CLARO and RAPSODI ASICs irradiation at the CN facility of the INFN-LNL

Angelo Cotta Ramusino, Bartłomiej Rachwał

Reason for the test and its goals

- after the visit at the GELINA facility it became clear that the facility would only provide thermal neutrons (although they might provide an Am-Be source for irradiation with high energy neutrons) for the July test → I asked Roberto Stroili and Flavio for another "parasitic" beam test at LNL. The test has been carried out by R. Stroili, F.Dalcorso, R. Malaguti and myself on June 18th -19th 2012
- the goal of the test was to measure SEL (single event latch-up) similarly to what had been done for the EASIROC- ASIC
- a suitable Single Event Latchup protection and detection circuit had already been designed (R. Malaguti, A.C.R.) to bias the ASICs and limit the current in case of occurence of latch-up; a digital output of this circuit would be available to flag a SEL condition to a remote controller; a PROTECTION_CLEAR input is available at the circuit to restart after a power cut-off
- a simple data acquisition unit with analog and digital input/output has been used to monitor the current consumption of the Device Under Test (DUT), to monitor the PROTECTION_ON flag and to clear it if necessary
- the ACTEL development kit used in previous tests at LNL has been employed in this test as a relative radiation monitor; SiPMs were also added at the end of the stack of DUTs and their dark current has been monitored as a further check

goal of the ASIC test at the INFN Laboratori Nazionali di Legnaro (LNL) and at the GELINA: to assess permanent damage and SEL cross section of ASICs in 0.35um CMOS technology

- **permanent (total dose effects) damage test:**

1) the ASIC under test is characterized before irradiation: for the CLARO and the EASIROC ASICs we are going to record the linearity response of the internal DACs and the S-curves for the comparators. The RAPSODI ASIC#2 chips have been characterized by the designer, W.Kucewicz
2) the same characterization is repeated after irradiation and differences, if evident, are analyzed.

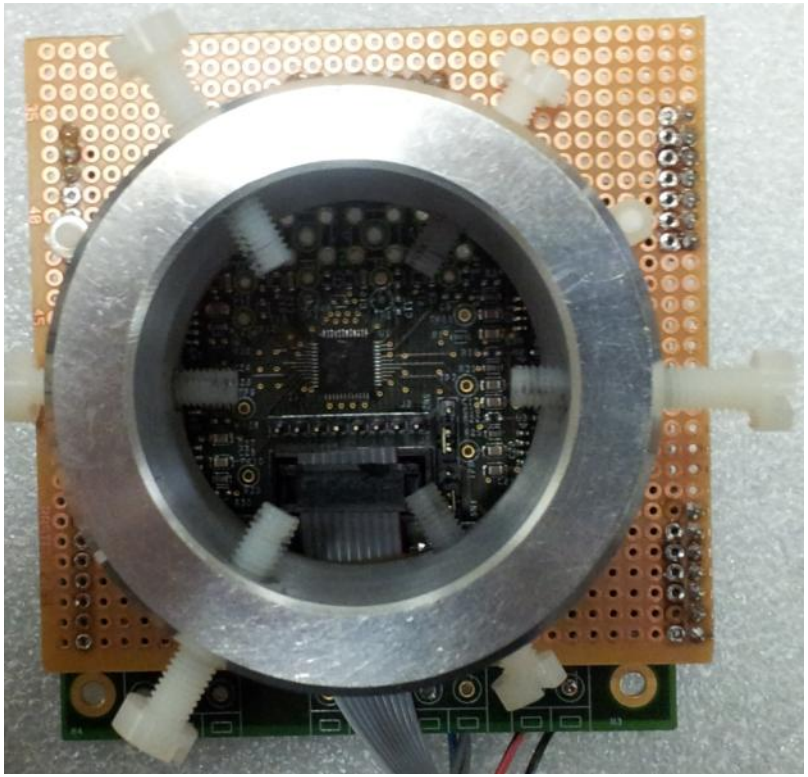
- **Single Event Latchup (SEL) test:**

1) the ASIC is powered, throughout the irradiation period, by means of a SEL detector circuit which cuts the ASIC supply voltage if a large and sudden increase in the supply current is detected. An off-the-shelf digital I/O module is used to remotely reset the circuit and count the occurences.

- **Single Event Upset (SEU) test:**

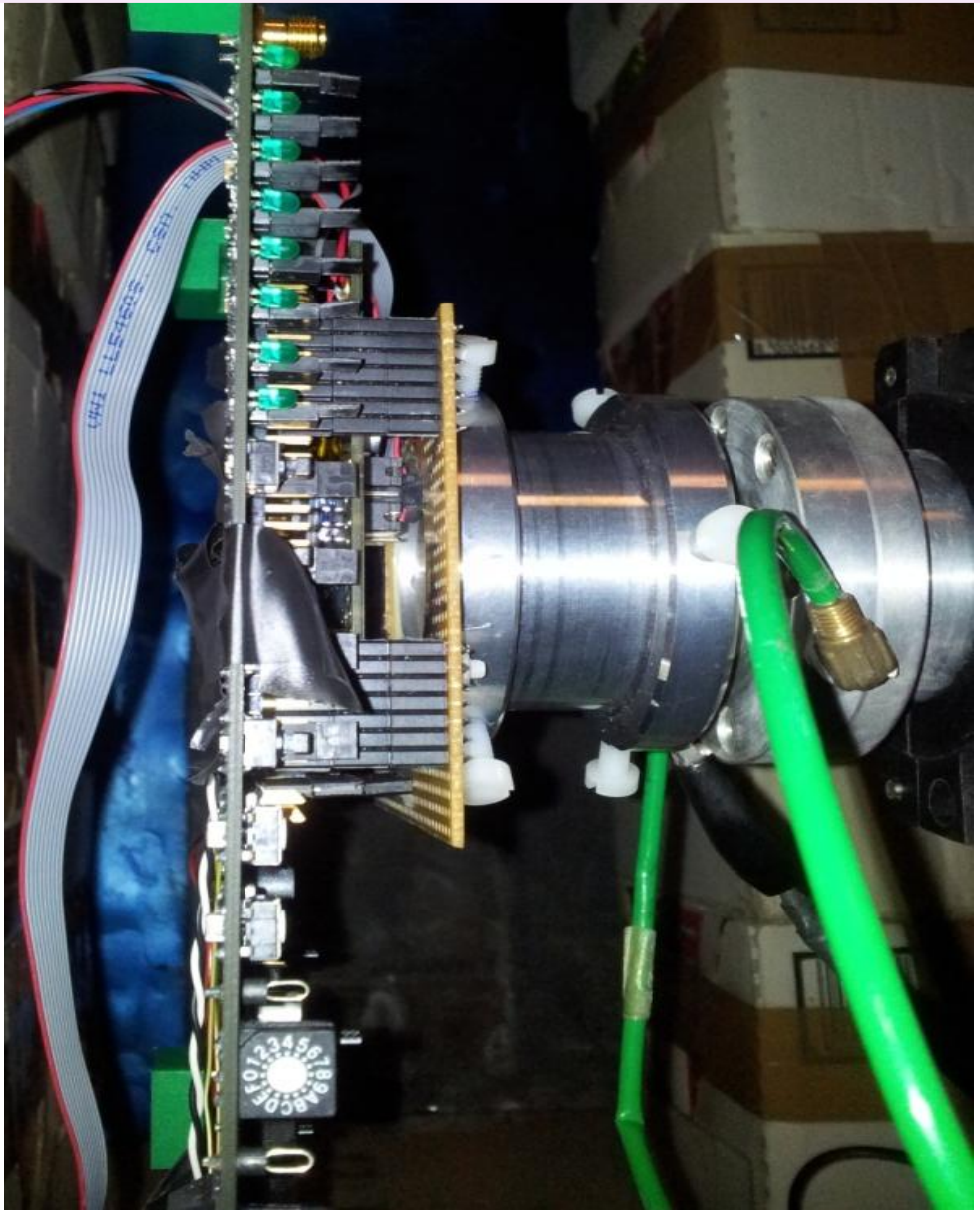
Since the CLARO and the RAPSODI ASIC#2 do not have any readback digital register this test can only be conducted for the EASIROC chip (and it has already been conducted infact at the LNL facility on 2011).

- ASIC irradiation test setup at LNL: CLARO installation details



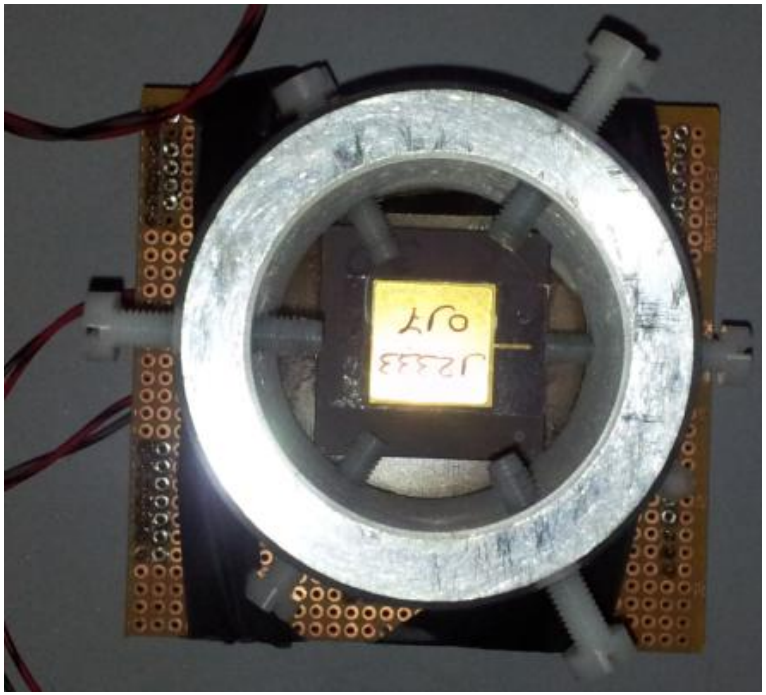
The support for the CLARO fastened to the mounting flange and plugged onto the FPGA development board used as a neutron flux monitor

- ASIC irradiation test setup at LNL: CLARO installation details

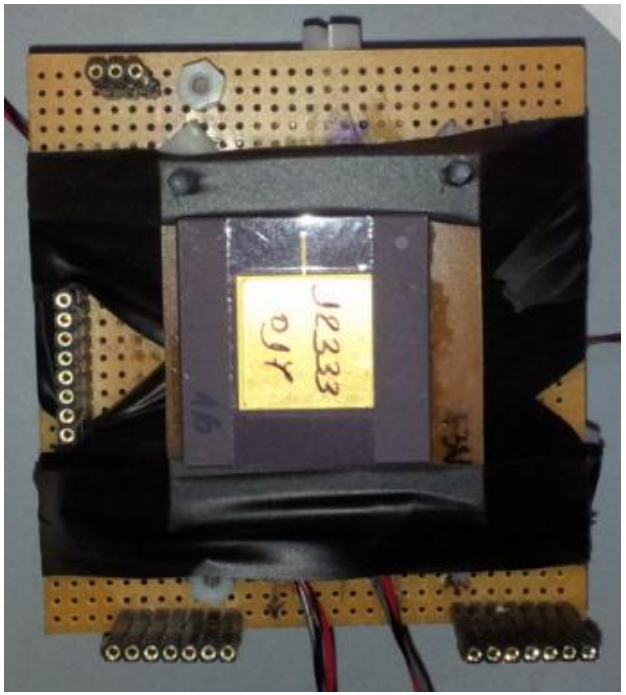


The support for the CLARO placed in front of the source
and plugged onto the FPGA development board used as a neutron flux monitor

- ASIC irradiation test setup at LNL: RAPSODI #2 installation details

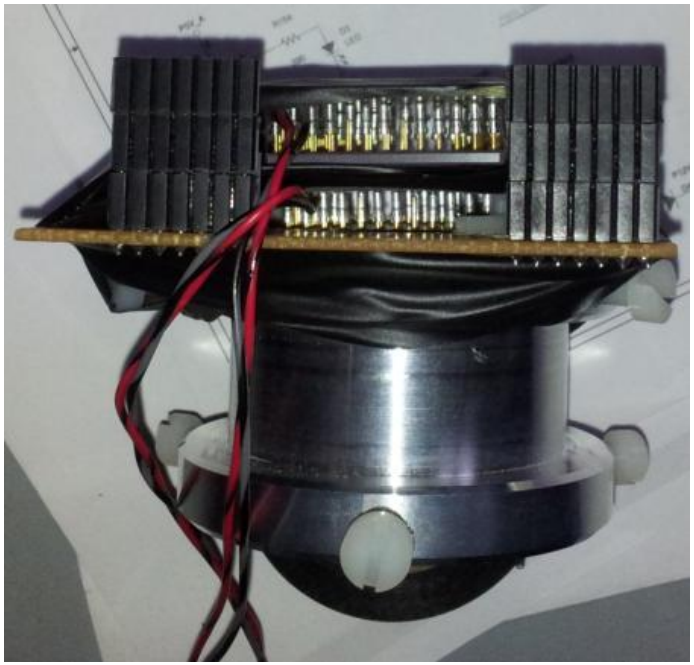


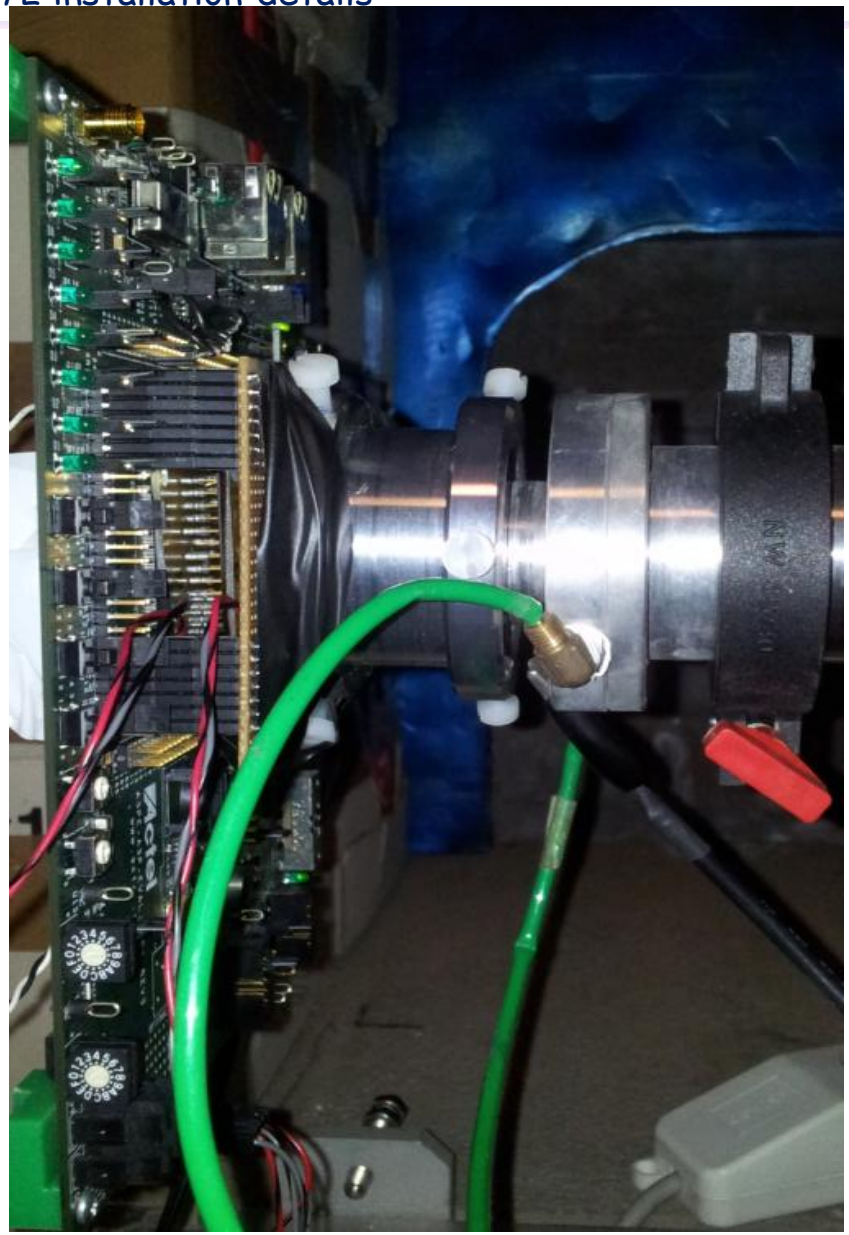
Chip #30 closest to the neutron source



Chip #16 furthest from the neutron source

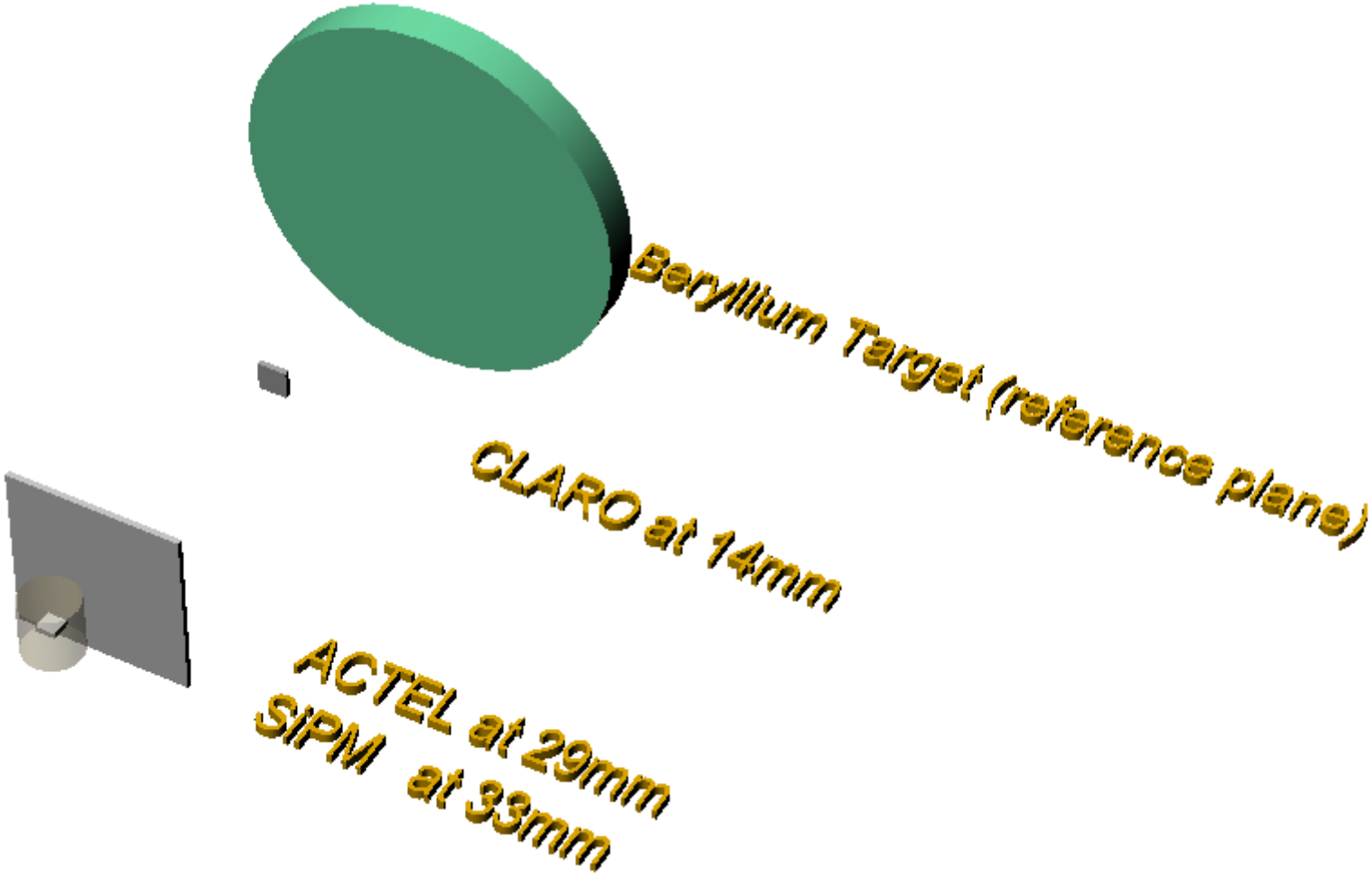
- ASIC irradiation test setup at LNL: RAPSODI #2 installation details





The stack of chips placed in front of the source and plugged onto the FPGA development board used as a neutron flux monitor

Preliminary results of CLARO irradiation (June 18th 2012)



Preliminary results of CLARO irradiation (June 18th 2012)

If both the side lengths (α and β) of the base of the pyramid and the distance (d) from the center of the base rectangle to the apex of the pyramid (the center of the sphere) are known, then the above equation can be manipulated to give

$$\Omega = 4\arctan\frac{\alpha\beta}{2d\sqrt{4d^2+\alpha^2+\beta^2}}.$$

CLARO#1 had been characterized (Bartek Rachwal, A.C.R.) in Ferrara before irradiation and will be characterized again to determine permanent effects.

NO SEL were detected during irradiation with an estimated fluence of about 10^{12} n/cm^2

SOLID ANGLE OMEGA	CLARO #1 (FE)	ACTEL	SensL+MPPC
sterad (sr)	0,011446756	0,094058015	0,000229555
alfa (cm)	0,15	0,9	0,05
beta (cm)	0,15	0,9	0,05
alfa * beta = (cm^2)	0,0225	0,81	0,0025
distance d = (cm)	1,4	2,9	3,3
denominator (cm^2)	7,862467806	34,44047619	43,56249993
total charge (μC) delivered to Beryllium target	2159		
neutron Yield/sr/uC @ E(deuteron)=4 Mev	1,02E+09		
hardness factor @ Ed=4 MeV	1,146		
total neutrons crossing the DUT during the irradiation test	2,51E+10	2,07E+11	5,04E+08
total 1MeV equivalent neutrons crossing the DUT during the irradiation	2,88E+10	2,37E+11	5,78E+08
fluence (neutrons /cm^2) @ DUT location	1,12E+12	2,61E+11	2,02E+11
fluence (neutrons /cm^2) of 1MeV equivalent neutrons @ DUT location	1,28E+12	2,99E+11	2,31E+11

Preliminary results of CLARO irradiation (June 18th 2012)

If both the side lengths (α and β) of the base of the pyramid and the distance (d) from the center of the base rectangle to the apex of the pyramid (the center of the sphere) are known, then the above equation can be manipulated to give

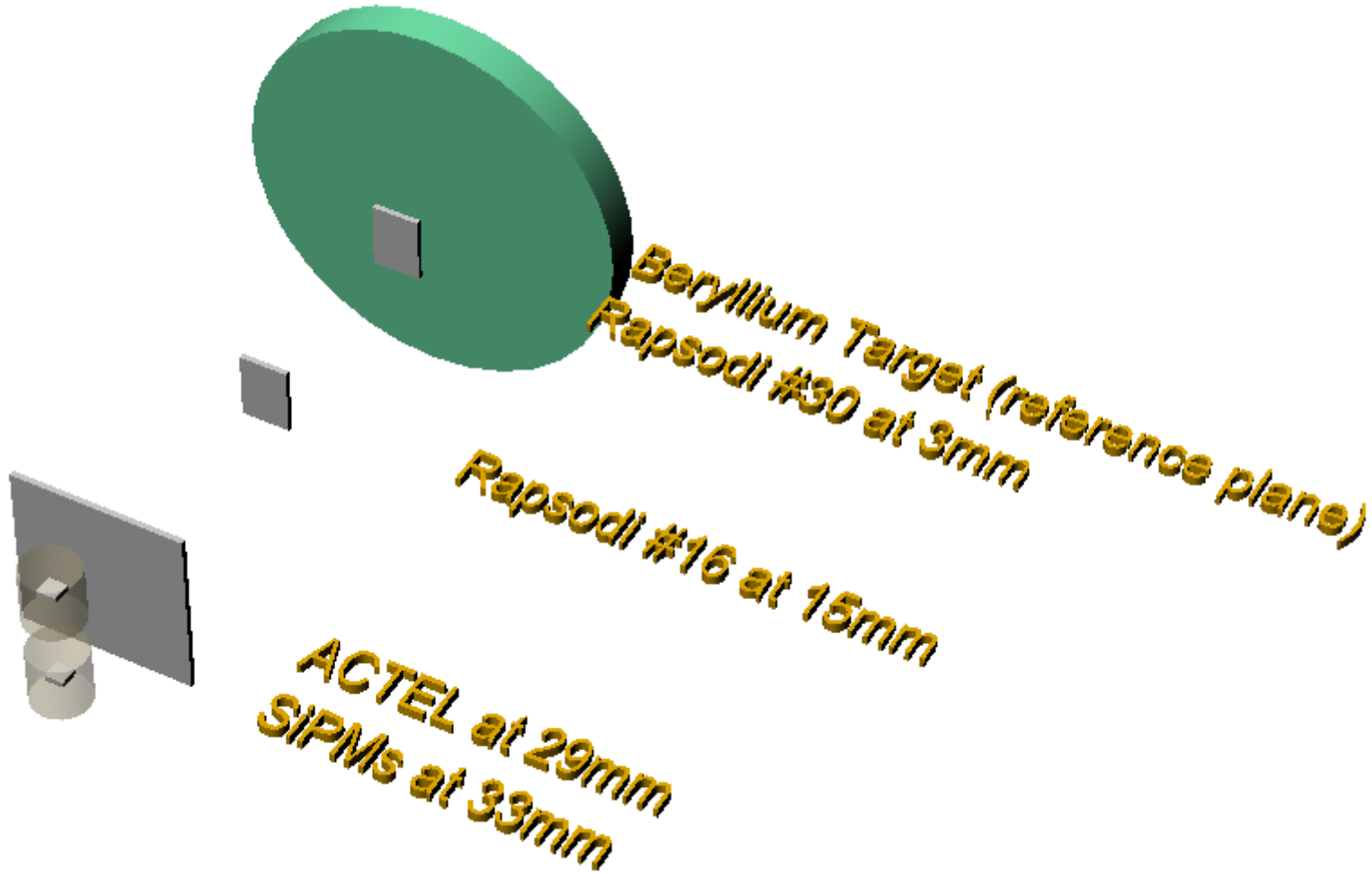
$$\Omega = 4\arctan\frac{\alpha\beta}{2d\sqrt{4d^2+\alpha^2+\beta^2}}.$$

CLARO#2 had been characterized (C. Gotti, G.Pessina) at INFN Mi-Bicocca before irradiation and will be characterized again to determine permanent effects.

NO SEL were detected during irradiation with an estimated fluence of about 10^{12} n/cm^2

SOLID ANGLE OMEGA		CLARO #2 (MI)	ACTEL	SensL+MPPC
sterad (sr)		0,011446756	0,094058015	0,000229555
alfa (cm)		0,15	0,9	0,05
beta (cm)		0,15	0,9	0,05
alfa * beta = (cm^2)		0,0225	0,81	0,0025
distance d = (cm)		1,4	2,9	3,3
denominator (cm^2)		7,862467806	34,44047619	43,56249993
total charge (μC) delivered to Beryllium target	2217			
neutron Yield/sr/uC @ E(deuteron)=4 Mev	1,02E+09			
hardness factor @ Ed=4 MeV	1,146			
total neutrons crossing the DUT during the irradiation test		2,58E+10	2,12E+11	5,18E+08
total 1MeV equivalent neutrons crossing the DUT during the irradiation		2,96E+10	2,43E+11	5,93E+08
fluence (neutrons /cm^2) @ DUT location		1,15E+12	2,68E+11	2,07E+11
fluence (neutrons /cm^2) of 1MeV equivalent neutrons @ DUT location		1,32E+12	3,07E+11	2,37E+11

Preliminary results of RAPSODI ASIC #2 irradiation (June 18th 2012)



Preliminary results of RAPSODI ASIC #2 irradiation (June 18th 2012)

If both the side lengths (α and β) of the base of the pyramid and the distance (d) from the center of the base rectangle to the apex of the pyramid (the center of the sphere) are known, then the above equation can be manipulated to give

$$\Omega = 4\arctan\frac{\alpha\beta}{2d\sqrt{4d^2+\alpha^2+\beta^2}}.$$

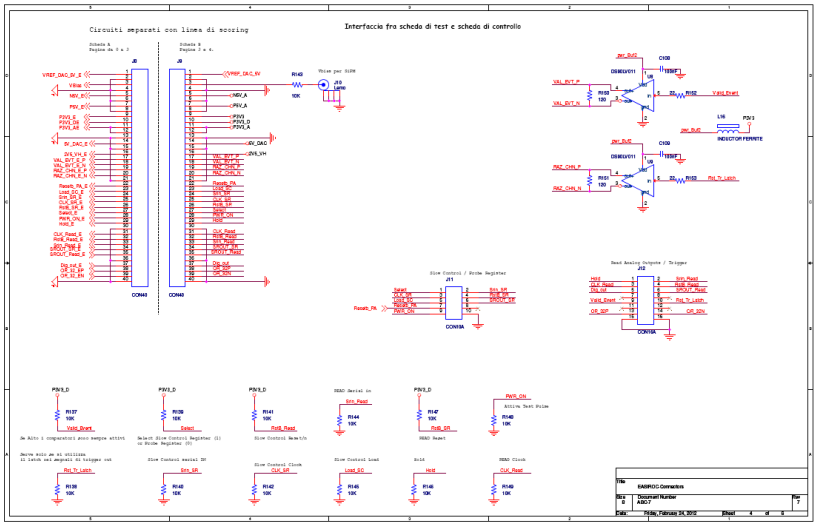
the RAPSODI ASIC#2 chips had been characterized by Woitek Kucewicz in Krakow before irradiation and will be characterized again to determine permanent effects.

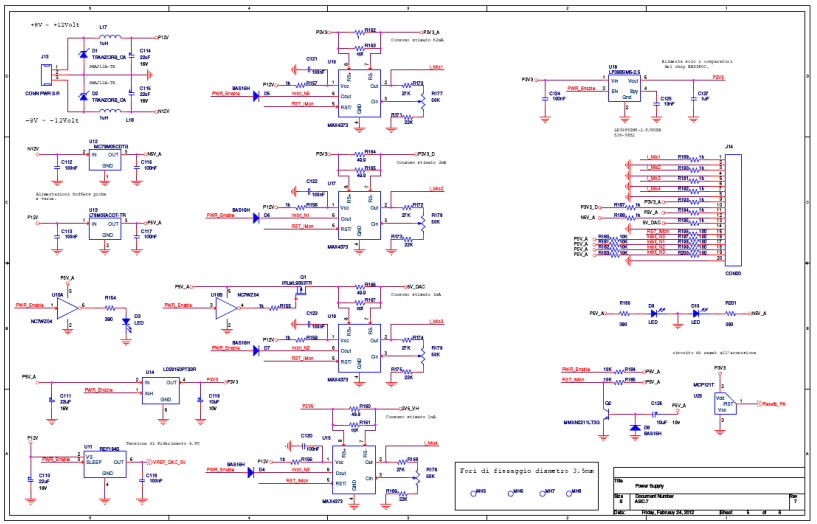
NO SEL were detected during irradiation with an estimated fluence in excess of 10^{12} n/cm^2

SOLID ANGLE OMEGA	RAPSODI #30	RAPSODI #16	ACTEL	SensL+MPPC
sterad (sr)	0,780122373	0,038494067	0,094058015	0,000229555
alfa (cm)	0,35	0,35	0,9	0,05
beta (cm)	0,25	0,25	0,9	0,05
alfa * beta = (cm^2)	0,0875	0,0875	0,81	0,0025
distance d = (cm)	0,3	1,5	2,9	3,3
denominator (cm^2)	0,442944692	9,092029476	34,44047619	43,56249993
total charge (μC) delivered to Beryllium target	2544			
neutron Yield/sr/uC @ E(deuteron)=4 Mev	1,02E+09			
hardness factor @ Ed=4 MeV	1,146			
total neutrons crossing the DUT during the irradiation test	2,02E+12	9,96E+10	2,43E+11	5,94E+08
total 1MeV equivalent neutrons crossing the DUT during the irradiation	2,31E+12	1,14E+11	2,79E+11	6,81E+08
fluence (neutrons /cm^2) @ DUT location	2,88E+13	1,15E+12	3,08E+11	2,38E+11
fluence (neutrons /cm^2) of 1MeV equivalent neutrons @ DUT location	3,30E+13	1,32E+12	3,53E+11	2,72E+11

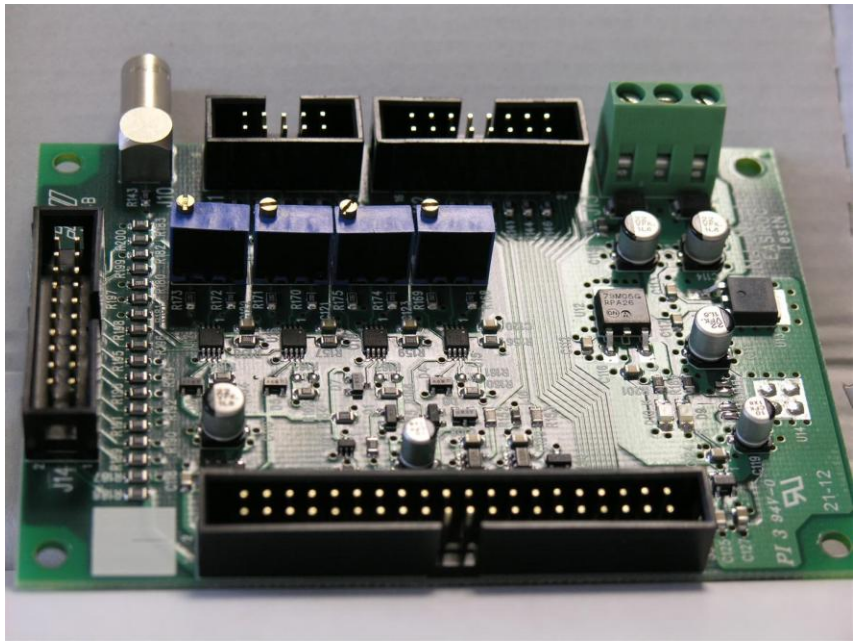
SuperB IFR electronics: preparing for irradiation tests

- ASICs test fixtures: the Single Event Latchup detection/protection board



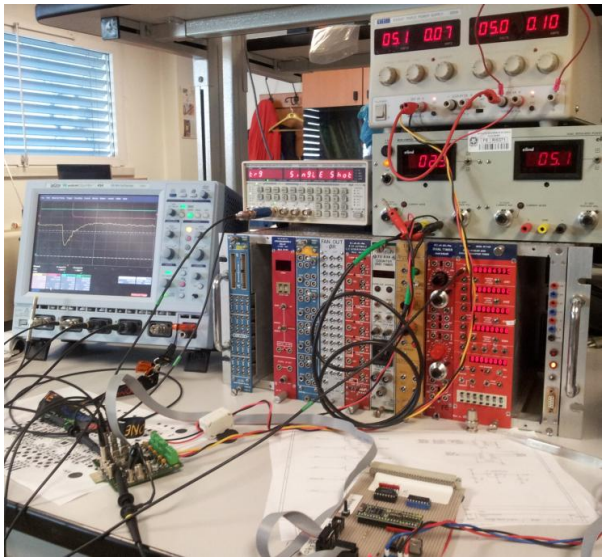


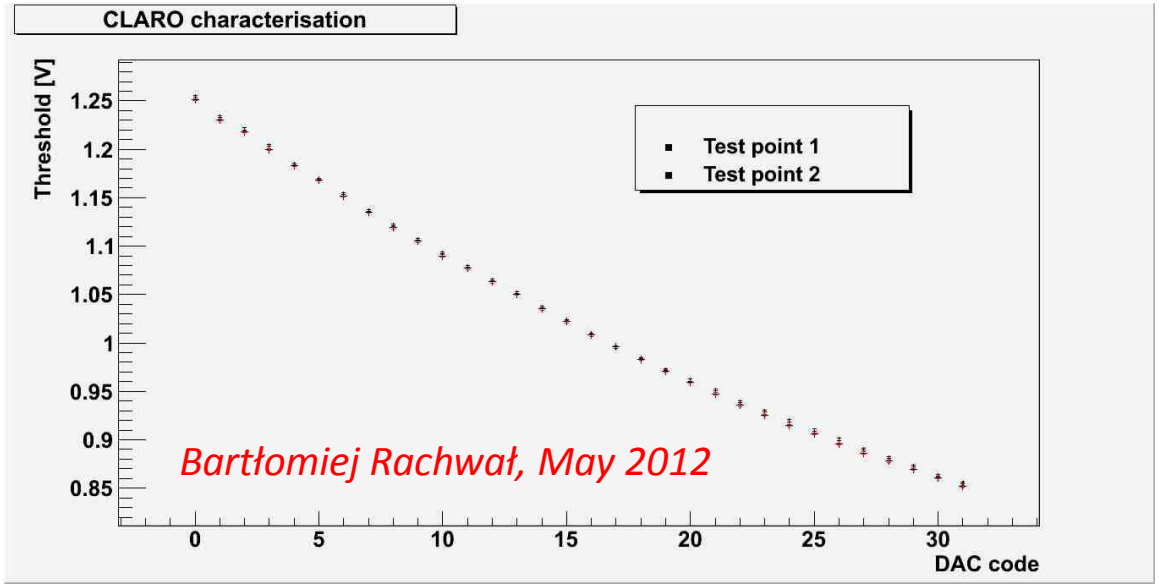
R.Malaguti, A.C.R., INFN-FE Apr. 2012



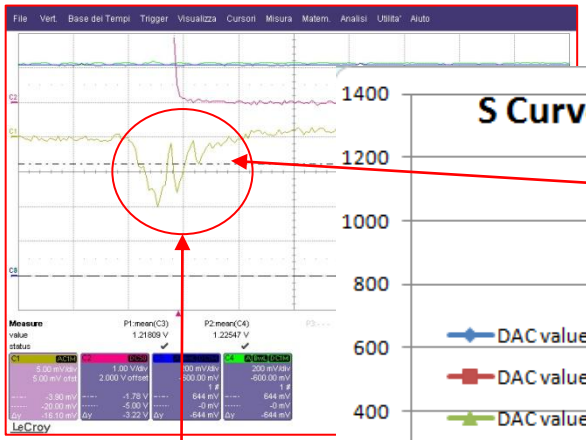
SuperB IFR electronics: preparing for irradiation tests

- pre-irradiation characterization of the target ASICs

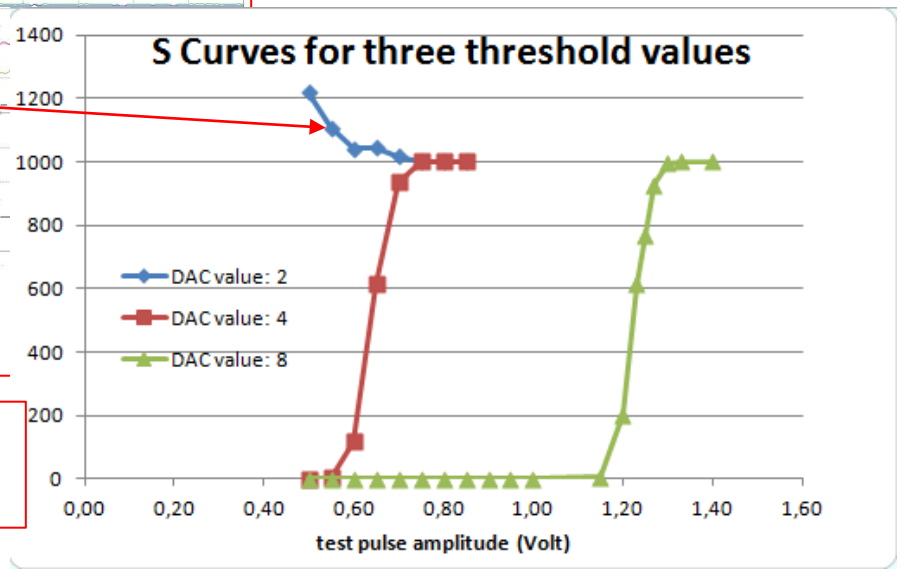




CLARO characterization test setup at INFN_FE.
The tests have been performed by Bartłomiej Rachwał, visiting PhD student from Cracow University



Monitoring the analog and digital outputs introduces some artifact at lower threshold settings

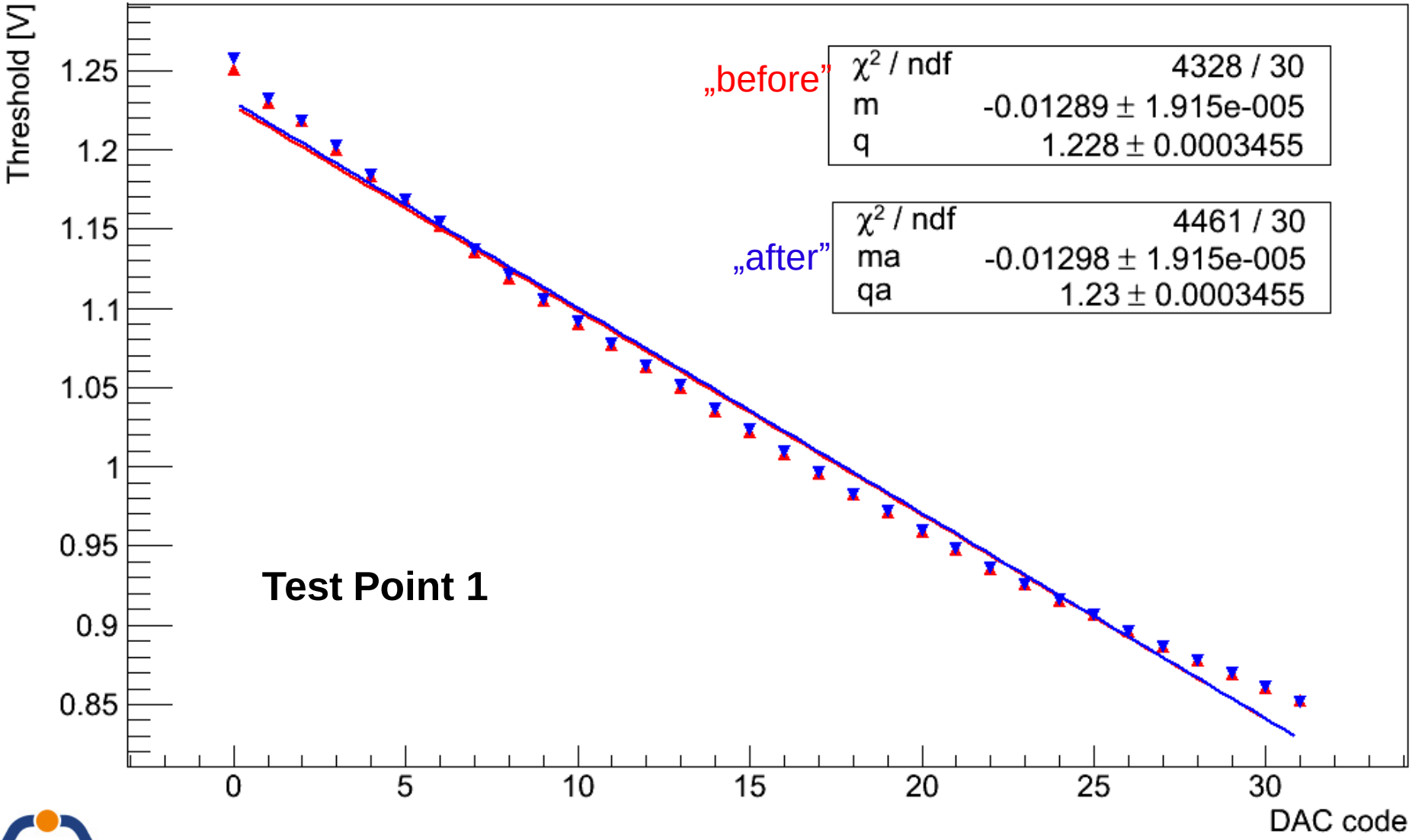


CLARO board

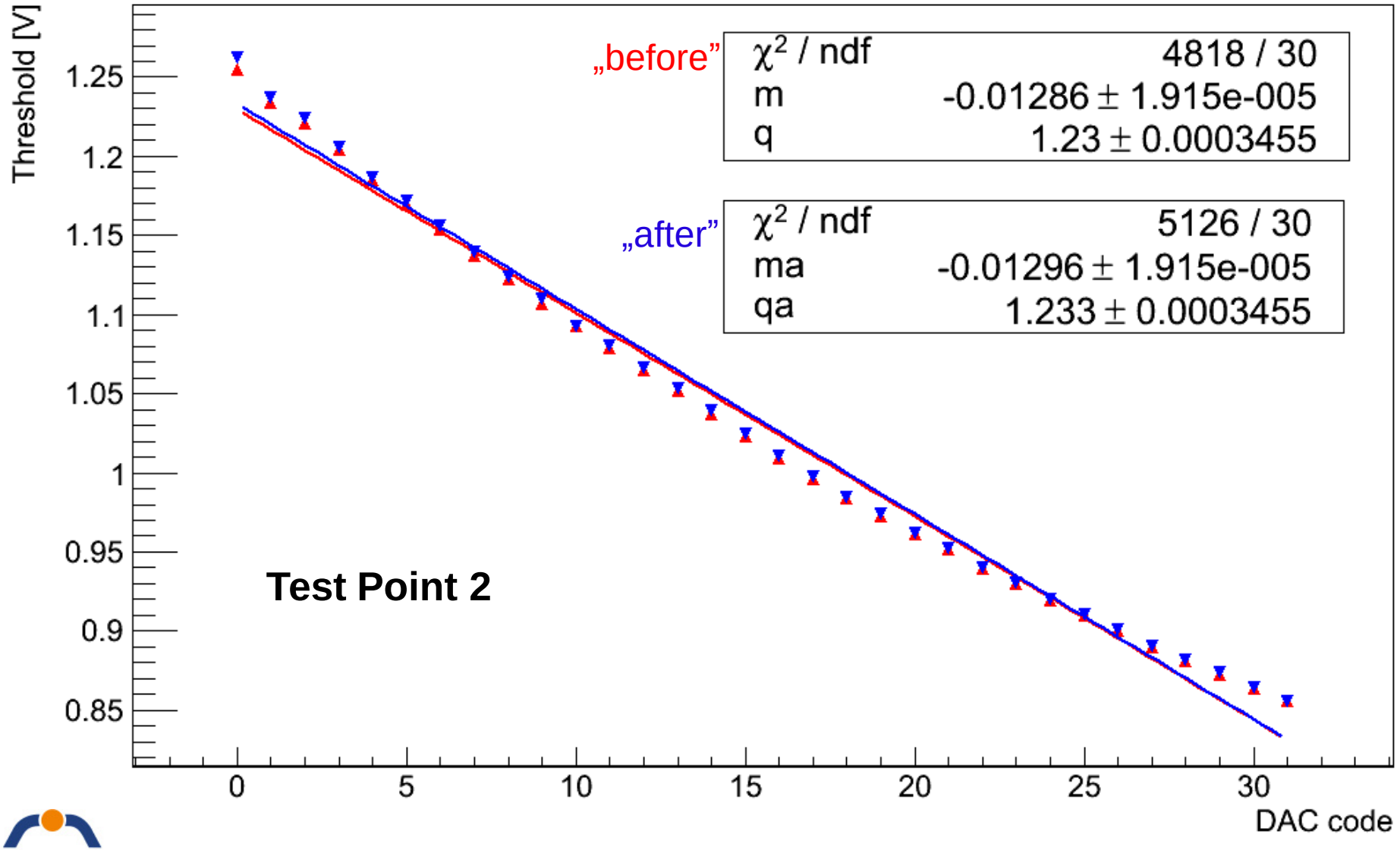
Linear characterization

Threshold Voltage vs. DAC code

CLARO board - Linear characterizationThreshold Voltage vs. DAC code



CLARO board - Linear characterizationThreshold Voltage vs. DAC code



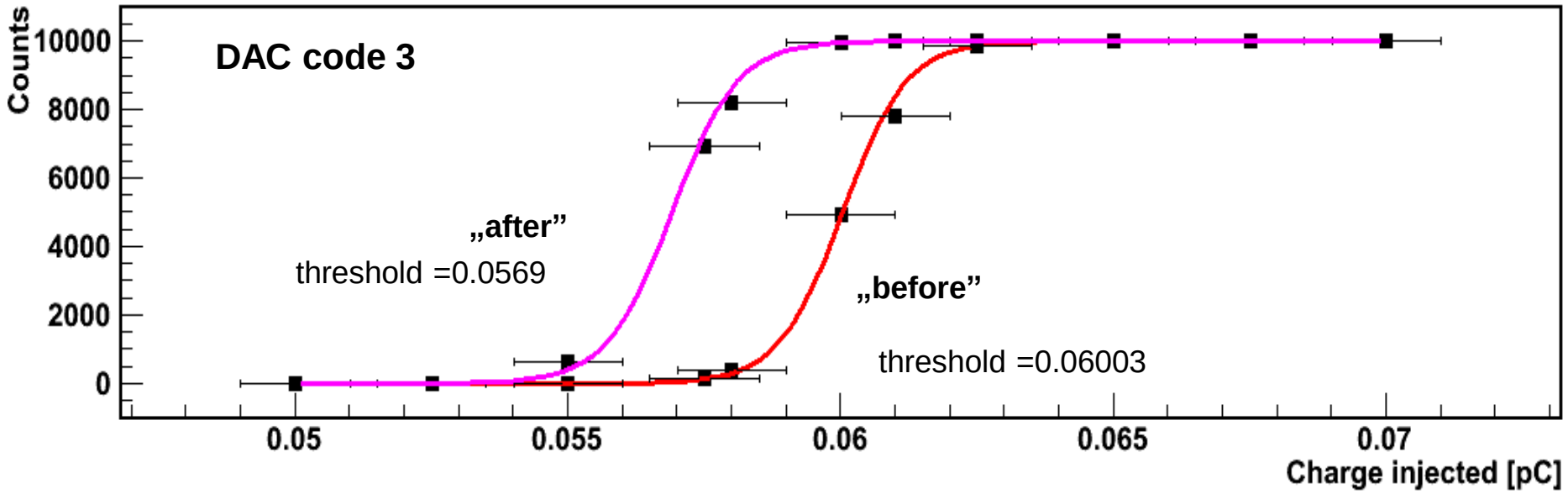
		DAC 3		DAC 4		DAC 8		DAC 16	
Channel A	Burst 1E+4	**Threshold [pC]**							
		before : 0.06003	after: 0.0569	before : 0.0859	after: 0.08143	before : 0.176	after: 0.1707	before: 0.3381	after: 0.3178
		shift = 0.00313 (5.21%)		shift = 0.00447 (5.20%)		shift = 0.0053 (3%)		shift = 0.0203 (6%)	
		Slopes from linear fittings : **before** = 0.0213 ± 0.0005 **after** = 0.0199 ± 0.0004 (6.6%)							
	Burst 1E+5	**Threshold [pC]**							
		before : 0.05981	after: 0.05742	before: 0.08533	after: 0.08146	before: 0.1779	after: 0.1705	before: 0.3376	after: 0.3176
		shift = 0.00239 (4%)		shift = 0.00387 (4.5%)		shift = 0.0074 (4.16%)		shift = 0.02 (5.9%)	
		Slopes from linear fittings: before= 0.0213 ± 0.0005 after= 0.0199 ± 0.0005 (6.6%)							
Channel B	Burst 1E+4	**Threshold [pC]**							
		before : 0.07327	after: 0.06716	before : 0.1031	after: 0.09307	before : 0.2082	after: 0.1911	before : 0.4013	after: 0.3623
		shift = 0.00611 (8.3%)		shift = 0.01003 (9.7%)		shift =0.0171 (8.2%)		shift = 0.039 (9.7%)	
		Slopes from linear fittings: before= 0.0251± 0.0005 after=0.0226± 0.0005 (9.9%)							
	Burst 1E+5	**Threshold [pC]**							
		before : 0.07288	after: 0.0676	before: 0.1008	after: 0.09297	before : 0.2088	after: 0.1911	before : 0.4	after: 0.362
		shift = 0.00528 (7.25%)		shift =0.00783 (7.77%)		shift = 0.0177 (8.5%)		shift = 0.038 (9.5%)	
		Slopes from linear fittings: before= 0.0251±0.0005 after= 0.0226±0.0005 (11%)							
Channel C	Burst 1E+4	**Threshold [pC]**							
		before : 0.07344	after: 0.07152	before : 0.09742	after: 0.0952	before : 0.1839	after: 0.1812	before : 0.3349	after: 0.329
		shift = 0.00192 (2.6%)		shift = 0.00222 (2.28%)		shift = 0.0027 (1.47%)		shift = 0.0059 (1.76%)	
		Slopes from linear fittings: before= 0.0200±0.0005 after=0.0197±0.0005 (1.5%)							
	Burst 1E+5	**Threshold [pC]**							
		before : 0.07344	after: 0.07145	before : 0.09696	after: 0.09508	before : 0.1844	after: 0.1811	before : 0.3355	after: 0.3278
		shift = 0.00199 (2.7%)		shift = 0.00188 (1.94%)		shift = 0.0033 (1.79%)		shift = 0.0077 (2.3%)	
		Slopes from linear fittings: before= 0.0201±0.0005 after= 0.0196±0.0005 (2.5%)							
Channel D	Burst 1E+4	**Threshold Voltage**							
		before : 0.08028	after: 0.07984	before : 0.1042	after: 0.1035	before : 0.1898	after: 0.1892	before : 0.335	after: 0.3335
		shift = 0.00044 (0.5%)		shift = 0.0007 (0.67%)		shift = 0.0006 (0.3%)		shift = 0.0015 (0.45%)	
		Slopes from linear fittings: before=0.01947±0.00049 after=0.01939±0.00049 (0.4%)							
	Burst 1E+5	**Threshold Voltage**							
		before: 0.0801	after: 0.07977	before: 0.1041	after: 0.1036	before: 0.1897	after: 0.189	before: 0.3345	after: 0.3315
		shift = 0.00033 (0.41%)		shift = 0.0005 (0.48%)		shift = 0.0007 (0.37%)		shift = 0.0003 (0.9%)	
		Slopes from linear fittings: before= 0.01944±0.00049 after= 0.01923±0.00049 (1.1%)							

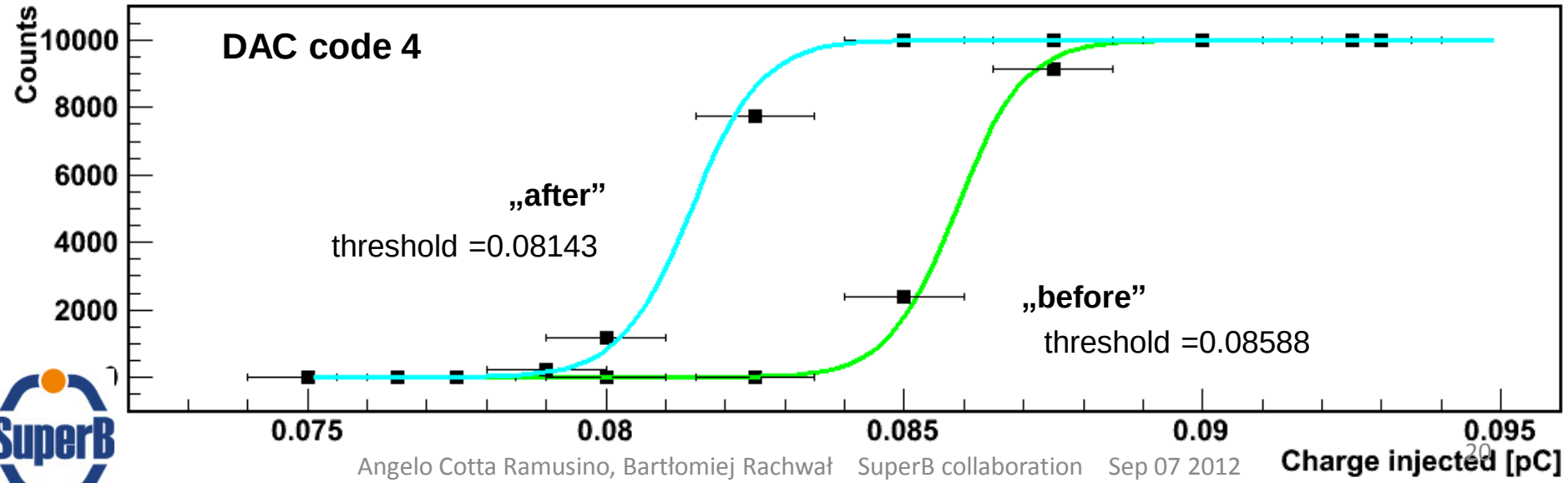
CLARO board

Channel A

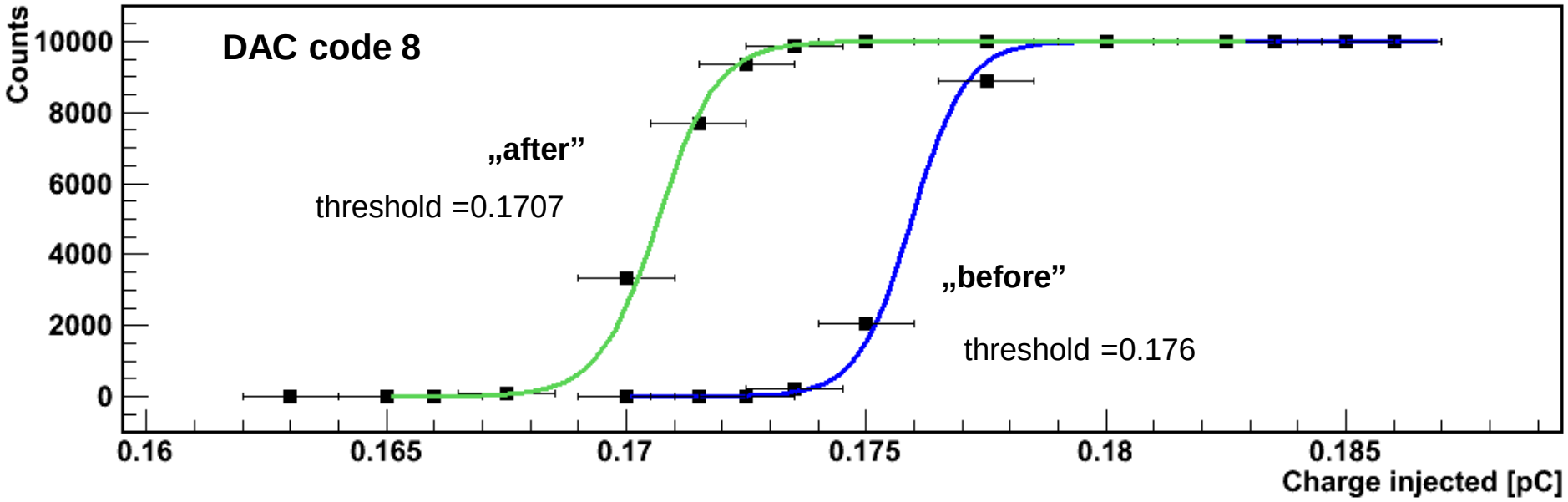
Pulser Trigger - Burst 1E+4 & 1E+5

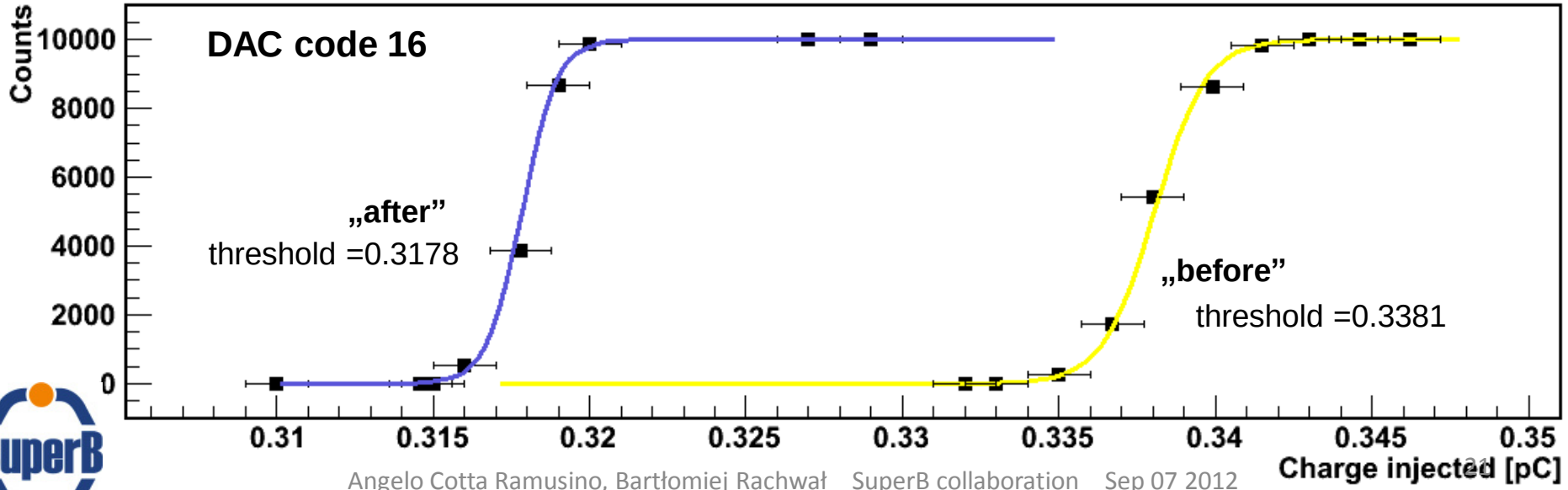
CLARO board - **Channel A**: Pulser Trigger - Burst 1E+4



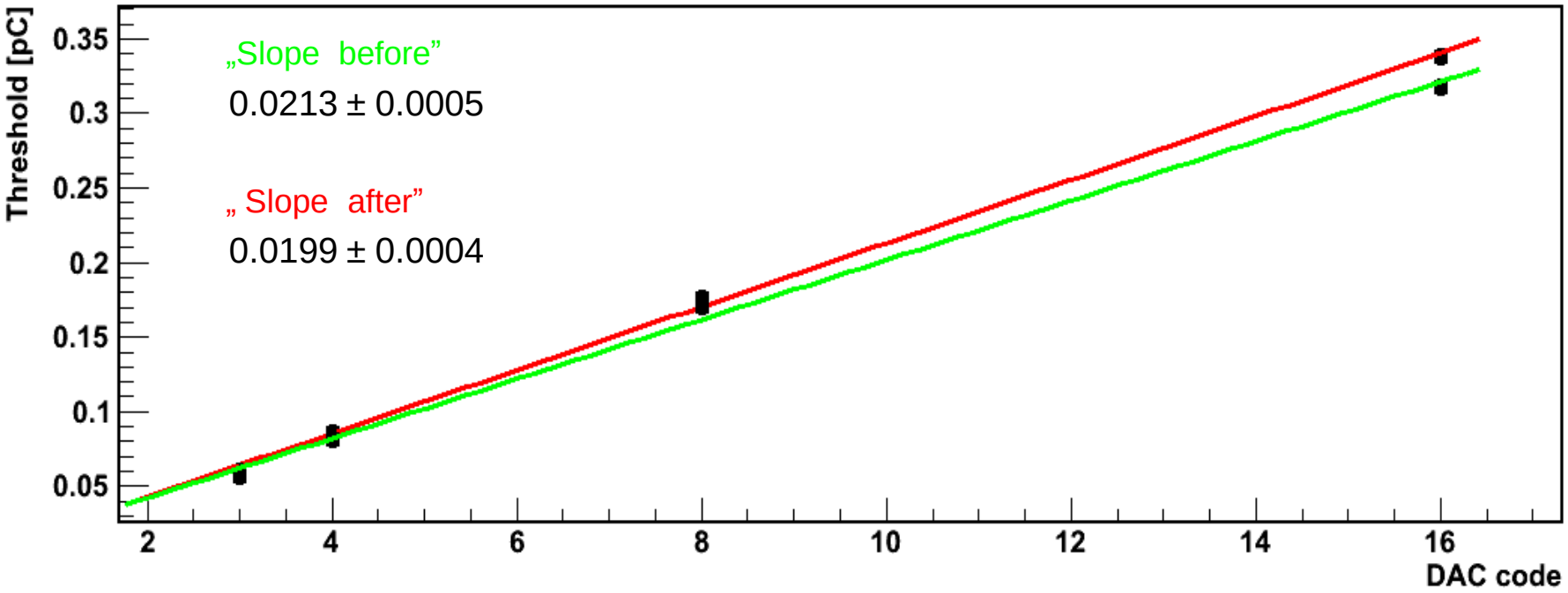


CLARO board - **Channel A**: Pulser Trigger - Burst 1E+4

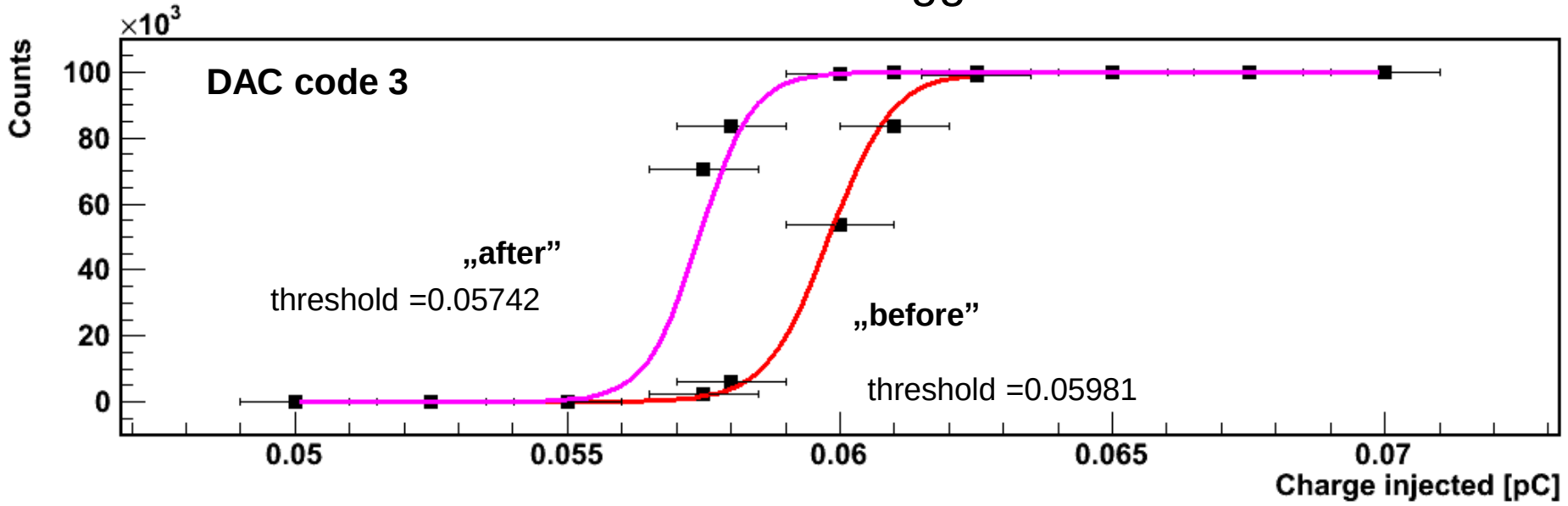


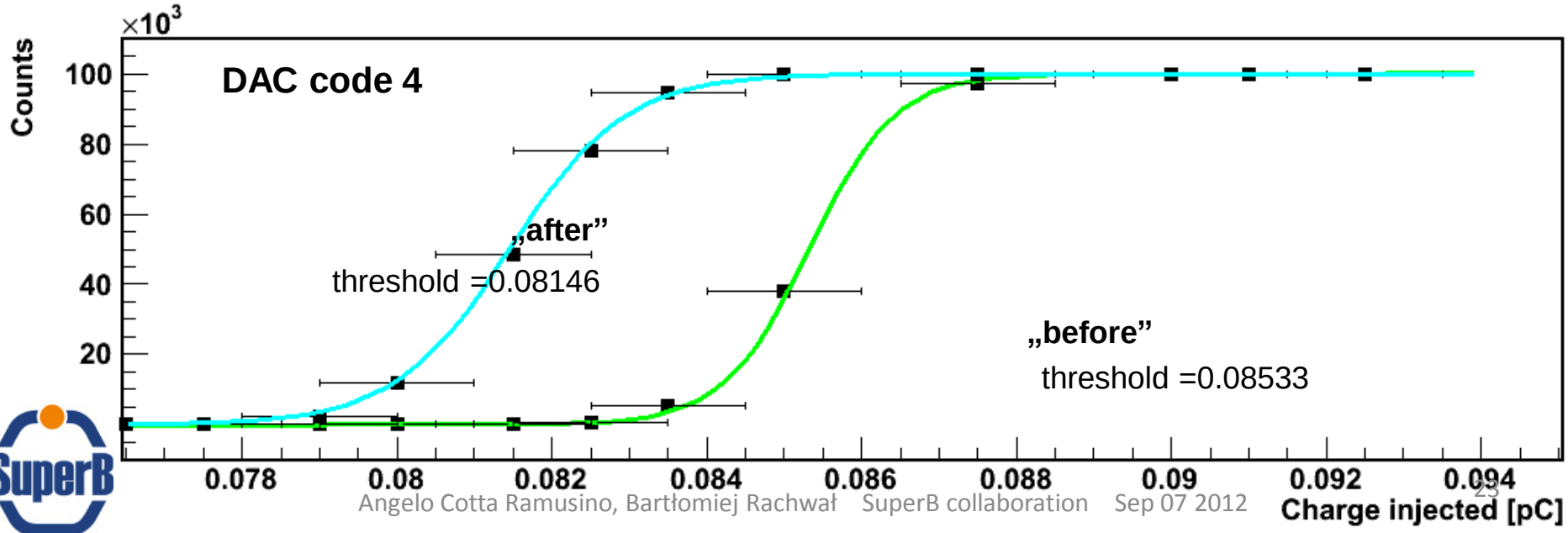


CLARO board - **Channel A**: Pulser Trigger - Burst 1E+4

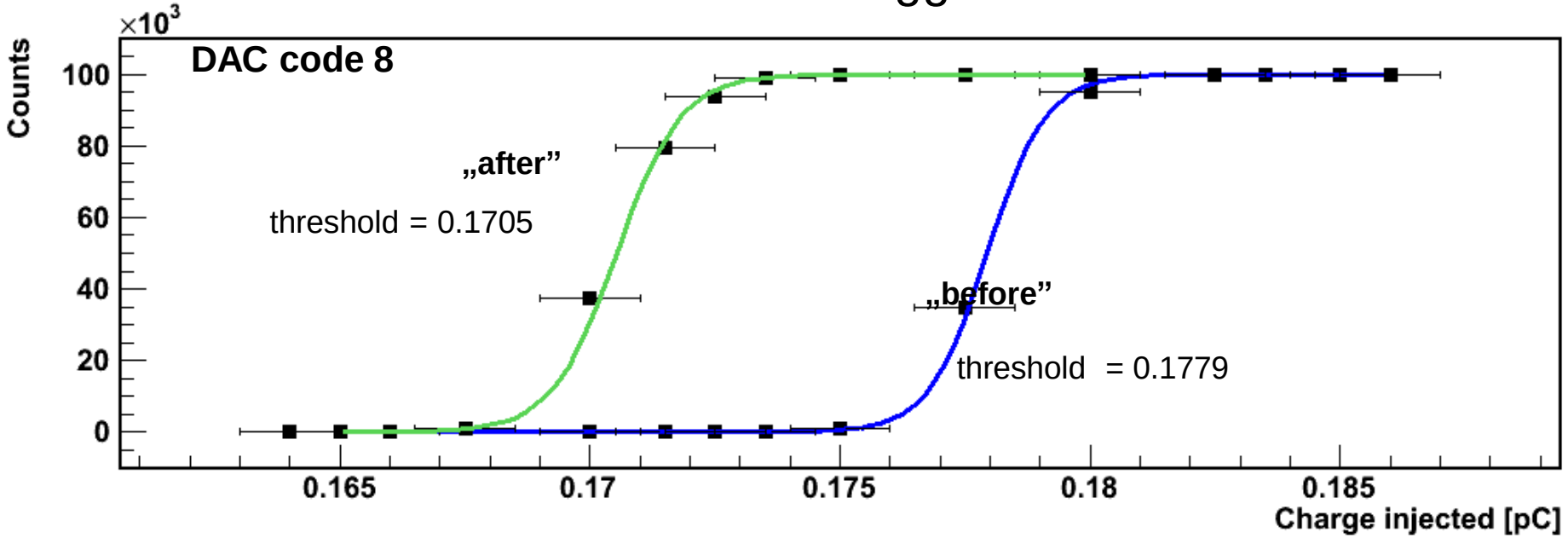


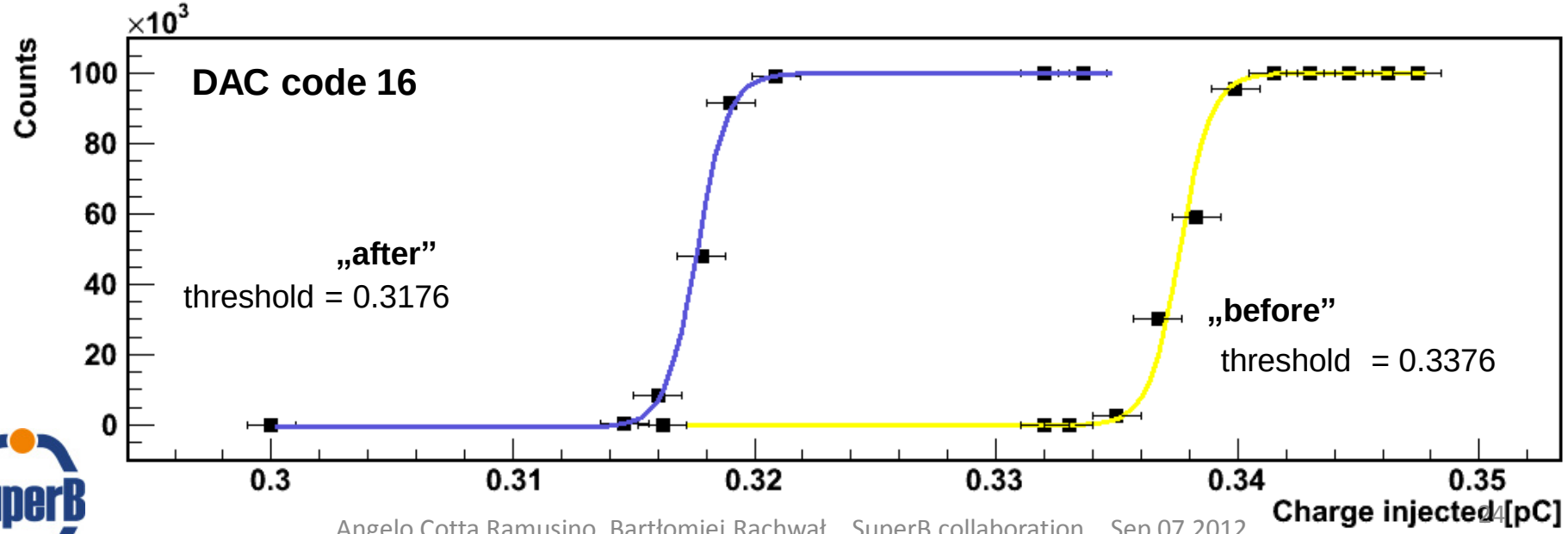
CLARO board - **Channel A**: Pulser Trigger - Burst 1E+5



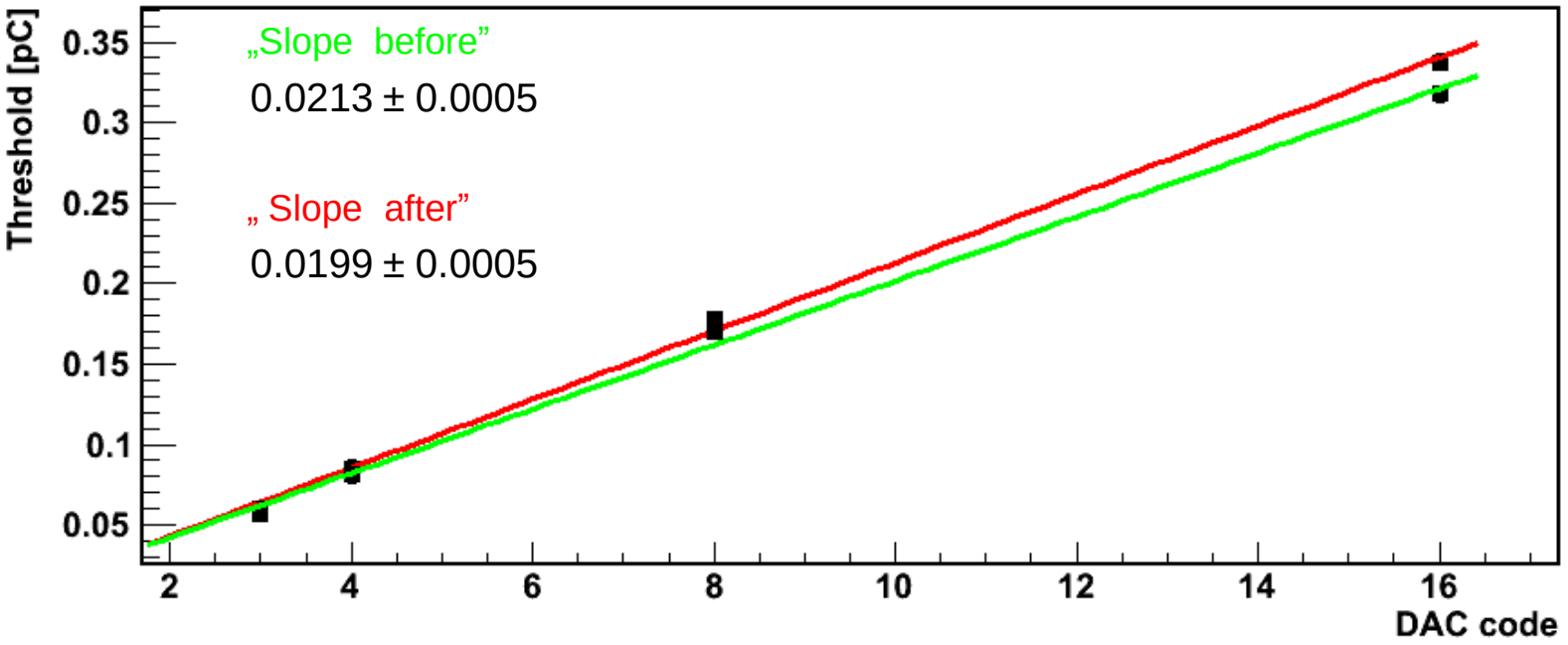


CLARO board - **Channel A**: Pulser Trigger - Burst 1E+5





CLARO board - **Channel A**: Pulser Trigger - Burst 1E+5

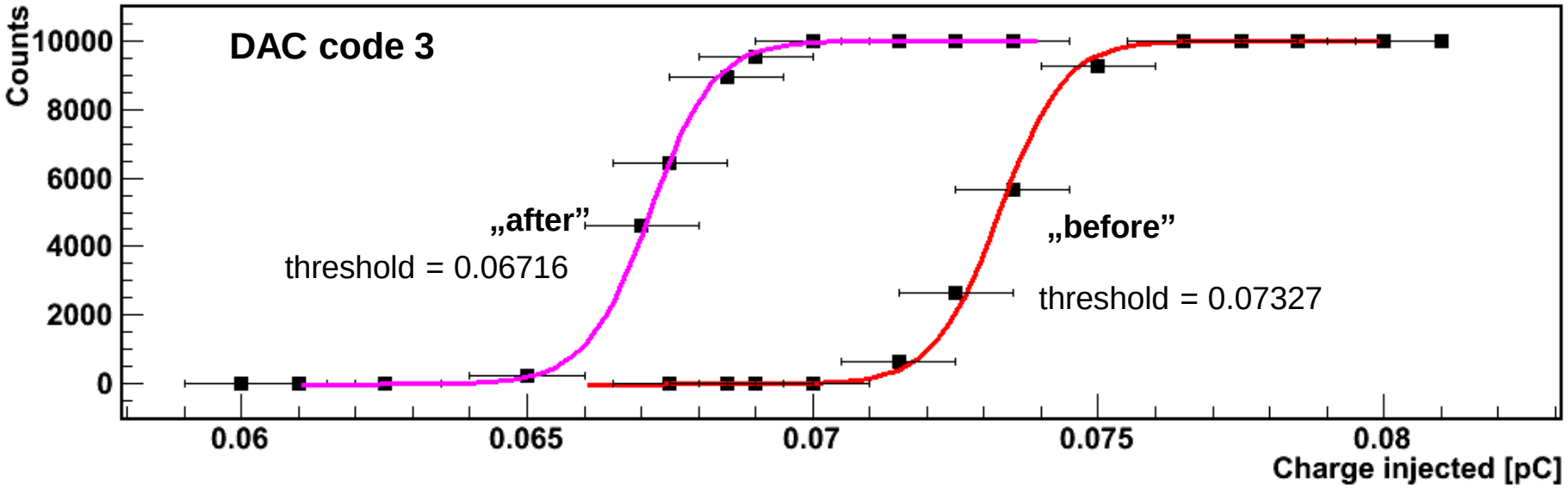


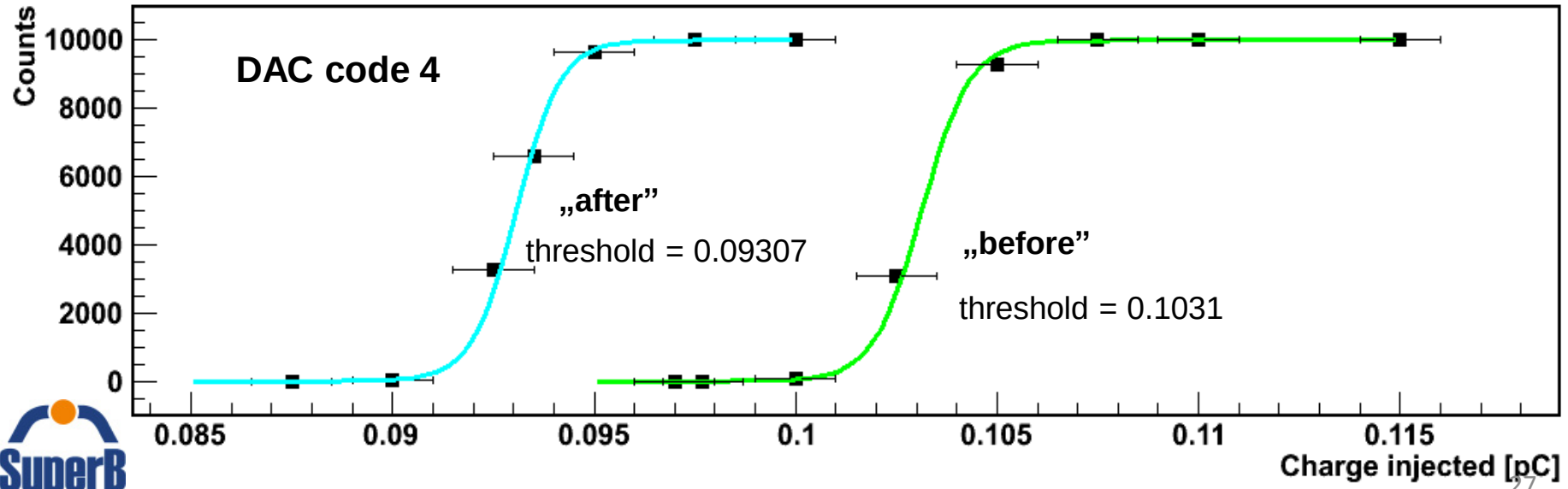
CLARO board

Channel B

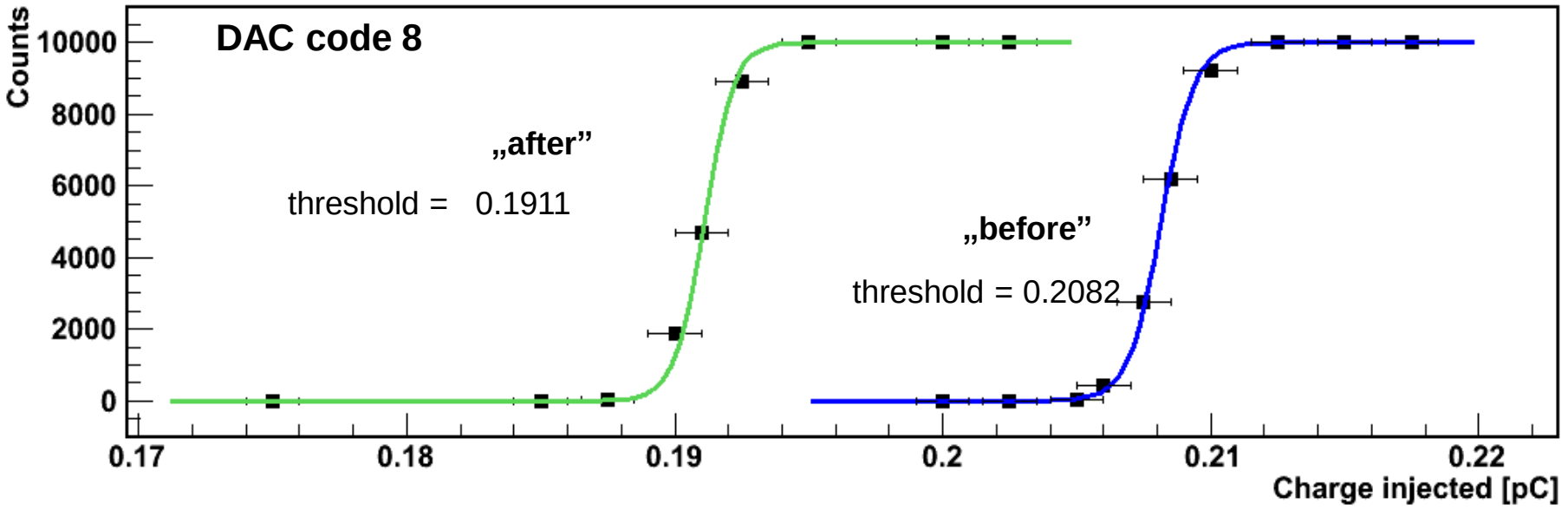
Pulser Trigger - Burst 1E+4 & 1E+5

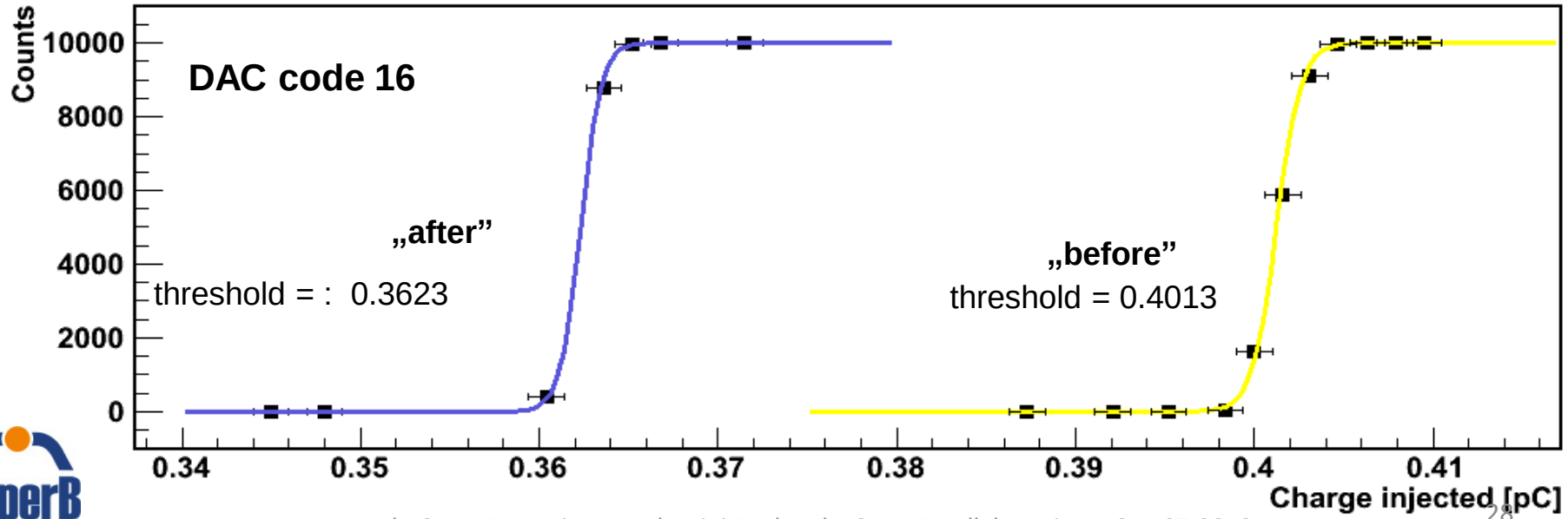
CLARO board - **Channel B**: Pulser Trigger - Burst 1E+4



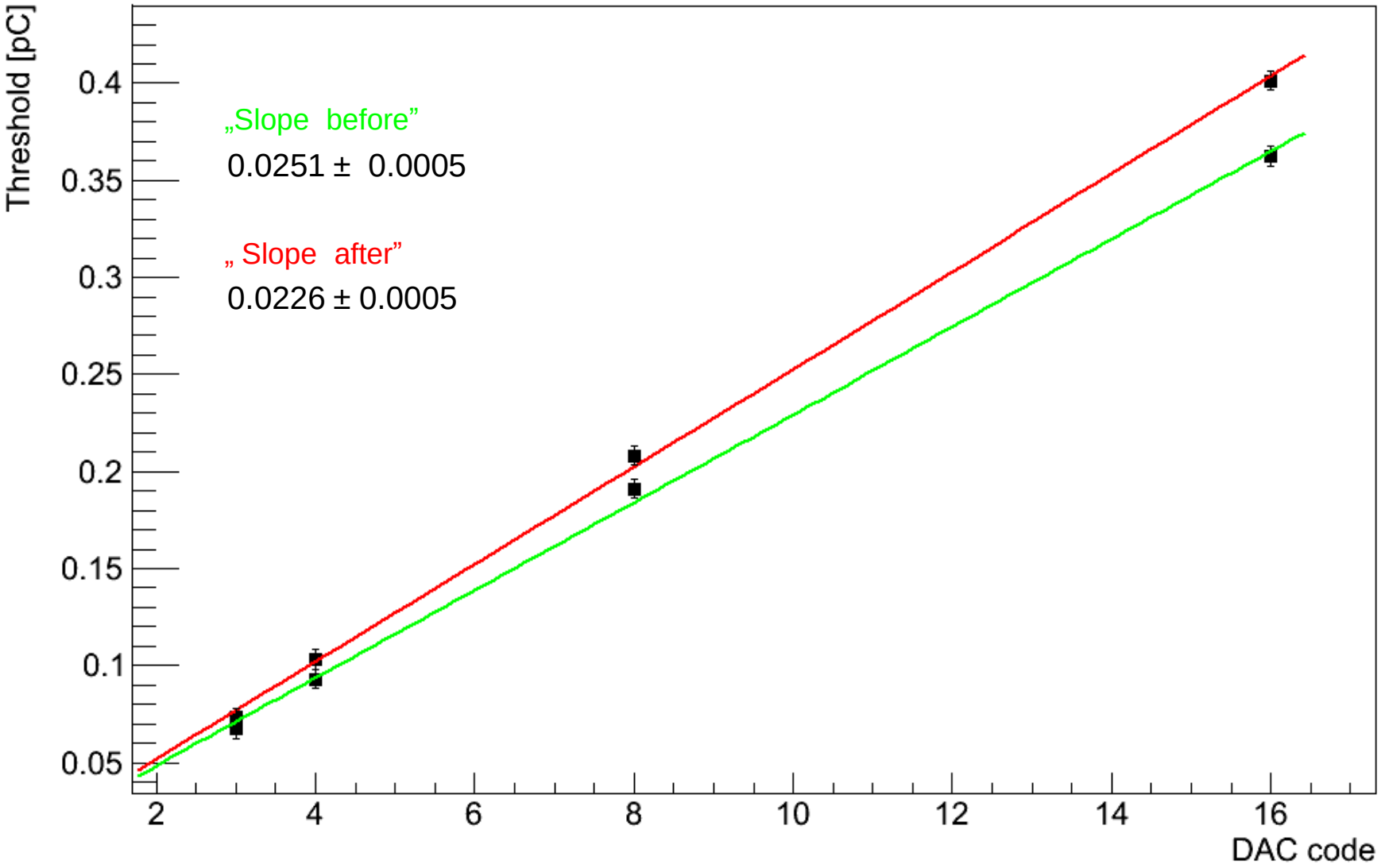


CLARO board - **Channel B**: Pulser Trigger - Burst 1E+4

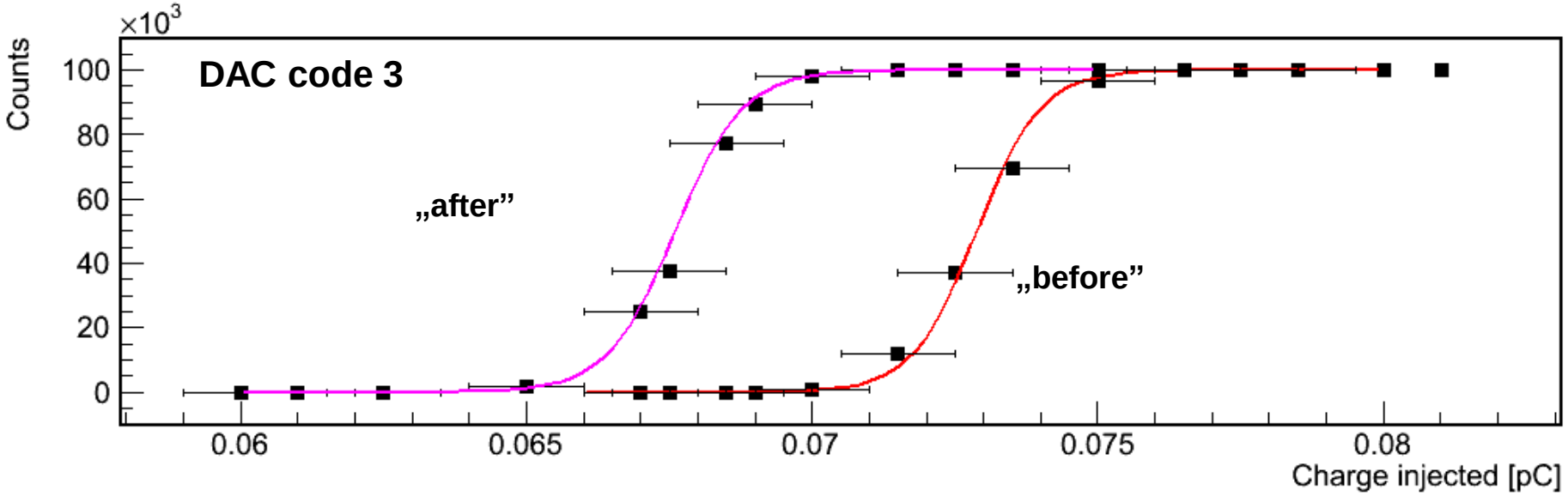


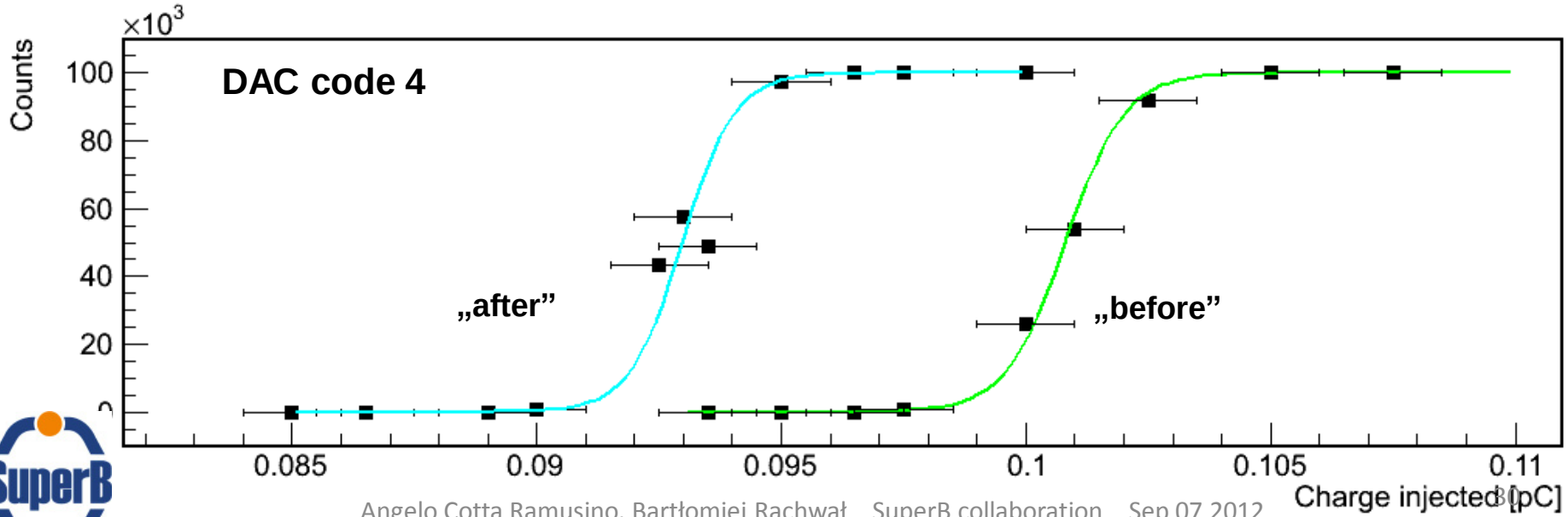


CLARO board - **Channel B**: Pulser Trigger - Burst 1E+4

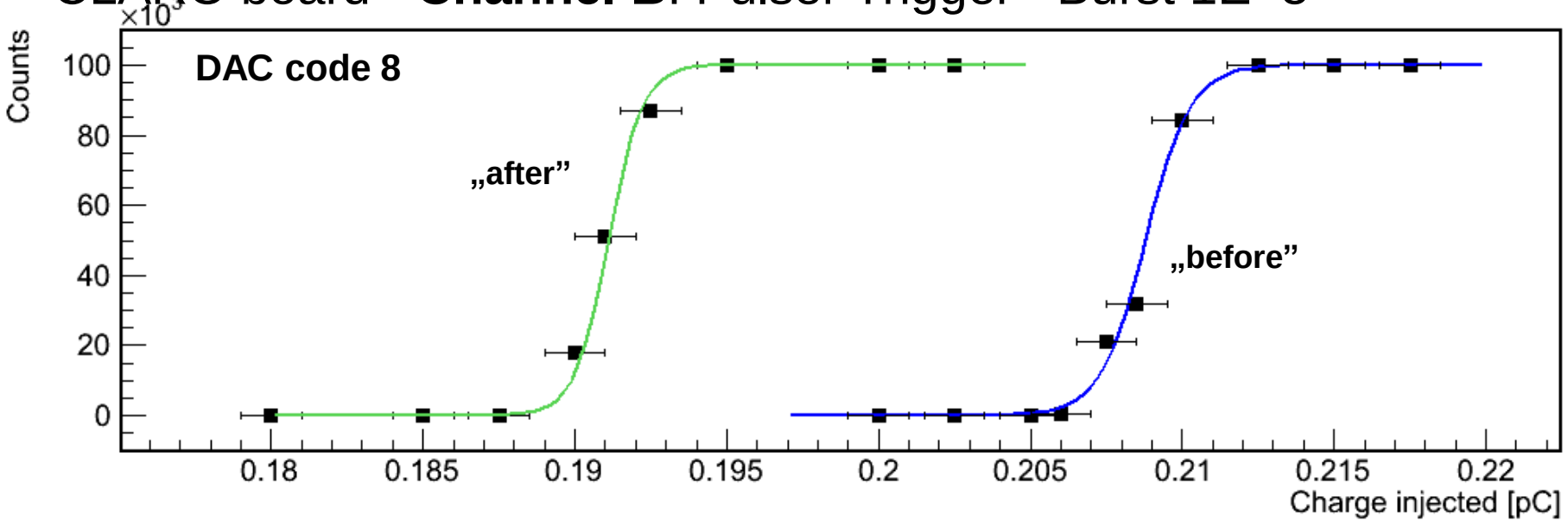


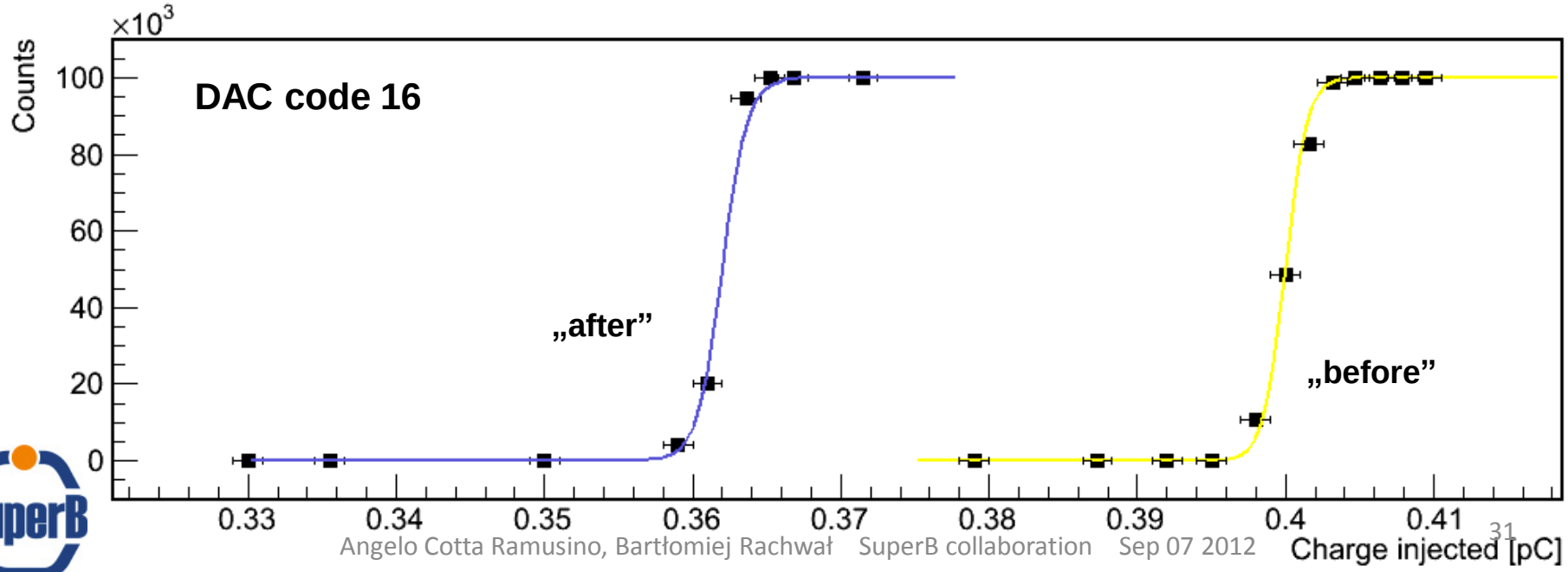
CLARO board - **Channel B**: Pulser Trigger - Burst 1E+5



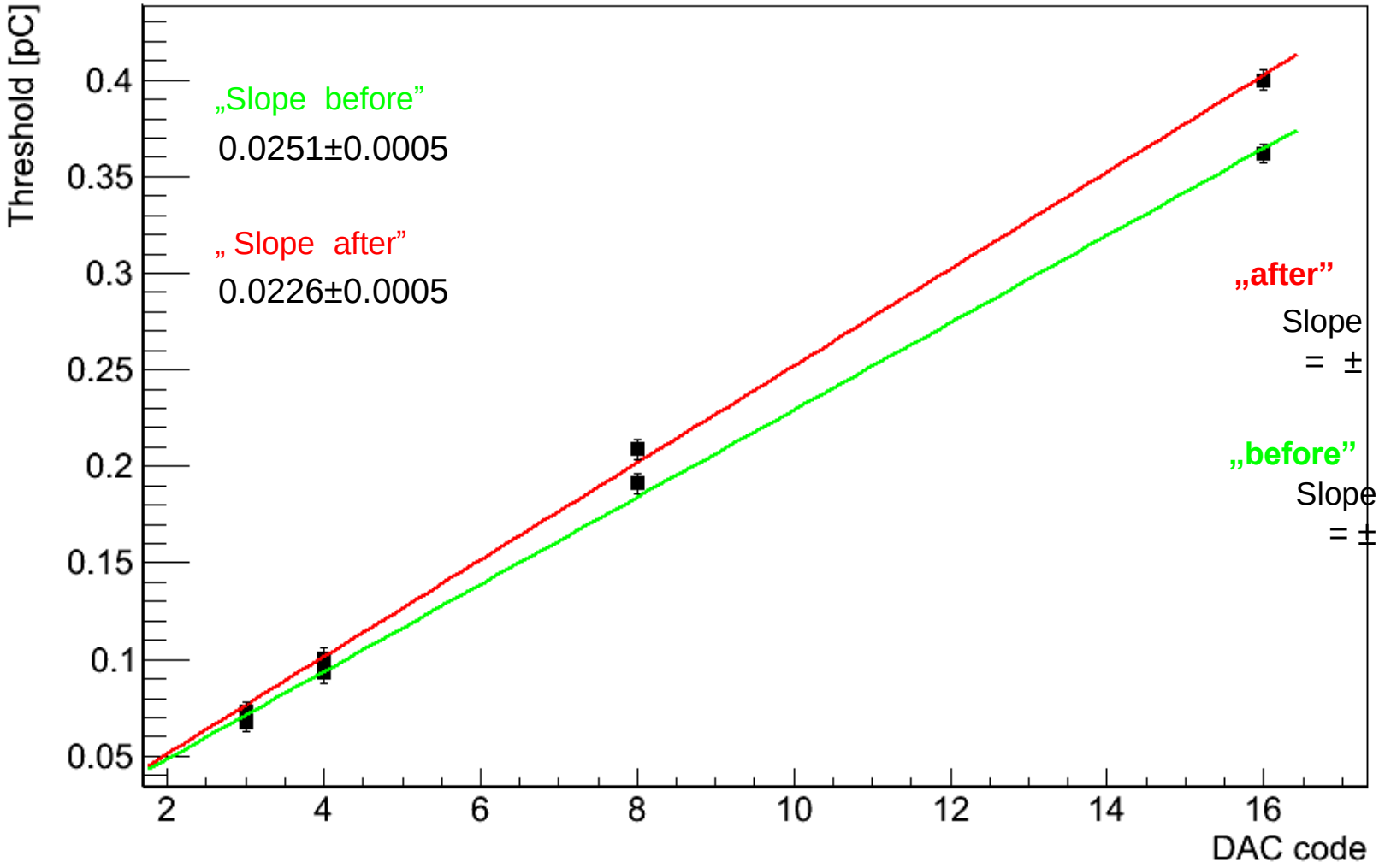


CLARO board - **Channel B**: Pulser Trigger - Burst 1E+5





CLARO board - **Channel B**: Pulser Trigger - Burst 1E+5

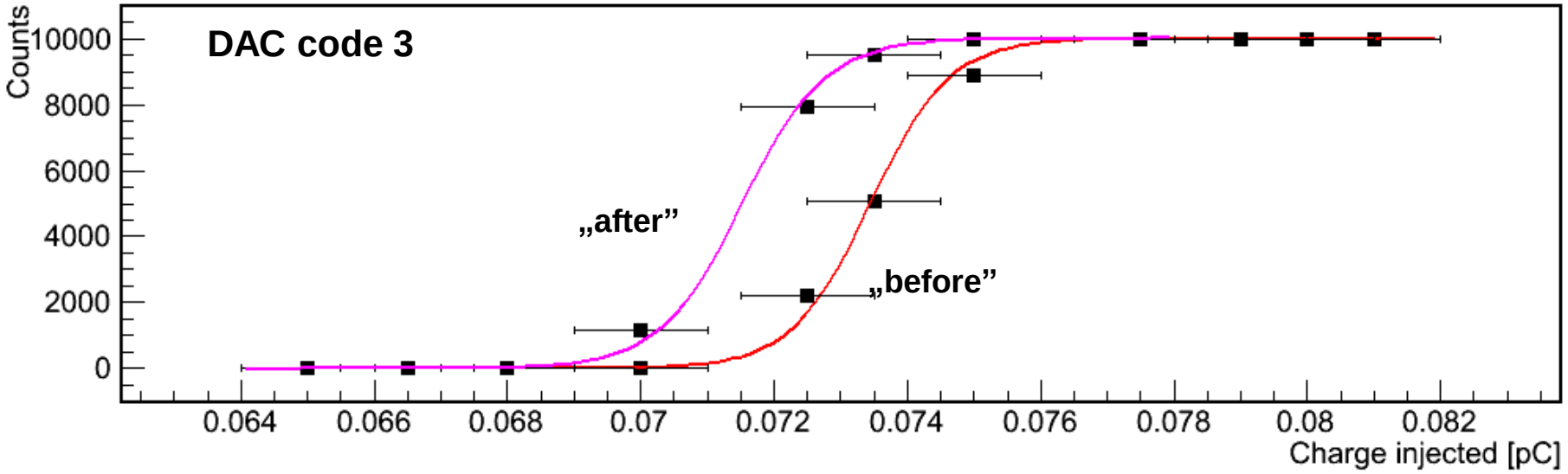


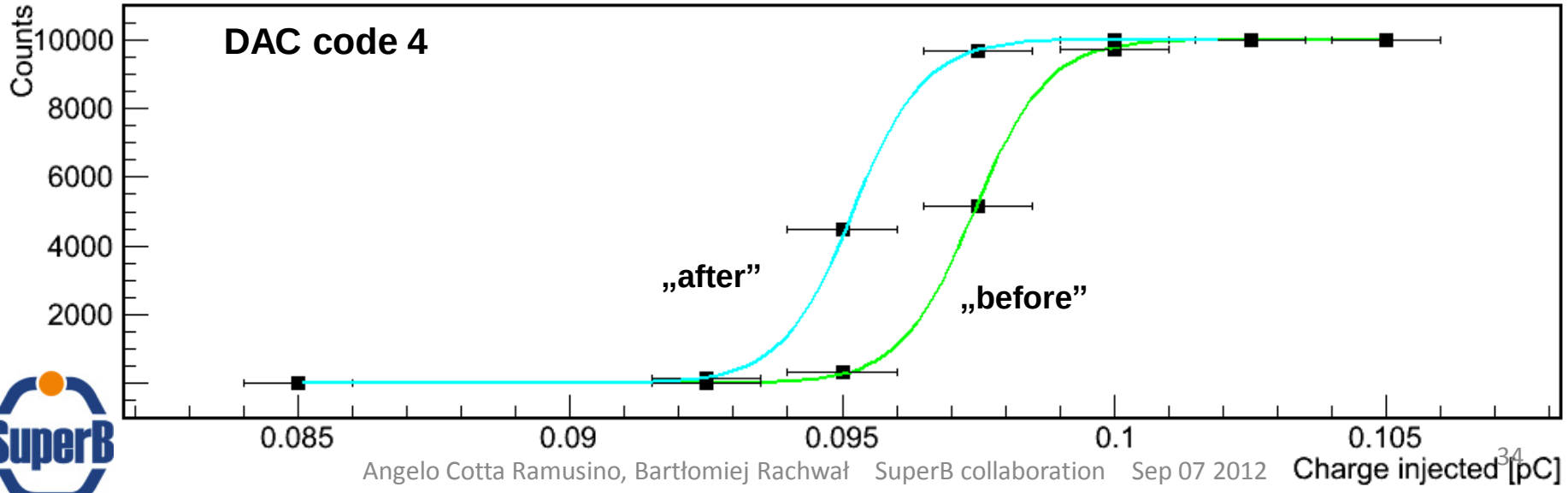
CLARO board

Channel C

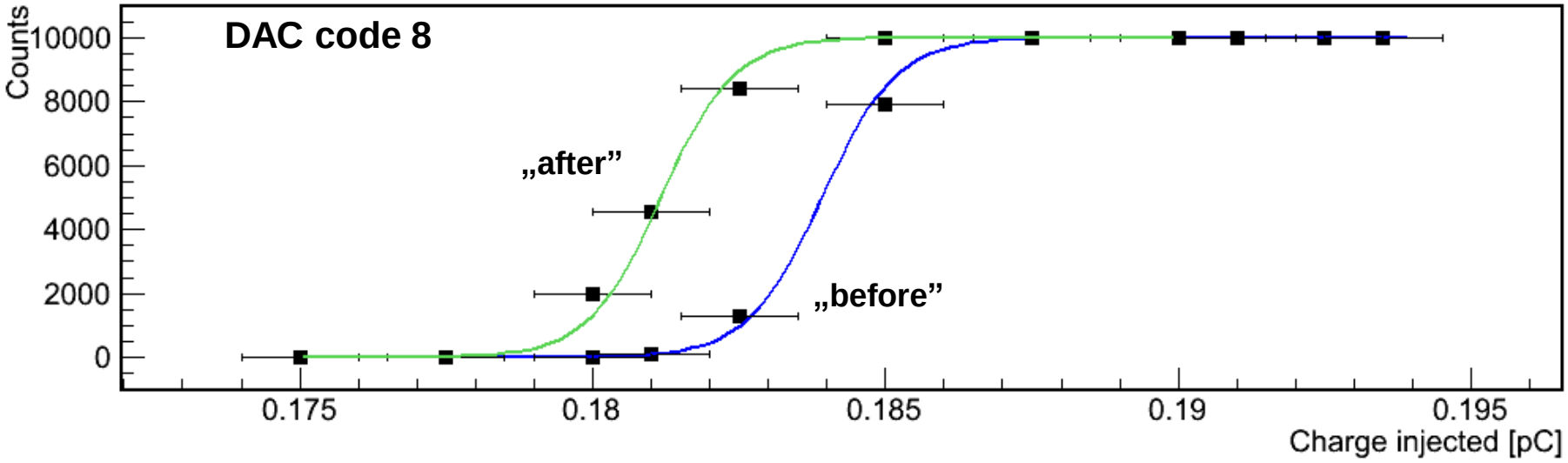
Pulser Trigger - Burst 1E+4 & 1E+5

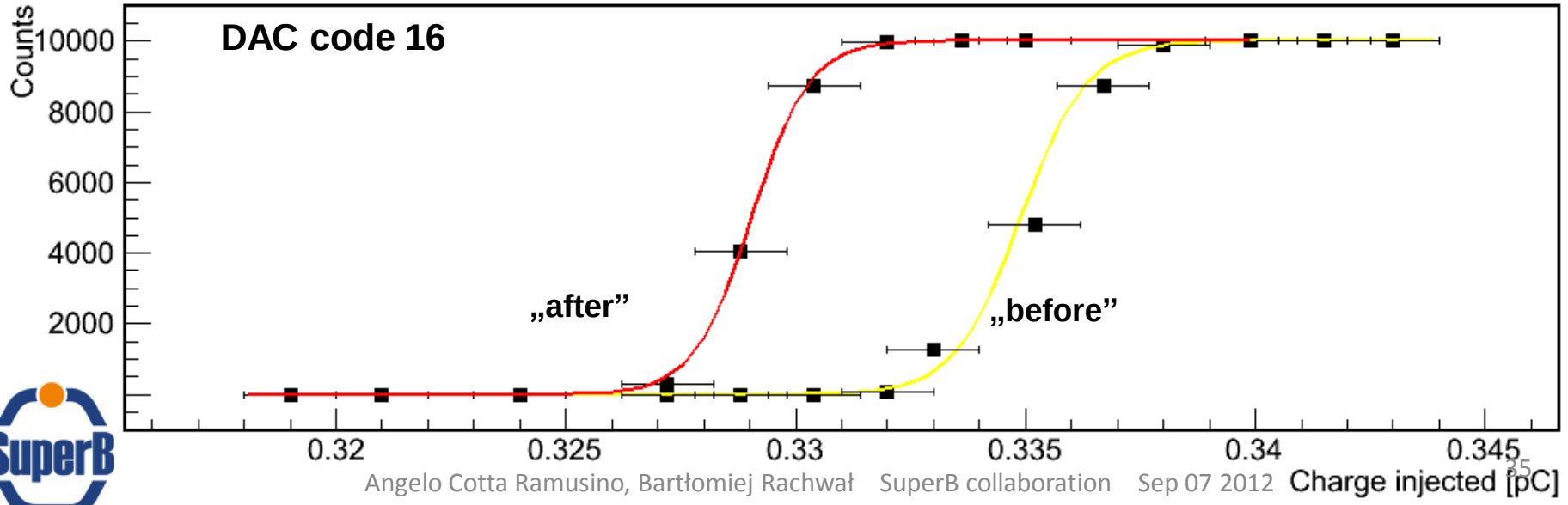
CLARO board - **Channel C**: Pulser Trigger - Burst 1E+4



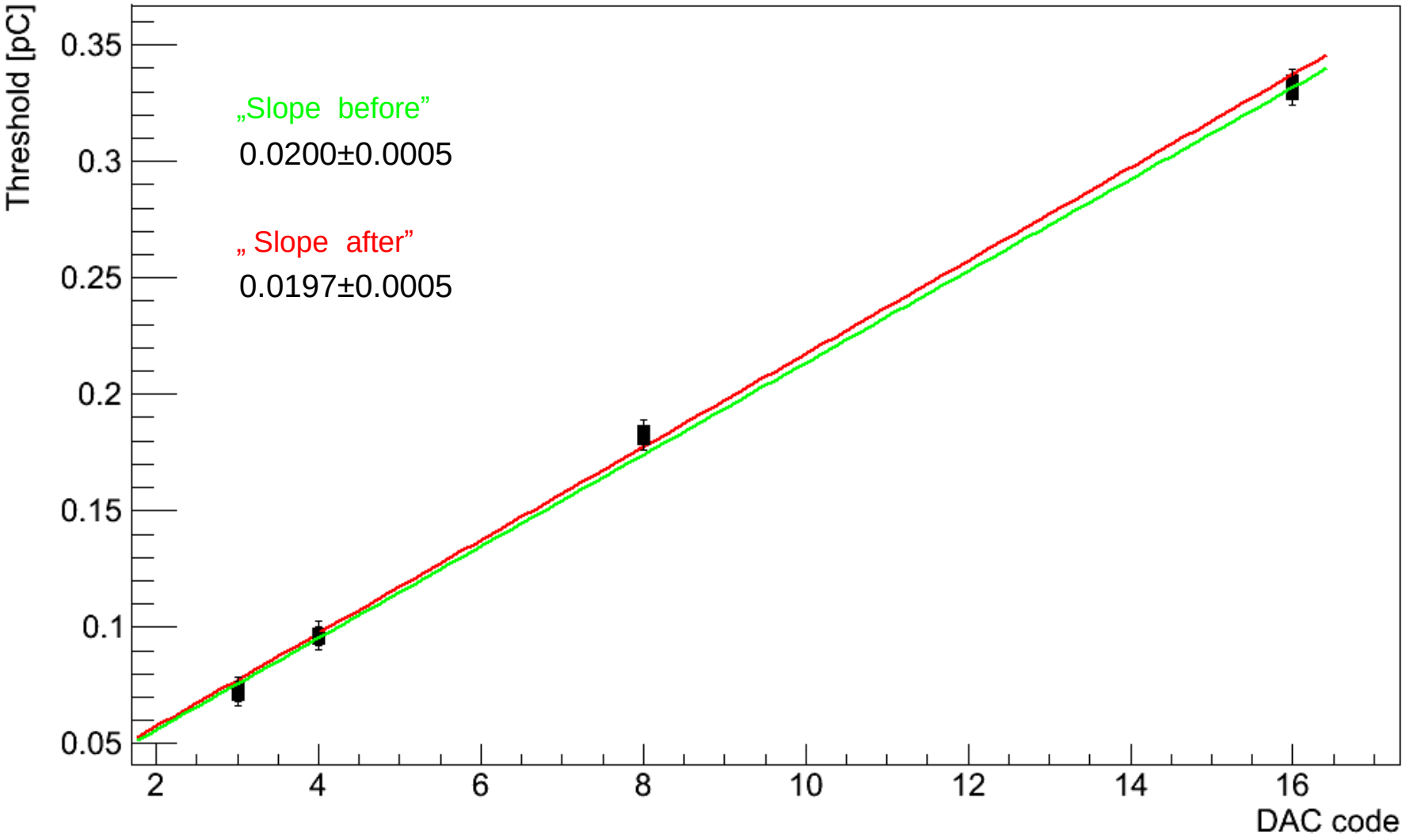


CLARO board - **Channel C**: Pulser Trigger - Burst 1E+4

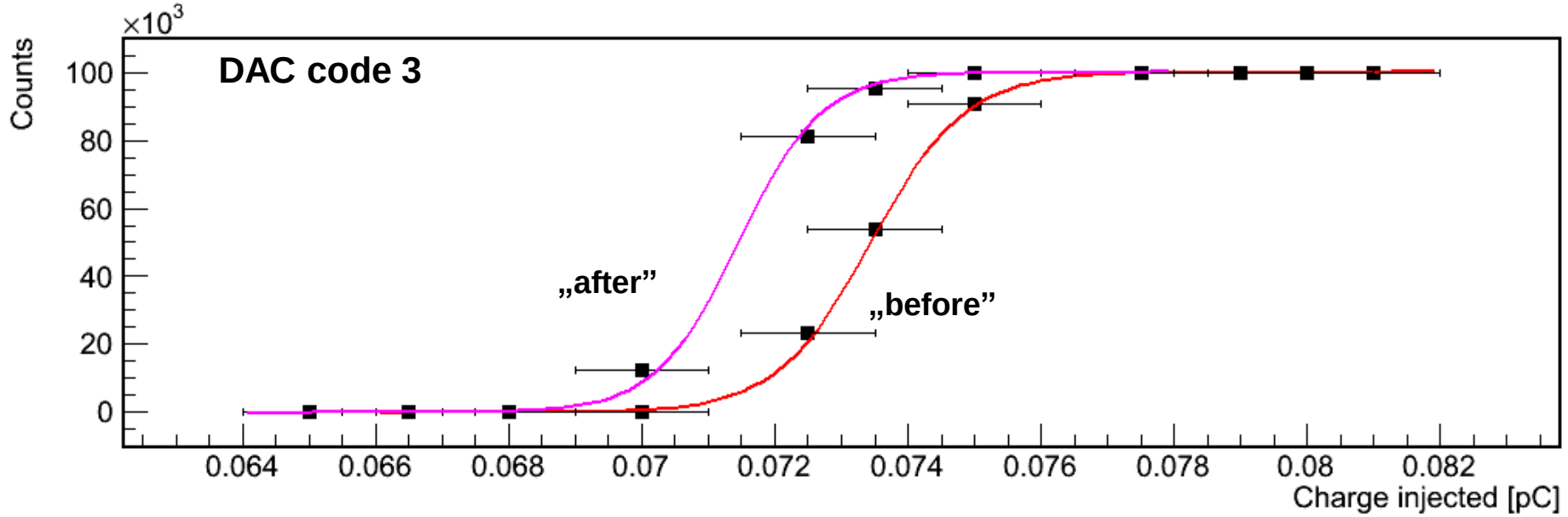


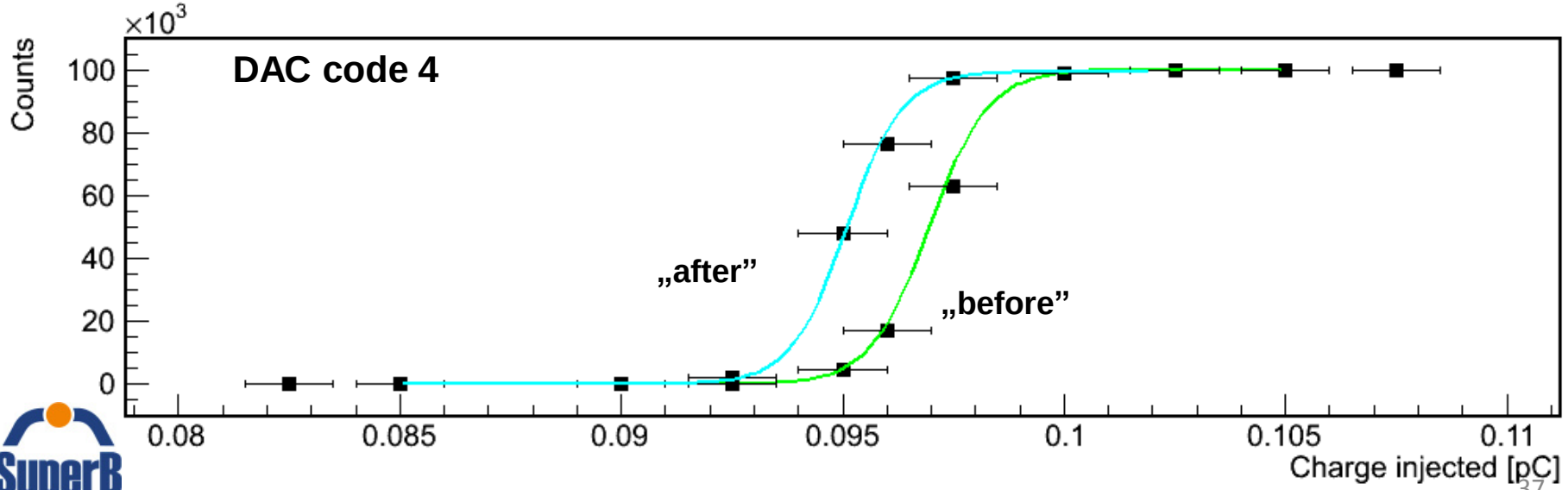


CLARO board - **Channel C**: Pulser Trigger - Burst 1E+4

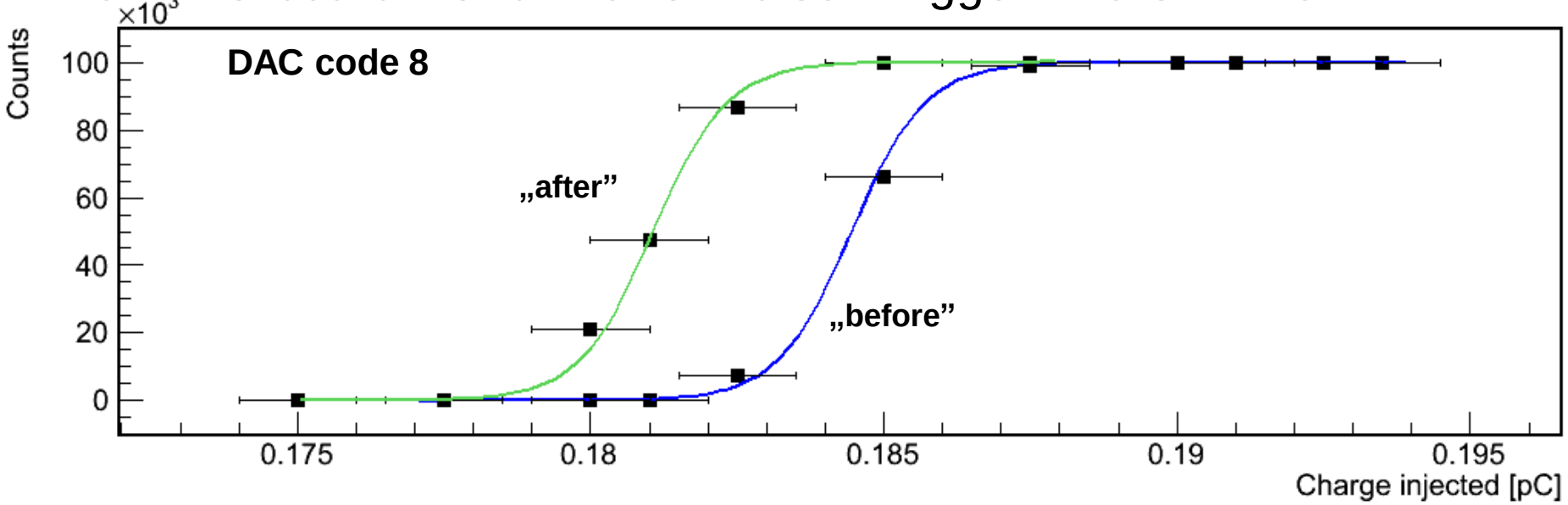


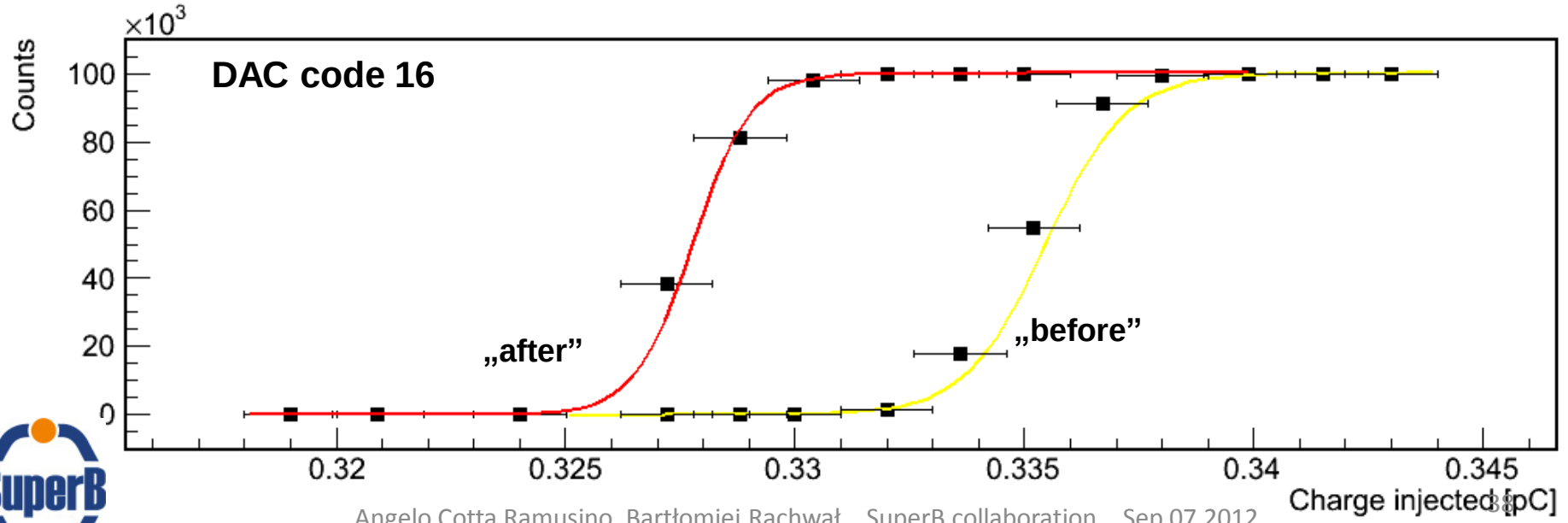
CLARO board - **Channel C**: Pulser Trigger - Burst 1E+5



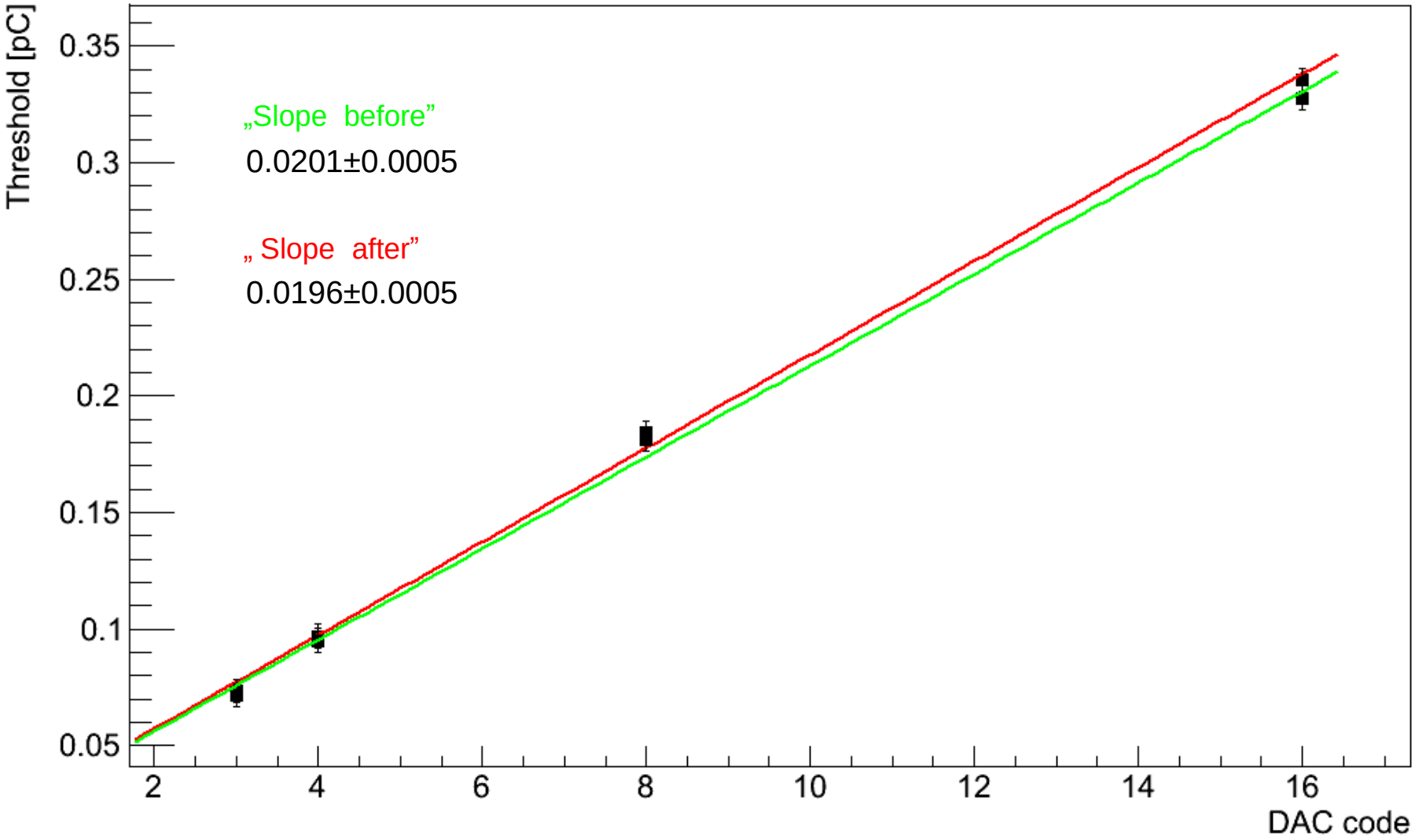


CLARO board - **Channel C**: Pulser Trigger - Burst 1E+5





CLARO board - **Channel C**: Pulser Trigger - Burst 1E+5



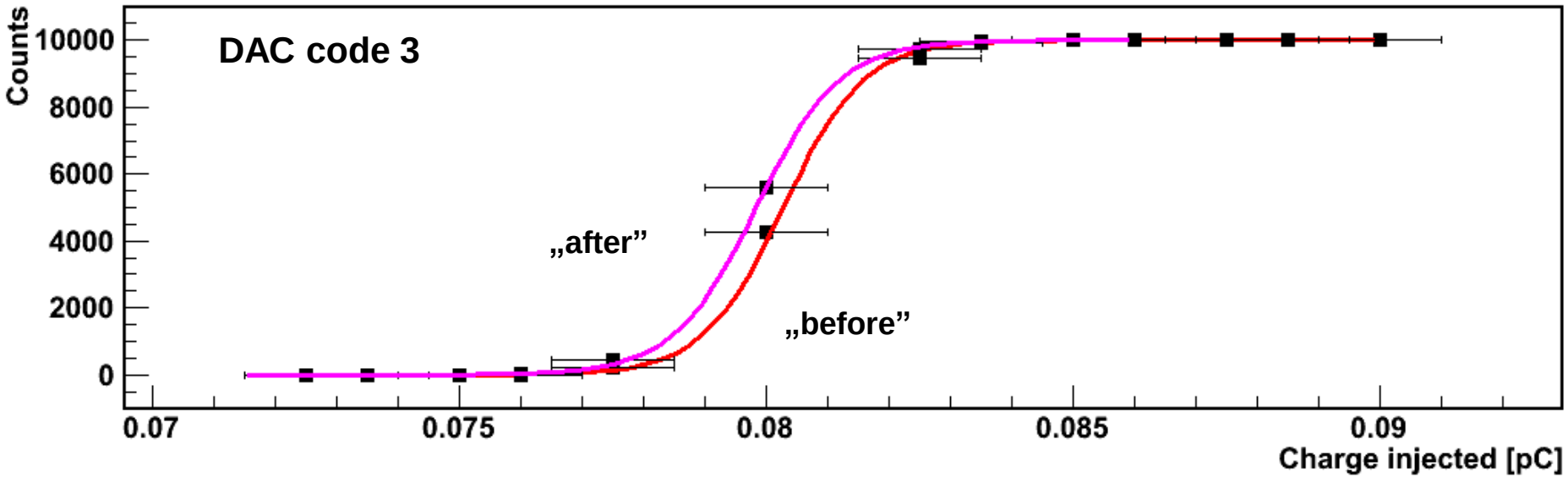
CLARO board - **Channel D**: Pulser Trigger - Burst 1E+4

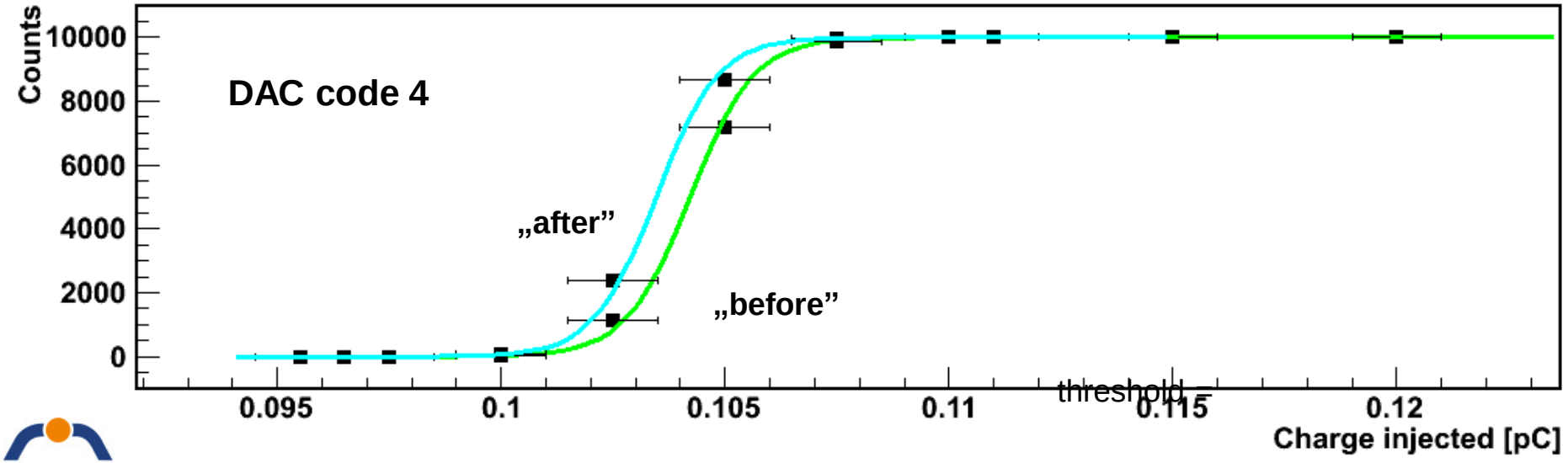
CLARO board

Channel D

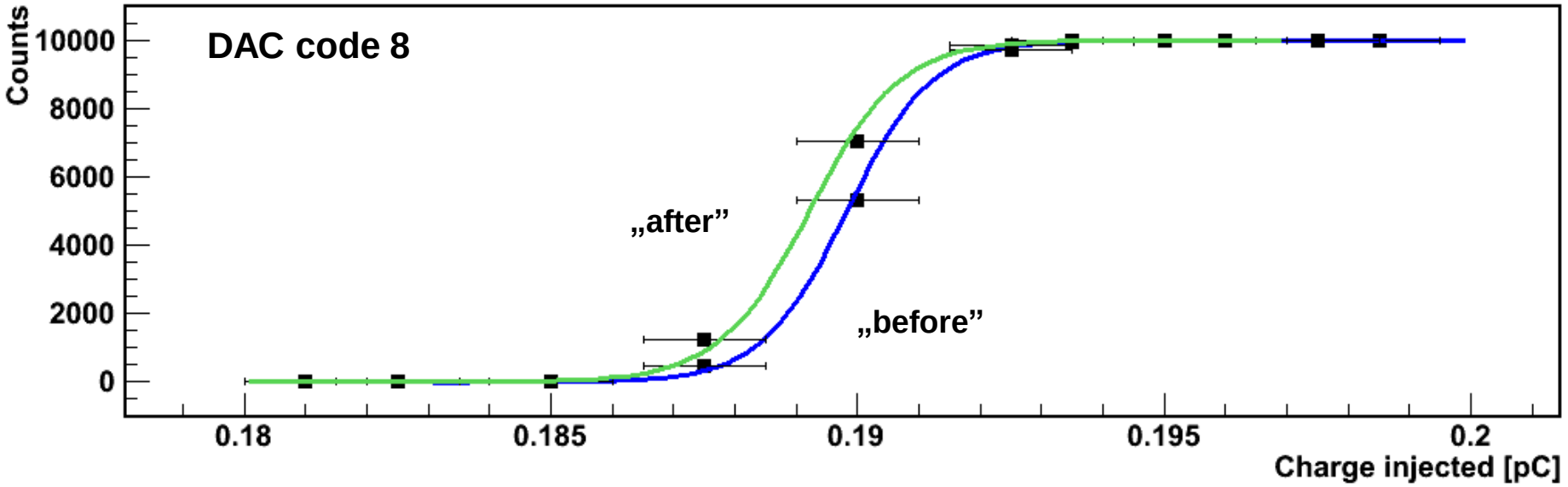
Pulser Trigger - Burst 1E+4 & 1E+5

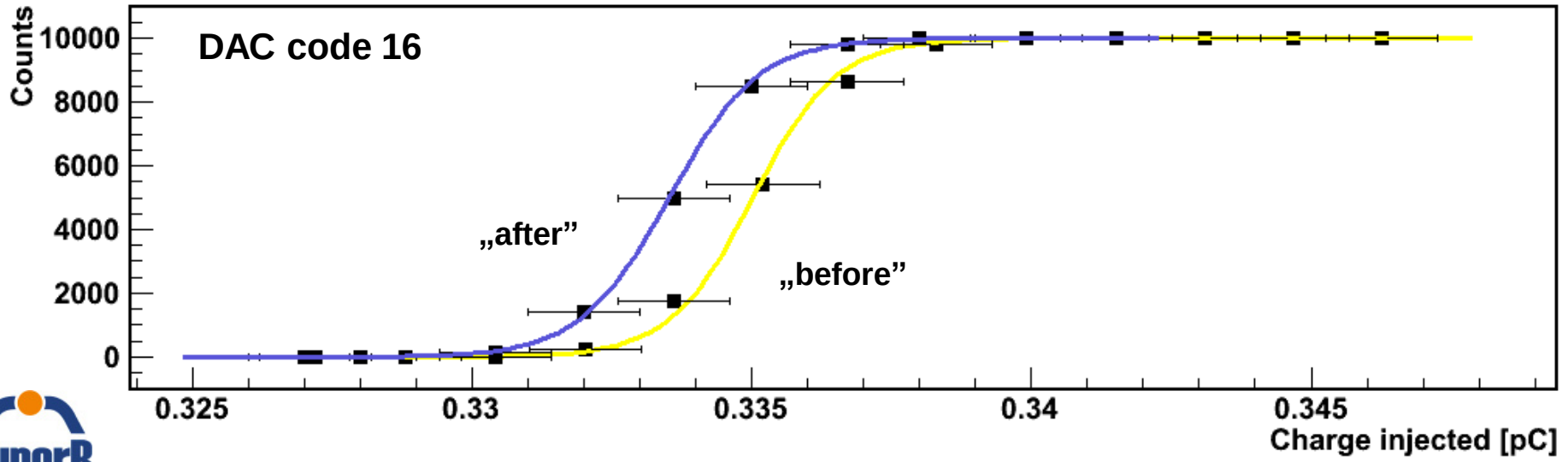
CLARO board - **Channel D**: Pulser Trigger - Burst 1E+4



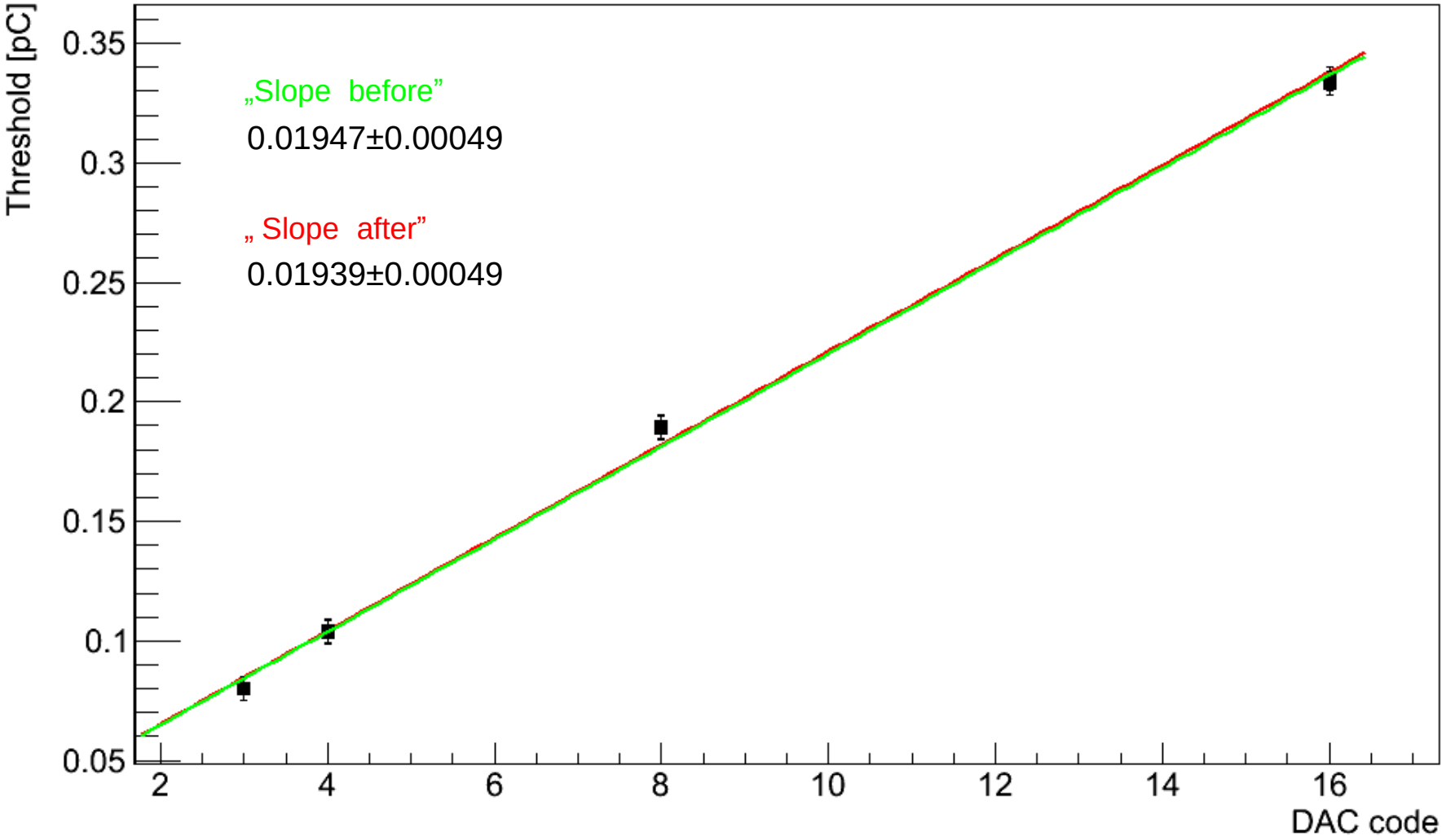


CLARO board - **Channel D**: Pulser Trigger - Burst 1E+4

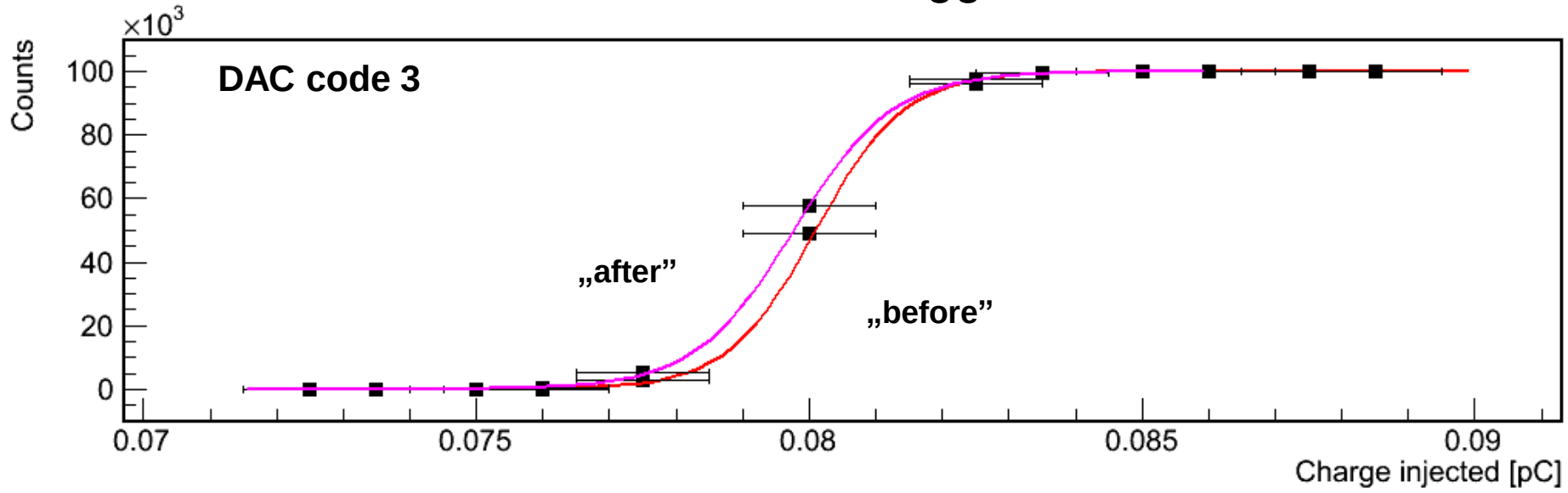


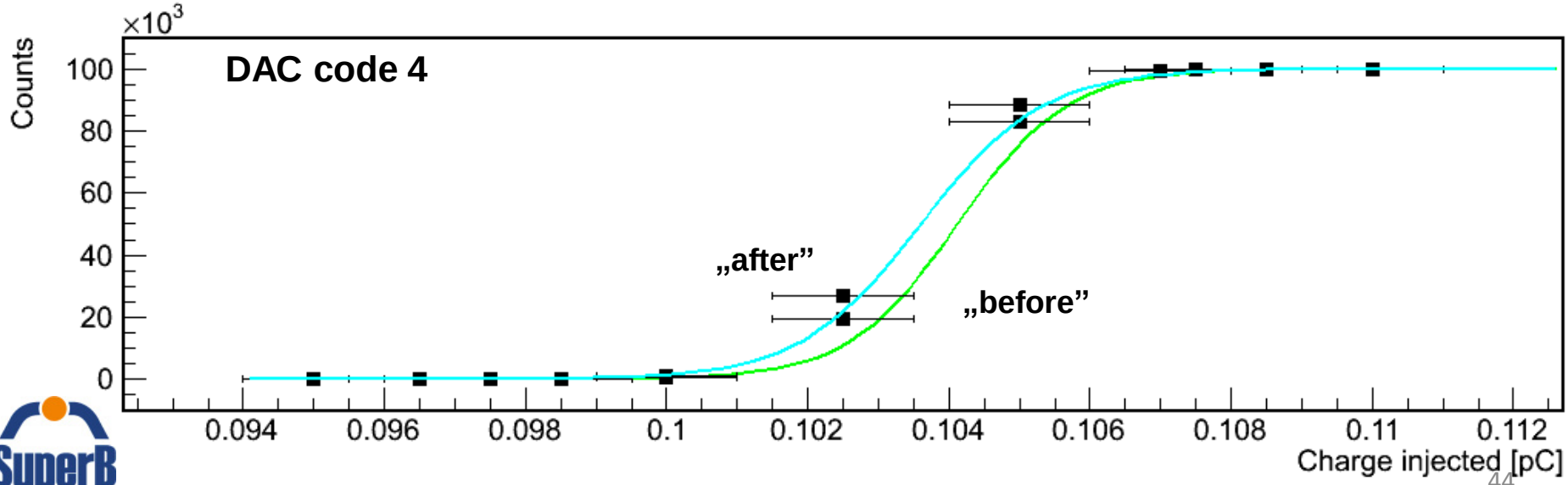


CLARO board - **Channel D**: Pulser Trigger - Burst 1E+4

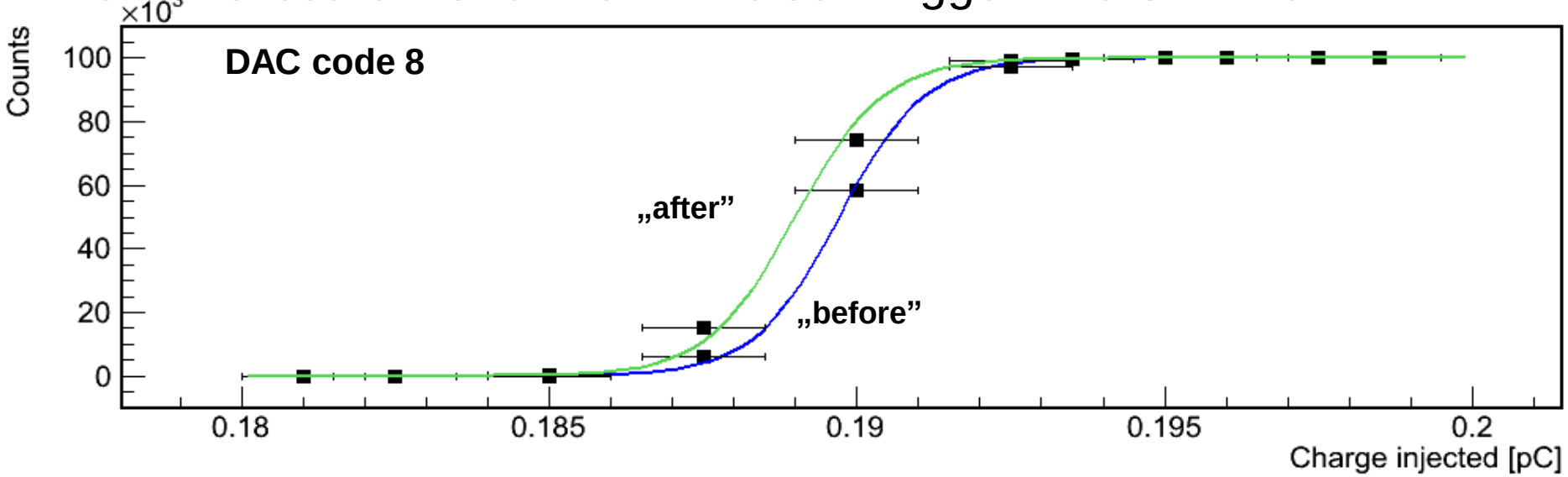


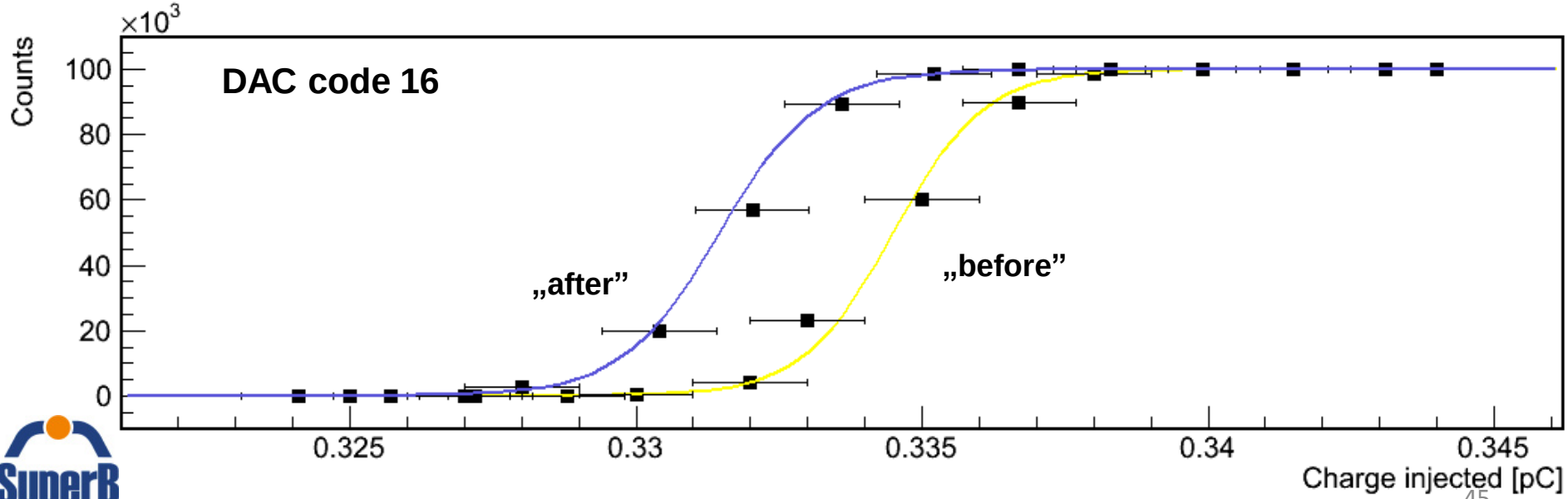
CLARO board - **Channel D**: Pulser Trigger - Burst 1E+5





CLARO board - **Channel D**: Pulser Trigger - Burst 1E+5





CLARO board - **Channel D**: Pulser Trigger - Burst 1E+5