SAND2021-9805C

Sandia National Laboratories

EFFECTS OF VACUUM IMPEDANCE CHANGES ON MITL FLOW USING 3D ELECTROMAGNETIC PIC SIMULATIONS

Troy C. Powell, Keith L. Cartwright, Timothy D. Pointon, Andrew Biller, Theodore C. Grabowski

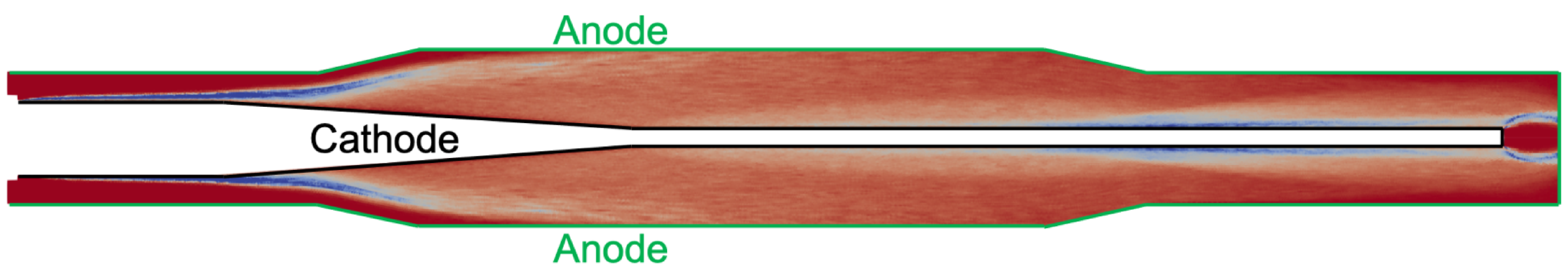
Vacuum impedance changes in Magnetically Insulated Transmission Line (MITL) flow has been shown via simulation to have profound impact on MITL flow patterns. Using EMPHASIS, a 3D Unstructured Time Domain Electromagnetics Particle-In-Cell (PIC) code, it was shown that the HERMES III extended MITL exhibits 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/Fluid/Hybrid 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.

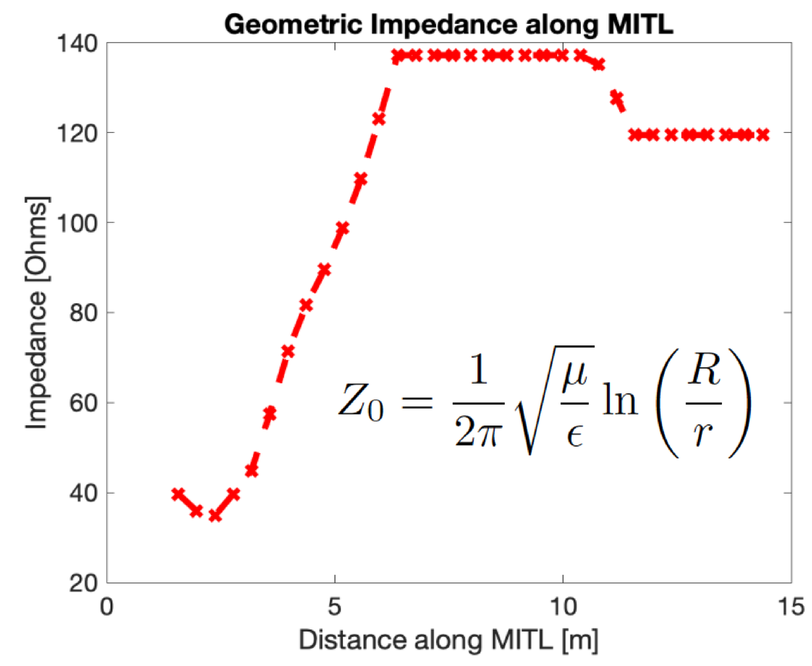
The extended MITL on HERMES III has been redesigned with constant impedance and now shows considerably reduced current loss. It is shown that when delivering current to a Bremsstrahlung diode this increases the gamma dose measured on the external faceplate of the diode by at least a factor of two. As a result, doses measured at greater distances from the faceplate are also increased. Geometry choice as well as comparison between simulation and experimental performance of the redesigned MITL is reported and discussed. The new MITL has current sensors on both the anode and cathode at several locations along the MITL so the voltage can be estimated[1,2] and that approximation can be compared to the simulations. Electron temperature in the MITL can have a large effect upon the estimated voltage[2]. The pressure was varied in simulation and compared to the experimental data to determine the approximate experimental electron temperature. These data are then correlated with the dose measurements made on the surface of the faceplate as well as at greater distances from the diode.

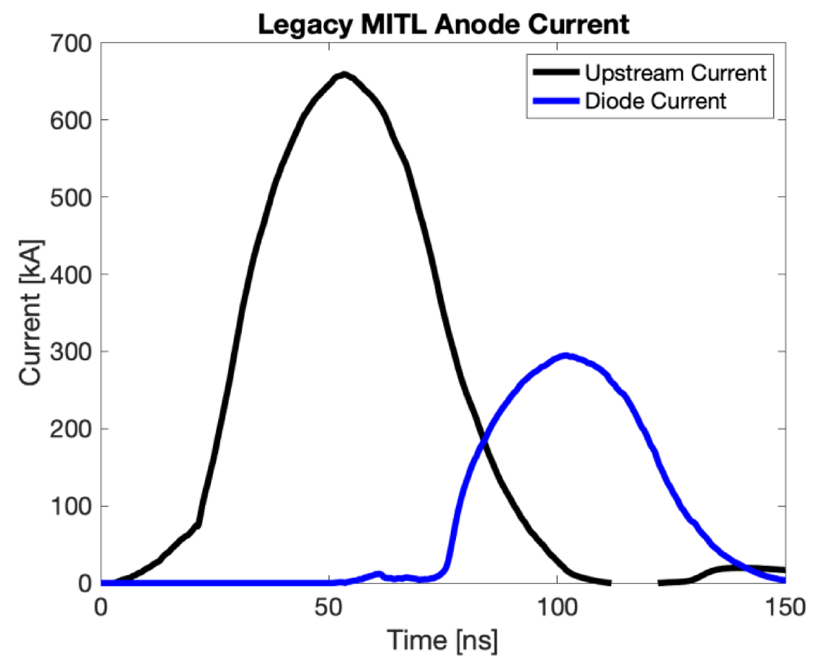
[1] - P. F. Ottinger and J. W. Schumer, "Rescaling of Equilibrium Magnetically Insulated Flow Theory Based on Results from Particle-In-Cell Simulations", Physics of Plasmas Vol. 13, June 2006

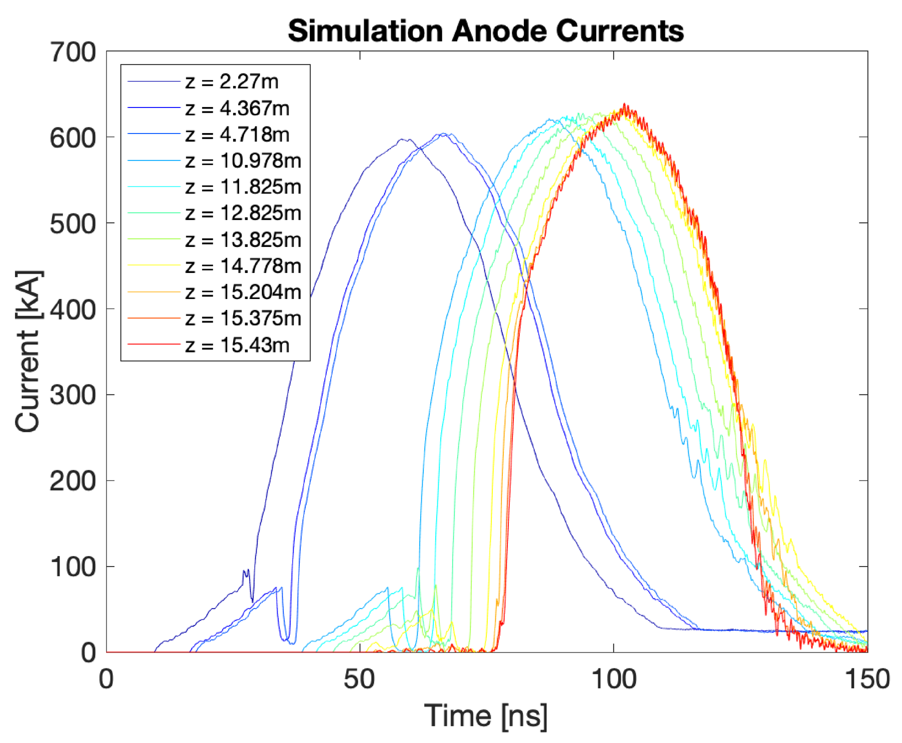
[2] - P. F. Ottinger, J.W. Schumer, D. D. Hinshelwood, and R. J. Allen, "Generalized Model for Magnetically Insulated Tranmission Line Flow", IEEE Transactions on Plasma Science, Vol. 36, No. 5, October 2008

Legacy Configuration

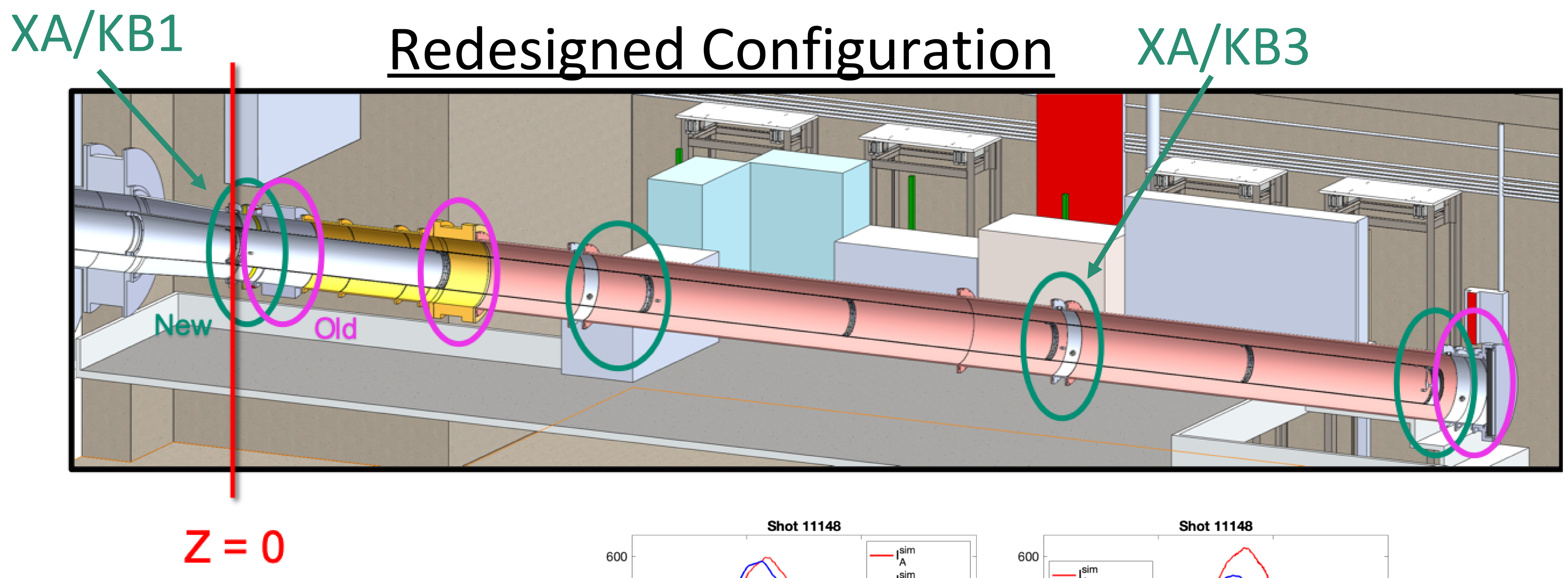


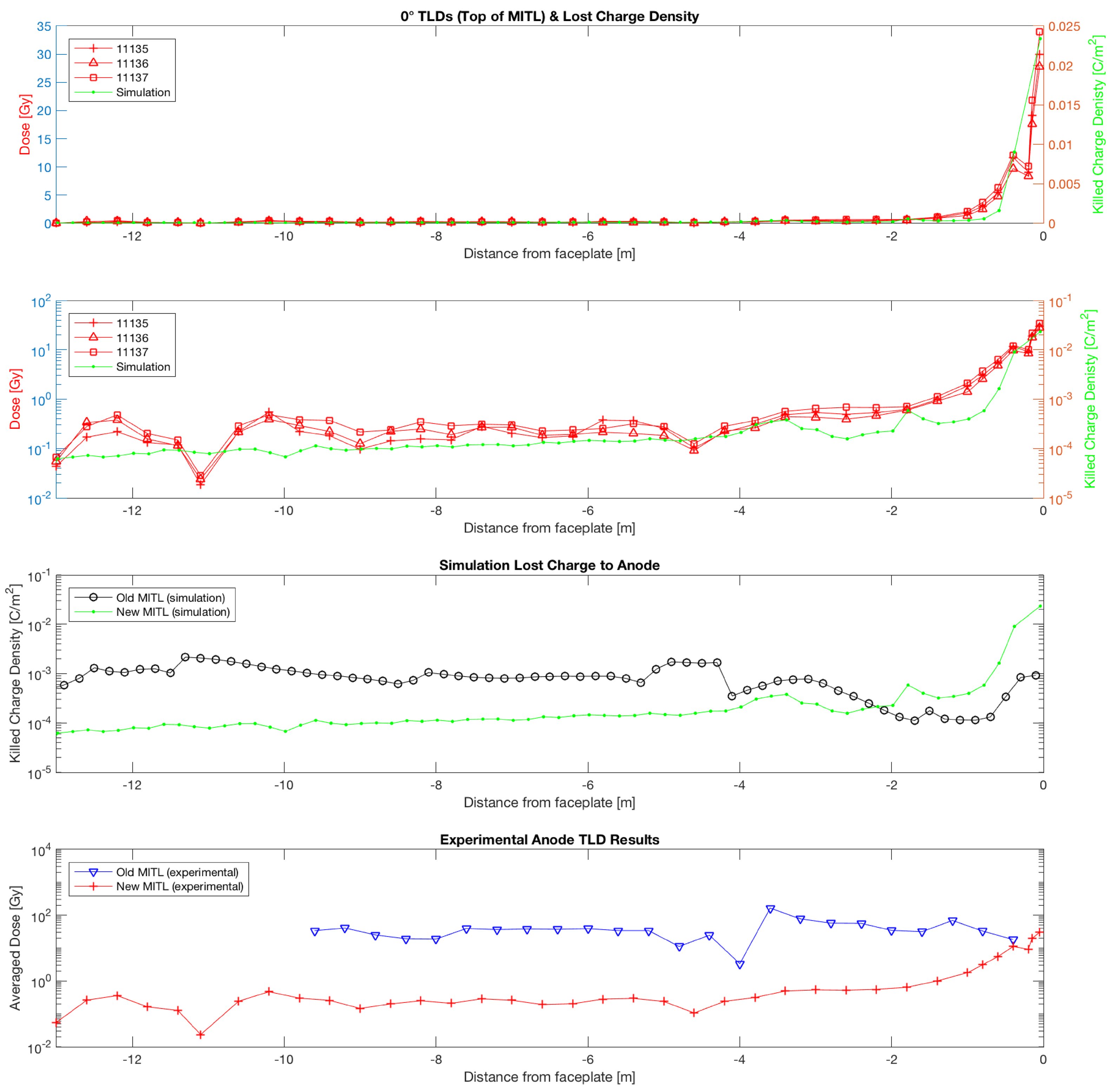


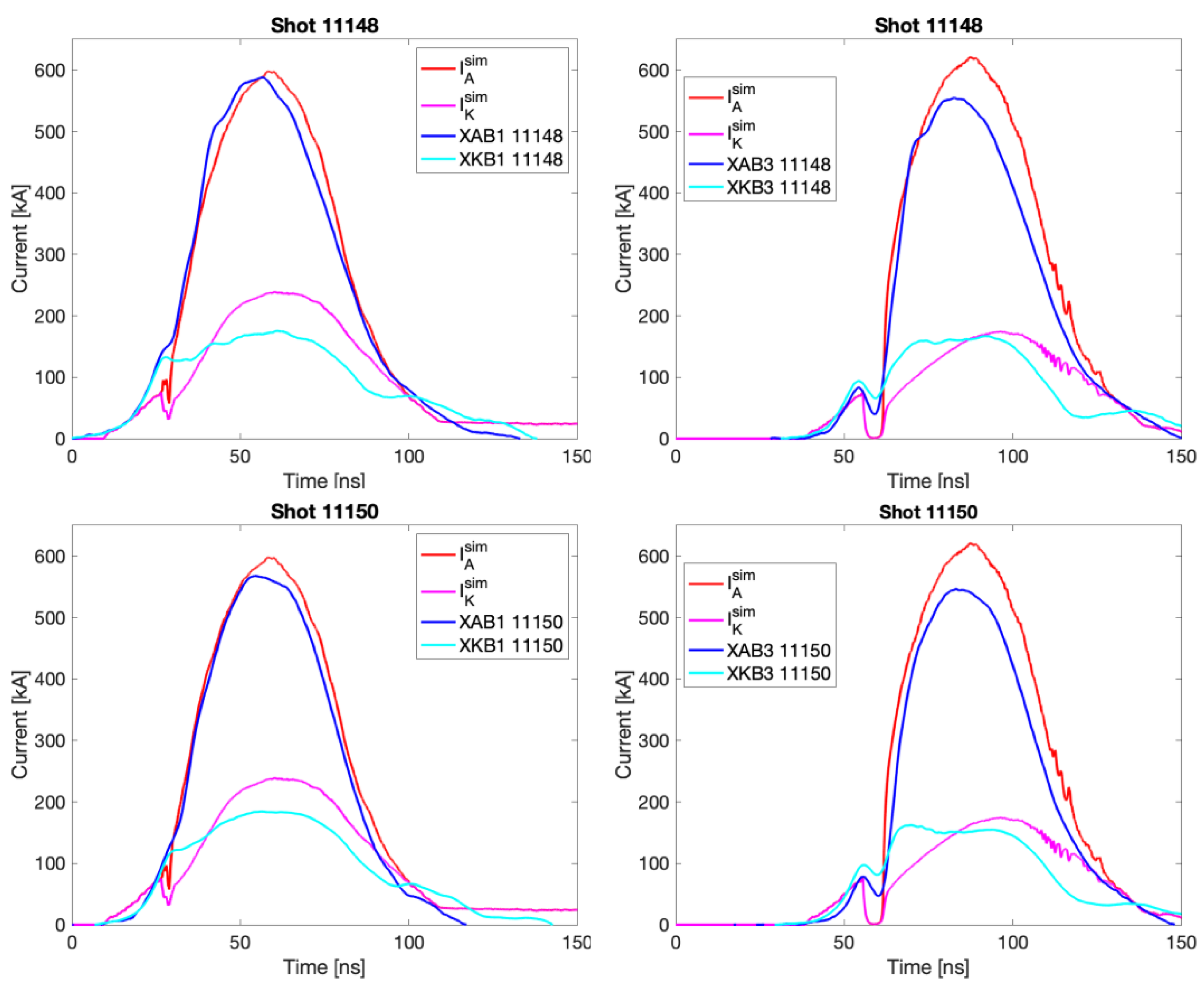




Redesigned Configuration



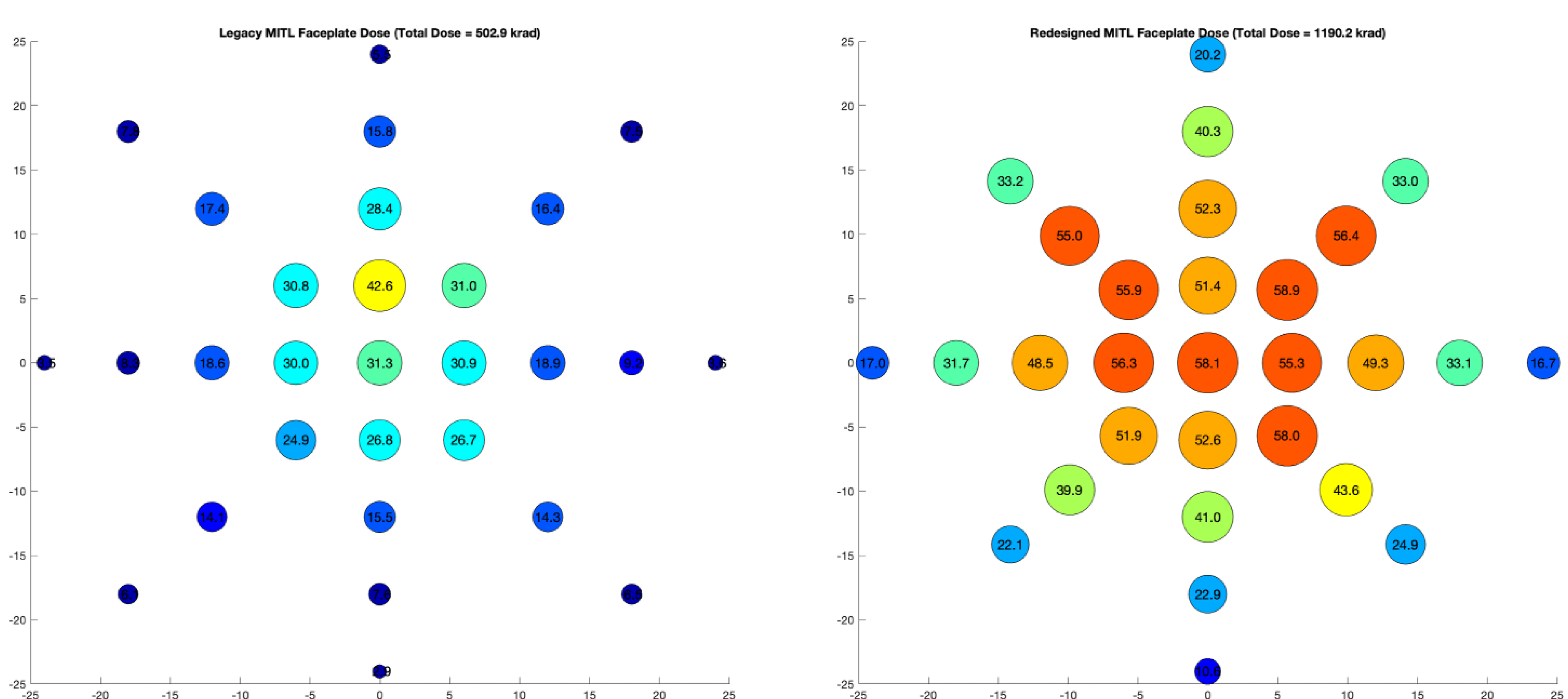


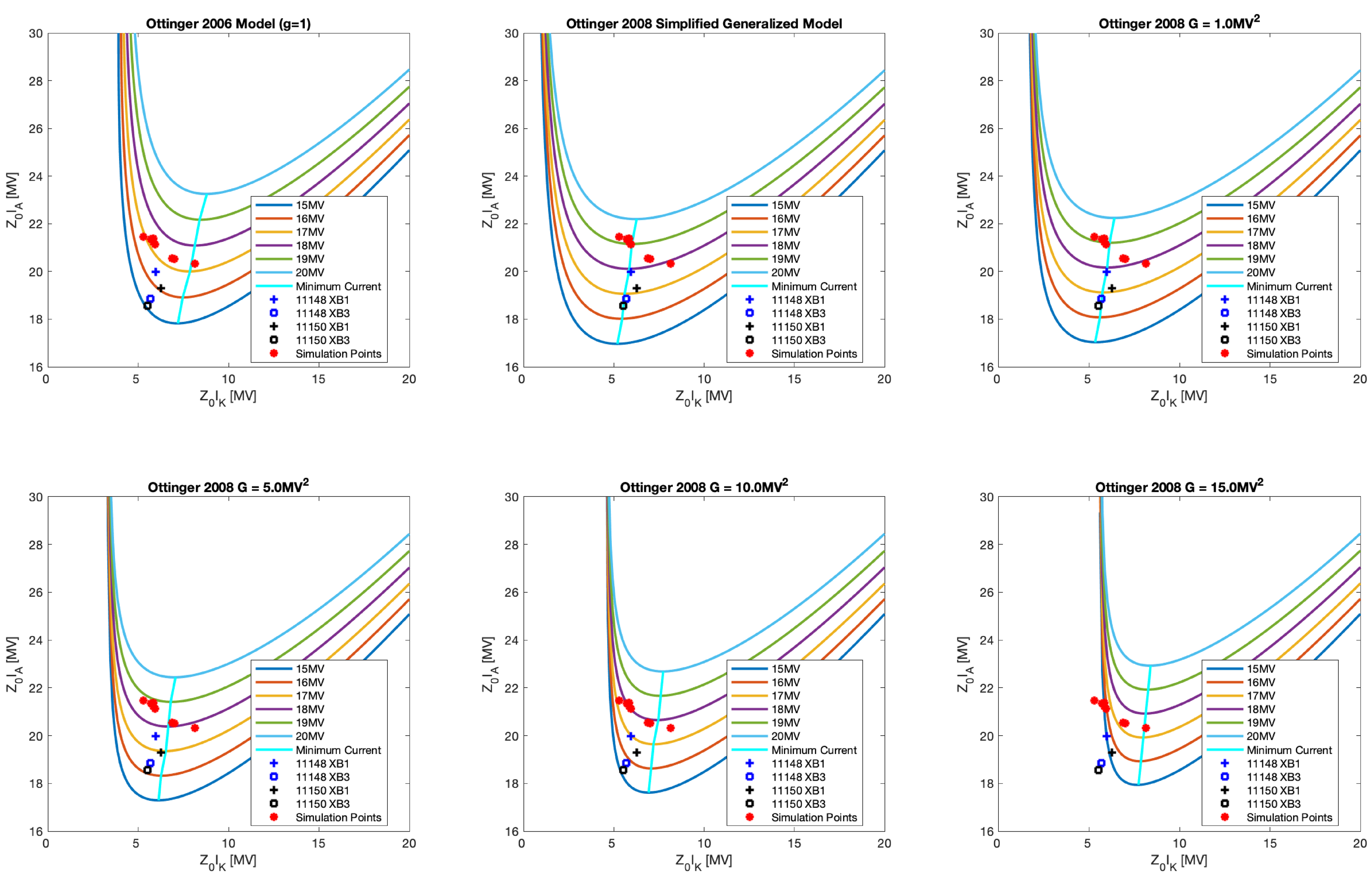


$$V_{Ott(06)} = Z_0(I_A^2 - I_K^2)^{1/2} - \frac{gmc^2}{2e}\frac{I_A^2 - I_K^2}{I_K^2} \qquad V_{Ott(08)} = Z_0(I_A^2 - I_K^2)^{1/2} - \frac{mc^2}{e}\frac{I_A - I_K}{I_K}$$

$$V_{Ott(08)} = Z_0\sqrt{I_A^2 - I_K^2} - \frac{mc^2}{e}\frac{Z_0 I_A - \left[Z_0^2 I_A^2 - \left(Z_0\sqrt{I_A^2 - I_K^2} + \frac{4T_m d^2/\varepsilon_0}{Z_0\sqrt{I_A^2 - I_K^2}}\right)^2\right]^{1/2}}{\left[Z_0^2 I_K^2 - \left(Z_0\sqrt{I_A^2 - I_K^2} + \frac{4T_m d^2/\varepsilon_0}{Z_0\sqrt{I_A^2 - I_K^2}}\right)^2\right]^{1/2}}$$

$$G \equiv 4T_m d^2/\varepsilon_0$$





Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. ____________

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.