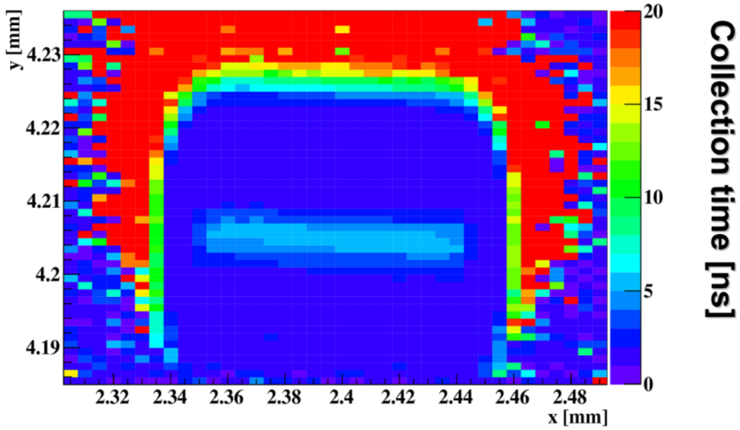
A novel Transient-Current-Technique based on the Two- Photon-Absorption process for the characterization of the HV-CMOS deep n-well

PIXELS 2016, September 5th, 2016



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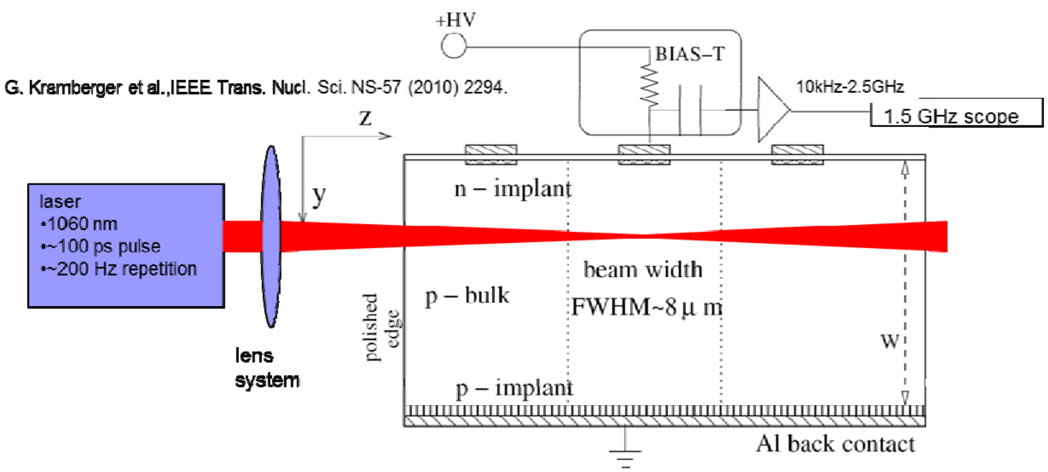
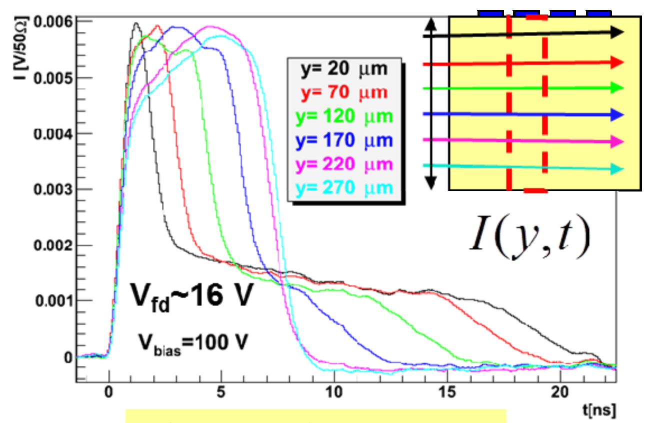
Transient-Technique Basics

- Study of transient current of laser-generated non-equilibrium carriers provides information of many internal diode's characteristics: space-charge geometry, trapping times, CCE, mobility,...
- Capital tool for the understanding of the detector's radiation tolerance



From G. Kramberger, Advanced TCT systems, Vertex 2014



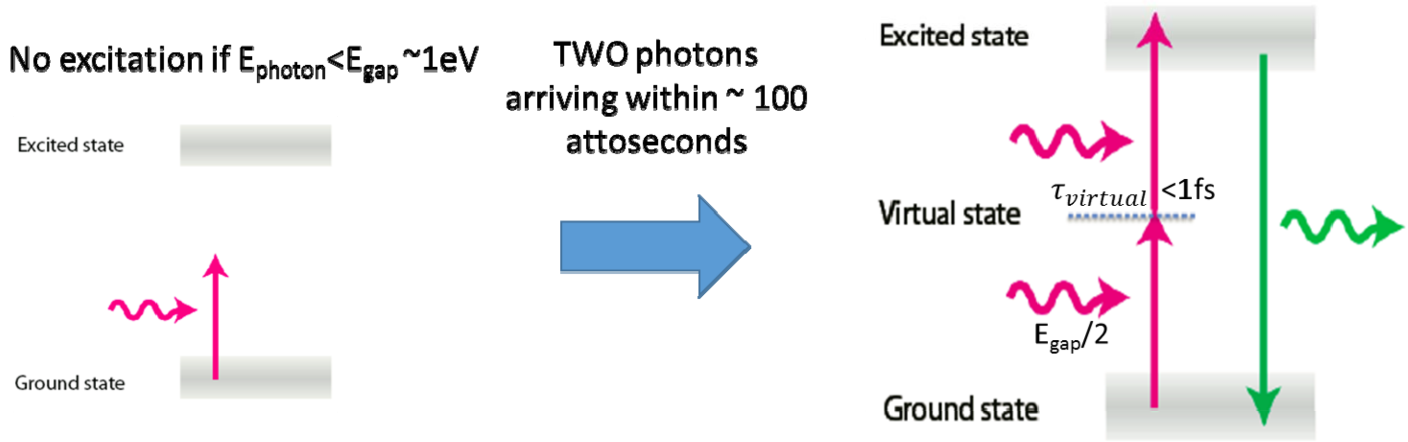
$$I(y,t \sim 0) \propto v_e + v_h$$

Transient-Current Technique Basics (2)

- Ideally, a TCT technique with non-equilibrium free carriers generation in a very localized volume (micrometric-scale voxel) should allow the best E field mapping and geometry determination of the semiconductor junctions with very small size features of the new generation of position-sensitive-detectors

- Let's see what non-linear optics can do for us…

Two-Photo-Absorption Process in Semiconductors 101



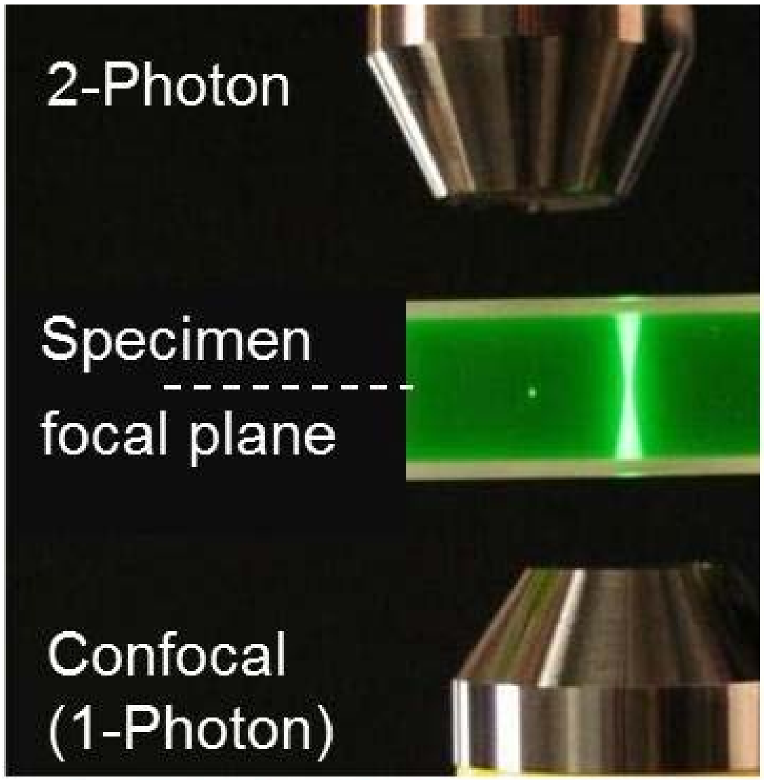
$$\tau_{virtual} \sim \frac{\hbar}{E_{gap}/2} \sim 0.1x10^{-15}s$$

Predicted in 1931 by
Maria Goppert-Mayer
1963 Nobel Prize in Physics

In fluorescent molecules, two photon pumping was demonstrated by Webb et al in 1990.

Two-Photo-Absorption Process in Semiconductors 101 (2)

"A picture is worth a thousand words"



Photography: Ciceron Yanez, University of Central Florida

TPA-TCT is a way to **generate very localized electron-hole pairs** in semiconductor devices (microscale volume).

TPA-TCT **simplifies the arrangement to inject light into the device and the unfolding** of the device internal Electric field and other relevant parameters of the theoretical model.

TPA-eTCT on a HV-CMOS: Set-up

TPA laser facility

→Measurements conducted at the Singular Laser Facility of the UPV (Bilbao, Spain).

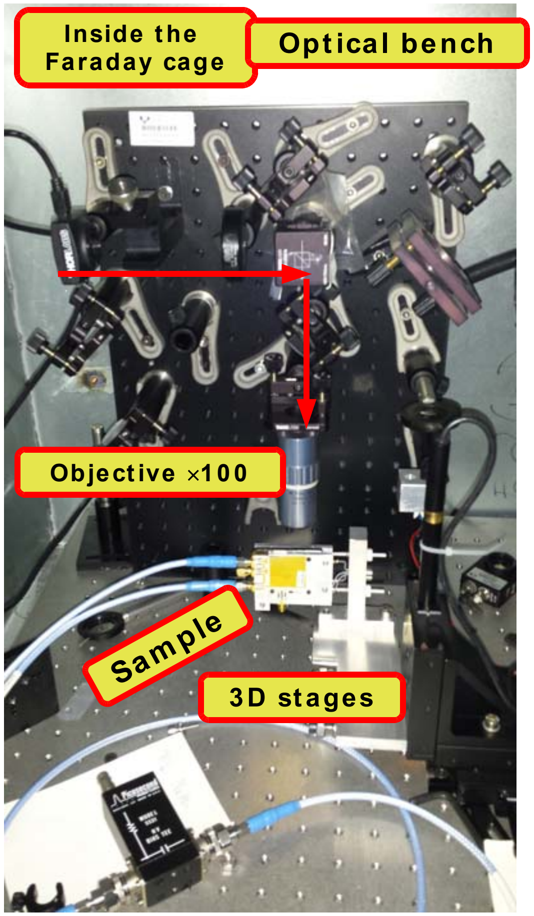
http://www.ehu.es/SGIker/es/laser/

→Very flexible and tunable laser system (intensity, λ, pulse duration...)

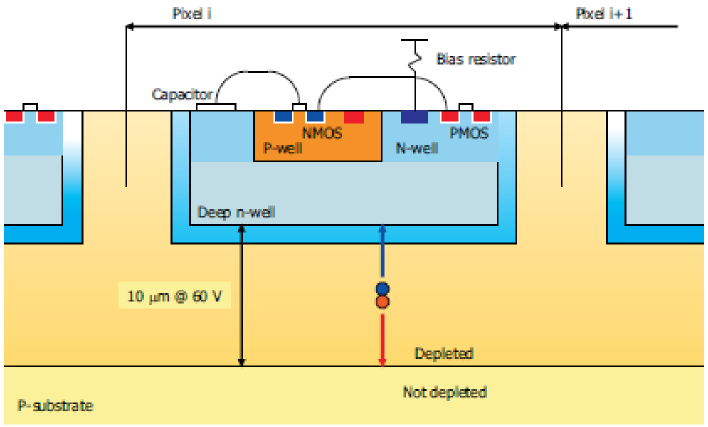
→Access granted via RD50 collaboration.

→See backup for full specs

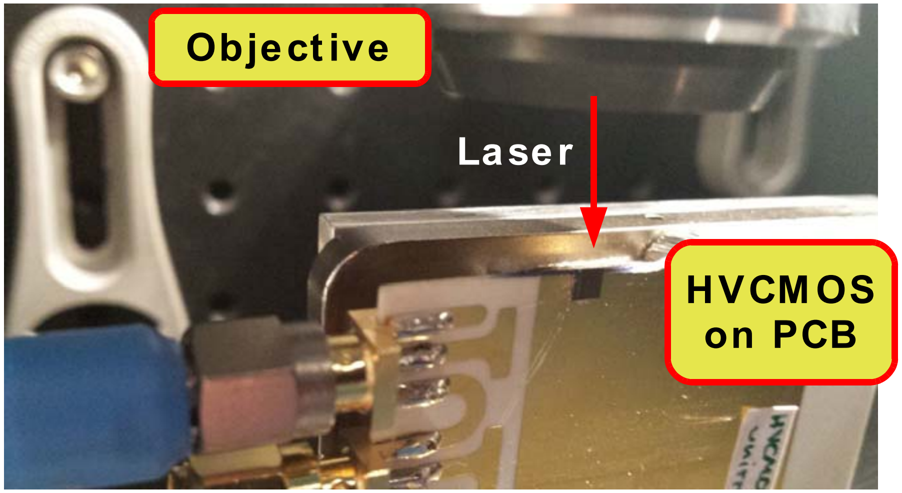
In this study:
λ= 1300 nm, 12 nm bandwidth, Δt= 240 fs

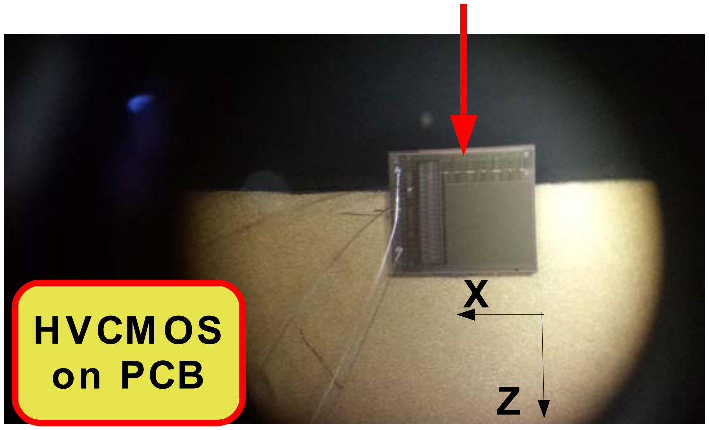


TPA-eTCT on a HV-CMOS: Set-up (2)

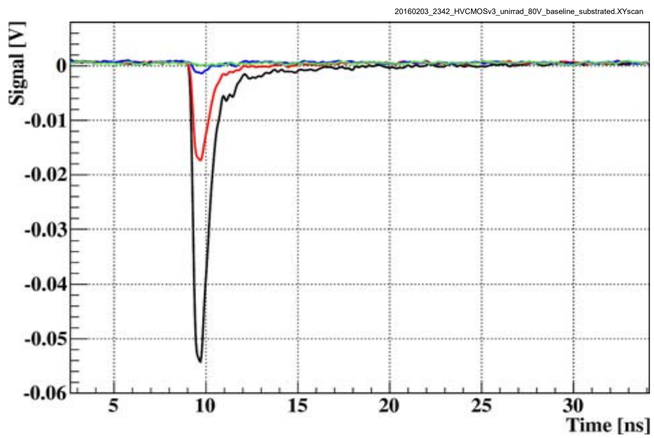


– Analog readout of of the laser-induced signal collected by deep N-Well (no on-chip amplification)

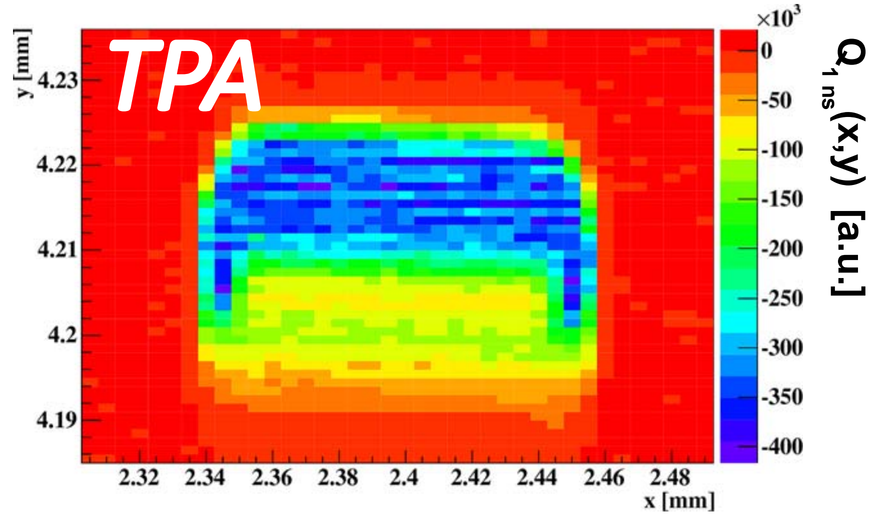




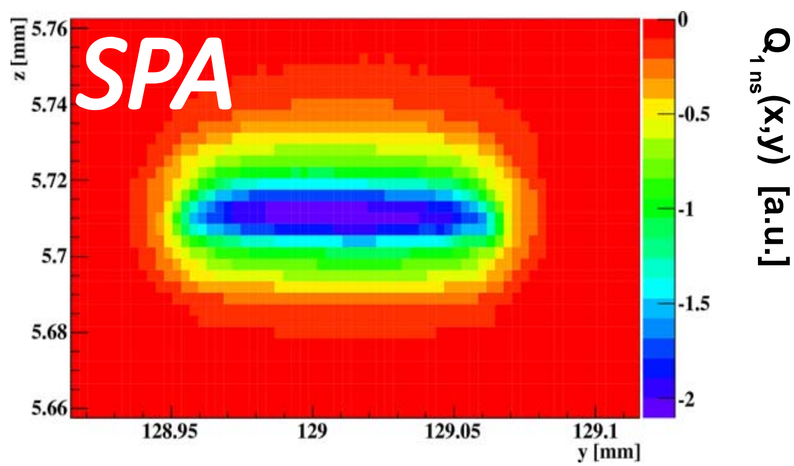
TPA-eTCT: Charge Collection Efficiency.



TPA-TCT: Charge in 1 ns, -80 V, unirradiated HVCMOSv3

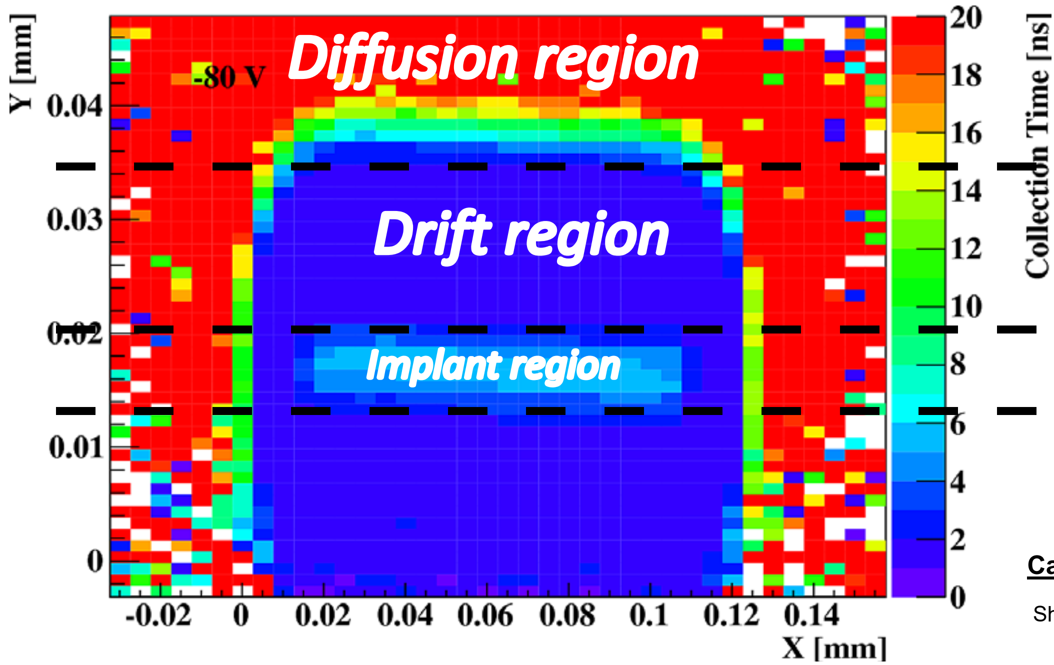


SPA-TCT: Charge in 1 ns, -80 V, unirradiated HVCMOSv3

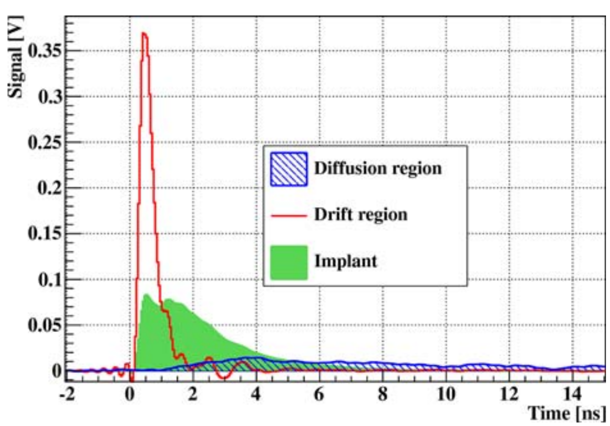


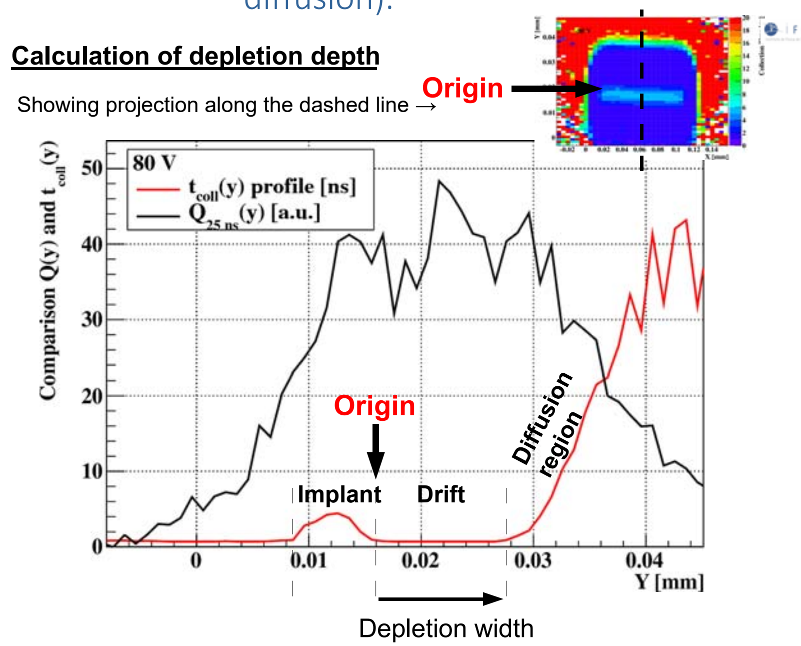
- Fast transient current (~ 1ns) to estimate the E field.
- TPA provides a much better "E field" mapping resolution than Single-Photon Absorption.

TPA-eTCT: Collection Time (95% signal)



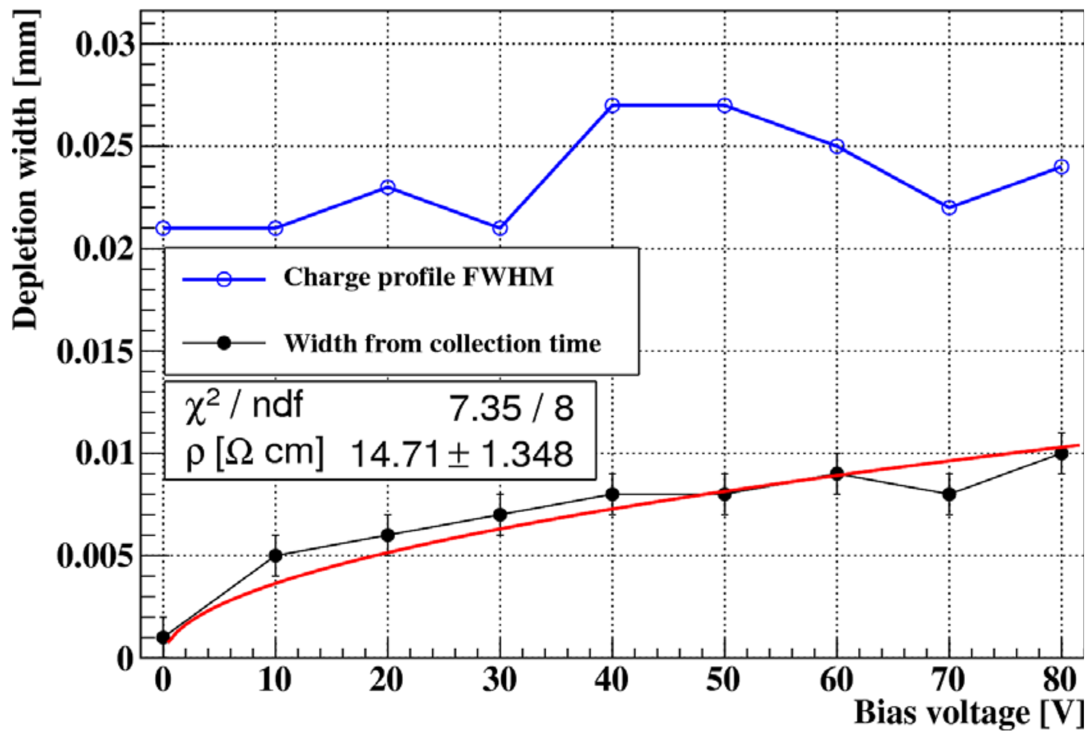
- Distinct waveform shape depending on zone of illumination.
  - Drift region: fast
  - Diffusion region: slow
  - At the implant double peak observed in the waveform (two contributions one for drift and another from diffusion).





TPA-eTCT: Depletion depth vs Vbias

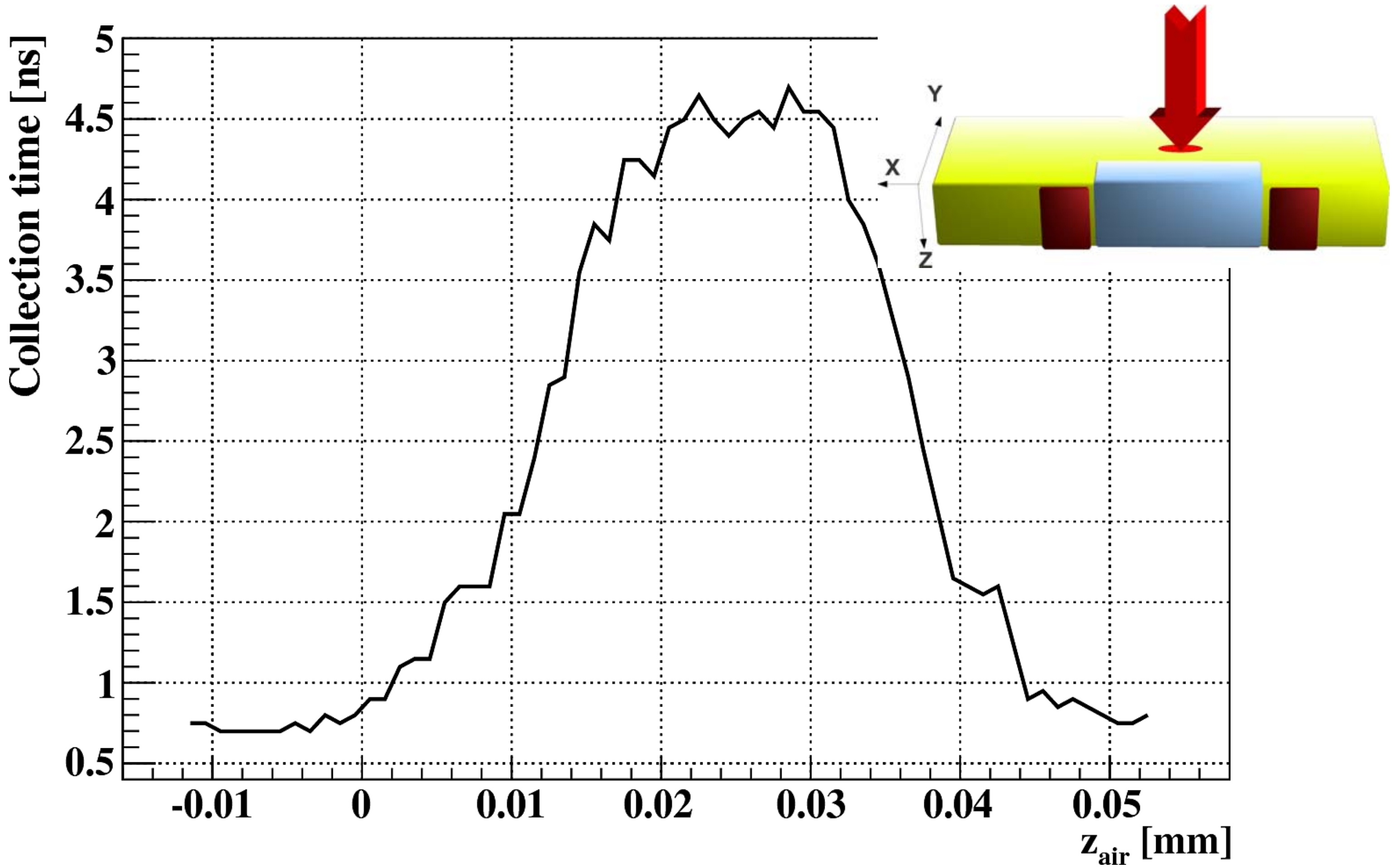
– Doping estimation (resistivity) Assuming abrupt n-in-p junction.



$$w_p[\mu m] = 0.3\sqrt{\rho[\Omega\,cm]V}$$

Calculated resitivity 15 Ω.cm
(10 Ω.cm nominal)

TPA-eTCT: Implant depth (along Z)

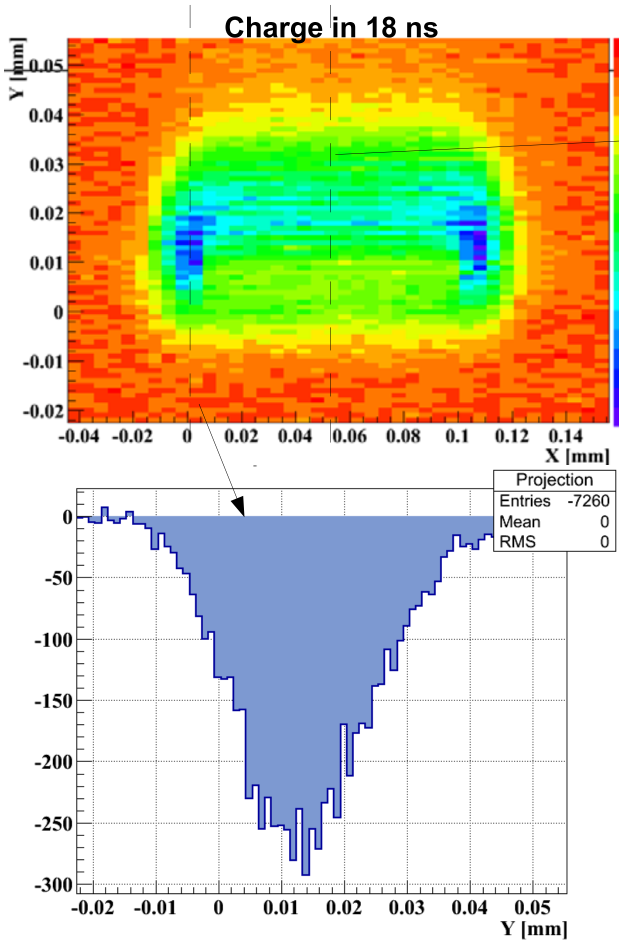


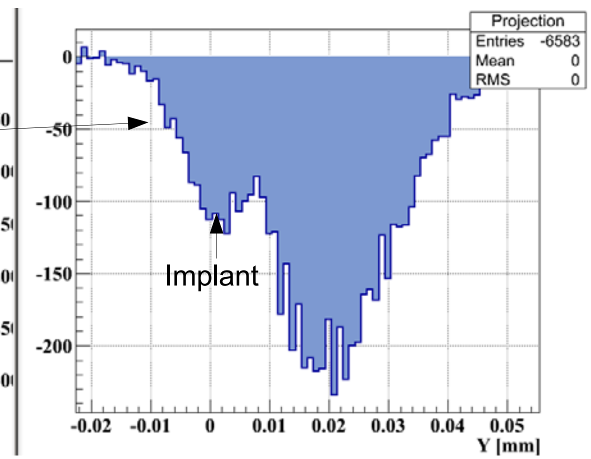
Collection time of signals shows implant depth~100 μm

This measurement is not possible with Single Photon Absorption SPA-TCT

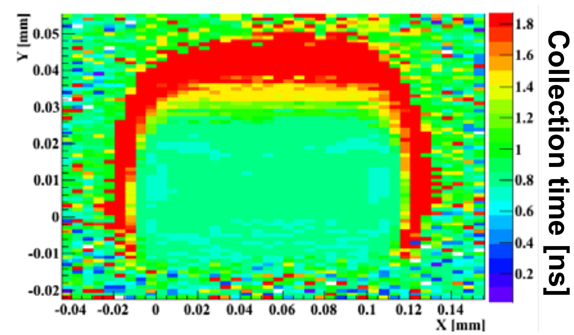
TPA-eTCT: Neutron Irradiated HV-CMOS

- **7×1015 neq/cm2** (Caveat: high leakage current 620 mA @50 V)
- VERY PRELIMINARY
- Dedicated TPA-eTCT characterization campaign going on this week on irradiated HV-CMOS samples.



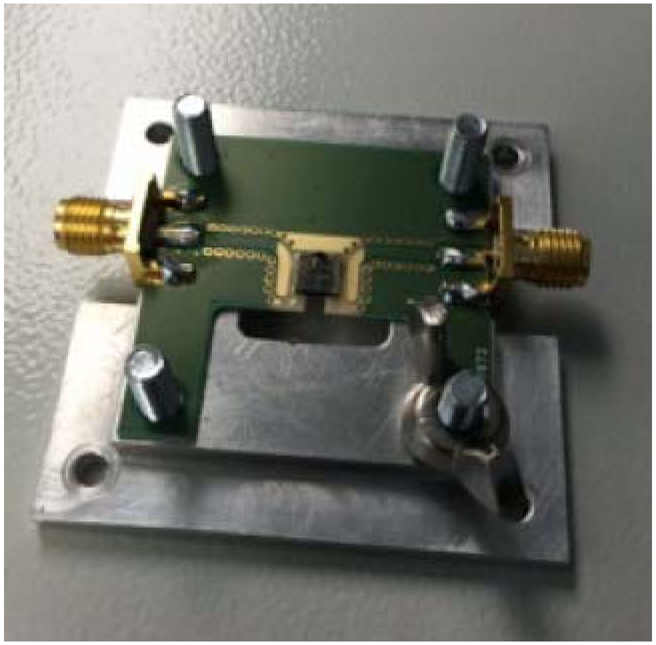


Increased charge at corners
Hints for DNW in collected charge map

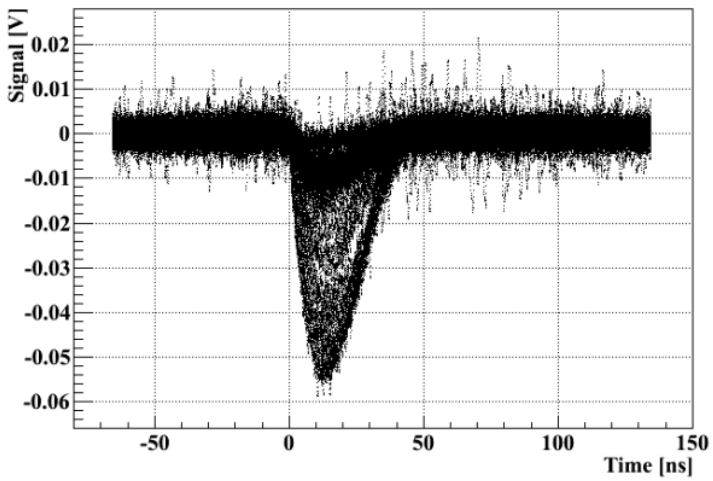


Other possible (exclusive) application

- First sub-bandgap laser-induced signals in **diamond detectors**.
- 3D diamond detector provided by A. Oh (U. Manchester)
- Quick and simple test.



λ=400 nm
Very first glimpse. This was a proof of principle to assert if any TPA signal was visible or not



Approximately 50 ns wide pulses
Rise time ~ 7 ns
Long pulses, in Si, are associated to plasma effect

Summary

- Development of a TPA based TCT technique validated both on non-irradiated and irradiated sensors.
- Localized charge carrier generation: High-resolution 3D mapping of the charge collecting junction and simpler unfolding of sensor's performance characteristics.
- First distinct determination of the deep n-well on HV-CMOS devices and precise determination of its sensitive volume and resistivity
- New opportunities: dedicated studies on diamond sensors, active-edge pixels, signal amplification junctions, …

Thank you !

F. Rogelio et al, Two Photon Absorption and carrier generation in semiconductors
https://indico.cern.ch/event/334251/contributions/780784/

I. Vila et al, A novel Transient Current Technique based on the Two Photon Absorption (TPA) process
https://indico.cern.ch/event/334251/contributions/780782/

I. Vila et al, Investigation on the radiation resistance of HV-CMOS and pin diodes using a Transient Current Technique based on the Two-Photon-Absortion Process
https://indico.cern.ch/event/452766/contributions/1117347/

M. Fernández et al, High-resolution three-dimensional imaging of a depleted CMOS sensor using an edge Transient Current Technique based on the Two Photon Absorption process (TPA-eTCT)
(http://www.sciencedirect.com/science/article/pii/S0168900216304569).