SiD: Hadron Calorimetry

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LCWS07-Hamburg
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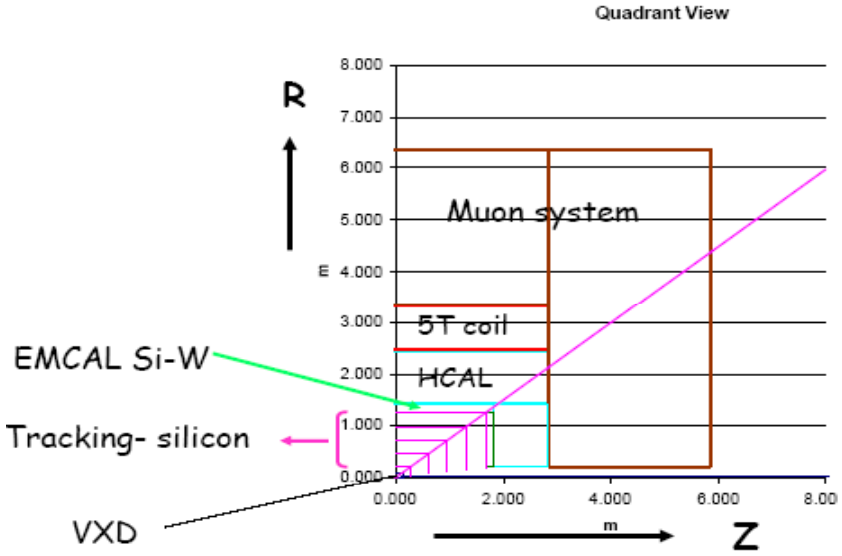
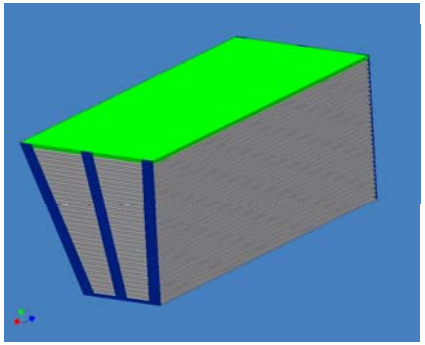
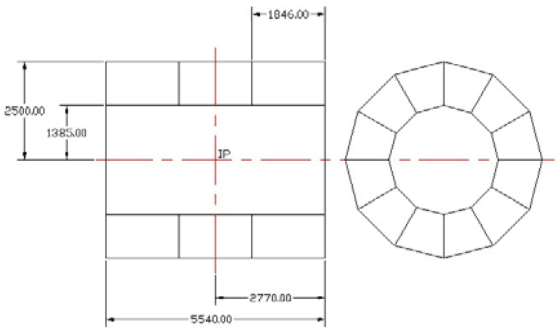
HCAL Considerations







Dimensions of Barrel

- **Guiding Principles**
  - **Optimized for PFA**
  - **Small radius to improve resolution, control costs**
- **Baseline**
  - **Gap size < ~10mm**
  - **Barrel: 34 20-mm SS absorbers → 4 λ_o**
  - **Two endcaps**
  - **Resistive Plate Chambers**
- **Major questions:**
  - **Absorber: SS or W?**
  - **Segmentation: 1cm^2 through 9cm^2?**
  - **Sampling needed beyond magnet?**
  - **<u>Active medium?</u>**

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More on PFA Requirements

- **Tracking:**
  - **Efficiently allow tracking of charged particles through volume.**
- **Jet Resolution:**
  - **Sufficient depth such that any loss in the coil or energy measured with degraded resolution (relative to the HCal) in the outer detectors does not significantly impact jet energy resolutions.**
  - **Sufficient cell size allows true and efficient separation and association of closely spaced energy clusters with the correct tracks.**
  - **Sufficient sampling so as not to significantly degrade the jet energy resolution via the sampling term.**
- **Simulations are essential, especially for understanding design parameters and technology capabilities, these efforts are covered in the next talk by John Jaros**

Readout Technologies Under Consideration

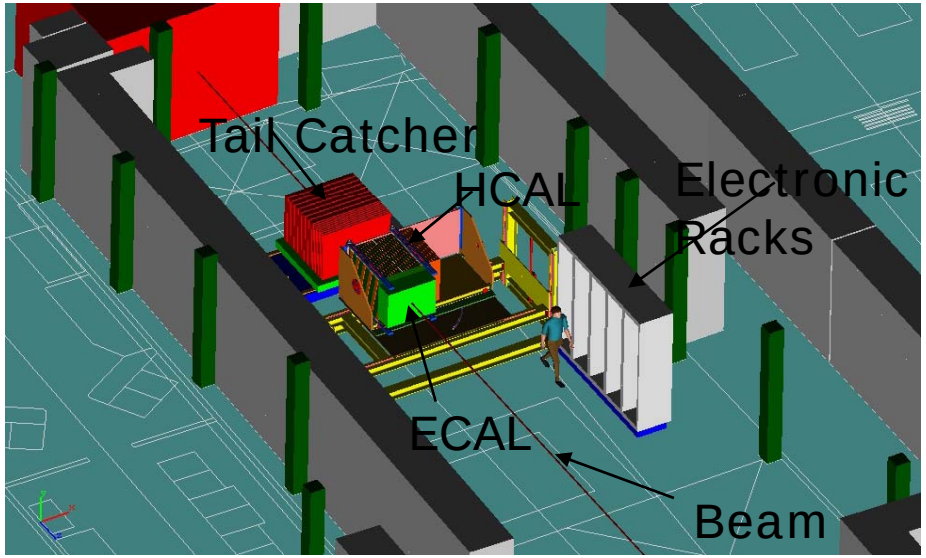
- **Gaseous Readout: fine segmentation, straightforward assembly, inexpensive**
  - Resistive Plate Counters
  - Gaseous Electron Multipliers & Micromegas
- **Scintillator Readout: high sampling fraction, well understood**
  - Solid state photomultipliers (MPPC, SiPM, MRS…)
- **Basic approach**
  - Demonstrations
  - Simulations

  → Leading to Large Prototypes

R&D Well Matched to CALICE

Calorimeter for ILC

- **Technology**
  - **Gain large scale, long-term experience with**
    - **Now Scin/solids readout**
    - **Next gaseous detectors**
  - **Identify critical operational issues**
- **Physics:**
  - **Structure of hadron showers**
  - **Validation of simulation**
  - **Development of particle flow algorithms**
- **Running at CERN and FNAL 2006 – 2008**
- **Numerous CALICE talks this week**



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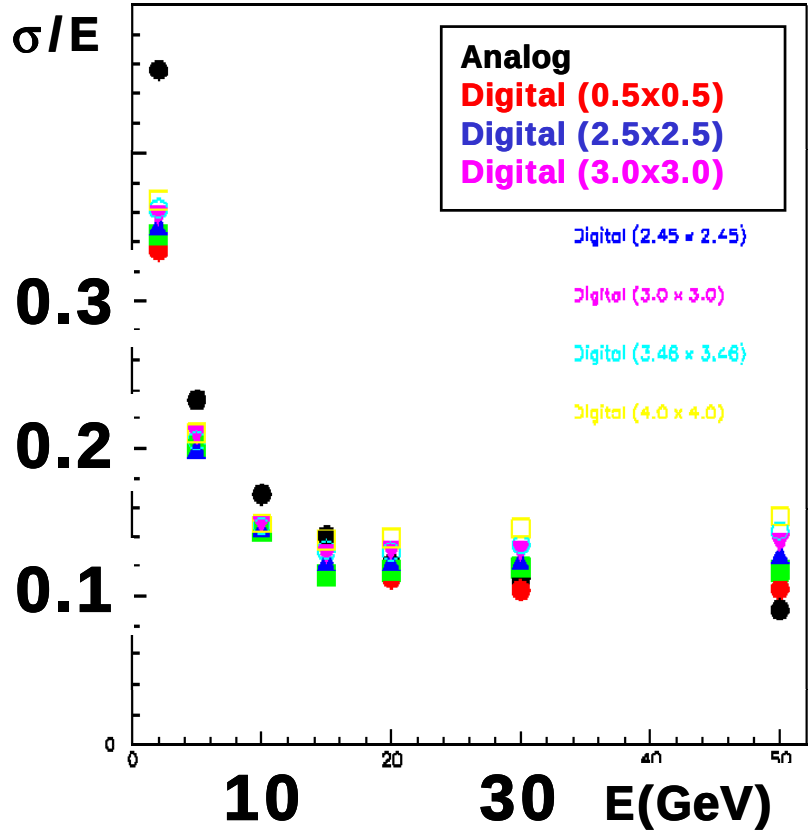
Resistive Plate Chambers

- **RPC**
  - Single Gap
  - Coated glass as resistive plates
  - Avalanche mode
- **Small pads ~1cm²**
  - Reduce confusion between tracks and clusters
  - 1 bit resolution preserves single particle resolution

Pion Resolution Non-projective SiD



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Prototype RPC Results

- **Parameter space thoroughly explored:**
  - One or two gas gaps
  - One or two glass plates
  - High or low resistivity coatings
  - Streamer and avalanche mode
  - Gas mixtures
  - Voltage
  - Stability
- **Performance metrics investigated with sources, cosmic rays, and beam:**
  - MIP detection efficiency vs Multiplicity
  - Noise rate
  - Rate capability

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

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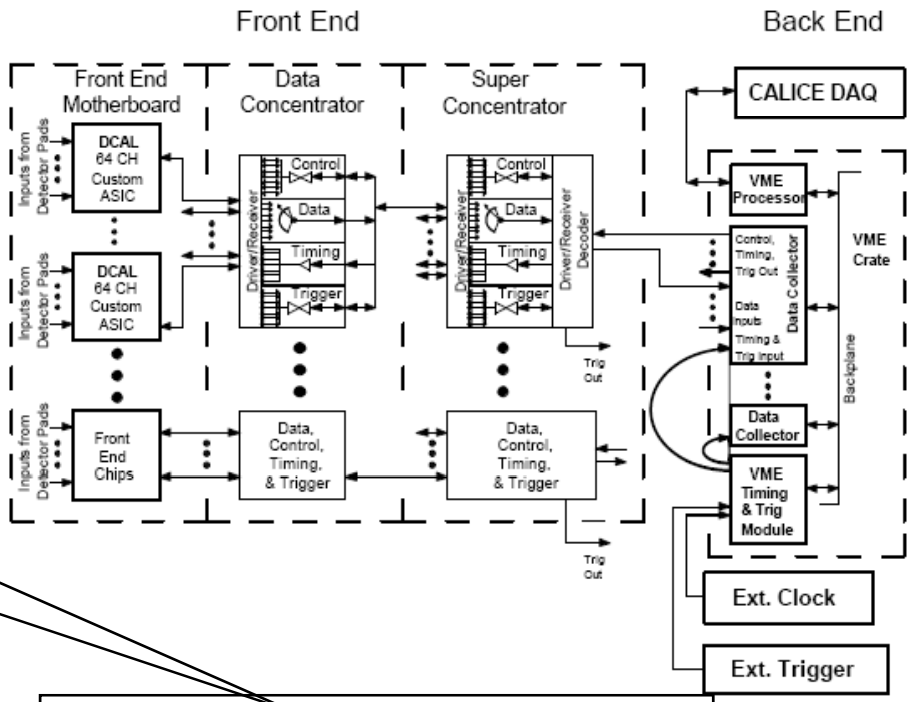
RPC Slice Test

- **Ten chamber, 2500 channel "test slice" in development for June 2007 FNAL beam**
  - **New chamber design**
  - **Cosmic ray and test beam stacks assembled**
  - **Ten RPCs with complete (RPC and GEM) readout chain:**
    - **64 channel pad boards**
    - **FE boards and DCAL ASIC**
    - **Data concentrators and collectors**
    - **Timing and trigger units.**
  - **Prototype and production underway**
- **Preliminary work for a 400k channel 1m³ prototype**



Just commissioned!

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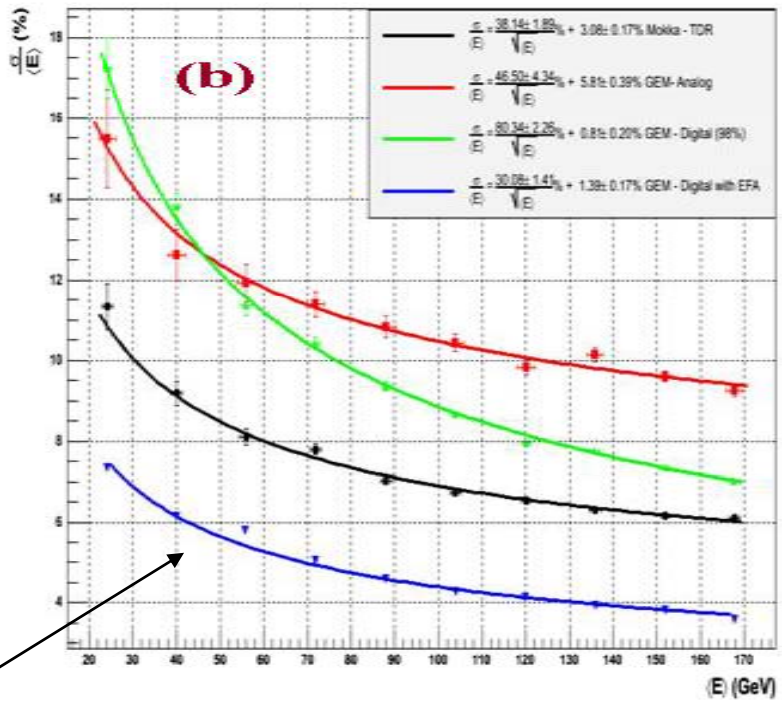
Gas Electron Multipliers

- **Foil separates drift and amplification gap**
- **PCB for anode ~1x1cm² pixel readout possible**
- **Uniform, MIP efficient, and fast.**
- **Digital performance encouraging**



NOT TO SCALE

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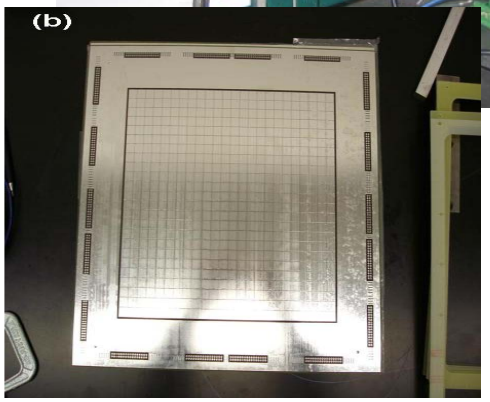
SiD Members: University of Texas-Arlington, Washington

Prototype GEM Results

- **Small prototype tests similar to those for RPC**
  - **MIP efficiency ~95%**
  - **Multiplicity 1.3**
- **Focus has been on production of chambers with large foils**
- **Test beam efforts first in Korea and just recently at Fermilab (March-April)**
- **Efficiency and cross-talk measurement analysis underway (CALICE talk)**



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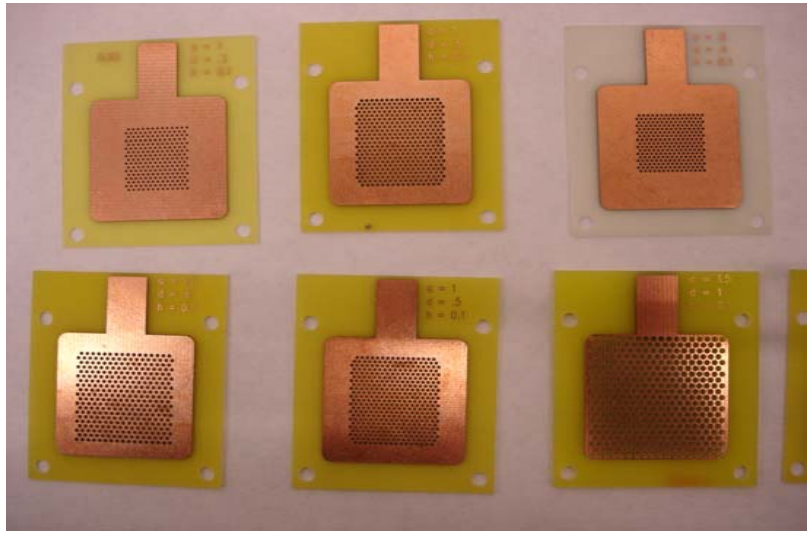
GEM Plans

- Participating in slice effort (2007)
- Testing ASIC designs as well
  - Fermilab DHAL
  - SLAC KPiX
- Investigating
  - 3M-company 30cmx1m foils (2007, beam 2008)
  - Thick GEMS (2008)
- And preparing for $1m^3$ prototype



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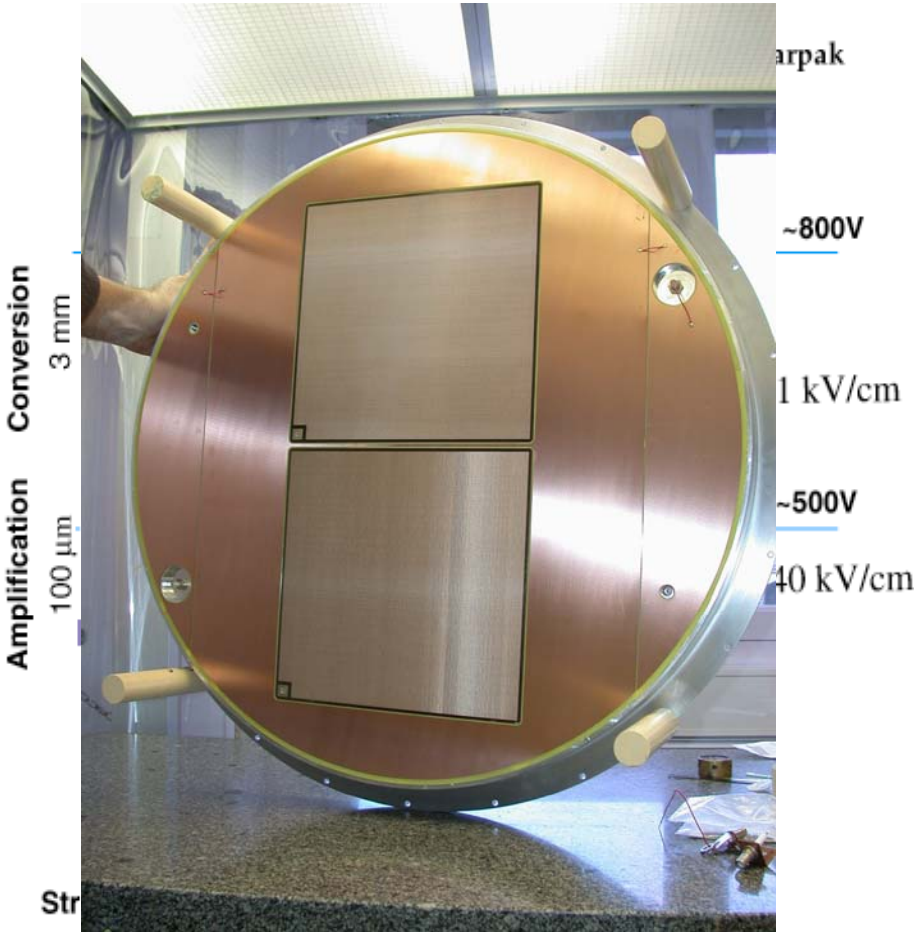
Micromegas

- Similar to GEMs
- Fine mesh separates 3mm drift and 0.1mm amplification gaps
- Can produce planes in a single lamination process – “bulk micromegas” used for T2K prototypes.



SiD Members: LAPP-Annecy

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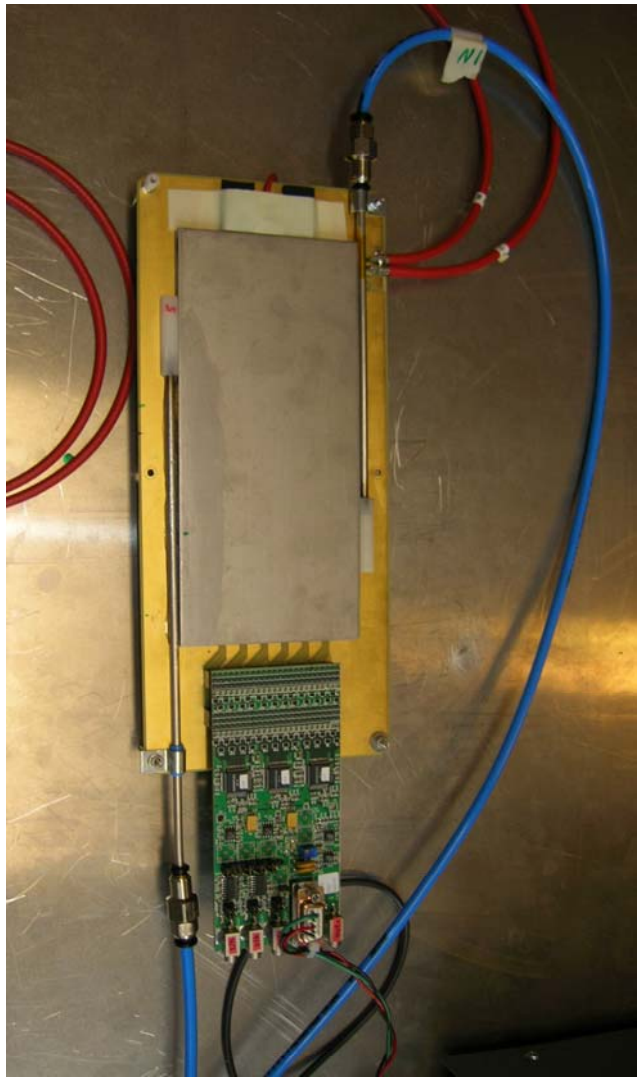
Micromega Plans

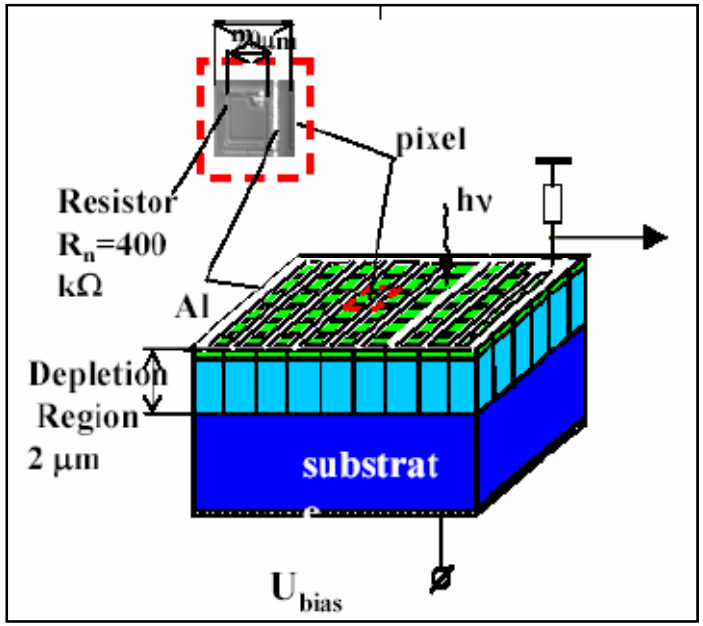
- **First phase:**
  - Design and production of small “bulk: prototypes
  - Three 6x16 pad planes built.
  - Study with sources and cosmic rays.
- **Second Phase:**
  - 80x320 mm^2 PCB with integrated electronics under design.
  - Sixteen planes will be combined into a 640x640 mm^2 detector
  - Beam tests and studies

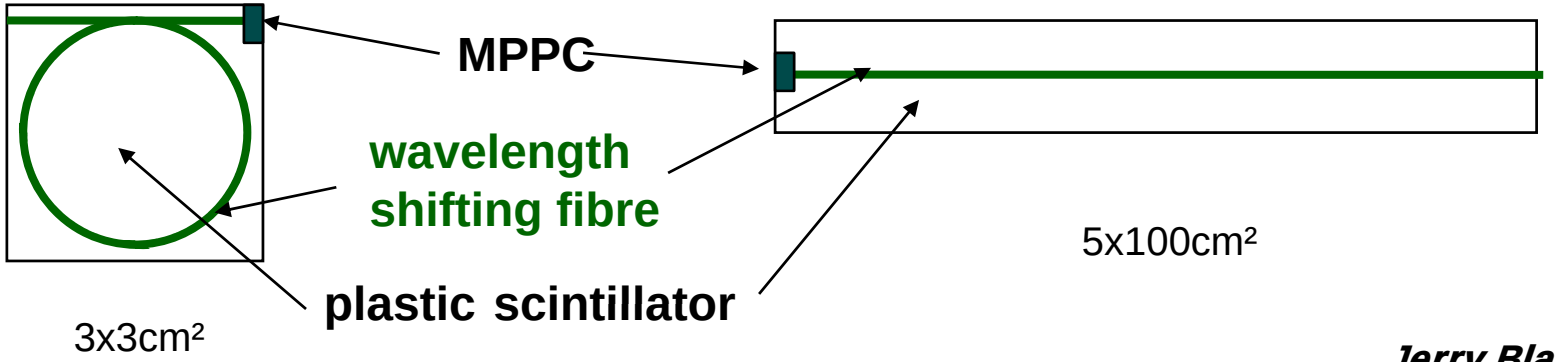


SiD Members: LAPP-Annecy

Scintillator / Solid State

- **Scintillator, typically**
  - **0.5mm thick**
  - **~3x3 cm²**
- **Configurations based on tiles & strips**
- **Sensors: Many vendors…**





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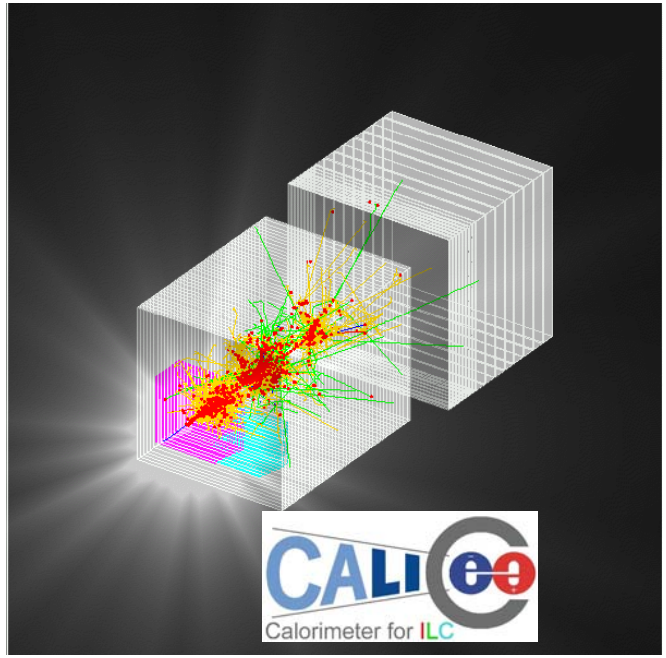
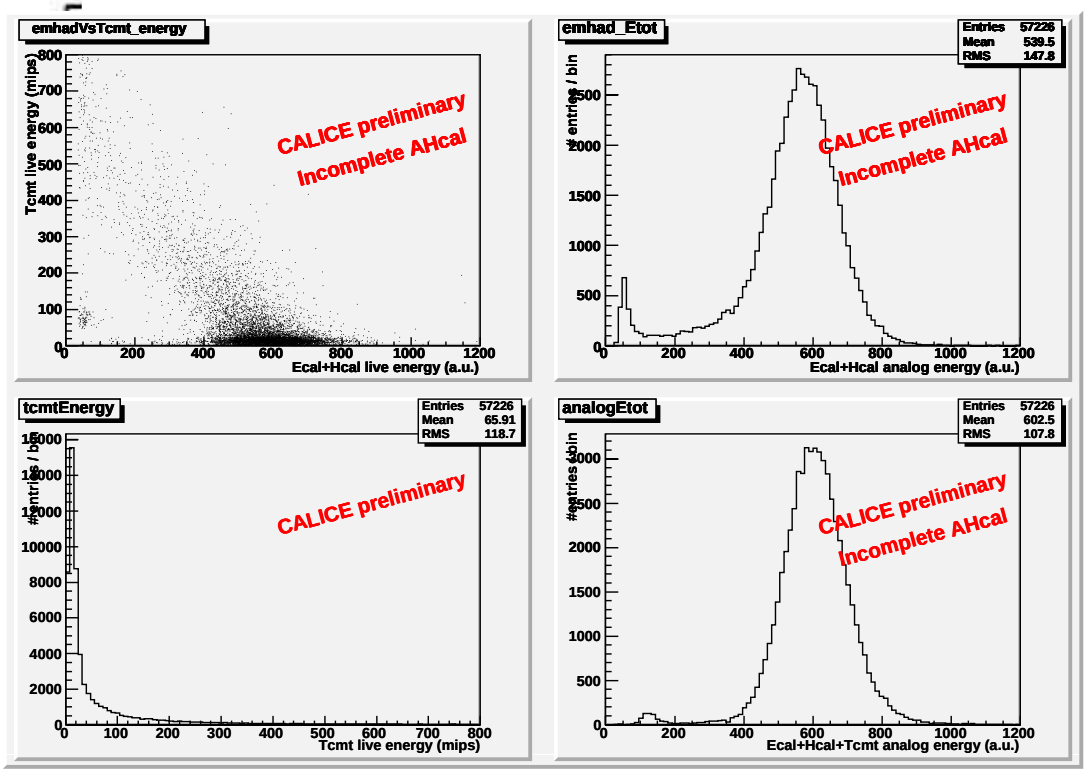
Scintillator / MPPC Results

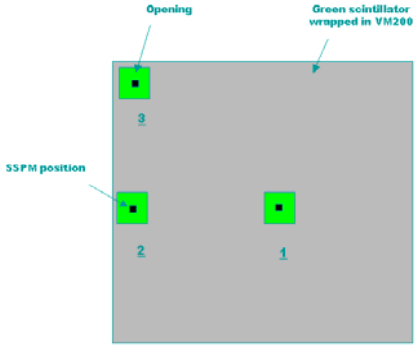


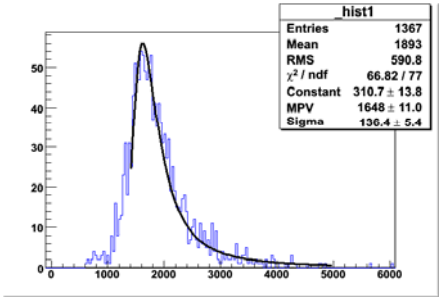


Containment

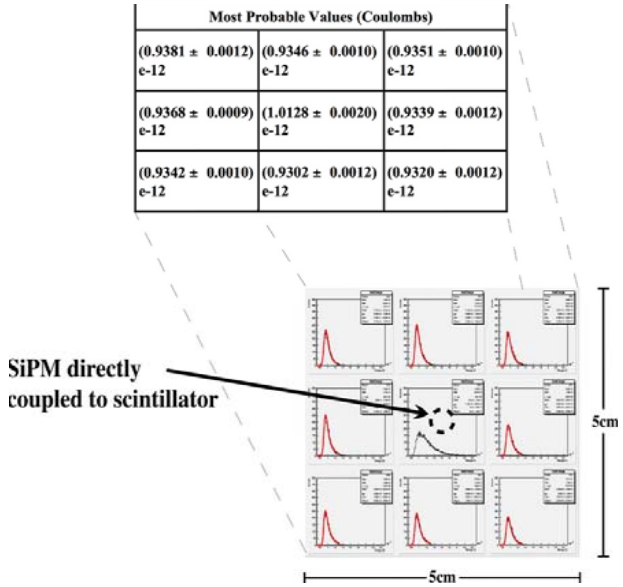
- AHCAL + ECAL + TCMT
- 20 GeV Pion

Scin / MPPC Direct Coupling & Plans

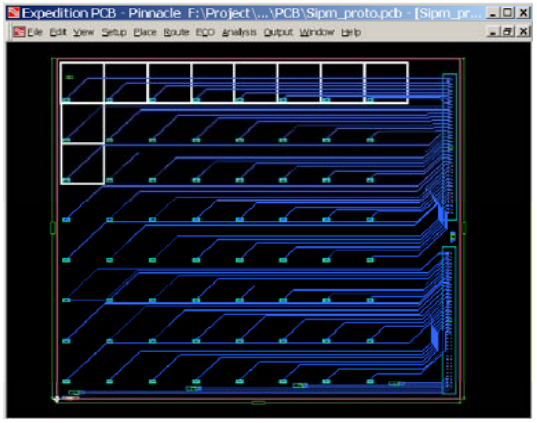




Position	CPTA(+/-15%)	Hamamatsu
Center	100%	16.8+/-2.5 PE
Edge	92%	19.3+/-3.0 PE
Corner	71%	Not Measured
Center(no grease)	Not Measured	10.8/-1.5 PE



1) **Understand / Optimize Direct Coupling**
2) **Construction of integrated Scin / sensor / readout PCBs**
3) **2007 test beam**



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SiD HCAL Steps Forward

- **June, 2007 (LCWS07) Reports**
  - Gaseous: GEM / RPC Slice Test
  - Scintillator / MPPC: CALICE analysis & direct coupling investigations
- **Late 2007 Review:**
  - Evaluate technology options
  - PFA Simulations report
  - Completion 1st generic engineering study
  - Decision on next prototype step for EDR
    - Full stack or ILC prototype
- **Mid-2008 Review:**
  - Technology choice or choices for CDR
  - Review progress of prototype projects

Performance Criteria	Technology Issues	Cost
MIP efficiency/pad	Maturity and history	Development costs
Hit multiplicity/pad	Reliability	Assembly and test costs
Uniformity of response across active element	Component availability	Active layer % of total
Ease of calibration	Active layer thickness	Total HCal cost
Track/cluster separability	Smallest element size	
Response to neutrons	Ease of assembly, testing, installation, commissioning	
PFA jet resolution at Z-pole, 200 Gev, 500 GeV	Recovery time after i) hits & ii) significant beam event	
	Rate of discharge (gas)	
	Ageing affects	
	Sensitivity to magnetic field	
	Technical risk	

Closing Comments

- SiD has made progress with baseline HCAL using RPCs.
- Has intentionally left the door open for other possibilities including GEMs & Micromegas & Scin/Solid State Sensors.
- Members are contributing to world-wide R&D efforts, particularly in the framework provided by the highly successful CALICE collaboration.
- Interplay between concepts and R&D efforts will yield more capable detectors.

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