



Beam Cal

Testbeam Results for GaAs and Radiation-hard Si Sensors

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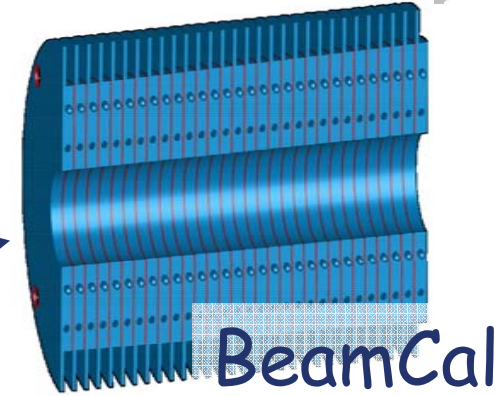
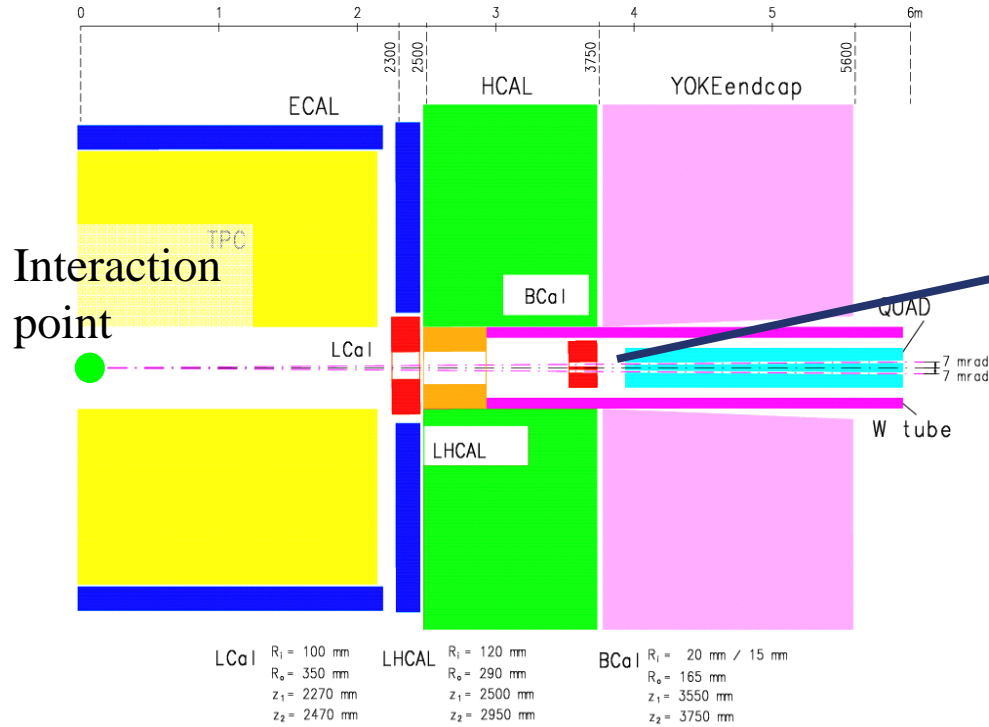
Outline



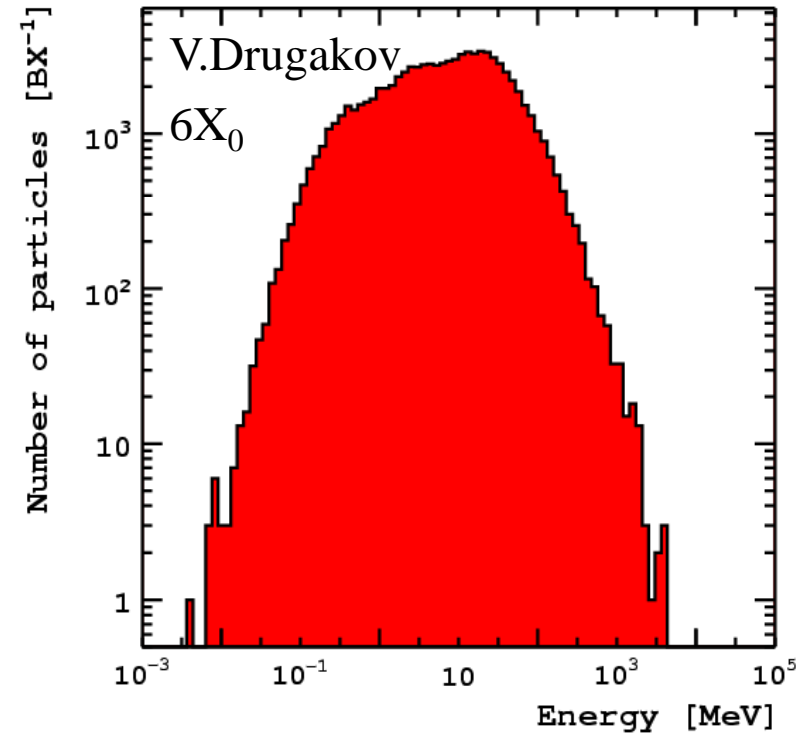
- Motivation
- Testbeam Darmstadt 2007
- GaAs Sensors
- Si Sensors



Motivation



Beamstrahlung pairs:
 mean energy @ about 10 MeV
 expected dose ~ 10 MGy/year





Testbeam Darmstadt

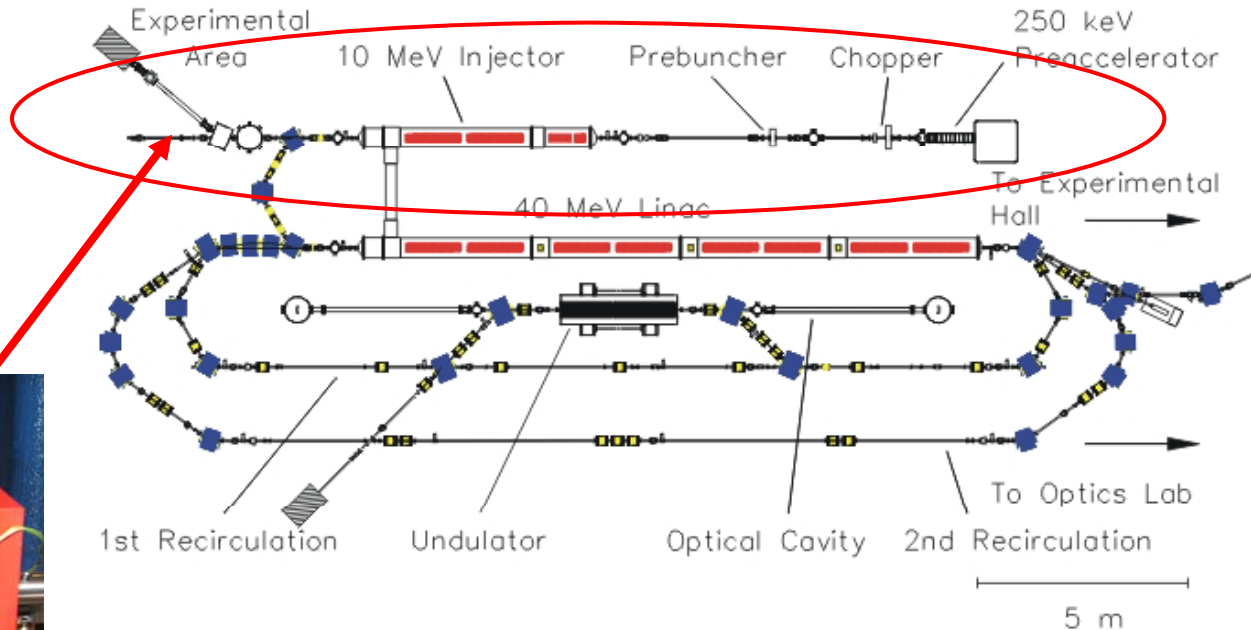
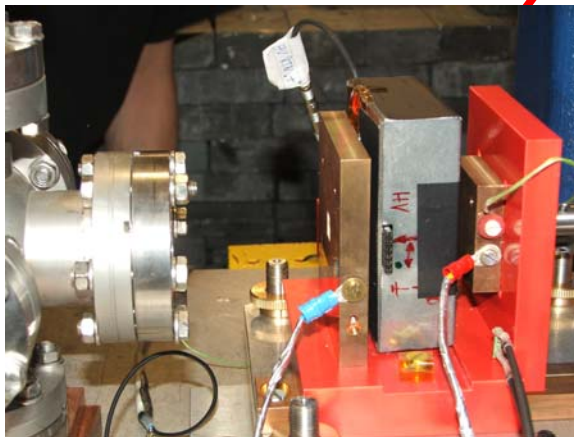


End of June 2007

10 MeV electrons

supported by many FCAL members and collaborators

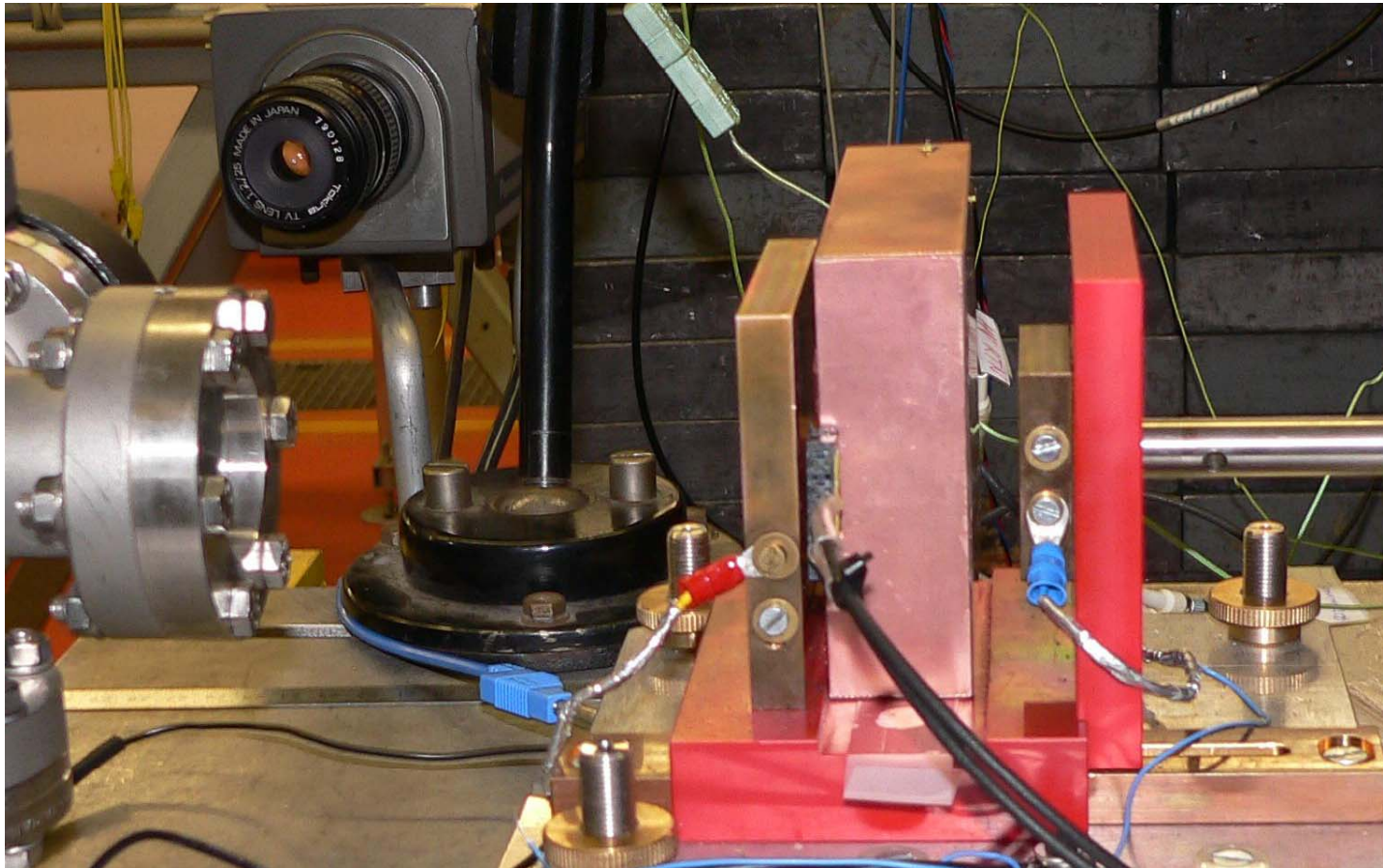
Teastbeam Setup



accumulated dose up to 5.5 MGy per sample

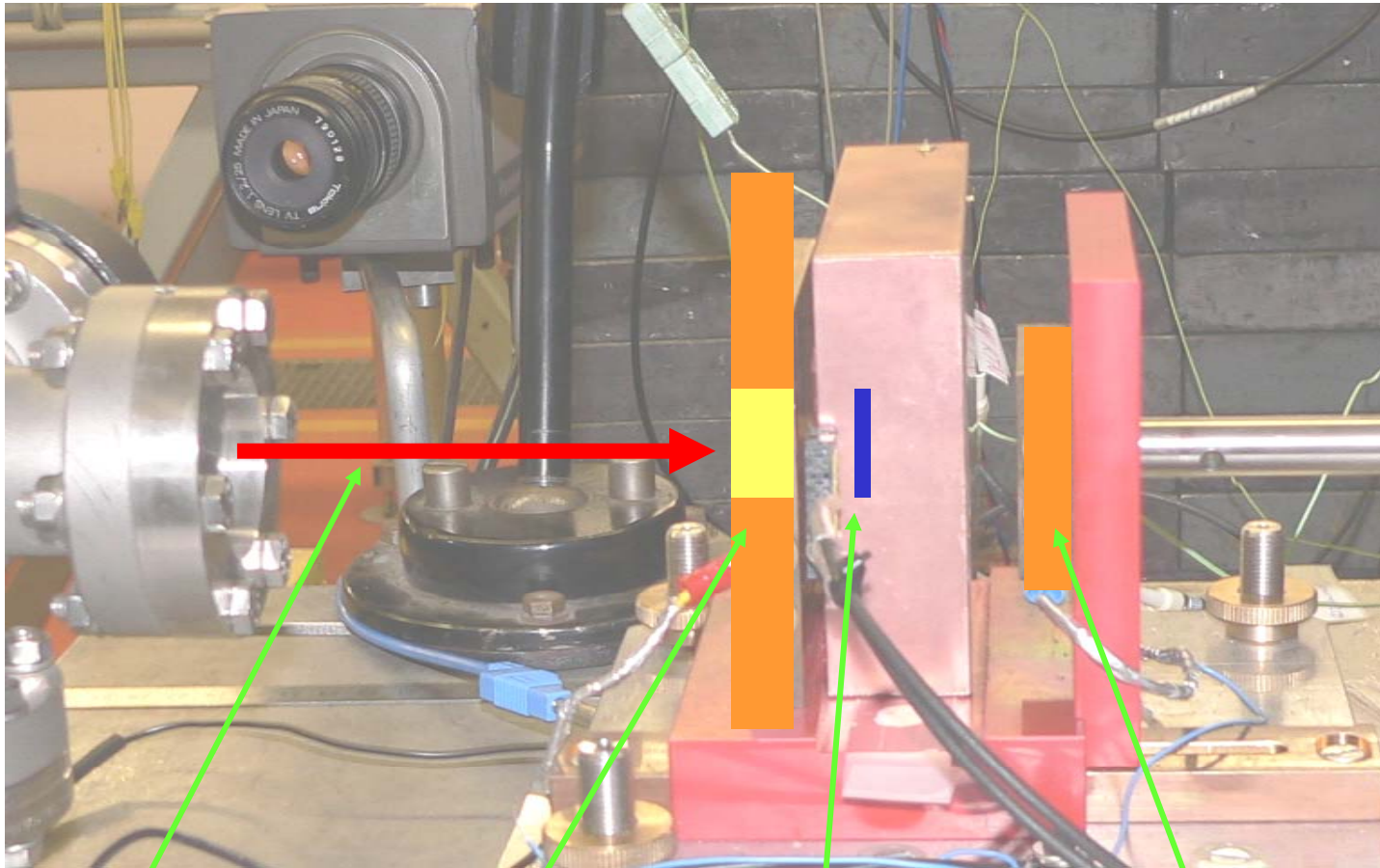


Testbeam Setup





Testbeam Setup



Beam

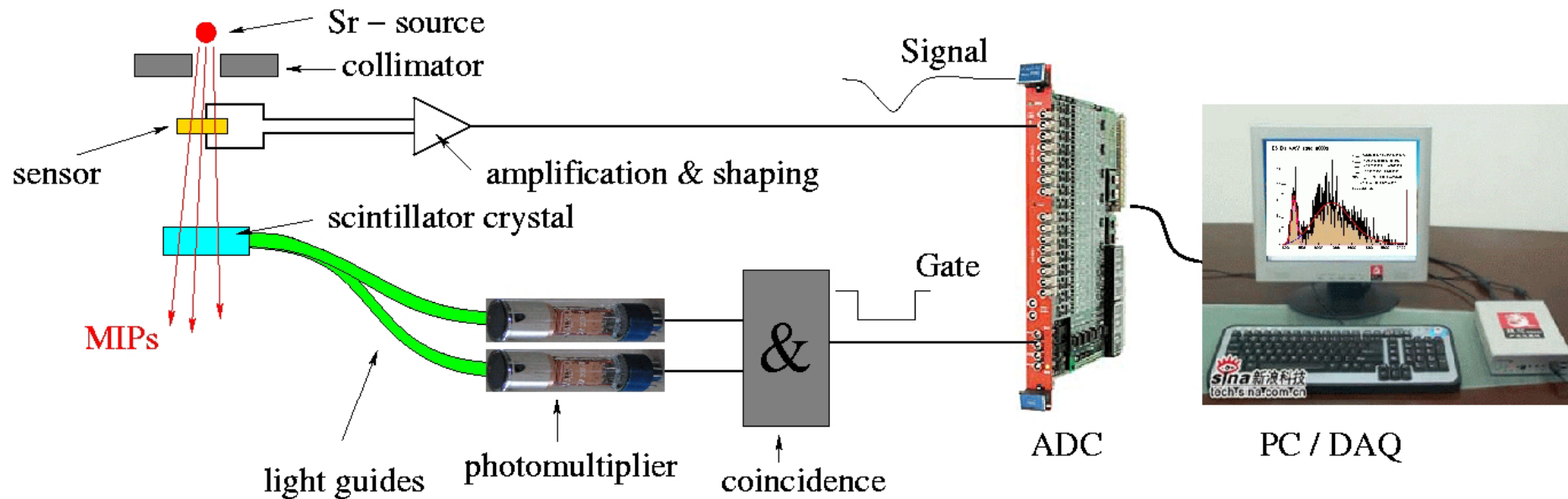
Collimator

Sensor

Faraday Cup



CCD Setup



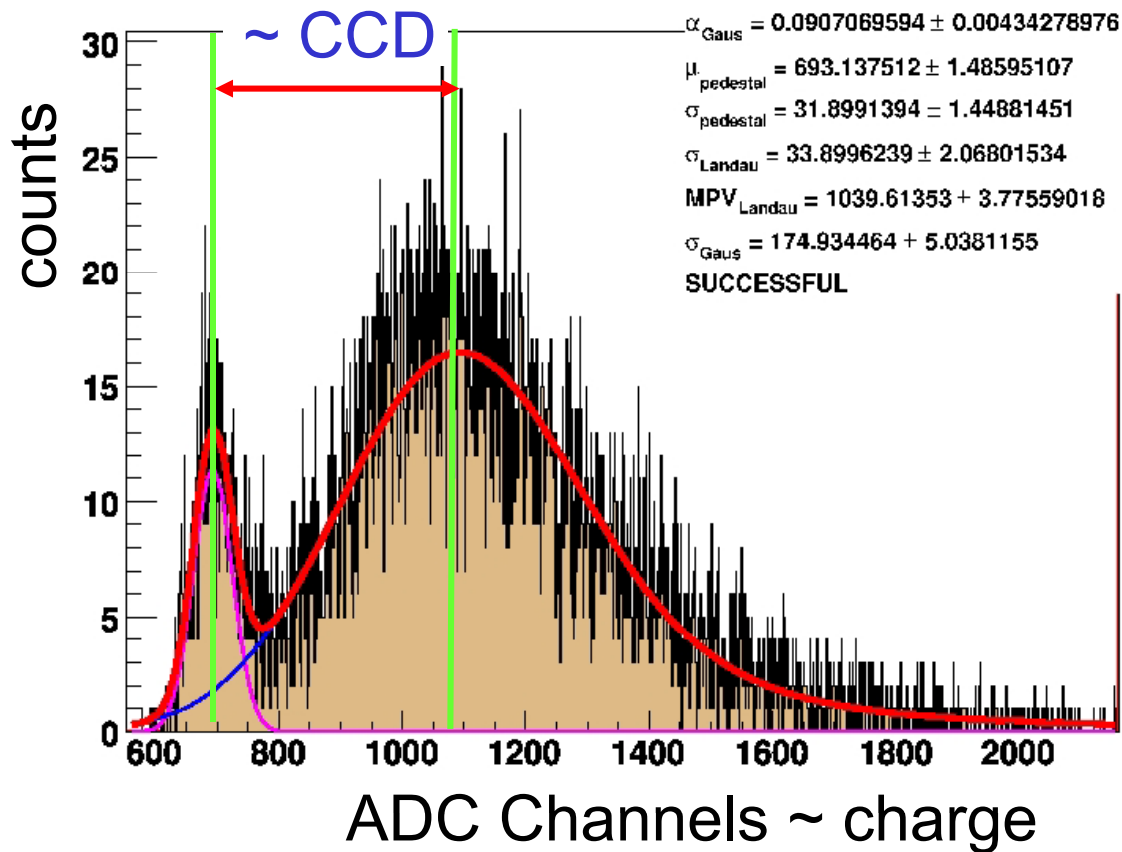
voltage applied on the sensor sample all the time



CCD



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





Irradiation Time-Table



- **pCVD diamond** (Element 6)
up to 5.5 MGy
- **sCVD diamond** (GSI DA)
up to 2.5 MGy
- **Radiation-hard Silicon** (BNL)
up to 90 kGy
- **GaAs** (JINR)
up to 0.9 MGy

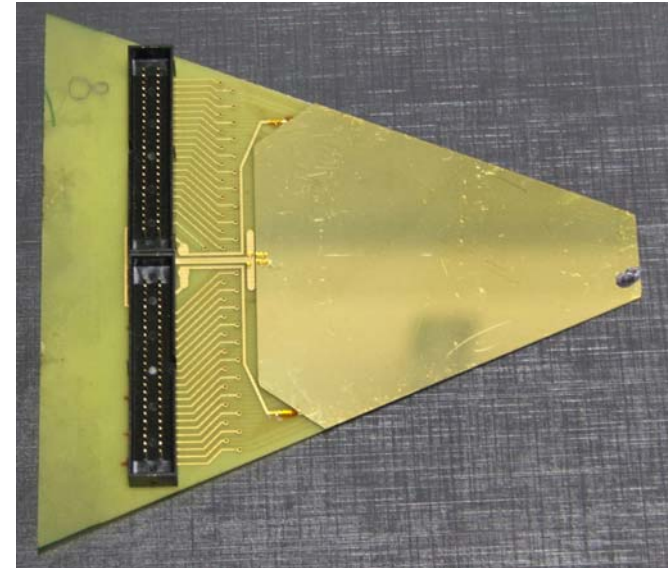


GaAs



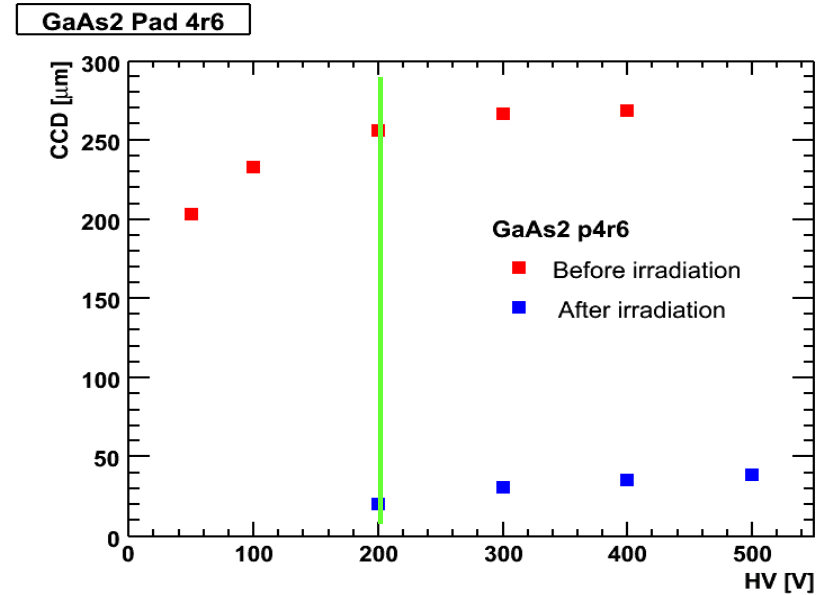
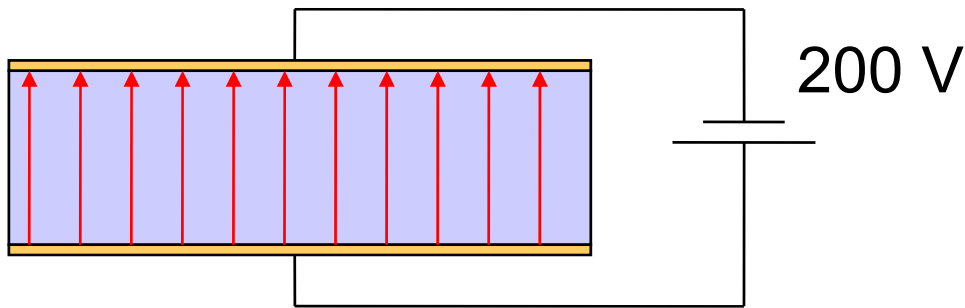
- Supplied by FCAL group at JINR
- Produced by Siberian Institute of Technology, Tomsk
- Two samples

- semi-insulating GaAs doped by Sn (shallow donor)
- compensated by Cr (deep acceptor): to compensate electron trapping centers EL2+ and provide *i*-type conductivity.





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

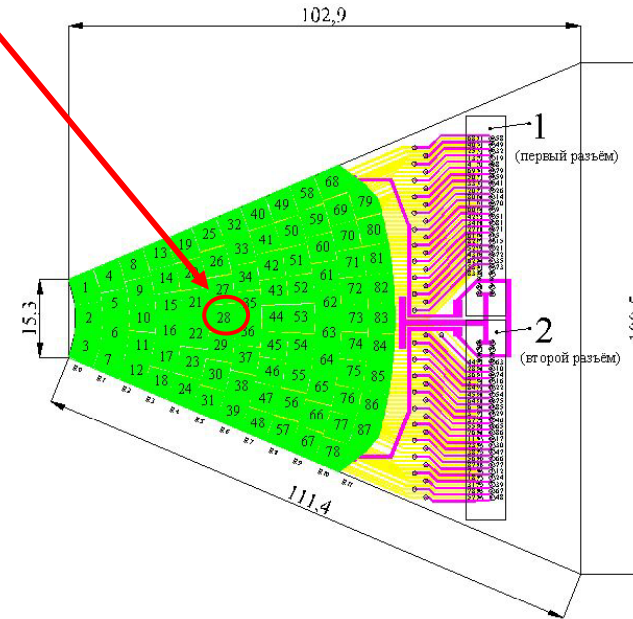
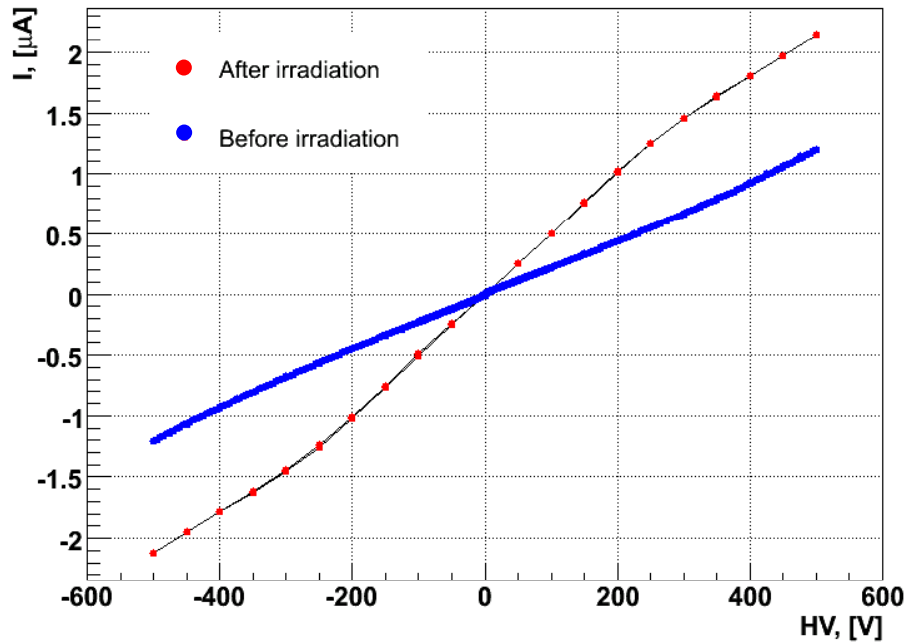
structure provided by metallisation (similar to diamond)



GaAs - Before Irradiation



GaAs2 Pad 4r6



Almost linear IV characteristics → ohmic resistor

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

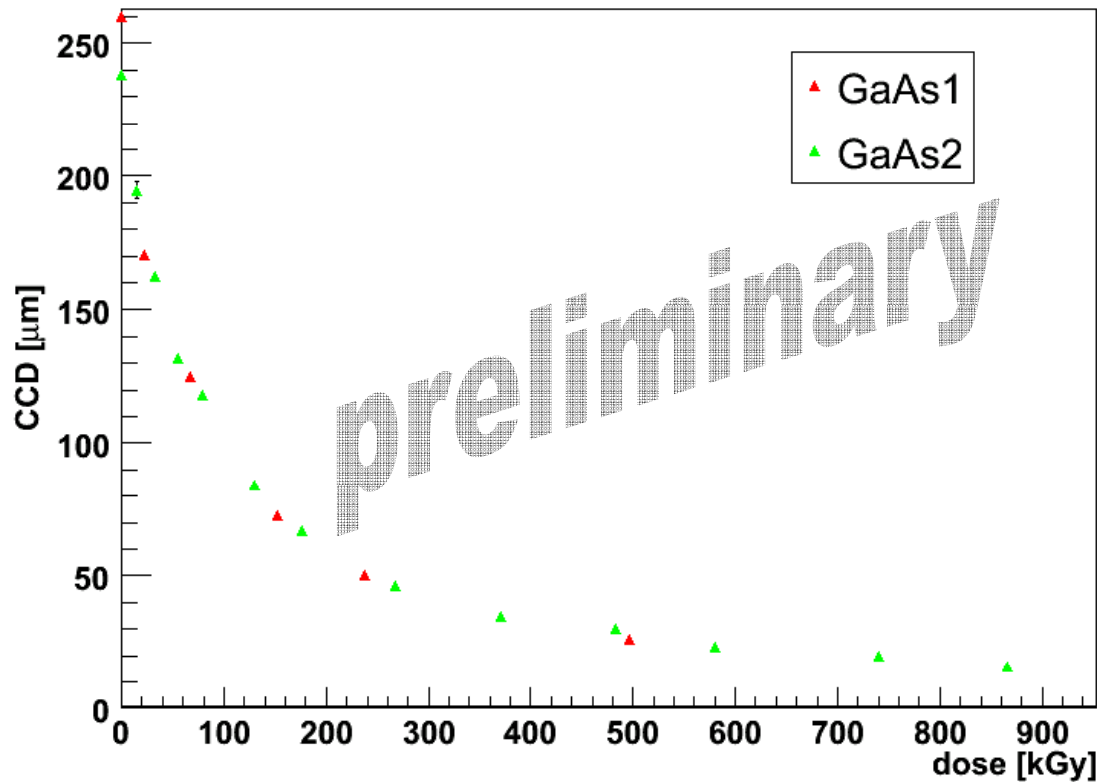
IV curve = temperature dependend due to semi-conducting character



GaAs - While Irraditaion



CCD vs DOSE for central pad (pad 4 ring 6 @ 200 V)



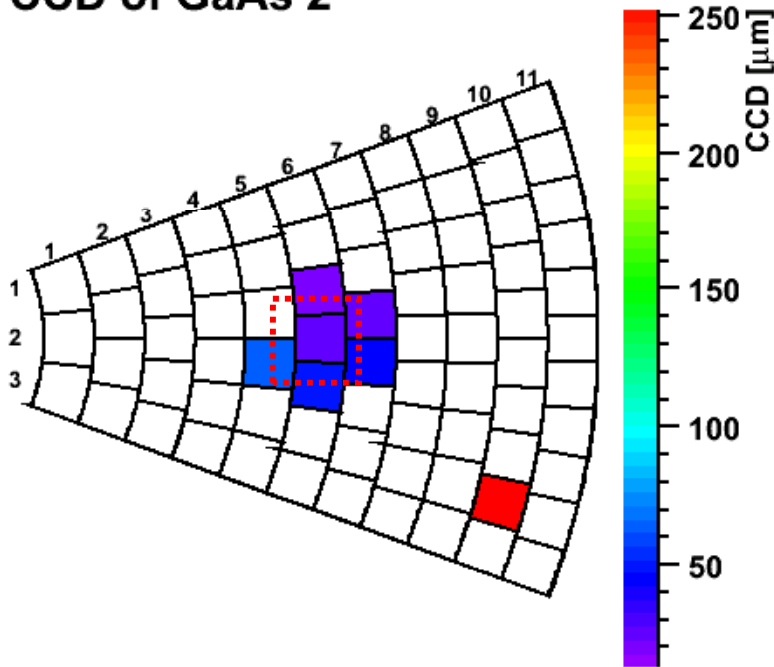
- No pumping as for pCVD diamond
- **Before irradiation:**
CCD = 50% of sensor thickness
- **While irradiation:**
almost exponential CCD drop
- **After irradiation (about 1 MGy):**
CCD = 3% of sensor thickness



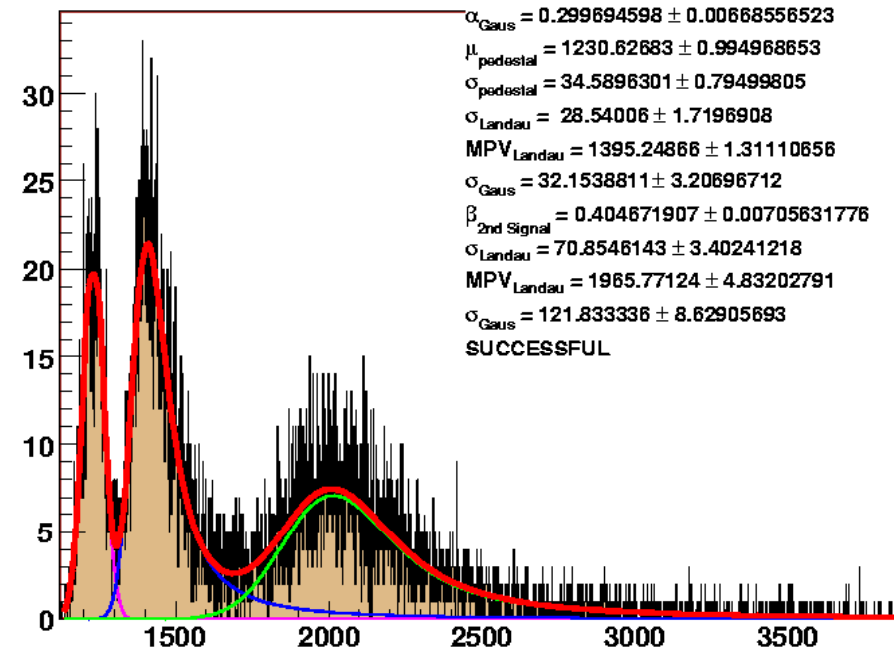
GaAs - After Irradiation



CCD of GaAs 2



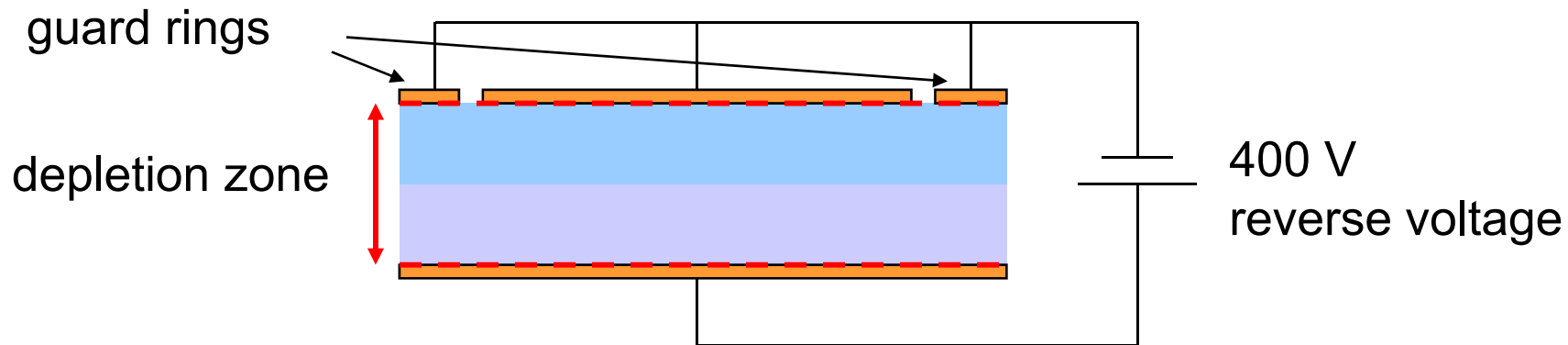
GaAs2_05-09-07_+200V_r6p5_003



- Spatial CCD distribution corresponds to beam profile
- Pad with 2 regions - due to collimation while irradiation → No Trap Diffusion
- Dark Current increased up to about $2 \mu\text{A} @ 500 \text{ V}$



Radiation-Hard Silicon



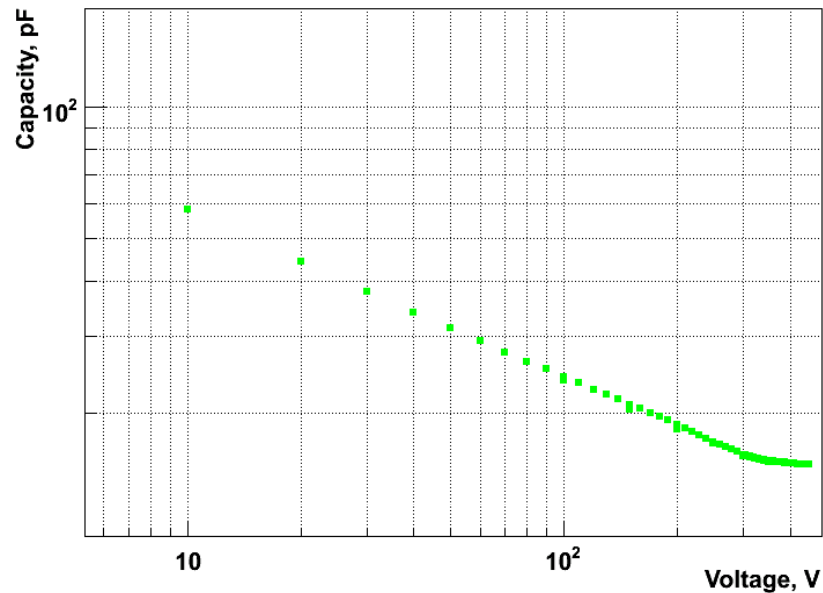
- supplied by **BNL** (Zheng Li)
- radiation hard, thickness 380 μm , 5x5 mm^2
- pn-junction in reverse voltage regime
- works as solid state ionisation chamber, but active volume = depletion zone
signal by drifting excess charge carriers
- guard rings to avoid surface currents



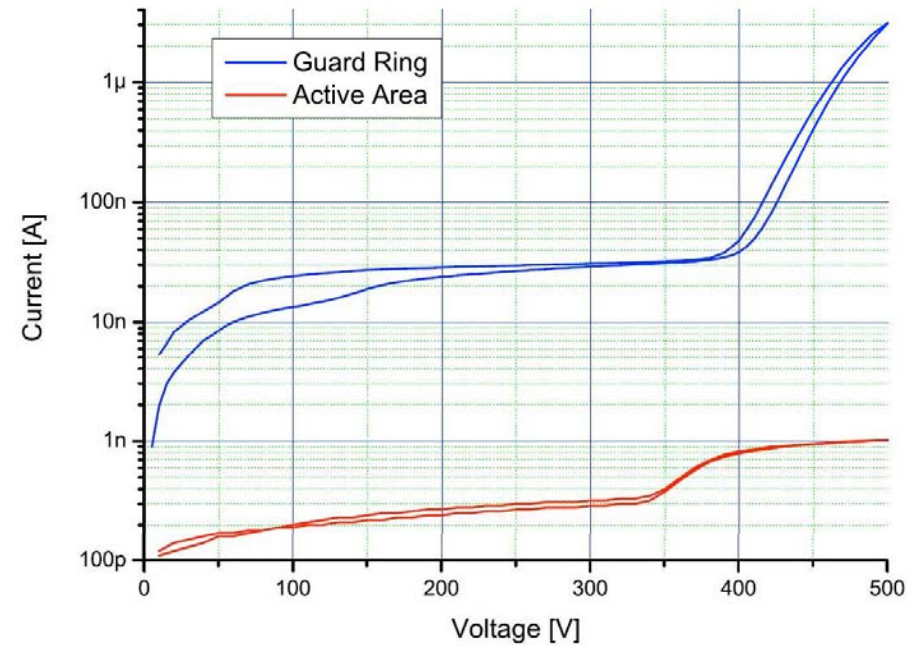
Silicon - Before Irradiation



C-V characteristic



Brookhaven Si_05-06-07



depletion voltage: 336 V → operational voltage 400 V

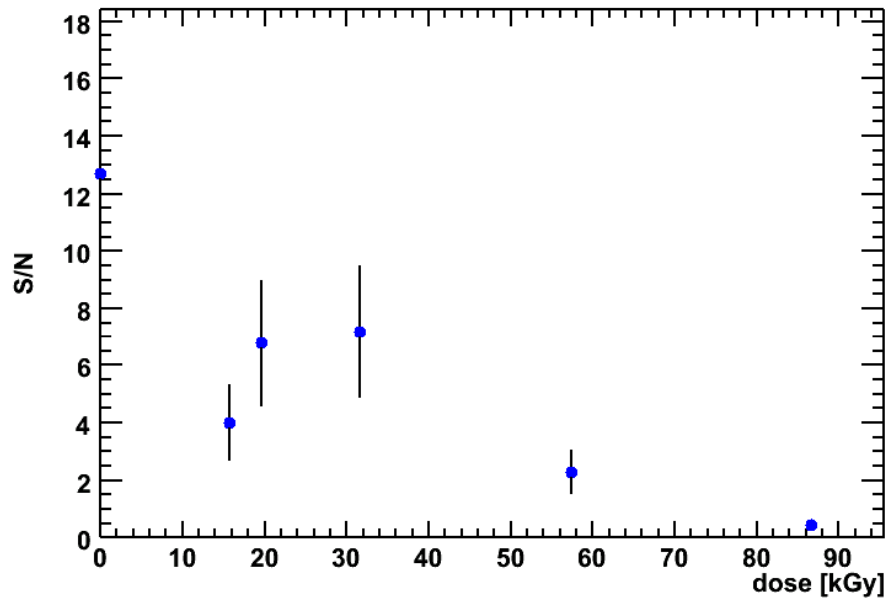


Silicon - While Irradiation



Si_BNL1

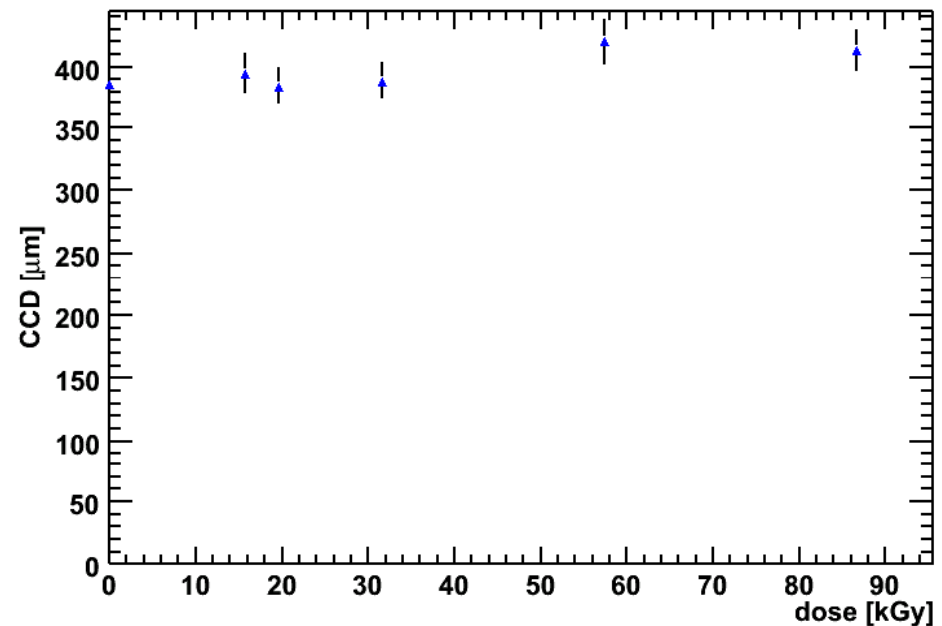
Signal-to-Noise vs DOSE



- CCD remained constant
- Noise increased strongly

Si_BNL1

CCD vs DOSE



preliminary

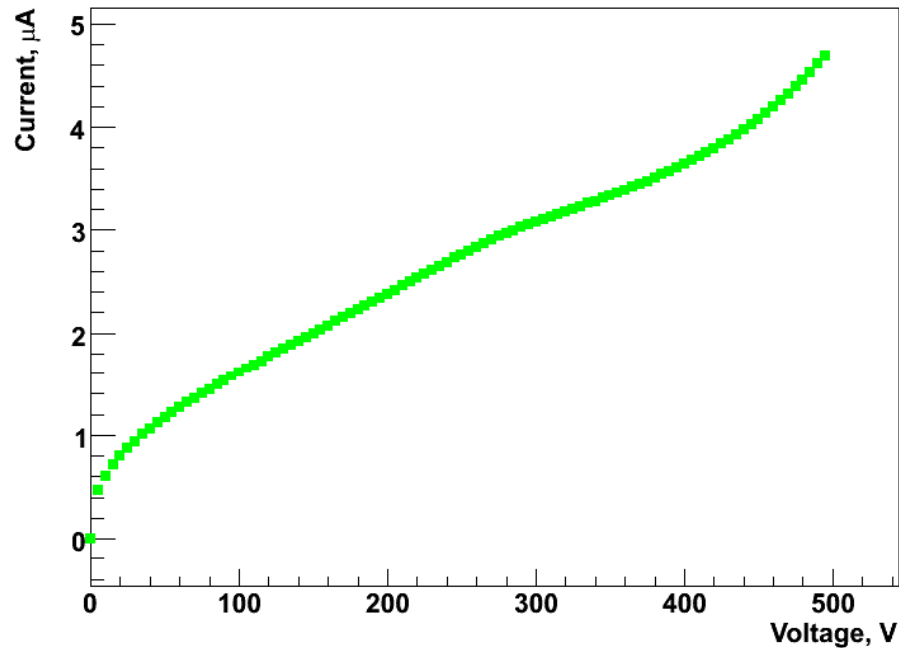
10/5/2007



Silicon - after Irradiation



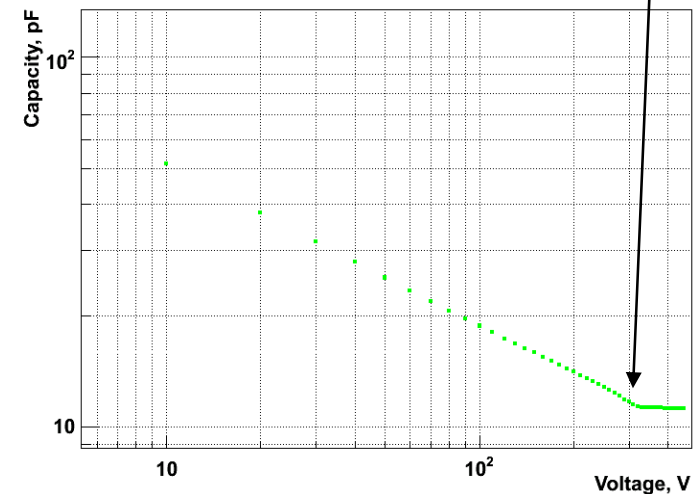
Active area current



- pn junction character maintained (same depletion voltage)
- dark current increased

no CCD measurement possible due to noise

C-V characteristic





Summary



- **GaAs (JINR):**
 - **high drop of CCD** within 1 MGy, but predictable, signal/noise ok
 - **larger dark currents** w.r.t. diamond
- **Radiation-hard Silicon (BNL):**
 - **CCD stable** in the measured range
 - ID as pn-junction kept
 - **high noise** growth with accumulated dose, cooling recommended by manufacturers