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# RSD2

## The new production of AC-LGADs at FBK

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for the RSD group (**FBK** and **INFN Torino**)

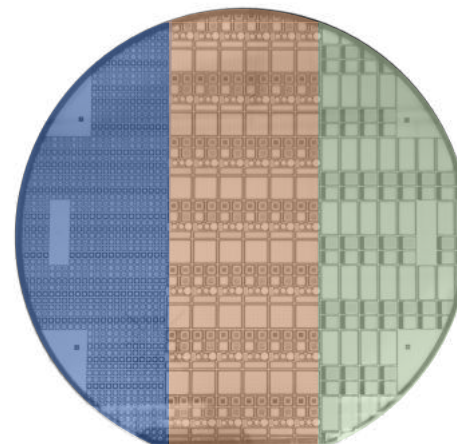
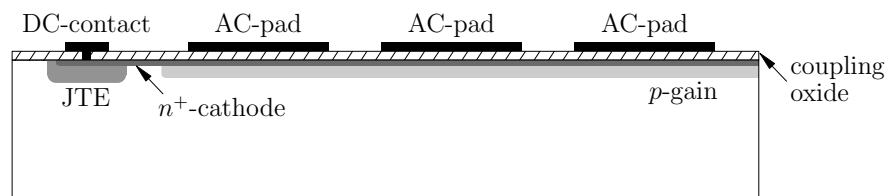


39<sup>th</sup> RD50 Workshop – València, 17-19 November 2021

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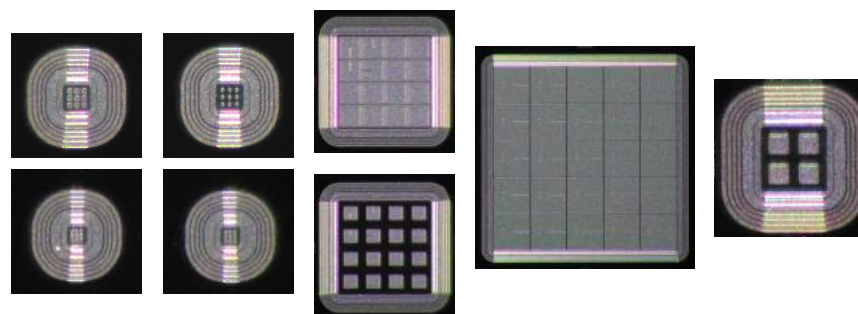
# Towards the 4D tracking

## The RSD1 batch



RSD1 (2019)

wafer #	<i>n</i> -plus dose	<i>p</i> -gain dose	dielectric thickness	<i>p</i> -stop dose	substrate
1	B	0.92	normal	B	FZ 55μm
2	B	0.94	normal	A	FZ 55μm
3	B	0.94	normal	B	Epi 45μm
4	B	0.94	thick	B	FZ 55μm
5	B	0.96	thick	B	FZ 55μm
6	C	0.92	normal	B	Epi 45μm
7	C	0.94	normal	A	FZ 55μm
8	C	0.94	normal	B	FZ 55μm
9	C	0.96	normal	B	FZ 55μm
10	C	0.96	thick	B	FZ 55μm
11	D	0.92	normal	B	FZ 55μm
12	D	0.94	normal	B	Epi 45μm
13	D	0.94	normal	B	FZ 55μm
14	D	0.96	thick	B	Epi 45μm
15	D	0.96	thick	C	FZ 55μm



pad pitch: 50 to 500 μm  
pad size: 30 to 490 μm

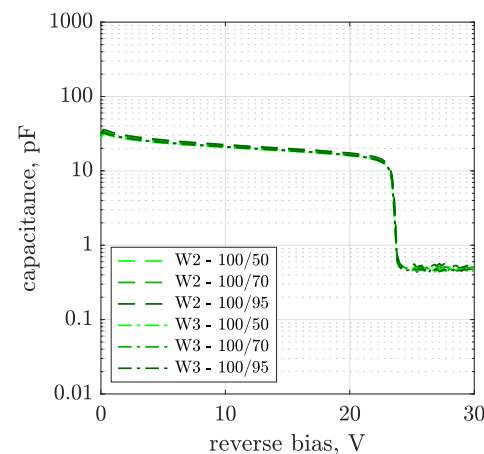
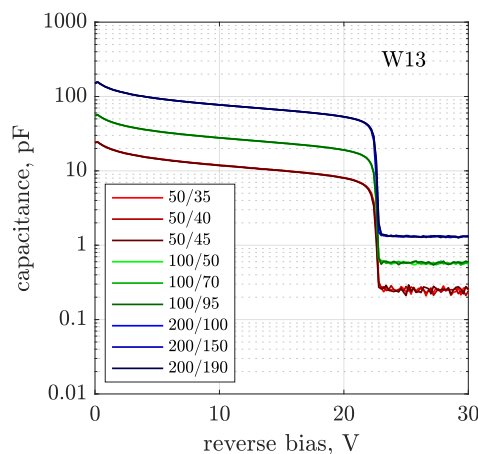
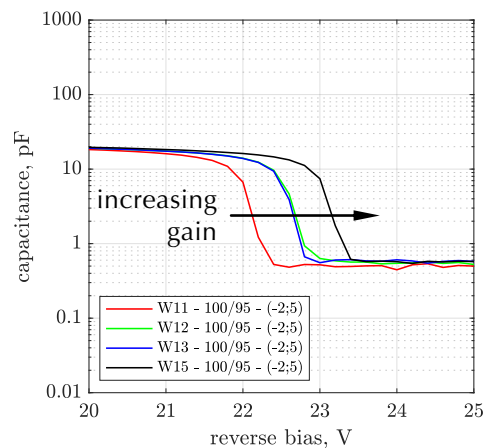
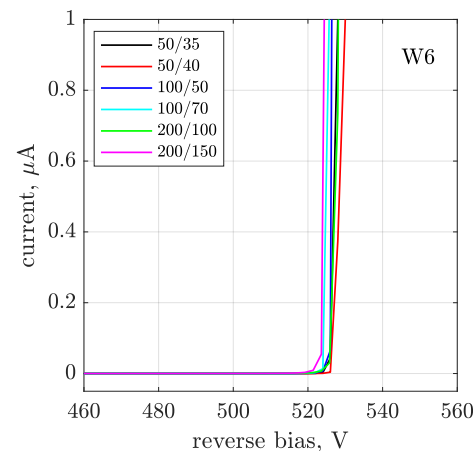
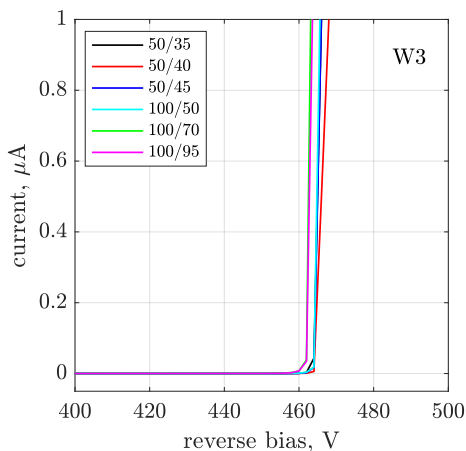
strip RSD sensors with pitch  
75 and 180 μm

See my 2019 talk at the 34<sup>th</sup> RD50 Workshop in Lancaster:  
<https://indico.cern.ch/event/812761/contributions/3459062/>

# Towards the 4D tracking

From **RSD1** electrical tests:

- ▶ **No mask defects** (stepper)
- ▶ **Extremely low mortality**
- ▶ **Accurate process**
- ▶ **Uniform process**

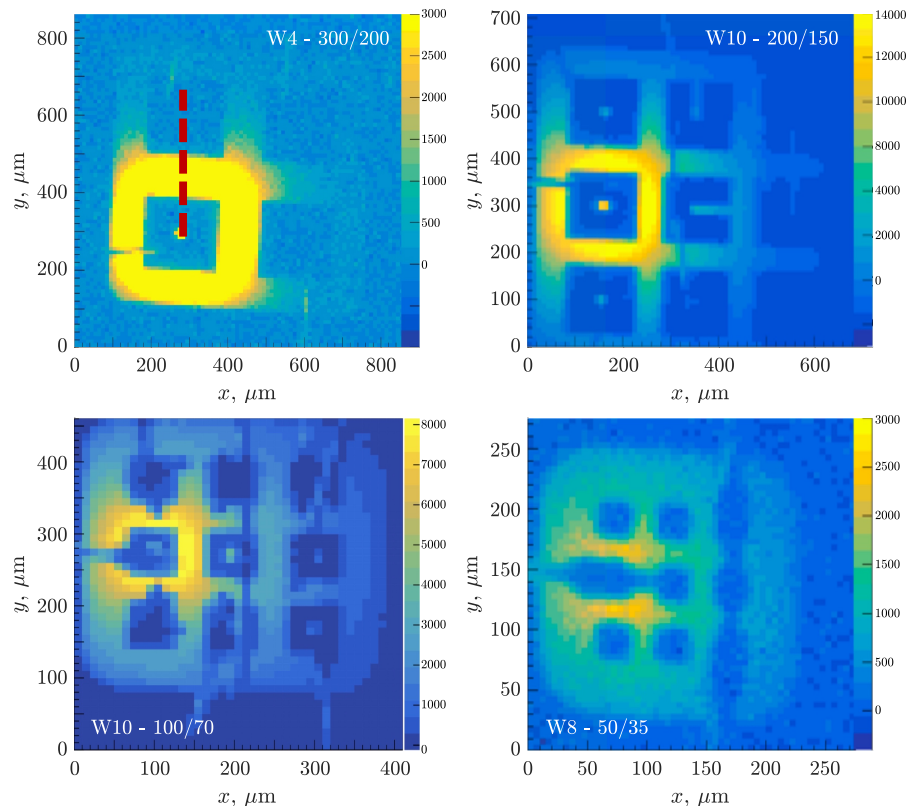


More details in <https://arxiv.org/abs/2003.04838>

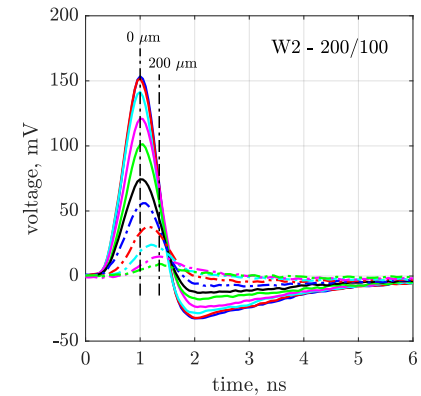
# Towards the 4D tracking

## RSD1 dynamic characterization

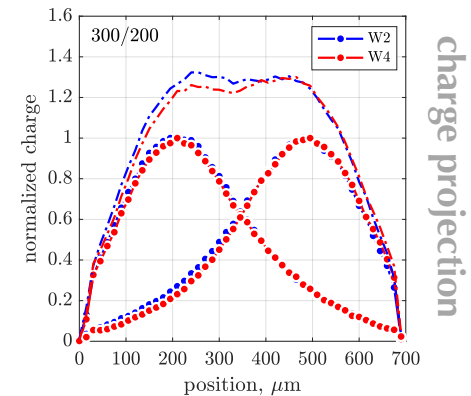
2D maps of charges



TCT scan



waveforms



charge projection

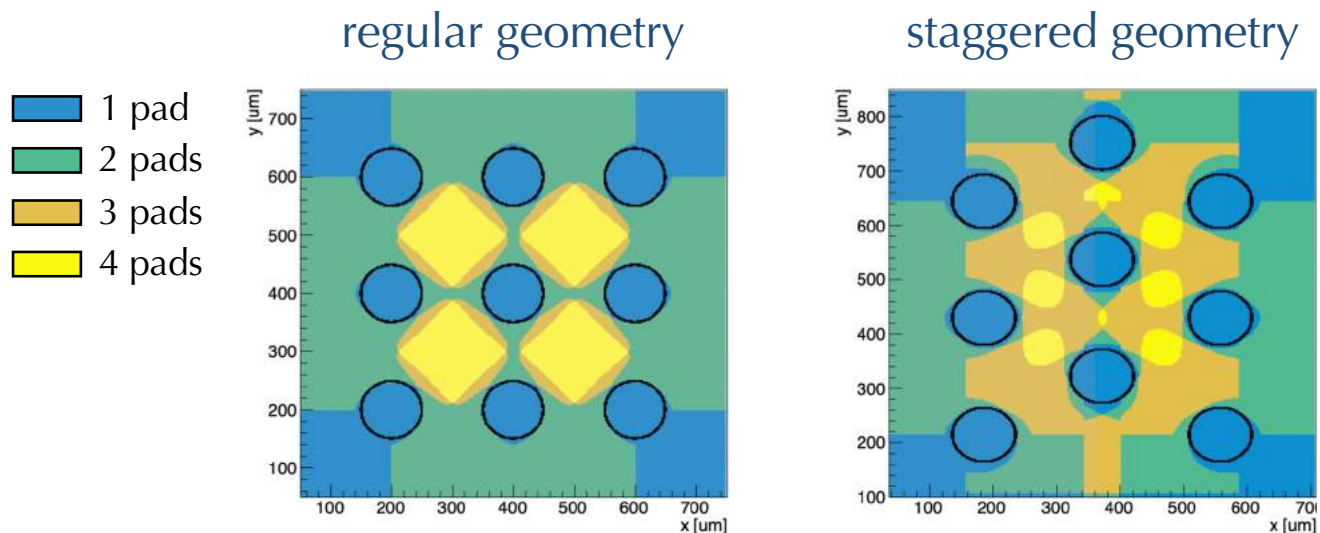
More details in <https://doi.org/10.1109/LED.2019.2943242> and <https://arxiv.org/abs/2003.04838>



# Towards the 4D tracking



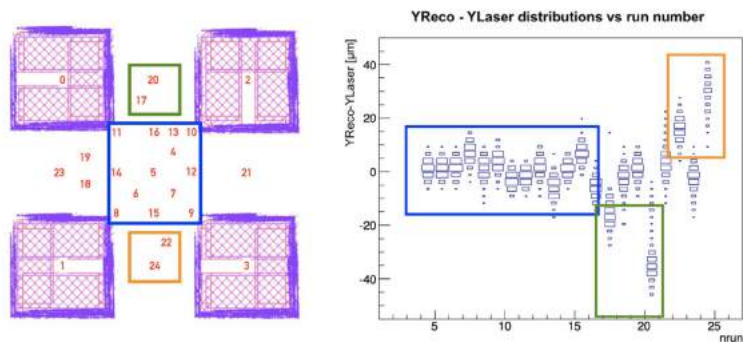
## RSD1 dynamic characterization



More details in <https://doi.org/10.1016/j.nima.2021.165319> and <https://doi.org/10.1088/1748-0221/16/03/P03019>

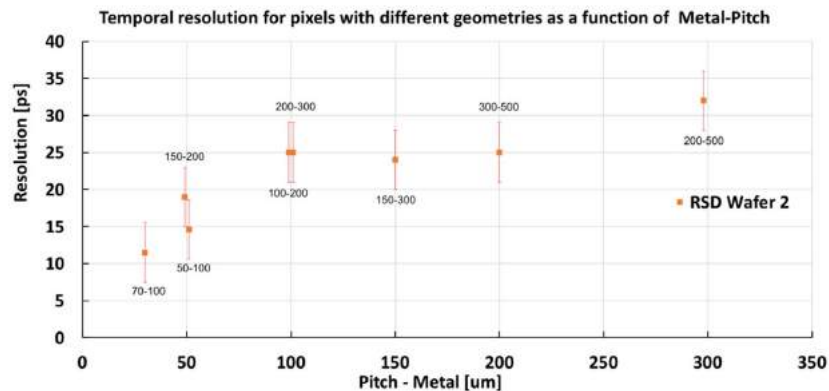
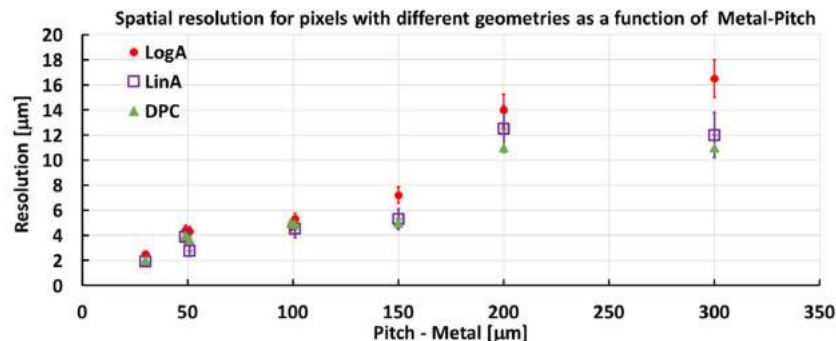
# Towards the 4D tracking

## RSD1 dynamic characterization:



Spatial and temporal resolutions from TCT measurements for different RSD pad-pitch geometries. These results refer to studies where the laser has been shot in the interpad region of the sensors, as shown in Fig. 10.

Pad-pitch geometry	Spatial resolution [μm]	Temporal resolution [ps]
50-100	4.3	14.7
70-100	2.5	11.5
100-200	4.8	25
150-200	4.4	19
150-300	7.2	24
200-300	5.3	25
200-500	16.5	32
300-500	14	25



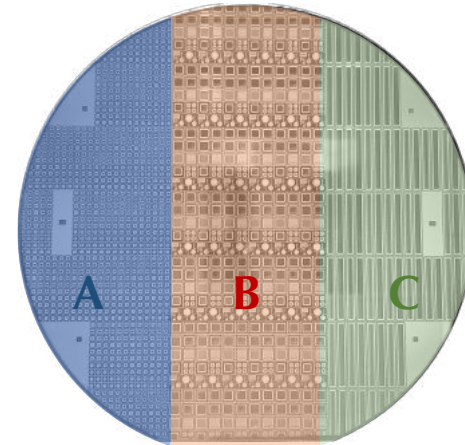
More details in <https://doi.org/10.1016/j.nima.2021.165319> and <https://doi.org/10.1088/1748-0221/16/03/P03019>

# The new RSD2 production



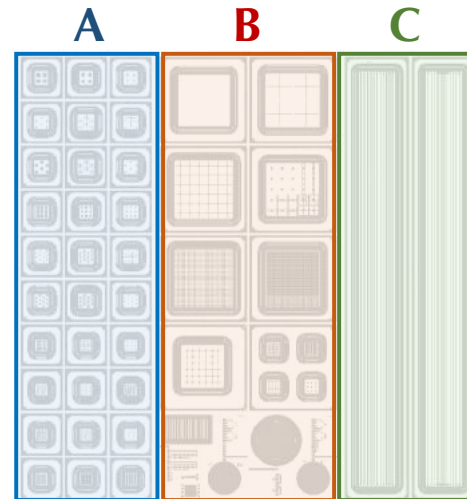
The **RSD2** batch:

- ▶ higher **p-gain** dose
- ▶ slightly decreased **n-plus** dose
- ▶ thin dielectric
- ▶ dose **B** of **p-stop** implants



RSD2

wafer #	n-plus dose	p-gain dose	metal thickness	substrate	C spray
1	A	0.96	thick	FZ 55 $\mu\text{m}$	N
2	A	0.96	normal	FZ 55 $\mu\text{m}$	N
3	A	0.98	normal	FZ 55 $\mu\text{m}$	N
4	A	1.00	normal	FZ 55 $\mu\text{m}$	N
5	B	1.00	normal	FZ 55 $\mu\text{m}$	N
6	B	1.00	normal	Epi 45 $\mu\text{m}$	N
7	B	0.98	normal	FZ 55 $\mu\text{m}$	N
8	B	0.96	normal	Epi 45 $\mu\text{m}$	N
9	B	0.96	normal	Epi 45 $\mu\text{m}$	N
10	B	0.96	normal	Epi 45 $\mu\text{m}$	1.0
11	C	0.96	normal	Epi 45 $\mu\text{m}$	N
12	C	0.96	normal	Epi 45 $\mu\text{m}$	0.8
13	C	0.98	normal	FZ 55 $\mu\text{m}$	N
14	C	0.98	normal	Epi 45 $\mu\text{m}$	N
15	C	0.94	normal	FZ 55 $\mu\text{m}$	N

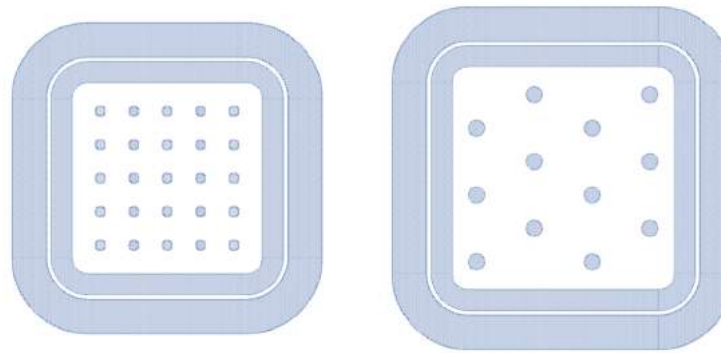


**pad pitch:** 25 to 500  $\mu\text{m}$   
**pad size:** 15 to 440  $\mu\text{m}$

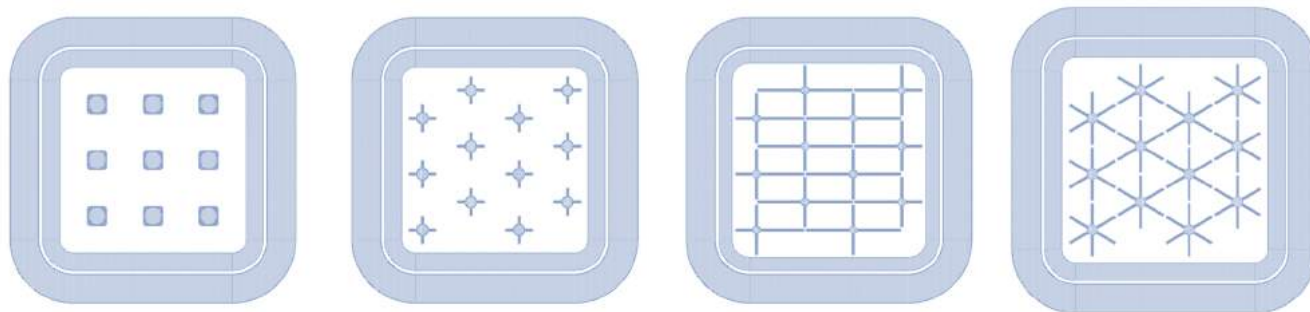
**strip RSD sensors** with pitch  
 75 and 150  $\mu\text{m}$

# RSD2 design and layout

- ▶ Two different **array configurations**: *regular* and *staggered*

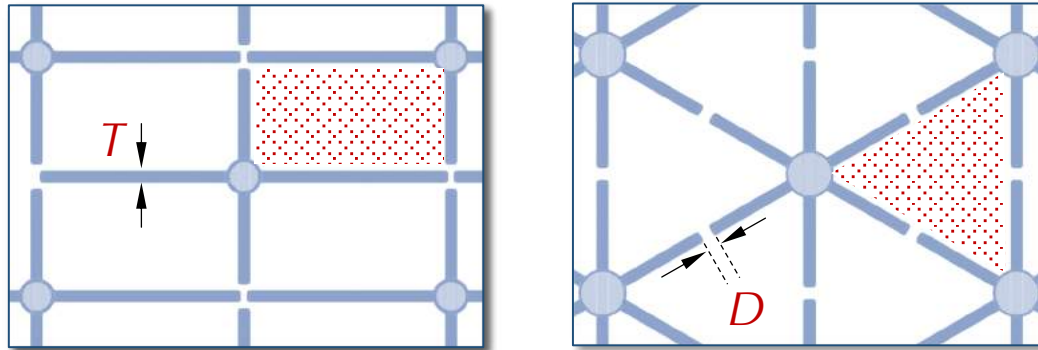


- ▶ Several **pad geometries**: *squares, circles, crosses, stars, etc...*

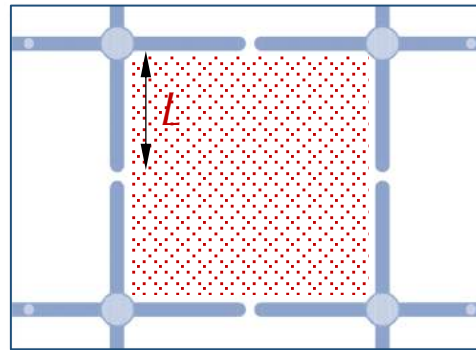


# RSD2 design and layout

- ▶ **Signal confinement** with *cross* or *star* AC-pads in the **staggered arrays**:

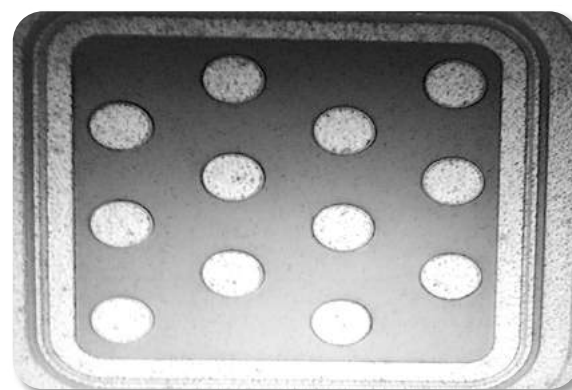
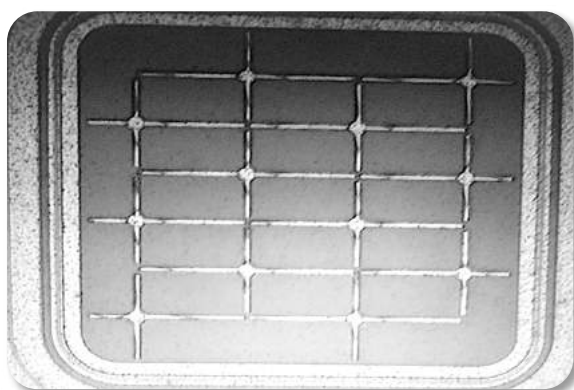
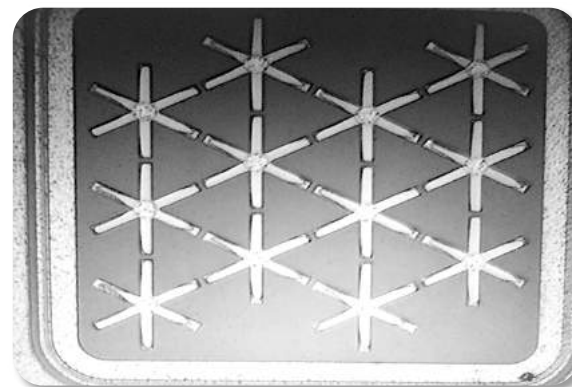
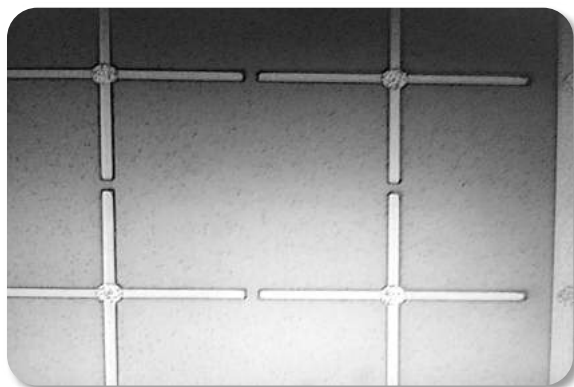


- ▶ and in the **regular arrays**:



# RSD2 design and layout

... some nice pictures of the RSD2 readout electrodes...

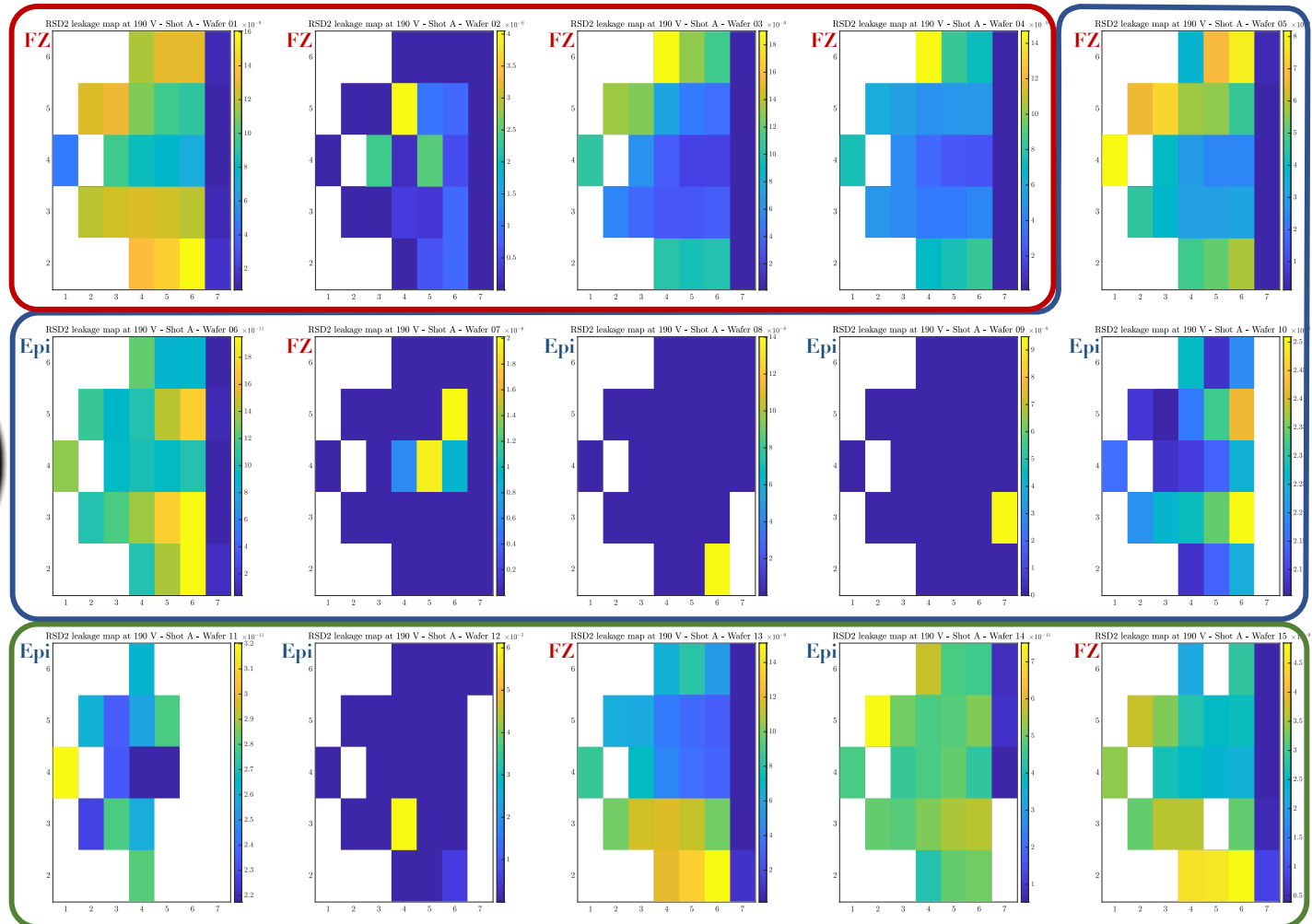
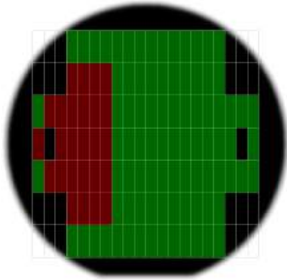


INFN-FBK design patent submitted to the Italian Ministry of Economic Development (MISE), application number **102021000011444**, May 2021

# RSD2: uniformity test

**Block A**

**290-300  $\mu\text{m}$   
~200 V**



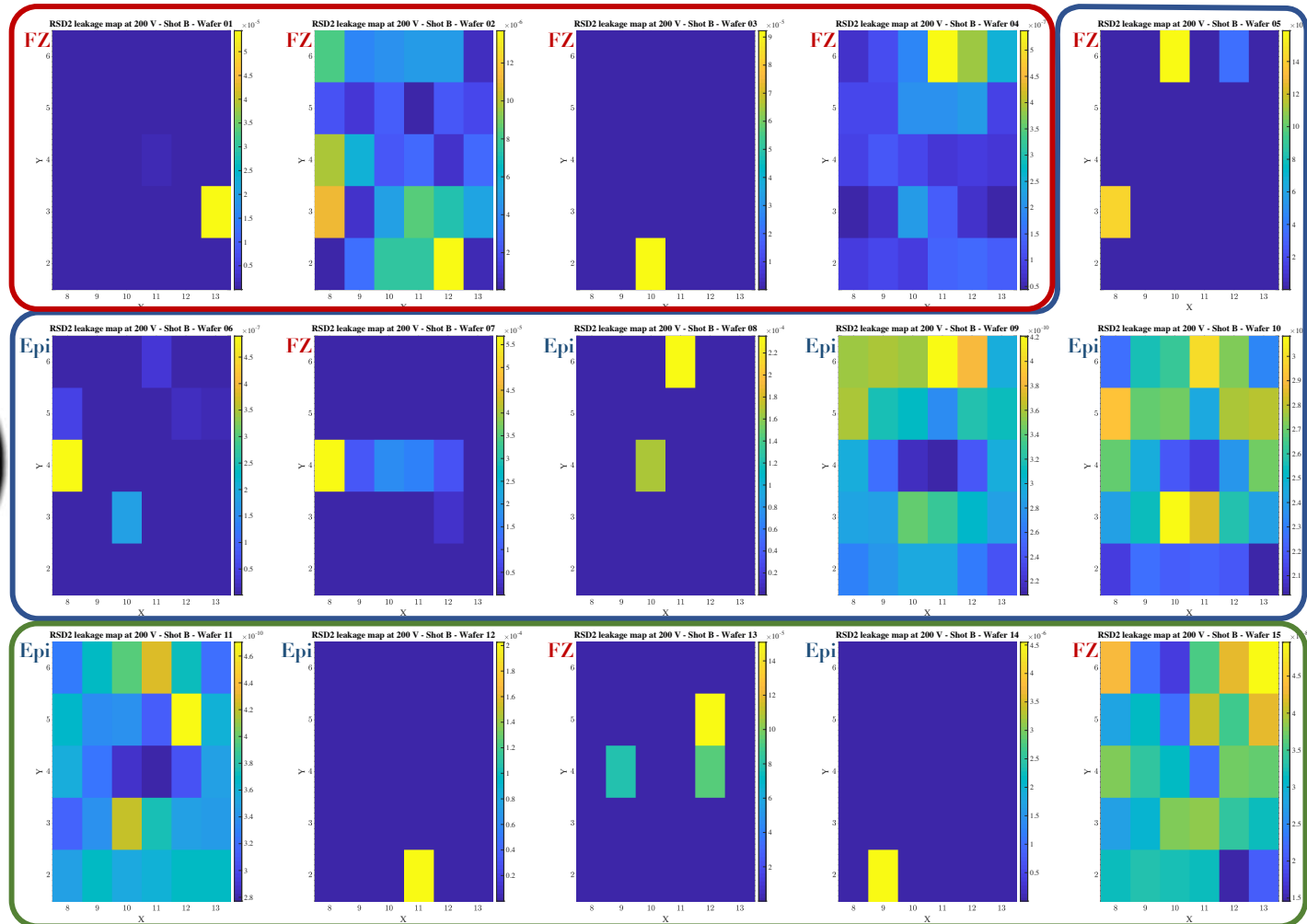
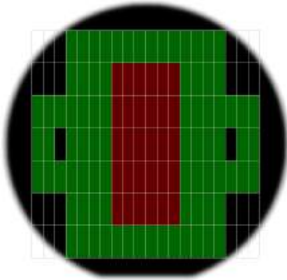




# RSD2: uniformity test

Block B

blank RSD  
~200 V

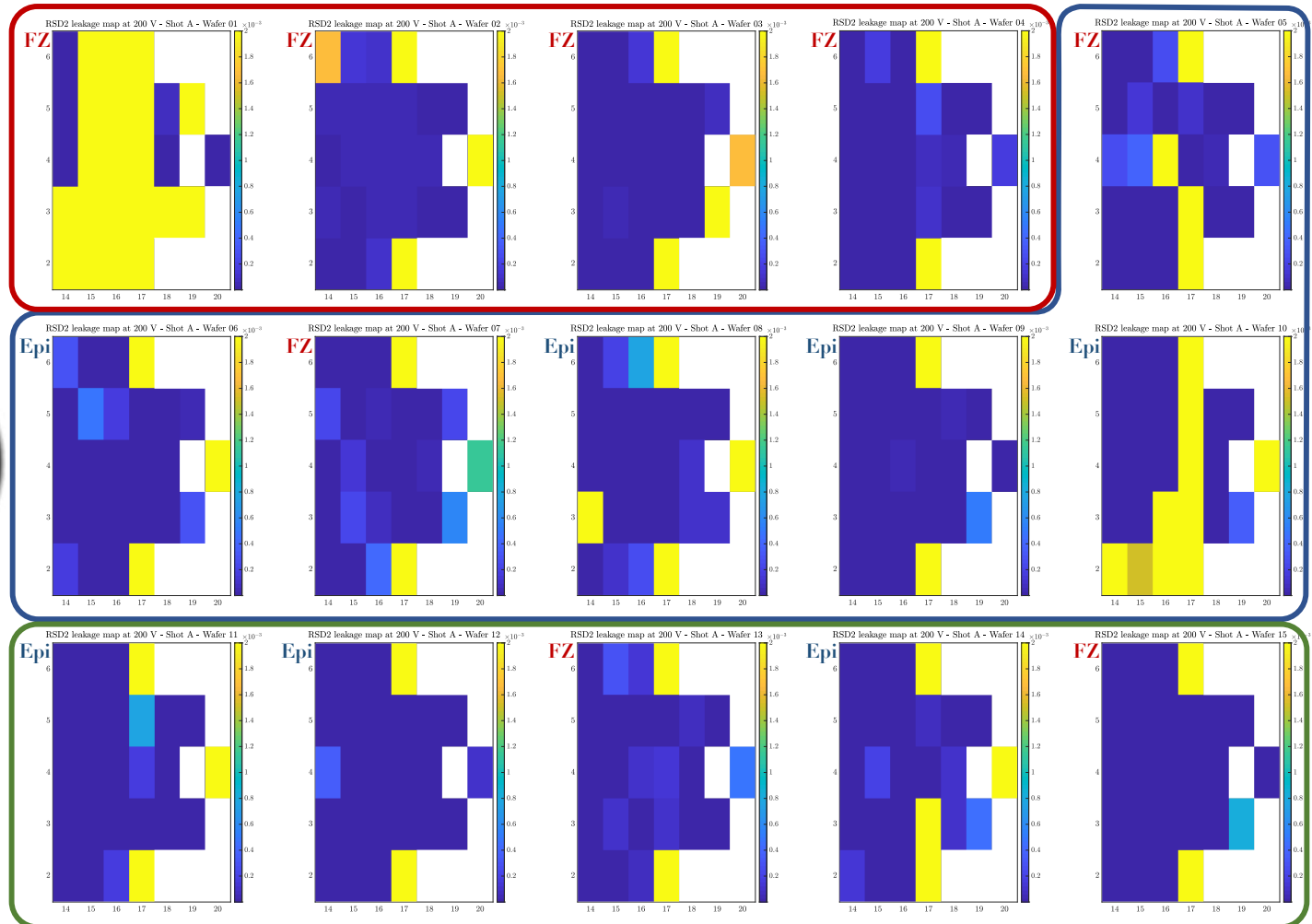
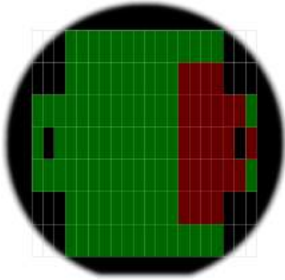




# RSD2: uniformity test

Block C

strip RSD  
~200 V

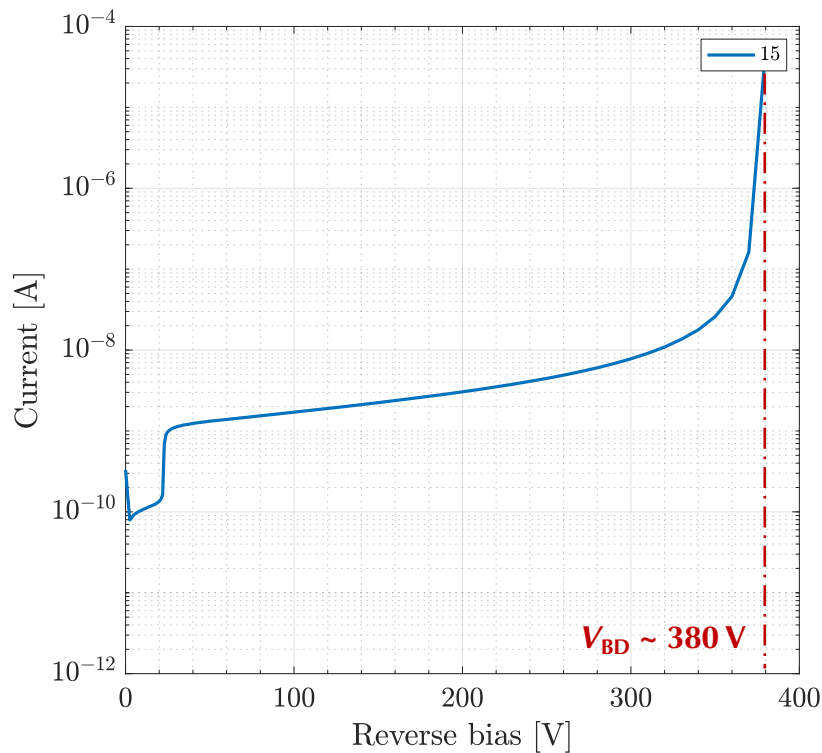
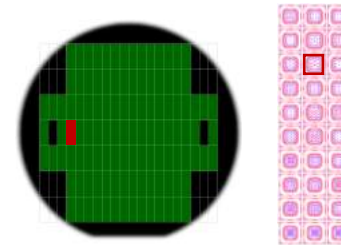


# RSD2: first electrical tests - I



Gain dose **0.94**

Block A – 2x3 290-300 stars



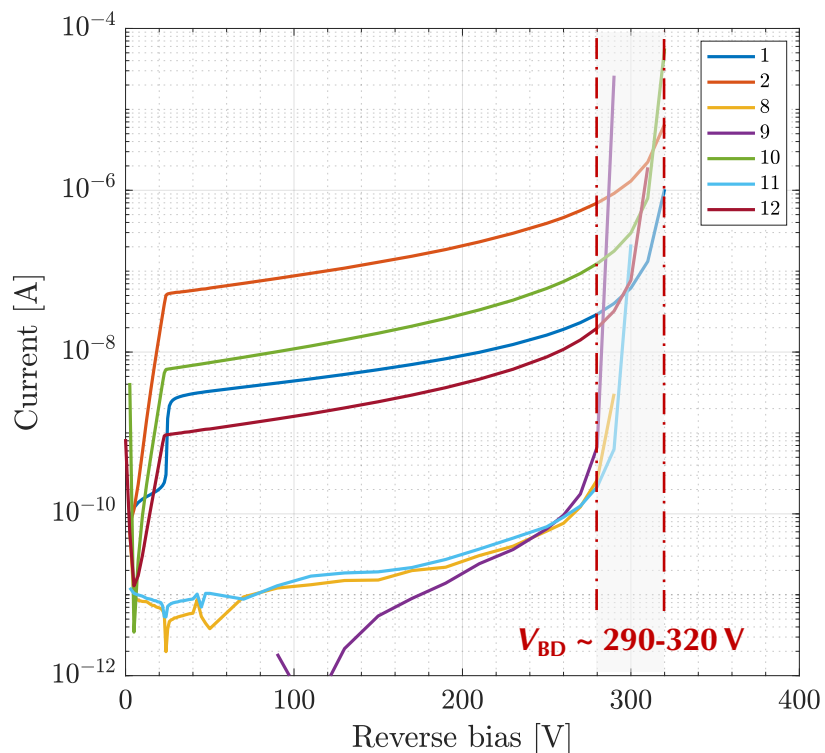
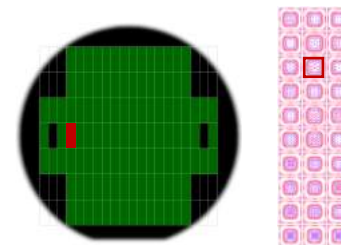
wafer #	<i>n</i> -plus dose	<i>p</i> -gain dose	metal thickness	substrate	C spray
1	A	0.96	thick	FZ 55 $\mu\text{m}$	N
2	A	0.96	normal	FZ 55 $\mu\text{m}$	N
3	A	0.98	normal	FZ 55 $\mu\text{m}$	N
4	A	1.00	normal	FZ 55 $\mu\text{m}$	N
5	B	1.00	normal	FZ 55 $\mu\text{m}$	N
6	B	1.00	normal	Epi 45 $\mu\text{m}$	N
7	B	0.98	normal	FZ 55 $\mu\text{m}$	N
8	B	0.96	normal	Epi 45 $\mu\text{m}$	N
9	B	0.96	normal	Epi 45 $\mu\text{m}$	N
10	B	0.96	normal	Epi 45 $\mu\text{m}$	1.0
11	C	0.96	normal	Epi 45 $\mu\text{m}$	N
12	C	0.96	normal	Epi 45 $\mu\text{m}$	0.8
13	C	0.98	normal	FZ 55 $\mu\text{m}$	N
14	C	0.98	normal	Epi 45 $\mu\text{m}$	N
15	C	0.94	normal	FZ 55 $\mu\text{m}$	N

# RSD2: first electrical tests - I



Gain dose **0.96**

Block **A** – 2x3 290-300 stars



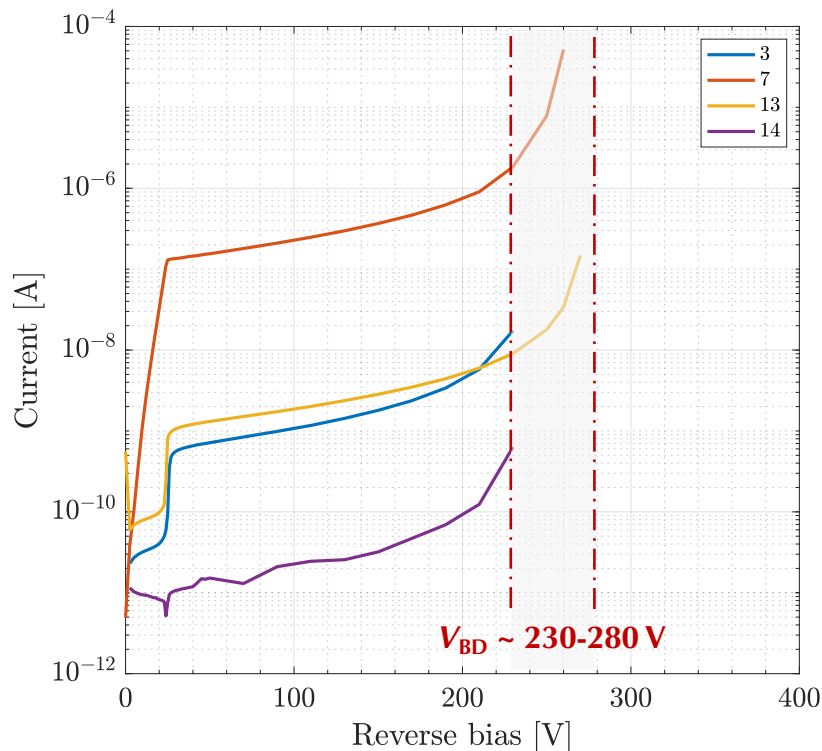
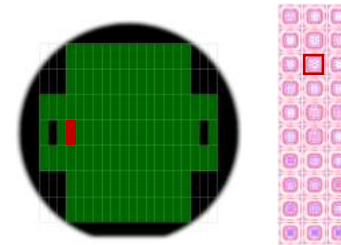
wafer #	n-plus dose	p-gain dose	metal thickness	substrate	C spray
1	A	0.96	thick	FZ 55 $\mu\text{m}$	N
2	A	0.96	normal	FZ 55 $\mu\text{m}$	N
3	A	0.98	normal	FZ 55 $\mu\text{m}$	N
4	A	1.00	normal	FZ 55 $\mu\text{m}$	N
5	B	1.00	normal	FZ 55 $\mu\text{m}$	N
6	B	1.00	normal	Epi 45 $\mu\text{m}$	N
7	B	0.98	normal	FZ 55 $\mu\text{m}$	N
8	B	0.96	normal	Epi 45 $\mu\text{m}$	N
9	B	0.96	normal	Epi 45 $\mu\text{m}$	N
10	B	0.96	normal	Epi 45 $\mu\text{m}$	1.0
11	C	0.96	normal	Epi 45 $\mu\text{m}$	N
12	C	0.96	normal	Epi 45 $\mu\text{m}$	0.8
13	C	0.98	normal	FZ 55 $\mu\text{m}$	N
14	C	0.98	normal	Epi 45 $\mu\text{m}$	N
15	C	0.94	normal	FZ 55 $\mu\text{m}$	N

# RSD2: first electrical tests - I



Gain dose **0.98**

Block A – 2x3 290-300 stars



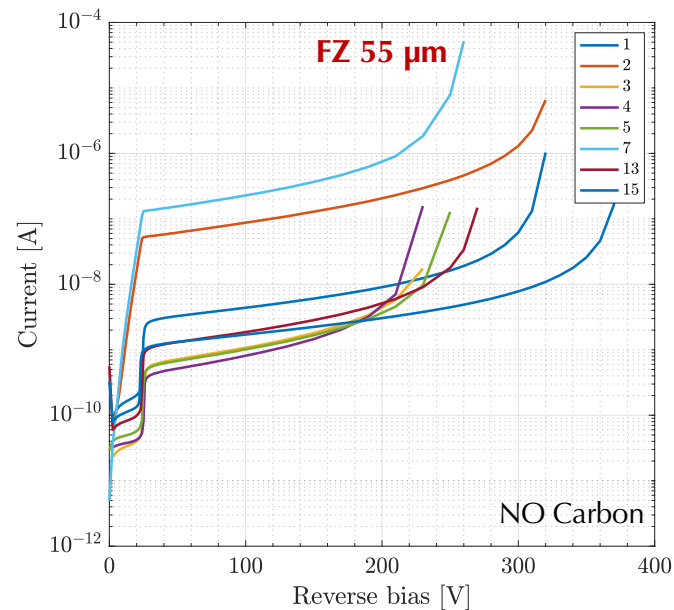
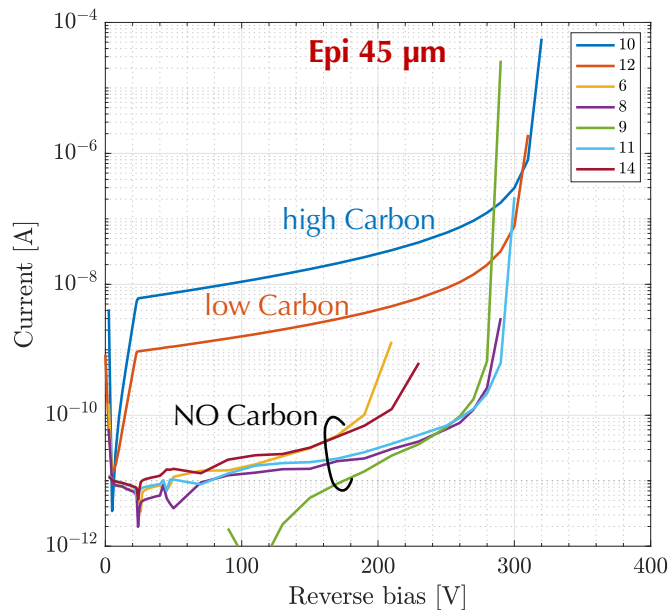
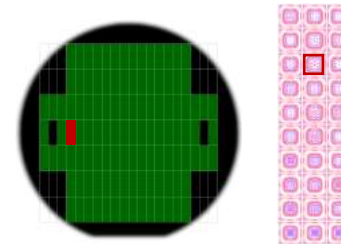
wafer #	n-plus dose	p-gain dose	metal thickness	substrate	C spray
1	A	0.96	thick	FZ 55 $\mu\text{m}$	N
2	A	0.96	normal	FZ 55 $\mu\text{m}$	N
3	A	0.98	normal	FZ 55 $\mu\text{m}$	N
4	A	1.00	normal	FZ 55 $\mu\text{m}$	N
5	B	1.00	normal	FZ 55 $\mu\text{m}$	N
6	B	1.00	normal	Epi 45 $\mu\text{m}$	N
7	B	0.98	normal	FZ 55 $\mu\text{m}$	N
8	B	0.96	normal	Epi 45 $\mu\text{m}$	N
9	B	0.96	normal	Epi 45 $\mu\text{m}$	N
10	B	0.96	normal	Epi 45 $\mu\text{m}$	1.0
11	C	0.96	normal	Epi 45 $\mu\text{m}$	N
12	C	0.96	normal	Epi 45 $\mu\text{m}$	0.8
13	C	0.98	normal	FZ 55 $\mu\text{m}$	N
14	C	0.98	normal	Epi 45 $\mu\text{m}$	N
15	C	0.94	normal	FZ 55 $\mu\text{m}$	N

# RSD2: first electrical tests - II



## Carbon spray implant

Block A – 2x3 290-300 stars

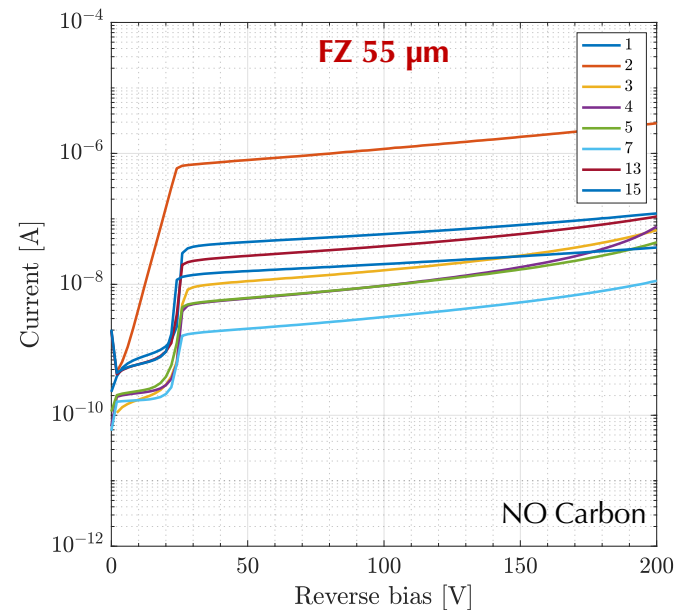
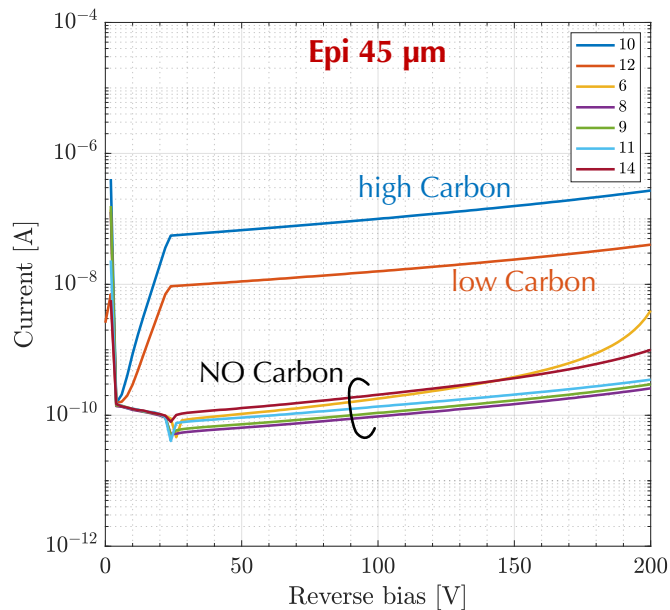
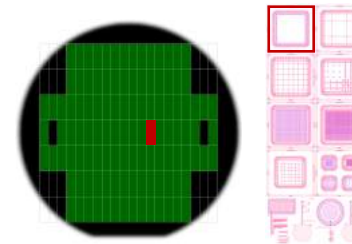


# RSD2: first electrical tests - II



## Carbon spray implant

Block B – blank RSD

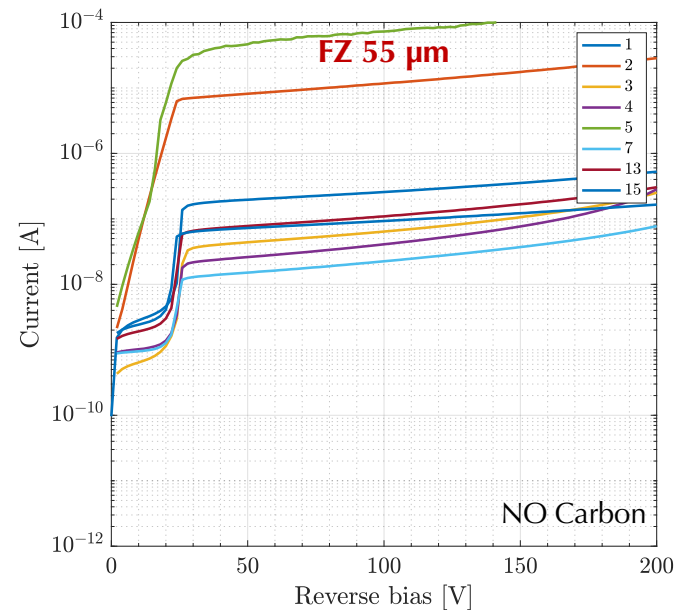
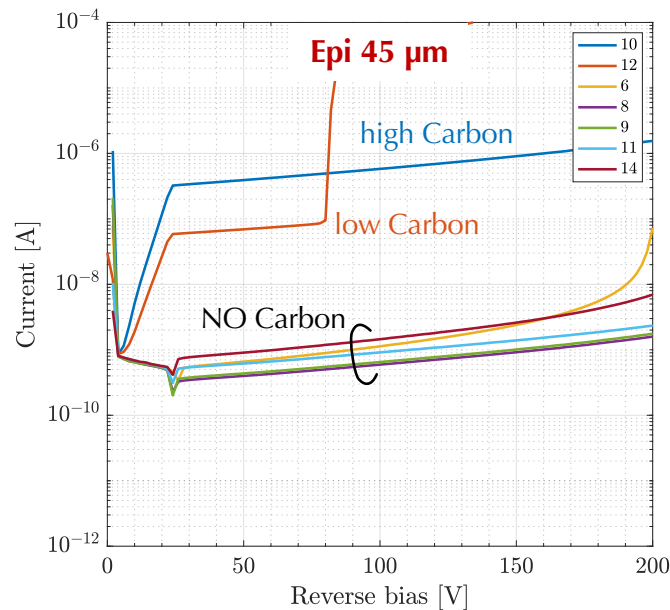
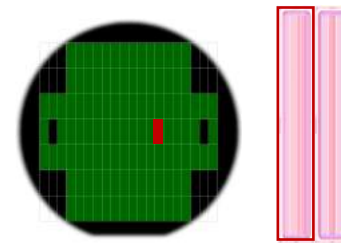


# RSD2: first electrical tests - II

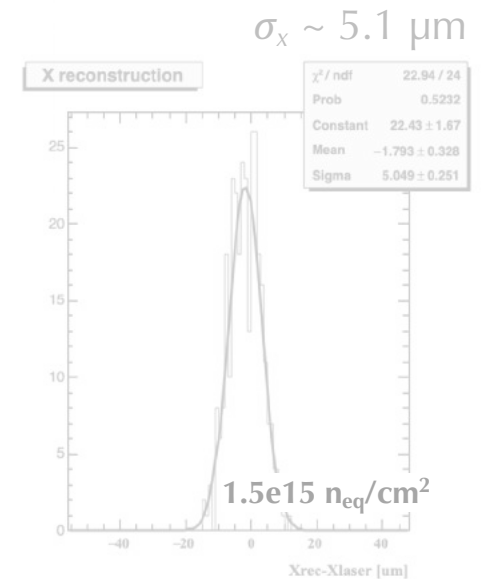
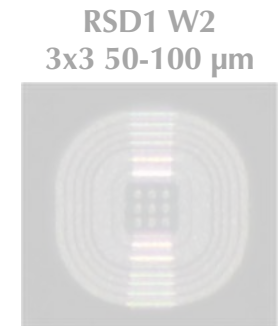
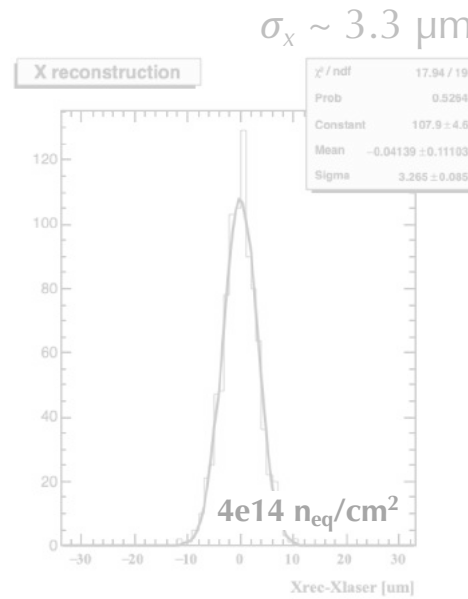
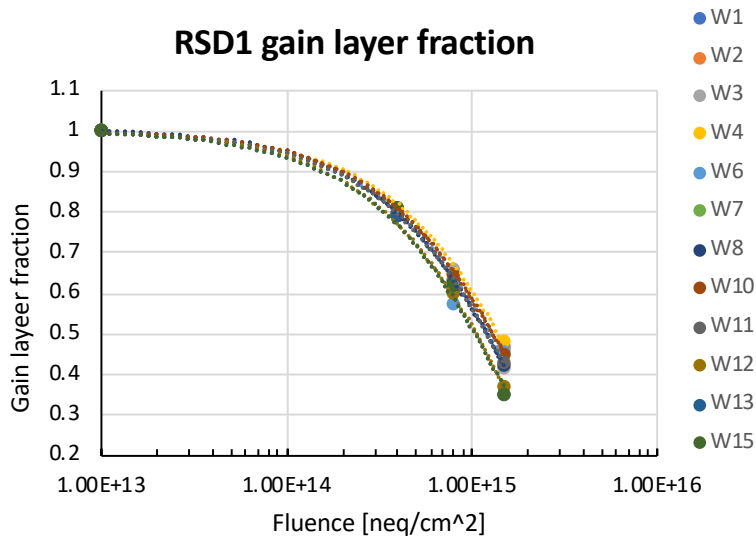


## Carbon spray implant

Block C – strip no.1

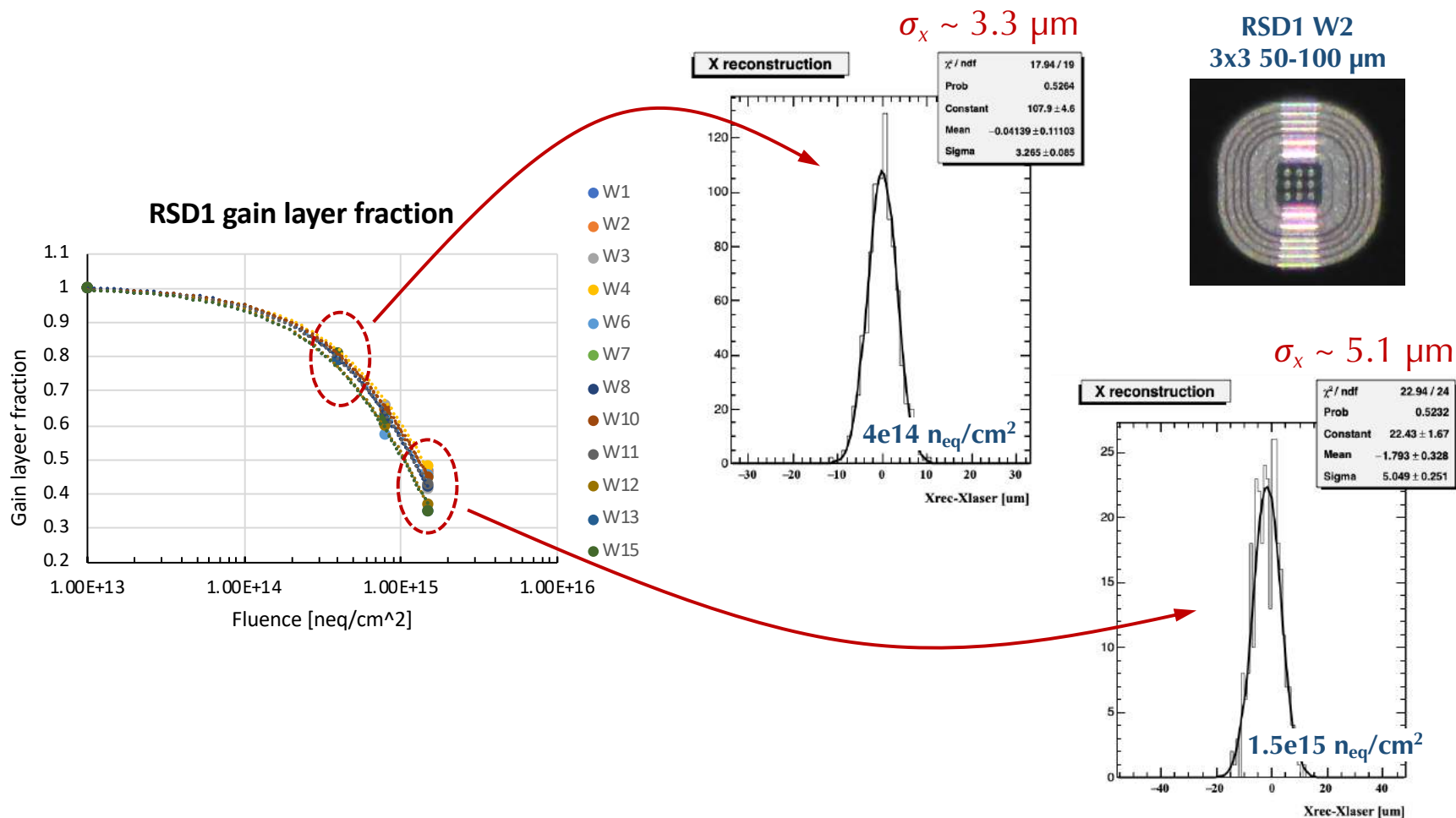


# RSD radiation resistance

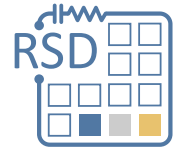




# RSD radiation resistance



# Acknowledgments



We kindly acknowledge the following funding agencies and collaborations:

- ▶ **INFN–CSN5, RSD Project**
- ▶ **FBK-INFN** collaboration framework
- ▶ **Horizon 2020**, Grants no. UFSD669529 and 654168 (**AIDA-2020**)
- ▶ **U.S. Department of Energy** Grant no. DE-SC0010107
- ▶ **Dipartimenti di Eccellenza, Torino University** (ex L.232/2016, art. 1, cc. 314, 337)

This work would not have been possible without (in alphabetical order):

**R. Arcidiacono, A. Bisht, G. Borghi, M. Boscardin, N. Cartiglia, M. Centis Vignali, G.-F. Dalla Betta, M. Ferrero, F. Ficorella, G. Gioachin, O. Hammad Alì, A. D. Martinez Rojas, L. Menzio, L. Pancheri, G. Paternoster, F. Siviero, V. Sola, and M. Tornago**

**Thank you for the attention!**

# RSD References



- ▶ Paper on NIM-A about the numerical design of RSD: [link](#)
- ▶ Paper on IEEE-EDL about the first demonstration of fine segmented RSD1: [link](#)
- ▶ Paper on laser/beam-test studies on RSD1: [link](#)
- ▶ Paper on machine learning studies applied to RSD: [link](#)
- ▶ Database and info about the RSD project: [link](#)

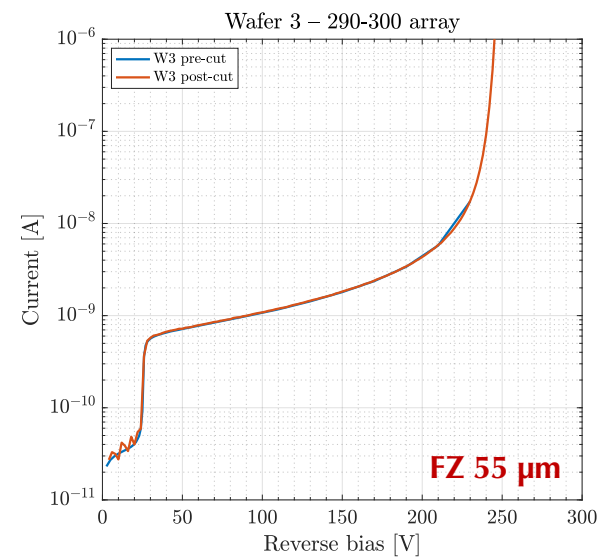
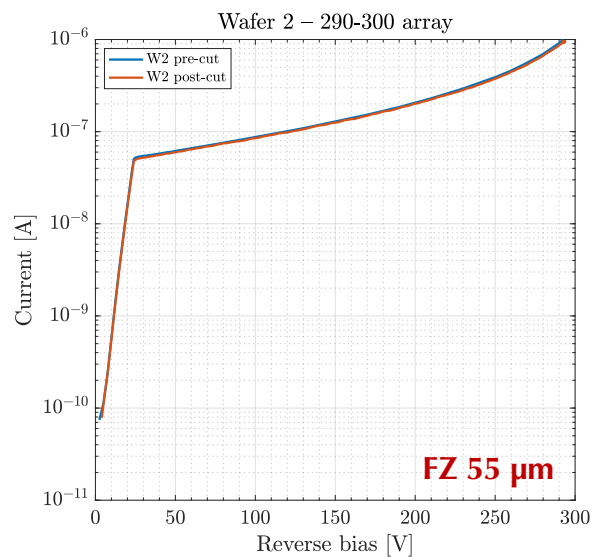
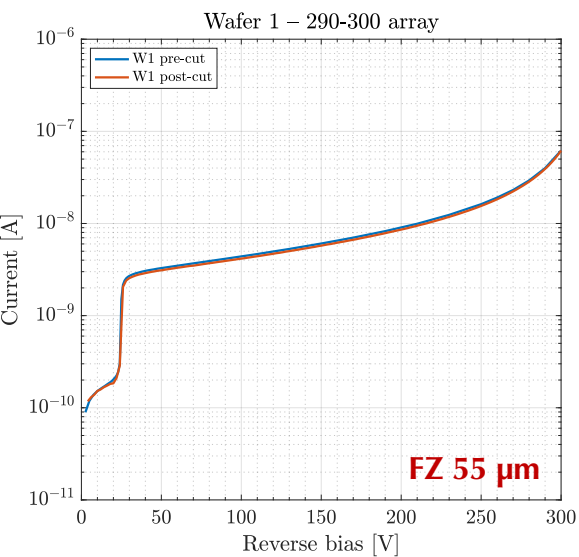
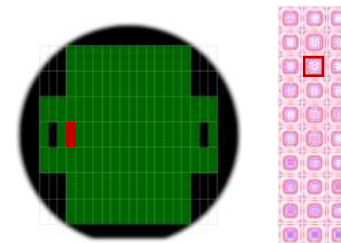
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# Backup

# RSD2: wafer dicing

Block A – 2x3 290-300 stars

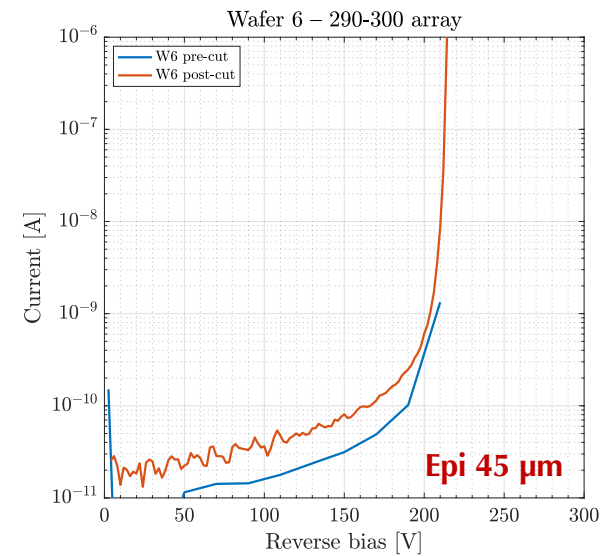
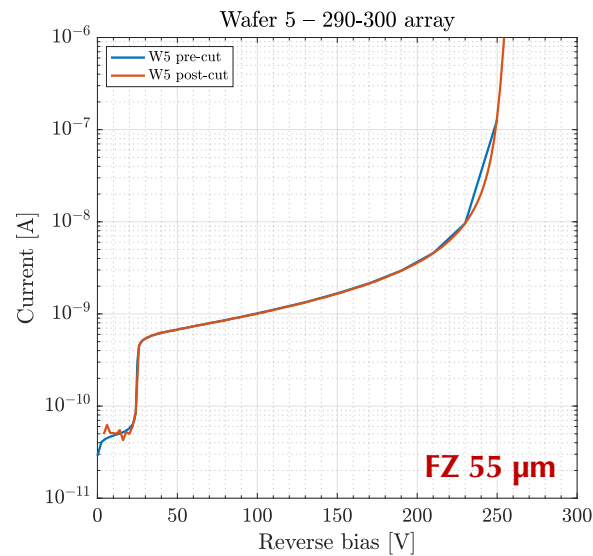
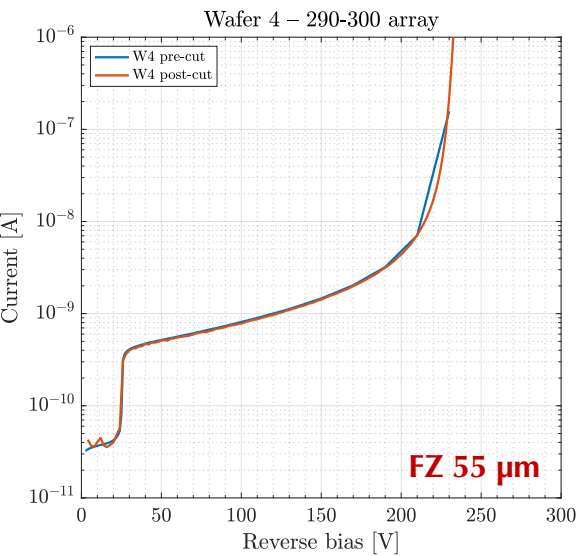
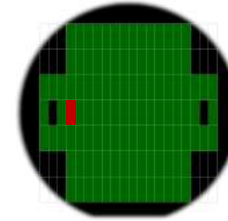
■ pre-cut  
■ post-cut



# RSD2: wafer dicing

Block **A** – 2x3 290-300 stars

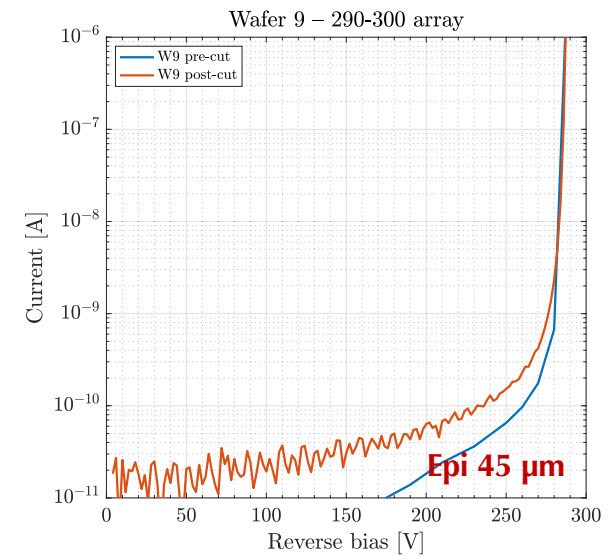
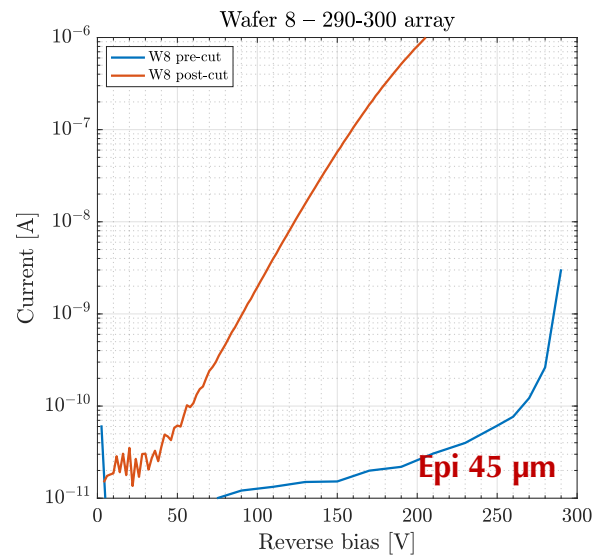
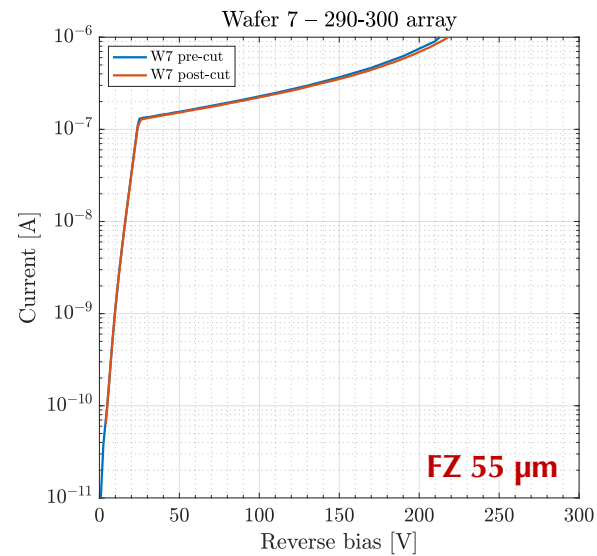
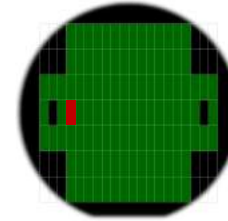
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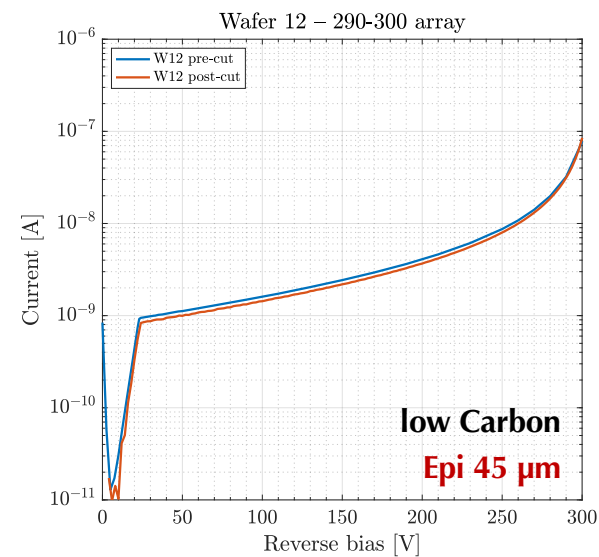
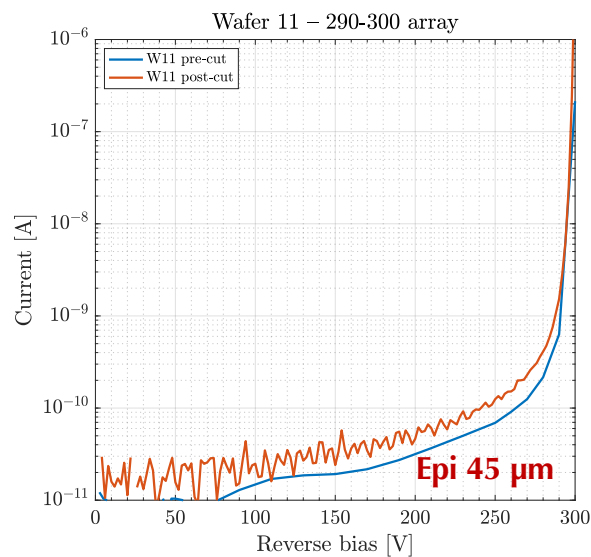
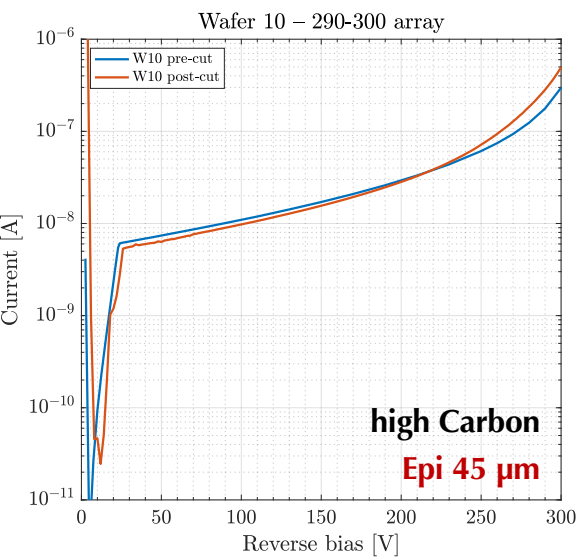
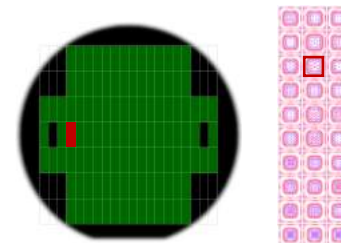
■ pre-cut  
■ post-cut



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Block A – 2x3 290-300 stars

■ pre-cut  
■ post-cut





# RSD2: wafer dicing



Block A – 2x3 290-300 stars

■ pre-cut  
■ post-cut

