Charge Collection in Neutron Irradiated Micron SSD

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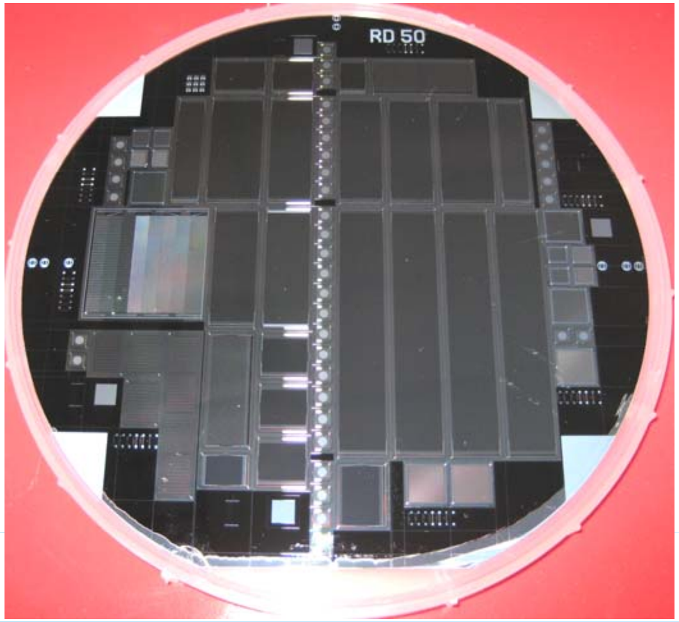
Micron 6” RD50 Run

6 in.



Diameter	Type	Orientation	Silicon	Ohm-cm	Thickness (µm)	No. Of wafers	Structure
6 inch	P-Type	<100>	FZ	11000	300	1 (36)	N – P
6 inch	P-Type	<100>	MCZ	1000	300	1 (25)	N – P
6 inch	N-Type	<100>	MCZ	500	300	(20)	P – N
6 inch	N - Type	<100>	FZ	3000	300	(5)	P – N
6 inch	N - Type	<100>	MCZ	500	300	1 (5)	N – N
6 inch	N - Type	<100>	FZ	3000	300	1 (5)	N - N

RD50 6” Common Project

Special devices to Brookhaven, PSI and Syracuse.
All pads and strips to UCSC (except n-on-n to Liverpool)

	# processed	**# received**	**RD50 Request = # of wafers** **30% yield**	**50% yield**	More?
p-on-n					
FZ	2+2	4	2	3	ok
MCz	2+10	5	6	10	ok
n-on-p					
FZ	6	6	12	18	(ok)
MCz	2+3	5 (2 good?)	8	13	need
n-on-n					
FZ	1	1	2	3	(ok)
MCz	1+1	2	2	3	(ok)

Propose to make an additional run n-on-p FZ and MCz

RD50 6" Common Project: Breakdown Chart

type	substrate	wafer #	# tested	# bad	Arrival
McZ	n on p	2552-7	7	0	First Batch
FZ	n on p	2551-7	8	0	First Batch
FZ	n on p	2551-4	8	0	Second Batch (arrived 5/22)
FZ	n on p	2551-1	9	0	Second Batch (arrived 5/22)
FZ	n on p	2551-6	9	0	Second Batch (arrived 5/22)
FZ	n on p	2551-2	9	0	Third Batch (arrived 7/11)
FZ	n on p	2551-3	9	0	Third Batch (arrived 7/11)
MCz	n on p	2552-6	10	0	Third Batch (arrived 7/11)
FZ	p on n	2535-8	9	0	Fourth Batch (arrived 8/10)
FZ	p on n	2535-9	8	0	Fourth Batch (arrived 8/10)
MCz	p on n	2552-14	8	0	Fourth Batch (arrived 8/10)
MCz	p on n	2552-10	7	0	Fourth Batch (arrived 8/10)
FZ	P on N	2535-7	4	0	5th Batch (arrived 10/9)
FZ	P on N	2535-10	0	0	5th Batch (arrived 10/9)
FZ	N on N	2535-12	0	0	5th Batch (arrived 10/9)
MCz	P on N	2552-9	2	0	5th Batch (arrived 10/9)
MCz	P on N	2552-11	0	0	5th Batch (arrived 10/9)
MCz	P on N	2552-12	0	0	5th Batch (arrived 10/9)
MCz	N on P	2553-12	22	12	5th Batch (arrived 10/9)
MCz	N on P	2553-13	22	16	5th Batch (arrived 10/9)
MCz	N on P	2553-14	22	1	5th Batch (arrived 10/9)

RD50 6” Common Project Testing Activities

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Neutron and Proton and Pion (Aug. ’07)irradiation of SSD and Diodes

Liverpool, Glasgow: CCE with SSD and diodes

UCSC: CCE with SSD, both p-type and n-type, C-V, i-V on SSD and Diodes

Ljubljana: CCE with Diodes, C-V, i-V on SSD and Diodes

“Availability of parts from the Common RD50 run on MICRON 6" wafers”

Helsinki : Thermal Treatment (thermal donor generation) in MCz

Barcelona:

Glasgow

Pisa

UCSC Binary DAQ

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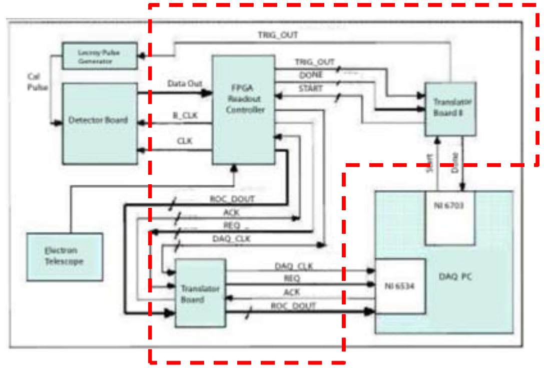
Data Acquisition System at UCSC

System Upgrade

Old *DAQ System (PTSM 2003)*



The FPGA readout controller and two translator boards were replaced by a ***single*** *Xilinx Embedded System board allowing direct ethernet connection to the DAQ PC.*

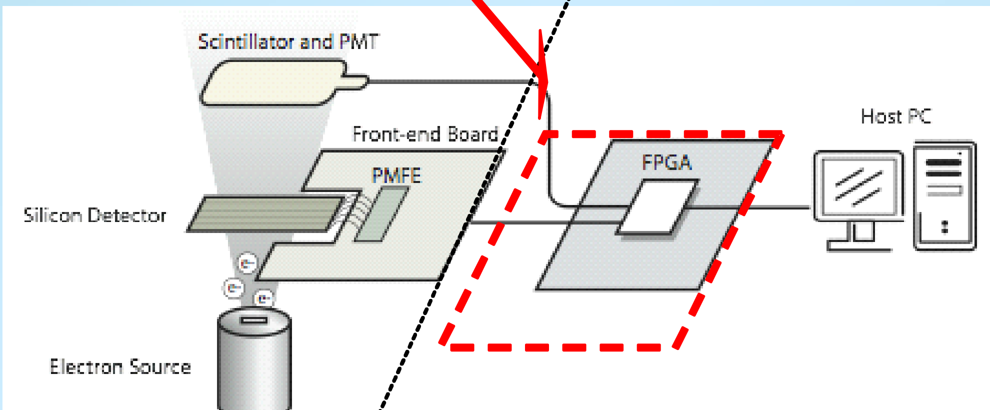
Embedded Particle Tracking Silicon Microscope: An Independent Data Acquisition System for Silicon Detector Characterization. K. Arya. Bachelors CE Thesis, UC Santa Cruz. 2007.

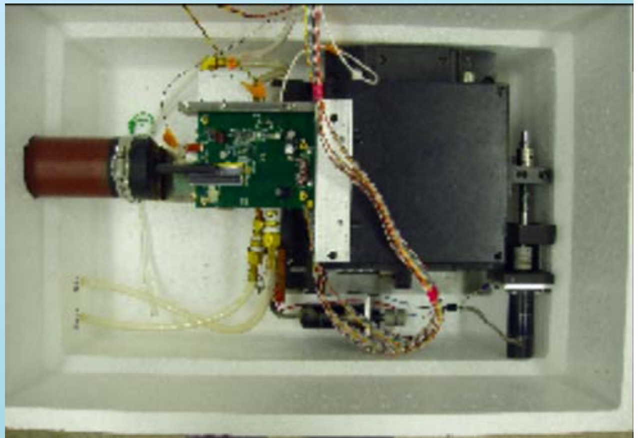
The Particle Tracking Silicon Microscope PTSM. H. F.W. Sadrozinski, et. al. IEEE Trans. Nucl. Sci., 51, 5, (2004) 2032.

Xilinx ML405 Embedded System

Embedded System XILINX

Measurements carried out at low temperature

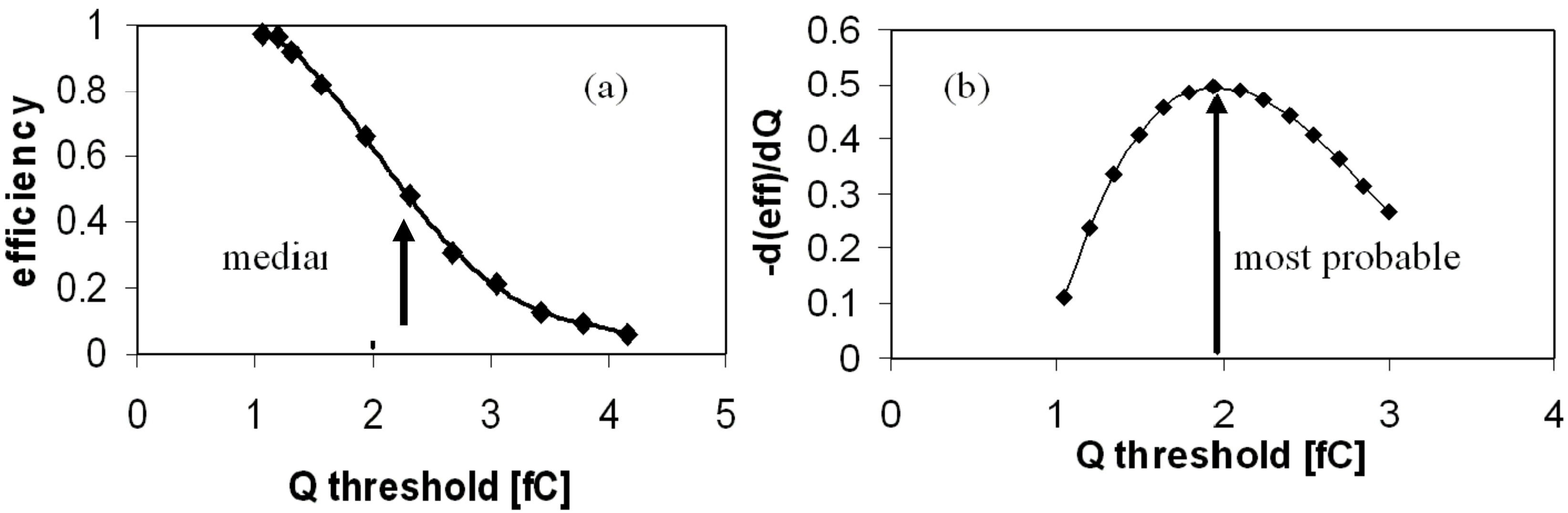




Charge collection system has binary readout from an AC coupled SSD with 100 ns shaping time

Threshold curves ->

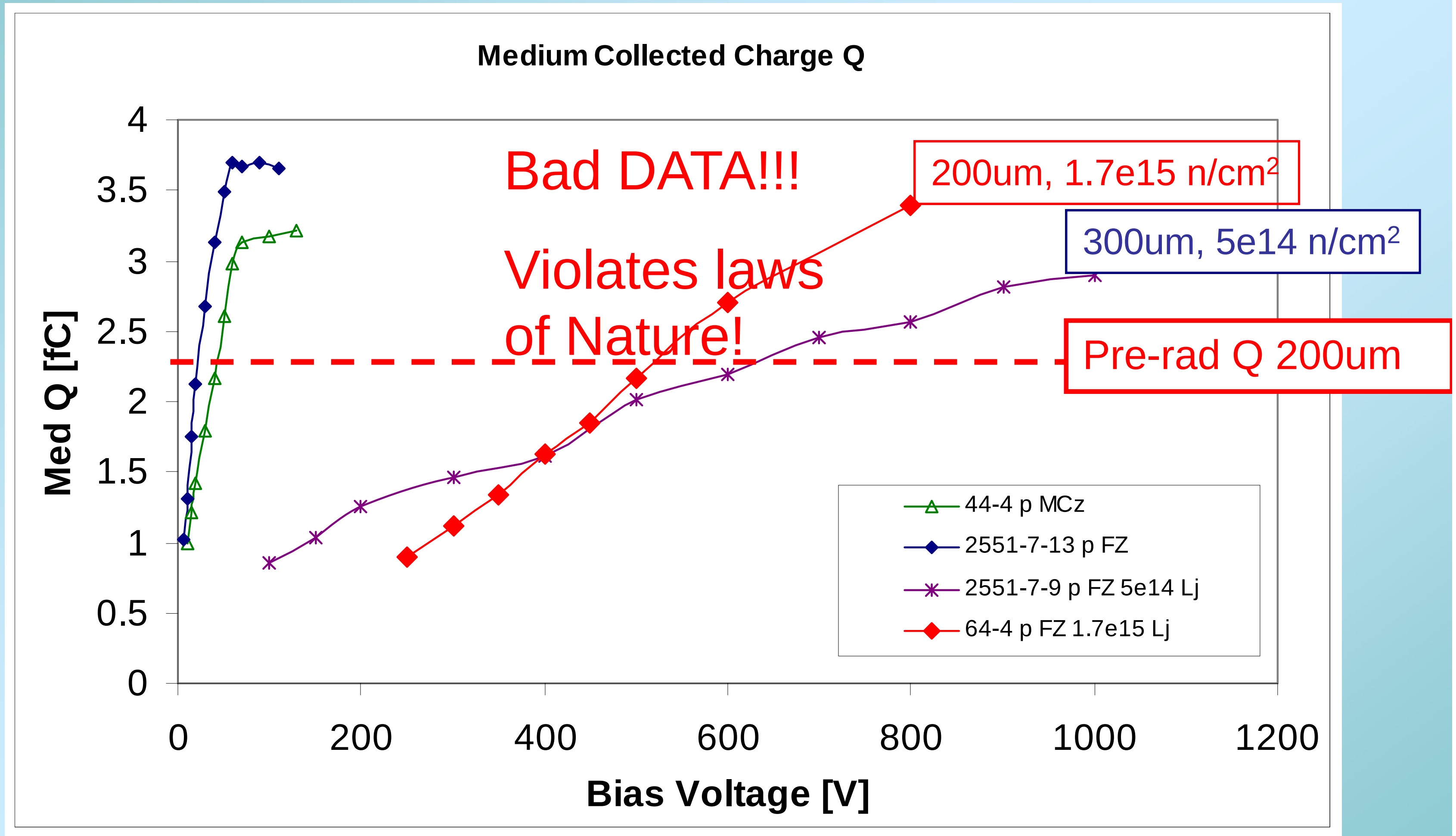
Statistical evaluation of:
Efficiency at 1 fC threshold
Median (50%) and Peak (most probable)



Time over Threshold TOT ->

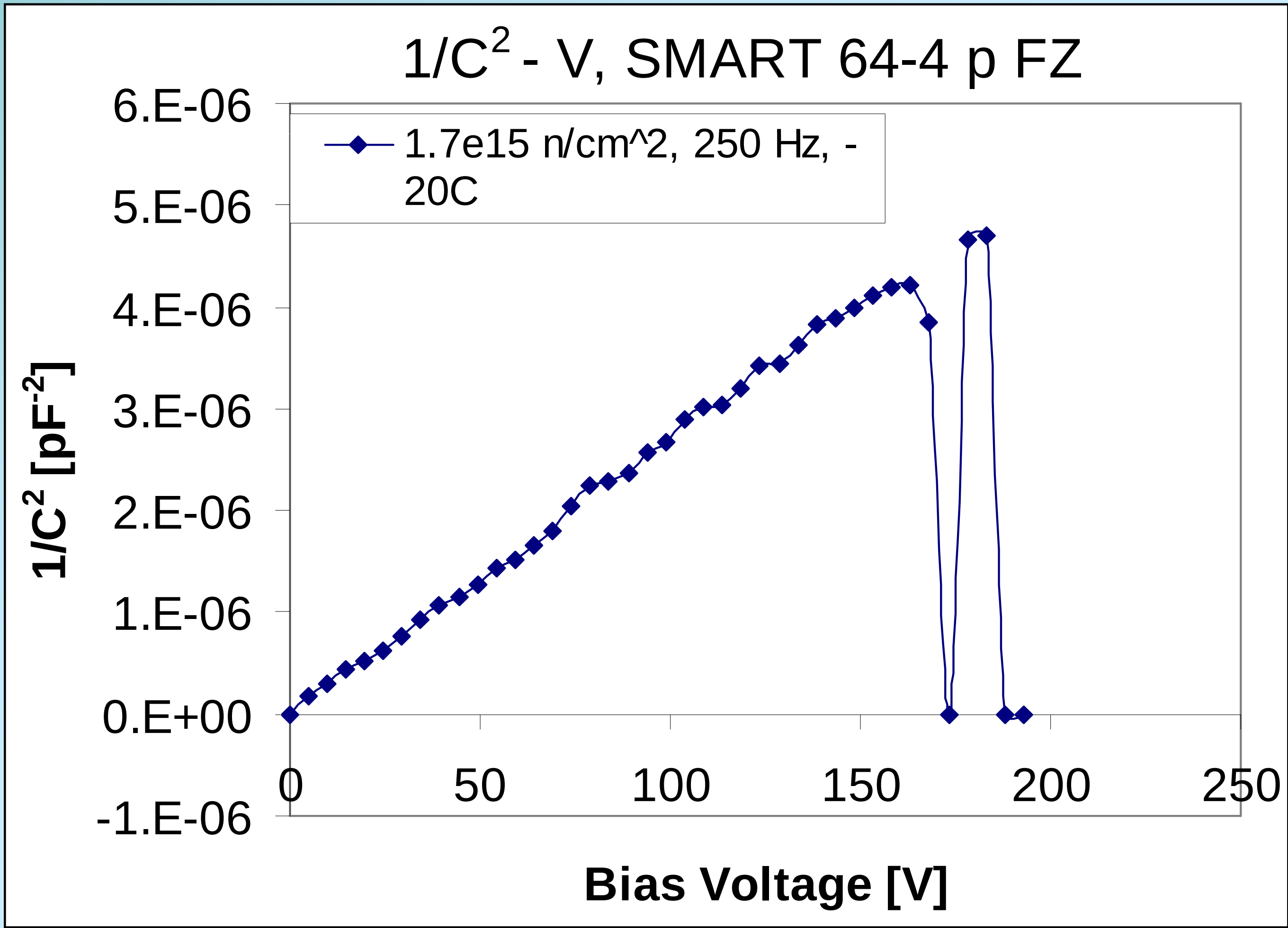
Analog Measurement event-by-event
In the moment only used for data validation

Problem with Micro Discharge



All 300 um, but SMART 64-4 p FZ (200um)

Problem with LCR Meter: "OVRLD"

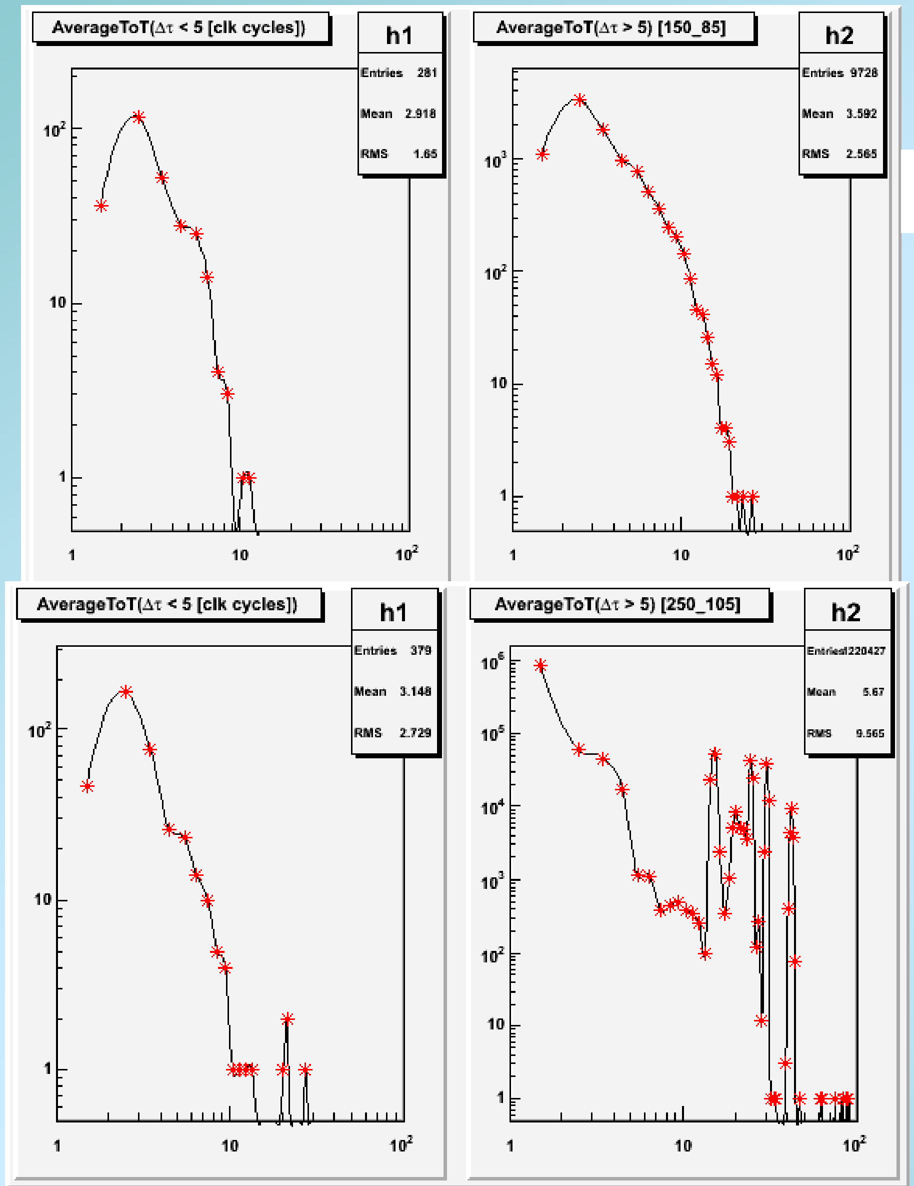


All SMART P-type SSD have non-physical C values above ~200V bias

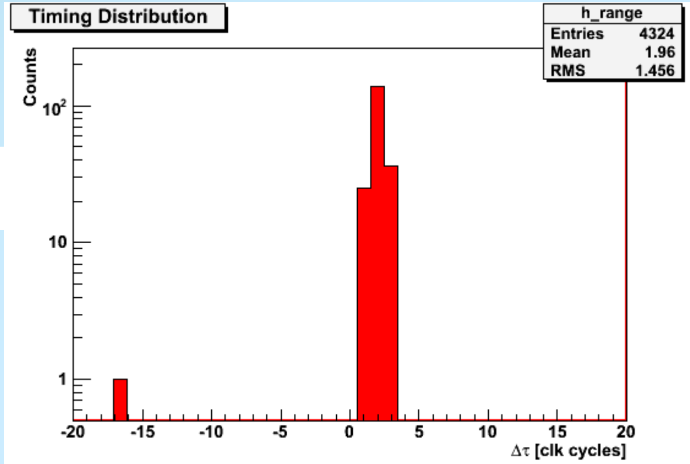
Problem with TOT on SMART 64-4 : “Breakdown”

TOT = Pulse height

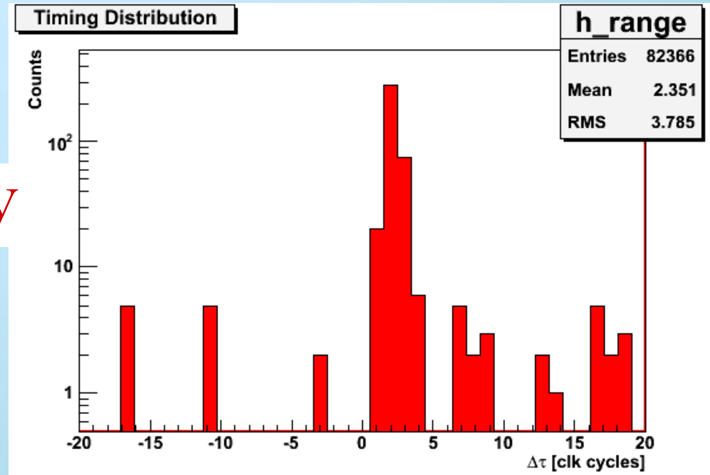
Time difference Sci-SiC



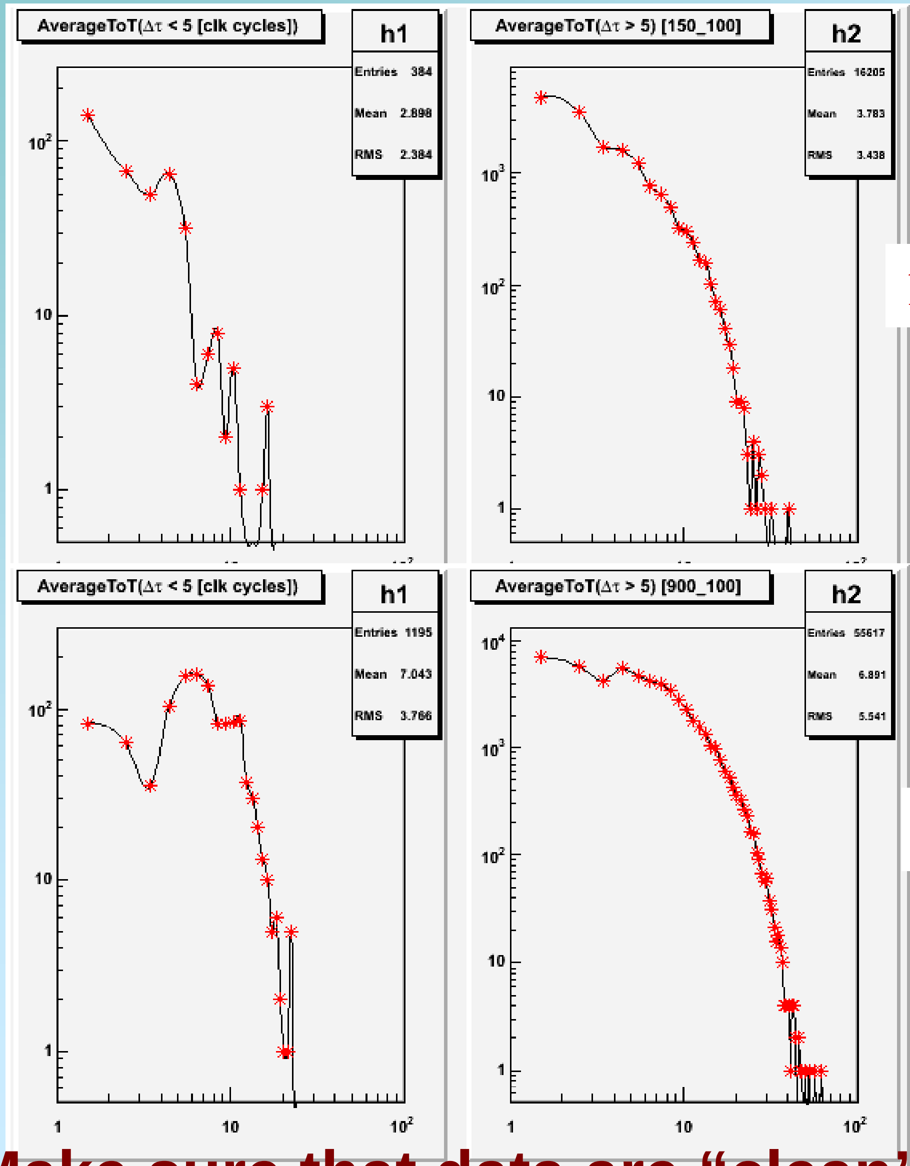
150V



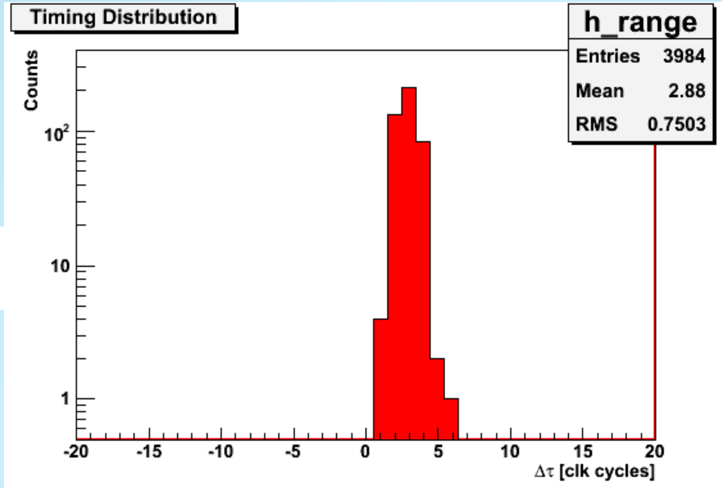
250V



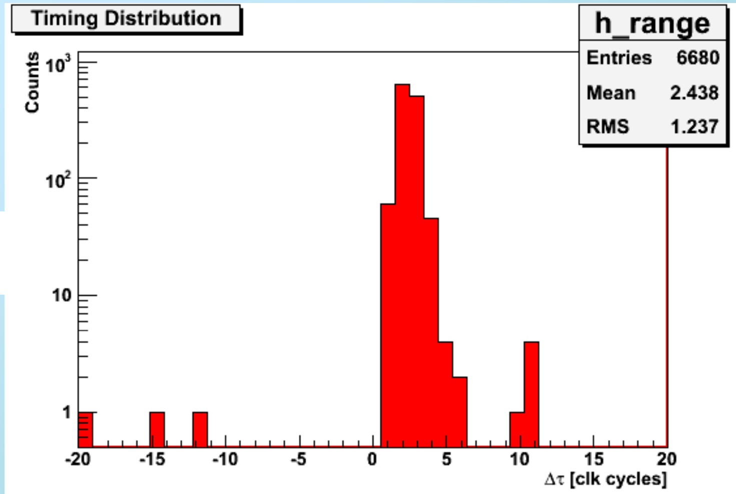
No TOT Problem on Micron 2553 n-on-n: "No Breakdown"



150V



900V



Make sure that data are "clean" by taking out of time data!

Micro Discharge shows up in Counting Rate

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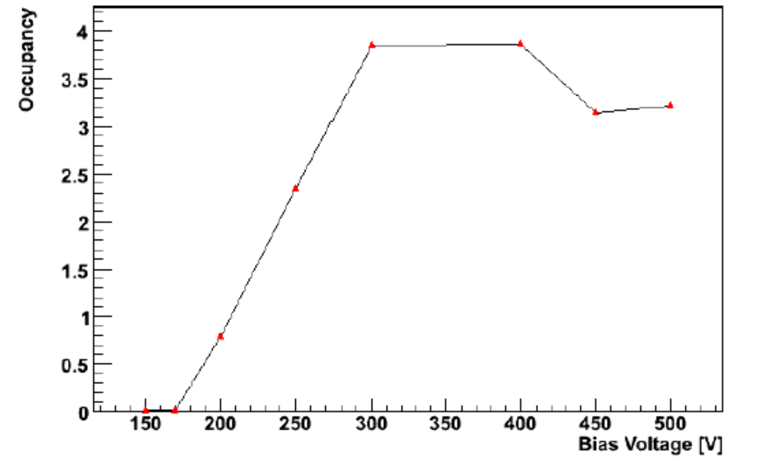


Figure 2. Occupancy vs. Bias Voltage at 1 fC for the 64-4 SMART detector

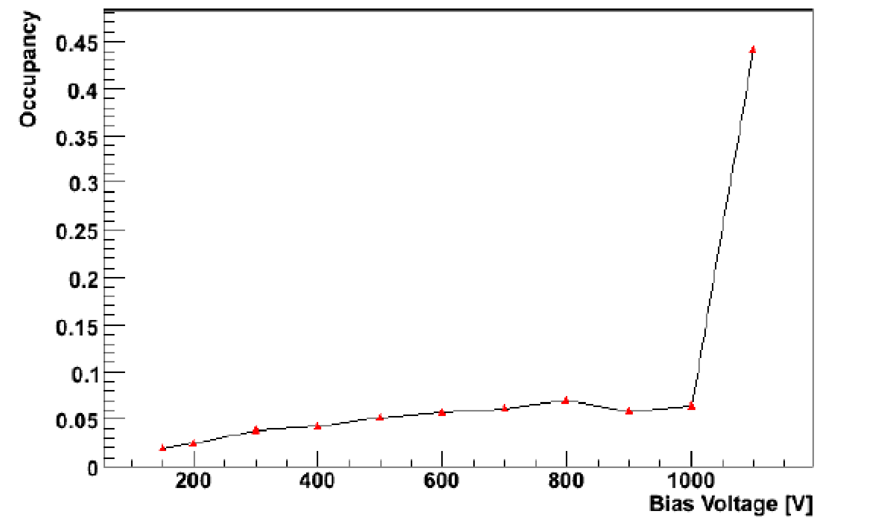
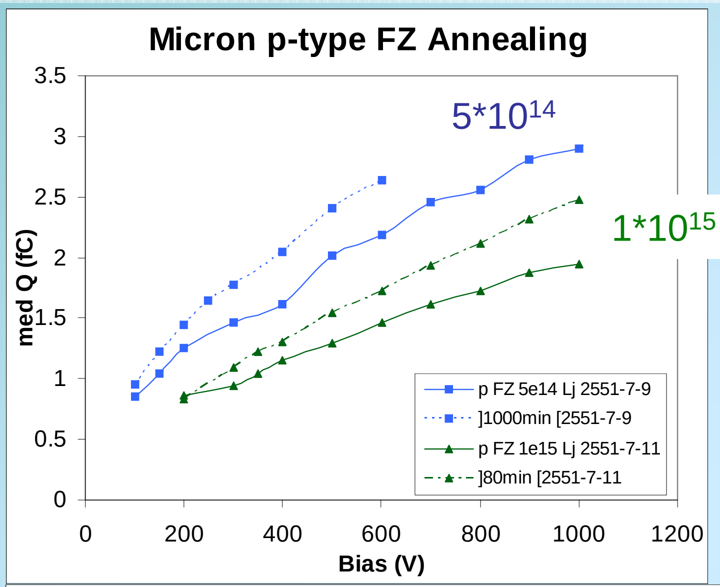
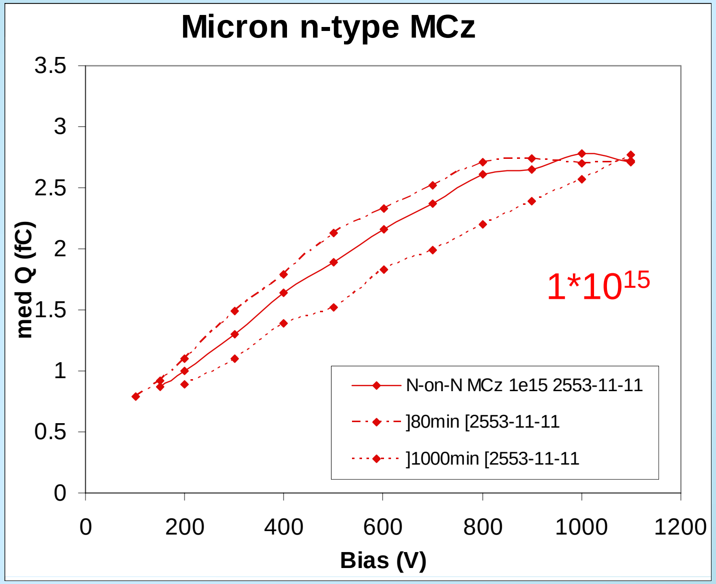


Figure 3. Occupancy vs. Bias Voltage at 1 fC for the 2553-11-11 MICRON detector

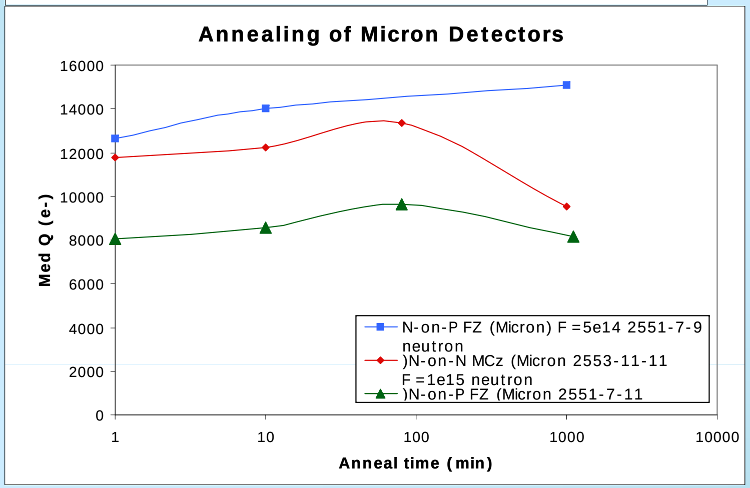
Annealing

For p-on-n LHC sensors, annealing during and after irradiation was a major source of engineering and operational difficulties, since the sensors needed to be kept cold at all times to prevent detrimental “anti”-annealing.



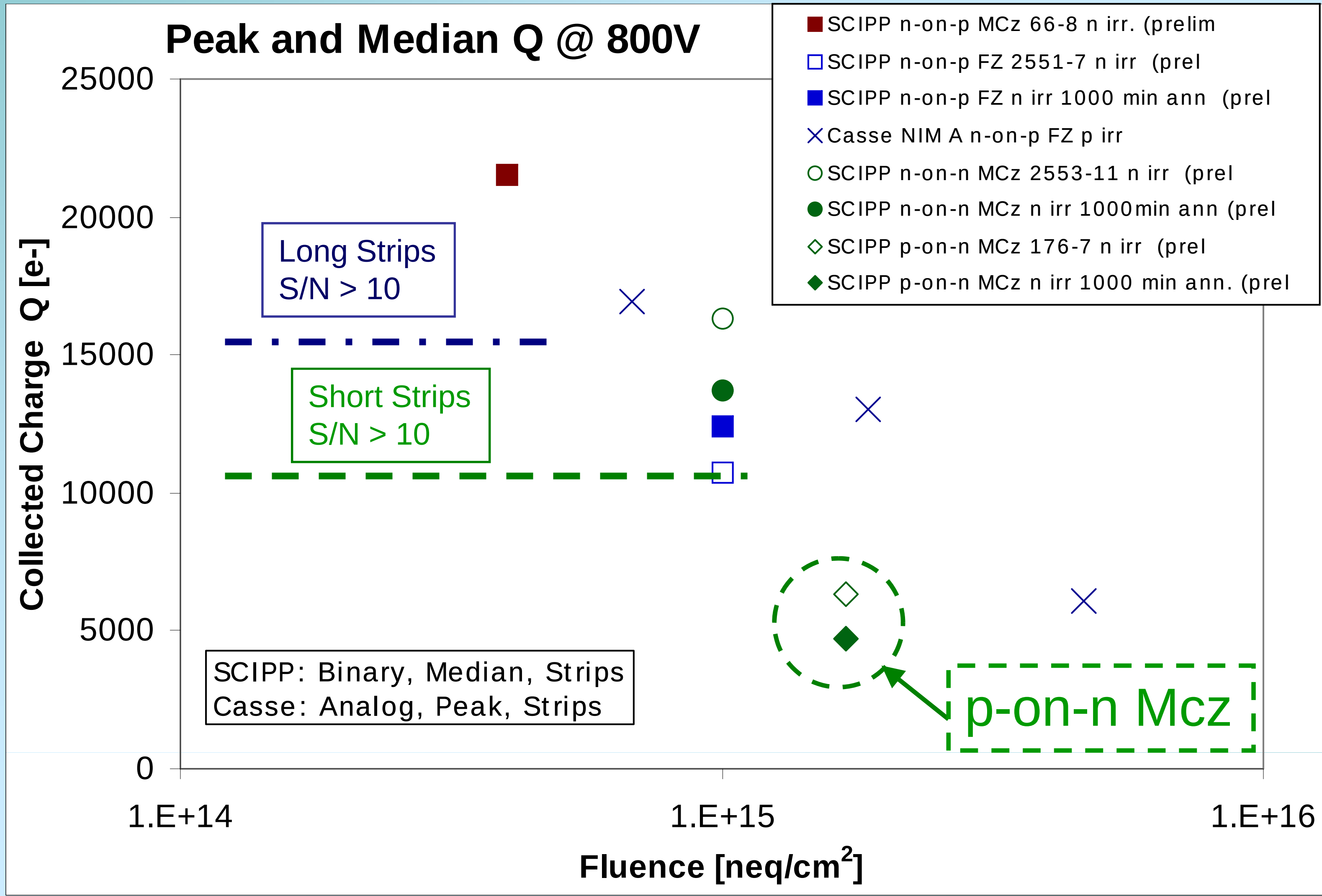


Accelerated annealing at elevated temperature 1000min @60 ^oC = 514 days @RT



At sLHC fluences, annealing is much less pronounced, and open the possibility that sensors need to be cooled only during operations to control the leakage current, but not during beam-off time to prevent anti-annealing

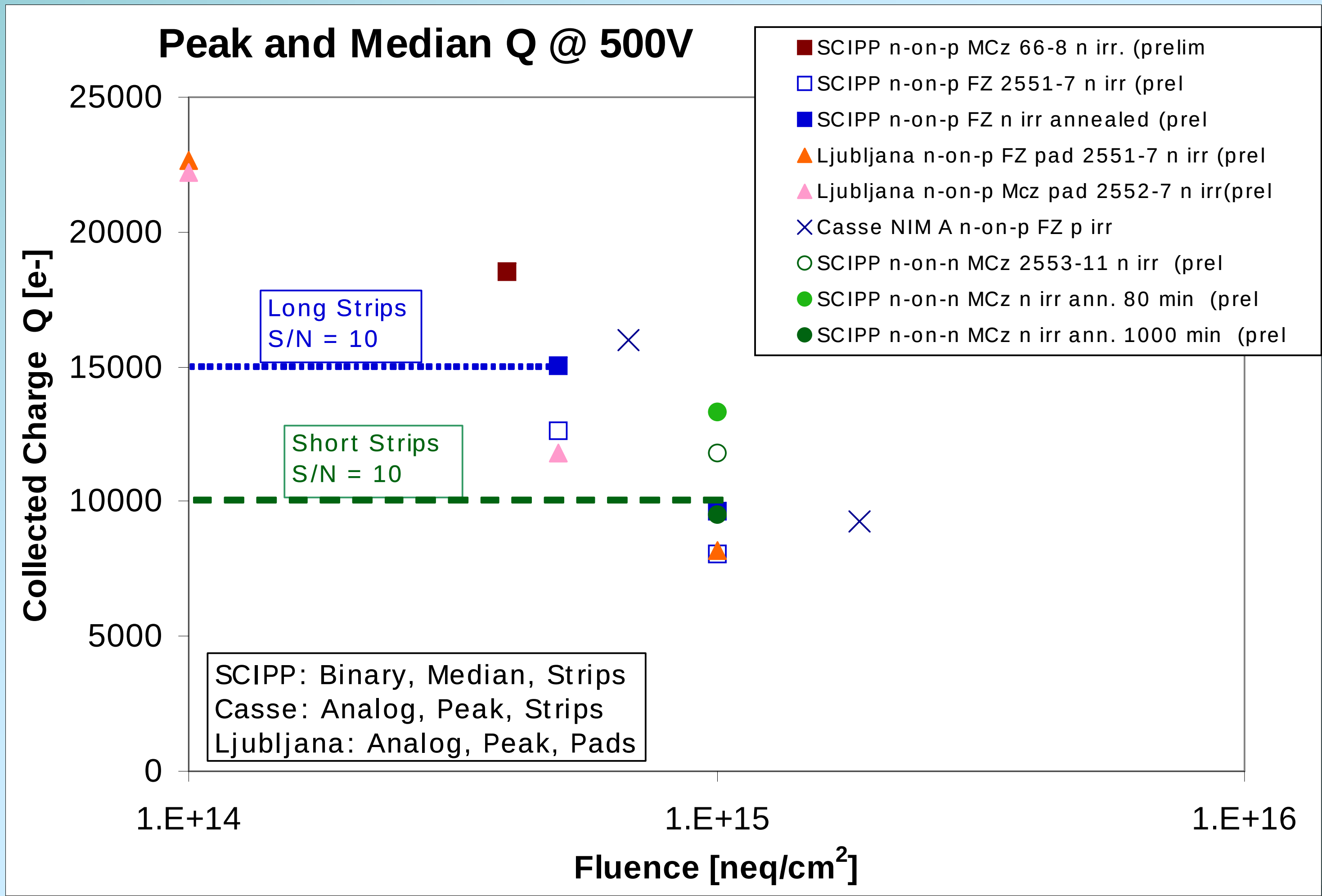
Charge Collection in Upgrade Strips



N-on-p strip sensors are sufficiently radiation-hard for the sLHC

Charge Collection in Upgrade Strips

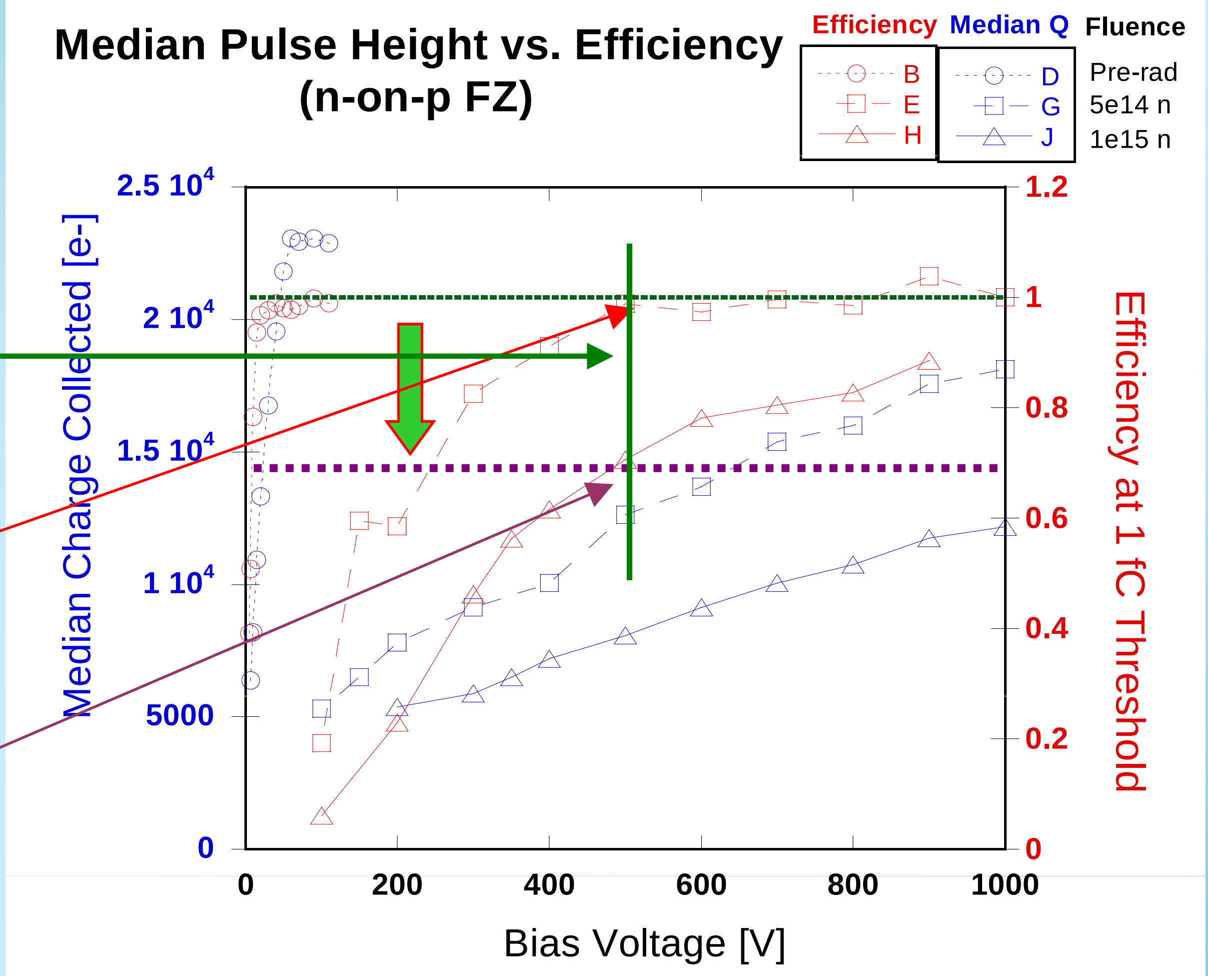
ATLAS bias voltage is constraint to < 500V (cables!).



N-on-p strip sensors are sufficiently radiation-hard for the sLHC ?

Efficiency vs. Collected Charge

- For tracking sensors with **binary readout**, the **figure of merit** is not the collected charge, but the **efficiency**.
- **100% efficiency** is reached at a signal-to-noise ratio of **S/N ≈ 10**.
- For **long strips** (5e14 cm^{-2}) with a signal of about 14ke, the usual threshold of 1fC = 6400 e can be used.
- For **short strips** (1e15 cm^{-2}) with a signal of about 8ke, the threshold needs to be reduced to about 4500 e, i.e. electronics must be designed for a noise of ~700e.



Short strips efficient if threshold can be lowered

Conclusions

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Confirm advantage of electron collection for high fluences

Charge collected on neutron irradiated N-on-P Si sensors is sufficient for short strips and long strips in the LHC Upgrade Tracker. Threshold on short strips FEE needs to be lower than 1 fC.

Small amount of annealing in N-on-P FZ (beneficial) and N-on-N MCz (detrimental) bodes well for the thermal management at the SLHC

Satisfactory agreement between neutron irradiated sensors with binary readout and proton irradiated sensors with analog readout.

Consistent high voltage operation of Micron p-spray n-on-p SSD.

Microdischarge needs to be watched!

Acknowledgments

Thanks to

RD50 collaborators in Ljubljana, Louvain, CERN, Karlsruhe, PSI, UCSC for carrying out the irradiations:

Maurice Glaser (CERN)

Otilia Militaru (Louvain)

Vladimir Cindro (Ljubljana)

Alex Furgeri (Karlsruhe)

Max Wilder, Christopher Betancourt, Mark Gerling (UCSC)

RD50 Bet Oct 17, 2006

“Will the "Kramberger effect" be traced to a temperature effect?”

Betting was heavily against (all in SFrs)

Against		For	
Moll	5	Hartmut	5
Vladimir Ci	1000	Thor	40 kr
Noman	2	Panja	3.75
Thor	5	Maurice	2
Gregor	5	Elena	10Kopek
VladPad	5	VladPad	2
Simon	5		
Alex?	10		
Uli	10		
	47		12.75
Sum	59.75		

Results shown at Vilnius makes it unlikely that temperature is the sole cause.

Proposal to pay off the bet in a communal way:

Bookie will forgo his usual proceeds (50% of total) and pay for drinks in the Bar tonight at 7 pm

RD50 6" Common Project: Pion Irradiation at PSI

	2.00E+14	1.00E+15	2.00E+15
N-on-P FZ			
Diodes	x4	x4	x4
Detector	x3	x3	x4
N-on-P MCz			
Diode1	x4	x4	x4
Detector	x3	x3	x4
P-on-N FZ			
Diode2	x4	x4	x4
Detector	x3	x3	x4
P-on-N MCz			
Diode2	x4	x4	x4
Detector	x3	x3	x4

Attained Fluences ~2x smaller

RD50 6" Common Project: Proton Irradiation at CERN

	2.00E+14	5.00E+14	1.00E+15	2.00E+15	5.00E+15
N-on-P FZ					
Diode	2x	2x	2x	2x	2x
Detector	2x	2x	2x	2x	2x
N-on-P MCz					
Diode	2x	2x	2x	2x	2x
Detector	1x	1x	1x	1x	
P-on-N FZ					
Diode	2x	2x	2x	2x	2x
Detector	2x	2x	2x	2x	2x
P-on-N MCz					
Diode	2x	2x	2x	2x	2x
Detector	2x	2x	2x	2x	2x

RD50 6" Common Project: Neutron Irradiation at Ljubljana

	2.00E+14	5.00E+14	1.00E+15	2.00E+15	5.00E+15
N-on-P FZ					
Diode	2x	2x	2x	2x	2x
Det 1cm	1x	1x	1x	1x	1x
Det 3cm	1x	1x	1x	1x	1x
N-on-P MC					
Diode	2x	2x	2x	2x	2x
Det 1cm	1x	1x	1x	1x	1x
Det 3cm	1x	1x	1x	1x	1x
P-on-N FZ					
Diode	2x	2x	2x	2x	2x
Det 1cm	1x	1x	1x	1x	1x
Det 3cm	1x	1x	1x	1x	1x
P-on-N MCz					
Diode	2x	2x	2x	2x	2x
Det 1cm	1x	1x	1x	1x	1x
Det 3cm	1x	1x	1x	1x	1x
N-on-N FZ					
Diode	2x	2x	2x	2x	2x
Det 1cm	1x	1x	1x	1x	1x
Det 3cm	1x	1x	1x	1x	1x