Field and Charge Collection studies on pion irradiated p-type Float Zone strip detectors

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18th RD50 Workshop, Liverpool, 23-25 May 2011

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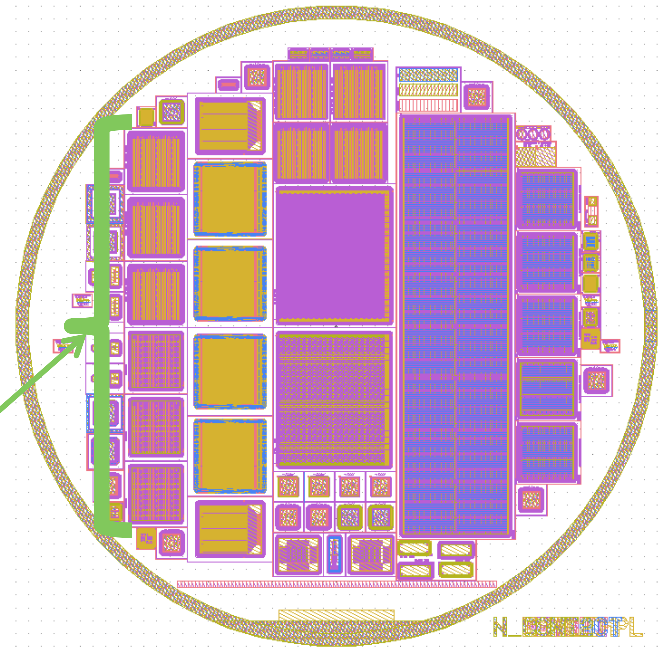
Motivations

- Studying field profile characteristics of FZ-p type silicon irradiated with pions
- Correlation of field profile development with Charge Collection Efficiency within the detector
- Comparison of the results with literature results obtained with different techniques on different structures (diodes)

Added later on:

Investigating the influence of potential other parameters on the development of detector profiles…

Studied Material:



Producer:

CIS pixel/strips production 2009

Material:

FZ n-on-p
Thickness 285 um
Initial resistivity > 10 kOhm
Initial V_dep 35-40 V

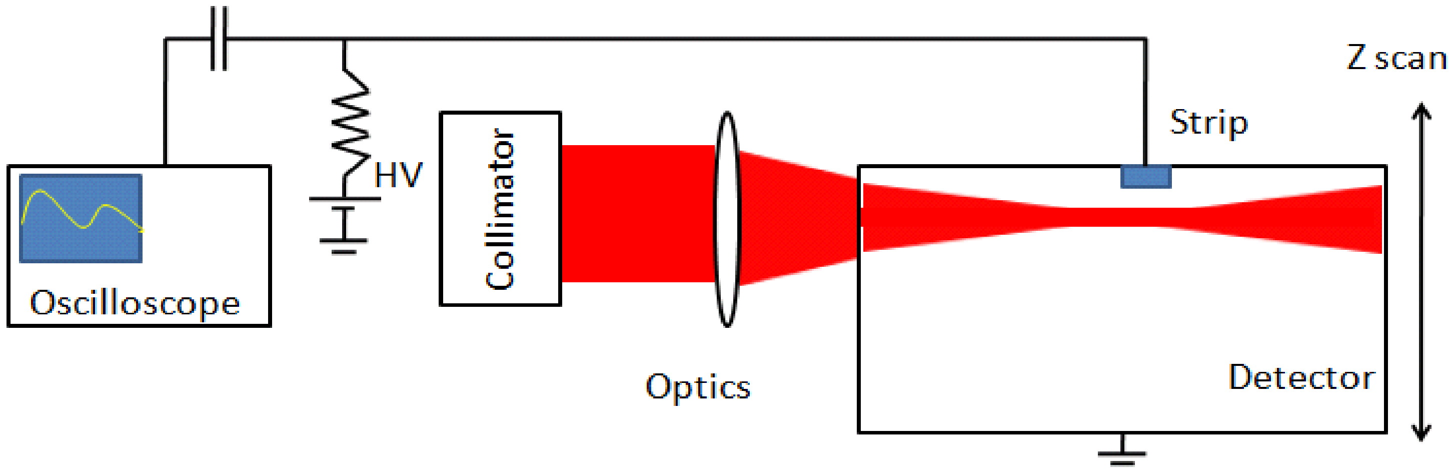
Structures:

Ministrip detectors (10x10 mm^2)
128 strips, 80 um pitch, 20 um strip width
DC Coupling of the strips (Thanks to J. Haerkoenen for providing AC-Coupled pitch adaptors for Alibava measurements)

Irradiation:

200 MeV pion irradiation in Villingen (PSI), summer 2010
Maximum fluence: 1.0x15 pions/cm^2

CERN Edge-TCT setup



- 1060 nm, 80 ps FWHM laser pulse
- 16 μm FWHM focusing underneath the strip.
- 1.8 GHz Phillips amplifier (50 dB)
- Decoupling Bias-Tee (750kHz-12GHz)

Edge TCT allows detector probing by means of localized charge generation at given depths inside the detector. Drift velocity, charge collection efficiencies profiles can thus been generated.

Prompt current method was used to extrapolate drift velocities profile.
(ref. G. Kramberger et al. doi:10.1109/TNS.2010.2051957)

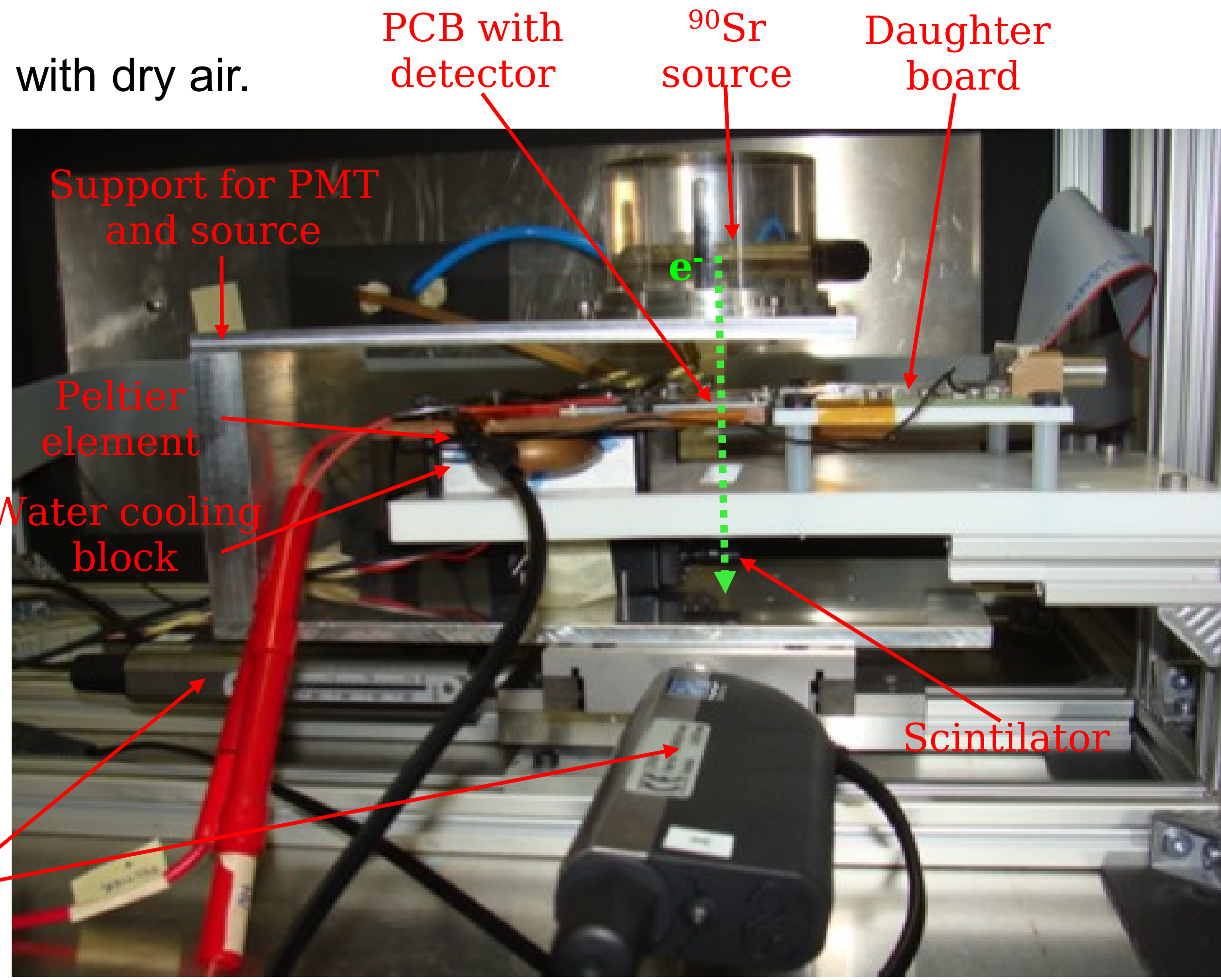
CERN Alibava β CCE Setup

Alibava based setup
- Setup enclosed in Al box, flushed with dry air.

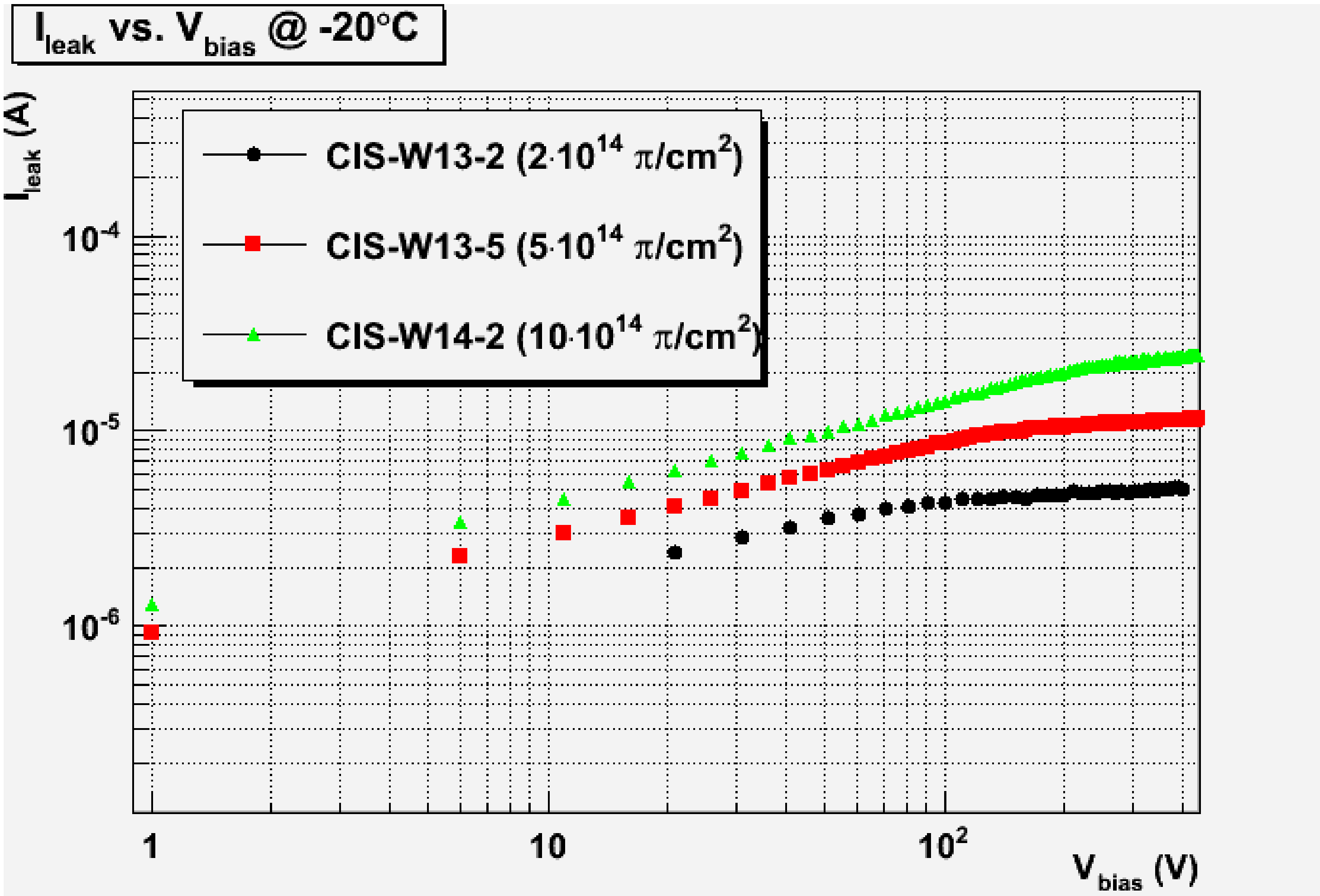
Cooling of detector
- Water cooled peltier
- Temperatures down to -25°C

Source
- 3.7MBq ^{90}Sr electron source, placed ~2cm above the detector
- PCB itself acts as a moderator to stop slow electrons

Trigger signal
- Provided by scintillator with PMT,
- Collimation by ~1mm hole in the ^{90}Sr holder plate



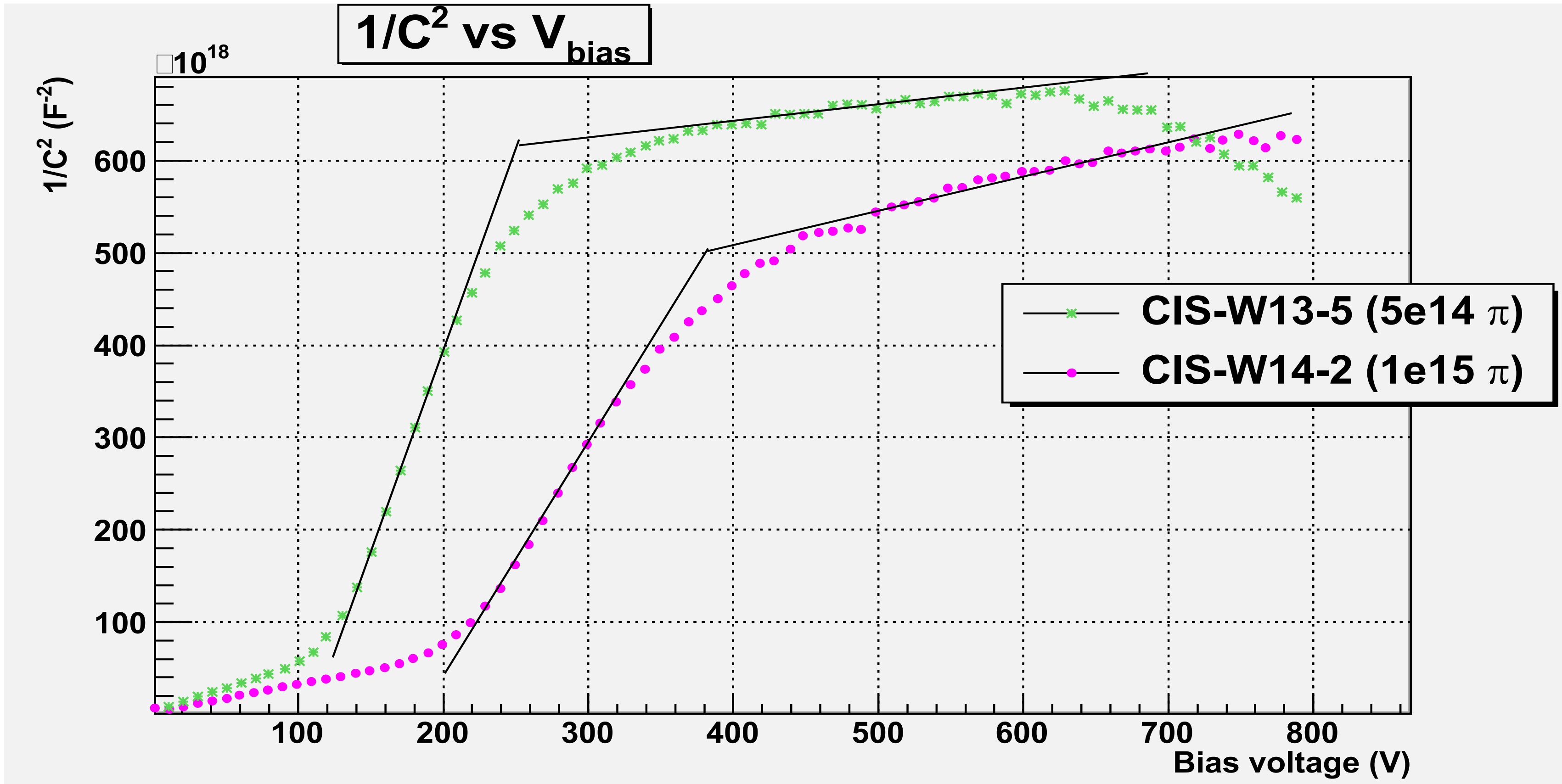
Fluence check (IV measurements @ -20° C)



Fluence from IV (α=3.99e-17, k=1.14)

W13-2 - dosimetry: 1.65e14 π (4.68e14 neq) - IV: 1.46e14 neq
W13-5 - dosimetry: 4.11e14 π (4.68e14 neq) - IV: 3.81e14 neq
W14-2 - dosimetry: 8.39e14 π (9.70e14 neq) - IV: 8.51e14 neq

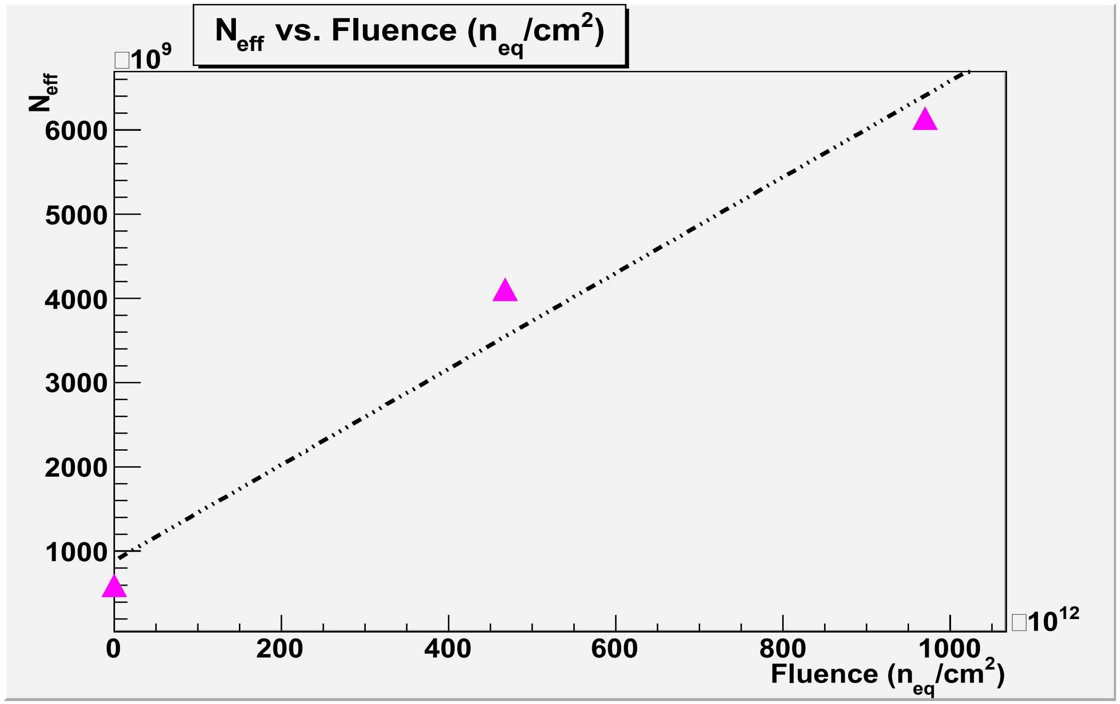
Depletion voltages from IV and CV



Depletion voltages from CV(-25C, 55 Hz) and IV:

W13-5 Vd(CV) = 254 V, Vd(IV)=128 V
W14-2 Vd(CV) = 379 V, Vd(IV)=241 V

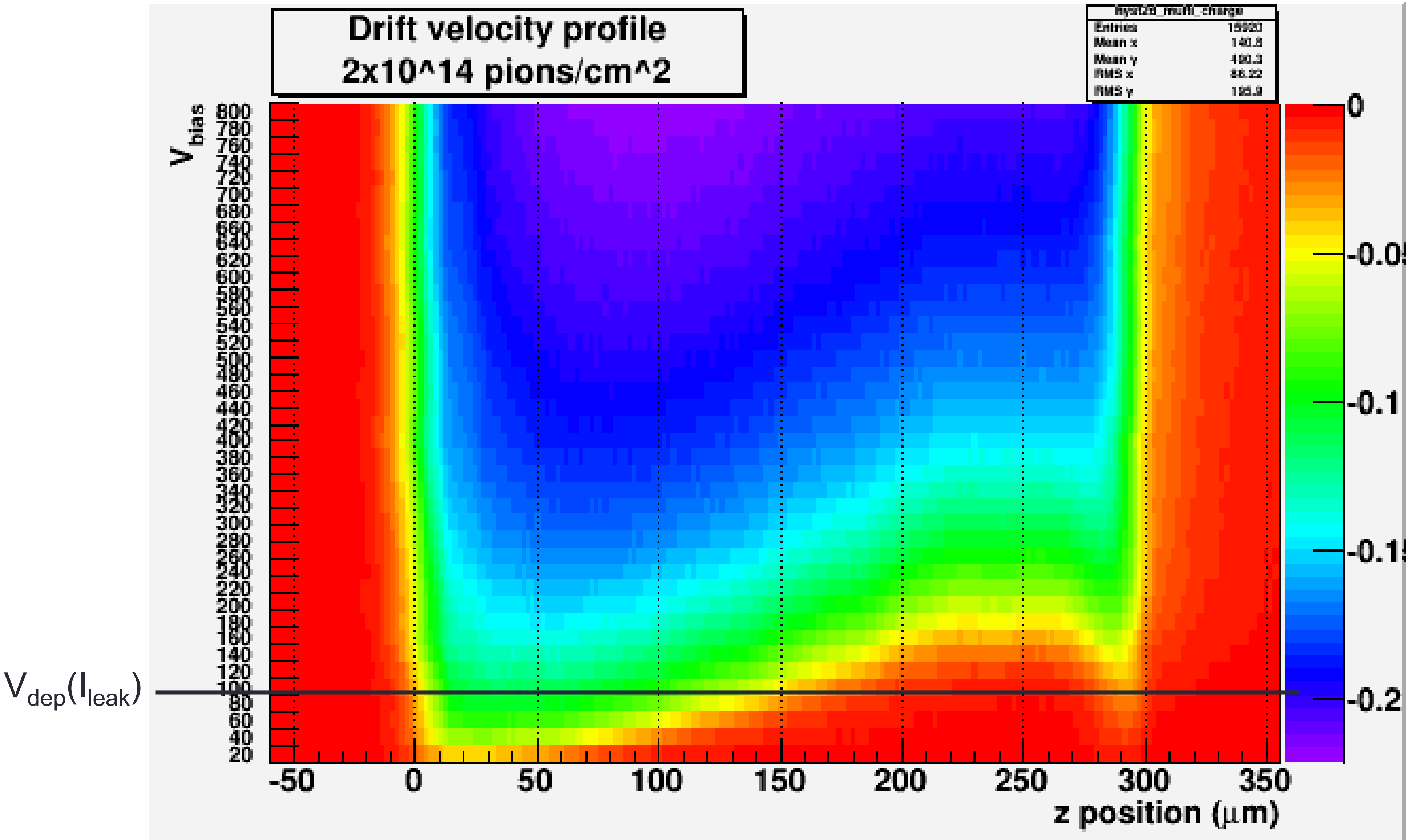
Defects introduction rate:



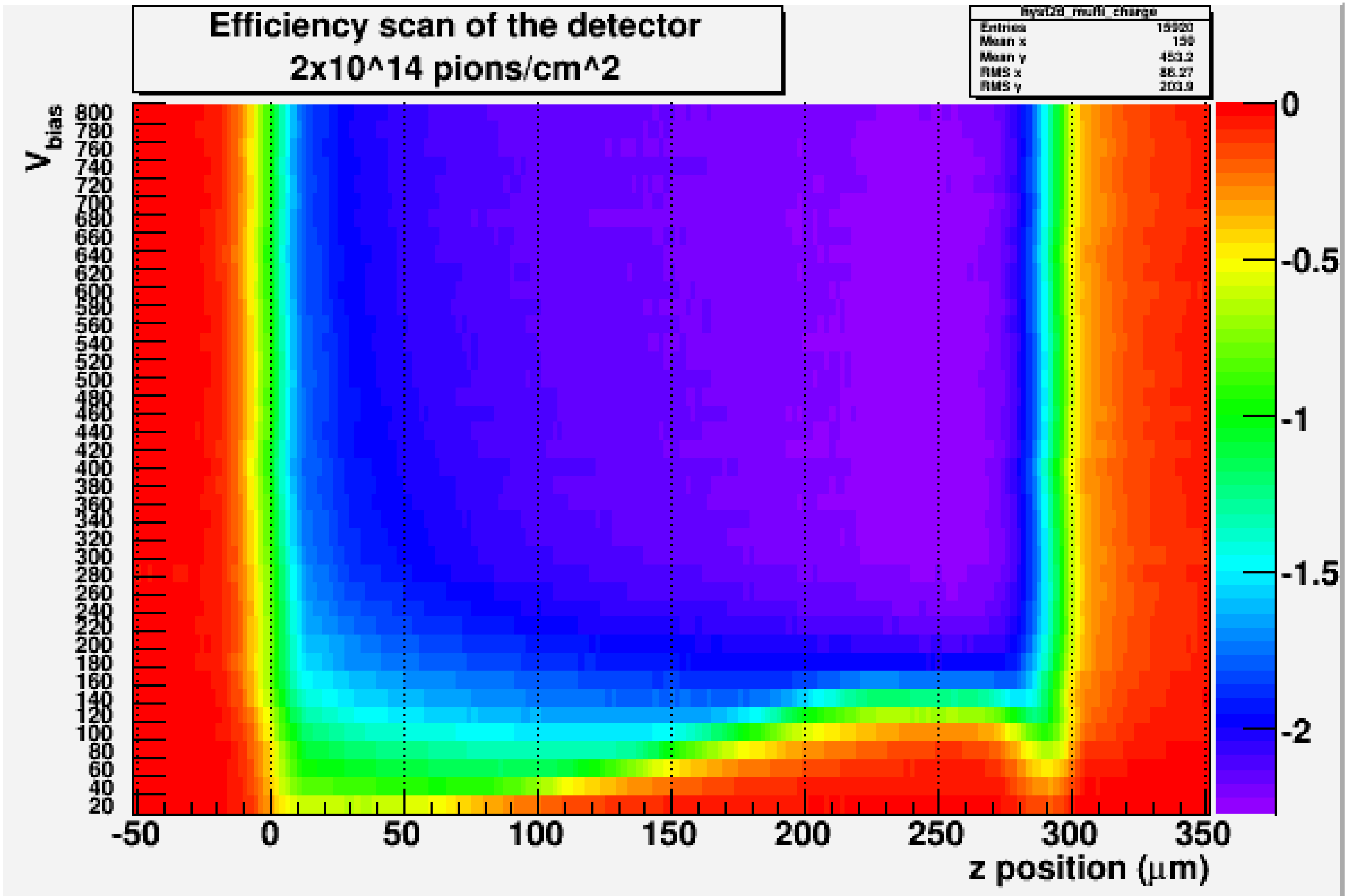
Our data: 5.7±1 x 10^{-3} cm^{-1}

Reference: 13.4±1.6 x 10^{-3} cm^{-1} *(G. Kramberger et al doi:10.1016/j.nima.2009.10.139)*

Drift velocity profile: 2×10^{14} π/cm^2 irradiated detector

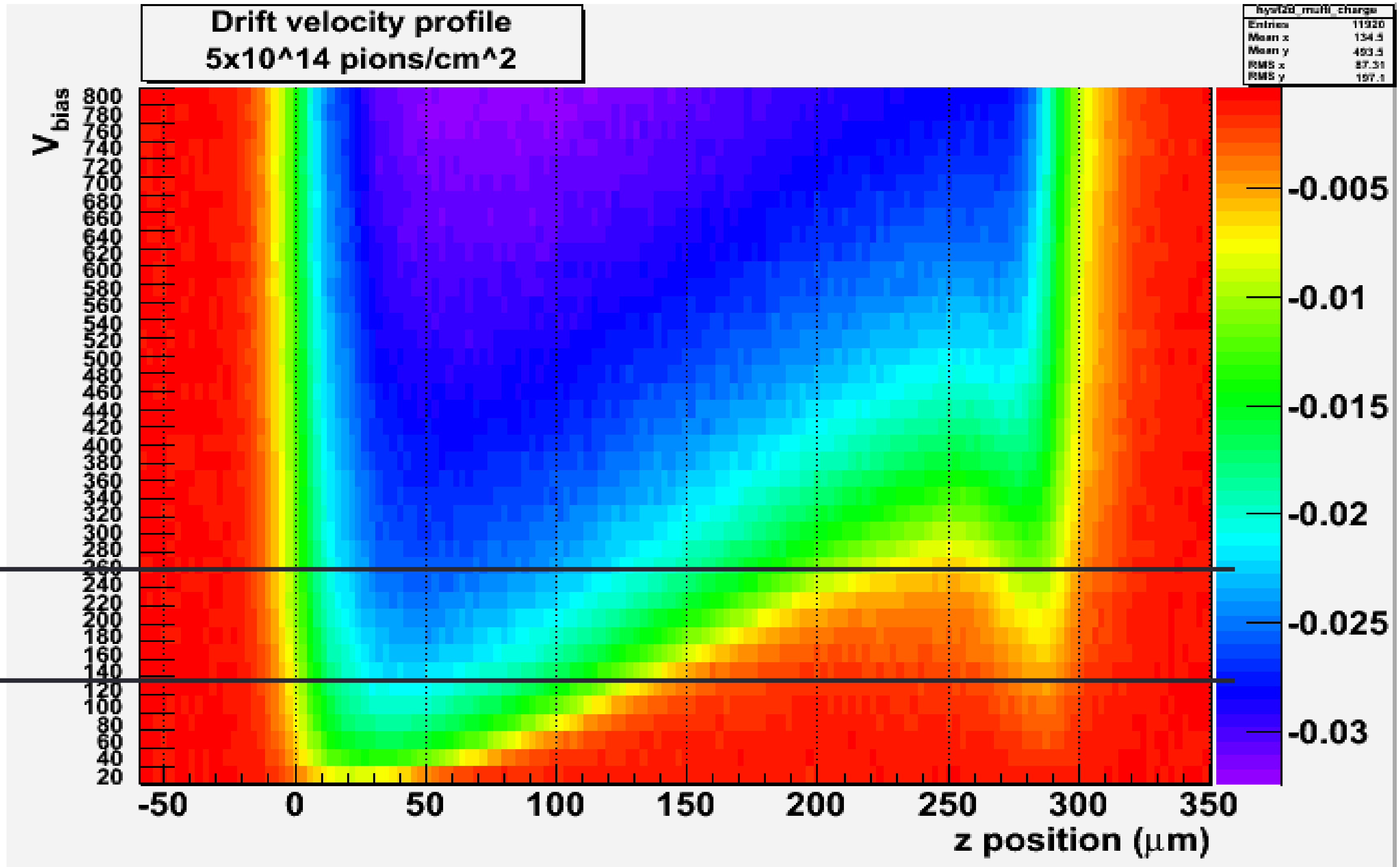


Efficiency scan: $2x10^{14}$ π/cm^2 irradiated detector



Back of the detector becomes more efficient than front region at high voltages

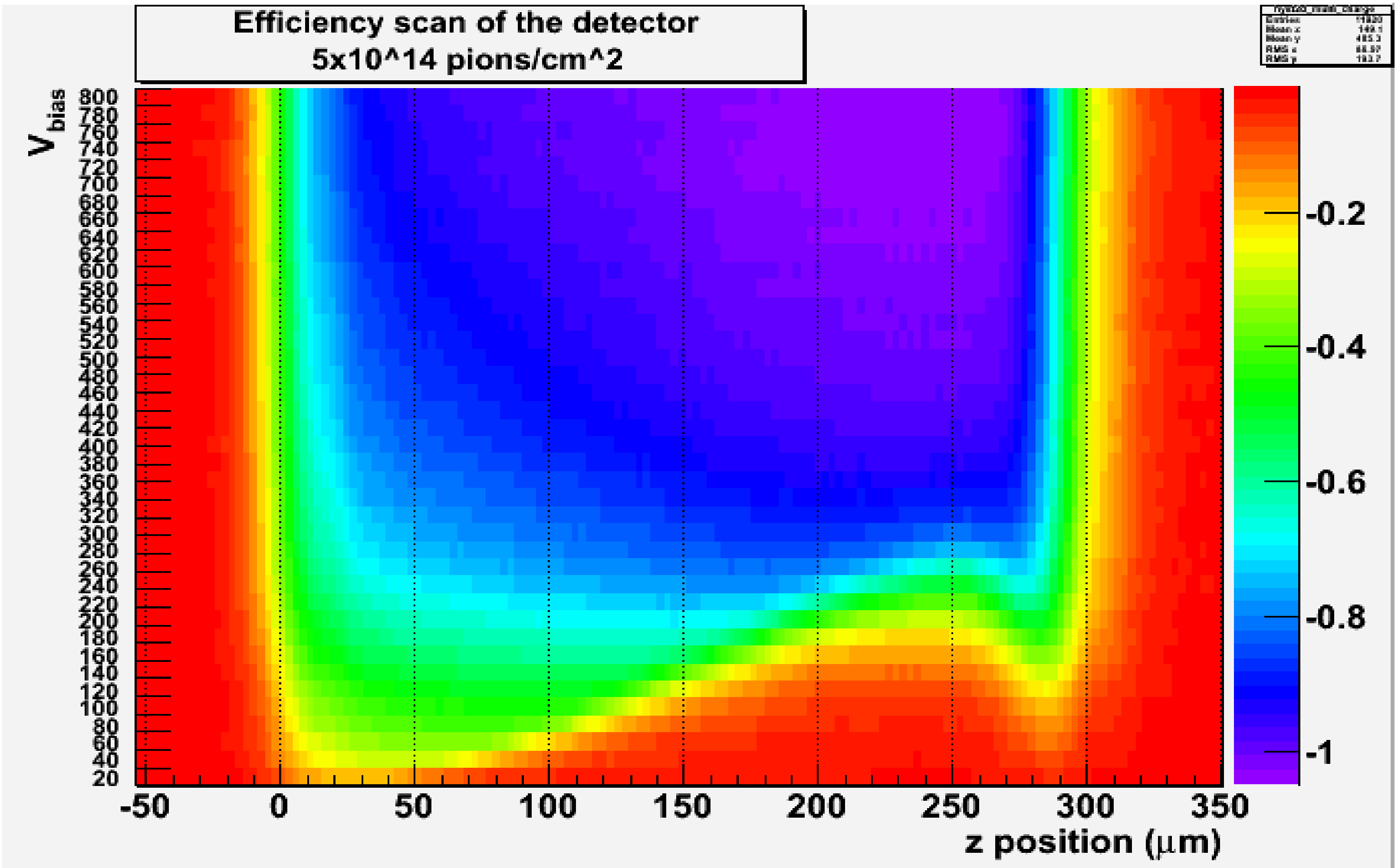
Drift velocity profile: $5x10^{14}$ π/cm^2 irradiated detector



$V_{dep}(C)$

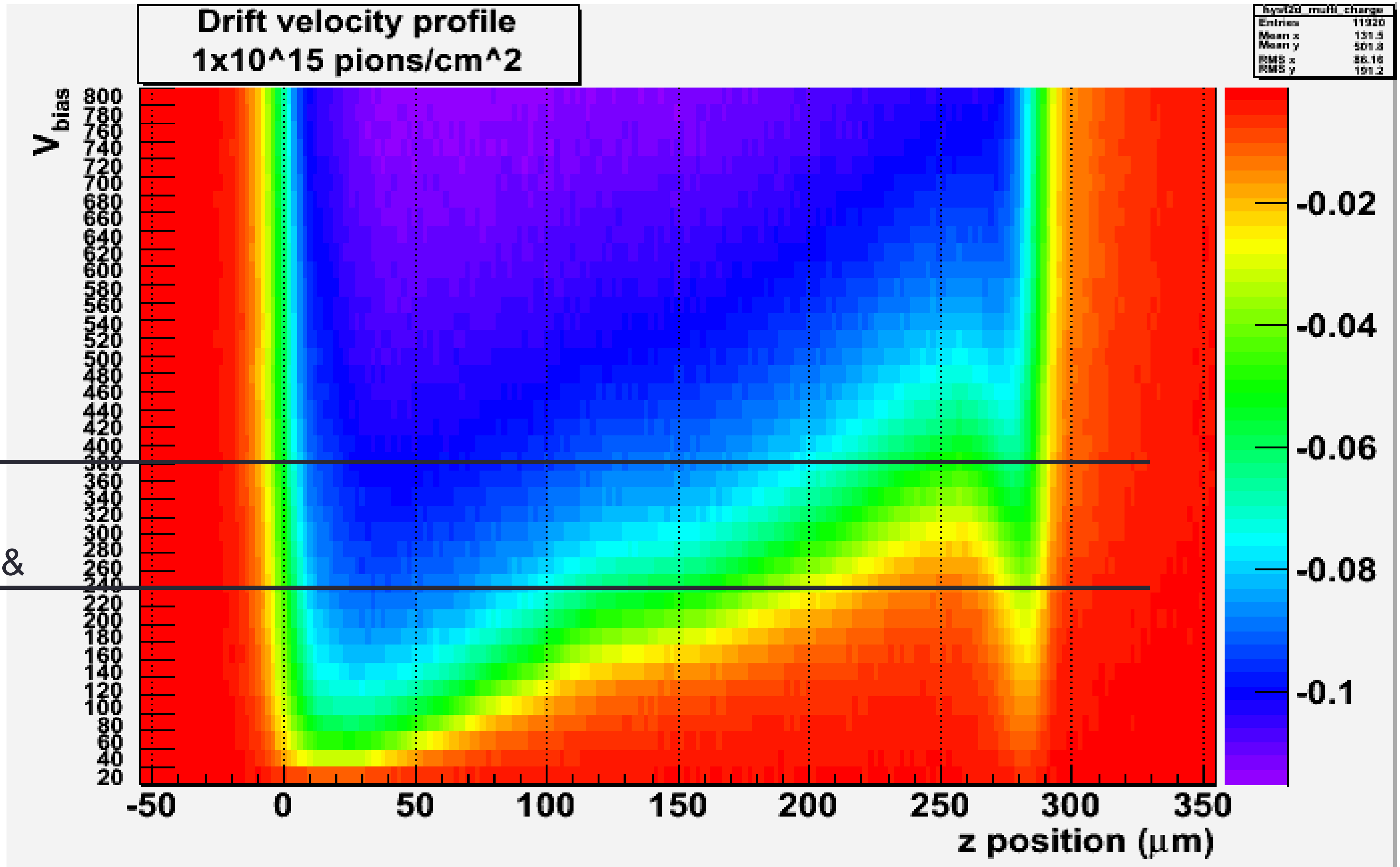
$V_{dep}(I_{leak})$ &
CV first
kink

Efficiency scan: $5x10^{14}$ π/cm^2 irradiated detector



Back of the detector becomes more efficient than front region at high voltages

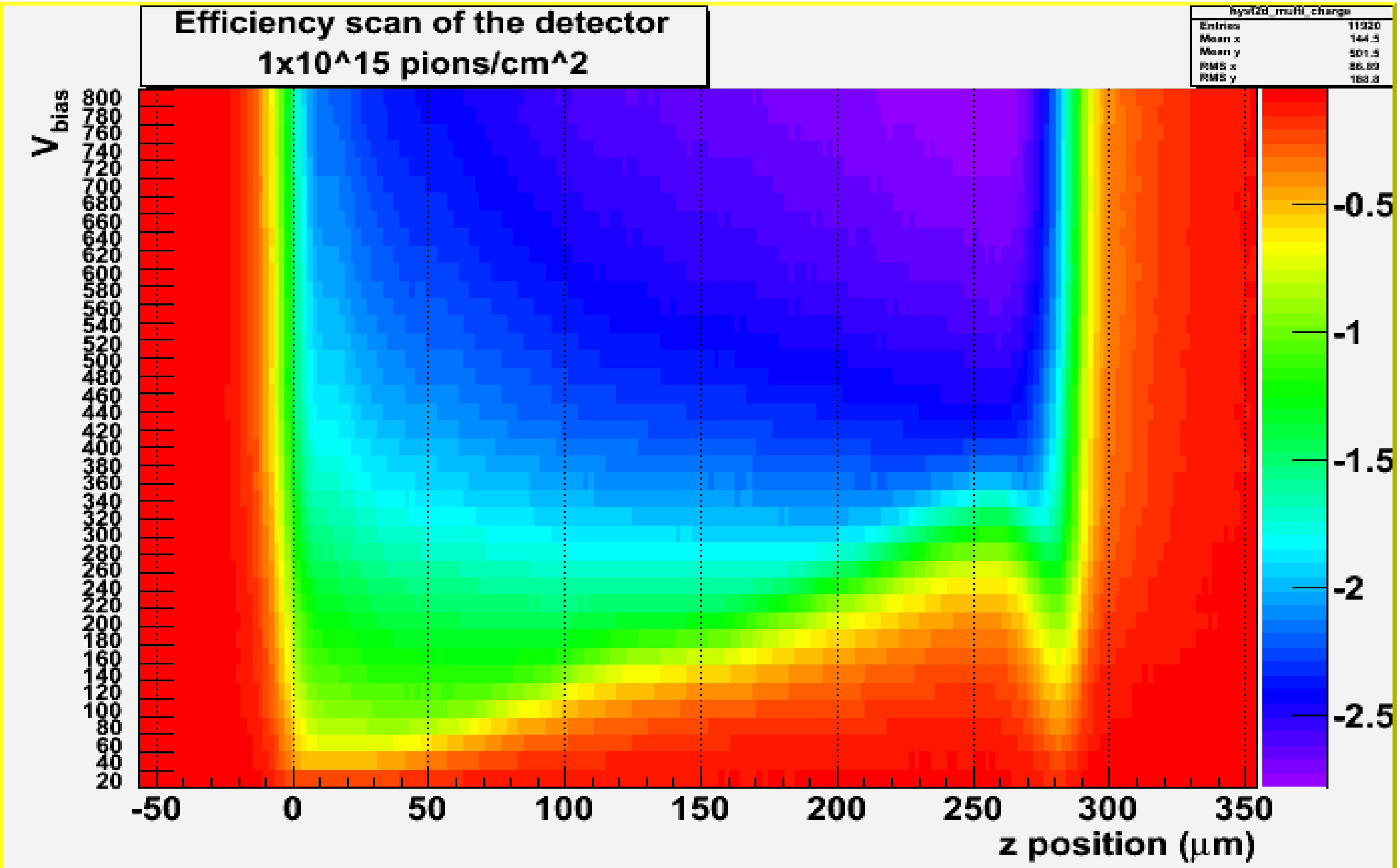
Drift velocity profile: $1x10^{15}$ π/cm^2 irradiated detector



V_{dep}(C)

$V_{dep}(I_{leak})$ & CV first kink

Efficiency scan: $1x10^{15}$ π/cm^2 irradiated detector



Again, more efficiency in the back region at high voltages. Trapping is influencing less carriers generated in this region (might be due to higher drift velocity of electons that have anyway lifetimes comparable to holes)

Some Intermediate considerations:

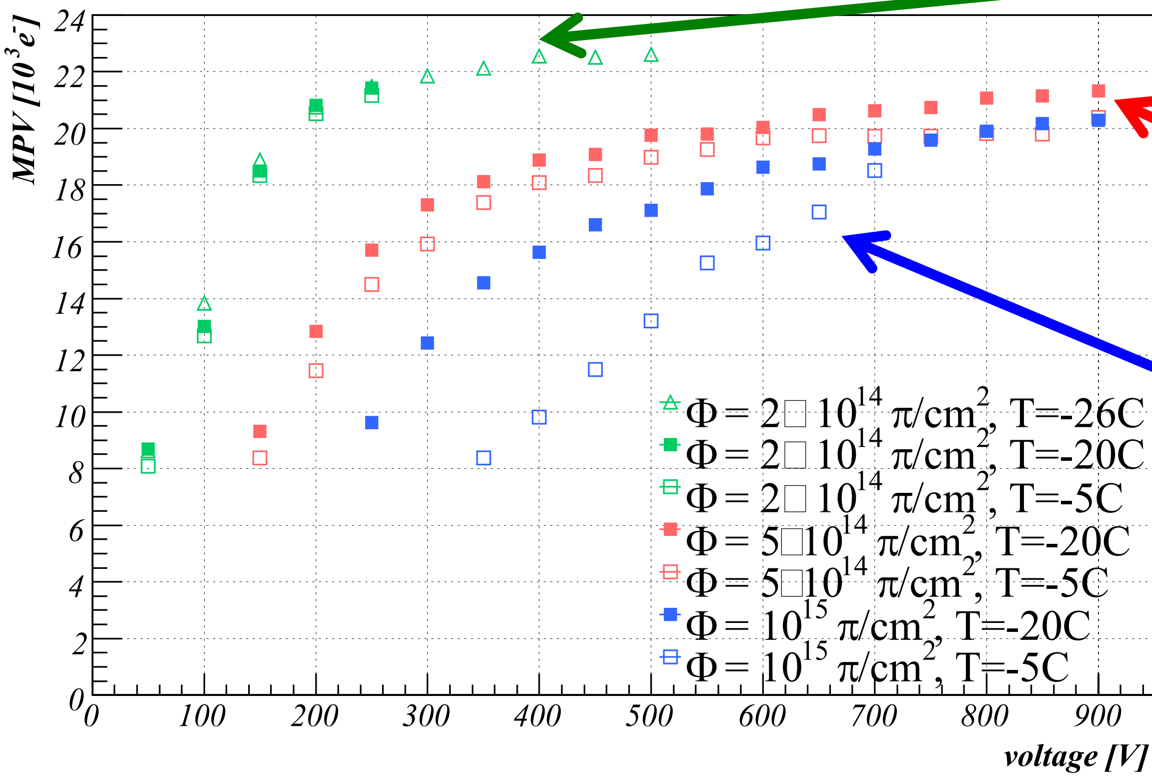
Even after irradiation, fields continue developing from the front side of the detector.

Depletion voltage behavior looks linear with fluence, as expected.

However, *depletion voltage is too low* when compared to previous literature results, by almost a factor 3 (!!!)

Since measurement in literature were made at 20° C, we tried to investigate the detectors at higher temperature (with due constrains related to the fact that a 1x1 cm^2 detector takes 16 times more current than a standard 2.5x2.5 mm diode.

Collected charge (Alibava β⁻ CCE)



No major dependance from temperature for detector $2 \cdot 10^{14}$ π/cm^2

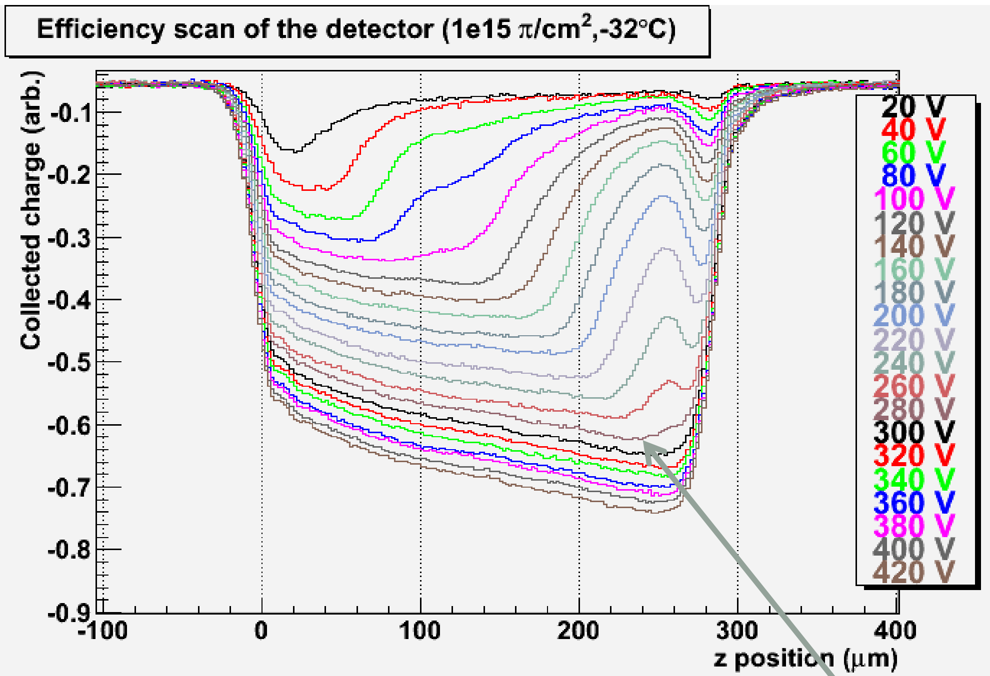
$5 \cdot 10^{14}$ π/cm^2: about 15 V difference in depletion voltage between -5⊕C and -20⊕C

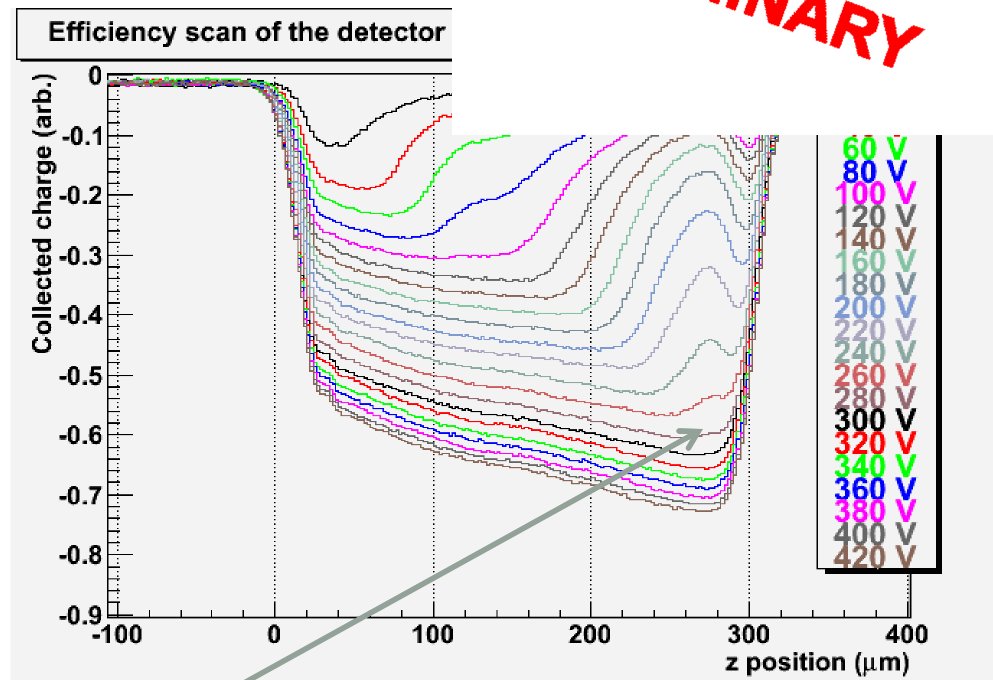
$10 \cdot 10^{14}$ π/cm^2: about 150 V difference in depletion voltage between -5⊕C and -20⊕C

For higher fluences there is a clear temperature dependance of depletion voltage.

Temperature dependence study with Edge-TCT for detector irradiated with $10 \cdot 10^{14}$ π/cm^2 (1/2)

PRELIMINARY

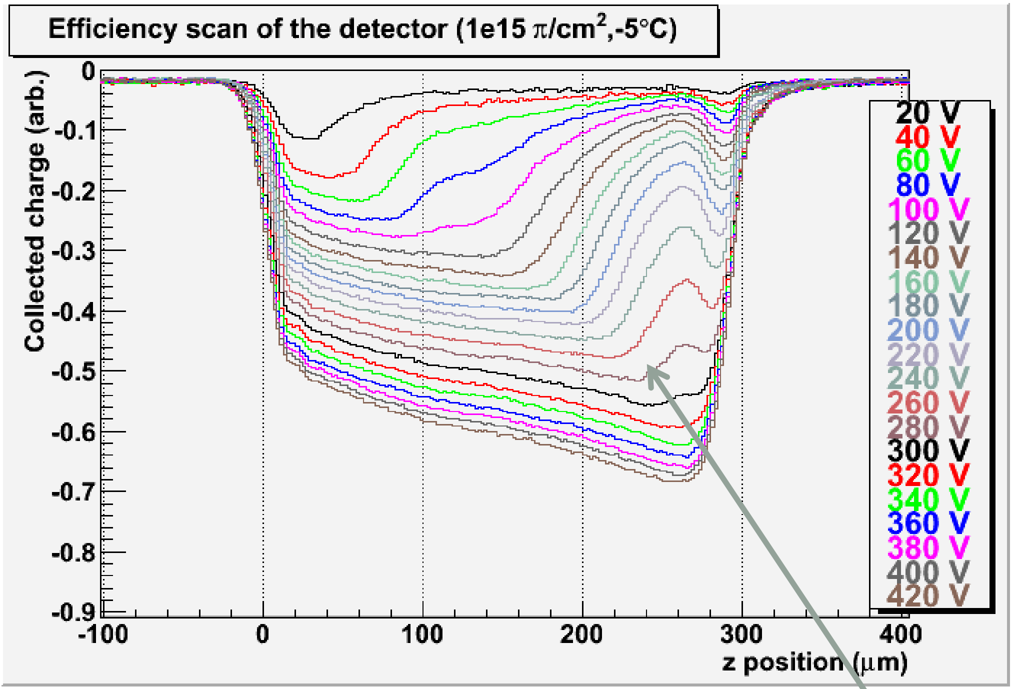


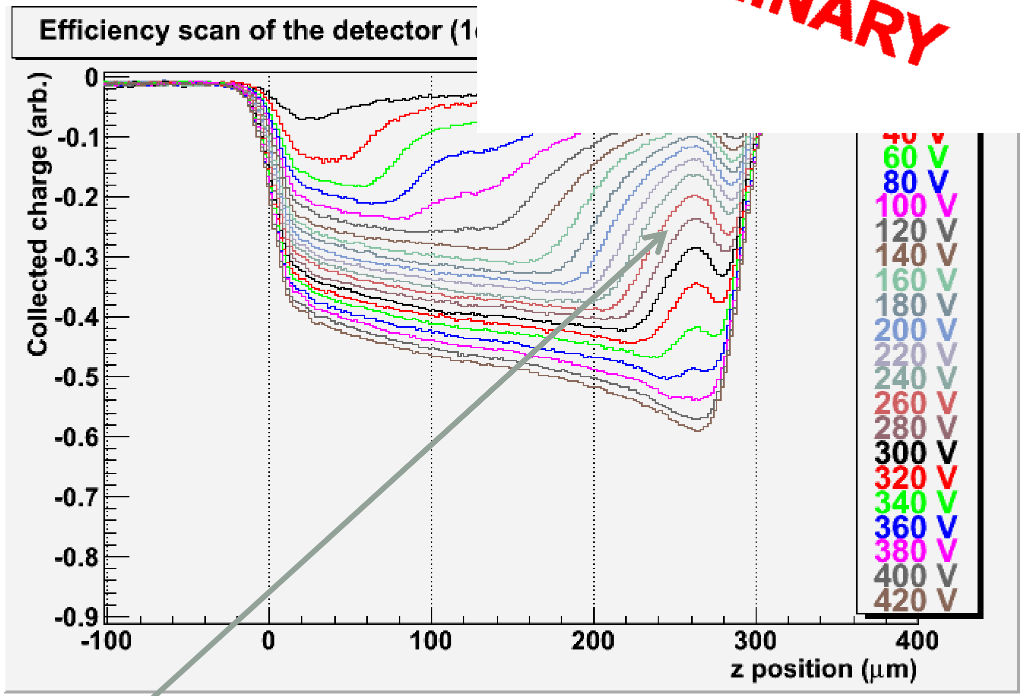


No major change in the depletion voltage between -32° C and -20° C.
Active region on the front merges with the one on the back @ 280 V.

Temperature dependence study with Edge-TCT for detector irradiated with $10 \cdot 10^{14}$ π/cm^2 (2/2)

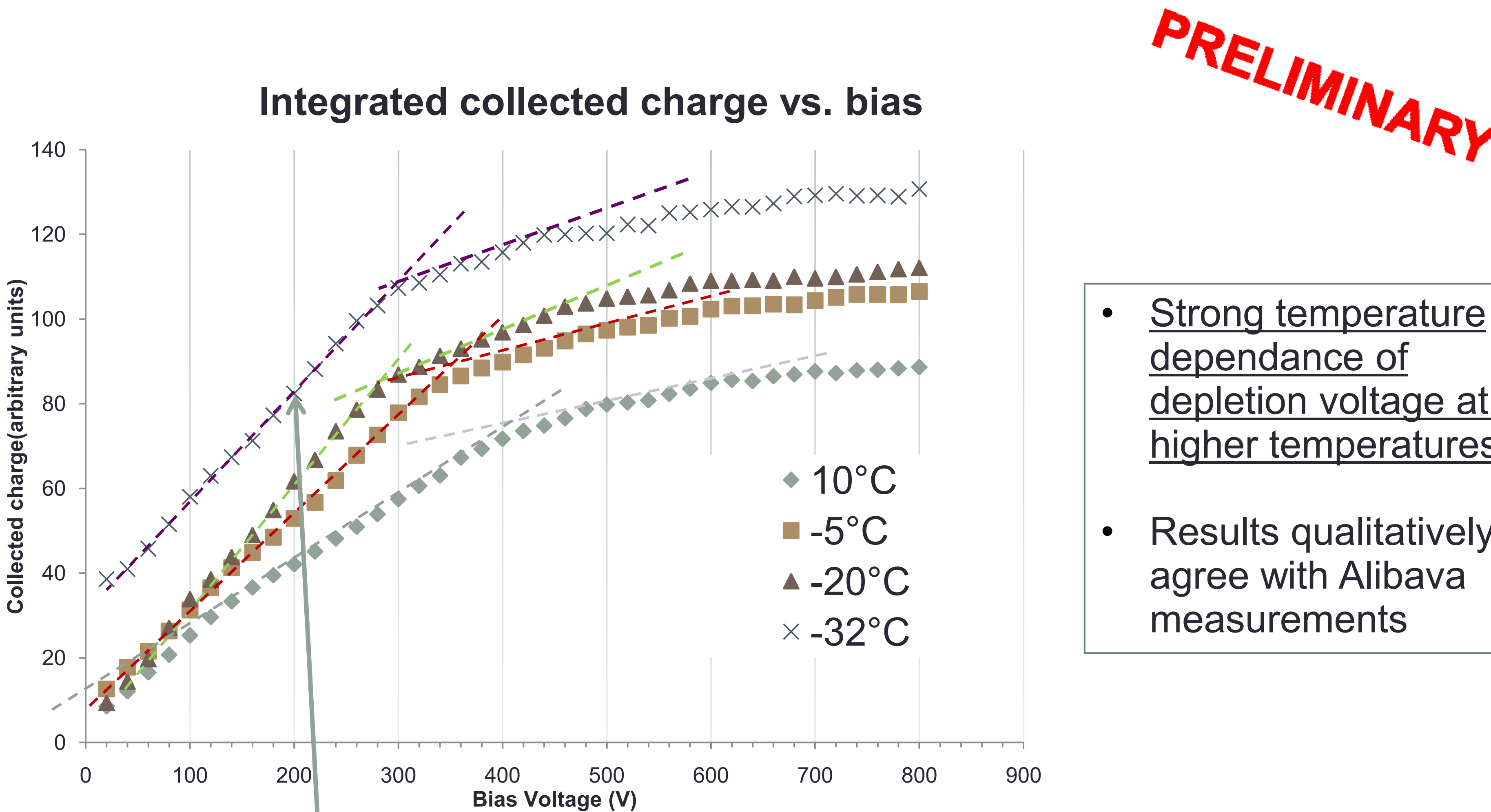
PRELIMINARY





At -5° C, at 300 V, signs of underdepletion at 280 V.
At 10° C, detector is clearly underdepleted at 280 V. Depletion achieved @ 380 V

Overview of collected charge for detector irradiated at 10·10^14 π/cm^2



- Strong temperature dependance of depletion voltage at higher temperatures
- Results qualitatively agree with Alibava measurements

Baseline shift artificially induced by microdischarges at low temperature (breakdown)

Conclusions

- Fluence check agreed well from the point of view of current increase, in reasonable agreement with dosimetry expected values (within 20%)
- Even after high pion fluences, field develops starting almost exclusively from the front side.
- Total collected charge even at 1e15 π/cm^2 fluence is at its maximum already at 350 V at -20° C
- Depletion voltage @ -20° C is too low. Measured values are about three times lower than what would be expected (previous results from K. Kaska, 15th RD50 Workshop, G. Kramberger doi:10.1016/j.nima.2009.10.139).
- A temperature dependance has been found for higher fluences and higher temperatures More investigation is in progress to check wheather the effect can be observed also in other fluences and on a wider temperature range.