Physical limits on the inter-strip resistance for planar strip sensors (Effect of R(int) on signal pulses)

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Introduction: R(int) value

Typically for strip sensors we want to have high enough inter-strip resistance to avoid signal spread/sharing between the strips:

- Increased cluster size may lead to worse positional resolution.
  - It may improve it in some cases… but then R(int) needs to be very well controlled!
- Increased charge sharing leads to reduced signal per strip. This is generally undesirable for high radiation damage environment due to signal reduction with fluence.

Sometimes the metric chosen for R(int) is comparison with R(bias), e.g. M. Mikestikova et al, NIM A 831 (2016) 197

This is a sufficient condition, since R(bias) is chosen to be large enough to hold charge during the readout by design:

R(bias)*C(strip) >> t(readout)

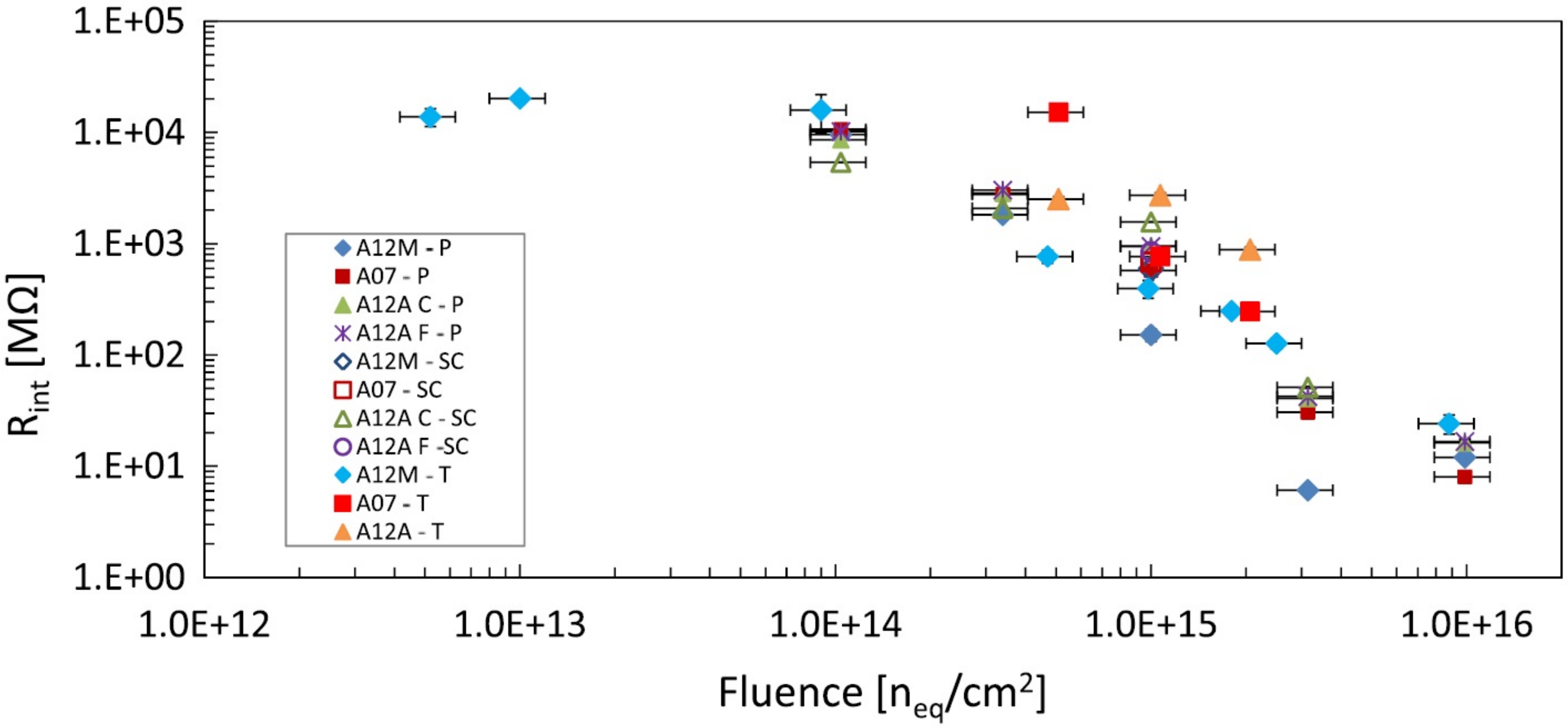
However, how low can R(int) go?

Introduction: R(int) vs Fluence

In a recent study (M. Mikestikova et al, NIM A 831 (2016) 197) R(int) was found to vary very significantly over a large range of fluence. In principle, it may depend on:

1) Ionizing dose through Q(interface) build-up
2) Temperature (current dependence on T), (Y. Unno et al, NIM A 731 (2013) 183)
3) Fluence: if there is acceptor removal in p-stop or p-spray
4) Vbias: Field effect of suppressing lateral charge movement.

p irradiations



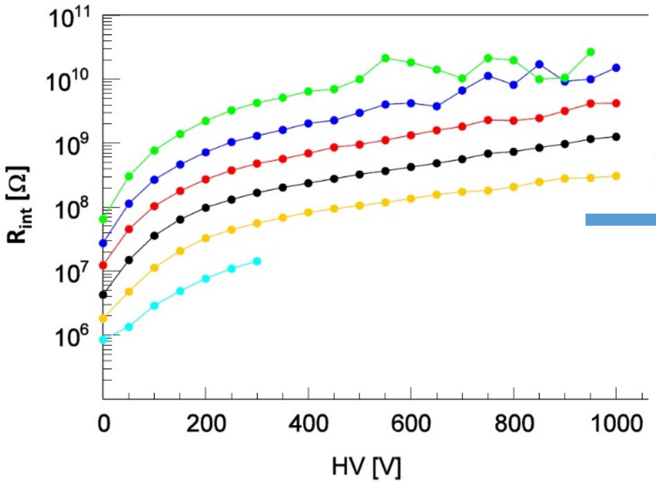
Introduction: R(int) vs Temperature

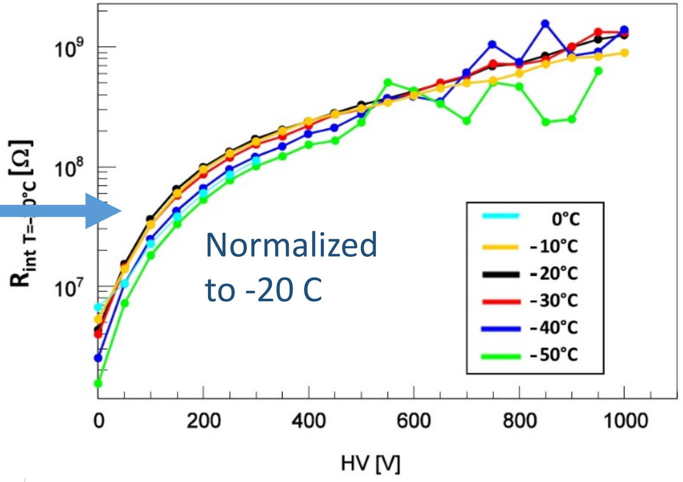
According to TCAD simulations, R(int) ~ 1/I(leak), introducing temperature dependence.

Measurements are roughly consistent with this: variance with temperature is greatly reduced using I (T).

p irradiation

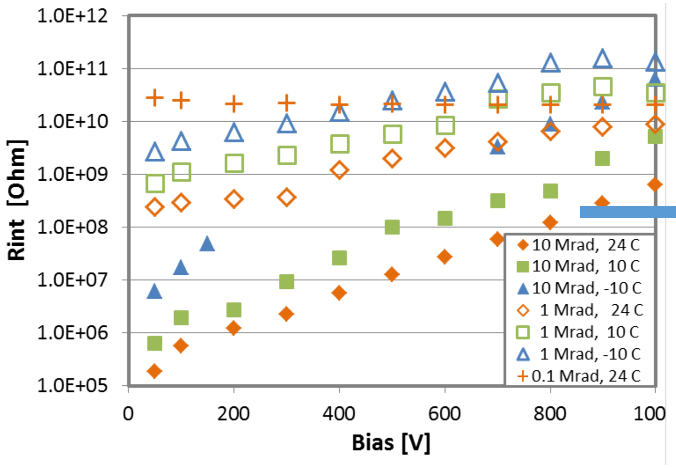
M. Mikestikova et al, NIM A 831 (2016) 197

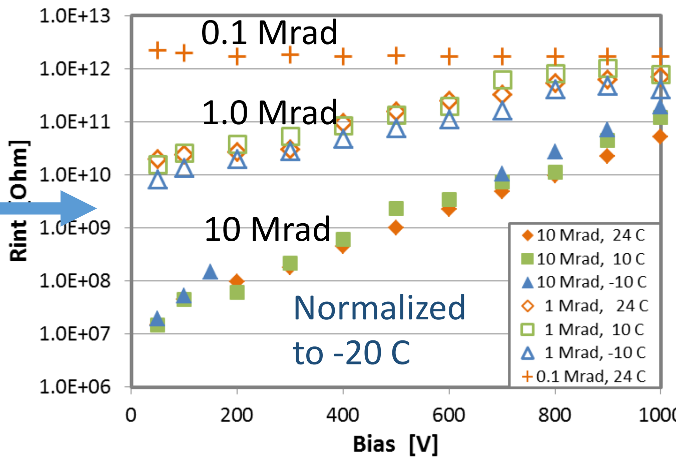




γ irradiation

Z. Liang et al (UCSC)





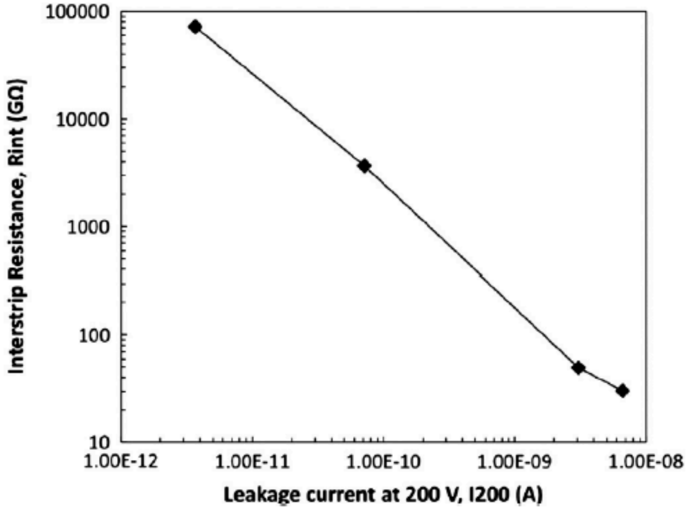
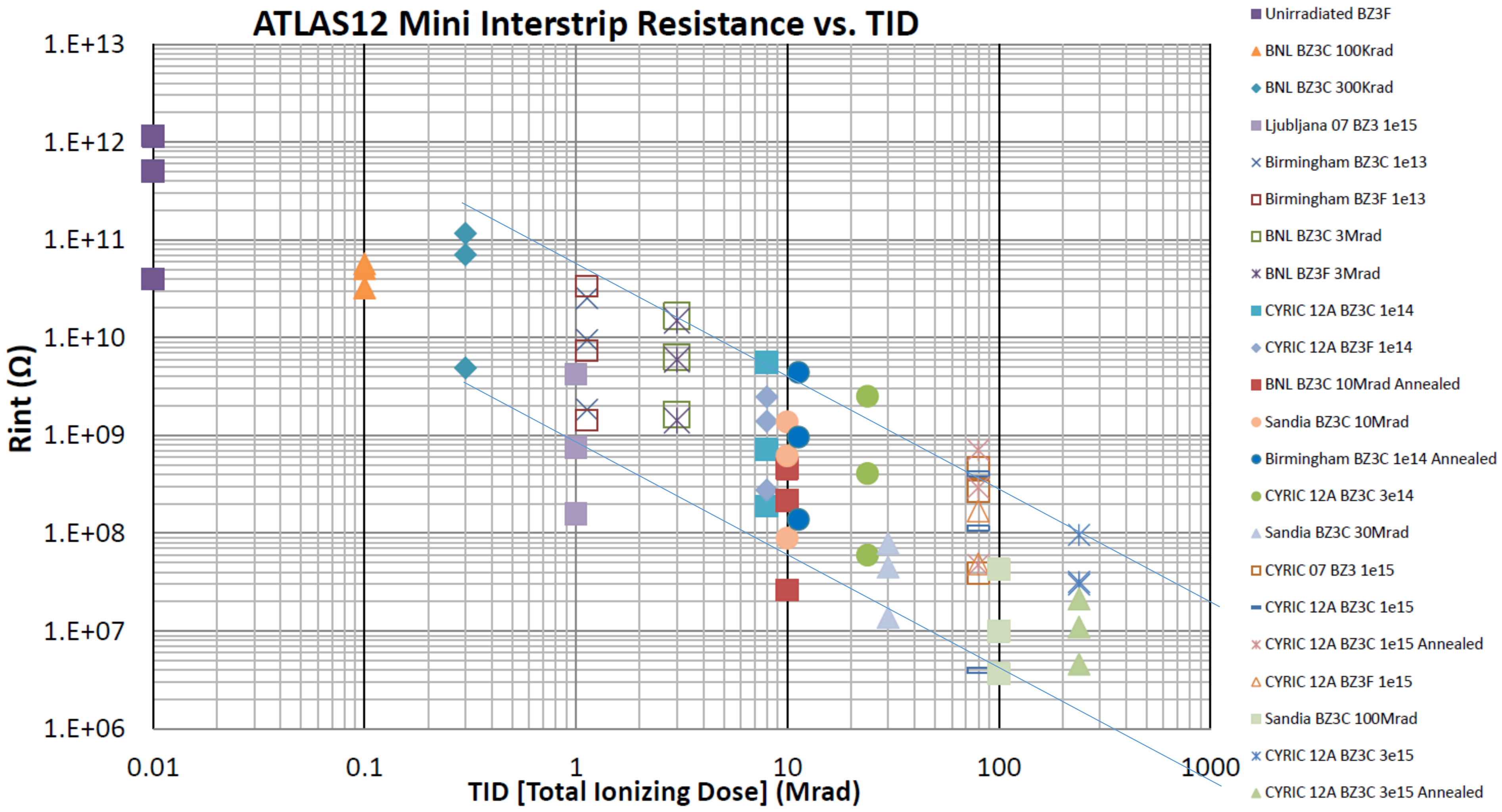


Fig. 7. TCAD simulated interstrip resistance as a function of leakage current.

Y. Unno et al, NIM A 731 (2013) 183

Introduction: R(int) vs Ionizing Dose



K. To,
UCSC Bachelor's Thesis.

Measurements at 10, -5, -15 C for each sensor.

R(int) ~ $\text{Dose}^{-1.1}$

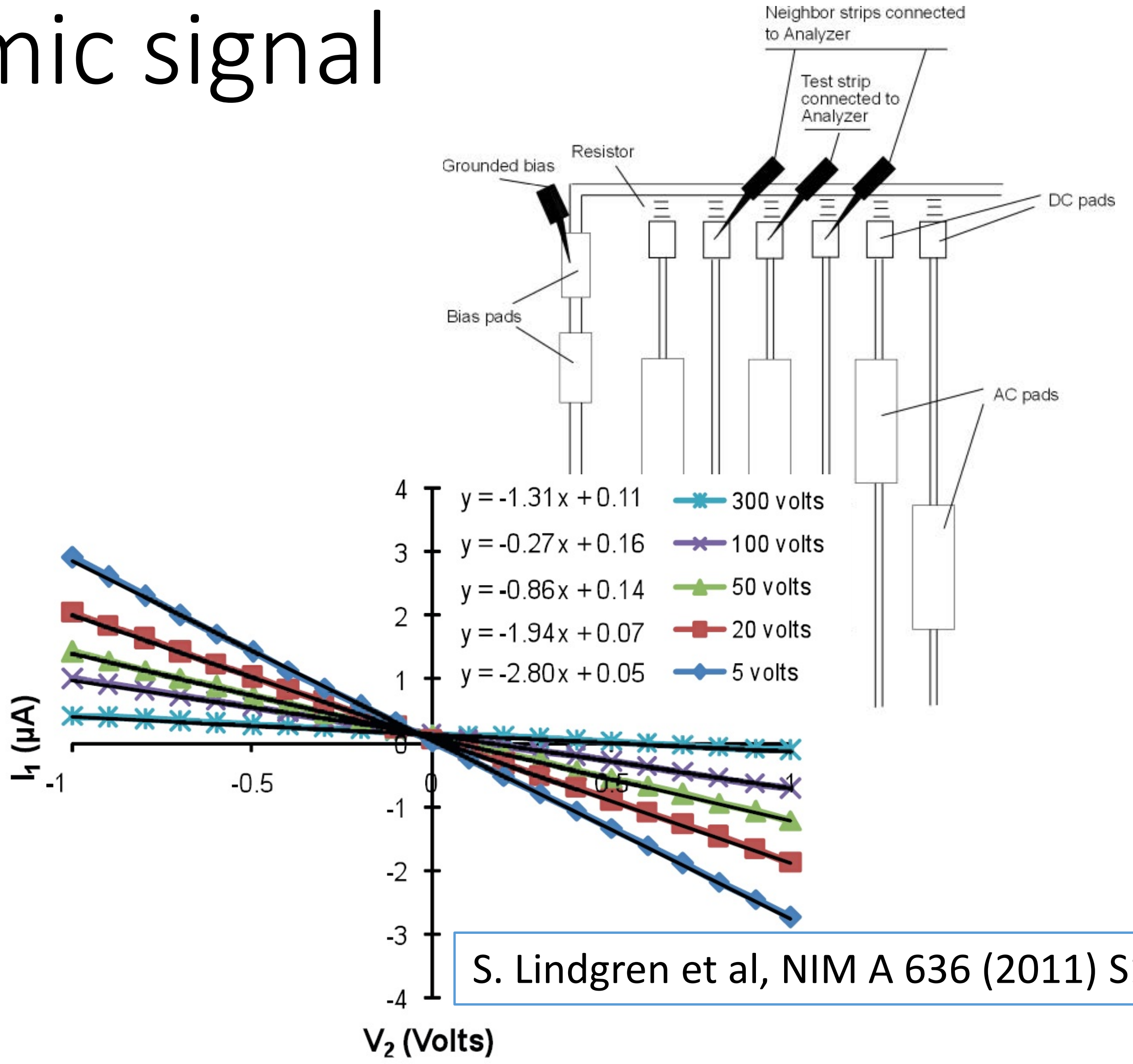
R(int) can get below characteristic scale of 1 MΩ for high dose and/or temperature

Introduction: IV vs dynamic signal

The easiest way to measure R(int) is through static IV measurement between the strip and its neighbors.

In reality the signal time scale (collection and readout) make it a dynamic system.

In principle, one could inject a dynamic signal into a strip. But we decided to simulate a strip system and to see the effect of different R(int) values first.



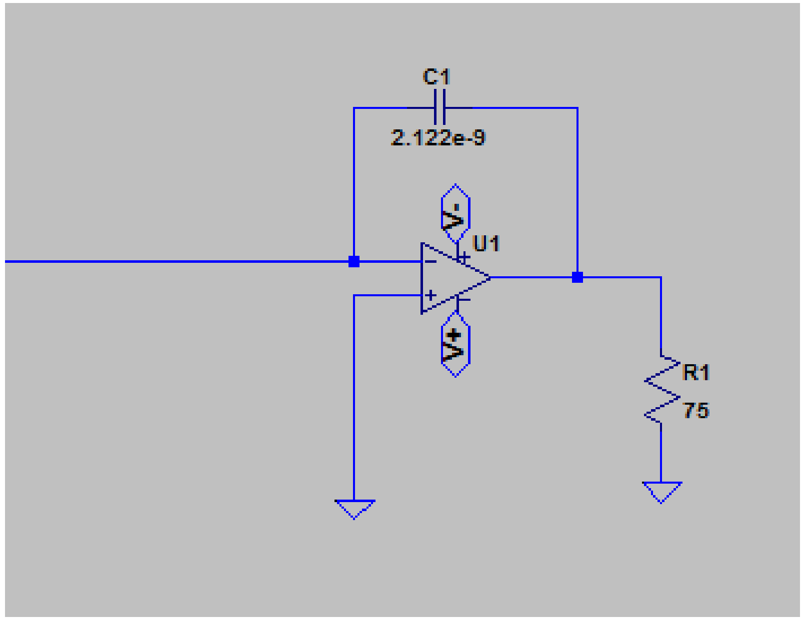
S. Lindgren et al, NIM A 636 (2011) S111

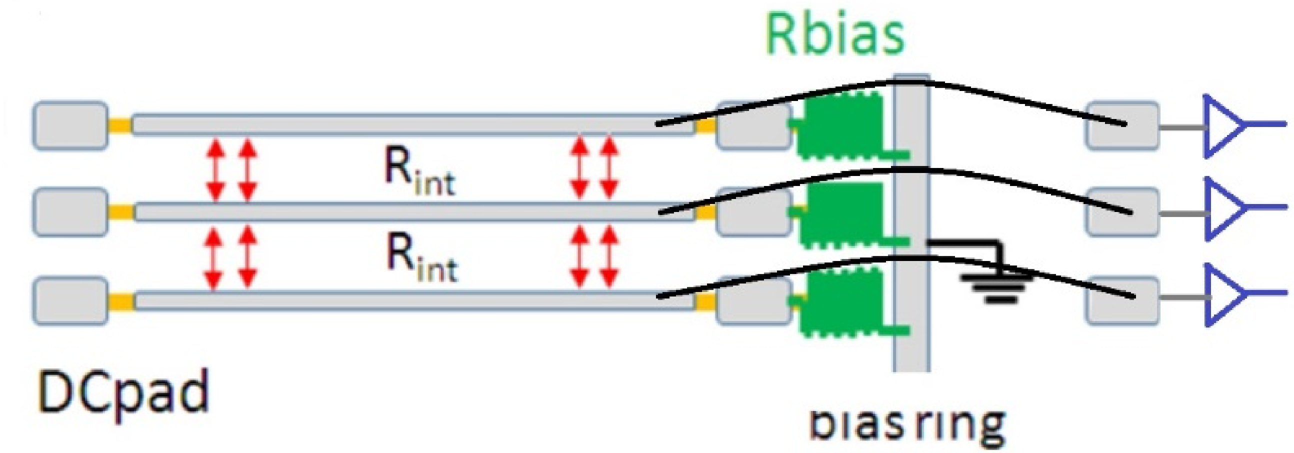
Fig. 3. The current through the test strip vs. the voltage applied to the neighbors

Simulation: Amplifier model

Simulation involving dynamic signal has to incorporate amplifier functionality.

A typical amplifier has input impedance O(100 Ω). In this simulation we used an opamp with feedback capacitance and effective input impedance of 80 Ω.



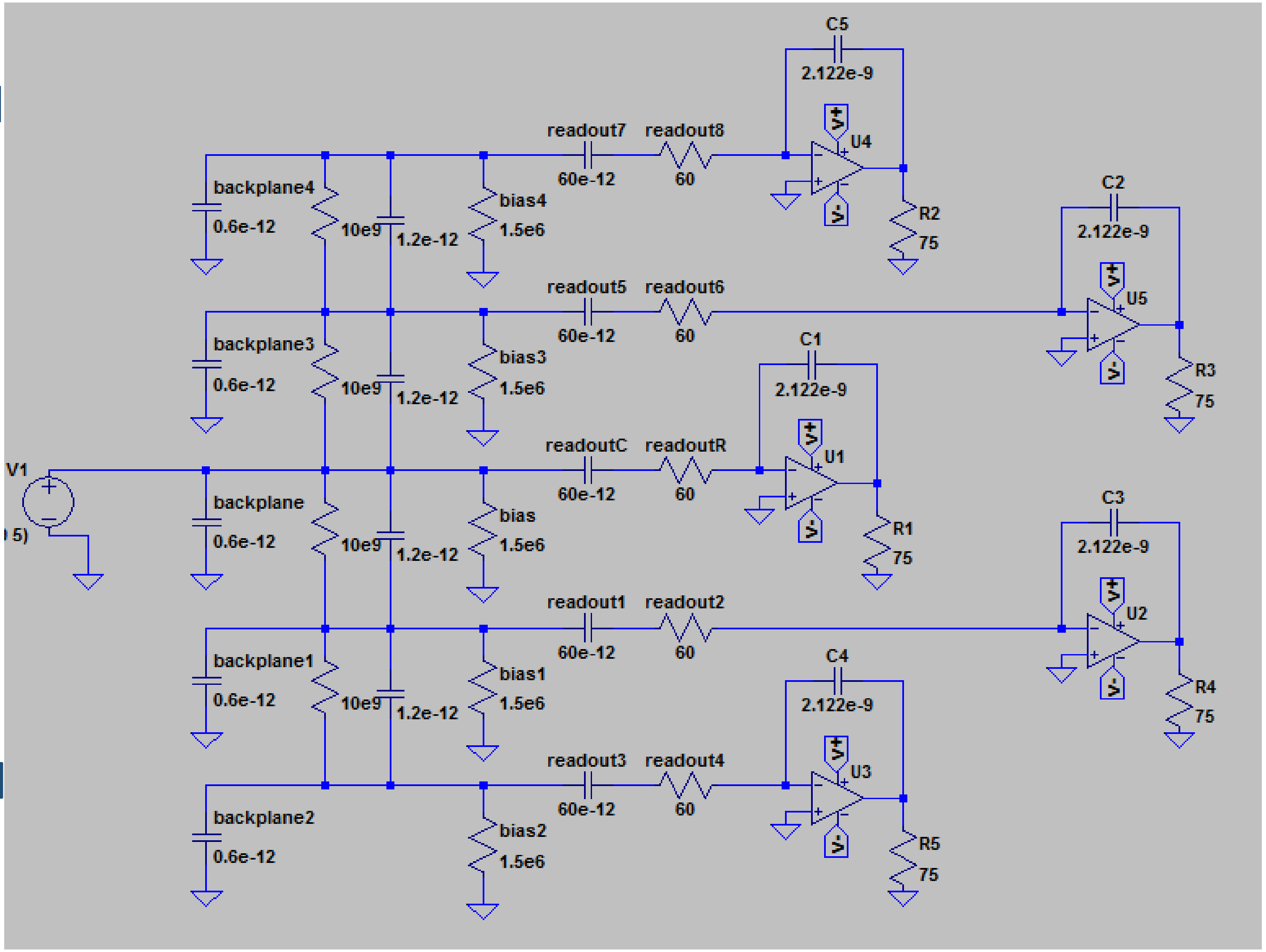


Sensor Model

Created a 5-strip model with typical values of:

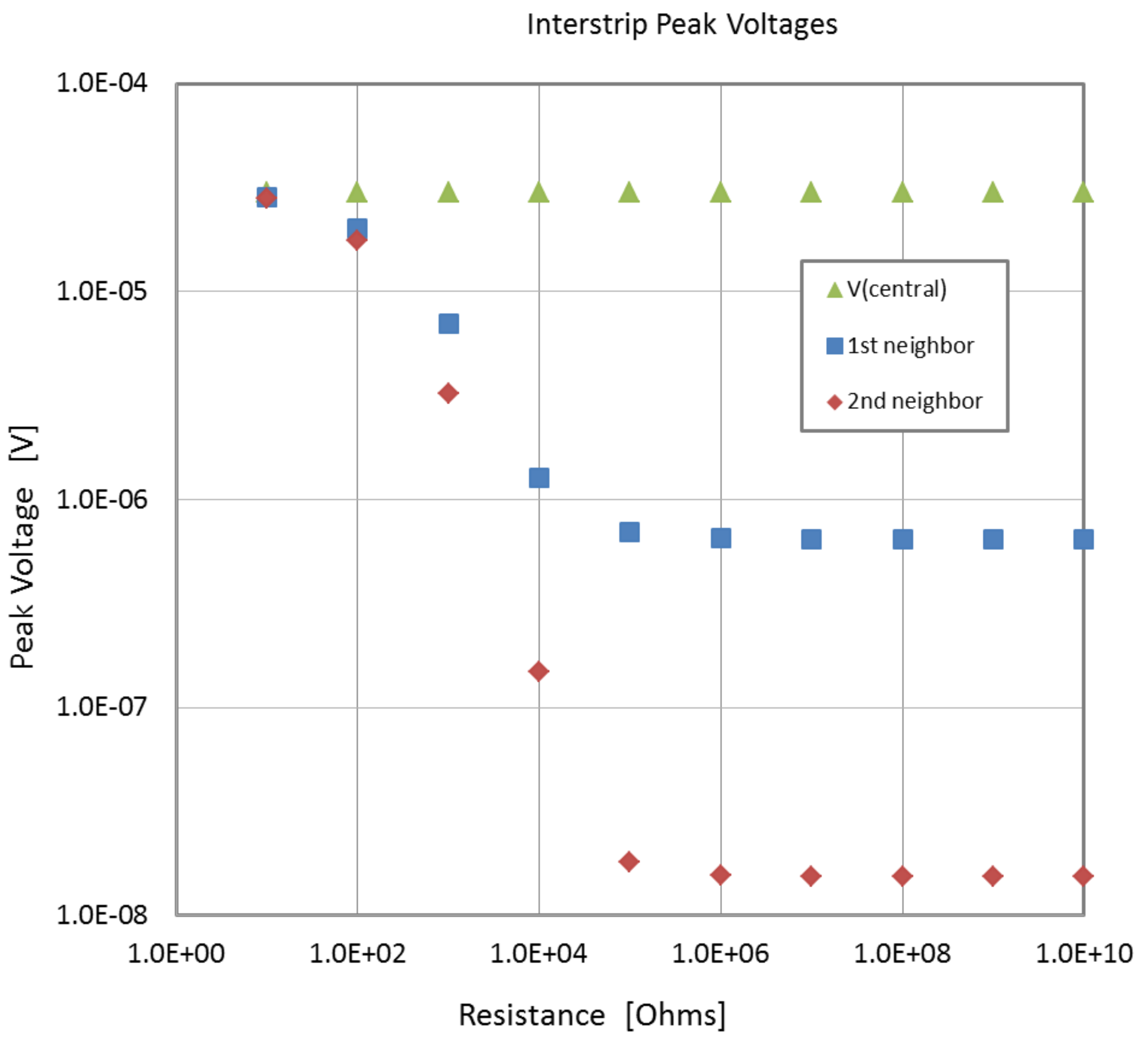
- C(int) = 2.4 pF
- C(back) = 0.6 pF
- C(couple) = 60 pF
- R(strip) = 60 Ω
- R(bias) = 1.6 MΩ
- R(int) = 10^{1}-10^{10} MΩ

Injected charge in the central strip, looked at the amplifier pulses on the preamp output for the strip and the neighbors.



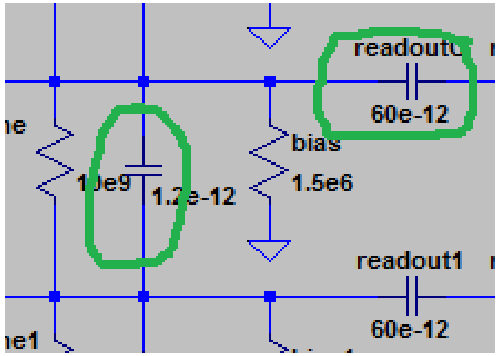
Results for pulse maxima (0)

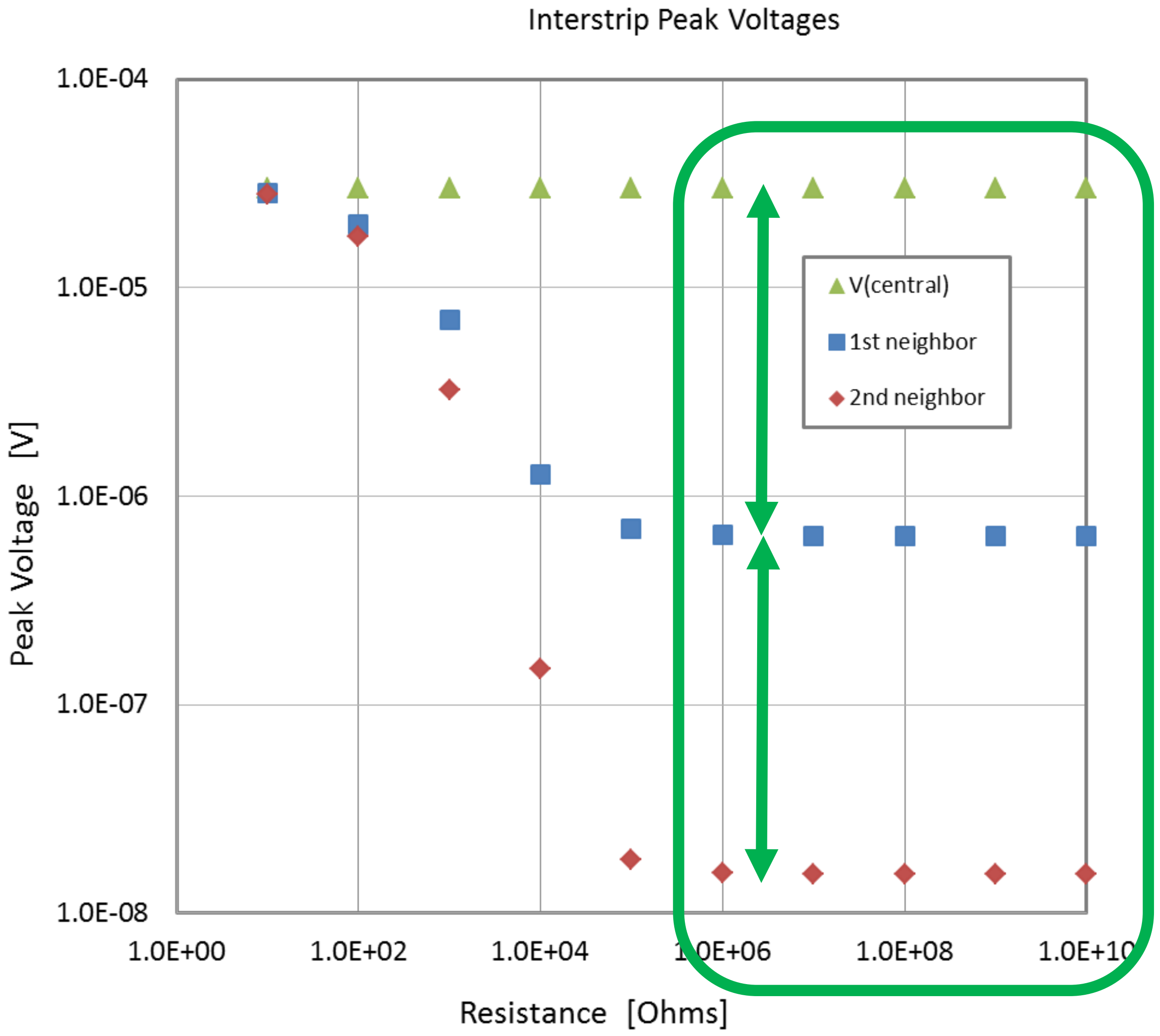
We varied the R(int) value in the simulation and looked at pulse maxima on the central strip and its neighbors. There are several features of the resulting plot.



Results for pulse maxima (1)

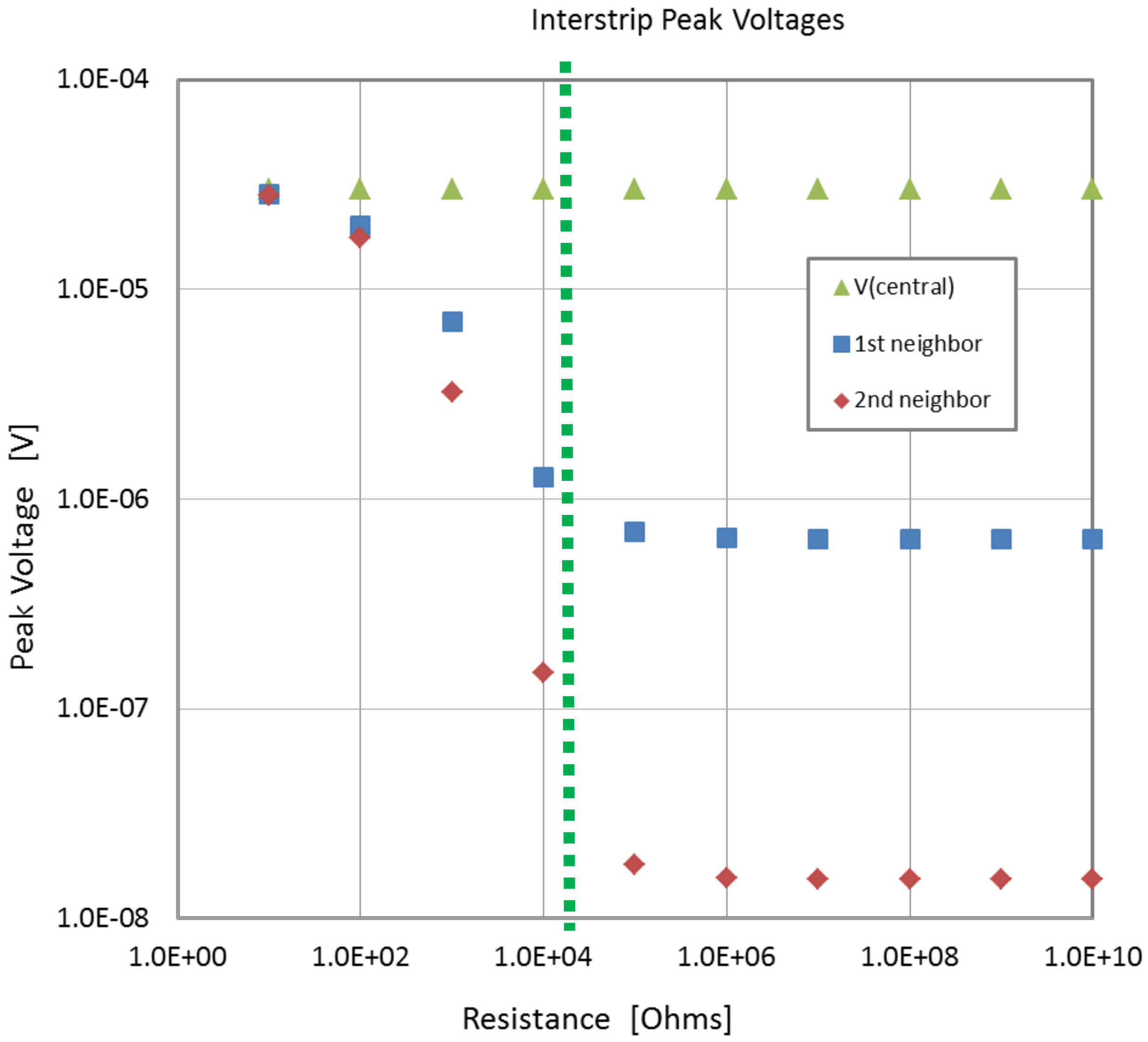
- The neighboring signal is flat at high R(int). A capacitive charge division between the coupling capacitor and C(int) ?
  - $V(\text{central})/V(1^{st}) = 46.$
  - $V(1^{st})/V(2^{nd}) = 42.$
  - Values in simulation: C(couple)/C(int) = 50.





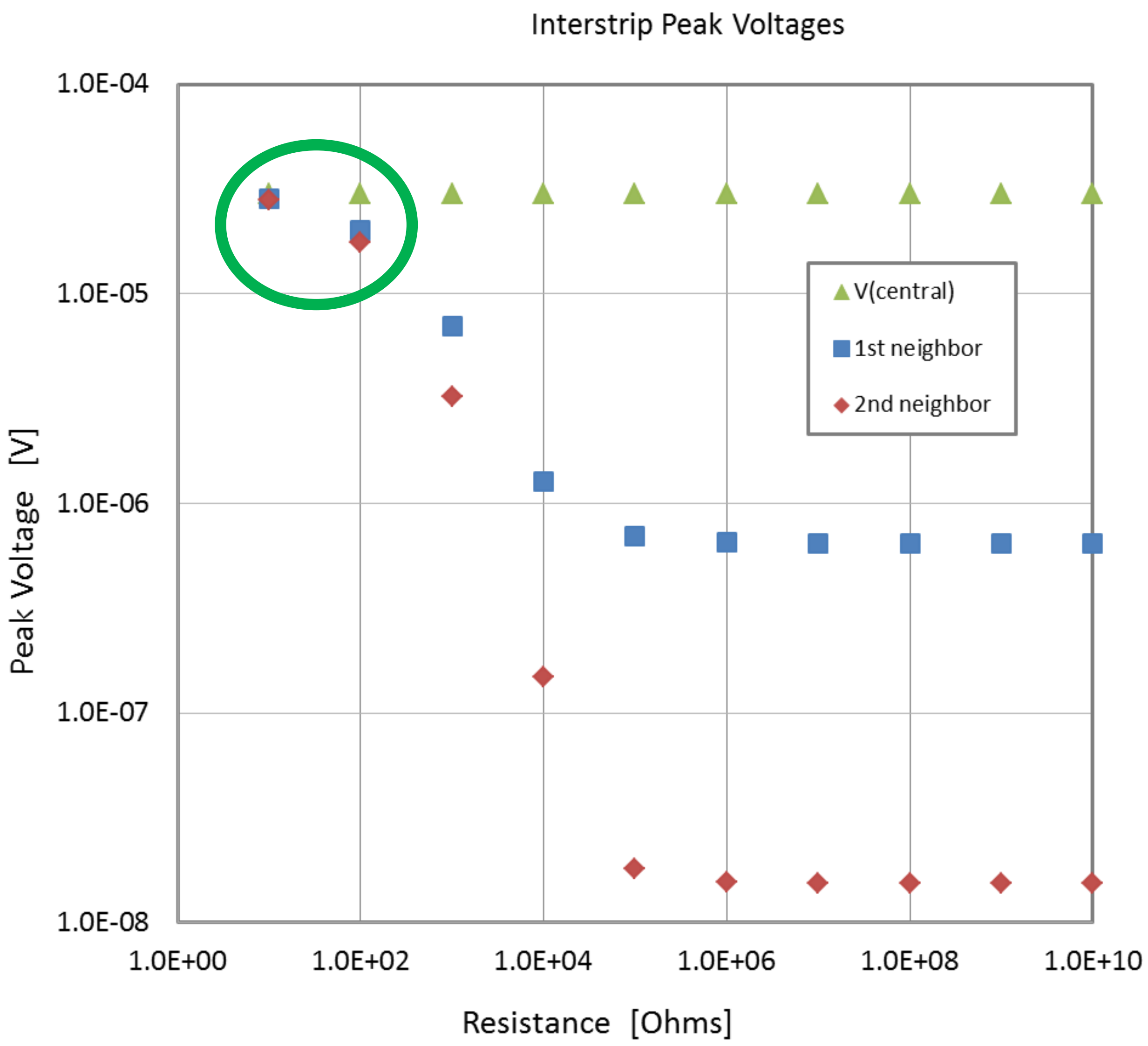
Results for pulse maxima

- Neighbor signals rises significantly below R(int) = ~10 kΩ. A competition with C(int)? A simple estimate of 1/(ωC) => 55 kΩ.



Results for pulse maxima

- V(central) is too flat at low R(int). Likely due to signal modeling as voltage source (should've had finite charge)



Conclusions

Interstrip resistance has significant dependence on ionization dose, temperature, voltage, possibly fluence. Roughly R(int) ~ Dose$^{-1.1}$. It is possible to have R(int) ~< R(bias) for high doses and/or extreme operation conditions.

Looked at a SPICE model of a sensor with preamps to identify values of R(int) that start to affect signal spread to neighboring strips:

- It seems that for high R(int) the neighbor's signals are x50 less than for the primary strip, likely determined by the ratio of coupling and inter-strip capacitances.
- R(int) value where the neighbor signal starts to rise above this level is about 10 kΩ, a lot lower than the typical R(bias) ~ 1 MΩ

To-do:

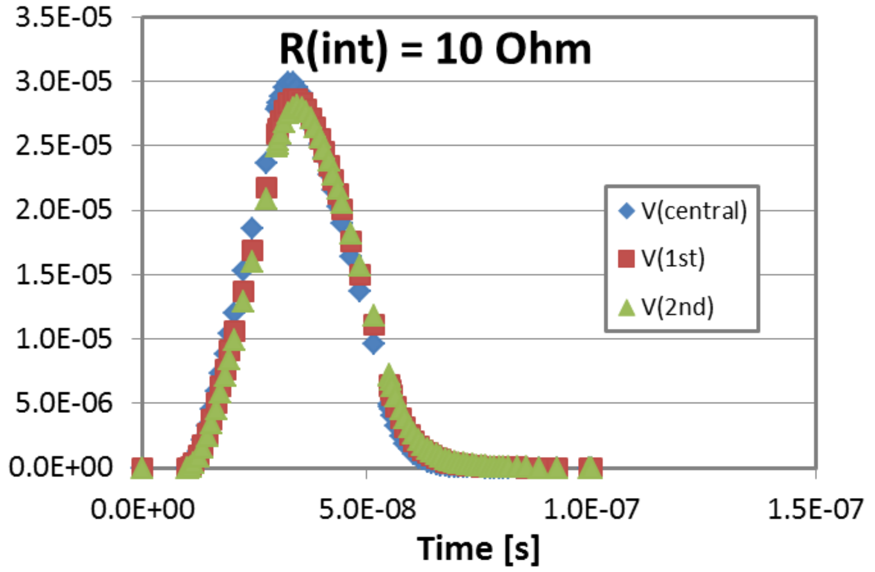
1) fix the simulation issues (Zin and pulse modeling.)

2) Find out what the 10 kΩ value depends on.

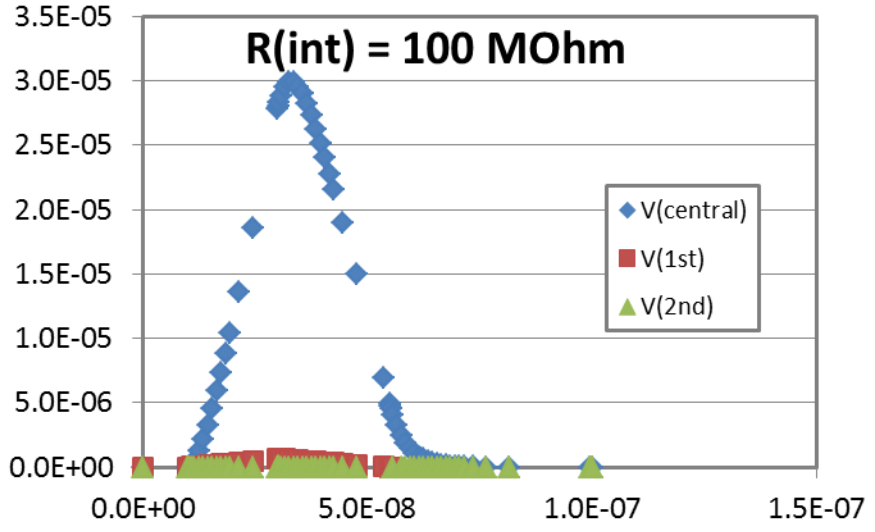
It would be of interest to do a practical test. However, one would need to get such low R(int) values, perhaps with extra resistors in a test strip sensor.

Backup

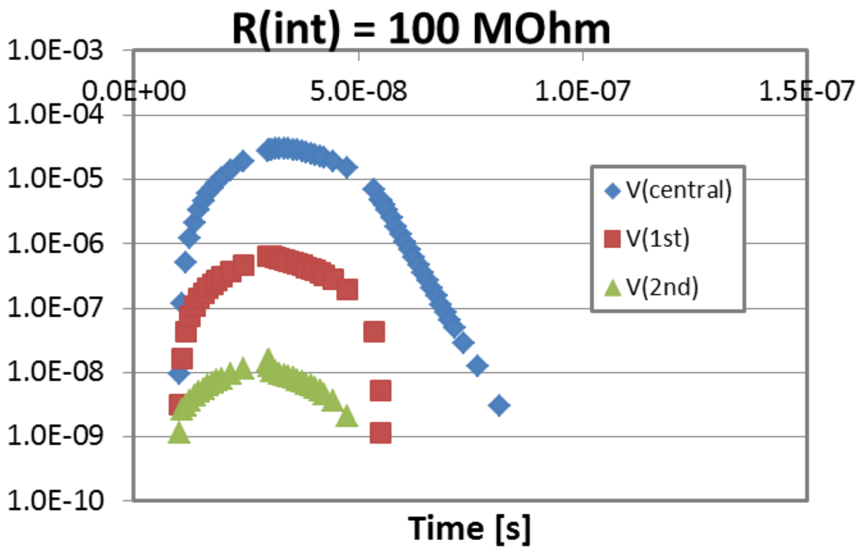
Waveforms



R(int) = 10 Ohm
3.5E-05
3.0E-05
2.5E-05
2.0E-05
1.5E-05
1.0E-05
5.0E-06
0.0E+00
0.0E+00
5.0E-08
1.0E-07
1.5E-07
Time [s]
V(central)
V(1st)
V(2nd)



R(int) = 100 MOhm
3.5E-05
3.0E-05
2.5E-05
2.0E-05
1.5E-05
1.0E-05
5.0E-06
0.0E+00
0.0E+00
5.0E-08
1.0E-07
1.5E-07
V(central)
V(1st)
V(2nd)



R(int) = 100 MOhm
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
0.0E+00
5.0E-08
1.0E-07
1.5E-07
Time [s]
V(central)
V(1st)
V(2nd)

V(bias) dependence