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# MODELING THE RITS-6 TRANSMISSION LINE

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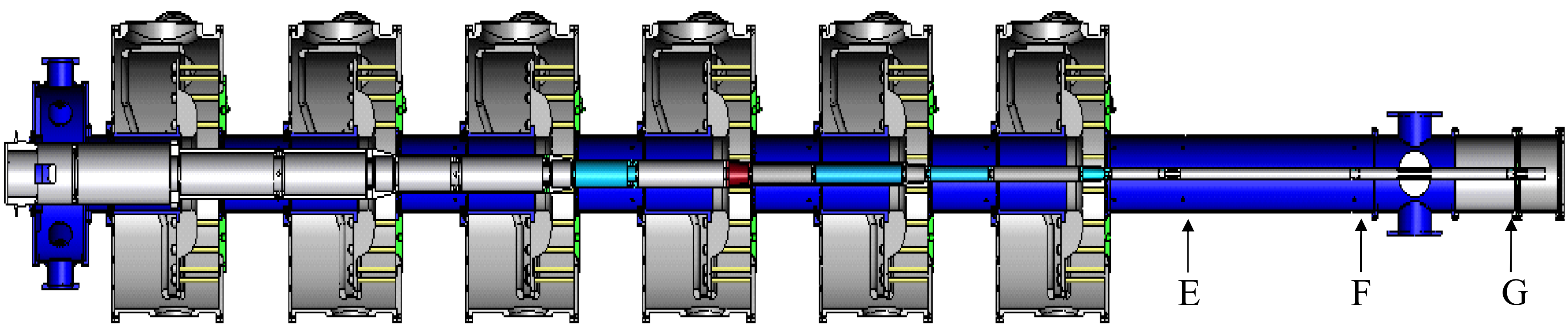
# RITS-6 Schematic

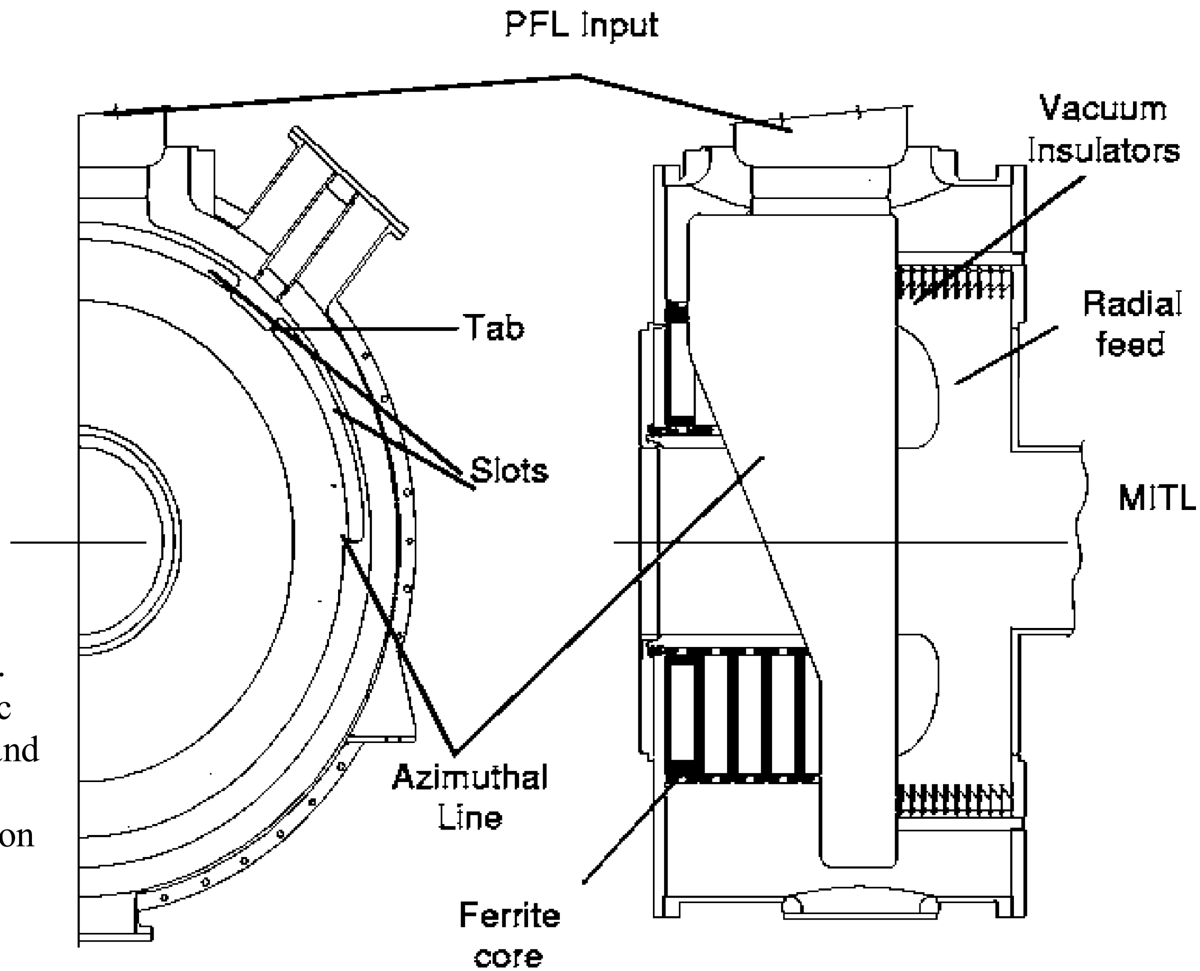
RITS-6 is a six-cell upgrade to Sandia National Laboratories' RITS Induction Voltage Adder (IVA) accelerator built to investigate sources for pulse-power-driven flash radiography. The system is designed to deliver 120 kA at voltages in excess of 10 MV in 70 ns for the 102.9-Ω transmission line. Six separate pulses, generated in 7.8-Ω parallel water-insulated pulse forming lines, are added in series with induction voltage adder (IVA) cells. The individual cells are joined in series by a vacuum coaxial magnetically insulated transmission line (MITL). The pulses are timed to arrive nearly simultaneously in the MITL to form the high-voltage drive pulse.




Schematic of RITS-6 IVA accelerator

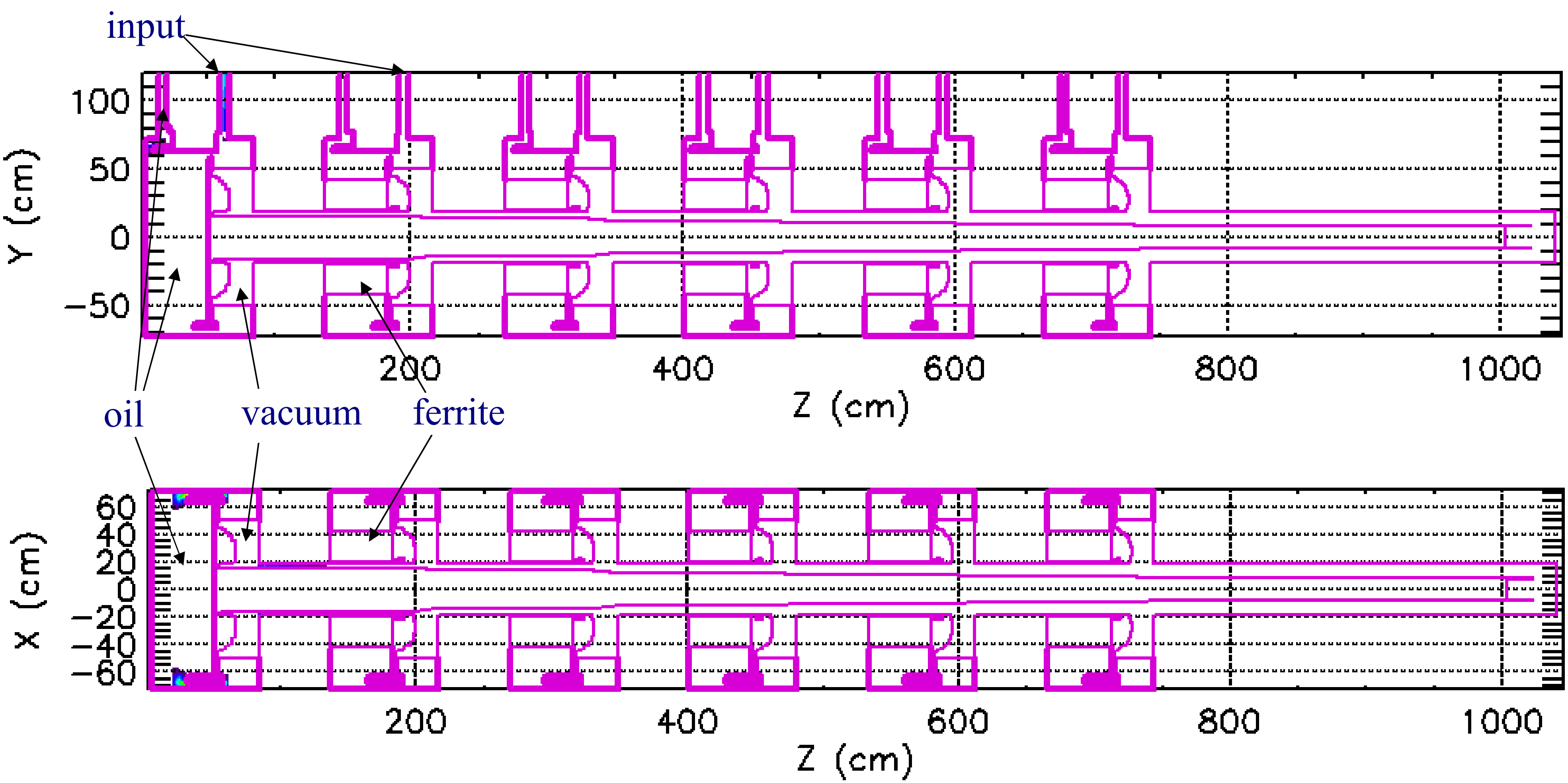
# RITS-6 Power Feed:
# Azimuthal Transmission Line

Each IVA cell has a radial point feed with a tapered azimuthal transmission line to distribute the incoming pulse around the bore of the cell.




Tabs were omitted following a study by D.L. Johnson, *et al*., "Magnetic Insulation, Power Flow, and Pulse Power Results on RITS-3," 14th Intl. Conf. on High-Power Particle Beams, 123 (2002).

# LSP Representation of RITS-6 in 3D




<u>Simulation parameters</u>

- resolution in transmission line vacuum region:

$\Delta x$=1.1 mm

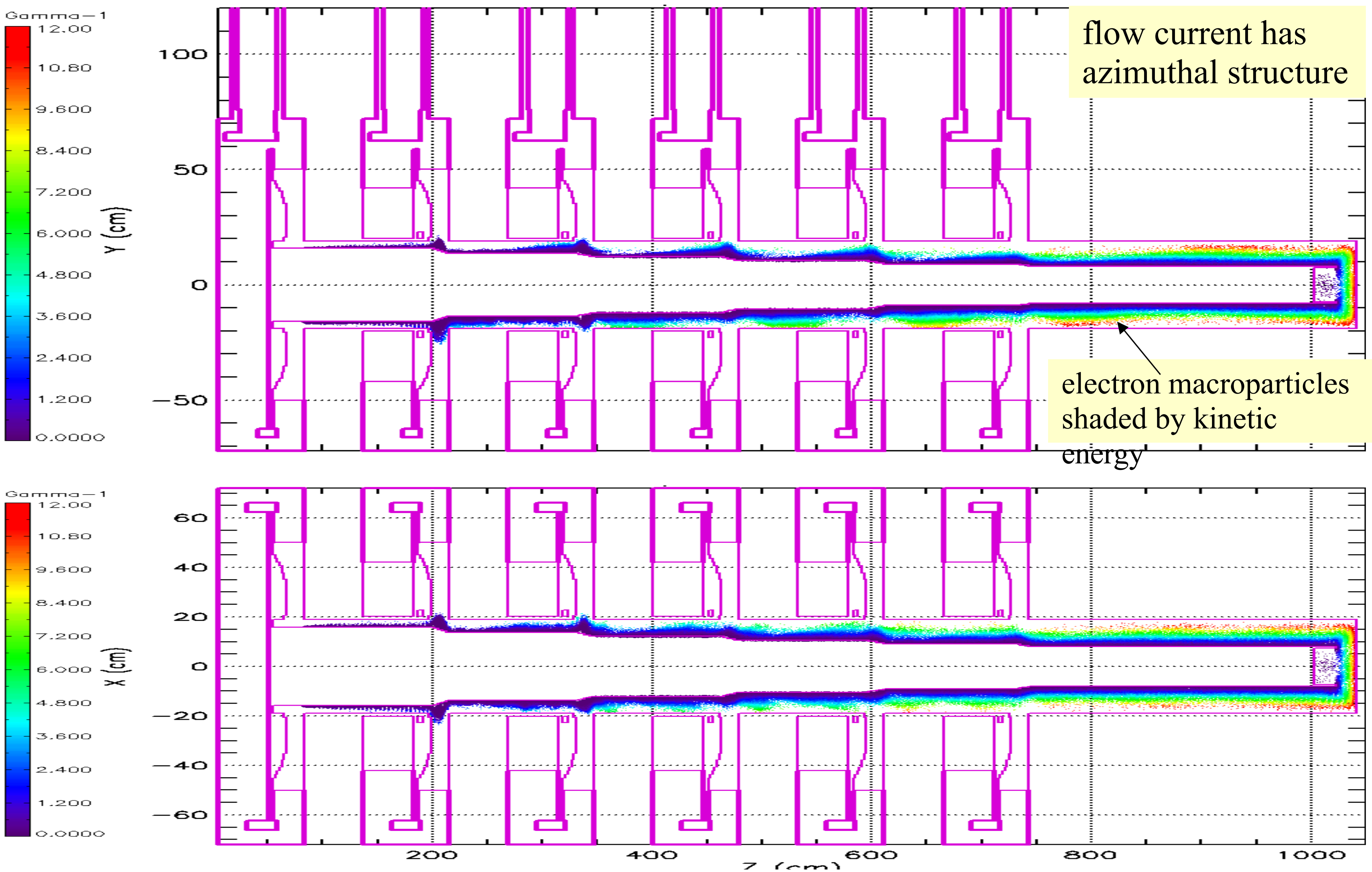
$\Delta y$=1.1 mm

$\Delta z$=1.23 – 1.43 cm

- full transmission line modeled, including large-area diode
- output from PFLs to radial feed modeled as a circuit
- space-charge-limited emission of electrons
- modified from RITS-3 study by B. Oliver *et al*., "Two and three-dimensional MITL power-flow studies on RITS," 14$^{th}$ Intl. Pulsed Power Conf., 395 (2003).

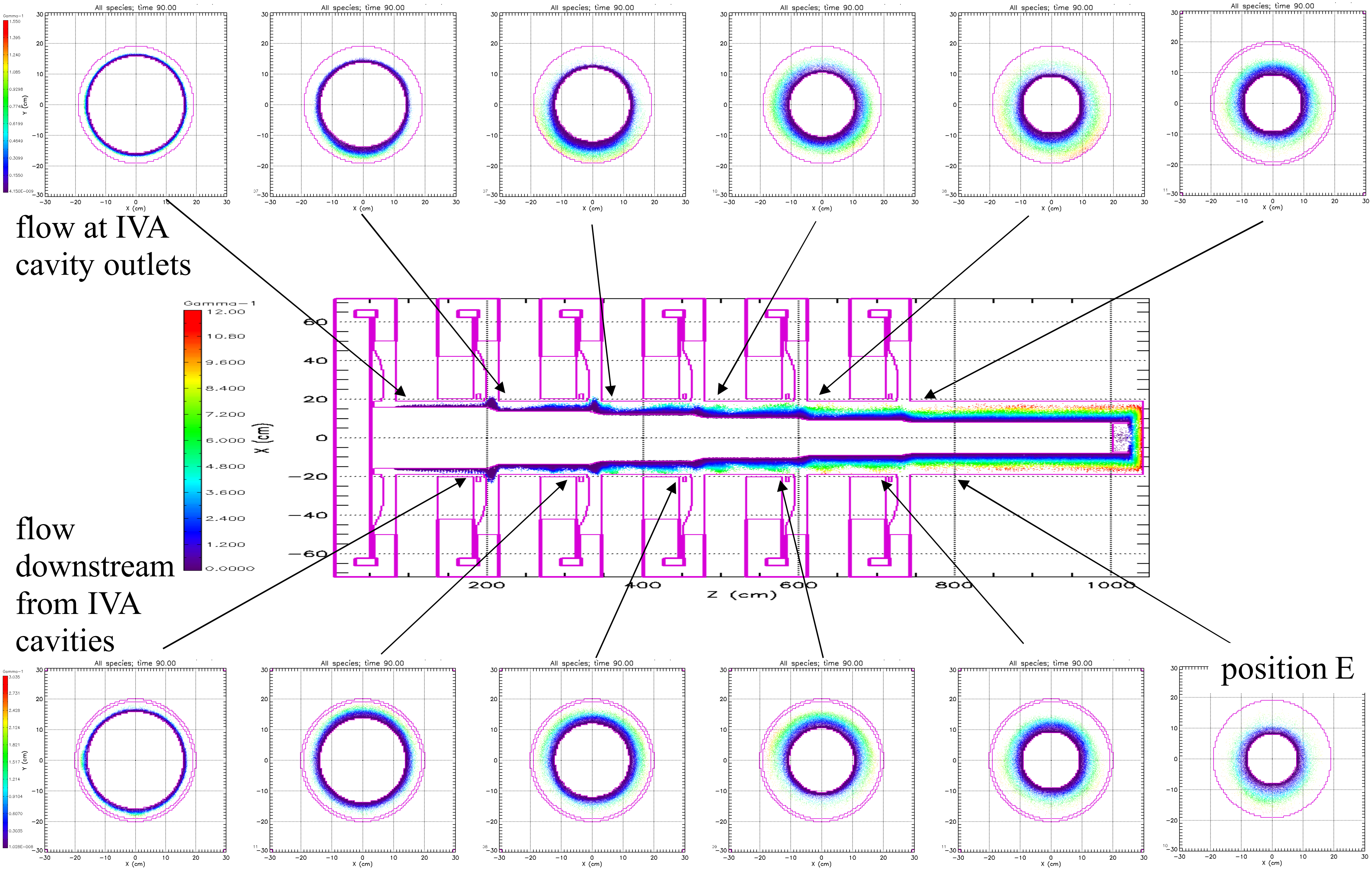
# Power Flow in 3D

Flow current is asymmetric at IVA cell junctions.



# Power Flow in 3D

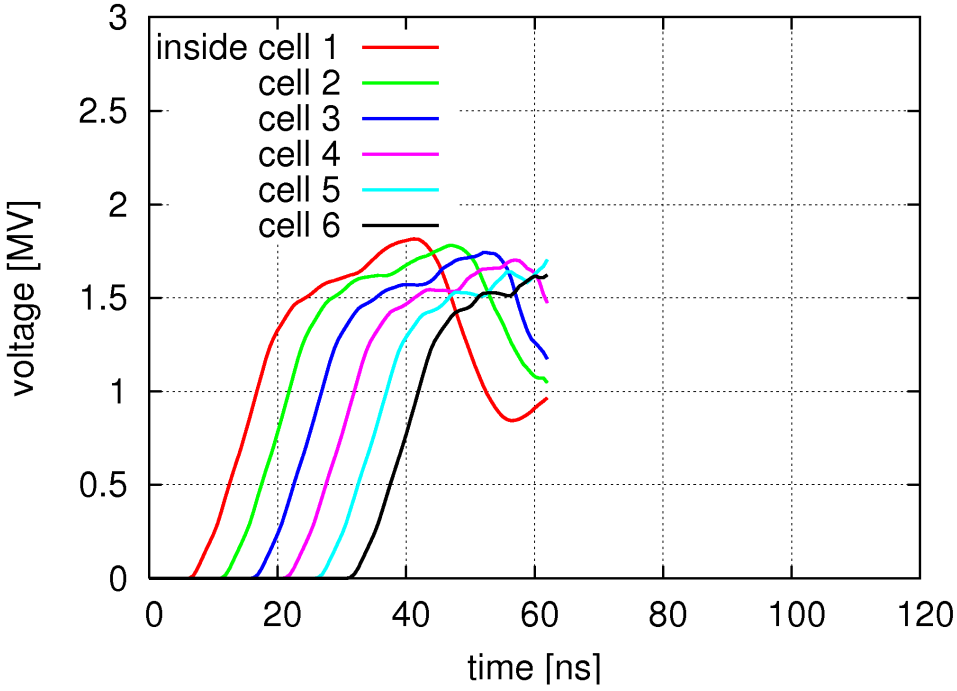
Flow becomes symmetric downstream from azimuthal transmission lines.



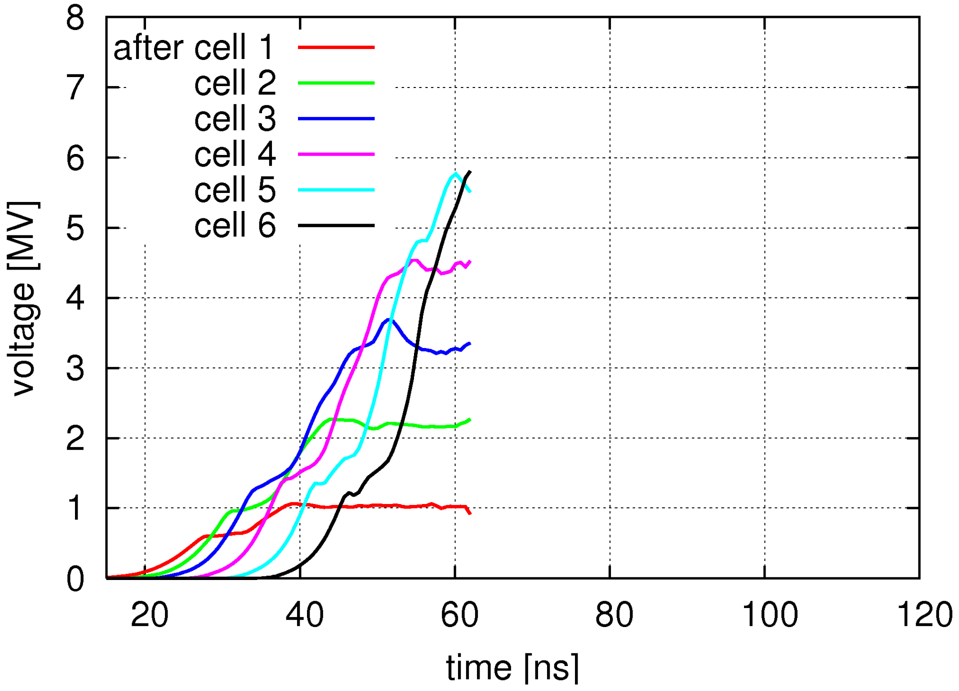
# Electrical Characteristics
# Full 3D Simulation with PFL Circuit

Simulation voltages using the PFL circuit model:

Voltages measured inside each IVA cell



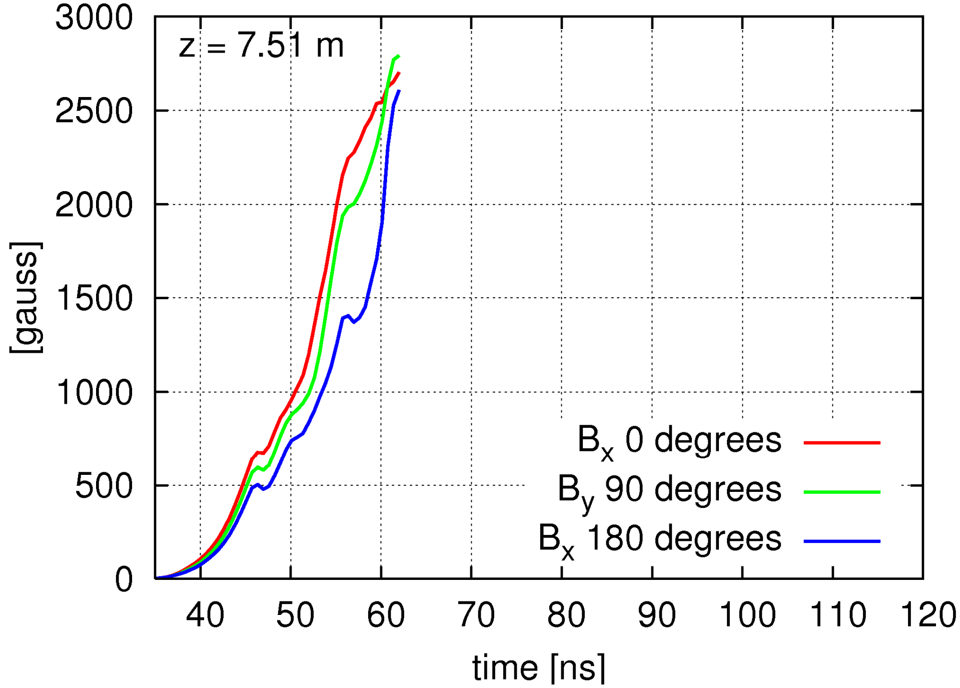

MITL Voltages after each IVA cell



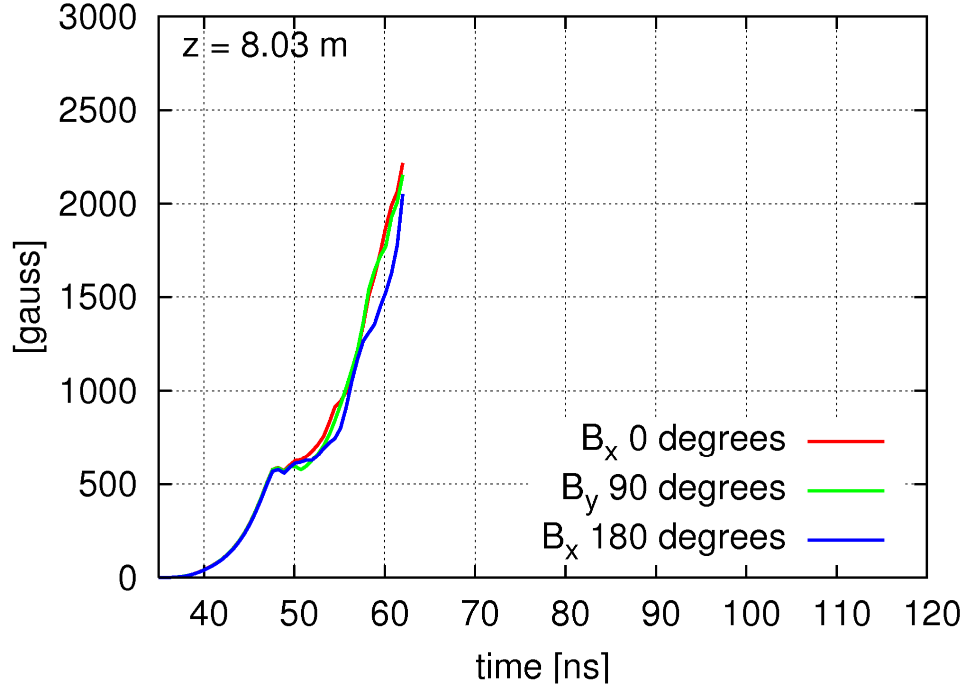
# Azimuthal Variations in Flow Current

Current is reasonably symmetric by position E.

Magnetic field probes just after 6th IVA cell



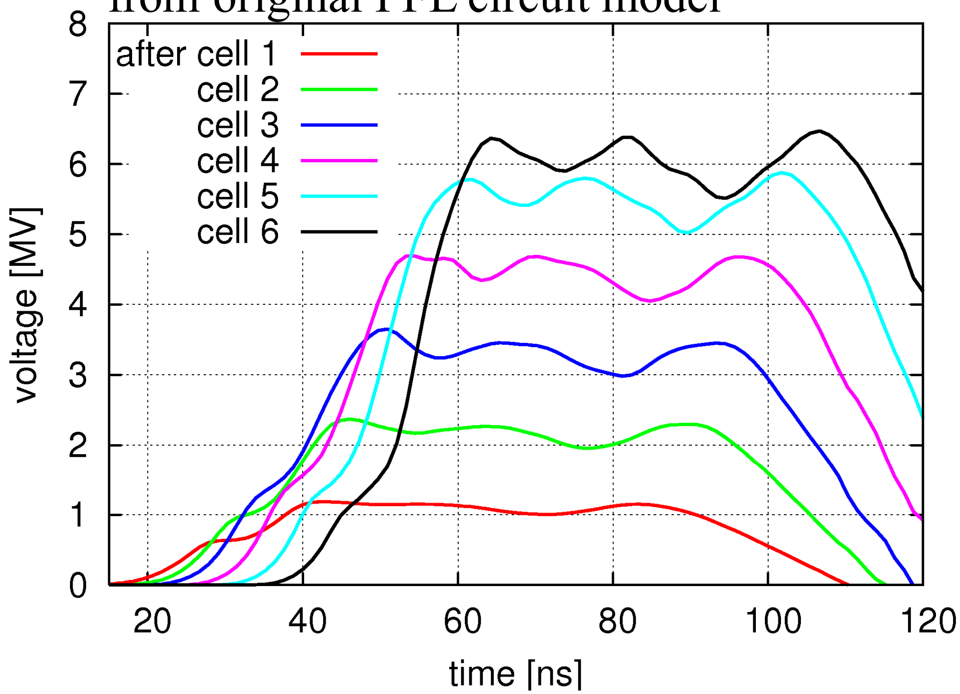

Magnetic field probes at position E



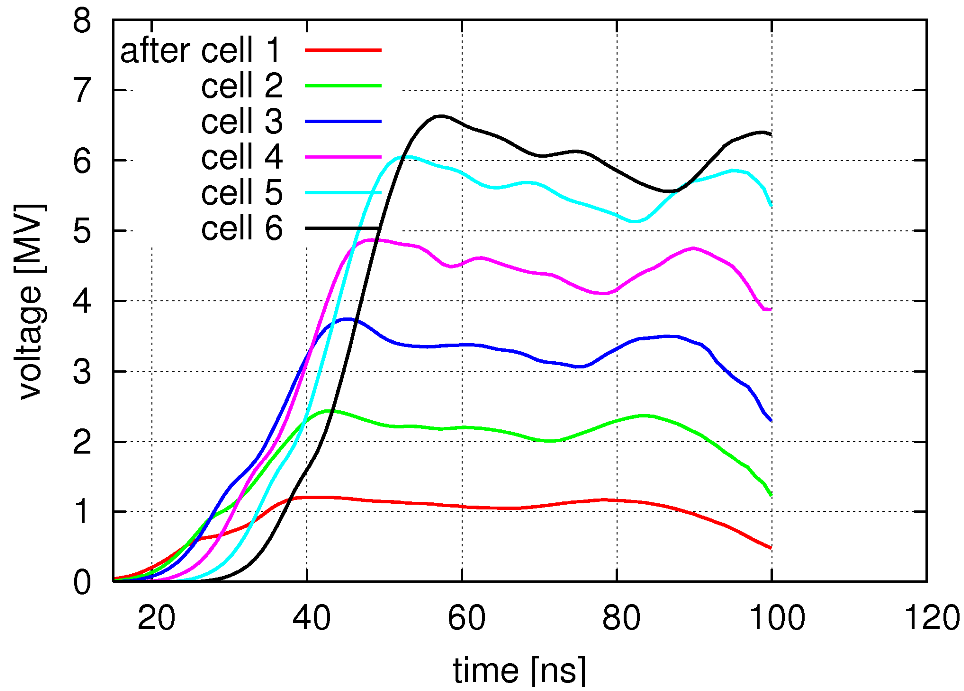
# Electrical Characteristics
# Impact of PFL Circuit Parameters on Pulse Oscillations

Original parameters in the circuit modeling the pulse feed include 7.8-Ω PFL and subsequent switches and lines, terminating with a 9.8-Ω connection to the radial feed, all enclosed in an oil dielectric. This resulted in 50-Ω oscillations in the drive pulse. Similar oscillations are observed on RITS-6. Changing electrical parameters in the circuit model changed the downstream oscillation frequency.

Voltages after each IVA cell
from original PFL circuit model




Voltages after each IVA cell
with reduced oil dielectric constant



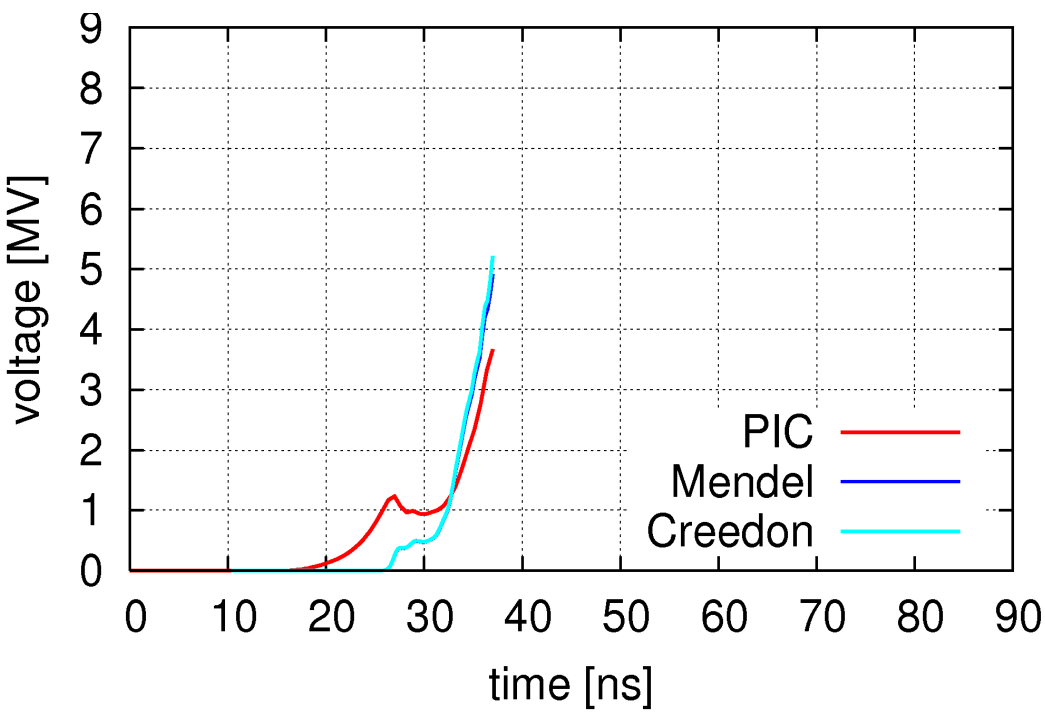
# Comparison of Voltages from PIC and Theory

Mendel's pressure balance theory [Laser Pert. Beams **1** 311 (1983)] (with F=G=1):

$$V = Z_0 \left(I_a^2 - I_c^2\right)^{1/2} - \frac{0.511}{F}\left(\frac{I_a}{I_c} - 1\right)\left[G\left[2F\left(\frac{I_a}{I_c} + 1\right)\right]^{1/2} - 1\right]$$

Creedon model [J. Appl. Phys. **46** 2946 (1975)]:

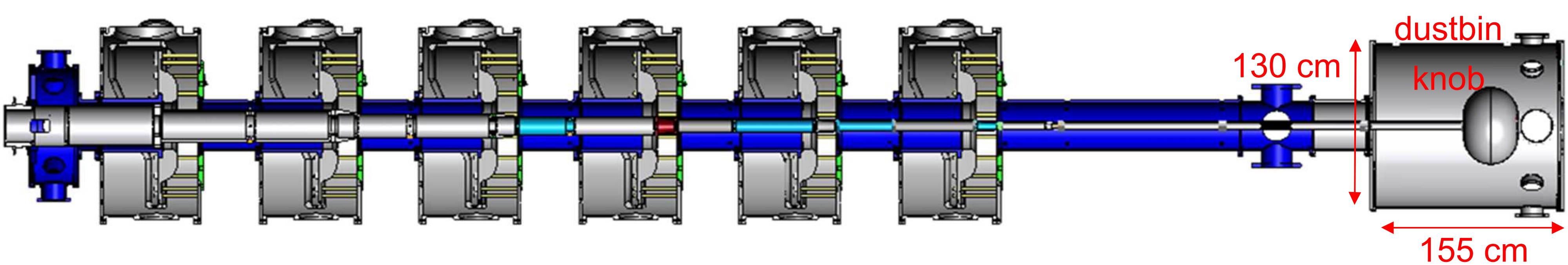
$$V = Z_0 \left(I_a^2 - I_c^2\right)^{1/2} + 0.511\left[\frac{I_a}{I_c} - \left(\frac{I_a^2}{I_c^2} - 1\right)^{1/2} \ln\left[\frac{I_a}{I_c} + \left(\frac{I_a^2}{I_c^2} - 1\right)^{1/2}\right] - 1\right]$$




Voltages typically agree between simulation and these theories when simulations have high spatial resolution.

# Conclusions and Outlook

- PIC simulations are a valuable tool for uncovering potential problems with transmission line power flow.
- MITL electrical diagnostics rely on symmetric, laminar current flow. 3D simulations of RITS-6 accelerator including radial pulse feeds enable predictions of flow current distribution. Current is symmetric by diagnostic position E.
- Voltages typically agree between simulation and the theories of Mendel and Creedon when simulations have high spatial resolution.
- Preliminary studies show that drive-pulse oscillations may be manipulated by changing the switch and line impedances and the oil dielectric constant in the PFL circuit. Future work will determine if the 125-MHz oscillation measured along the RITS-6 MITL can be reproduced.
- An optional "dustbin" and "knob" may be added as an extension of the transmission line for low-impedance loads to re-direct excess sheath current away from the diode (shown below). Future 3D simulations will be conducted to examine asymmetries in sheath in the dustbin region.




Schematic of RITS-6 IVA accelerator with dustbin and knob