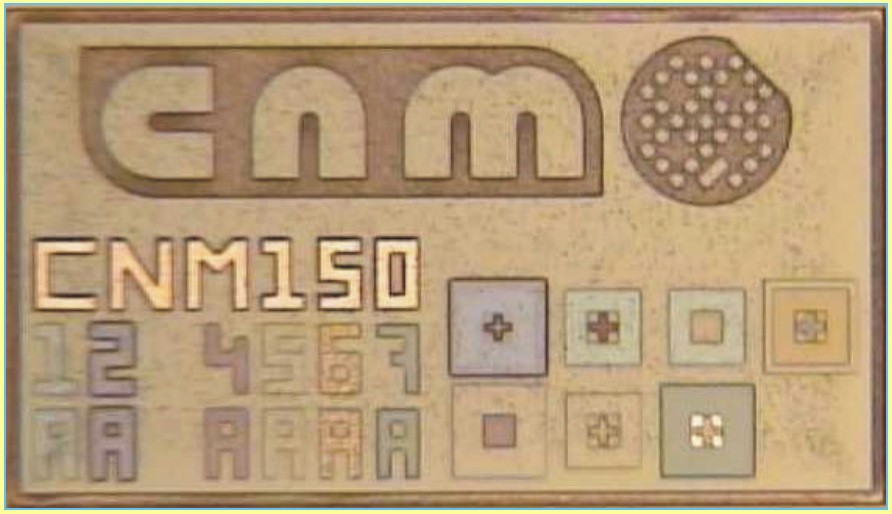
Comparison of radiation hardness of P-in-N, N-in-N and N-in-P silicon pad detectors in std-FZ, oxg-FZ, and MCZ

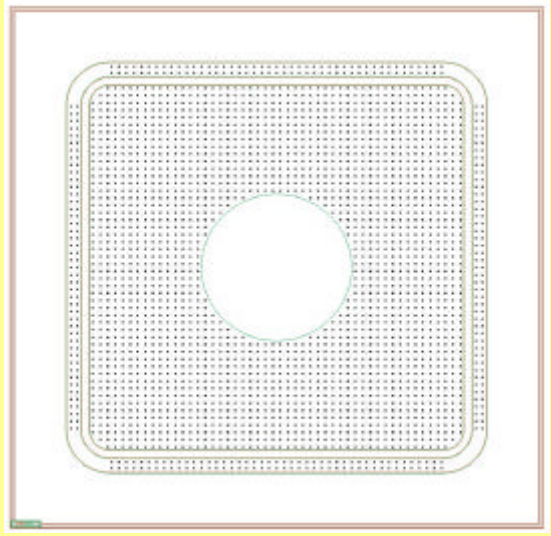


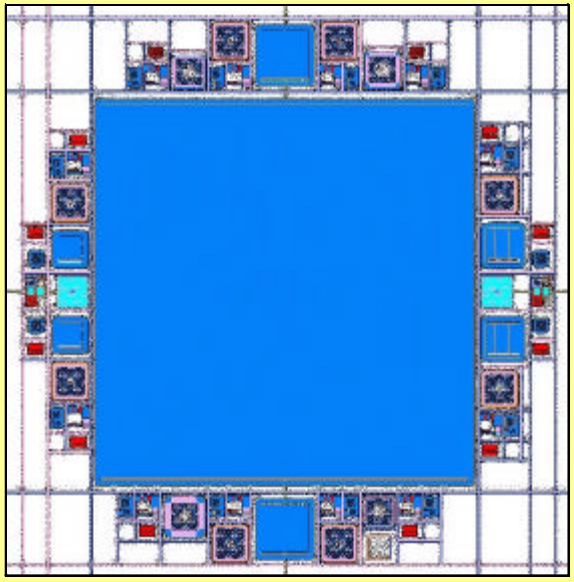
M. Lozano, G. Pellegrini, C. Fleta, J. M. Rafí, M. Ullán, F. Campabadal, G. Casse, P. Allport

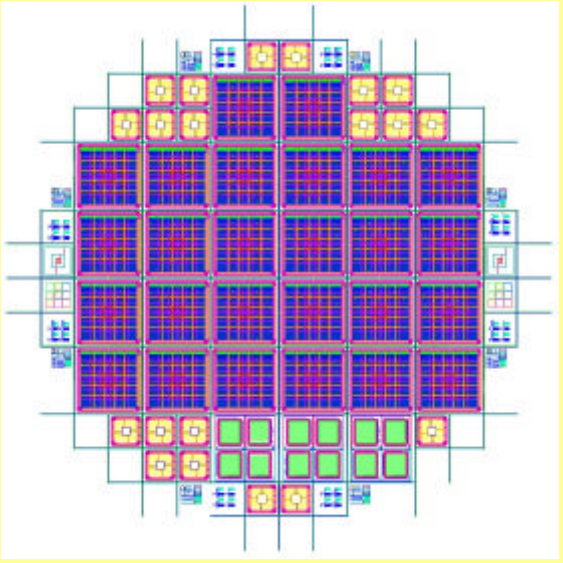
IMB-CNM (Barcelona)
University of Liverpool

Available masks

- ROSE diodes
- P-in-N strips
- RD50 N-in-N, N-in-P (not processed any device yet)

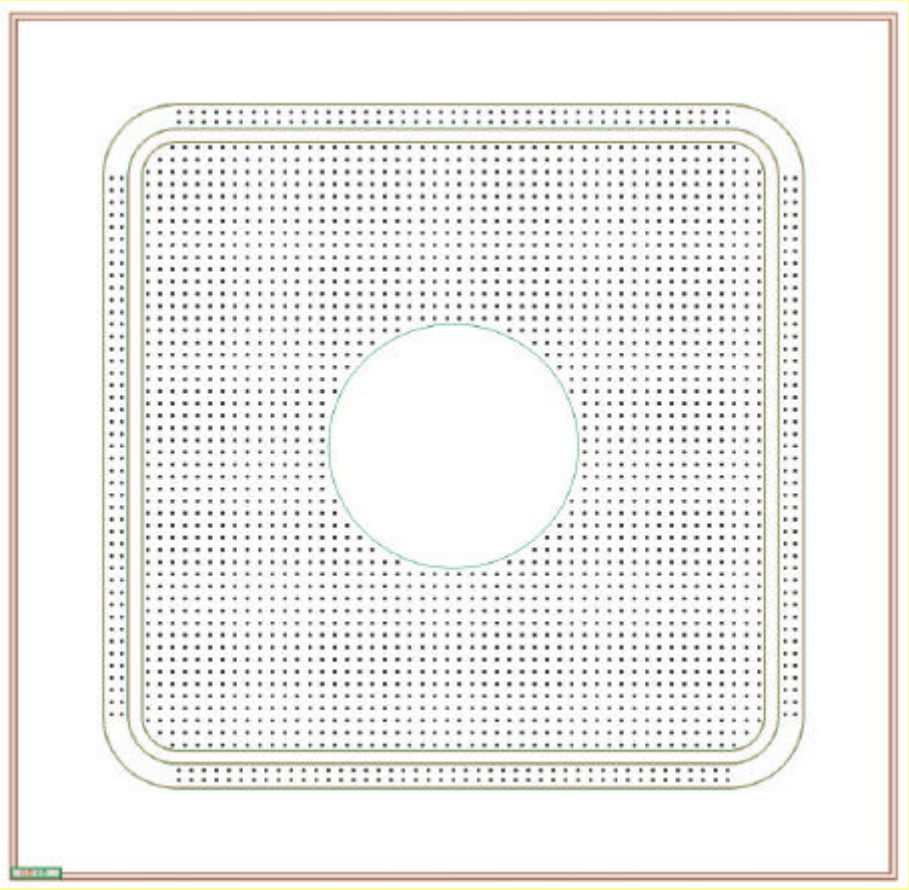






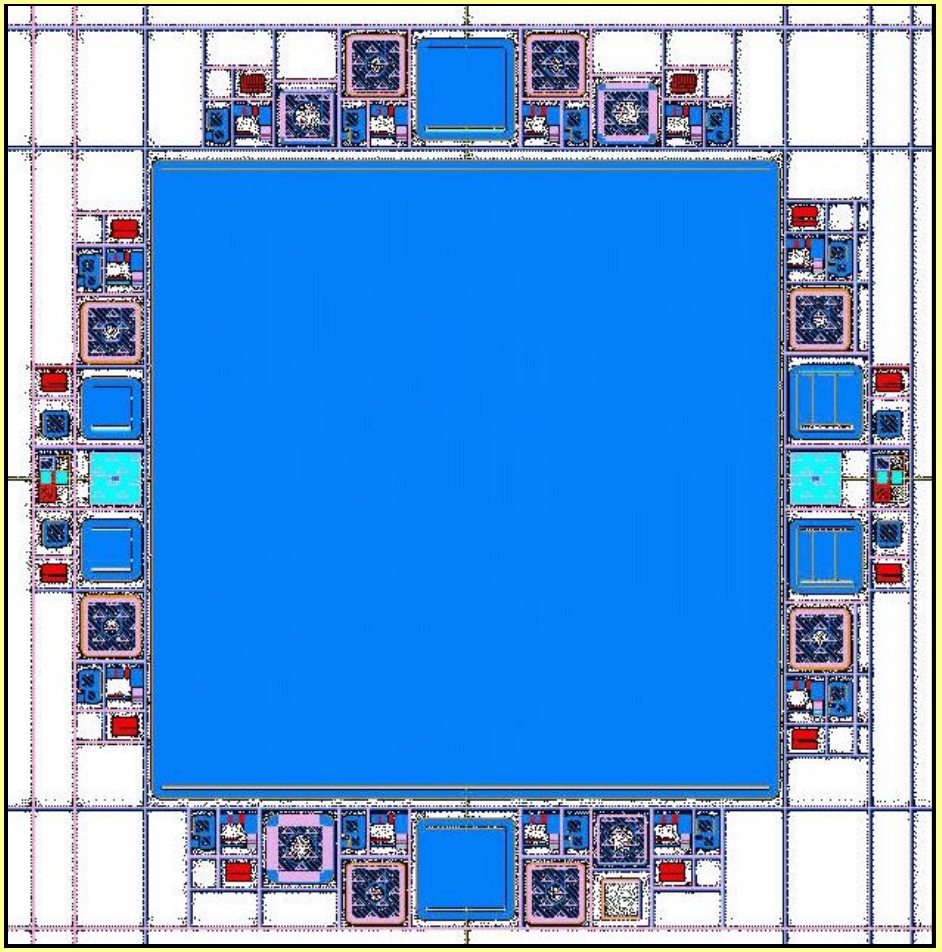
Available masks

- **Pad diodes mask set**
- **From the former ROSE (RD48) collaboration**
- **Characteristics**
  - **Active area: 5×5 mm2**
  - **guard ring: 200 µm wide at 100 µm distance from the central diode**
  - **Do not have p-stops**



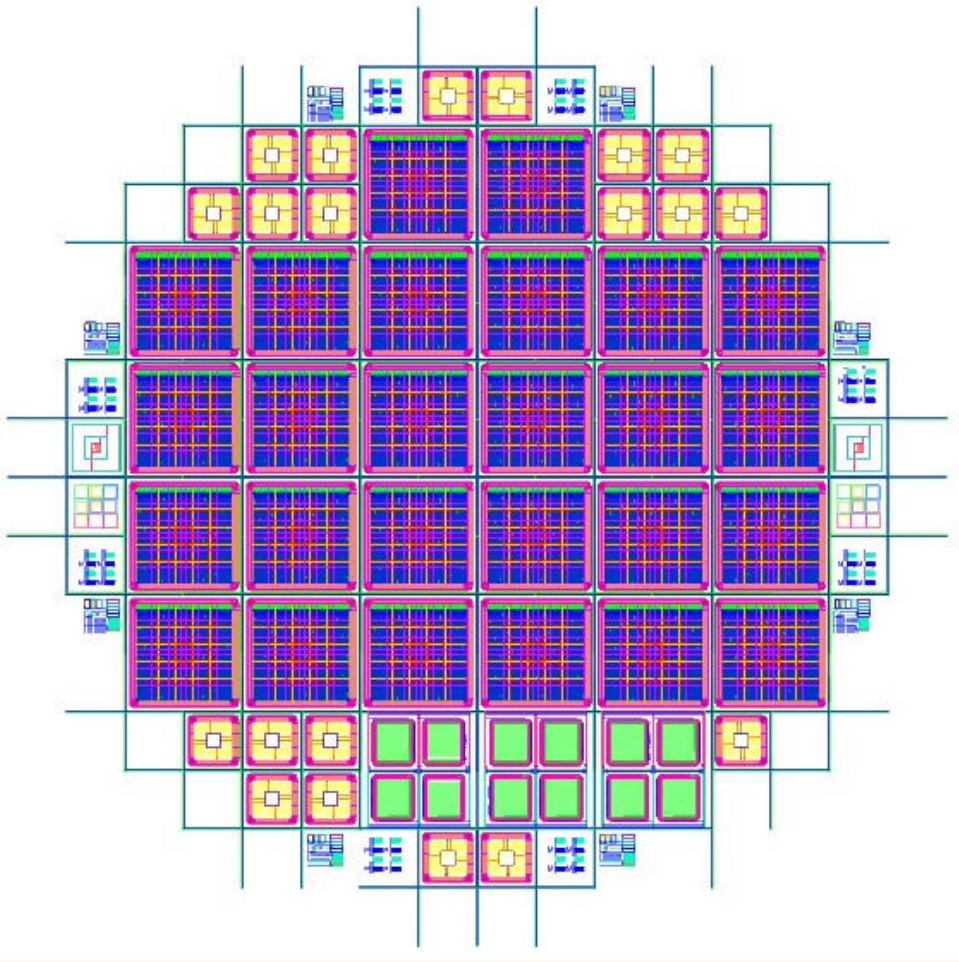
Available masks

- **Full strip diodes mask set**
  - + Optimized for N-in-P technology
  - + Can be used for P-in-N. Also for N-in-N with limitations (only one side processing)
  - + Characteristics:
    - – High resistivity poly biasing
    - – Capacitively coupled
- **Structures**
  - + One large area detector 6x6 cm^2
  - + 12 complete test structure sets
  - + 8 pad detectors 5x5 cm^2
  - + 18 baby strip detectors
- **Designed between Univ. Liverpool and IMB-CNM**



Available masks

- **Full strip diodes mask set**
  - + N-in-N and N-in-P technology
  - + Double side process
  - + Characteristics:
    - – High resistivity poly biasing
    - – Capacitively coupled
    - – One metal layer
- **Structures**
  - + 26 baby strip detectors
  - + 20 pad detectors
  - + 12 pixel detectors
  - + 8 complete test structure sets
- **Designed by RD50 collaboration**
  - + Test structures by IMB-CNM
  - + Pixels by PSI



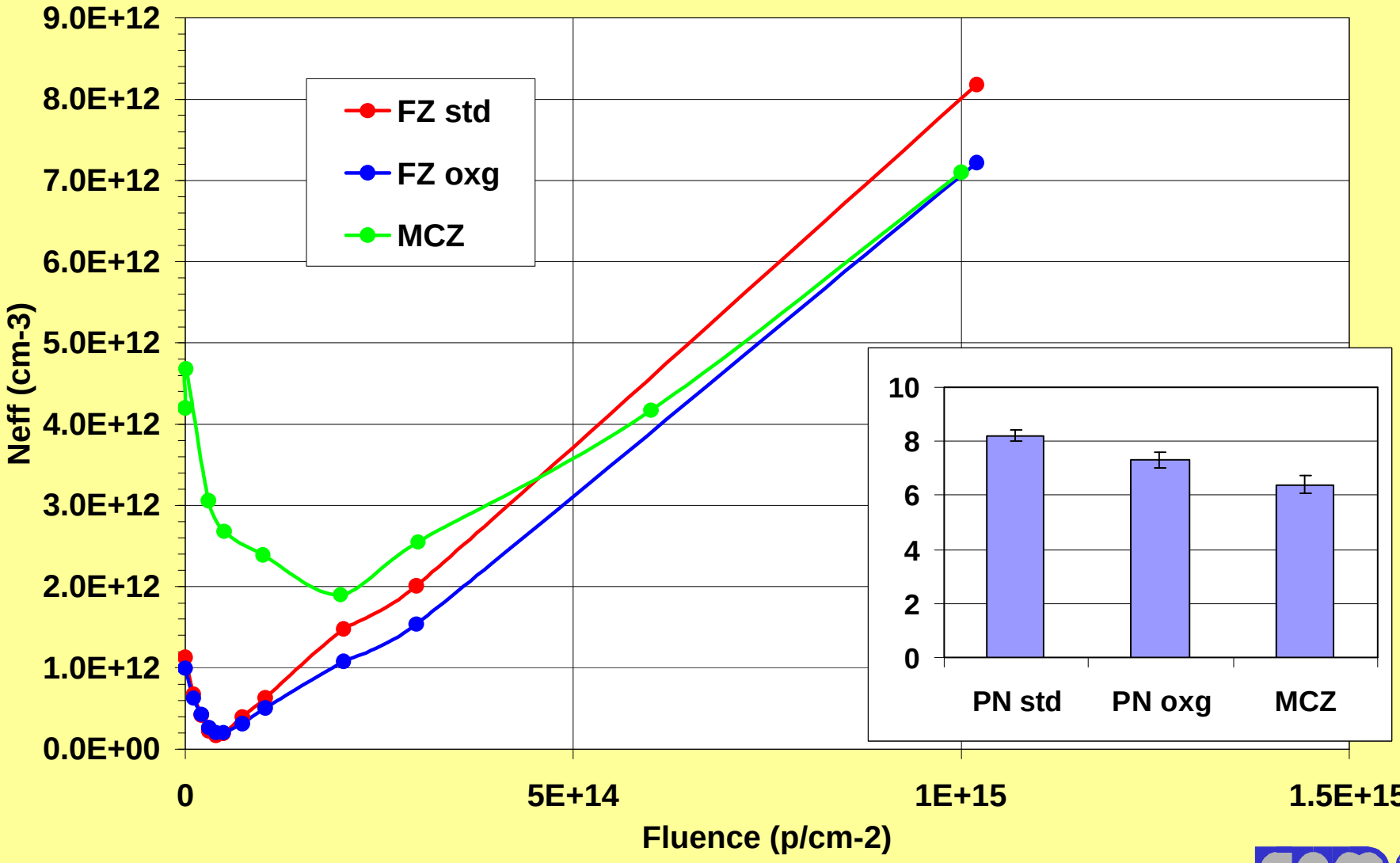
Experiments

- **Two categories of devices**
- **Simple P-in-N pad detector**
  - + **Simple process**
    - – **No poly, no capacitors**
  - + **Different materials**
    - – **Std FZ, oxg FZ, MCZ**
- **Pad and baby detectors in complex technology**
  - + **Different technologies: P-in-N, N-in-P, N-in-N**
  - + **P-stops implants at different doses**
  - + **no p-spray**

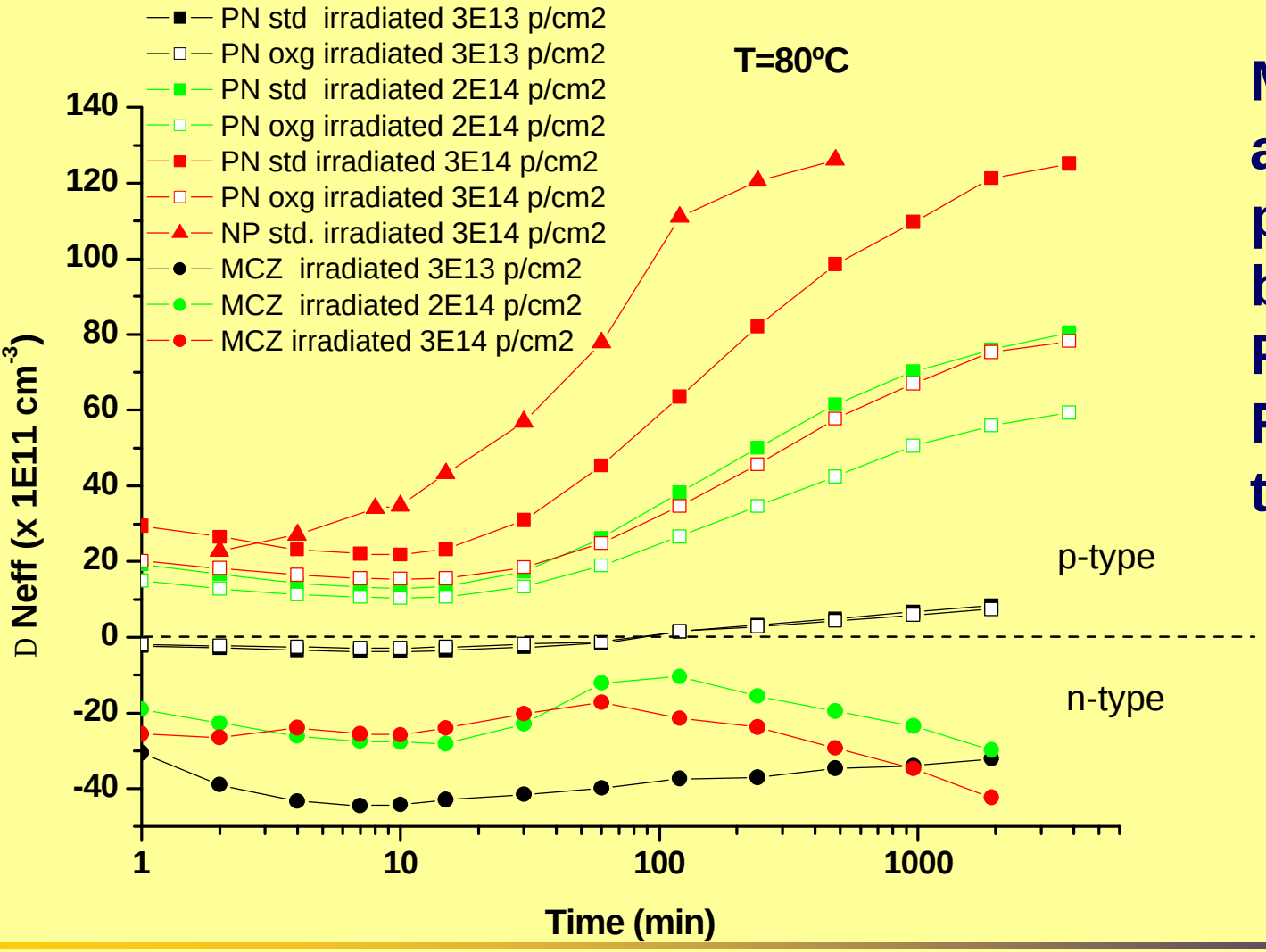
Experiments on simple pad detectors

- **Fabrication of pad detectors with ROSE mask with materials**
  - **Standard FZ**
  - **Diffusion oxygenated FZ**
  - **Magnetic CZ**
- **Irradiation doses: from 1e13 to 1e15 (and 1e16) and annealed 4 min at 80ºC**
- **Annealing studies for some fluences at 80ºC**

Neff variation with dose



Annealing behavior



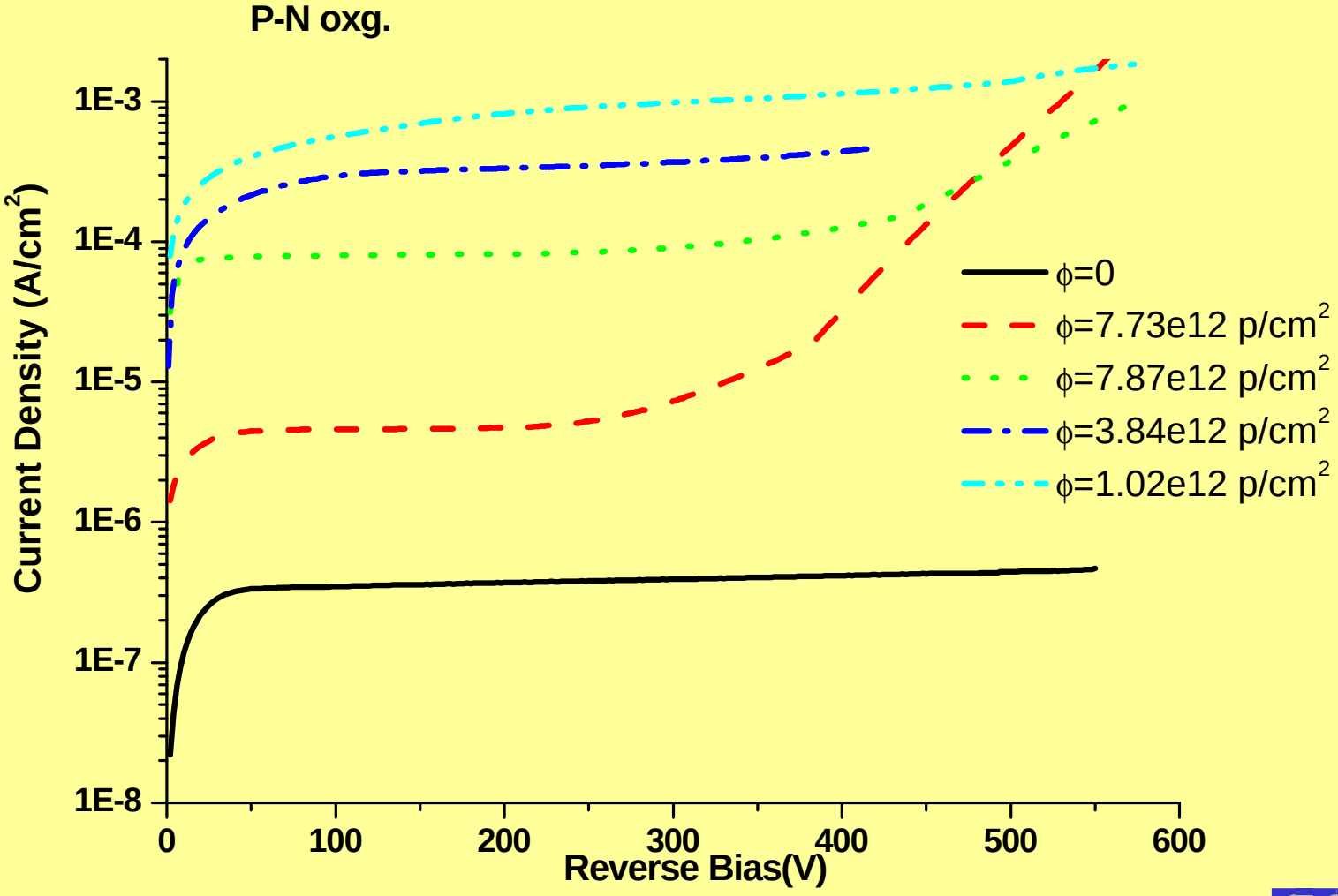
More data already presented by Giulio Pellegrini at RESMDD this week

Experiments on "complex" pad detectors

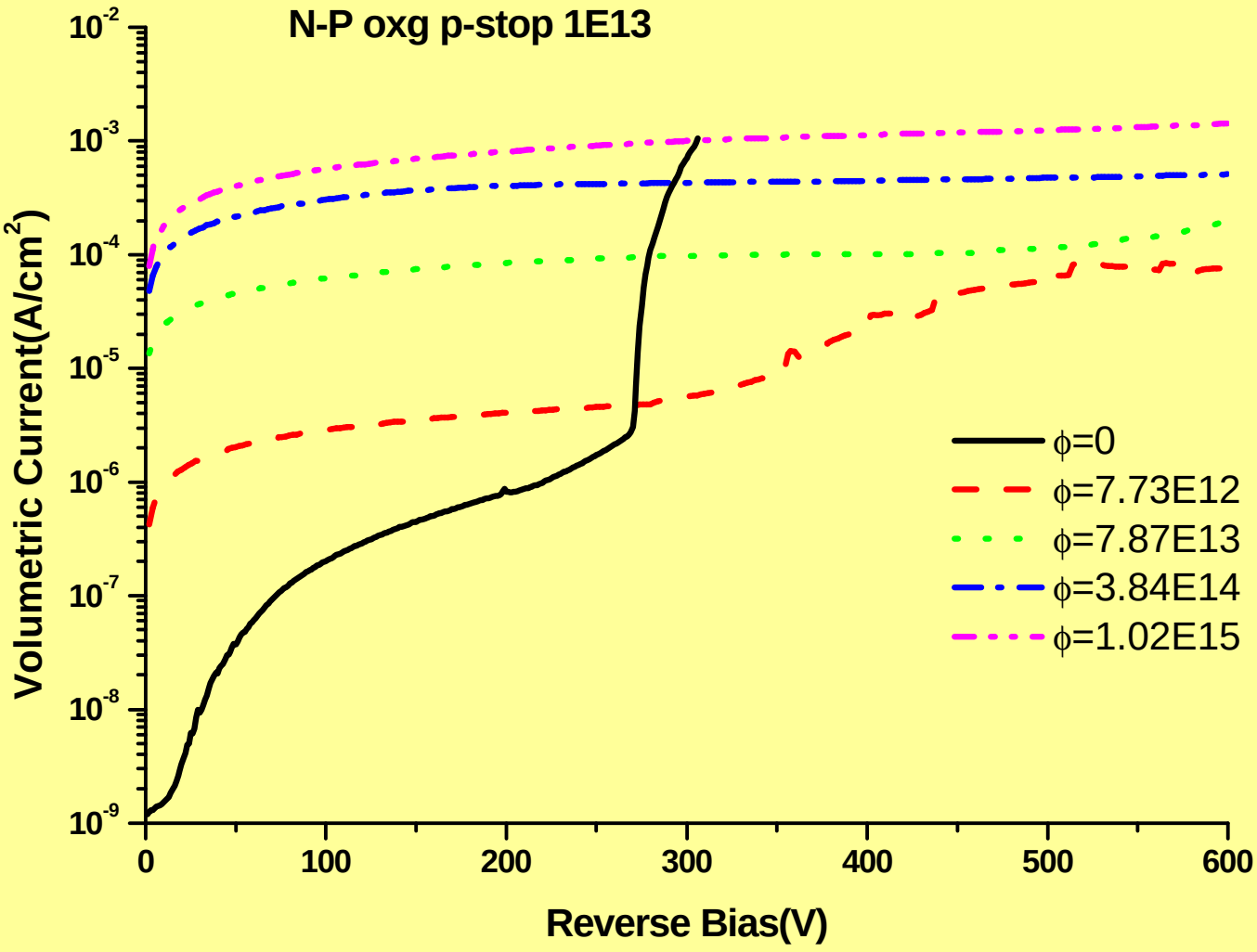
- Fabrication of pad and baby detectors with N-in-P mask
- with materials
  - Standard FZ
  - Diffusion oxygenated FZ
- and with technologies
  - P-in-N
  - N-in-P
  - N-in-N

- Irradiation doses: from 1e13 to 1e15 (and 1e16)
- Only pads tested

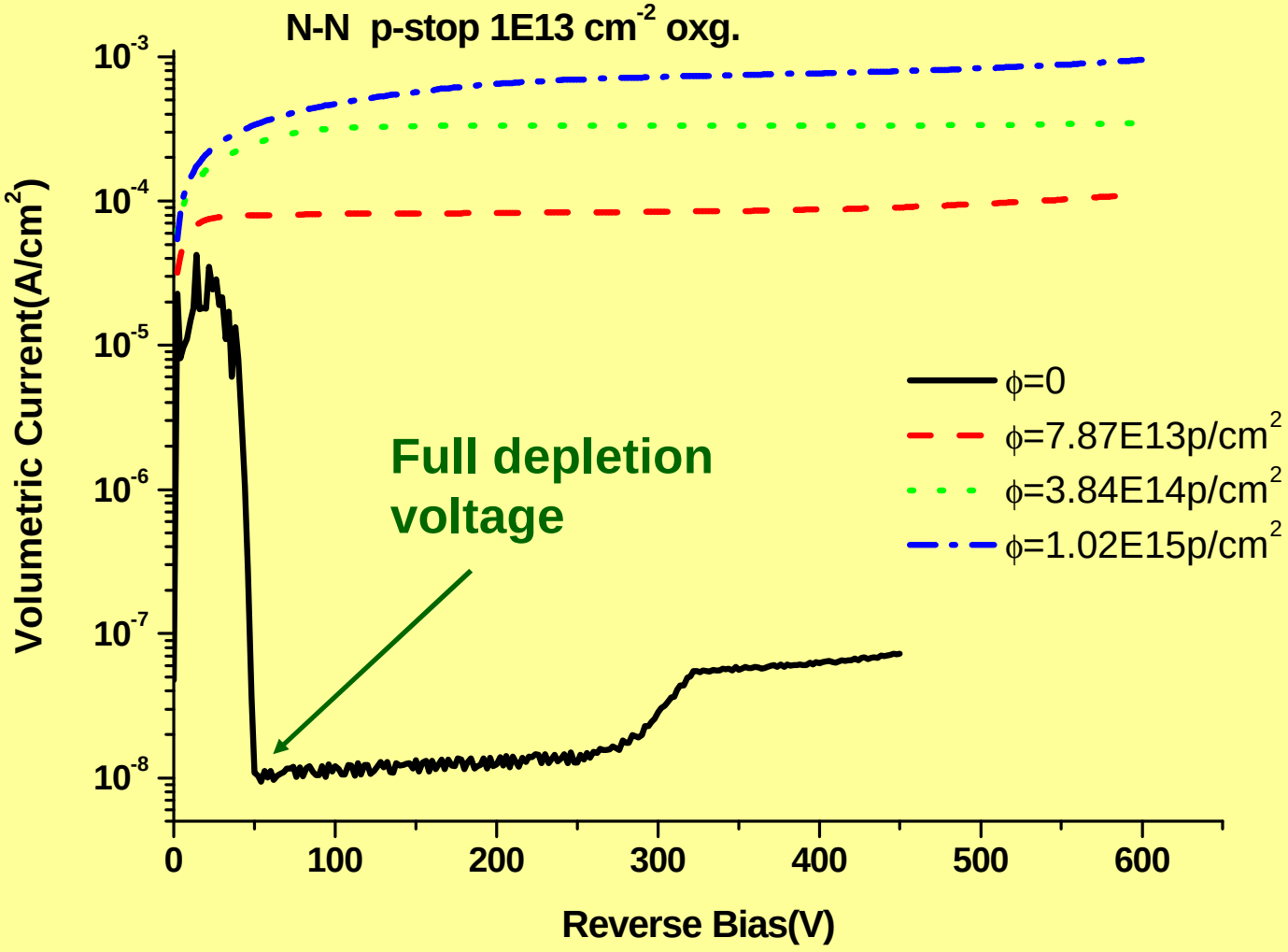
Leakage current: P-in-N



Leakage current: N-in-P diodes

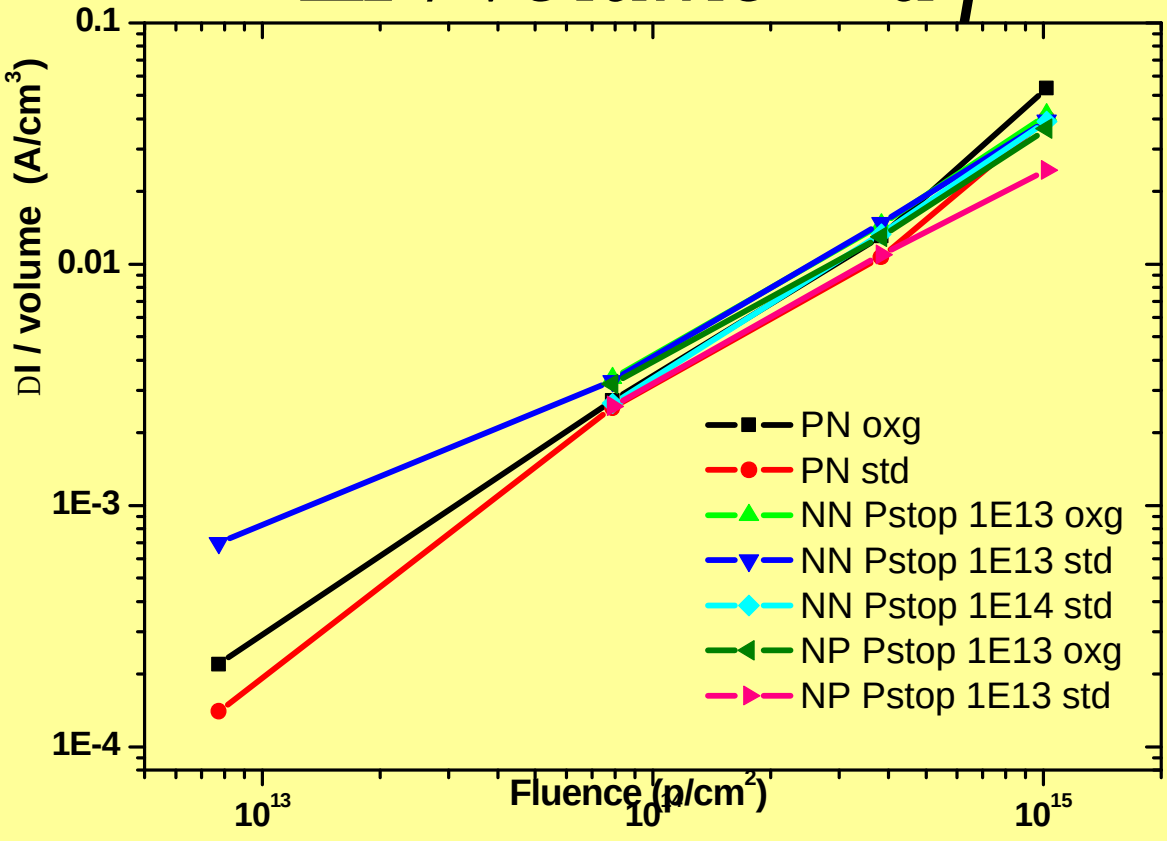


Leakage current for N-in-N diodes



Parameter a

$$\Delta I / volume = a f$$



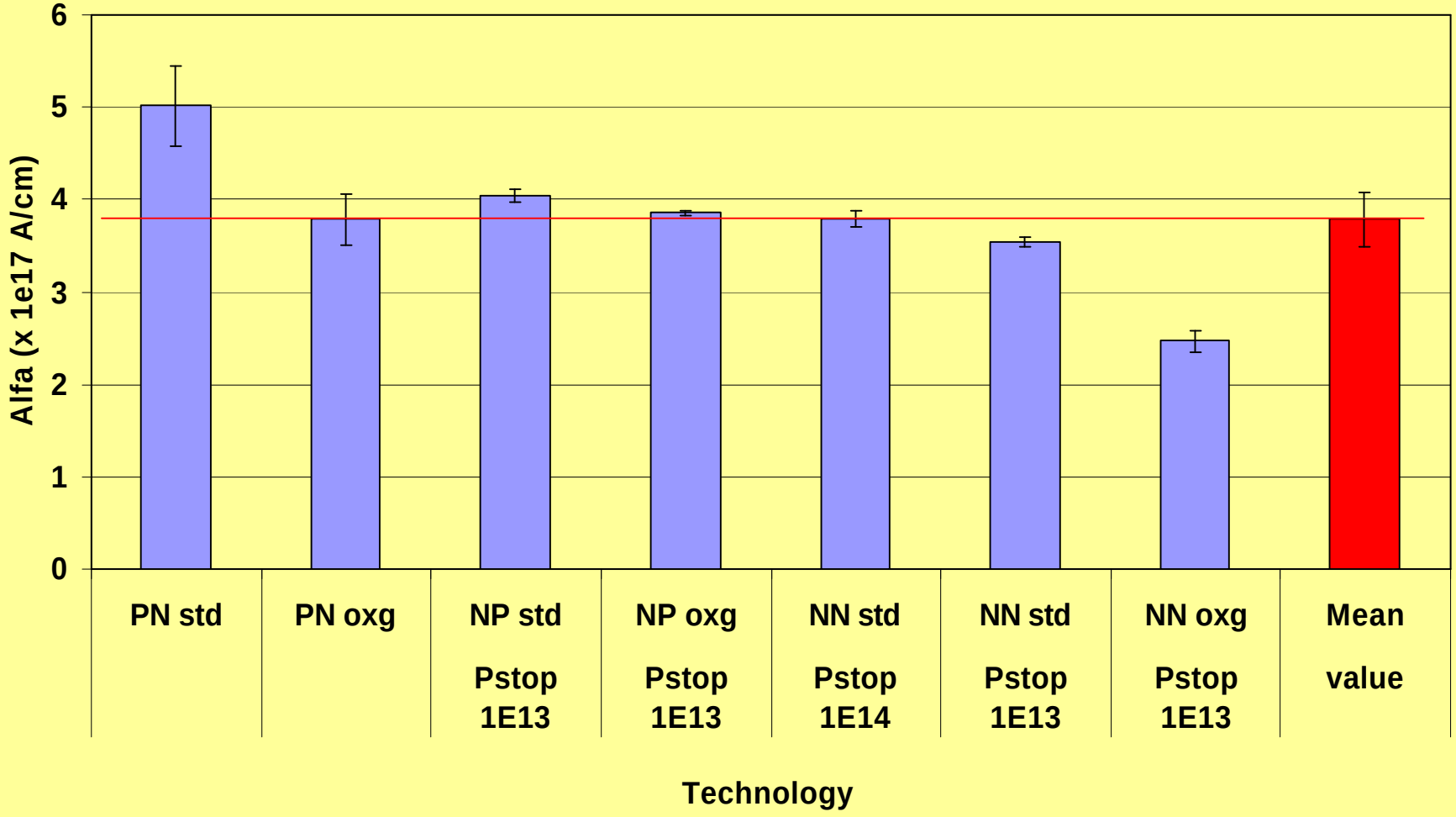
Currents were normalized to 20ºC according to equation: $I \sim T^2 \exp(-E_0/2kT)$ with E_0=1.12 eV.

Parameter a

Technology	P in N		N in P	
P-stop	-	-	1.00E+13	
substrate	Std	Oxg	Std	Oxg
a ($\times 10^{-17}$ A/cm)	5.01 ± 0.44	3.78 ± 0.27	4.04 ± 0.07	3.86 ± 0.03
a_{eq} ($\times 10^{-17}$ A/cm)	8.09 ± 0.7	6.1 ± 0.43	6.52 ± 0.11	6.22 ± 0.04

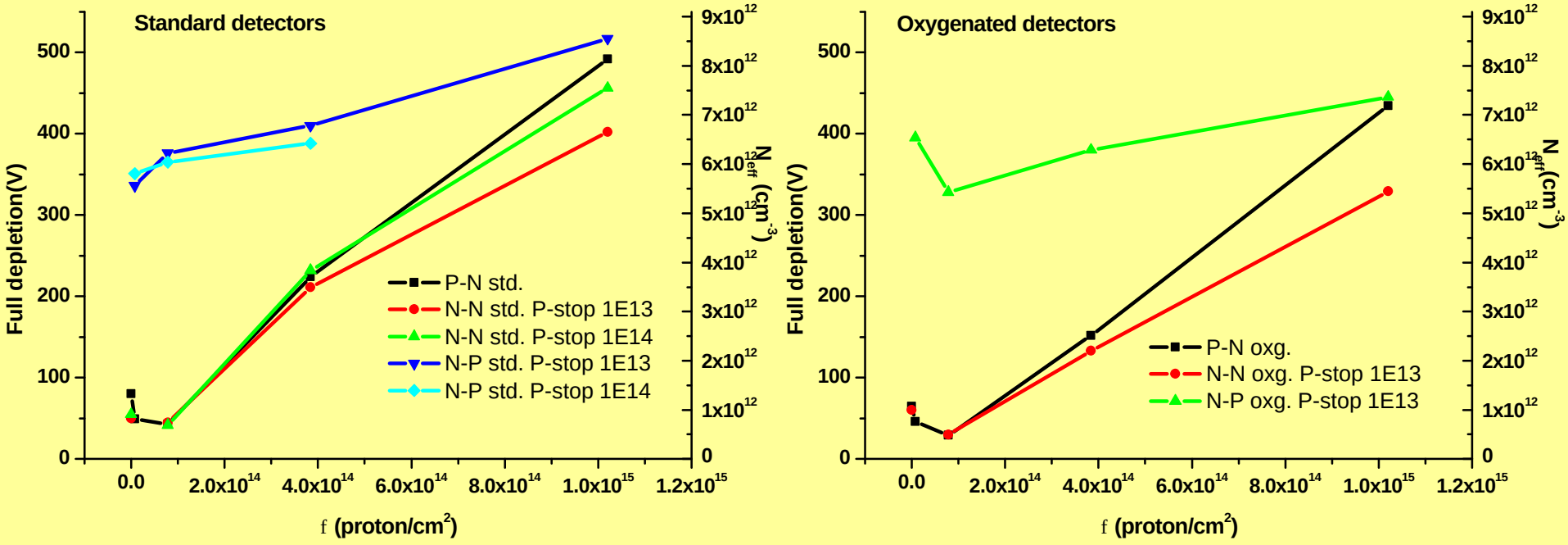
Technology	N in N			Mean value of the three technologies
P-stop	1.00E+14	1.00E+13		
substrate	Std	Std	Oxg	
a ($\times 10^{-17}$ A/cm)	3.79 ± 0.09	3.55 ± 0.05	2.47 ± 0.11	**3.78 ± 0.3**
a_{eq} ($\times 10^{-17}$ A/cm)	6.11 ± 0.14	5.72 ± 0.09	3.98 ± 0.18	**6.10 ± 0.48**

Parameter a


Alfa (x 1e17 A/cm)
6
5
4
3
2
1
0
PN std
PN oxg
NP std
Pstop
1E13
NP oxg
Pstop
1E13
NN std
Pstop
1E14
NN std
Pstop
1E13
NN oxg
Pstop
1E13
Mean
value
Technology

Full depletion vs. fluence

$$N_{eff} = b f$$



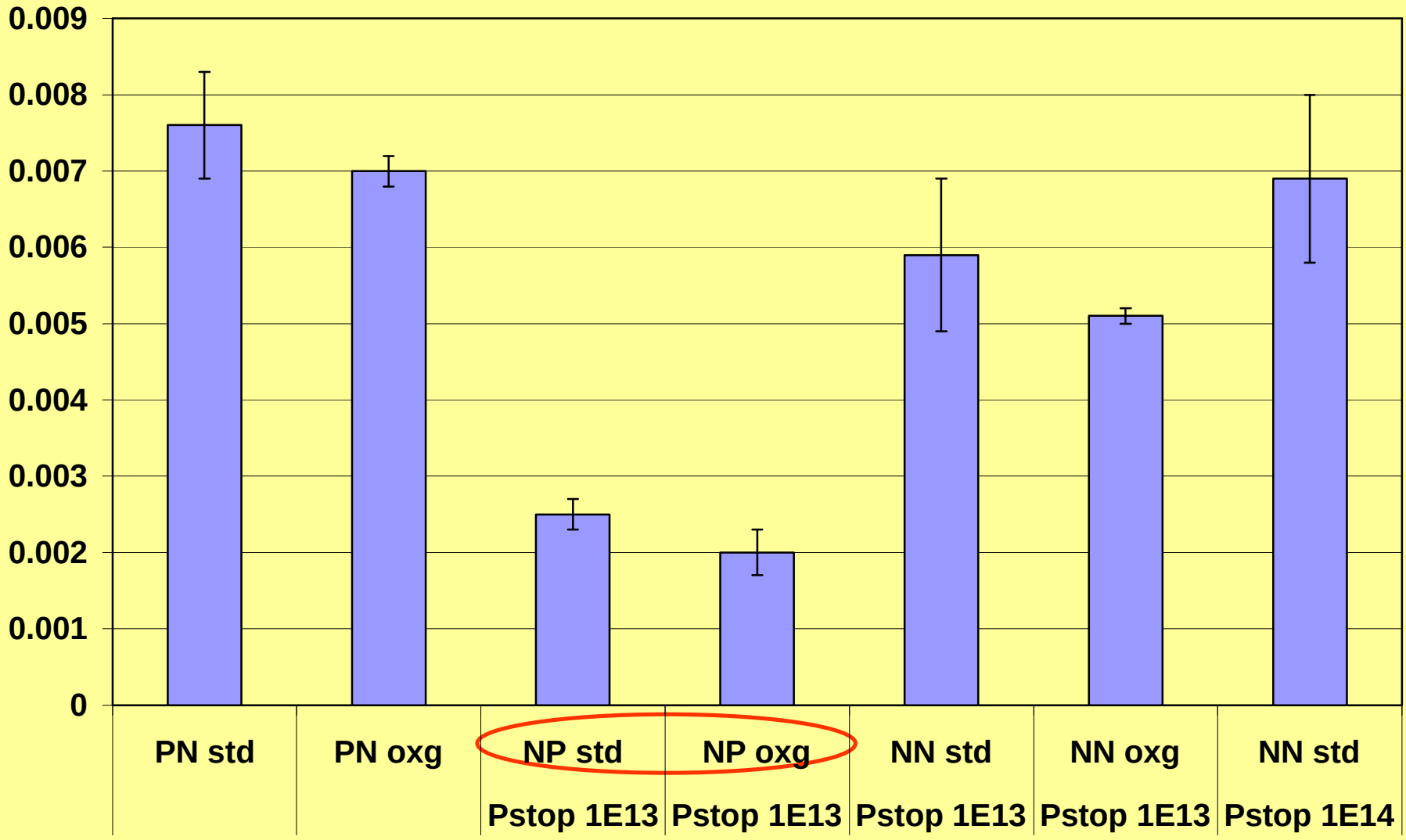
The last 3 fluences in these plots were used to calculated the value of b.

Parameter b

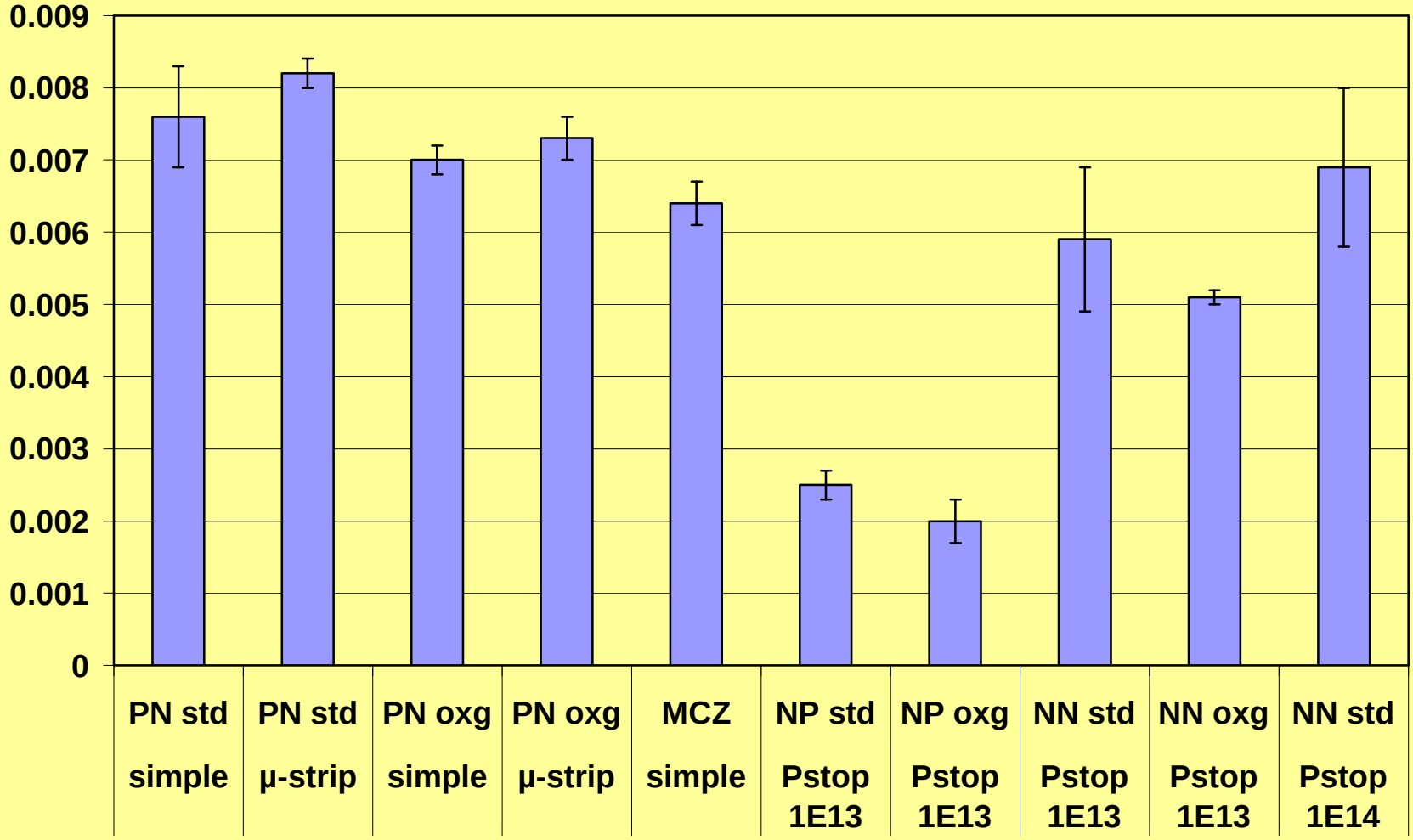
Technology	P in N		N in P	
P-stop	---	---	10^{13} cm^{-3}	
substrate	Std	Oxg	Std	Oxg
b (×10^{-3} cm^{-1})	7.6 ± 0.7	7.0 ± 0.2	2.5 ± 0.2	2.0 ± 0.3
b_{eq} (×10^{-3} cm^{-1})	12.2 ± 1.1	11.3 ± 0.3	4.0 ± 0.4	3.2 ± 0.4

Technology	N in N		
P-stop	10^{14} cm^{-3}	10^{13} cm^{-3}	
substrate	Std	Std	Oxg
b (×10^{-3} cm^{-1})	6.9 ± 1.1	6.0 ± 0.1	5.1 ± 0.1
b_{eq} (×10^{-3} cm^{-1})	11.1 ± 1.7	9.6 ± 1.5	8.3 ± 0.2

Parameter b


0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
PN std
PN oxg
NP std
NP oxg
NN std
NN oxg
NN std
Pstop 1E13
Pstop 1E13
Pstop 1E13
Pstop 1E13
Pstop 1E14

Summary of all beta data



Conclusions

- **Alfa is constant (as expected)**
- **Beta behavior**
  - + **Slightly increased by complex processing**
  - + **Oxygenation improves beta**
  - + **MCZ has best value (for N type)**
  - + **Beta for P type is the best**
- **Annealing behavior**
  - + **Bad for P type**
  - + **Excellent for N-type MCZ**
- **Missing**
  - + **CCE measurement in babies**
  - + **Extend results up to 1e16 protons/cm2**