Electrical Acceleration of Boron via Segmented Electrodes

Theophilus Human
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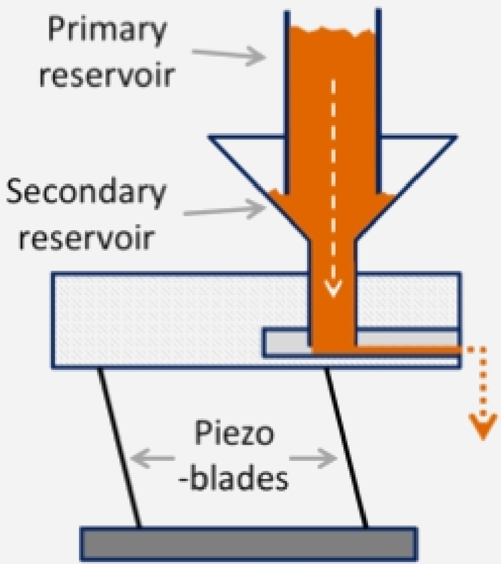
Physics constraints and modeling to determine system specifications

Impurity Powder Dropper (IPD)

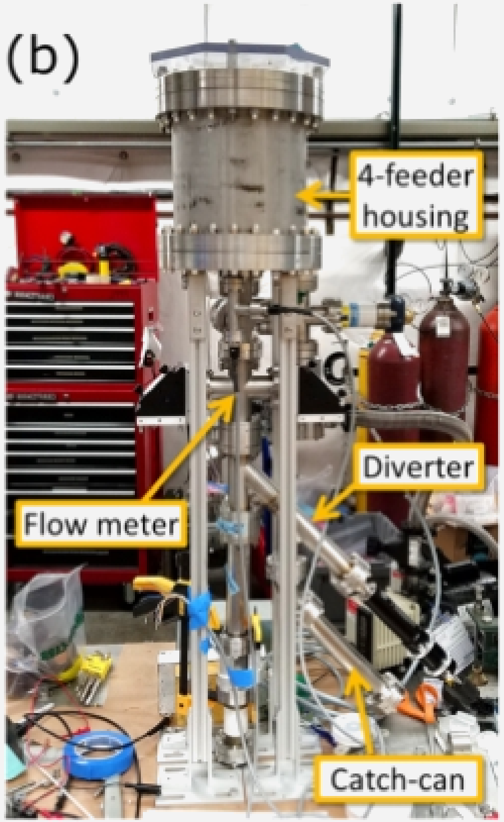
Boron powders are currently used to coat plasma facing components (PFCs) to prevent power reductions and system instabilities.

Powder Dropper (a) delivers granulated boron agitated by a piezo-driver system which causes gravity accelerated powder injection.

(a)

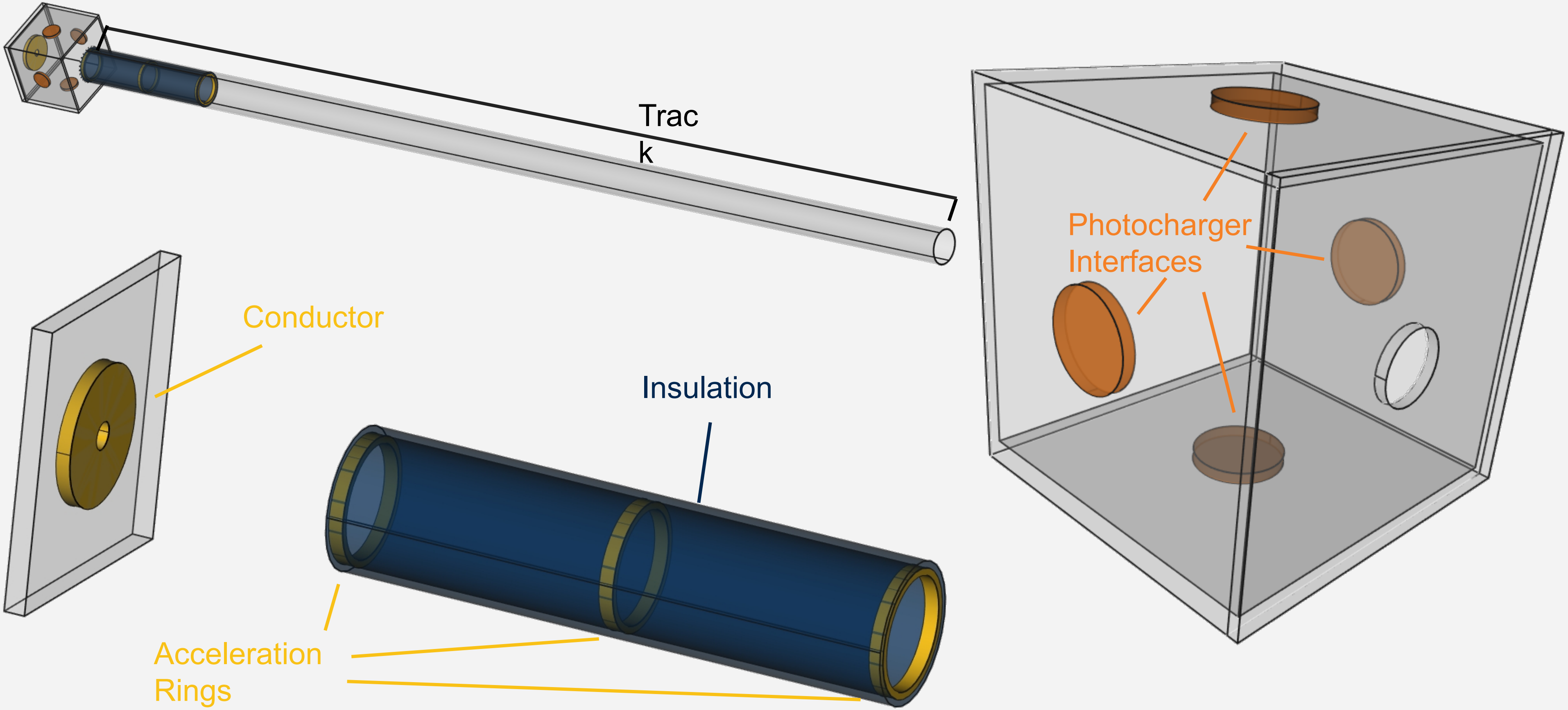


(b)

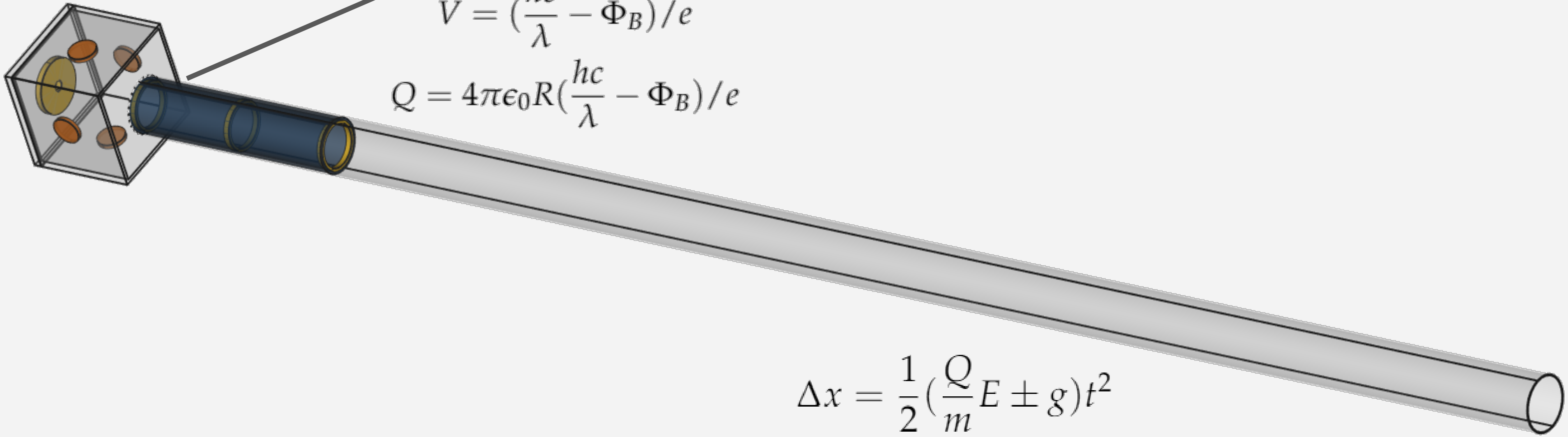


[1] A.Nagy,A.Bortolon,D.M.Mauzey,E.Wolfe,E.P.Gilson,R.Lunsford,R.Maingi,D.K.Mansfield,R.Nazikian,and A. L. Roquemore. A multi-species powder dropper for magnetic fusion applications.Review of Scientific Instruments, 89(10K121), Oct 2018. doi: 10.1063/1.5039345.

Electrical Injection System Overview



Theory



$$Q = CV$$

$$C = 4\pi\epsilon_0 R$$

$$V = (\frac{hc}{\lambda} - \Phi_B)/e$$

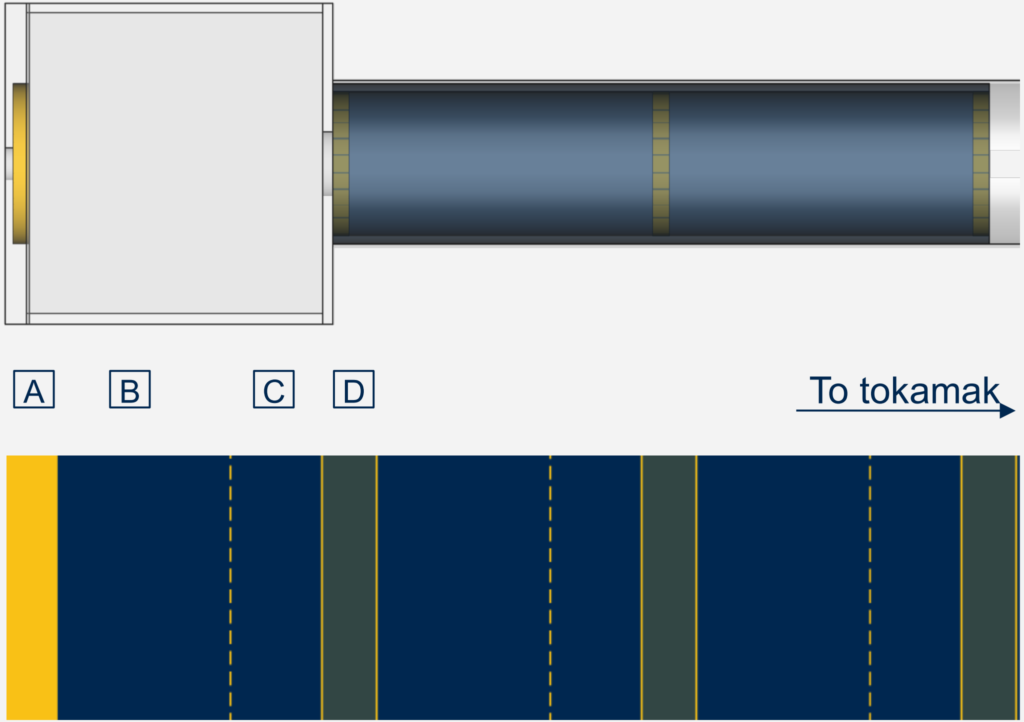
$$Q = 4\pi\epsilon_0 R(\frac{hc}{\lambda} - \Phi_B)/e$$

$$\Delta x = \frac{1}{2}(\frac{Q}{m}E \pm g)t^2$$

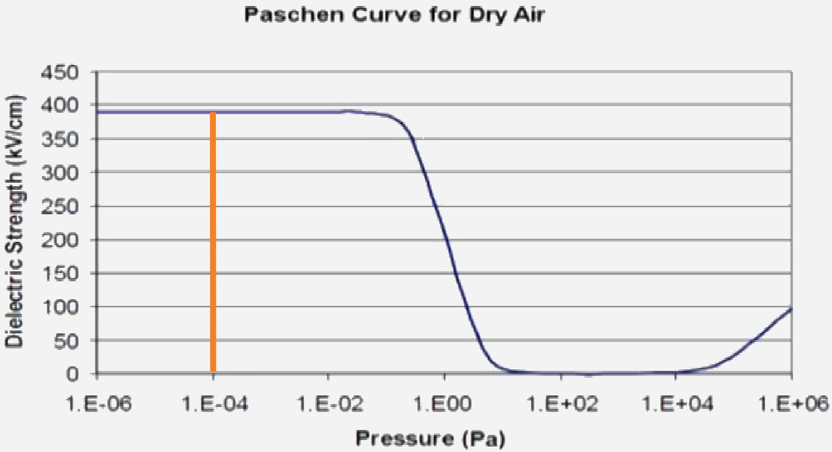
$$t = \sqrt{\frac{2 * \Delta x}{\frac{Q}{m}E \pm g}}$$

[1] A. A. Sickafroose, J. E. Colwell, M. Horányi, and S. Robertson. Photoelectric Charging of Dust Particle in Vacuum.Physical Review Letters, 84(26), June 2000.

Physical Considerations



A. Conductor
B. Acceleration Space
C. Gap Space
D. Ring



Vacuum operations at 10^{-6} mbar (orange line), 3 subregions are major pd behavior changes

Breakdown limit ~$4x10^4$ kV/m

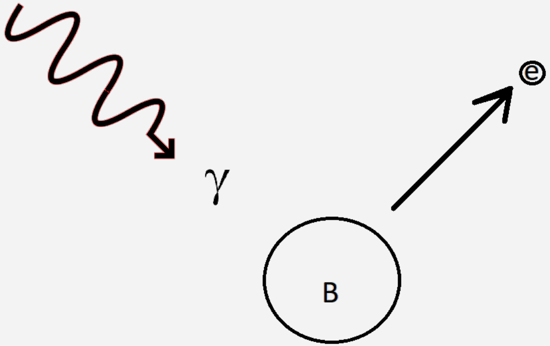
Operating voltage on each ring was chosen to be 10 kV due to ceramic break requirements

[1] Ravi U. Magre and K. Chandra Obula Reddy. COMPARATIVE STUDY OF VARIOUS PRES-SURE MEASUREMENT TECHNIQUES IN VACUUM INTERRUPTER BOTTLE.Internationa lResearch Journal of Engineering and Technology (IRJET), 3(12), Dec 2016.

Charge Method (UV Lamps)

Various UV lamp setups were initially considered

Analyzed Source:
UV-C Lamp
Power = 800 W
λ = 250 nm



Segmented Acceleration Electrodes (UV)

UV Charging velocity profile.

V_{ring} = 10 kV

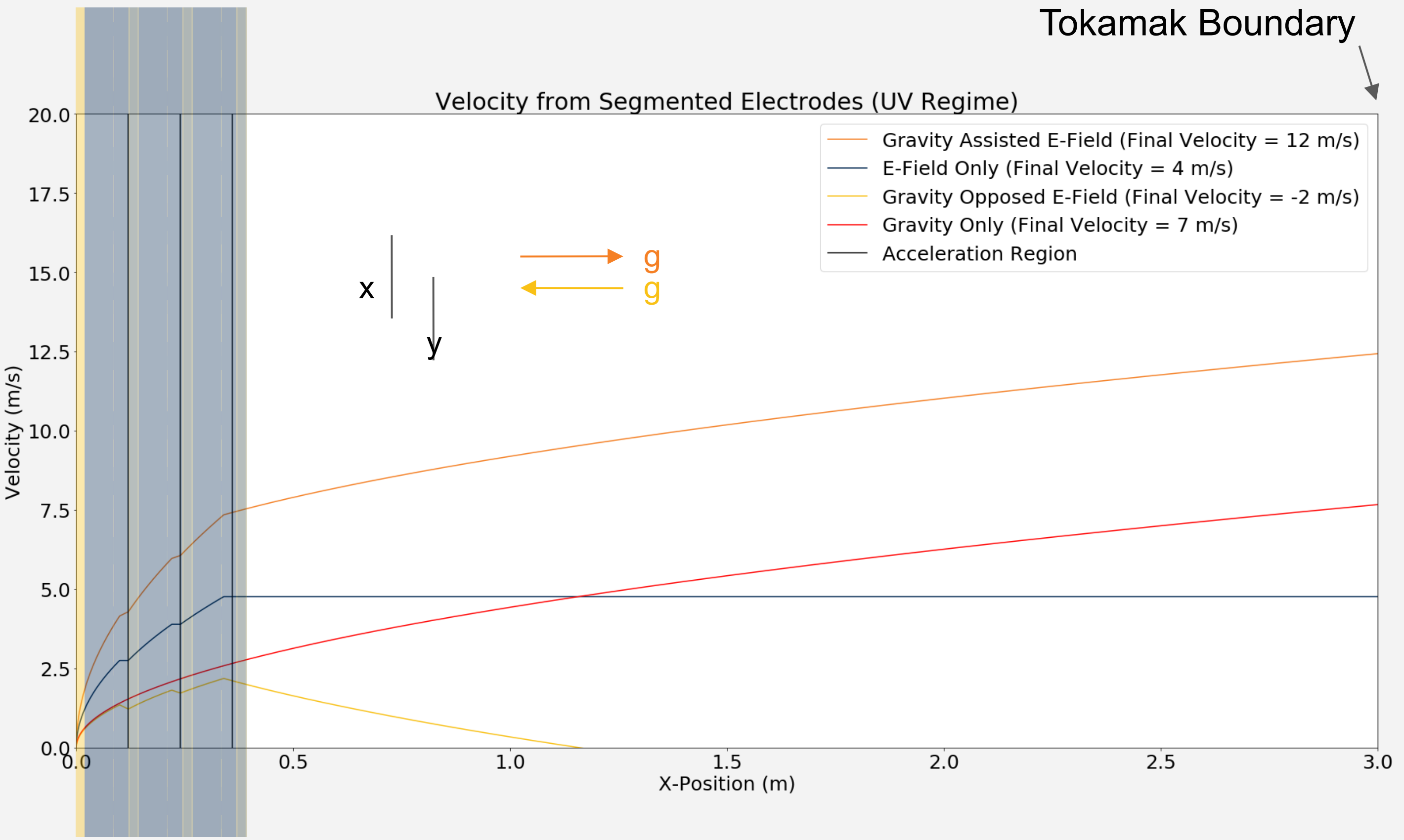
d_{ring} = 12 cm

E = 167 kV/m

v_f ~ 4 m/s

transit time ~ 327 ms

Insufficient velocity gain.



Charge Method (X-Ray Emitters)

Analyzed a number of X-Ray sources.

Example Source:

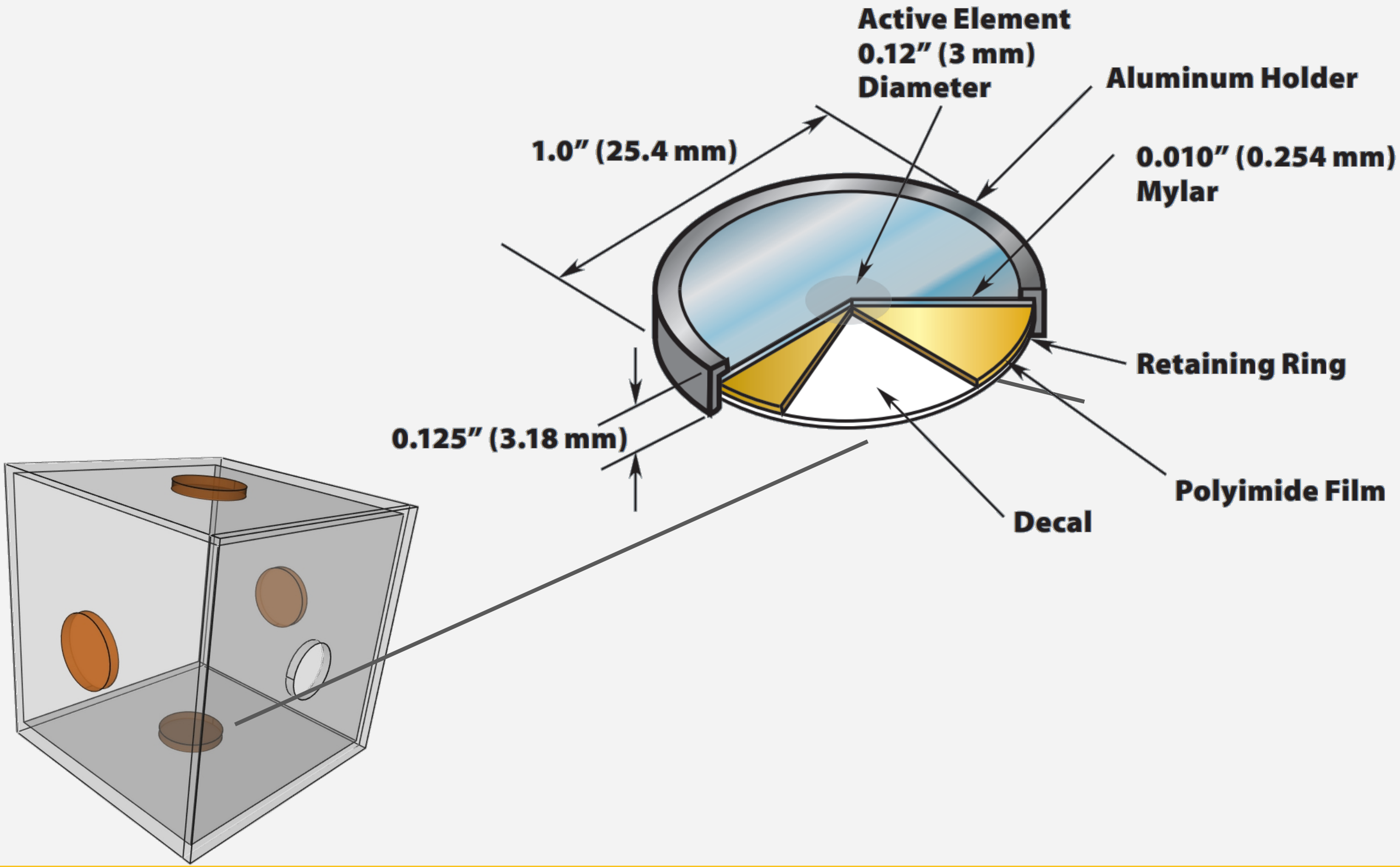
Fe-55

Activity = 1-100 µCi

KE_{γ} = 5.8-6.5 KeV

λ ~ 0.1 nm

$t_{1/2}$ = 999 days



Segmented Acceleration Electrodes (X-Ray)

X-Ray charging velocity profile.

V_{ring} = 10 kV

d_{ring} = 12 cm

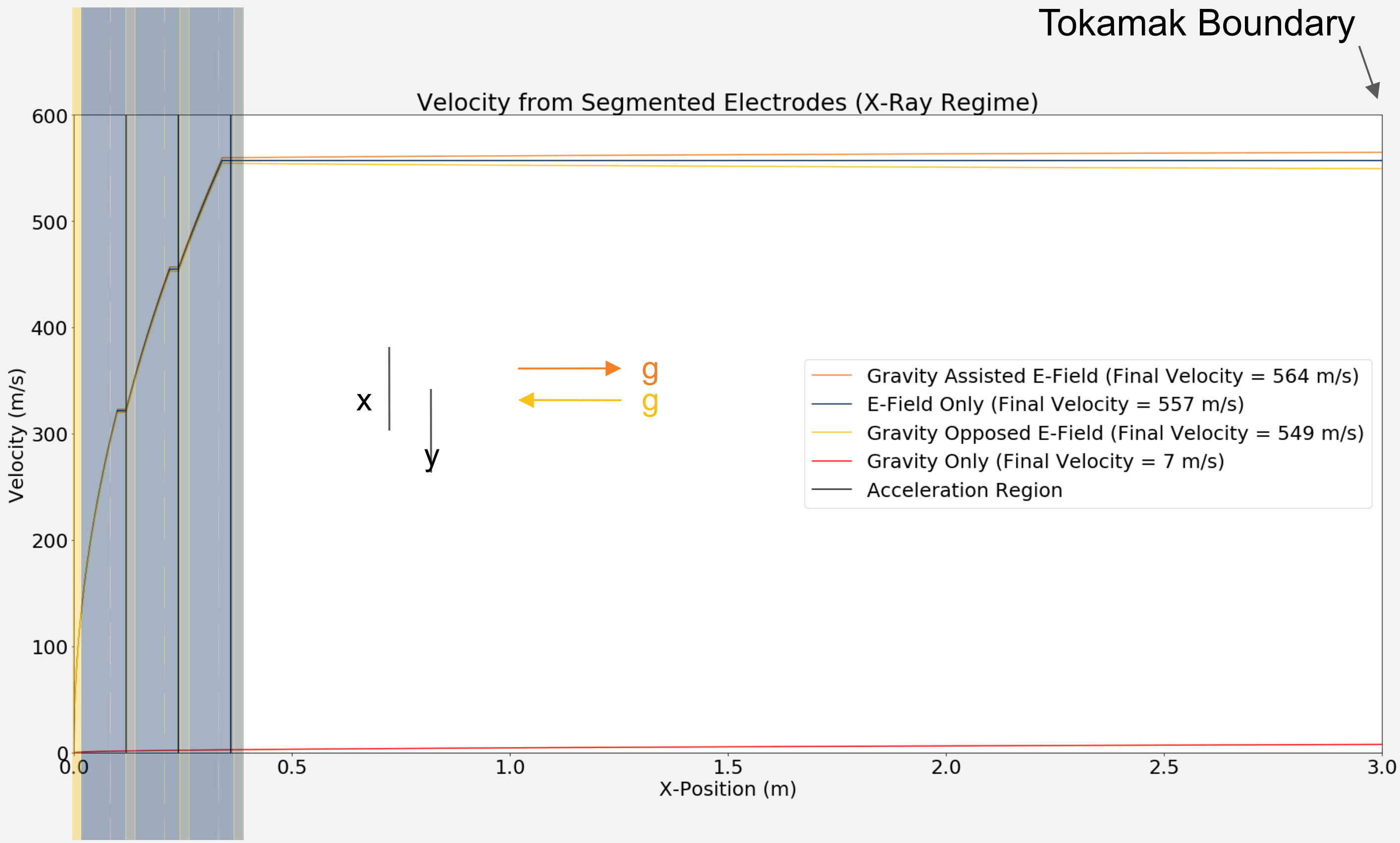
E = 167 kV/m

KE_{γ} = 5.8-6.5 KeV

v_f ~ 560 m/s

transit time ~ 3 ms

Good velocity gain, poor charge time.



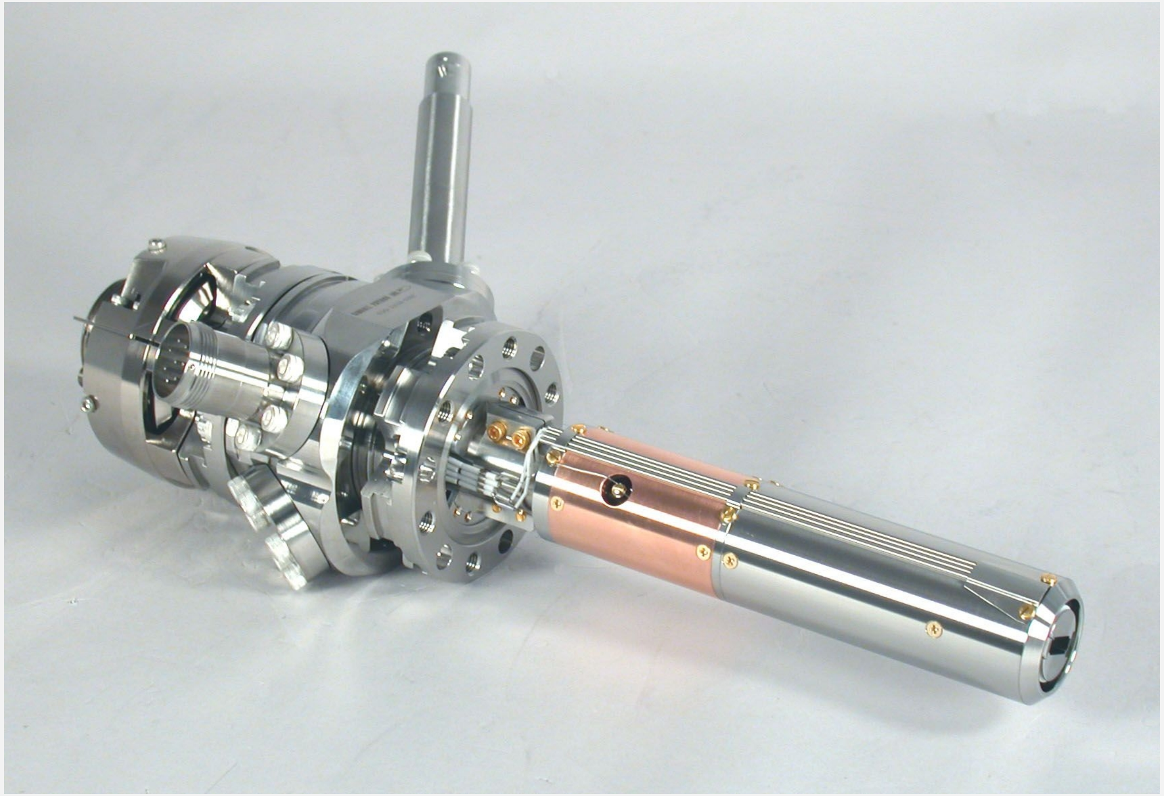
Charge Method (Electron Gun)

Electron gun charge method provides sufficient charge magnitudes with good charge times.

Energy Ranges: 1 eV to 100 keV

Beam Current Ranges: 1 nA to 20 mA

Spot Size Ranges: 15 µm (focused column) to 500+ mm (flood beams)



B-Field Influence

B-Fields from the tokamak can cause deflection in the tube.

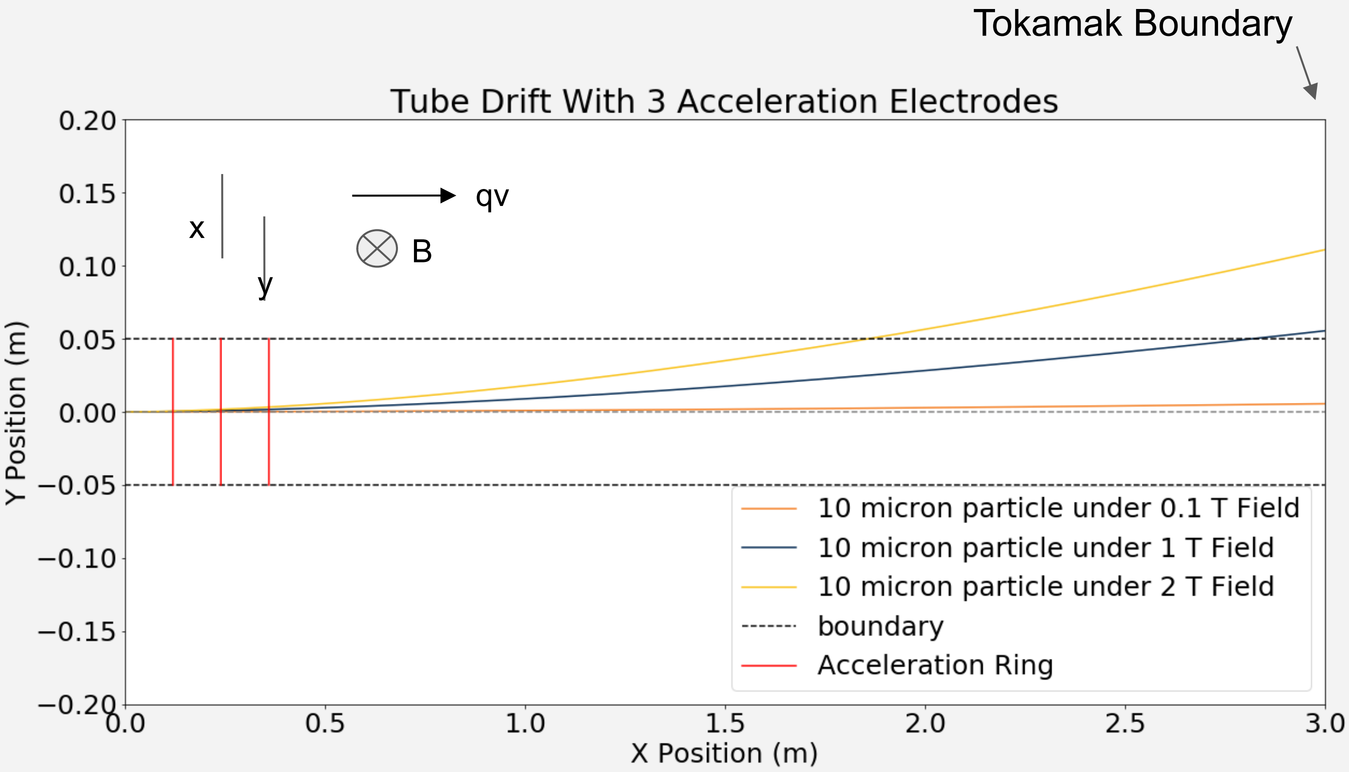
V_{ring} = 10 kV

d_{ring} = 12 cm

KE_{γ} = 5.8-6.5 KeV

Solutions: increasing speed, mu metals, balancing electrodes

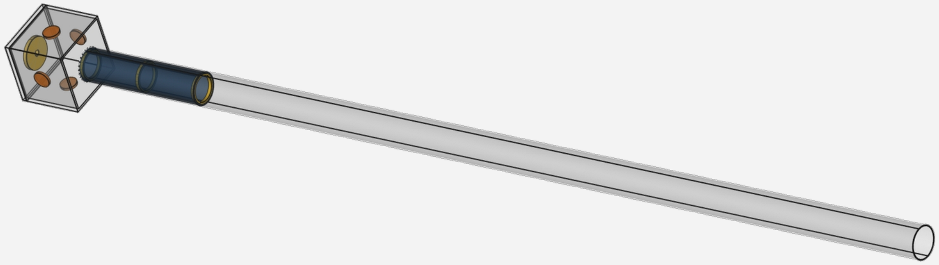
Gravity effects are insignificant to offset



Future

Future work includes additional fine tuning of deflection controls, shut off system, diagnostic integration, electron gun integration, IPD integration, timing system design, and proof of concept testing.

This system opens the possibility of complex ablation studies granule radius and velocity can be varied.



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PPPL
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