Vidyo meeting,
16.1.2014

Tests of the irradiated ATLAS-12 sensors

A.Chilingarov and H.Fox

Lancaster University, UK

LANCASTER UNIVERSITY

Contents

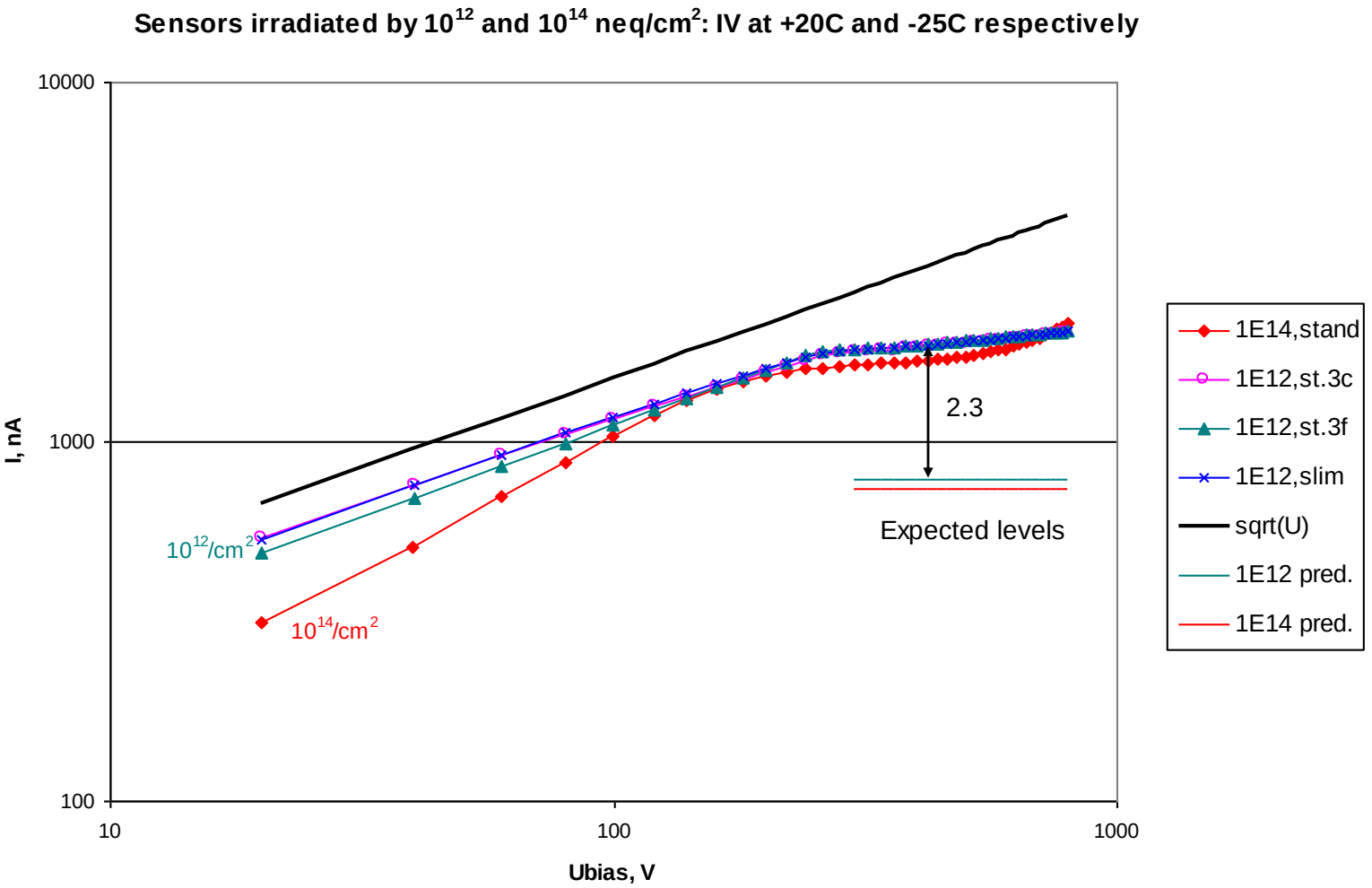
LANCASTER UNIVERSITY

1. Introduction. Sensors and their irradiations

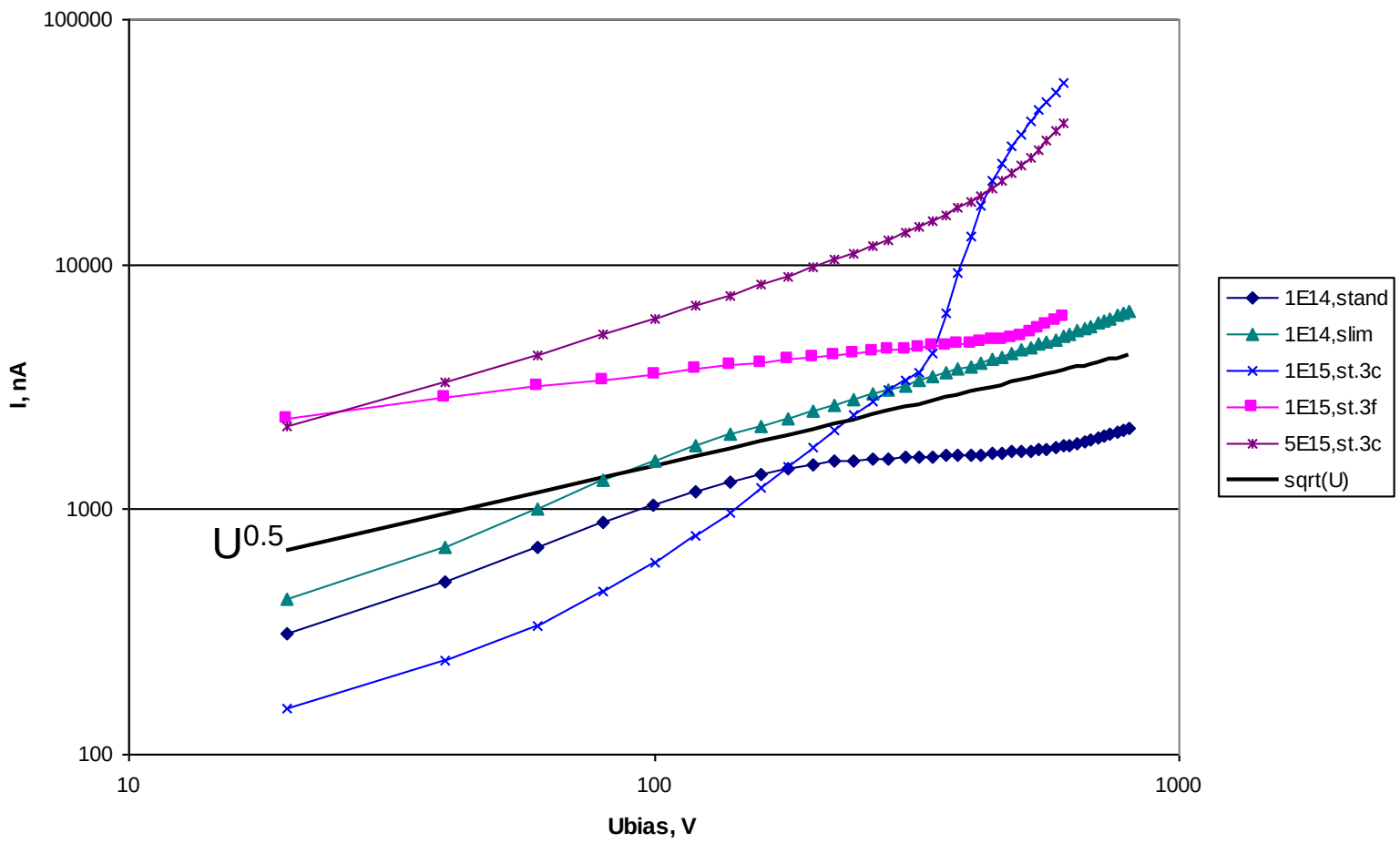
Sensor	Edge type	Fluence, neq/cm^2	Dose, Mrad
W631-BZ3C-P4	Standard	1E+12	0.115
W623-BZ3F-P3	Standard	1E+12	0.115
W607-BZ3C-P2	Slim	1E+12	0.115
W627-BZ3C-P12	Standard	1E+14	11.5
W610-BZ3C-P4	Slim	1E+14	11.5
W633-BZ3C-P12	Standard	1E+15	115
W627-BZ3F-P5	Standard	1E+15	115
W636-BZ3C-P12	Standard	5E+15	575

All sensors were irradiated by 27 MeV protons and annealed for 10 days at a temperature of ~ 21^{o}C. The sensors irradiated by 10^{12} neq/cm^2 were tested at the Probe Station at +21^{o}C. The other sensors were tested in a special DUT box typically at -25^{o}C and sometimes at -35^{o}C.

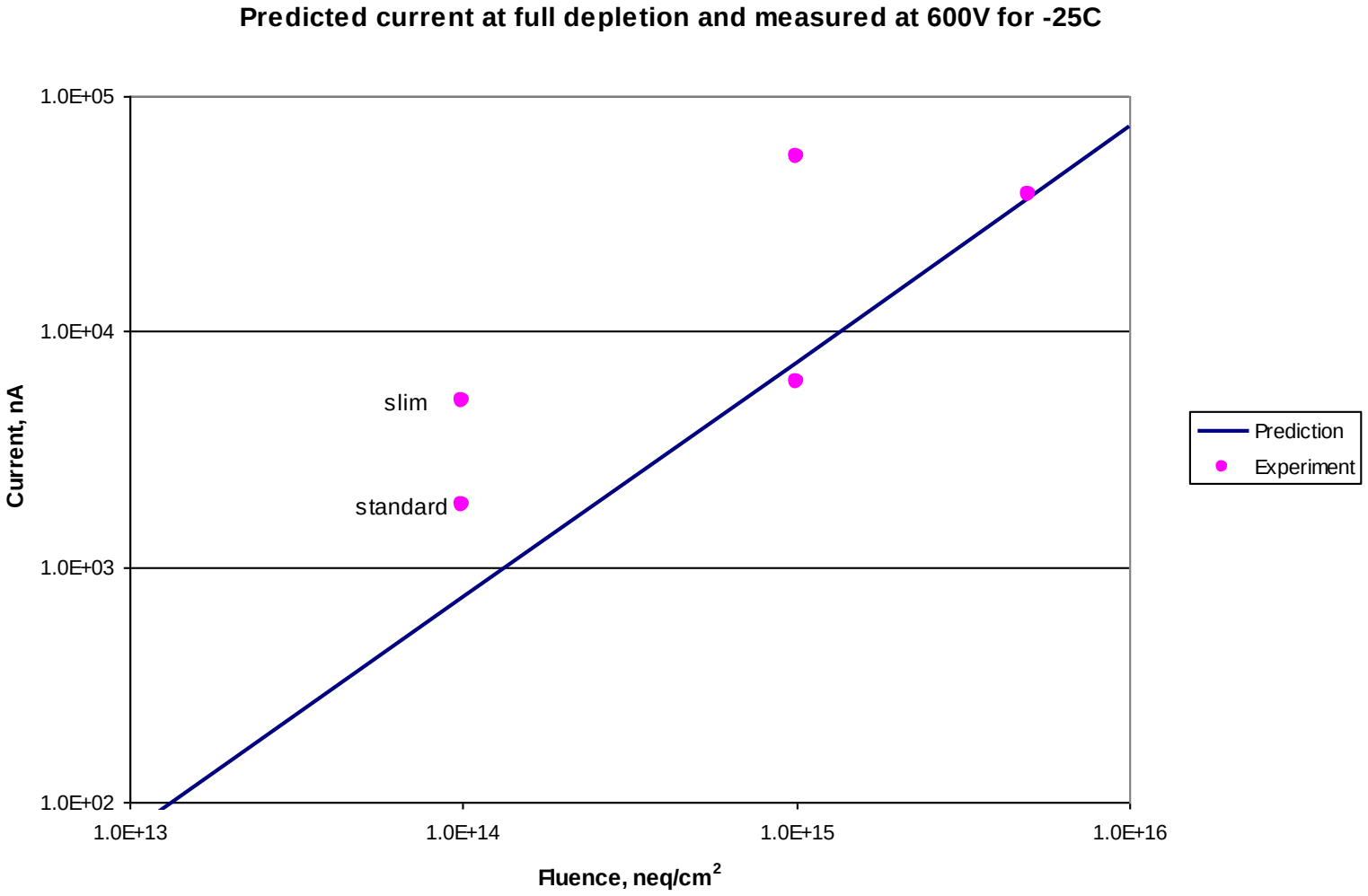
2. IV characteristics



The IV curves for low fluence sensors. The black line shows $U^{0.5}$ dependence and the colour lines the levels expected from $\alpha(20^oC)=4\ 10^{-17}$ A/cm. Temperature correction coefficient between 20°C and -25°C was taken as 107.

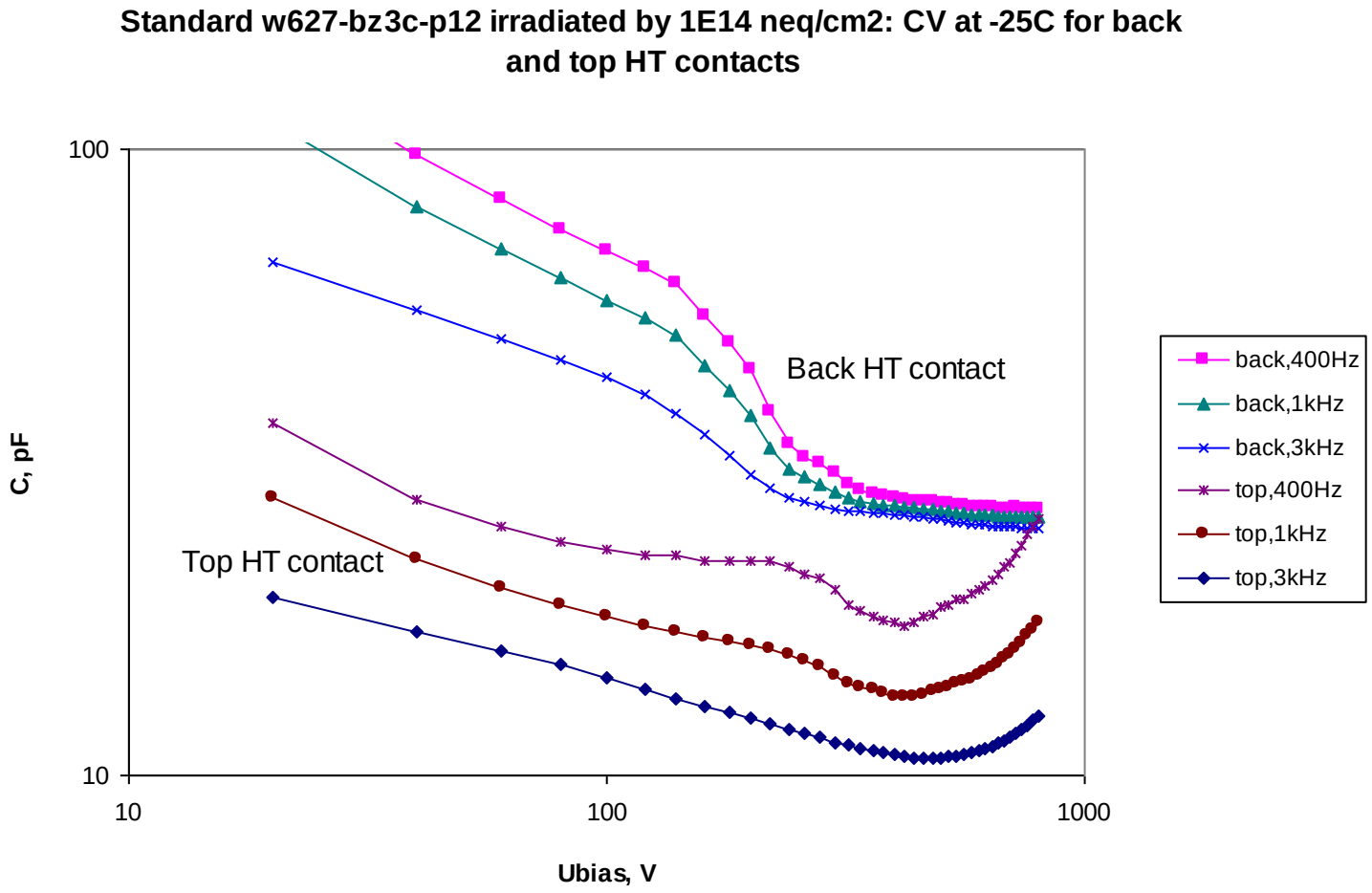


IV at -25°C for fluences 10^{14} – 5 10^{15} neq/cm^2. Only the standard sensor irradiated by 10^{14} neq/cm^2 exhibits a kink allowing depletion voltage estimate.

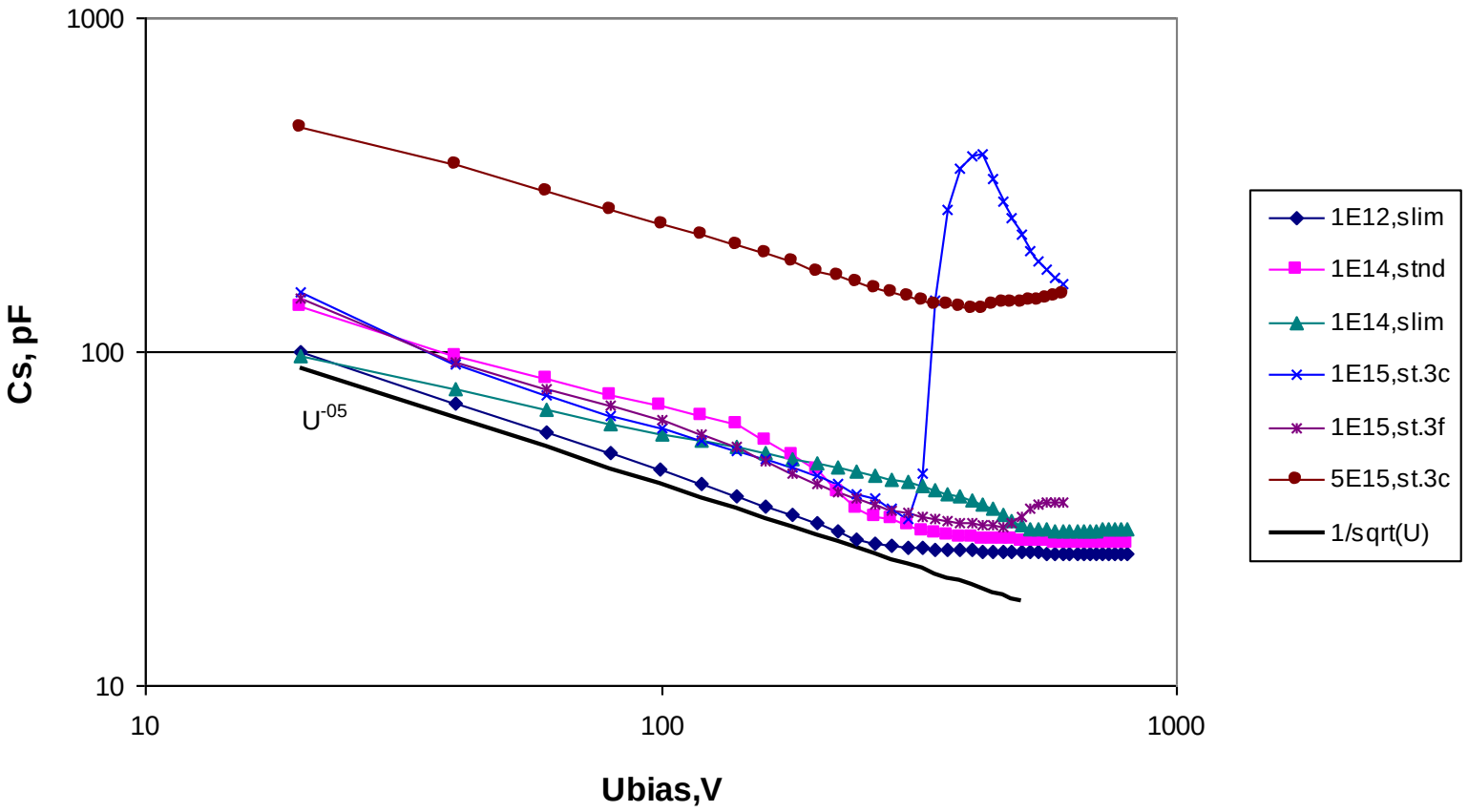


The current measured at 600V and expected for a fully depleted sensor. Note that for the fluence above 10^{14} neq/cm^2 the sensors are not depleted at 600V.

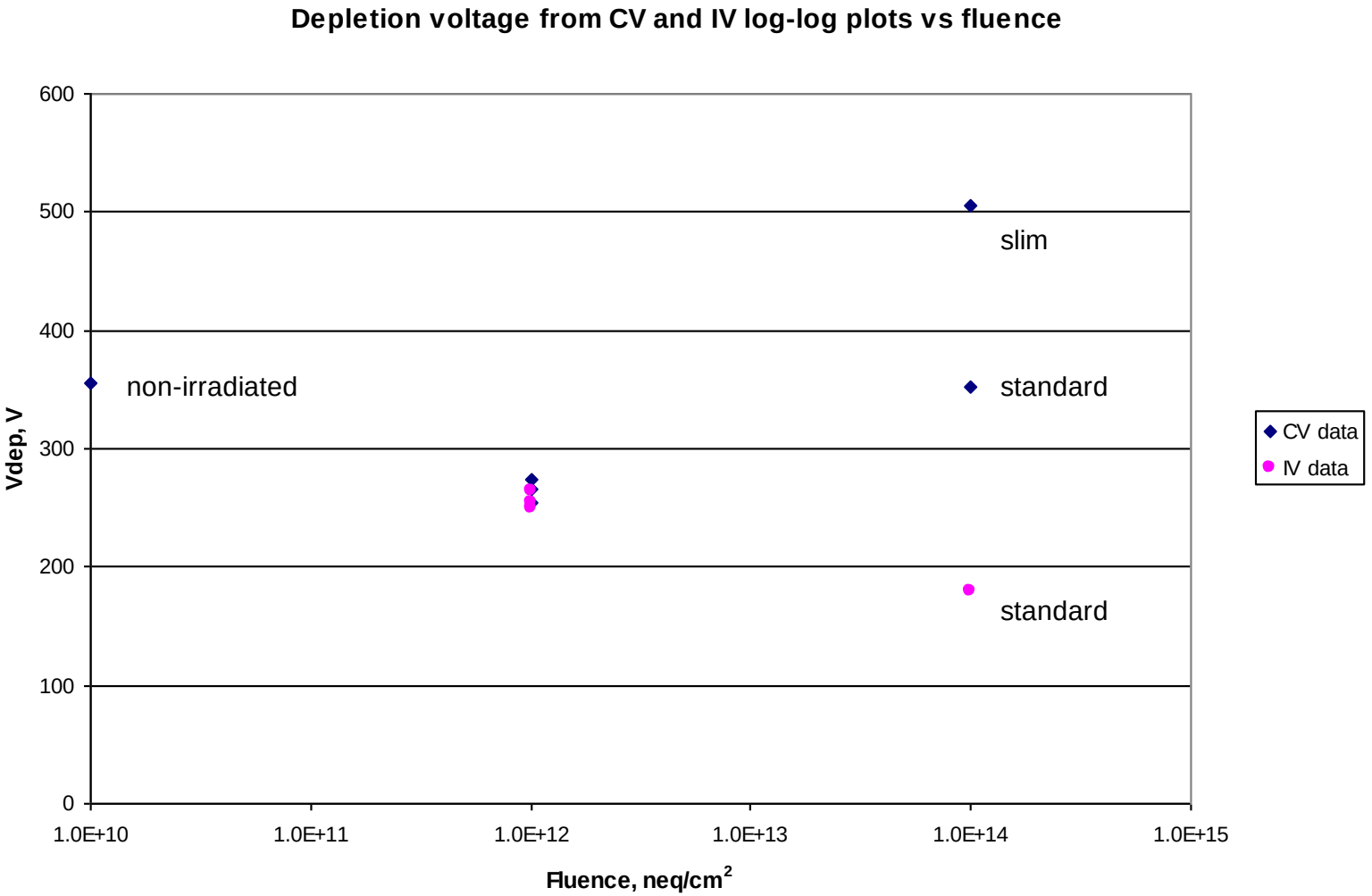
2. CV and depletion voltage



A surprise result: for the sensor irradiated by 10^{14} neq/cm^2 the CV curves look very strange when the top HT contact is used instead of the back side.

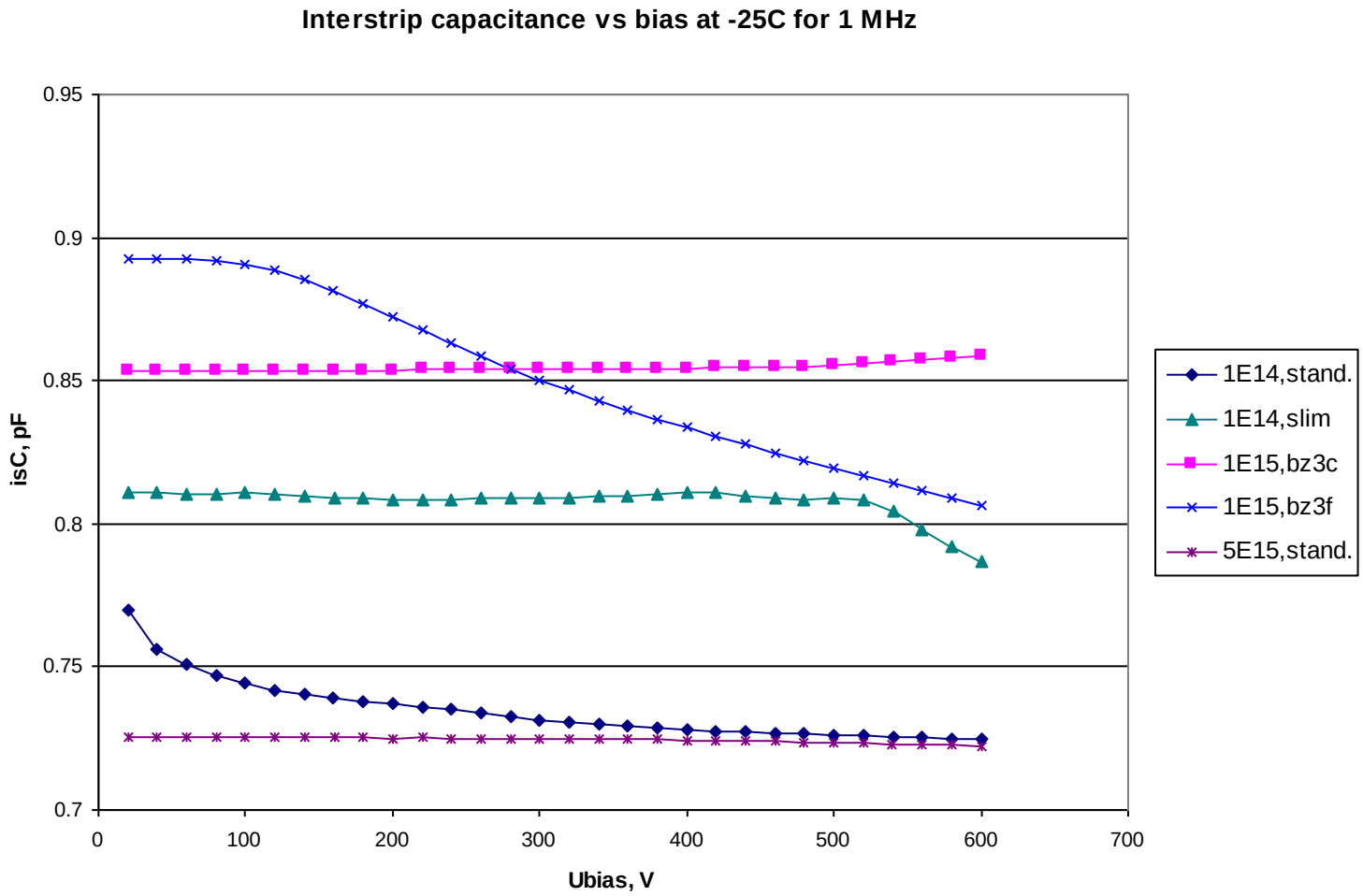


CV for all sensors. The line shows the U^{-05} dependence. A “kink” exists only up to the 10^{14} neq/cm^2 fluence. At high bias the curves are distorted by the high current.

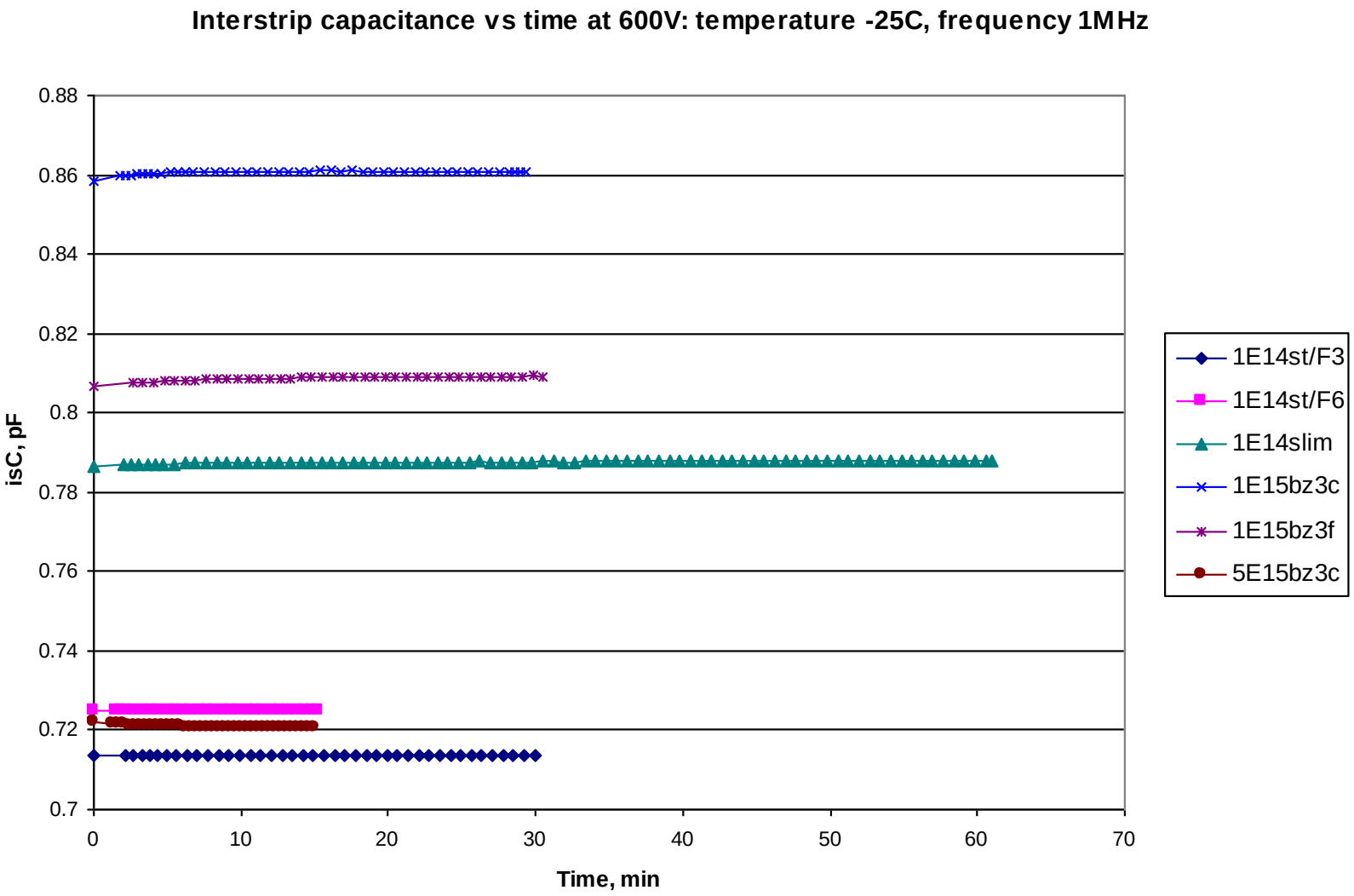


Depletion voltage found from the kink position in the log(C) vs. log(Ub) and log(I) vs. log(Ub) curves. The value for the non-irradiated sensors is put on the y-axis.

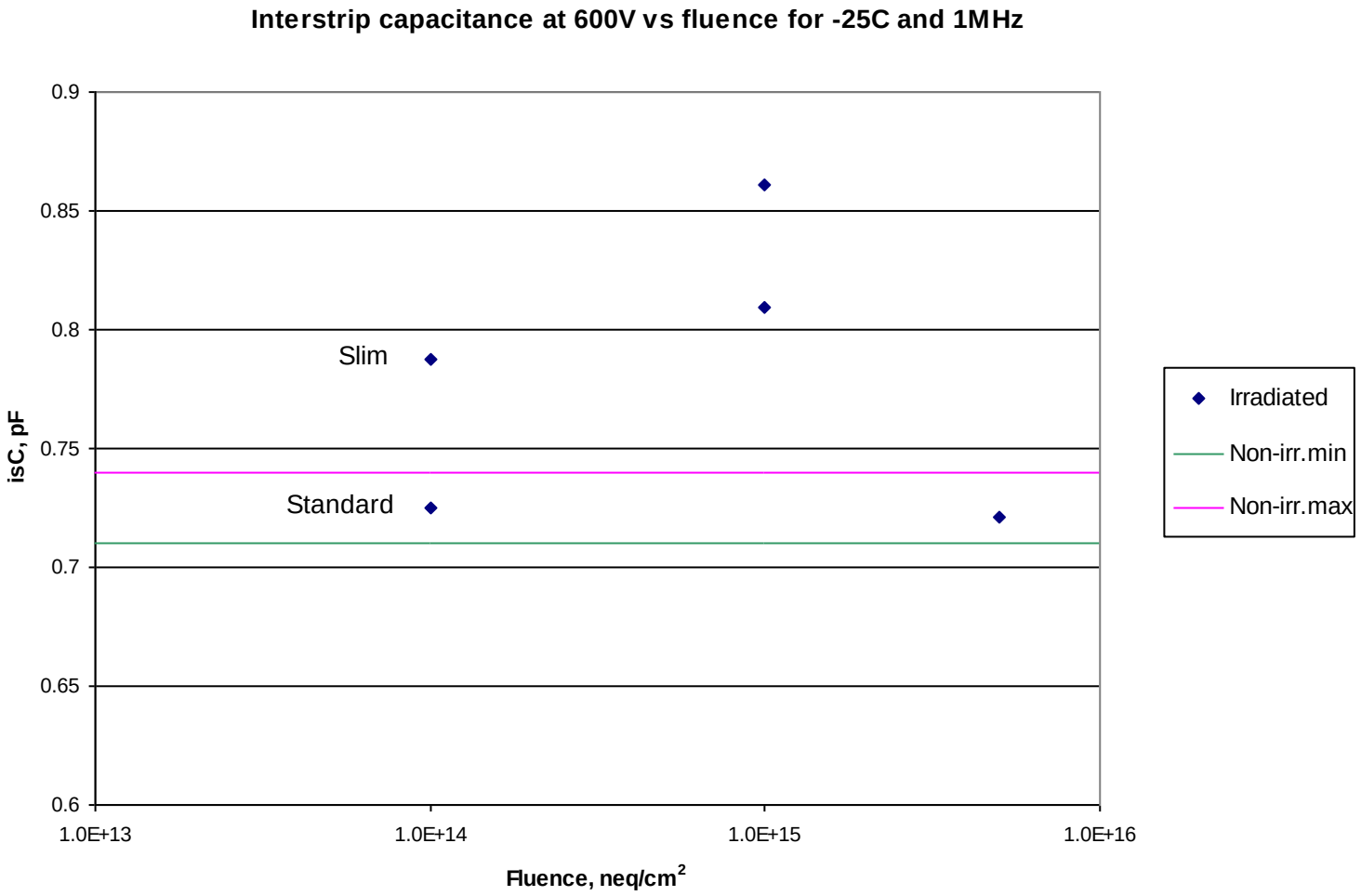
4. Interstrip capacitance



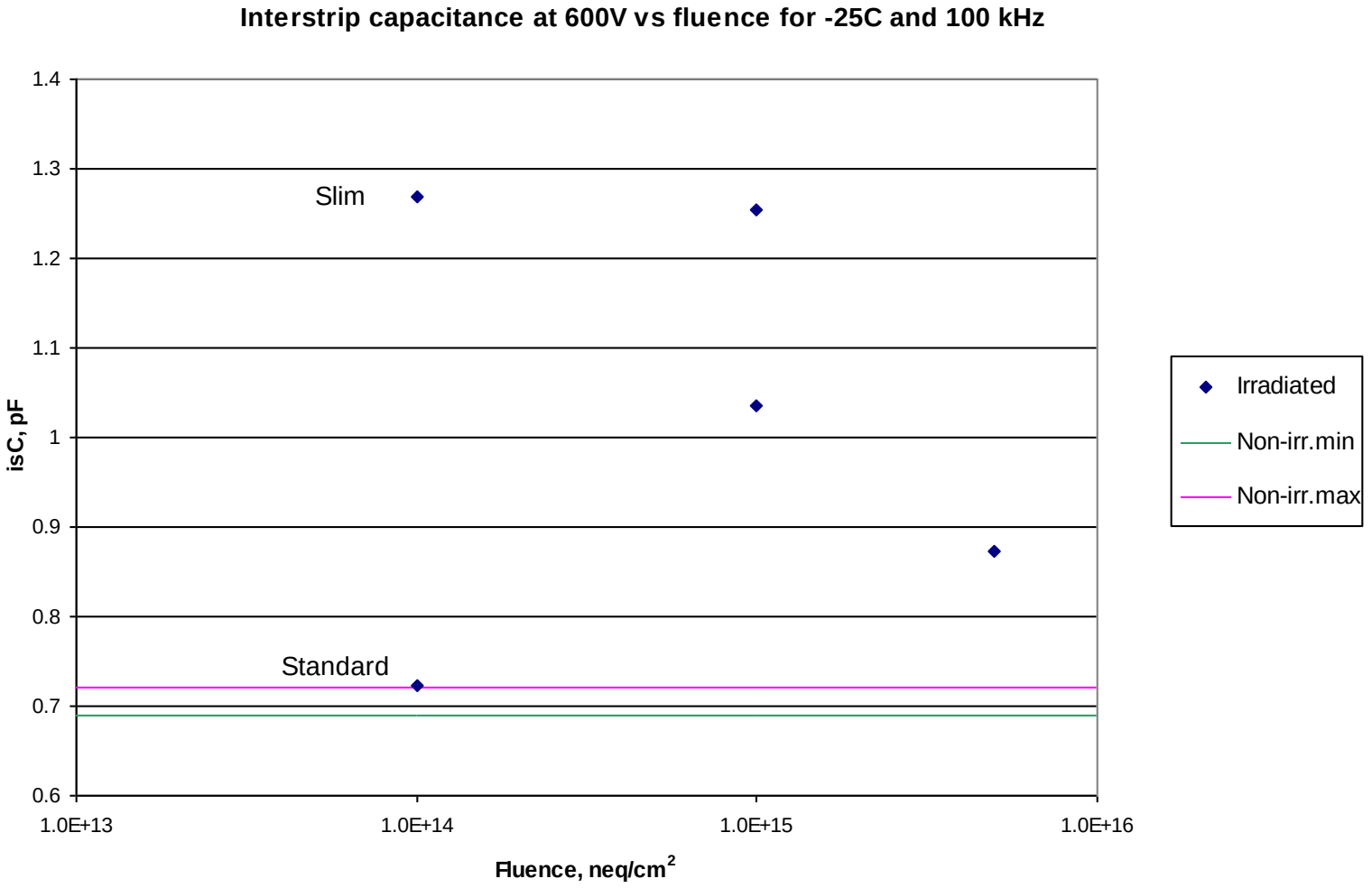
The capacitance was measured between a strip and its two immediate neighbours. The CV curves here are for 1 MHz frequency.



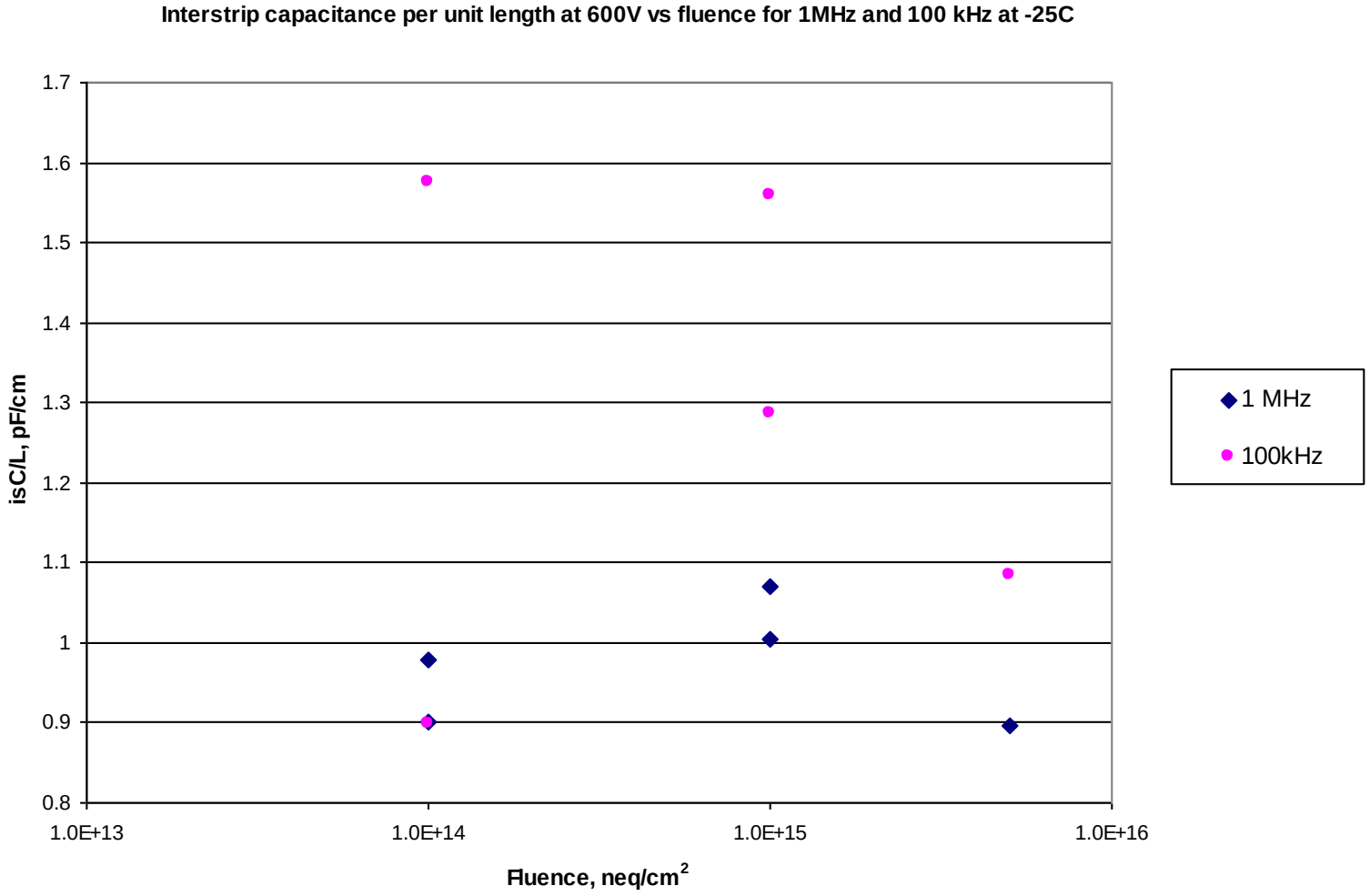
After the bias ramp the capacitance remained stable in time. Standard sensor irradiated by 10^{14} neq/cm^2 was measured in the test frame 3 with top HT contact and in the frame 6 with the backside contact. The results are close.



Interstrip capacitance at 1 MHz vs. fluence. The lines show the minimal and maximal values measured in the same conditions with ATLAS 07 un-irradiated sensors. For some irradiated sensors the Cis is above the non-irradiation level by up to ~20%.

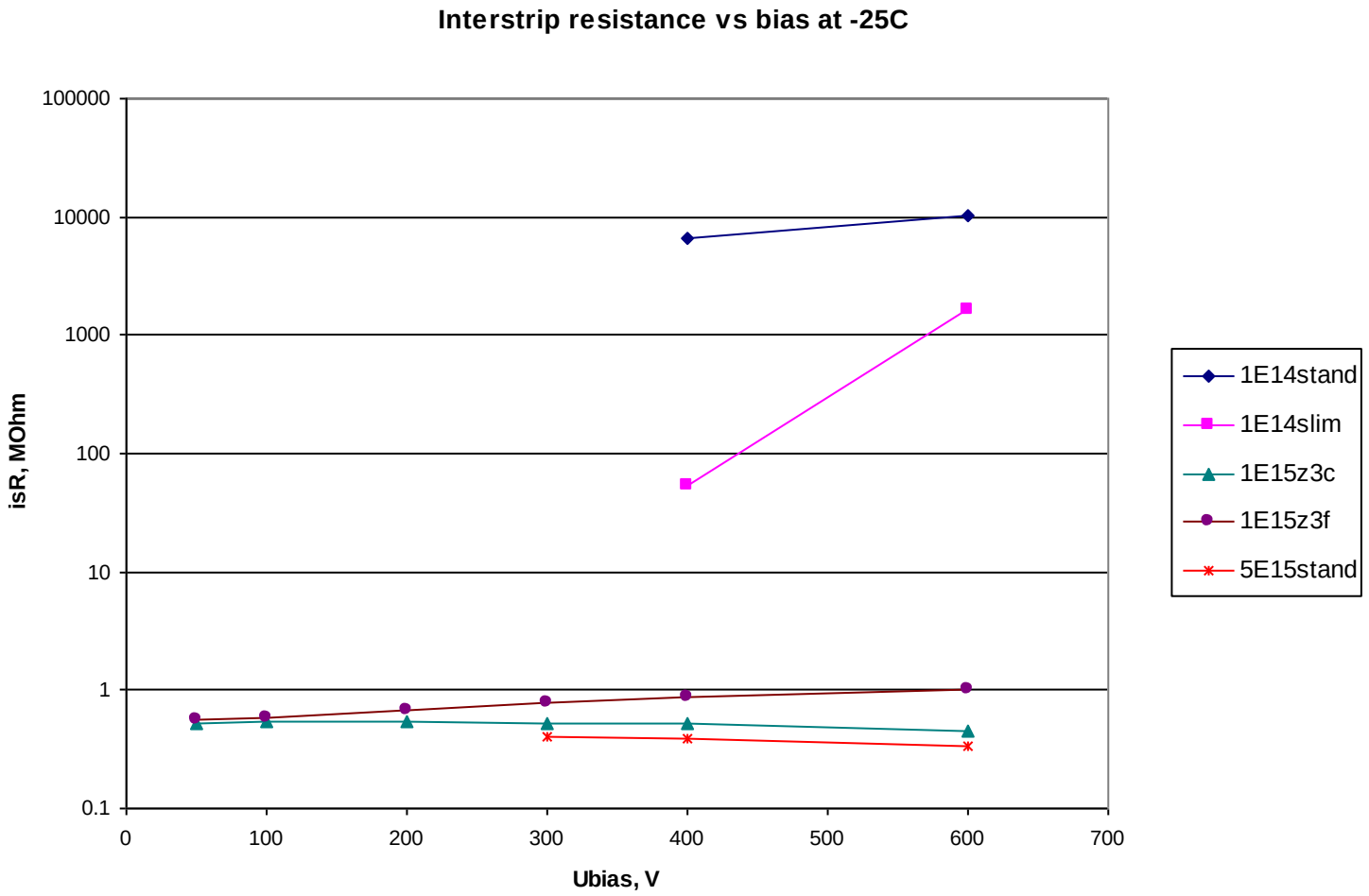


For 100 kHz the Cis excess in comparison to the non-irradiation level is significantly higher than for 1 MHz.

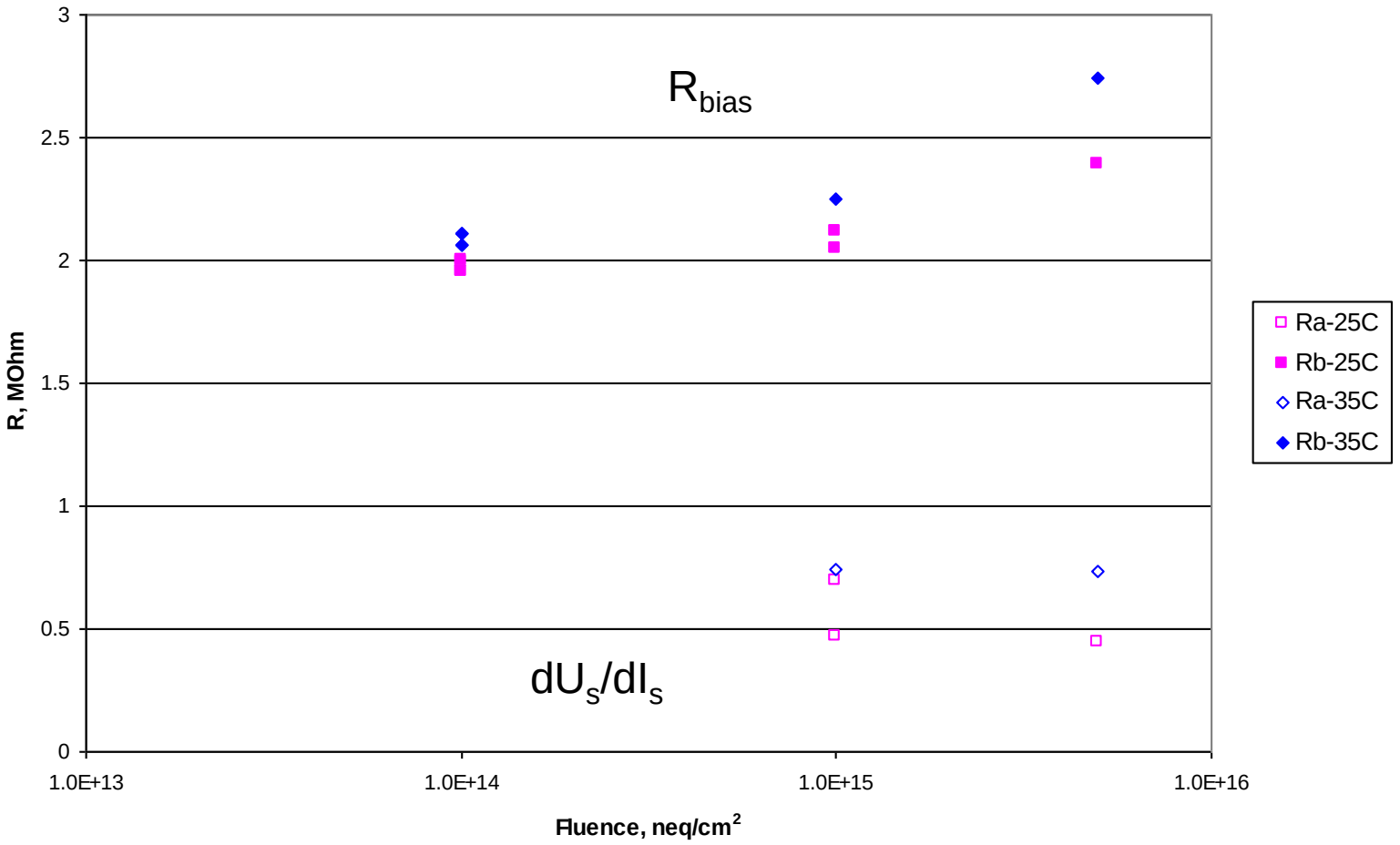


Normalised by the strip length of 0.80 cm the Cis is noticeably higher than the specs value of 0.8 pF/cm. For more relevant 1 MHz frequency it is closer to the specs.

5. Interstrip resistance

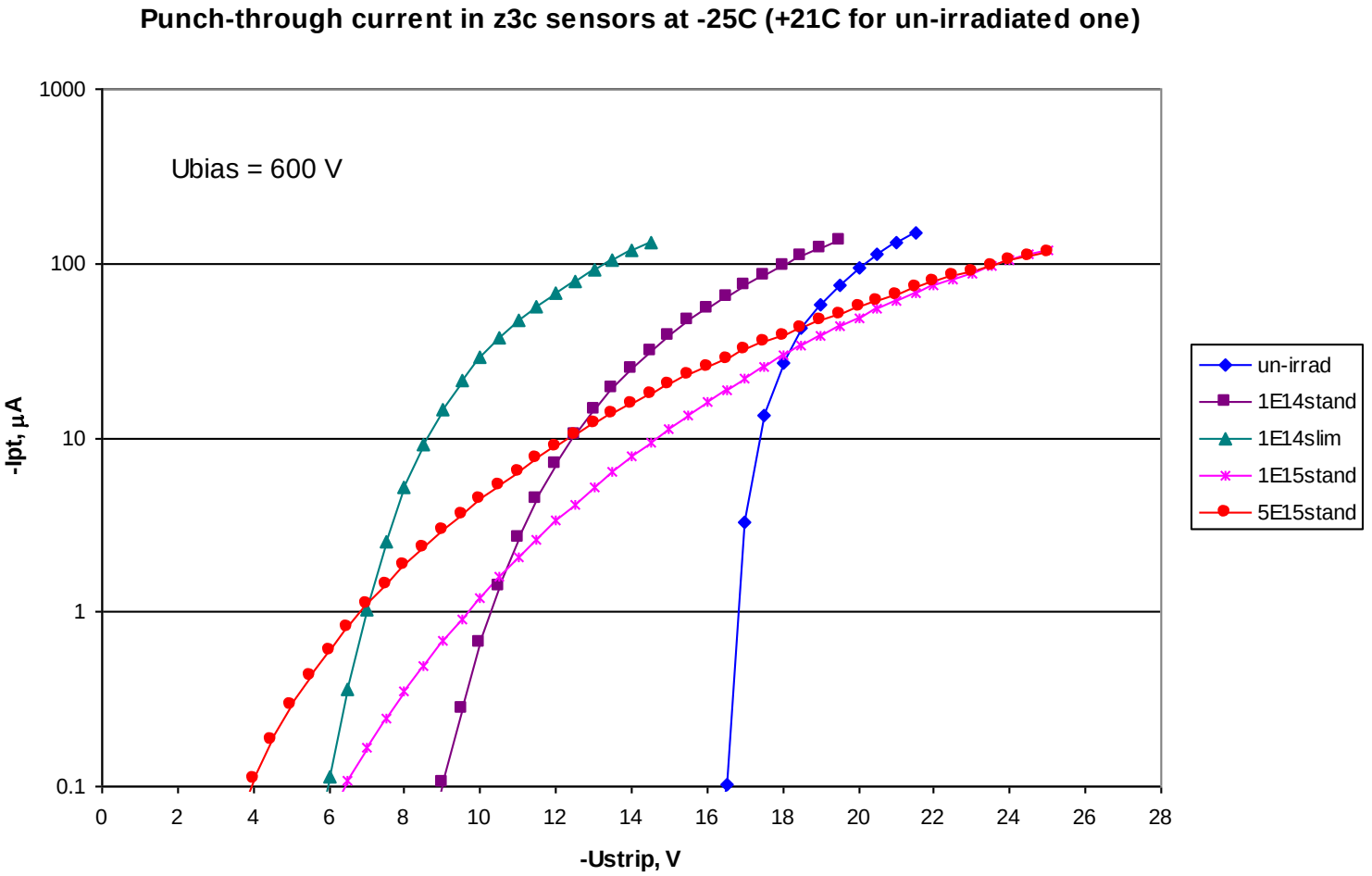


For fluences ≥ 10^{15} neq/cm^2 the interstrip resistance drops to 0.3 – 1 MOhm. At -35^{o}C it increases but only by a factor of ~2.

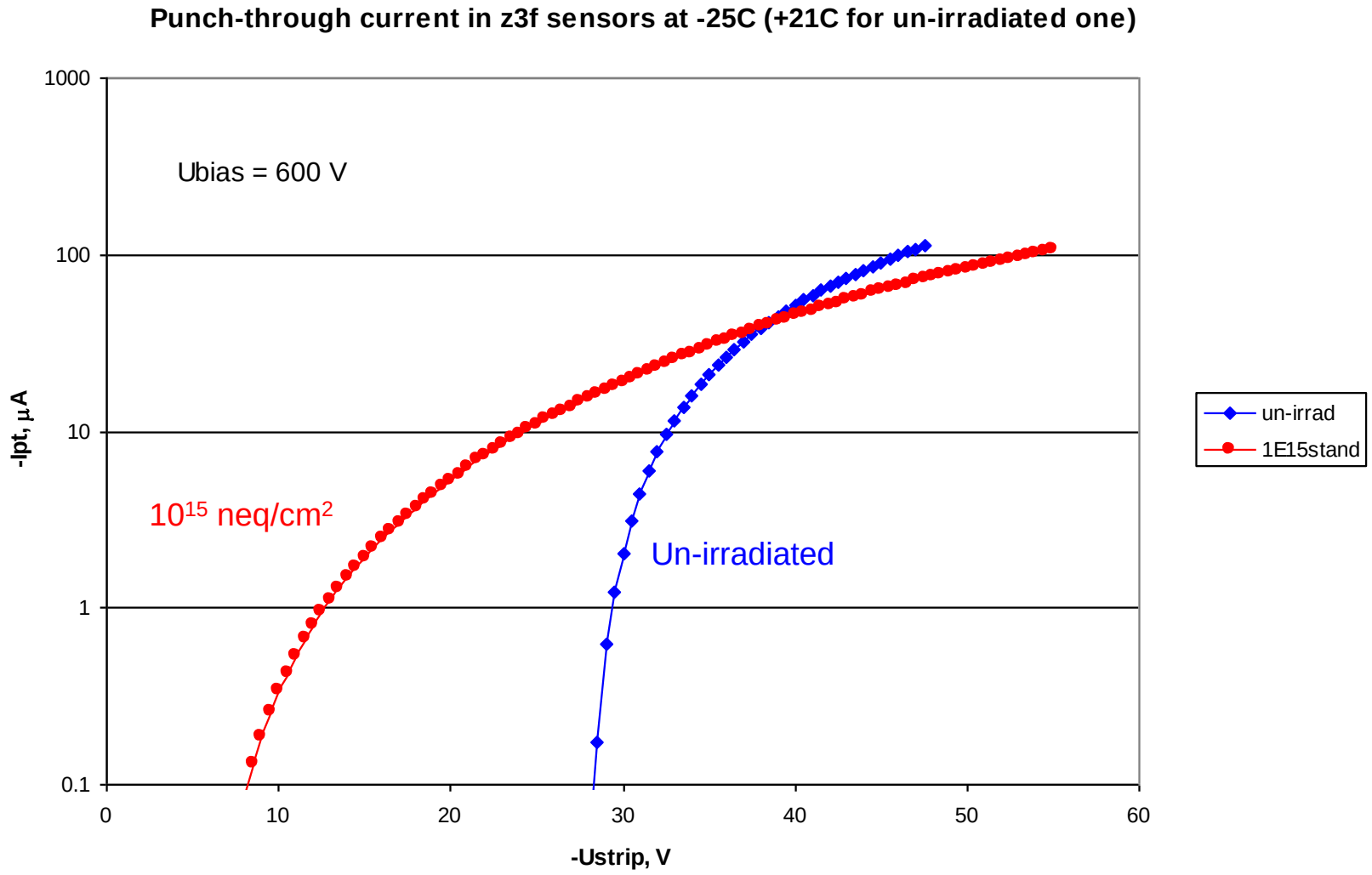


Low interstrip resistance isR makes an apparent bias resistor at the master strip, $Ra=dU_{strip}/dI_{strip}$, much lower than Rbias but the reconstructed Rbias values are reasonable.

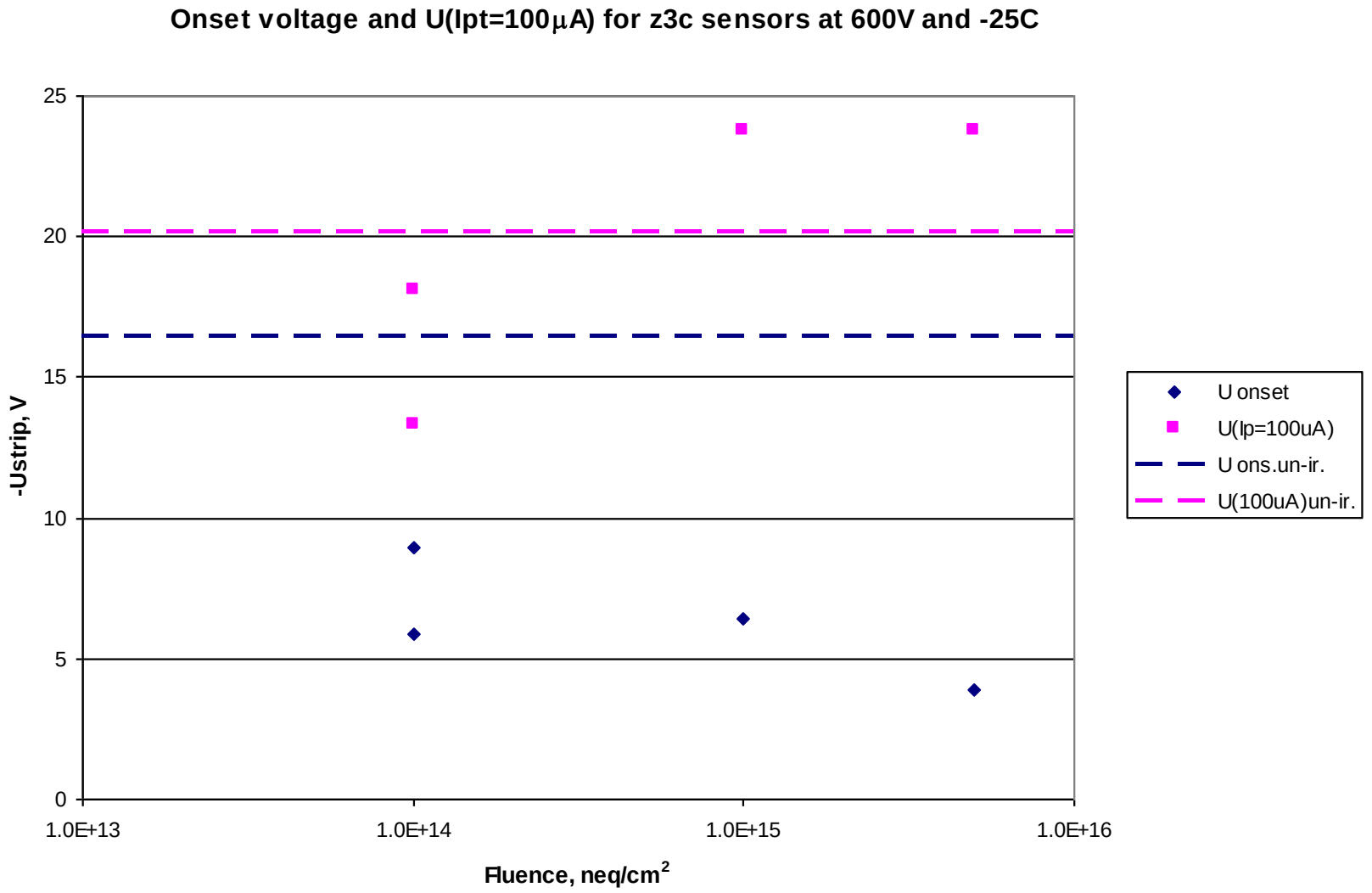
6. Punch-through properties



With irradiation the onset voltage decreases but the PT current gradient becomes less steep. The data here are for the PTP structure z3c implemented in the main sensor.



The same behaviour is observed for the PTP structure z3f though as expected it operates at higher U_{strip}.

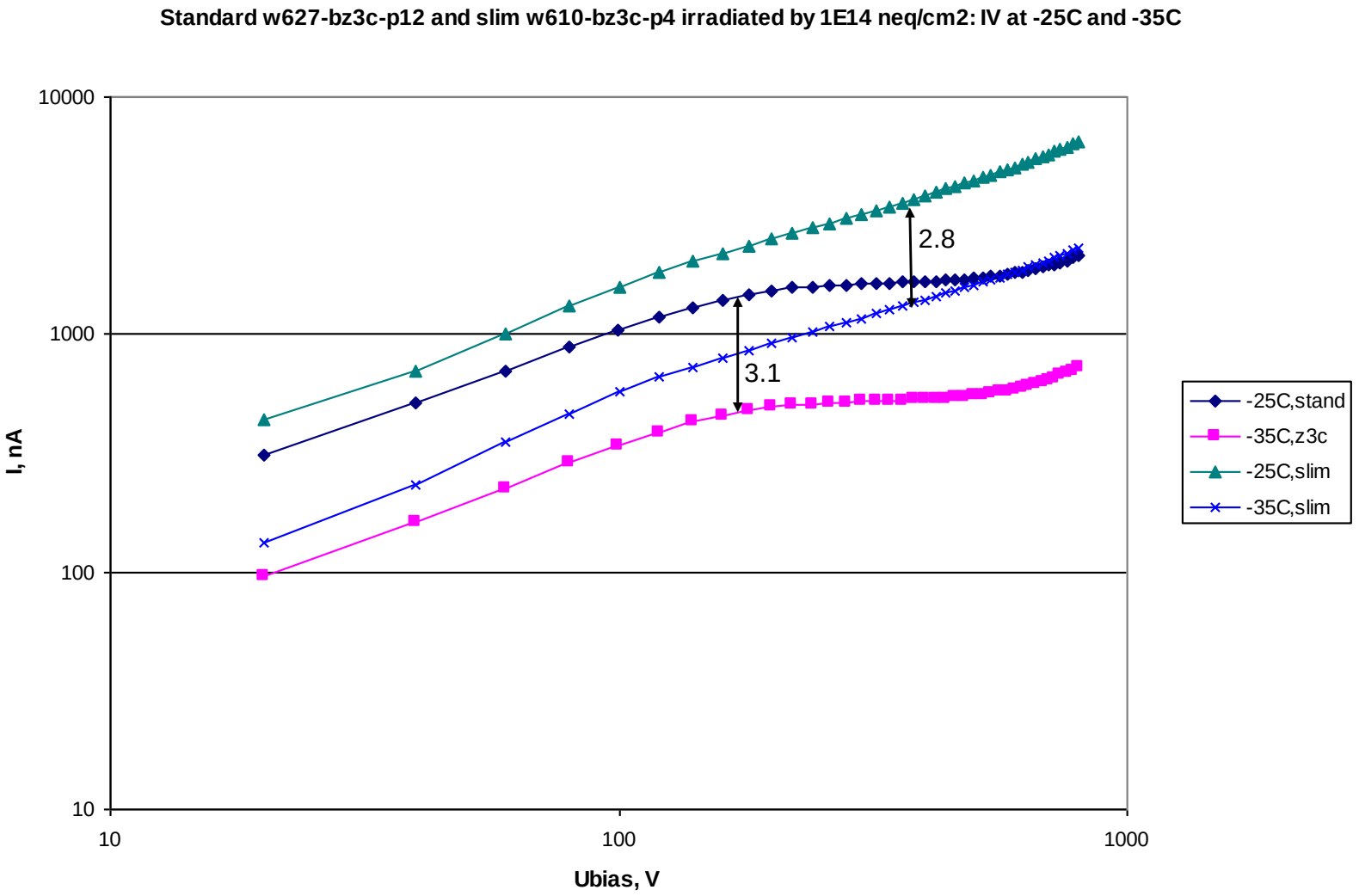


PT onset and the voltage for I_{pt}=100 μA in z3c sensors. The lines are the values for the un-irradiated sensor.

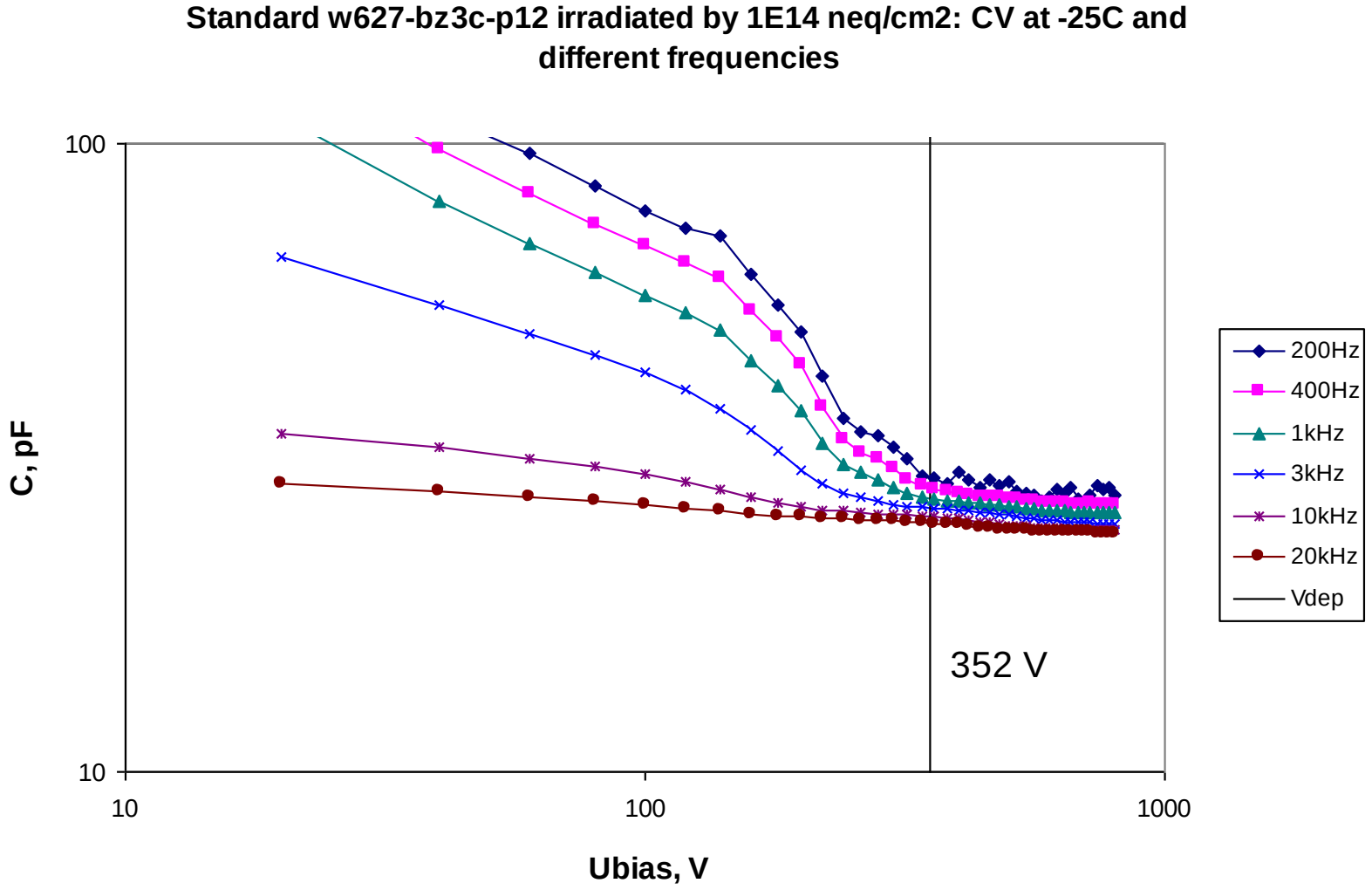
7. Conclusions

1. The currents in irradiated sensors are higher than anticipated from the pure bulk generation current.
2. Up to the fluence of 10^{14} neq/cm^2 the depletion voltage remains below 600 V. For higher fluence the CV measurements do not allow V_{dep} measurement.
3. The interstrip capacitance in irradiated sensors may exceed that before irradiation by ~20% at 1 MHz. The excess is even higher at 100 kHz.
4. For the fluence ≥ 10^{15} neq/cm^2 the interstrip resistance drops down to 0.3 -1 MΩ. However it is still large compared to the input impedance of the FE electronics which is of ~1 kΩ.
5. Up to the maximum investigated fluence of 5 10^{15} neq/cm^2 the punch-through protection structure of z3c type allows draining of 100 μA current with the DC voltage at the strip of less than 25 V.
6. The sensors remain fully operational up to the maximum investigated fluence.

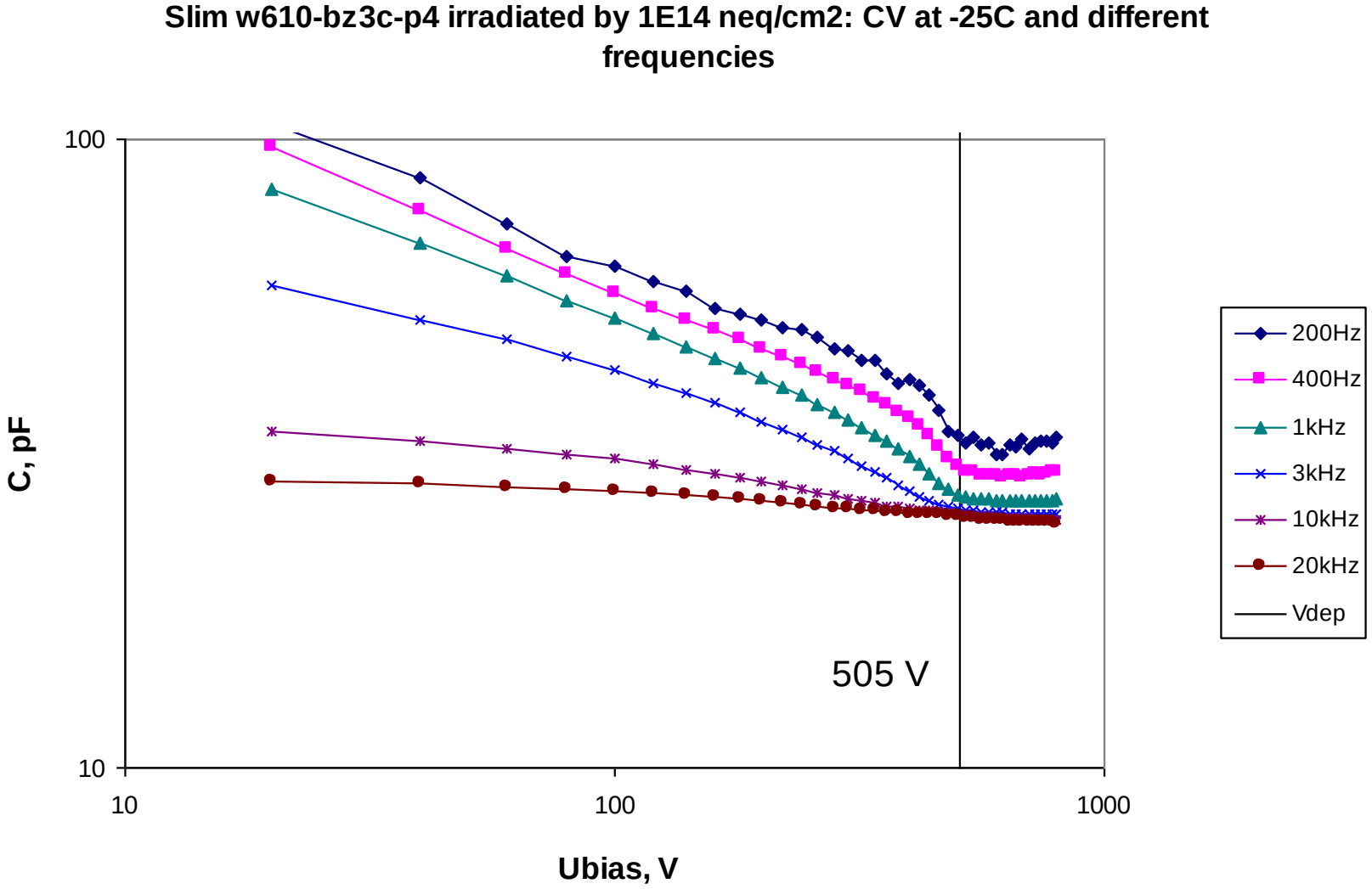
Backup slides



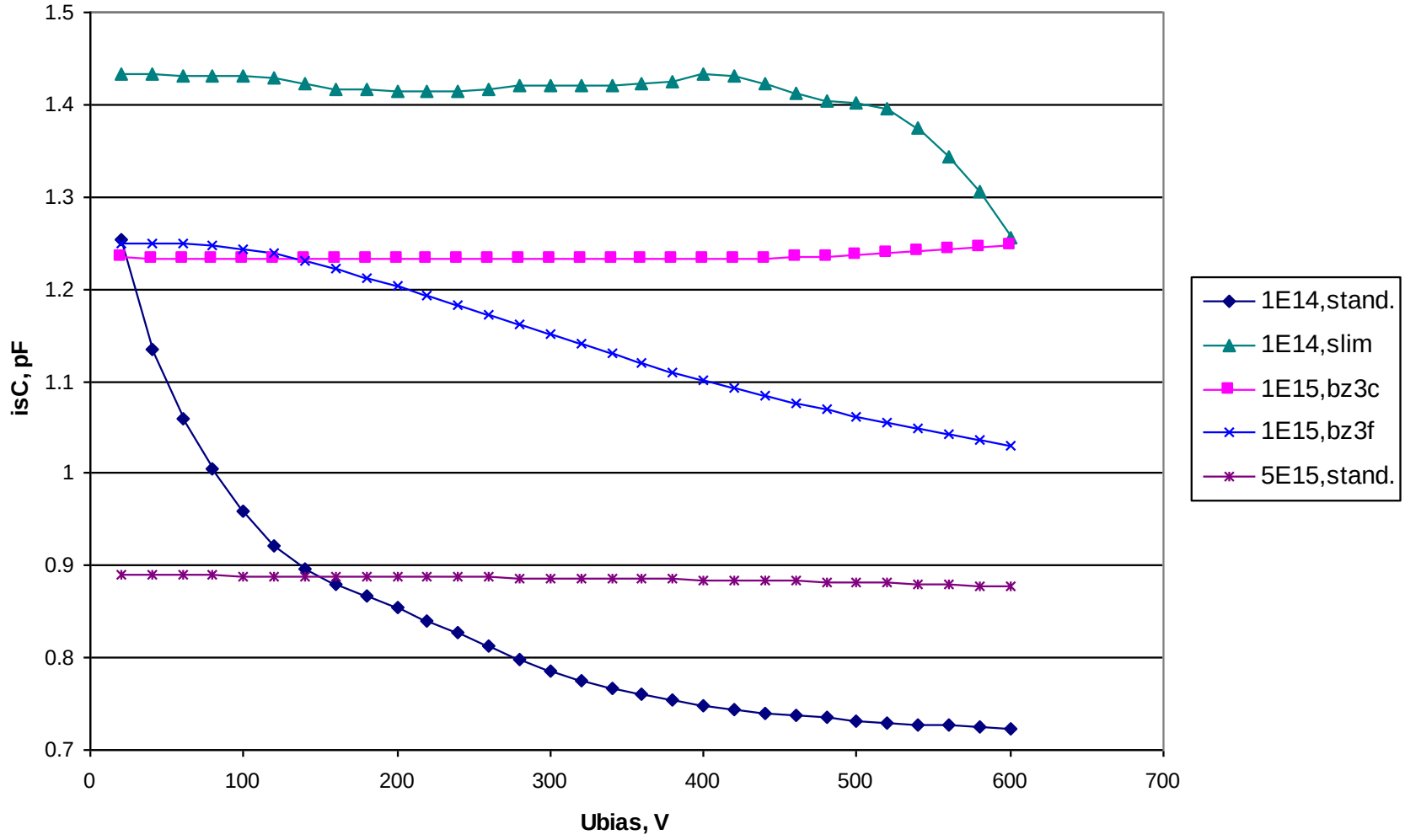
IV at -25°C and -35°C for the standard and slim sensors irradiated by 10^{14} neq.cm^2.
The correction coefficient expected for the bulk generated current is 3.6.

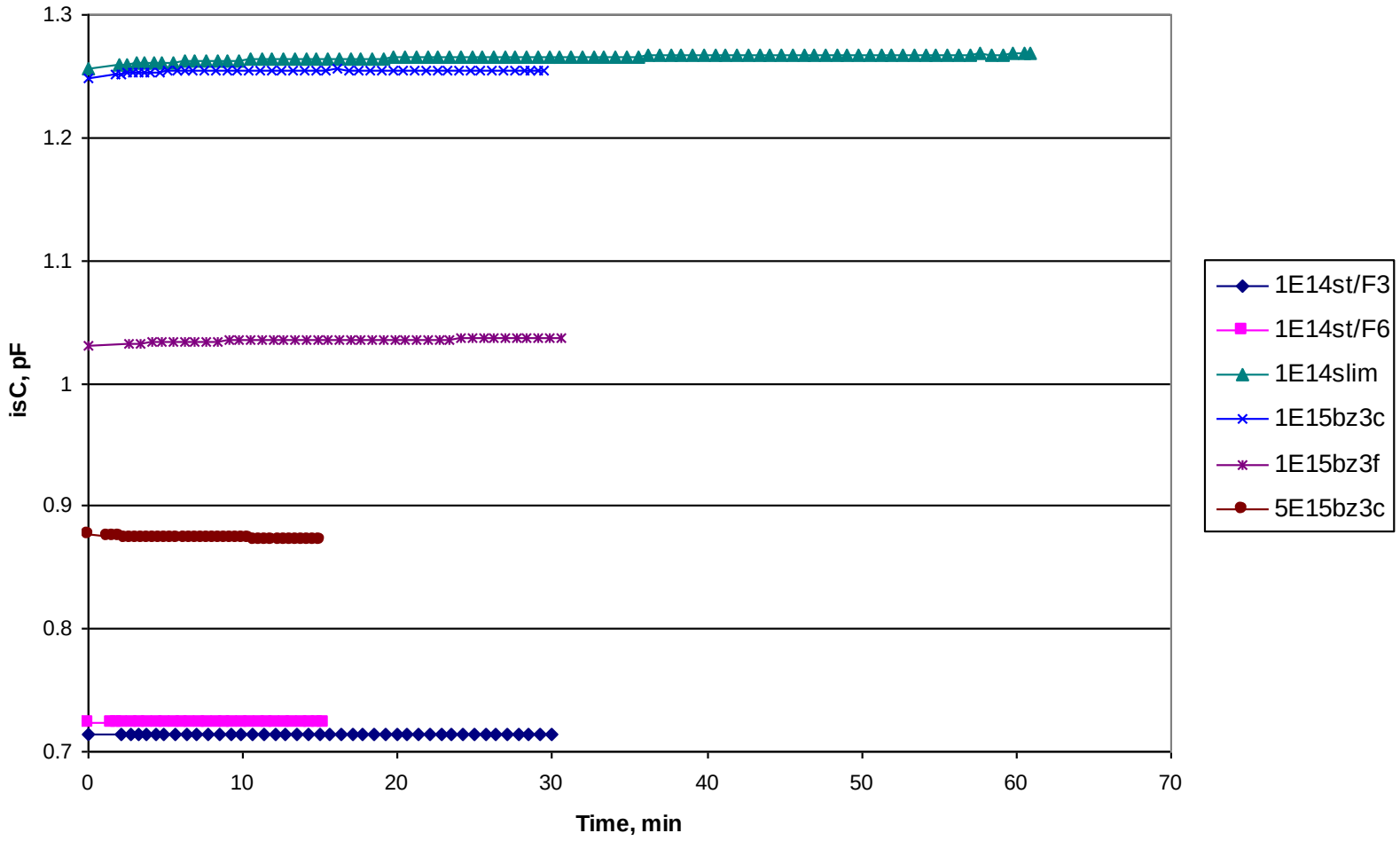


The C_s-V curves at frequencies from 200 Hz to 20 kHz for the standard edge sensor irradiated by 10^{14} neq/cm^2. The vertical line shows the “kink” position for the 400 Hz curve.

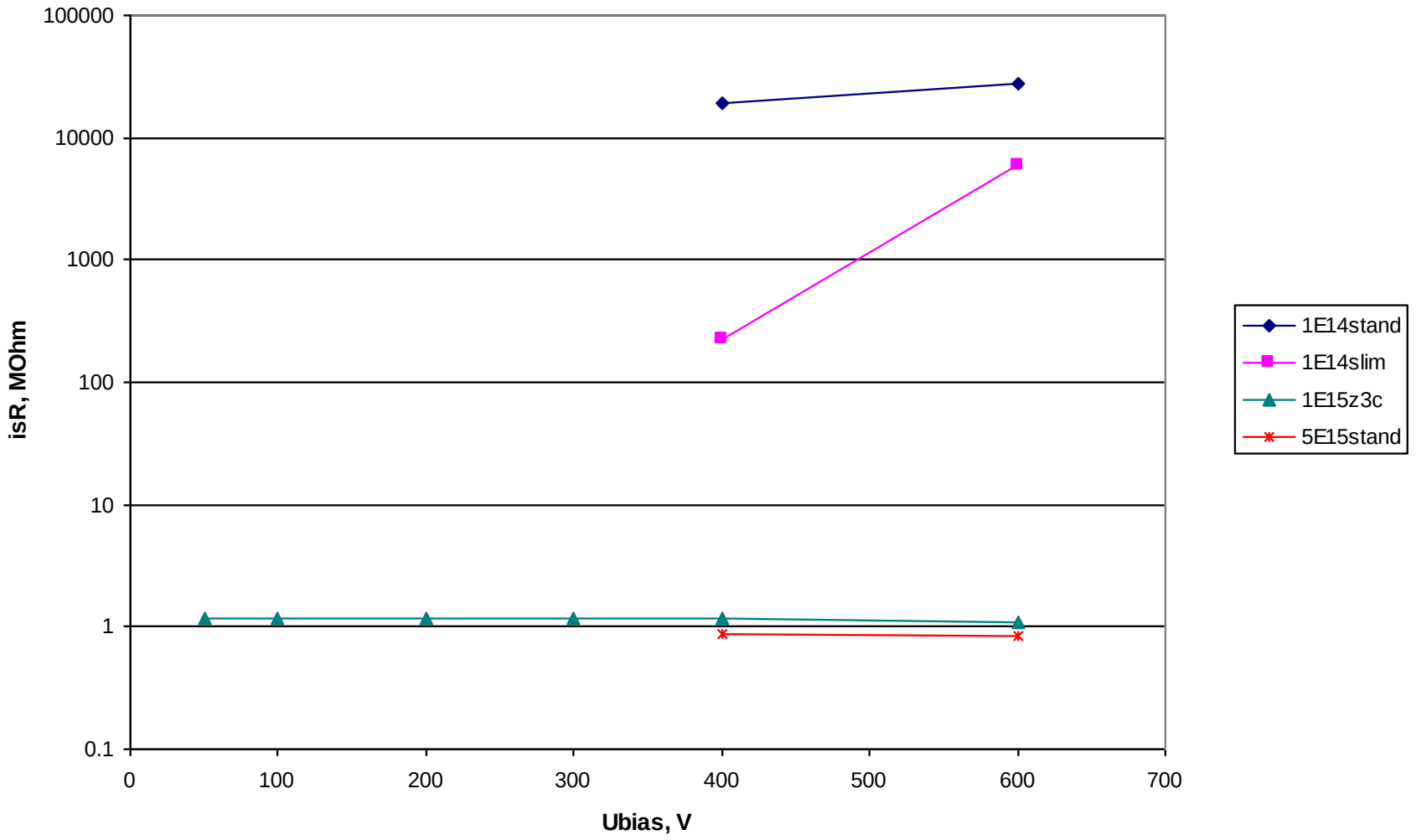


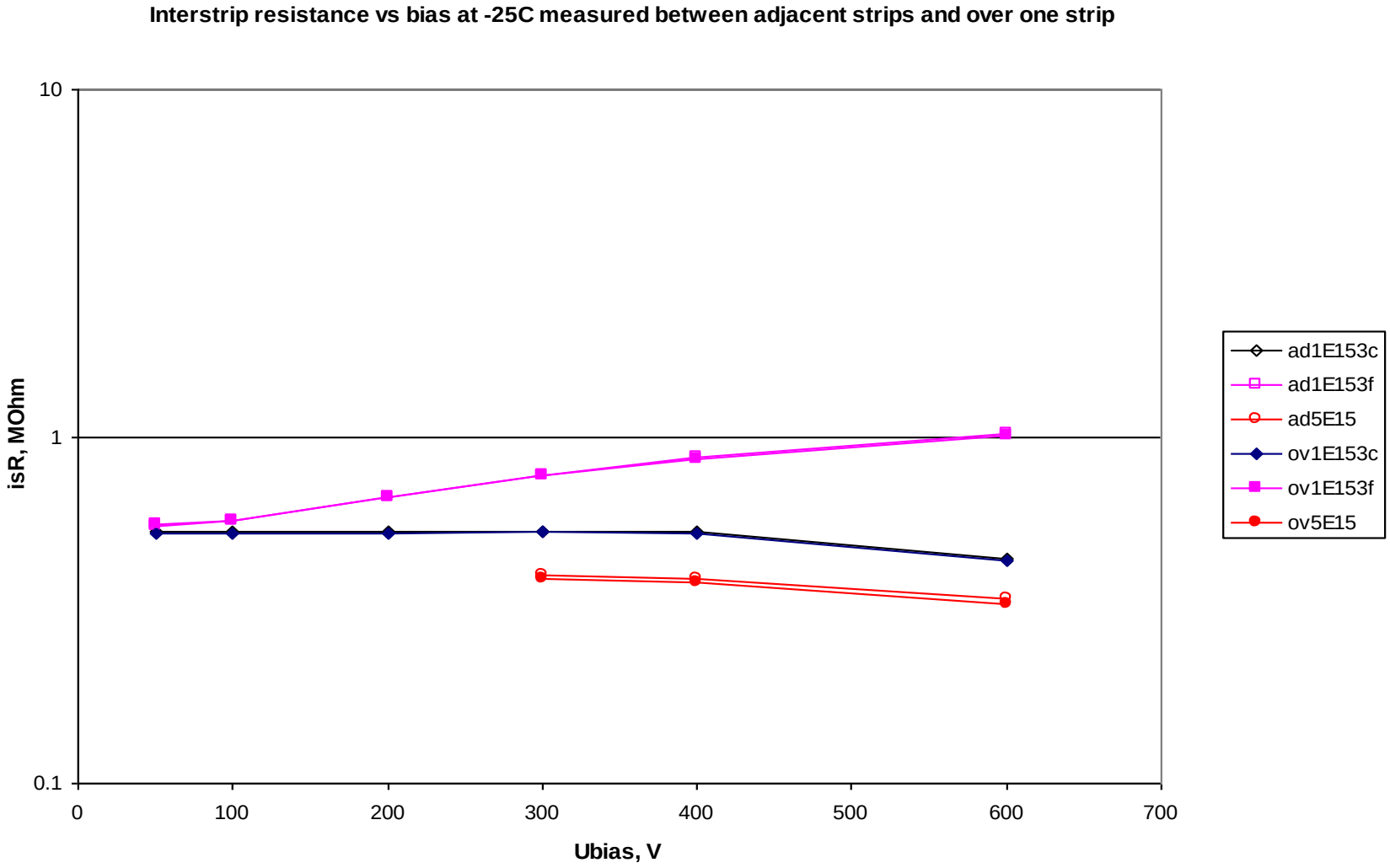
The C_s-V curves at frequencies from 200 Hz to 20 kHz for the slim edge sensor irradiated by 10^{14} neq/cm^2. The vertical line shows the “kink” position for the 400 Hz curve.


Interstrip capacitance vs bias at -25C for 100 kHz
isC, pF
Ubias, V
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0
100
200
300
400
500
600
700
1E14,stand.
1E14,slim
1E15,bz3c
1E15,bz3f
5E15,stand.

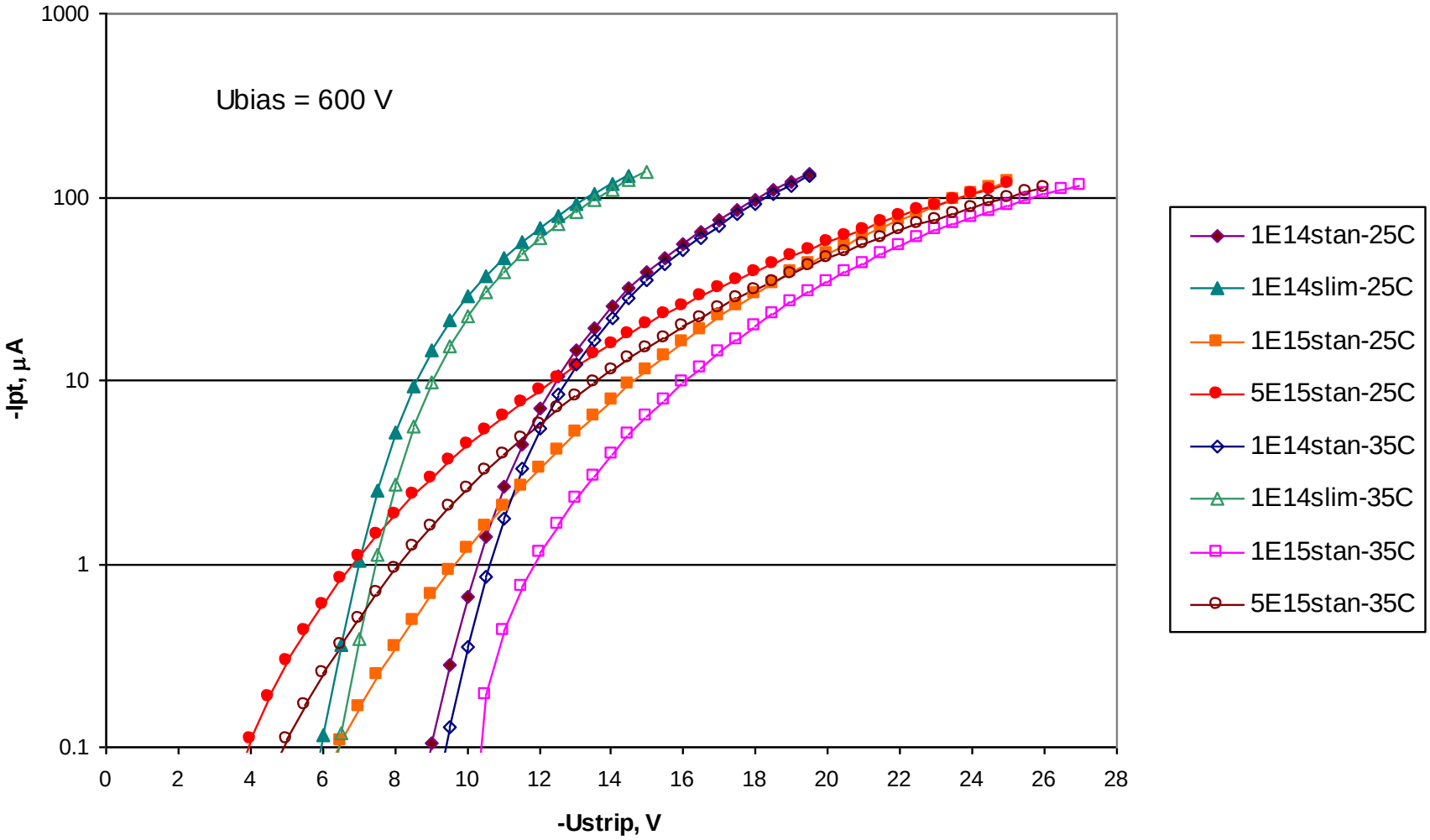


After the bias ramp the capacitance remained stable in time. Standard sensor irradiated by 10^{14} neq/cm^2 was measured in the test frame 3 with top HT contact and in the frame 6 with the backside contact. The results are close.


Interstrip resistance vs bias at -35C
100000
10000
1000
100
10
1
0.1
isR, MOhm
0
100
200
300
400
500
600
700
Ubias, V
1E14stand
1E14slim
1E15z3c
5E15stand



For low isR it can be measured not only by signal from the adjacent strip but also by that from the next neighbour. The results are close, which confirms the validity of the used simple model with equal isR between all strips.



The difference between the PT currents at -25ºC and -35ºC is small.