Study of the long-term stability of thin scCVD* based detector for alpha spectroscopy

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* – scCVD: single crystalline chemically vapored diamond

Outline

- Motivation
- Material and methods
- Experimental setup
- Data Processing
- Results
- Conclusions
- Acknowledgments
- References

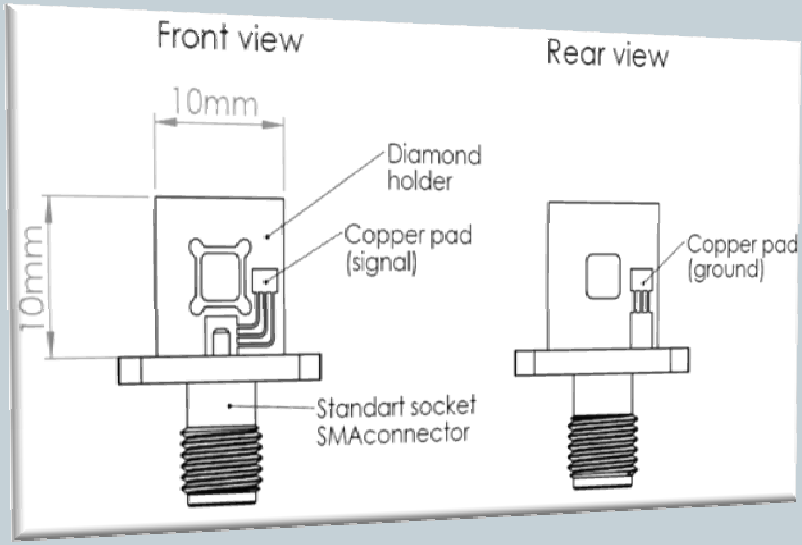
Motivation (reasons)

- Existence of deep and shallow trapping levels affect the charge collection efficiency of the diamond device preventing its use over long term measurements.
- This statement is valid for polycrystalline CVD sample, but also for single crystalline CVD sample because of unexpected uncertainties in the reproducibility of the material quality
- There is a lack of long term stability studies on thin single crystalline CVD samples

Motivation (aims)

- In this talk the study of the long term stability for thin (90μm) scCVD samples (irradiated with alpha source) is presented.
- The dependence on long term stability as a function of the electrode metallization is presented as well.
- Knowledge of the long term stability should be very useful for designing a compact portable alpha-particle detector.

Materials



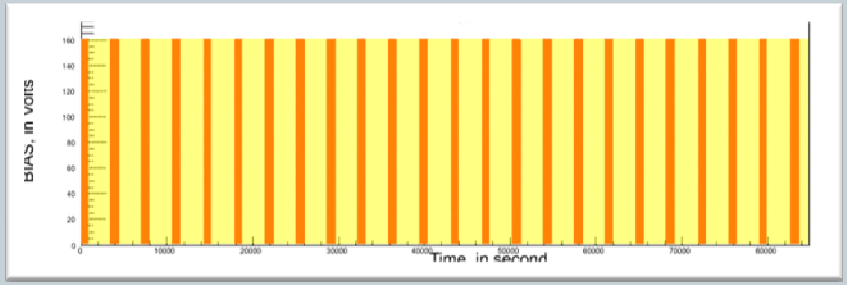
- 2x scCVD (electronic grade) diamond samples 3.0x3.0x0.09 mm (produced by Element Six) and provided by GSI.
- These samples labelled as Dmd#1 and Dmd#2 were fabricated at RBI with Au (100 nm) and/or Al/Au(100/30 nm) electrodes in a sandwich configuration with a square shape and area of 4 mm^2.

PCB enclosure properties:
1)Standard straight SMA connector
2)PCB designed to minimize the capacitance between pads and increase the total resistance
3)Special window to fix the diamond on PCB

Some properties of sc CVD detectors	With Al-electrodes BIAS 160 V	With Au-electrodes BIAS 160V
Resistivity	10^{13} Ω·cm	10^{13} Ω·cm
Capacitance	~ 2.0 pF	~ 2.0 pF
Holes mobility	965.5 cm^2/V·cm*	1553 cm^2/V·cm
Electrons mobility	1982 cm^2/V·cm*	1560 cm^2/V·cm
* – no Schottky effect included in calculation		

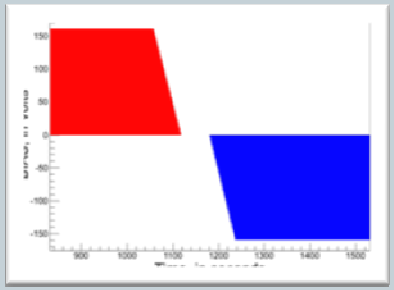
Methods

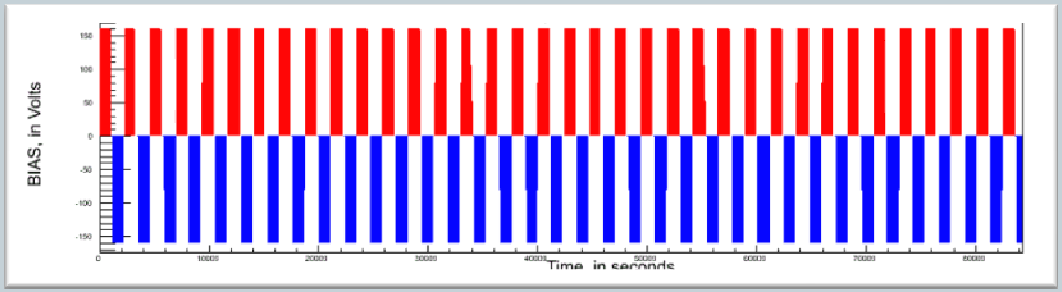
1) Study of the long term stability by using the constant BIAS.



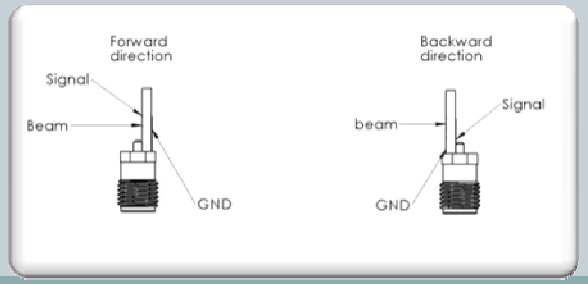
Data recording rate:1 event/second
Data extracted – 1000 events (red)
Data skipped – 2600 events (yellow)
Data taking never stopped

2) Study of the long term stability by using a newly developed BIAS alternating unit.

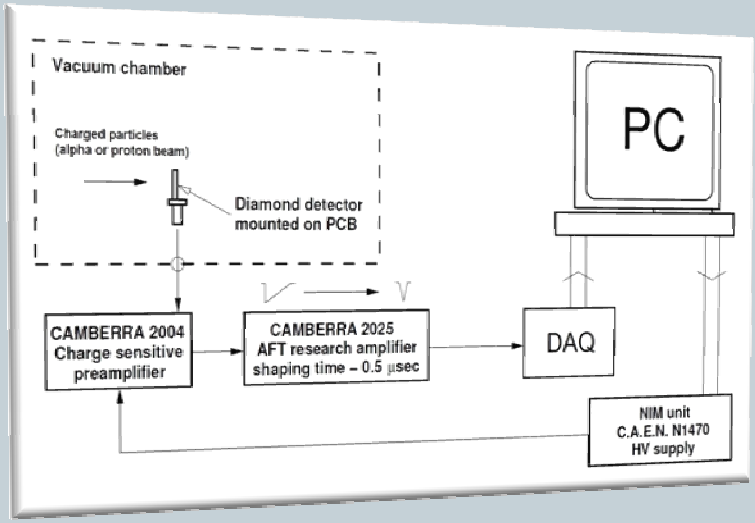




Irradiation of the devices (for both type of detectors) were performed in two different modalities: forward and backward:



Schematic of the experimental setup



DAQ performed by Tektronix DPO4054 with a maximum sampling time of 400 ps.

Measurements on detectors were performed on both bias polarities at 160 V (E=17.8 kV/cm)

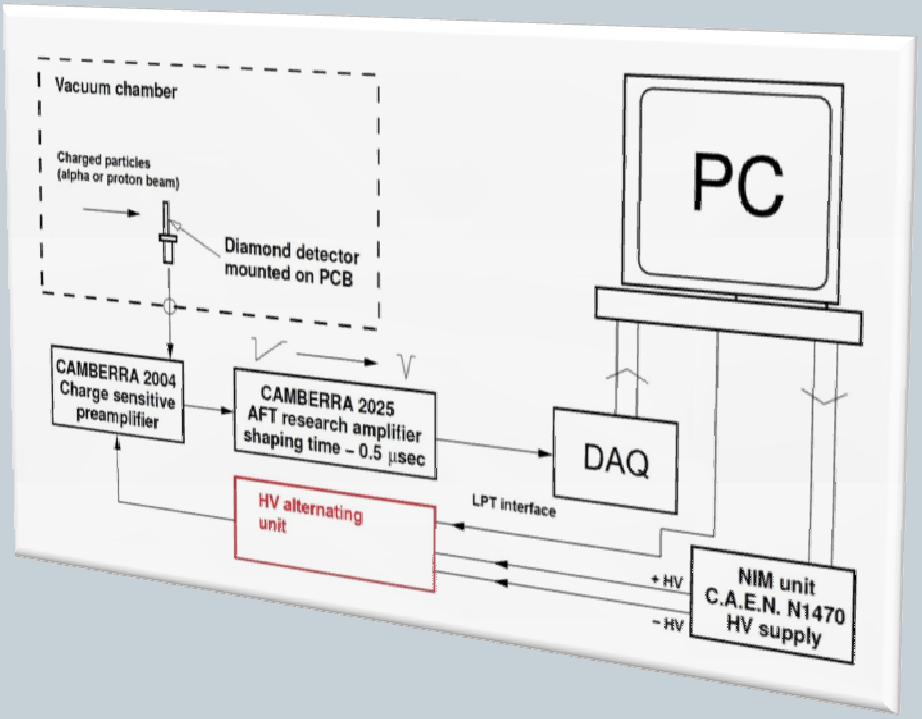
Schematic of the experimental setup adopted using charge sensitive amplifier Camberra 2004 in a chain with Camberra 2025. As DAQ we used:

a) oscilloscope Tektronix DPO4054 connected to the PC via USB
b) CANBERRA ADC 8701 in chain of the Xilinx FPGA based data transfer system

As charged particle source we used :

a) 2 MeV proton beam;
b) ^{210}Po alpha-source (for short term measurements only);
c) 3-line spectrometric alpha-source based on ^{244}Cm+^{241}Am+^{239}Pu (for all measurements).

Schematic of the experimental setup [BIAS alternating unit added]

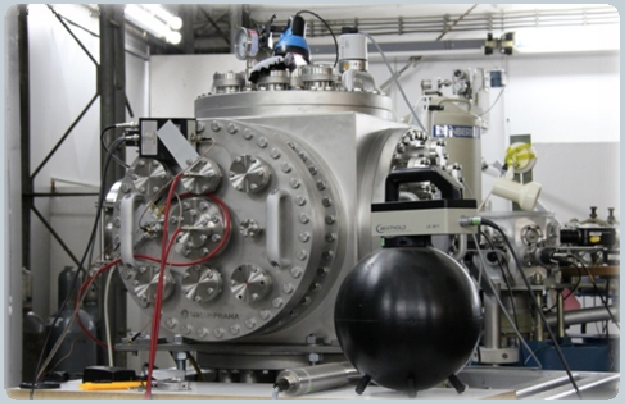


Front side, HV connectors

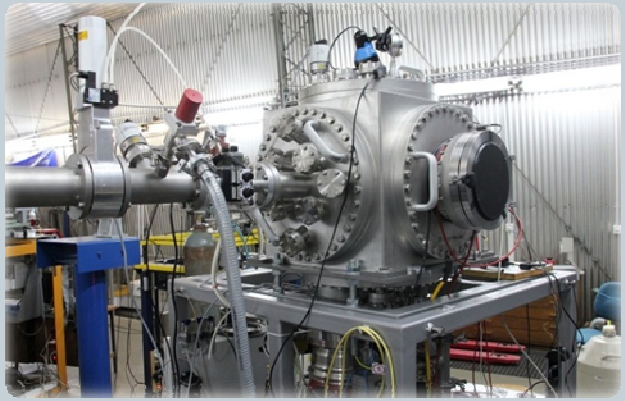
Back side with D-sub 25 pin connector for LPT port

The BIAS alternating unit was added with the aim to study its influences on the long-term stability measurements.

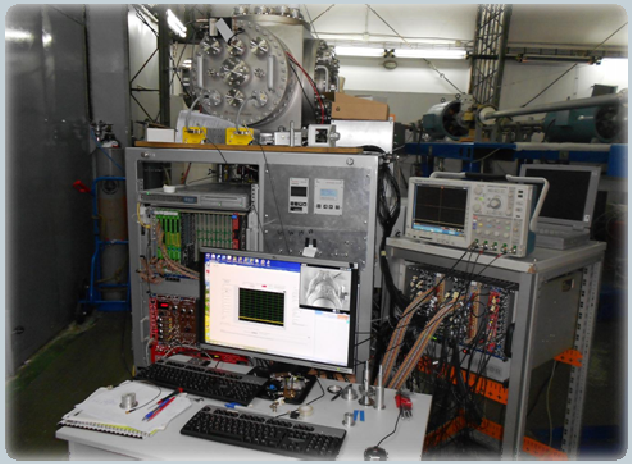
Environment: PD scattering testing chamber for FP7 PD project



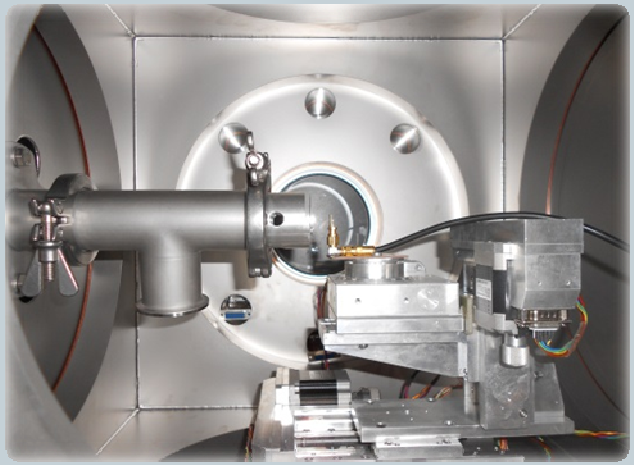
Rear view of the chamber



Front view of the chamber



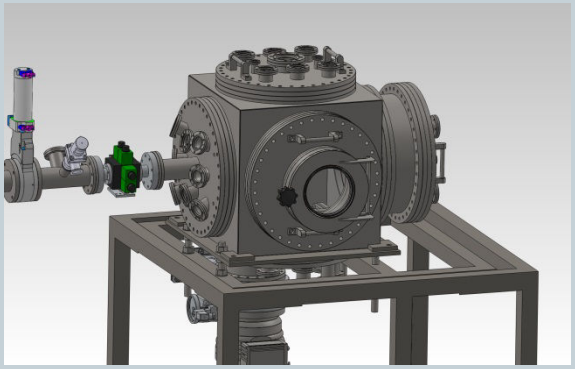
General view

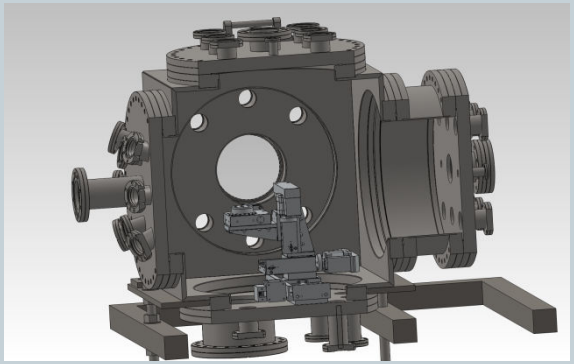


The svCVD detector installed into the chamber

Environment: PD scattering testing chamber for FP7 PD project (continue)

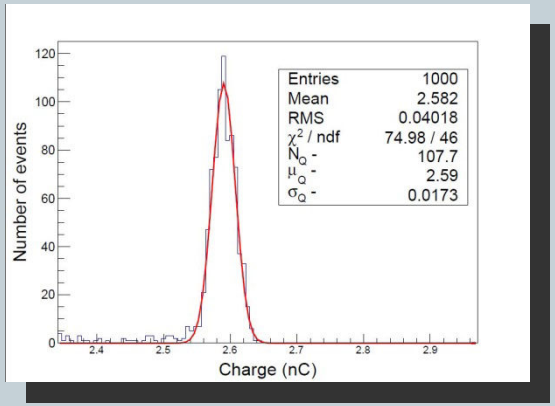
The vacuum chamber was designed from scratch, should be modular, tailored to the existing experimental facility, and assembled from numerous vacuum chamber elements and accessories.



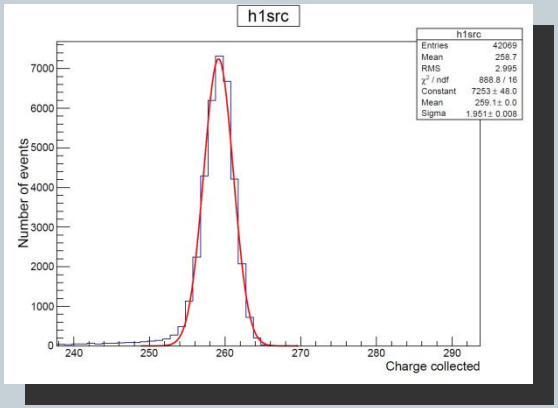


- Vacuum up to 10^{-6} mbar;
- Possible to provide the external beam in air or other medium;
- Up to 200x300 mm in dimensions of the target/detector can tested;
- 4D-mainpulator: 3L linear translation stages with 200x100x50 mm travel distance "+" 1R rotation stage;
- Step along the linear axis is 2 μm, rotation along the vertical axis is 174.5 μrad;
- Option to increase the number of the axis to 5D by adding the goniometer;
- System fully controlled remotely via PC;
- Two cameras installed to perform the fine adjustments to the beam position, and chamber visualization;
- Slit system to control the beam size with windows aperture of 0÷12 mm in step of 2 μm. Thick and fine polished tungsten blades allows stable particle beams size.

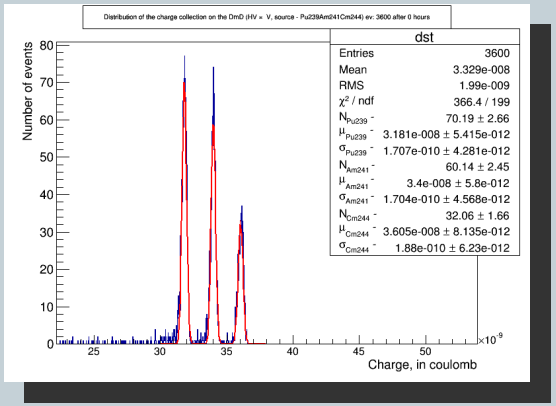
Energy resolution of manufactured scCVD detectors [Short run]



Charge distribution
Spectroscopic resolution up to 1.7% is achieved.
Source - ^{210}Po alpha-particles source



Charge distribution
Spectroscopic resolution up to 1.7% is achieved.
Source – 2 MeV protons

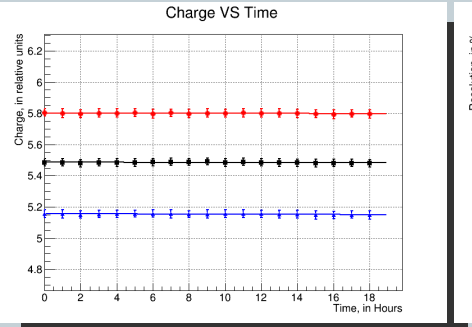


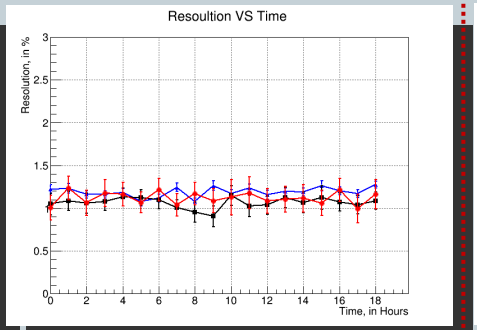
Charge distribution
Spectroscopic resolution up to 1.4% is achieved.
Used 3-line spectroscopic alpha source:
^{244}Cm+^{241}Am+^{239}Pu.

BIAS applied to scCVD detectors: 160 V

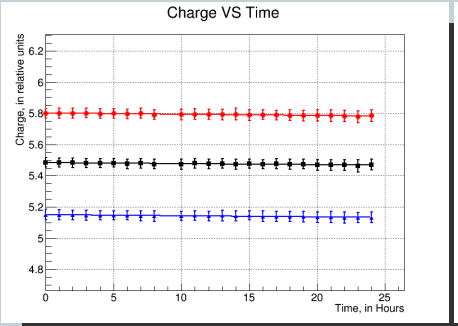
Study of long term stability (Carriers: holes) [constant BIAS applied]

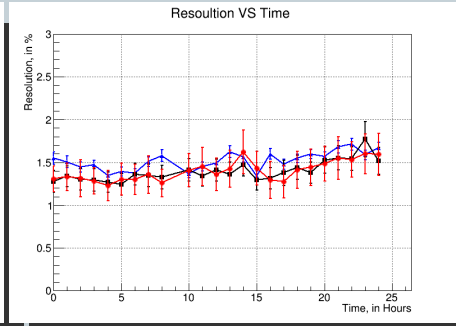
Forward direction





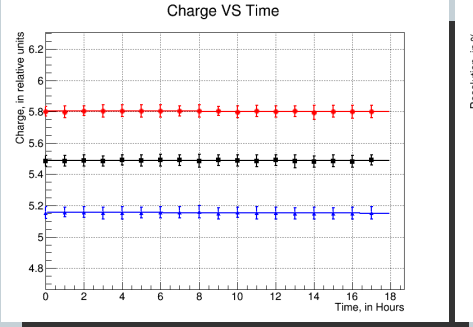
Aluminium electrodes

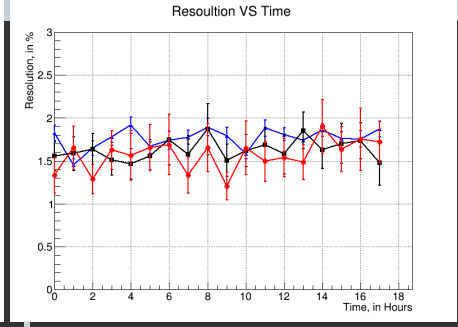




Gold electrodes

Backward direction





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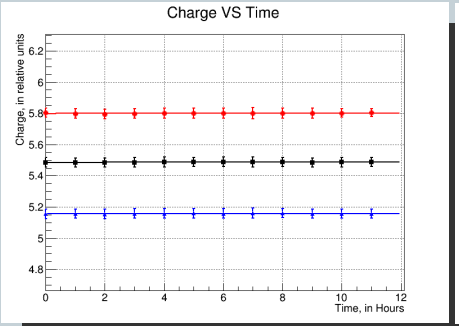

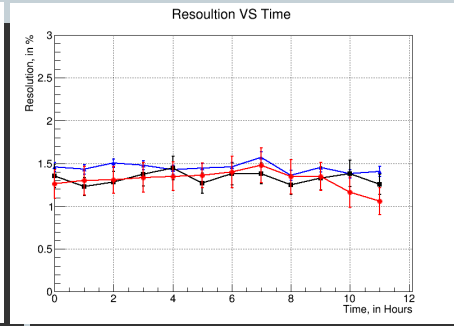

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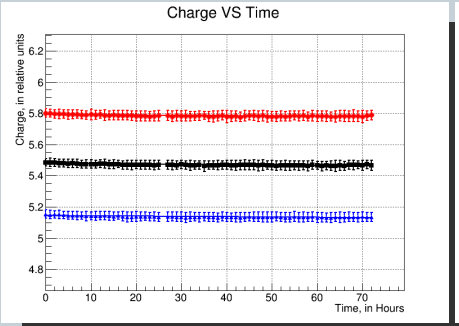
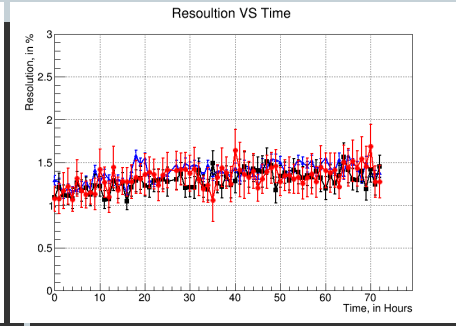
BIAS applied to scCVD detectors: 160 V

Study of long term stability (Carriers: electrons) [constant BIAS applied]

Forward direction





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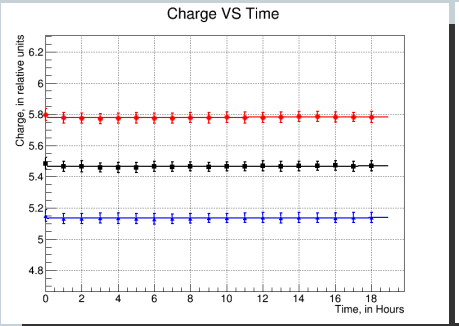
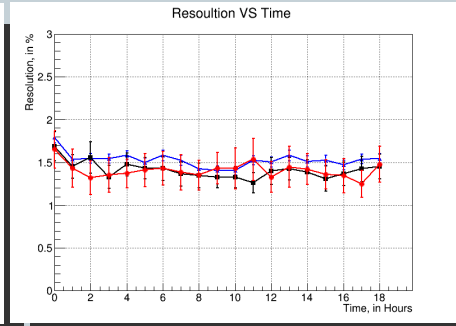
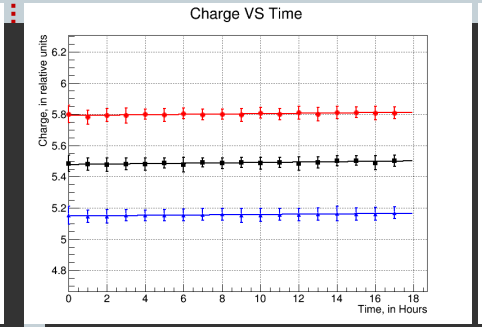
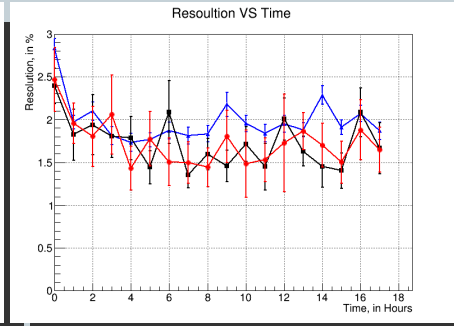




Gold electrodes

Backward direction





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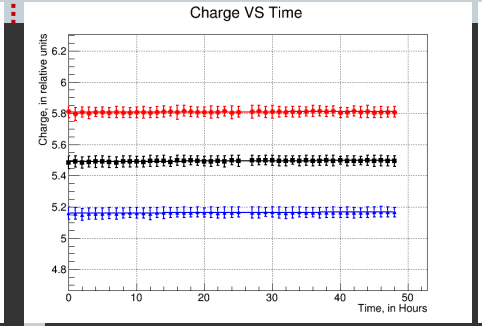
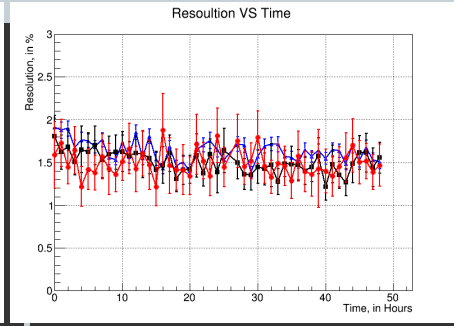


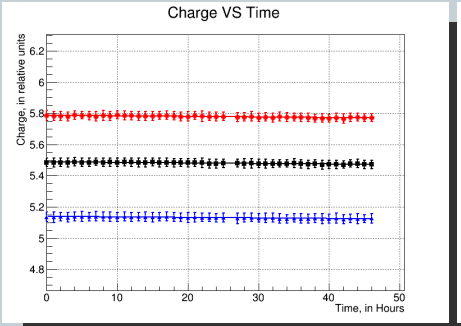


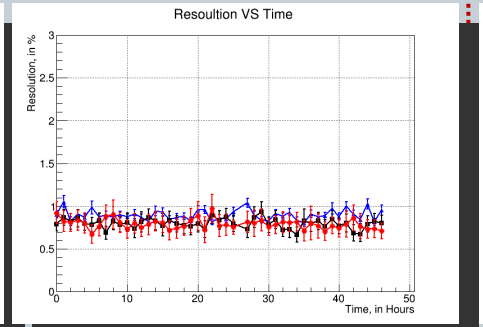
Gold electrodes

BIAS applied to scCVD detectors: 160 V

Study of long term stability (Carriers: holes) [switching polarity of BIAS]

Forward direction





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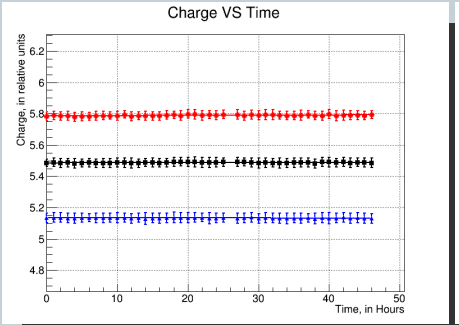

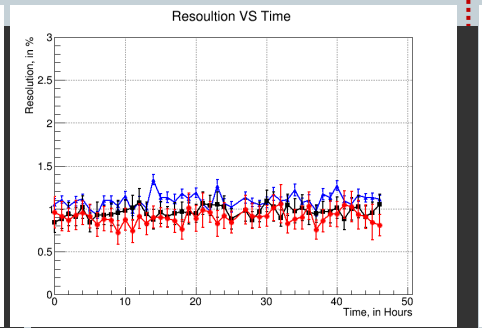

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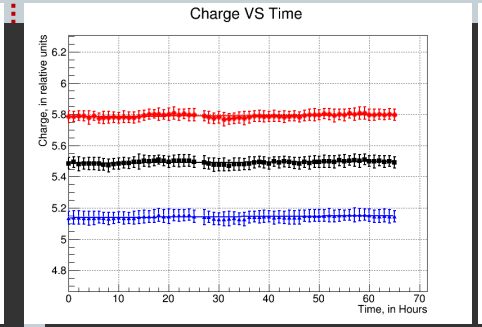
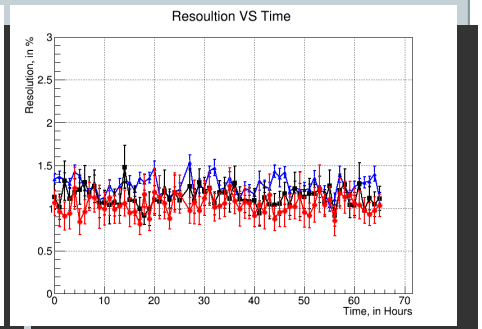
Backward direction





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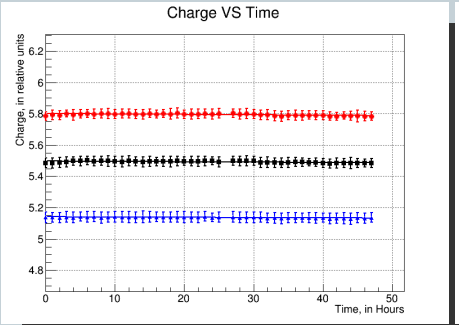

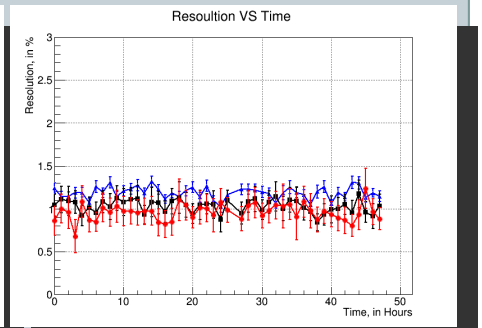

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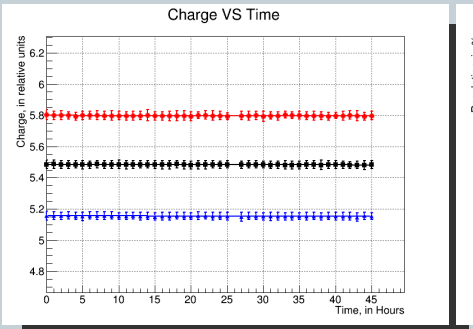
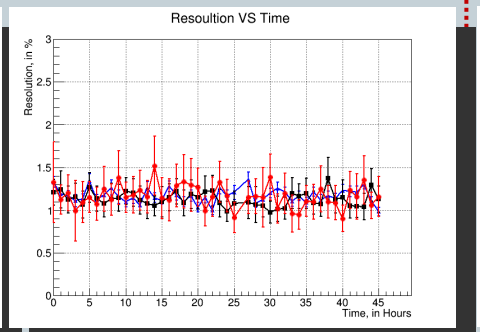
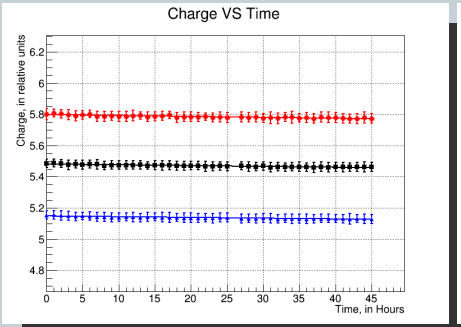
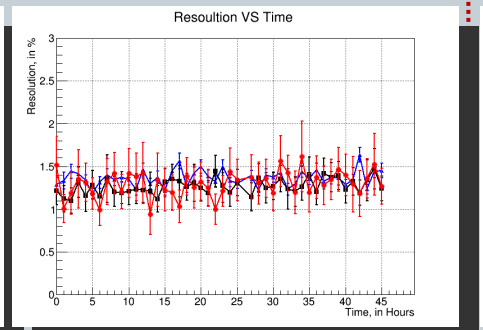




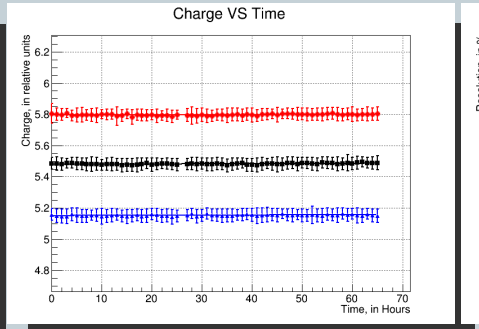
Aluminium electrodes

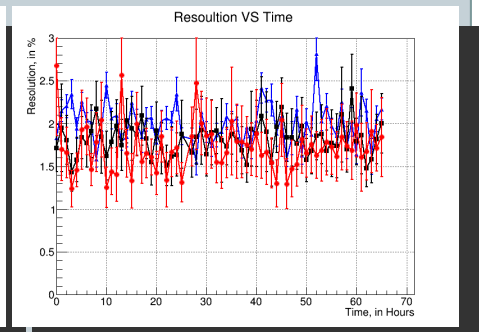




Gold electrodes

Backward direction





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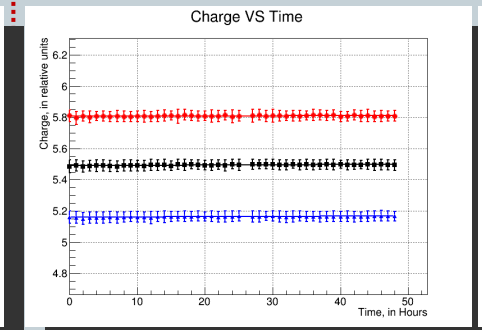
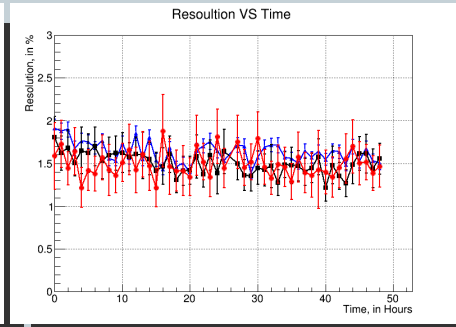




Gold electrodes

BIAS applied to scCVD detectors: 160 V

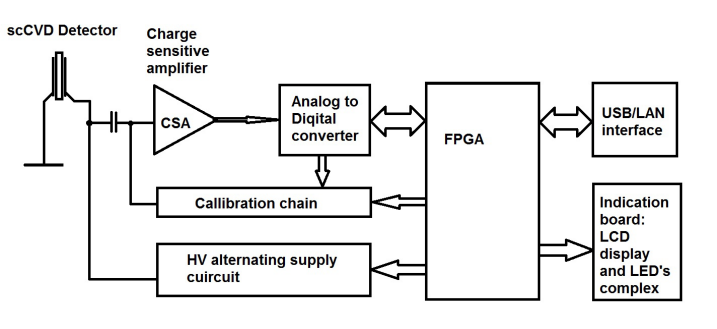
Results: charge collection instability [constant BIAS applied]

	Device	Electrode	Carrier	Charge collection instability (MeV/h) for			Instant Resolution
				^{244}Cm	^{241}Am	^{239}Pu	
Forward	Dmd #1	Al	h	$-2.40\cdot10^{-4}$	$-2.15\cdot10^{-4}$	$-3.23\cdot10^{-4}$	1.2%
			e	$-1.86\cdot10^{-4}$	$-1.99\cdot10^{-4}$	$-1.94\cdot10^{-4}$	1.5%
	Dmd #1	Au	h	$-7.85\cdot10^{-4}$	$-6.34\cdot10^{-4}$	$-6.84\cdot10^{-4}$	1.5%
			e	$2.94\cdot10^{-4}$	$2.08\cdot10^{-4}$	$2.03\cdot10^{-4}$	1.5%
Backward	Dmd #1	Al	h	$-2.01\cdot10^{-4}$	$-0.64\cdot10^{-4}$	$-3.53\cdot10^{-4}$	1.8%
			e	$11.70\cdot10^{-4}$	$12.78\cdot10^{-4}$	$9.54\cdot10^{-4}$	2.0%
	Dmd #1	Au	h	$3.08\cdot10^{-4}$	$2.09\cdot10^{-4}$	$1.34\cdot10^{-4}$	1.4%
			e	$-6.36\cdot10^{-4}$	$-7.10\cdot10^{-4}$	$-7.63\cdot10^{-4}$	1.6%

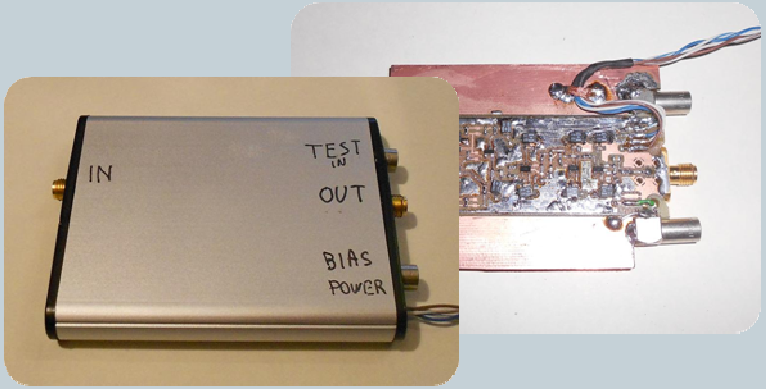
Results: charge collection instability [switching polarity of BIAS]

	Device	Electrode	Carrier	Charge collection instability (MeV/h) for			Instant Resolution
				^{244}Cm	^{241}Am	^{239}Pu	
Forward	Dmd #1	Al	h	$-3.74\cdot10^{-4}$	$-3.42\cdot10^{-4}$	$-3.34\cdot10^{-4}$	0.9%
			e	$-0.44\cdot10^{-4}$	$-0.62\cdot10^{-4}$	$-0.88\cdot10^{-4}$	1.2%
	Dmd #1	Au	h	$1.29\cdot10^{-4}$	$0.54\cdot10^{-4}$	$-0.42\cdot10^{-4}$	1.0%
			e	$-5.97\cdot10^{-4}$	$-5.11\cdot10^{-4}$	$-4.71\cdot10^{-4}$	1.4%
Backward	Dmd #1	Al	h	$2.10\cdot10^{-4}$	$1.80\cdot10^{-4}$	$2.17\cdot10^{-4}$	1.2%
			e	$0.69\cdot10^{-4}$	$0.99\cdot10^{-4}$	$0.91\cdot10^{-4}$	2.0%
	Dmd #1	Au	h	$-2.74\cdot10^{-4}$	$-2.24\cdot10^{-4}$	$-1.68\cdot10^{-4}$	1.1%
			e	$0.998\cdot10^{-4}$	$1.87\cdot10^{-4}$	$1.56\cdot10^{-4}$	1.6%

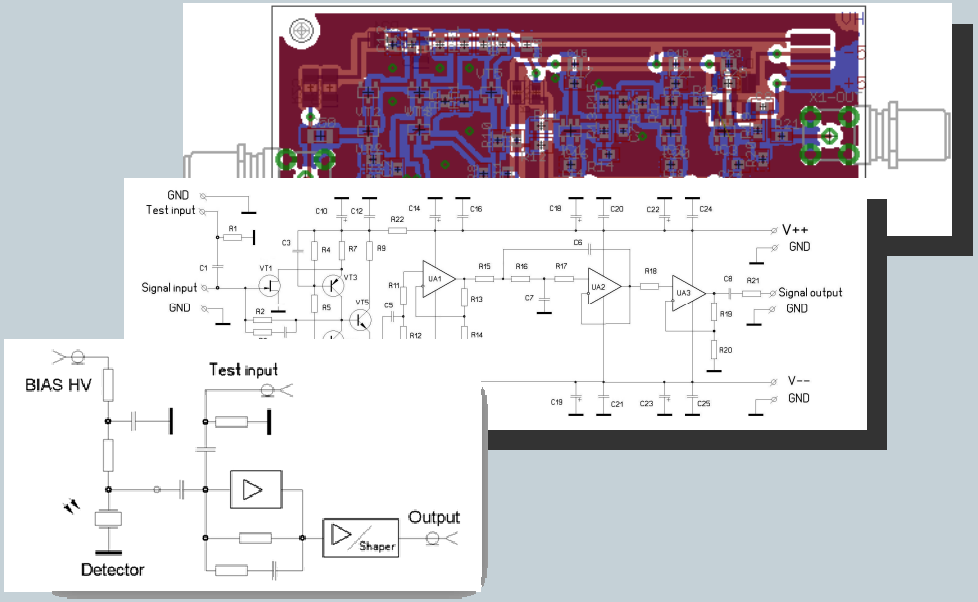
Concept of the design for the alpha particle detector with BIAS alternating included



General schematic



First prototype of the charge sensitive amplifier



Design of the charge sensitive amplifier

Summary/Conclusions

- The scCVD detectors created at RBI show stable spectroscopic resolution over 24 h irradiated by low intensity alpha particle source.
- No depenpence due to electrode type affected to the long term stability.
- On long run, detectors show stable instant spectroscopic resolution ~1.4% and ~1.4% for Al and Au respectively.
- Using the alternating BIAS unit, on long run, detectors show better spectroscopic resolution ~1.0% and 0.9% for Al and Au respectively, especially for holes carriers and in forward direction.

Acknowledgment

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The authors also want impress thanks to the Dr. Z. Siketić, A. Gajski, D. Španja and Ž. Periša (RBI) for great support and valuable help in technical support and help in maintenance the experiments.

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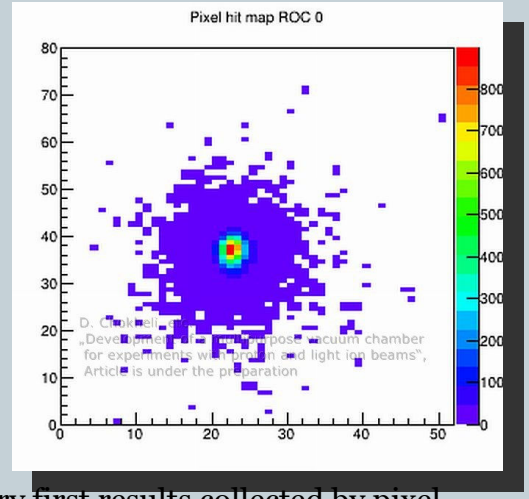
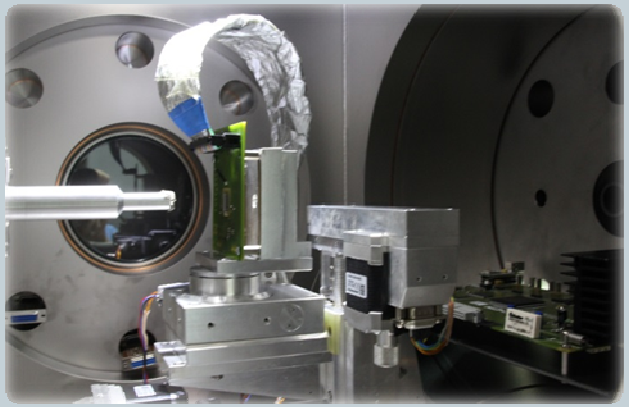
Using the extented in air beam in experiments with CMS pixel detector

ROC pixel detector on PCB board with holder.
The ROC was close by cap for safety



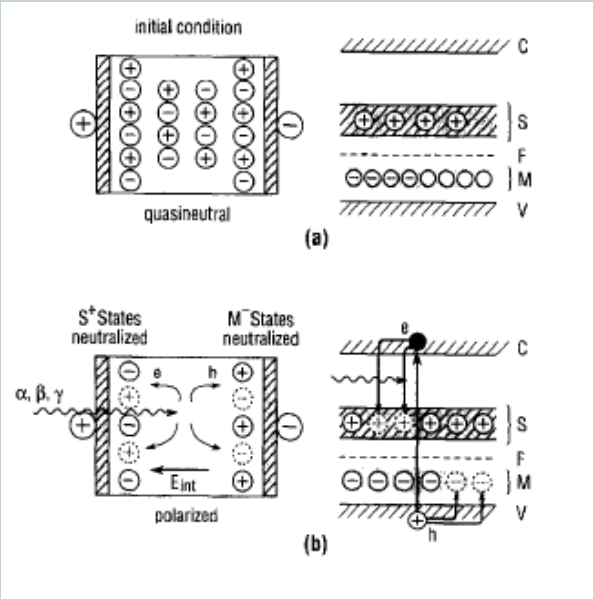
Very first results collected by pixel detector using proton 2 MeV beam in air.



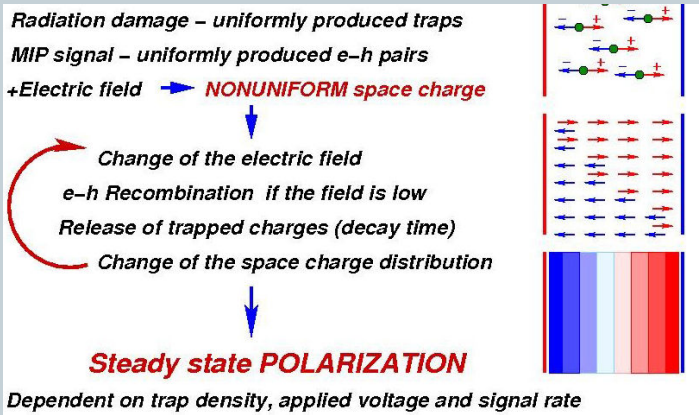
Inside of the chamber: the one ROC pixel detector is placed in front of the nozzle extracting the 2 MeV proton beam in air.

The pixel array is organized in 26 Double Columns (DC) and 80 rows, which add up to 4160 Pixel Unit Cells (PUC) per ROC. The size of a PUC is 100 mm*150 mm (r*z). Each pixel cell contains an analog part with pre-amplifier, shaper, sample-hold mechanism and a comparator with an adjustable threshold. The input of the pre-amplifier is bump-bonded to the sensor. In addition to the analog part there is a digital part with four trim bits for a fine adjustment of the global threshold and a calibrate mechanism to inject charge in to the pre-amplifier. The total amount of transistors per PUC is 251

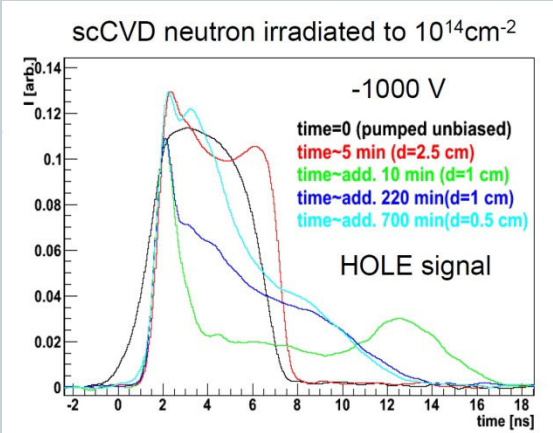
Charge collection deterioration model



Origin of the polarisation
E.-K. Souwm R.J. Meilunas
Nucl.Instr. and Meth, in Phys. Res A 400(1997) 69-86



Sergej Schuwalow, DESY Zeuthen
4th NoRHDia Workshop @ GSI



Polarization affects to the signal in 500 μm thick 500 scCVD.

(G. Kramberger, for CERN-RD 42 collaboration)