BeamCal for ILC Detectors

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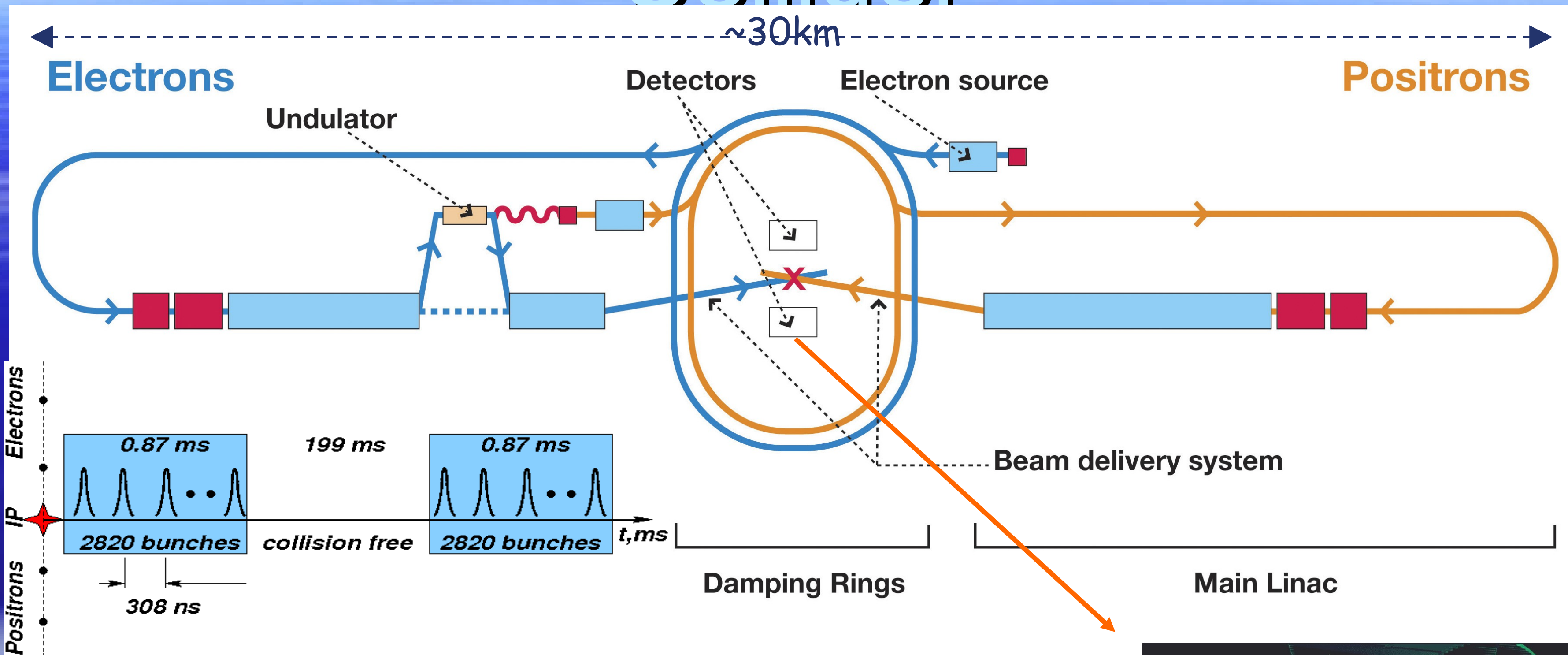
On behalf of the FCAL collaboration

Overview

- Accelerator
- ILC detector(s)
- Very forward region: design and challenges
- BeamCal
- Sensor R&D
- FEE
- Summary

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

The International Linear Collider



<u>Parameters:</u>

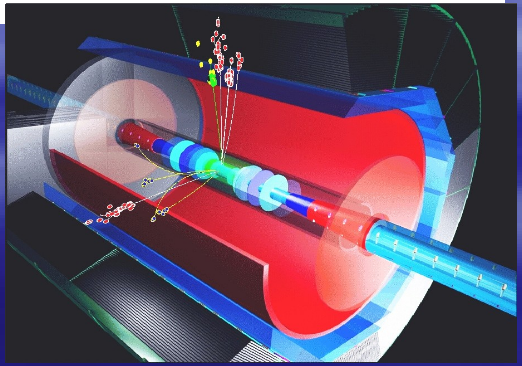
500 GeV (1 TeV upgrade possible)

2×10^{34} $cm^{-2}sec^{-1}$

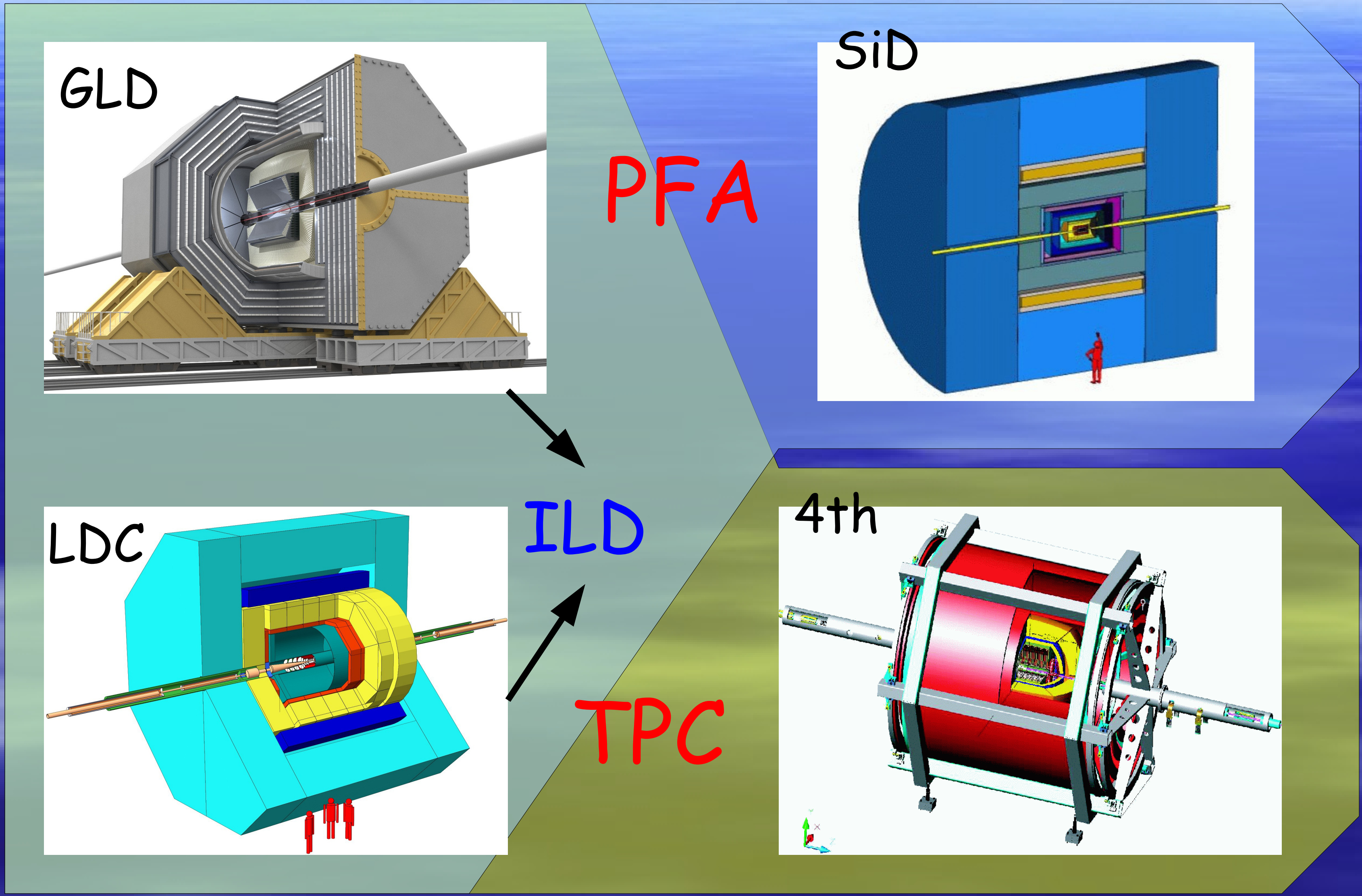
electron polarization ~80 %

positron polarization ~30 % (60 %)

beam sizes: $\sigma_x \approx 600nm$, $\sigma_y \approx 6nm$, $\sigma_z = 300\mu m$

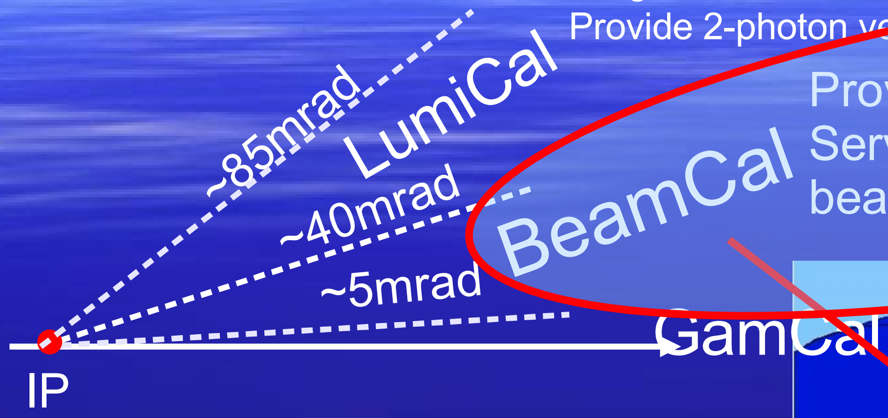


Detector concepts



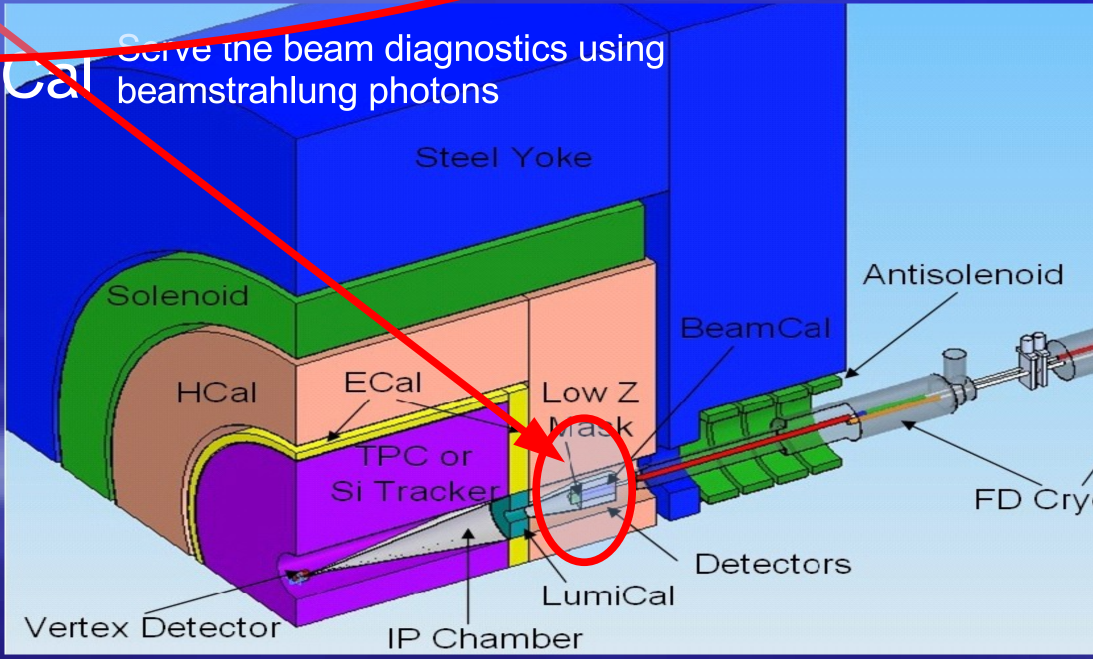
Very Forward Region

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

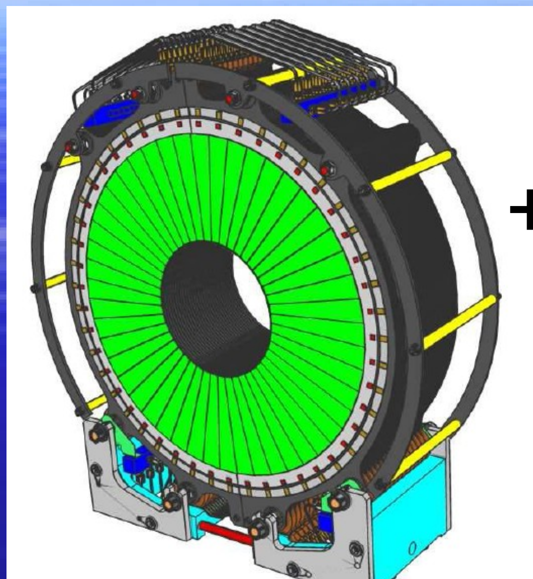


Provide 2-photon veto
Serve the beam diagnostics using beamstrahlung e^+e^- pairs

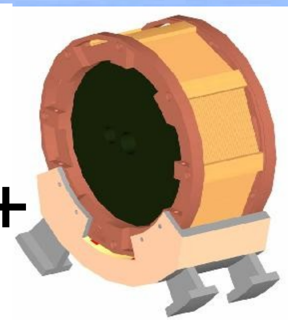
Serve the beam diagnostics using beamstrahlung photons



Forward Calorimetry



+



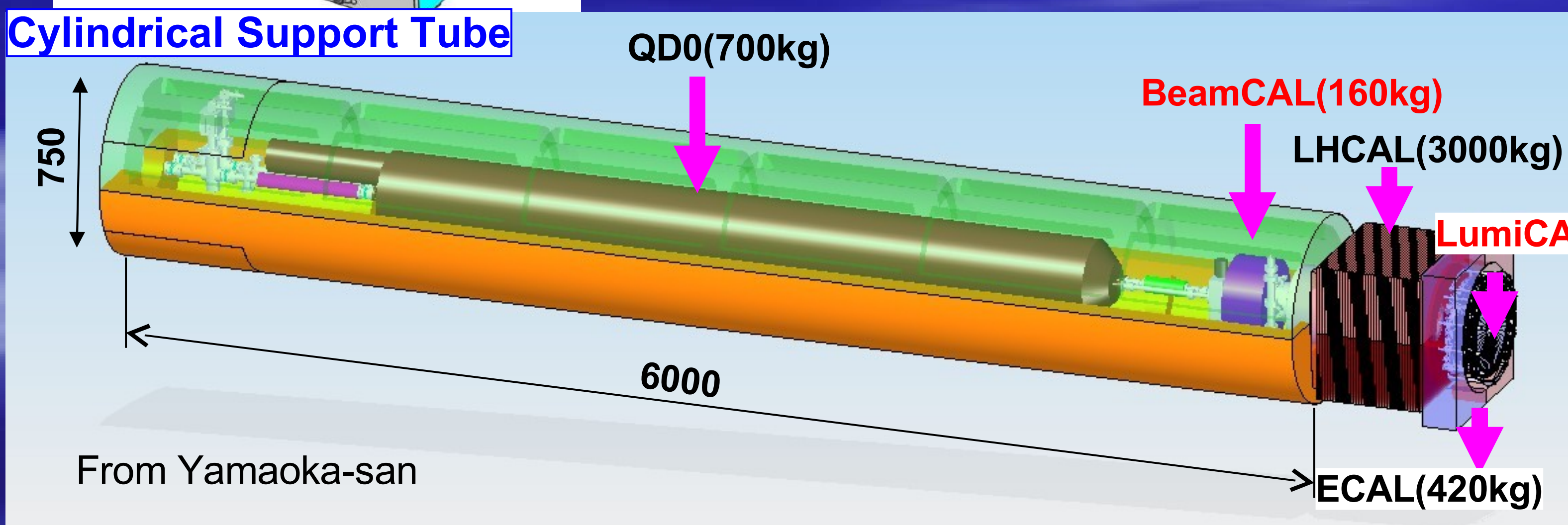
+ GamCal (~185 m)

(fast readout)

BeamCal (rad. Hardness)

+Pair-monitor in front

LumiCal (precision)



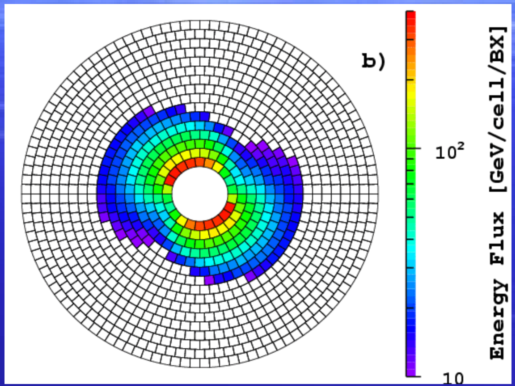
BeamCal: Beam Diagnostics

- 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

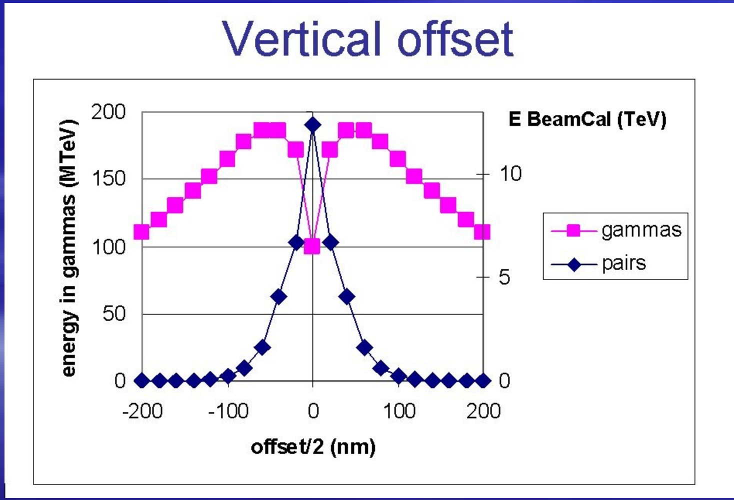
  Important for beam tuning.

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

  Radiation hard sensors



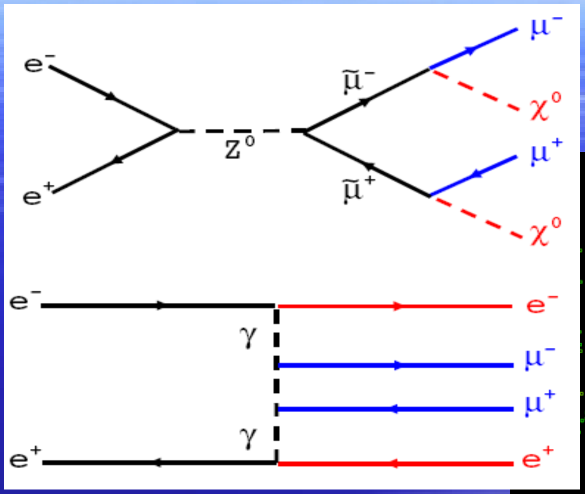
Energy deposition from Beamstrahlung in the innermost calorimeter (BeamCal)

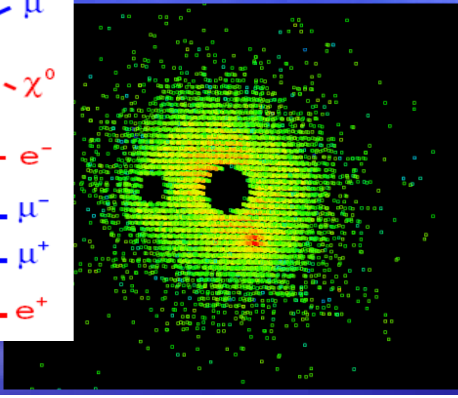


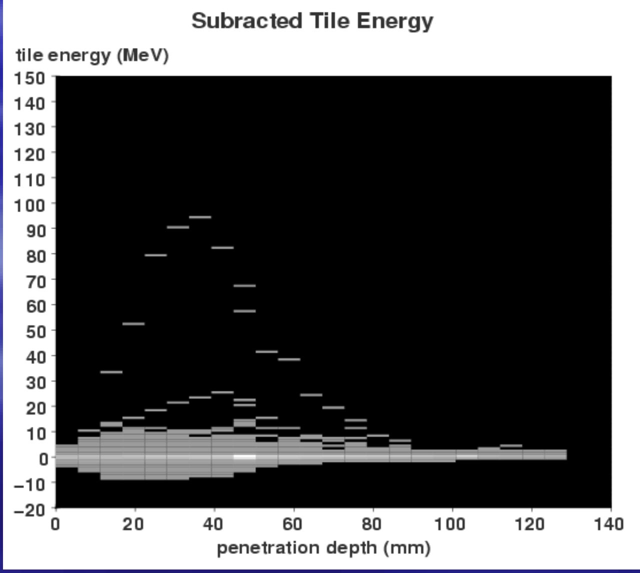
The ratio is ~ to L, feedback for beam tuning.

BeamCal: 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



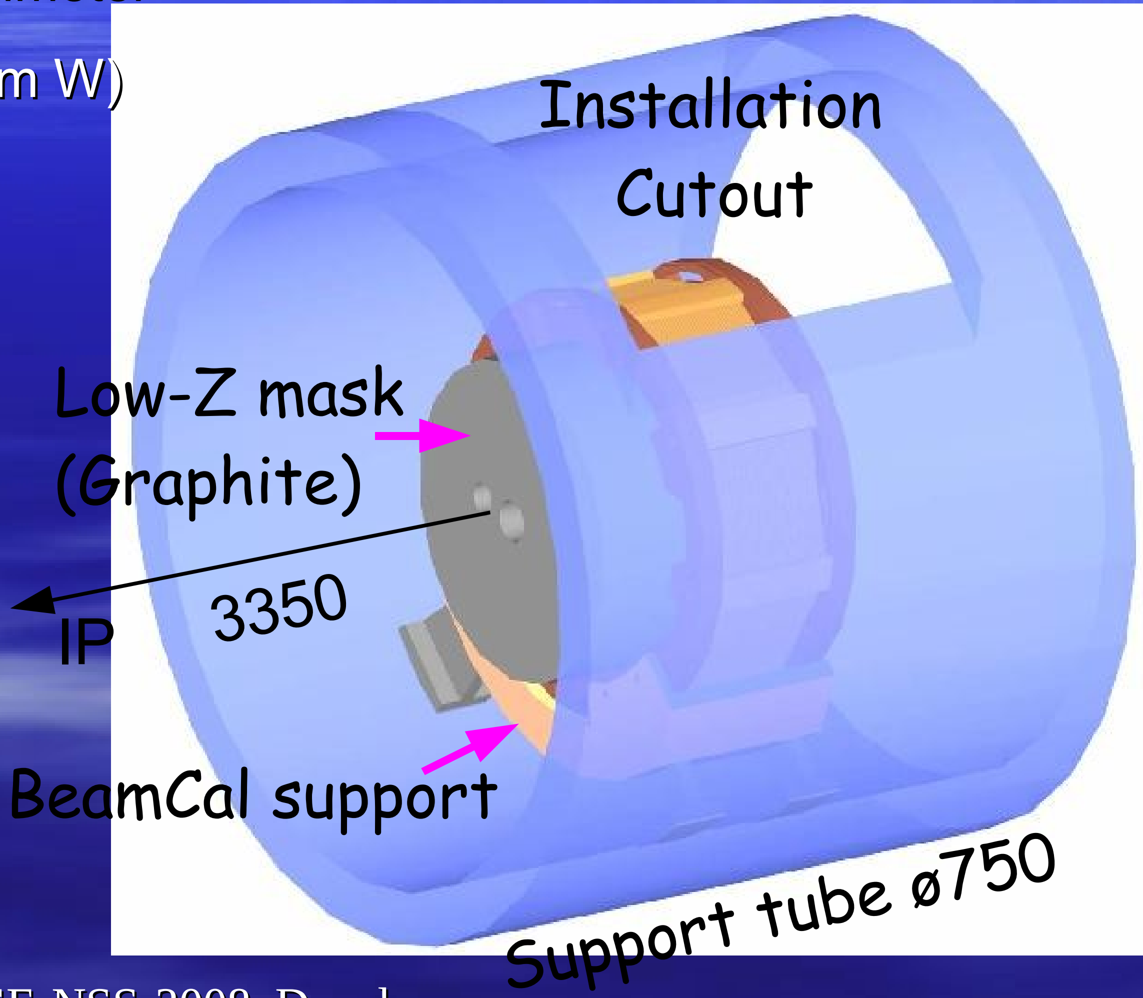




BeamCal

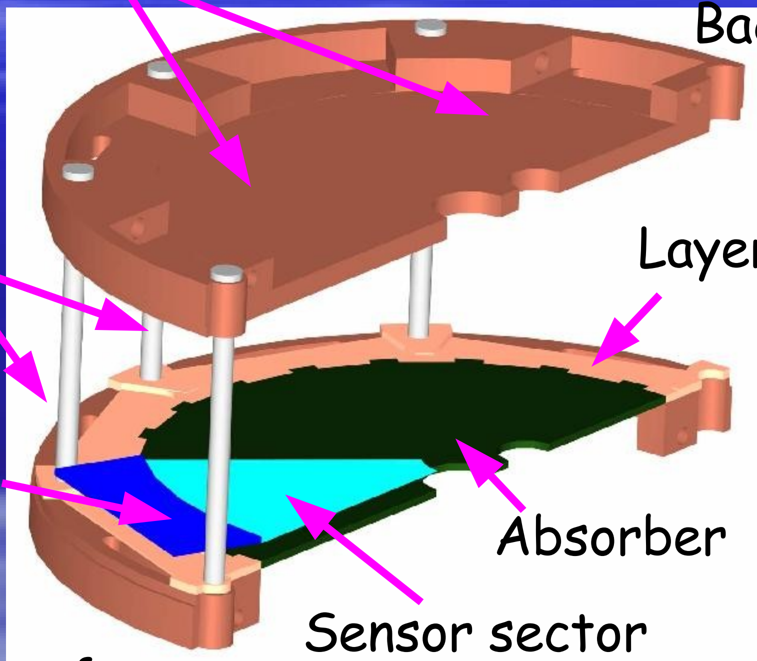
- Compact, smallest possible Moliere radius
- 30 X_0 ???/W sampling calorimeter
- Layer thickness ~X_0 (3.5 mm W)
- Sensor thickness ~0.5 mm
- X/Y/Z = 24.2/0/±3450
- Weight ~160 kg (+ support)
- 10 cm Graphite in front
- Rin (sensor) 20 mm
- Rout (sensor) 150 mm
- Rout (mech) 200 mm
- θ range 5.8 – 43.5 mrad
- ~40K R/O channels

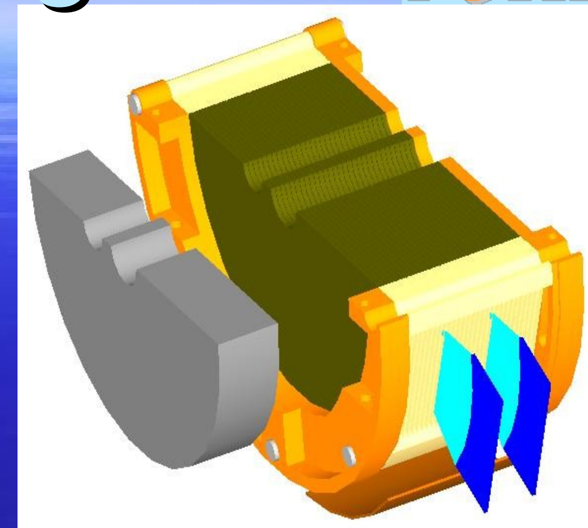
http://www-zeuthen.desy.de/ILC/fcal/



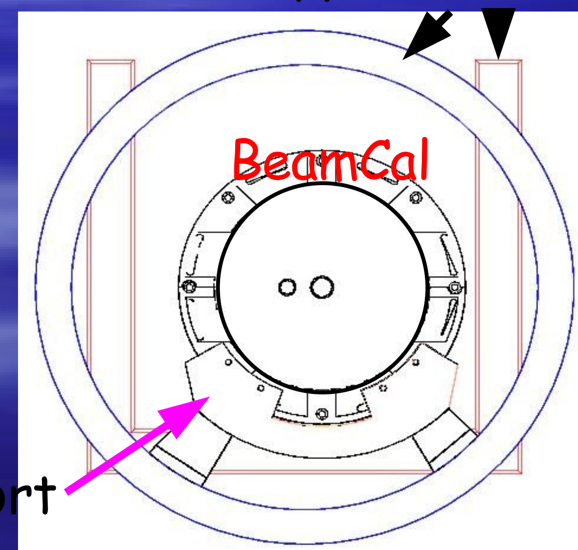
BeamCal design

Place for connectors/extra electronics





Support tube

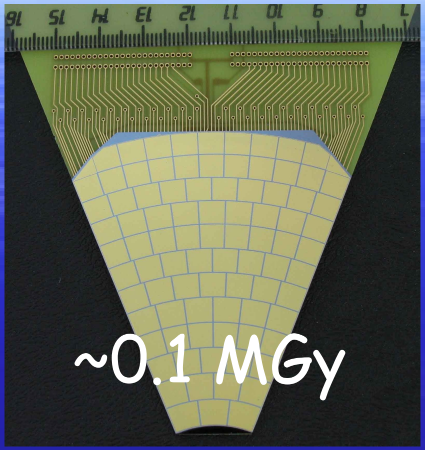


Sensor R&D

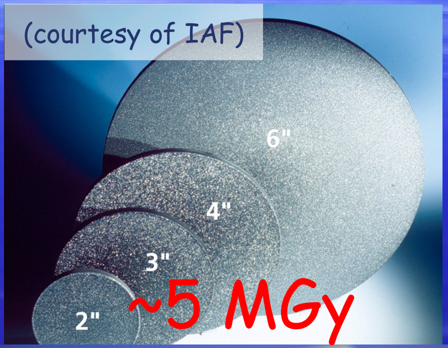
- GaAs (baseline):
  - semi-insulating GaAs, doped with Sn and compensated by Cr
  - produced by the Siberian Institute of Technology
  - available on (small) wafer scale
- pCVD diamonds:
  - radiation hardness under investigation (e.g. LHC pixel detectors)
  - high mobility, low $\varepsilon_R = 5.7$, thermal conductivity availability on wafer scale
- SC CVD diamonds:
  - large and fast signal
  - available in sizes of few mm^2
- New: Sapphire, Quartz:
  - relatively cheap
  - available in large sizes (<12")

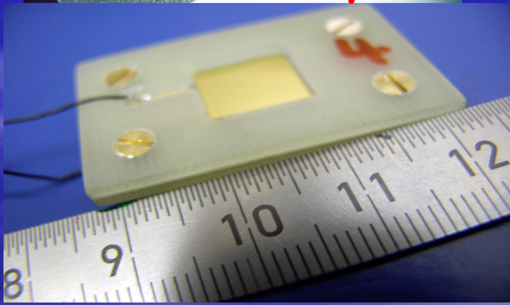
CVD = Chemical Vapor Deposition

GaAs

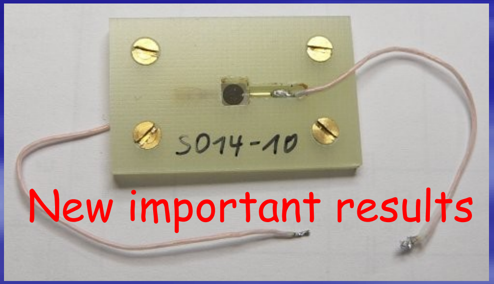


polycrystalline CVD diamond





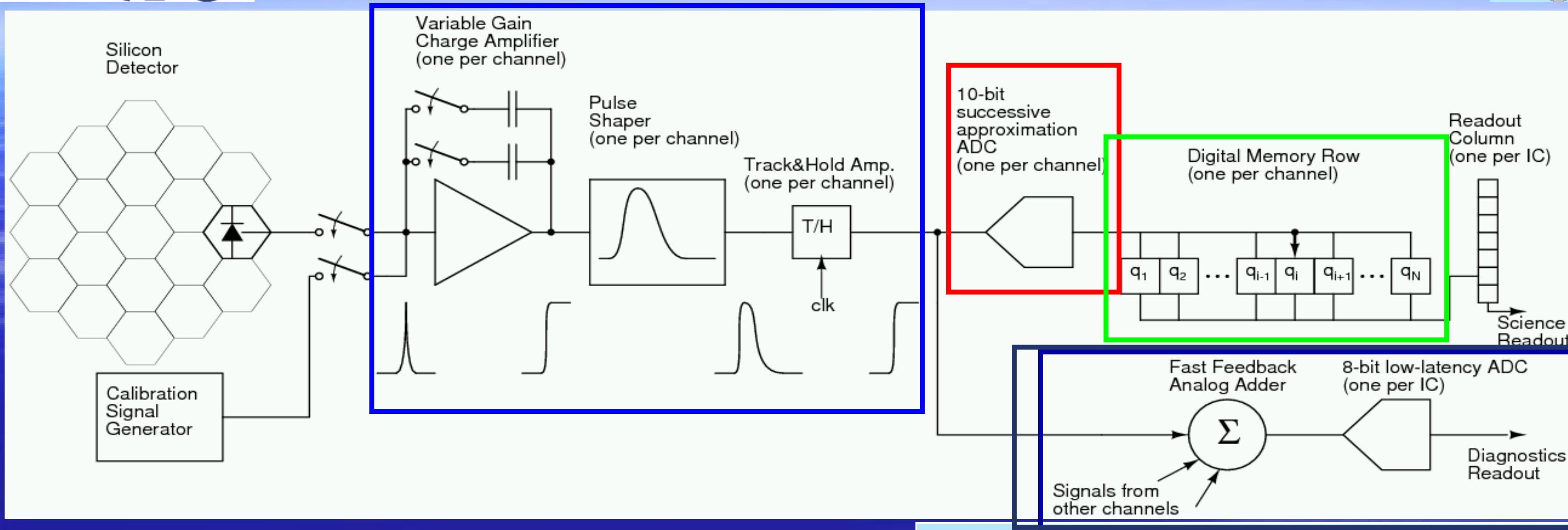
Single crystal CVD diamond

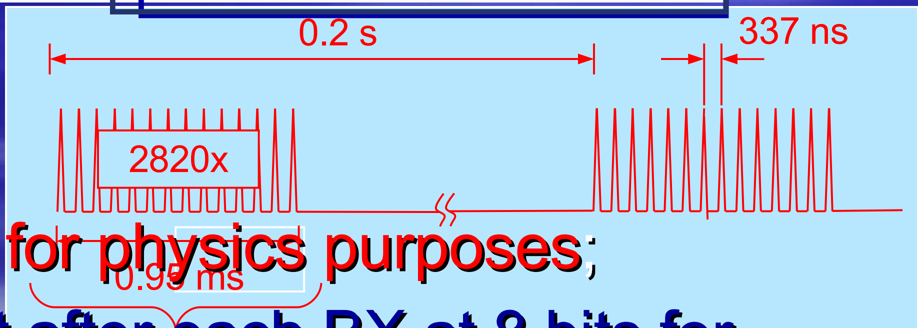


Sapphire

? MGy – under study

BeamCal FEE





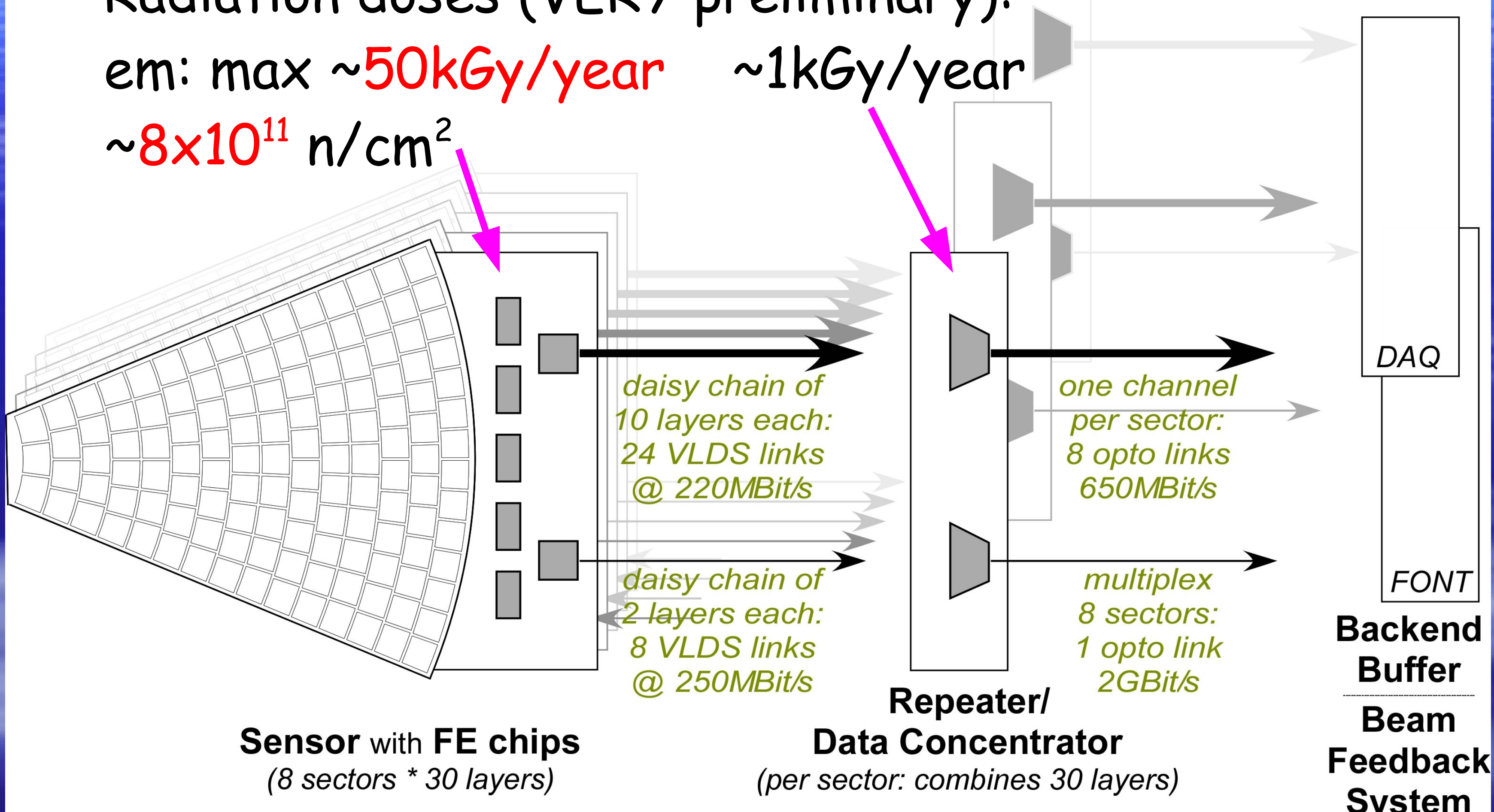
- 32 channels per chip
- All data are read out at 10 bits for physics purposes;
- Sum of all channels is read out after each BX at 8 bits for beam diagnosis (fast feedback), low latency output
- TSMC CMOS 0.18 mm technology.

BeamCal Readout

Radiation doses (VERY preliminary):

em: max ~50kGy/year ~1kGy/year

~8x10^{11} n/cm^2

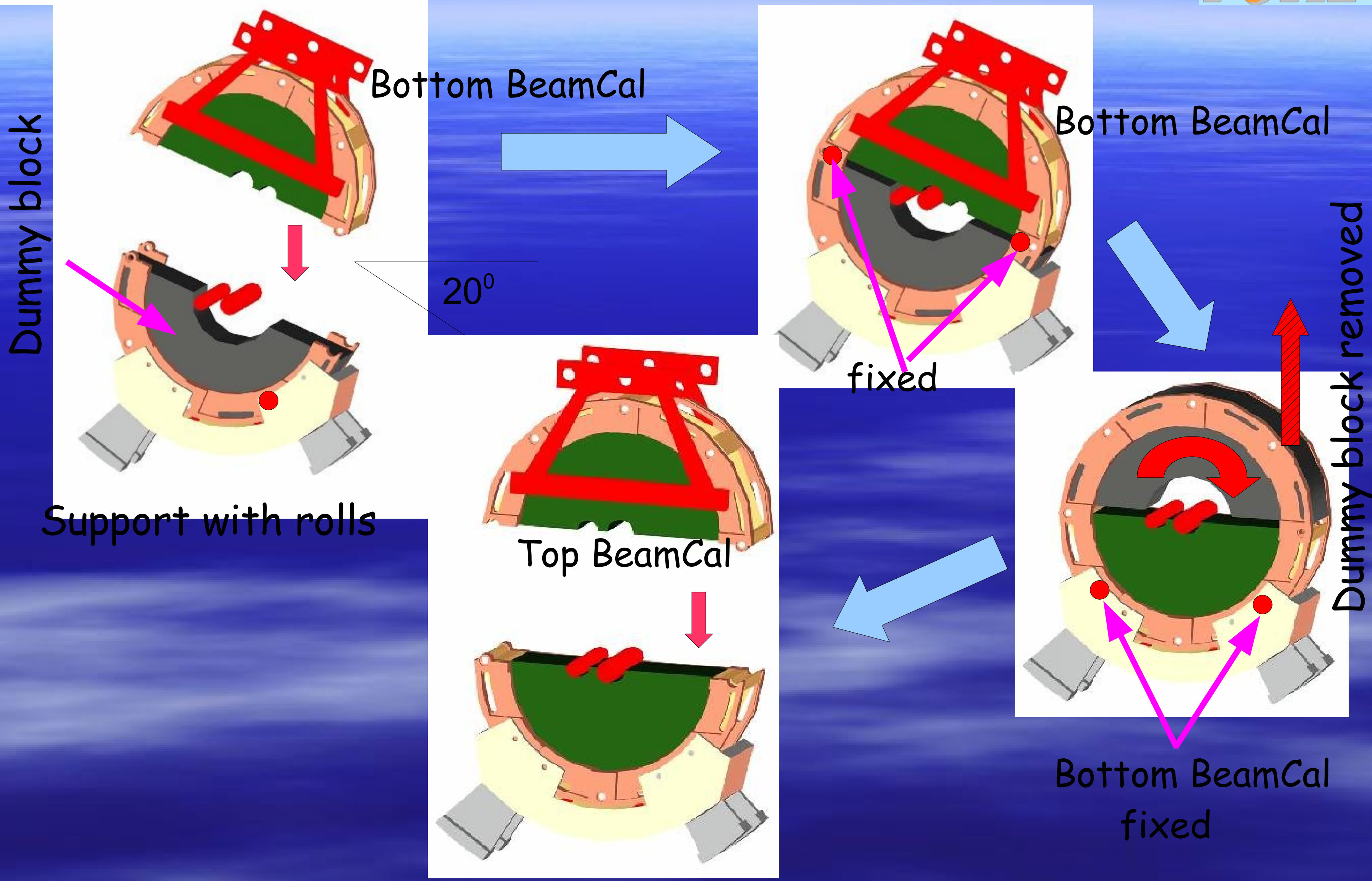


Summary

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

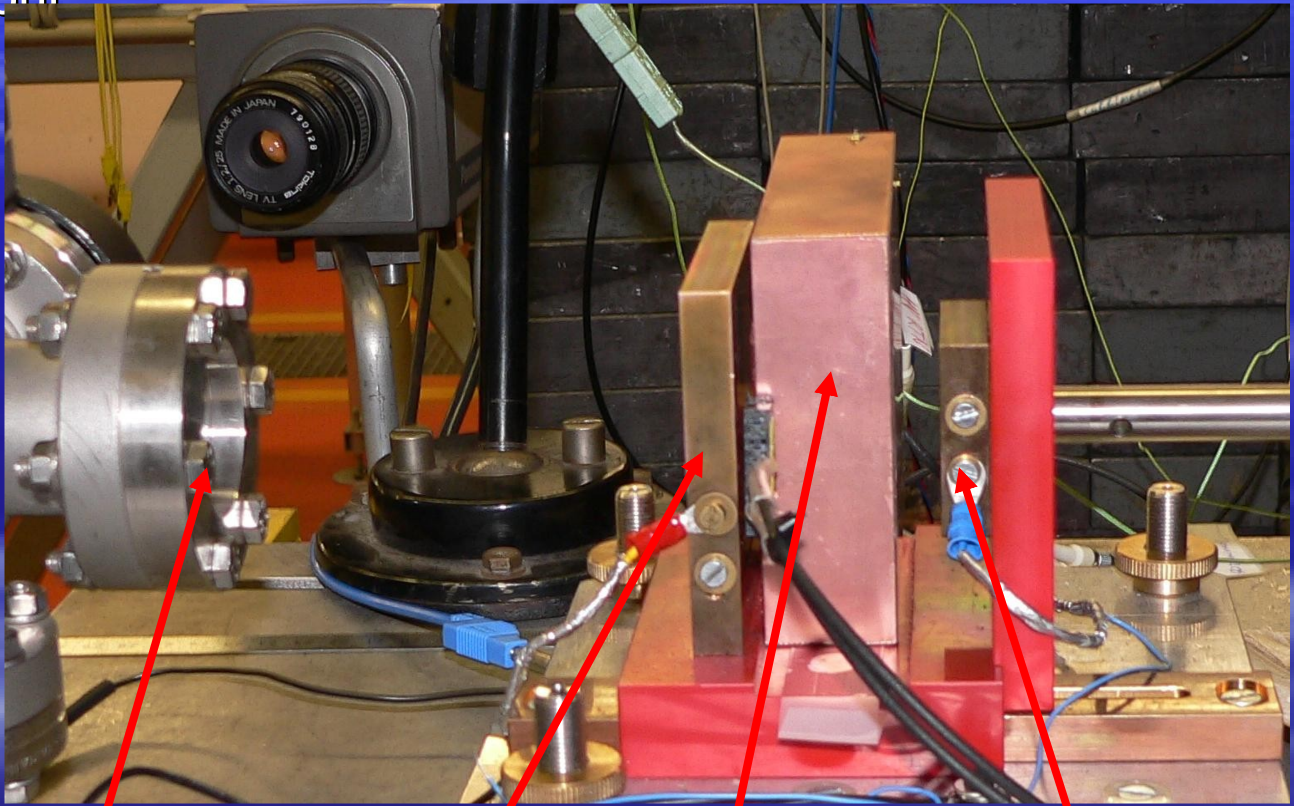
Transition from mainly design work to sensor and front-end electronics development, system tests and prototyping.

BeamCal installation



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/hour



Beam exit window

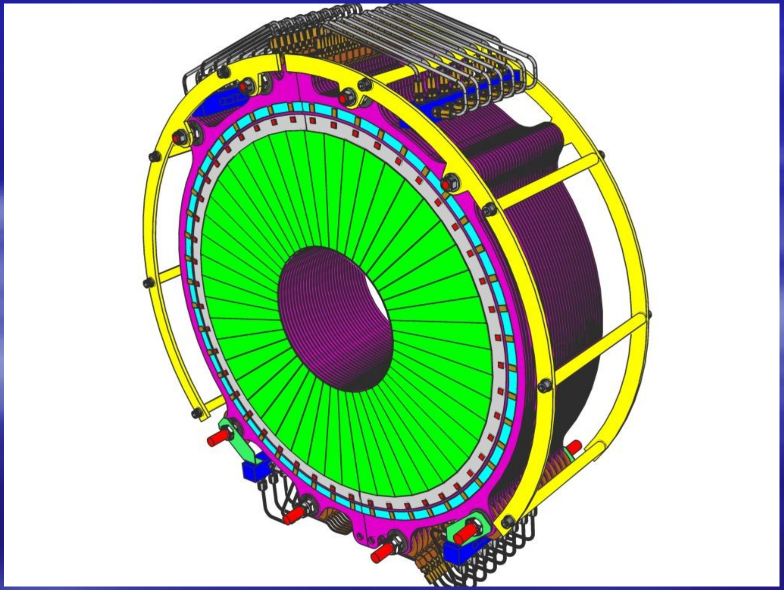
Collimator (I_{Coll})

Sensor box (I_{Dia}, T_{Dia}, HV)

Faraday cup (I_{FC}, T_{FC})

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;
  - Azimuthal cell size = 131 mrad;
  - Radial cell size = 0.8 mrad;
  - z position = 2270 mm.

Si sensors placement accurate to several μm.

Irradiation of pCVD Diamonds

- After absorbing 5 – 6 MGy:

pCVD diamonds
are still operational.