IMB-CNM and IFIC activities in P-type detectors

M. Lozano, C. Fleta*, G. Pellegrini, M. Ullán, F. Campabadal, J. M. Rafí

CNM-IMB (CSIC), Barcelona, Spain

(*) Currently at University of Glasgow, UK

S. Martí, C. García, C. Lacasta, M. Miñano

IFIC (CSIC), Valencia, Spain

Prague, 26th June 2006

Index

- Our first intention was to report only the "Development of Moderated p-spray Isolation Techniques for P-type Detectors at CNM"
- Unfortunately, the clean room process is not yet finished
- We will explain the activities of CNM and IFIC in P-type detectors

TOPICS

I. Finishing of RD50 processing

II. Simulation and processing of moderated p-spray isolation techniques

III. First module with 3 cm p-type strip detectors

I. Finishing of RD50 processing

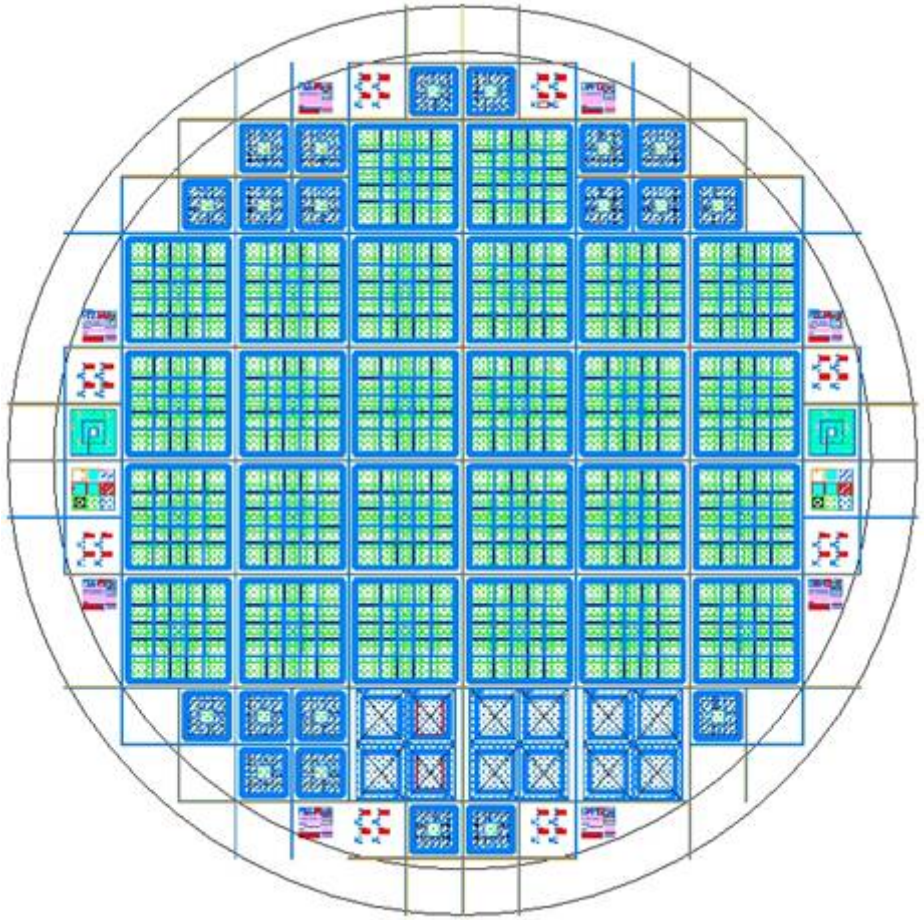
RD50 process

- The p-spray technology is ready
- We have found a set of implant conditions that offer enough strip insulation, keeping the breakdown voltage high enough
  - **Energy, E=100 keV, dose = 3×10^{12} cm^{-2}**
- We checked with gamma irradiation that the insulation is kept after oxide charge saturation
- A set of 22 wafers has been processed using RD50 microstrip mask set with the above implant conditions
- Wafers are diced and will be stored at CERN for irradiation and/or collection

Reminder of RD50 process

Technology	Wafers	Growing method	Type	Wafer origin	Comments
P-in-N	4	MCZ	N	RD50	>500 Ω·cm, 300 µm
	2	EPI	N	RD50	thickness ~ 150 µm
N-in-P	4 (+1)	MCZ	P	RD50	>2 kΩ·cm, 300 µm
	4	FZ	P	CNM	
	4 (+1)	FZ	P	CNM	Oxygen enriched DOFZ
	2	EPI	P	RD50	thickness ~ 150 µm
N-in-N	2	FZ	N	CNM	Single side processing
TOTAL	22 (+2)				

Reminder of RD50 microstrip mask set



Technology

- P-in-N and N-in-P

Mask set

- Designed by the RD50 Collaboration
- Double-side processing
- One metal layer

Structures

- 26 microstrip detectors
  - Polysilicon biasing resistors
  - Capacitive coupling
  - P-spray insulation
  - No p-stops
- 20 pad detectors
- 12 pixel detectors
- 8 test structure sets

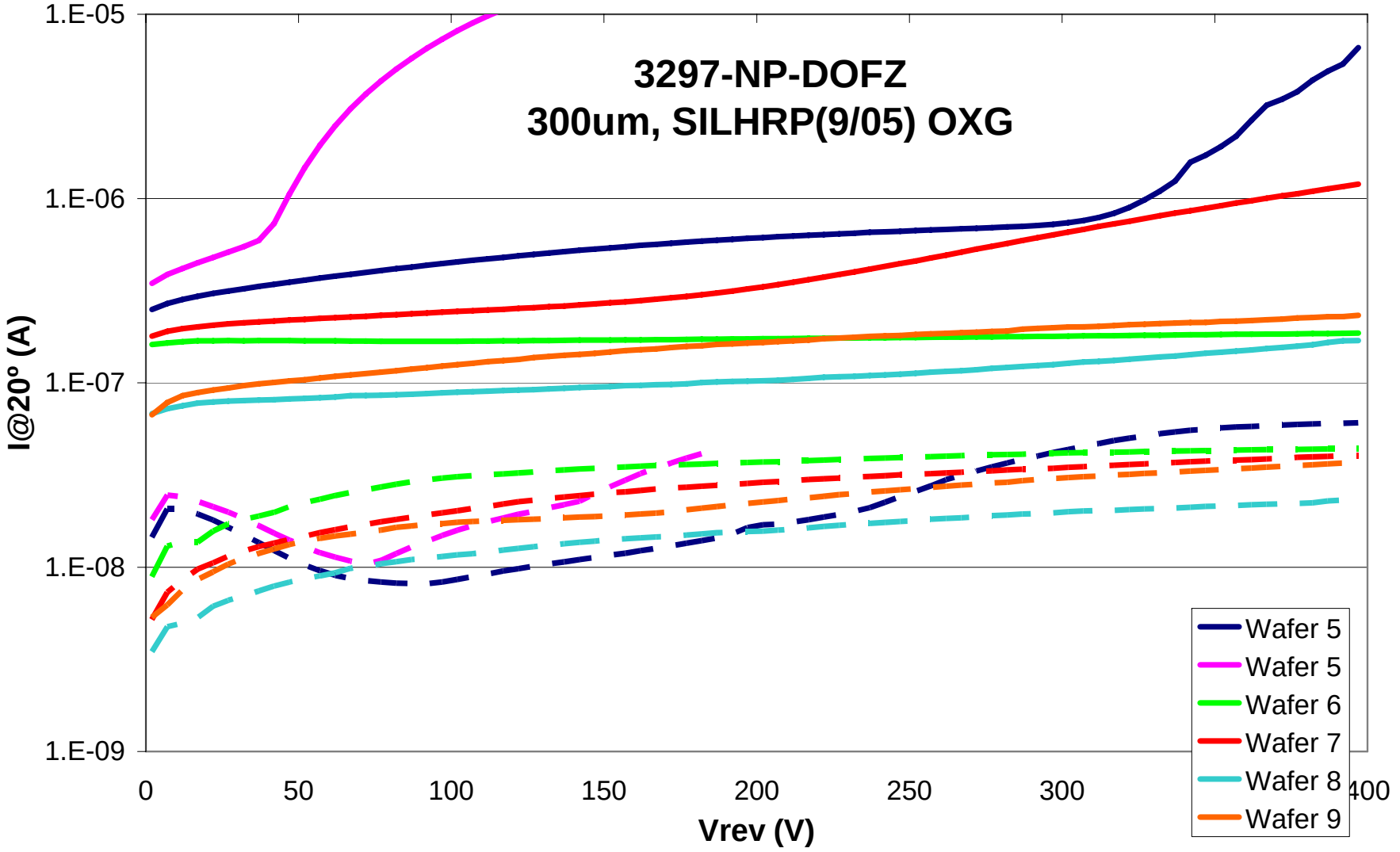
Results

- IV plots of un-diced wafers
  - detector: solid line
  - ring: dashed line
  - Absolute current at 20ºC plotted
  - Diode area = 1 cm^2 aprox.

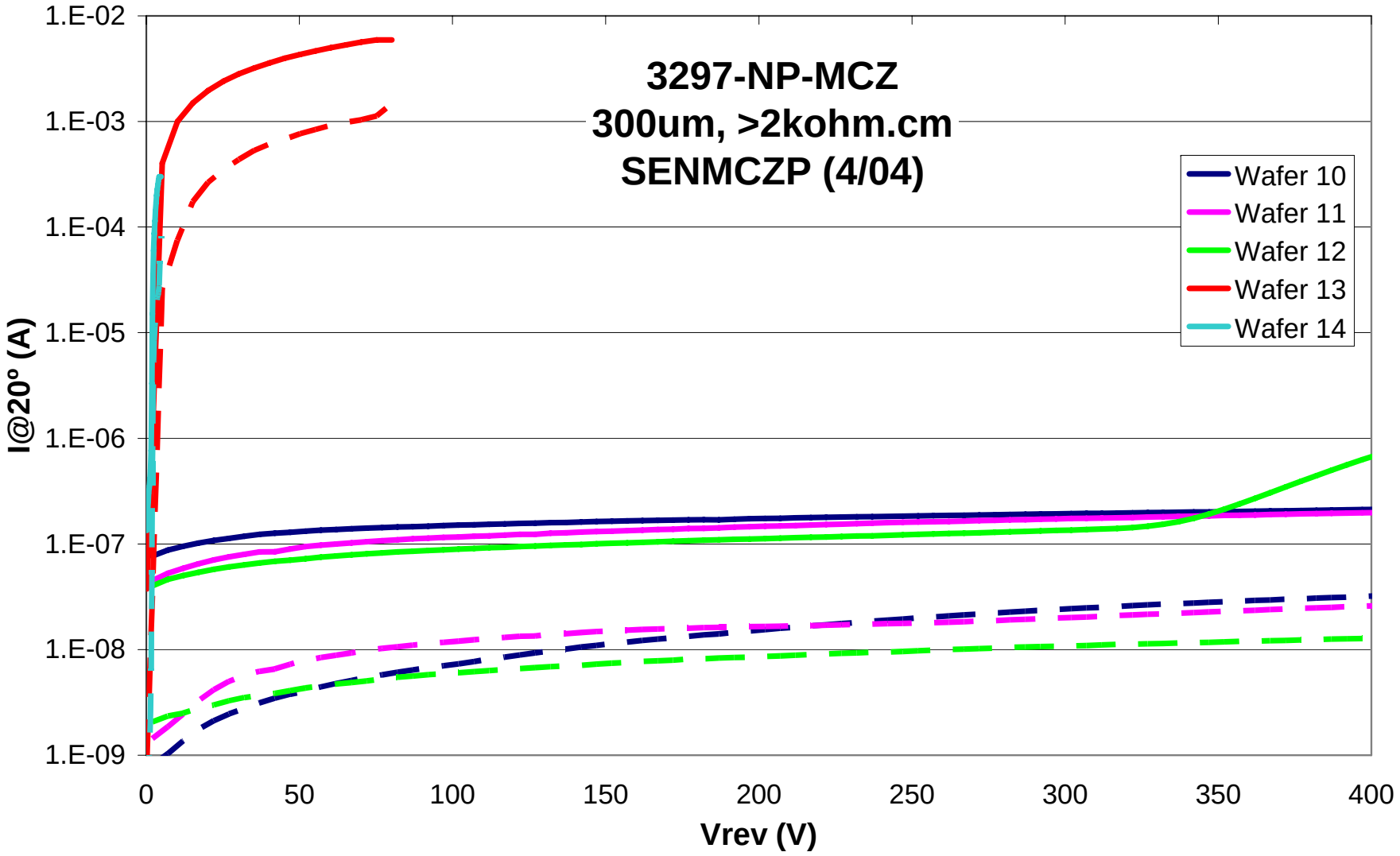
- Good performance for most of the wafers

- Irreversible breakdown in some wafers n-in-n & n-in-p.
  - Oxide damage
  - Always in guard ring
  - V_{BD} well above V_{FD}, no problem for use, but care must be taken

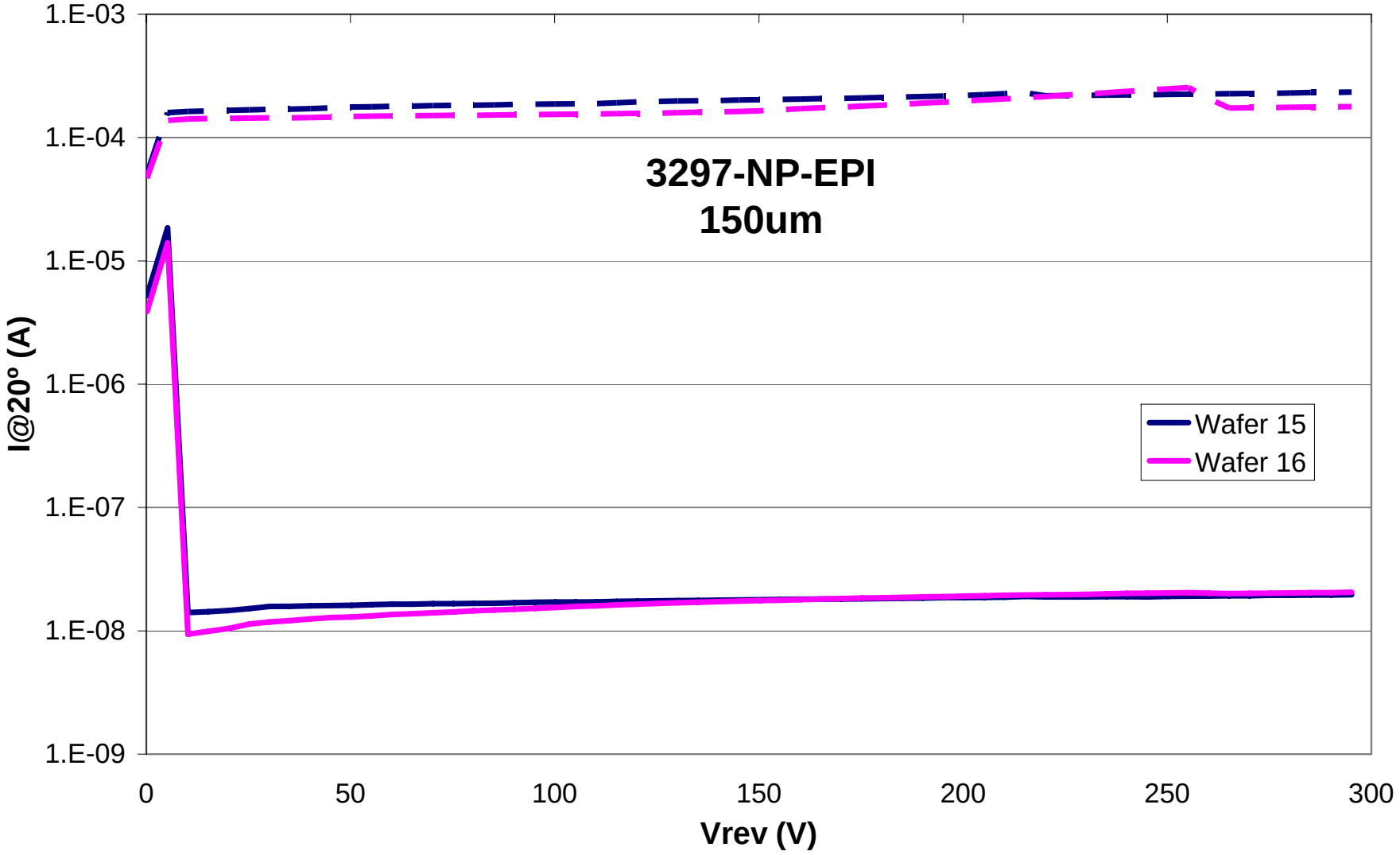
N-in-P DOFZ


3297-NP-DOFZ
300um, SILHRP(9/05) OXG
I@20° (A)
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
0
50
100
150
200
250
300
400
Vrev (V)
Wafer 5
Wafer 5
Wafer 6
Wafer 7
Wafer 8
Wafer 9

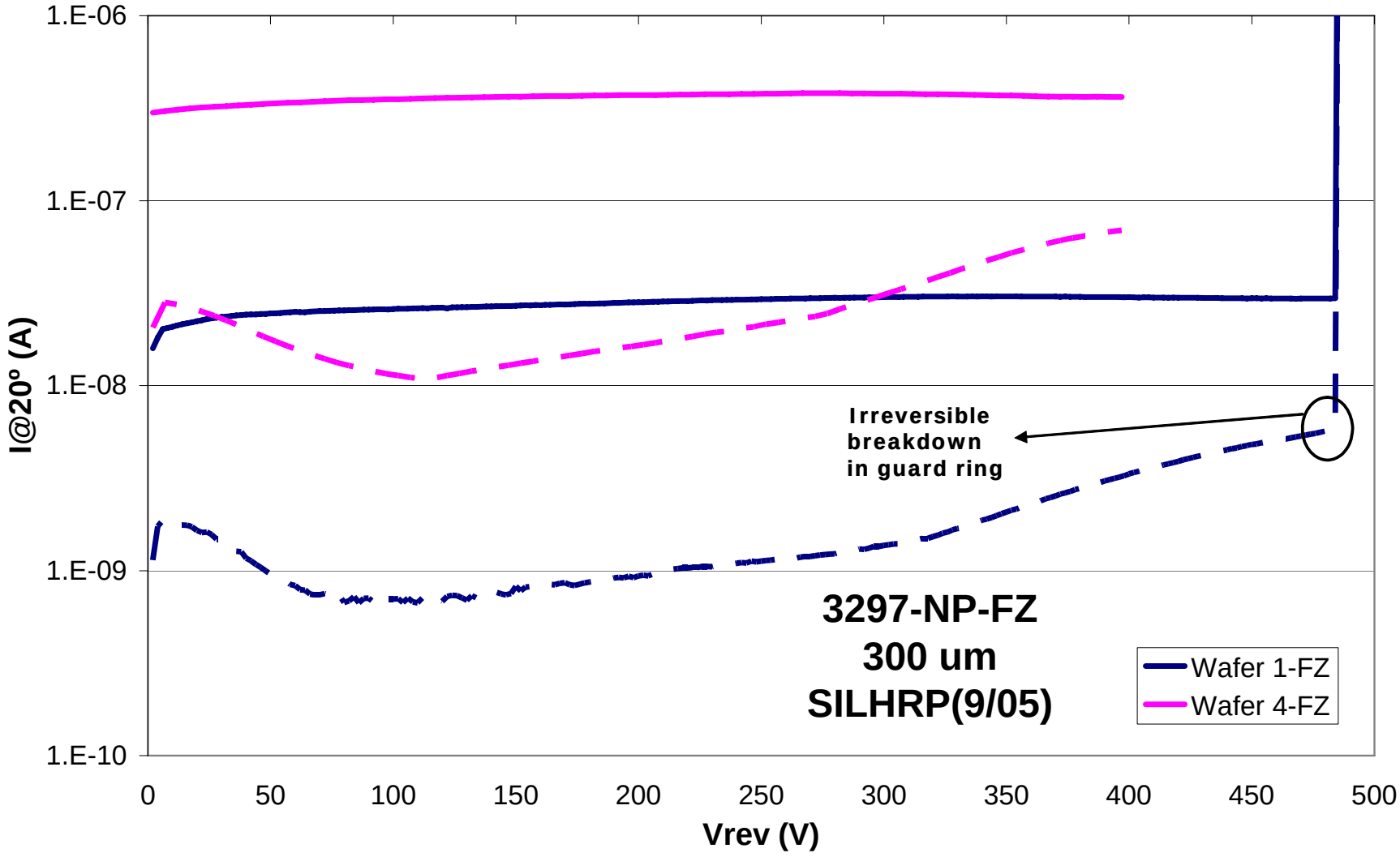
N-in-P MCZ


3297-NP-MCZ
300um, >2kohm.cm
SENMCZP (4/04)
Wafer 10
Wafer 11
Wafer 12
Wafer 13
Wafer 14
I@20° (A)
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
0
50
100
150
200
250
300
350
400
Vrev (V)

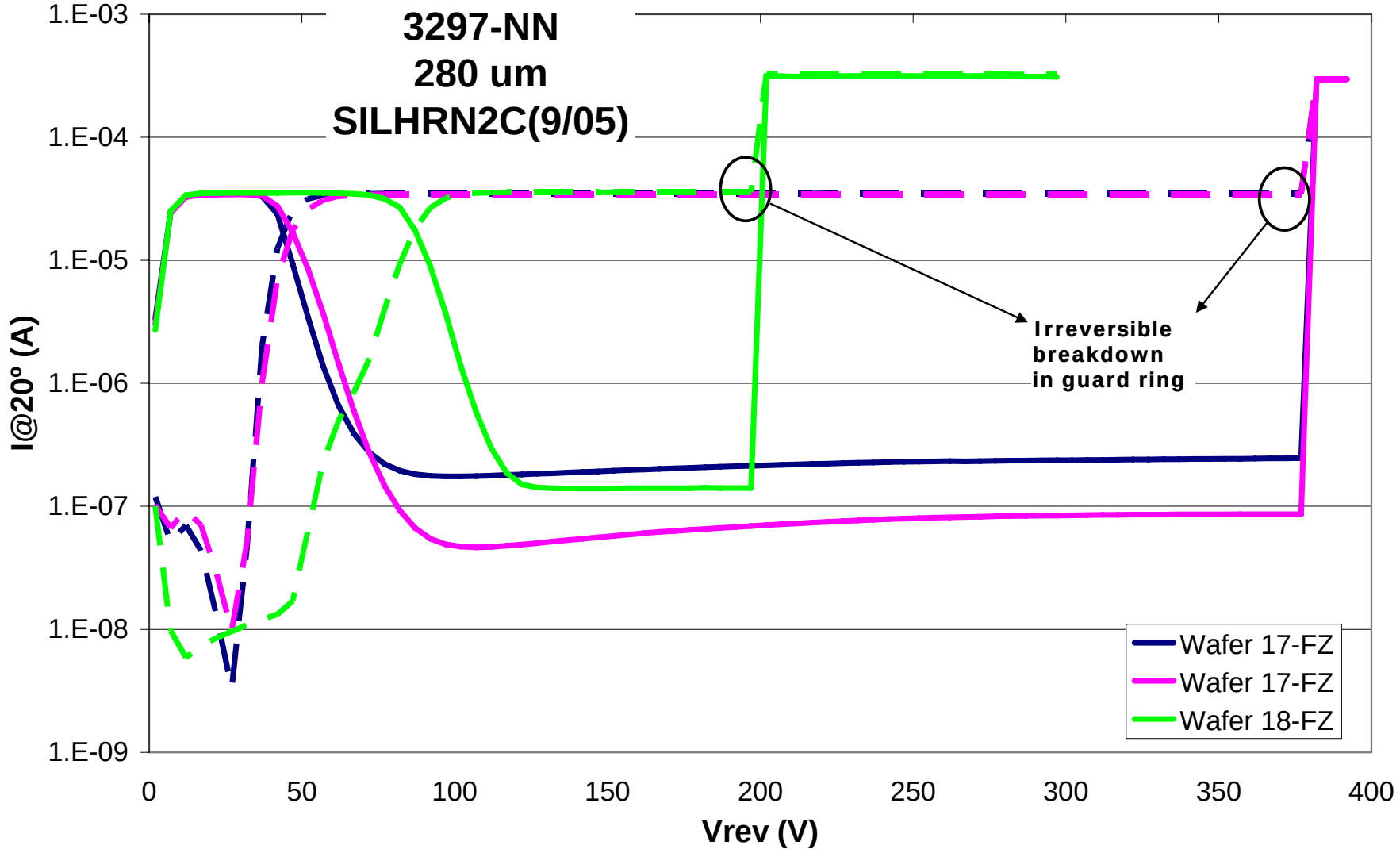
N-in-P EPI


1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
I@20° (A)
3297-NP-EPI
150um
Wafer 15
Wafer 16
0
50
100
150
200
250
300
Vrev (V)

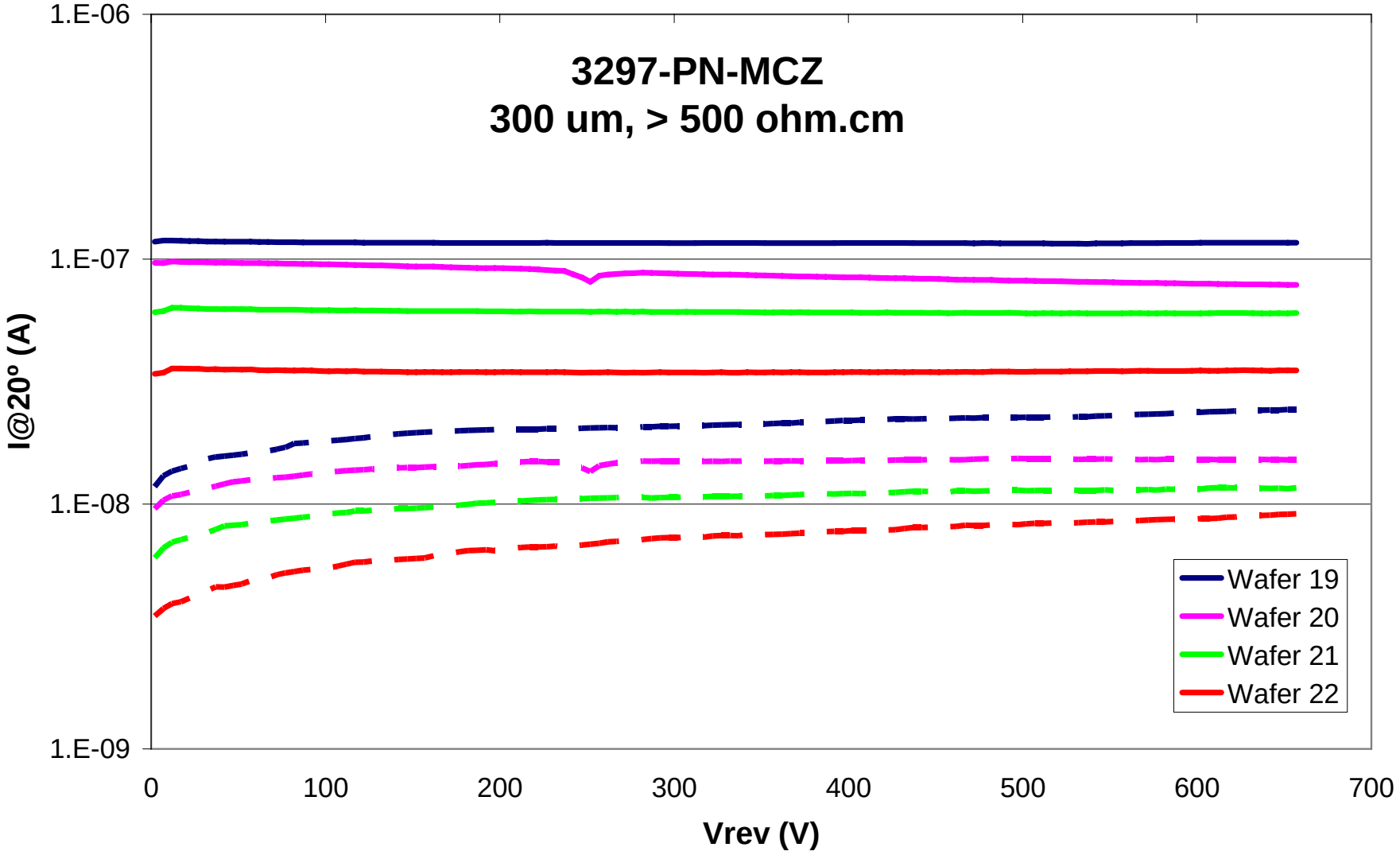
N-in-P FZ


1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
I@20º (A)
0
50
100
150
200
250
300
350
400
450
500
Vrev (V)
Irreversible breakdown in guard ring
3297-NP-FZ
300 um
SILHRP(9/05)
Wafer 1-FZ
Wafer 4-FZ

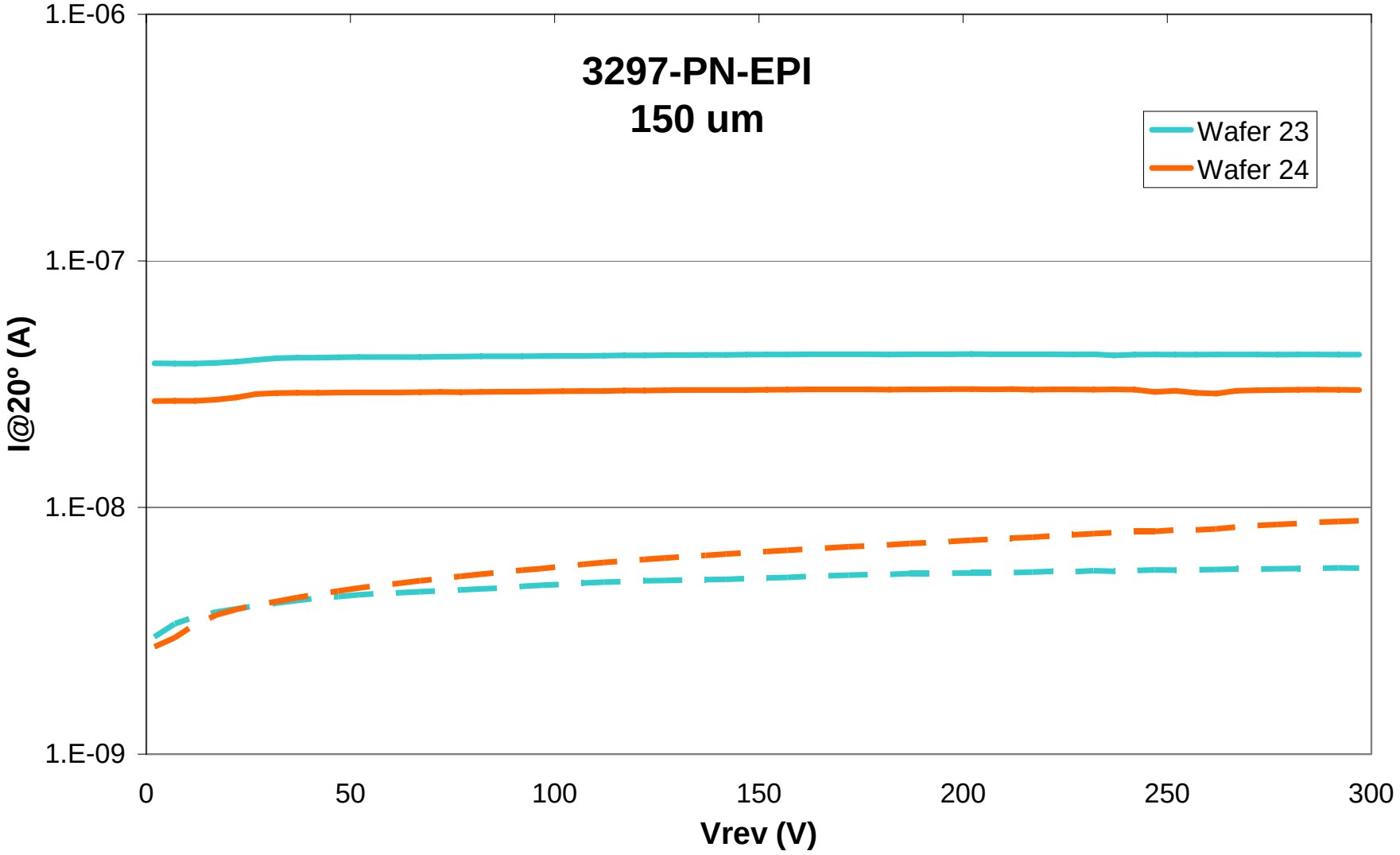
N-in-N FZ


3297-NN
280 um
SILHRN2C(9/05)
I@20° (A)
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
0
50
100
150
200
250
300
350
400
Vrev (V)
Irreversible
breakdown
in guard ring
Wafer 17-FZ
Wafer 17-FZ
Wafer 18-FZ

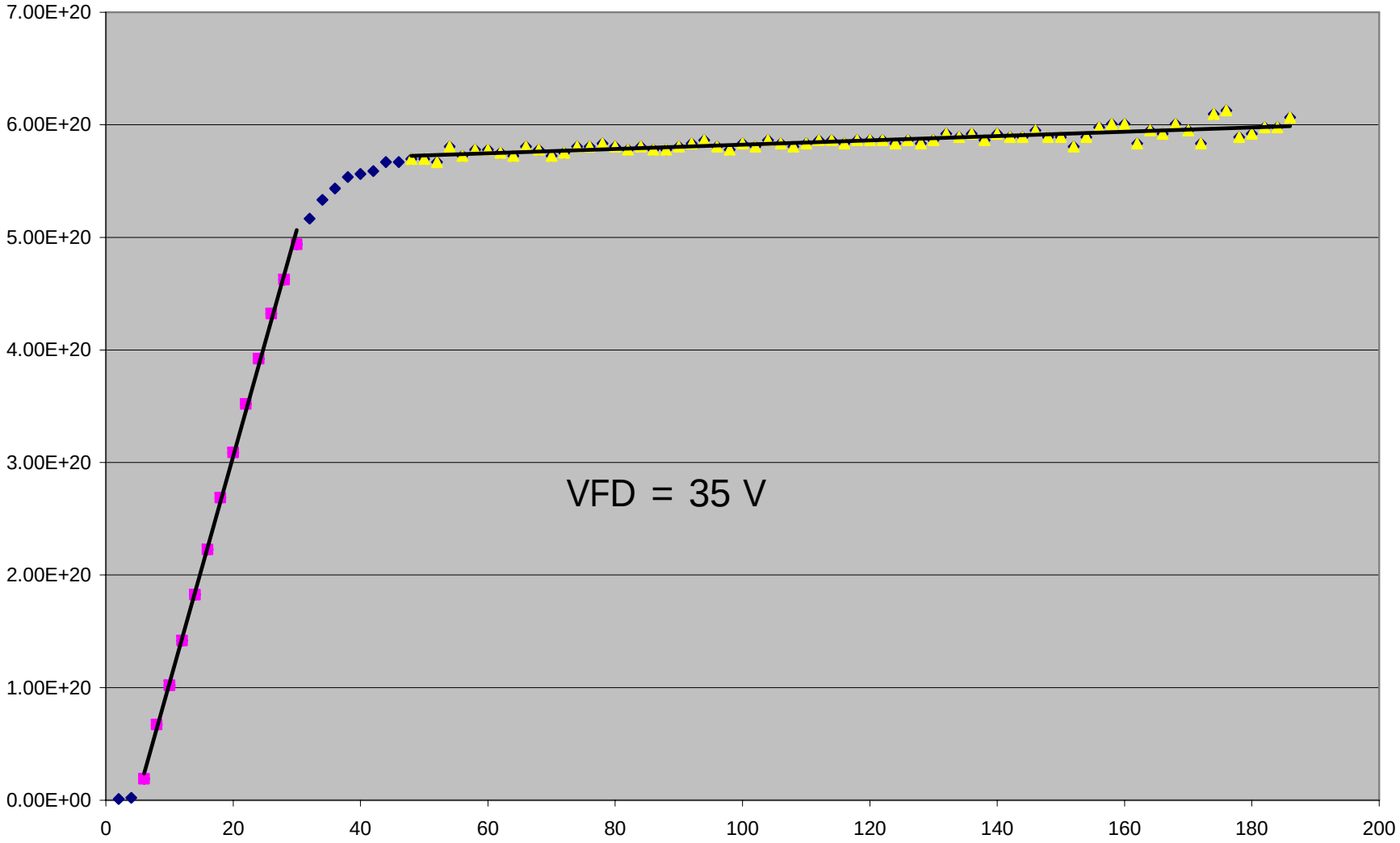
P-in-N MCZ


3297-PN-MCZ
300 um, > 500 ohm.cm
I@20° (A)
1.E-06
1.E-07
1.E-08
1.E-09
0
100
200
300
400
500
600
700
Vrev (V)
Wafer 19
Wafer 20
Wafer 21
Wafer 22

P-in-N EPI


3297-PN-EPI
150 um
Wafer 23
Wafer 24
1.E-06
1.E-07
1.E-08
1.E-09
I@20° (A)
0
50
100
150
200
250
300
Vrev (V)

N-in-P FZ CV curve



Some comments

- Similar current levels for all substrates (10^{-7} A/cm^2)
- Same for ring current in (almost all) p-n and n-p (10^{-8} A)
- That means that n-in-p are so well insulated that they behave like p-in-n
- Wafers 13 and 14 (p-MCZ) and 15 and 16 (p-EPI) behave as if they do not have p-spray.
  - Ring current very high, diode current normal
  - Not due to substrate type
  - Consecutive wafers: problem with ion implanter?
  - Dicing and irradiation will improve problem
- N-in-n as expected
  - No backside implant

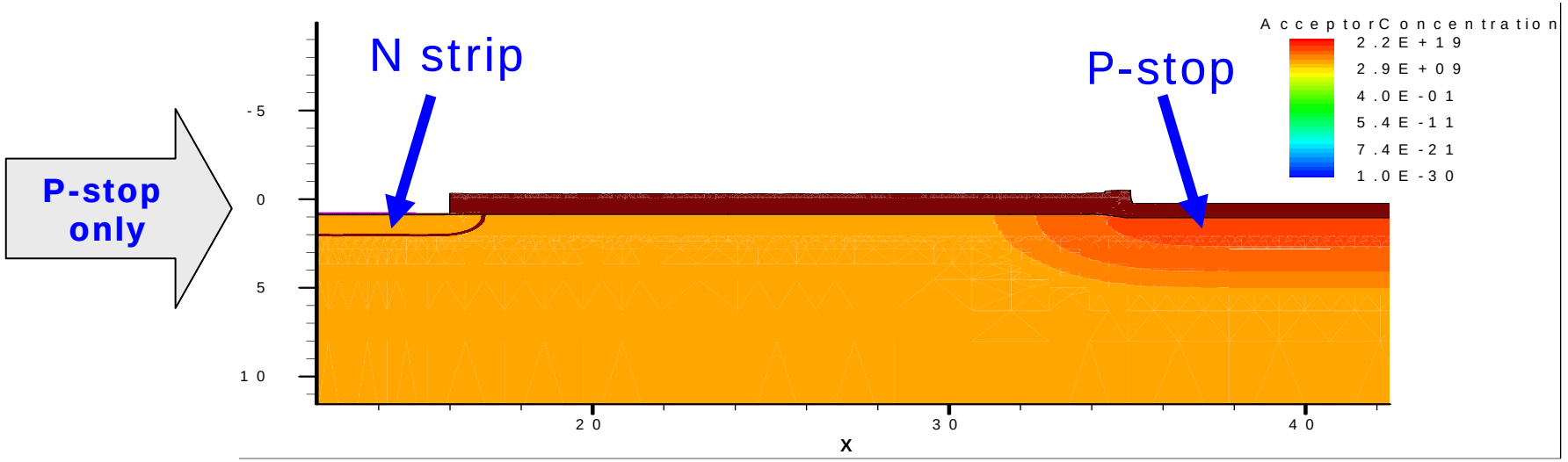
II. Simulation and processing of moderated p-spray isolation techniques

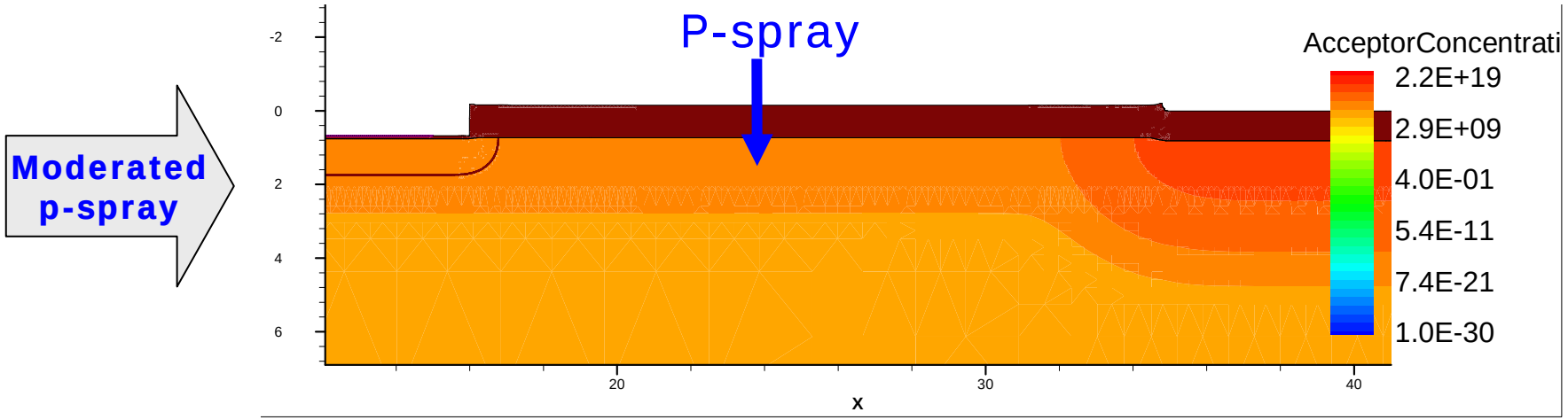
Moderated p-spray

- As already presented in February in Trento
- We have developed through simulation a technology for p-type detectors with moderated p-spray insulation
- Boron implant parameters are selected from our previous experience with microstrip with p-stops:
  - 50 keV, 10^{13} cm^{-2}, implant oxide thickness

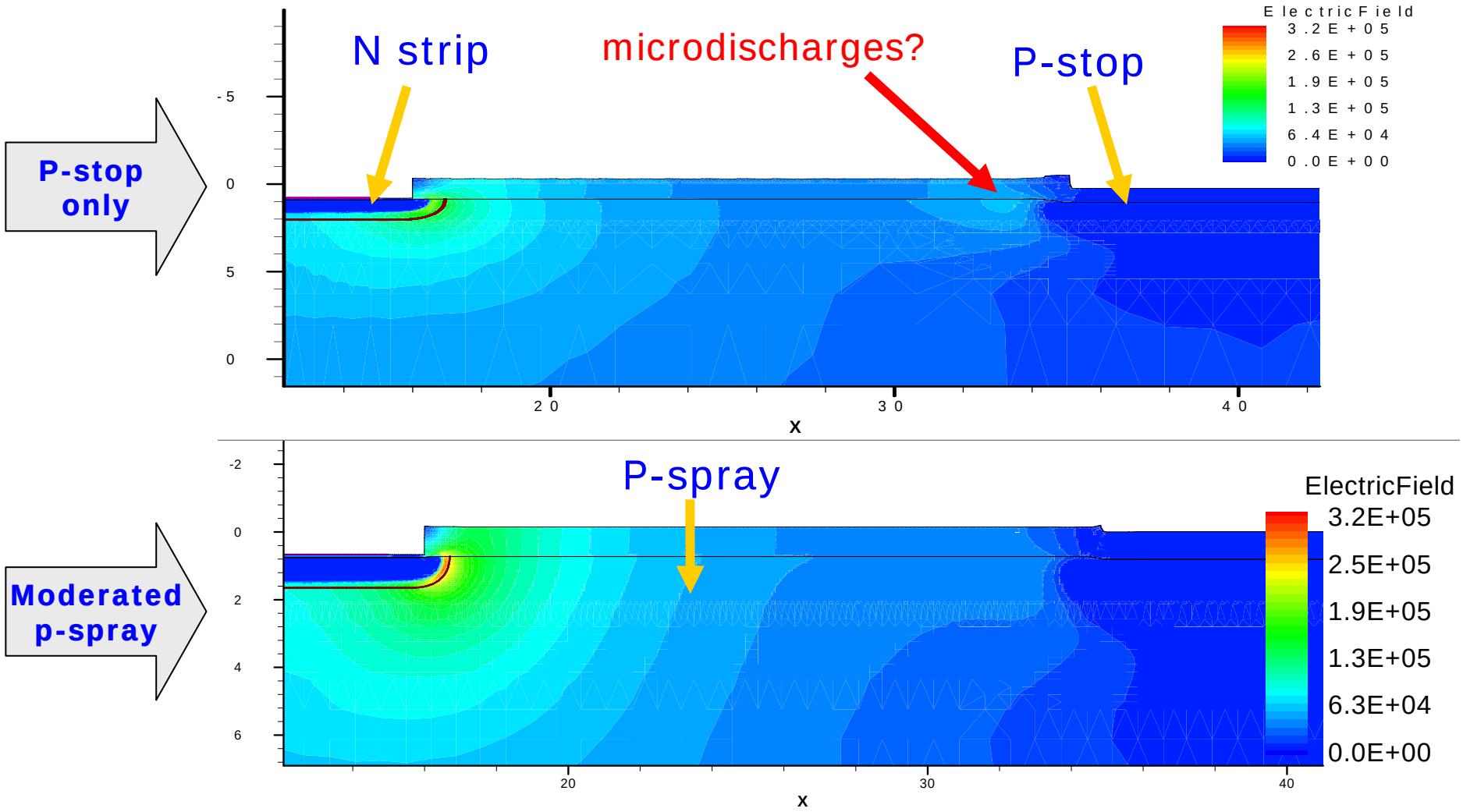
- With less p-spray implanted charge, we obtain:
  - High VBD,
  - Good insulation,
  - Eliminate the high field corner in the p-stop causing microdischarges

Doping profile comparison





Electric field comparison

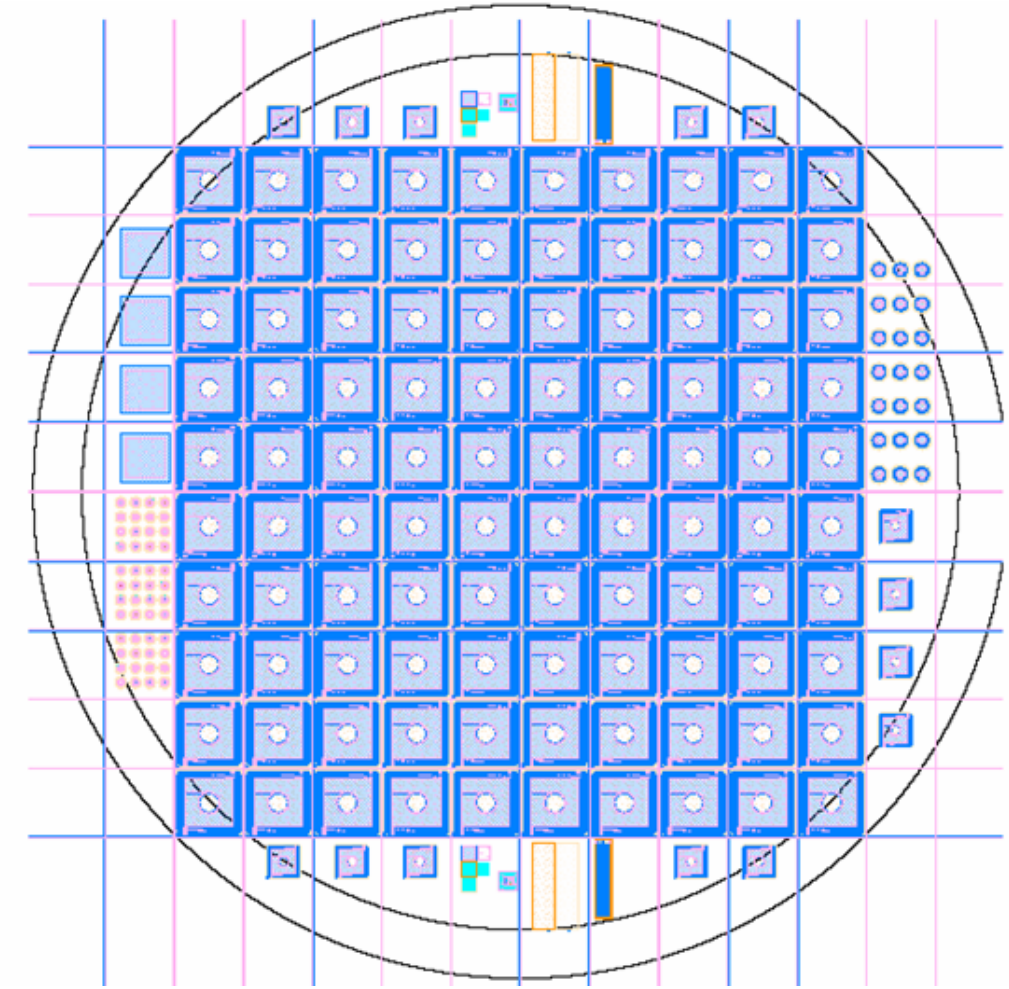


Technology

- First: oxidation, photolitograpy p-stop regions, wet oxide etching, re-oxidation, photoresist striping
- At this point there are two different oxide thicknesses
  - **thin oxide in the p-stop area and a thicker oxide on the rest of the silicon surface ("p-spray area")**
- P-implant (Energy 50 keV, dose 10^{13} cm^{-2})
- Finish with the usual fabrication process

- First fabrication batch with mask set CNM275
  - pad detectors
  - process with dummy poly deposition to have the same thermal budget as in microstrips
  - Finished in one week
  - MCZ and FZ silicon with p-stop, p-spray and moderate p-spray.

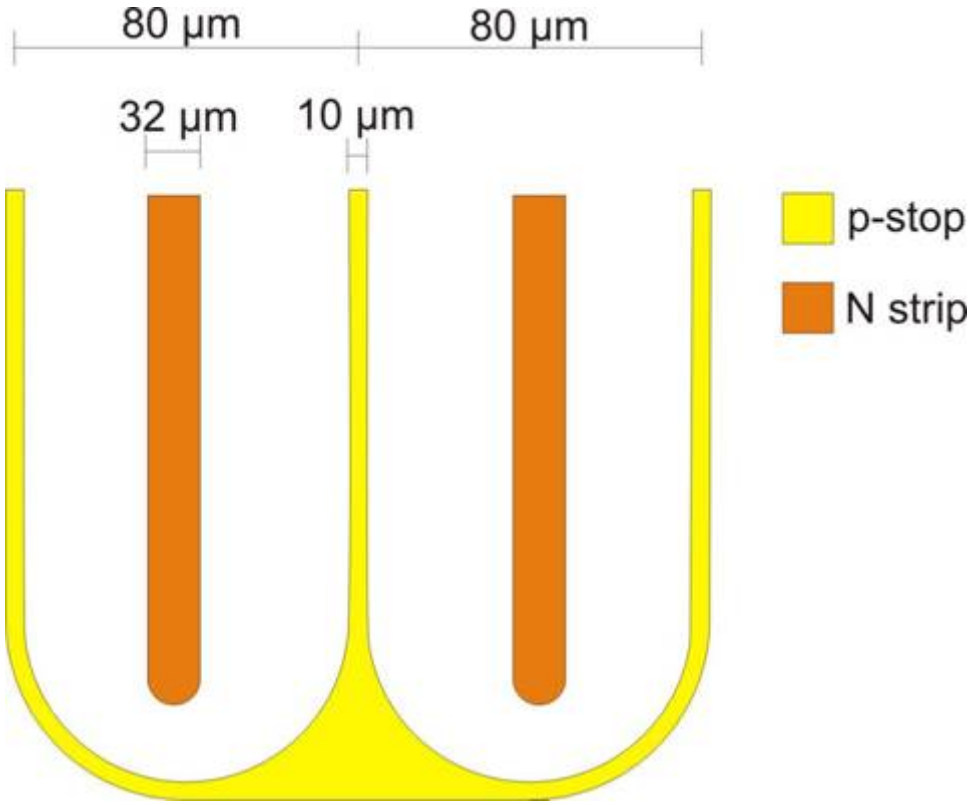
CNM275 mask set



- New mask set to replace old ROSE set
- 100 pad diodes with improved guard ring
- Diodes are labelled from 00 to 99.
- Only one type of diodes
- Designed for simplicity and fast dicing
- Other test structures

New mask design

- One additional layer needed from RD50 microstrip mask set – is being laid out.
- Common p-stops
  - p-spray increases safety
- Distance between n-strip and p-stop is maximized
  - To achieve higher breakdown voltages
  - narrow p-stops



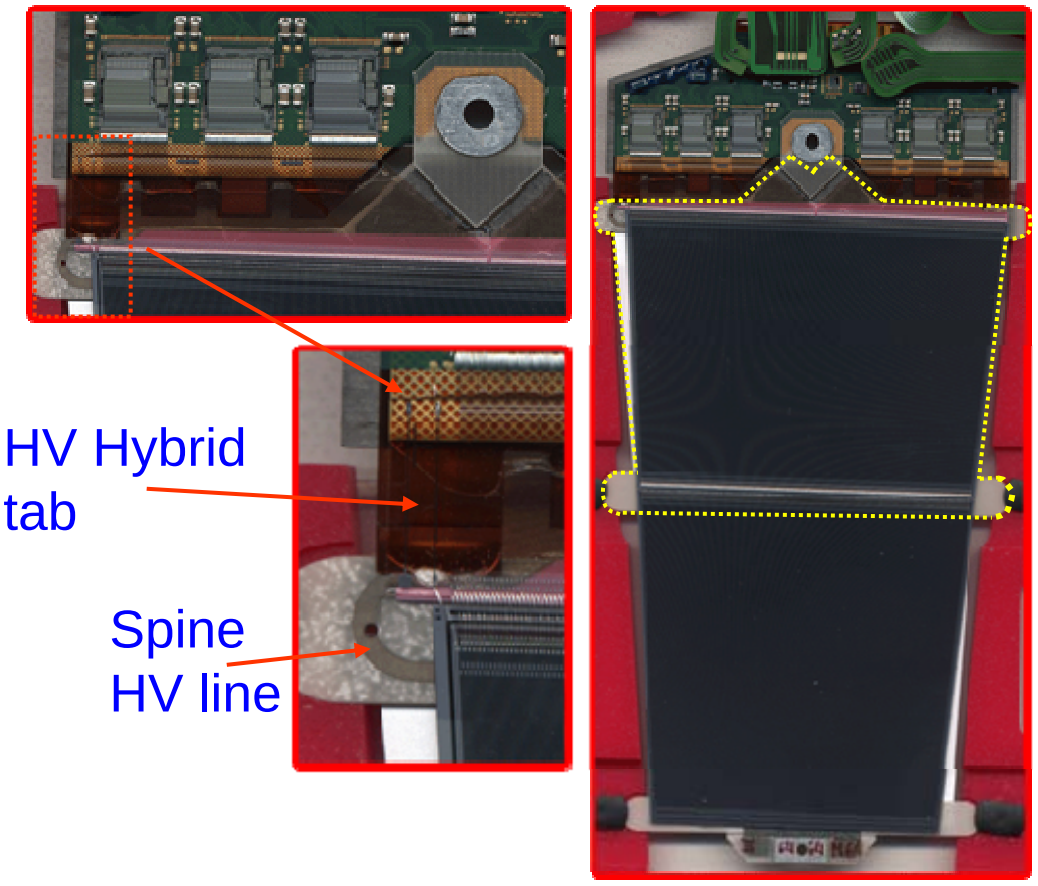
III. First modules with 3 cm p-type strip detectors

ATLAS SCTDAC readout for p-type sensors

- Aim: to read a 3 cm p-type detector using the ATLAS SCTDAC readout.
- SCTDAC is optimised for n-type sensor.
- SCT readout: binary ABCD3T chip.
- We have assembled at IFIC-Valencia a “pseudo SCT module” with a 3cm p-type sensor and a 3 cm n-type sensor (from CNM-Barcelona) to crosscheck, using all the assembly tools of the SCT end-cap module: assembly jigs, bonding jigs, fan-in adaptors, test box and frames, etc..

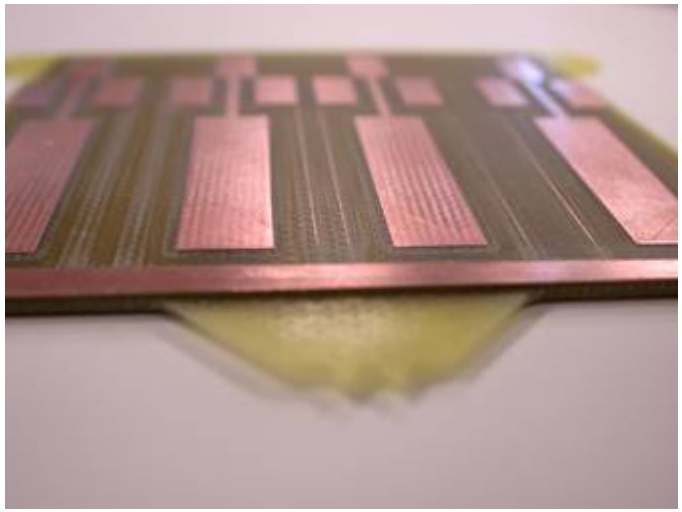
ATLAS SCT middle end-cap module

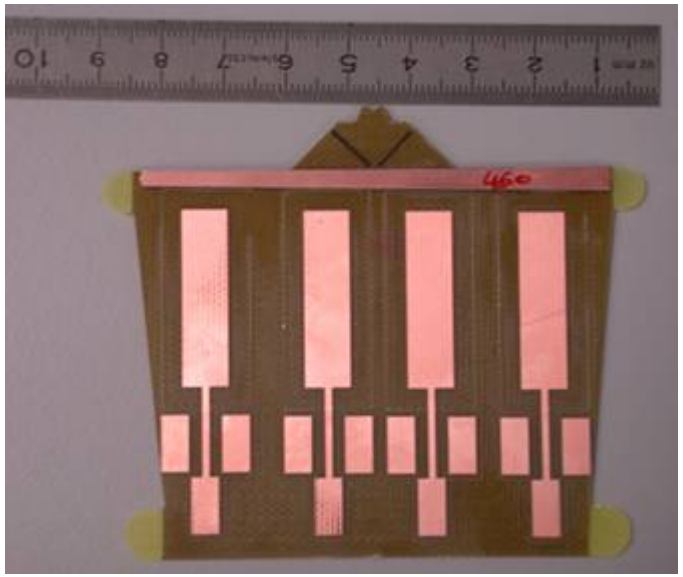
- We have fabricated a support structure with the shape of a detector and the spine arms, to fit in the bonding jigs (same dimensions and highs of a SCT module).
- The HV hybrid tab are cut. The detector depletion will not be done through the hybrid.



Support structure

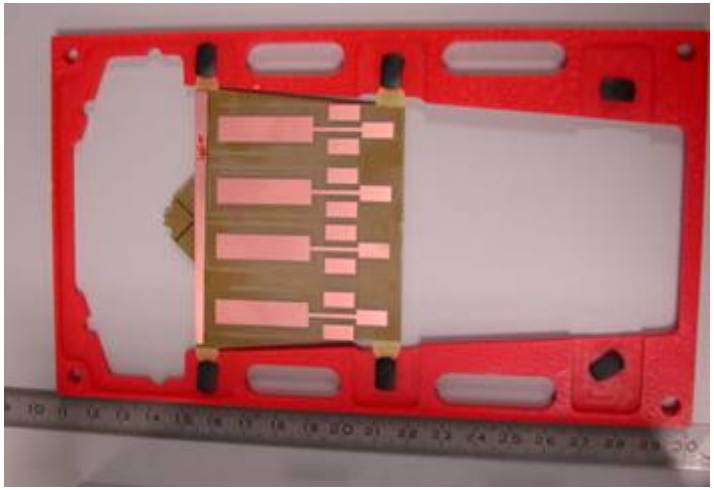
The support structure has been manufactured using a circuit board, the 3cm detector will be hold in the cupper rectangles.





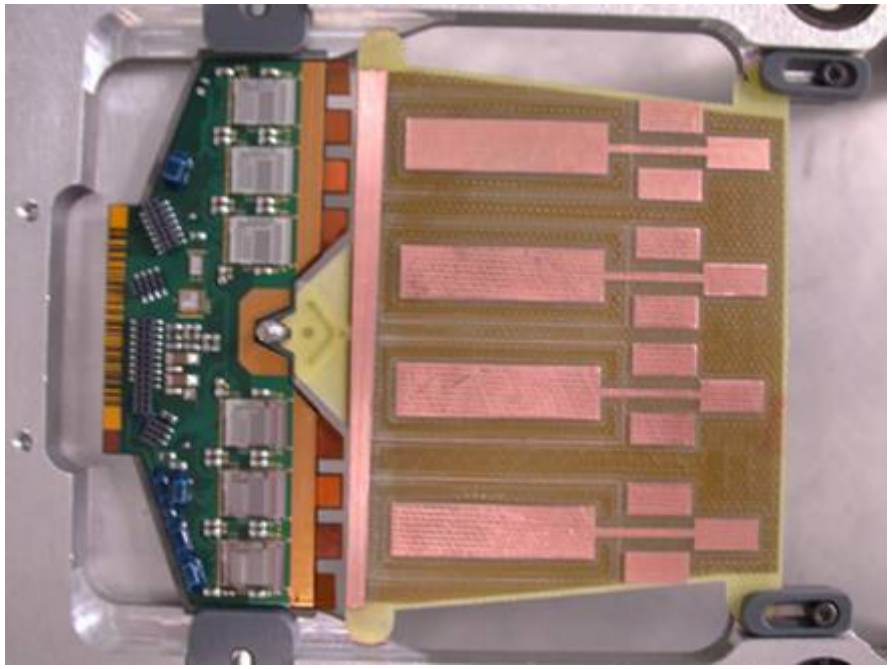
The height of the support structure fits in the assembling and bonding jigs

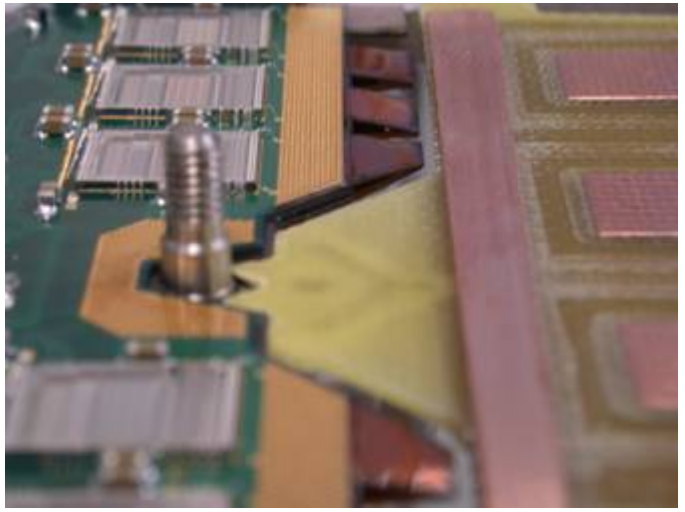
The structure fits in the transport frame

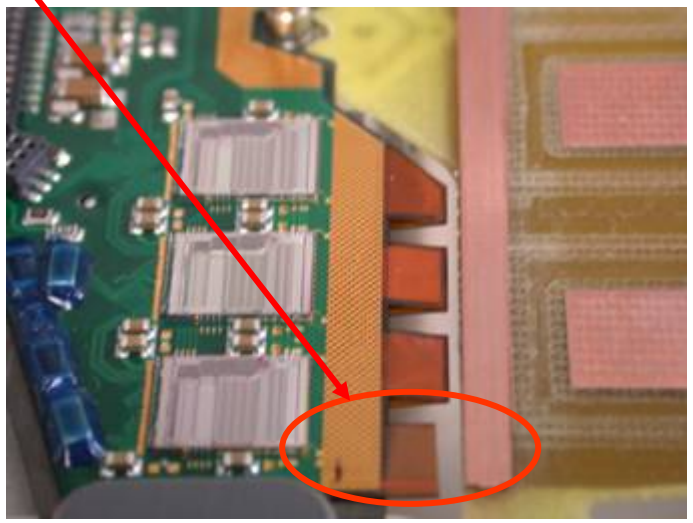


Hybrid assembling

- Gluing of the hybrid in the SCT assembly jig. The HV tab has been cut

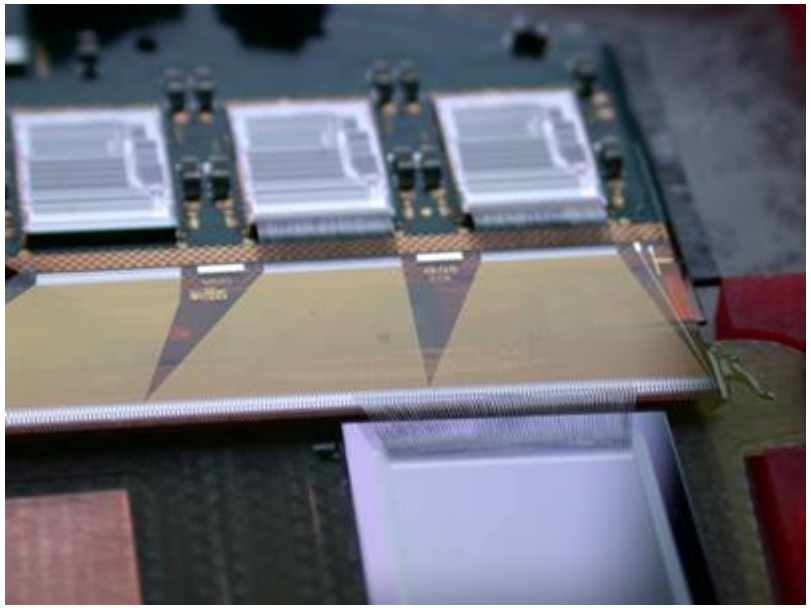


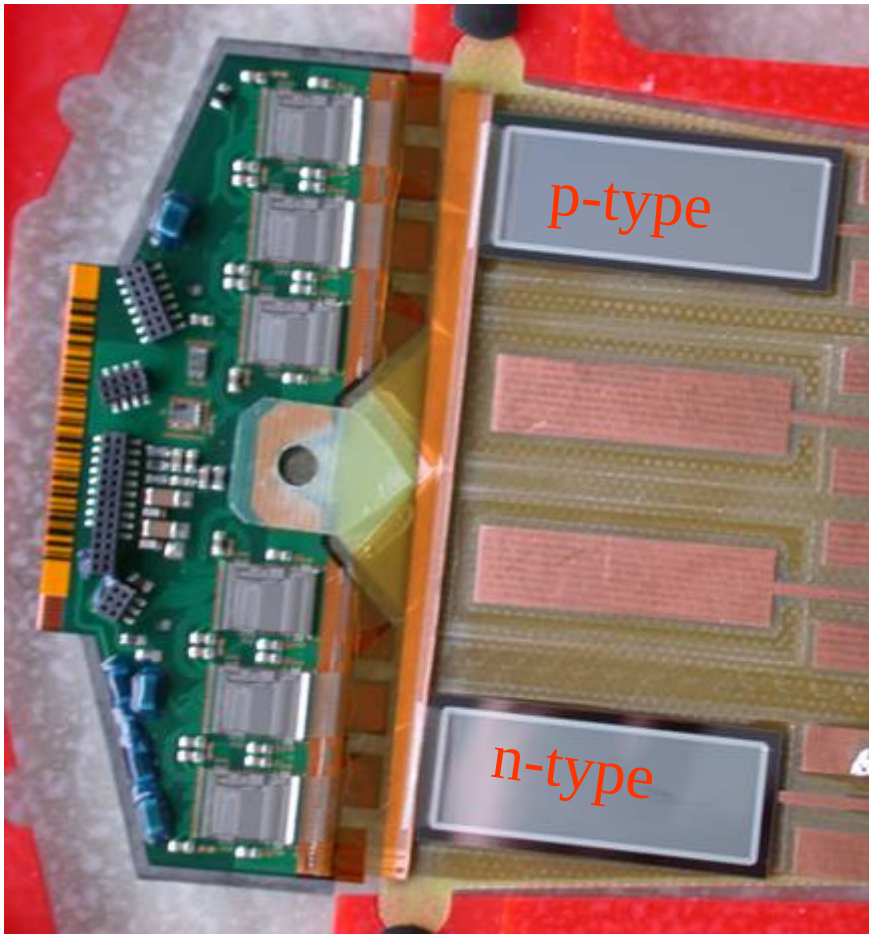




Fan-in and detector gluing

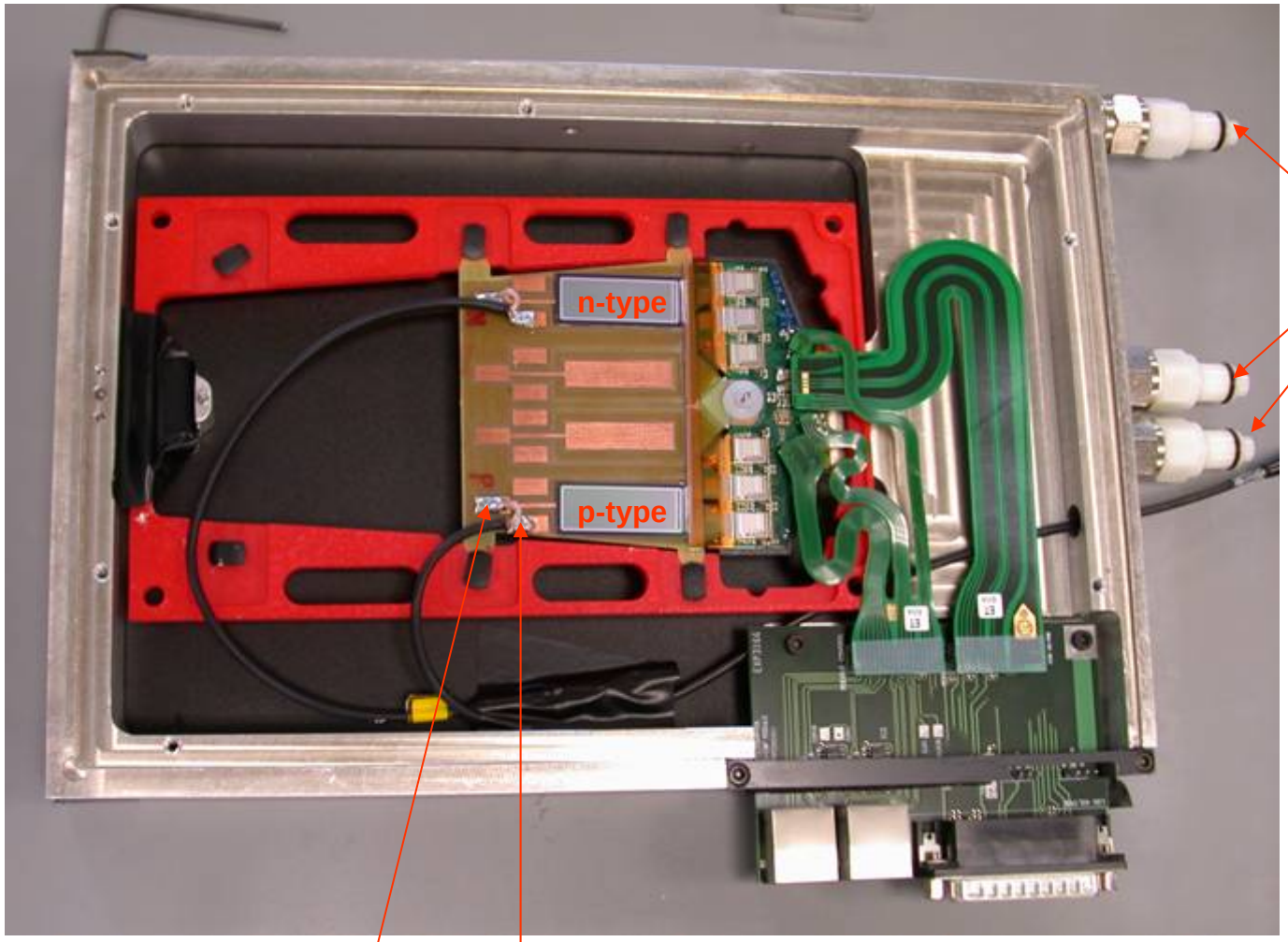
Fan-in gluing jig





Detector to fan-in and fan-in to chip bonding

Module in the test box



Cooling injecting cold air

The detectors are not read simultaneously.

Detector biasing:

+HV for n-type

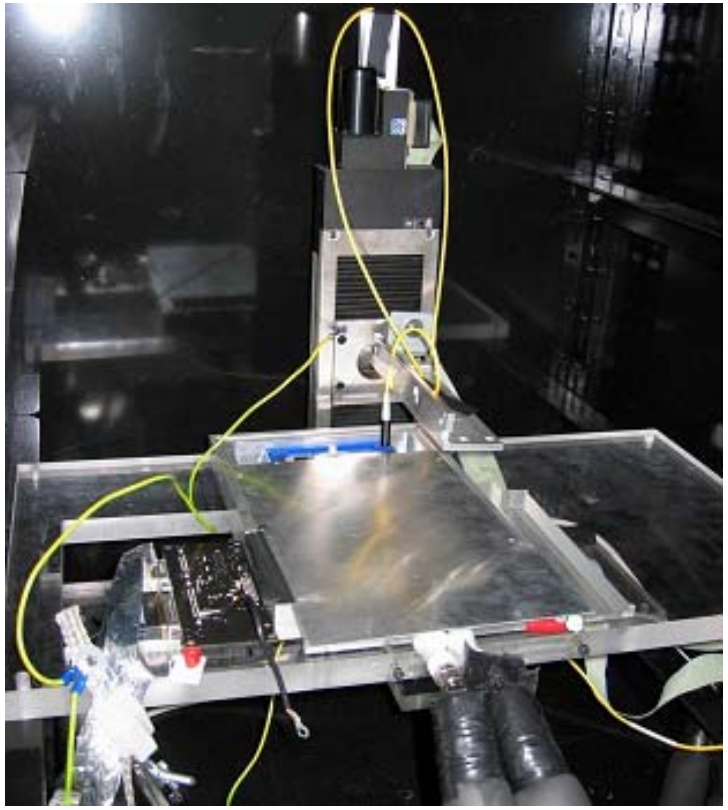
–HV for p-type

HV to the back plane

Strips to ground

Work in progress:

- Modifying SCTDAC to read negative pulses for p-type sensors.
- Laser and source setups ready to do a full study.
- Still place in this module for two more sensors.
- Irradiated sensor available to be assembled at 10^{15} n/cm^2 .



IFIC-Valencia automatic laser system with 3 staged and automatic focusing in 20 min.