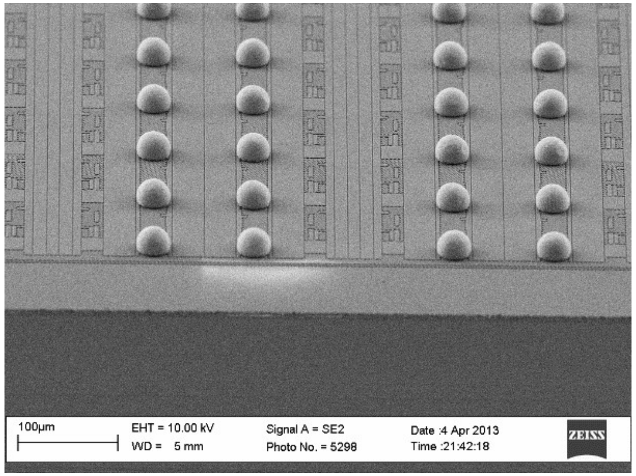
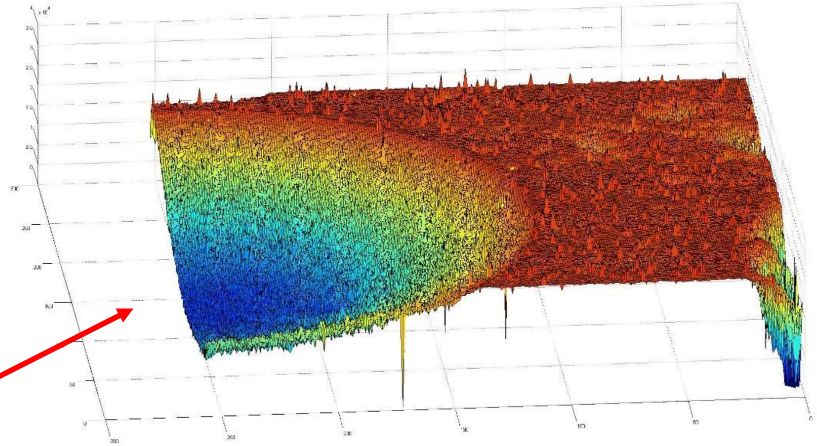
Detector research at Ruđer Bošković Institute (RBI)
- Status report October 2018

http://lnr.irb.hr/PaRaDeSEC/

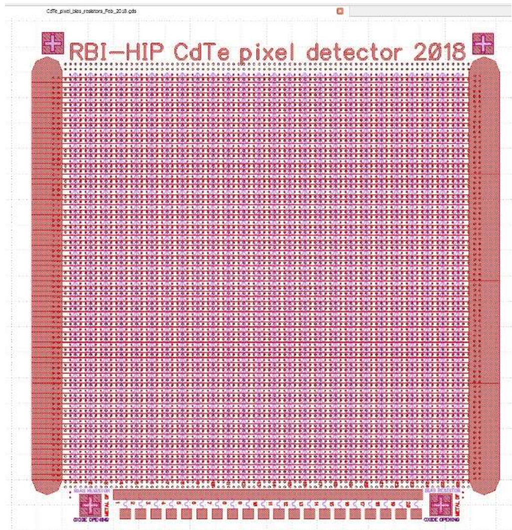




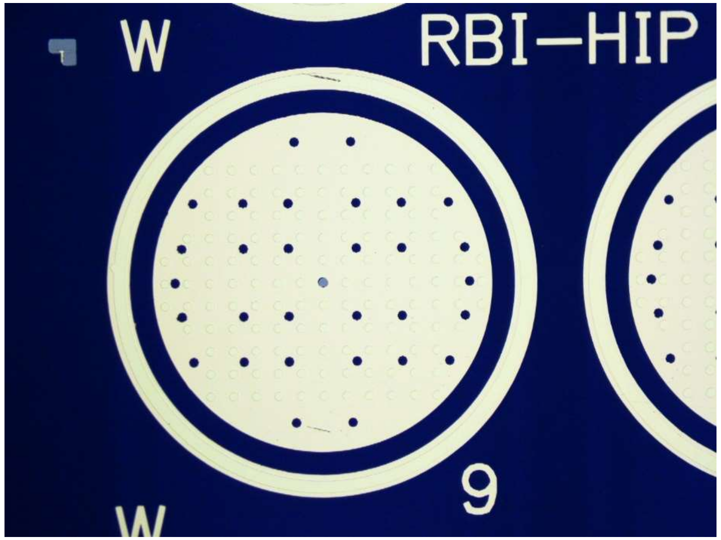
Spatially resolved Charge Collection Efficiency (CCE) of a CdTe X-ray detector. The signal is excited by 2 MeV proton beam

Outline

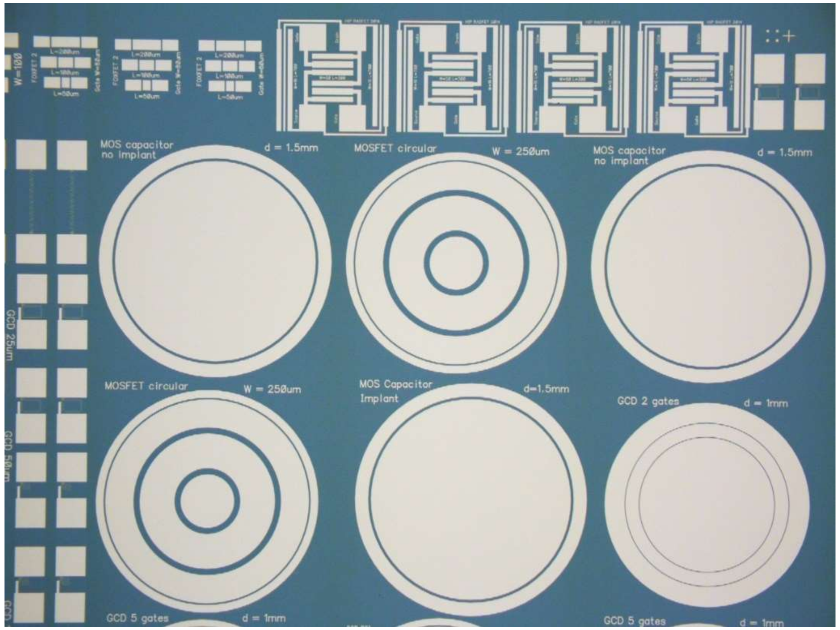
- Who we are ?
- Our facilities and key technologies
- Direct conversion X-ray CdTe detectors
- Silicon Drift Detectors (SDD)
- Silicon detectors with scintillator conversion materials



Layout of a CdTe pixel detector. The pixel matrix is 52 × 80 = 4160 pixels in double column. Area 1 cm^2. Layout is compatible for Flip-Chip bonding with PSI46dig Read-Out Chip (ROC) used within CMS experiment at Large Hadron Collider (LHC).



Experimental CdTe X-ray detector. Small circular openings allow laser light to penetrate for Transient Current Technique (TCT) measurements.



Radiation MOSFET (RADFET), MOS capacitors and Gate Controlled Diode (GCD) test stuctures on silicon chip

Who we are ?

PaRaDeSeC = Particle and Radiation Detectors and Electronics in Croatia

The Team:

Dr. Jaakko Härkönen

Dr. Valery Chmill

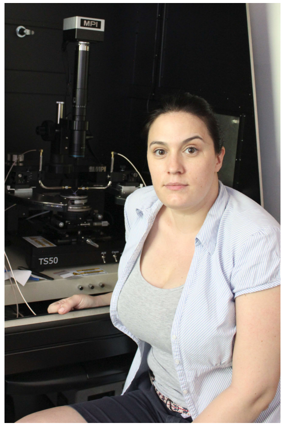
Dr. Andrey Starodumov

Dr. Aneliya Karadzhinova-Ferrer

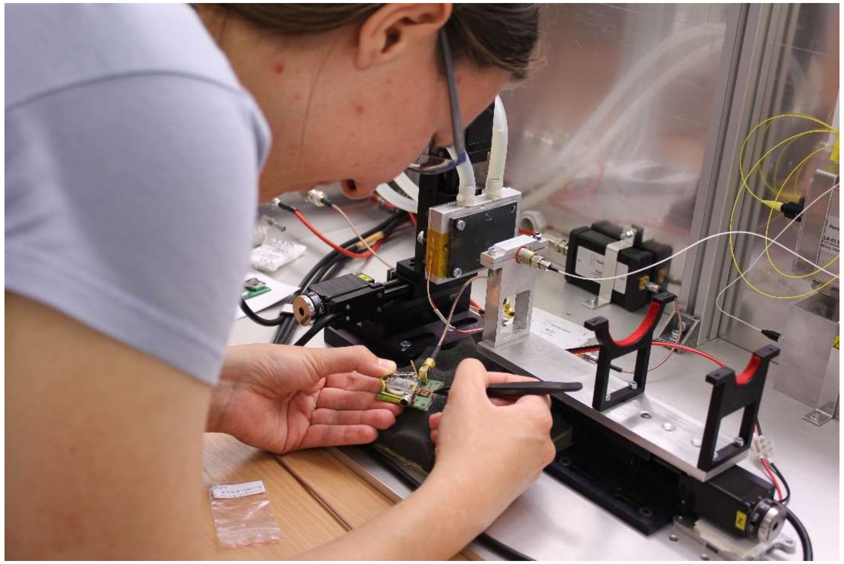
Dr. Matti Kalliokoski

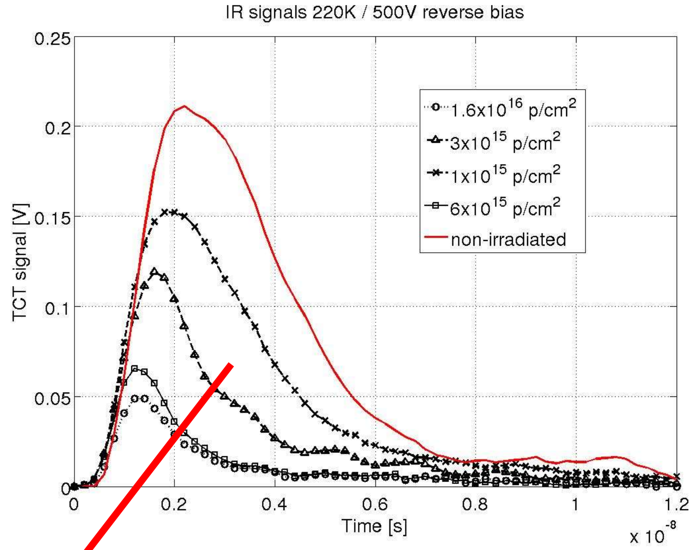
Ms. Ana Petric (M.Sc student)

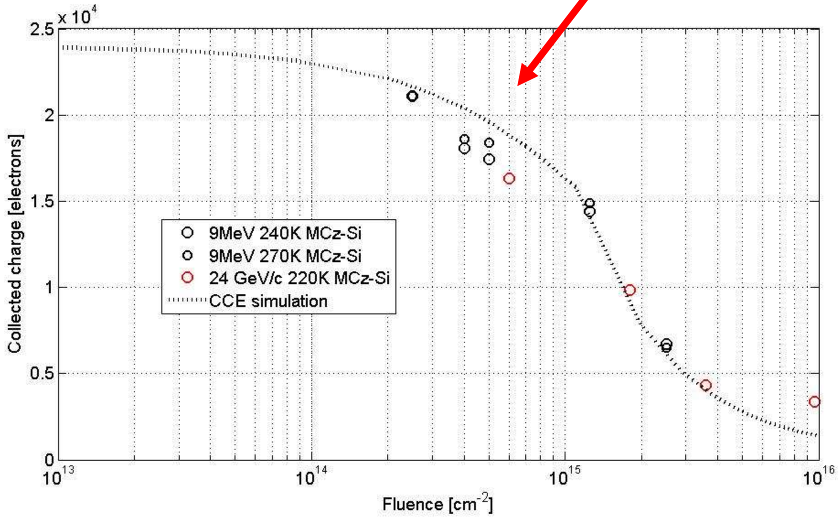
contact: name + @irb.hr



Part I -Facilities and key technologies

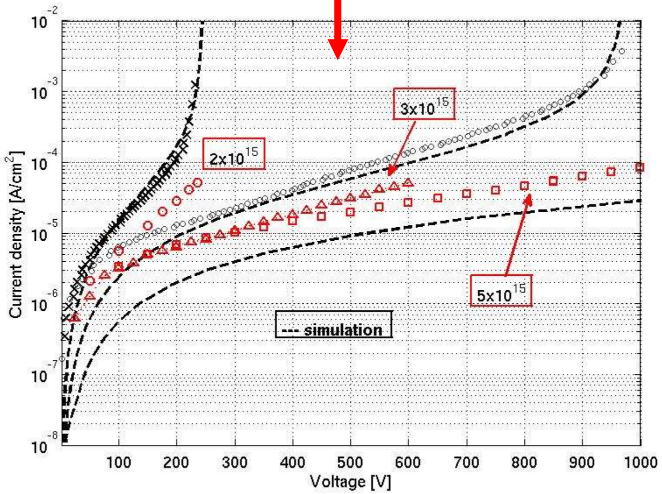


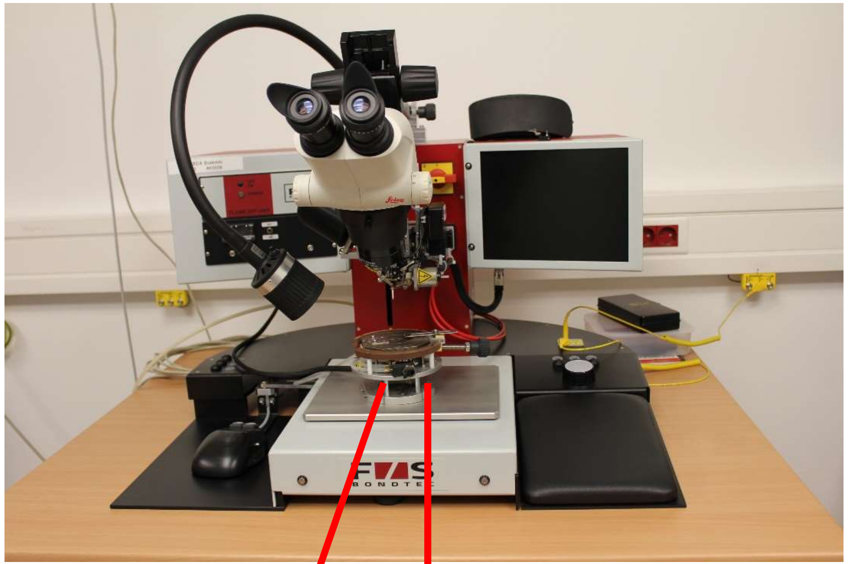


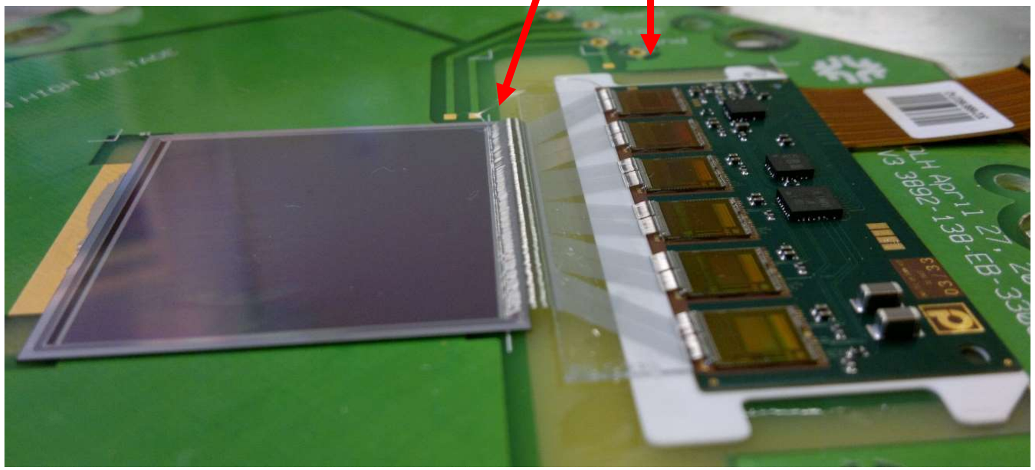


Transient Current Technique (TCT) setup

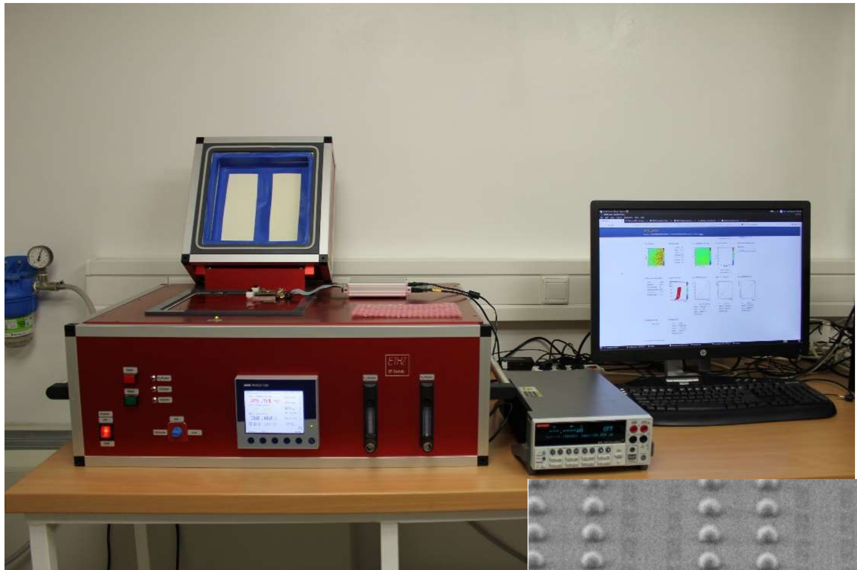
Probe station / Wire bonder

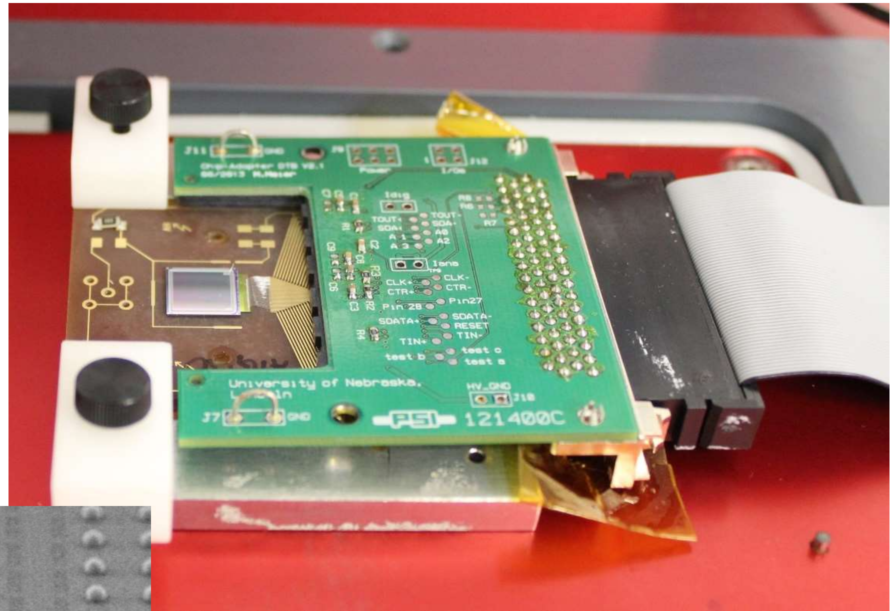


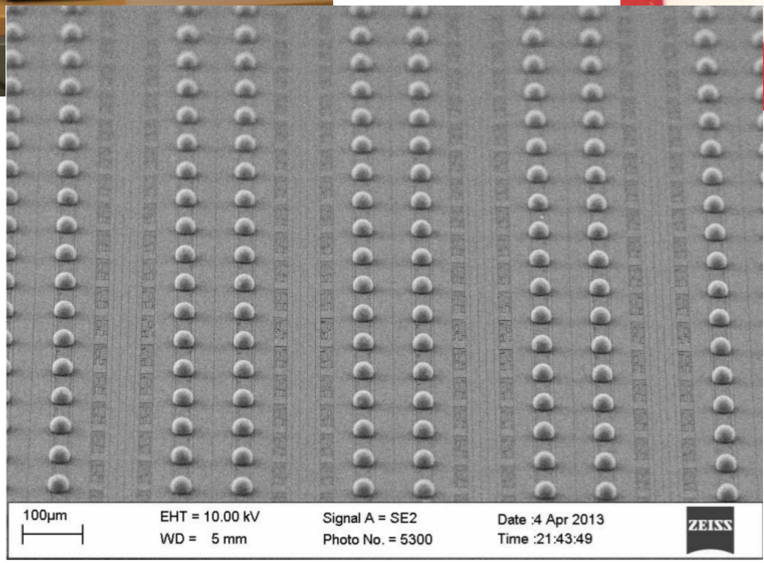




Test platform for pixel detectors

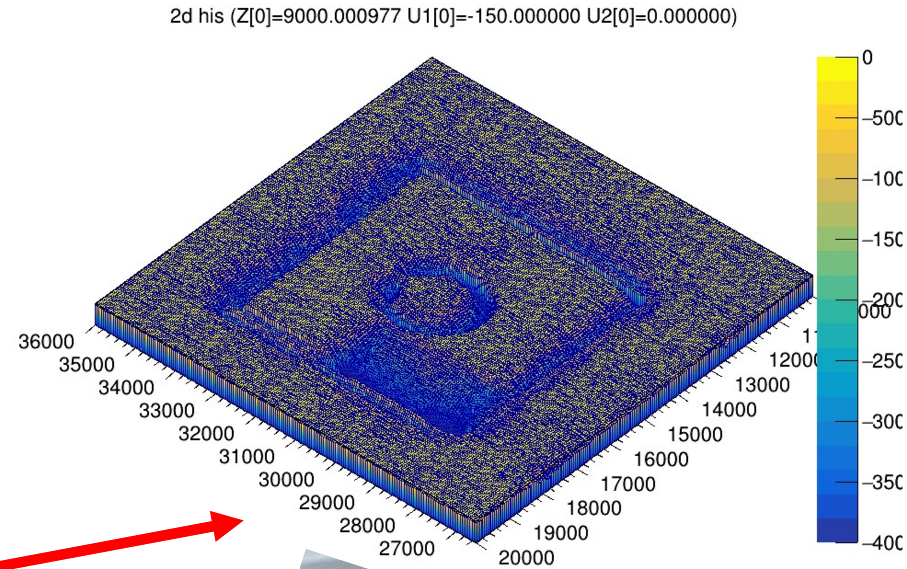


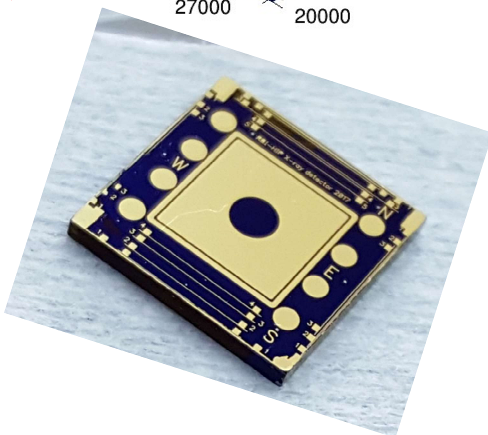




Silicon pixel particle detector
52 × 80 = 4160 pixels in double column (PSI46dig ROC) used in CMS experiment at LHC of CERN

Scanning microfocused ion beam at RBI Accelerator lab





Research strategy

Medical Application
Nuclear Safety
Satellite missions
Astrophysics

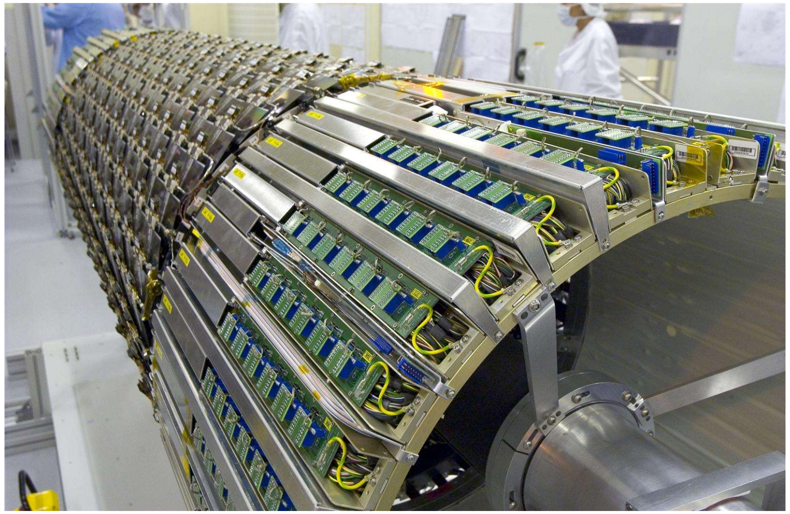
Development of next generation CMOS ASIC read-out electronics

Particle tracking detectors
Next generation pixel detectors
Radiation Hardness
Fundamental research

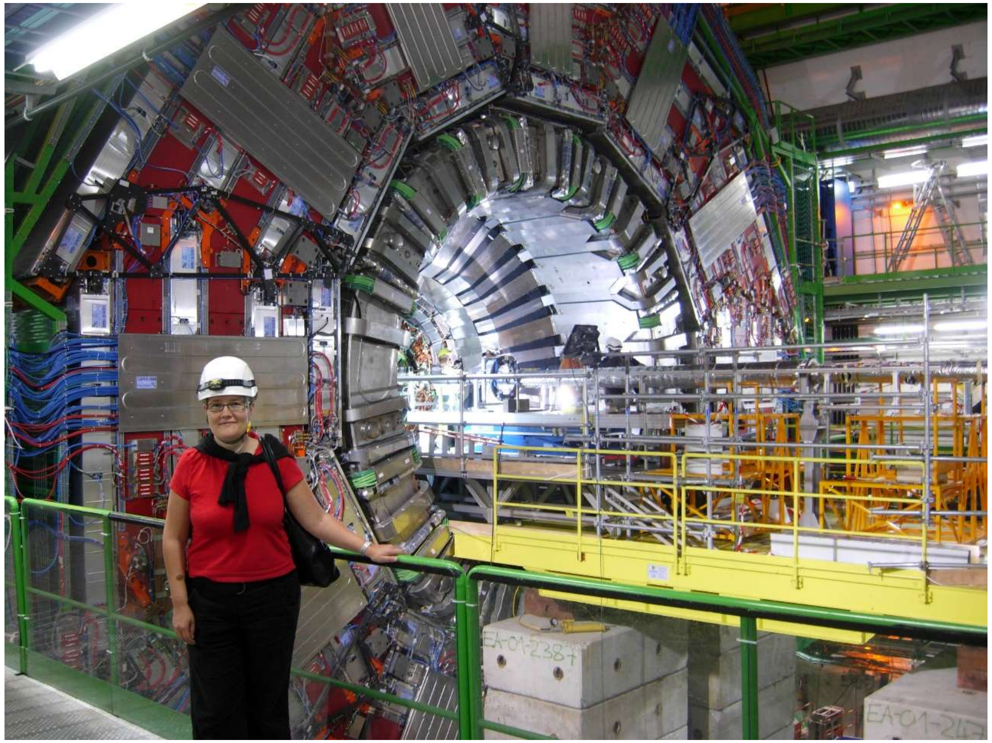
Reserch training
Outreach & dissemination
Cooperation with industrial partners

Part II – Detectors for particle physics experiments

General requirements
- Radiation hardness
- Relatively low costs
- Feasibility in large scale / industrial production
- Robustness



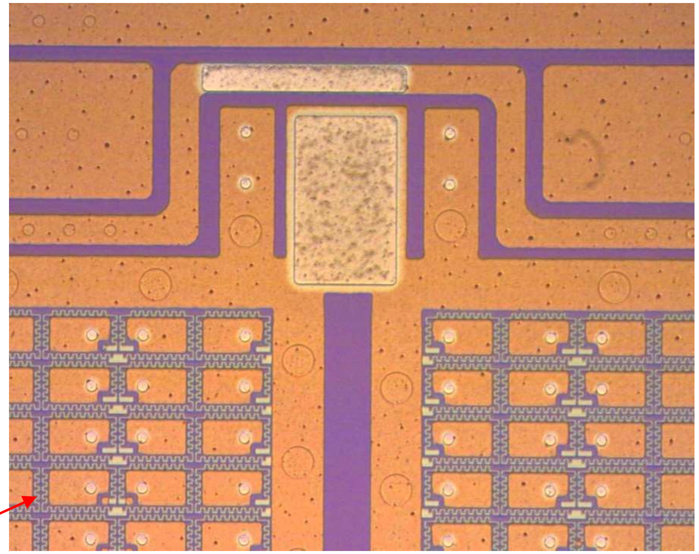
Pixel detector particle tracker detector of CMS (Compact Muon Solenoid) experiment at the CERN LHC accelerator.

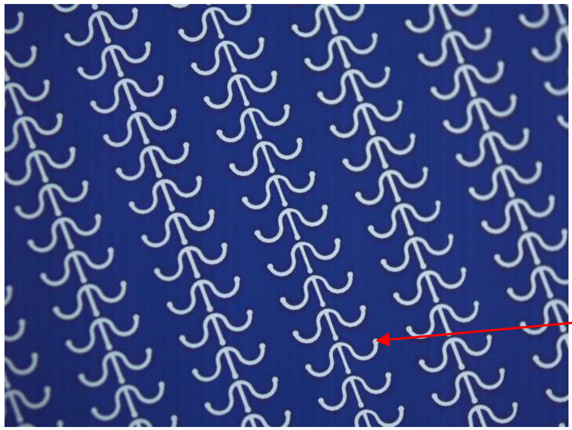


CMS detector ~100m underground in LHC Point 5 in Cessy, France.

Future key technology for radiation detectors - Atomic Layer Deposition (ALD)

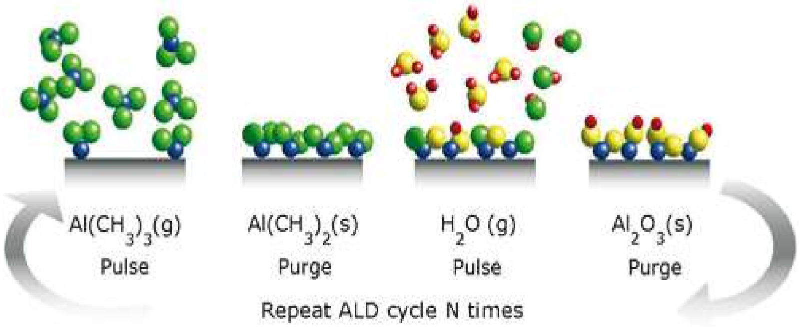
- The ALD method is based on the successive, separated and self-terminating gas–solid reactions
- Thin films are grown monolayer by monolayer
- Very high capacitance and resistance densities are achievable
- ALD provides many potentially interesting material systems.
- With ALD one can tailor amount and type of oxide charge
- ALD is pinhole free deposition
- ALD is low temperature process, typically 100-300° C
- CdTe was coated by aluminum oxide (Al_2O_3) deposited at 150° C
- ALD results in conformal thin films, i.e CdTe chip edges became also passivated by Al_2O_3



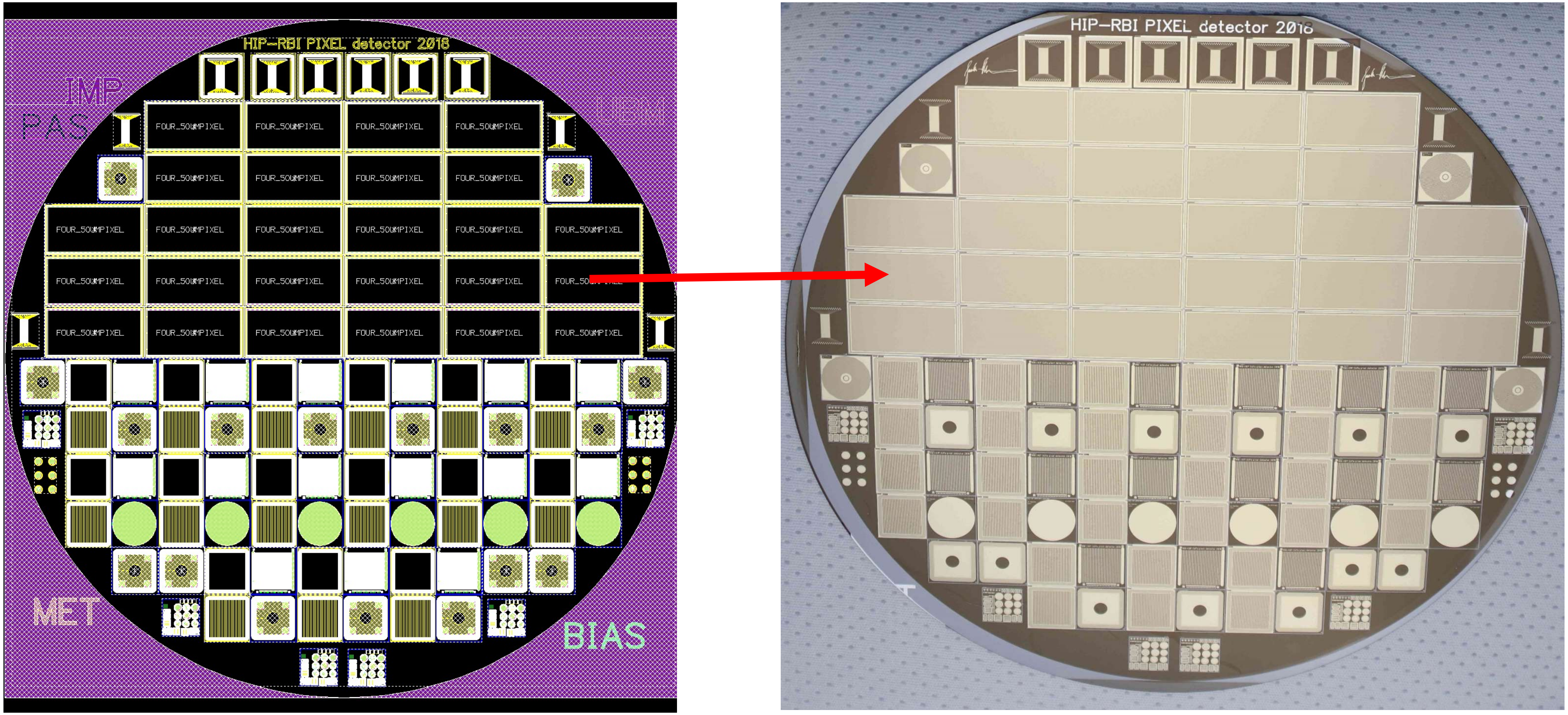


Silicon pixel detector coated with ALD grown Al_2O_3 and with integrated bias resistors. Bias resistors connect resistively pixels with each other and allow Quolity Assurance IV probing prior expensive Flip-Chip bonding. That crucial especially with difficult in inhomogenous materials such as 1cm^2 CdTe chips.

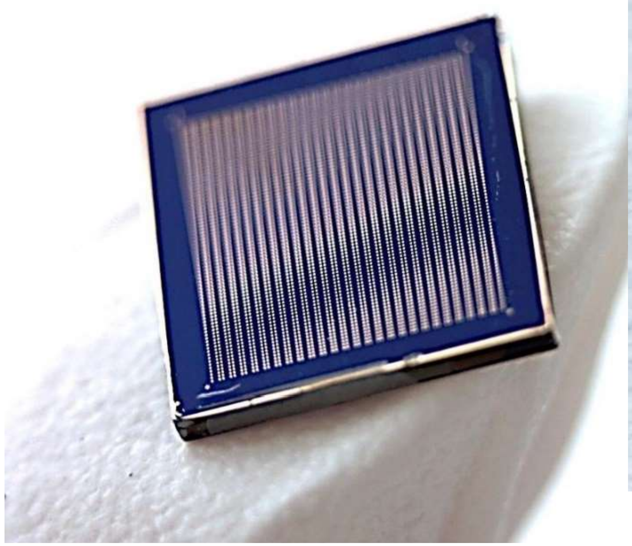
Al_2O_3 coated Si test chip with bias resistors.



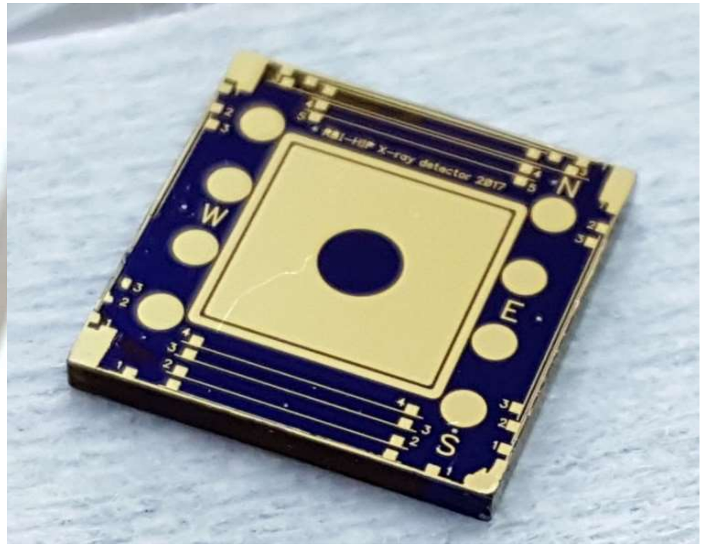
Particle detectors made jointly by HIP and Micronova Nanofabrication Center



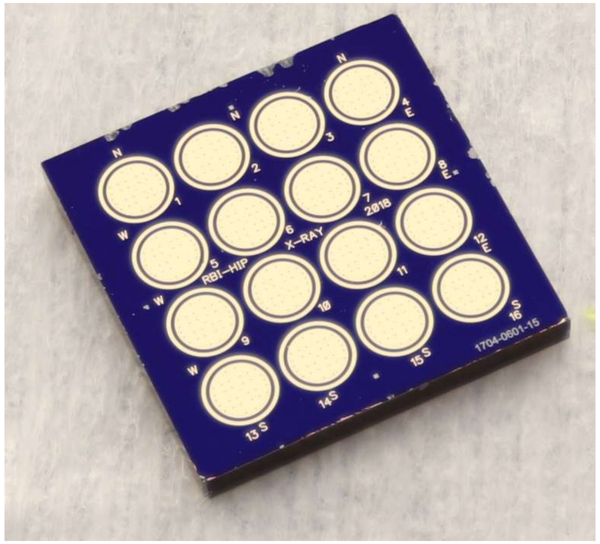
Part III -Direct X-ray conversion CdTE detectors



CdTe X-ray pixel detector
52 × 80 = 4160 pixels in double column (PSI46dig ROC)



CdTe X-ray pad detector for nuclear safety applications

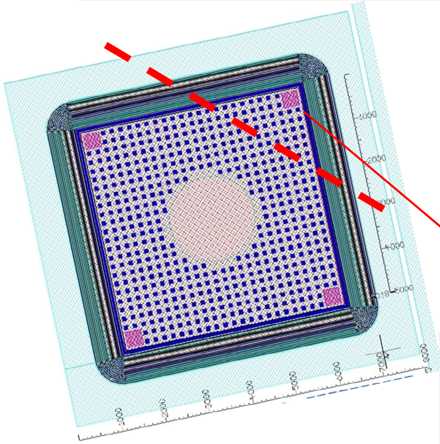


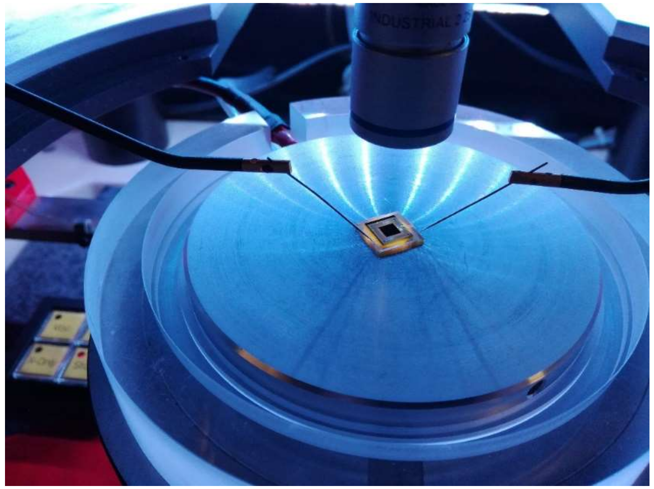
CdTe X-ray 4 × 4 pixel detector. Possible use e.g for CERN antihydrogen experiments

Methods for photon detectors characterization

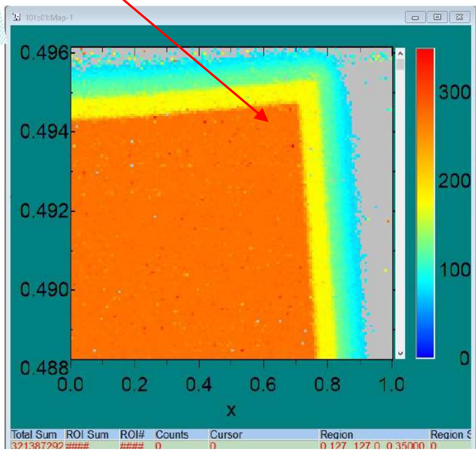
Transient Current Technique (TCT) set up. Detector signal is excited by picosecond pulsed laser and response waveform recorded by oscilloscope

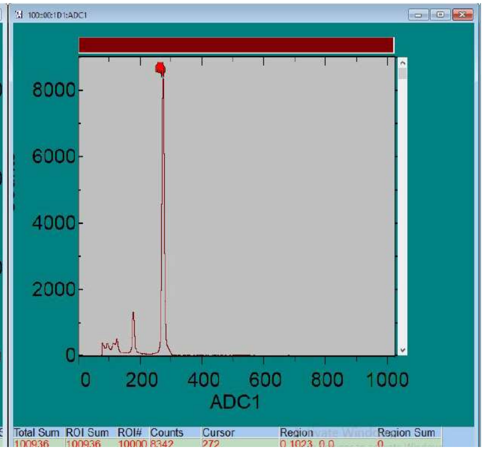
µm focused scanning proton beam in Zagreb. Proton beam scans a detector with electrical contacts. Four color chart reveals spatially resolved relative CCE

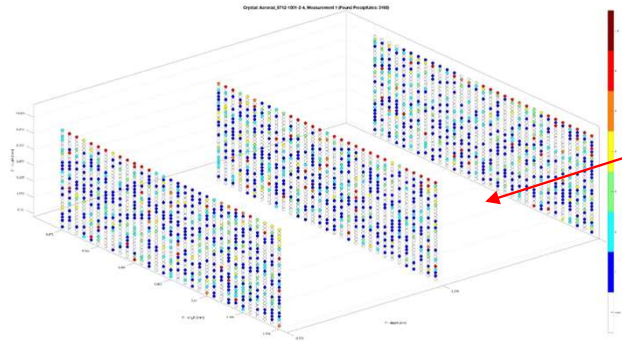




CdTe X-ray detector at probe station in Helsinki

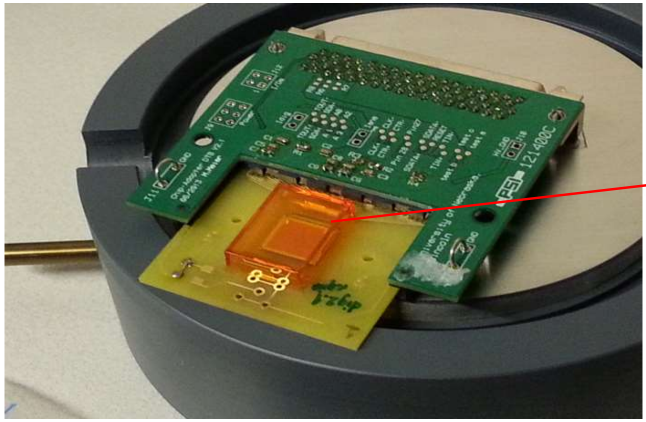




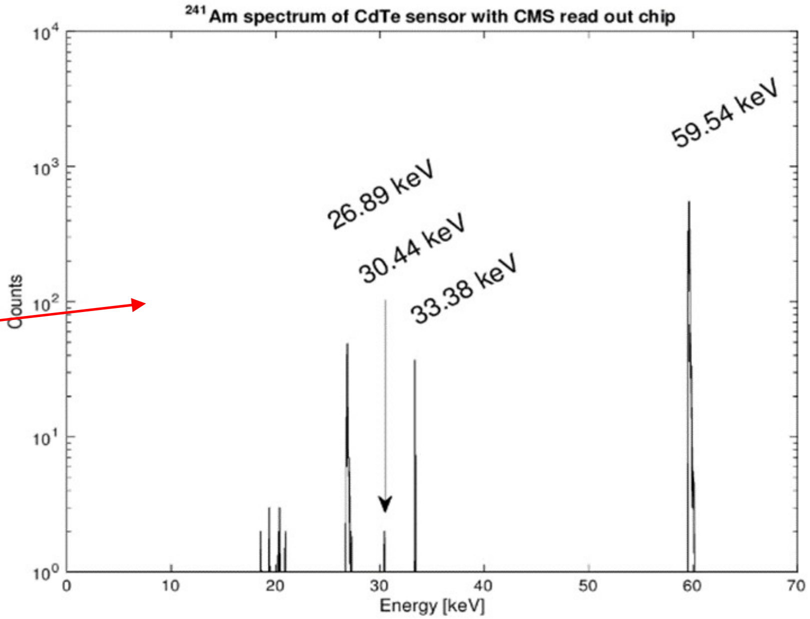


3D FTIR infrared spectroscopu in Helsinki. This is used to QA characterization of CdTe crystals. IR absorption reveals extended crystallographic defects in CdTe

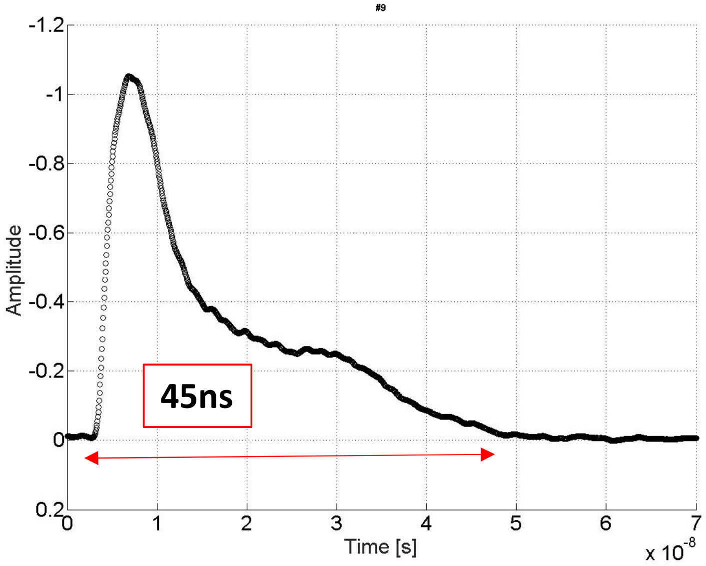
Selected results CdTE detectors

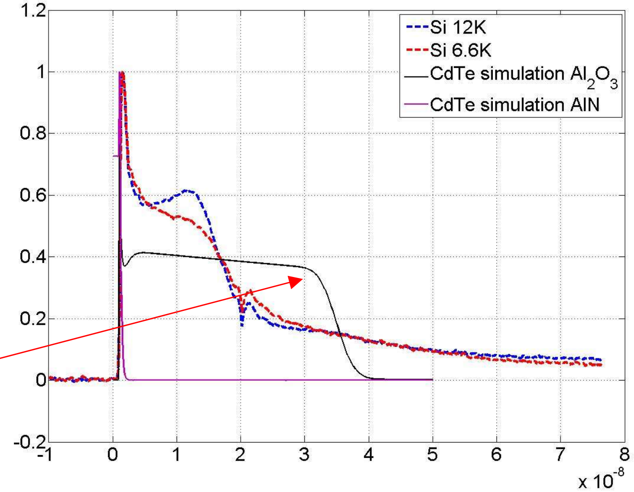


CdTe X-ray pixel detector
52 × 80 = 4160 pixels in double column (PSI46dig ROC)



CdTe X-ray pixel detector spectrum with ^{241}Am source

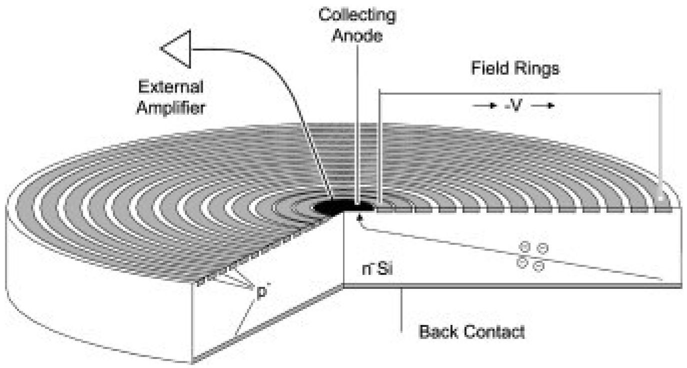




TCT transient of a CdTe X-ray pad detector. The detector is 1000µm thick and results on electron current transient with ≈45ns duration. Experimental data is reproducible with TCAD simulations

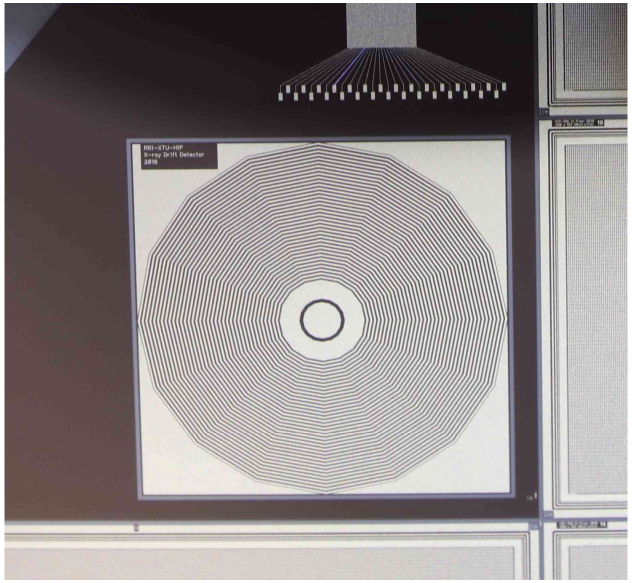
Silicon drift detectors (SDD)

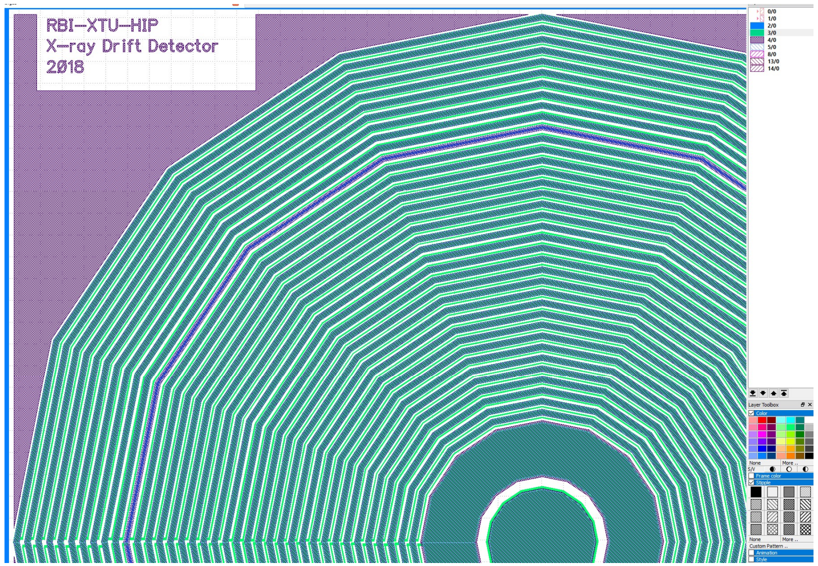
- SDD is based on field rings and collecting anode in center
- Potential drop over field rings ~500V
- Current signal from anode is proportional to energy of X-rays
- Field rings are lightly p+ doped (=additional implantation)
- SDDs are used e.g. to detect soft X-rays during satellite missions.

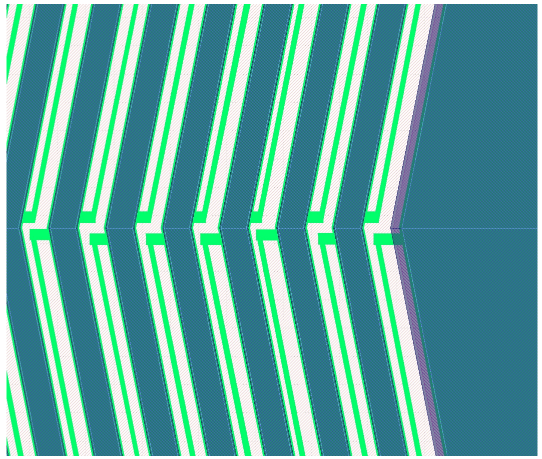


Picture from "Silicon drift detectors for high count rate X-ray spectroscopy at room temperature", by P. Lehner et al., NIMA 458 2001.

- With ALD it is possible to realize very high resistance density thin films
- RBI-HIP-XTU joint project is produce SDD where ~500V potential drop takes place over resistors that are placed between n+ heavily doped implants (GREEN color)
- If resistance is sufficiently high, only very small current is needed results in Vdrop ≈ 500V
- That´s important for space missions.

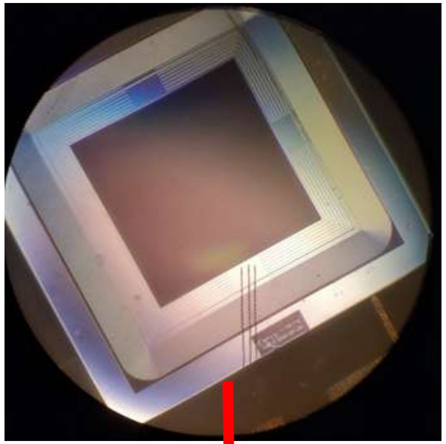


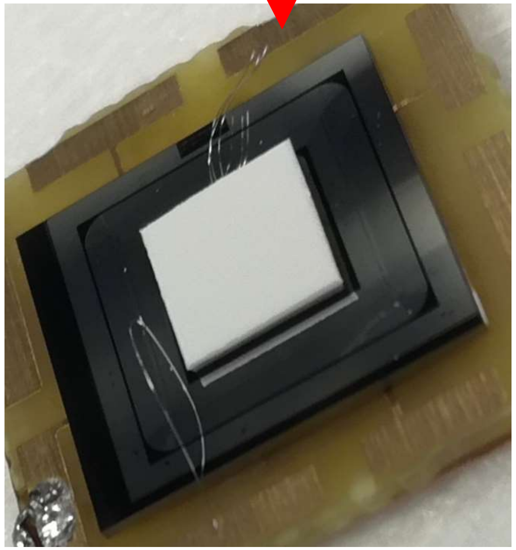


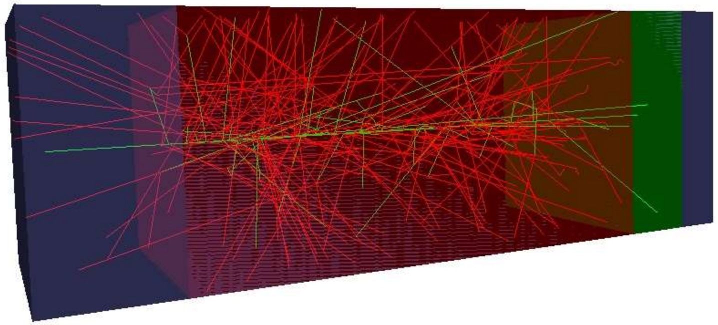


Silicon detectors with scintillator (SiS)

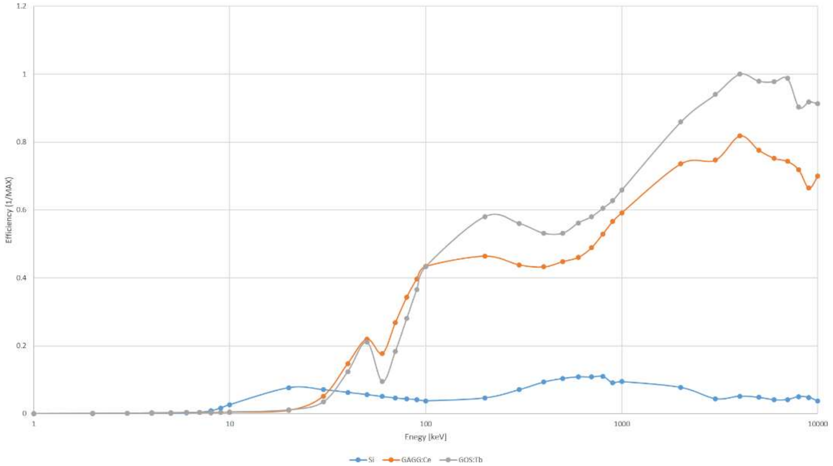
- Terbium doped Gadolinium oxysulfide (Tb:GOS) scintillator attached with HIP Si detector
- Tb:GOS provided by Specom Oy, Finland
- Light elements such as nitrogen or oxygen emit ~10 MeV gammas when illuminated by neutron source





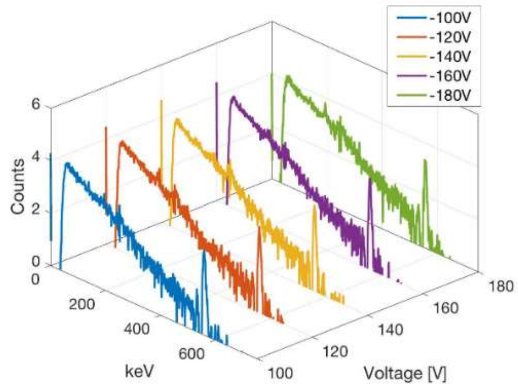


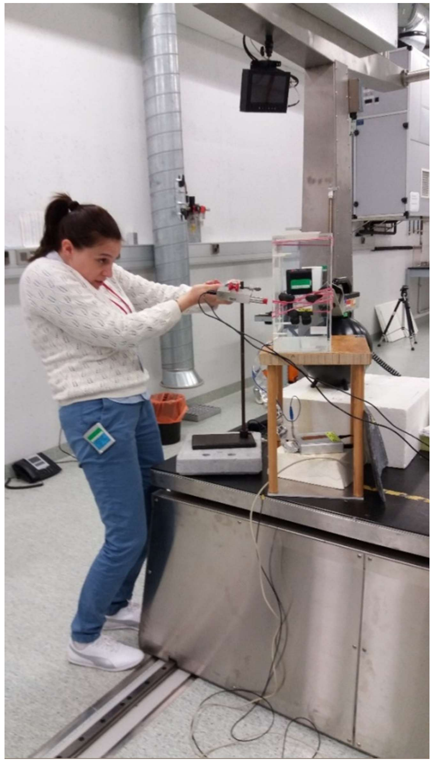
GEANT4 simulation illustration of Tb:GOS response for 140 keV photons. The simulation was done for 2mm thick Tb:GOS**. Efficieny is peaking at about 10 MeV photons**. Response can be tuned for lower energies by thinner scintilator



Summary

- RBI PaRaDeSeC team has on-going common activity to develop new and innovative photon detectors.
- Our main research lines are Si particle detectors, CdTe direct X-ray conversion detectors, SDD and SiS technologies.
- Applications of these detectors are e.g. fundamental physics research, astrophysics, medical imaging and nuclear safety / decomissioning.
- Detectors are processed at Micronova nanofabrication center in Finland (www.micronova.fi)
- Atomic Layer Deposition (ALD) technology has many properties, which make it very attractive process method for radiation detectors.
- We do close collaboration with companies and research groups in Europe, United States and Asia.





Aneliya Karadzhinova-Ferrer measuring X-ray detector