THE UNIVERSITY of LIVERPOOL

Recent results with n-in-p miniature microstip detectors after heavy proton irradiation

G. Casse – University of Liverpool

OUTLINE

- Motivation for using n-in-p diode structure in finely segmented devices
- Results after heavy proton irradiation in term of CCE(V)
- Conclusions and perspectives

It is now well accepted and well supported by measurements that the degradation of the CCE(V) is remarkably reduced by reading out the segmented silicon detector from the n-side rather than from the p-side. This read-out was usually implemented by segmented the ohmic contact on devices made with the *standard* n-type substrate. The limitation with these devices is the higher processing cost (double sided imaging), and, to a lesser extent, that the junction side (and the high electric field) is on the opposite side before irradiation. Both the migration of the junction after type inversion and the extra cost due to the double-sided processing can be avoided by using a p-type bulk substrate. What is though the impact of the p-type substrate on the radiation hardness properties?

Moreover, is there an influence of oxygenation on the radiation hardness of p-type substrates?

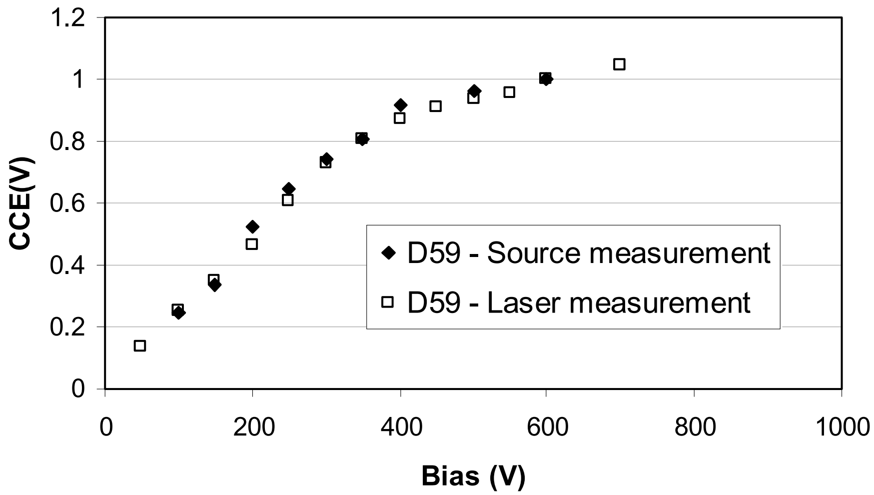
A few sets of 1×1 cm^2, 280±10 μm microstrip detectors have been produced by CNM-Barcelona with oxygen enriched and standard p-type wafers using a mask-set designed by the University of Liverpool. The initial full depletion voltage (V_{fd}) was about 350 V.

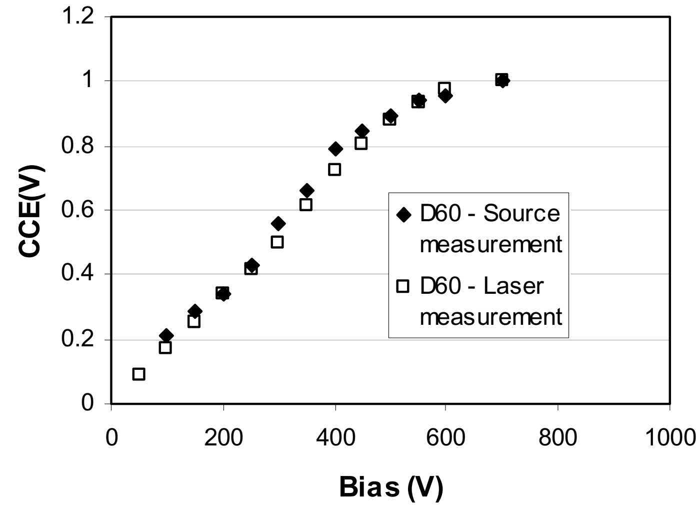
A few of them have been irradiated to 1.1, 3 and 7.5 10^{15} $p \cdot cm^{-2}$ in the CERN-PS at room temperature and unbiased. The detector irradiated to 3. 10^{15} cm^{-2} was standard p-type substrate, while the other devices were oxygen-enriched.

The detectors were measured after irradiation under illumination with a β-source (^{106}Ru) and 1060 nm pulsed laser, in *diode configuration* (all strips connected to a common bar and read-out with a wide-band single channel amplifier) and in *LHC configuration* (each strip connected to LHC-speed analogue electronics).

Comparison with the different measurements methods

1060 nm laser vs source measurement (*in diode configuration*)

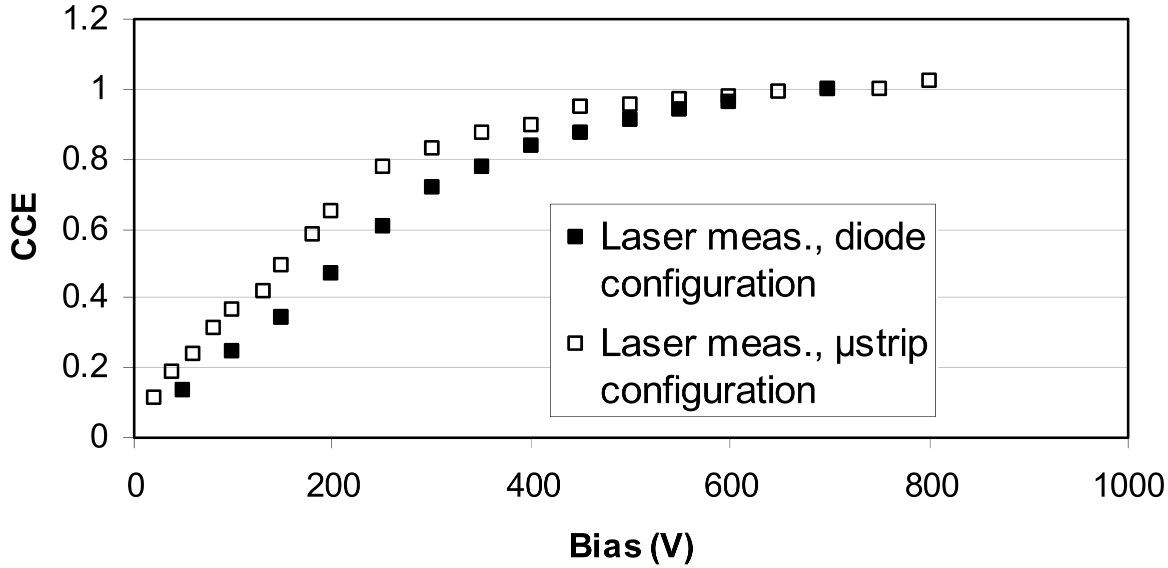




After 1.1 10^{15} p cm^{-2}

THE UNIVERSITY of LIVERPOOL

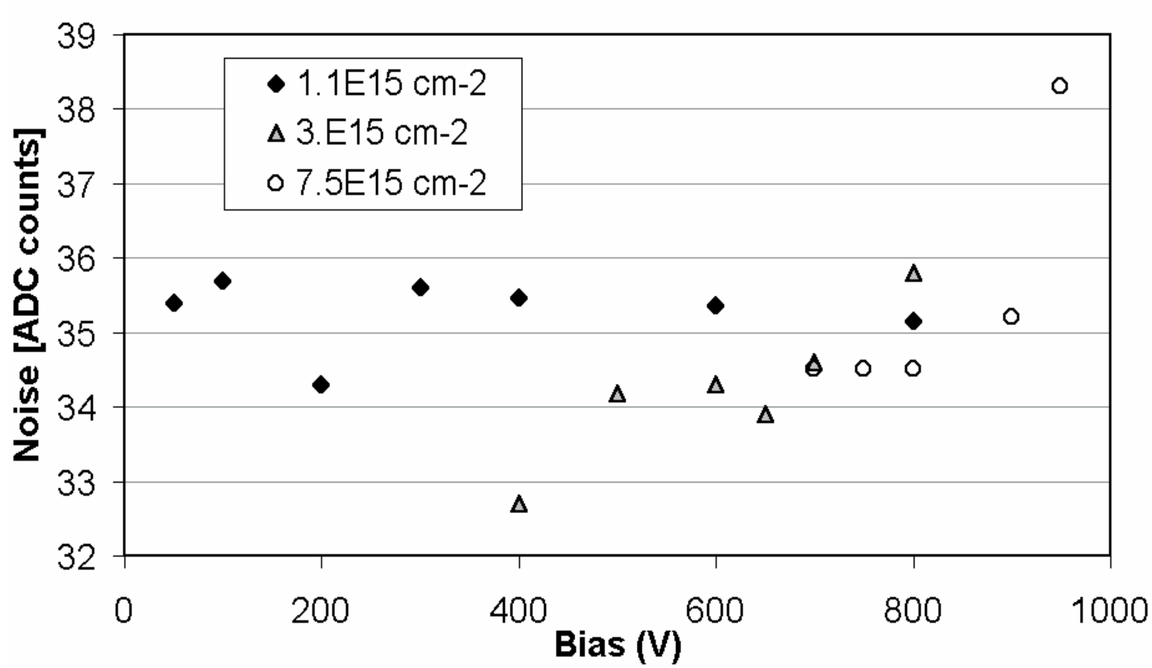
Diode configuration vs *LHC configuration* (1060 nm laser)



After 1.1 10^{15} p cm^{-2}

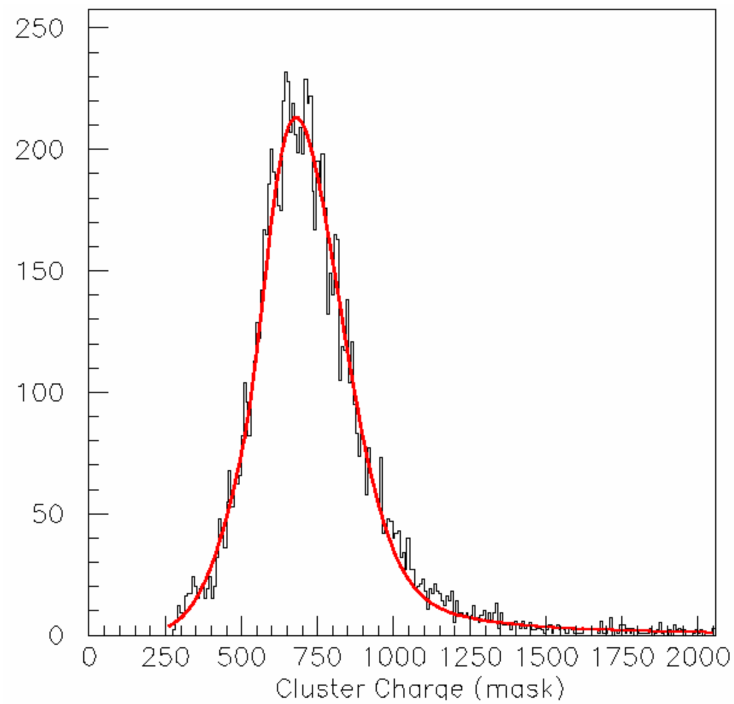
Studies in LHC configuration

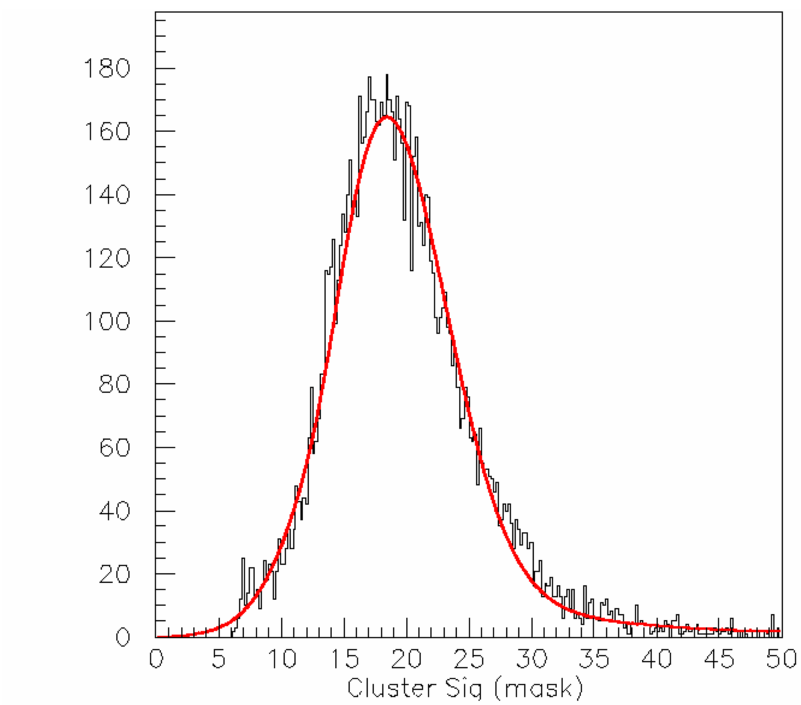
Noise as a function of the applied voltage for three different irradiation doses. The pre-irradiation value is about 35 ADC counts, similar to the value found after irradiation.



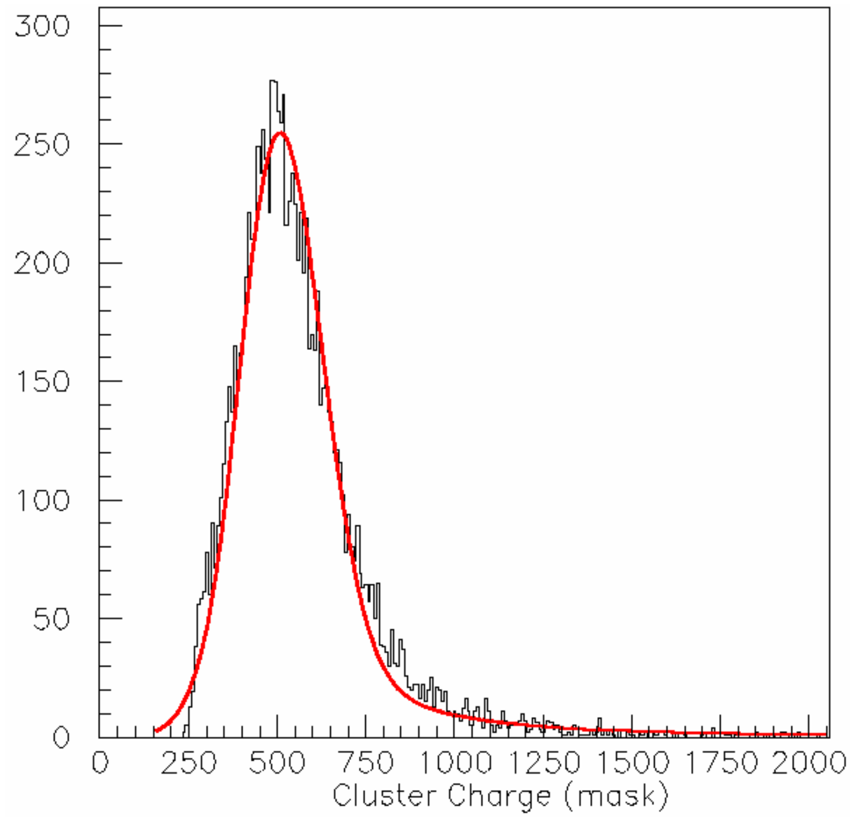
THE UNIVERSITY of LIVERPOOL

Signal and cluster significance after 1.1 10^{15} p cm^{-2} (800 V)

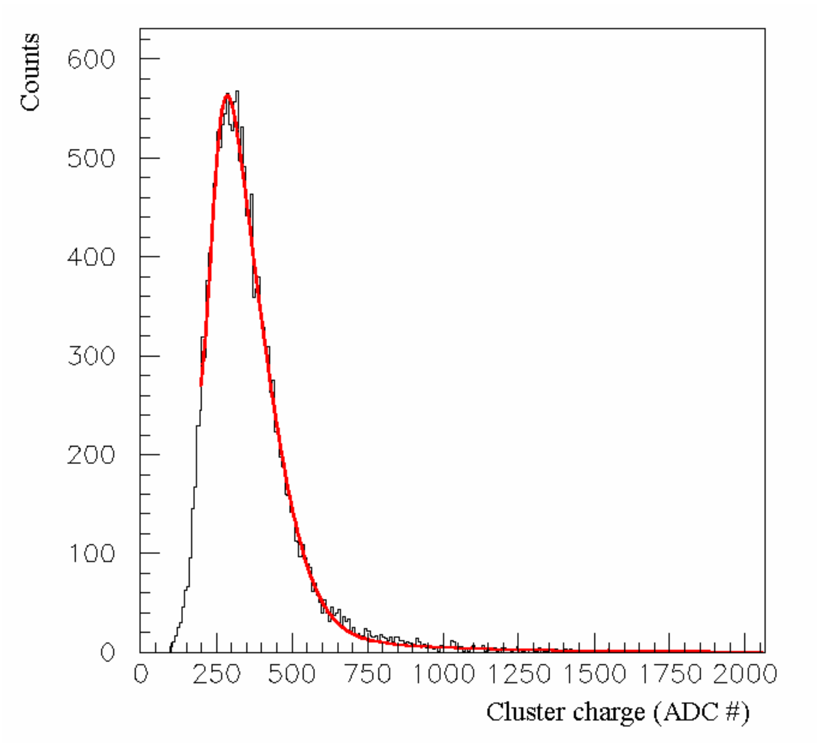


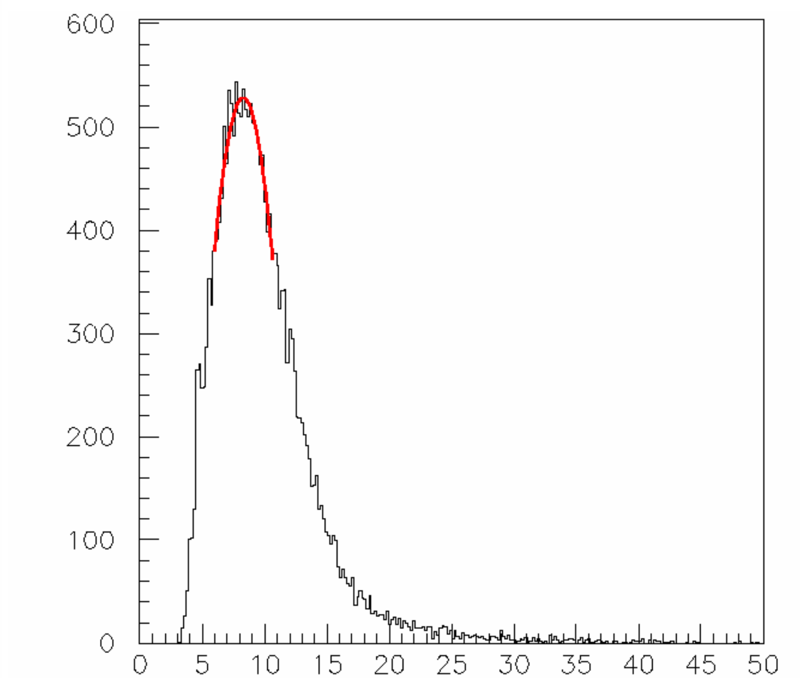


Signal after 3. 10^{15} p cm^{-2} (700 V)



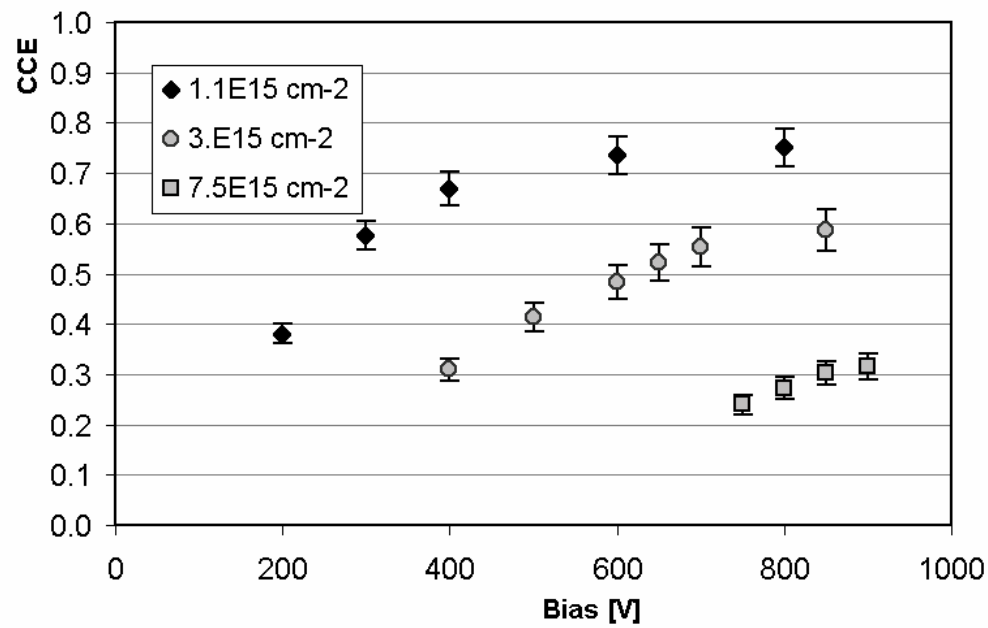
Signal and cluster significance after 7.5 10^{15} p cm^{-2} (900 V)



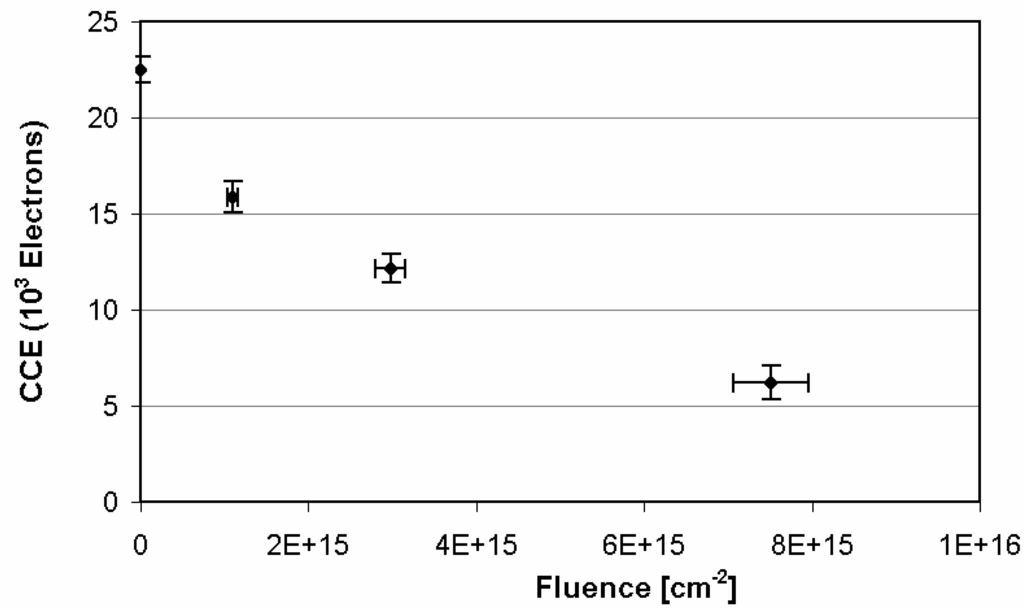


THE UNIVERSITY of LIVERPOOL

CCE(V) vs applied bias voltage, normalised to the pre-irradiation value, of n-in-p detectors after 1.1, 3 and 7.5 10^{15} p cm^{-2}. The detector irradiated to 3. 10^{15} cm^{-2} is standard p-type substrate, while the other devices are oxygen-enriched.



Degradation of the collected charge as a function of the irradiation fluence for n-in-p microstrip detectors. The applied voltages are 800, 800 and 900 volts for the three different irradiation fluences, respectively.



CONCLUSIONS:

Oxygenated p-type substrates have been successfully used to produce miniature microstrip detectors which were able to operate adequately for use as tracking detectors after doses of up to 7.5 10^{15} p cm^{-2}.

Identical devices made with standard p-type silicon were succesfully operated after 3. 10^{15} p cm^{-2}. Further studies are required to investigate whether the oxygenation of p-type substrates brings any advantage, but such detectors appear to be suitable to be used for silicon detectors experiencing extremely high level of hadron radiation.

PERPECTIVES:

As long as the input noise (input capacitance) is kept relatively small (<10pF), microstrip (ministrip, strixels….) detectors with n-side read-out, and in particular p-type bulk, appear to be well usable for future SuperColliders. This read-out geometry also overcome the necessity of reduced thickness of the devices, which can be decided on the basis of other considerations (low mass vertex detectors…).

After 7.5 10^{15} p cm^{-2} the n-in-p devices were still able to collect >6500 e^-, corresponding to a ionisation depth of 90 μm of a <u>non-irradiated</u> device.

More systematic studies are needed in this very promising direction: role of oxygen, CZ materials, how much over-bias is useful (CCE(V) saturation due to trapping….)