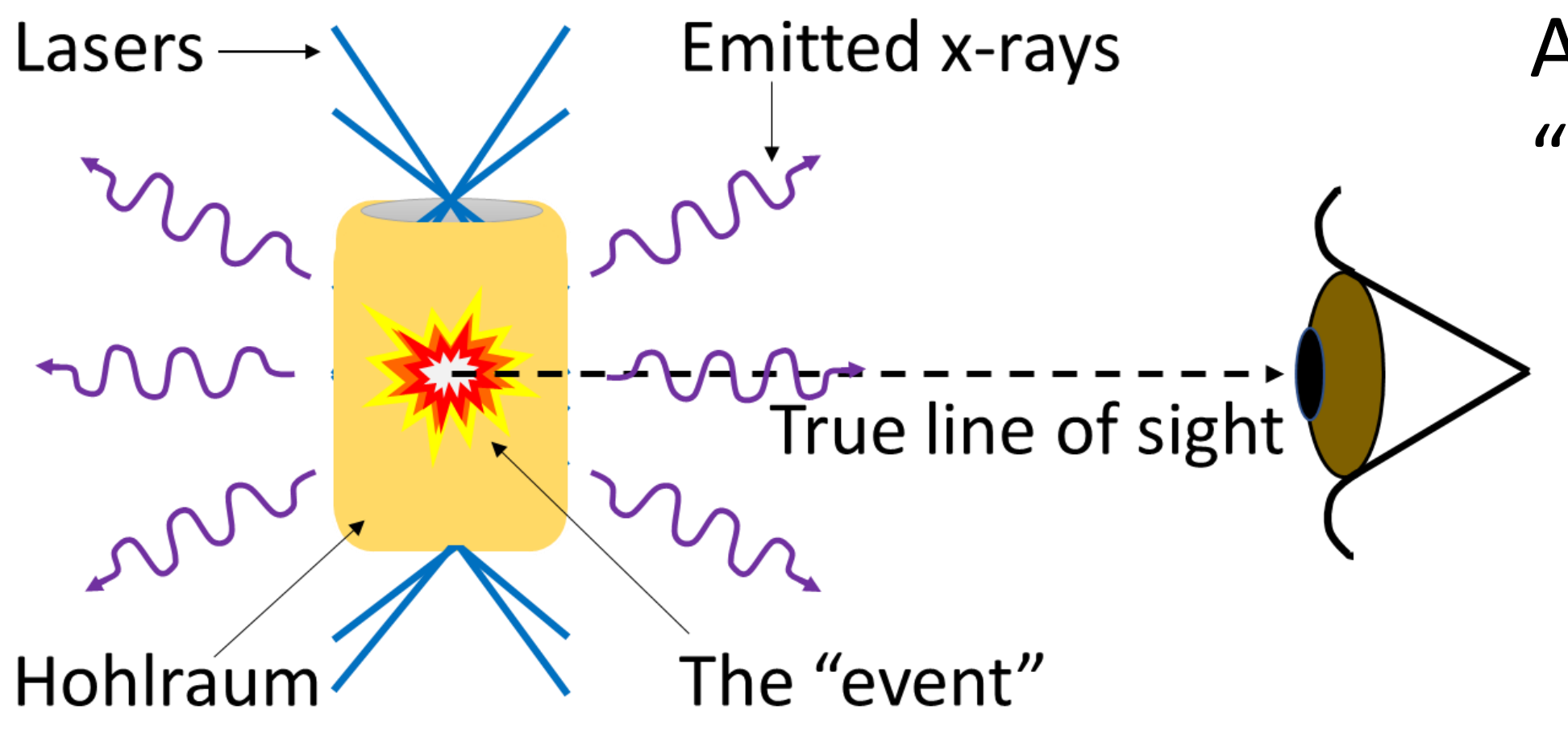
Simulating Space Charge Effects of Photocathode in SLOS

M. A. Mort*, C. G. Brown, A. C. Carpenter, and C. Trosseille

University of California, Davis*, NIF, Lawrence Livermore National Laboratory

Abstract: *Using the simulation software CST Particle Studio, a model will be developed for the space charge effects on a transmission photocathode used in diagnostic single line-of-sight (SLOS) cameras. The space charge effect limits temporal and spatial resolution which affects data gathered by SLOS. The model will help diagnose how the space charge effect limits SLOS data and will be a building block for future improvements of the integrated system.*

Introduction to Single Line-of-Sight

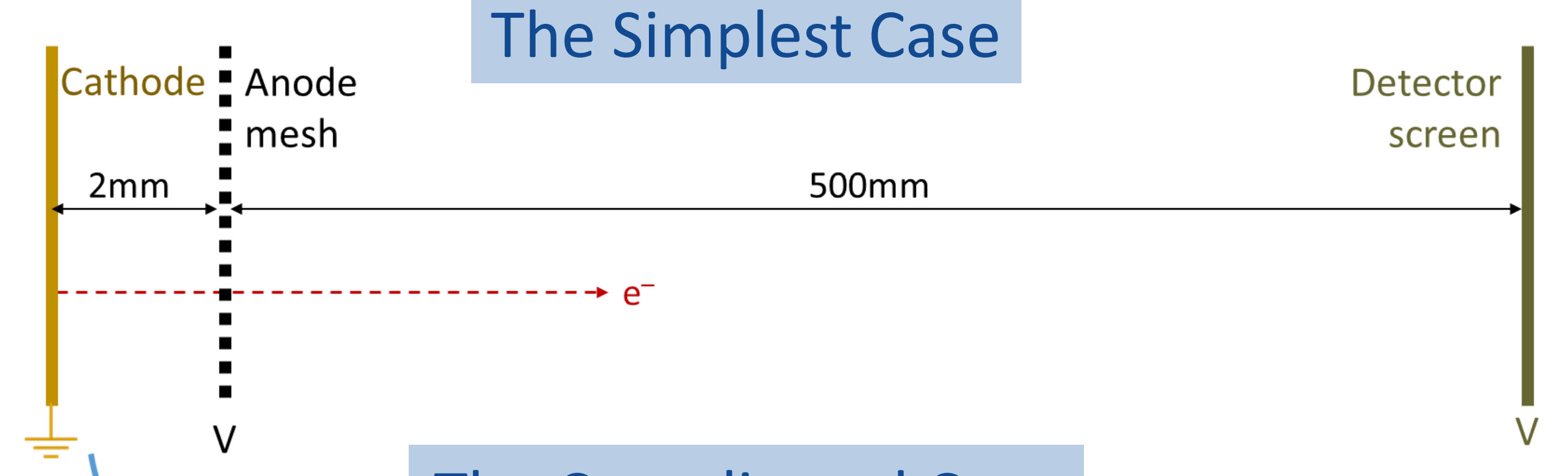


Advantages of a single "true line-of-sight":

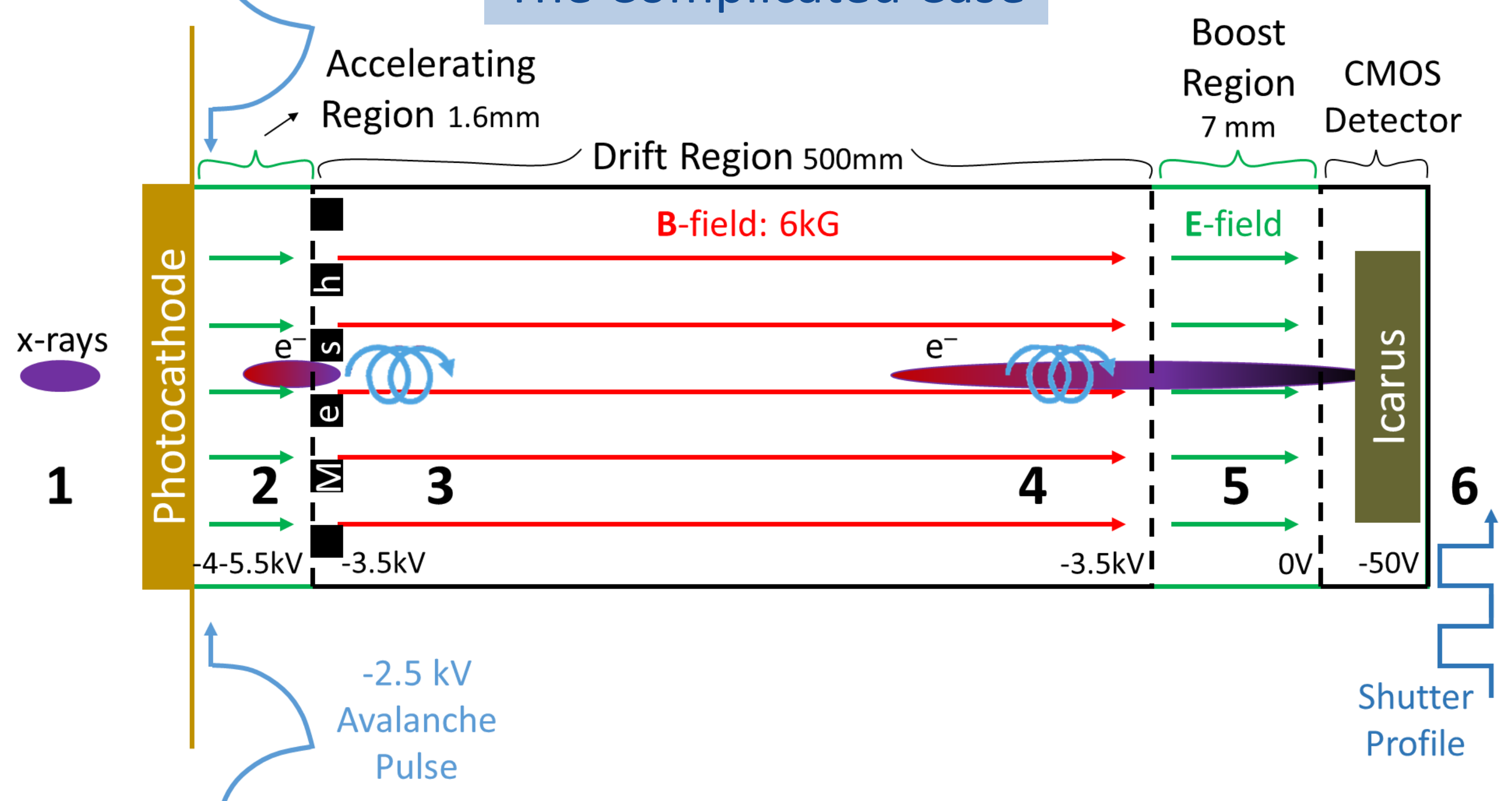
1. No parallax
2. Improved temporal resolution
3. More efficient use of x-ray optics

Background of SLOS Components

The Simplest Case



The Complicated Case

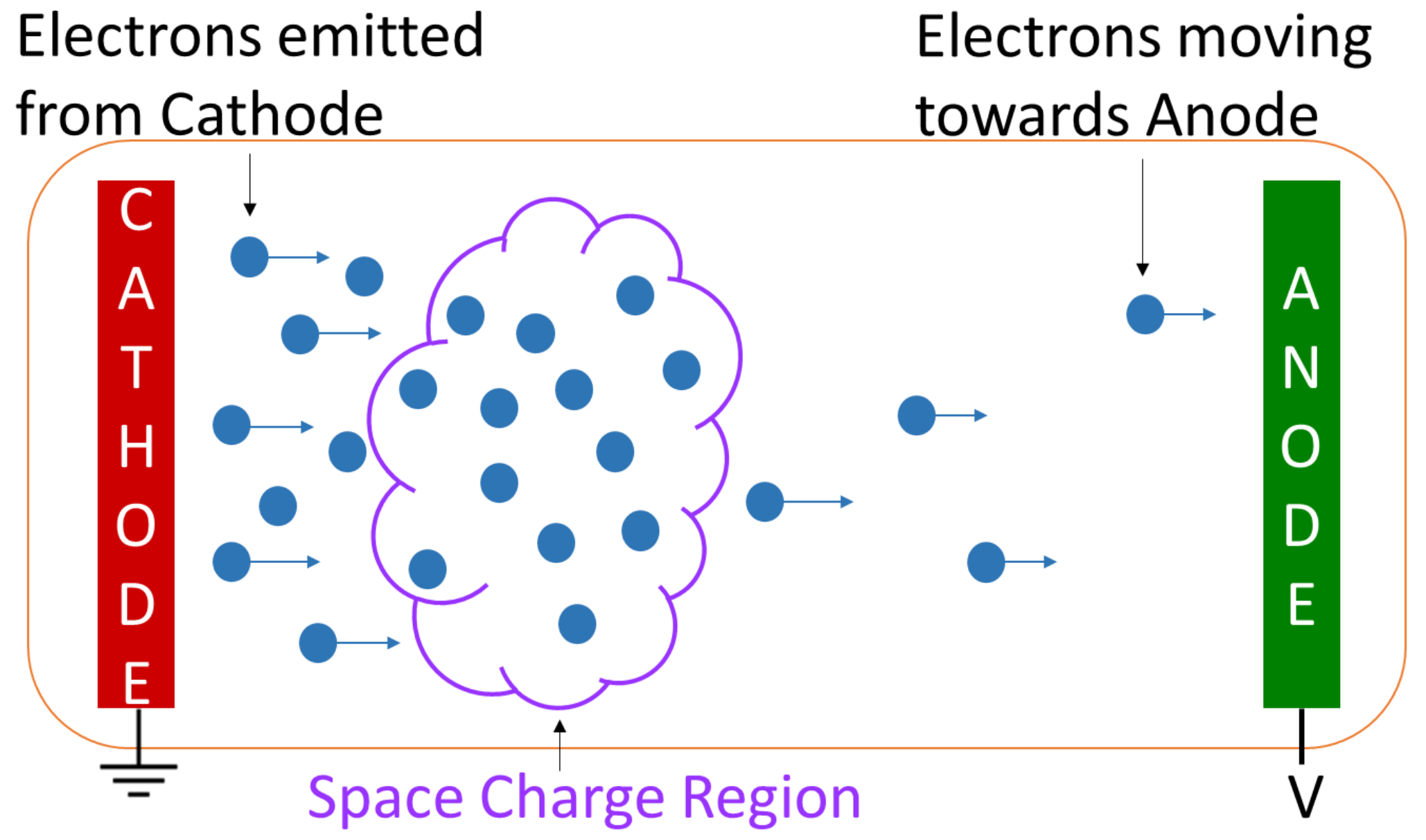


1. X-rays hit the photocathode and photoelectrons are emitted
2. Avalanche pulses collide to produce variant e-field that accelerates the photoelectrons towards the anode mesh
3. Accelerated electrons propagate down the drift tube in cyclotron orbits set by the Larmor radius
4. The input x-ray pulse has dilated ~50x as the electrons disperse down the drift tube
5. The boost region accelerates electrons further before impinging on the CMOS detector
6. The dilated electron pulse is collected over several ns wide frames by CMOS detector/Icarus

The **Challenge** of Mitigating Space Charge

Space Charge: electrons emitted from the photocathode collect in a cloud of negative charge close to the surface

The Space Charge Effect occurs when electrons from the cathode form a negatively charged cloud (space charge) of sufficient density to repel and oppose the emission of additional electrons from the cathode



Initial Results of Electron Trajectory

Initial Conditions	
Magnification	74
AK gap	1.6 mm
Drift tube length	500 mm
Voltage (V_o, no ramp)	-1000 V

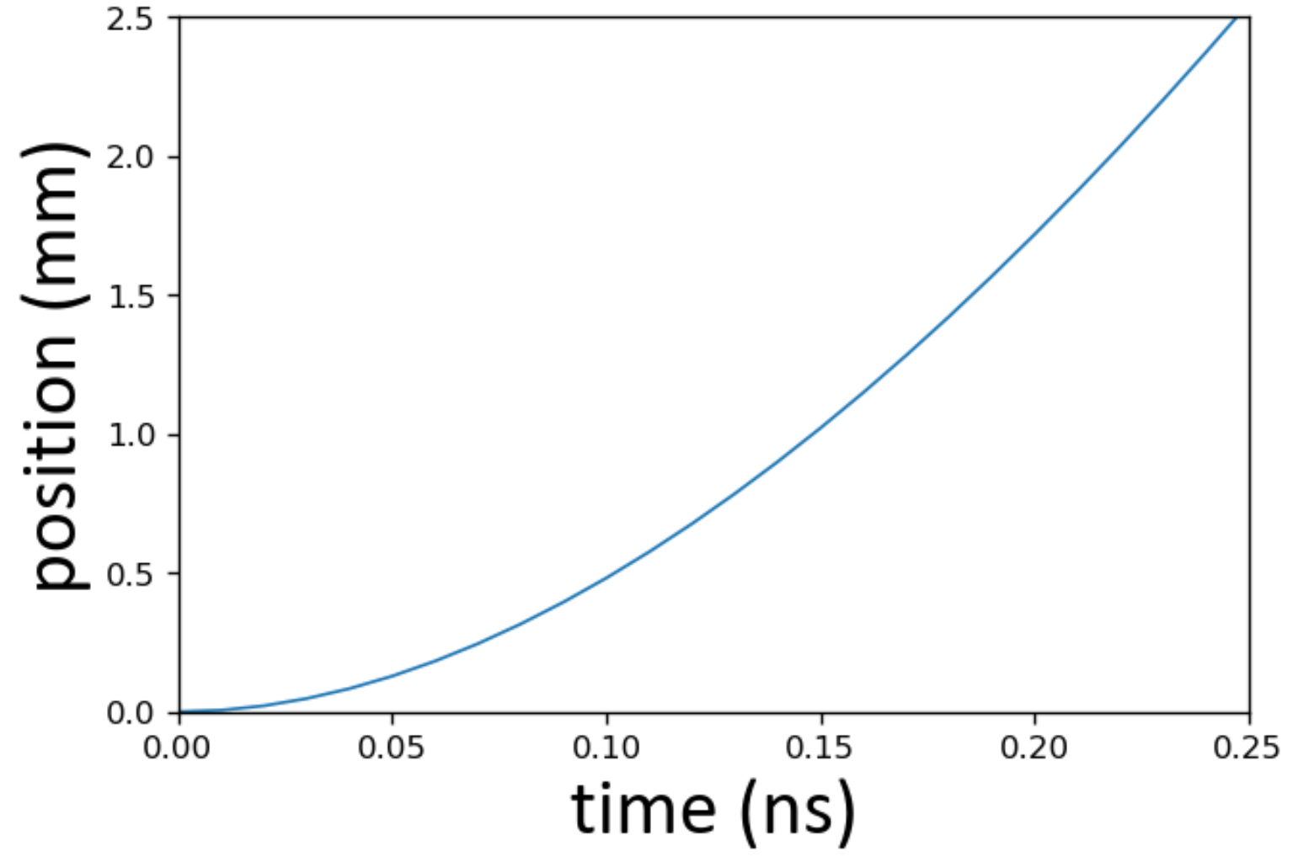
Electron Trajectories			
Electron number	1st	100th	e⁻ birth spread
Time left Cathode (ns)	0.0	15.0	15.0
Time crossed Anode (ns)	0.192	214.4	e⁻ arrival spread
Time to Detector (ns)	33.7	1143.8	1110.1
Velocity of e⁻ at Detector (Mm/s)	14.8	0.439	

$$V(t) = \frac{V_0}{[1 + (M-1)\frac{t}{T_0}]^2}$$

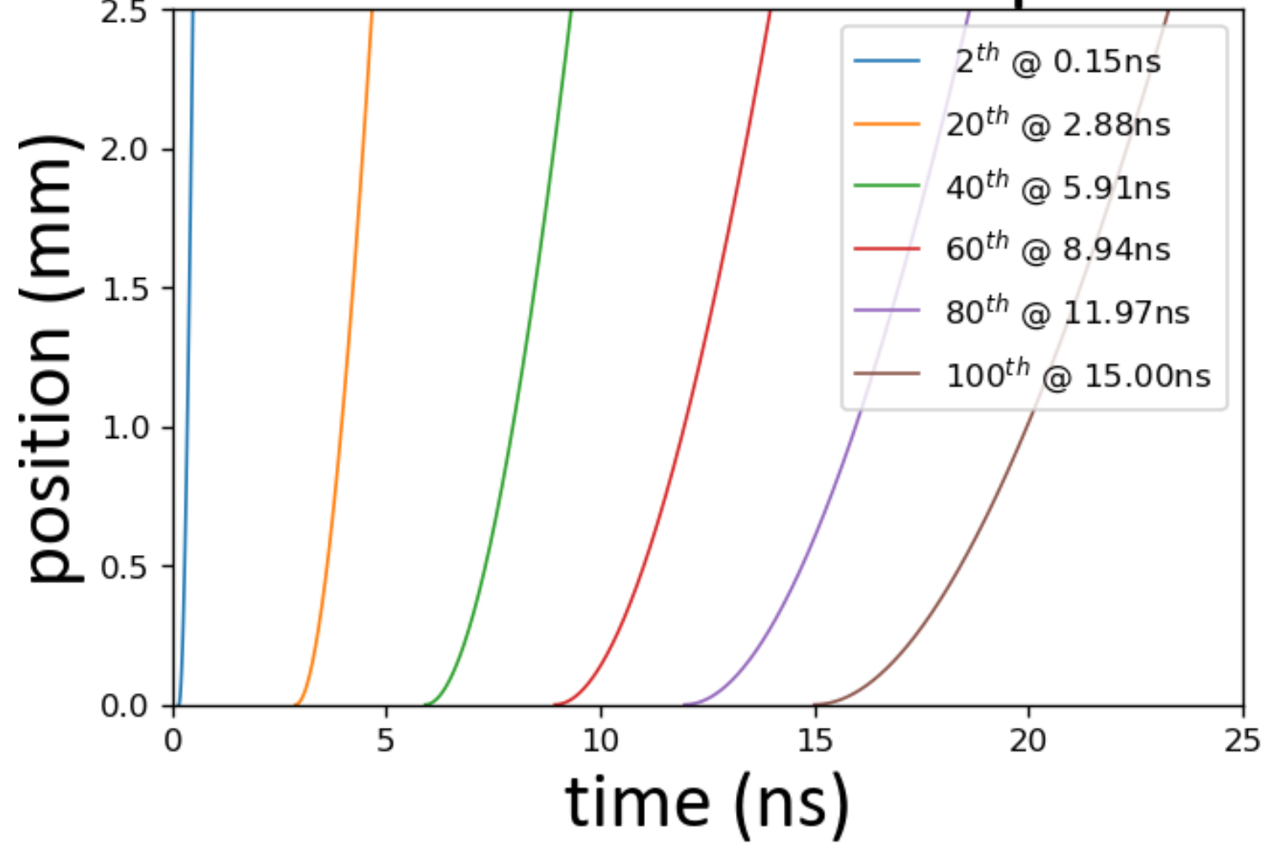
Voltage Ramp

Each electron that successively leaves the cathode is slower since it experiences a different force from the changing Electric Field set by the Voltage Ramp.

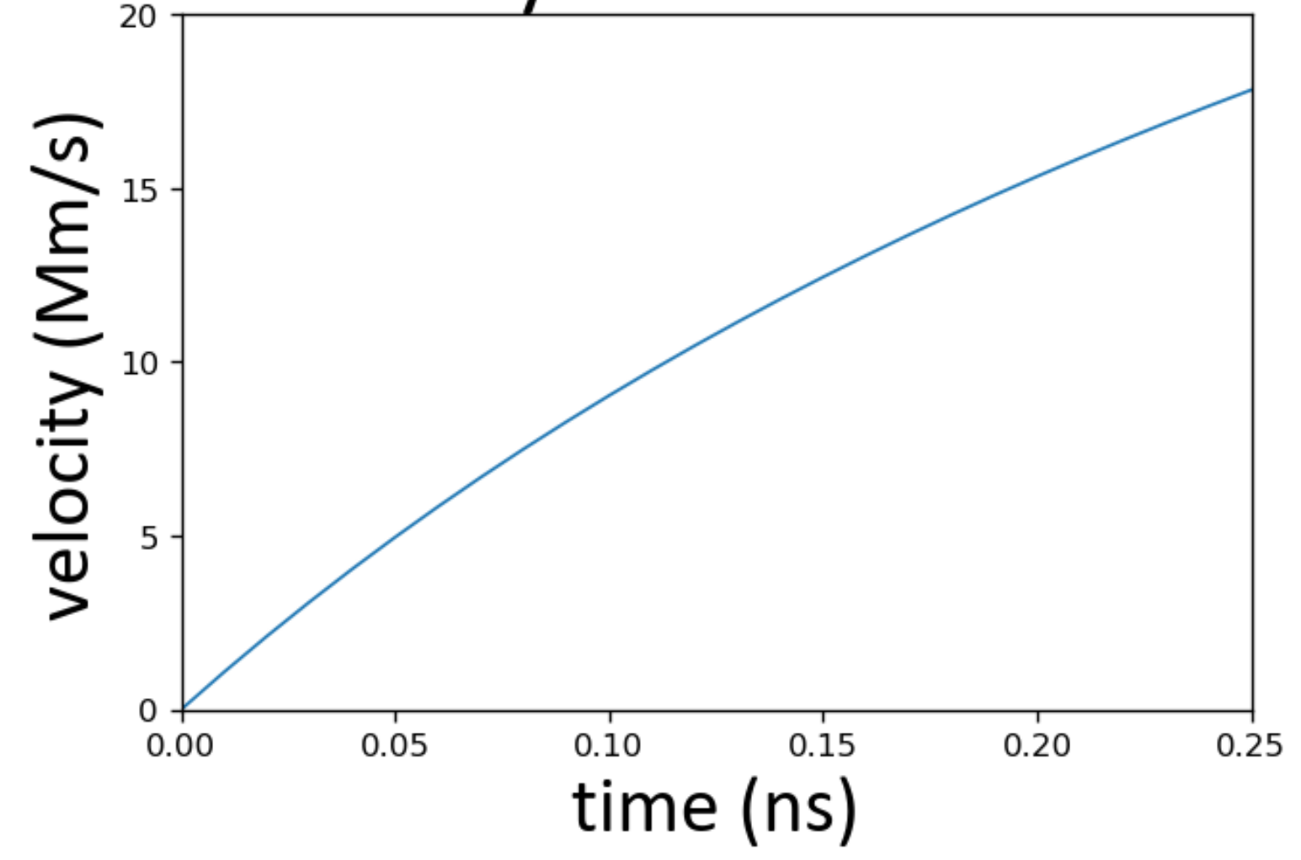
Position of First Electron



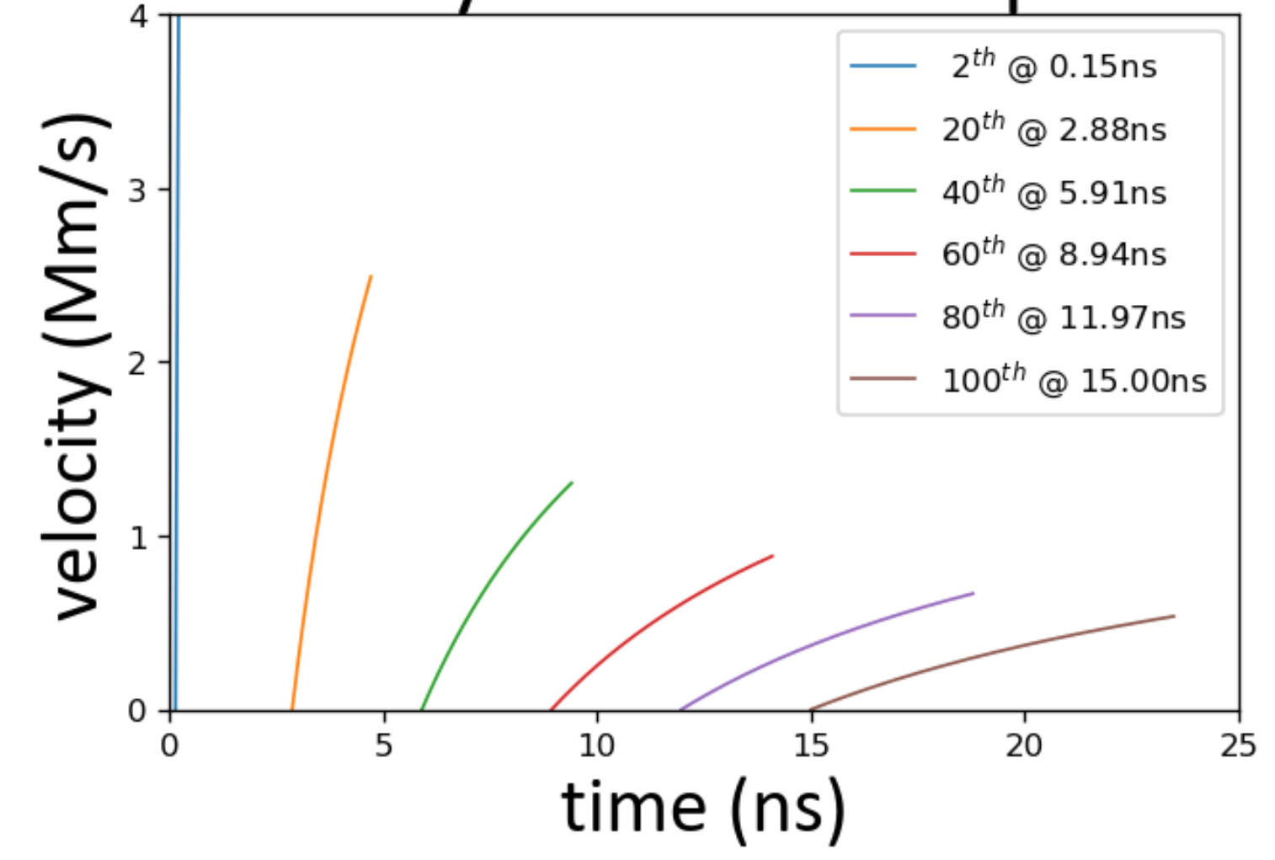
Position of Electron Spread



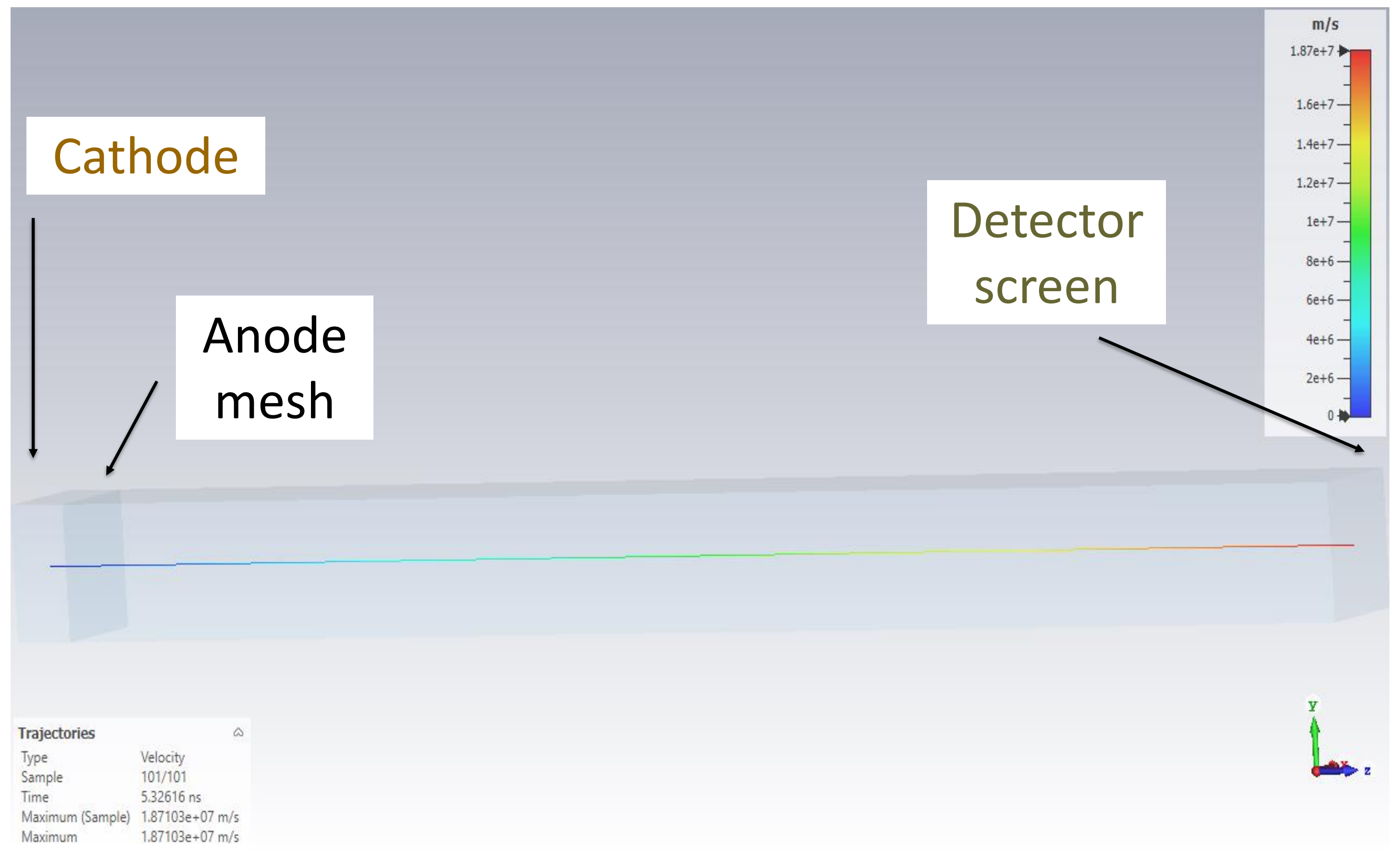
Velocity of First Electron



Velocity of Electron Spread



Future Work in CST



Trajectories

Type	Velocity
Sample	101/101
Time	5.32616 ns
Maximum (Sample)	1.87103e+07 m/s
Maximum	1.87103e+07 m/s

The Simplest Case set up with a particle point source in CST Particle Studio. The trajectory of the velocity is shown.

Features to implement and consider:

- Voltage Ramp → Discrete Port
- Particles emitted to match the "event" → Gaussian
- Length of drift tube magnitude much larger than AK gap → multiple simulations
- Anode mesh electrons pass through → PIC

Acknowledgments

Thank you to Charlie Brown and Arthur Carpenter for their mentorship. Many thanks to Clement Trosseille for the opportunity to work on this project. Additional thanks to Phillip Datte, Emily Hurd, Charlie Hunt, and Matthew Dayton for further support and answers.

LLNL-POST-782942

National Ignition Facility • Lawrence Livermore National Laboratory • Operated by the US Department of Energy

This work performed under the auspices of the U.S. Department of Energy and an appointment to the Office of Science, Science Undergraduate Laboratory Internship (SULI) Program at the Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.