Sensor test facilities and recent testbeam ventures

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DESY/UNI-HH

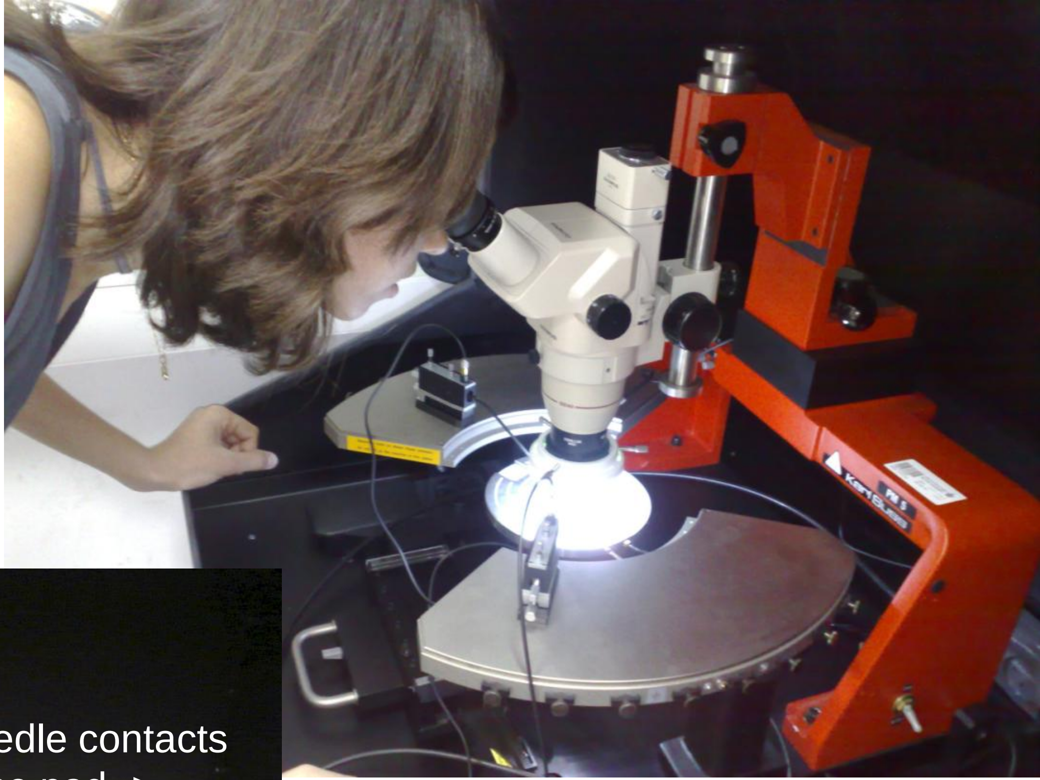
On behalf of the FCAL collaboration

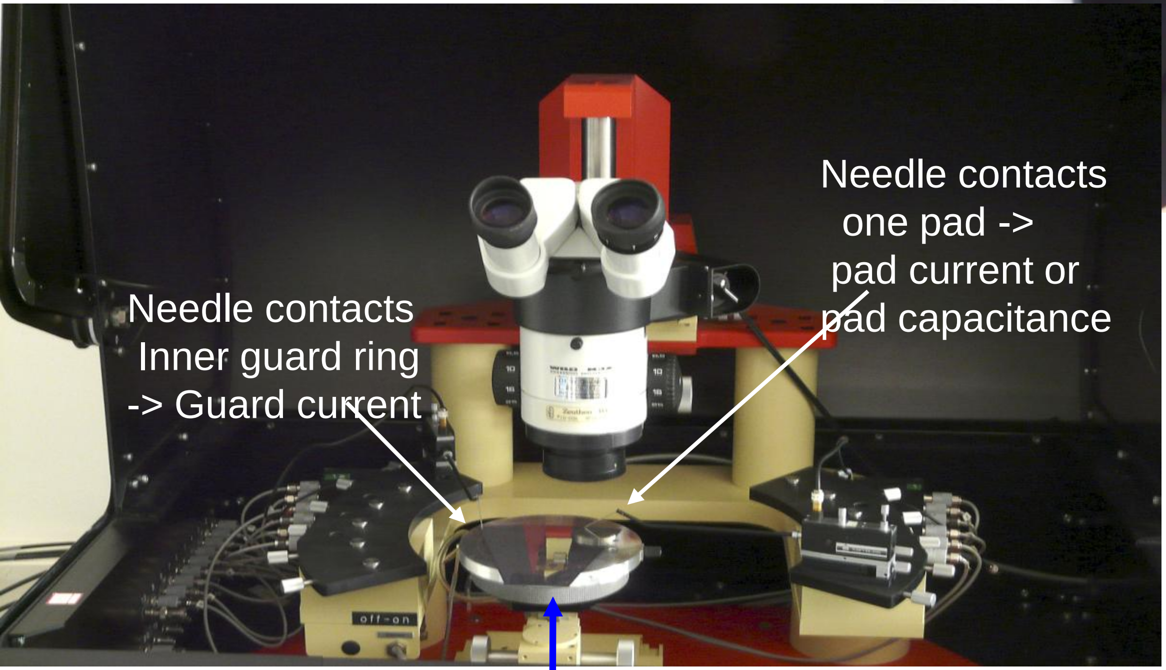
Outline

- Infrastructure:
  - Probe stations, electrical tests of LumiCal & BeamCal sensors
  - ^{90}Sr setup – sensor tests at the lab with electrons
  - high intensity beam measurements
- Sensors study @ ELBE (FZD Rossendorf)
- System test at DESY testbeam, Aug 2010
- Future: full system test at the beam (FP7)
- Conclusions

Infrastructure: Probe Stations

Tel-Aviv University



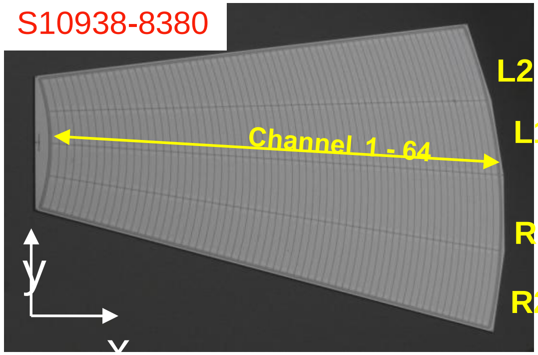


Backplane contacted via Al table ('+' of high voltage)

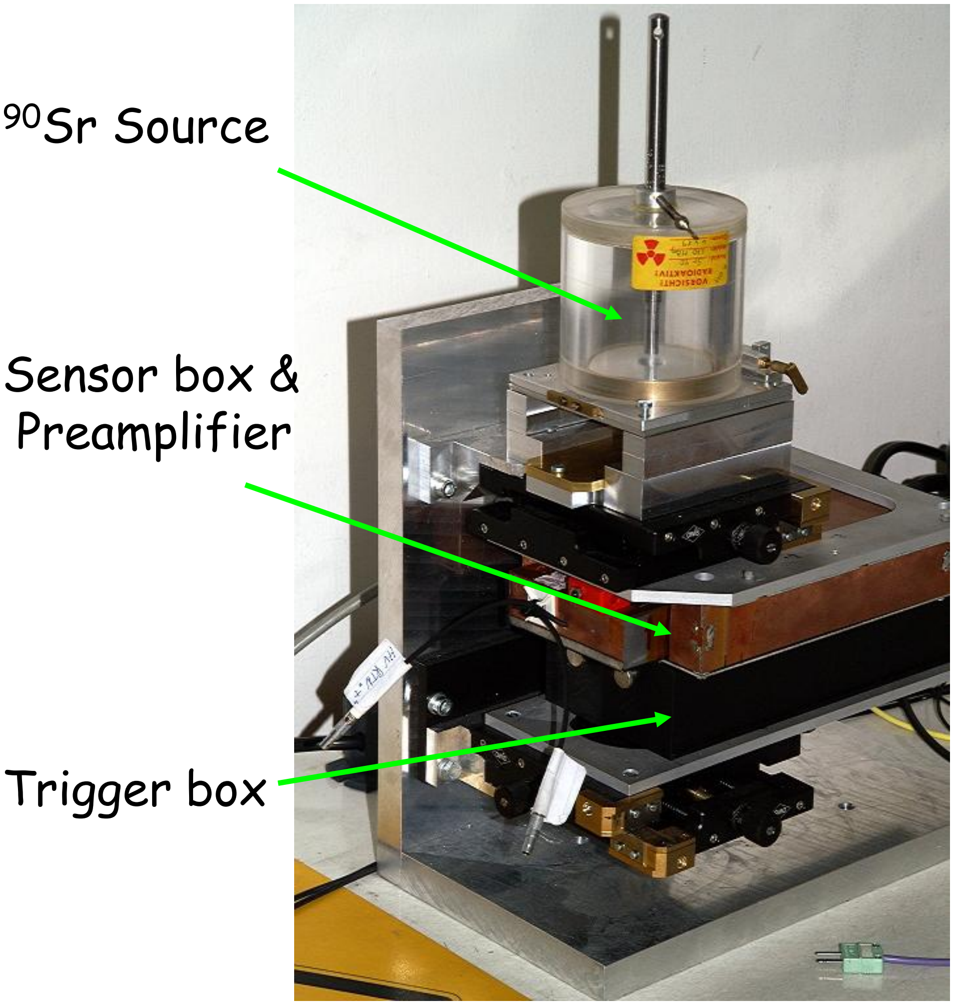
DESY - Zeuthen

LumiCal Sensor Tests

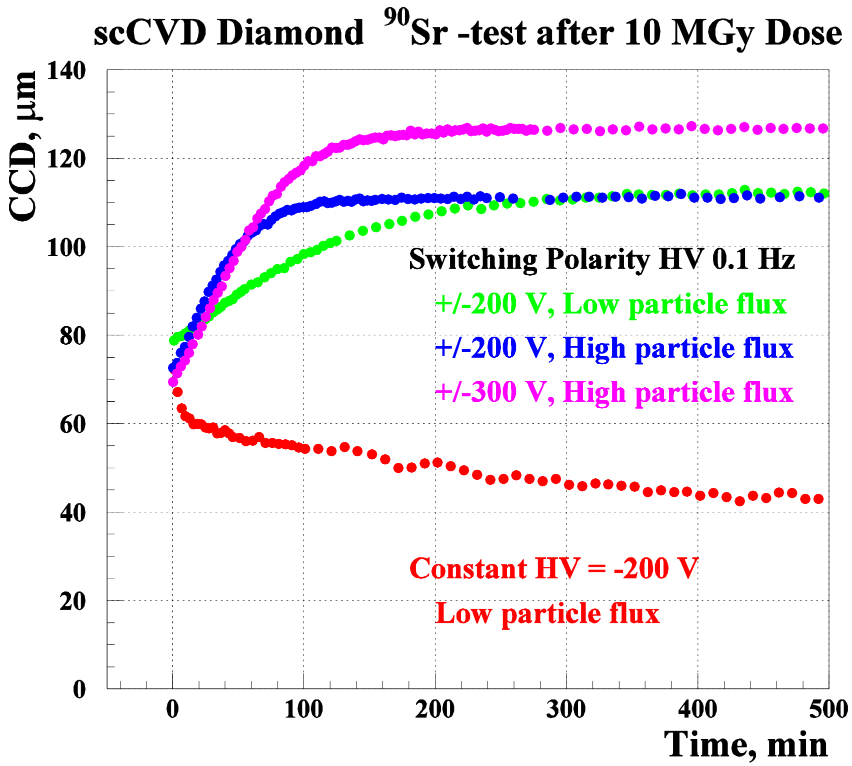
Hamamatsu
S10938-8380



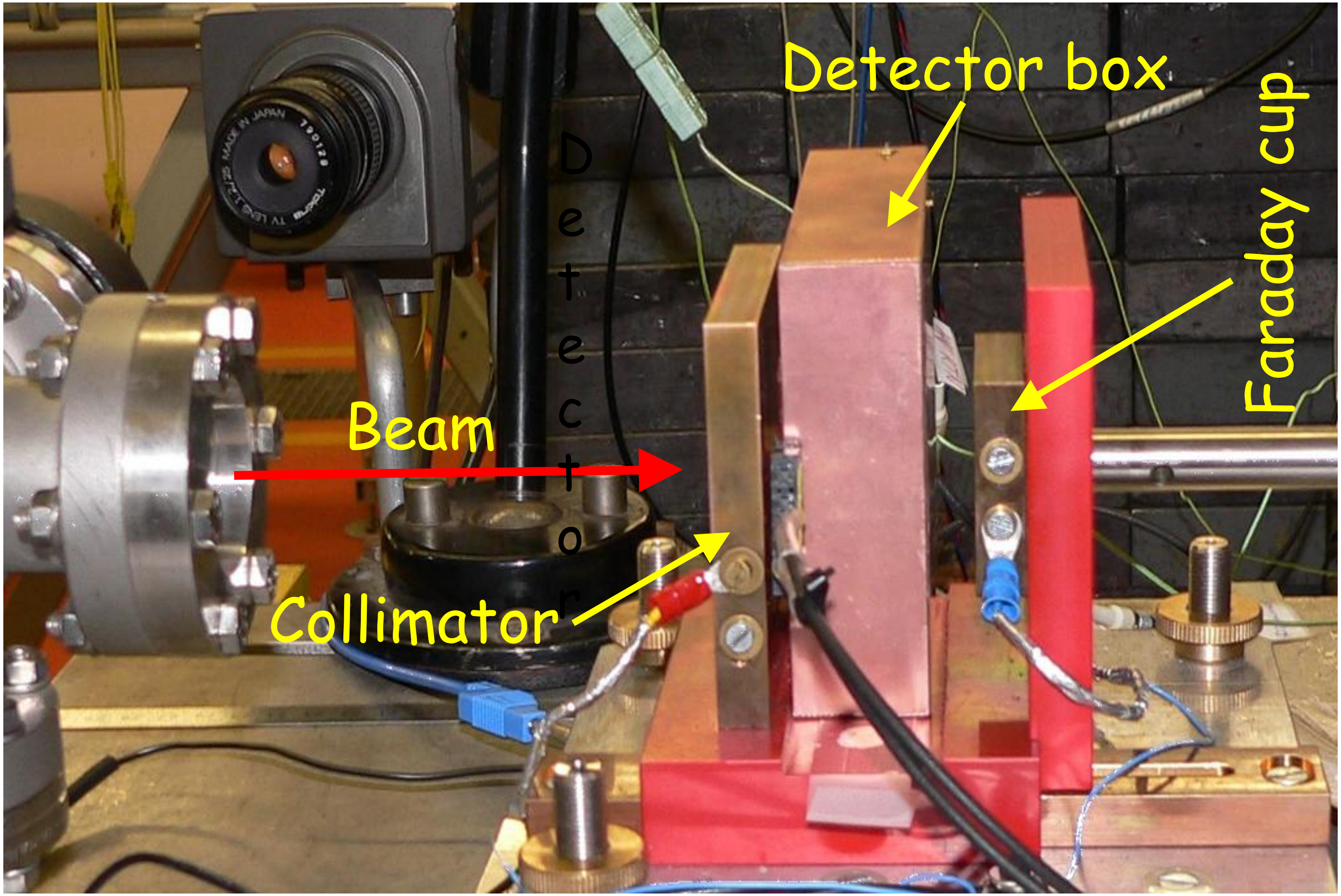
Infrastructure: BeamCal sensor tests in the lab



Detailed study of the rad. damaged sensors
Influence of various operation conditions



Infrastructure: High dose irradiation at the beam



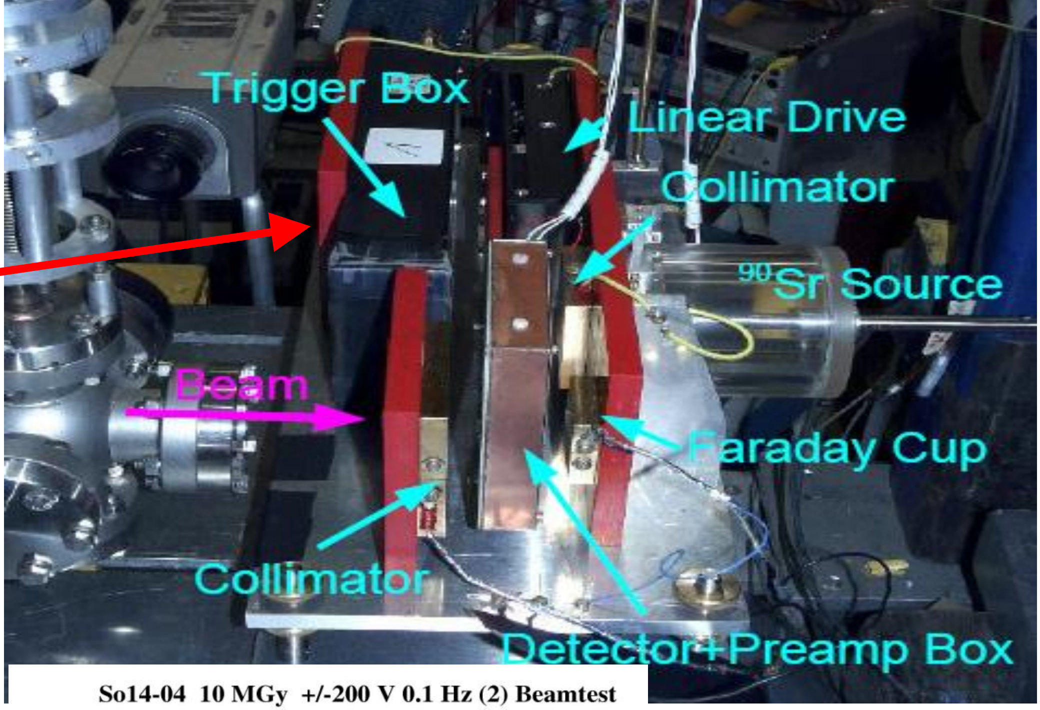
Infrastructure: BeamCal Sensors study at the beam

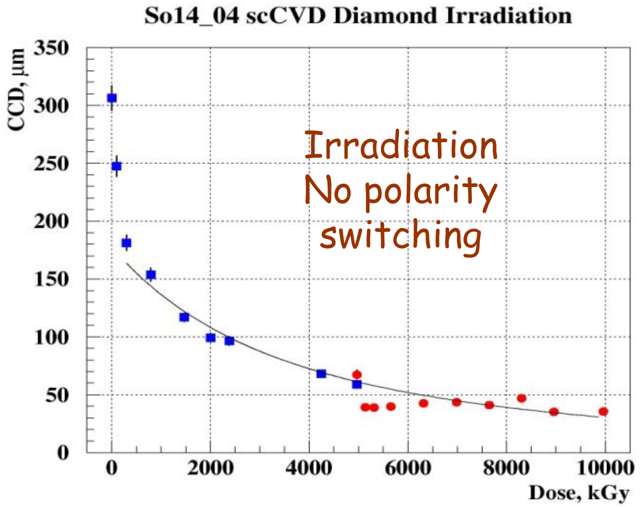
Setup for Beam Pumping Measurements

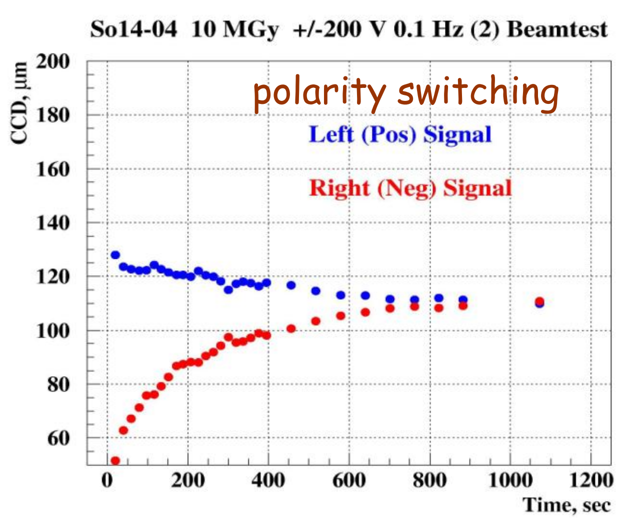
scCVD diamond (E6), 5x5x0.3 mm^3

Irradiated in 2007 up to 5 MGy

2008: up to 10 MGy







Infrastructure summary: EUDET-Report-2009-08 VFCAL task status report

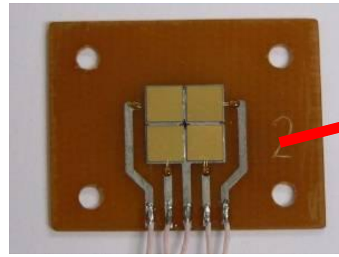
BeamCal Sensors example

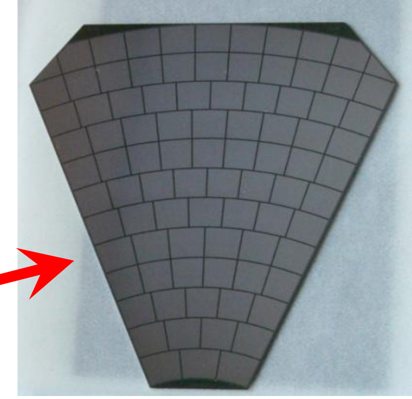
Baseline: GaAs

Up to 600 kGy a MIP signal from all sensors is clearly seen

Sensors with a lower concentration of shallow donor and Cr as deep acceptor show better radiation tolerance (up to 1 MGy)

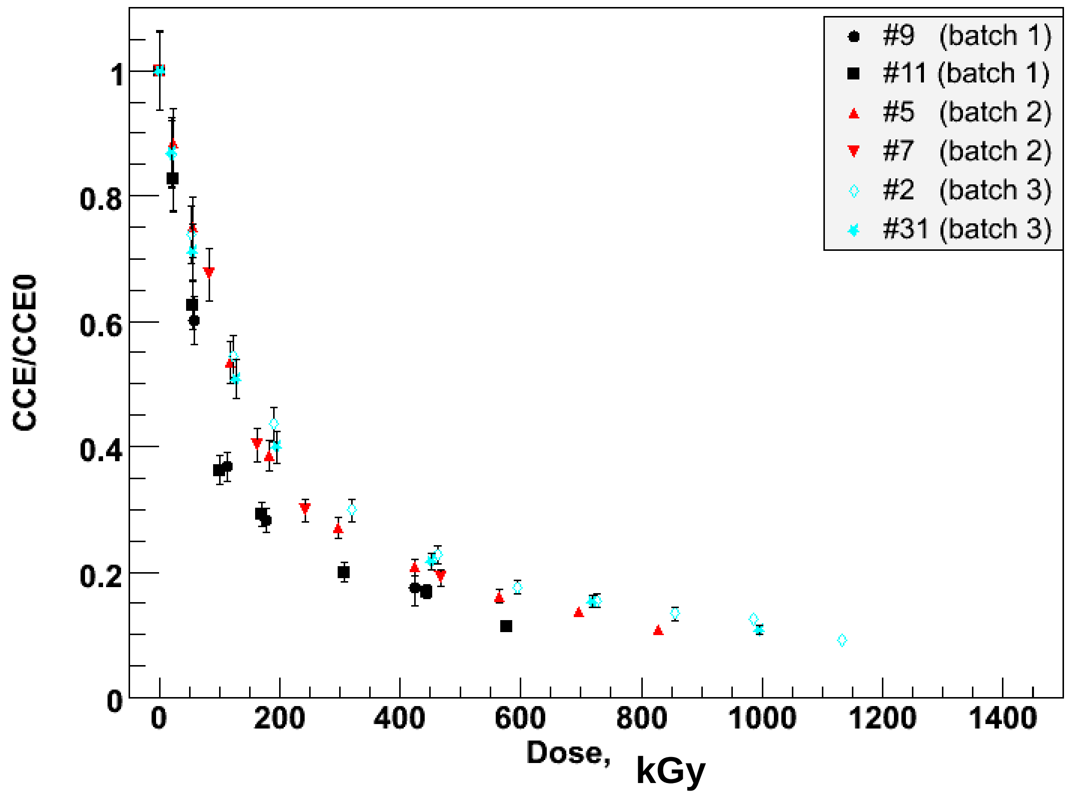
GaAs





BeamCal sector prototype

GaAs:Cr CCE vs dose



BeamCal Sensors, Sapphire

Band gap: 9.9 eV

(diamond: 5.5 eV, Si: 1.12 eV)

Single crystal, 1x1x0.05 cm^3

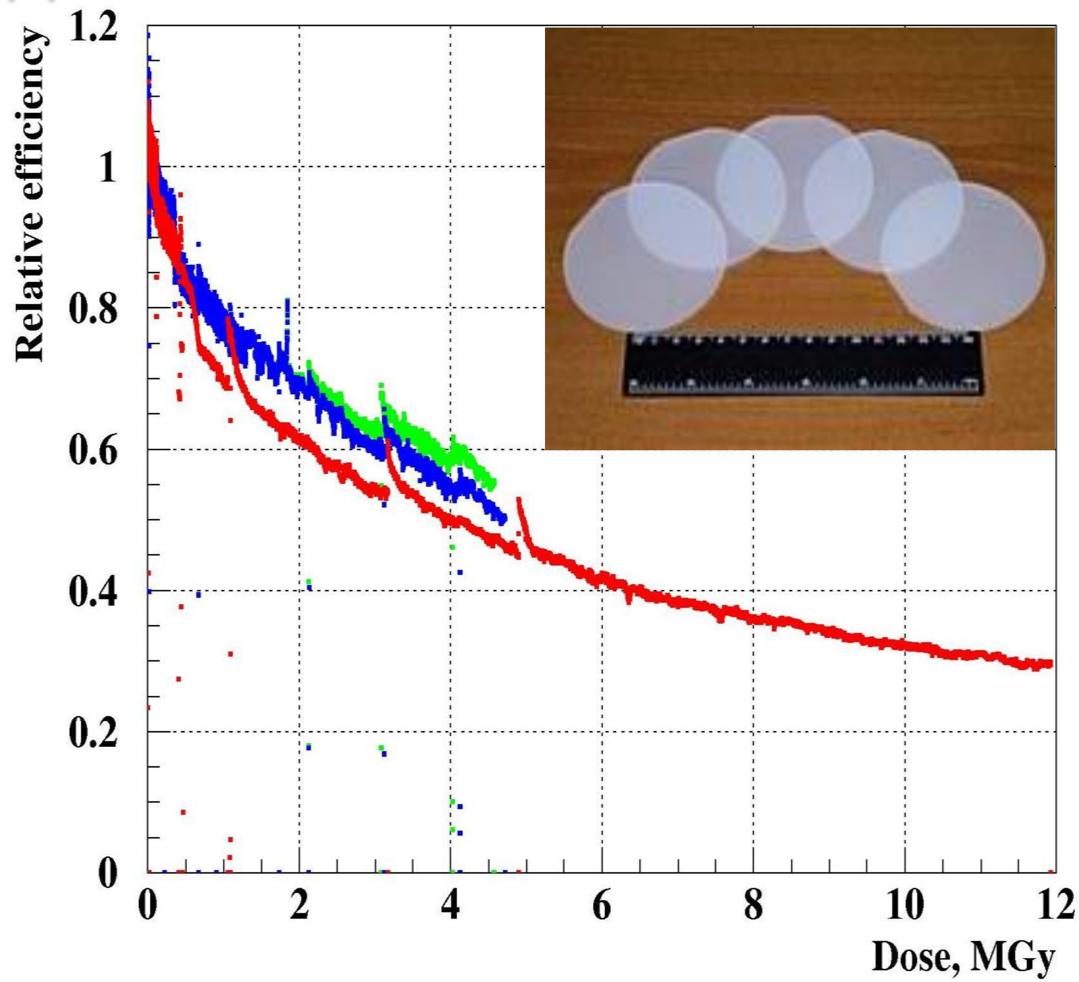
Wafer: up to 30 cm diameter

Metallization: Al 200 nm or

50/50/100 nm Al/Ti/Au

Normalized ratio of the detector and Faraday cup currents

Sapphire Crb2 and Crb6 samples



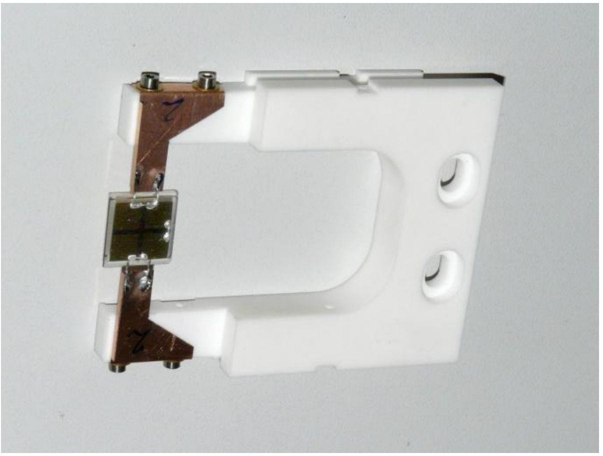
Charge collection efficiency: few % for nonirradiated samples

~ 30 % of the initial charge collection efficiency after 12 MGy

Test in PITZ

Electron beam, 14.5 MeV, bunches

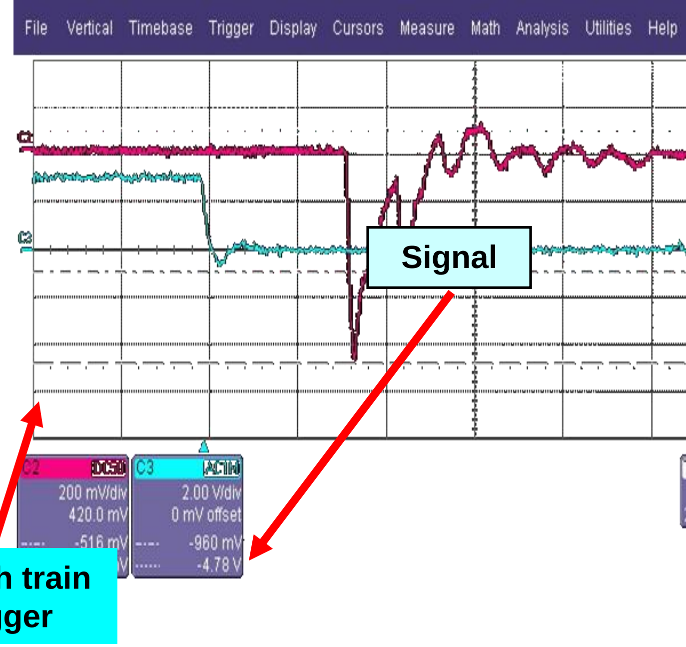
Diamond sensor was installed in the vacuum of the beam pipe

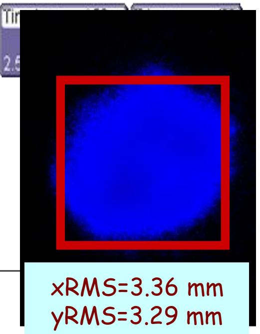


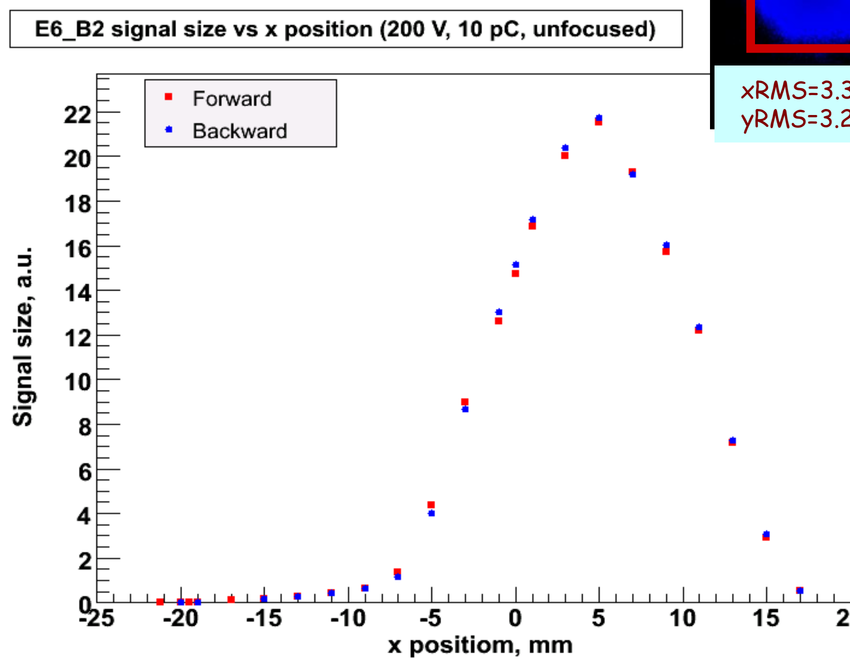
Moving the sensor through an electron beam,

Bunch charge 1 pC – 1 nC,
Beam spot: few mm^2
Beam profile

EMI doesn't disturb operation

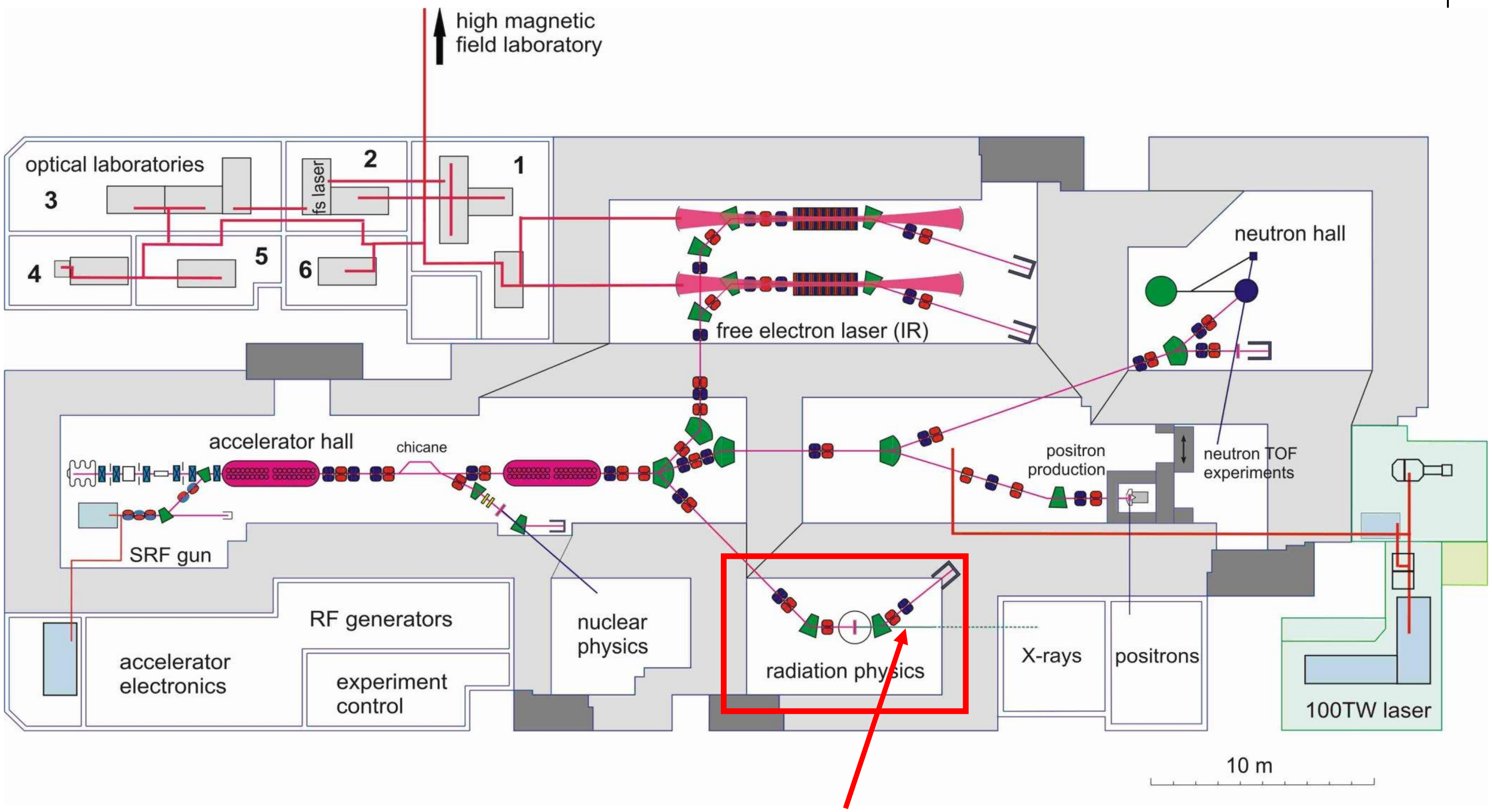






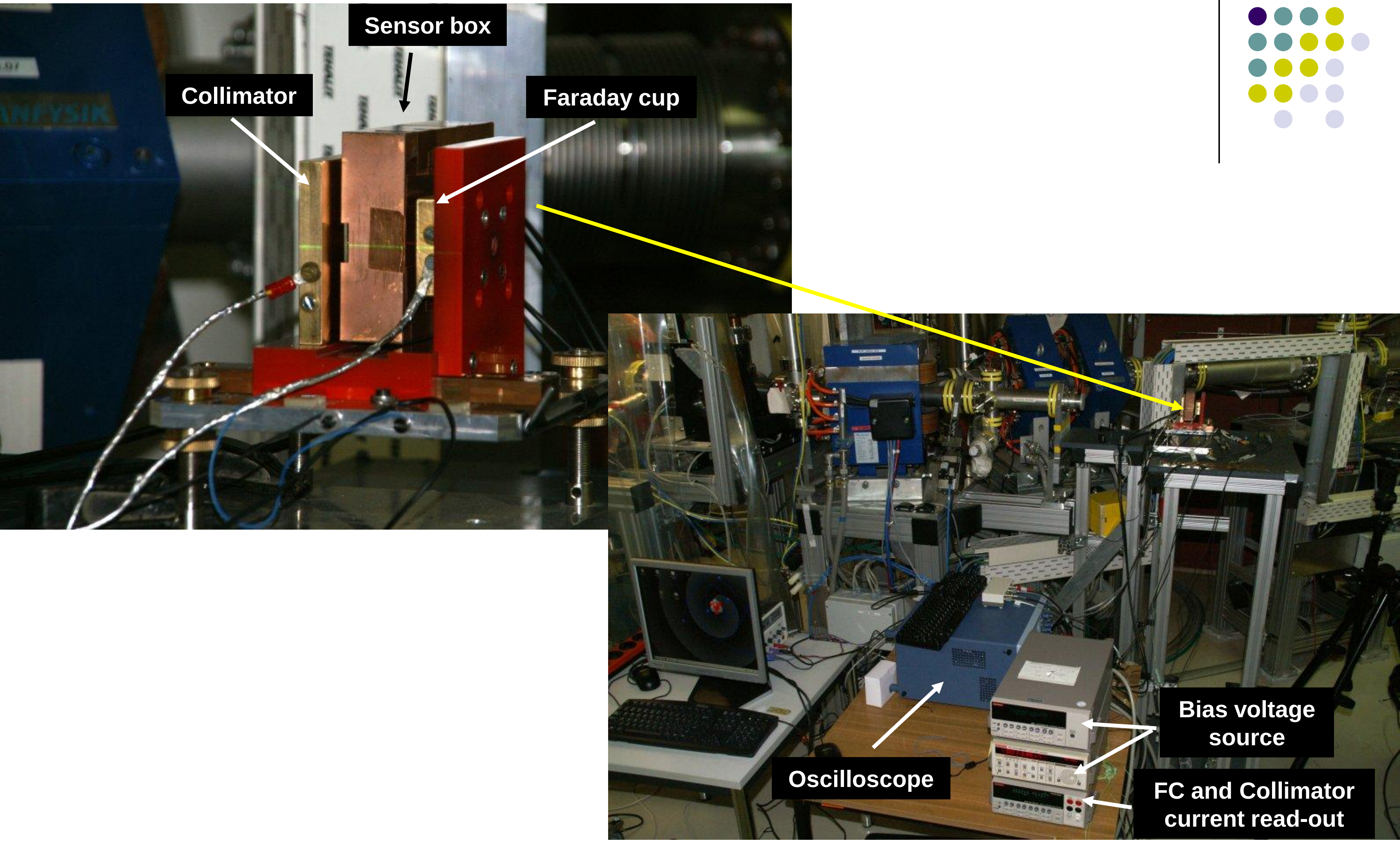
Testbeam February 2010, Dresden

ELBE facility (FZD Rossendorf)



20 MeV electron beam

Testbeam February 2010, Dresden



Goals

1. Observe signals directly (without amplifier & shaper) from different kinds of sensors under different conditions:

- scCVD diamonds of usual thickness (320 μm)
- thin scCVD diamond (100 μm)
- single crystal sapphires

- fresh sensors
- irradiated sensors

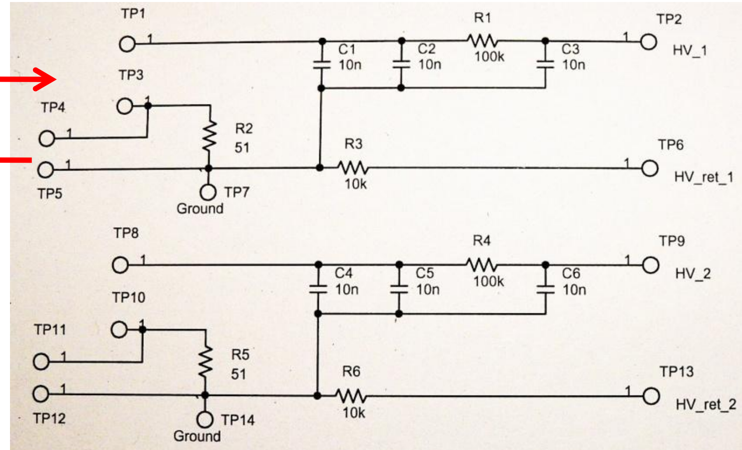
2. Estimate charge carrier mobility for sapphire

3. Irradiation hardness studies of a thin scCVD diamond

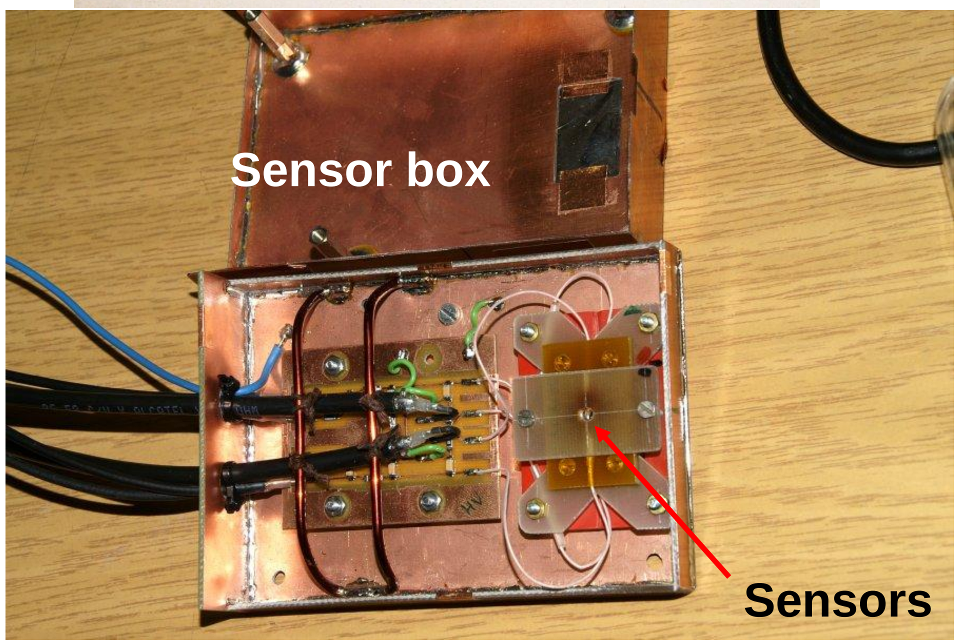
Sensor box

Sensor →

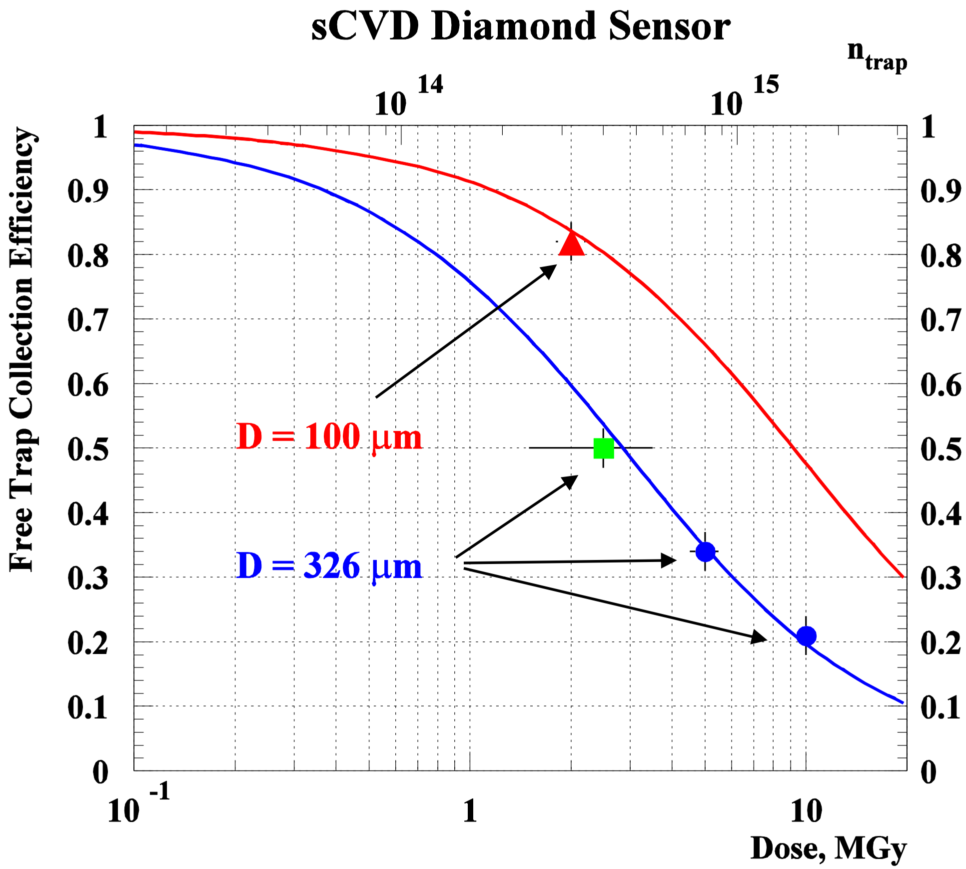
Signal ←



Bias voltage feed and signal read-out



Free trap charge collection efficiency of radiation damaged scCVD diamond



E = 6000 V/cm

When free traps are uniformly distributed in the bulk, CCE could be calculated analytically:

$$CCE_0 = \frac{2}{aD}\left(1 - \frac{1 - exp(-aD)}{aD}\right)$$

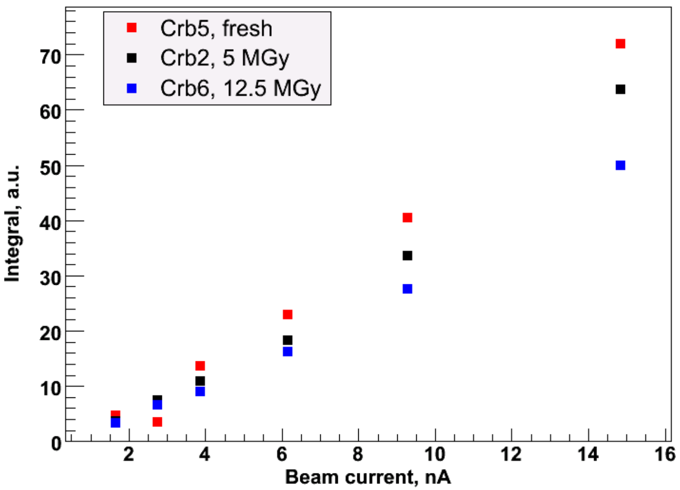
Where D - detector thickness,

a is proportional to the trap density and trapping cross section.

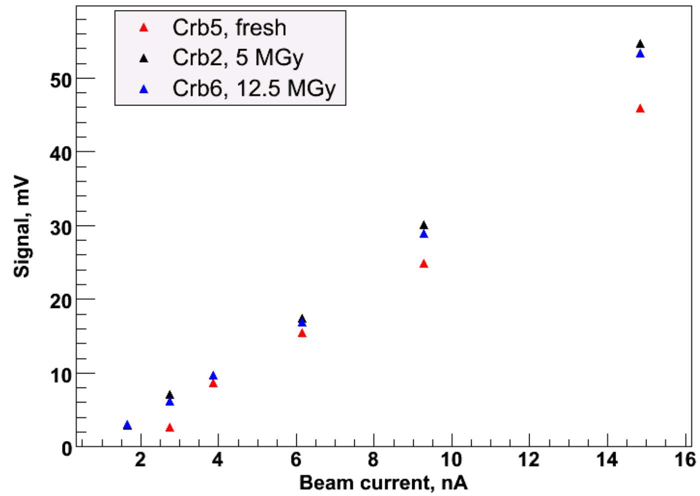
Free trap case => sensor is irradiated by UV light before CCE measurement.

Study of Sapphire sensors (preliminary)

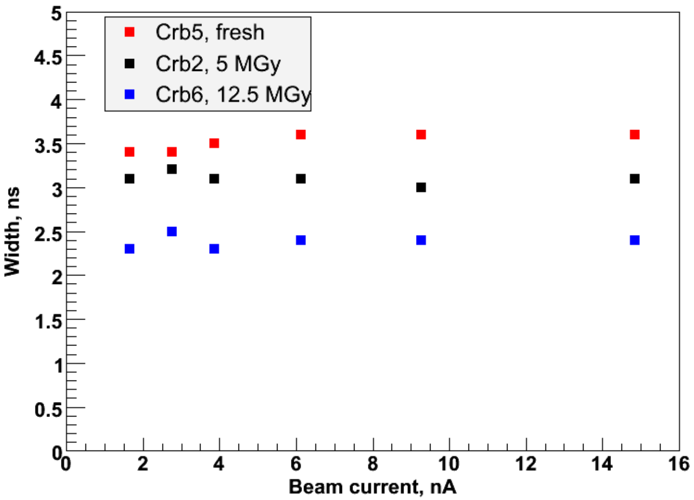
Sapphire signals - Charge integration



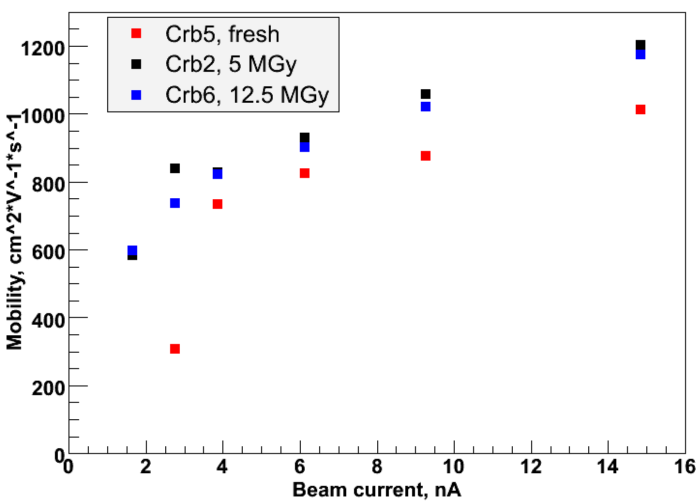
Sapphire signals - Direct conversion



Signal width vs beam current - Sapphires

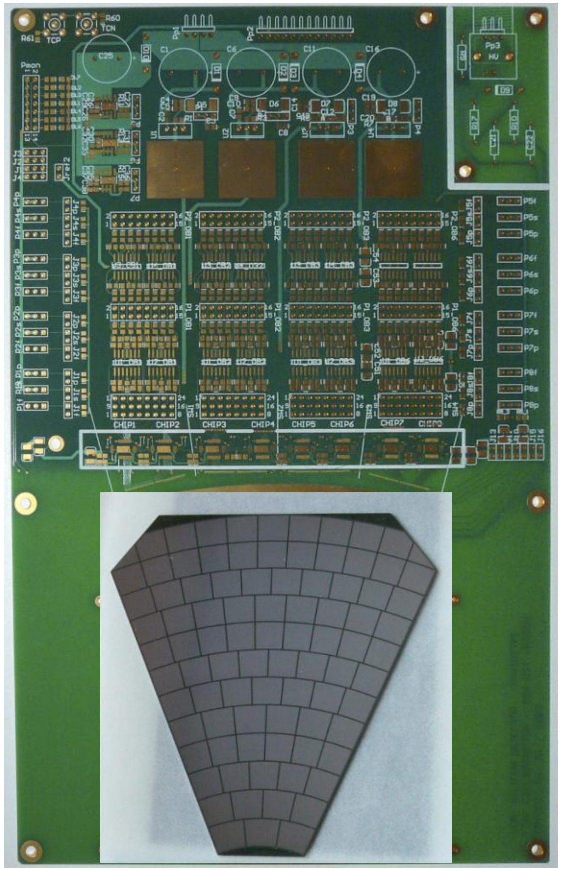


Charge carrier mobility - Sapphires



System Test (Sensors,Fanout,FE electronics)

(Last year slide)



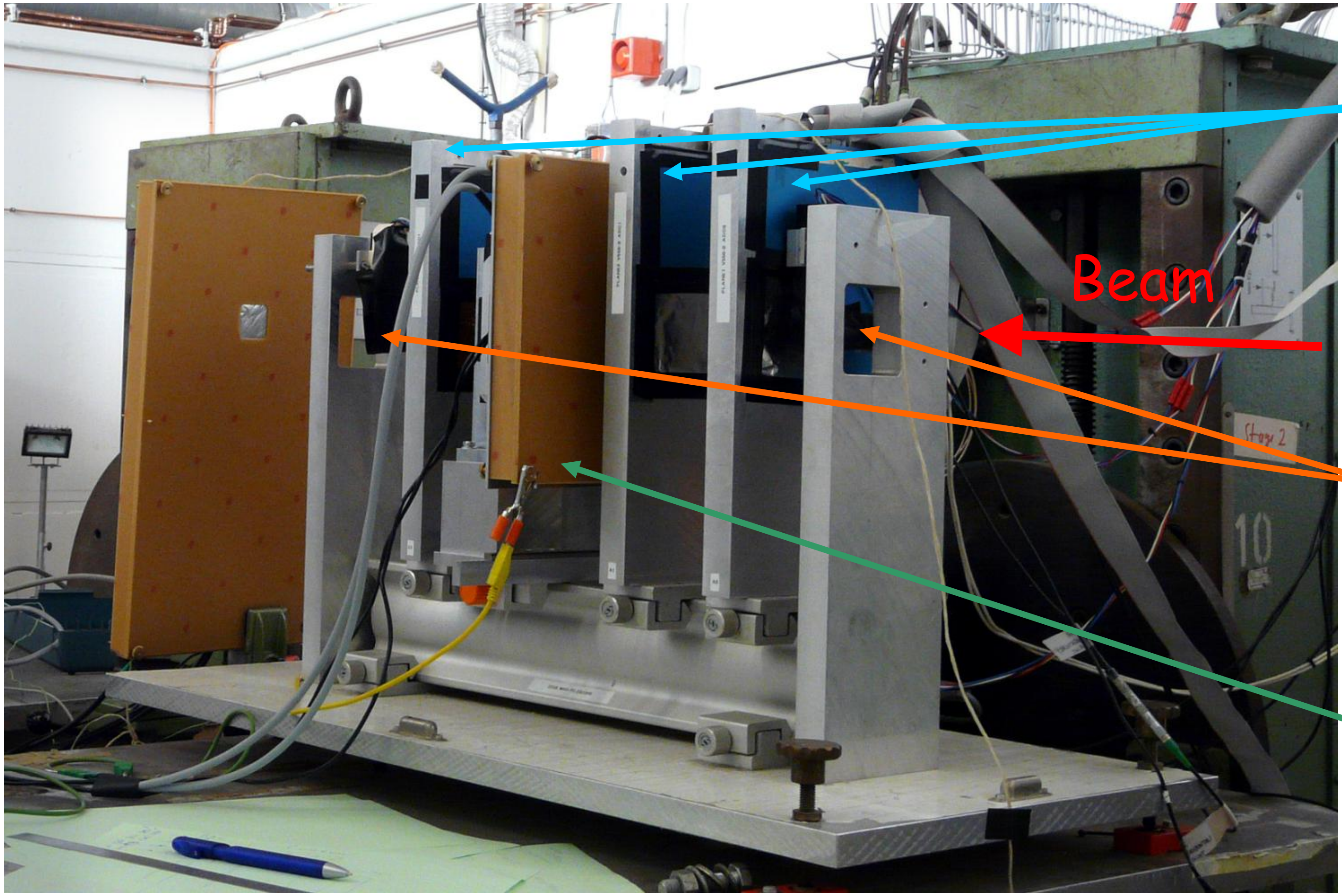
Template of a readout board, to be instrumented with FE ASICS

Readout/Fanout of sensors

- state of the art fine pitch PCB, (100…200μm for current few channel FE chips)
- matters of crosstalk & capacitive load
- wire bonding or bump bonding to pads (wire bonding needs ~ 3mm gap between absorber tiles; conductive glueing also discussed)
- wire bonding to FE chip
- Silicon and GaAs sensor samples
- Beam test planned 2010

System tests: testbeam @ DESY, August 2010

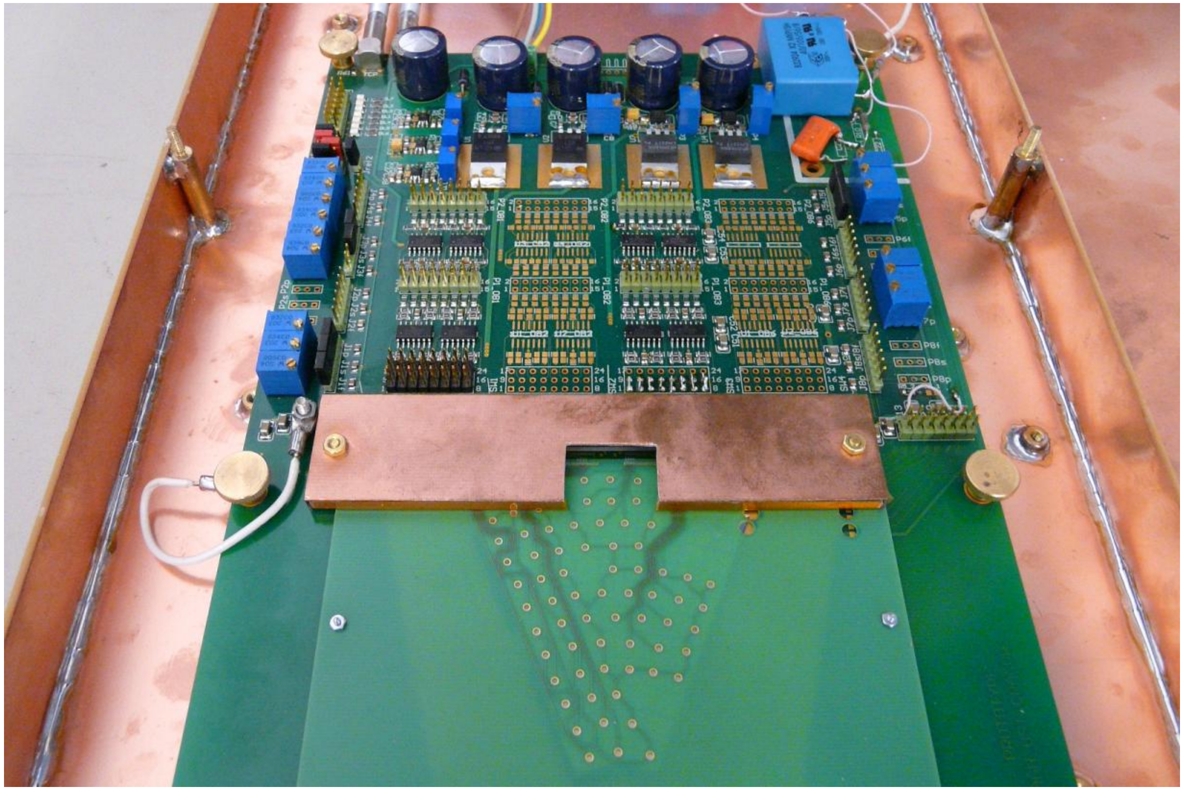
4.5 GeV electron beam



System tests: testbeam @ DESY, August 2010

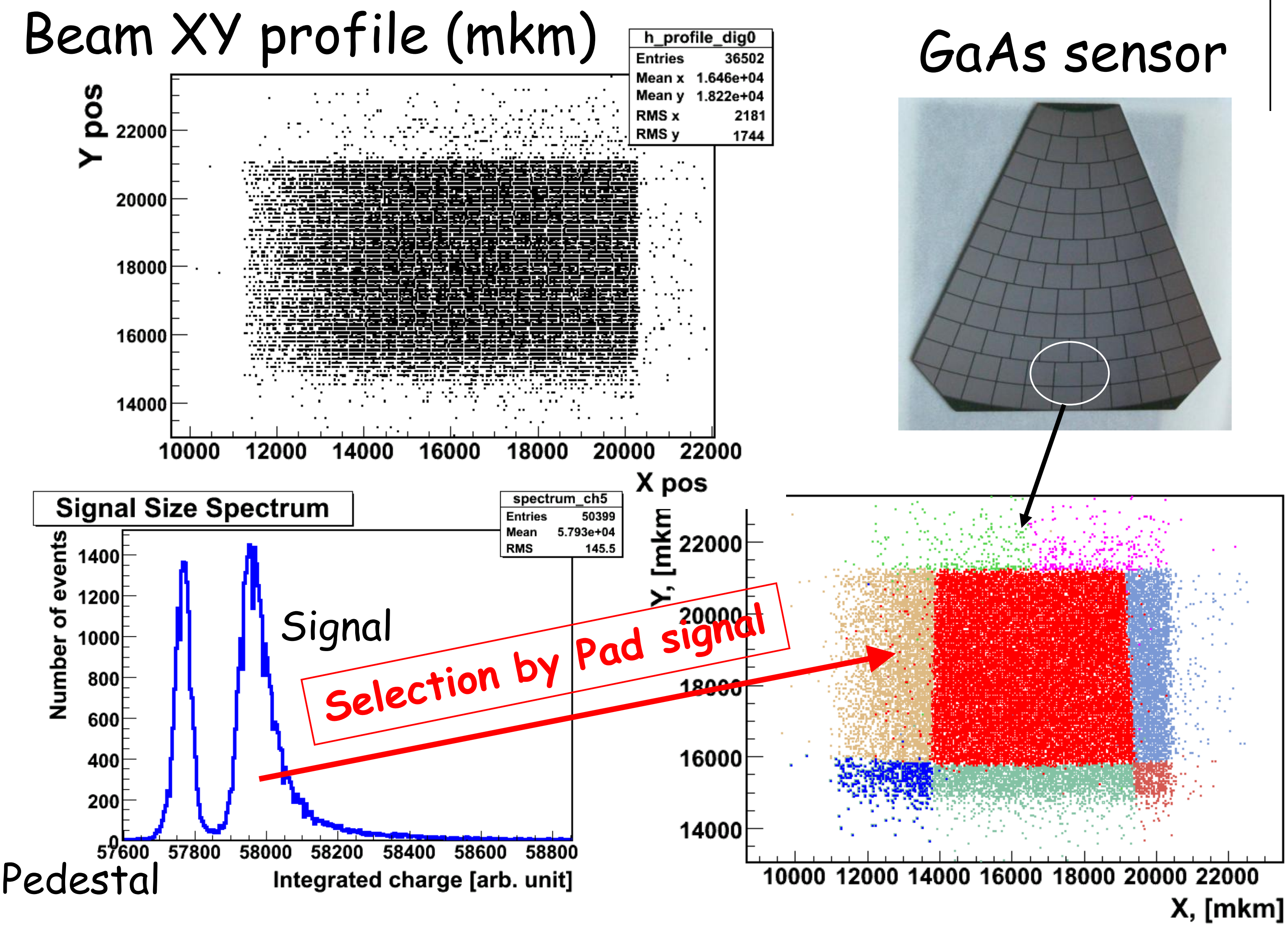
Precise XY-table

Detector box (BeamCal sensor installed)

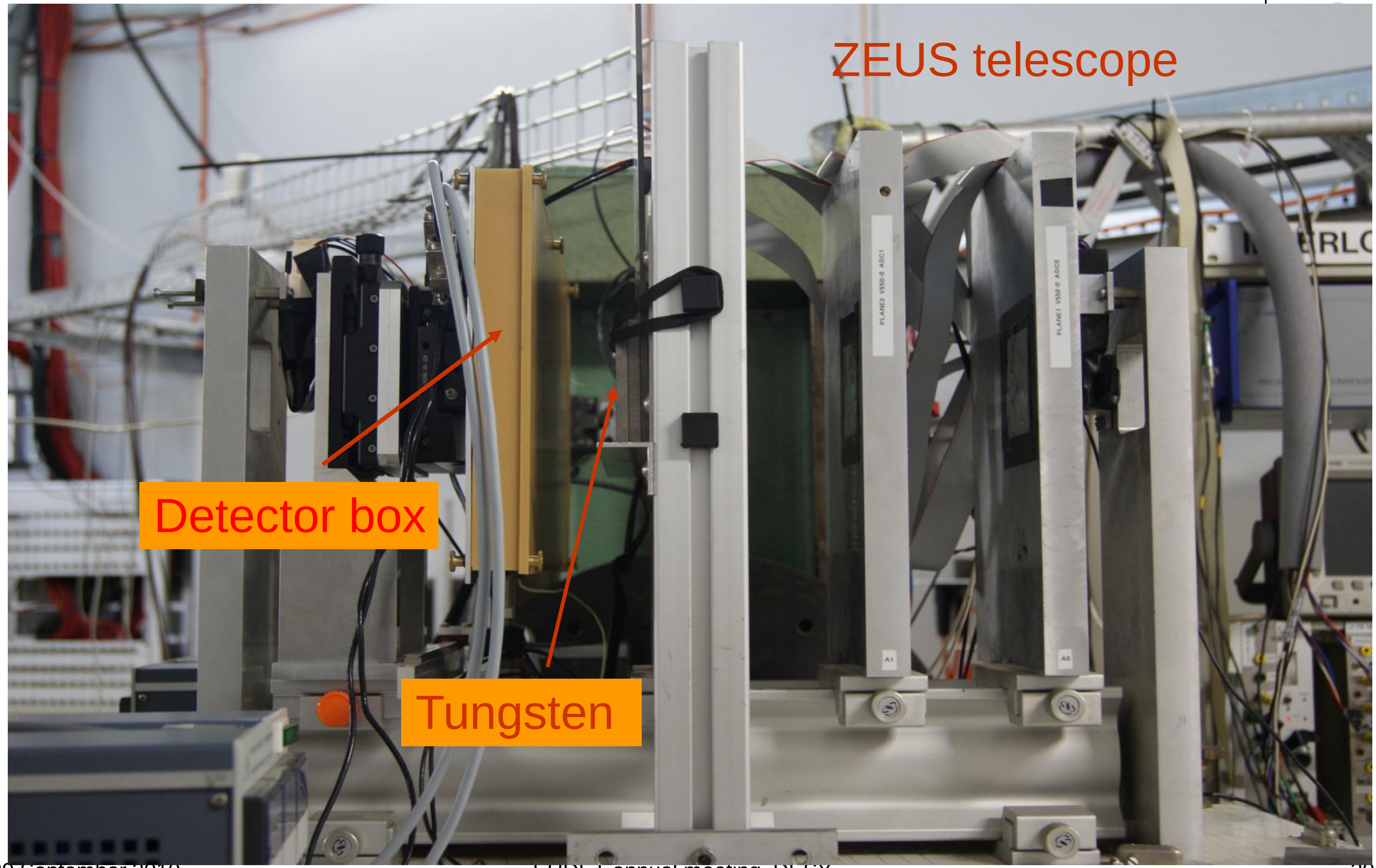


Similar box for the LumiCal sensor

System test: testbeam @ DESY, August 2010
First results for BeamCal sensor prototype

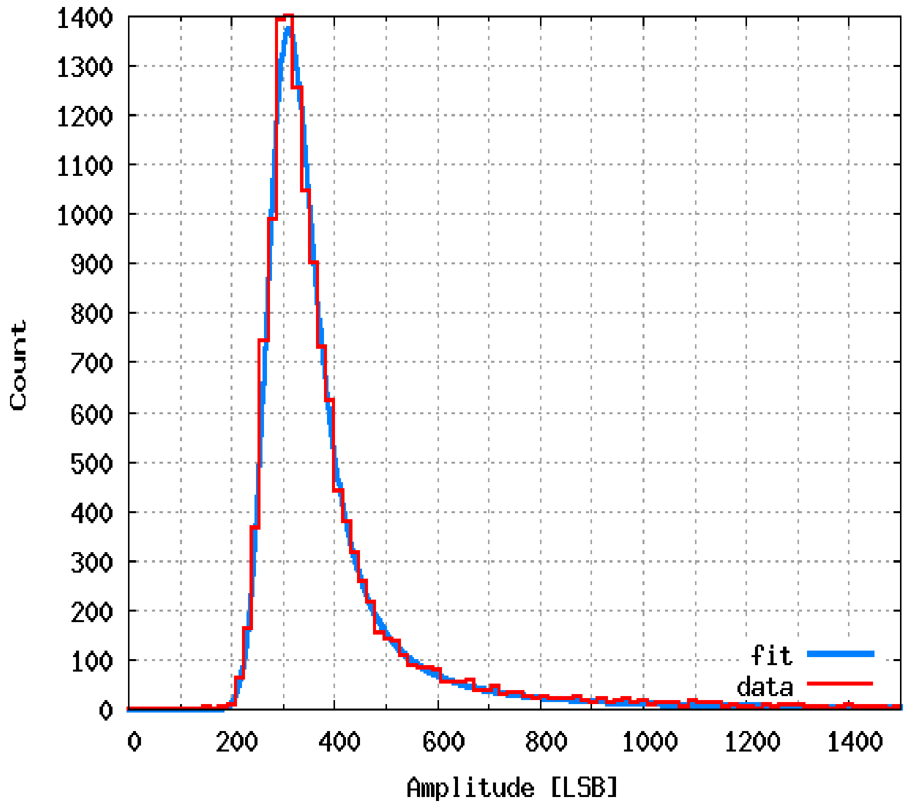


LumiCal on a testbeam at DESY

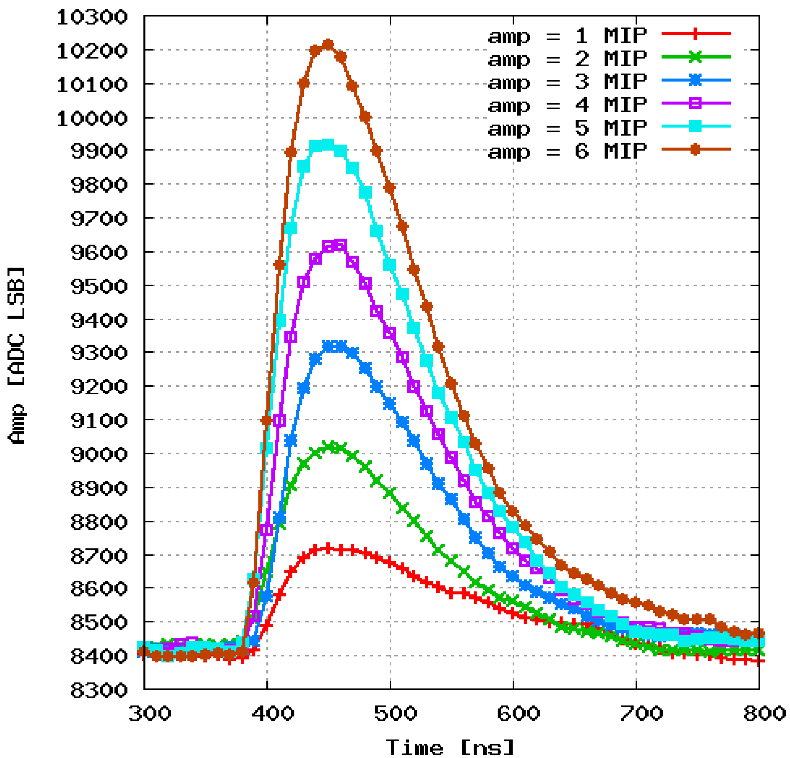


LumiCal testbeam results (1)

runs without tungsten absorber



Energy deposition in single channel fits Landau distribution



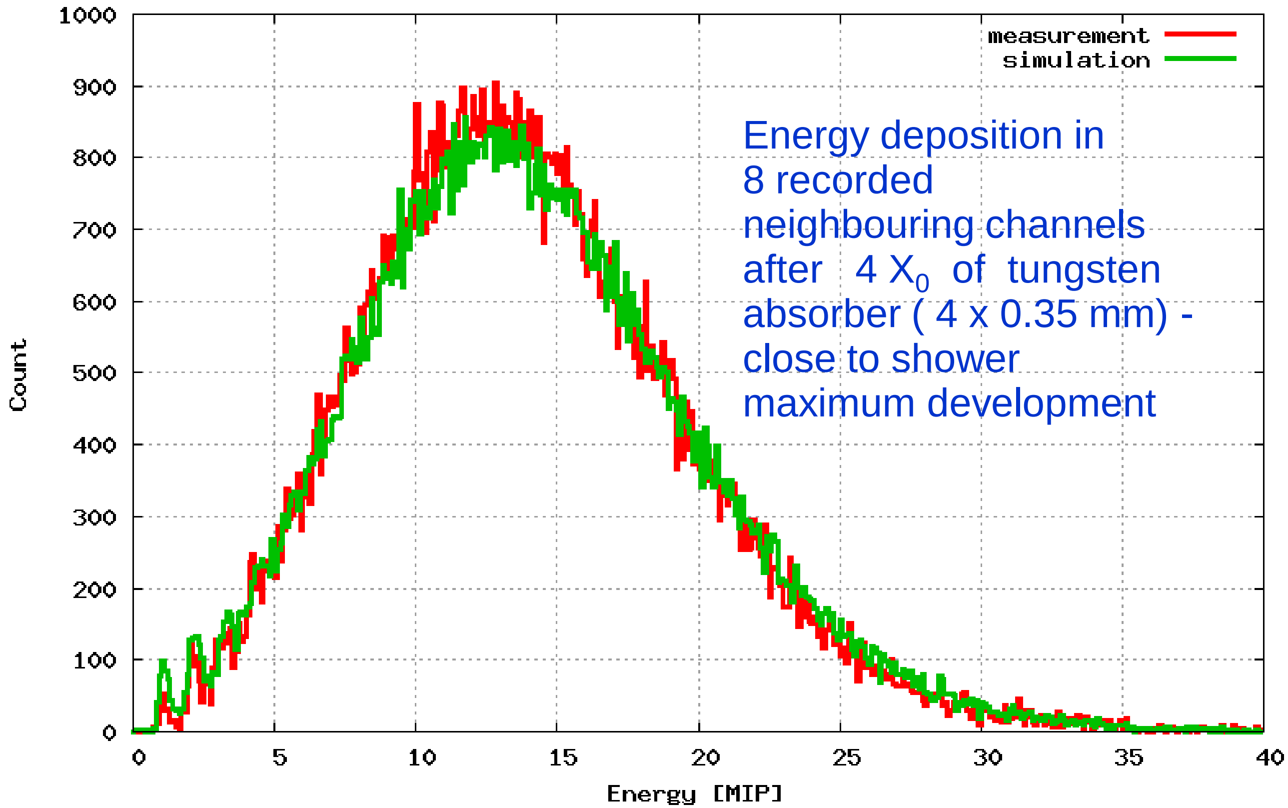
Time response of single front-end channel

LumiCal testbeam results (2)

Data and MC simulation (Geant 4)

Preliminary results

Electron beam energy : 4.5 GeV

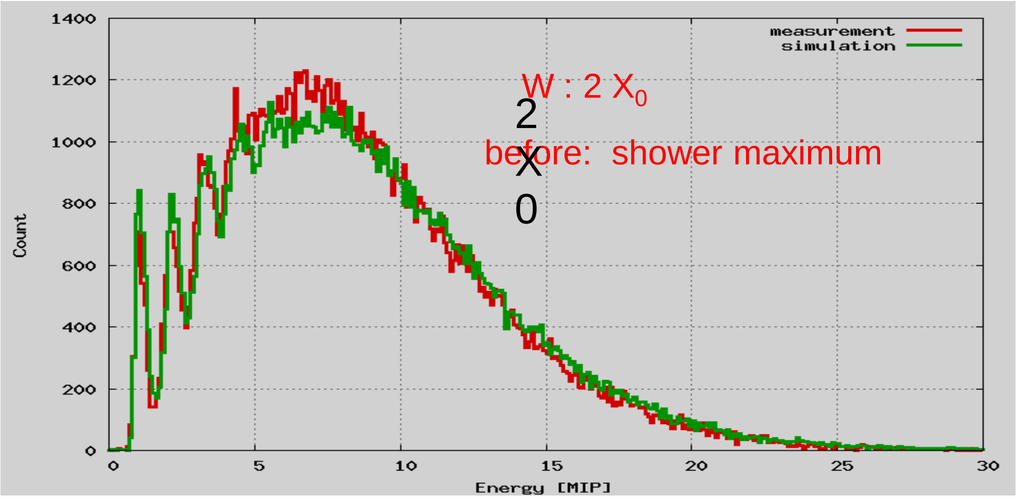


A good agreement with MC prediction

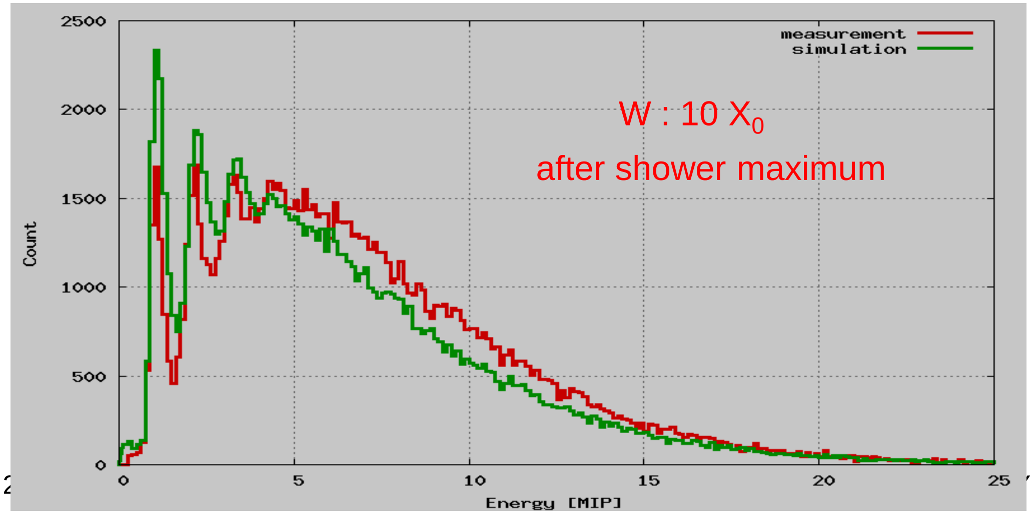
LumiCal testbeam results (3)

Data and MC : different thickness of tungsten absorber

Preliminary results



MC distributions are sensitive to a value of an air gap between absorber and sensors used in simulation (a few cm)



The observed differences between data and MC are under study. Wrong value of air gap in MC?

Next: System test in a beam with FCAL module -> FP7

Infrastructure to verify performance simulations:

A flexible tungsten absorber structure, depth 10 X_0, precise mechanics

Multichannel FE and ADC ASICS to instrument 10 consecutive sensor layers

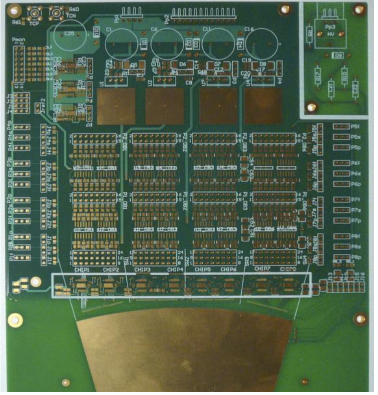
Tools to assembly 10 sensor sectors

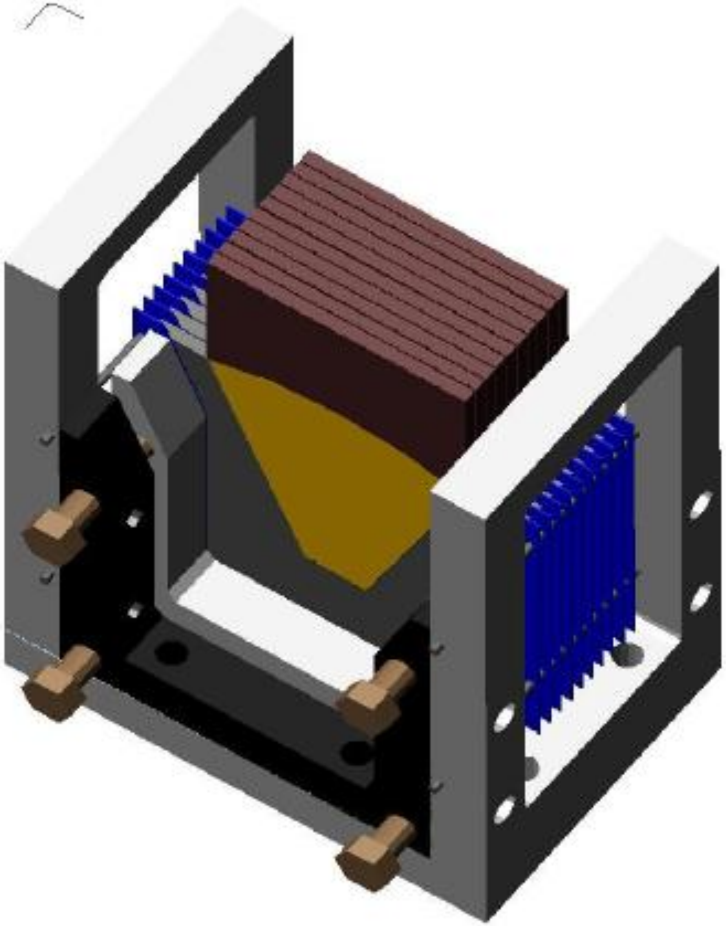
Optical position control of the sensor sectors wrt the tungsten frame

DAQ (common with other components)

Power pulsing (common developments)

10x





Conclusions

- Infrastructure for VFCAL sensors evaluation is ready
- Prototyping of Si sensors for LumiCal successful. Sensors are tested using probe stations at Cracow, DESY and Tel-Aviv
- Investigation of the radiation hardness of GaAs, Diamond and Sapphire BeamCal sensor prototypes done up to 12 MGy dose
- Sensor studies at ELBE (FZD Rossendorf) bunched beam Feb 2010 done
- System test (sensors+fanout+FE) at DESY testbeam done
- NEXT: FCAL Module system test at the beam in future (FP7)

Backup slides

BeamCal Sensors, GaAs

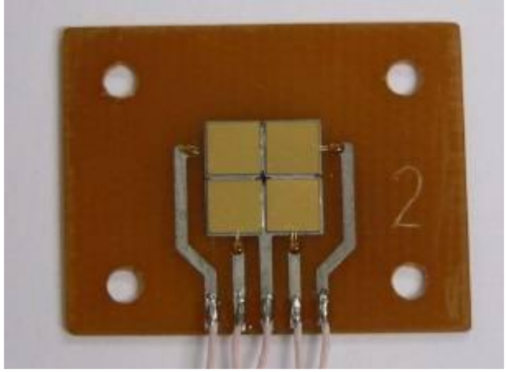
- n-type (Te or Sn - shallow donor) GaAs grown by Liquid Encapsulated Czochralski (LEC) method in Siberian Institute of Physics and Technology (Tomsk, Russia)
- low-ohmic material, filling the electron trapping centers EL2+
- Cr (deep acceptor) diffusion

-> high-ohmic

Thicknesses 150 – 500 μm

Metallization:
V (30 nm) + Au (1 μm) from both sides

Irradiation in a 8,5 MeV electron Beam, Doses up to 1.5 MGy



Initial n-GaAs	Fabrication method
№1, n ≈ (1 -1.5)*10^{17} $см^{-3}$,Te	Diffusion of Cr under temperatureT2
№2, n ≈ (5 - 6)*10^{16} $см^{-3}$, Te	Diffusion of Cr under temperature Tm
№3, n ≈ (1 - 3)*10^{16} $см^{-3}$, Sn	Diffusion of Cr under temperature T1
№4, n ≈ (2 - 5)*$10^{16}$$см^{-3}$, Te	p-ν-n- structure*

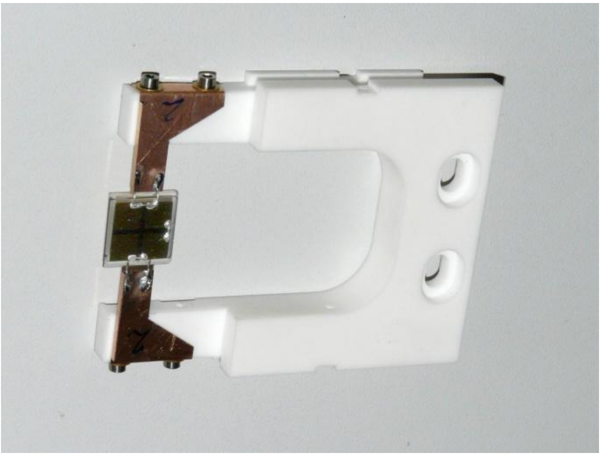
Notice T1 < Tm<T2.

* - presence in the detector n- type low-resistance domain, all other detectors №1, 2, 3 had structure m-i-m: metal- insulator (high-resistance GaAs) –metal.

Test in PITZ

Electron beam, 14.5 MeV, bunches

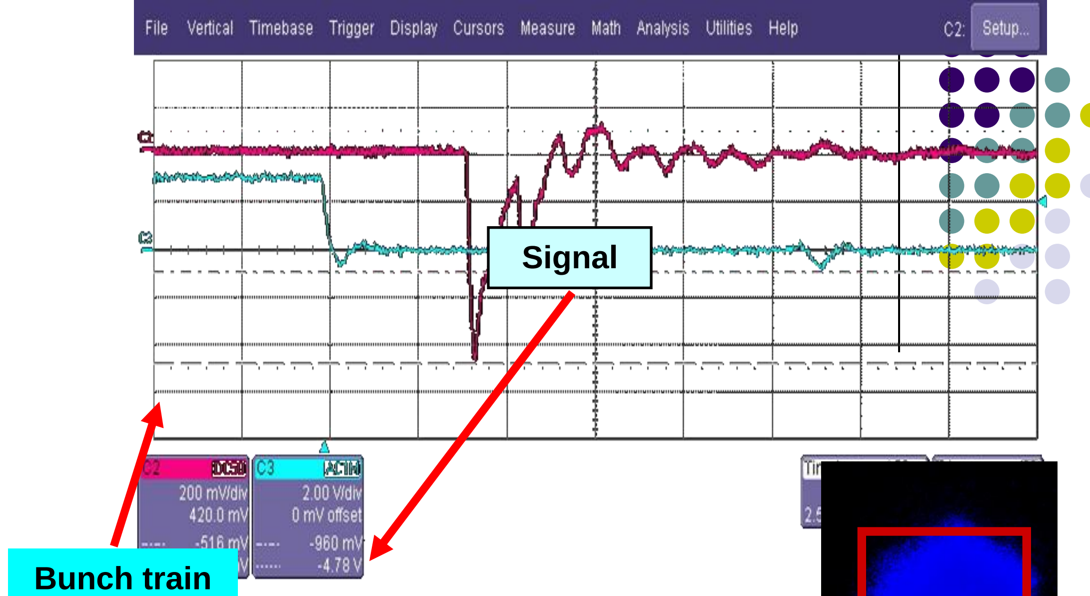
Diamond sensor was installed in the vacuum of the beam pipe

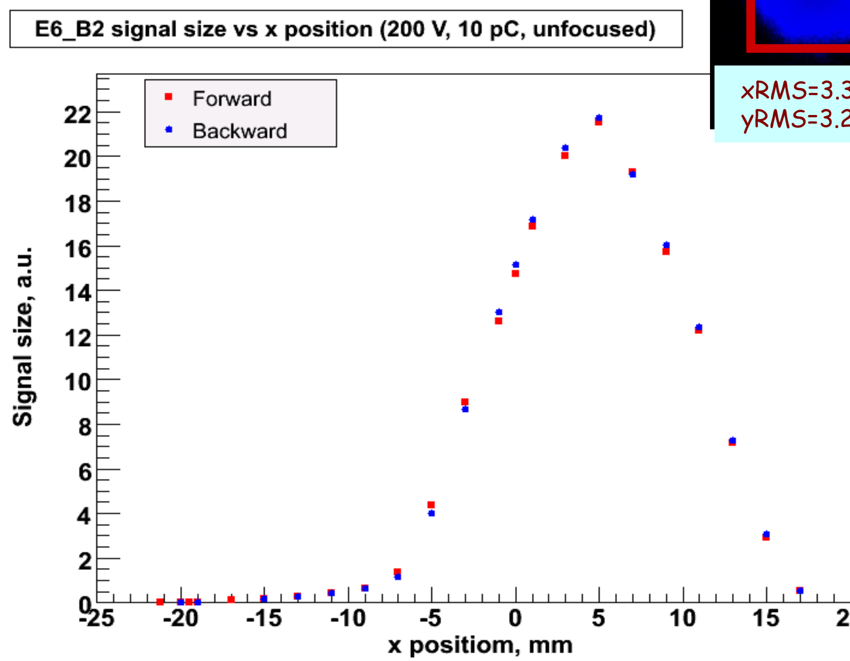


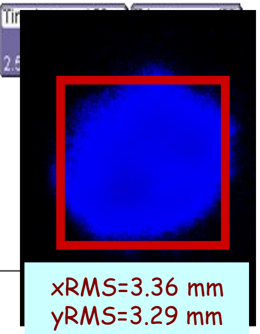
Moving the sensor through an electron beam,

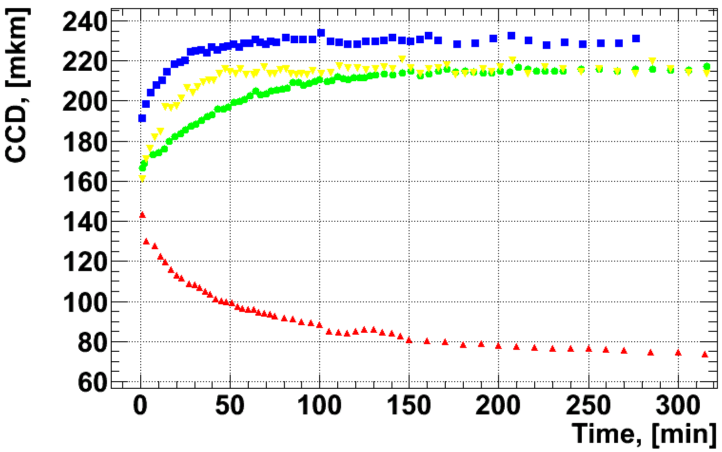
Bunch charge 1 pC – 1 nC,
Beam spot: few mm^2
Beam profile

EMI doesn't disturb operation








CCD, [mkm]
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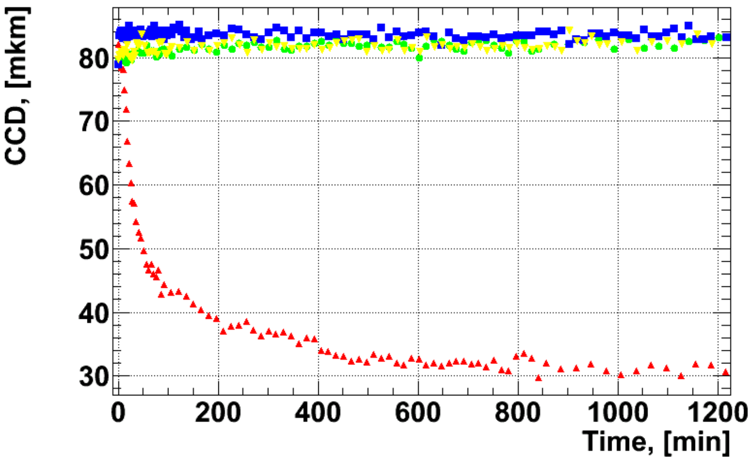
200
180
160
140
120
100
80
60
0
50
100
150
200
250
300
Time, [min]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60
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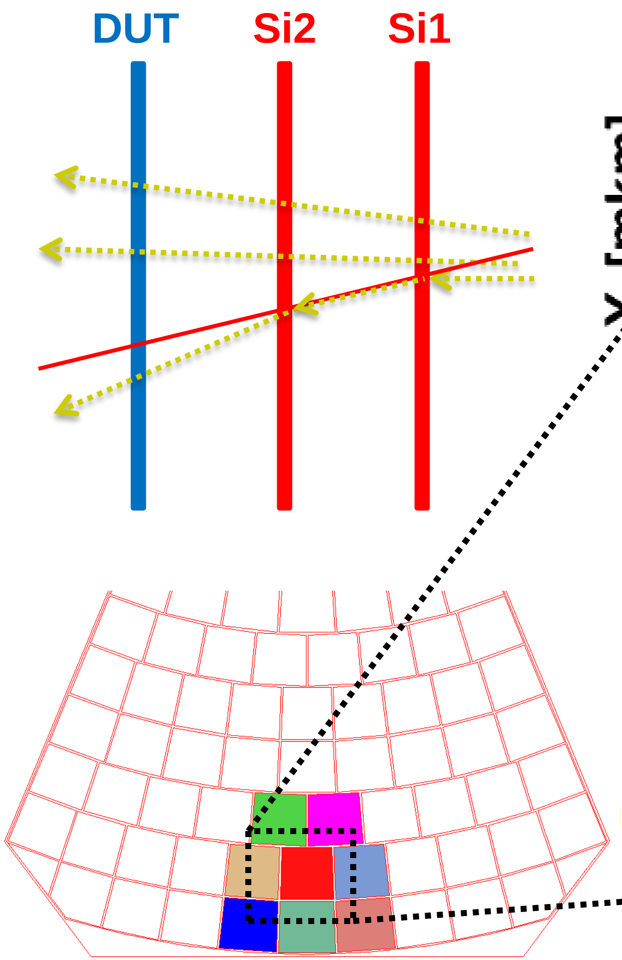
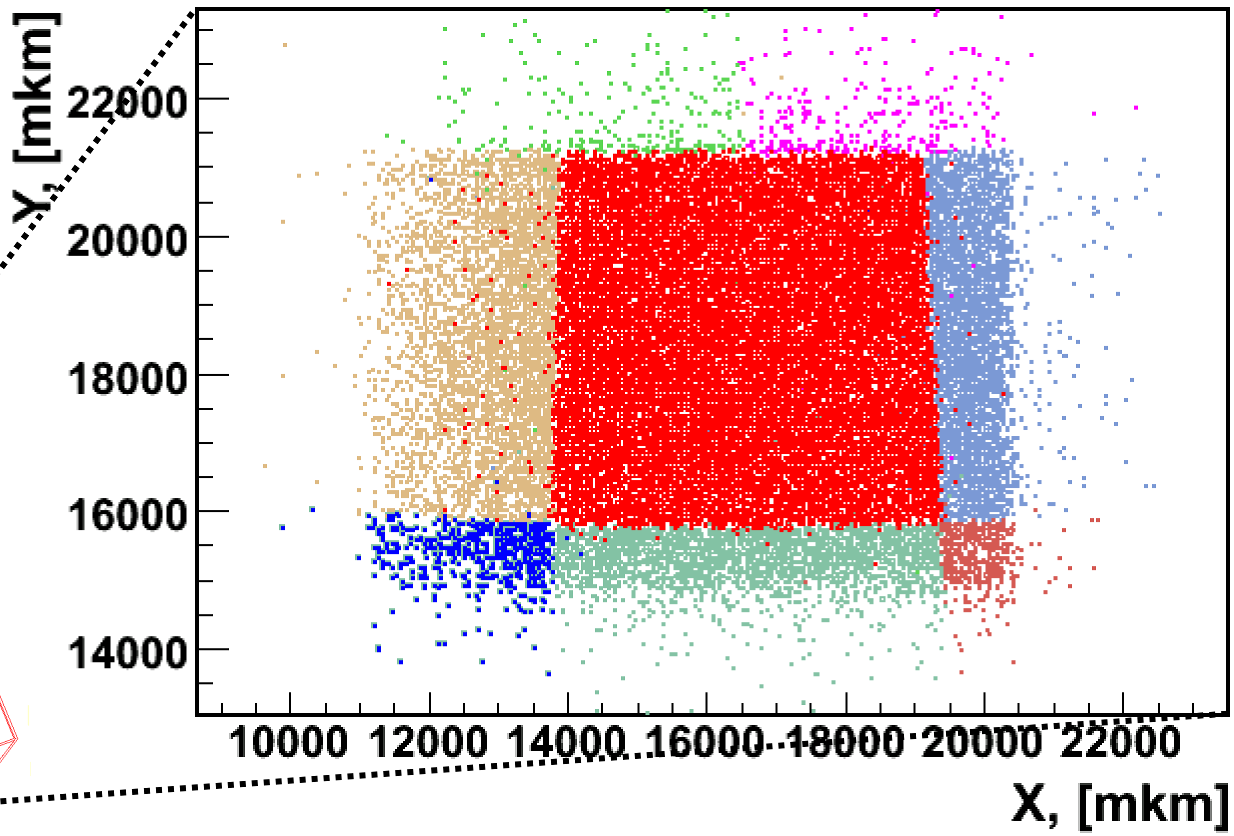
0
200
400
600
800
1000
1200
Time, [min]

Tracking





Region 4

Reconstruction of position in the Sensor Box

Application at FLASH

FCAL designed, constructed and installed a Beam-Condition Monitor at FLASH (4 diamond and 4 sapphire sensors

Operation in the “9 mA” run of FLASH was successful