Radiation hardness characterisation of HVCMOS with the Transient Current Technique

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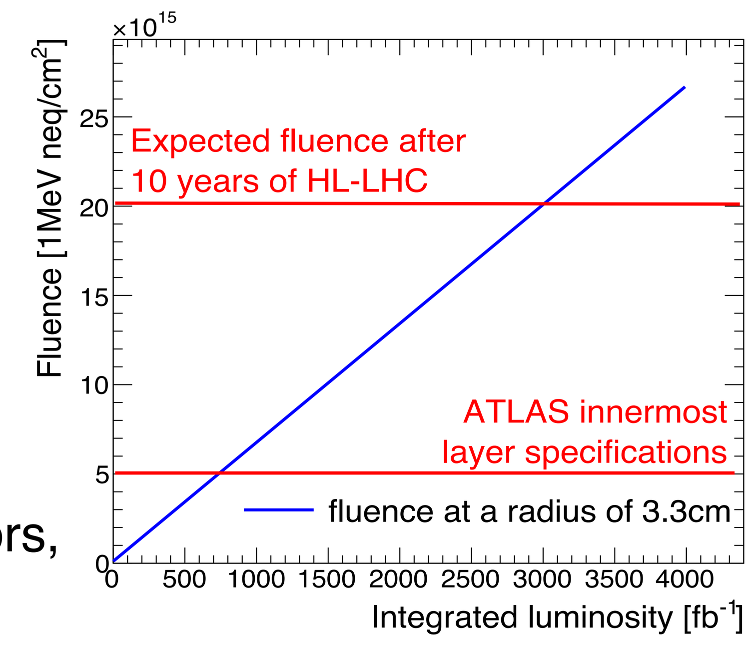
ATLAS inner tracker upgrade for the HL-LHC

The HL-LHC project aims to increase the luminosity by a factor of 10 beyond the LHC's design value.

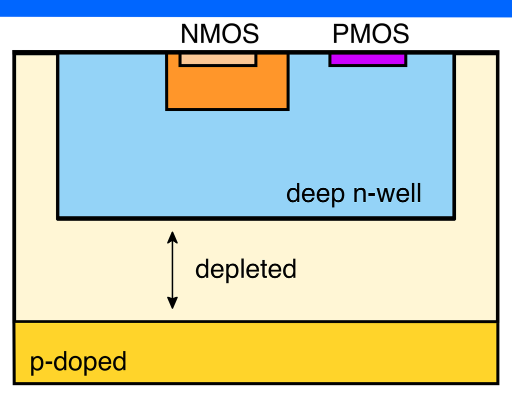
Tracking detector upgrade is needed for:
- separation of primary vertices in a busy environment
- efficient readout
- tolerance to high radiation doses

ATLAS will replace its Inner Detector with a full-silicon tracker (ITk) [1]. The total expected dose is studied with simulations and all the technologies are being tested in those conditions.



The Transient Current Technique has been used to characterise the performance after irradiation of HV-CMOS sensors, technology candidate for the 5th pixel layer of the new traking system, positioned 279 mm from the collisions

HV-CMOS and the AMS H35 Demonstrator



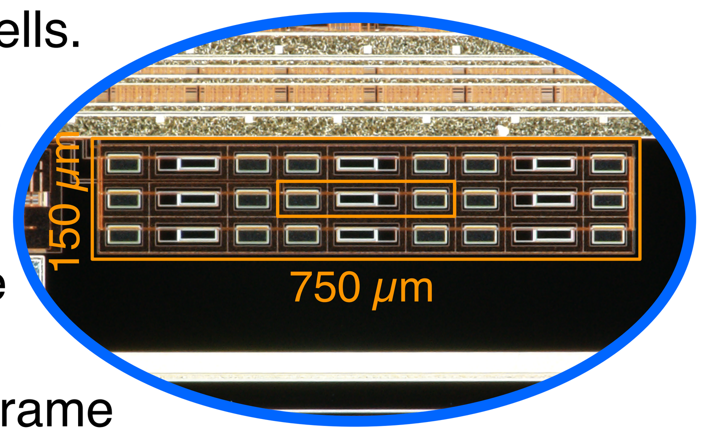
CMOS technology embedded in each pixel shielded by a deep n-doped well

↓

possibility to operate at high voltage (HV)

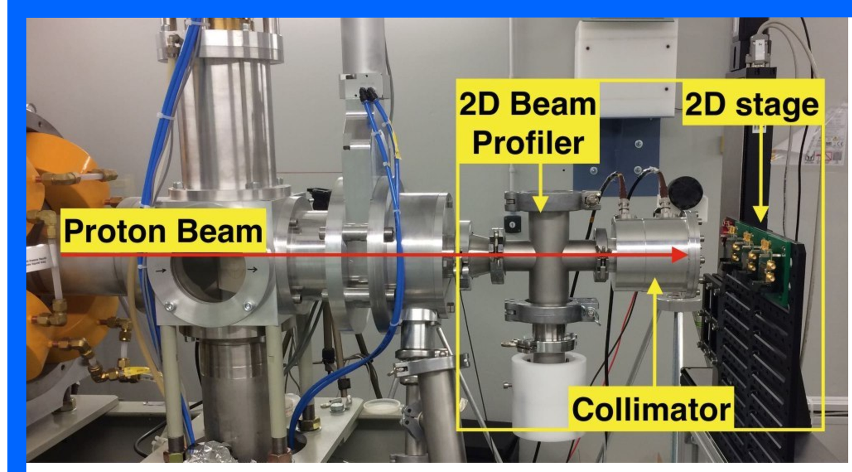
Pros:
- monolithic, no bump-bonding ⟶ lower material budget
- collection by drift ⟶ radiation hardness

H35 Demo - HV-CMOS technology by AMS [2]
- 4 matrices + some non instrumented test structures
- 4 different resistivities: 20, 80, 200 and 1000 Ωcm
- 250x50 μm^2 pixels, divided in 3 n-wells.



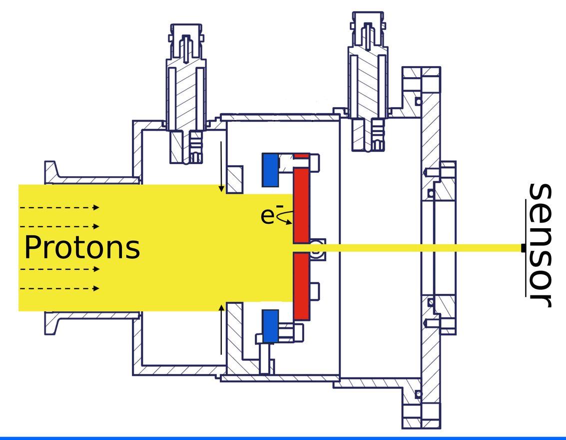
Test structures for TCT located at the edge of the chip 3x3 matrix with two read-out channels: central pixel and frame

Proton irradiation



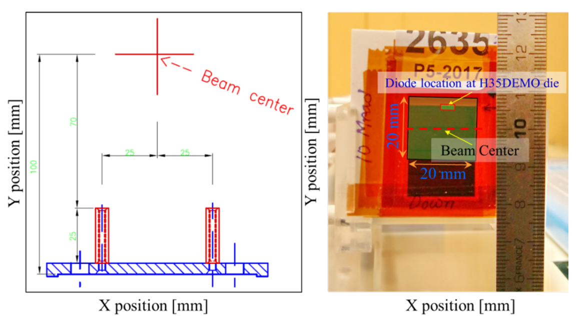
Bern Medical Cyclotron [3]
- 16.7 MeV protons
- 3.6 hardness factor
- sensors irradiated mounted on boards

⟶ possibility to irradiate, measure, irradiate again multiple times!

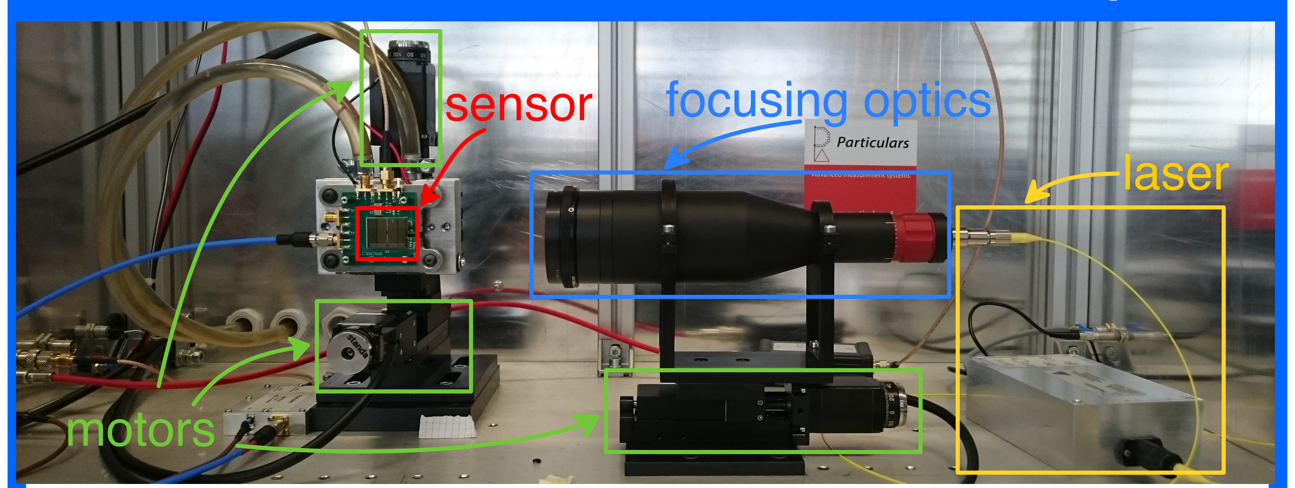


Dose monitored online: measurement of the beam current density on different layers of collimators

PS east area IRRAD facility [4]
- 24 GeV protons
- 0.6 hardness factor
- 4 accumulated fluences targeted in this campaign: 1x10^{14}, 3x10^{14}, 6x10^{14} and 1x10^{15} 1MeV n_{eq}/cm^2

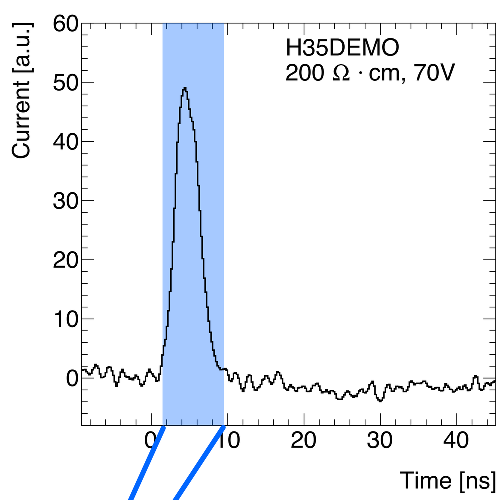


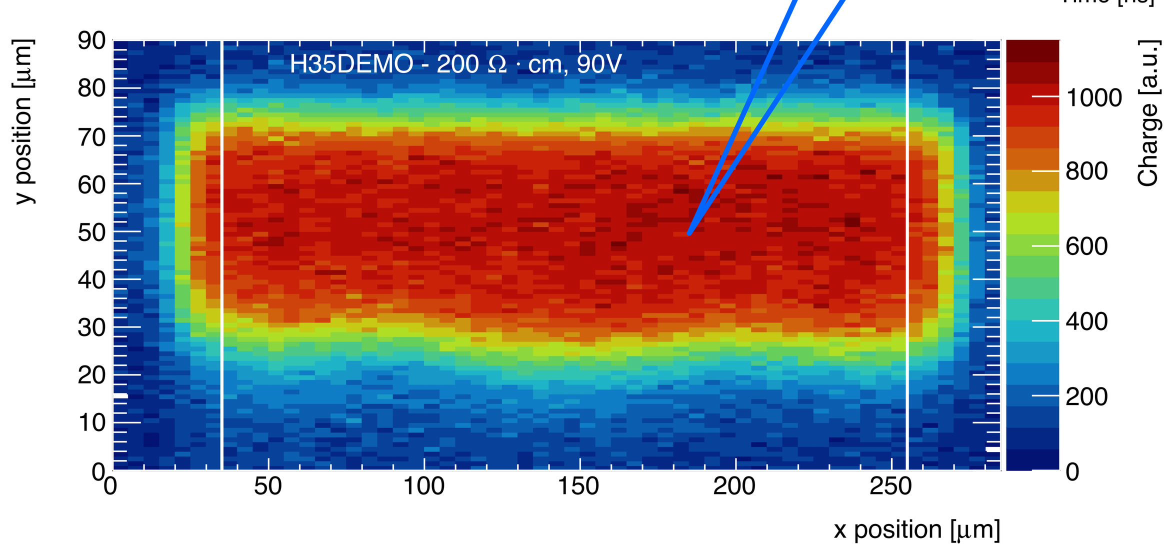
The Transient Current Technique



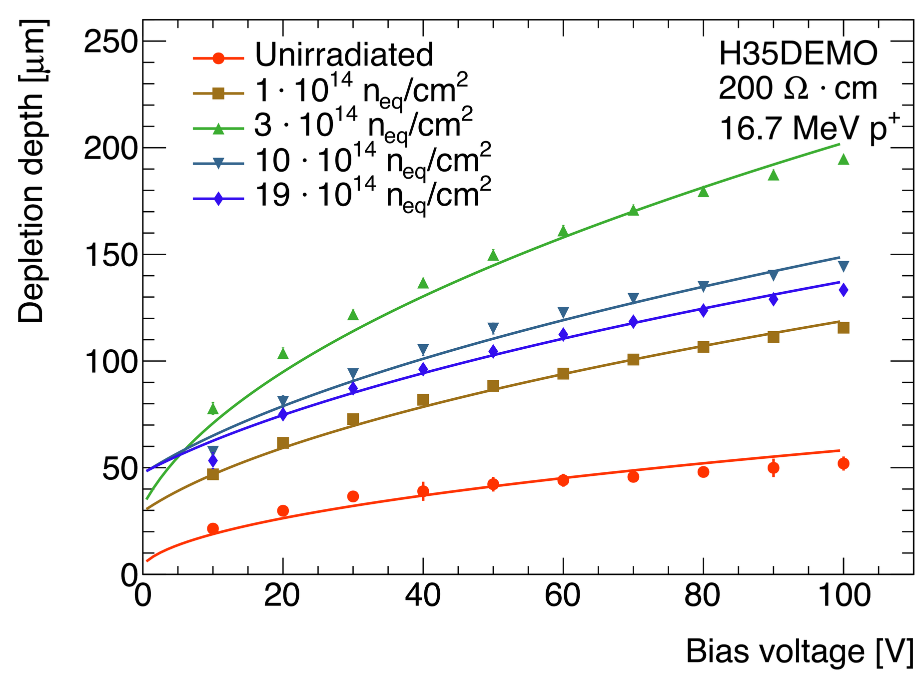
Pulsed IR laser beam to generate electron-hole pairs with μm precision in a silicon detector.

The measurements of the charge are collected by moving the laser along the sensor edge allow to create a 2D map of the active area.





Evolution of the depletion depth

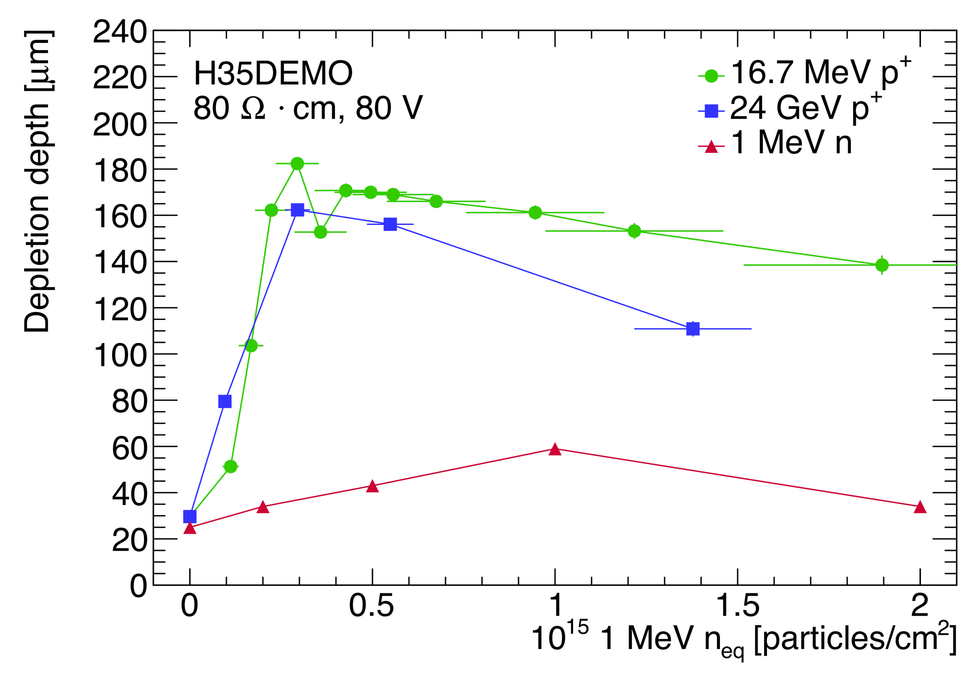


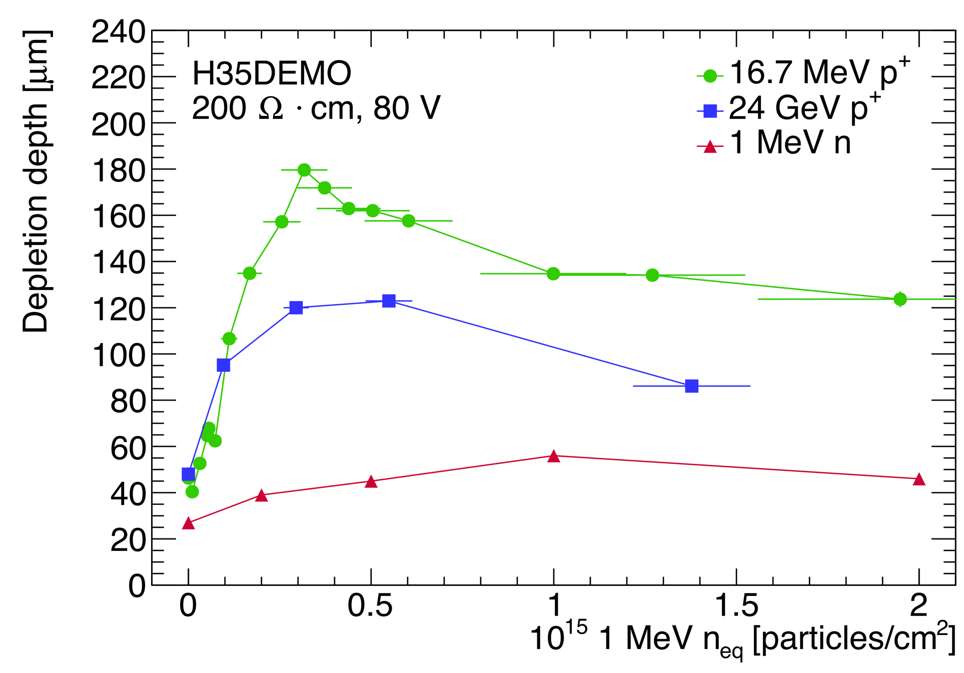
From the 2D maps the depletion depth is measured at different bias voltages after every step of irradiation

Observations:
- similar trend for the 2 irradiation campaigns
- increase of the depletion depth due to initial acceptor removal, then slow decrease
- stronger effect for low resistivities (up to 8 times the original size!)
- more moderate for the high resistivities (~30%)

The same test structures have been characterised in [5] after neutrons irradiation

Acceptor removal effect more pronounced with protons!





[1] ATLAS Collaboration, Technical Design Report for the ATLAS Inner Tracker Strip Detector, Tech. Rep. CERN-LHCC-2017-005. ATLAS-TDR-025, CERN, Geneva, Apr, 2017.
[2] E. Vilella et al., Prototyping of an HV-CMOS demonstrator for the High Luminosity-LHC upgrade, 2016 JINST 11 C01012.
[3] P. Scampoli, K. von Bremen, S. Braccini, and A. Ereditato, The New Bern Cyclotron Laboratory for Radioisotope Production and Research, Conf. Proc. C110904 (2011) 3619–3621.
[4]F. Ravotti, M. Glaser, and M. Moll, Upgrade scenarios for irradiation lines:: Upgrade of the Proton Irradiation Facility in the CERN PS EAST AREA.
[5] E. Cavallaro et al., Studies of irradiated AMS H35 CMOS detectors for the ATLAS tracker upgrade, JINST 12 (2017) C01074.