Low temperature electrical characteristics of irradiated strip sensors

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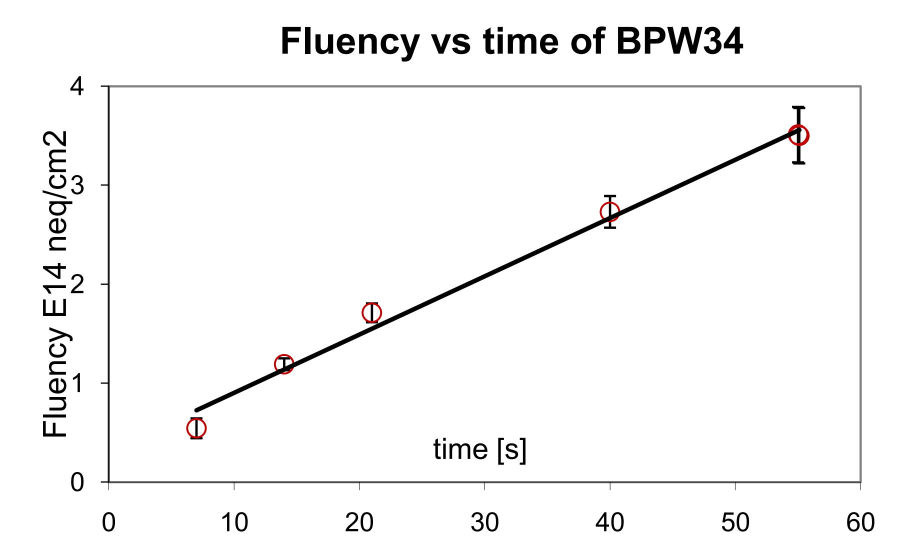
An exposition time was calibrated by diodes BPW34 from CERN

Fluency Φ [neq/cm2/mV]=9.1E09*(Virr--Vo), where Virr and Vo are voltages generating current of 1mA at 20˚C in open direction.



4E14	2E15	1E16
W12BZ4AP4	W13BZ4AP4	W13BZ1P7
W12BZ4BP10	W13BZ4BP10	W13BZ2P2
W12BZ4CP16	W13BZ4CP16	W13BZ5P11
W12BZ4DP22	W13BZ4DP22	W13BZ6P22

Pneumatic transport of sensors in the channel H1.

Mini-sensor is closed in PVC envelops which is placed inside plastic tube Ø=3cm and length of 8cm.

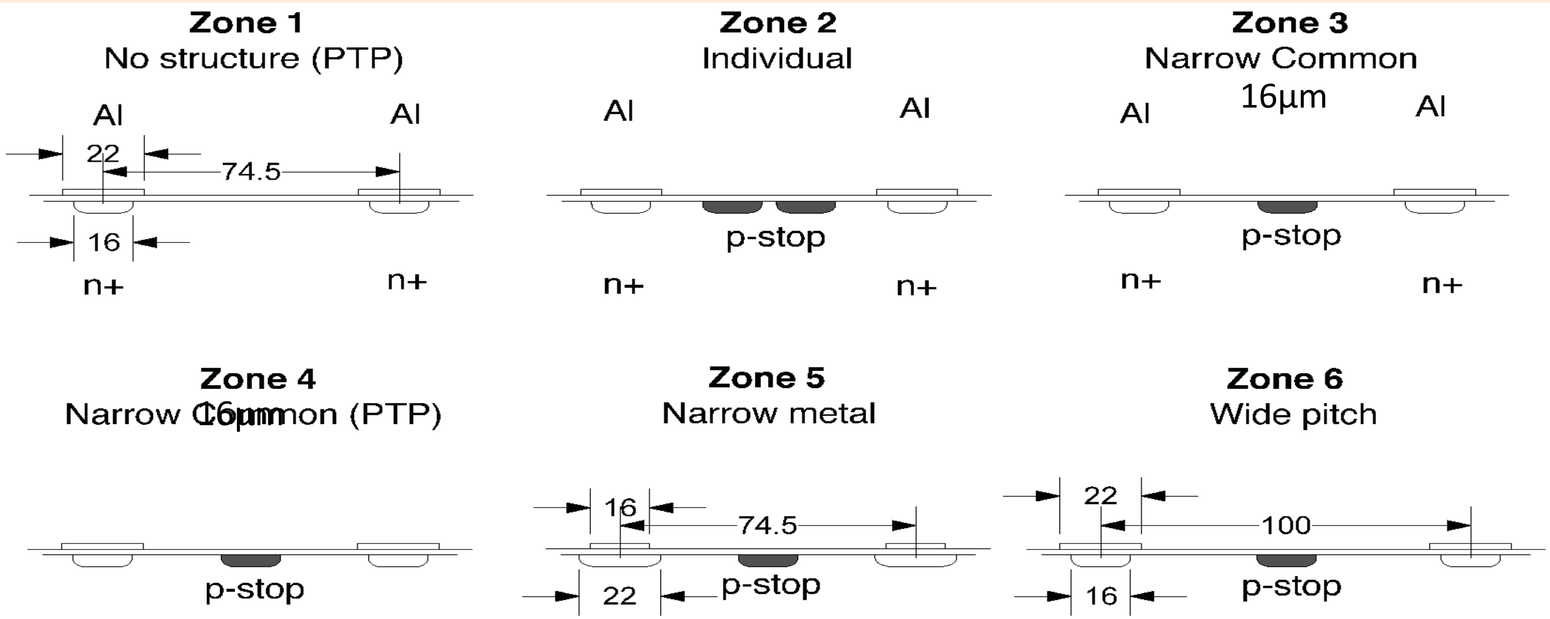
There is no cooling in the channel H1 and therefore after 3 min the tube with sensor must be removed from reactor due to high temperature (~55˚C) and cooled before next step of irradiation

Fluency rate on LVR15 at 9.9MW

Fluence neq/cm2	Exposition seconds	3min irrad
4E14	54.6	1x
2E15	272.9	2x
1E16	1364	8x

Annealing: ~60 days at 23C

Basic sensor characteristics



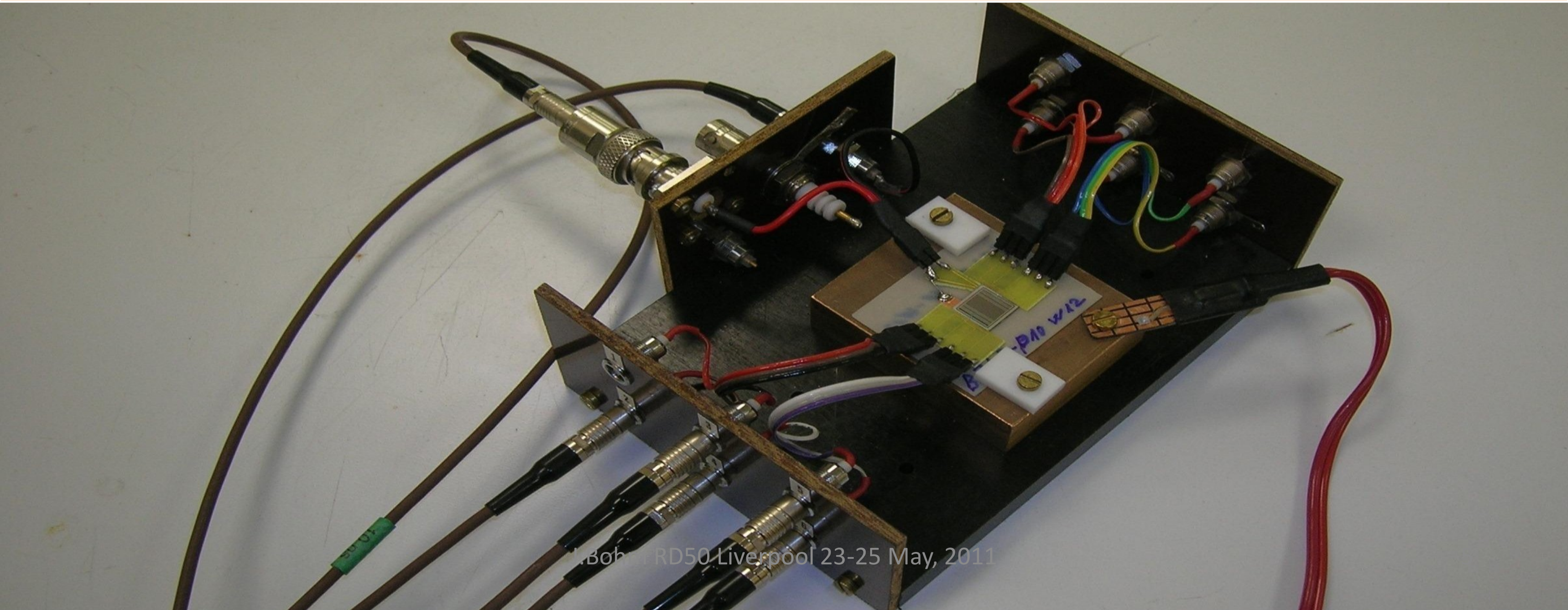
The micro-strip silicon **miniature sensors of 1cmx1cm** (strip length 0.8cm) are ATLAS07 Series I fabricated by Hamamatsu Photonics (HPK) using 6” (150 mm) process technology . The baseline is ***p-type*** float zone silicon of resistance ~6.7kΏ with crystal orientation <100> and having **thickness of 320 μm**. Sensors are single-sided with capacitivly coupled readout ***n-type* strips** which are biased through polysilicon resistors. The readout strips with ***pitch 74.5 μm*** are electrically isolated by a common and floating p-implant (‘**p-stop’ isolation**) with doping concentration of **$1x10^{12}$ions/cm^2** (wafers W12 and W13)

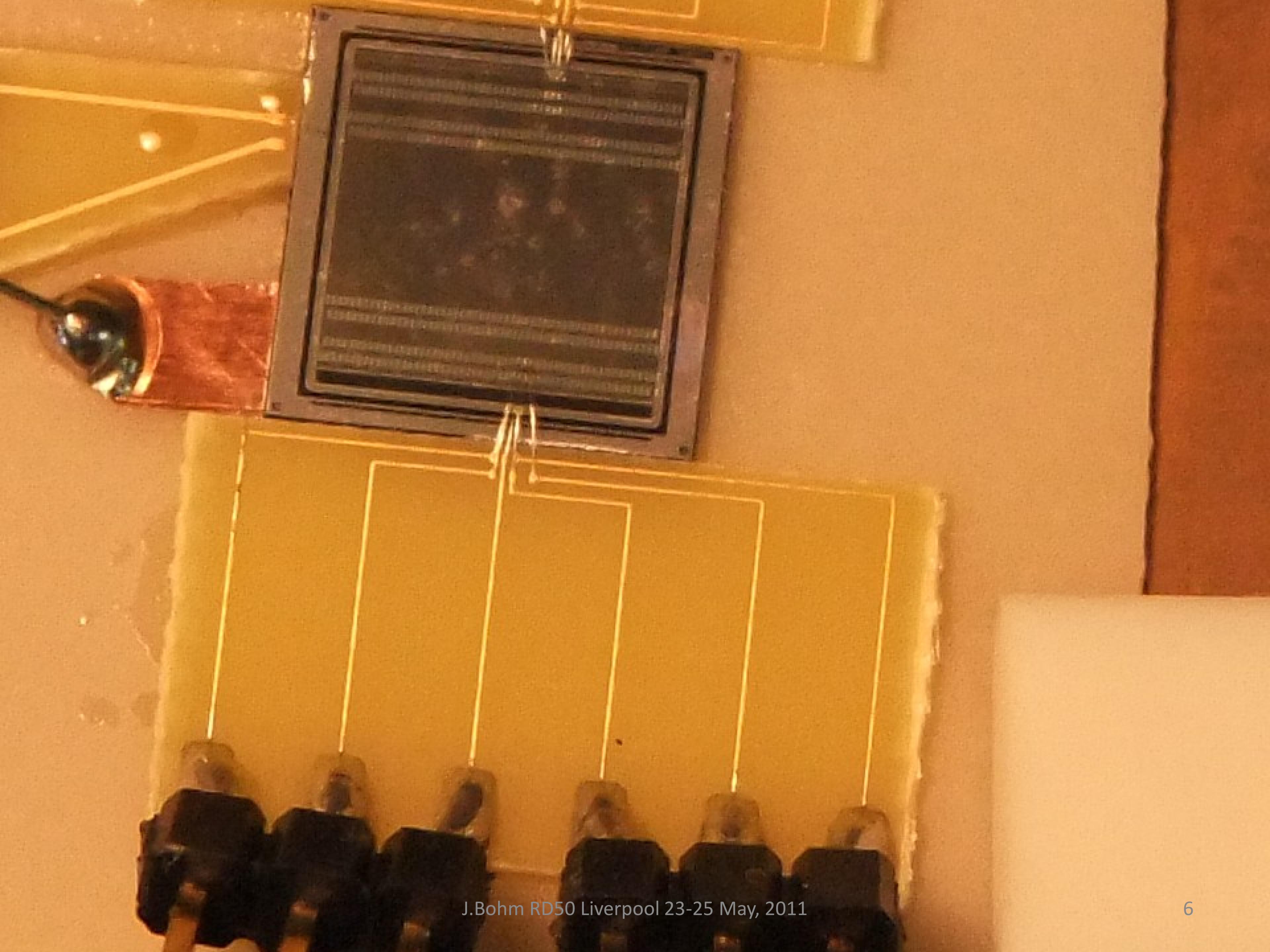
EXPERIMENTAL SET-UP FOR TEMPERATURE -30 C

Measurement of the sensor basic characteristics at working temperature -30C which is supposed for upgraded ATLAS ID at sLHC.

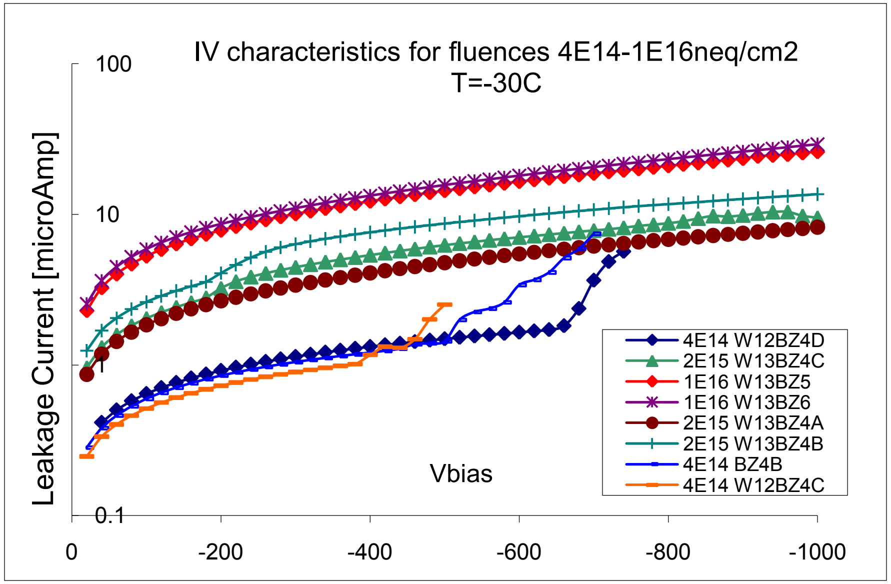
Six AC and DC pads of the randomly selected neighboring strips are bonded to PCB and contacted to connectors . Ceramic plate 0.4mm with high heat conductivity is placed on Cu-cube. The Cu-tape serves as the backplane electrode glued to sensor.

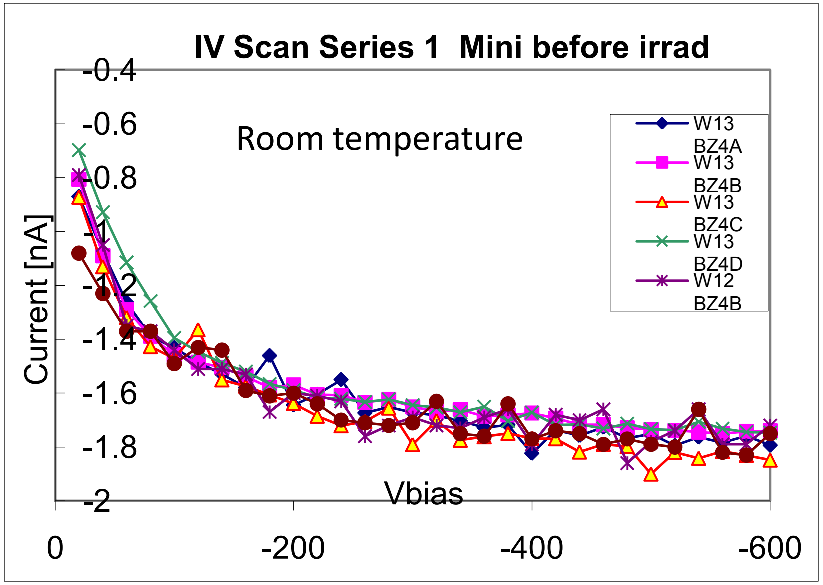
Results are still preliminary

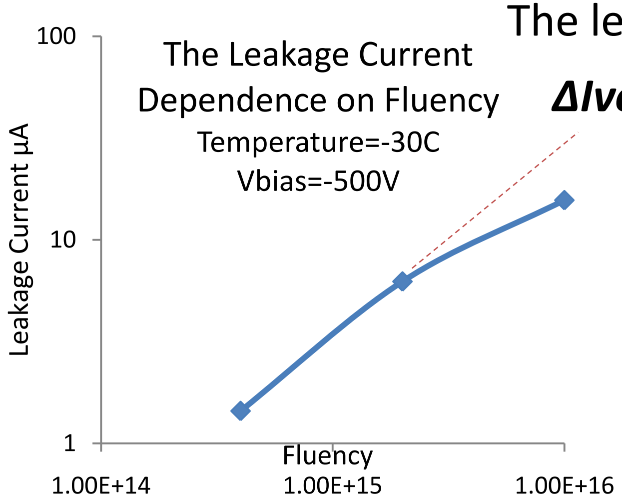




BULK IV AND CV CHARACTERISTICS





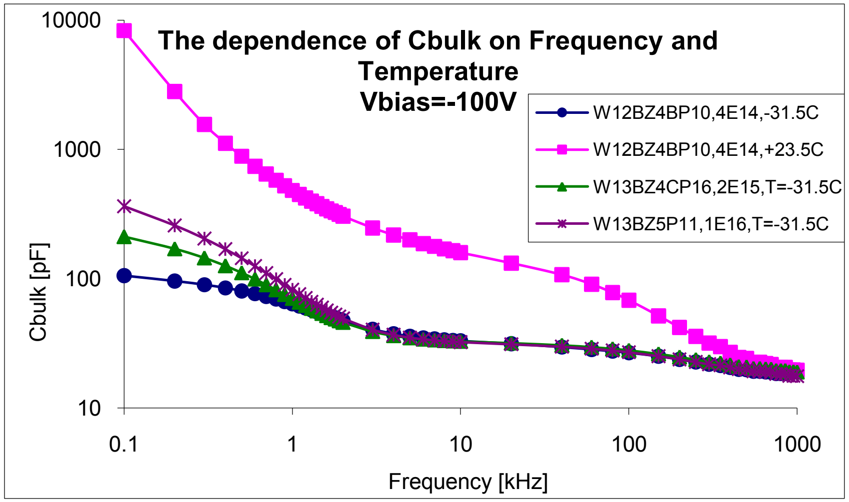


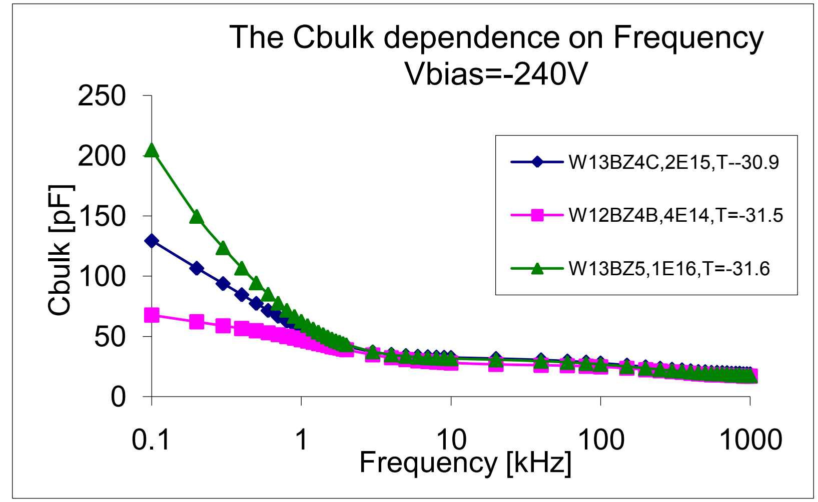
The leakage current is increasing with fluency as it was expected

ΔIvol/V = αΦ is valid for fluences lower than ~E13neq/cm2

The lower leakage current for fluency 1E16 neq/cm2 than one which could be expected from the linear dependence, needs confirmation.

Bulk CV Characteristics





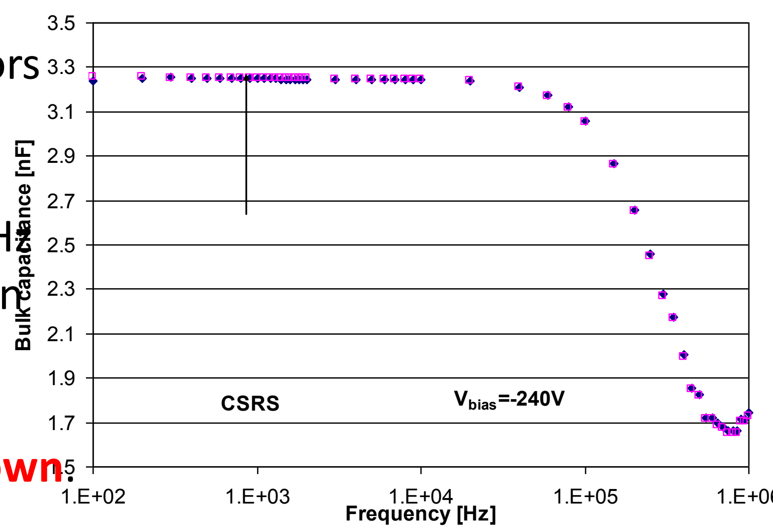
There is a big difference in the Cbulk frequency dependence of irradiated and non-irradiated sensors mostly in the **non-depleted region**.

-**Above ~2kHz Cbulk does not depend on fluency**

-**Cbulk strongly depends on temperature**: For 100Hz Cbulk at room temperature is 100 times higher than Cbulk after irradiation up to 4E14 but both capacitances are the same for 1MHz.

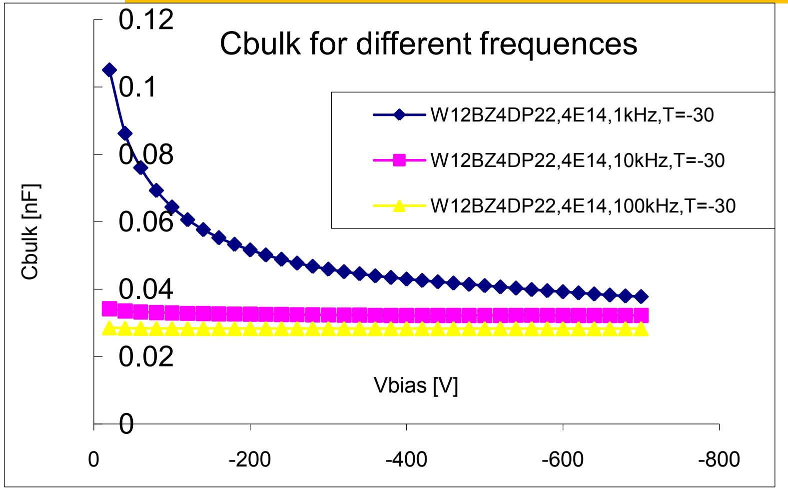
Photon /neutron ratio on reactor in Rez is not known!

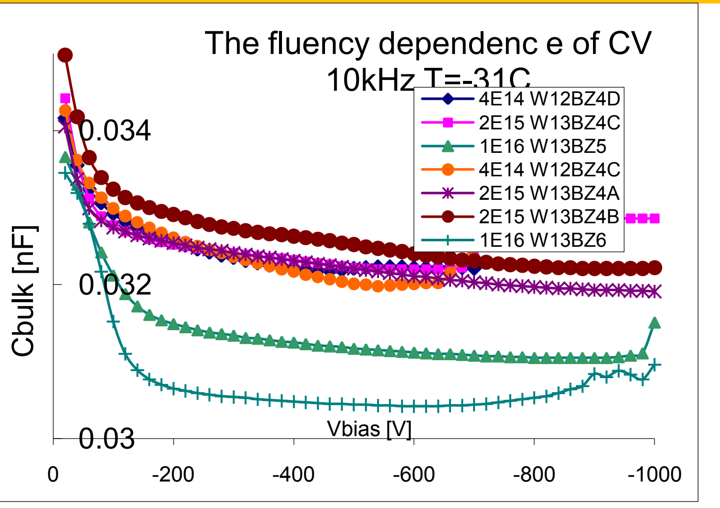
Radiation damage in the surface region?



Room temperature, non-irrad, Vbias=240V

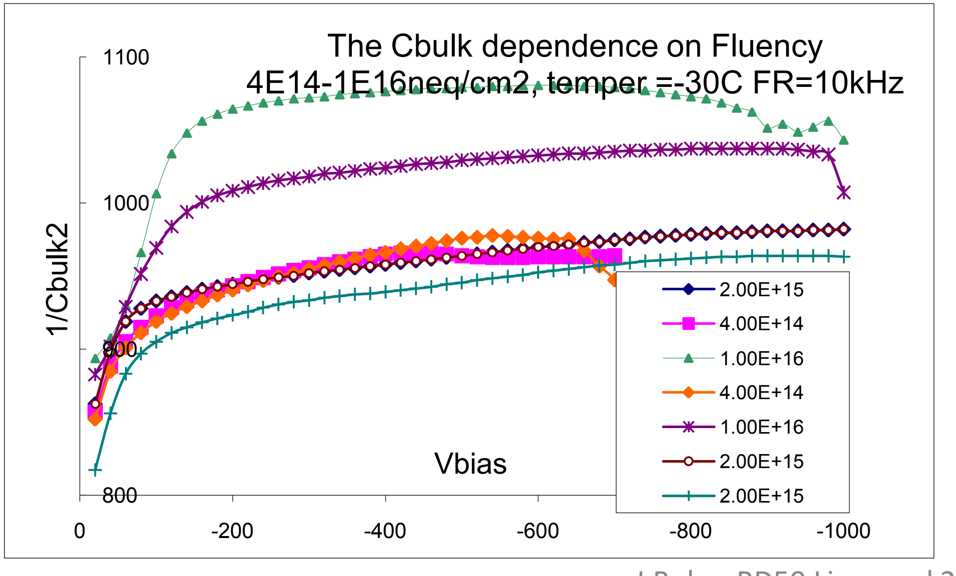
BULK CV CHARACTERISTICS

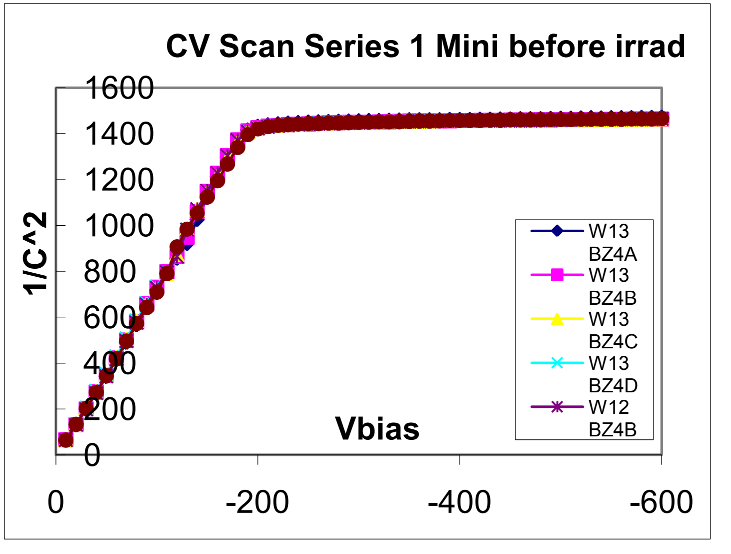




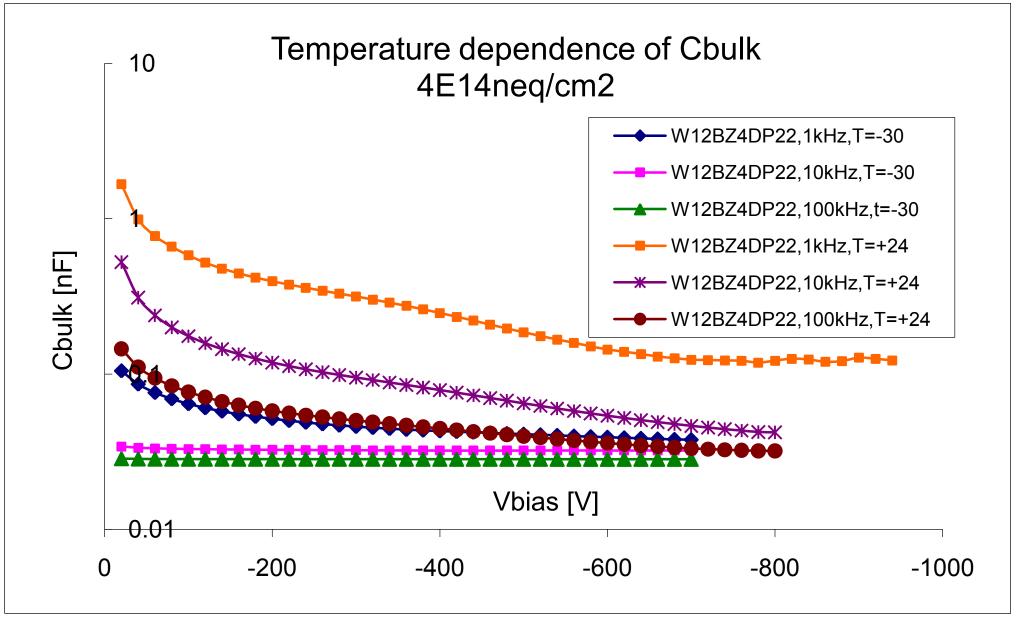
The Vbias dependence of Cbulk for 10kHz is different for various fluences

Vfd for various fluences seems to be even lower than one for non-irradiated sensors after long annealing. It will be checked by CC measurement with laser.



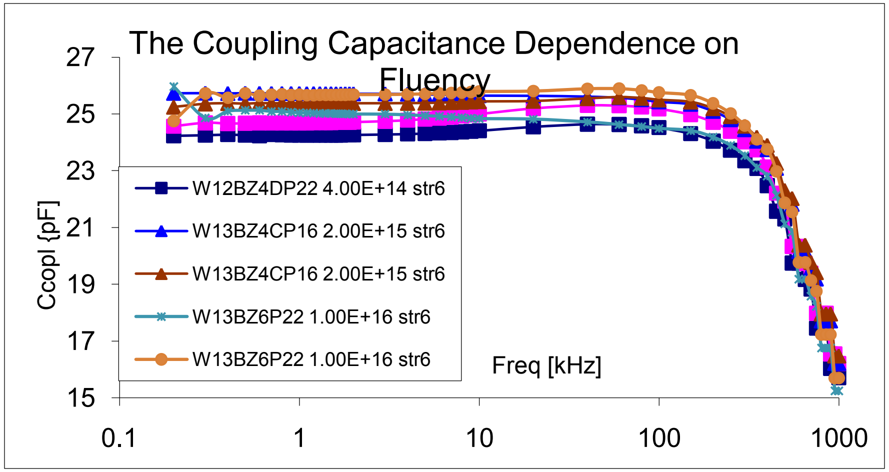


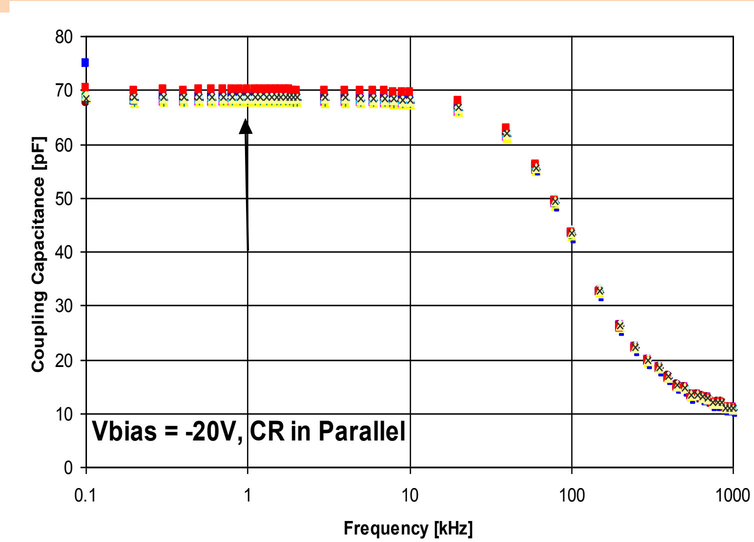
Bulk CV Characteristics

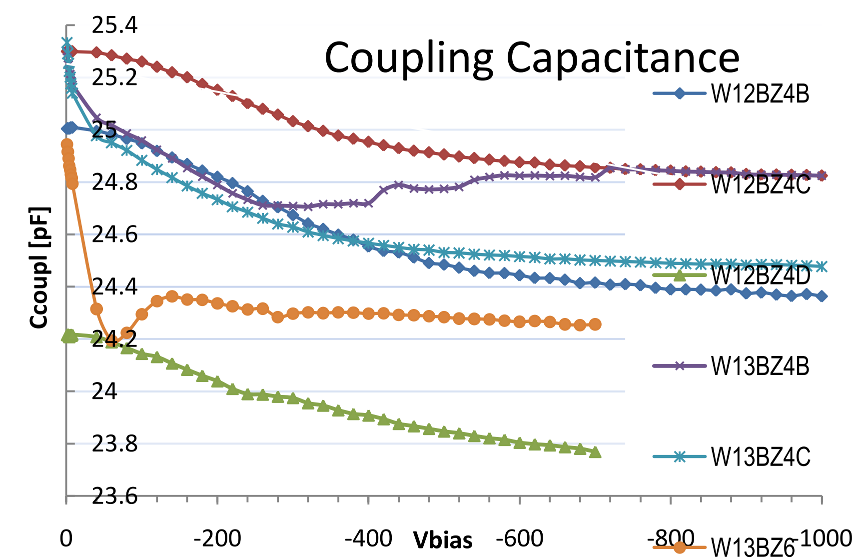


Behavior of Cbulk characteristics needs more delicate investigation

Coupling Capacitance

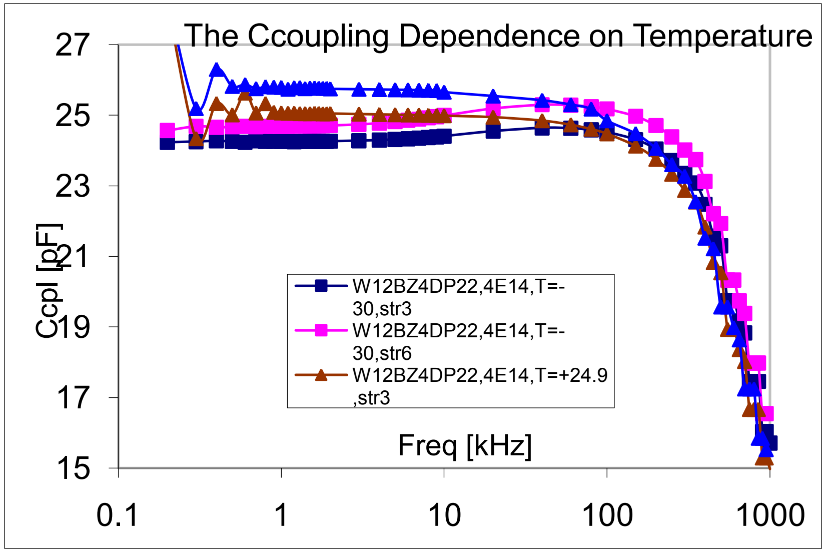


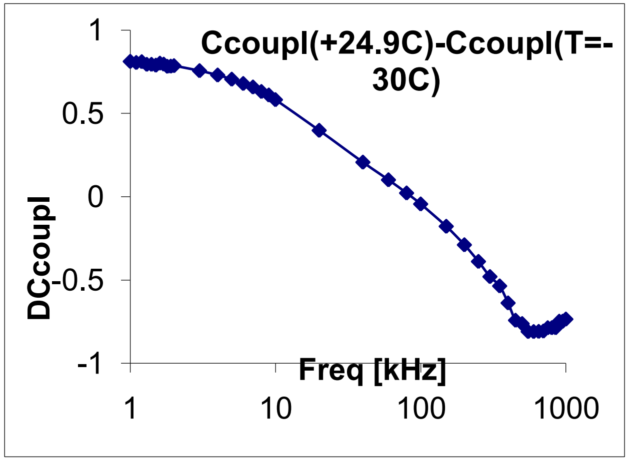




Frequency characteristic of C coupling is flat up to 100kHz for irradiated sensors and it does not depend on fluency. <Ccoupl>=30pF/cm

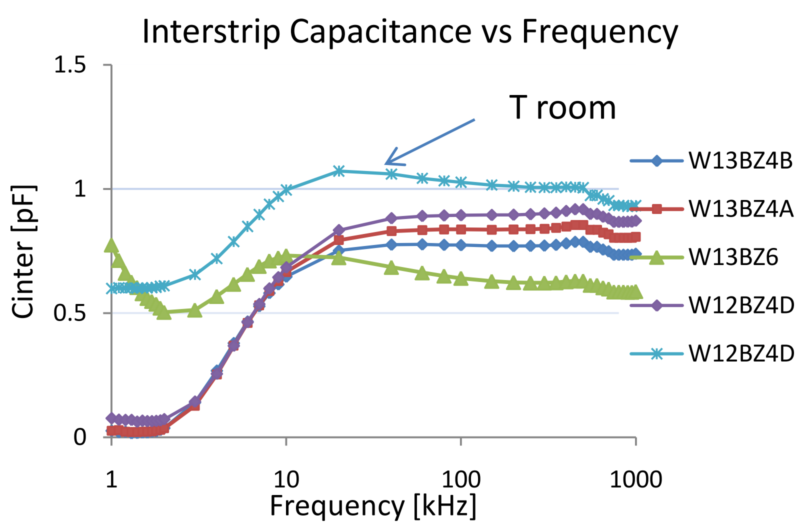
Coupling Capacitance

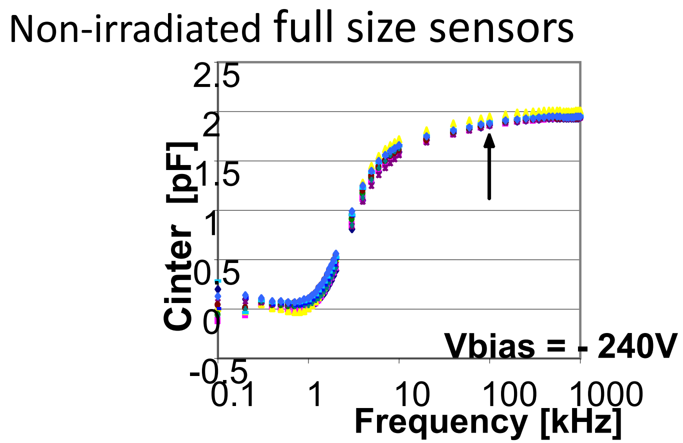


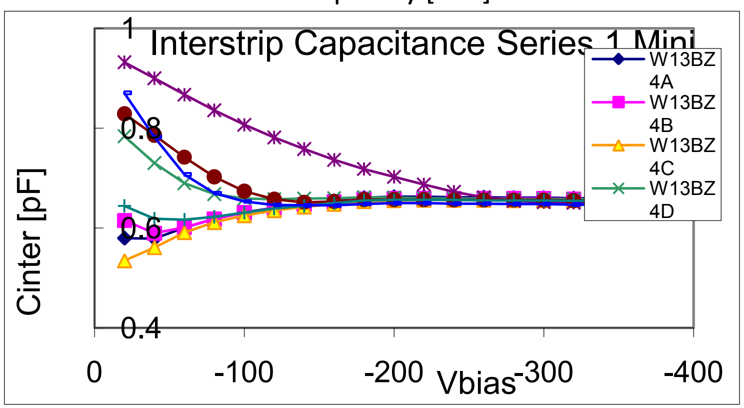


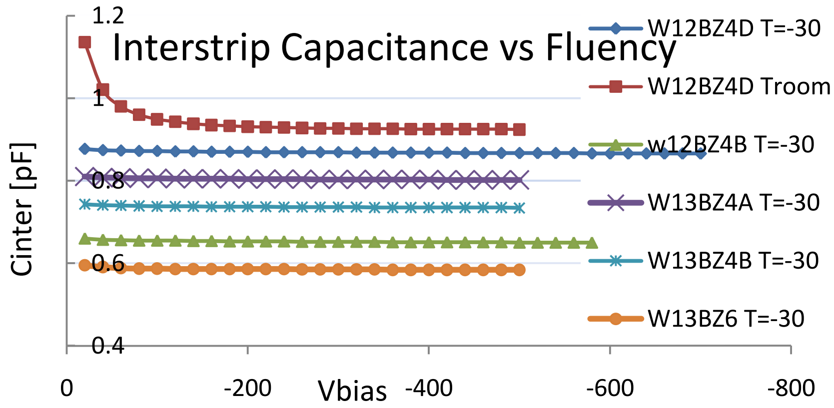
Temperature dependence of Ccoupl is very weak

Interstrip Capacitance





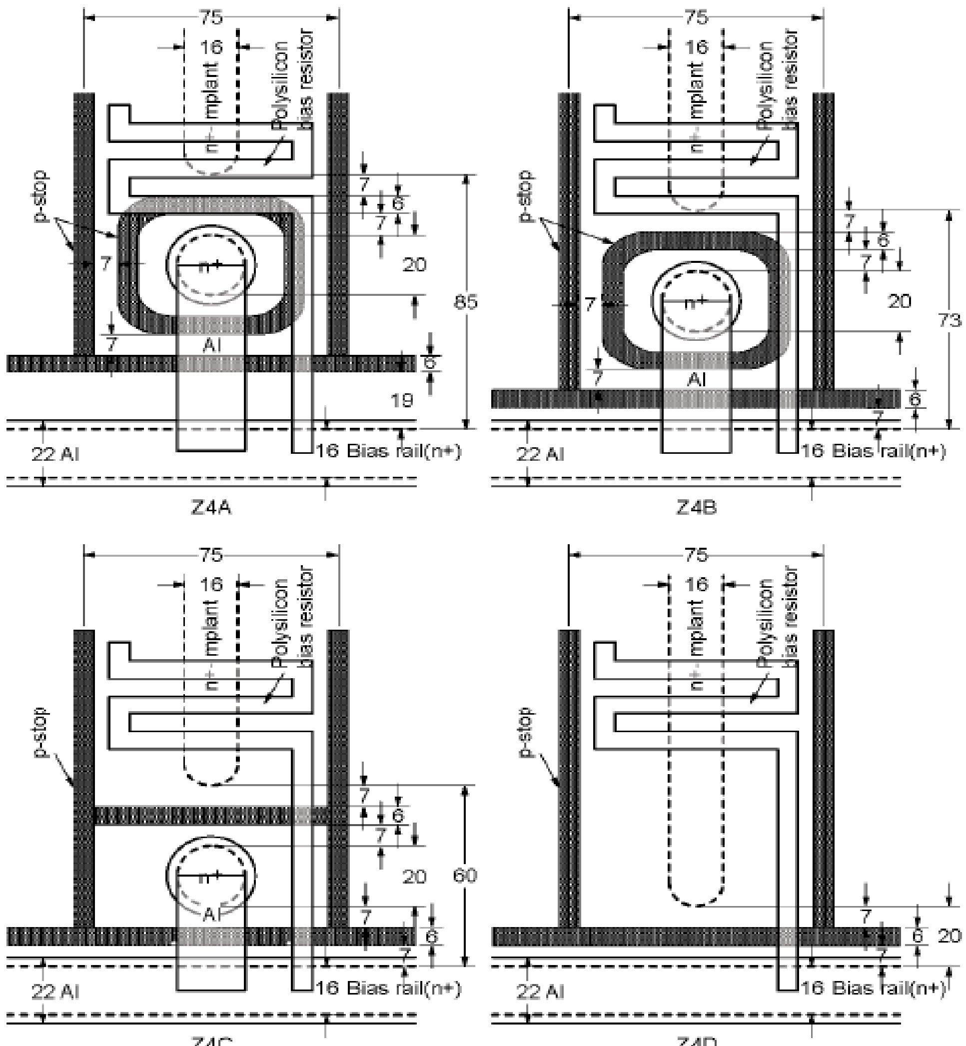




Weak dependence of the Interstrip Capacitance on fluency: <Cinter>=0.9pF/cm

Punch Through Protection Structures

Z4A Z4B

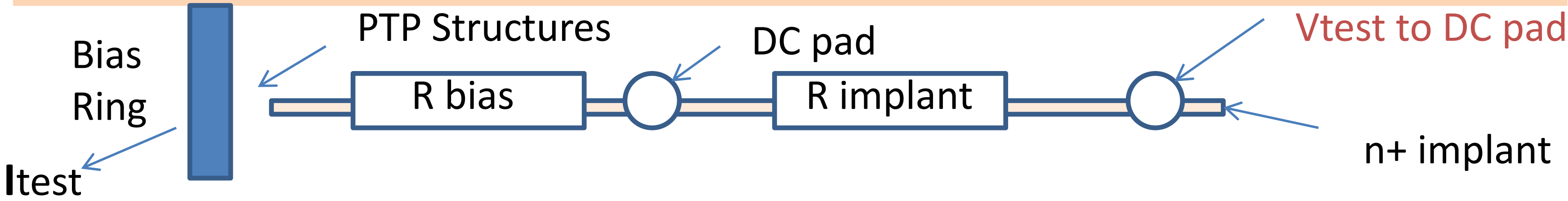


Z4C Z4D

When a large amount of charge is deposit in the sensor by a beam splash, a large current flows through the bias resistor and drops the potential of the n-strips implant toward the backplane bias voltage, thus generating a spike of voltage across the AC coupling insulator.

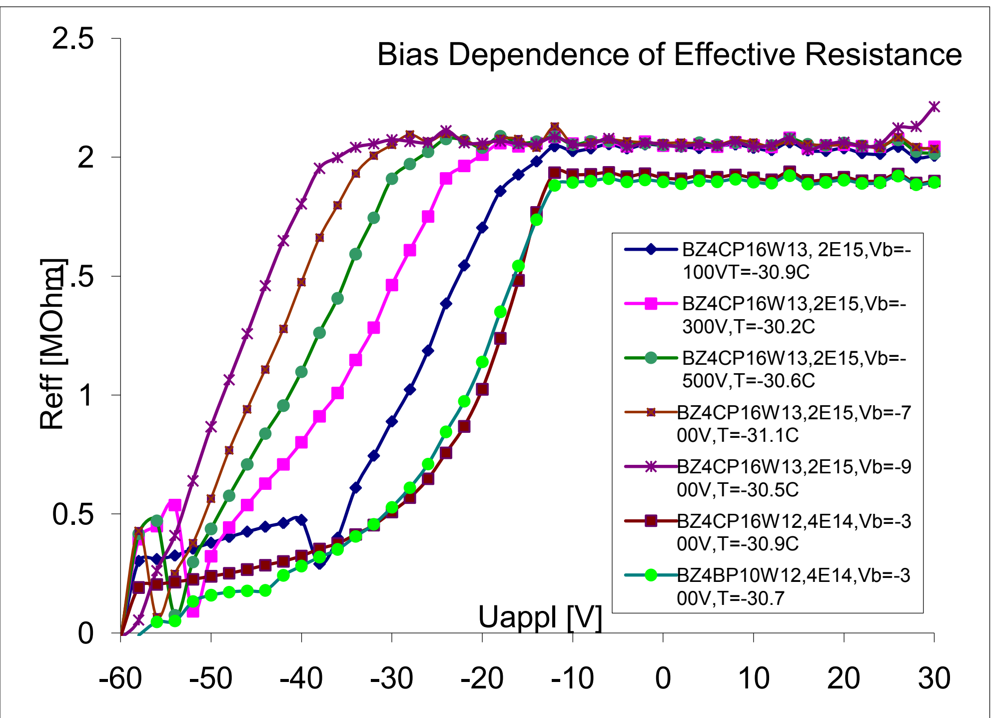
When the distance between the bias rail and the n-strip implants is appropriate, this voltage between the bias rail and the n-strip implants can be limited.
This distance is 20 µm.

Punch Through Protection - DC-method



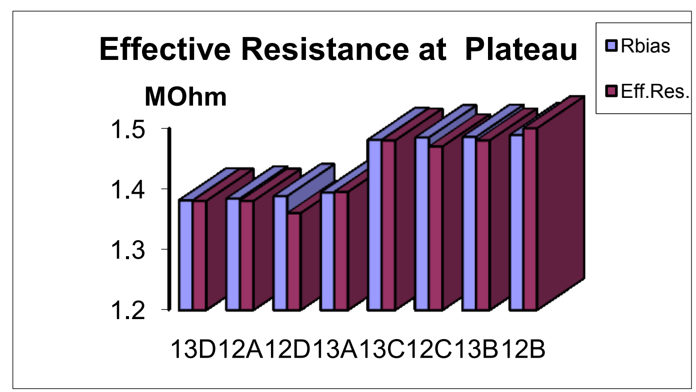
Reff=Vtest/Itest, where Vtest is an applied voltage (Uappl) to DC pad and Itest is an current between DC pad and the bias ring**. Rpt** is supposed to be parallel to Rbias

Punch-Through Voltage is the Test Voltage for **Rbias=Rpt**, i.e. for Reff=Rbias/2

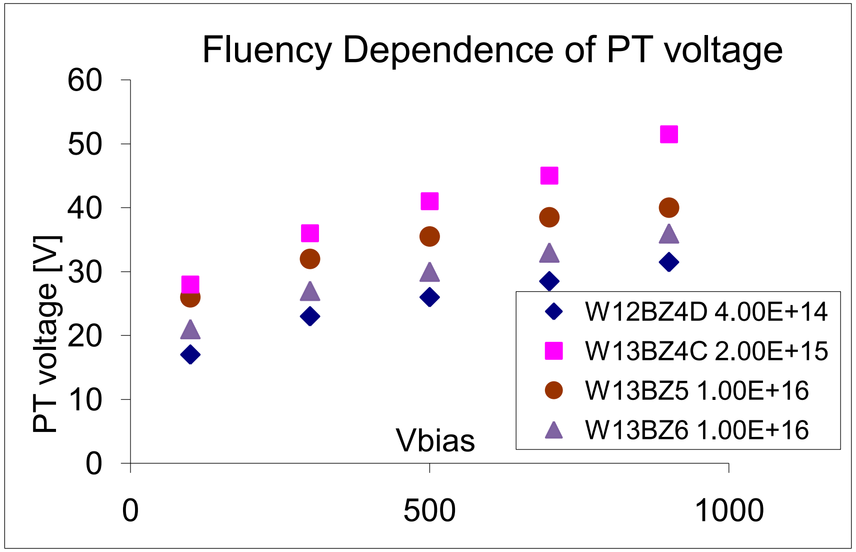


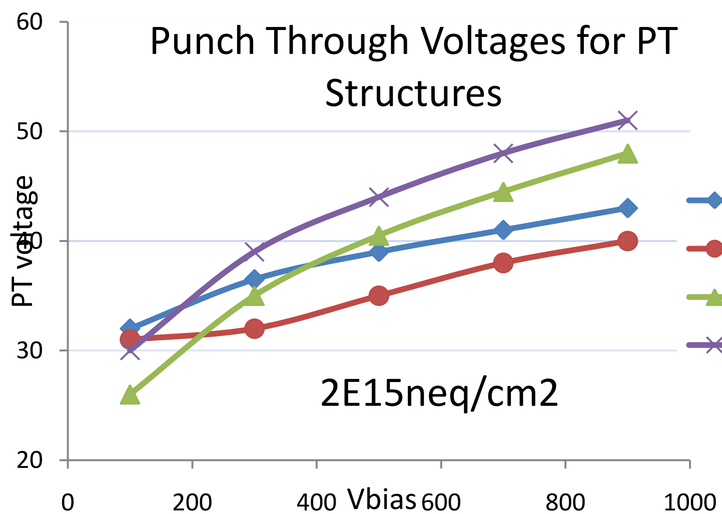
Reff=1 / (1/Rbias+1/RPT)

Sensors before irradiation



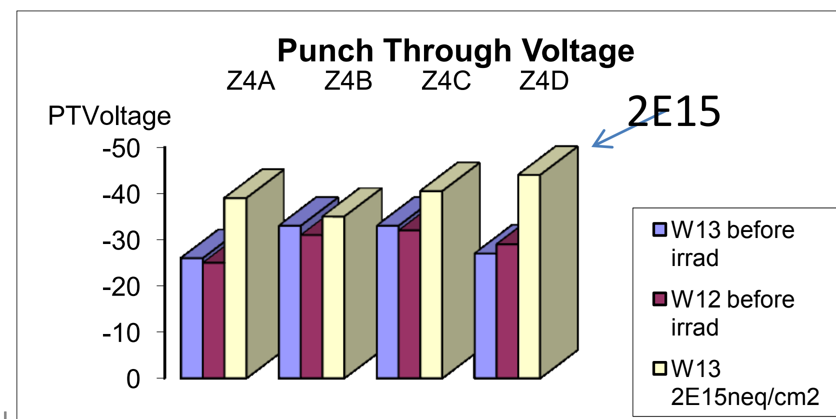
Punch Through Protection - DC-method



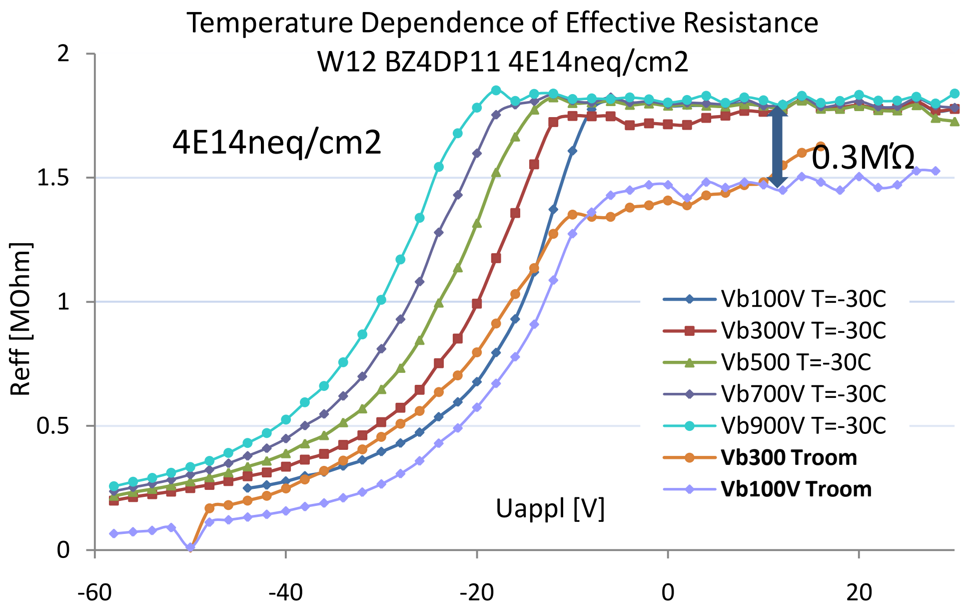


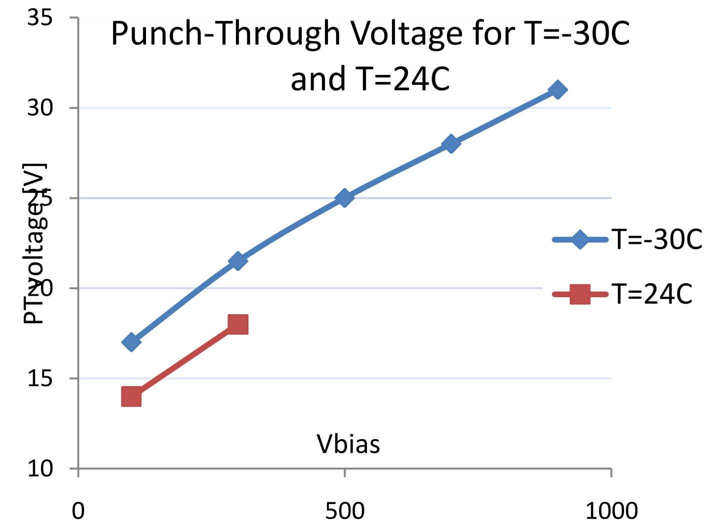
-PT voltage is increasing with bias voltage
-PT voltage is increasing with fluency
-PT voltage is higher for irradiated sensors than one for non-irradiated sensors.
-PT voltage for sensors Z4D and Z4C (the simplest PTP structure) is higher by ~10V than one for Z4A and Z4B.

There is no saturation of PT voltages even for PTV≥Vfd. It agrees with the Santa Cruz result (C.Betancourt, Oxford, March 2011): 'Finite implant resistance (Rimp=19.4kΩ) isolates PTP structure from the far implant end ."



Temperature Dependence of Punch-Through Voltage?





PT voltage is slightly higher for low temperature (-30C) than for room temperature (24C). The difference would be explained by lower bias resistance for room temperature than for -30C.

It is worth to measure temperature dependence of bias resistor.

Conclusion

* ATLAS07 Series I mini-sensors of HPK have been irradiated on reactor LVR15 in Rez up to three fluences: 4E14, 2E15 and 1E16neq/cm^2
* Sensors were measured at temperature -30C which is planned for ID and sLHC
* **A rise of the leakage current with fluency is not linear. Values at 1E16neq/cm2 should be confirmed.**
* **Above ~2kHz Cbulk does not depend on fluency**
* **Cbulk strongly depends on temperature**
* **Vfd after 2 months annealing seems to be lower than one for non-irradiated sensors? Confirmation by CC measurement is needed**
* **Frequency characteristic of C coupling does not depend on fluency and temperature: < Ccoupl>=30pF/cm**
* **Weak dependence of the Interstrip Capacitance on fluency: <Cinter>=0.9pF/cm**
* **PT voltage is increasing with fluency.**
* **There is no saturation of PT voltage even for Vpt≥Vfd**
* **An evidence that Rbias rises with decreasing temperature – it should be confirmed**

Measurement will continue also with a laser. More mini sensors are needed