Radiation hardness tests at JINR

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GaAs:Cr after 1.5 MGy

JINST 7 P11022 2012

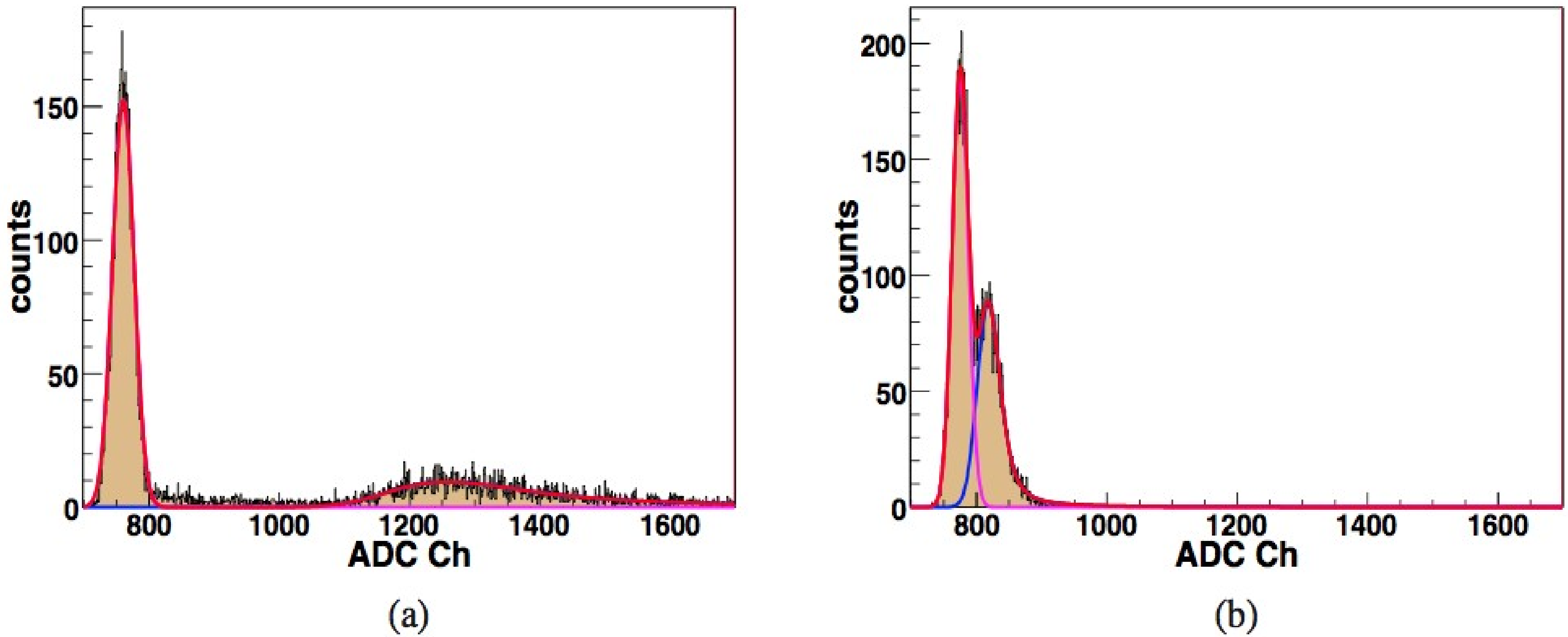


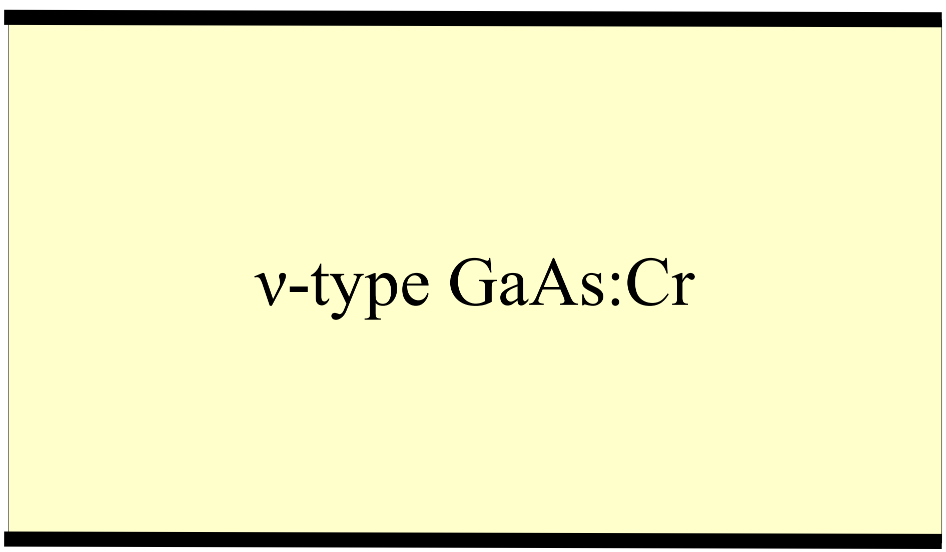
Figure 5: Spectrum from an unirradiated sensor GaAs2 (a) and from the same sensor after absorbing a dose of 1.5 MGy (b).

The idea of Tomsk GaAs:Cr

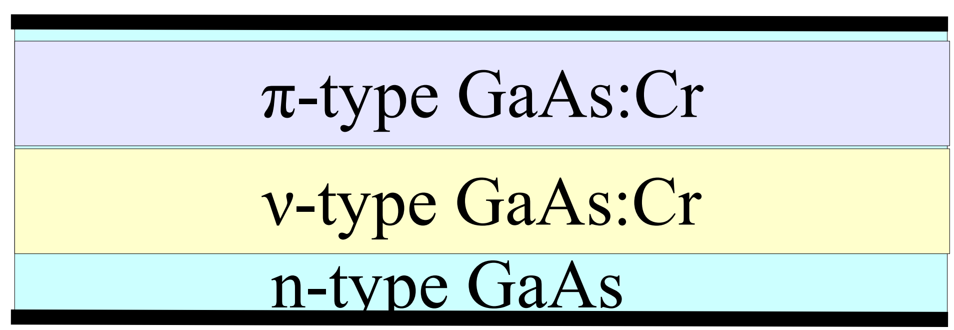
- **LEC SI-GaAs — commercially available**
  - difficult to control the impurities at low level
  - EL2 centers capture the electrons (τ~0.2 ns)
- **n-type SI-GaAs = LEC Si-GaAs doped with Nd~10^{17} donors (Sn or Te) – also commercially available**
  - EL2 centers are compensated
  - n-type, low resistivity
- **Compensated GaAs = n-type SI-GaAs compensated with Cr (or Fe)**
  - high resistivity (=low free carrier concentration)
  - type depends on Cr concentration: p-type (π-type) if $N_{Cr}>N_d$ and n-type (ν-type) if $N_{Cr}<N_d$
  - N_{Cr} and N_d are 'macroscopic': it is possible to control the material properties in wide range

Two types of GaAs:Cr detectors

- 'Resistive' GaAs:Cr
  - resistivity ~10^9 Om*cm
  - active thickness up to 1 mm
  - electron drift length up to 2 mm



- πν junction structure
  - active thickness is determined by πν junction (~0.1-0.2 mm depending on Ubias)
  - resistivity and CCE is Ok



Radiation hardness tests of 199x - protons

V.B. Chmill et al. / Nucl. Instr. and Meth. in Phys. Res. A 395 (1997) 65–70

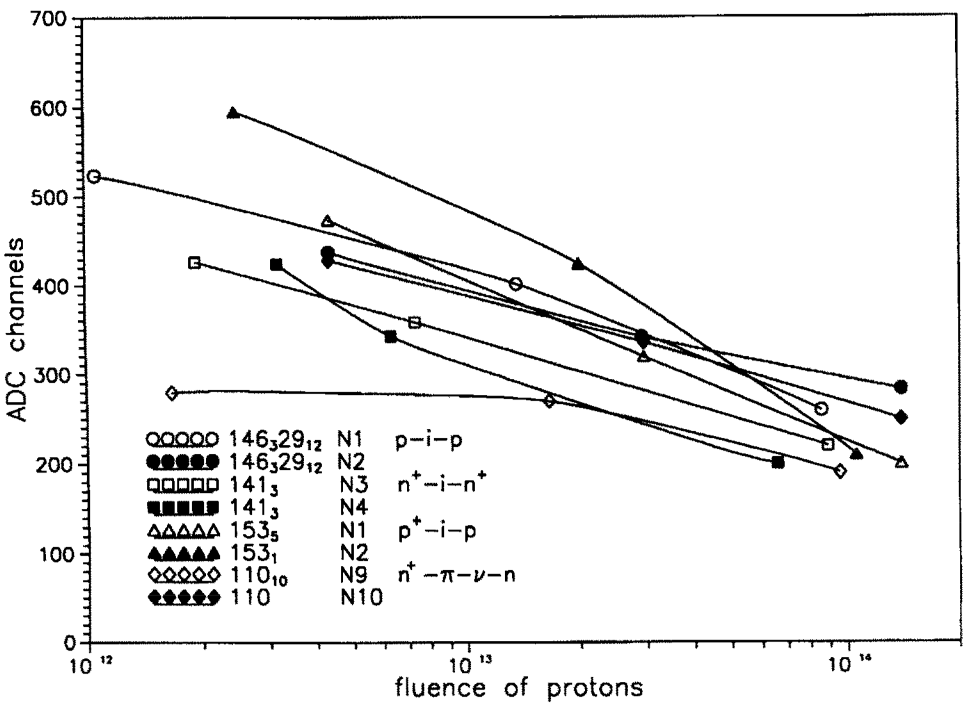


Fig. 2. Proton irradiation, first run.

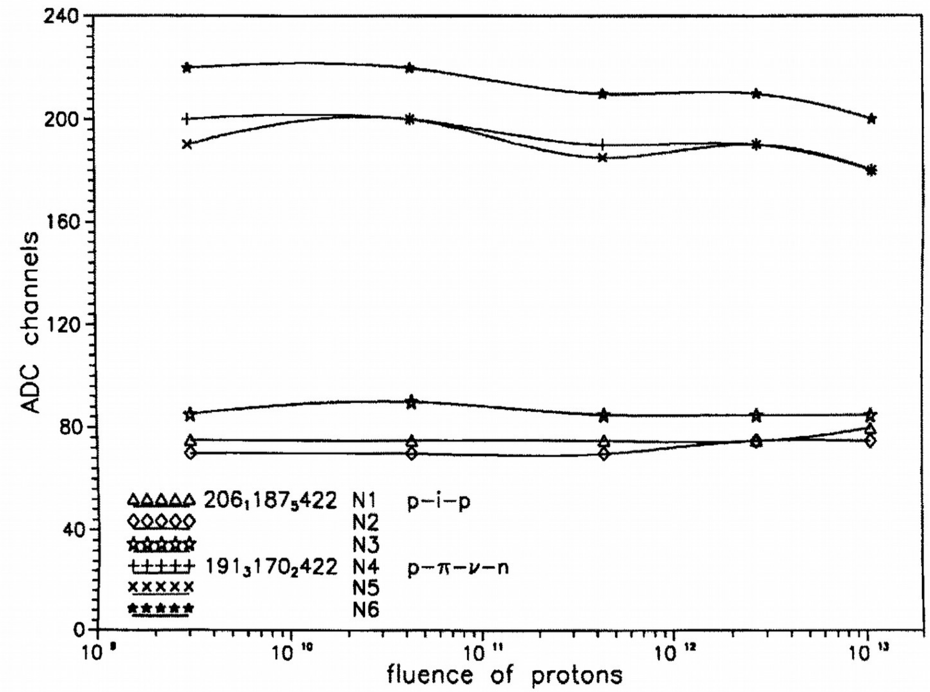


Fig. 3. Proton irradiation, second run.

1 GeV protons from Protvino booster
Two different irradiation rates

Radiation hardness tests of 199x - neutrons

V.B. Chmill et al. / Nucl. Instr. and Meth. in Phys. Res. A 395 (1997) 65–70

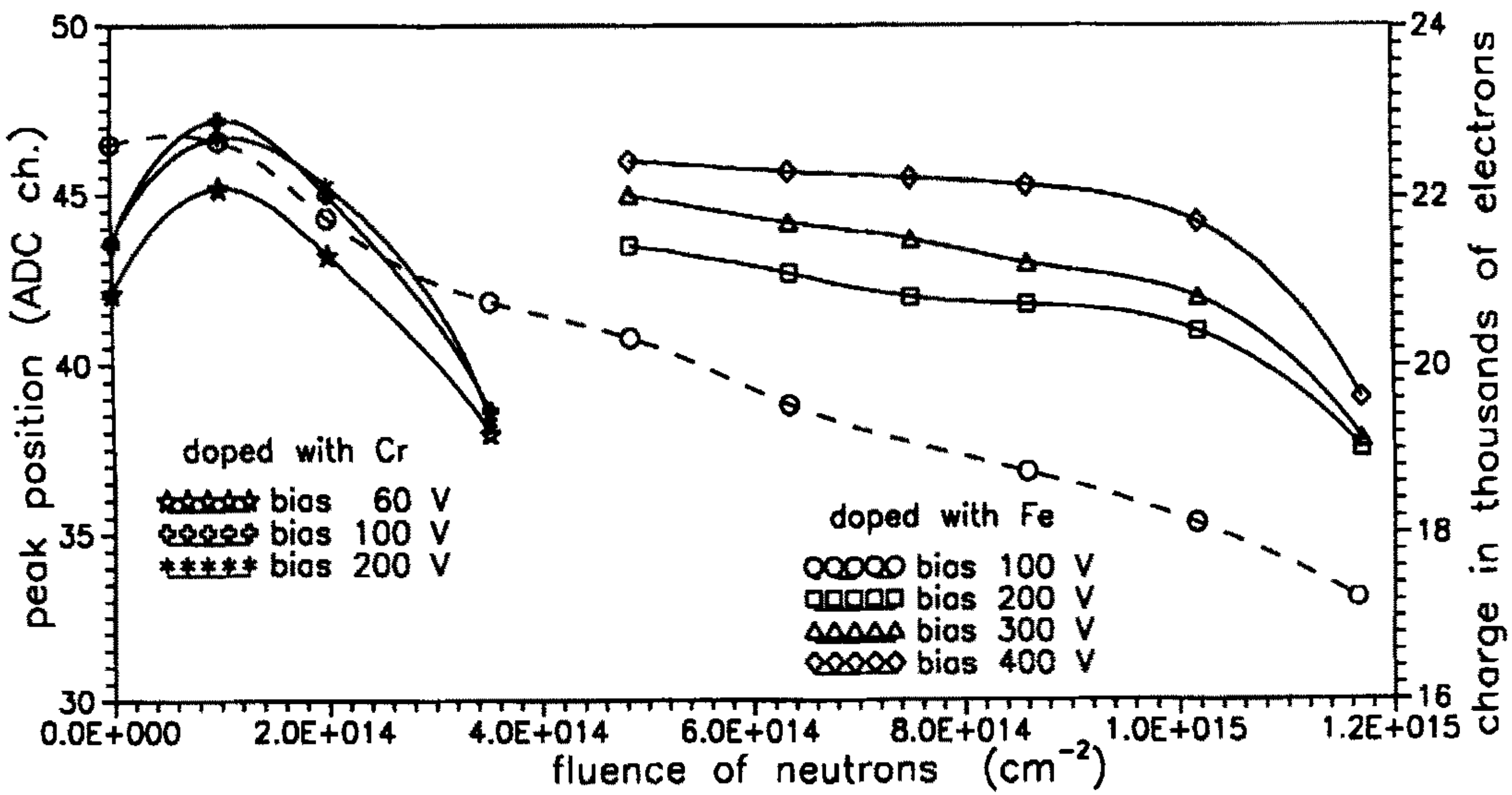


Fig. 1. Neutron irradiation.

Conclusions possibly important to FCAL

- GaAs:Cr and GaAs:Fe detectors based on $\pi\nu$ junction structure may have the same or better radiation hardness comparing with the 'resistive' GaAs:Cr
- $\pi\nu$ junction structures were never tested systematically in electron beams.
- Last radiation hardness studies of detectors like these took place about 20 years ago
- We never reported (= never systematically studied) the dependence of the radiation degradation on the irradiation rate

Pad Detectors at JINR

About 50 GaAs pad detectors based on $\pi\nu$ junction of different type have been manufactured in Tomsk by our request

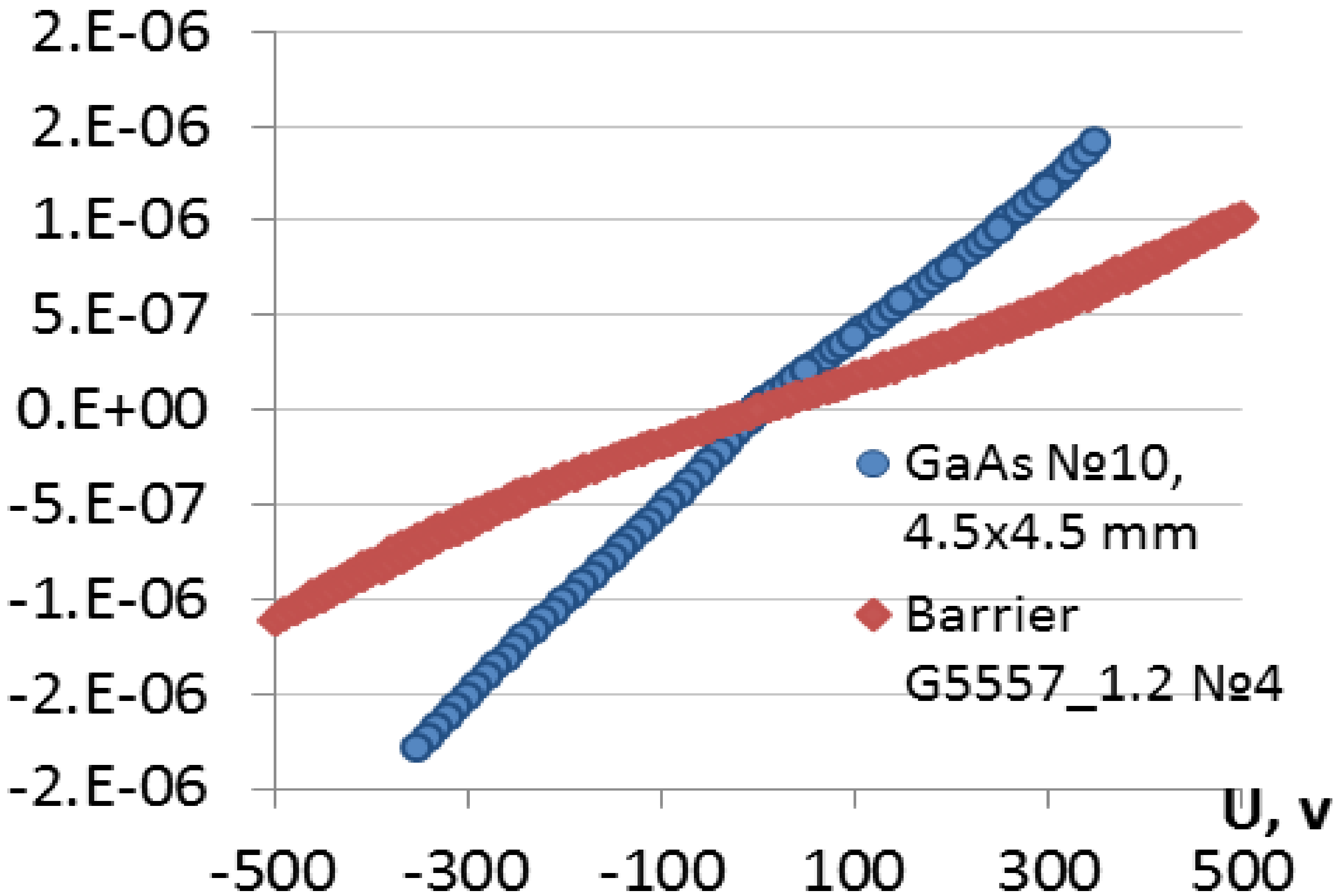
- 6 wafers with different dopant concentration and diffusion regime

- thickness of 300 μm

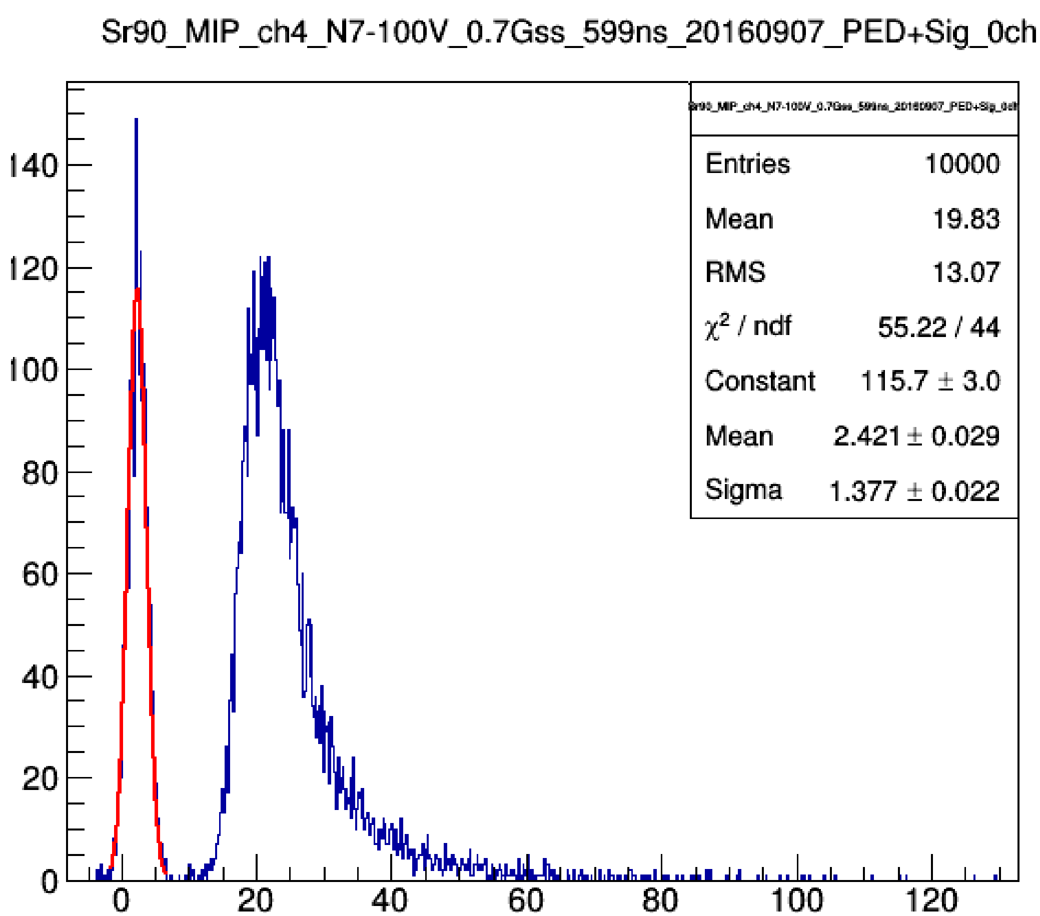
- carrier electron concentration from $8*10^{16}$ to $3*10^{17}$ cm^{-3}

Characterisation before irradiation was already made in collaboration with ISS (Romania)

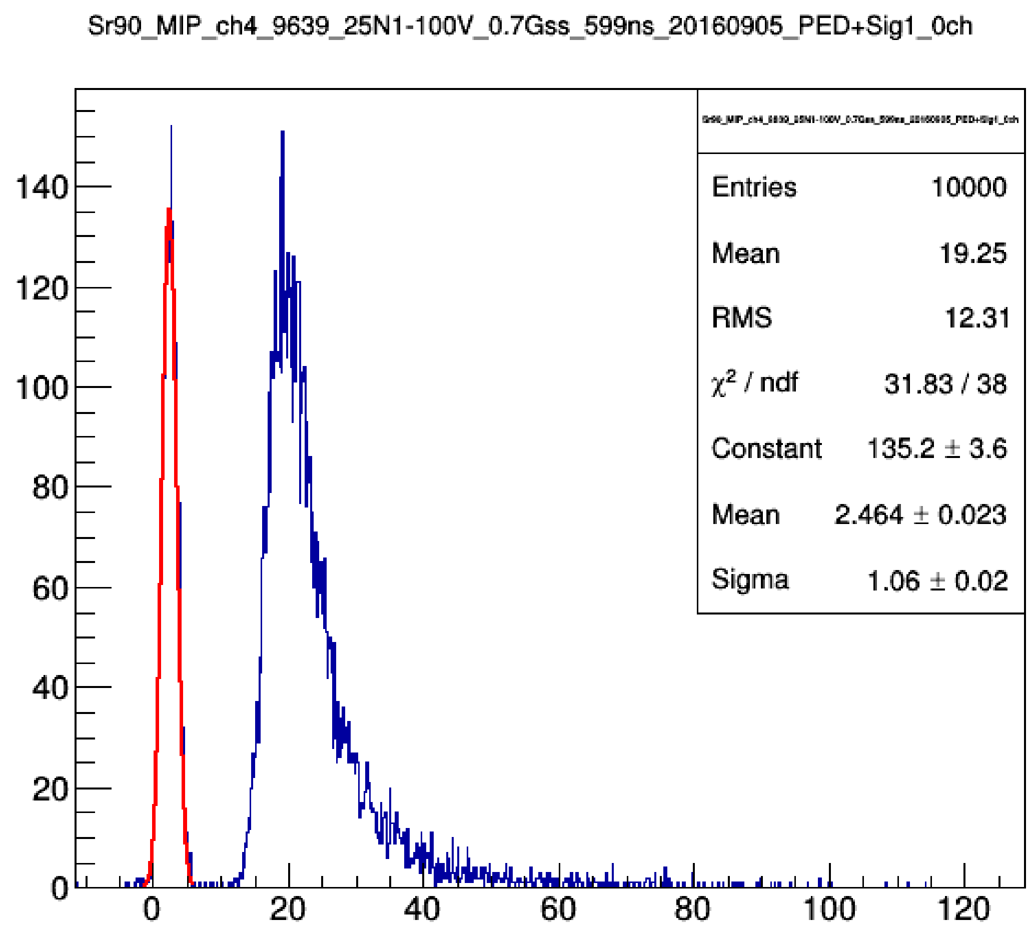
IV measurement



MIP spectra

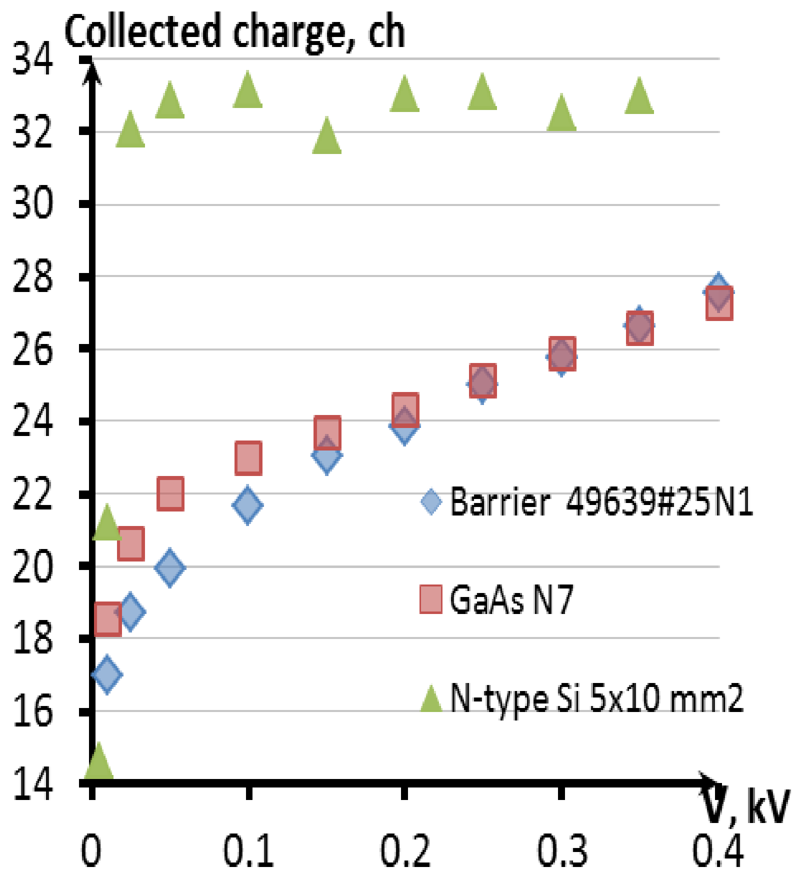


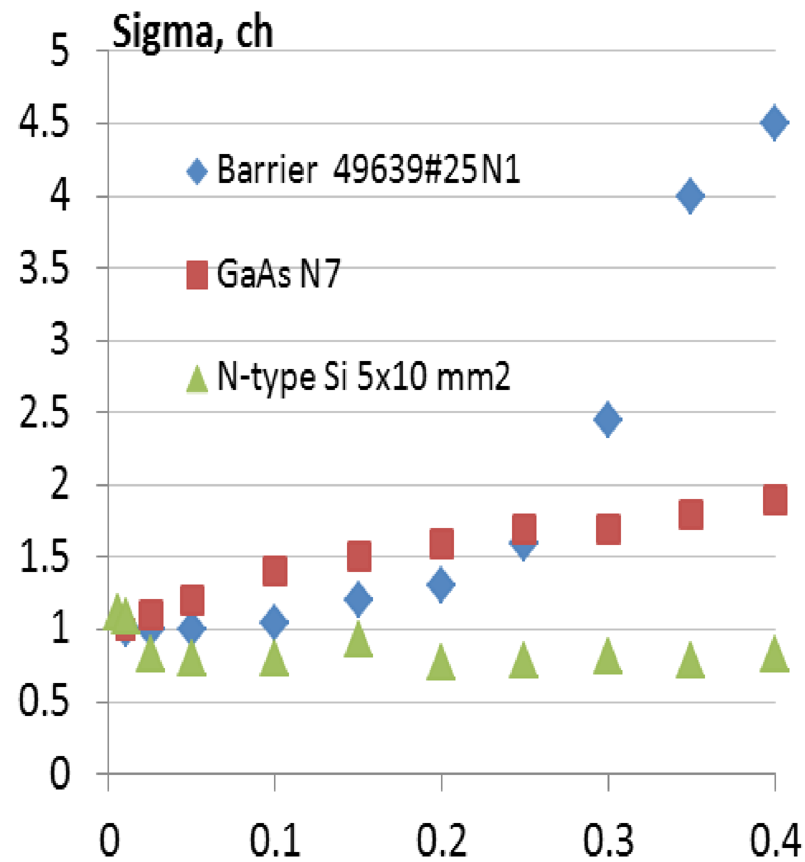
Resistive GaAs:Cr



pπνn junction structure GaAs:Cr

CCE measurement





Linac-200 at JINR

Part of refurbished 800 MeV linac MEA from NIKHEF

- 22 MeV electrons
- Current in bunch 15 μA
- Bunch width 2 μs
- Bunch frequency 10-250 Hz
- Focal spot ~ 1 mm, can be defocused up to 20 mm
- Estimated doserate for GaAs ~ 600 kGy/hour

Summary and plans

- GaAs:Cr detectors based on $\pi\nu$ junction structures demonstrated an excellent radiation hardness during the LHC R&D in Protvino. Lack of interest in the next decades due to the lower efficiency to X-rays in comparison with resistive GaAs:Cr
- Radiation hardness tests of GaAs:Cr detectors based on $\pi\nu$ junction are planned at JINR during October, 1-10 this year
- If the results are encouraging, maybe we need to make a full-scale pad plane for the future FCAL beam tests?