

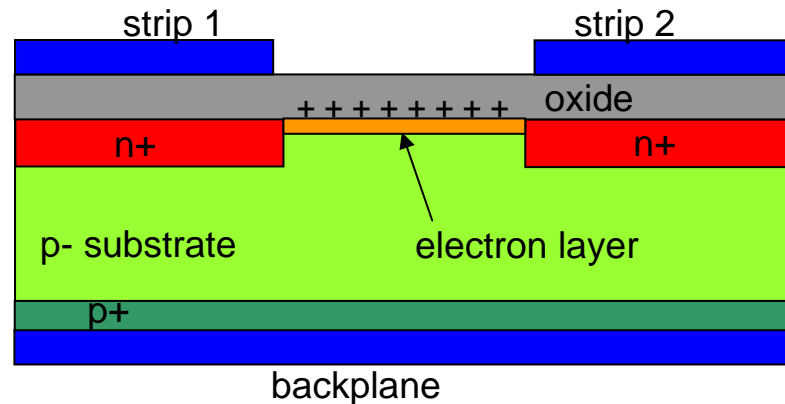
TCAD simulations of isolation structures for n⁺-on-p silicon microstrip detectors

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Outline

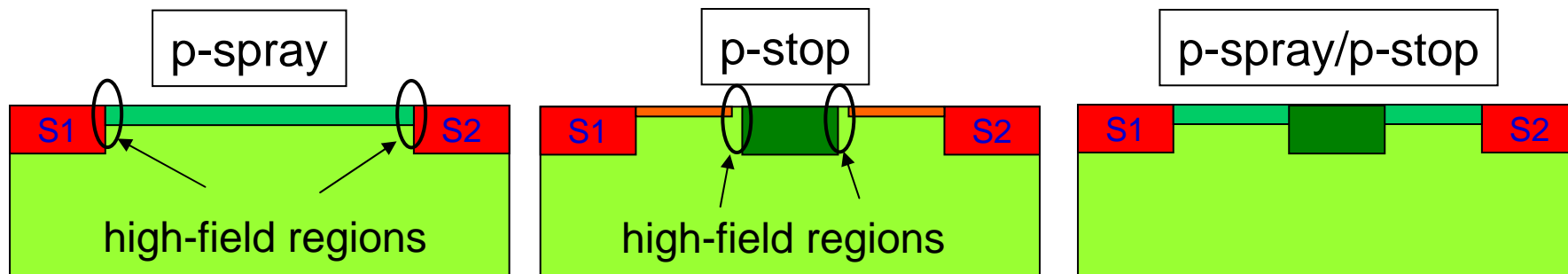
- Why is this work needed?
- Device Simulations
 - p-spray
 - p-spray experience @ ITC-irst
 - p-stop
 - combined p-spray/p-stop
- Conclusion

Why are simulations needed?



isolation structure
needed to interrupt the
inversion layer between
the strip

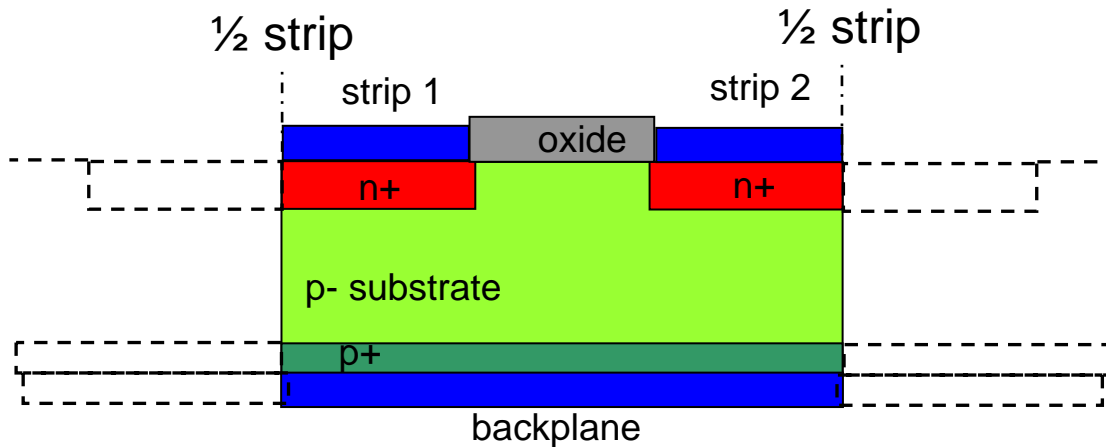
3 techniques available (from n⁺-on-n technology):



Each technique affects differently V_{BR} and C_{int}
⇒ simulations are needed to evaluate impact

Simulated structure

2D simulations of a cross section orthogonal to the strips



Reference structure:

pitch = $80\mu\text{m}$

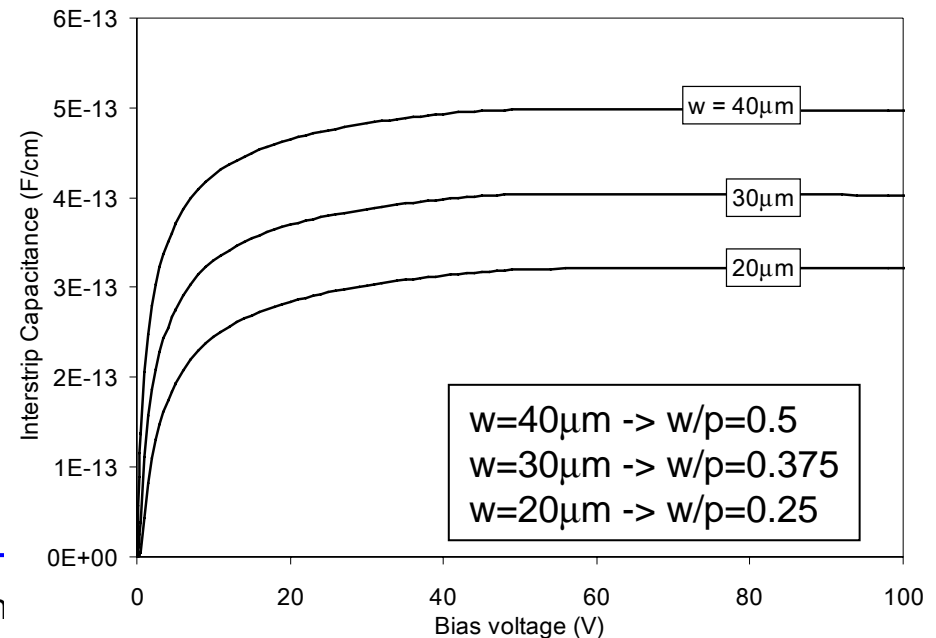
n^+ width = $30\mu\text{m}$

$N_a = 7e11\text{cm}^{-3}$

$W = 300\mu\text{m}$

$Q_{\text{ox}} = 4e11\text{cm}^{-2}$

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

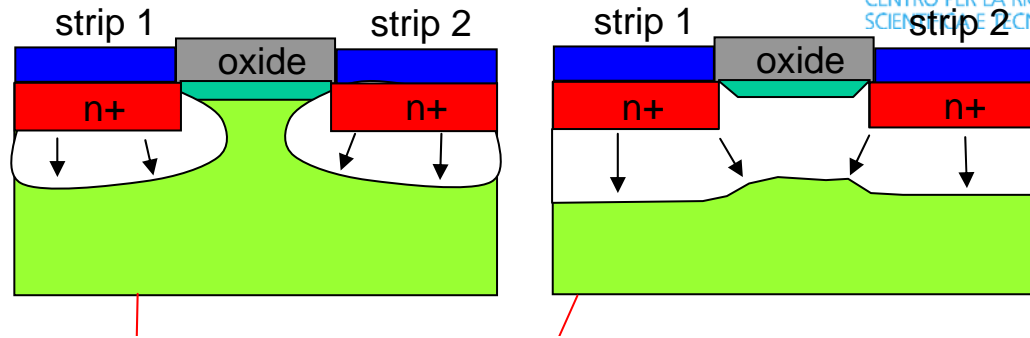


p-spray

Breakdown (1)

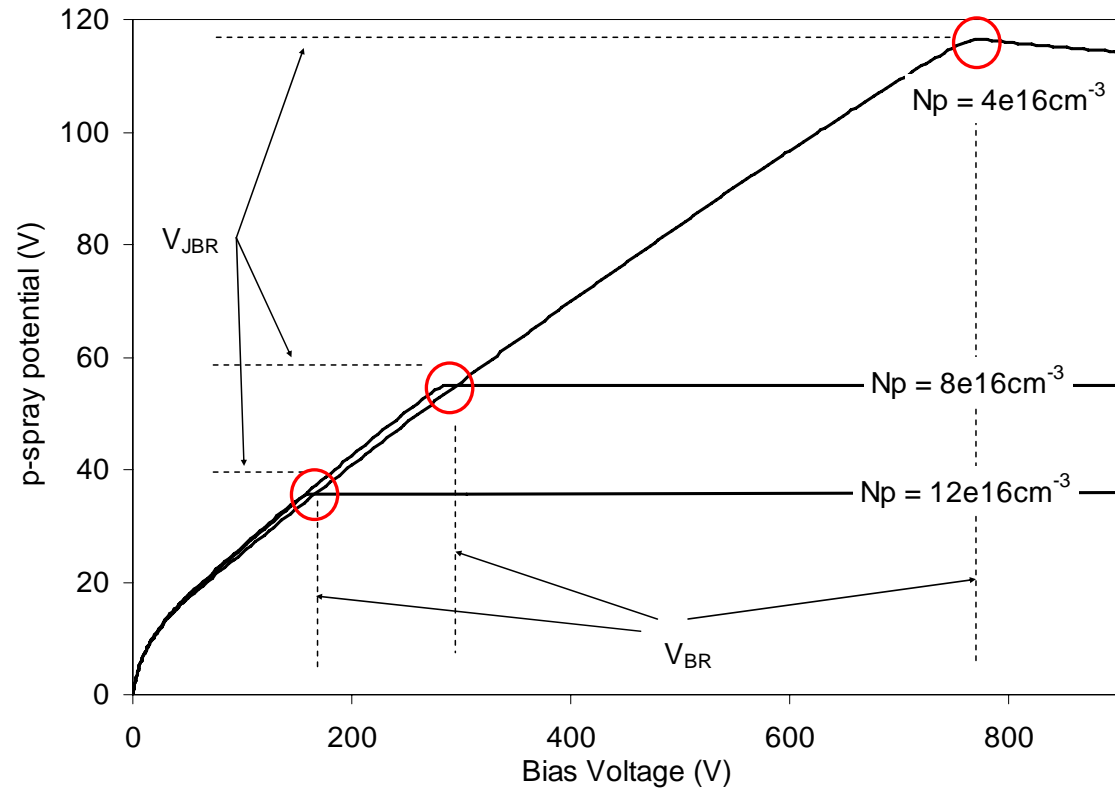
Three p-spray peak concentrations:

- $N_{p1} = 4e16 \text{cm}^{-3}$
- $N_{p2} = 8e16 \text{cm}^{-3}$
- $N_{p3} = 12e16 \text{cm}^{-3}$



V_{JBR} = potential difference between p-spray and strip which causes breakdown
 V_{BR} = bias voltage for which we reach V_{JBR}

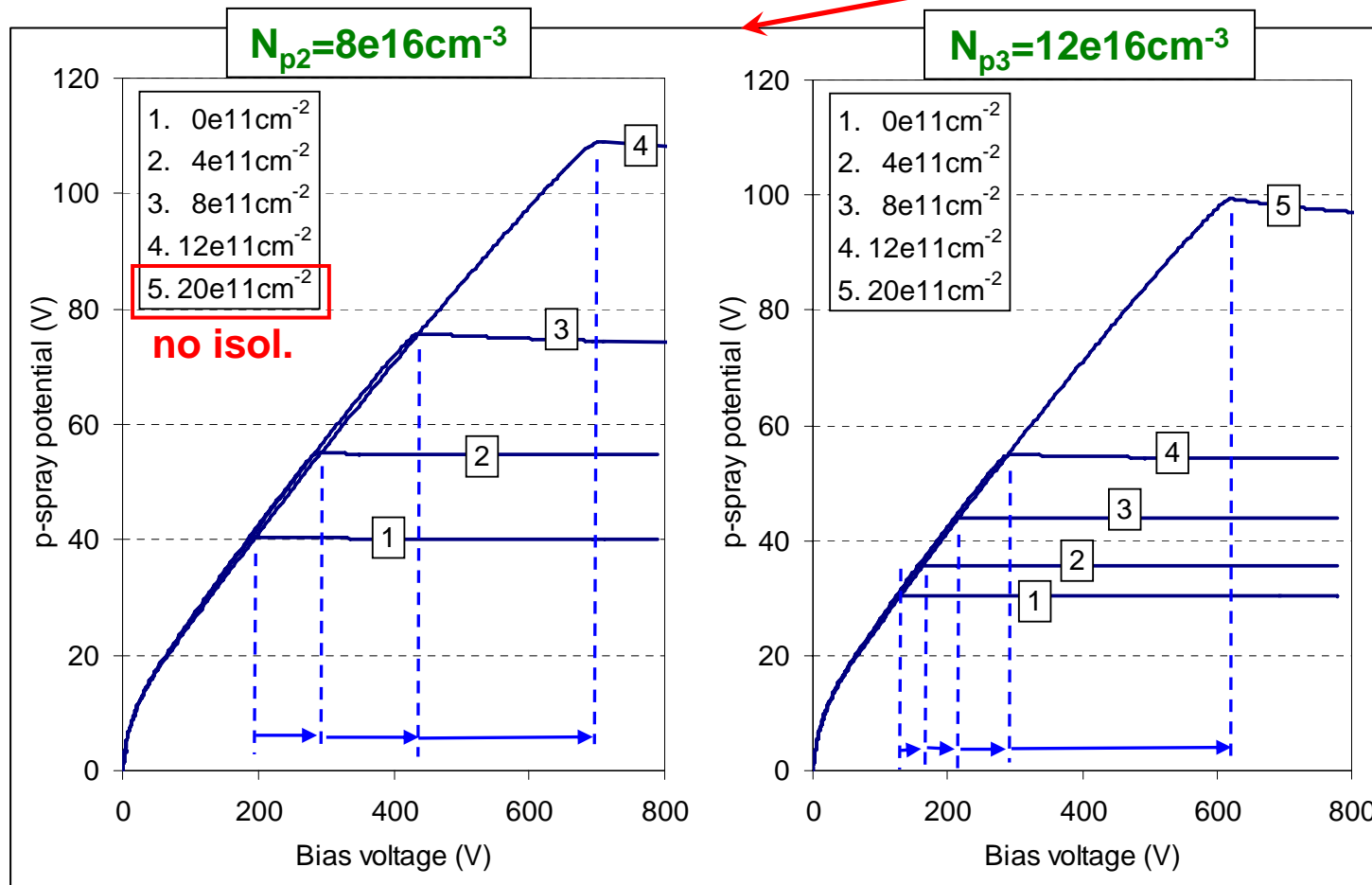
High $N_p \Rightarrow$ High V_{JBR}
 \Rightarrow high V_{BR}



Breakdown (2)

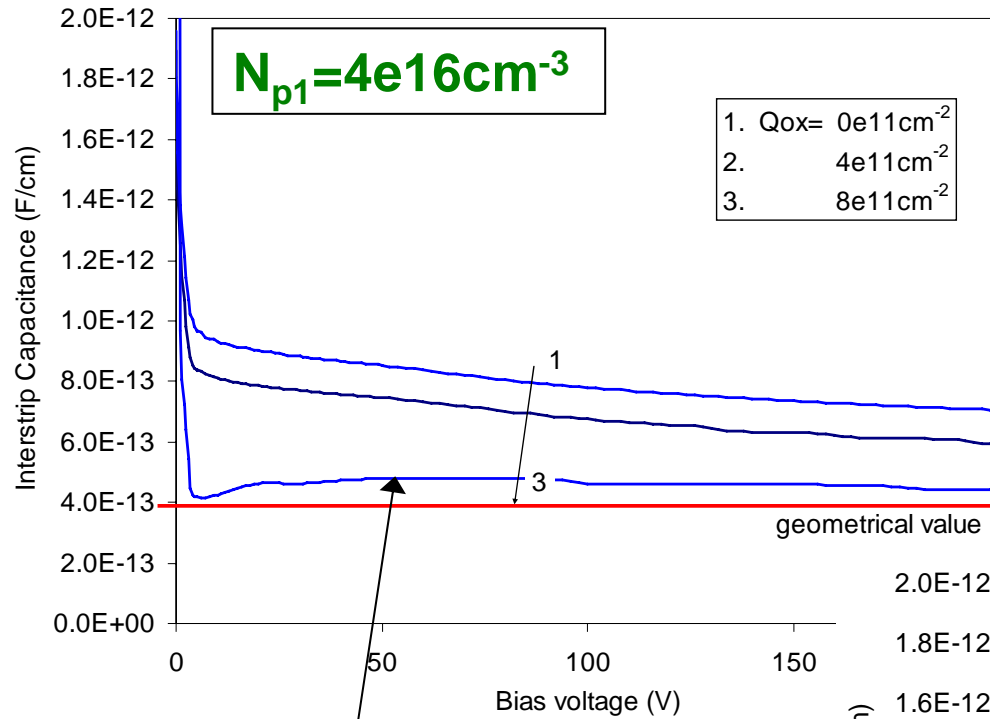
V_{BR} depends on:

- 1) slope of $V_{p-spray}$ 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



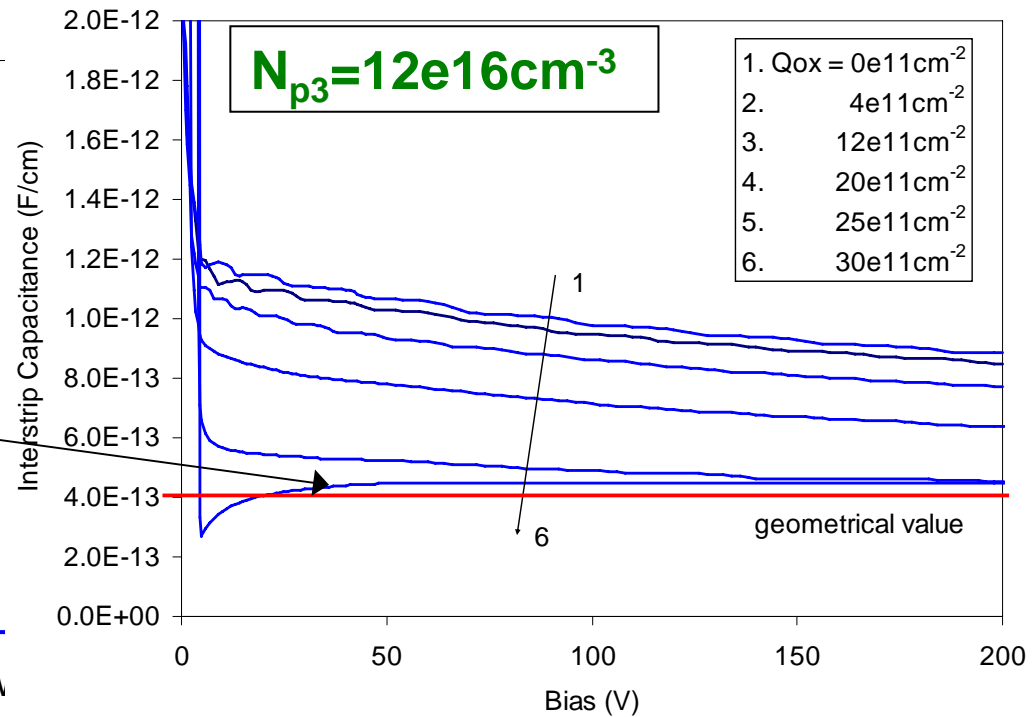
V_{BR} increases for increasing Q_{ox} because V_{JBR} level increases

Interstrip capacitance (1)



C_{int} increases with N_p
 C_{int} decreases with Q_{ox}

p-spray completely compensated
 \Rightarrow no isolation

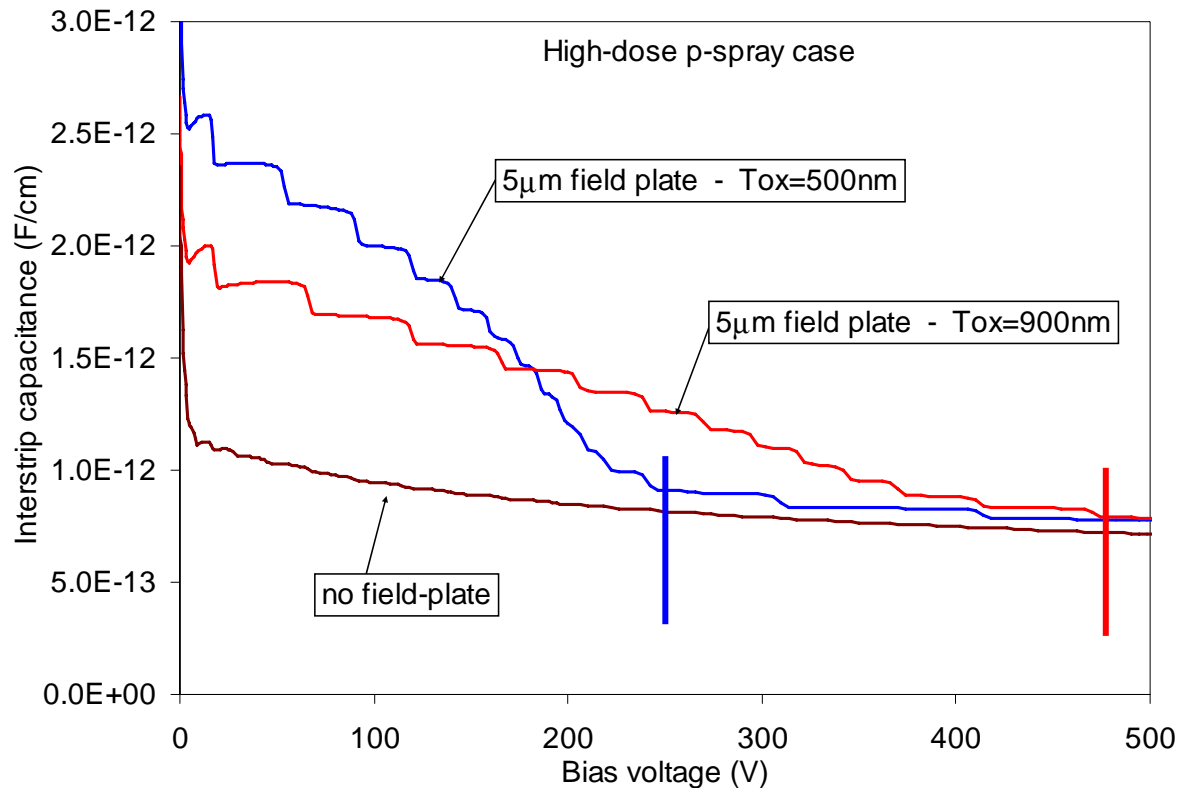
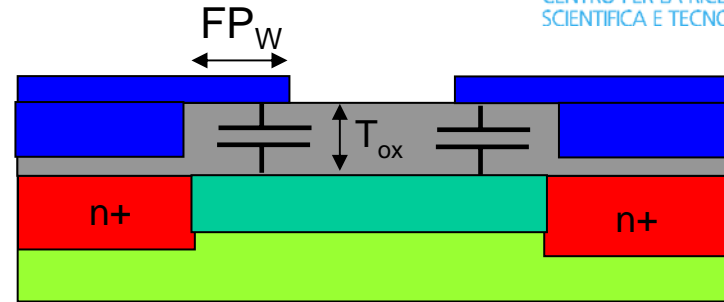


Interstrip capacitance (2)

Effect of field-plate

increases C_{int} by:

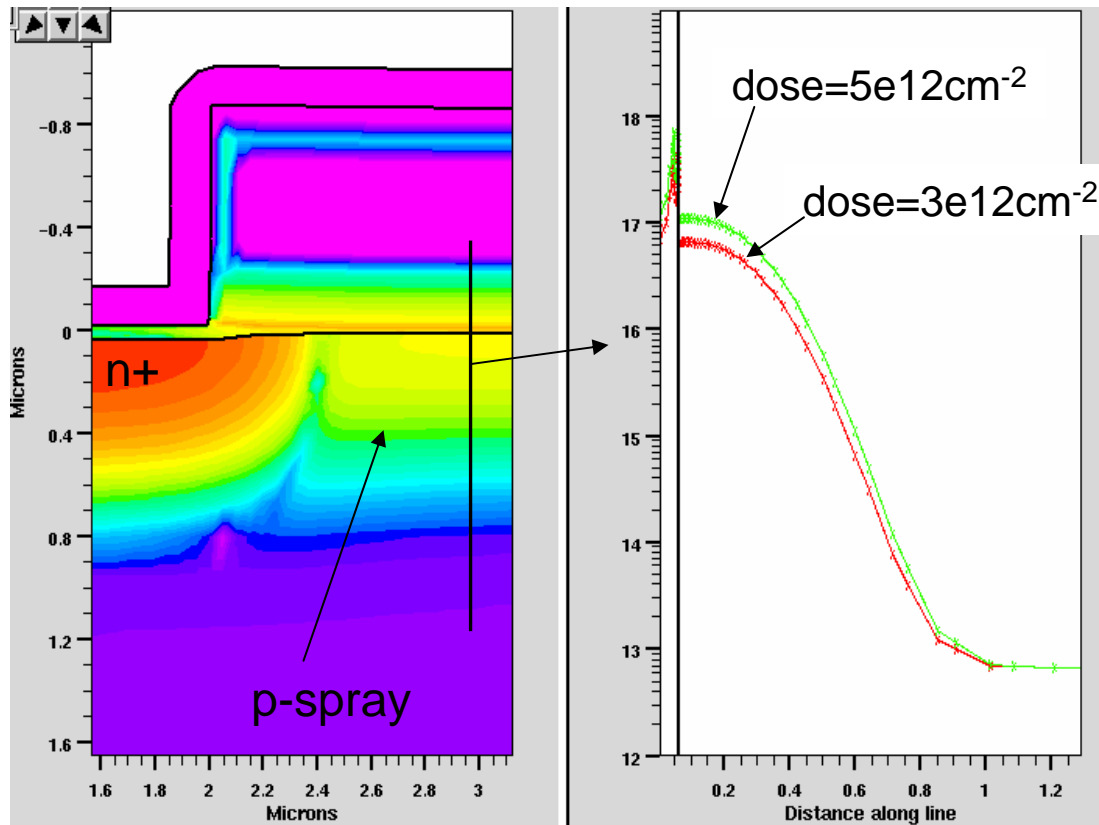
$$C = 0.5 * \epsilon_{ox} * (FP_W * L) * T_{ox}^{-1}$$



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

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

Net-doping conc. p-spray profile along cut-line

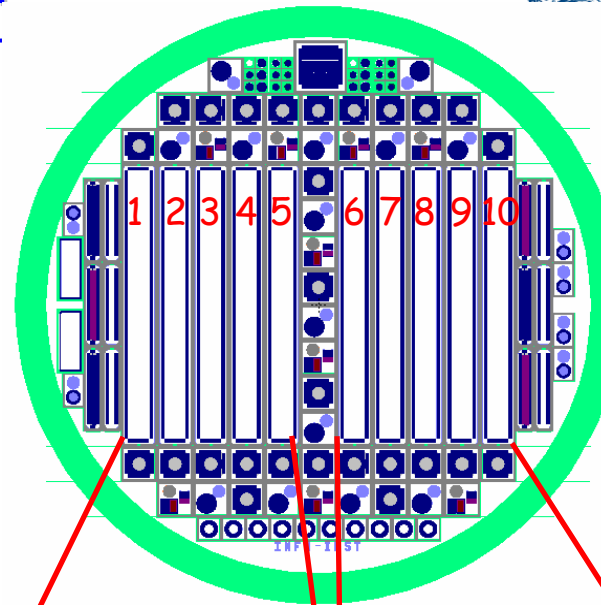


2 p-spray doses
were used
(labeled as low-dose
and medium-dose)

Both doses isolate
before irradiation

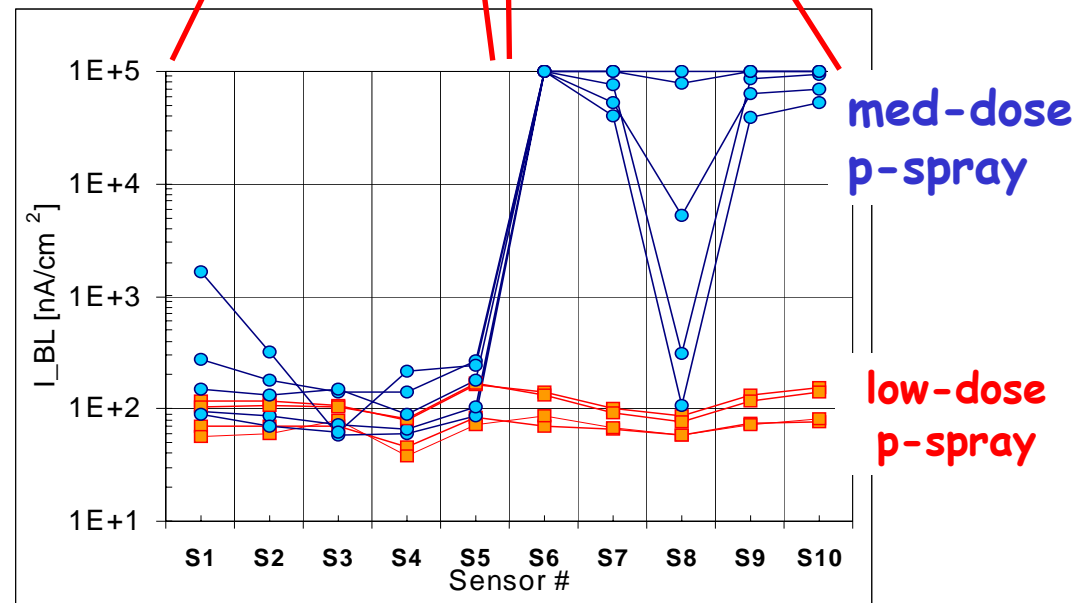
p-spray @ irst - breakdown

det#	pitch [um]	w/p	metal overhang
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



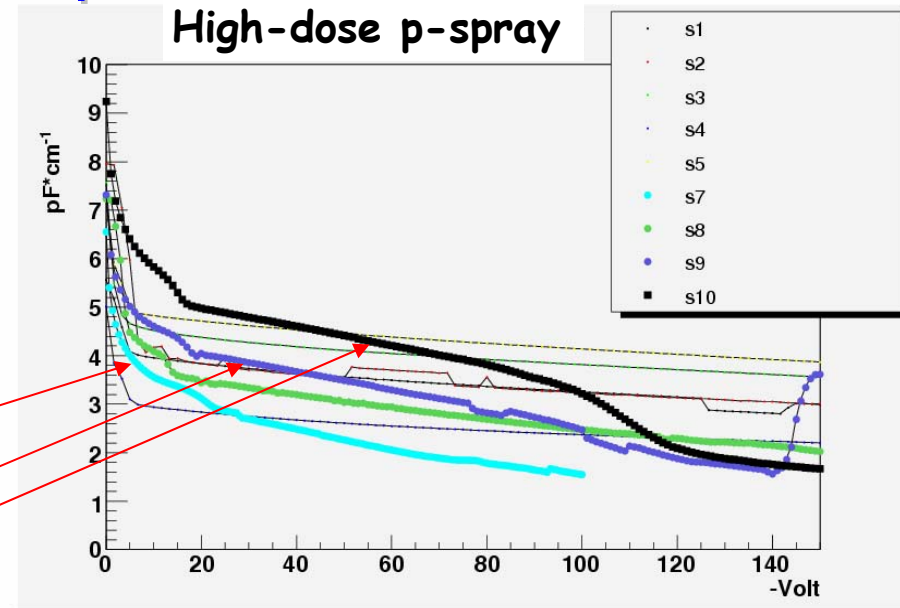
$V_{bias} = 100V$

- 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⁺

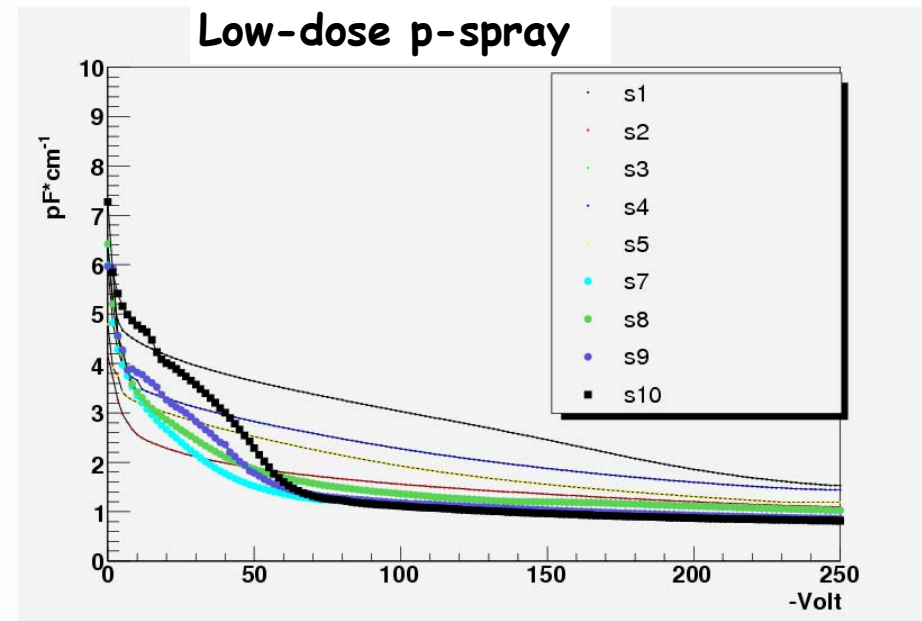


p-spray @ irst – interstrip capacitance

det#	pitch	w/p	metal overhang
	[μm]		
1	50	0.3	4
2	50	0.4	4
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4	50	0.3	2
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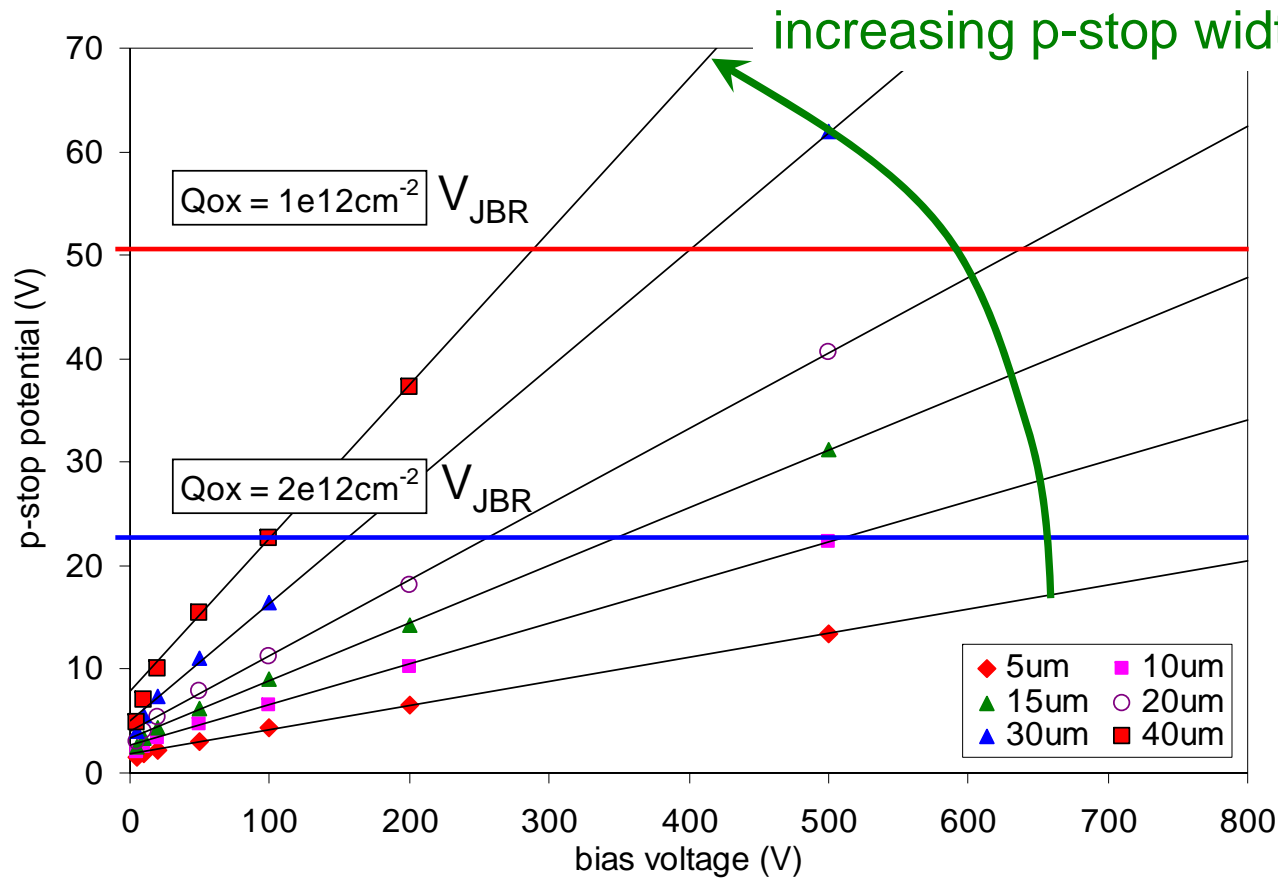
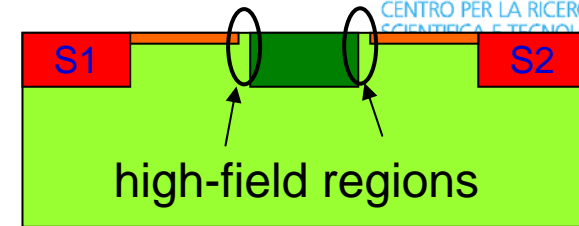
- At “low” voltages cap. dominated by field-plate:
 - larger field plate \Rightarrow higher capacitance
 - higher dose p-spray \Rightarrow longer decay



p-stop

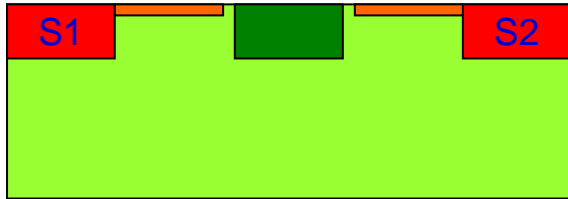
Breakdown

- Similar approach to p-spray:
1. determine $V_{p-spray} = f(V_{BIAS})$
 2. determine V_{JBR} level

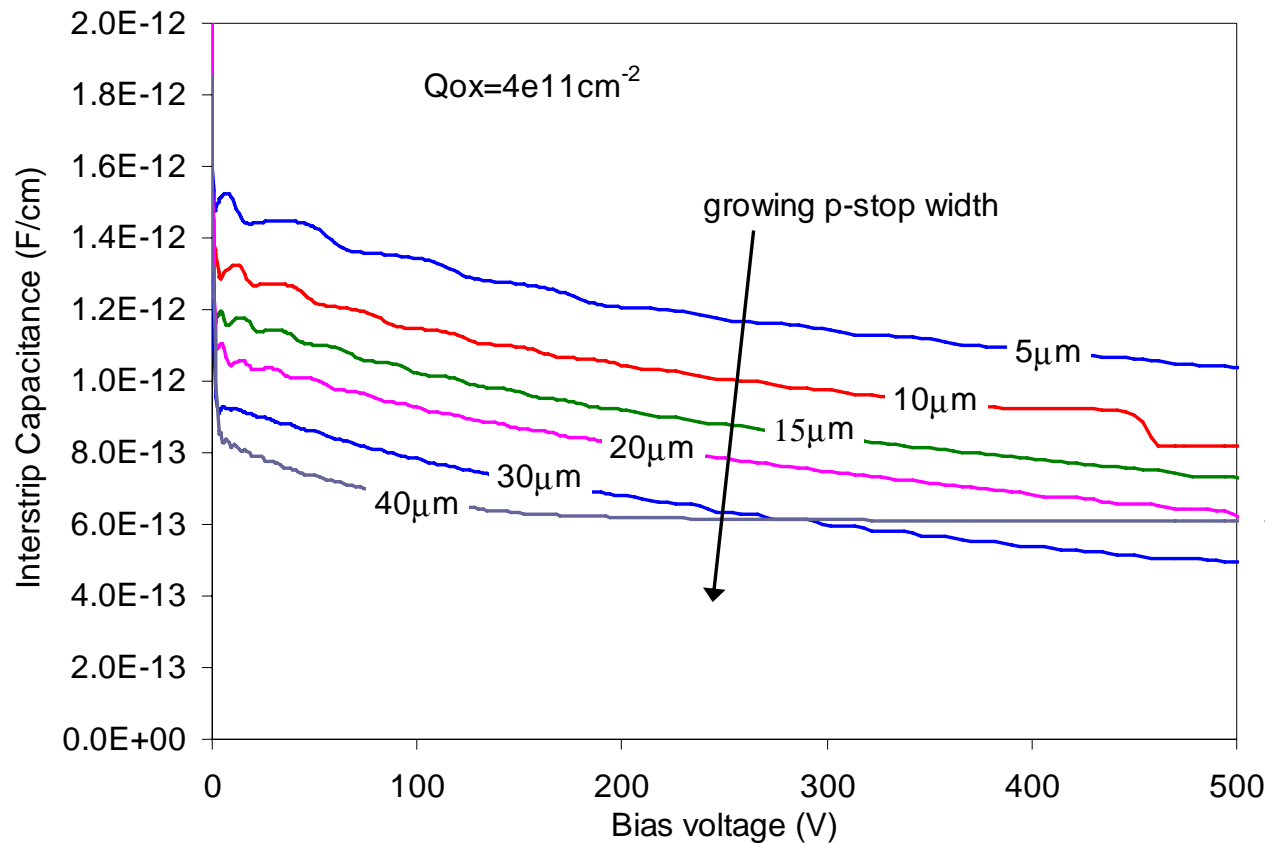


p-stop potential is higher for wide implants
 ⇒ better narrow p-stop from the breakdown viewpoint

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

combined
p-spray/p-stop

Concept

p-spray:	V_{BR}	- low before irradiation - improves for increasing Q_{OX}	improves with Q_{OX}
	C_{int}	- improves with irradiation	
p-stop:	V_{BR}	- high before irradiation - decreases for increasing Q_{OX}	deteriorates with Q_{OX}
	C_{int}	- high and deteriorates for inc. Q_{OX}	

⇒ interesting solution is to combine the previous two using:

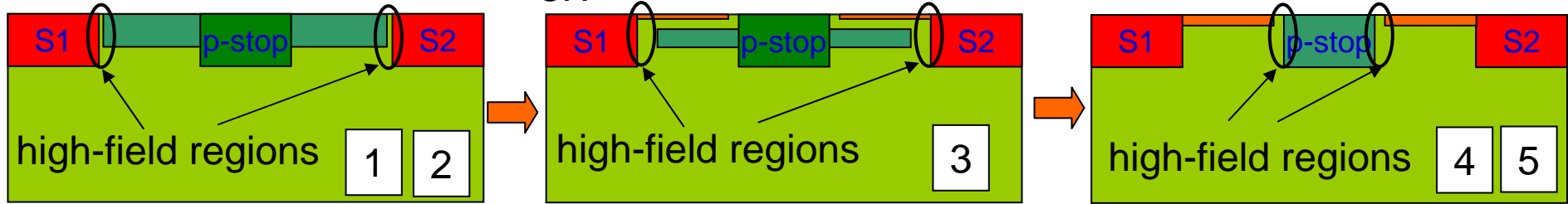
- medium dose p-spray (to have sufficiently high initial V_{BR})
- 20/30 μ m wide p-stop (to have low capacitance for high Q_{OX})

Technology:

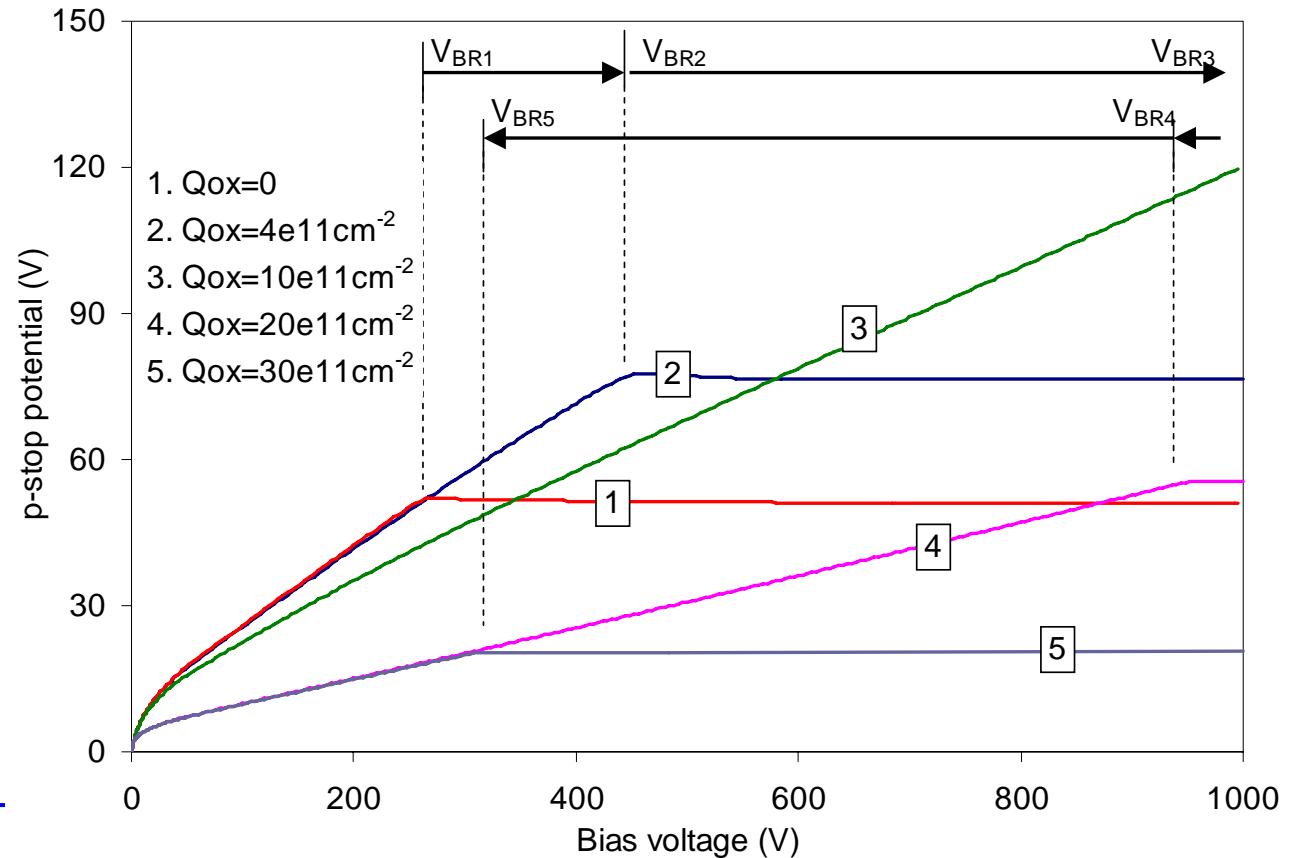
- moderated p-spray
(isolation structure realized with single implantation step)
- combined p-spray/p-stop
(two implantation steps)

Breakdown

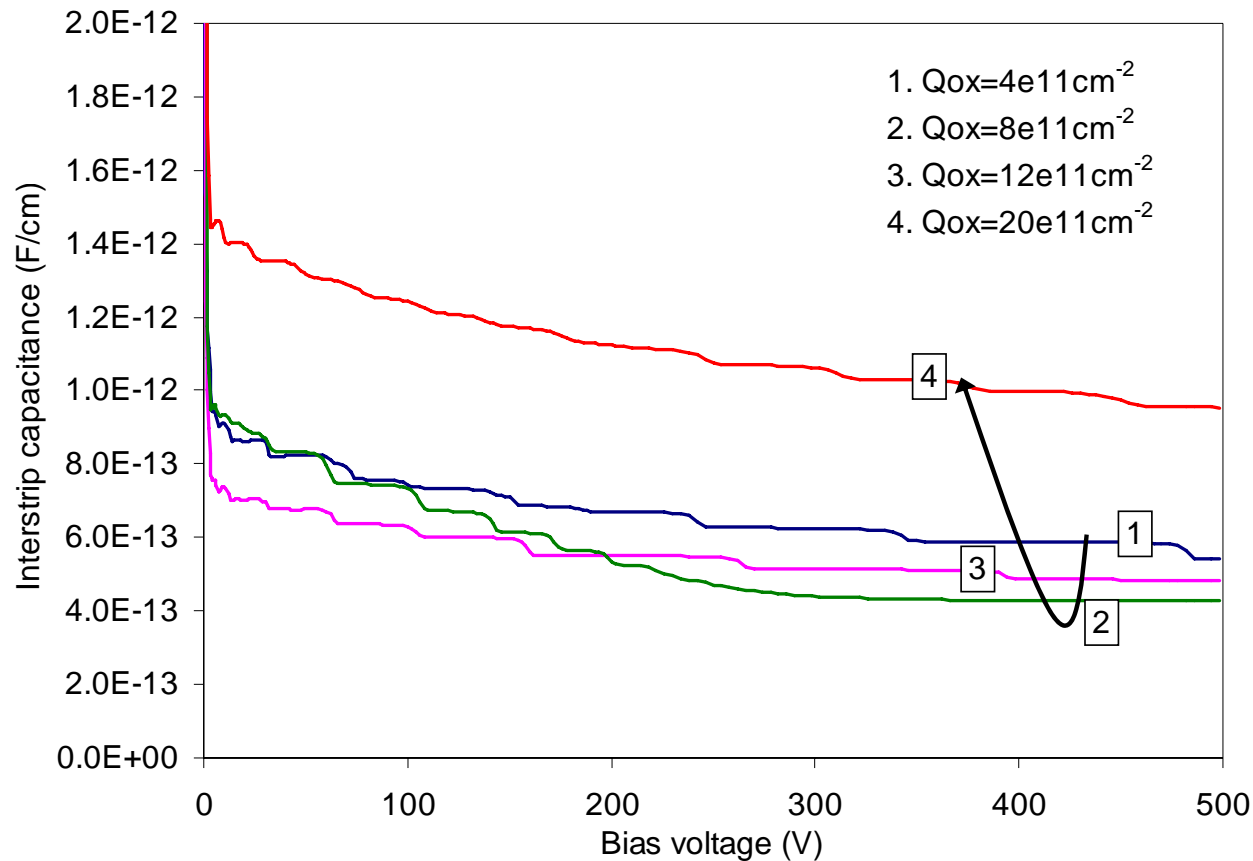
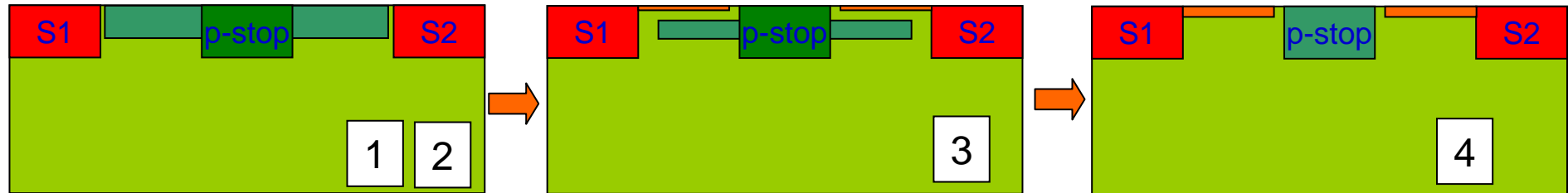
For increasing Q_{OX} :



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



Interstrip capacitance



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

Conclusion

- 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)