The Forward Region Calorimetry

Ch. Grah for the FCAL Collaboration

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  - **radiation hard sensors**
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The FCAL Collaboration

13 Institutes from 10 countries:

- University of Colorado, Boulder
- Brookhaven National Lab, Upton
- Yale University, New Haven
- Laboratoire de l Accélérateur Linéaire, Orsay
- Royal Holloway University, London
- AGH University, Krakow
- Institute of Nuclear Physics, PAN, Krakow
- DESY
- Joint Institute Nuclear Research, Dubna
- National Center of Particle & HEP, Minsk
- Academy of Science, Prague
- VINCA Inst. of Nuclear Sciences, Belgrade
- Tel Aviv University

- Cooperation with SLAC

Supported by:
- EUROTeV,
- EUDET,
- NoRHDIA
- INTAS
- DOE

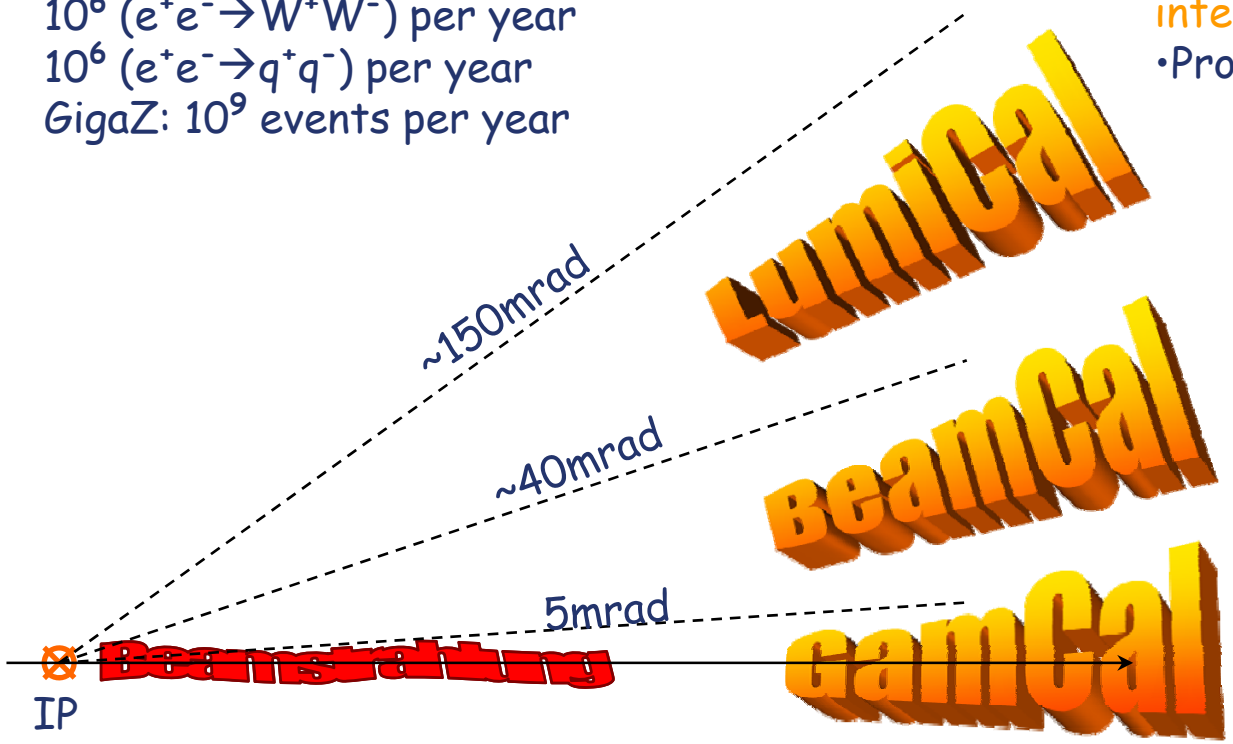
http://www-zeuthen.desy.de/ILC/fcal/

Tasks of the Forward Region

ECal and Very Forward Tracker acceptance region.

Physics at the ILC, e.g.:
10^6 ($e^+e^- \rightarrow W^+W^-$) per year
10^6 ($e^+e^- \rightarrow q^+q^-$) per year
GigaZ: 10^9 events per year

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



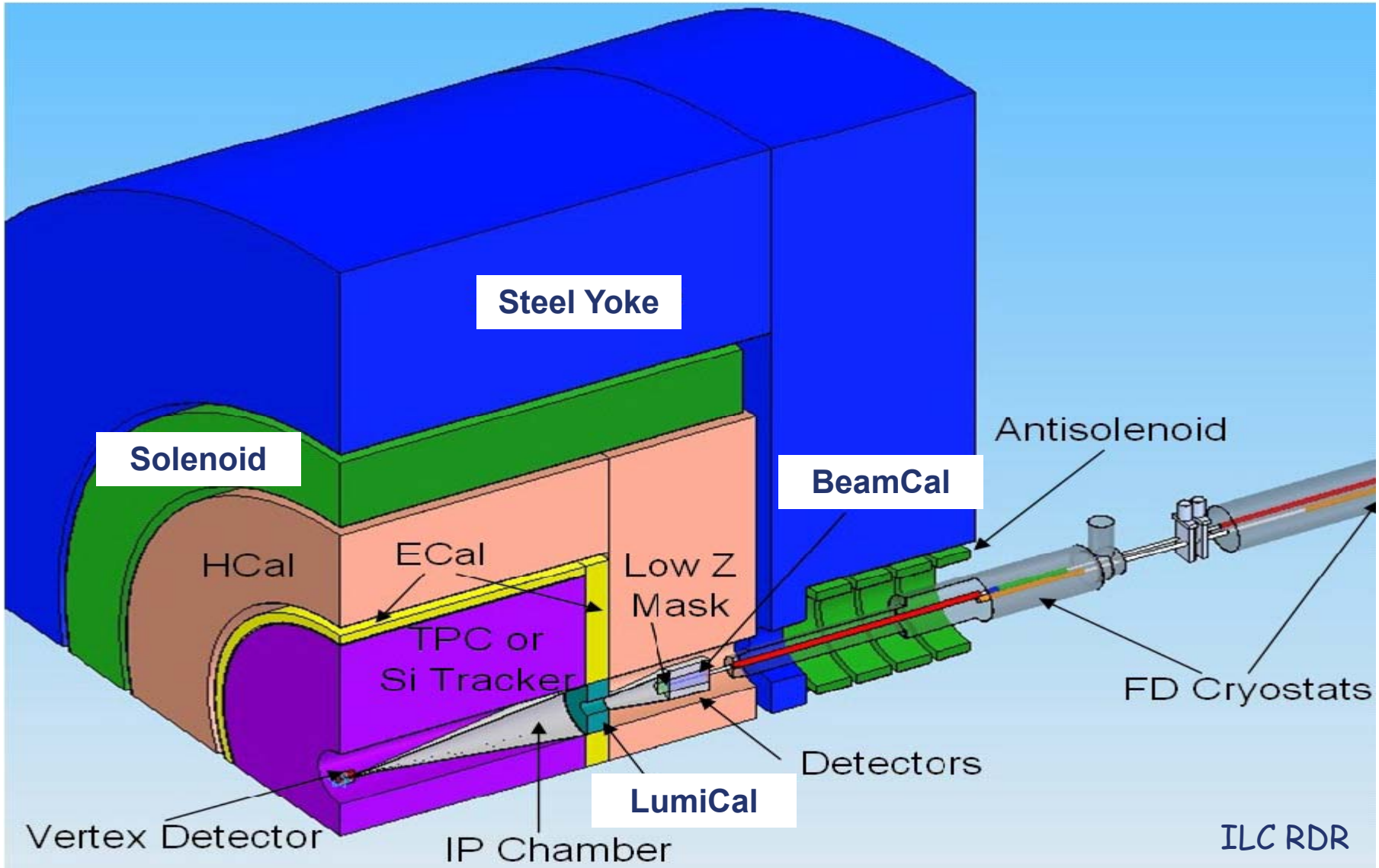
- Provide 2-photon veto
- Serve the beamdiagnostics using beamstrahlung pairs

- Serve the beamdiagnostics using beamstrahlung photons

Challenges:

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

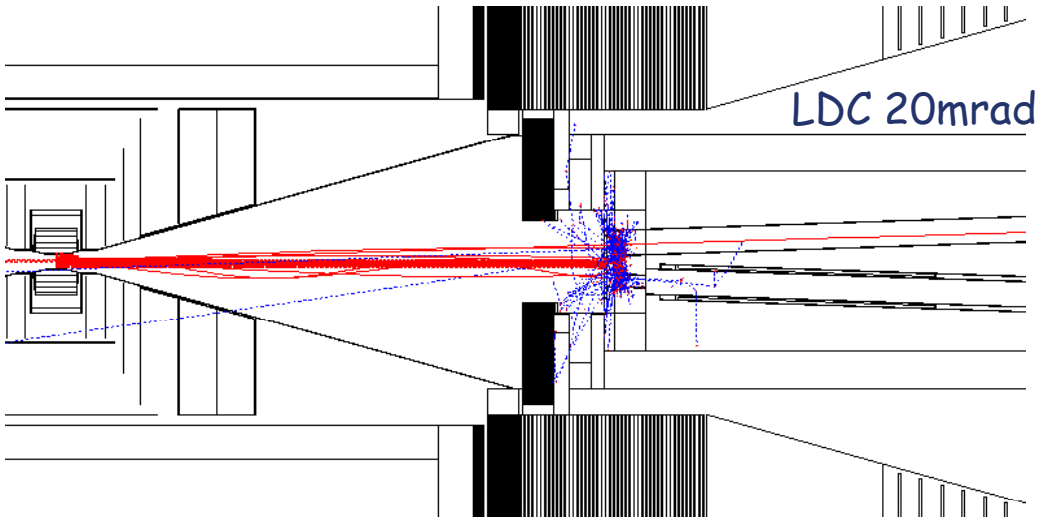
Design of the Forward Region



Forward Region Overview

- The FCAL Collaboration develops the Very Forward Detectors, LumiCal, BeamCal and GamCal.
- Due to the small bunch size σ_x~650nm, σ_y~5.7 nm and the high bunch charge, N x 10^{10}/bunch, beamstrahlung becomes important.
- The geometry has to be carefully optimized to minimize background due to the beamstrahlung pairs.

	LDC			SID		
	R_{Inner}	R_{Outer}	Z_{Pos}	R_{Inner}	R_{Outer}	Z_{Pos}
	mm	mm	mm	mm	mm	mm
LumiCal	80	350	2270	60	200	1800
BeamCal	20	165	3550	16	110	3000
GamCal	-	-	~180m	-	-	~180m

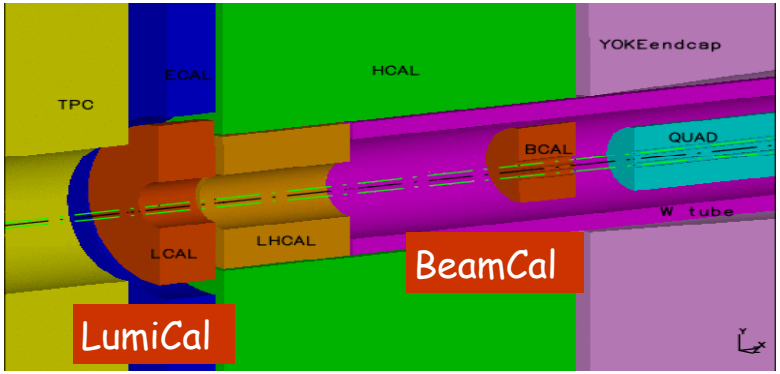


The LumiCal

Precise Measurement of the ILC's luminosity

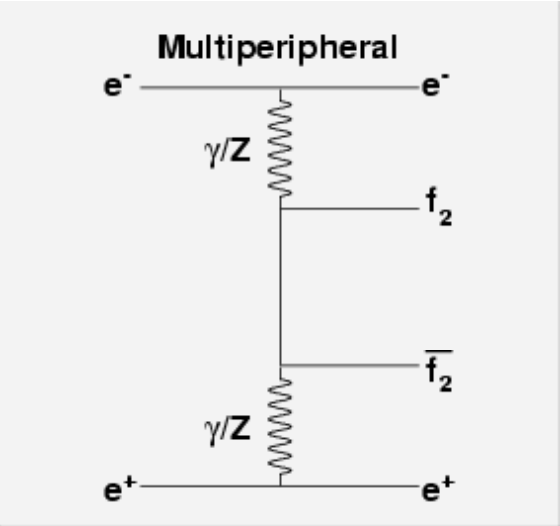
Precise Measurement of the Luminosity

- Required precision is $\Delta L/L \sim 10^{-4}$ (GigaZ) and $\Delta L/L \sim 10^{-3}$ at higher energies.

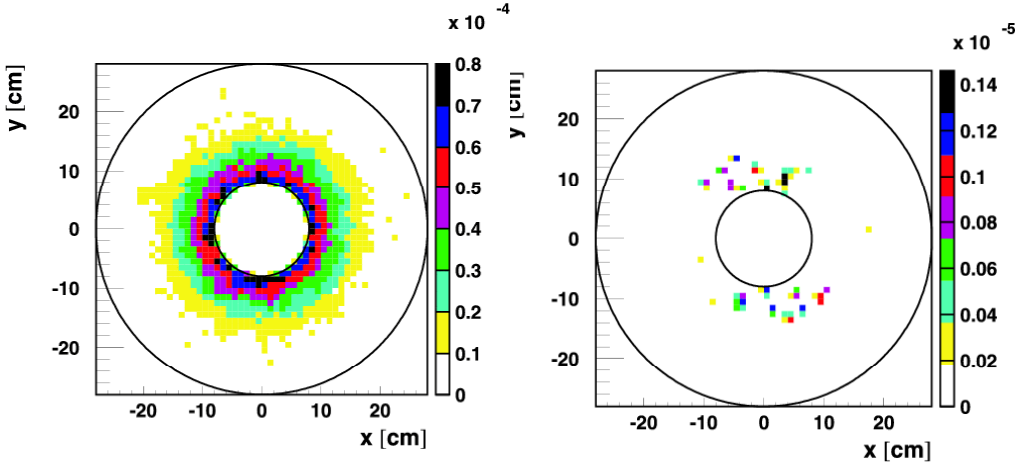


- Bhabha scattering ee->ee(γ) is the gauge process:
  - **Count Bhabha event in a well known acceptance region => $L = N/\sigma$**
  - **High statistics at low angles ($N_{Bhabha} \sim 1/\theta^3$) => need about 1 year of running at design luminosity**
  - **Well known electromagnetic process (LEP: 10^{-3}): the current limit on the theoretical cross section error is at ~5 10^{-4}.**
  - **We work in collaboration with theory groups to improve this limit (in Zeuthen, Katowice, Krakow and Tel Aviv).**

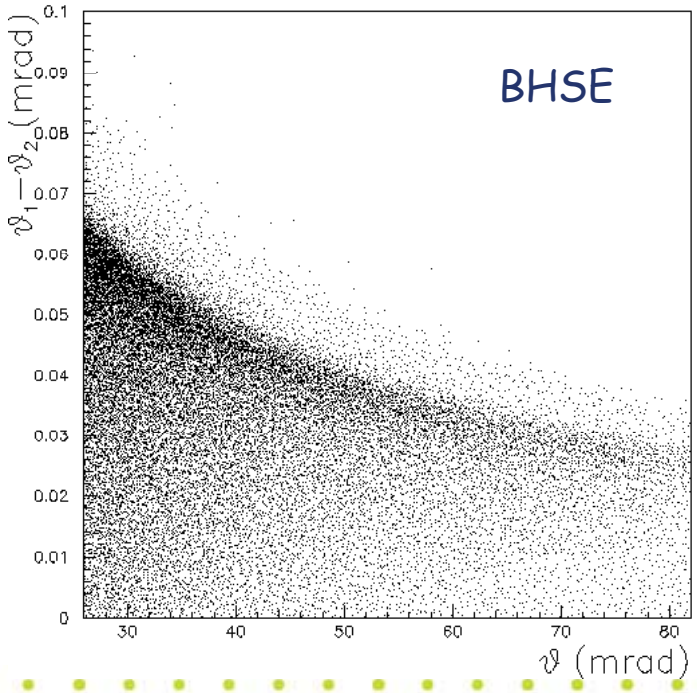
Physics Background and Beam-Beam Effect



2-photon rejection



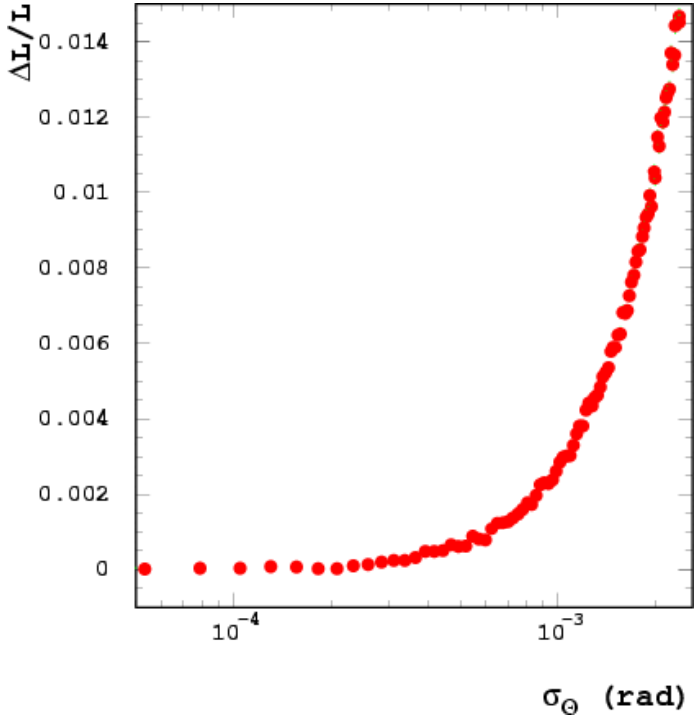
- 2-photon events are the main background.
- We determined an efficient set of cuts to reduce the background to the level of 10^{-4}.



- The Bhabha Suppression Effect is due to the EM deflection and energy loss by beamstrahlung of the Bhabhas.
- The bias can be of the order of some %. These effects can be reduced but need further study.

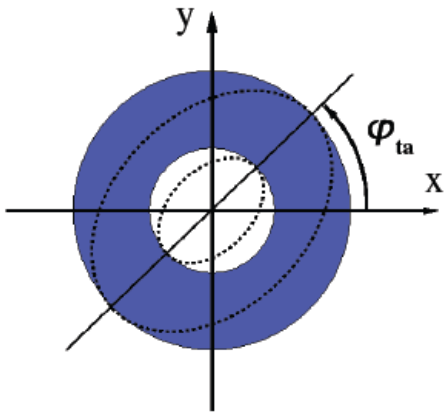
Requirements on the Mechanical Precision

MC simulations of LumiCal:
Derive requirements on design, segmentation, mechanical precision and impact of different magnetic field/crossing angles.

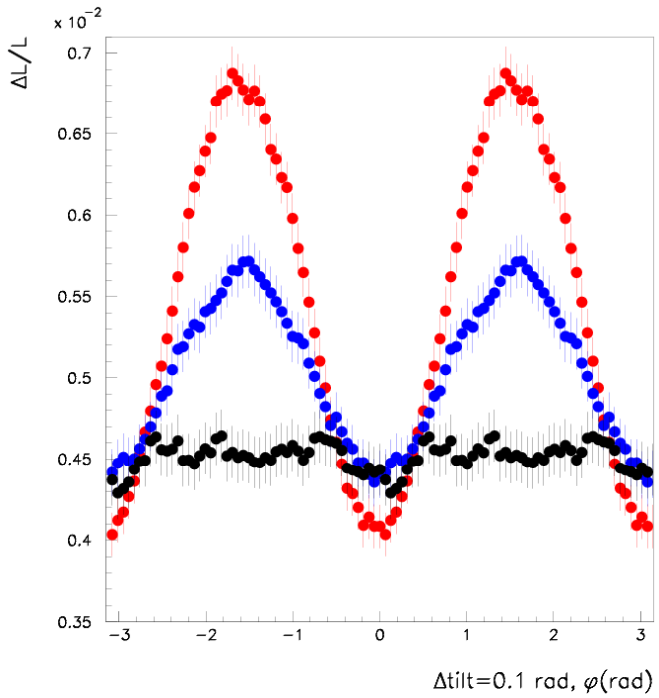


ΔL/L	1.0 10^{-4}
inner radius	4.2 μm
radial offset	640 μm
distance	300 μm

LumiCal: Systematics



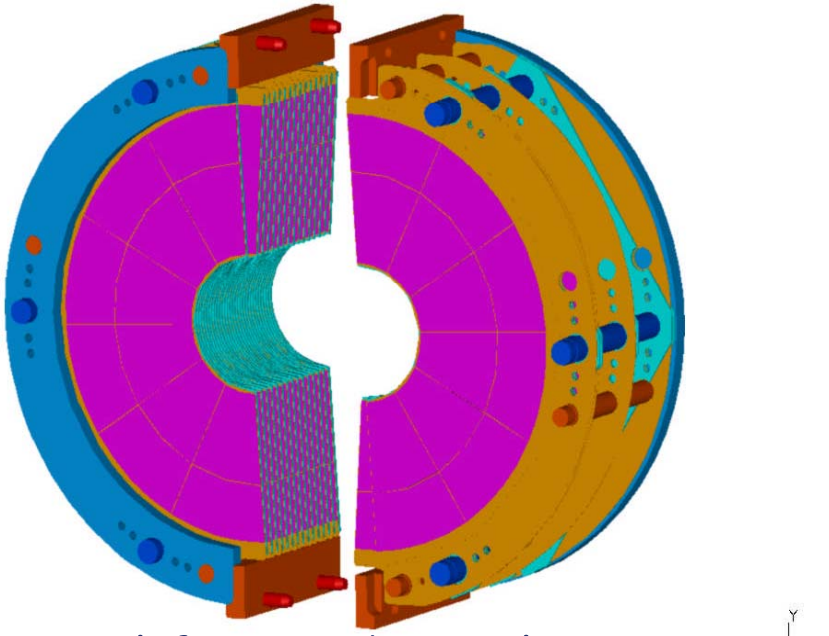
- Headon, 14,20 mrad X-angle outgoing beam
- 14 mrad X-angle detector axis
- 20 mrad X-angle detector axis



Recommendation:
place LumiCal around outgoing beam and tilt it accordingly.

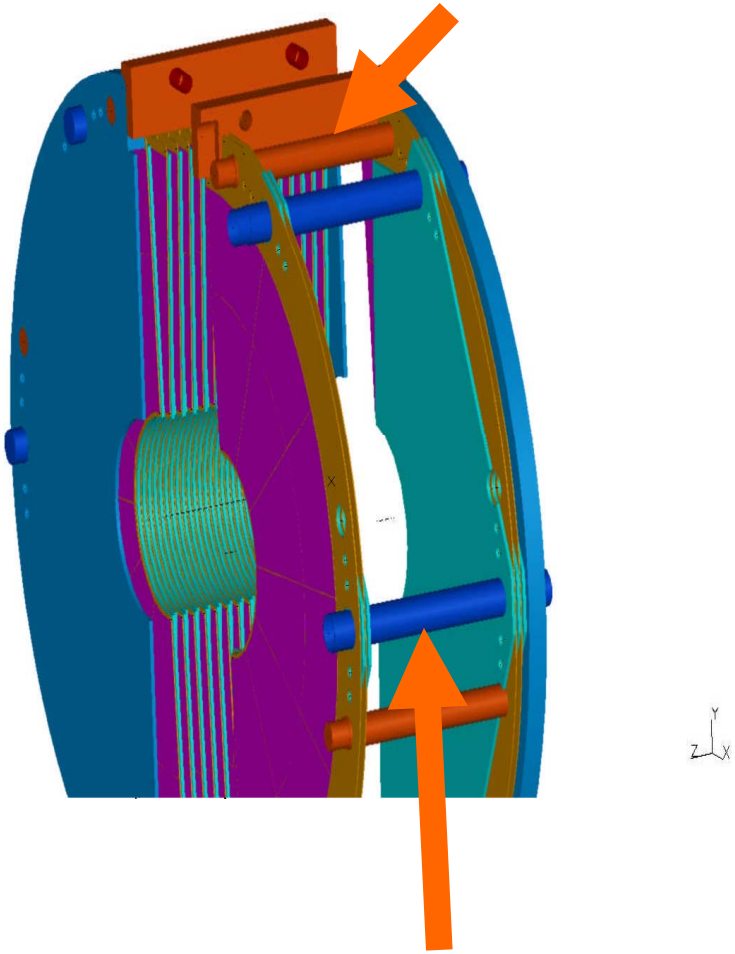
Mechanical Design

Si/W sandwich calorimeter,
30-40 layers
laser position monitoring system



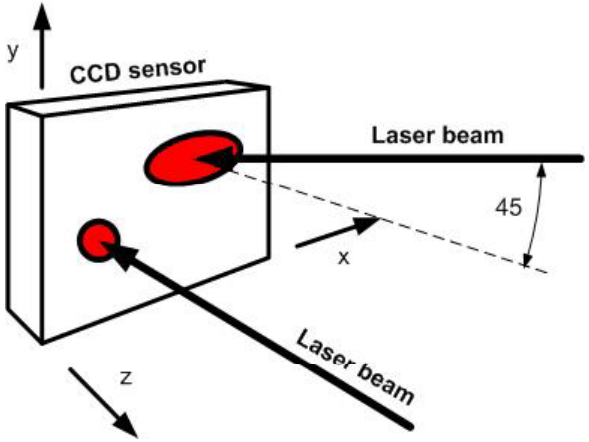
Mechanical frame: decouple sensor support from absorber support structure, alternative designs under investigation.

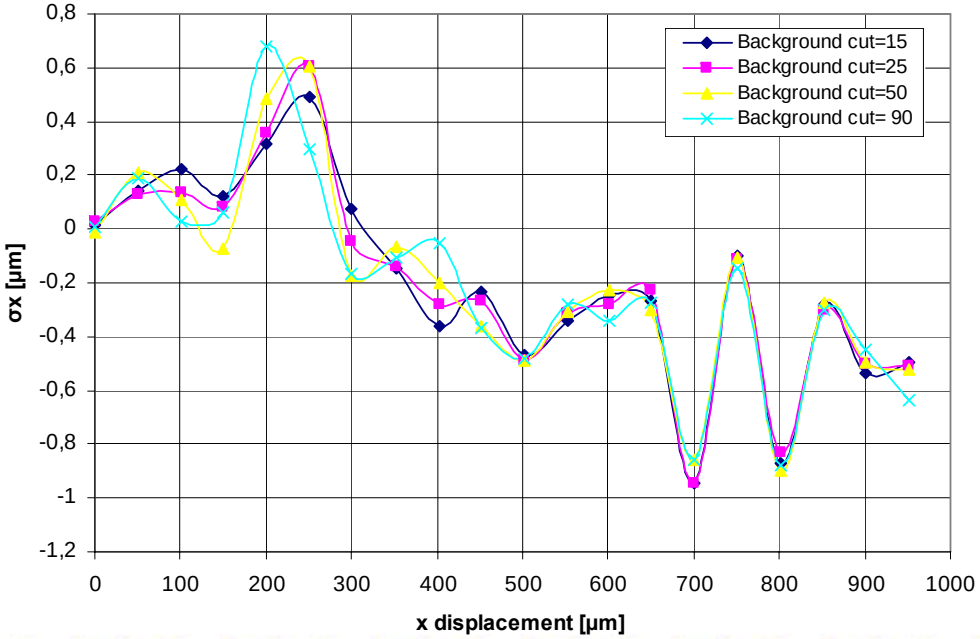
Sensor carriers

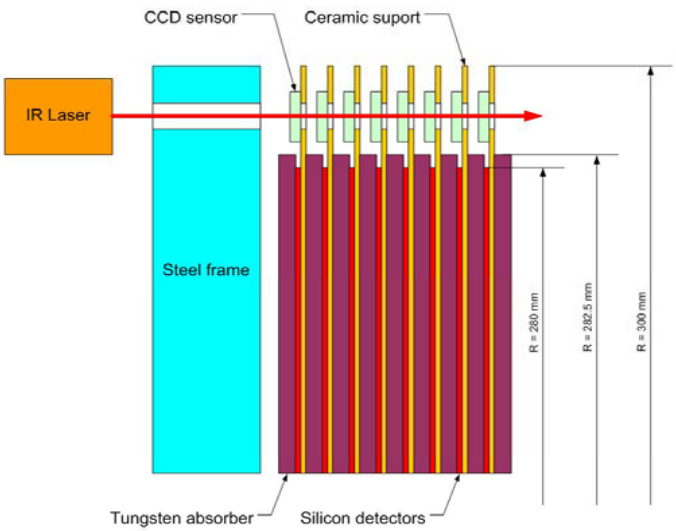


Absorber carriers

Laser Alignment System





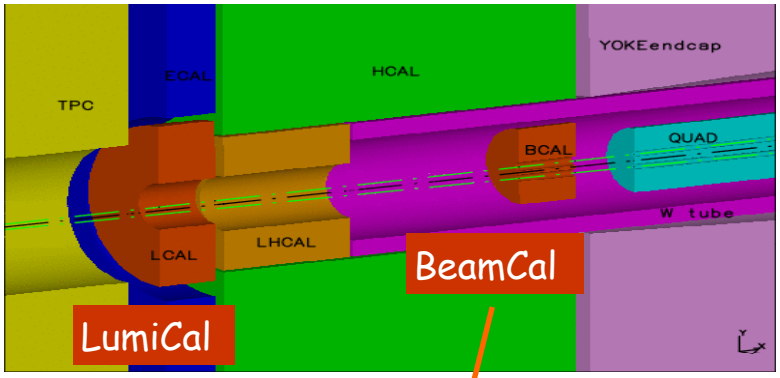


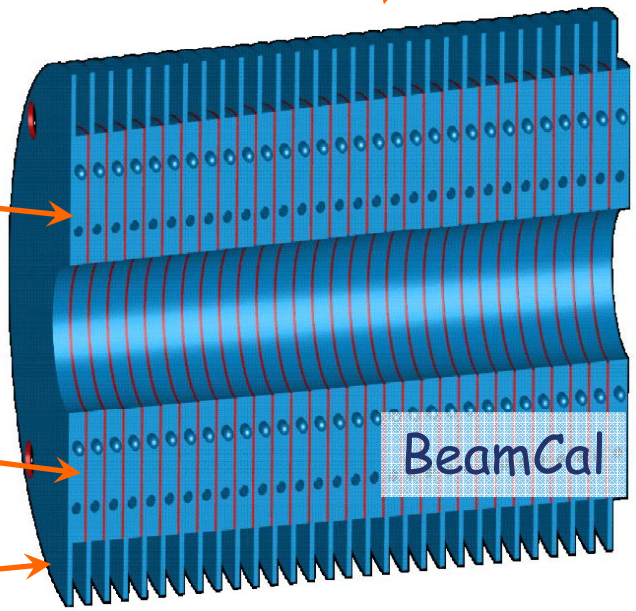
The BeamCal

Particle Veto at Lowest Polar Angles

BeamCal Design

- Compact em calorimeter with sandwich structure:
  - 30 layers of 1 X_0
    - o3.5mm W and 0.3mm sensor
  - Angular coverage from ~5mrad to ~45 mrad
  - Moliére radius $R_M \approx$ 1cm
  - Segmentation between 0.5 and 0.8 x R_M





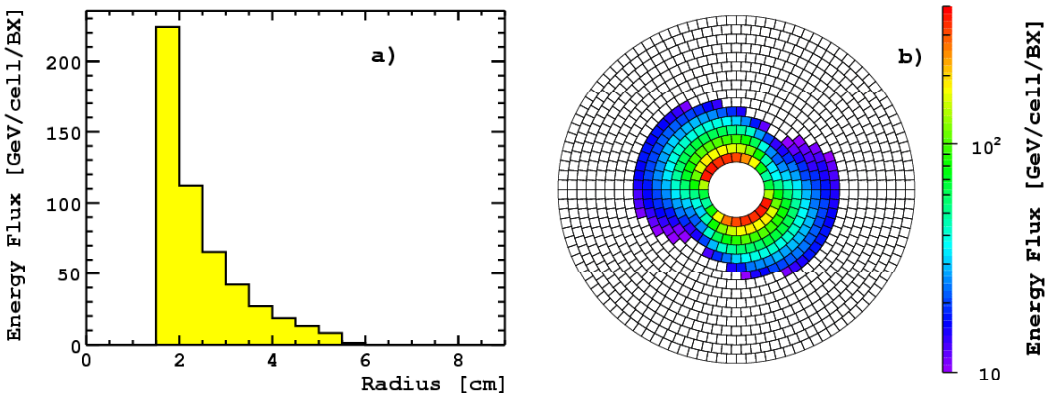
W absorber layers

Radiation hard sensors with thin readout planes

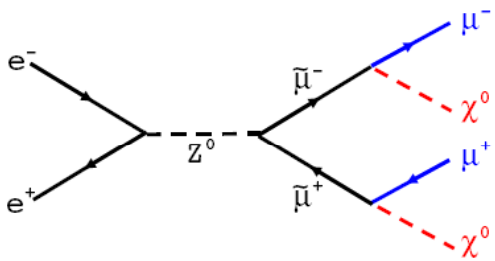
Space for readout electronics

BeamCal Challenges

- BeamCal will extend the sensitive region to lowest polar angles.

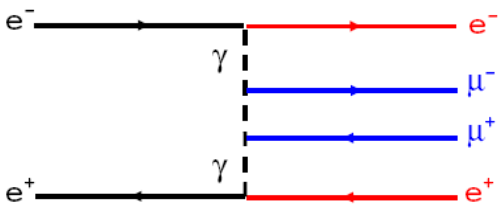


- Challenge:
  Detect single high energetic particle on top of a background of 10^4 low energetic e^+e^- pairs.



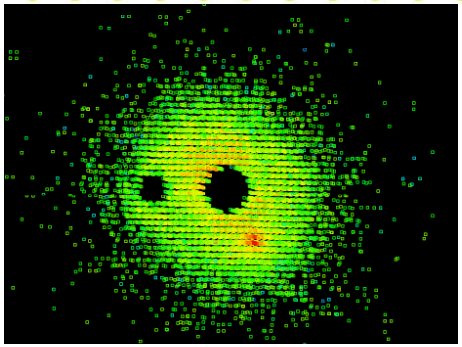
Physics signal:
e.g. SUSY smuon production

- BeamCal serves also as part of the beam diagnostics system (see talk by B.Morse)

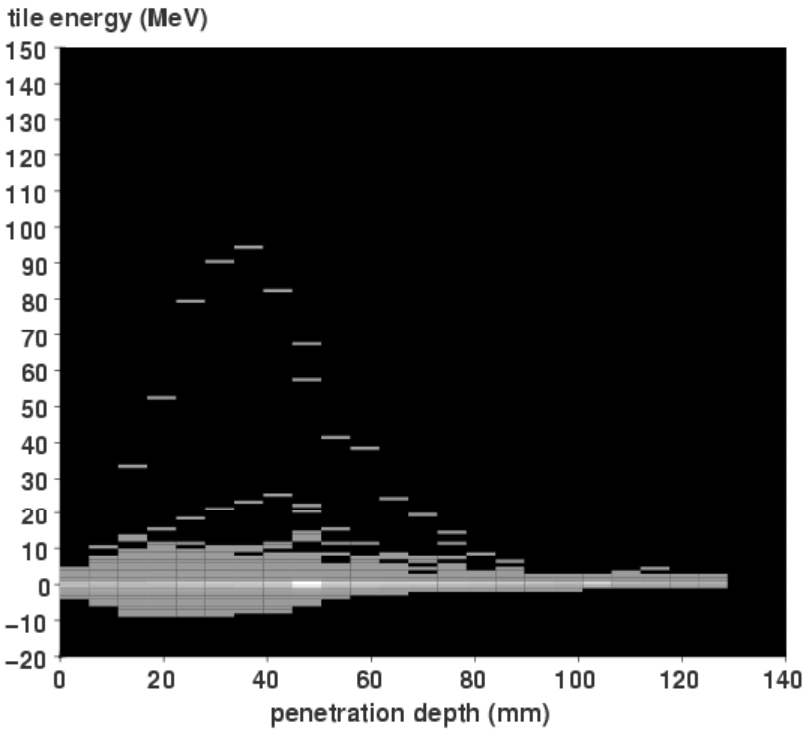


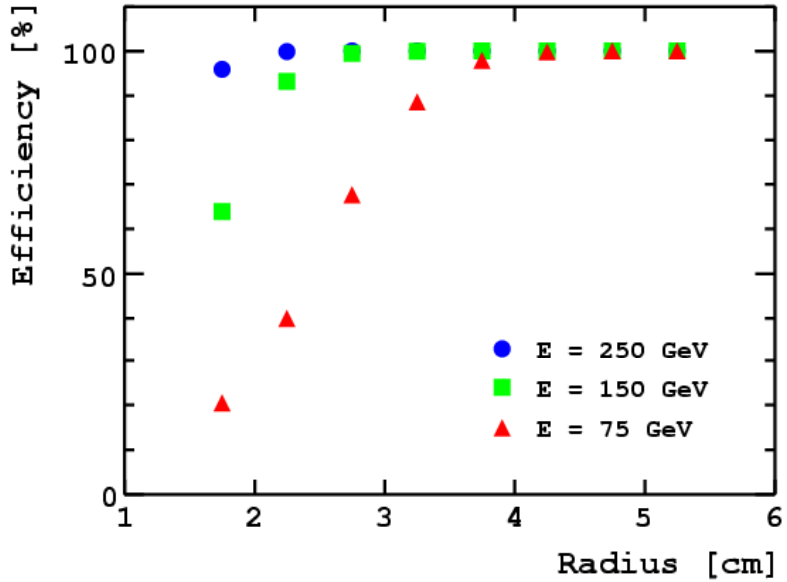
Background signal:
2-photon event, may fake the upper signal if the electron is not detected.

Particle Veto



Subracted Tile Energy





- 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 $O(10^4)$.

FCAL R&D

Radiation Hard Sensors

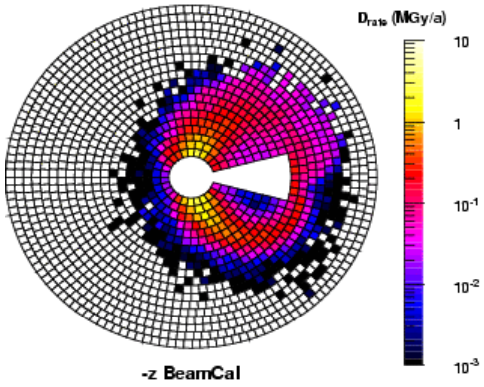
R&D Capabilities of the FCAL Collaboration

- Sensor test capabilities available:
  - **Desy-Zeuthen, TAU, Krakow, Brookhaven, Prague, Minsk, JINR**
- Electronics development capabilities available:
  - **Krakow, Brookhaven, Minsk**
- Electronics test capabilities available:
  - **Desy-Zeuthen, Krakow, Brookhaven, Minsk**
- Integration facilities (clean room, wire bonder etc.)
  - **Desy-Zeuthen, Brookhaven, JINR**

Radiation Hard Sensor Materials

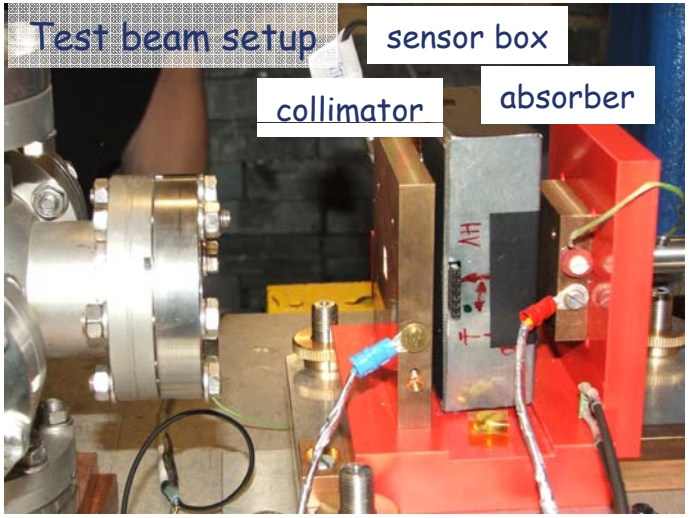
- BeamCal: high energy deposition from low energetic pairs from beamstrahlung.

≈ 5 MGy/a



- We investigate several alternatives:
  - **CVD diamond sensors**
  - **GaAs sensors**
  - **SiC**
  - **radiation hard silicon**

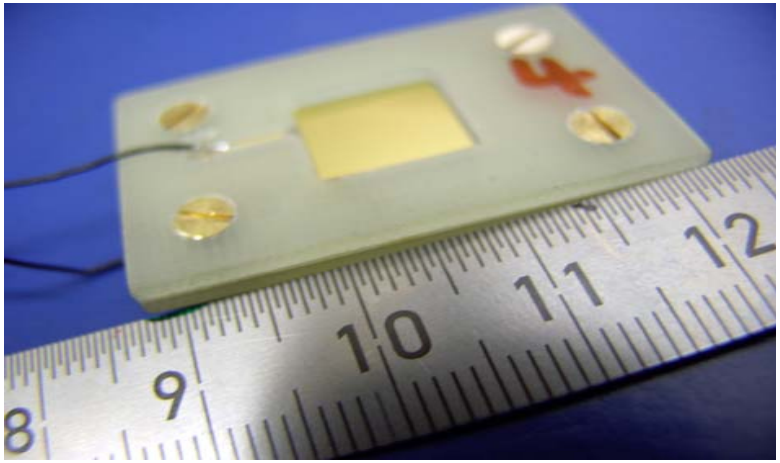
- We perform different characterizing laboratory measurements (I-V, C-V, MIP response, low dose irradiation) as well as test beam measurements.



Polycrystalline Chemical Vapour Deposited Diamonds

- Samples from two manufacturers are under investigation:
  - **Element Six$_{TM}$**
  - **Fraunhofer Institute for Applied Solid-State Physics – IAF**

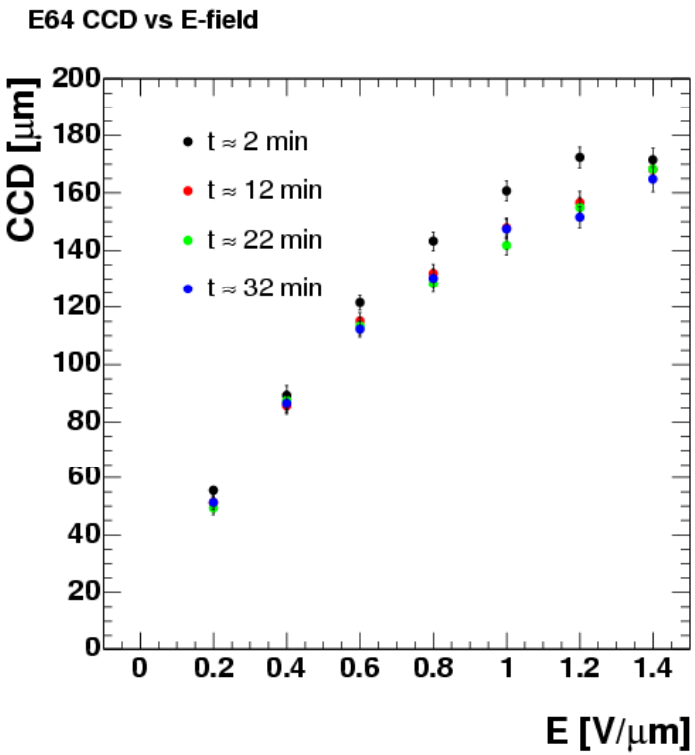
- 1 x 1 cm^2, 200-900 µm thick



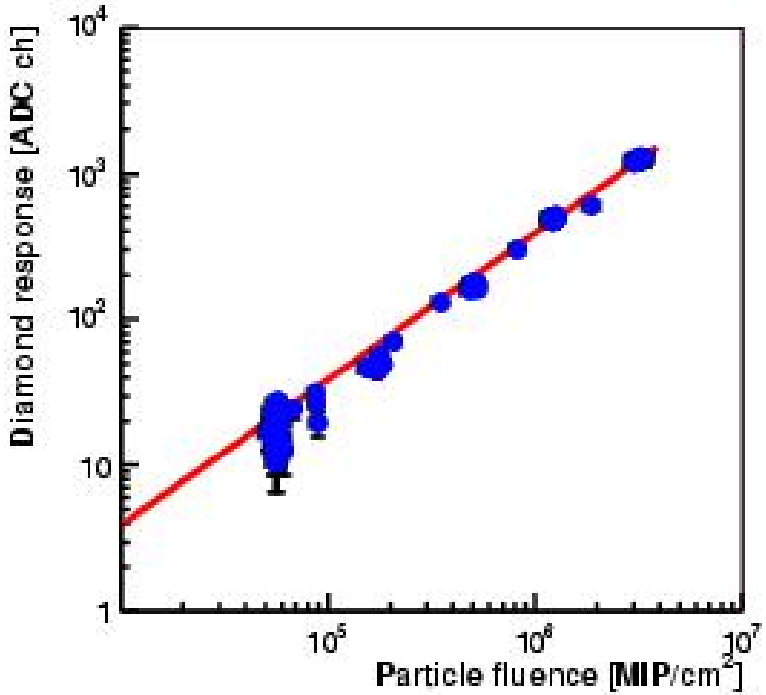
Investigation of Sensors

polycrystalline CVD Diamond

response vs electric field



response vs particle fluence

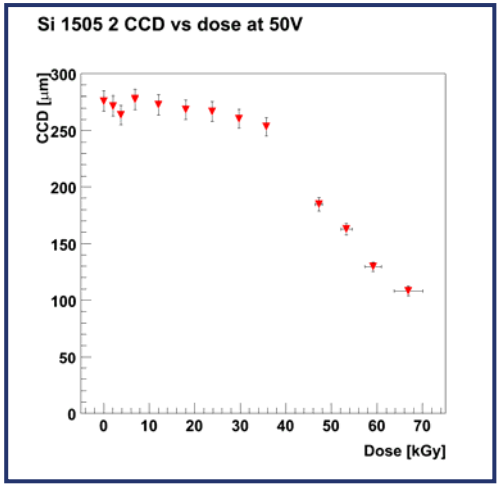


$CCD = Q_{meas}/Q_{induced} \times thickness$

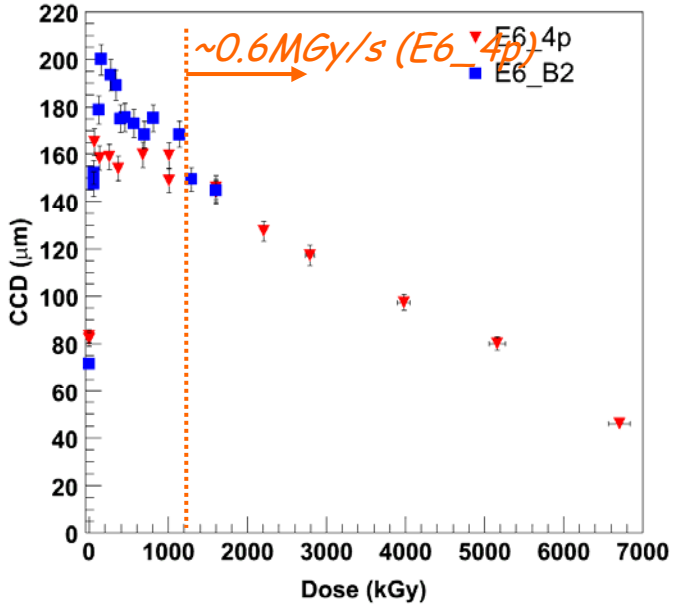
Results for High Dose Irradiation

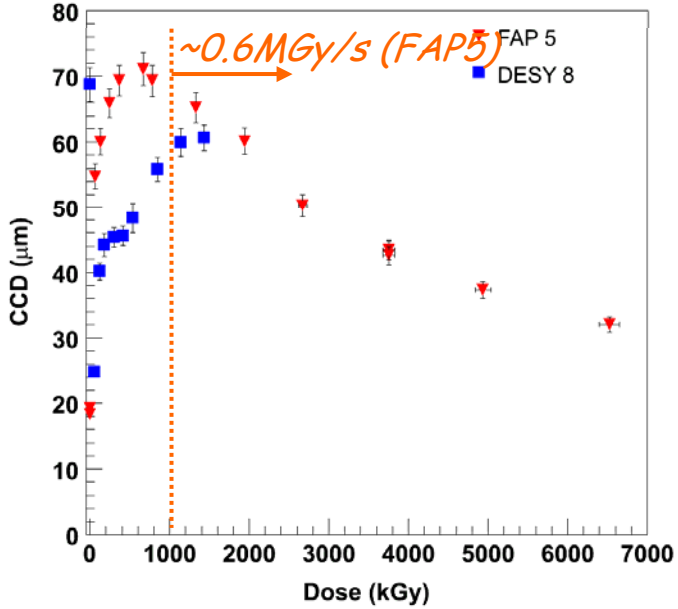
Test beam at the
S-DALINAC
Tech. University of Darmstadt

Silicon starts to degrade at 30 kGy.
High leakage currents.
Not recoverable.

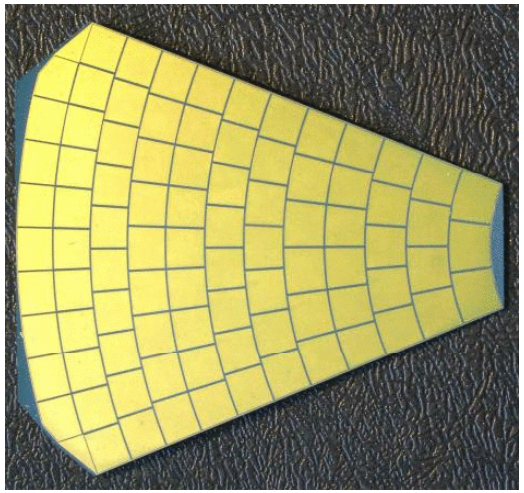


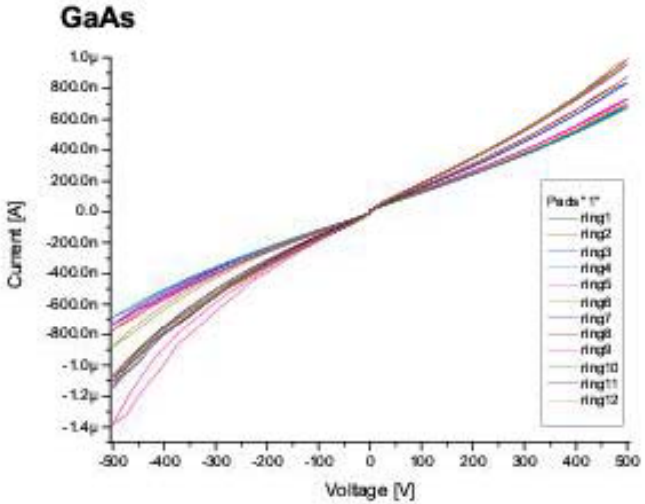
CVD diamonds still operational after absorbing 7MGy.

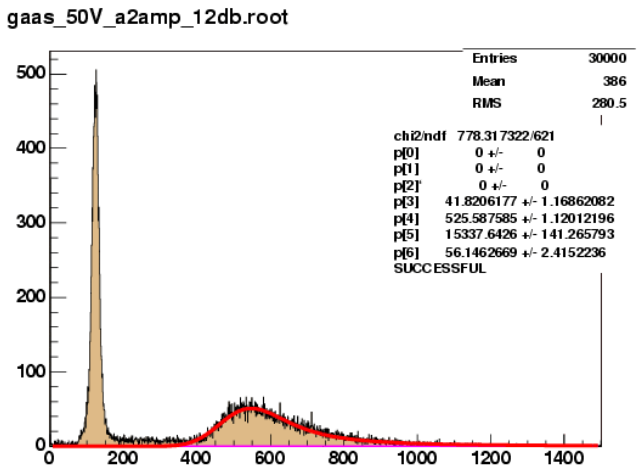


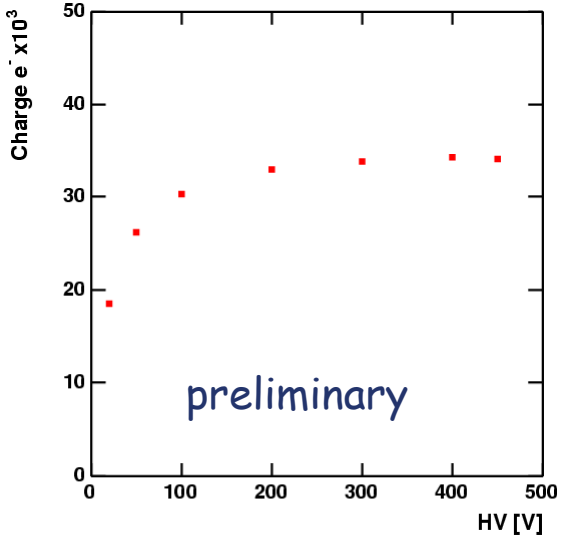


Alternative Sensor Material: GaAs









response vs electric field

- Investigation of GaAs prototype started.
- Investigated a first SiC prototype and expect to get more.
- Just got radhard Si prototype to investigate.
- Next irradiation test beam end of June.

Summary

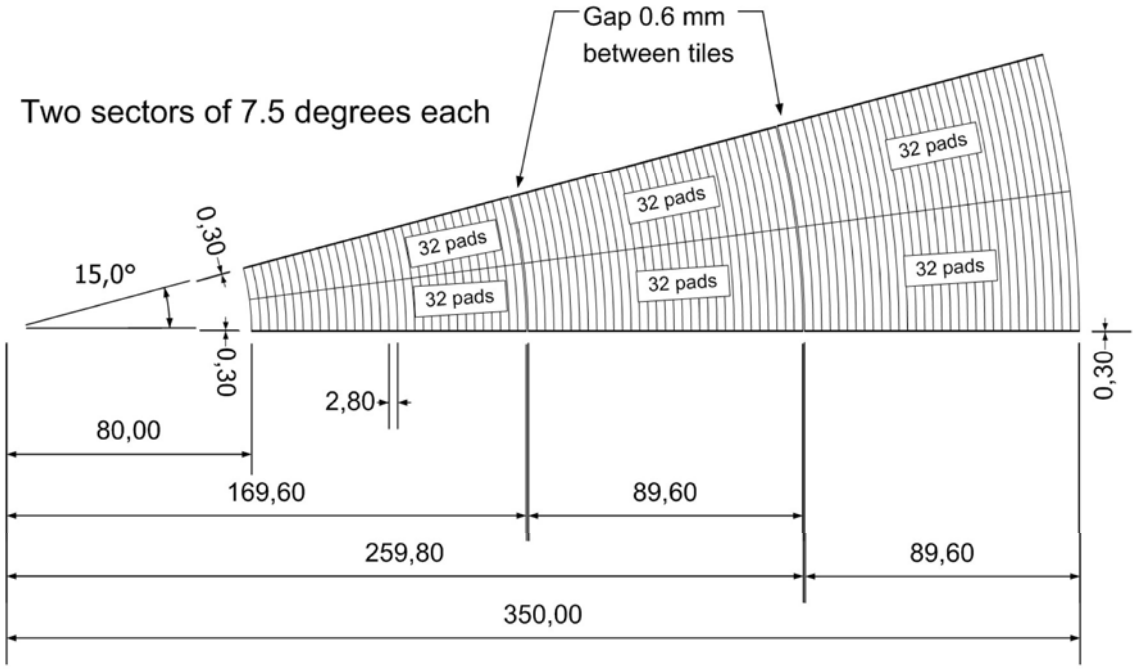
- The FCAL Collaboration develops the detectors in the very forward region of the ILC independent of a detector concept.
- MC simulations allowed to develop a very clear understanding of the physics background, beam-beam effects and the requirements on positioning and precision.
- Precision and position monitoring is essential for the LumiCal. Radiation hard sensors are of crucial importance for the BeamCal.
- We have an intensive R&D activity on radiation hard sensors. We investigate CVD diamond, GaAs, SiC and start to investigate radiation hard Si.
- In the next talks:
  - **we will introduce the concept of beam diagnostics and the GamCal detector.**
  - **We will present our efforts on the development of readout electronics for Lumi- and BeamCal.**

Milestones for the Next 3 Years

- More realistic simulation of LumiCal and the impact of the Bhabha selection criteria on the luminosity measurement.
- Completion of the performance studies for BeamCal including additional effects and a realistic readout chain.
- Detailed simulation for the design of the GamCal system.
- Processing of the first layout of front-end electronics and performance tests.
- Design and construction of a full sensor plane for LumiCal and BeamCal for beam tests.
- Continuation of the radiation hardness studies for CVD diamonds, GaAs and Si sensors in low energy electron beams.

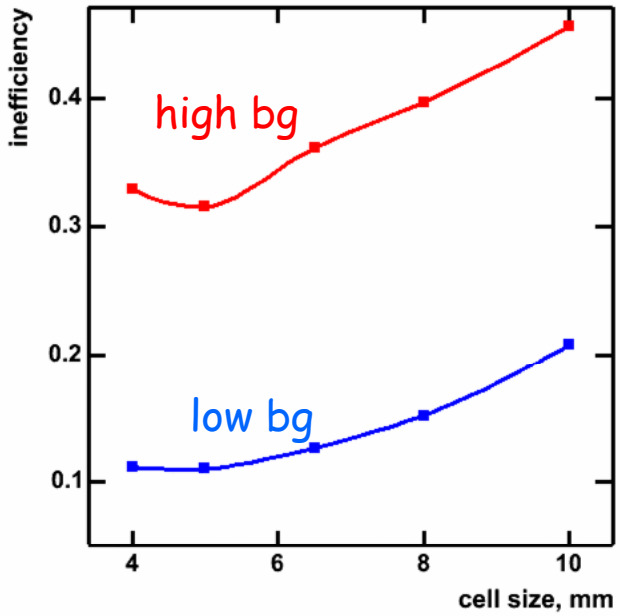
Backup Slides

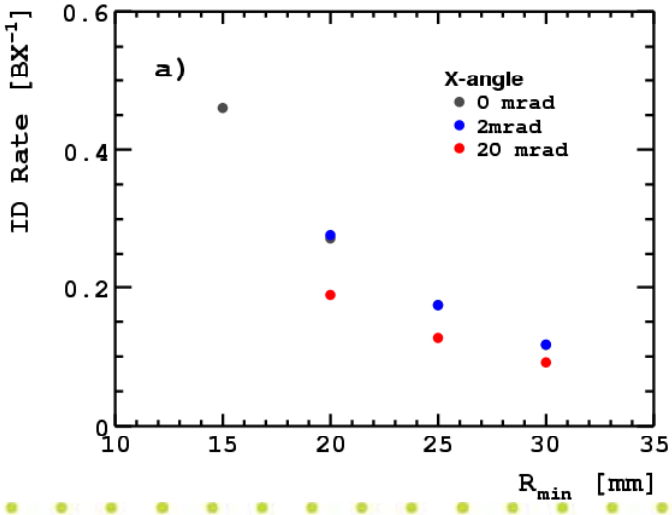
Silicon Sensors for LumiCal

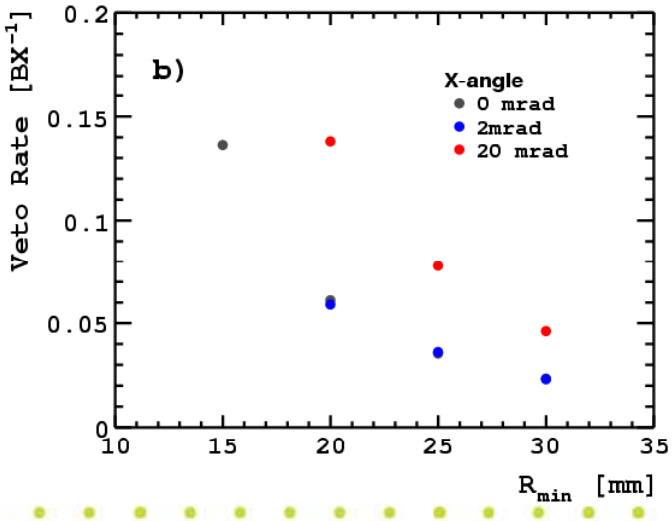


- For LumiCal the precision is of major importance.
- Radiation is not an issue in this region.
- The gaps between sensor tiles should be kept as small as possible.

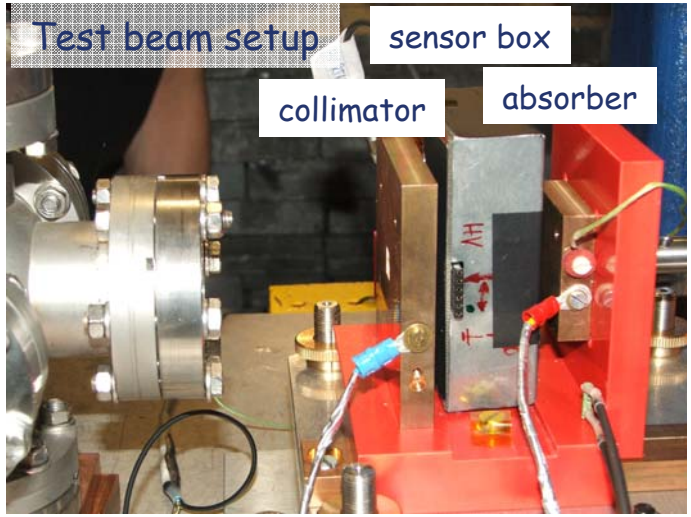
Veto Efficiency and misinterp. Bhabhas



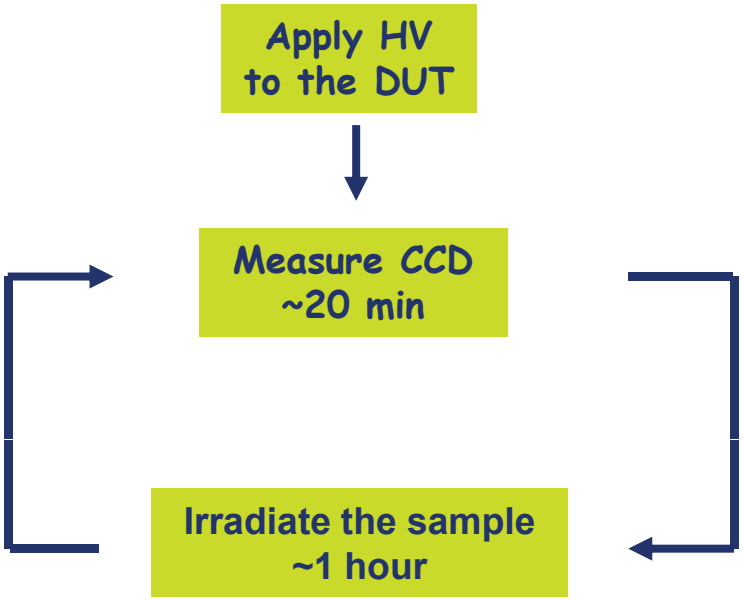




Preparations and Programme



Samplse	Thickness, μm	Dose, MGy
E6_B2 (E6)	500	>1
DESY 8 (IAF)	300	>1
FAP 5 (IAF)	470	>5
E6_4p (E6)	470	>5



CCD: Charge Collection Distance