Charge losses close to the Si-SiO_2-interface*)

1. Why study?
2. Measurement techniques
3. Results
4. Conclusions

*) work mainly done by T. Poehlsen + S.Schuwalow, Hamburg

Why study?

1. Impact on charge collection, charge sharing, charge memory
   - enhanced charge collection time + increased plasma effect

     → signal spreading + losses + spill over to next XFEL bunch
2. Stability of sensor performance (calibration!)
   - surface conditions impact on device stability (breakdown, operation in vacuum and/or finite humidity)
   - stability of charge collection vs. time and operating conditions
   - stability of dark current, capacitances (noise) vs time
3. Understand boundary conditions for simulations

→ Is it a problem at all? **and if yes**

→ Is there a sensor design which avoids all that?

(NB. In my opinion an "old unresolved" problem of Si sensors which has caused malfunctioning of sensors in the past)

Measurement techniques

2.1 Sensors investigated:

- DC coupled strip sensor from Hamamatsu (50 µm pitch)
- AC coupled strip sensor from CIS (80 µm pitch) – for this sensor we have a good knowledge of several technological parameters

(both sensor have an overall passivation (apart from bonding windows))

→ **results similar** (only results of DC-sensor shown)

→ **independent of technology?**

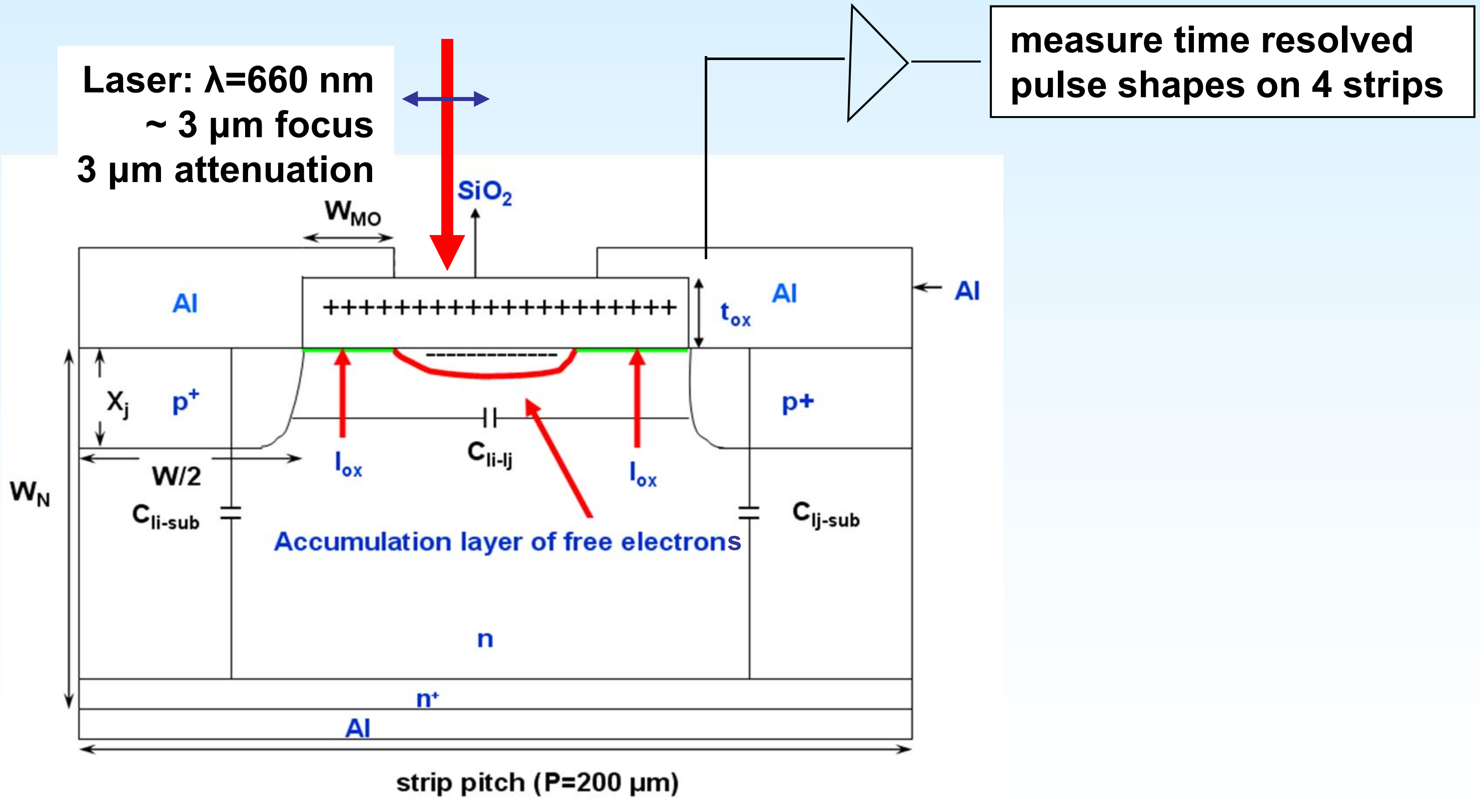
Geometry parameters of DC- and AC-coupled strip sensors:

Parameter	DC-coupled strip sensor	AC-coupled strip sensor
Pitch	50 µm	80 µm
Gap	39 µm	60 µm
Width of implantation	11 µm	20 µm
Depth of implantation	-	1.2 µm
Metal overhang	2 µm	-2 µm
Number of strips	128	98
Length of strips	7956 µm	7800 µm
Thickness of sensor	450 µm	285±10 µm
Thickness of SiO_2/Si_3N_4	334 nm	(200+50) nm & (300+50) nm
Thickness of passivation	1 µm	1 µm
Orientation	(1 1 1)	(1 0 0)

Measurement techniques

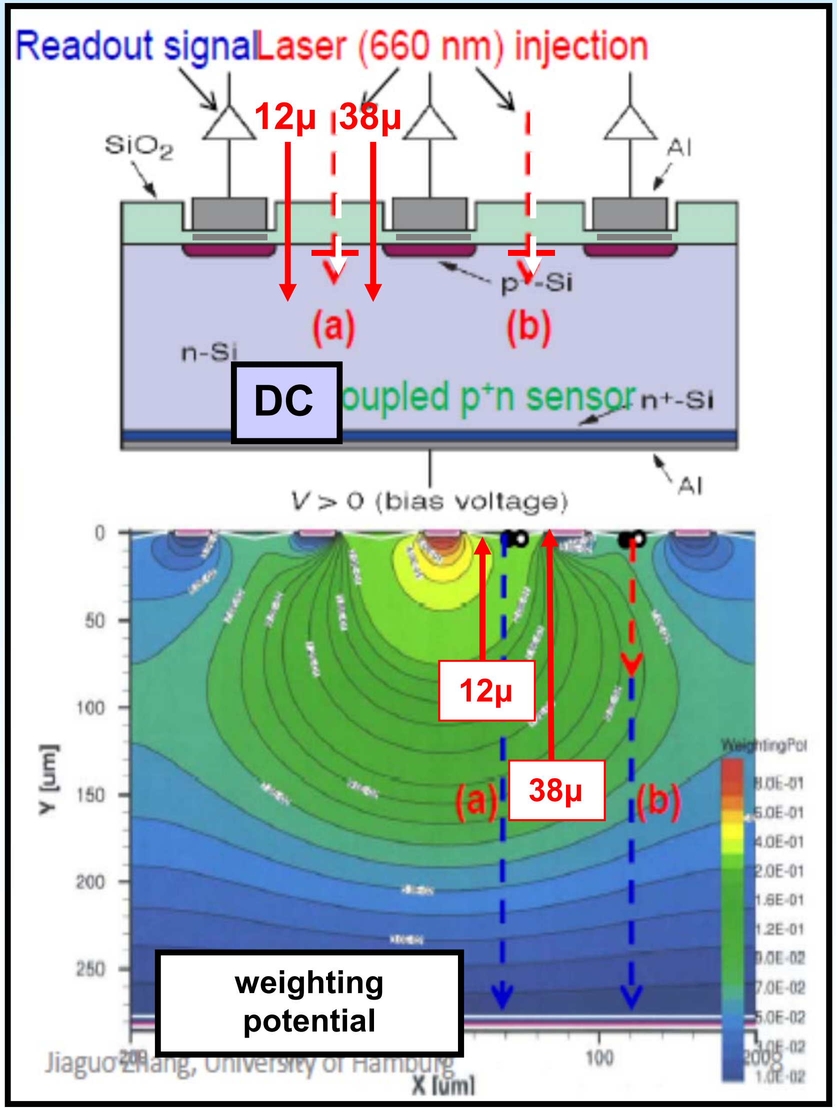
2.2 Scan with laser light

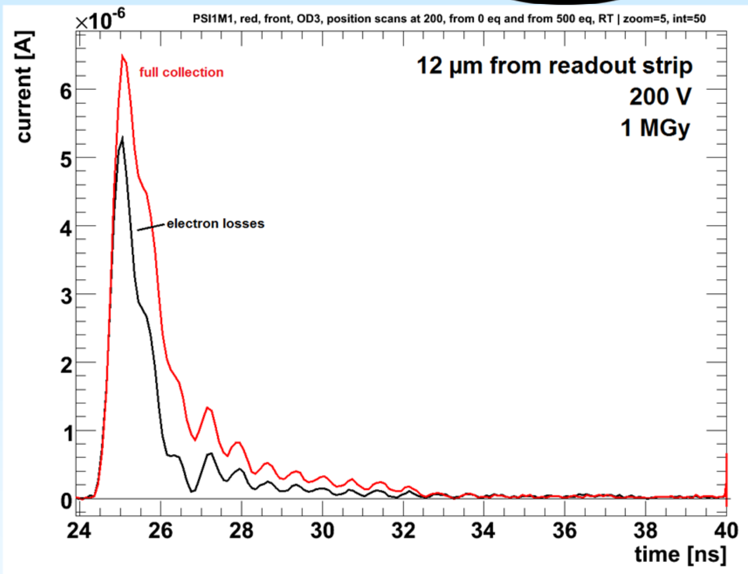
- make voltage scans + change humidity (N_2-jet <-> cup with H_2O)
- measure pulse shape vs. position, time + control (change) humidity
- record also current

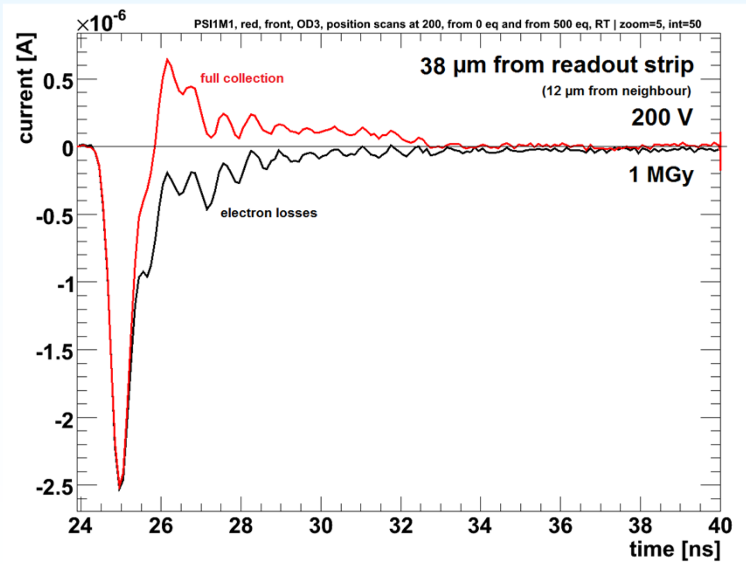


Measurement techniques

2.3 Pattern of electron losses



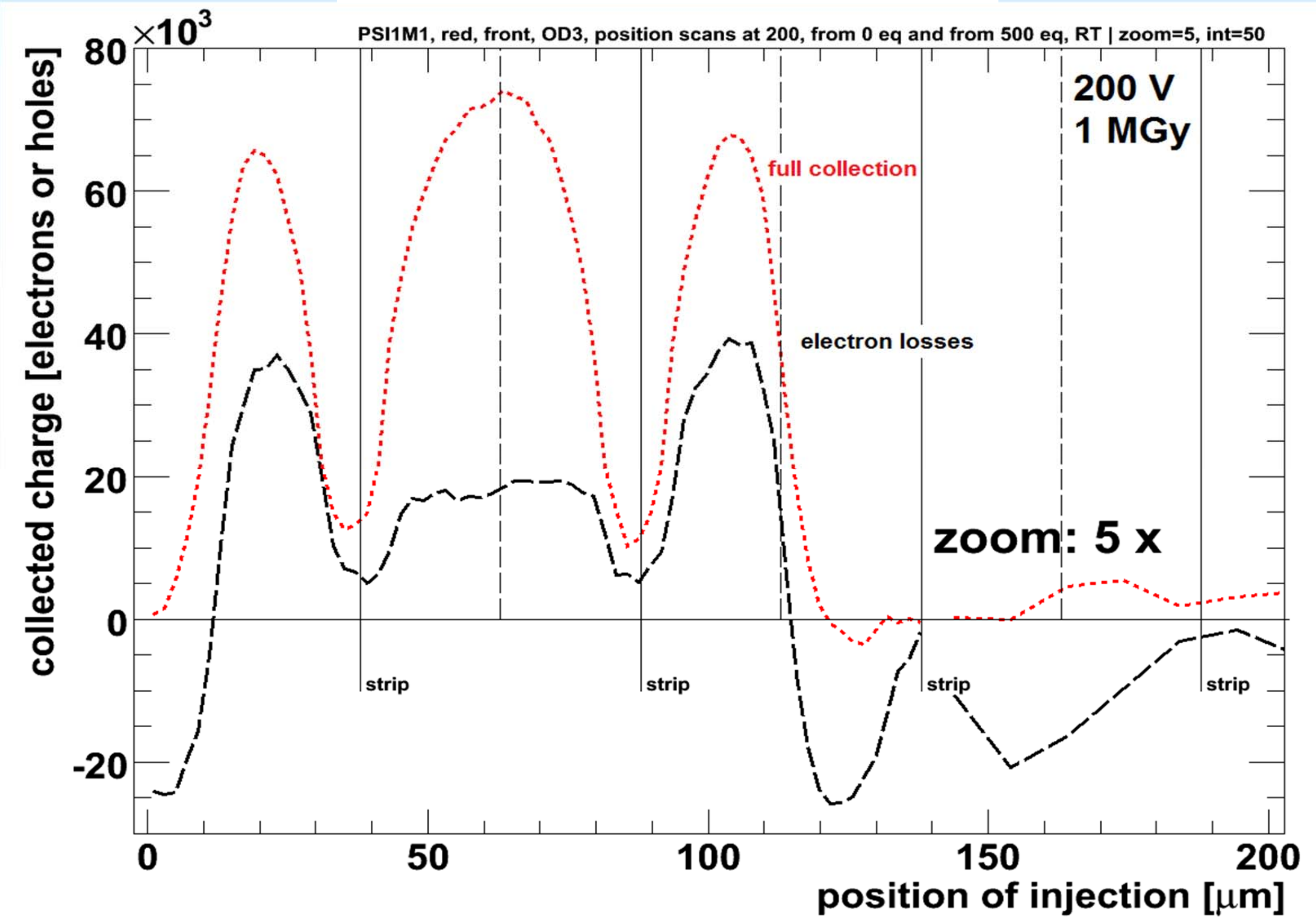




Measurement techniques

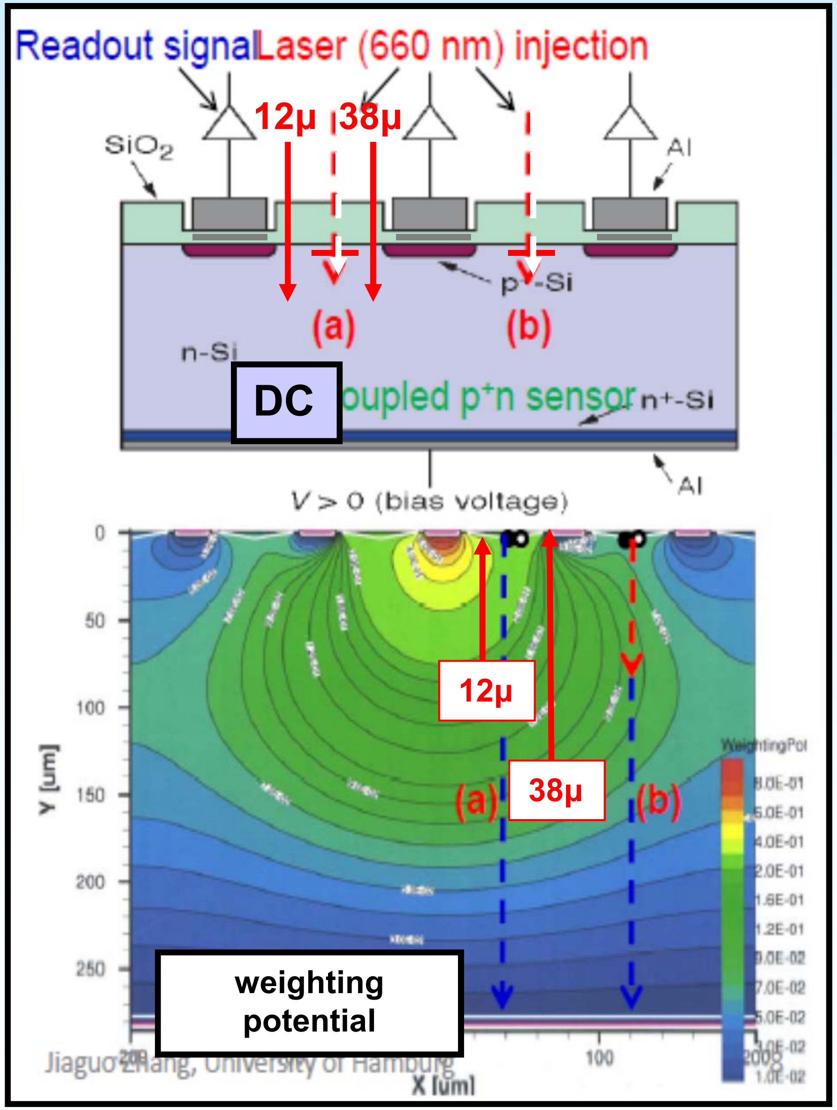
2.3 Pattern of electron losses

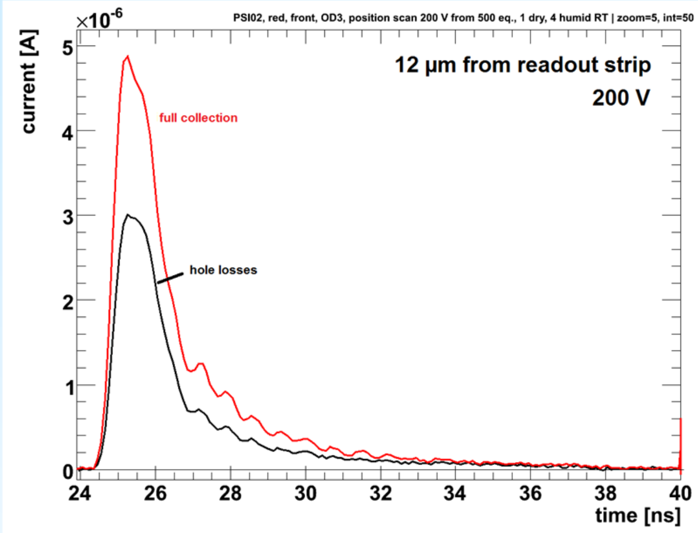
Sum of 2 strips (at 38 and 88 μm)

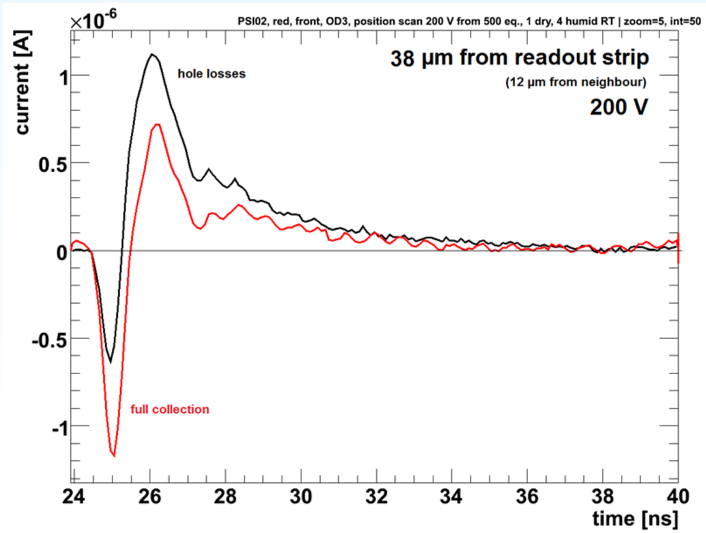


Measurement techniques

2.4 Pattern of hole losses



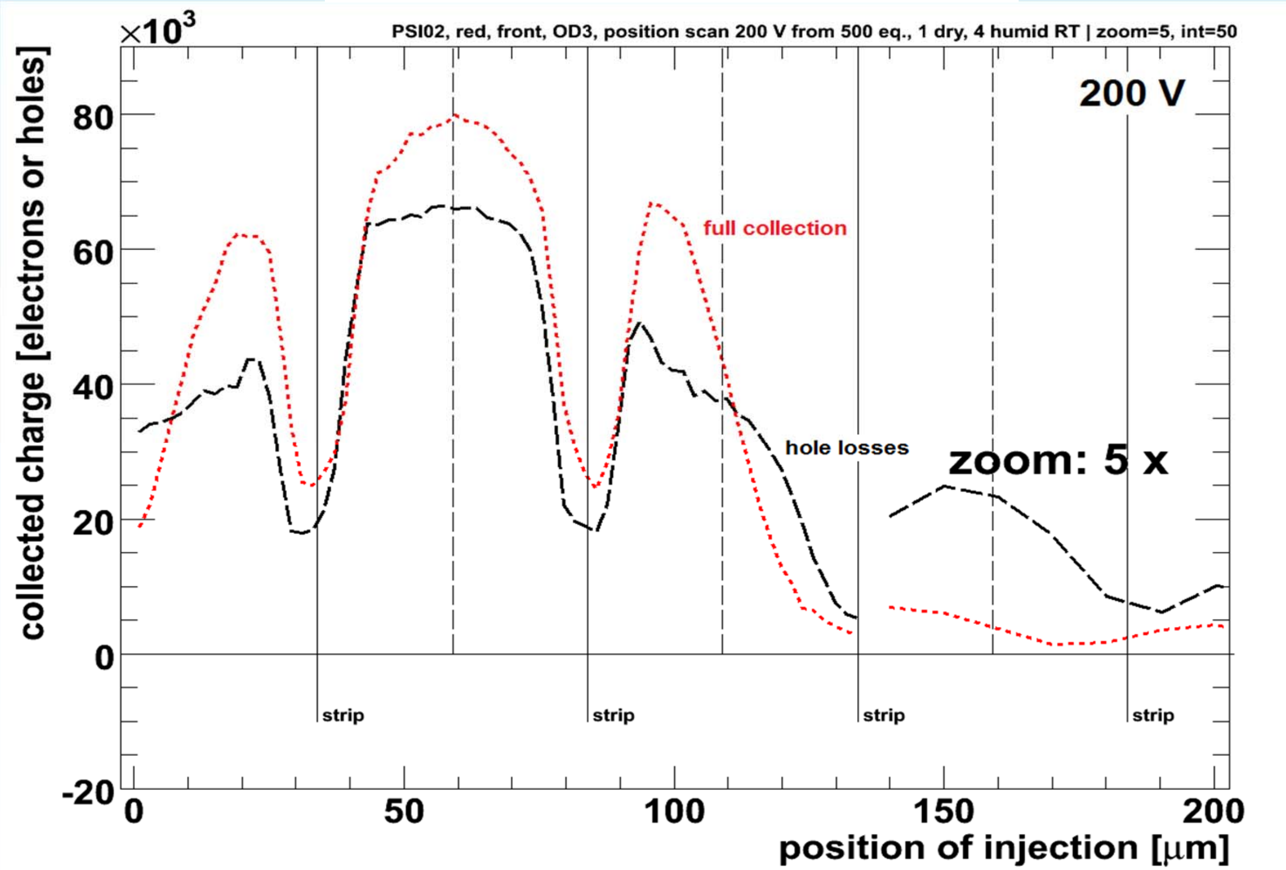




Measurement techniques

2.4 Pattern of hole losses

Sum of 2 strips (at 34 and 84 µm



Results

3.1. Unirradiated sensor

"steady-state" if sensor for some time in "humid" conditions

V-ramp ↑↓ in steady-state → no losses

V-ramp ↑ from steady-state at 0V under "dry" condition: electron losses

- 100 V	~ 60%
- 200 V	~ 40 %
- 300 V	~ 10 %
- 400 V	no losses observed
- 500 V	no losses observed

V-ramp↓from steady-state at 500 V under "dry" condition: hole losses

- 100 V	~ 85%
- 200 V	~ 80 %
- 300 V	~ 75 %
- 400 V	~ 50%
- 500 V	no losses observed

- stable (> 1 day) conditions for "dry = N_2" conditions
- change (< 1 hour) to "steady-state" for "humid" conditions

Results

3.2. 1 MGy irradiated sensor

"steady-state" if sensor for some time in "humid" conditions

V-ramp ↑↓ → **electron losses**
- **100 V ~ 50% e-losses**
- **200 V ~ 45% e-losses**
- **300 V ~ 30% e-losses**
- **400 V ~10% e-losses**
- **500 V ~ 0% no losses**

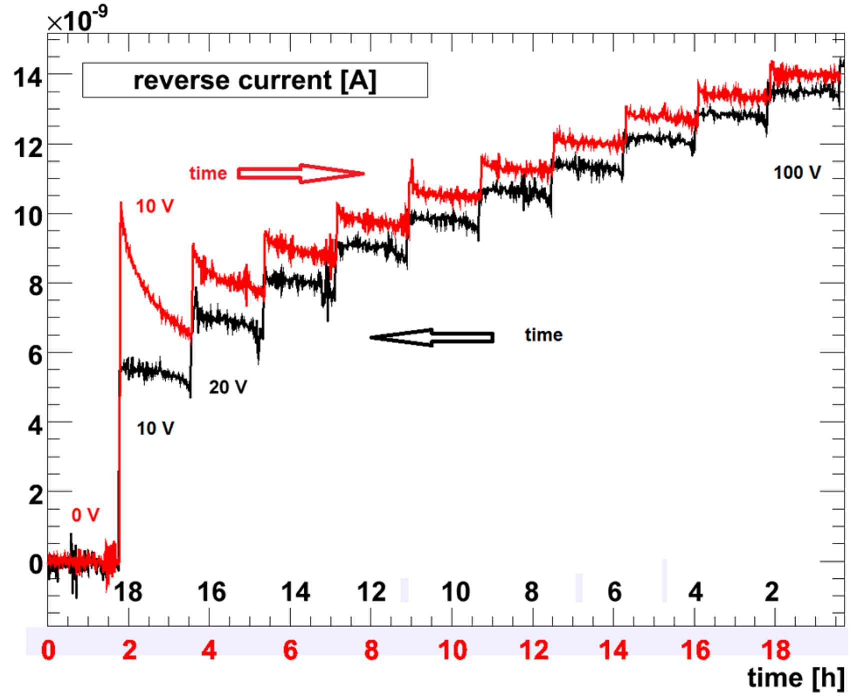
V-ramp ↑ starting from steady-state at 0 V "dry cond." → **electron losses**
- **200 V ~90% e-losses**
- **500 V ~80% e-losses (stable for > 6 h)**

V-ramp ↓ starting from steady-state at 500 V "dry" → **electron losses**
- **200 V ~ 0% losses at t = 0**
  ~ 20% e-losses at t = 6 h

dark current (=surface current) also shows time dependence:

- V-ramp ↑
  → steady-state reached from above

- V-ramp ↓
  → steady-state reached from below



Conclusion

- **Measurements are reproducible !**
- **Similar results for sensors from 2 vendors**
- **Non-irradiated sensors:**
  - **hole or electron losses, depending on direction of voltage ramping for "dry" conditions (stable over > 1day !)**
  - **no losses for "wet" conditions**
- **Irradiated sensor:**
  - **electron losses (NB up to 90 %!) for < 500 Volts**
  - **time dependence of current correlated with e-losses**
- **Physics origin of effect unclear – in particular unclear how to simulate it (boundary conditions on top of oxide an at SiO_2-interface not clear)**
- **Still to understand impact on sensor performance at XFEL**
- **Impacof surface effects on max. operating voltage**
- **Does high conductive passivation stabilize sensors ?**