Radiation damage of monolithic pixel detectors

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Outlook

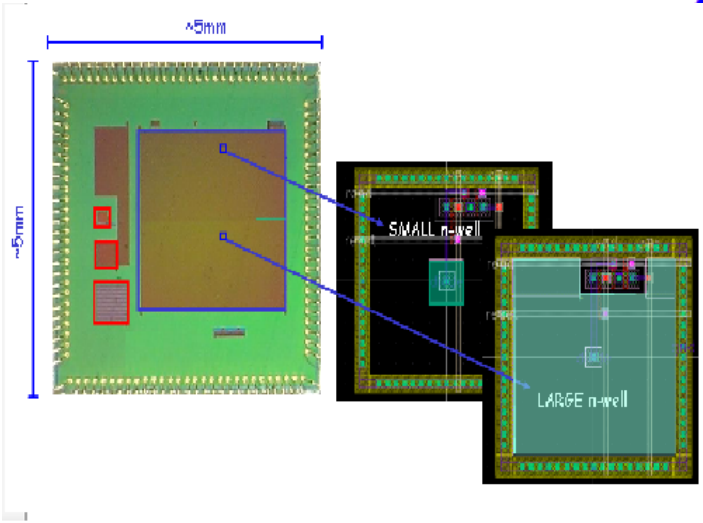
- Characterization of sensor already damaged
- Irradiation of new sensors at LNS Catania
- Dosimetric Characterization of a X-ray tube

INFN Perugia plans for AIDA

- **Irradiation of Monolithic Active Pixel Sensors to study their resistance to radiation damage.**
  - 180 nm non-epitaxial (RAPS03 Sensors);
  - 130 nm epitaxial (Micron Imagers);

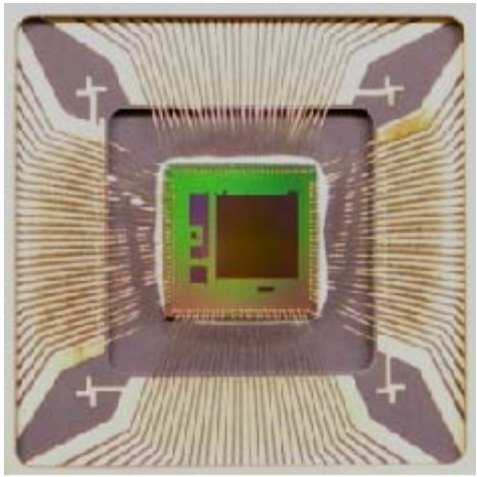
Sensors to be studied: RAPS03

Research Prototypes from INFN Perugia



- **RAPS03:**
- non-epitaxial
- 180 nm technology
- 10 μm pixel size
- charge collection depth ~ 30 μm

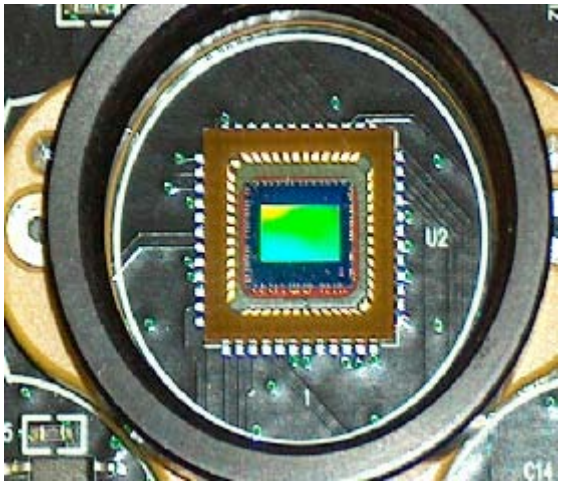
- 4 128x128 pixels matrices
- 2 with small photodiode size (4 μm^2);
- 2 with large photodiode size (77 μm^2);
- 512 μs – 4 s integration time;
- 600 mV dynamic range;



Micron Imagers MT9xx

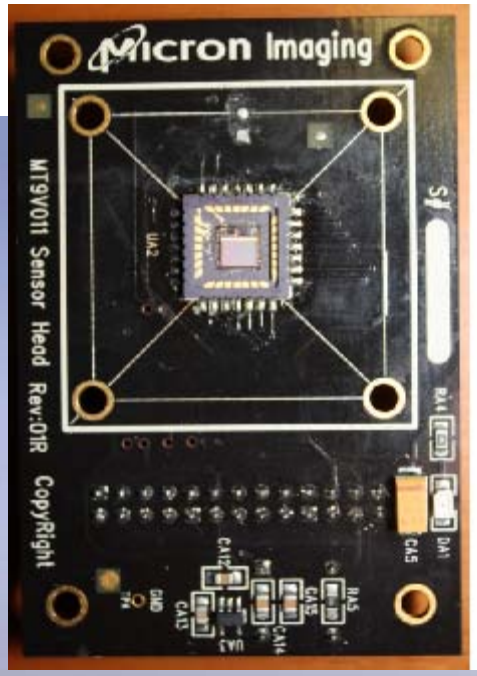
CMOS Imagers fabricated by Aptina Imaging.

- very high pixel granularity (> 300000)
- thin epitaxial layer (~ 2-5 μm)
- 130 nm technology
- small pixel size (< 6 μm)



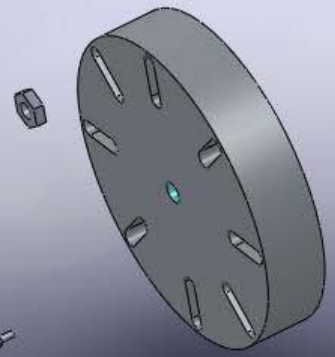
Previous Irradiation

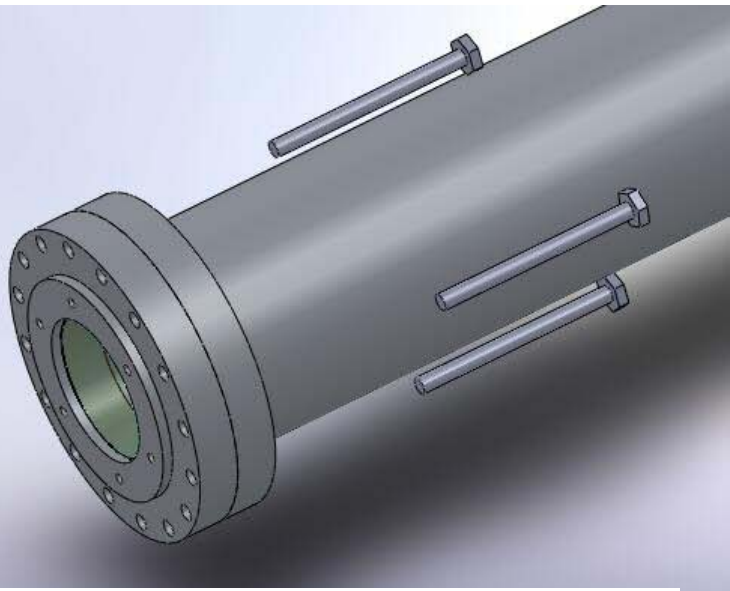
MT9V011: 24 MeV proton beam @ LNS; fluence 0.6 10^{14}/cm^2



MT9V011

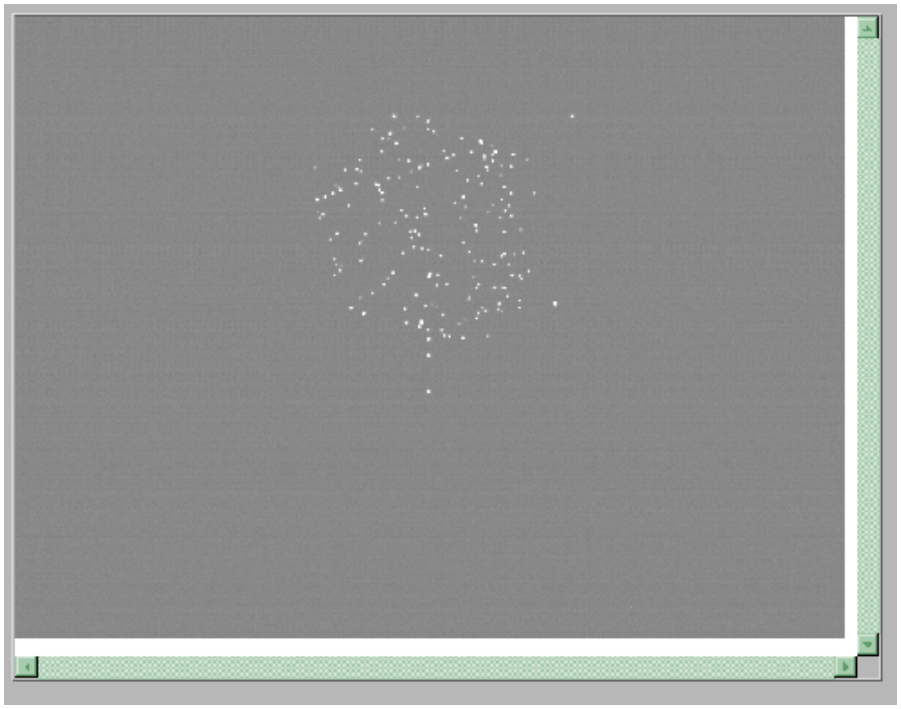
Collimator

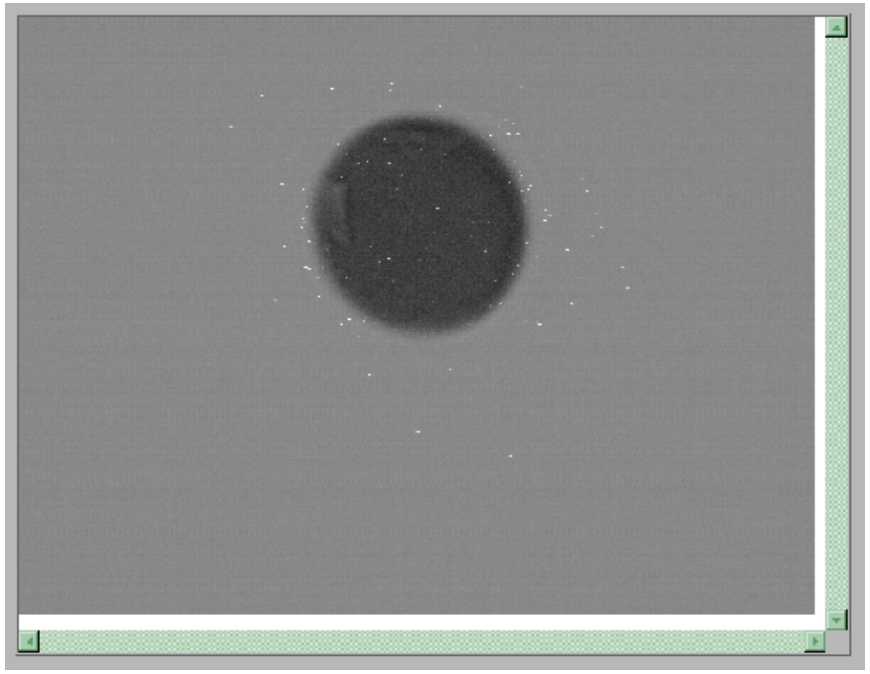




Accelerator exit window

Observation during Irradiation

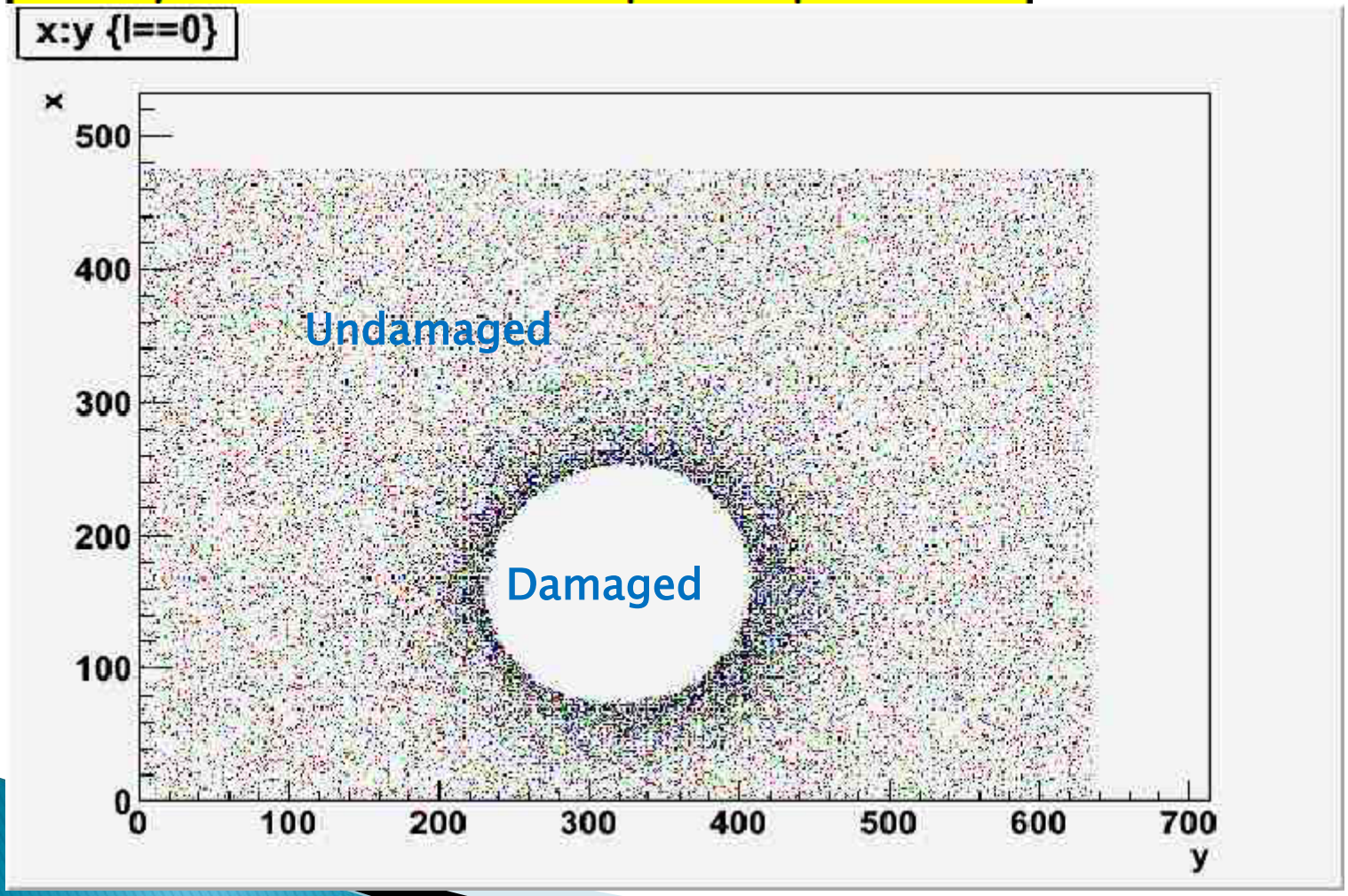




- Pedestal variation;
- Increased pixel noise;

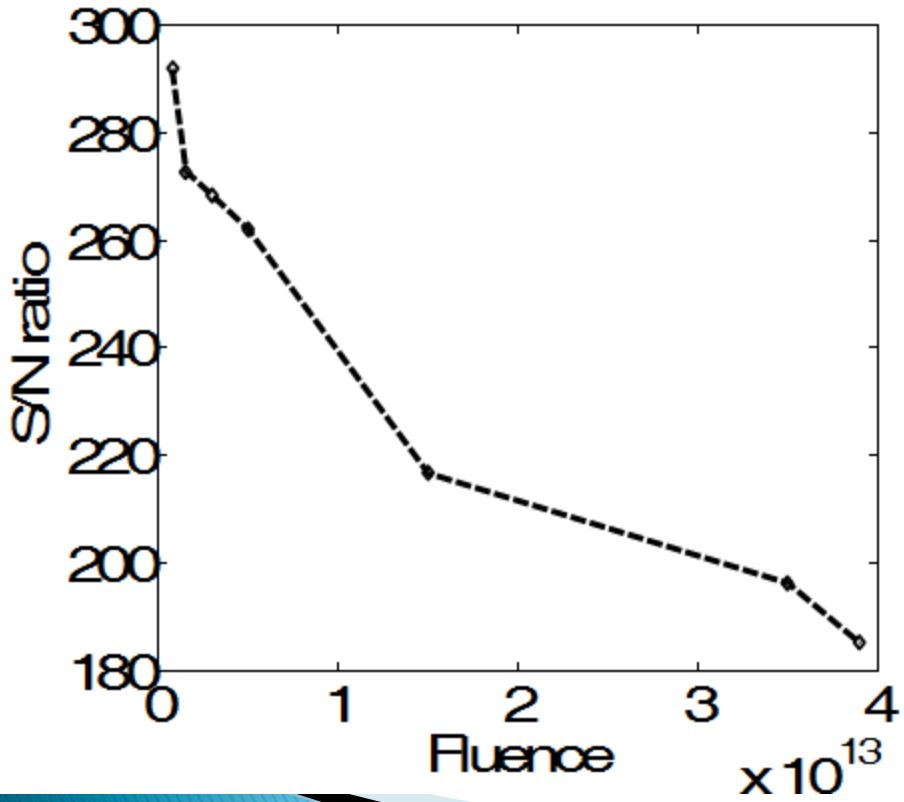
Test with X-ray after irradiation I

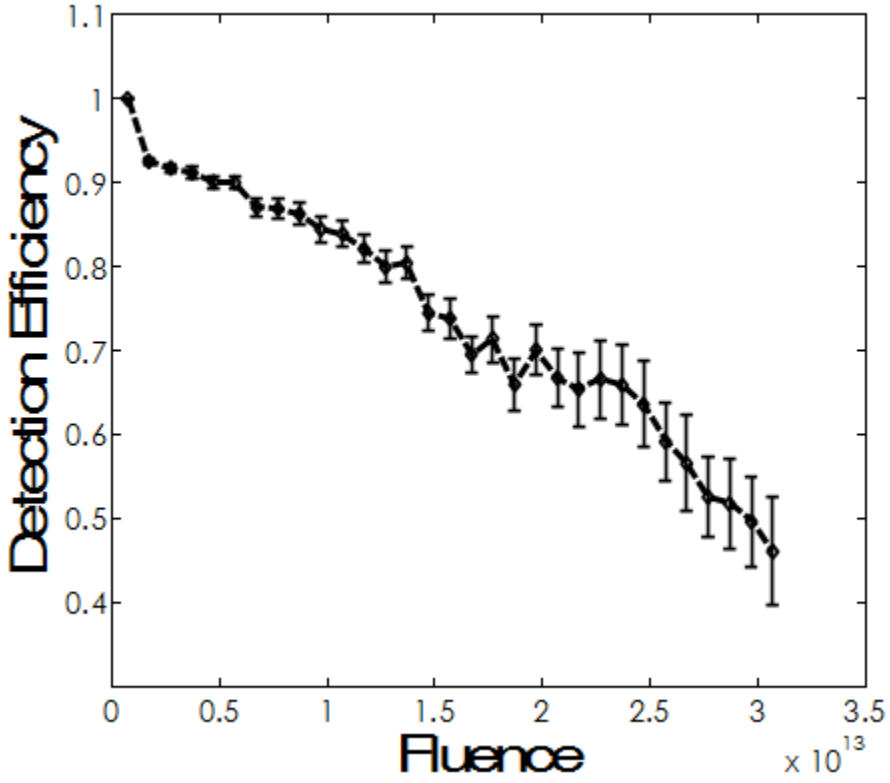
X-ray beam @ 37 keV peak spectrum



Test with X-ray after irradiation II

The S/N variation for fully collected 8.0 keV photons and the detection efficiency have been measured.

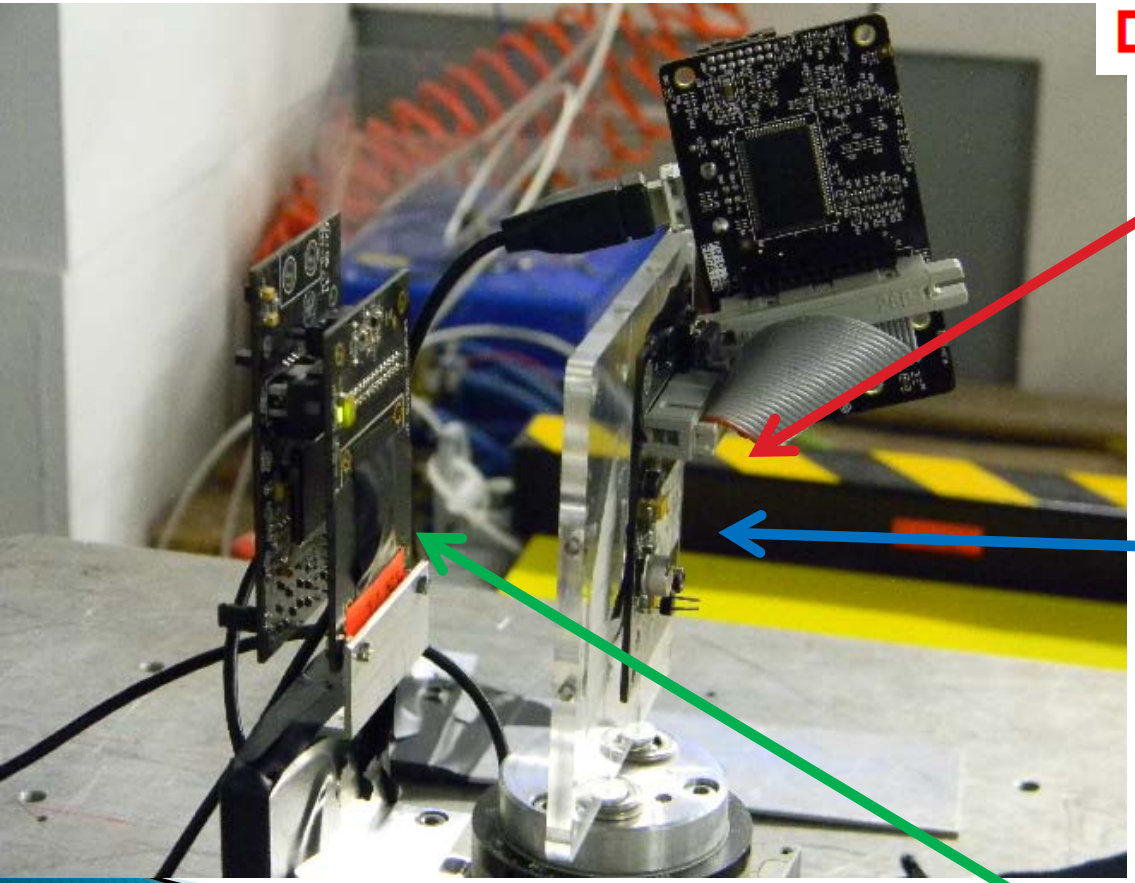




Test at LNF-BTF with 500 MeV electrons

- Two MT9V011 sensors, one damaged and one undamaged have been exposed to the beam.
  - Undamaged sensor used to measure electron flux homogeneity.
  - Damaged used to measure variation of detection efficiency and of charge collection efficiency (S/N).

Test setup



Damaged MT9V011 sensor

500 MeV electron (positron) beam.

electron flux ~ 5-10 times the positron flux

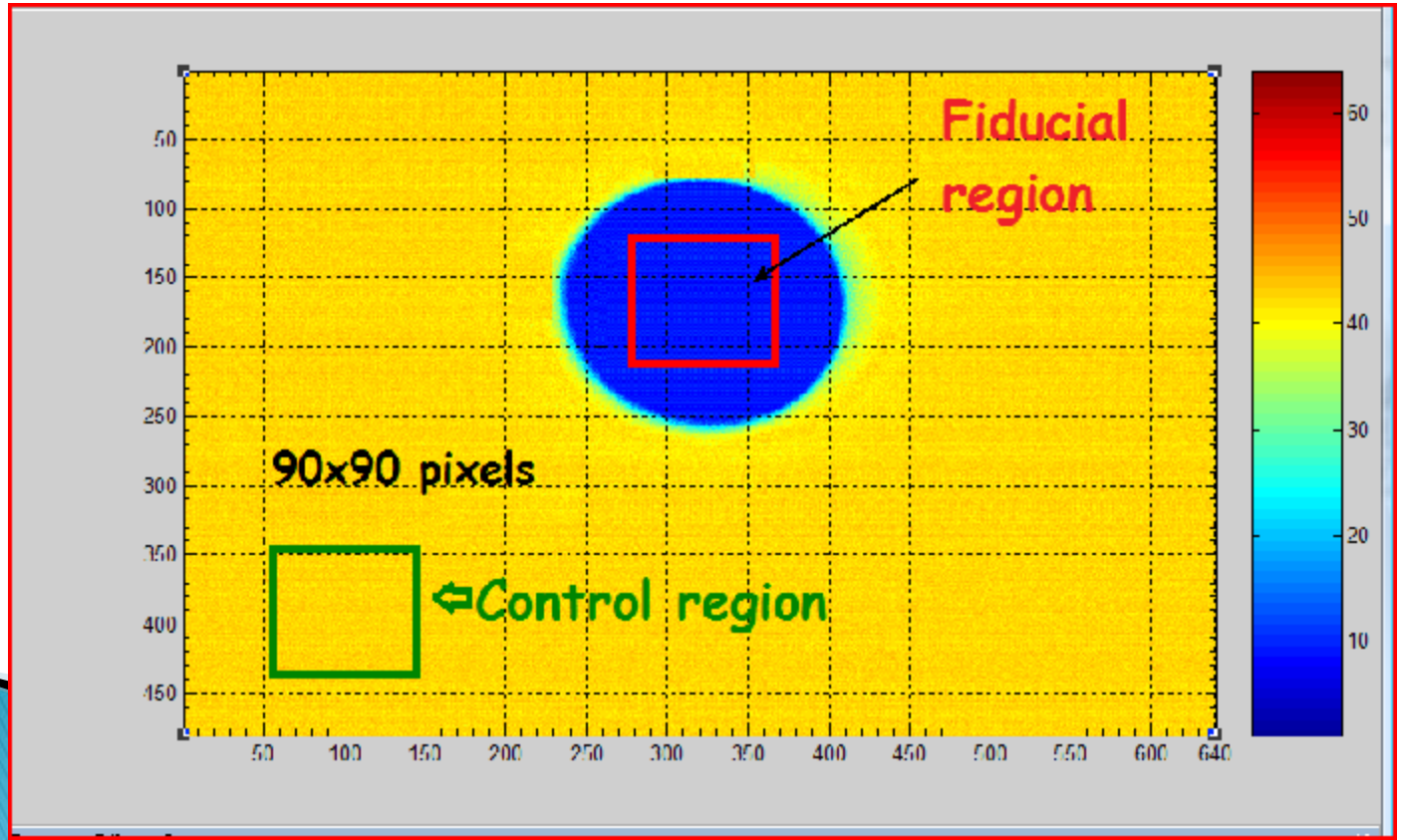
Undamaged MT9V011 sensor

Definition of regions

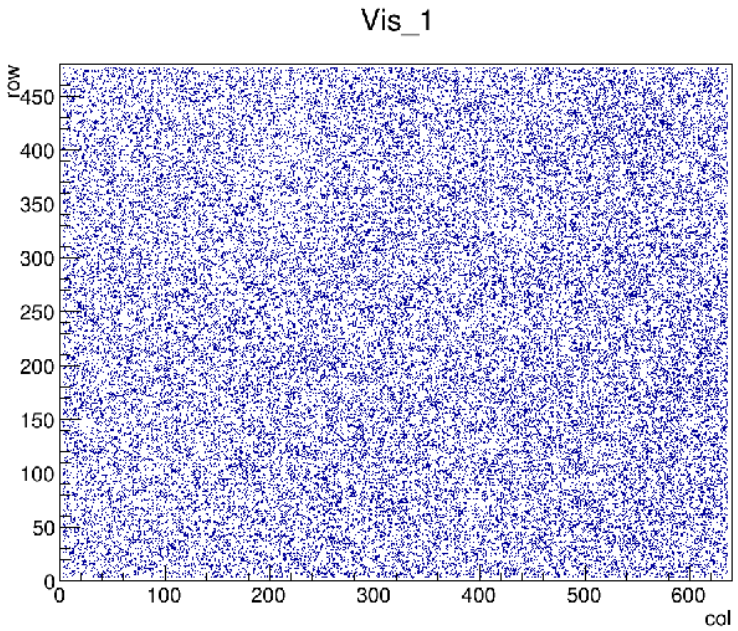
Then define two regions on the damaged sensor:

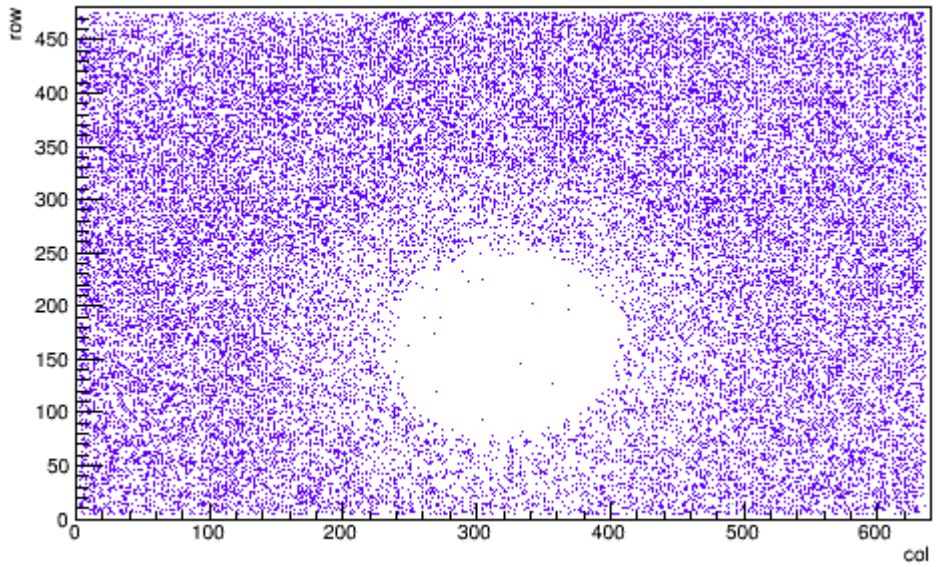
- one inside the most damaged area (signal region);

- one ouside the damaged area (control region);

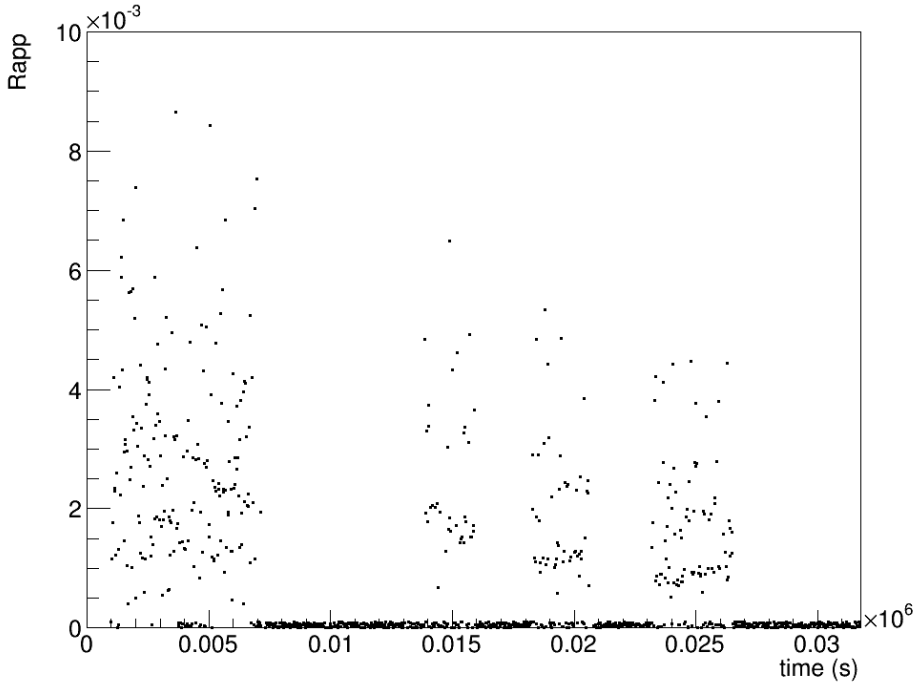


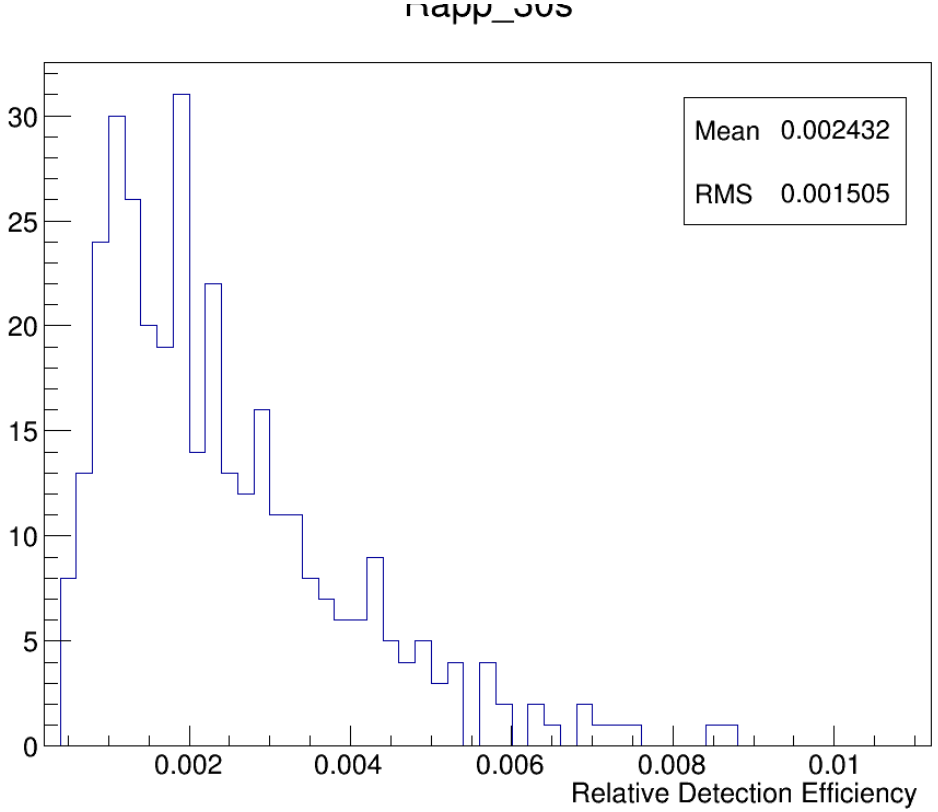
Control sensor and damaged sensor





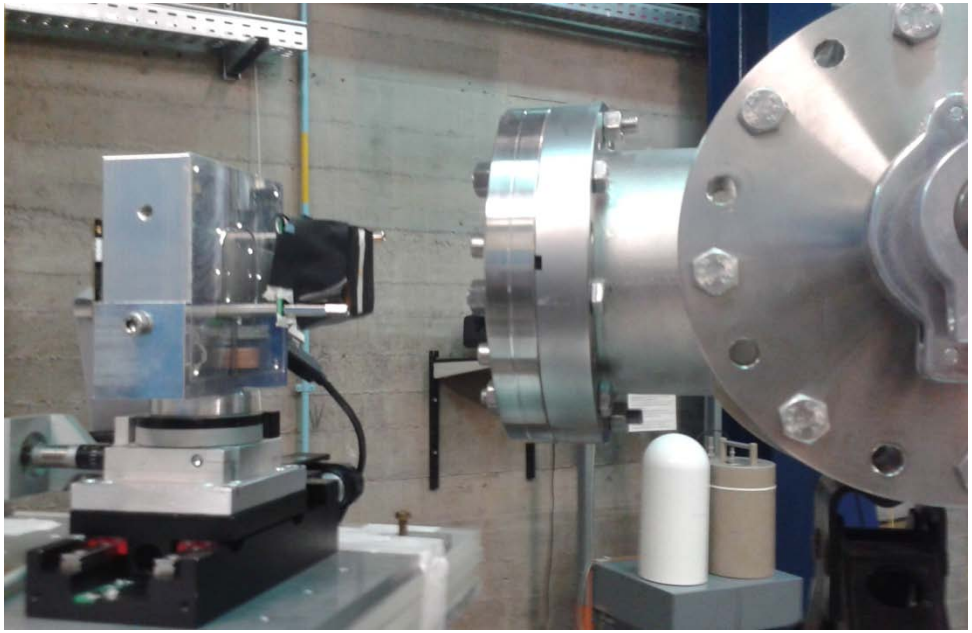
Ratio between particle detection effficiency between damaged/undamaged region





After 6 * 10^{13} p/cm^2 relative efficiency is 0.24 ± 0.15%

Irradiation test at LNS – Catania

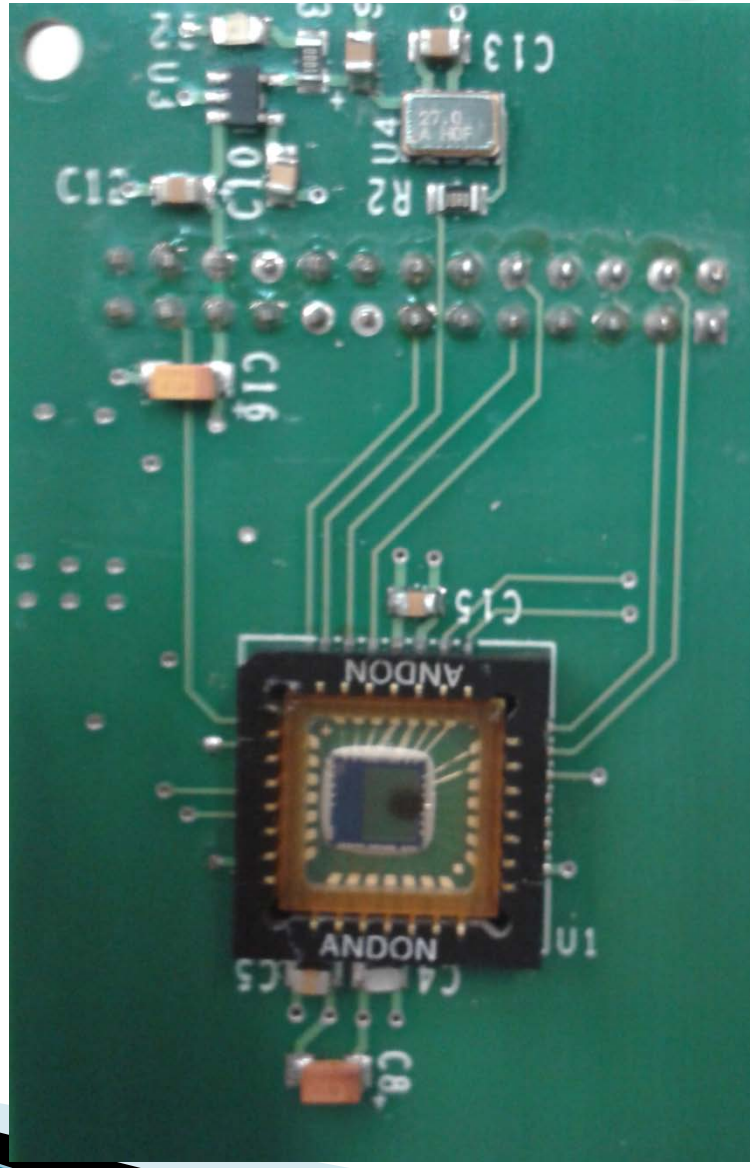


Sensori	RAPS03	MT0V011	MT9T012	MT9T013	MT9T031
Pixel size [µm]	10x10	5.6x5.6	2.2x2.2	1.75x1.75	3.2x3.2
substrate	Non-epi	Epi (4 µm)	Epi (2.5 µm)	Epi (2.5 µm)	Epi (4µm)
Technology	180 nm	130 nm	130 nm	130 nm	130 nm

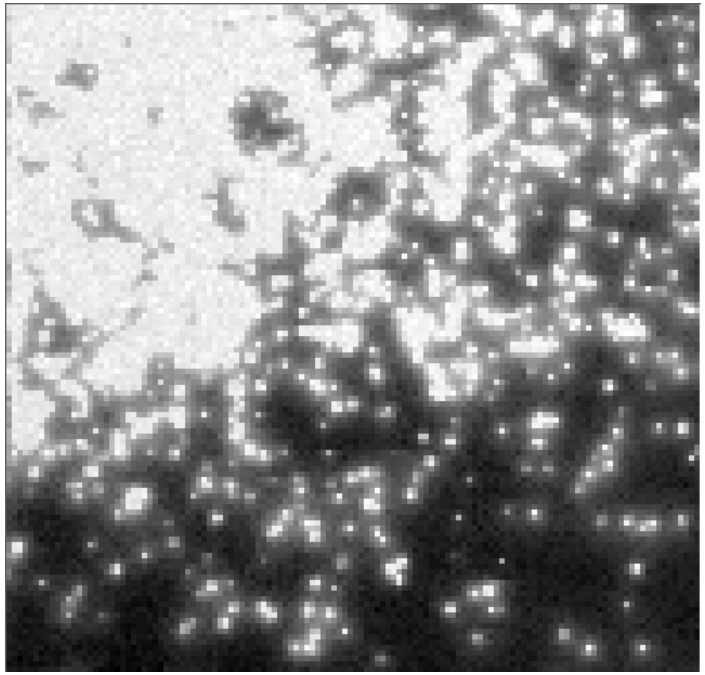
Radiation characteristics of the LNS proton beam used

- 14 MeV Energy 20 nA current
- Irradiation up to about $5*10^{13}$ p/cm^2
- Total dose absorbed: 21 Mrad
- Displacement damage dose $1.5 * 10^{14}$ n_{eq}/cm^2
- Irradiation was performed alternating low rate (10 pA) for testing and high rate (Current 20 nA) for damaging

Visual proof of damage



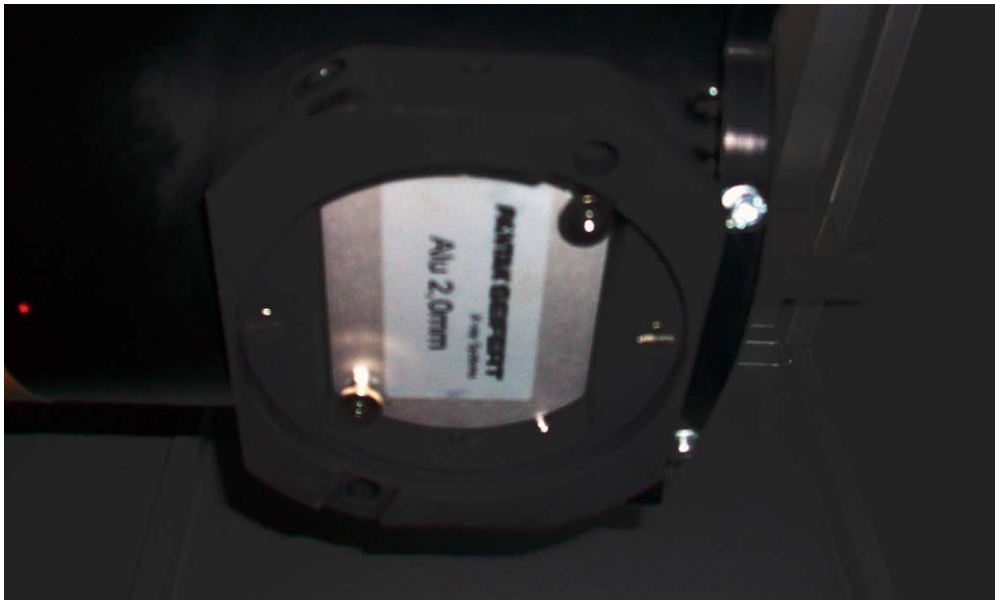
Event display during irradiation



High flux for damage

Low flux for testing

X-ray machine



- 900 W (200 kV max) tube taken from AMS (designed for radiation damage for space studies)
- Under calibration for dose rate characterization
- Dose rate maximum about 10 rad/s unsuitable for very high doses but reasonable for test at reduced rate up to 10 Mrad

Conclusions (… mostly future activities)

- MT9V011 analysis soon will be completed
- RAP03 and other 4 imagers from micron irradiated under further characterization and analysis
- X-ray tube under dosimetric calibration for radiation damage