Preliminary analysis of Red TCT measurements on LGAD's produced at CNM-Barcelona Focus on Gain and uniformity

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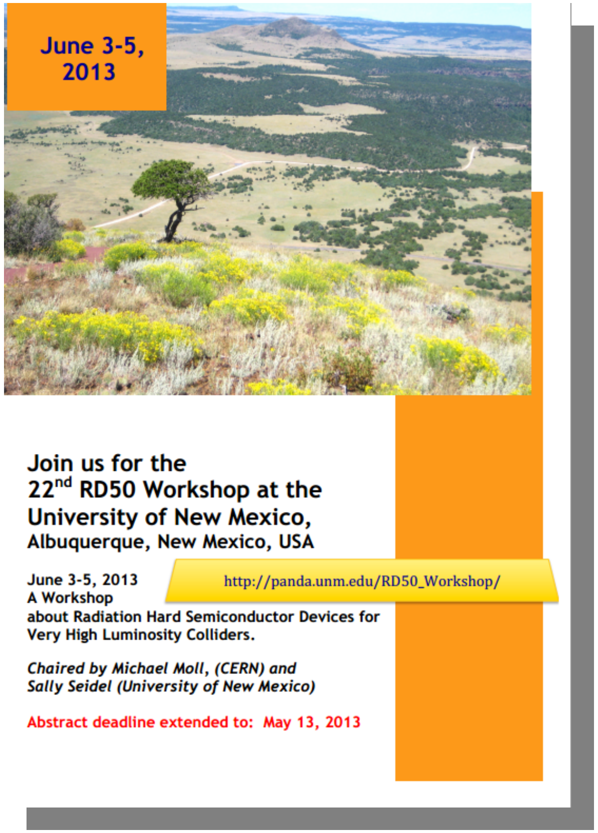

June 3-5 2013, 22nd RD50 Workshop, University of New Mexico, Albuquerque, New Mexico, USA

Wafer 9, f9, g9 [PiN diode]

Wafer Number	P-layer Implant (E = 100 keV)	Substrate features
1	1.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
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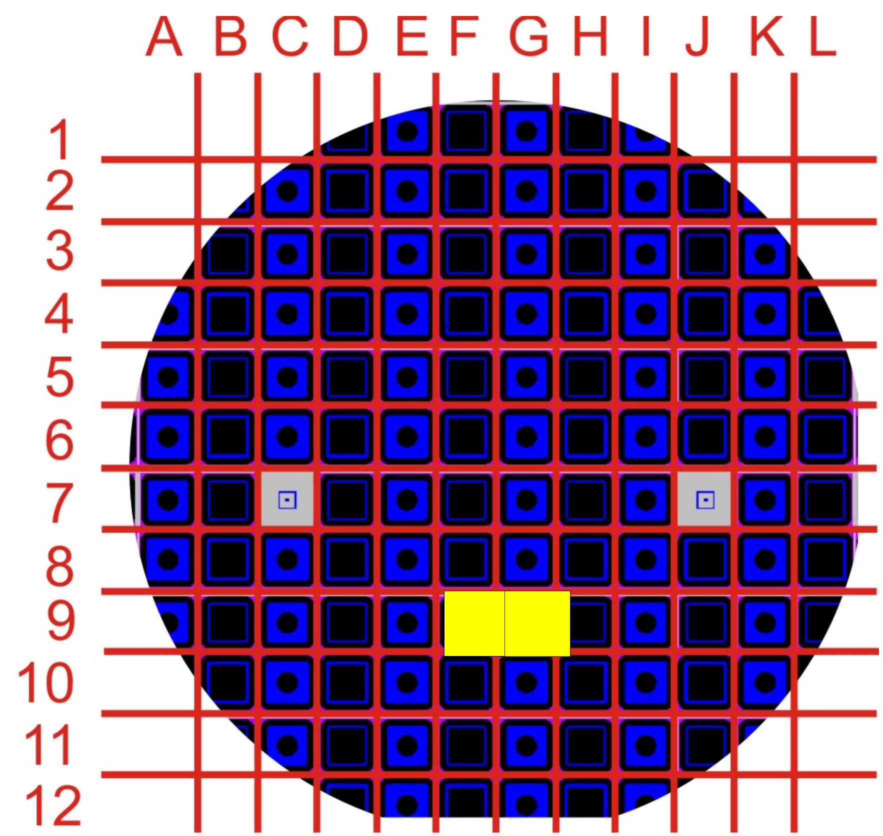
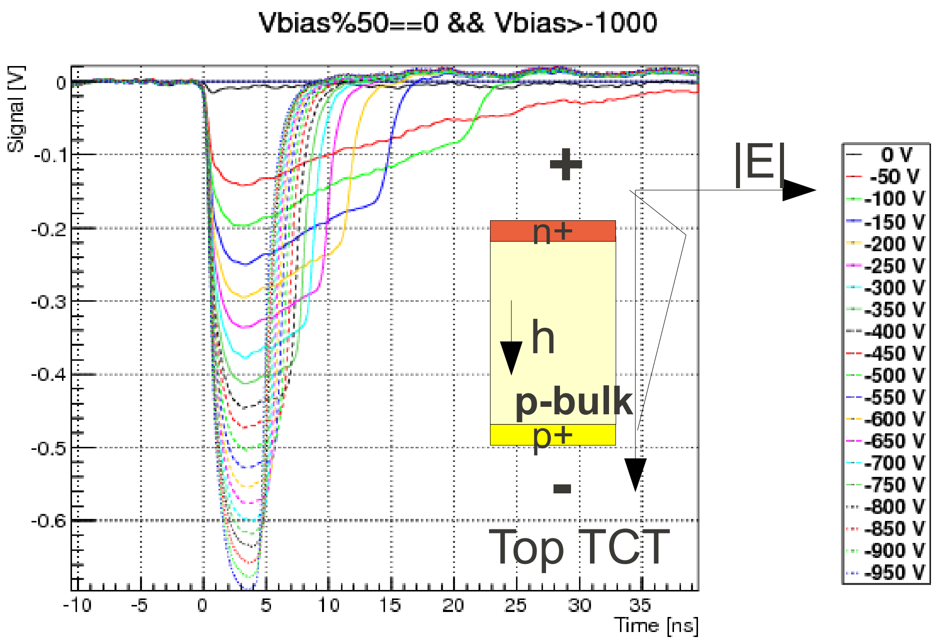
Low doping (wafers 6–7)

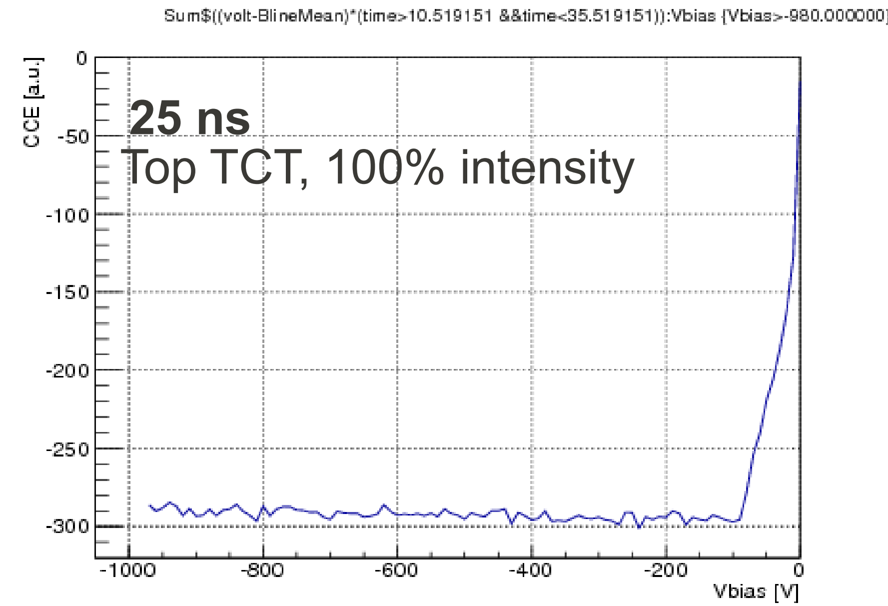
High doping (wafer 8)

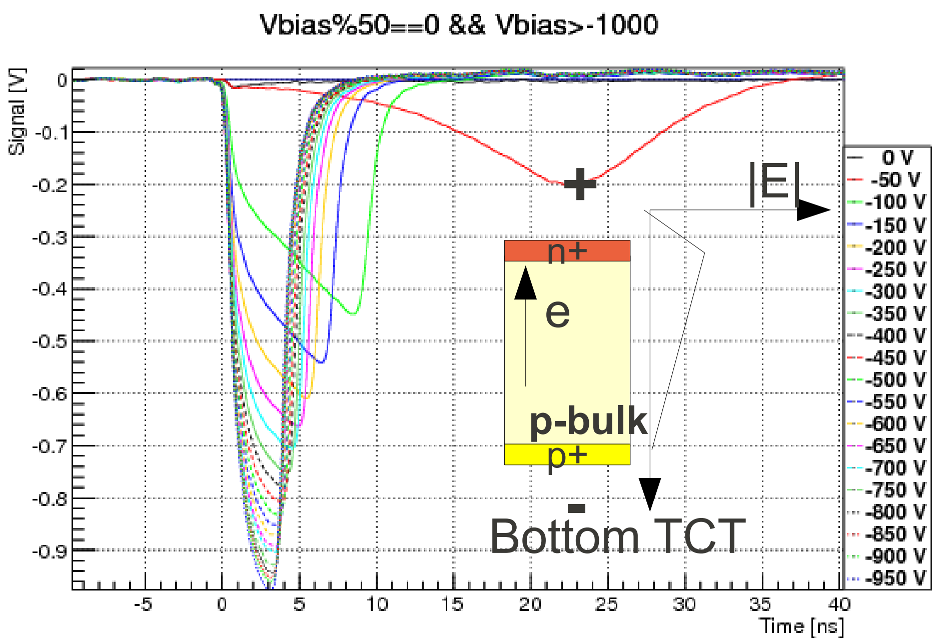
No doping (wafer 9)

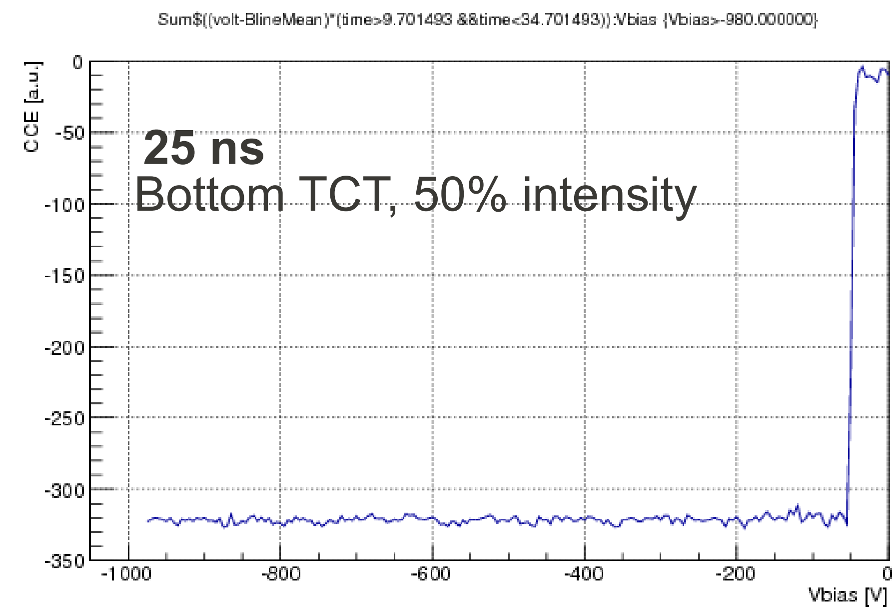


Wafer 9, f9 (PiN) [no amplification built-in]









Wafer 6, g11, h11 [$1.5\times10^{13}cm^{-2}$]

Low doping

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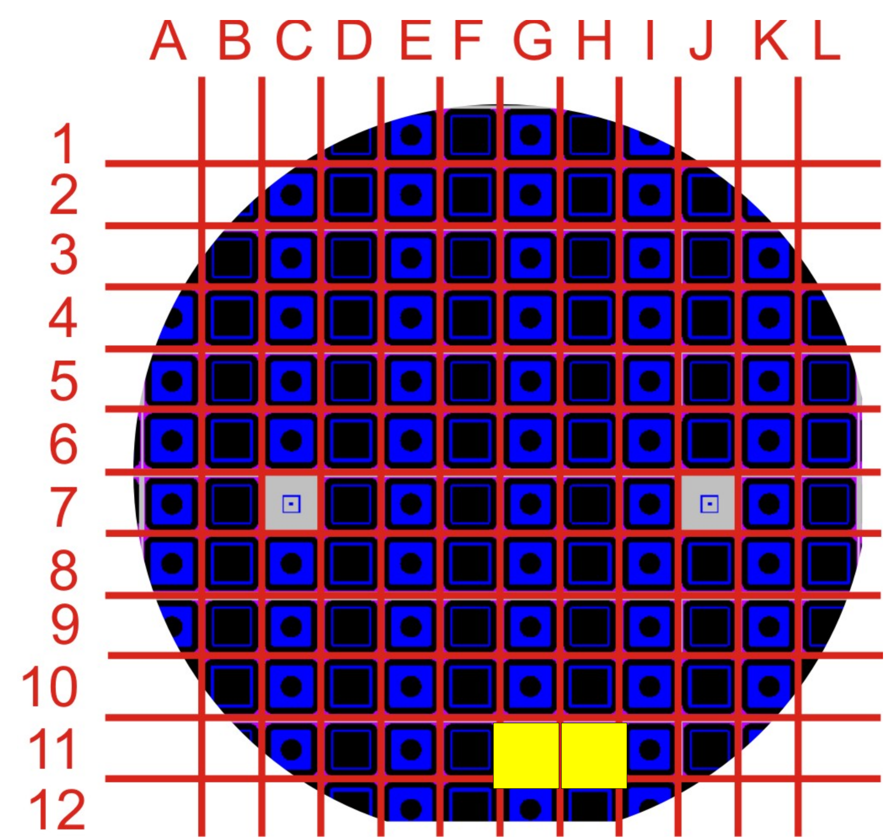
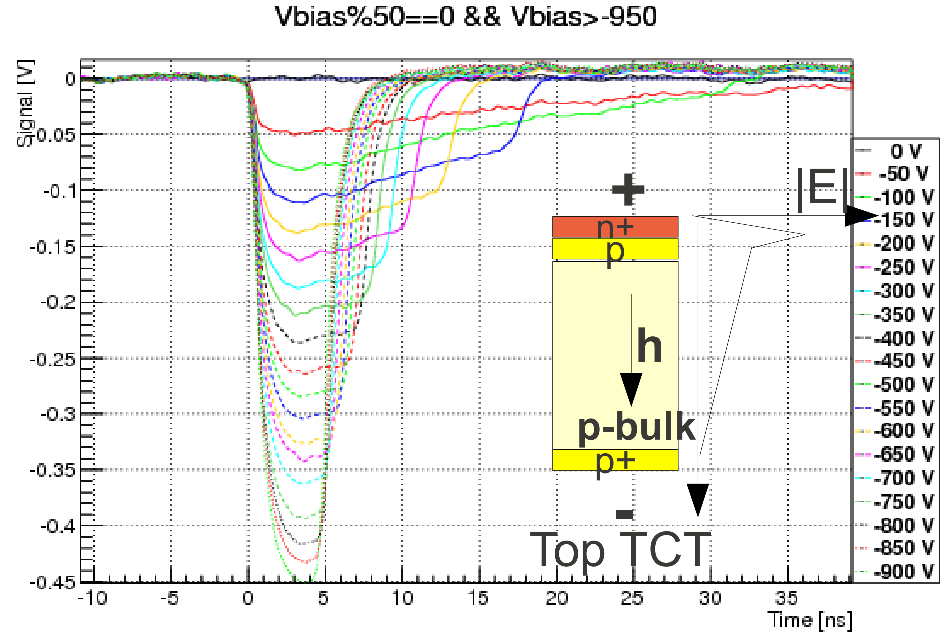
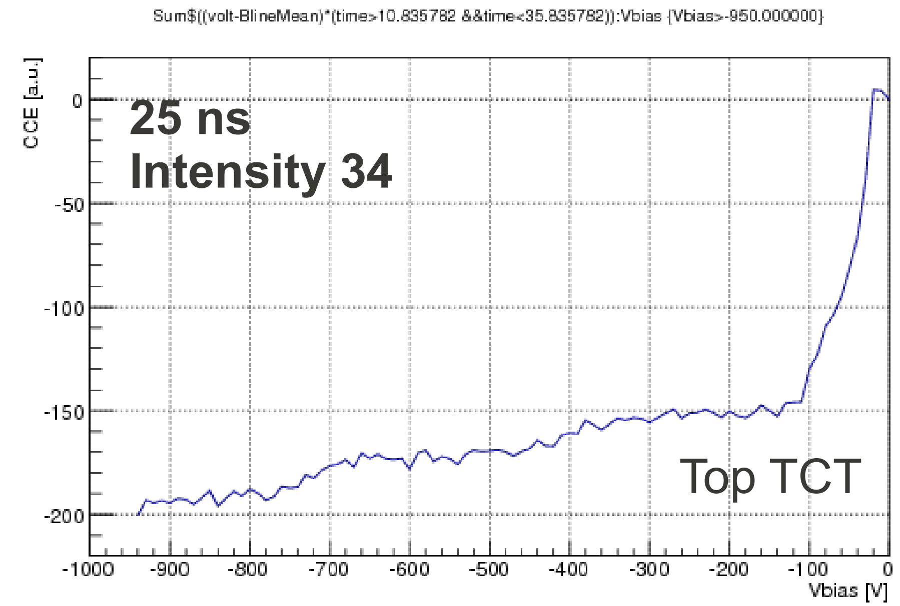
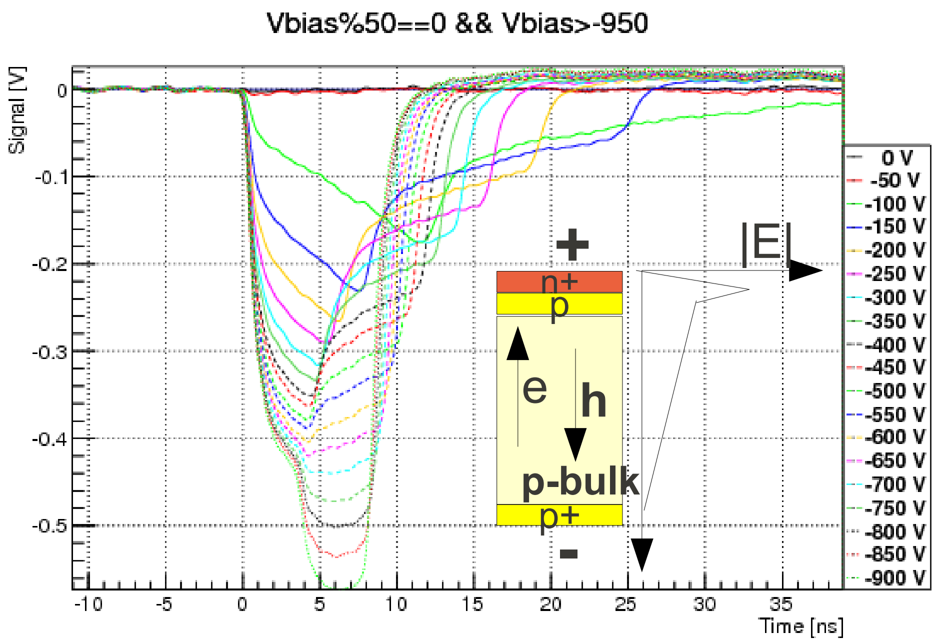


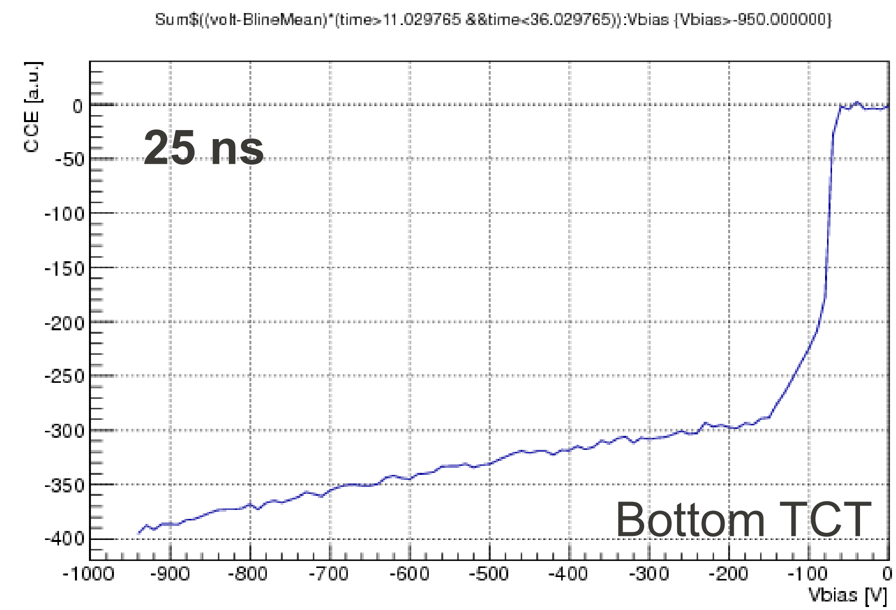
Wafer 6, h11 [1.5×10^{13} cm^{-2}]







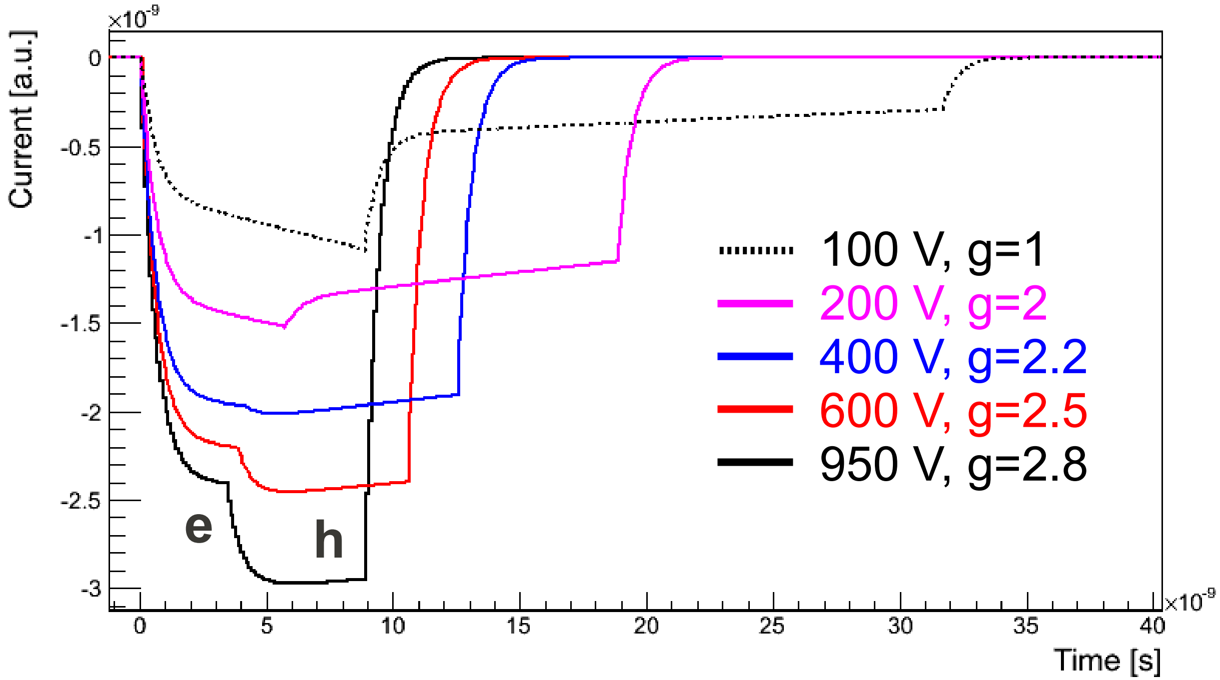
Bottom TCT

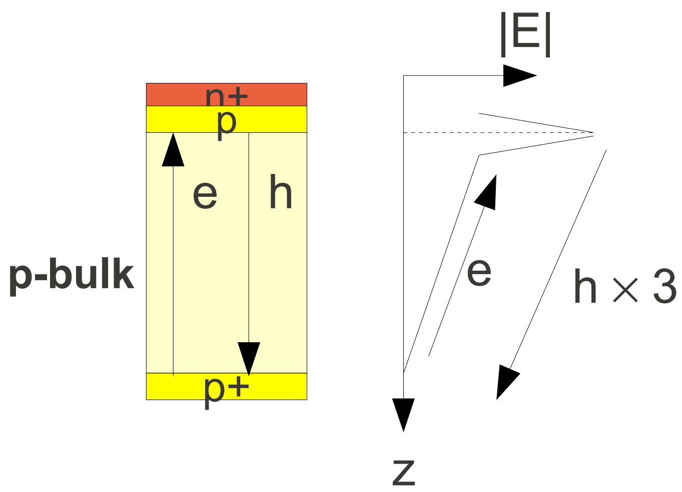


Amplification observed

Ad-hoc simulation (qualitative interpretation of data):

Input:
P-bulk, Cend=10 pF, Vdep=50 V
Gain(950V)=2.8 .... Gain(200)=2





Electrons injected from the back → travelling to n+ strips. Multiplication occurs, then equivalent to holes "injected" from top.

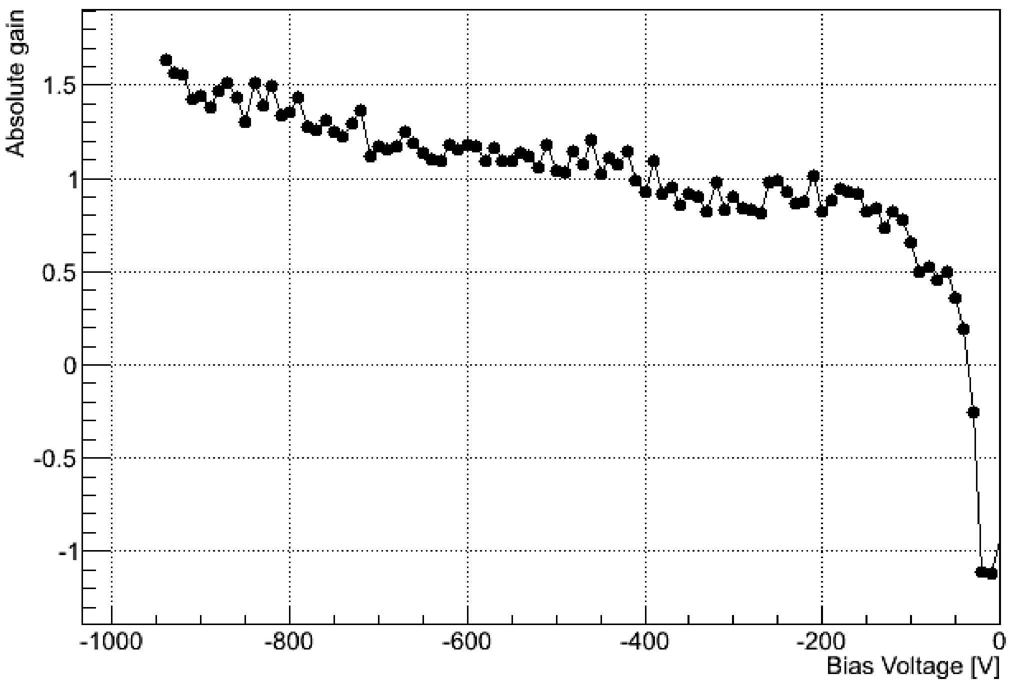
Gain definition

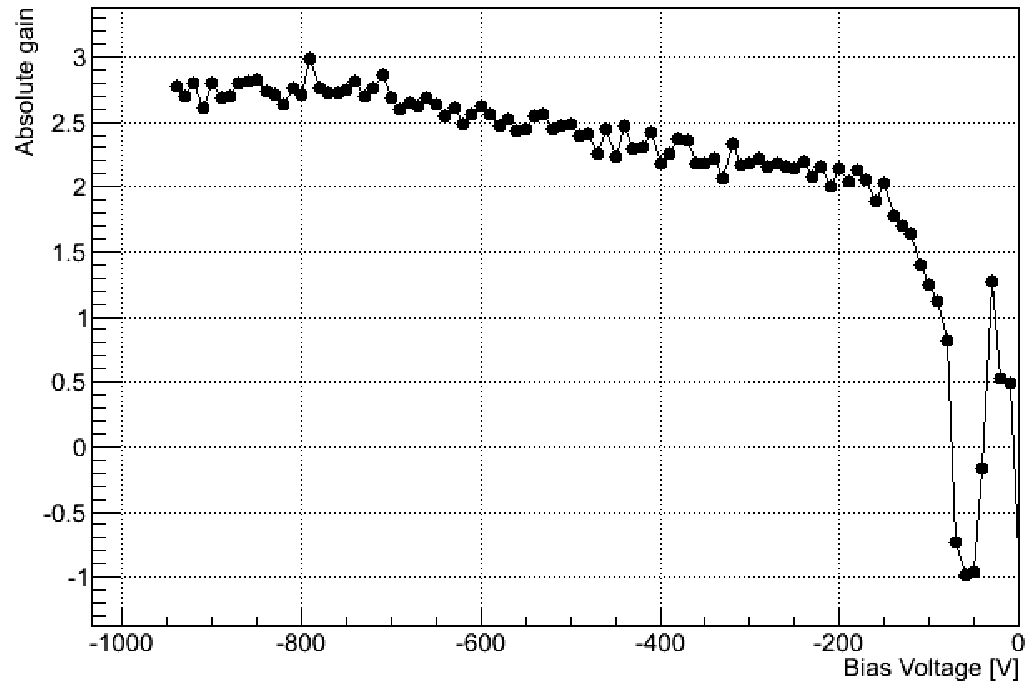
For instance, **in back injection:**
Reference diode: we inject 50 pC, we **read** 50 pC
DUT: we (assumed) injected 50 pC, we **read** 150 pC

MF=(150-50)/50=2
Gain=150/50=3

I will assume gain=multiplication factor+1

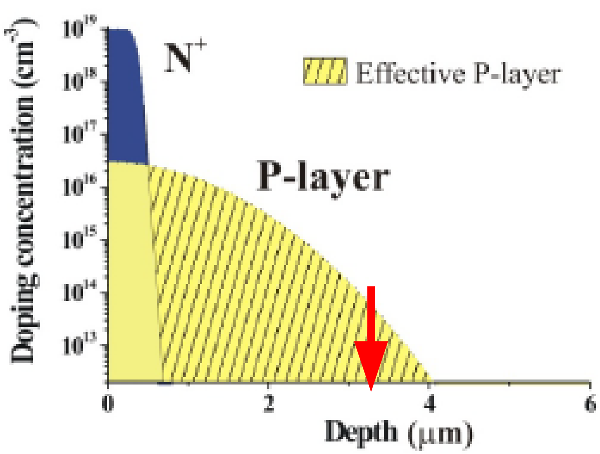
Wafer 6, h11 [$1.5\times10^{13}cm^{-2}$], gain





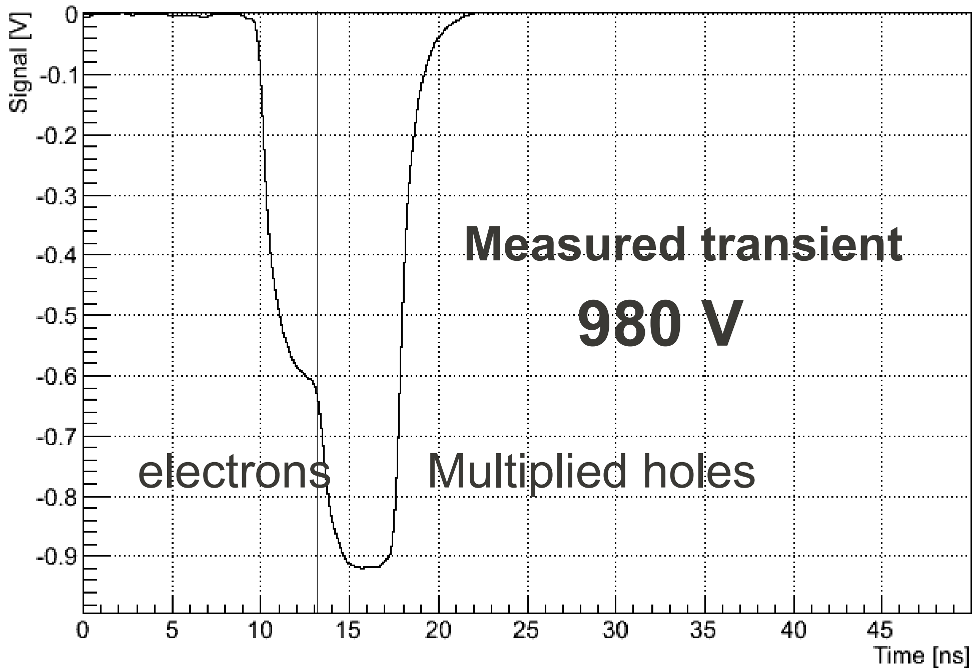
Wafer 6, h11 top illumination
Low multiplication factor

Wafer 6, h11, bottom illumination
Higher multiplication factor



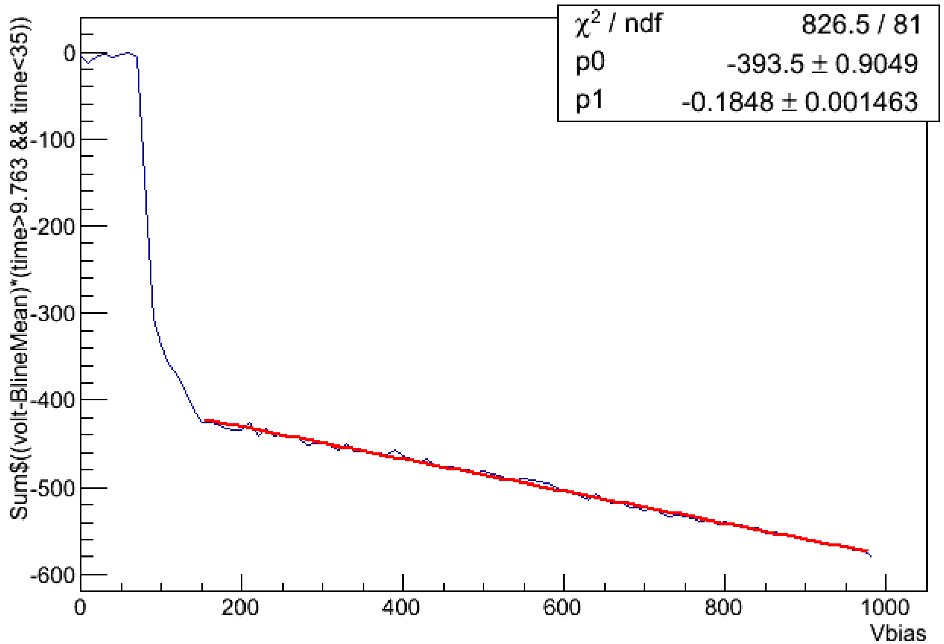
Interpretation for lower gain seen in top injection:
Maybe eh pairs generated inside P+ region do not see all the E-field → produce less ionizations.

Estimation of gain without reference diode at V>>V_{dep}



At V>>Vdep the RC tails are short for a diode of 10 pF

MF(V=980)=Q(h)/Q(e)=3



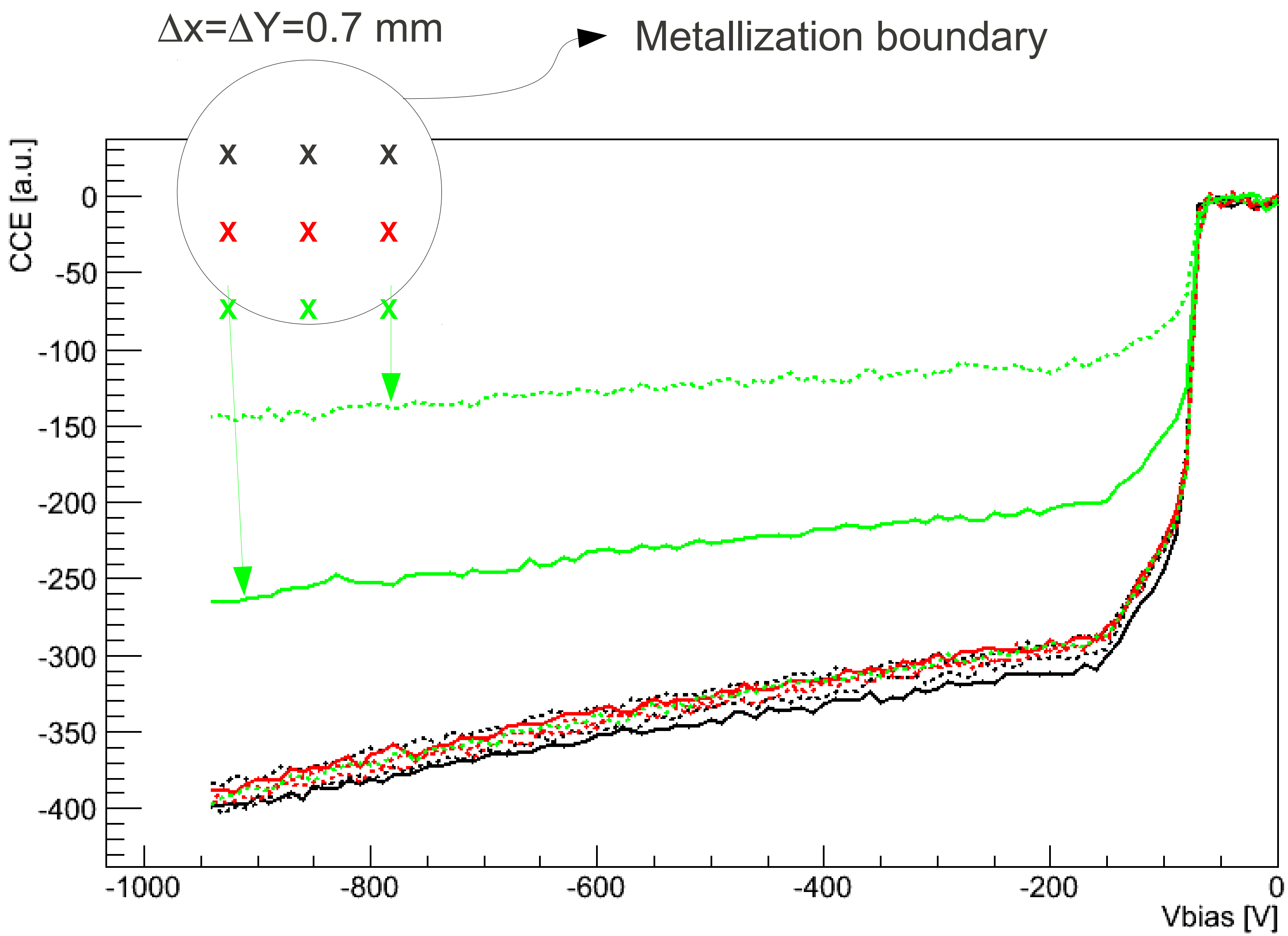
Gain at lower voltages, extracted from CCE curve:

CCE(980)/CCE(140)=MF(980)/Mf(140)

Then MF(140)=2.2

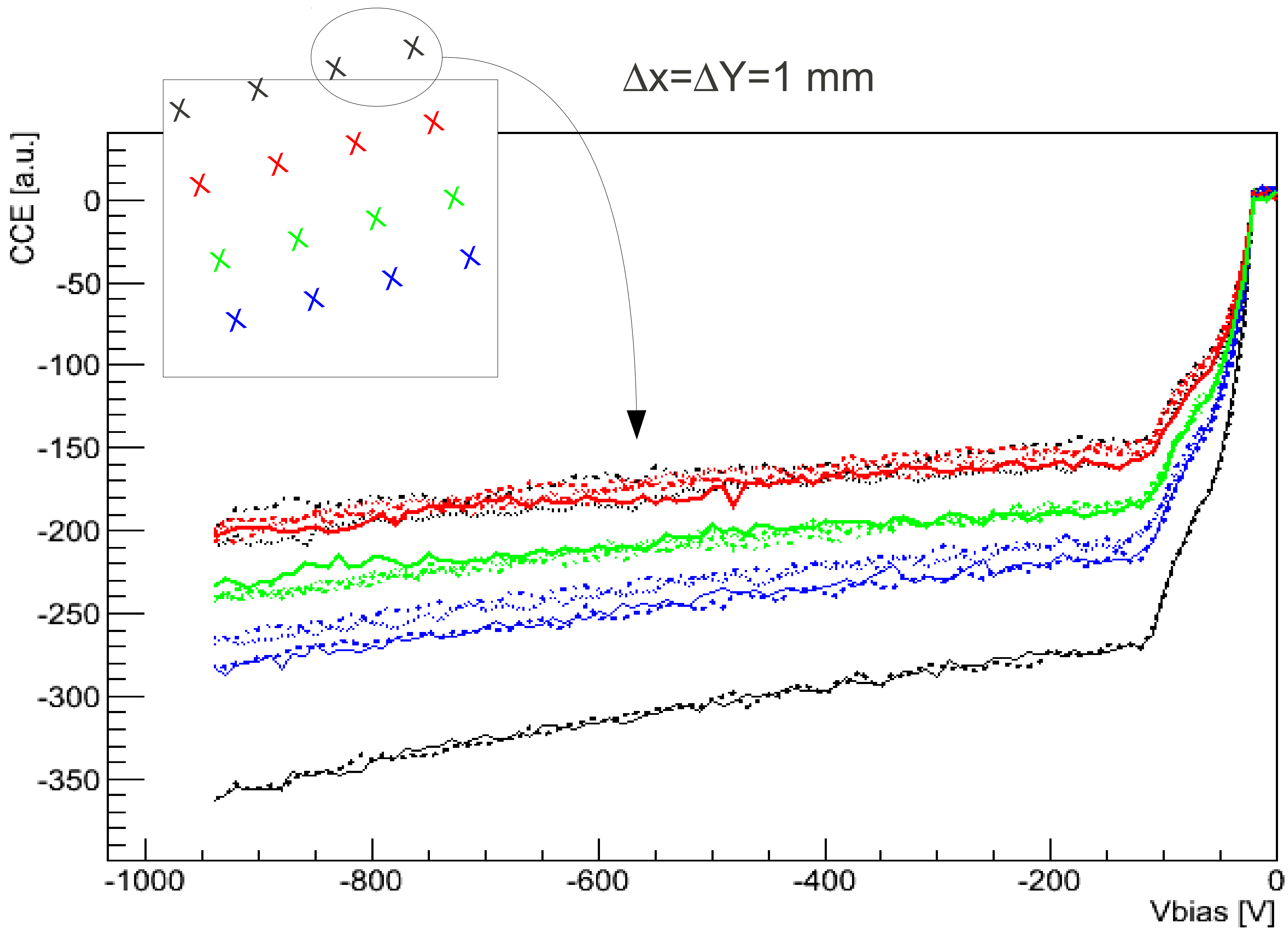
Agrees with former method but statistics=1 case!

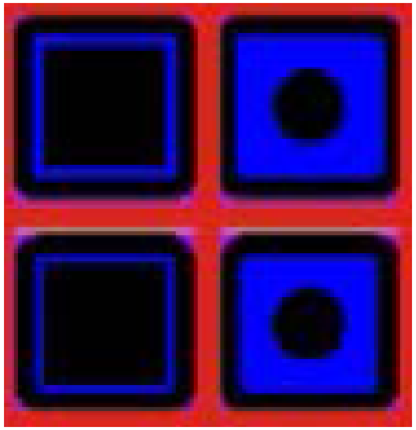
Uniformity scan, rear side illumination, w6 h11 tune 34



Outliers are likely misalignment of the laser grid wrt the sensor window

Uniformity scan, junction side, w6 h11 tune 34





Possible misalignment.
In any case, compared to former slide, we can say that the junction side is less uniform than the ohmic side.
To be studied: effect of 2x400 nm layers of passivation (SiO_2/Si_3N_4)

Wafer 7, f11, k9 [$1.6\times10^{13}cm^{-2}$]

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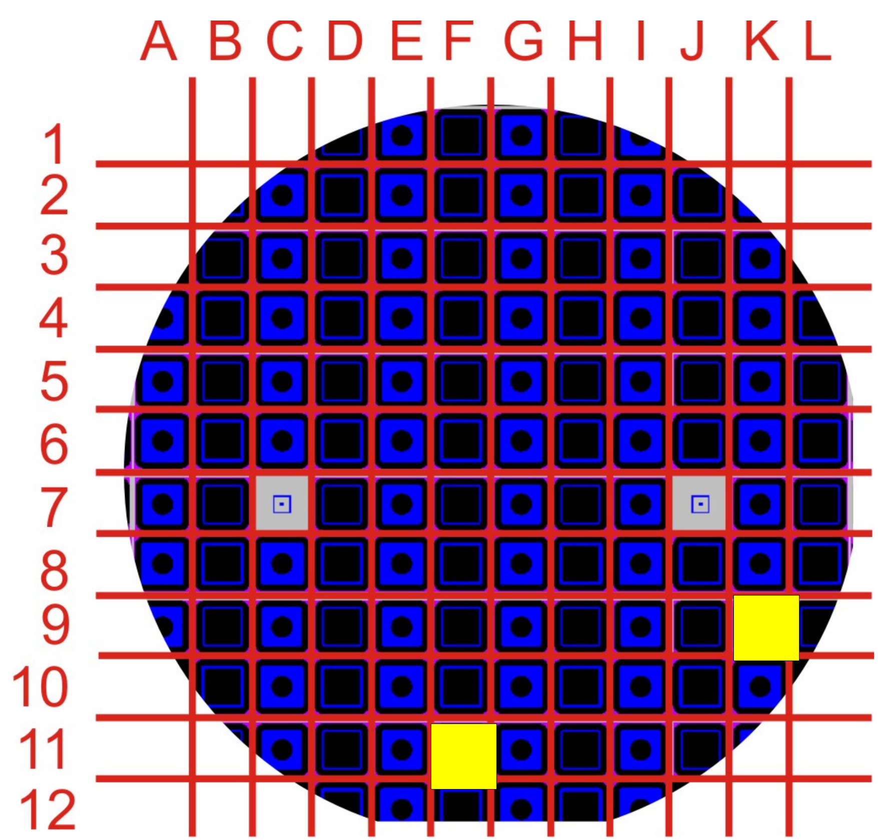
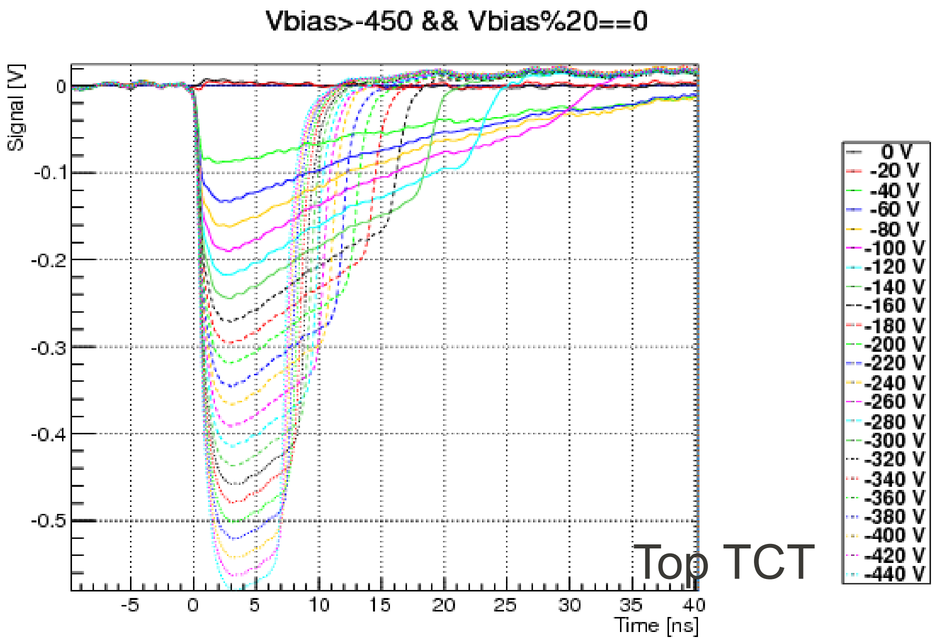
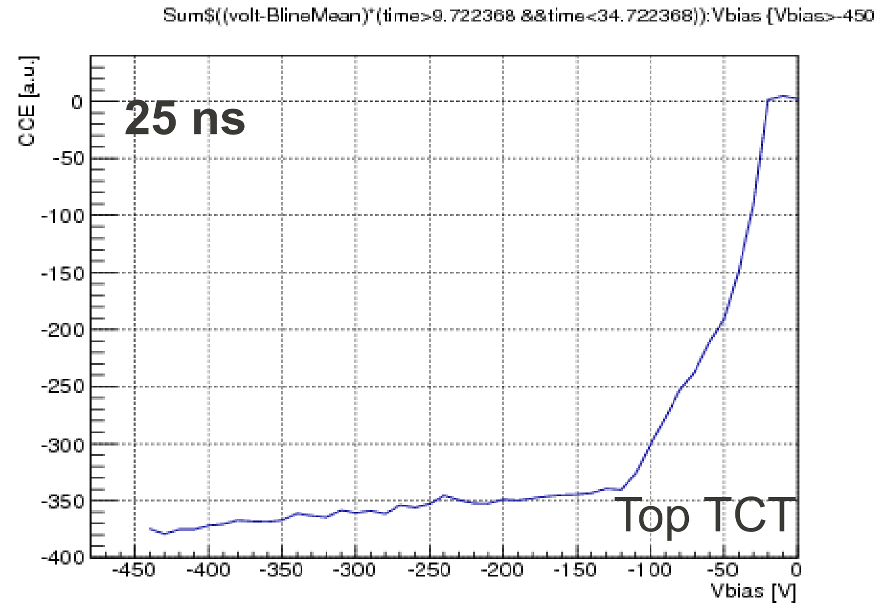
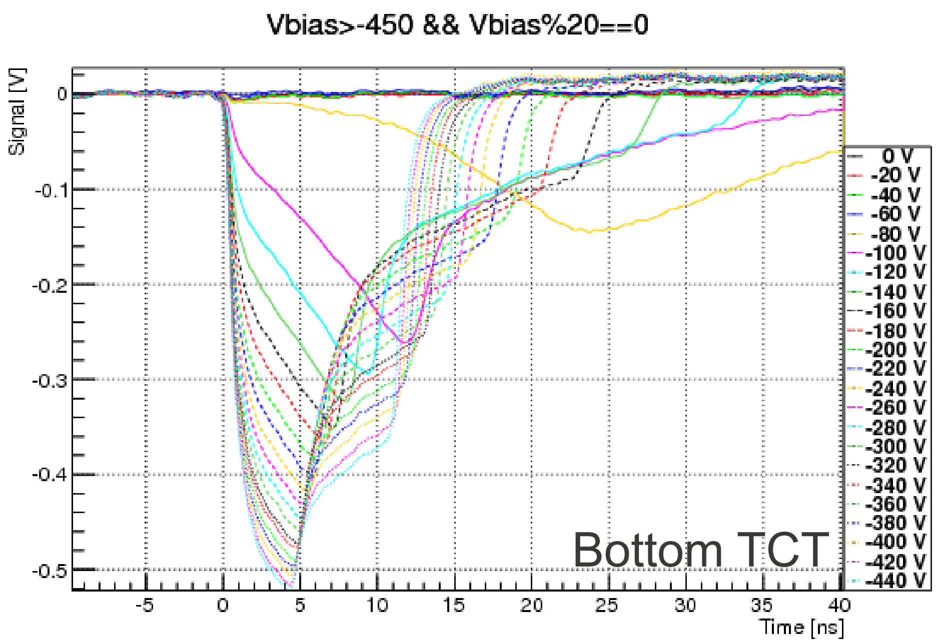
Slightly higher doping

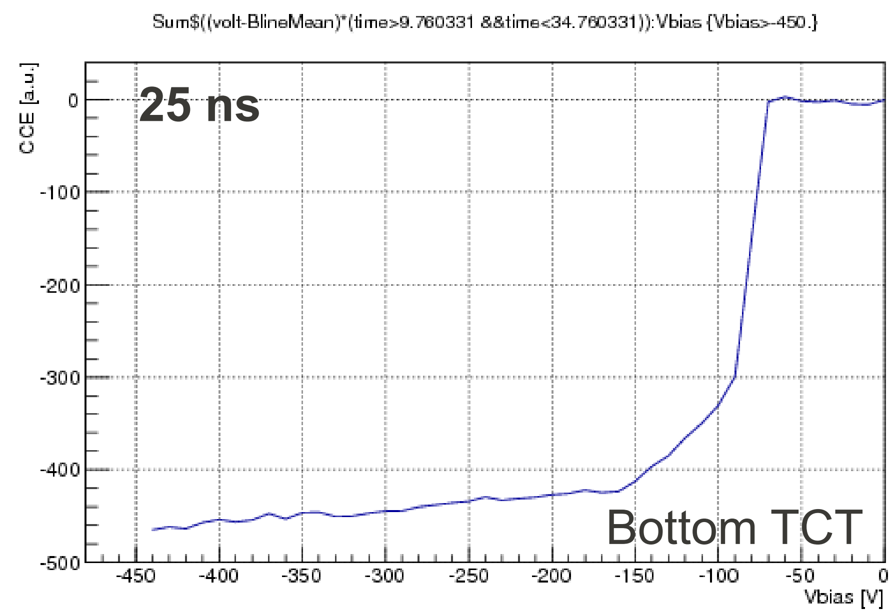


Wafer 7, k9 [$1.6\times10^{13}cm^{-2}$], same tune (34)







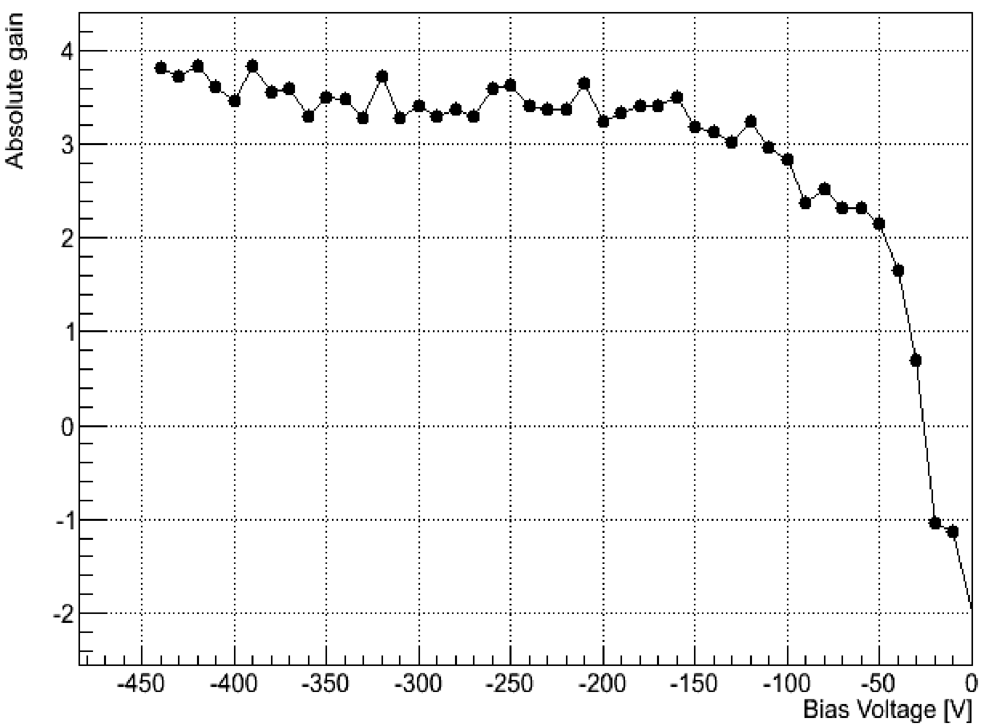


Top illumination, breaks at -450V, before the bump due to h overcomes the e peak

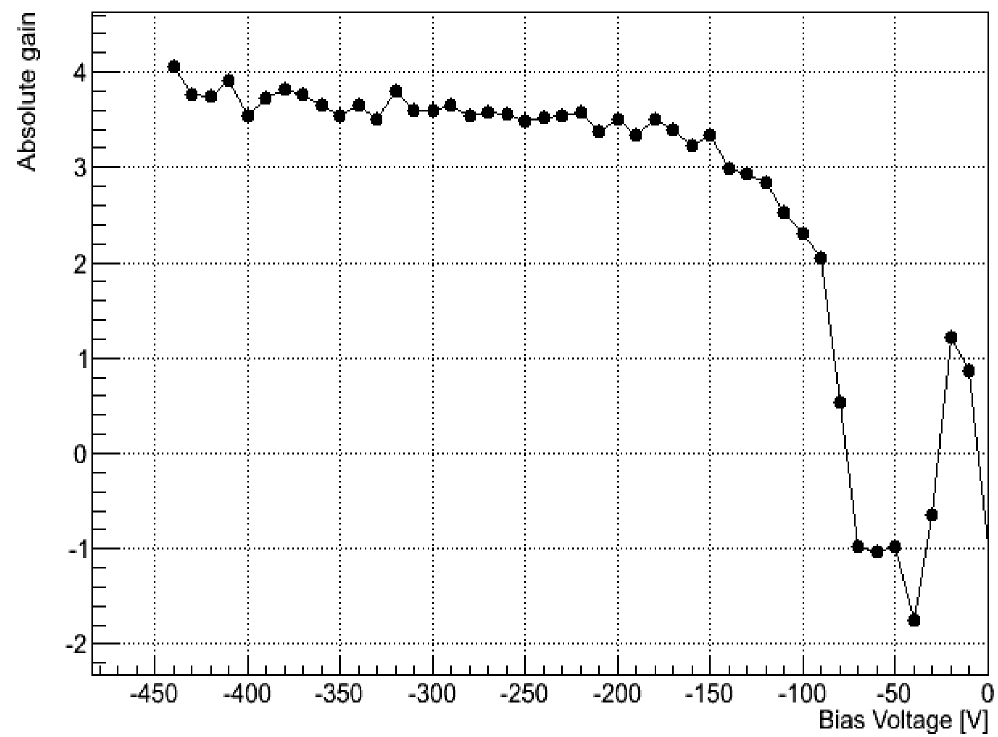
Multiplication observed

Wafer 7, k9 [$1.6\times10^{13}cm^{-2}$], gain

Gain calculated comparing diode to reference PIN diode, measured at the same power



Wafer 7, K9, top illumination



Wafer 7, K9, bottom illumination

>×3 mult. factor for Vbias>100 V

×4 at Vbias~400V

Summary

- First look at the red-TCT data on LGAPDs
- PiN diode taken as reference to calculate the gain
- Wafer 6, lower doping:
  MF: ~1.5 (top), ~2.5 (bottom)
  Uniformity: 30% (top), ~2% (bottom)
- Wafer 7: slightly higher doping
  MF: ~3.5 (top and bottom)
  Uniformity no data yet
- Wafer 8: results need to be understood (see backup)

Wafer 8 ?

Wafer 8, k4, k8 [$2\times10^{13}cm^{-2}$]

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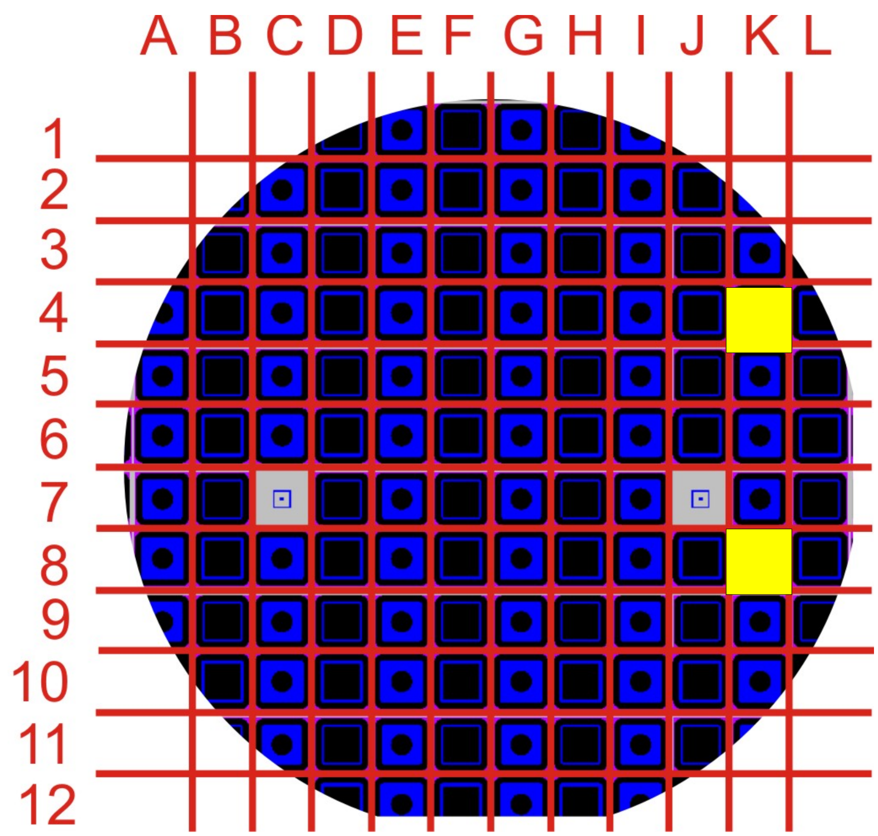
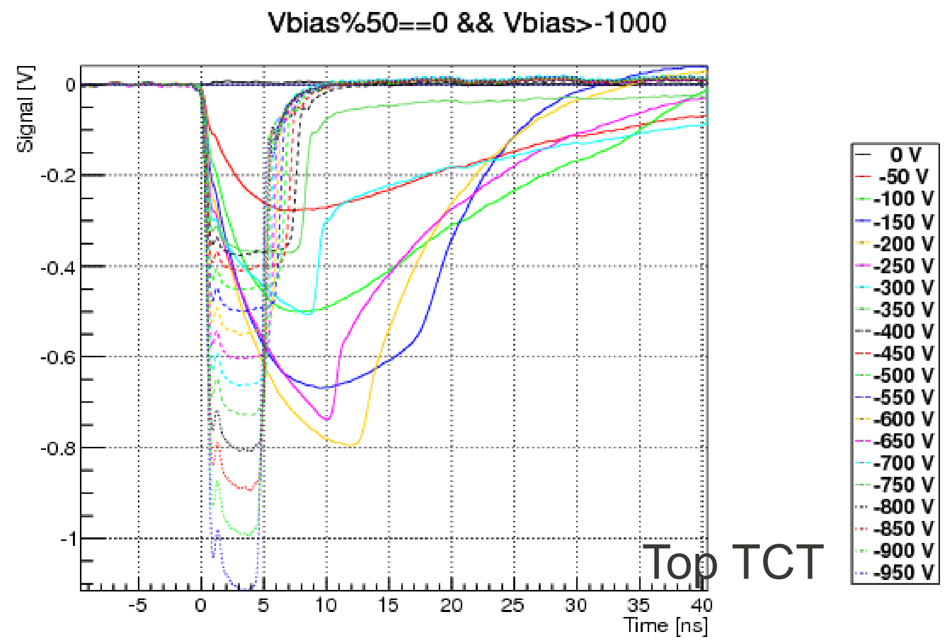
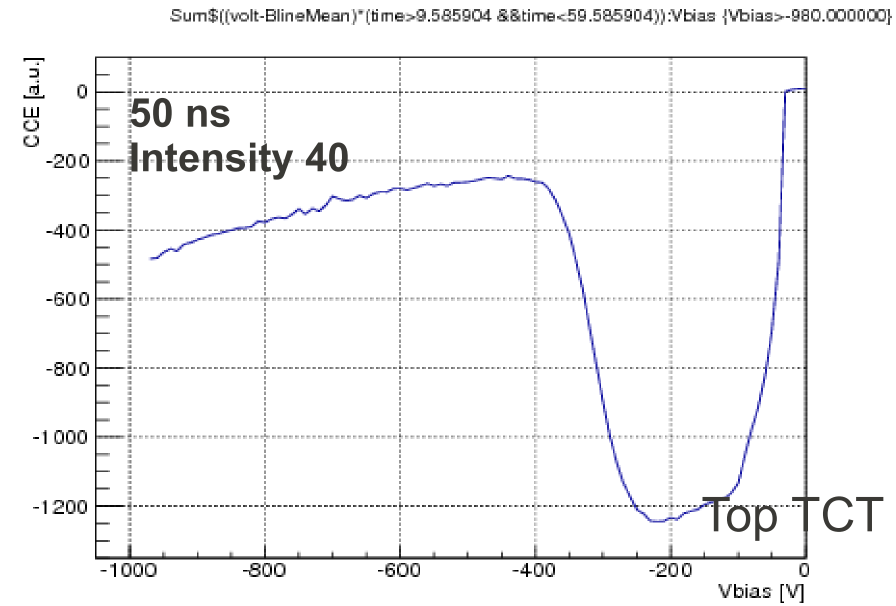
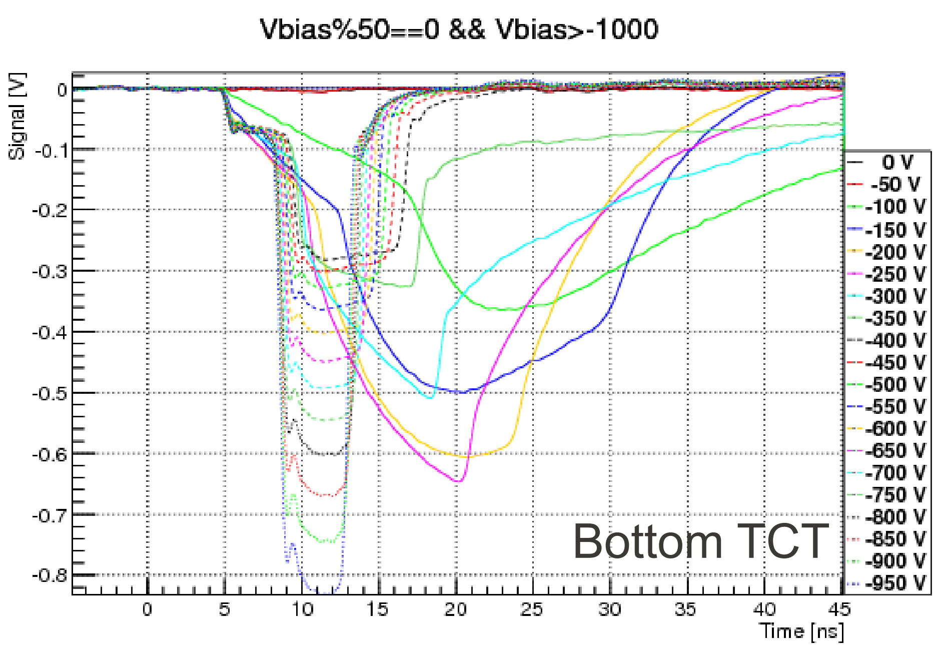
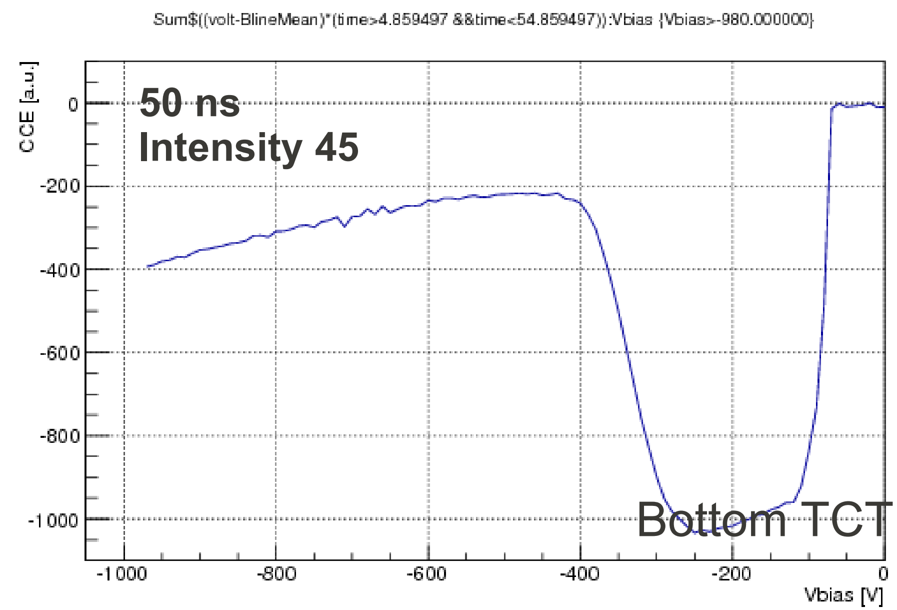


Wafer 8, k8 [$2\times10^{13}\mathrm{cm}^{-2}$]









Breaks at -250V

Wafer 8, k8 [$2\times10^{13}cm^{-2}$]