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Effects of Vacuum Impedance Changes on MITL Flow Using 3D Electromagnetic PIC Simulations

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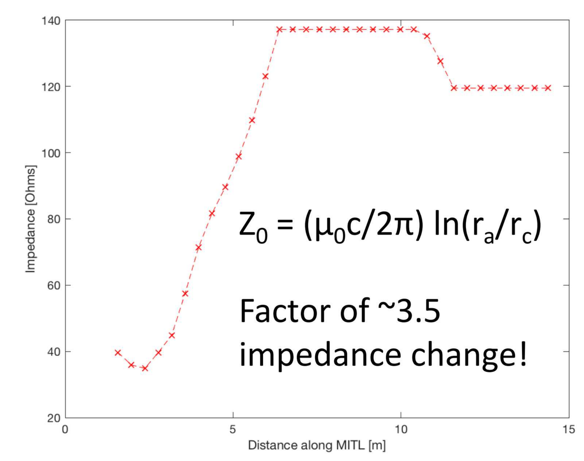
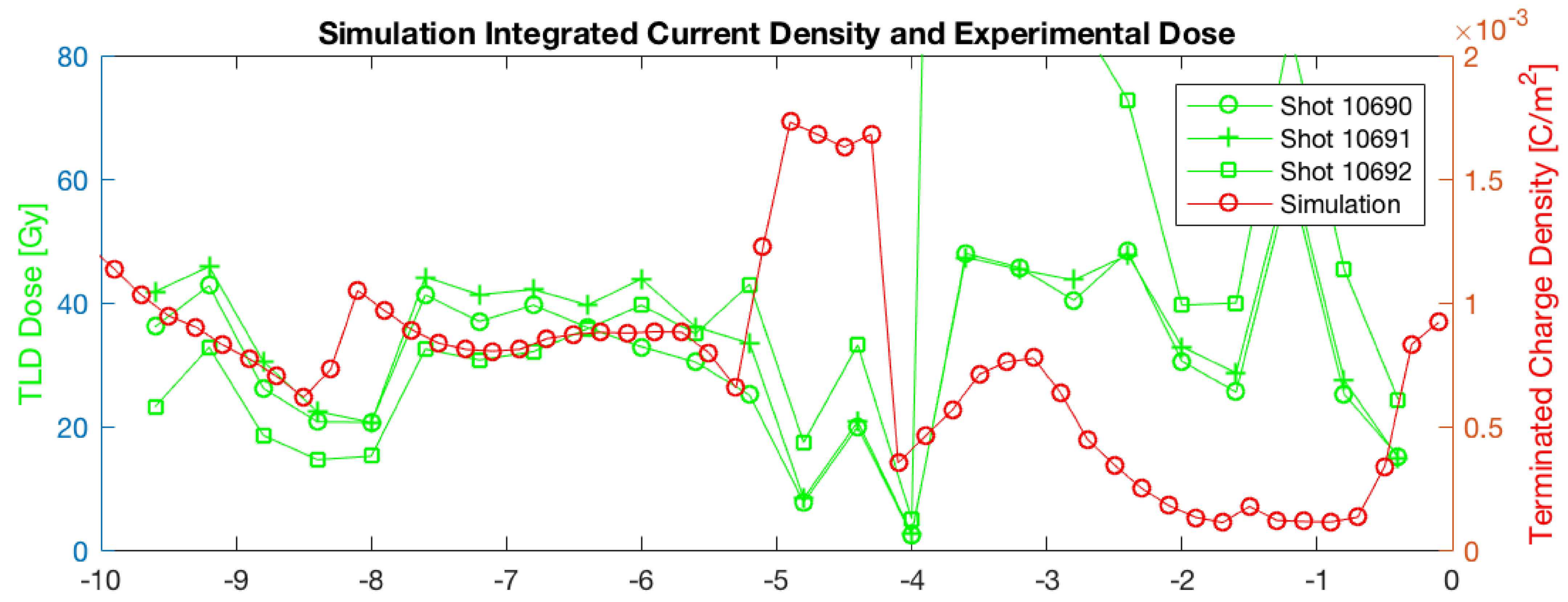
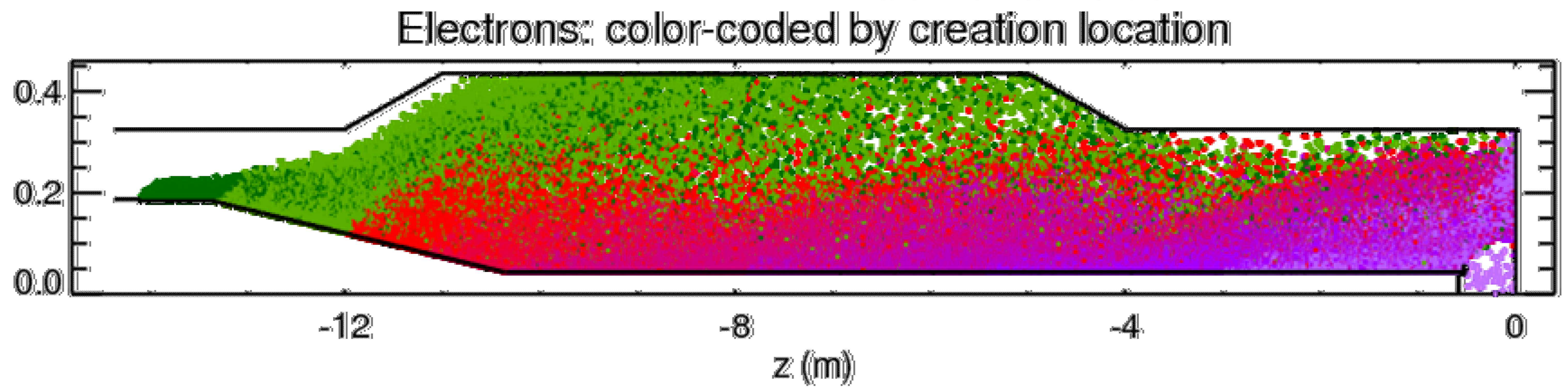
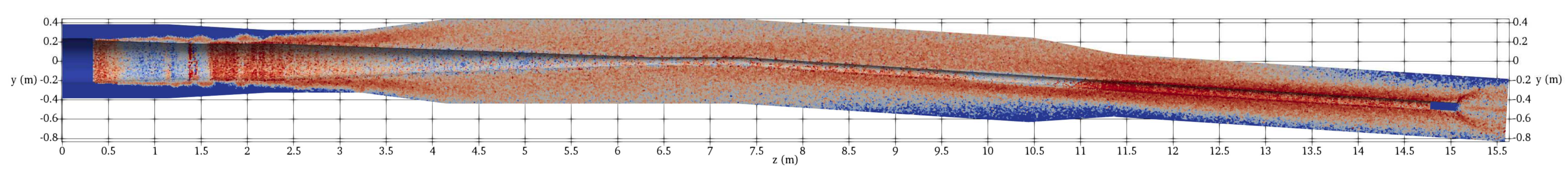
Abstract

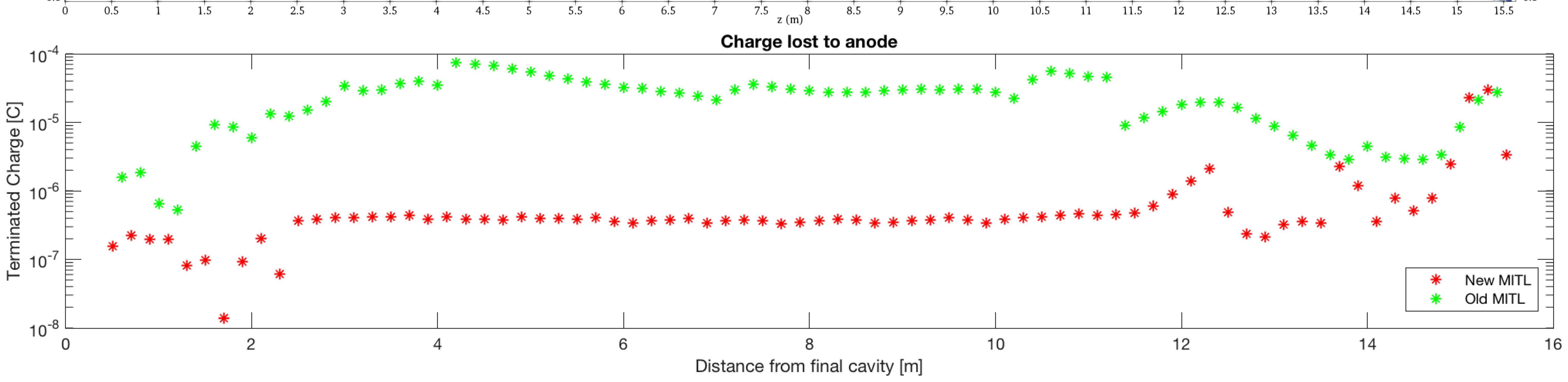
Vacuum impedance changes in Magnetically Insulated Transmission Line (MITL) flow has been shown via simulation to have profound impact on MITL flow patterns. Using EMPHASIS, a 3D Unstructured Time Domain Electromagnetics Particle-In-Cell (PIC) code, it was shown that the HERMES III extended MITL exhibits significant power loss due to changes in vacuum impedance. Results are compared with those using QUICKSILVER, a structured EM PIC code and EMPIRE, another unstructured EM PIC code. All codes agree with each other, and, more importantly, with experimental current measurements. Further evidence of electron loss in the MITL is given by strong thermoluminescent dosimeter (TLD) readings along the outer surface of the MITL anode. The MITL has recently been redesigned with constant impedance and simulation now shows virtually no current loss. It is expected that this will increase the dose output of HERMES III by at least a factor of 2. Geometry choice is reported and discussed. Predictions of current shunt and B-dot data from EMPHASIS are also discussed.

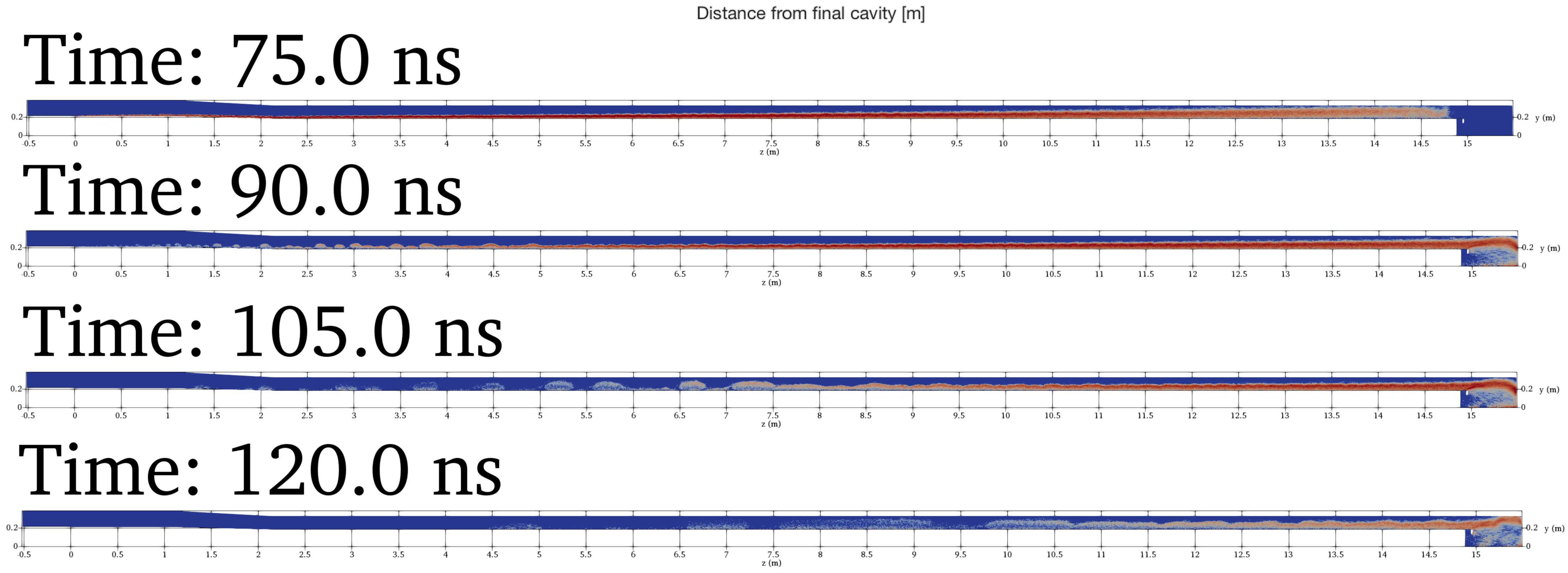


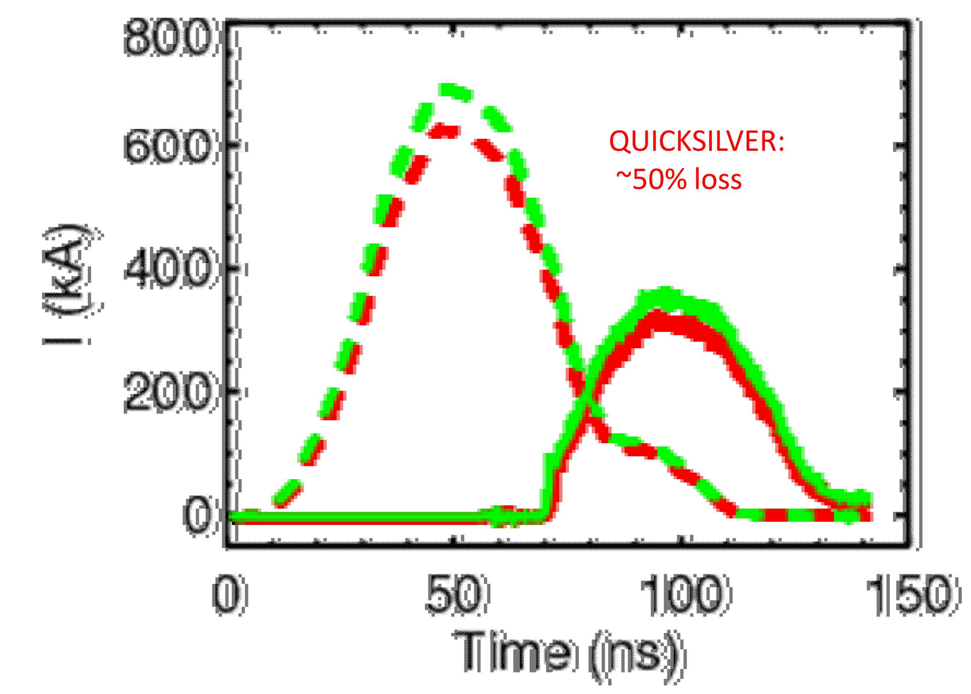


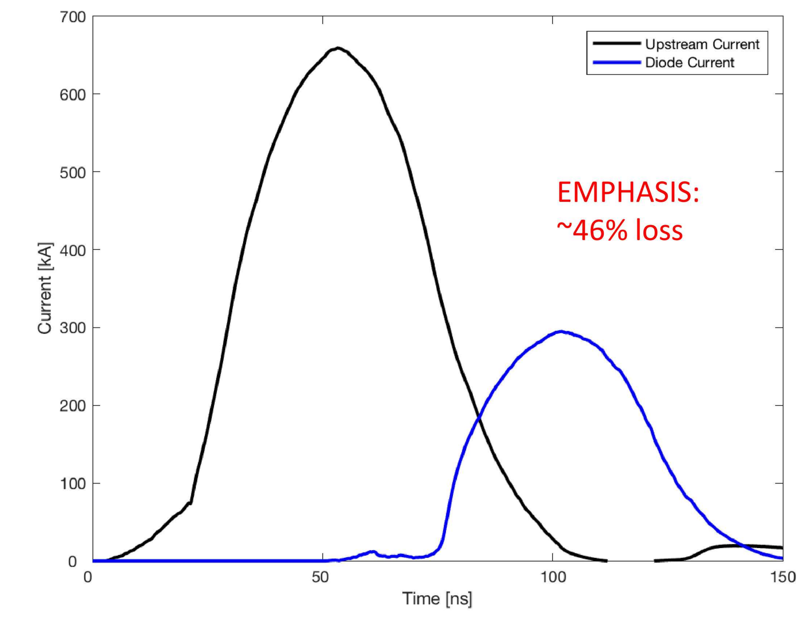












Problem

Impedance changes in extended MITL configuration caused massive current loss. So we want to design a constant impedance MITL.

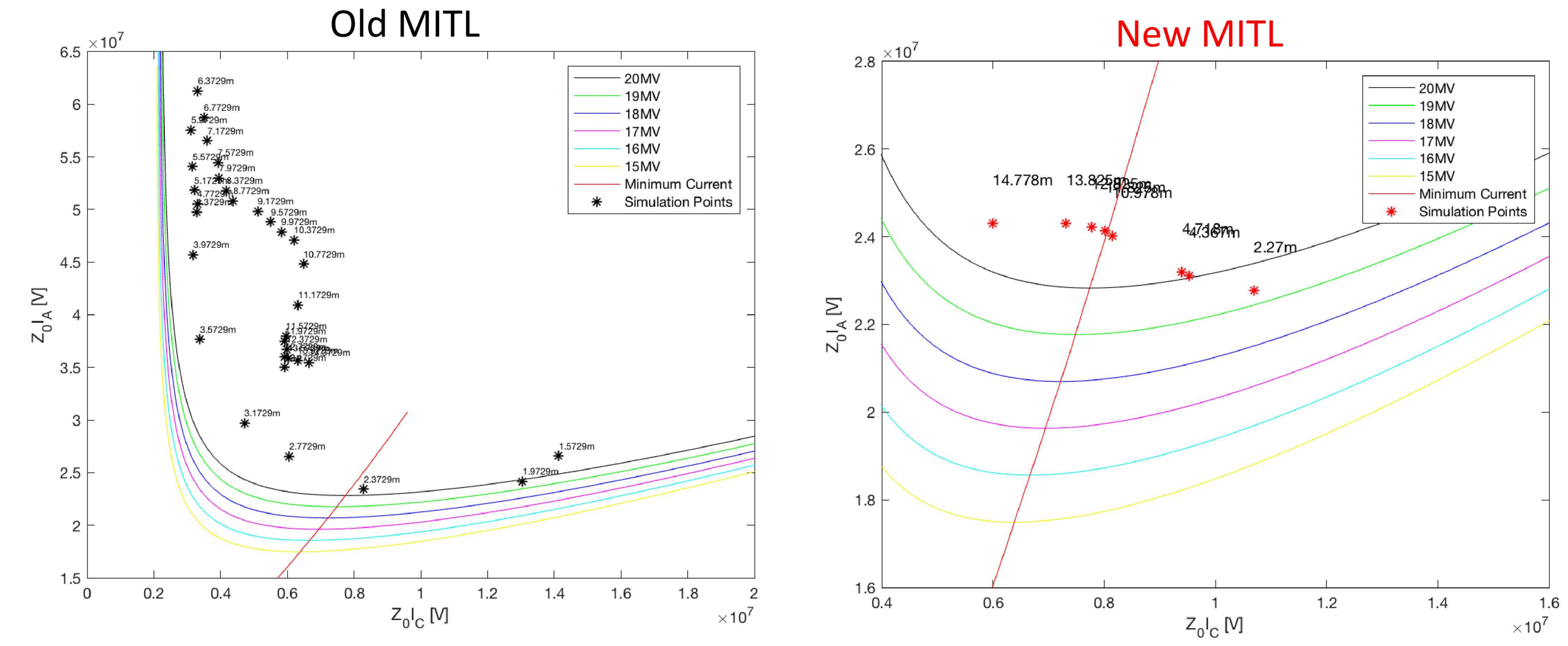
Observations

EMPHASIS and QUICKSILVER accurately predict current loss.

Simulation current density and experimental dose agree reasonably insofar as structure, so where loss occurs can be predicted.

Charge lost in MITL is ~2 orders of magnitude lower for New MITL, though the diode region is similar in loss. New MITL shows no significant current loss.

Old MITL current agrees with Ottinger's generalized MITL flow model [1] (neglecting electron pressure) up until significant losses are seen (around 6 meters in). The new MITL also agrees reasonably with this model and remains near the minimum current operating point.



Conclusions and Future Work

Geometric impedance plays a large role in MITL flow – impedance matching is crucial for power flow applications.

Newly designed MITL should increase dose by at least a factor of 2.

Compare to experimental current shunts, B-dots, and dose measurements.

Simulate with EMPIRE and compare results.

References

[1] – Ottinger, Paul F., Schumer, Joseph W., Hinshelwood, David D., Allen, Raymond J. *Generalized Model for Magnetically Insulated Transmission Line Flow.* IEEE Transactions on Plasma Science, Vol. 36, No. 5, October 2008

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