BeamCal sensors overview

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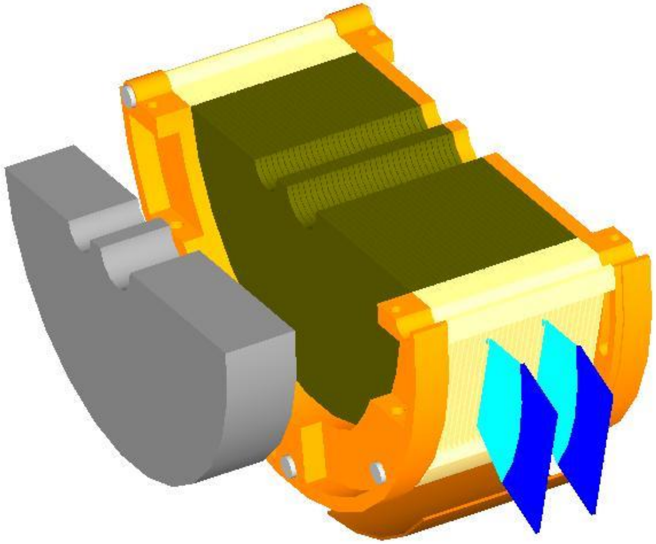
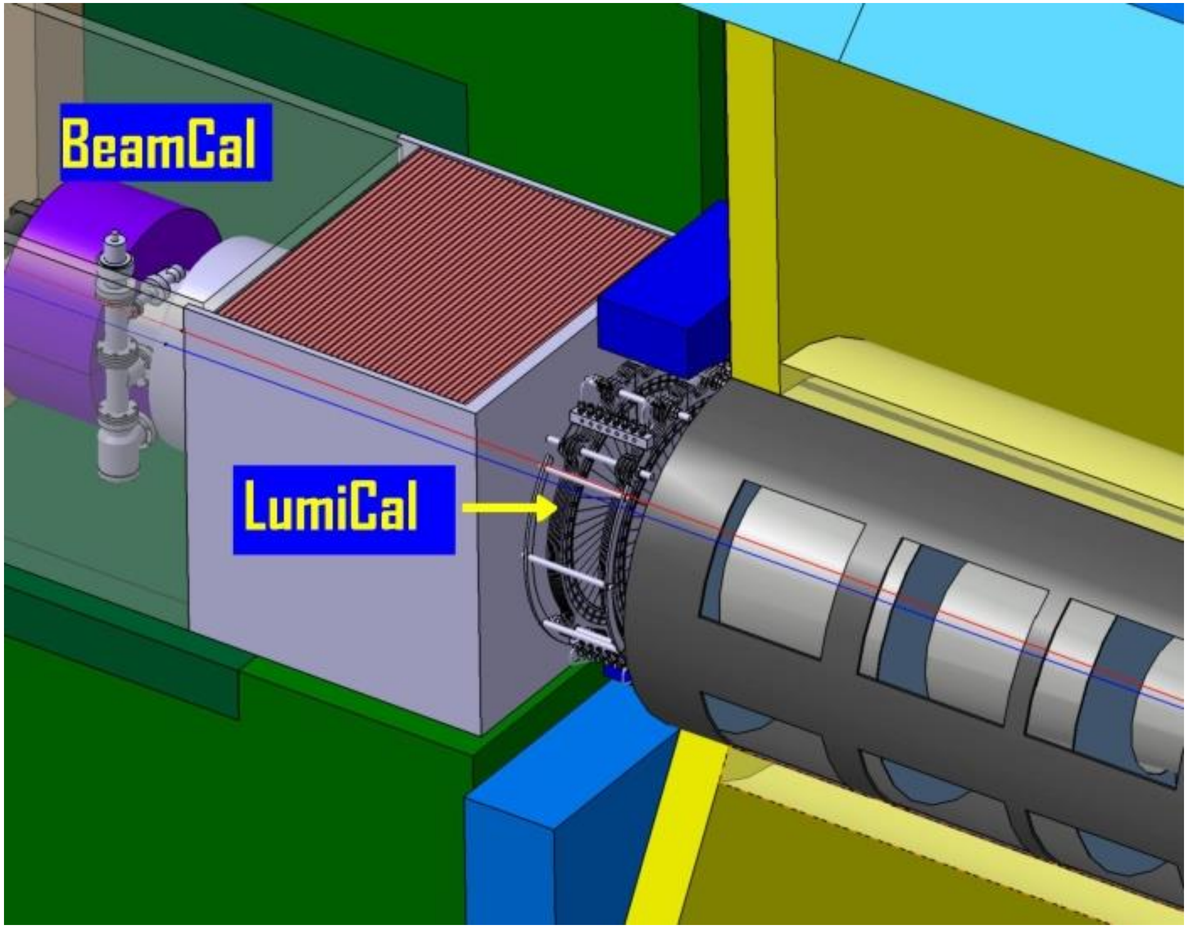


BeamCal sensor requirements



BeamCal should be compact, small Moliere radius needed:
-sampling calorimeter with solid state sensors, tungsten as absorber.

Severe load at small radii due to beamstrahlung:
- radiation hard sensors (up to 1 MGy annual dose)

Bunch-by-bunch operation:
- fast response of sensors

Test beam studies, physical calibration:
- sensitivity to MIPs

Sensor material properties

	Sapphire	Diamond	GaAs	Si
• Density, g/cm^3	3.98	3.52	5.32	2.33
• Dielectric constant	9.3 – 11.5	5.7	10.9	11.7
• Breakdown field, V/cm	$\sim 10^6$ *	10^7	$4 \cdot 10^5$	$3 \cdot 10^5$
• Resistivity, $\Omega \cdot cm$	$>10^{14}$	$>10^{11}$	10^7	10^5
• Band gap, eV	9.9	5.45	1.42	1.12
• El. mobility, $cm^2/(V \cdot s)$	>600 **	1800	~8500	1360
• Hole mobility, $cm^2/(V \cdot s)$	-	1200	-	460
• MIP eh pairs created, eh/μm	22	36	150	73

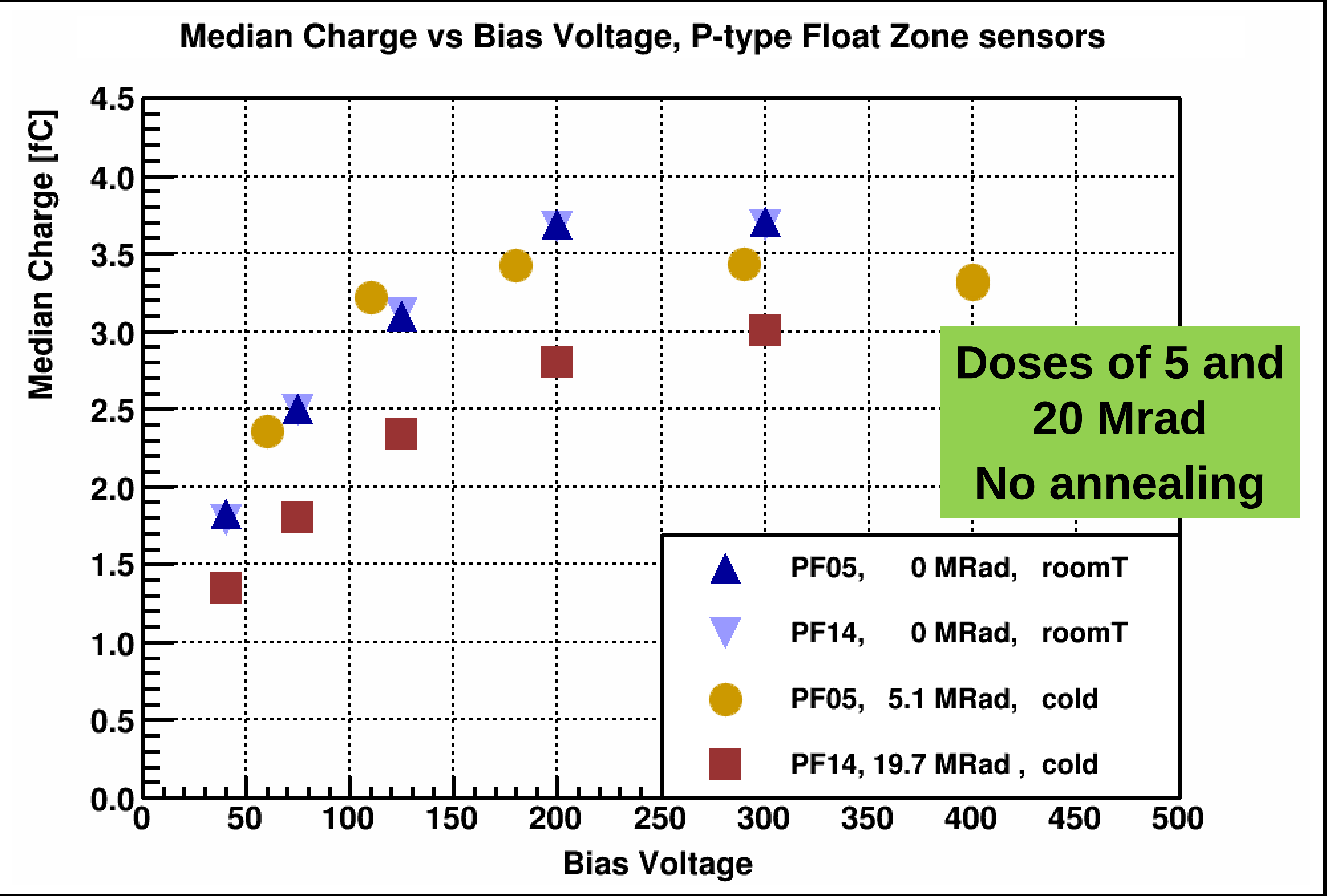
* Typical operation field $\sim 1\text{-}2 \cdot 10^4$ V cm^{-1}

** at 20ºC, ~30000 at 40ºK

Radiation Hardness

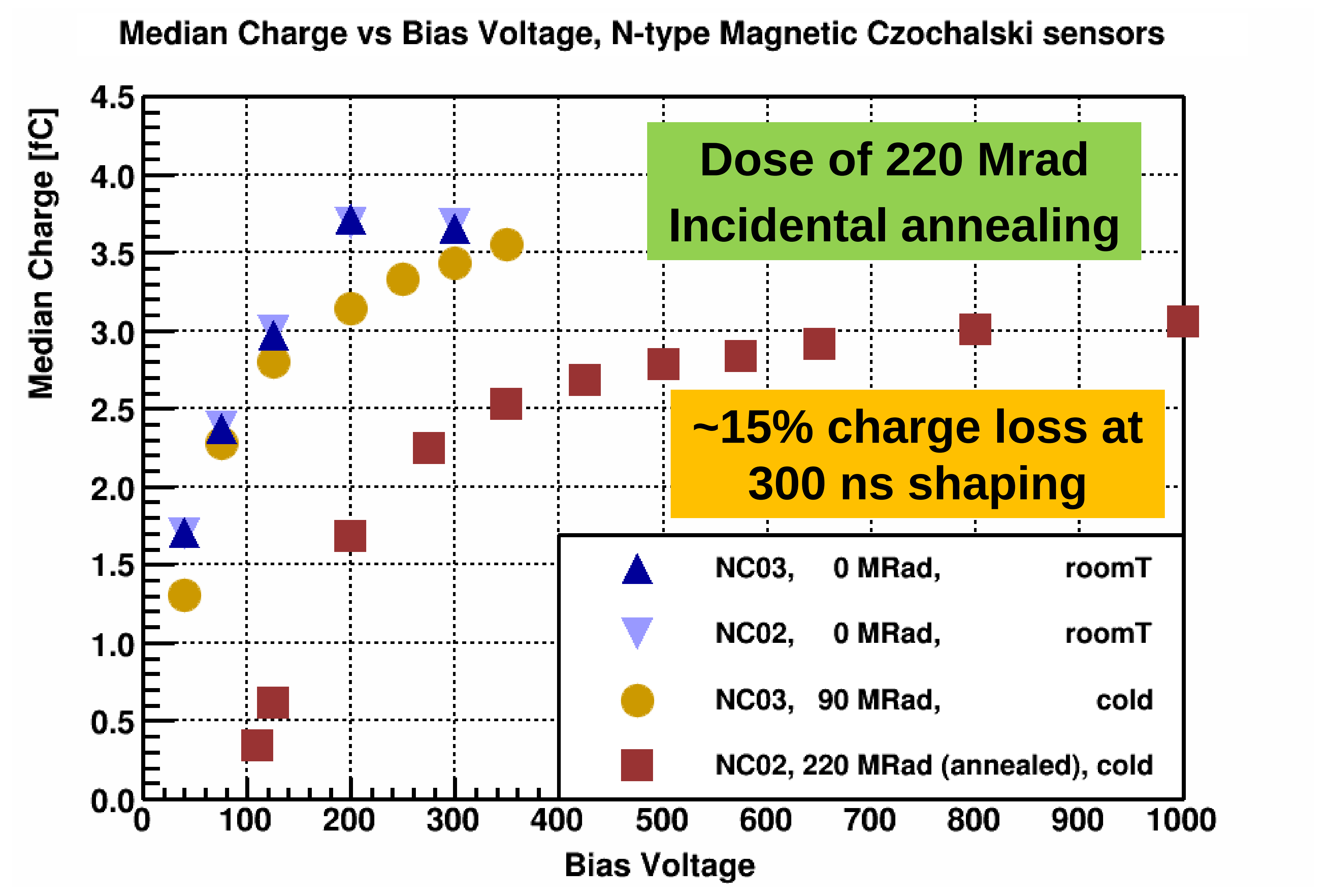
Bruce Schumm,
25th FCAL WS

Results: PF sensors

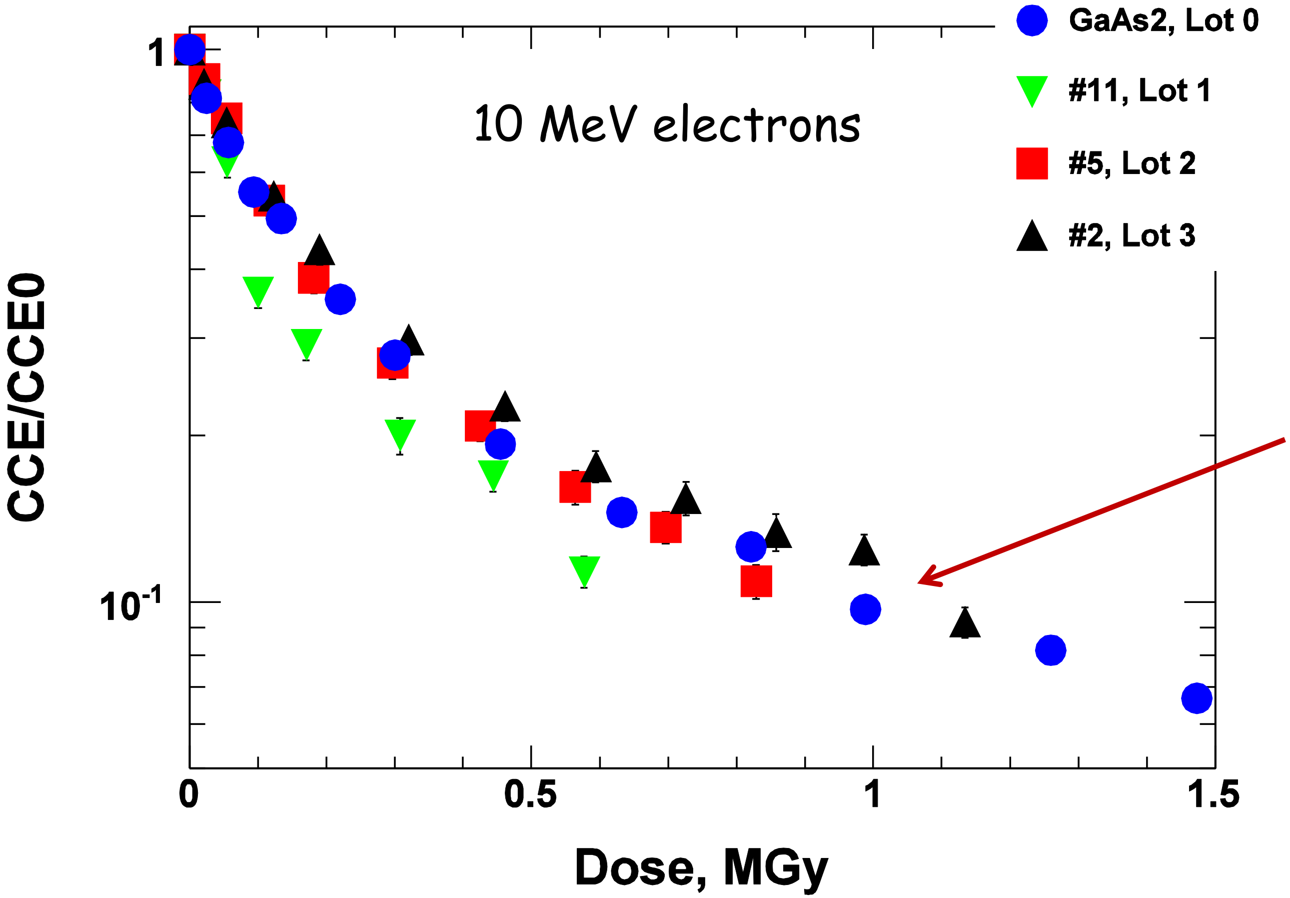


Bruce Schumm, 25th FCAL WS

Results: NC sensors



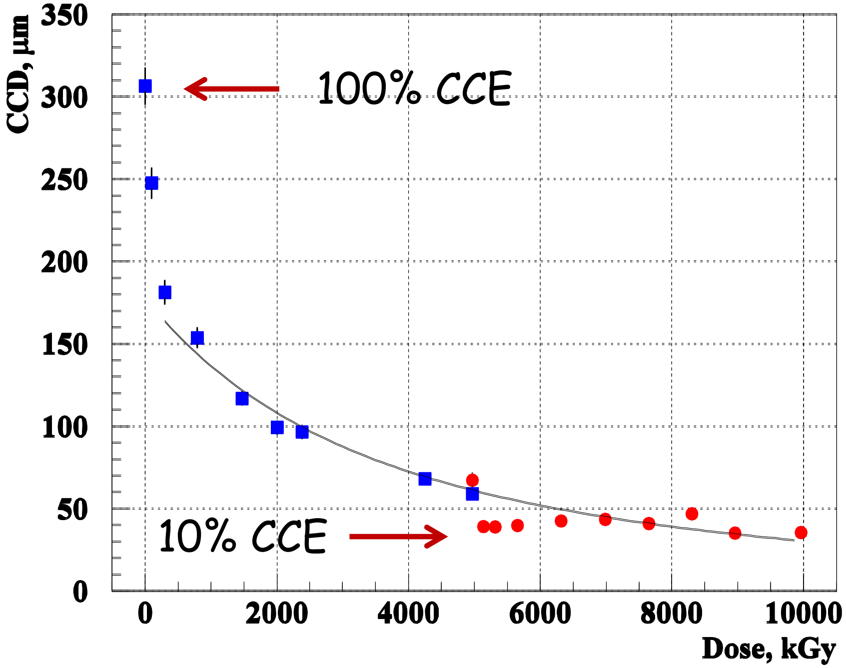
Irradiation of GaAs sensors



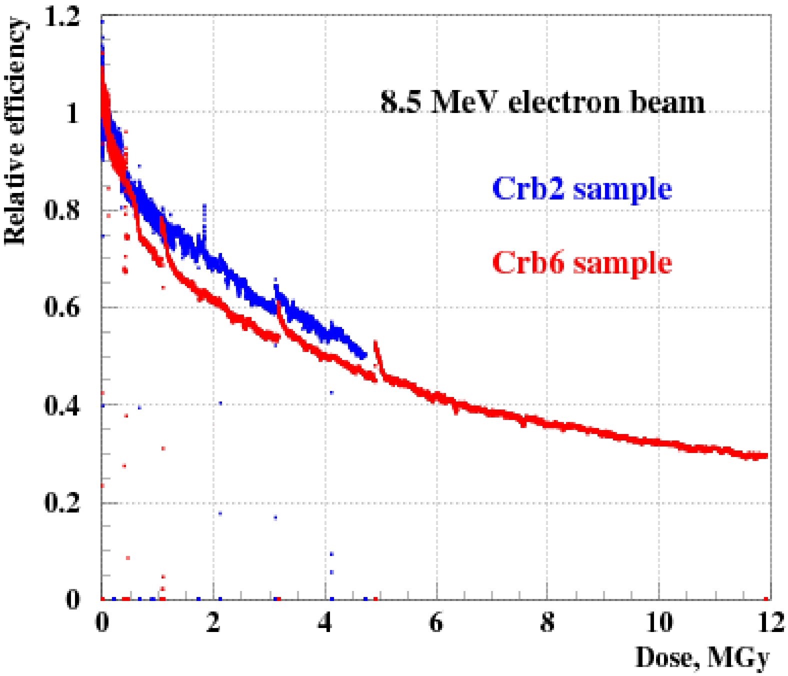
Few μA leakage current after 1 MGy dose (extra noise!)

Irradiation of sapphire and diamond sensors at ~10 MeV electron beam

Single crystal CVD diamond



Single crystal sapphire

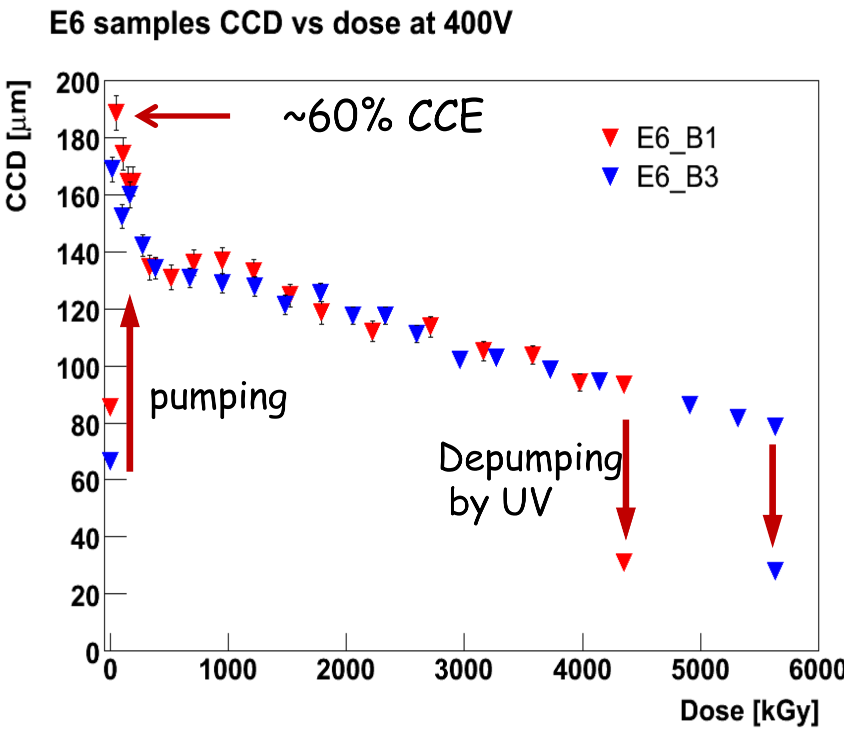


Leakage current after irradiation is still at few pA level

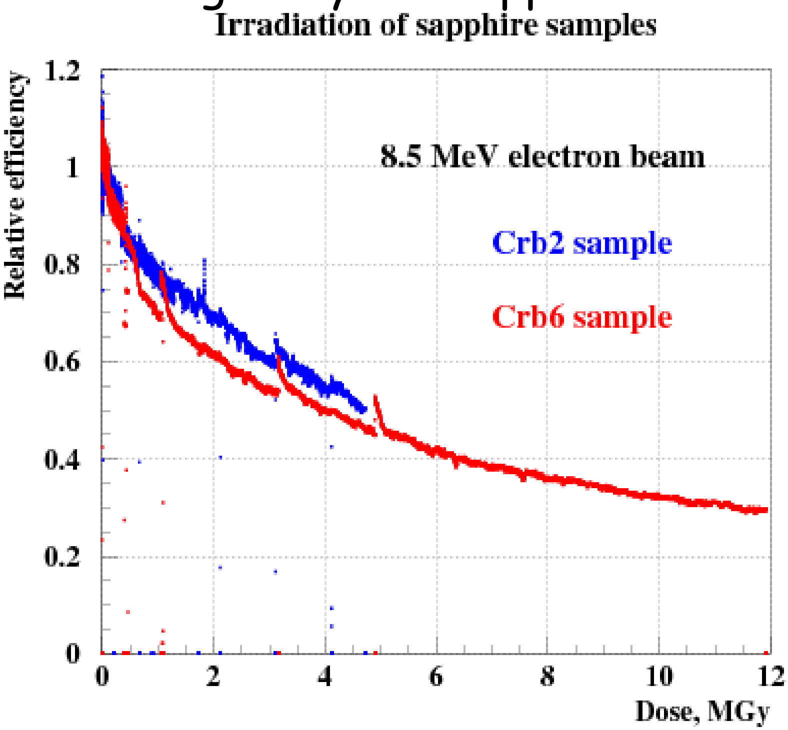
10 MGy ~ $5 \cdot 10^{16}$ MIPs ~ $2.5 \cdot 10^{15}$ [1 MeV neq] (NIEL,Summers)

Irradiation of sapphire and diamond sensors at ~10 MeV electron beam

Polycrystalline CVD diamond



Single crystal sapphire



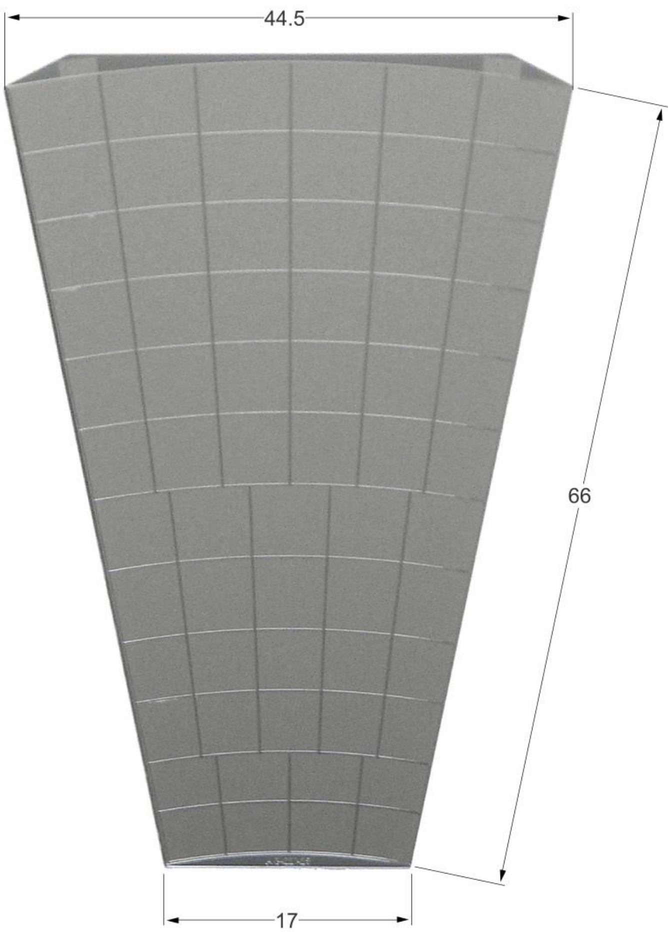
Leakage current after irradiation is still at few pA level

10 MGy ~ $5 \cdot 10^{16}$ MIPs ~ $2.5 \cdot 10^{15}$ [1 MeV neq] (NIEL,Summers)

BeamCal design

Baseline design

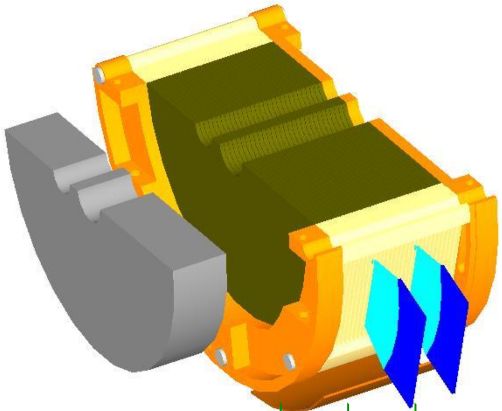
- 30 layers (3.5 mm W + 0.5 mm sensor*)
- Rin = 20 mm, Rout(sens)=150 mm
- Sensor material - GaAs

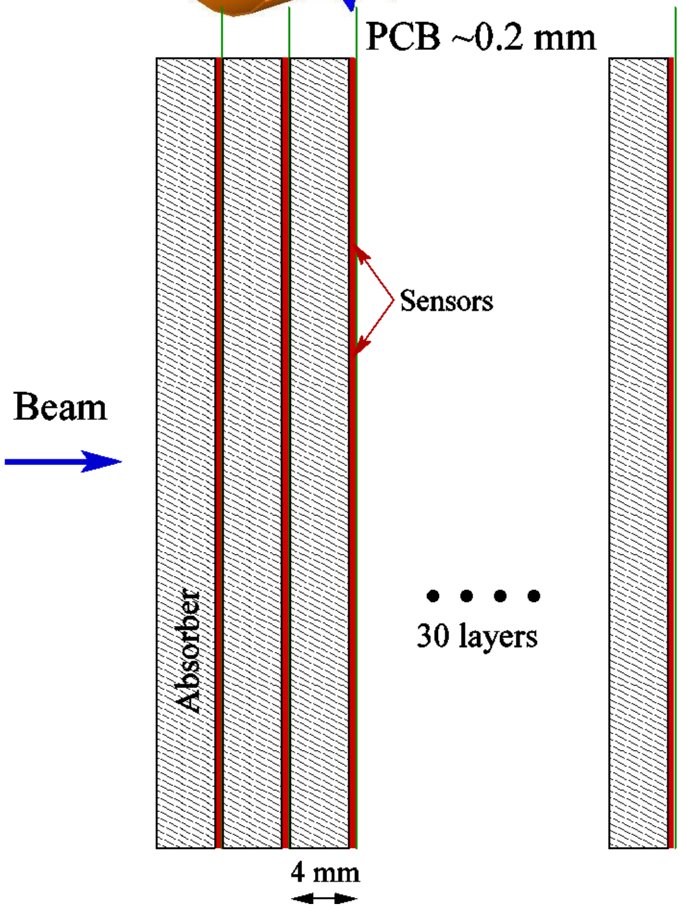


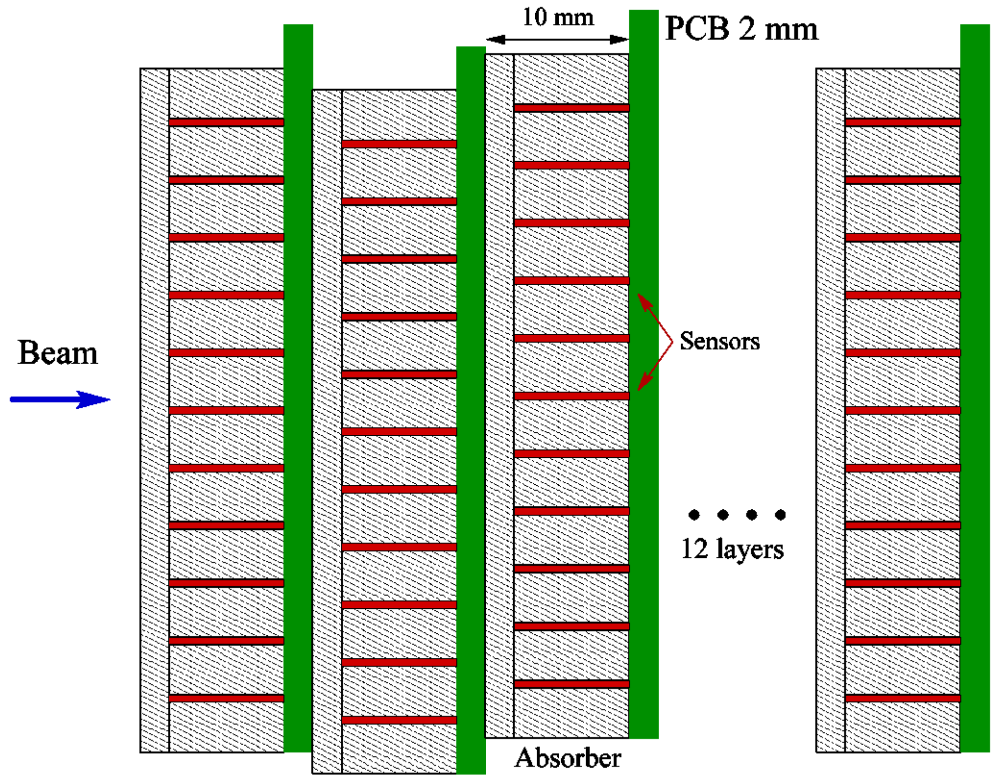
Sensor prototype:

- Wafer size – 74 mm eff. diameter
- Thickness 500μm (thinner – problematic)
- 2 rings of sensors (GaAs + Si for outer?)
- Thin fanout PCB (Hans), bonding (2 options)
- Cost ~650 Euro/pc (312kE/Calorimeter, even if only inner ring is made out of GaAs)

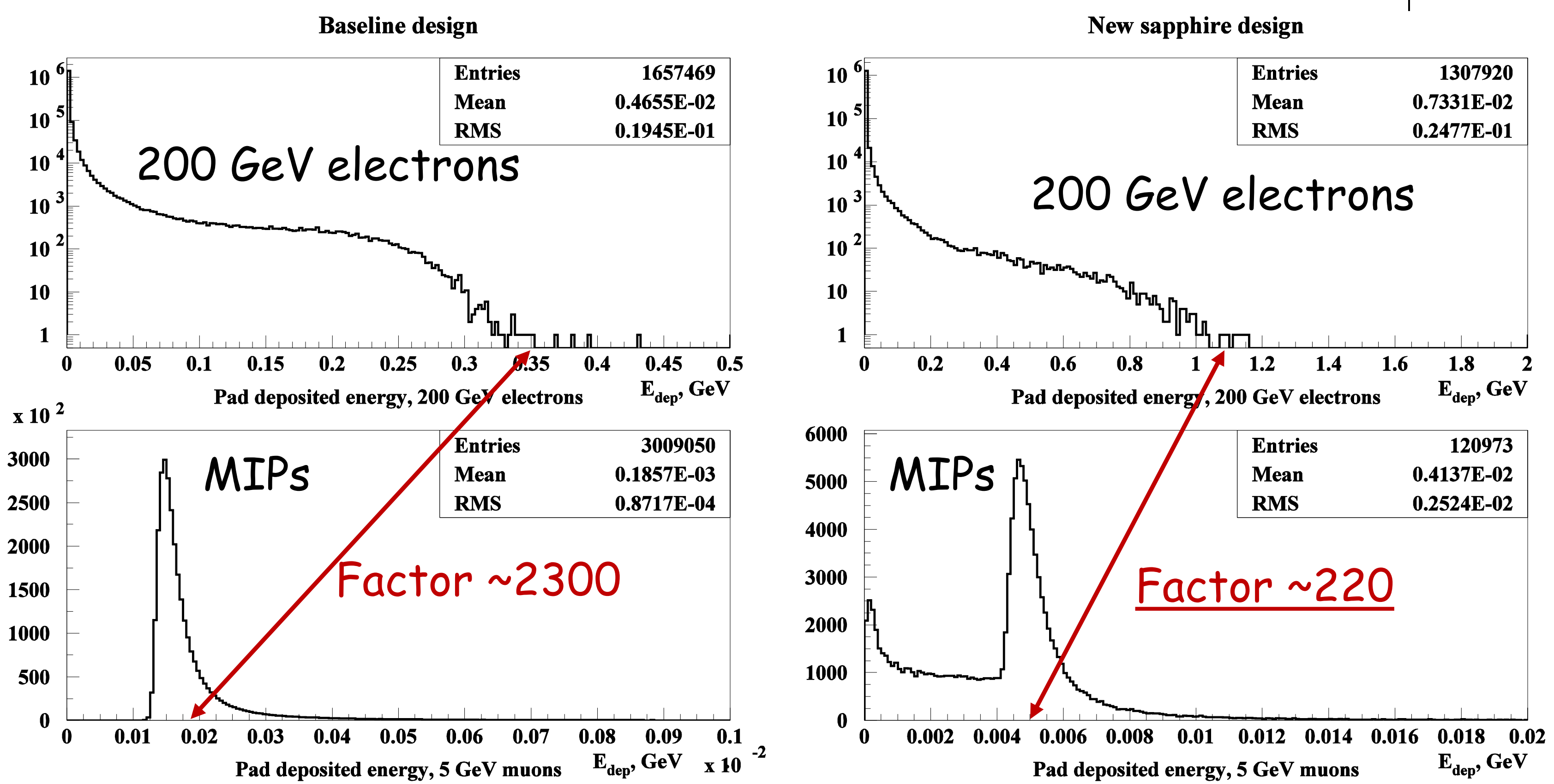
Modification of BeamCal design for sapphire sensors application





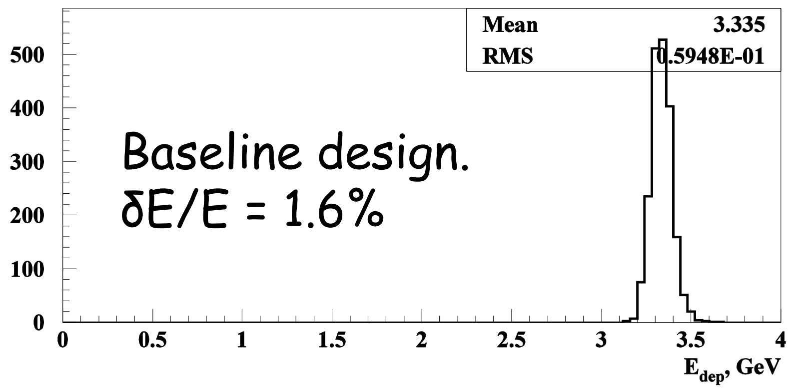


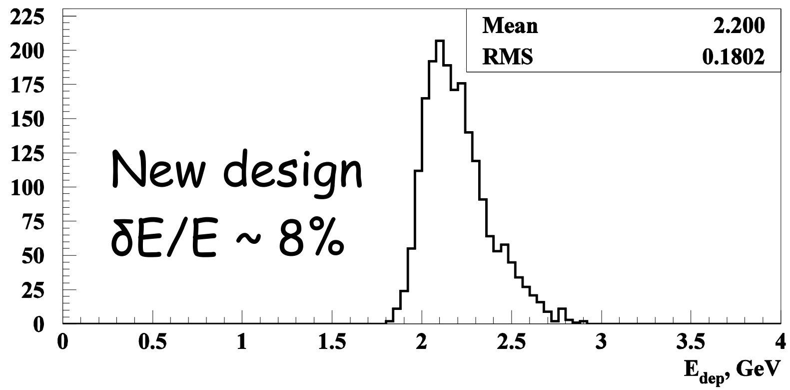
Dynamic range needed for BeamCal Readout (high energy electrons/MIPs)

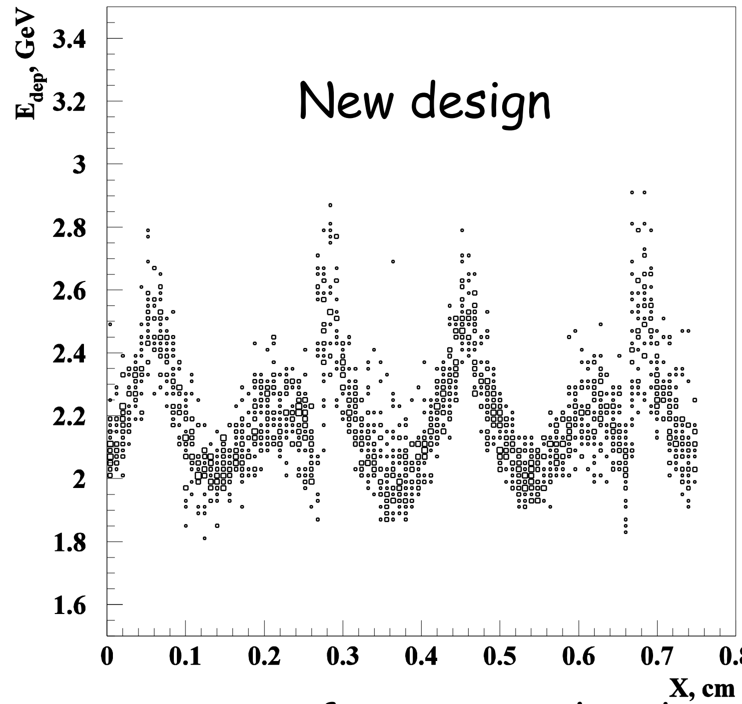


BeamCal energy resolution

200 GeV electrons,   GEANT3 Monte Carlo







Response nonuniformity in the direction, perpendicular to the strips, depends on relative layer positioning. Further optimization is needed.

Plans

- Prepare 4 GaAs sensor planes for the next test beam
- Sapphire sensors: detailed BeamCal design, MC studies
- Develop sapphire wafers quality control (UV + visible light?)
- New design BeamCal prototype, based on sapphire sensors
- Test beam studies
- Manpower? Resources?