

# Recent results from lab-test measurements with irradiated 3D FBK-irst Pixel sensors

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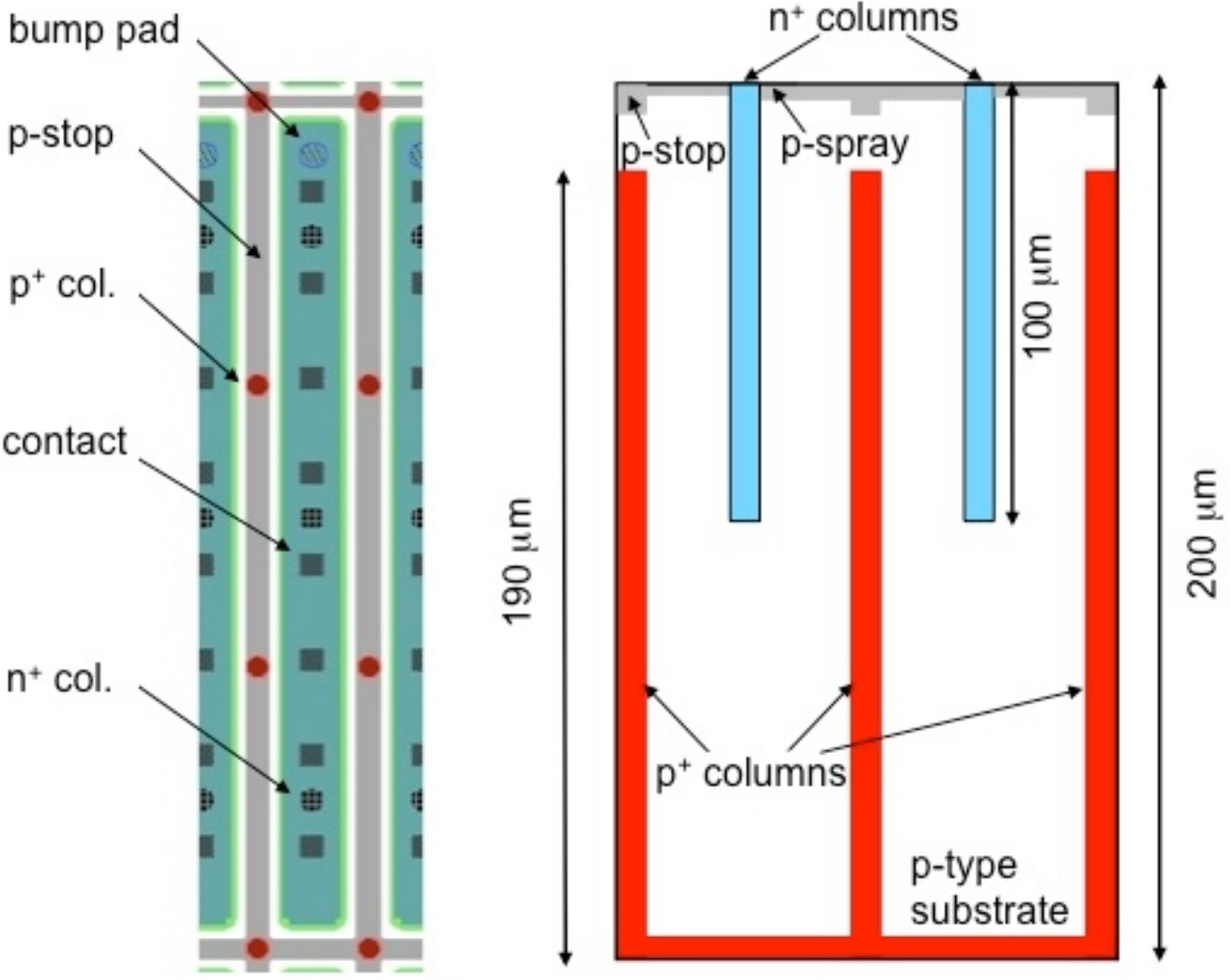
on behalf of

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# Sensors overview

- Double Side Double Type Column
  - batch so far fabricated for FE-I3 (p-type substrate, 200um, IBS DRIE)



3E type

Parameter	Unit	Value
		<b>3D-DTC-2</b>
Substrate thickness	μm	200
Junction column thickness	μm	100 -110
Ohmic column thickness	μm	180 -190
Column overlap	μm	90 - 100
Substrate doping concentration	cm <sup>-3</sup>	1 × 10 <sup>12</sup>
Lateral depletion voltage	V	3
Full depletion voltage	V	12
Capacitance vs backplane	fF/column	35
Leakage current @ Full depletion	pA/column	< 1
Breakdown voltage	V	> 70

For more info see talks by C. Da Via and E. Vianello


# Irradiation campaign

- Facilities:
  - CERN PS protons at 24 GeV (thanks to M. Glaser)
  - Karlsruhe protons at 25 MeV (thanks to A. Dierlamm & Helmholtz Alliance)
  - Ljubljana neutrons (thanks to V. Cindro)
- Irradiated different pixel flavors
  - 2x 2E-type at  $1 \times 10^{15} n_{eq}$  (KA and LJ)
  - 2x 3E-type at  $1 \times 10^{15} n_{eq}$  (KA and LJ)
  - 2x 4E-type at  $1 \times 10^{15} n_{eq}$  (KA and LJ)
  - 1x 2E-type at  $2 \times 10^{15} n_{eq}$  (PS)
  - 1x 4E-type at  $2 \times 10^{15} n_{eq}$  (PS)
  - 1x 4E-type at  $3 \times 10^{15} n_{eq}$  (LJ)
  - 1x 3E-type at  $5 \times 10^{15} n_{eq}$  (LJ)

ATLAS-IBL Target Fluence



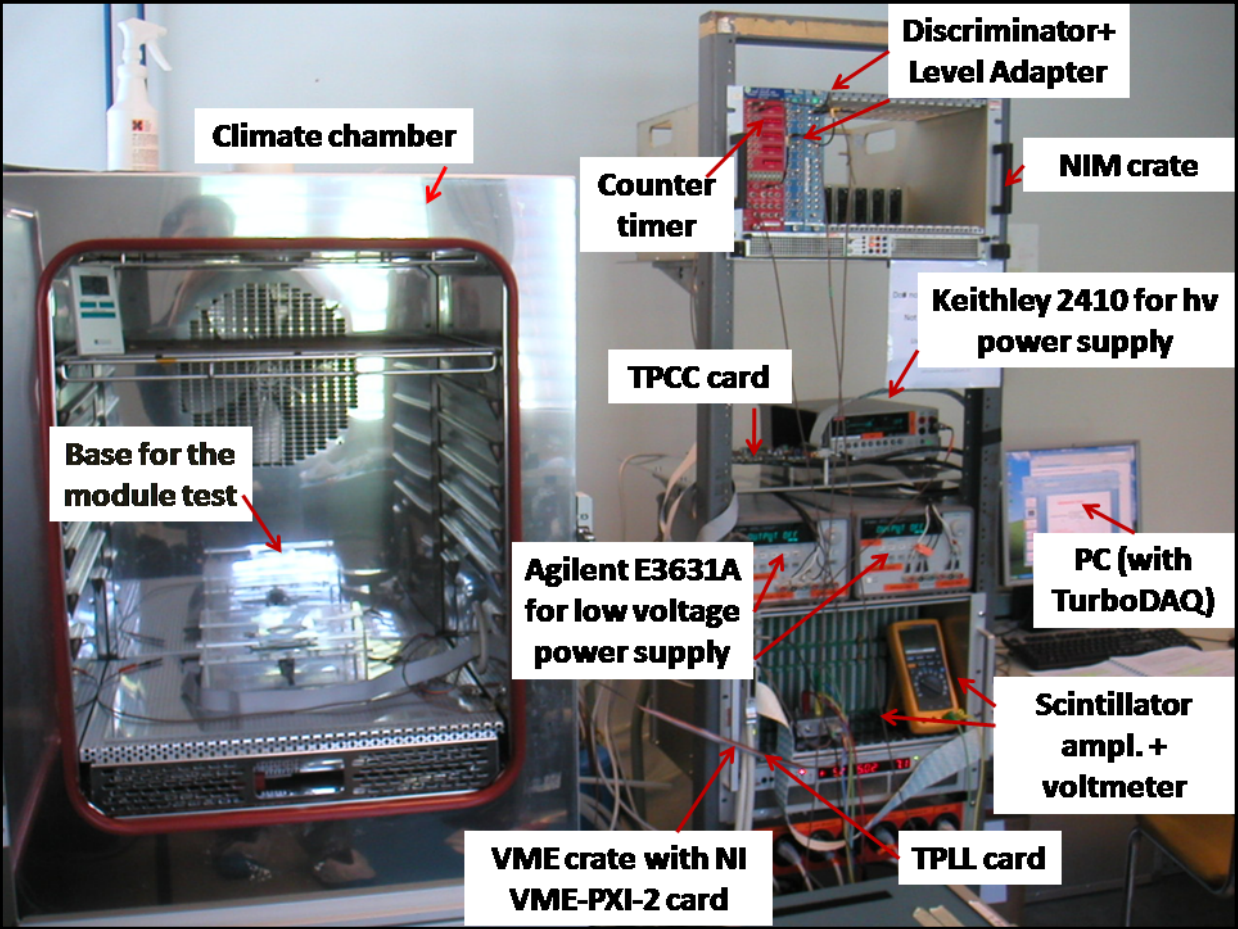
# Sensors qualification program

- Lab-test measurements before & after irradiation
  - Leakage current vs Bias voltage at different temperature
  - Threshold & Noise measurements at different Bias voltages
  - Self-trigger with Gamma source-test (e.g.: Am241)
  - External-trigger with Beta source-test (Sr90)
- Beam test at CERN SPS w/ and w/o B field  See talk by Andrea Micelli
  - Efficiency as a function of tilt angle
  - Charge collection as function of tilt angle
  - Charge sharing probability vs tilt angle

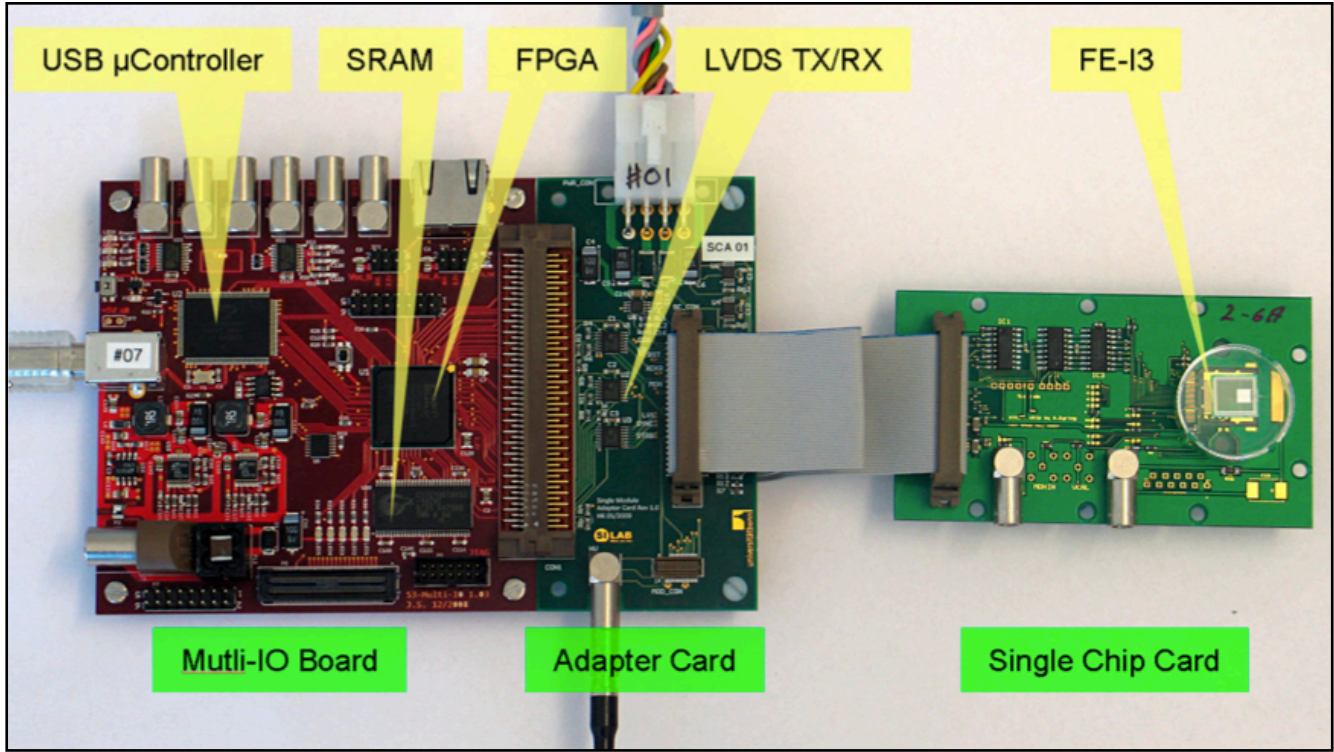


# ATLAS FE-I3 experimental setup

- Two different DAQ-system have been used to perform Lab-measurements:
  - TurboDAQ (based on PC-to-VME interface)
  - USBPix (based on USB interface)

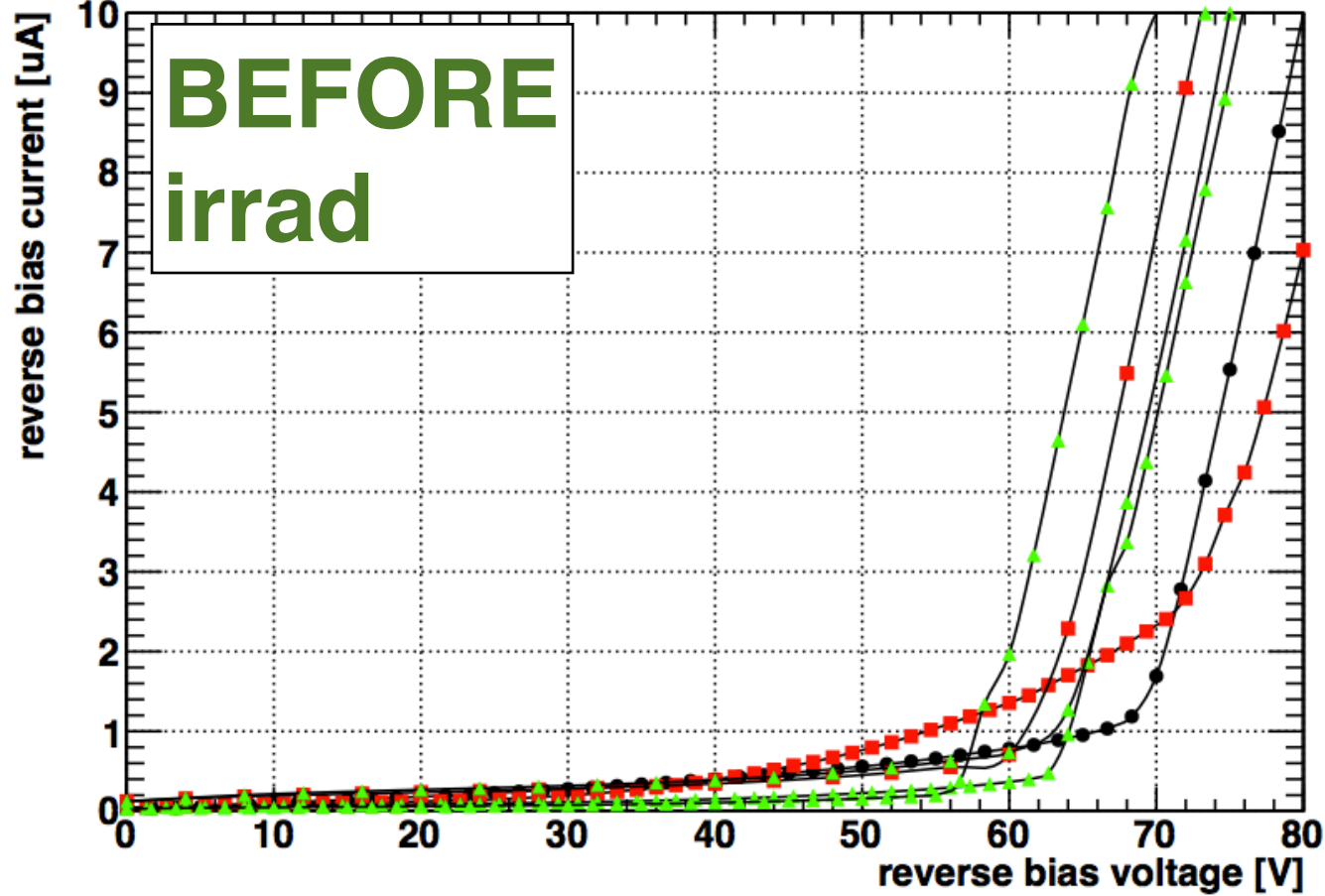


TurboDAQ  
for FE-I3 readout system

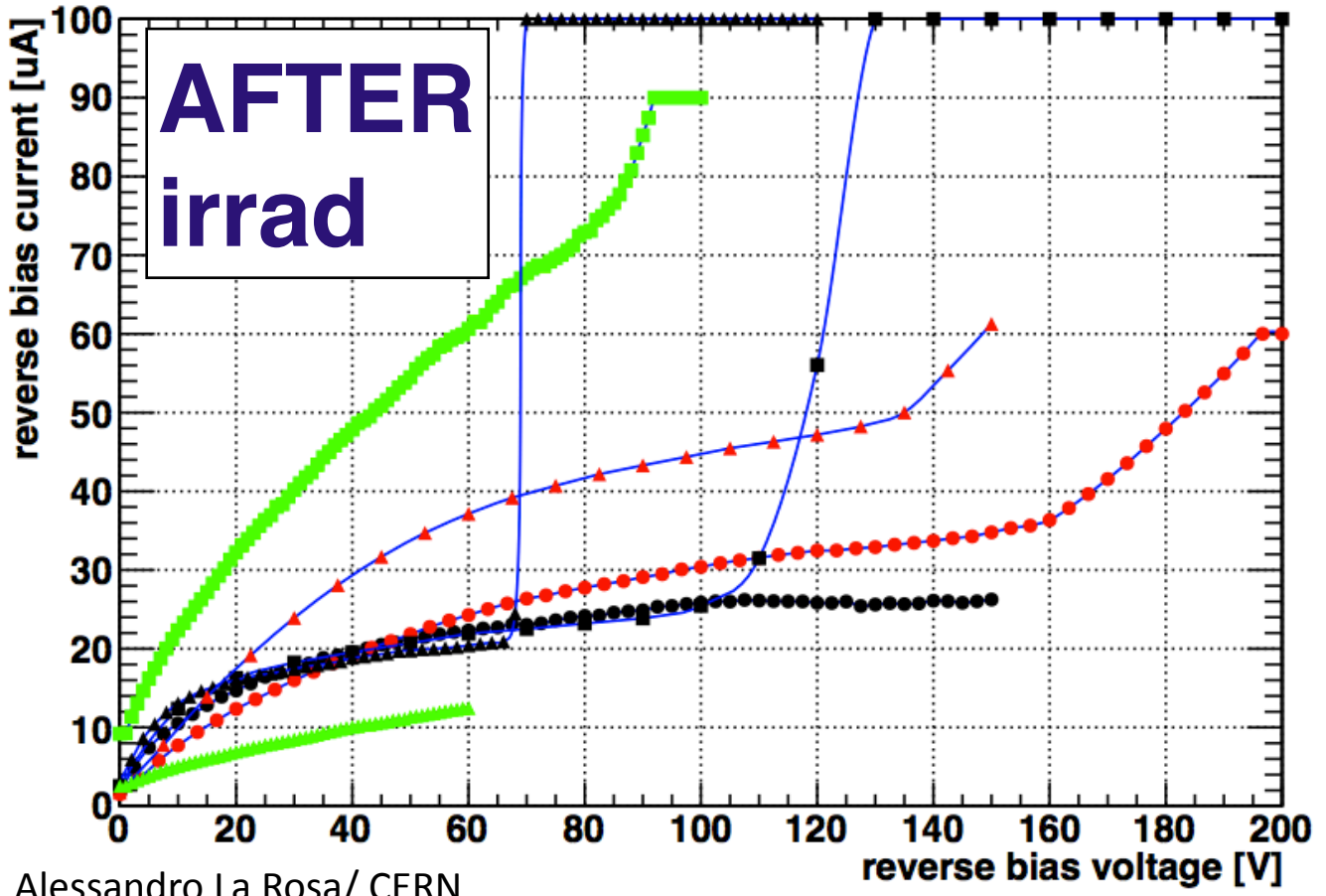
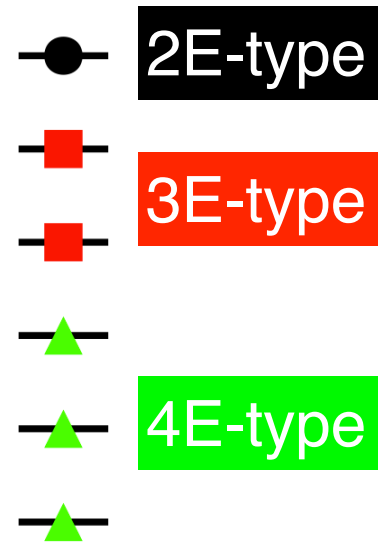


USBPix  
for FE-I3 (and FE-I4) readout system

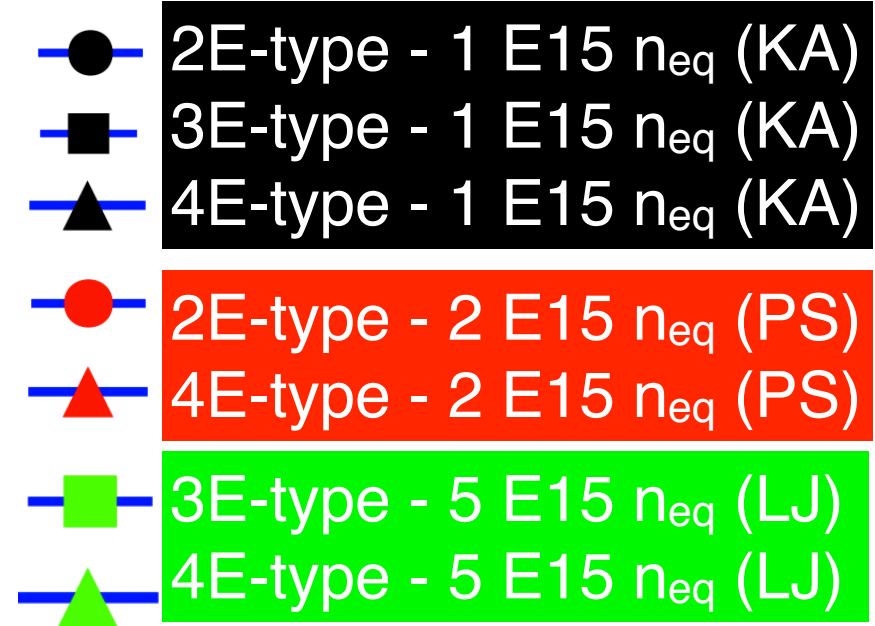
# Leakage currents



- Before irradiation
  - tests performed at room temperature (23°C)



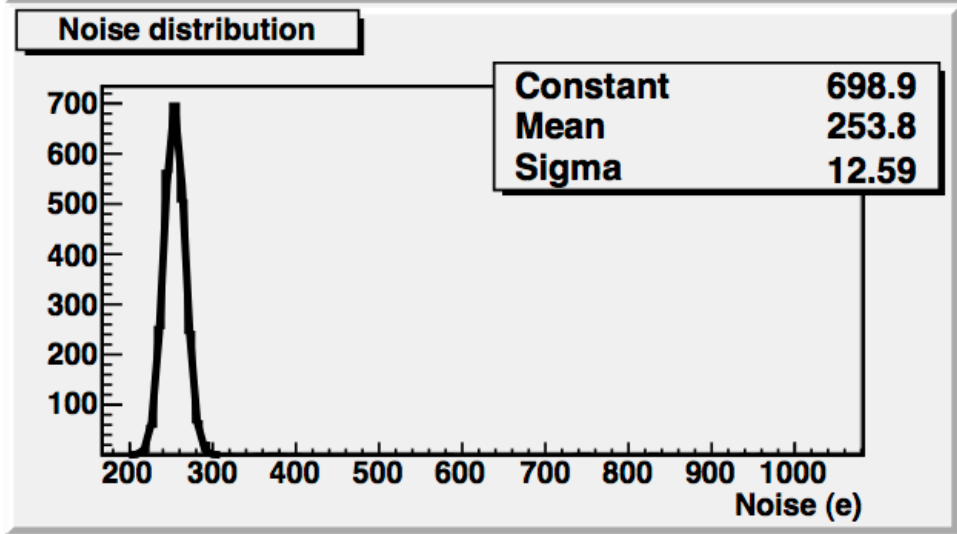
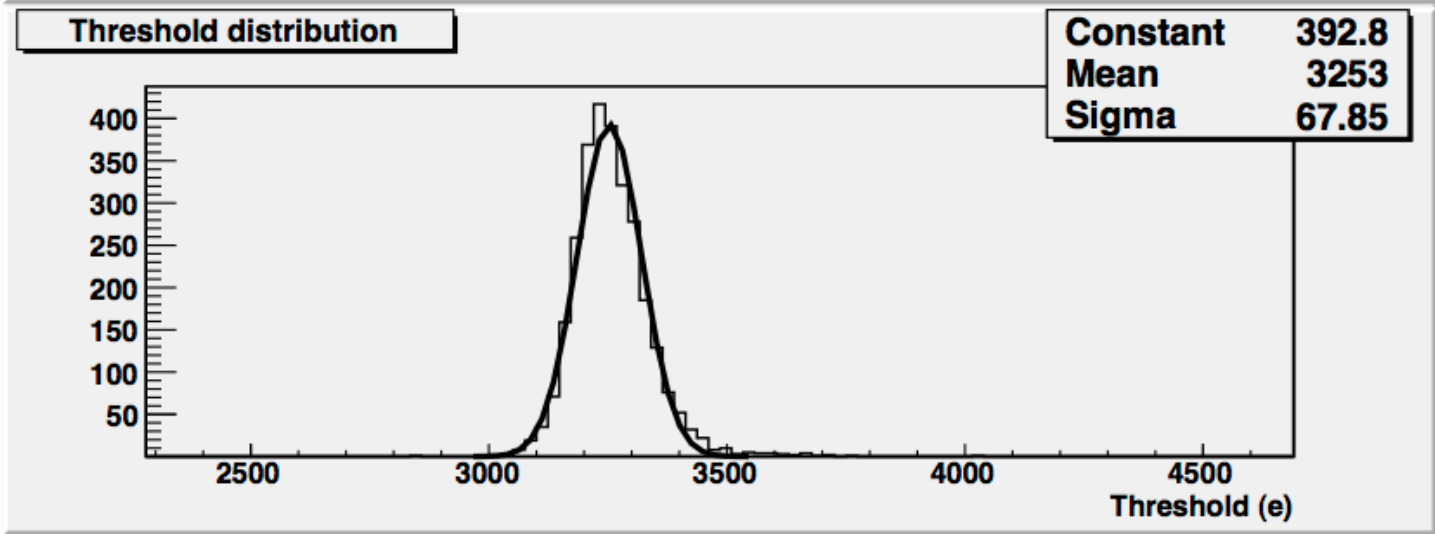
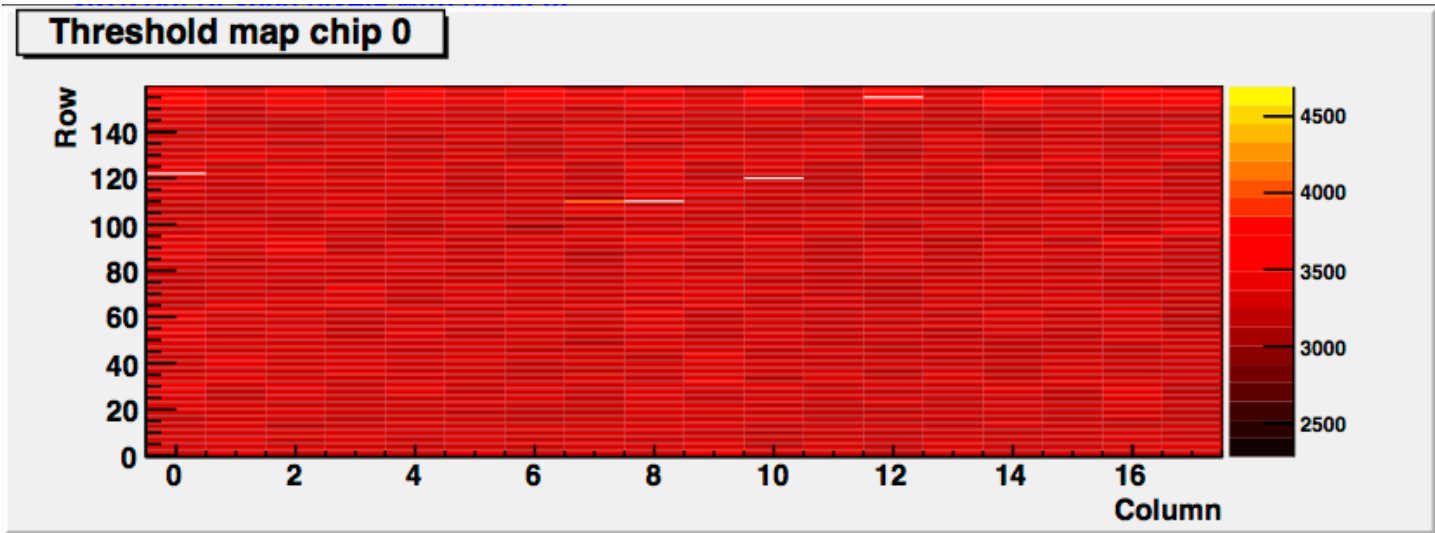
- After irradiation
  - tests performed at -20°C





# Threshold and noise measurements

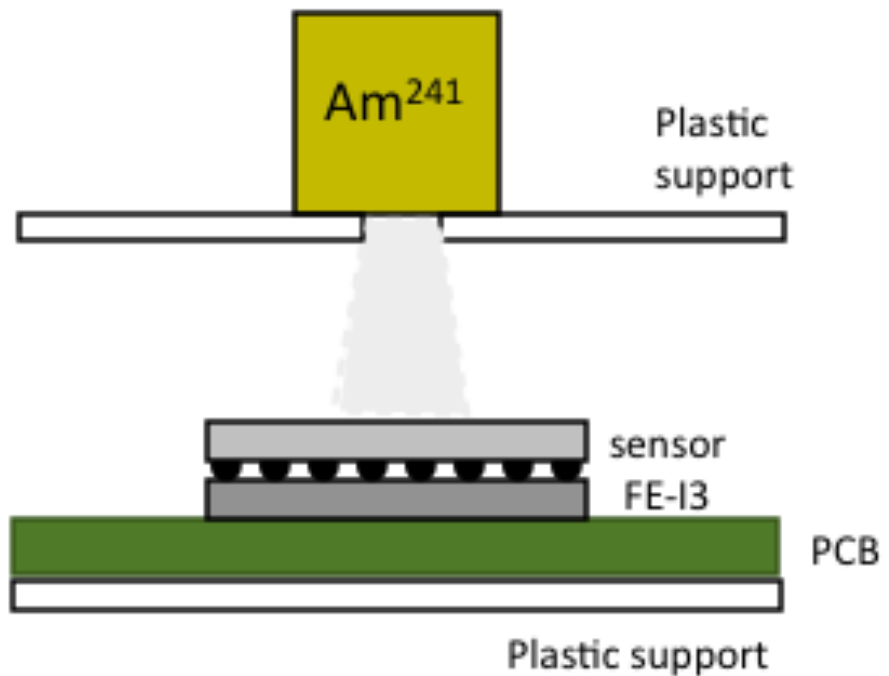
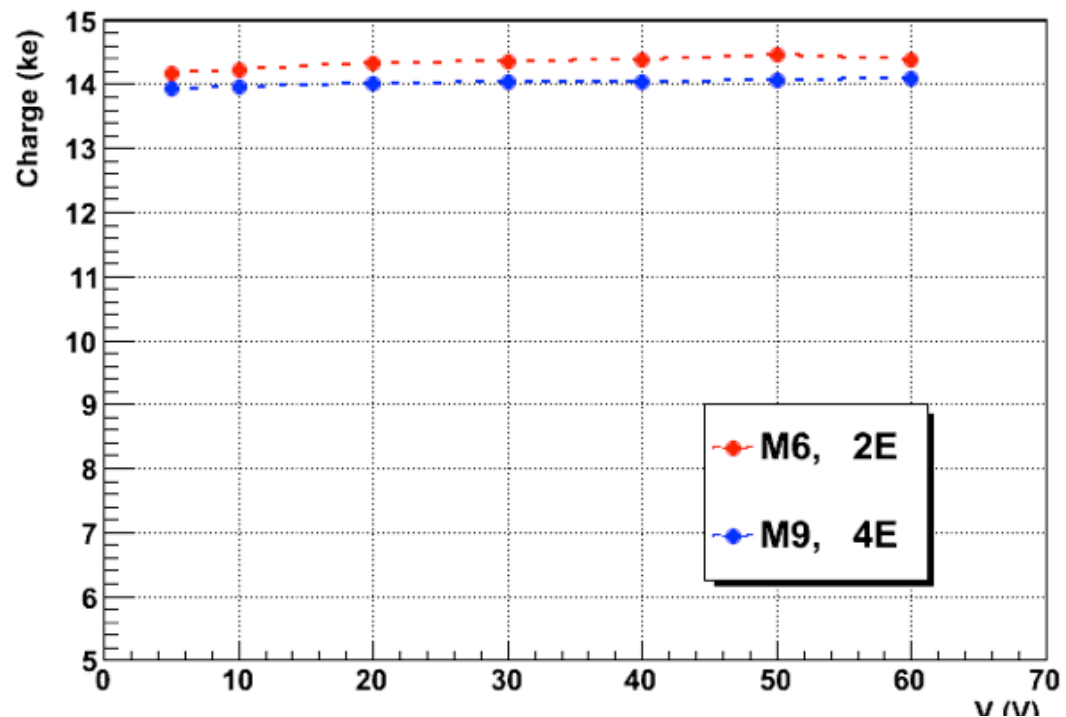
- 3E-type irradiated up to  $5 \times 10^{15} n_{eq}$  (LJ)
  - Measurements performed at -20°C
  - FE tuned with a target threshold of 3.2ke and with 60 ToT at 20ke-



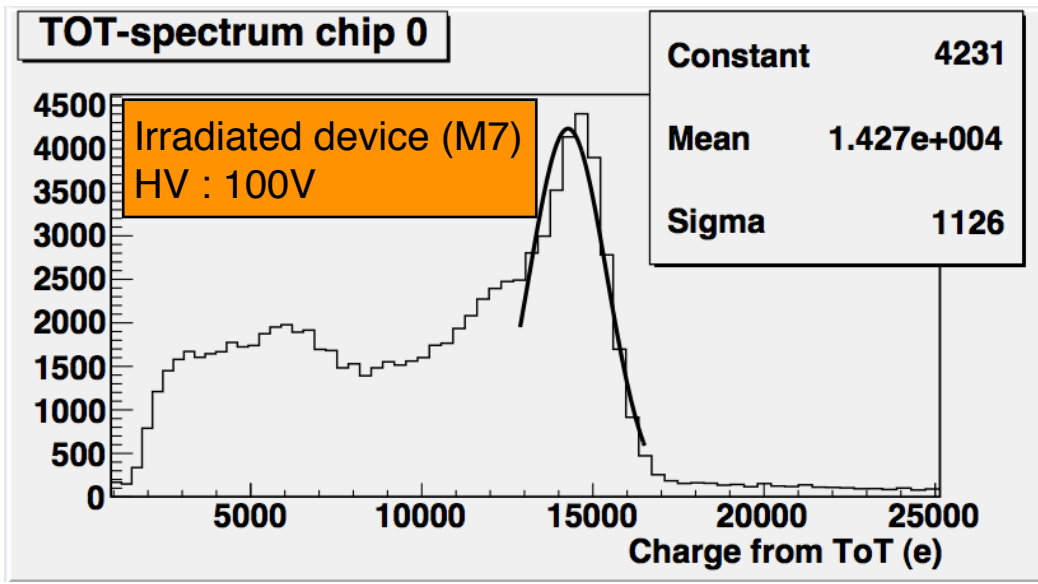
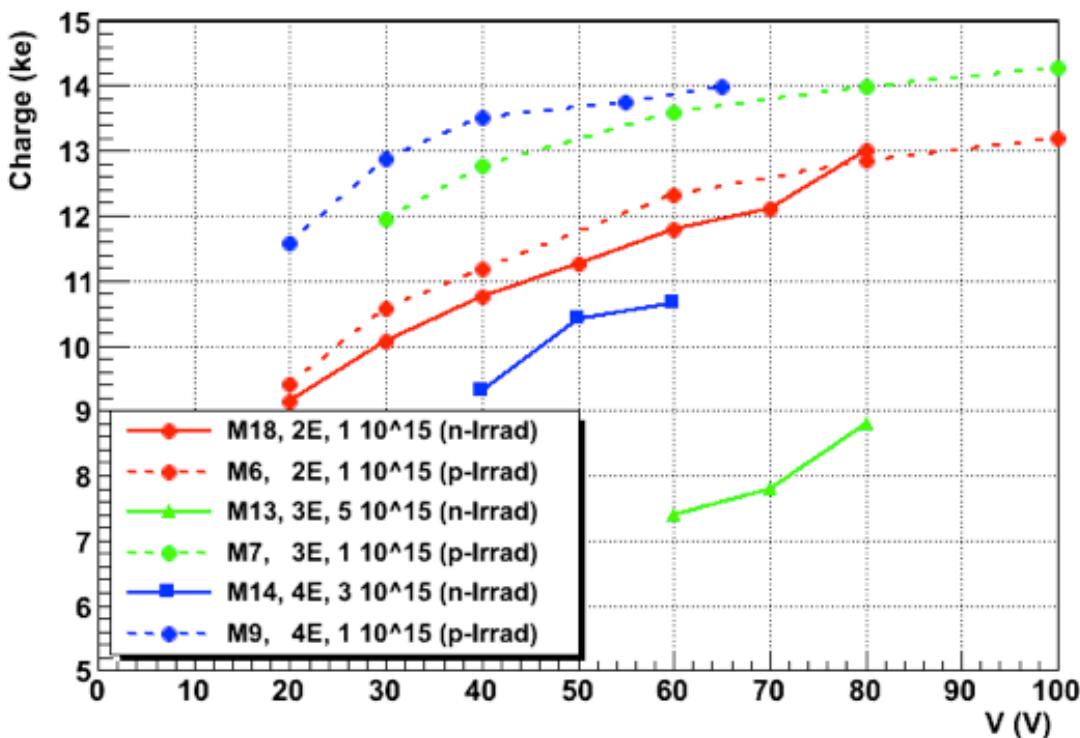
# Self-trigger operation with Am<sup>241</sup> source

- Overview of Sr90 source-test measurement before and after irradiation
  - measurement performed at +23°C for unirrad devices
  - measurement performed at -20°C for unirrad devices

BEFORE irradiation



AFTER irradiation

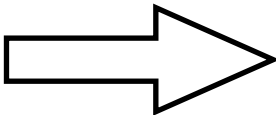
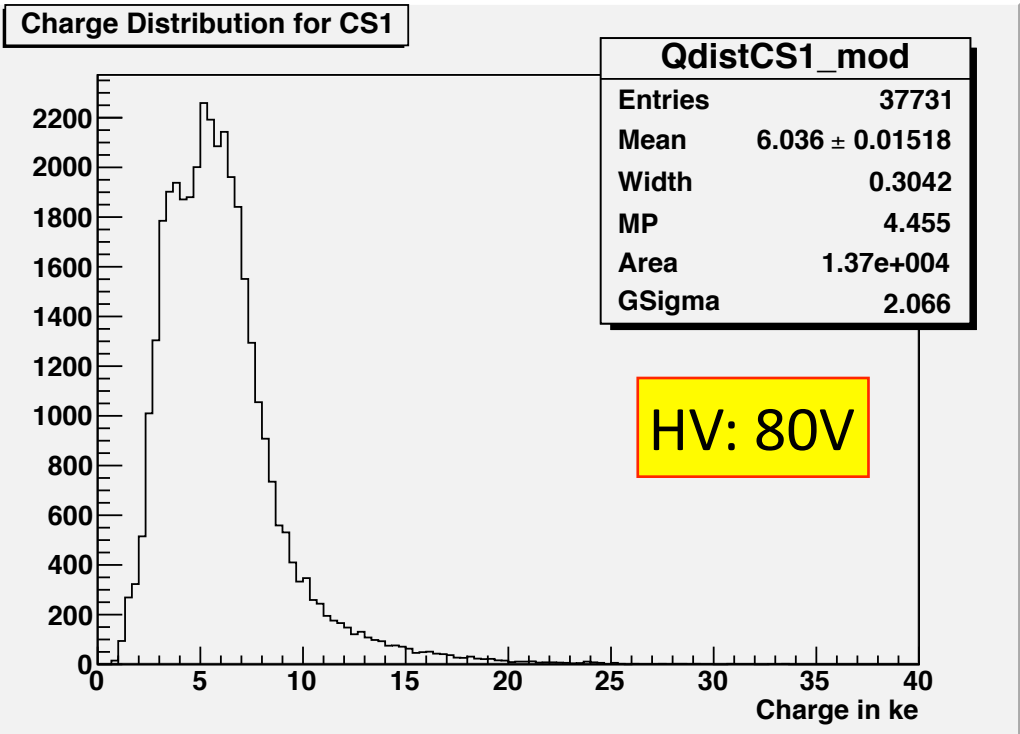
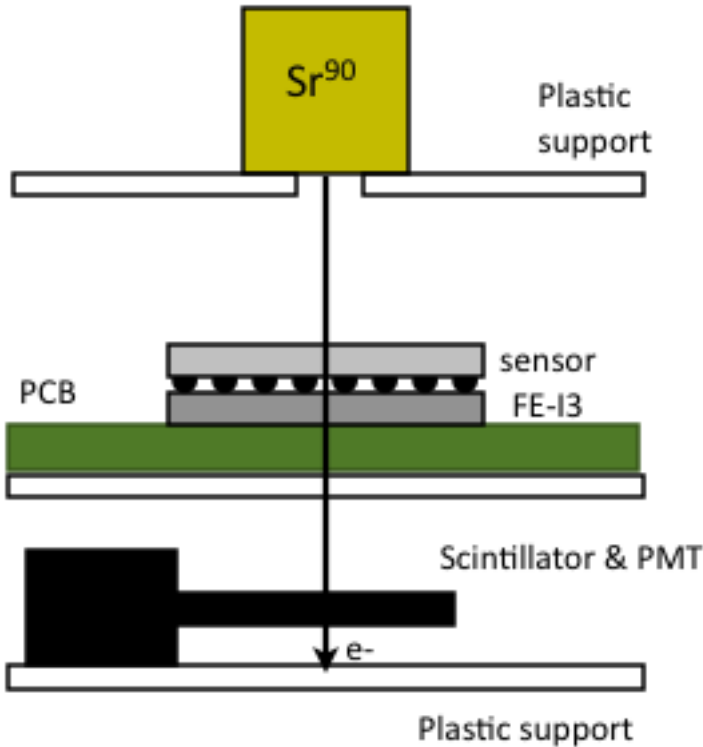
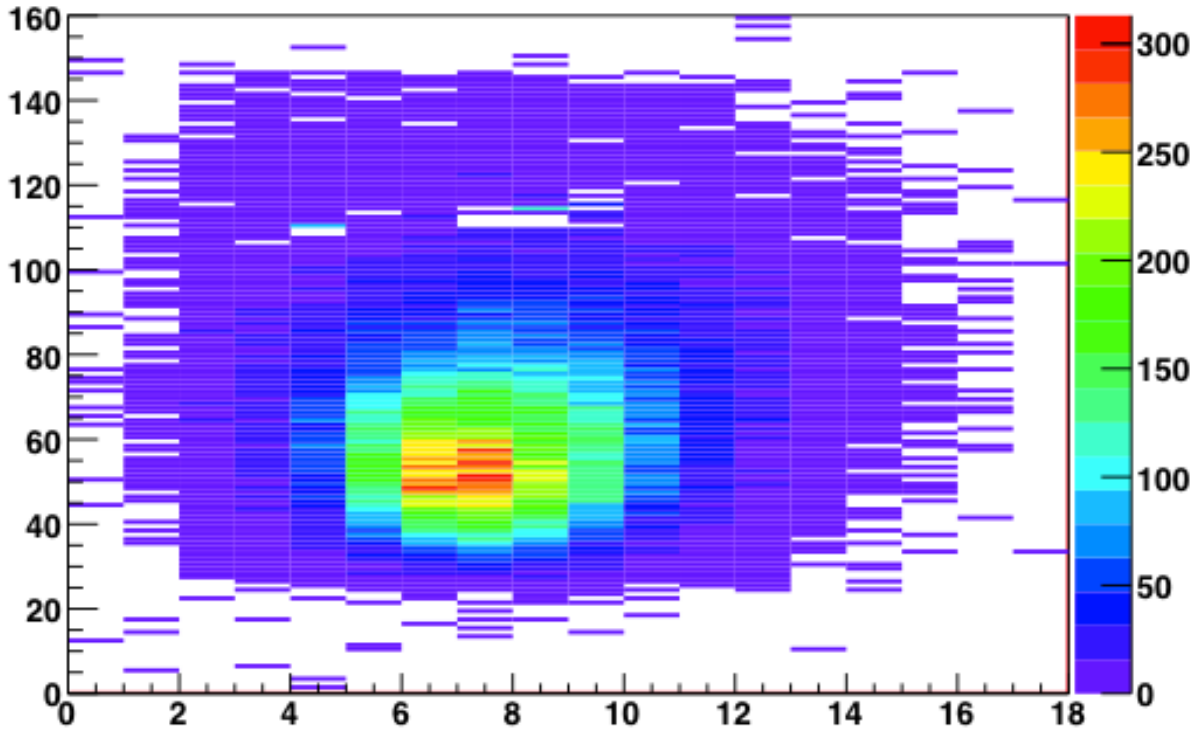




# External-trigger operation with Sr<sup>90</sup> source

- Measurements performed with irradiated device up to 5x10<sup>15</sup> n<sub>eq</sub>

Cooling System: Climate chamber with an environment temperature of -20 °C

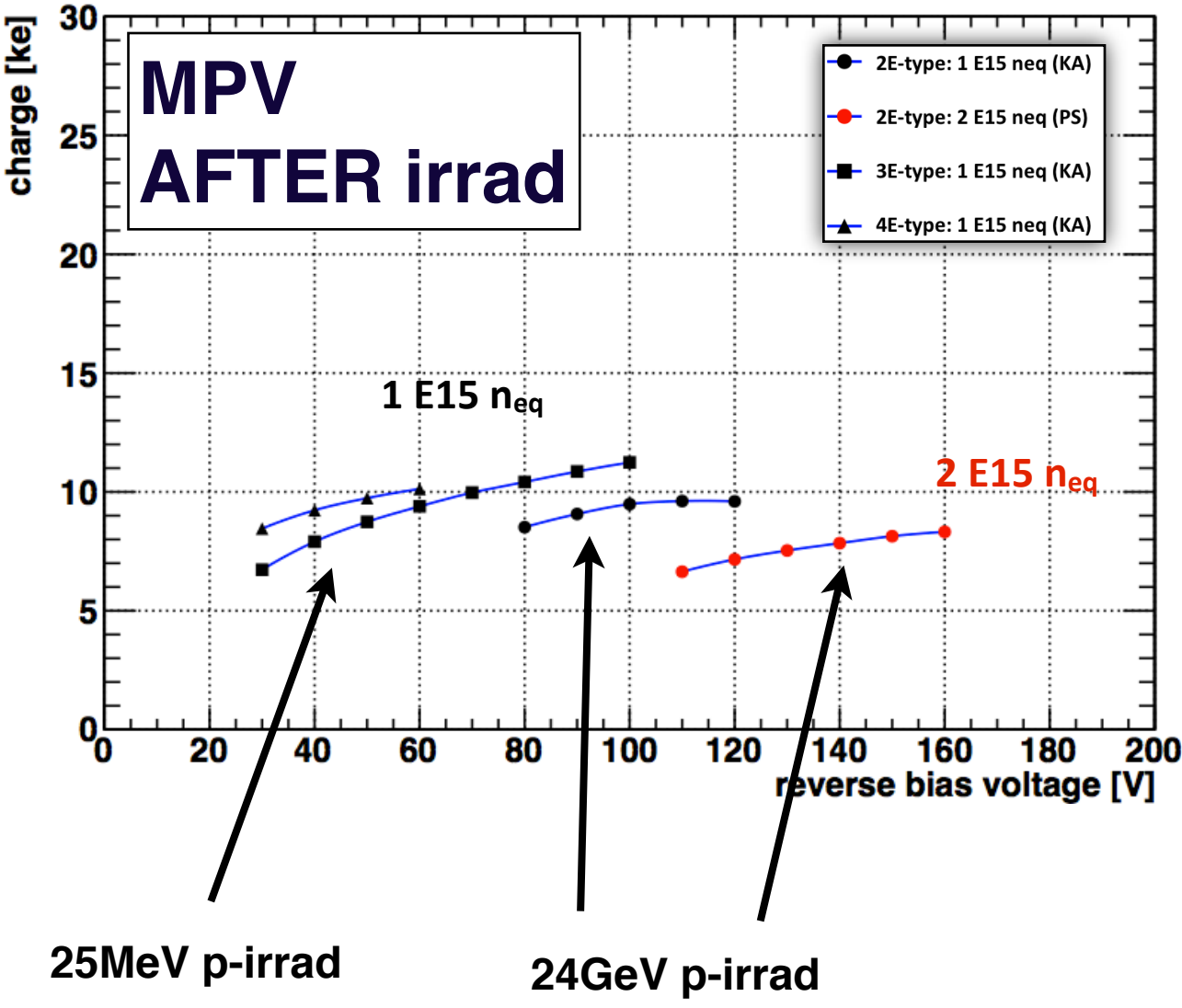
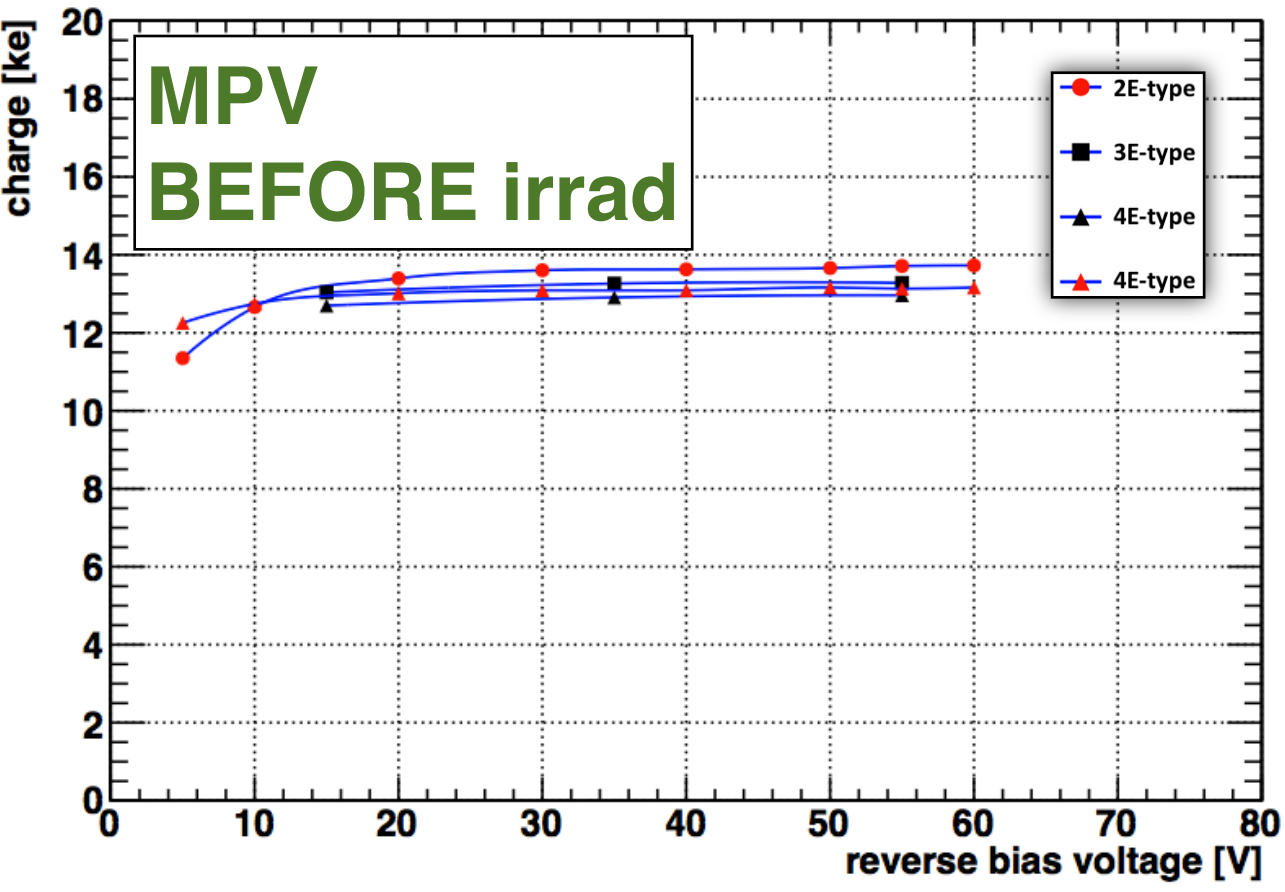


~ 40% w.r.t collected charge before irradiation  
(DUT: 200um thick with 90-100um column overlap!!)

Collected charge in agreement with what has been observed during beam tests (see talk by A, Micelli)

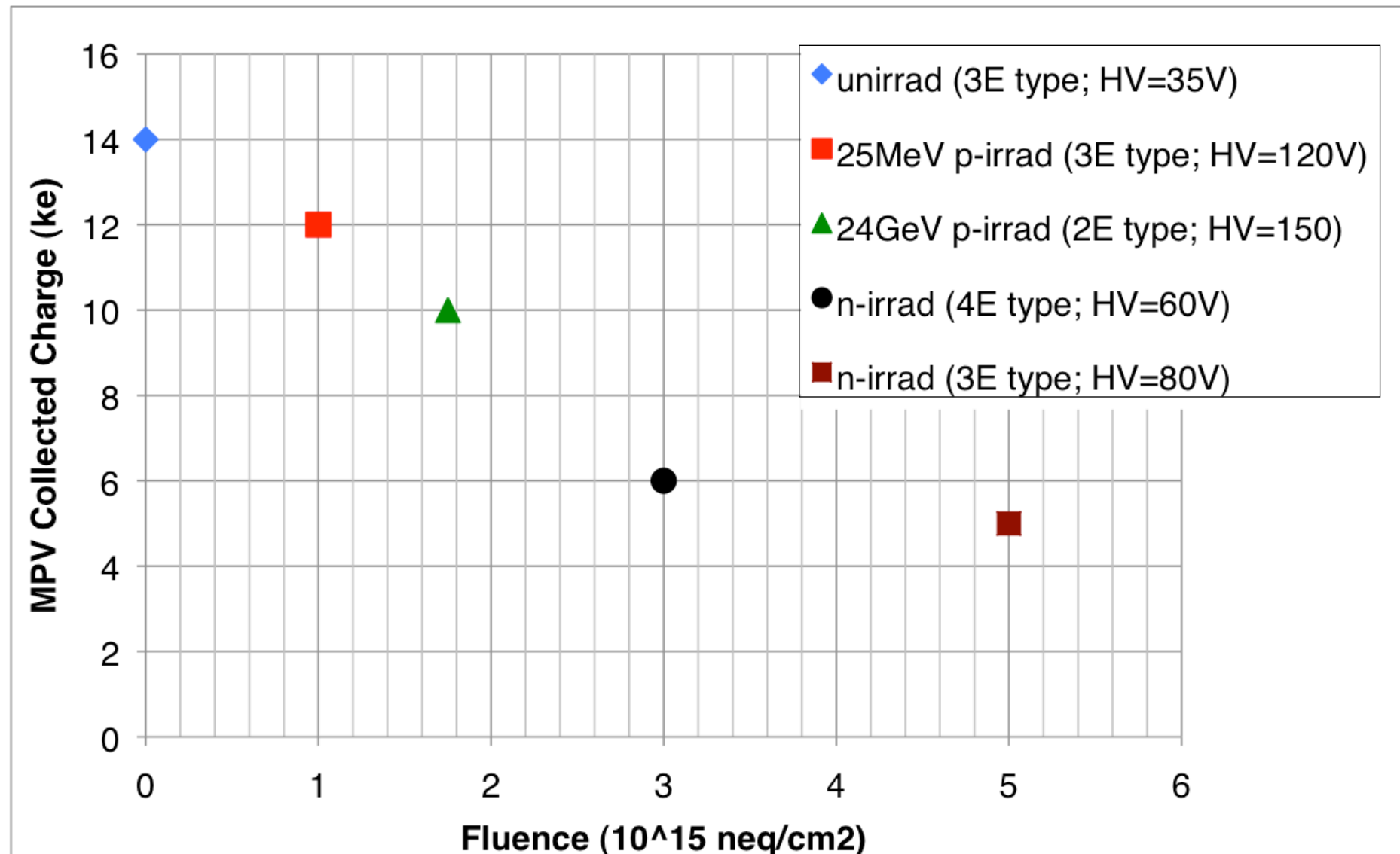
# External-trigger operation with Sr<sup>90</sup> source

- Overview of Sr90 source-test measurement before and after irradiation
  - measurement performed at +23°C for unirrad devices
  - measurement performed at -20°C for unirrad devices



# Collected charge vs fluences

- Measurement performed with different FBK irradiated sensors
  - Sr90 source test (external triggered)
  - Five different sensors under test (irradiated at CERN, Karlsruhe and Ljubljana)
  - HV chosen in agreement with the best sensor-working-point



# Summary and outlook

- Several Double-side Double Type Column FBK sensors of different flavors have been tested before and after irradiation
- Devices irradiated up to  $5 \times 10^{15} \text{ n}_{\text{eq}}$  (ATLAS-IBL target fluence)
  - ➔ First prototypes (with short column overlap) have shown good performance from lab-test measurements.
- Development of 3D sensor technology is proceeding with encouraging result and new FBK full column (200um thick) have been recently bump-bonded on FE-I3 chip.
  - Lab-test measurements on-going
  - Beam tested at DESY with 4GeV e-beam
  - Irradiation campaign started aiming to ATLAS-IBL target fluence

