Charge collection and C-V

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The SMART Collaboration

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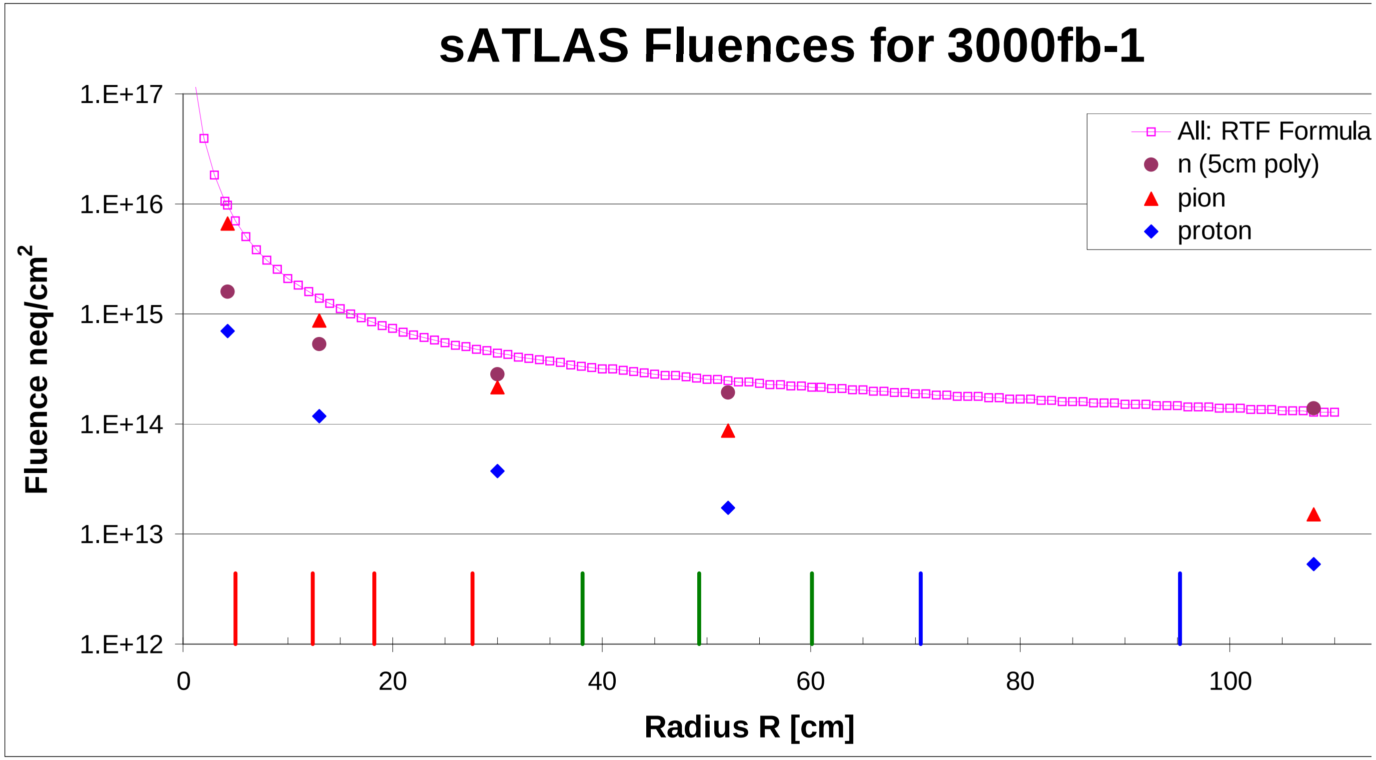
ATLAS Upgrade Design for:

$1*10^{15}$ neq/cm^2 short strips, $4*10^{14}$ neq/cm^2 long strips

(includes 2x safety factor)

New: p-type, neutrons



Depletion: C-V and CCE: Temp and Frequency

C(V) ~ 1/d

CCE(V) ~ d   expected collected charge = 3.5 fC*C_o/C(V)

At low temps, use low frequency! RT: 10 kHz,-10^o C: 400 Hz, -20^o C: 250 Hz

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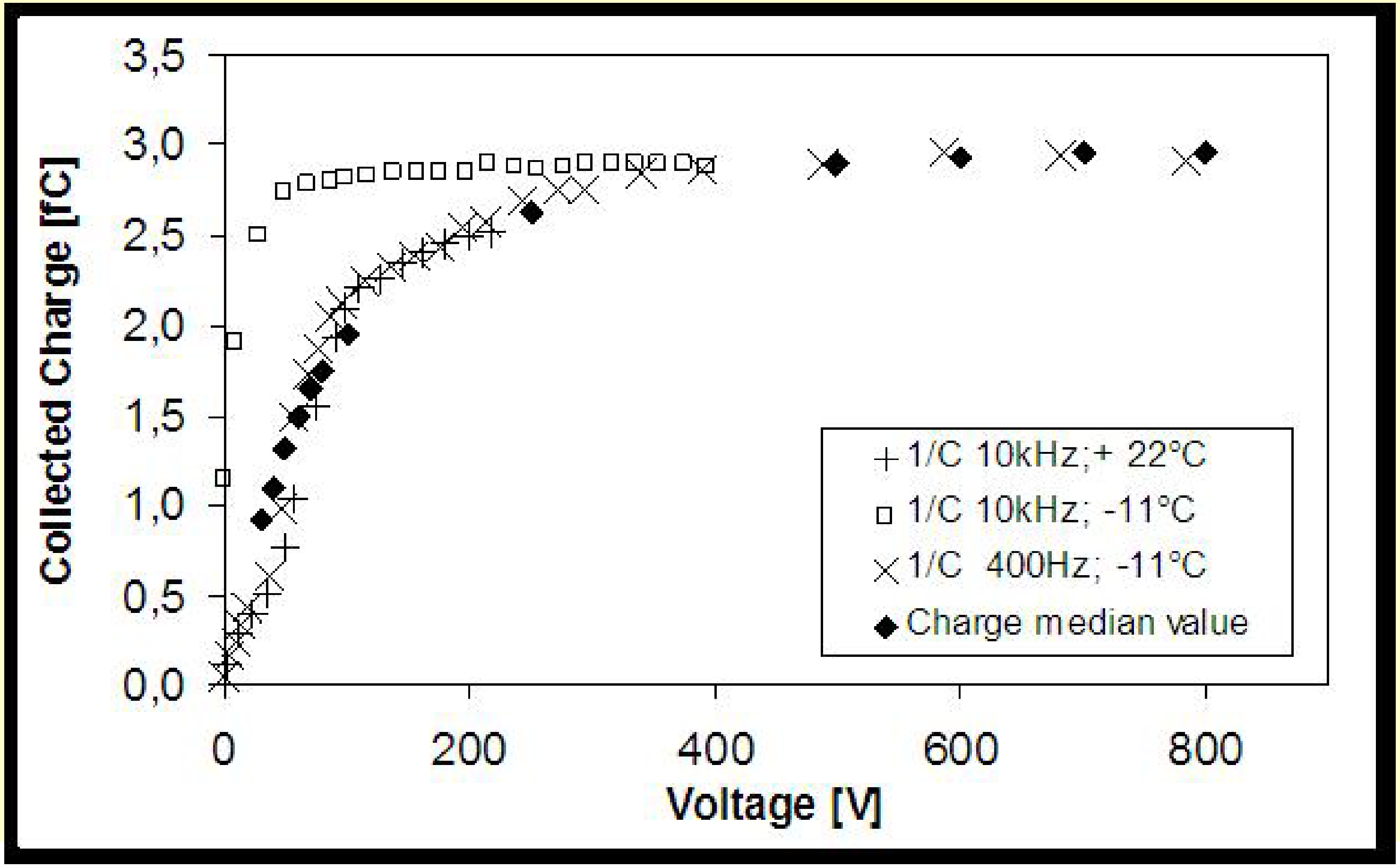
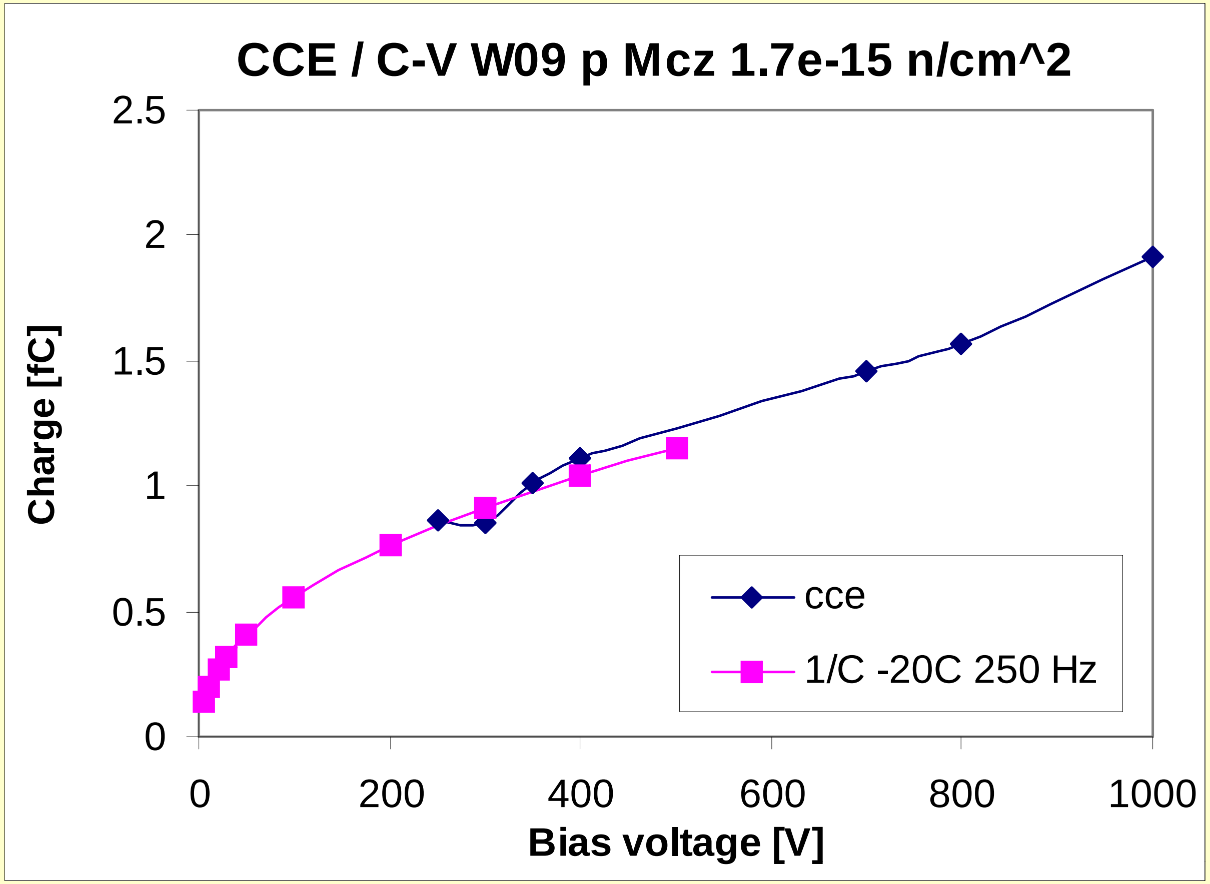


Neutrons

SCIPP Measurements on p-type MCz with neutron irradiated sensors.

Absolute prediction of 1/C

Agrees well with CCE



Neutrons vs. Protons?

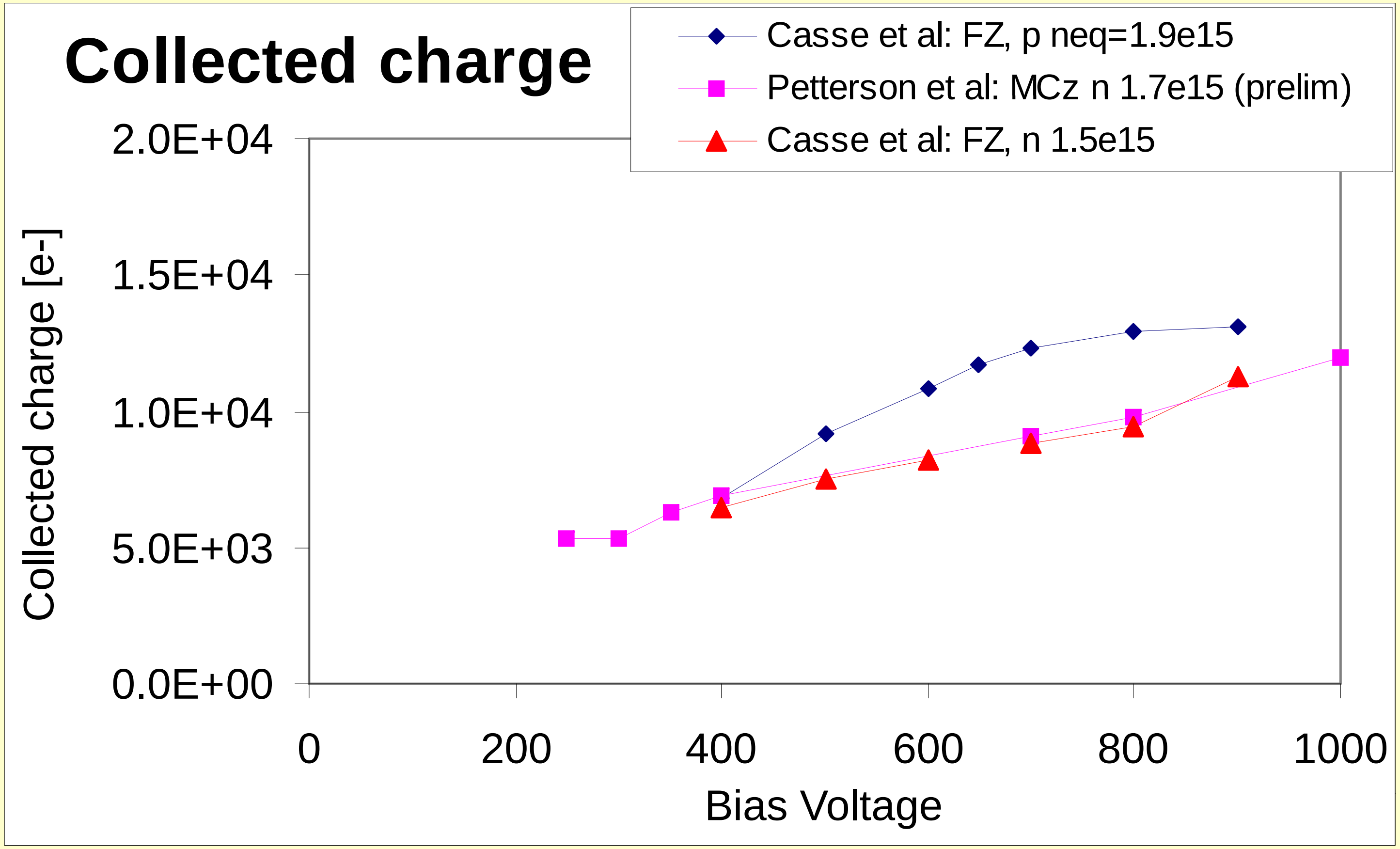
Caveats:

Binary vs. Analog (Single-strip vs. Sum?)

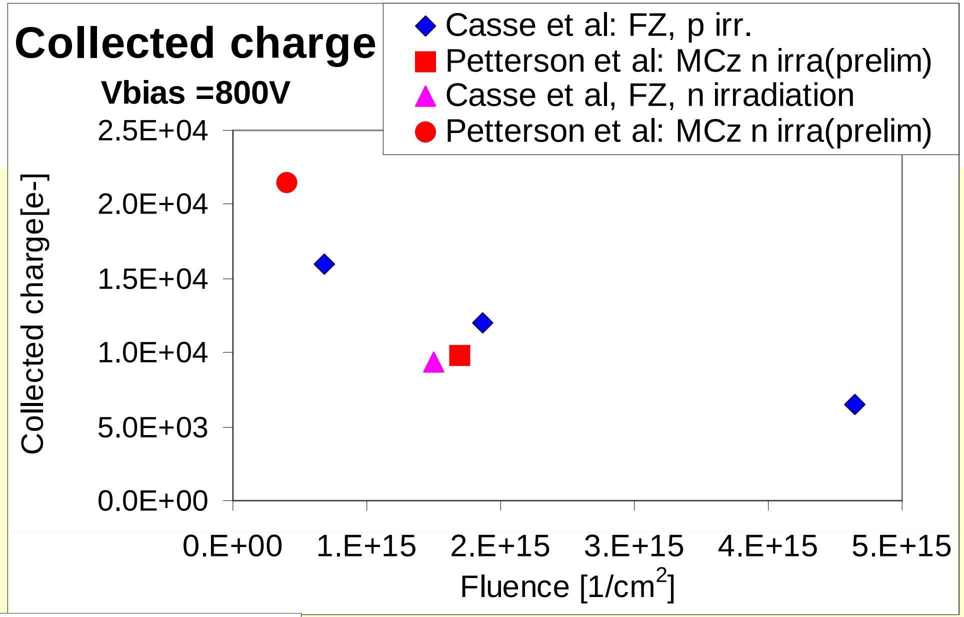
Median vs. Most probable

FZ vs. MCz, Starting Depletion Voltage

100 ns vs. 25 ns



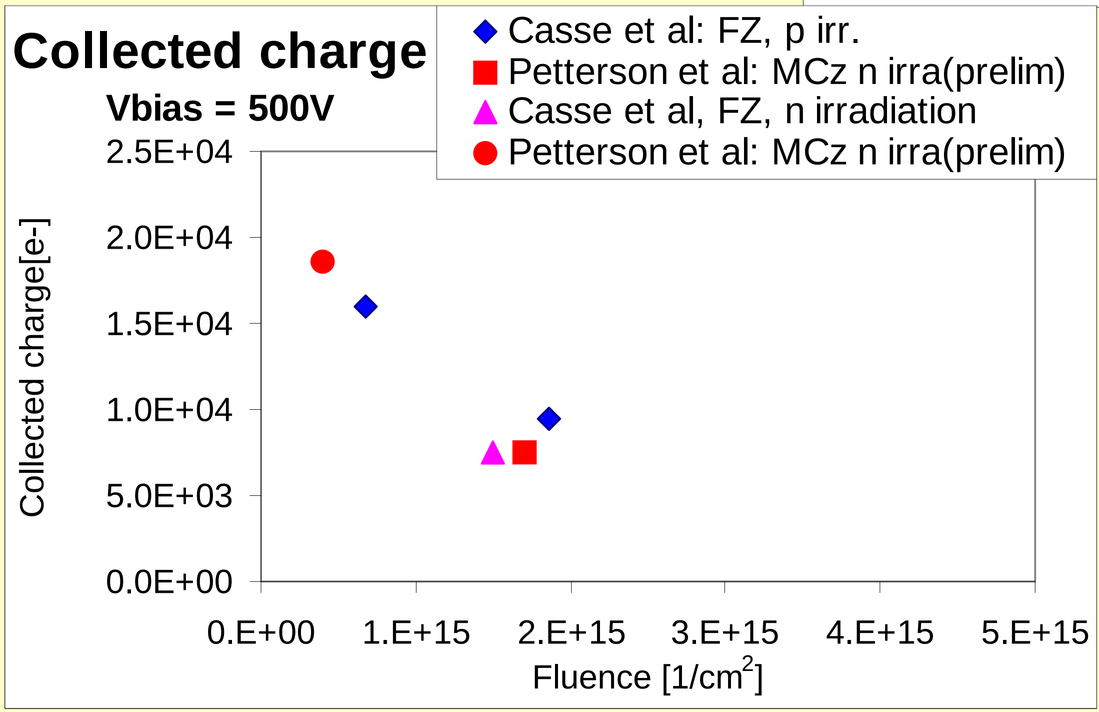
Charge collection



Short strips:

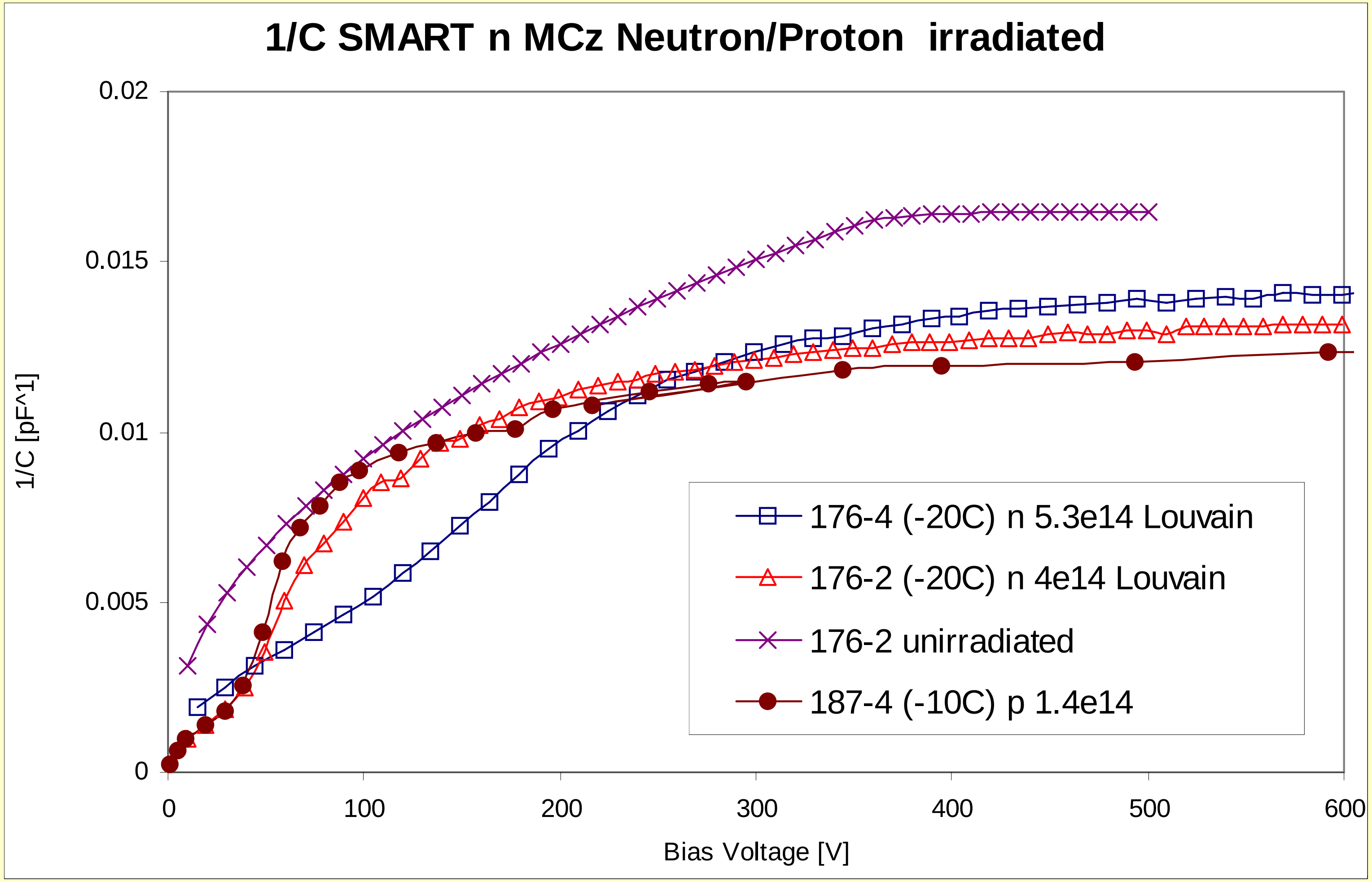
At target fluence and 500V Bias:

Sufficient yield for good signal-to-noise



Wafer: n MCz

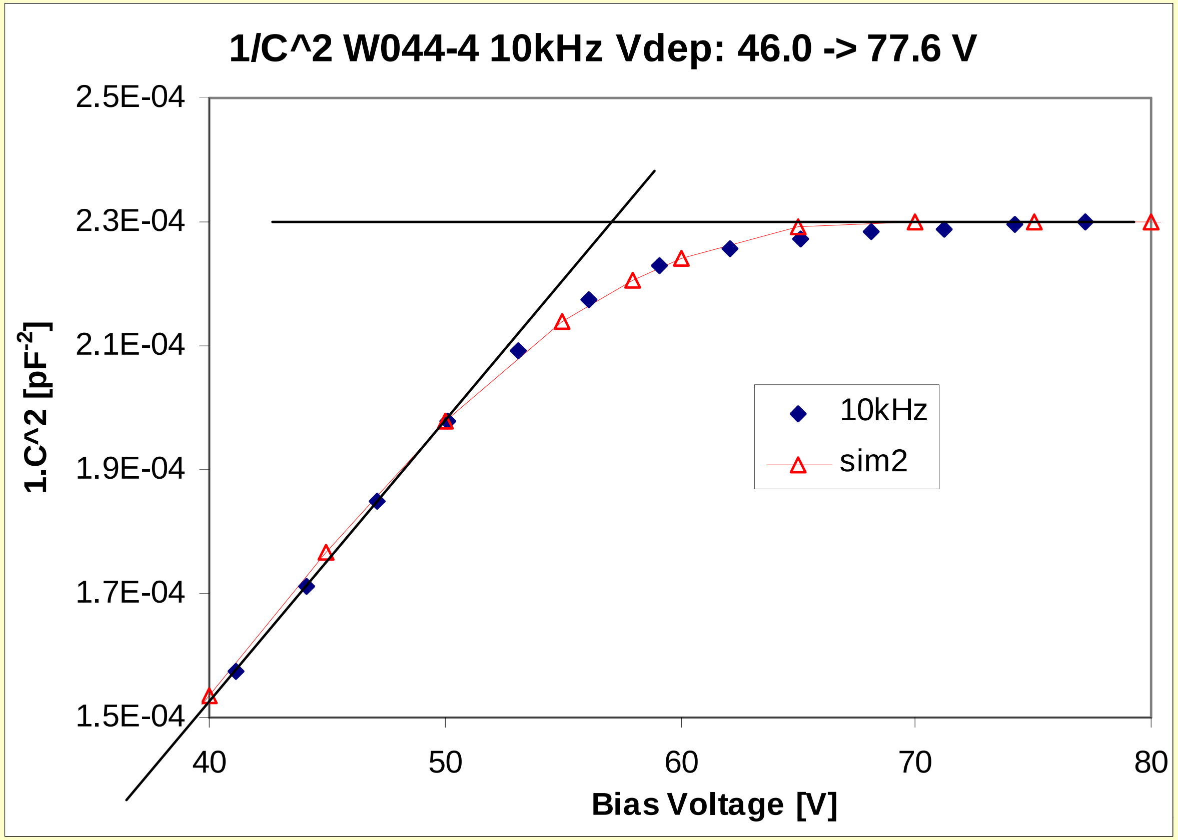
Evidence for Double-Junction instead of “Inversion”.



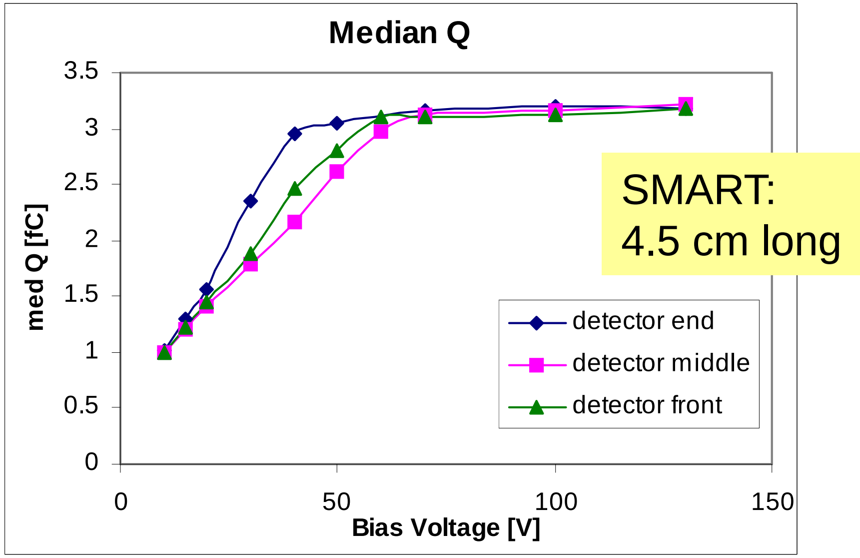
Wafer: MCz SMART

Non-uniform doping density in MCz:

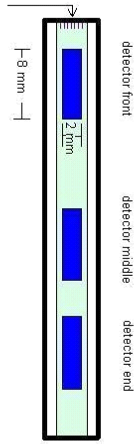
Simple simulation of parallel capacitors with different depletion voltages reproduces the $1/C^2$ curves.



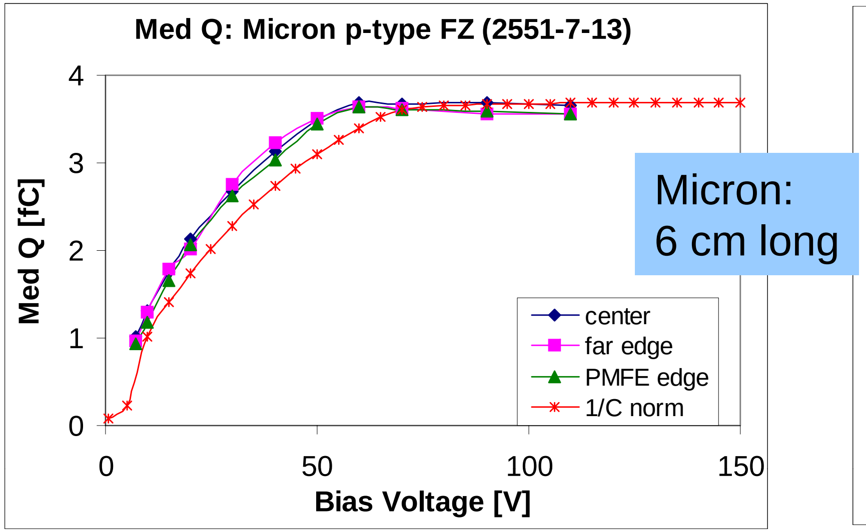
MCz Wafer Uniformity with CCE: SMART vs. Micron

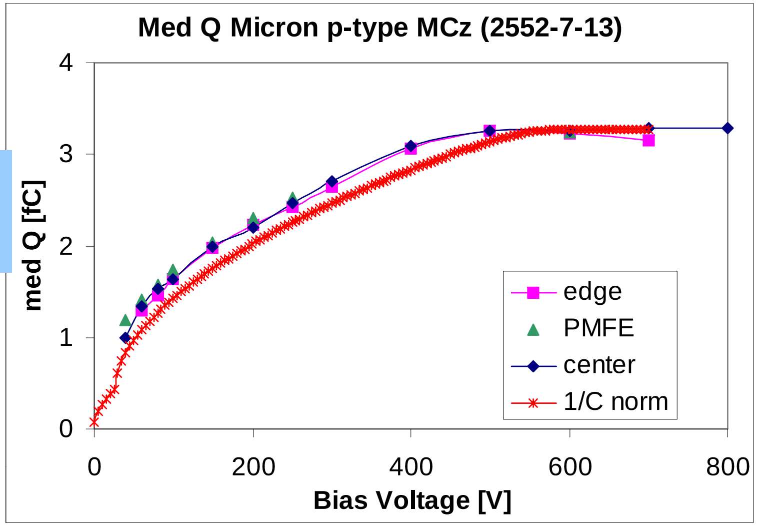


Charge collection at 3 positions along strips:

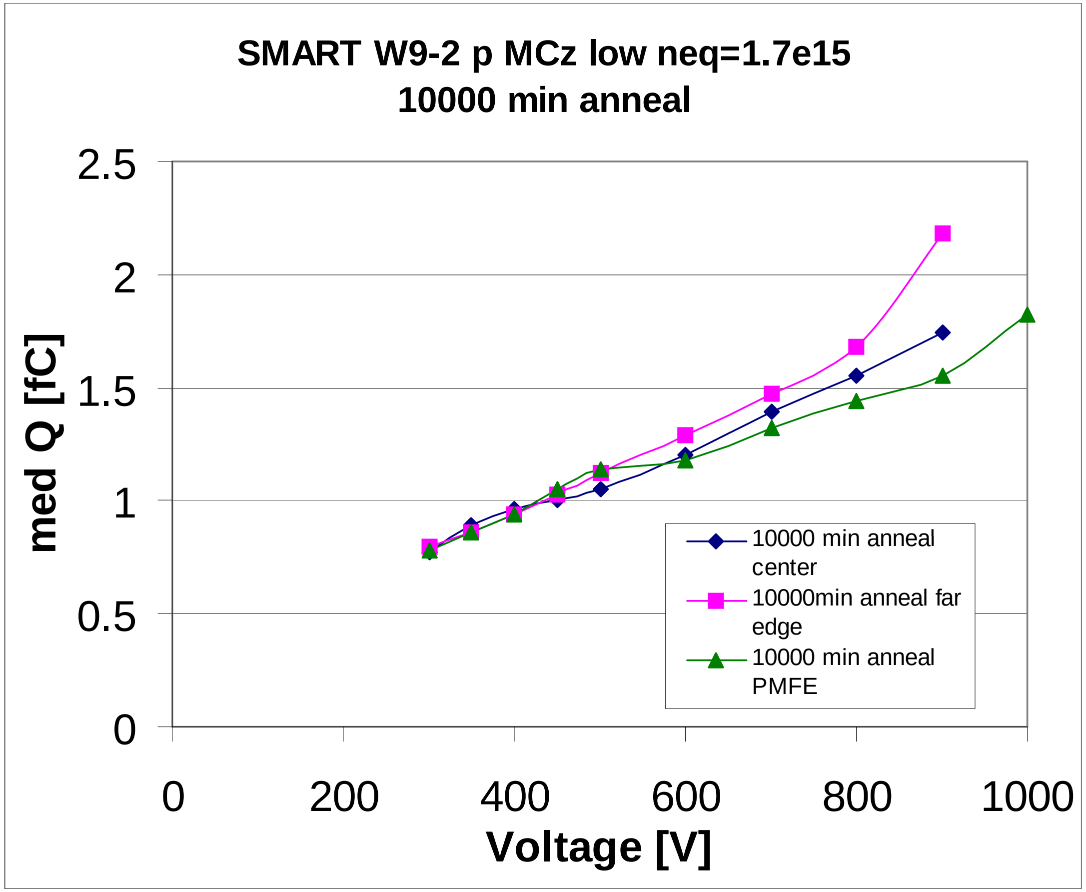


Micron has excellent uniformity along strips and across the wafer

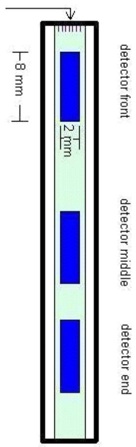




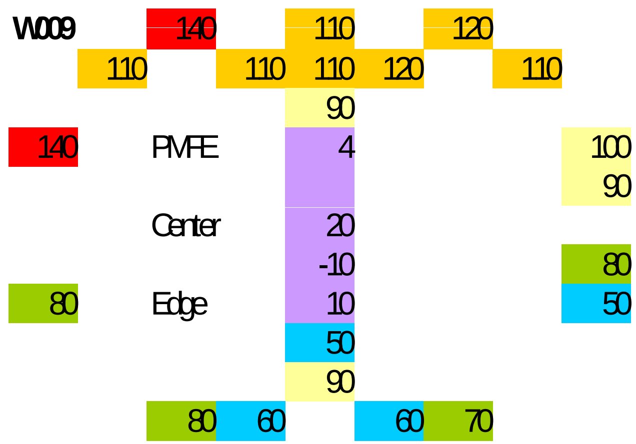
MCz Wafer Uniformity with CCE: Post Neutron Irradiation



Charge collection at 3 positions along strips:



SMART:
4.5 cm long



Depletion Voltage non-uniform even after 1.7e15 neq/cm^2
→ Original doping density matters!

Annealing

New data: CCE annealing for n-type and p-type MCz similar time structure as C-V

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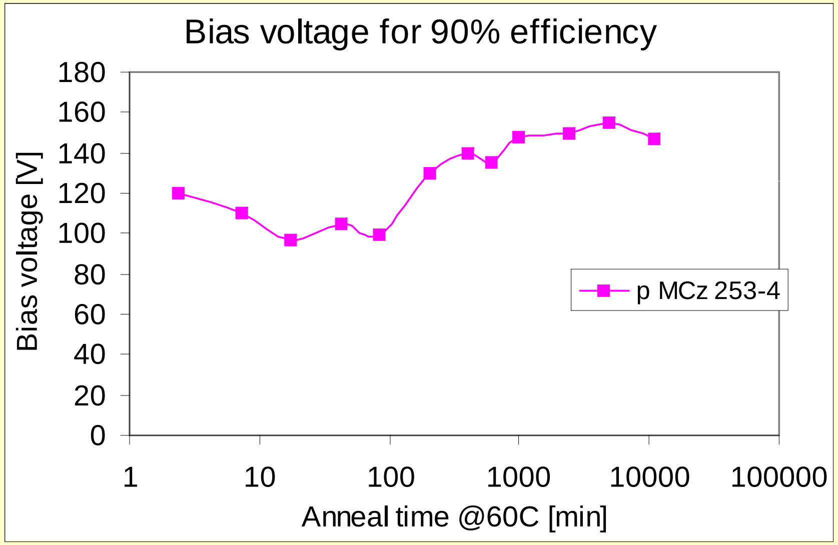
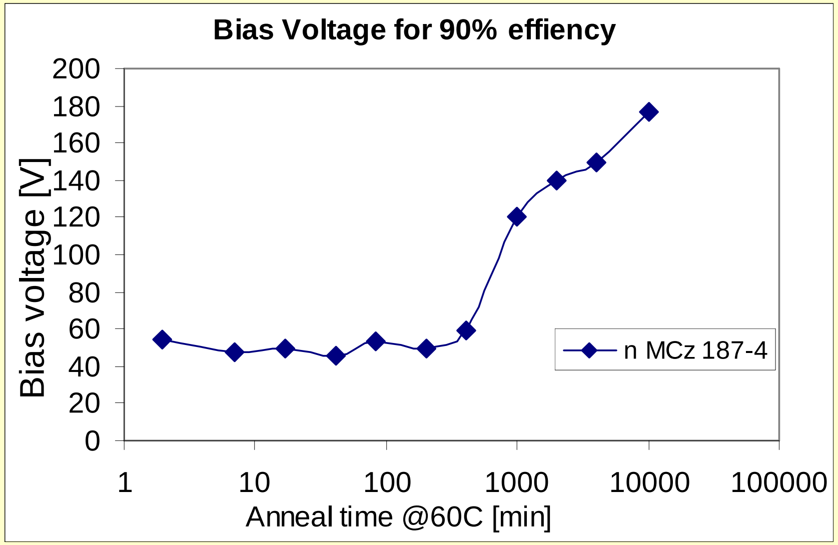
Irradiated with 26 MeV p
to ~2*10^{14} cm^{-2}
Binary readout 100ns,
^{90}Sr beta source

1000min @60 ºC = 514 days @RT





Annealing

CCE annealing for p-type MCz after 1.7e15 neq/cm^2

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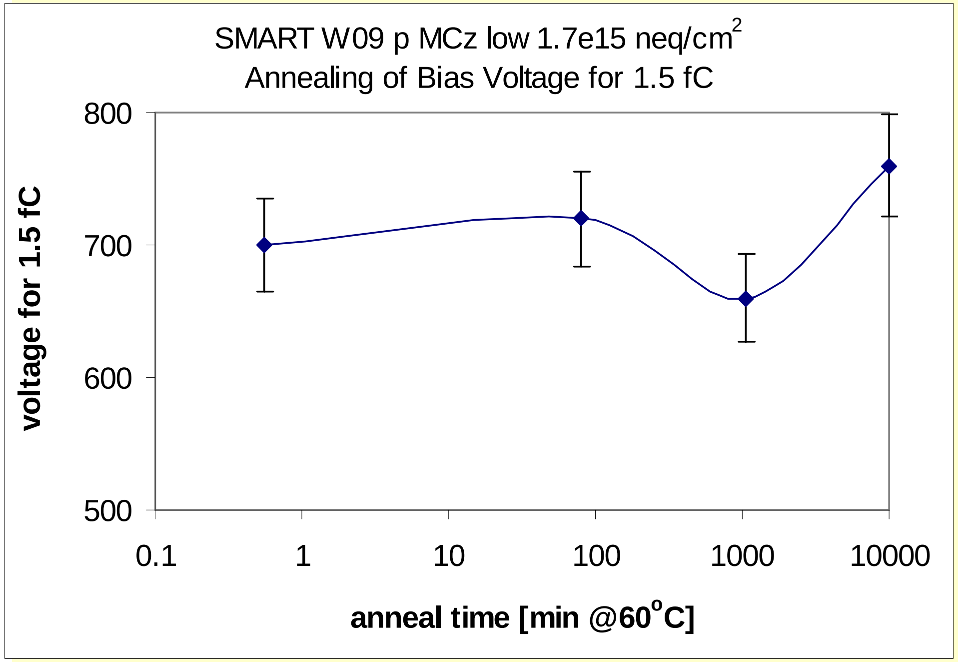
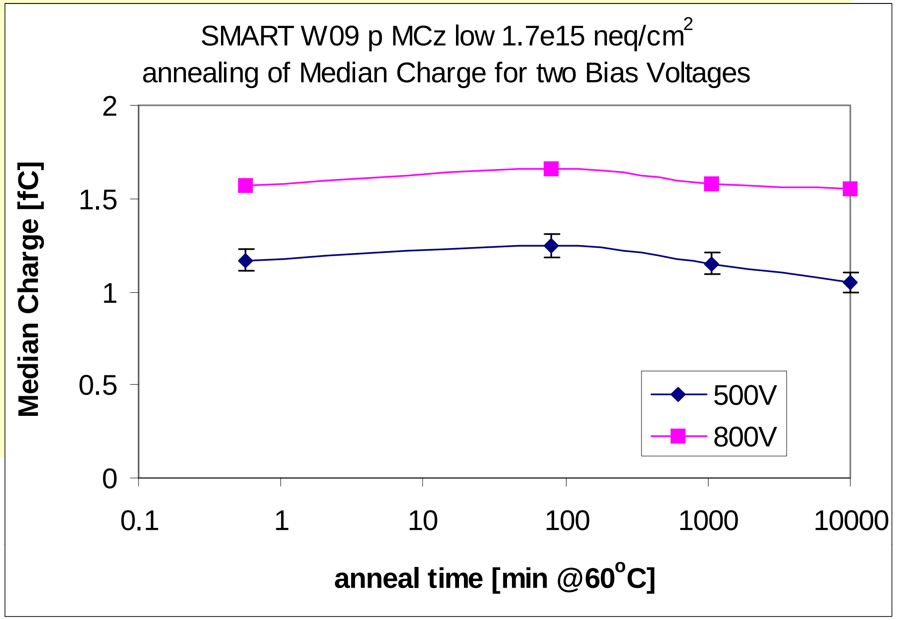
Irradiated with reactor neitrons
to ~1.7*10^{15} cm^{-2}
Binary readout 100ns,
^{90}Sr beta source

1000min @60 ºC = 514 days @RT



Very little annealing
even at high neutron fluences



Conclusions

ATLAS Upgrade expected Fluence 5e14 neq/cm^{2},

Design for 2x larger fluence => good S/N expected

Find good agreement between CCE and 1/C if measured at low f, low T.

Intense Program to understand neutron damage, about 20% worse than protons?

Very little annealing of CCE for p-type MCz after 4e14 and 1.7e15 neq/cm^{2}

Thanks to RD50 collaborators in Ljubljana and Louvain
for efficient and (for us painless) irradiation