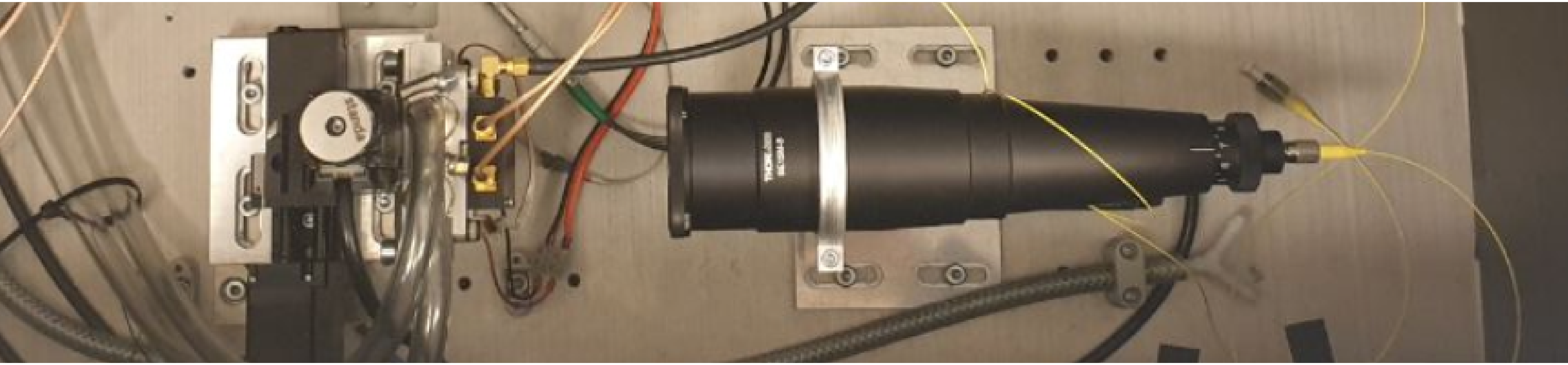
Intro to the DESY TCT system

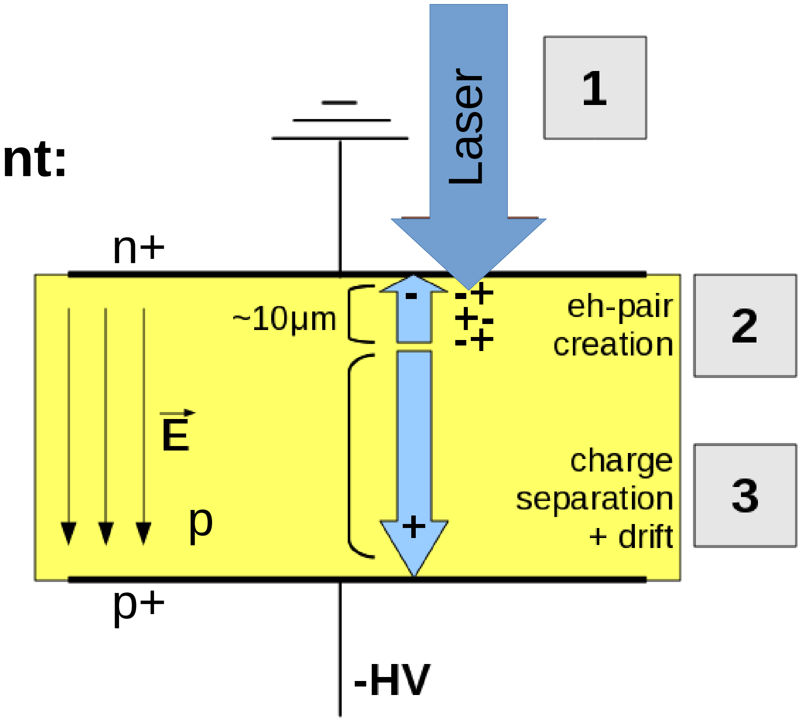
Old but gold?



<u>Hendrik Jansen</u>

What is TCT?

The Transient-Current Technique (TCT) measurement:



1) Laser is directed onto a sample
2) eh-pairs are created inside the device
3) Electric field separates charges
4) Drifting charges induce current (Ramo-Theorem)

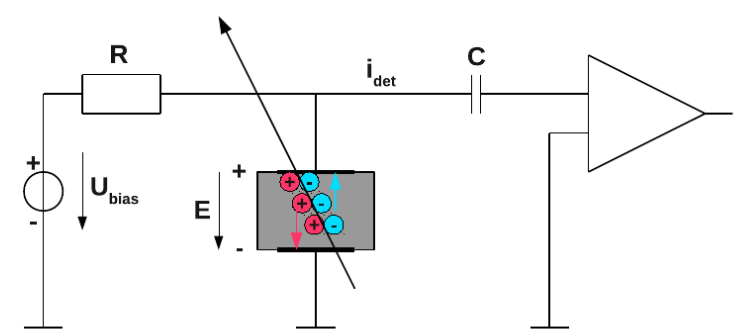
→ measure the transient current using fast (GHz) amplifier.

4

$$i(t)=n(t)\,e\,v(E)\,E_w$$

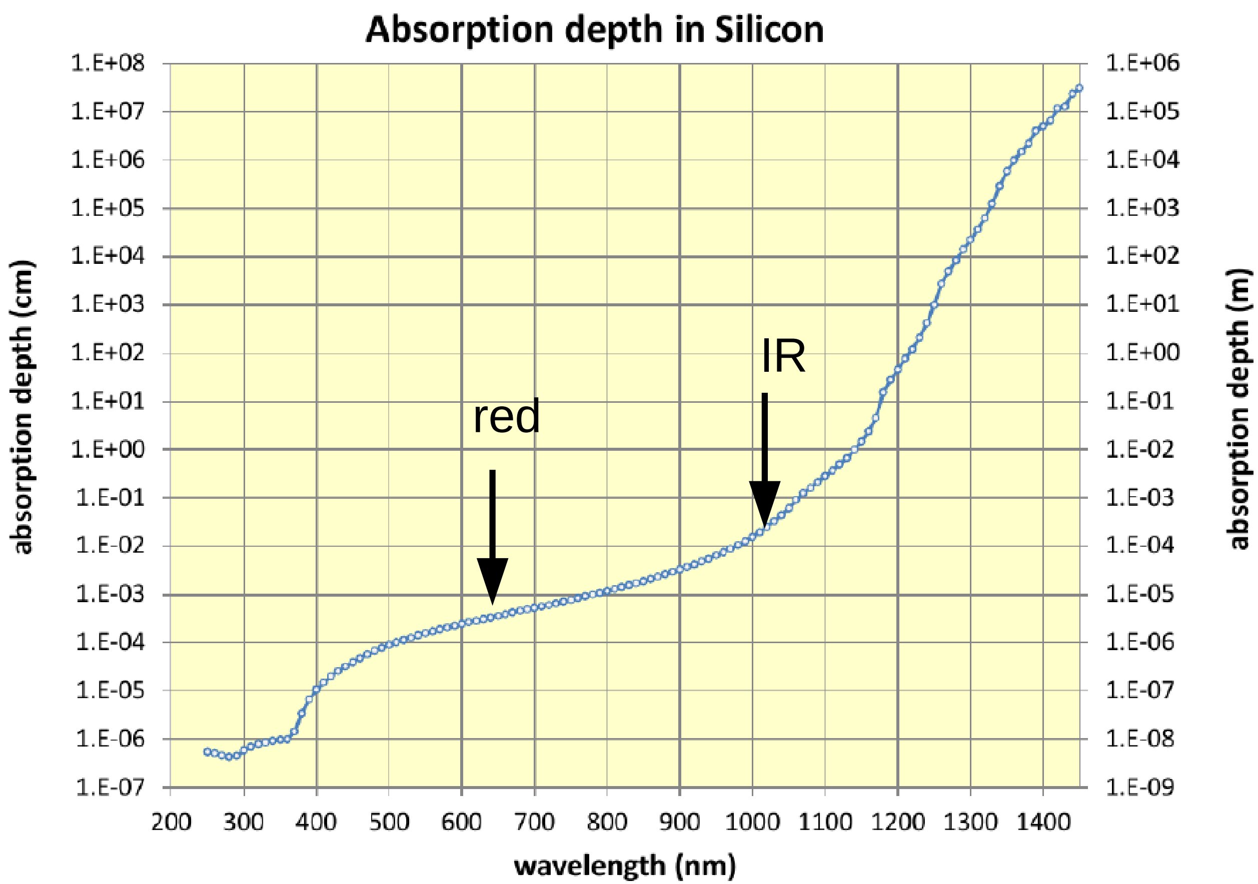
In p-type silicon with red laser, measure mostly h^+/e^- for top/bottom TCT.

Bias Sensor and read via AC-coupling on HV-side or via DC-coupling from LV-side.



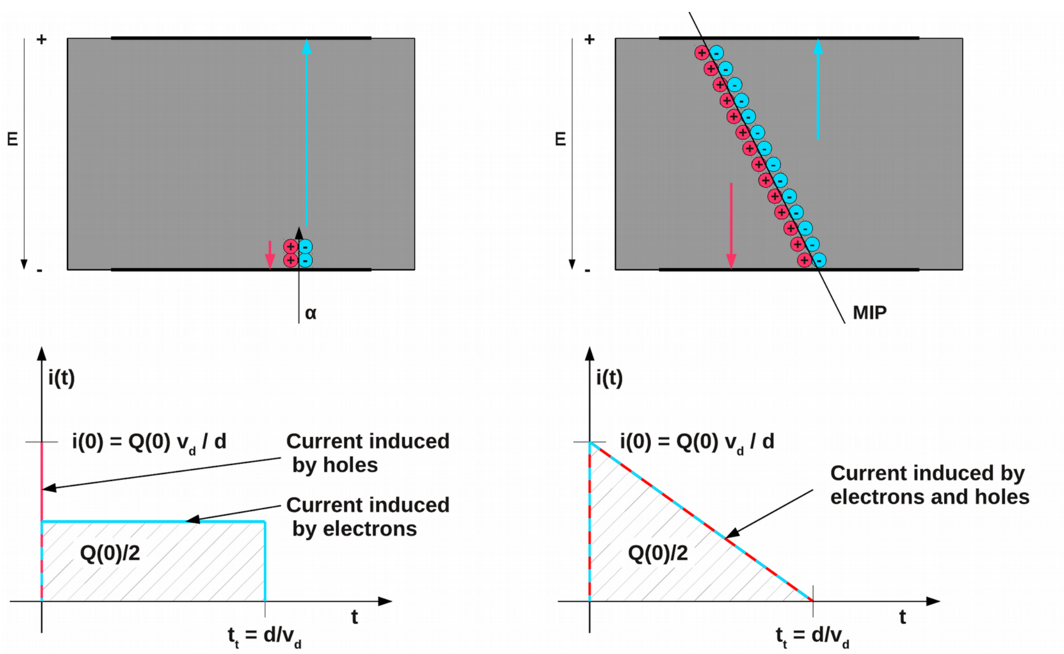
How does a TCT signal look like?

Let's first look at the charge creation



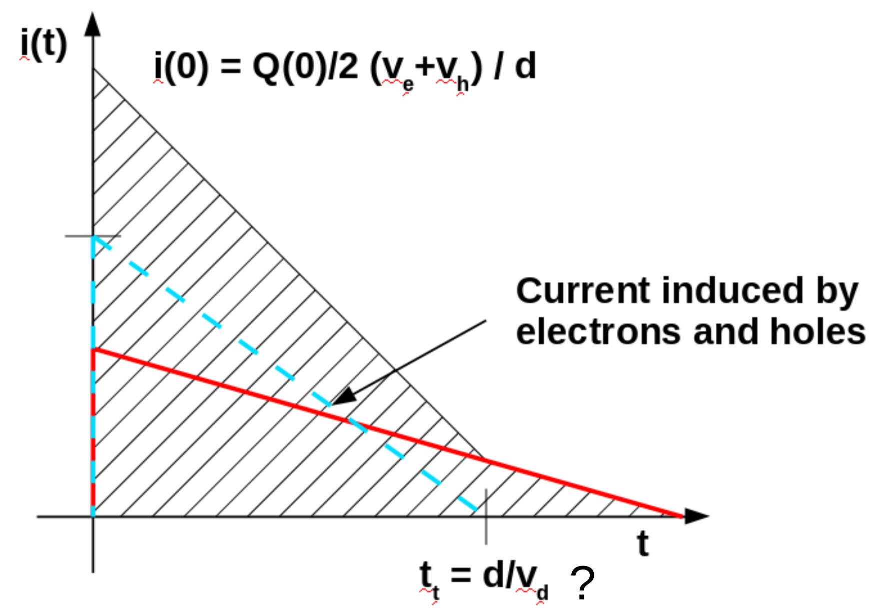
How does a TCT signal look like?

In theory, for flat E-field and constant E_w



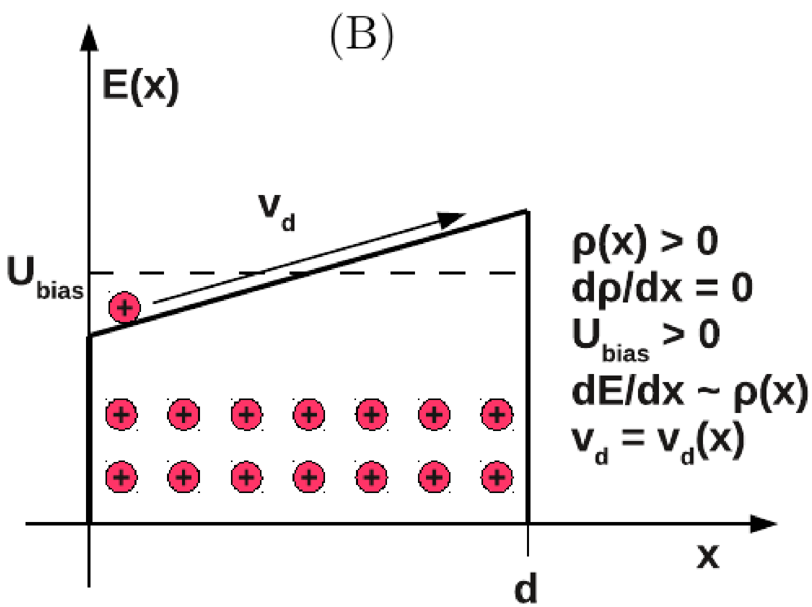
Zero charge density
→ constant E-field
→ constant v_{drift}

MIP: With different drift velocities



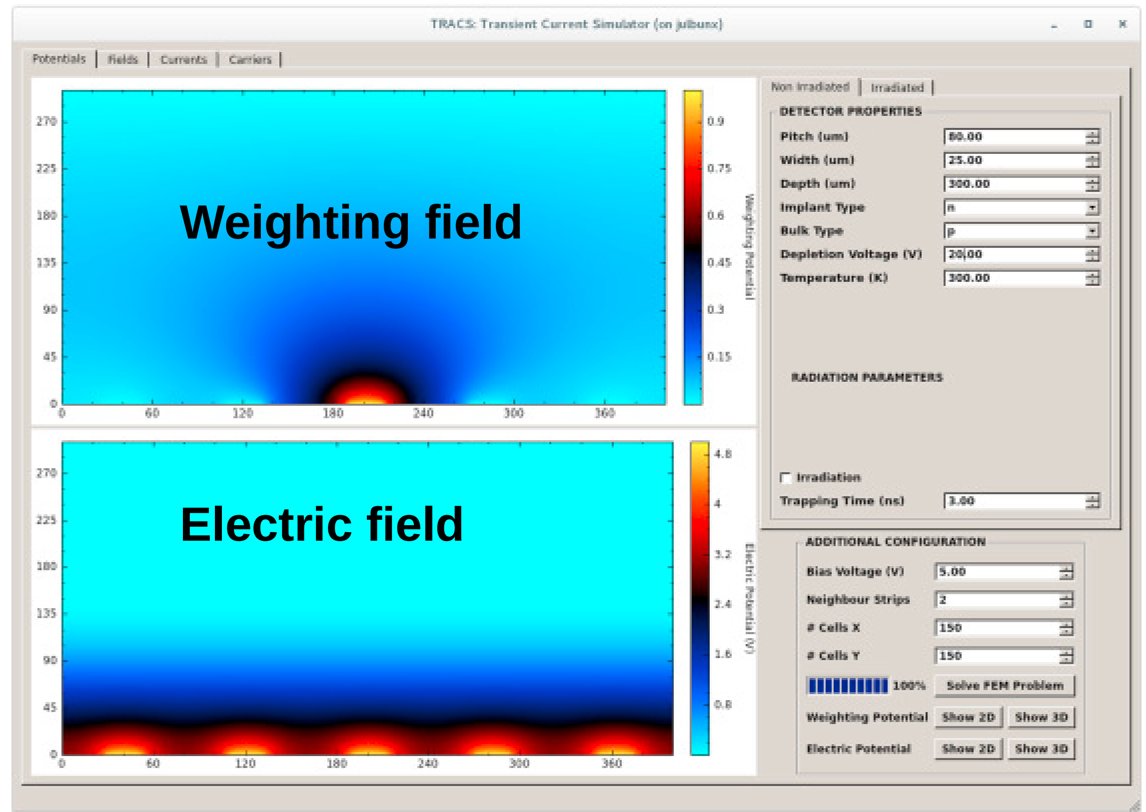
How does a TCT signal look like?

With spatially dependent E



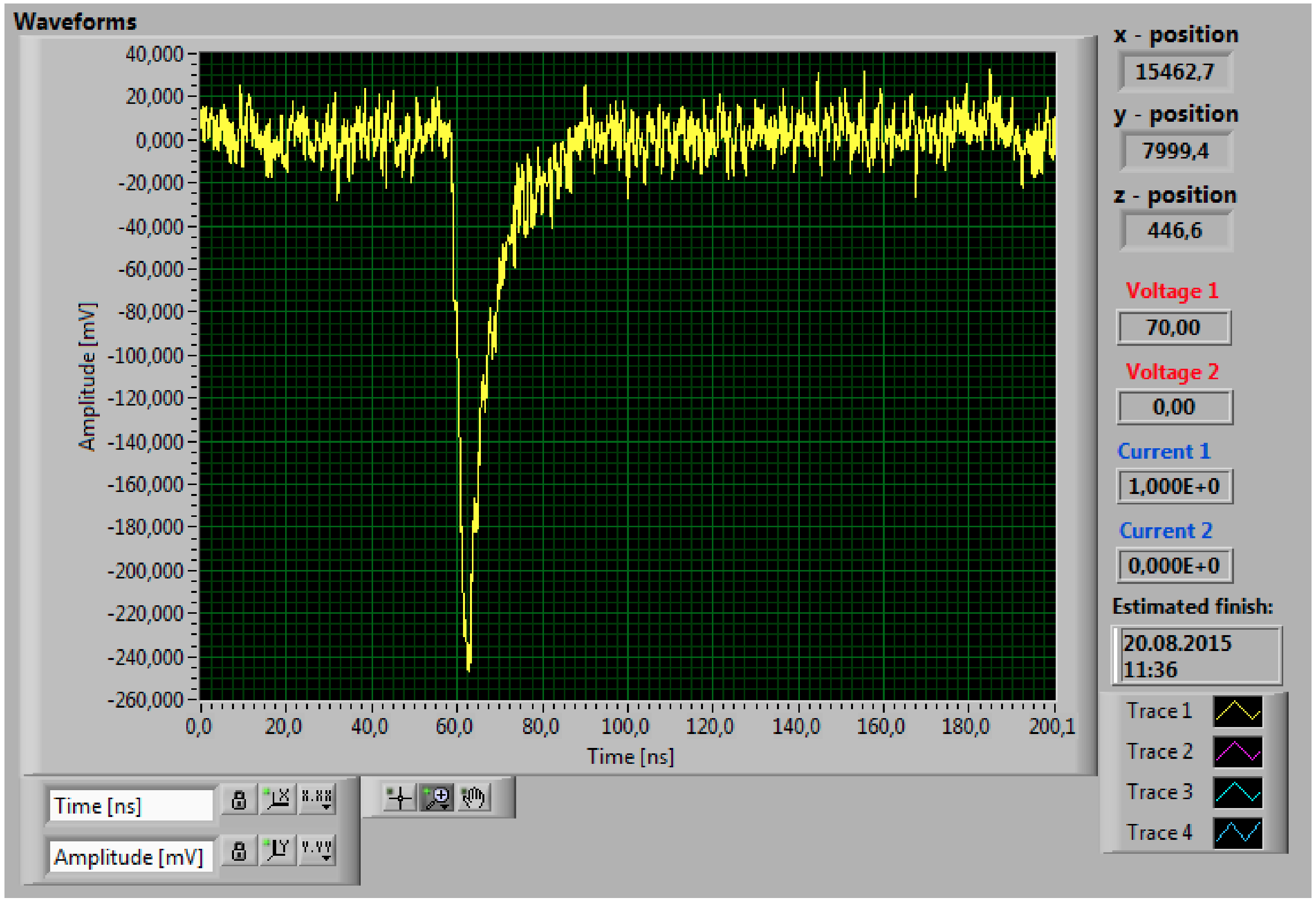
Constant charge density
→ Linear E-field
→ Exponential v_{drift}

E_w from a strip detector



How does a TCT signal look like?

In practice, with E_w from a strip detector, and transfer functions from electronics

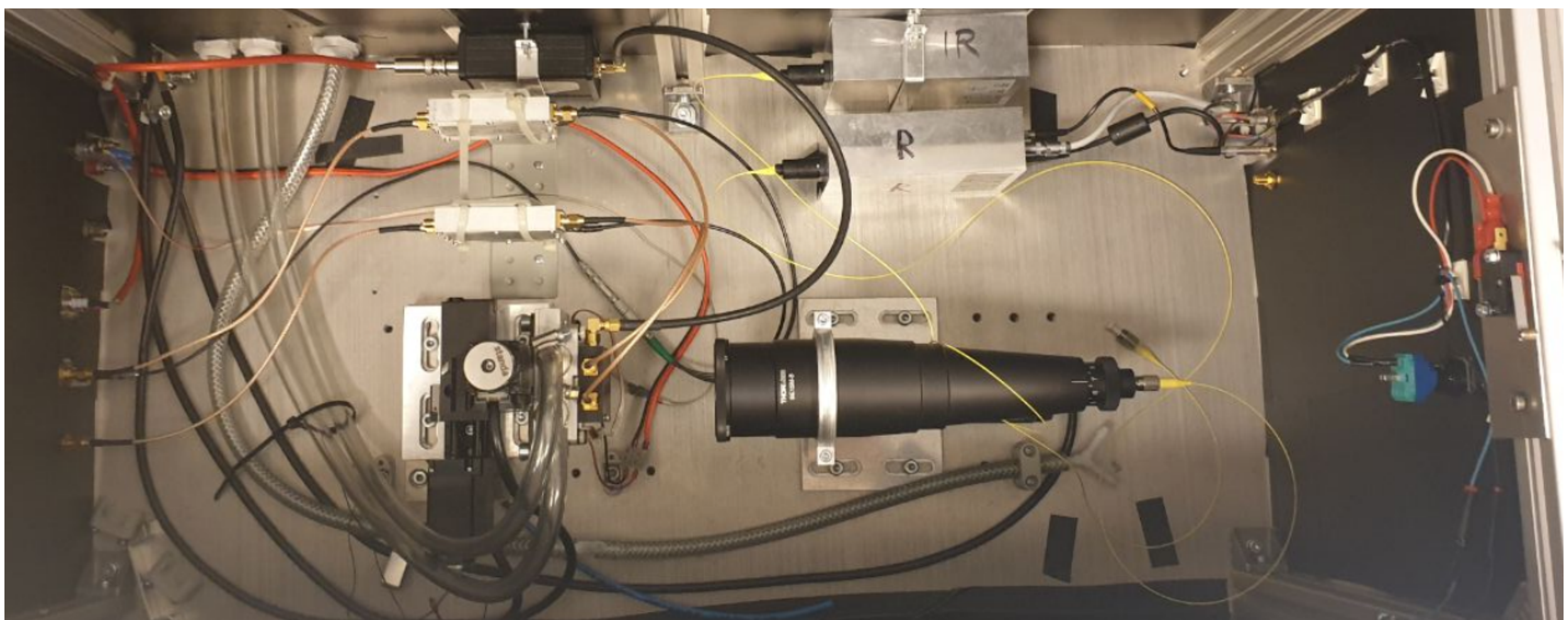


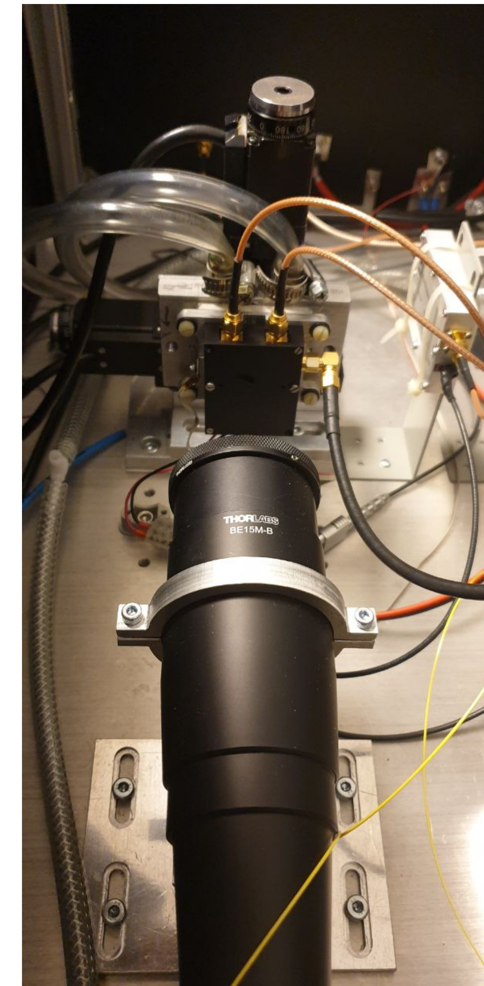
The TCT system at DESY

Acquired ~2013 (?) by Doris, vendor: Particulars Slovenia
http://particulars.si/

Assembled and complemented in 2014 by Hendrik

Used by Mykyta in 2015 and during EDIT school in 2020





The TCT system at DESY

Some specifications of interest

Component	Parameter	Properties
Laser		
	Laser diode	
	wavelength:	660 nm, 1064 nm (optional others)
	pulse power:	few m.i.p. - 100 m.i.p. (equivalent in 300 micron Si)
	pulse width:	<350 ps - 4000 ps (tunable)
	coupling:	single core fibre
	Driver	
	control:	with PC over USB
	running mode:	single pulse: 50 Hz - 1MHz
		patter mode: mHz to 100 kHZ
		1024 bits deep sequence of pulses
		minimum distance between two pulses 440 ns
	external control:	external NIM logical signal
	I/O:	ext. trigger in/trigger out MC/trigger out laser
Optics		
	beam spot (FWHM):	<11 microns@1064 nm, <8 microns@660 nm
	coupling:	fibre coupled
	attenuation:	through collimator on beam-expander
Mechanics		
	size:	
	translation:	3-axis computer controlled
	load/stage:	2 kg
	moving range:	5 cm x 5 cm x 5cm (x,y,z)
	position resolution:	< 1 micron
	Control:	via USB
Electronics		
	amplifier:	53 dB
	Bias-T range:	>1000 V
	frequency range:	<0.3 MHz->3000 MHz
Mounting brackets		
	cooling type:	Peltier element
	heat remover:	water / inlets provided
	cooling power:	40W (dT~40C)
	test sample box:	2.5x3 cm2 - other sizes optional
	mounting plane:	5 cm x 5 cm

Assorted features

Environmental

- cooling via Peltier element (-30 C)
- PID controller for Peltier
- Dry air from wall distributor
- Heat sink via Huber chiller

Positioning

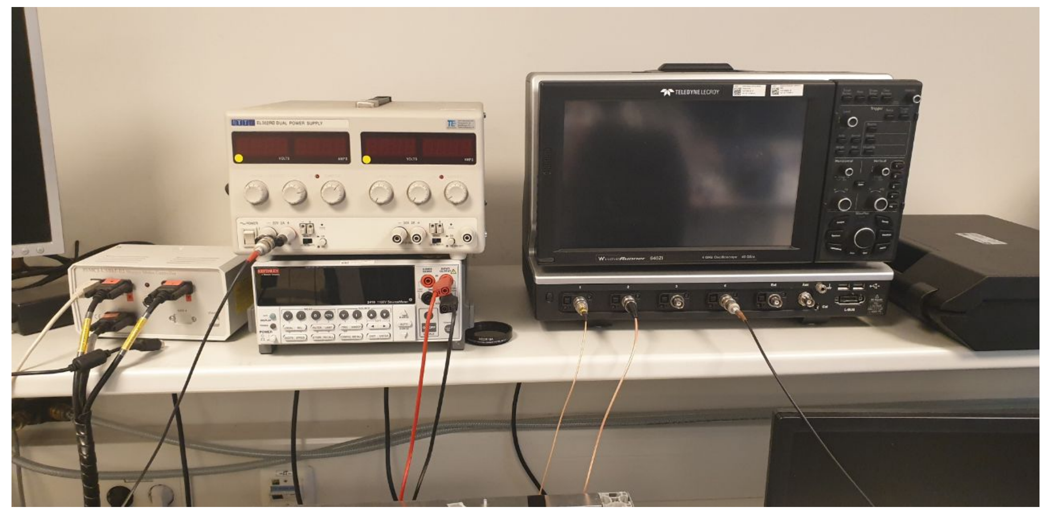
- x-y (sample) and z (optical distance)
- Via stepper, no driver for W10

Monitoring

- Beam splitter (10:90 and 50:50)
- Diode for shot-by-shot monitoring

Bias and readout

- Keithley 2410
- Wave Runner 640 Zi, 4 GHz, 40 GS/s
- Two 2 GHz amplifiers, ~50 dB
- LV power supply



NB: $t_{10\%-90\%} \approx 0.36 / 2\text{ GHz} = 180\text{ ps}$

Our PCB

Designed at DESY

For Top/Bottom/Edge-TCT

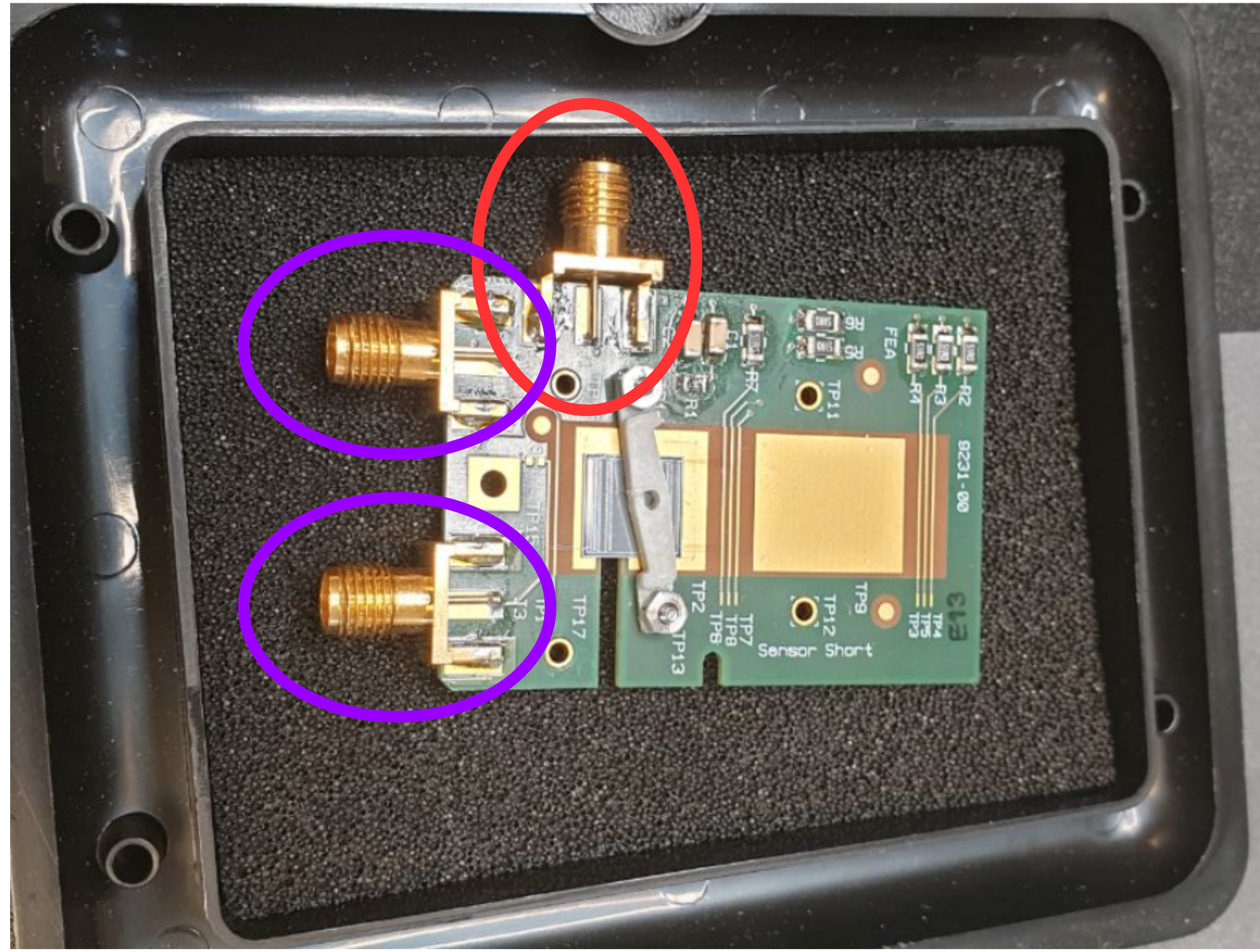
Usual sensor size:
10 mm x 10 mm

Up to 30 mm x 10 mm

Input: HV from J1

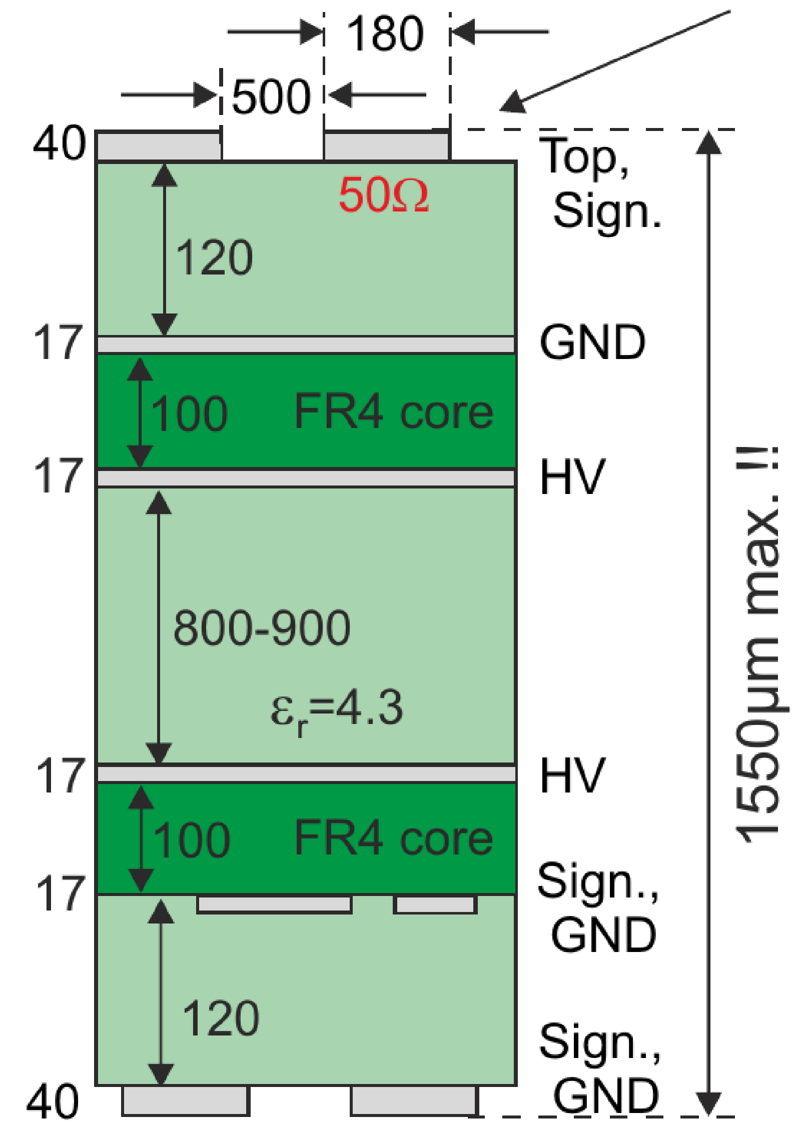
Output: Two signals

Hold-down clamp
→ No glue needed



Layer view

- High analogue bandwidth
- Flat (symmetric layers)
- Impedance-matched traces
- No “ringing” observed
  (as in many other setups)
- Bonding on traces instead of pads



PCB with mount

- 3D printed hold-down clamp

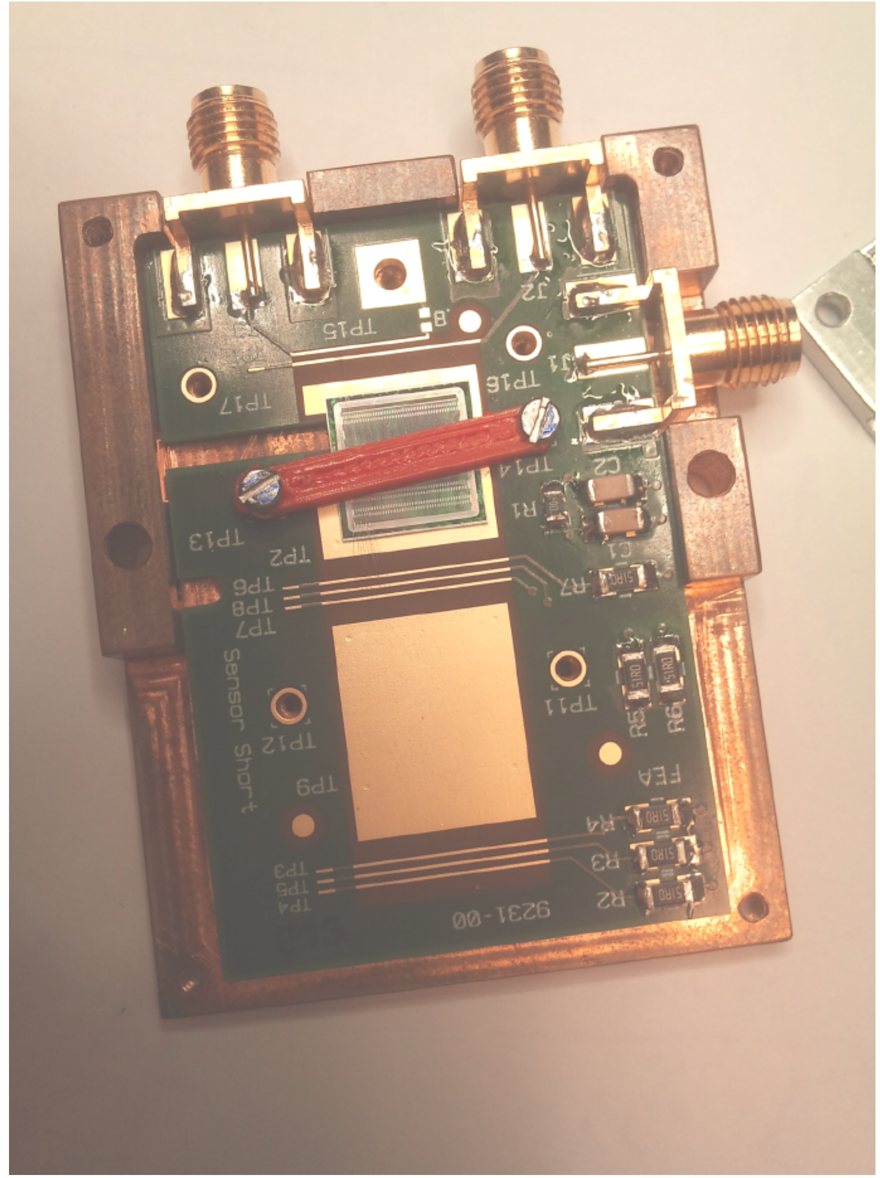
- One PCB per sensor

- Copper mount designed @UHH

- Need two mounts:

1) Measurement
2) Bonding

Openings for Top/Bottom/Edge TCT in mount and lit



The DAQ+C system

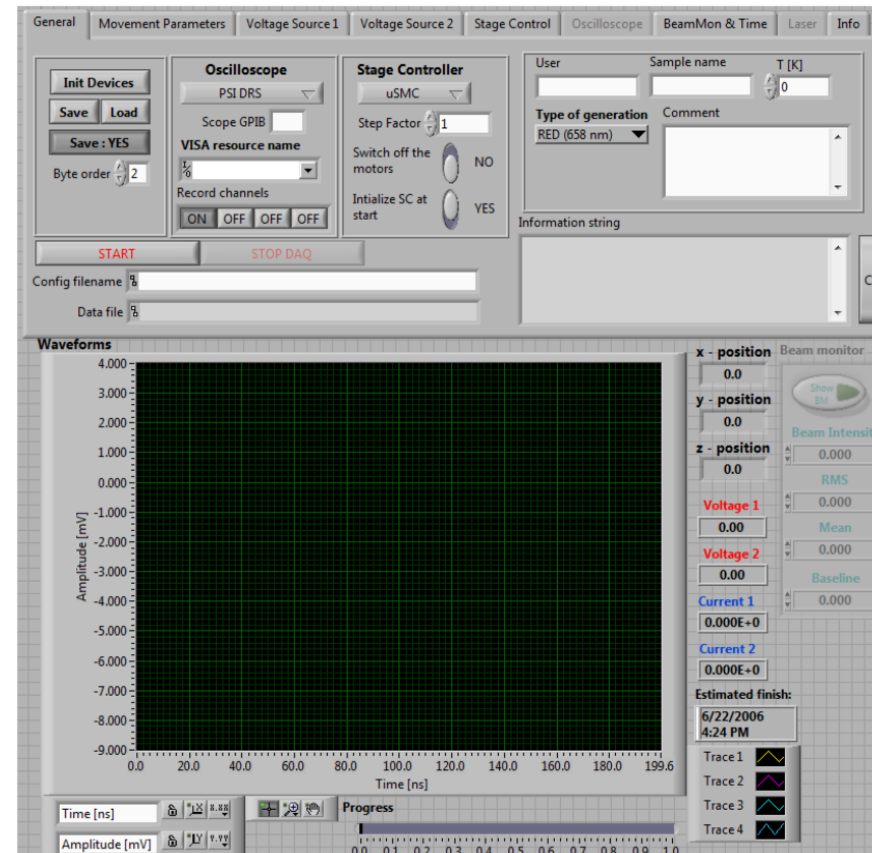
Interface b/w hardware and development environment

Is originally based on Scope + NI-VISA + LabView + Code by Gregor Kramberger
http://particulars.si/TCTAnalyse/index.html
(last changed in 2013 (?))

Manual from 2016

LV VI was always, and probably still is buggy

Allows for automated scanning in various dimensions (x,y,z, V_{bias})



Caveat

System is from ~2013, some parts from 200x.

Stepper for the stages is controlled via USB, need appropriate driver + FW.

“DAQ” is actually DAQ+Control system.

No driver update for W10, the W7 one did not work
- Either stick with a W7 PC + LV
→ No LAN connection, stuck in the past … and with W7 ...

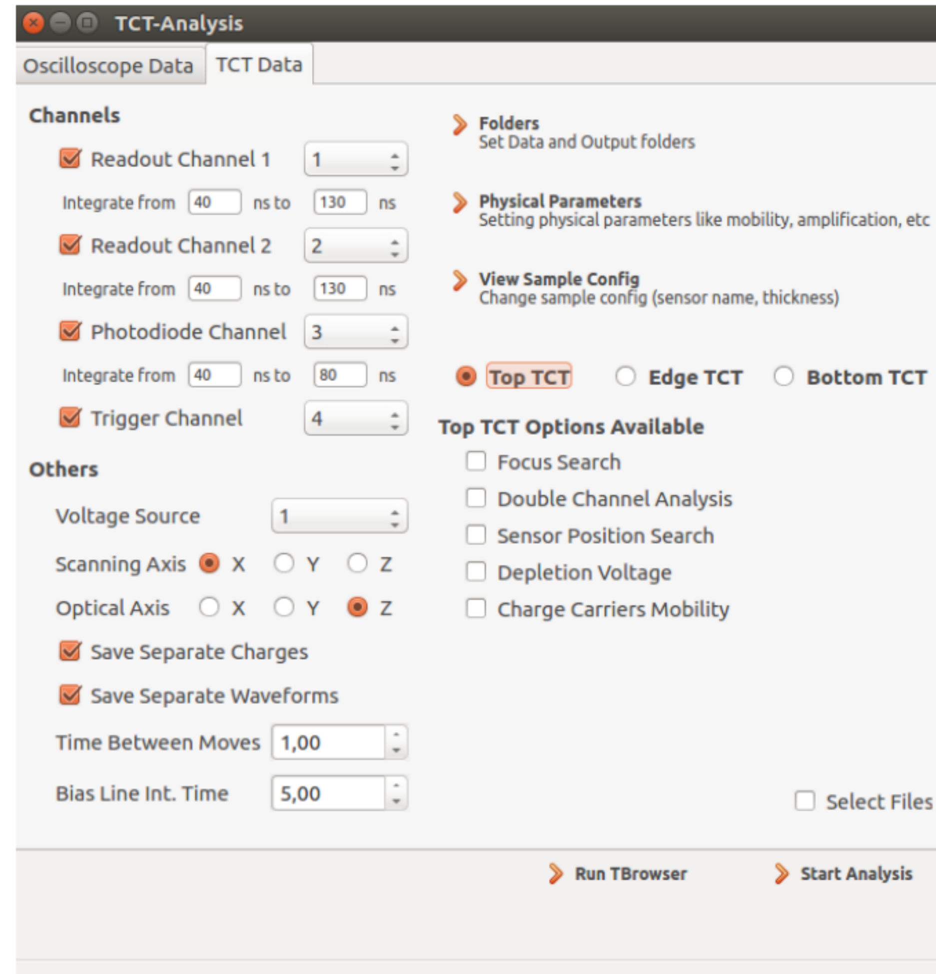
- Or, at least update the system (new stepper controller)
→ Spend money on new stepper (1000+ Euros), make sure that all components work under W10 (laser driver, temperature controller). Stuck with W10.

- And maybe, re-write the “DAQ+Control system” in C++ to avoid LV altogether
→ Spend time on DAQ+C system

The analysis framework

Mykyta and me:
Save binary from LabView
Use library from Gregor
Write perform analysis compiled C++/ROOT.
Cmake for creating make files, etc.

https://github.com/garankonic/TCT-analysis
(last edit 2017)

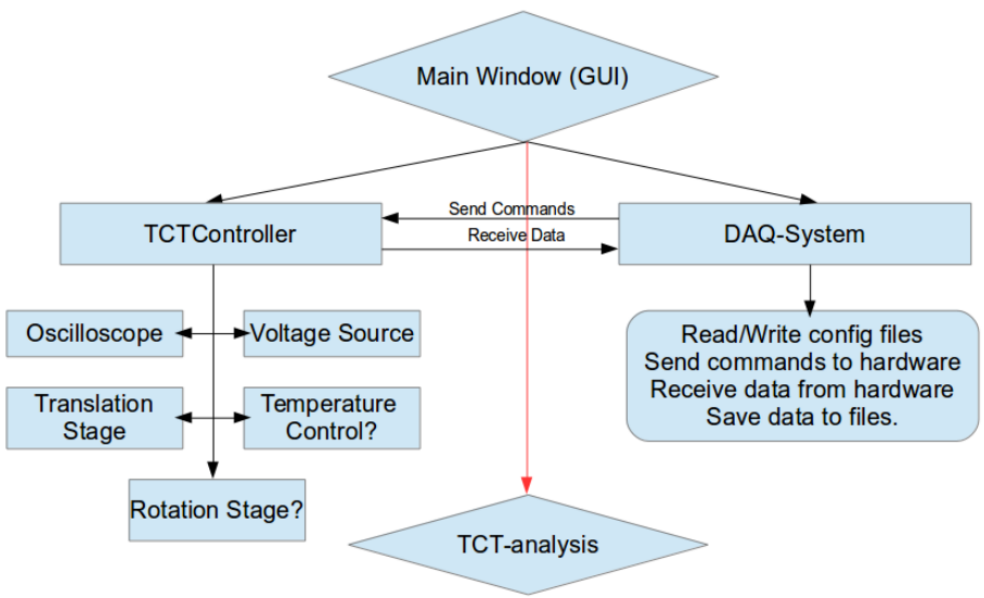


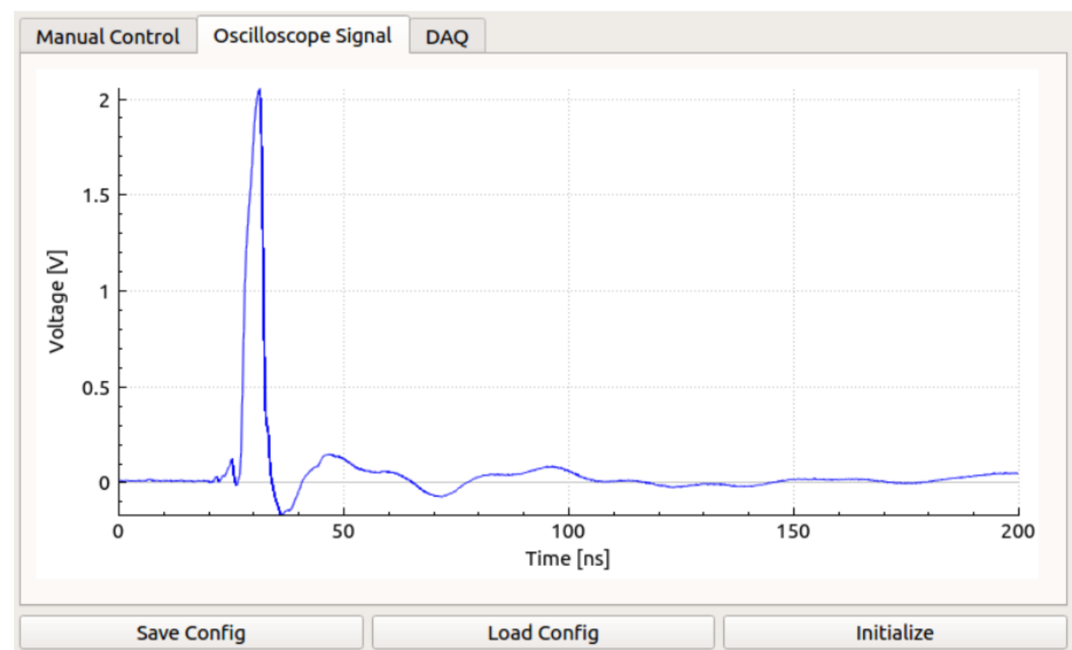
The DAQ system 2

In 2017, Oleksandr started a C++ based DAQ+C as summer student project. https://github.com/korostysh/TCT-daq

Communication with oscilloscope is based on "LeCroy X-Stream Oscilloscopes Remote Control ". http://cdn.teledynelecroy.com/files/manuals/wm-rcm-e_rev_d.pdf

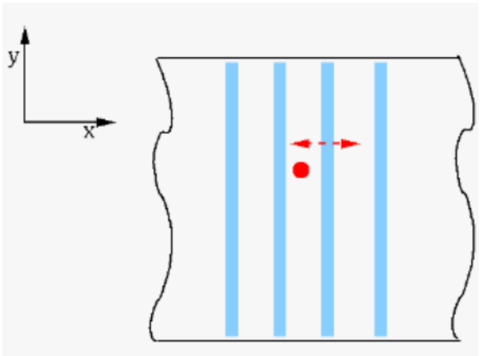
AFAIK, there is no manual or documentation.



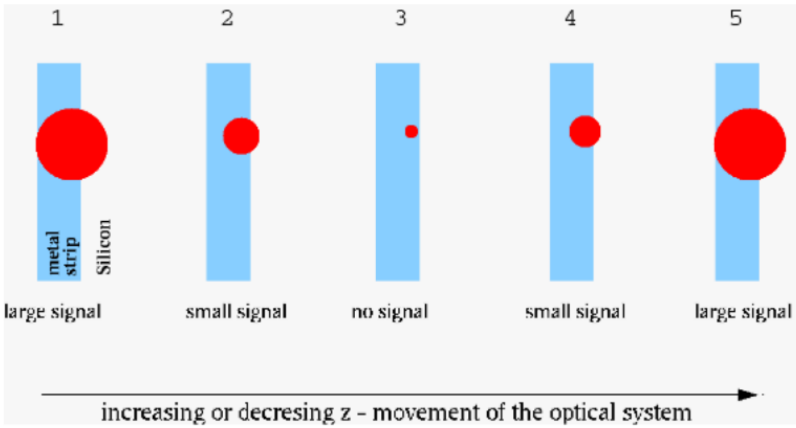


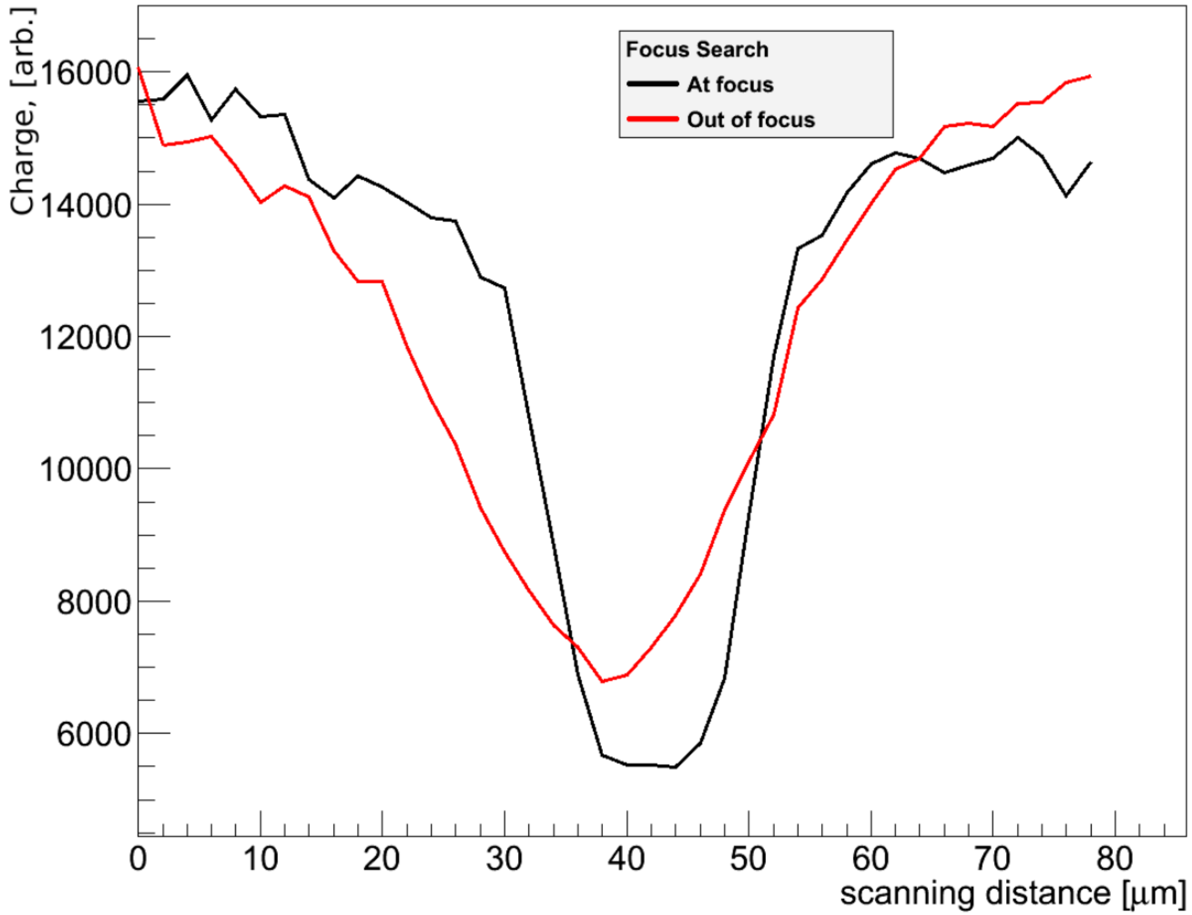
What was achieved in 2015? Top TCT

Scan along surface, perform focus finding



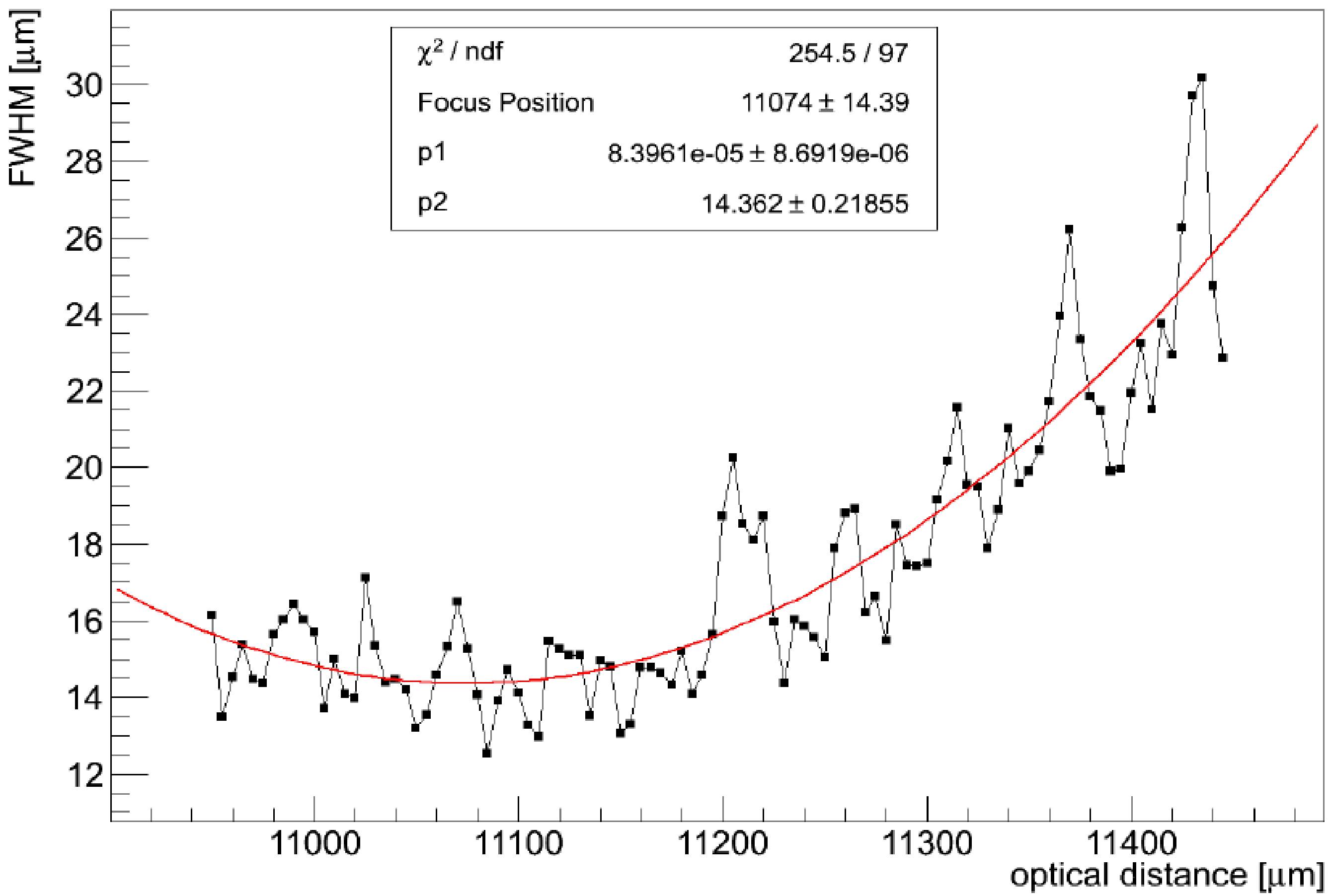
(a) Scan along X axis.





What was achieved in 2015? Top TCT

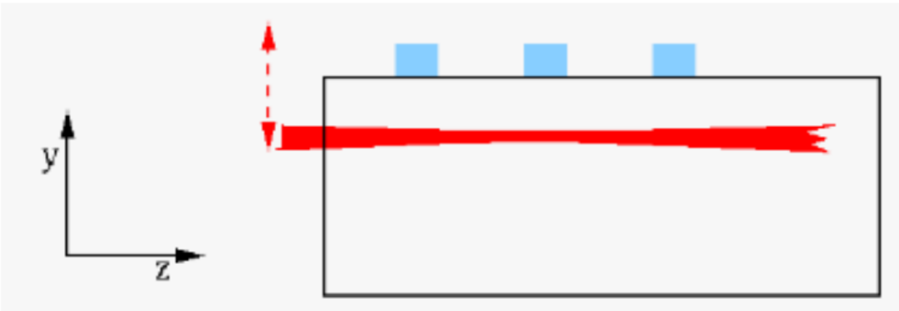
Minimum of “FWHM” finds position with focus at sensor surface

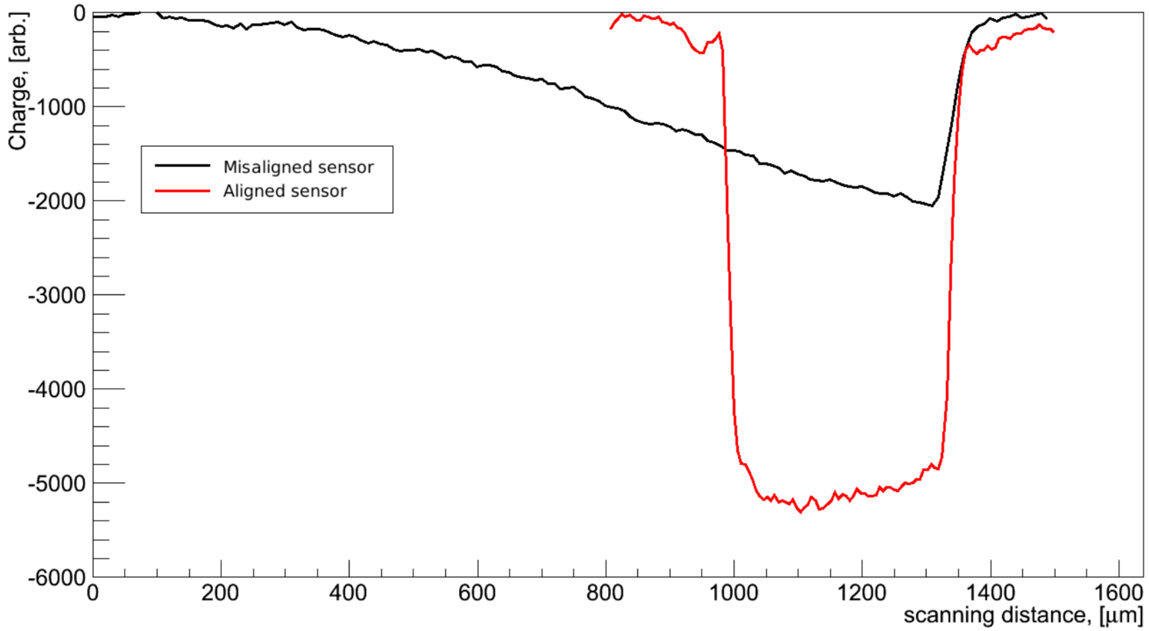


Probably, FWHM is the sum of the widths for Erf-Fit of left and right edge

Edge TCT

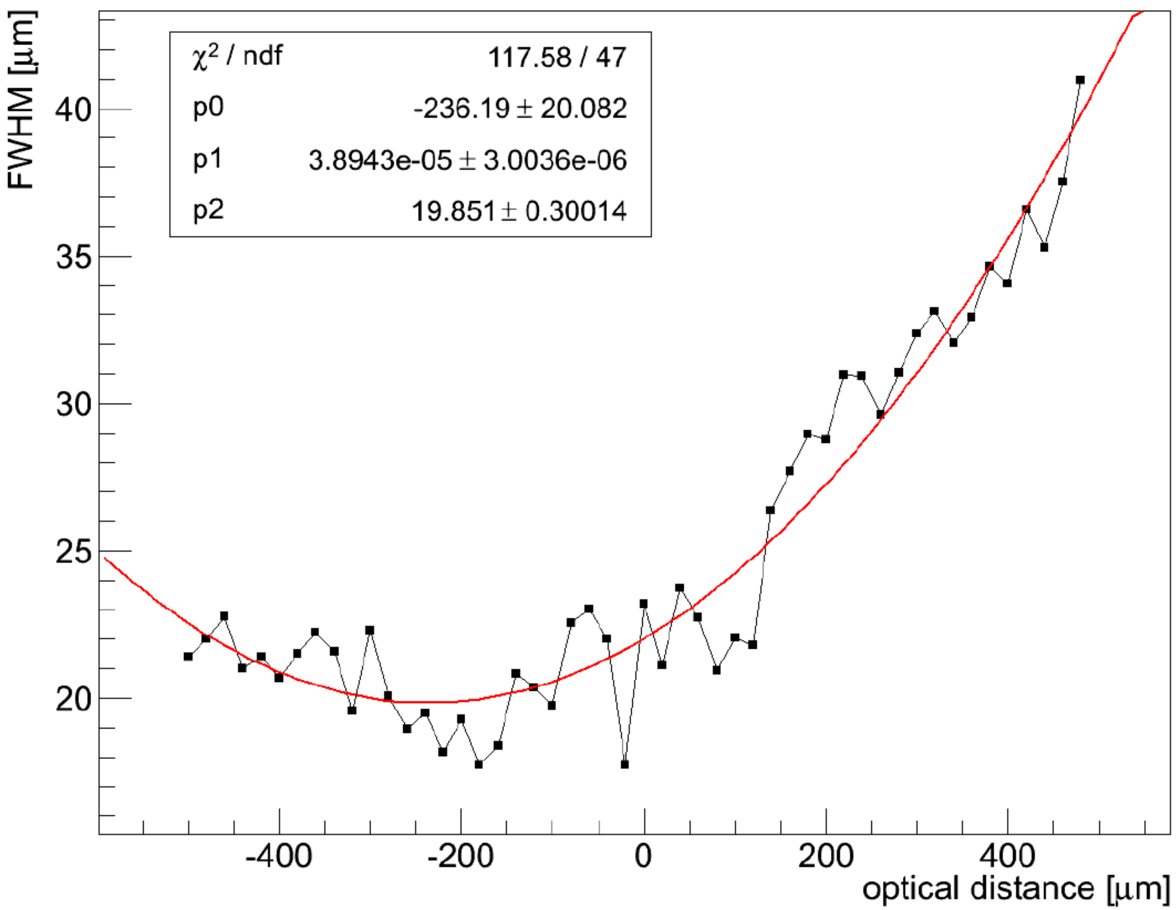
Shoot from the side, scan along depth, perform focus finding





Edge TCT

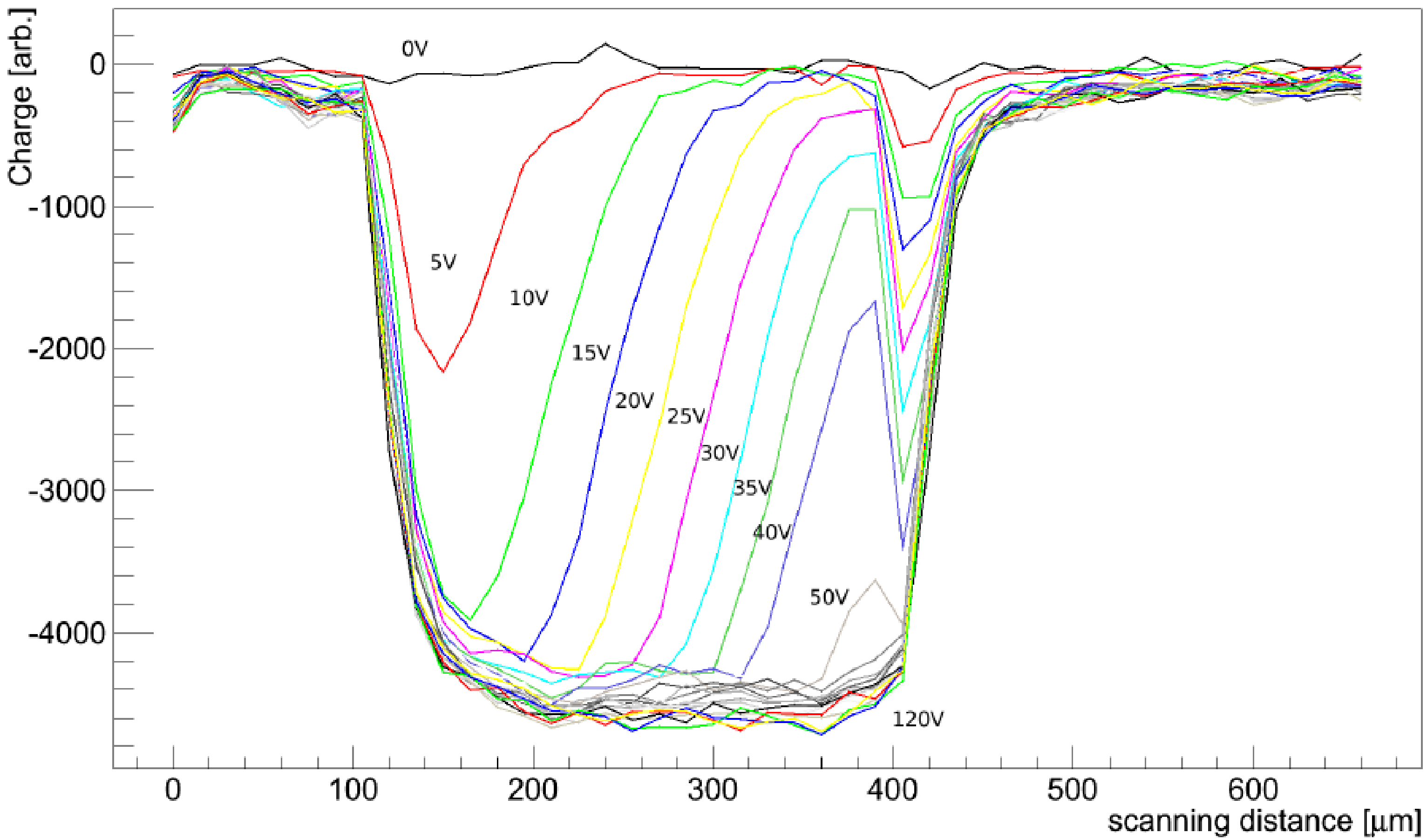
Minimum of FWHM finds position with focus below connected strip



Probably, FWHM is the sum of the widths for Erf-Fit of left and right edge

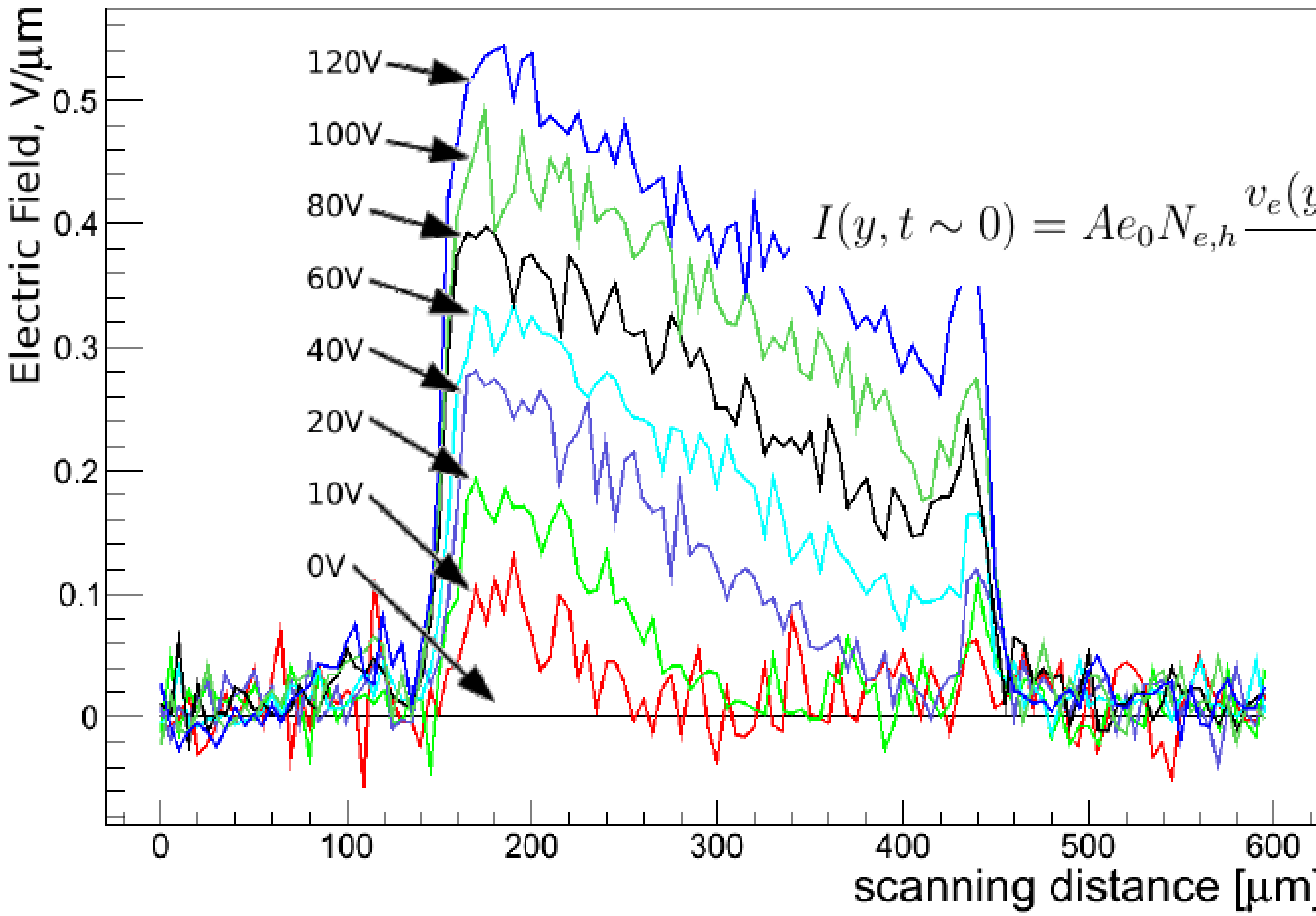
Edge TCT

Charge profiles along depth: Integrate current pulse for each position



Edge TCT

Electric field profiles along depth using the initial current



What is the trick here?

$$I(y, t\sim 0) = Ae_0 N_{e,h} \frac{v_e(y) + v_h(y)}{W} = Ae_0 N_{e,h} \frac{\mu_e(y) + \mu_h(y)}{W} E(y).$$

$$V_{bias} = \int_0^W E(y)dy.$$

Conclusion

TCT measurements can yield important insights to your device.

TCT measurements are to be interpreted with care!

The system has slightly aged …

DAQ+C never worked like a charm … needs effort for scientific use.