## 19th RD50 Workshop

# Annealing study on 24 GeV/c proton irradiated p-type detectors

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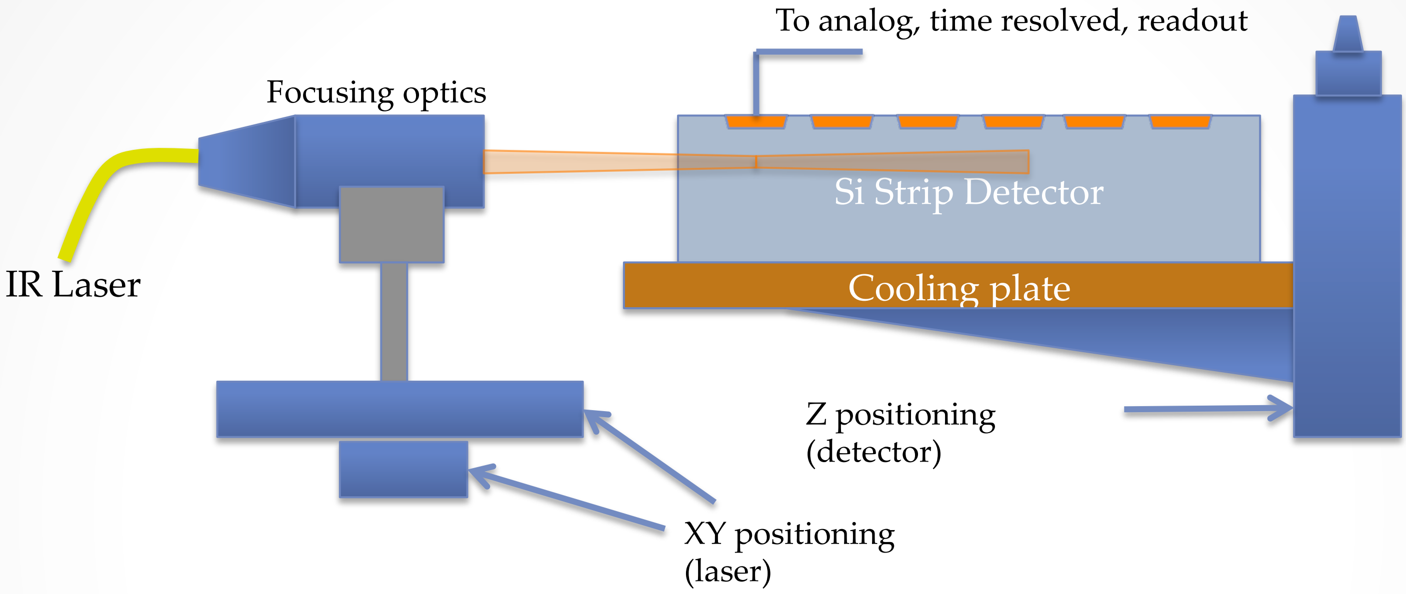
# Outline

- Motivation
- Edge TCT setup
- Charge scaling between different detectors (preliminary)
- Samples and irradiation
- Results
  - Measurement conditions
  - Edge-TCT characterization
  - Overview of total CCE
  - Overview of $i_{leak}$
- Conclusions

# Motivation

- Field and efficiency profile determination in p-bulk n-readout ministrip detectors after 24 GeV/c proton irradiation – unique combination of clusters and point defects
- Study of the annealing behavior of collected charge and field development
- Study of the effect of oxygen-enrichment (MCz) on field development
- Cross comparison of the results between detectors with different oxygen concentration (SIMS are on the way…)

# Edge-TCT setup



To analog, time resolved, readout

Focusing optics

Si Strip Detector

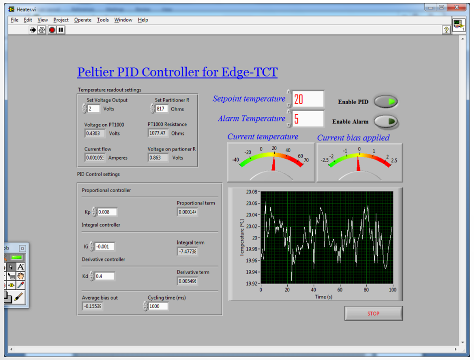
IR Laser

Cooling plate

Z positioning
(detector)

XY positioning
(laser)

Latest enhancement: Temperature PID control allowing both heating and cooling of the detector -> on-board annealing studies, keeping the laser configuration unchanged



Peltier PID Controller for Edge-TCT

Temperature readout settings

Set Voltage Output: 2 Volts
Set Partitioner R: 817 Ohms
Voltage on PT1000: 0.4303 Volts
PT1000 Resistance: 1077.47 Ohms
Current flow: 0.00105 Amperes
Voltage on partioner R: 0.863 Volts

Setpoint temperature: 20
Alarm Temperature: 5

PID Control settings

Proportional controller
Kp: 0.008
Proportional term: 0.00014
Integral controller
Ki: -0.001
Integral term: -7.4773
Derivative controller
Kd: 0.4
Derivative term: 0.00549
Average bias out: -0.1553
Cycling time (ms): 1000

# Charge scaling method (CSM)

- Integration of the whole pulse length gives an extimation of the charge collection efficiency of the detector.
- However we still have to deal with arbitrary units: it's not possible to know beforehand how much of the laser light will make it to the strip – Factors influencing are several:
    - Light reflection on the surface
    - Depth of the strip (polishing is taking a way an arbitrary thickness of the edge)
- However it's still possible to make a relative comparison of the collected charge in different detectors using a small trick:
- For small enough fields:

$$v_{drift} = k \cdot |E| \Rightarrow \int v_{drift}(x) \cdot dx = k \int |E(x)| dx = kV_{bias}$$

If we thus compare the $v_{\text{drift}}$ integrals over two different detectors, at a voltage far from causing saturation, we can use the ratio of those two integrals to rescale all the pulses

# CSM: limitations

- Drift velocity is computed from integrating over the first 0.5 ns of the pulse. The determination of the integration window is completely manual. As careful one might me, a small alignment error will always be there
    - binning related to the sampling of the oscilloscope doesn't help

- This bin-shift can lead to an error up to 20%
- Still, it allows "soft" comparison between collected charges profiles

CSM was used here to rescale the charge collection efficiencies of the two
measured detectors.

(method has to be cross checked with unirradiated detector of the same family – rescaling has to be regarded as "preliminary")

# Samples and irradiation

DETECTORS:

- 2010 Micron RD50 Production
- Detectors characterized: FZ n-on-p, MCz n-on-p, ministrip geometry
  - 80 um strip pitch
  - 20 um strip width

IRRADIATION:

- Irradiated at CERN PS with 24 GeV/c protons in P1-2011
- Irradiation fluence: $1 \bullet 10^{16}$ p/cm$^2$ ($6.2 \bullet 10^{15}$ $n_{eq}$/cm$^2$)

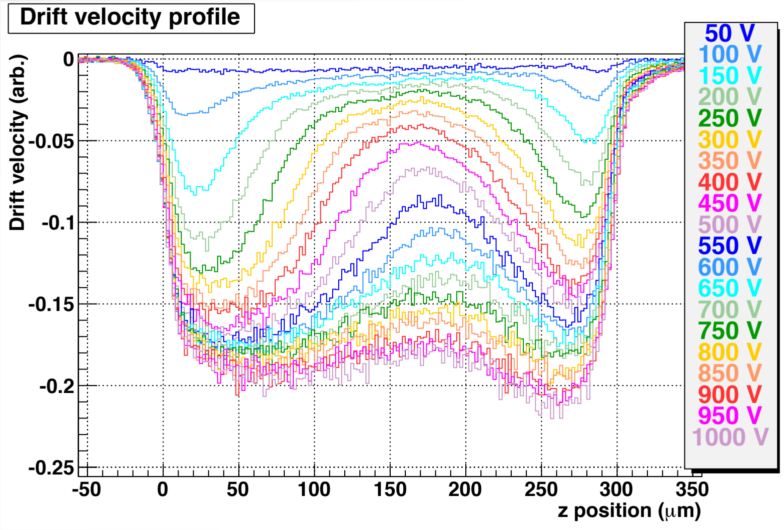
# Measurement procedure

- Measurement temperature: -25°C
- Drift velocity profile extracted with prompt-current method
- Efficiency scanned performed over 25 ns integration window
- Annealing on-board at 60°C without changing the main laser parameters (focusing distance, power, ecc.) – comparison between measurements on same detector is so ensured.
- Rescaling of the measurement with CSM to have comparable results (within 20% error)

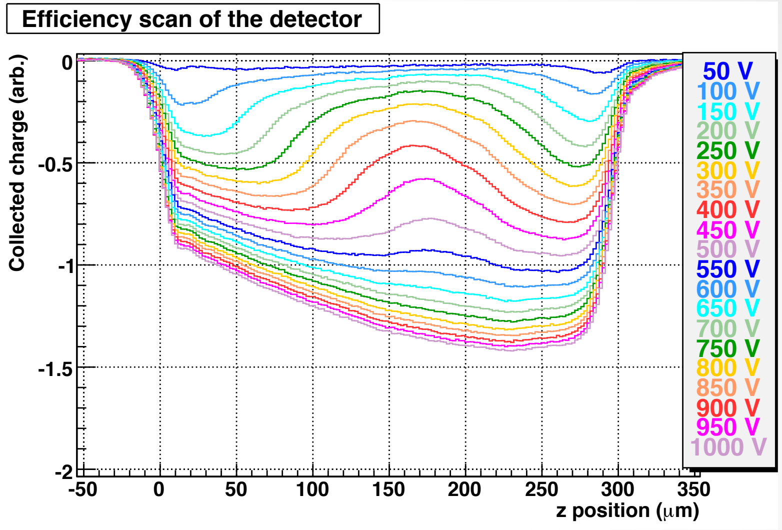
- For the annealing steps after 1200 mins at 60°C detectors were checked for "standard bistable" behavior – i.e. leaving detector overnight at RT and remeasuring. – No change observed.

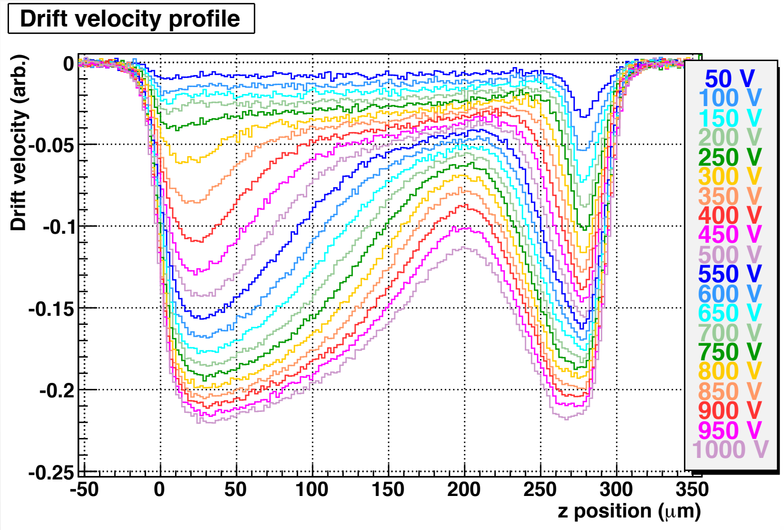
Details on Edge-TCT and related analysis techniques: G. Kramberger et al. IEEE TNS, VOL. 57, NO. 4, AUGUST 2010, p. 2294

# ETCT – no annealing

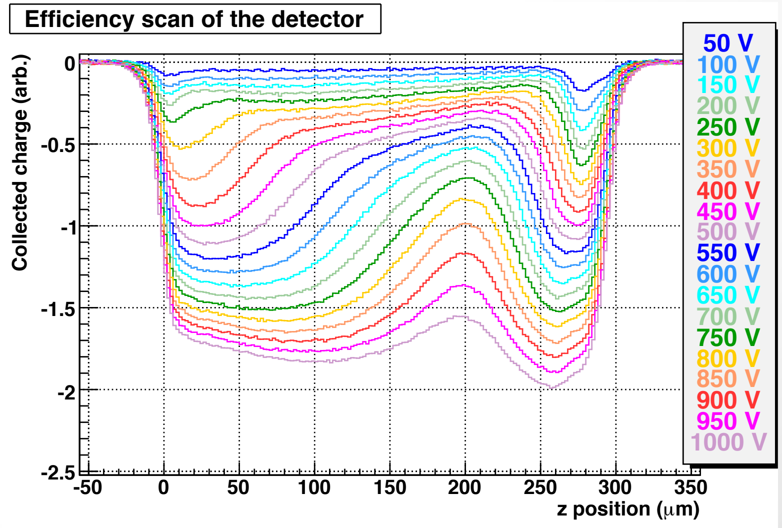


FZ

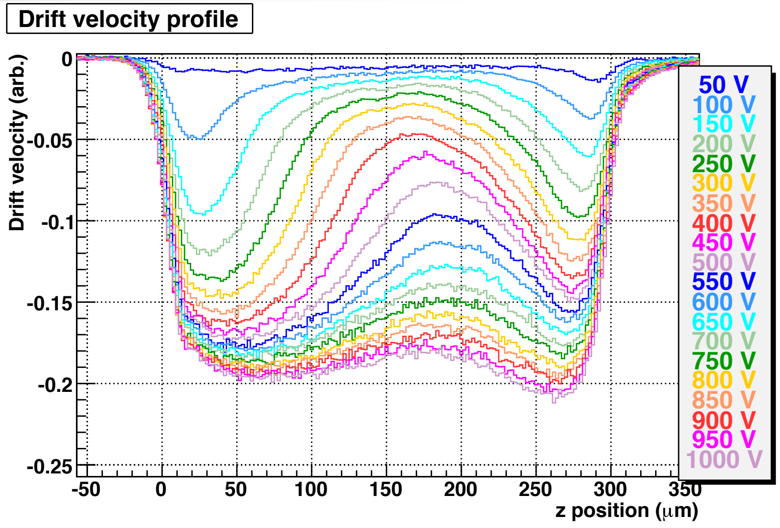




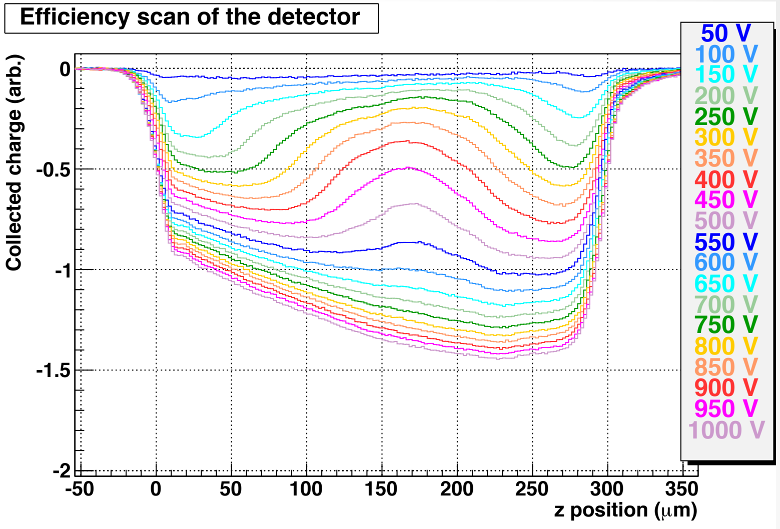
MCz

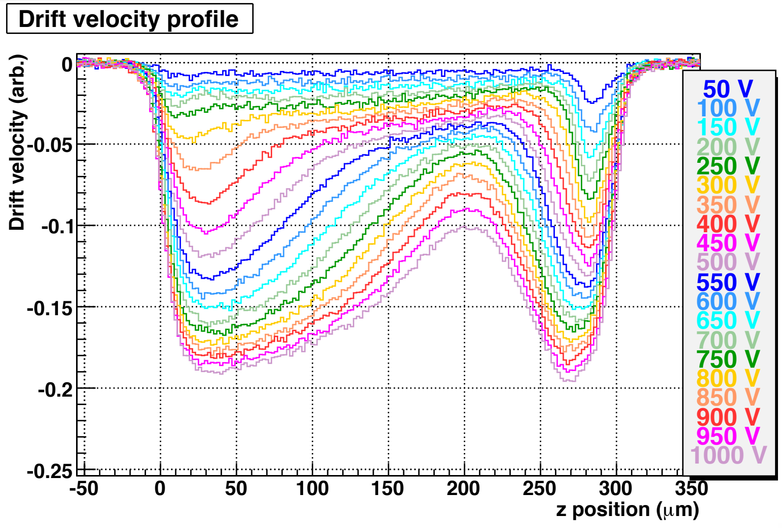


# ETCT– 80 mins ann.

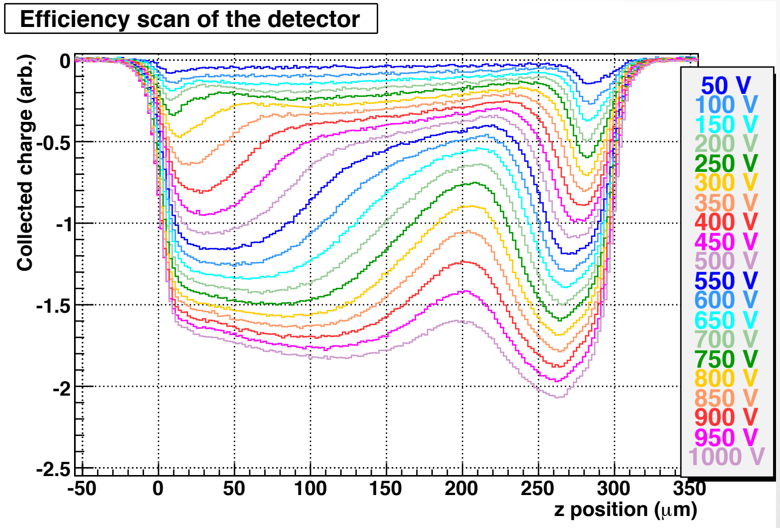


FZ

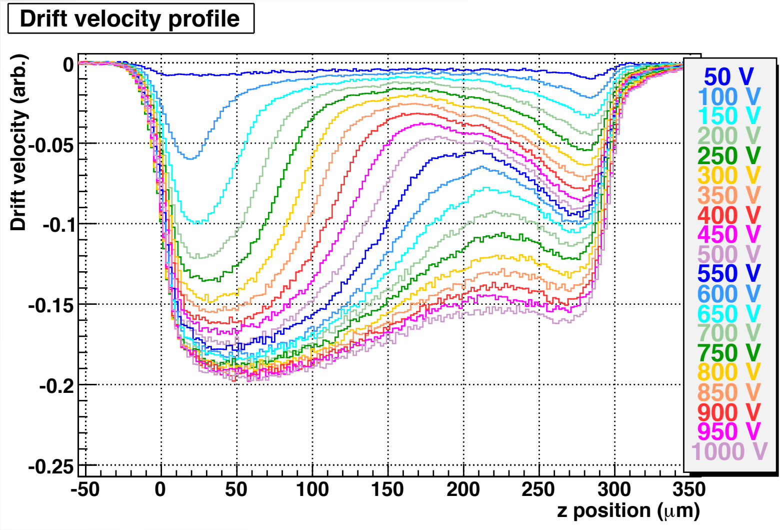




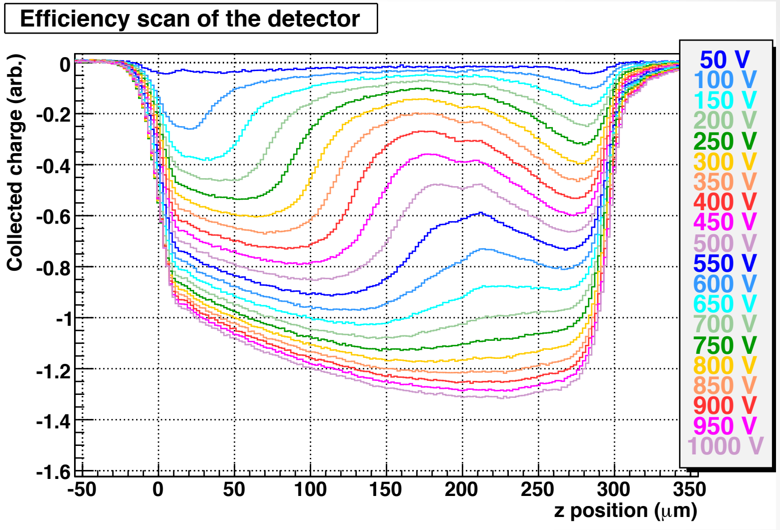
MCz

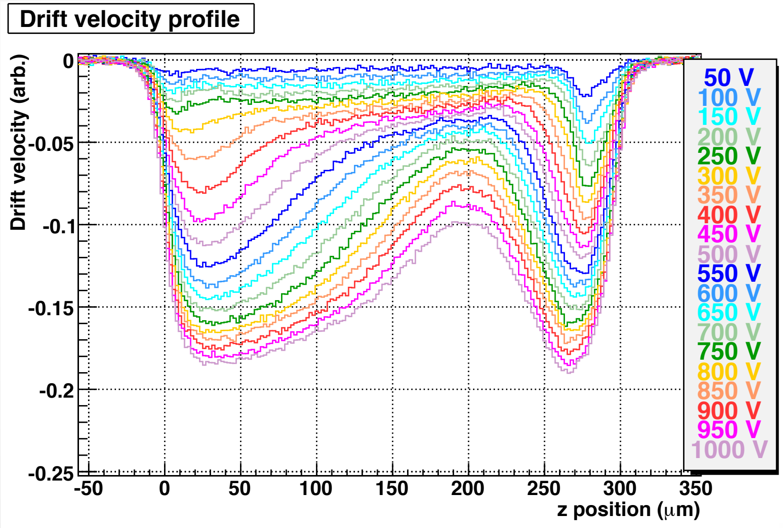


# ETCT – 240 mins ann.

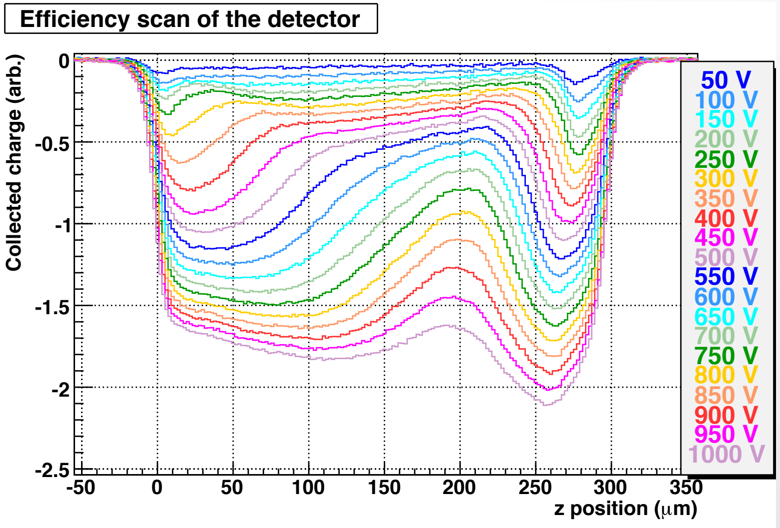


FZ

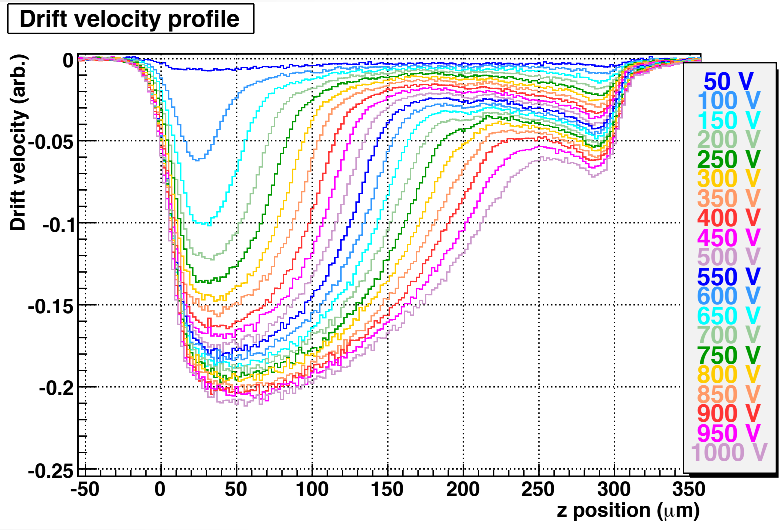


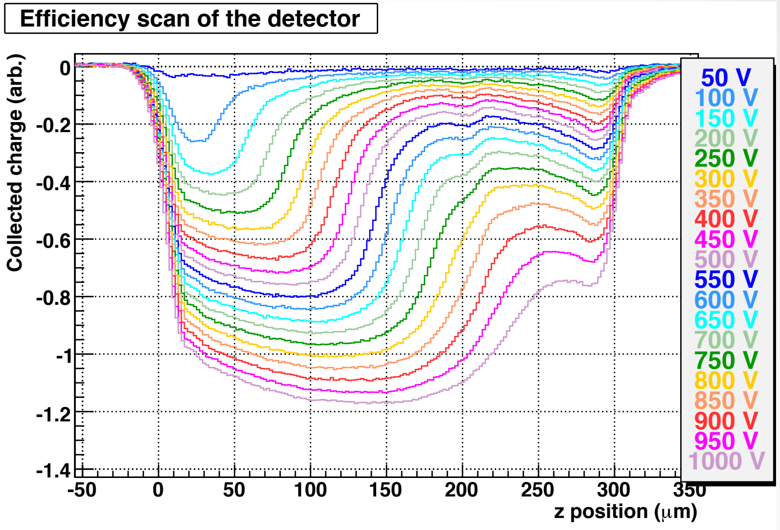


MCz

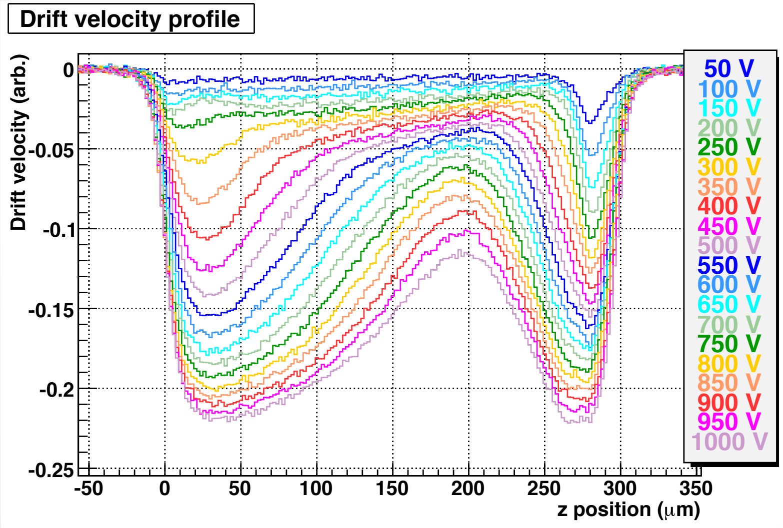


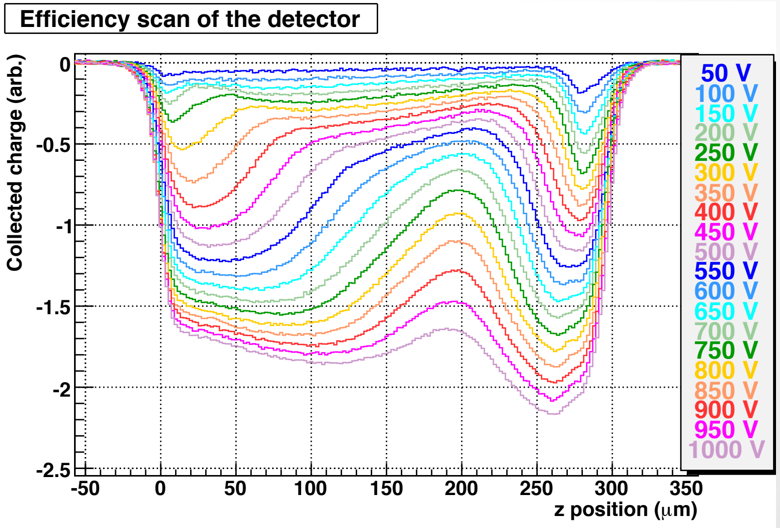
# ETCT – 560 mins ann.


Drift velocity profile


Efficiency scan of the detector

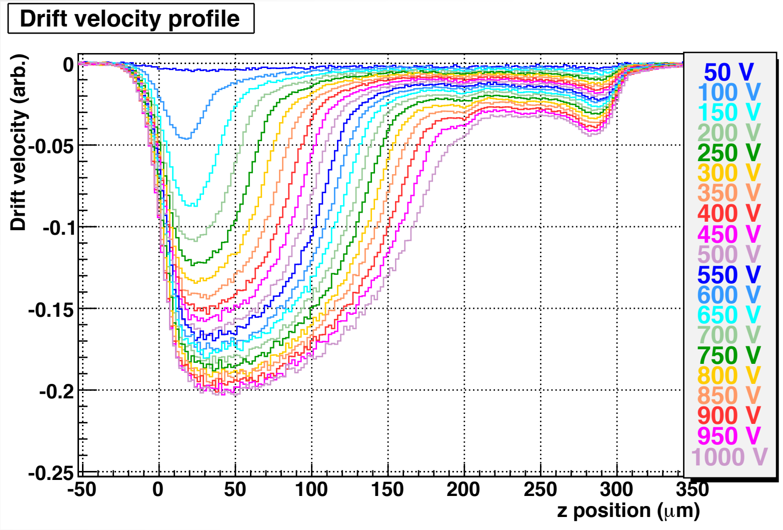
FZ

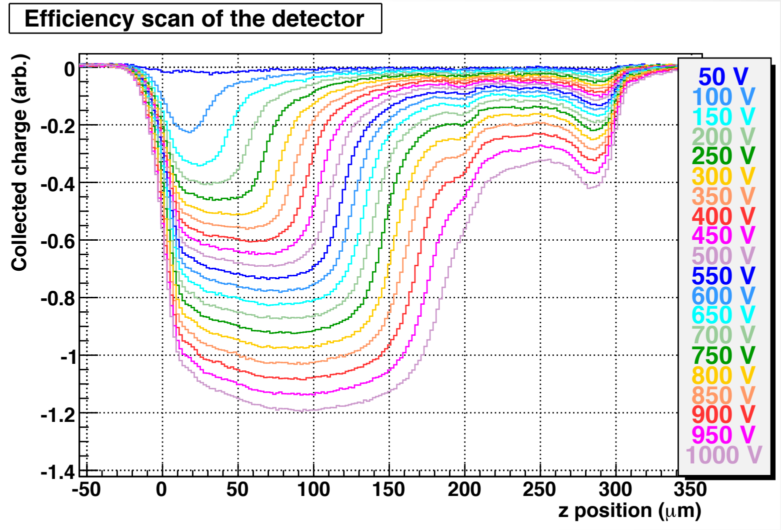

Drift velocity profile


Efficiency scan of the detector

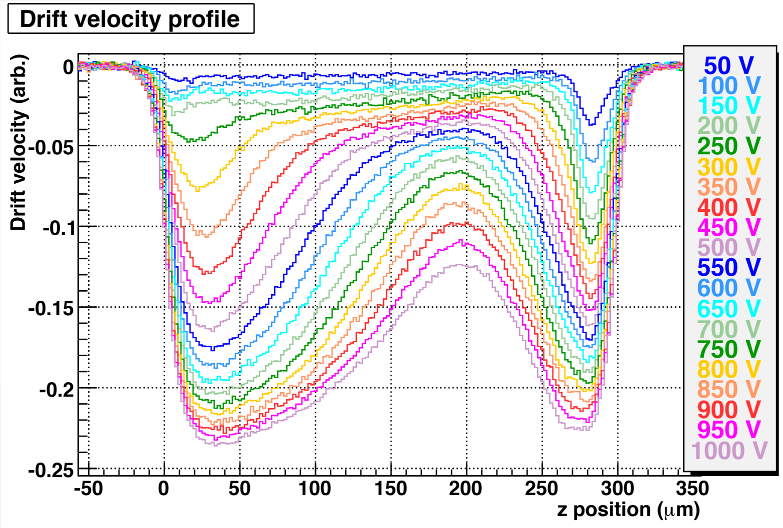
MCz

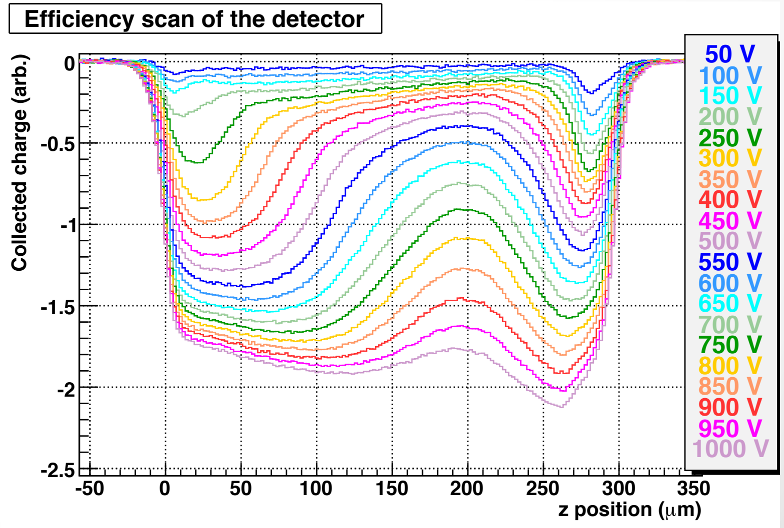
# ETCT – 1200 mins ann.





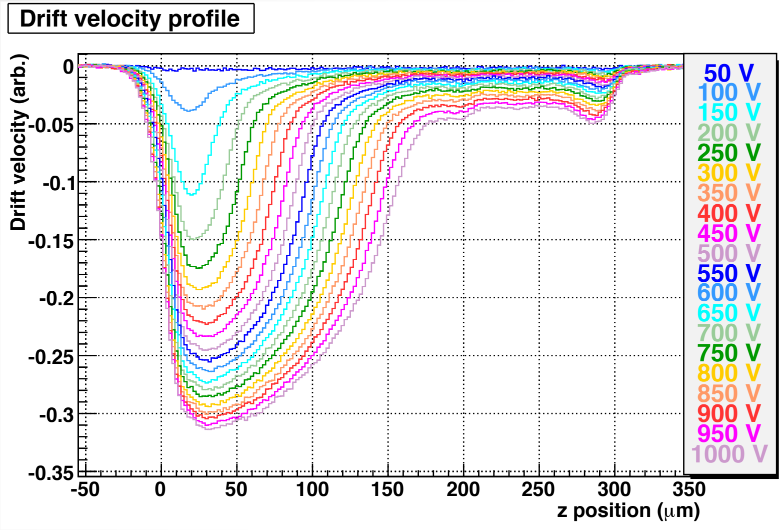
FZ



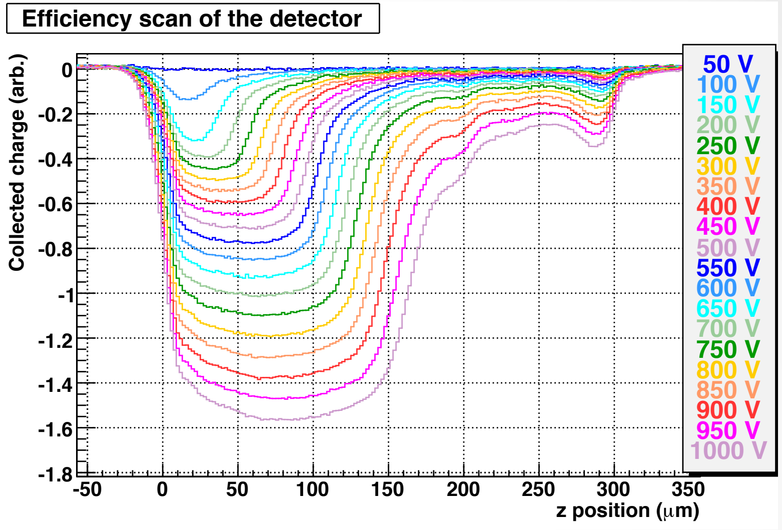


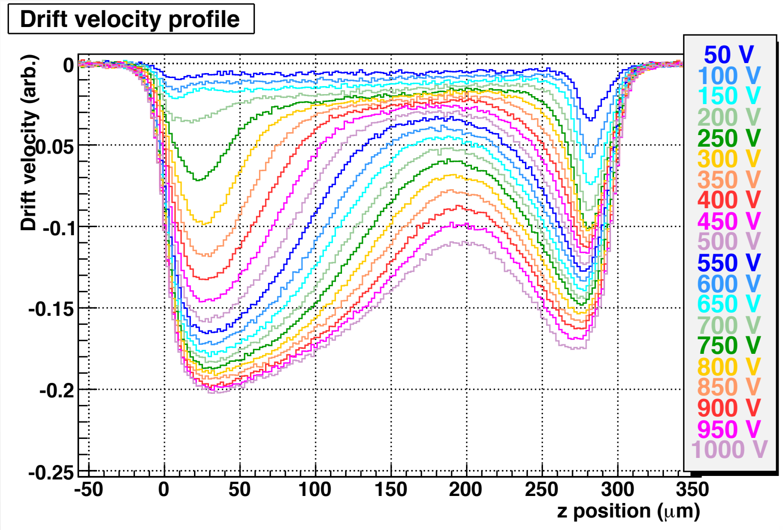
MCz

# ETCT – 2480 mins ann.

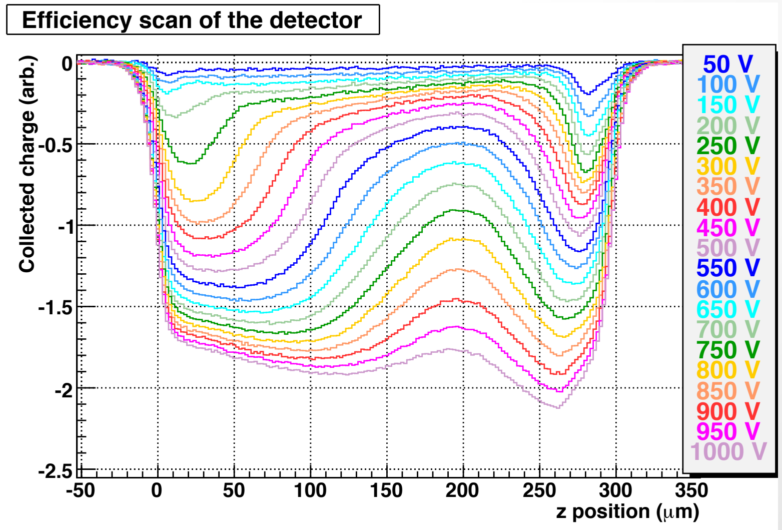


FZ

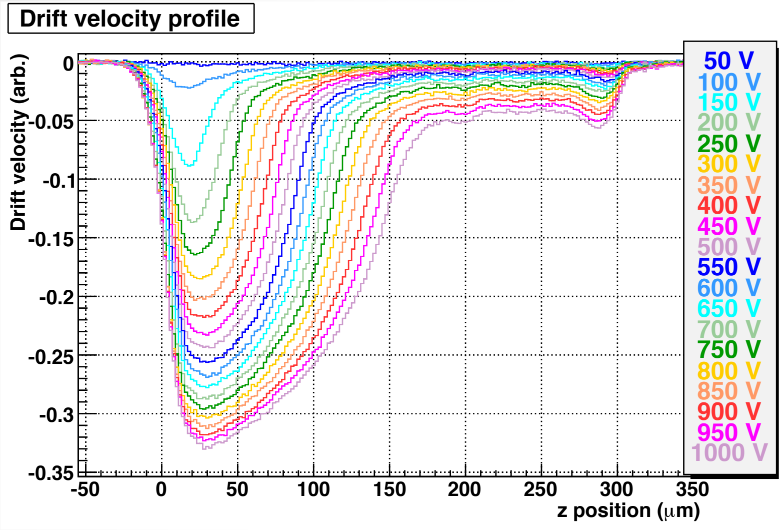


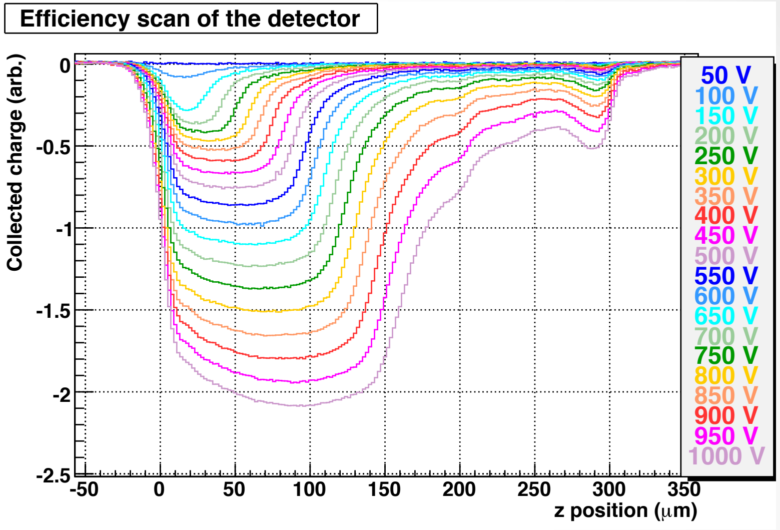


MCz

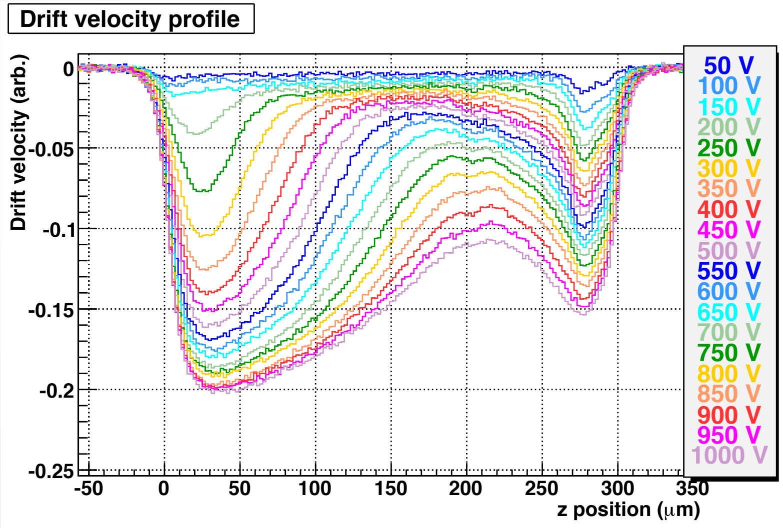


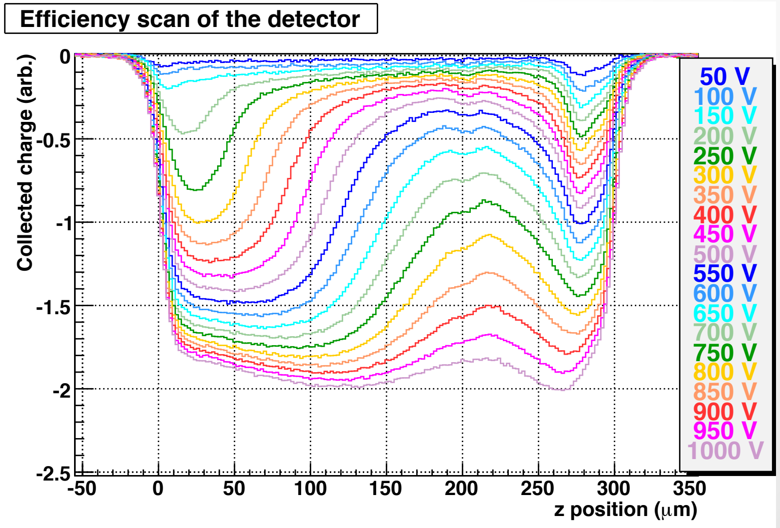
# ETCT – 5040 mins ann.





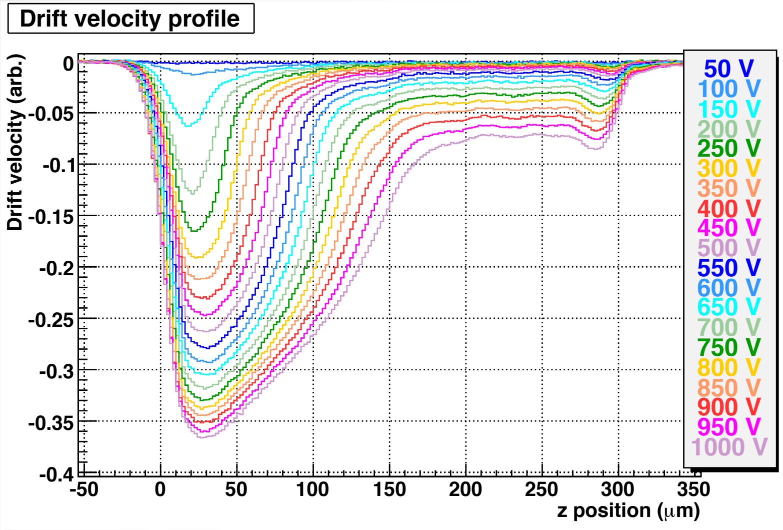
FZ



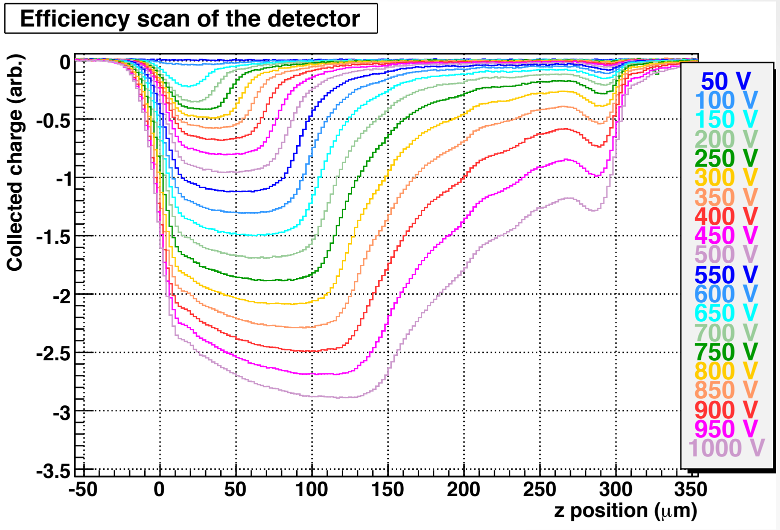


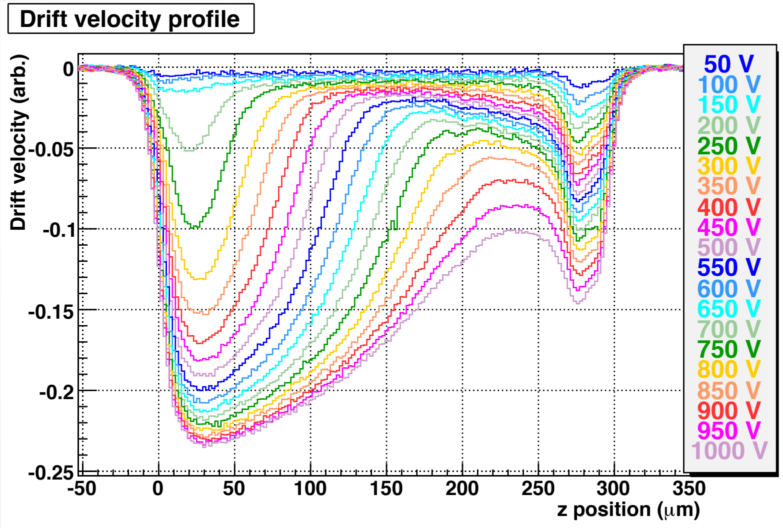
MCz

# ETCT – 10200 mins ann.

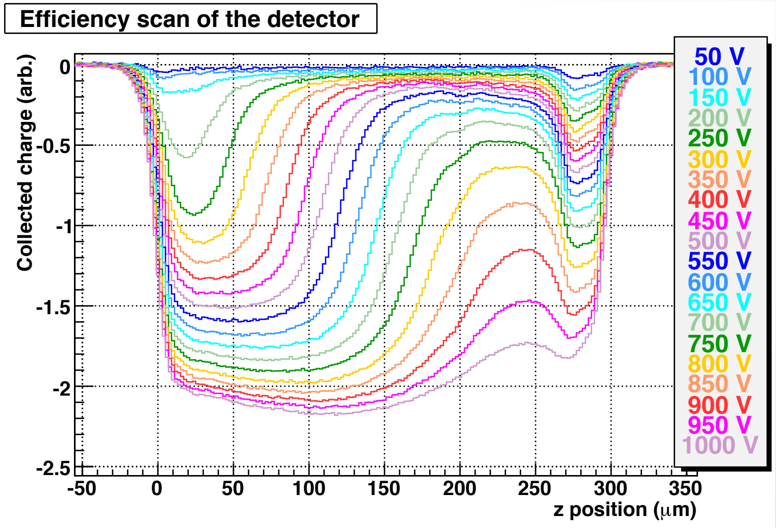

Drift velocity profile

FZ


Efficiency scan of the detector


Drift velocity profile

MCz

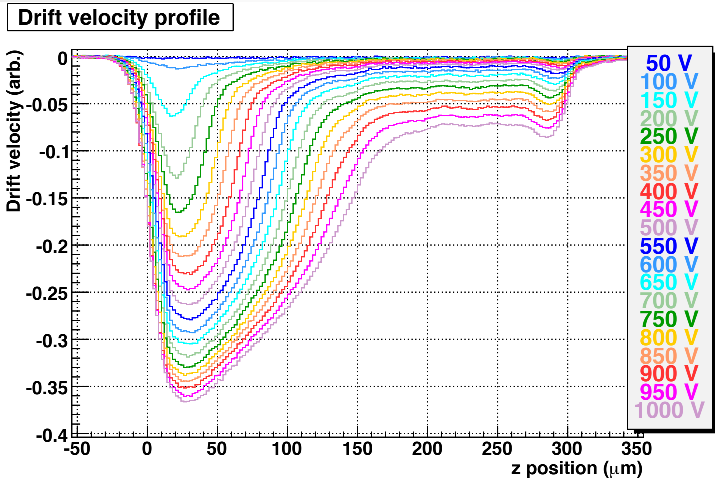

Efficiency scan of the detector

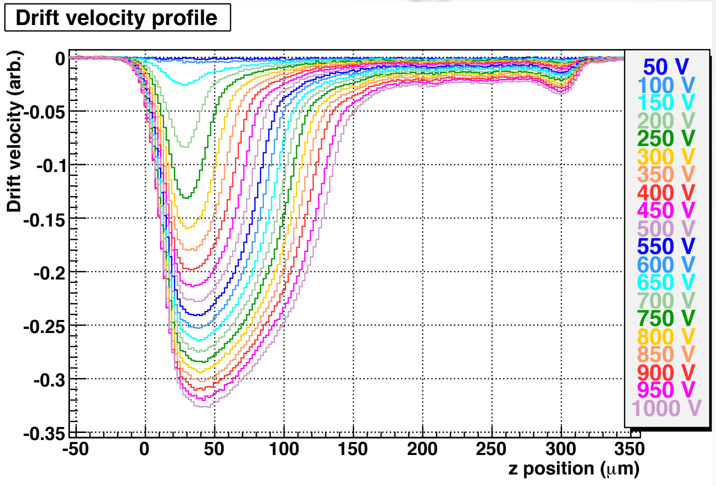
# Float Zone CM "Quenching"

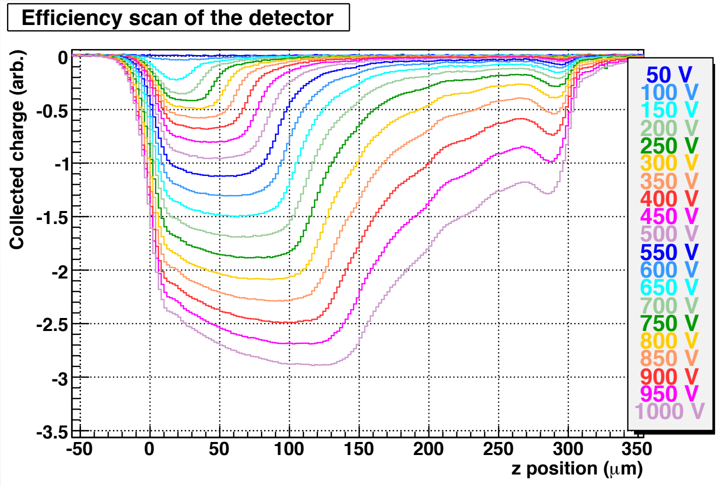
- It was casually observed that after 10200 minutes of annealing, FZ was developing a "memory"…
- High current injection, either performed in reverse at high temperature or in forward at -25°C (I~700 uA in both cases) changes the field and efficiency configuration, "turning off" the charge multiplication.
- The effect can be reversed by leaving the detector overnight at room temperature.
- The defect can survive in its active state for > 2 days at -25°C…

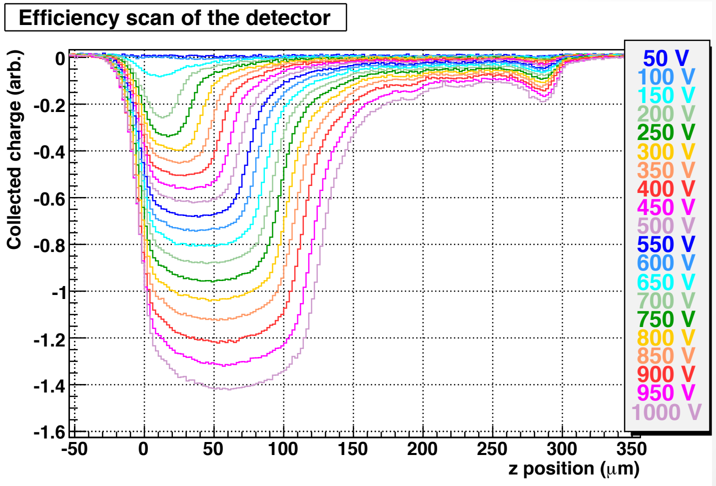
Plots on next slide…

# Float Zone CM "Quenching"





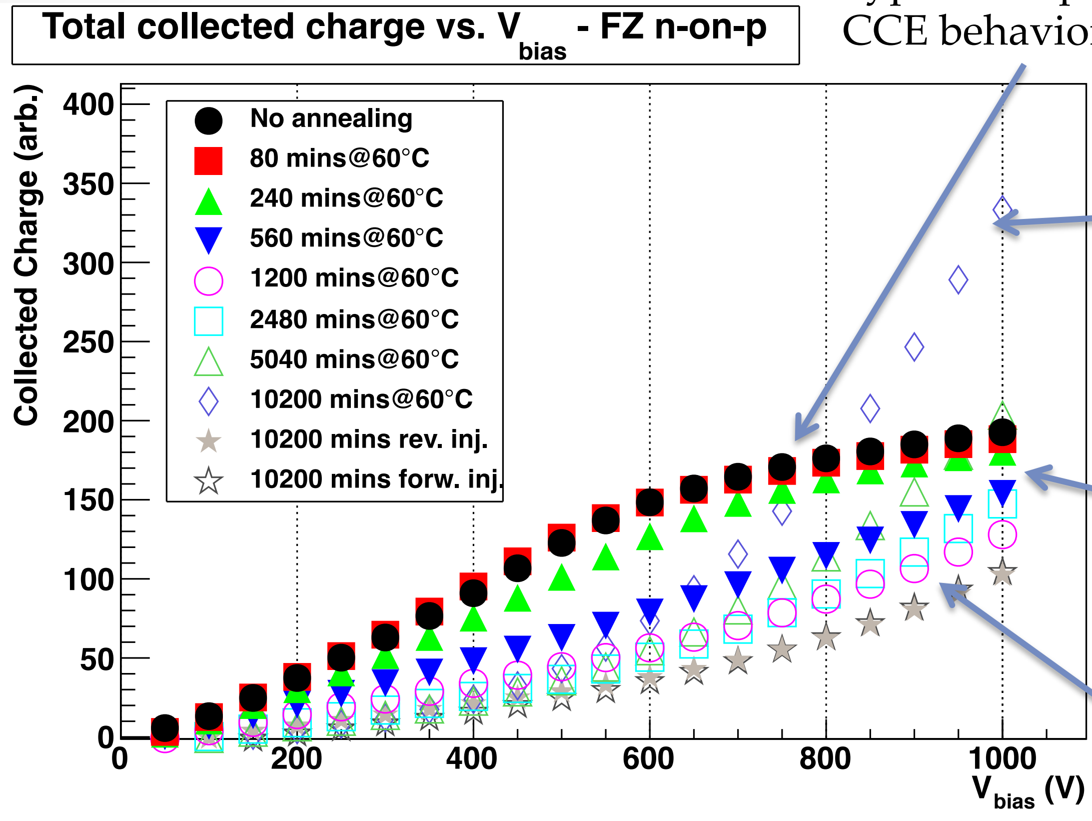




Immediately after annealing

After 700 uA forward injection

# Total collected charge - FZ



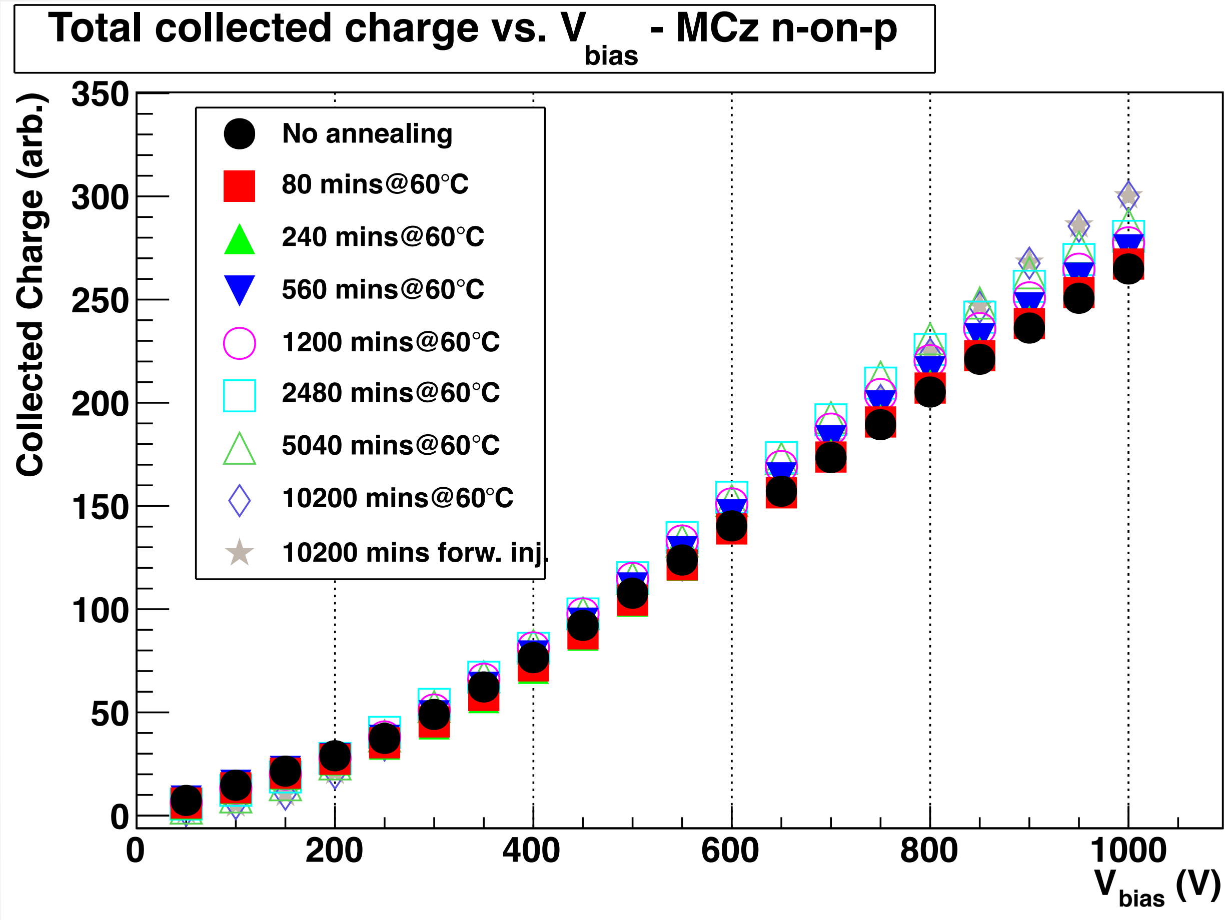
Typical "depleted" CCE behavior

Strong charge multiplication after high annealing times

Evident CM beginning from 2480 mins at 60°C

Bistable effect(s?) seems to turn off a noticeable part of the CM effect.

# Total collected charge - MCz



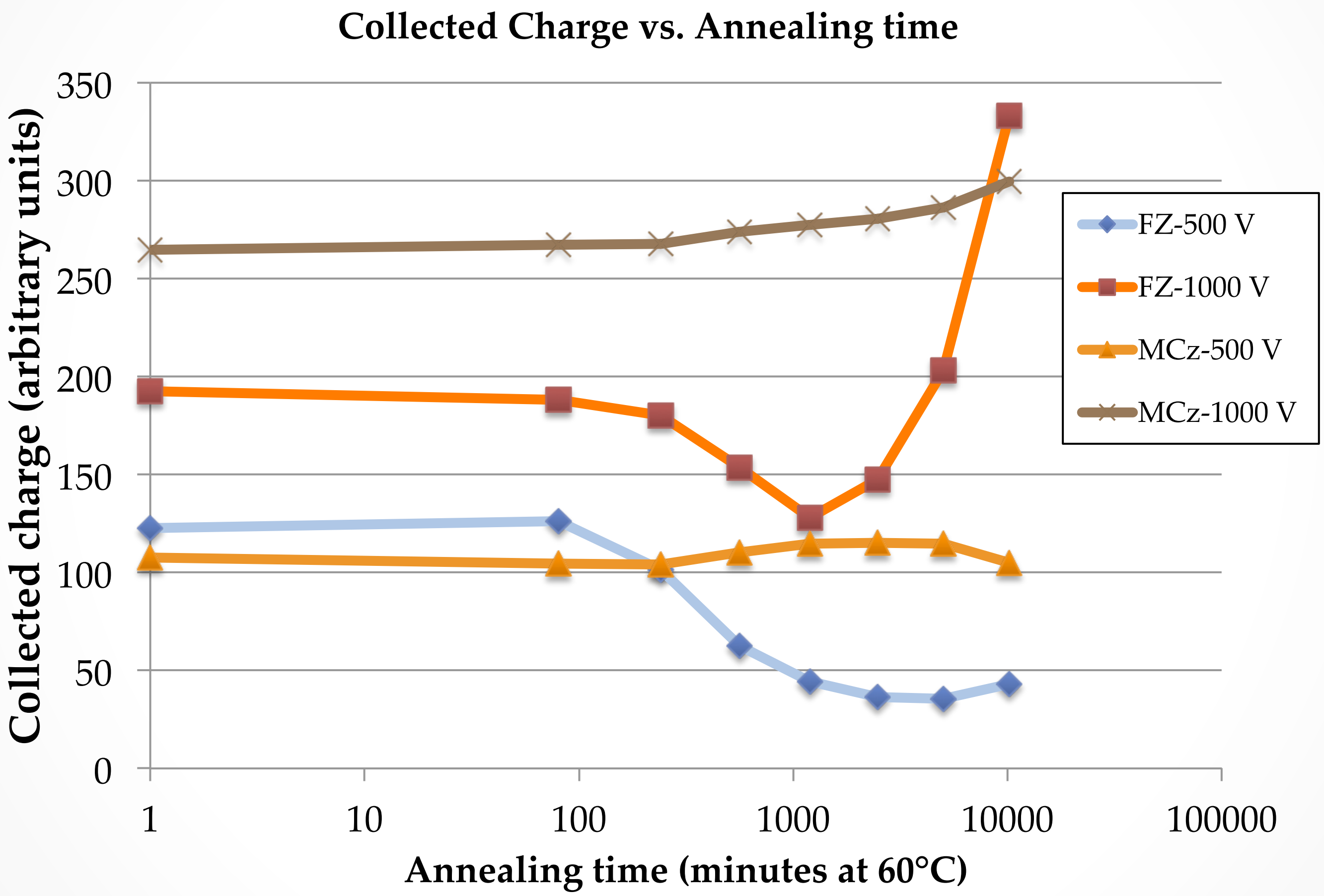
No obvious CM evidence

–

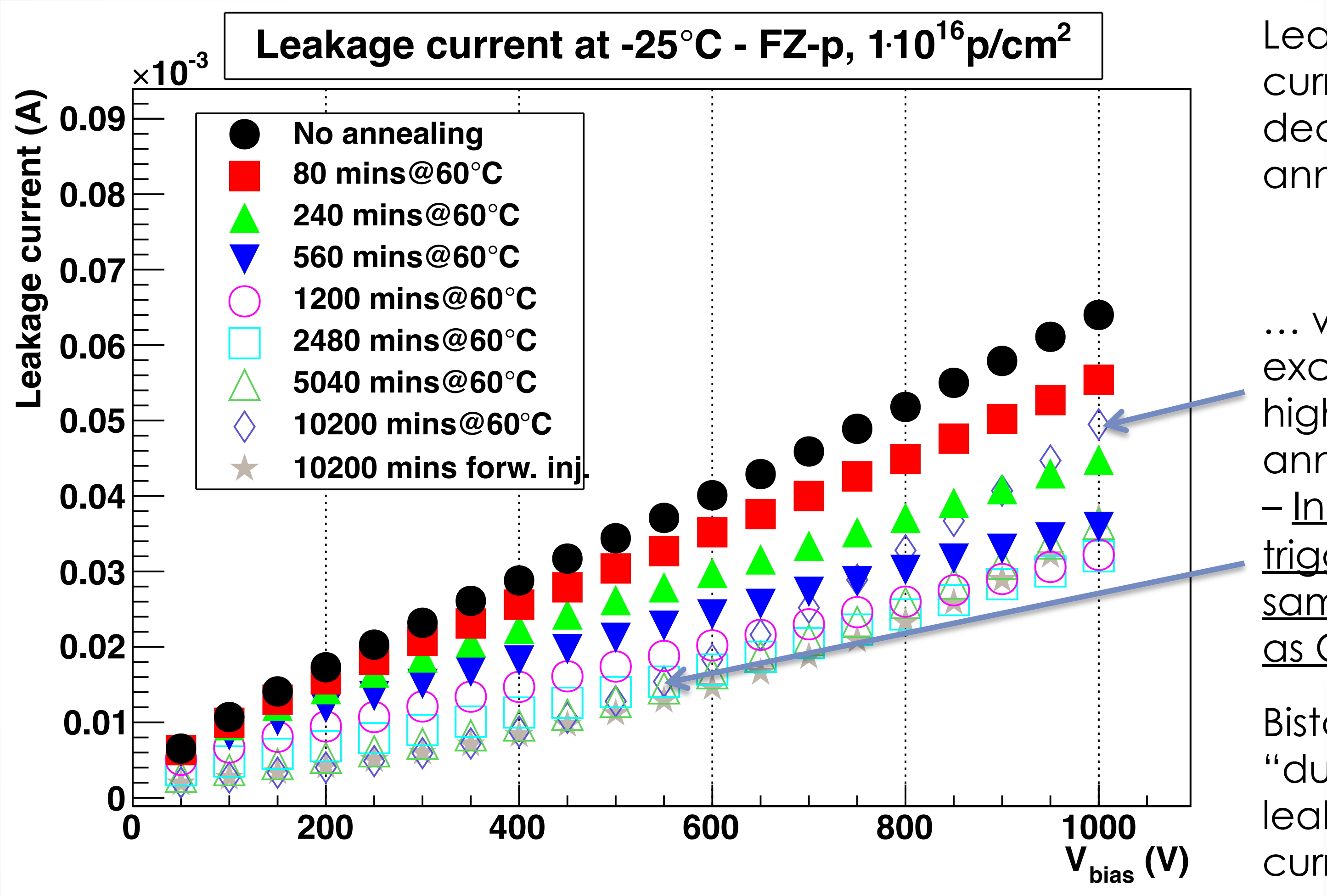
No evidence of bistable effect as well

Annealing seems to have no influence on collected charge

# Collected charge - comparison



# Leakage Current with Annealing - FZ



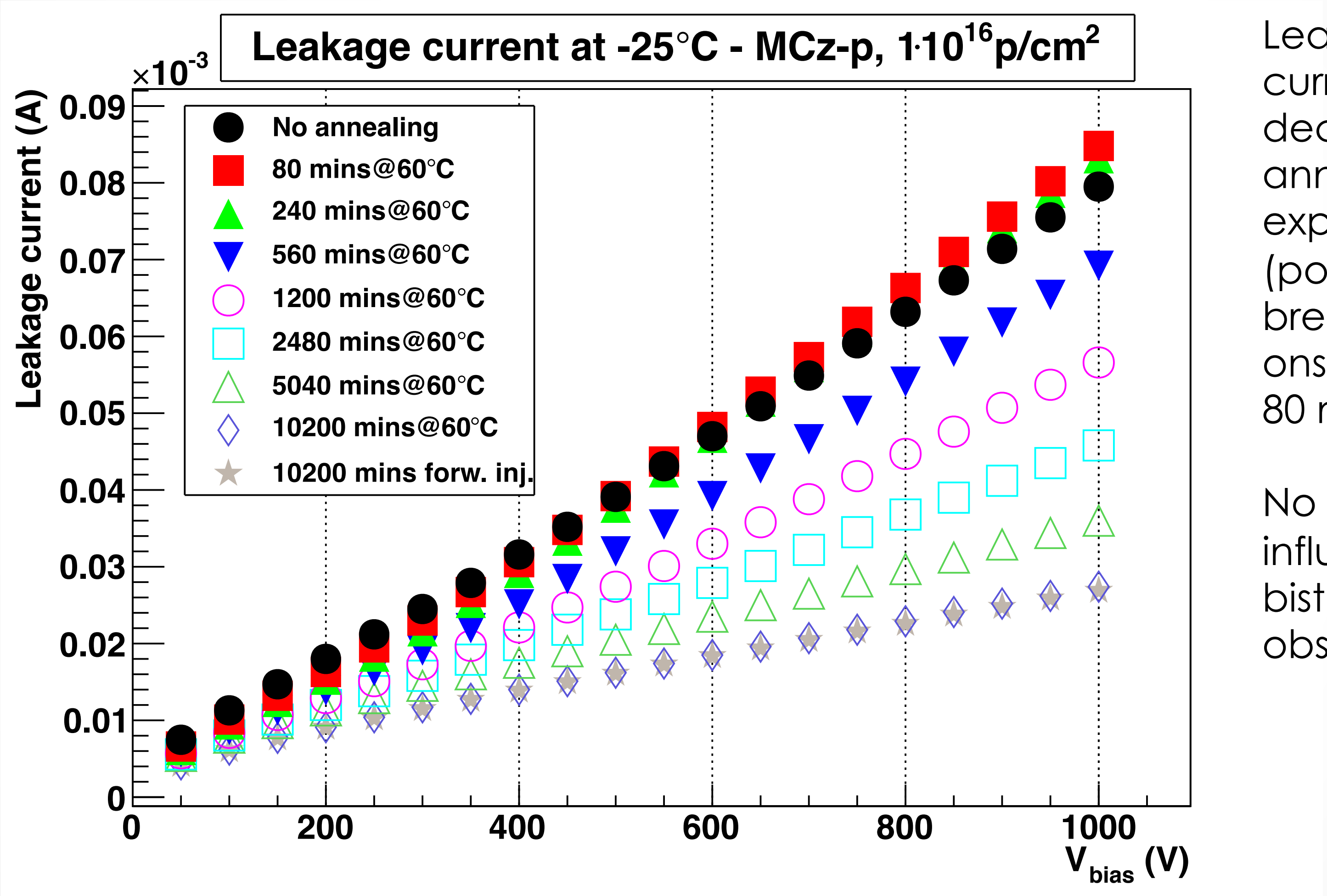
Leakage current decreasing with annealing…

… with the exception of highest annealing step – <u>Increase triggered at same voltage as CM</u>

Bistable defect "dumping" leakeage current as well

Note: guard-ring not connected

# Leakage Current vs. Annealing - MCz



Leakage current decreasing with annealing as expected (possible small breakdown onset only after 80 minutes)

No evidence of influence of the bistable effect observed in FZ

Note: guard-ring not connected

# Conclusions

- Edge-TCT measurements performed at several annealing steps show radically different behavior for FZ and MCz silicon
- FZ devices show a double junction field configuration. Annealing brings to an overall acceptor-introduction.
  - At higher annealing time, virtually all the field is concentrated in the strip region.
  - Important CM onsets here
  - A bistable defect was observed, affecting both the field (CM dumping) and the leakage current – If we look in the direction of field attenuation in the strip region, the defect should contribute with a positive space charge.
- MCz silicon is by far less sensitive to annealing.
  - The collected charge is almost unaffected even after high annealing times.
  - The leakage current still follows the expected trend.
  - No bistable defect was observed in this kind of device – Most probably high oxygen concentration are gettering the defect observed in FZ.
- Studies are ongoing on the other materials from Micron-RD50 2010
  - p-on-n, n-on-n devices.
  - CSM will be developed further to verify method reliability

Thank you…