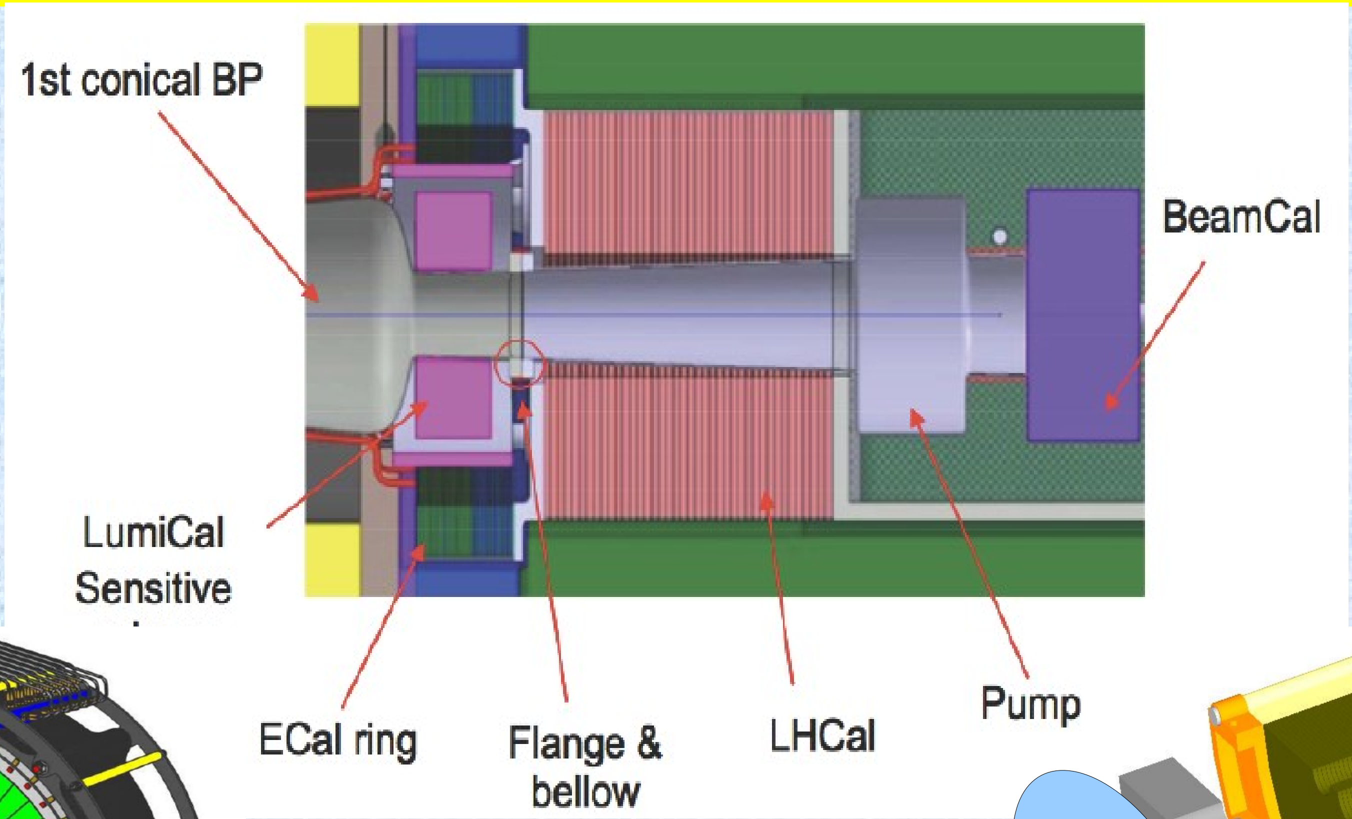
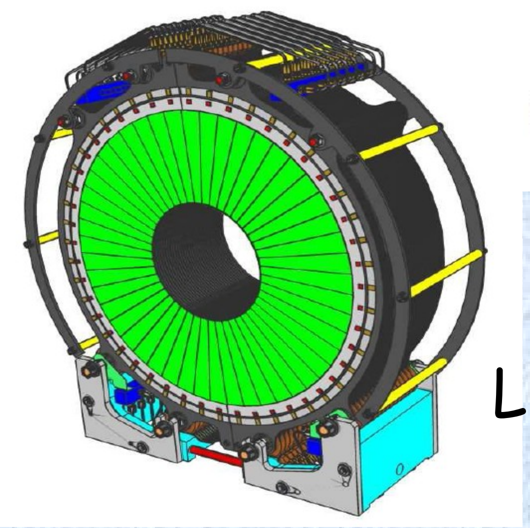
Forward Calorimetry

S.Schuwalow, DESY

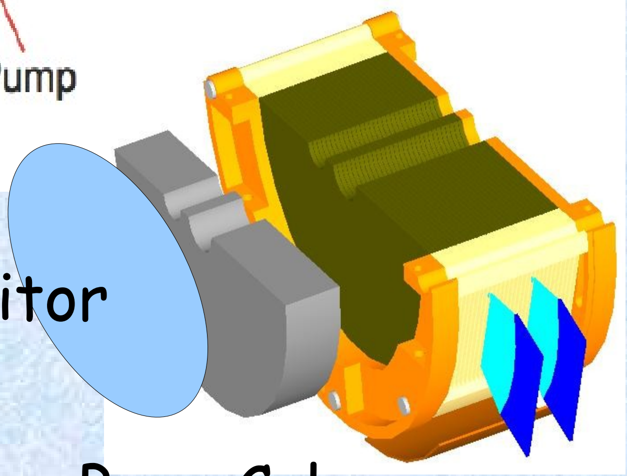
- LumiCal
- BeamCal & Pair Monitor
- Data Transfer & Integration
- Priority R&D Topics
- Challenges of Very Forward Detectors

Calorimeters in the very forward region (14 mrad xa)





LumiCal



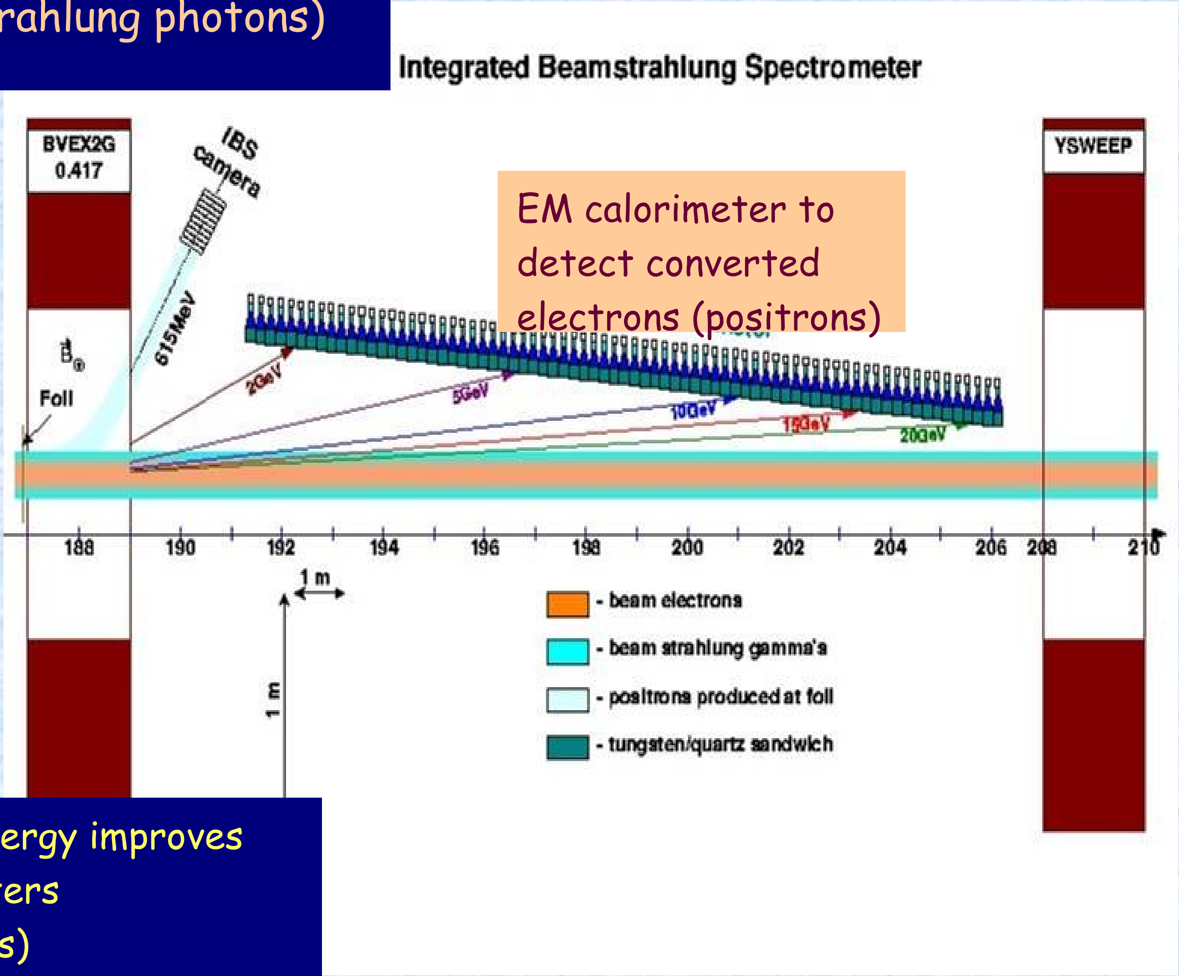
Pair Monitor

BeamCal

+ one more calorimeter, GamCal

~ 180 m from IP

< 1 mrad aperture (beamstrahlung photons)



EM calorimeter to detect converted electrons (positrons)

Thin foil to convert beamstrahlung photons

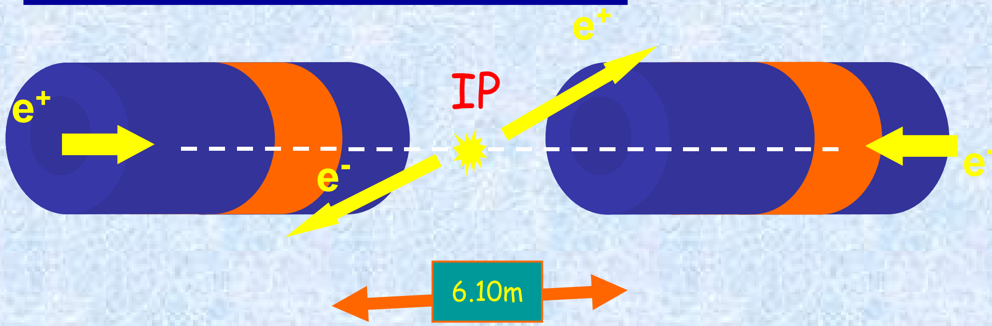
Measuring only the total photon energy improves the measurement of beam parameters significantly ! (reduced correlations)

Also sensitive at low luminosities

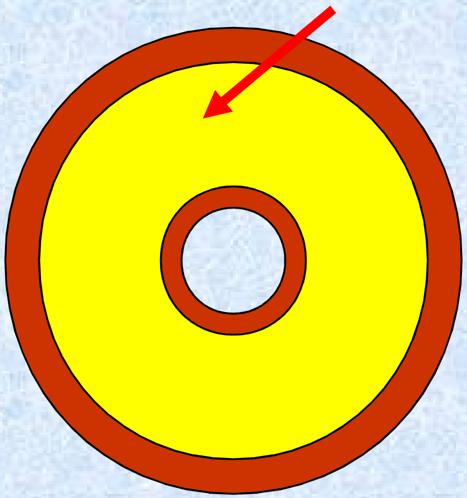
LumiCal

Precise Luminosity measurement

Gauge process: $e^+ e^- \rightarrow e^+ e^- (\gamma)$



Fiducial volume for event counting



$\mathcal{L} = N / \sigma$

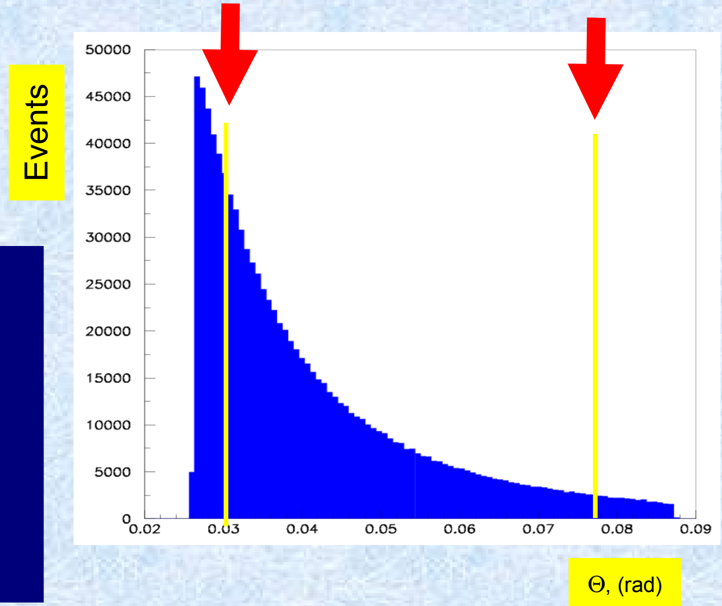
Count Bhabha events

From theory

Goal: Precision $<10^{-3}$

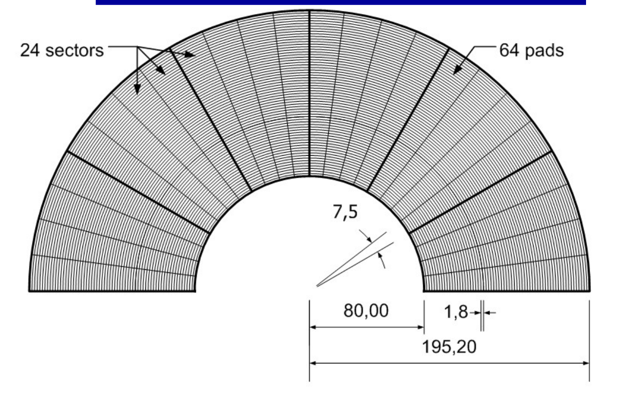
Challenges:

- compact calorimeter (small Moliere radius)
- small bias in θ ($<\mu$rad)
- small bias in energy scale (0.1%)
- fast readout

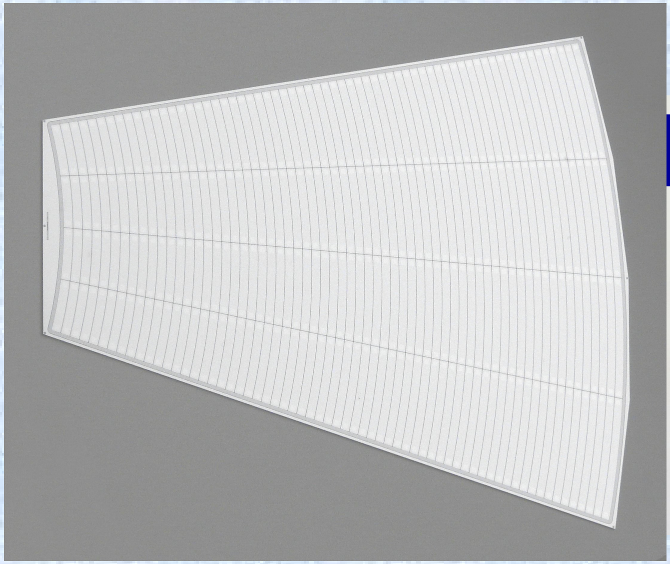


LumiCal Sensors

Half sensor plane (design)



Prototype sector (March 2009)

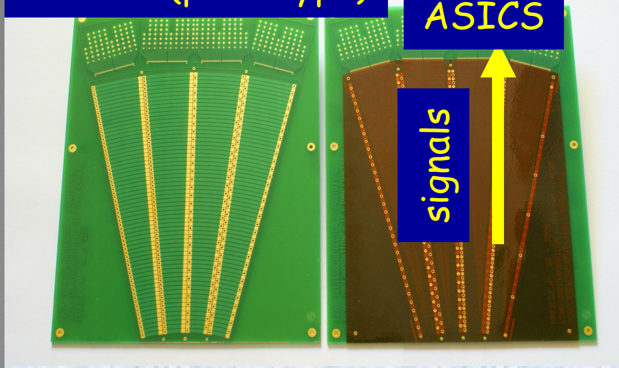


N-type silicon, p⁺ strips, n⁺ backplane,
Crystal Orientation <100>
320 μm thickness ± 15 μm
Strip pitch: 1800 μm
Strip p⁺ width: 1600 μm
Strip Al width: 1700 μm

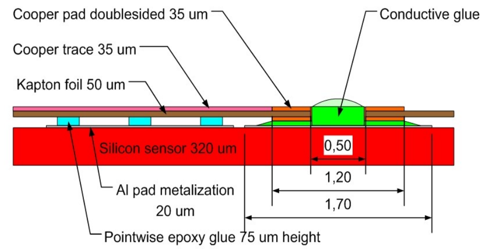
Masks for prototypes ready (Hamamatsu)
Prototype sensors delivered in March

In parallel: development of the fanout

Fan-out (prototype)



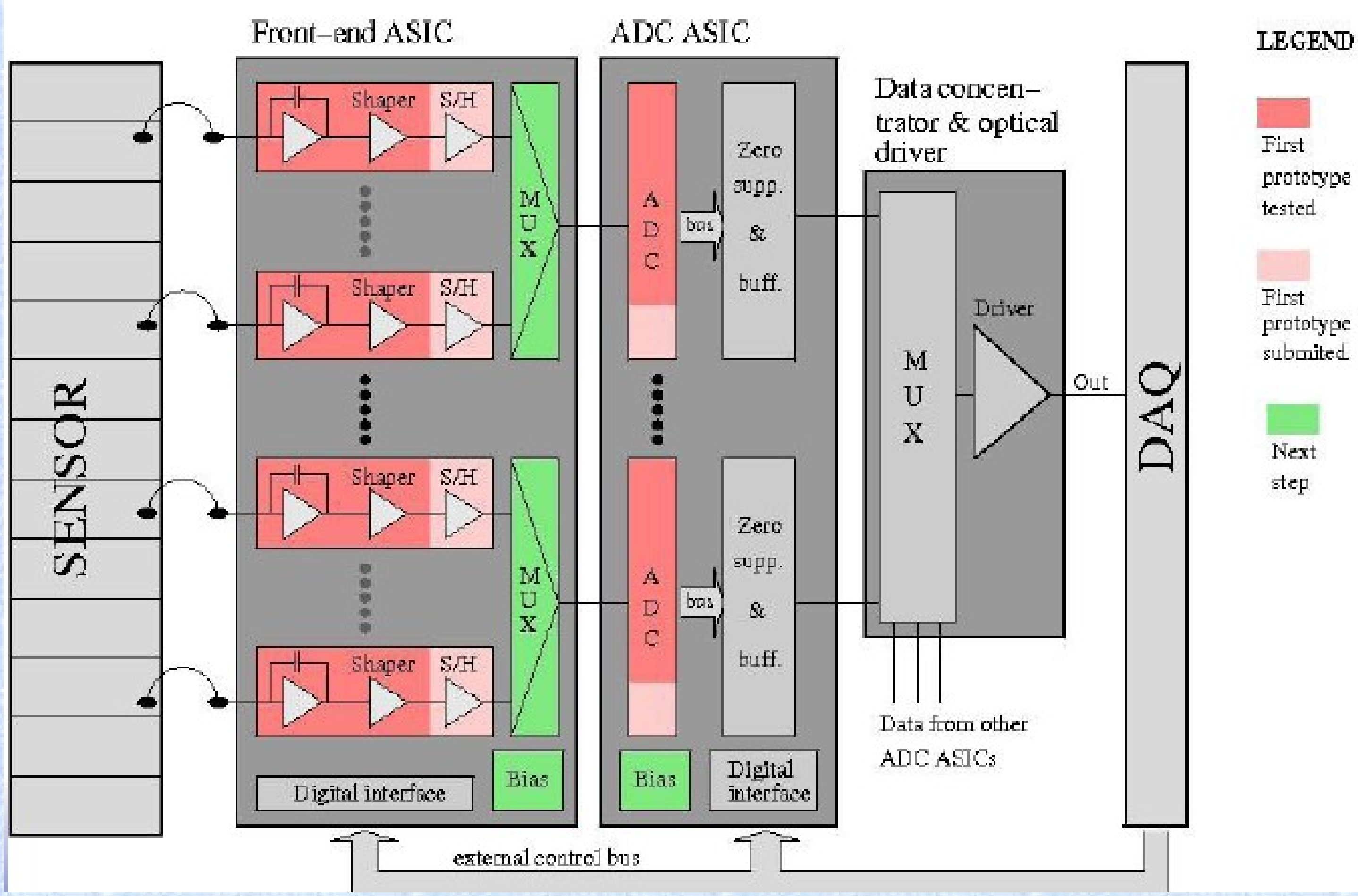
Contact details



FE Electronics, LumiCal

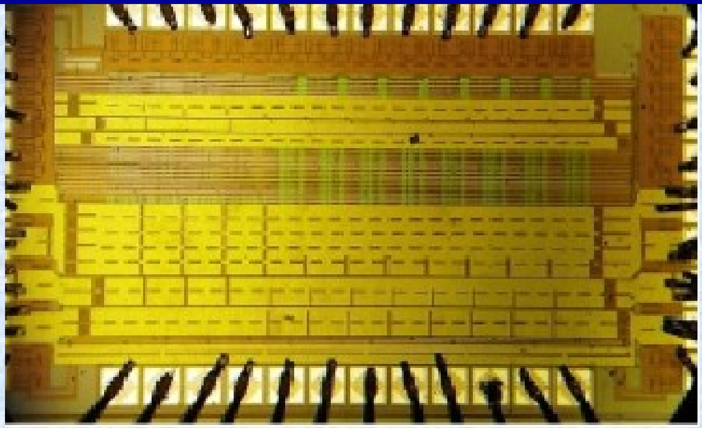
- One FE ASIC will contain 32 - 64 channels, 10 bit
- One ADC will serve several channels (MC simulations not finished)
- AMS 0.35 μm technology
- prototypes of the FE ASIC and ADC ASIC available,

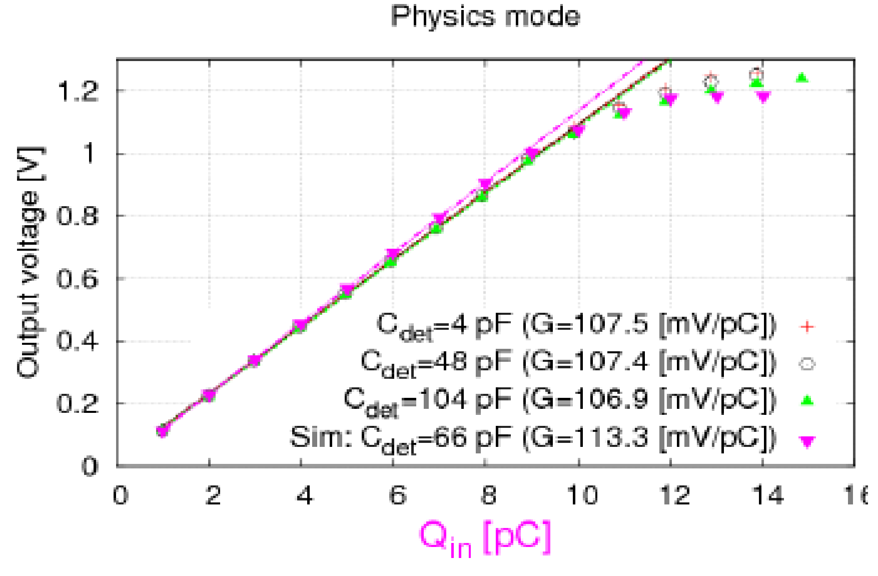
Tests of the FE ASICS so far promising.



FE Electronics, LumiCal

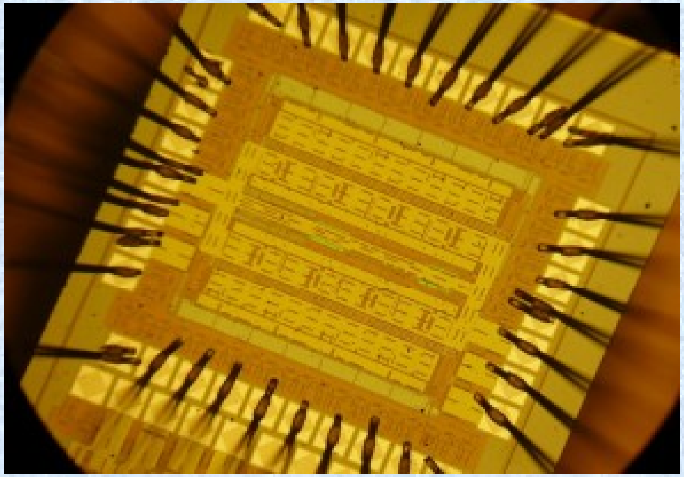
FE ASIC:
8 channels per chip, 4 with MOS feedback resistance,
4 with passive Rf feedback



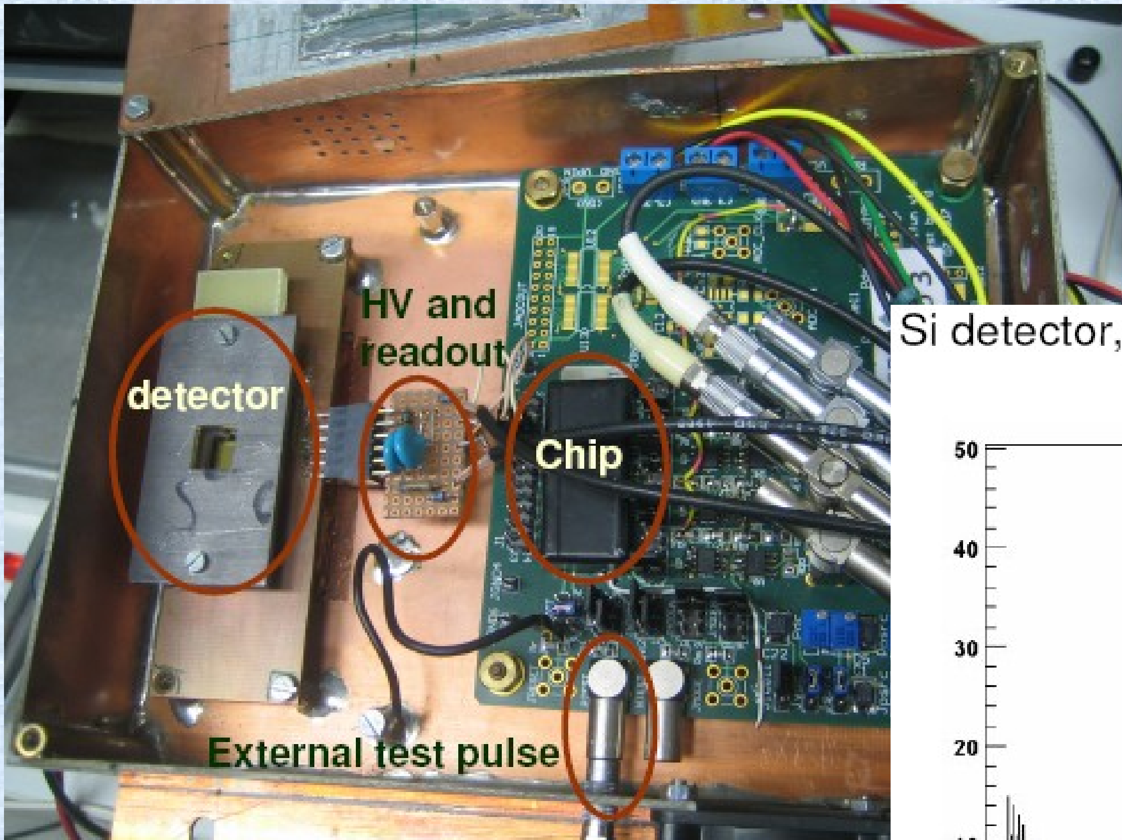


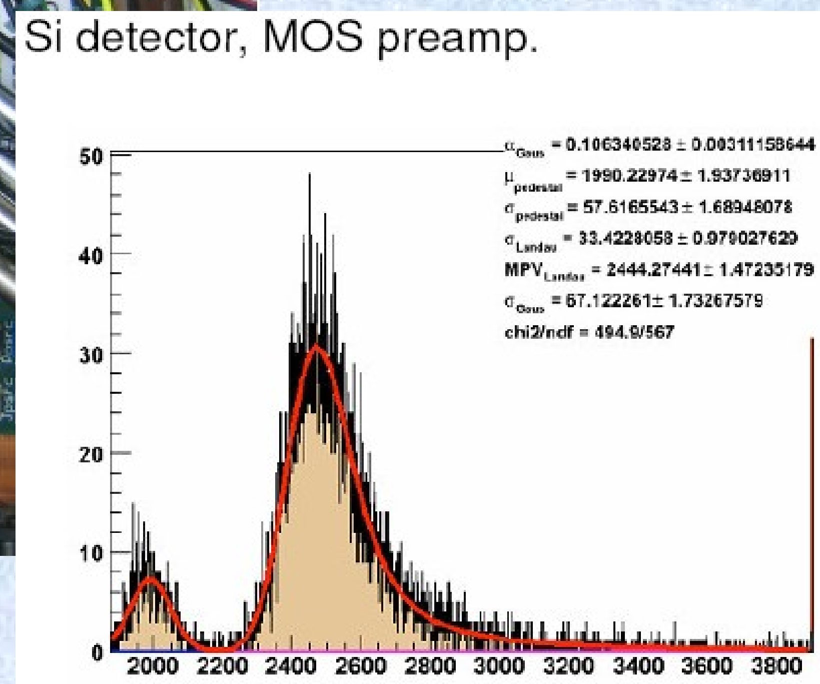
ADC ASIC:
- Pipeline architecture
- 10 bit resolution
- Maximum sampling rate 35 MHz

Submission ADC and DAC Sept. 2008
Prototypes obtained in November

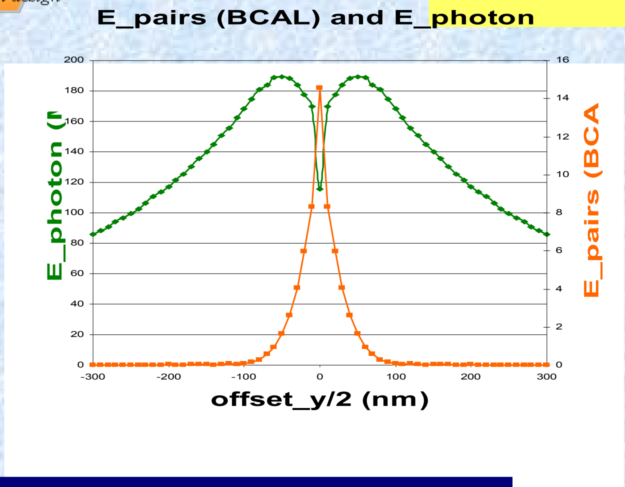


First successful tests of the analog part with a single pad sensor





BeamCal, Pair Monitor, GamCal

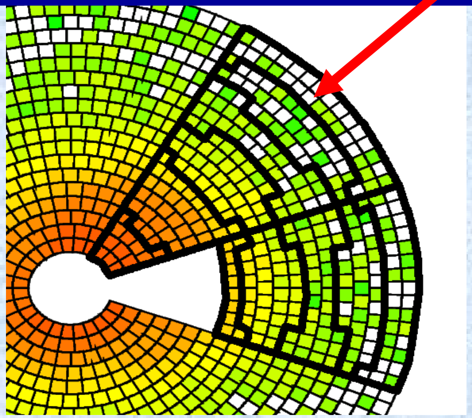


BeamCal, Pair Monitor, GamCal

Fast feedback for beam tuning, beam diagnostics using beamstrahlung;

Beamparameter determination on percent level

Fast analog summation of pad-groups



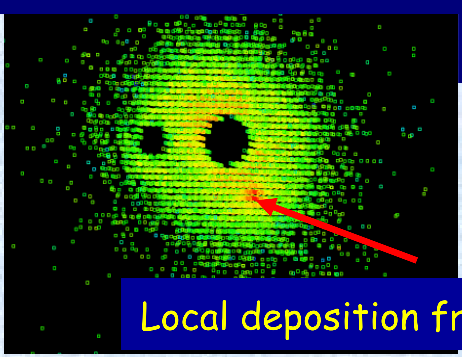
BeamCal

Hermeticity,
Electron veto at low angles

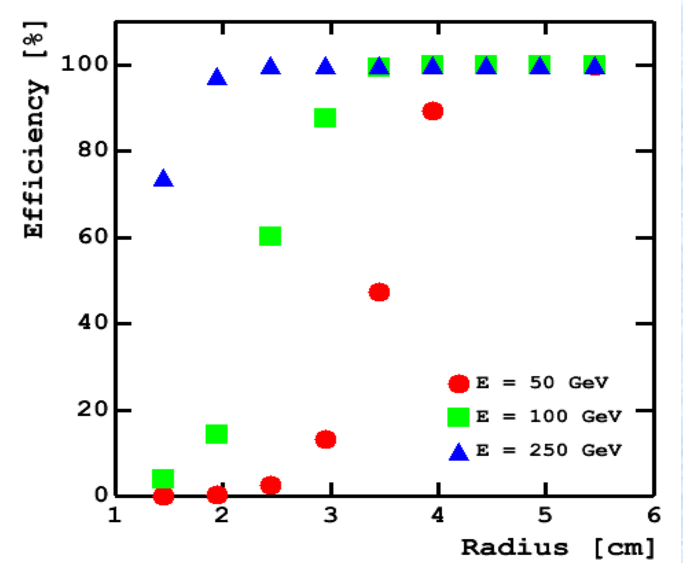
Mask for the inner detectors

Challenges:

- compact calorimeter (small Moliere radius)
- radiation hard sensors (~ MGy)
- fast readout

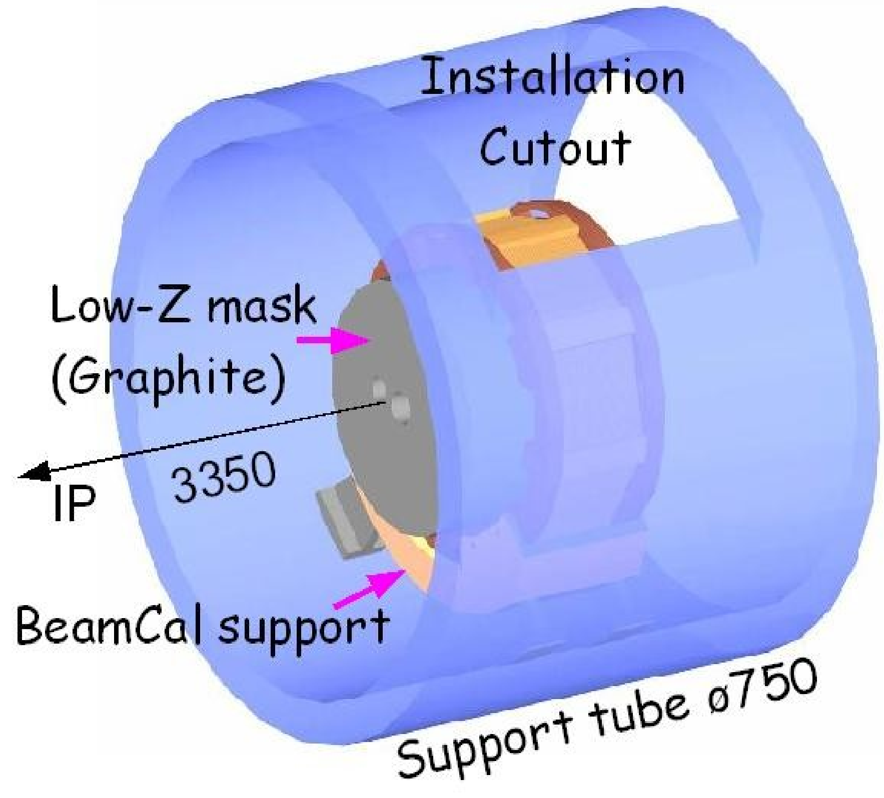


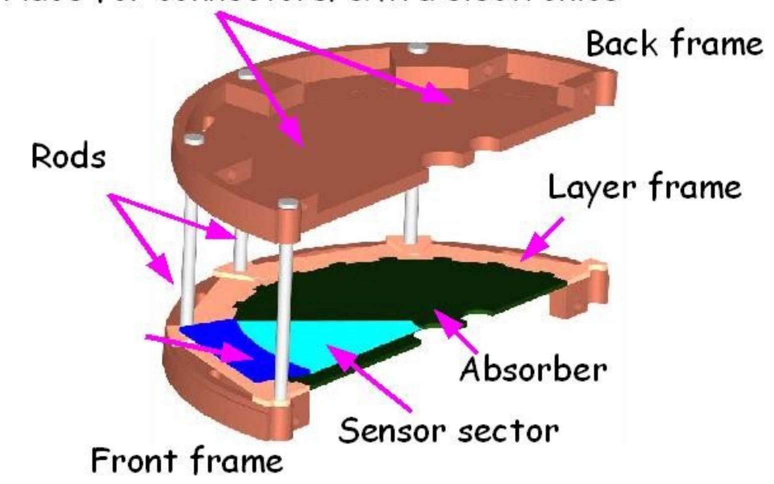
Local deposition from a single high energy electron

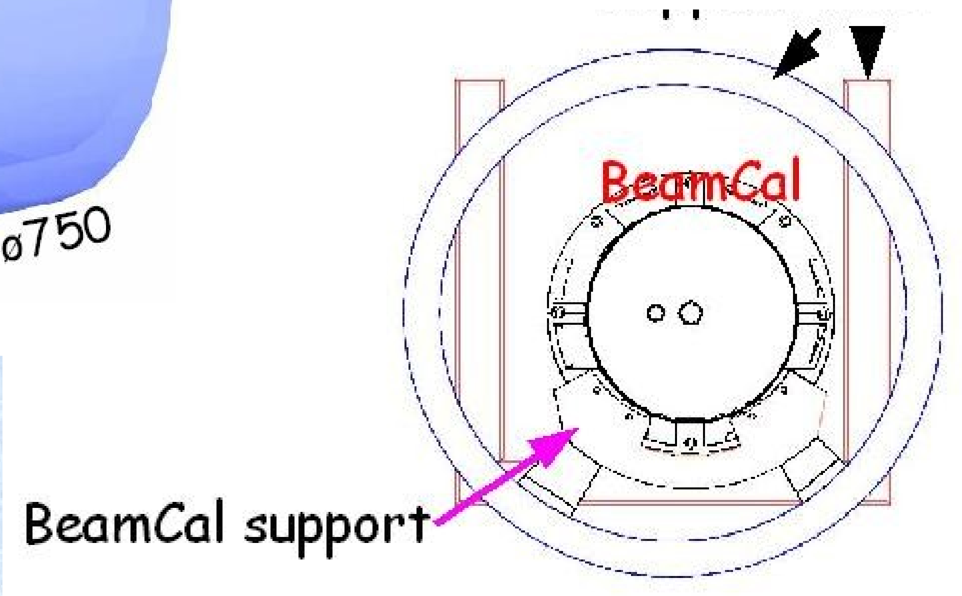


BeamCal Mechanics

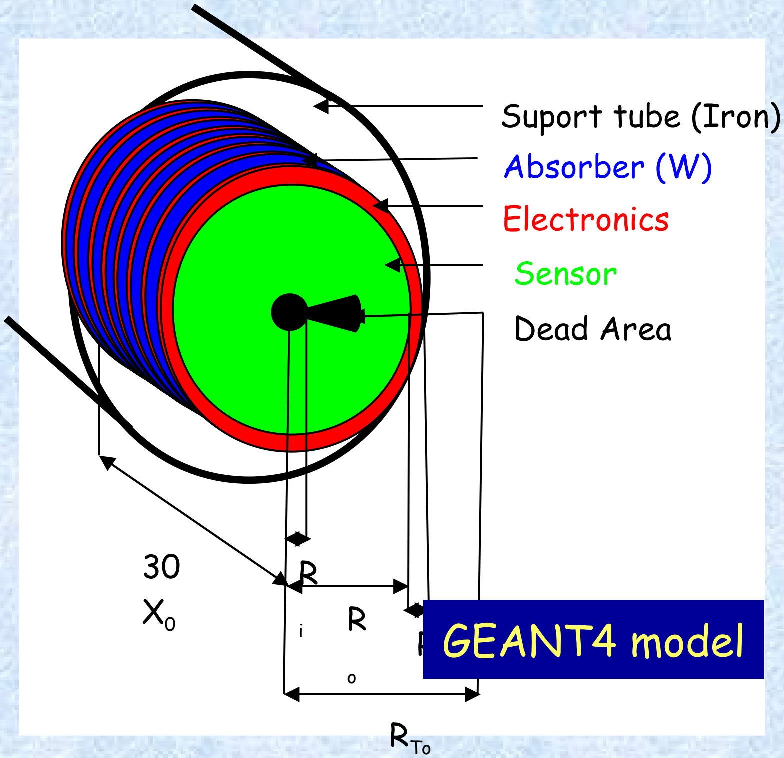
http://www-zeuthen.desy.de/ILC/fcal/







Radiation Dose and neutron fluxes BeamCal

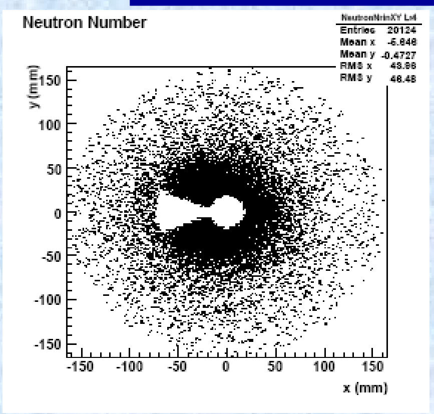


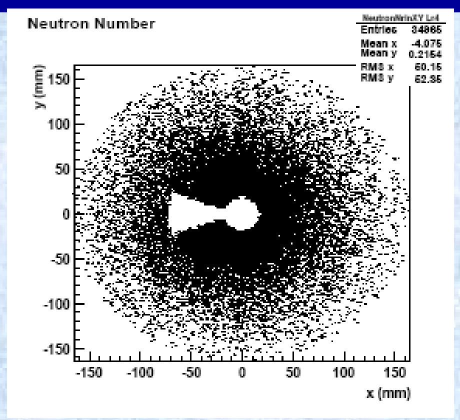
GEANT4 model

Electromagnetic dose for FE electronics:

< 100 Gy /year

Neutron flux inside sensors:





Neutron flux through FE electronics:

10^{10} neutrons/mm^2/year

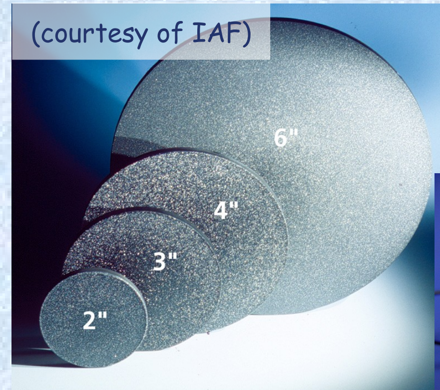
Two different 'physics lists'

10^{12} neutrons/mm^2/year
(needs more detailed studies)

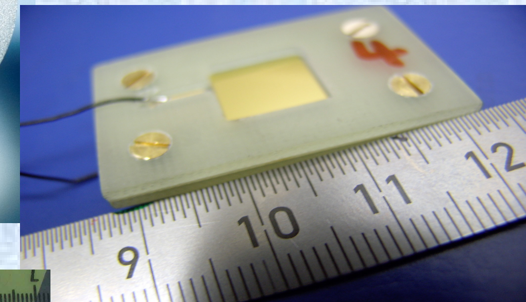
Sensor R&D BeamCal

pCVD diamonds:

- radiation hardness under investigation (e.g. LHC beam monitors, pixel detectors)
- advantageous properties like: high mobility, low $\varepsilon_R = 5.7$, thermal conductivity

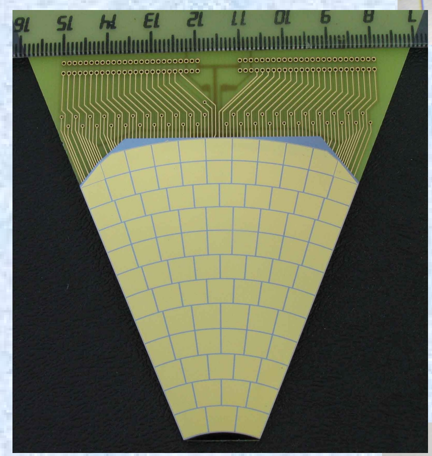


polycrystalline CVD diamond



GaAs:

- semi-insulating GaAs, doped with Sn and compensated by Cr
- produced by the Siberian Institute of Technology

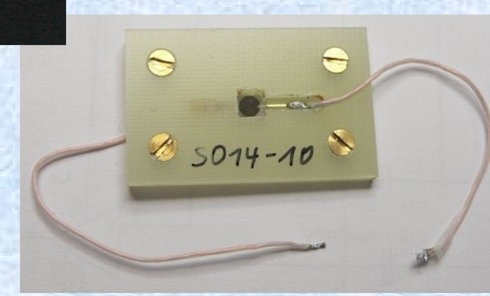


GaAs

SC CVD diamonds:

- available in sizes of mm^2

Sapphire, Quartz – first studies in the lab and at the beam (Dec 2008)

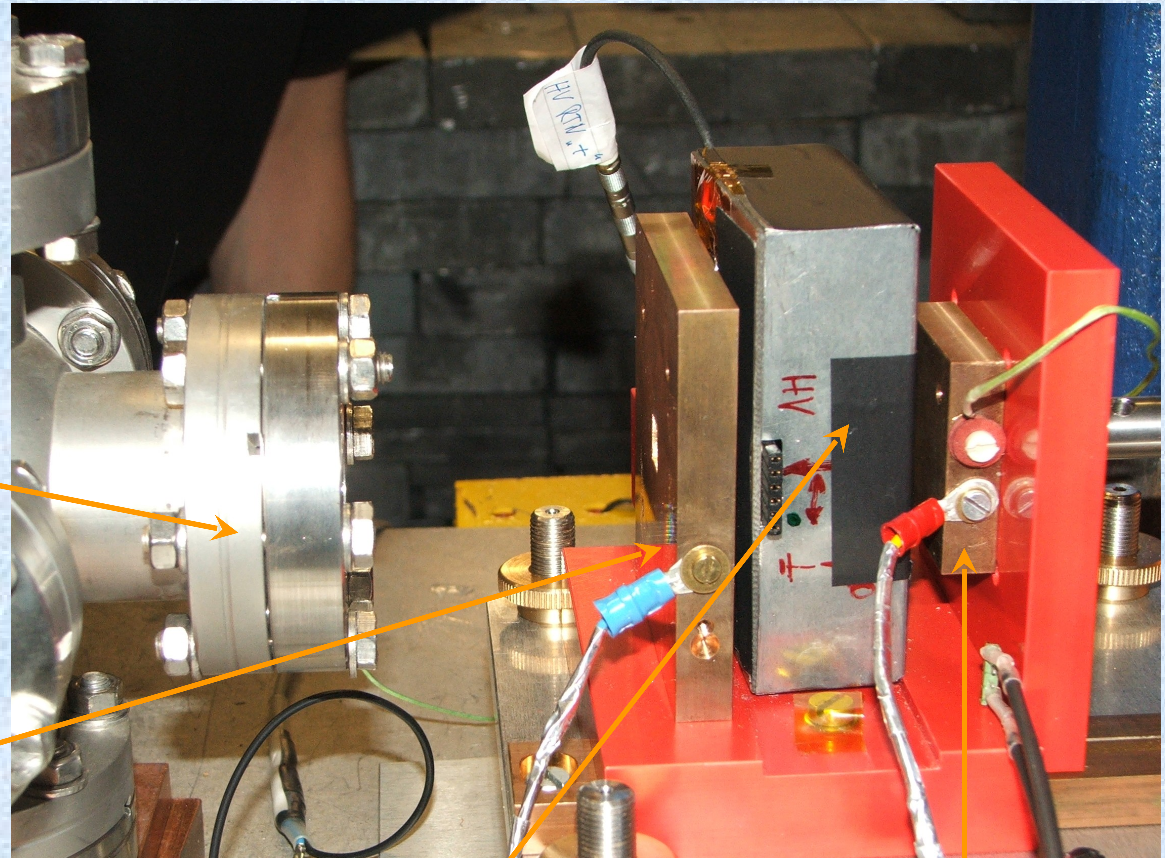


Single crystal CVD diamond

Test Beam Equipment and sensor tests

Setup used for radiation hardness tests at the SDALINAC accelerator

TU Darmstadt



exit window of beam line

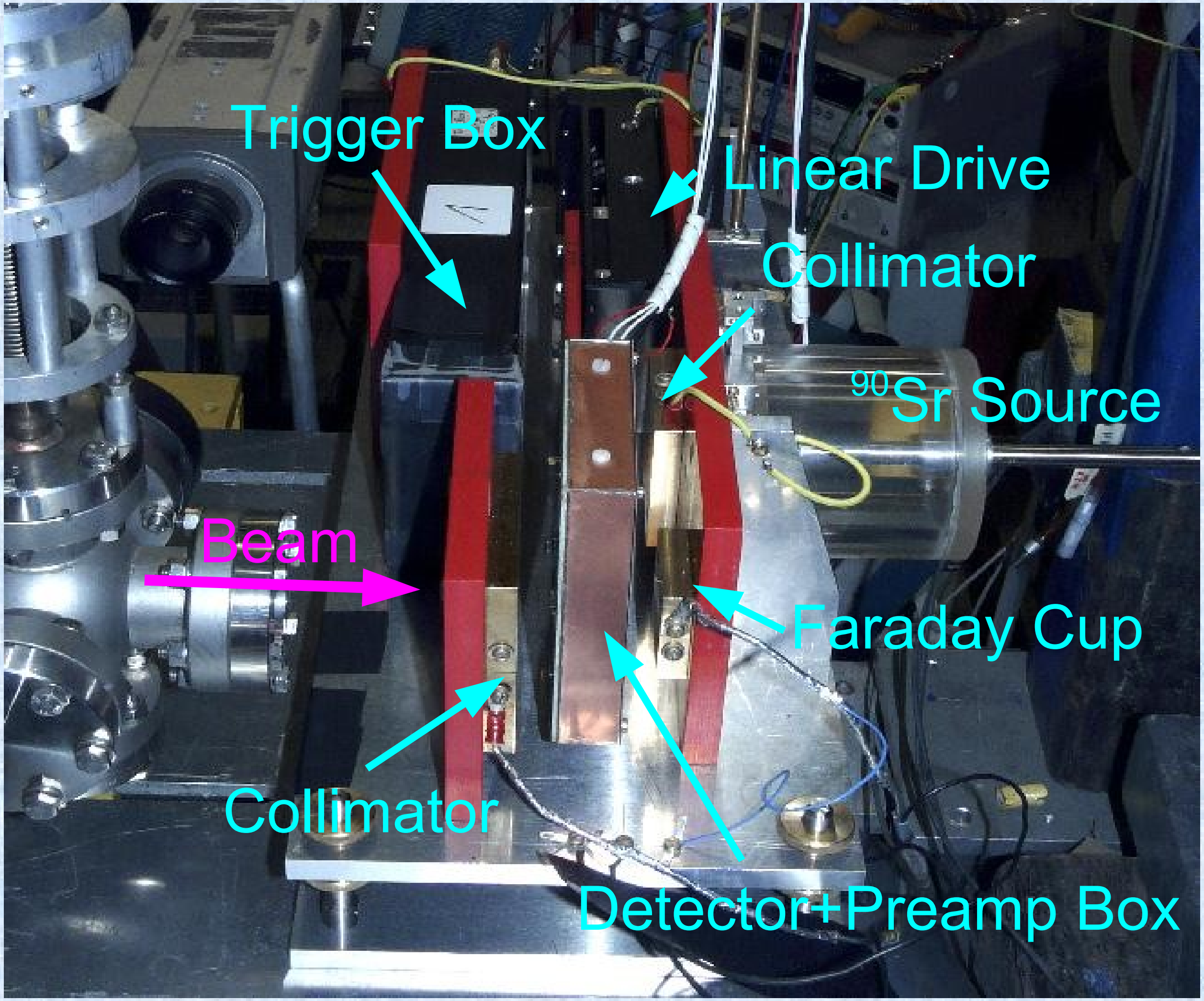
collimator (I_{Coll})

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

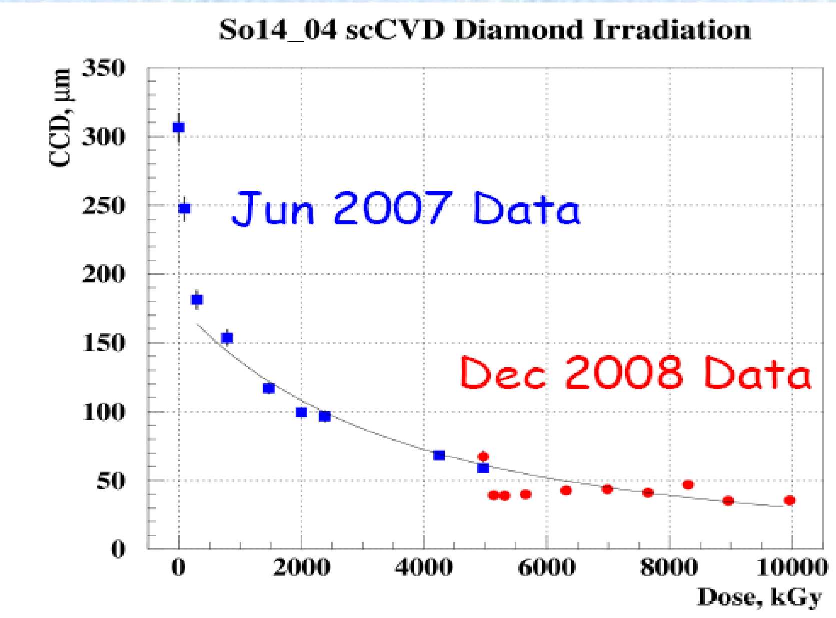
Faraday cup (I_{FC}, T_{FC})

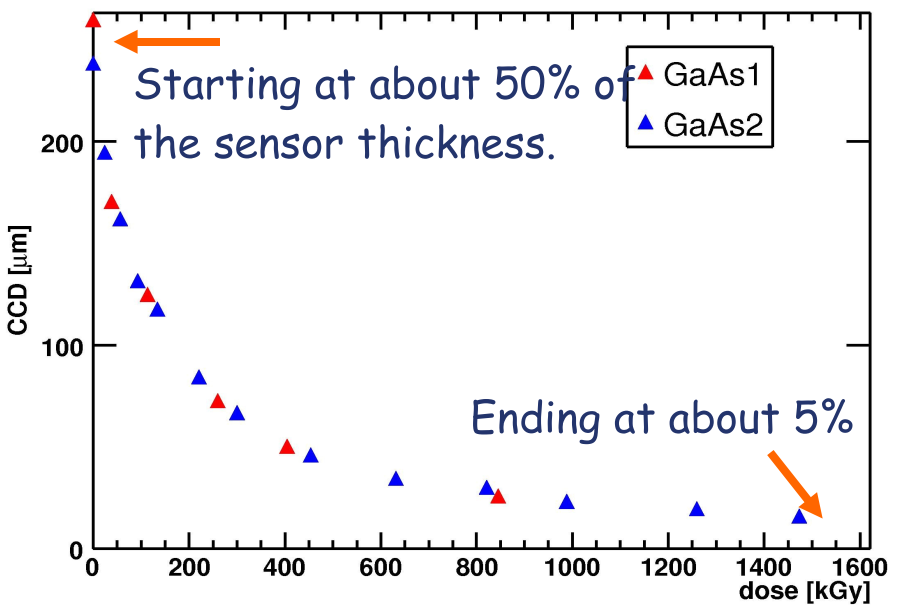
Completed and more comfortable: more efficient use of the beam

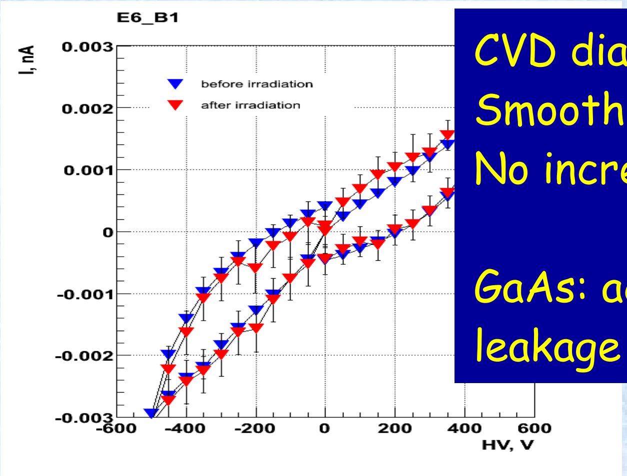
Beam Pumping Tests



Sensor irradiation tests

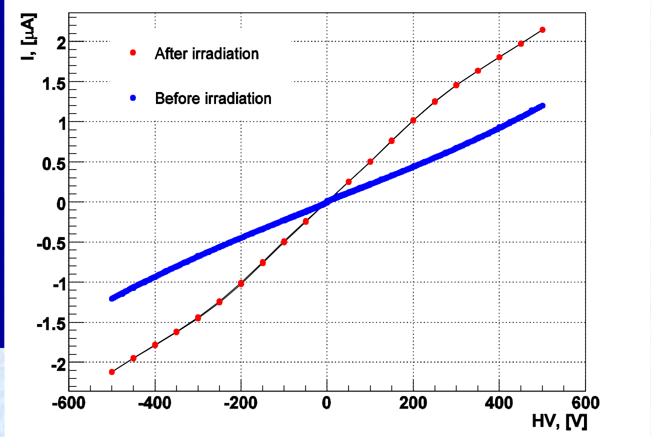




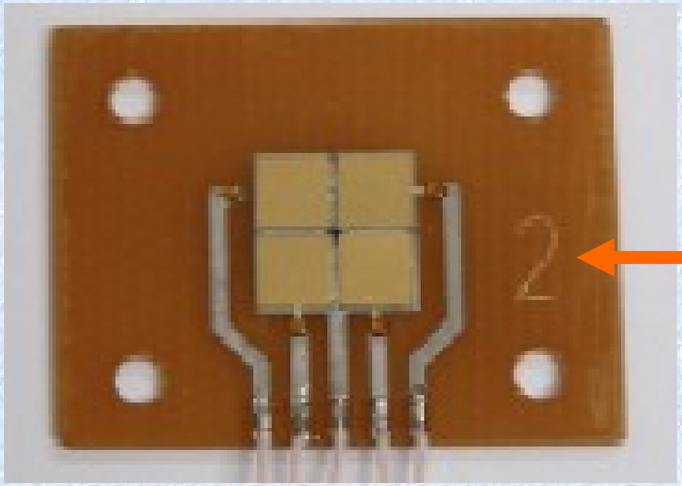


CVD diamond sensors:
Smooth degradation
No increase of leakage current.

GaAs: acceptable increase of the leakage current



Sensor tests



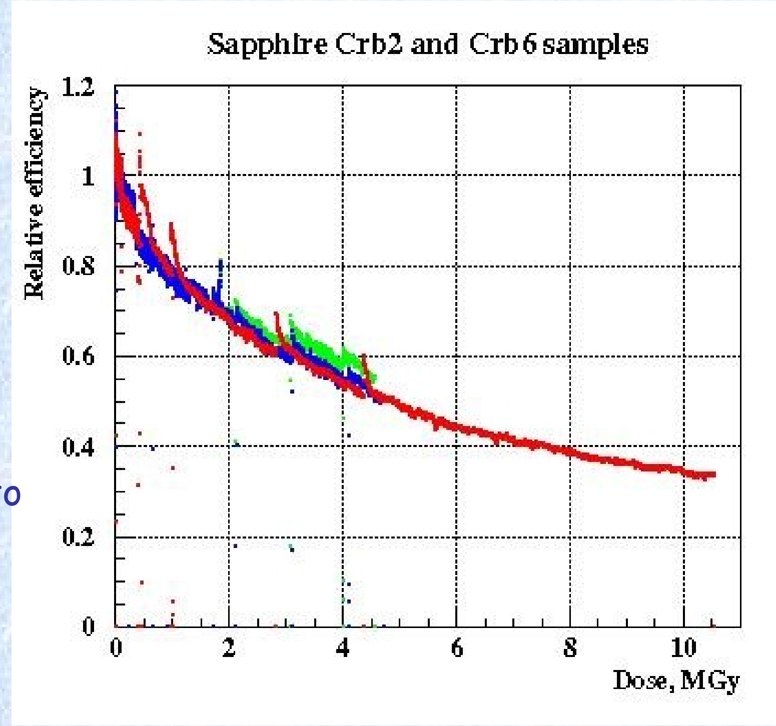
A new batch of GaAs sensors with Cr concentrations between 10^{16} and 10^{18} was recently delivered, testbeam measurements completed

Sensors made of single crystal sapphire

CCE is a few %

At a dose of ~ 12 MGy the signal current dropped to 30 % of its initial value!

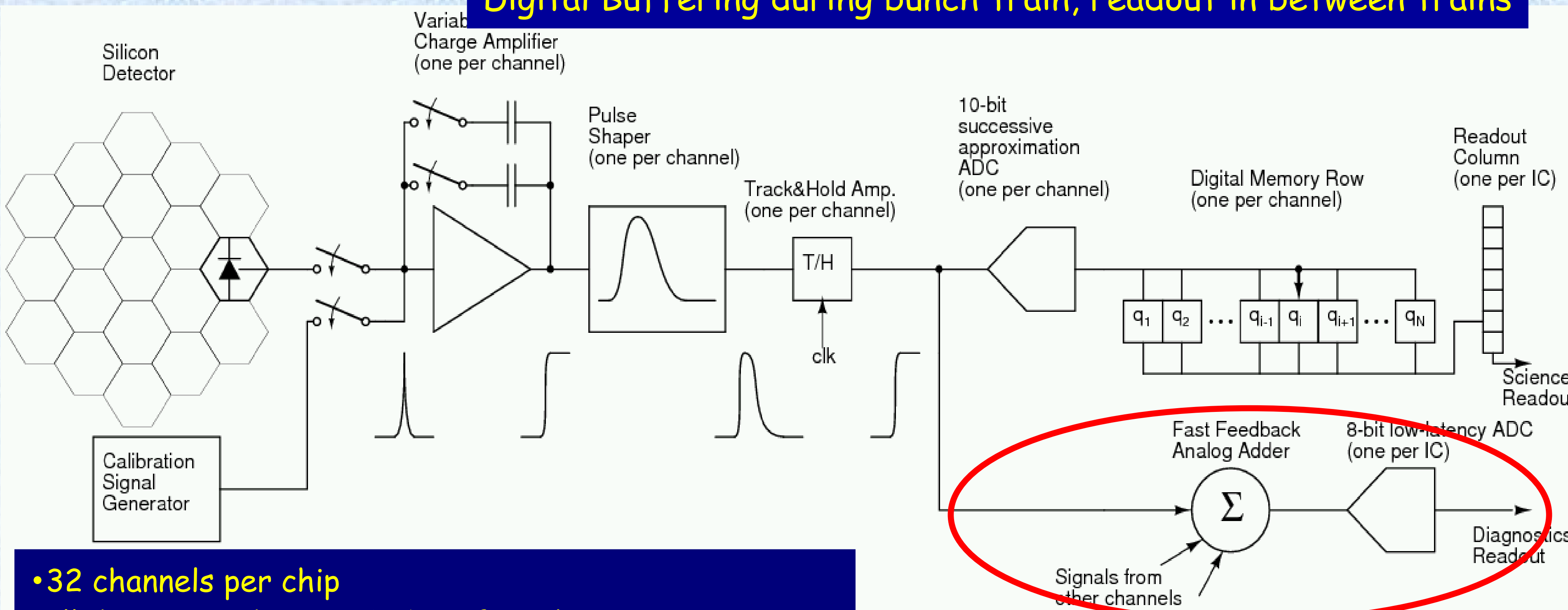
12 MGy ~ 10^{17} e^-/cm^2



FE electronics, BeamCal

Dedicated FE electronics for BeamCal, based on KPiX

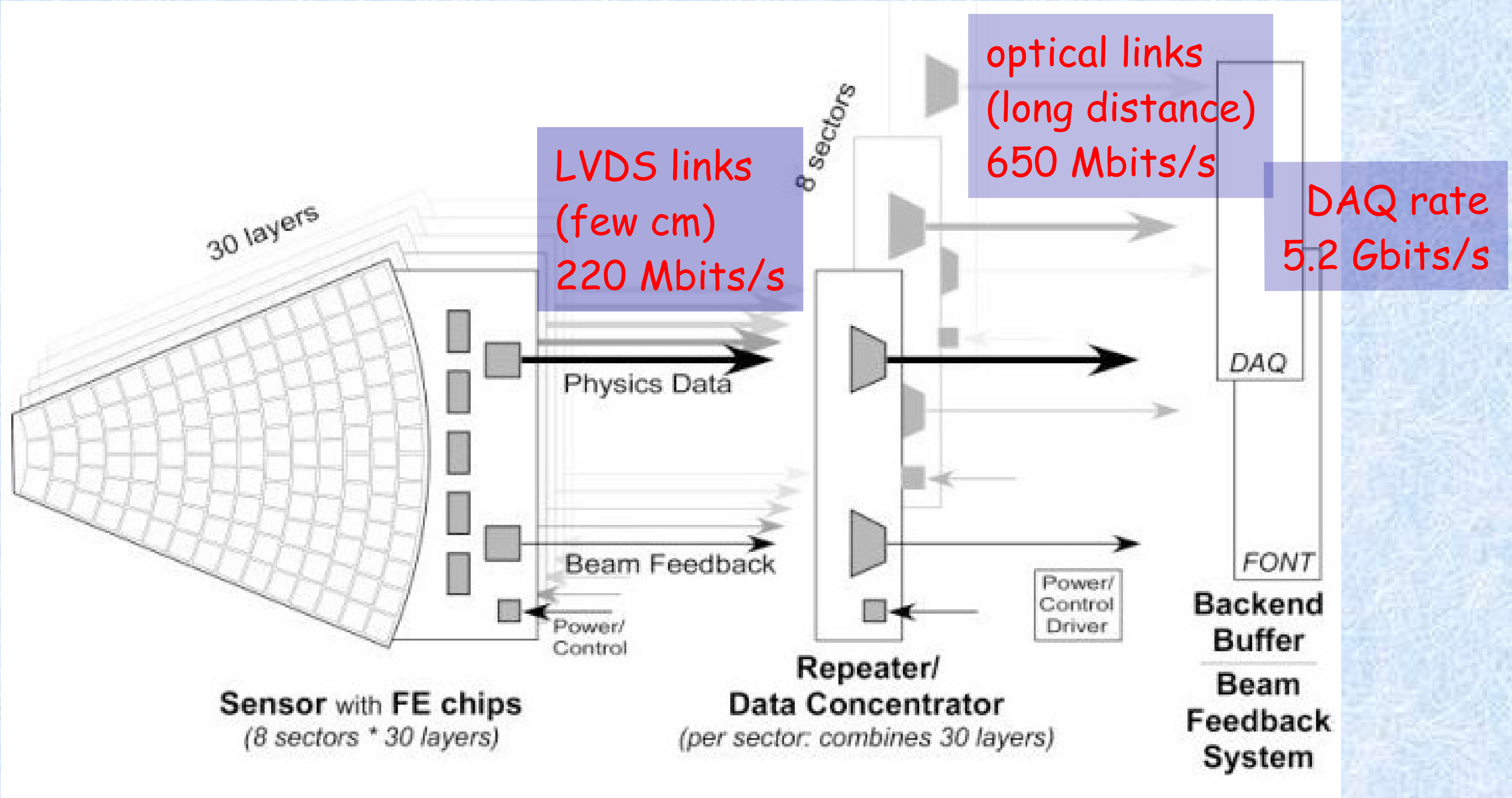
Digital Buffering during bunch train, readout in between trains



- 32 channels per chip
- all data is read out at 10 bits for physics 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

Fast analog adder for groups of pads used for fast feedback

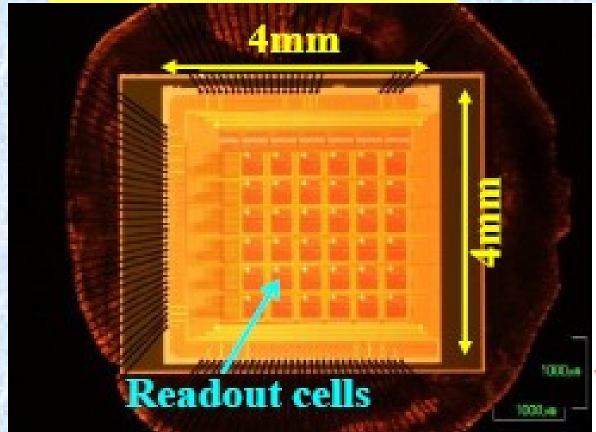
BeamCal Data Transfer

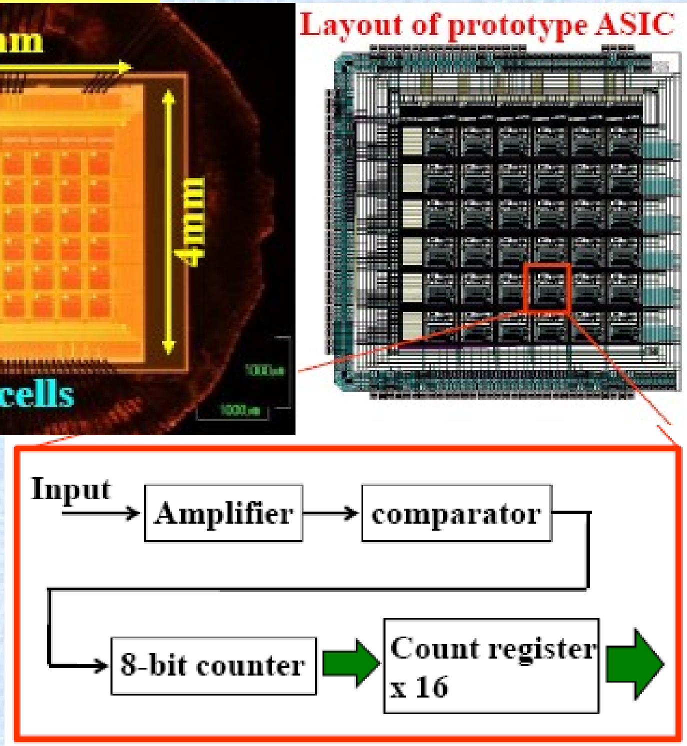


First step: concept based commercial components
Second step: dedicated prototype for a system test

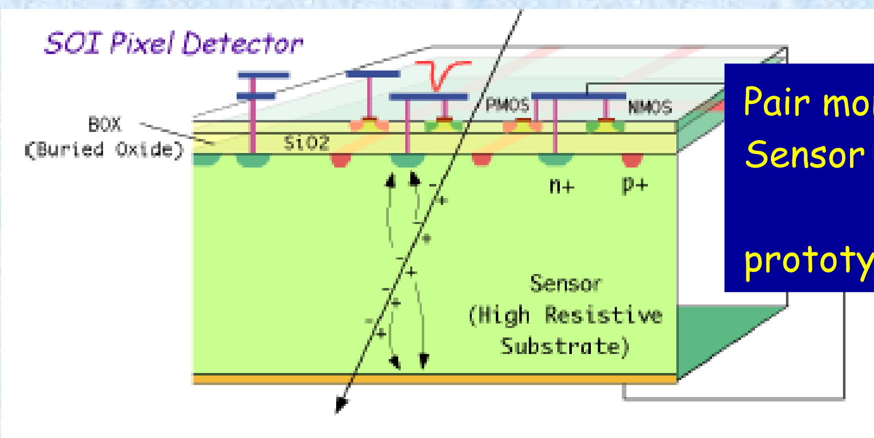
Pair Monitor

ASIC for the pair monitor
.25 mm TSMC technology
# of pixel: 36
Pixel size: 400 x 400 mm2
Bump bonding to a sensor





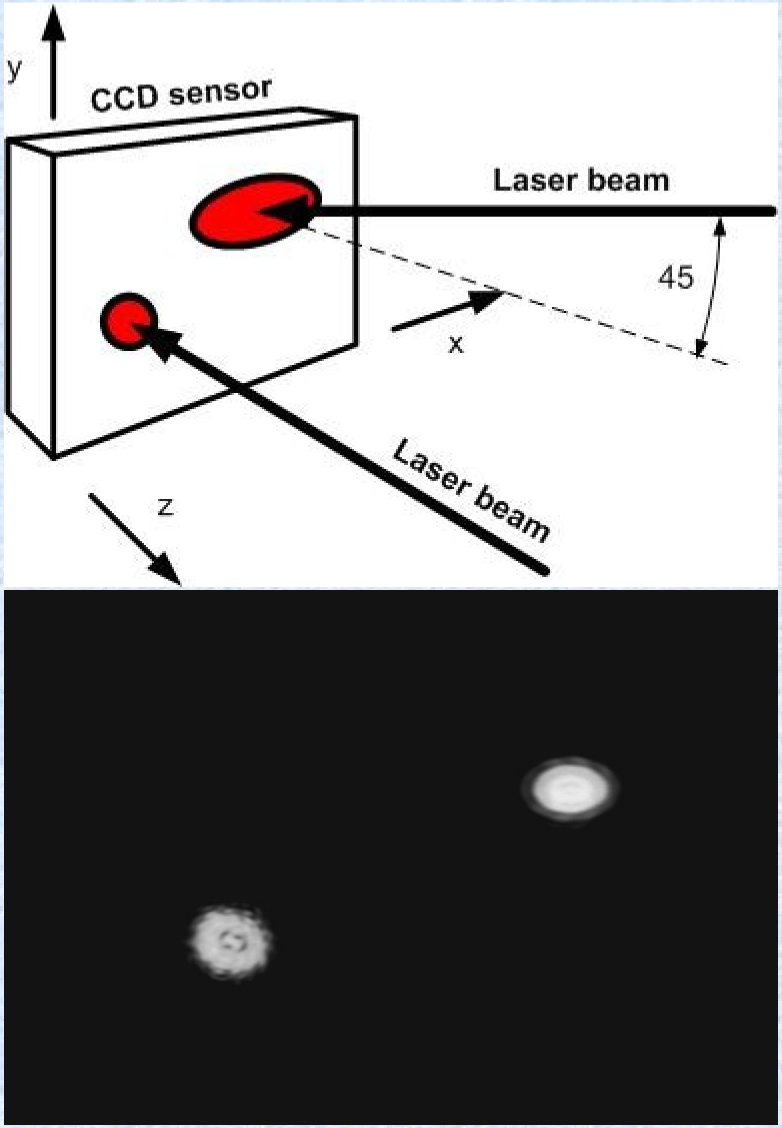
Prototype produced and successfully tested

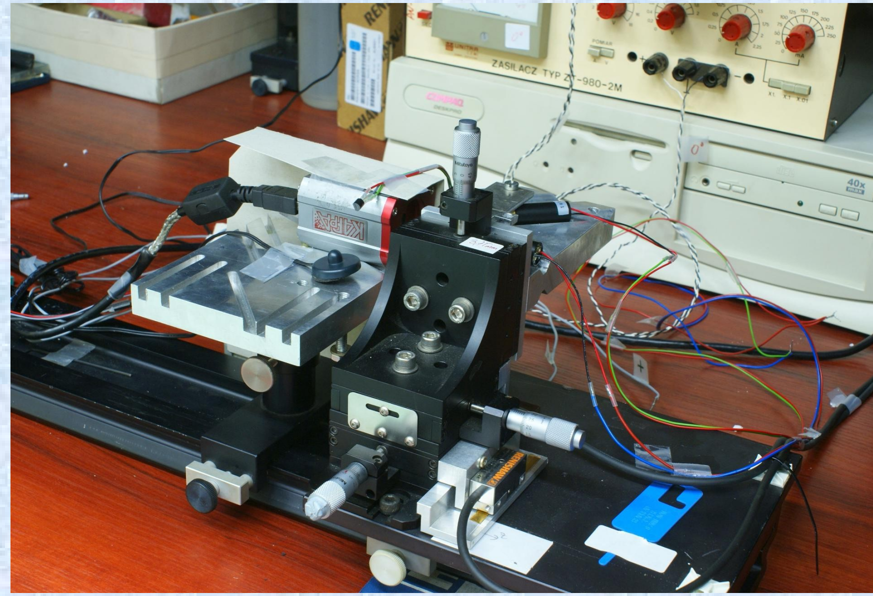


Pair monitor will use SoI technology,
Sensor and readout ASIC embeddd in the same wafer;

prototype 2009

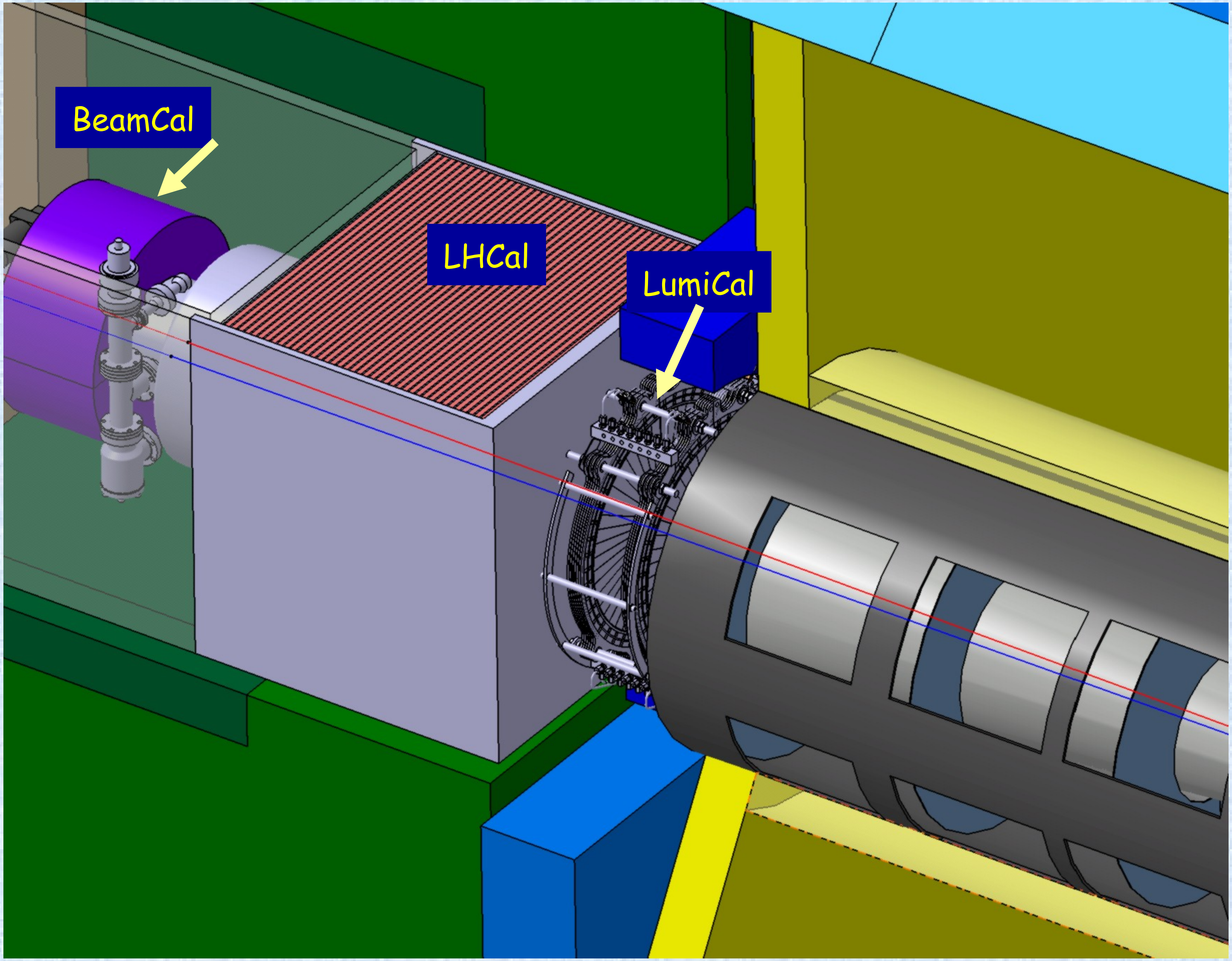
LumiCal Laser Position Monitoring





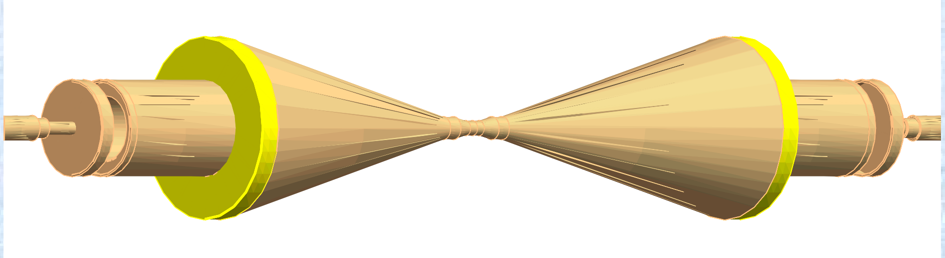
Over short distances accuracies reached:
Displacements in the x-y plane: +-0.5 μm
Displacements in z direction: +- 1.5 μm

ILD Integration



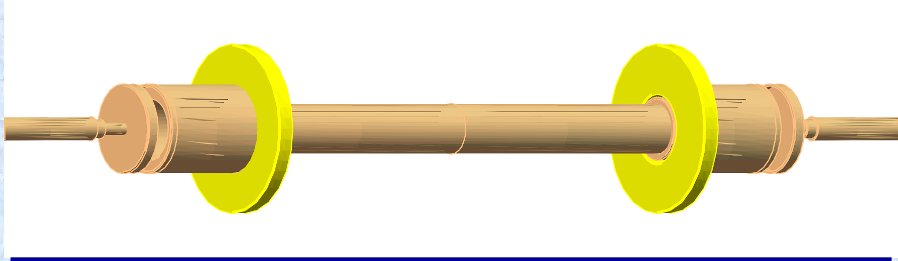
Beampipe Design

Conical, central part Be



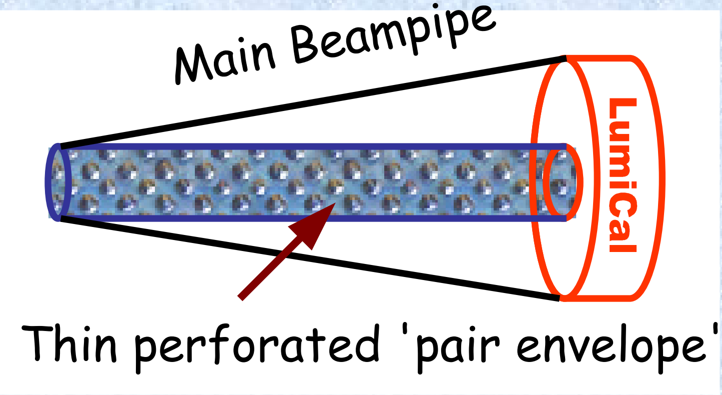
Pro: minimum material in front of LumiCal
Contra: vacuum, HOM, mechanics

Cylindrical, full Be, inner radius 5.5 cm (14 mrad crossing angle)

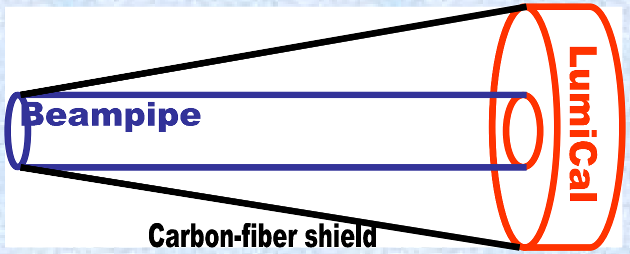


Pro: facilitates mechanics, vacuum
Contra: material in front of LumiCal, pre-showering, electron measurement?

Possible solution of vacuum and HOM problems:



Difference in the Bhabha count rate: $(1 \pm 2) \times 10^{-4}$; uncritical !
However: don't use the 'free space' for other purposes!



Possible solution

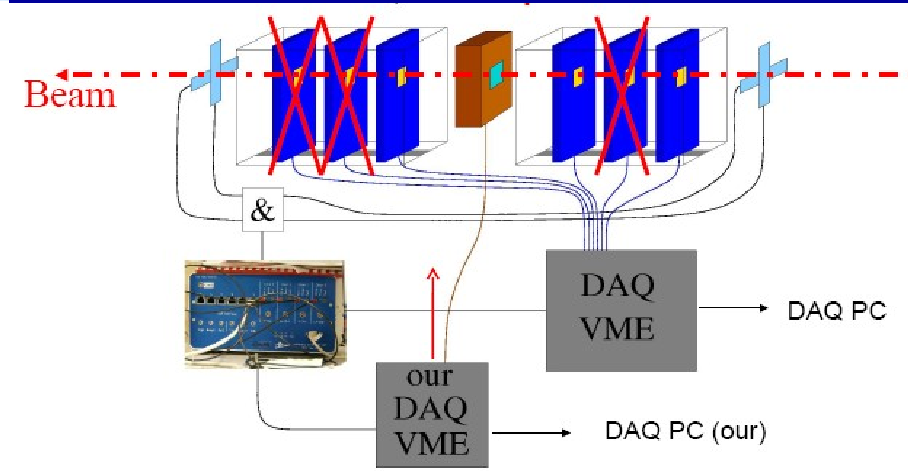
Conclusions

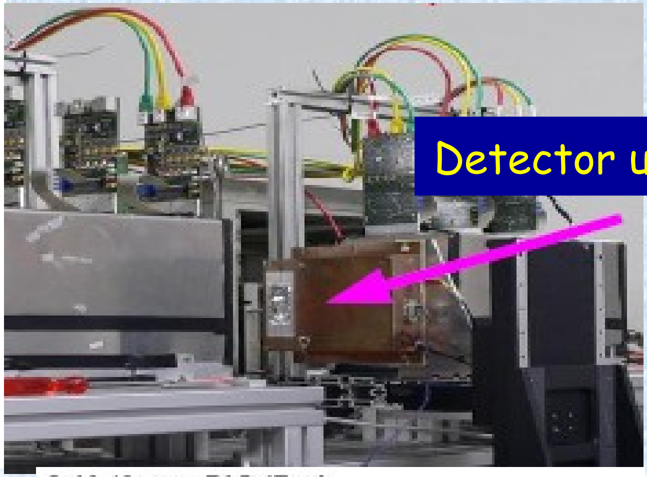
Priority topics within FCAL:

- Large area radiation hard sensors for calorimetry (BeamCal)
- Precise position measurement of electromagnetic showers (Sensors for LumiCal, position monitoring)
- ASICS with high readout speed, large dynamic range, large buffering depth and low power dissipation, allowing fast feedback for luminosity optimization
- Prototyping and test of more complex subsystems to prepare compact sampling calorimeters

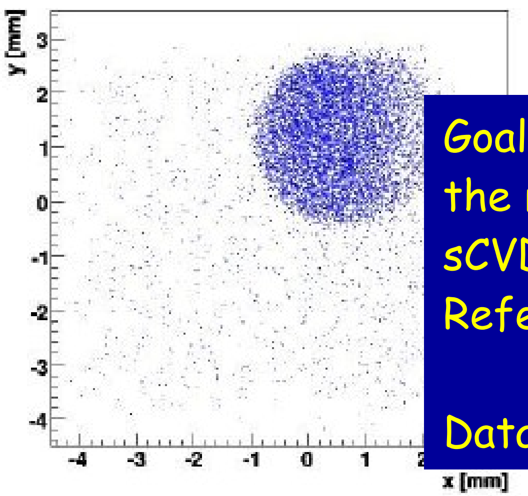
Sensor Tests

Testbeam equipment for sensor performance studies using the EUDET telescope





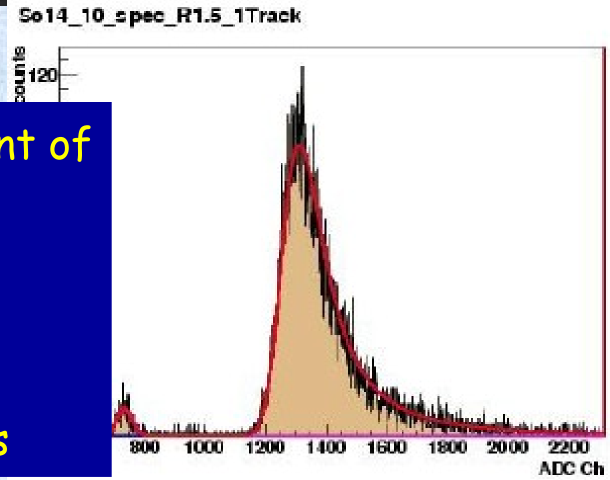
Detector under test



Reconstructed hits with detector signal

Goal: precise measuremnt of the reponse of sCVD diamonds; Reference sensor

Data analysis in progress



Sensor response with the track pointing to active detector area

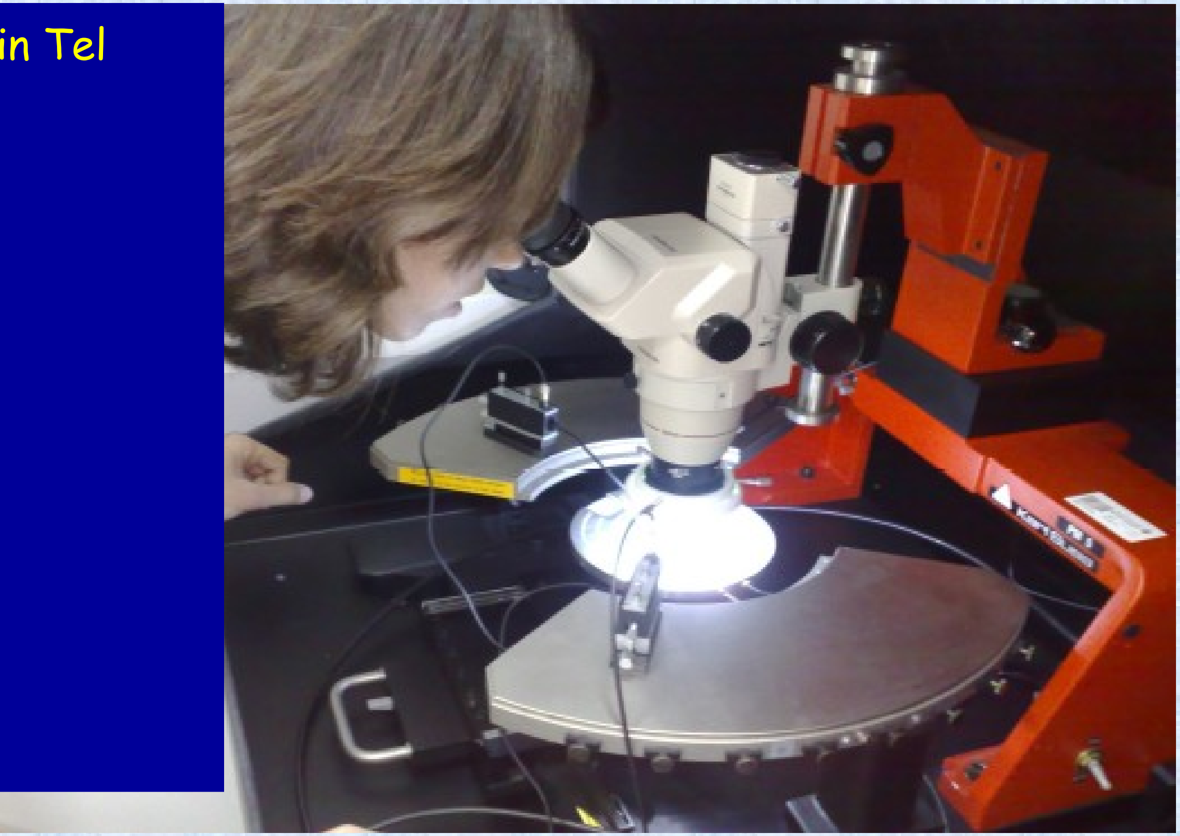
Infrastructure

A dedicated silicon lab is created in Tel Aviv:

- Computer monitored prob station
- Computer supported I(V), C(V) measurements

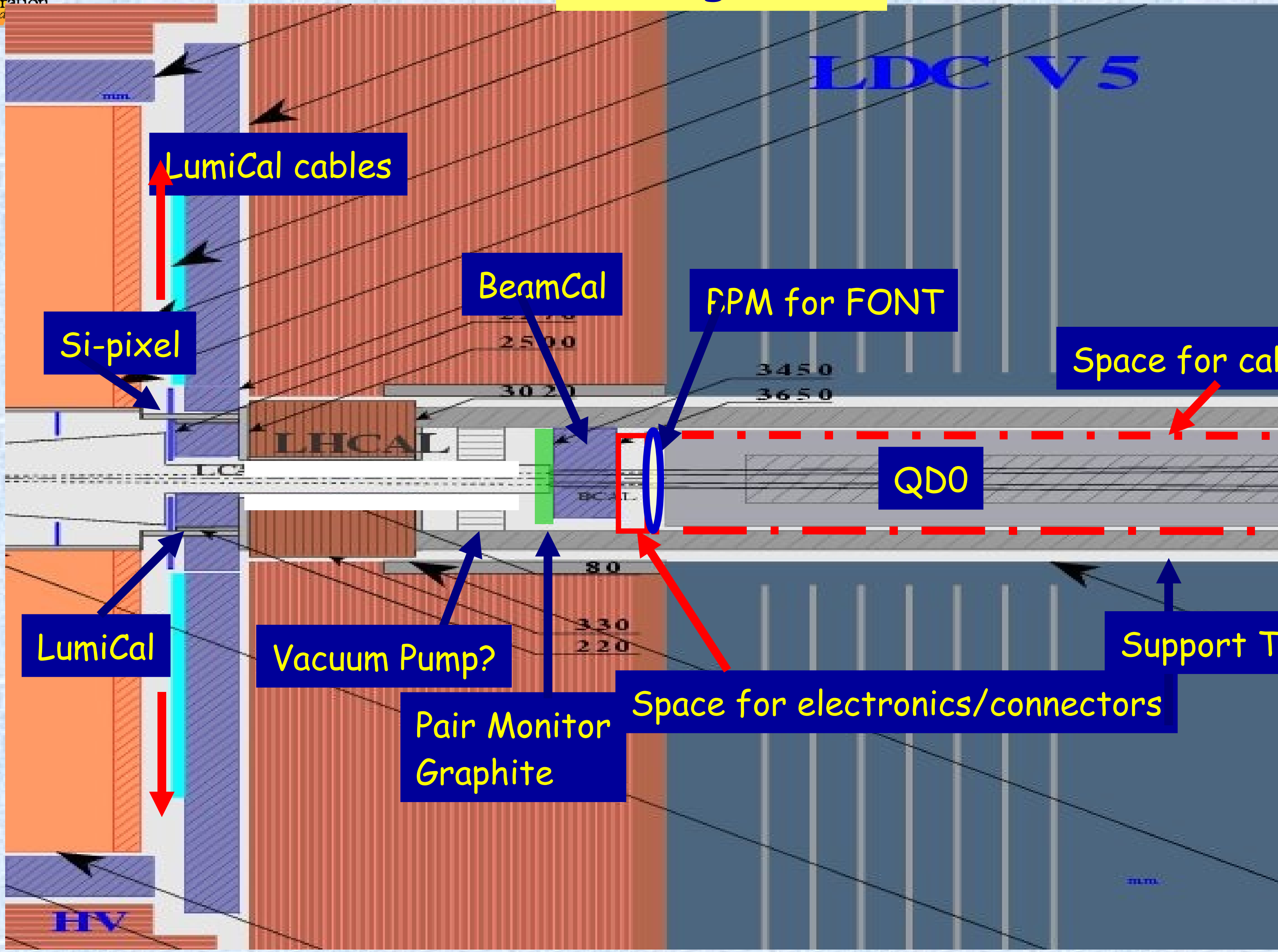
in preparation:

- clean room
- spectroscopic set-up



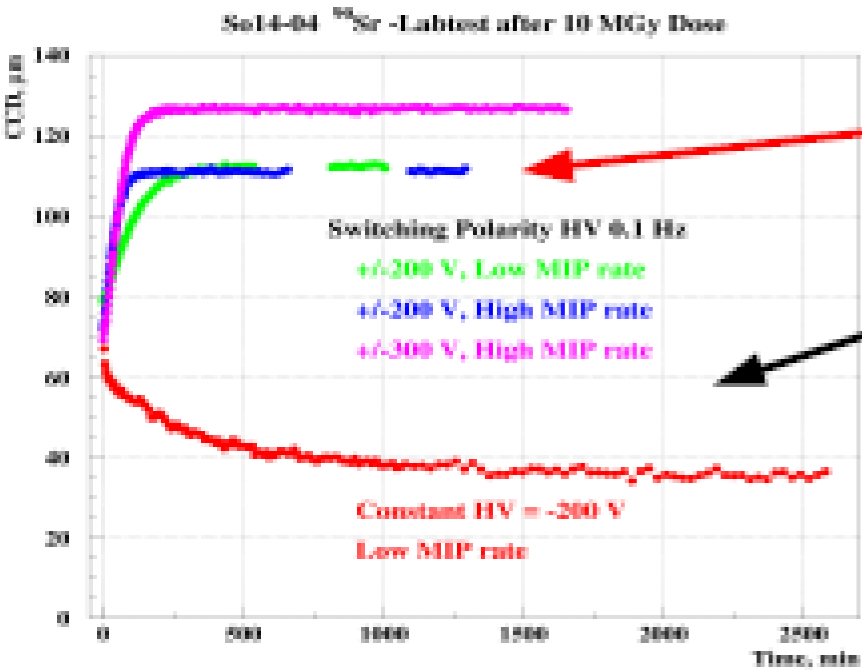
A dedicated HEP lab building is designed for detector R&D, planned to be ready mid 2009

Integration



Tests at Zeuthen 2009: CCD vs time

After 10 MGy



First 500 min data taking: