Recent developments of CERN RD39 Cryogenic Tracking detectors Collaboration

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On behalf of CERN RD39 Collaboration

http://rd39.web.cern.ch/RD39/

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Outline

- Introduction
- Current injected detectors
- LHe temperature TCT setup
- Edgeless silicon detectors

Introduction

Charge collection efficiency :

$$CCE = CCE_{GF} \times CCE_{t} = \frac{w}{d} e^{-t_{dr}/\tau_t}$$

CCE_{GF} : geometrical factor (w : depletion depth , d : detector thickness)

CCE_t : trapping concerns

$$w = \sqrt{\frac{2\varepsilon\varepsilon_0 V}{eN_{eff}}} \text{ and } \frac{w}{d} = \sqrt{\frac{V}{V_{fd}}}$$

N_{eff} : effective doping concentration

t_{dr} : carrier drift time

τ_τ : trapping time

V_{fd} : full depletion voltage

Trapping time

Trapping time : strong dependence on irradiation level

$$\tau_t = \frac{1}{\sigma v_{th} N_t}$$

$v_{th} \sim 10^7$cm s^{-1} thermal velocity (saturation)

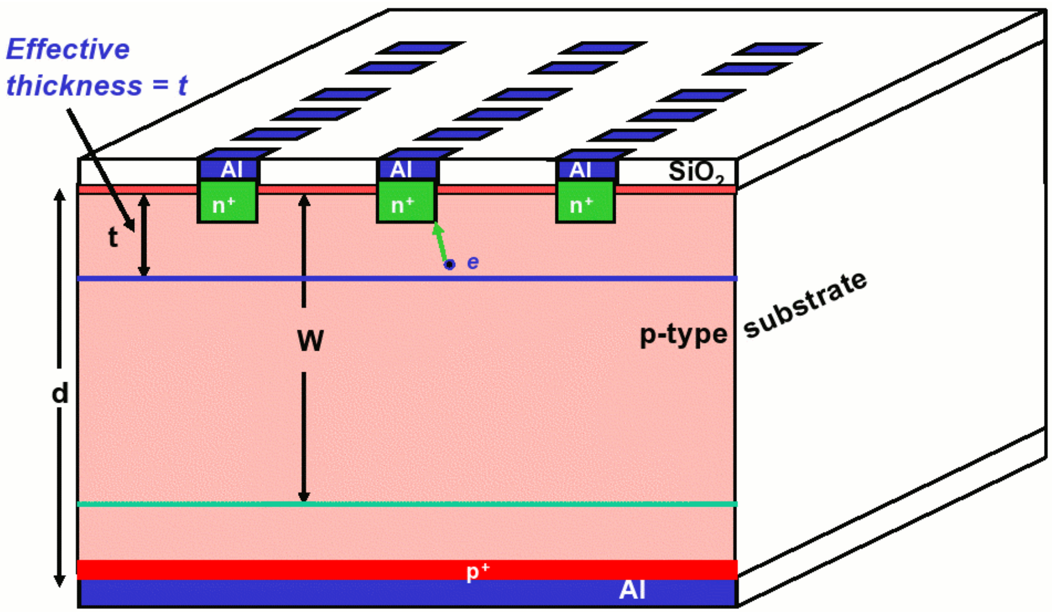
σ : capture cross section of the trap

N_t : concentration of such traps <-> fluence Φ_n

Fluences / effective thickness :

- At LHC : for $\Phi_n = 10^{14}$ n_{eq}/cm^2 , $\tau_t \sim 20$ ns ! <=> 2 mm : not a problem
- At SLHC : for $\Phi_n = 10^{16}$ n_{eq}/cm^2 , $\tau_t \sim 0.2$ ns ! <=> 20 µm : effective thickness

Effective thickness



$$\tau_t = \frac{1}{\sigma v_{th} N_t}$$

$Q(t) = Q(w) \cdot t/w$

$Q(w) = W/d \cdot Q_0$

$Q(t) = Q_0 \cdot t/d$

$1/\tau_t = \gamma \, \Phi_n$ H.W. Kraner et al., Nuclear Instruments and Methods in Physics Research A326 (1993) 350-356

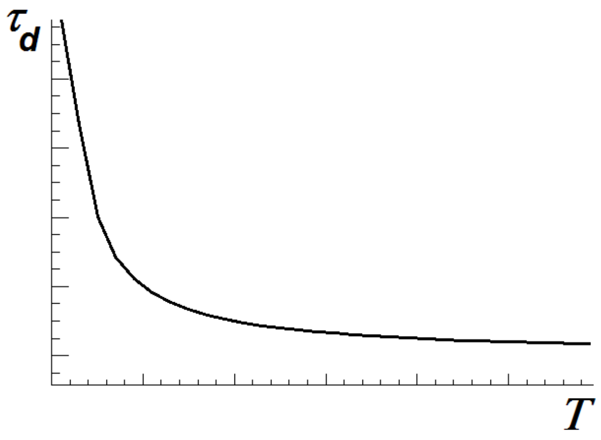
- $\gamma_e = 7.50 \times 10^{-7}$ cm²/s , $\gamma_h = 3.75 \times 10^{-7}$ cm²/s
- for $\Phi_n = 10^{16}$ n_{eq}/cm^2: $\tau_{t,e} = 0.13$ ns , $\tau_{t,h} = 0.26$ ns

Trapping distance (or *effective charge collection distance* d_{eff}) :

$d_{eff} \leq \tau_t \times V_s = 20$ µm << min(d,w)

Detrapping time

Strong dependance on temperature :



$$\tau_d = \frac{1}{\sigma v_{th} N_C e^{-E_t/kT}}$$

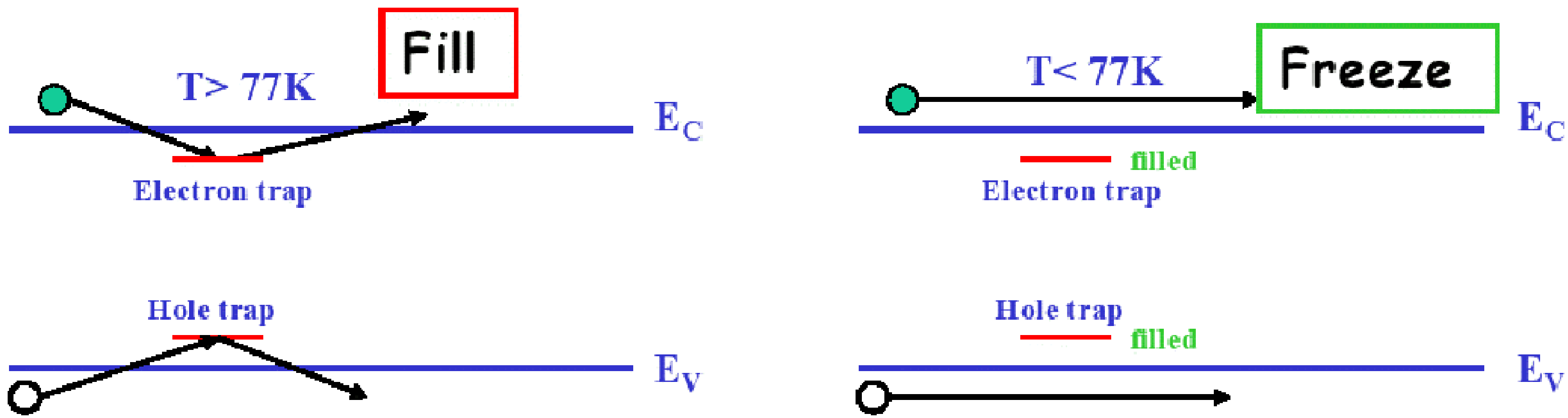
N_C : electric state density

E_t : trap energy level (deep or shallow)

Shallow level : A center (O-V) E_c = -0.18 eV with $\sigma \approx 10^{-15}$ cm^2

T(K)	300	150	100	77	60	55	50	48	47	46
τ_d	3.7 ns	3.9 µs	4 ms	2 s	1.22 hrs	1.2 days	53 days	302 days	2.1 years	5.47 years

Freezing traps



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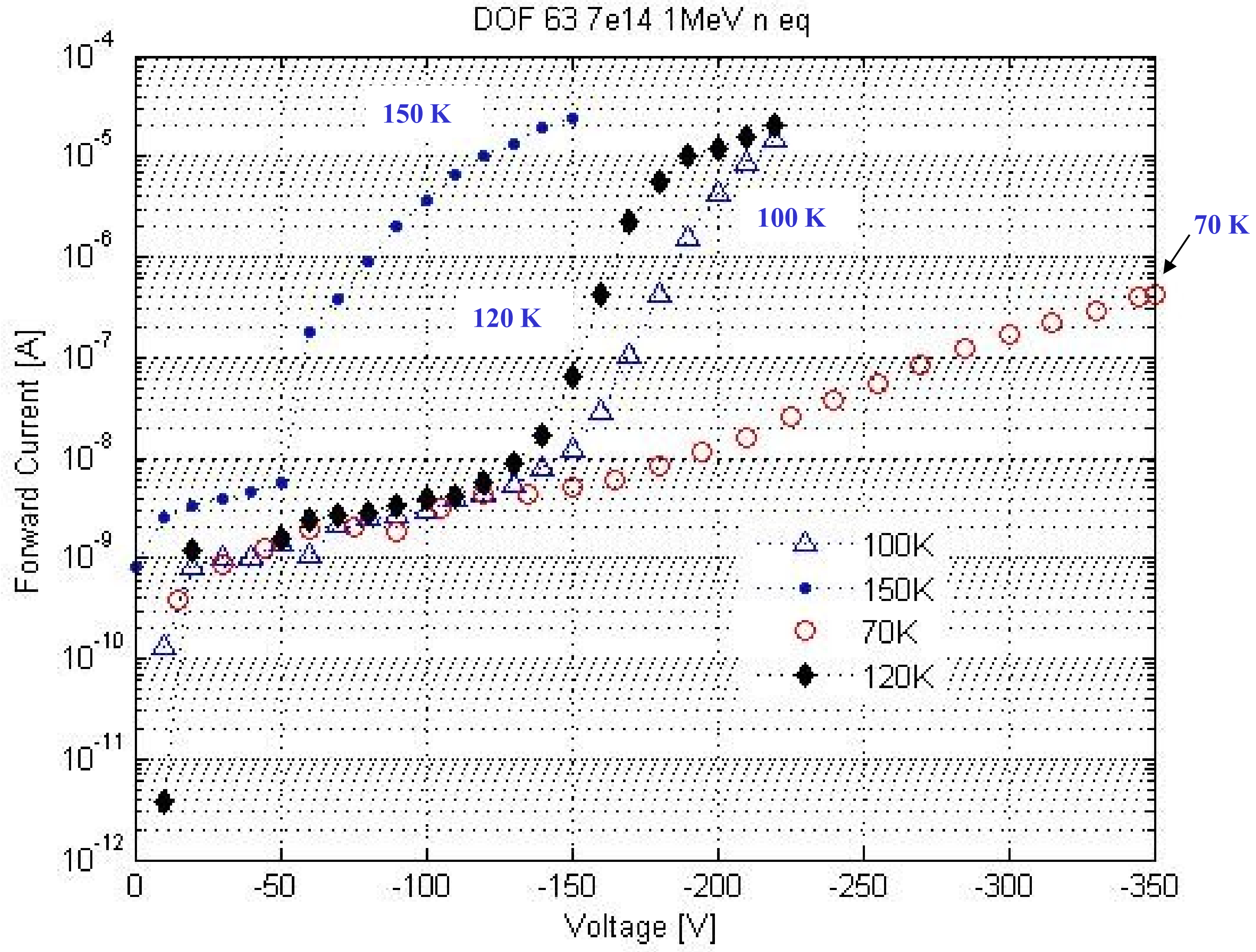
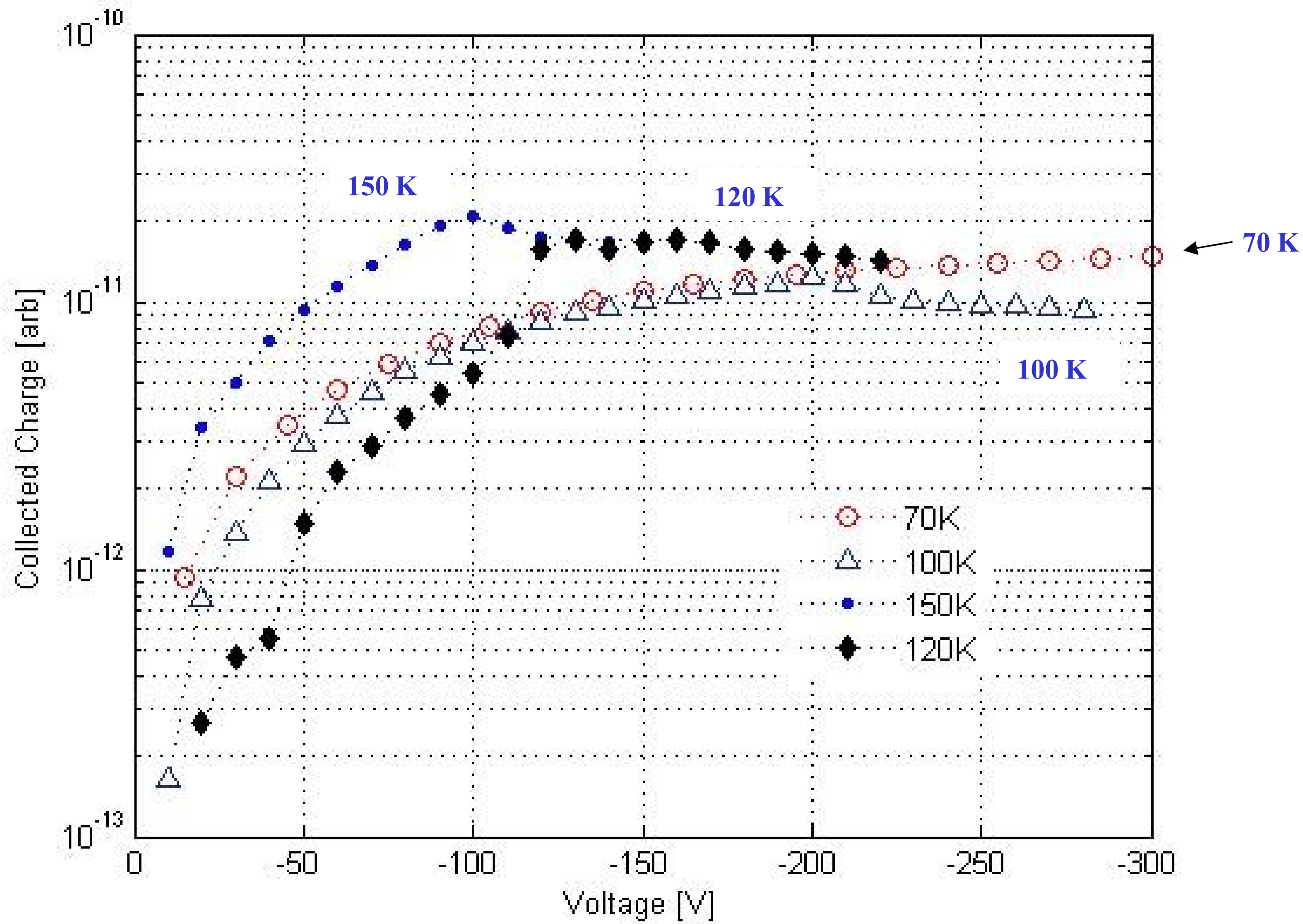
CID


DOF 63 7e14 1MeV n eq
150 K
100 K
70 K
120 K
Forward Current [A]
Voltage [V]
100K
150K
70K
120K
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
0
-50
-100
-150
-200
-250
-300
-350

CID



150 K
120 K
70 K
100 K
Collected Charge [arb]
10^{-10}
10^{-11}
10^{-12}
10^{-13}
0
-50
-100
-150
-200
-250
-300
Voltage [V]
70K
100K
150K
120K

LHe TCT setup

Sub Liquid Nitrogen temperature : CCE measurements with a fast TCT setup at CERN

Transient Current Technique -> picosecond laser (30ps FWHM, λ = 678nm)

- Laser on n+ implant : hole injection
- Laser on p+ implant : electron injection

By the TCT measurement

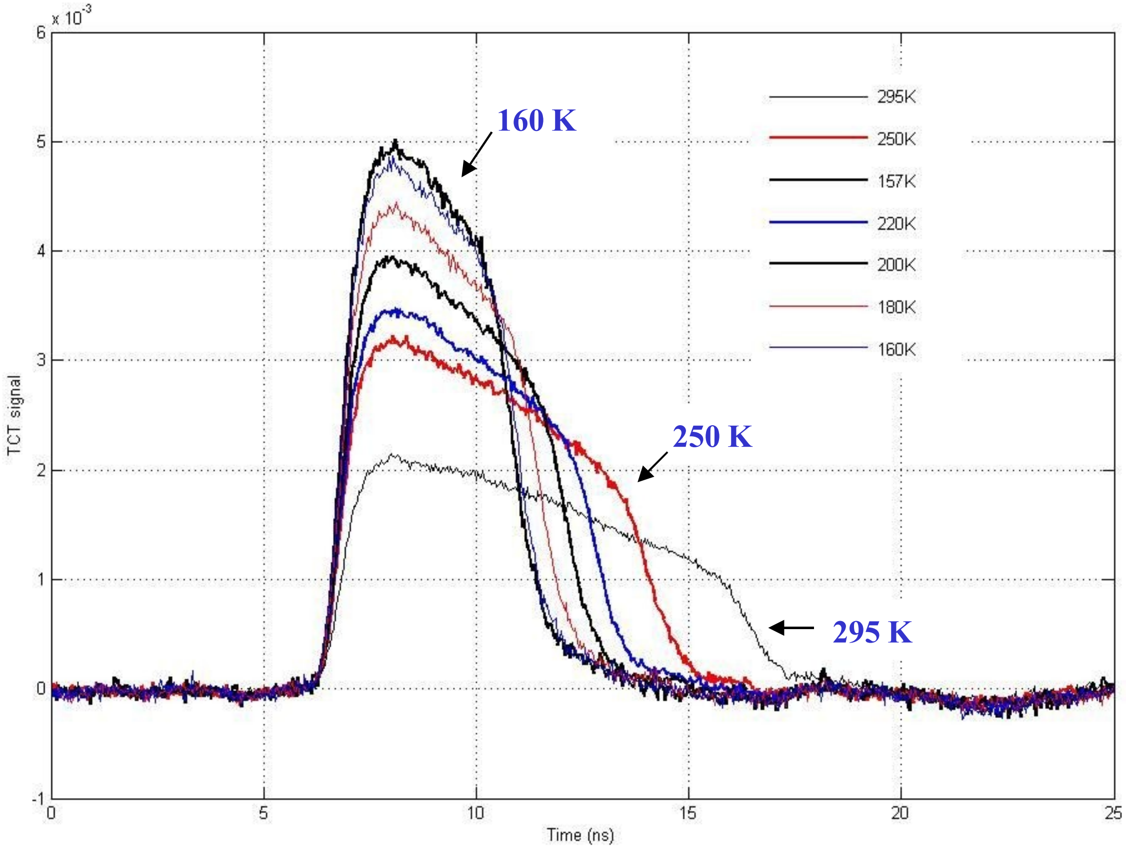
- the full depletion voltage
- effective trapping time
- the sign of the space charge in the bulk.

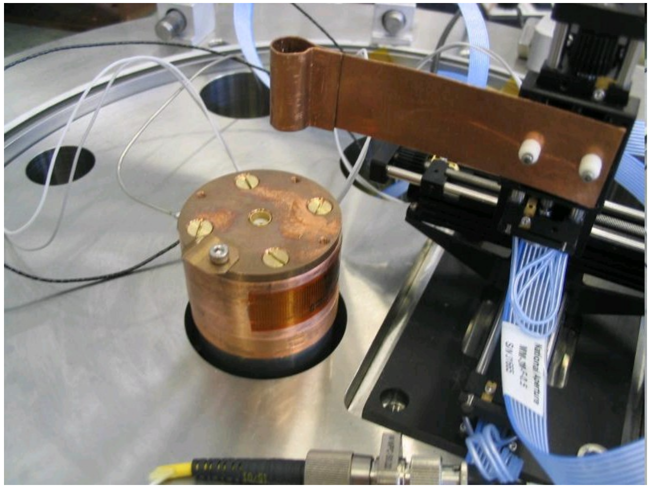
Detection of the dominant type of charge carrier, electron or hole, which drifts across the whole detector

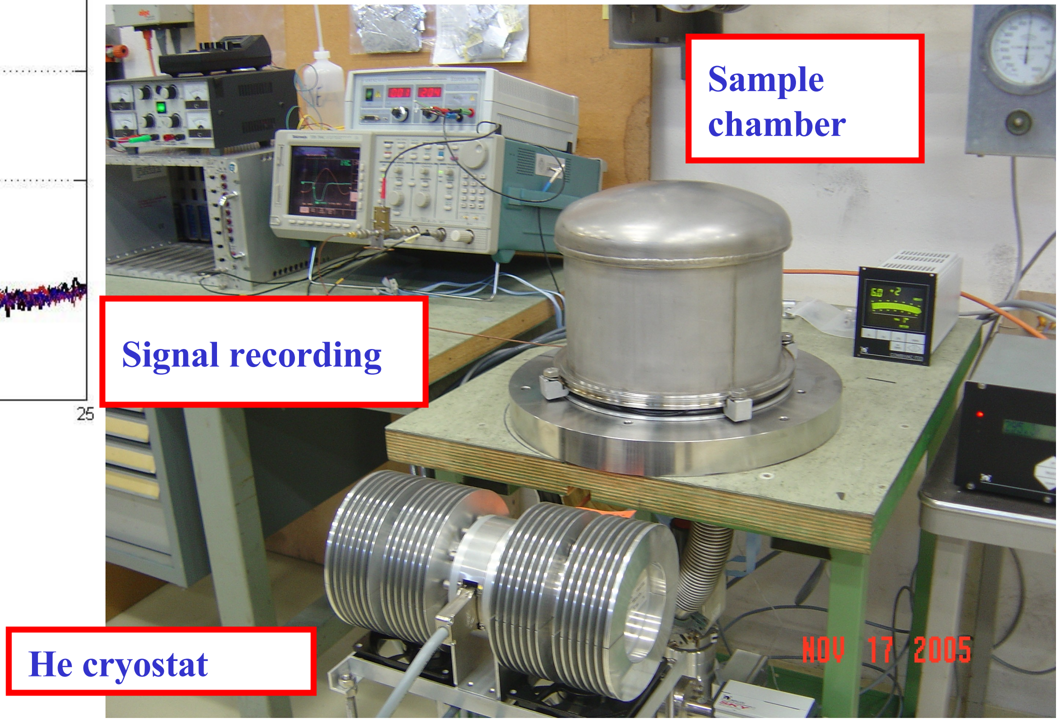
He Cryostat -> temperature range : [2K ; 300K] : “LHe-TCT”

Calibration & CCE measurements are under way

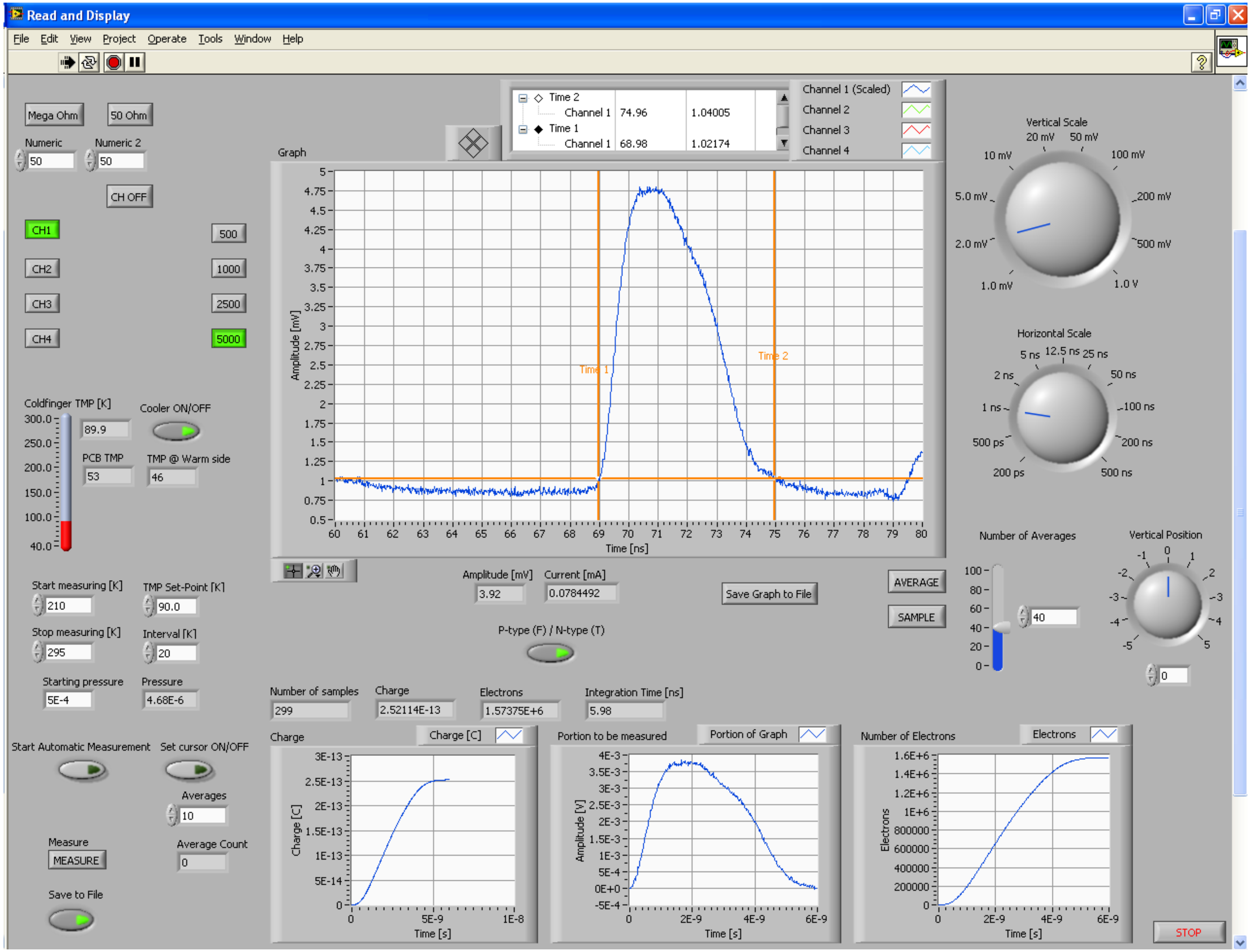
TCT

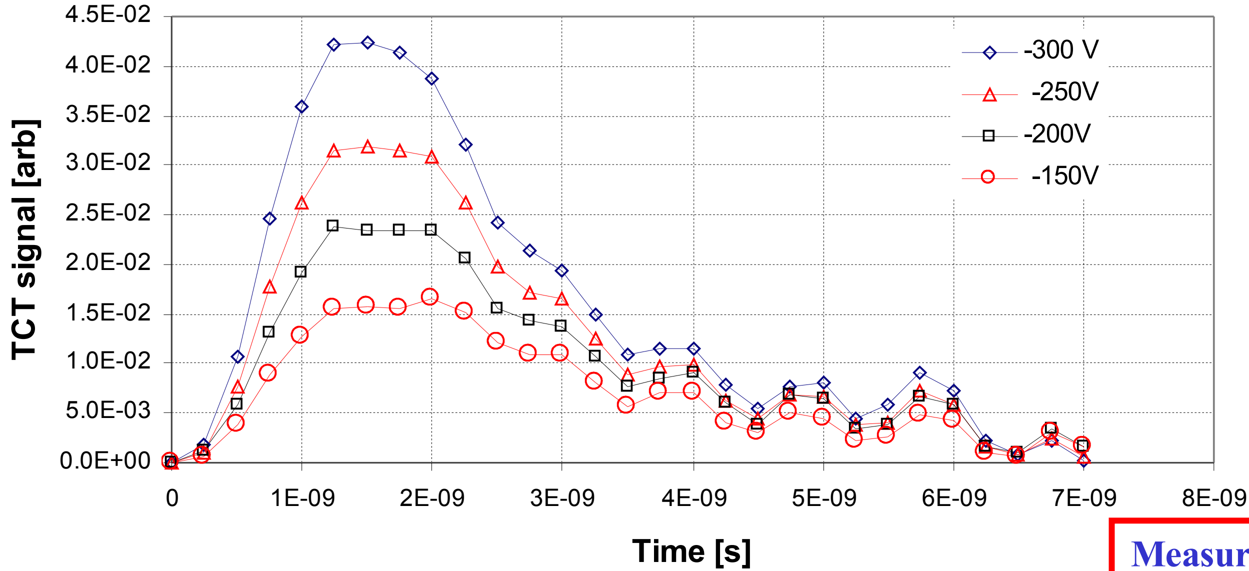

x 10^-3
TCT signal
Time (ns)
0
5
10
15
20
25
-1
0
1
2
3
4
5
6
295K
250K
157K
220K
200K
180K
160K
160 K
250 K
295 K



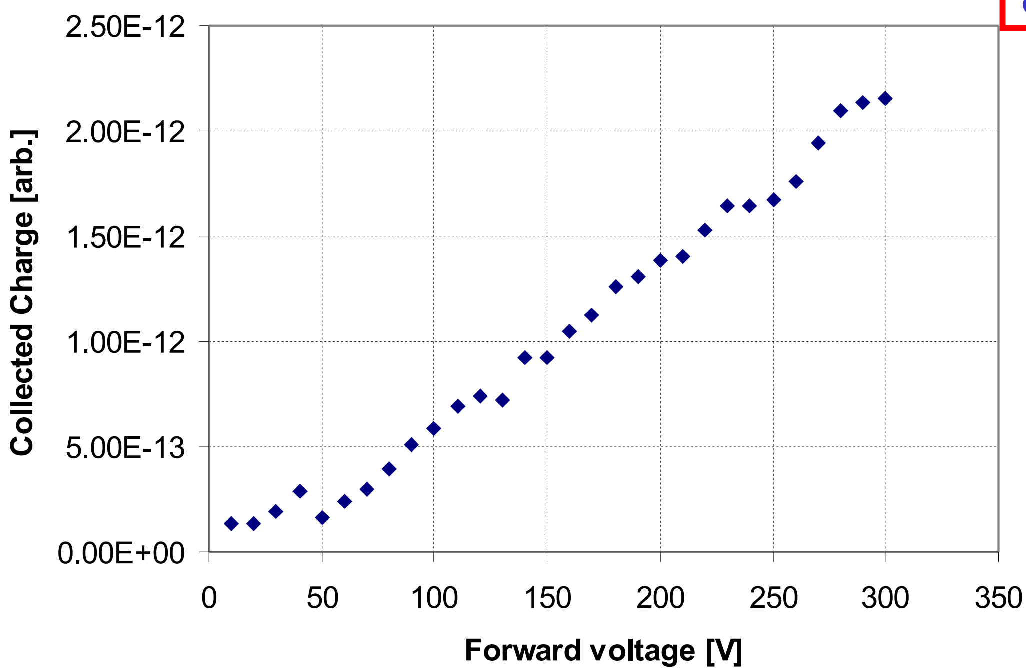

Sample chamber
Signal recording
He cryostat
NOV 17 2005

TCT computer interface





Measurements from He cryostat, at 60K



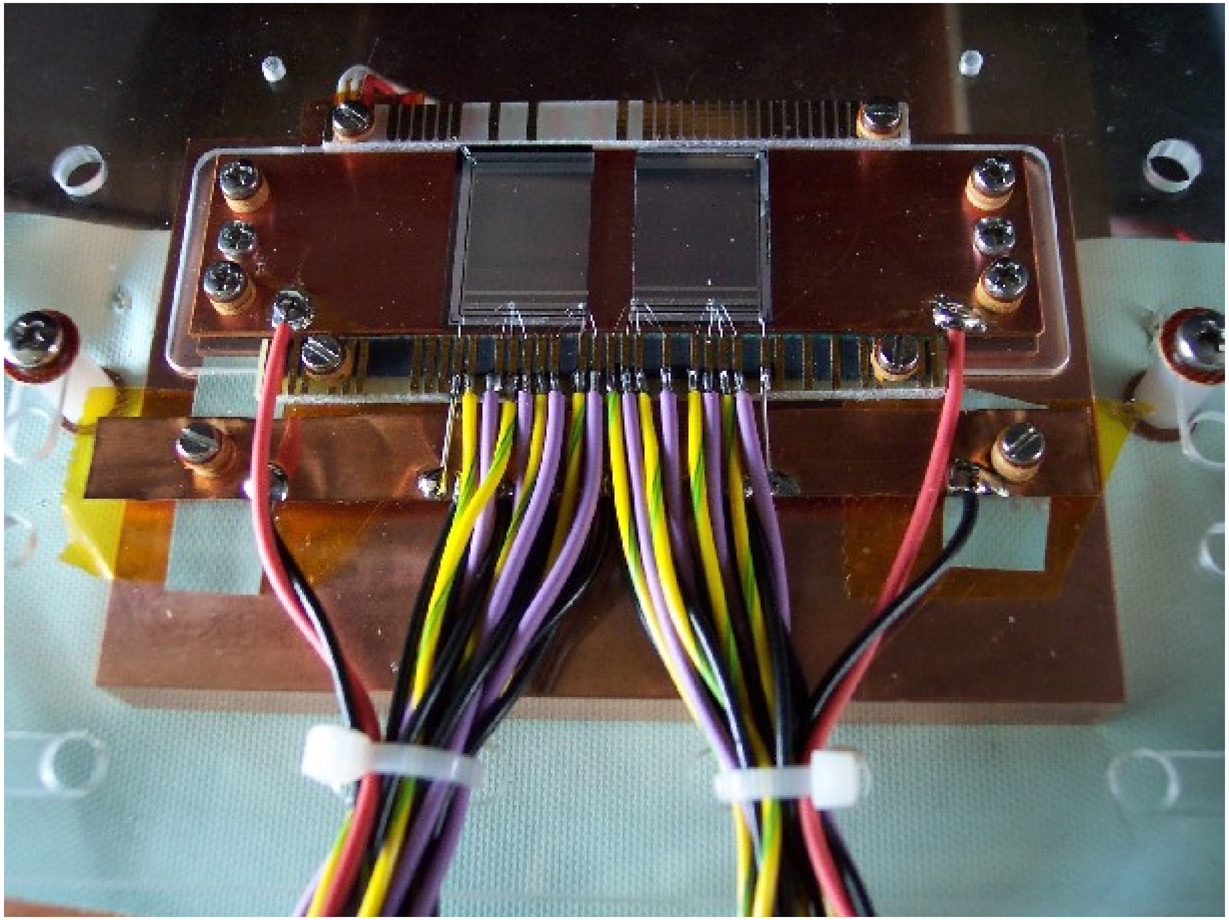
P-type MCZ, red laser $1x10^{15}/cm^2$

Edgeless silicon detectors

New cut technique under study : plasma cut sensors

- plasma cut edgeless sensors

- here : regular CMS baby detectors

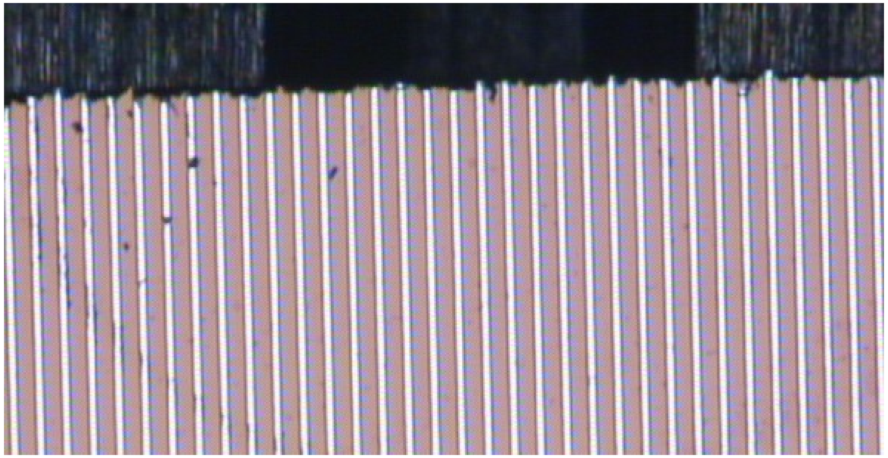


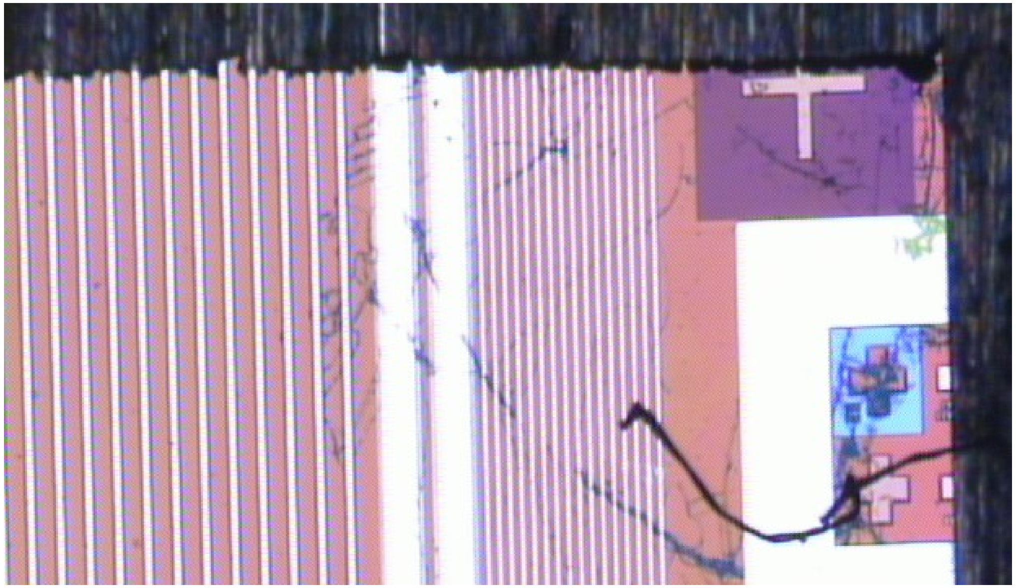
Sensors :

- Single-sided
- FZ
- 1.5 cm long microstrips
- 320µm thick
- p+/n/n+/Al

Irradiation with 20MeV neutrons foreseen next months

Plasma etching

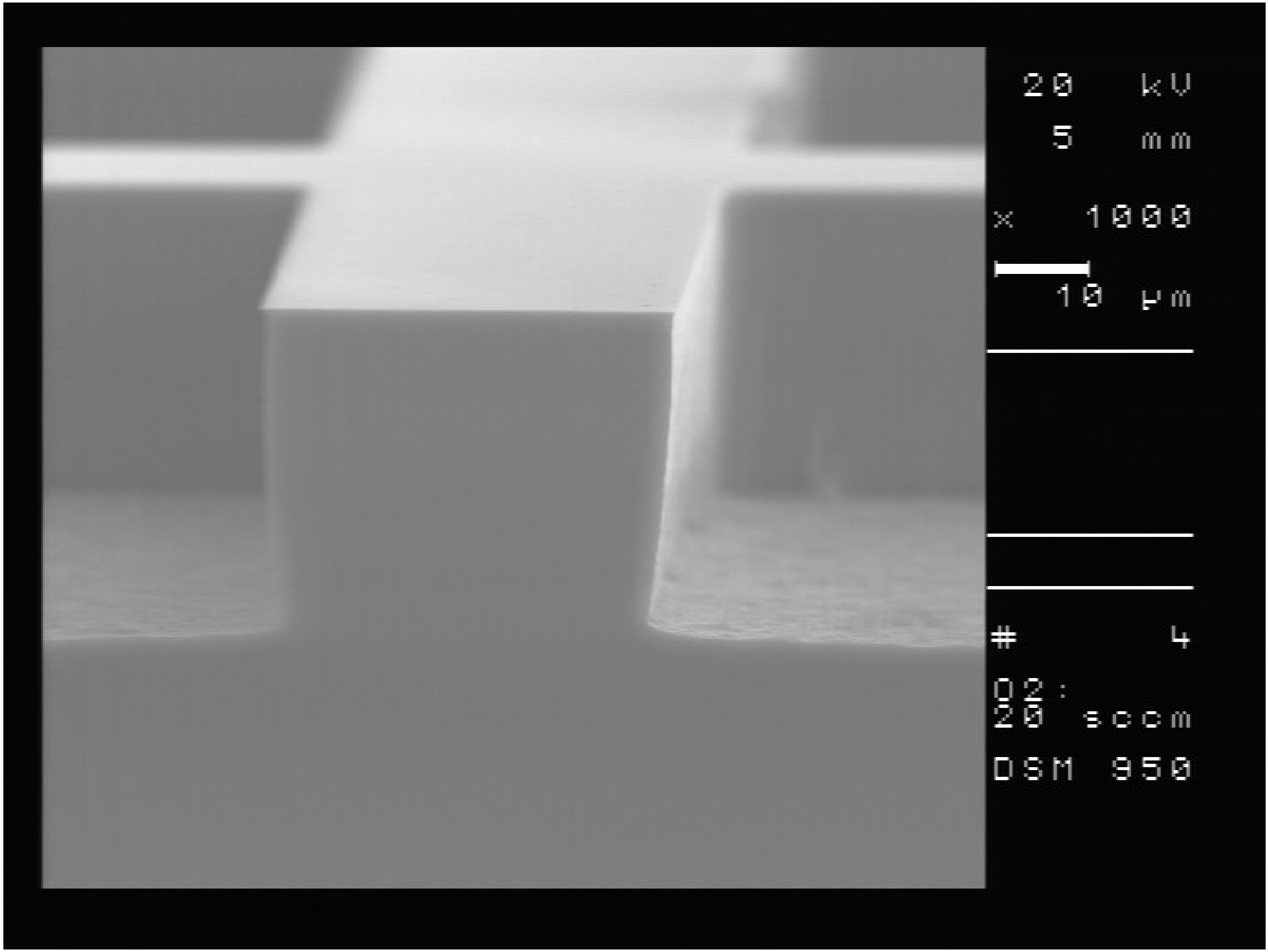




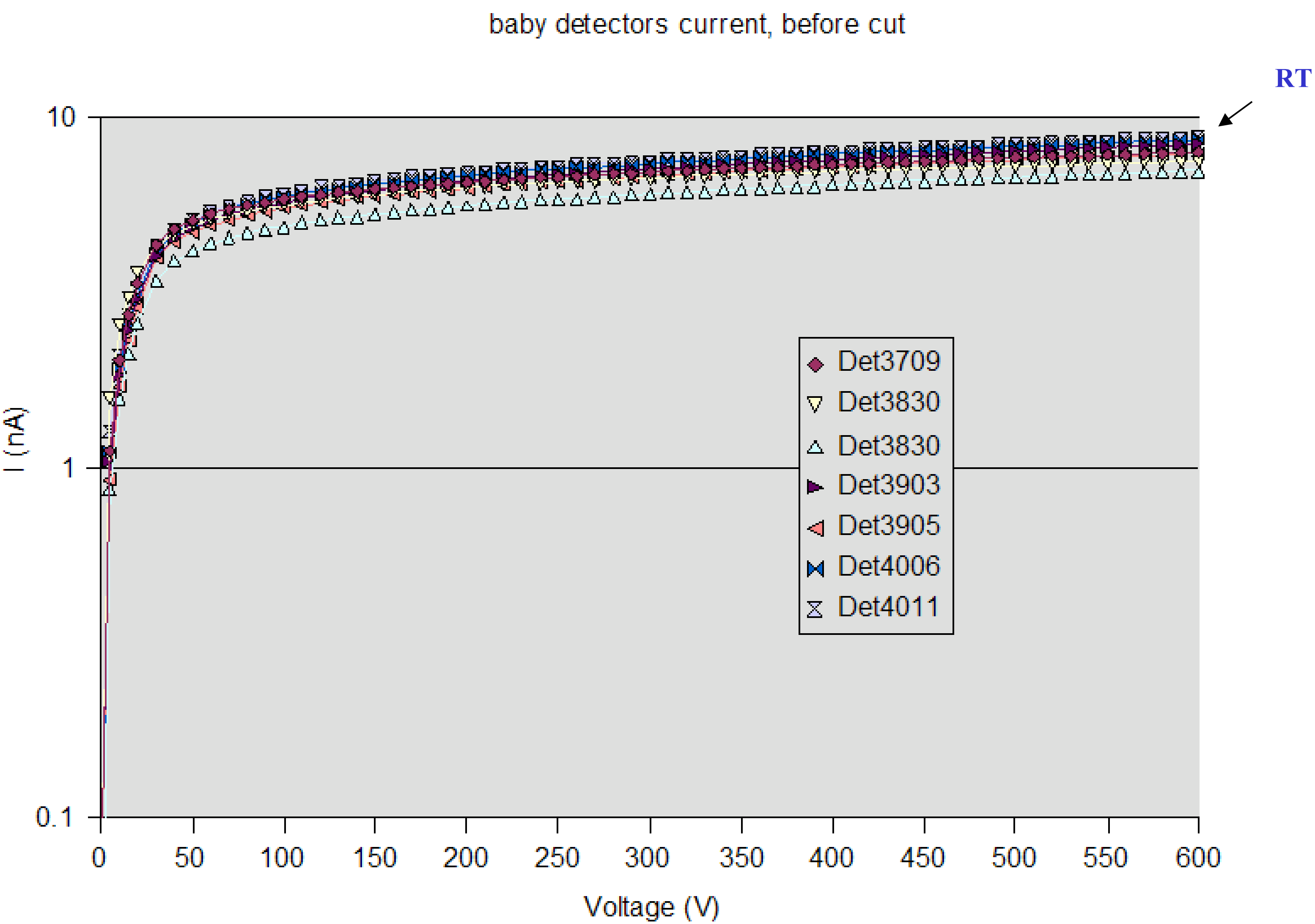
Etch parameters:

- Temperature -110ºC
- ICP-Power 1-2 kW
- CCP-Power 1-3 W
- SF_6 flow max. 100 sccm
- O_2 flow 12-20 sccm
- Pressure 10-20 mTorr

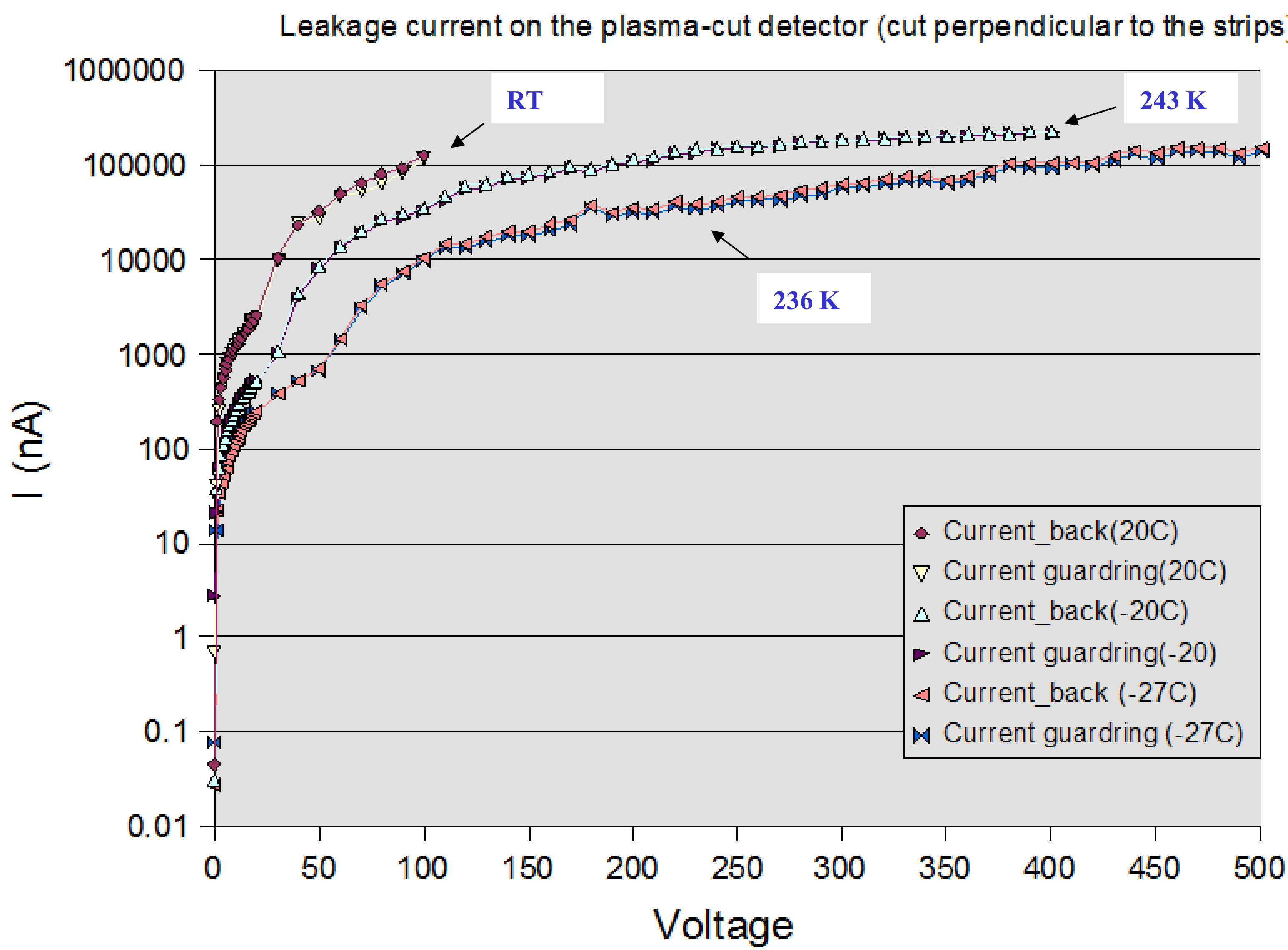
Plasma etching



IV curves before etching



IV curves after etching



Louvain Laser setup

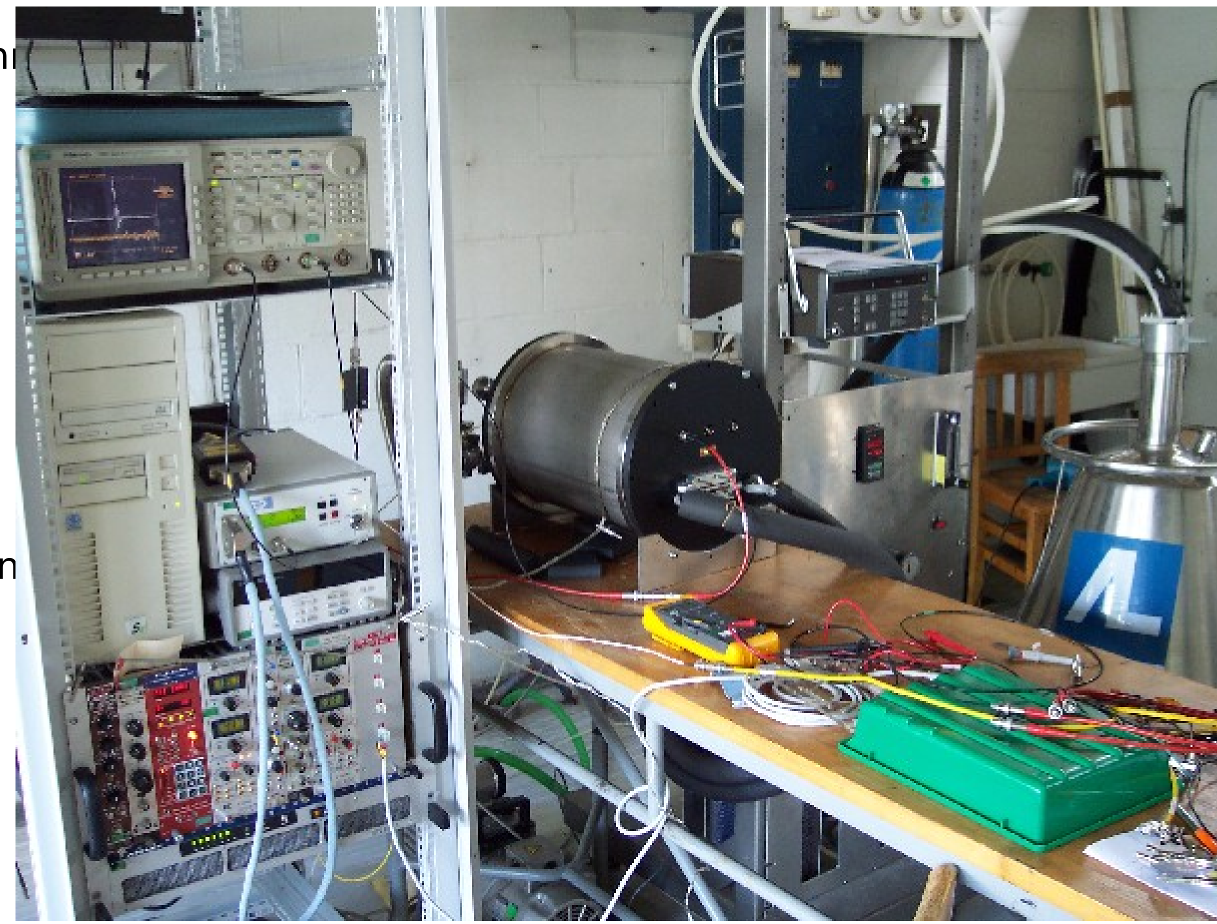
Setup

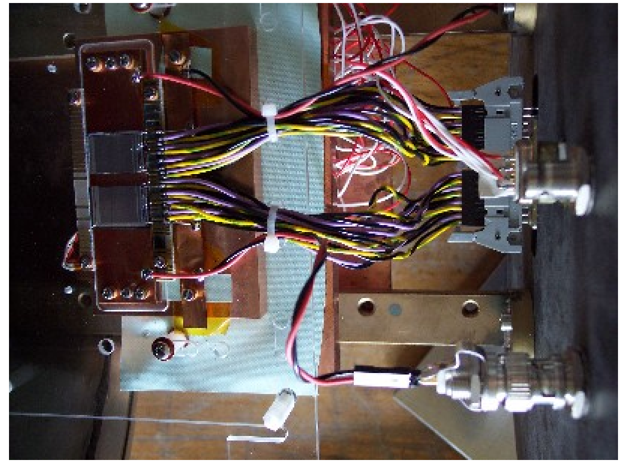
Setup for CCE measurement in Louvain, including :

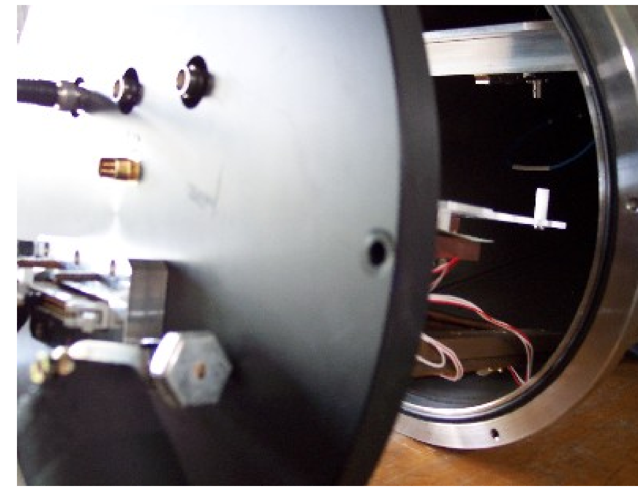
- a picosecond pulsed laser (677n
- a wideband bipolar amplifier
- a vacuum tank
- a temperature controller

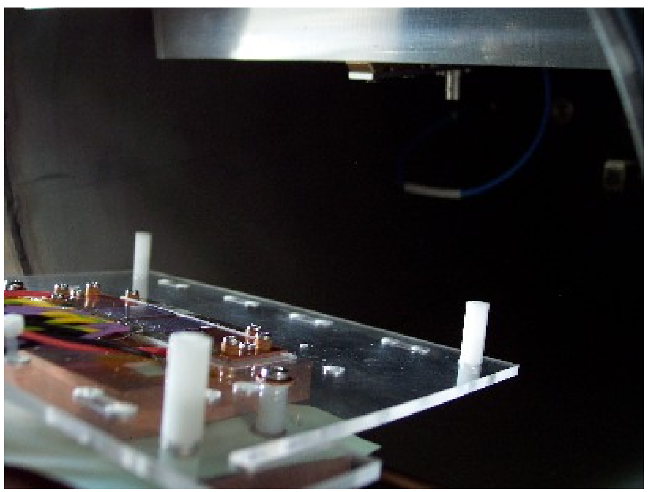
  + LNi cooling

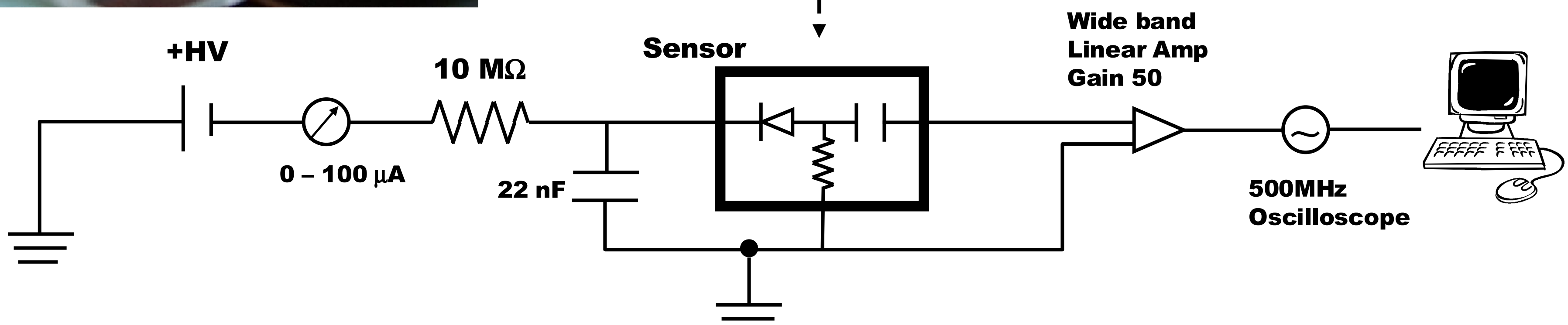
- computer controlled environmen
- other usual machinery










Laser
λ = 677 nm
32 ps FWHM
1 MHz max
+HV
0 – 100 µA
10 MΩ
22 nF
Sensor
Wide band
Linear Amp
Gain 50
500MHz
Oscilloscope

Neutron beam

Fast neutron beam

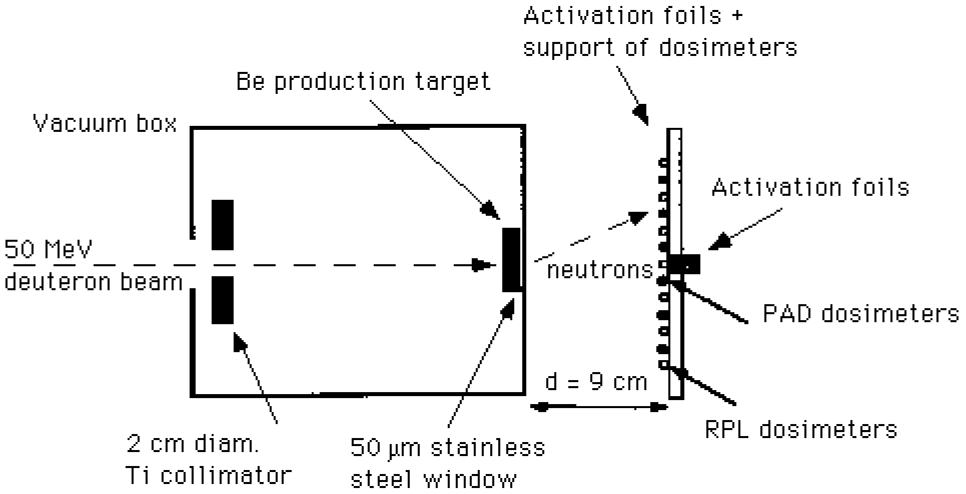
The neutron irradiation will be performed with the fast neutron beam :

- based on ^{9}Be +d -> n +X, using a 50 MeV deuteron beam on a 1 cm thick beryllium target

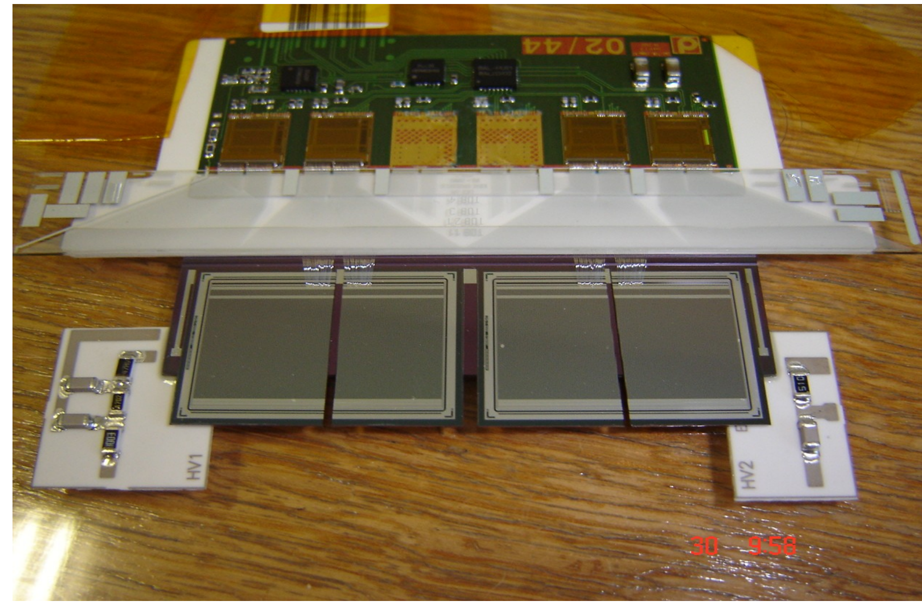
- the deuteron beam is accelerated by the Louvain-la-Neuve isochronous cyclotron

http://www.cyc.ucl.ac.be

http://www.fynu.ucl.ac.be/themes/he/RD50/index.html



Edgeless module prototype



Sensors :

- Single-sided
- 1.5 cm long microstrips
- 320µm thick
- p+/n/n+/Al
- few nA/cm^2 at V_{fd} , before cut.
- 10^5 times higher (100 µA) , after the cut
- Standard laser-dicing (BNL) + chemical treatment
- Two geometries : along the strip (a few µm) ; angular cut (a few degrees)

Electronics :

- CMS tracker front-end hybrids (with 4 APV25 readout chips)

Perspectives

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