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Preliminary results on TPA studies on LGADs at ELI Beamline

Presented by Gordana Medin

Full list of authors is on the next page

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- **JSI**
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  - Nicolo Cartiglia, Valentina Sola

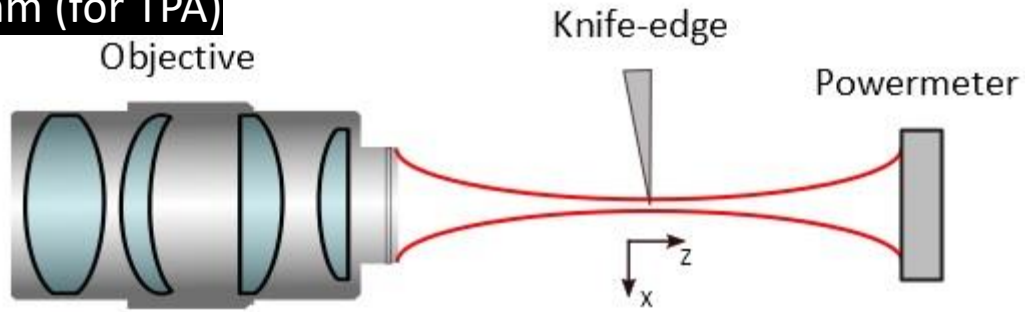
OUTLINE

- ❑ Gaussian Beam Optics
- ❑ Quadratic relation between collected signal (in Si) and laser power
- ❑ Charge Generation via TPA (LGAD& PIN)
- ❑ Z-scan (LGAD & PIN)
- ❑ First measurements with TPA (LGAD & PIN)

Beam profile and parameters at 1550 nm (for TPA)

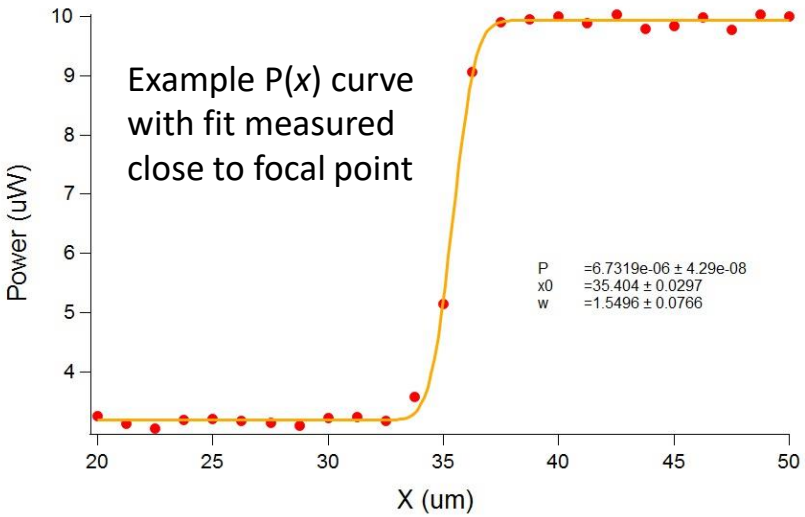
$$P_{measured} = \frac{P}{2}\left[1 - erf\left(\frac{\sqrt{2}(x - x_0)}{w}\right)\right]$$

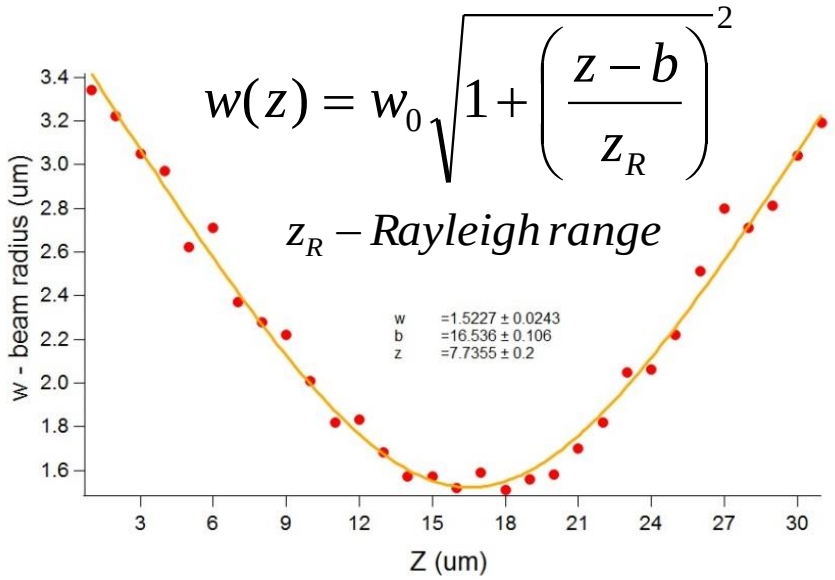
w – $1/e^2$ *radius Gaussian beam*



100X Mitutoyo Plan Apo NIR HR
Infinity Corrected Objective
λ = 1550 nm

1. P(x) measured for series of Z points around focal point
2. w(Z) obtained by fitting for every Z
3. w_0 and Z_R obtained by fitting w(Z) curve





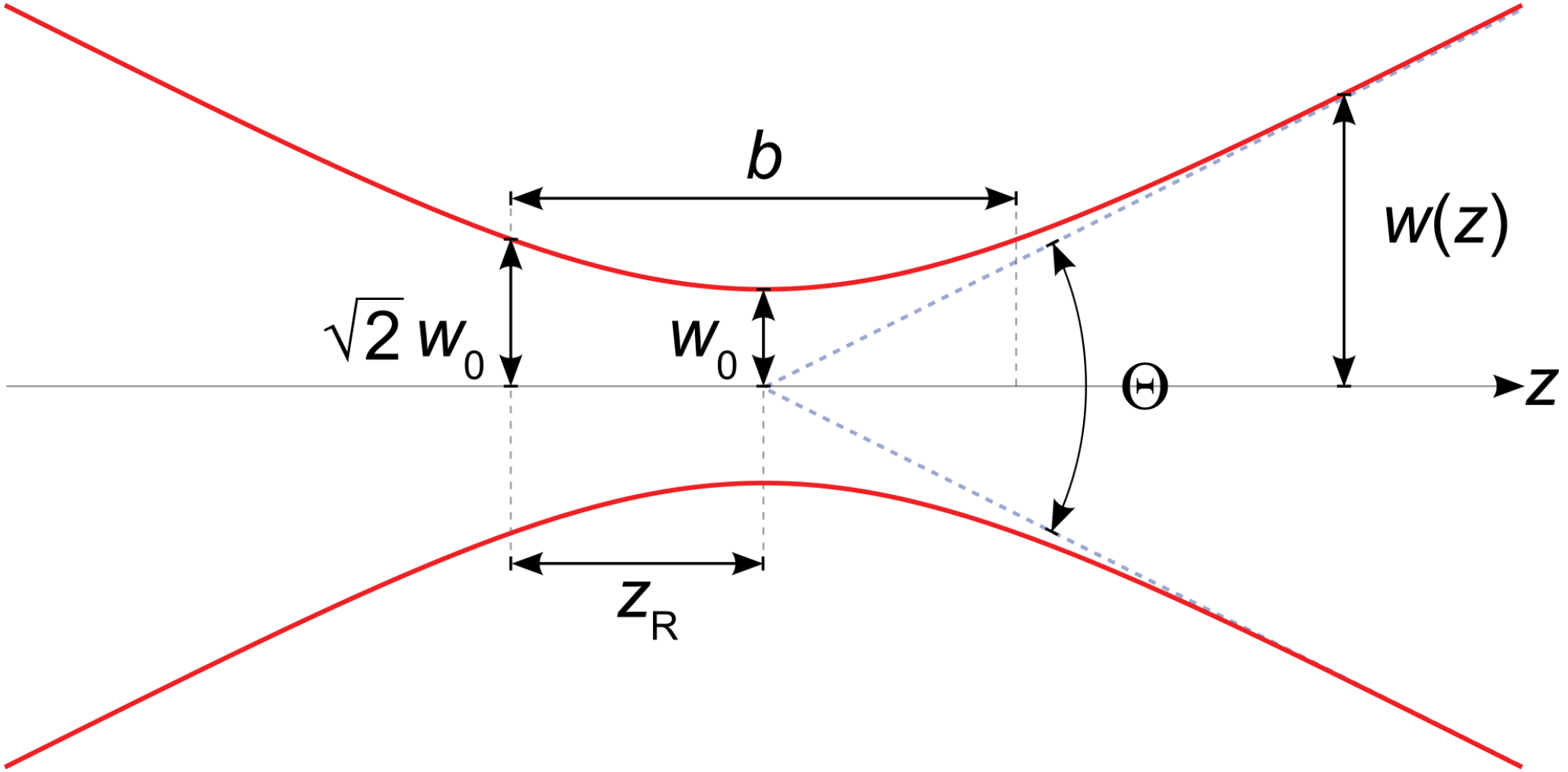
$$w(z) = w_0\sqrt{1 + \left(\frac{z - b}{z_R}\right)^2}$$

z_R – *Rayleigh range*

Final parameters (in air):
$w_0 = 1.52\ \mu m$
$Z_R = 7.74\ \mu m$

In Si : refractive index correction needed
$n = 3.48$ *at 1550 nm*

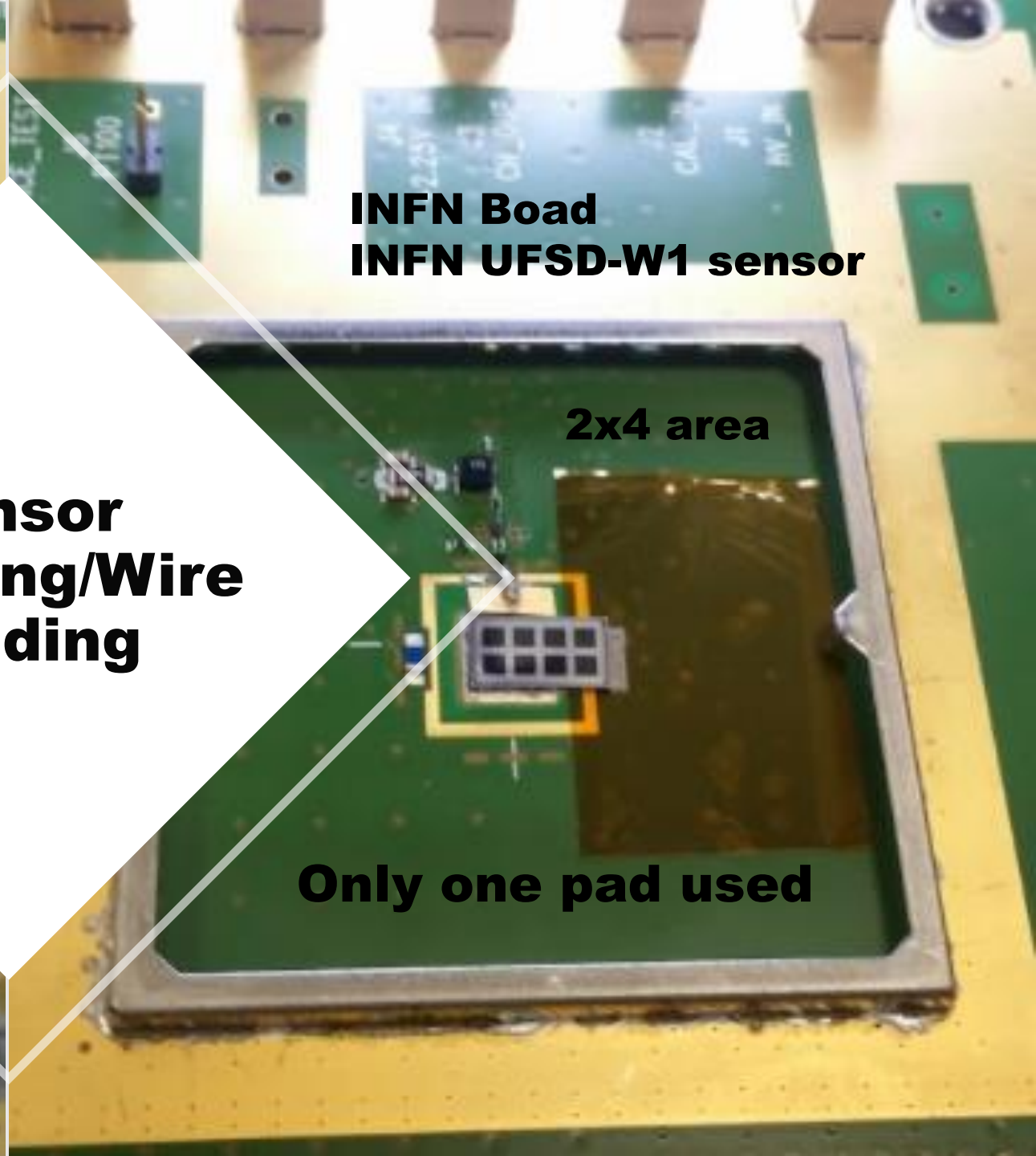
$NA = 0.31$ (nominal NA=0.7 but probably not valid for focal point)



At ELI Beamline final parameters (in air): $w_0 = 1.52$ µm. $Z_R = 7.74$ µm

For comparison: TCT-TPA at CERN: w0 = 1.7 µm, Z_R = 17 µm

Sensor mounting/Wire Bonding



Proof of 2PA in W25 PIN
Indication to 3PA &Plasma contribution

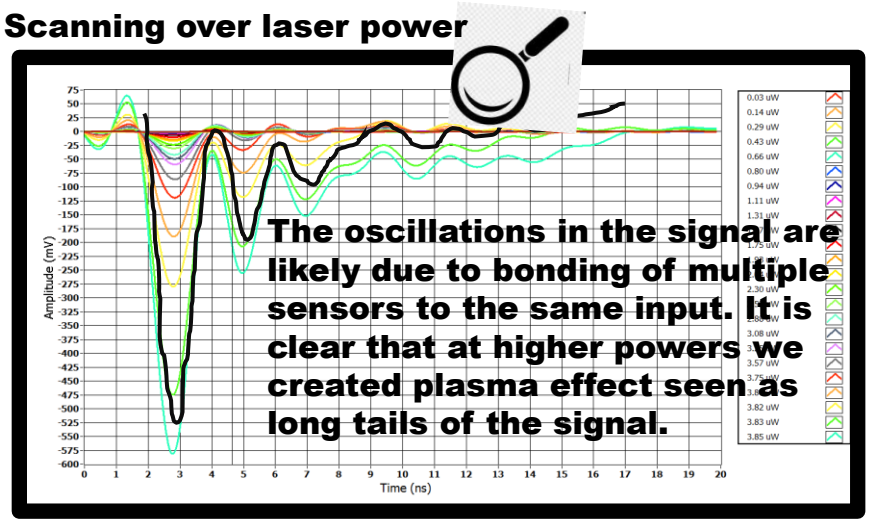
Signal ~ Irradiance²

$$\frac{dN(r,z)}{dt} = \frac{\beta I^2(r,z)}{2\hbar\omega} \Rightarrow \Delta N(r,z) = \frac{\beta I^2(r,z)}{2\hbar\omega}\Delta t$$

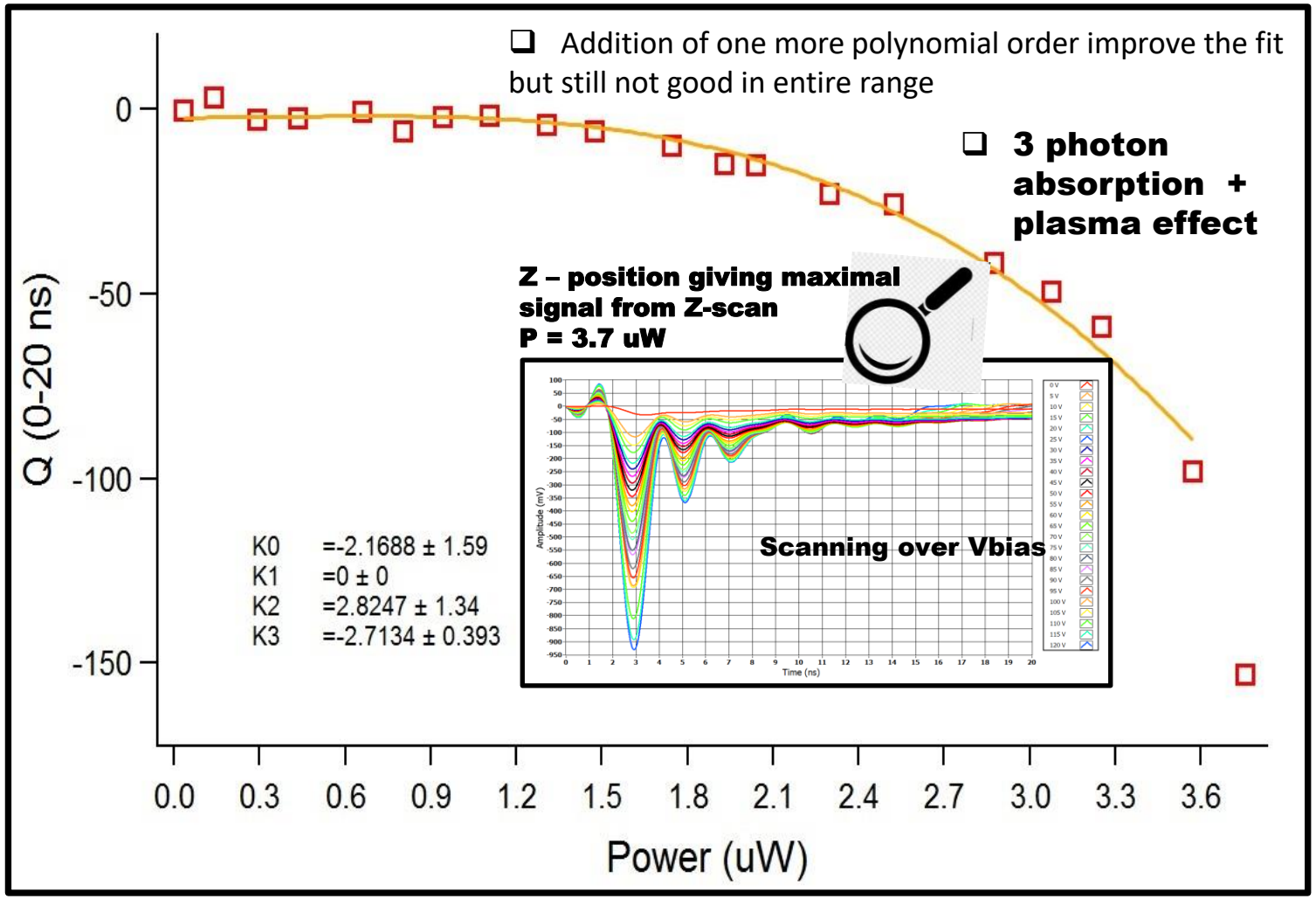
$Q \propto N$ $\quad$ $P \propto I$

- Quadratic relation between collected signal (in Si) and laser power

Z – position giving maximal signal from Z-scan
V_{bias} = -100 V
Scanning over laser power



- Addition of one more polynomial order improve the fit but still not good in entire range
- **3 photon absorption + plasma effect**



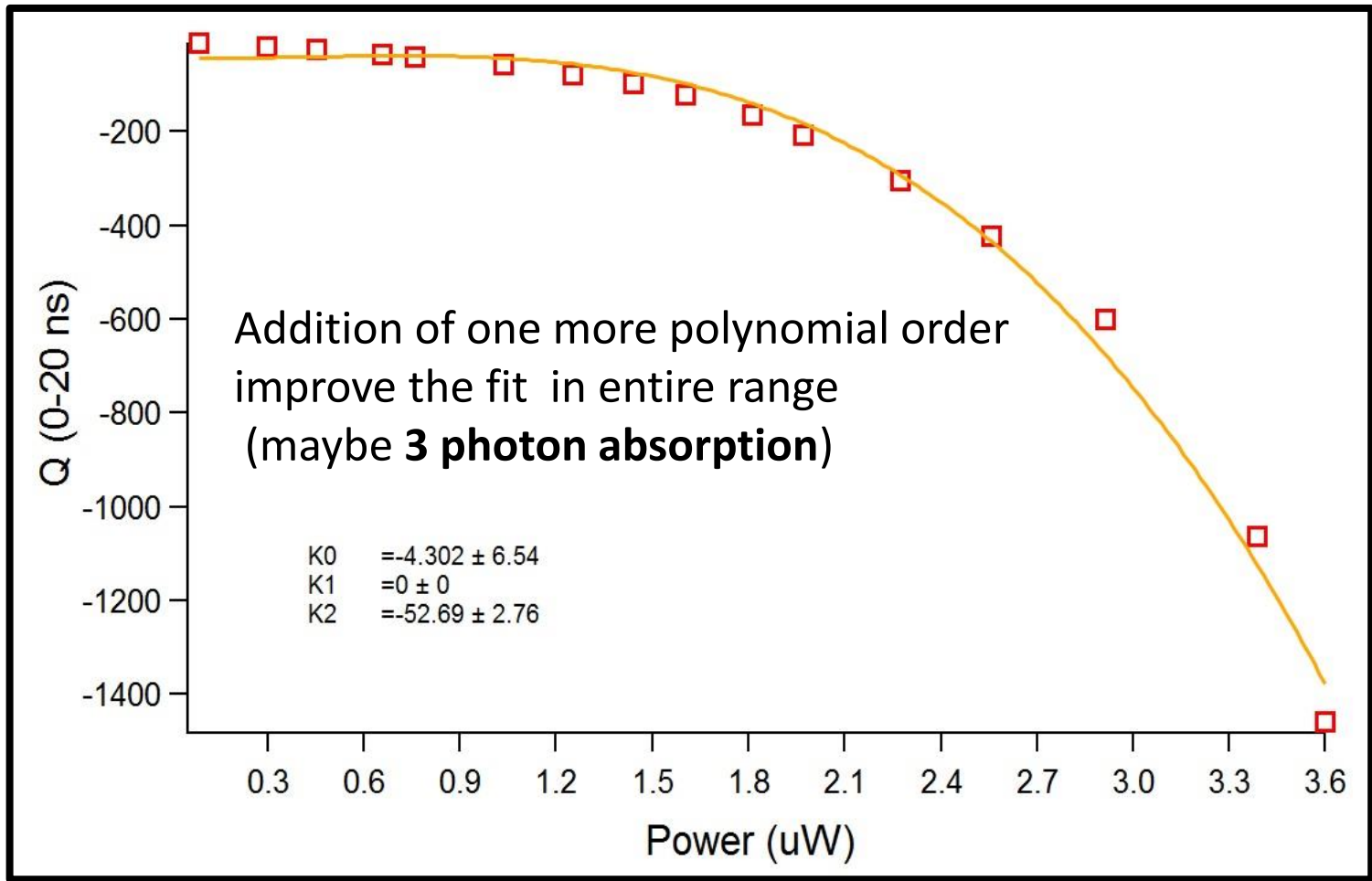
Proof of TPA
LGAD WF25 (HPK-P2)

Signal ~ Irradiance²

$$\frac{dN(r,z)}{dt} = \frac{\beta I^2(r,z)}{2\hbar\omega} \Rightarrow \Delta N(r,z) = \frac{\beta I^2(r,z)}{2\hbar\omega}\Delta t$$

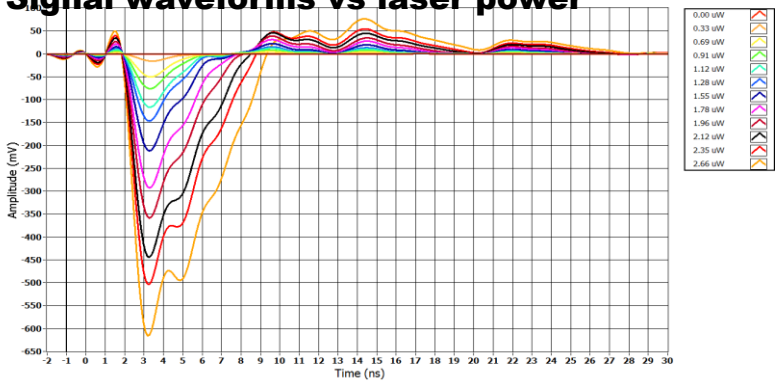
$Q \propto N$ $P \propto I$

- Quadratic relation between collected signal (in Si) and laser power

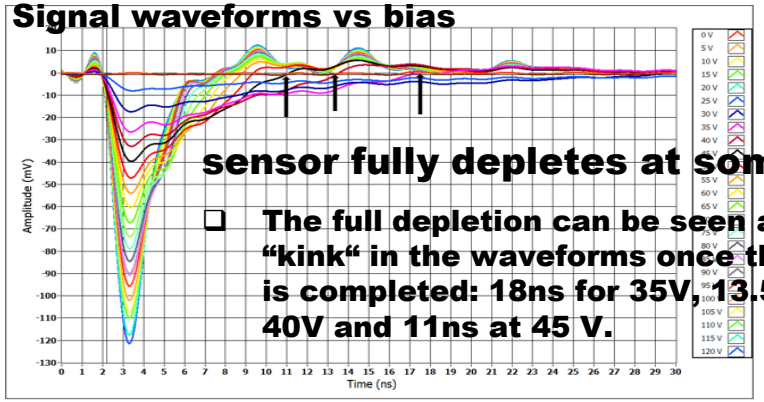


Proof of TPA LGAD INFN: UFSD –W1

Z – position giving maximal signal from Z-scan
V_{bias} = -100 V
Signal waveforms vs laser power

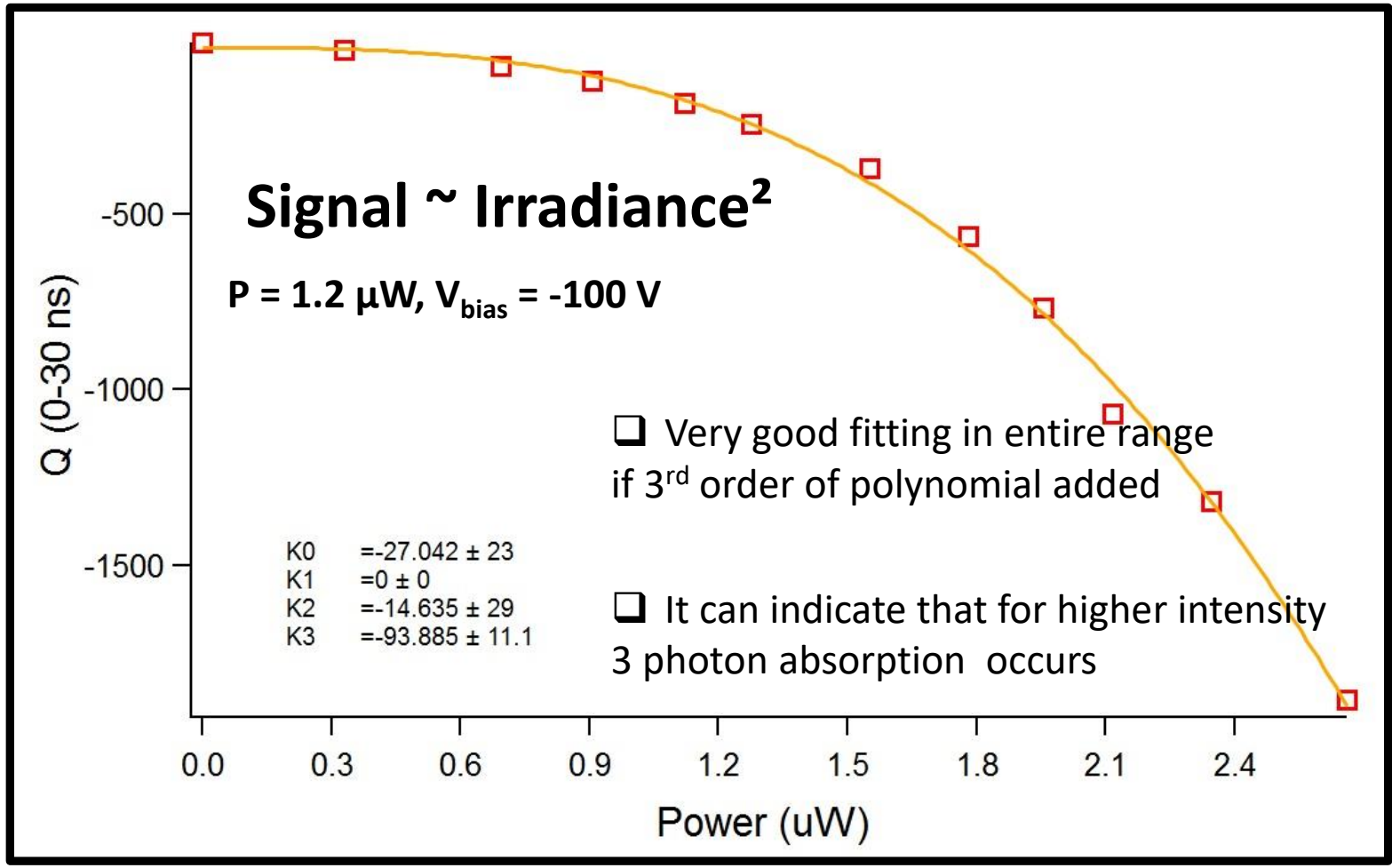


Z – position giving maximal signal from Z-scan
P = 1.1 µW
Signal waveforms vs bias

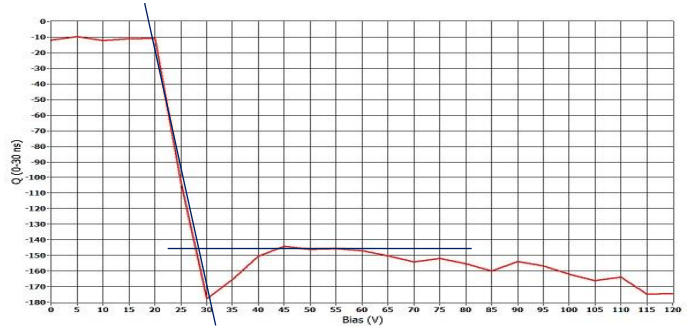


sensor fully depletes at some 35-40V

- **The full depletion can be seen as the "kink" in the waveforms once the drift is completed: 18ns for 35V, 13.5 ns at 40V and 11ns at 45 V.**



Q-V plot

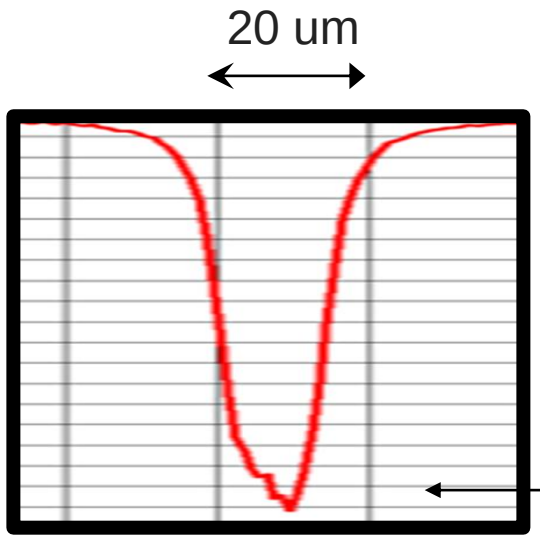


Proof of TPA

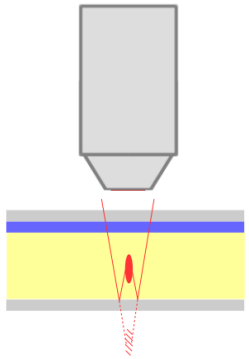
$PIN_{ref(WF25)}$

Z-Scan

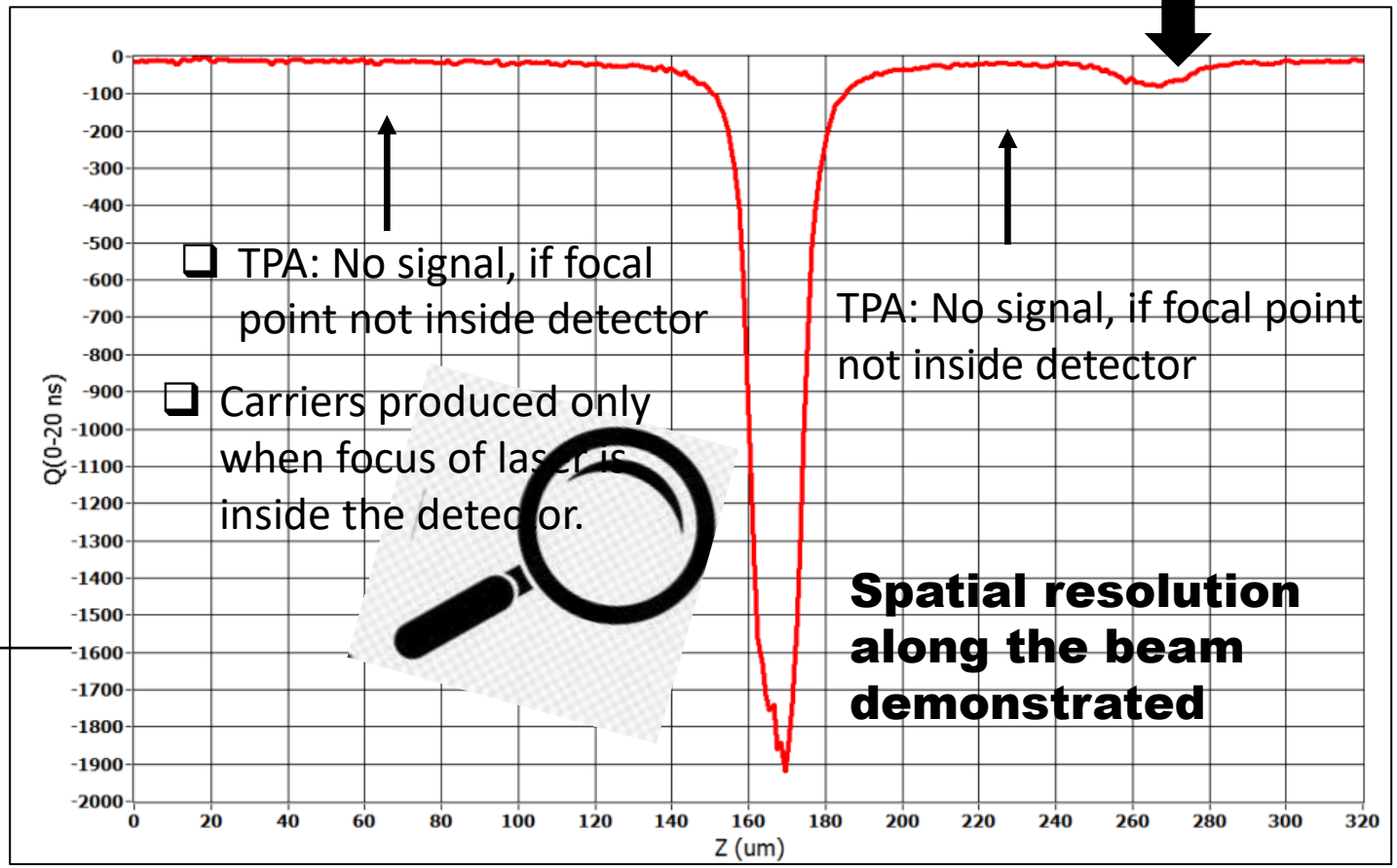
P = 3.2 uW, V_{bias} = -100 V



- FWHM is ~14-15 um which taking into account refractive index gives you ~50 um, which is the thickness of devices



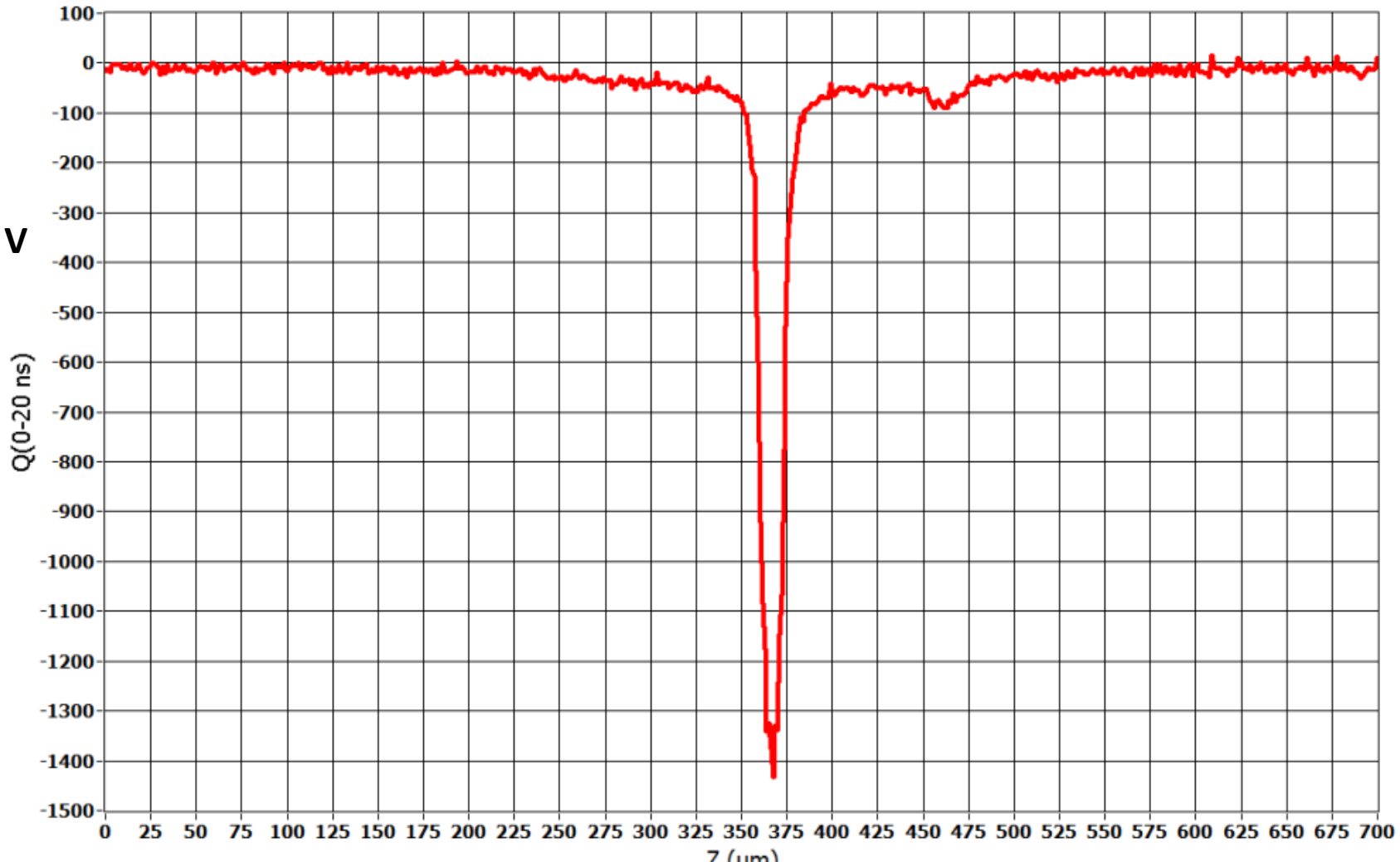
The second peak Z2 is very likely coming from the reflection of the light from the bottom of the sensor. The sensors is comprised from: 50um sensitive bulk on the silicon substrate wafer which is metallized at the bottom. It could happen that at right position the reflected beam causes TPA in the active region



Proof of TPA
LGAD WF25 (HPK-P2)

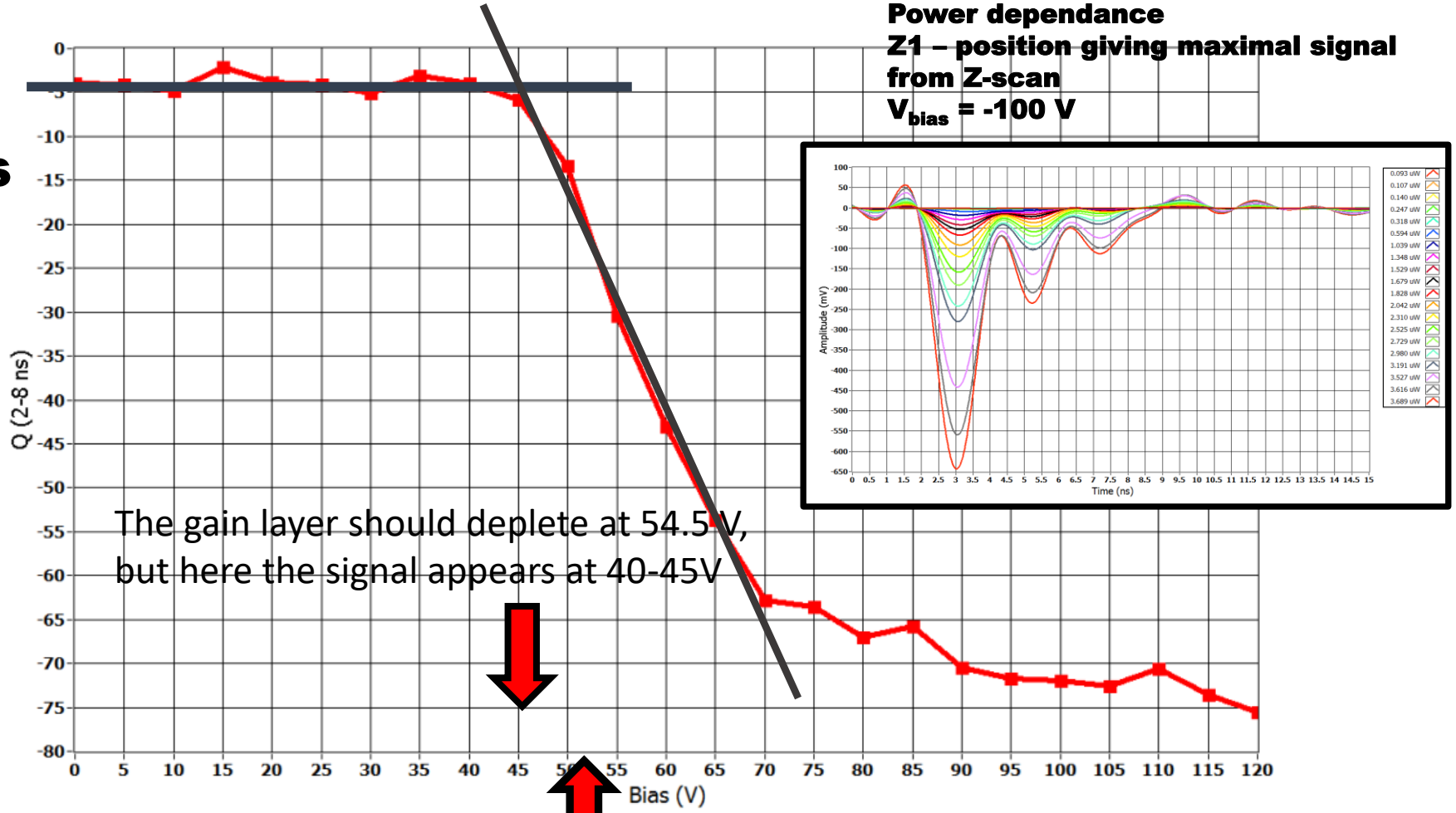
Z-Scan

P = 3.7 µW, V_{bias} = -100 V



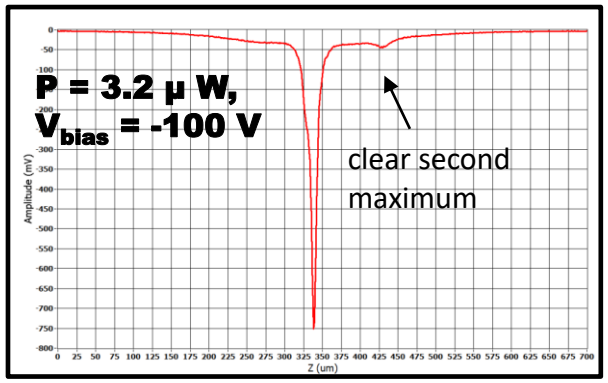
First characterisation of LGAD with TPA: Determination of gain layer depletion voltage (Vgl)

LGAD W36
Q vs. HV Bias
P = 3.2 µW



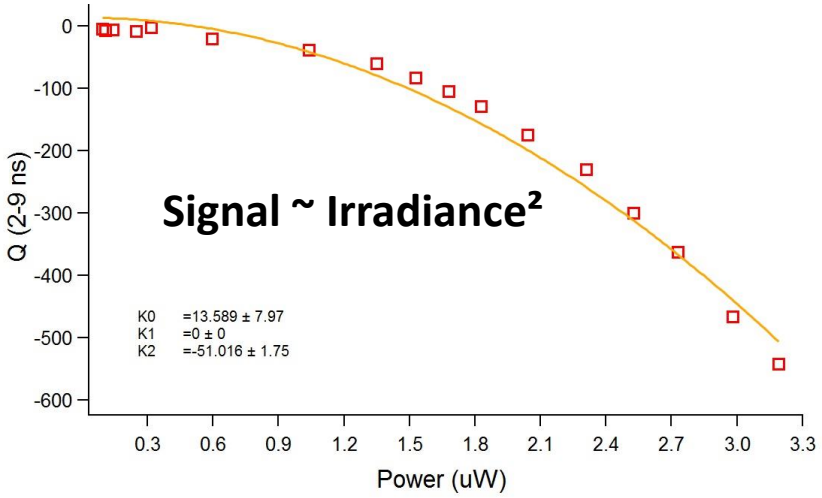
Power dependance
Z1 – position giving maximal signal from Z-scan
V_{bias} = -100 V

Z-scan (front to back) on LGAD W36

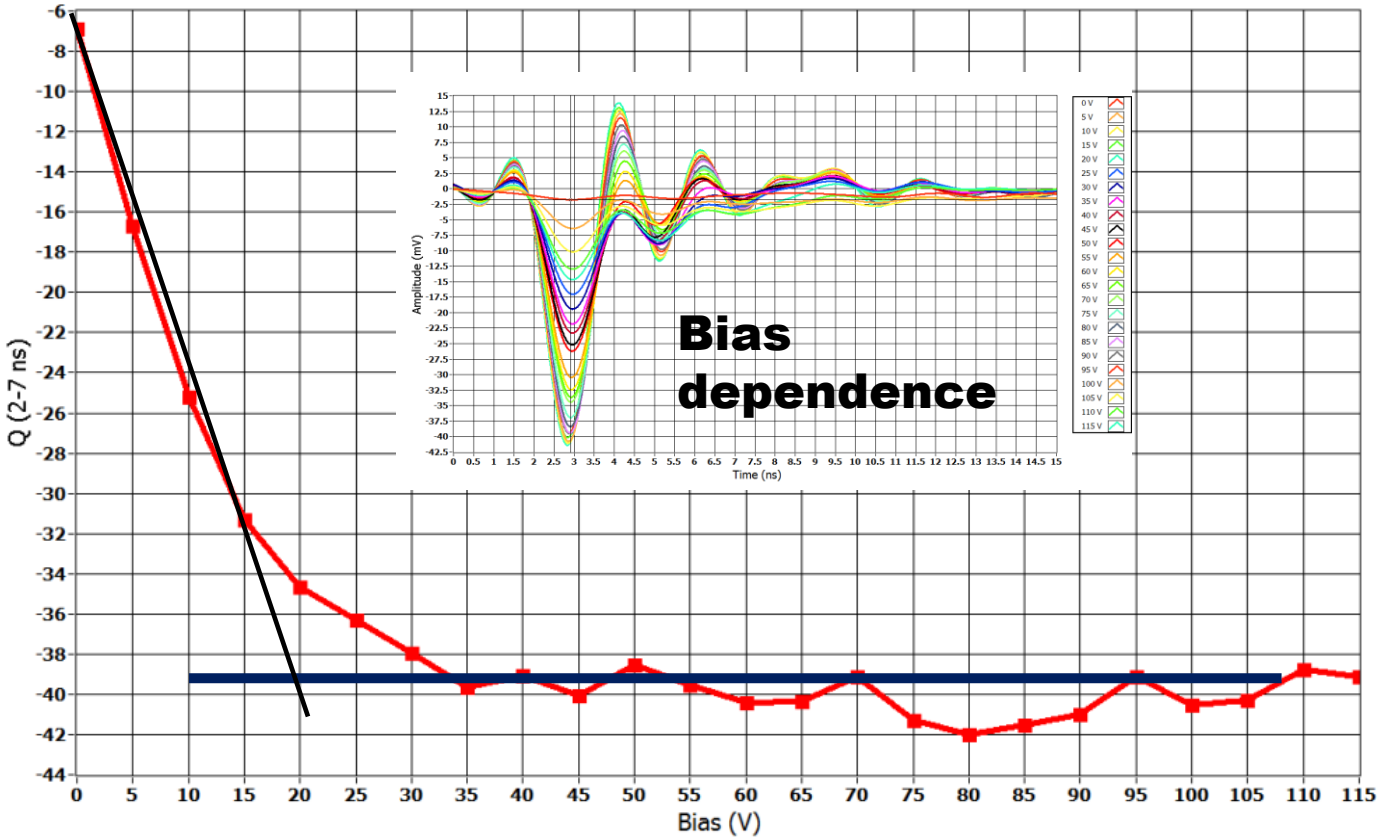


First/preliminary characterisation of PIN with TPA:
Vfd

Z – position giving maximal signal from Z-scan
P = 70 nW
PIN36



Q vs. HV Bias



Conclusion

- The first in the world compact and comprehensive fs-TCT which will have both, TCT-SPA and TCT-TPA is under commissioning at ELI Beamlines
- Uniqueness of set up: both, standard TCT at 800 nm but with fs-laser and also 3D scanning of sensor with TPA at 1550 nm.
- The excellent beam parameters achieved: w0 = 1.52 µm. ZR = 7.74 µm
- TPA process in a diode (top injection) is demonstrated.
- First/preliminary characterisation with TPA: gain layer depletion voltage and foot voltage in LGAD.
- We are still developing some parts of the system: DAQ, cooling
- Study on sensors just with 2nd amp and without timing boards under discussion (we have quite large signal in LGAD and it would be easier to achieve lower temperature)

Acknowledgment

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