The Very Forward Region of the ILC Detectors

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FCAL Collaboration

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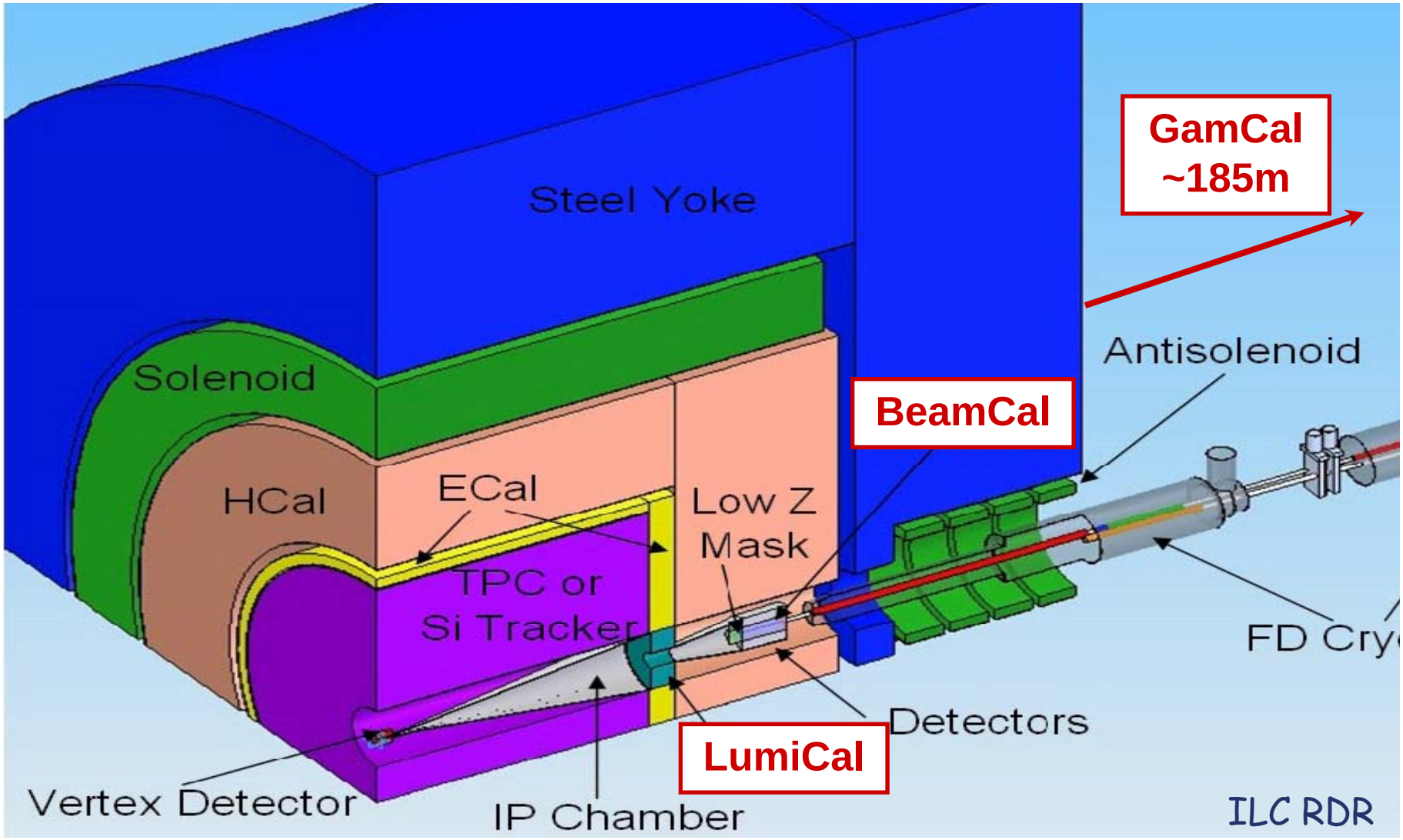
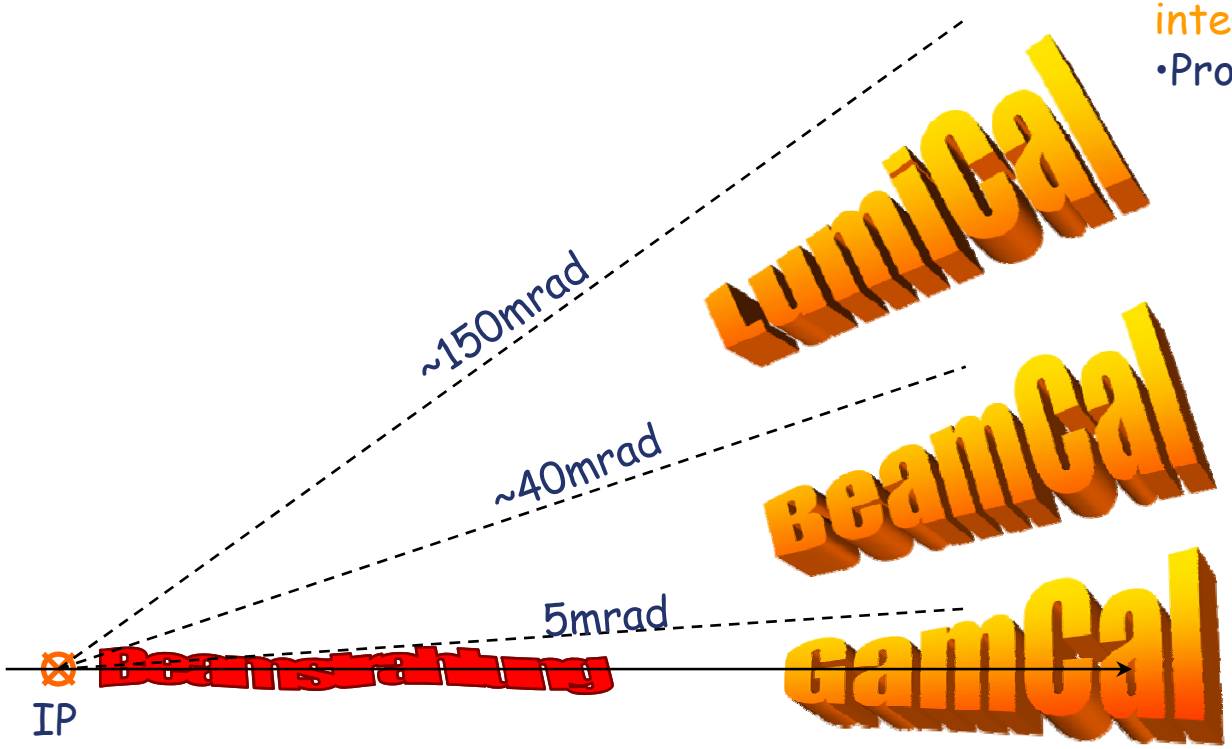
- Forward Calorimetry Overview
  - **LumiCal, BeamCal**
- Beamdiagnostics using BeamCal and GamCal
- BeamCal Electronics R&D
- Summary

Design of the Forward Region



Tasks of the Forward Region

ECal and Very Forward Tracker acceptance region.



- Precise measurement of the integrated luminosity ($\Delta L/L \sim 10^{-4}$)
- Provide 2-photon veto

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- Serve the beamdiagnostics using beamstrahlung pairs
- Pair Monitor (see talk by Itoh)

- Serve the beamdiagnostics using beamstrahlung photons

Challenges:

High precision, high occupancy, high radiation dose, fast read-out!

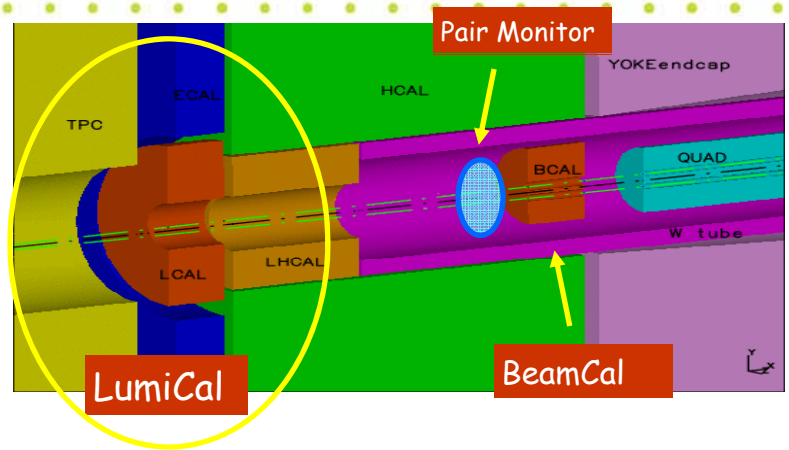
The LumiCal

Precise Measurement of the ILC's luminosity

Precise Measurement of the Luminosity

- Required precision is:

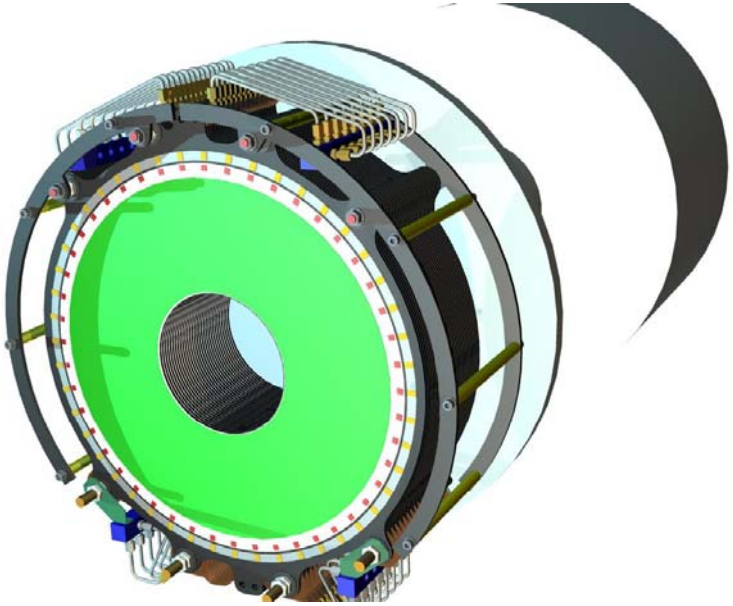
  $\Delta L/L \sim 10^{-4}$ (GigaZ 10^9/year)
  $\Delta L/L < 10^{-3}$ ($e^+e^- \rightarrow W^+W^-$ 10^6/year)
  $\Delta L/L < 10^{-3}$ ($e^+e^- \rightarrow q^+q^-$ 10^6/year)

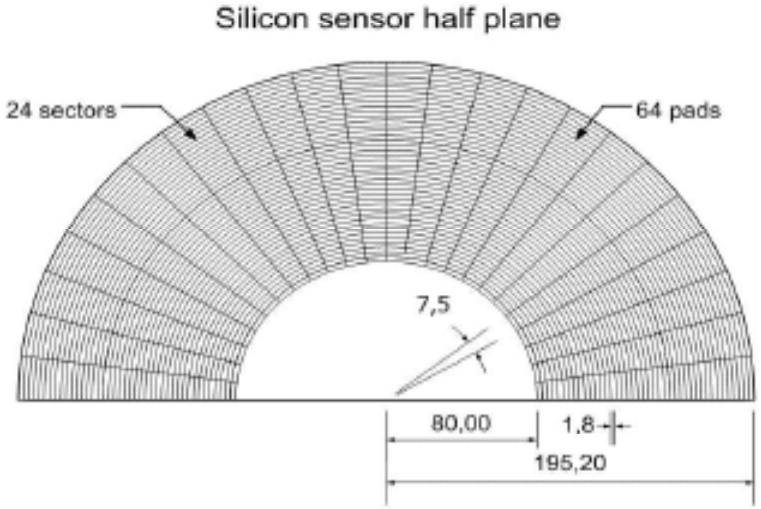


- Bhabha scattering ee->ee(γ) is the gauge process:
  - **Count Bhabha event in a well known acceptance region => L = N/σ**
  - **High statistics at low angles => $N_{Bhabha} \sim 1/\theta^3$**
  - **Well known electromagnetic process (LEP: 10^{-3}): the current limit on the theoretical cross section error is at ~5 10^{-4}.**

LumiCal: Design Parameters

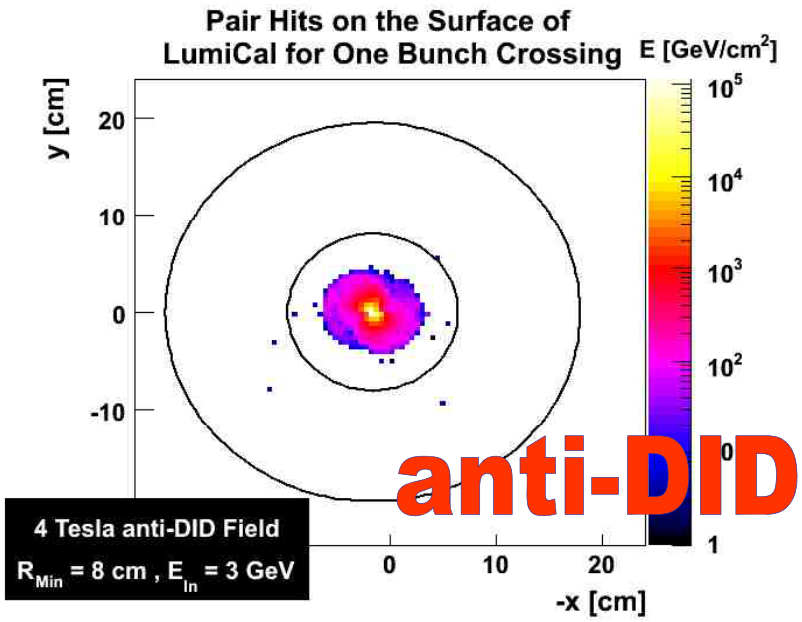
- 1. Placement:
  - **2270 mm from the IP.**
  - **Inner Radius - 80 mm**
  - **Outer Radius - 190 mm**
- 2. Segmentation:
  - **48 sectors & 64 cylinders:**
  - **Azimuthal Cell Size - 131 mrad**
  - **Radial Cell Size - 0.8 mrad**

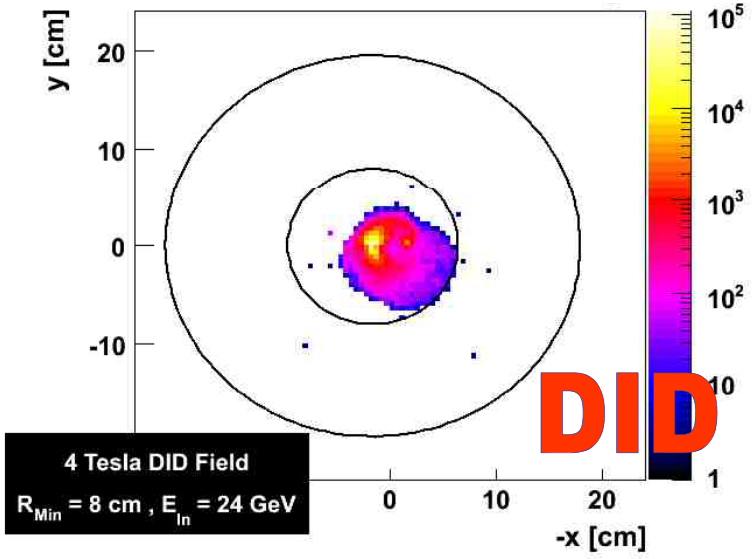




- 3. Layers:
  - **Number of layers - 30**
  - **Tungsten Thickness - 3.5 mm**
  - **Silicon Thickness - 0.3 mm**
  - **Elec. Space - 0.1 mm**
  - **Support Thickness - 0.6 mm**

LumiCal Aperture



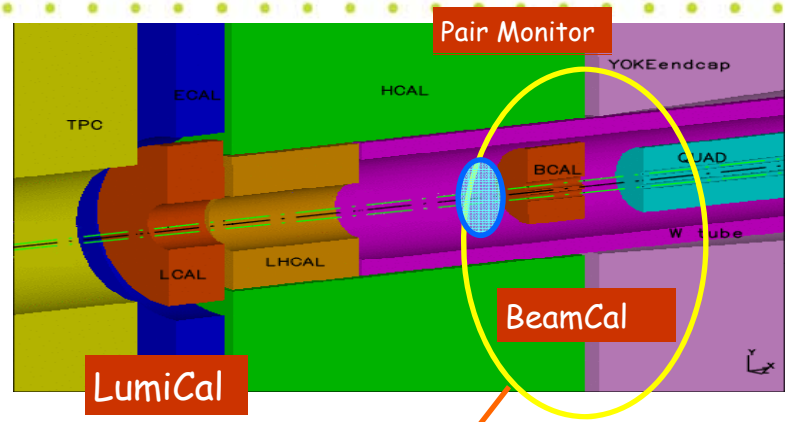


- The inner radius of 80mm (z = 2270mm) keeps a security margin of about 1 cm for the beamstrahlung pairs in the anti-DID case.

The BeamCal and Beamdiagnostics

BeamCal Design

- Compact em calorimeter with sandwich structure:
  - 30 layers of 1 X_0
    - 3.5mm W and 0.3mm sensor
  - Angular coverage from ~5mrad to ~45 mrad
  - Moliére radius $R_M \approx 1$cm
  - Segmentation between 0.5 and 0.8 x R_M

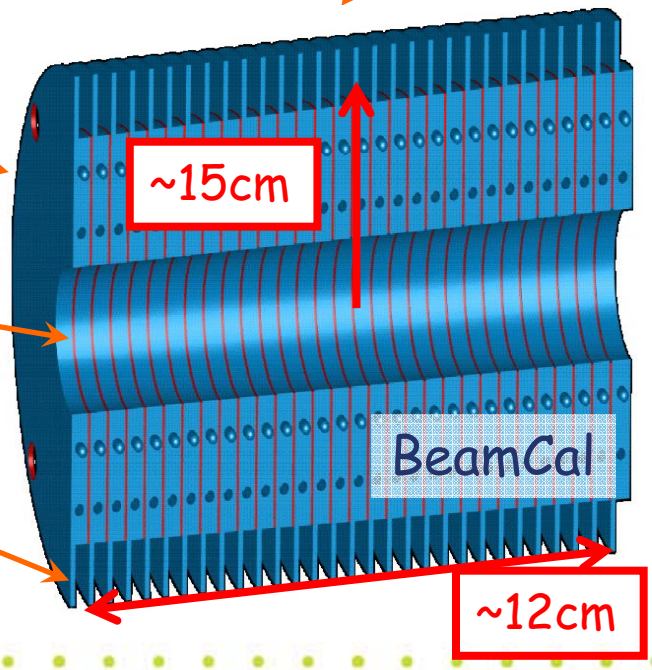


W absorber layers

Radiation hard sensors with thin readout planes

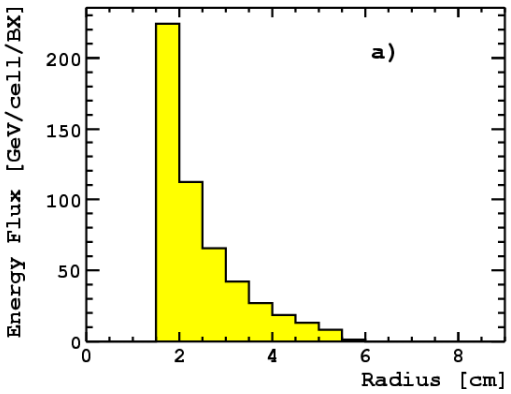
Space for readout electronics

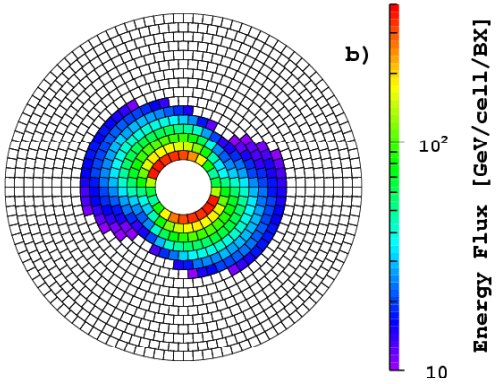
+ graphite in front of BeamCal to reduce backscattering

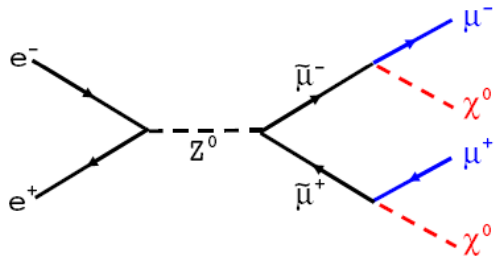


BeamCal Challenges

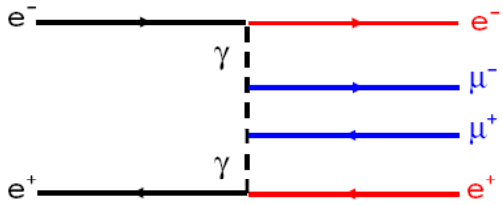
- BeamCal will extend the sensitive region to lowest polar angles.
- Challenge:
  Detect single high energetic particle on top of a background of 10^4 low energetic e^+e^- pairs.
- BeamCal serves is part of the beam diagnostics system, providing a 'beamstrahlung pair' information to the feedback system.







Physics signal:
e.g. SUSY smuon production



Background signal:
2-photon event, may fake the upper signal if the electron is not detected.

Fast Beamdiagnostics

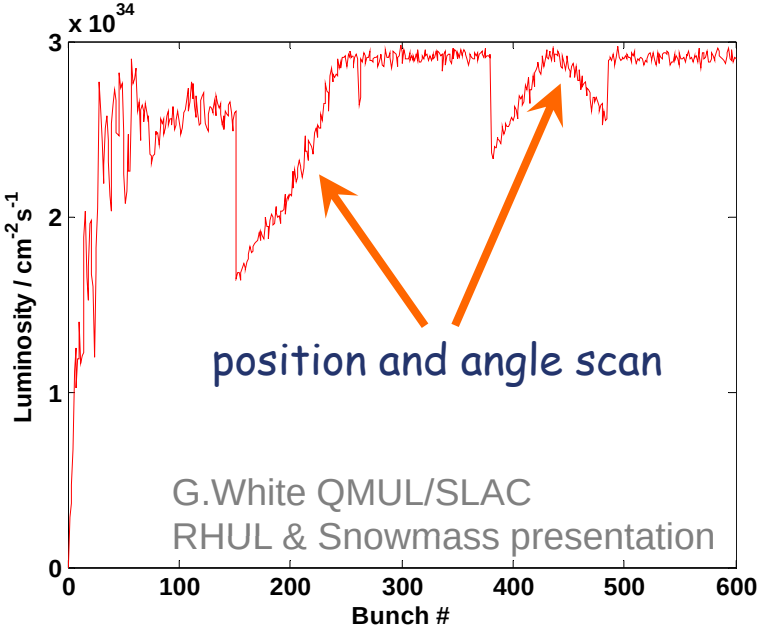
- Obtain as much information about the collision as possible.
- BeamCal measures the energy of pairs originating from beamstrahlung.
- GamCal will measure the energy of the beamstrahlung photons.
- Generate a fast feedback signal in realtime.

Define a signal proportional to the luminosity which can be fed to the feedback system.

1. Standard procedure (using BPMs)
2. Include pair signal (N) as additional input to the system

Increase of luminosity of 10 - 15%

Simulation of the Fast Feedback System of the ILC.



Requirements on BeamCal

- Use the pair background signal to improve the accelerator parameters.

  - **The spatial distribution of the energy deposition from beamstrahlung pairs contains a lot of information about the collision.**
  - **Use a fast algorithm to extract beam parameters like:**

beam sizes (σ_x, σ_y and σ_z)
emittances (ε_x and ε_y)
offsets (Δ_x and Δ_y)
waist shifts (w_x and w_y)
angles and rotation (α_h, α_v and φ)
Particles per bunch (N_b)

Concepts of the Beamstrahlung Pair Analysis

Simulate Collision
with **Guineapig**
1.) nominal parameter set
2.) with variation of a specific beam parameter
(e.g. σ_x, σ_y, σ_z, $\Delta\sigma_x$, $\Delta\sigma_y$, $\Delta\sigma_z$)
G.White: 2nd order dependencies

Produce photon/pair output
ASCII File

A.Sapronov: BeCaS1.0

Run full GEANT4 simulation
BeCaS and calculate energy deposition per cell
(geometry and magnetic field dependent)

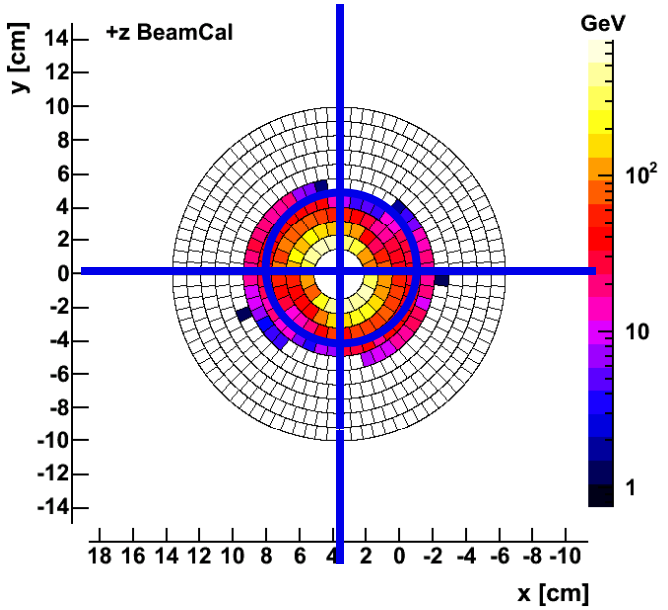
Calculate Observables and write summary file

Do the parameter reconstruction using
1.) linear approximation (Moore Penrose Inversion Method)
2.) using fits to describe non linear dependencies

LC-DET-2005-003
Diagnostics of Colliding Bunches from Pair Production and Beam Strahlung at the IP
Achim Stahl

Moore Penrose Method

$$\begin{pmatrix}\text{Observables}\end{pmatrix} = \begin{pmatrix}\text{Observables}\end{pmatrix}_{\text{nom}} + \begin{pmatrix}\text{Taylor}\\ \text{Matrix}\end{pmatrix} \begin{pmatrix}\Delta \text{BeamPar}^{*}\end{pmatrix}$$



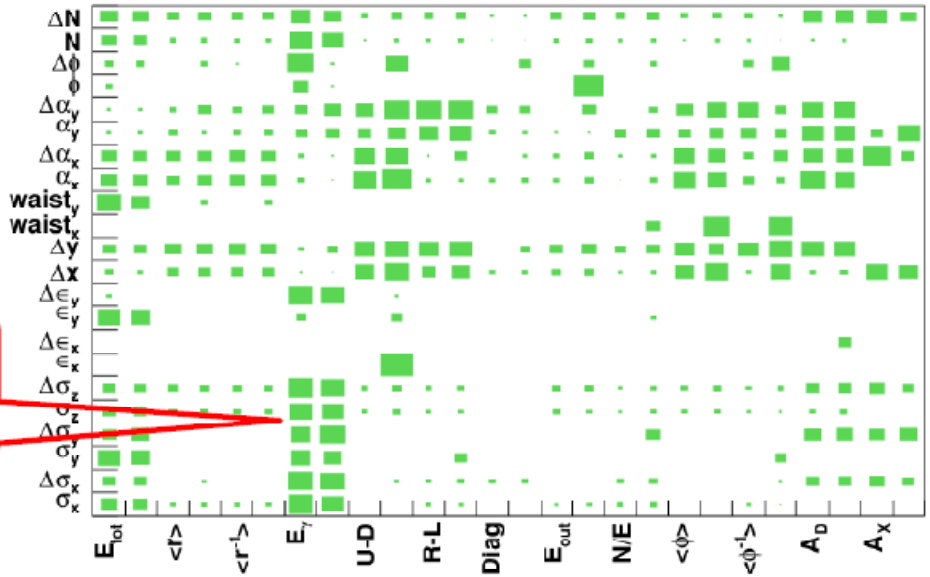
- observables:
  - total energy
  - first radial moment
  - inv. radial moment
  - l/r, u/d, diag asymmetries
  - E(ring ≥ 4) / Etot
  - E / N
  - phi moment
  - inv. phi moment
  - f/b asymmetries
  - total photon energy (extern)

- beam parameters (diff and av)
  - bunch sizes
  - emittances
  - beam offsets
  - waist shifts
  - bunch rotations
  - profile rotations
  - number of particles

Beam Parameter Reconstruction

Single parameter reconstruction using whole calorimeter data

			2mrad (old)		20mrad DID		20mrad DID + Ephot		14mrad antiDID + Ephot	
BP	Unit	Nom.	μ	σ	μ	σ	μ	σ	μ	σ
σ_z	μm	300	300.75	**4.56**	307.98	**4.72**	299.80	**1.69**	301.09	**1.65**
ε_x	10^{-6}m rad	10	11.99	**7.61**	-	**-**	-	**-**	9.94	**2.16**
Δx	nm	0	4.77	**14.24**	4.55	**8.14**	4.57	**8.13**	-3.84	**11.80**
α_x	rad	0	0.002	**0.016**	0.010	**0.025**	-0.001	**0.025**	-0.071	**0.017.**



High significance of information from gammas for bunch sizes reconstruction.

A.Sapronov

Photon energy can be provided by GamCal.

Observables/Beam Parameters

- E_tot: Total energy
- R_mom: Radial moment
- Irmom: "Inverted" rmom
- Z_mom: Z moment
- Izmom: "Inverted" zmom
- E_gam: Gamma energy
- UDimb: Up-Down imbalance
- RLimb: Right-Left imbalance
- DgImb: Diagonal imbalance
- NovrE: N/E
- Phi_M: Phi moment
- IphiM: "Inverted" phimom
- A_dir: forward-backward direct asymmetry
- A_xsd: forward-backward crossed asymmetry

Combination of both BeamCals.

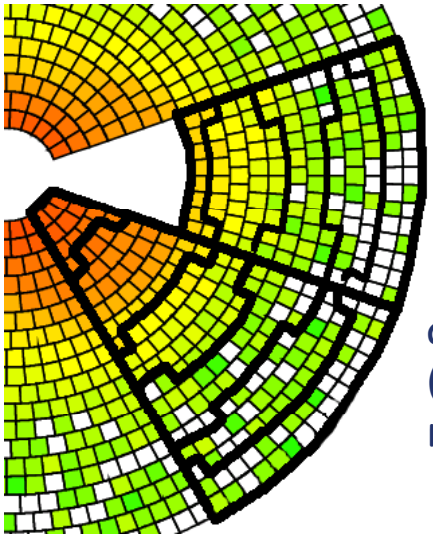
- Bunch width x (nm), Ave/Diff
- Bunch width y (nm), Ave/Diff
- Bunch length z (μm), Ave/Diff
- Emittance in x (10^{-6} m rad), Ave/Diff
- Emittance in y (10^{-9} m rad), Ave/Diff
- Beam offset in x (nm)
- Beam offset in y (nm)
- Horizontal waist shift-x (μm)
- Vertical waist shift-y (μm)
- # of part. per bunch (10^{10}), Ave./Diff.

- No angle reconstruction (can be optimized by scans)
- Some beam parameter constrained by external measurements.

...and Data Reduction

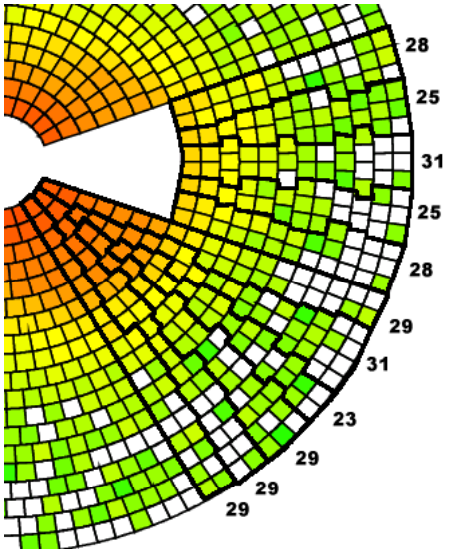
- Possible schemes for clustering (readout electronics)
- No clear indication of a preferred layer combination.

rel. precision of the vertical beam offset reco



angular clusters (prefered for reconstruction)

radial clusters (prefered for electronics)



Multiparameter Reconstruction

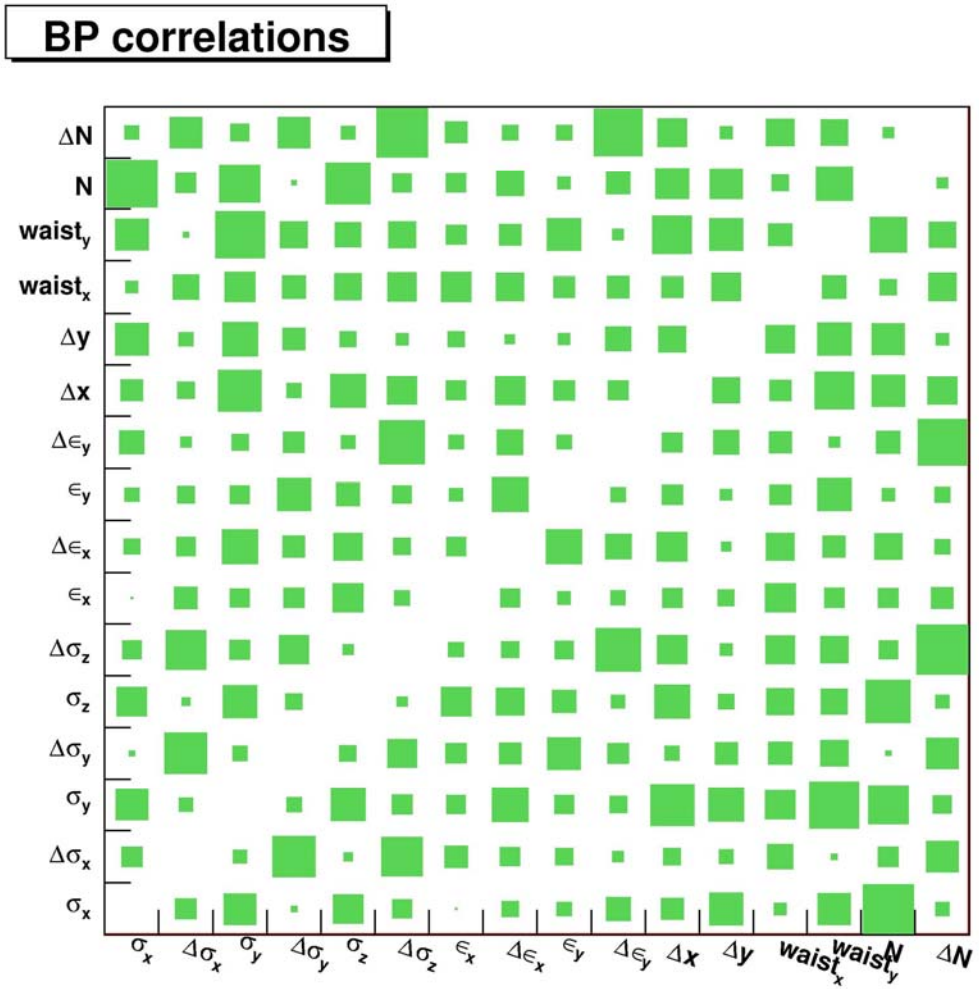
Beam Par	Unit	Nominal	Resolution
σ_x	nm	655	21.913
$\Delta\sigma_x$	nm	0	20.261
σ_y	nm	5.7	1.288
$\Delta\sigma_y$	nm	0	0.845
ε_y	10^{-9} m rad	40	4.079
$\Delta\varepsilon_y$	10^{-9} m rad	0	3.384
Δx	nm	0	13.608
Δy	nm	0	1.427
$waist_x$	μm	0	154.515
$waist_y$	μm	0	90.873
N	10^{10}	2.0	0.050
ΔN	10^{10}	0	0.107

Full Multiparameter Reconstruction (except angles) using:

- 32 channel cluster (angular)
- layers 8/9 (summed)
- constraint on emittance of 10%
- digitization of 8 Bit

Correlations

- Correlations between beam parameters are there. Some are very large.
- We might reduce correlations by using other sources of information.
- We might also just be able to give a resolution on a combination of highly correlated parameters.



FCAL R&D

Electronics

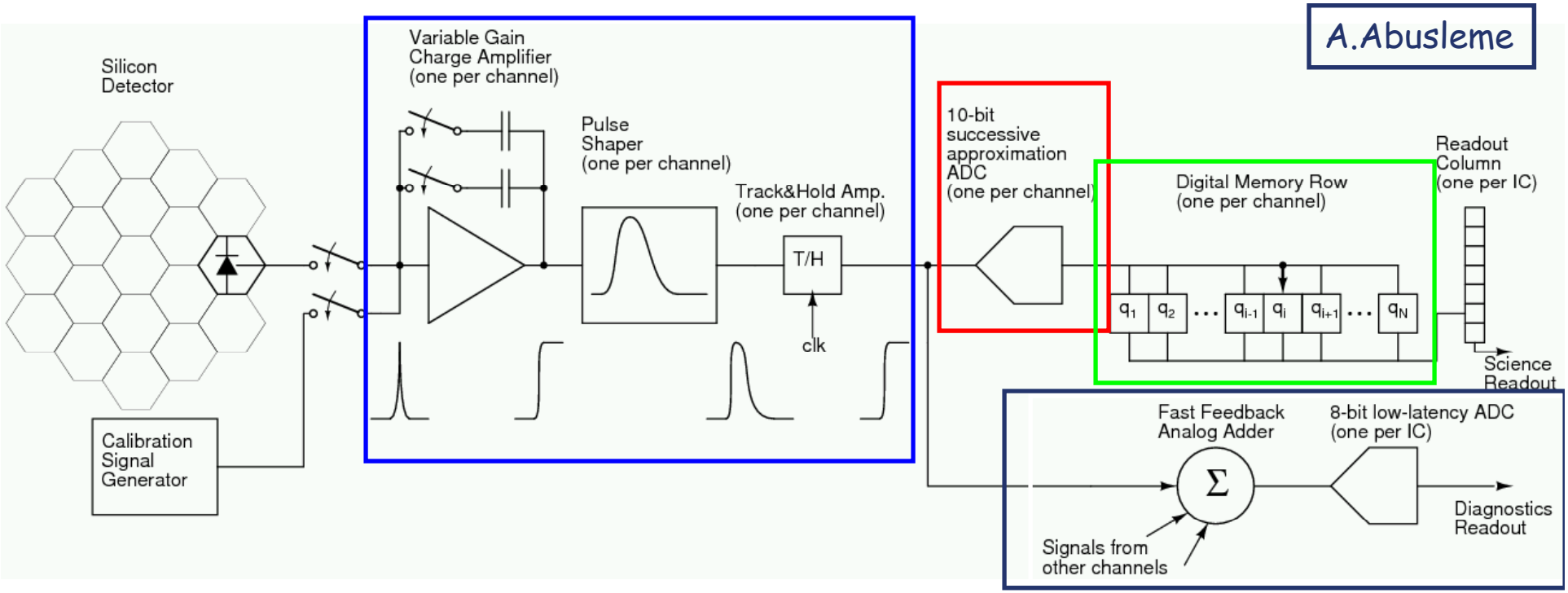
BeamCal Electronics

A.Abusleme

- 32 channels per chip
- High occupancy, all data is read out at 10 bits for science purposes;
- Low latency output, sum of all channels is read out after each bx at 8 bits for beam diagnosis (fast feedback)
- Prototype in 0.18-μm TSMC CMOS technology

➢ April 2007:	High level design complete
➢ July 2007-July2008:	Layout design
➢ August 2008:	Verification complete
➢ October 2008:	Prototype ready
➢ January 2009:	Prototype tests complete

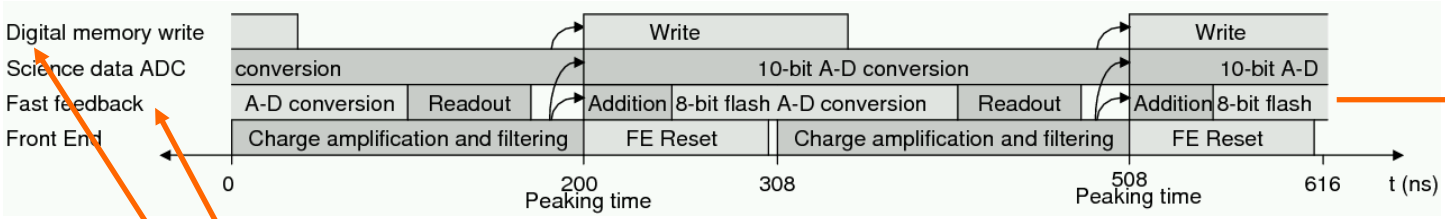
BeamCal Electronics Operation



- Dual-gain front-end electronics: charge amplifier, pulse shaper and T/H circuit
- Successive approximation ADC, one per channel
- Digital memory, 2820 (10 bits + parity) words per channel
- Analog addition of 32 channel outputs for fast feedback; low-latency ADC

Timing and Architecture

A.Abusleme

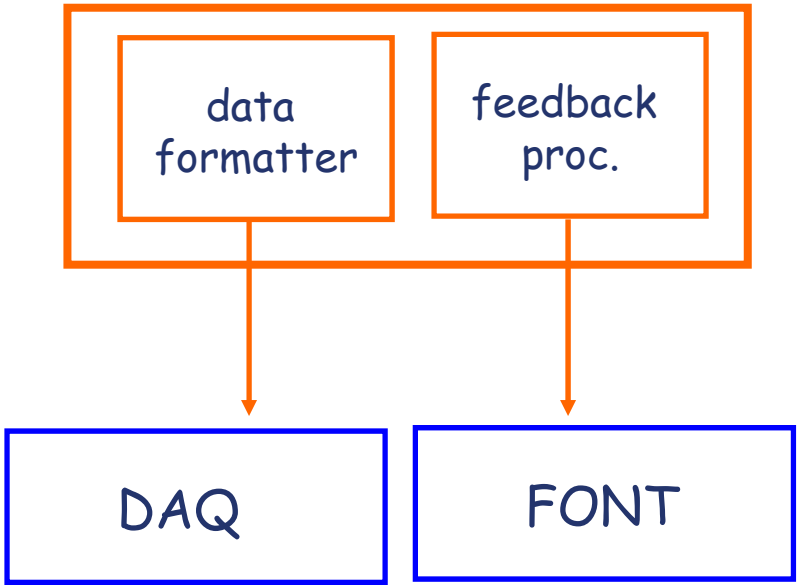


~ 50 signals
per layer of BeamCal

Readout in real time and with low latency (~1 μs)

Readout between bunch trains

Pair Monitor,
GamCal etc



Need one more level in the readout architecture for the interface to FONT and to the detector DAQ.

Summary

- The geometry of LumiCal (and BeamCal) has been adjusted for the 14mrad (AntiDID) option.
- Beam Parameter Reconstruction using BeamCal has been tuned for a multi parameter reconstruction.
- Results are very interesting but some beam parameters are highly correlated.
- BeamCal electronics are currently being designed, implementing a fast feedback link (32 channel clusters/8 bit).