Signal multiplication in irradiated SiC p-in-n diodes

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J. Duarte, M. Fernández, E. Navarrete, C. Quintana, Diego Rosich,
I. Vila Álvarez
Instituto de Física de Cantabria (CSIC-UC)

C.Torres Muñoz, J.García-López, M.C.Jiménez Ramos, M.Rodríguez-Ramos
Universidad de Sevilla – Centro Nacional de Aceleradores

R. Montero
Universidad del País Vasco

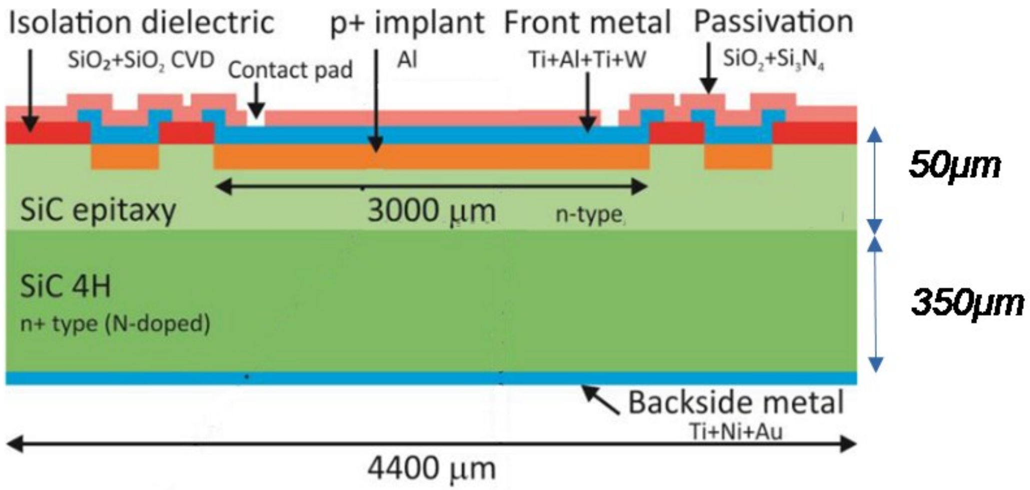
Outline

- Recapitulation of previous results
- TPA-TCT study with continuous optical carrier injection.
- Evidence (and discussion) of hole multiplication at the n+ contact in neutron irradiated SiC p-in-n diodes.
- Summary

Previous results (1)

SiC p-in-n diode becomes a **dielectric after irradiation**

- IMB-CNM SiC planar pad diodes P in N
- Non metallized top contact for laser illumination
- Sample 1MW2 - non-irradiated
- Sample F2W1 - 10^{15} n_{eq}/cm^2 at ATI in Vienna



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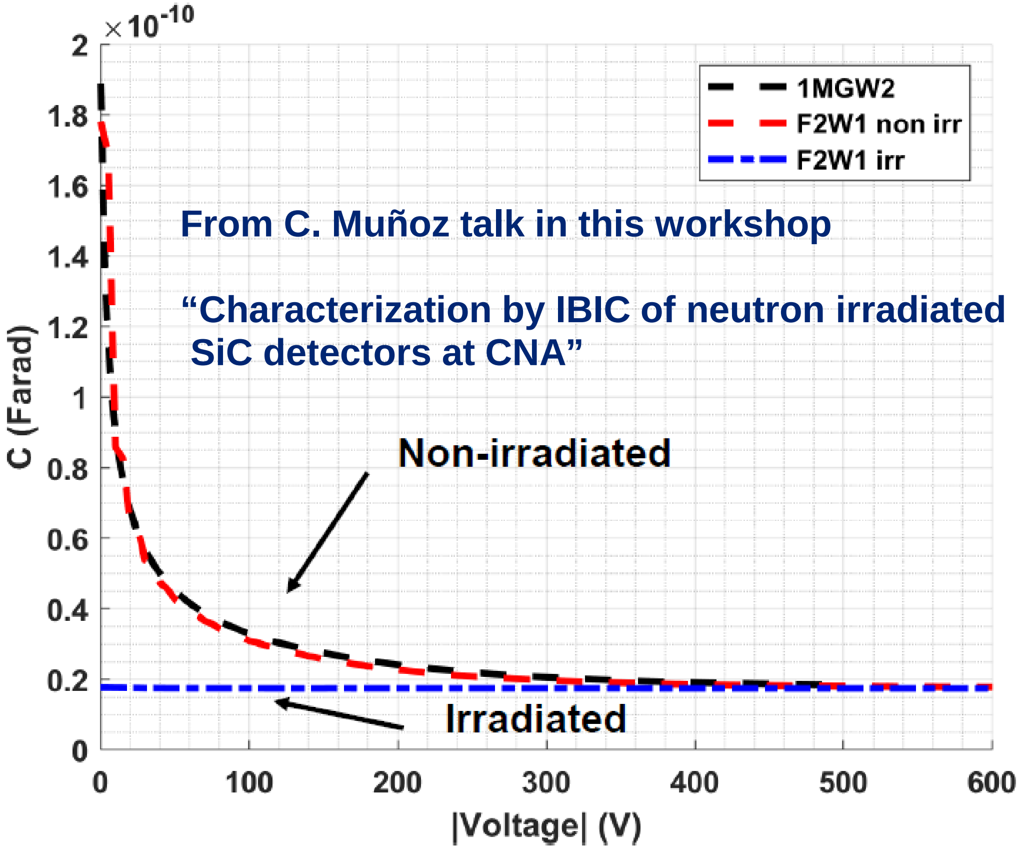


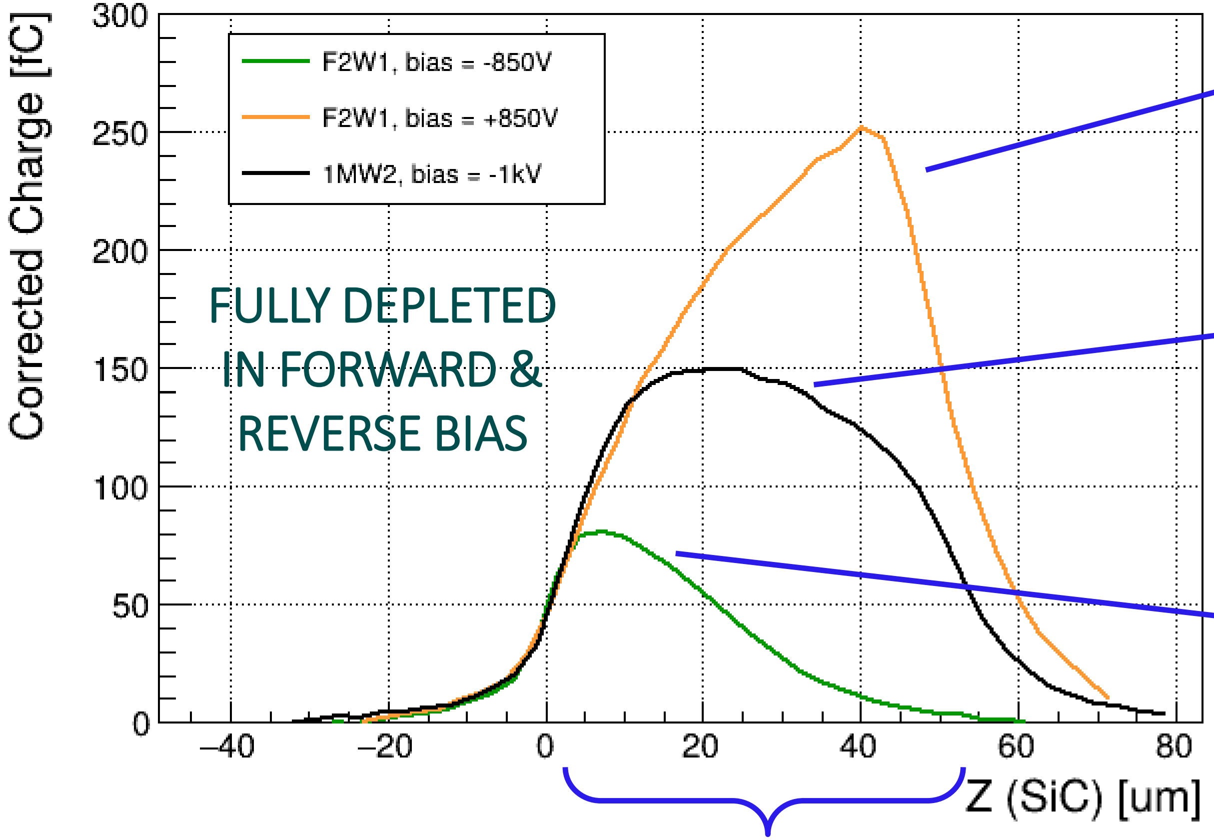
From C. Muñoz talk in this workshop

"Characterization by IBIC of neutron irradiated SiC detectors at CNA"

Constant CV on irradiated samples for all bias voltages (positive and negative) and equal to the full-depletion capacitance of the non-irradiated diode)

Previous results (2):
Signal multiplication in the forward -biased irradiated sample

TPA-TCT z-scan of irradiated sample [41st RD50 workshop , 18th Trento workshop]



FULLY DEPLETED
IN FORWARD &
REVERSE BIAS

Diode active thinkness

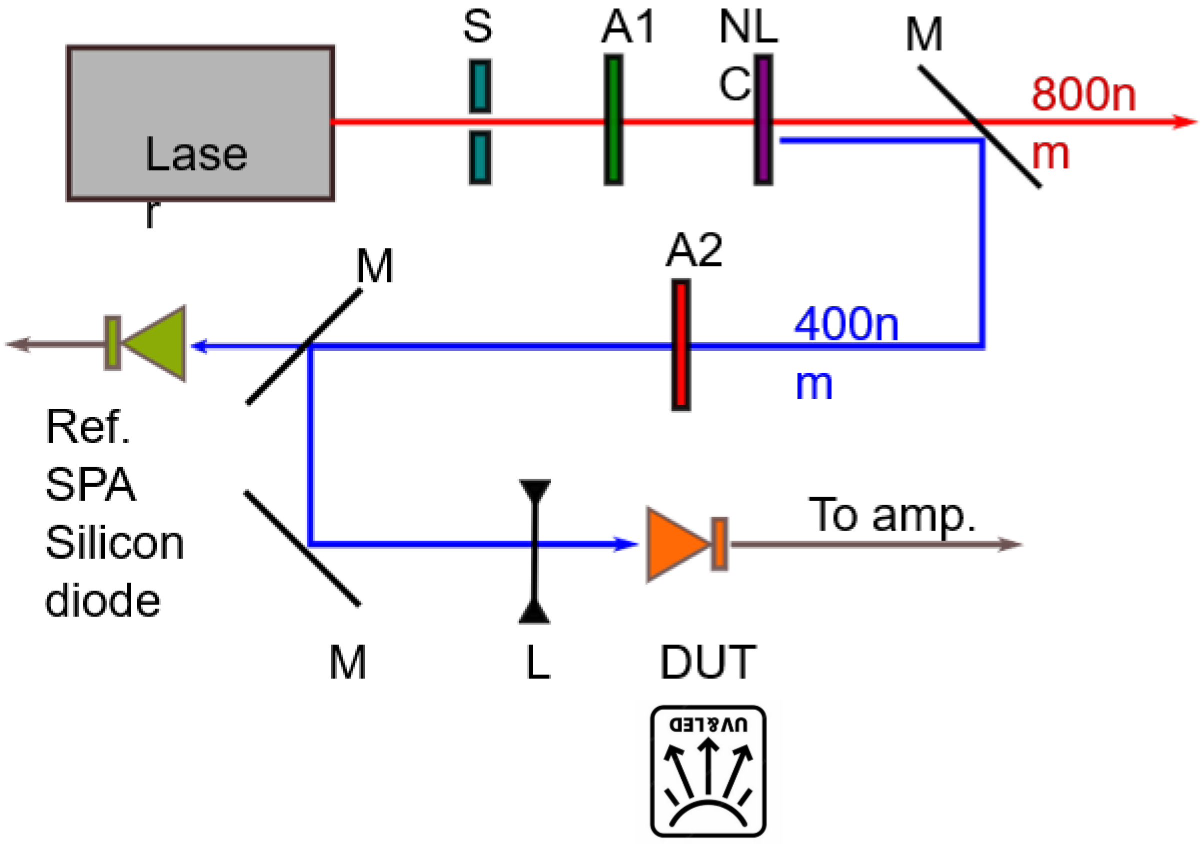
Forward-biased irradiated
Maximal signal at the back side
(hole drift towards the back side)

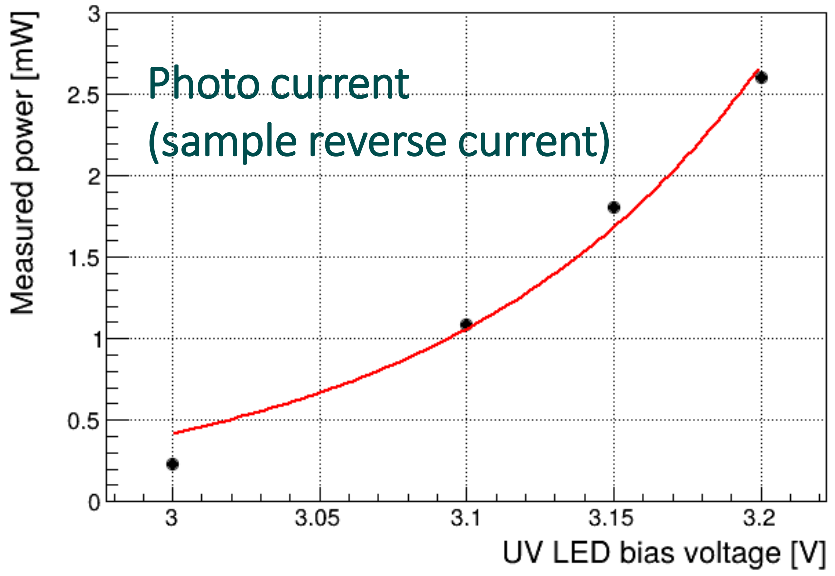
Reverse-biased non irradiated
Uniform signal along the thinkness
(hole drift towards the front-side)

Reverse-biased irradiated
Maximal signal at the front-side
(hole drift towards the front-side)

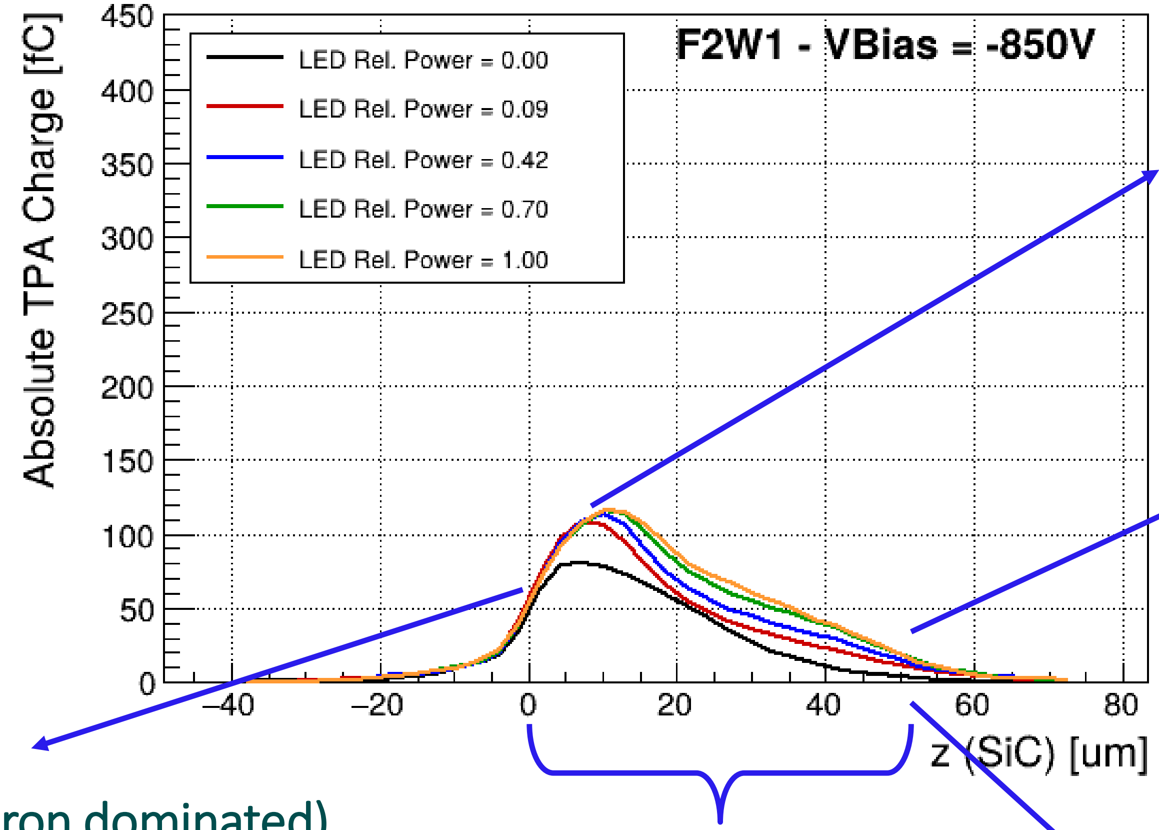
TPA-TCT with Optical Injection of both Carriers

Injection of electrons and holes illuminating the sample with a full penetrating UV light (370 nm LED) → partial filling of carrier traps.





Reverse biased Irradiated sample: Optical Injection of carriers



Close to the front-side
Mild recovery of the signal
(eletron dominated)

Close to the back side
Strong recovery of the signal
(hole dominated signal)

Close to the front-side
the signal is higher (electron dominated)

Diode active thinkness

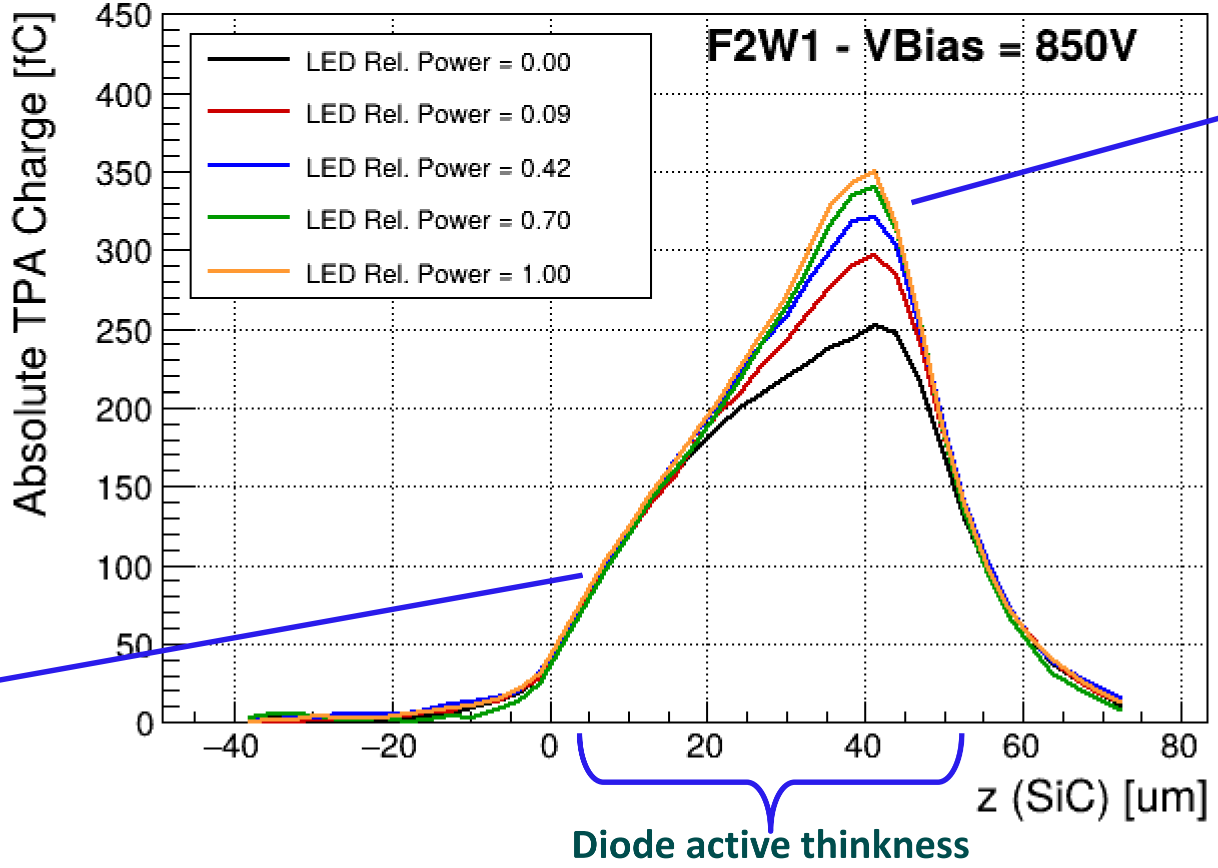
Close to the back-side
the signal is lower (hole dominated)

Reverse-biased Irradiated sample: Optical Injection of carriers (2)

- Observation:
  - The reverse-biased signal of the irradiated diode is predominantly created by electrons.
  - During the optical injection of both carriers, the charge recovery is primarily driven by holes.
- Conclusion:
  - Irradiation significantly reduces the hole lifetime compared to the electron lifetime.

Forward biased Irradiated sample: Optical Injection of carriers

Hippothesis: Hole traps are to be partially filled by the (large) forward current, maybe dominated by holes. Therefore, the optically injected carriers are not expected to have a significant impact on the signal.



Close to the back side:
- Recovery of the signal
- hole collection side.

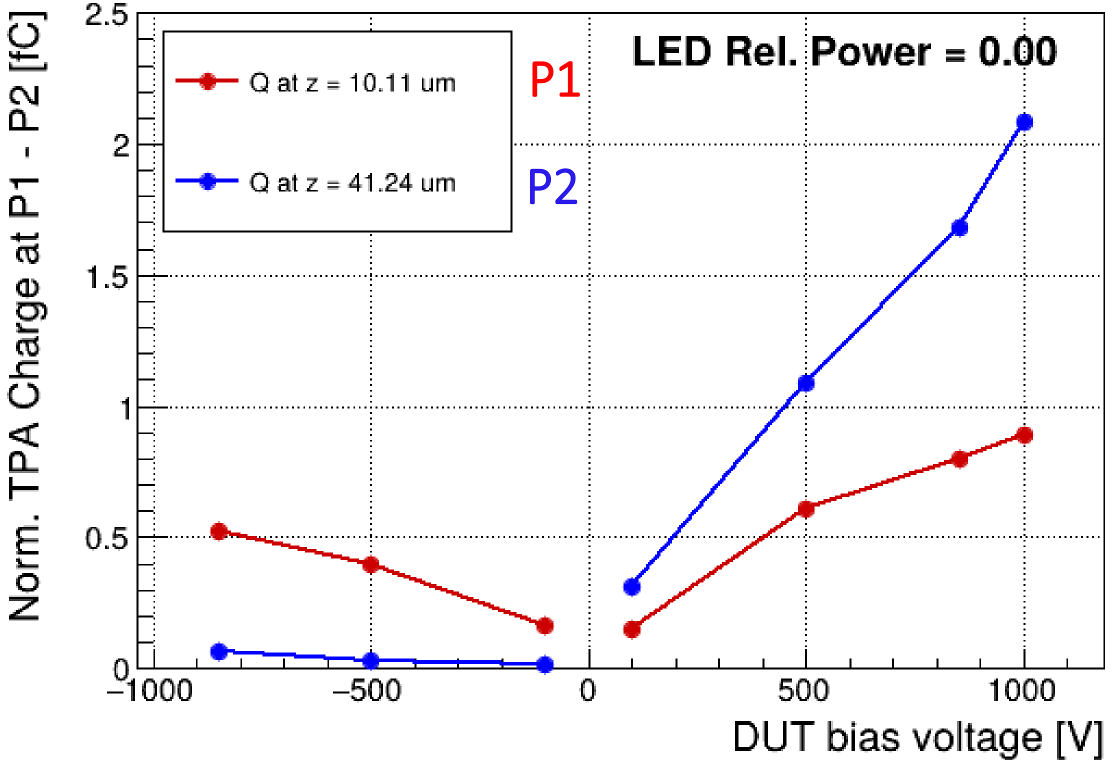
WHY?

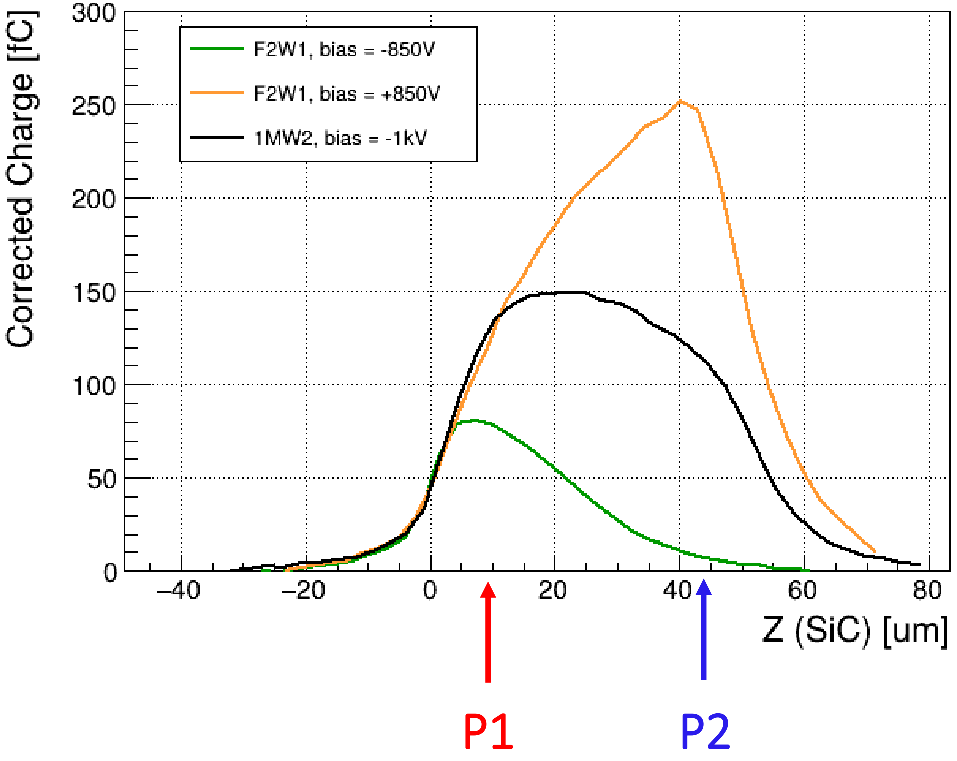
RECALL THAT IN SiC HOLES DRIVE THE AVALANCHE MULTIPLICATION

Close to the front-side:
- hole dominated
- the signal is lower.
- Not strengthen of the signal with optical injection

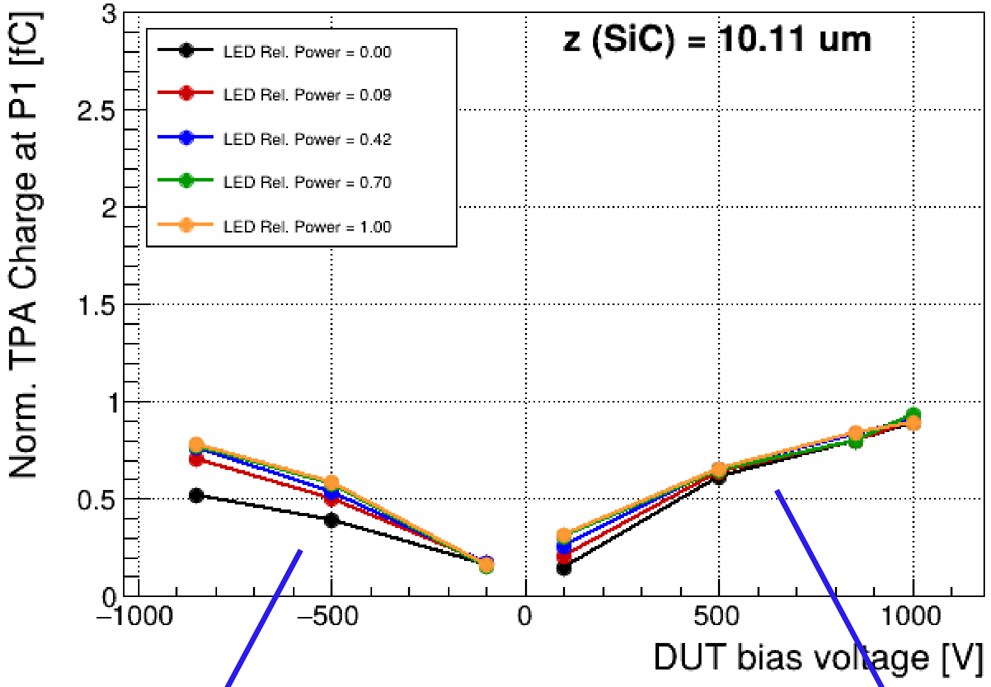
Irradiated sample: Charge vs Bias Voltage

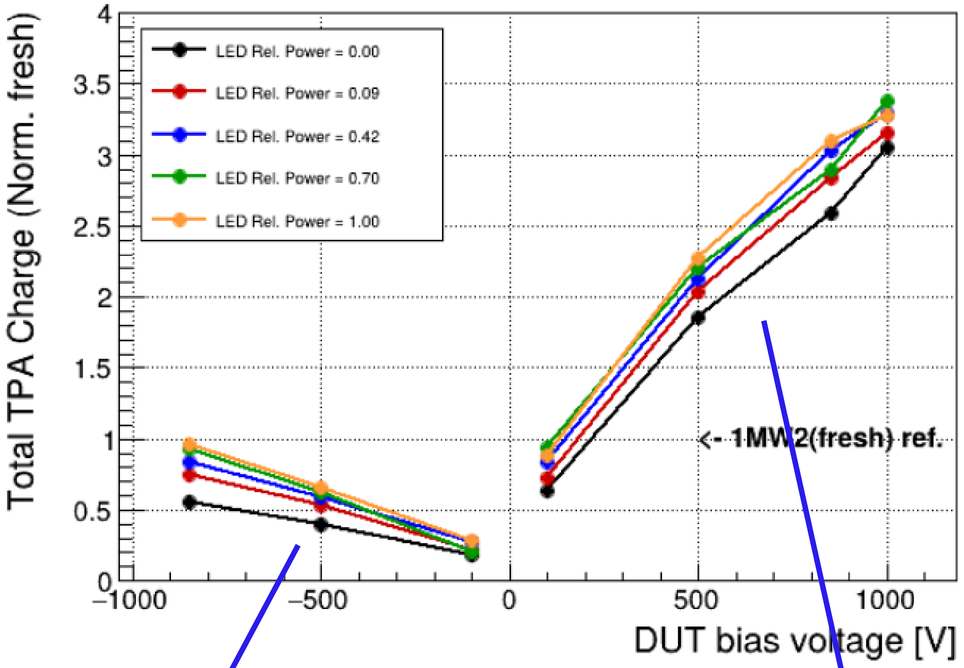
- Strong increase of the signal (higher than the non-irradiated diode) on the back side with bias voltage under forward bias.
- The more the carrier generation voxel approaches the back side (**reduced hole drift distance**) the larger the signal becomes.
- **Indication of hole multiplication due to a high electric field deep into the active thickness**





Irradiated sample: Charge vs Bias Voltage under optical Carrier injection





Strong increase of Signal due to optical Injection of charge

As expected not clear effect of the Optical injection of carriers

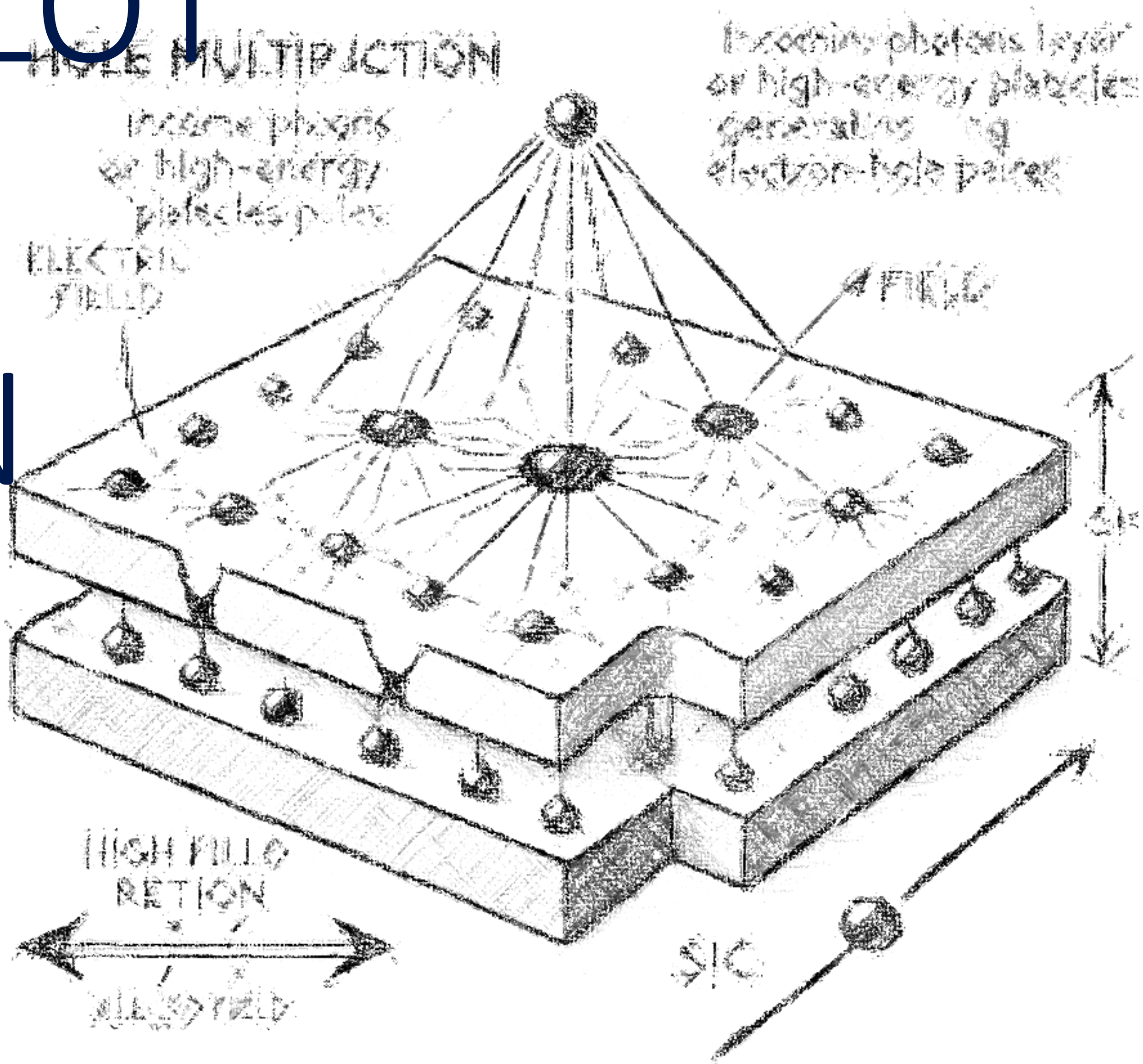
Strong increase of Signal due to optical Injection of charge

Mild increase of signal due to optical Injection of charge (larger mean free path effect reinforced by avalanche gain)

Summary

- Investigated the nature of the observed signal multiplication by optical injecting holes and electrons.
- After irradiation, hole trapping is more likely than electron trapping.
- The multiplied signal is observed near the n+ implant in forward bias, could be attribute to hole multiplication, caused by a stronger electric field near the n+ contact in convination with the strong hole trapping.
- IBIC and TPA-TCT both yield the same result and interpretation
- **Can we engineer this effect to harness it for practical applications?**

THANKS A LOT FOR YOUR ATTENTION



Another AI created HI edited closing slide picture