Full-size ATLAS Sensor Testing

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On behalf of the ATLAS R&D group
Development of n-in-p Silicon Sensors for very high radiation environment

R&D50 Workshop, CERN, 16-18.11.2009

Testing of large area ATLAS07 Series I sensors manufactured by Hamamatsu Photonics

Testing before irradiation

Total number of tested sensors: 19

ATLAS institutes involved in testing:

University of Cambridge **2 sensors: W15, W16**

J.R.Carter, B. Hommels, D. Robinson

Stony Brook University **9 sensors: W19, W21-23, W25-29**

B. DeWilde, R. Maunu, D. Puldon, R. McCarthy, D. Schamberger

Institute of Physics AS CR and Charles University, Prague

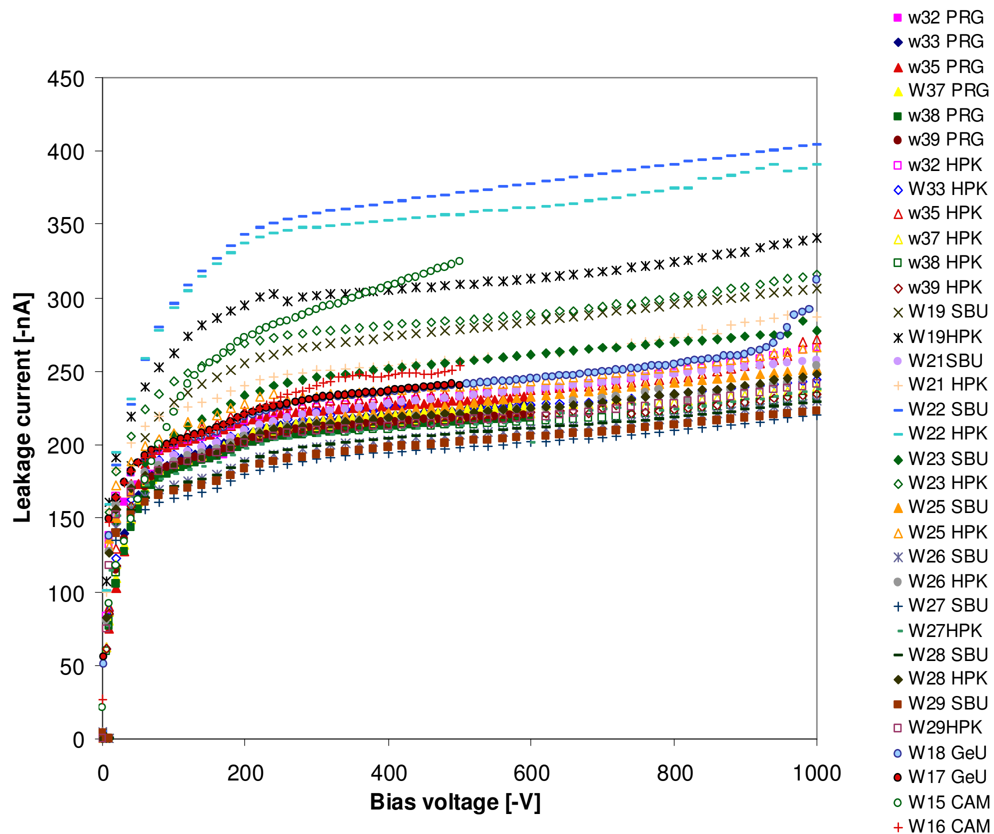
6 sensors: W32, W33, W35, W37, W38, W39

J. Bohm, J. Broz, Z. Dolezal, P. Kodys, P. Kubik, M. Mikestikova

Geneva University **2 sensors: W17, W18**

A. Clark, D. Ferrèrre, S. G. Sevilla

. IV characteristics of large area ATLAS07 Series I sensors normalized to 20°C.



No microdischarges with exception of W18 having slow breakdown at ~420V but after a "training", no microdischarge up to 1000V.

"Training of detectors" :

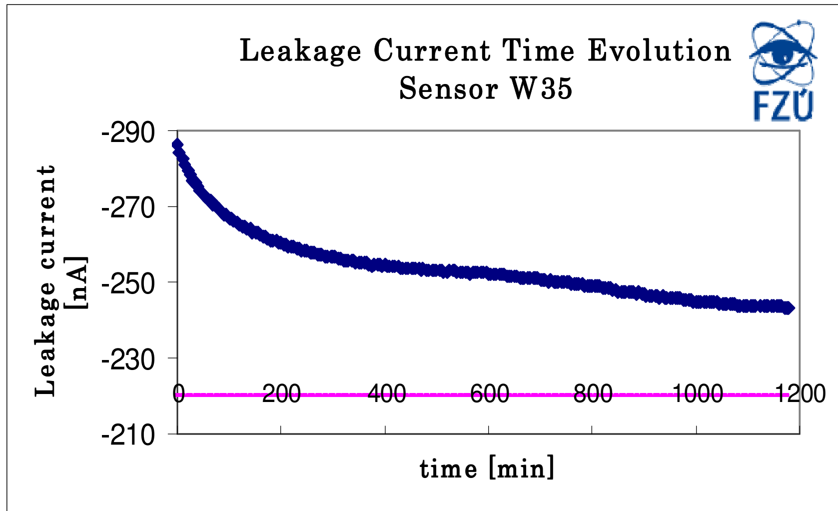
Detector is biased by the breakdown voltage at current ~10μA for 10-20 min or longer time.

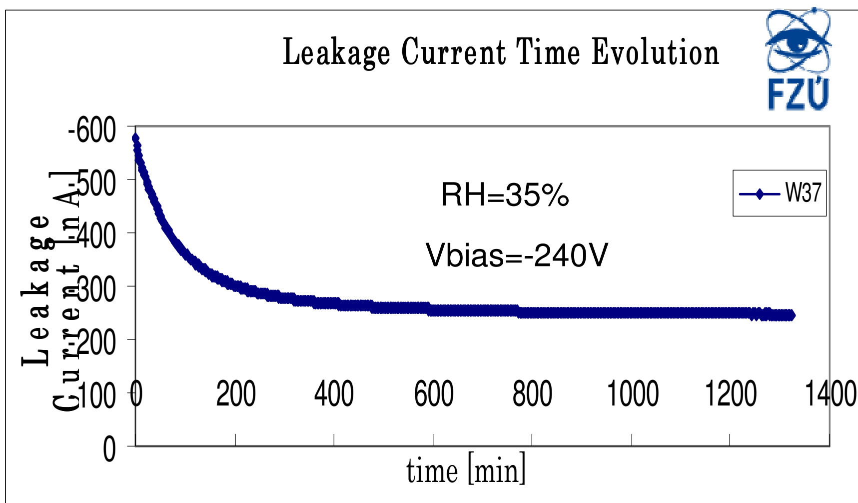
Note: Leakage current should be measured with time delay of several seconds (10s) after ramping up bias voltage and measured for both cases, the ramping up and the ramping down of Vbias. See note of **A.Chilingarov at RD50 Recommendations.**

All tested sensors satisfy the ATLAS07 Technical Specification Ileak<20μA

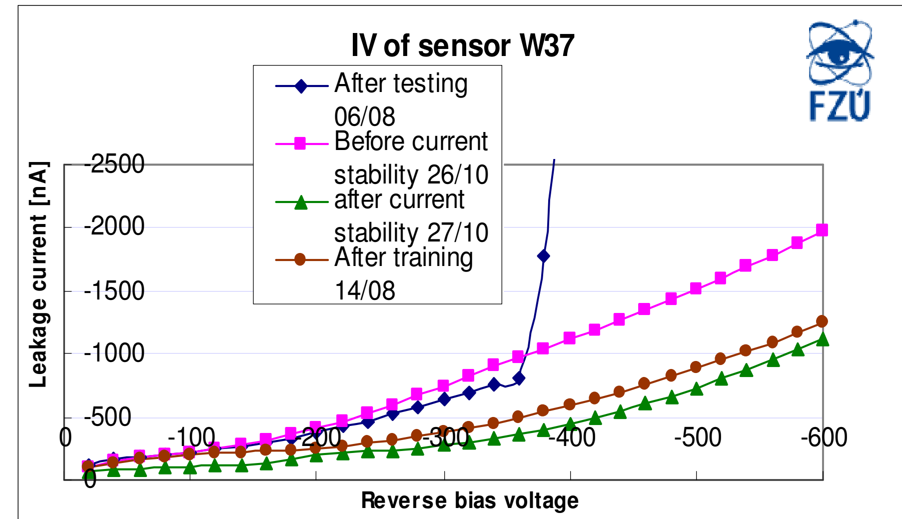
Time Evolution of Leakage Current

After the quality acceptance tests the measured leakage current was usually higher by 10-30%.



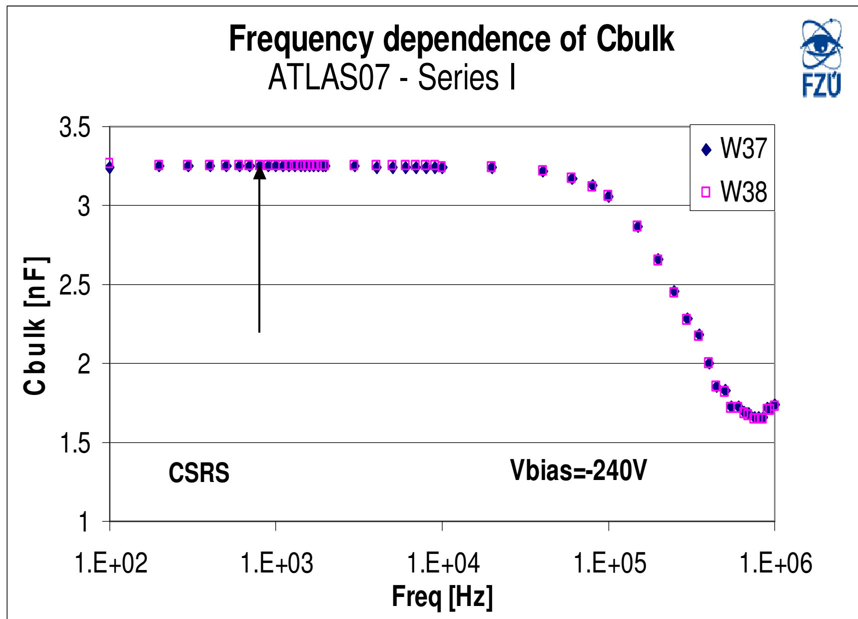


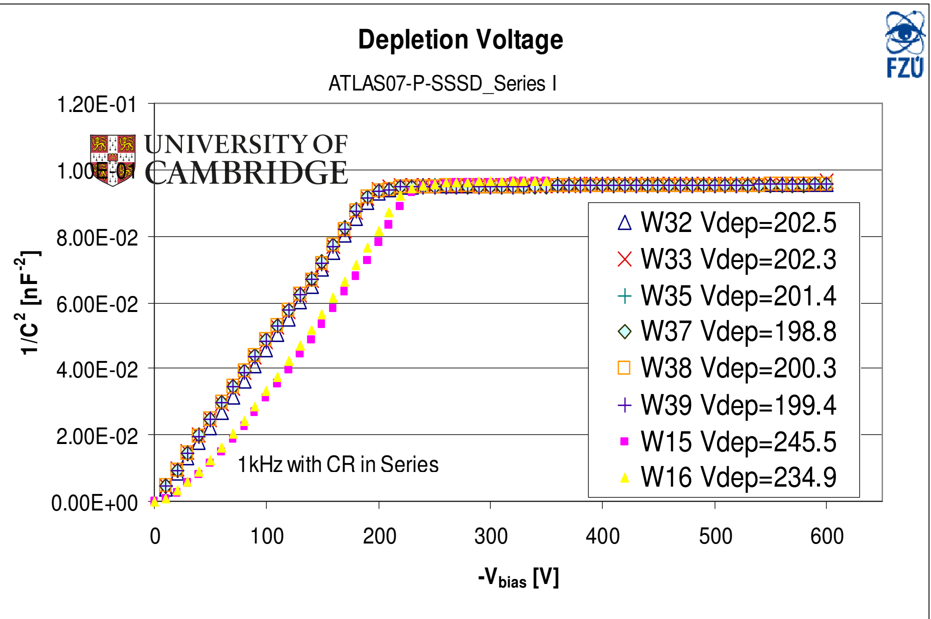
Leakage current is decreasing with time for sensors having slow breakdown after testing.



After ~20 hours of “training” slow breakdown of W37 at -360V disappeared and IV characteristic was restored.

Depletion Voltage





Frequency dependence of a bulk capacitance of sensors W37 and W38 measured at 240 V with CR in series.

Cbulk =3.25nF on plateau

Estimated values of Vdep

Prague	6 sensors	199-203V
Stony Brook	2	190-210V
Cambridge	2	235, 245V

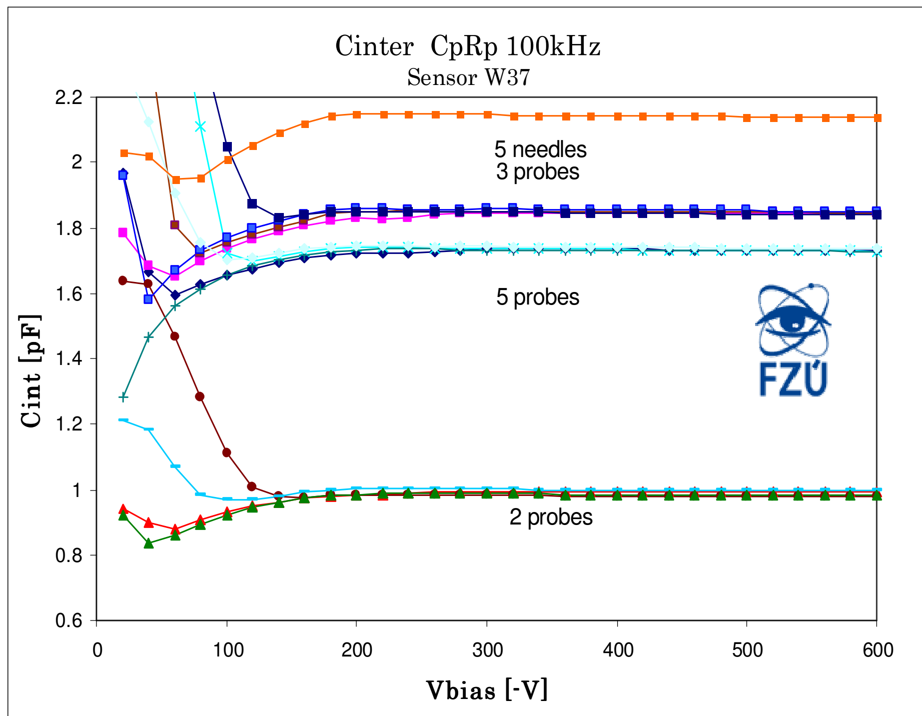
Bulk capacitance measured between backplane and bias ring by LCR meter with *CSRS* function at 1*kHz*

V_{dep} extracted as crossing of the linear rise 1/C^2 and the saturated value

Very smooth behavior of CV

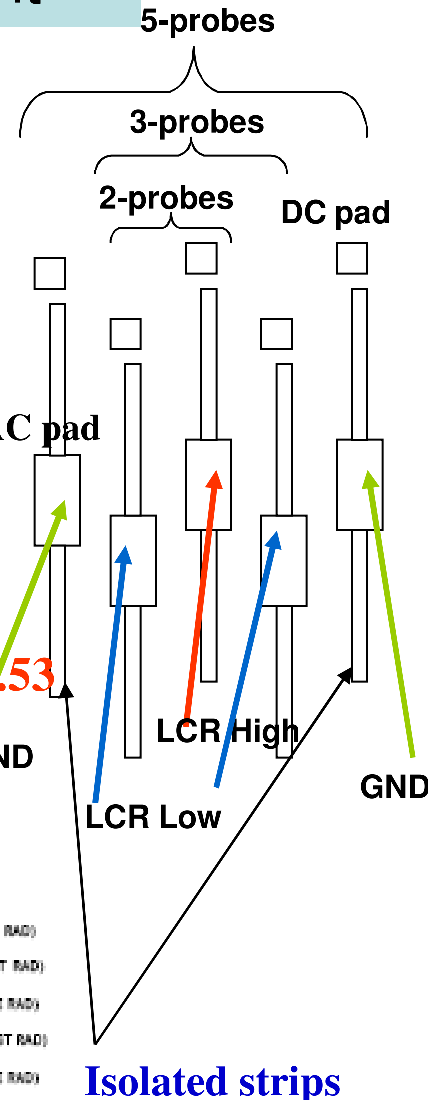
Summary: All tested sensors satisfy specifications: Vdep<500V

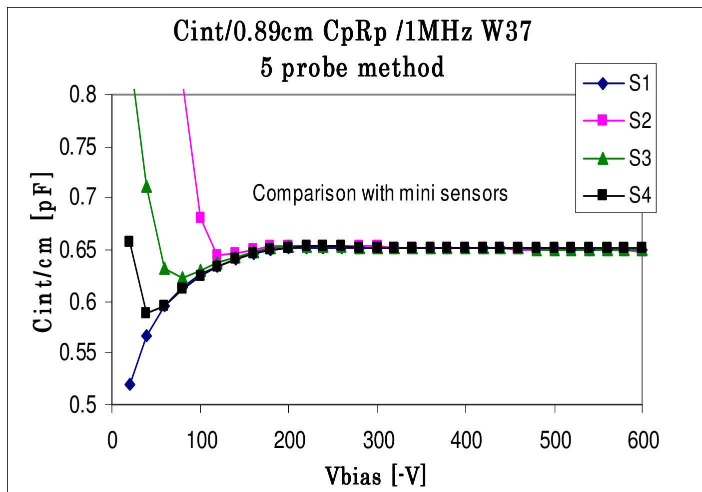
Inter-strip Capacitance – Methods of Measurement

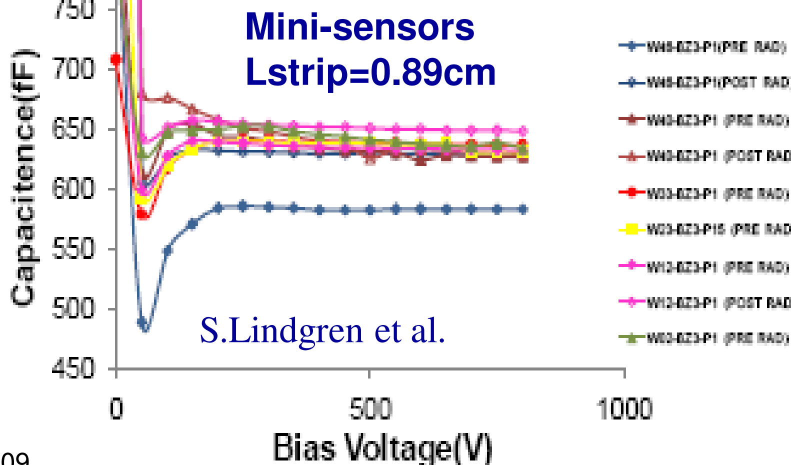


Different methods of Cint measurement
Five-probe method:
S.Lindgren et al.
Santa Crus University

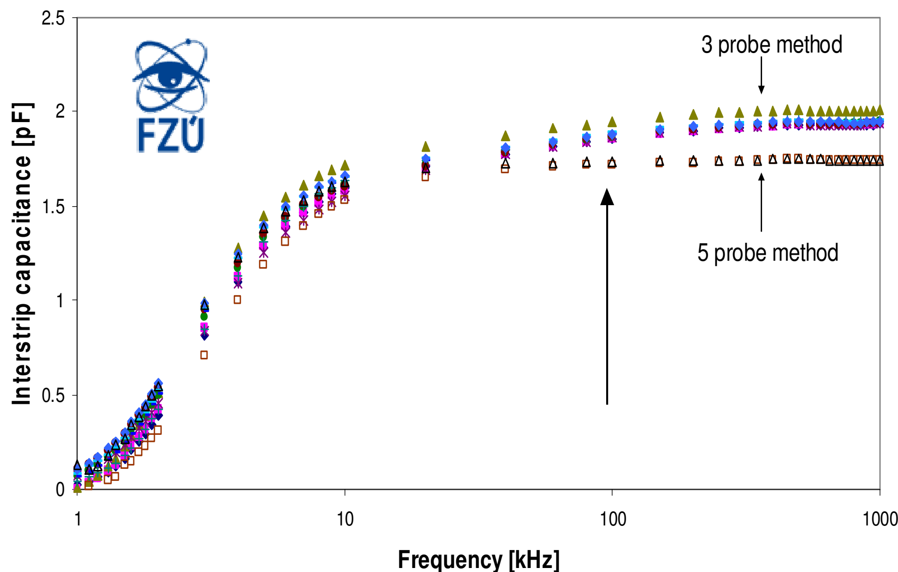
Cint(5-pr)/Cint(3-pr)= 0.939 and 0.913 for 100kHz and 1MHz, respect.
Cint(2-pr)/Cint(5-pr)=0.53





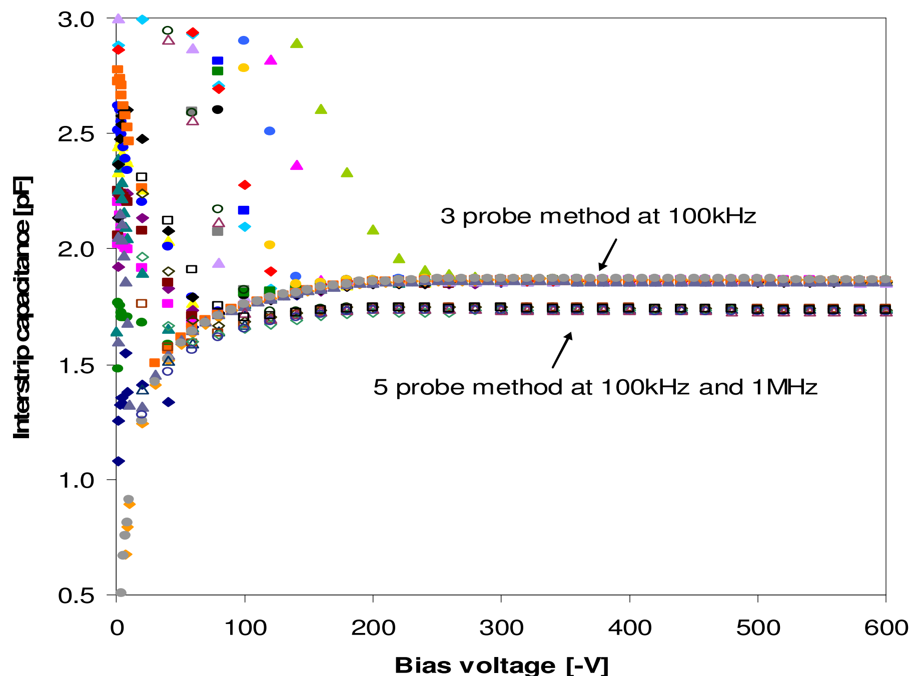


Inter-strip Capacitance – Bias Scan



Frequency dependence of inter-strip capacitance measured with three-probe method (full symbols) and with five-probe method (open symbols) at *Vbias*= -240 V.

Technical Specification defines upper limit: Cint / 1cm < *1.1pF* measured by three-probe method at *100kHz* with CR in parallel.



W33-Seg1
W33-Seg2
W33-Seg3
W33-Seg4
W35-Seg1
W35-Seg2
W35-Seg3
W35-Seg4
W37-Seg1
W37-Seg2
W37-Seg3
W37-Seg4
W38-Seg1
W38-Seg2
W38-Seg3
W38-Seg4
W39-Seg1
W39-Seg2
W39-Seg3
W39-Seg4
W32-Seg1
W32-Seg2
W32-Seg3
W32-Seg4

Inter-strip capacitance as a function of the reverse bias voltage measured at randomly selected strips from each sensor segment with the three-probe method at *100 kHz* (full symbols) and with the five-probe method (open symbols) at *100 kHz* and *1 MHz* test frequencies.

***Cint* has complicated behavior at low bias voltages but becomes constant beyond FDV**

Recommendation: Measure *Cint* at *1MHz* Test frequency with function *CR in* parallel by three- probe method.

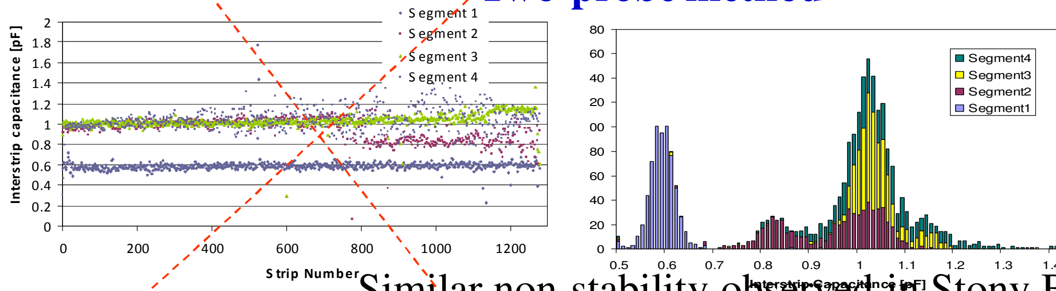
J.Bohm, R&D50 Conference, CERN 17.11.09

Strip Scan of *Cint* by Two-probe and Three-probe methods

Hartmut Sadrozinski initiated three-probe method for the Strip Scan of *Cint*

The aim of strip-to-strip measurements is to study strip integrity and uniformity of electrical characteristics over the whole sensor .It requires probing 1280 strip pads on each of four sensor segments. A switching matrix was used to perform multiple tests on adjacent strips at each step of an automatic probe station (simultaneous measurement of *Ccoupl, Rbias, Istrip, Idiel, Rint,Cint*)

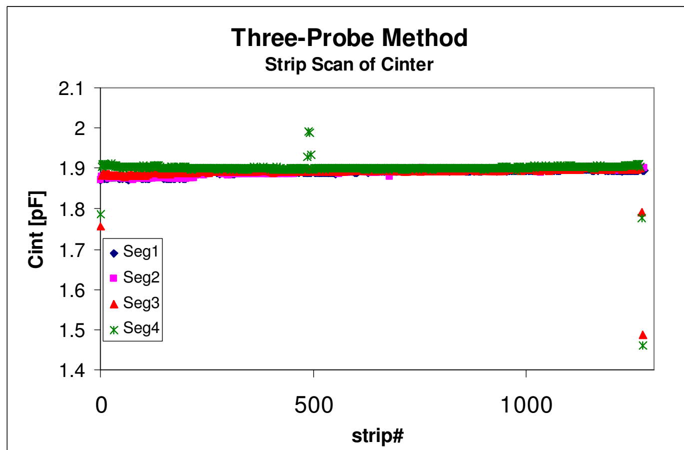
Two-probe method

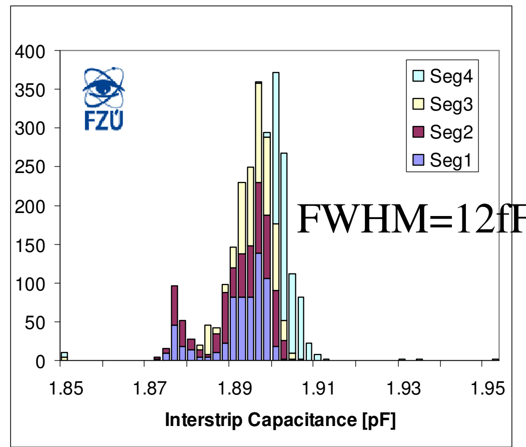


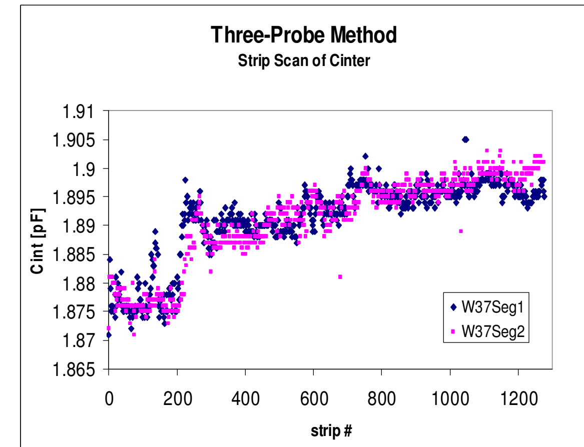
Very probably capacitance of the switching matrix is not stable and it changes by several hundreds of fF.

Similar non-stability observed in Stony Brook and Prague

Measurement in Prague with three-probe method without switching matrix

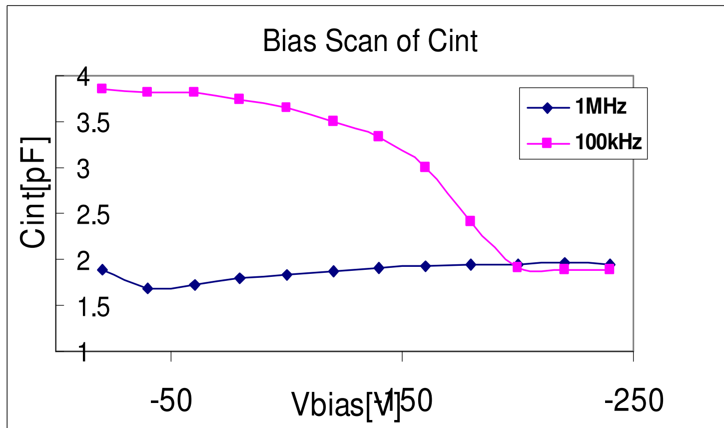


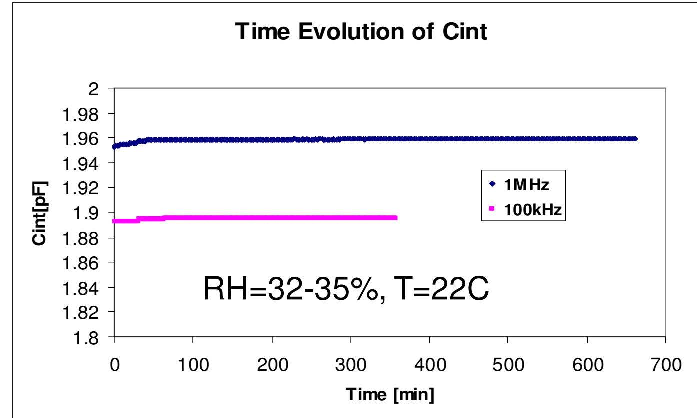




Three-probe method confirmed perfect parameter uniformity over whole large Hamamatsu sensor

Time Evolution of Inter-strip Capacitance





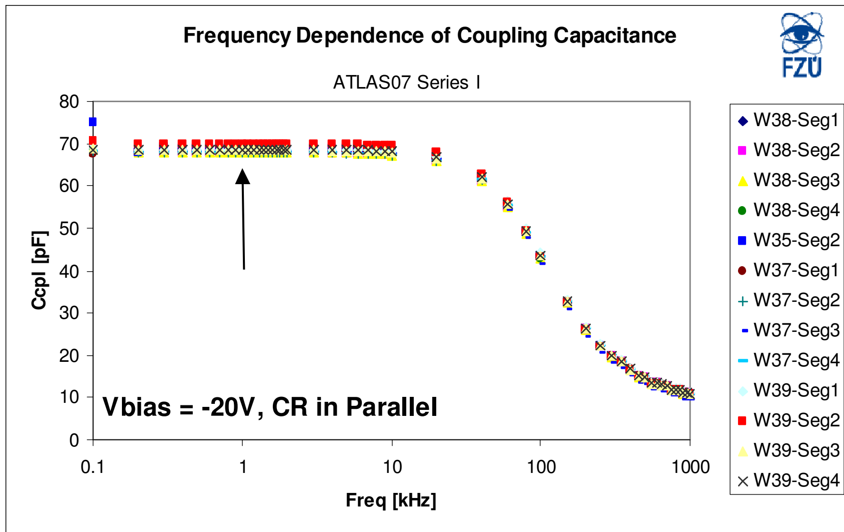
Cint measured by three-probe method at 100kHz and 1MHz test frequency

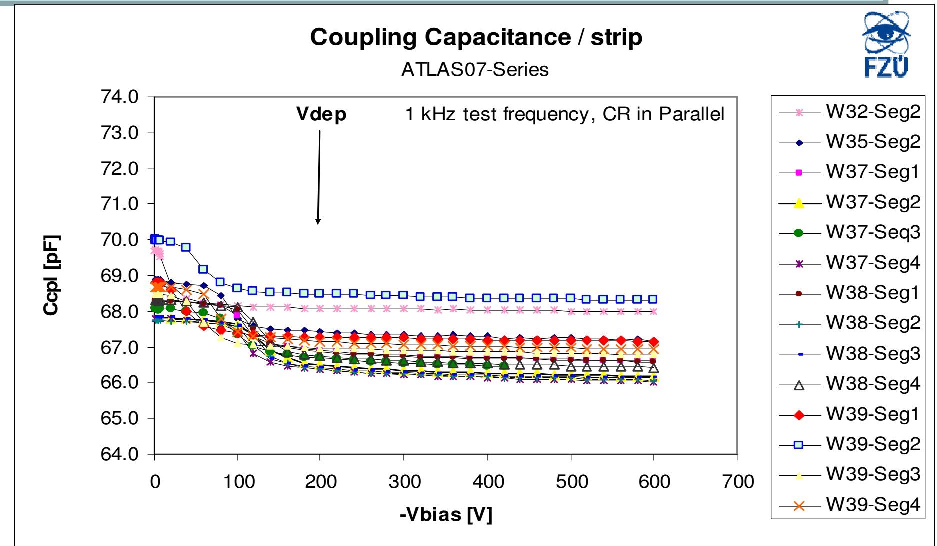
There is no decrease of Cint with time as it was observed on SCT sensors

A. Chilingarov, Nucl. Instr. and Meth. A 560 (2006) 118-121.

Very good surface isolation of ATLAS07 sensors

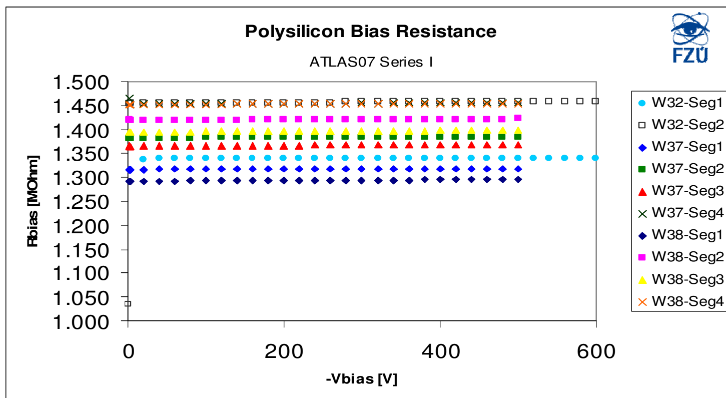
Coupling Capacitance/Bias Resistance





IV scan made by SMU for voltages 1V-6V applied to implant DC pad. *Rbias=dUappl/dI*

ATLAS07 Specification: C_{cpl} measured between strip metal (AC pad) and strip implant (DC pad) at 1kHz with CR in parallel **≥ 20pF/cm**

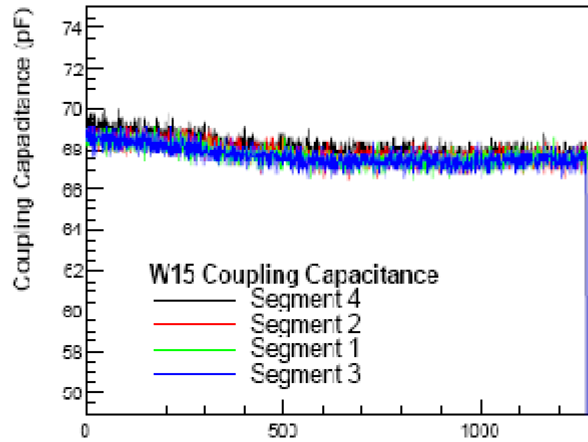


C_{cpl}/cm>27.8pF

Rbias is constant while n-p junction is closed (Vbias=-0.7V)

ATLAS07 Specification: Rbias = 1.5±0.5MΩ

Strip Scan of Coupling Capacitance and Bias Resistor

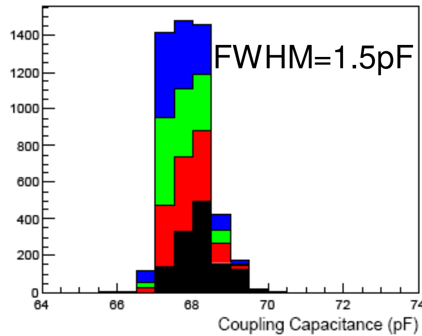


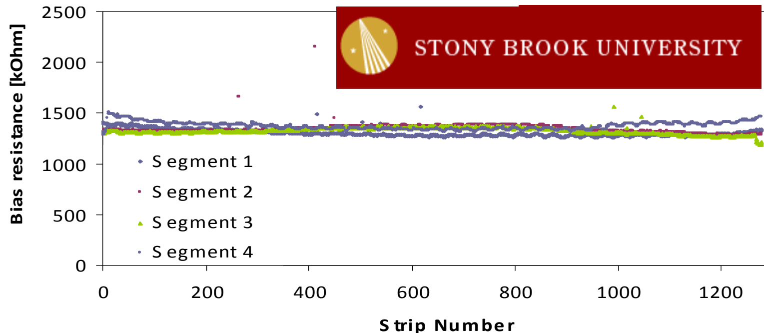
In the strip scan Ccoupl and Rbias are measured by LCR meter between AC pad and Bias Ring, CR in series at 100kHz test frequency

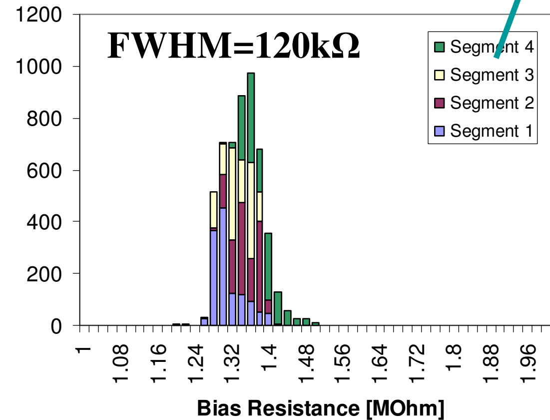
2 DC pads contacted: *Rint, Istrip*

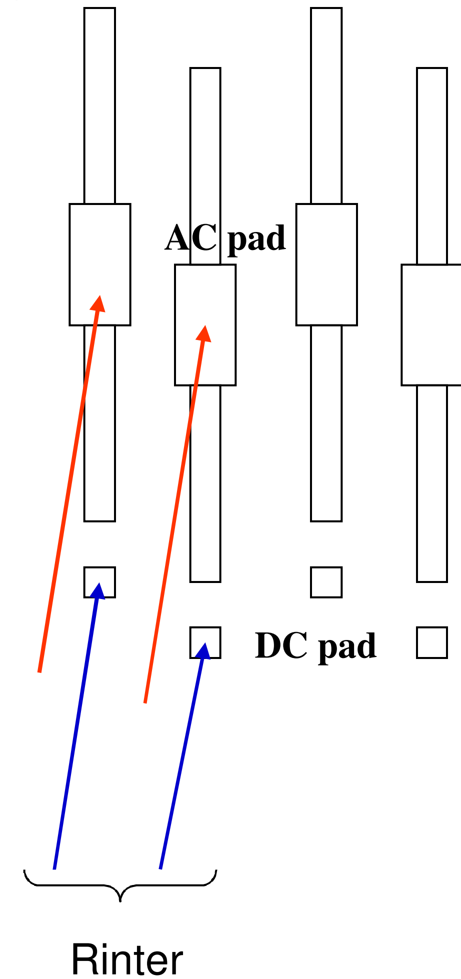
1 AC pad and BR: *Ccoupl, Rbias, Idiel*

3 AC pads contacted: *Cinter*



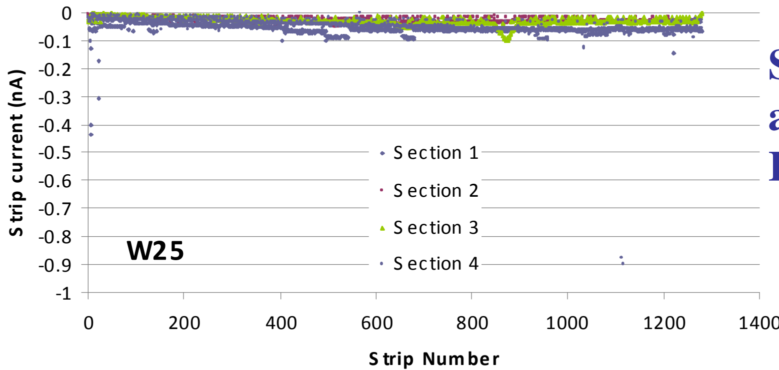






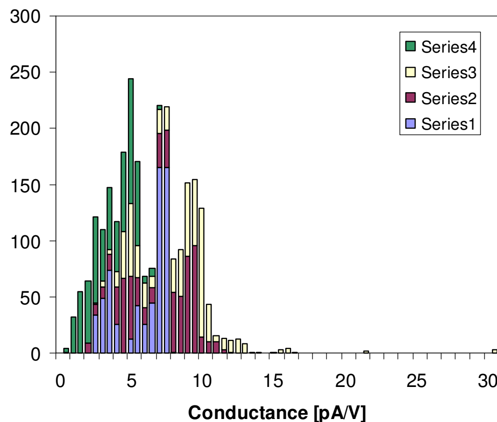
No openings and shorts were found on tested sensors W15, W16, W23, W25, W38 – in total 23040 strips

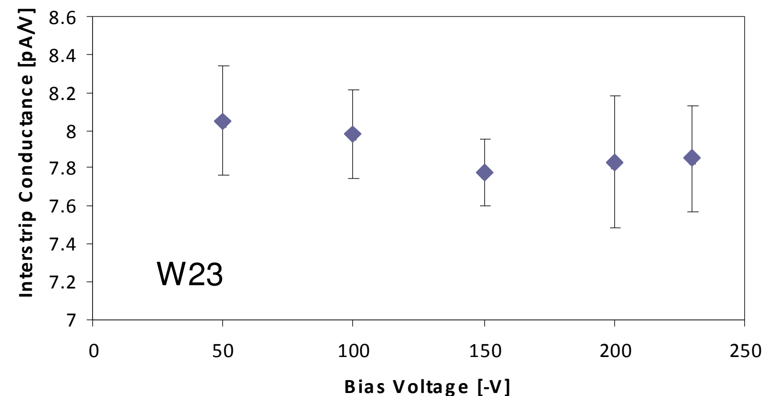
Strip Scan of the Strip Current and Inter-strip Resistor



Strip current was measured between the DC pad on an implant strip and the ground of a fully depleted sensor. Istrip probes the bulk and *n*-implant homogeneity

The inter-strip resistance has been measured on pair of strips of a fully depleted sensor: SMU applied voltages ±10V to the DC pad and current to ground was measured on second strip.

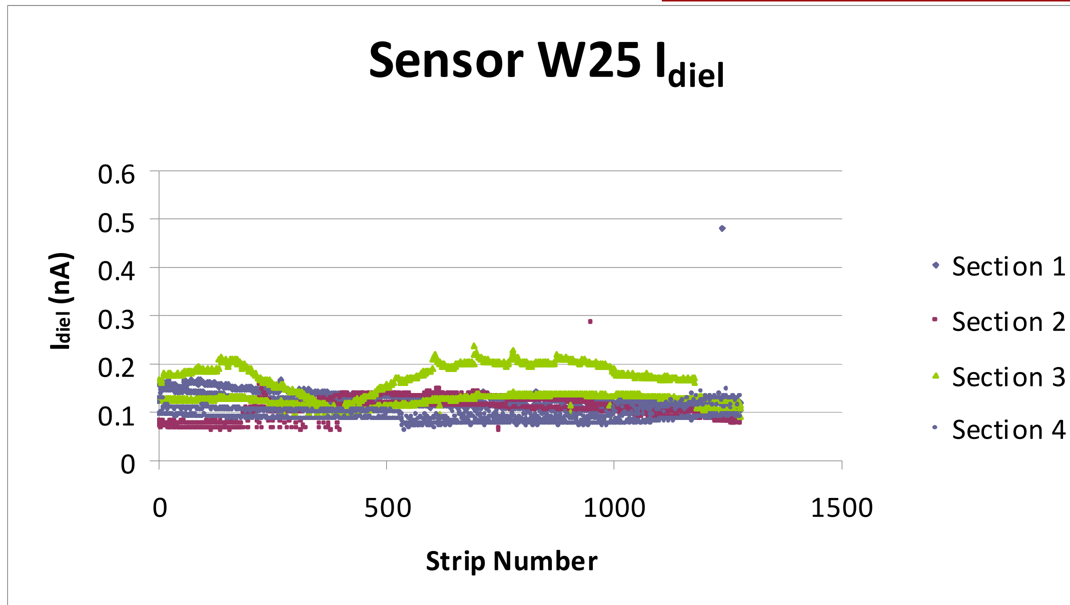




***Rinter=1/conductance* is equal to 300GΩ/cm**

Current through the coupling dielectric

The current flowing through the coupling dielectric was measured by SMU at 100V applied to the AC pad



No pinhole have been observed on all tested sensors W23, W25, W38 – in total 12800 strips

Comparison of measured parameter values with Technical Specification

	ATLAS07 Specification	Measurement
Leakage Current	< 200 µA at 600 V	200 nA – 370 nA
Full Depletion Voltage	< 500 V	190 V – 245 V
Coupling Capacitance at 1 kHz	> 20 pF/cm	>28 pF/cm
Silicon Bias Resistance	1.5±0.5 MΩ	1.3 MΩ - 1.6 MΩ
Current through dielectric	I_{diel} < 10 nA Pinhole: I_{diel} >>10 nA	< 10 nA
Strip Current	No explicit limit	< 2 nA
Inter-strip Capacitance 3 probe method 100kHz 5 probe method	< 1.1 pF/cm	0.7 pF/cm – 0.8 pF/cm 0.66pF/cm- [1] 0.75pF/cm
Inter-strip Resistance per cm	> 10x R_{bias} ~ 15 MΩ	> 150 GΩ

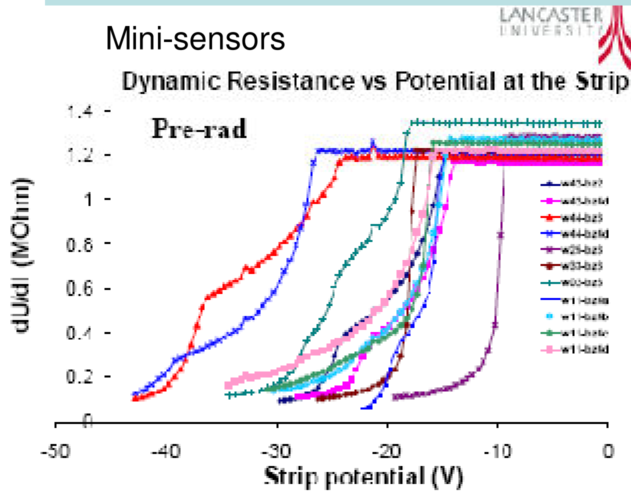
[1] For a noise estimate the five-probe method

All tested sensors satisfied Technical Specification of non-irradiated sensors for leakage current and full depletion voltage as well as for coupling capacitance, bias resistance, inter-strip capacitance and resistance measured with the bias voltage scan. **The onset voltage of micro-discharges for ATLAS07 large area sensors is VMD > 1000V.**

Strip scans were performed on six sensors. Measurements of coupling capacitance and the current going through coupling dielectric show that there are **no defects on 23040 tested strips: no pinholes, punch-through defects, shorts, or openings of metal strips**. Measurements of coupling capacitance and bias resistance on one strip as well as measurements on pairs of strips of the inter-strip resistance and the three-probe measurement of *Cint* confirmed no systematic deviations from uniform distributions.

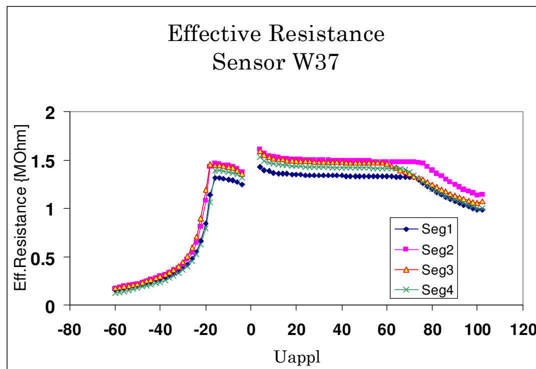
All evaluated sensors passed the quality acceptance tests

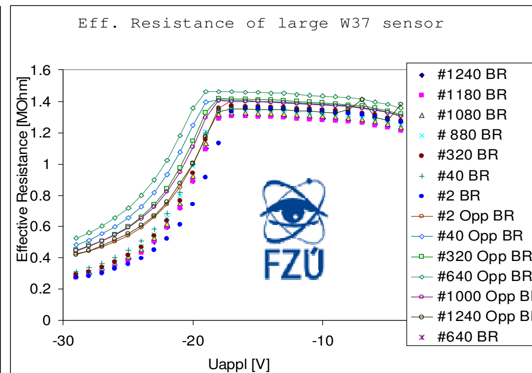
Punch-through Voltage



It was found that the behavior of 1 cm test structures with and without PTP was very similar (Z3 and Z4) (S.Lindgren et al) Voltage is applied on DC pad and current is measured on bias ring.
Hartmut Sadrozinski initiated measurement for full size sensor

Full size sensors with 2.38cm strips with p-stop only have similar behavior (Sensor W37) as mini-sensors.

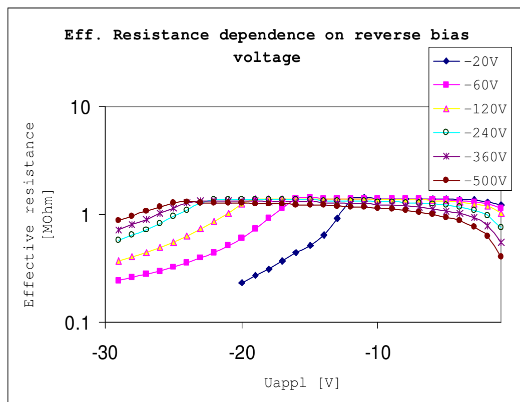


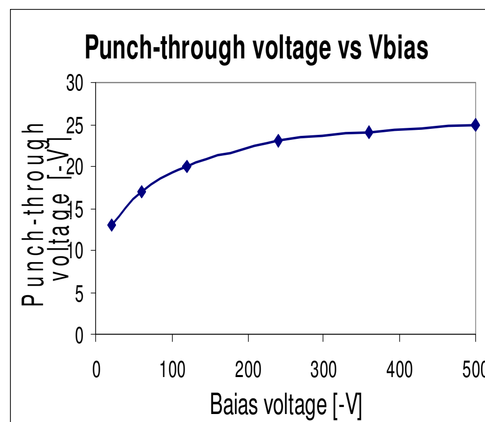


PRELIMINARY

a) DC pad closely to bias resistor (BR)
b) DC pad on opposite side to BR

Case b) has PTV higher by 1,2V than case a) and eff. res. is also higher by 0.1MOhm for b) than for a). No dependence on strip # was seen.





Punch-through voltage (PTV) depends on bias voltage

J.Bohm, R&D50 Conference, CERN 17.11.09