TCAD simulations of isolation structures for n^+-on-p silicon microstrip detectors

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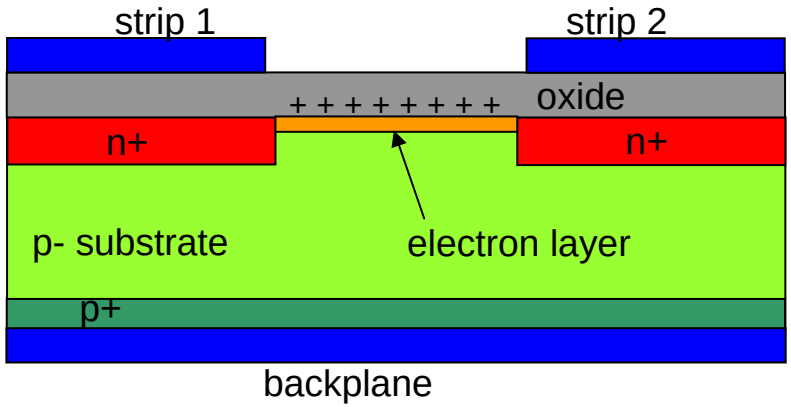
Outline

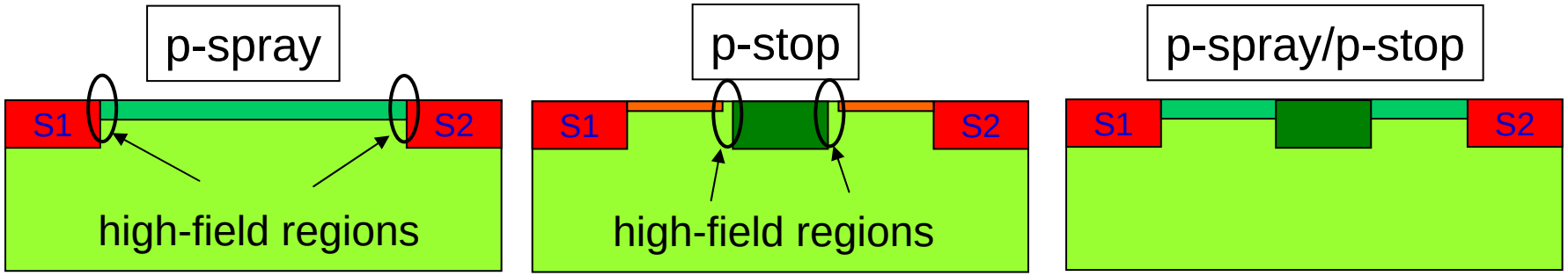
- Why is this work needed?
- Device Simulations
  - p-spray
    - p-spray experience @ ITC-irst
  - p-stop
  - combined p-spray/p-stop
- Conclusion

Why are simulations needed?



isolation structure needed to interrupt the inversion layer between the strip

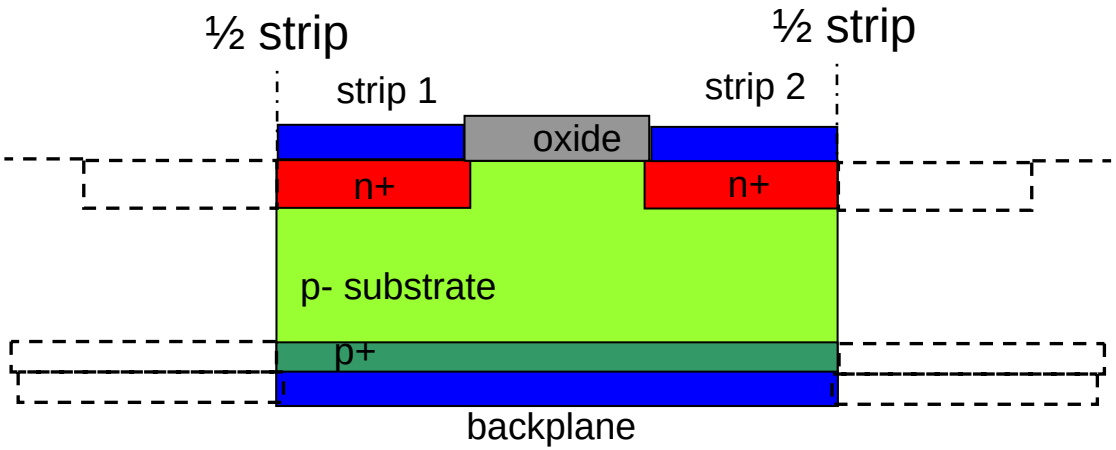
3 techniques available (from n^+-on-n technology):



Each technique affects differently $\mathbf{V_{BR}}$ and $\mathbf{C_{int}}$
$\Rightarrow$ simulations are needed to evaluate impact

Simulated structure

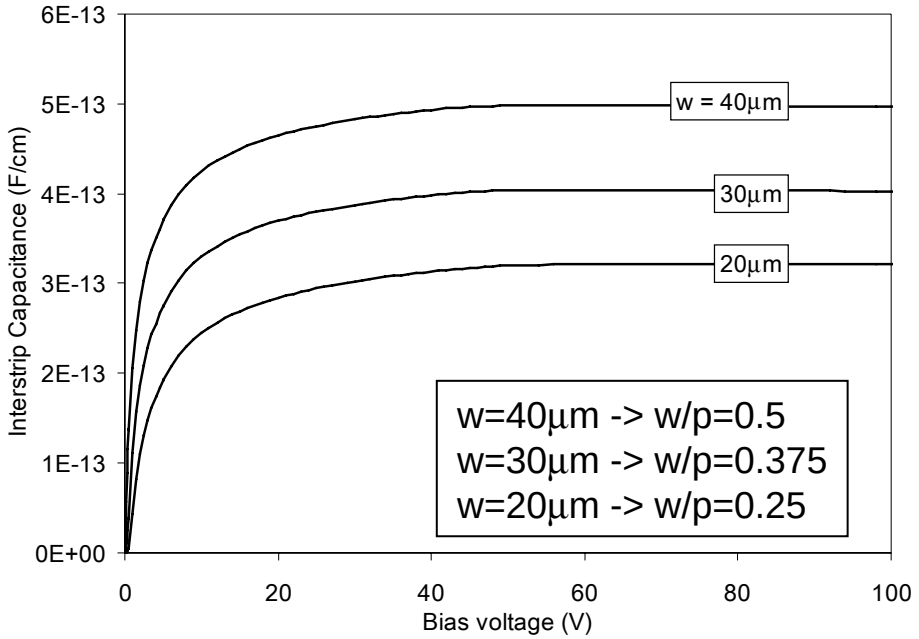
2D simulations of a cross section orthogonal to the strips



Reference structure:

- pitch = 80µm
- n^+ width = 30µm
- $N_a = 7e11cm^{-3}$
- W = 300µm
- $Q_{ox}=4e11cm^{-2}$

Pure geometrical C_{int}
(i.e. $Q_{ox}=0$, no isol. struct)



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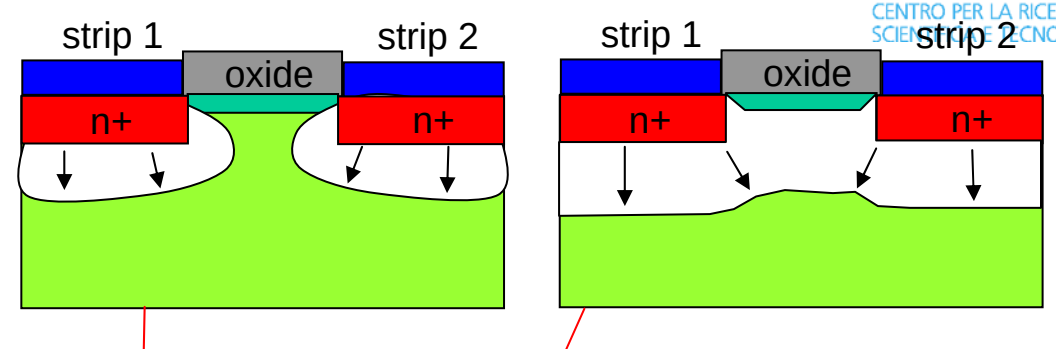
p-spray

Breakdown (1)

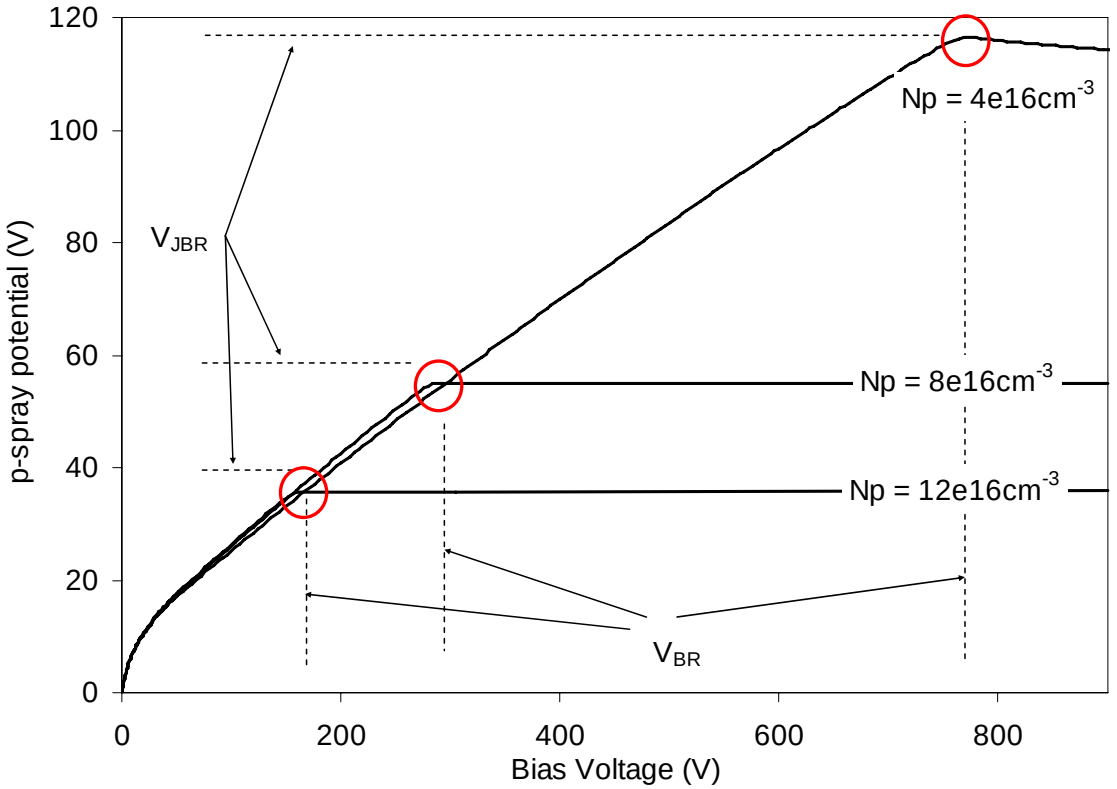
Three p-spray peak concentrations:
- $N_{p1}=4e16cm^{-3}$
- $N_{p2}=8e16cm^{-3}$
- $N_{p3}=12e16cm^{-3}$



V_{JBR} = potential difference between p-spray and strip which causes breakdown

V_{BR} = bias voltage for which we reach V_{JBR}

High Np => High V_{JBR}
=> high V_{BR}

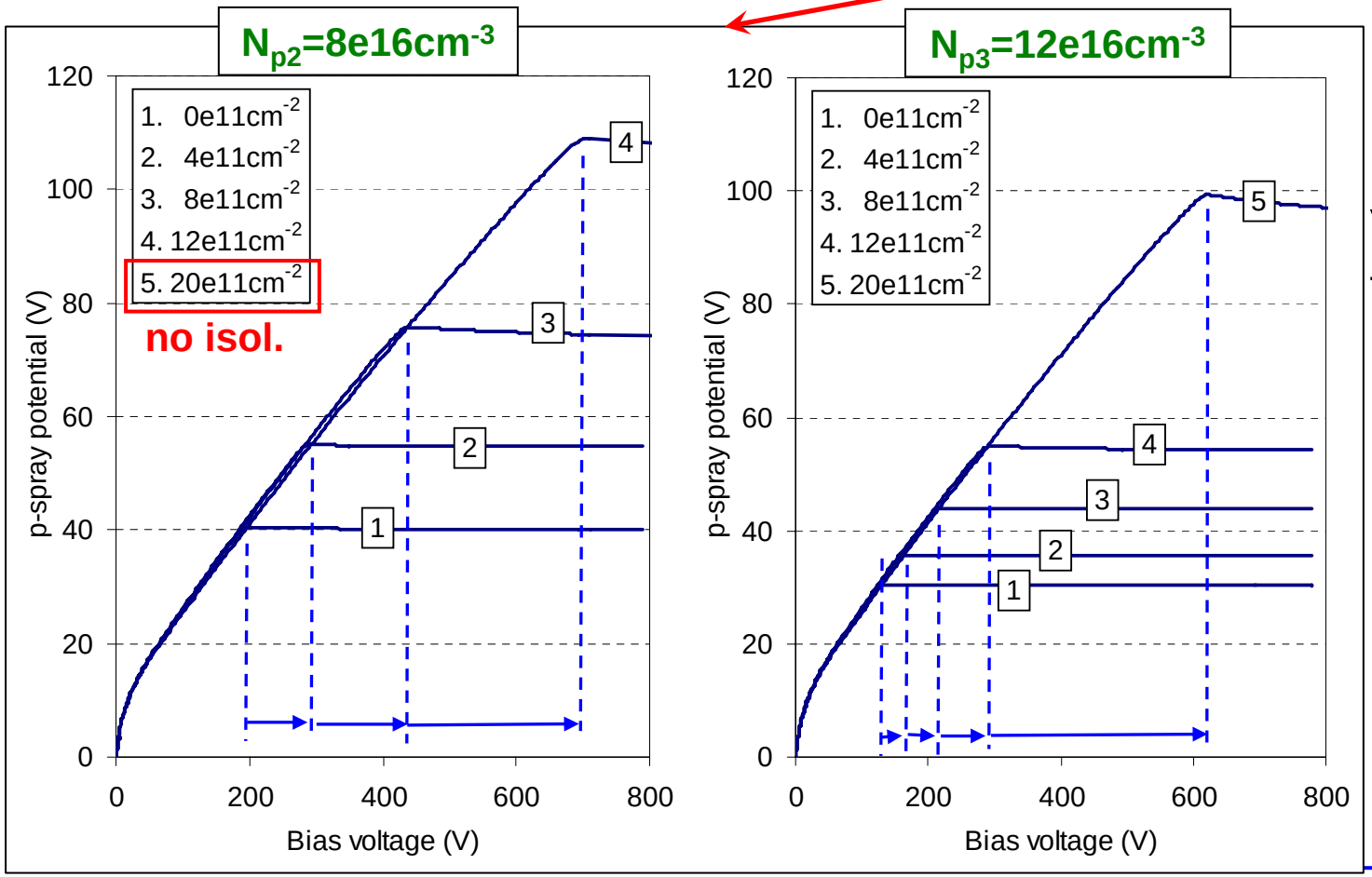


Breakdown (2)

V_{BR} depends on:

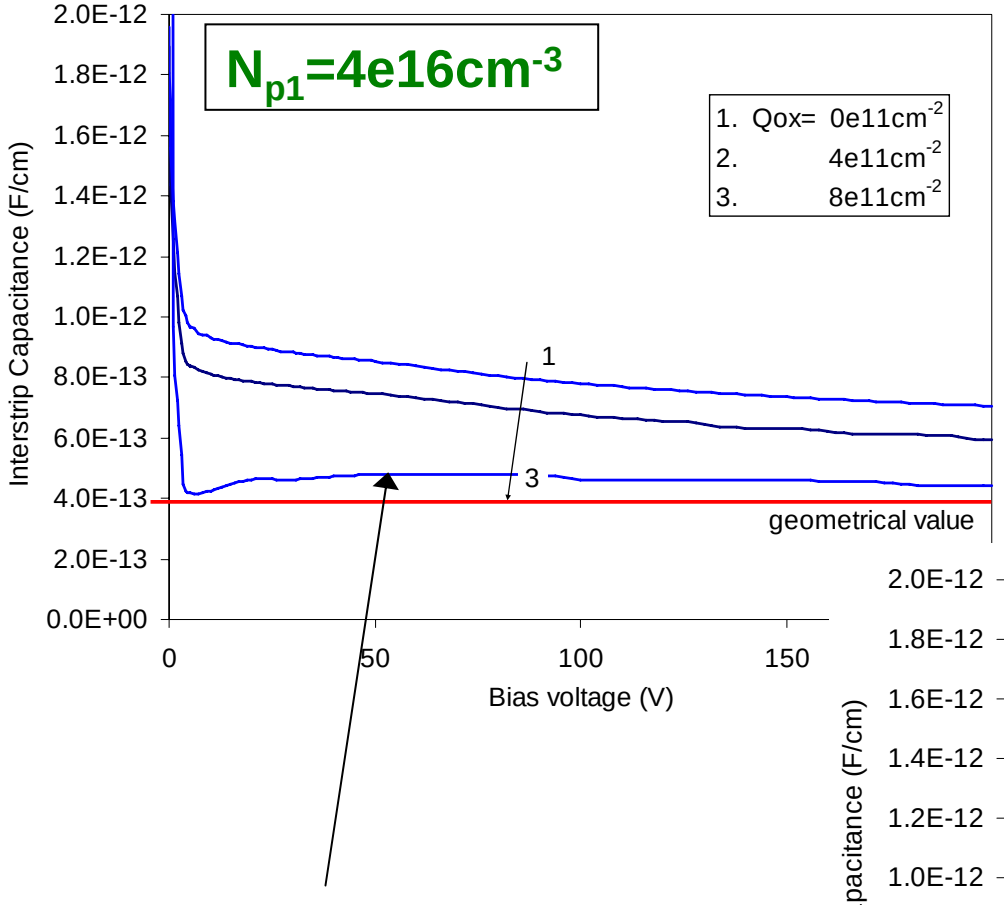
1) slope of $V_{p\text{-}spray}$ *vs* V_{BIAS} which depends on **w/p** and **N_a**

2) V_{JBR} level which depends on **N_P**, **Q_{OX}** and **field-plate**



V_{BR} increases for increasing Q_{ox} because V_{JBR} level increases

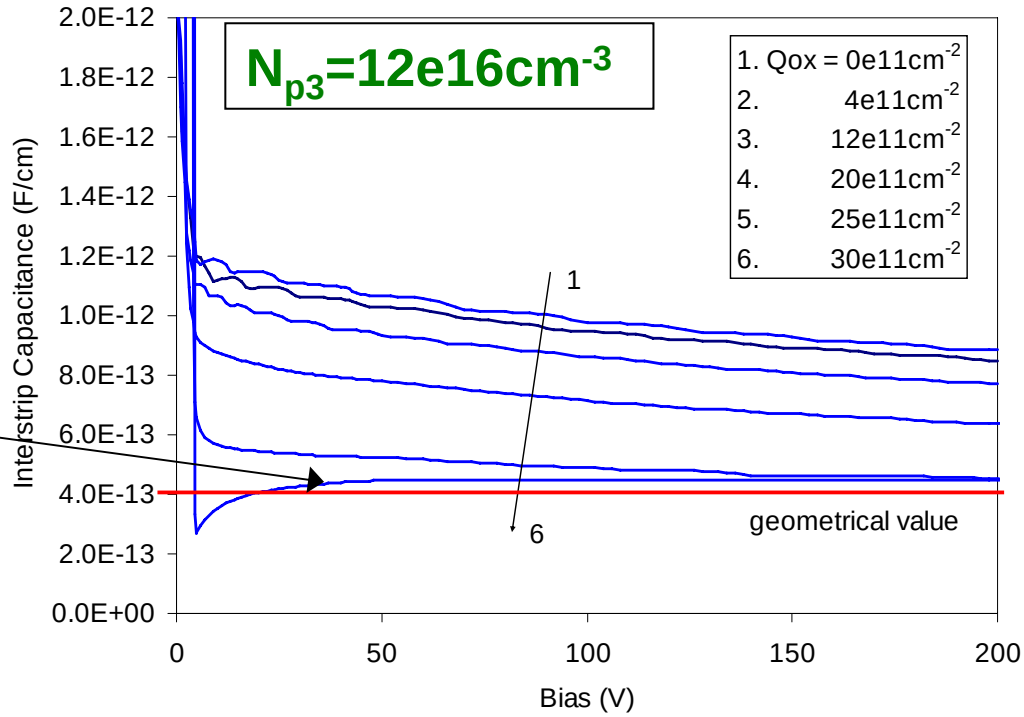
Interstrip capacitance (1)



C_{int} increases with N_p

C_{int} decreases with Q_{ox}

p-spray completely compensated
=> no isolation

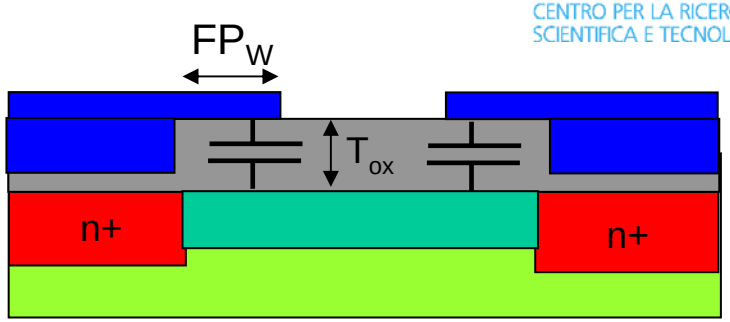


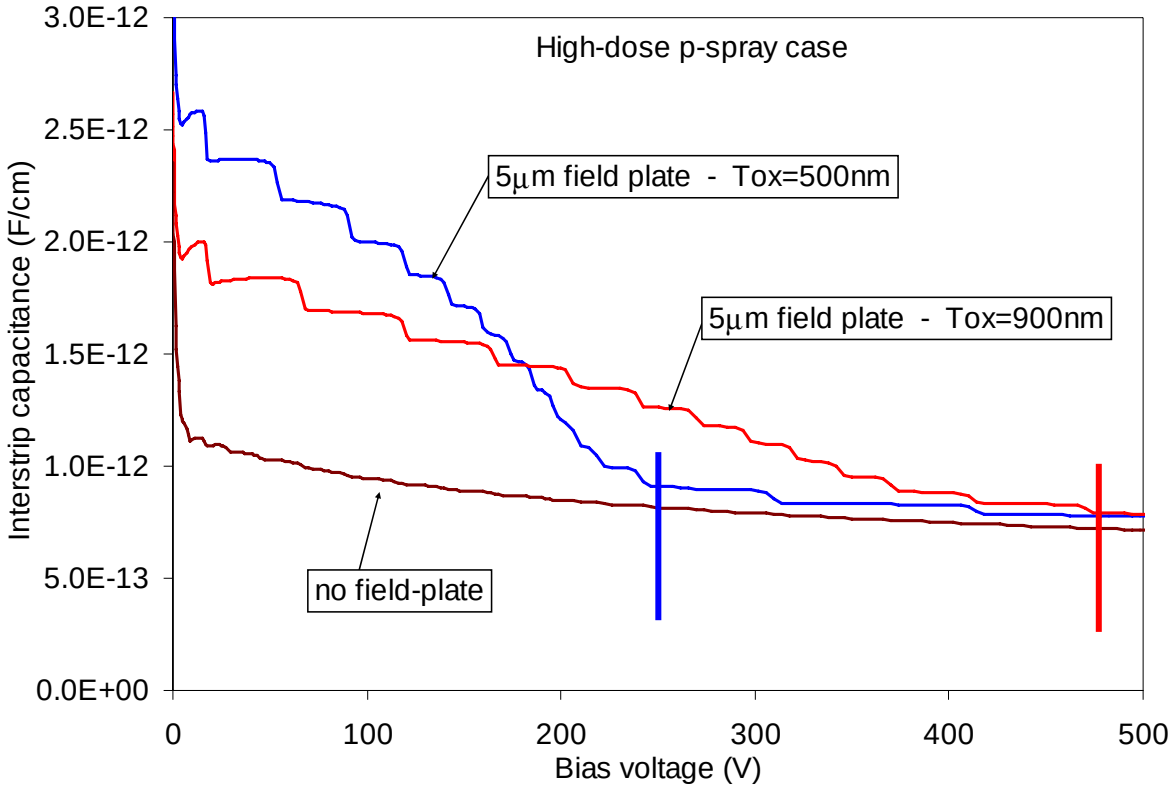
Interstrip capacitance (2)

Effect of field-plate

increases C_{int} by:

$$C=0.5 * \varepsilon_{ox} * (FP_W * L) * T_{ox}^{-1}$$



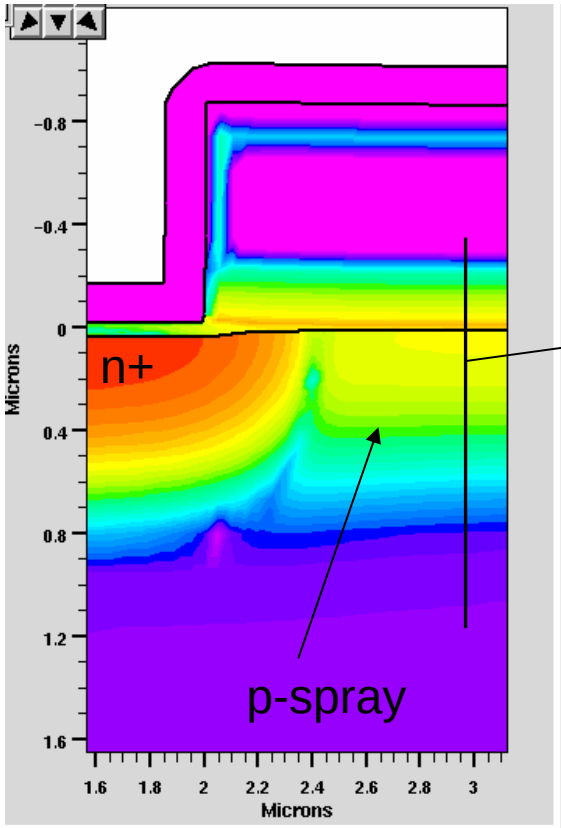


Additional component decreases because p-spray is progressively depleted by field-plate

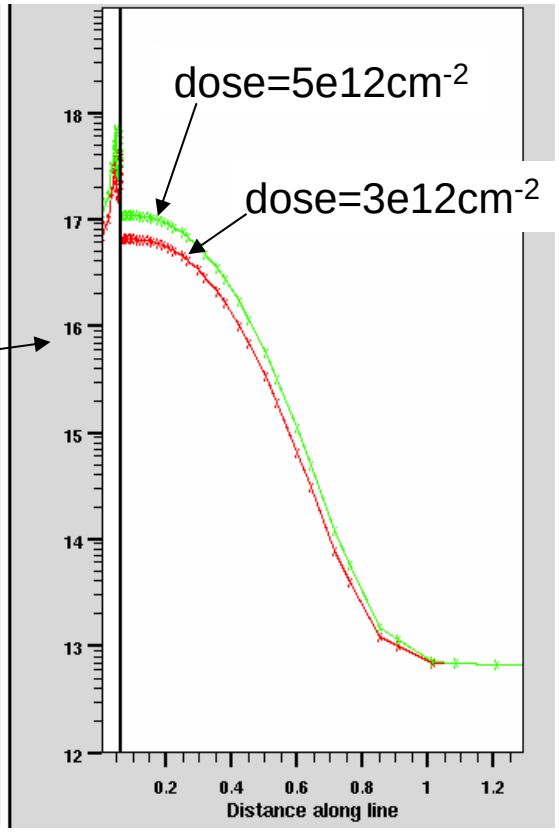
p-spray @ irst

First n^+-on-p detectors with p-spray fabricated in 2004

Net-doping conc.



p-spray profile along cut-line

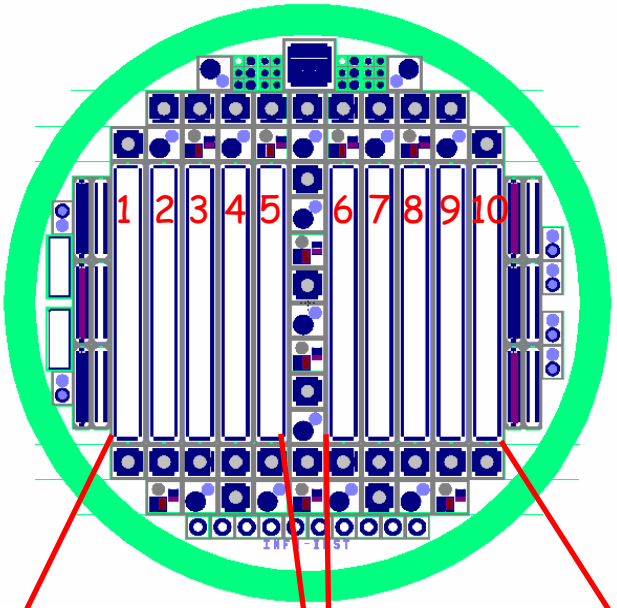


2 p-spray doses were used (labeled as low-dose and medium-dose)

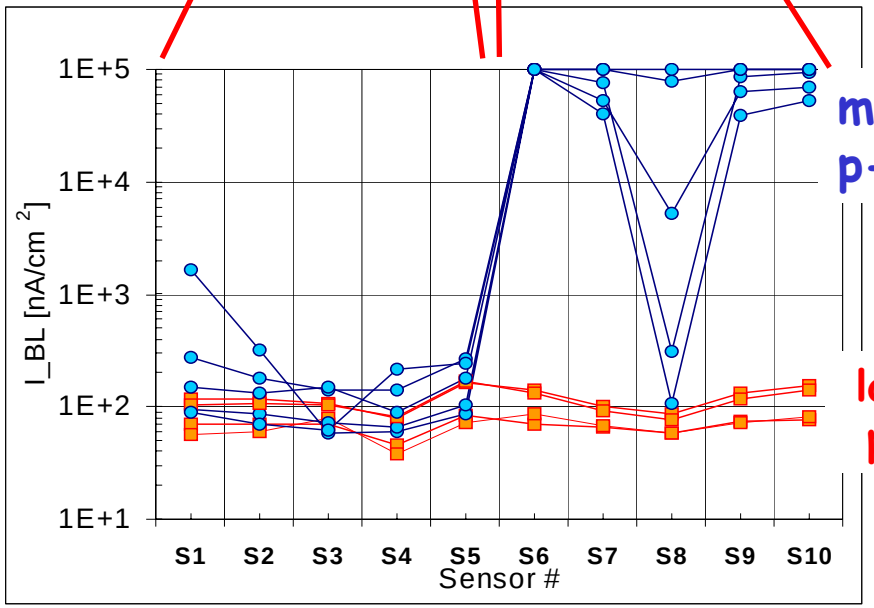
Both doses isolate before irradiation

p-spray @ irst - breakdown

det#	pitch	w/p	metal overhang
	[um]		
1	50	0.3	4
2	50	0.4	4
3	50	0.5	4
4	50	0.3	2
5	50	0.3	6
6	100	0.15	4
7	100	0.25	4
8	100	0.35	4
9	100	0.25	6
10	100	0.25	8



V_{bias}=100V

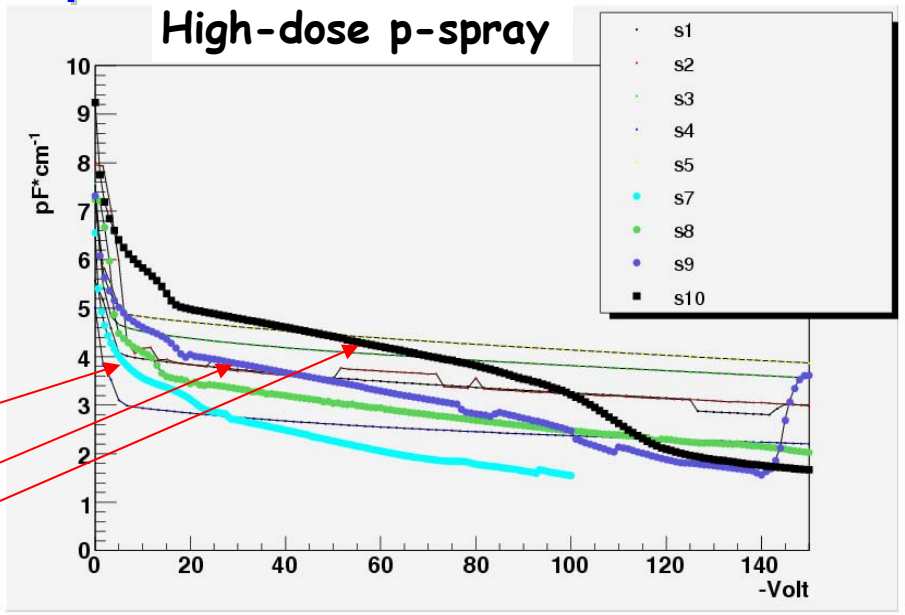


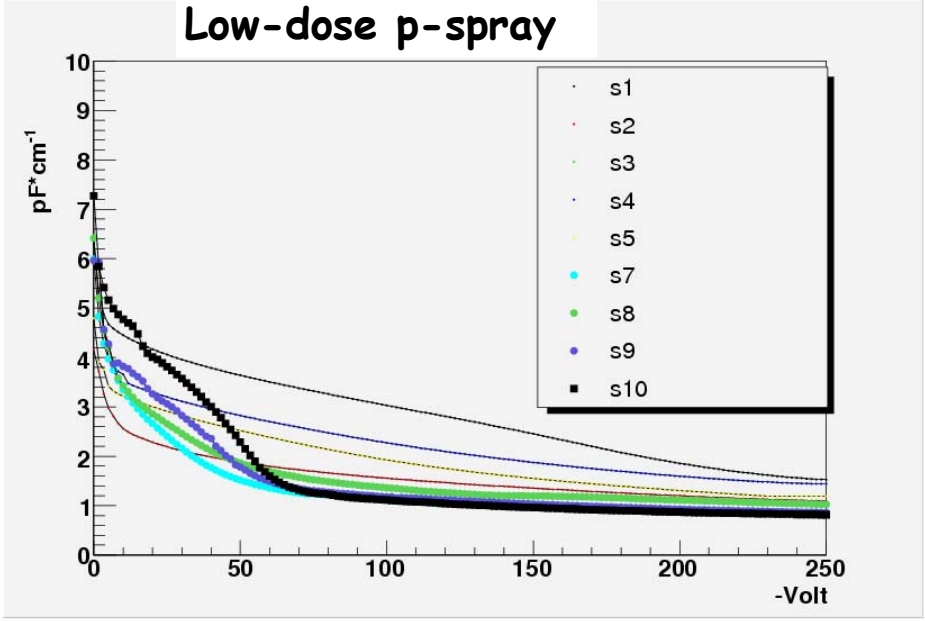
- Low dose p-spray no BD
- Medium dose p-spray:
  - 50µm pitch no BD
  - 100µm pitch BD

- Exception:
  - med. dose 100µm pitch no BD because of larger p^+

p-spray @ irst – interstrip capacitance

det#	pitch	w/p	metal overhang
	[um]		
1	50	0.3	4
2	50	0.4	4
3	50	0.5	4
4	50	0.3	2
5	50	0.3	6
6	100	0.15	4
7	100	0.25	4
8	100	0.35	4
9	100	0.25	6
10	100	0.25	8





- At “low” voltages cap. dominated by field-plate:
  - larger field plate
    => higher capacitance
  - higher dose p-spray
    => longer decay

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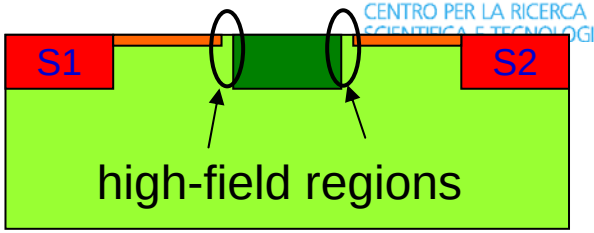
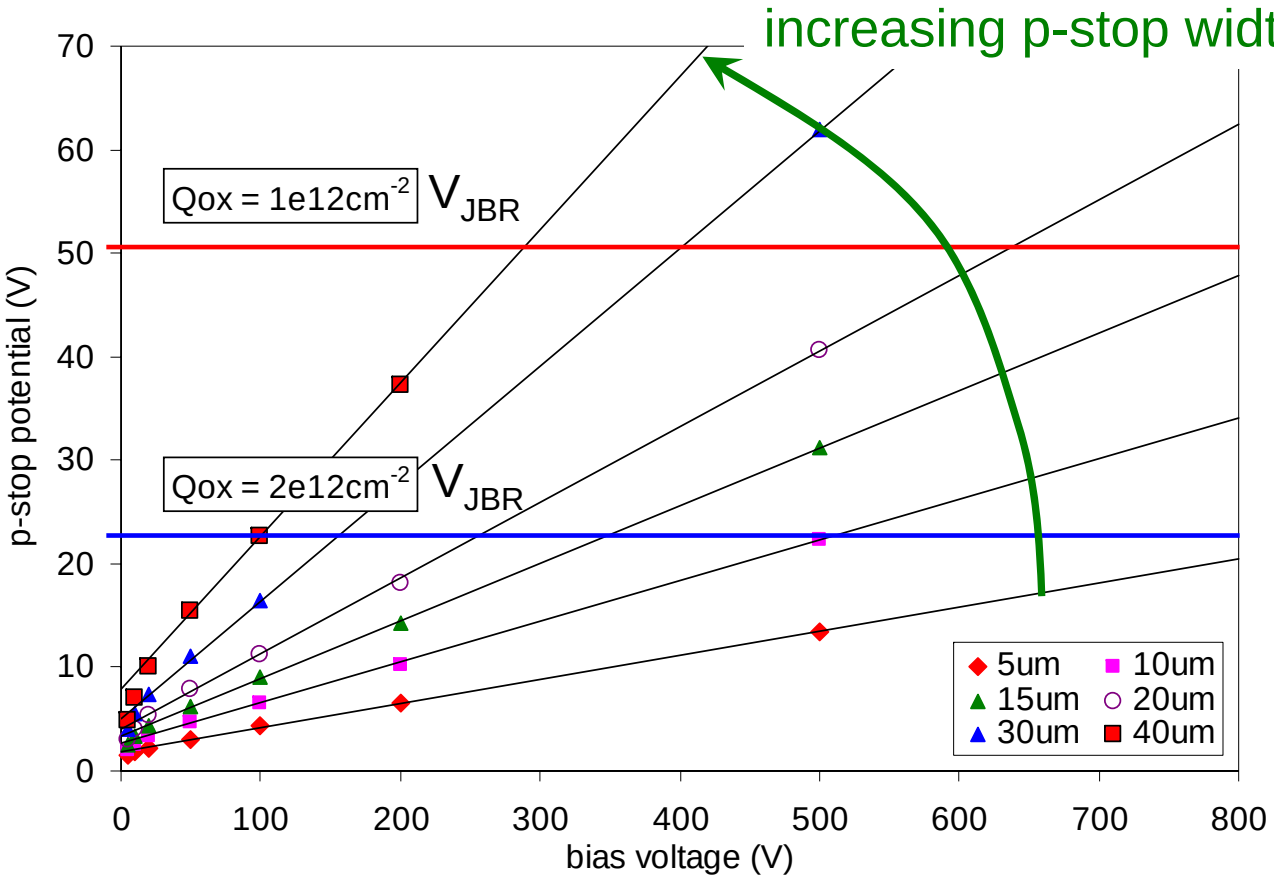
p-stop

Breakdown

Similar approach to p-spray:

1. determine $V_{p\text{-}spray} = f(V_{BIAS})$
2. determine V_{JBR} level

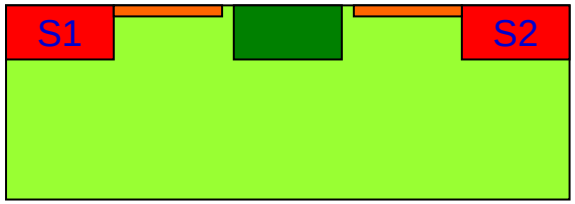




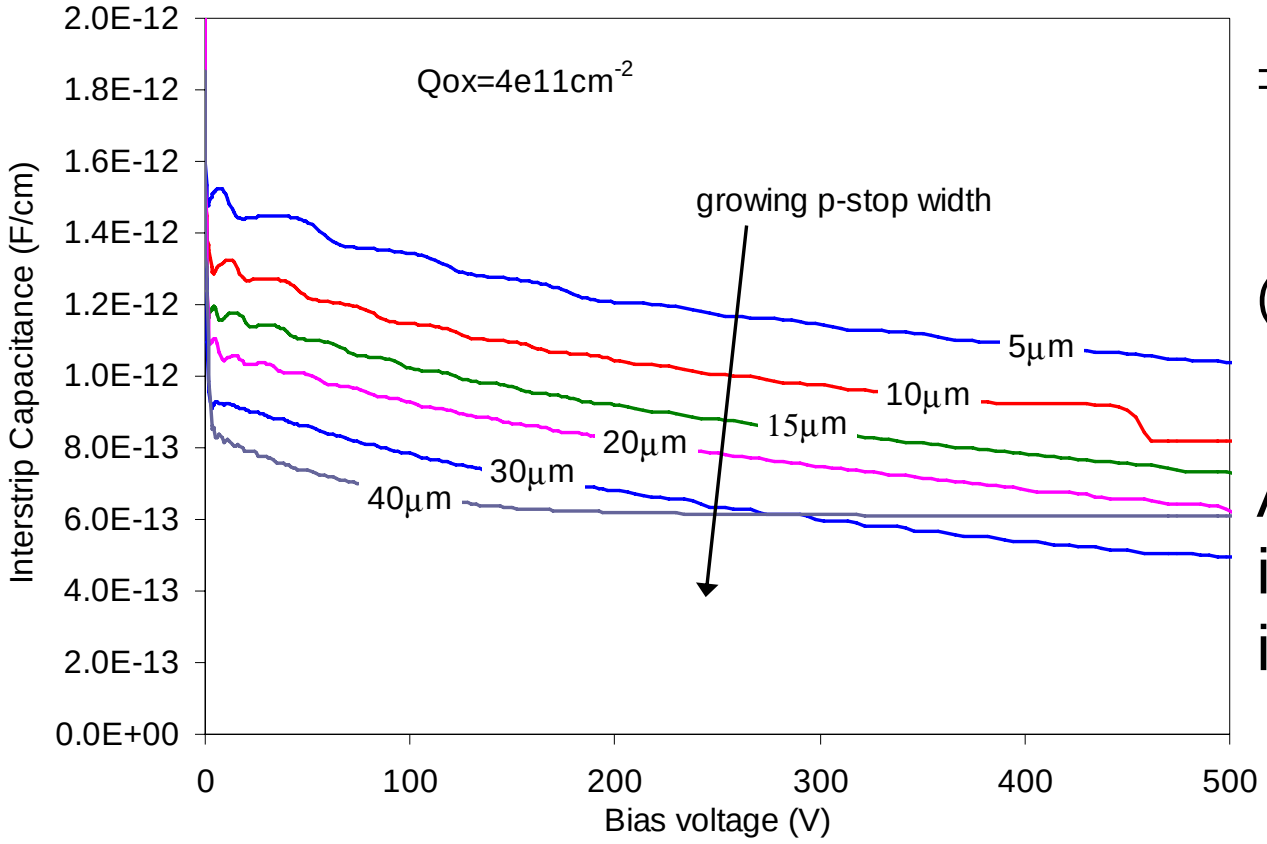
p-stop potential is higher for wide implants

⇒ better narrow p-stop from the breakdown viewpoint

Interstrip capacitance



inversion layer acts as an extension of the n^+ strip



⇒ narrow p-stop implies higher capacitance (opposite trend with respect to breakdown)

As Q_{ox} increases, interstrip capacitance increases

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combined p-spray/p-stop

Concept

p-spray: V_{BR} - low before irradiation
- improves for increasing Q_{OX}

C_{int} - improves with irradiation

improves with Q_{OX}

p-stop: V_{BR} - high before irradiation
- decreases for increasing Q_{OX}

C_{int} - high and deteriorates for inc. Q_{OX}

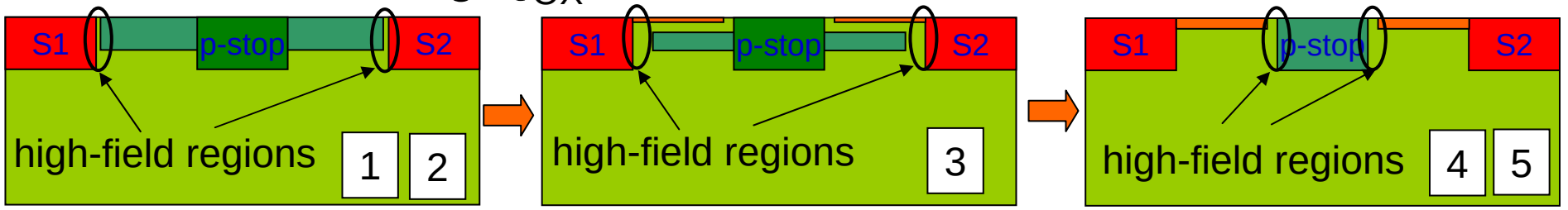
deteriorates with Q_{OX}

⇨ interesting solution is to combine the previous two using:
- medium dose p-spray (to have sufficiently high initial V_{BR})
- 20/30μm wide p-stop (to have low capacitance for high Q_{OX})

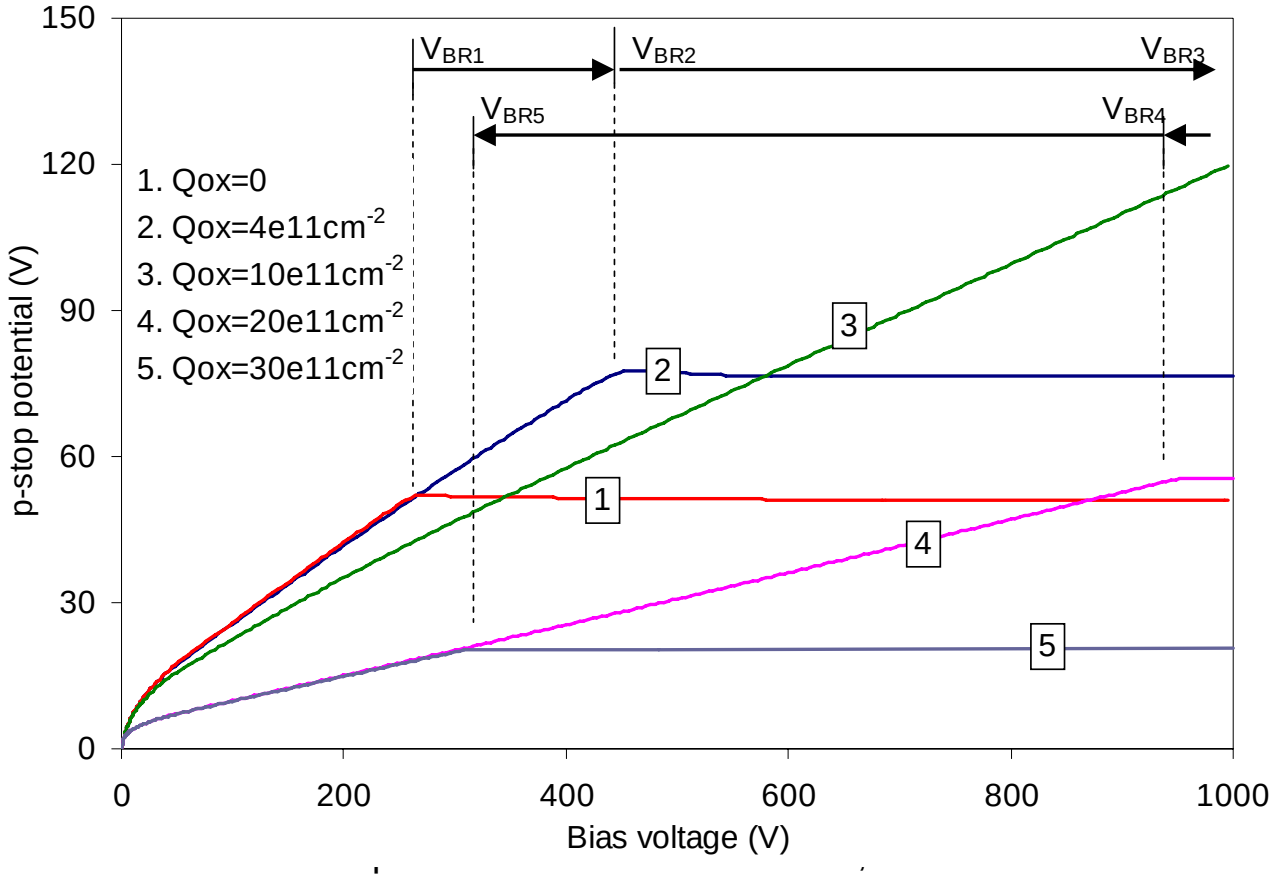
Technology: - moderated p-spray
(isolation structure realized with single implantation step)
- combined p-spray/p-stop
(two implantation steps)

Breakdown

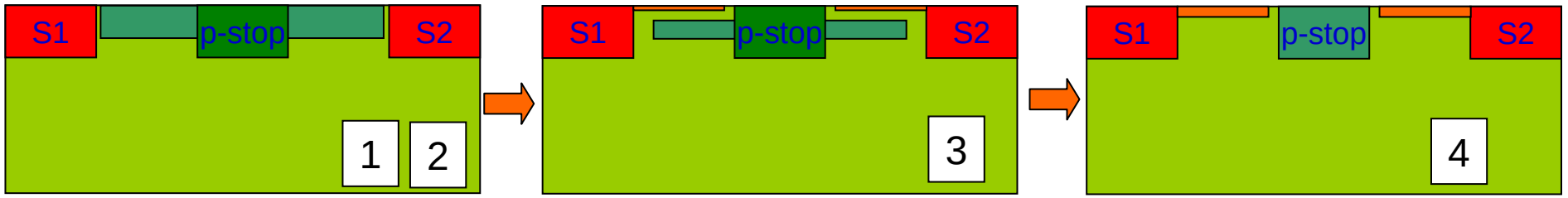
For increasing Q_{OX}:

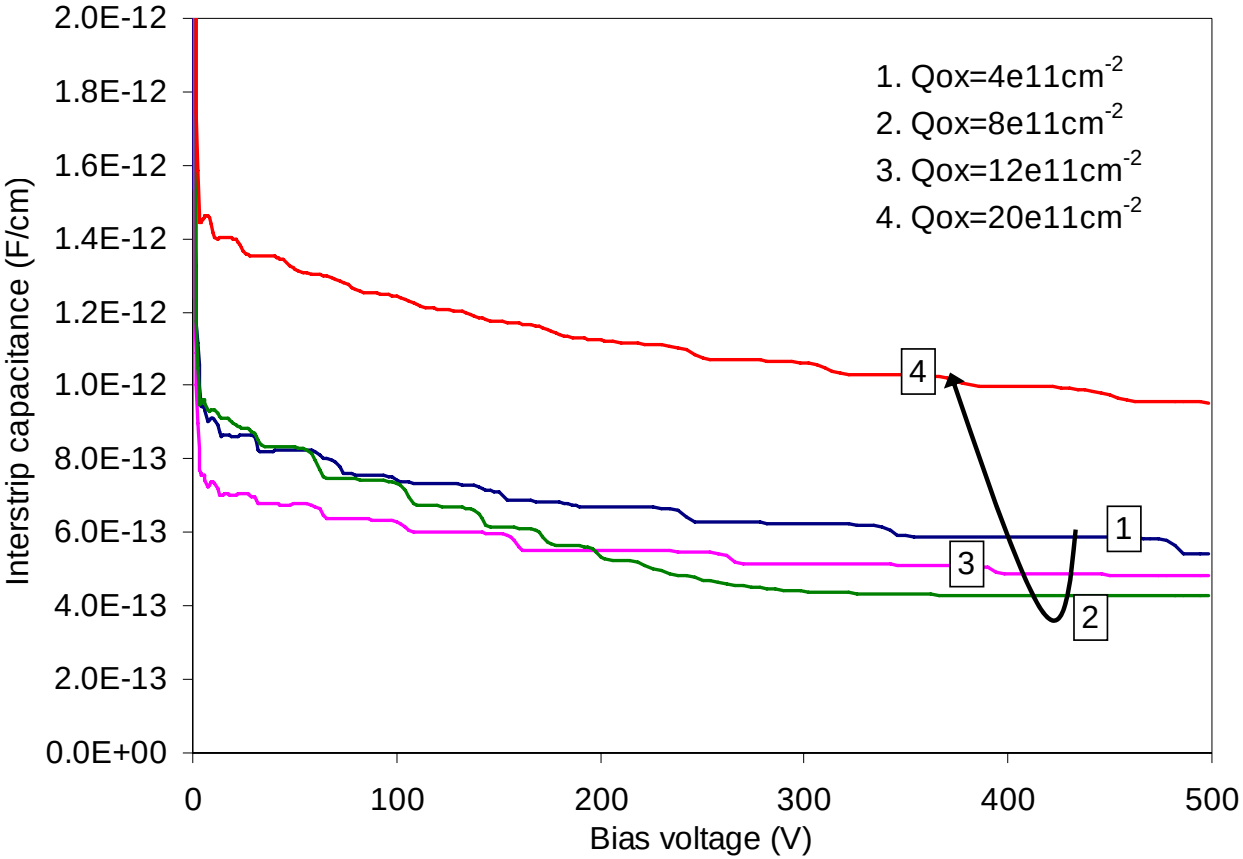


V_{BR} first increases (typical of p-spray) than decreases (typical of p-stop) as Q_{OX} grows



Interstip capacitance





C_{int} first decreases (typical of p-spray) than increases (typical of p-stop) as Q_{OX} grows

Conclusion

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- simulations well reproduce both breakdown and interstrip capacitance behavior in the p-spray case
- Among the simulated isolation structures, the combined p-spray/p-stop technology seems to be the most effective
  (as for n+-on-n detectors)