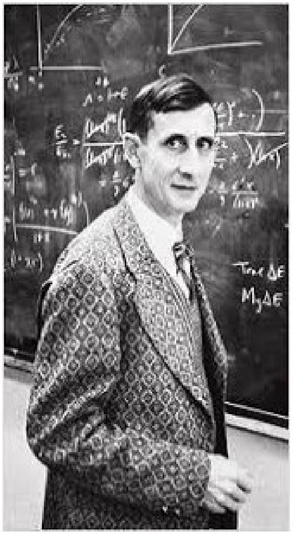
Instrumentation breakthroughs in RD50 collaboration

Marcos Fernández García
IFCA Santander & CERN-SSD

43rd RD50 Workshop – 28th Nov-Dec 1st 2023 - CERN



New directions in science are launched by **new tools, much more often than by new concepts**. The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained.

Freeman Dyson

Outline

- New Tools developed within RD50 framework:
  LGAD → *Enabling 4D tracking* in HEP (see dedicated talk by G. Pellegrini)
  edge-TCT
  TPA-TCT → *Enabling 3D characterization* of silicon detectors

- Readout Tools for silicon sensors, developed within RD50 collaboration:
  Alibava, Caribou (partially)

- Existing Technologies adapted to RD50 needs :
  DLTS & TSC → See Iona Pintille's talk

- Instrumentation enabling precise measurements:
  Decoupling box for CV measurements
  Off-the-shelf sub-ns pulsed laser

- Standardization RD50 measurement protocols

Transient Current methods, first steps

- Reverse citation search points at early 1960’s as the genesis of experimental TCT, with the development of the time of flight method to study drift velocity in silicon

1961-1965 **1968** **1971**

1st Theoretical

NUCLEAR INSTRUMENTS AND METHODS **12** (1961) 278–290; NORTH-HOLLAND PUBLISHING CO.

TRANSIT TIME OF CHARGE CARRIERS IN THE SEMICONDUCTOR IONIZATION CHAMBER

P. A. TOVE and K. FALK

Institute of Physics, University of Uppsala, Uppsala, Sweden

Received 31 January 1961

The transit time of charge carriers and the resulting pulse rise time are considered theoretically for a semiconductor particle detector, with particular reference to silicon detectors. Results

1st Experimental

REFERENCES

1. A. Alberigi Quaranta, M. Martini and F. Cipolla, *Phys. Lett.* **17**, 2, 102 (1965).
2. A. Alberigi Quaranta, M. Martini, G. Ottaviani, G. Redaelli and G. Zanarini, To be published in the *Proceedings of the Semiconductor Nuclear Particle Detectors and Circuits Conference*, Gatlinburg, Tennessee (1967).

Only a tiny fraction of the extensive body of work carried out

Solid-State Electronics Pergamon Press 1968. Vol. 11, pp. 685–696. Printed in Great Britain

A. Alberigi Quaranta, M. Martini, G. Ottaviani, G. Redaelli, G. Zanarini

EXPERIMENTAL RESULTS ON THE DRIFT VELOCITY OF HOT CARRIERS IN SILICON AND ASSOCIATED ANISOTROPIC EFFECTS

The method is based on the use of inversely biased junctions where it is possible to create a high number of electrons and holes by means of ionizing radiations.

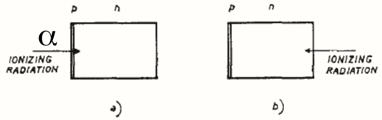
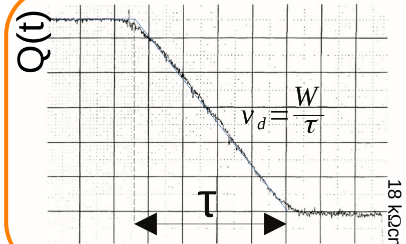


Fig. 1. Schematic view of the situation of ionizing radiation impinging (*a*) near the metallurgical junction; (*b*) at the opposite side of the space charge region.



$v_d = \frac{W}{\tau}$

18 kΩcm

Fig. 3. A typical recorded pulse. Horizontal scale: 2 nsec/major division.

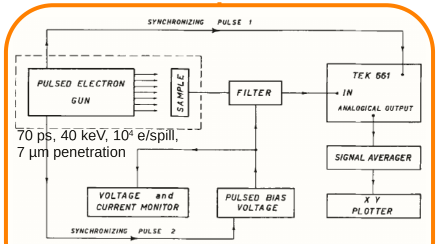
J. Ph. Chem. Solids Pergamon Press 1971. Vol. 32, pp. 1707–1720. Printed in Great Britain.

DRIFT VELOCITY OF ELECTRONS AND HOLES AND ASSOCIATED ANISOTROPIC EFFECTS IN SILICON*

C. CANALI, G. OTTAVIANI and A. ALBERIGI QUARANTA

Istituto di Fisica, Università di Modena, Via Vivaldi 70, Modena, Italy

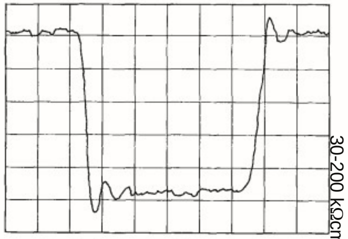
(*Received* 10 *August* 1970; *in revised form* 23 *November* 1970)



70 ps, 40 keV, 10^4 e/spill,
7 µm penetration

Fig. 2. Block diagram of the experimental setup.

Signal Averager Computer ND-801 is unknown to Google



30-200 kΩcm

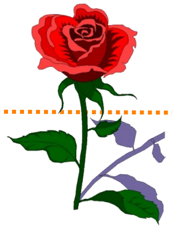
Fig. 3. Typical waveform of the current signal due to electron transport at 300°K. The width of the diode is 500 μm, and the applied voltage is 1250 V. The drift velocity obtained from this signal is $9 \cdot 23 \times 10^6$ cm/sec. Horizontal Sensitivity 1 ns./division.

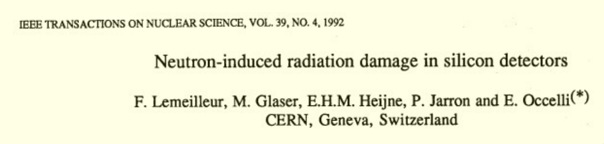
Measurements between 0.01 - 5 V/µm
T=77-300 K

90's: TCT methods introduced in RD48 and used/developed heavily since then

1992

1993



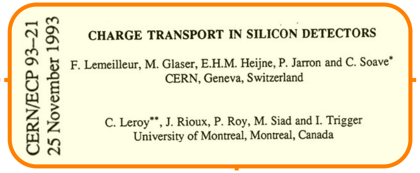


IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 39, NO. 4, 1992

Neutron-induced radiation damage in silicon detectors

F. Lemeilleur, M. Glaser, E.H.M. Heijne, P. Jarron and E. Occelli(*)
CERN, Geneva, Switzerland

α,β particles

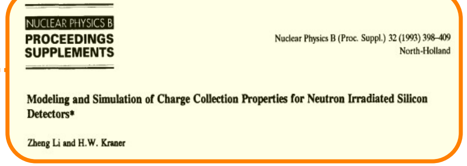


CERN/ECP 93–21
25 November 1993

CHARGE TRANSPORT IN SILICON DETECTORS

F. Lemeilleur, M. Glaser, E.H.M. Heijne, P. Jarron and C. Soave*
CERN, Geneva, Switzerland

C. Leroy**, J. Rioux, P. Roy, M. Siad and I. Trigger
University of Montreal, Montreal, Canada

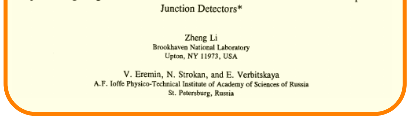


NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

Nuclear Physics B (Proc. Suppl.) 32 (1993) 398–409
North-Holland

Modeling and Simulation of Charge Collection Properties for Neutron Irradiated Silicon Detectors*

Zheng Li and H.W. Kraner

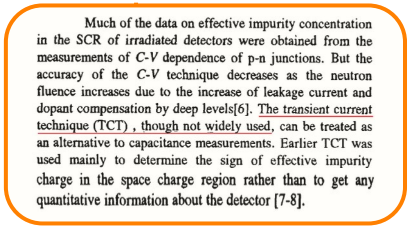


IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 40, NO. 4, AUGUST 1993 367

Investigation of the Type Inversion Phenomena: Resistivity and Carrier Mobility in the Space Charge Region and Electrical Neutral Bulk in Neutron Irradiated Silicon p^+-n Junction Detectors*

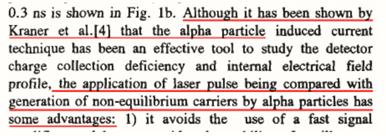
Zheng Li
Brookhaven National Laboratory
Upton, NY 11973, USA

V. Eremin, N. Strokan, and E. Verbitskaya
A.F. Ioffe Physico-Technical Institute of Academy of Sciences of Russia
St. Petersburg, Russia



Much of the data on effective impurity concentration in the SCR of irradiated detectors were obtained from the measurements of C-V dependence of p-n junctions. But the accuracy of the C-V technique decreases as the neutron fluence increases due to the increase of leakage current and dopant compensation by deep levels[6]. The transient current technique (TCT), though not widely used, can be treated as an alternative to capacitance measurements. Earlier TCT was used mainly to determine the sign of effective impurity charge in the space charge region rather than to get any quantitative information about the detector [7-8].

1st Laser TCT



0.3 ns is shown in Fig. 1b. Although it has been shown by Kraner et al.[4] that the alpha particle induced current technique has been an effective tool to study the detector charge collection deficiency and internal electrical field profile, the application of laser pulse being compared with generation of non-equilibrium carriers by alpha particles has some advantages: 1) it avoids the use of a fast signal

MIP-like

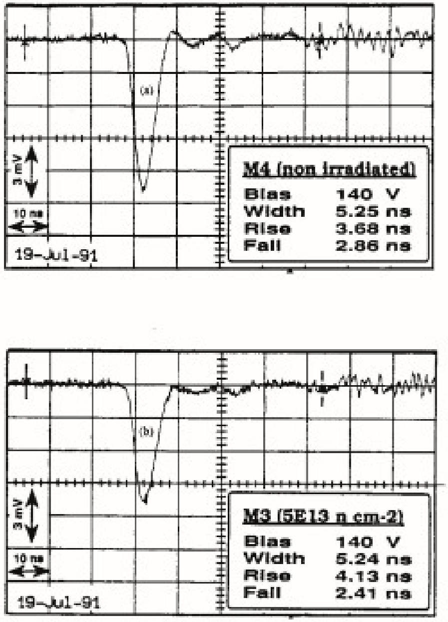


Fig. 13 Typical time development of the signal current response to relativistic electrons: (a) for a non-irradiated diode, (b) for an irradiated one (5.10^{13} n cm^{-2}).

α-back injection

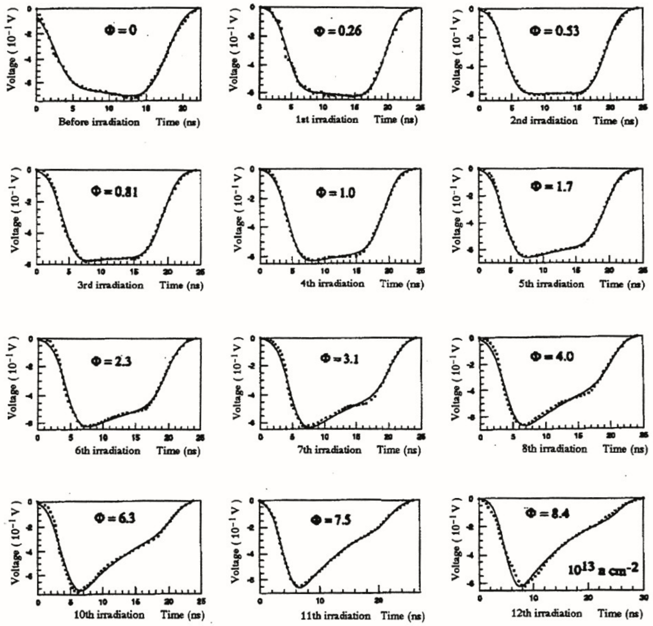
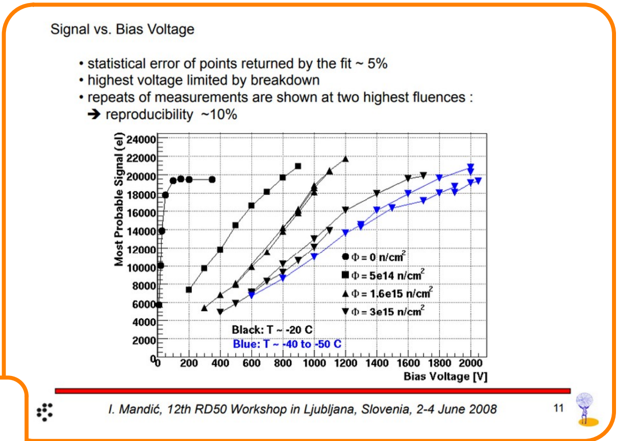


Fig. 9 Fits (full line) of the current pulse response to α particles incident on the back side of a 317 µm thick detector (M4), biased at 160 V, and for successive levels of fluence ϕ up to 8.4×10^{13} n cm^{-2}.

Just picked 4 examples from **many** available.

“… new directions in science are launched by new tools”

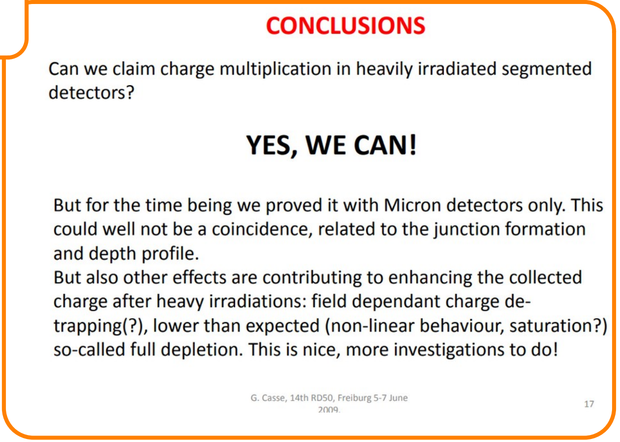
- In **2008-2009** puzzling results from measurements of charge collection for irradiated detectors at HV. Not only charge is recovered but increased!


Signal vs. Bias Voltage

- statistical error of points returned by the fit ~ 5%
- highest voltage limited by breakdown
- repeats of measurements are shown at two highest fluences : ➔ reproducibility ~10%

I. Mandić, 12th RD50 Workshop in Ljubljana, Slovenia, 2-4 June 2008 11

Micron μstrips, FZ, p-type, 300 μm, 1 cm^2


CONCLUSIONS

Can we claim charge multiplication in heavily irradiated segmented detectors?

YES, WE CAN!

But for the time being we proved it with Micron detectors only. This could well not be a coincidence, related to the junction formation and depth profile.
But also other effects are contributing to enhancing the collected charge after heavy irradiations: field dependant charge de-trapping(?), lower than expected (non-linear behaviour, saturation?) so-called full depletion. This is nice, more investigations to do!

G. Casse, 14th RD50, Freiburg 5-7 June 2009 17

- In 2009 JSI-Ljubljana presented a new tool to study E-field of segmented detectors and study multiplication
- Inspired in grazing angle technique for pixel detector

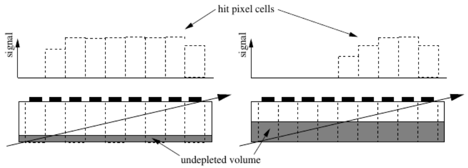
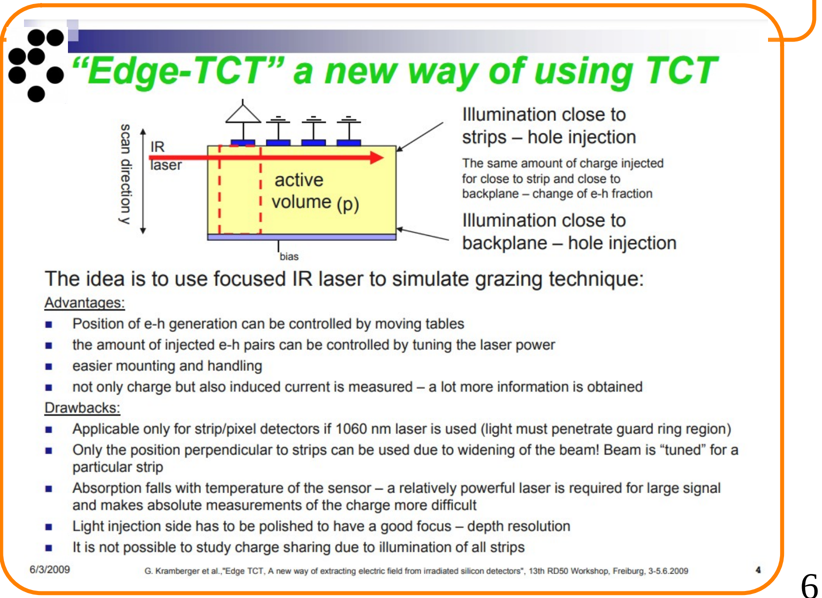


Fig. 2.16. The grazing angle method for the study of sensor depletion. An ionizing beam crosses several pixels at a shallow angle. The cluster size is used to determine the depletion depth. The situation for two different depletion depths is shown

Pixel detectors from fundamentals to applications
L. Rossi, P. Fischer, T. Rohe, N. Wermes

Grazing angle: powerful technique, but requires specialized equipment: TB & telescope

14th RD50, 2009


“Edge-TCT” a new way of using TCT

Illumination close to strips – hole injection

The same amount of charge injected for close to strip and close to backplane – change of e-h fraction

Illumination close to backplane – hole injection

The idea is to use focused IR laser to simulate grazing technique:

Advantages:

- Position of e-h generation can be controlled by moving tables
- the amount of injected e-h pairs can be controlled by tuning the laser power
- easier mounting and handling
- not only charge but also induced current is measured – a lot more information is obtained

Drawbacks:

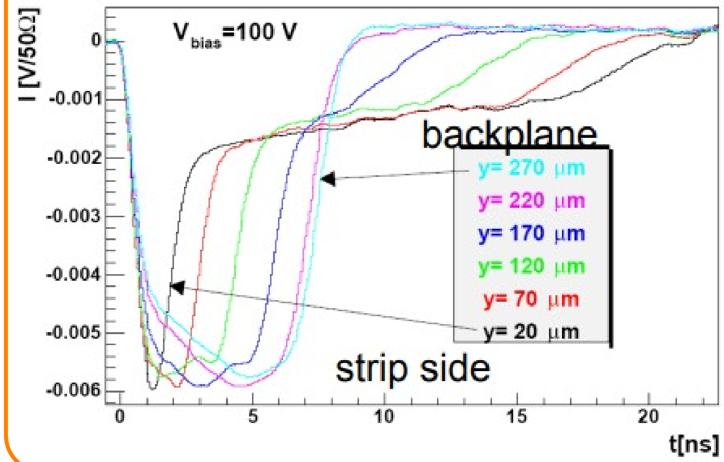
- Applicable only for strip/pixel detectors if 1060 nm laser is used (light must penetrate guard ring region)
- Only the position perpendicular to strips can be used due to widening of the beam! Beam is “tuned” for a particular strip
- Absorption falls with temperature of the sensor – a relatively powerful laser is required for large signal and makes absolute measurements of the charge more difficult
- Light injection side has to be polished to have a good focus – depth resolution
- It is not possible to study charge sharing due to illumination of all strips

6/3/2009 G. Kramberger et al.,"Edge TCT, A new way of extracting electric field from irradiated silicon detectors", 13th RD50 Workshop, Freiburg, 3-5.6.2009 4

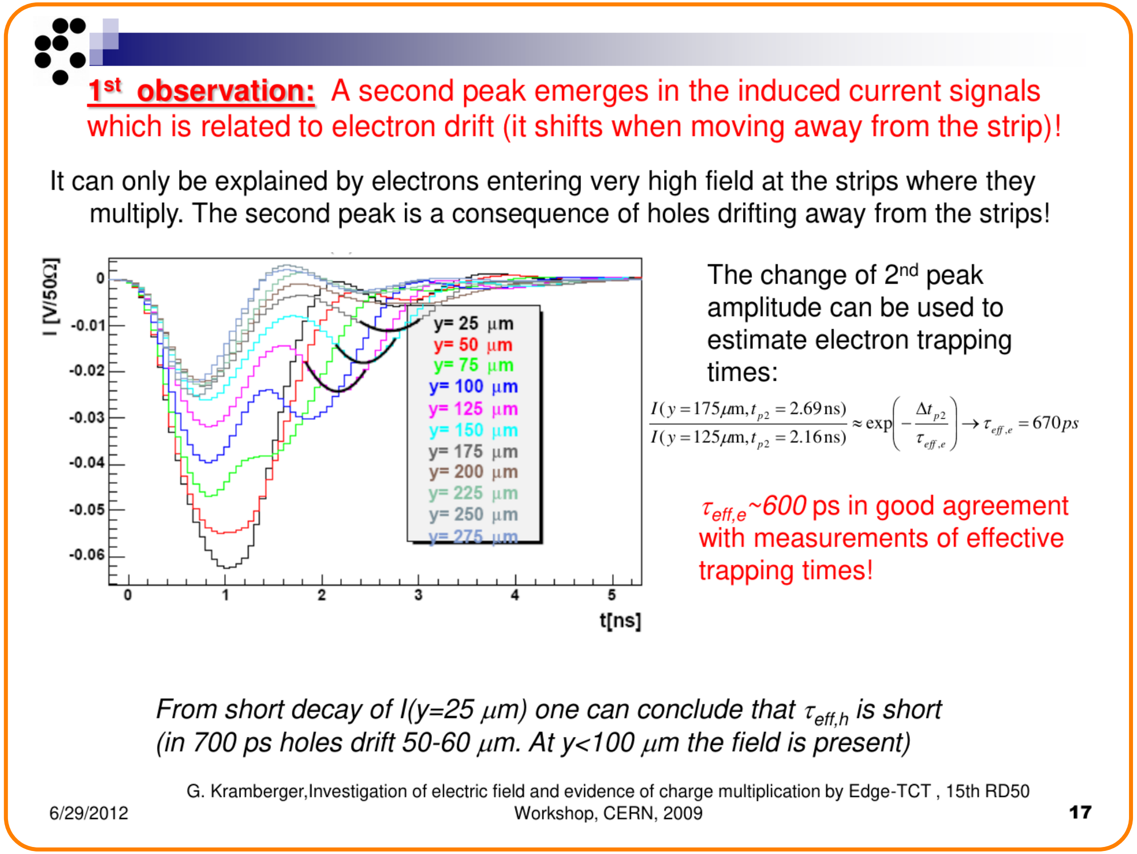
Edge-TCT: new tool developed in RD50

- Edge-TCT surpasses normal incidence TCT by adding resolution throughout the bulk and introducing new analysis tools

15th RD50, 2010



Already “raw data” clearly shows distinctive electron and hole separation



1st observation: A second peak emerges in the induced current signals which is related to electron drift (it shifts when moving away from the strip)!

It can only be explained by electrons entering very high field at the strips where they multiply. The second peak is a consequence of holes drifting away from the strips!

The change of 2nd peak amplitude can be used to estimate electron trapping times:

$$\frac{I(y=175\mu\mathrm{m}, t_{p2}=2.69\,\mathrm{ns})}{I(y=125\mu\mathrm{m}, t_{p2}=2.16\,\mathrm{ns})} \approx \exp\left(-\frac{\Delta t_{p2}}{\tau_{eff,e}}\right) \rightarrow \tau_{eff,e}=670ps$$

$\tau_{eff,e}$~600 ps in good agreement with measurements of effective trapping times!

From short decay of I(y=25 µm) one can conclude that $\tau_{eff,h}$ is short (in 700 ps holes drift 50-60 µm. At y<100 µm the field is present)

6/29/2012

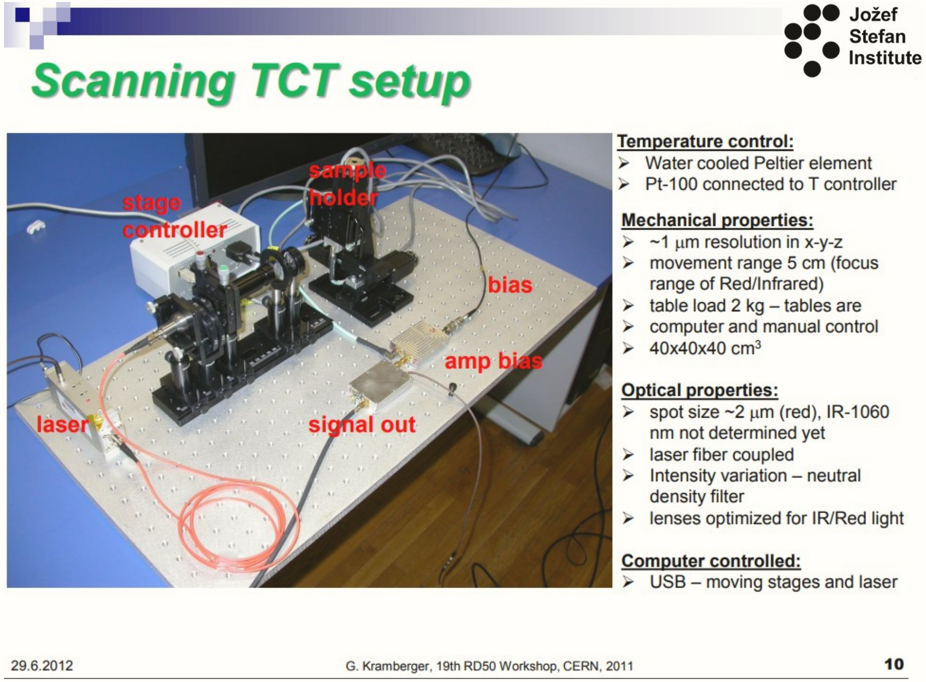
G. Kramberger, Investigation of electric field and evidence of charge multiplication by Edge-TCT , 15th RD50 Workshop, CERN, 2009

17

Edge-TCT evolution: from tabletop prototype to commercial

2011 **2013-….**

19th RD50, 2011 “A Low-Cost scanning TCT setup”



Scanning TCT setup

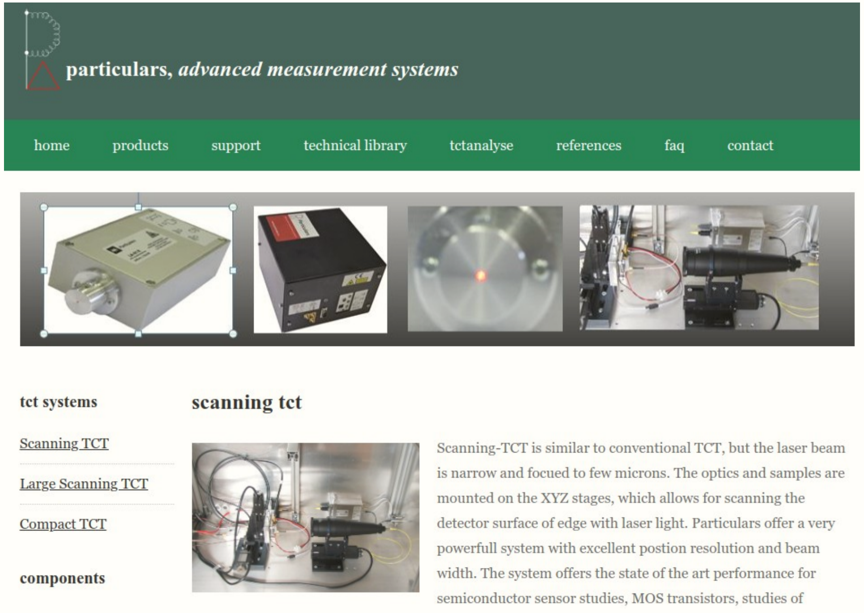
Temperature control:
- Water cooled Peltier element
- Pt-100 connected to T controller

Mechanical properties:
- ~1 μm resolution in x-y-z
- movement range 5 cm (focus range of Red/Infrared)
- table load 2 kg – tables are
- computer and manual control
- 40x40x40 cm^3

Optical properties:
- spot size ~2 μm (red), IR-1060 nm not determined yet
- laser fiber coupled
- Intensity variation – neutral density filter
- lenses optimized for IR/Red light

Computer controlled:
- USB – moving stages and laser

29.6.2012 G. Kramberger, 19th RD50 Workshop, CERN, 2011 10



scanning tct

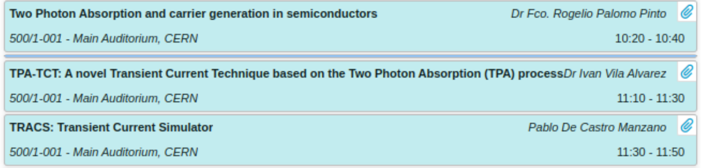
Scanning-TCT is similar to conventional TCT, but the laser beam is narrow and focued to few microns. The optics and samples are mounted on the XYZ stages, which allows for scanning the detector surface of edge with laser light. Particulars offer a very powerfull system with excellent postion resolution and beam width. The system offers the state of the art performance for semiconductor sensor studies, MOS transistors, studies of

Since 2013, Particulars supplies custom made HW & SW for turn-key TCT/edge-TCT

Two Photon Absorption-TCT

- 2013-2014: TPA-TCT emerged from the integration of TCT techniques for testing the bulk of silicon sensors with the application of TPA to detect Single Event Upsets in electronics.
- Non-linear laser absorption leads to carrier generation confinement along the beam propagation direction: 3D laser resolution

15th RD50, 2014



Two Photon Absorption and carrier generation in semiconductors	*Dr Fco. Rogelio Palomo Pinto*
500/1-001 - Main Auditorium, CERN	10:20 - 10:40
TPA-TCT: A novel Transient Current Technique based on the Two Photon Absorption (TPA) process	*Dr Ivan Vila Alvarez*
500/1-001 - Main Auditorium, CERN	11:10 - 11:30
TRACS: Transient Current Simulator	*Pablo De Castro Manzano*
500/1-001 - Main Auditorium, CERN	11:30 - 11:50

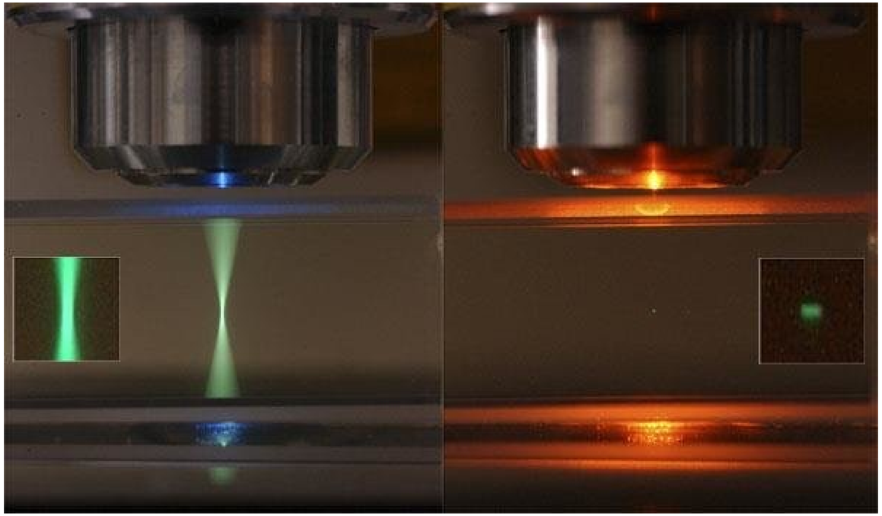
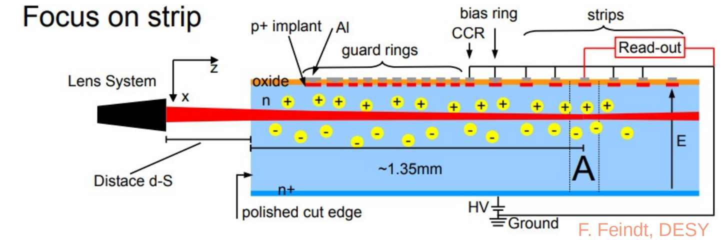


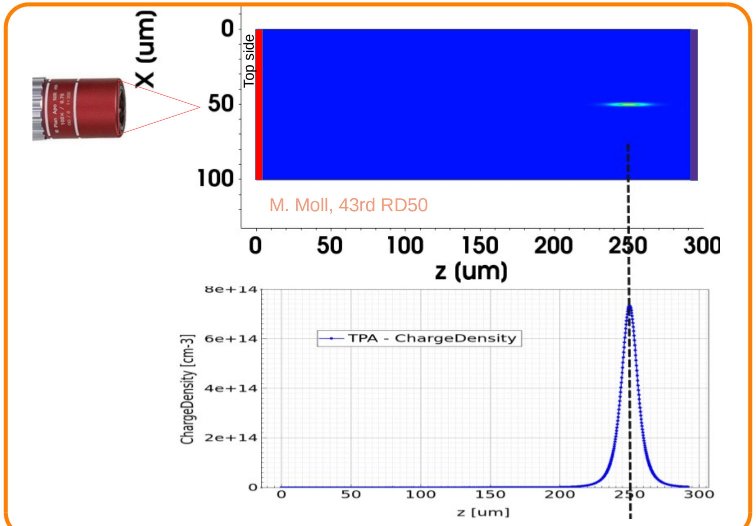
Image by: Steve Ruzin and Holly Aaron, UC Berkeley

Edge-TCT



F. Feindt, DESY

Two Photon Absorption-TCT



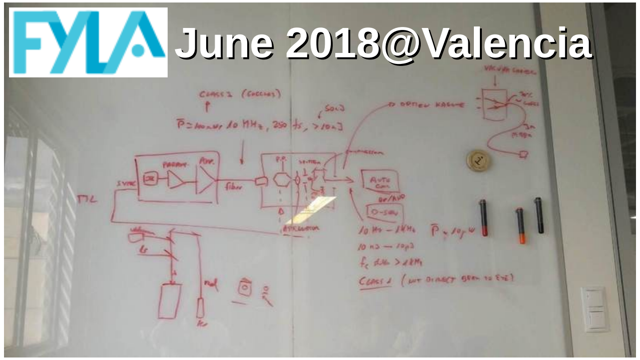
M. Moll, 43rd RD50

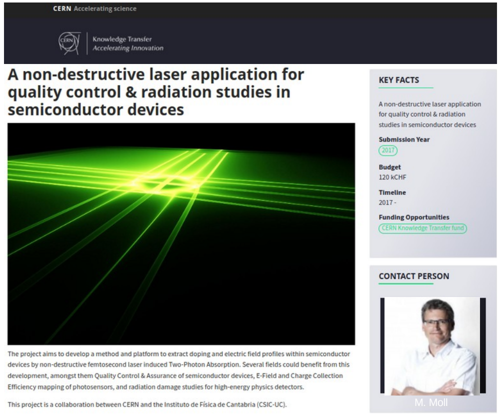
TPA-TCT journey: from concept to commercialization to precise measurements

2018

2019

2022


June 2018@Valencia


CERN Accelerating science

A non-destructive laser application for quality control & radiation studies in semiconductor devices

The project aims to develop a method and platform to extract doping and electric field profiles within semiconductor devices by non-destructive femtosecond laser induced Two-Photon Absorption. Several fields could benefit from this development, amongst them Quality Control & Assurance of semiconductor devices, E-Field and Charge Collection Efficiency mapping of photosensors, and radiation damage studies for high-energy physics detectors.

This project is a collaboration between CERN and the Instituto de Física de Cantabria (CSIC-UC).

KEY FACTS

A non-destructive laser application for quality control & radiation studies in semiconductor devices

Submission Year: 2017

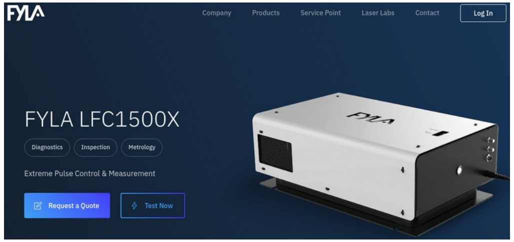
Budget: 120 kCHF

Timeline: 2017 -

Funding Opportunities: CERN Knowledge Transfer fund

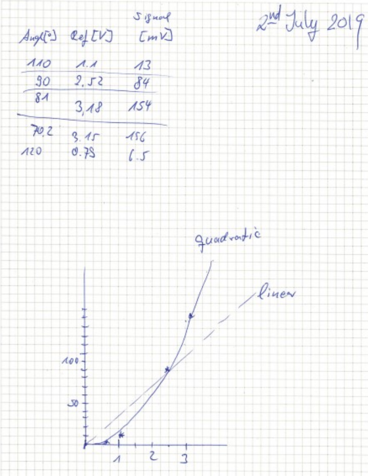
CONTACT PERSON

M. Moll

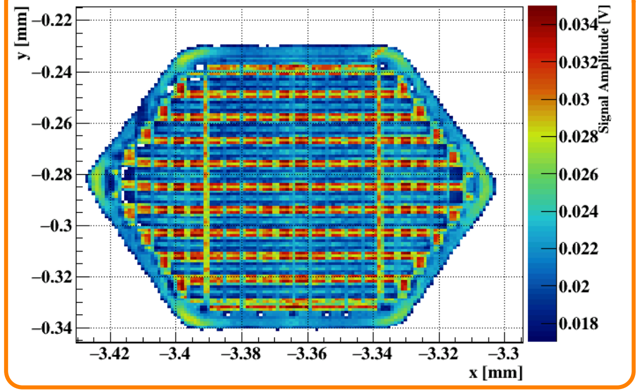


FYLA LFC1500X

Extreme Pulse Control & Measurement


2nd July 2019

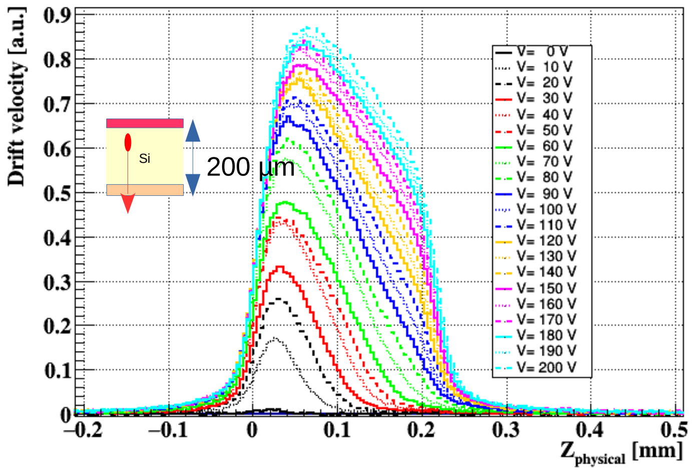
Angle[°]	Ref [V]	Signal [mV]
110	1.1	13
90	2.52	84
81	3,18	154
70.2	3.15	156
120	0.78	6.5

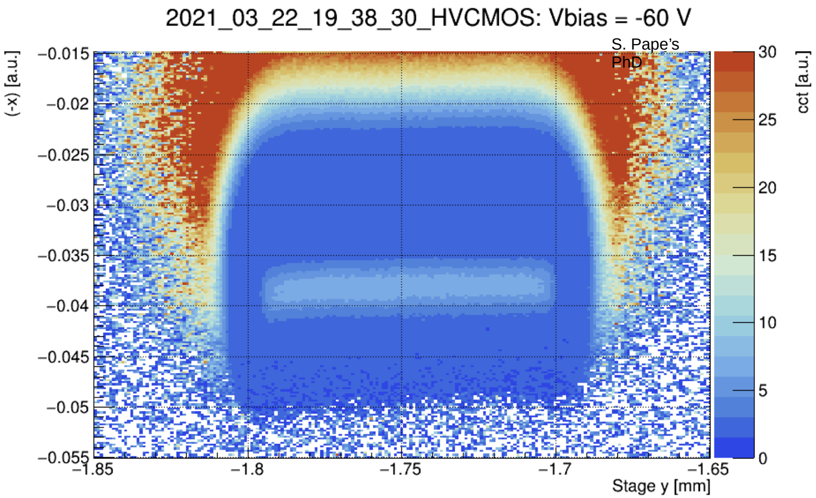


UniGe picoAD

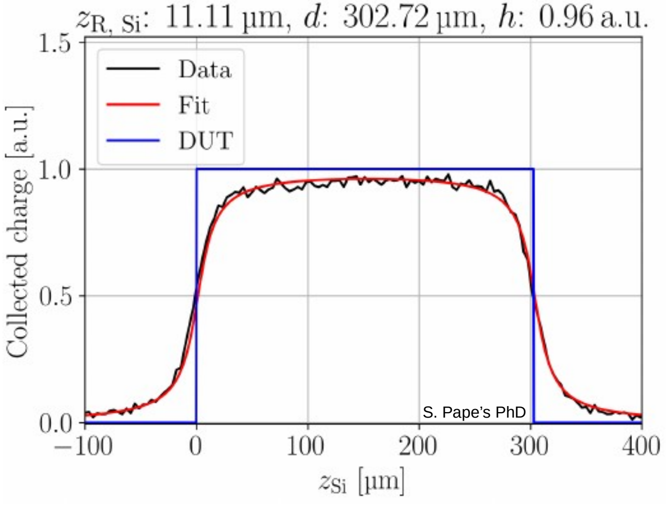
RD50 common projects:
2015-03
2016-04
2017-02

TPA-TCT performance

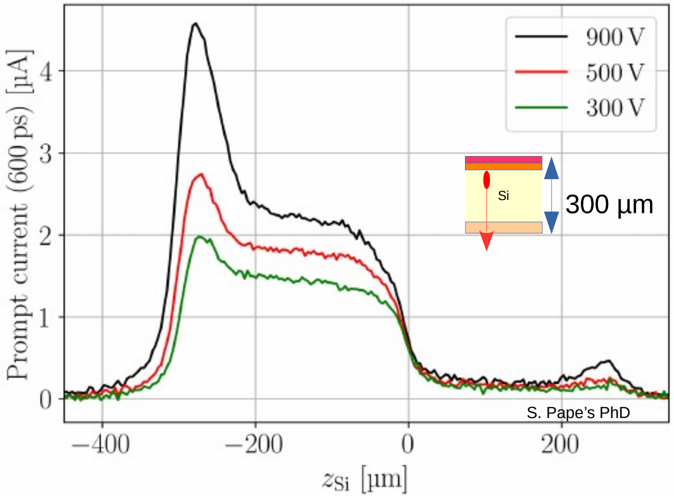




S. Pape's PhD



S. Pape's PhD



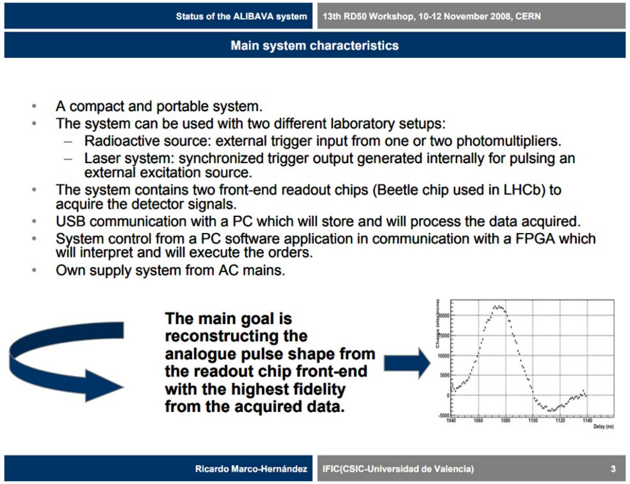
S. Pape's PhD

The Alibava readout system

Alibava readout

R. Marco, 13th RD50, 2008


DAQ&Analysis SW included


Status of the ALIBAVA system | 13th RD50 Workshop, 10-12 November 2008, CERN

Main system characteristics

- A compact and portable system.
- The system can be used with two different laboratory setups:
  - Radioactive source: external trigger input from one or two photomultipliers.
  - Laser system: synchronized trigger output generated internally for pulsing an external excitation source.
- The system contains two front-end readout chips (Beetle chip used in LHCb) to acquire the detector signals.
- USB communication with a PC which will store and will process the data acquired.
- System control from a PC software application in communication with a FPGA which will interpret and will execute the orders.
- Own supply system from AC mains.

The main goal is reconstructing the analogue pulse shape from the readout chip front-end with the highest fidelity from the acquired data.

Ricardo Marco-Hernández | IFIC(CSIC-Universidad de Valencia) 3

Extensively used in the community, up to 27 Alibava contributions reported in our workshops

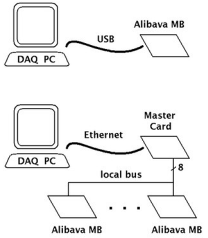
Now commercialized by:

Alibava telescope

M. Lozano, 21st RD50, 2012

Hardware Architecture

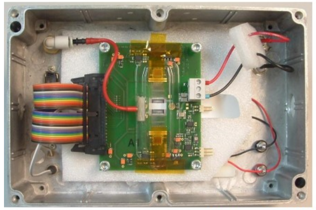
- It is based on the existing Alibava readout system we have developed a multi plane system to be used as a test beam telescope.
- Every Alibava Mother Board is controlled and synchronized by a Master Card and a PC
- The standard MB have the USB controller substituted by a faster interface
- Local data/address bus between the master card and Alibava MBs
- Log data to PC via 100M Ethernet



M. Lozano,21st RD50 Workshop, Cern 14-16 Nov 2012

DUT box

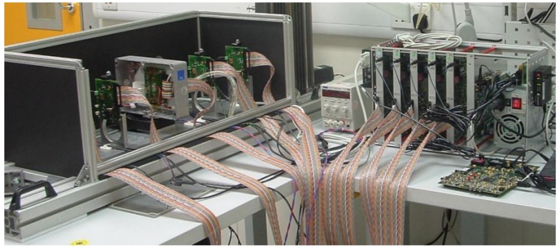
- To read out the DUT there is a new daughter board and a cooling box for irradiated detector testing



M. Lozano,21st RD50 Workshop, Cern 14-16 Nov 2012

Prototype

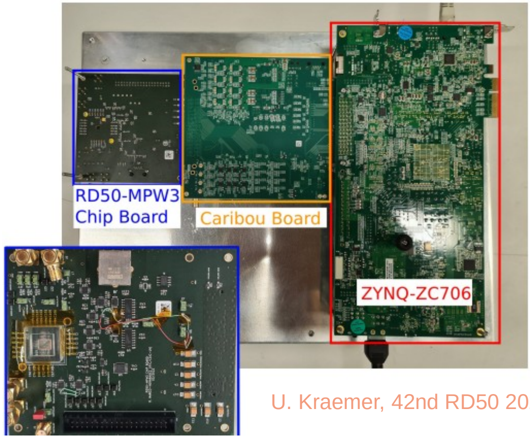
- The first prototype is built with four XY planes
- It is already working and we have taken data at CERN
- We are working in the improvement of the track reconstruction algorithm



M. Lozano,21st RD50 Workshop, Cern 14-16 Nov 2012

Caribou readout system

- Caribou (Control and Readout Itk BOard) is a flexible open-source DAQ system developed and used within several collaborative frameworks (CERN EP R&D, RD50, AIDAinnova) for lab. & beam tests of pixels



U. Kraemer, 42nd RD50 2023

Zynq (SoC) board with Yocto linux,
Control and Readout (CaR) board
Chip board

The common CaR board hardware has been developed at Brookhaven National Laboratory (BNL)

- Originally used to characterize silicon pixel detectors for:
  - ATLAS ITk upgrade
  - CLIC vertex&tracker.

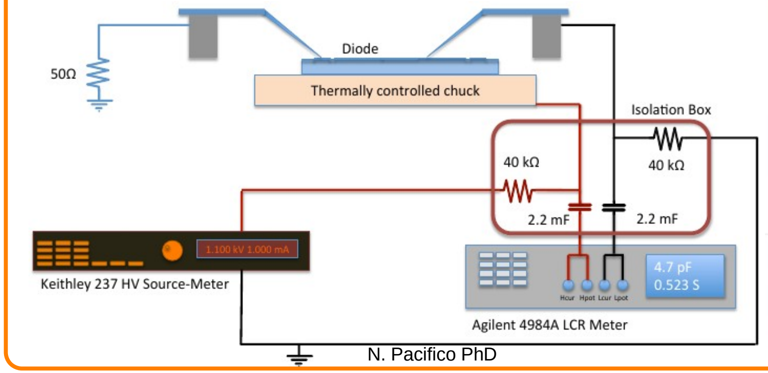
- Used in RD50 as DAQ for MPWx chips

- Latest extension includes an 8 channel TDC prototype (10 ps resolution).

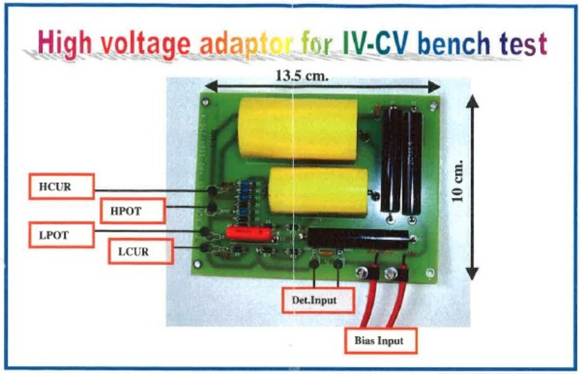
RD50 common projects
2021-01
2023-04

Instrumentation enabling precise measurements

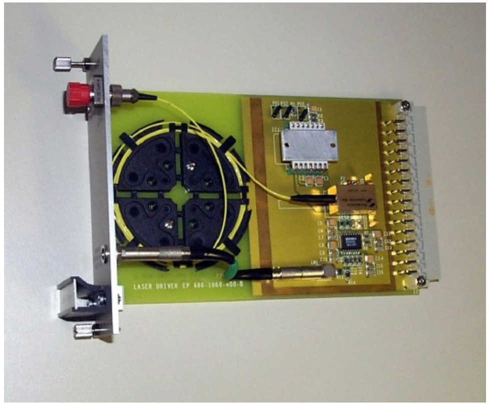
M. Glaser’s Decoupling Box: allows applying HV to detector to measure Capacitance characteristics
(schematics available for DIY)

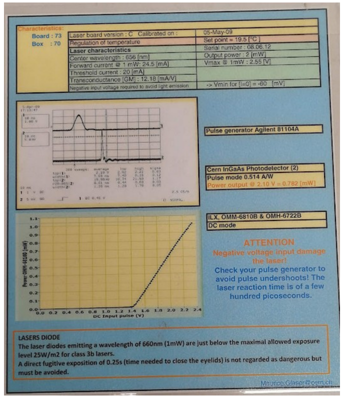


N. Pacifico PhD



M. Glaser’s sub-ns laser (660/1060 nm) for TCT measurements
Specs





Characteristics:
Board : 73
Box : 70

Laser board version : C Calibrated on :	05-May-09
Regulation of temperature	Set point = 19.5 [°C]
Laser characteristics	Serial number : 08.06.12
Center wavelength : 656 [nm]	Output power : 2 [mW]
Forward current @ 1 mW: 24.5 [mA]	Vmax @ 1mW : 2.55 [V]
Threshold current : 20 [mA]	
Transconductance [GM] : 12.18 [mA/V]	
Negative input voltage required to avoid light emission	-> Vmin for [I=0] = -60 [mV]

Pulse generator Agilent 81104A

Cern InGaAs Photodetector (2)
Pulse mode 0.514 A/W
Power output @ 2.10 V = 0.782 [mW]

ILX, OMM-6810B & OMH-6722B
DC mode

ATTENTION
Negative voltage input damage the laser!
Check your pulse generator to avoid pulse undershoots! The laser reaction time is of a few hundred picoseconds.

LASERS DIODE
The laser diodes emitting a wavelength of 660nm (1mW) are just below the maximal allowed exposure level 25W/m2 for class 3b lasers.
A direct fugitive exposition of 0.25s (time needed to close the eyelids) is not regarded as dangerous but must be avoided.

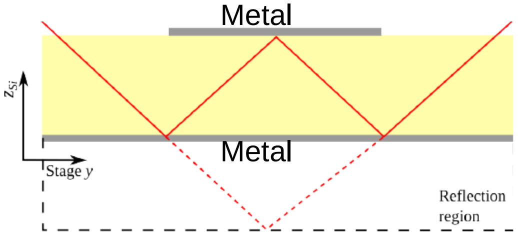
Maurice.Glaser@cern.ch

RT<1 ns
Width~2 ns

Innovative tools, advanced analysis

- (Edge&TPA)-TCT extend the reach of standard TCT : **depth profiling.** Associated to that came new techniques as Prompt Current (edge) and Weighted Prompt Current (TPA) used to estimate drift velocity profiles

- TPA's **mirror technique** uses backside reflection combined with 3D resolution to measure below top metals. Very useful for pixelated structures.



- TCT (both laser and RS) has become instrumental for the accurate characterization of the **time resolution** of silicon sensors.

- **Fast simulation tools** (kDetSim, WF2, TRACS…) calculate induced current pulses. TCT has become a bridge between simulation and experiment.

- Alibava (Caribou) allowed easy access to segmented readout for strips (pixelated structures) to a wide community of users.

Conclusions

- RD50 has been a central force for community interaction, significantly contributing to the development of characterization techniques like edge-TCT and TPA-TCT along with defect characterization tools. RD50 was the driving force in the development of established technologies such as p-type silicon, LGAD sensors, 3D detectors, and others.

- This new instrumentation has been developed to meet our specific needs. Its availability in the market is directly attributed to the contributions and advancements made within the RD50 collaboration.

- Two established spin-off companies, Alibava and Particulars, along with the laser producer (FYLA) serve as evidence that the work developed inside RD50 extends beyond the laboratory. More to come with the application of LGADs beyond HEP.

- Mr. Dyson: The effect of RD50’s tool-driven revolution has been to explain new concepts like: SCSI, double junction, E-field of irradiated detectors, charge multiplication, gain reduction in LGADs,…

Backups

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

[redacted]

CERN/ECP 93–21
25 November 1993

CHARGE TRANSPORT IN SILICON DETECTORS

F. Lemeilleur, M. Glaser, E.H.M. Heijne, P. Jarron and C. Soave*
CERN, Geneva, Switzerland

C. Leroy**, J. Rioux, P. Roy, M. Siad and I. Trigger
University of Montreal, Montreal, Canada

References

[1] P. A. TOVE and K. FALK, Transit time of charge carriers in the semiconductor ionization chamber, *Nucl. Instrum. Methods*, **12** (1961) 278.

[2] G. CAVALLERI et al., On the induced charge in semiconductor detectors, *Nucl. Instrum. Methods*, **21** (1963) 177.

[3] P. A. TOVE and K. FALK, Pulse formation and transit time of charge carriers in semiconductor junction detectors, *Nucl. Instrum. Methods*, **29** (1964) 66.

[4] A. ALBERIGI QUARANTA et al., On the information available from the rise time of the charge pulse supplied by semiconductor particle detectors, *Nucl. Instrum. Methods*, **35** (1965) 93.

[5] A. TARONI and G. ZANARINI, Space charge limited currents in p-n junctions, *Phys. Chem. Solids*, **30** (1969) 1861.

[6] G. CAVALLERI et al., Extension of the RAMO's theorem as applied to the induced charge in semiconductor detectors, *Nucl. Instrum. Methods*, **92** (1971) 137.

[7] E. GATTI and P. F. MANFREDI, Processing the signals from solid-state detectors in elementary-particle physics, *Riv. Nuovo Cim.* **9**, No. 1 (1986).

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[9] P. JARRON, Fast silicon detector systems for high-luminosity hadron collider experiments, Proc. of the ECFA Study Week, CERN 89–10, (ECFA 89–124), Vol. 1 (1989) 287.

[10] F. LEMEILLEUR et al., Electrical properties and charge collection efficiency for neutron-irradiated *p*-type and *n*-type silicon detectors, *Nucl. Phys. B (Proc. Suppl.)* **32** (1993) 415.

[11] H. W. KRANER et al., The use of the signal current pulse shape to study the internal electric field profile and trapping effects in neutron damaged silicon detectors, *Nucl. Instrum. Methods*, **A326** (1993) 350.

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[13] Z. LI et al., Investigation of the type inversion phenomena: resistivity and carrier mobility in the space charge region and electrical neutral bulk in neutron irradiated silicon p^+–n junction detectors, *IEEE Trans. Nucl. Sci.* **40,** No. 4 (1993) 367.

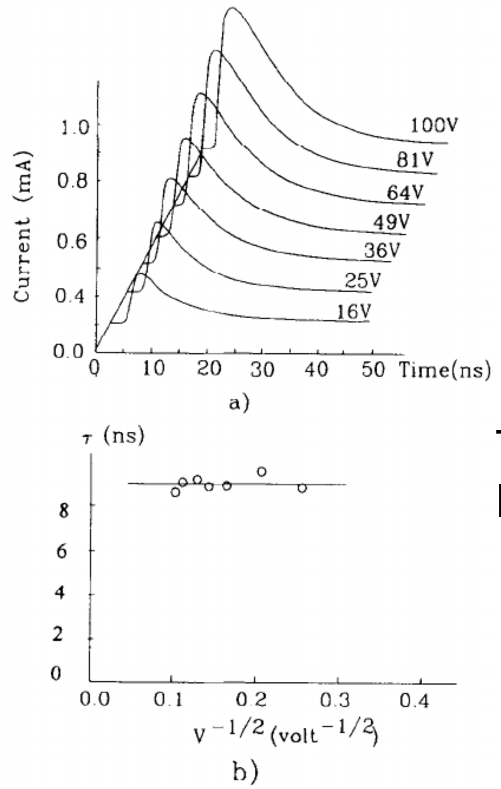
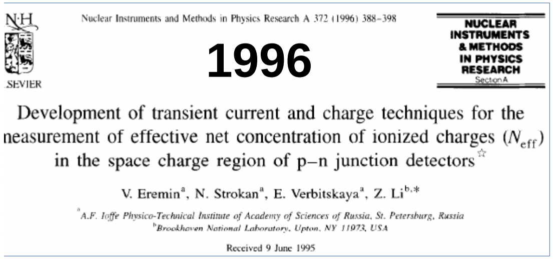


Fig. 8. Example of N_{eff} measurement using current pulse decay time for deep level compensated detector (neutron fluence is $\phi_n = 2.65 \times 10^{13}$ cm^{-2}): (a) a set of current responses at different biases; (b) decay time constant τ versus bias. The corresponding N_{eff} is 1.3×10^{12} cm^{-3}.

GaAs heterojunction laser with ns pulses



N·H
SEVIER

Nuclear Instruments and Methods in Physics Research A 372 (1996) 388–398

1996

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Development of transient current and charge techniques for the neasurement of effective net concentration of ionized charges (N_{eff}) in the space charge region of p–n junction detectors ☆

V. Eremin[a], N. Strokan[a], E. Verbitskaya[a], Z. Li[b,*]

[a] A.F. Ioffe Physico-Technical Institute of Academy of Sciences of Russia, St. Petersburg, Russia
[b] Brookhaven National Laboratory, Upton, NY 11973, USA

Received 9 June 1995

TCT methods to calculate Neff from fits to pulse tails

$$\tau = \frac{d}{\mu}\left(\frac{\varepsilon\varepsilon_0}{2eN_{eff}}\right)^{1/2}\frac{1}{\sqrt{V}}.$$

Nuclear Instruments and Methods in Physics Research A 604 (2009) 246–249

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

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2009

Electrical properties of the sensitive side in Si edgeless detectors

E. Verbitskaya[a,*], G. Ruggiero[b], I. Eremin[a], I. Ilyashenko[a], A. Cavallini[c], A. Castaldini[c], G. Pellegrini[d], M. Lozano[d], S. Golubkov[e], N. Egorov[e], K. Konkov[e], T. Tuuva[f]

[a] Ioffe Physico-Technical Institute, St. Petersburg, Russian Federation
[b] CERN, Geneva, Switzerland
[c] University of Bologna, Bologna, Italy
[d] Centro Nacional de Microelectrónica, CNM-IMB (CSIC), Barcelona 08193, Spain
[e] RIMST, Zelenograd, Moscow, Russian Federation
[f] LUT Lappeenranta, Finland

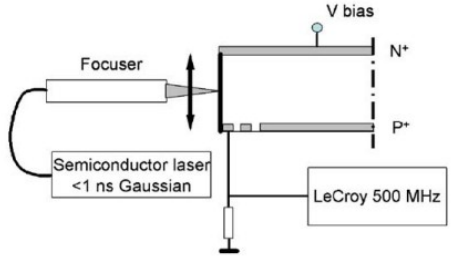
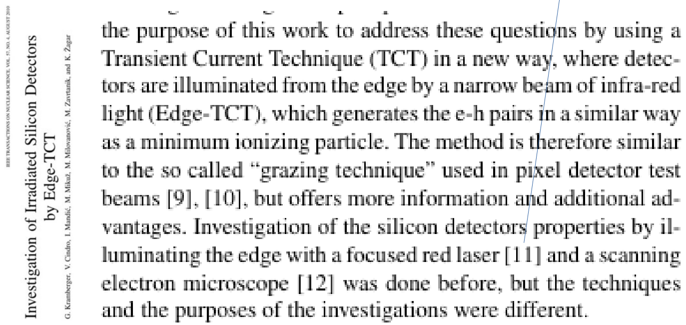


Fig. 2. Schematic of the STCT setup.



IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 57, NO. 4, AUGUST 2010

Investigation of Irradiated Silicon Detectors by Edge-TCT

G. Kramberger, V. Cindro, I. Mandić, M. Mikuž, M. Milovanović, M. Zavrtanik, and K. Žagar

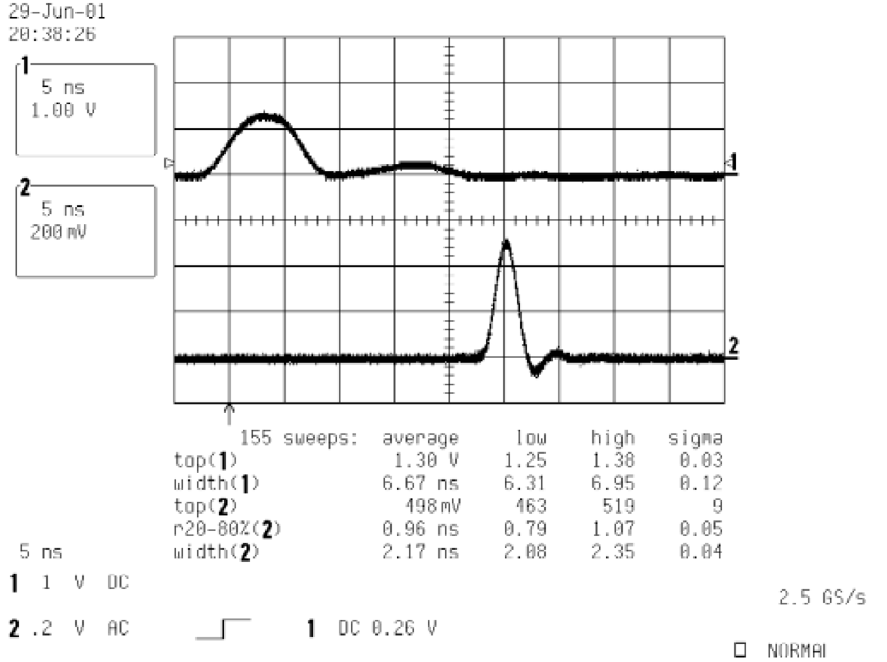
the purpose of this work to address these questions by using a Transient Current Technique (TCT) in a new way, where detectors are illuminated from the edge by a narrow beam of infra-red light (Edge-TCT), which generates the e-h pairs in a similar way as a minimum ionizing particle. The method is therefore similar to the so called "grazing technique" used in pixel detector test beams [9], [10], but offers more information and additional advantages. Investigation of the silicon detectors properties by illuminating the edge with a focused red laser [11] and a scanning electron microscope [12] was done before, but the techniques and the purposes of the investigations were different.

See also TCT review in the 2nd TCT workshop by M. Zavrtanik (2nd TCT workshop)

Characteristics:

Board : 43
Box : 41

Laser board version : C Calibrated on :	24-Mar-02
Regulation of temperature	Set point = [°C]
Laser characteristics	Serial number : 27812
Center wavelength : 1053 [nm]	Output power : 1 [mW]
Forward current @ 1 mW: 30.5 [mA]	Vmax @ 1mW : 2.06 [V]
Threshold current : 15 [mA]	
Transconductance [GM] : 11.63 [mA/V]	
Negative input voltage required to avoid light emission	-> Vmin for [I=0] = -100 [mV]

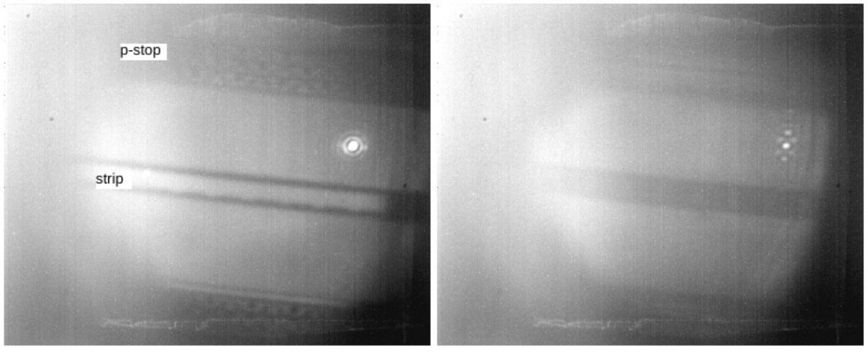


```
29-Jun-01
20:38:26

155 sweeps:   average    low    high   sigma
top(1)         1.30 V    1.25   1.38   0.03
width(1)       6.67 ns   6.31   6.95   0.12
top(2)          498 mV    463    519      9
r20-80%(2)     0.96 ns   0.79   1.07   0.05
width(2)       2.17 ns   2.08   2.35   0.04

5 ns
1  1  V  DC
2 .2  V  AC          1  DC 0.26 V
                                    2.5 GS/s
                                    NORMAL
```

Pulse generator Agilent 81104A

O/E converter TIA-950
DC coupling
Gain 1200 V/W
Response @ 1060 nm 70%
Top(2) = 498 mV
Power output @ 1.30 V = 0.55 [mW]

Maurice.glaser@cern.ch



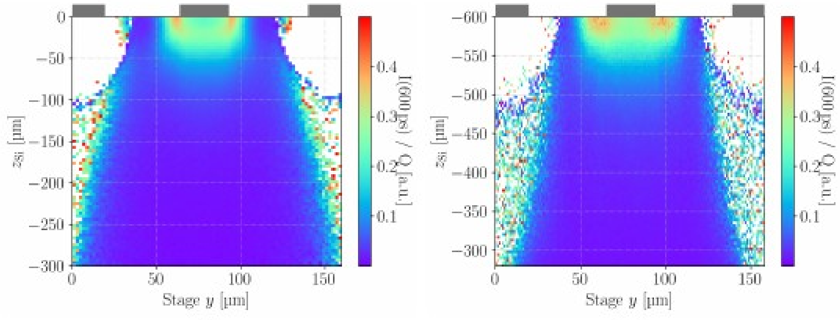
(a) (b)

Figure 6.6: Picture of the passive CMOS strip detector, recorded with the IR microscope. (a) The focal plane aligns with the top surface and the laser is between the strip metal and the p-stop. The laser's focal point is seen as a bright spot. (b) Mirror image at the same position. The focal plane is one device thickness behind the DUT and shows the top side metals from below. The focal point is positioned like sketched in figure 6.5.

Top TPA mirrroring technique

Left: Midpoint between strip&p-stop illluminated directly from top

Right: Same point illuminated (from top) when the beam has been reflected in the back. Diffraction effects observed.



(a) (b)

Figure 6.8: Comparison between the weighted prompt current measured with back side illumination (a) and the mirror image obtained with top side illumination (b) in the Micron strip detector [24]. The mirror image exploits the reflection at the metallised back side to obtain a measurement below the top side metal. Note that the ordinate in (b) is counter directed to the ordinate in (a), because the reflection scans the volume from the back towards the top side. The colour scales in both figures are the same and the axes are according to the reference system in figure 6.7a.

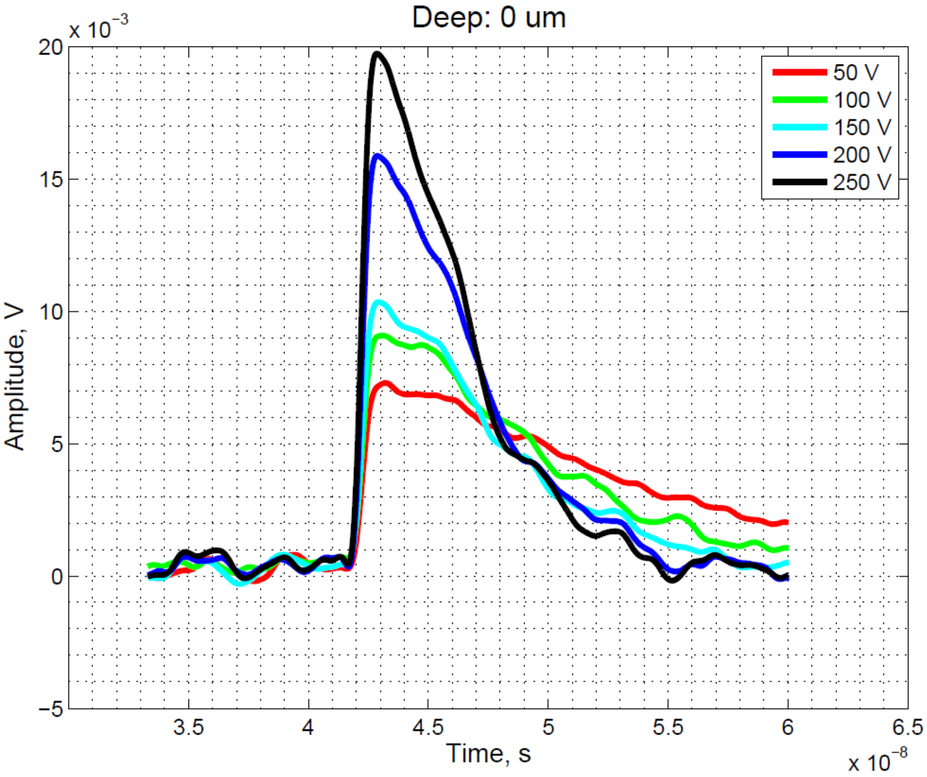
Left: WPC if a microstrip detector backside illuminated via bottom TPA through metal opening.

Right: WPC from top-TPAusing the mirroring technique.

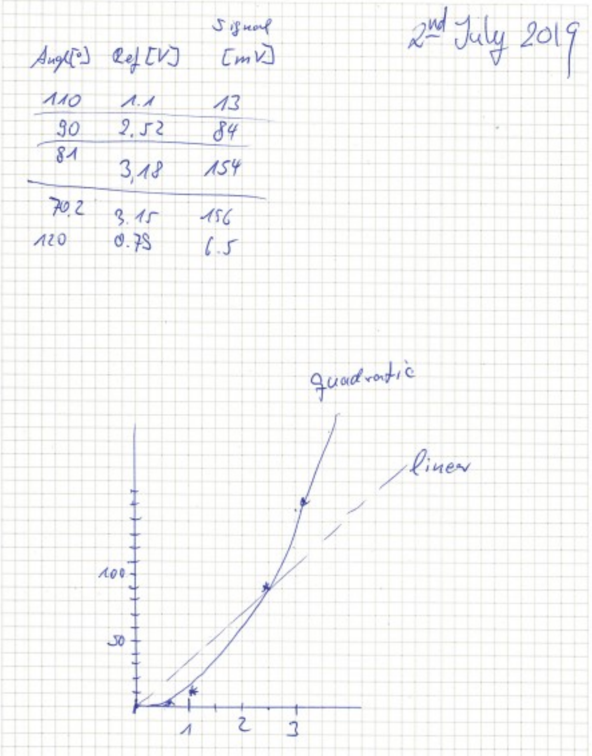
In both cases, the white regions are those where Q→0, since WPC=I(600 ps)/Q

S. Pape’s PhD thesis

12th of March of 2013, **first** TPA **measurement** in Bilbao

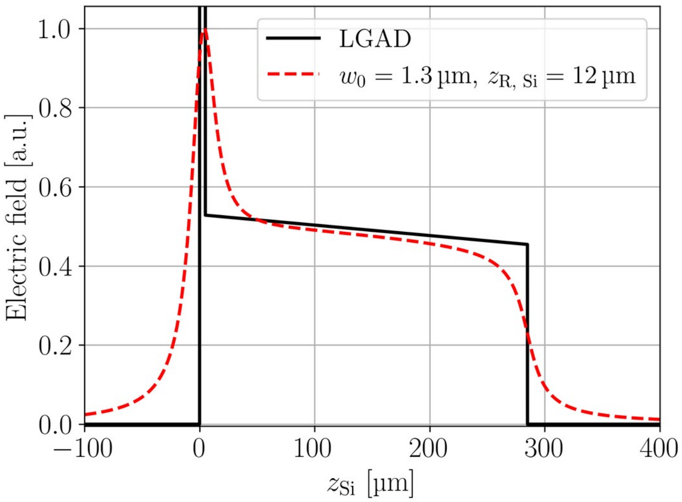


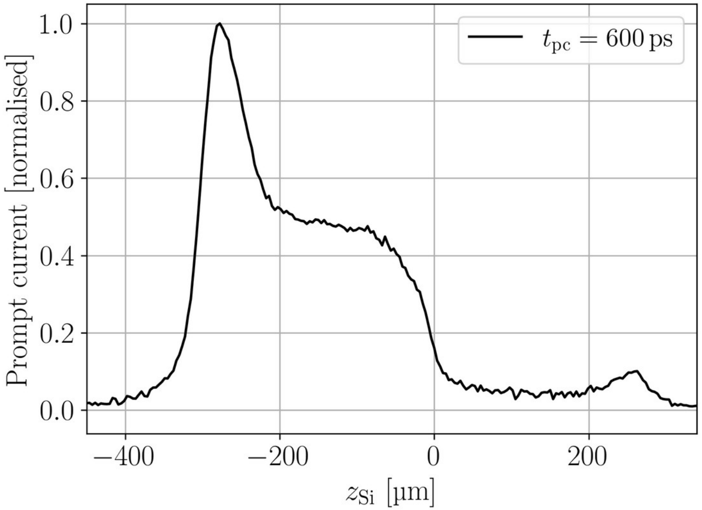
CERN-2nd July 2019



2nd July 2019

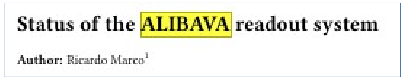
Angl[°]	Ref [V]	Signal [mV]
110	1.1	13
90	2,52	84
81	3,18	154
70.2	3.15	156
120	0.78	6.5


LGAD
$w_0 = 1.3\,\mu\mathrm{m},\ z_{\mathrm{R,\,Si}} = 12\,\mu\mathrm{m}$
Electric field [a.u.]
0.0
0.2
0.4
0.6
0.8
1.0
−100
0
100
200
300
400
z_{Si} [µm]


$t_{\mathrm{pc}} = 600\,\mathrm{ps}$
Prompt current [normalised]
0.0
0.2
0.4
0.6
0.8
1.0
−400
−200
0
200
z_{Si} [µm]

27 contributions

13th RD50 2008

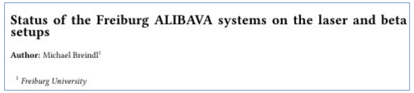

Status of the ALIBAVA readout system

Author: Ricardo Marco[1]

14th RD50 2009


Neutron irradiation for p-type sensors. Detector characterization with ALIBAVA system

Authors: Mercedes Minano Moya[1]; Urmila Soldevila[Nana]


Status of the Freiburg ALIBAVA systems on the laser and beta setups

Author: Michael Breindl[1]

[1] *Freiburg University*


Status of the CERN ALIBAVA system

Authors: Eduardo Del Castillo Sanchez[1]; Michael Moll[1]

[1] *CERN*

15th RD50 2009


Alibava - a discussion on Software and FAQ

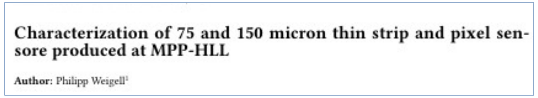
Author: Henry Brown[1]

[1] *University of Liverpool*


Alibava system upgrade

Author: Ricardo Marco Hernandez[1]

[1] *Instituto de Fisica Corpuscular (IFIC)-Universitat de Valencia-U*


Characterization of 75 and 150 micron thin strip and pixel sensore produced at MPP-HLL

Author: Philipp Weigell[1]

16th RD50 2010


CCE and TCT measurements in Karlsruhe - System Commissioning

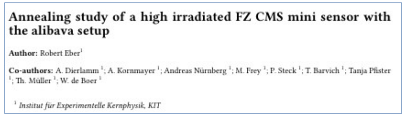
Author: Robert Eber[1]


Charge collection measurements on irradiated planar silicon strip sensors

Authors: Michel Walz[1]; Ulrich Parzefall[1]

[1] *Freiburg University*

17th RD50 2010


Annealing study of a high irradiated FZ CMS mini sensor with the alibava setup

Author: Robert Eber[1]

Co-authors: A. Dierlamm [1]; A. Kornmayer [1]; Andreas Nürnberg [1]; M. Frey [1]; P. Steck [1]; T. Barvich [1]; Tanja Pfister [1]; Th. Müller [1]; W. de Boer [1]

[1] *Institut für Experimentelle Kernphysik, KIT*


Annealing CCE study on HPK FZ p-on-n ministrip detectors.

Authors: Christopher Lucas[1]; Irena Dolenc[2]; Michael Moll[2]; Nicola Pacifico[3]

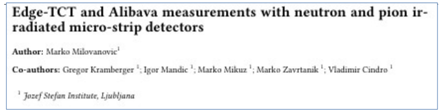
Co-author: Otilia Militaru [4]

[1] *University of Bristol (UK)*

[2] *CERN*

[3] *University of Bari / CERN*

18th RD50 2011


Edge-TCT and Alibava measurements with neutron and pion irradiated micro-strip detectors

Author: Marko Milovanovic[1]

Co-authors: Gregor Kramberger [1]; Igor Mandic [1]; Marko Mikuz [1]; Marko Zavrtanik [1]; Vladimir Cindro [1]

[1] *Jozef Stefan Institute, Ljubljana*


Edge TCT and Charge Collection Efficiency study on pion irradiated n-on-p strips

Authors: Irena Dolenc Kittelmann[1]; Markus Gabrysh[1]; Michael Moll[1]; Nicola Pacifico[2]

19th RD50 2011


Charge collection measurement on slim edge sensors with the ALiBaVa system.

Author: Riccardo Mori[1]

Co-authors: Hartmut Sadrozinski [2]; Mara Bruzzi [3]; Vitaliy Fadeyev [4]


Characterization of the new Stripixel detectors

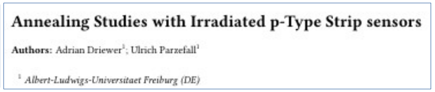
Author: Daniela Bassignana[1]

Co-authors: Celeste Fleta [1]; David Quirion [1]; Giulio Pellegrini [1]; Manuel Lozano [1]; Tuure Tuuva [2]; Zheng Li


A comparative study of mixed irradiated sensors made of different silicon base material

Authors: Florian Petry[1]; Robert Eber[2]

Co-authors: Alexander Dierlamm [2]; Andreas Kornmayer [2]; Felix Bögelspacher [1]; Pia Steck [1]; Thomas Mueller [3]; Tobias Barvich [4]; Wim De Boer [2]


Annealing Studies with Irradiated p-Type Strip sensors

Authors: Adrian Driewer[1]; Ulrich Parzefall[1]

[1] *Albert-Ludwigs-Universitaet Freiburg (DE)*

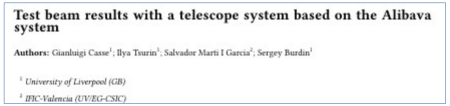
20th RD50 2012


Investigation of Charge Multiplication in Silicon Strip Detectors

Author: Lokman Altan[1]

Co-authors: Alexander Dierlamm [2]; Thomas Mueller [3]; Wim De Boer [2]

[1] *KIT - Karlsruhe Institute of Technology (DE)*

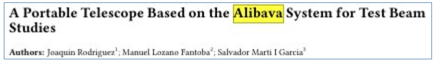

Test beam results with a telescope system based on the Alibava system

Authors: Gianluigi Casse[1]; Ilya Tsurin[1]; Salvador Marti I Garcia[2]; Sergey Burdin[1]

[1] *University of Liverpool (GB)*

[2] *IFIC-Valencia (UV/EG-CSIC)*

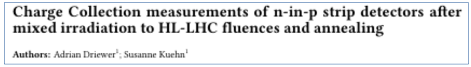
21st RD50 2012


A Portable Telescope Based on the Alibava System for Test Beam Studies

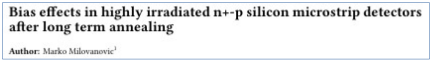
Authors: Joaquin Rodriguez[1]; Manuel Lozano Fantoba[2]; Salvador Marti I Garcia[3]


Multi-Project Wafer (MPW) Runs of Full Custom Pitch Adapters

Authors: Giulio Pellegrini[1]; Manuel Lozano Fantoba[1]; Miguel Ullan Comes[1]


Charge Collection measurements of n-in-p strip detectors after mixed irradiation to HL-LHC fluences and annealing

Authors: Adrian Driewer[1]; Susanne Kuehn[1]


Bias effects in highly irradiated n+-p silicon microstrip detectors after long term annealing

Author: Marko Milovanovic[1]

24th RD50 2015


Lorentz angle measurement on ATLAS silicon microstrip sensors

Author: Eda Yildirim[1]

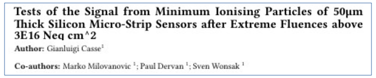
Co-authors: Ingrid-Maria Gregor [2]; Kerstin Tackmann [1]

[1] *Deutsches Elektronen-Synchrotron (DE)*


Impact of Low-Dose Electron Irradiation on the Charge Collection of n+p Silicon Strip Sensors

Authors: Alexandra Junkes[1]; Thomas Poehlsen[2]

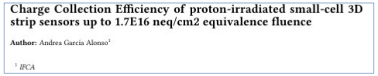
27th RD50 2015


Tests of the Signal from Minimum Ionising Particles of 50µm Thick Silicon Micro-Strip Sensors after Extreme Fluences above 3E16 Neq cm^2

Author: Gianluigi Casse[1]

Co-authors: Marko Milovanovic [1]; Paul Dervan [1]; Sven Wonsak [1]

32nd RD50 2018

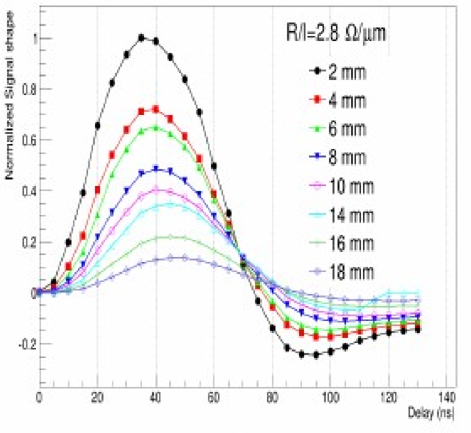

Charge Collection Efficiency of proton-irradiated small-cell 3D strip sensors up to 1.7E16 neq/cm2 equivalence fluence

Author: Andrea García Alonso[1]

[1] *IFCA*

Francisca J.M. Sanchez PhD:
We used the Alibava daq [95] system developed within the framework of the CERN RD50 collaboration. The analog front-end of the ALIBAVA system is based on the Beetle readout chip [119] used for the microstrip sensor readout of the silicon tracking subsystem of the LHCb experiment at LHC; consequently, the analog front-end shaper peaking time of the Alivaba system is set around 25 ns. Figure 4.6 shows a photo of one of the detectors mounted on the Alibava daughter board.

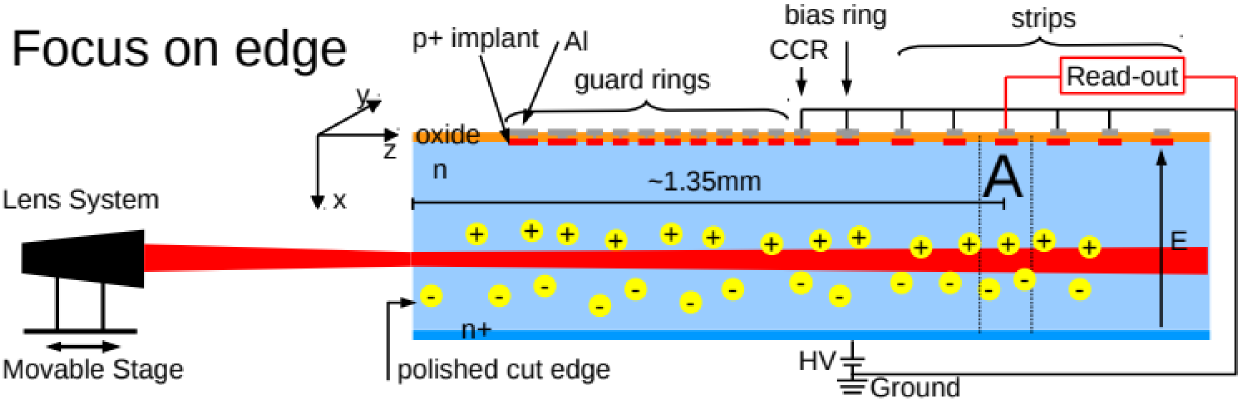
The Alibava DAQ system does not allow to record the whole shape of the analog signal. On the other hand it allows to reconstruct it thanks to a particular feature that permits to change the value of the delay between the trigger time (synchronous with the laser pulse) and the acquisition time (specifying the instant at which the shaper output is sampled) [123]. Setting different delays, in steps of 5 ns, from 0 to 130 ns, the pulse shape can be reconstructed. We recorded 20000 events for each time delay and found the amplitude of their distributions by fitting a Gaussian function to the peak region. In Figure 4.12 one example of one measurement is shown; for every beam position, 26 measurements of 20000 events were taken, one for each sampling time.



(a)

Edge-TCT: exploring the bulk

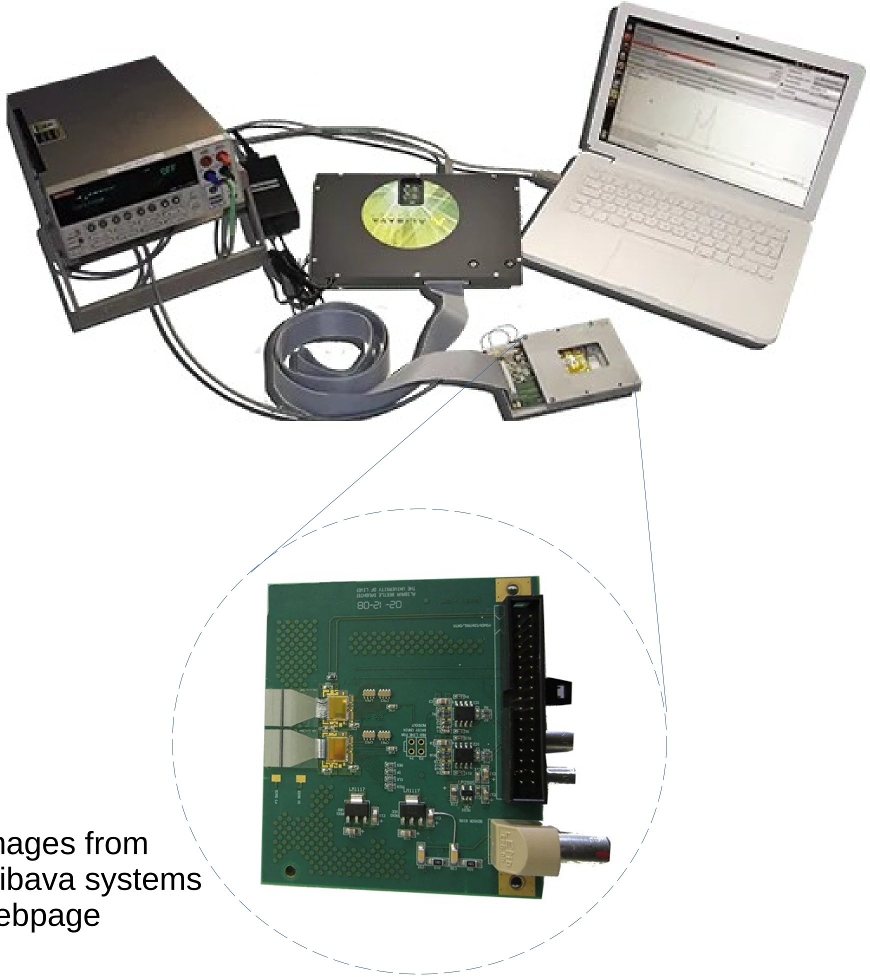
Edge-TCT is mostly applied to segmented detectors.
Single electrode readout surrounded by grounded electrodes → diode like weighting field
Applications: microstrips, HVCMOS,...



Finn Feindt, Master thesis (Un. Hamburg)

Prompt current method allows to estimate drift velocity and profile E-field (or something very close to it)

The Alibava readout system



Images from Alibava systems webpage

- Alibava is a portable and compact readout system for microstrip sensor readout.
- It is based on the Beetle readout chip, which is a front-end readout chip developed for the LHCb experiment.
- It can either accept ext. trigger from PM in (radioactive source mode) or provide a trigger (pulsed laser mode).

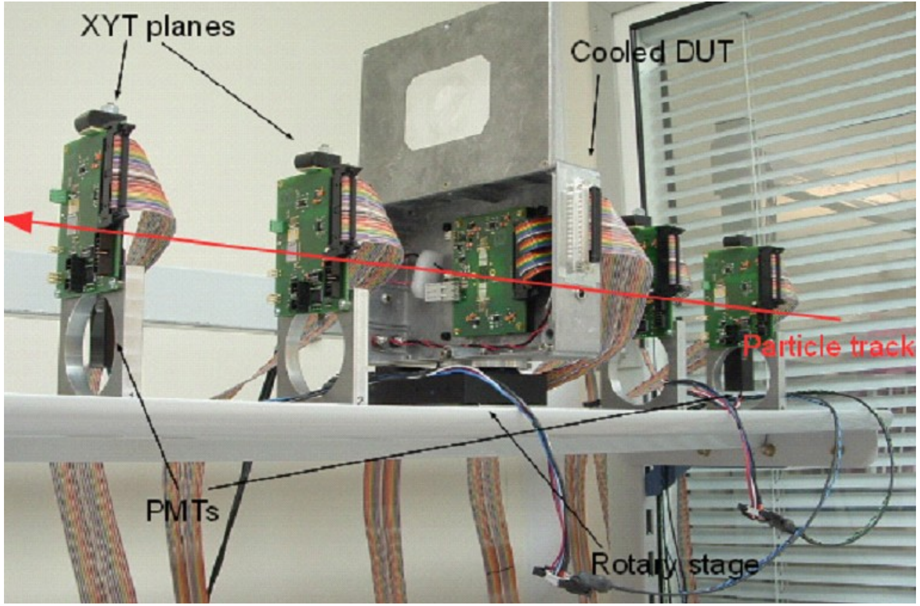
Components:
Daughter board: sensor carrier, 2 Beetles & fan-ins

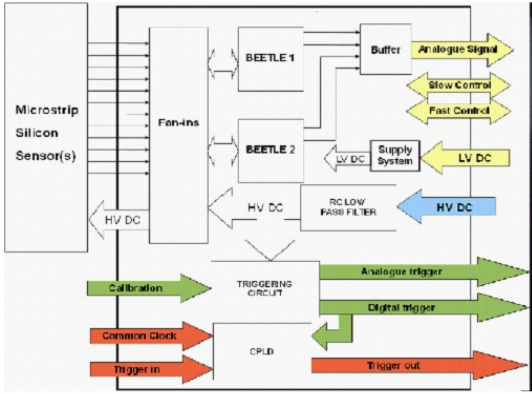
Motherboard: process analogue data from ROC, manages trigger.
USB communication with a PC

Control & analysis code ROOT based provided

Commercialised by Alibava systems

The Alibava telescope





R Marco-Hernández 2011 JINST 6 C01002

Tracking telescope with 4 XYT (T for trigger) stations, 1x1 cm², mounting 2 perpendicular, back-to-back 80 um pitch microstrips.

Trigger by 2 opposite scintillators

Each daughter board is readout by a MotherBoard (MB)

One master board synchronizes up to 16 MBs (12 DUTs), merges and transfers the data (ethernet).

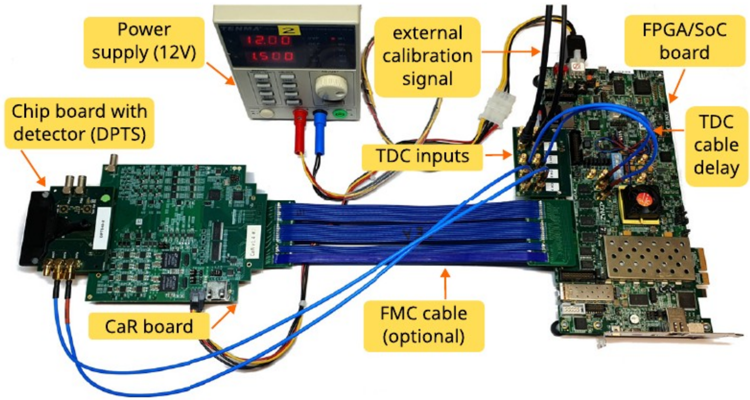
Triggers time-stamped with 600 ps resolution

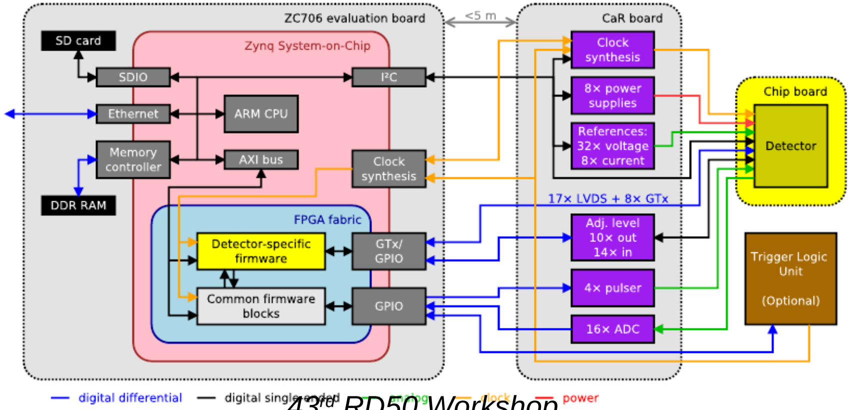
Control and analysis software in C++ to manage the system and to convert raw data into particle tracks

Caribou

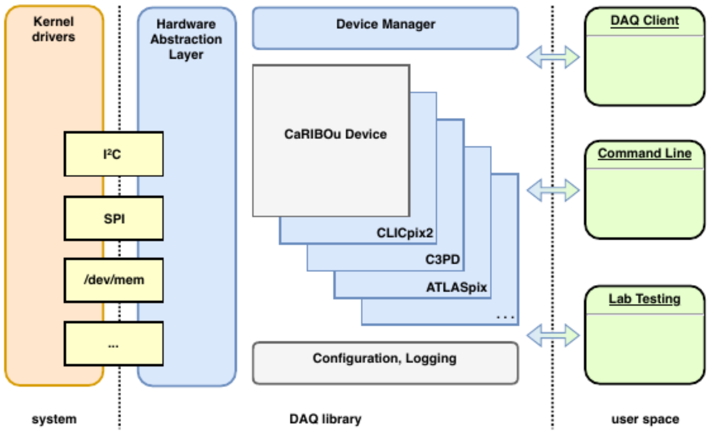
The Caribou data acquisition system is a versatile system for prototyping silicon pixel detectors. It consists of hardware and software components that can be used to quickly test and debug detector prototypes.

The hardware includes a Zynq System-on-Chip (SoC) board, a Control and Readout (CaR) board and a chip board .





The software includes a Yocto and Open embedded-based Linux distribution (Poky) and a DAQ software called Peary.



used to characterize silicon pixel detectors for ATLAS ITk upgrad as well as for a CLIC vertex&tracker