Construction the RPC Digital Hadron Calorimeter Physics Prototype

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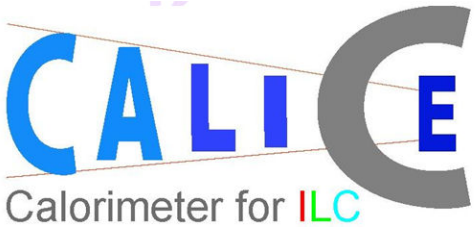

CALICE collaboration meeting at UTA

RPC DHCAL Collaboration

Argonne

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Jacob Smith
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RED = Electronics Contributions
GREEN = Mechanical Contributions
BLUE = Students
BLACK = Physicist

1 m^3 – Digital Hadron Calorimeter Physics Prototype

Description

Readout of 1 x 1 cm^2 pads with one threshold (1-bit) → Digital Calorimeter
40 layers each ~ 1 x 1 m^2
Each layer with 3 RPCs, each 32 x 96 cm^2
~400,000 readout channels
Layers to be inserted into the existing CALICE Analog HCAL structure

Purpose

Validate DHCAL concept
Gain experience running large RPC system
Measure hadronic showers in great detail
Validate hadronic shower models

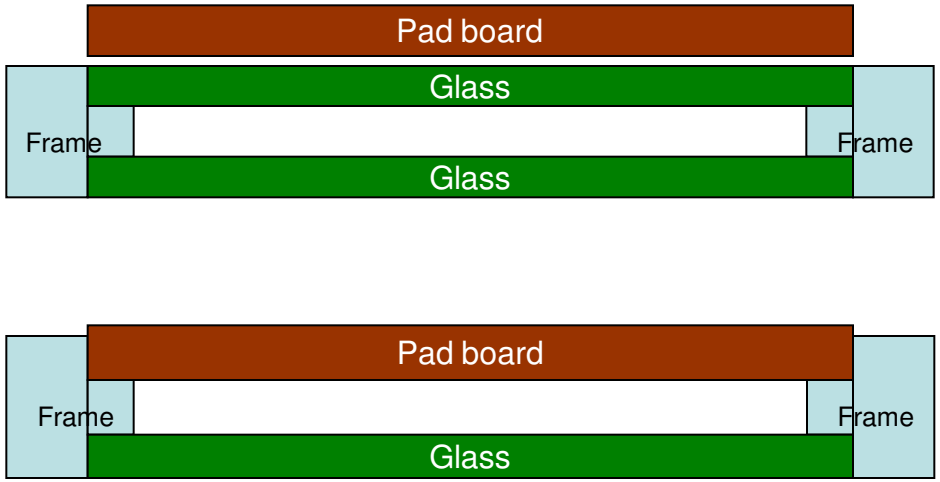
Status

Started construction in 2008 - 09

RPC Construction

RPC design

2 – glass RPCs
1 – glass RPCs (developed at Argonne)
Gas gap size 1.1mm
Total RPC thickness < 3.4mm
Dead area ~5% (frame, spacer)



Chambers needed

~120 + spares

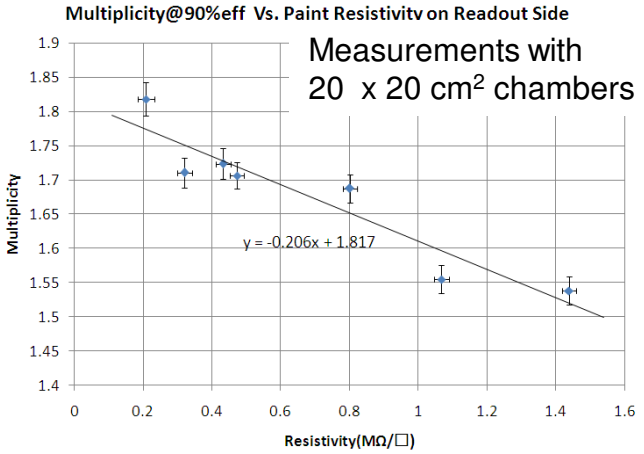
Material

Glass in hand for 300 chambers
Kilometers worth of PVC frame extruded

Assembly steps

Spraying of glass plates with resistive paint
Cutting of frame pieces
Gluing frame
Gluing 1st glass plate onto frame
Put in fishing line
Gluing 2nd glass plate onto frame
Mounting of HV connection, etc.

Spraying of the glass sheets



Challenge

Produce a uniform layer with $R_{\square} = 1 - 5\ M\Omega$
(value only critical for thin plate, thick plate can be lower)

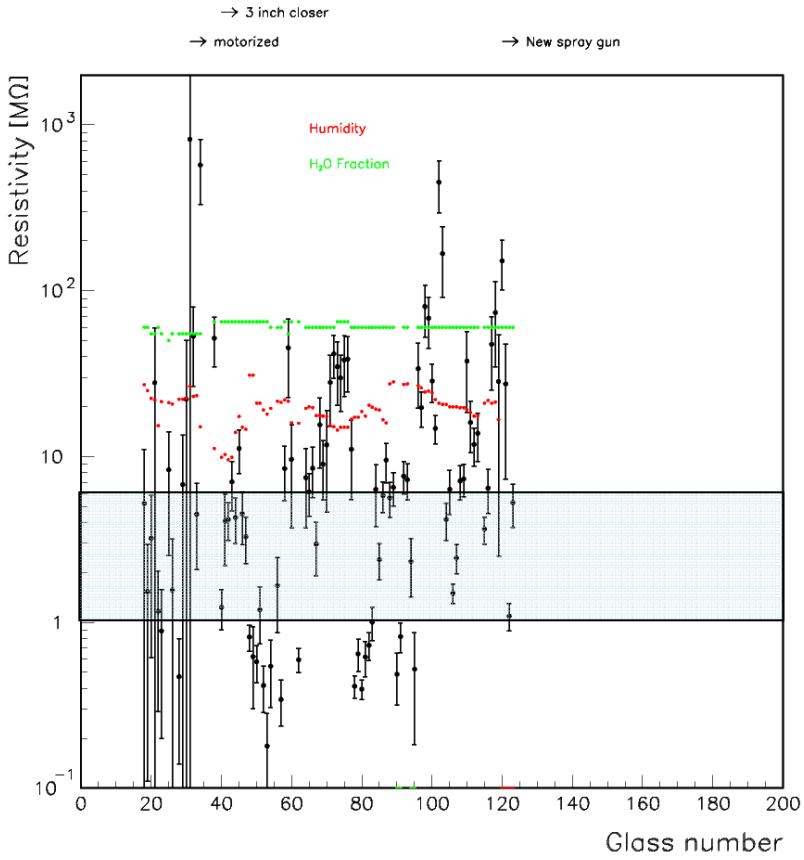
New paint (artist paint) identified

Reasonably cheap
Non toxic
2 component mixture (BLACK and GREEN)
Needs to be sprayed

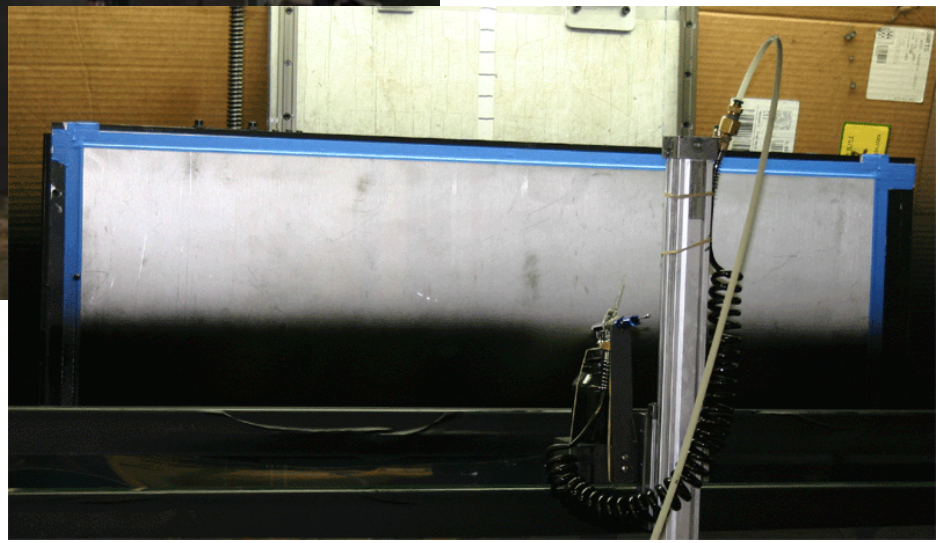
Production

Been struggling with spraying for a while

Poor uniformity in a single plate
Mean value not well controlled from plate to plate
Low yield: ~ 60% passes quality cut
Slow: barely match RPC assembly speed

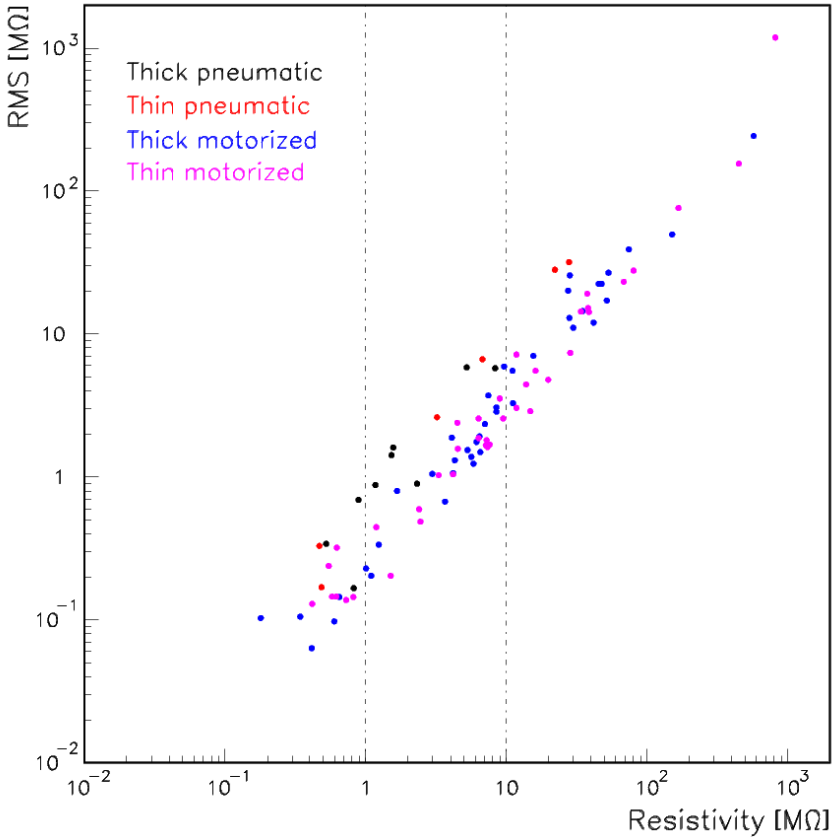


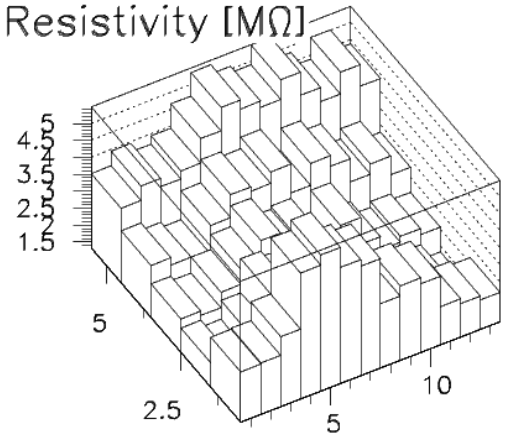
Spraying setup



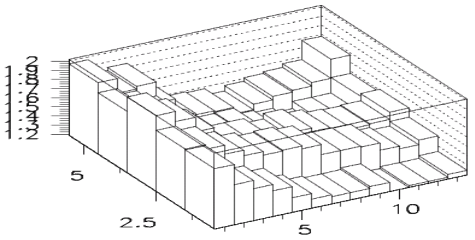
Improving paint spraying

- **(almost) Exhaustively studied all spraying conditions**
  - Environmental temperature, humidity
  - Air brush pressure, flow rate, nozzle cleanliness
  - Paint ratio and quality
  - Horizontal slide speed
- **Improvement 1**: pneumatic slide → motor driven
  - Significantly improved uniformity
- **Improvement 2**: air brush → spray gun
  - Further improved uniformity
  - We believe that we are in control of the mean value now
  - Much faster spraying process
- We are close to claim: **problem solved**



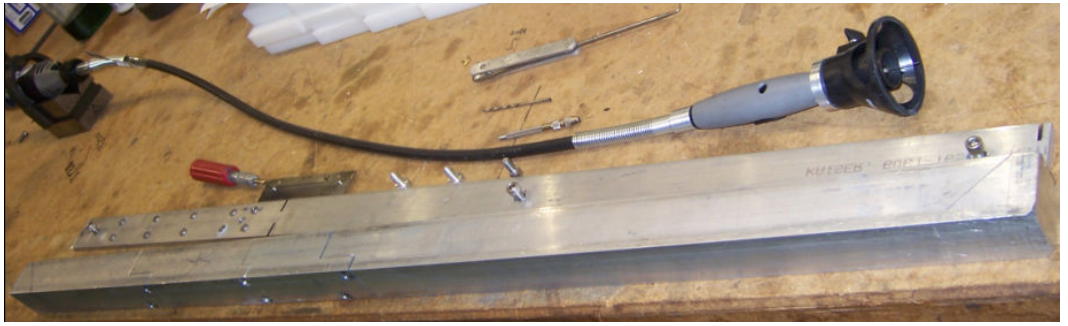


Air brush



Spray gun

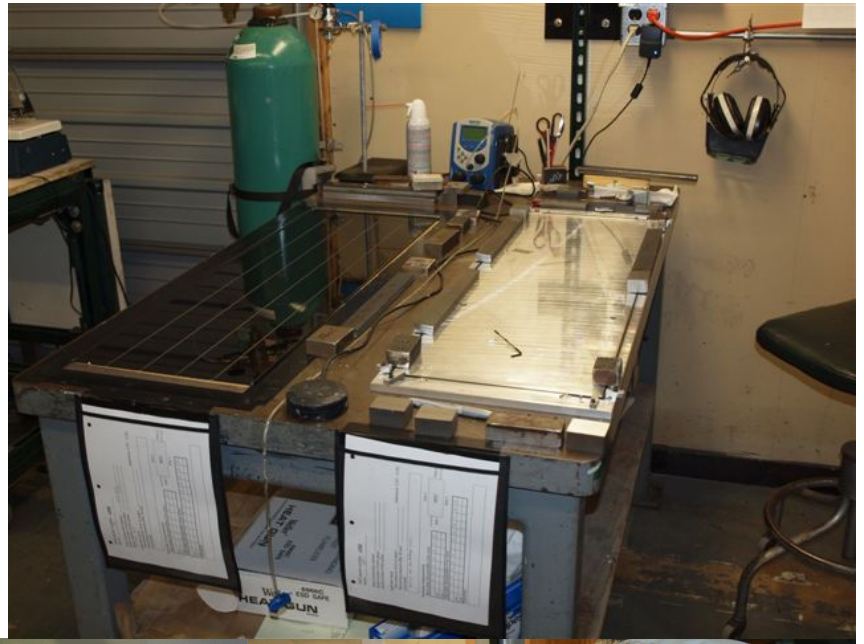
RPC Assembly



Cutting frames

Dedicated (adjustable) cutting fixture
Cut length to .2mm precision
Drill holes

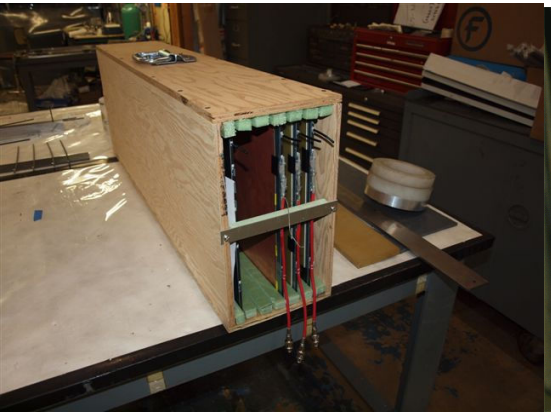
Assembly



Dedicated gluing fixture
Frame/gap glued to ~0.1mm precision
Very time consuming process:
~1 RPC/day/tech, 3 RPC produced/day

Production

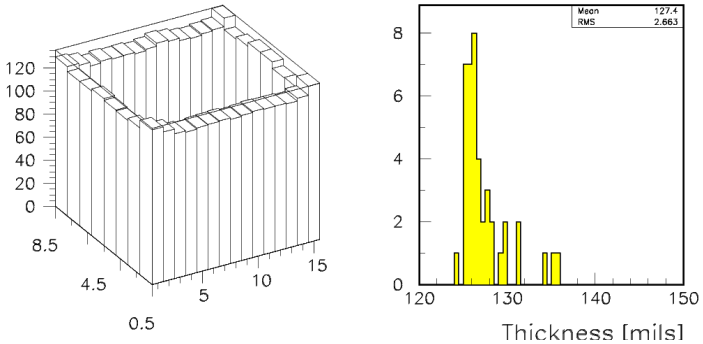
30+ final RPC completed or near complete
Full speed production started



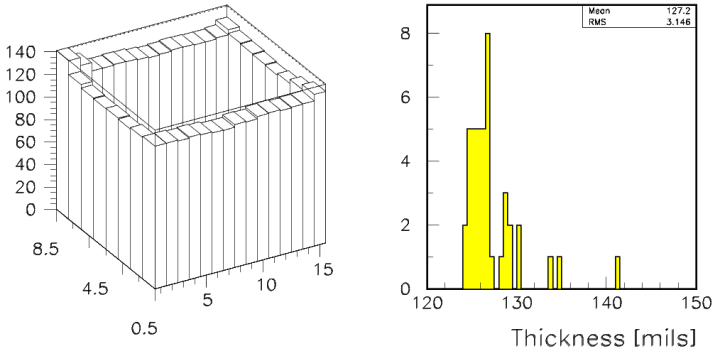
Quality assurance

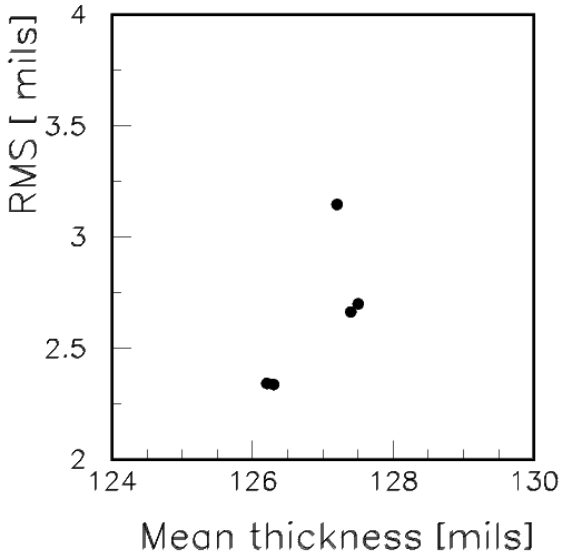
- Pressure test
  - Test at 0.3 inch of water pressure
  - Pass if pressure drop < 0.02 inch in 30sec
  - Chambers not passing in 1st test are repaired
  - All repaired chambers pass 2nd test so far
- Gap size measurement
  - Gap sizes of all chambers are measured along the edges
  - Gap sizes along all edges are controlled at ~0.1mm level (central region assured by spacers)
  - Corner regions are worse (but within 1-2 cm from corner)
    - Typical ~0.1mm thicker
    - A few corners are ~0.3 – 0.4mm thicker
    - Currently related to the way corners are glued
    - In the process of improving the procedure
- HV test
  - Chambers are tested with HV before put readout board on
- Chamber rejection: only 4 so far
  - 2: wrong glass sheet
  - 1: tubing arranged in wrong direction (typical learning process)
  - 1: gas inlet/outlet in wrong place, glass cracked

RPC 018



RPC 012

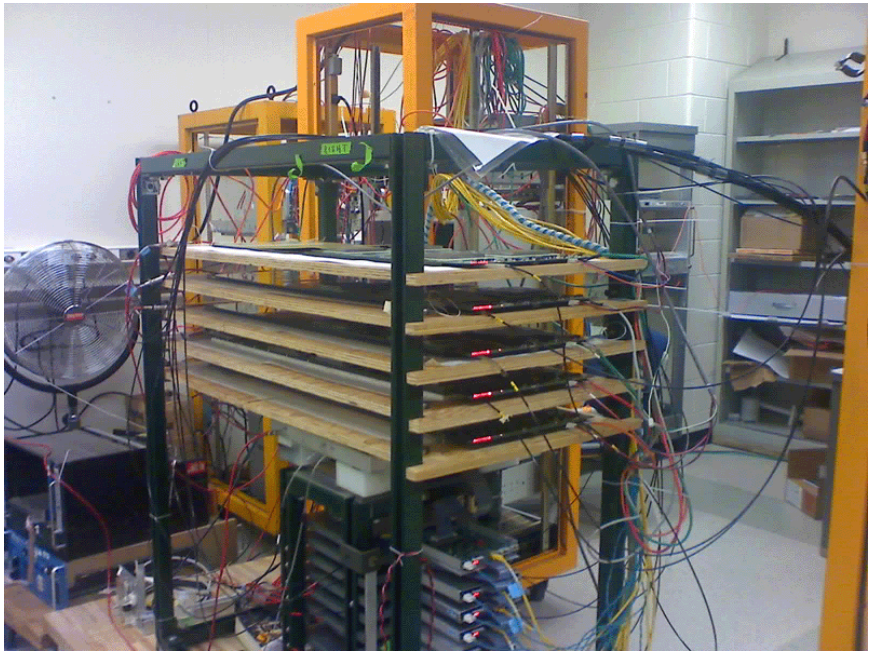




Test of production RPC with new (full size) board

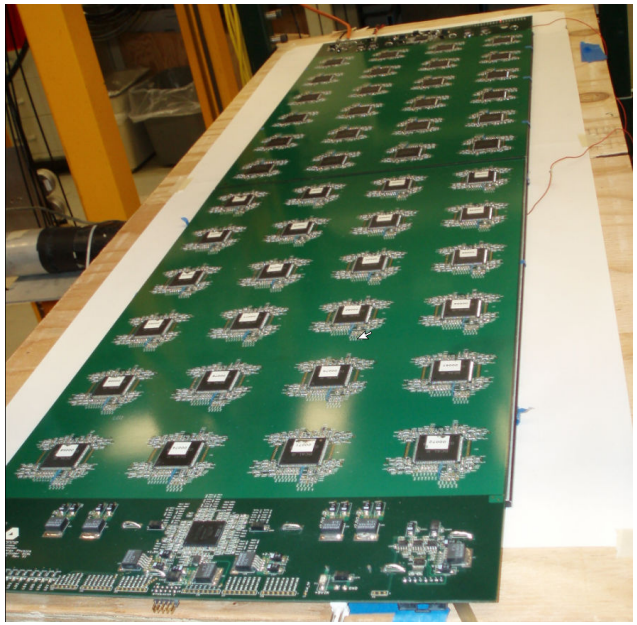
Setup

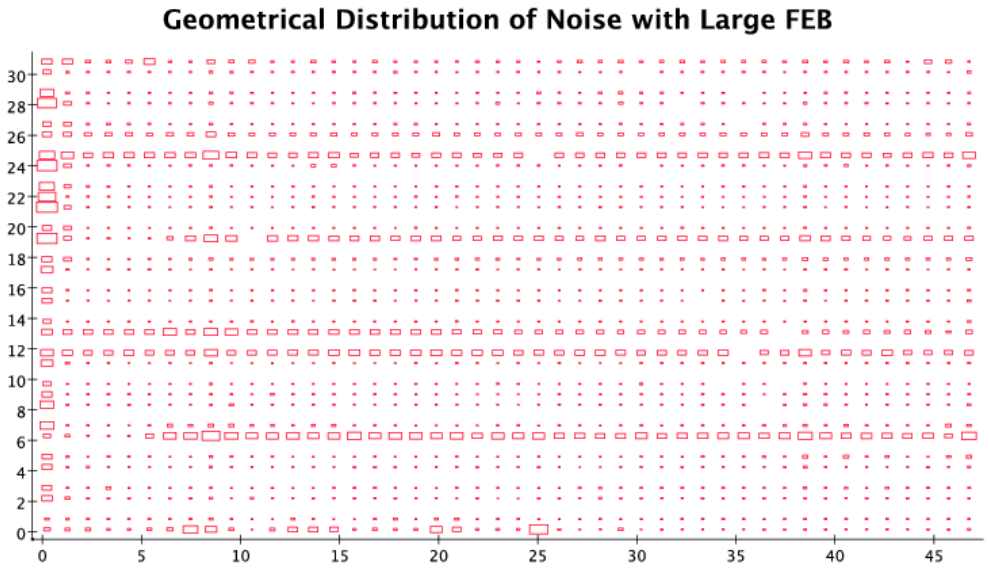
Uses up to 7(4) small chambers from VST
Currently 5(4) large chamber with 7(5) board
Will increase to ~10 large chambers
Will be used for RPC/FE board check out



Data taking

First events on 9/11/2009
Just finished prototype FE board tests
Large cosmic/noise/Qinj data set

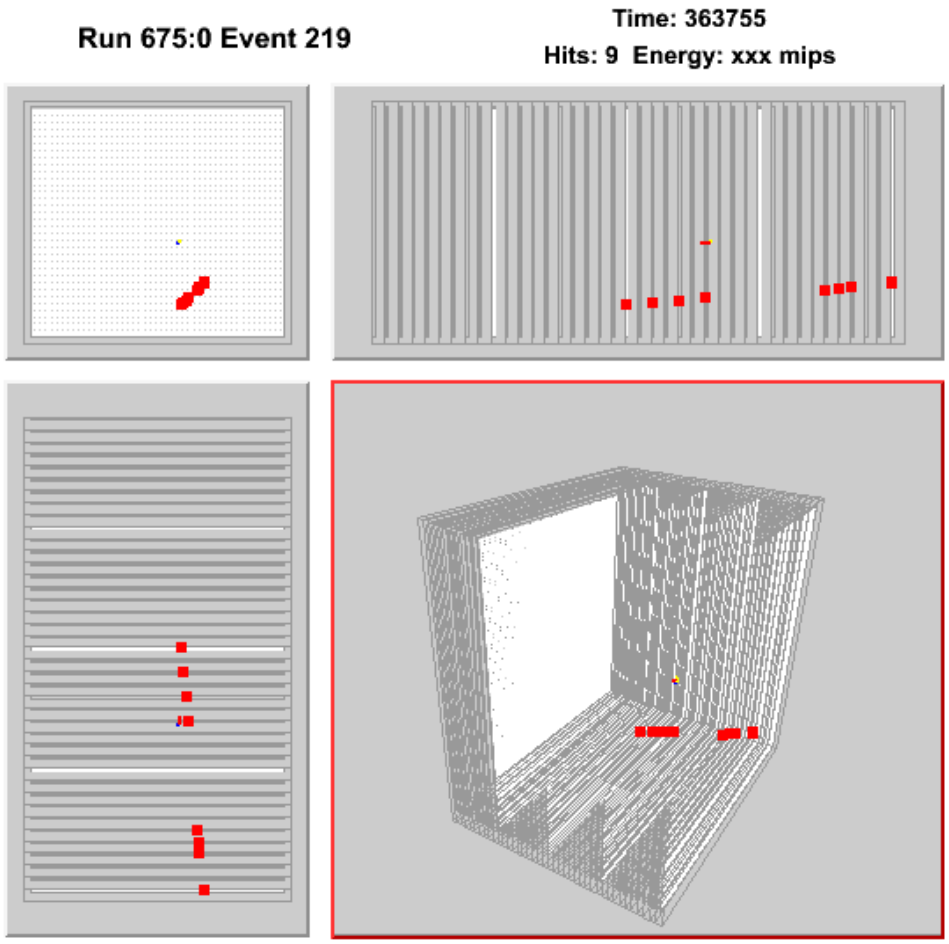


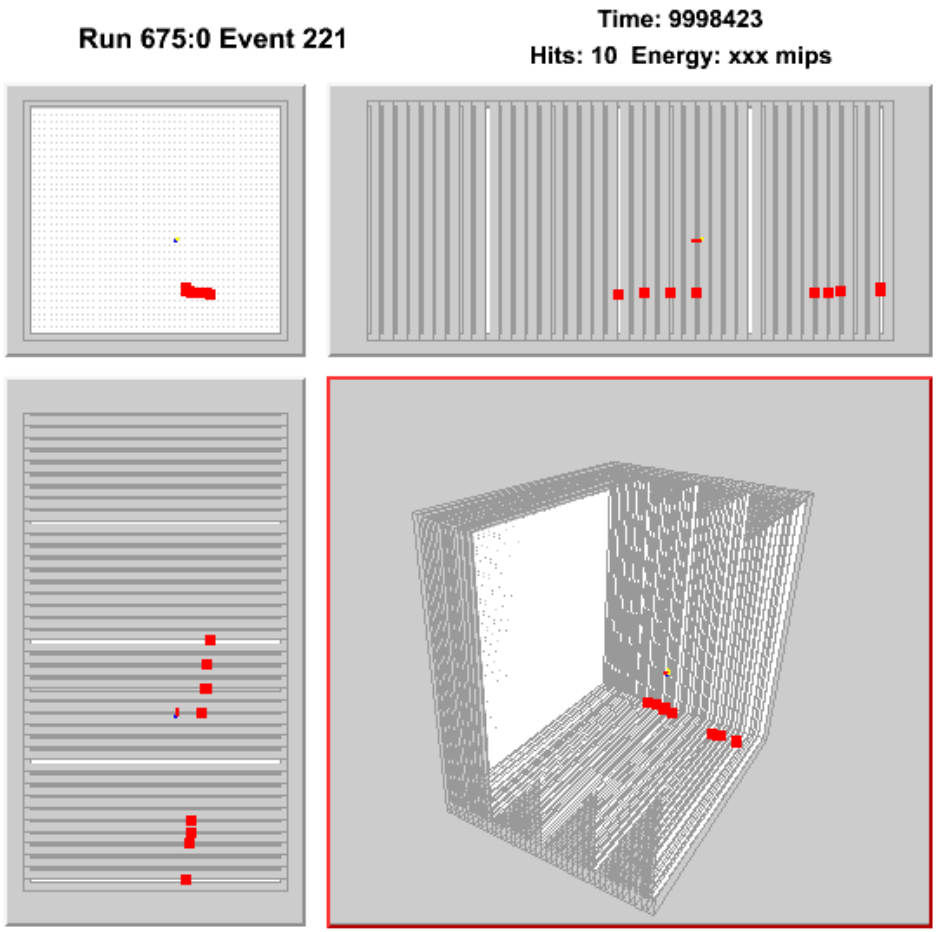


Some electronic test results

- "Spark Tests"
  - One RPC has a 'feature' of sparking at a known voltage
  - Initially will send nearby FE boards to a funky state
  - Shielded data cable and improved grounding solved the problem
- Tested noise floor of new FE boards
  - Noise performance (significantly) better than VST boards
- Eliminated ALL data errors in system
  - NO data error ever observed in cosmic ray data
  - Eliminated a trivial DCOL firmware bug that creates check sum errors
  - Found 1 error mode in the last few weeks when push the system off the design limit (high rate)
  - Eliminated this error mode last week (firmware improvement)
  - Currently system run smoothly in ALL conditions (low threshold, high rate, sparks(?!))

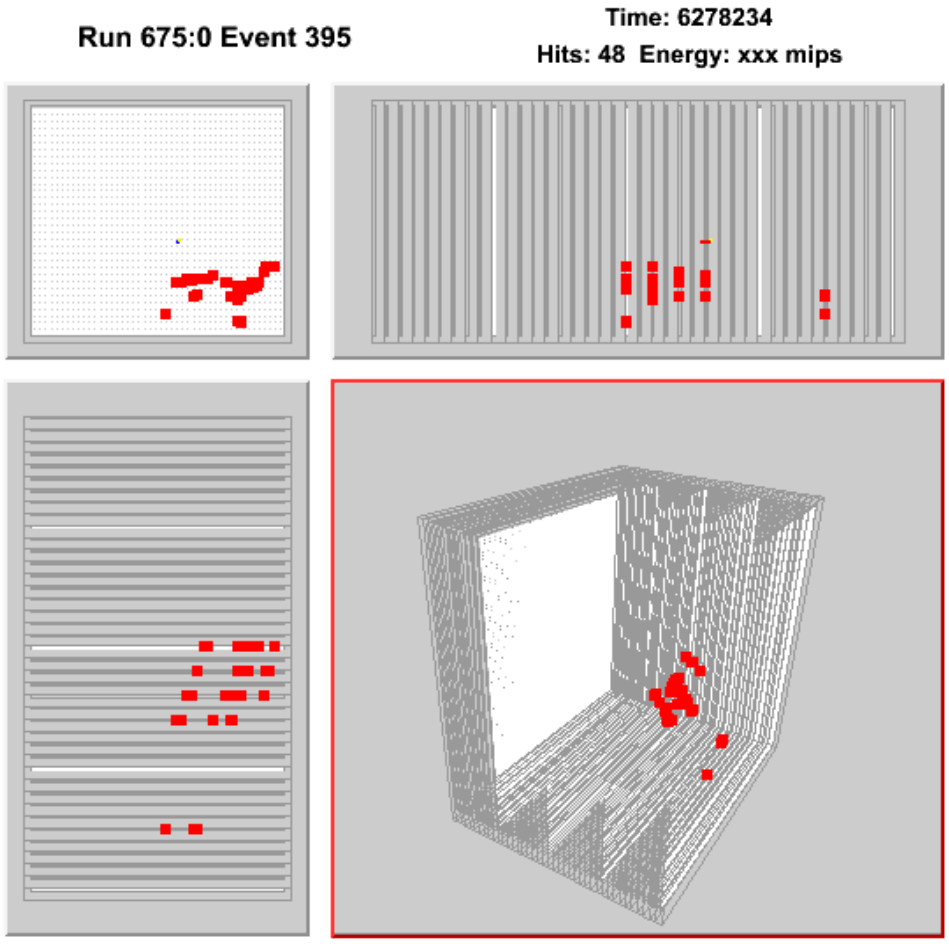
Some cosmic ray events: single track

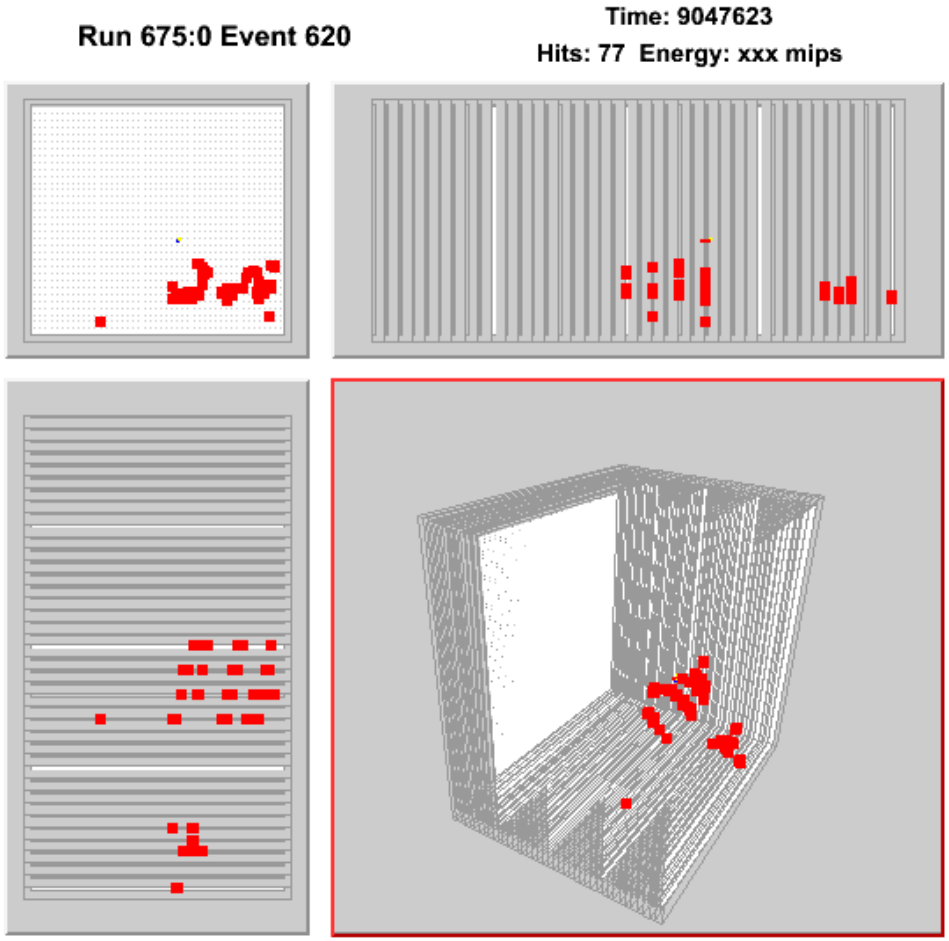




Cosmic ray data analysis in progress

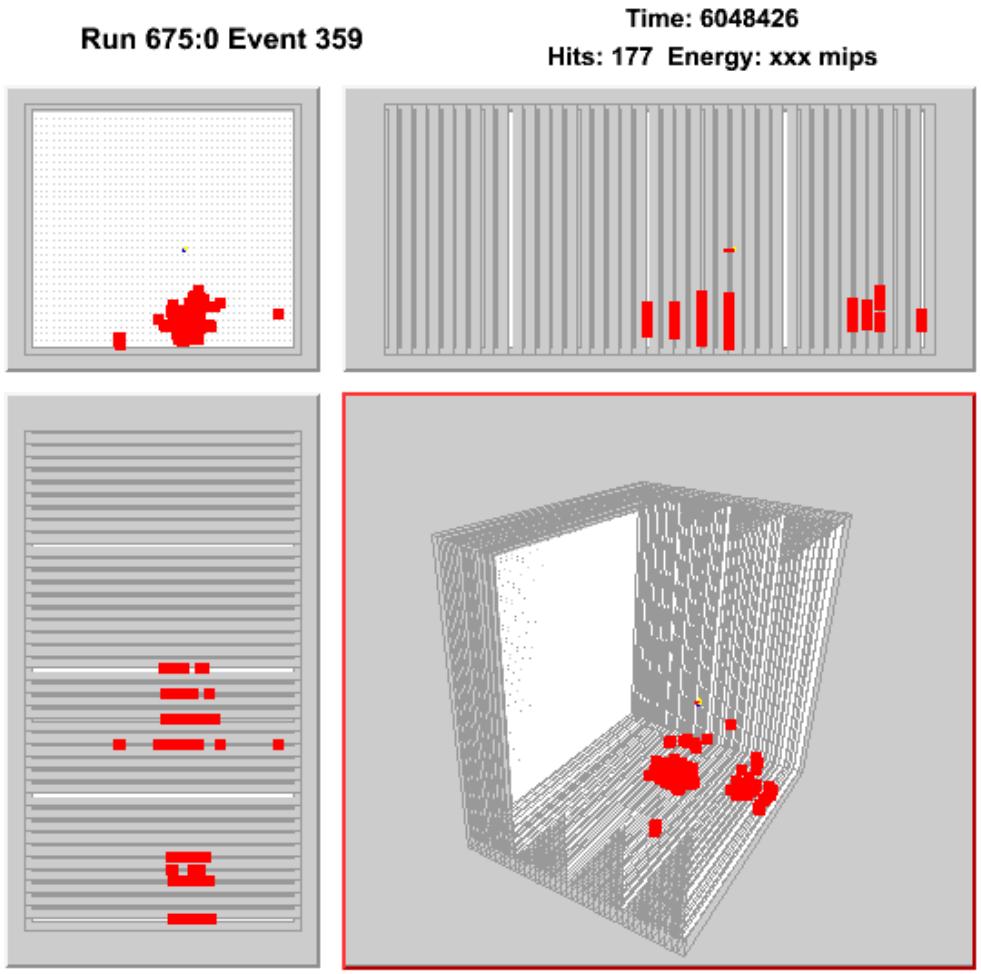
Some cosmic ray events: multiple tracks

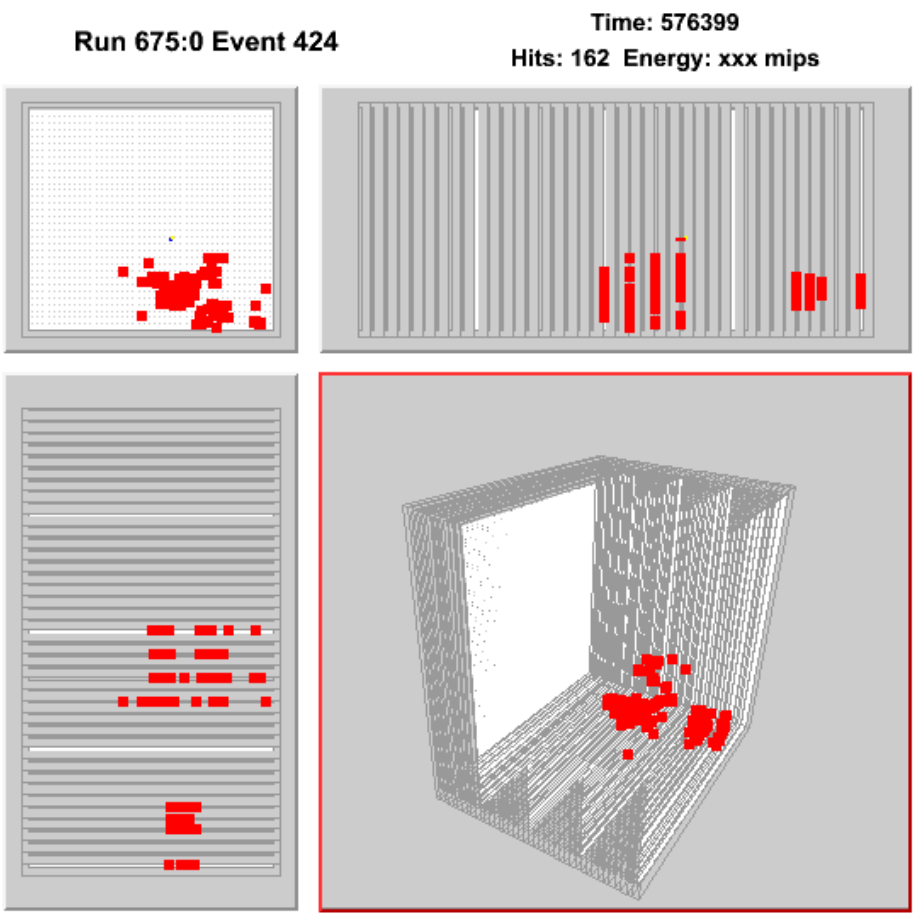




Cosmic ray data analysis in progress

Some cosmic ray events: air shower?





Cosmic ray data analysis in progress

Cosmic ray test stand

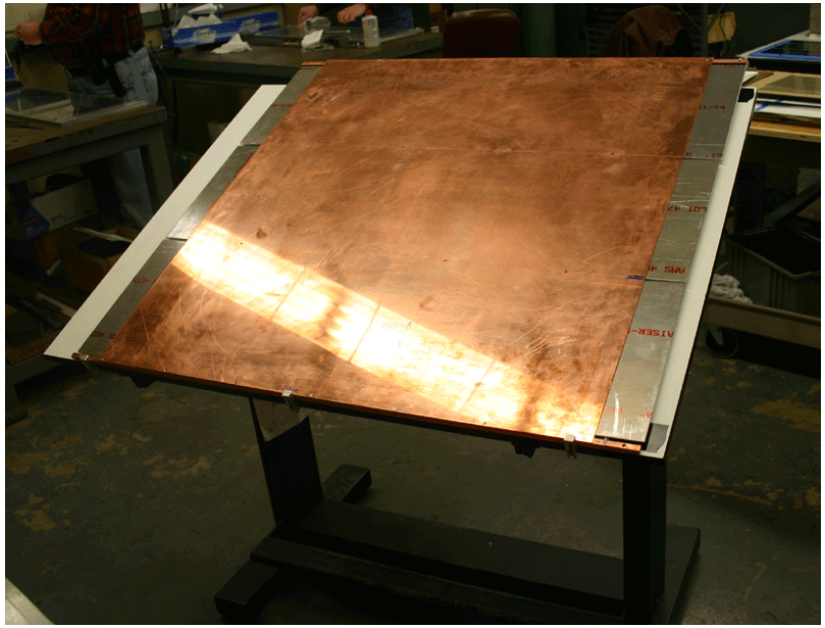
- **Current issue**
  - Uses scintillator trigger, only map out part of an RPC at a time
  - Low trigger rate (~10/min)
  - Takes forever to map out entire RPC
- **Planned changes**
  - Remove VST and trigger counters
  - Expand to ~10 large RPC's
  - Run in self-trigger (triggerless) mode
- **Challenges**
  - New event builder: rely entirely on timing information of hit packages (no help from trigger packages)
    - Find cosmic ray tracks out of RPC noise hits
    - Tried with VST, should not be a major challenge
  - Data size: ~10GB/day
    - Need timely data processing, data storage
    - Throw away raw data, only keep built cosmic ray events?
  - Soft tracks?
- **Cassette test stand**
  - All finished cassettes will be put into a hanging structure for continuous test
  - Expect to run in self-trigger mode, utilize same event building/analysis
  - Qinj runs from time to time to test readout system

Cassettes

Purpose

Protect RPCs, cool front-end ASICs, compress RPCs/FE boards

Design



2 x 2mm copper sheets + cooling tube on top
Will fit into CALICE Analog HCAL structure
Uses nylon strings to compress the two copper sheets

Prototypes

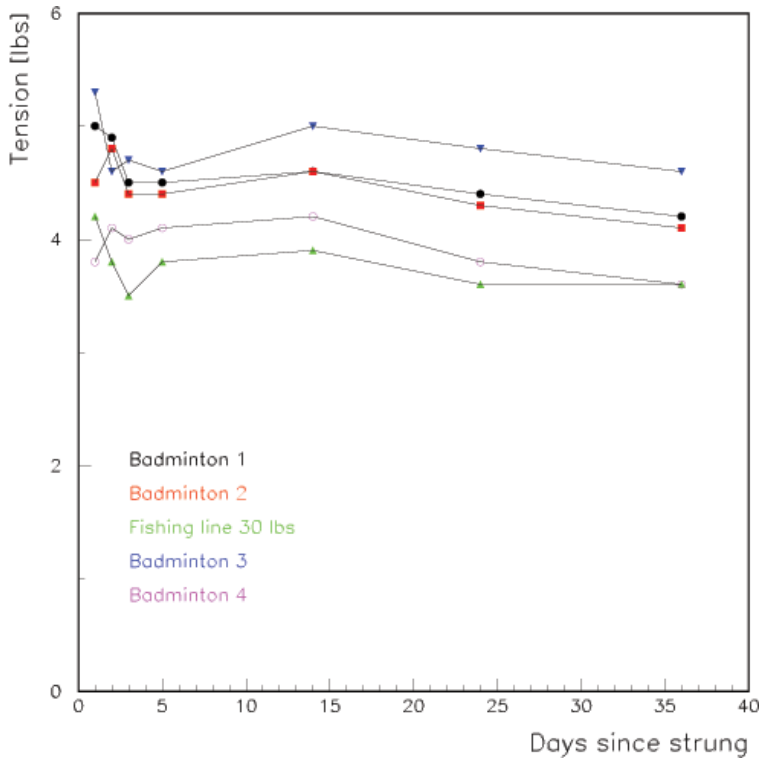
First one built with all final dimensions
Tested out with 3 RPCs and 6 FE boards
Assembled again with 3 RPCs and 6 mock-up boards
Tested in the CALICE Analog HCAL absorber structure

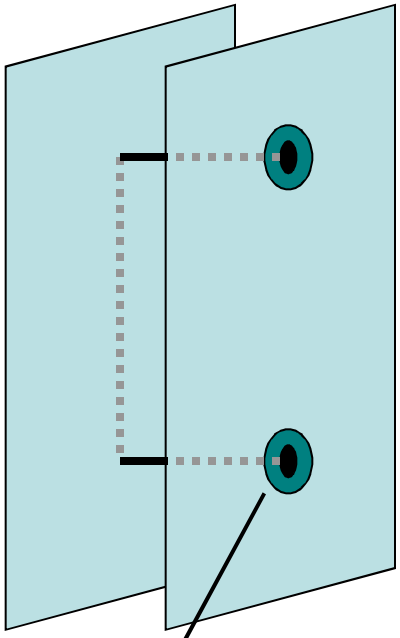
Assembly

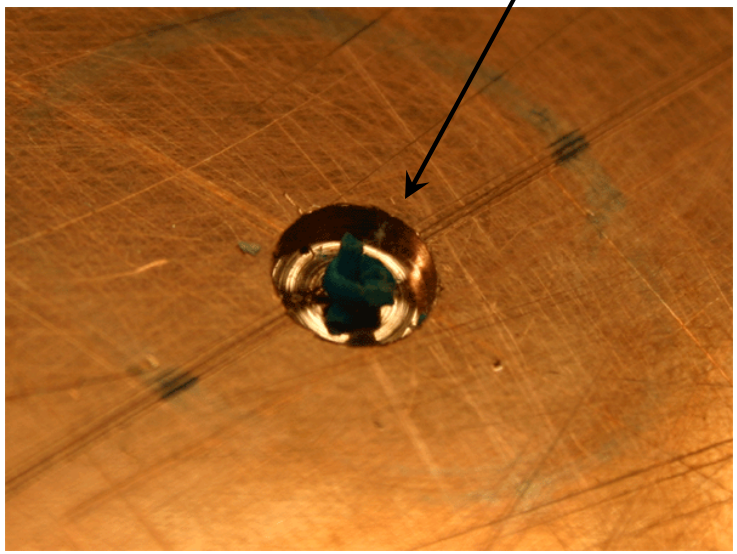
Not expected to be labor-intensive

Cassette design: press two plates together

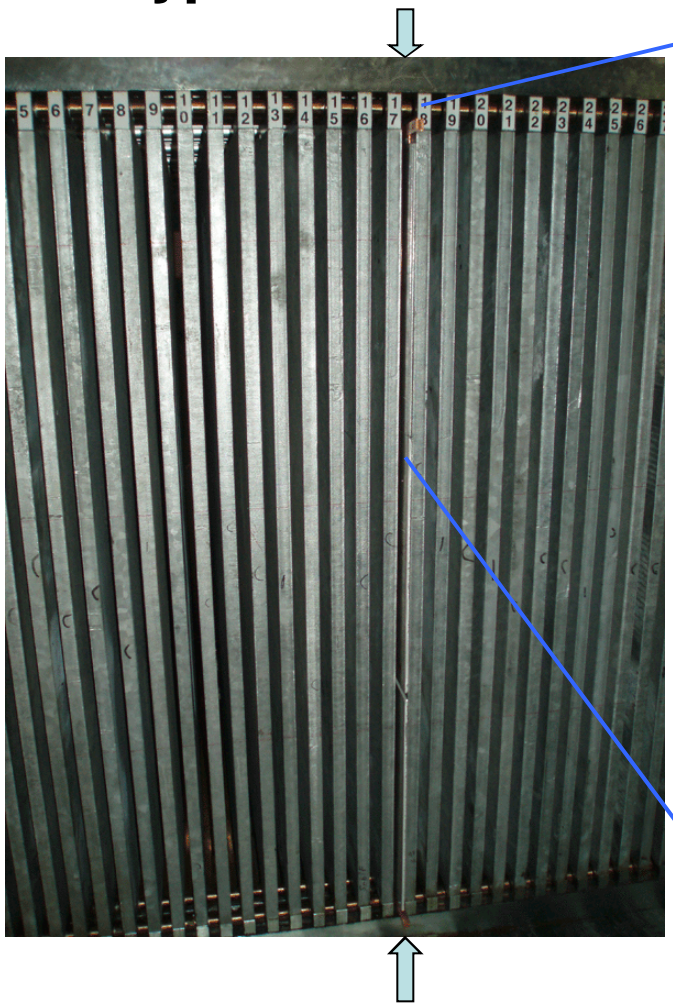
- It is important to keep positive pressure on the two metal plates of the cassette
  - Ensure good thermal contact with ASIC's
  - Ensure good contact between RPC and pad board
- Solution: use pre-tensioned nylon string
  - String go between the RPC's
- Tested several string candidates
  - Pre-tensioned to ~4 – 5 pounds
  - No significant drop over ~ 30 days





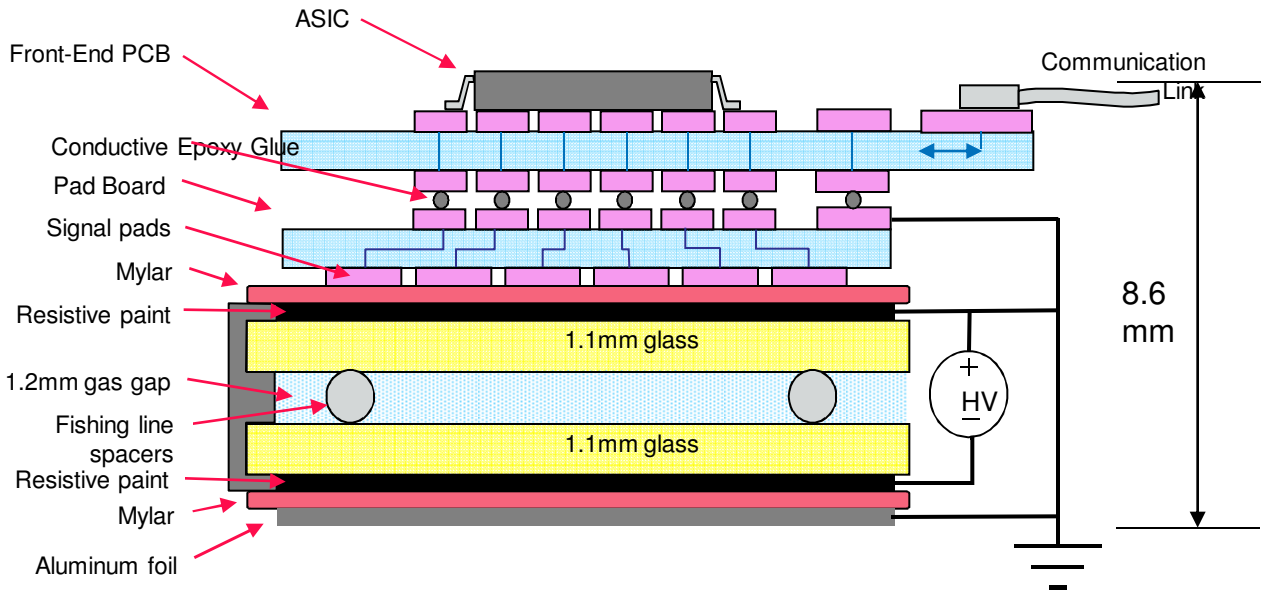


Prototype cassette tested in CALICE stack



Cassette fits perfectly into CALICE absorber stack
No damage during ANL → Fermilab → ANL transportation

FrontEnd/DCON board + Pad board

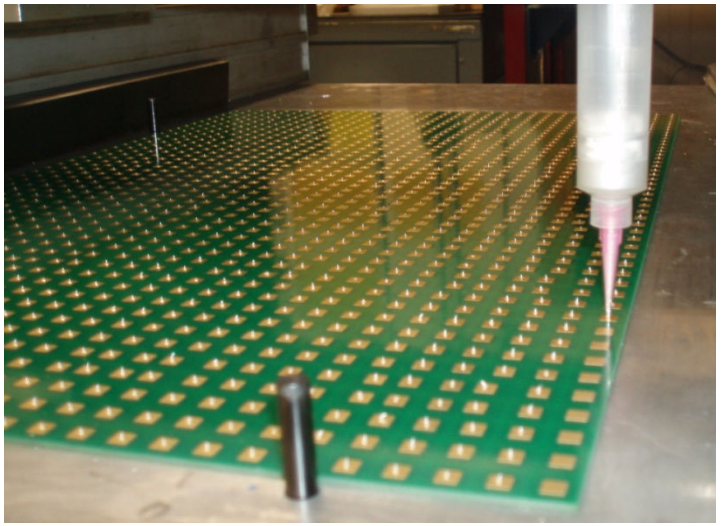


- Build FE and pad boards separately to avoid blind and buried vias (cost and feasibility issue)
- Glue the two boards together with conductive epoxy

- Tried out in VST: all glued by hand (~10 boards)
  - Failing rate < 1%
- Extrapolation to 1m3 not trivial
  - VST: 256 glue dots/board → 1m3: 1536 glue dots/board

Gluing fixture for Pad- and FE-boards

Initial Goal:1536 glue dots in less than 3 hours



Fixture

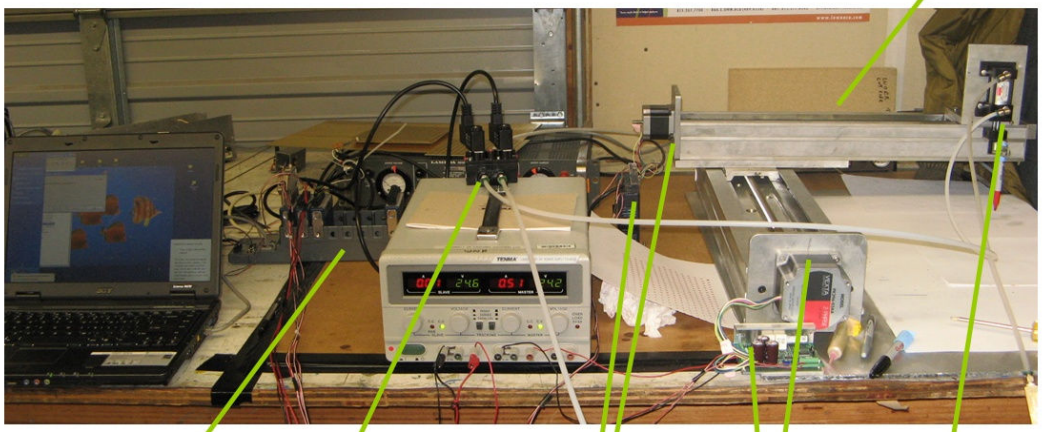
Designed, built and commissioned

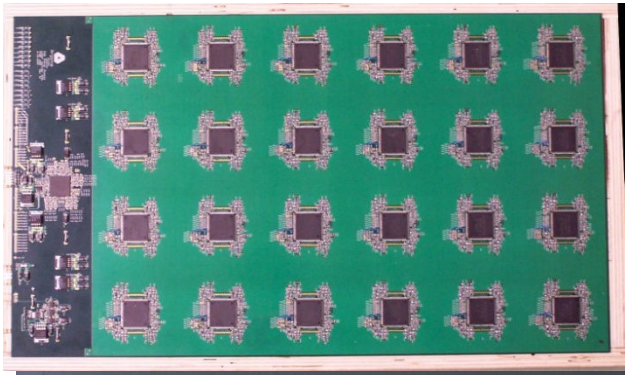
Practice

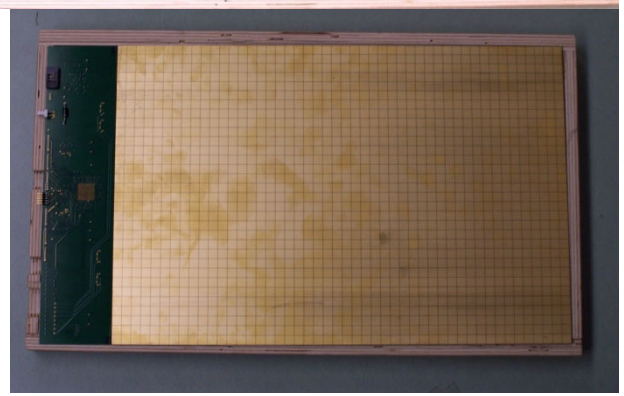
Glued 8 full size boards successfully

Production

~55 minutes/board
can glue 6 - 8 boards/day







Peripherals

Gas

Mixing rack – done
Distributing rack – almost done
- Recently decided not to expand old rack
- Parts for a new rack (partially) arrived
- New rack assembly in progress

Low Voltage

7 Wiener power supplies in hand
1st distribution box built and in use
being torture tested at full load (8 FE boards)

High Voltage

Units in hand
Computer control programs commissioned

Summary

RPC construction is progressing well
- Issues mostly resolved, production in full speed
- Quality assurance in place

Cosmic ray test stand ready for RPC/electronic tests
- Still working on self-trigger running (event building/analysis)

Cassette design proven, production start soon

FE/pad boards gluing ready and tested

HV, LV, gas systems are mostly ready

Physics prototype construction status

Task	Status	Comment
RPC construction	30% done	Much more tedious than anticipated
Cassette construction	Design complete 1st prototype assembled Material on order	Costly, but not very labor intensive
Front-end electronics	Prototypes fully debugged Boards in fabrication	Pursued a very conservative approach
Back-end electronics	DCOL 100% done New TTM in fabrication	
Low voltage	Power supplies in hand 1st distribution box assembled and tested Parts for all units on order	
High voltage	Units in hand Computer controlled program completed	
Gas system	Gas mixer completed and tested Decision to built 2nd distribution rack Parts on order	
DAQ software	Implemented into CALICE framework 99% complete	
Event builder and display	Event building started Event display complete	
Data analysis	Started to reconstruct tracks in CR data	Lots of experience from VST
Simulation	RPC response simulated Implementation of DHCAL into MOKKA ongoing	

Gary's talk

Jacob's talk

Physics prototype plans

Task	Dates	Comments
Construction	Complete by June 30th	Should not slip much more…
Cosmic ray testing of cubic meter	April through August	
Installation into Mtest	Early September	
1st data taking period	September - October	DHCAL standalone (with TCMT)
2nd data taking period	December	Combined with ECAL
3rd data taking period	Early in 2011	DHCAL standalone or combined
Disassembly and shipping of stage	March 2011	Hard deadline