Very Forward Instrumentation: BeamCal

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FCAL Collaboration

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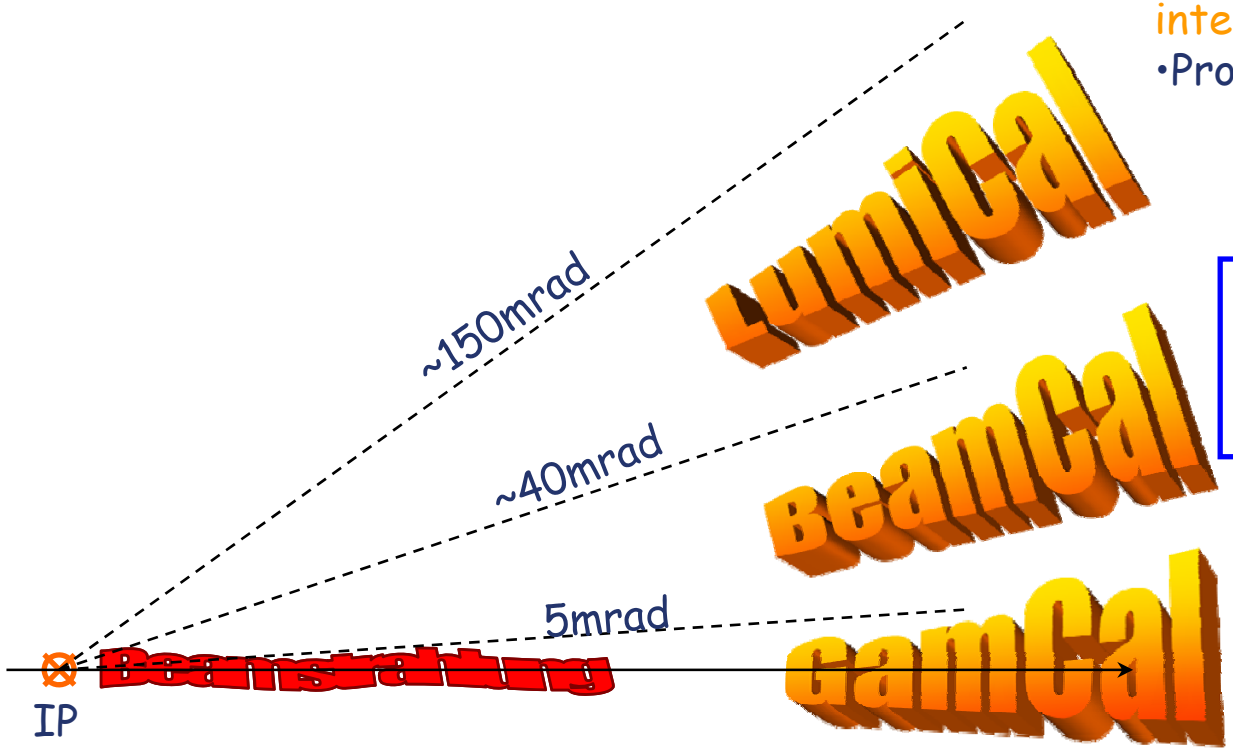
Tasks of the Forward Region

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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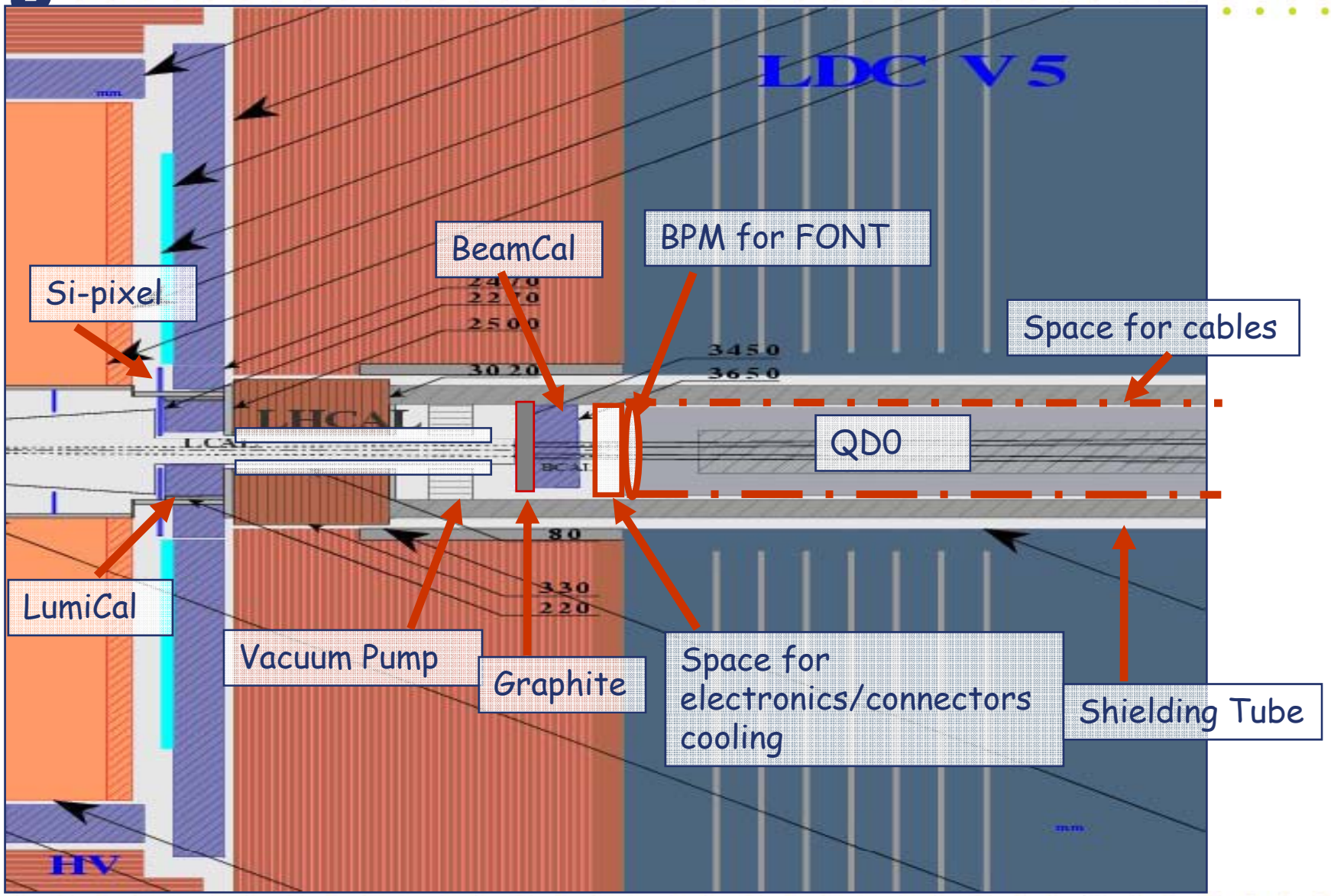
- Serve the beamdiagnostics using beamstrahlung pairs

- Serve the beamdiagnostics using beamstrahlung photons

Challenges for BeamCal:

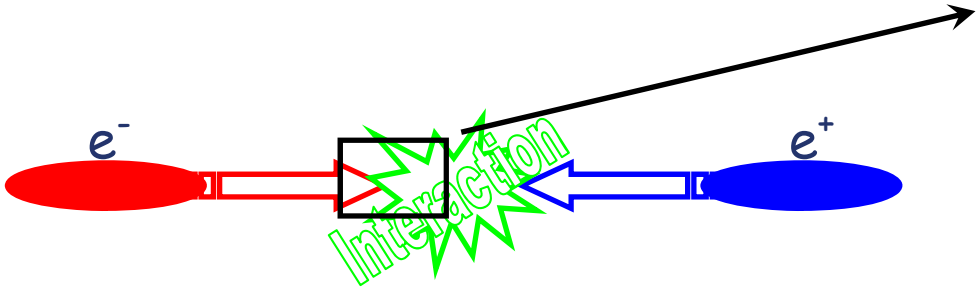
High occupancy, high radiation dose, fast read-out, high number of channels (10^5)!

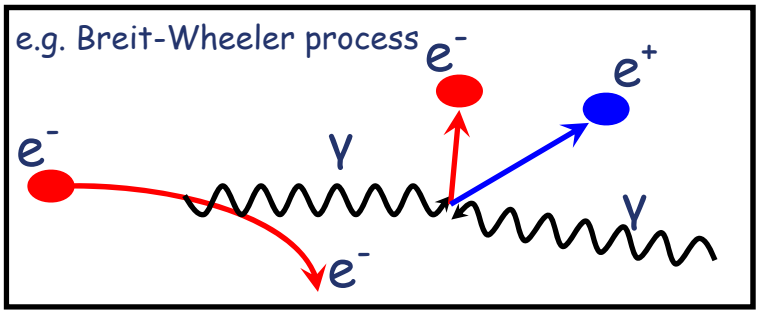
Forward Region (LDC)



The Challenges for BeamCal

Creation of beamstrahlung at the ILC



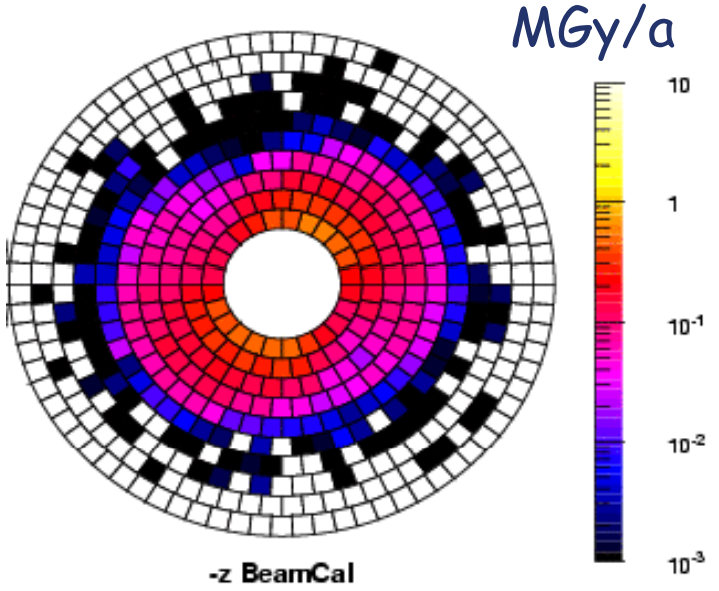


- e+e- pairs from beamstrahlung are deflected into the BeamCal
- 15000 e^+e^- per BX

  => 10 – 20 TeV total energy dep.
- **up to 10 MGy per year** strongly dependent on the beam and magnetic field configuration

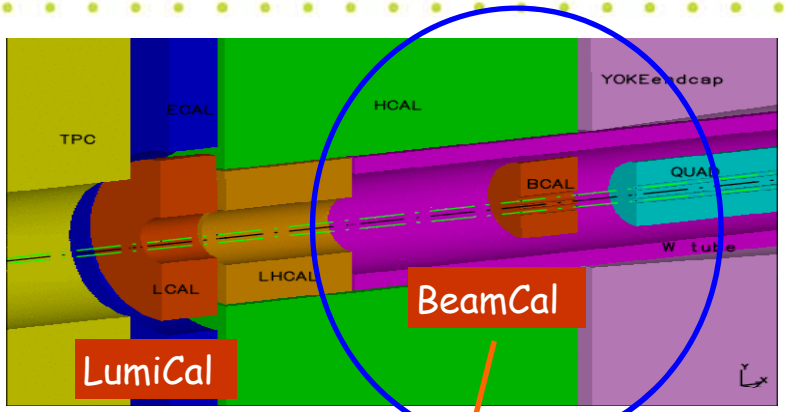
  => radiation hard sensors
- Detect the signature of single high energetic particles on top of the background.

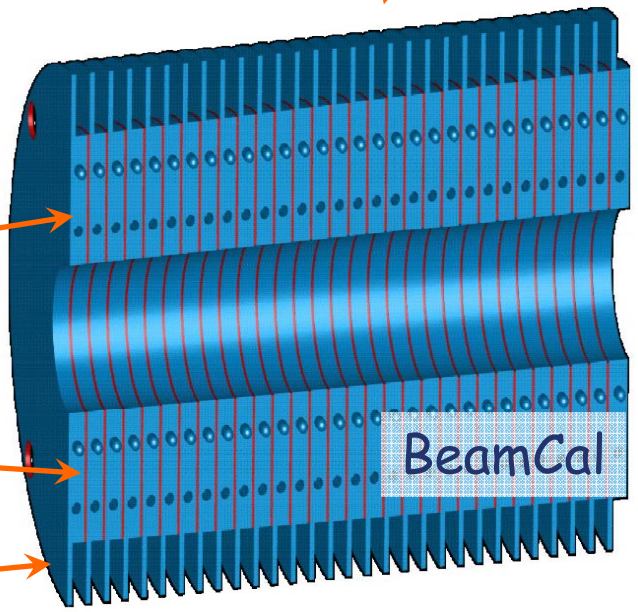
  => high dynamic range/linearity



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
  - Design for LDC V5:
    - z = 3450 mm
    - inner radius of sensitive area: 20 mm
    - outer radius of sensitive area: 150 mm
    - incoming beam pipe: 15 mm





W absorber layers

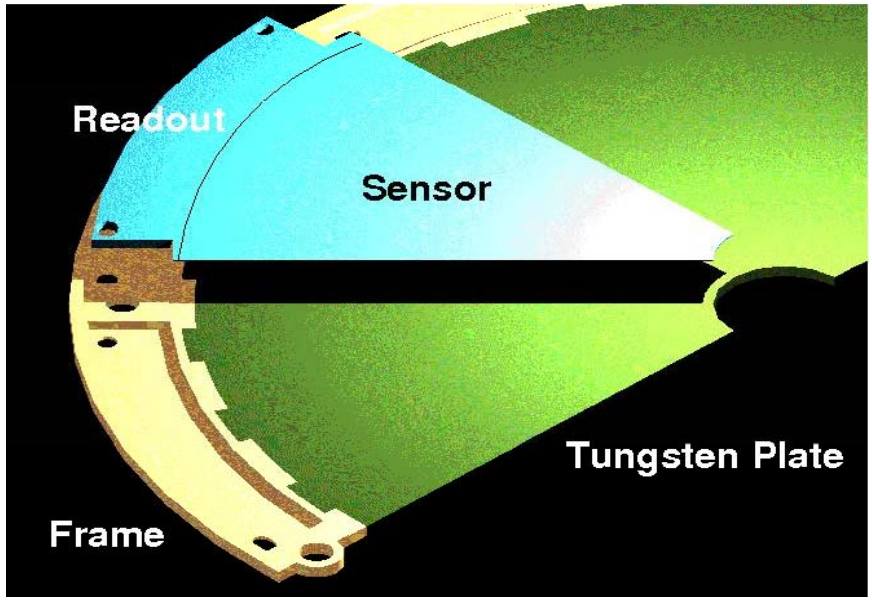
Radiation hard sensors with thin readout planes

Space for readout electronics

drawing not to scale

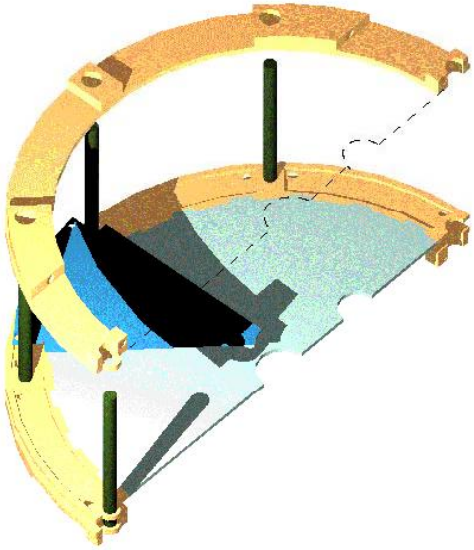
BeamCal Mechanics

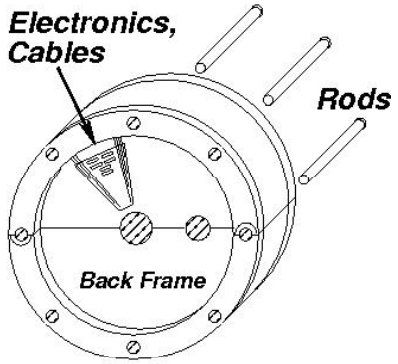
Sensor and R/O Hybrid



- Total outer radius: 220 mm
- Graphite shield of 10 cm
- Total weight: about 200 kg
- Upper part of the shielding tube must be removable
- Crane operation necessary for assembly/disassembly

Assembly, Cabling, Extra Electronics



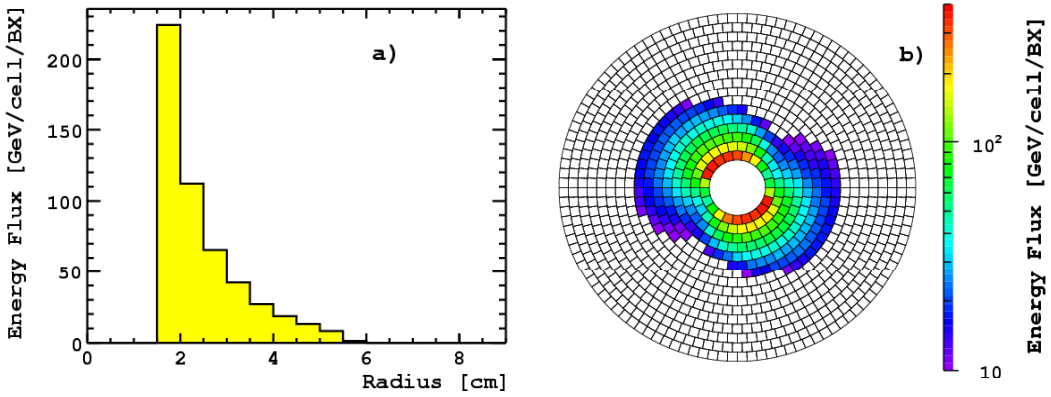


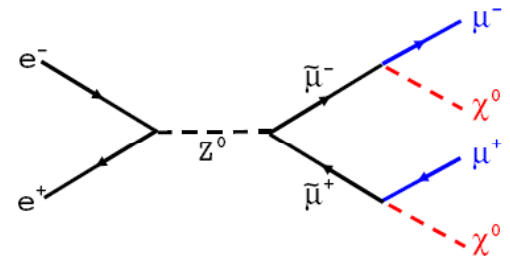
Back view

Additional space in front of and behind BeamCal is needed for electronics, cooling etc..

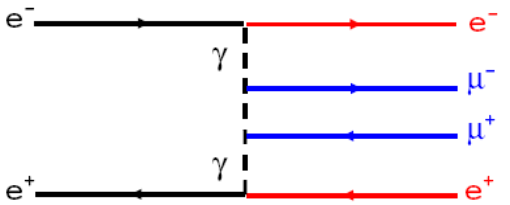
The Jobs of BeamCal

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



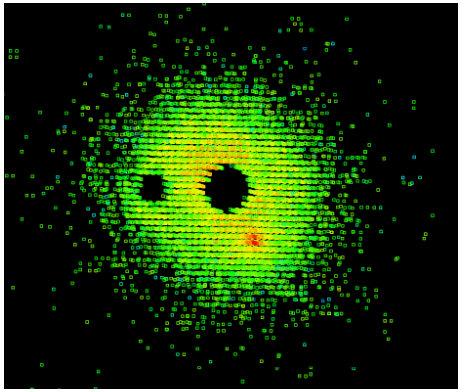


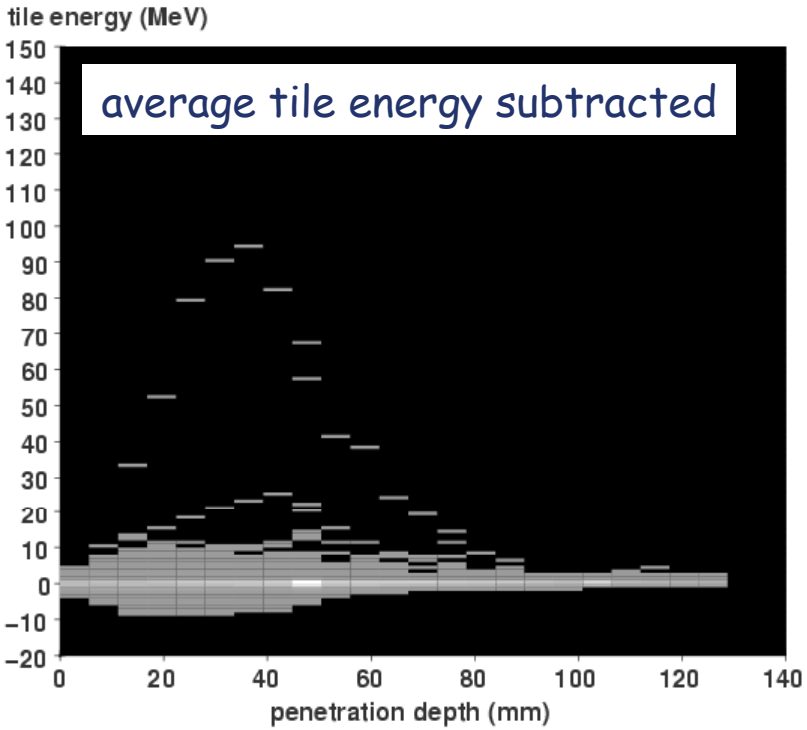
Physics signal:
e.g. SUSY smuon production

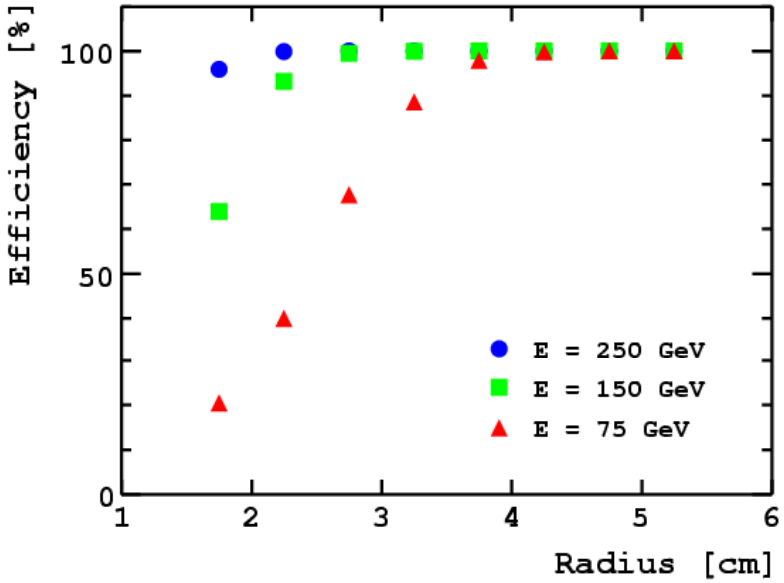


Background signal:
2-photon event, may fake the upper signal if the electron is not detected.

Particle Veto







- We developed algorithms to efficiently veto single high energetic particles down to lowest polar angles.
- We investigated the impact of different layouts, cell sizes, etc..
- We need radiation hard sensors with a large dynamic range $O(10^4)$.

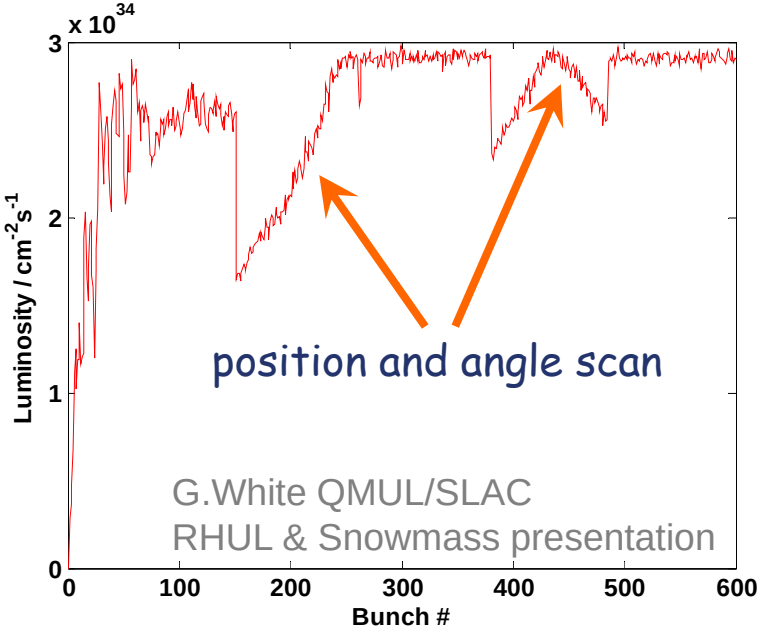
Beamdiagnostics

- 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.

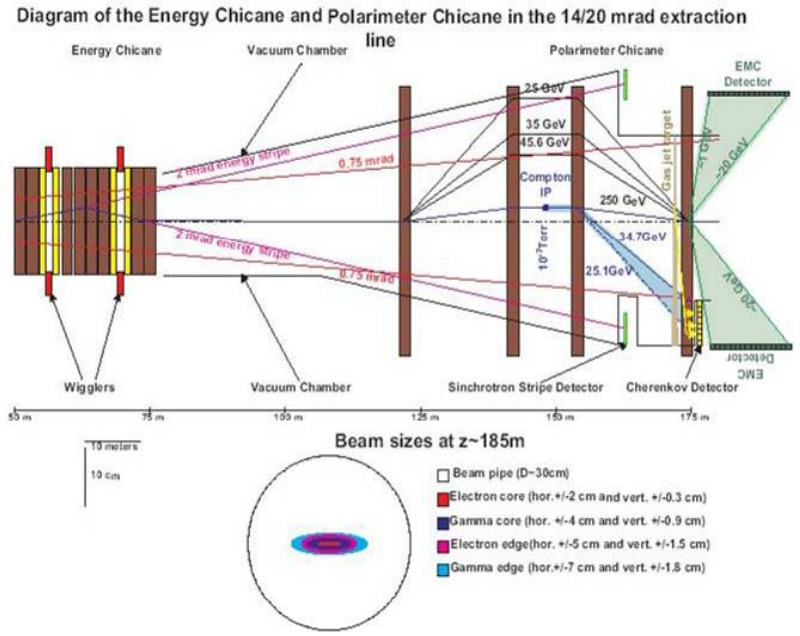
1. Standard procedure (using BPMs)
2. Include pair signal (N) as additional input to the system

Increase of luminosity of 10 - 15%

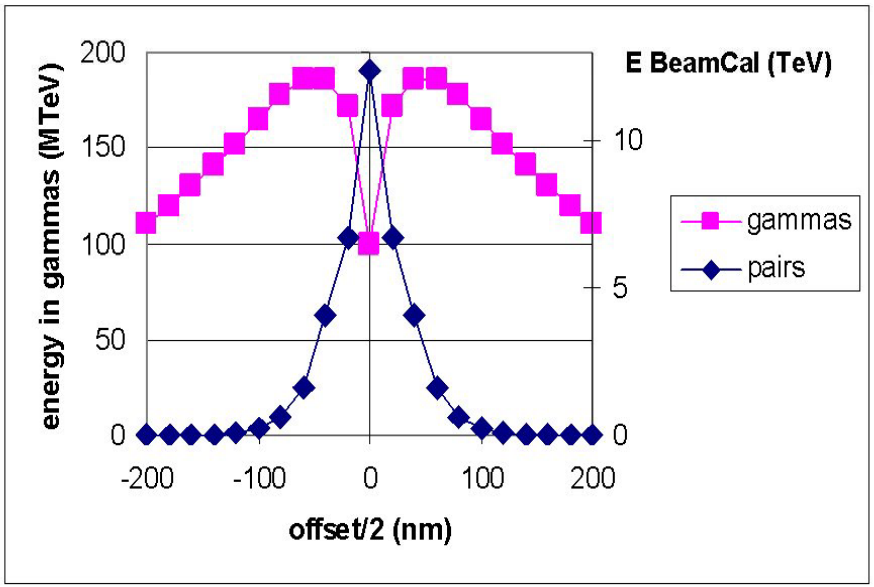
Simulation of the Fast Feedback System of the ILC.



GamCal: Measuring Beamstrahlung Photons



Vertical offset



GamCal is a beamstrahlung photon detector in the extraction line of the ILC (at about 180 m).
It uses a target (e.g. a gas jet) and an extraction magnet to deflect the ‚opposite' charge particles.

complementary information from
1. total photon energy vs vertical offset
2. BeamCal pair energy vs vertical offset

Advanced Beamdiagnostics

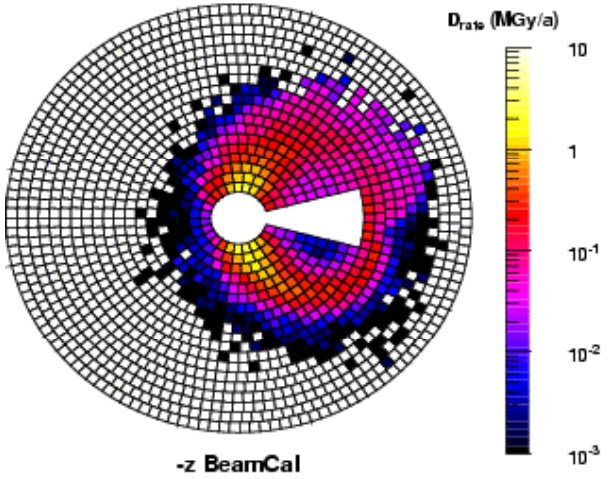
- What else can we learn about the collision?
- Use the beamstrahlung pair and photon signal to determine and improve the accelerator parameters.

  - **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)

Beam Parameter Reconstruction

Defining a set of observables from the spatial distribution of the energy deposition enables to reconstruct beam parameters of the primary beam.



Single parameter reconstruction using whole calorimeter data

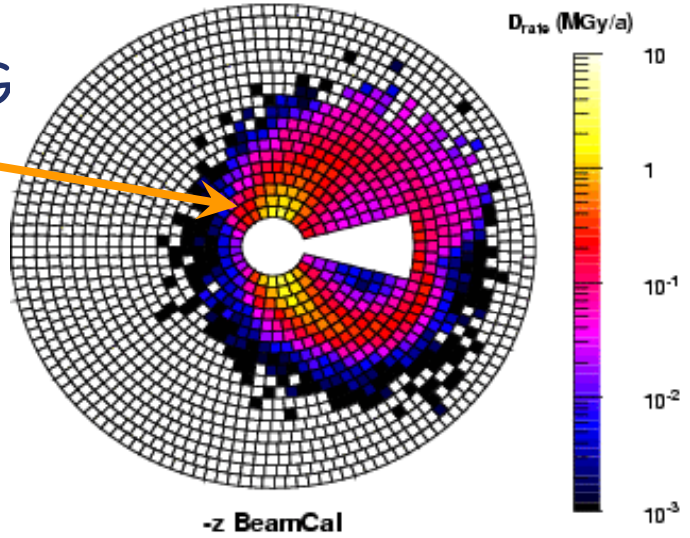
			2mrad (old)		20mrad DID		20mrad DID + Ephot		14mrad antiDID + Ephot	
BP	Unit	Nom.	μ	σ	μ	σ	μ	σ	μ	σ
σ_z	μm	300	300.75	**4.56**	307.98	**4.72**	299.80	**1.69**	301.09	**1.65**
ε_x	10^{-6}m rad	10	11.99	**7.61**	-	-	-	-	9.94	**2.16**
Δx	nm	0	4.77	**14.24**	4.55	**8.14**	4.57	**8.13**	-3.84	**11.80**
α_x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

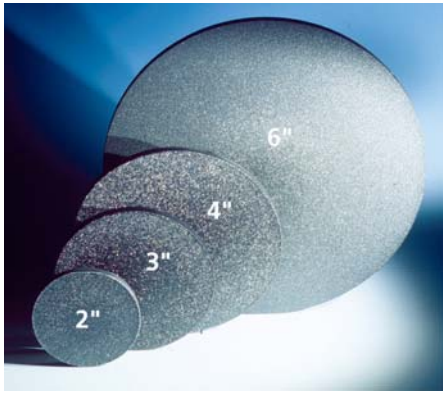
Radiation Hard Sensor Materials

- BeamCal: high energy deposition from low energetic pairs from beamstrahlung.

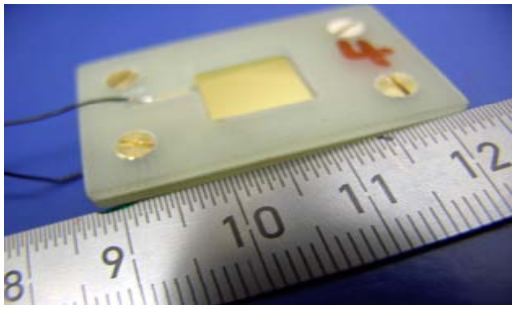
- We perform an extensive R&D program on candidate materials for the BeamCal:
  - **pCVD diamond**
  - **GaAs**
  - **radiation hard silicon**
  - **SC CVD diamond**

≈ 5 MG

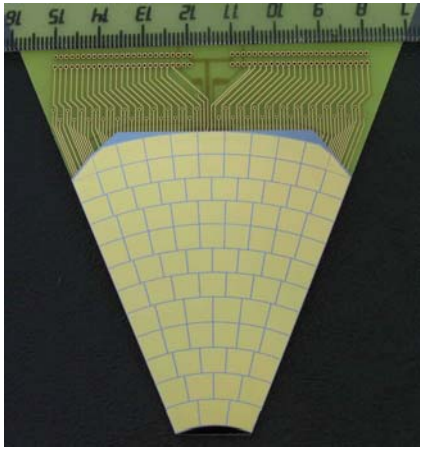




polycrystalline CVD diamond



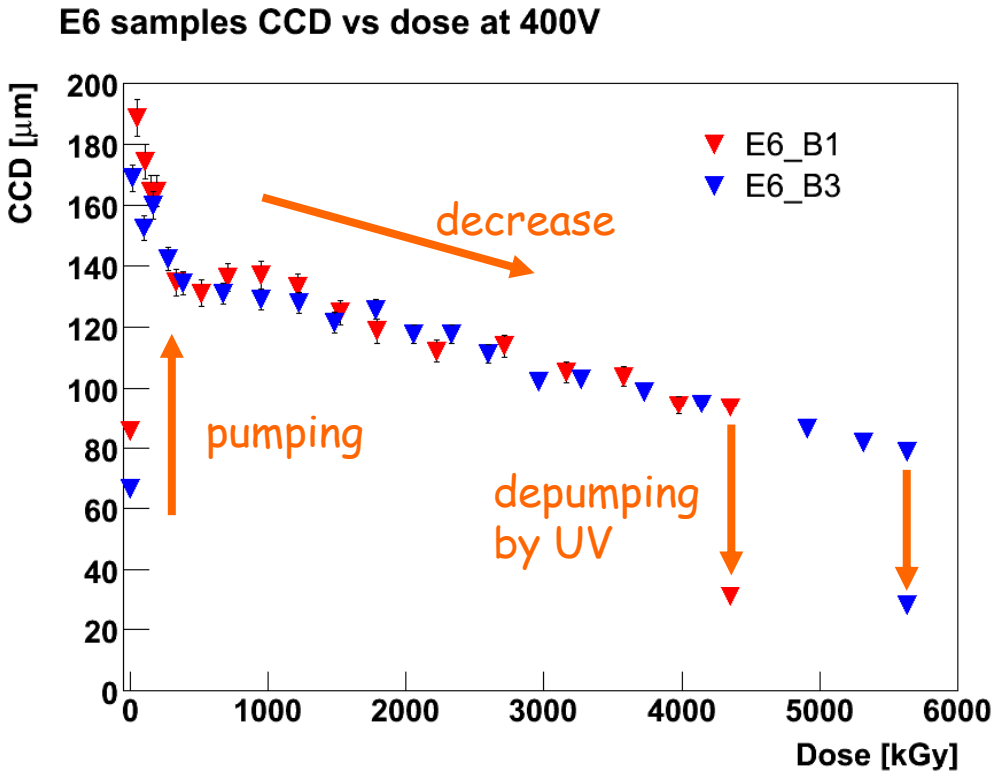
GaAs

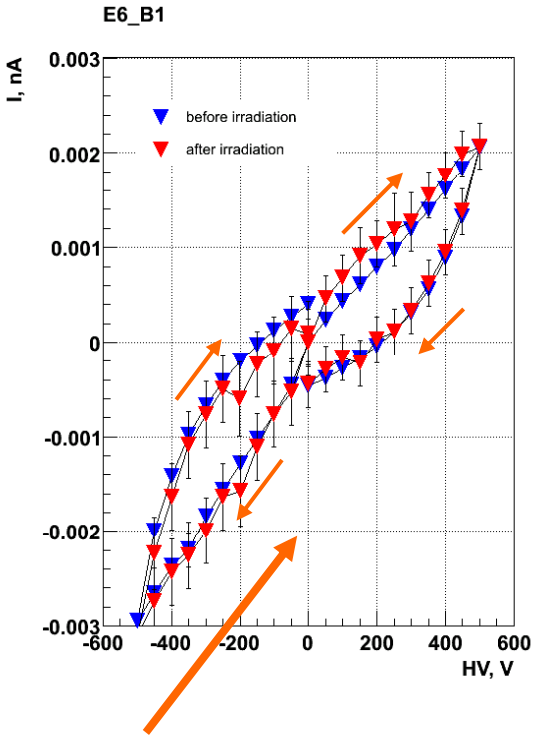


Irradiation of Polycrystalline CVD Diamond

After absorbing 5-6 MGy:

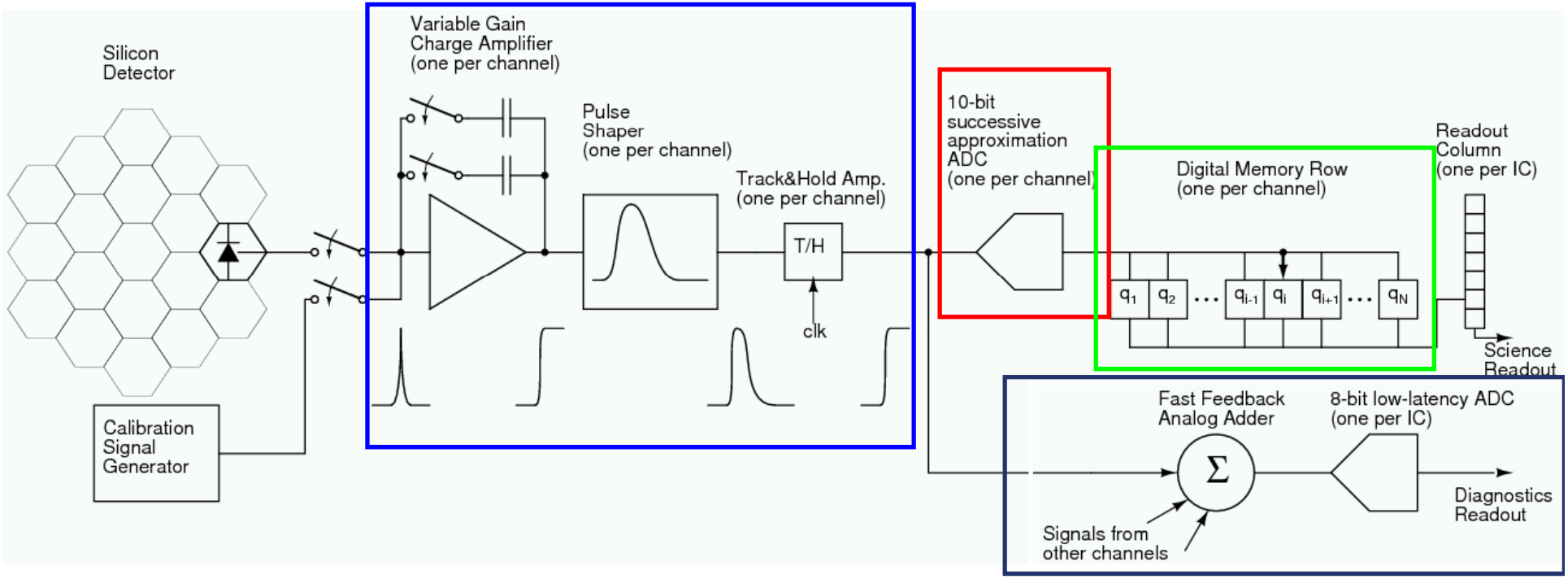
CVD diamonds still operational.





- Very low leakage currents (~pA) after the irradiation.
- Decrease of the charge collection distance.

Development of BeamCal Electronics



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

Summary

- BeamCal will extend the detector coverage to polar angles as low as 5 mrad.
- BeamCal is a powerful system to veto high energetic particles at lowest angles and to provide information about the collision to the feedback system.
- Radiation hard sensors are of crucial importance for the BeamCal.
- The BeamCal electronics is designed to provide a fast feedback signal to the accelerator.

Basic Considerations for the ILD BeamCal

- How large is the magnetic field and what are the details of the magnetic field in the forward region?
  - **Determines the shape/radius of the beamstrahlung pair cone.**
- How large is L*?
  - **Determines the z-position of BeamCal.**