PSFC

Alcator C-Mod

Halo current measurements using Langmuir 'rail' probes in Alcator C-Mod

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Outline

- Motivation
- Langmuir ‘rail’ probes
- Edge safety factor
- Halo flux width
- Halo region resistivity
- Summary

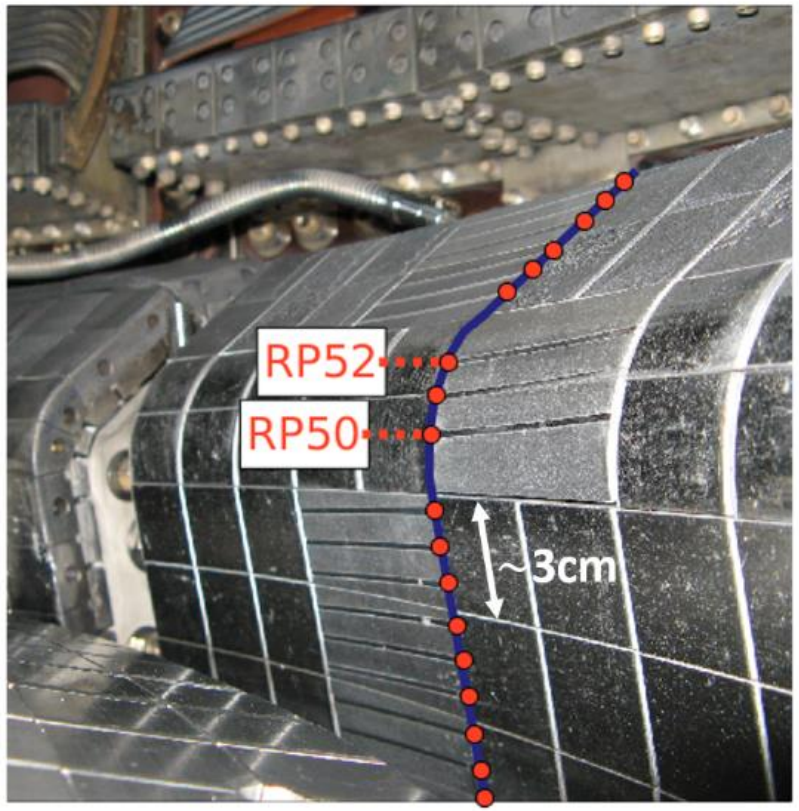
Motivation: Accurate predictive modeling of halo currents is needed for future devices like ITER

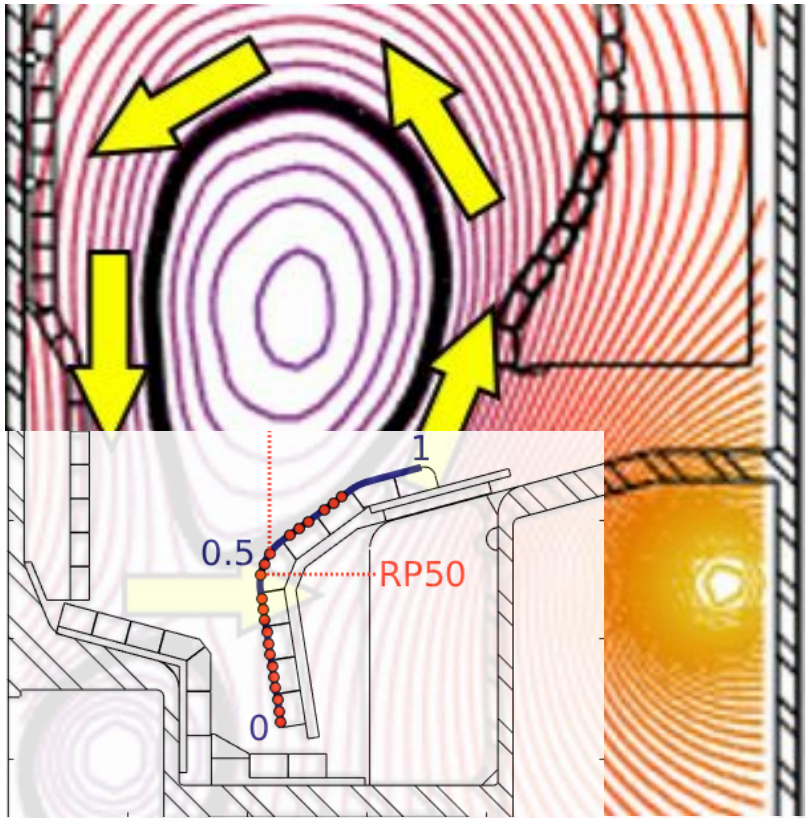
Simulation inputs:

- Halo region resistivity/temperature
- Halo flux width
- Edge safety factor q_{edge} “triggers”

Sayer NF 1993
Bandyopadhyay IAEA FEC 2008
Paccagnella NF 2009

Measurements from a new poloidal array of Langmuir ‘rail’ probes in C-Mod can help guide simulation efforts





Kuang NME 2016
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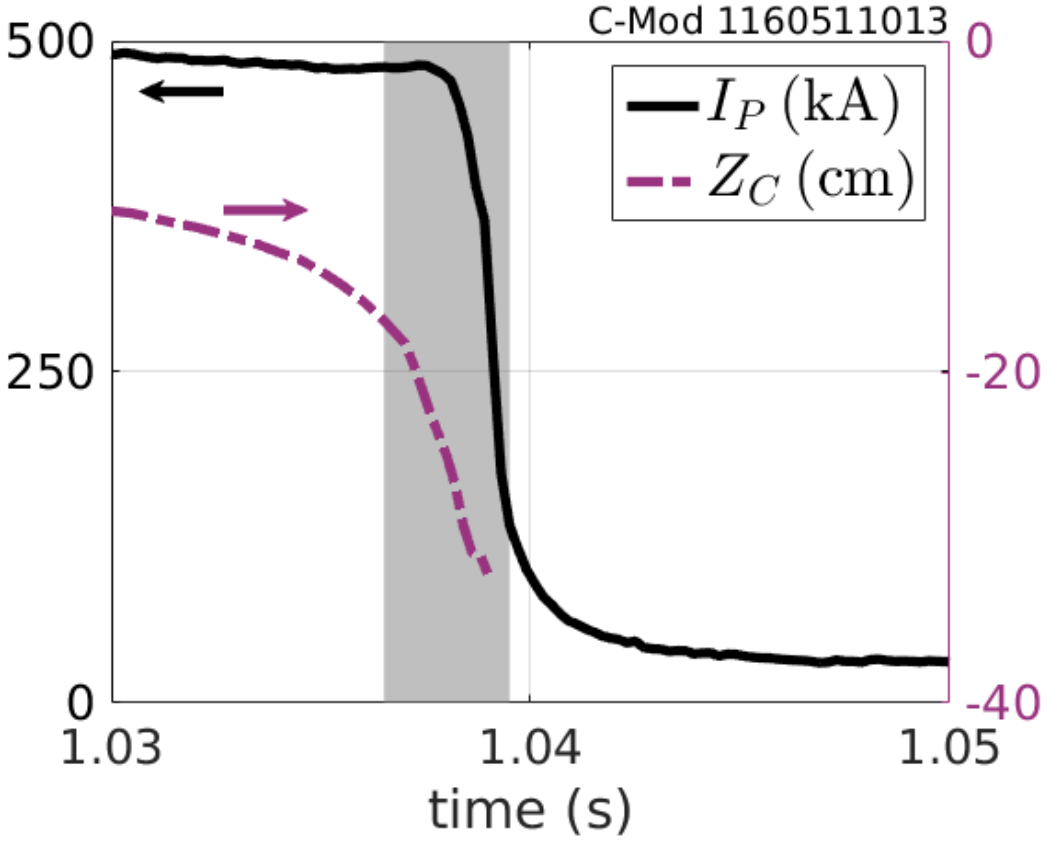
Rail probes measure plasma “sliding” down the divertor during downward Vertical Displacement Events (VDEs)



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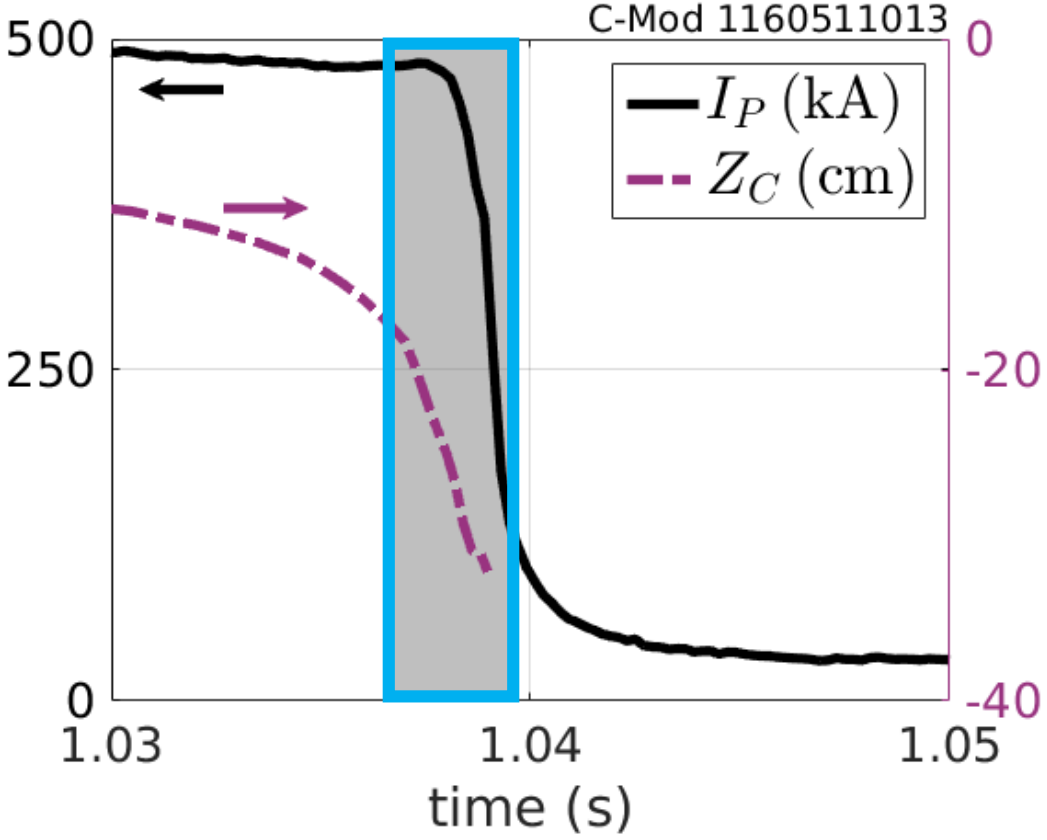
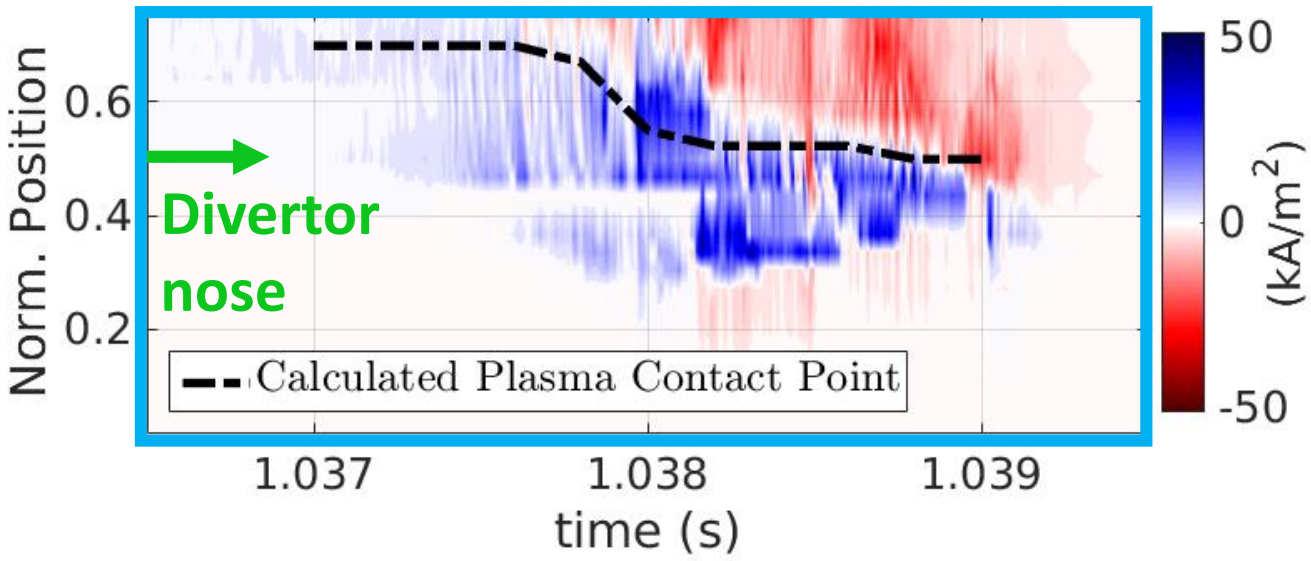
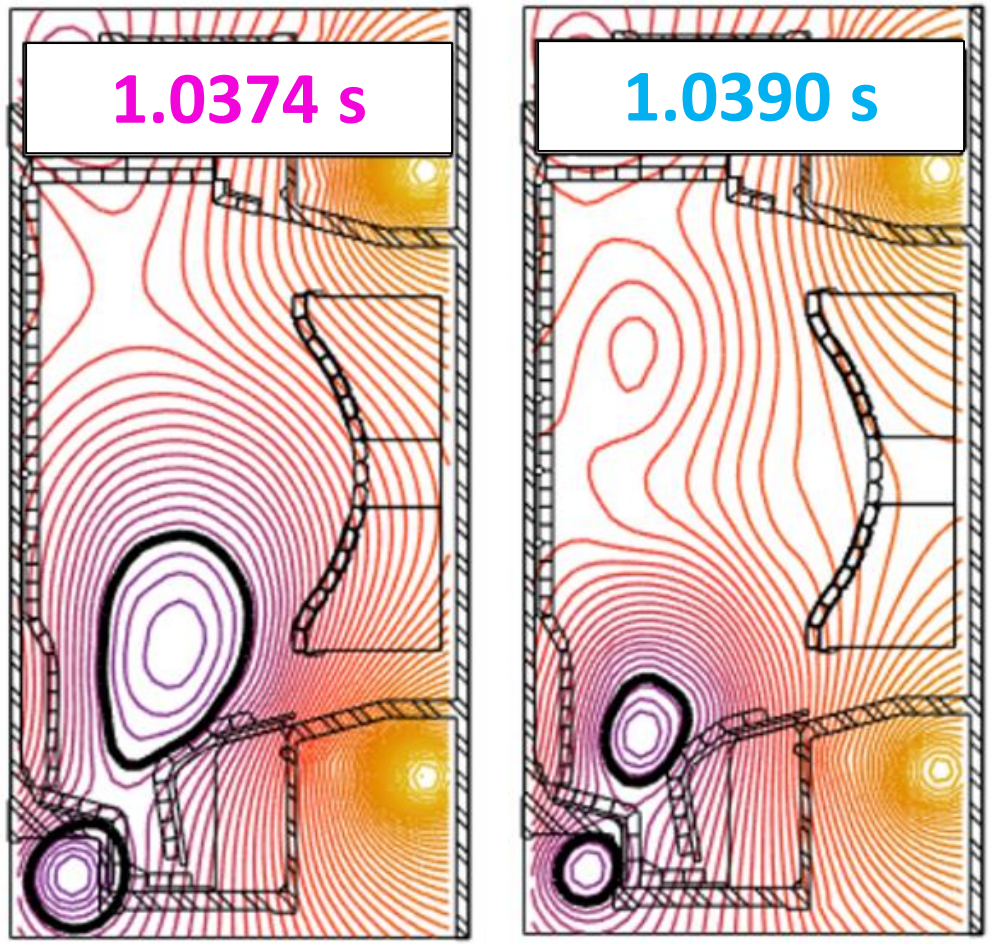


Blue/**Red** = current flowing ***into***/***out of*** probe



Magnetic reconstructions of the plasma boundary match the plasma-divertor contact point with experiment



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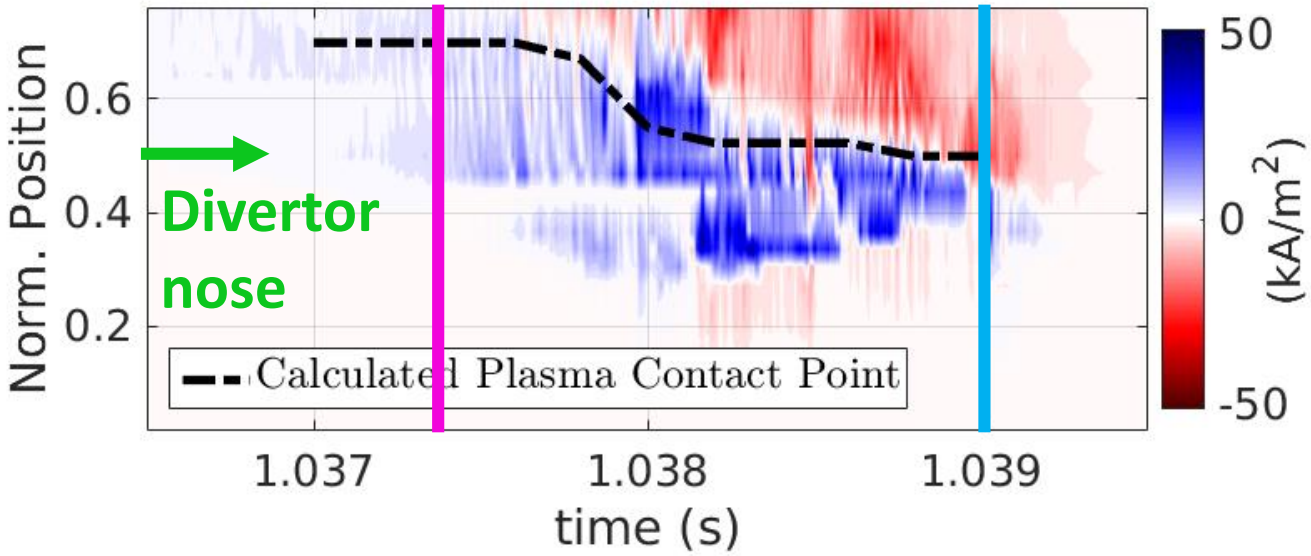

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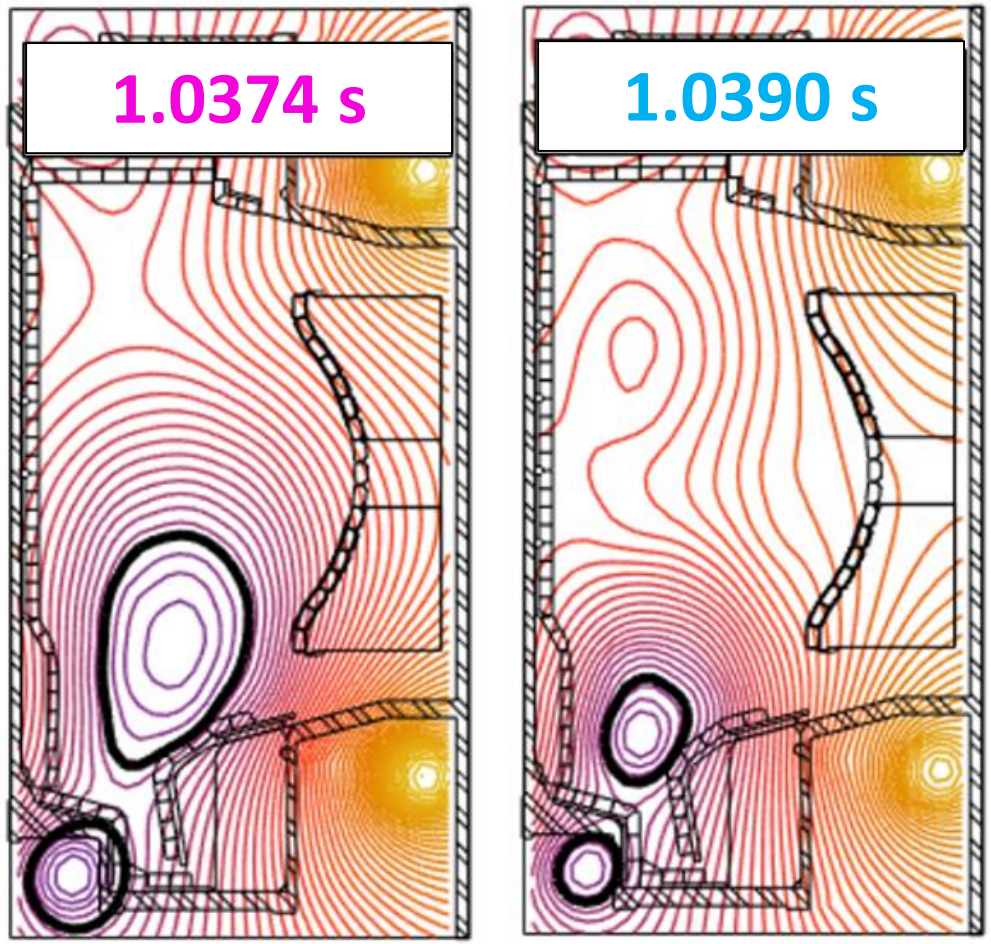

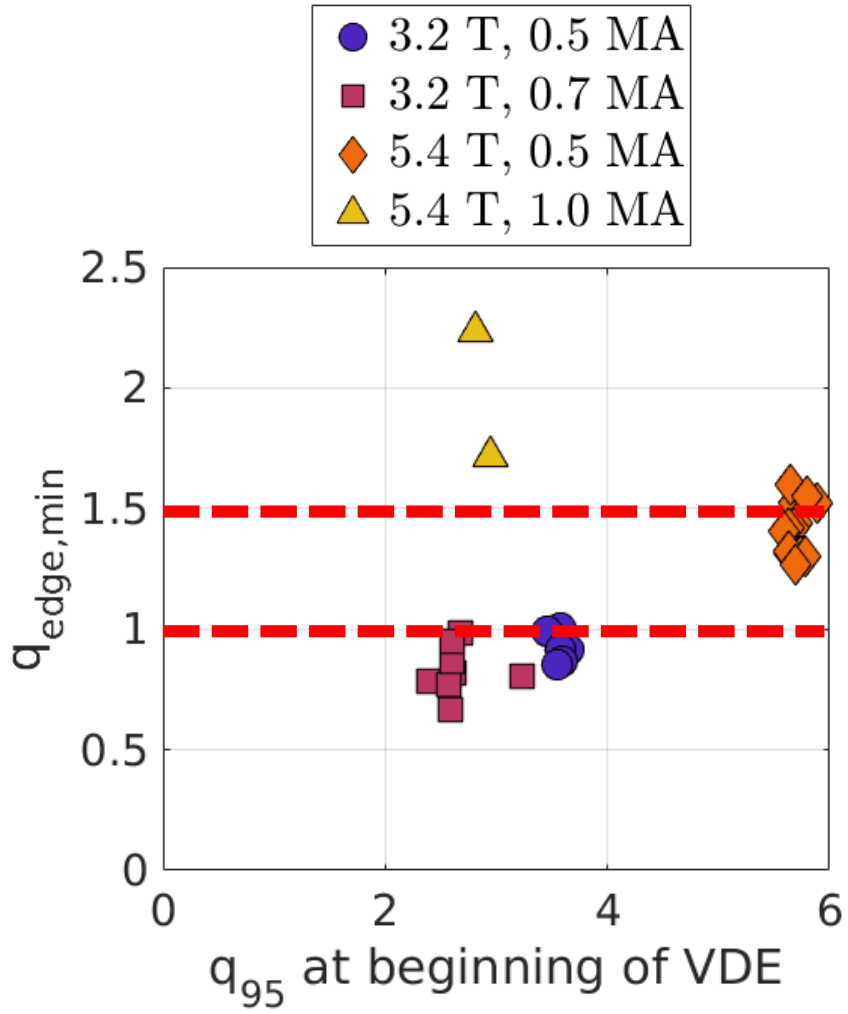

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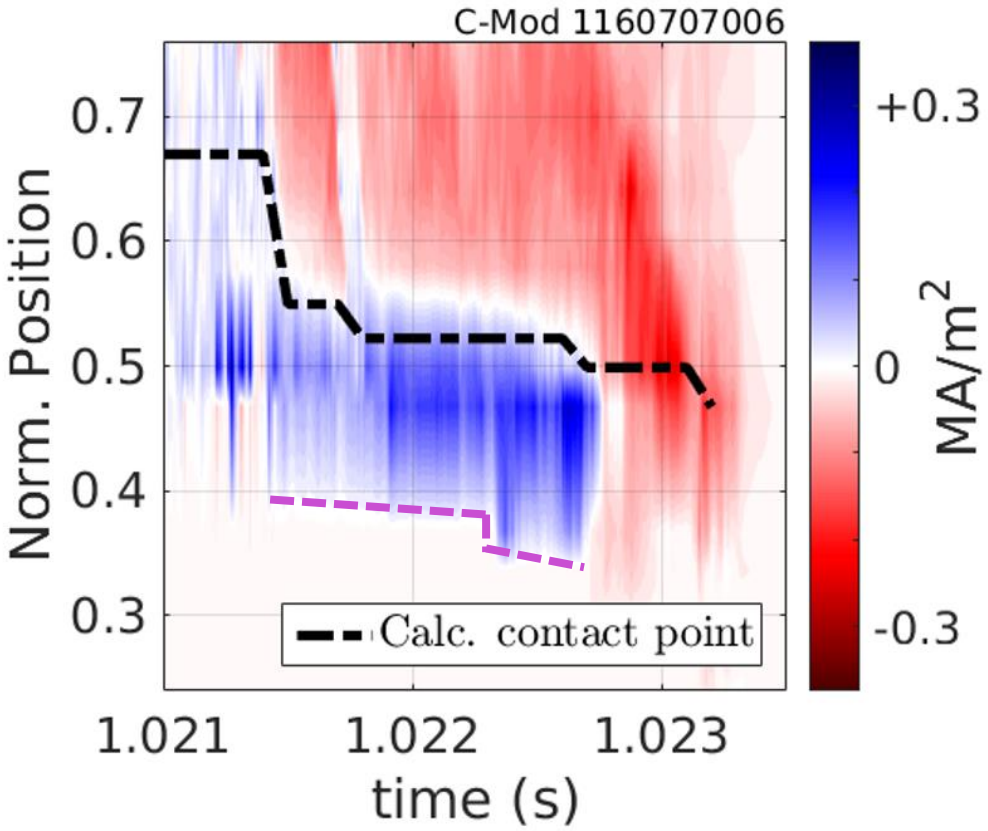
Halo flux width calculated from the halo current "footprint" on the divertor is consistent with simulations



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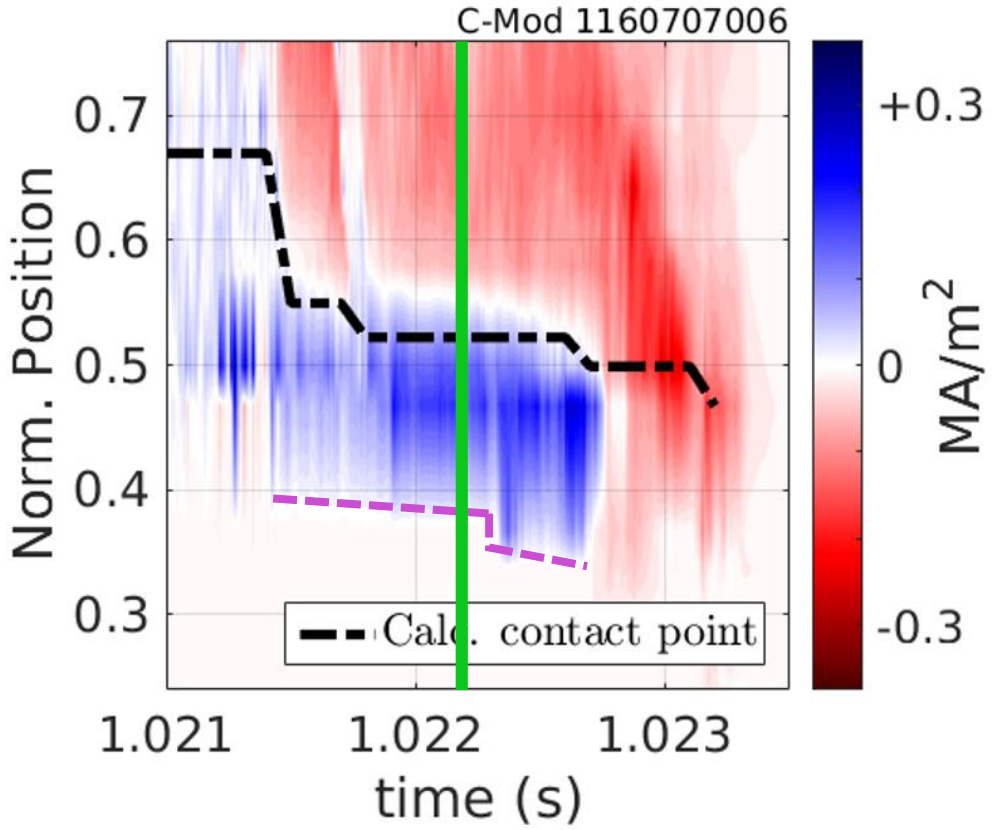

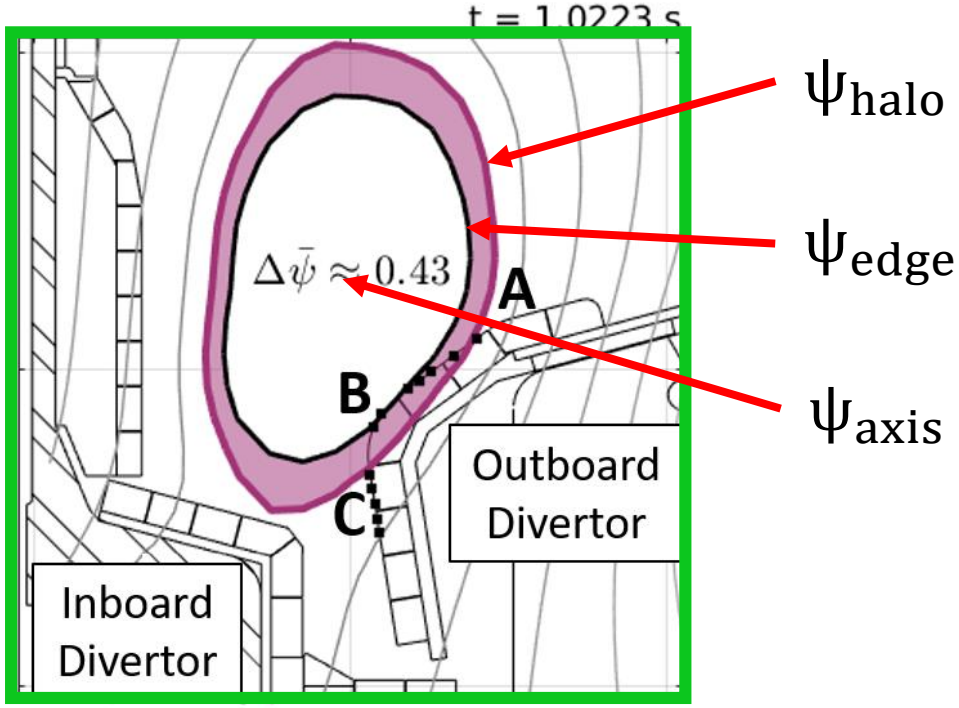

$$\Delta\bar{\psi} = \frac{\psi_{halo} - \psi_{edge}}{\psi_{edge} - \psi_{axis}}$$

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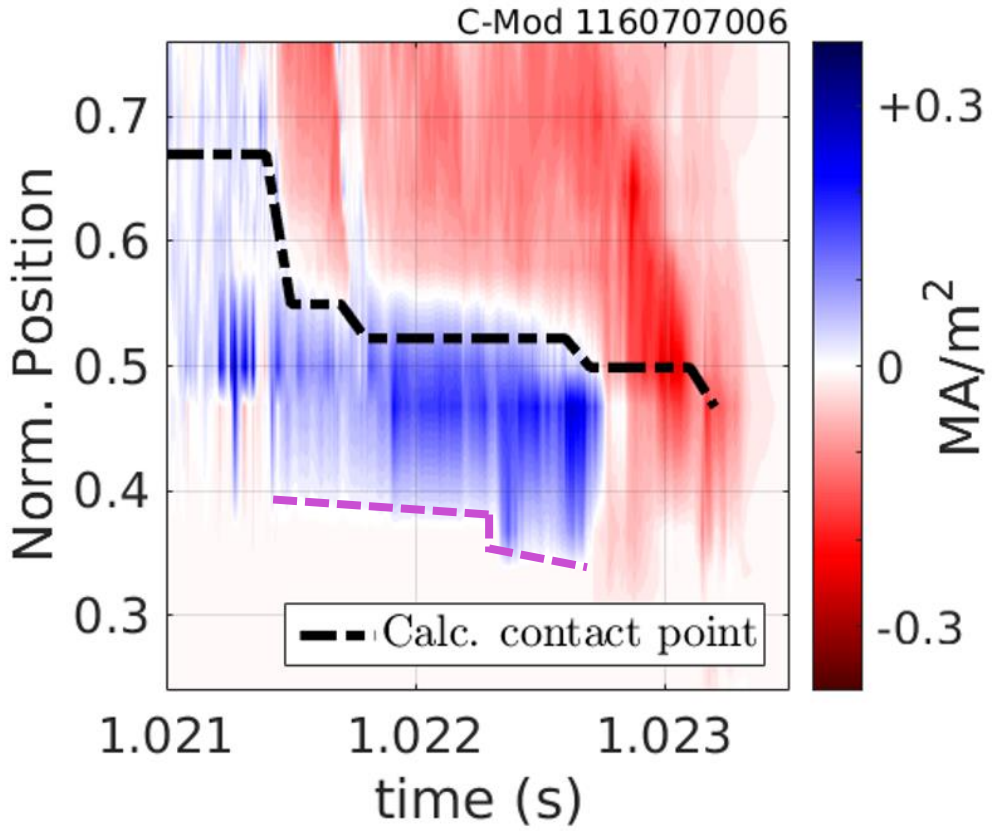

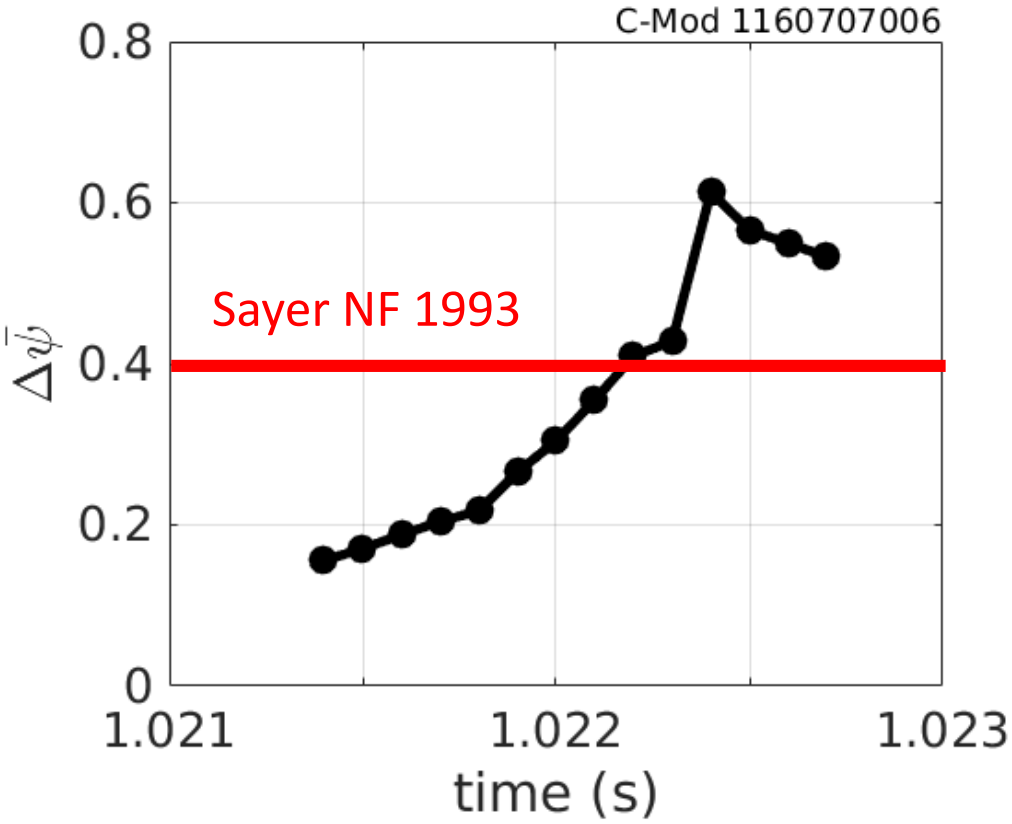

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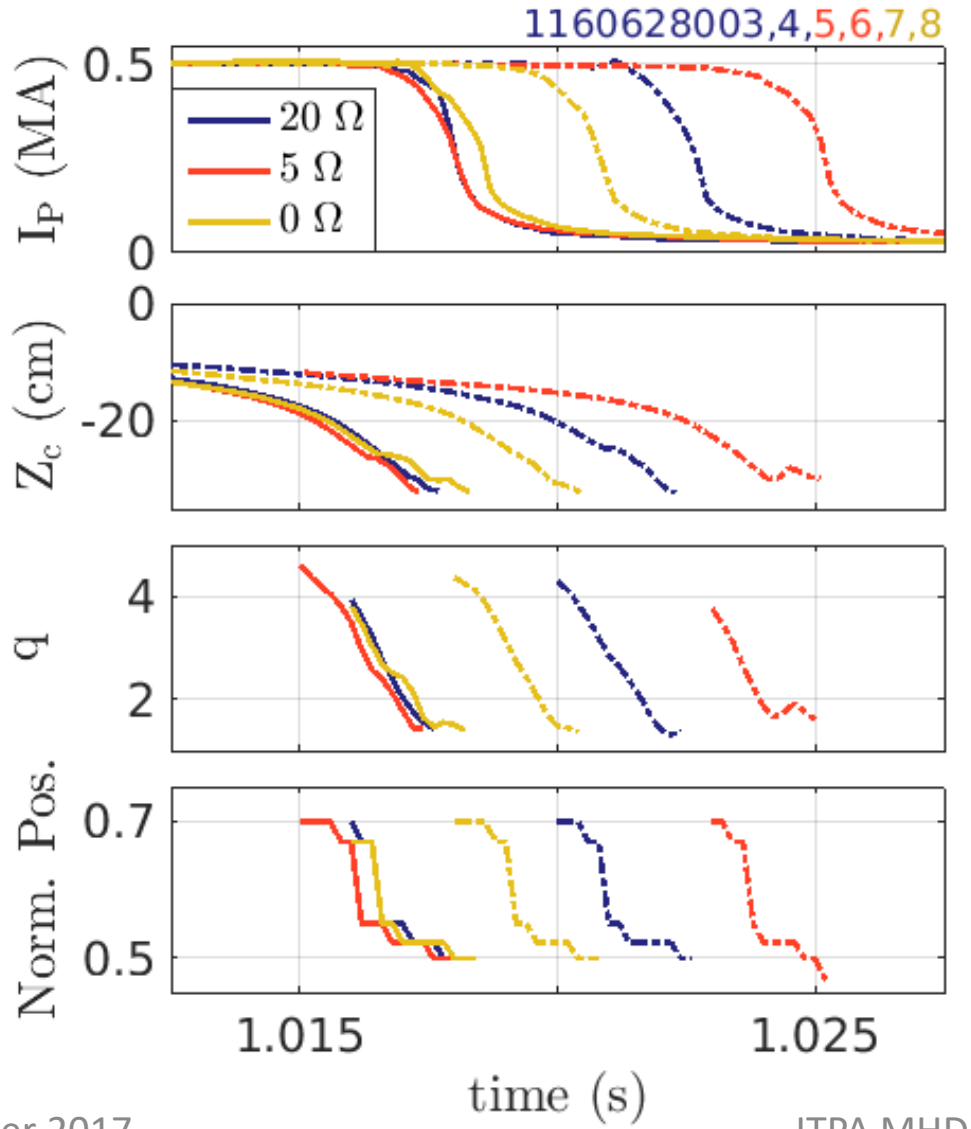
Halo current measurements from reproducible VDEs can be used to estimate the halo region/sheath resistance



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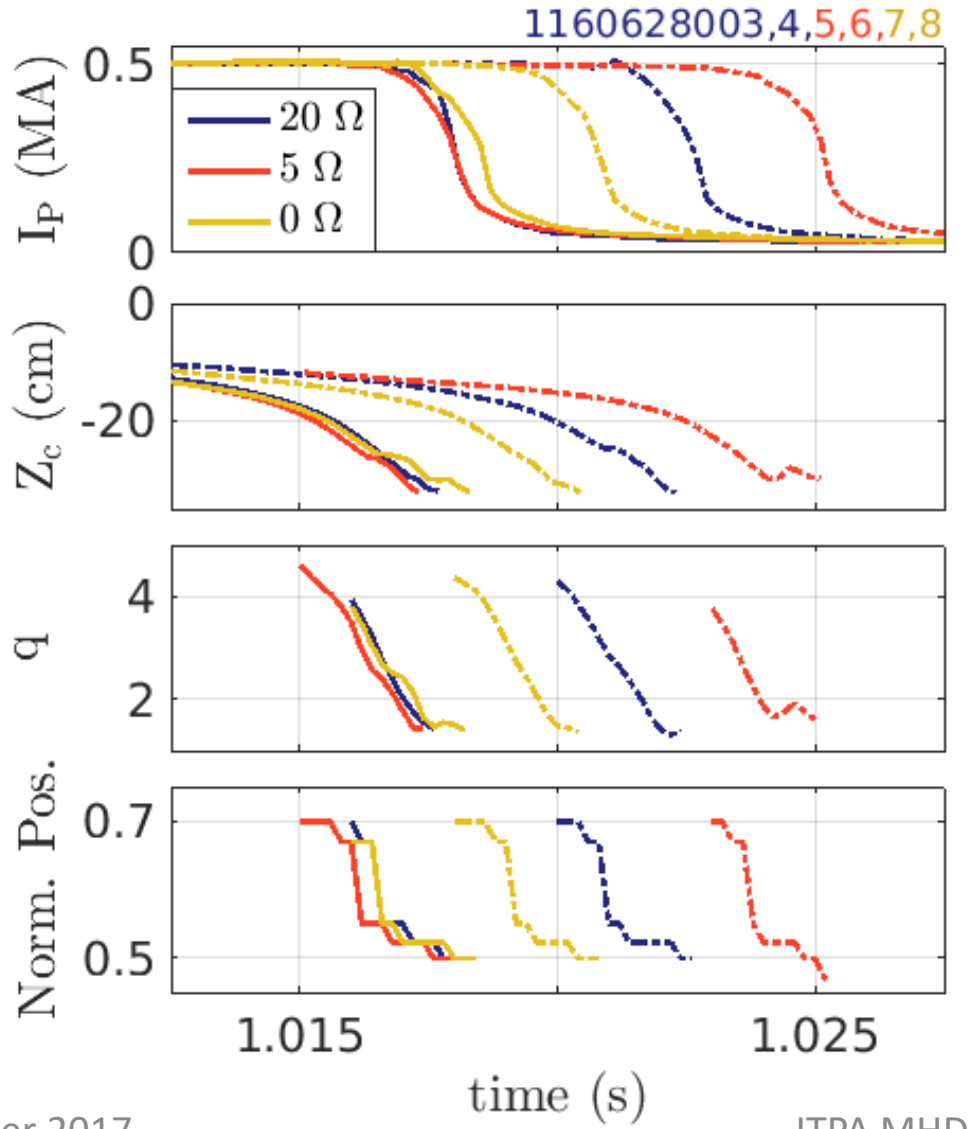

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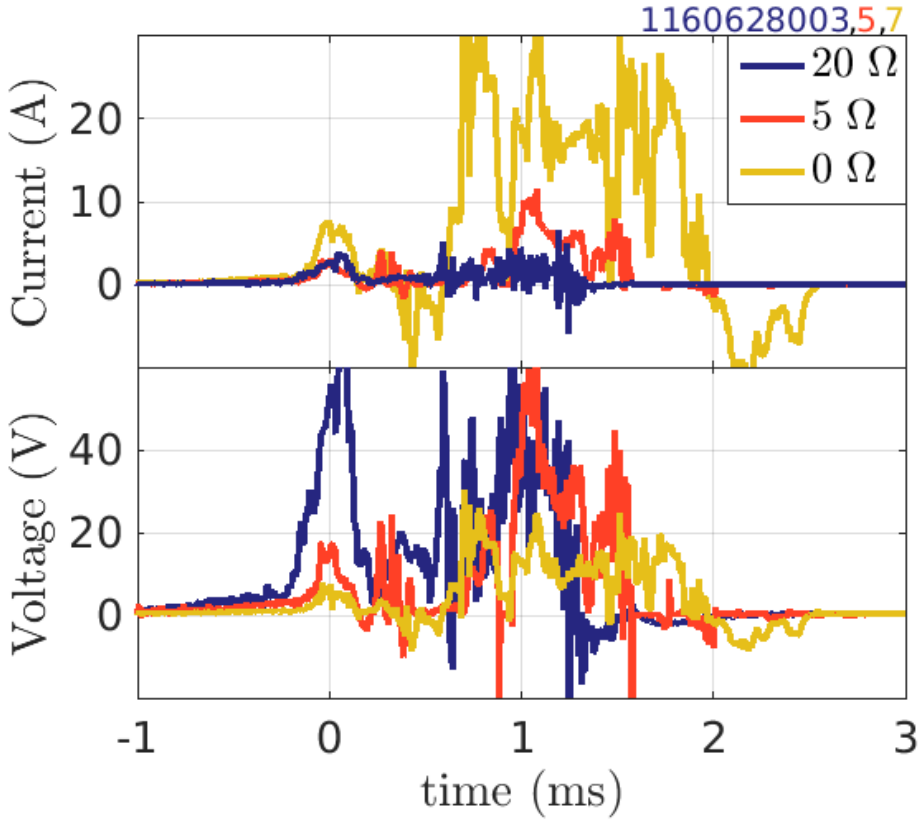

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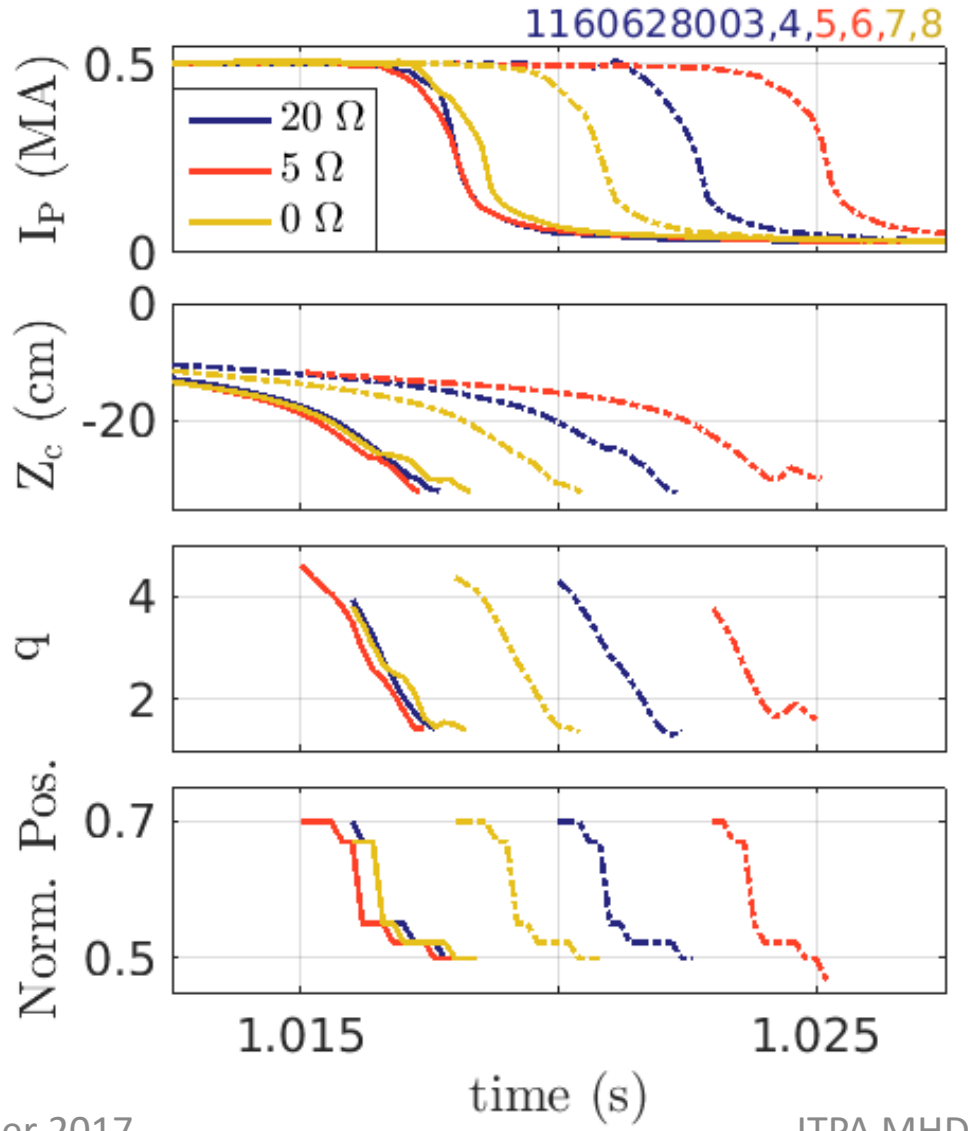

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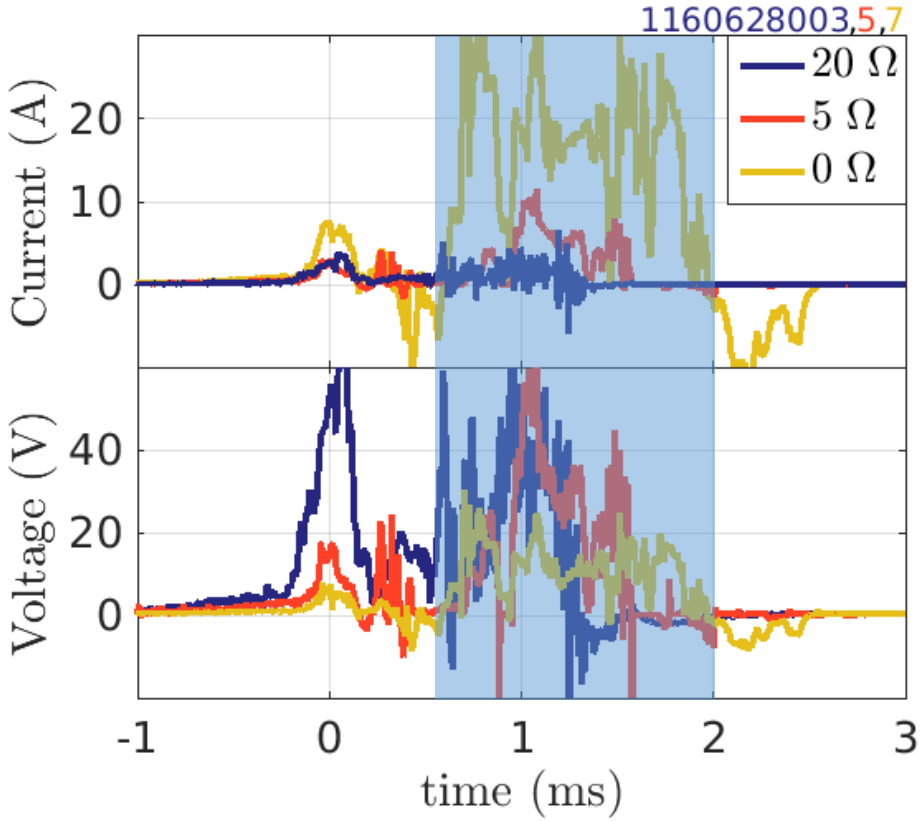

~16 A

~11 V

The effective resistance of the halo region is calculated to be ~0.5-2 Ω

$$V_{eff} = I_{measured} \times \mathbf{R_{eff}} + V_{measured}$$

$$-L_h \frac{d}{dt}(I_{measured})$$

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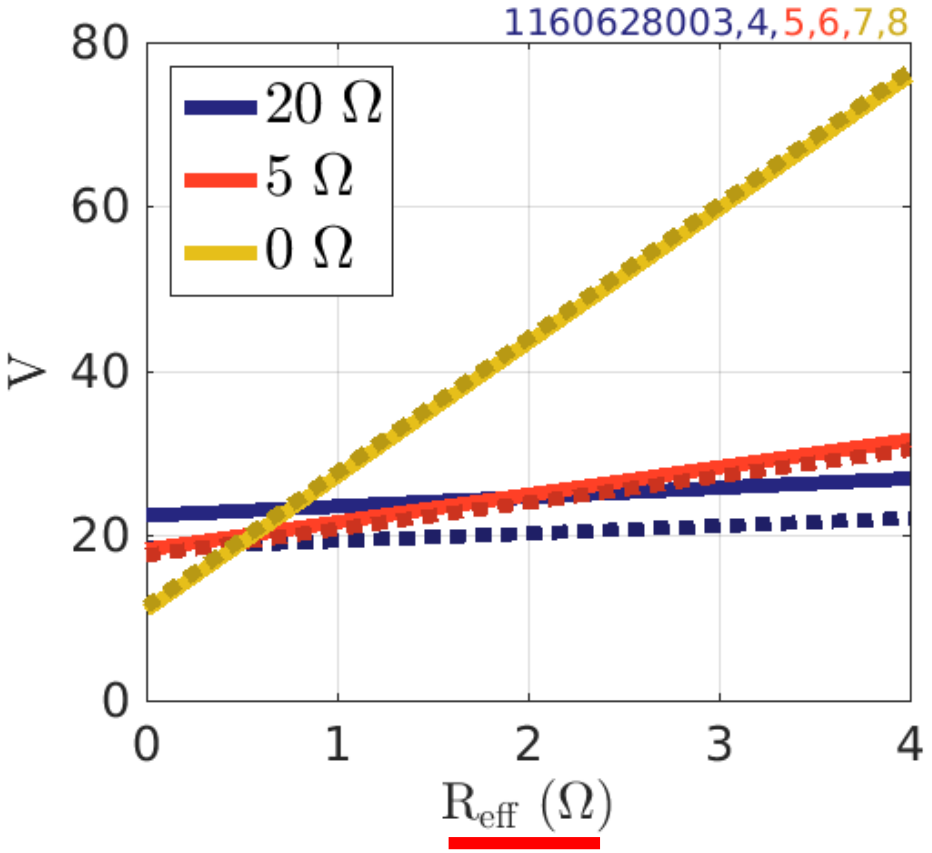

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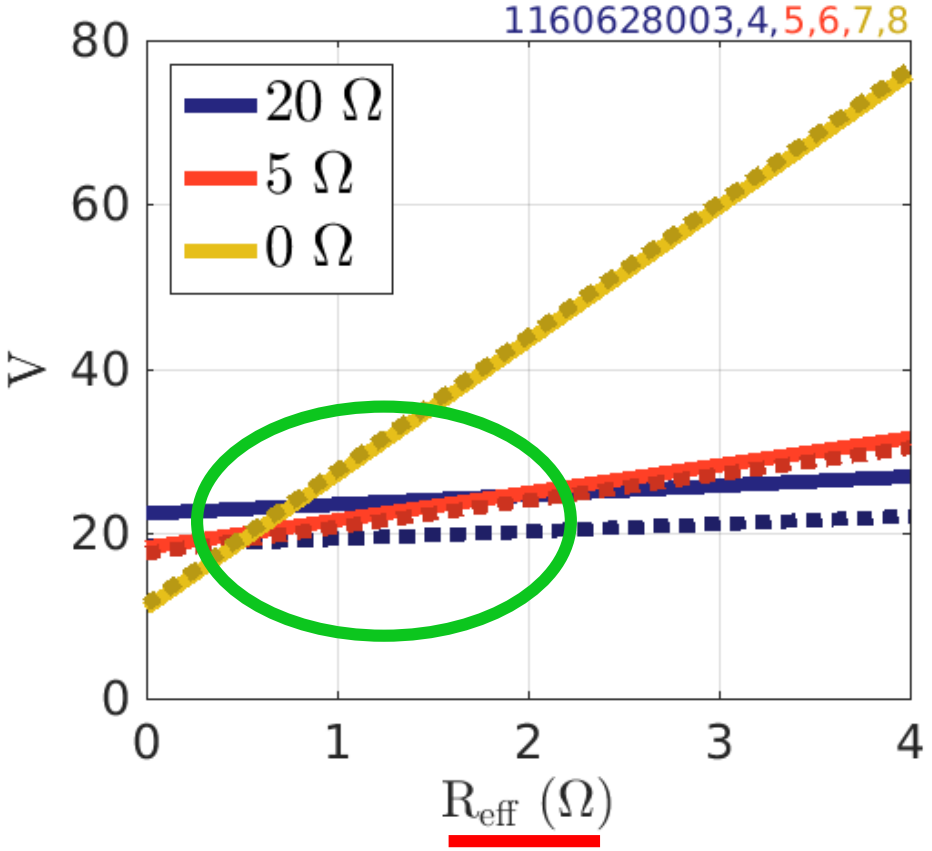
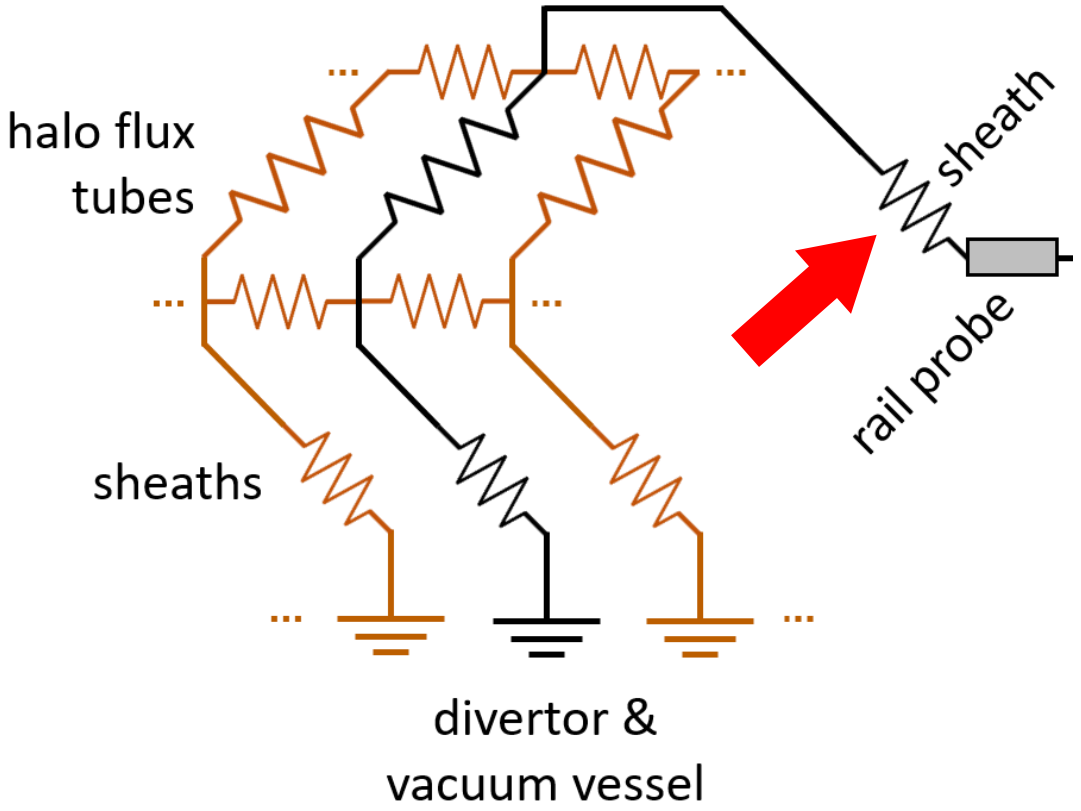
Rail Probe	Resistance R_{eff} (Ω)
RP50	0.8 ± 0.7
RP52	1.3 ± 0.9



Cross-field current sharing dominates at the rail probe, so we find an upper bound for the sheath resistance



Spitzer resistivity predicts a halo region temperature around 47-75 eV

$$\eta_{halo} = R_{halo}\, A_{cs} / L_c$$

$$\approx (13.7\ \Omega - \mathbf{2*0.8\ \Omega}) * (5\ mm^2)/(2\pi R_0 q_{edge})$$

$$\sim 6.3\ \mu\Omega\text{-m}$$

→ For Z_{eff} = 1-2, Spitzer temperature $\mathbf{T_e \sim 47\text{-}75\ eV}$

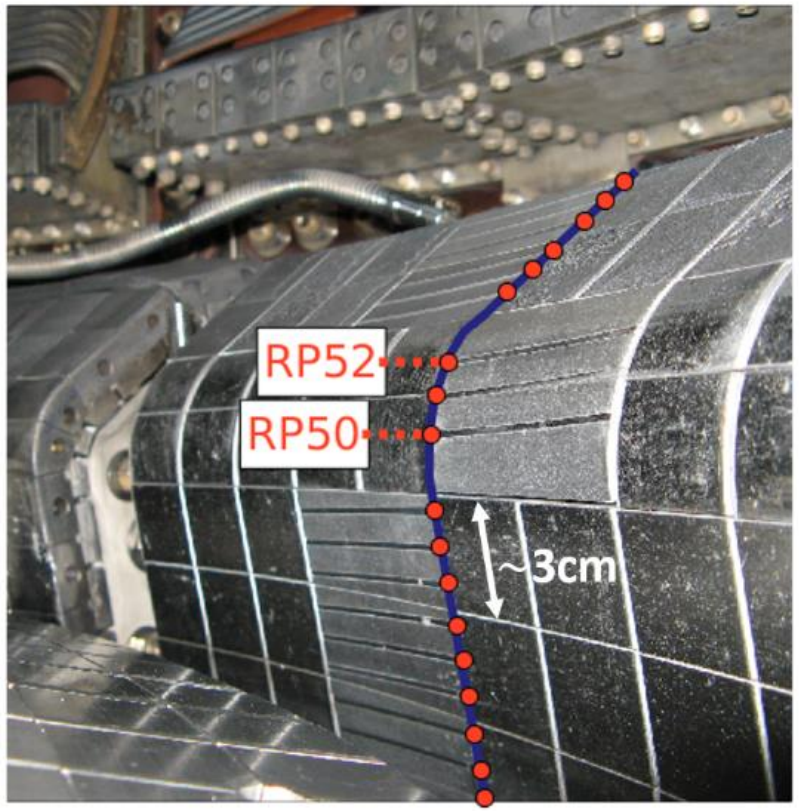
On the upper end of typical simulation values of 1-50 eV

Summary

- A poloidal array of Langmuir ‘rail’ probes measures halo current on C-Mod
- The edge safety factor decreases to approximately rational values (~1 and 3/2) before plasma termination ✓
- The halo flux width varies between ~15-60% ✓
- An upper bound for the sheath resistance of ~1 Ω is measured
- The temperature of the halo flux region is estimated to be ~47-75 eV ✓

Backup slides

Measurements from a new poloidal array of Langmuir ‘rail’ probes in C-Mod can help guide simulation efforts



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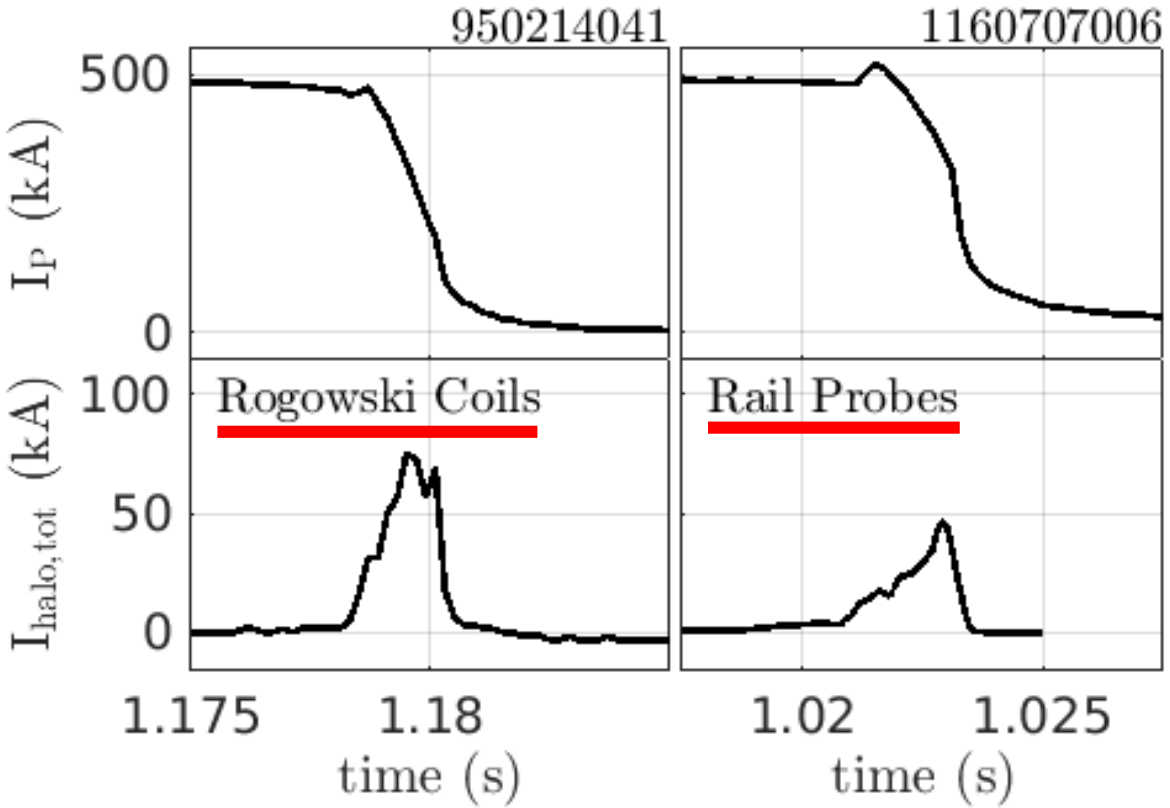

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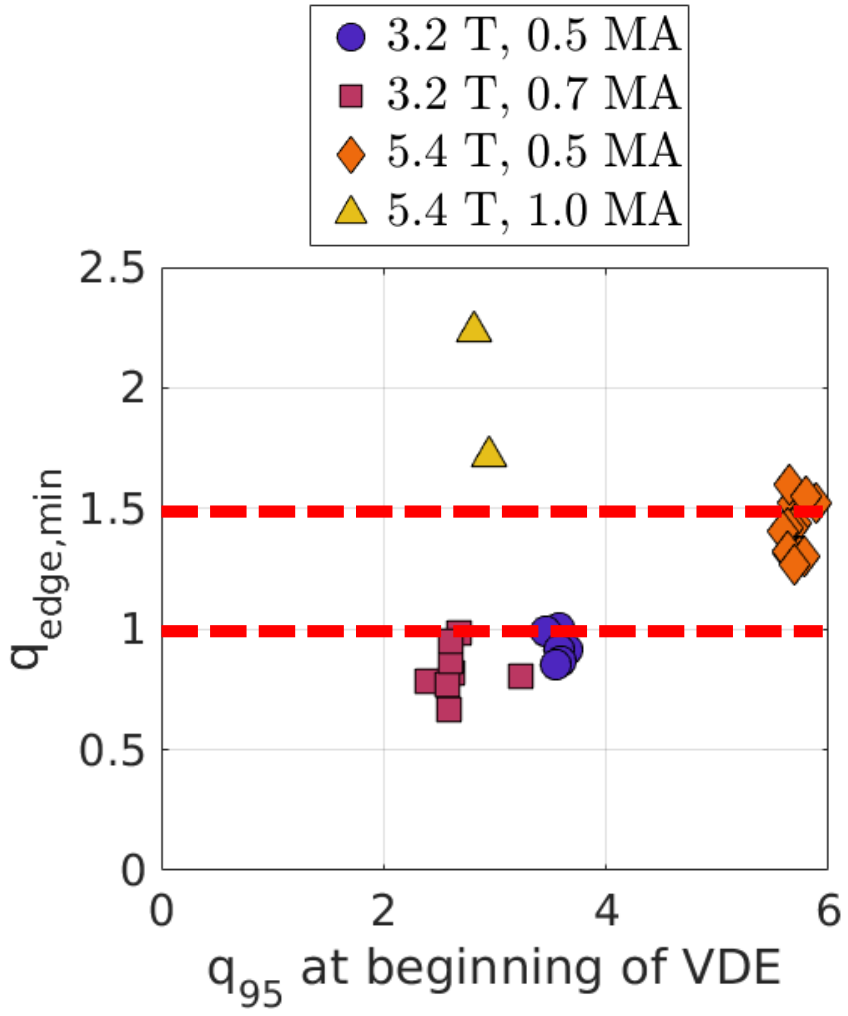
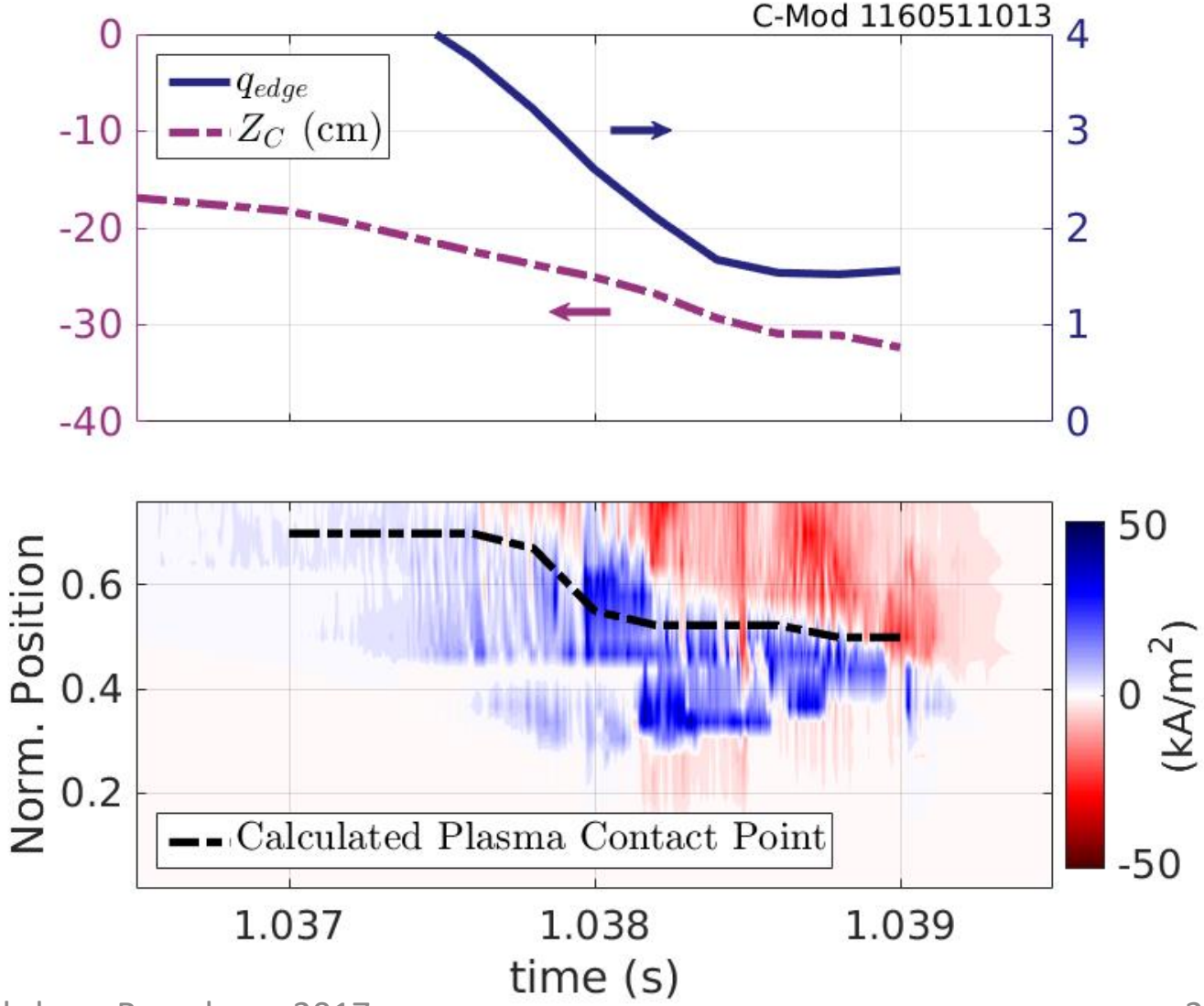
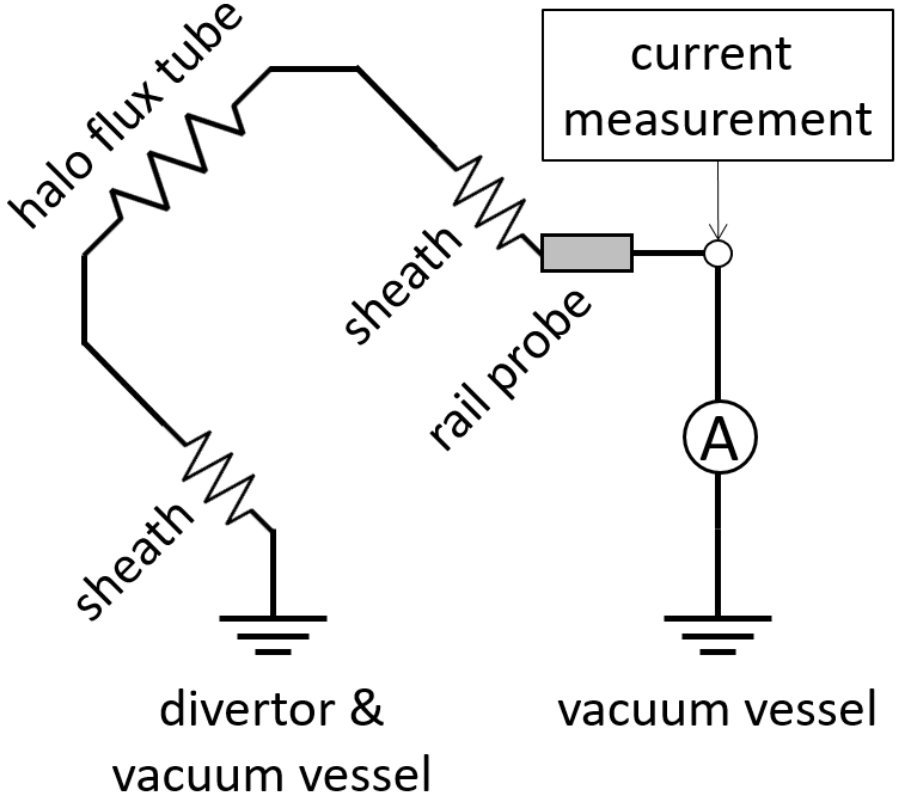
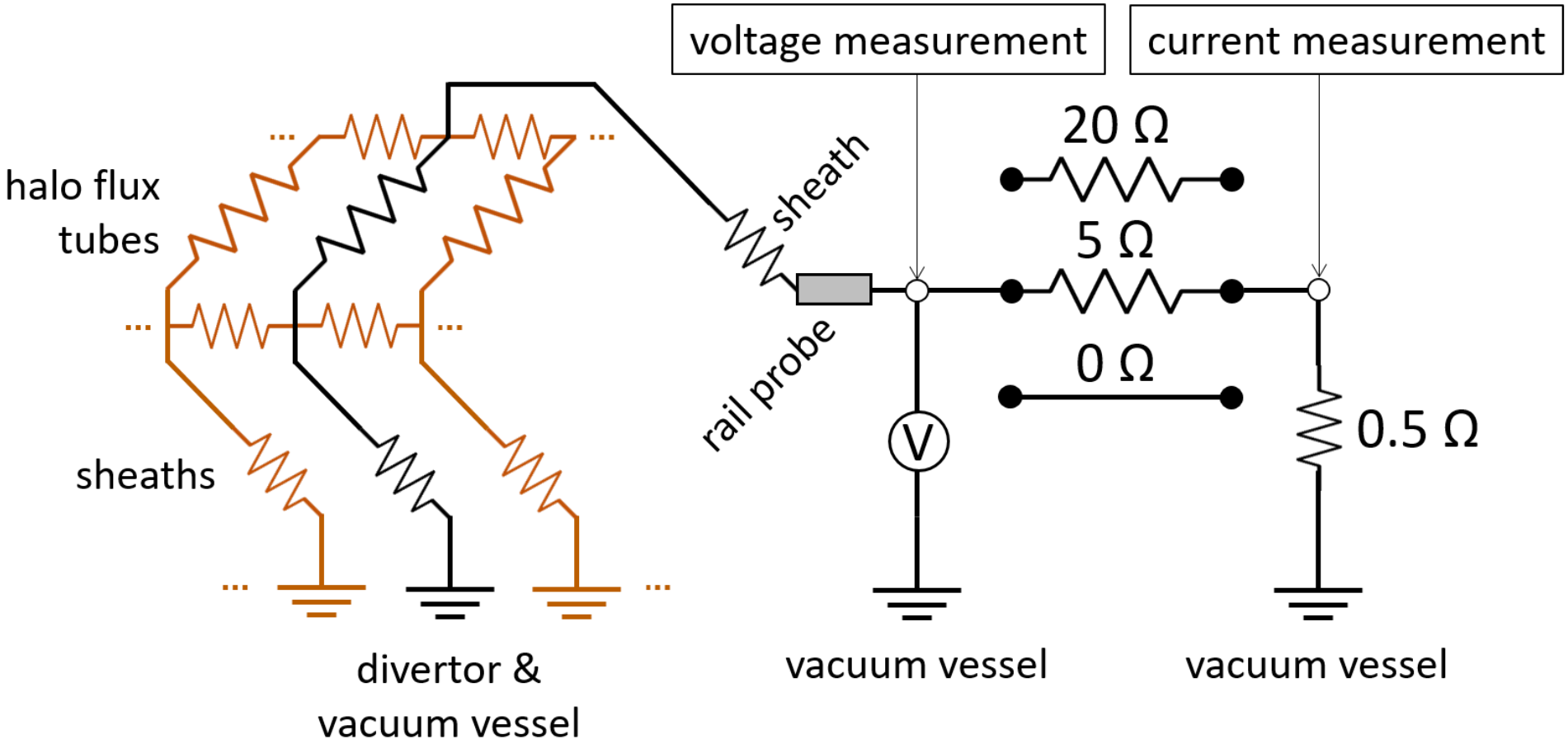




For a perfectly-grounded rail probe…



A more realistic picture…



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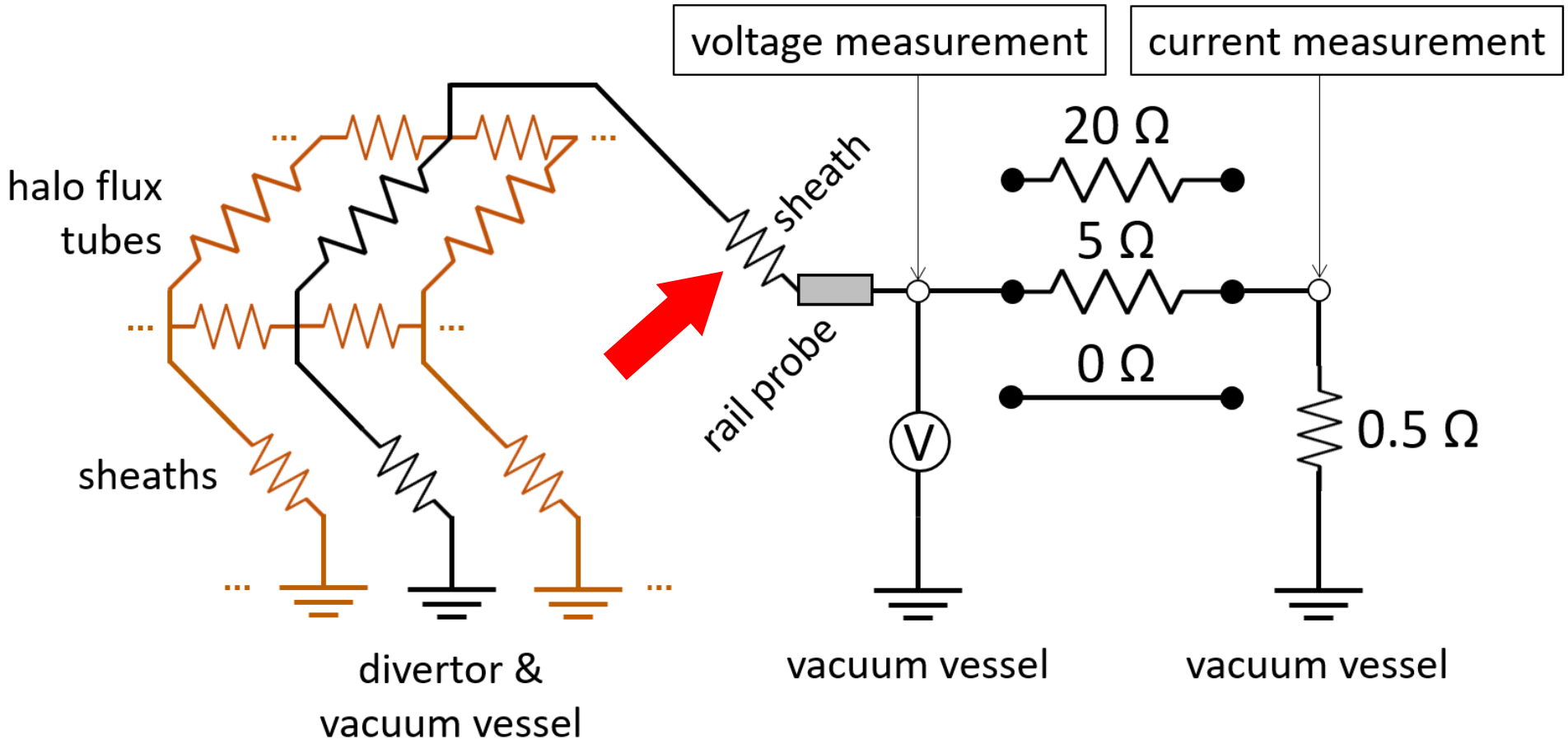

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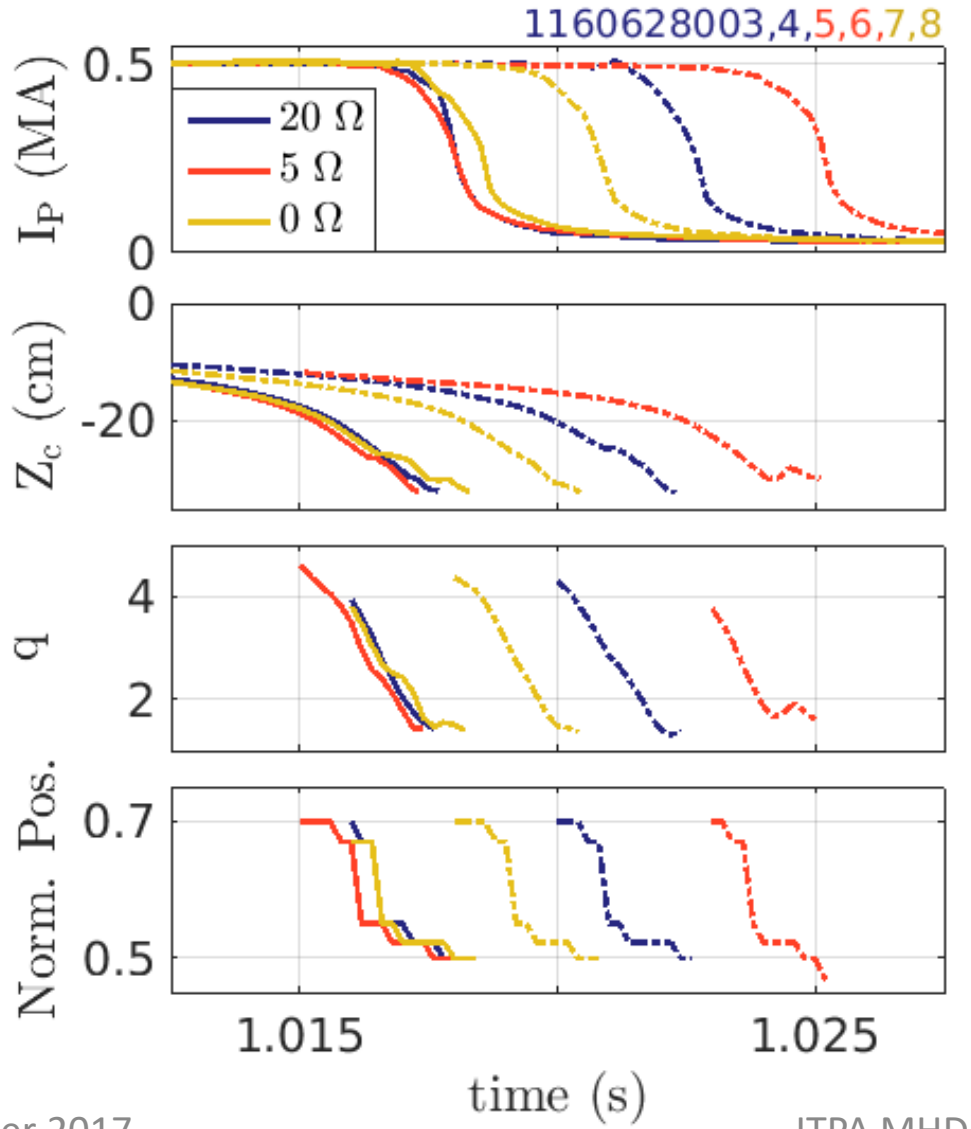

$$V_{loop} = V_{pol} + q \cdot V_{tor} \approx -\left(B_0 \frac{dA}{dt} + q \cdot L \frac{dI_P}{dt}\right)$$

Discharge No.	RP Resistor (Ω)	V_{loop} (V)
1160628003	20	**251**
1160628004	20	**211**
1160628005	5	**238**
1160628006	5	**251**
1160628007	0	**217**
1160628008	0	**245**

The effective resistance of the halo region is calculated to be ~0.5-2 Ω

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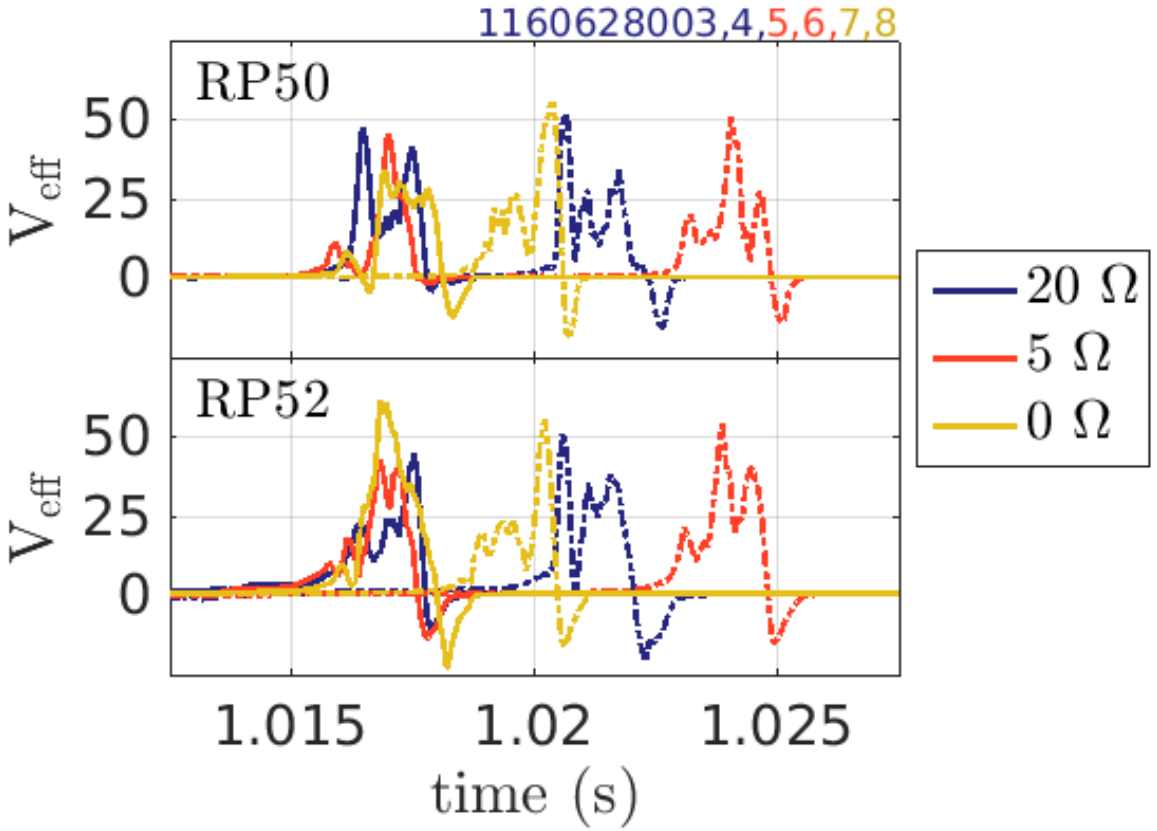

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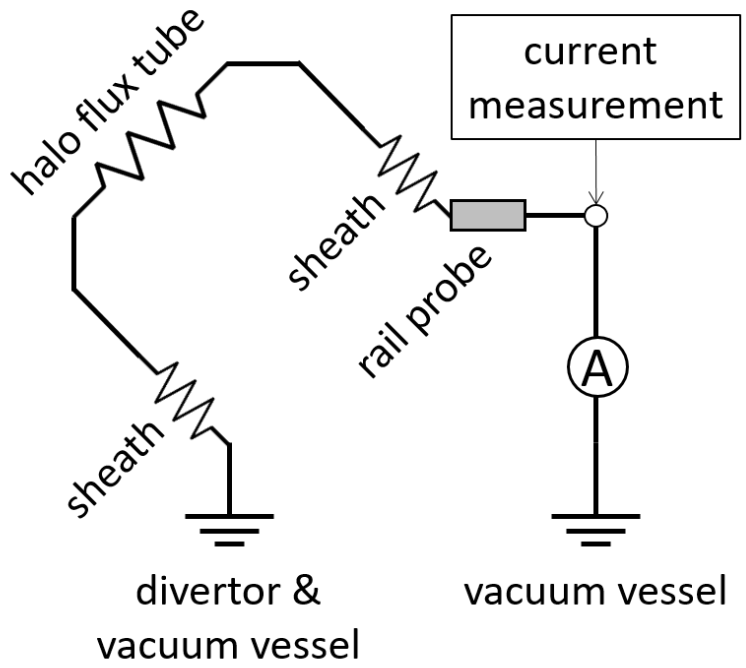

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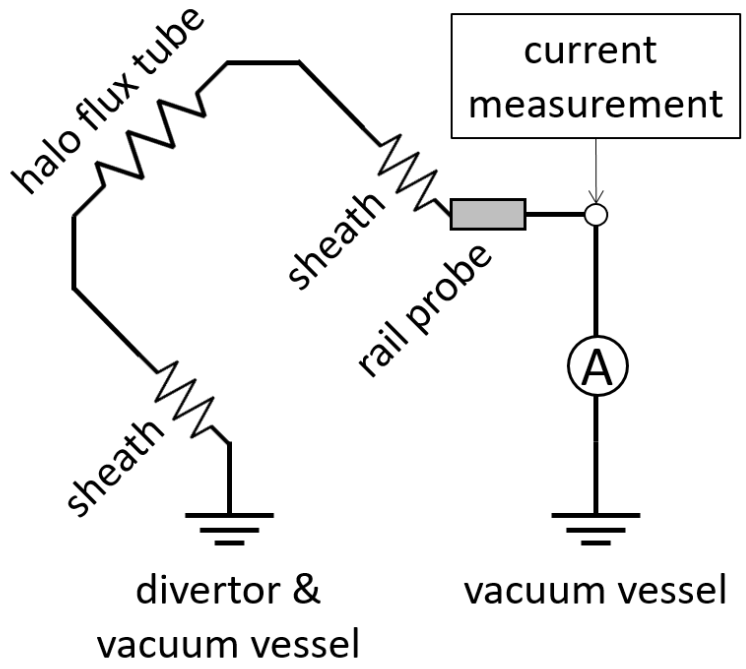
$$230\ \mathrm{V} = 16\ \mathrm{A} \times \mathbf{R_{halo}} + 11\ \mathrm{V}$$



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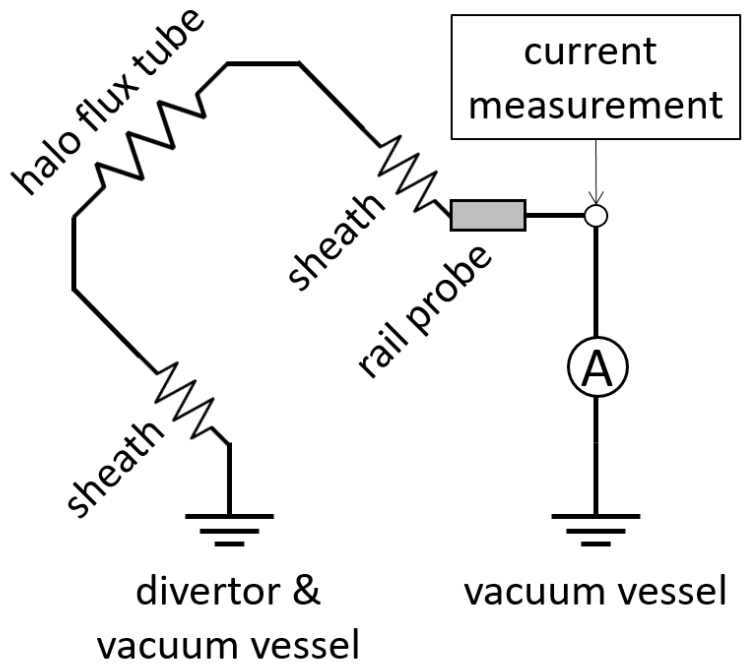

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$$\rightarrow\ \mathbf{R_{sheath}} \leq 1\ \Omega$$