Update on Thin Silicon Detectors Results

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OUTLINE:

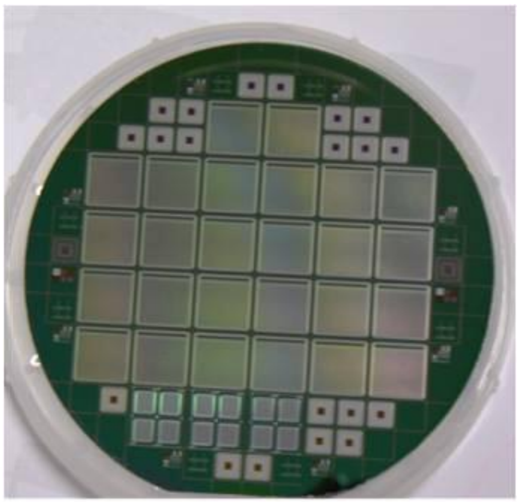
Silicon detectors are the choice for the present and future High Energy and, increasingly, Nuclear Physics experiments for Vertexing and Tracking.
The request for reducing the mass of these sensors, for a number of Physics reasons in the various application fields, get more and more pressing. Radiation tolerance is one of the aspects that these lower mass sensors will need.
Here I describe the radiation tolerance of different thicknesses silicon micro-strip sensors.

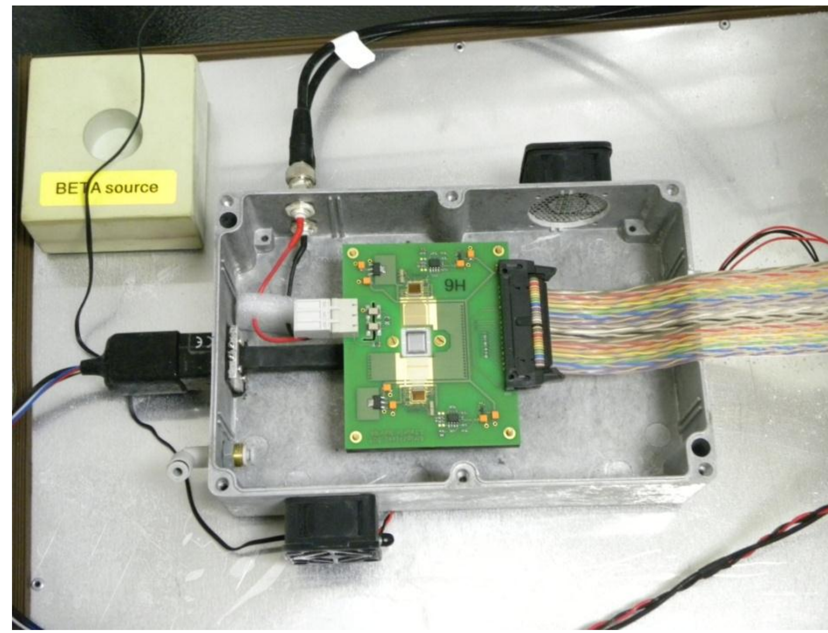
Low mass: a real need

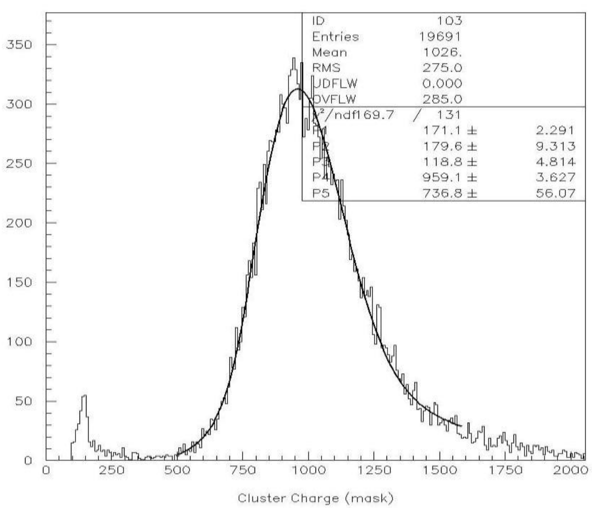
Future Vertex and Tracker detectors at the HL-LHC
E^+-e^- colliders
LHeC colliders
Nuclear physics experiments
B-factories ....
All these experiments would benefit (and some strictly require) very low mass sensors.

The method

Sensors made by Micron Semiconductor on 4” wafers with thicknesses 50, 100, 140, 300 μm. 1x1 cm^2, 80 μm pitch, n-in-p devices. The 50 μm thick would break (mechanically) when attached to the cooling block due to the different CTE. No measurements available after irradiation (when cooling is needed).







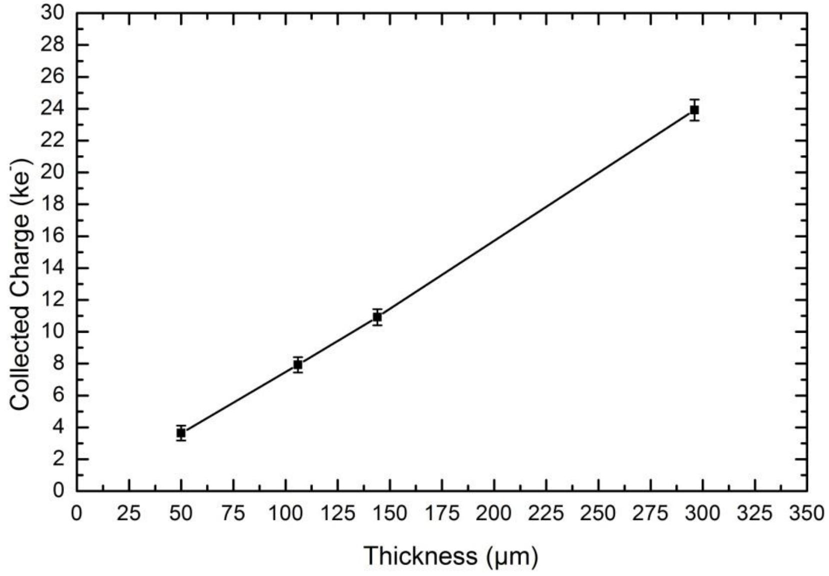
Mip signal from ^{90}Sr source

Analogue information from the Alibava board (equipped with Beetle chip)

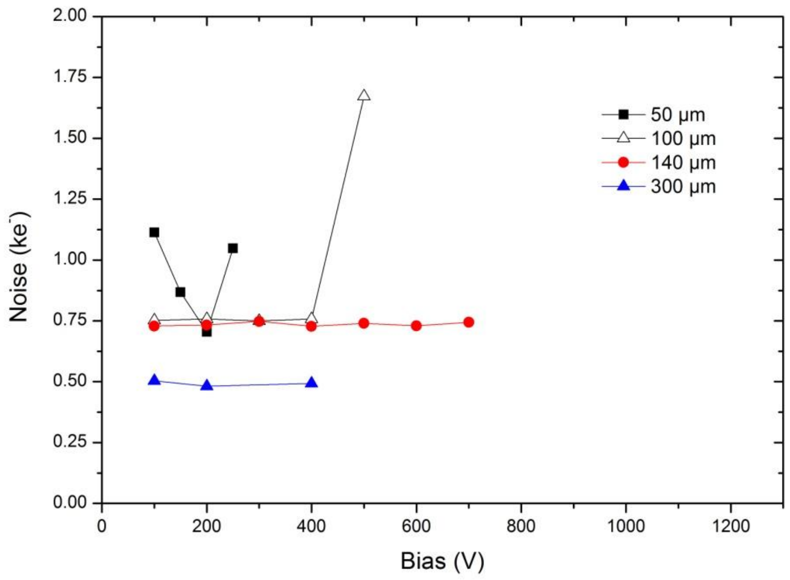
Irradiations performed in the JSI Ljubljana research nuclear reactor

Measurements before irradiation

Charge Collection vs Bias (CC(V)) for the 50, 100, 140, 300 μm un-irradiated sensors. As expected the signal varies linearly with thickness



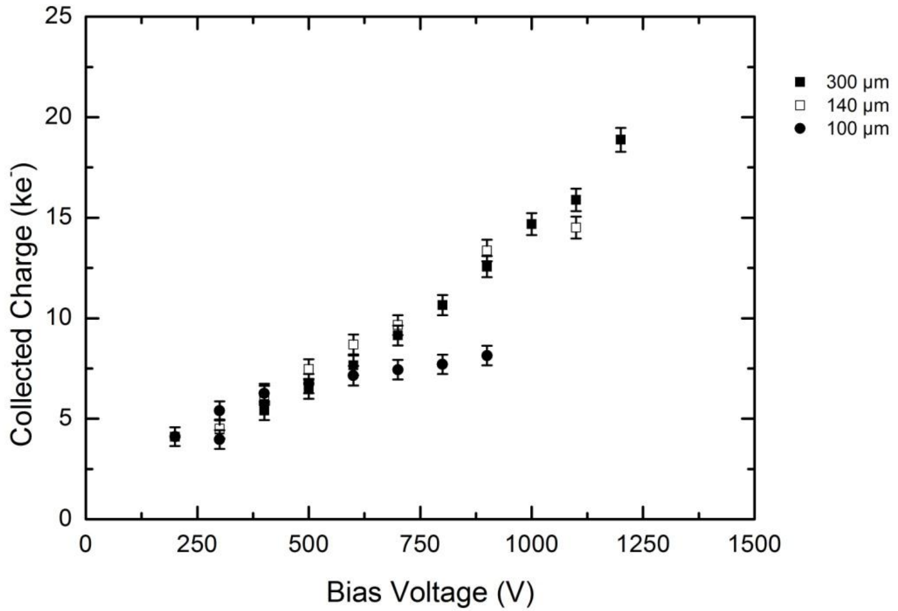
Noise for un-irradiated detectors of various thicknesses.



Degradation of the CC(V) with fluence

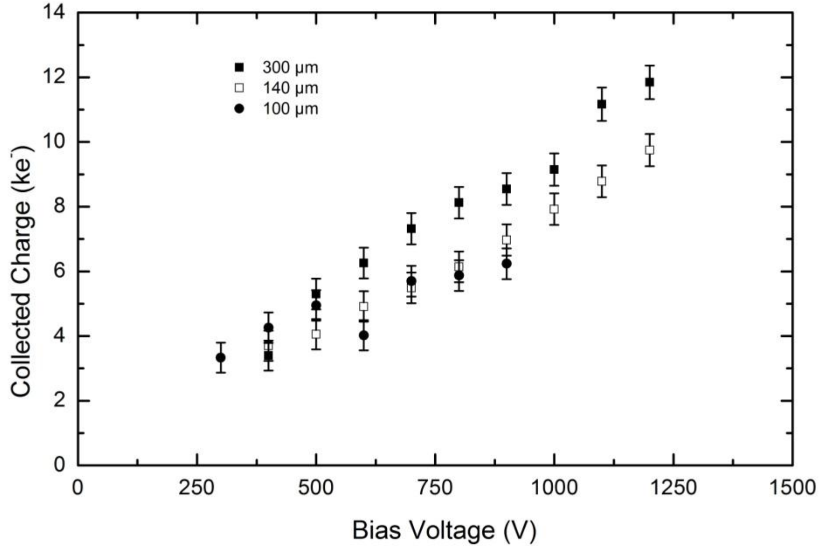
$2x10^{15}\ n_{eq}\ cm^{-2}$

Notice that the CC(V) for the 140μm thick sensor exceeds the expected charge ionised by a mip in that thickness of silicon.



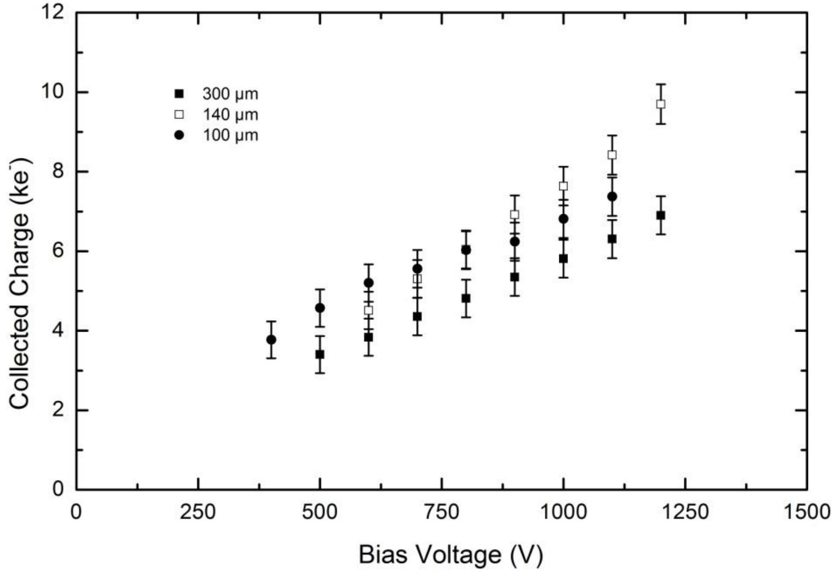
Degradation of the CC(V) with fluence

$5x10^{15}$ n_{eq} cm^{-2}

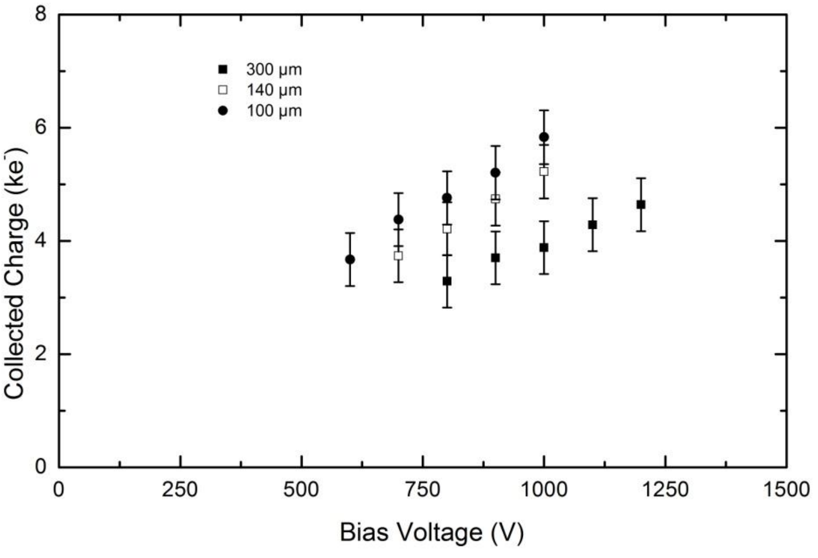


Degradation of the CC(V) with fluence

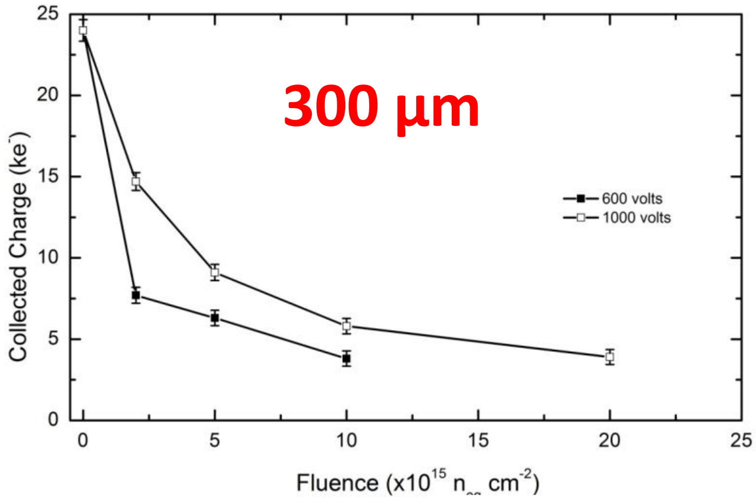
$1x10^{16}$ n_{eq} cm^{-2}

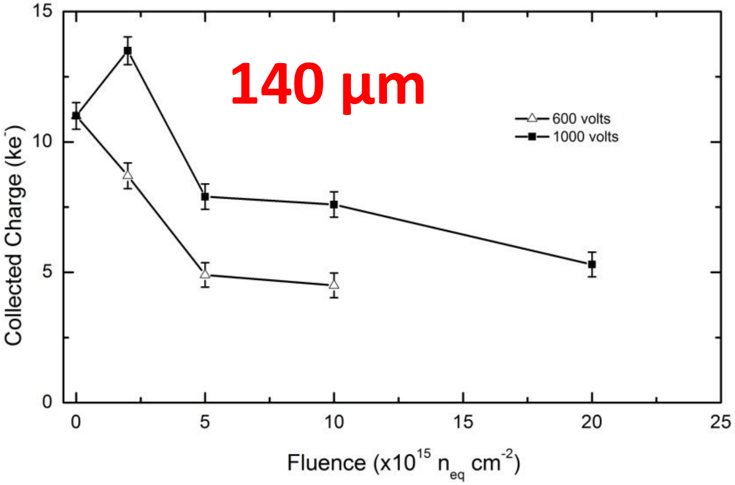


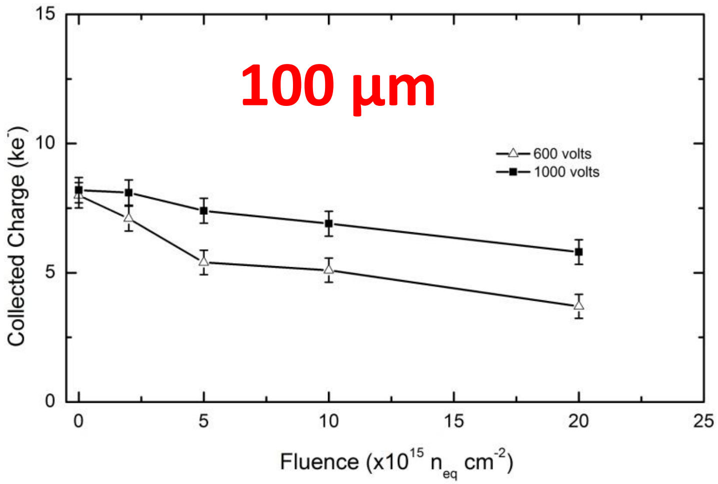
$2x10^{16}$ n_{eq} cm^{-2}



Degradation of the CC(V) with fluence at 600 and 1000V



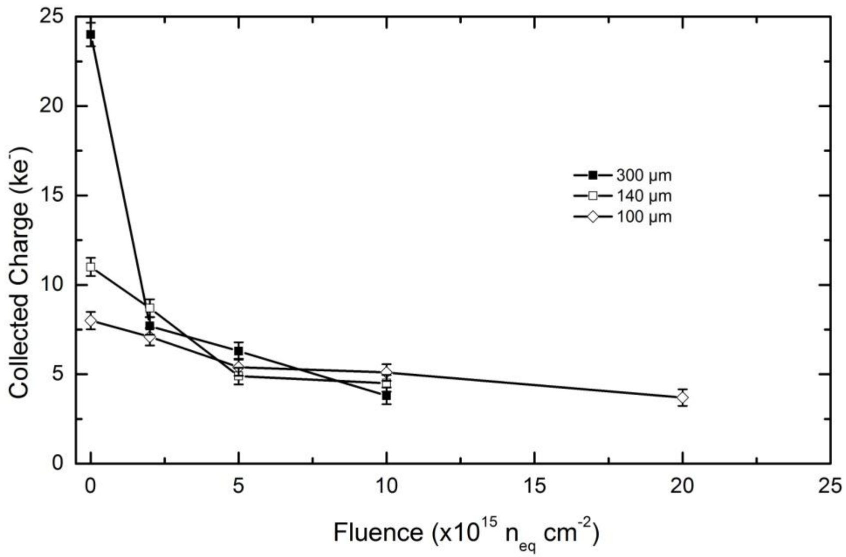


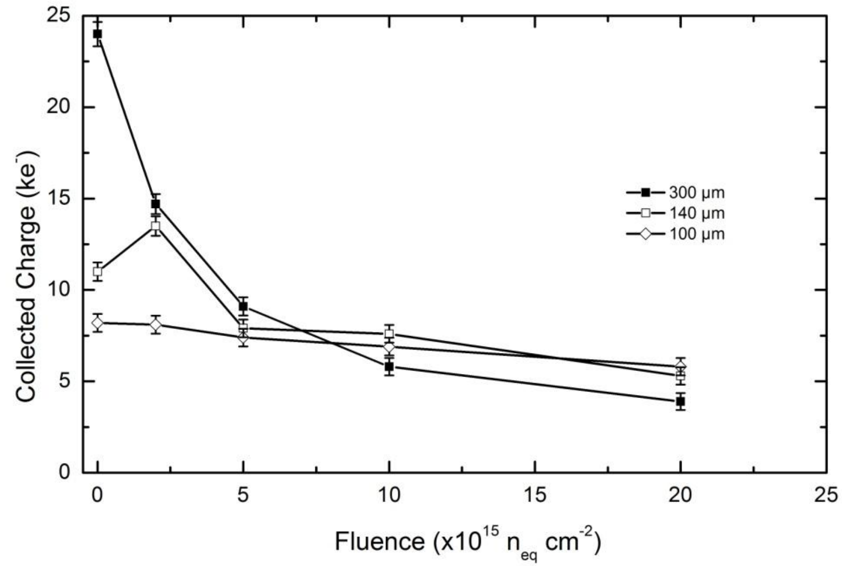


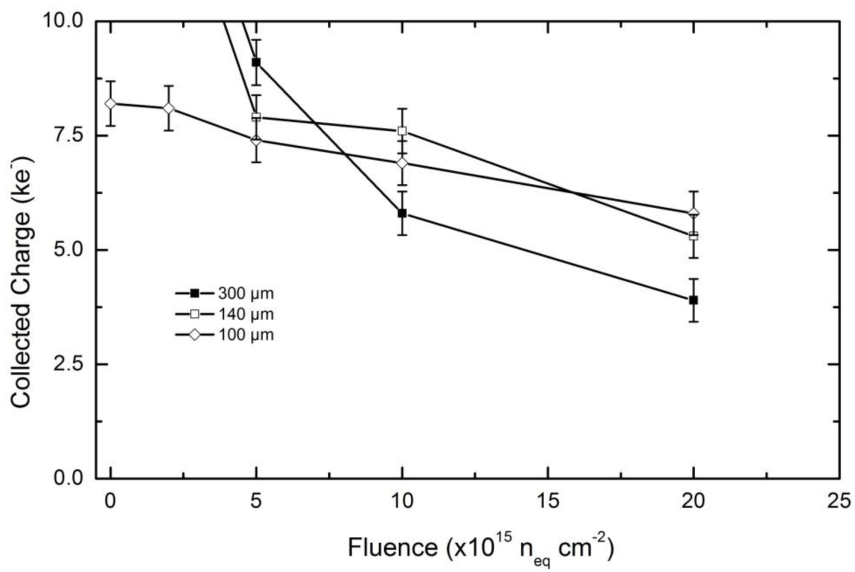
Degradation all thicknesses

1000 V

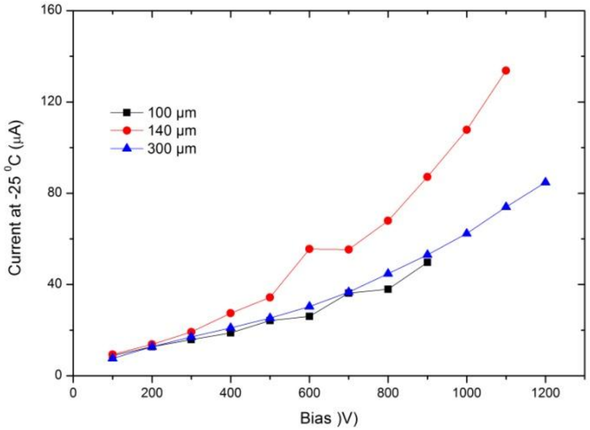
600 V

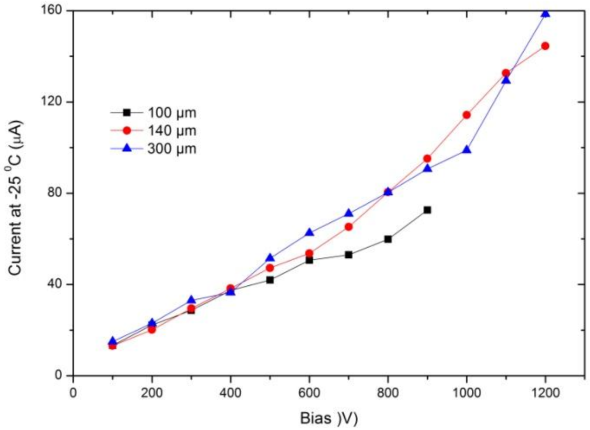


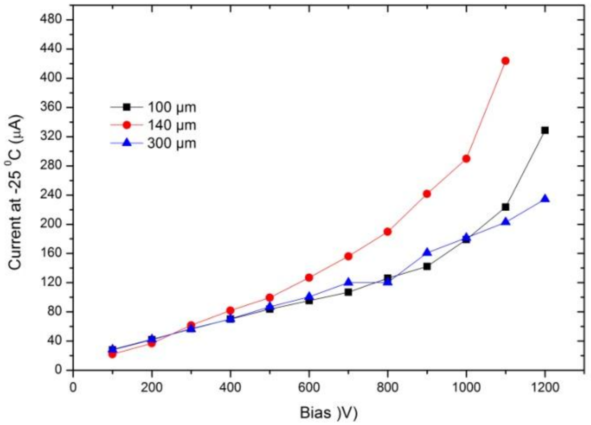


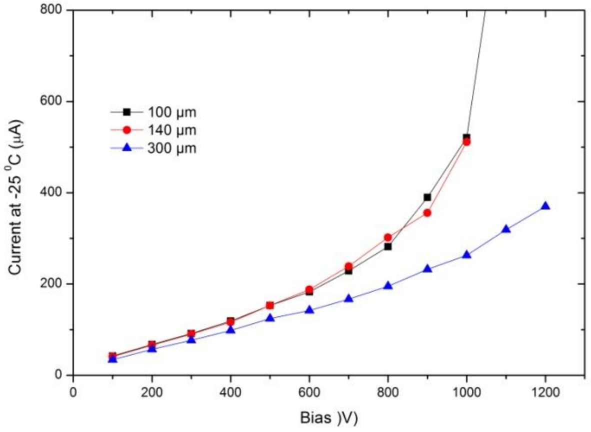


Currents after the various fluences

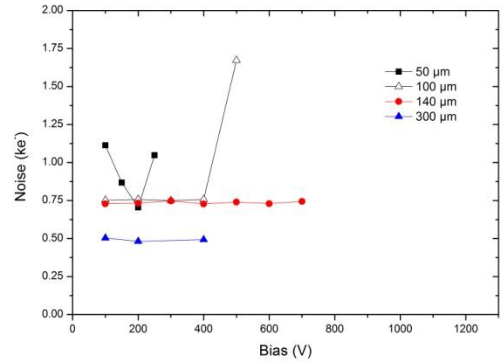




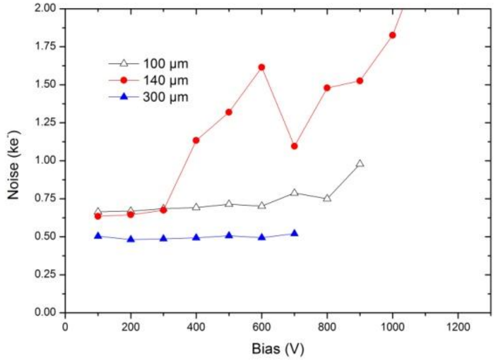




Noise



Noise (ke⁻)
Bias (V)
50 µm
100 µm
140 µm
300 µm



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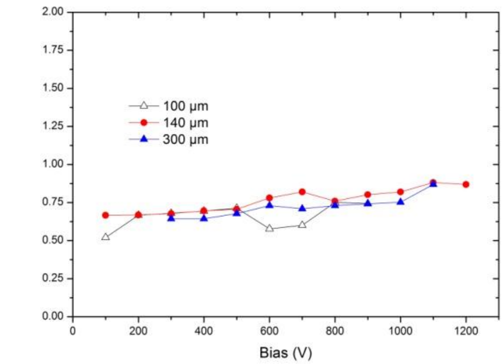

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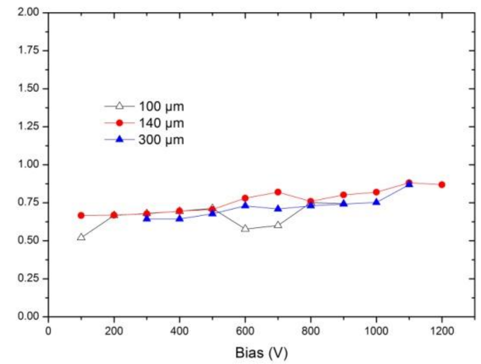

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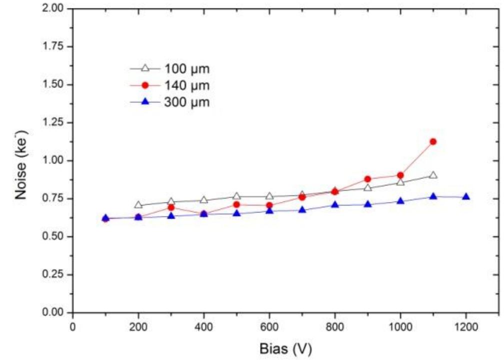

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Bias (V)
100 µm
140 µm
300 µm

CONCLUSIONS

Thin silicon sensors is an available technology. Pixel and microstrip sensors can be produced down to at least 50μm thickness.

It has been shown that thin sensors are offering advantages in term of radiation hardness with hadron irradiation. These advantages are substantial above 5E15 n_{eq} cm^{-2}. At doses below this (large) value, the 300 μm thick devices appear to perform similarly to the thinner sensors both in term of charge collection and reverse current. They have slightly reduced noise due to the lower input capacitance.

At extreme doses the thin sensors offer rather consistent advantages, increasing the signal collected at ‘lower’ voltages. It has been shown that 100 μm thick sensors can detectably outperform the 140 μm thick ones. Thinner sensors have not been measured after irradiation due to mounting problems and operation in cold. These measurements are planned soon to provide reference data for the thin sensor option after large hadron doses.