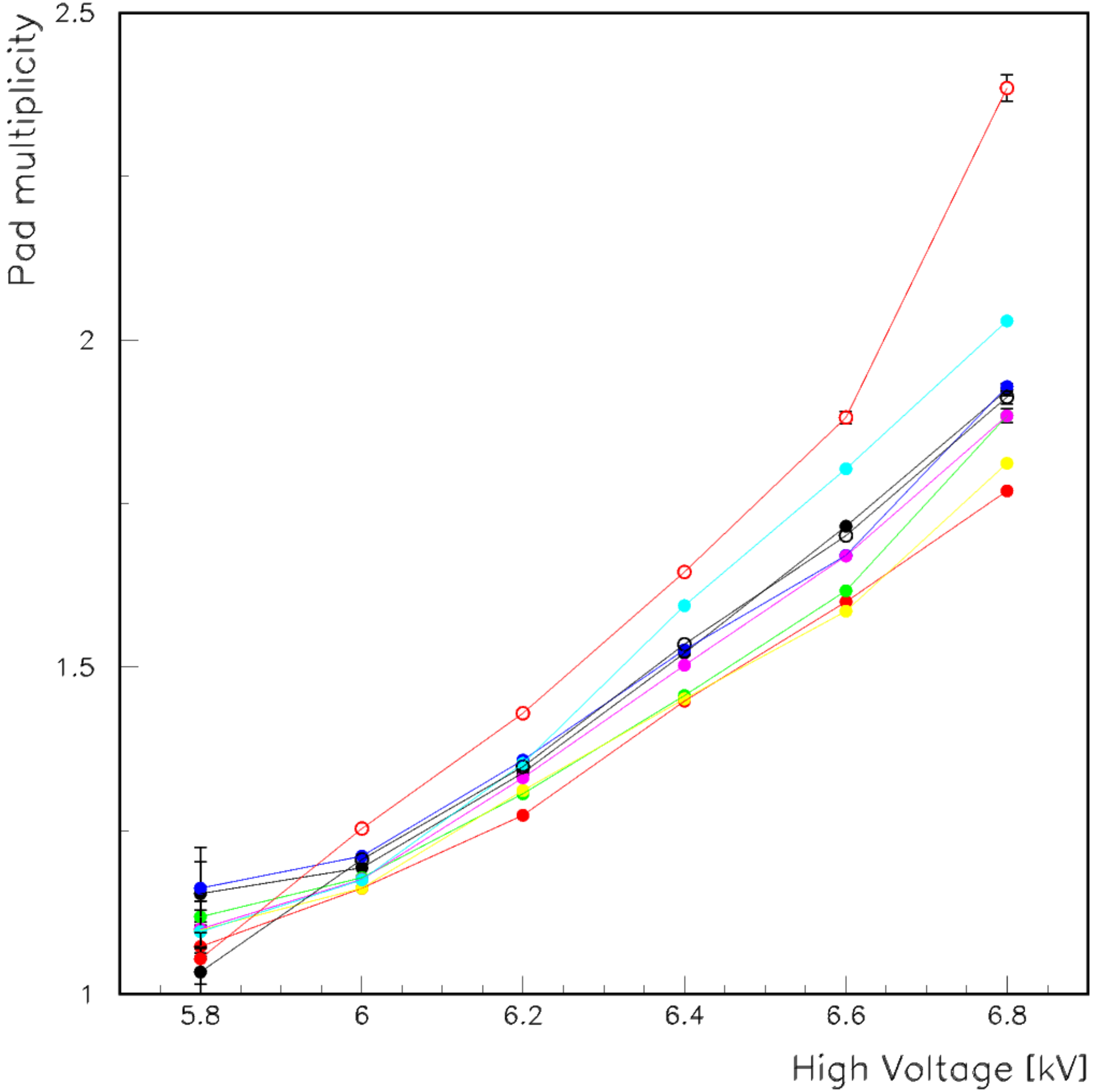
Next with Tungsten ?

Next also other gas based HCAL $1m^3$'s: RPC based semi-digital and micro-megas based.

Especially gratifying for me…… after 5 years of pushing finally in testbeam. Over one year long construction period

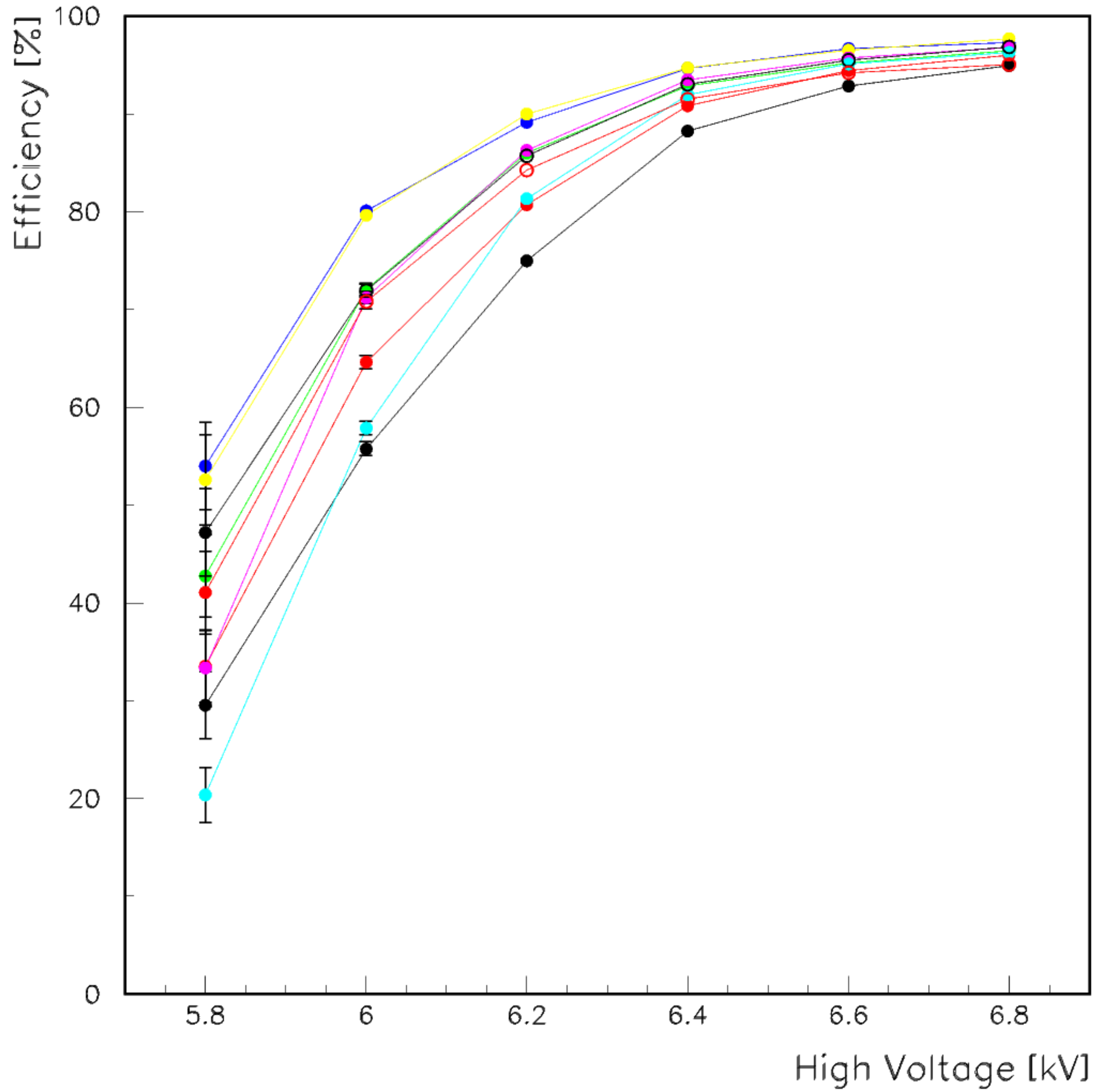


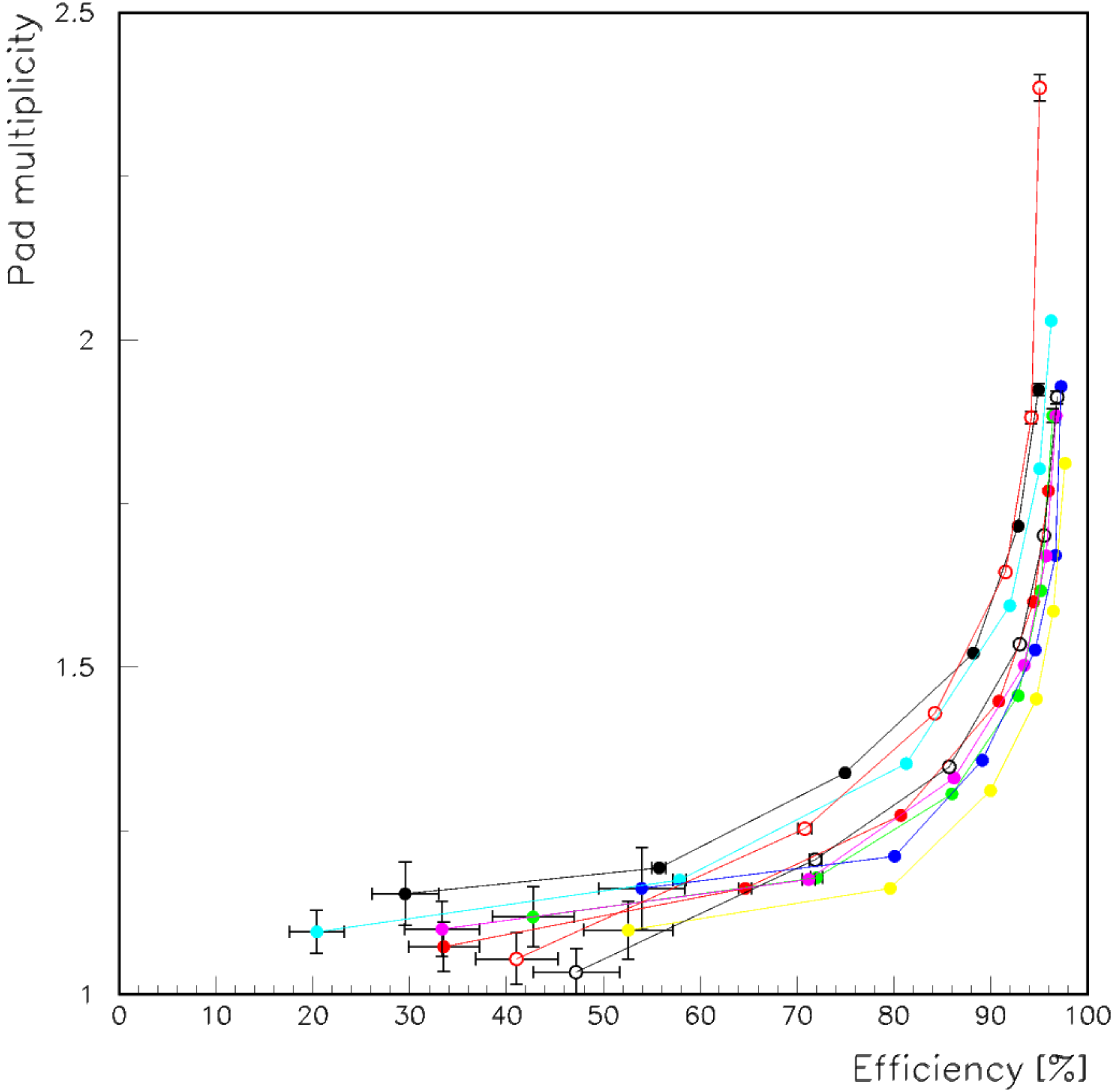
Backup slides


Pad multiplicity
2.5
2
1.5
1
5.8
6
6.2
6.4
6.6
6.8
High Voltage [kV]

Cuts

- At most 1 cluster/tracking l
- χ^2/DOF < 1.0
- N_{track} > 5
- x_{int} within 0.0 ÷ 95.0
- y_{int} within 0.0 ÷ 31. 0




Pad multiplicity
2.5
2
1.5
1
0
10
20
30
40
50
60
70
80
90
100
Efficiency [%]

Installation into CALICE absorber Structure

With help from DESY

Testbeam started last Friday