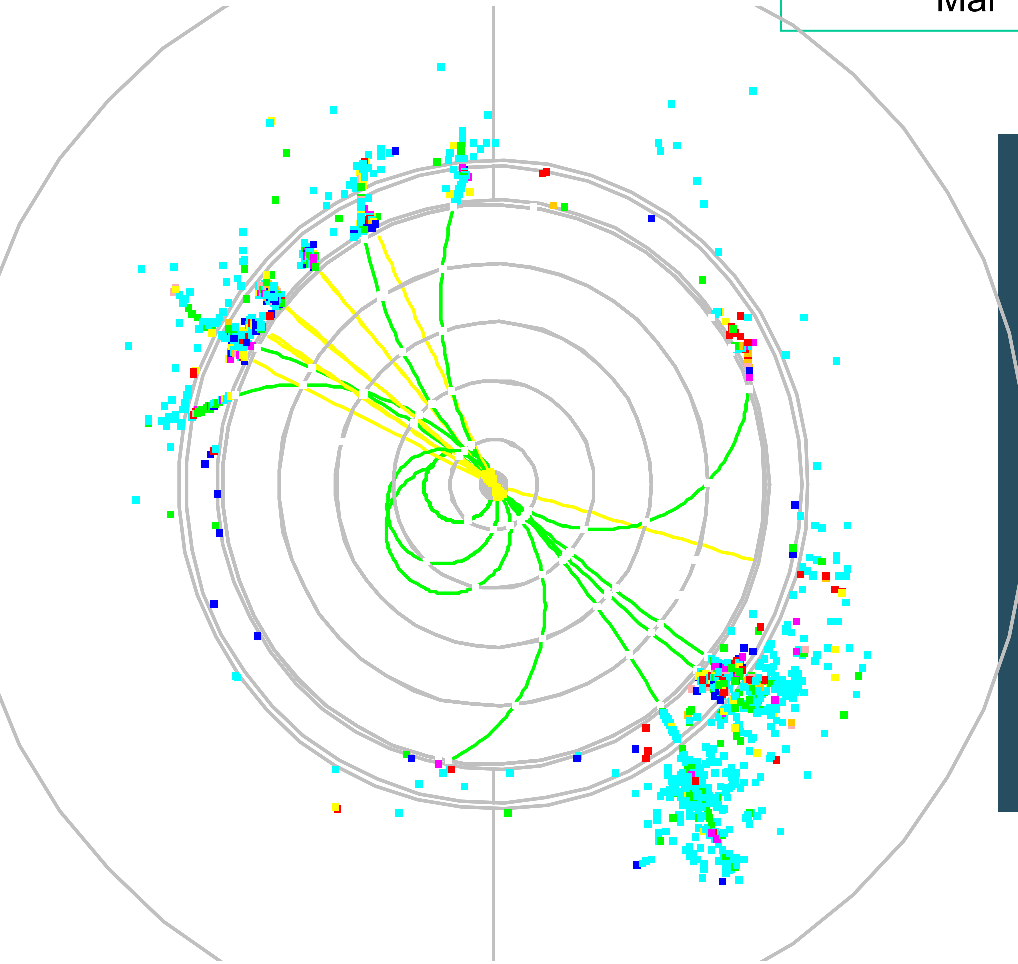
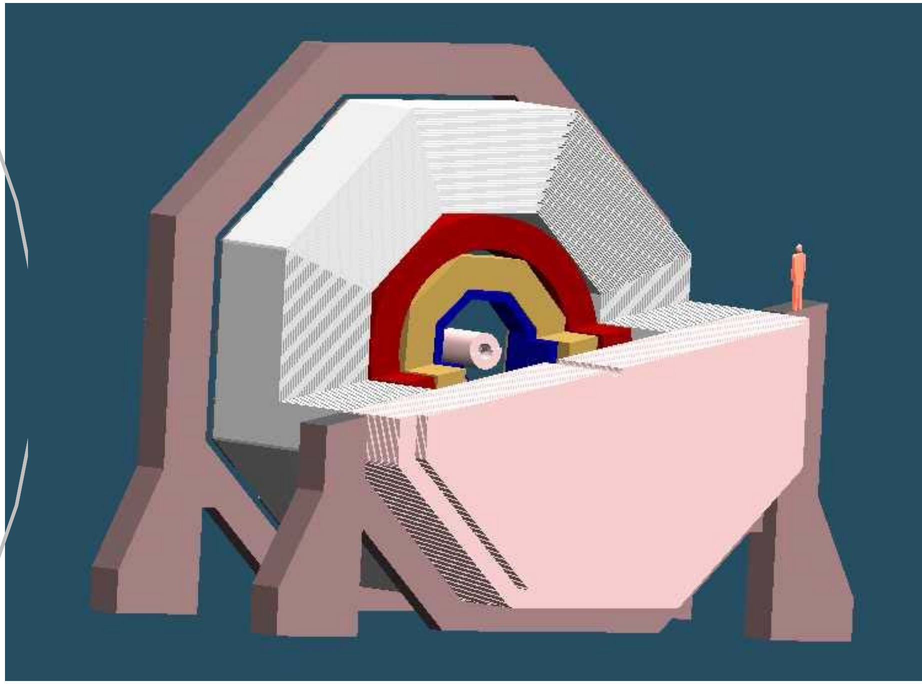
SiD Calorimetry: “Technical Progress Report”

R. Frey and Jose Repond

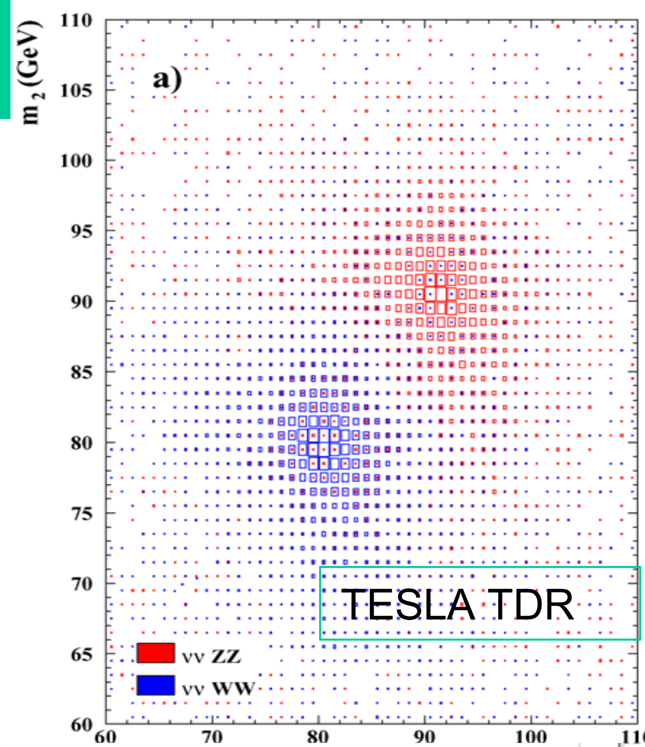
SiD Meeting, SLAC

Mar 17, 2005

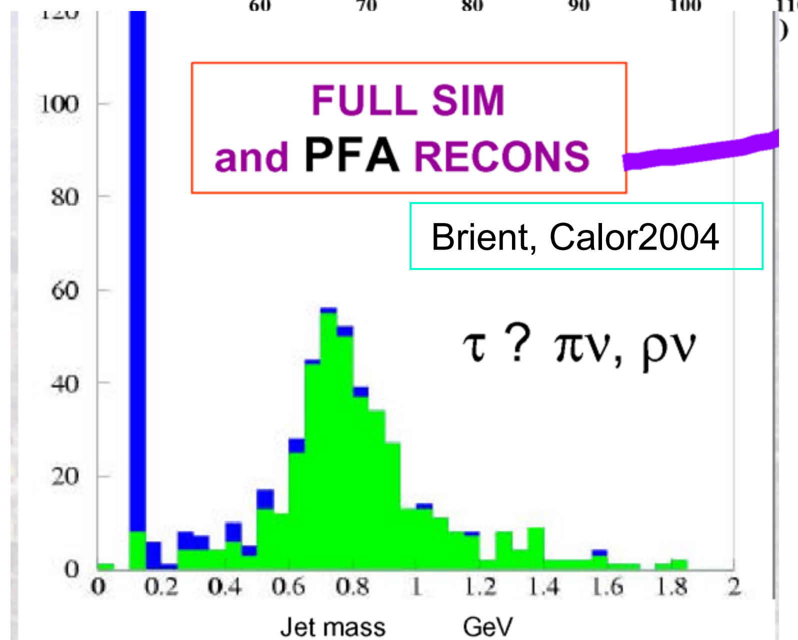




calorimeter requirements



- Must be ready to reconstruct *new* final states…
- which will include:
  - Multi-jet final states
    - With or without beam constraint
  - Leptons
    - *including* tau
  - Heavy quarks
  - Missing energy/mass
  - *Combinations of these*
  - (non-pointing) neutrals
- And in addition, we need to provide:
  - Bhabha recon.: x, E (endcaps)
  - very far forward e- tags



general (contd)

1. Charged particles in jets more precisely measured in tracker
2. Jet energy 64% charged (typ.)

Separate charged/neutrals in calor.

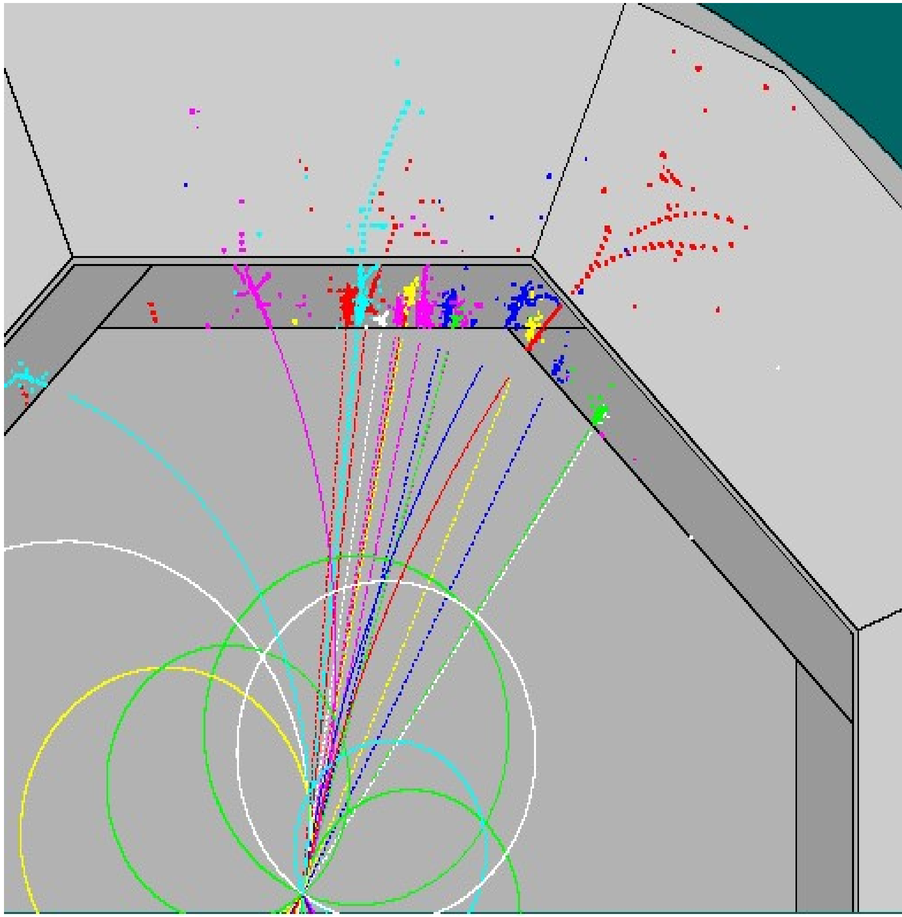
⇒ The “Particle Flow” paradigm

In this case, jet energy resolution (at the LC) will be dominated by pattern recognition (“confusion”).

And this resolution will be quite good, $\sim 0.3 / \sqrt{E}$.

So the emphasis is on “imaging”:

- ECAL: dense, highly segmented
- HCAL: highly segmented (, dense)



H. Videau

Standard SiD

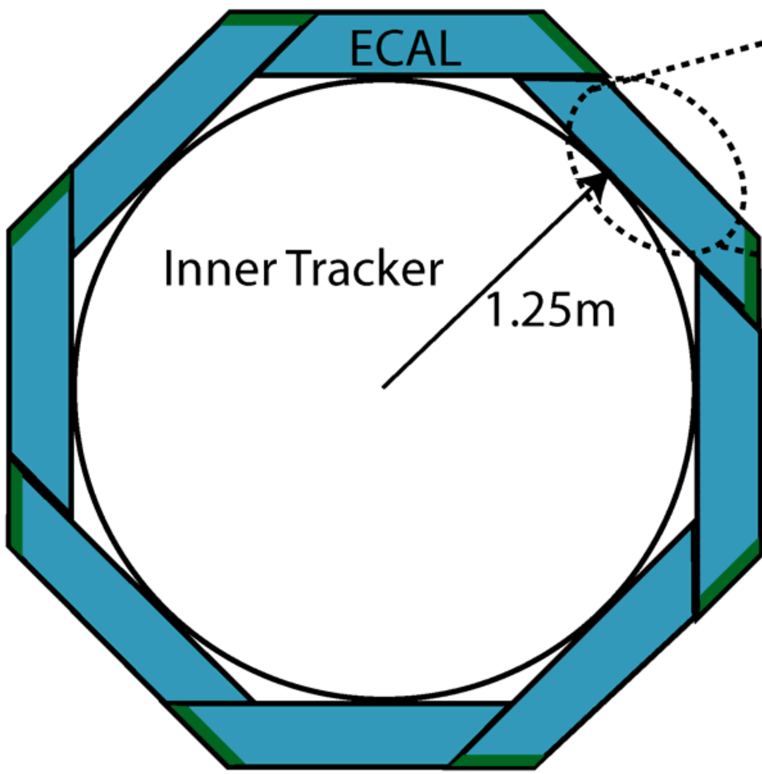
- ECal
  - Silicon – tungsten
  - 20 x 5/7 X0 + 10 x 10/7 X0
  - 16 mm^2 pixels
  - 1 mm gaps
- HCal (digital)
  - RPCs, GEMs (, scint. tiles)
  - $\approx 4\ \lambda$: 34×2 cm Fe (W ?)
  - RPCs and GEMs: $\approx 1\ cm^2$ "pixels"
  - RPCs: few mm gaps

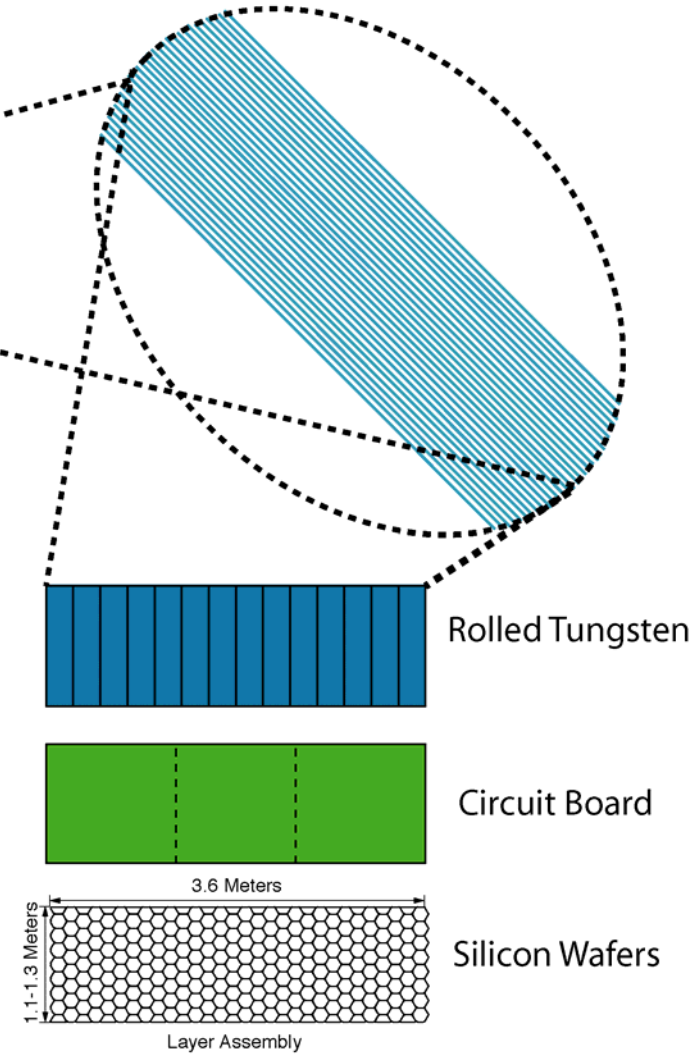
Glass RPCs are the leading technology, but pursuing >1 technology to address different potential concerns:

- cost
- reliability
- rate capability
- hit multiplicity
- ease of construction and assembly

Si-W Concept – SiD version

Si-W Calorimeter Concept



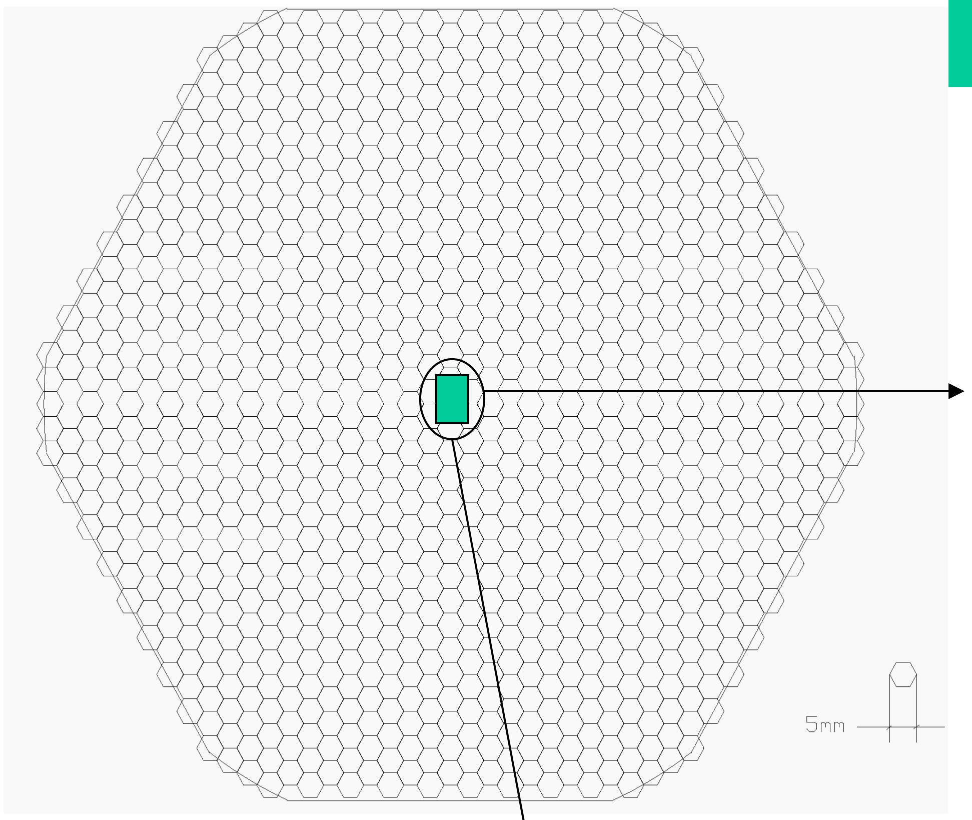


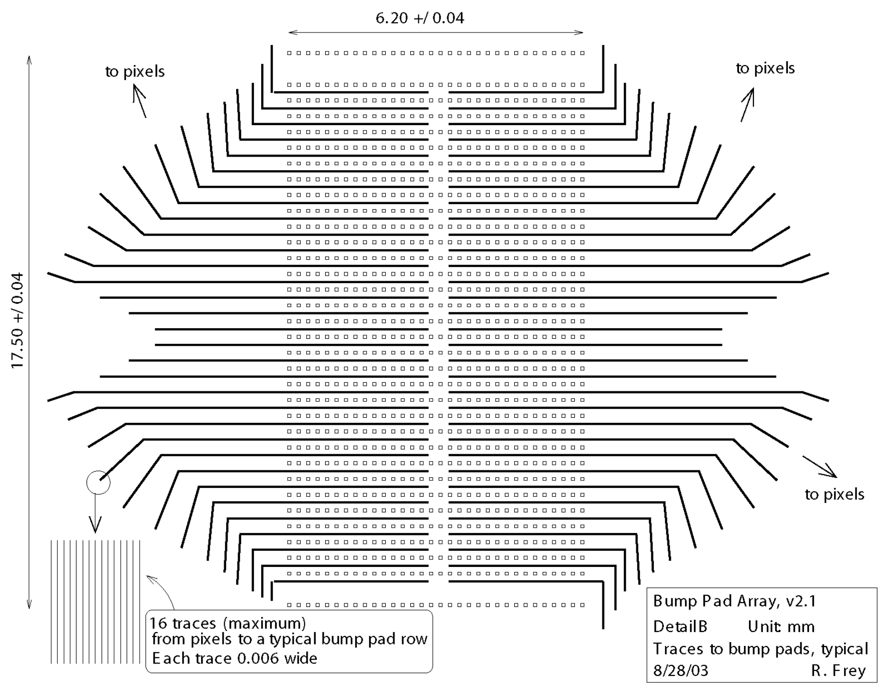
Transverse Segmentation ~5mm

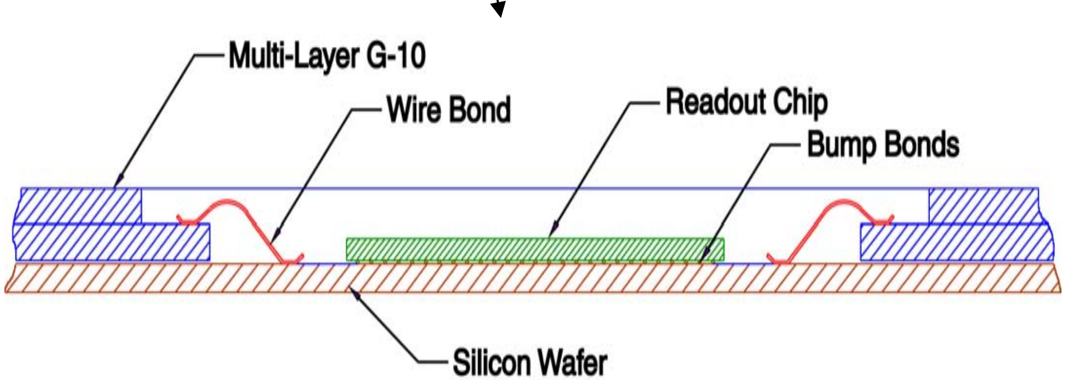
30 or fewer long. samples

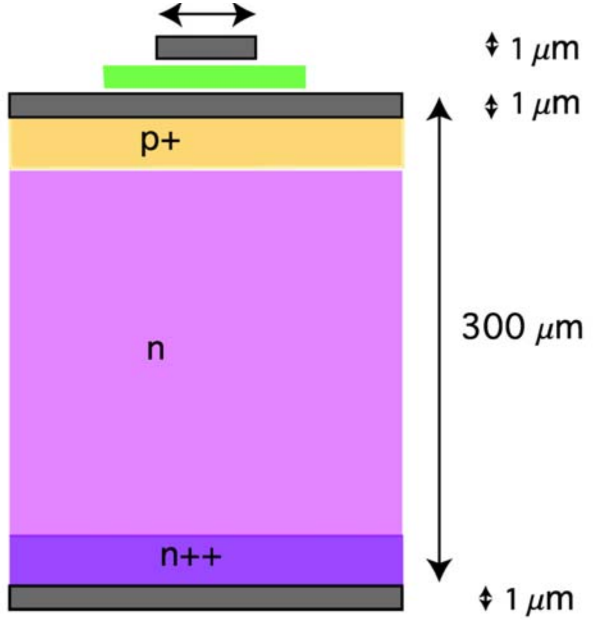
Energy Resolution ~15%/$E^{1/2}$

Wafer and readout chip









SiD Si/W Features

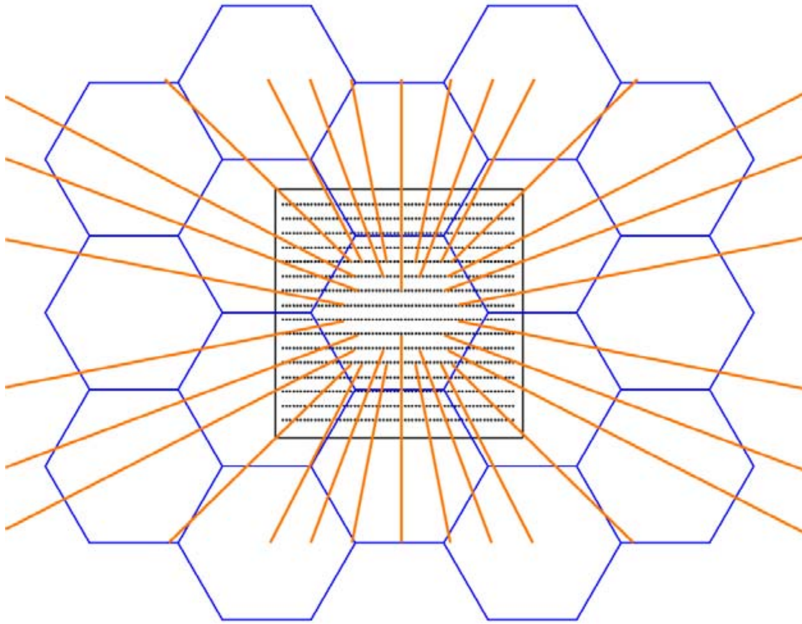
- "Channel count" reduced by factor of 10^3
- Compact – thin gap ~ 1mm
  - Moliere radius 9mm → 13 mm
- Cost nearly independent of transverse segmentation
- Power cycling – only passive cooling required
- Dynamic range OK
- Readout at pixels:
  - Low capacitance
  - Good S/N

Current configuration:

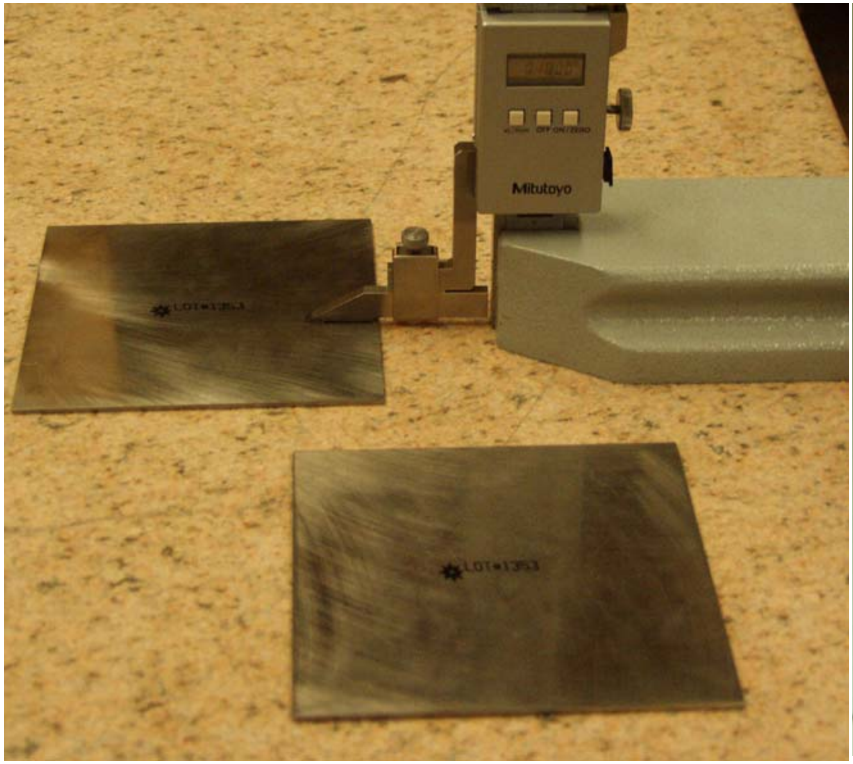
- 5 mm pixels (16 mm^2)
- 30 layers:

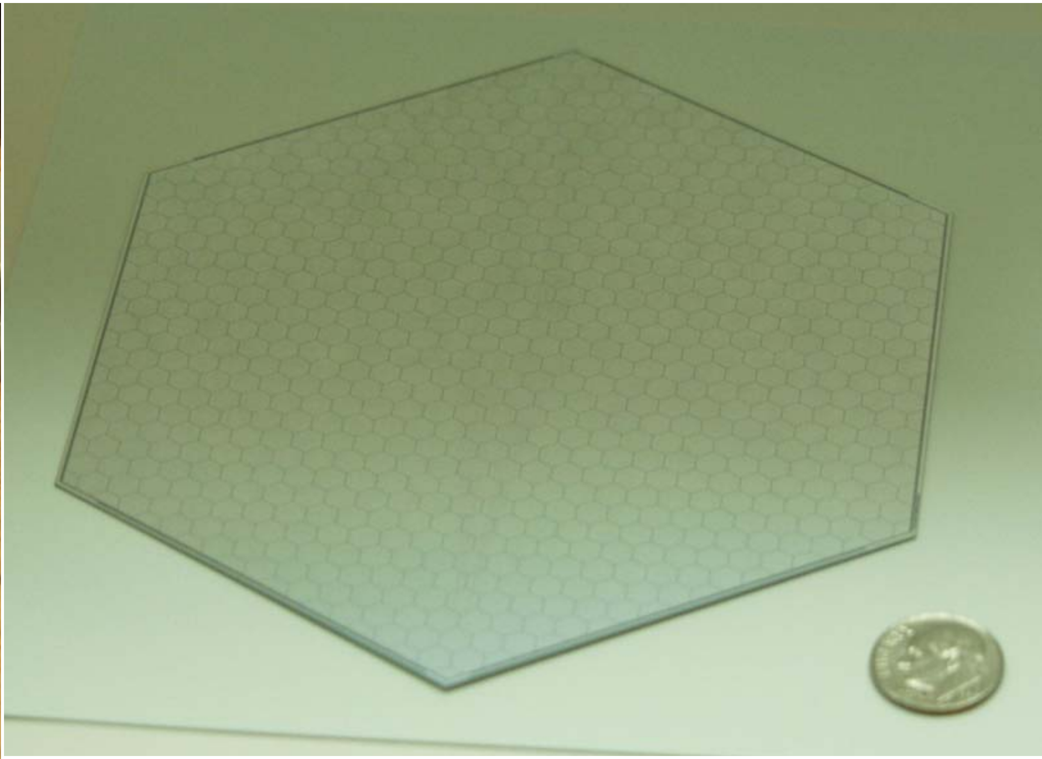
  20 x 5/7 X0 +

  10 x 10/7 X0



Components





<u>Tungsten</u>

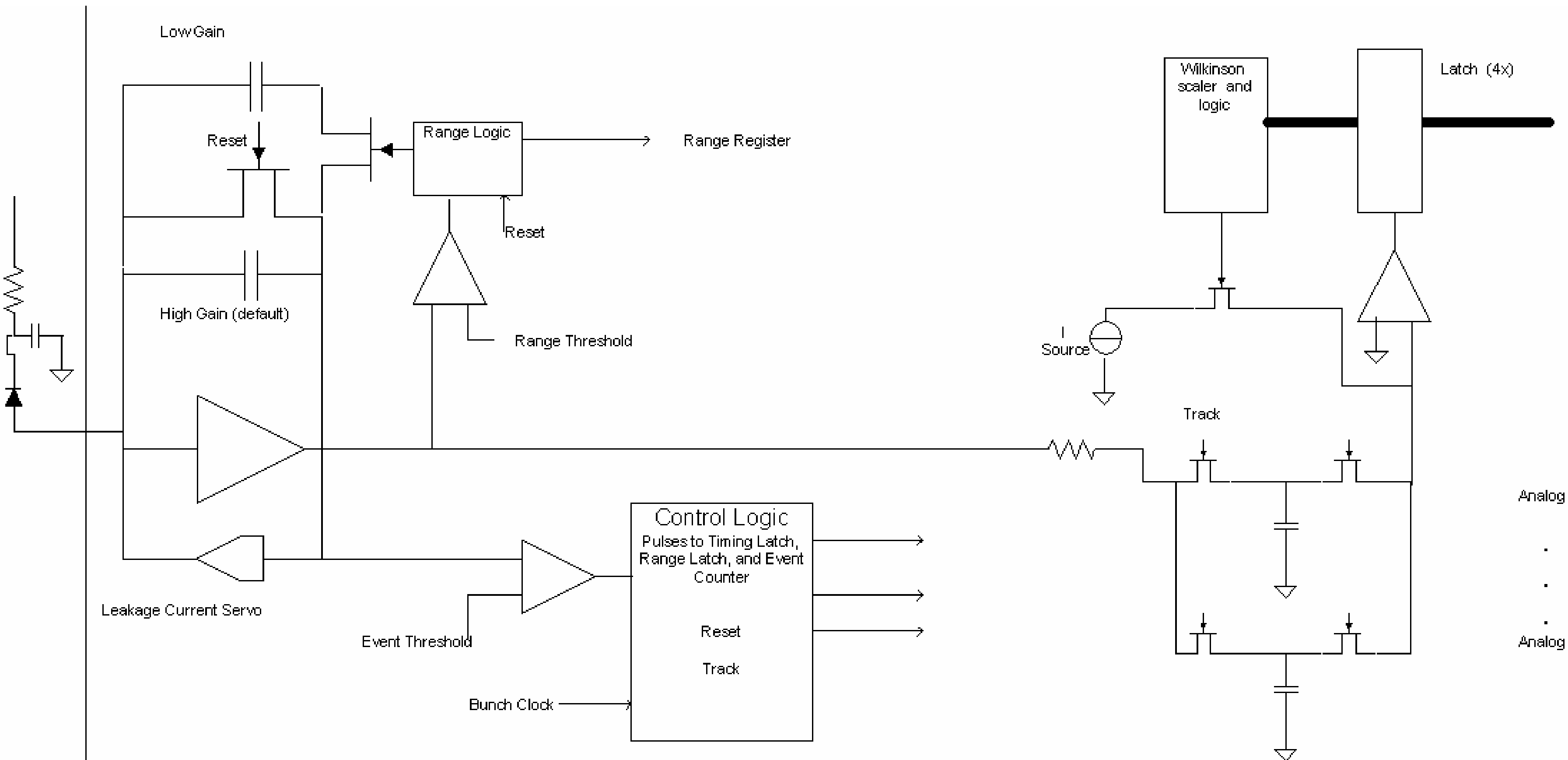
- Rolled 2.5mm
  - down to 1mm OK
- Very good quality
  - < 30 µm variations
- 92.5% W alloy
- Pieces up to 1m long possible

<u>Silicon</u>

- Hamamatsu detectors (10)
- Compatible with design concept for LC ECal (pixel size, traces, bump-bonding pads, etc)
- Lab tests look fine

Electronics for a Cold LC

D. Freytag, V. Radeka, M. Breidenbach

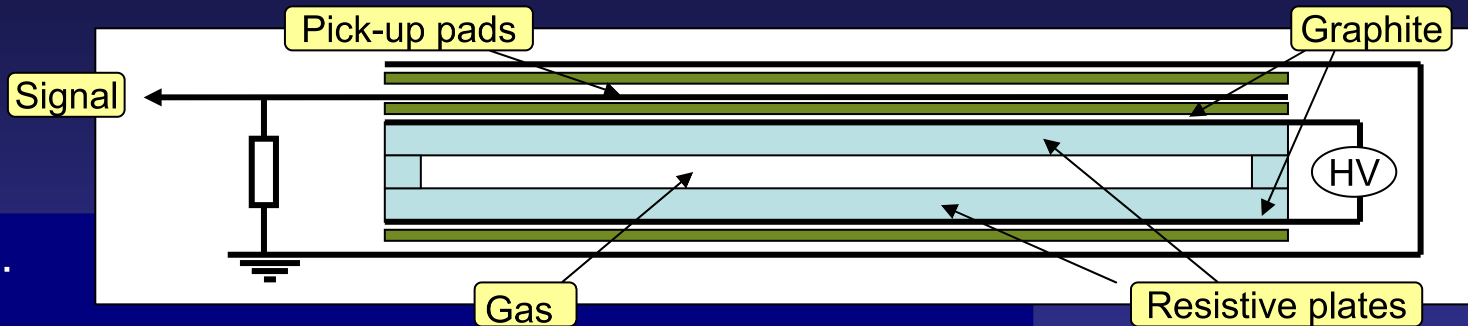


Simplified Timing

There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits).
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier output. (~150 ns)
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the signal at T0 is held on the Sample Capacitor .
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an event, while the high gain (small) capacitor is reset each bunch crossing (except while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.

Glass RPCs



RPCs are…

simple, robust, cheap, quiet, well understood, reliable
adaptable to different requirements (TOF, high efficiency, large area…)

Name	**Area** [cm^2]	**# of gas gaps**	**# of glass plates**	**Glass thickness** [mm]	**# of graphite layers**	**Surface resistivity** [MΩ/□]
Air0	20 x 20	2	3	0.85	2	0.3
Air1	20 x 20	2	3	1.1	2	0.2
Air2	20 x 20	2	3	1.1	2	1.2
Air3	20 x 20	1	2	1.1	2	1.0
Air4	20 x 20	1	2	1.1	2	1.0 + 50
Air5	20 x 20	1	2	0.85	2	1.5 + 2.4
Air6	30 x 91	1	2	1.1	2	1.5 + 2.5
Air7	20 x 20	1	2	1.1	1	1.0
Air8	20 x 20	1	2	1.1	0	0
Air9	20 x 20	1	1	1.1	0	0

Lei Xia's

Conclusion

- We have built and tested over 10 RPCs, including a full size prototype chamber
- We did all the tests we planned to do:
  - Tests with single pad and multiple readout pad
  - Tests with analog and digital readout
  - Test of both large and small chambers
  - Test of rate capability
  - …
- We totally understand our detector, and we are ready to build RPCs for the $1m^3$ test beam section

Front-end ASIC

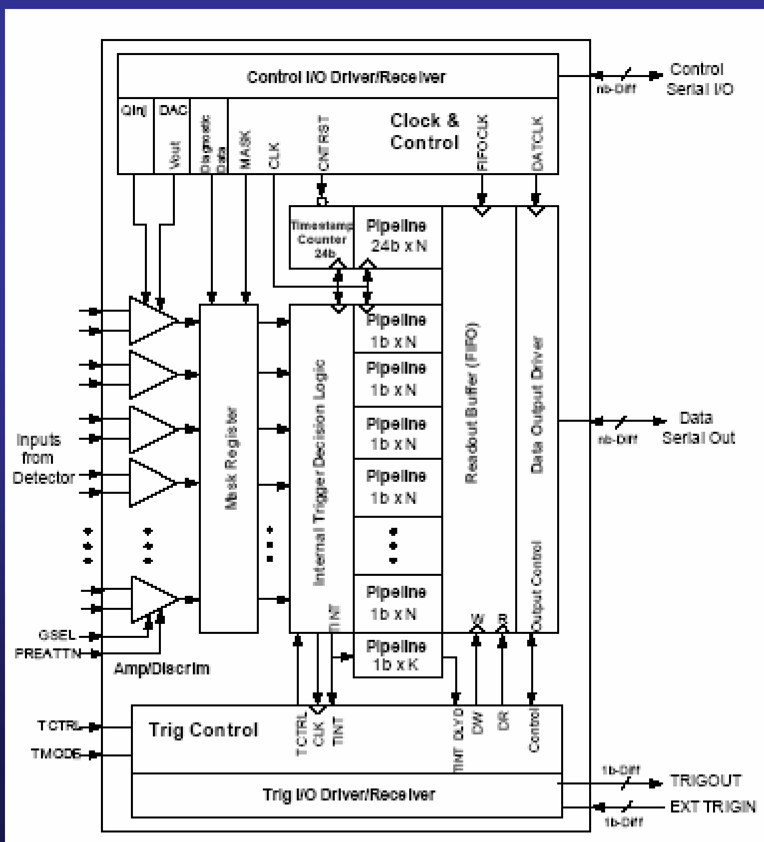
64 inputs with choice of input gains

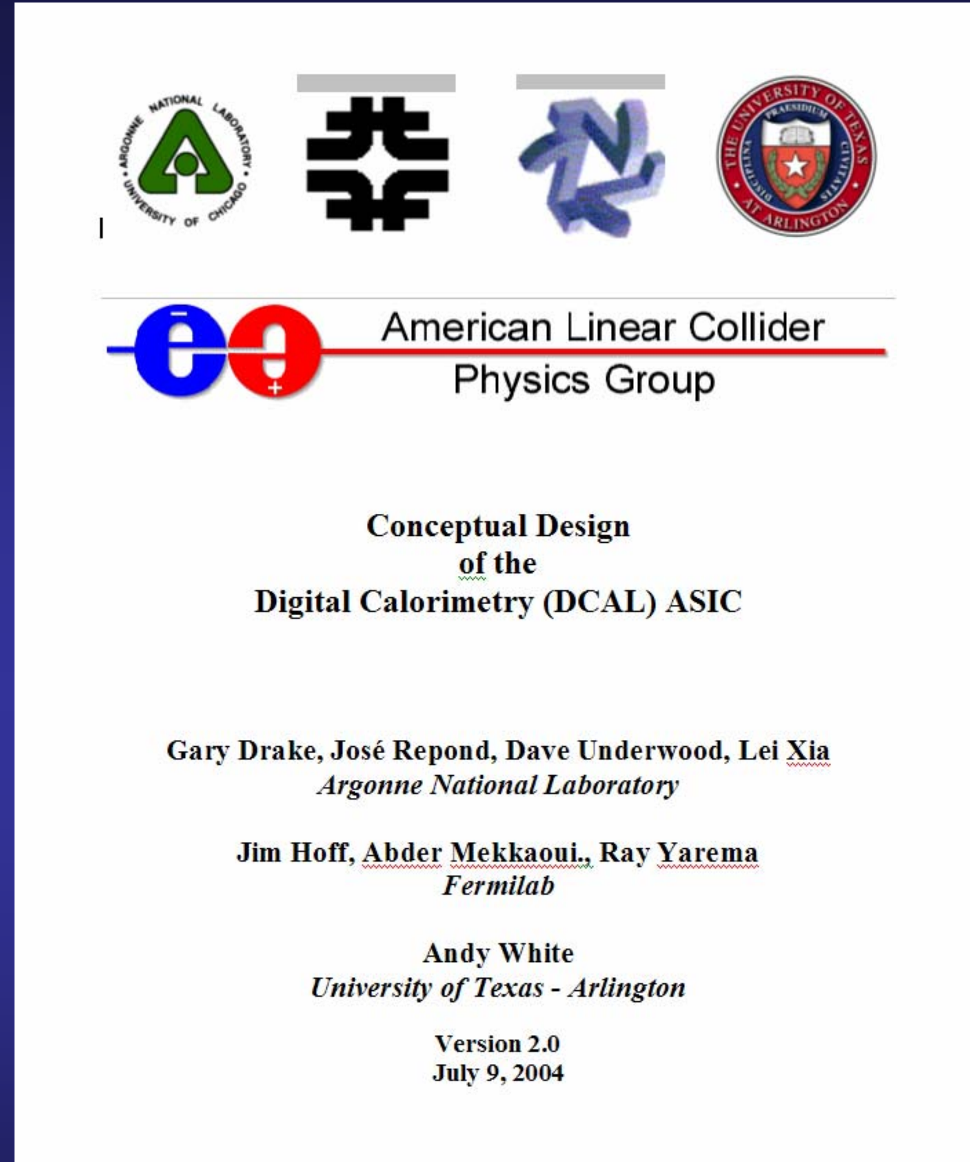
RPCs (streamer and avalanche), GEMs…

Triggerless or triggered operation

100 ns clock cycle

Output: hit pattern and time stamp





American Linear Collider Physics Group

Conceptual Design of the Digital Calorimetry (DCAL) ASIC

Gary Drake, José Repond, Dave Underwood, Lei Xia
Argonne National Laboratory

Jim Hoff, Abder Mekkaoui., Ray Yarema
Fermilab

Andy White
University of Texas - Arlington

Version 2.0
July 9, 2004

ASIC performance specified in 41 page document

GEMs

C. GEMs

Fig. 14 (a) Chemical etching Process of a GEM (b) A GEM foil

A new concept of gas amplification was introduced in 1996 by Sauli: the Gas Electron multiplier (GEM) [27] manufactured by using standard printed circuit wet etching techniques' schematically shown in Fig. 14(a). Comprising a thin (~50 µm) Kapton foil, double sided clad with Copper, holes are perforated through (fig. 15b). The two surfaces are maintained at a potential gradient, thus providing the necessary field for electron amplification, as shown in Fig. 15(a), and an avalanche of electrons as in Fig. 15(b).

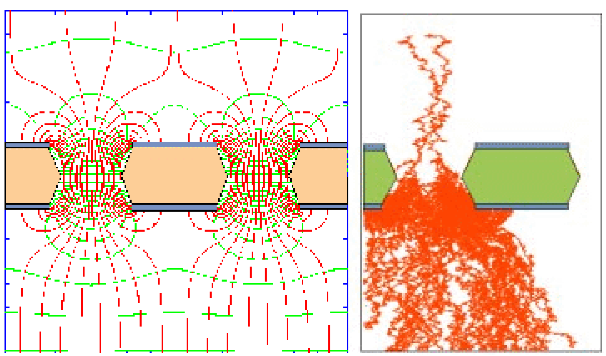
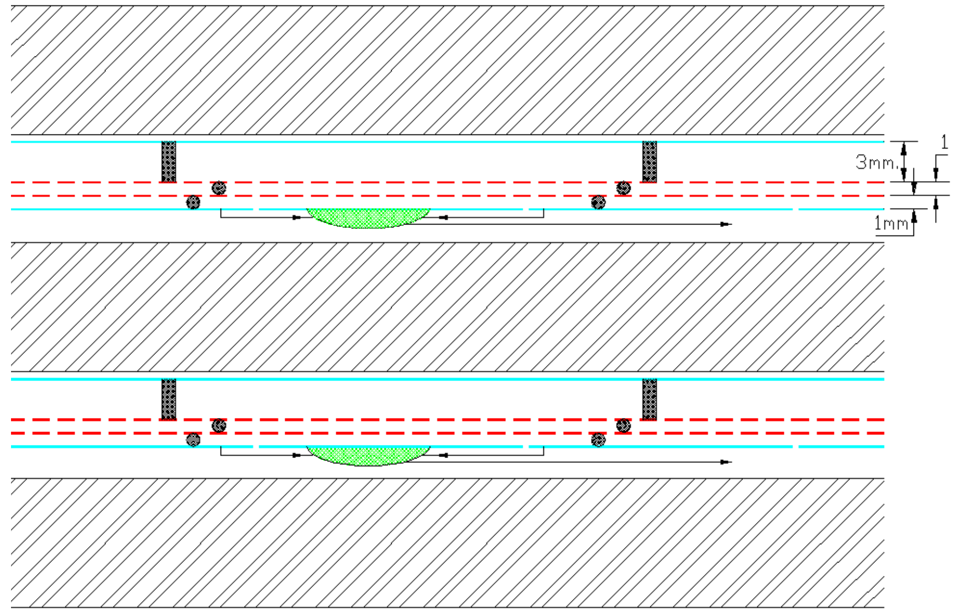


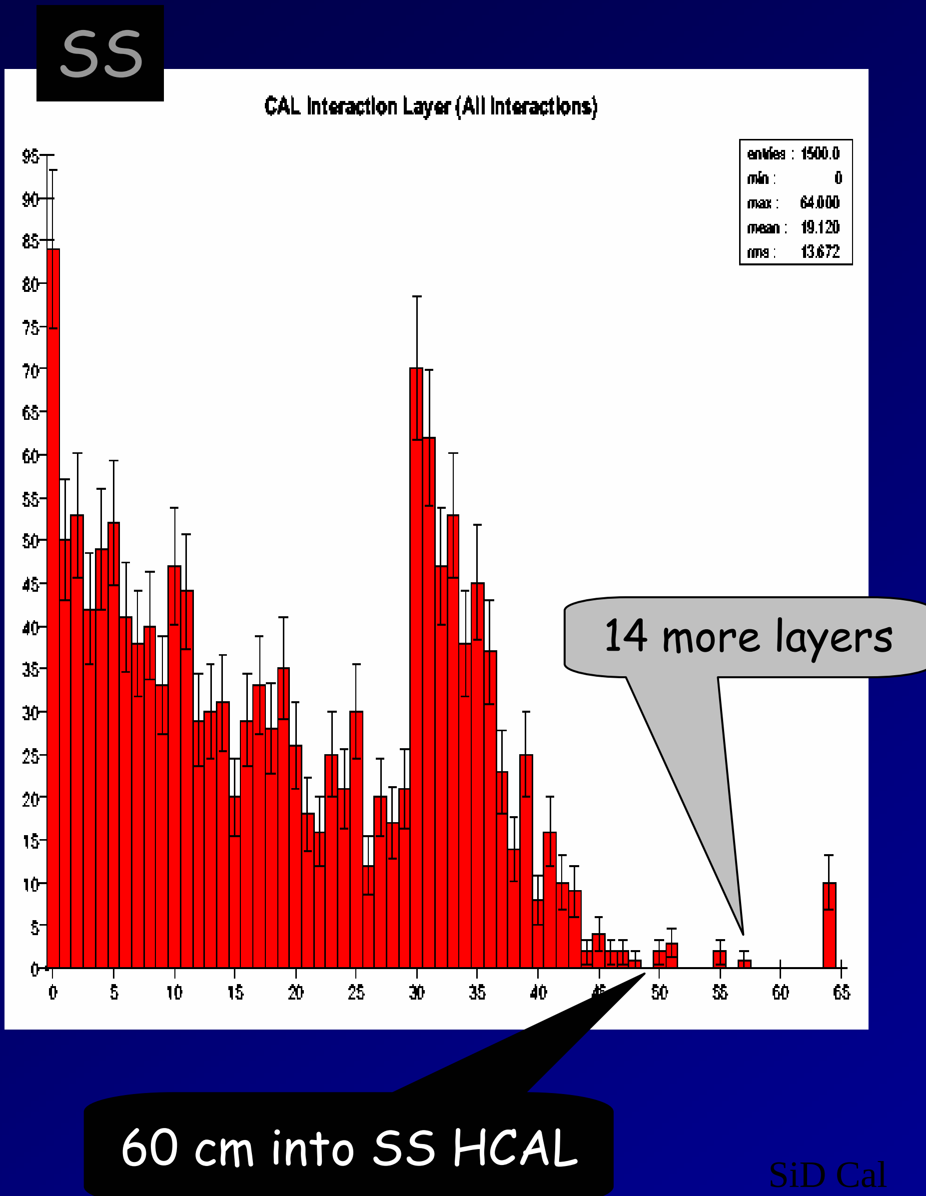
Fig. 15(a) Electric Field and (b) an avalanche across a GEM channel

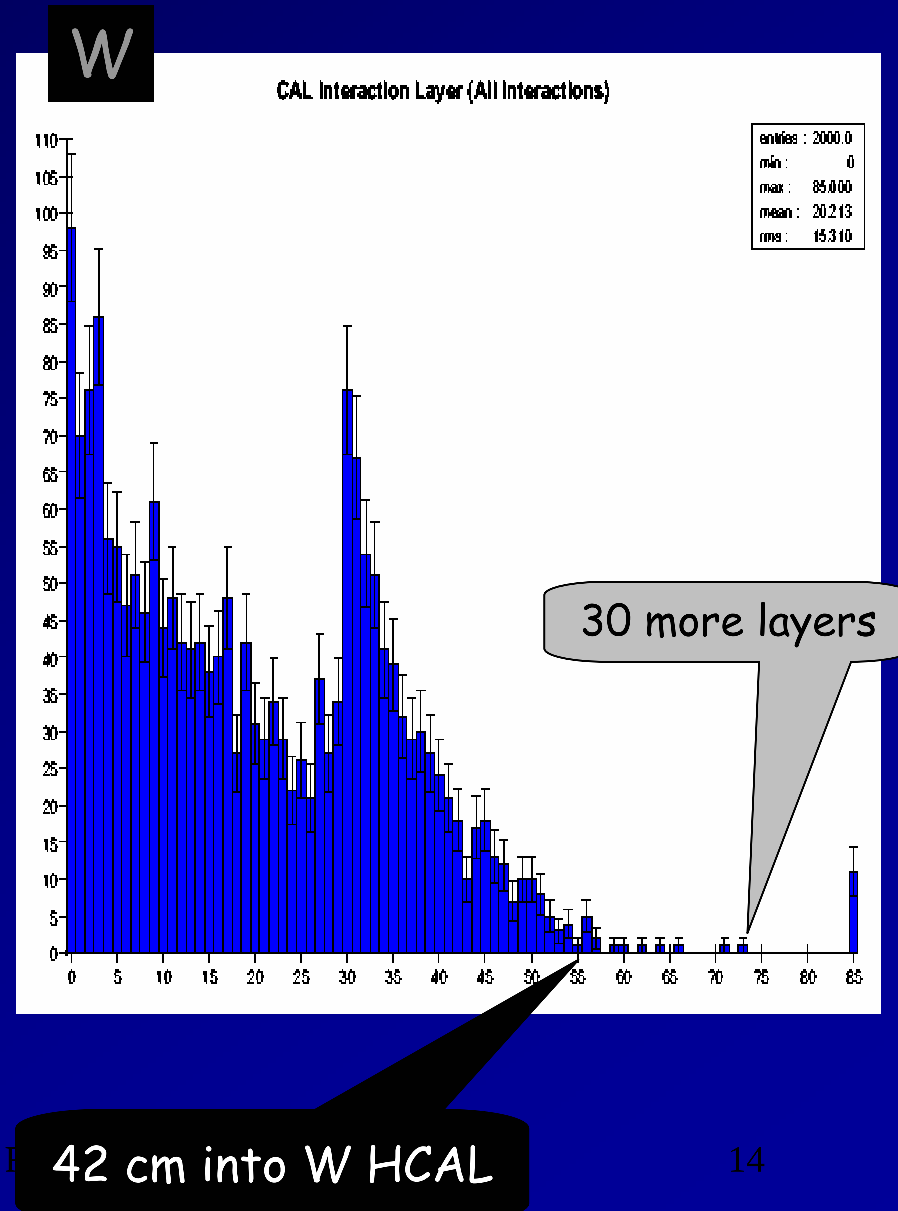
Coupled with a drift electrode above and a readout electrode below, it acts as a highly performing micropattern detector. The essential and advantageous feature of this detector is that amplification and detection are decoupled, and the readout is at zero potential. Permitting charge transfer to a second amplification device, this opens up the possibility of using a GEM in tandem with an MSGC or a second GEM.



Key: producing cost-effective GEM foils in bulk (industry: 3M)

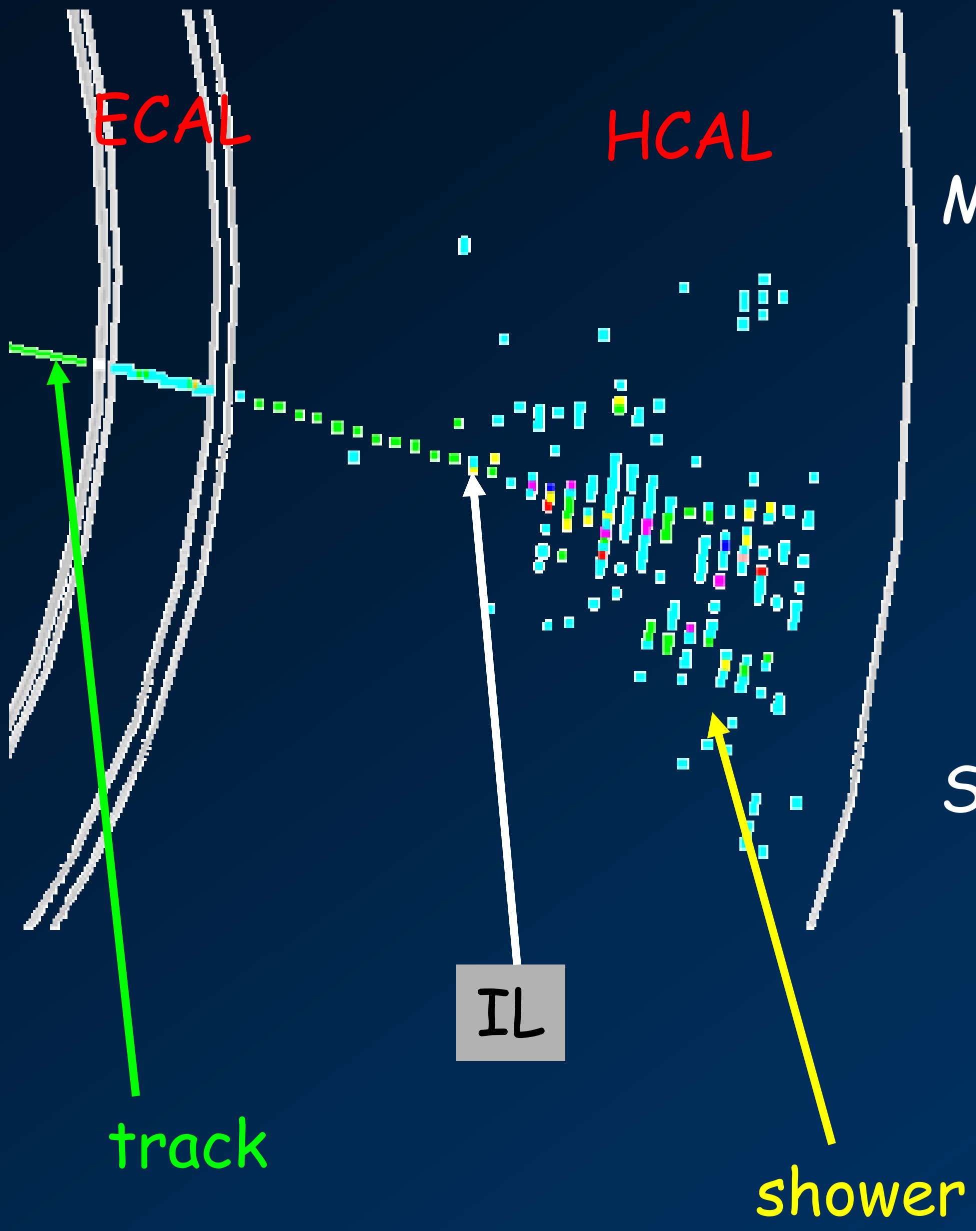
HCal Absorber: Steel or Tungsten ? (S. Magill)





Shower reconstruction by track extrapolation

S. Magill



Mip reconstruction :

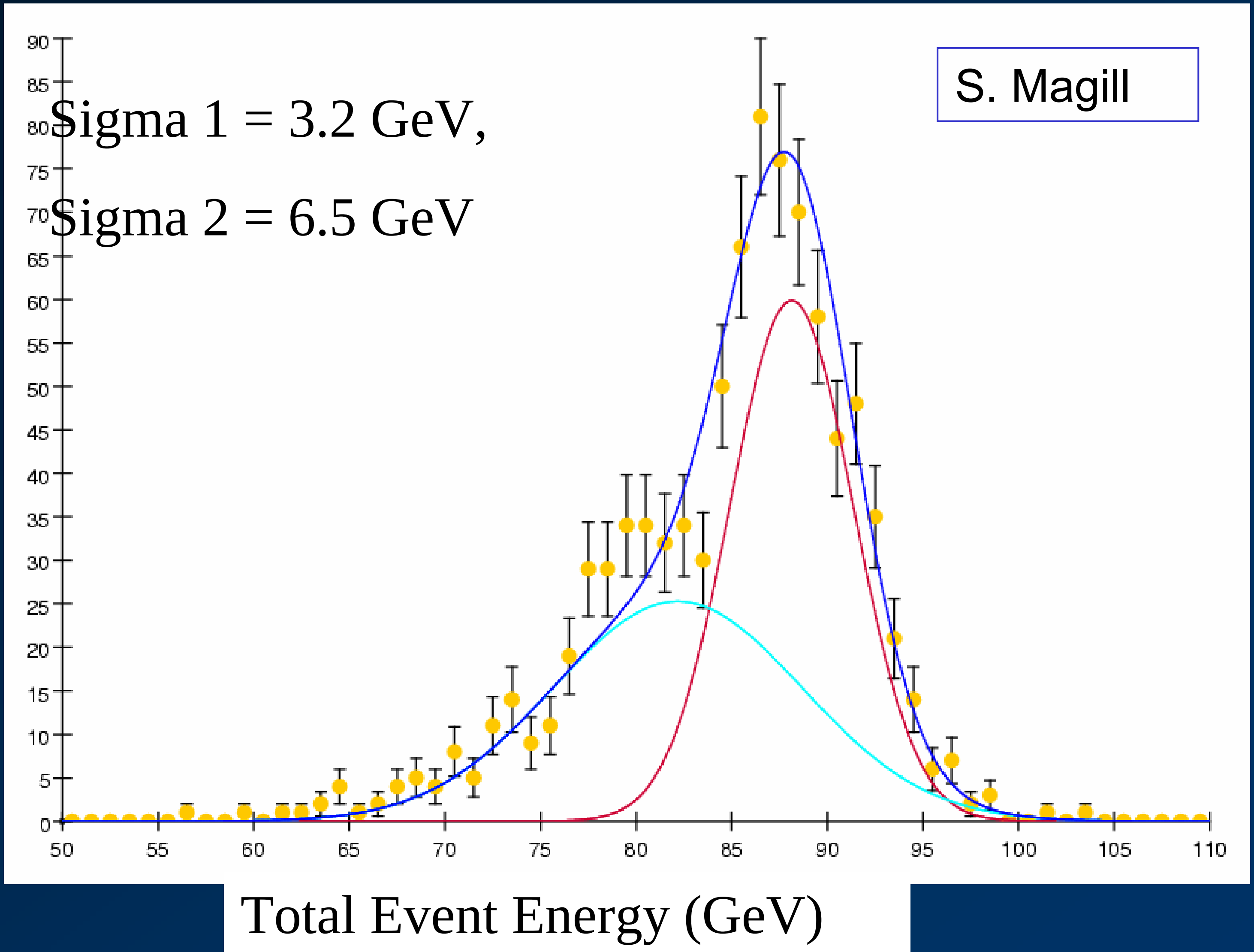
- Extrapolate track through CAL layer-by-layer
- Search for "Interaction Layer"
- -> Clean region for photons (ECAL)

Shower reconstruction :

- Define tubes for shower in ECAL, HCAL after IL
- Optimize, iterating tubes in E,HCAL separately (E/p test)

PFA: not quite there yet, but good progress

Tracks+Photons+Neutral Clusters



Simulation - organization

Argonne SiD PFA workshop

[last update: Wednesday 02 March 2005]

Date/Time: Friday 21 January 2005 from 09:00 to 00:00
Location: Argonne
Room: 362-2-H240
Chair: Repond,J

Friday 21 January 2005

A.	ANL	**Introduction** (PFA_frey.link)	**R.Frey**
B.	ANL	**Current SiD Design** (PFA_weerts.link)	**Weerts,H**
C.	ANL	**PFA Developments** (PFA_magill1.link)	**Magill, S**
D.	ANL	**PFA News from Paris LD meeting** (PFA_chakraborty.link)	**Chakraborty, D**
E.		**PFA Ingredients: Track Matching** (PFA_magill2.link)	**Magill, S**
F.		**PFA Ingredients: Photons** (PFA_graf.link)	**Graf, N**
G.		**PFA Ingredients: Neutral Hadron Clustering** (PFA_zutshi.link)	**Zutshi, V , Chakraborty,D**
H.		**PFA Ingredients: MIP tracking** (PFA_mader.link)	**Mader, W**
I.		**PFA Ingredients: Other Algorithms** (PFA_cassell.link)	**Cassell, D**
J.		**How to Put Everything Together** (PFA_kuhlmann.link)	**Chakraborty, Graf, Kuhlmann**
K.		**Discussion of Plan**	**All**
L.		**Wrap Up** (PFA_subtasks.link)	**Repond, J**

NICADD agenda server

Comments & questions please send to ***webmaster***.

- Clearly important to share progress and results
- For now, co-opt (half of) the ALCPG calor. meetings
- Will need to re-visit this as participation expands

The Test Beam Program

- Particle Flow will be tested and detectors optimized using full Monte Carlo simulations
- These Monte Carlos (ie Geant4) *must* be validated with test beam
  - A new regime: “Imaging” hadron (and em) calorimeters
  - Previous MC-cal comparisons not especially relevant
  - A new level of shower detail available for comparison to MC

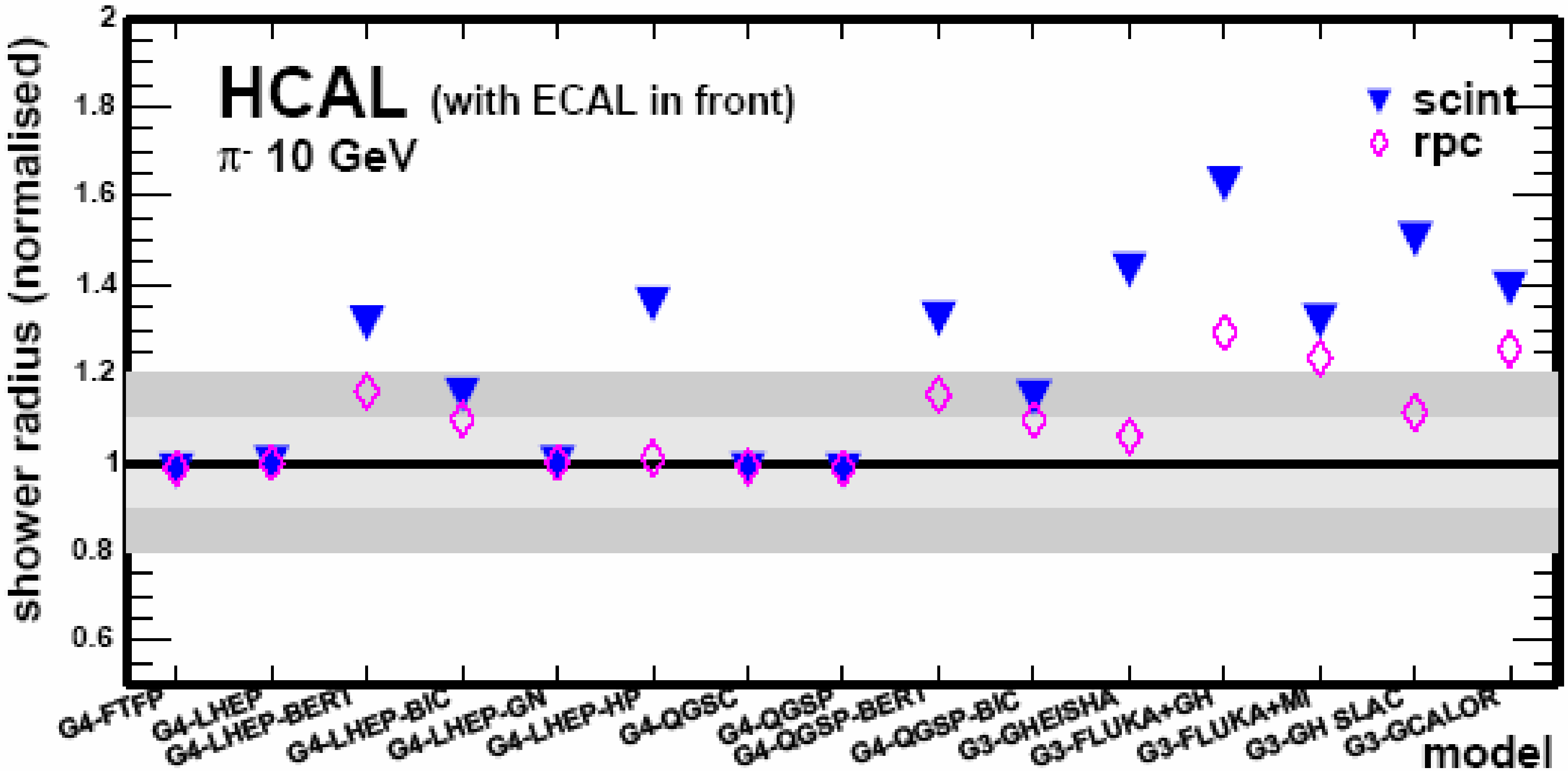
⇒ The FNAL test beam MOU

- Hadron showers are spatially large ⇒ a large prototype is needed (with an ECal in front)
  - 1 m^3 , $\sim 4\times 10^5$ HCal readout channels (30 ECal channels)
- This requires money (more than current LCRD/UCLC awards)

⇒ NSF MRI proposal: UT Arlington, Argonne, Oregon (960k$)

Si/W ECal + RPC/GEM HCal

G Mavromanolakis, D. Ward



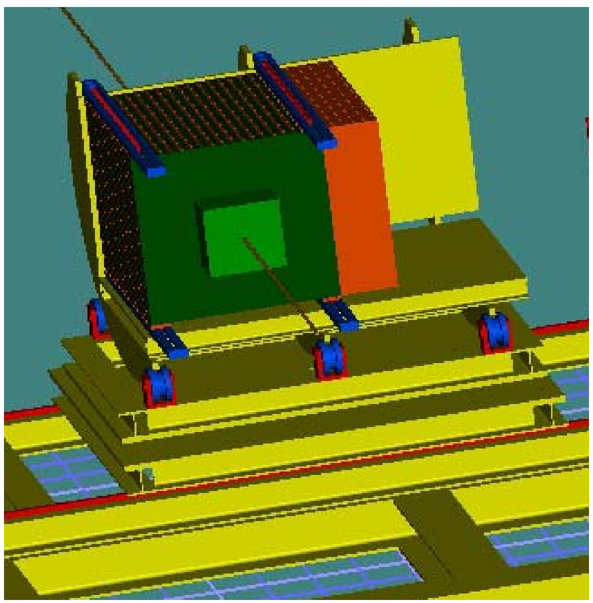
The CALICE HCal structure calls for 2cm steel absorber.

Need a 2nd configuration? Tune MC to one, predict the 2nd.

Tungsten?

the test beam program (contd.)

FNAL-TM-2291
Test beam MOU



Responsibilities	Beam Test Contact		Institution
Primary Physicist in Charge of Beam tests	J. C. Brient, J Yu		Ecole Polytechnique, University of Texas at Arlington
Daily Experimental Contact	J Repond, V. Zutshi		ANL, NIU/NICADD
Fermilab Liaison	E Ramberg		Fermilab
EM Calorimeter			
Si-Tungsten	CALICE	J. C. Brient	LLR Ecole Polytechnique
	US	D. Strom (P), M Breidenbach (T)	University of Oregon, SLAC
Scintillator-Tungsten	T Takeshita		Shinshu
Scintillator-Si-Tungsten	G. Wilson		University of Kansas
Scintillator-Si-Lead	P. Checchia		INFN Padova
Scintillator-Tungsten	U. Nauenberg (P), E. Erdos(T)		University of Colorado
Hadronic Calorimeter			
Scintillator-Steel (CALICE)	F Sefkow, M Danilov		DESY, ITEP
RPC-Steel (CALICE)	Russian	V Ammosov	IHEP
	US	J. Repond (P) L. Xia (T)	ANL
GEM-Steel (CALICE)	A. White (P), J. Li (T)		University of Texas at Arlington
Muon –detector/Tail-catcher			
Scintillator-Steel (CALICE)	V. Zutshi, F. Sefkow		NIU/NICADD, DESY
Scintillator-Steel Muon Detector	H. E. Fisk		FNAL, UCD, NIU, IU, Univ. of Notre Dame
RPC-Steel	Marcello Piccolo		Frascati

the test beam program (contd.)

Possible schedule (Jose Repond) :

Year	Calorimeter	Beam time request
2005	ECAL (CALICE)	3 weeks (electrons)
2006	Analog HCAL	4 weeks (hadrons, muons)
	ECAL + Analog HCAL + Tail catcher	5 weeks (hadrons)
2007	Digital HCAL (RPCs)	5 weeks (hadrons, muons)
	ECAL + Analog HCAL + Tail catcher	5 weeks (hadrons)
	ECAL + Digital HCAL + Tail catcher	10 weeks (hadrons)
	ECAL (US)	3 weeks (electrons)
	Digital HCAL (GEMs)	5 weeks (hadrons, muons)
2008	ECAL + Digital HCALs + Tail catcher	10 weeks (hadrons, muons)

Also: ECAL US) technical test at SLAC… 2005 ?

Detector R&D involvement

RPC R&D and test beam	Argonne, Boston, Chicago, FNAL, Iowa
GEM R&D and test beam	UT Arlington, Tsinghua, U. Washington
Scintillator Tiles R&D	N. Illinois
Silicon - tungsten	SLAC, Oregon, Brookhaven, Davis

Note: These are only the U.S.-based groups who have expressed a specific interest in SiD. In particular, the CALICE groups in Europe pursuing Si/W ECal and RPCs could be listed.

Simulation involvement

Simulation infrastructure	SLAC, N. Illinois
Algorithm dev.: photon finder	SLAC, Iowa, Argonne
Algo. dev.: MIP tracking	Iowa, N. Illinois, Kansas St
Algo. dev.: neutral hadron clusterer	N. Illinois, Argonne, SLAC
Putting the pieces together: PFA	Argonne, SLAC, UT Arlington

Summary and Goals

- Excellent progress on detector R&D
  - RPCs for HCal "ready to go"
  - GEMs for HCal – more R&D needed
  - Si/W – first readout chips in few months
  - Scint. tile HCal – SiPM config., segmentation?
- Good simulation progress
  - Getting close to viable PFAs

Goals:

- Test beam program: validate simulations at unprecedented level of detail.
  - detailed shower measurements
  - Tune MC to this (then predict a 2nd config.?)
- Develop acceptable PFAs

$\Rightarrow$ Optimize detector design using the tuned PFAs.

B, R, segmentation (trans,long), depth, etc

(Will we always need the full PFAs to make progress on detector optimization?)

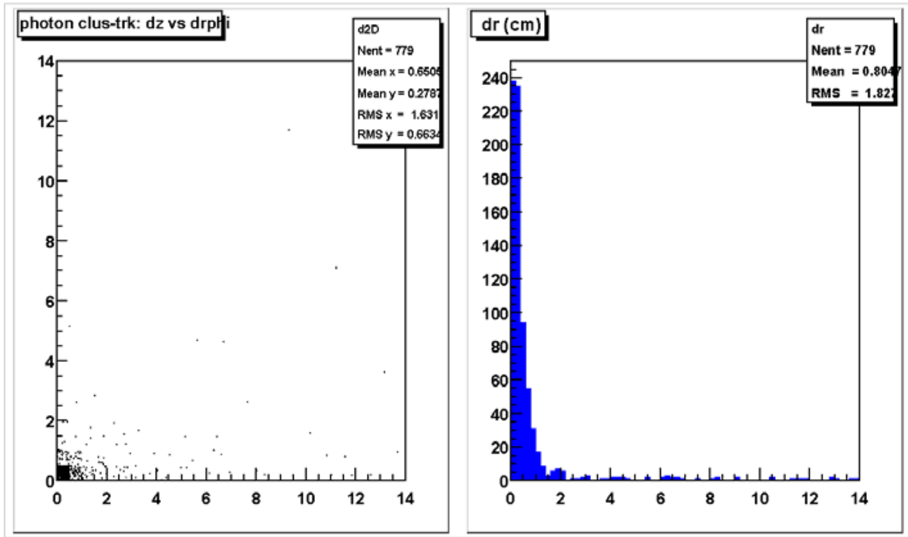
Separation of Cluster and nearest charged track (extrapolated)

Small Detector: $BR^2 = 3.4$ T-m^2 , $R_m = 0.9$ cm

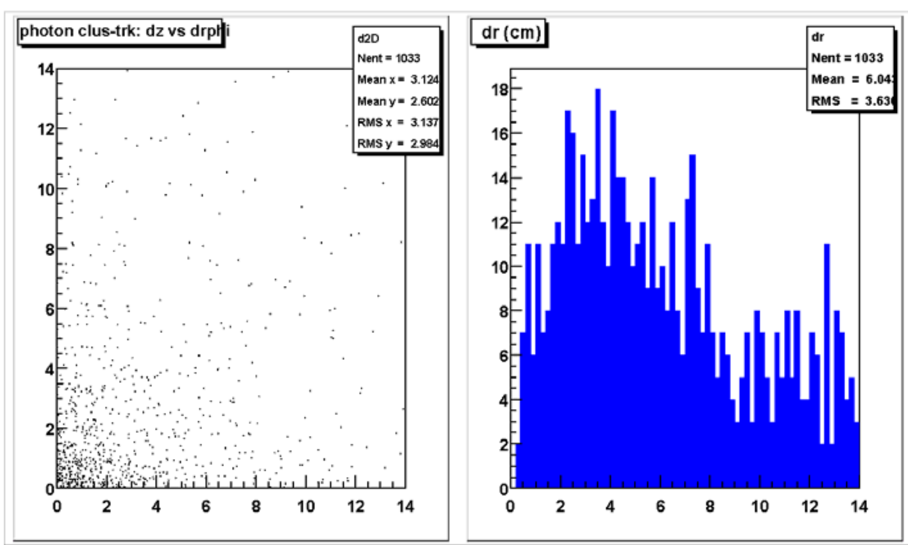
($dr \equiv$ bend $\oplus$ non-bend separations)

M. Iwasaki, 2000

- Cluster is due to a $\pi^{\pm}$:

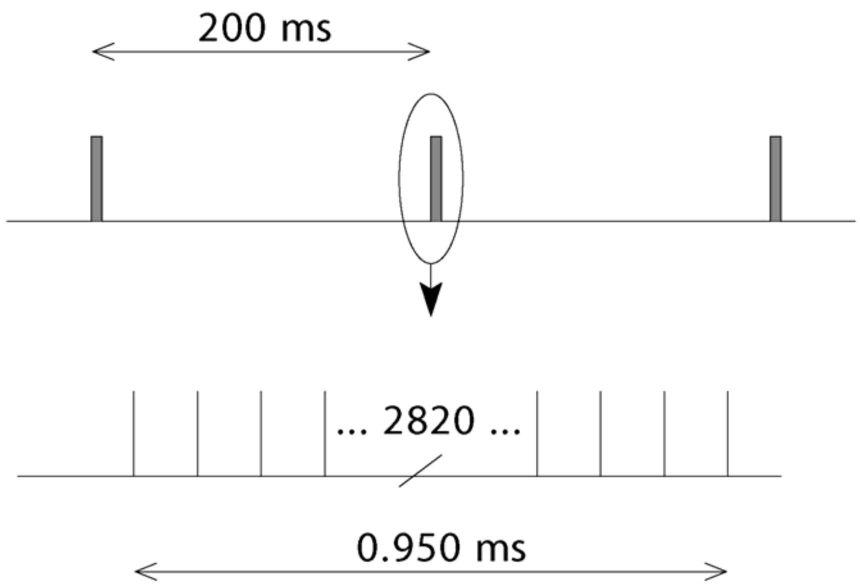


- Cluster is due to a γ:



Beam crossing time structure

Cold

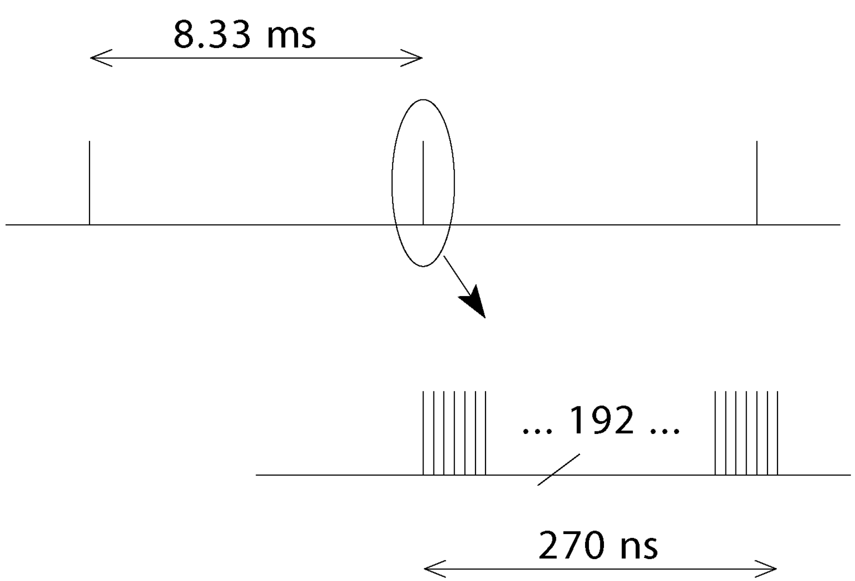


Bunch trains at 5 Hz

Bunch crossings at 337 ns

- Fast readouts: OK, no pileup
- pipeline
- bx live: 5×10^{-3}

Warm



Bunch trains at 120 Hz

Bunch crossings at 1.4 ns

- Pileup over bunch train
- Or fast timing
- bx live: 3×10^{-5}

$\Rightarrow$ power pulse