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Charge Collection Study of Heavily Irradiated Silicon Microstrip Detectors

17th RD50 Workshop – CERN, 17-18 November 2010

Outline

- CCE measurements
  - CERN Alibava setup
  - Charge collection efficiency vs. annealing time
  - Giving an overview of detectors at LHC operative limits
- Edge-TCT measurements
  - CERN Edge-TCT setup
  - Drift velocity and CCE scan
- Conclusions

Motivations

Aim of the work was to assess the effects of annealing on the performances of the current generation microstrip detectors (e.g. to provide information in case of a cooling system shutdown) .

- HPK FZ p-on-n strip detectors irradiated with 24 GeV/c protons (CERN) and 1 MeV neutrons (Louvain La Neuve) up to a maximum eq. fluence of $1 \cdot 10^{15}$ n_{eq}/cm^2
- CCE of the detectors tested with CERN Alibava setup
- Final assessment of one particular detector performed with CERN Edge-TCT setup

Detectors

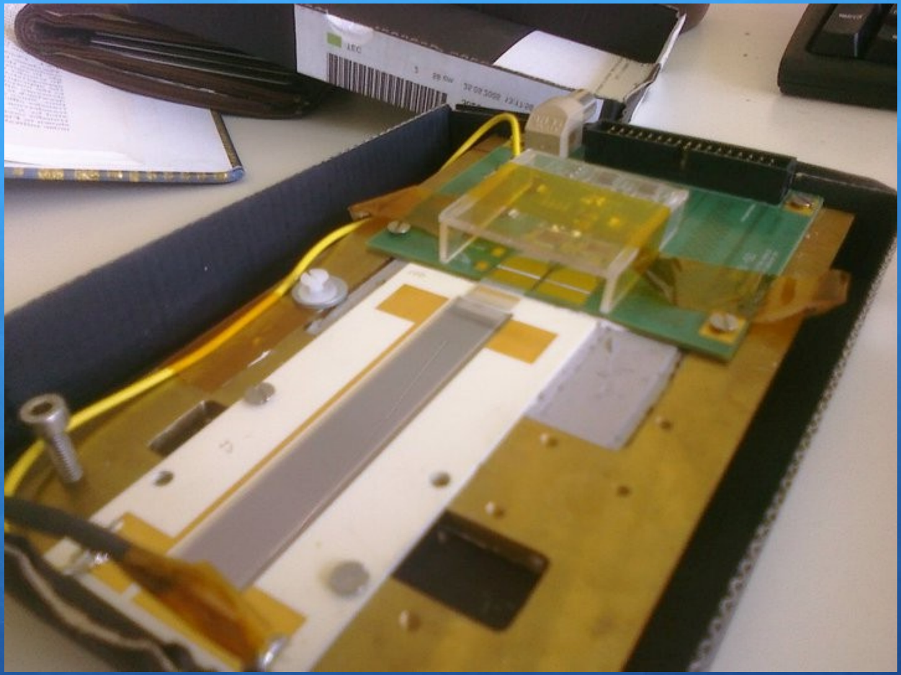
- p-in-n type detectors
- HPK 6-inch cutoffs, pitch: 80 µm, thickness: 300 µm
- Irradiated with protons (PS @ CERN) and neutrons (Louvain de Neuve, Belgium)
- Fluence range (neq): $3 \cdot 10^{14}$ - $10 \cdot 10^{14}$

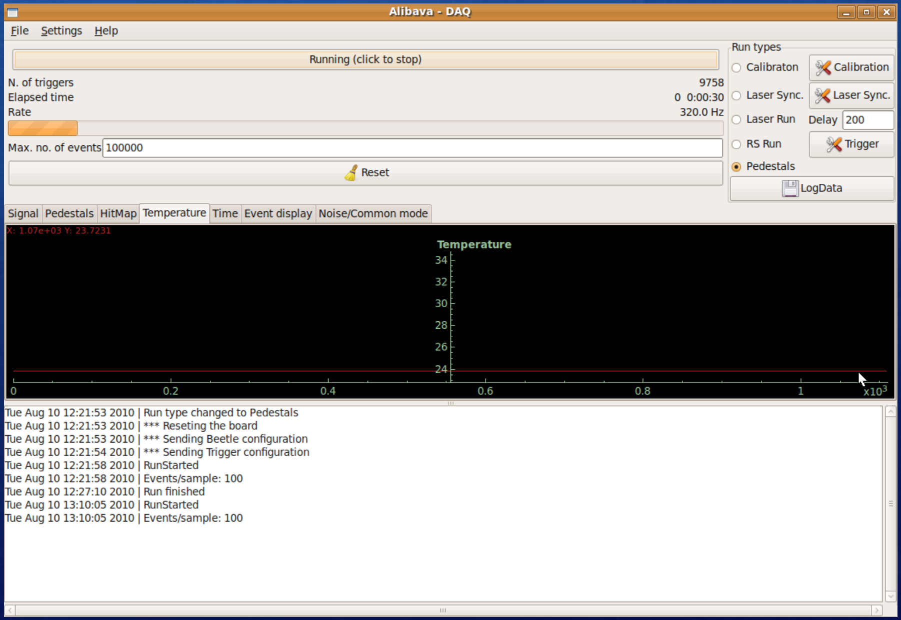
Proton Fluence (24 GeV p.cm^{-2})	Neutron Fluence (1 MeV n.cm^{-2})	Equivalent 1MeV n
-	3×10^{14}	3×10^{14}
-	5×10^{14}	5×10^{14}
-	10×10^{14}	10×10^{14}
4.8×10^{14}	-	3×10^{14}
8.1×10^{14}	-	5×10^{14}

- A detector irradiated to 16e14 *protons* did not produce any measurable landau up to the breakdown voltage (500 V). The results will be omitted.

ALIBAVA DAQ System

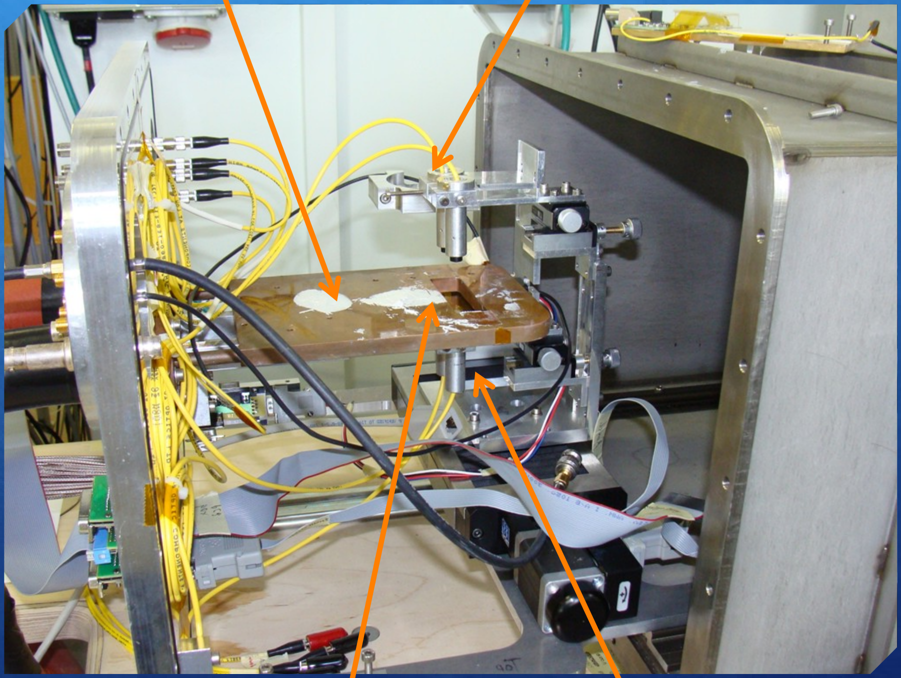
- Hardware
  - Daughter Board – contains front end electronics (BEETLE) and experimental sensors
  - Mother Board – connected to DB via ribbon cable, then to PC via USB.
- Software
  - ALIBAVA software – gives real time readout from the test board. Gives temperature, event display, noise, signal etc. Provides control over datasets to be collected.





CCE Setup

- Alibava setup, sw version 0.1.5.1 (automatic voltage ramping implemented)
- Daughter board is encased inside a metal box.
- 3.6 MBq Sr-90 fast beta source providing incident electrons.
- 2 mm plastic moderator for stopping soft electrons
- Cooled with liquid cooling system to -20°C.
- Flushed with dry air, dew point <-80°C.
- Triggered by single scintillator placed beneath detector.
- Seed cut: SNR>5, neighbor cut: SNR>3



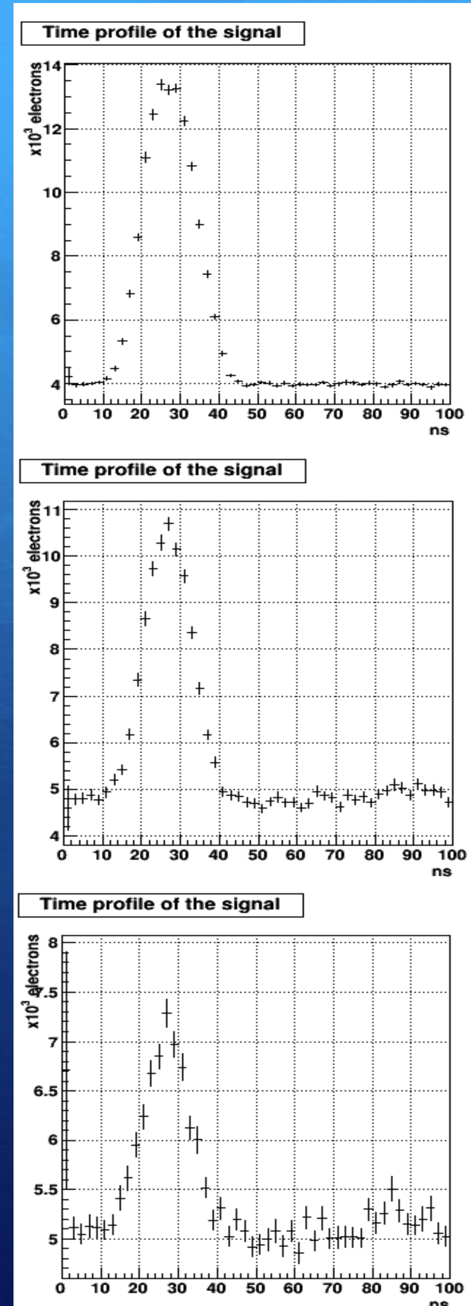
CCE details

- Data collected from 100,000 events for voltages from 50 to 1100 volts, 50 V steps
- Collected measurement and pedestal file for each voltage, and calibration file for each DB at each temperature.
- Annealing of the detector at 60˚C, keeping it bonded with the daughterboard
- Annealing steps continued until cumulative time of 5040 minutes (with only one exception, 1e15n stopped at 2480 mins for performing Edge-TCT)

Signal shape

- Time profile of the signal degraded with annealing
- Landau curve plotted with time cuts of 20-30 ns
- Generated charge collection histogram accuracy decreases with annealing

(all graphs opposite taken from $5 \cdot 10^{14}$n irradiated detector, V_{bias}=500 V)

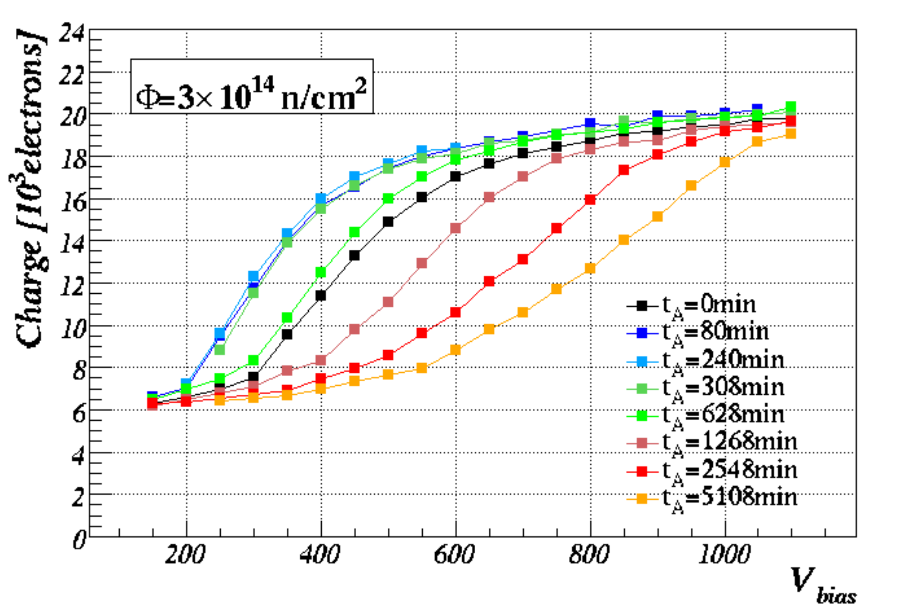


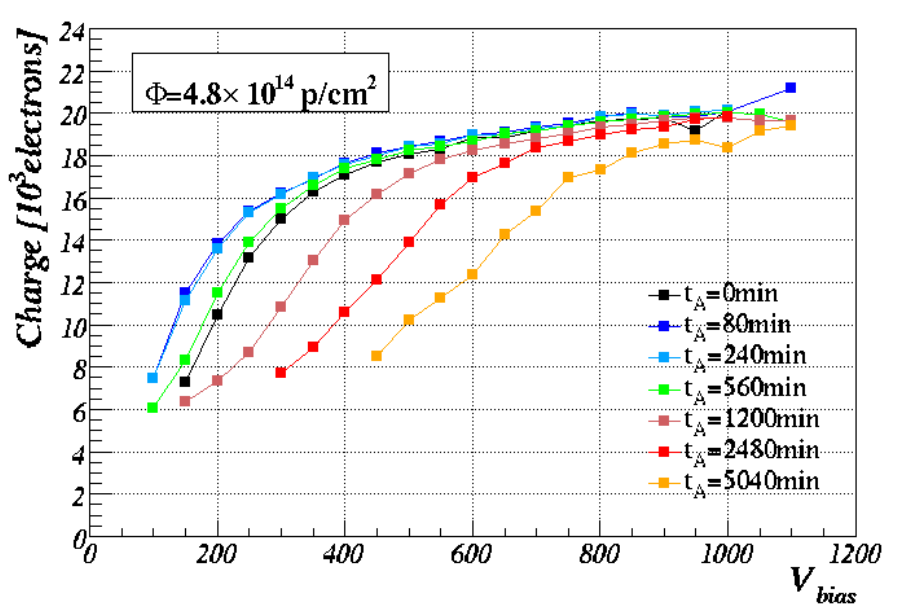
0 mins @ 60°C

1200 mins @ 60°C

5040 mins @ 60°C

CCE of irradiated detectors ($3 \cdot 10^{14} n_{eq}$)





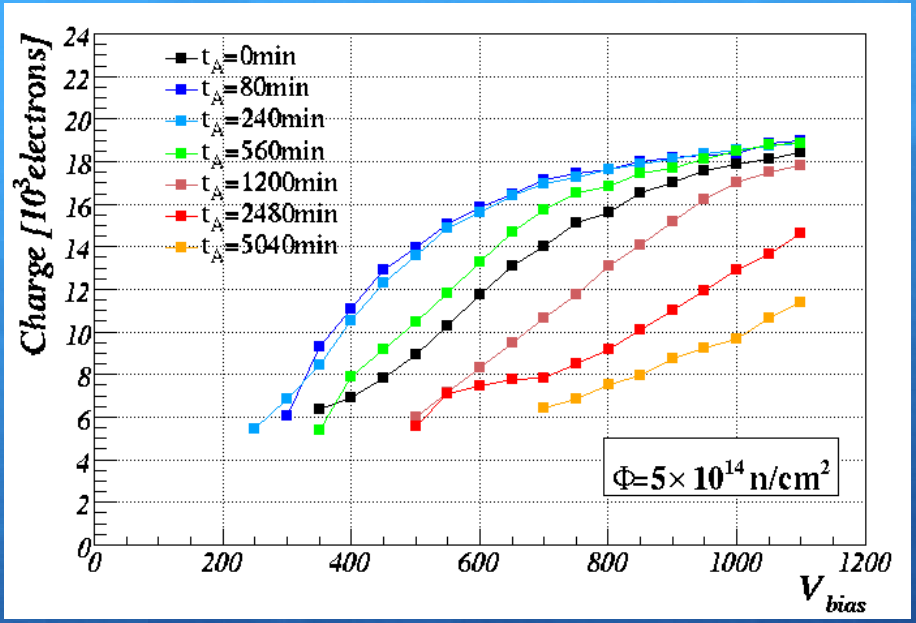
- Proton irradiated detector shows a higher CCE (lower depletion voltage), but also with higher noise levels (microdischarges), which prevented Landau fits at lower voltages.

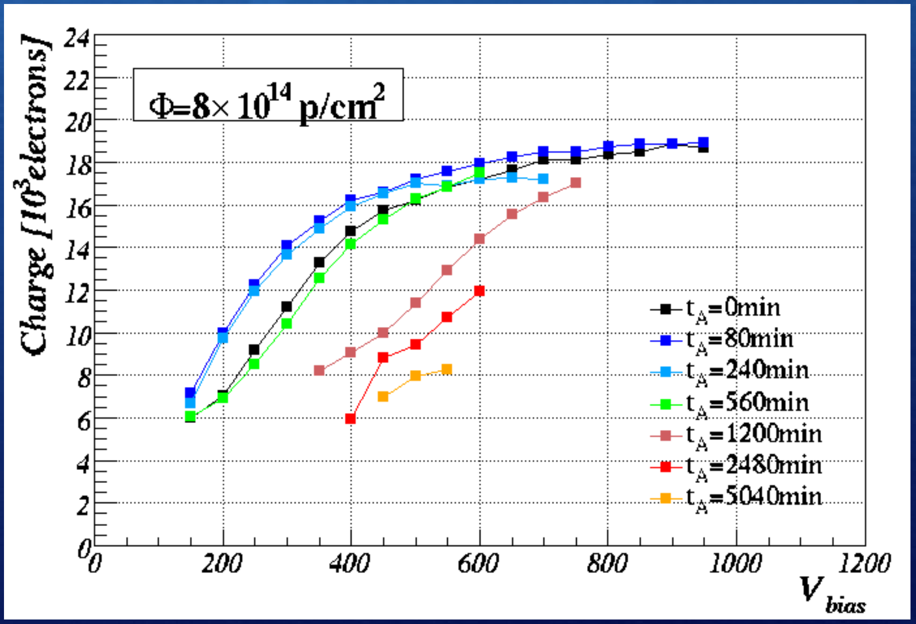
- Minimum annealing step occurs between 80 and 240 mins (@ 60°C)

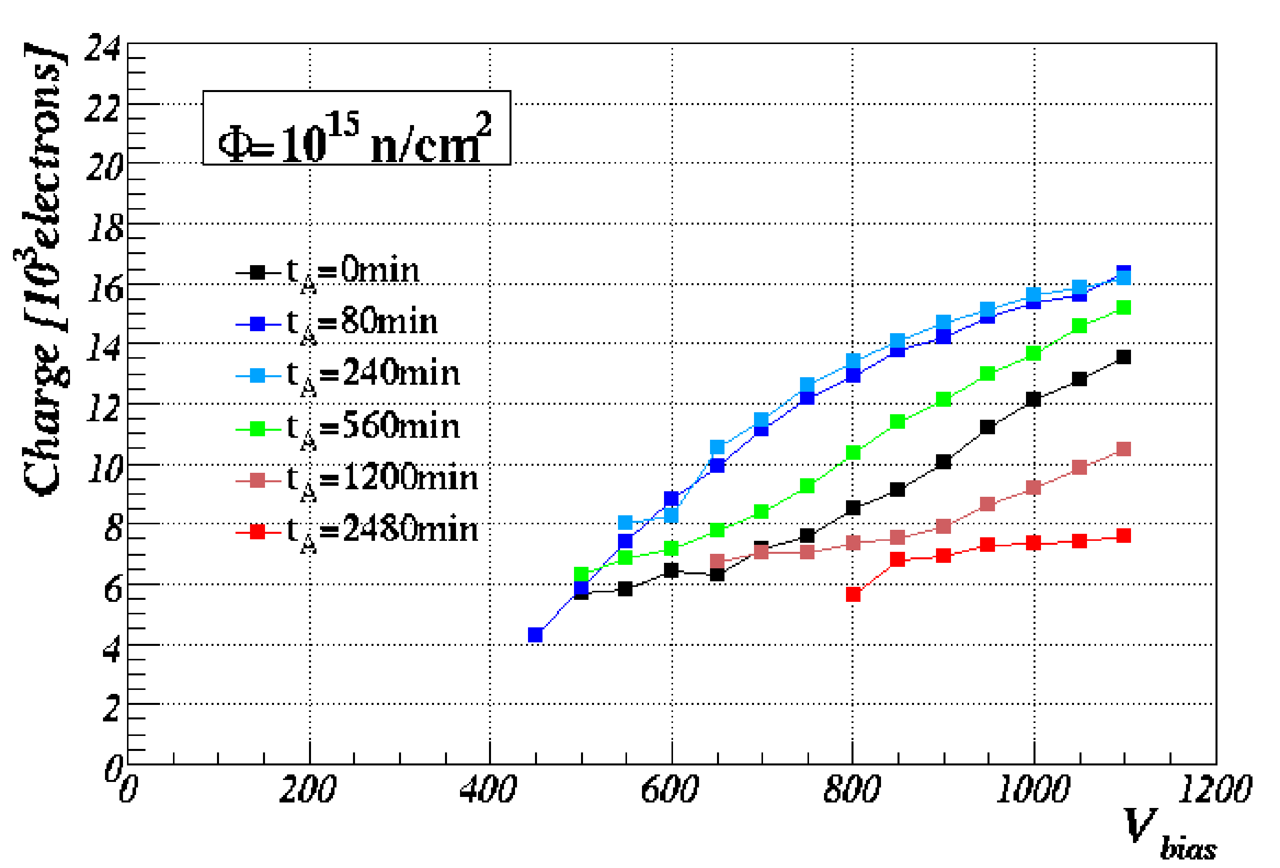
- Collected charge @ 500 V for neutron irradiated detector drops to 7500e, 10000e for the proton irradiated

CCE of irradiated detectors ($5 \cdot 10^{14} n_{eq}$)

- Collected charge values for the proton irradiated sample are higher than those for neutron irradiated
- Proton irradiated detector goes into early breakdown starting from 1200 minutes of annealing.
- End values of collected charge @ 500 V is 8000 e for proton irradiated and < 6000 for neutron irradiated

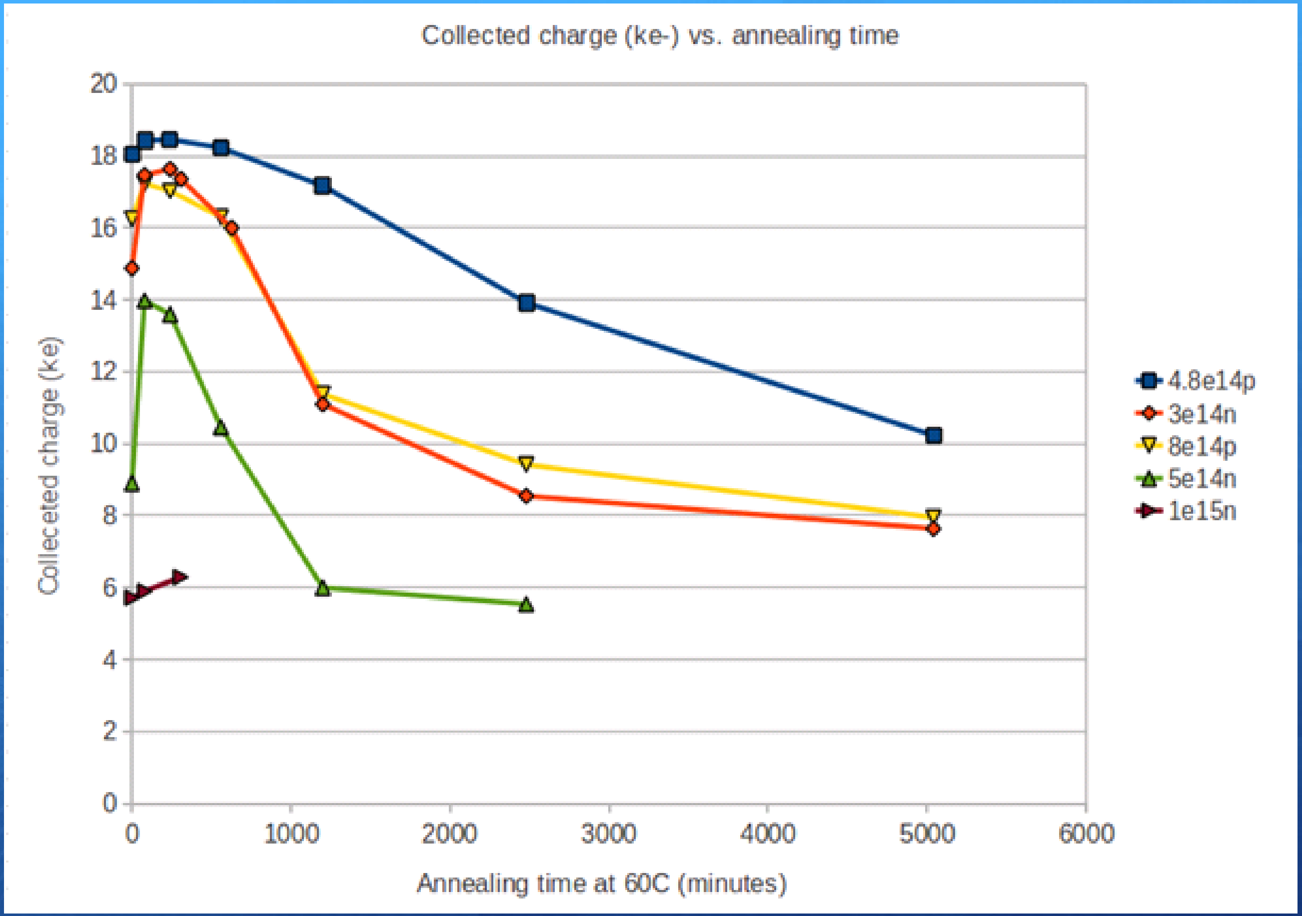






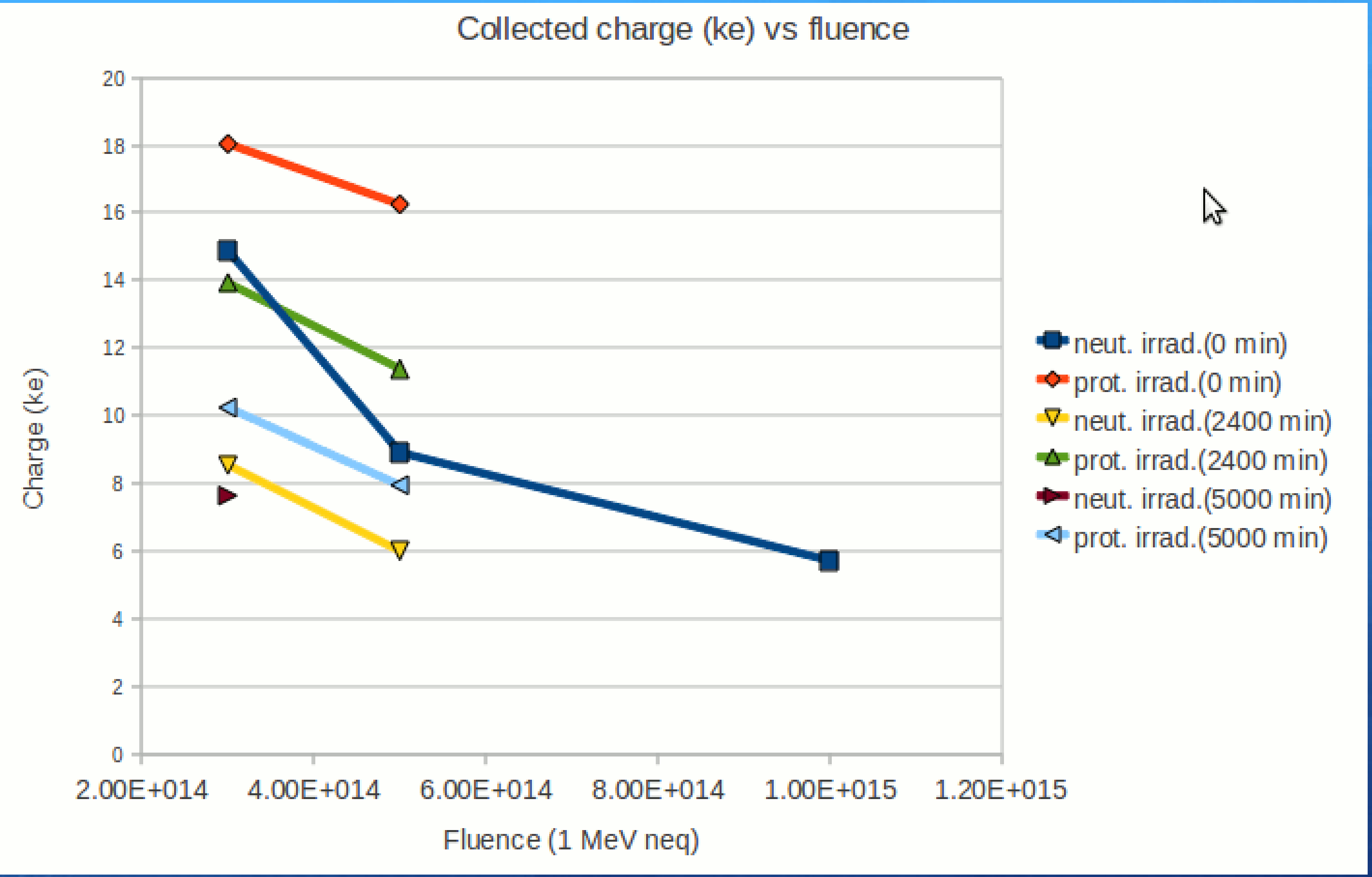
1e15n – Most Irradiated detector

- Annealing stopped at 2480 minutes for performing Edge-TCT (see next slides)
- CCE shows that detector doesn't reach depletion
- Strong effect of beneficial annealing (up to 40% more charge collected)



Comparisons: charge vs. annealing time @ 500 V

- Stronger influence of beneficial annealing for neutron irradiated detectors (with the exception of most irradiated one)
- Reverse annealing degrades quickly the performances of the neutron irradiated detectors, even at the lowest fluence



Comparisons: charge vs. fluence @ 500 V

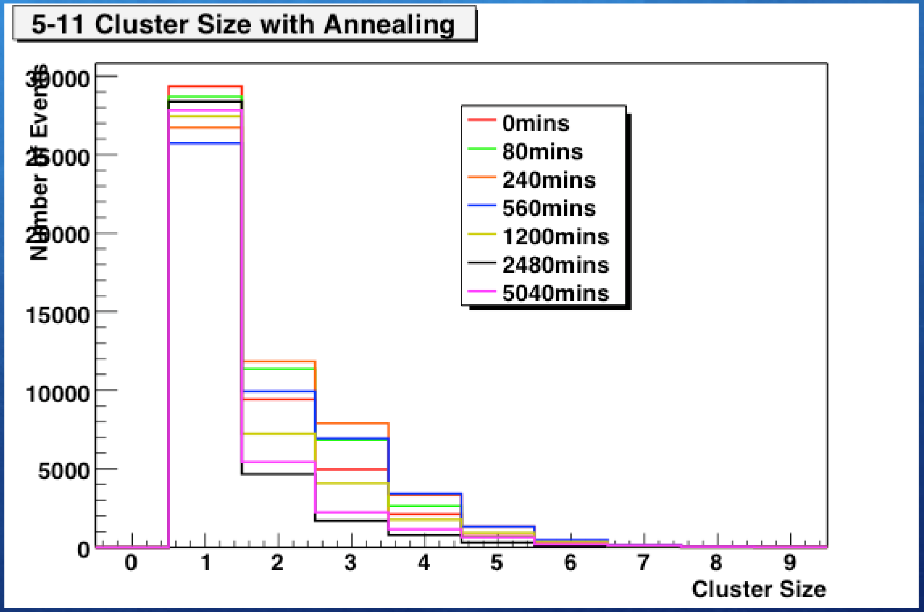
- Stronger dependance, with no annealing, of neutron irradiated detectors to fluence
- Proton irradiated detectors didn't survive to higher fluences to electrical damage caused by charged irradiation

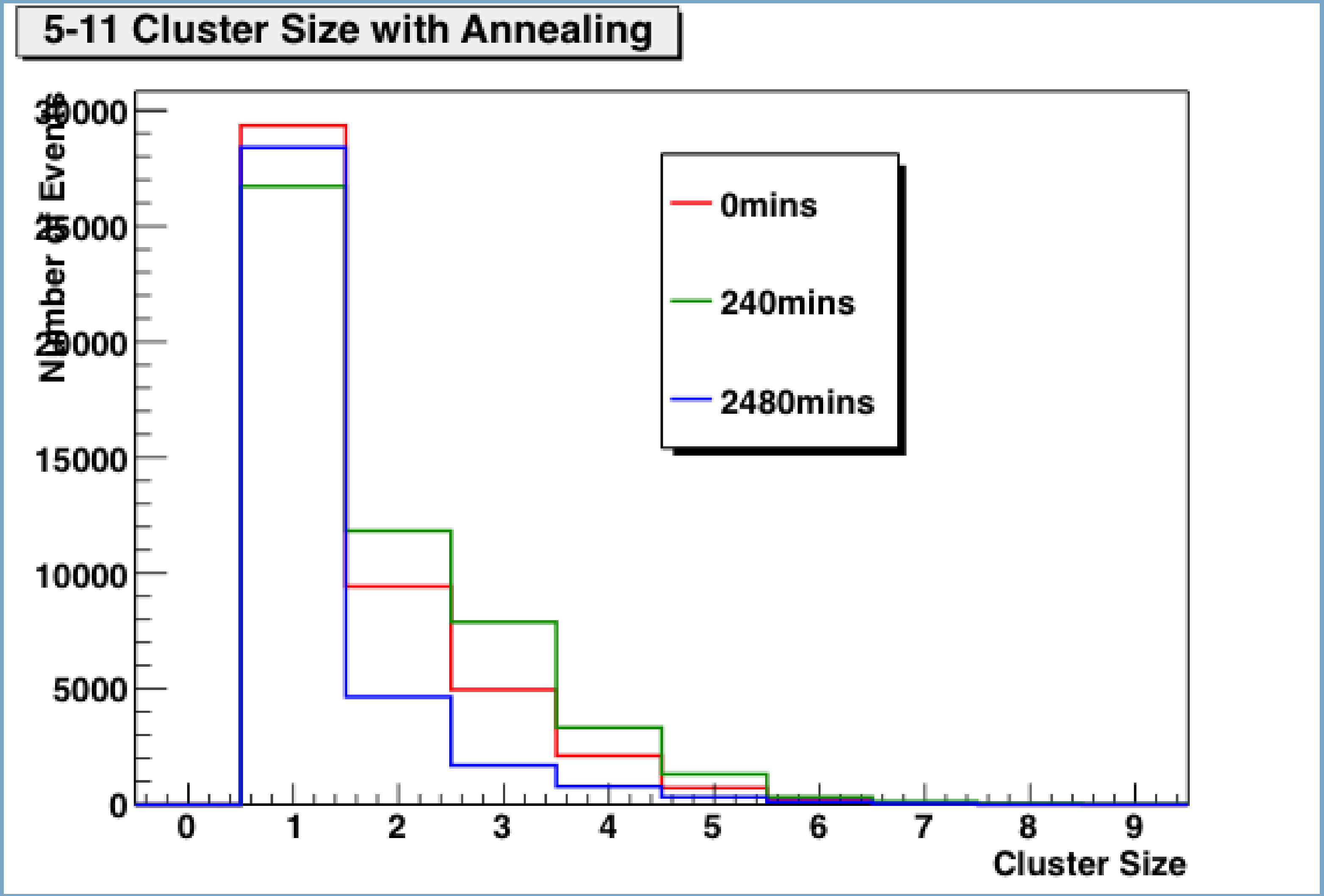
Cluster Width

- Important parameter for center-of-mass position measurements

- Lower charge deposited in neighboring strips->less strips exceeding the neighbor cut->cluster size decreases.

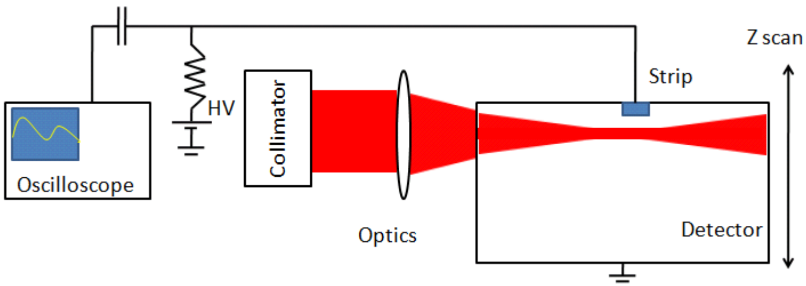
- Cluster width decreases significantly with annealing





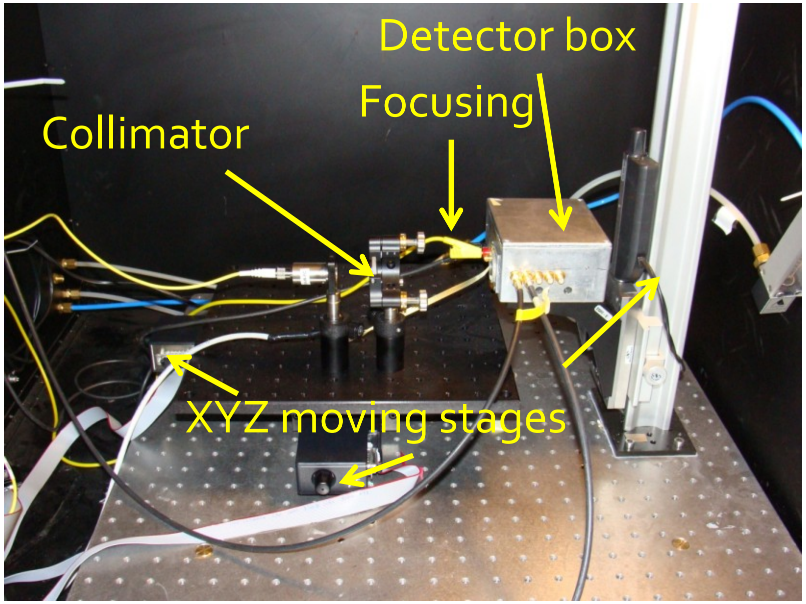
•Going from 0 minutes to 240 minutes (min. annealing step) can see widths increase
•Going from 240 minutes to 2480 minutes can see widths largely decrease – now mostly single strip wide

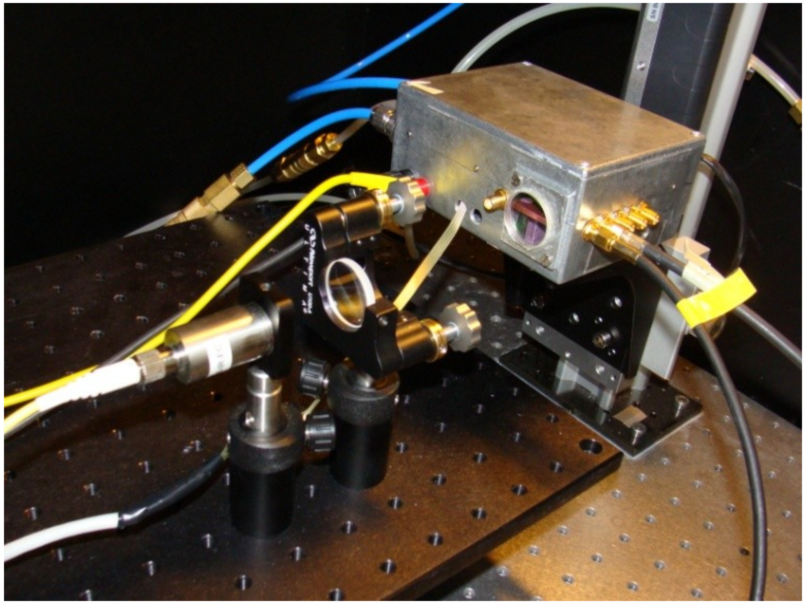
EDGE TCT-Setup



- 6 mm collimated laser beam (λ=1060 nm) focused on the side of the detector.
- Rayleigh length of the beam: ~300 μm
- FWHM of focused beam under the strip: 17 μm
- Peltier cooling (min temp. -35˚C)
- Detector polished to sub-micron level

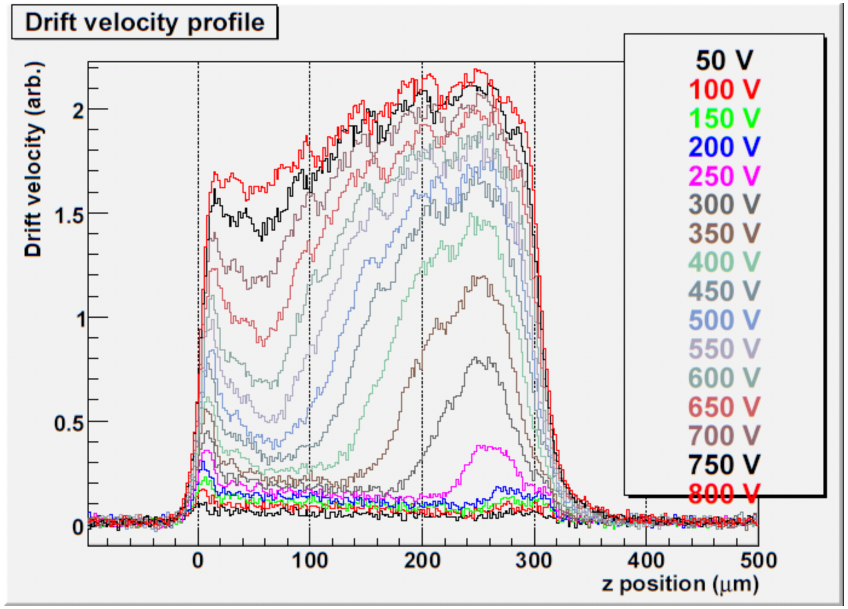
(for further information: G. Kramberger et al. – doi: 10.1109/NSSMIC.2009.5402213)

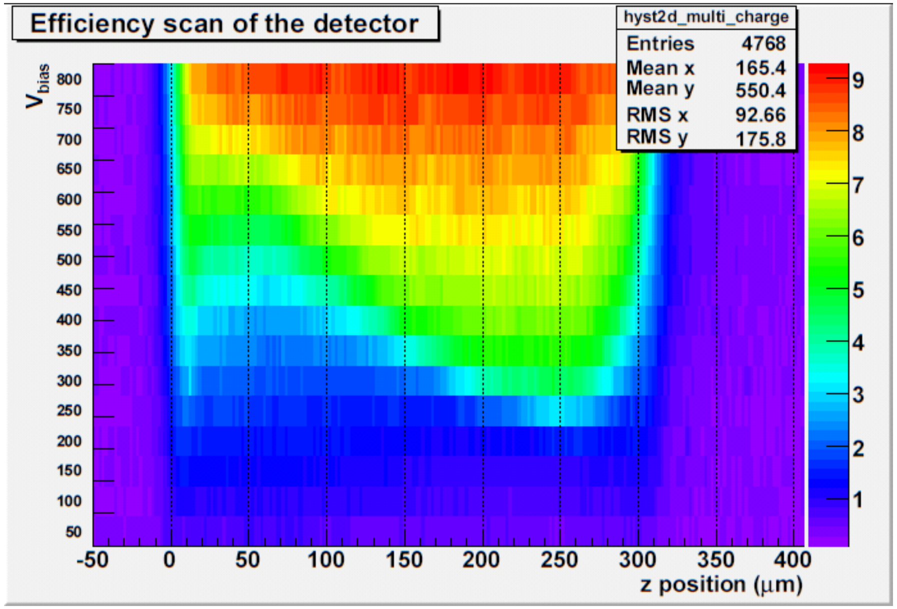




Edge-TCT, $1 \cdot 10^{15}$n after 2480 mins. ann.

- High field region (high drift velocities) moves towards the ohmic implant, as expected.
- Efficiency scan of the detector saturates at 800 V, showing that the whole bulk contributes to the signal to the same amount.
- At this annealing step CCE measurements have shown a viable Landau fit starting from 800 V coinciding with the voltage at which the “efficient region” of the detector reaches the high weighting field close to the strip.





Conclusion

- Detectors submitted to extensive annealing process following irradiation to fluences comparable to the upper end of LHC irradiation and beyond.
- Annealing has a strong effect on charge collection efficiency even on the least irradiated detectors.
- Differences between proton and neutron studies indicate proton irradiated detectors have better collection but there are as well detrimental effect on noise and the electrical characteristics of the detector (note that the Alibava integration time of 25 ns used here resembles current LHC readouts and therefore analysis)
- Cluster size (and hence potential position resolution of the detector related to it) significantly decreases following annealing
- Edge-TCT measurement on a neutron irradiated detector show that the minimum bias required to extract a Landau distributed signal coincides with the efficiency region of the detector reaching the area near the strip (where the weighting field is maximum).
- Further to this, 3 more radiation damaged detectors will be tested, irradiated to 1e14n, 1.6e14p (resembling the near-future scenarios of the LHC) and one with mixed irradiation up to 5e14n_{eq}.

Thank you for listening

Are there any questions?

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