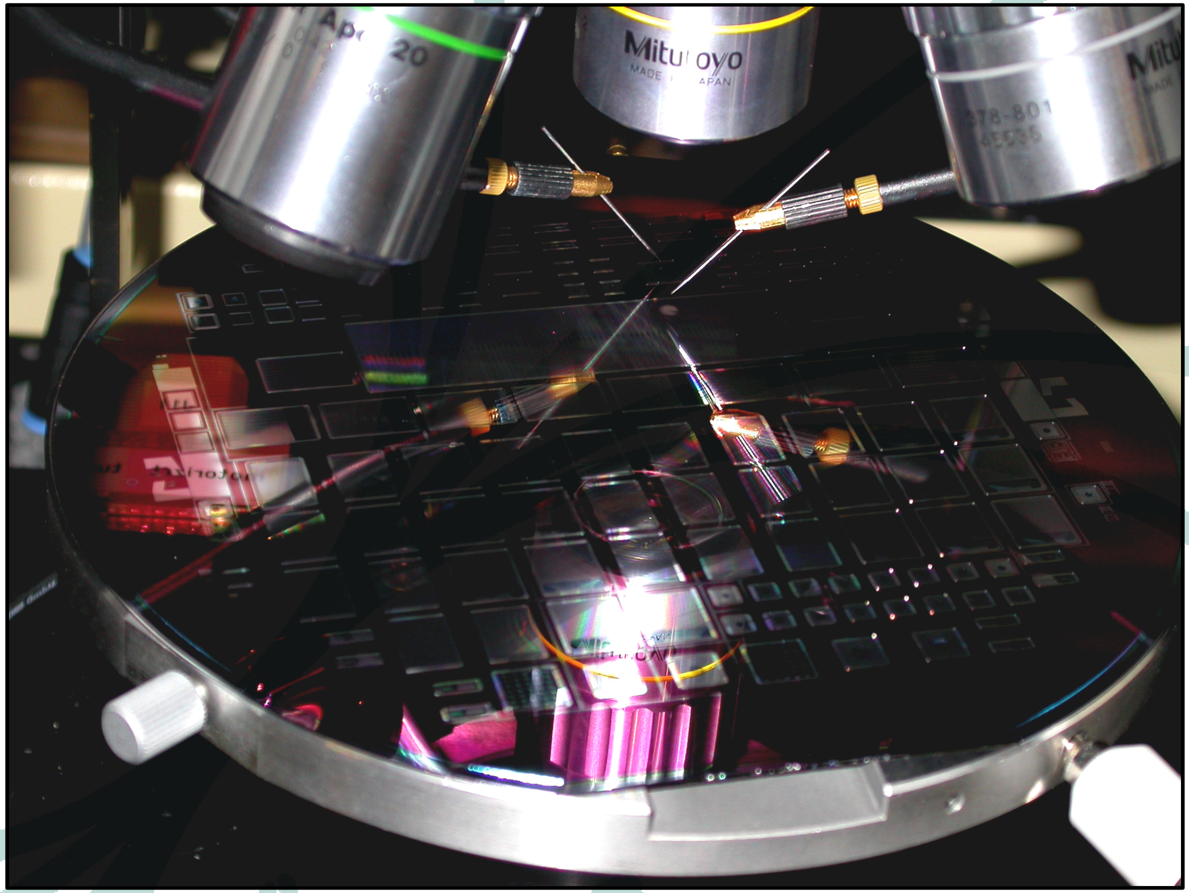
First characterizations of thin SOI and epitaxial n-in-p sensors



FSP 101 ATLAS GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

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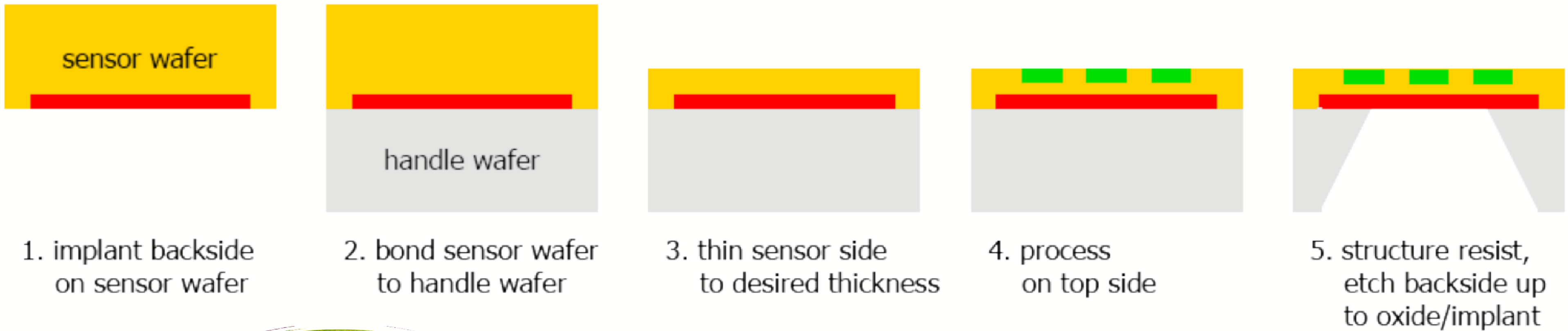
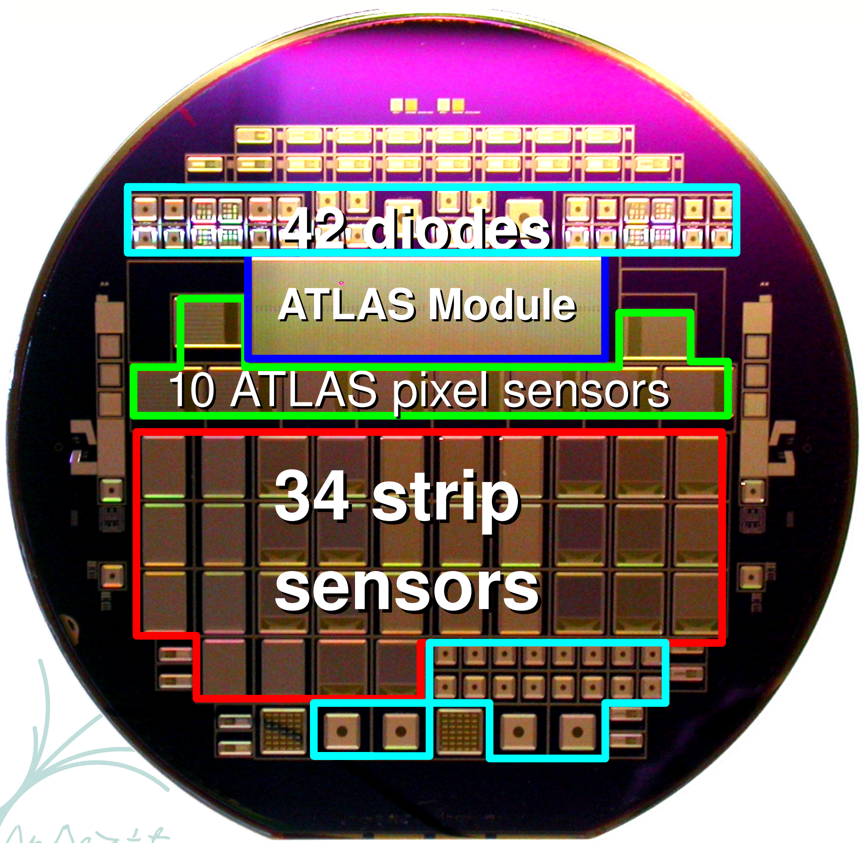
Overview

- SOI production:
  - Characteristics
  - Standard vs. slimmed guard rings
- RD-50 epi production:
  - Characteristics
  - Infrared images of hot spots
  - Simulation analysis
- Alibava

Thin SOI Production

Thinning of wafers: "Choose thickness wisely..."





Present thin SOI Production:

- 12 (13) 6" SOI wafers
- 4 n-type (ρ=360 Ωcm) and 8 p-type (ρ≥2 kΩcm)
- 75µm and 150µm active thickness
- First characterizations of:
  - Diodes, Strips,Pixel sensors
- 8 wafers (4 n-type, 4 p-type) are prepared for the SLID 3D-Integration. 4 wafers are characterized and prepared for irradiations.

Upshot

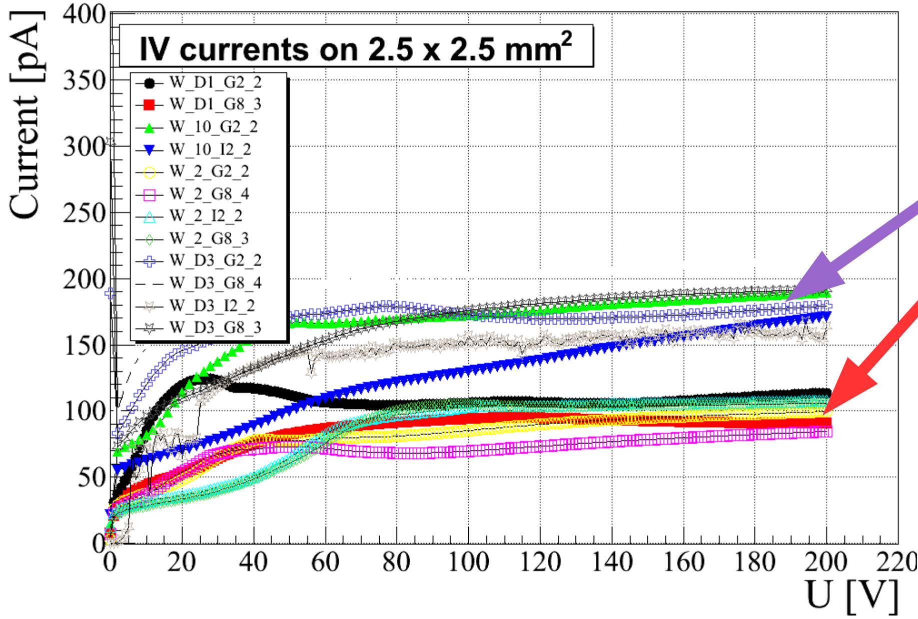
Overall characteristics of our main production:

- Results shown here are mainly from the 4 wafers with the lowest V_{bd} among the 8 p-type ones (best 4 were chosen for SLID-Interconnection).

#	Bulk	thickness	P-spray
D1	p	75	low (moderated+homogeneous)
2	p	75	high (moderated+homogeneous)
10	p	150	high (moderated+homogeneous)
12	p	150	low (moderated+homogeneous)

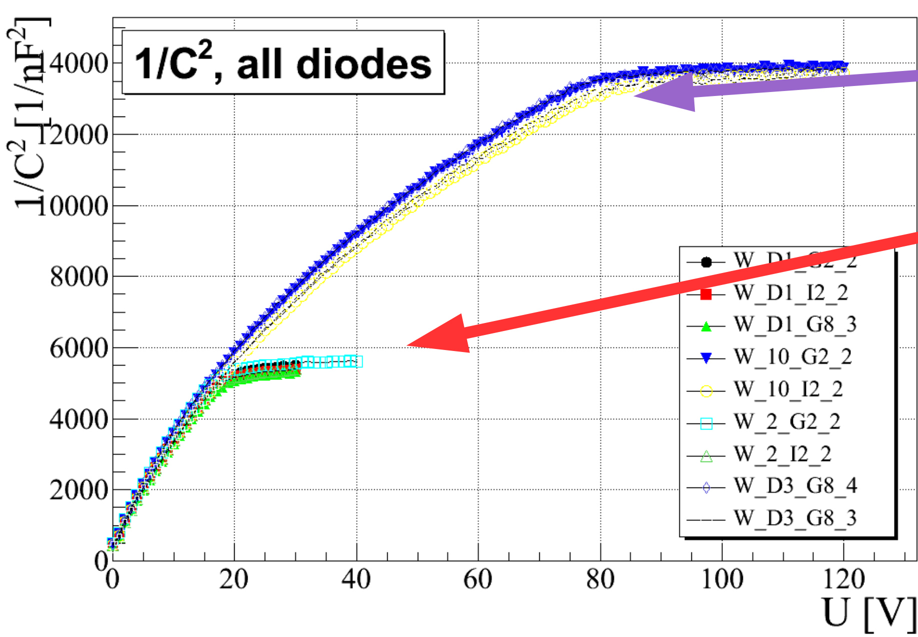
- Very good performance before irradiation, especially compared to the full depletion voltage.
- Very good yield (only 1 out of 80 pixel sensors could not be depleted).
- Slimmed guard rings work very well.

Diodes



IV characteristics of n-in-p diodes:

- 2.5 x 2.5 mm^2
- "thick" sensors (150µm).
- thin sensors (75µm).
- Low leakage currents ~1.5-3 nA/cm^2, roughly scaling with the thickness.



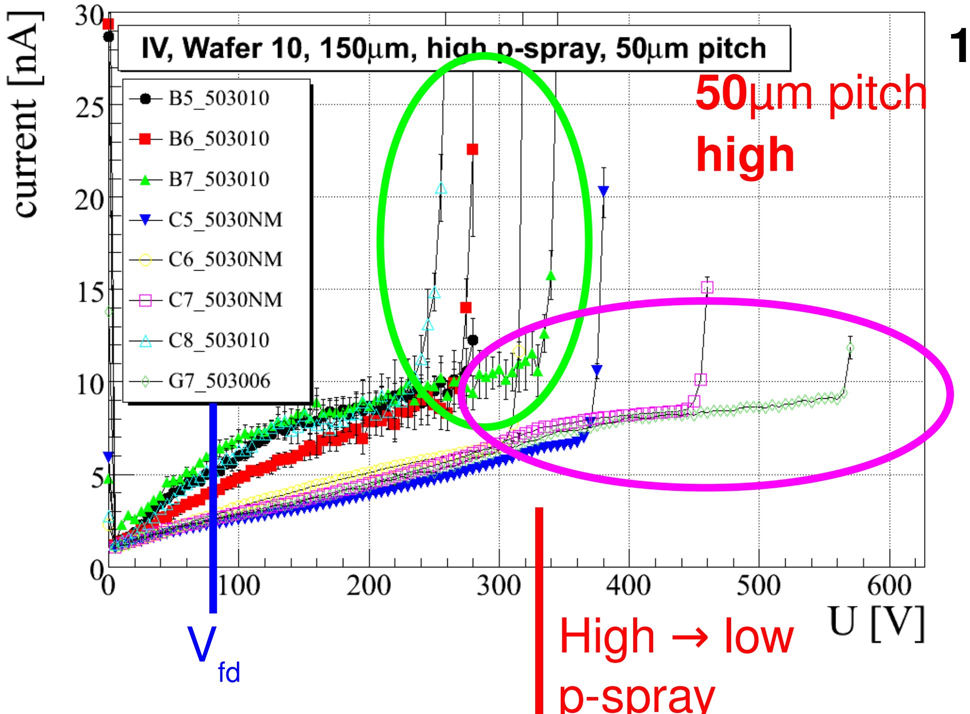
CV-characteristics:

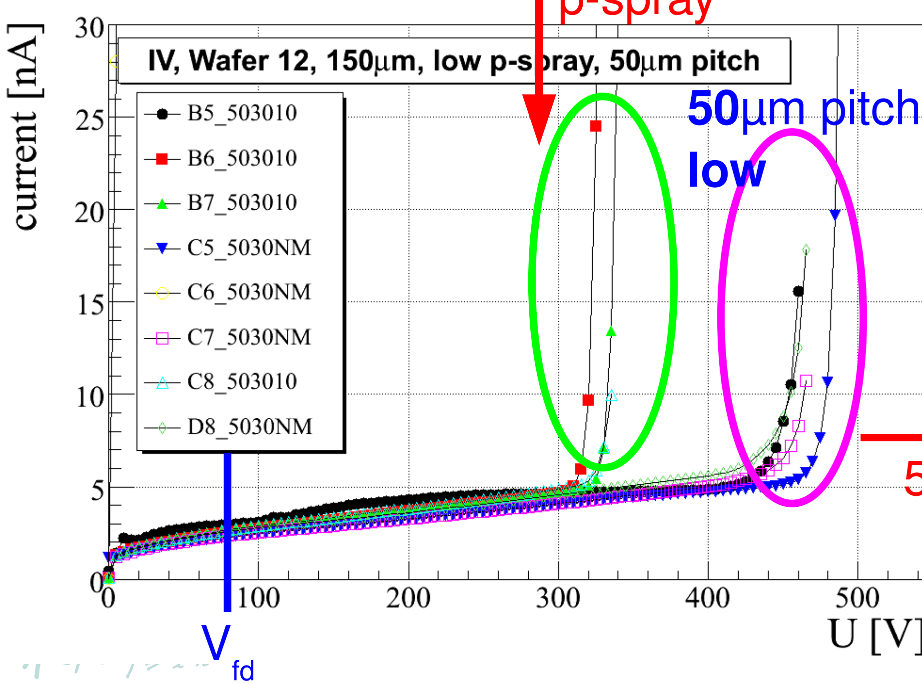
- Full depletion of the 150µm thin sensors at V_{fd}~80V.
- Full depletion of 75µm thin sensors at V_{fd}~20V.
- Good scaling with d² visible.
- Values are as expected from calculations with known resistivity.

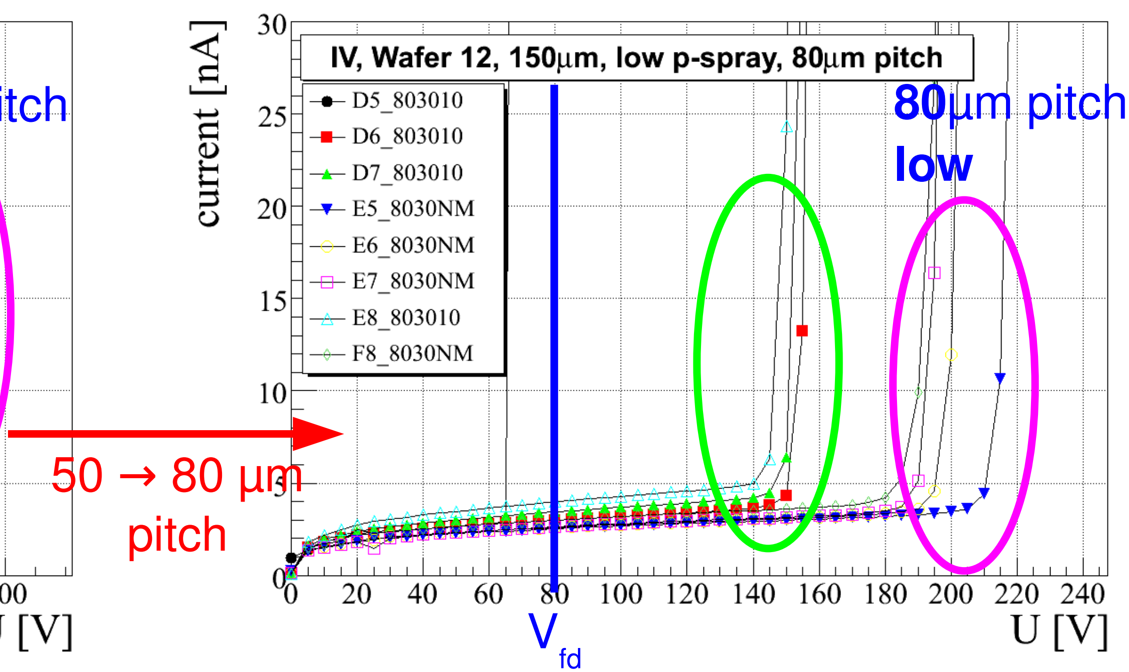
Strip sensors 150µm

150µm Strip sensors**:**

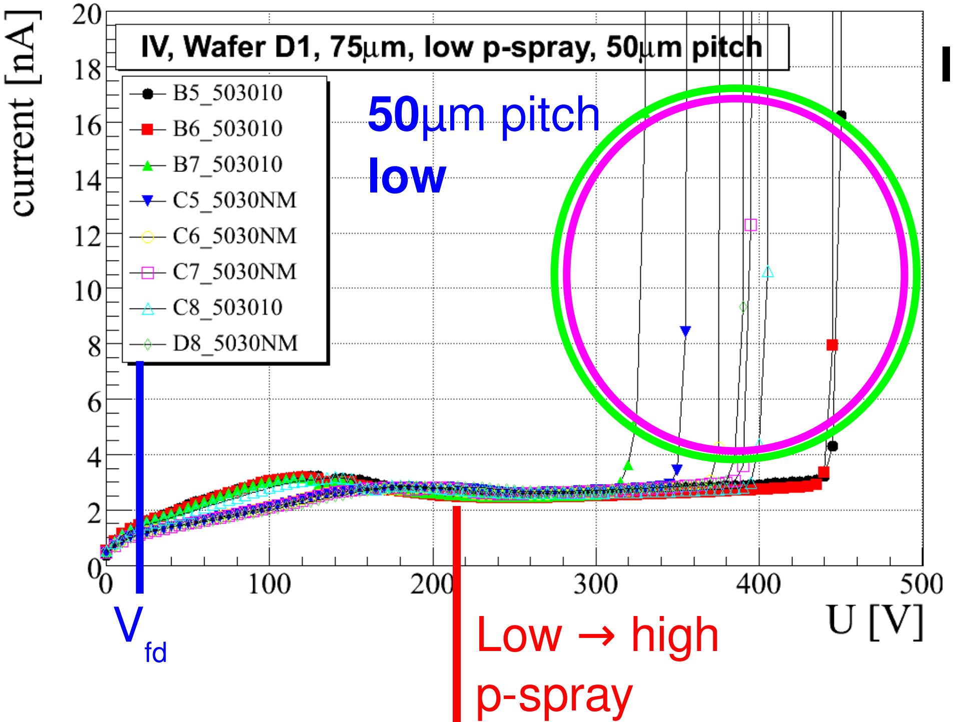
- Two p-spray implant options "high" and "low"
- Moderated and homogeneous p-spray.
- 50µm and 80µm pitch.
- Good break down performance for 50µm pitch. V_{bd} ~ 250 to 550 V (~3-7 x V_{fd}).
- A little less for 80µm pitch (~2 x V_{fd})





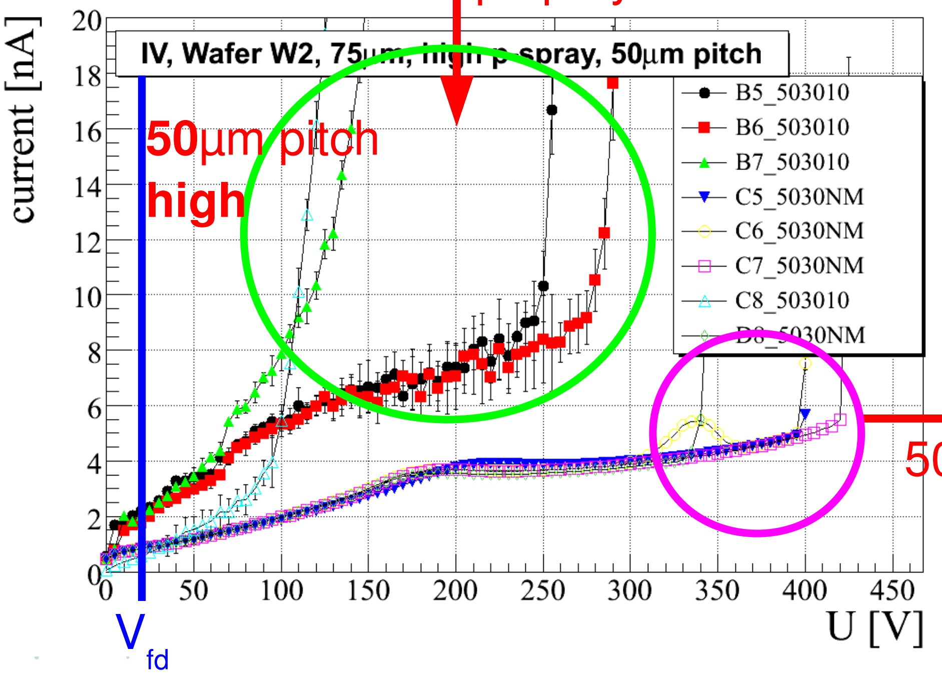


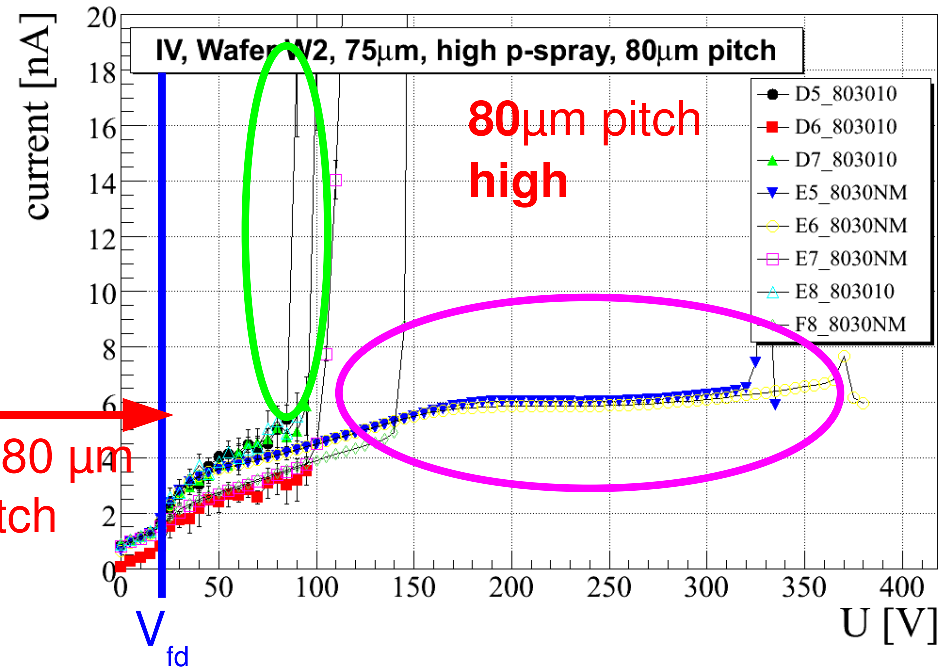
Strip sensors 75µm



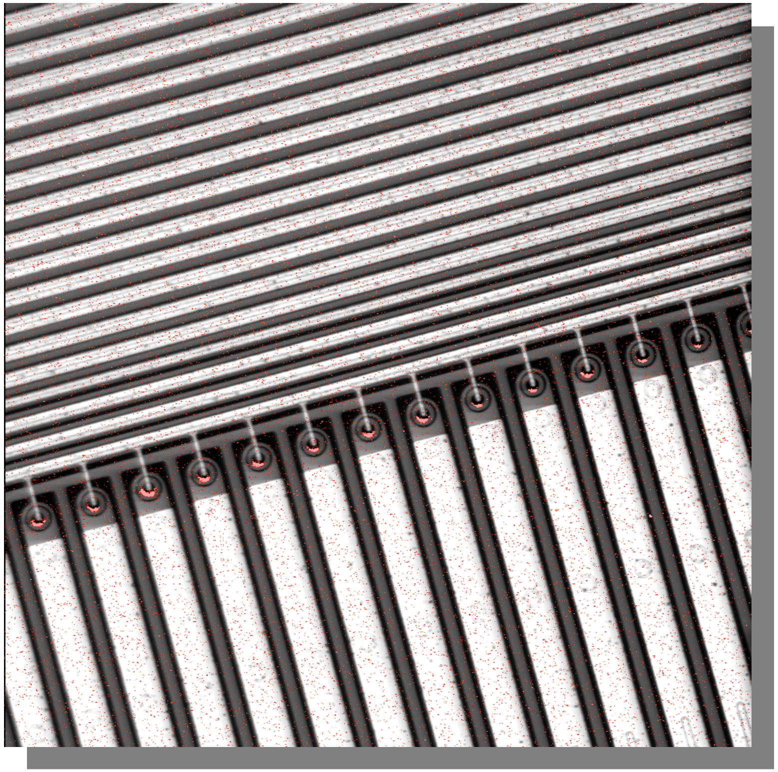
IV measurements:

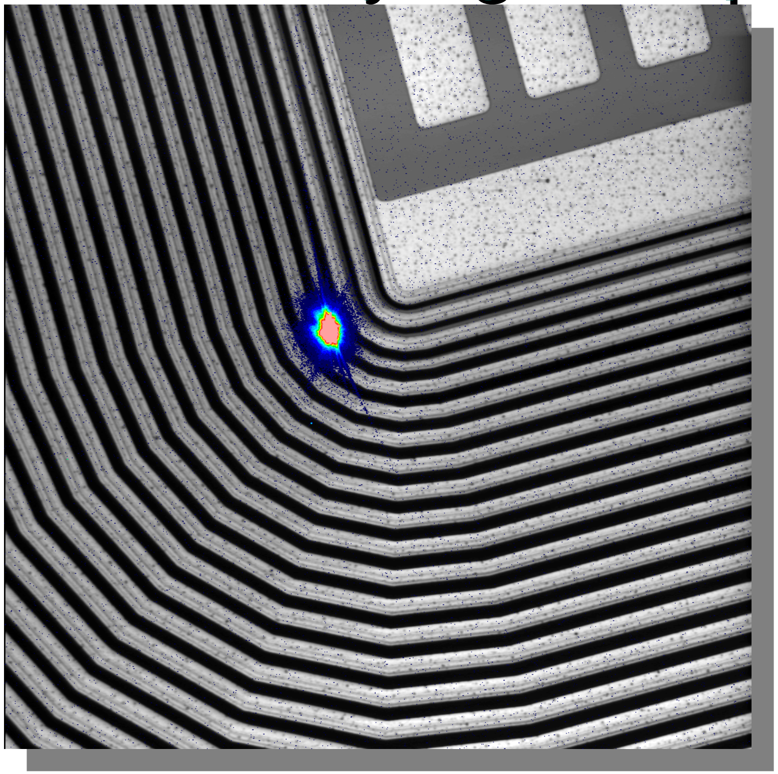
- Very good performance for all low p-spray and homogeneous p-spray sensors. V_{bd} ~ 300 - 450 V = 15 – 22 x V_{fd}!
- Also good performance for moderated 50µm pitch with high p-spray. V_{bd} ~ 4 - 13 x V_{fd}.
- Lower break downs of moderated 80 µm pitch sensors with high p-spray V_{bd} ~ 4 x V_{fd}.





Identifying hot spots

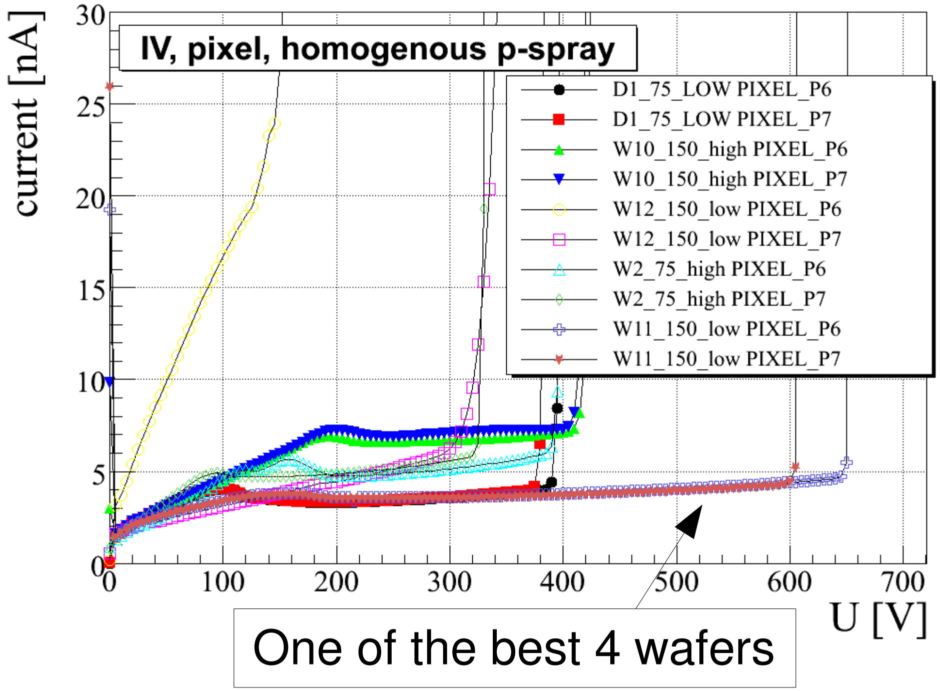




PHEMOS (infrared) analysis:

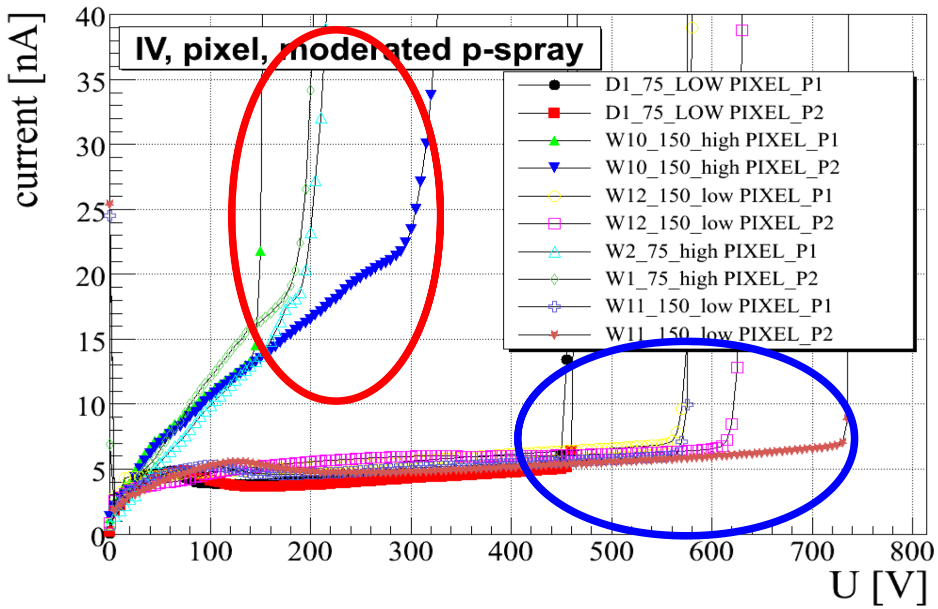
- Punch through: Signs of break downs in the punch through region. Optimizations are difficult since the process technology sets limits to sizes and distances.
- Guard Rings: Break downs between the 4th and 5th guard rings of the homogeneous (@ 400-450 V) p-spray and moderated (@ 550 - 600V) sensors. Improvements have been adopted to the current CiS production.

Thin pixel sensors



Homogeneous p-spray:

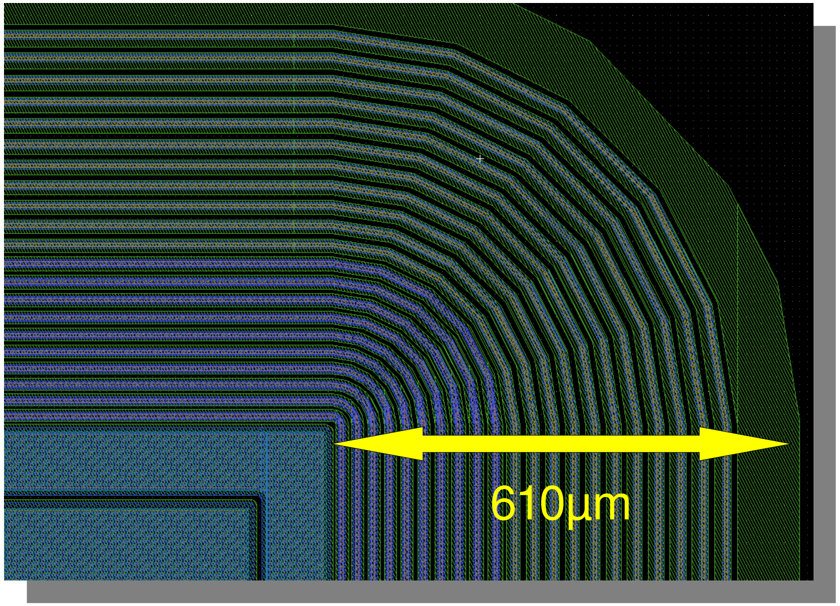
- Very high break down voltages between 300 and > 600V.
- Very good yield: only 1 out of 80 sensors is faulty.
- Low leakage currents.



Moderated p-spray:

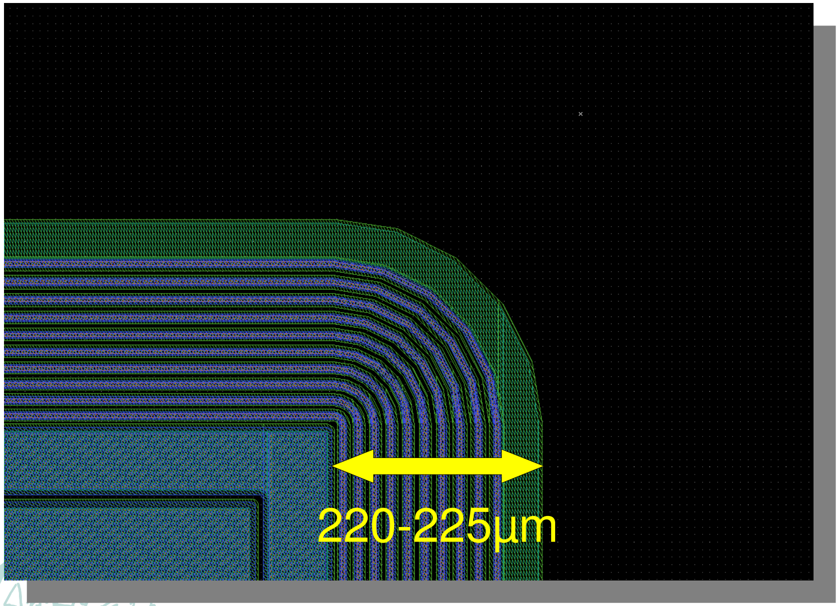
- Very high break down voltages for the low p-spray option between 450 V and > 700 V.
- Good break down voltages for the high p-spray option: 140 V – 300 V.

Diodes w/ slimmed guard ring structures



Diodes with standard guard ring size:

- 4 different design options
- 21 guard rings
- Used for most diodes
- Used for strips and pixels

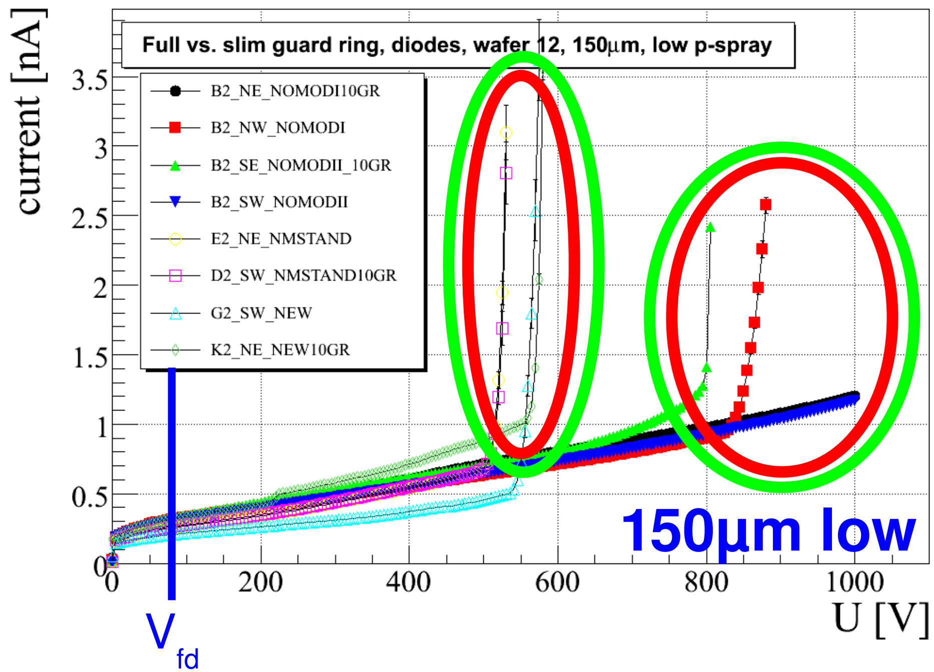


Slimmed guard ring structure:

- Same 4 design options
- Only 10 guard rings
- Used for a subset of diodes

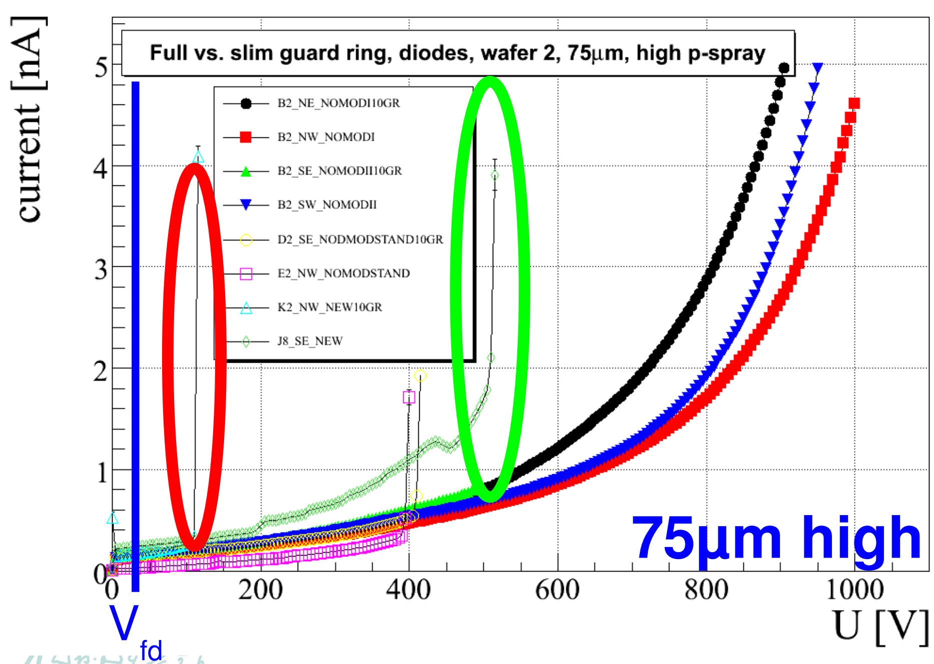
Active area of all diodes for the comparison: 2.5 x 2.5 mm²

Diodes w/ slimmed guard ring structures



150µm, low p-spray:

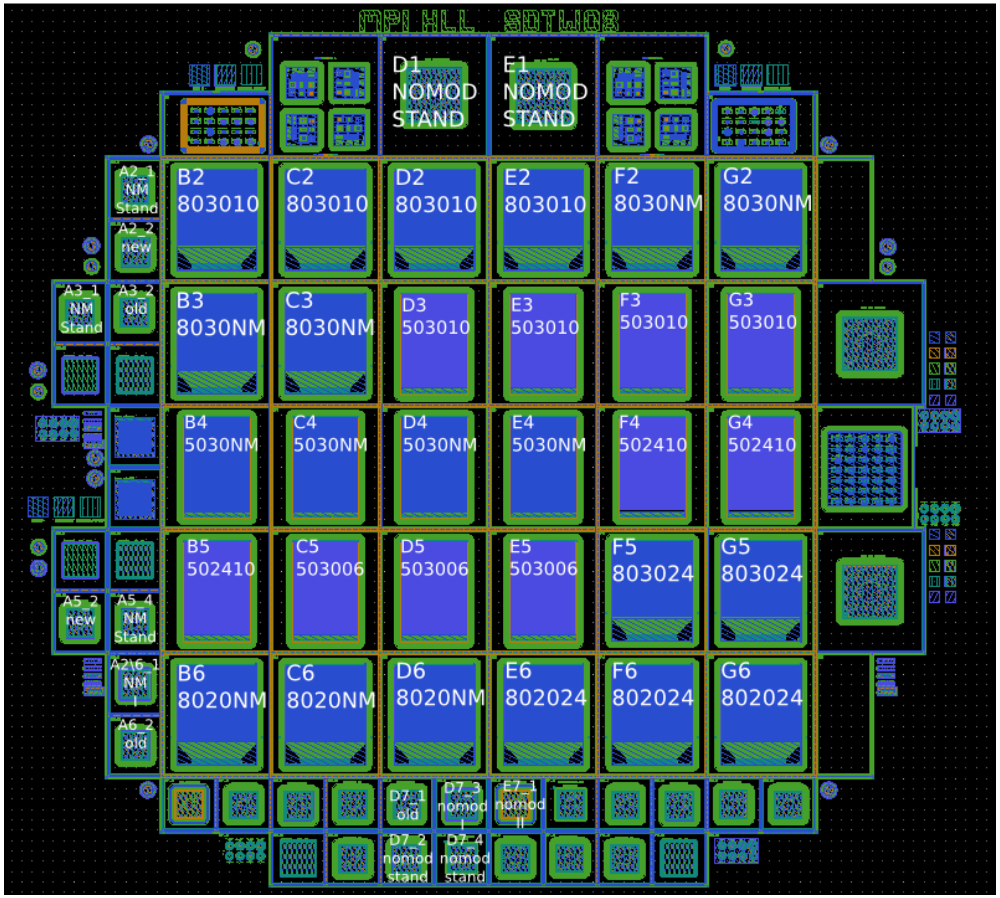
- Shown: all 4 guard ring designs with a standard and a slim guard ring version each (total of 8 options).
- No characteristic differences between the 21 guard ring and the 10 guard ring options.
- Guard ring option "NOMOD_I" with 10 guard rings even reaches 1000V (=12.5 V_{fd}) at less than 1.5 nA



75µm, high p-spray:

- Comparison of same diode types.
- Up to 100V (5 x V_{fd}) no strong characteristic differences visible.
- Above 100V, 10GR moderated diodes have a lower V_{bd}, than 21GR.
- Guard ring options "NOMOD_I" and "NOMOD_II" with 21 and 10 guard rings reach 500V (=25 V_{fd}) at less than 1 nA.

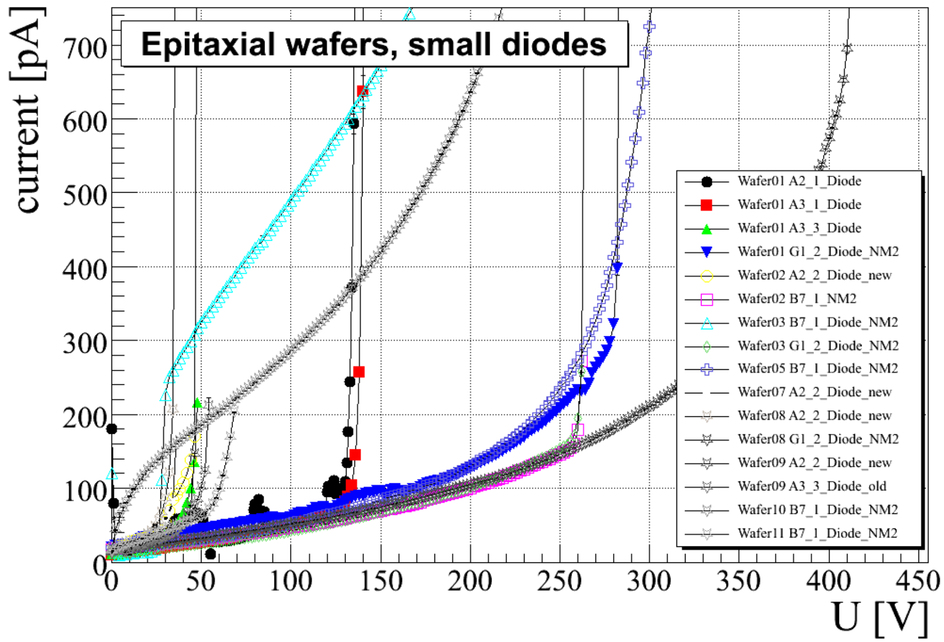
Epitaxial RD-50 production



Thin Epi RD-50 Production:

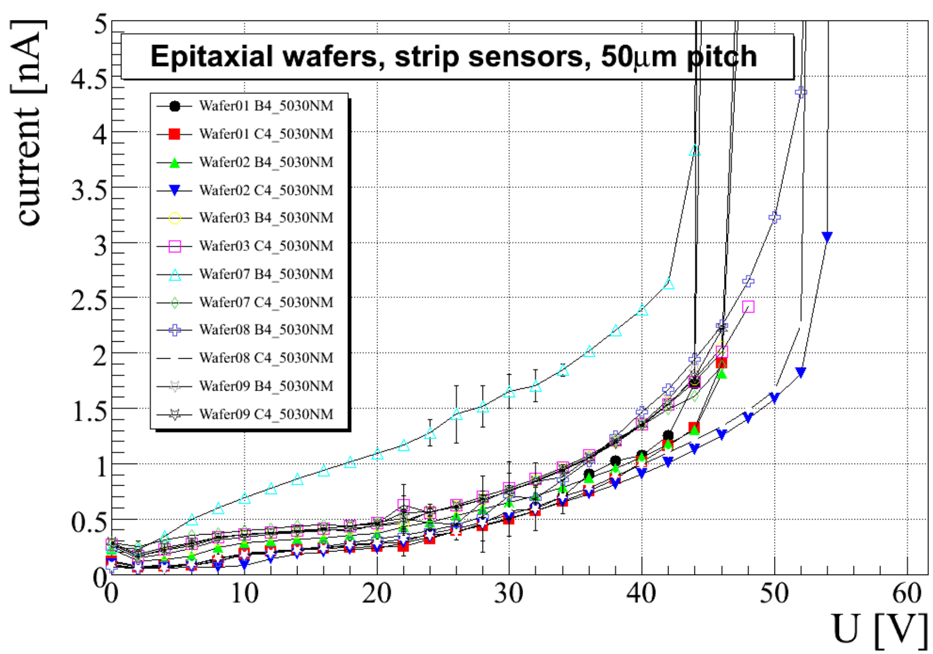
- 12 4“ Epi wafers (p-type bulk).
- 50µm (wafer #1-6) and 75µm (#7-12) active thickness.
- Same designs for strips and diodes as in our SOI production
- Nominal resistivities: ρ=150 Ωcm (50µm) and ρ=300 Ωcm (75µm).
- Calculated from V_{fd}:
  - 50µm: V_{fd}~120V → ρ~220 Ωcm
  - 75µm: V_{fd}~180V → ρ~350 Ωcm
- First characterizations before and after cutting: IV, CV, infrared investigation of hot spots.

Epitaxial RD-50 production: Strip sensors



Diodes:

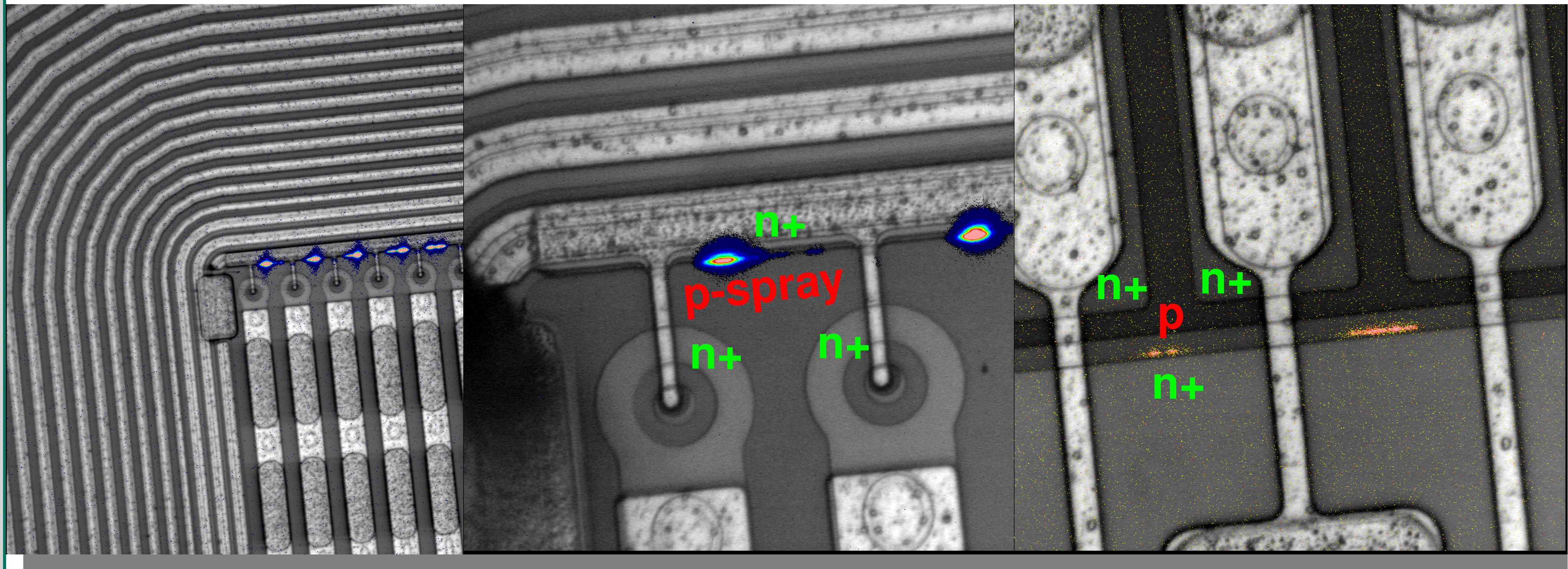
- 2.5 x 2.5 mm^2, moderated and homogeneous guard rings.
- Some homogeneous diodes go up to V_{bd} > 250V.
- Moderated diodes (and some not-moderated) do not reach 100V.
- Improvements after irradiation are expected.



Strips:

- Moderated and not moderated strips show similar behavior (50µm pitch).
- Moderated 80µm pitch break even lower (V_{bd} ~30V).
- Thin (50µm) and thick (75µm) strips show similar behavior, i.e. low currents but break at around 50V.

Hot spot search with PHEMOS

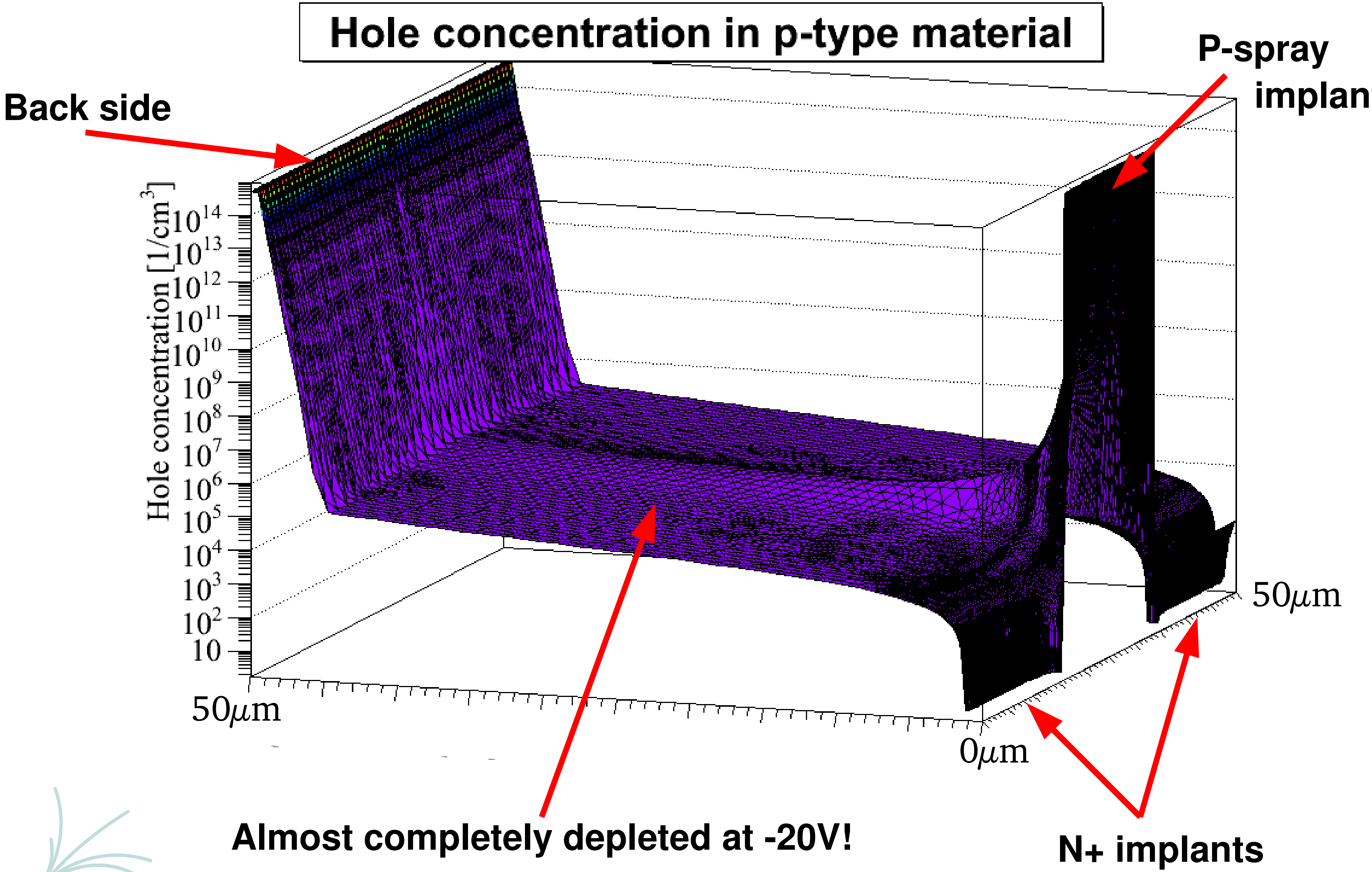


PHEMOS (infrared) analysis:

- Signs of break downs seen at both ends of the strips.
- In both cases the break downs occur between the high potential n+-implant side and the p-spray of the largest area that needs to be depleted.
- Comparing simulations with TeSCA were carried out to estimate the potentials and electric fields between the n+ strips and p-spray implants in low and high resistivity p-type material.

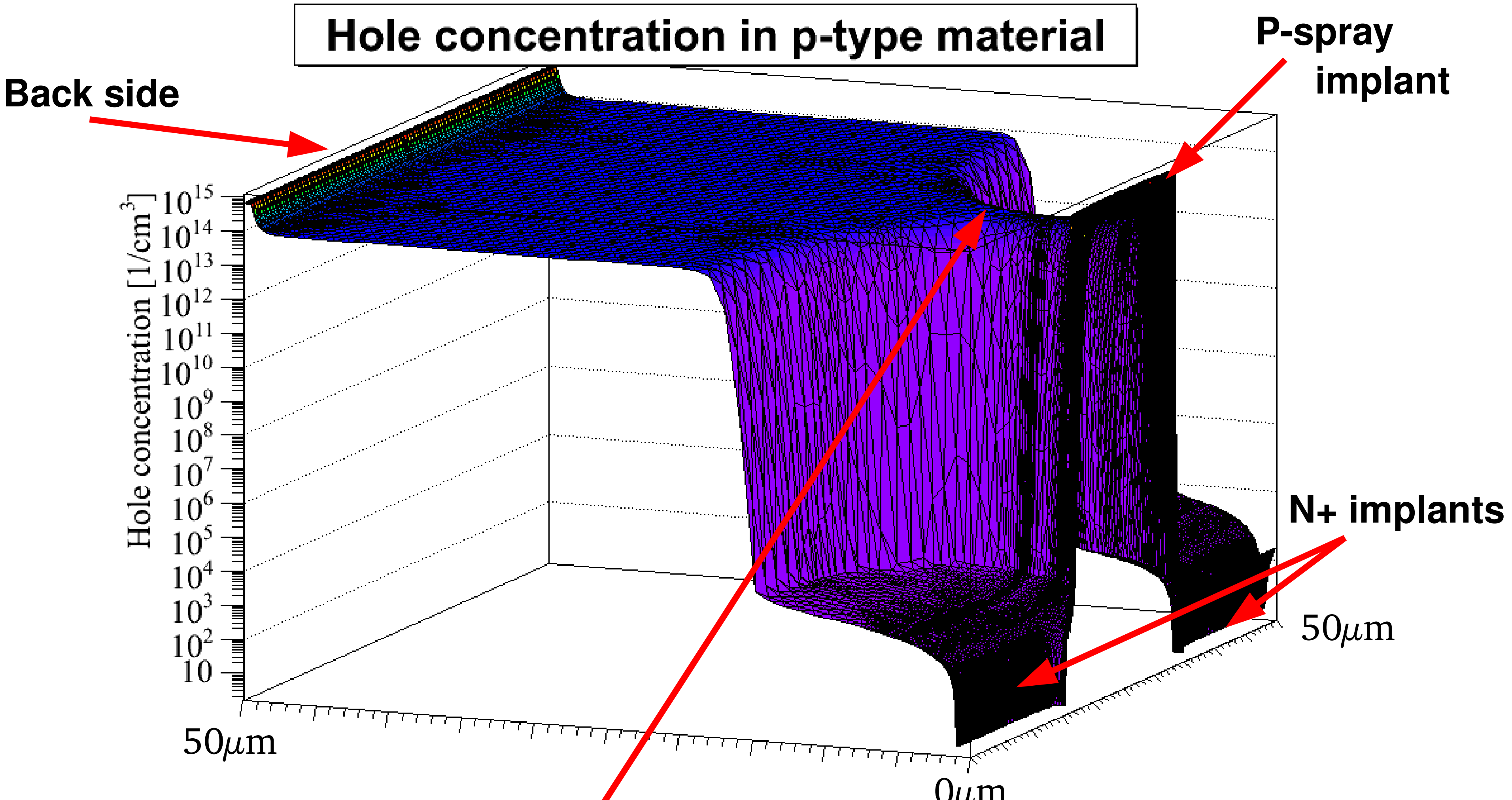
TeSCA simulations

2000 Ωcm, 20 V bias, 50µm thickness, 50µm pitch:



TeSCA simulations

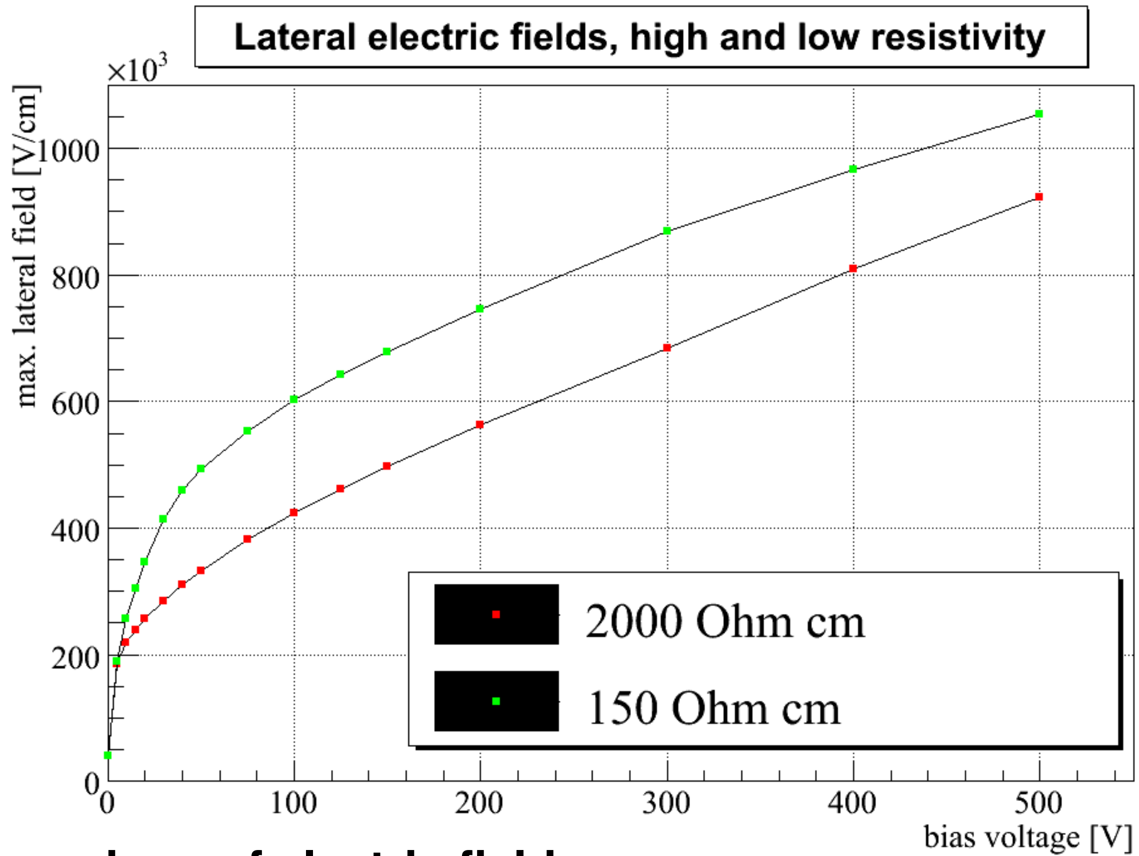
150 Ωcm, 20 V bias, 50µm thickness, 50µm pitch:



P-spray not pinched off at -20 V:

- Back side potential is passed to the front side p-spray
- P-spray is at -20V!

TeSCA simulations

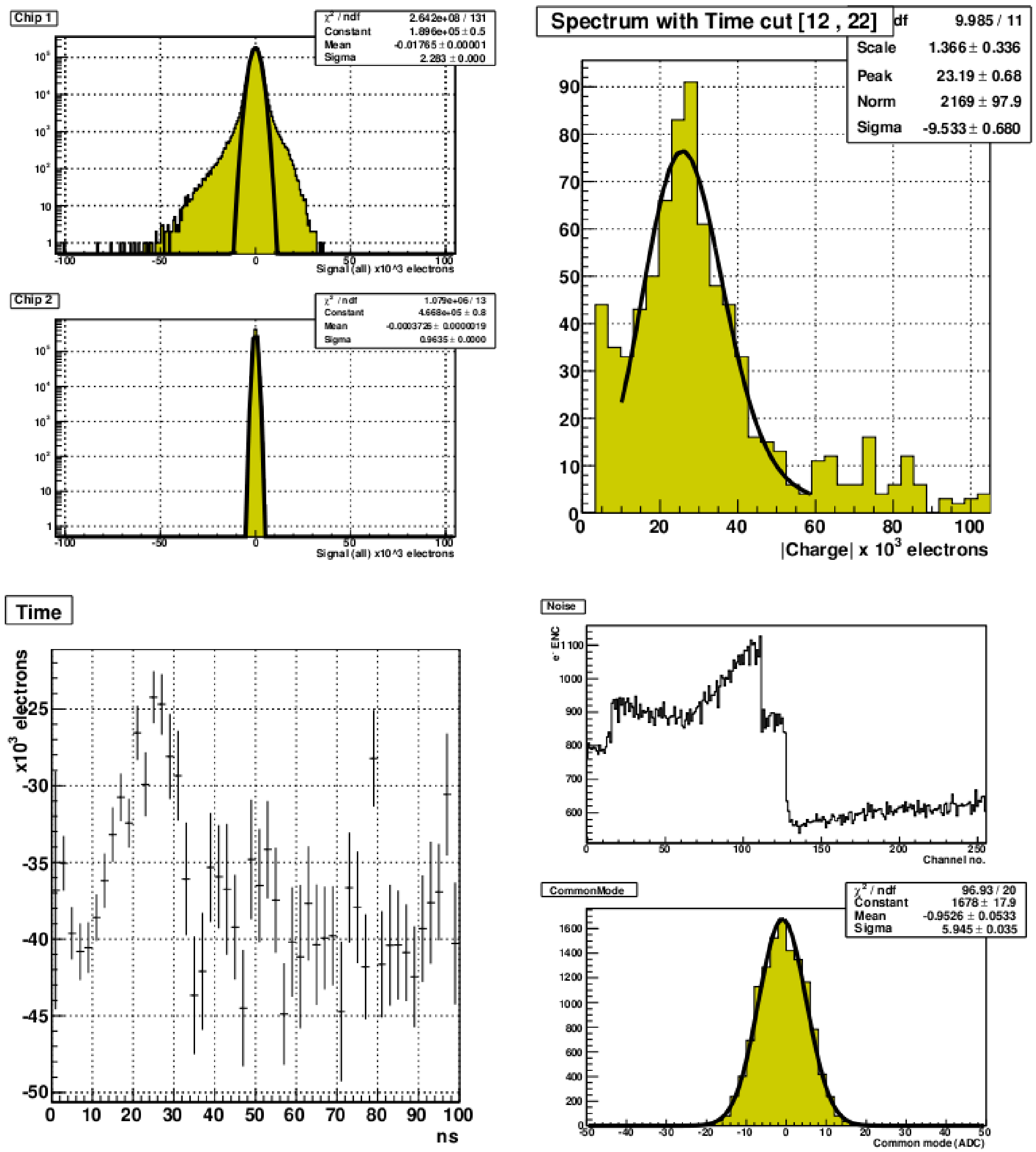


Qualitative comparison of electric fields:

- Low resistivity silicon shows considerably higher fields (at 100 V about 50% difference).
- Simulated were only 50µm pitch sensors. For the 80µm pitch and the edge-areas of the strips the p-spray pinch-off will occur even later, resulting in even higher fields.

First CCE measurements w/ Alibava

3072 events out of 12000 single triggers:



Alibava:

- Alibava arrived a few weeks ago and was build up in a climatized test stand.
- So far a single 80µm pitch (d=285µm) strip sensor was bonded to one of the beetle chips for testing.
- A Sr-90 source was used for generating MIPS.
- Two scintillators+PMTs are used to trigger signals. This allows for coincidence triggering.
- After two days without many optimizations of the setup a nice 23k electron signal was visible.
- Tuning of the setup will follow.
- Software works out of the box but running stability should be improved to take data in long runs.

Conclusion

SOI Production:

- 75µm and 150µm sensors show very good break down behavior.
- Pixel and strip sensors show a very good yield.
- Slimmed guard ring structures perform as well as standard structures with low p-spray and almost as good with high p-spray.

RD-50 epi Production:

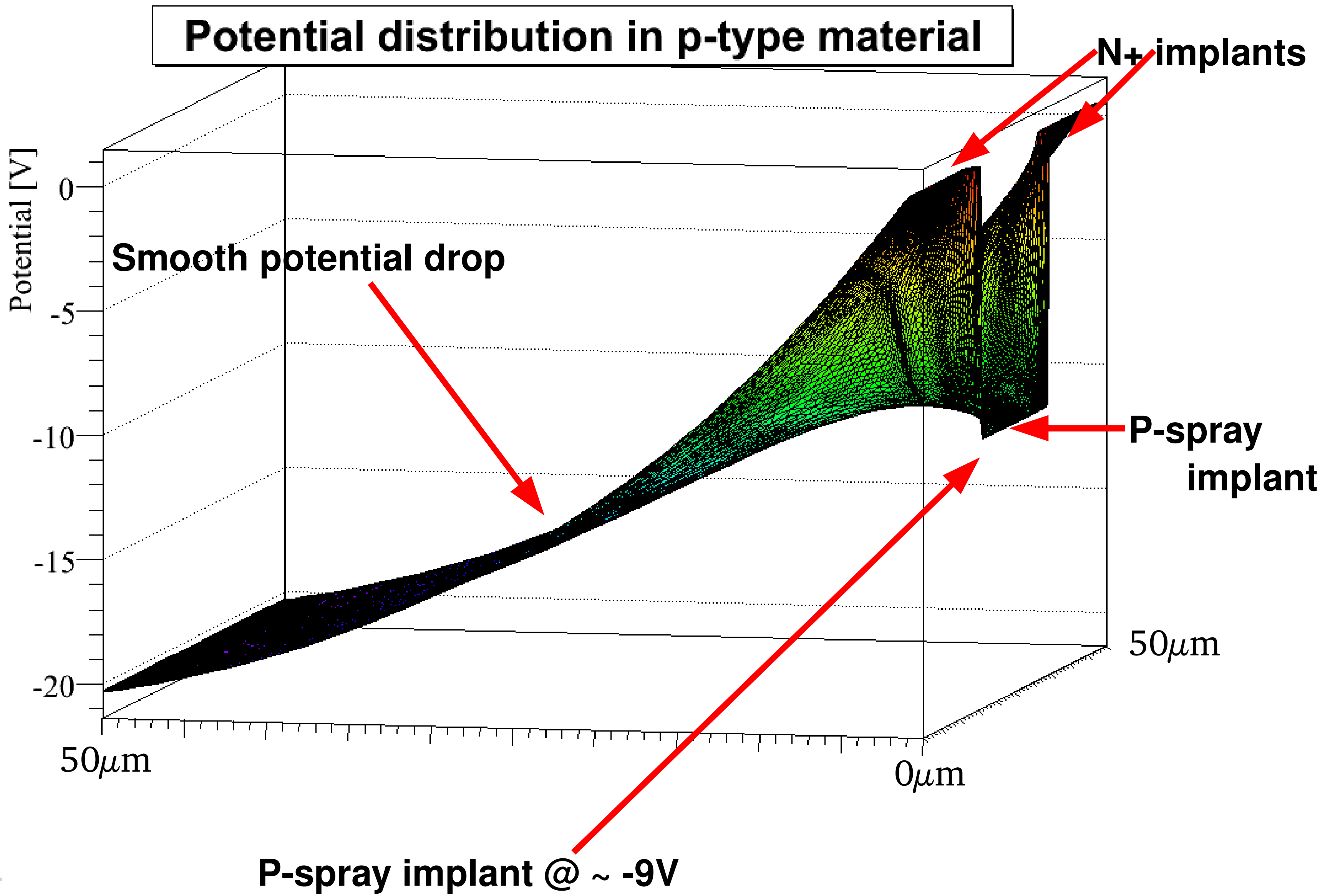
- Many diodes and strips have low break down voltages but are expected to improve after proton irradiations.
- Break downs are located between the n+ and p-spray implants.
- Simulations suggest that the low resistivity might be the reason for high electric fields at the front surface.

Alibava:

- Is up and running out of the box.
- The next weeks will be used to optimize our setup for CCE measurements.

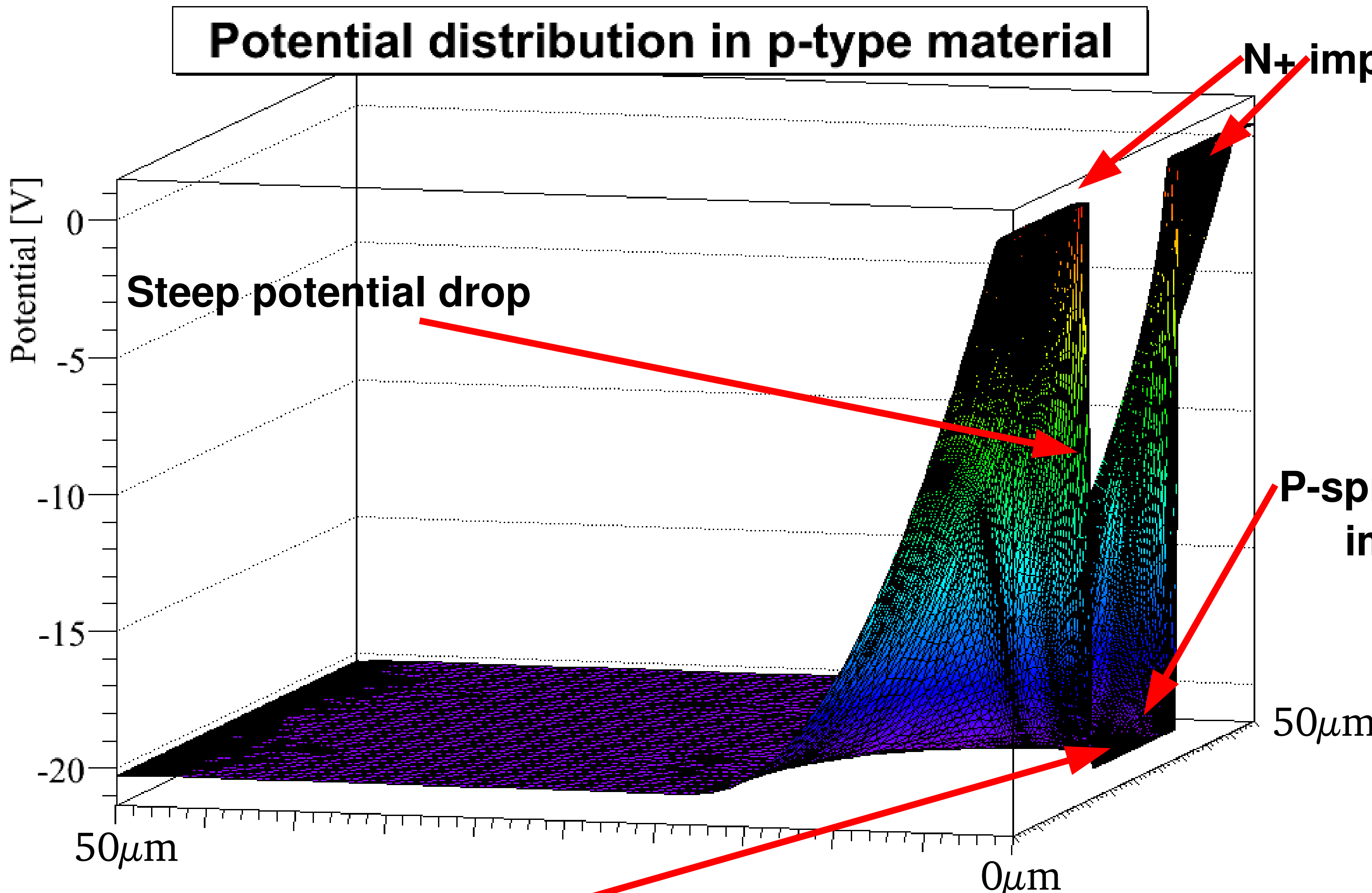
TeSCA simulations

2000 Ωcm, 20 V bias, 50μm thickness, 50μm pitch:



TeSCA simulations

150 Ωcm, 20 V bias, 50µm thickness, 50µm pitch:



P-spray implant @ ~ -20V

→ High potential gradients between n+ and p-spray!