September 19th, 2012
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update on Strasbourg activities on CMOS pixel developments

Exploration of 0.18 µm technology with MIMOSA-32: preliminary results on radiation hardness

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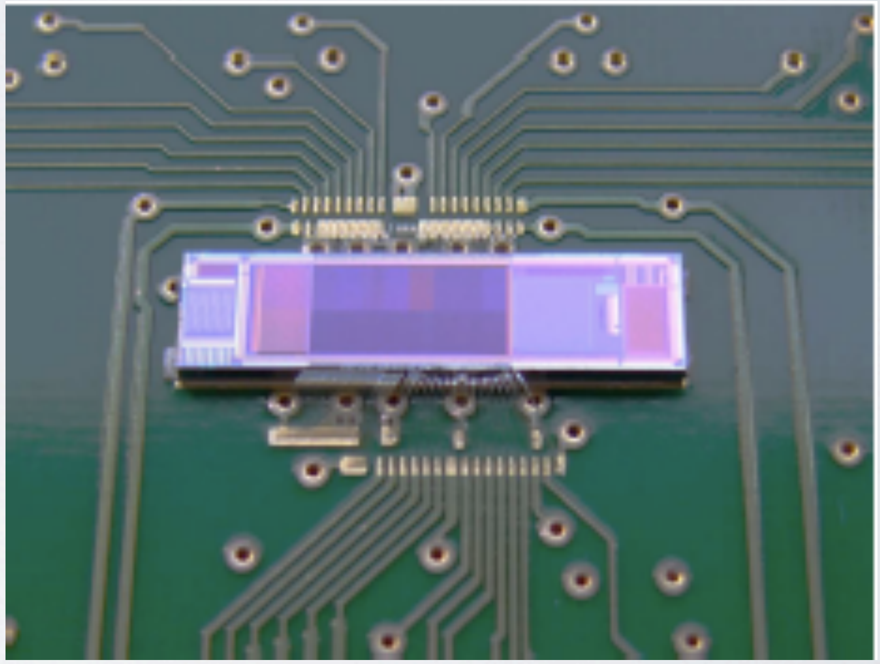
MIMOSA-32 prototype

- Submitted in Oct. 2011, delivered in January 2012.

- Technology:
  - 0.18 μm.
  - epitaxial layer: 18 μm thick, High-Resistivity 1-5 kΩ.cm.
  - read-out: rolling shutter.

- Prototype sub-divided in several blocks:
  - Explore pixel sizes: 20x20, 20x40 and 20x80 μm^2.
  - Explore charge amplification and collection systems: diode sizes ~9-15 μm^2,
    ➣ pixels labelled P1-P9, L4-1 and L4-2.
  - Explore discrimination:
    1 discriminator at each column end,
    in-pixel discrimination (16x80 μm^2 pixels).

  ➣ total surface ~ 43 mm^2.



- Preliminary laboratory and beam tests results on: noise, SNR, detection efficiency, cluster multiplicity.

experimental setup

- Lab tests:
  - ^{55}Fe source.

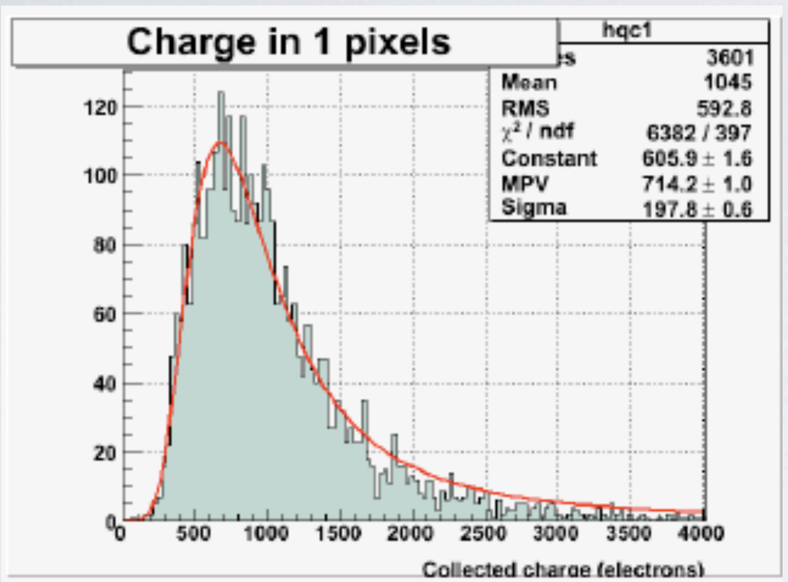
- Beam tests:
  - 3 periods: June, July and August. ➛ Next in November?
  - Telescope: strip sensors.
  - Trigger: scintillator ~2x2 mm^2.
  - Beam: SPS T4-H6 line, 60 and 120 GeV π^-.

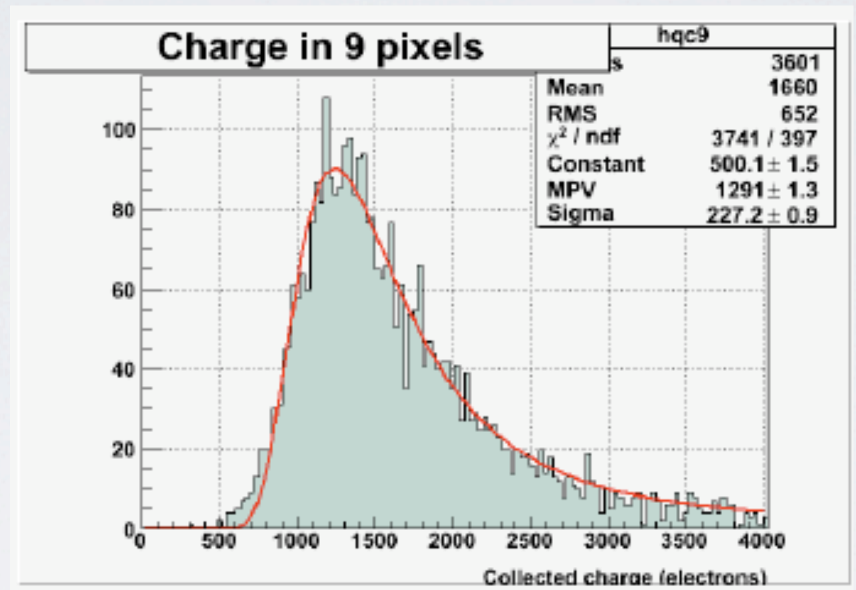
- Tests performed on CMOS sensors:
  - $T_{coolant}$ = 15 and 30 °C.
  - Ionising doses: 1 and 3 MRad.
  - Non-ionising fluences: 0.3 - 1.0 - 3.0 x10^{13} n_{eq} / cm^2,
  - Combined irradiations: 1 MRad + 10^{13} n_{eq} / cm^2.

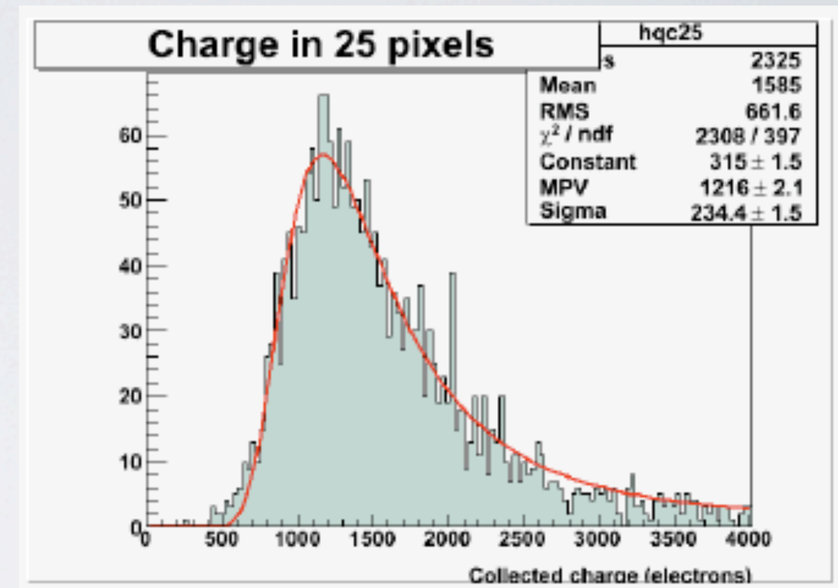
- Hits in M-32:
  - Sample of ref. tracks: ~ 5x10^4 tracks in total ➛ 3x10^3 tracks/measurement.
  - S/N (seed) > 5.
  - No cut on neighbouring pixels.
  - Information stored for 5x5 pixels = seed + 1st and 2nd crowns.

charge collection

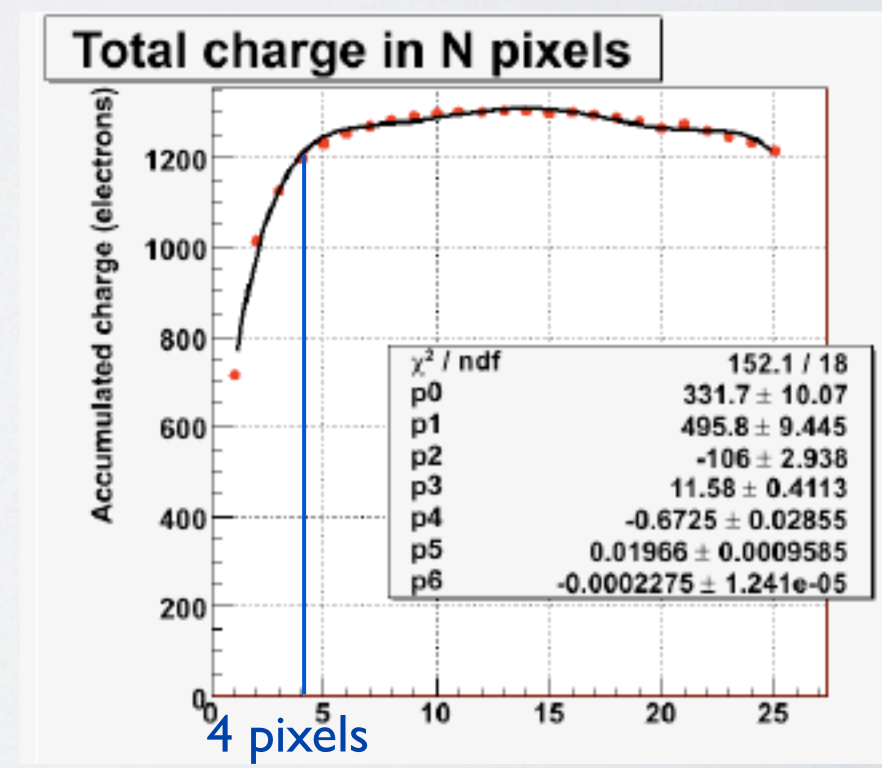
Pixel P1: 20x20 μm^2, diode self-bias.
No irradiation.
$T_{coolant}$ = 15 °C.







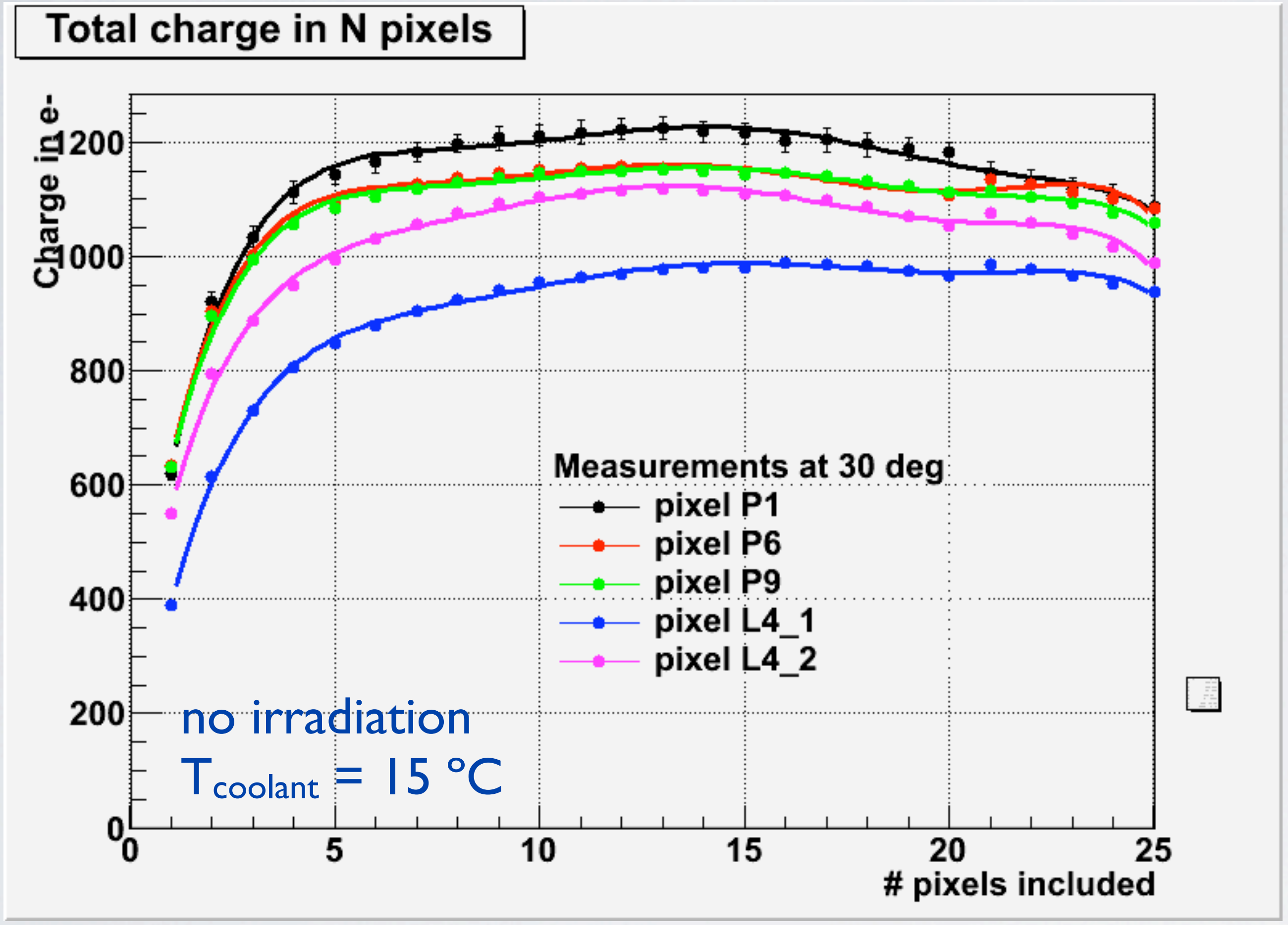
pixels ranked with ↘ signal.

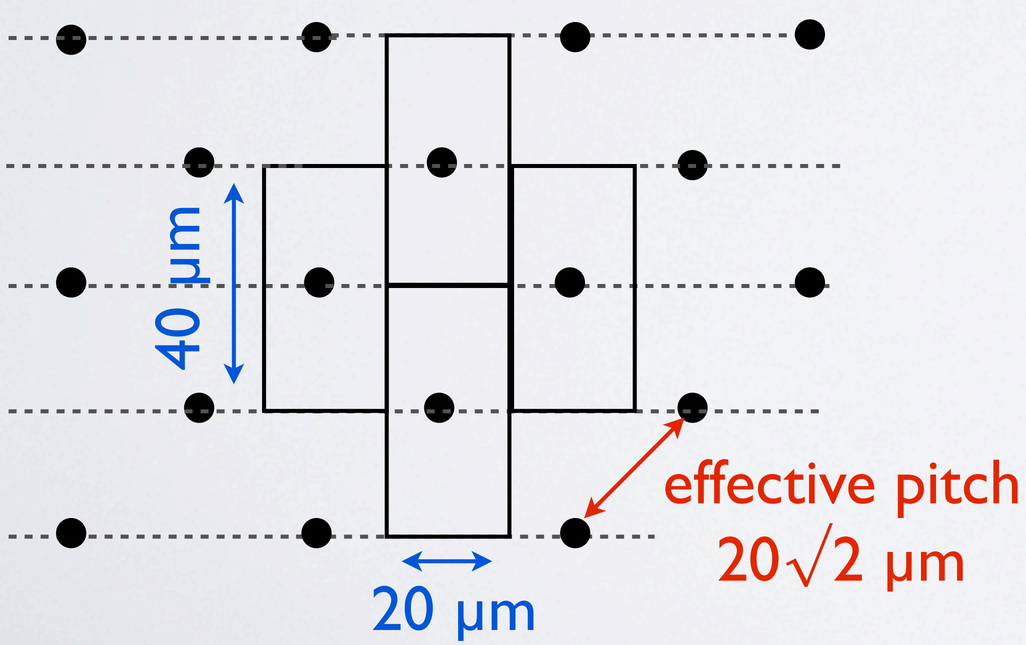


- Seed pixel: 40-50 % of total charge.
- **Within 4 pixels: ~100 % of total charge.**

➢ Confirms High Resistivity (limited thermal diffusion).

comparisons between different pixel designs





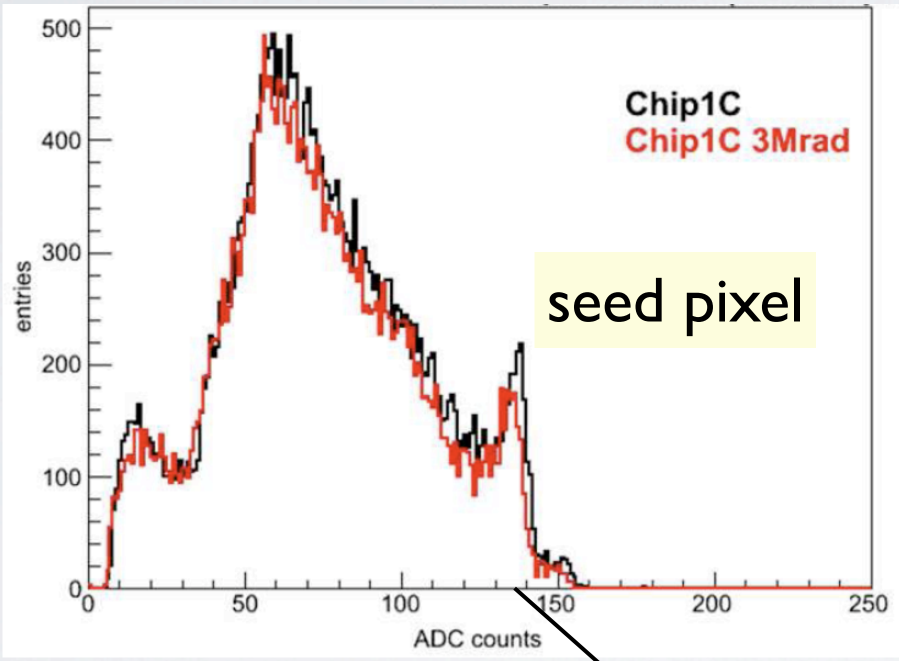
- P1: 20x20 µm², 1 sensing diode 10.9 µm² diode self-bias.
- P6: 20x20 µm², 1 sensing diode 10.9 µm² 3T.
- P9: 20x20 µm², 1 sensing diode 10.9 µm² 3T, deep P-well.
- L4_1: 20x40 µm², 1 sensing diode 9 µm², staggered diodes.
- L4_2: 20x40 µm², 2 interconnected diodes, staggered diodes.

- No parasitic charge collection with deep P-well.
- Elongated pixels ➛ less charge collected (lower diode density, smaller diode).
  But still SNR = 22
  before irradiation and at $T_{coolant}$ = 30 °C.

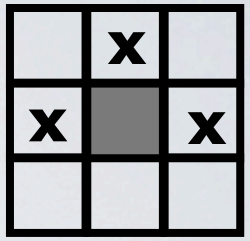
ionising irradiation

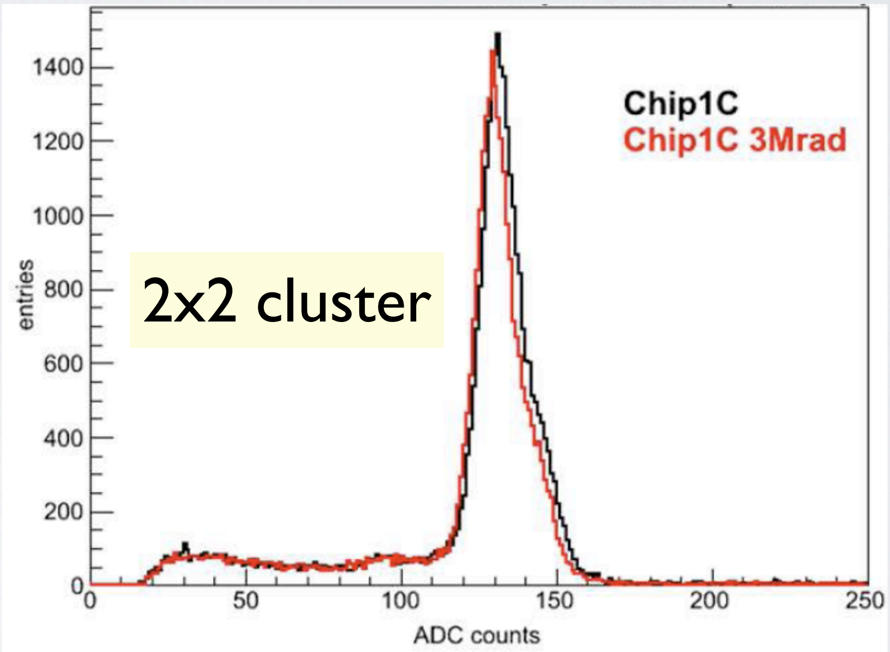
- Lab tests with ^{55}Fe source.
  20x20 μm^2 pixels.
  Ionising dose: 3 MRad.

· seed pixel:
40-50 % of total charge



· 2x2 pixels cluster (1st crown):
nearly 100 % of total charge.



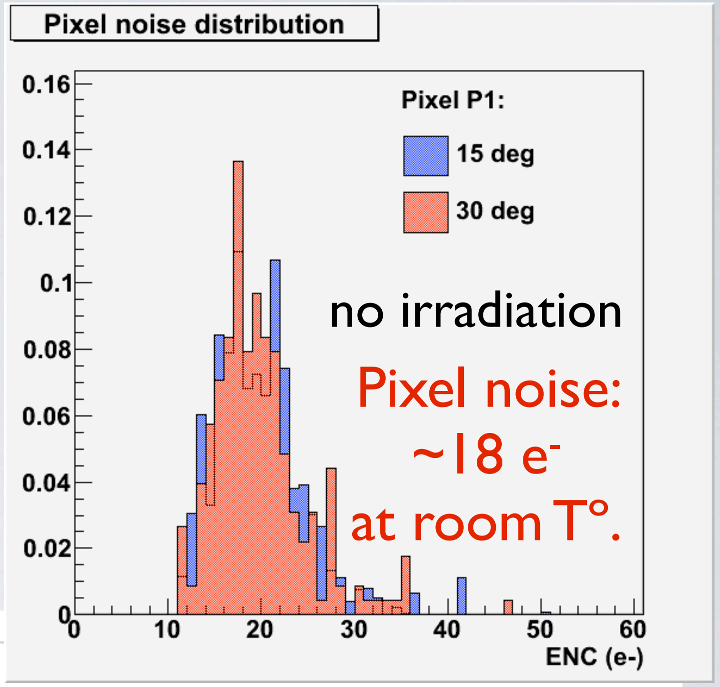


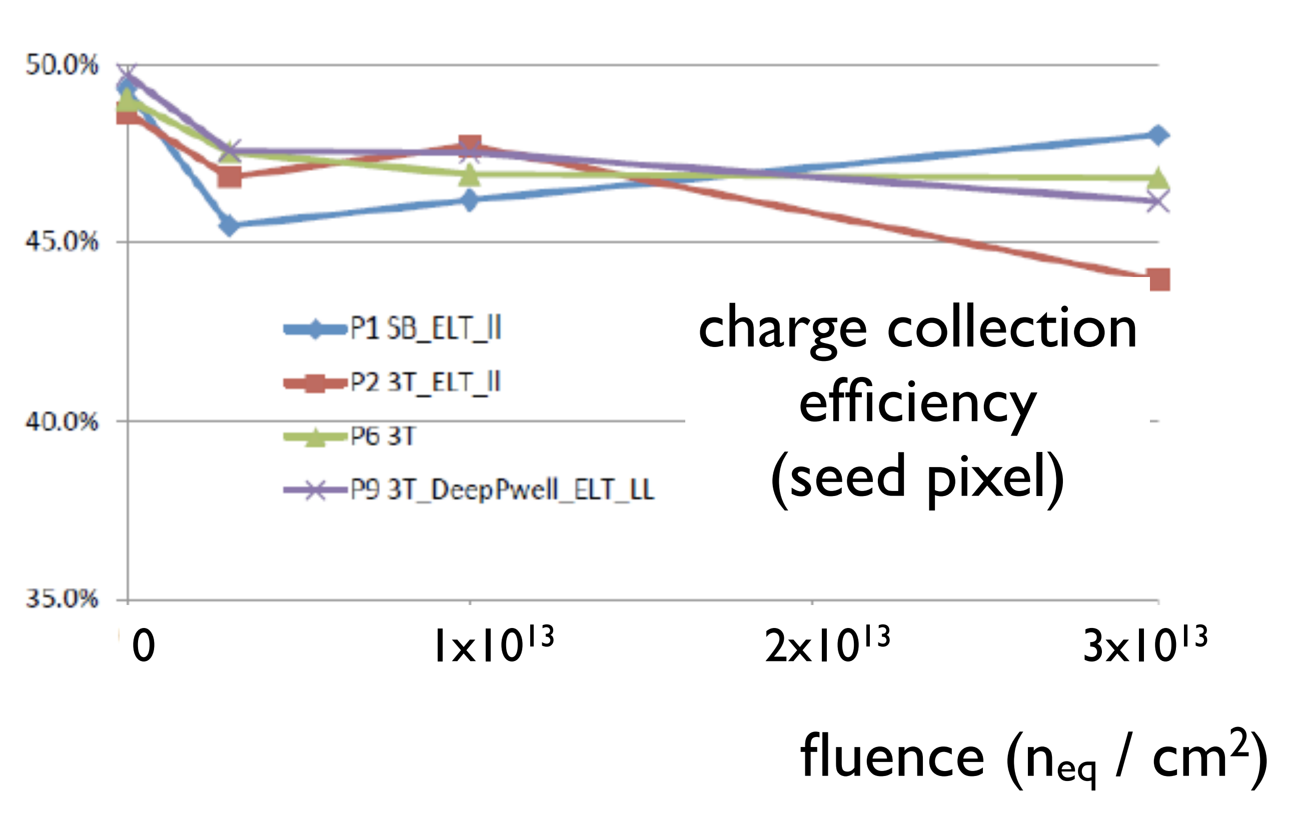
the particle crosses near the sensing diode
➛ 100 % of the charge collected

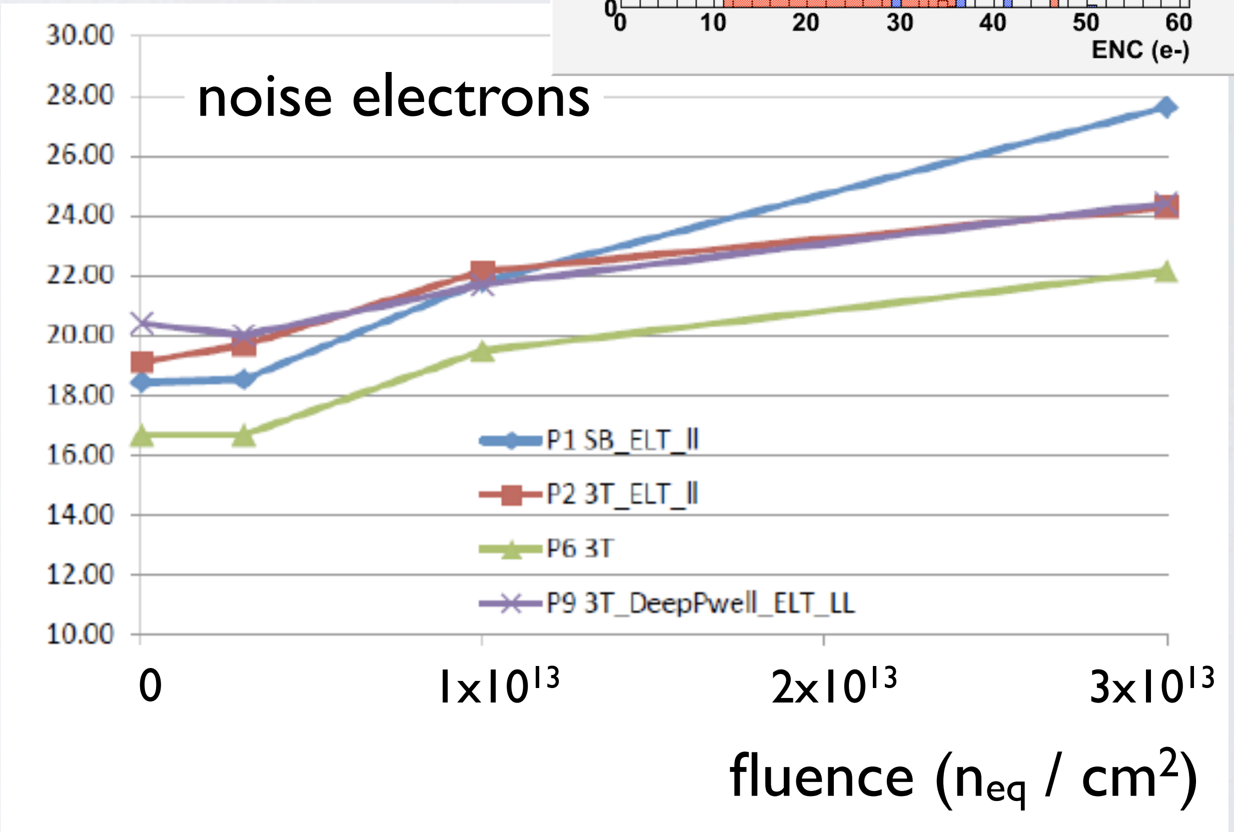
Irradiation: 3 MRad ➛ no impact on charge collection at room T°

non-ionising irradiation (I)

- Lab. tests with ^{55}Fe source.
  $T_{coolant}$ = 15 °C.
  fluences: 0.3 - 1.0 - 3.0 $\times 10^{13}$ n_{eq} / cm^2.







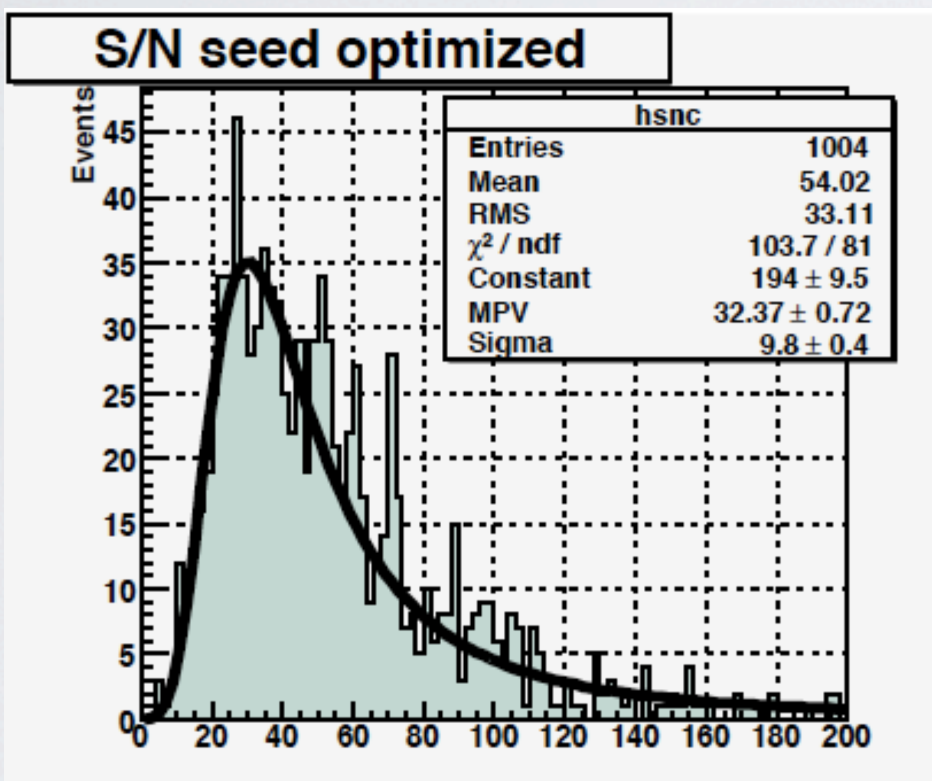
➛ signal seems not to be degraded by traps induced by bulk damages after non ionising radiations.

➛ evolution with fluence seems due to a typical effect of leakage current.
Noise increase modest up to fluences of 1×10^{13} n_{eq} / cm^2.

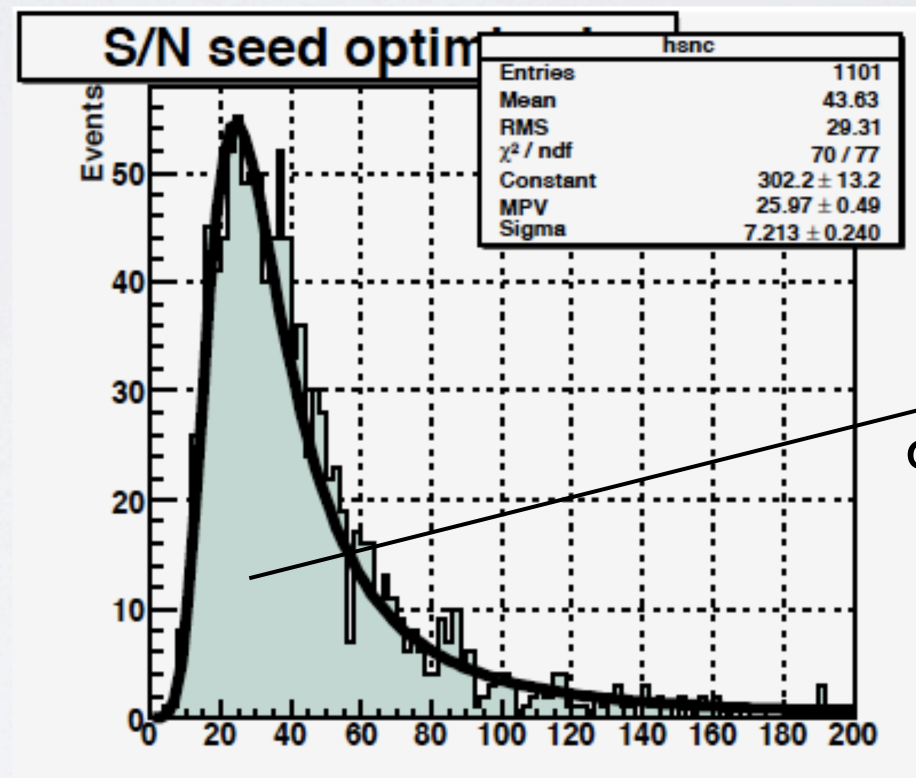
non-ionising irradiation (2)

- Beam test with 60 GeV π^-.
  $T_{coolant}$ = 30 °C.
  20x20 μm^2 pixels.

S/N ~ 32 before irradiation ➛ S/N ~ 26 after 1.0×10^{13} n_{eq} / cm^2.



before irradiation



after 1.0×10^{13} n_{eq} /cm^2

N ↗

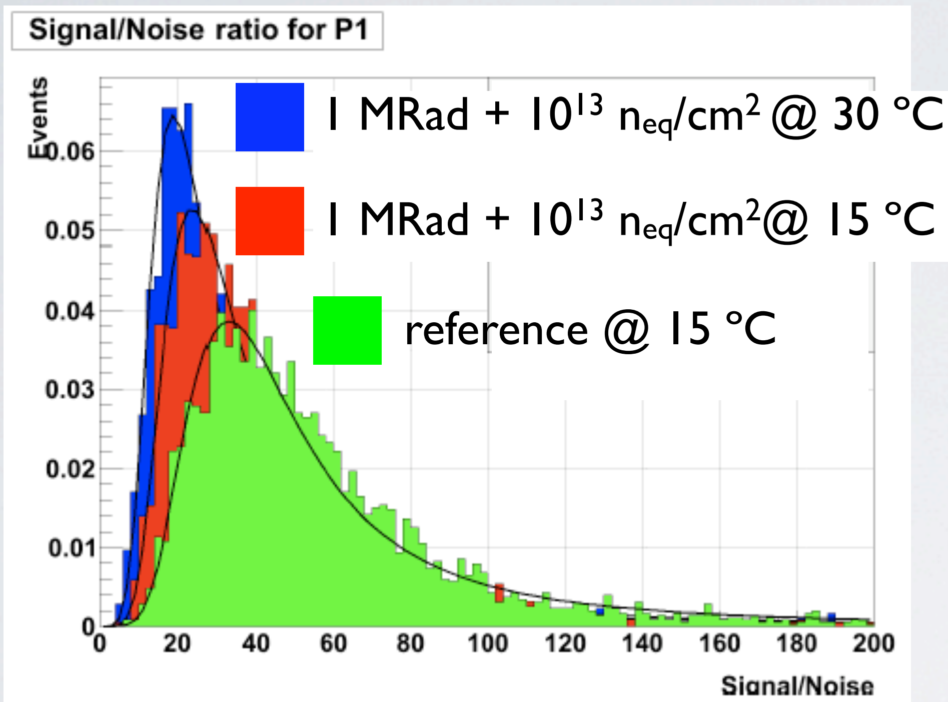
but shape of S/N distribution also changes

↓

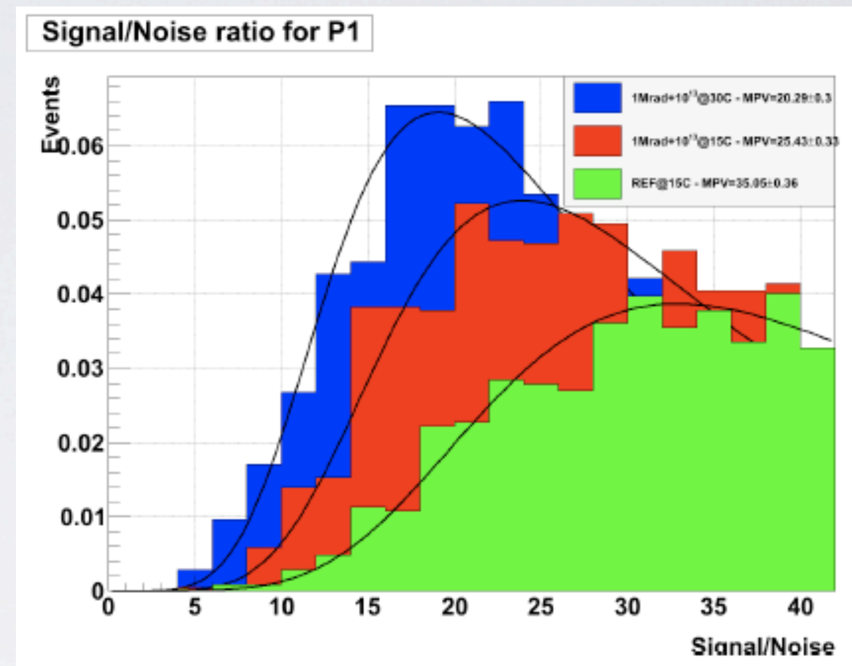
impact on detection efficiency

combined I+NI irradiation (I)

P1: 20x20 μm² pixel
diode self-bias



zoom →

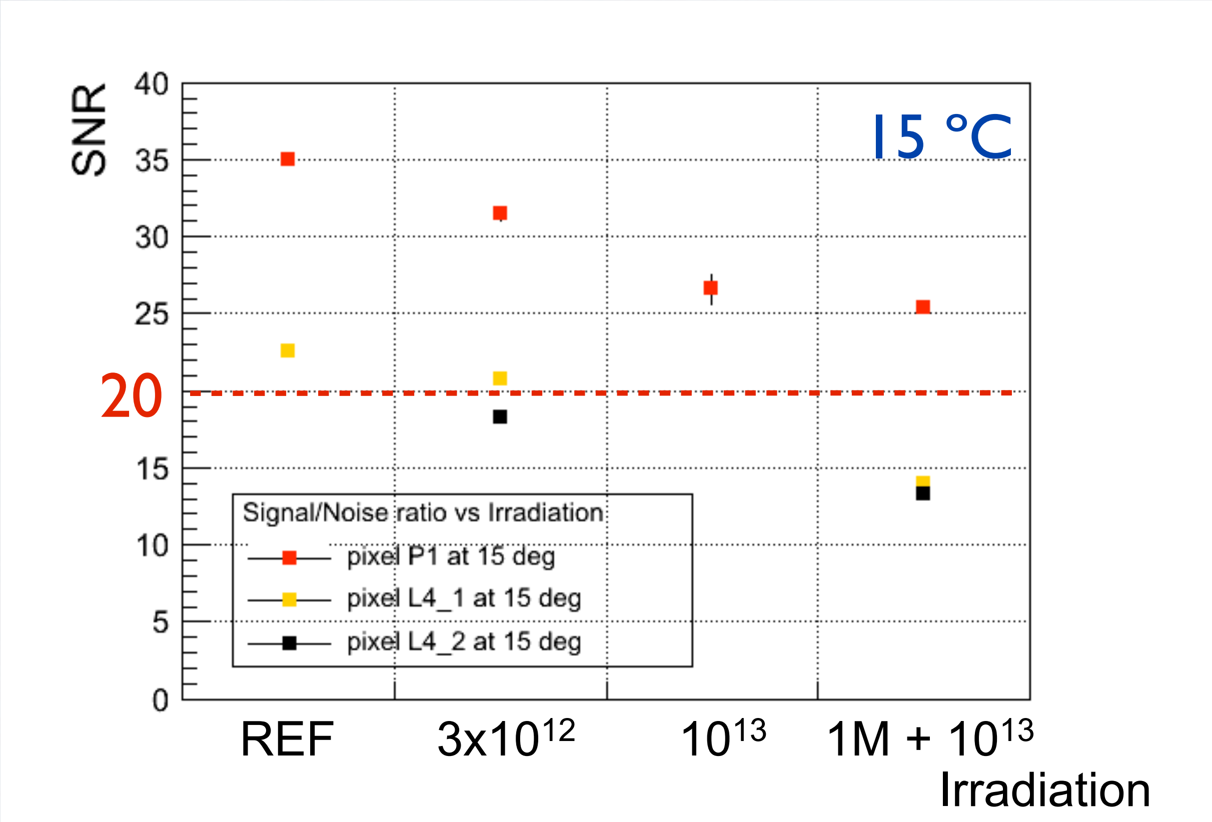


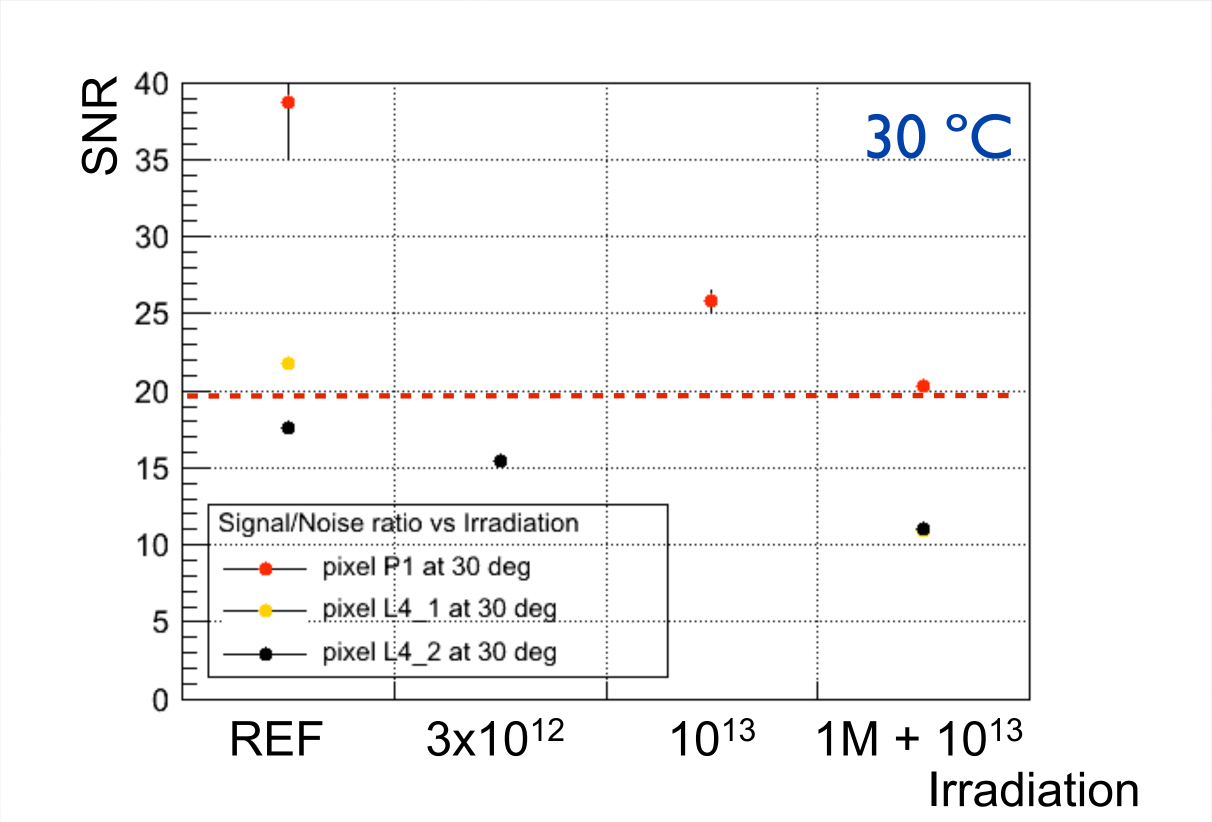
MPV = 20.3 ± 0.3
MPV = 25.4 ± 0.3
MPV = 35.1 ± 0.4

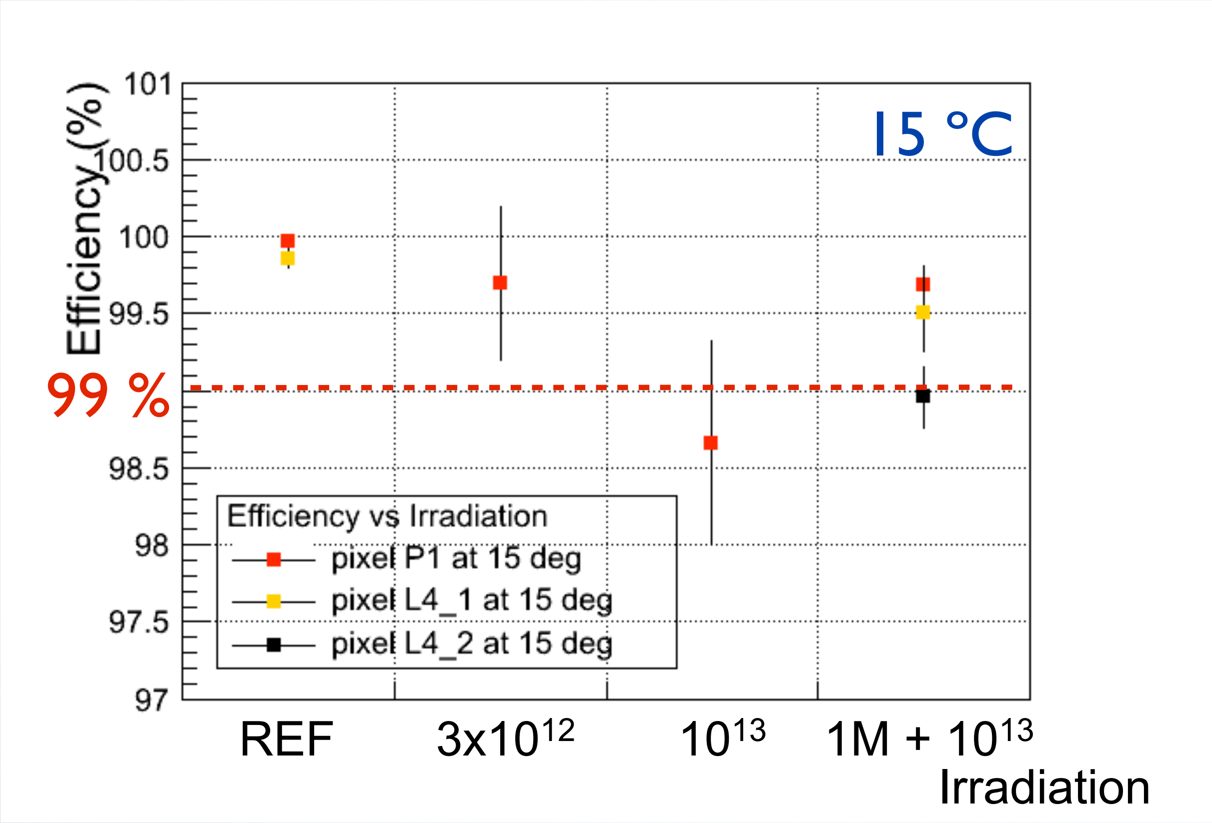
irradiation	S/N (MPV)		efficiency (%)	
	15 °C	30 °C	15 °C	30 °C
0 (reference)	35.1 ± 0.4	38 ± 4	99.97 ± 0.03	100 ± 1
1 MRad + 10^{13} n_{eq}/cm^2	25.4 ± 0.3	20.3 ± 0.3	99.69 ± 0.12	99.61 ± 0.15

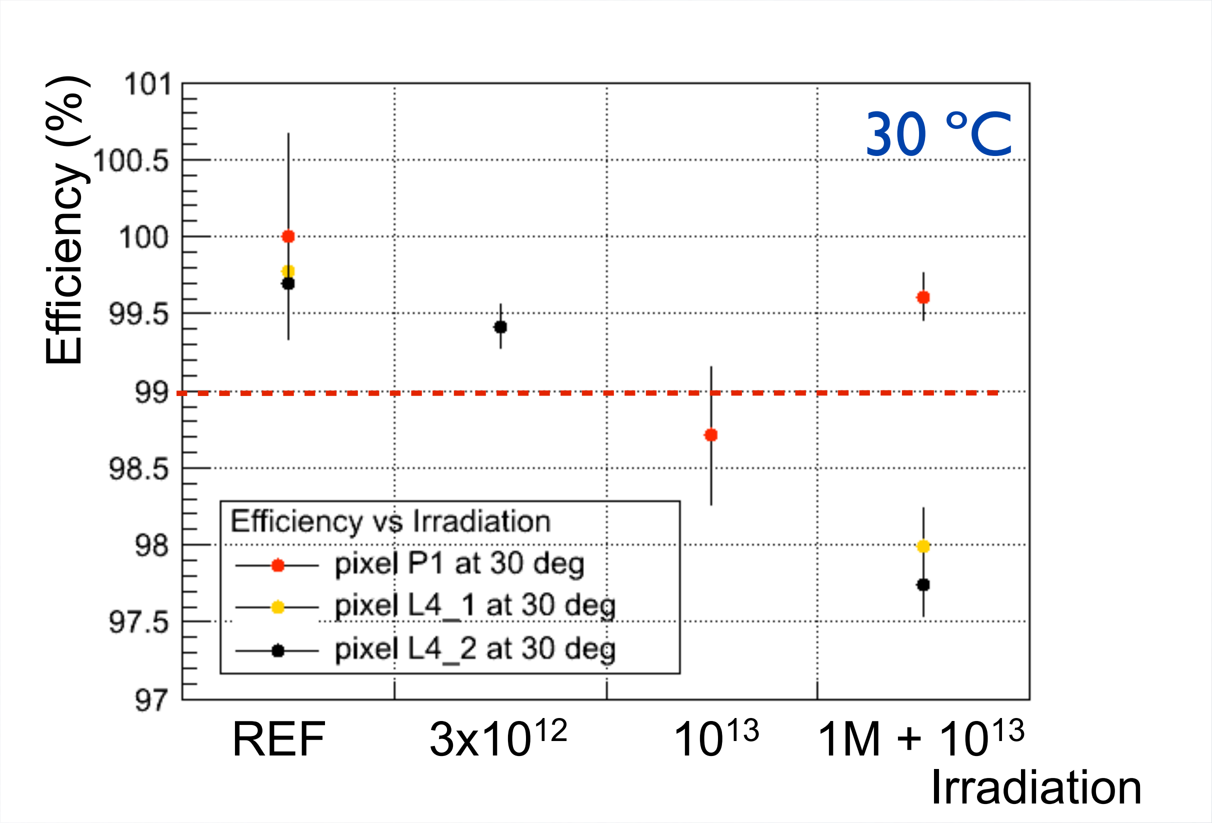
➛ **SNR > 20 after 1 MRad + 10^{13} n_{eq}/cm^2 even at $T_{coolant}$ = 30 °C.**
SNR shape changes after irradiation ➛ detection efficiency remains excellent (~ 100 %) !

combined I+NI irradiation (2)









summary

- Square 20x20 μm^2 pixels:
  - Totality of the charge collected over 4 pixels.
  - Detection efficiency ~ 100 %
    even at 30 °C and after combined I+NI irradiation.
  - Different charge collection performances observed if self-bias T or diode.
  - Deep P-well does not parasite charge collection.

- Elongated 20x40 μm^2 pixels:
  - Less charge collected and higher noise than square pixels.
  - But still detection efficiency ≥ 99 % at 15 °C after combined I+NI irradiation,
    ~ 98 % at 30 °C after combined I+NI irradiation.

➛ very encouraging results.

next steps

“towards a rad-hard sensor with a read-out time ~ 1.5 μs”

- MIMOSA-32: validation of the 0.18 μm technology.
  - Complete the data analysis of past beam tests (June, July and August): spatial resolution, ...
  - Next beam test foreseen in November at CERN: other radiation doses, ...
  - New submission of MIMOSA-32 in 0.18 μm in July: test of amplification.
- MIMOSA-22THR: validation of the optimised rolling shutter architecture.
  - Submission December 2012.
  - 2 different chips:
    - translation of MIMOSA-22AHR (0.35 μm techno.) with end-of-column discrimination.
    - simultaneous 2-row encoding with 2 discriminators/column ➛ twice faster.
- SUZE-02: validation of the sparsification.
  - Submission Autumn 2012.
  - Sparsification for 2 and 4 // rows ➛ data flow and power reduction.
- AROM-1 (Accelerated Read-Out Mimosa): validation of the in-pixel discrimination.
  - Submission 2013.
  - Simultaneous 4-row encoding with in-pixel discrimination ➛ 8 times faster.