Evolution of CERN particle detector functionality during hadron irradiations and possible trends to enhance radiation hardness

Institute of Applied Research at VU

department of "New material research and measurement technologies"

activities at CERN

- **CERN rd39 programme "Cryogenic Si detectors"**

- **CERN rd50 programme "Radiation hard semiconductor devices for very high luminosity colliders"**

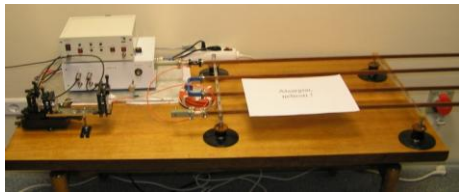
- **FP7 & H2020 CERN "AIDA" projects**
  "Advanced European Infrastructures for Detectors at Accelerators"

Particle beam & stopping range profiling

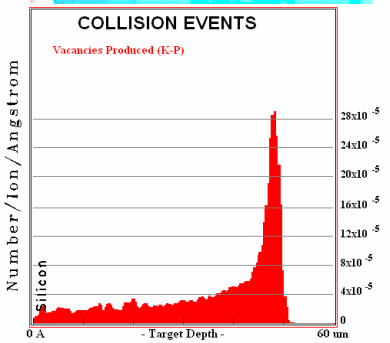
VU proprietary instruments for remote monitoring and dosimetry

VUTEG-4-CERN

VUTEG-3-HE

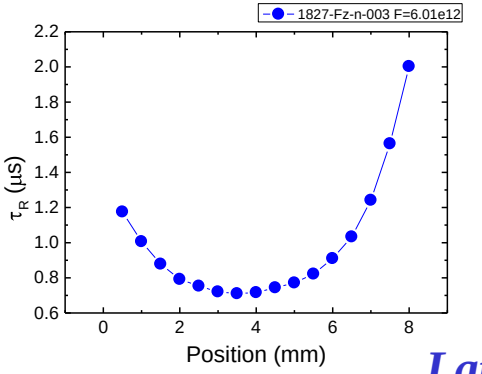


VUTEG-5-AIDA

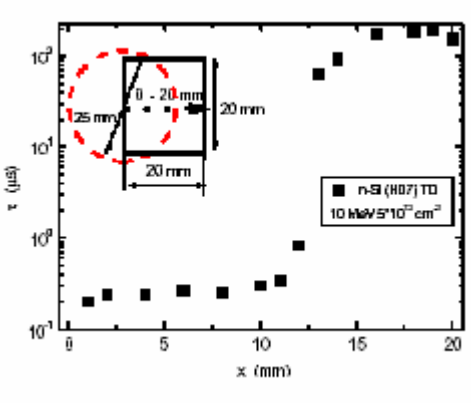


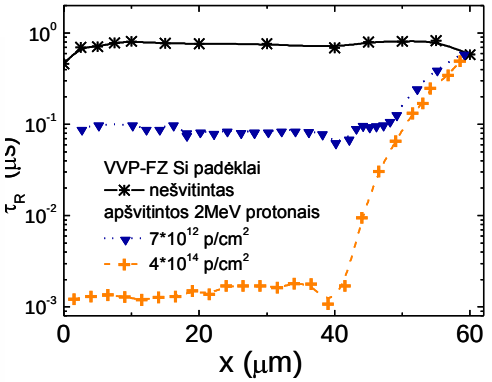
10 MeV protons

2 MeV protons



26 GeV/c protons &
300 MeV/c pions

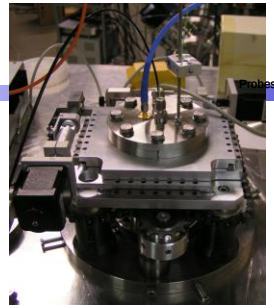


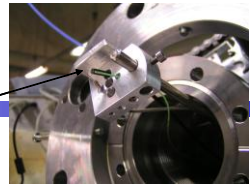


Lateral profiling

Depth profiling

Arrangement for the in situ monitoring of evolution of particle detector functionality





VUTEG-3

①

②

③

Accelerator laboratory

Visual control system

STA-01 laser driver

Microchip laser

Attenuator

Telescope system

FC adapter

Fiber line

15 m

Irradiation chamber

3-D positioning system

VC

Probes

Sample

beam

circulator

MW oscillator

MW bridge

MW waveguide

MW waveguide line

MW coax

Cold finger

T

Amplifier

TDS5104

MW detector

Controller for steppers

PC-NB

PC-NB for control of experiments

Coaxial lines

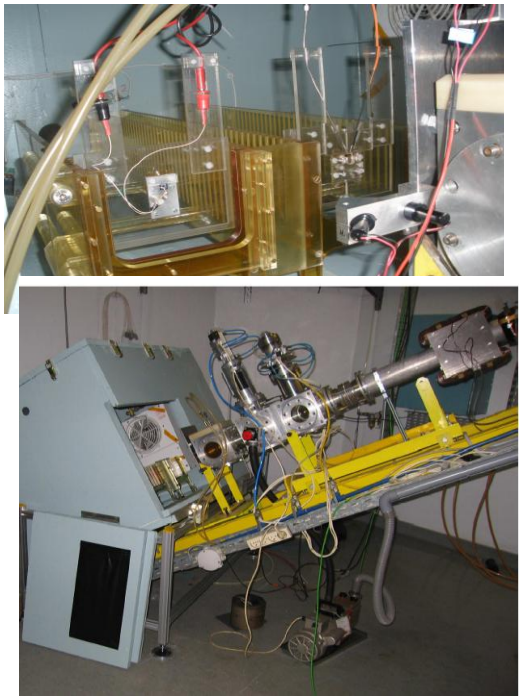
UTP

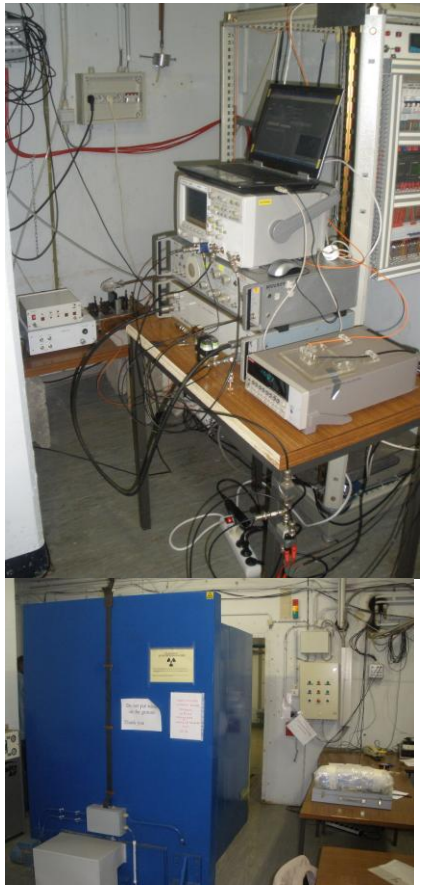
LAN

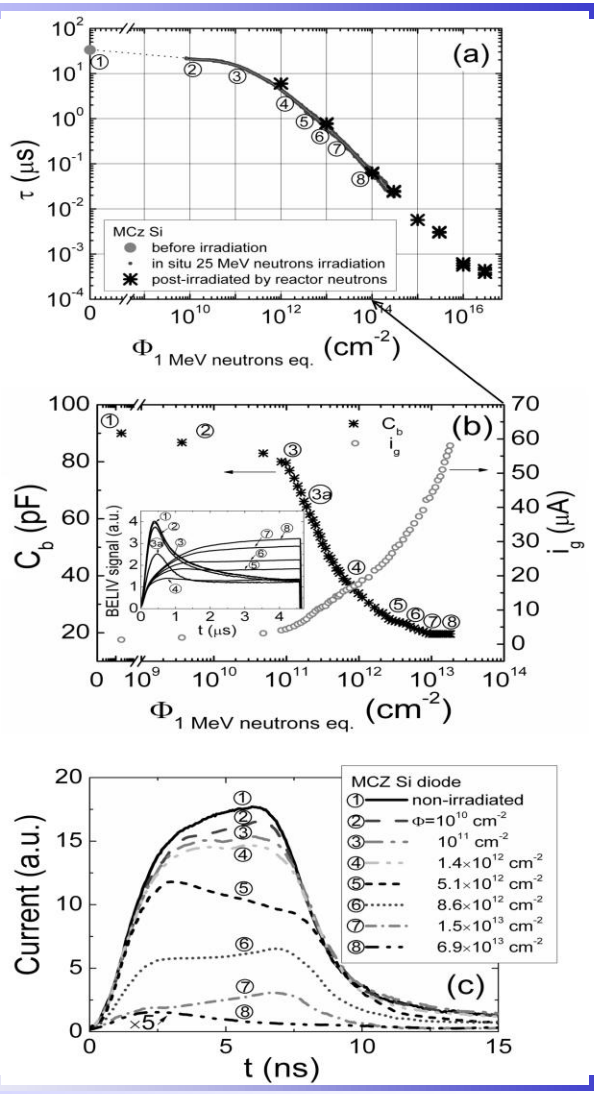
Evolution of Si detector characteristics during spallator neutron irradiation

Correlated evolution of the MW-PC, BELIV and ICDC characteristics during spallator neutrons irradiation:

transients registered every 10 ms, - more than 10^5 on each curve; irradiation - bunches of 4 ns



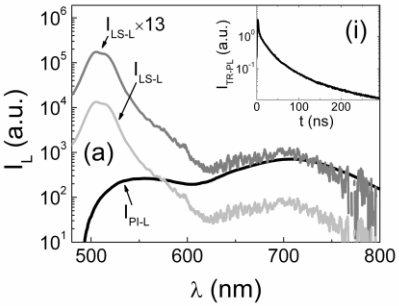


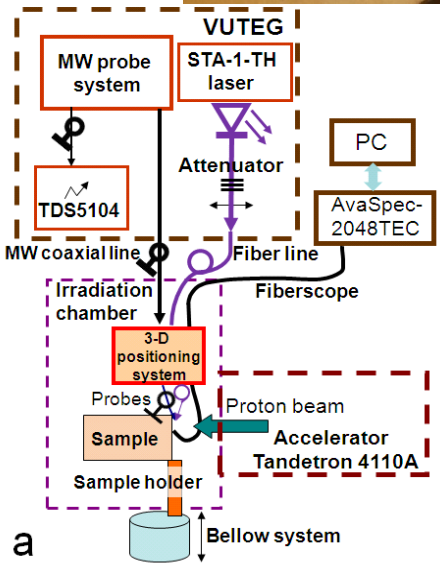


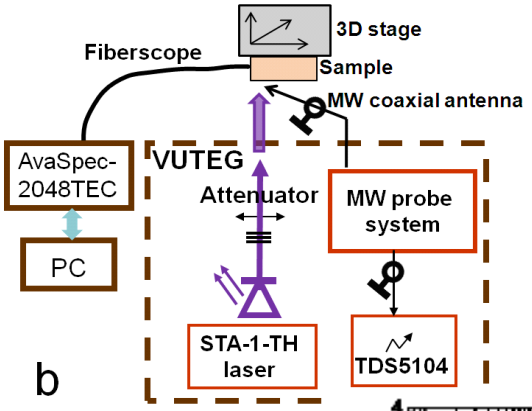
E. Gaubas, T. Ceponis, A. Jasiunas, et al, Correlated evolution of barrier capacitance charging, generation and drift currents and of carrier lifetime in Si structures during 25 MeV neutrons irradiation, Appl. Phys. Lett. 101 (2012) 232104.

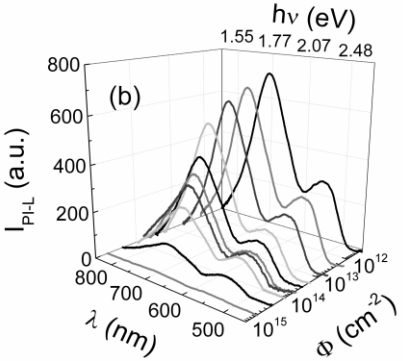
Evolution of characteristics of double-response radiation sensors during proton beam irradiations

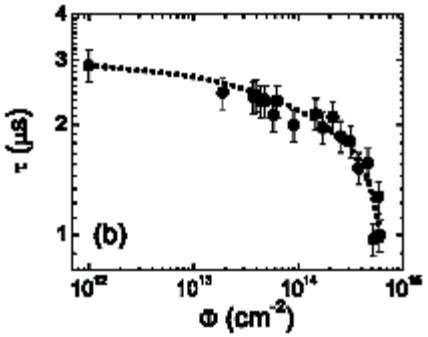
Polycrystalline-CdS, MOCVD GaN

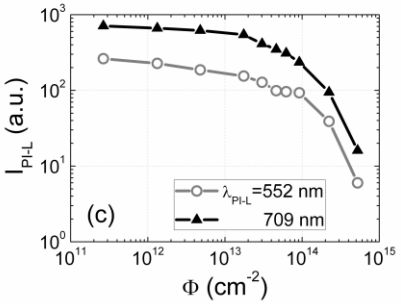










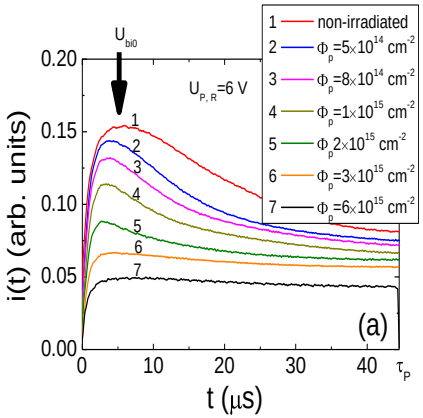


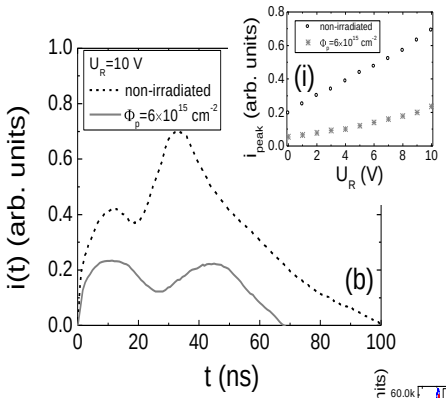
E.Gaubas, T. Ceponis, A. Jasiunas, et al „Correlative analysis of the in situ changes of carrier decay and proton induced photoluminescence characteristics in chemical vapor deposition grown GaN“ Appl. Phys. Lett. 104, 062104 (2014).

E. Gaubas, T. Ceponis, A. Jasiunas, et al *In situ* variations of proton induced luminescence in ZnSe crystals. J. Phys. D: Appl. Phys. 47 (2014) 265102.

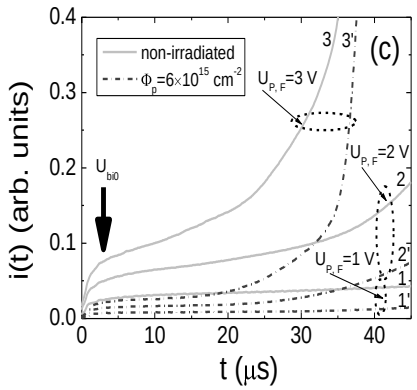
Evolution of characteristics of double-response sensors made of GaN MQW LED structures during proton beam irradiation

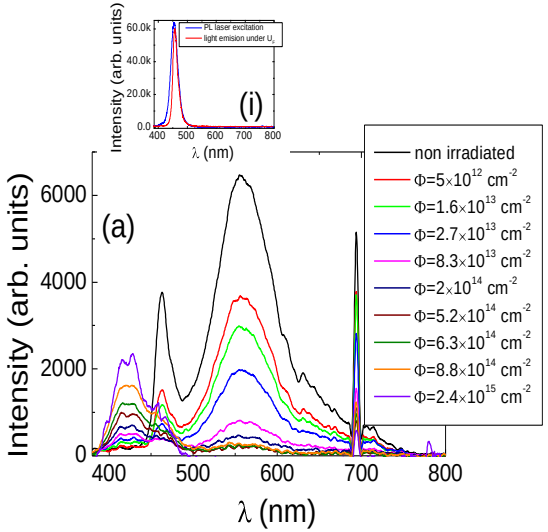
Electrical signals

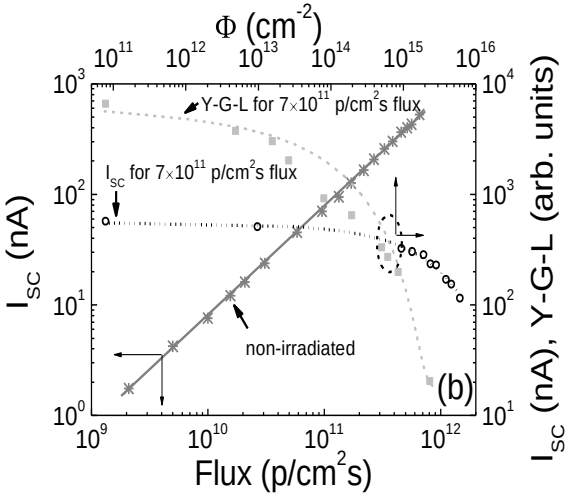




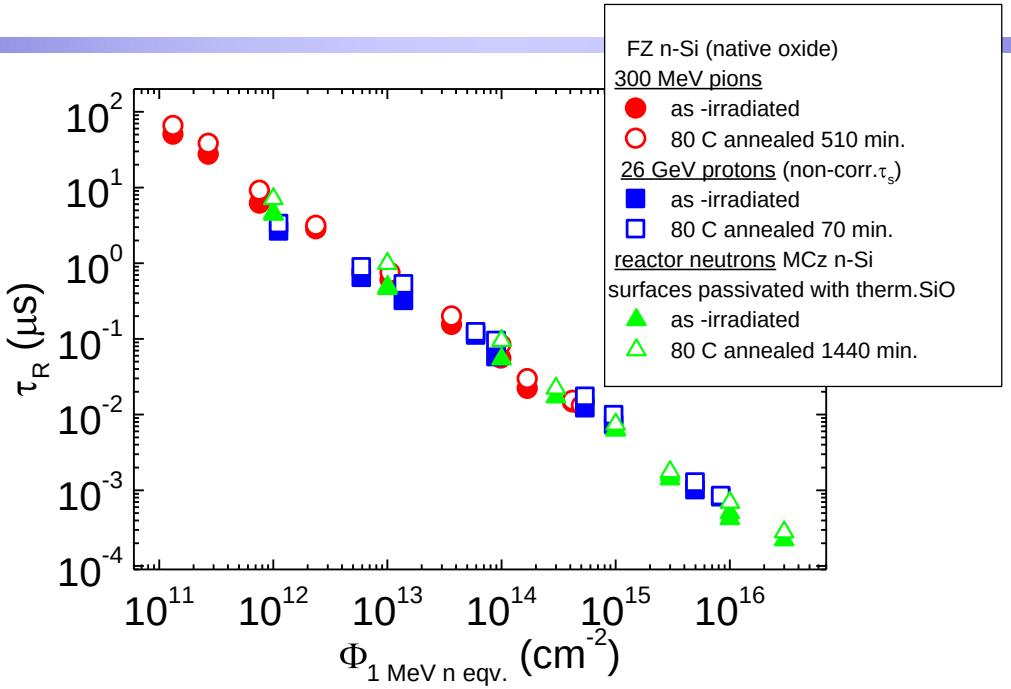
Optical signals

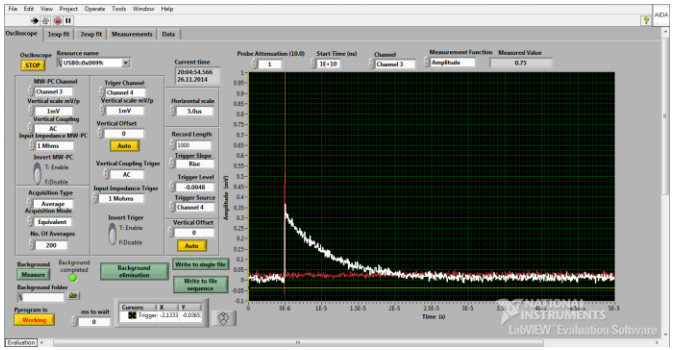


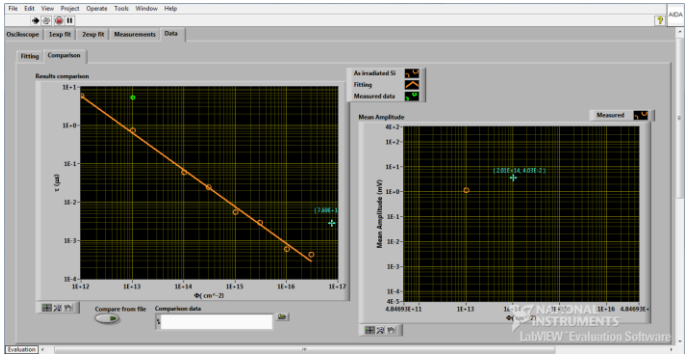




Dosimetry monitoring

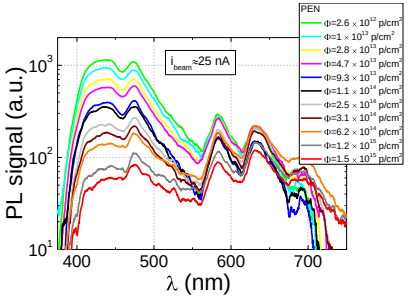


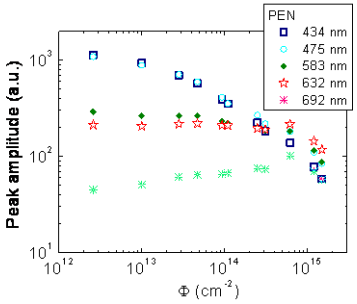


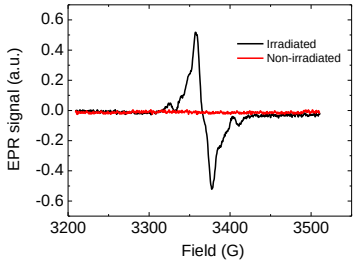


Tandem sensors made of organic material composed with semiconductors for spectrally resolved dosimetry

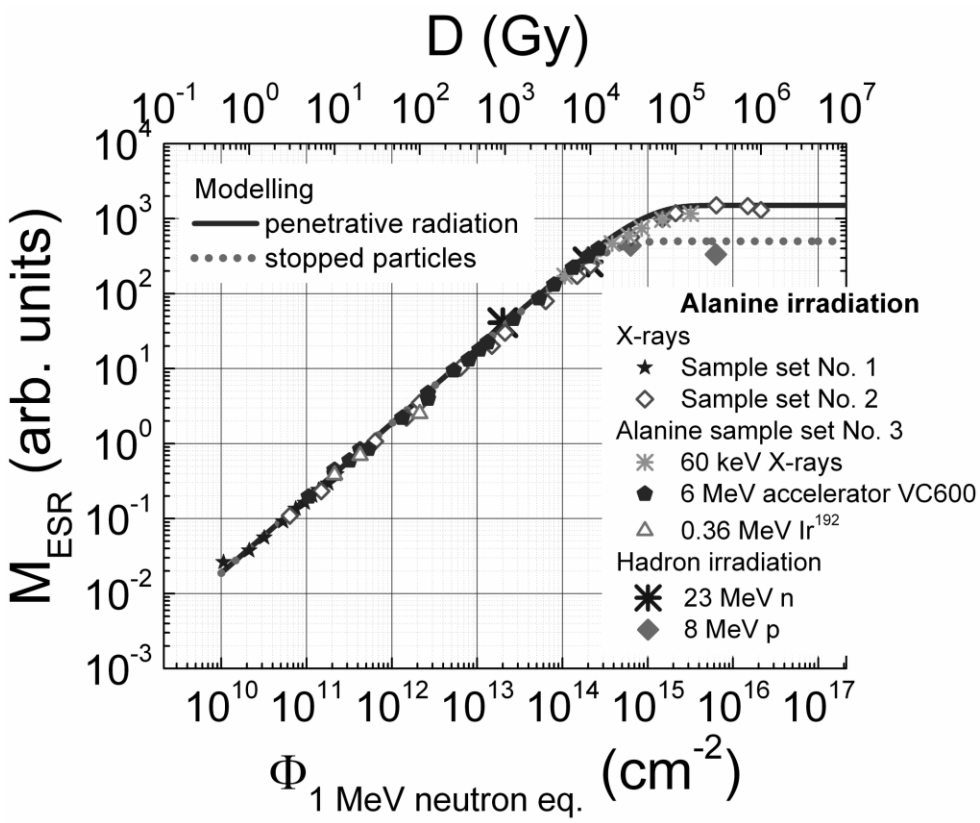
Poly-ethylen naftalat





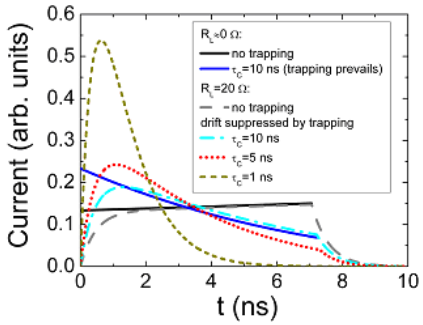


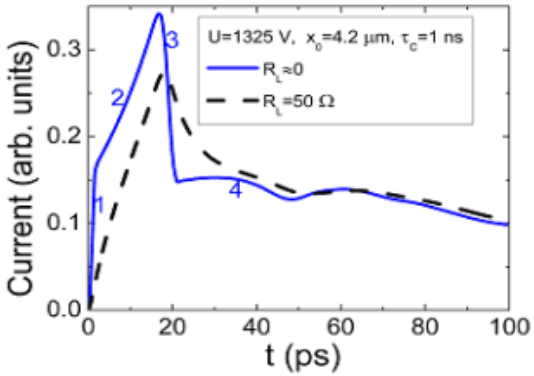
Alanine-Si

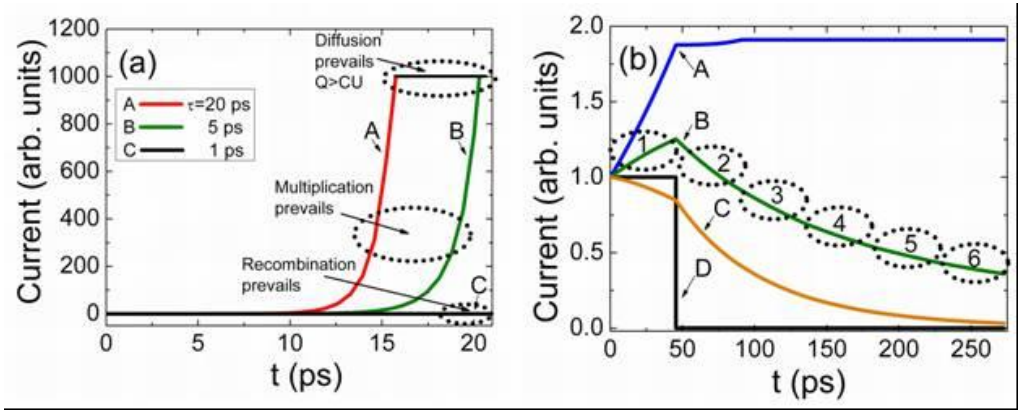


Computing technologies and simulation/design platforms
Synopsys TCAD, DFT, Cadence

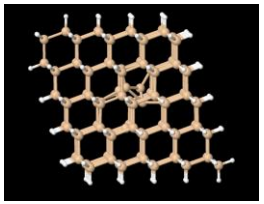
Detectors with internal amplification (LGAD, FAD)





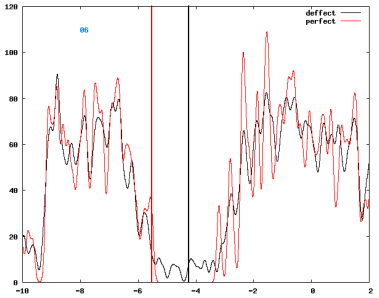


Cluster of intersititial and vacancy defects is modeled as a region of randomly displaced atoms from their crystaline positions.



Example of defect cluster:
Number of atoms displaced – 17
Size of cluster ~2 nm

DOS

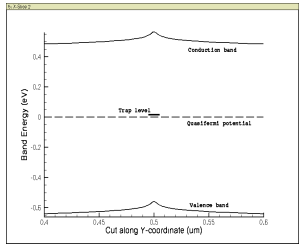


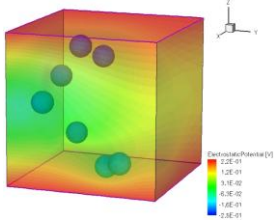
Density of electron states (DOS) in crystal with defect clusters (black) compared with the one in perfect crystal (red). Vertical lines indicate the highest energy level occupied states. DOS is calculated for 25 different randomly generated defect clusters.
All defect clusters have states with energy levels in band gap !

Study of nano size defect clusters effect on macroscopic features of material.

High energy particles bombardment creates damaged regions with trap levels:
1) Damaged region is treated as a spheric inclusion of different material with its own properties such as gap, effective mass, mobility, midgap states, etc.
2) According to literature, cluster dimensions ~20-100 nm, Concentration of traps within a cluster ~10^{18} – 10^{20} cm^{-3}

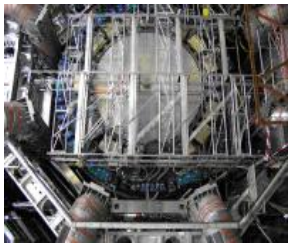
Gossick model: sphere shape cluster of acceptor type traps. Size of cluster 50 nm, acceptor energy levels E_c-0.55eV, concentration 10^{19} cm^{-3}. Charge collected by traps creates potential, which is screened by conduction electrons. Doping N_d = 10^{12} cm^{-3}, screening radius 0.4 um.

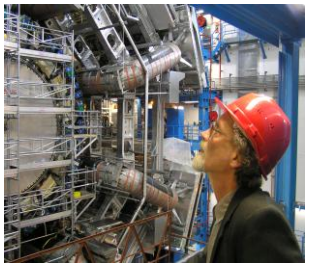


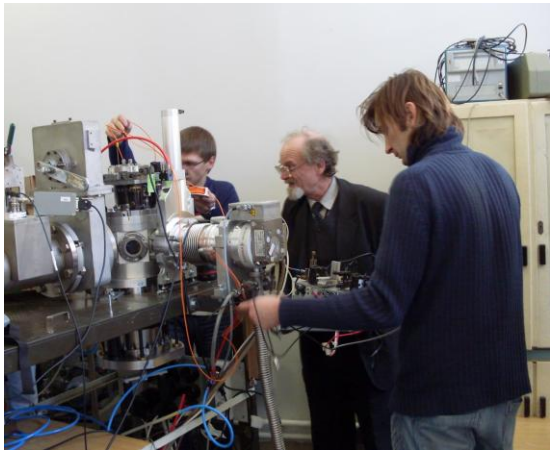


E. Gaubas, T.Ceponis, V.Kalesinskas, J.Pavlov, J.Vysniauskas, „Simulations of operation dynamics of different type GaN particle sensors“, *Sensors* 2015, *15(3)*, 5429- 5473.

Research team







Thank You for attention!