

# ILC Calorimetry Test Beam Status

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# ILC Calorimeter R&D overview

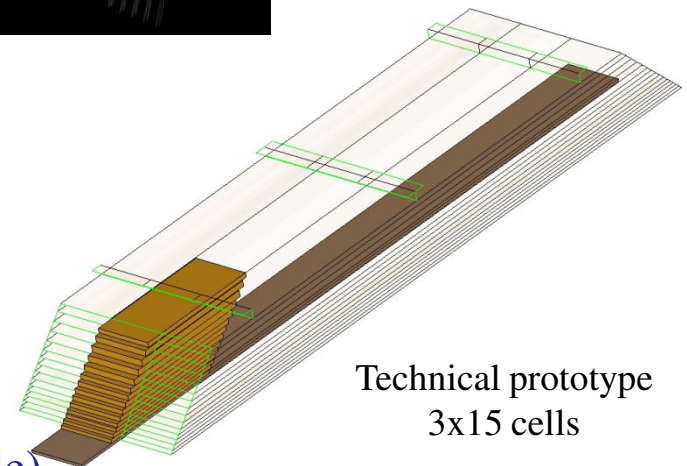
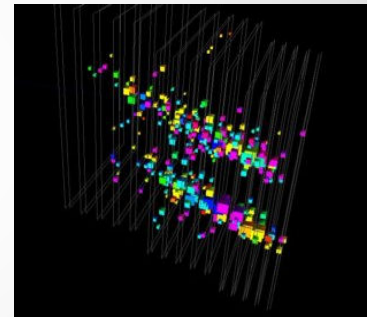
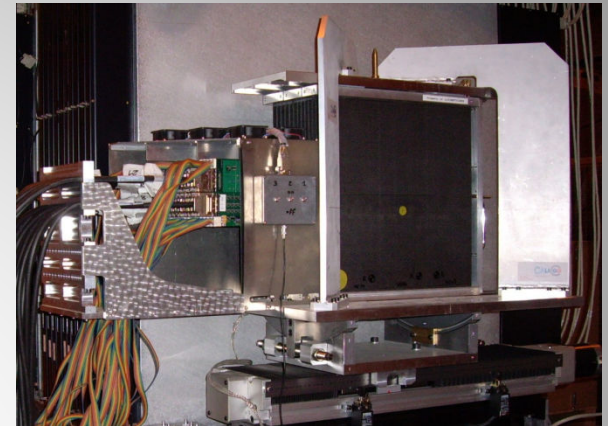
- PFA calorimetry
  - Address very fine granularity needed for PFA jet measurement
  - Develop readout system to handle huge number of channels
  - Develop new sensors
- Dual readout calorimetry
  - Address single particle energy resolution
  - Develop dual readout methods to measure EM and HAD shower components separately
- *CALICE* collaboration
  - Many efforts are part of *CALICE* collaboration
  - Some efforts are NOT
- **This is NOT an R&D progress report**

# PFA calorimetry: EM calorimeter

- *CALICE* Si-W ECAL
- SiD Si-W ECAL
- *CALICE* Scintillator-W ECAL
- *CALICE* MAPS Digital ECAL

# PFA ECAL: CALICE Si-W

- Features Si active layer with fine readout cells ( $1 \times 1 \text{ cm}^2 \rightarrow 0.5 \times 0.5 \text{ cm}^2$ )
- R&D well advanced: physics prototype beam test largely done
  - Standalone test + combined test with CALICE AHCAL
  - Analysis on-going
  - Comparison with MC simulation
- Future test beam plan:
  - 2010 (~summer): combined test with CALICE RPC DHCAL
  - Major R&D shift to technical prototype
  - 2010 – 2012: small scale tests expected (@ DESY or CERN)
  - 2012 (if not earlier): technical prototype test (details to be decided)



Technical prototype  
3x15 cells

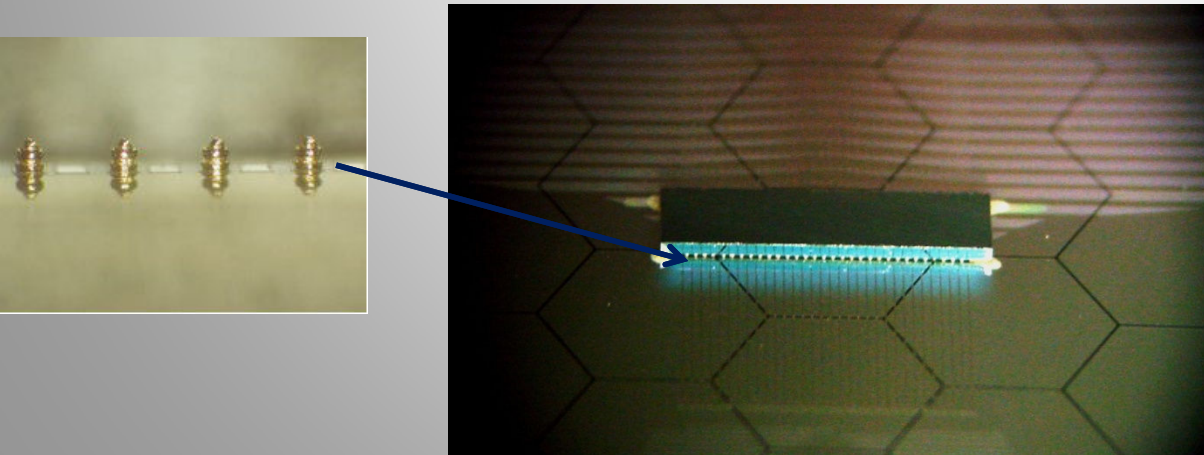
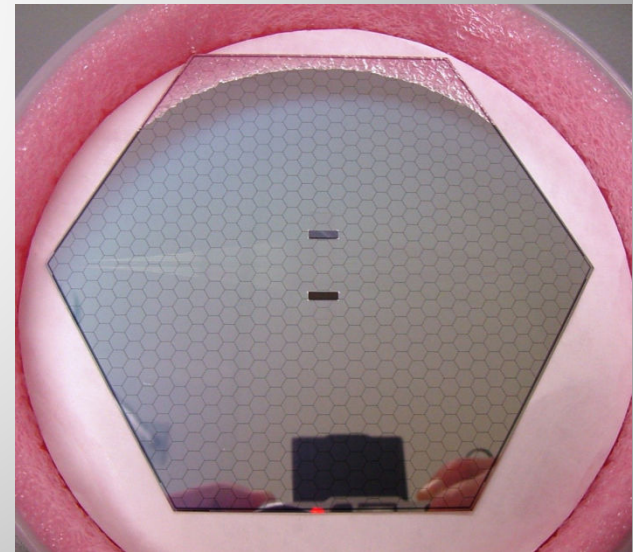
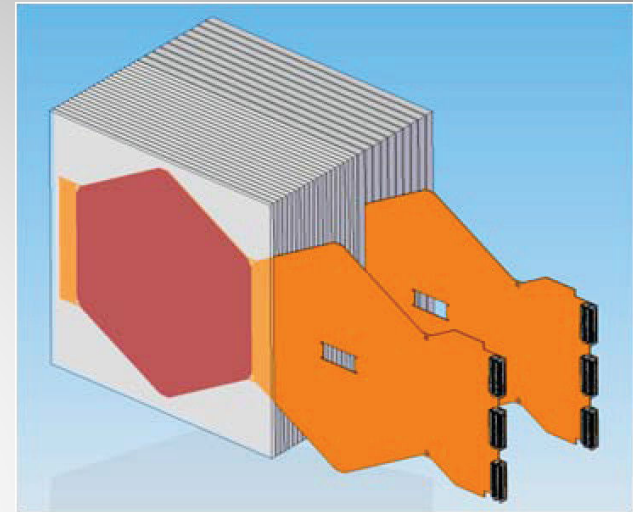
(my simple definition)

Physics prototype: sensor & absorber in place, not readout

Technical prototype: readout in place as well (~ ILC module)

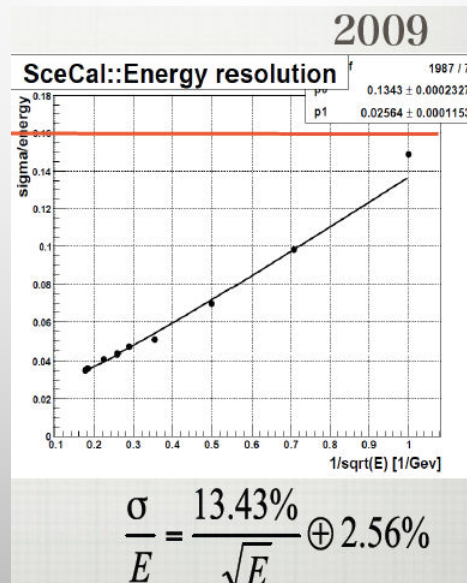
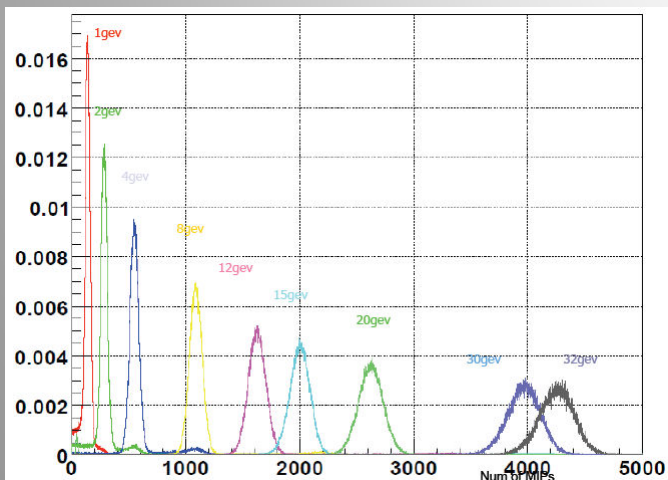
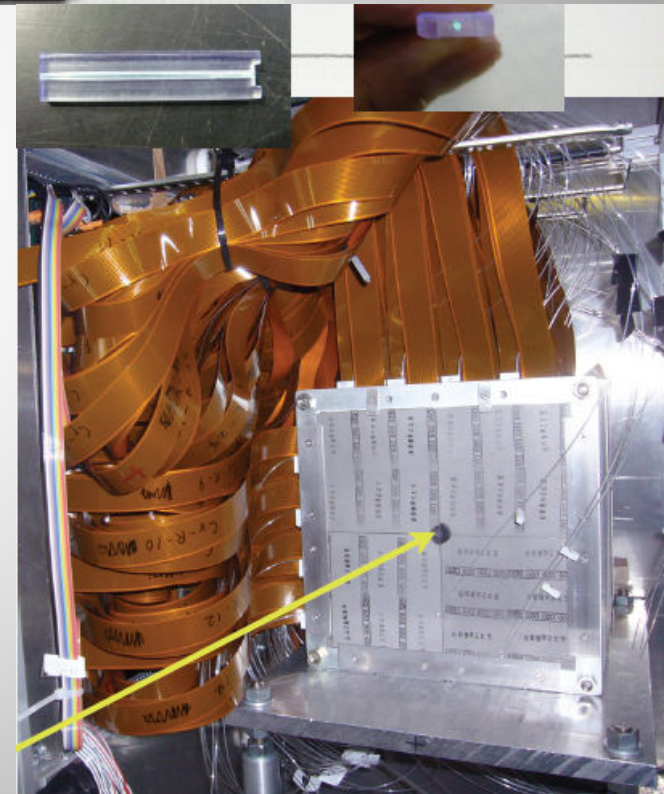
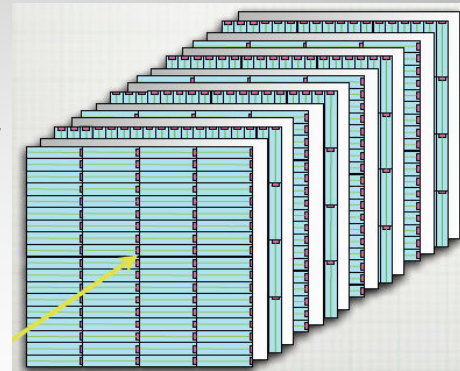
# PFA ECAL: SiD Si-W ECAL

- Features Si active layer with very fine readout cells ( $\sim 0.13\text{cm}^2$ )
- KPiX readout chip to handle large number of channels
  - Goal is 1024ch/chip (1 wafer)
    - Latest 256ch prototypes (KPiX-8) perform OK
    - 1024ch version by the end of 2009
  - Bump-bonded directly onto wafer
    - Multiple trials completed (gold bump-bonds)
- Beam test plan:
  - (Physics/Technical) prototype  $\sim 2010$
  - Standalone test
    - Electrons of 5-10 GeV or more, well localized
    - LC-like time structure (for KPiX electronics)
    - Rate of zero,1,2 electrons per bunch
    - Proposed SLAC electron test beam would be ideal
  - Combined test with HCal prototype: hadron beam



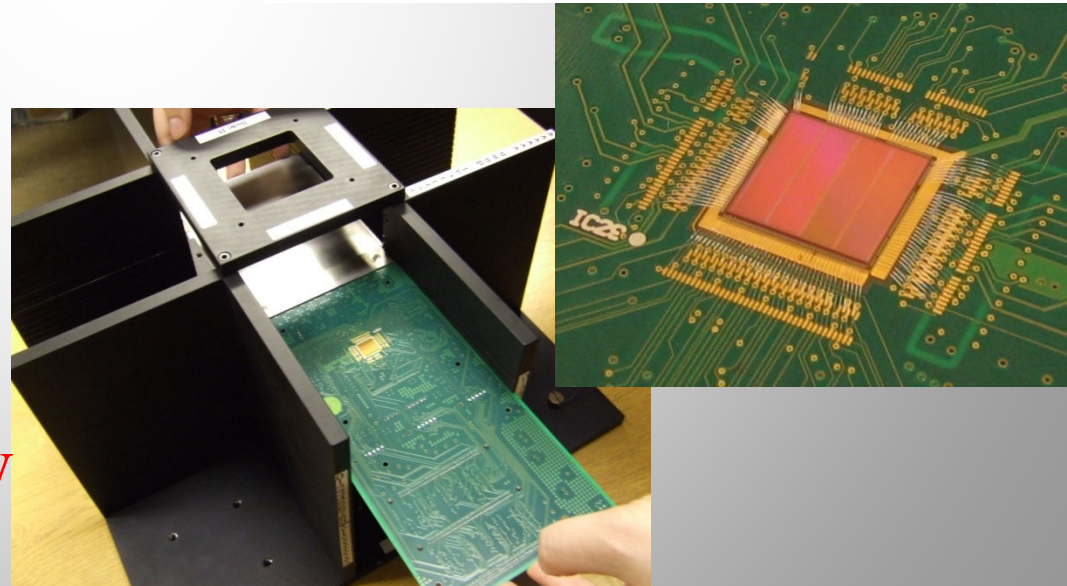
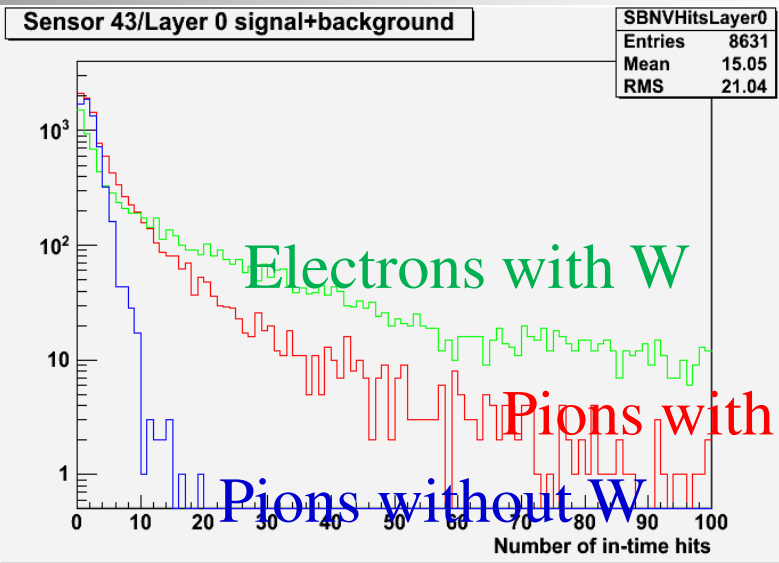
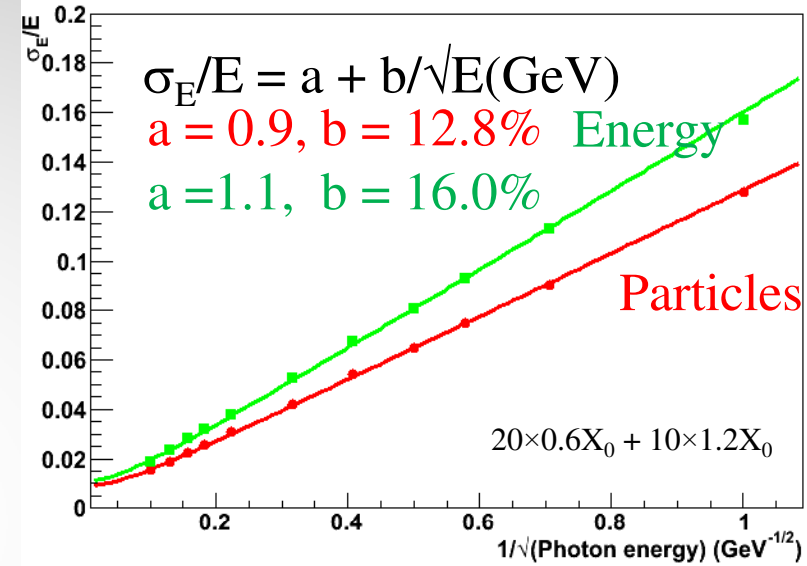
# PFA ECAL: CALICE Scintillator ECAL

- Features small scintillator strips (10x45x3mm<sup>3</sup>) readout by MPPC
- Physics prototype constructed and tested
  - Data analysis on-going
- Future test beam plan
  - Small scale test for improved scintillator sensors for ECAL and HCAL planned for the next 3 years
  - Beam: electrons and hadrons



# PFA ECAL: CALICE MAPS Digital ECAL

- Features Si sensor with tiny cells ( $\sim 50\mu\text{m}$ ): digital readout (count particles not energy)
- Sensor test recently at CERN
  - MIP data as well as some ‘shower’ data
- Future beam test plan
  - Early 2010: more sensor test at DESY with electron beam
  - Currently bidding for summer 2010 CERN beam time for test with higher energy electron
  - 2011: prototype layer (for physics prototype) test at DESY possible
  - Physics prototype by 2012



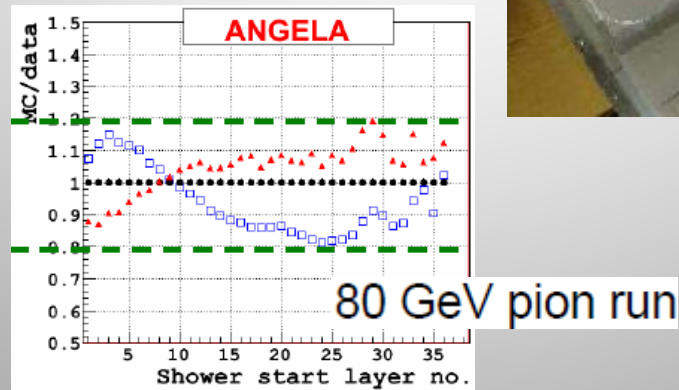
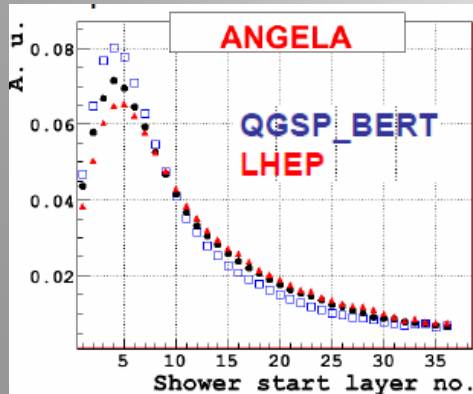
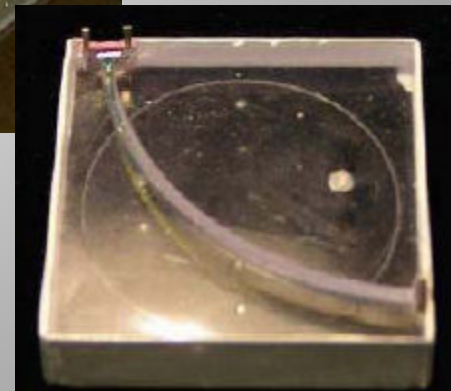
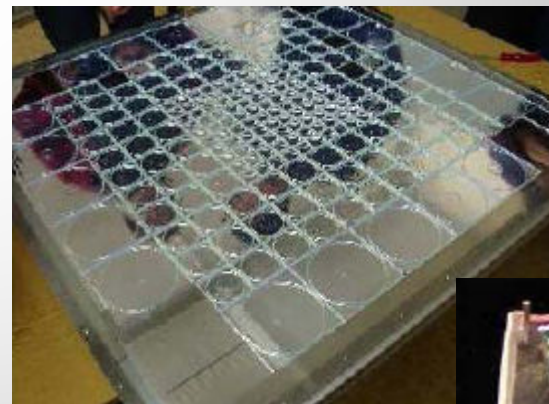
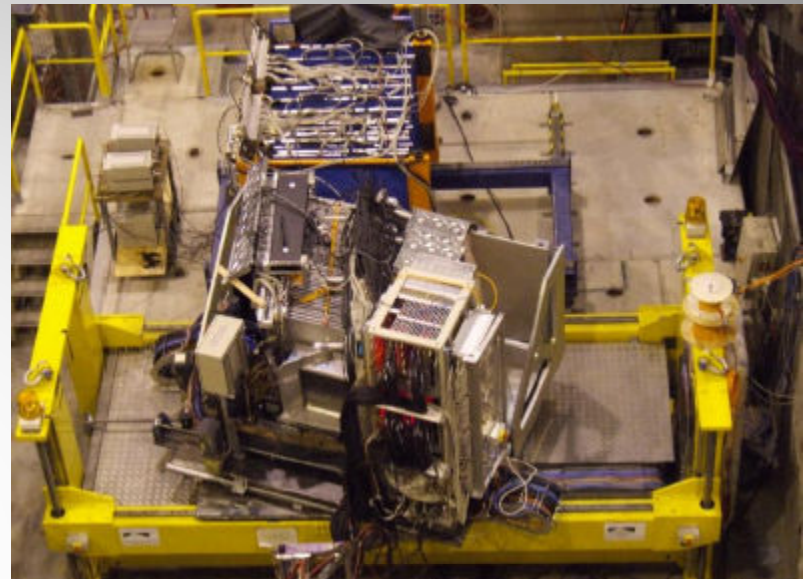
# PFA Calorimetry: HCAL

- *CALICE* Scintillator Analog HCAL (AHCAL)
- *CALICE* RPC Digital HCAL (DHCAL)
- *CALICE* MicroMegas DHCAL
- *CALICE* GEM DHCAL
- *CALICE* RPC Semi-Digital HCAL (sDHCAL)



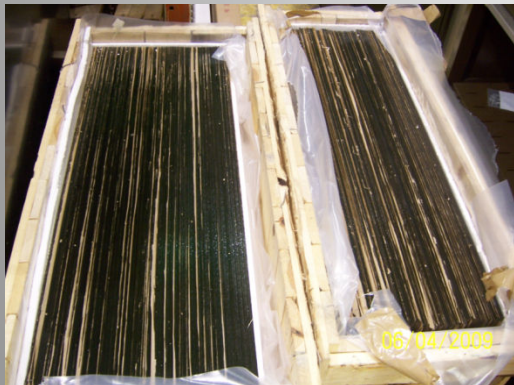
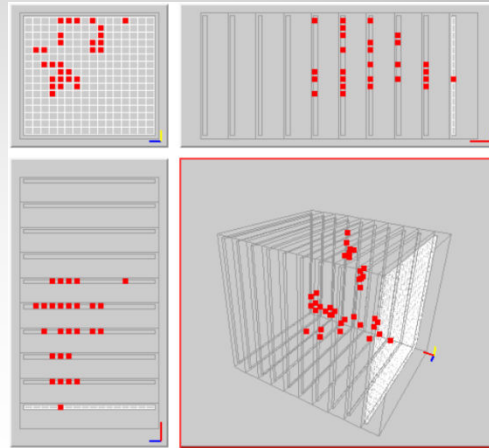
# PFA HCAL: Scintillator AHCAL

- Features  $3 \times 3 \text{ cm}^2$  scintillator tiles and SiPM readout
- R&D well advanced:  $1 \text{ m}^3$  physics prototype beam test done
  - Standalone test and combined test with CALICE ECAL
  - Analysis on-going
  - First comparison with MC simulation
- Future test beam plan
  - Commission of integrated electronics and tile modules in 2009
  - Full cassette test in 2010
  - Mini-stack for EM showers in 2010/2011
  - Prefer DESY test beam for these tests
  - Full HCAL technical prototype test is too uncertain for current discussion
  - Also considering tests with current AHCAL layers in a tungsten absorber structure



# PFA HCAL: RPC DHCAL

- Features RPC as active medium and  $1 \times 1 \text{ cm}^2$  pads with digital readout
- Done tests with RPCs and small stack (slice test) at Fermilab MTBF
- Currently constructing 1 m<sup>3</sup> physics prototype
  - Expect to finish by Spring 2010
  - Reuse CALICE AHCAL absorber structure
- Beam test plan
  - Layer test planned for Feb 2010
  - Spring 2010 stand alone test for DHCAL physics prototype (with TCMT)
  - Followed by combined test with CALICE ECAL (and TCMT)
  - Test with muon, electron, pion and proton



Glass for RPCs

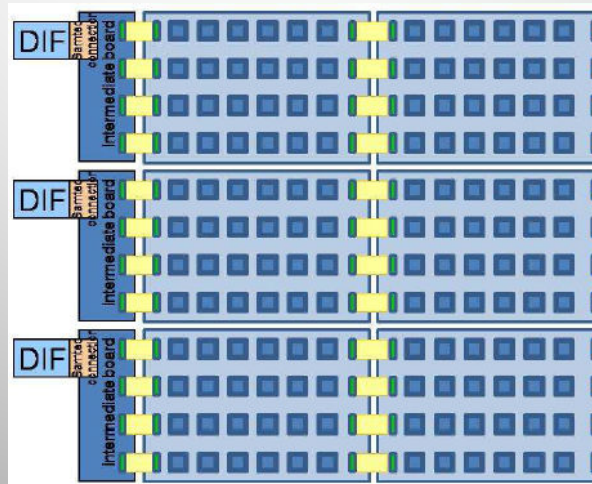
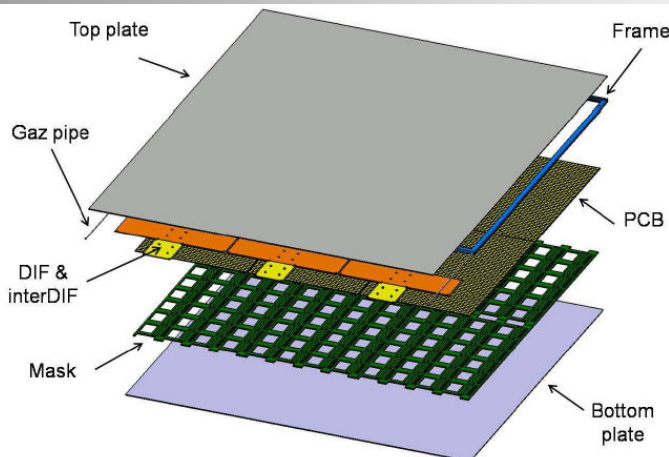
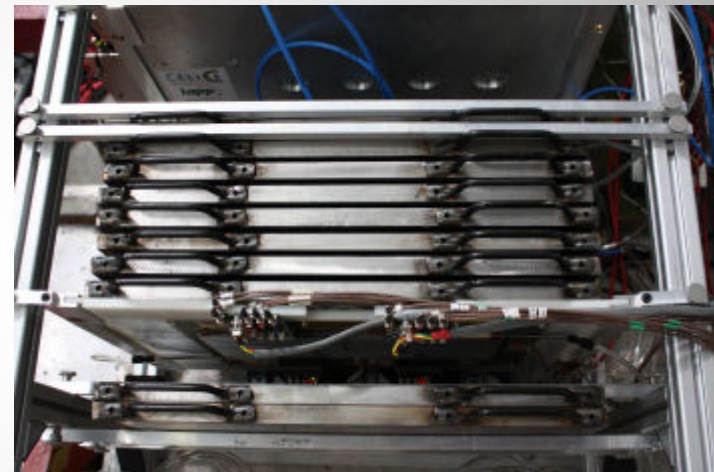
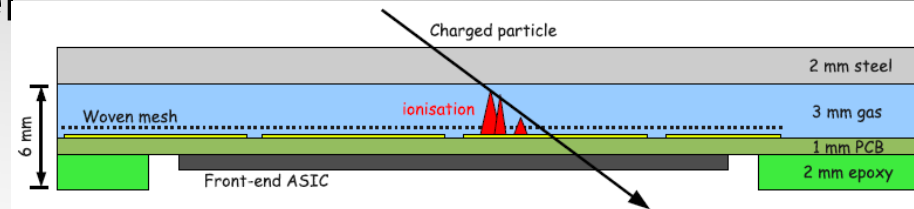


Electronic readout components



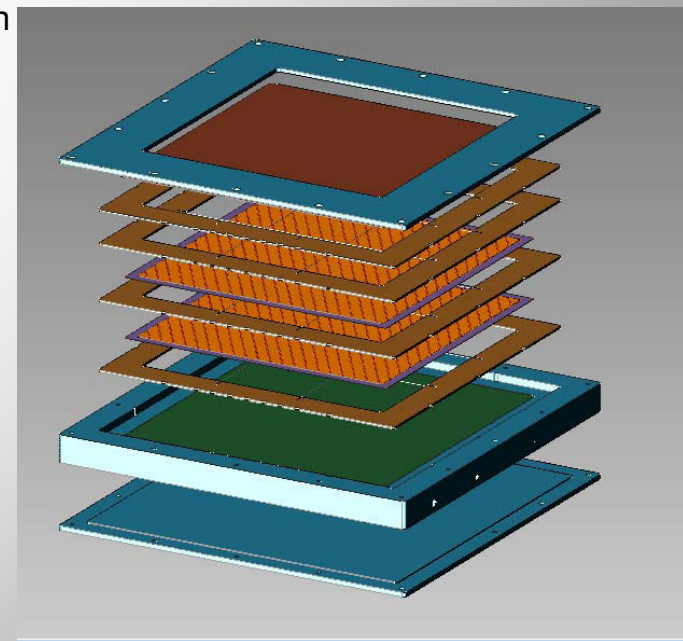
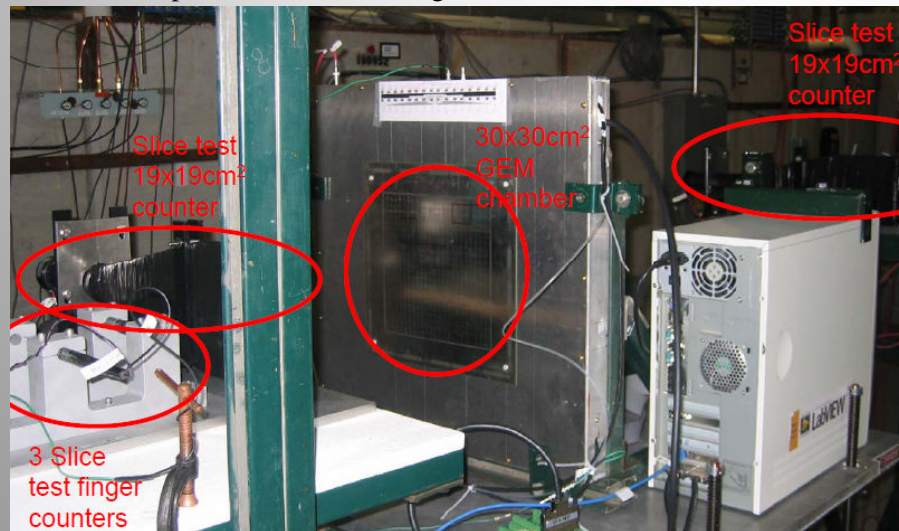
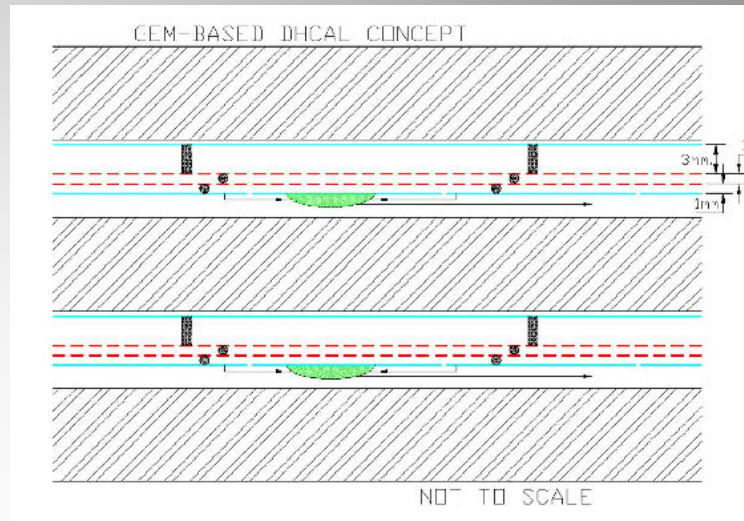
# PFA HCAL: MicroMegas DHCAL

- Features MicroMegas active layer and  $1 \times 1 \text{ cm}^2$  pads with digital readout
- Sensor/readout test at CERN
  - Chamber characterization measured in beam
  - More tests coming up
- Future beam test
  - More sensor/readout test (CERN)
  - $1 \text{ m}^2$  layer test
  - $1 \text{ m}^3$  “technical prototype” (uncertain at this point)



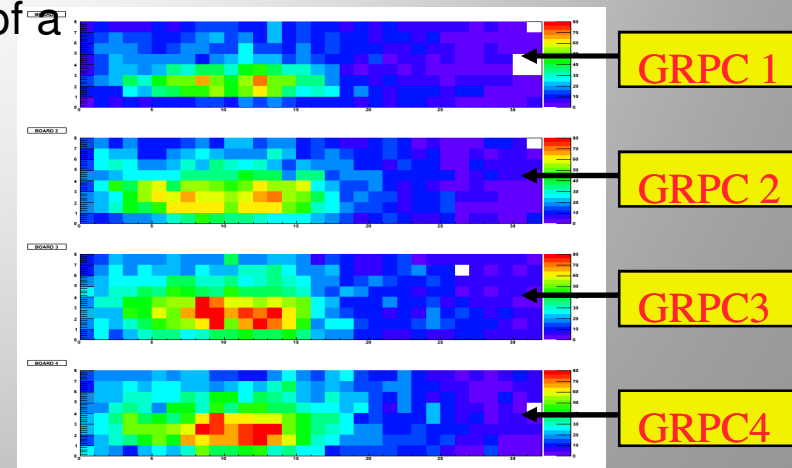
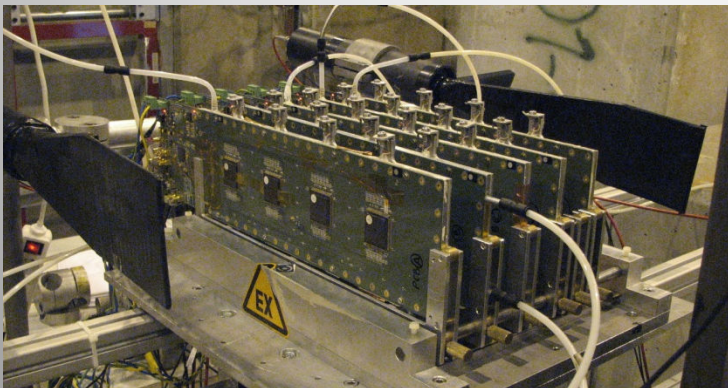
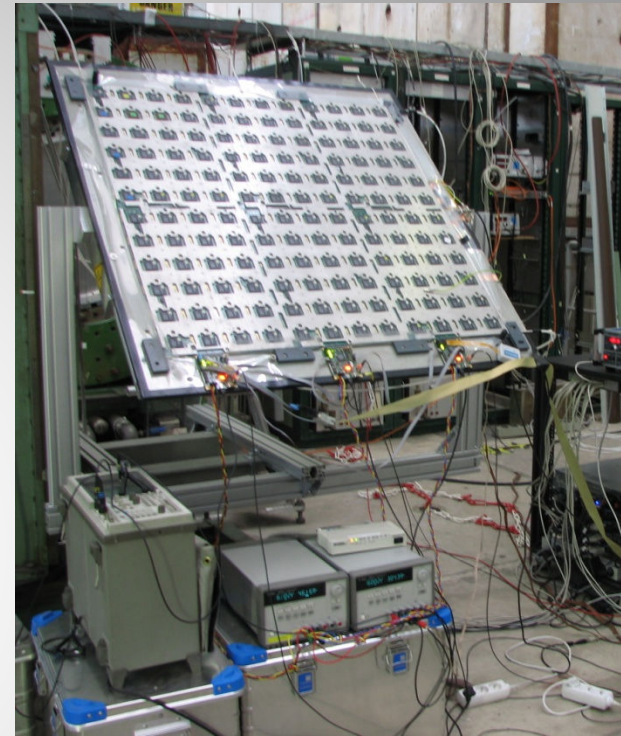
# PFA HCAL: GEM DHCAL

- Features GEM active layer and  $1 \times 1 \text{ cm}^2$  pads with digital readout
- Sensor irradiation test in Korea
- Sensor/readout test at MTBF
  - Chamber characterization
  - More tests coming up
- Future beam test plan at Fermilab MTBF
  - Late 2009 – early 2010: completion of  $30 \text{ cm} \times 30 \text{ cm}$  chamber characterization
    - 1-2  $30 \text{ cm} \times 30 \text{ cm}$  double GEM with 64ch KPiX-7
  - Early 2010 – late 2010:  $33 \text{ cm} \times 100 \text{ cm}$  unit chamber characterization
    - With available KPiX chip
  - Late 2010 – mid 2011:  $1 \text{ m}^2$  plane GEM DHCAL performances in the CALICE stack
    - ~5 planes inserted into existing CALICE calorimeter stack
    - Run with either Si/W or Sci/W ECALs
    - RPC planes in the remaining HCAL slots



# PFA HCAL: RPC Semi-Digital HCal

- Features RPC as active medium and  $1 \times 1 \text{ cm}^2$  pads
- Semi-Digital readout: digital readout with multiple ( $\sim 3$ ) thresholds
- Sensor/readout tests at CERN
  - 4-5 small RPC test
  - $1 \text{ m}^2$  layer test
  - Test of RPC built with semi-conductive glass
- Future test beam plan at CERN
  - First part of 2010:
    - Test RPCs with different coatings and different techniques (silk screen printing...)
    - Test another  $1 \text{ m}^2$  layer equipped with the Hardroc2 (second version with 3 threshold and power pulsing)
  - Second part of 2010: test a part (if not all) of a “technical prototype”

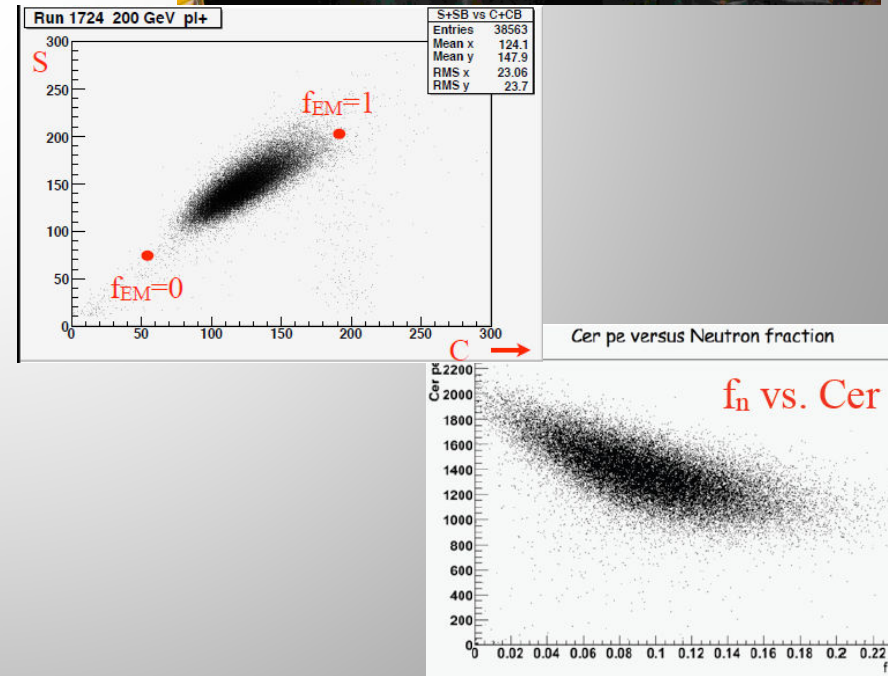


# Dual Readout Calorimetry

- Fiber dual readout calorimeter (DREAM)
- Totally Active Crystal dual readout

# Dual Readout: Fiber (+ Crystal)

- Features dual readout that measures scintillation light and Cerenkov light on an event by event basis
  - Neutron measurement also considered
- Beam test at CERN H4 beam line since 2004
  - 2004 DREAM module only; e, mu, pi 20 -> 300 GeV
  - 2006 DREAM with two-directional C and S fibers; first test of PWO crystals
  - 2007 PWO as function of angle, beam, and temp. PWO used with DREAM as "calorimeter system"
  - 2008 DREAM+leakage counters; BGO matrix; several crystals vs. angle, particle
  - 2009 DREAM+leakage counters; a few new Cerenkov fibers; BGO matrix; several new crystals; neutron measurements
- Future test beam plan at CERN H4
  - Continue crystal tests; neutron measurements



# Dual Readout: Totally Active Crystal

- Features dual readout and totally active crystal calorimeter
- Simulation studies underway
- Beam test planned at Fermilab MTBF
  - MoU in place
  - Single crystal test
    - Light yield,
    - Scintillation/Cherenkov separation
    - Different photo detectors and light collection schemes
    - Geometries, etc.
  - EM-sized module to test the calibration schemes
  - Full scale module (to much uncertainty at this point)



# Summary

R&D effort	Sensor/readout /layer test	Small module	Large module
CALICE SiW ECal	2010 – 2012		2010: combined test with DHCAL 2012: technical prototype
SiD SiW ECal	?		2010
CALICE ScW ECal	2010 – 2012		
CALICE MAPS ECal	2010 – 2011		2012
CALICE AHCAL	2009 – 2010	2010 – 2011	(technical prototype) (current AHCAL layers with W)
CALICE RPC DHCAL	2010		2010 (1m <sup>3</sup> prototype)
CALICE MicroMegas DHCAL	Yes		(“technical prototype”)
CALICE GEM DHCAL	2009 – 2010		2010 – 2011 (5 x 1m <sup>2</sup> )
CALICE RPC SDHCAL	2010		Later 2010 (part of “technical prototype”)
Fiber Dual Readout (DREAM)			2010 –
Totally Active Dual Readout	Yes	(Yes)	(Yes)

Immediate future

Further away