Beam Cal

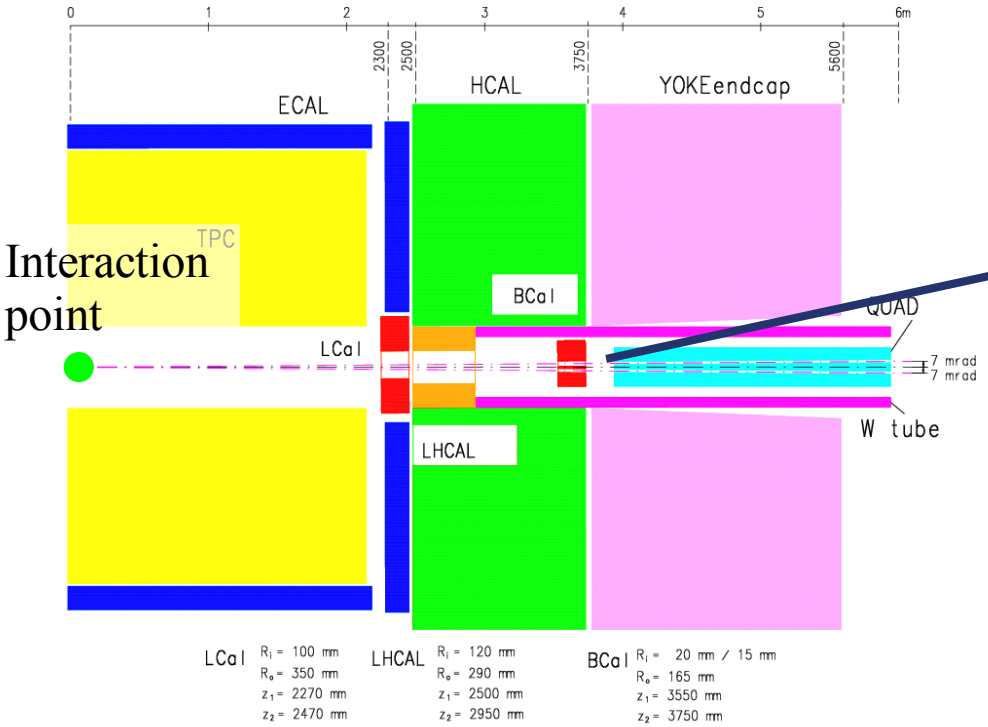
Testbeam Results for sCVD, pCVD and GaAs Sensors

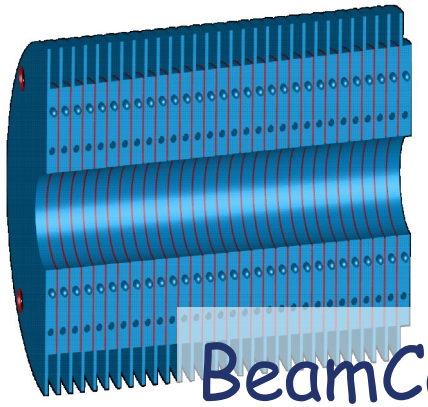
Sergej Schuwalow & FCAL group DESY Zeuthen

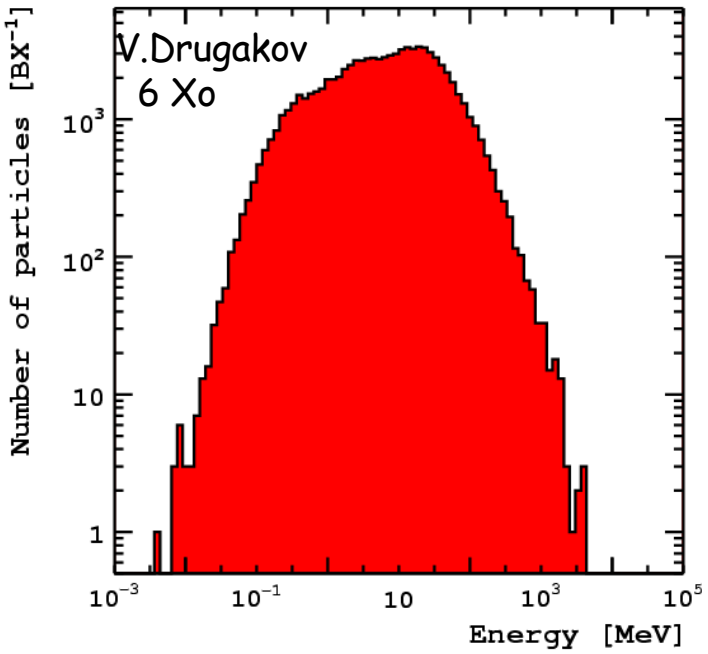
Outline

- Motivation
- Testbeam Darmstadt 2007
- sCVD Sensors
- pCVD Sensors
- GaAs Sensors
- Polarization effects (sCVD)
- Sensor -> detector sensor plane

Motivation







Beamstrahlung pairs shower:

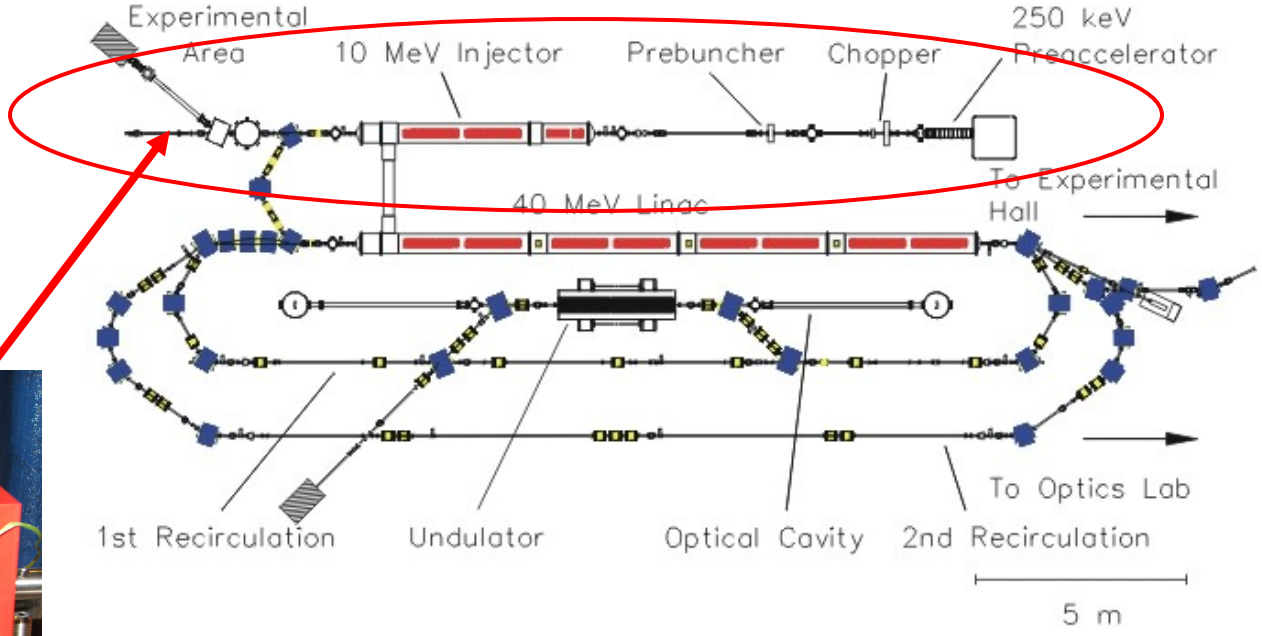
m.p. energy @ about 10 MeV
expected dose ~ 10 MGy/year

Testbeam Darmstadt

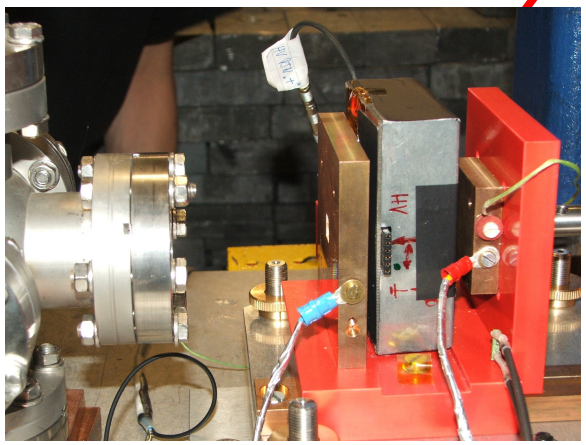
End of June 2007

supported by many FCAL members and collaborators

10 MeV electrons

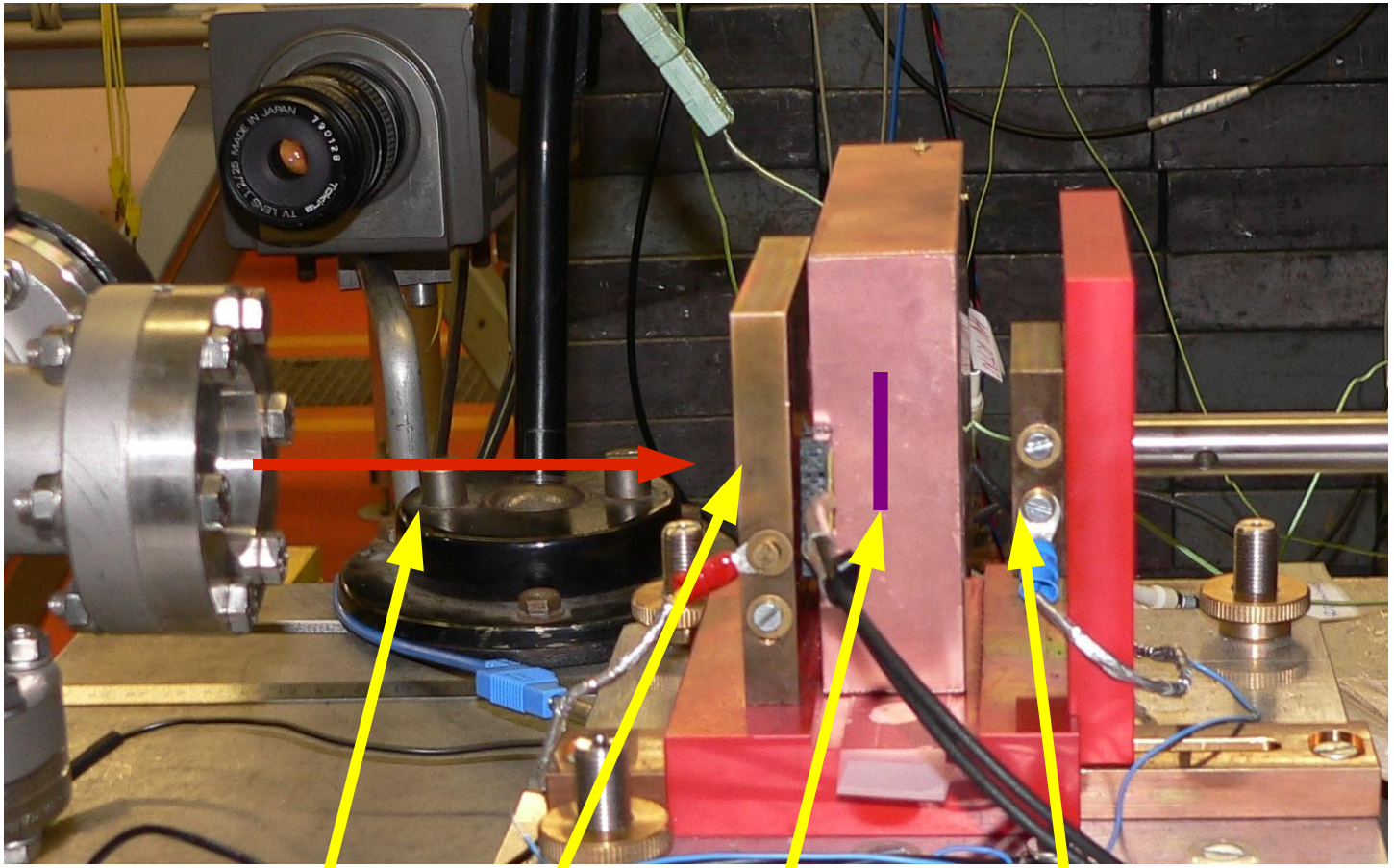


Teastbeam Setup

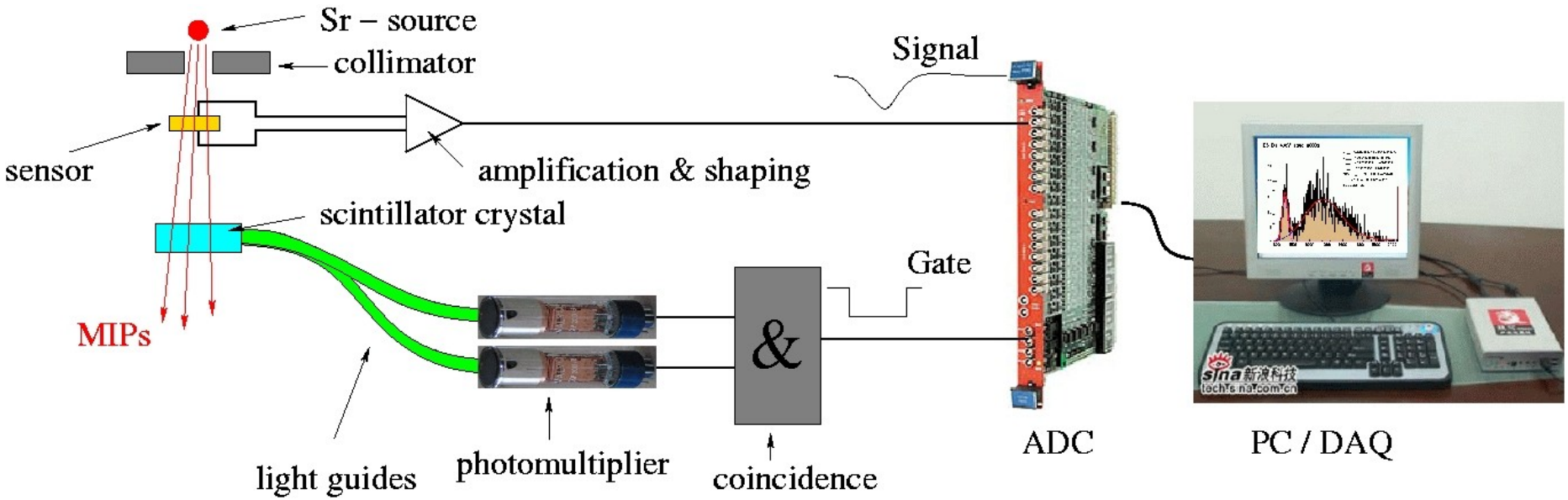


accumulated dose up to 5.5 MGy per sample

Testbeam Setup



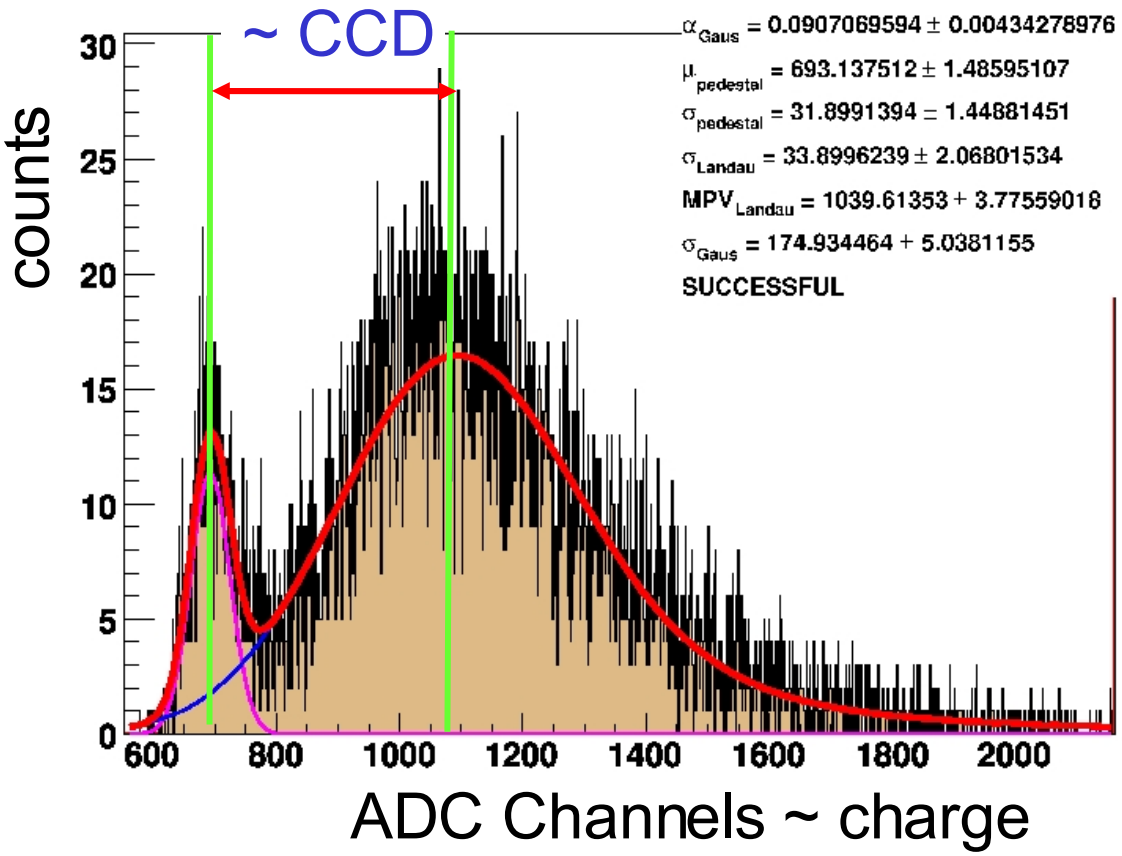
CCD Setup



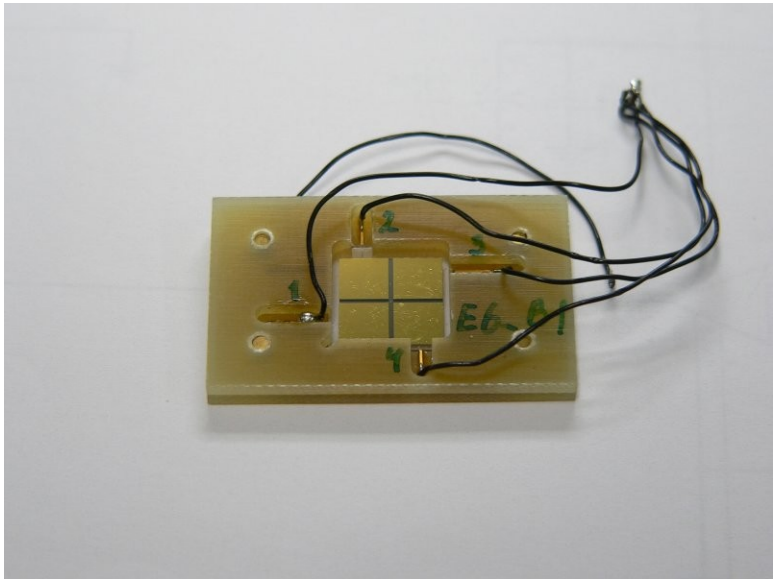
voltage applied on the sensor sample all the time

CCD

- CCD = mean drift distance
- related to collected charge via Ramo's theorem

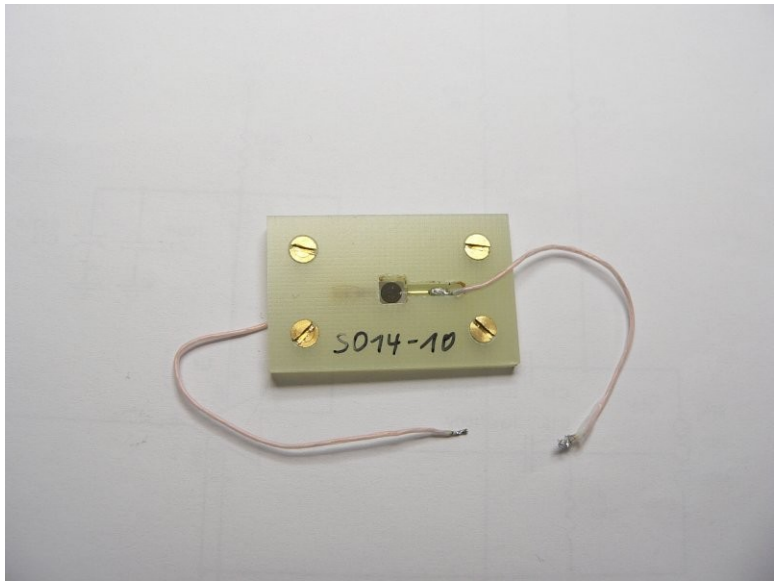


CVD diamond samples



pCVD diamonds
active area 10x10 mm², thickness 500 µm
Ti-Pt-Au metallization

Irradiated up to 5.5 MGy

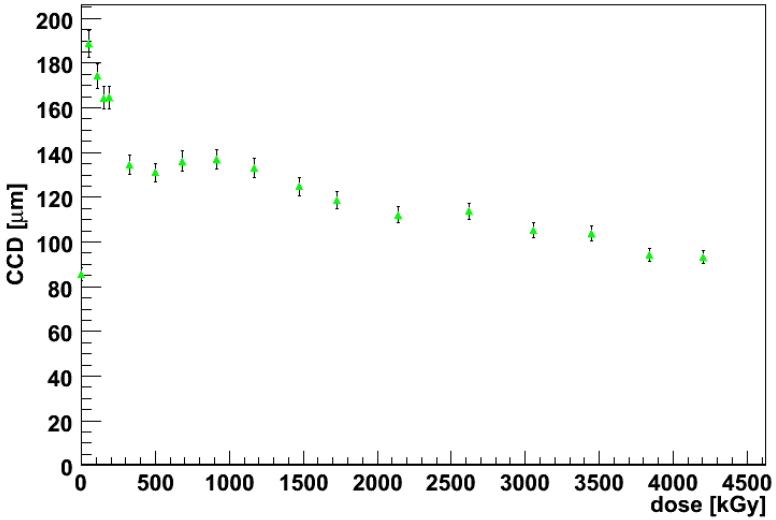


scCVD diamond
area 5x5 mm², thickness 340 µm, metallization Ø3mm

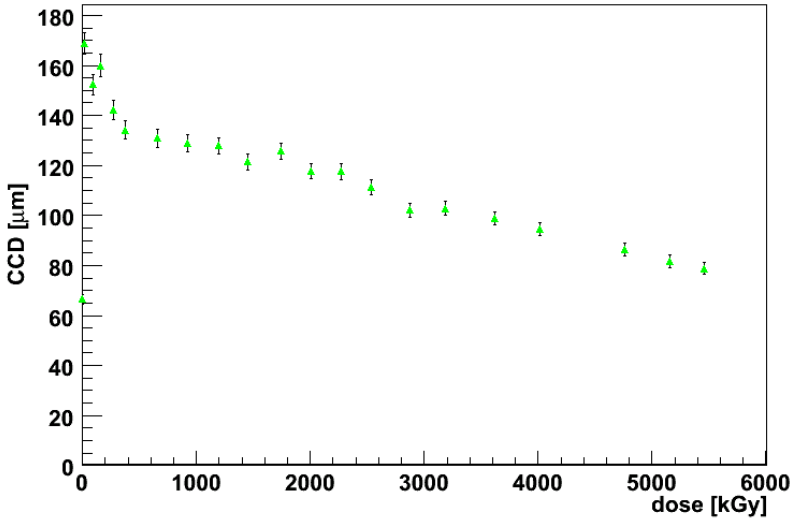
Irradiated up to 2.7 MGy

Results from testbeam'07

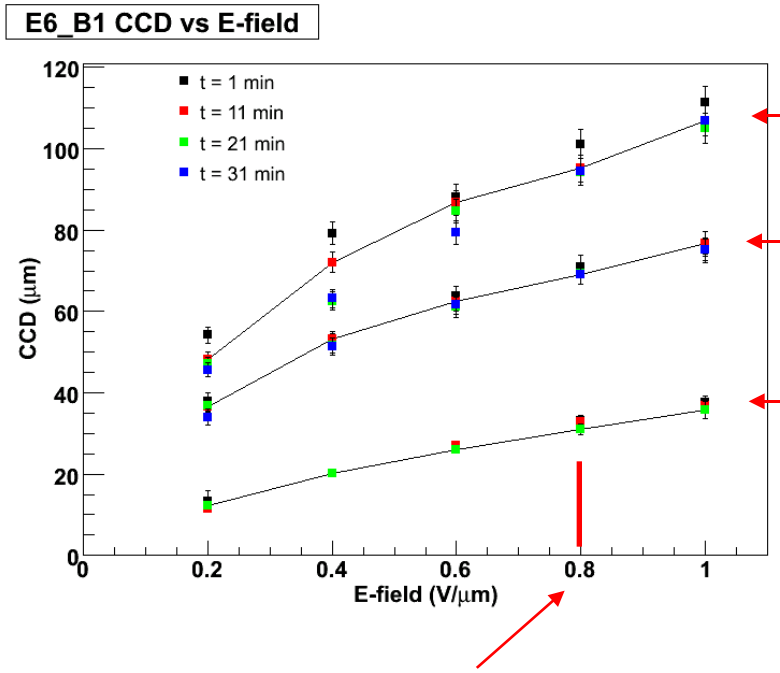
E6_B1



E6_B3



Similar behavior: first pumping, then the CCD decreases

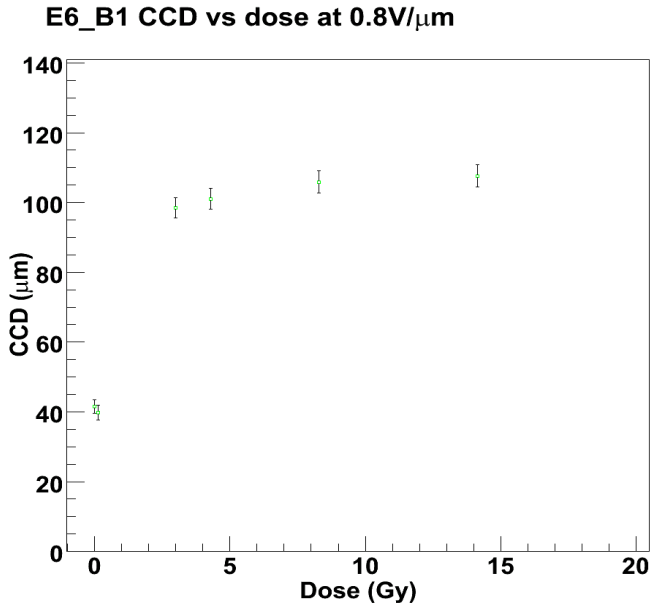


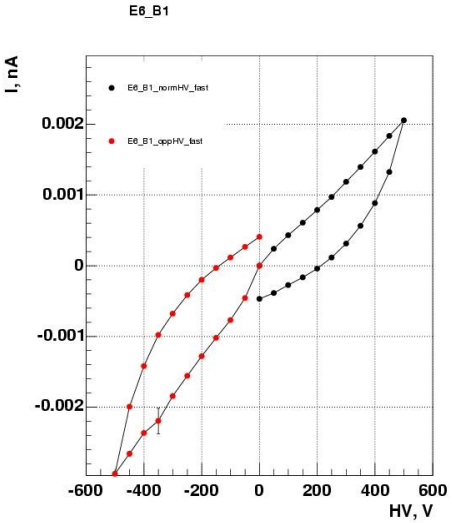
Before irradiation

After irradiation before UV illumination

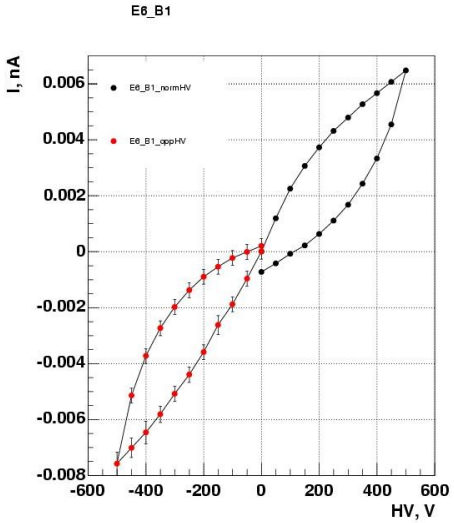
After irradiation, UV illuminated

Value used at testbeam



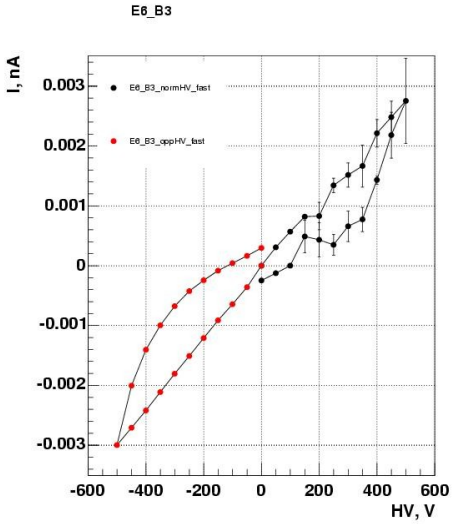


Before

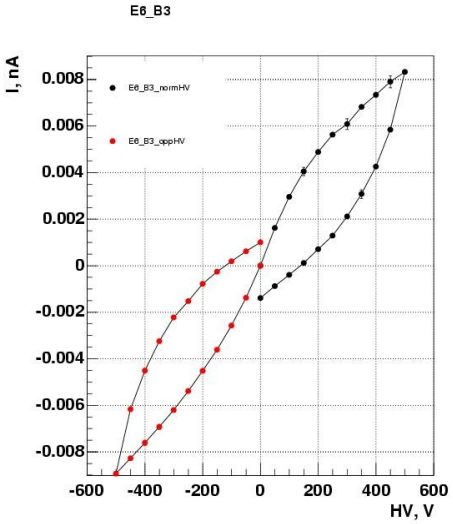


After

I-V characteristics

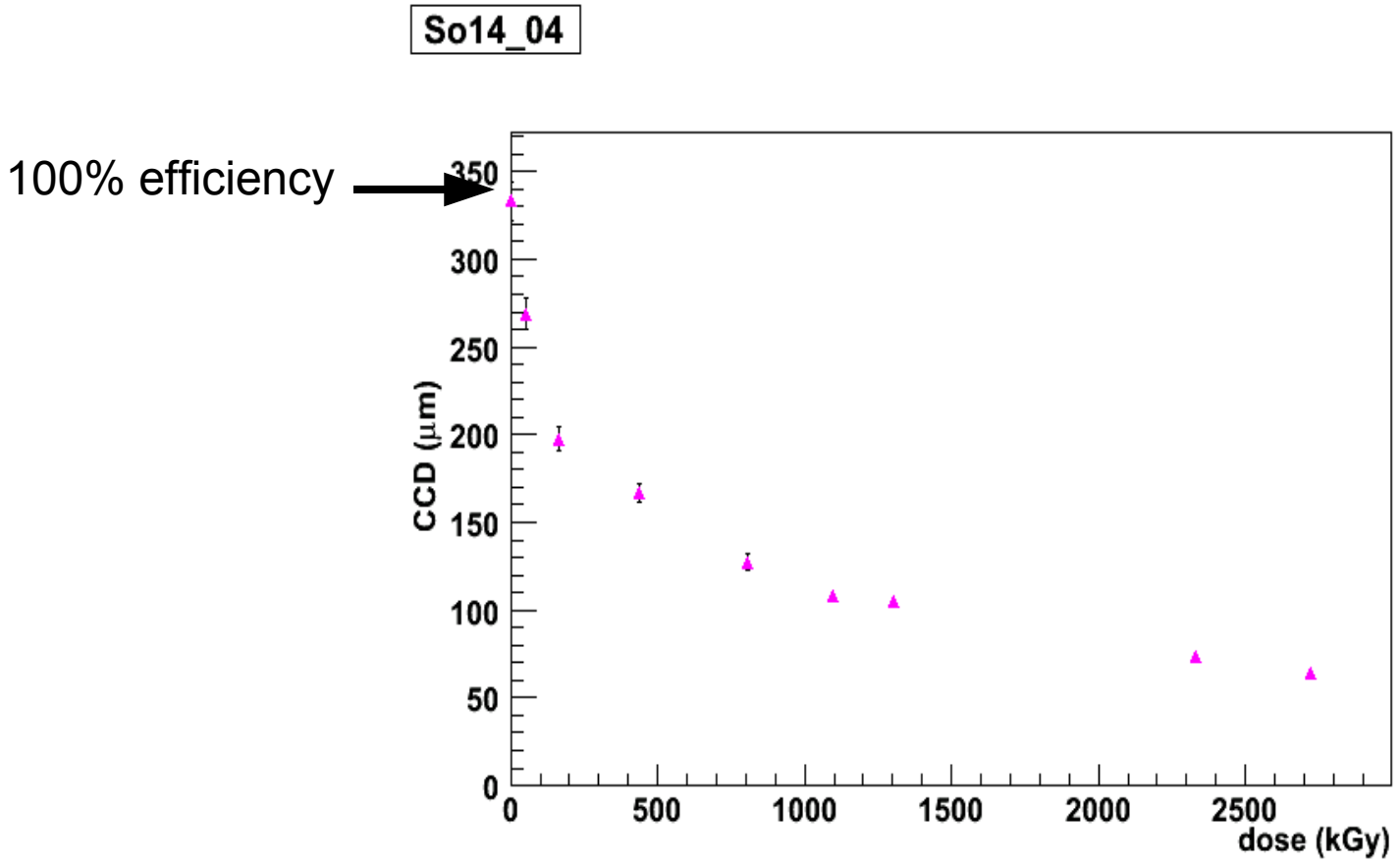


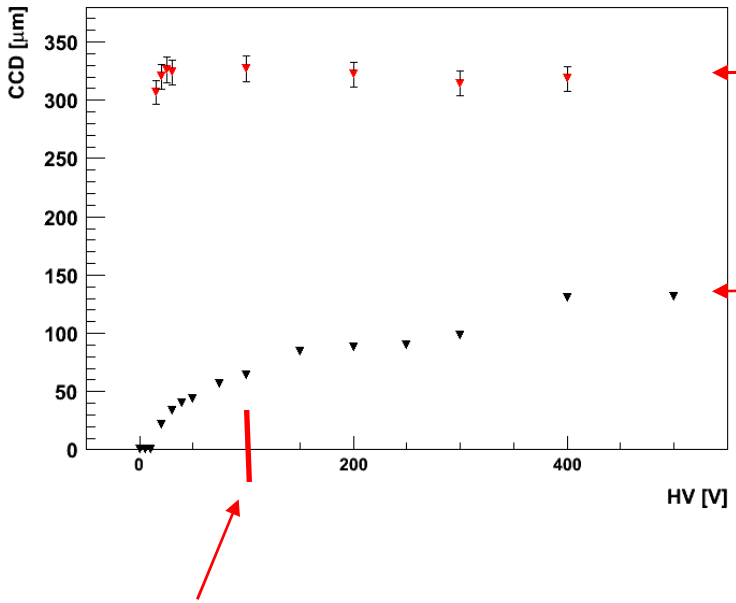
Before



After

ScCVD testbeam-07 results

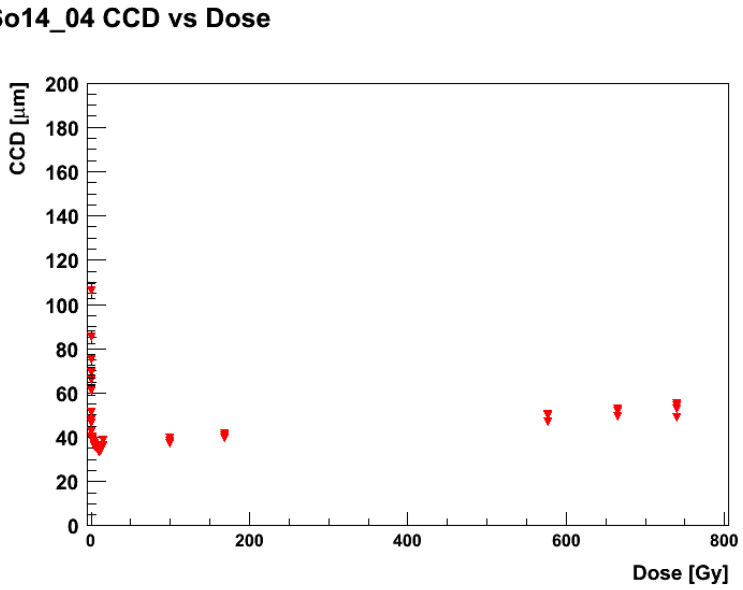




Before irradiation

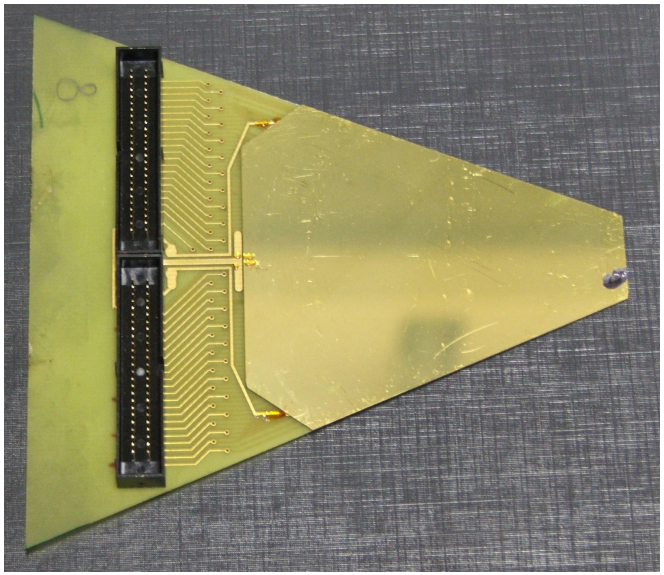
After irradiation

Value used at testbeam



GaAs

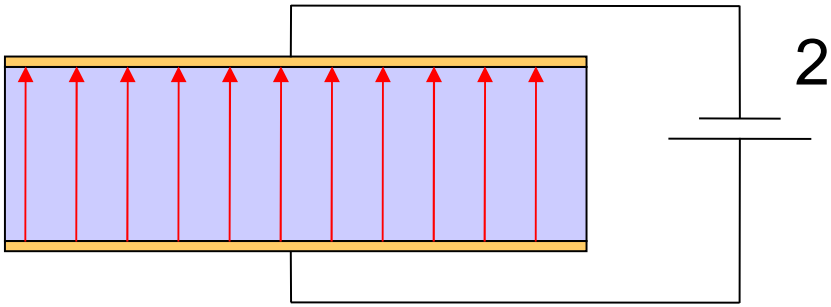
- Supplied by FCAL group at JINR
- Produced by Siberian Institute of Technology, Tomsk
- Two samples

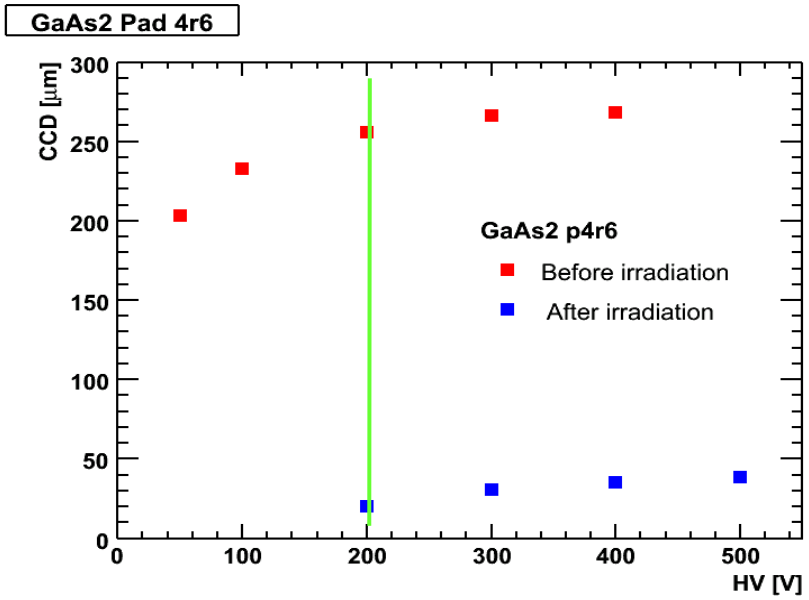


- semi-insulating GaAs doped by Sn (shallow donor)
- compensated by Cr (deep acceptor)

Irradiated up to 0.9 MGy

GaAs





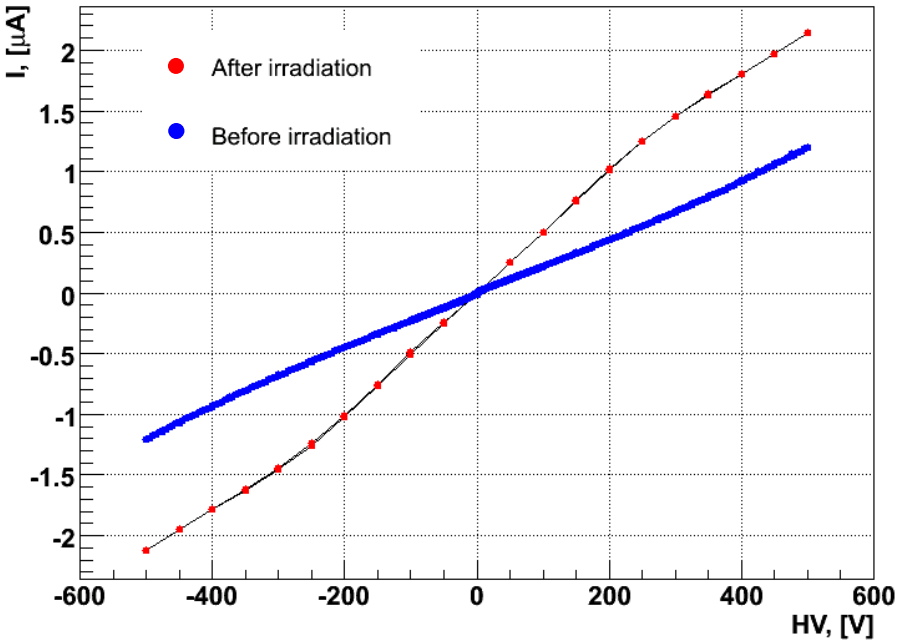
500 µm thick detector is divided into 87 5x5 mm pads, mounted on a 0.5 mm PCB with fanout

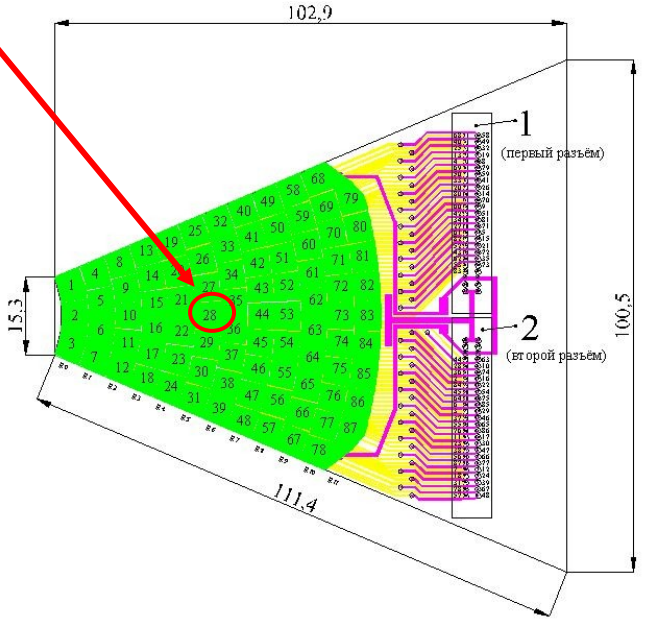
Metallisation is V (30 nm) + Au (1 µm)

works as a solid state ionisation chamber;
signal eh pairs drifting in the E field
structure provided by metallisation (similar to diamond)

GaAs - Before Irradiation

GaAs2 Pad 4r6



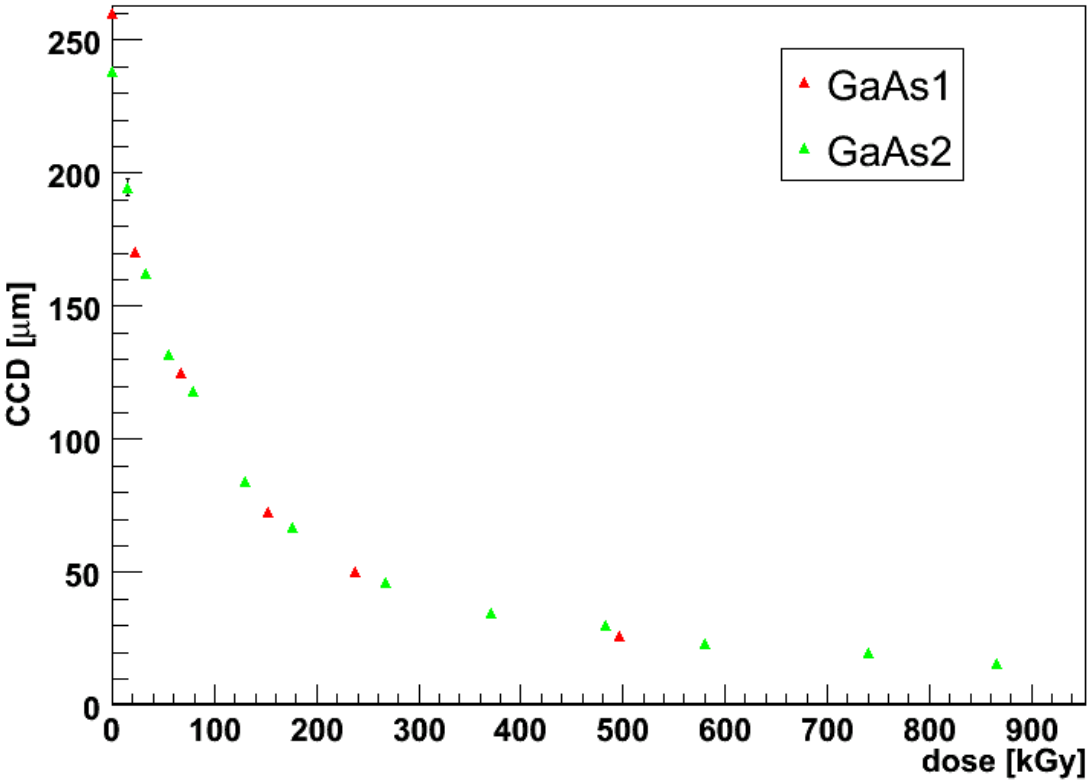


Almost linear IV characteristics → ohmic resistor

$R_{pad} \approx 500\ M\Omega$, Pad capacity about 12 pF, Dark Current 1 μA @ 500 V

IV curve = temperature dependend due to semi-conducting character

GaAs Sensors

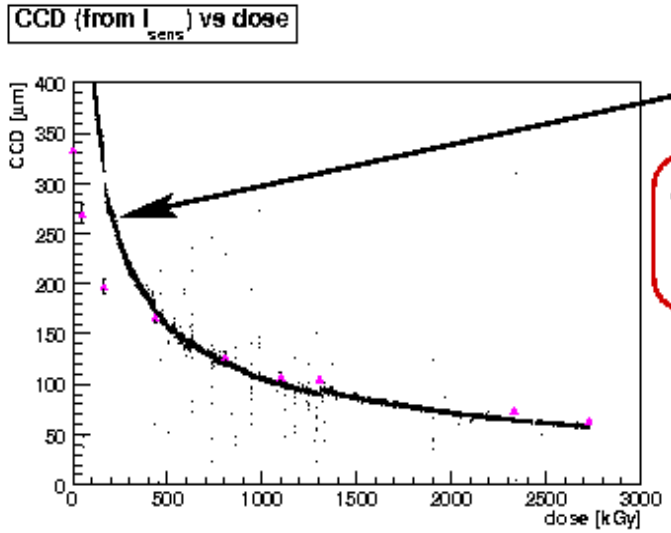


- No pumping as for pCVD diamond

Before irradiation
CCD = 50% of sensor thickness

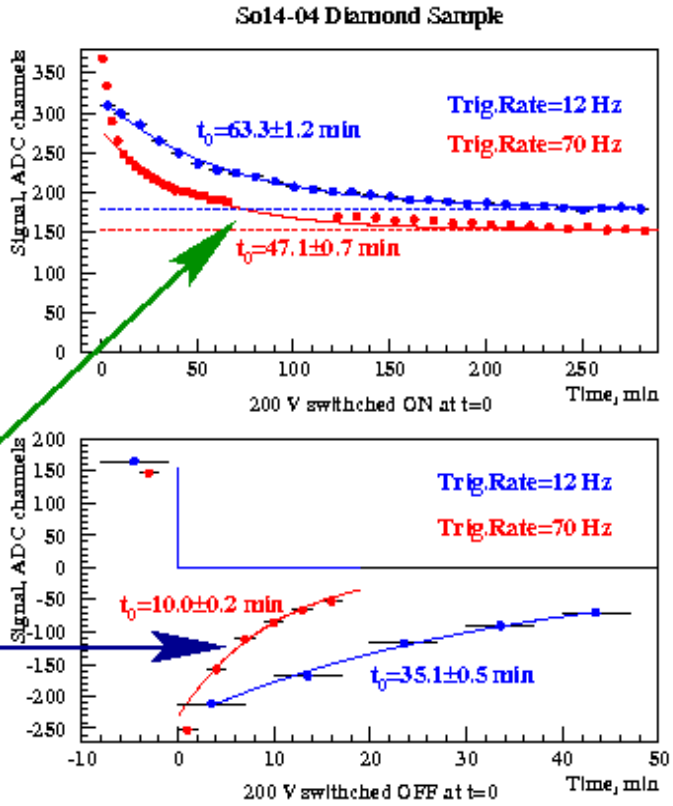
After irradiation (about 1 MGy)
CCD = 3% of sensor thickness

Experimental Data



Sensor current vs dose measurements

Trapping/ detrapping? mechanism???
Recombination?



sCVD detector after 2.7 MGy;
Measurements with ^{90}Sr–source

Time and Rate dependent signal

After switching HV off the signal of opposite polarity is observed

Dynamical Polarization

Polarization Model

Radiation damage – uniformly produced traps

MIP signal – uniformly produced e–h pairs

+Electric field → *NONUNIFORM space charge*

↓

Change of the electric field

e–h Recombination if the field is low

Release of trapped charges (decay time)

Change of the space charge distribution

↓

Steady state POLARIZATION

Dependent on trap density, applied voltage and signal rate

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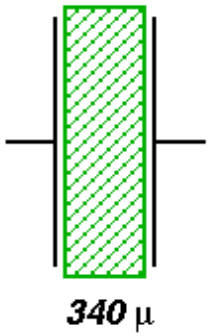
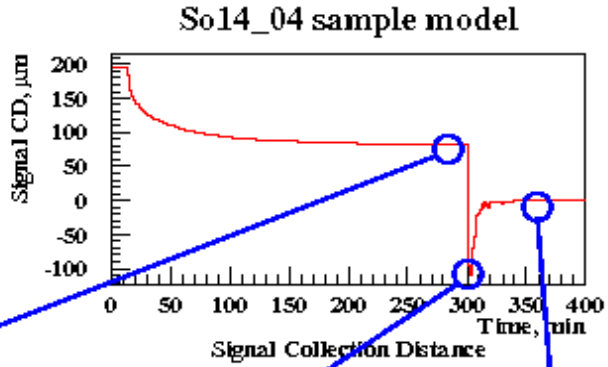
Polarization Model: CCD vs time

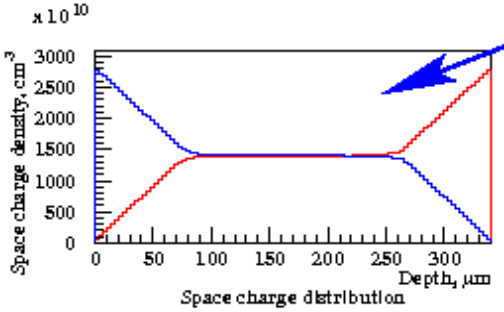


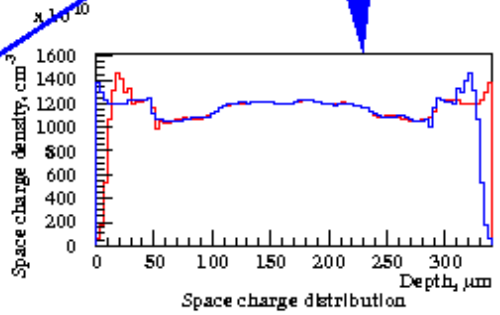
HV = 200 V

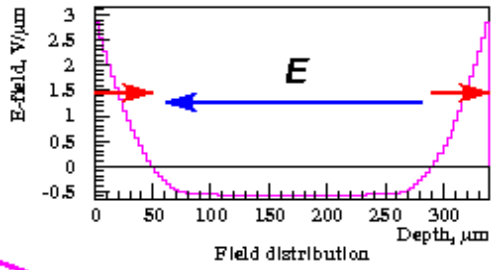
Applied at t = 0;

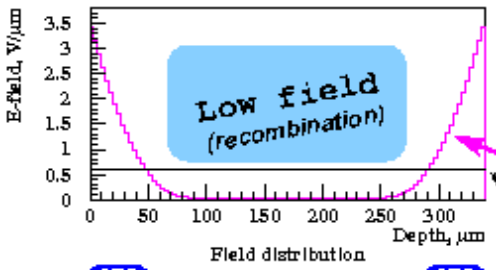
switched OFF at t=300





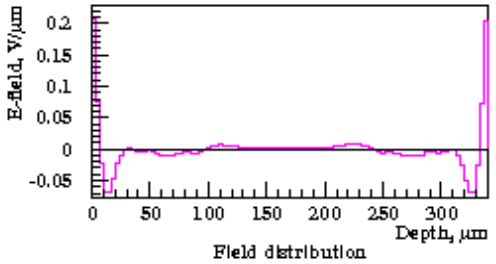






Steady state field

Initial field



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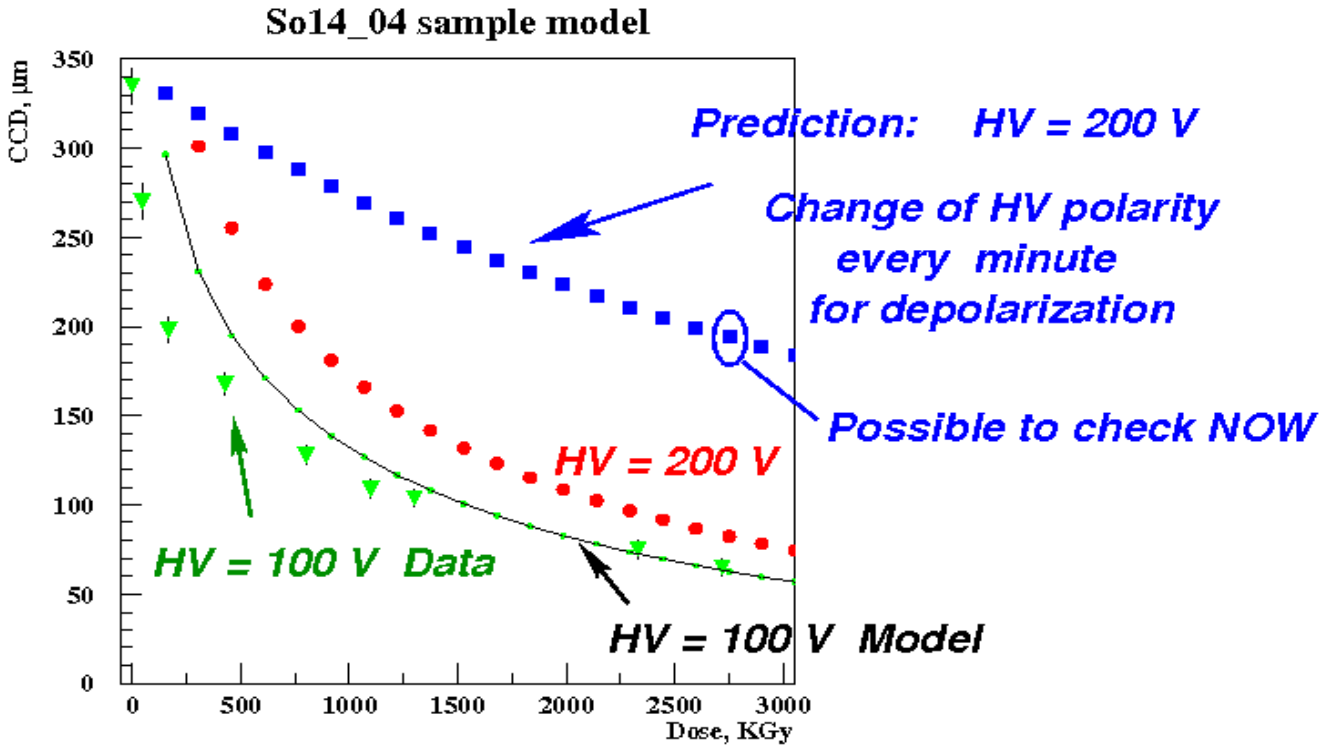
Polarization Model: CCD vs dose

(Assuming linear dependence of trap density vs dose)



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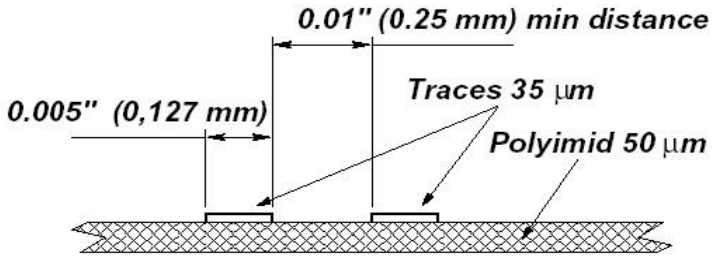
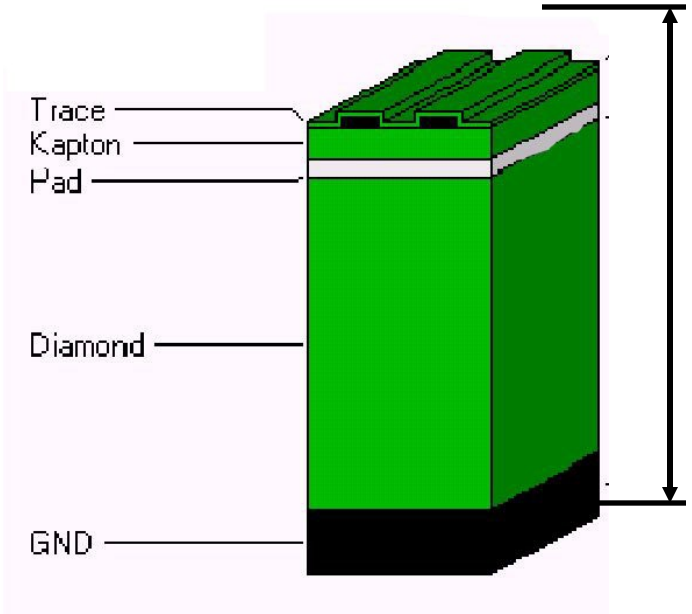
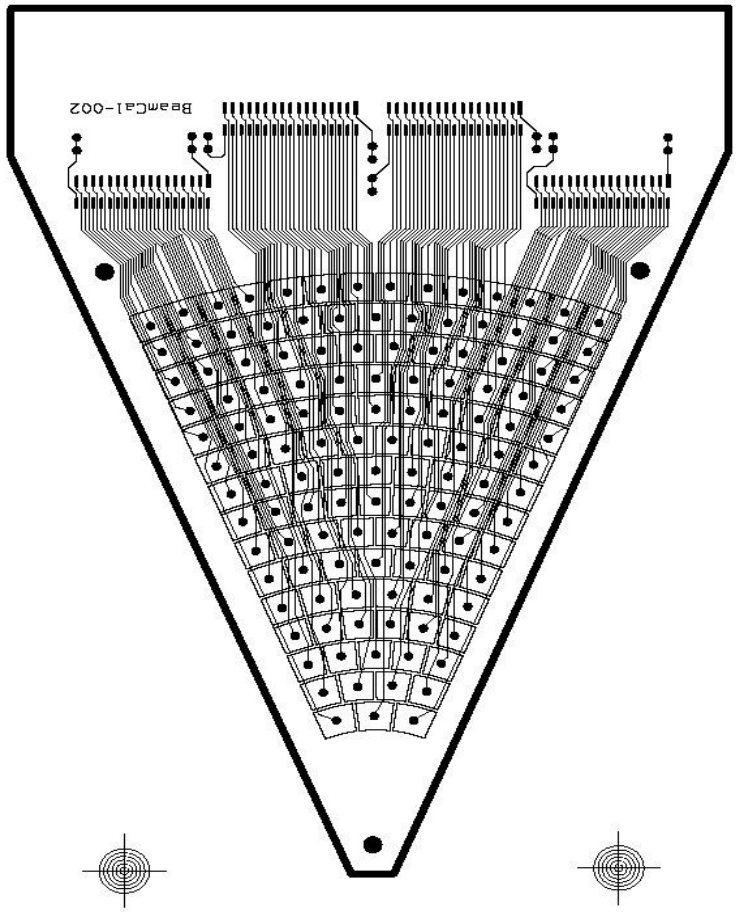
Test Structure Design





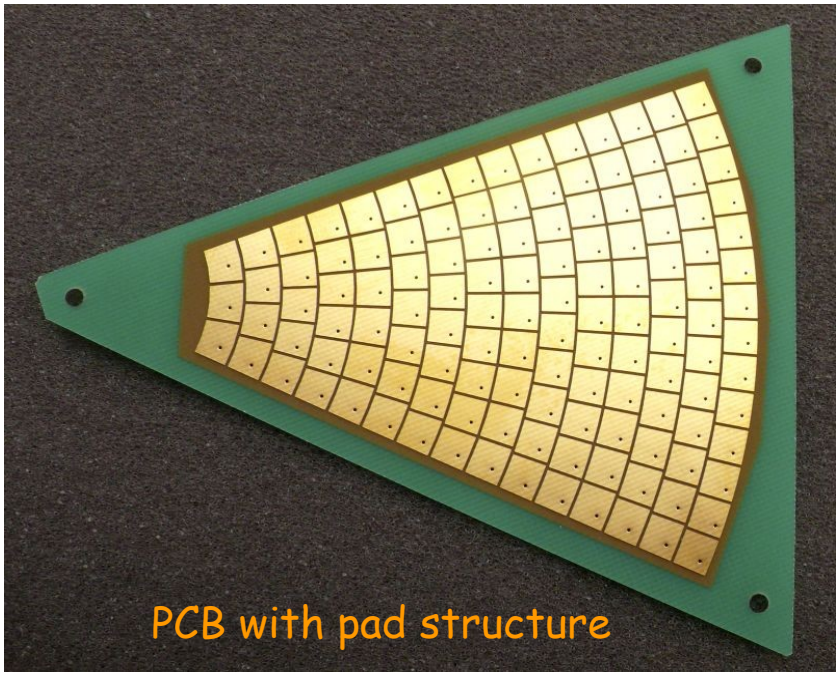
500 µm



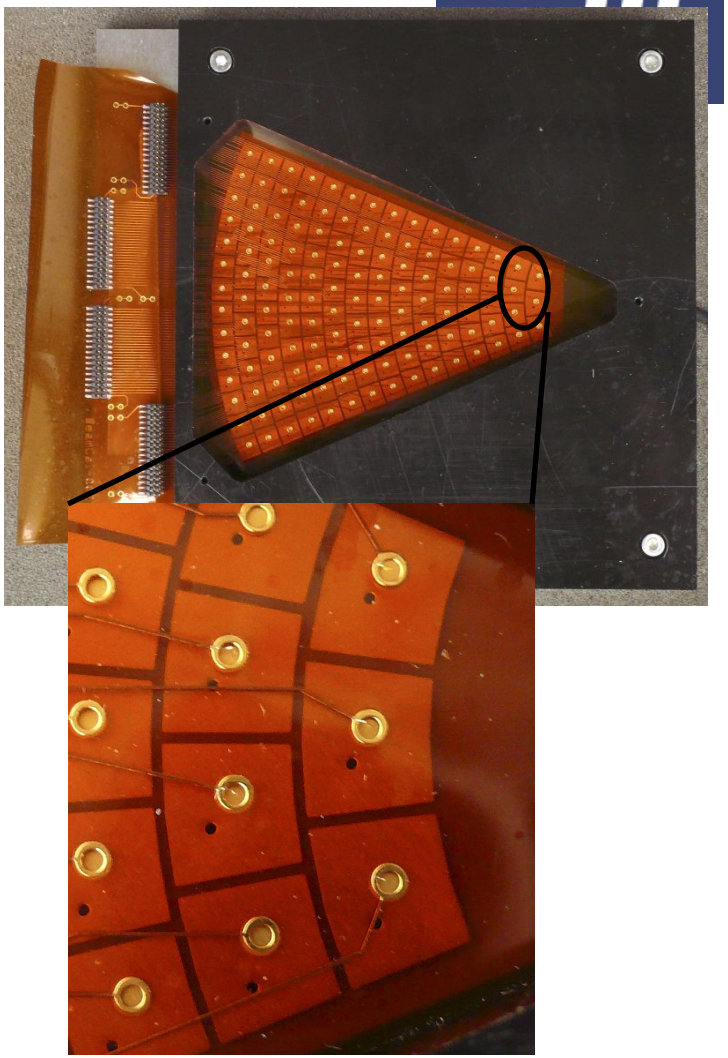
Prototype readout structure

Capton foil with conductive traces

+

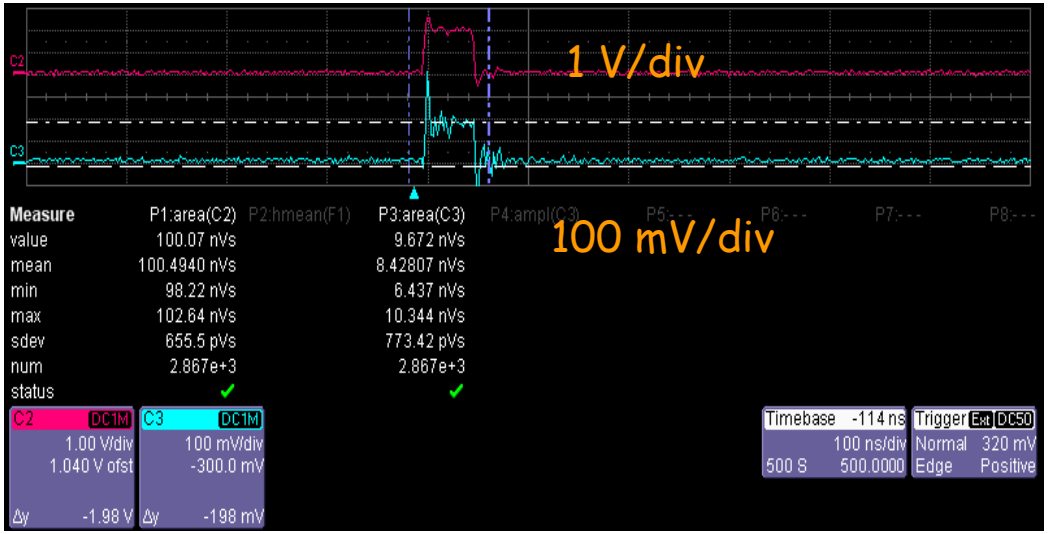


PCB with pad structure



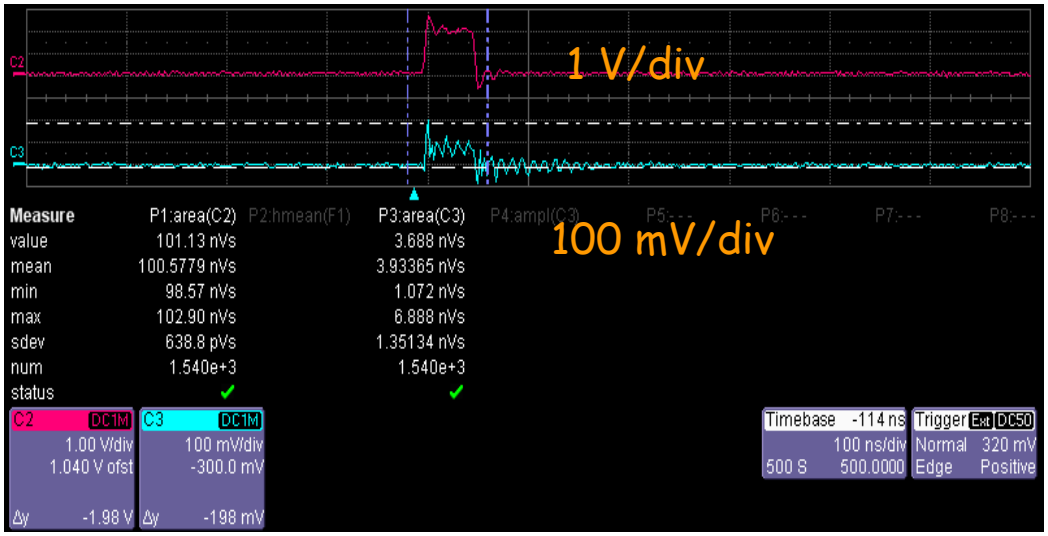
Readout structure prototype with metal pads bonded to capton readout

Prototype results



Simple experiment with signal generator and scope

Signal to crosstalk ratio approx 100/8
i.e. 8% crosstalk @
9.5 pF input capacitance



4% crosstalk @
19.5 pF input capacitance

Trace-to-Pad capacitance approx 0.8 pF

Summary

- Both poly- and single-crystalline CVD sensors stood the absorbed doses of several MGy and still able to operate properly
- GaAs sensors were operational after 500 kGy (but have larger dark current w.r.t. diamond)
- Strong polarization effects are observed in the radiation damaged sCVD
- Polarization Model is in a good agreement with observed phenomena
- Some steps towards the Readout Plane prototyping:
  - PCB simulating Readout pad structure
  - capton-based PCB for signal collection
  - first cross-talk measurements had been done
- SPICE model for the Readout Plane simulation is prepared
- To be done: .....a lot