Surface Properties of ATLAS07 SSD

- Voltages on the surface of n-on-p sensors
- Surface Parameters pre-rad
  - Interstrip R
  - Interstrip C
- Gamma and Proton Irradiation
- Surface Parameters post-rad
  - Interstrip R
  - Interstrip C

Additional info:

- Breakdown (Hara)
- Gluing (Affolder)

H. F.-W. Sadrozinski
SCIPP, UC Santa Cruz
For the ATLAS Upgrade Strip Sensor Collaboration

Testing of ATLAS07

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ATLAS Upgrade Silicon Strip Detectors (SSD)

SCIPP

ATLAS project	Development of non-inverting Silicon strip detectors for the ATLAS ID upgrade		
ATLAS Upgrade Document No:	*Institute Document No.*	*Created:* **28/12/2005**	*Page:* **1 of 11**
		Modified: **18/05/2006**	*Rev. No.:* **1.04**

- Share expertise and cost within the ATLAS groups
- Leverage rad-hard experience with p-type SSD (RD50, KEK) including many manufacturers
- Sensor fabrication with the only viable large-volume and high-quality manufacturer (Hamamatsu HPK)
- Produce proto-type test structures (radiation damage, isolation, ..)
- Produce full-size sensors to support module/stave program (stereo, bonding, gluing, thermal management,..)

KEK
Tsukuba
Liverpool
Lancaster
Glasgow
Sheffield
Cambridge
QML
Freiburg
MPI
Ljubljana
Prague
Barcelona
Valencia
UC Santa Cruz
BNL
Stony Brook

ATLAS07

Purpose

- Full size 10 cm x 10 cm for Modules/Stave
- Set of test structures for technology development

Delivery target

- Pre-series Feb. 2008
- 2nd Pre-series Sep. 2008
- Production Mar 2009

Wafer

- 150 mm p-FZ(100)
- 320 µm thick

n-strip isolation

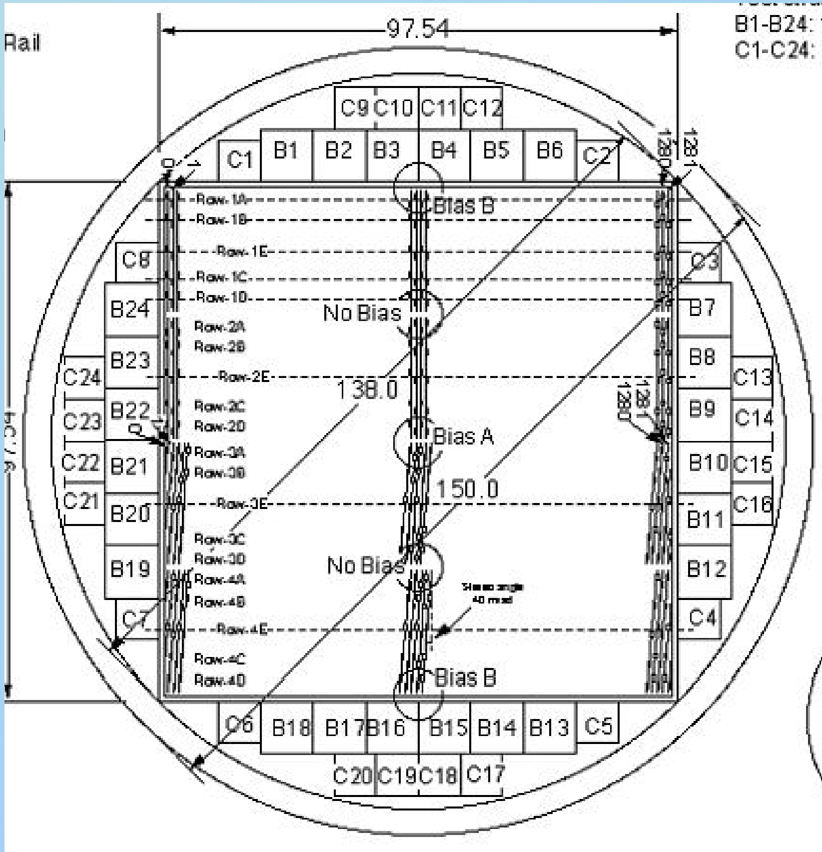
- Individual p-stop
- P-spray
- P-spray + p-stop

Stereo

- 40 mrad
- Integrated in half area
- Dead area: 2 mm

Strip segments

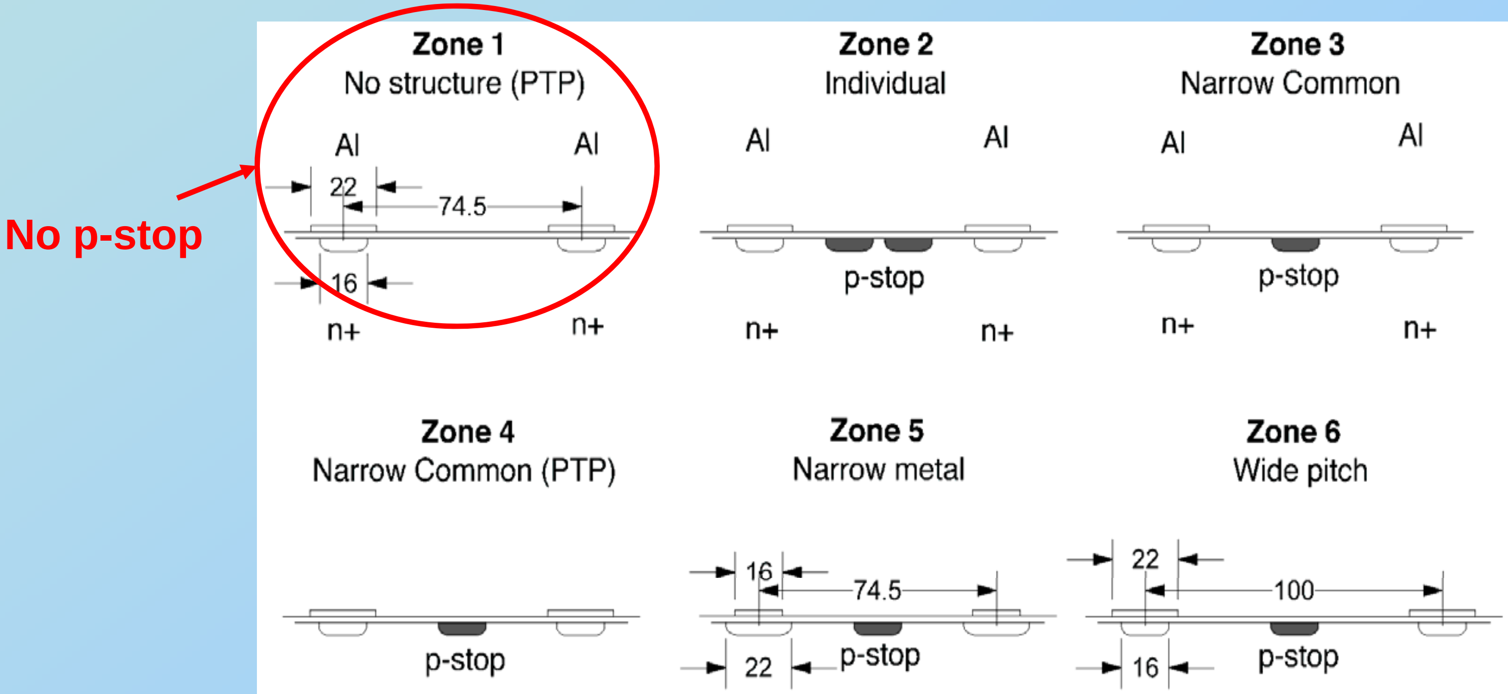
- 4 for Short Strips
- LS: segments wire-bonded



Axial-Stereo Sensor

Test Structures in ATLAS07

Collecting electrons promises much better charge collection performance in irradiated silicon sensors than collecting holes (like in the SCT), yet due to an accumulation layer below the oxide, introduces sensitivity to the surface condition, e.g. one needs to test breakdown, strip isolation and interstrip capacitance, and potentially gluing on the surface depending on the surface treatment.
There are six versions ("Zones") of the ATLAS07 mini-SSDs with different strip isolation schemes.
Wafers # <20 have p-spray, Wafers # >20 have no p-spray.
Pre-series II has improvement in punch-through protection & p-spray dose variation

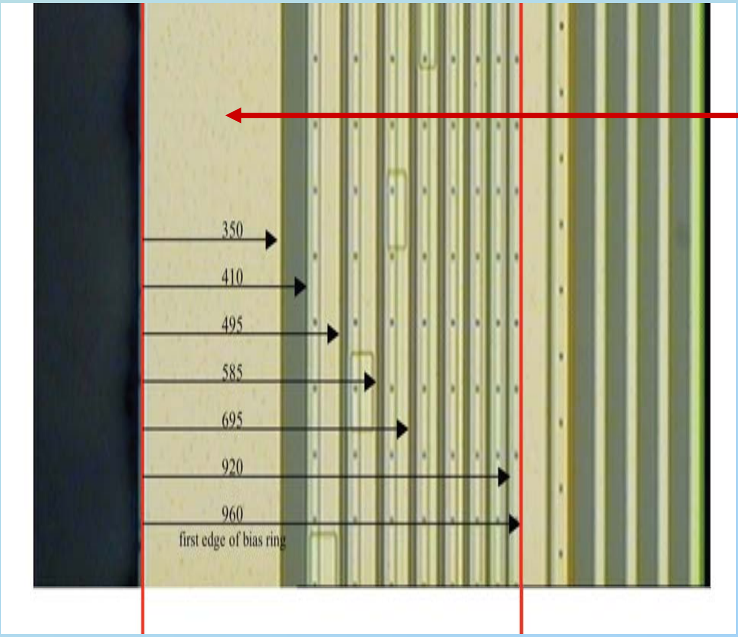


Voltages on strip side of n-on-p SSD

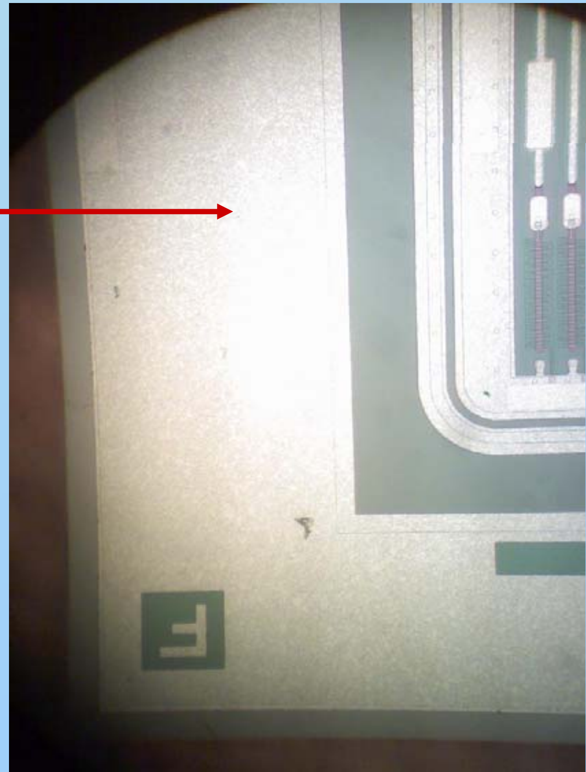
Issue:

Economical single-sided processing of n-on-p sensors

To reduce guard ring current, P+ implant brings the bias voltage (up to ~1000V) to the strip side. Same principle is used on p-on-n.



V_{Bias}

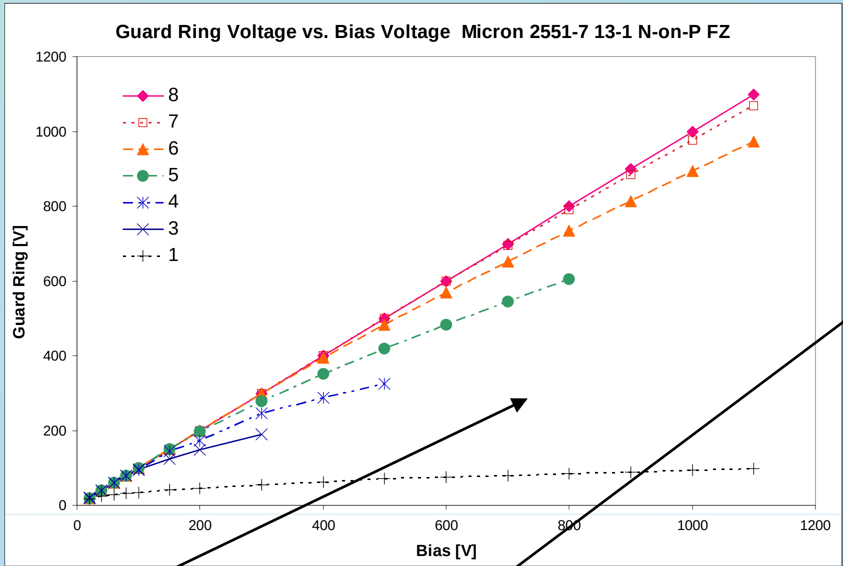


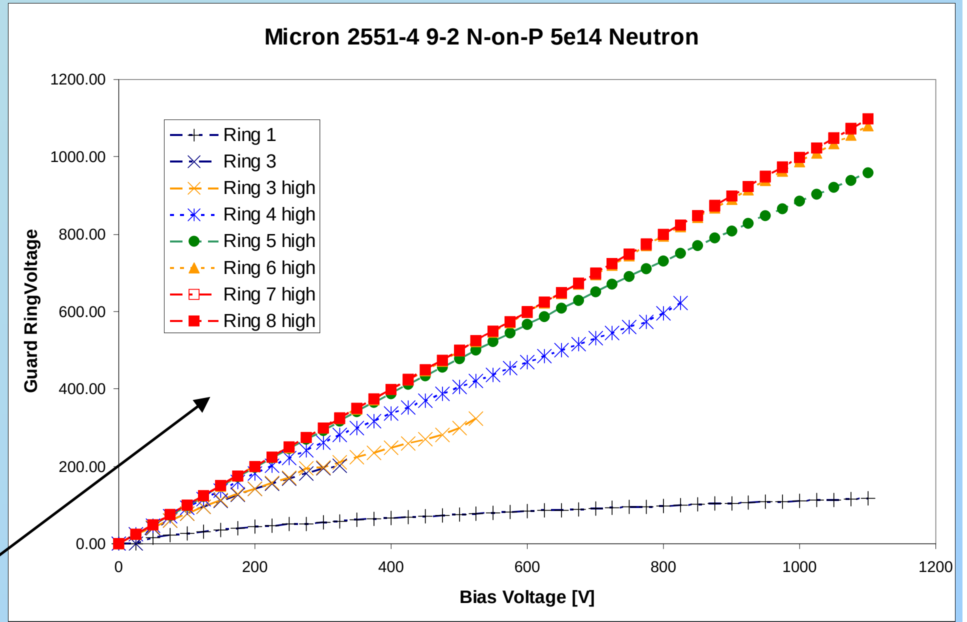
Micron 6” RD50 sensor
(~ 1mm inactive area, 8 guard rings,
P+ implant at edge)

ATLAS07 has only one guard ring
and larger distances edge – ring:
No access to measure voltages

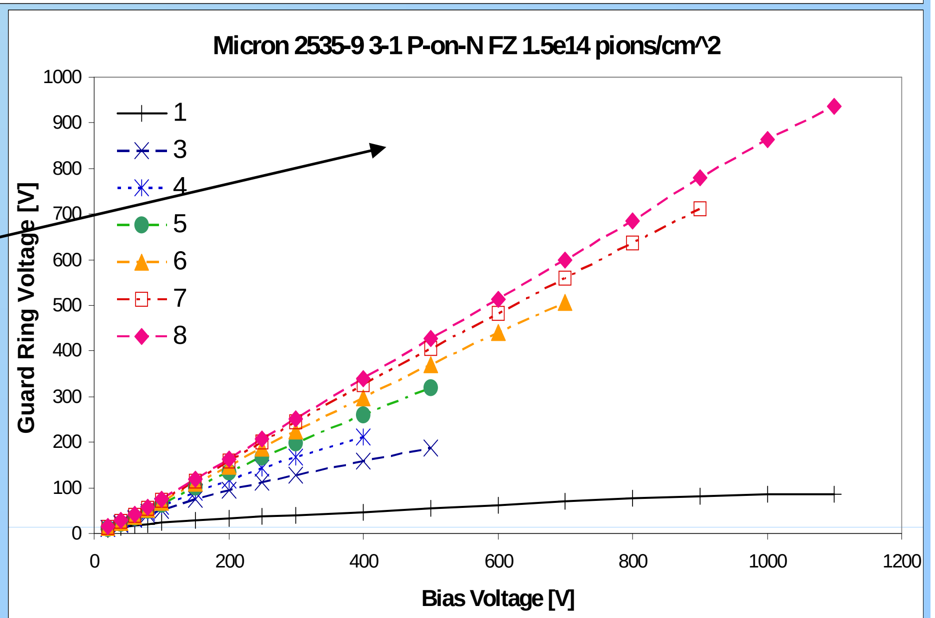
Voltages on the Surface of n-on-p SSD

For low-current sensors:
outermost guard ring on the SSD face is at Vdep, e.g. up to 1000V,
(innermost close to bias ring = ground)

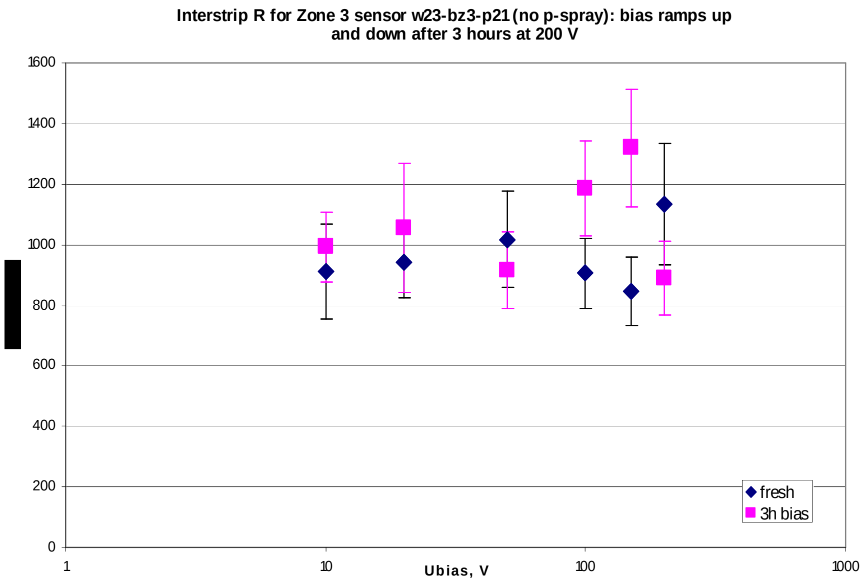


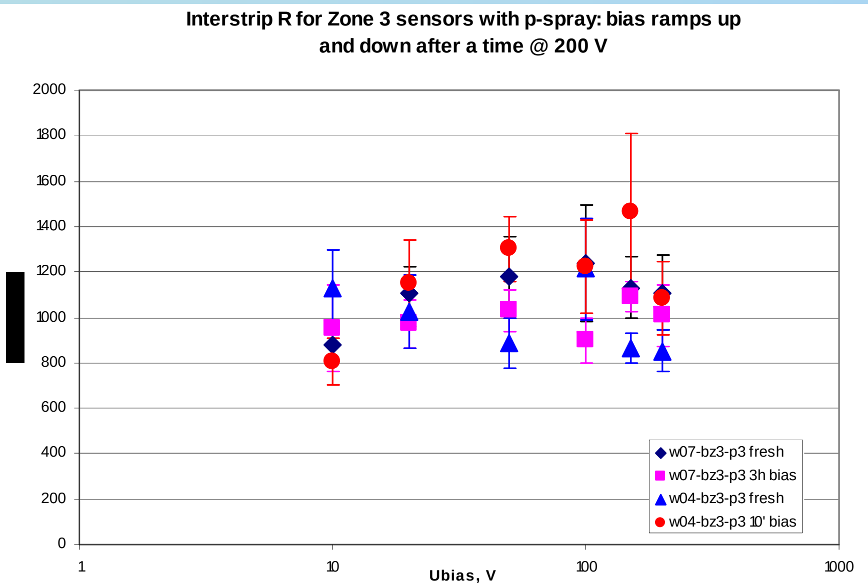


Pre-rad (n-on-p)
and post-rad (n-on-p & p-on-n)
guard ring voltages
vary from V_{bias} to GND
Hybrid designers
(and pixel bump-bonders!) be aware!



Time Variation of Interstrip Resistance R_{int}



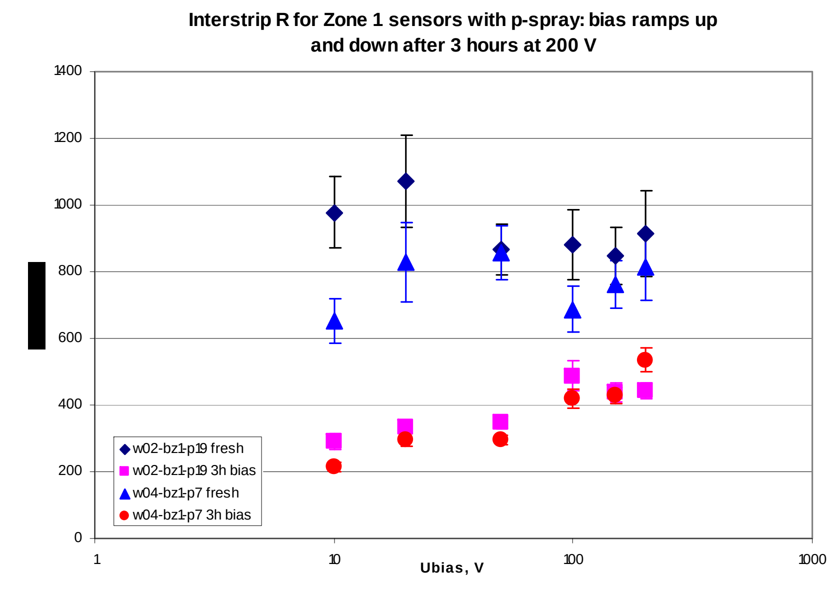


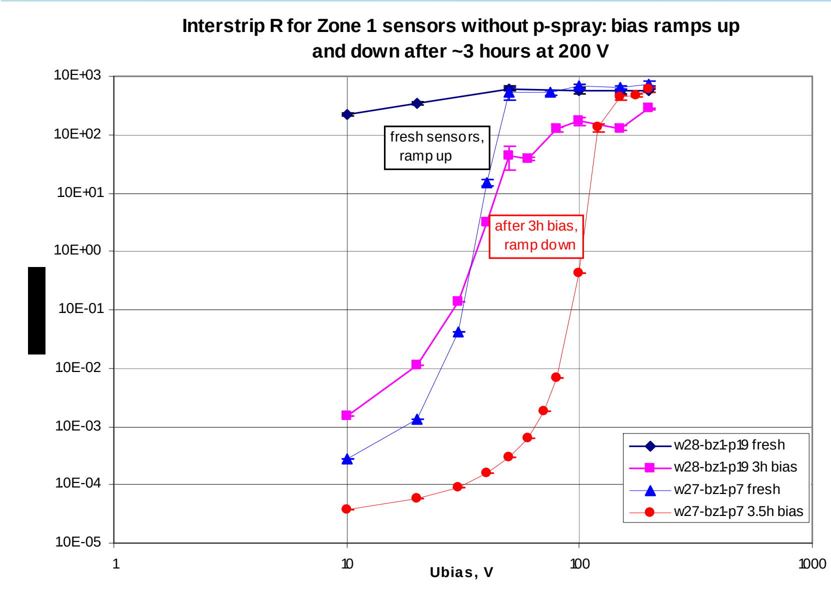
For zone 3 sensors (p-stop) the interstrip resistance R_{int} does not depend on bias in the range 10-200V and doesn't change after sensor remaining at 200V bias during 3 hours.

Typical R_{int} value is ~1000 GOhm.

A. Chilingarov, Lancaster U.

Time Variation of the Interstrip Resistance R_{int}





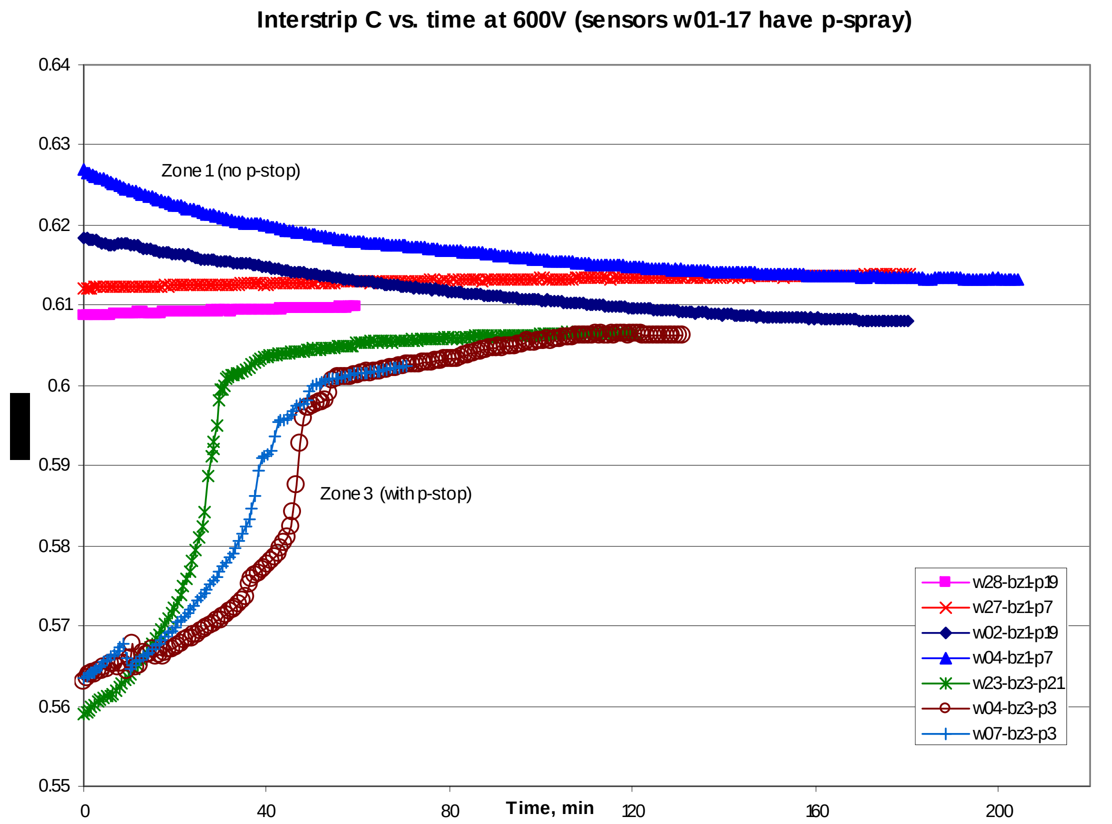
For fresh zone 1 sensors with p-spray the R_{int} also doesn't depend on bias in the range 10-200V but after 3 hour biasing by 200V it decreases and becomes slightly bias dependent with R_{int} value of ~500 GOhm above 100V bias.

For zone 1 sensors without p-spray the R_{int} behaviour is more complicated. Nevertheless above 100V bias the R_{int} remains above 100 GOhm even after 3 hours at 200V bias.

A. Chilingarov, Lancaster U.

Time Variation of Interstrip Capacitance C_{int}

Interstrip Capacitance to next neighbour pair:
Total capacitance ~ 30% higher

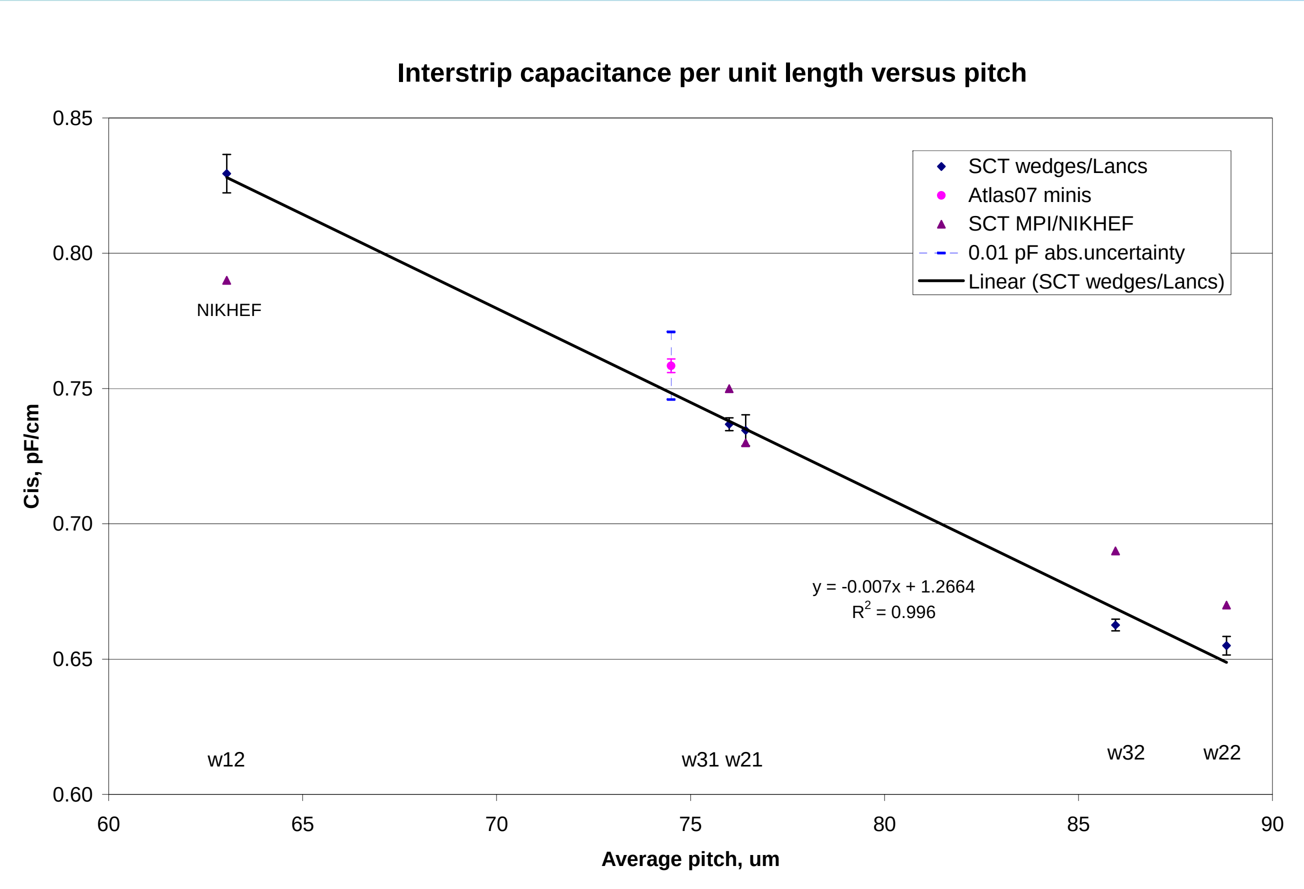


At 600V bias the C_{int} further converges with time to a common value of ~0.61 pF for all sensor types. Note that more than 2 hours may be needed for the C_{int} stabilisation. This phenomenon was extensively studied earlier for the SCT sensors

The present measure-ments were made at ~+22^{o}C and 35-45% relative humidity.

A. Chilingarov, Lancaster U.

C_{int} Comparison with the SCT sensors



The observed C_{int}/L agrees well with the data measured for the SCT sensors.
An absolute LCR meter uncertainty of 0.01 pF is also shown in the error.
Thus the C_{is} in ATLAS07 minis can be regarded as simply geometrical one.

A. Chilingarov, Lancaster U.

Gamma Irradiation at BNL

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- 8 ATLAS07 mini-SSD were irradiated at BNL to 1 Mrad, 5 biased, 3 unbiased.
- Breakdown behavior post-rad improved slowly, cleaning and N2 flow helped (?)
- All showed sensitivity to surface conditions (biased ones to a lesser extend)
- Suspect charge-up of surfaces as main cause, and that slow improvement of i-V on bonded sensors is due to slow bleeding of surface charges to grounded conductors
- Since charge-up can lead to breakdown through oxide, need to limit dose rate for future gamma irradiations

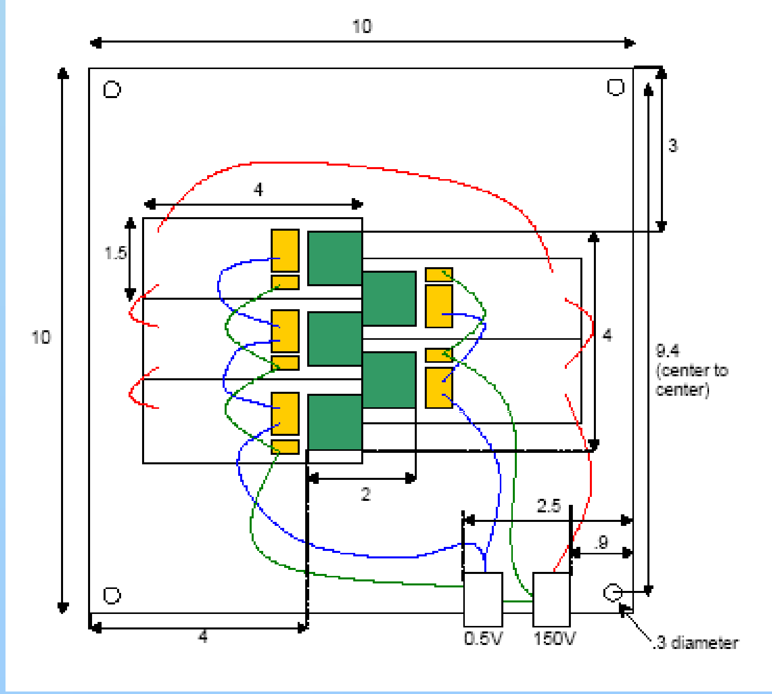
All Al readout traces are bonded out together

During irradiation bias the metal strips to +0.5 V wrt to bias ring. Bias back plane to 200V.

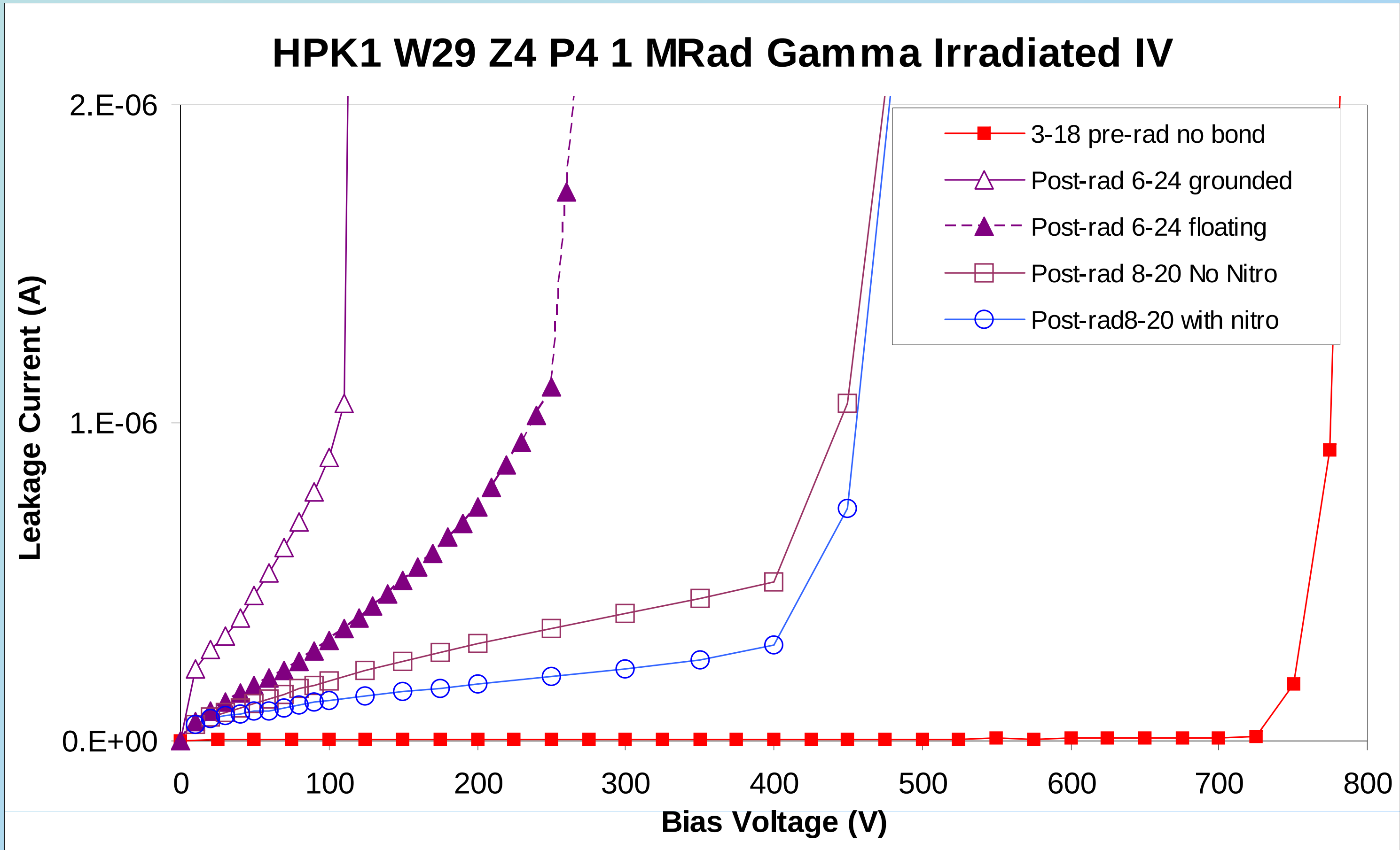
RT annealing for about 10 days.

Take i-V with the Al either "grounded" or "floating"

Measure
Isolation, Interstrip C, Breakdown



i-V post Gamma Irradiation



N2 flow needed? Bonded SSD improve slowly:
Charge bleed rate $\tau = \rho * \varepsilon$

Proton Irradiation of ATLAS07 mini SSD

“Low”-fluence proton runs

Analysis of gamma irradiations has proven to be difficult, presumably related to the very high resistivity of the passivation trapping charges on the surface during the high dose-rate irradation. Slow improvement over time has been observed.

Irradiation of HPK ATLAS07 sensors at Los Alamos Nat. Lab. (800 MeV Protons) organized by U. of New Mexico was stopped at $1.5*10^{13}$ neq/cm^2 after an operator fault, giving us a sample with low fluence protons. The total dose is ~ 500 kRad, an ideal place to study R_{int}, C_{int} and breakdown behavior, independent of large bulk currents.

Since the charge collection studies after high hadron fluences show us a very stable picture of the sensors (independent of the surface details), the decision which technology to use for strip isolation will be influenced by these low-fluence runs.

Strip Isolation post Proton/Gamma Irradiation

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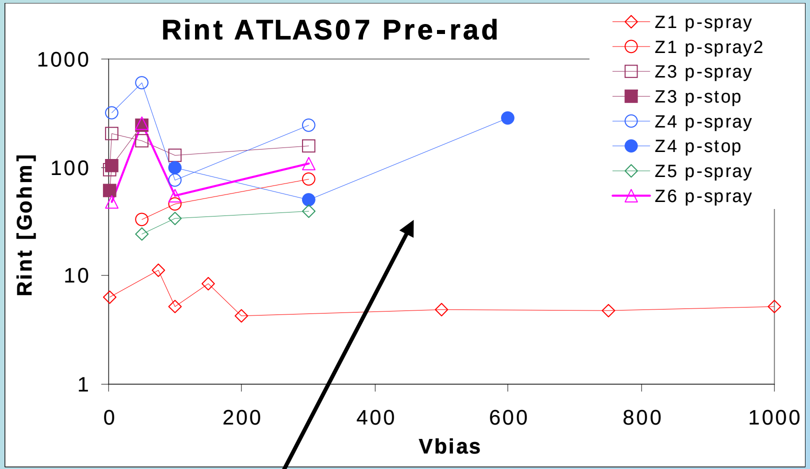
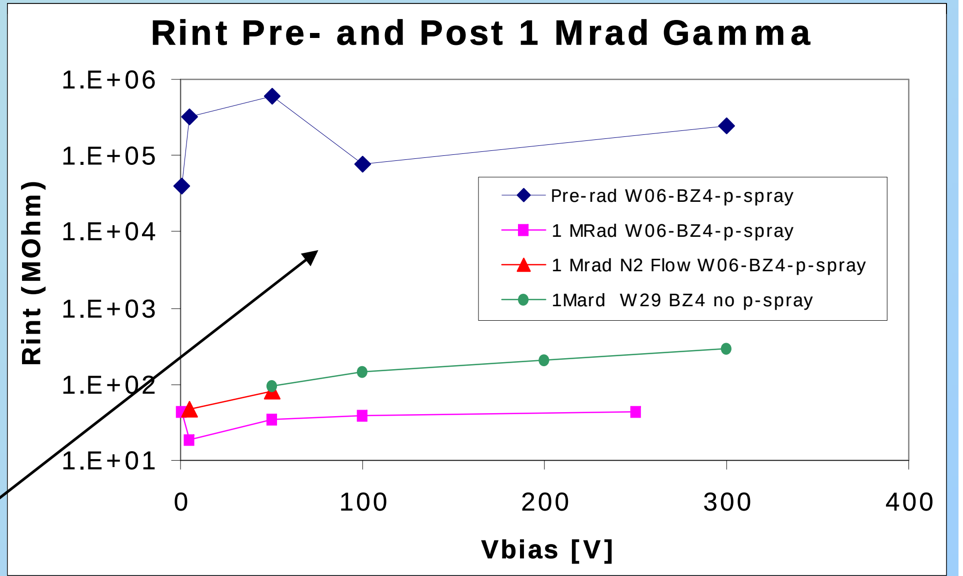
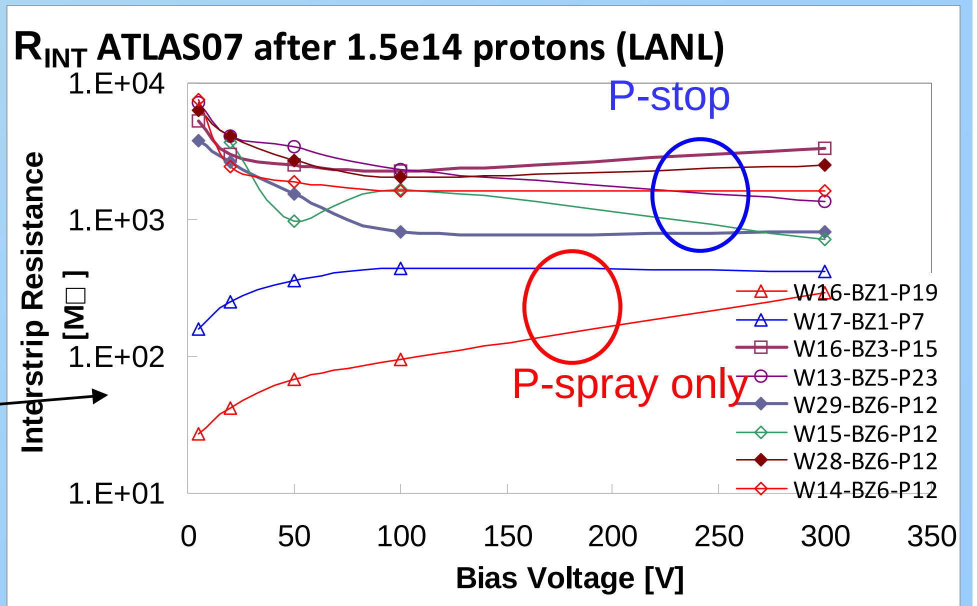




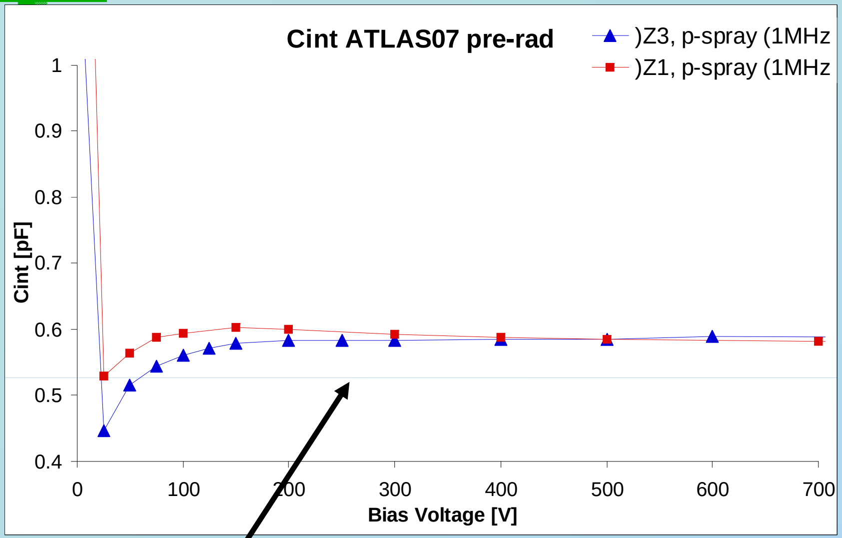
Pre-rad Rint =10's -100's of GΩ

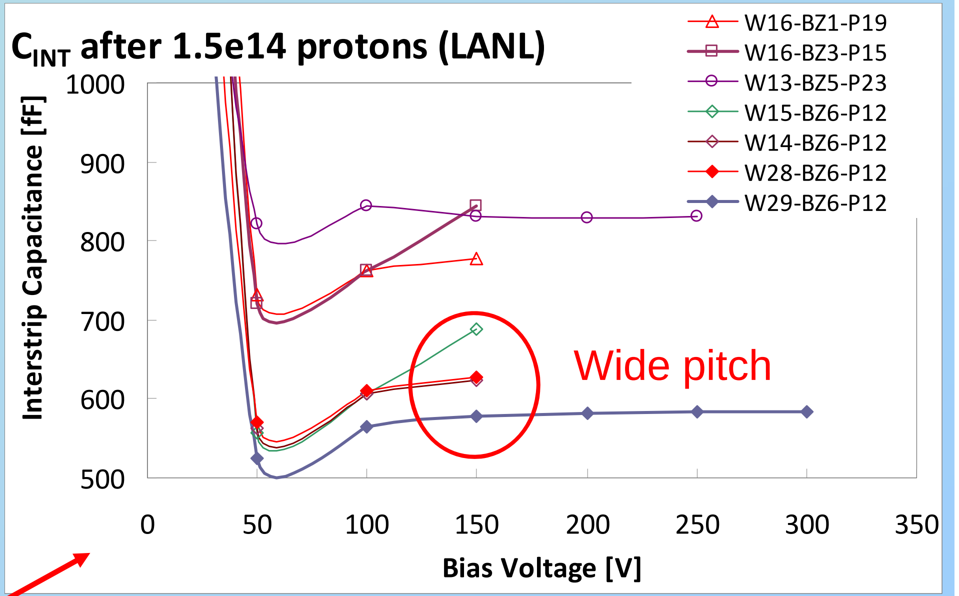
Gamma irradiation
reduces Interstrip Isolation:
Post-rad Rint =50's -100's of MΩ

Proton irradiation:
P-stop seems to provide more
robust isolation after proton irradiation



Inter-strip Capacitance post-rad Protons





Interstrip capacitance to next neighbor pair (total ~30% higher): close to 1 pF/cm.

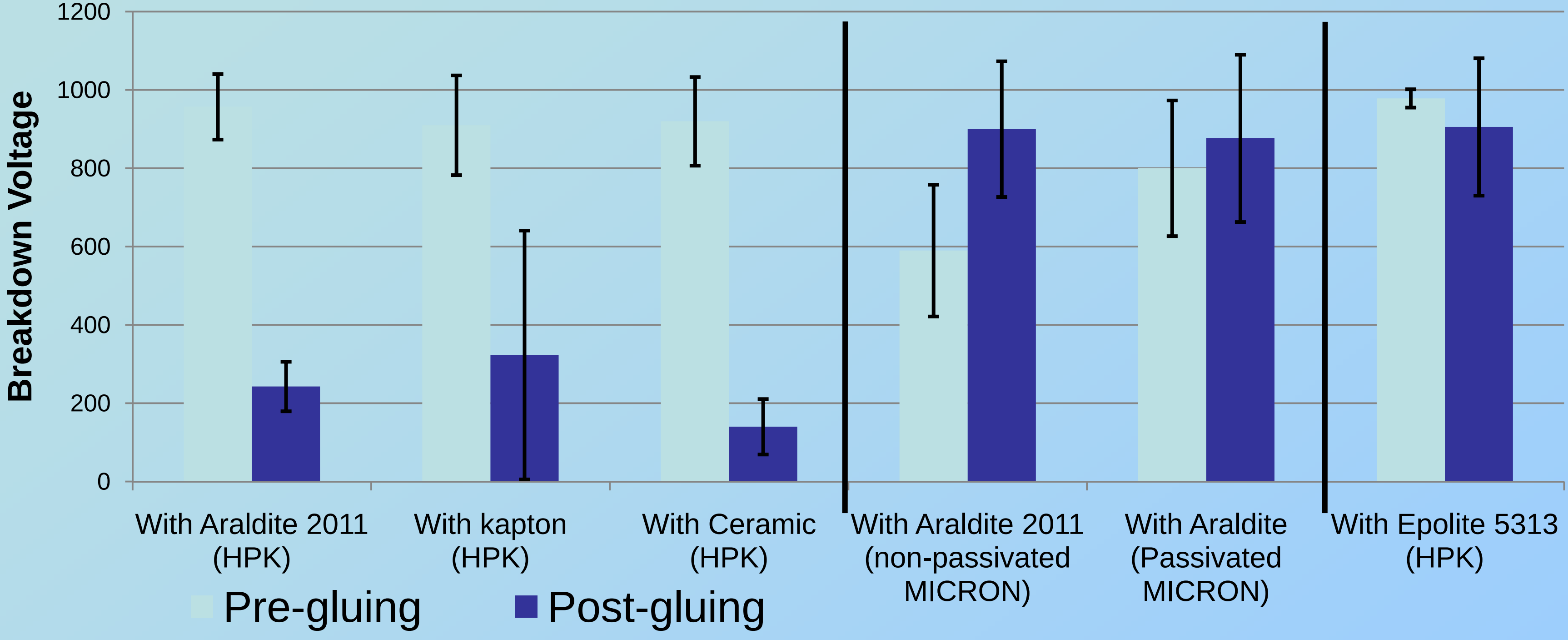
Pre-rad:

same value for p-spray with and without implants, “No” bias dependence for Zone 1 and Zone 3

Post-rad:
Somewhat higher after low-fluence proton irradiation. Correlated with reduced R_{int}?
No dependence on surface treatment (p-stop vs. p-spray)

Important for long strips: can expect C ~ 13 pf !

Summary of Gluing Results at Liverpool



Araldite 2011 interacts poorly with ATLAS07 sensors, but no ill-effects seen with passivated/unpassivated Micron sensors or p-on-n HPK sensors.

ATLAS07 with Epolite 5313 (electronics grade epoxy) has good performance but some surface sensitivity seen. Evidence so far suggests that issues might be different than with Araldite.
Irradiations are underway.

A. Affolder, Liverpool U.

IV-CV curves: Epolite ok, Araldite has V_{bd}=250V

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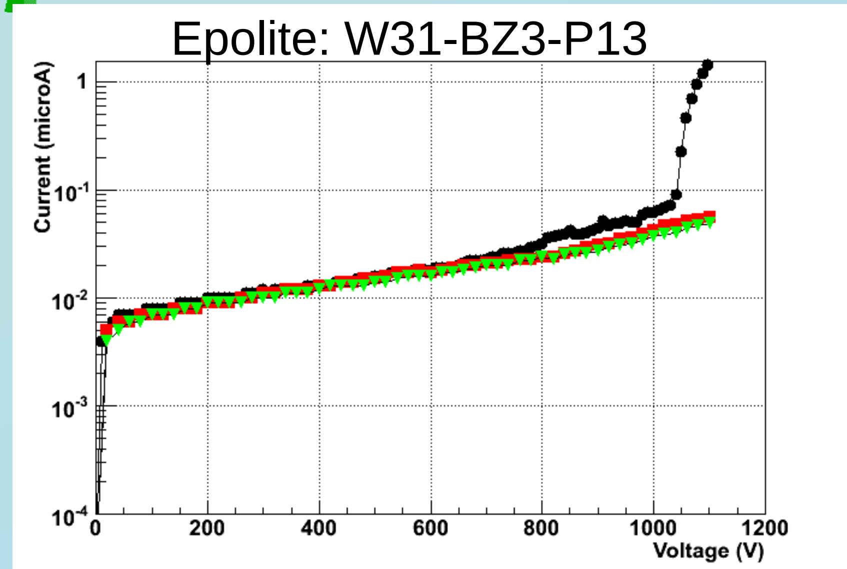
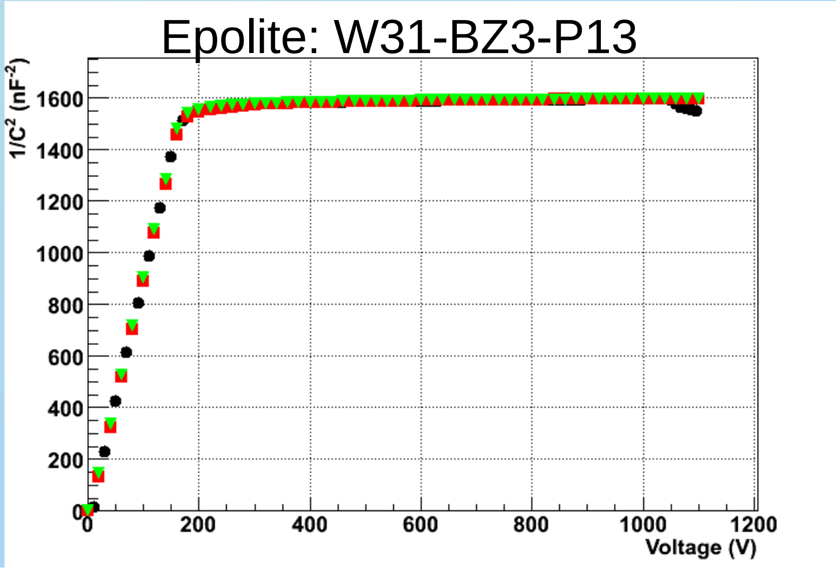
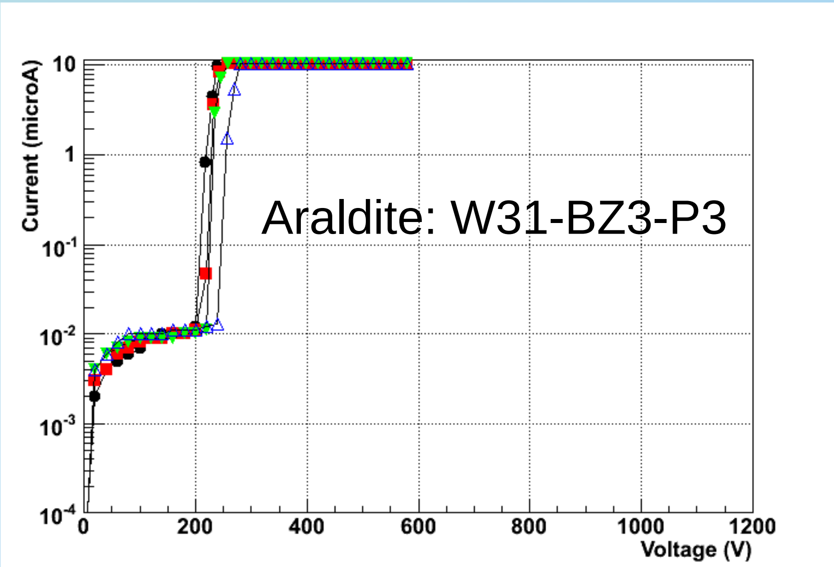
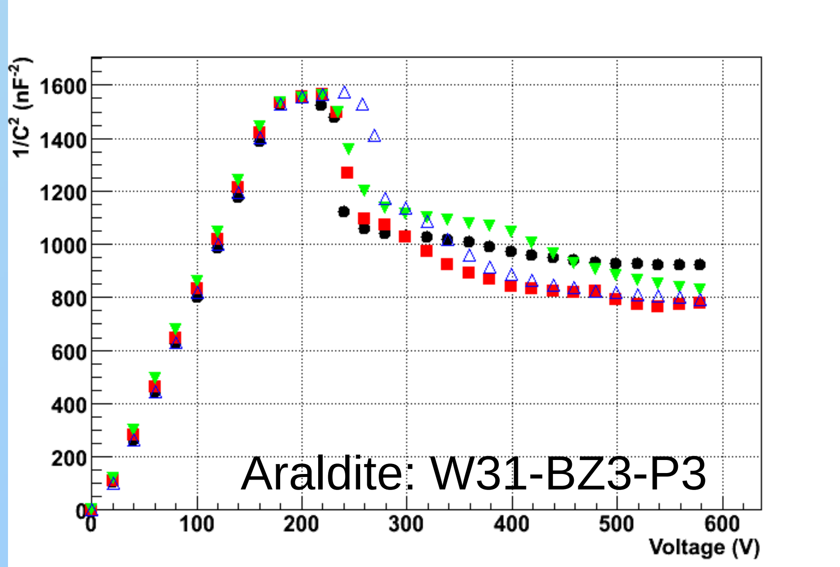


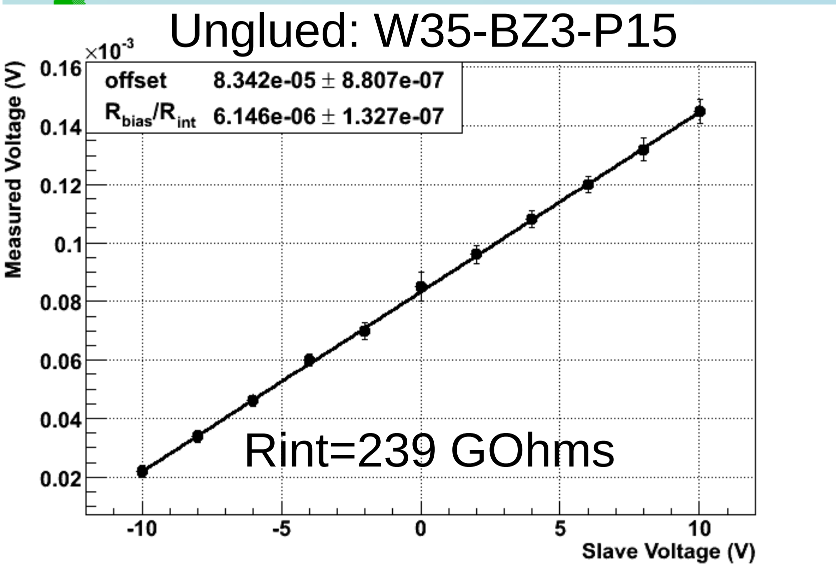


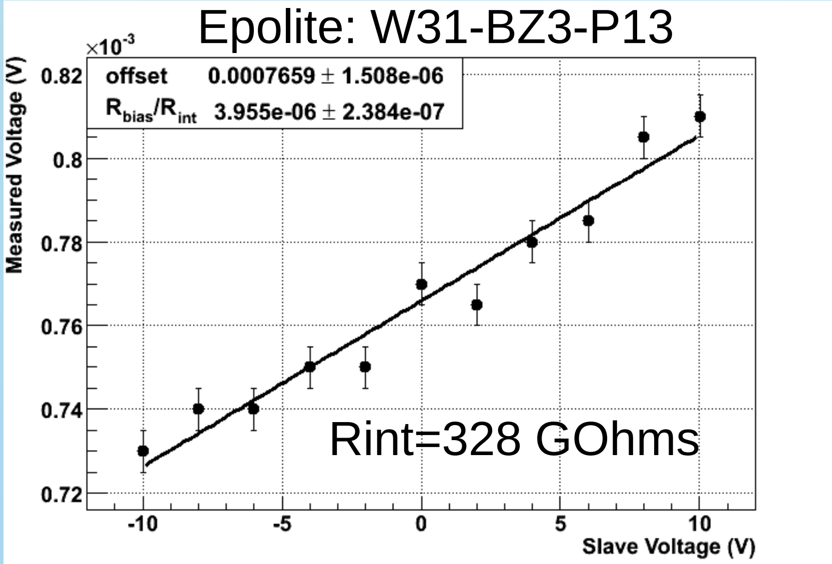


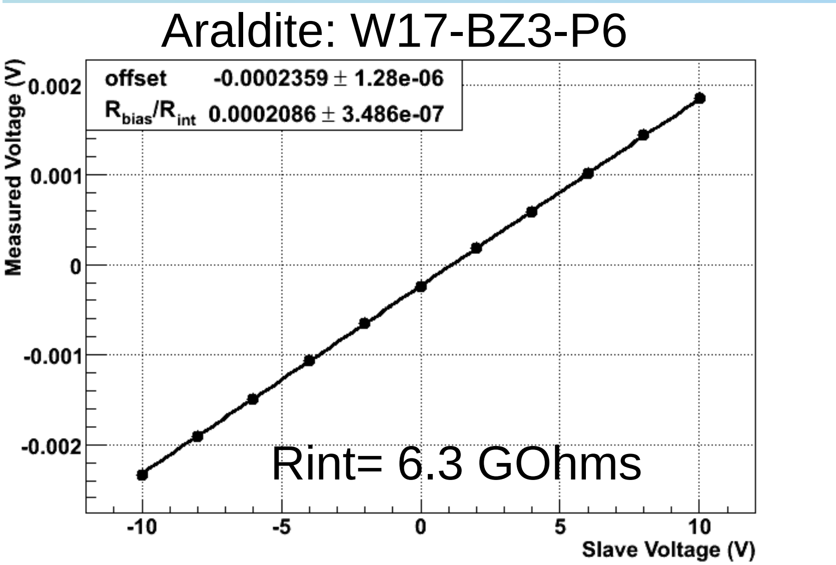


S. Paganis, Sheffield U.

Rinterstrip Measurements at Vbias=200Volts







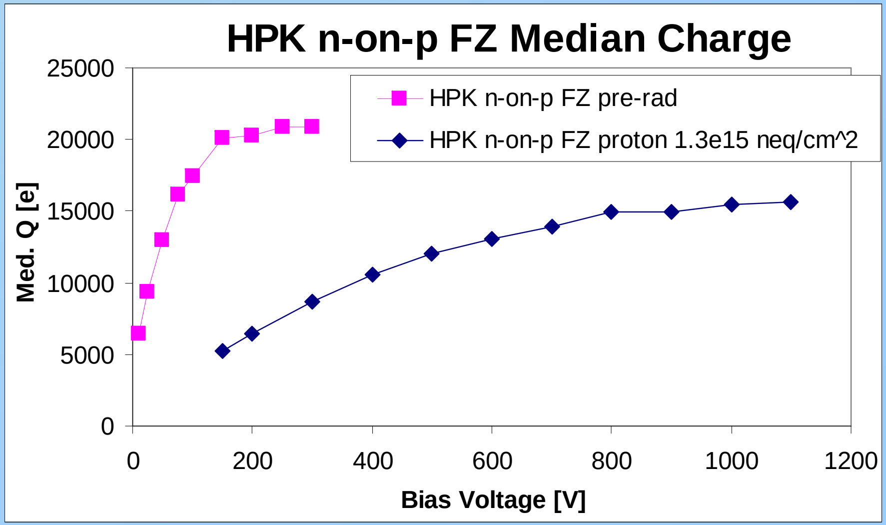
The Araldite glue presents low Vbd=300V and also low Rint << Rint-epolite.

More measurements and tests will follow.

S. Paganis, Sheffield U.

Conclusions

- ATLAS07 shows mature performance
- Inter-strip isolation and capacitance ~ same for all strip isolation schemes
- Gamma irradiated need much training/N2
- Testing of surface properties post-rad reveals differences due to strip isolation (p-spray only is inferior to p-stop)
- Sensors are stable after low-fluence proton irradiation
  - Inter-strip isolation reduced post-rad, p-spray worse than p-stop
  - Inter-strip capacitance slightly increased after proton irradiation
- Gluing with electronics grade epoxy is shown to work pre-rad, irradiations underway
- Hadron irradiated sensors show good signal-to-noise ratio : robust n-on-p designs by HPK:



SSD Performance Specifications

	pFZ initial	pFZ 5x10^{14}	pFZ 9x10^{14}	pMCZ Initial	pMCZ 5x10^{14}	pMCZ 9x10^{14}
Coupling type to amplifier	AC			AC		
Readout strip implant	N			N		
Strip pitch	75.6 μm			75.6 μm		
Coupling capacitance to amp Total for 2.4 cm strips	20 pF/cm 48 pF	20 pF/cm 48 pF	20 pF/cm 48 pF	20 pF/cm 48 pF	20 pF/cm 48 pF	20 pF/cm 48 pF
Capacitance of strip to all neighbour strips	1.3 pF/cm	1.3 pF/cm	1.3 pF/cm	1.3 pF/cm	1.3 pF/cm	1.3 pF/cm
Capacitance of strip to backplane	0.30 pF/cm	0.42 pF/cm	0.48 pF/cm	0.40 pF/cm	0.30 pF/cm	0.33 pF/cm
Extra capacitance in connections, e.g., fan-in	1 pF			1 pF		
Metal strip resistance	15 Ω/cm	15 Ω/cm	15 Ω/cm	15 Ω/cm	15 Ω/cm	15 Ω/cm
Bias Resistor	1.5 MΩ	1.5 MΩ	1.5 MΩ	1.5 MΩ	1.5 MΩ	1.5 MΩ
Max leakage current per strip for shot noise 2.4 cm strips at -15°C	0.5 nA	0.32 μA	0.6 μA	0.5 nA	0.32 μA	0.6 μA
Charge collection efficiency (at 500 V)	1	0.6	0.45	0.6	0.85	0.6
Collected charge (at 500 V)	24,000	14,000	11,000	14,000	20,000	14,000
Charge collection time	< 10 ns	< 10 ns	< 10 ns	< 10 ns	< 10 ns	< 10 ns