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Initial 3D Electromagnetic RF Gun Simulations with VORPAL

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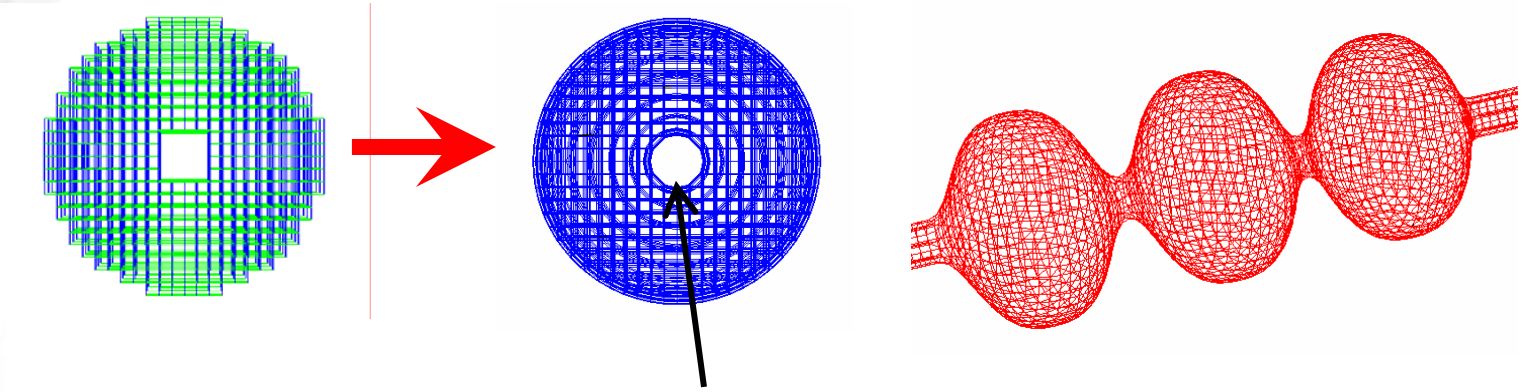
Motivation

- Generation of high order modes in an SRF electron gun with high average and peak current is a serious concern.
- Only a fully electromagnetic code can study this problem.
- The 3D massively parallel particle-in-cell (PIC) code VORPAL is uniquely suited for this application.
- We present initial simulations and preliminary benchmarking results with PARMELA.

VORPAL Geometry Representation Capability

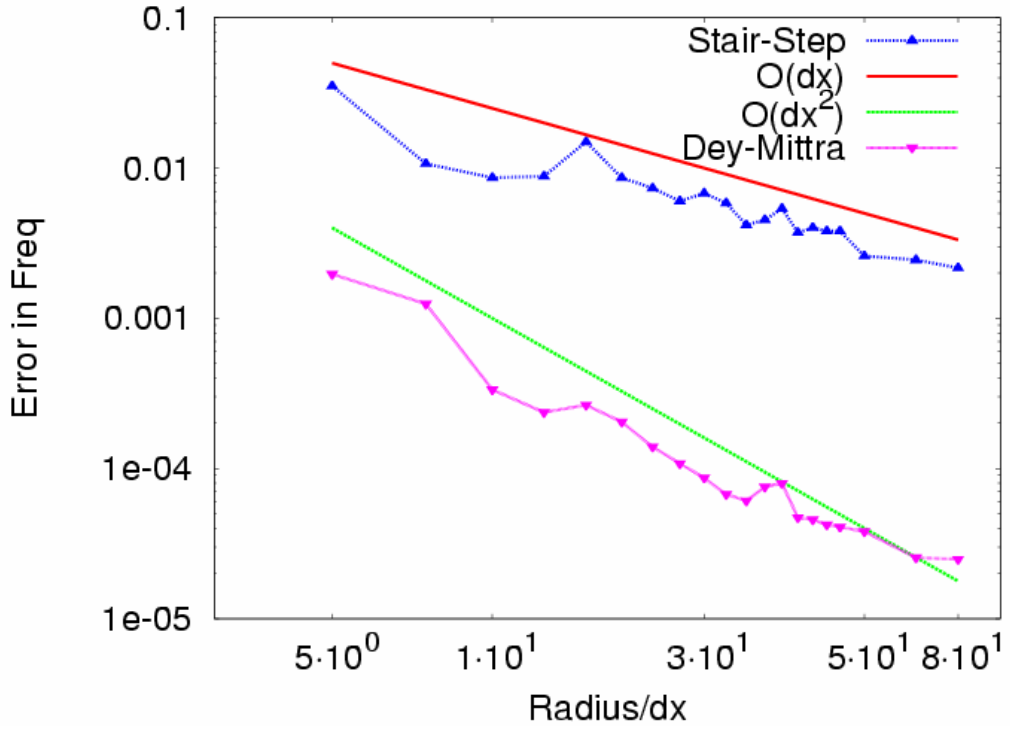
- VORPAL software is able to do curved surfaces modeling.



- Improves accuracy of wakefield and HOM coupling and propagation through apertures.
- Cavity focusing and defocusing effects during acceleration-deceleration passes.

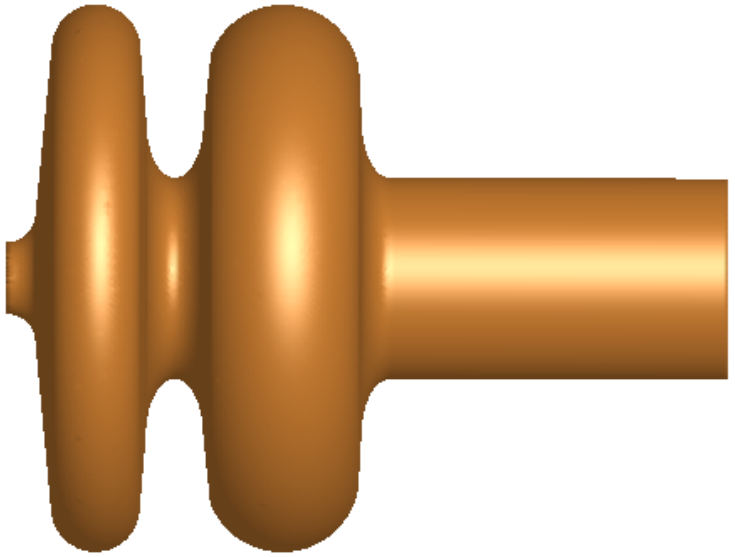
VORPAL Provides Second Order Accuracy for 3-D Accelerating Cavities

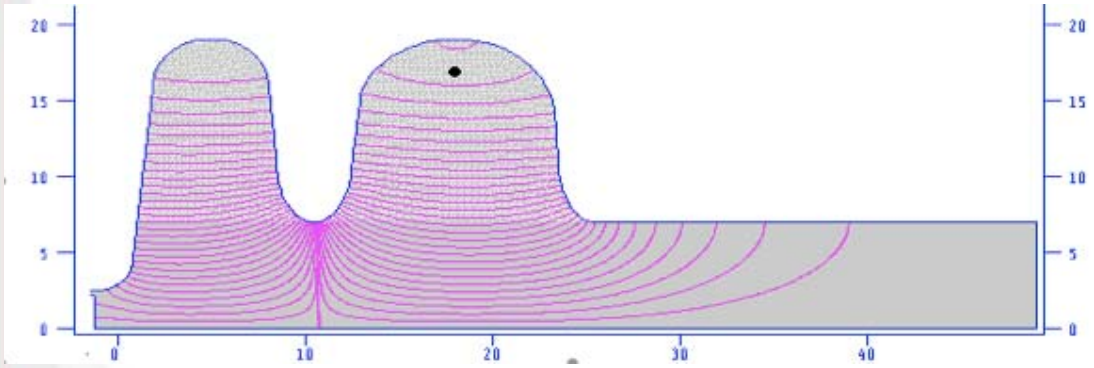
- Even the Mafia code uses stair-step (first order accurate) boundaries.
- Finite element codes cannot propagate intense beams



Simulation parameters are for the 1.5 Cell RF Gun Developed in BNL - (1)

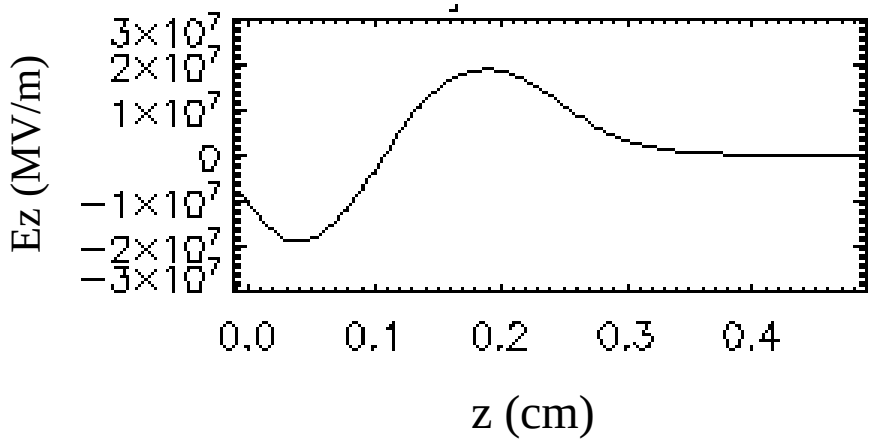
- 3D geometry of the gun in VORPAL:
- Based on a SUPERFISH axial symmetry description:



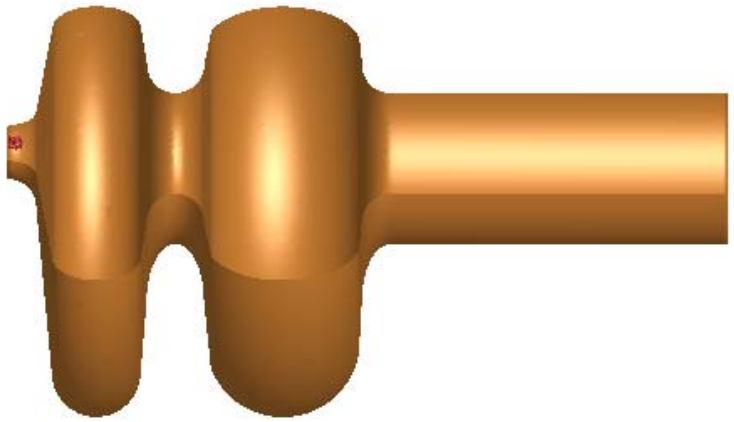


Simulation parameters used for the 1.5 Cell RF Gun Developed in BNL - (2)

- RF field frequency: 703.75 MHz
- RF field at cathode surface at t = 0: -8.28 MV/m
- RF phase: 40 degrees
- RF field amplitude: 30 MV/m
- Beer can beam shape with approximately 5.3 nC total charge
- Beam radius: 4 mm
- Beam length: 80 ps



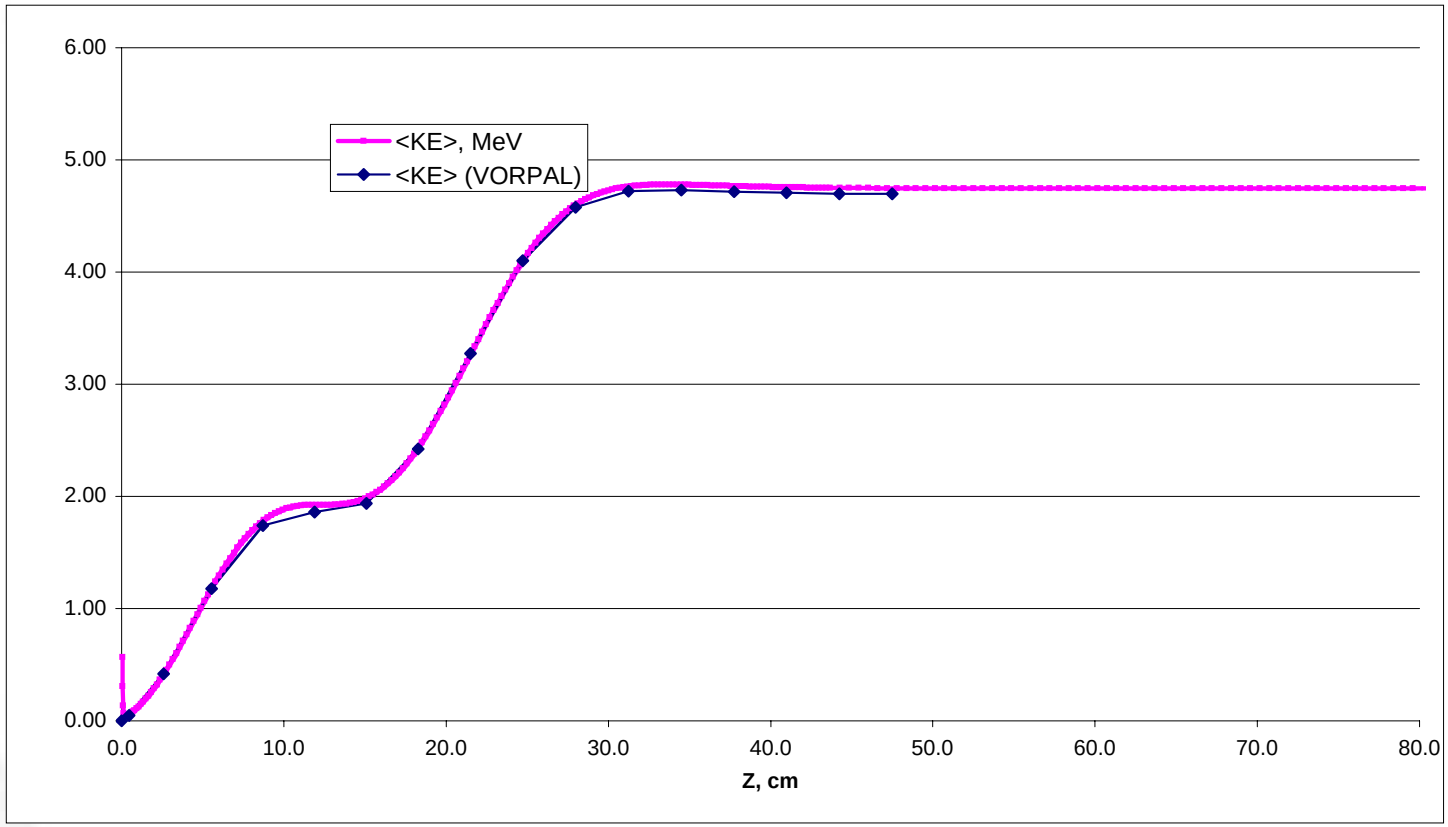
VorpalView* allows beam visualization in complex cavity geometry



*VorpalView has been developed by David Smithe, Seth Veitzer, Peter Stoltz, Peter Messmer, and the VORPAL team.

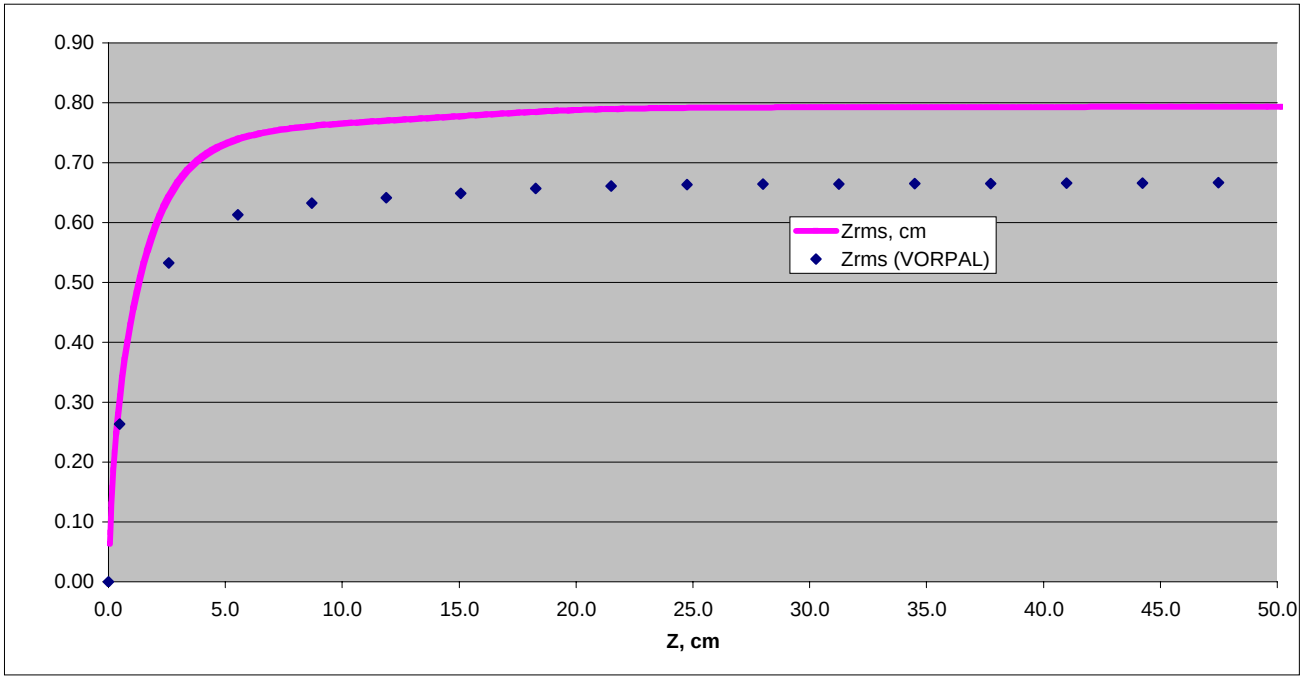
VORPAL Average Kinetic Energy Agrees Well with PARMELA

- Provides confirmation that accelerating RF fields are correct.



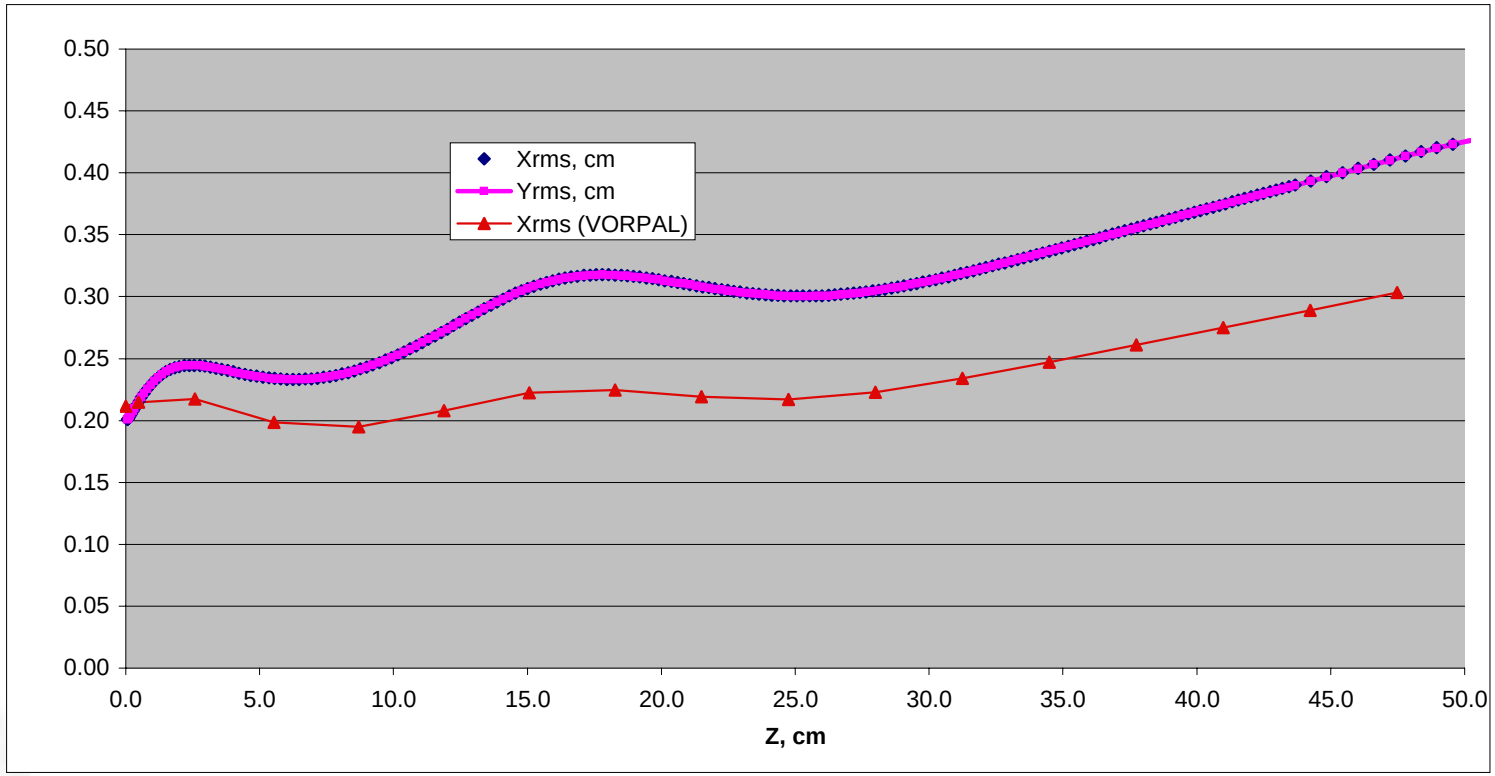
Comparison of RMS Bunch Length

- VORPAL simulation show shorter bunch length
  - The behavior is qualitatively similar.



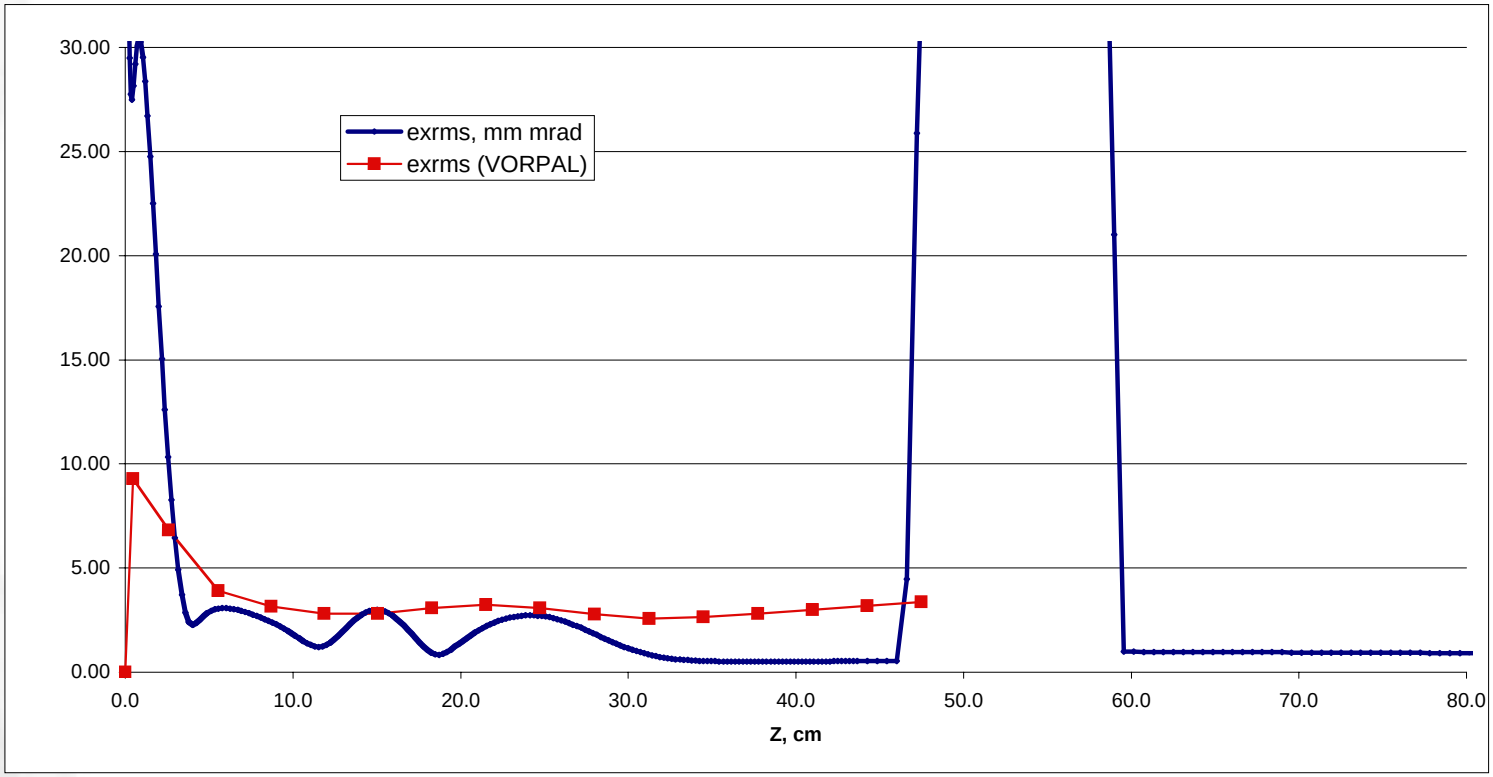
VORPAL Shows Qualitatively Similar Transverse RMS Size Behavior

- The observed transverse rms size was smaller in VORPAL (the beam was emitted with no thermal velocities).
- It is of interest to estimate the effect of the wake fields (considered in VORPAL) on this RMS size.



RMS Emittance

- Further studies are needed to understand the differences in the rms emittance, particularly the effect of wake fields included in VORPAL self consistently (and not considered in PARMELA)
- The jump in the PARMELA emittance at the end of the gun is due to the presence of a solenoid



Summary and Future Work

- 3D parallel PIC simulations with VORPAL demonstrated that the code is uniquely suited for SRF electron gun studies.
  - Initial simulations and preliminary benchmarking of VORPAL results show reasonable agreement with PARMELA
- Future studies will focus on using higher accuracy algorithms, PML boundary conditions, multiple bunches, secondary electron emission from diamond amplifiers, and photocathode physics.

Acknowledgments

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