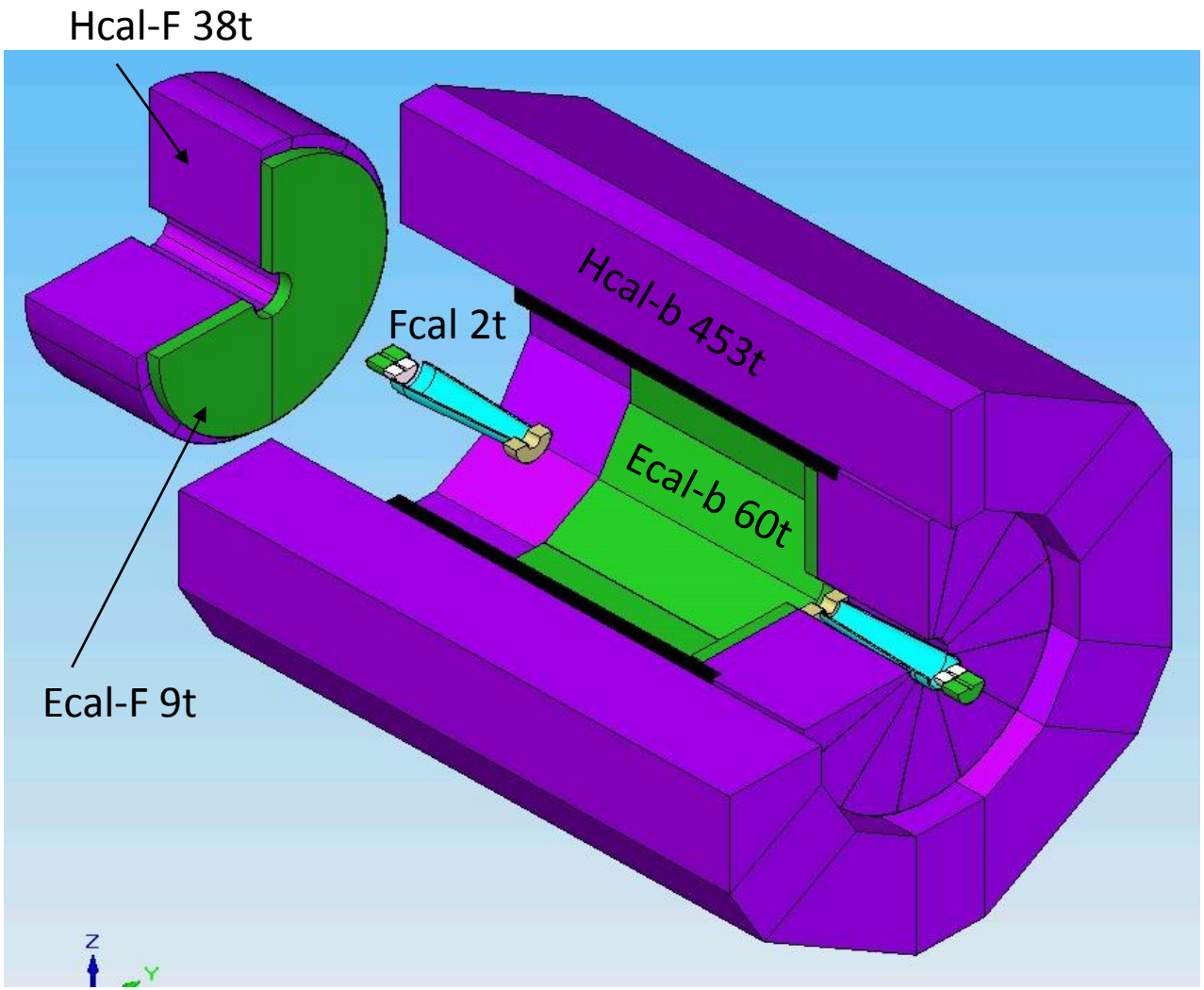
SiD Hadron Calorimeter System

The purpose of this talk:

- ✯ Describe the current design of the SiD HCal System
- ✯ List the possible alternative technology options
- ✯ Discuss “baseline” choice
- ✯ Discuss issues/ideas for improvement
- ✯ Invite your participation in future development

SiD Calorimeter System



SiD Calorimetry – Design Criteria

-> PFA-based system

-> Integrated part of SiD with tracking, muon systems

-> Calorimetry optimized for jet reconstruction and energy resolution

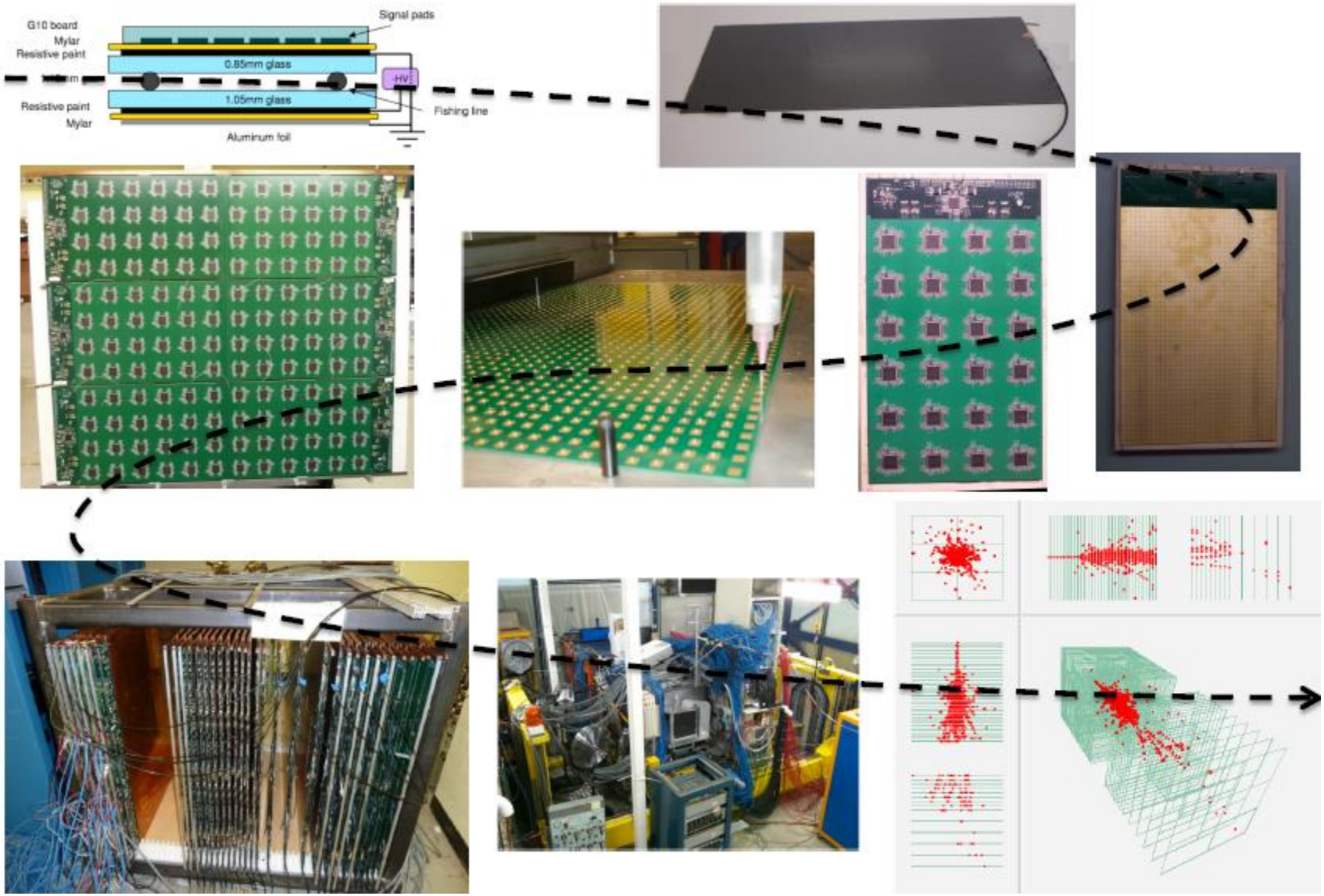
-> “Tracking calorimeters”, compact showers in ECAL, highly segmented (longitudinally and transversely) ECAL and HCAL.

-> Compact design – radially inside the superconducting solenoid

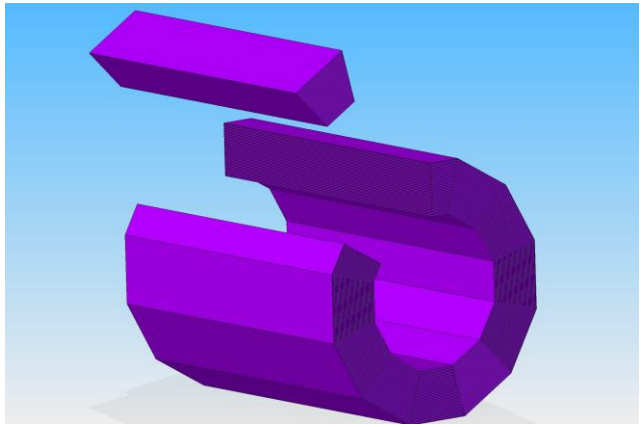
-> Iron flux return/muon identifier/energy leakage indicator

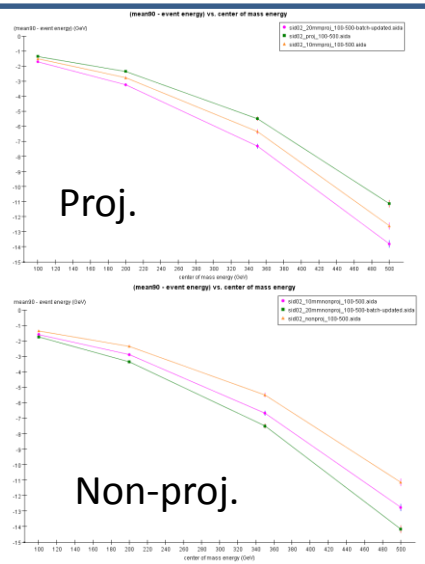
SiD - HCal RPC Baseline

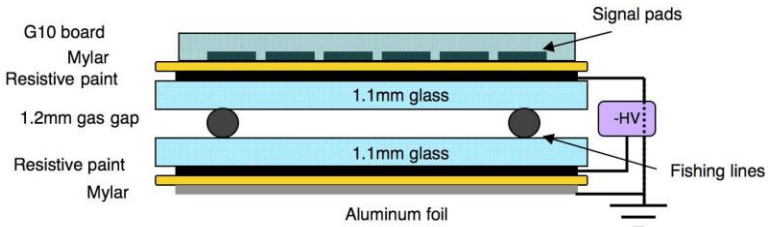
DHCAL Construction

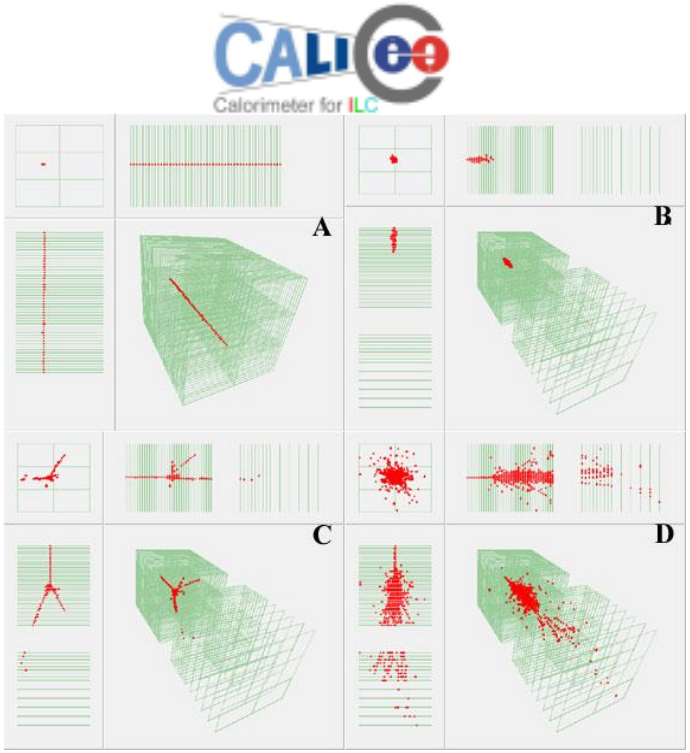


SiD Detector - Hadron Calorimeter









RPC has been SiD Baseline

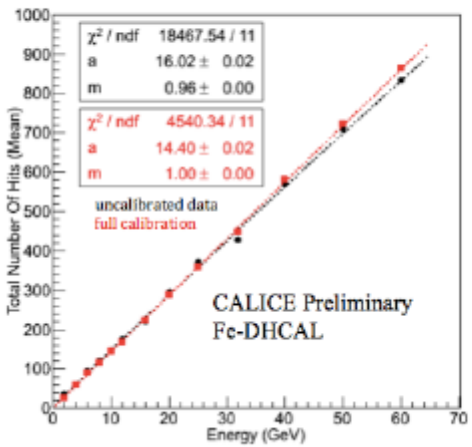
Test Beam	Muon events	Secondary beam
Fermilab	9.4 M	14.3 M
CERN	4.9 M	22.1 M
TOTAL	**14.3 M**	**36.4 M**

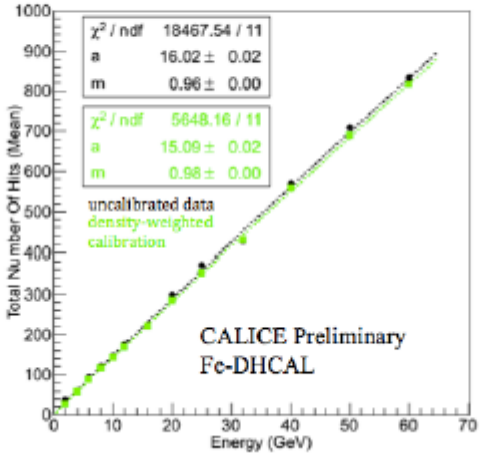
SiD Detector - Hadron Calorimeter - RPC

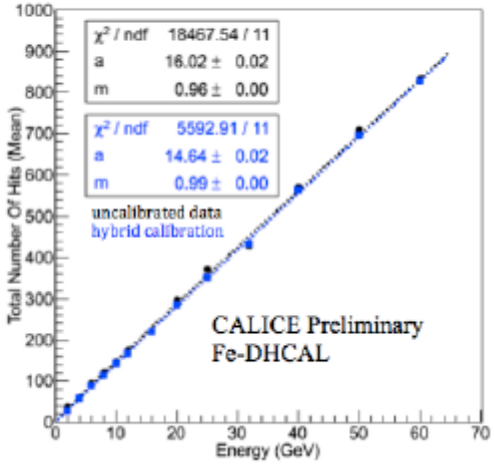
Linearity of pion response: fit to aE^m

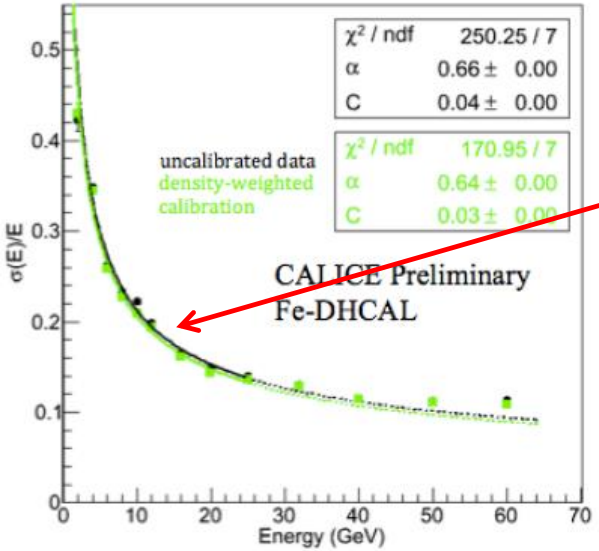
Many results!

Some examples:





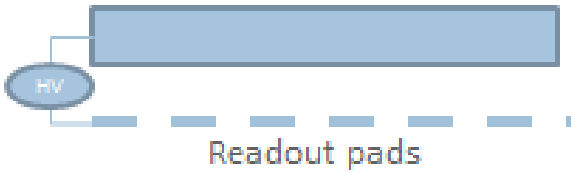




Calibration somewhat improves pion resolution

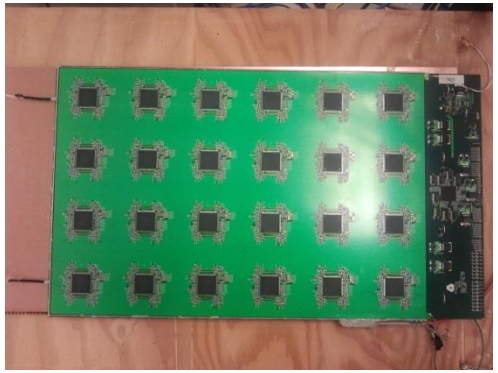
SiD Hadron Calorimeter – RPC new

1-glass RPCs



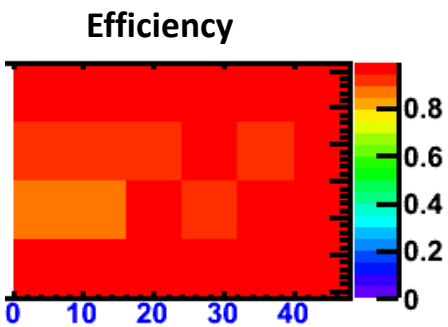
Offers many advantages

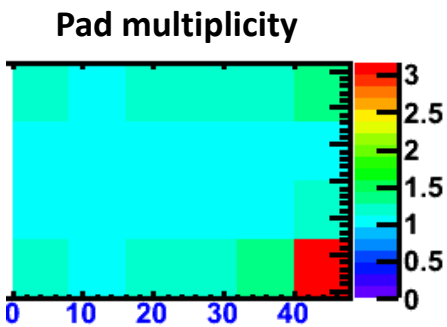
Pad multiplicity close to one
→ easier to calibrate
Better position resolution
→ if smaller pads are desired
Thinner
→ saves on cost
Higher rate capability
→ roughly a factor of 2



Status

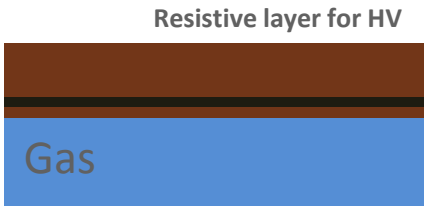
Built several large chambers
Tests with cosmic rays very successful
→ chambers ran for months without problems
Both efficiency and pad multiplicity look good





SiD Hadron Calorimeter – RPC new

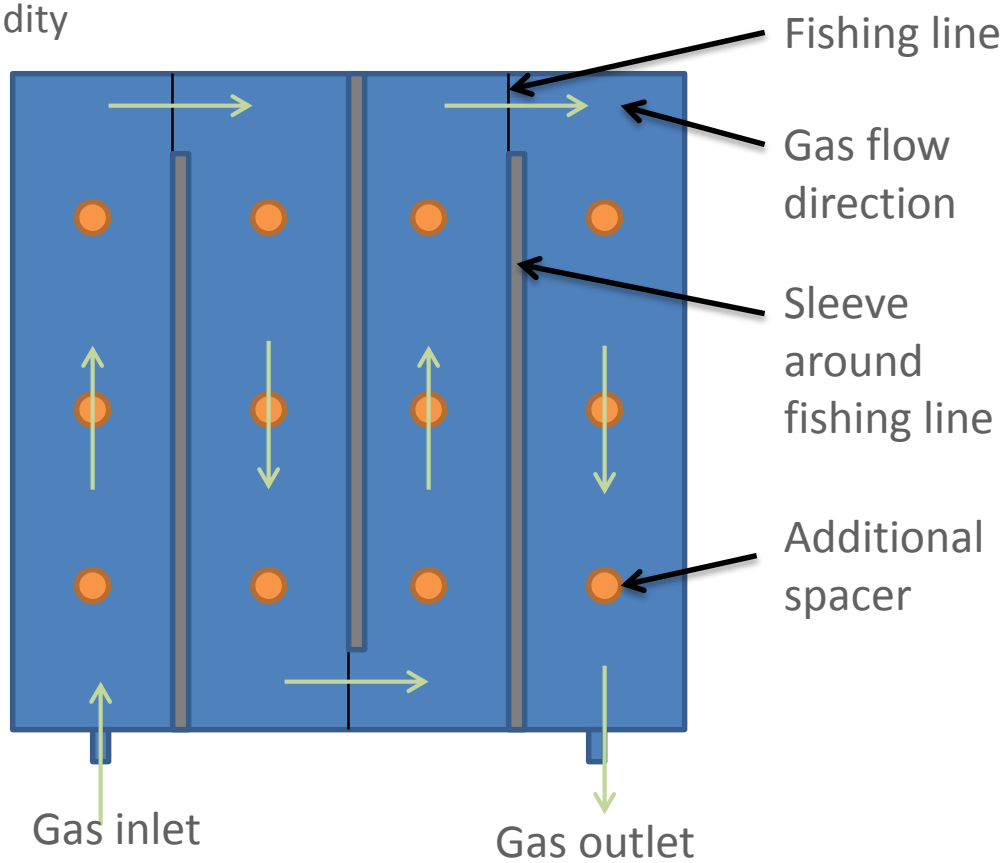
High-rate Bakelite RPCs



Bakelite does not break like glass,
is laminated
but changes R_{bulk} with dependence on humidity
but needs to be coated with linseed oil

Use of low R_{bulk} Bakelite with
$R_{bulk} \sim 10^8 - 10^{10}$ and/or Bakelite
with resistive layer close to gas gap

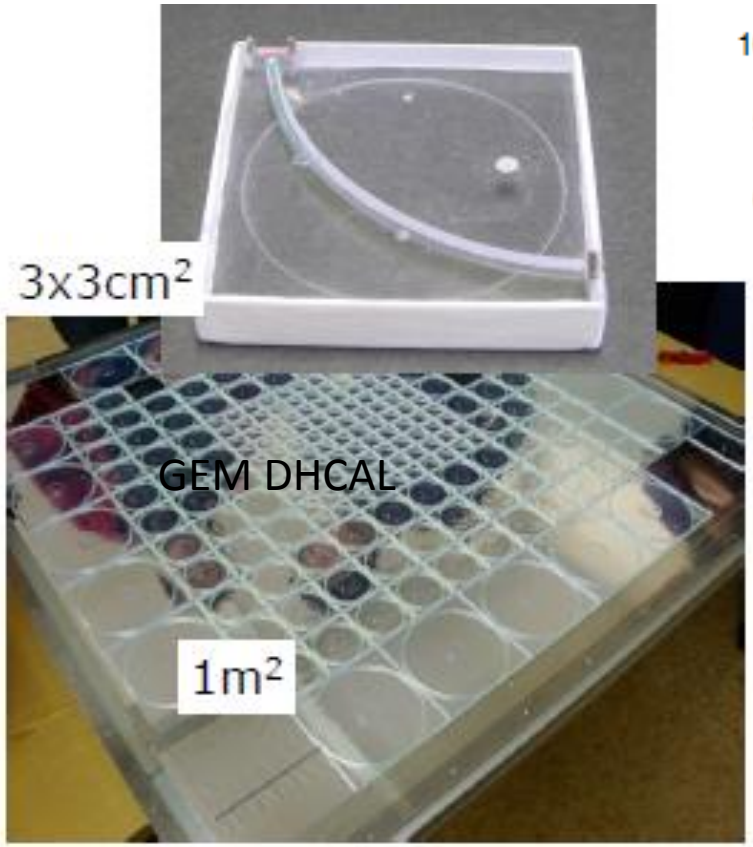
Several chambers built at ANL

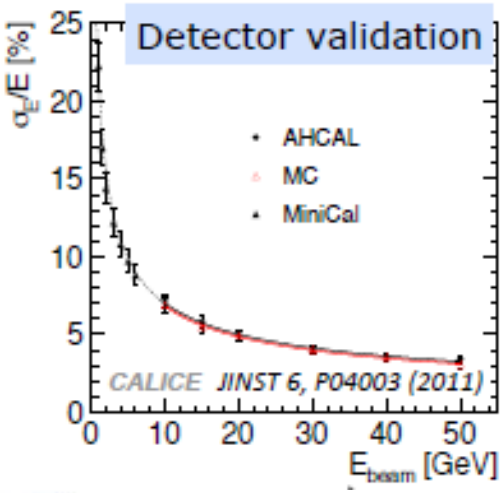


⇨ All activity is now stopped on the RPC-DHCAL

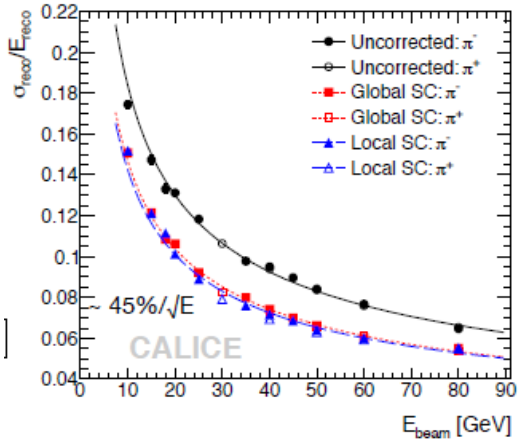
SiD Hadron Calorimeter - Options

Scintillator AHCAL

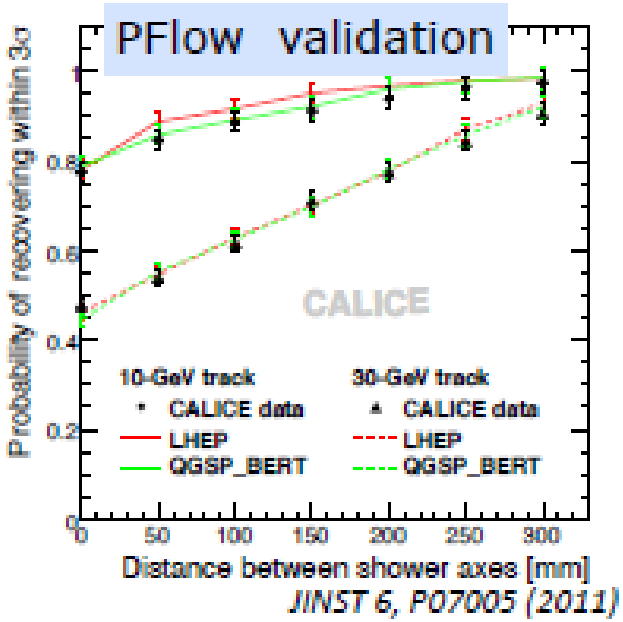




e- JINST 6 P04003 (2011)

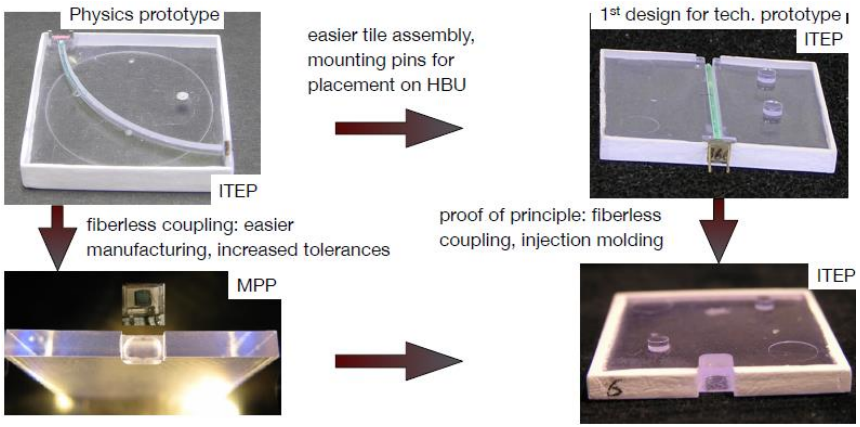


hadron JINST 7 P09017 (2012)

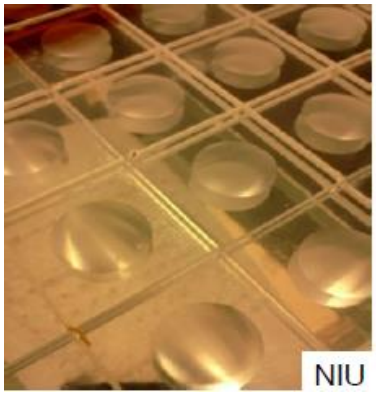


SiD Hadron Calorimeter - Options

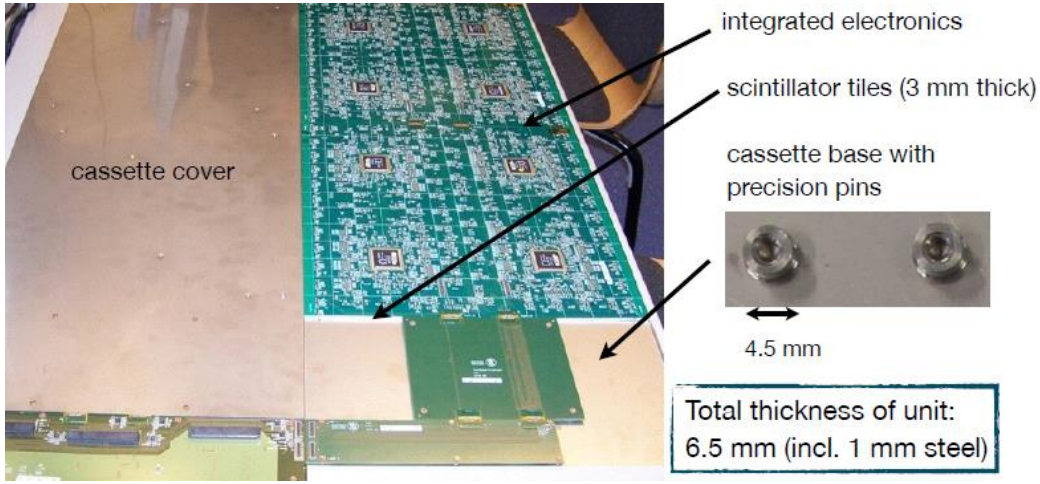
Tile evolution



"Megatile"

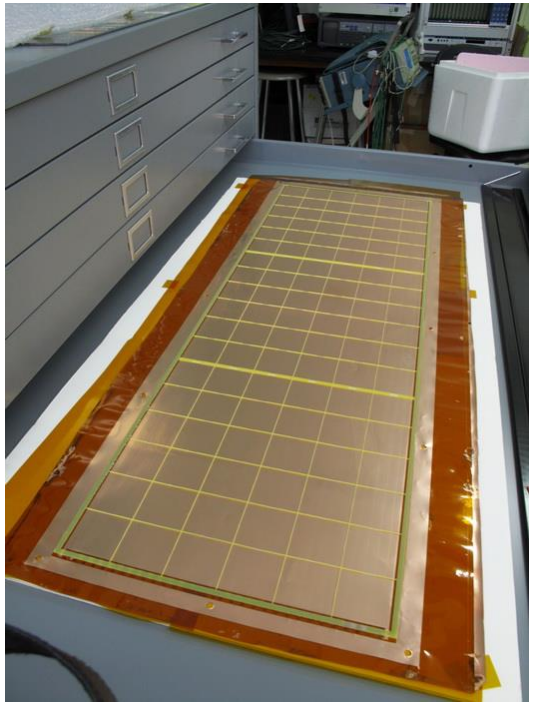


Large-scale production - automation

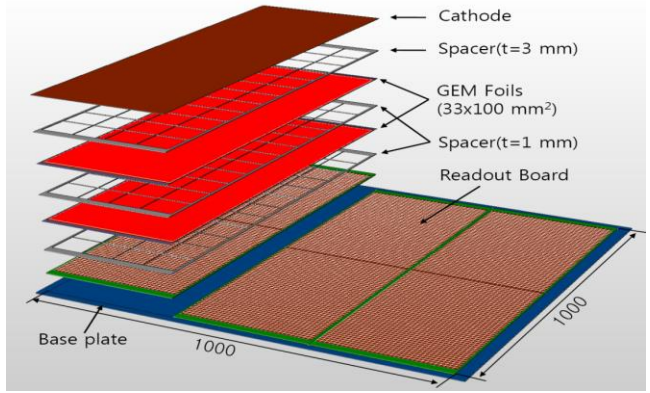


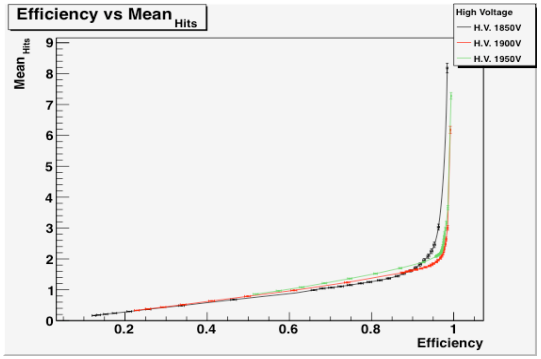
⇨ Study the scintillator AHCAL as a possible technology for SiD HCal

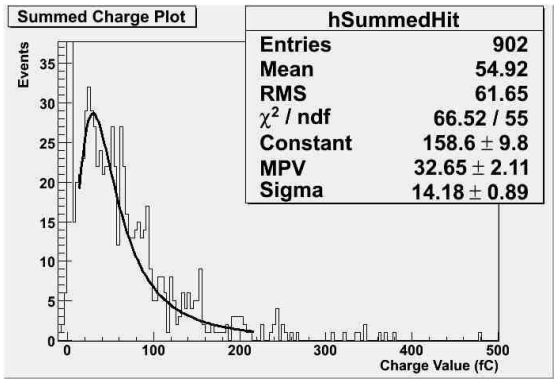
SiD Hadron Calorimeter - Options

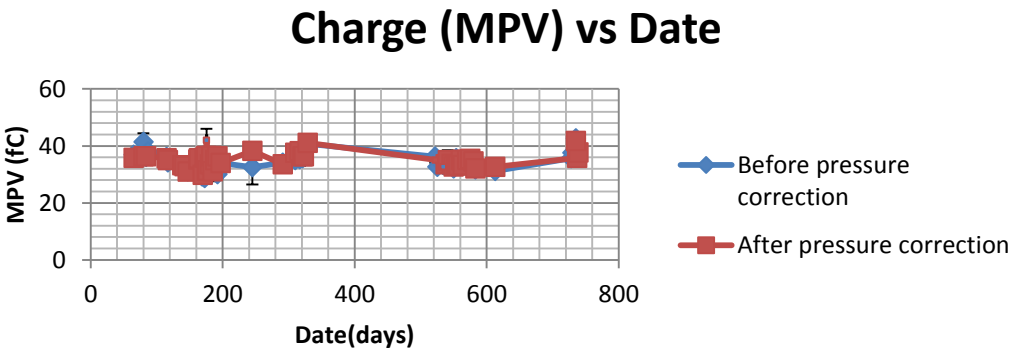


GEM DHCAL





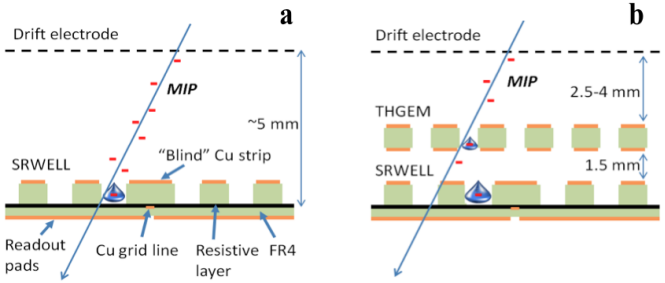


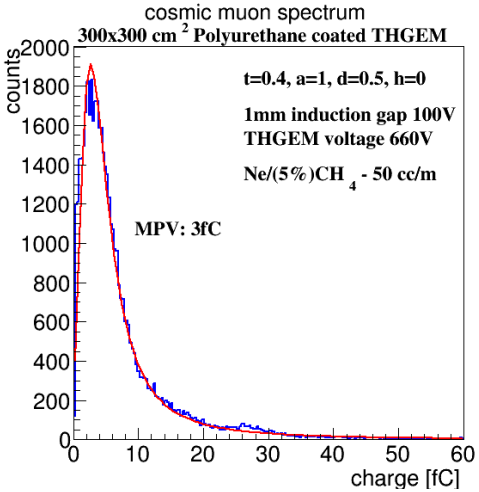


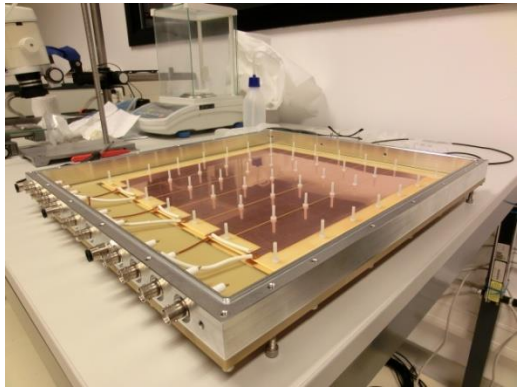
⇨Stalled by lack of detector R&D support

SiD Hadron Calorimeter - Options

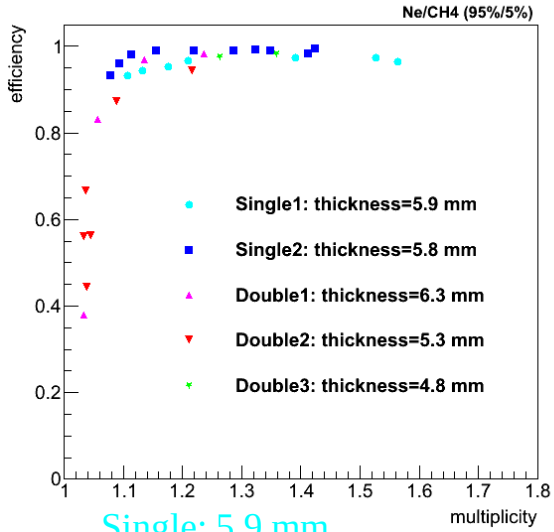
ThickGEM







The DHCAL requirements were met



Single; 5.9 mm
Single; 5.8 mm
Double; 6.3 mm
Double; 5.3 mm
Double; 4.8 mm

(Near) future plans

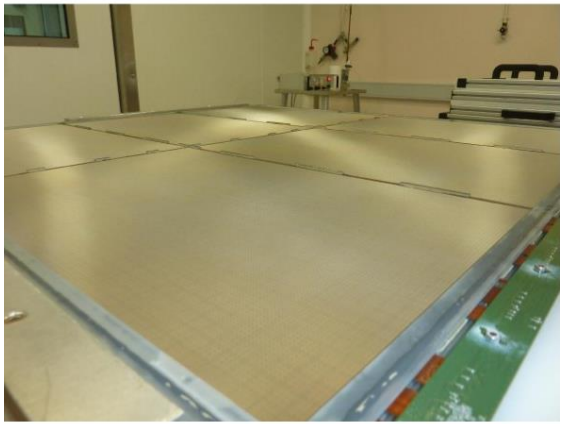
Build meter-scale single-stage detector
- One prototype in collaboration with Israeli industry
- Prototype(s) to test within CALICE's DHCAL module

Study extensively THGEM concepts with broader dynamic range
- RPWELL **Rubin 2013 JINST 8 P11004**
- Using newly developed techniques **Bressler 2014 JINST 9 P03005**
- Test in beam of 100 x 100 mm^2 prototype

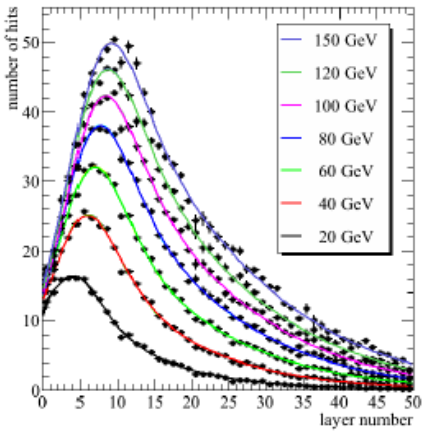
⇨ Development of large boards? Tiling, dead regions?

SiD Hadron Calorimeter - Options

CALICE Calorimeter for ILC



Micromegas

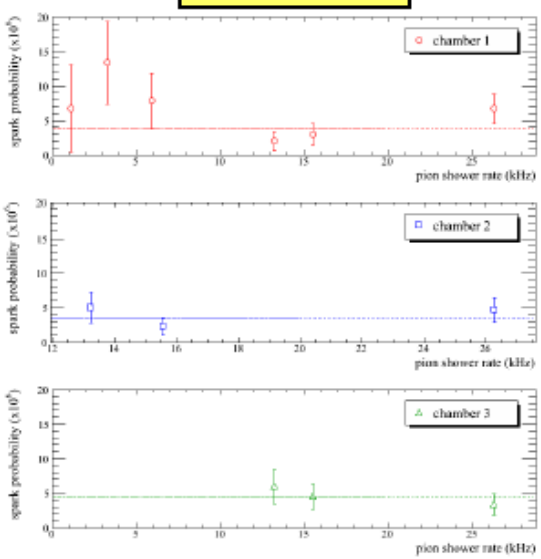


→ *1x1 m² large-area prototype "phase-space" explored (2nd paper submitted)*

The construction of an even larger prototype is not justified.

(functional chaining test of 4 un-Bulked MICROROC ASUs (2 m long SLAB) successful)

Sparks VS Rate



→ *Sparks can be suppressed with R-layers*

Signal linearity seems preserved up to 5 GeV (for electrons) but...
Is linearity preserved at higher energies?

Consequence on rate capability observed & understood.
What is the minimum resistivity necessary to insure protection against sparks?

→ Further prototyping (lower resistivity) & testbeams necessary.

Roadmap 2014-2015

Complete the resistive Micromegas R&D: optimise R-layer for calorimetry.

Prototyping (2014), testbeam (2015).

SiD Hadron Calorimeter - Options

A number of technologies have demonstrated the essential characteristics required for hadronic calorimetry as part of an integrated PFA-based system.

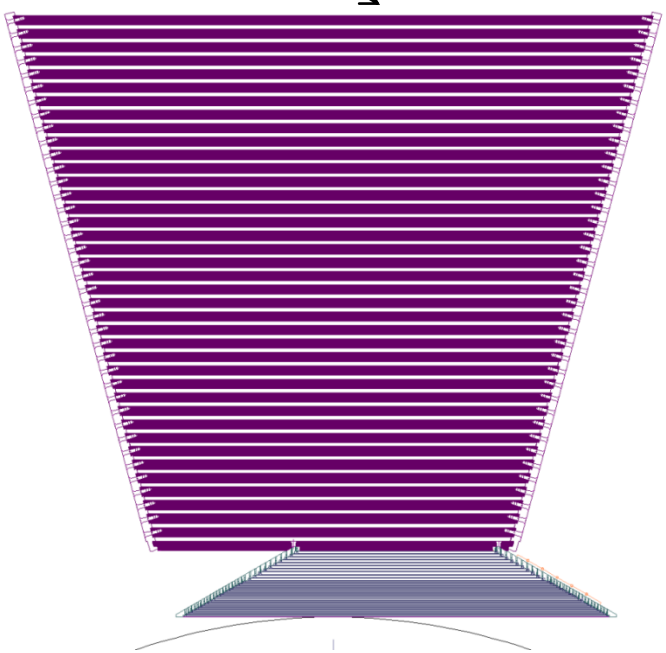
Technology selection will focus on:

- Efficiency/hit multiplicity performance
- Scalability of technology
- Robustness of technology
- Assembly issues
- Cost/m^2
- Long –term performance/stability
- Calibration issues (initial, ongoing)
- % dead regions
- Barrel/endcap rate requirements
- Compatibility with other subsystems
- Maintenance/access requirements

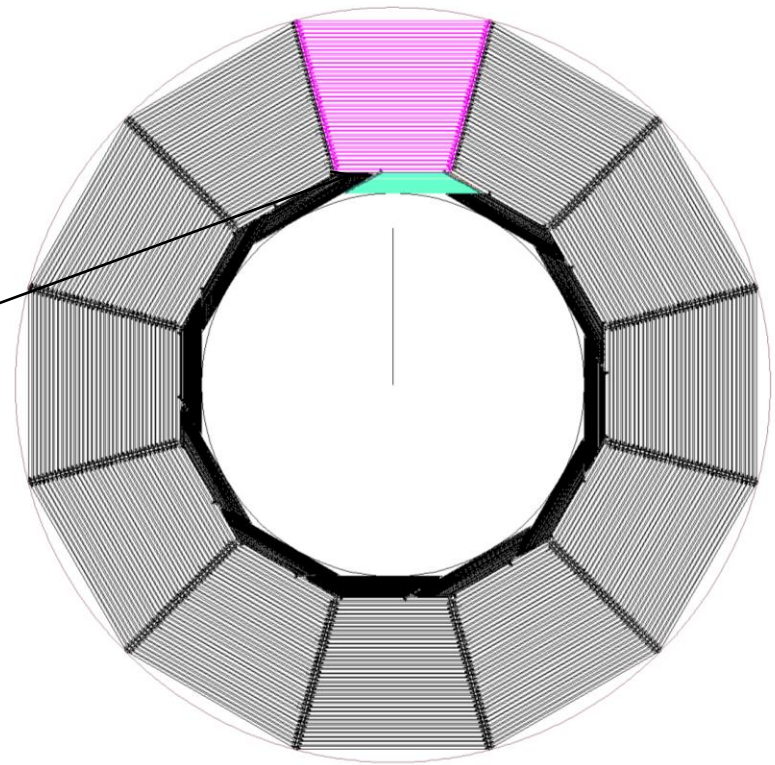
SiD Calorimeter - mechanics

ECAL module is built on first layer of HCal

HCAL module supports ECAL module



Note module overlap: No gaps; service cables at ends.



SiD Calorimeter System Questions

The basic calorimeter system design is 10 years old.
And we know (see the DBD) that we can deliver good results for the ILC Physics program, but…

-Is the present ECal + HCal arrangement optimized for PFA?
- If we started with our present knowledge from PFA studies, would we arrive at the same calorimeter system design?
- Is the aspect ratio optimized?
- Are the ECal and HCal depths optimized?
- What are the optimum cell sizes for ECal, HCal?
- What are the issues with a detailed (= realistic) implementation of the HCal in the SiD simulation?

SiD Calorimeter System
New Ideas ??

- Can we design a better integrated tracking/calorimeter system oriented for PFA

- Layer to layer intelligence – PFA ?

- How much of the PFA can we move into the “front-end”?

- For ILC, we have a large time interval (199ms) between bunch crossings – can we use this for PFA style processing?

- Could we use continuous feedback to do on-the-fly calibrations?

- What have we missed?

SiD Calorimeter System Conclusions

We have a number of alternative technology choices for HCal.

How do we best optimize the design and implementation of the system?

Are there new ideas we should consider/test before embarking on the TDR?

We welcome your ideas and input!

Let us know if you would like to join this work in any aspect.