The Forward Region of the ILC detector

Aura Rosca, West University Timisoara

IPRD08, Siena, 1 - 4 October 2008

Overview

- Accelerator
- ILC detector(s)
- Very forward region: design and challenges
- Summary

- Argonne, BNL, Vinca Inst., Univ. of Colorado, Cracow UST, Cracow INP, JINR, Royal Holloway, NCPHEP, Prague (AS), LAL Orsay, Tuhoku Univ., Tel Aviv Univ., West Univ. Timisoara, IFIN-HH, Yale Univ., DESY-Zeuthen
- Associated: Stanford Univ., IKP Dresden
- Guests from CERN.

Questions in Particle Physics

- Despite the spectacular success of the Standard Model, many questions remain:
  - Pattern of particle masses; why is the top so heavy?
  - Pattern of quark mixing? Lepton mixing?
  - Origin of CP violation? Baryogenesis?
  - Why 3 generations?
  - Unification?
  - Hierarchy
    - Why is the electroweak scale << Planck scale?
  - Dark matter?
  - Dark energy?
  - Quantum gravity?

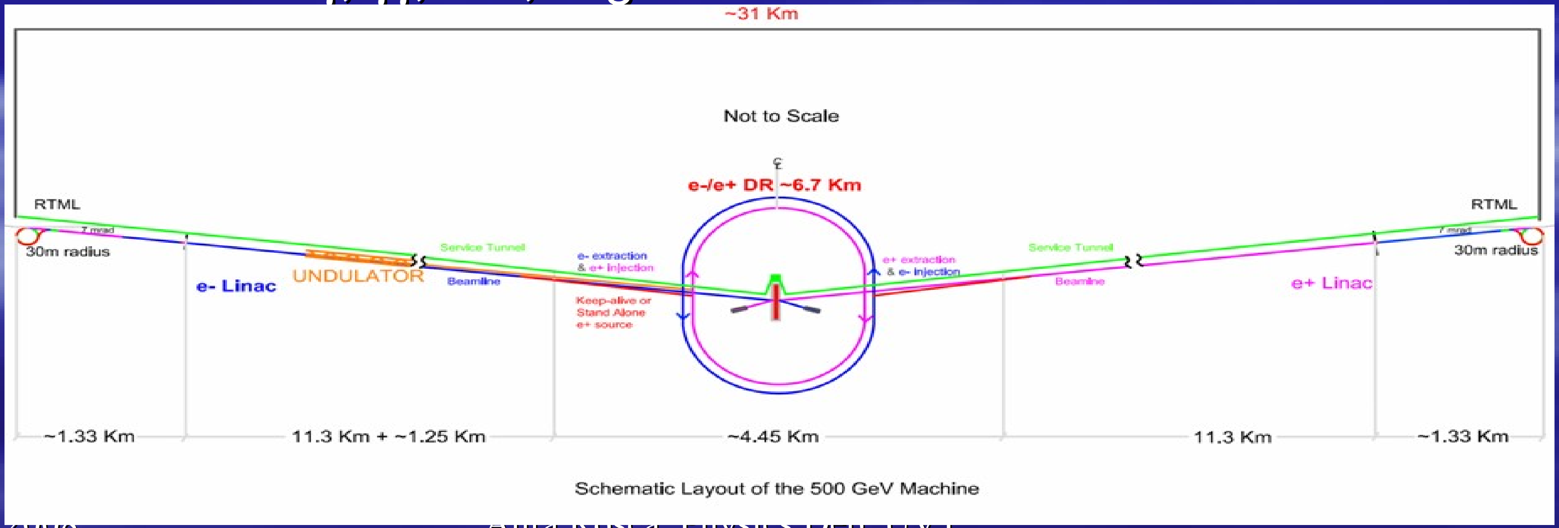
The Next Big Accelerator

- For precision measurements, want an e^+e^- collider to complement the existing hadron machines.
- There are strong theoretical reasons for wanting to achieve ~1TeV in energy.
- Synchrotron radiation effect too large, we cannot build such a machine as a circular accelerator

International Linear Collider

ILC Design

- First stage: 90-500 GeV
- Second stage: up to 1 TeV
- Luminosity: 500 fb^{-1}/4 years,
  1 ab^{-1} at 1 TeV → $L \sim 2 \times 10^{34}\ cm^{-2}s^{-1}$
- Polarization: 80% e^-, 50% e^+ (optional)
- Beam energy uncertainty: $< 10^{-3}$
- Options: $e^-\gamma$, $\gamma\gamma$, e^-e^-, GigaZ



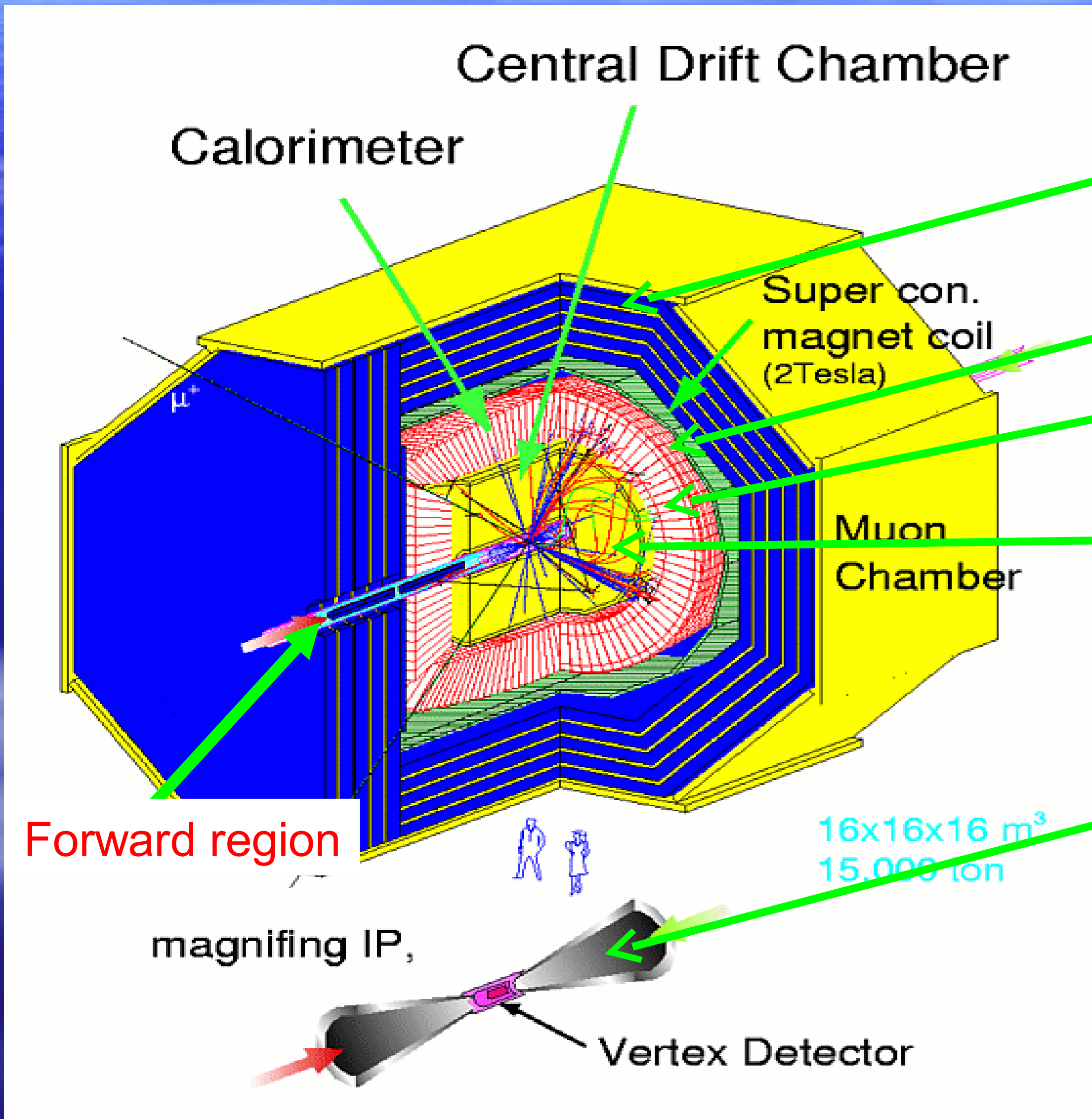
Detector Requirements

- Desire to fully reconstruct hadronic final states.
- Ability to tag heavy quarks.
- Excellent missing energy/mass sensitivity

Require:

- Exceptional momentum resolution, 1/10 x LEP
  - Large volume TPC or low mass Si μ-strip tracker
- Excellent vertexing capabilities 1/3 x SLD, 1/5-10 x LEP
  - 5-layers pixel Vertex Detector
- Particle flow Calorimetry
  - Imaging, non-compensating sampling calorimeter
- Hermiticity > 5 mrad
  - Minimal supports, on-detector readout.

ILC Detector



Muons (instrumented iron)

Hadrons (HCAL)

Photons, electrons (ECAL)

Track measurement (TPC)

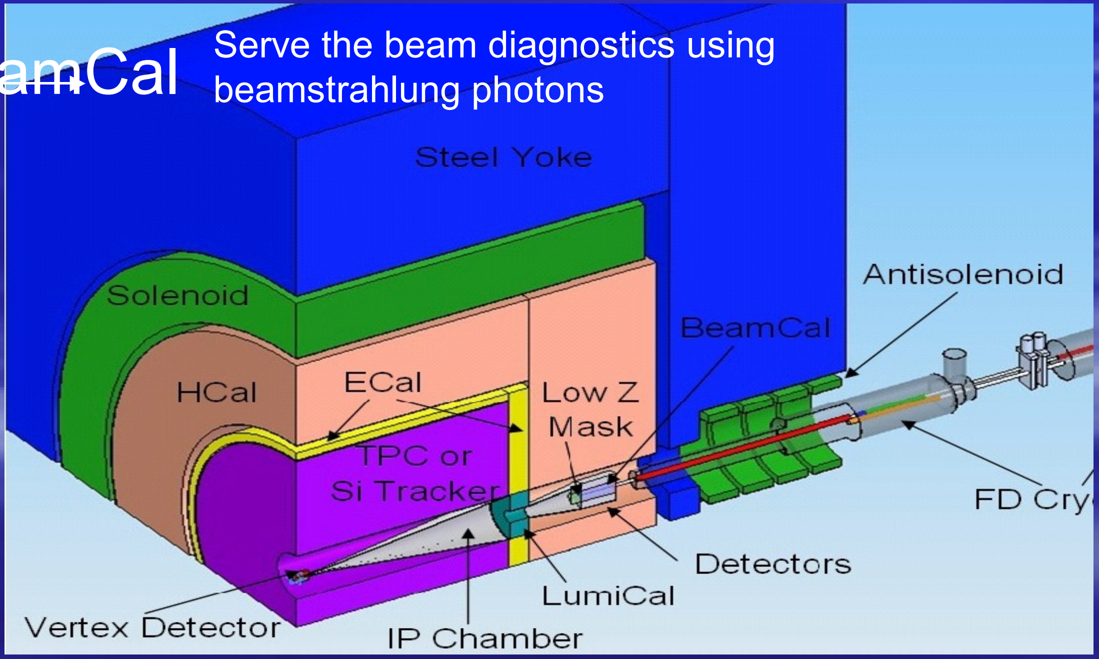
Flavour tagging
(pixel detectors)

Very Forward Region

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

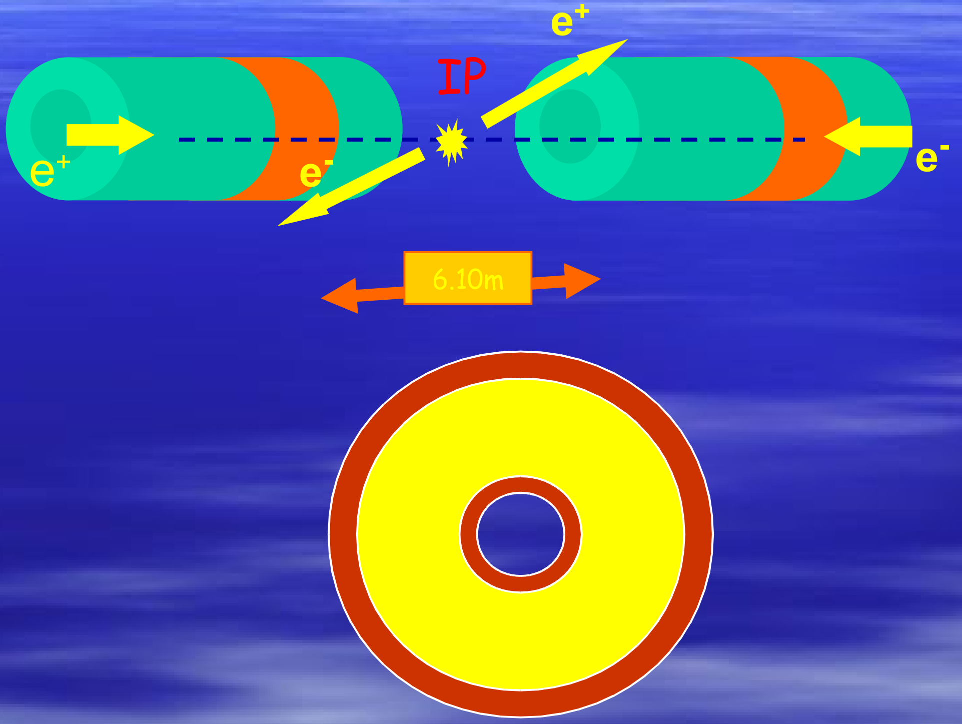
Provide 2-photon veto
Serve the beam diagnostics using beamstrahlung e^+e^- pairs

Serve the beam diagnostics using beamstrahlung photons



Luminosity measurement

- Precise luminosity measurement Gauge process: $e^+e^- \longrightarrow e^+e^- (\gamma)$



$$L = N / \sigma$$

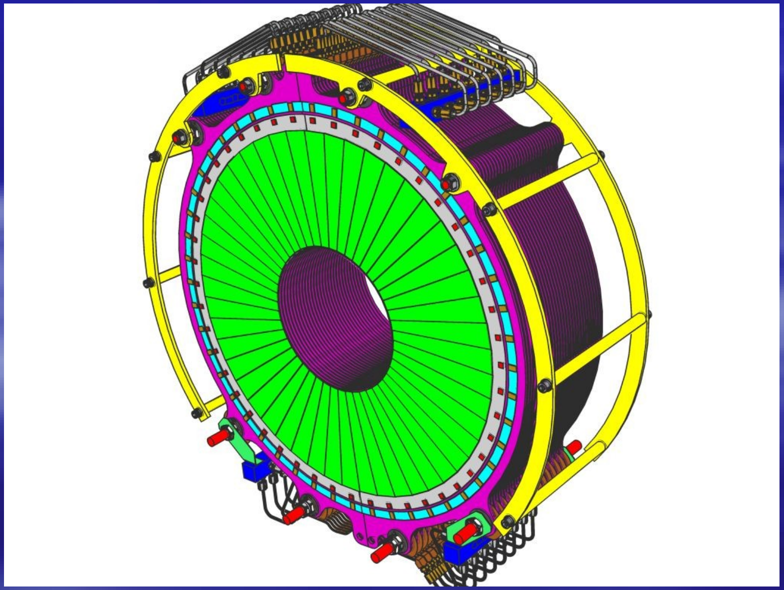
Count Bhabha events → N

From theory → σ

Goal : precision < 10^{-3} (10^{-4}) → Inner acceptance radius : < 10 μm
Distance between Cals. : < 600 μm
Radial beam position : < 1 mm

Luminosity Calorimeter

- Geometry
  - Tungsten thickness = 3.5 mm
  - Silicon thickness = 0.3 mm
  - R_{min} = 80 mm
  - R_{max} =195 mm



- Segmentation
  - 30 layers, 48 radial divisions;
  - Angular coverage from ~ 50 mrad to ~ 90 mrad, outside the reach of beamstrahlung pairs;
  - z position = 2270 mm.

Si sensors placement accurate to several μm.

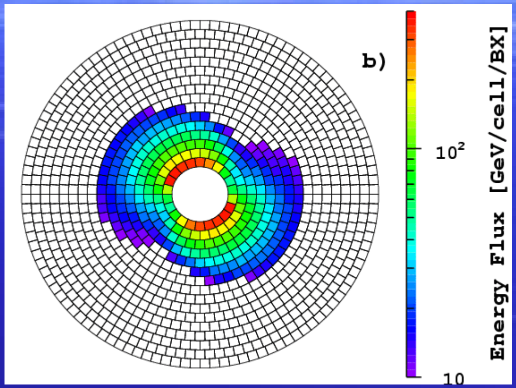
Beam Diagnostics

- Beamstrahlung is a new phenomenon at the ILC (nm beam sizes)
  - Bunches are squeezed when crossing (pinch effect)
  - Photon radiation (at very small angles)
  - Part of the photons converts to e^+e^- pairs (deflected to larger angles)
- A measurement of photons and pair energy allows a bunch-to-bunch luminosity estimate

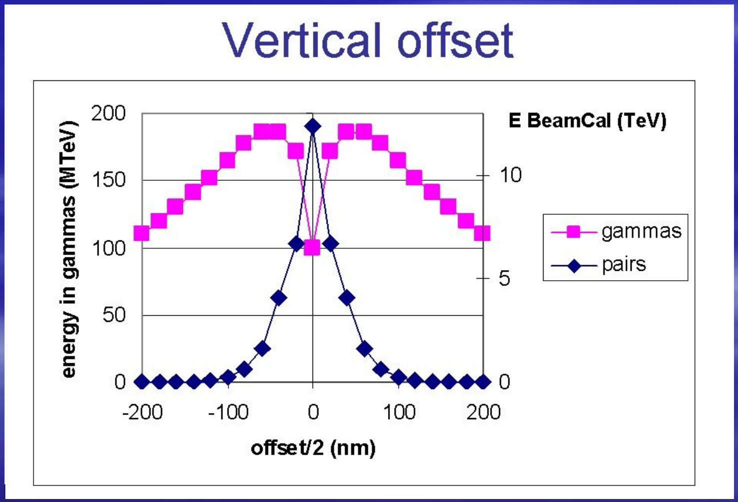
  Important for beam tuning.

- Dose absorbed by the sensors: up to 10 MGy/year

  Radiation hard sensors



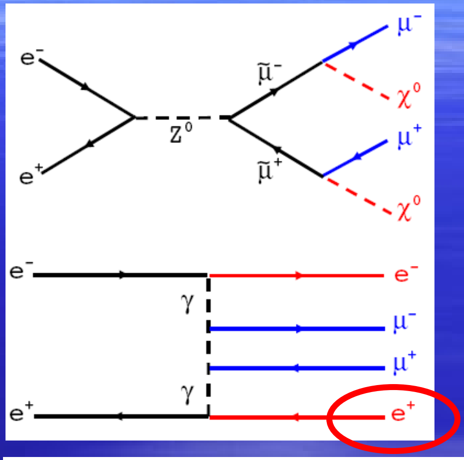
Energy deposition from Beamstrahlung in the innermost calorimeter (BeamCal)

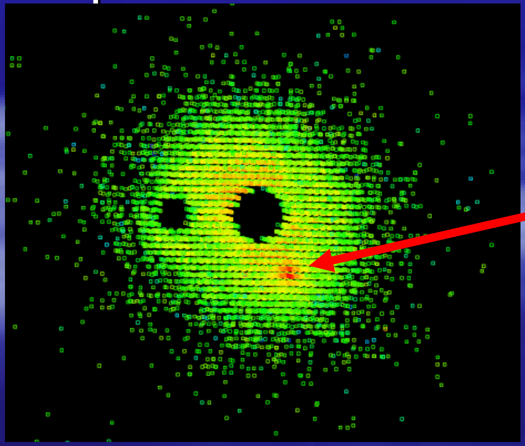


The ratio is ~ to L, feedback for beam tuning.

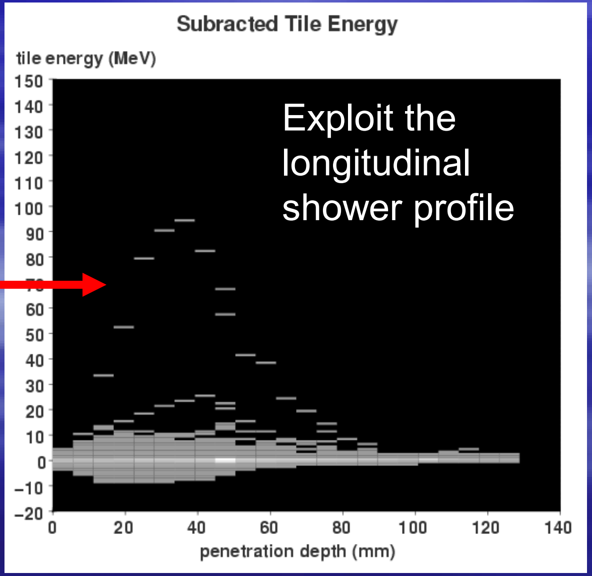
Physics

- Electron veto capability is required from physics down to small polar angles to suppress background in particle searches with missing energy signature (hermiticity)
  - e.g. Search for SUSY particles at small Δm



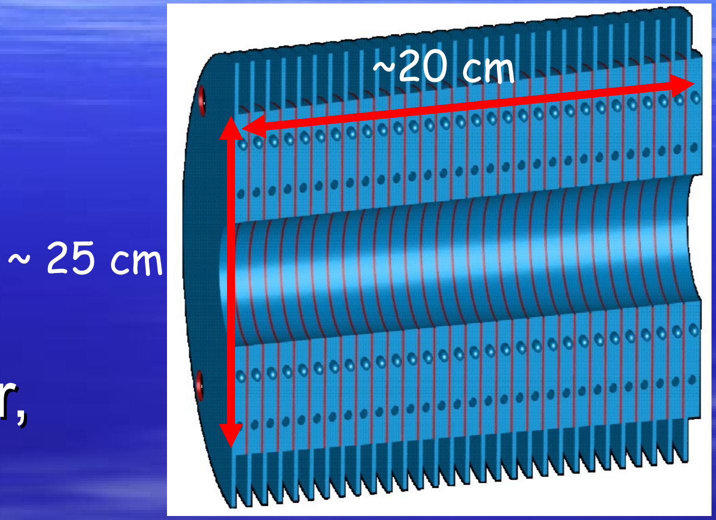


Local deposition from a high energy electron



Beam Calorimeter

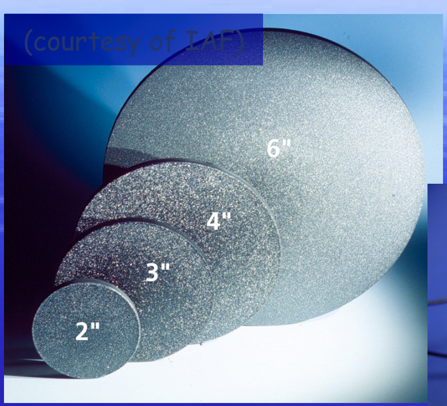
- EM calorimeter with sandwich structure:
  - 30 layers of 1 X0
    - 3.5mm W and 0.3mm sensor, 0.2mm readout
  - Angular coverage from 5mrad to 48 mrad
  - Moliére radius $R_M \approx 1\text{cm}$
  - Segmentation between 0.5 and 0.8 x R_M



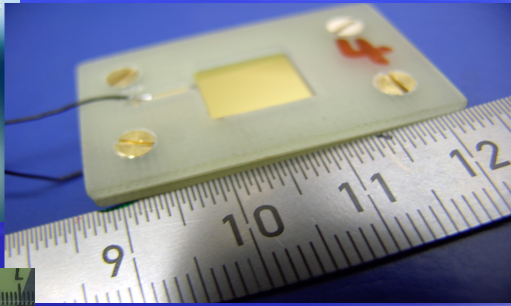
Design:
R_{min} = 20 mm
R_{max} = 150 mm
16 rings of ~ 8 mm
8 sectors
Subdivided into cells or pads
z position = 3450 mm

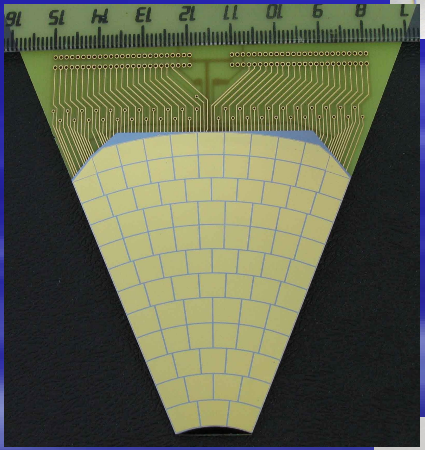
Sensor R&D

- pCVD diamonds:
  - Radiation hardness under investigation (e.g. LHC beam monitors, pixel detectors)
  - Advantageous properties like: high mobility, low ε_R=5.7, thermal conductivity.
- GaAs:
  - Semi-insulating GaAs, doped with Sn and compensated by Cr
  - Produced by the Siberian Institute of Technology.
- sCVD diamonds:
  - Available in sizes of mm².

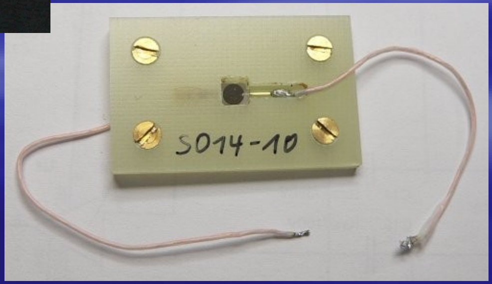


Polycrystaline CVD diamond





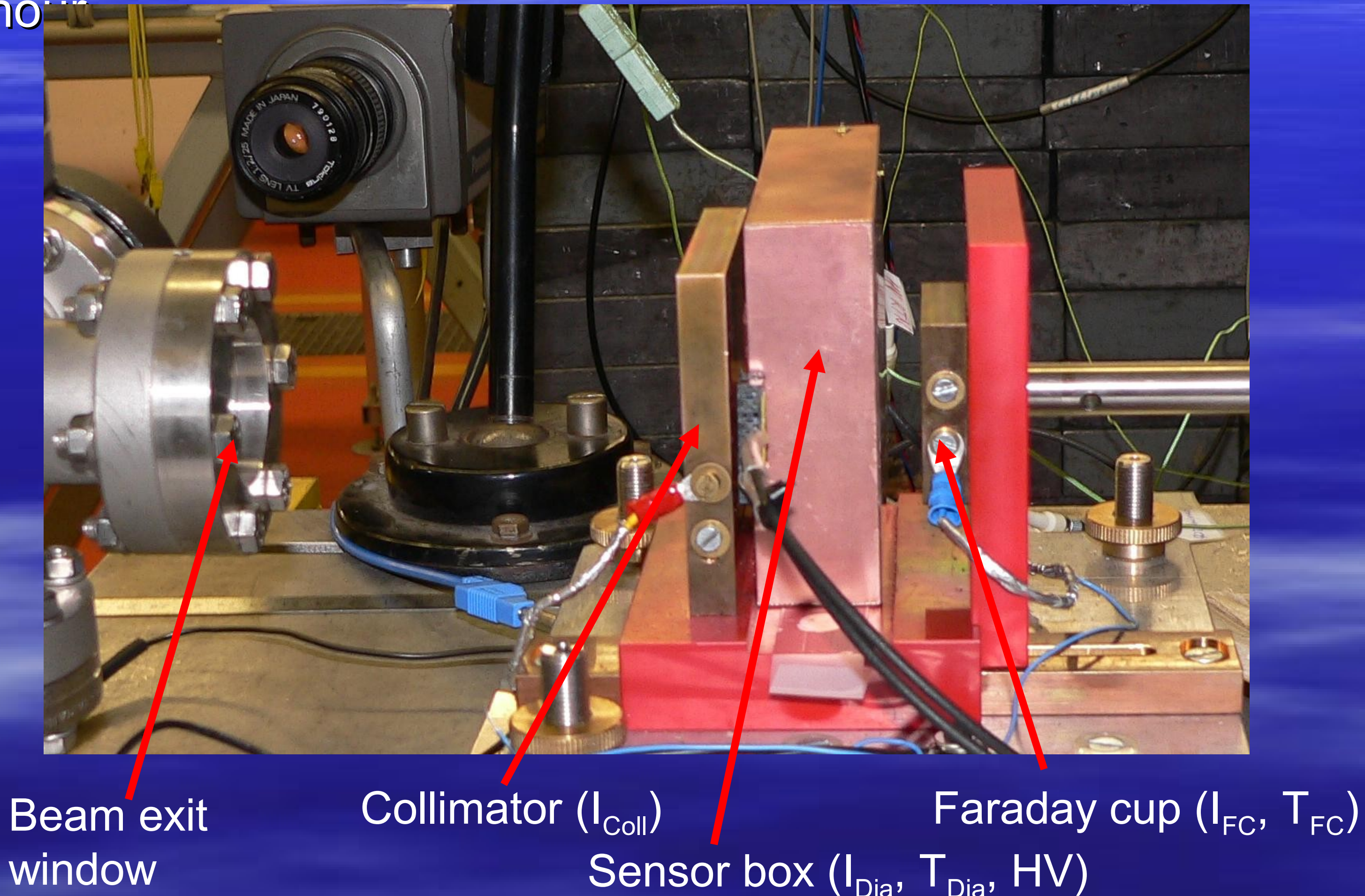
GaAs



Single crystal CVD diamond

Sensor R&D

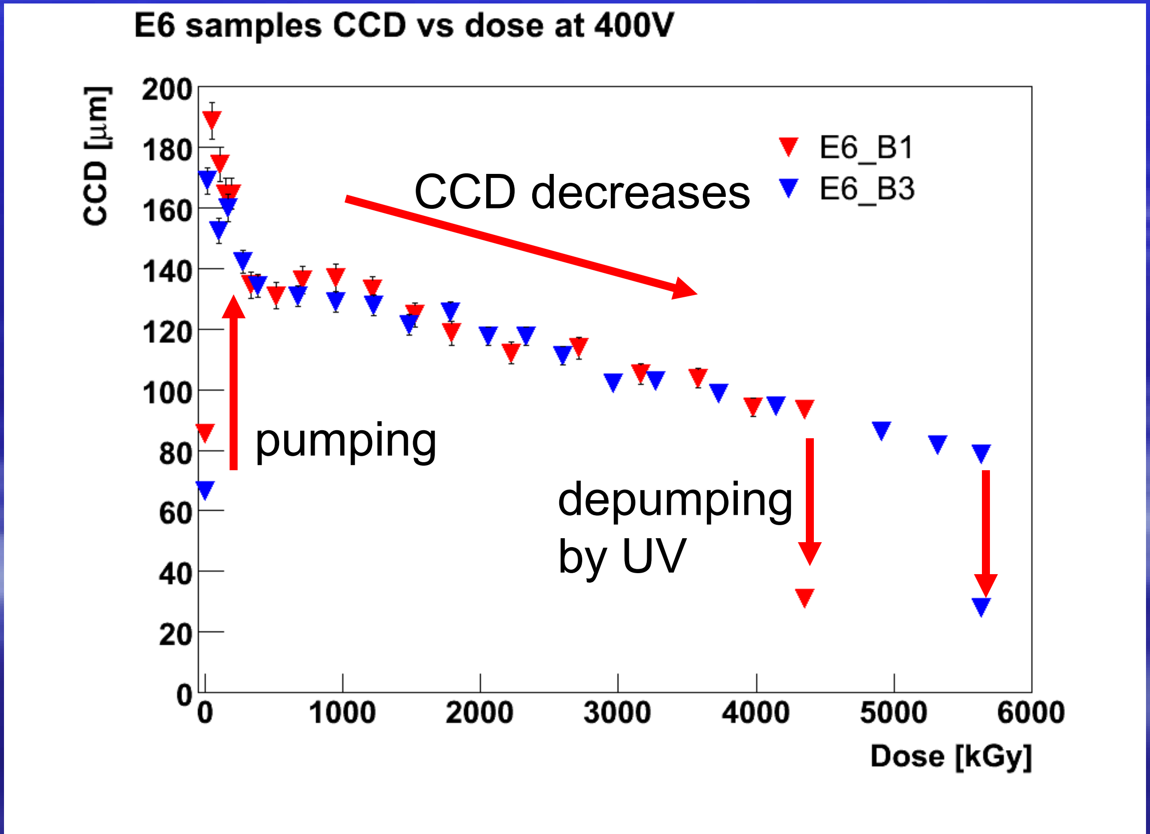
- Sensor performance as a function of the absorbed dose: electron beam at SDALINAC, 10 MeV, 10-50 nA beam current, 60-300 kGy/ho



Irradiation of pCVD Diamonds

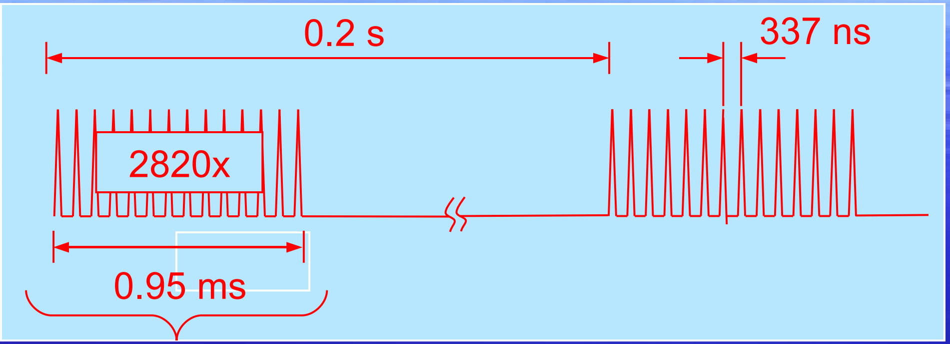
- After absorbing 5 – 6 MGy:

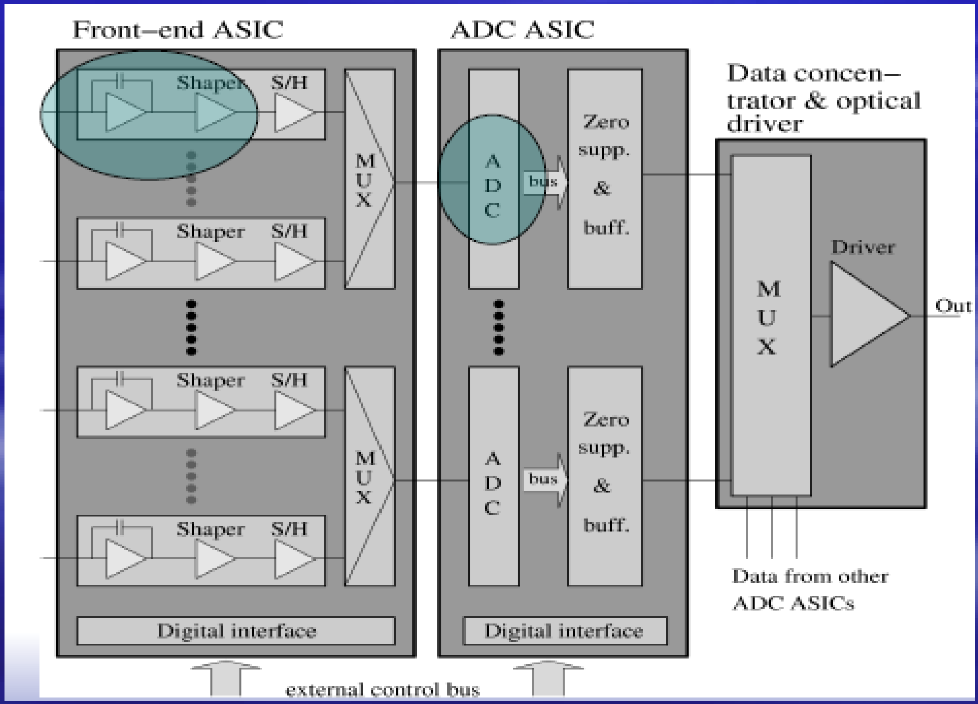
pCVD diamonds
are still operational.



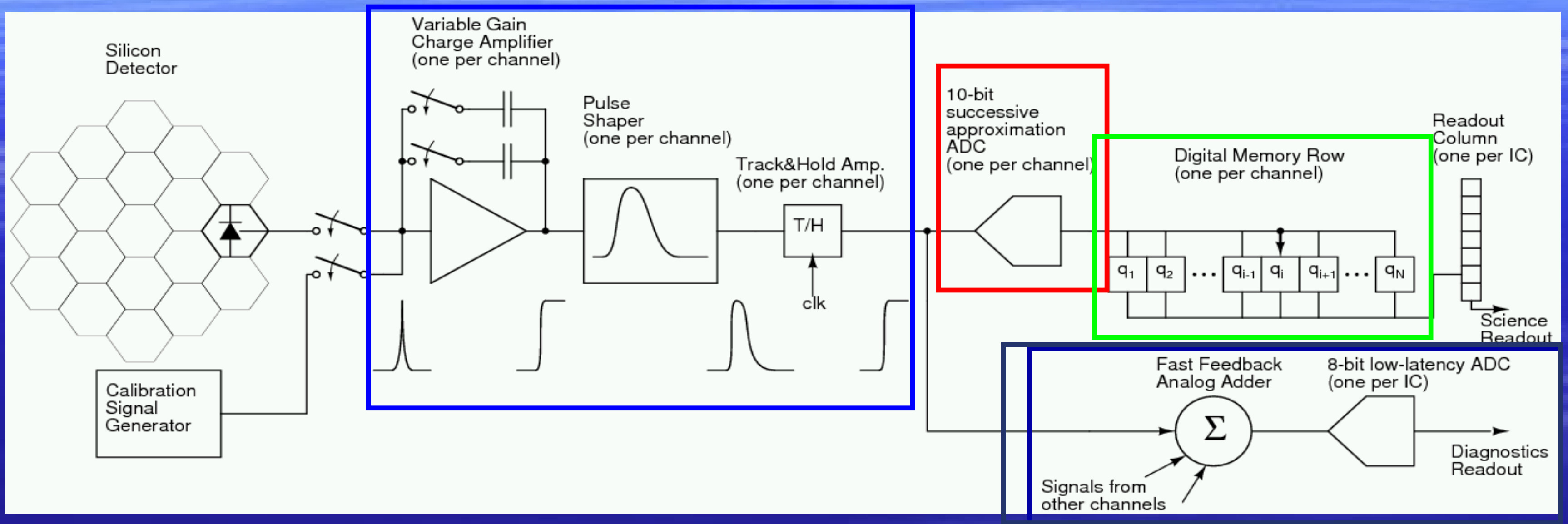
FE Electronics

- Accelerator delivers bunch trains:
  - Timing constraints for detectors and readout
  - High occupancy in the forward calorimeters – read out after each or a few bunch crossing.
  - Fast feedback.
- Solution for LumiCal: ASICs in AMS 0.35 µm technology
  - 1 FE ASIC contain 32-64 channels
  - 1 ADC for several channels.





BeamCal FEE



- 32 channels per chip
- All data is read at 10 bits for physics purposes;
- Sum of all channels is read out after each BX at 8 bits for beam diagnosis (fast feedback), low latency output
- TSMC CMOS 0.18 μm technology.

Summary

- The FCAL Collaboration develops detectors in the very forward region of the ILC detector;
- FCAL detectors will provide precise luminosity measurement (LumiCal), identification of single high energy electrons to the lowest possible angle relevant for new physics searches (BeamCal), beam diagnostics (BeamCal) and luminosity monitoring (BeamCal, GamCal);
- LumiCal must be positioned extremely precisely.
- Radiation hard sensors are essential for BeamCal;
- Electronics for all detectors should be fast (~100 ns), low power, radiation hard.

Transition from mainly design work to sensor and front-end electronics development, system tests and prototyping.