FCal Referees' Report

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DESY – PRC 68

November 2009

FCal Report Outline

- Introduction, previous review of FCal by PRC
- Components of FCal system
- Lumical
- Pair monitor
- Beamcal
- Observations, recommendations.

FCal review status

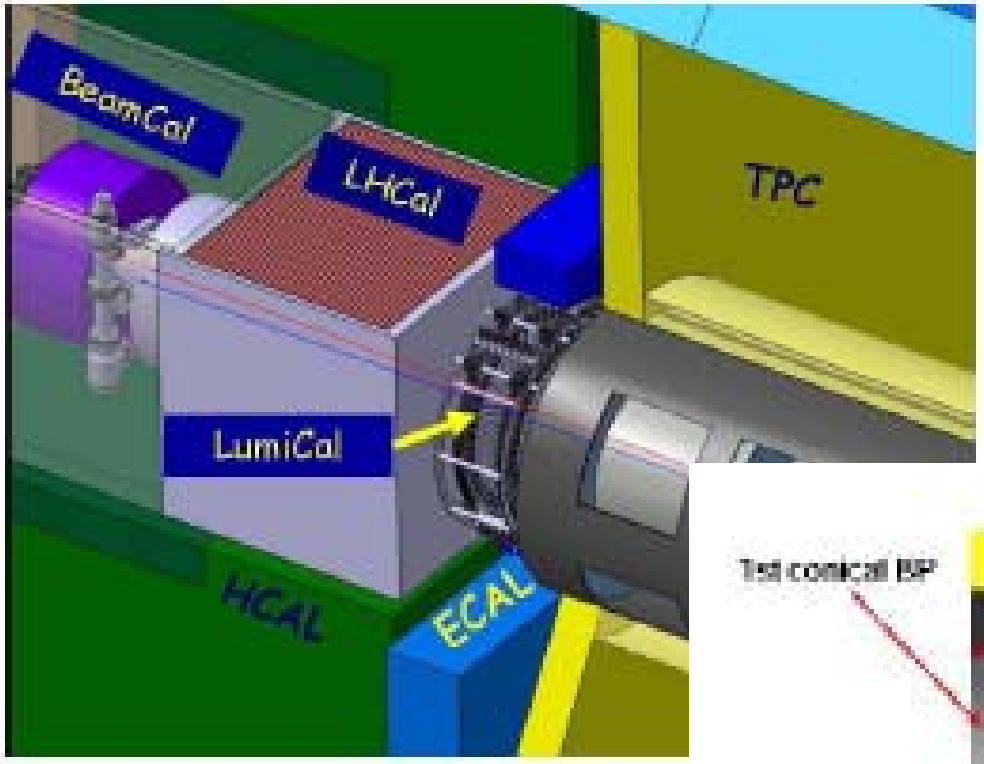
FCal Collaboration was last reviewed by the PRC in November 2007, with the following recommendation:

FCAL

The PRC acknowledges that FCAL is a challenging project, yet is very important for the whole ILC experiment. The PRC is impressed by the written report of their activities, where both physics requirements and the technical implications were clearly stated. The FCAL group is an active collaboration, and made progress in many areas. There is significant work left for the goal of prototypes in 2010. The PRC commends that the FCAL group brings together the community from a broad area. This effort is well appreciated by the World-Wide Study Group and indicates a strong leadership by the Zeuthen group. The PRC also commends that the FCAL group is well connected to the two prominent ILC detector concepts; ILD and SiD, and is working to develop LoIs by Oct. 1, 2008. The PRC notes that FCAL effort could be useful beyond the ILC detector, for example, for SLHC detectors. We recommend that the FCAL group continue to communicate with the machine group closely. The PRC recommends DESY to continue their support.

FCal example:

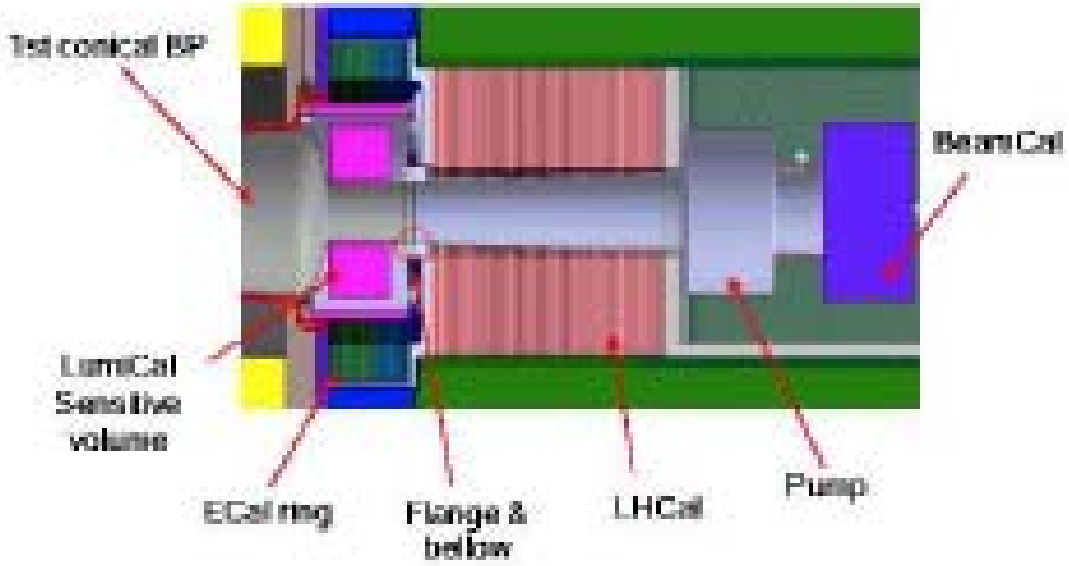
Components of the ILD Forward Region



Lumical

Beamcal

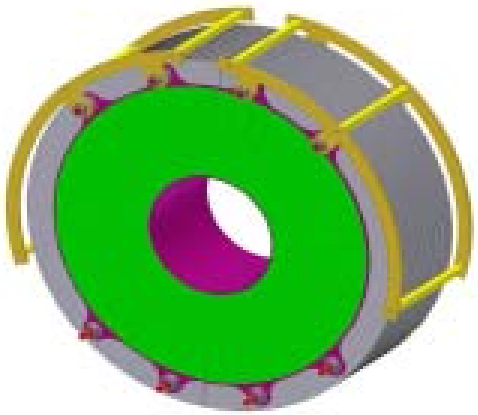
Pair Monitor



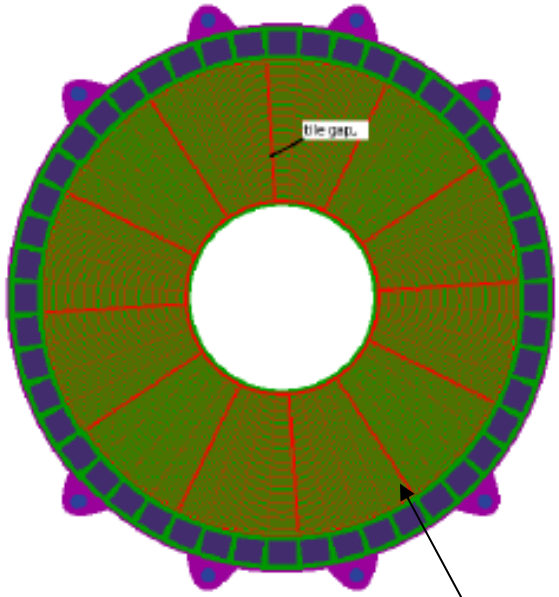
Lumical

- Function: Measurement of ILC luminosity using Bhabha events – goal $\Delta L/L = 10^{-3}$
- Location, design, mechanics
- Alignment
- Sensors
- Electronics
- Simulation
- Luminosity systematics

Mechanical design



Number of layers 30, 60?

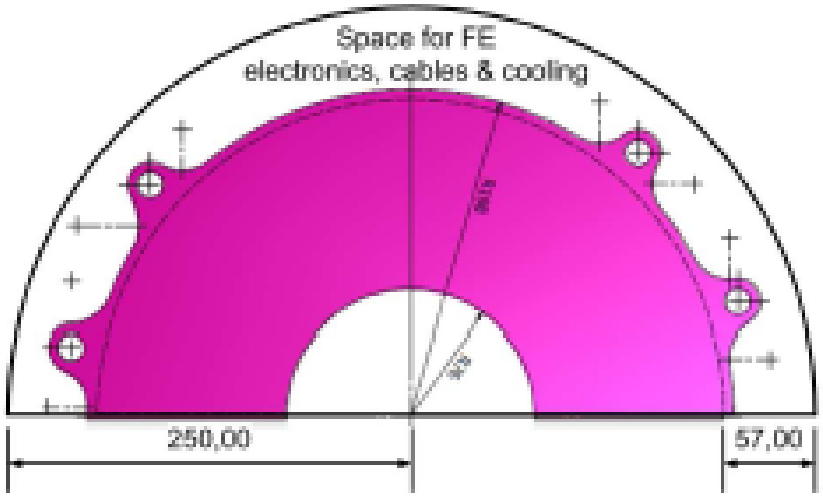


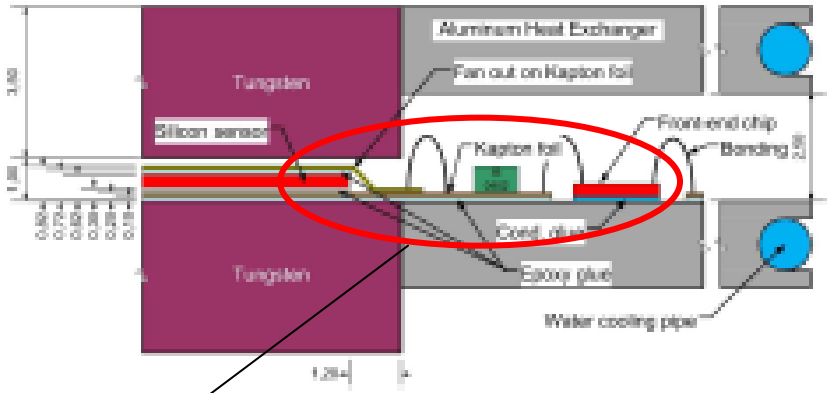
"significant simplicity"

Even/odd alternate plate rotation.

Concern over effect of gaps on energy resolution -> energy cutoff -> error on luminosity?

Mechanical design





Use of conductive glue (to save space) in this area?

Alignment

Requirements:

Lumical to reference frame 100-700μm

Distance between Lumical units 60-100μm

Position of inner radius of sensor layers <4μm (is this still the goal for 10^{-3}? - 10μm for 10^{-3}?)

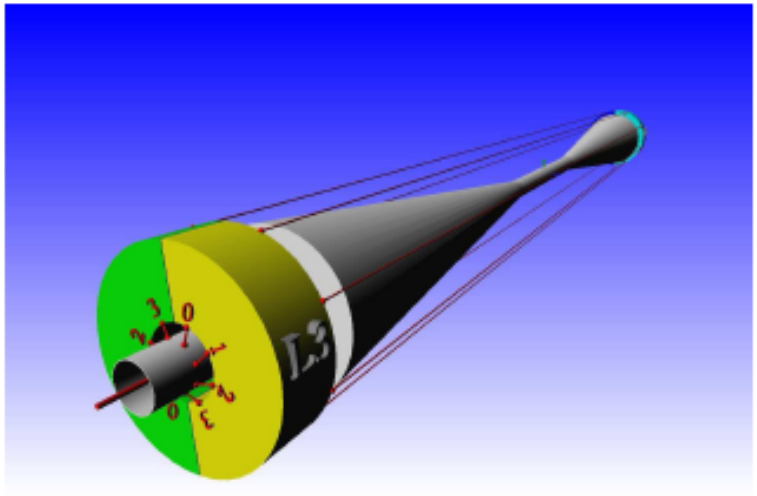
Initial tests of laser and capacitance change systems ->

eventually a FSI system.

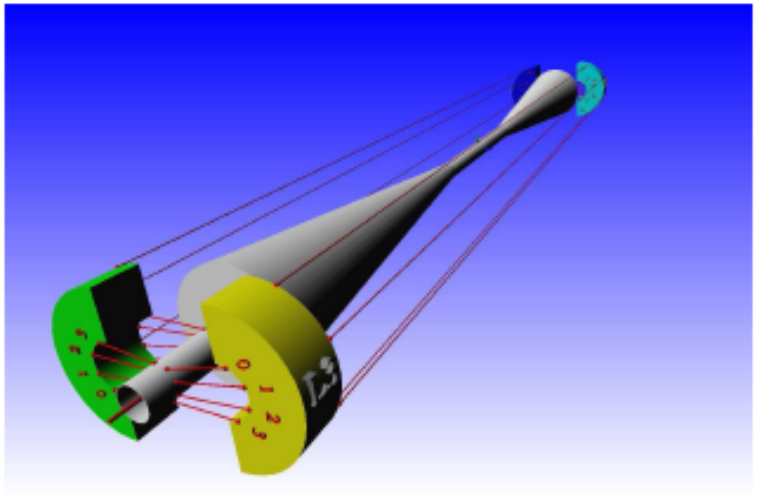
Why does FSI only achieve 100μm? (e.g. FSI for SiD TRK -> few μm)

Issue with precision needed for Si sensors – transparent CMOS/IR laser?? Effect on luminosity meas? Reduced active area?

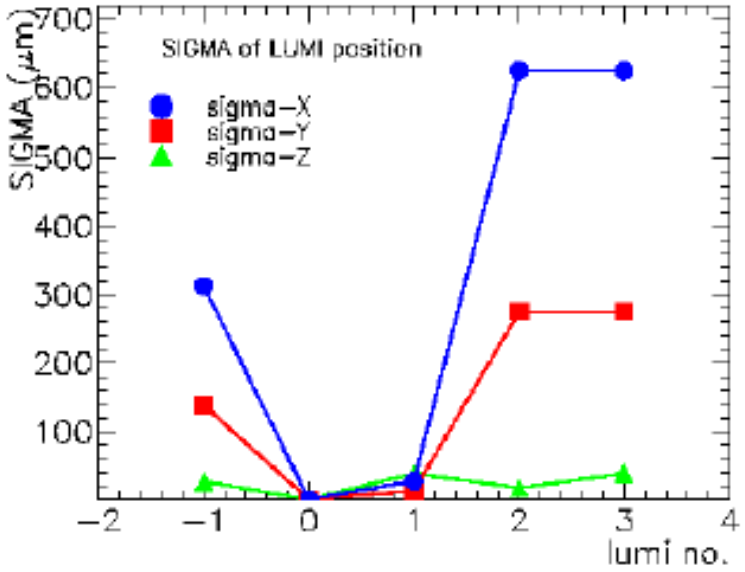
Alignment



(a) The calorimeter modules are closed



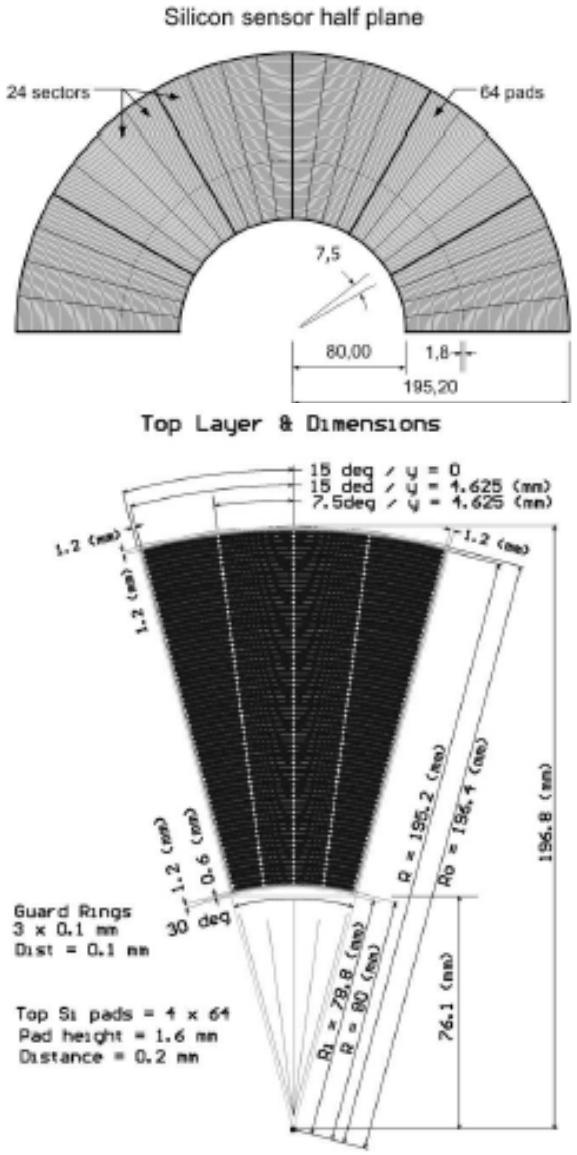
(b) They are open.



What are 1,2,3?

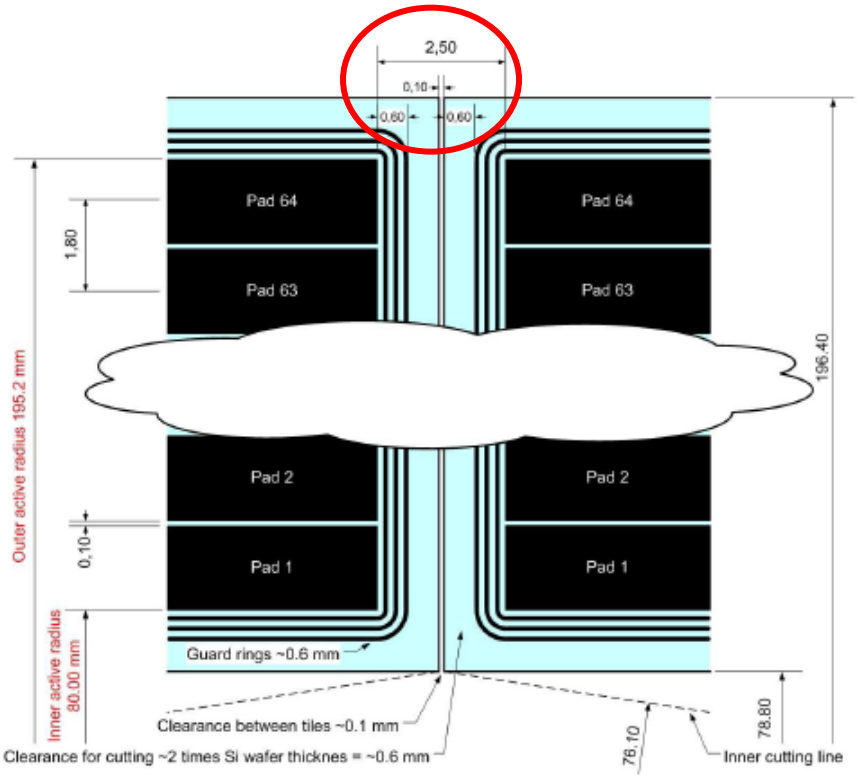
Why such a difference between x and y?

Sensors

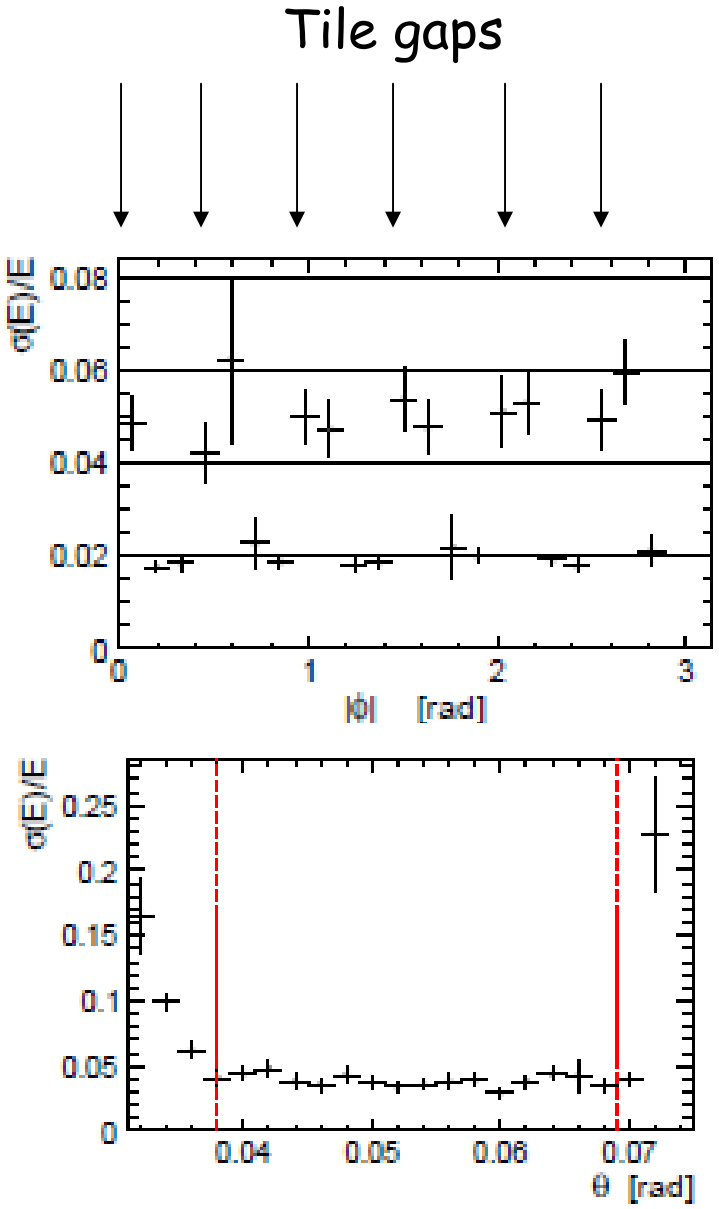


Now have real sensors under test!

Concern over effect of gaps on energy resolution – but simulation -> no effect on luminosity meas?



Sensors



Tests of 40 tiles

Cracow, Zeuthen, Tel-Aviv

Results are within expectations

-> see later/simulations

Prototype Lumical plans

- Building a "base module" Si, W plates, FE readout
- Test beam at DESY and CERN e^- + EUDET telescope support ??
- Positioning system esp. capacitance system -> O(μm), + laser position meas. system

Readout Electronics

- Physics and calibration modes

- Very large range of signal magnitudes (~2 fC for muons for calibration, O(10pC) for physics)

- What are the requirements on MIP calibration?

- Very high occupancy -> fast enough to resolve energy from individual bunches.

- Components: FE (amp + shaper), ADC, data concentrator

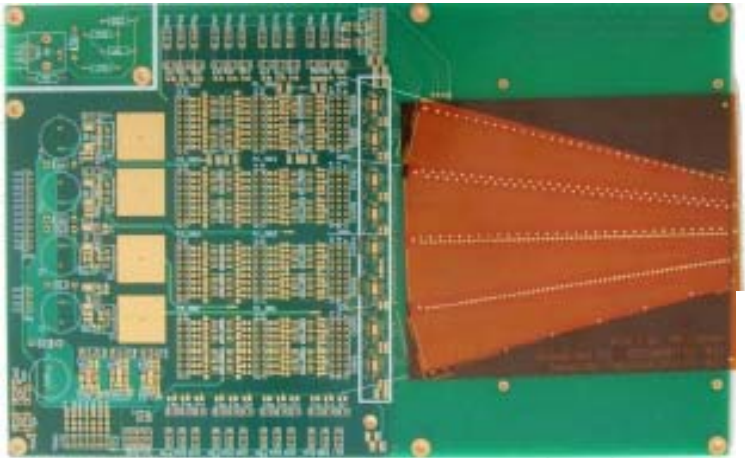
- Two prototype ASIC's developed: FE and ADC (2)

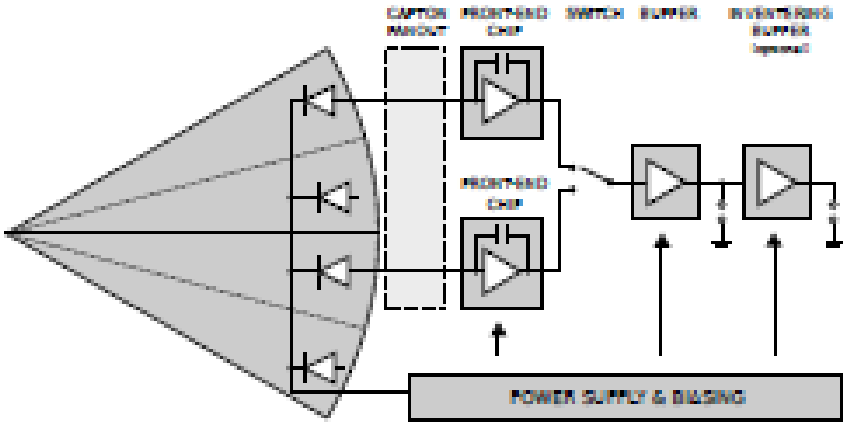
  FE ASIC – behaves as expected

  ADC ASIC – some issues with first ASIC, 2nd good

Readout Electronics

Next: full chain test (sensor, fanout, FE,…)



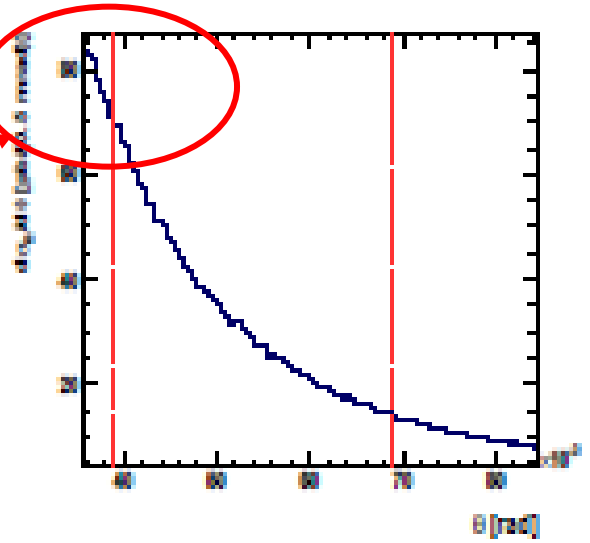


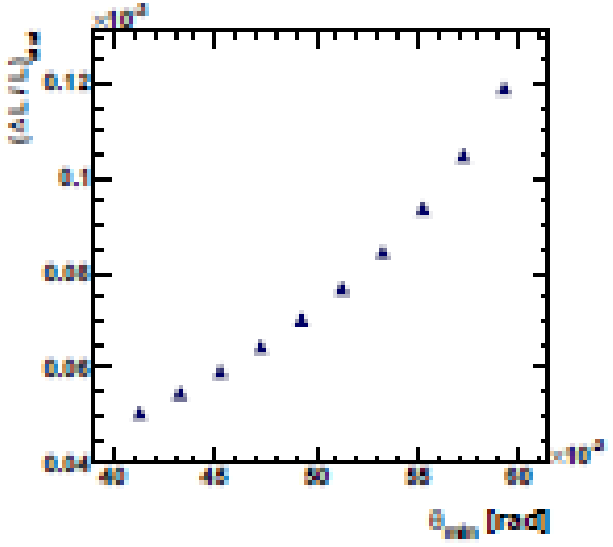
..But not prototype ADC (single channel) -> multi-channel version next step.

Simulations

- MOKKA used, BHWIDE, 10^6 Bhabha events
- Physics background from WHIZARD
- Beamstrahlung background from GUINEA-PIG

Steeply falling $d\sigma/d\theta$ -> sensitivity to angular acceptance.

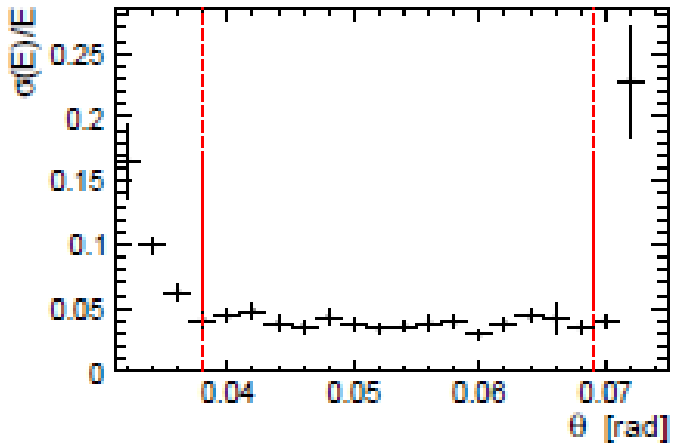




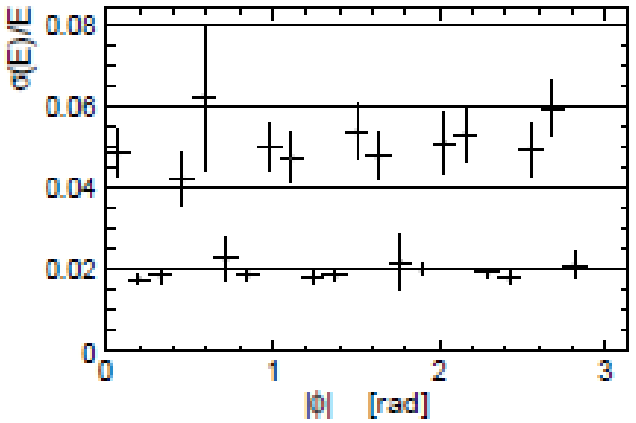
Goal: $\Delta L/L \sim 10^{-3}$ for ILC

Simulations

Limited size of Lumical, non-projective geometry, tile gaps -> significant dependence on shower position and energy



Energy resolution deterioration at acceptance edges



Effect of tile gaps -> exclude "leakage" regions -> reduce events/2 -> longer running time…

What was "gap" for simulation?

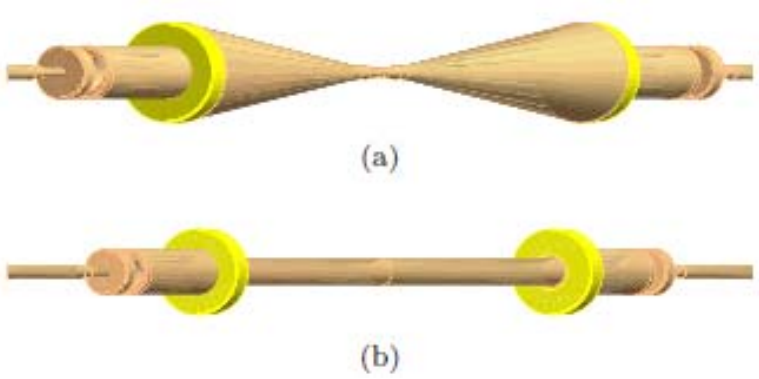
2 x 0.6mm or 2.5mm?

Simulations

- ? Bias in polar angle recon? Not alignment? Can this be corrected?
- Is a possible non-circular distortion allowed for?
- Why would a test beam help here?

Simulations

Luminosity and Beam pipe design



ILD current design: vacuum, power loss, B-field disturbance

Pre-showering -> E, θ effects?

Potential effect at $O(10^{-4})$

No choice so far – who decides?

Systematics

1) Beam-beam interaction – Bhabha suppression

(-4.41±0.05)% for present acceptance -> reduce to

(-1.51±0.05)% with acceptance cuts – but still significant contribution to goal of 10^{-3}?

Origin of ±0.05% ?

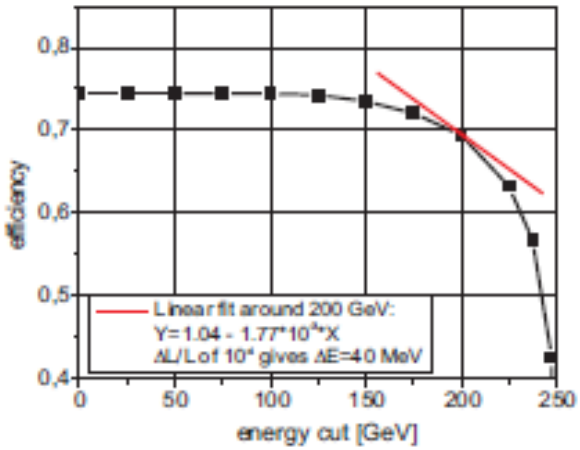
2) Four fermion background:

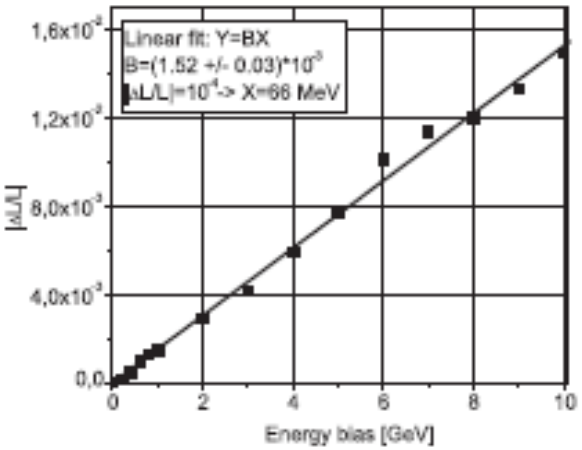
		500 GeV	1 TeV
B/S before selection	WHIZARD	$2.3 \cdot 10^{-3}$	$1.8 \cdot 10^{-3}$
	BDK	$7.9 \cdot 10^{-3}$	$3.6 \cdot 10^{-2}$
B/S after selection	WHIZARD	$2.0 \cdot 10^{-4}$	$3.5 \cdot 10^{-4}$
	BDK	$2.5 \cdot 10^{-4}$	$7.4 \cdot 10^{-4}$

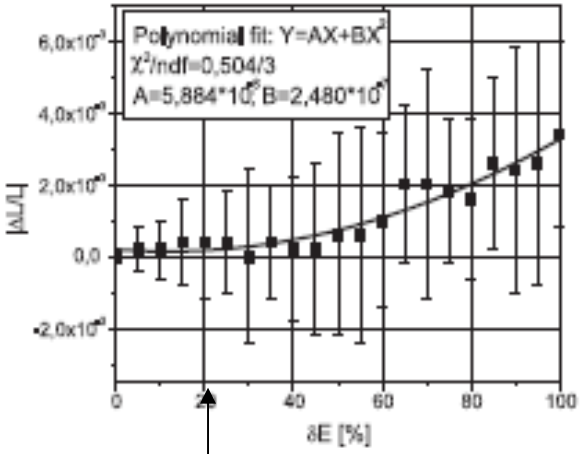
Significant differences?

Systematics

3) Energy resolution, energy scale bias







Need to know cut at 200 GeV to 40 MeV for 10^{-4}

-> $\Delta E/E = 2.10^{-4}$

21% -> $\Delta L/L = 2.3.10^{-4}$

How well will the energy scale be calibrated?

Challenging!

Comments and recommendations for Lumical

- The PRC recognizes significant progress in the design, sensors, electronics and simulation results.

- Need a clarification of the goal for $\Delta L/L$ (now 10^{-3})

- There appear to be several contributions to the error on the luminosity in the 10^{-4} – 10^{-3} range. Not clear how these contributions combine, and how changes in design affect the total error.

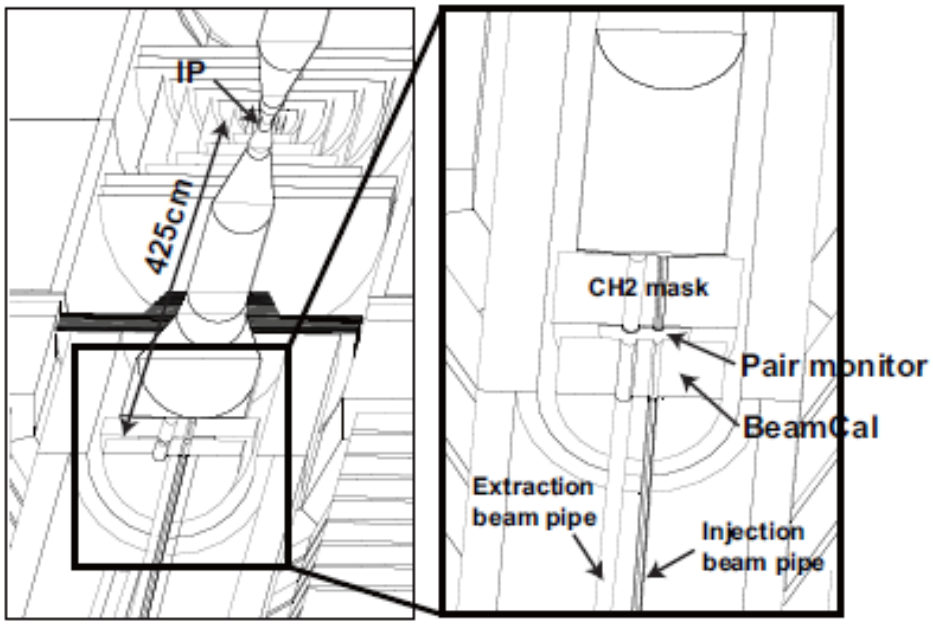
- The PRC requests that a table be provided that summarizes all the contributions to the error on the luminosity measurement, their magnitudes, origins, and strategy for reduction.

Pair Monitor

- Purpose
- Beam diagnostics – simulation results
- Sensor/ASIC

Pair Monitor

- Use e+e- pairs from IP, with hits in a new pair monitor layer, plus energy from Beamcal to measure beam size.



Single layer

Pixels 400μm x 400μm

Outer radius 10cm

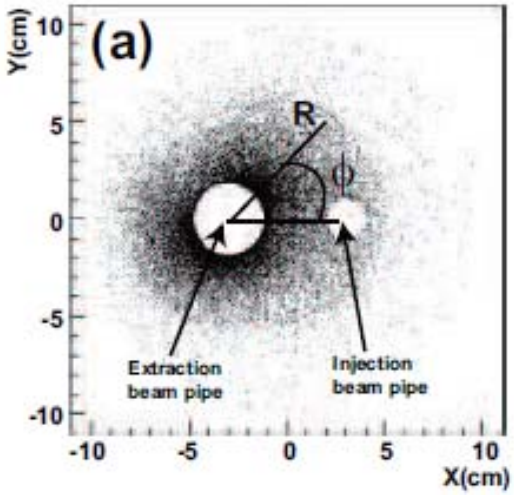
In front of Beamcal

σ_y needs ~1 nm accuracy of measurement

Pair Monitor - simulation

Full simulation (head-on collisions?)

Hit distribution:



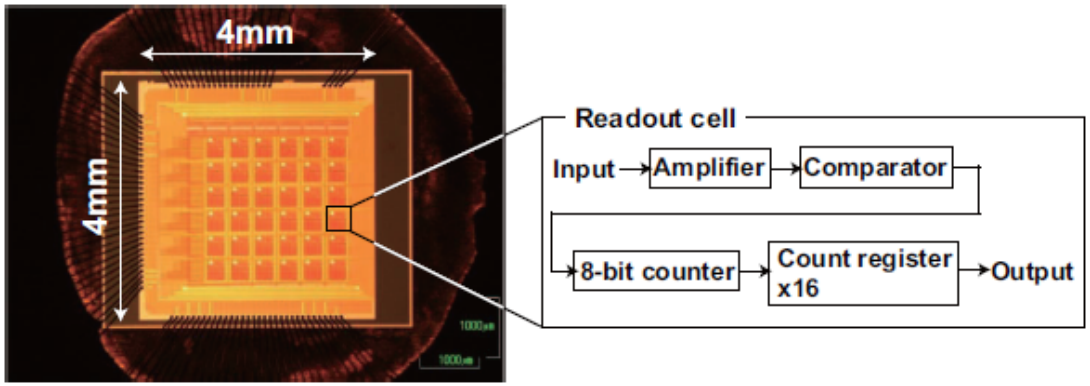
- Select measurement variables based on hits (total, regional) for Pair Monitor and shower size and regional energy ratios for Beamcal -> fit with 2nd order polynomial -> reconstruct beam size at IP with inverse matrix method.

	Pair Monitor	BeamCal	Combined
σ_x	3.2%	4.1%	2.8%
σ_y	10.1%	15.6%	8.6%
δ_y	8.0%	9.4%	7.4%

ILC σ_y is ~6nm -> can measure to 0.5nm

Pair Monitor – sensor/ASIC

- Beam profile variation within train -> 16 time slices/train
- Radiation dose for chip 1Mrad/year
- Prototype ASIC – 6x6 cells



- Chip appears to perform well; estimate S/N ~ 20,000/600 (est.)
- NEXT -> SOI (sensor+ASIC) -> first prototype – to be studied

Pair Monitor – comments etc.

- What happened to Gamcal? (2007) – not pursued.

- Comparison with ATF2 Compton monitor?

- Redundant Pair Monitor + Laser systems?

- Effects on beam (in)stability on the Pair Monitor + Beamcal method?

- Schedule for new ASIC?

- Which FCal collaborators? Japan.

Beamcal Review

- Purpose: e.g. SUSY physics – LSP/stau co-annihilation regulating amount of Dark Matter. Need forward veto of electrons from "$\gamma\gamma$" background.

- The challenge

- Beamcal design

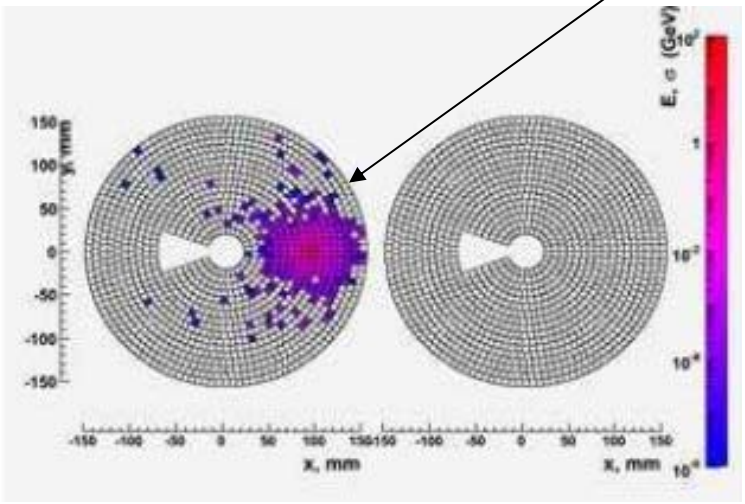
- Simulations results

- Electronics

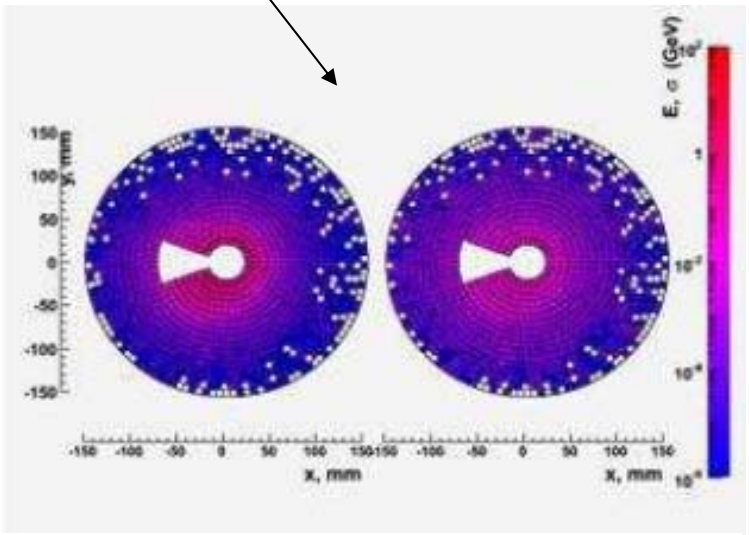
- Rad. hard sensors

The challenge

Find this……in this



(a) Energy deposition per cell (left) and standard deviation (right), in the 6^{th} layer

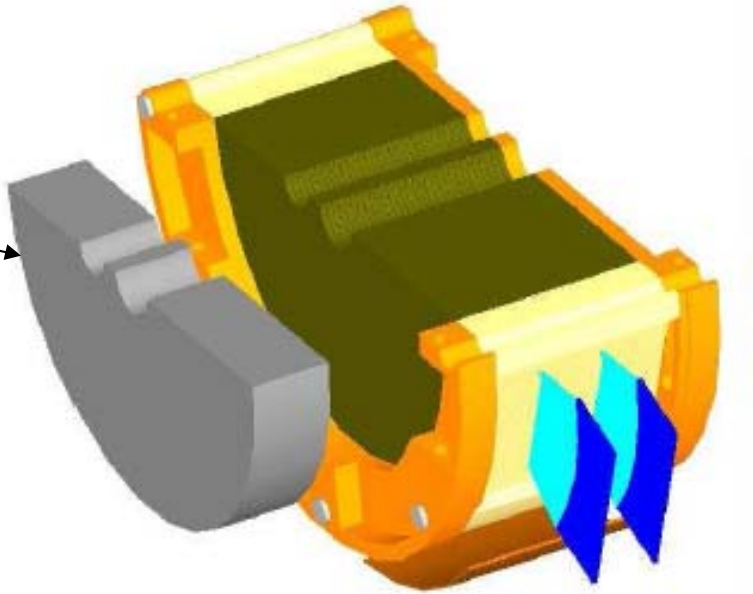


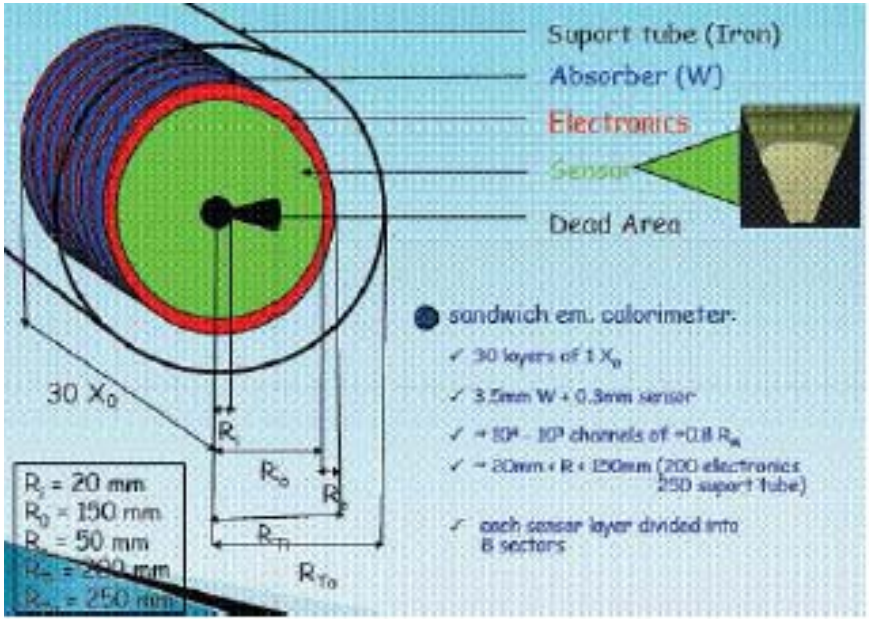
(b) Single high energetic electron shower in the whole calorimeter

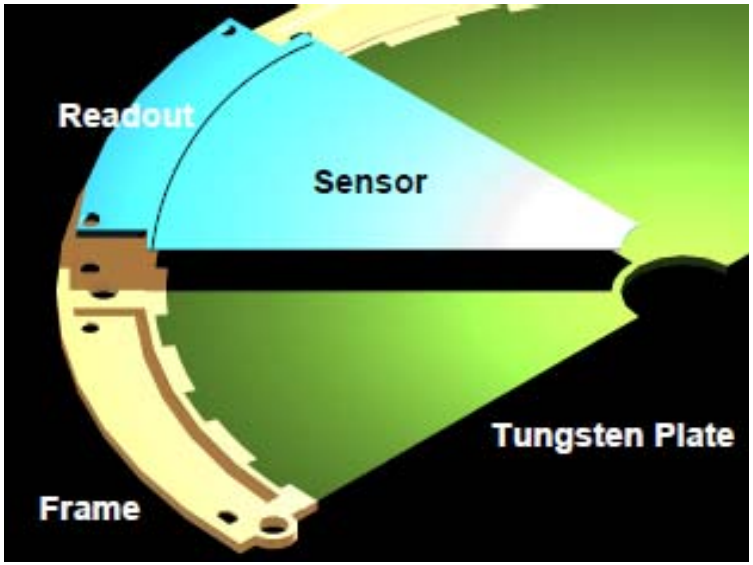
Background: low energy e+e- pairs

Beamcal design and mechanics

Graphite block – to absorb low energy backscattered particles



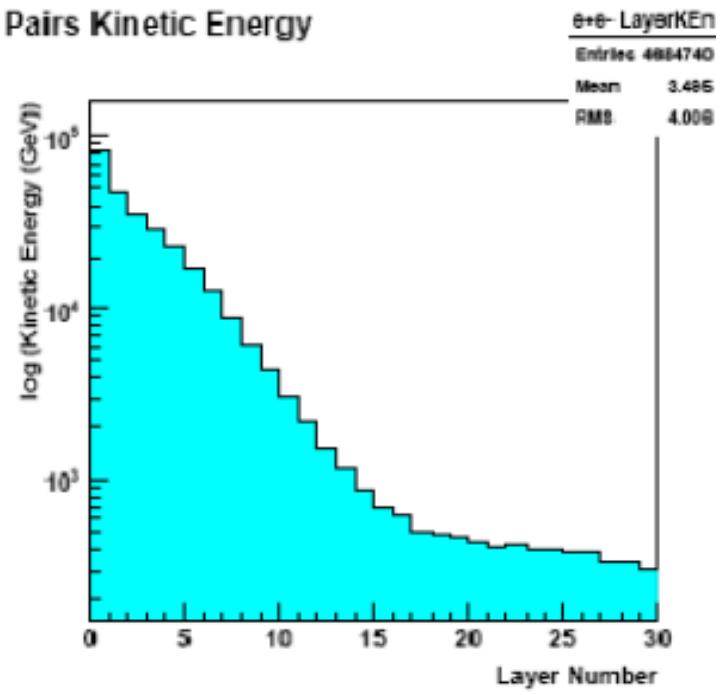




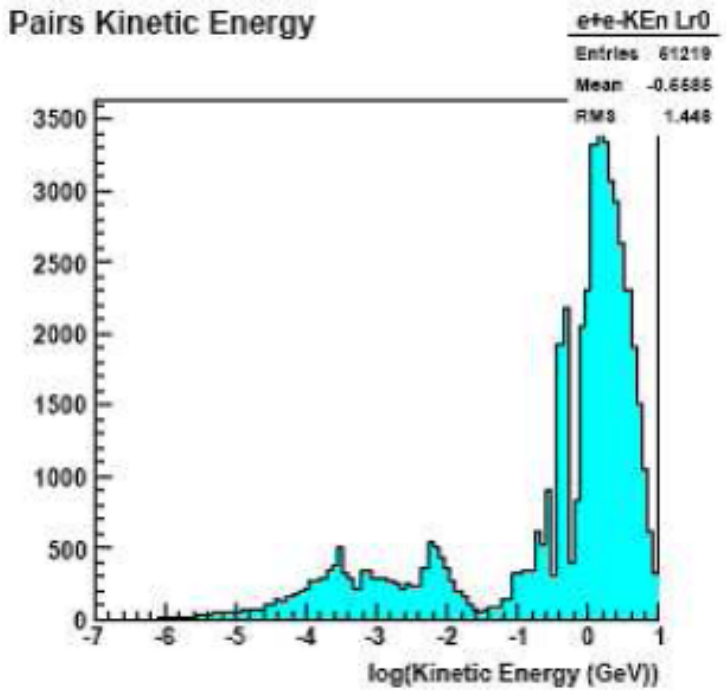
Simulation studies

- GUINEA-PIG, GEANT4 (inc. Lumical and QD0), BeCaS
- Two physics lists compared: Custom and QGSP_BERT_HP
- Pairs -> KE, energy deposition, dose
- Single HE e-
- Photons
- Neutrons – big difference between lists?

Simulation studies



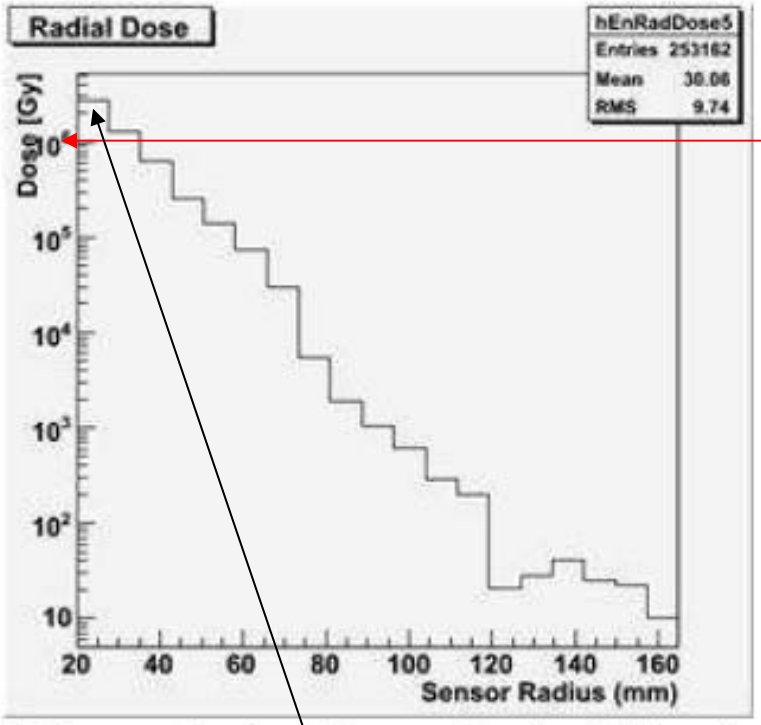
(b) QGSP_BERT_HP



(b) QGSP_BERT_HP

Custom list very similar

Simulation studies

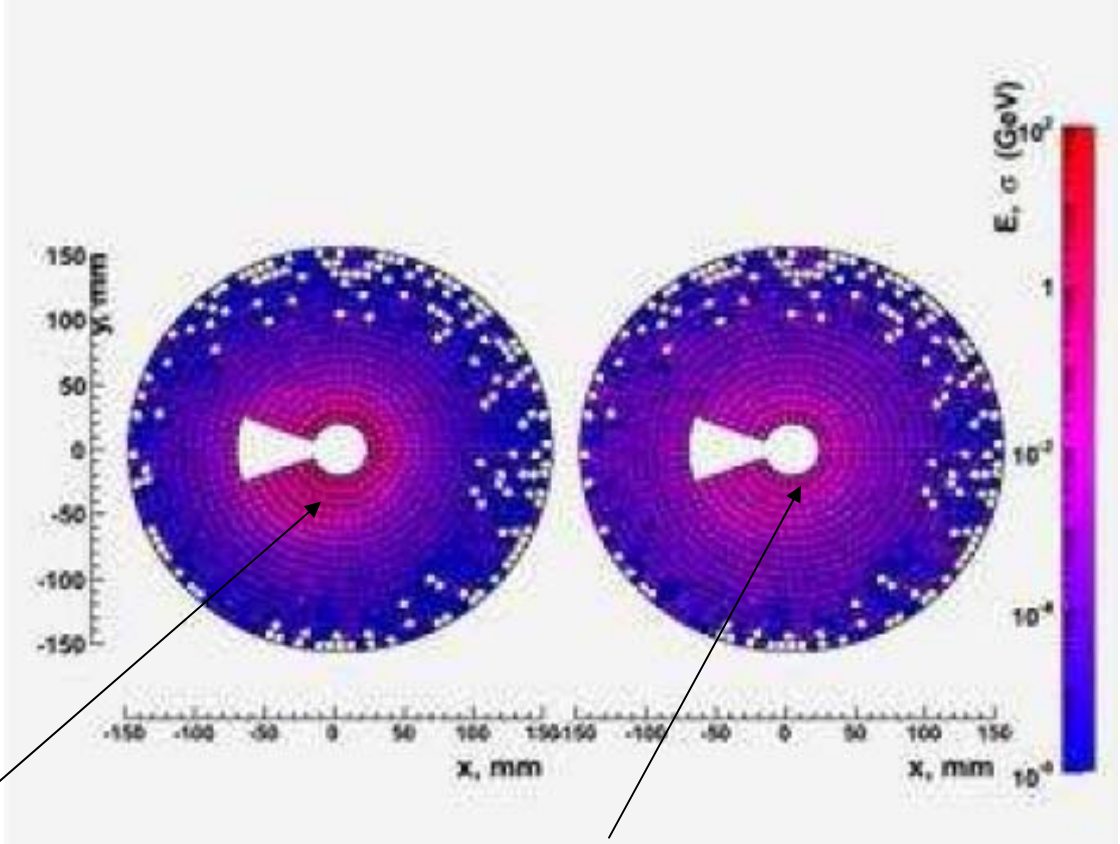


(b) Dose as a function of the sensor's radius (5 BX statistics)

1 MGy

"Cells near B.P. -> ~0.5 MGy/year", but figure shows ~3 MGy/year??

Simulation studies



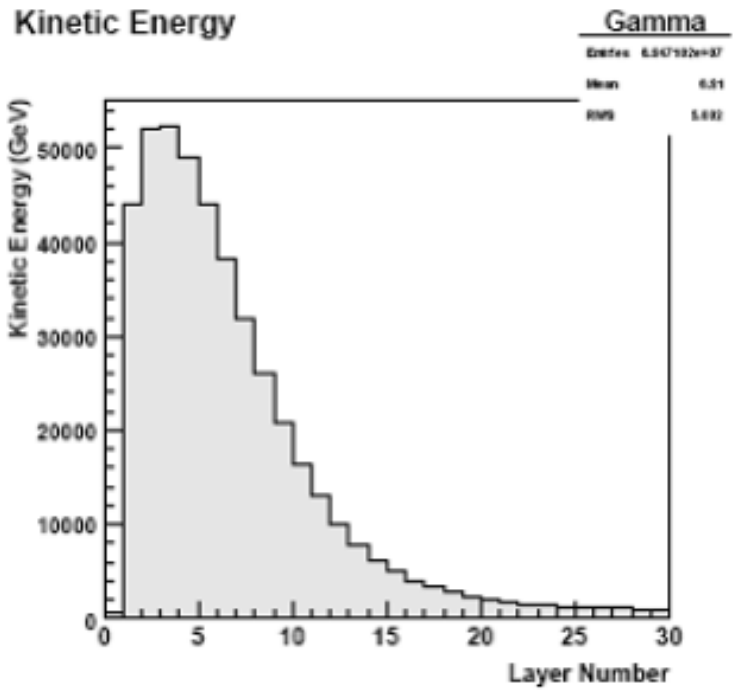
x10GeV/cell

Fluctuations ~0.1 GeV/cell

? Effect on detection efficiency for single HE electrons?

Simulation studies

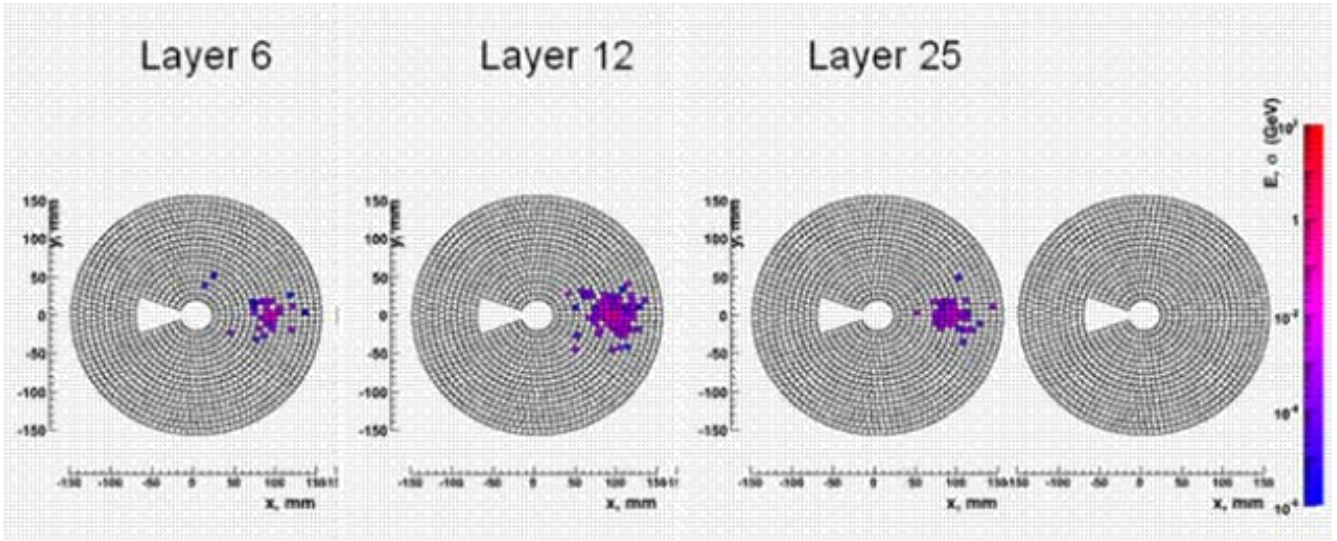
Photons

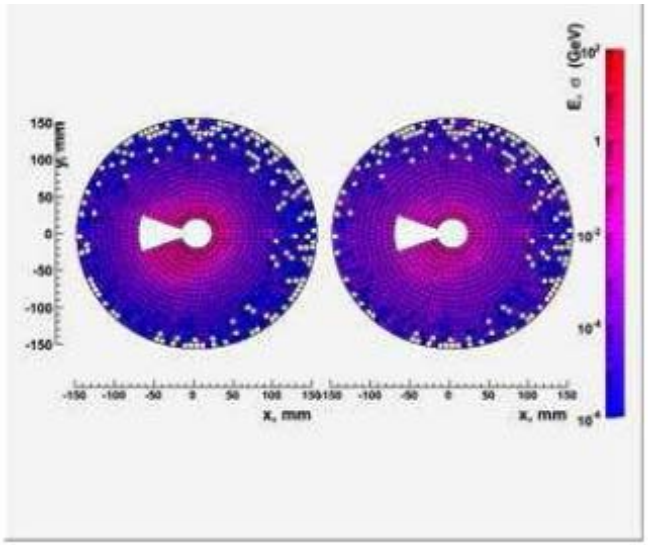


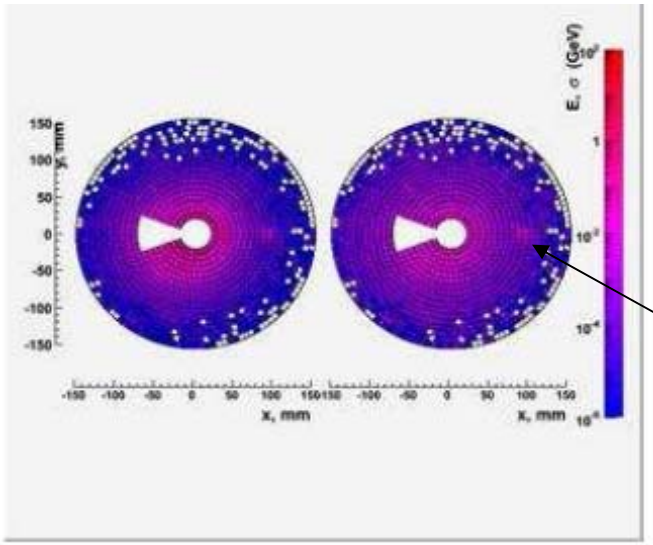
What is the deposited energy/layer?

Simulation studies

Single HE e-



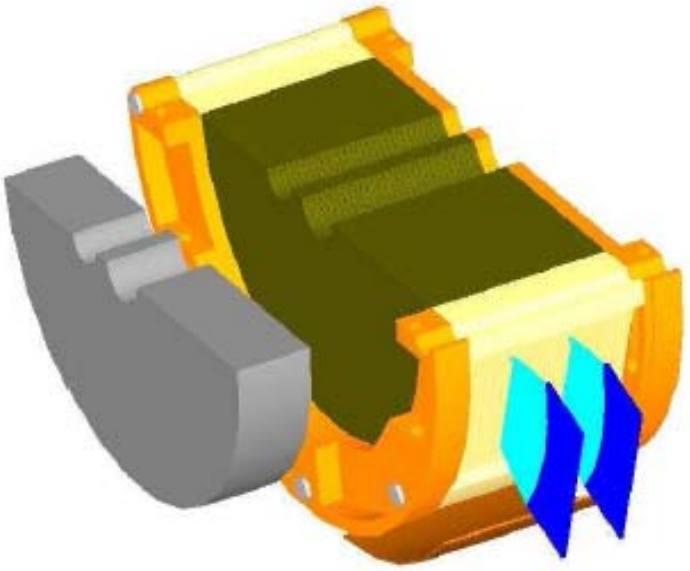


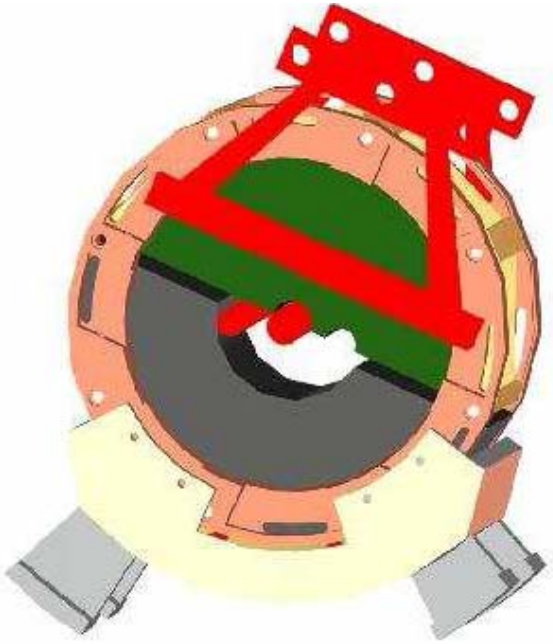


Why not show this for higher layer number?

Ease/efficiency of separation?

Beamcal Mechanics





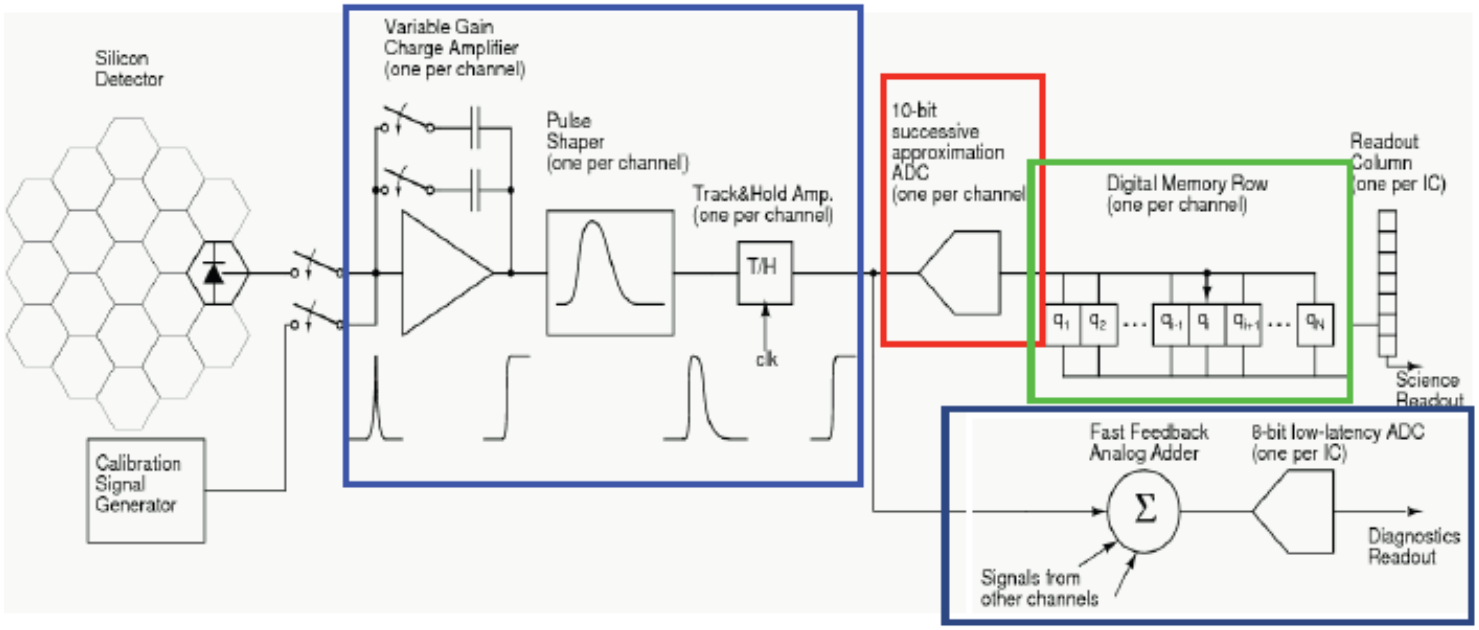
- How is the Beamcal positioned? Required position tolerance?
- How is installed Beamcal position monitored?

Beamcal Front End Electronics

Specifications for Beamcal ASIC:

- very high occupancy
- record data from every bunch crossing
- low latency output for beam diagnostic/tuning
- 130 MB/bunch train – held in front end
- each sector: 16 MB buffer, 650 MB/s readout rate

Beamcal Front End Electronics



- Design at Stanford University (KPIX technology)
- readout between bunch trains ('science readout')
- prepared for fast feedback (diagnostics readout to machine)
- prototypes expected in 2010

This was not described in the FCal report!?

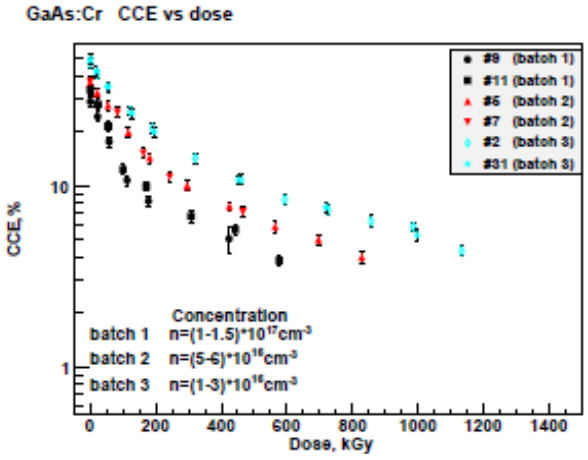
Beamcal – Radiation Hard Sensors

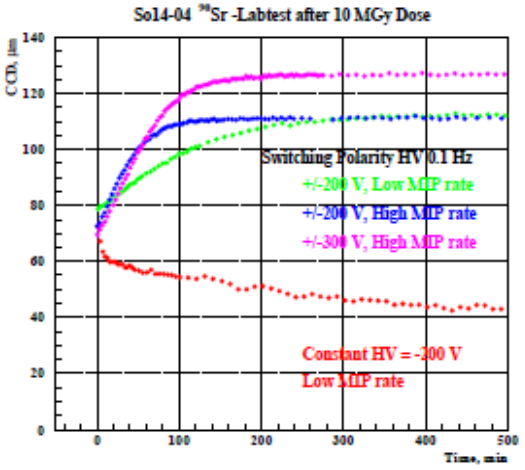
- Degradation of sensors with time, plus variation over Beamcal

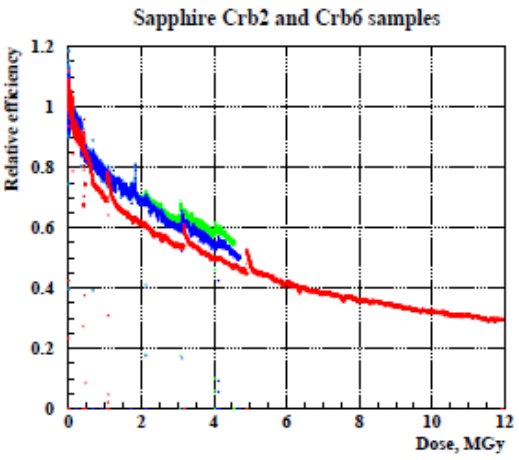
  -> effect on changing energy resolution?

  -> effect on efficiency of forward HE electron veto?

GaAs, CVD diamond, Sapphire results:







Beamcal comments

- Many simulation results presented – few conclusions?

- What is the plan for continued work?

- Are there ideas for a signal separation algorithm? - not yet.

Overall comments for FCal

Performance versus 2007 milestones:

1) "more realistic simulation of LumiCal and the study of the impact of Bhabha selection criteria on the luminosity measurement"

   -> Work has been done, but issues remain to be resolved

2) "completing the performance studies for BeamCal including additional effects and a realistic readout chain"

   -> Still ongoing, results given, but no conclusions yet

3) "detailed simulations for the design of the GamCal system"

   -> No more work on GamCal – proponents dropped out of FCal

4) "processing of the first layout of the front-end electronics and performance tests"

   -> Significant progress made, work ongoing

Overall comments for FCal

5) "design and construction of a full sensor plane for LumiCal and BeamCal for beam tests"

-> Started, sensors under test for LumiCal, but more time needed…

6) "continuation of the radiation hardness studies of CVD diamonds, GaAs, and Si sensors in low energy electron beams"

-> Work ongoing, interesting results

New Milestones:

- completion of a sensor plane prototype (2010);
- test of a sensor plane prototype in the beam (2010/11);
- conceptual design of the forward region of the CLIC detector (2010/11);
- completion of the BCM1F beam conditions monitor at CMS (2011).

Overall comments and recommendations for FCal

- The PRC congratulates the FCal collaboration on achieving progress on many fronts, drawing together resources from a broad community.

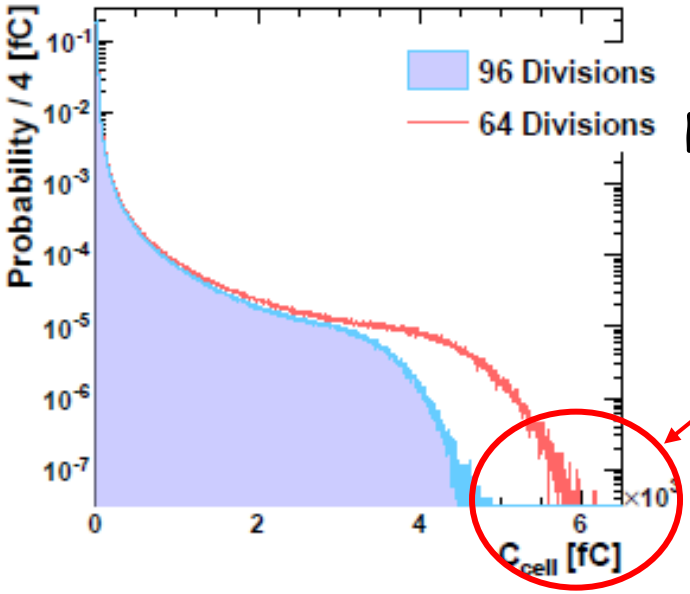
- A lot of work since 2007, significant progress, but an eclectic program -> need overall schedule + milestones and monitored progress.

- Tables of institutions/projects and support needed.

- Many developments tied to ILD -> presumably need answers for 2012? (and CLIC CDR for 2010)

Simulations

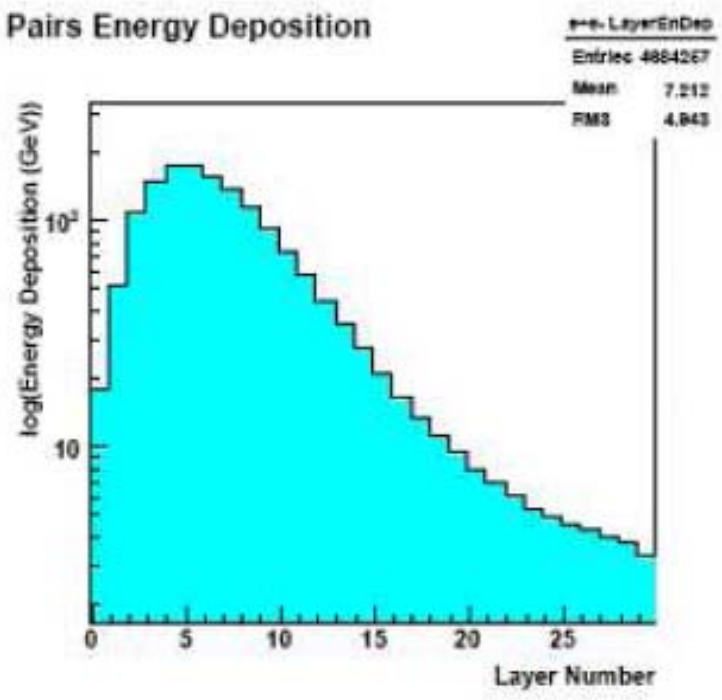
Electronics/signal sizes:



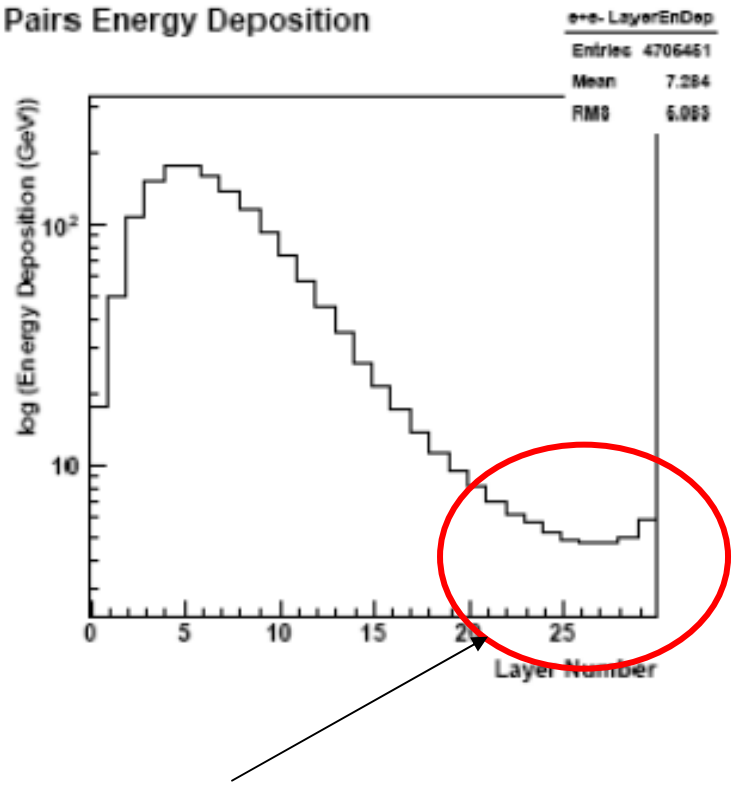
Range 3.9fC – 6pC

2fC – 10pC in electronics section

Simulation studies



(b) QGSP_BERT_HP



Backscatter from QD0