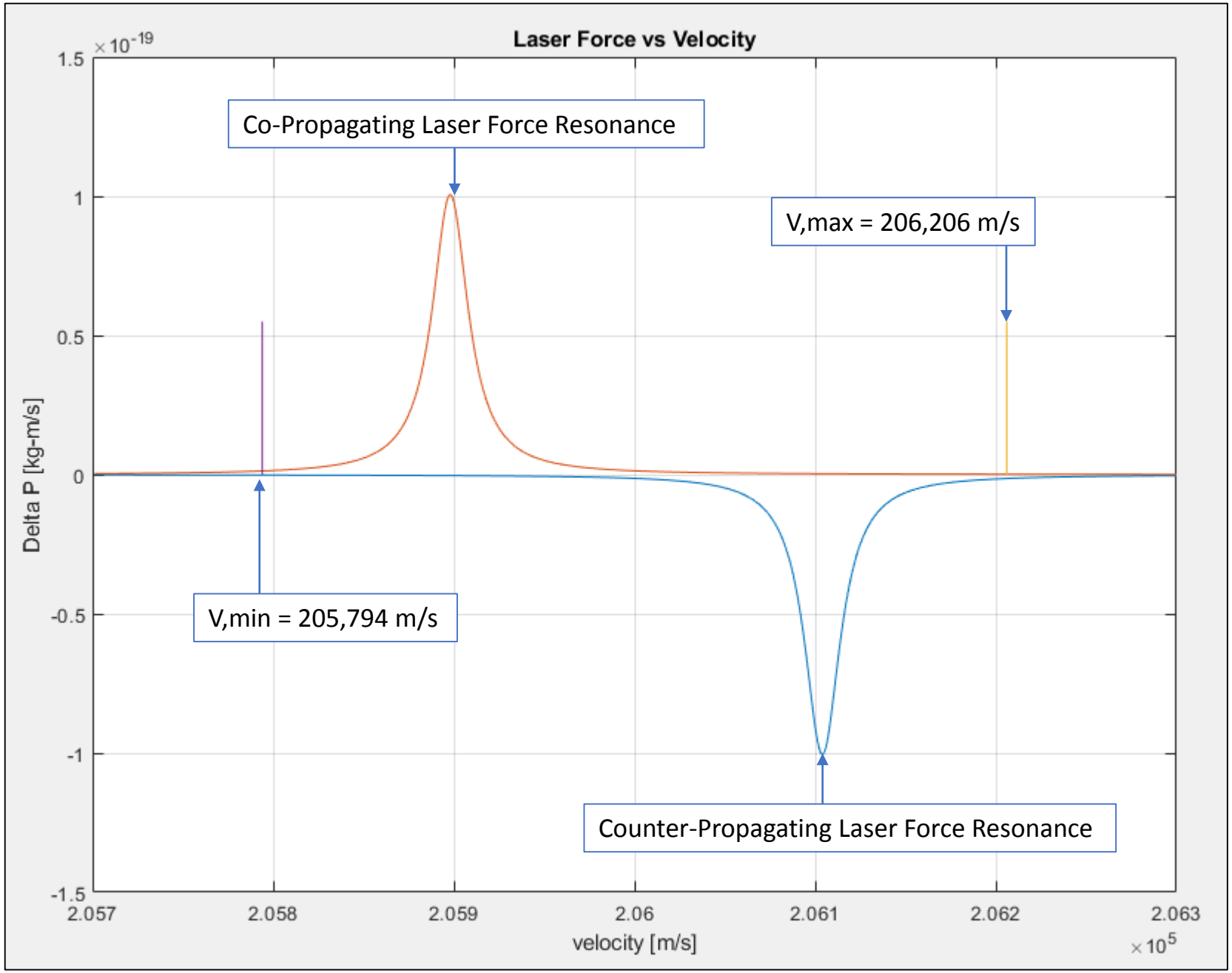
Laser Interaction Force vs 50 KeV 171 Yb+ Ion

Two lasers are interacting with ions within a straight section of a storage ring.

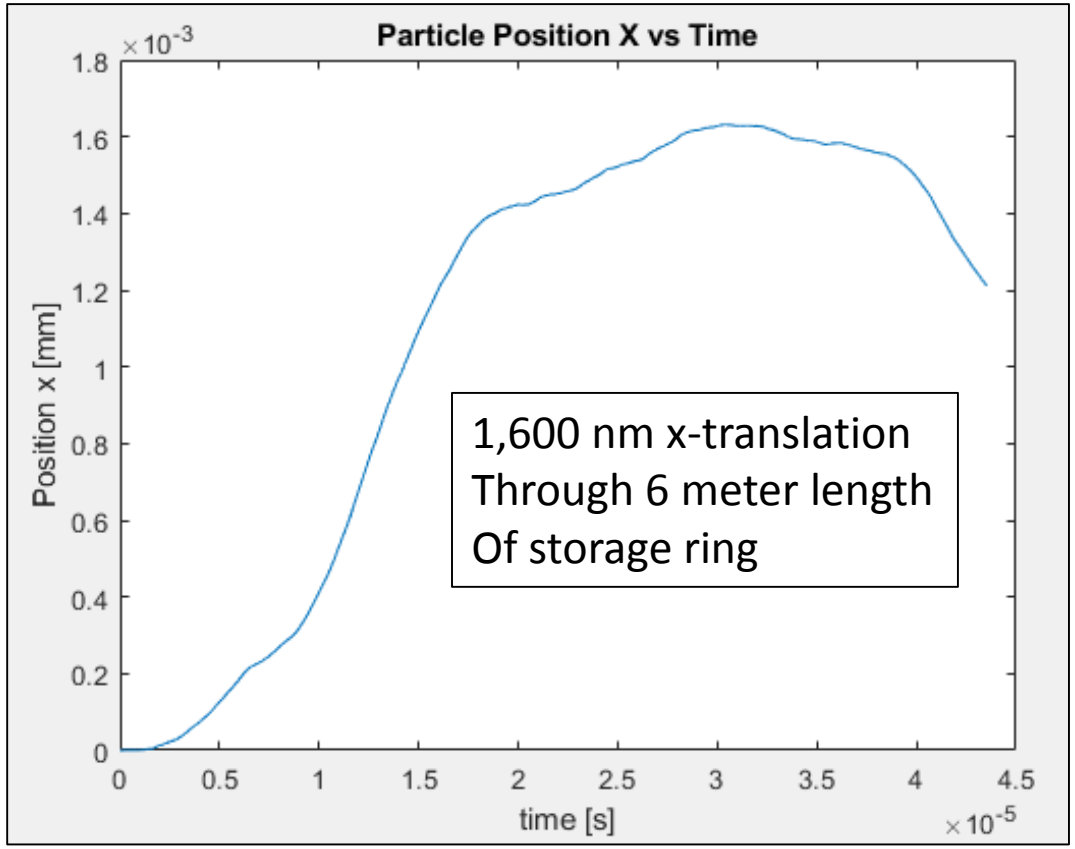
The velocity spread is +/- 0.1% from the nominal velocity of 206,000 m/s (50 KeV)Labeled as V,min and V,max.

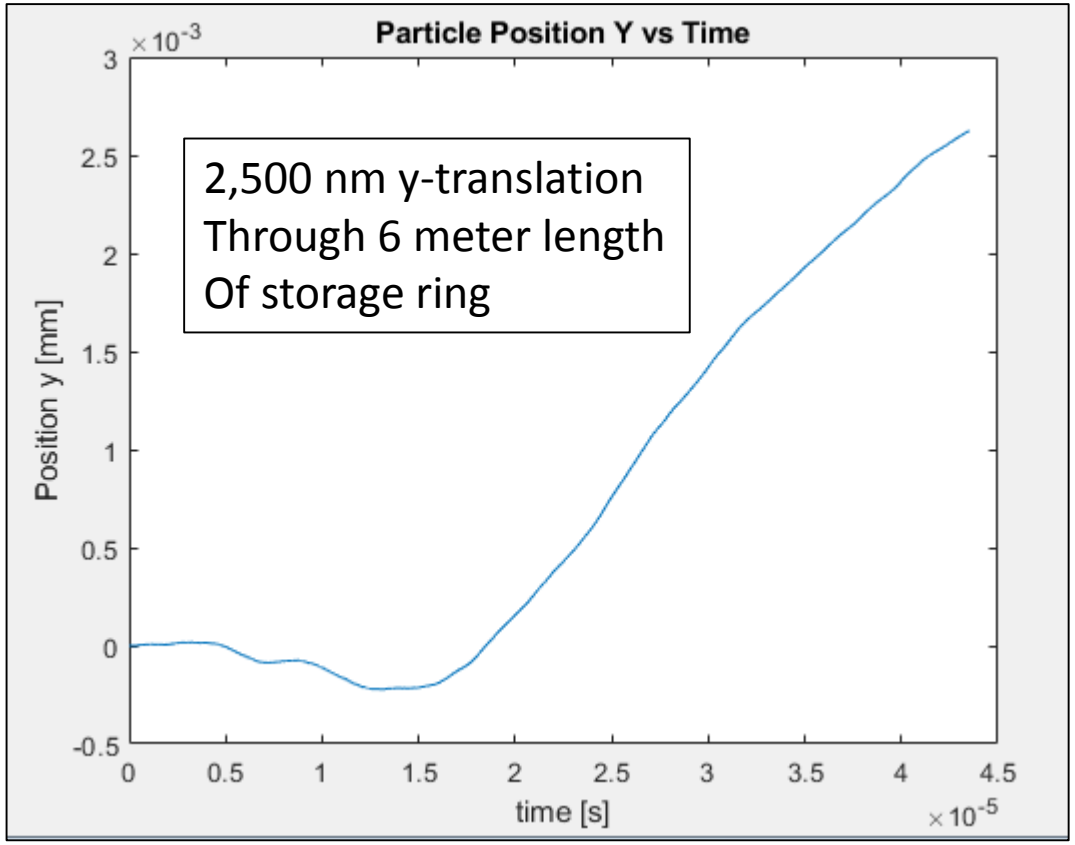
The co-propagating laser (red) resonance is indicated near V,min and the counter-propagating laser (blue) is indicated near V,max.



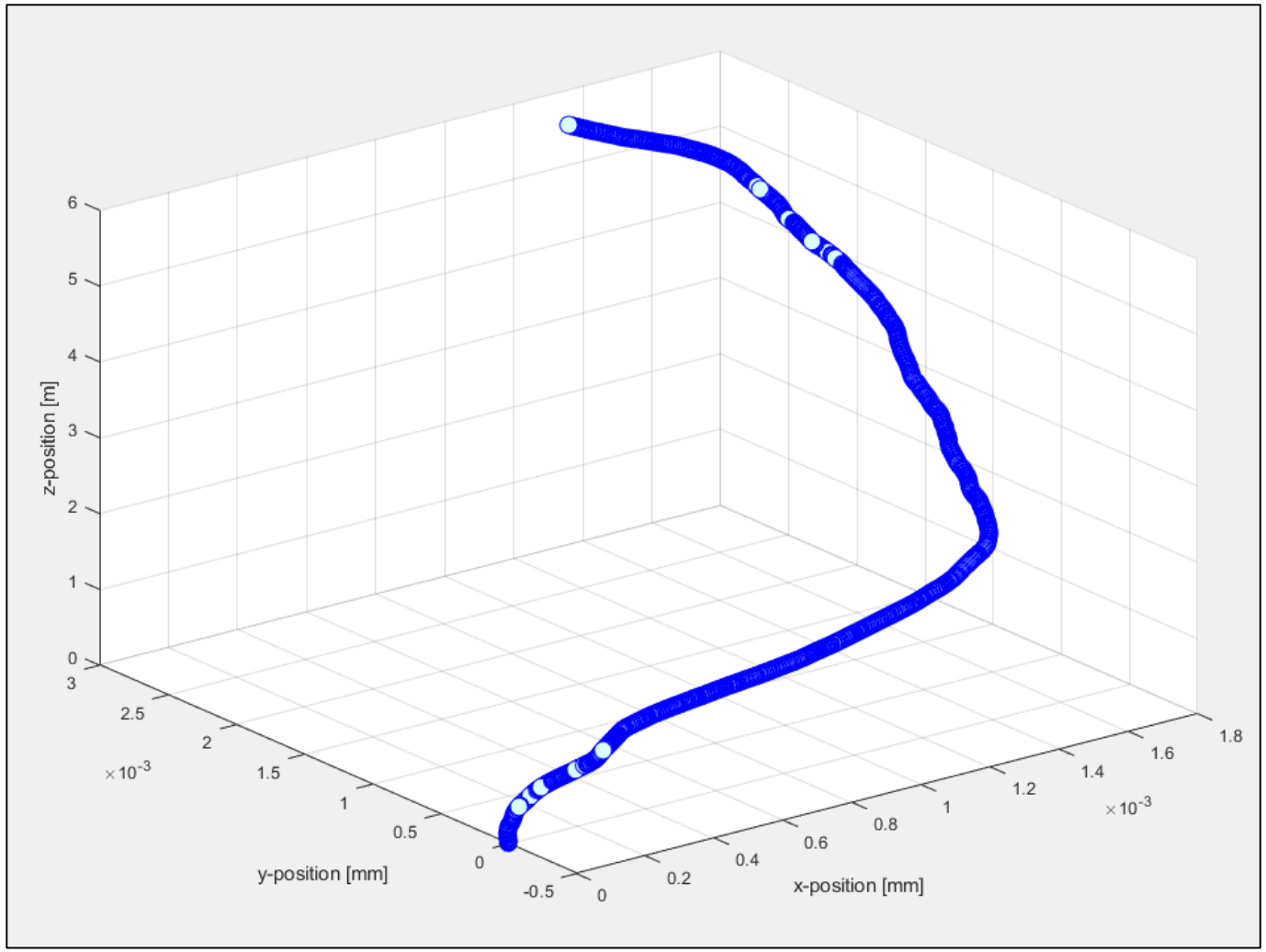
Spontaneous Emission Procedure:

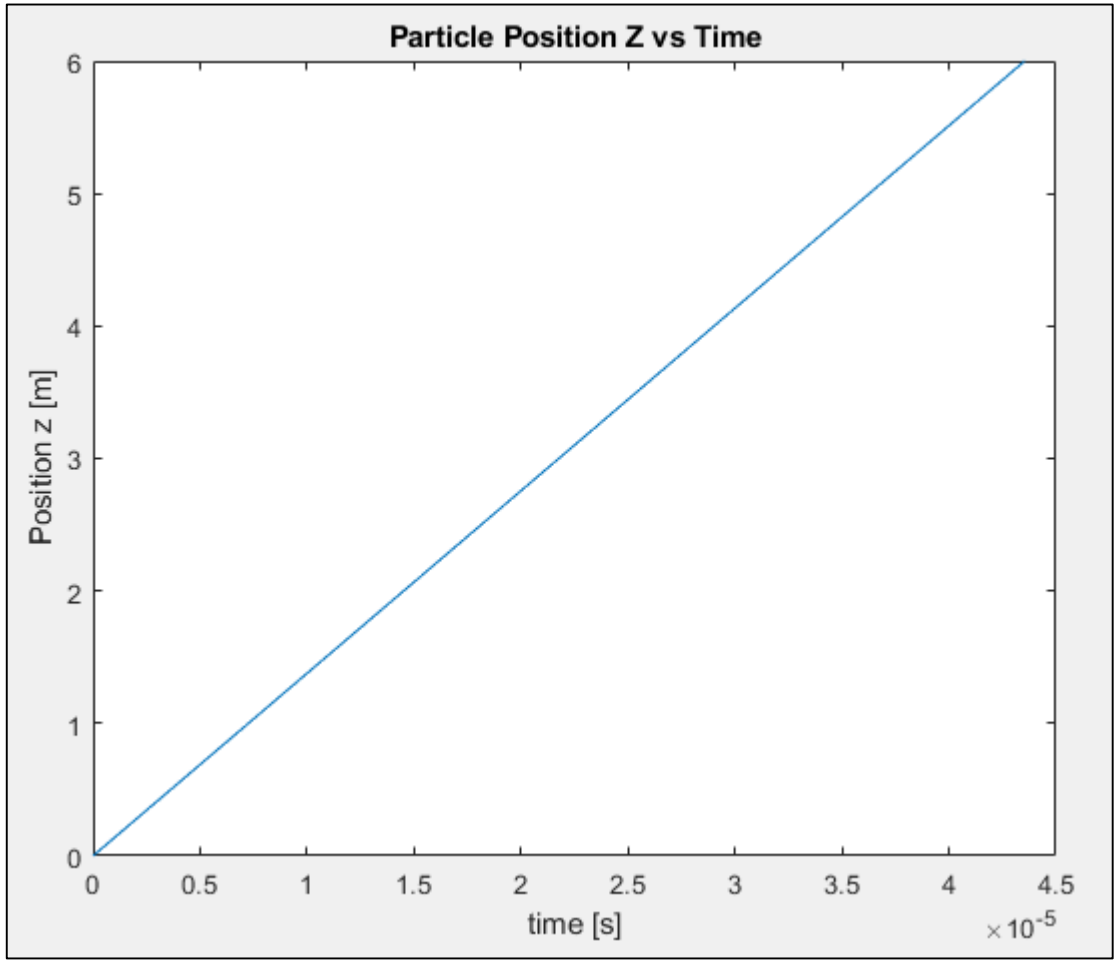
Spontaneous emission is modeled for an ion while transiting the Laser cooling section of the storage ring. The ion after excited decays after 8.1 ns to the ground state. During transition to ground state the ion emits a photon and undergoes a momentum change. The momentum change is modeled as a randomly generated direction vector which is multiplied by the force of hbar * k. The kick is applied every 8.1 ns randomly. The plots below show the delta from nominal path through the Laser cooling section starting at nominal 0 position (x,y)





3D Plot of Ion Transit in Spontaneous Emission Procedure





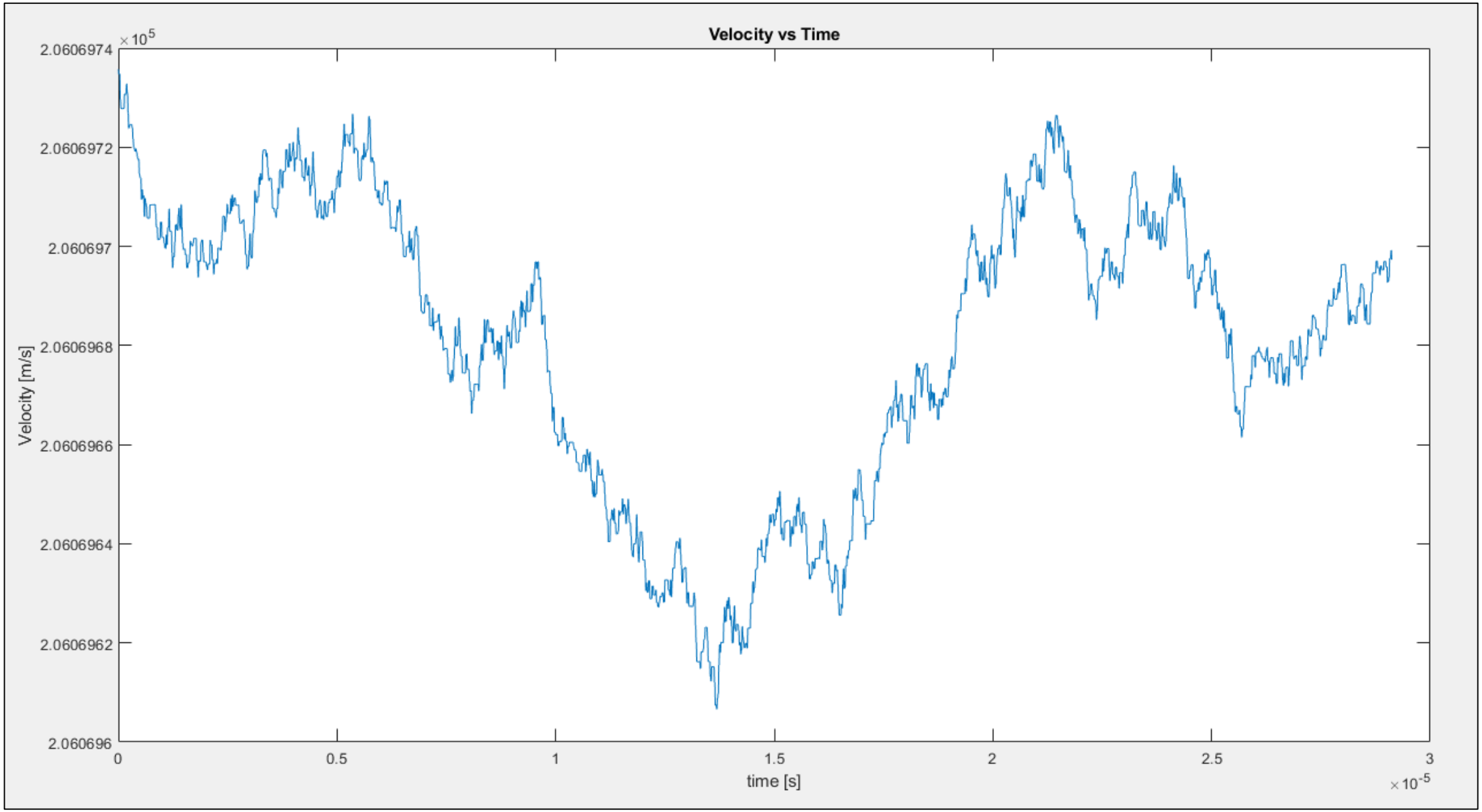
Laser Cooling Procedure:

The Accelerator Laser Force Procedure is used to determine a Co-propagating Laser frequency and a Counter-propagating Laser frequency which covers the required velocity spread of the ions within the storage ring.

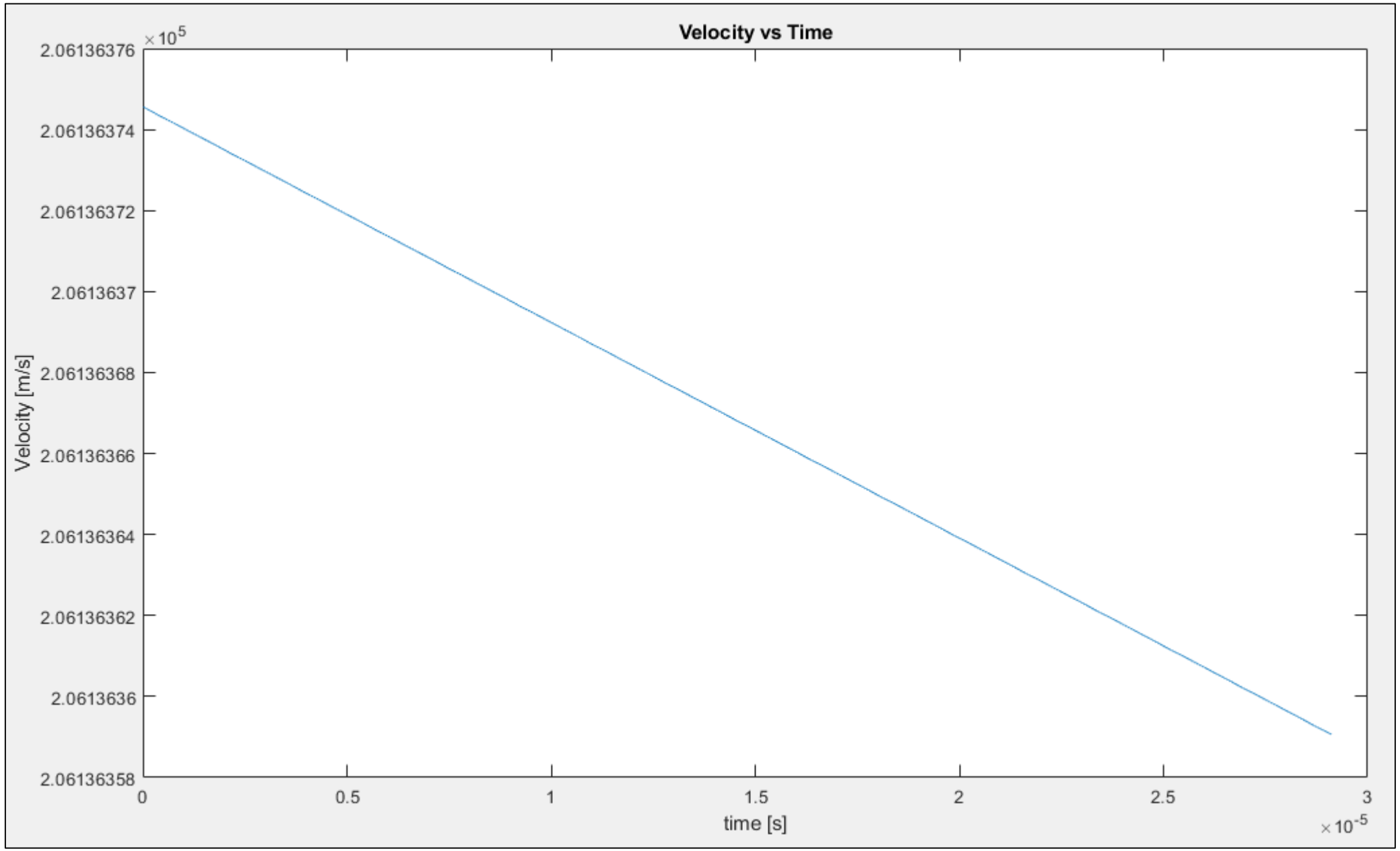
The spontaneous emission procedure indicates the “possible” x and y translation due to spontaneous emission through the Laser cooling section.

The Cooling procedure combines the Accelerator Laser Force Procedure and the Spontaneous Emission Procedure to simulate the micro-motion of the ion as it transits the Laser Cooling Section. Time, position, and velocity change which impact the Laser cooling force.

Velocity in Z-Direction while cooling and undergoing spontaneous emission (spontaneous emission ON)



Velocity in Z-Direction while cooling No spontaneous emission (spontaneous emission OFF)



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% 171 Yb+ Parameters
q = 1.60218e-19;                % Charge, coulombs
m = 2.875e-25;                  % 171 Yb+ mass, kg
m_0 = ((m*c*c)/q)/1000000000;   % 171 Yb+ Rest mass, GeV/c^2
tau = 8.1e-9;                   % S_1/2 to P_1/2 Lifetime, s
Lambda_0 = 369.5e-9;            % S_1/2 to P_1/2 Transition Frequency, m
omega_0 = (2*pi*c)/Lambda_0;    % Resonant Frequency
gamma = 1/tau;                  % Excited stated decay rate, 1/s
S_0 = 10;                       % Saturation; S_0 = I / I_s
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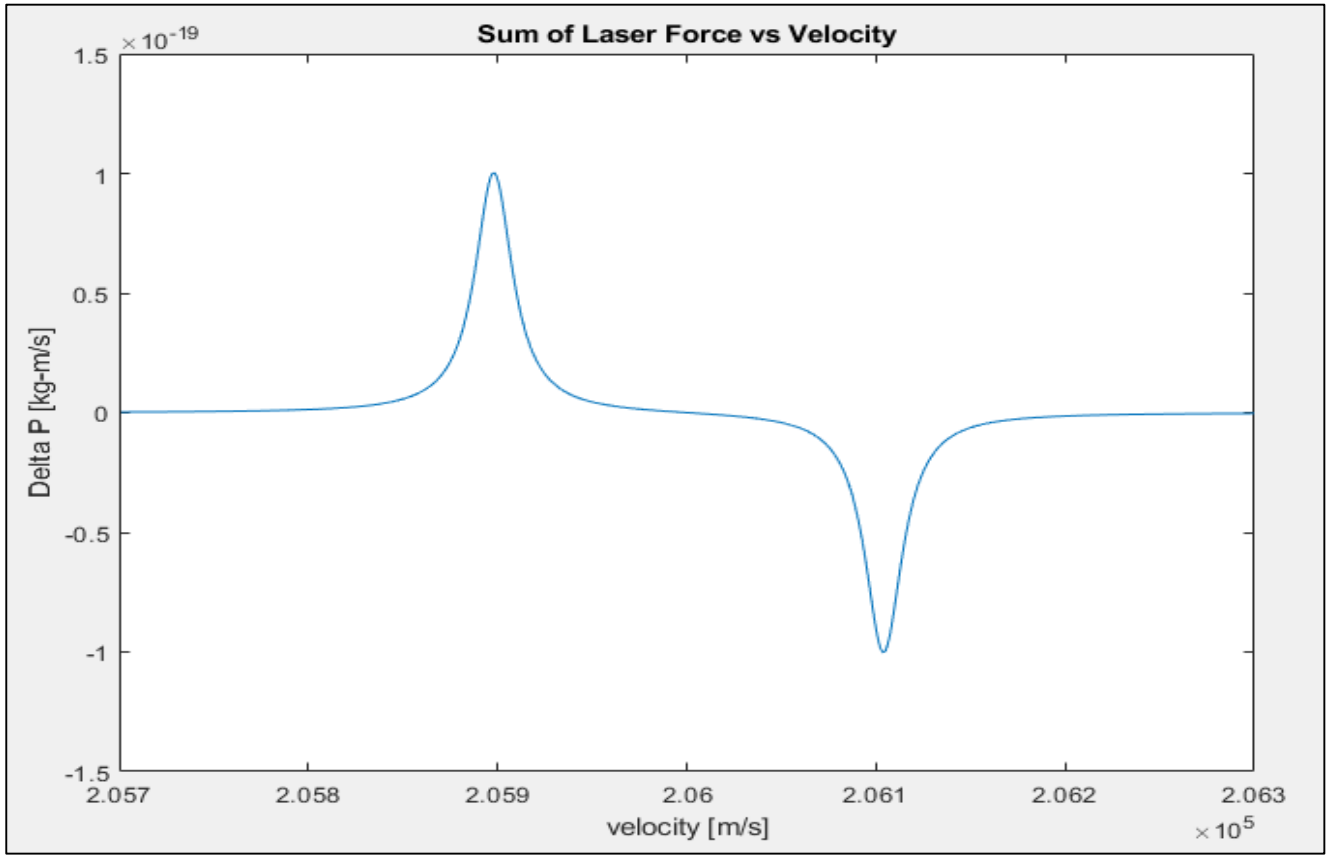
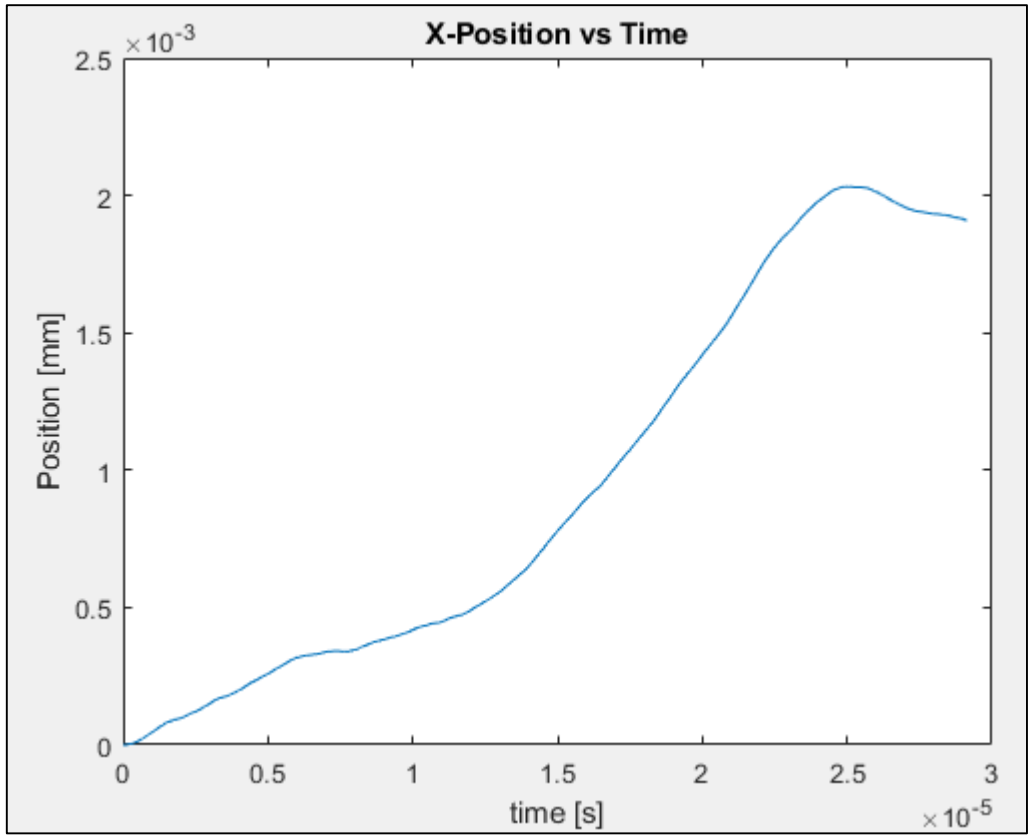
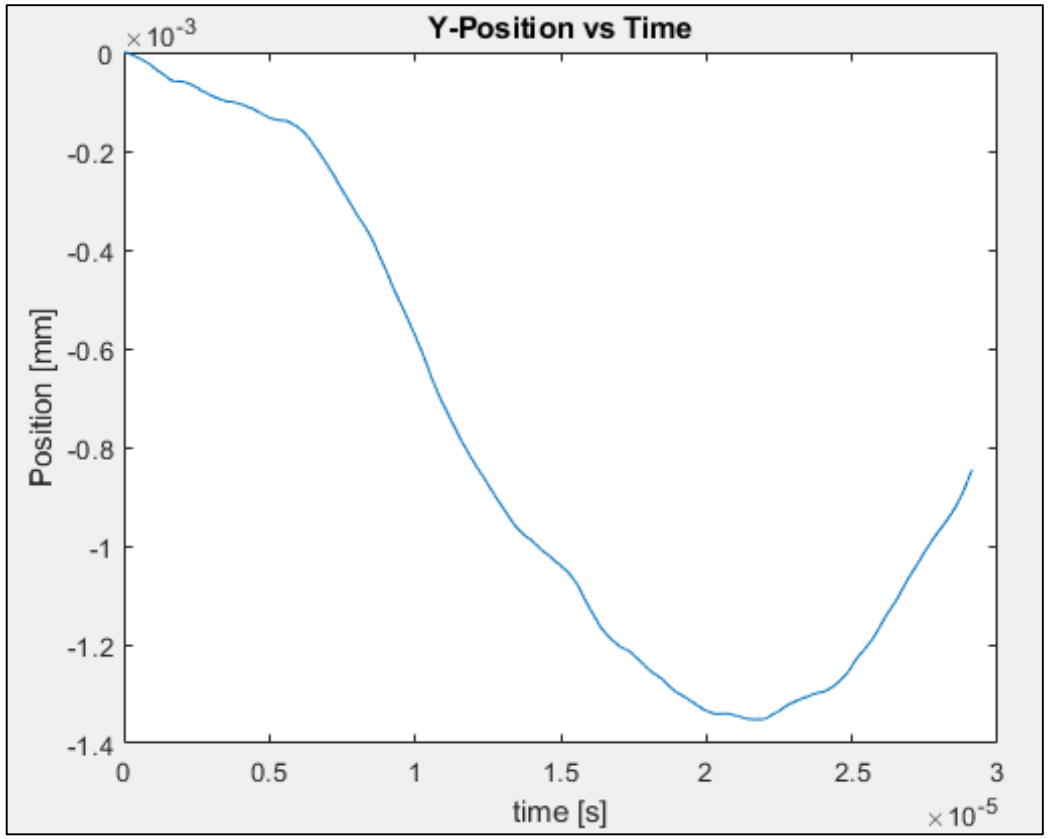
Ion Energy = 50 KeV

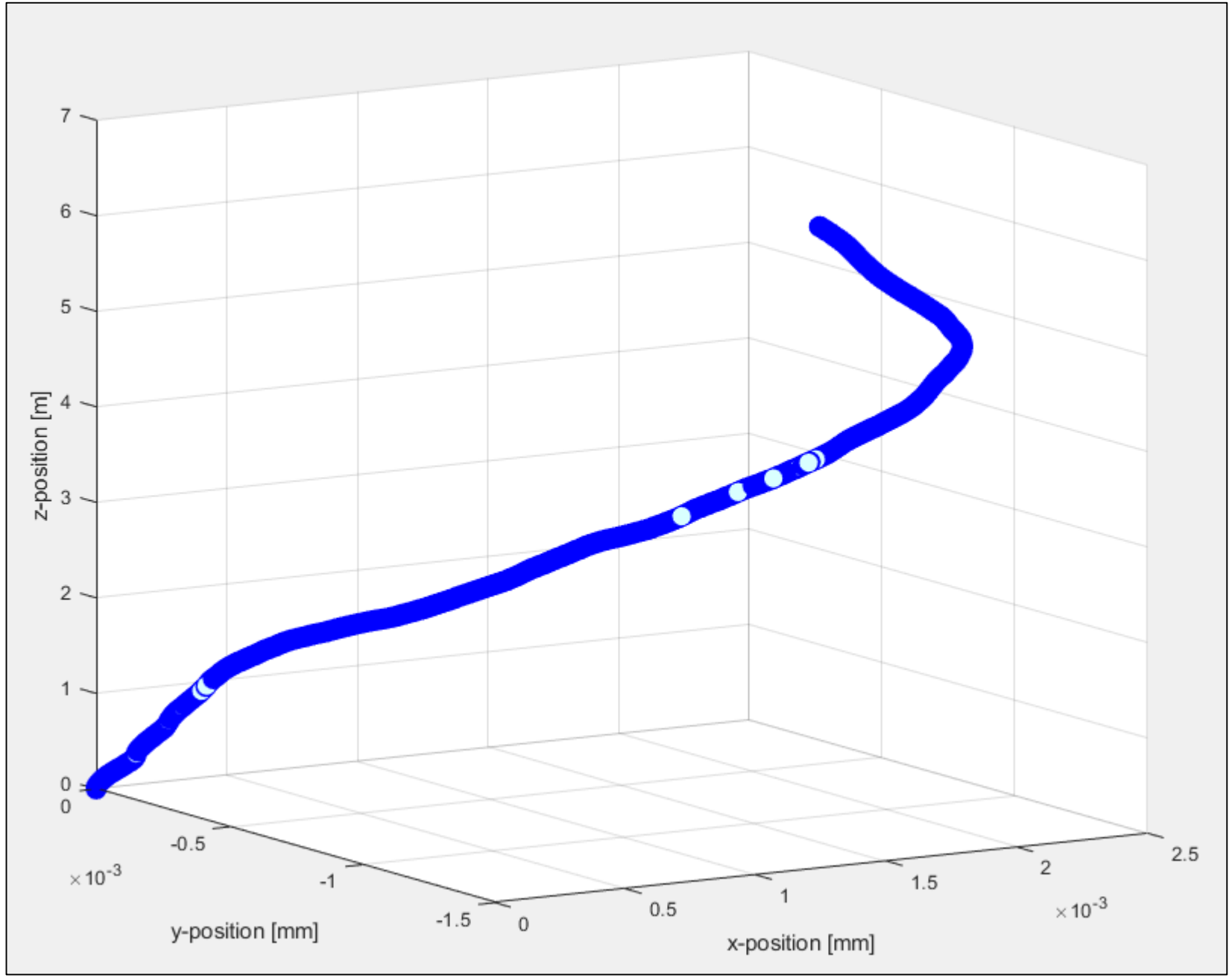
λ = 370 nm (Counter-propagating Laser)
λ = 369 nm (Co-propagating Laser)
λ = 369.5 nm (Resonant Wavelength)



Sum of Laser Force over Velocity spread


X-Position vs Time
×10^-3
2.5
2
1.5
1
0.5
0
Position [mm]
0
0.5
1
1.5
2
2.5
3
time [s]
×10^-5


Y-Position vs Time
×10^-3
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Position [mm]
0
0.5
1
1.5
2
2.5
3
time [s]
×10^-5


z-position [m]
7
6
5
4
3
2
1
0
0
-0.5
-1
-1.5
×10^-3
y-position [mm]
0
0.5
1
1.5
2
2.5
×10^-3
x-position [mm]