Construction of the DHCAL Prototype

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Argonne National Laboratory

CALICE Collaboration Meeting
University Hassan II
Casablanca, Morocco
September 22 – 24, 2010

DHCAL Collaboration

Boston University (Data Collector)

John Butler (Professor)
Eric Hazen (Electronics Engineer)
Shouxiang Wu (Electronics Engineer)

Fermilab (Front-end chip, Trigger and Timing Module, Event Display)

Alan Baumbaugh (Electronics Engineer)
Louis Dal Monte (Electronics Engineer)
Jim Hoff (Electronics Engineer)
Scott Holm (Electronics Engineer)
George Mavromanolakis (Postdoc)
Ray Yarema (Electronics Engineer)

University of Iowa (High Voltage and gas systems)

Burak Bilki (Graduate Student)
Edwin Norbeck (Professor Emeritus)
David Northacker (Mechanical Engineer)
Yasar Onel (Professor)

McGill University

François Corriveau (Professor)
Daniel Trojand (Graduate Student)*

Northwestern University

Nicholas Mucia (Graduate Student)
Brian Pollack (Graduate Student)
Mayda Velasco (Professor)

University of Texas at Arlington

Jacob Smith (Graduate Student)*
Jaehoon Yu (Professor)

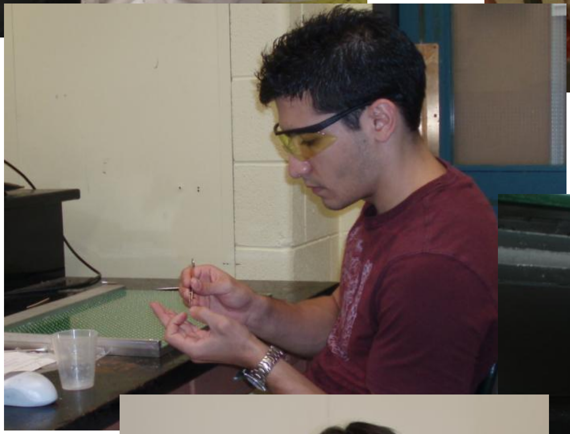
IHEP (Beijing)

Institute of High Energy Physics
Chinese Academy of Sciences

Qingmin Zhang (Postdoc)*

*Supported (in part) by Argonne





Argonne Electronics Group

Carol Adams (Electronics Technician)
Mike Anthony (Engineering Assistant)
Eddie Davies (Draftsman)
Patrick De Lurgio (Electronics Engineer)
Gary Drake (Electronics Engineer)
Bill Haberichter (Engineering Assistant)
Andrew Kreps (Electronics Engineer)
James Schlereth (Computer Scientist)
John Walendziak (Electronics Technician)

Argonne Mechanical Group

Robert Furst (Technician)
Victor Guarino (Engineer)
Zeljko Matijas (Technician)
Frank Skrzecz (Engineering Assistant)
Ken Wood (Engineering Assistant)
Allen Zhao (Engineer)

Argonne Physicists

Kurt Francis (Postdoc)
José Repond (Physicist)
David Underwood (Physicist)
Lei Xia (Physicist)

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

Overview

Chamber construction

- Spraying of glass → Measurement of $R_{\square}$
- Assembly of RPCs → Thickness measurement, leak test
- Attaching of HV connectors → HV tests

Electronics

- Front-end board fabrication and assembly → Tests
- Pad- and Front-end board gluing → Tests
- Data collectors
- Timing and trigger modules
- Cables

Cassettes

- Assembly
- Transportation to FNAL

Peripherals

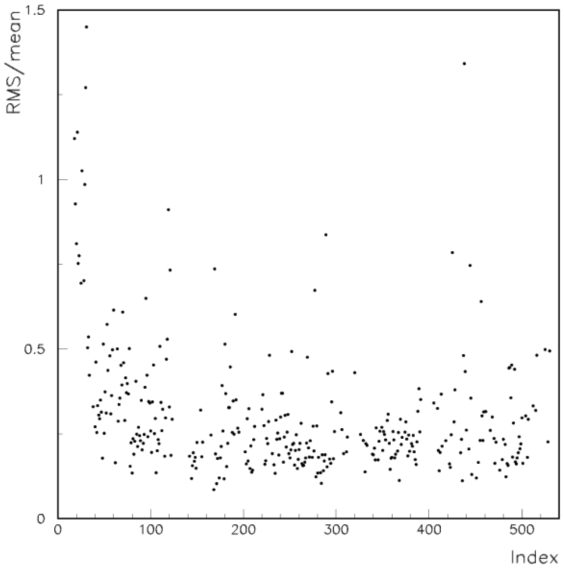
- Low voltage system
- High voltage system
- Gas system

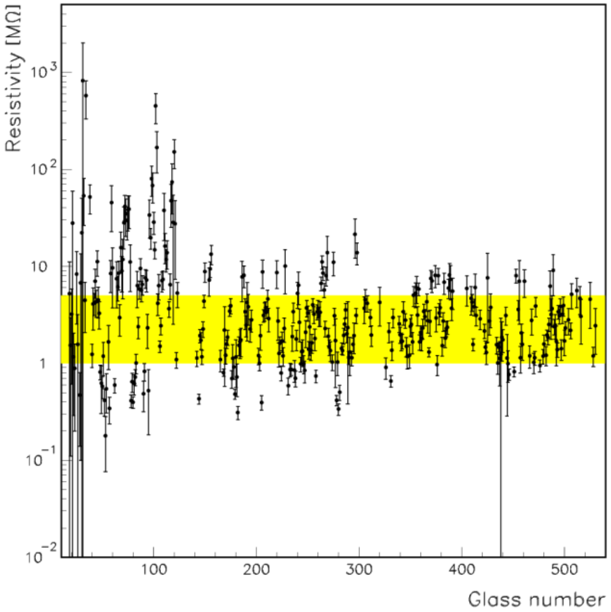
Glass Spraying

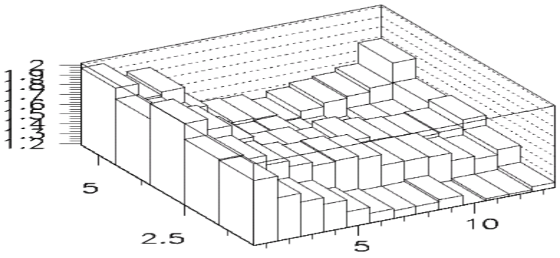
Need to coat anode glass with resistive paint with $R_\square$ = 1 – 5 MΩ
$R_\square$ of cathode glass not as important

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



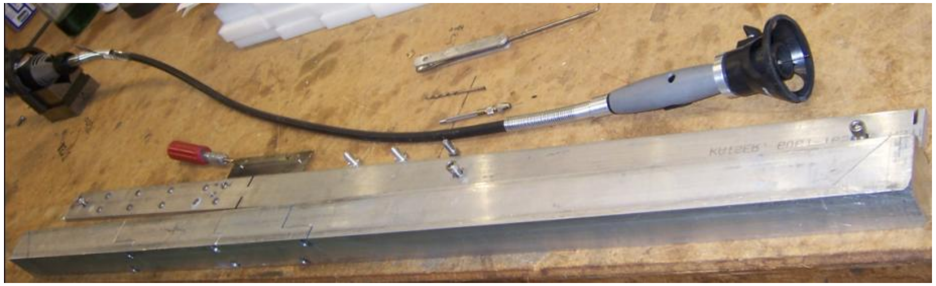




Production completed
Never gained complete control over $R_\square$
RMS actually rather good

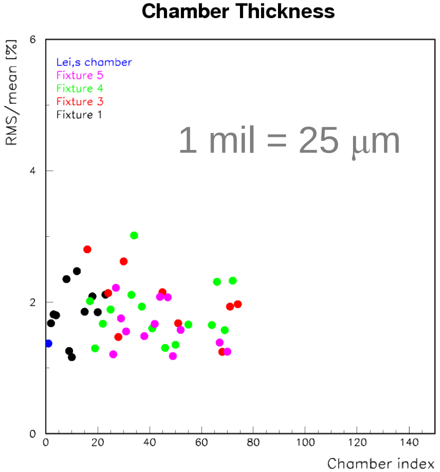
RPC Assembly

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

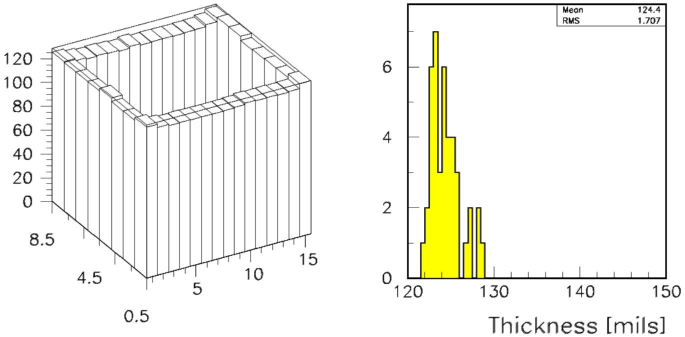


Built precision fixtures for assembly

- 1 frame cutting fixture
- 3 RPC assembly fixtures
- Assembly of 1 RPC/technician/day
- Produced a total of 149 chambers

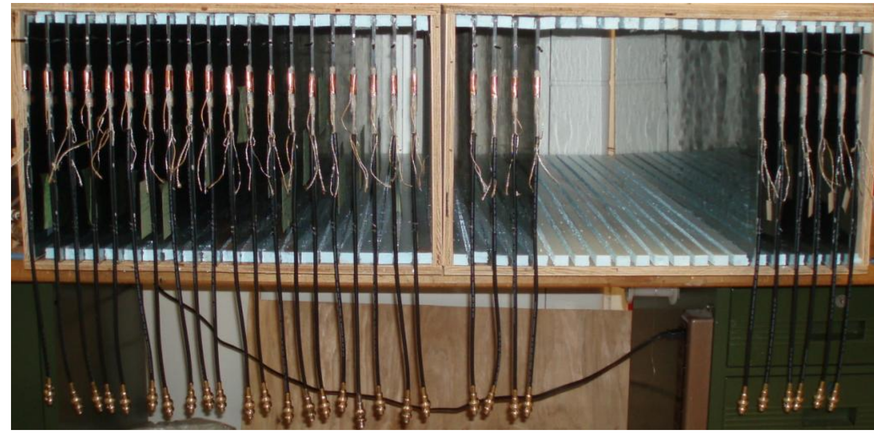


RPC 001



Production completed with 149/114 chambers
Thickness variation on rim acceptable
(not all chambers measured)
All chambers passed leak test at 0.3" of H_2O

HV Connection

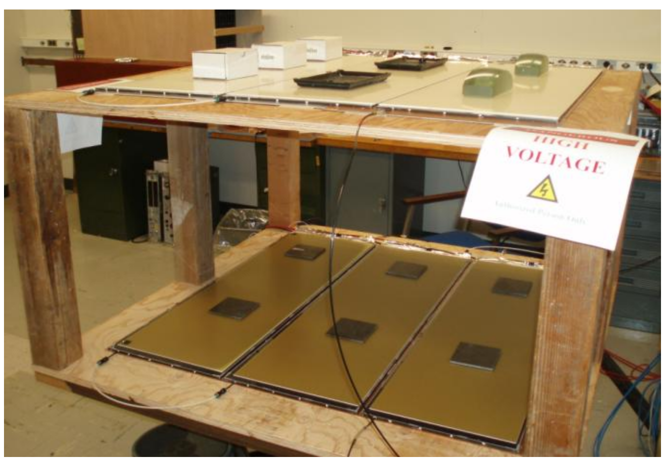


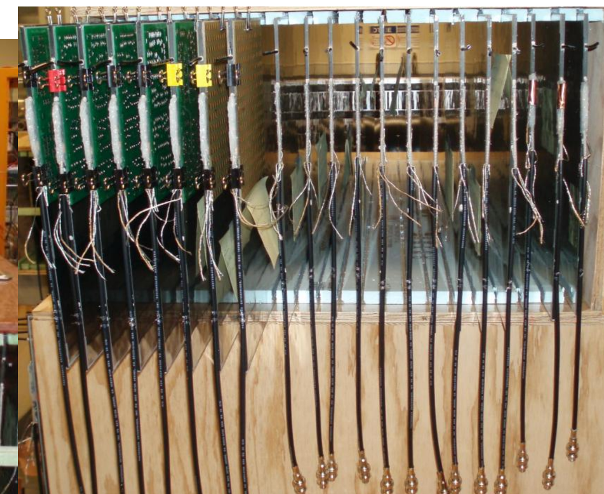
3 steps: 1) attach connector
2) cover chamber in Mylar sheets
3) protect connector with RTV

Nominal voltage 6.3 kV

Built test stand

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





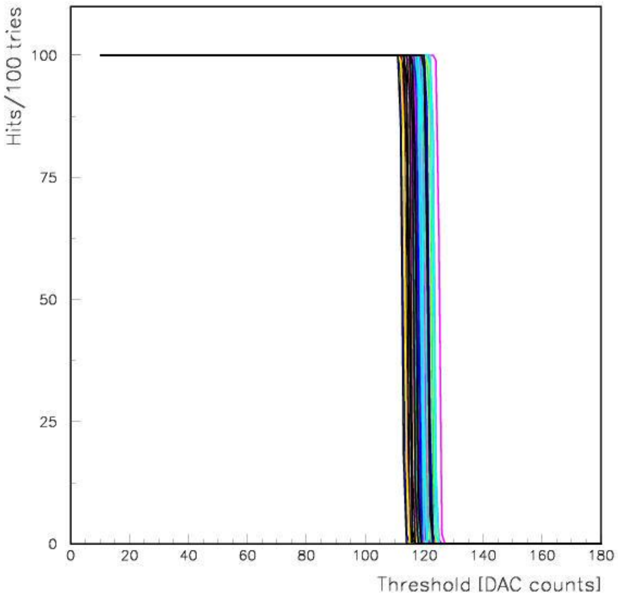
~127/114 chamber successfully tested at 7.0 kV
Currents ~ 0.25 μA/chamber

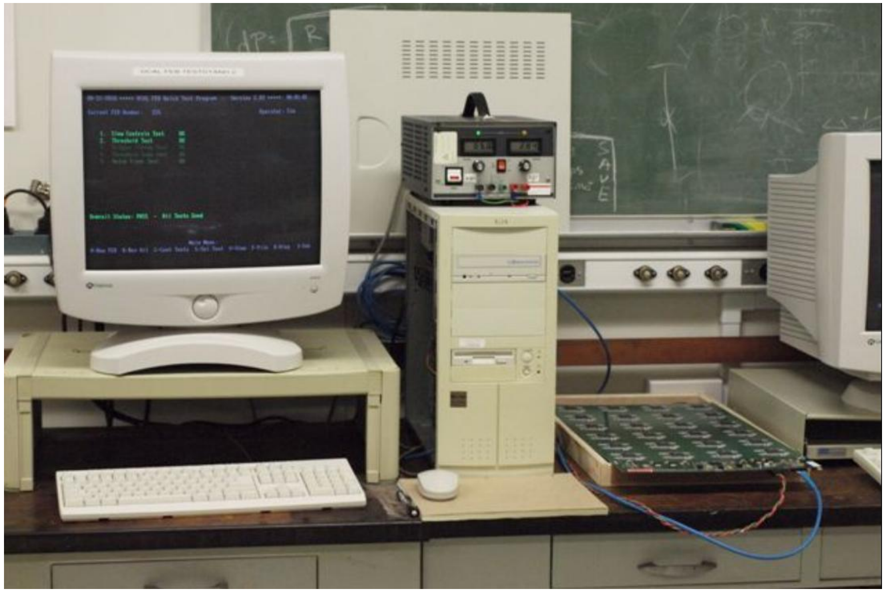
Front-end Boards

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
- Demanded less than 4/1536 dead channels

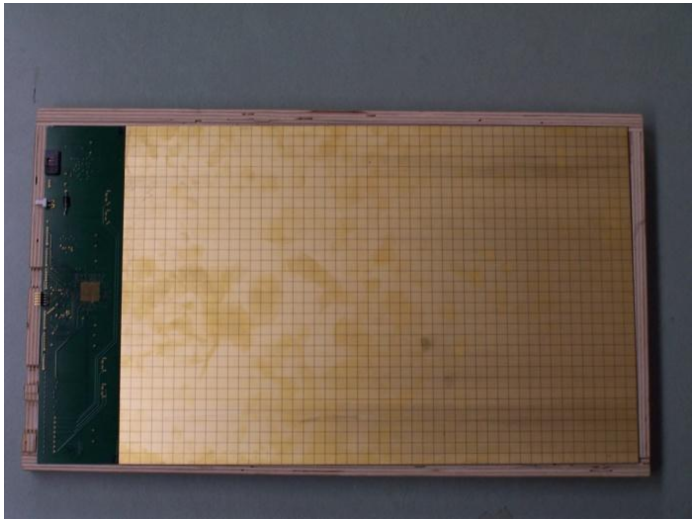




Testing complete
254/228 boards tested successfully

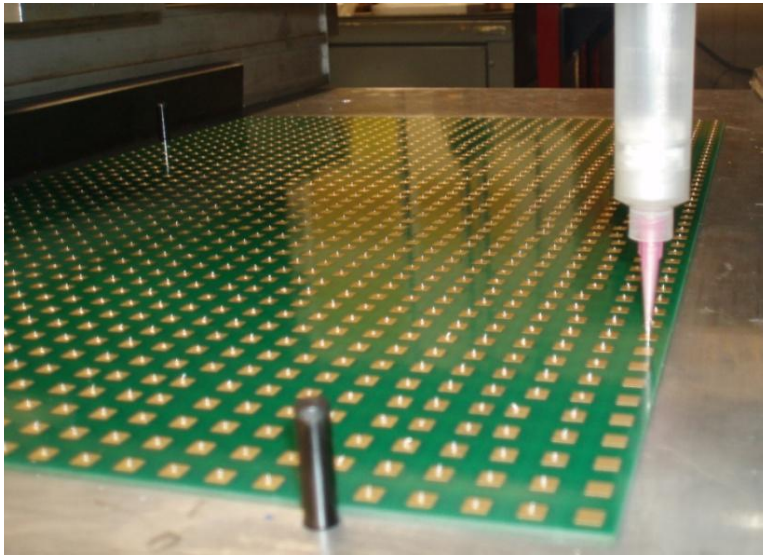
Pad- and FE-board Gluing

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



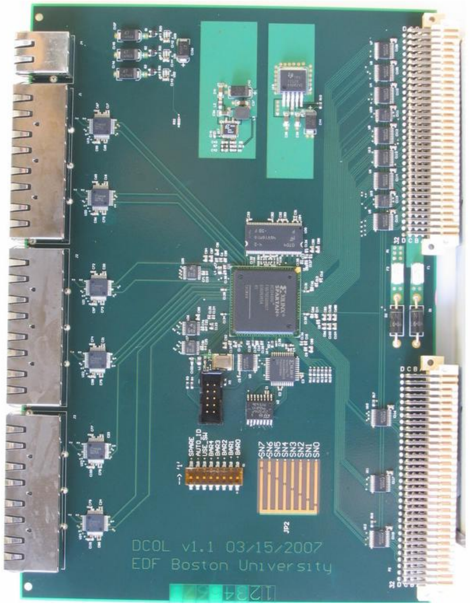
Built a gluing fixture

- 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
254/228 glued boards in hand

Data Collector Modules

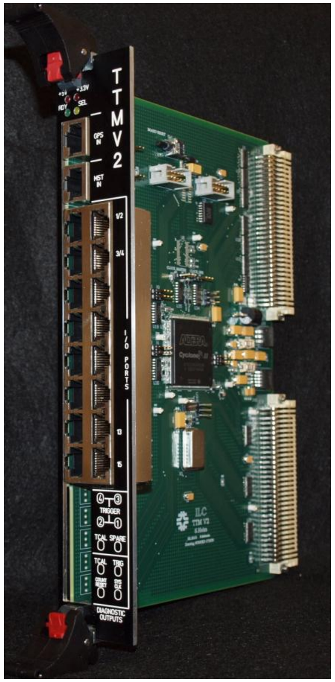


1 Data Collector Module per 12 front-end boards
Need 19 for cubic meter

Built test station at Boston

BOSTON UNIVERSITY

Production complete
30/20 boards delivered to Argonne



Timing and Triggering Module

Fermilab

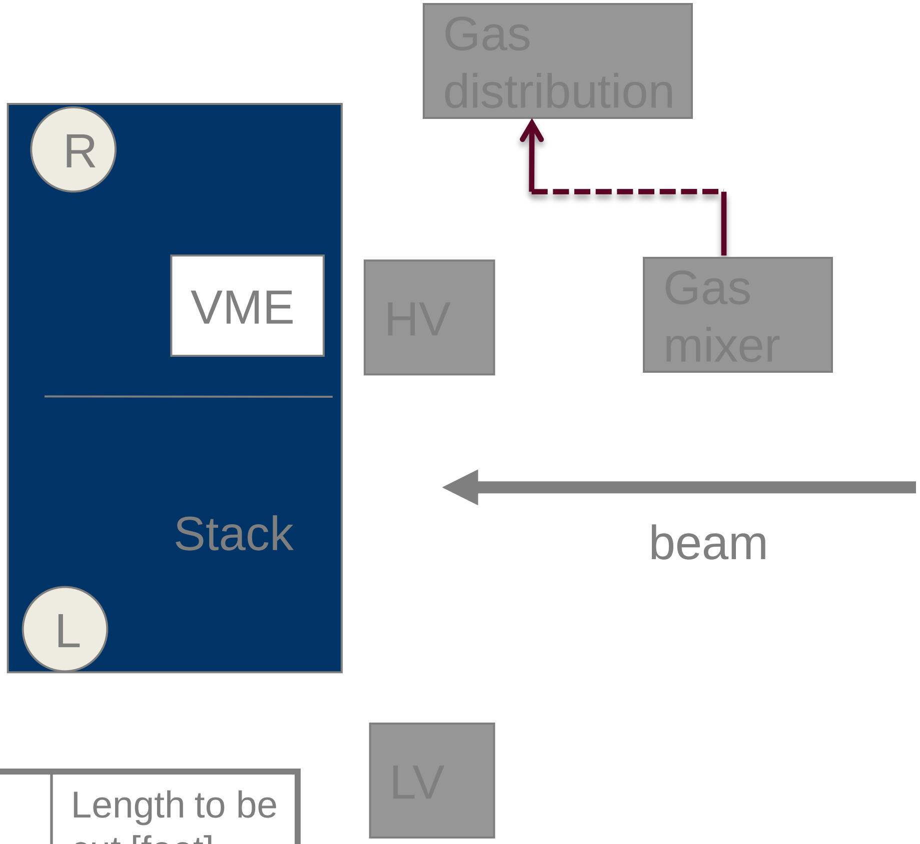
Provide control to up to 24 Data Collectors
Need 1 Master and 2 Slaves for cubic meter

Designed and debugged at FNAL

12 boards produced
6/3 assembled so far

Cables

Proposed layout in beam area



Cable	Amount needed	Measured length [feet]	Length to be cut [feet]
Signal	228	R/L = 19/22	28
Low Voltage 110 V	6	20	20
Low Voltage 5 V	76	24	30
High Voltage 110 V	3	25	25
High Voltage 6.5 kV	38	21	25

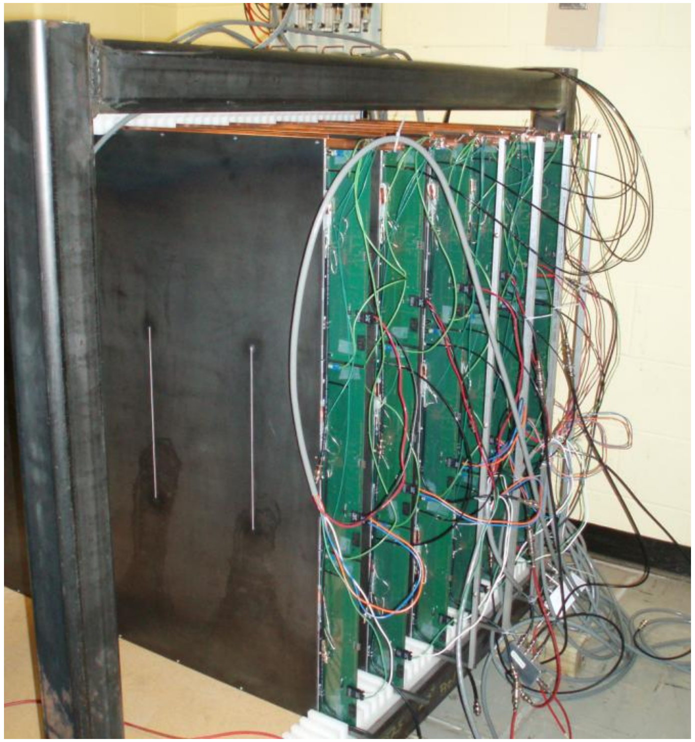
All cables + spares in hand

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

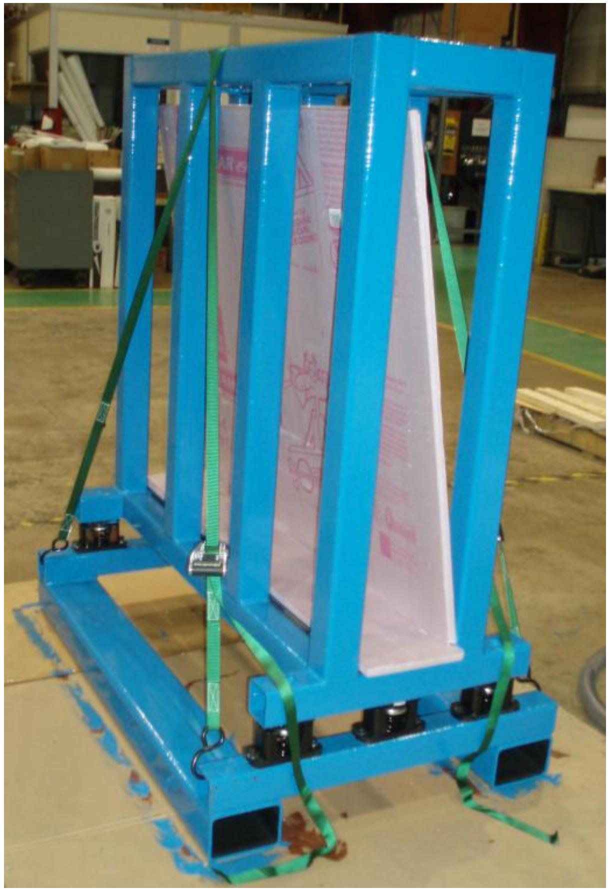
Assembly

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



15/38 cassettes assembled
Possible to assemble at least 5 cassettes/day

Cassette Transportation



Need to transport cassettes to FNAL
(glass breaks!)

Built transport fixture

Able to transport 8 cassettes at a time
Frame mounted on dampers to absorb shocks

Tested successfully with 1 cassette

- Loading on truck at ANL
- Transportation to FNAL
- Unloading from truck at Mtest
- Insertion into the CALICE stack
- Extraction from CALICE stack
- Loading onto truck at Mtest
- Transportation back to ANL
- Unloading at ANL

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 (virtually) complete

Commissioning/move/data taking

1) All layers will be powered up and tested at Argonne
2) Starting September 27th layers and crates will be transported to FNAL
3) Starting October 4th layers will be powered up and commissioned at FNAL
4) Starting October 9th we will accept beam
5) Test beam ends November 2nd

Test Beam Plans

Broadband muons for calibration

Calorimeter not rotated
Move calorimeter around to expose entire volume (4 x 4 positions)
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
1,2,4,8,12,16,20,24,32,40,48,60 GeV
(rough calculation: 100,000 events/E /(300 particles/spill)*(12 E) = 4,000 spills = 67 hours)

Broadband muons at 20^0

Only into center of calorimeter

Energy scans at 20^0

Into center of calorimeter
Some energy points

Conclusions

We have been busy since the last meeting in Texas

Construction is almost complete

Cassette assembly is not expected to take more than a few days

Commissioning is ongoing

We will have 38 layers in the test beam on October 9th

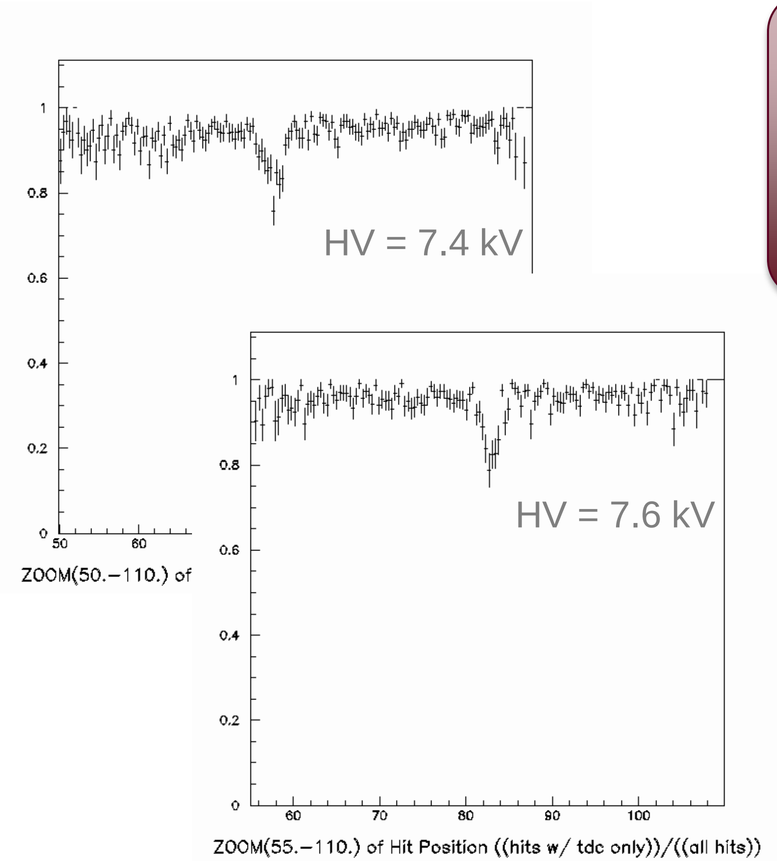
We will take data with the stack over the following 4 weeks

We will build more layers to equip the tail catcher

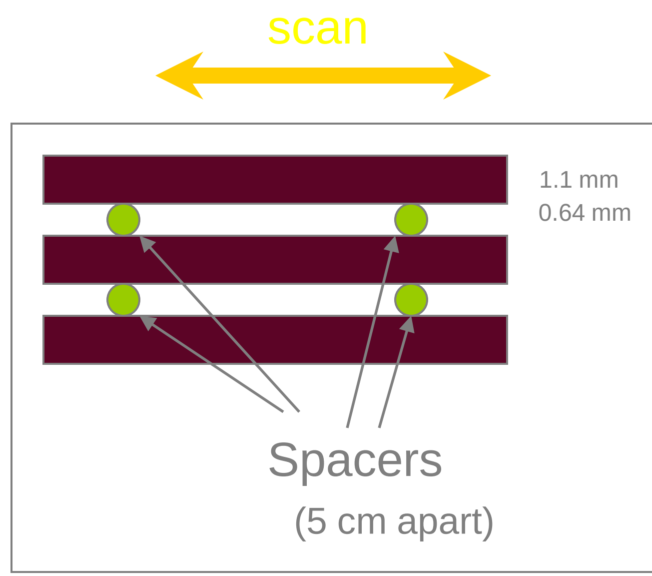
The second test period (including the ECAL) will be in January/February 2011

Backup Slides

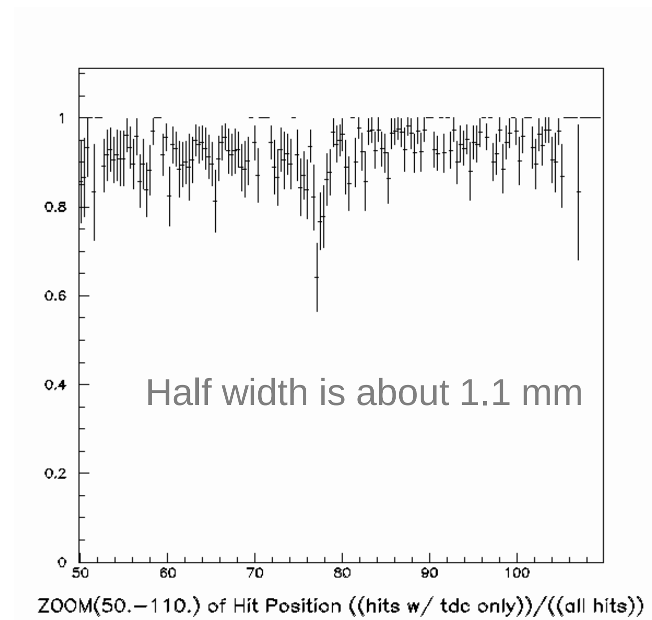
Efficiency across the spacer



Slide from October 2003



Select vertical tracks only



Half width about 1.8 mm

€ ~ 15% x 3 mm = 45% mm = 100% x 0.45 mm

Spacer Ø is 0.64 mm

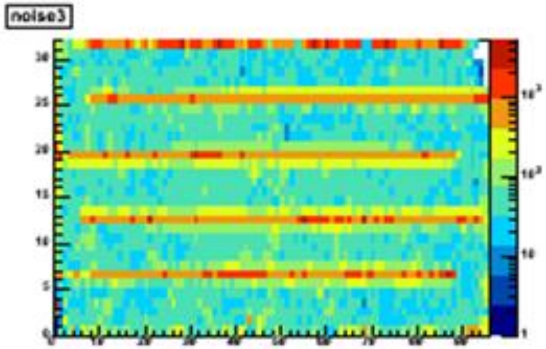
Efficiency loss due to fishing lines

Assuming inefficiency given by diameter of fishing line (it's better than that)

Inefficient area = I = N x L x D = 4 x 32.0 cm x 0.115 cm = 14.7 cm^2

Total area = A = L x W = 96.0 cm x 32.0 cm = 3072 cm^2

Inefficiency = I/A = 0.47 %

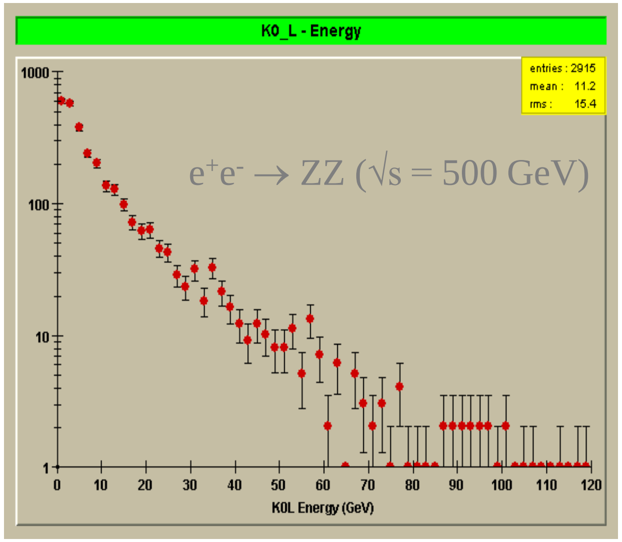


Assuming inefficiency given by D*2/3

Inefficiency = 0.31 %

Inefficiency due to fishing lines 0.3 - 0.4%

Neutral particles



250 GeV jets

Assuming 25% of these jets with $E^0_{particle}$ > 80 GeV

Fraction = 80GeV/250GeV x 0.25 = 8%
Overall neutral hadron energy ~10% of E_{jet}

Segmented calorimeter

Offers possibility of software compensation
Needs to be applied to the DHCAL

Nevertheless

Would be good to have better response at high energy

→ Finer granularity: 1 → 0.25 cm^2 (works in Monte Carlo)
→ Better single pad resolution (digital → semi-digital) ???