SENSOR DEVELOPMENTS (BeamCal)

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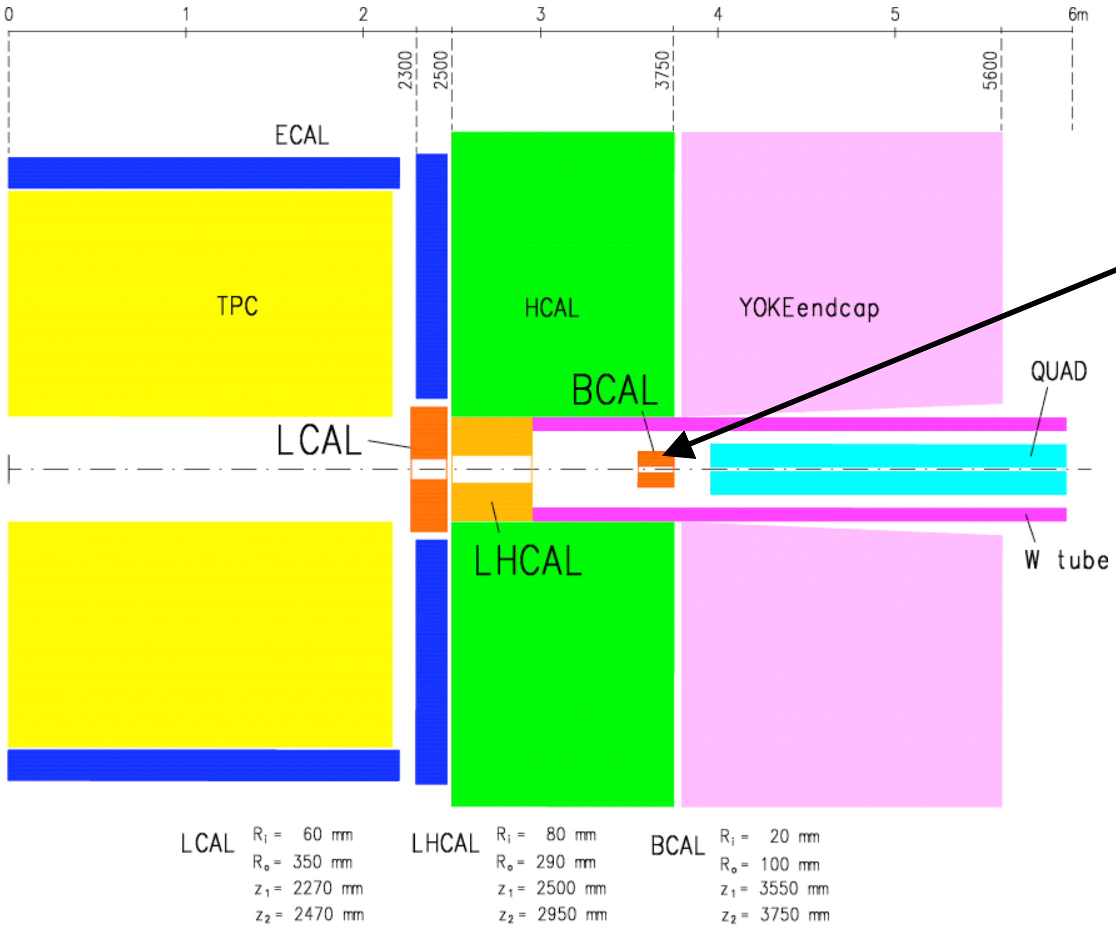
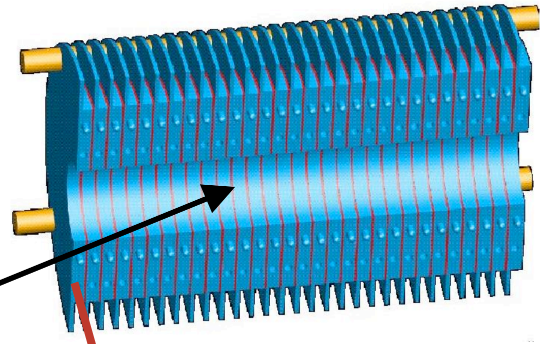
OUTLINE OF THIS TALK

1. Introduction
2. Silicon
3. CVD Diamonds
4. Gallium Arsenide
5. Silicon Carbide
6. Conclusions

INTRODUCTION





BeamCal

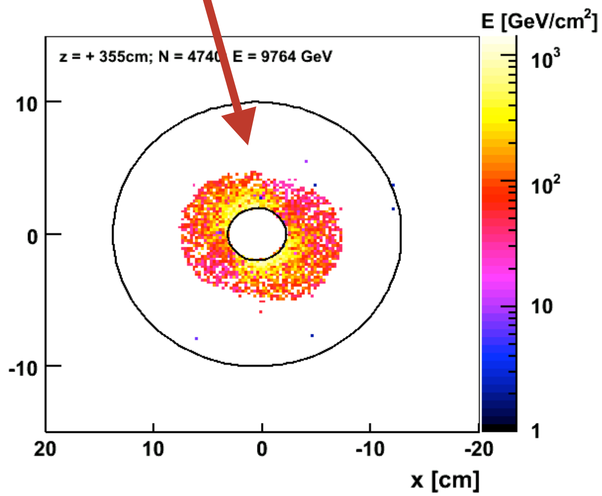
30 layers of

W / CVD diamond (?)

5 < ***ANGLE*** < 28 mrad

Energy deposition from beamstrahlung pairs in BeamCal:

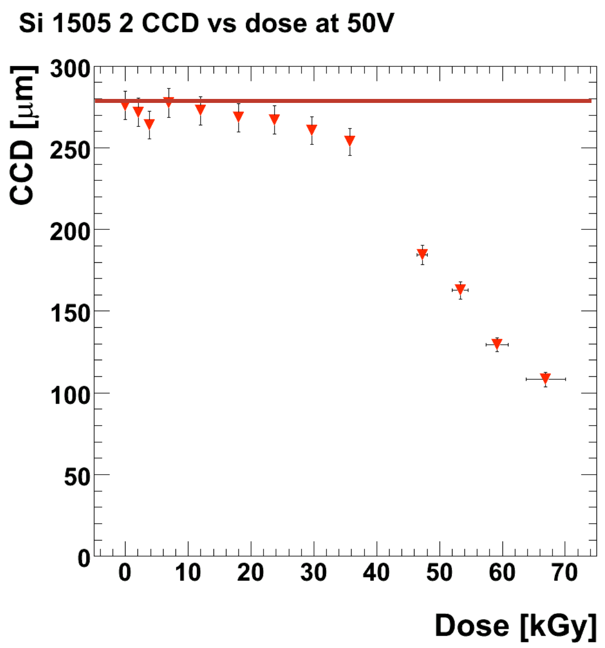
Dose of up to 10 MGy/a



SILICON (1)

- operated as ‘extended’ pn junction -> depleted intrinsic material (bandgap 1.12 eV)
- The only material which is fully ‘under control’: ***reference material***
  - technology: availability, structuring, testing, assembly
  - properties: signal yield, stability, long term behaviour
- Problem: radiation hardness:

Sample irradiated with e^-:
Thickness = 280 μm
Initial CCD = 280 μm
(100% collection efficiency)



- will improve significantly
- still not sufficient the inner radii of a planned BeamCal

SILICON (2)

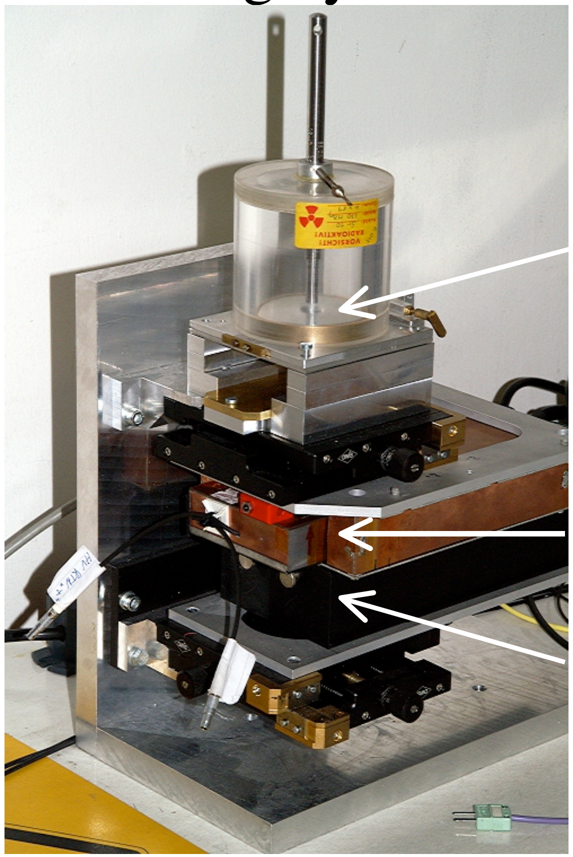
- Problem: radiation hardness:
  - design techniques (instead of p on n --> n in p: avoids type inversion)
  - different growth of substrate material (Czochralsky growth)
  - modification of substrate / doping (oxygenation etc.)

- All these ‘counter measures’ are expensive and time consuming
  --> ***joint effort in collaborations!***

- to be investigated: photo diodes with advanced radhard technology
  - samples from Zheng Li (Brookhaven) and Prague to be shipped soon, expected for next test beam end of June
  - I/V, C/V, spectra of MIPs
  - irradiation in electron beam planned (S-DALINAC)

CVD DIAMONDS - polycrystalline (1)

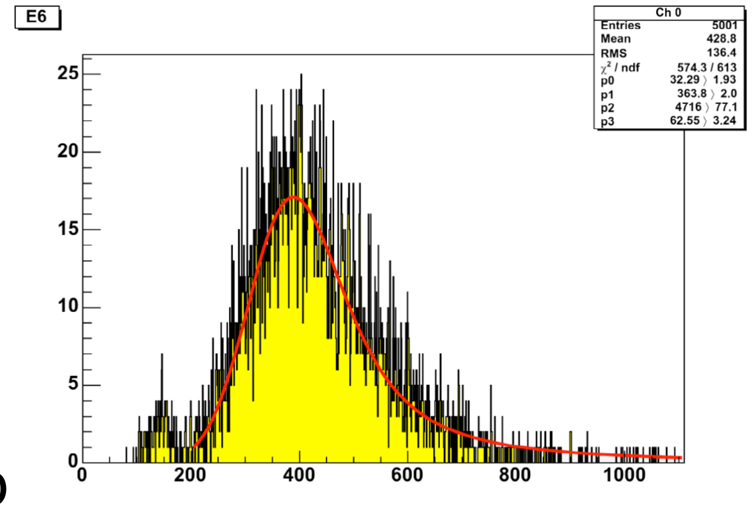
- operated as 'solid state ionization chamber' (bandgap ~ 5.5 eV)
- Different sources: IAF (Fraunhofer, Freiburg), E6
- state of the art: 4" wafers, 6" possible -> sensor areas > 50 **x** 50 mm^2
- structuring by metallization ('coarse patterns') w/o photolithography



Source (^{90}Sr)

Sensor, Preamp

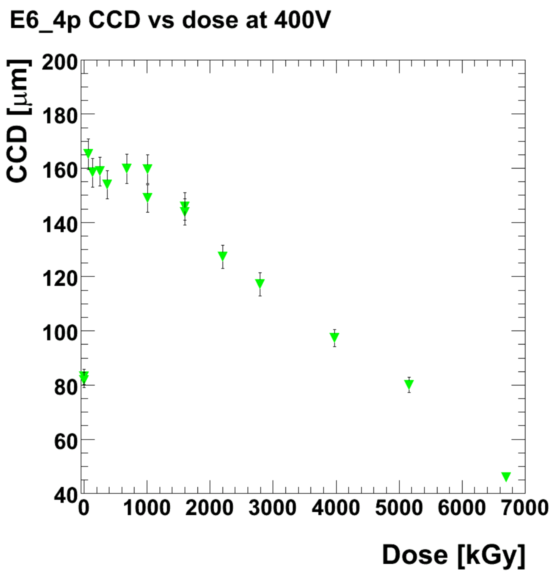
Trigger

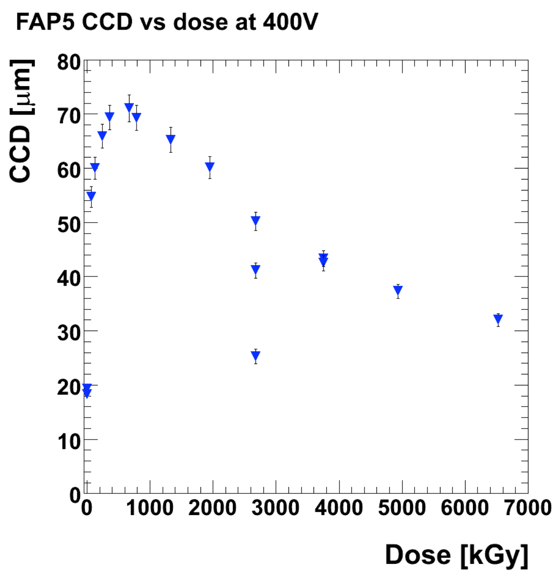


CCE measured:
(5 to 50)%

CVD DIAMONDS - polycrystalline (2)

- radiation hard (survival) but no stable and no predictible behaviour:
  - dependence of CCD on dose acquired (pumping / degradation)





  - dependence of pumping and degradation on dose rate applied
  - changes (vs irrad) observed: improvement, degradation
  - actual properties time dependent (relaxation, recovery)

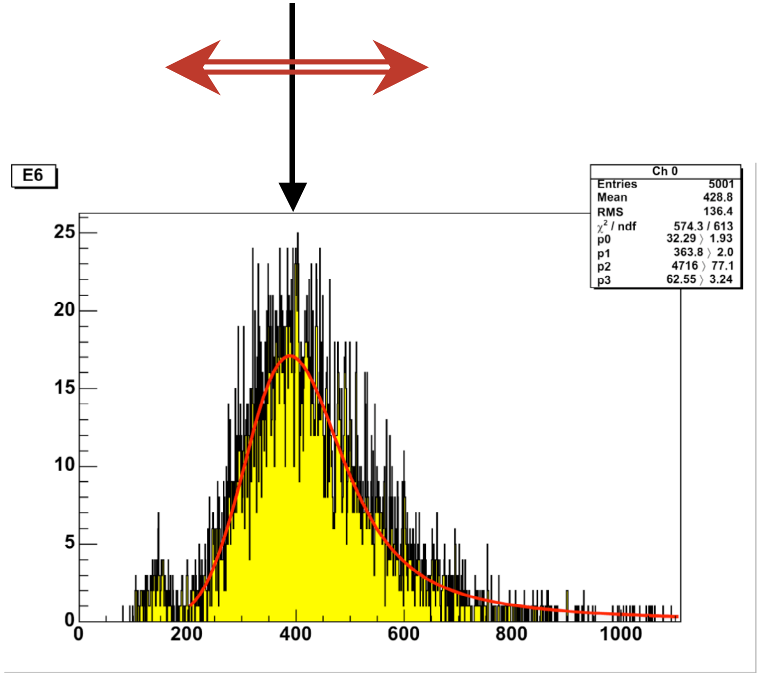
CVD DIAMONDS - polycrystalline (3)

- degradation of E6 and of FAP diamonds similar
- investigations of different samples with Raman spectroscopy:
    - significant lower N_2 content of E6
    - no clear correlation to CCD and rad hardness
    - methods to be improved
- annealing with TLC cycles observed (-> traps)
- annealing with UV observed (-> traps)

CVD DIAMONDS - polycrystalline (4)

- signal yield depends on
  - material (sample)
  - conditioning (history, pumping, dose acquired)
  - actual conditions (dose rate)

- applications w/o threshold:
  spectrometry
  - *instant recalibration necessary*



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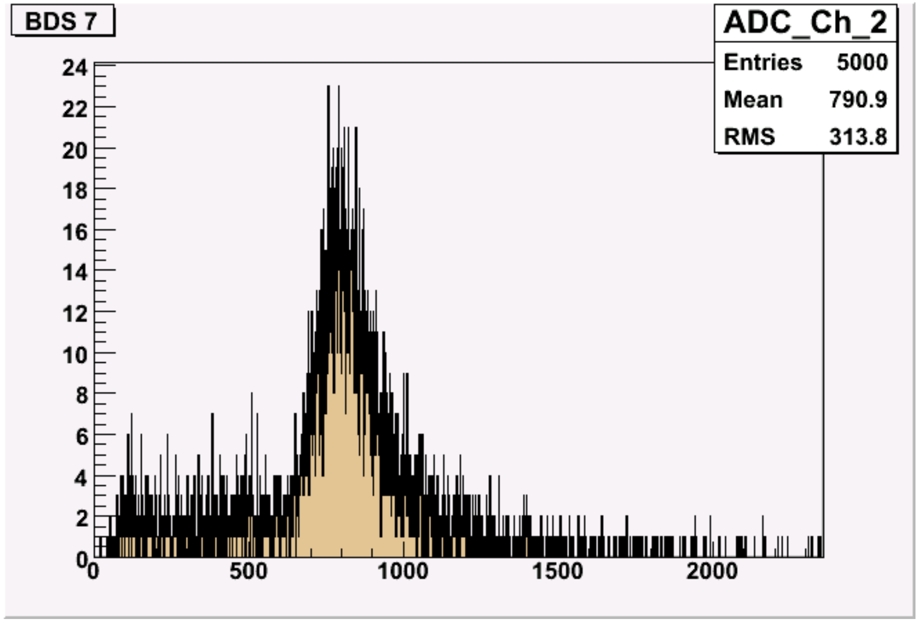
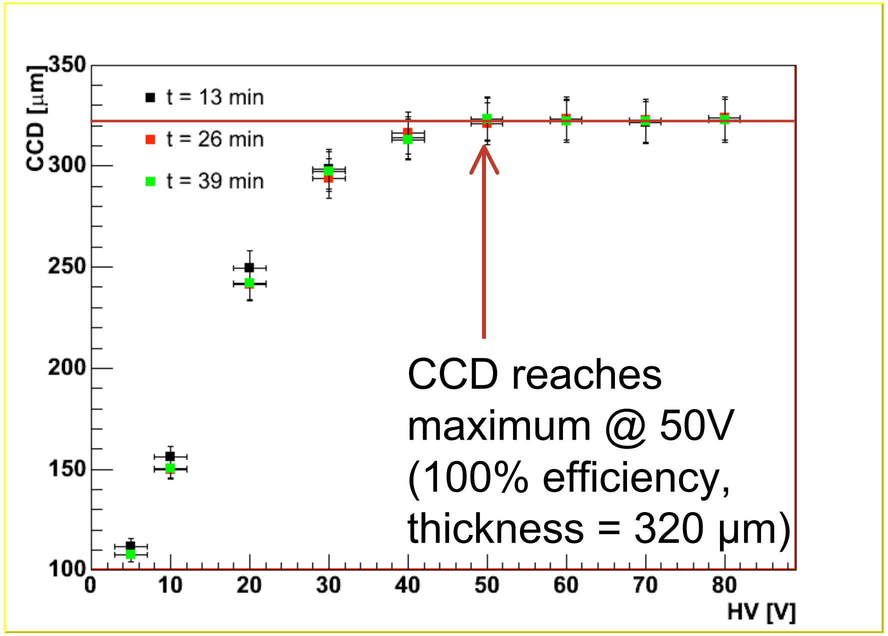
- applications with thresholds
  counting

CVD DIAMONDS - single crystals (1)

- Single Crystal (CVD grown on substrate) by E6
- Size: 5 x 5 mm², metallization 3 mm in diameter, 320 μm thick

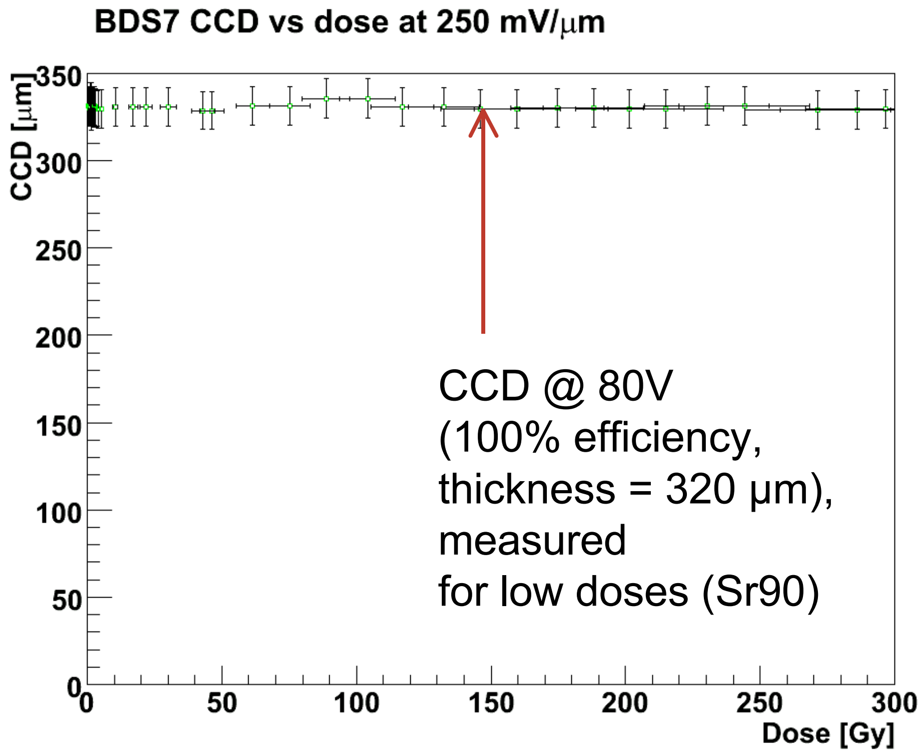


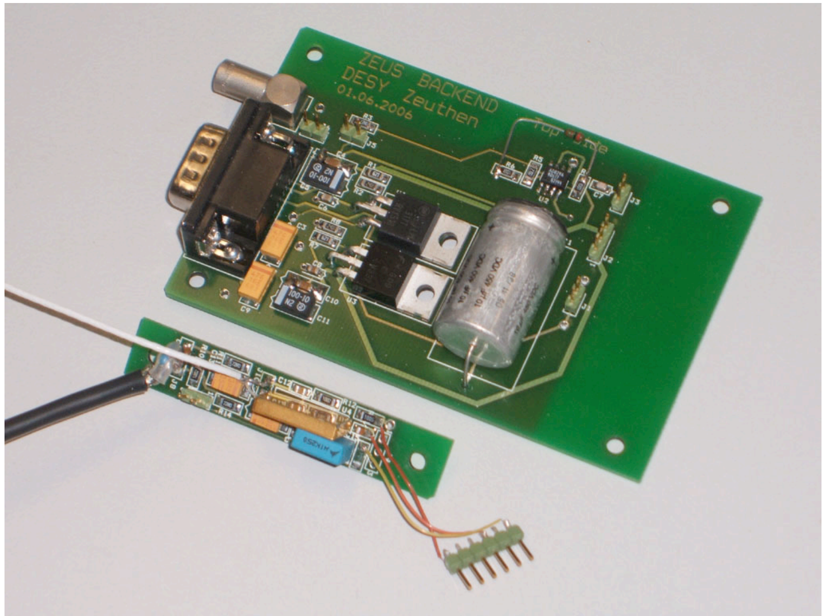


- Clearly separated spectrum of minimal ionizing particles
- 100% CCE, CCD = thickness, 1 mip results in 11.5 ke$^-$ (1.84 fC)

CVD DIAMONDS - single crystals (2)

- Stable for low doses (< 1kGy), higher doses not yet known



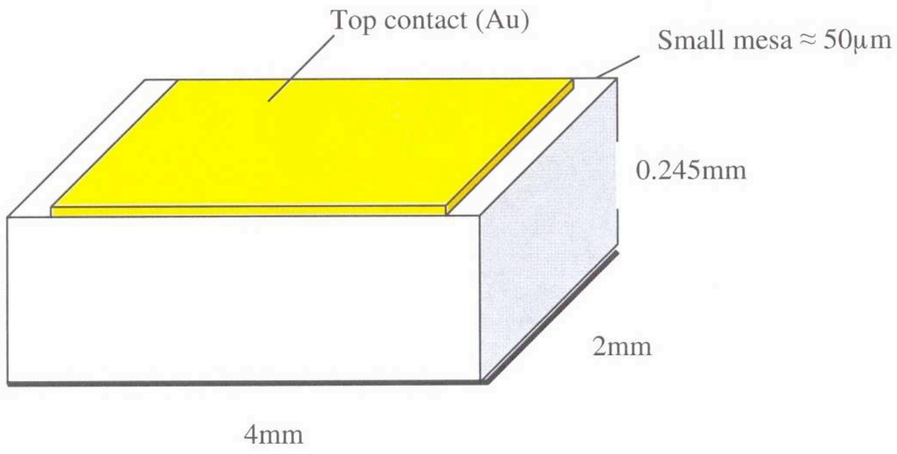


CVD DIAMONDS - single crystals (3)

- Installed in ZEUS (HERA, DESY Hamburg)
  close to interaction point (~ 3m)
- Used as a beam background monitor / counter
- Signals fed into DAQ (histogramming)
- Clear Correlation to beam currents (both: electrons, protons)
  (see talk of Alexandre Ignatienko)

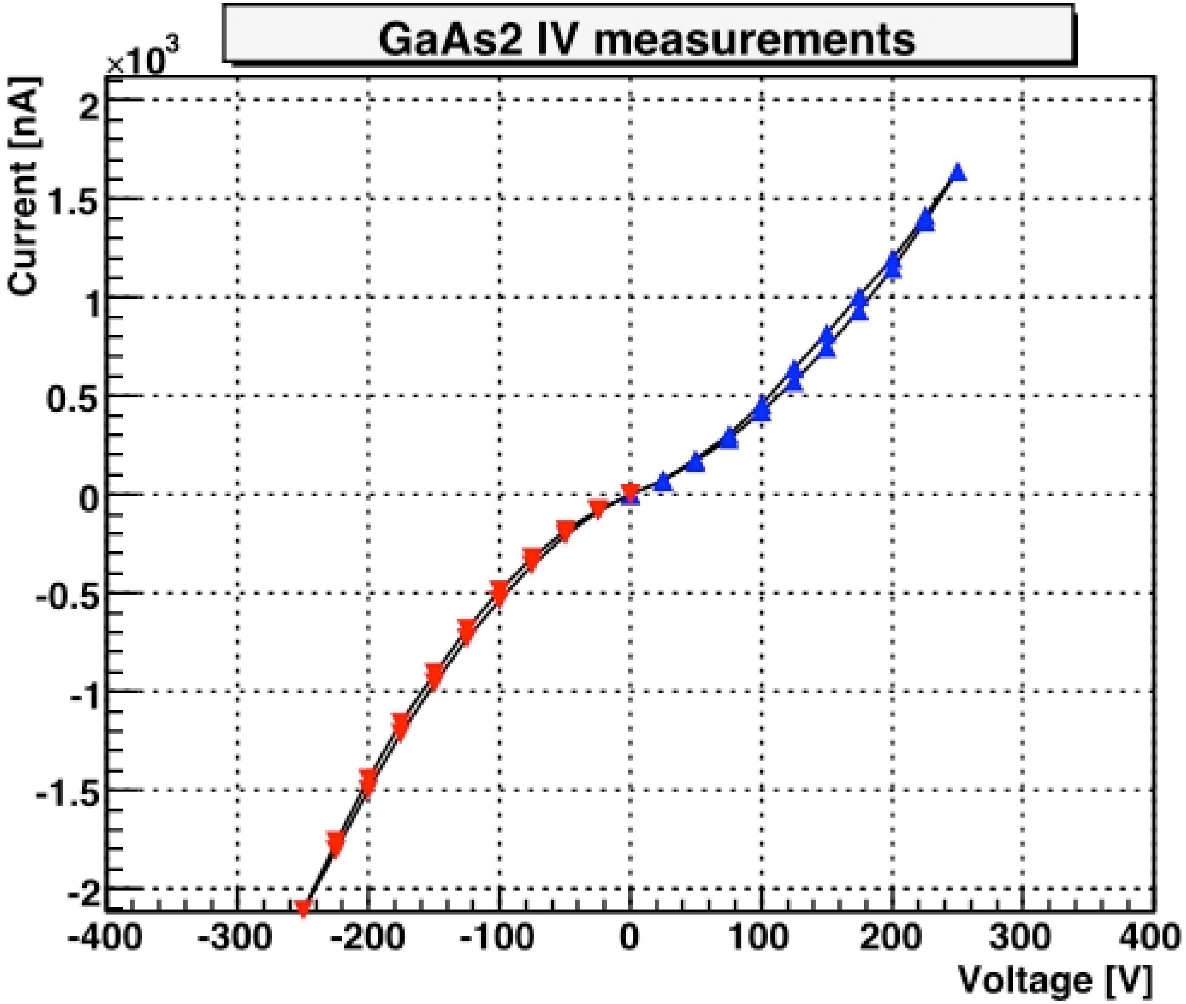
Gallium Arsenide (1)

- operated as
  - 'solid state ionization chamber' (bandgap: 1.42 eV) or as
  - 'extended pn junction': p-i-n structure



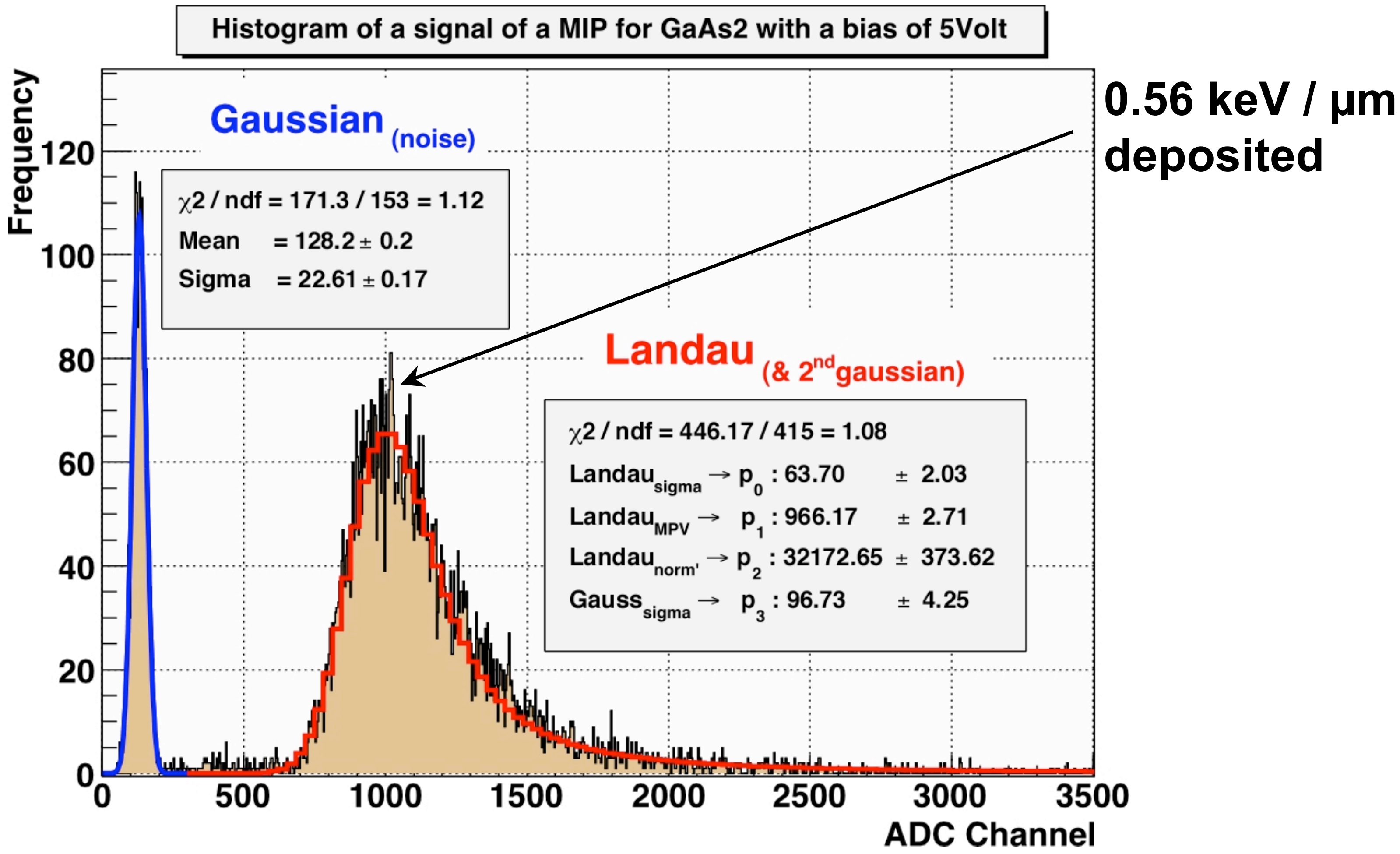
Gallium Arsenide (2)

- static measurements (I/V)



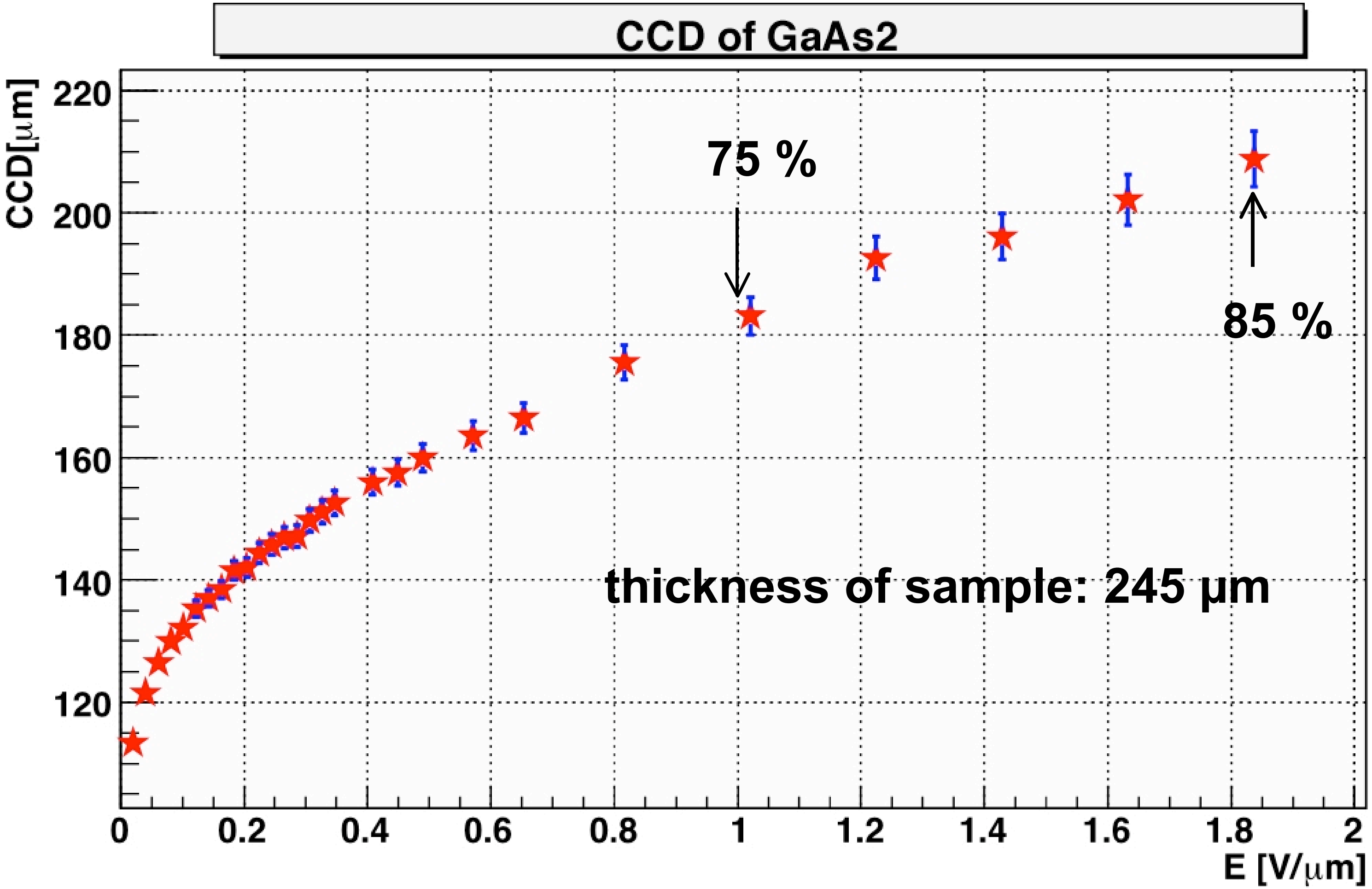
Gallium Arsenide (3)

- Spectroscopic measurements (Sr 90)



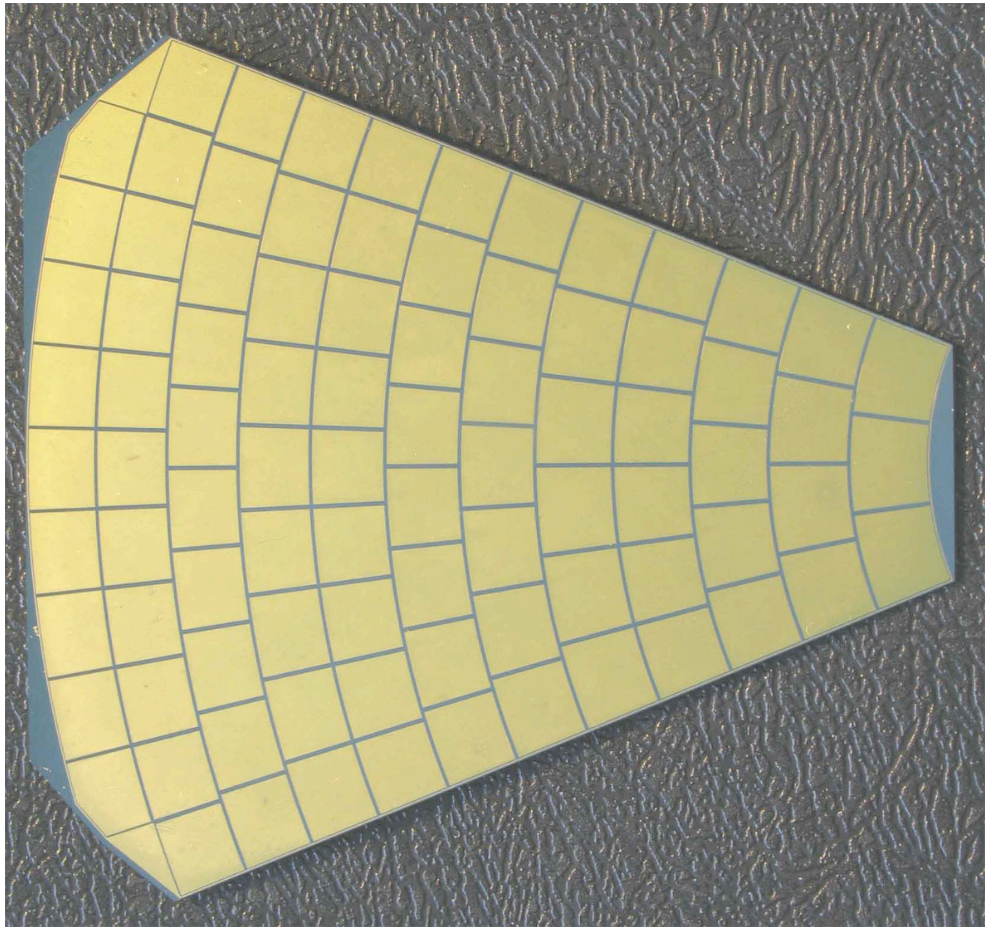
Gallium Arsenide (4)

- Spectroscopic measurements (^{90}Sr) vs. voltage -> CCD



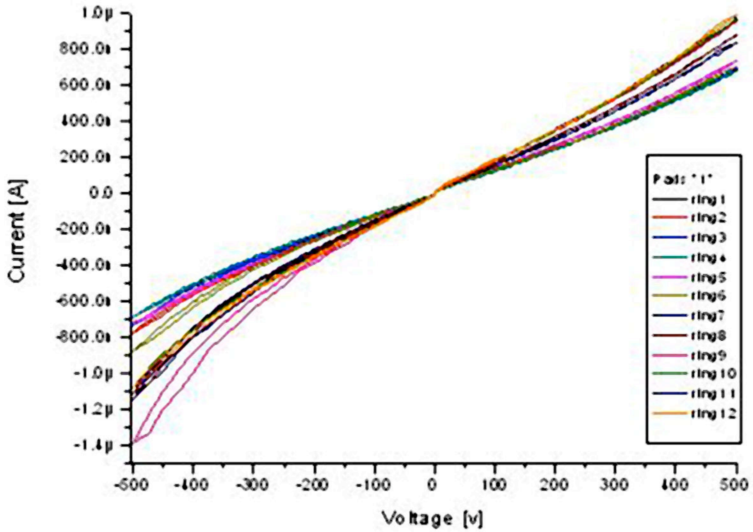
Gallium Arsenide (5)

- first detector sample with BeamCal geometry (Dubna / Tomsk)
- compensated (Cr doped) -> behaving as insulator



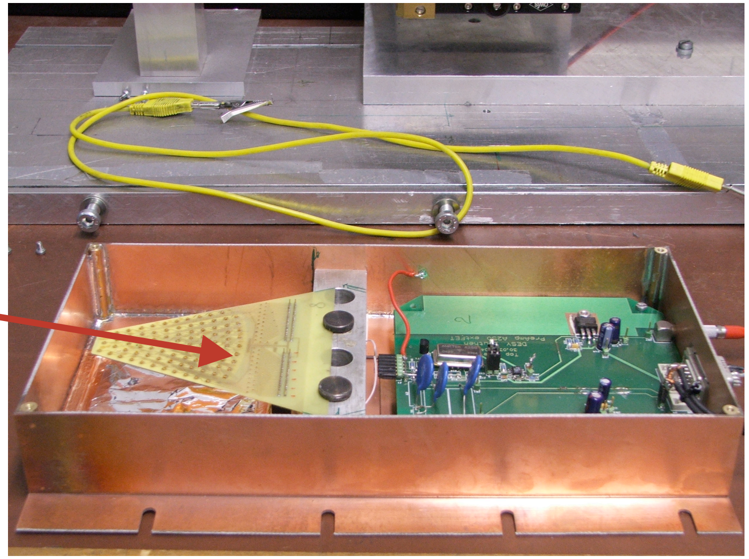
Gallium Arsenide (6)

- static measurements (I/V)



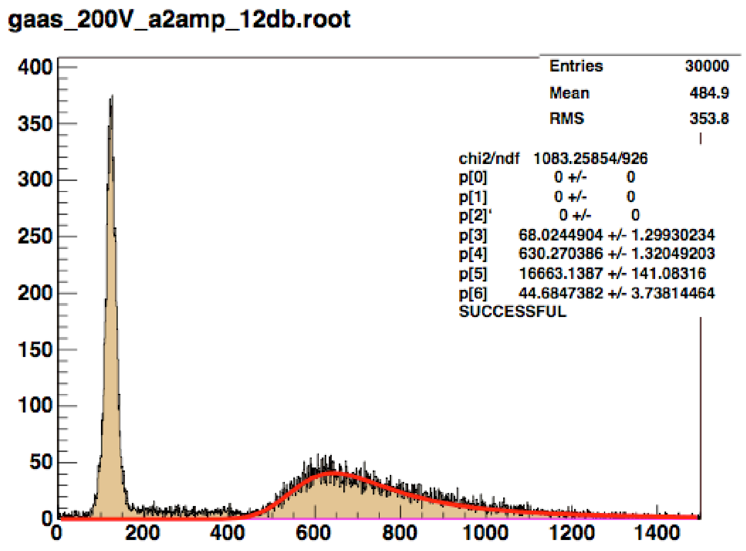
Typical I/V curve for different radii (power dissipation up to ~ 0.5 mW per pad!) <--> ~ 60 mW per sensor

Mounting of sensor into our test box to be measured with 90Sr

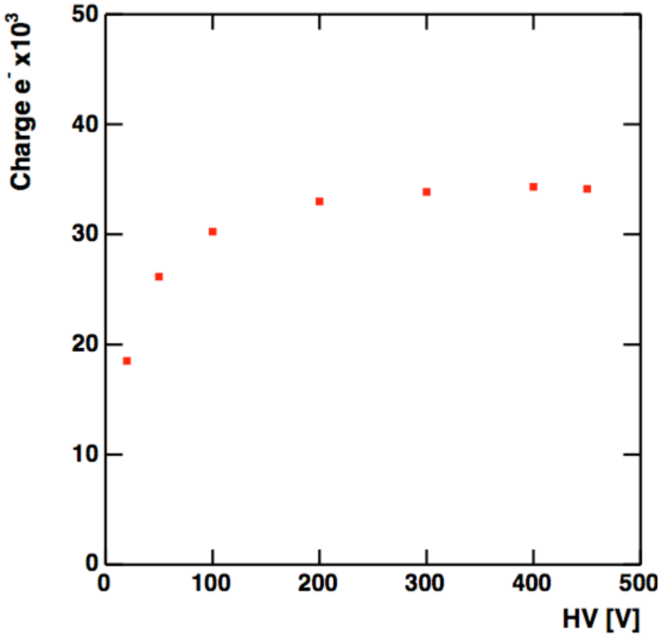


Gallium Arsenide (7)

- Particle detection:

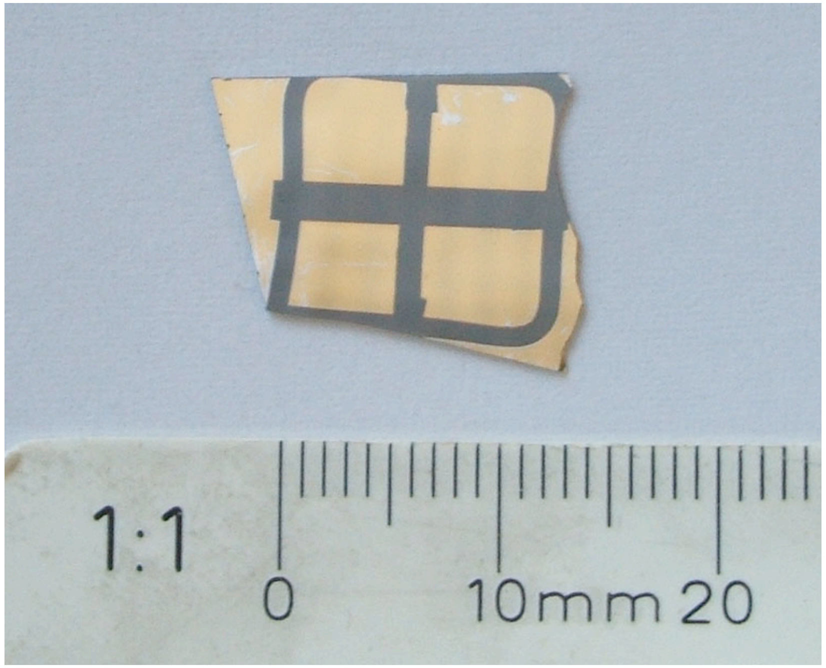


^{90}Sr spectrum of one pad (preliminary)
Courtesy:
Konstantin Afanaciev



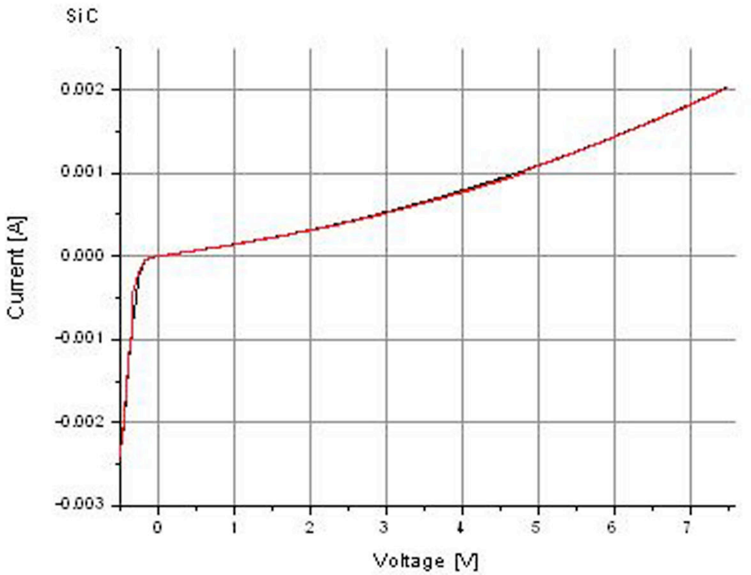
Silicon Carbide (1)

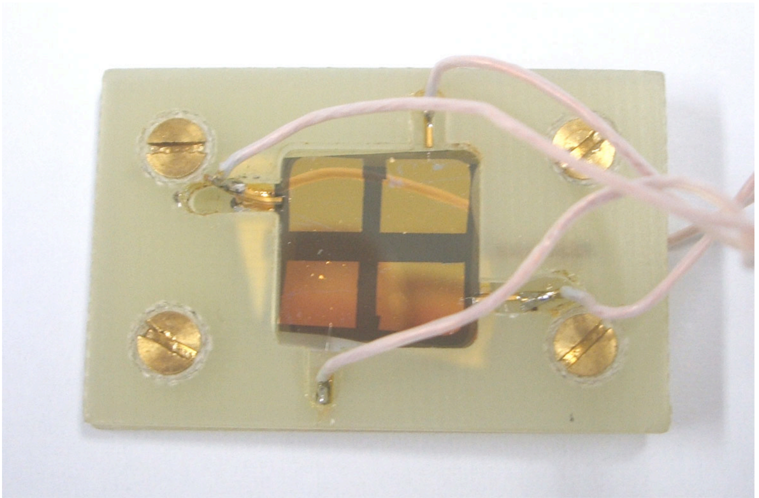
- wide bandgap material: ~ (3…3.35) eV
  -> solid state ionization chamber
- normally produced as epi layer (CVD) on silicon (industry!)
- SiC at wafer scale up to 75 mm (3”)
- still high defect densities (15 to 30 ‘micropipes’ per cm^2)
- cost per cm^2: (150 … 300) Euro
- metal deposition ->
    - Schottky contact
      -> annealing @ high T ->
      ohmic contacts
- planned collaboration
  with BTU Cottbus



Silicon Carbide (2)

• low ohmic material - see I/V curve:





• use for detection of ionizing particles impossible (recombination with leakage current)…

CONCLUSIONS

- harsh environment (irradiation) demands new detector materials
- current ***silicon*** does not survive the high rad level
    - test of developed sensors for such high rad levels
    - search for collaborators to share effort and cost
- ***GaAs***: growing knowledge and experience (LHC etc)
    - promising detector capabilities
    - samples investigated, measurements to be continued
- ***pCVD diamonds*** survive high doses
    - current samples are not (long term) stable as detectors
    - recommended only for counting applications (threshold!)
- ***Silicon Carbide*** is a candidate for radiation hardness
    - we need high ohmic material (difficult to get)
    - first investigated sample impossible to use