Gas DHCAL R&D

May 31, 2007

WWS CAL R&D Review, DESY

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For CALICE DHCAL Groups

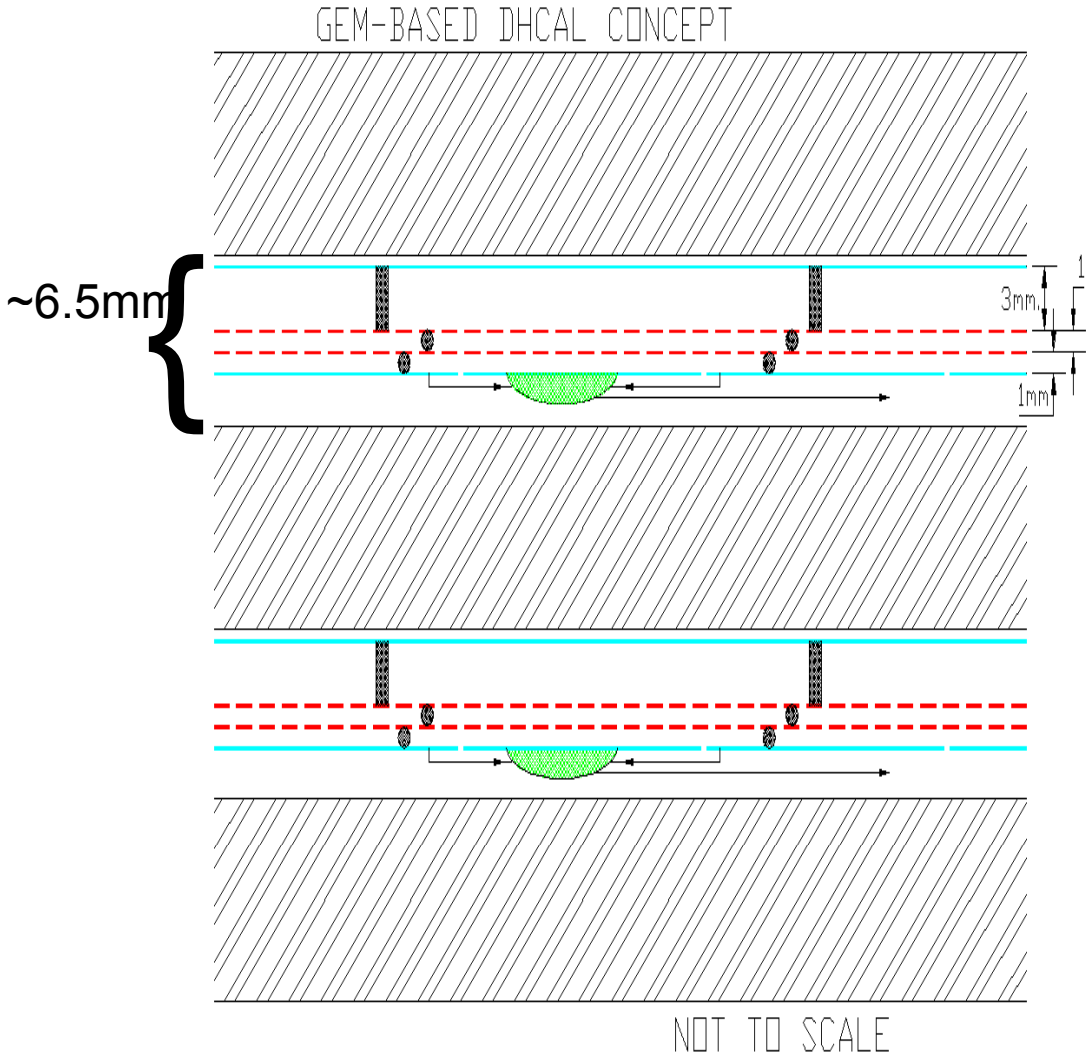
- Introduction
- Active Medium Technology R&D
- Electronics Development
- Putting all these together
  - Vertical Slice Test
  - Cubic Meter 40 layer Prototype Stack Beam Test
- Going beyond the physics prototype
- Schedule and plans
- Summary

What is DHCAL and Why?

- Particle Flow Algorithm perceived as a solution to accomplish good jet energy resolution necessary for ILC physics
- For optimized performance of PFA, minimizing confusion key
- Highly granular calorimeter necessary for such an optimization
  - 1cmx1cm laterally
  - Read out every layer longitudinally
- High granularity allows one bit readout ➔ reduction of costs in readout electronics
- Gas detectors allow such fine granularity

Basic Concepts

- Layer of gas detector sandwiched by absorber plates
- Embedded on-board digital electronics for rapid amplification
- Maintain active gap small to prevent excessive lateral shower spread

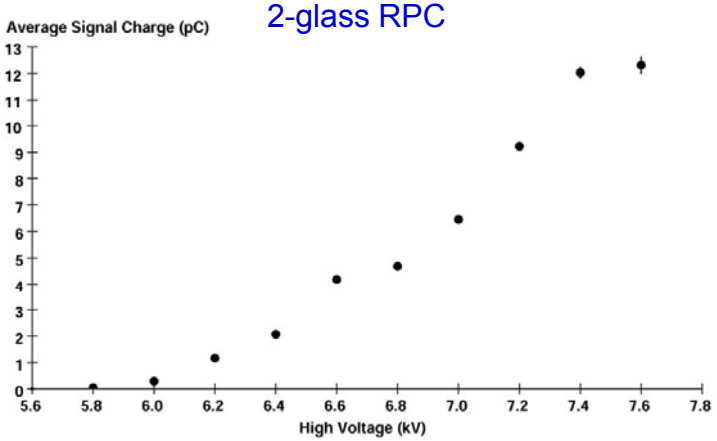


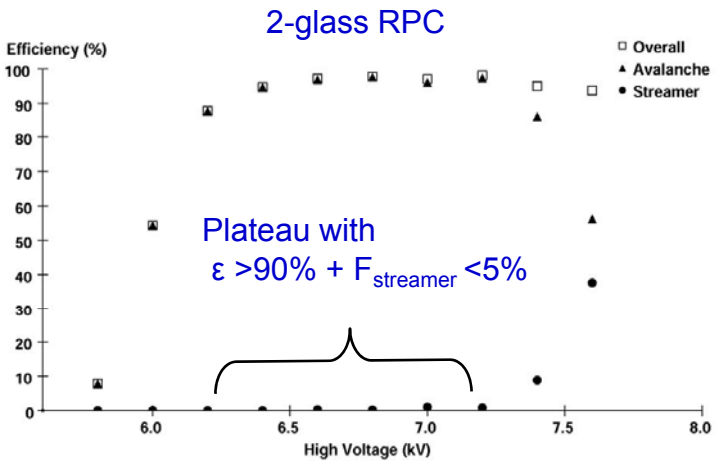
Active Media Technologies

- Resistive Plate Chambers (RPC): ANL and Protvino
  - Low cost and simple construction
  - Behaviors well understood
  - Rate limited by the recovery time (a few 100Hz)
- Gas Electron Multiplier (GEM): UTA
  - Low operation HV
  - Relatively new technology and characterization in progress
  - Short recovery time ➔ can handle high rate
  - Large area coverage ➔ GEM foil cost must be reduced
- Micromegas: LAPP, IPNL
  - R&D effort just begun
  - Similar to GEM
  - Cost relatively low

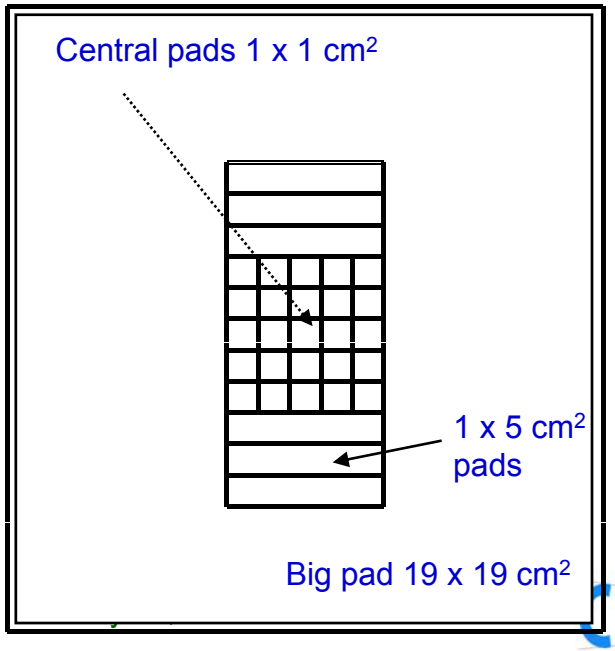
RPC Characterization Study Results

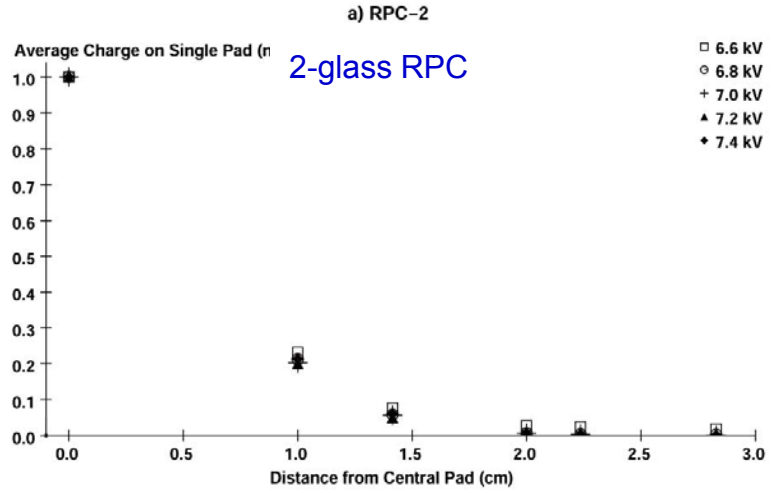
…some results with single readout pad of 16 x 16 cm^2





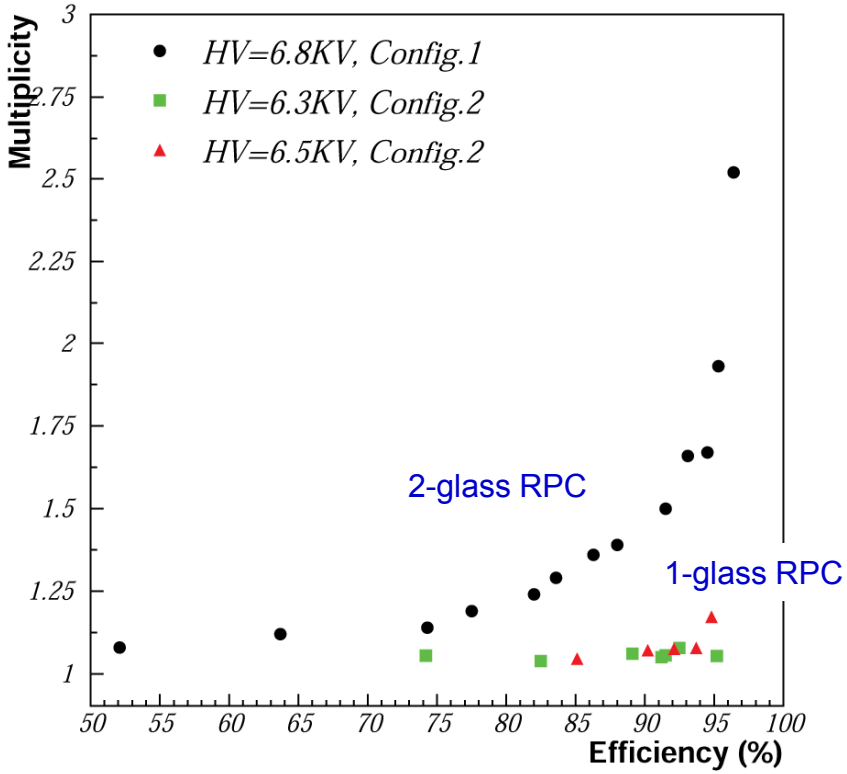
…some results with multiple readout pads of 1 x 1 cm^2





G. Drake *et al*., NIM A, 2007.04.160

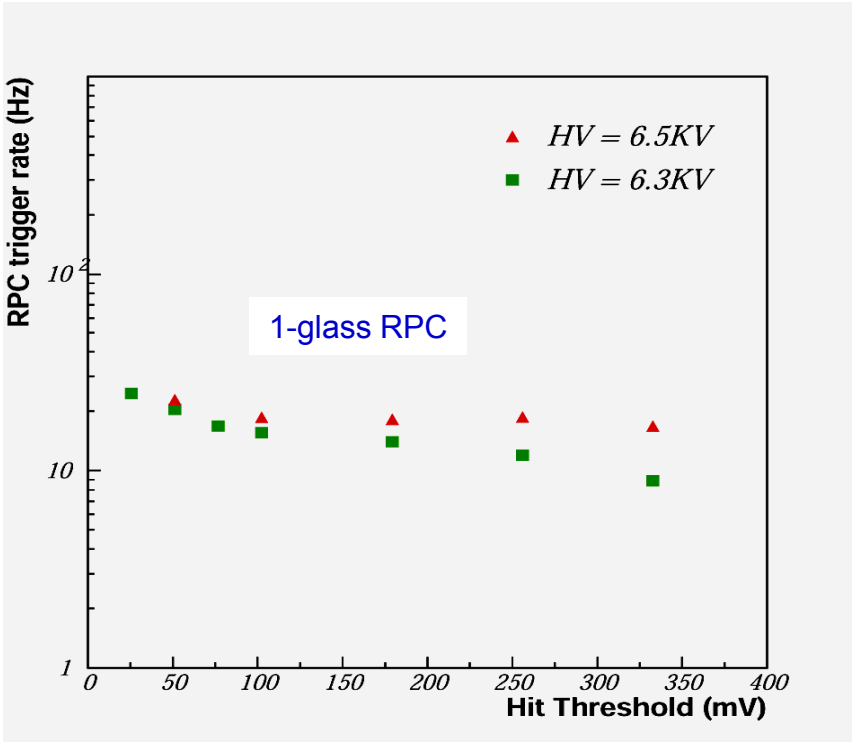
RPC Characterization Study Results, cnt'd



Pad multiplicity much reduced with 1-glass RPC

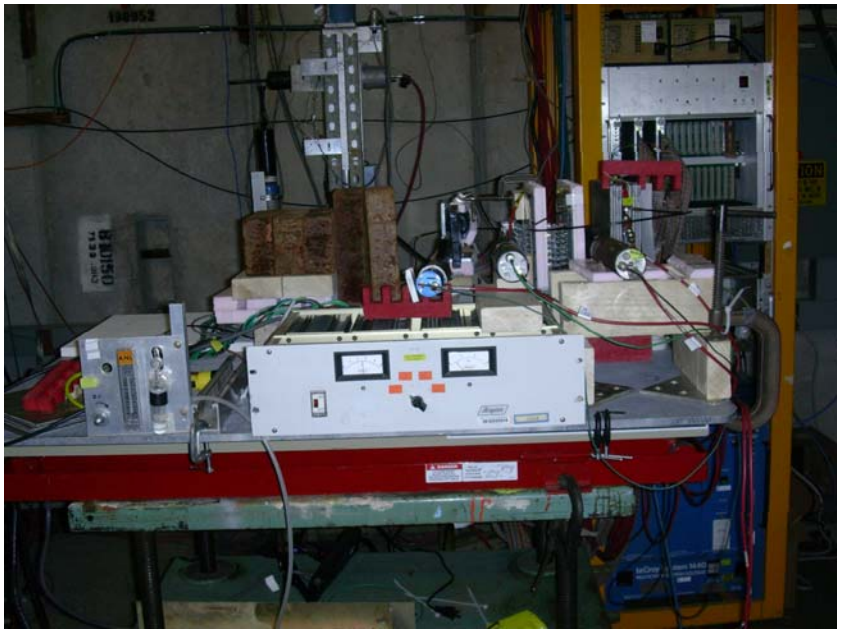
For ε ~ 70 ÷ 95% → M ~ 1.1

(this result recently confirmed by the Protvino group)



Long-term stability of 1glass RPC to be proven`

C) RPC Test beam @ FNAL



Tests included 3 chambers

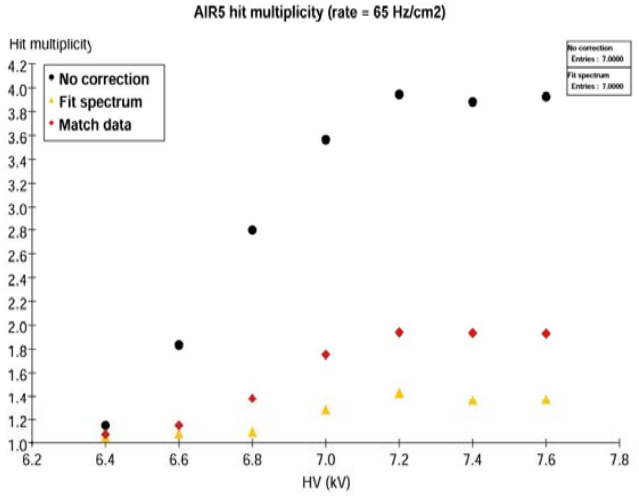
2-glass RPC with digital readout
1-glass RPC with digital readout
(2-glass RPC with independent digital readout)

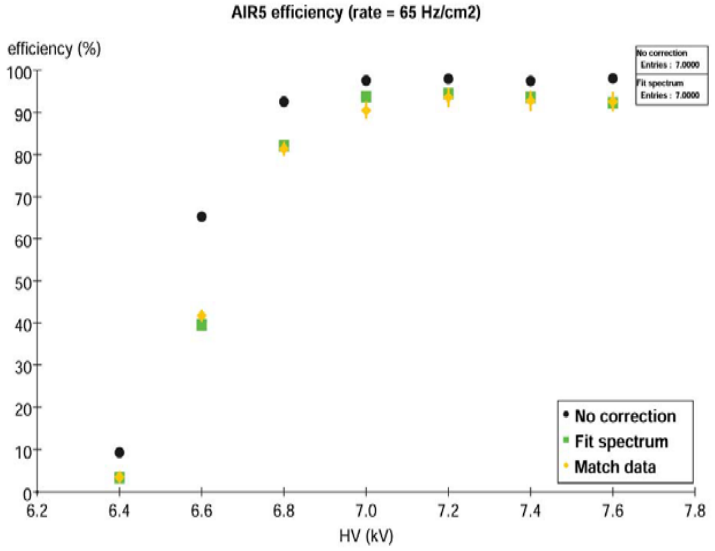
Tests took place in February 2006

Mostly ran with 120 GeV protons

Problem

Only realized later that trigger counter off beam axis
Triggered mostly on events which showered upstream
→ High multiplicity in the chambers





Great learning experience !!!!

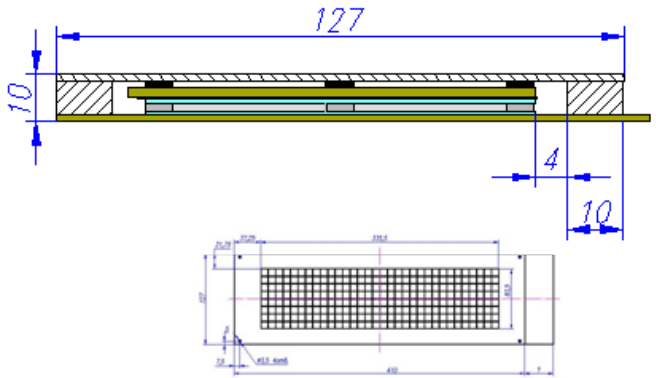
Results (after corrections) confirmed previous measurements with cosmic rays

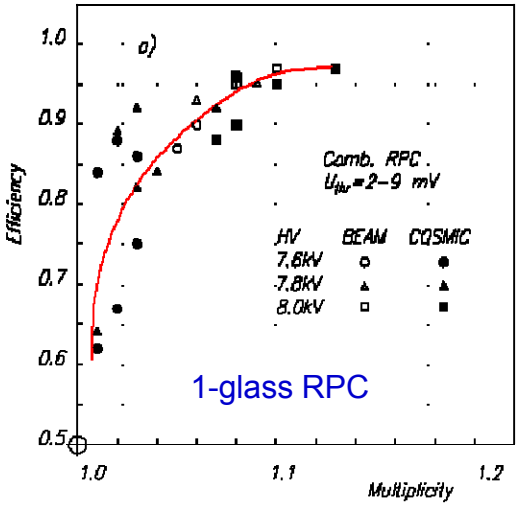
D) RPC construction and testing (Protvino)

Measurements with 1-glass plate chambers
- Pad multiplicity ~1.1 for an efficiency of 95%
- Confirms results obtained at ANL
- Long term tests ongoing

Constructed 4 chambers with 8x32 pads
- One sent to Lyon for testing
- Others waiting for MAROC chip + FE-board
- Successfully tested with strip readout

Preparation for 1 m² chamber construction
- Preparation of facility
- Cosmic ray test stand being assembled
- Design being finalized





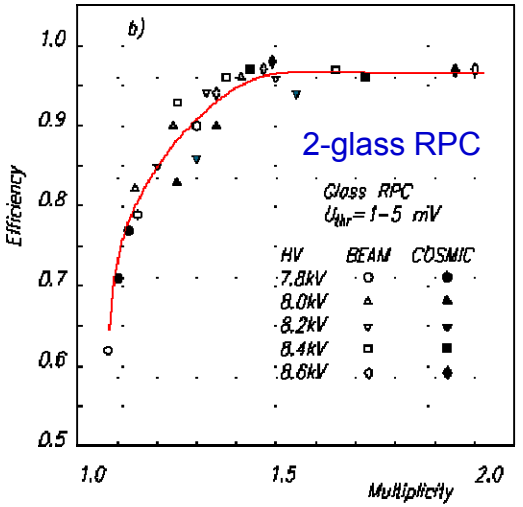


Fig. 7

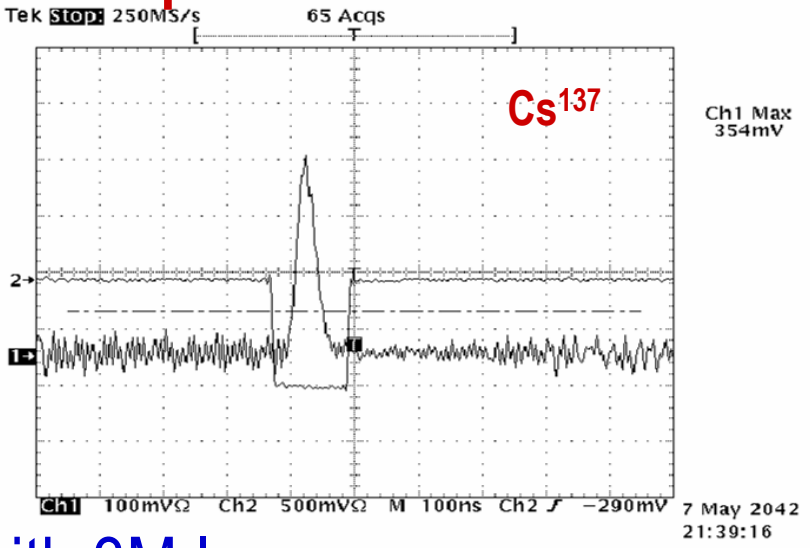
Summary of R&D with RPCs

Measurement	RPC Russia	RPC US
Signal characterization	yes	yes
HV dependence	yes	yes
Single pad efficiencies	yes	yes
Geometrical efficiency	yes	yes
Tests with different gases	yes	yes
Mechanical properties	?	yes
Multi-pad efficiencies	yes	yes
Hit multiplicities	yes	yes
Noise rates	yes	yes
Rate capability	yes	yes
Tests in 5 T field	yes	no
Tests in particle beams	yes	yes
Long term tests	ongoing	ongoing
Design of larger chamber	ongoing	ongoing

Many R&D topics completed

GEM DHCAL Development

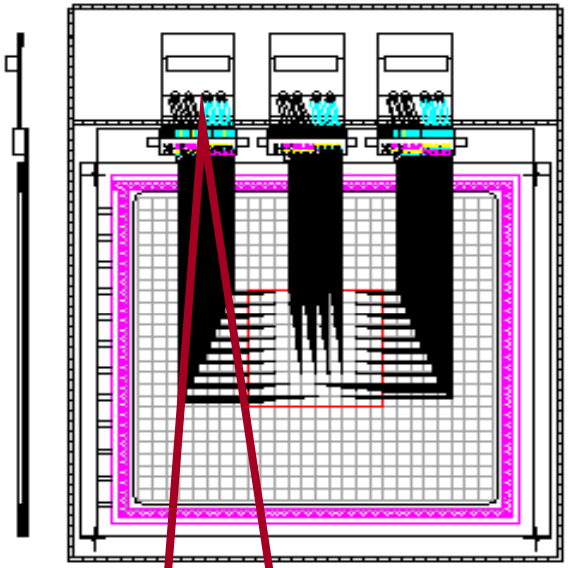
- Constructed prototype chamber w/ 10cmx10cm CERN GEM foil
  - Understood basic signal shape and behaviors of GEM foil chambers
  - Understood issues related to constructing chambers

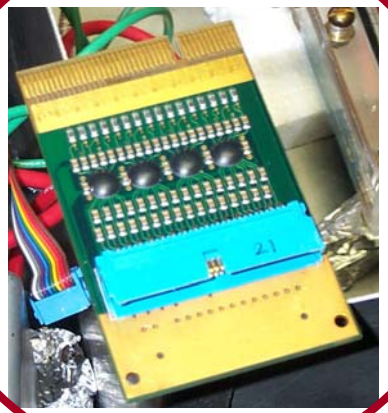


- Developed 30cmx30cm GEM foils with 3M Inc.
  - Foils HV tested and certified
  - Jigs made to mount foils, stack chamber.
  - Multilayer 30cmx30cm anode board made to work w/ Fermilab QPA02-based preamp cards
  - Continually operated, verifying operational stability
- Constructed and beam tested several chambers using these 30cmx30cm foils for beam tests for characterization

30cm x 30cm 3M GEM foils

12 HV sectors on one side of each foil.





HV Sector Boundary

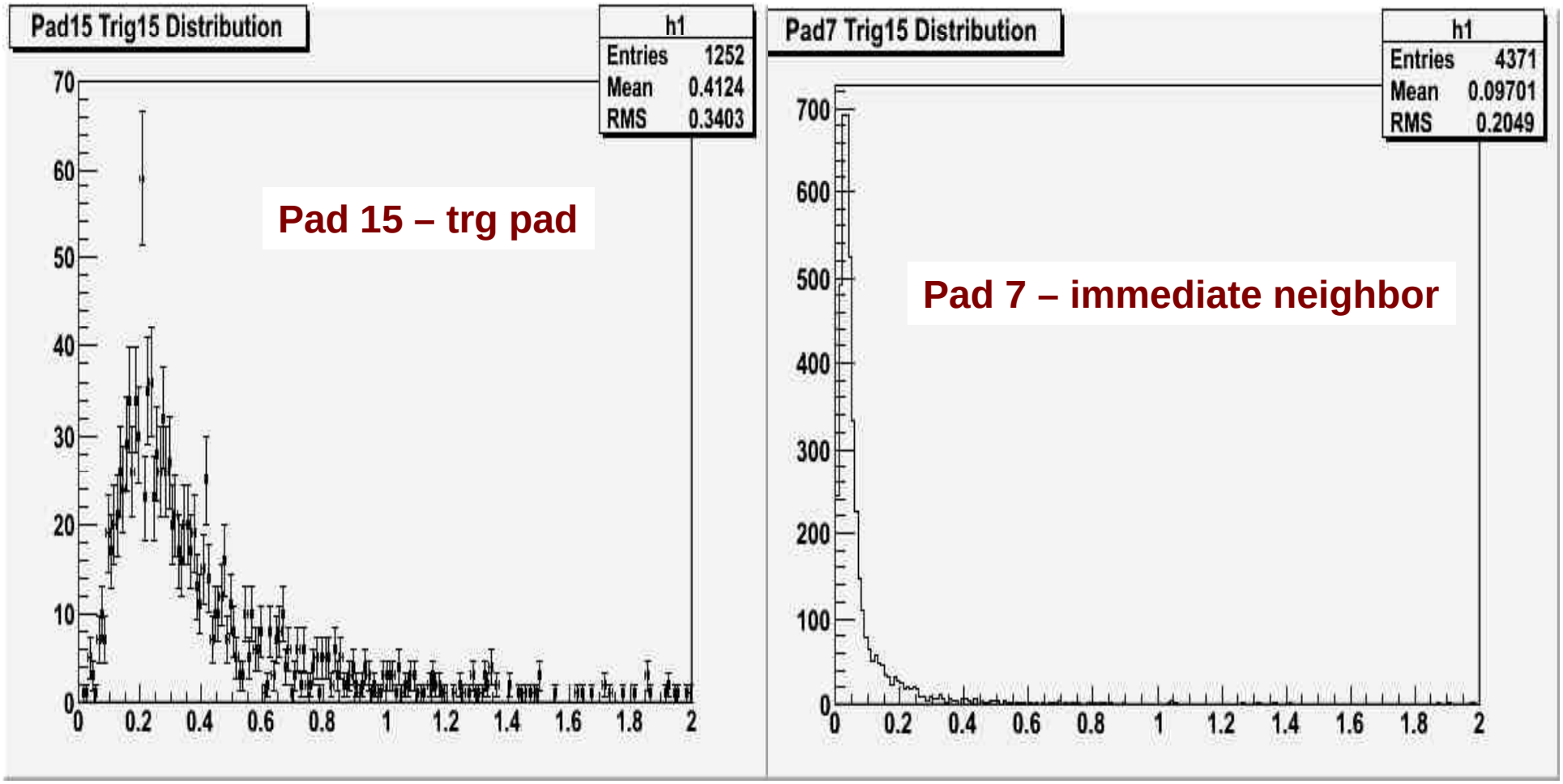
Preamps configured to read 96 pads in the center

Use 32 channel FNAL preamps

GEM Beam Tests

- KAERI in May 2006
  - Exposed a 30cmx30cm chamber to high flux, low energy electron beams
  - Exposure dosage equivalent to about 10 years of ILC running
  - No issues with the chamber operation found
- FNAL-MTBF in Spring 2007
  - Chamber characterization runs
  - 8 GeV mixed beam and 120 GeV protons
  - Data analysis in progress

120GeV Proton – Triggered pad & Neighbor, X-Talk measurement



Some GEM Results

- At the bench test using Sr90 source
  - W/ 40mV threshold ➔ 95% MiP efficiency observed
    - Consistent with our simulation study
  - Multiplicity: ~ 1.27
- From the beam test, the initial measurement of efficiency on 1cmx1cm pad
  - ~90% on the center 1cmx1cm pad when beam is well constrained on the pad
    - Corrections for multi particle events in the 200ns trigger gate needed
  - Initial measurement of the cross talk rates
    - In the two neighboring pads ➔ <25% but need to clean up results
  - Initial studies on double proton events show about 20% double proton events
  - Initial noise rate measurement : <0.2Hz

Front End DCAL Chip

Design

→ chip specified by Argonne
→ designed by FNAL

2nd version

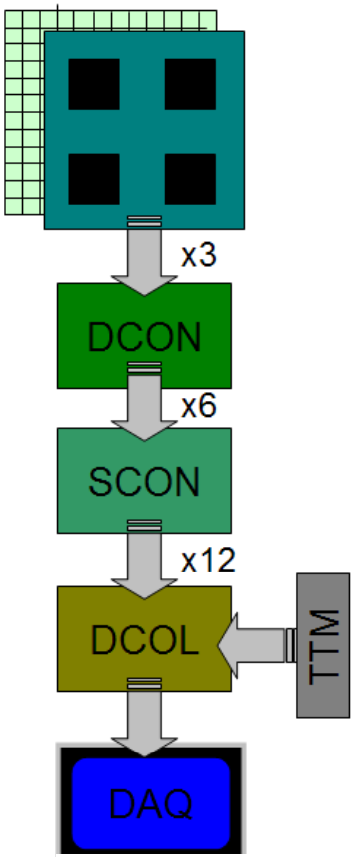
→ prototyped (40 chips in hand)
→ extensively tested at Argonne
→ tests complete
→ ordered 25 + 40 ad

Reads 64 channels
Has 1 adjustable threshold
Switchable gain for RPC and GEM
Provides
Hit patte
Ti)
de

Tremendous amount of effort!!
More details in the next talk!!

The DHCAL DAQ System

Vertical Slice Test : 12 layers of 256 channel each ➔ ~3000 channels
Prototype section: 40 layers of 1 m^2 → 400,000 readout channels



Front-end ASIC

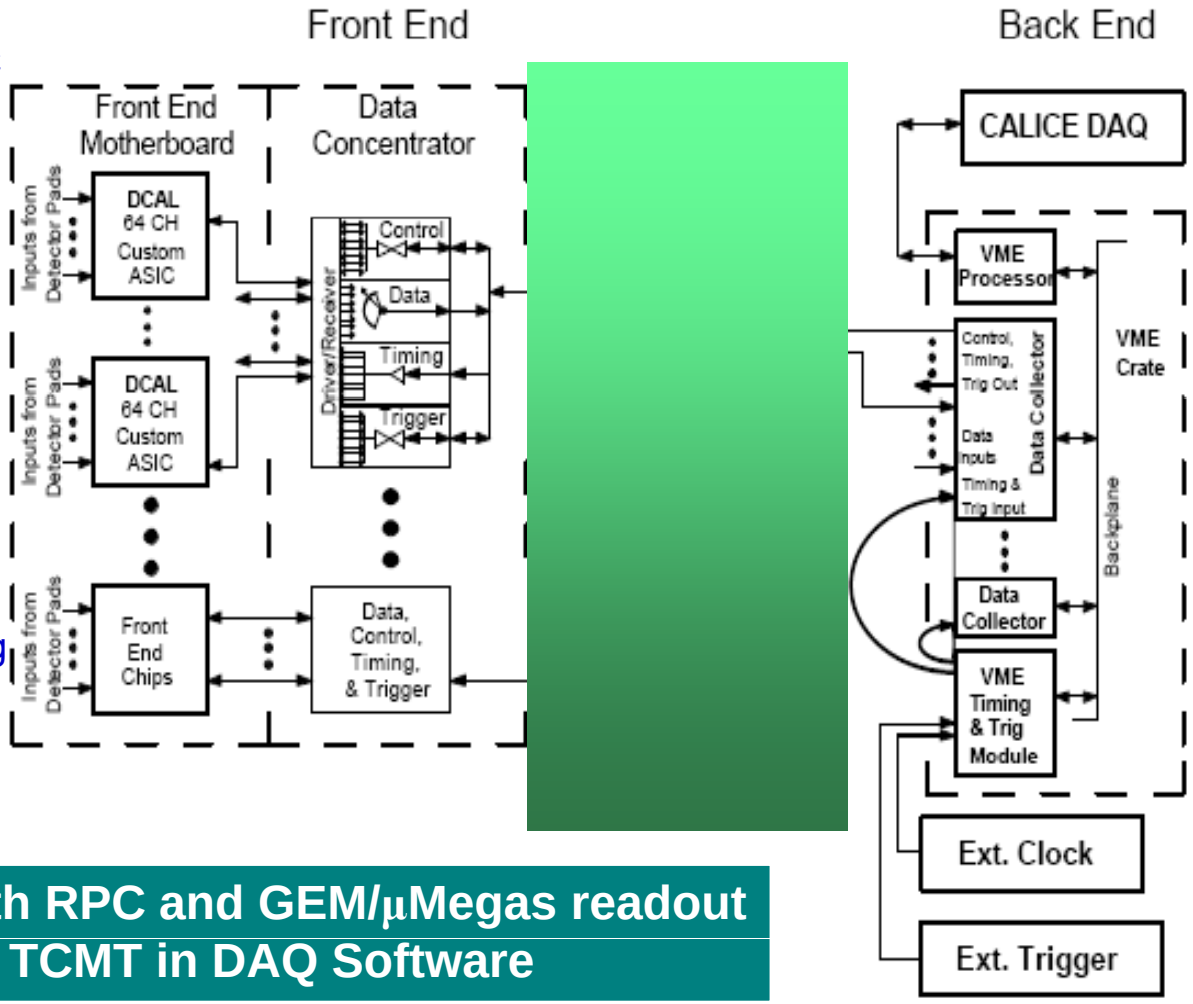
Pad and FEB

Data concentrator

Super Concentrator

VME data collection

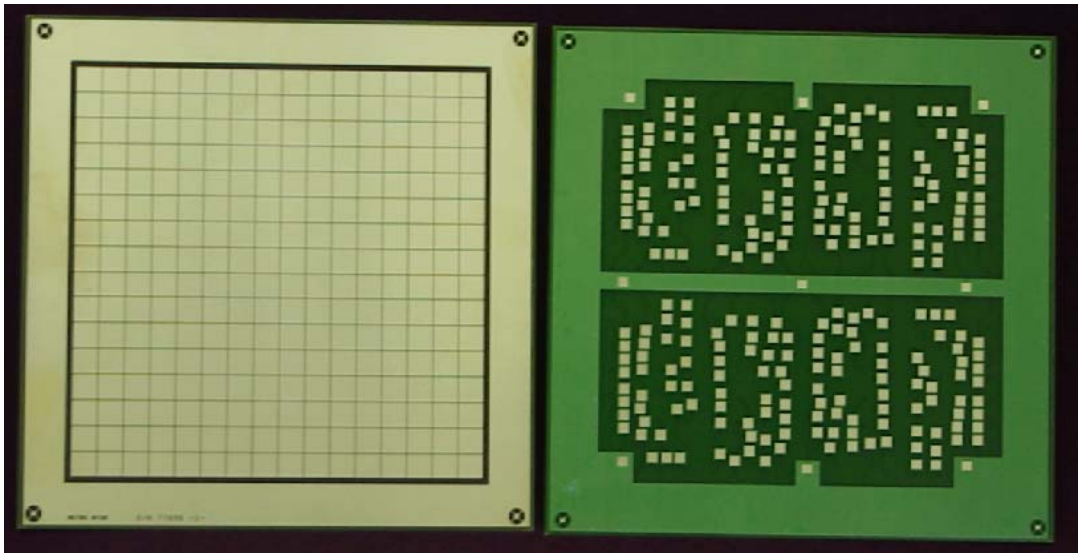
Trigger & timing system



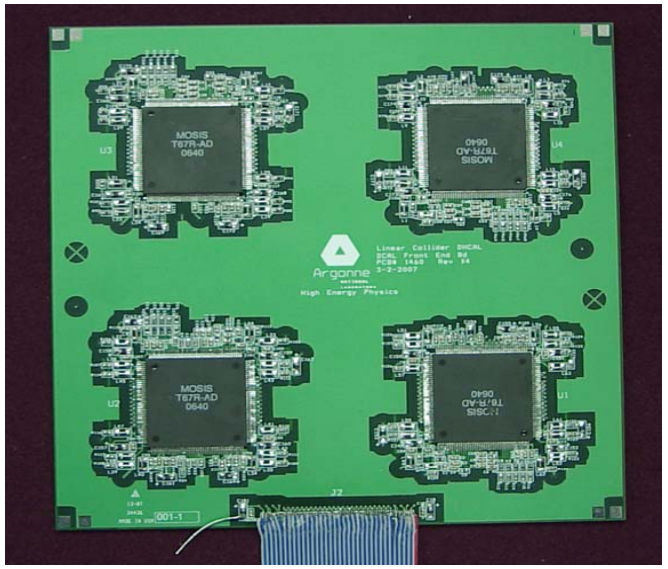
System designed for both RPC and GEM/μMegas readout
Integration w/ ECAL and TCMT in DAQ Software

Pad- and Front-end Boards

4-layer Pad-board VST – 20 x 20 cm^2
PS – 32 x 48 cm^2



16 x 16 cm^2 8-layer FEB



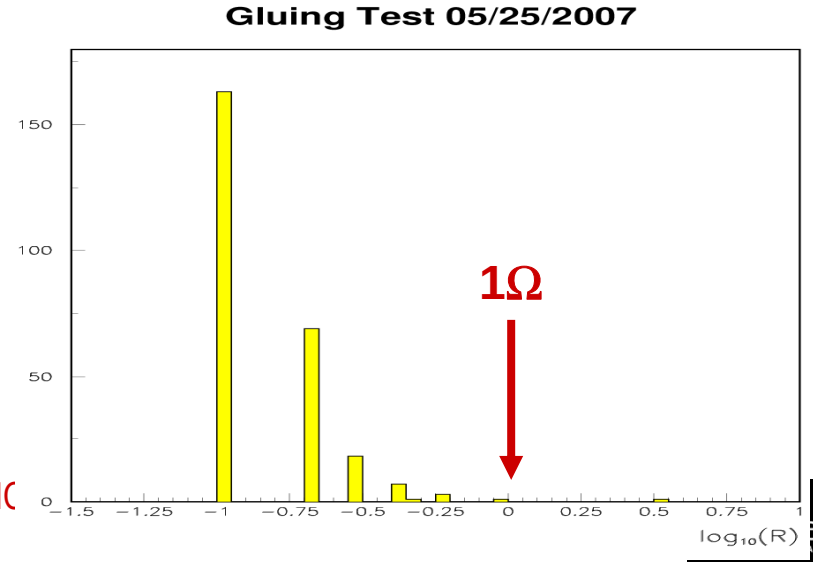
Glue Test Results

Resistance < 1 Ω

Glue dots small (<3 mm Ø) and regular

Edges lift off → additional non-conductive epoxy

2.5 Assembled as of today

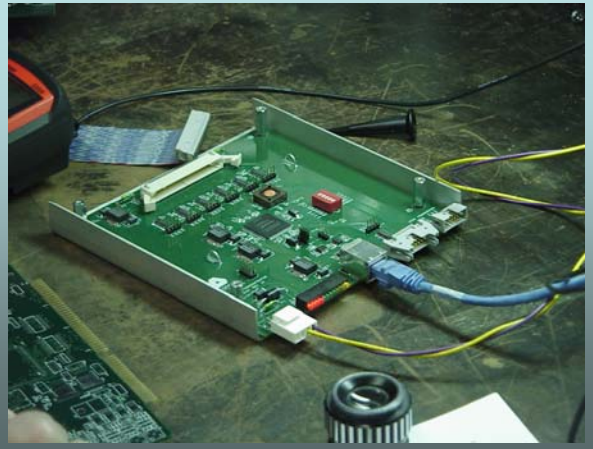


May 31, 2007

FE and BE DAQ Components

Data Concentrator

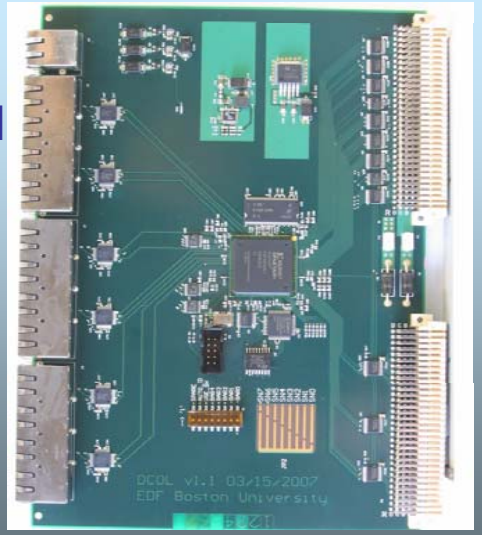
Reads 4/12 DCAL Chips
Sends data to DCOL/SDC



Design completed
Boards fabricated & tested

Data Collector

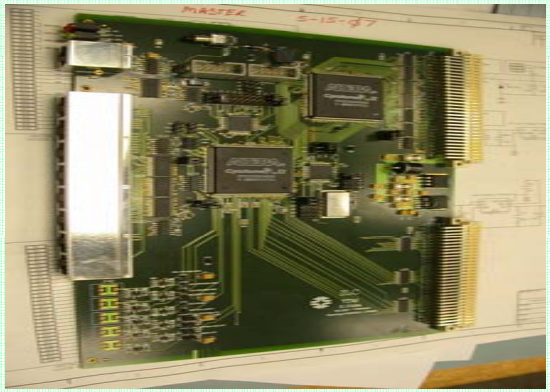
Reads packets of timestamps, addresses and hit patterns
Groups packets in buffers with matching timestamps
Makes buffers available for VME transfer



Design completed
Boards fabricated & tested

Timing and trigger module

Clock and Trg to DCOL boards
Need 1 module for VST/PS

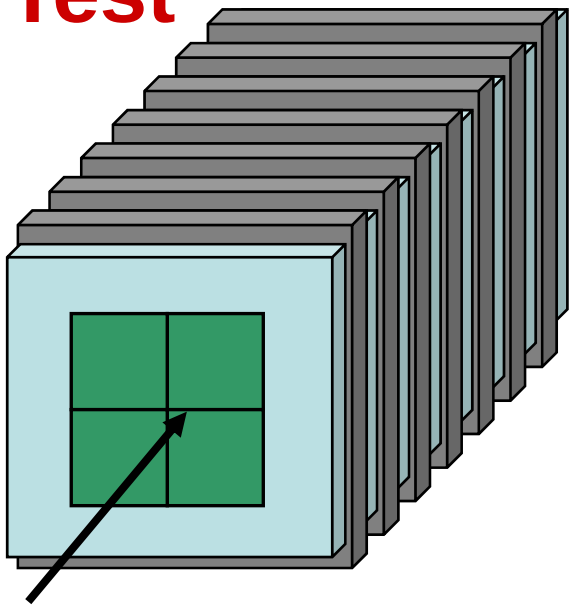


Design completed
Boards fabricated & tested

Summary of DAQ Components

Subcomponent	Vertical Slice Test		Same?	Prototype Section	
	Inputs → Outputs	Units needed		Inputs → Outputs	Units needed
Pad boards	256 → 256	10	≠	1584 → 1584	240
FE-boards	256 → 256 (analog) → 4 (digital)	10	=	256 → 256 (analog) → 4 (digital)	1440
FE-ASICs	64 → 1	40	=	64 → 1	5760
Data concentrators	4 → 1	10	≠	12→ 1	480
Super concentrators	–	–	≠	6 → 1	80
Data collectors	12 → 1	1	=	12 → 1	7
Trigger and timing module		1	=		1

Putting Together: Vertical Slice Test



Uses the 40 front-end ASICs from the 2nd prototype run

Equip ~10 RPC and 2 GEM chambers with 4 chips each

256 channels/chamber
~3000 channels total

Chambers interleaved with 20 mm copper - steel absorber plates

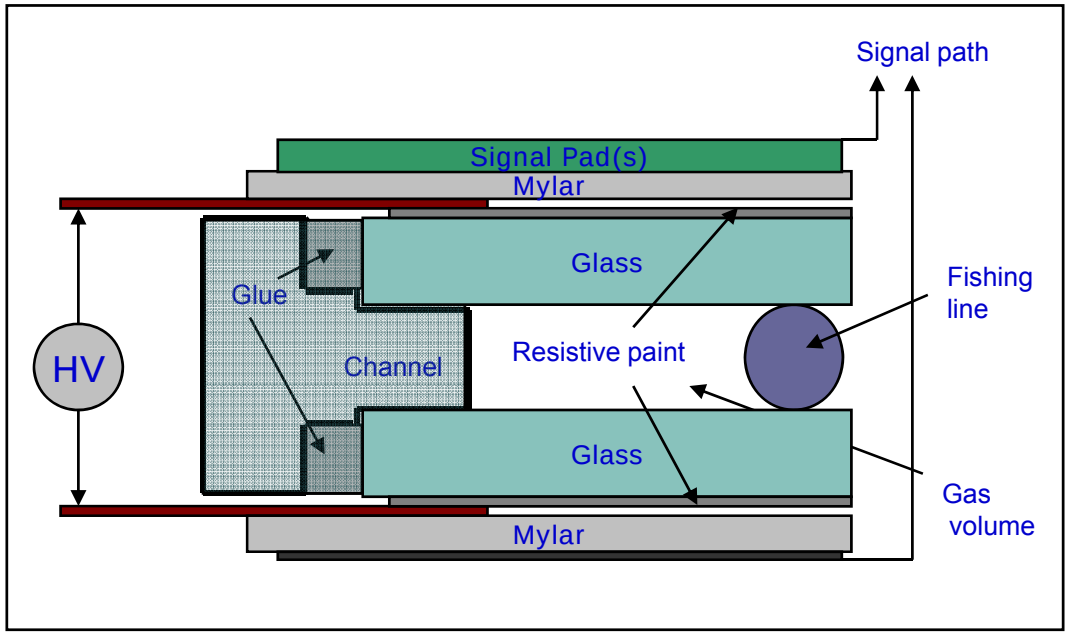
Electronic readout system virtually identical to the one of the prototype section

Tests in FNAL test beam planned for summer 2007 before Aug. 6

→ Measure efficiency, pad multiplicity, rate capability of individual chambers
→ Measure hadronic showers and compare to simulation

Validate RPC/GEM approach to finely segmented calorimetry
Validate concept of electronic readout

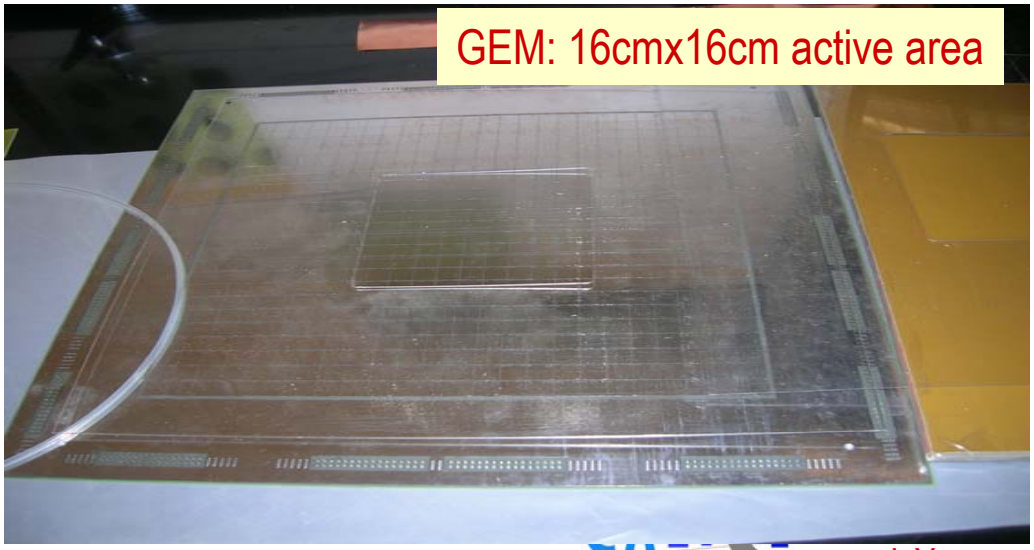
RPC&GEM construction and testing for the VST



RPC

New design with simplified channels

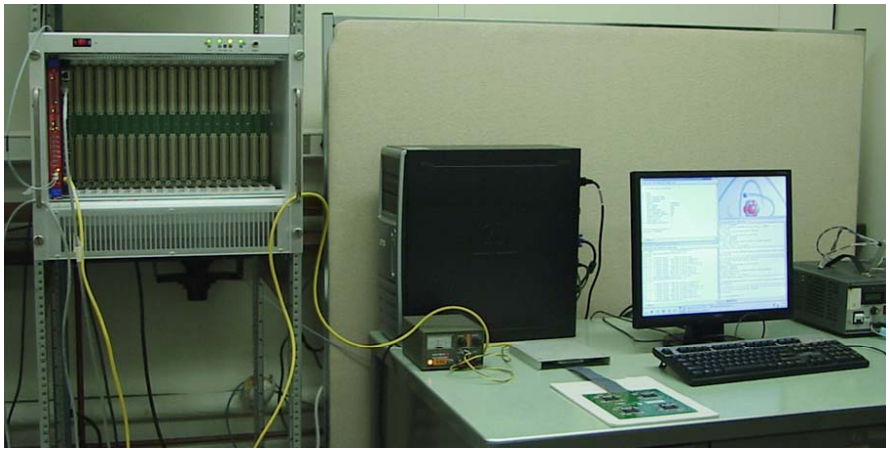
- 1st chamber assembled and tested
  - → Excellent performance
- 2nd chamber assembled and tested
  - → Excellent performance
- 3rd – 6th chambers assembly completed



GEM

- Four sets of 30cmx30cm GEM foils HV tested and certified
  - 2 Chambers with Digital Readout
  - 2 Chambers with Analog readout, taking advantage of available kPix chip
- Delrin frames for all four chambers in hand
- Awaiting for PB+FEB arrivals

Electronics Integration Test and Cosmic Commissioning



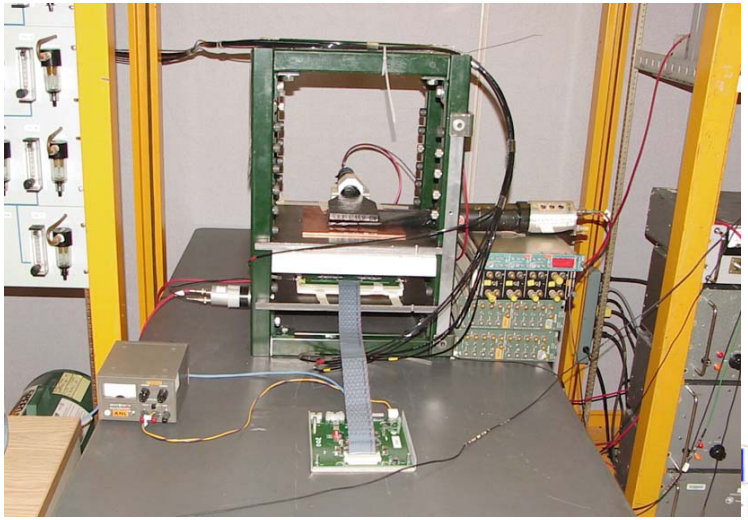
Working in self-triggered mode

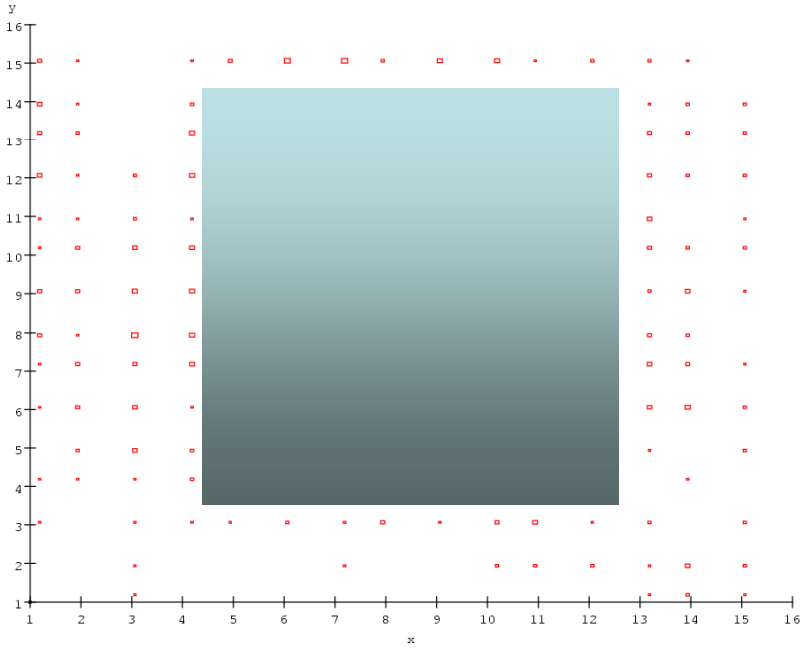
Setting threshold close to noise floor
→ Can control ASICs from DCOL
→ Can write events (time stamp + hit pattern) to disk

First 1,000 cosmic ray Hit distributions

Working in triggered mode with 1 RPC

Data analysis ongoing (→ ε, μ)



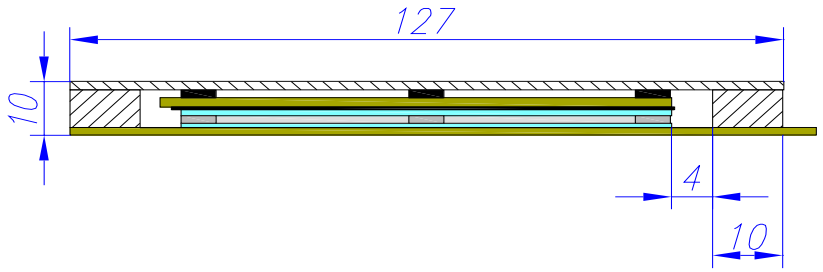


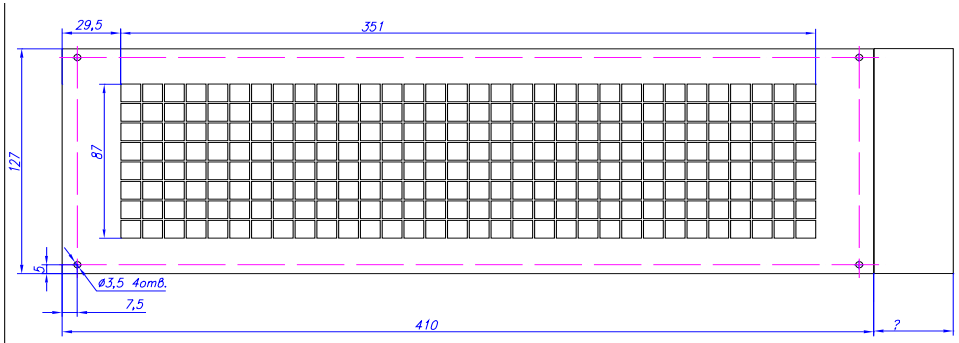
Putting together II: Cubic Meter PS

- Recent funding support allows the start of the construction of 1m^3 prototype stack with forty 1mx1m layers of RPC
  - 1cmx1cm lateral granularity, read out every layer
  - A total of 400k readout channels
  - The entire readout chain will have been tested through VST, except for the super-concentrator
- Will utilize CALICE beam test stack and mechanical support system, replacing AHCAL
- Large area GEM chamber to replace RPC layers as funding becomes available

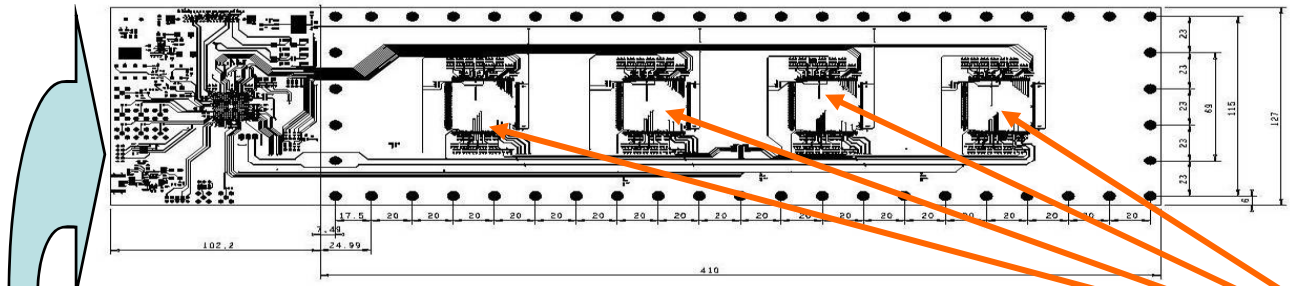
Realization of 8X32 pads detectors fully instrumented to validate the digital HCAL 2nd Gen electronics scheme.

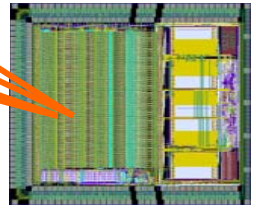
- **8X32 pads detector RPC: already built**





- **8-layers PCB** designed and optimized to reduce x-talk

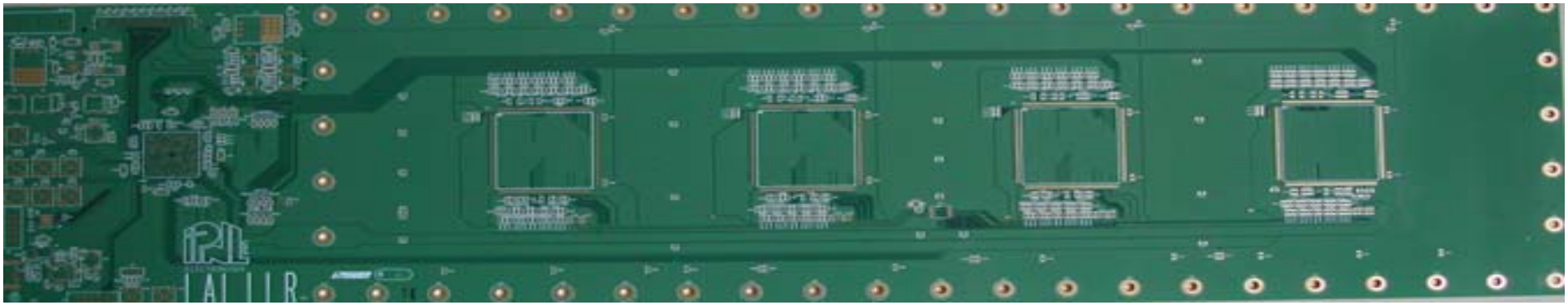


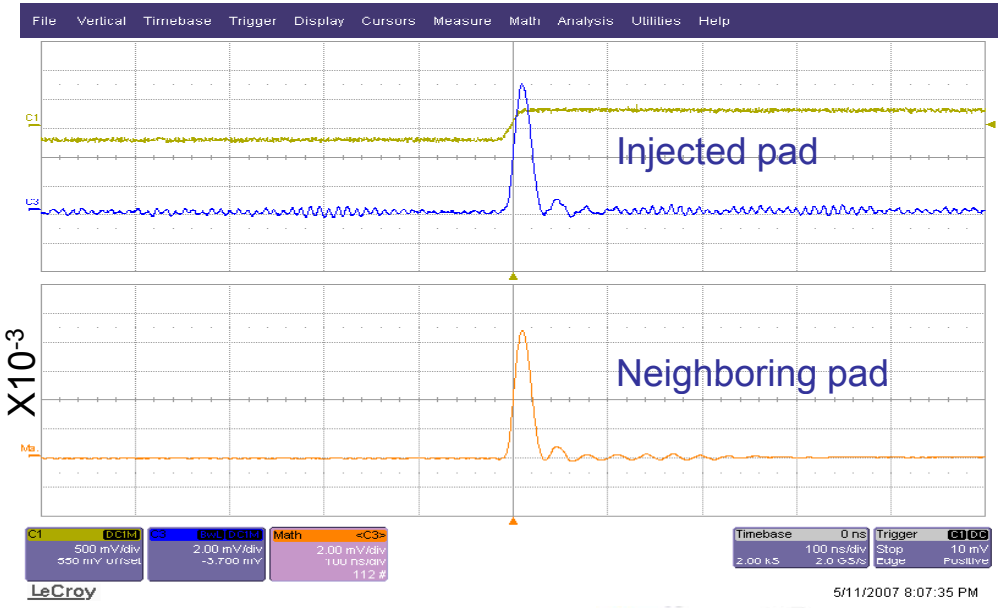


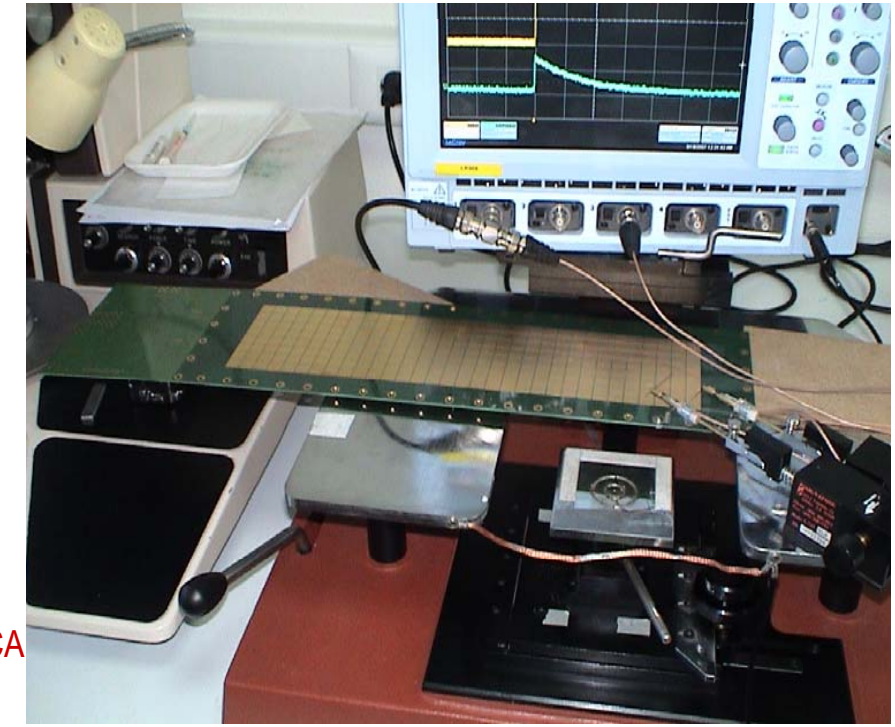
- **4 HARDROC:** already produced and tested
- **Readout** USB + FPGA realized
- Acquisition for both digital and analog outout is going on

CALICE
Calorimeter for ILC

- 800 µ thick 8-layers PCB with blind and buried vias
- 8X32 pads, 1 cm2 surface with 500µ separation between pads







X-talk measurement (<0.3 %)

Beyond the PS: Conceptual RPC BHCAL Prototype

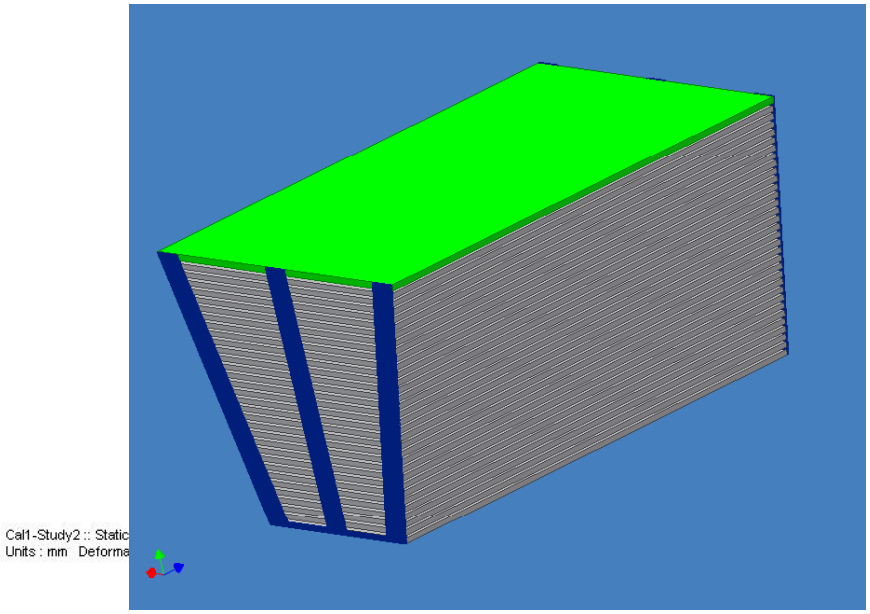
Working on a detailed design

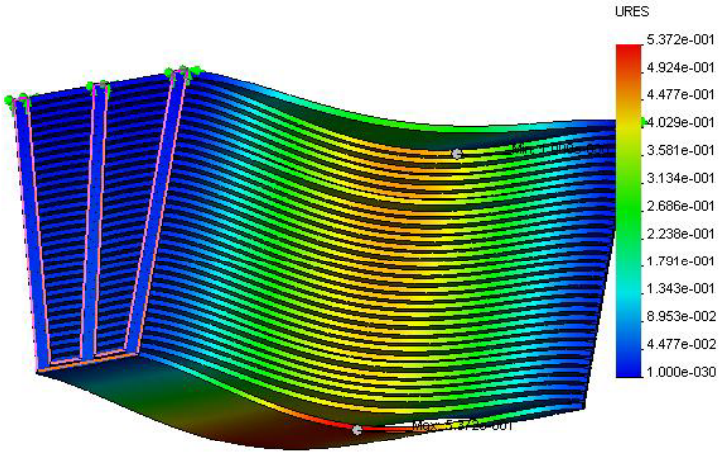
Variable size RPCs (wedge)
Integrated gas distribution system
Integrated HV/LV distribution system
Integrated front-end electronics

Will have to be tested in particle beam

→ Scalable prototype

Still far in the future…





FEA: Deflections <0.53mm

CALICE Calorimeter for ILC

Schedule and Plans

- Late 2007 – Mid 2008
  - Complete 1m^3 prototype RPC
  - Construct large scale GEM unit boards (30cmx1m)
  - Start constructing GEM chambers for 1m^3 prototype if funding allows
  - Test 8X32 fully equipped GRPC/μMEGAS w/ 2nd generation ASICs at DESY
- Mid – late 2008
  - Complete RPC beam exposure for MC validation together with CALICE Si/W and/or Sc/W ECAL
  - Construct a large area (1m^2) fully equipped GRPC/μMEGAS w/ 2nd generation ASICs and test at FNAL
  - Start GEM 1m^3 prototype stack construction
  - Beam test TGEM based prototype as an alternate, cost reducing solution
- Late 2008 – 2009
  - Complete GEM 1m^3 prototype stack
  - Beam exposure of (hopefully) a full 40 layer stack GEM DHCAL
  - Prototype stack w/ 2nd generation ASICs and mechanics

Conclusions

- Gas detectors can provide HCALs with unprecedented granularity
- One bit readout allows cost effective readout of large number of channels
- CALICE DHCAL groups working closely to provide critical information for ILC detectors
- RPC 1m^3 prototype stack to be tested in 2008 at FNAL followed by GEM and/or μMegas
- All DHCAL groups to participate in prototype beam tests and collaborate closely
- Beyond the physics prototype effort is in full steam