CHARACTERIZING A PARALLEL PLATE IMAGING DEFLECTOR

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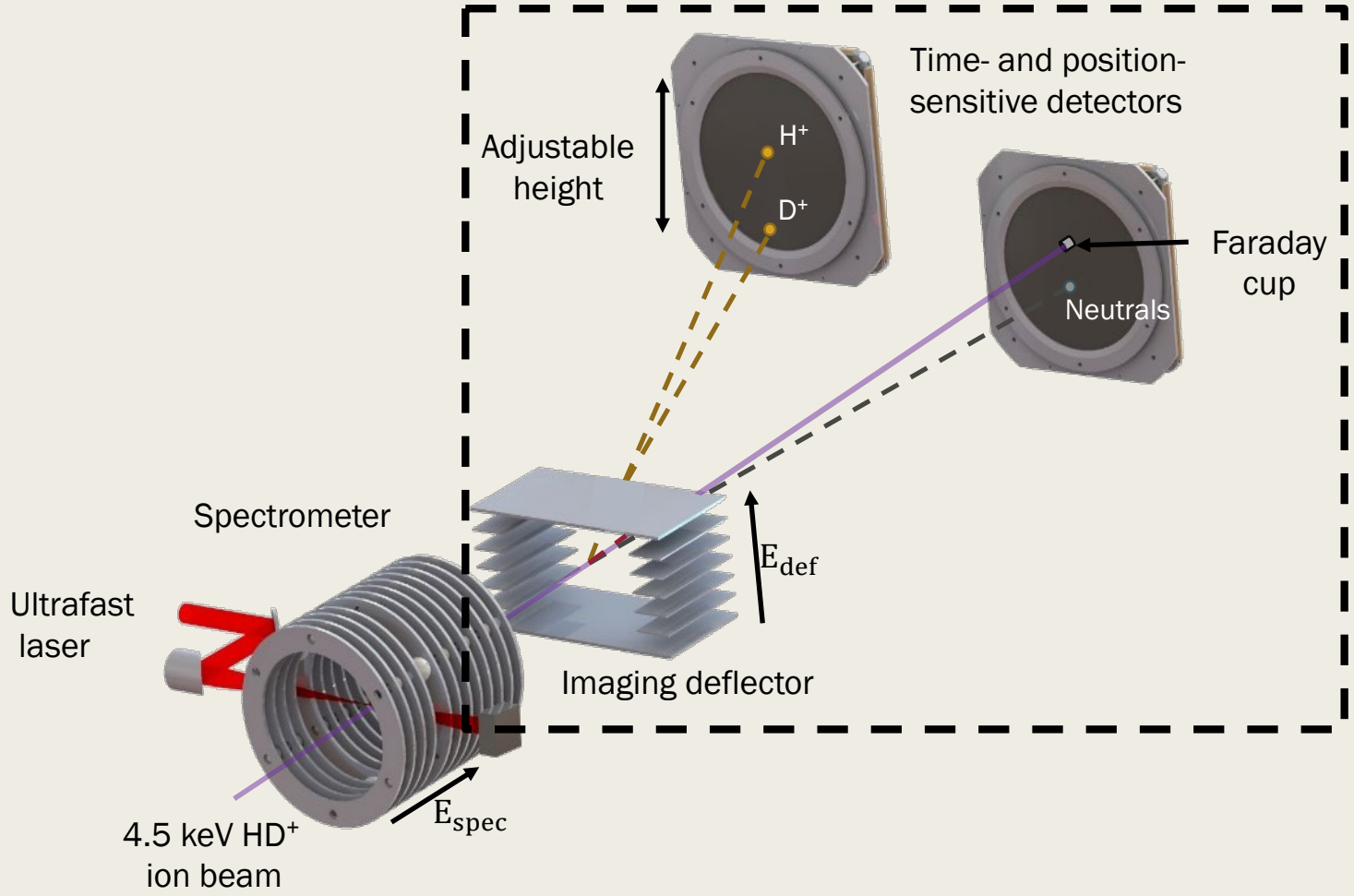
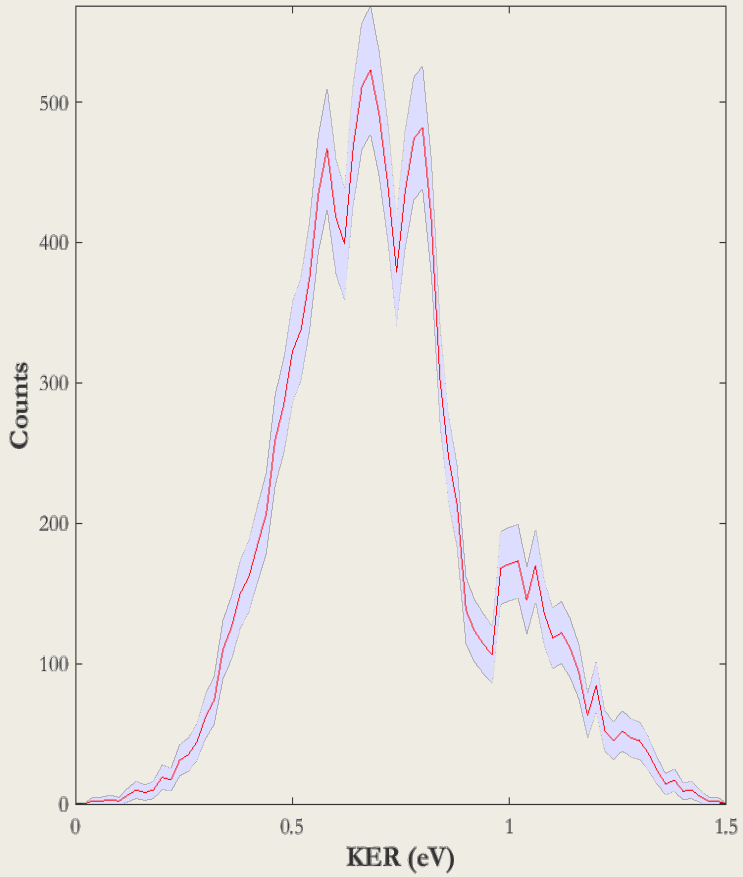
Understanding laser-molecular ion interactions using momentum imaging

- Measure final position and time of flight of each fragment
- Calculate momentum information, learn about fragmentation process
- My project does not deal with the spectrometer field.



Understanding laser-ion interactions using momentum imaging

- Examining fragmentation of HD^+ resulting from its interaction with a 790 nm laser pulse.
- $H^+ + D$ Dissociation channel

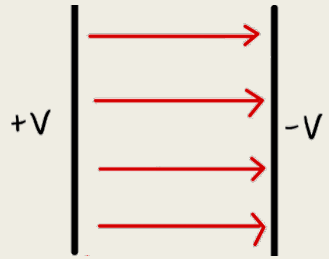


$H^+ + D$ vibrational states

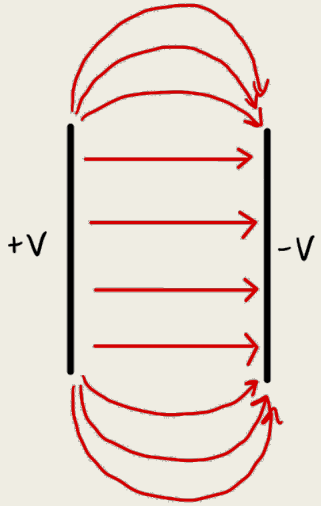
McKenna, J., et al. **Phys. Review A.** 80 (2009).

Goal

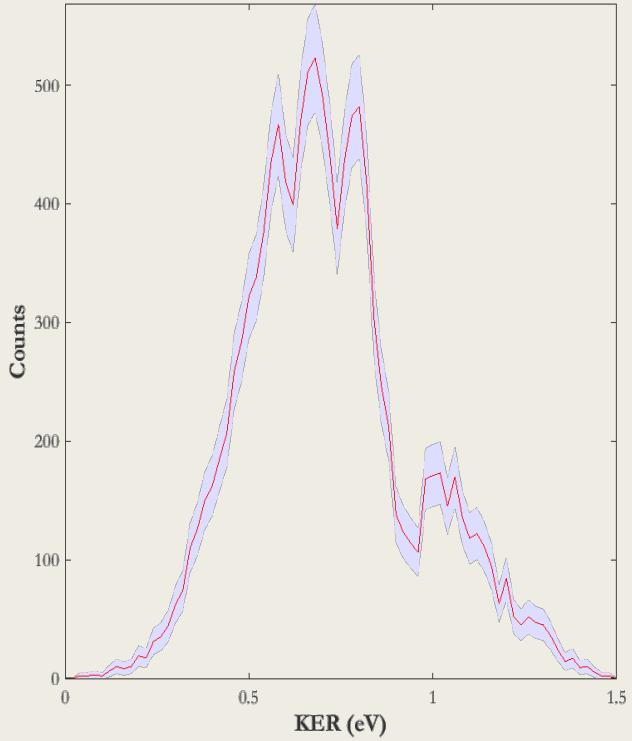
- There is a discrepancy between model (ideal) and real parallel plate deflector fields.
- Distortions in the real deflector field decrease the resolution of position and TOF data.



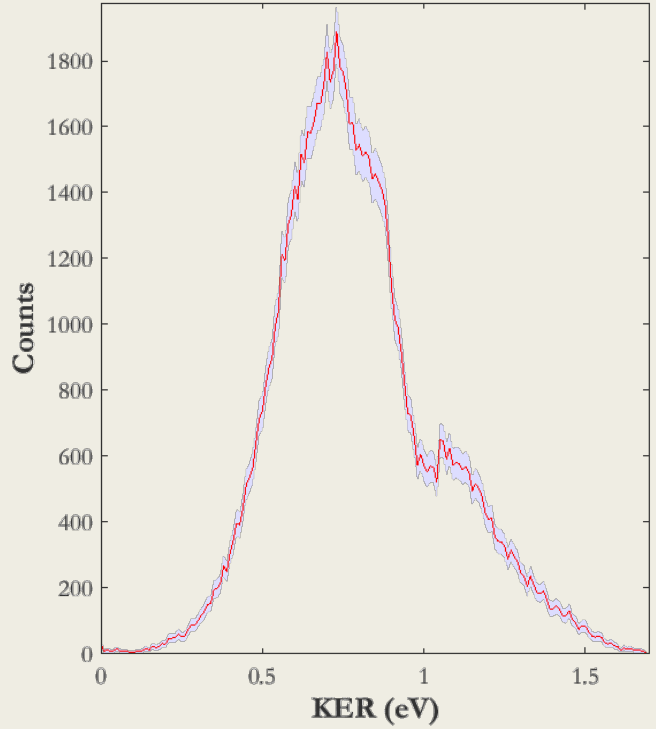
Ideal parallel plate deflector field lines



Real parallel plate deflector field lines



1-detector measurement without imaging deflector



2-detector measurement with imaging deflector

Goal

- Characterize imaging deflector to enable retrieval of momentum information.
  - *Use simulation to represent experimental data (real deflector field)*
  - *Generate analytical formula to fit simulated data*
    - The basis of this analytical formula is the model of an ideal parallel plate deflector
  - *Use analytical formula to find position and time of flight without deflector distortions*

Model

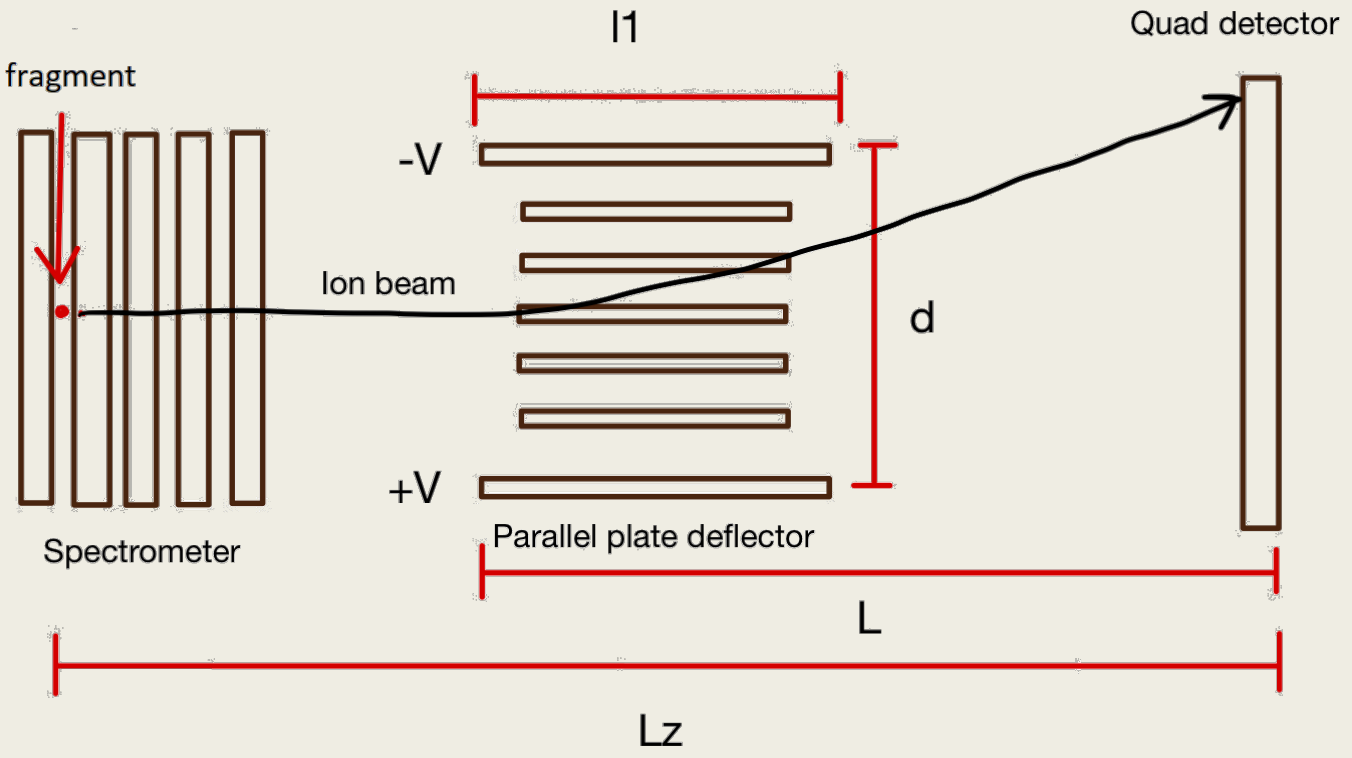
q = charge

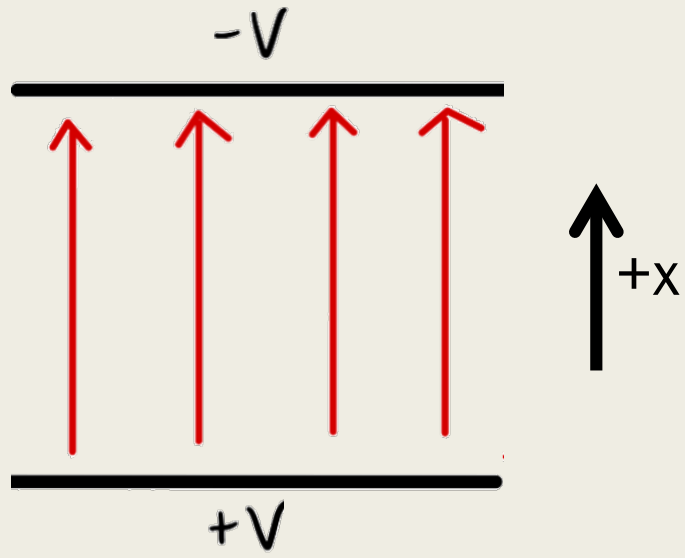
$\mathbf{E_z} = \frac{1}{2}mv_{0z}^2$

$\mathbf{v_{ix}}$ = dissociation velocity in x-direction

TOF = Time of flight

$$x_f = \frac{qVl_1}{E_z d}\left(L - \frac{l_1}{2}\right) + v_{ix}TOF \ldots \text{ or simply put, } x\ deflection \propto \frac{qV}{E_z}$$





Model

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q = charge

$\mathbf{E_z} = \frac{1}{2}mv_{0z}^2$

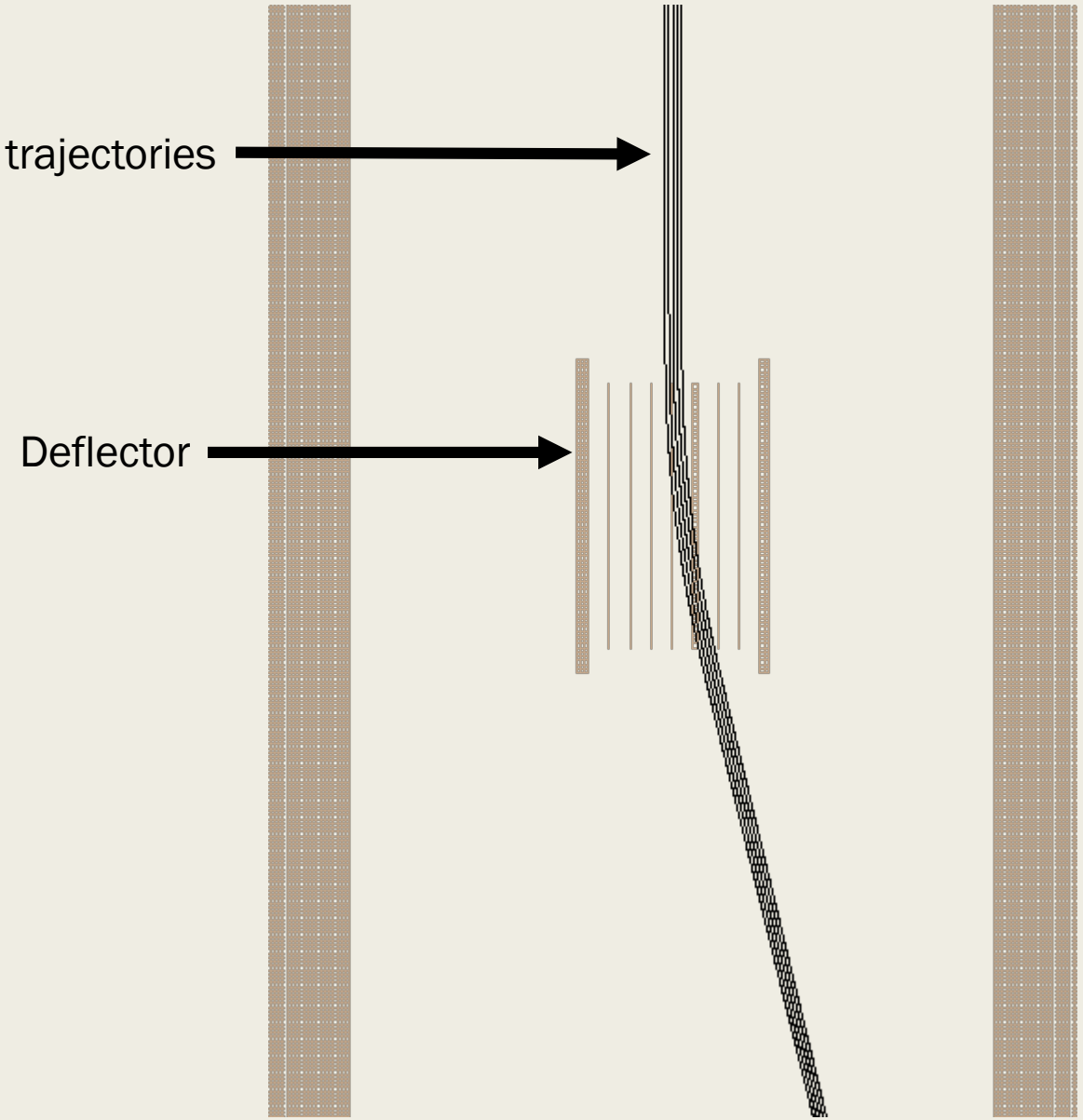
$\mathbf{v_{ix}}$ = dissociation velocity in x-direction

TOF = Time of flight

Characterize distortion in position by fitting the model to simulated data.

Methods

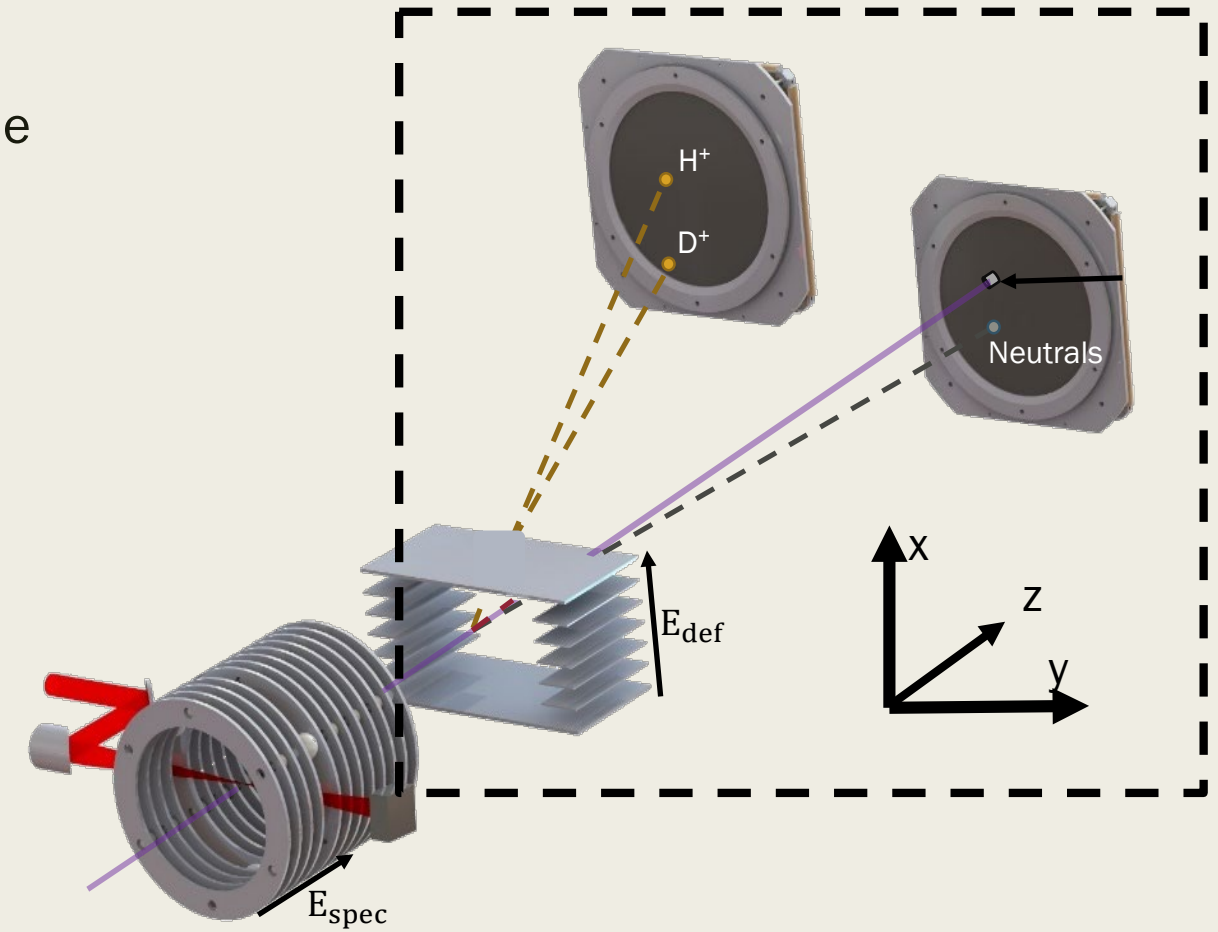
1. Generate initial conditions for simulation in Matlab
2. Collect time of flight, impact position, and other ion trajectory data in Simion
3. Compare simulated result to model, modify model equation and add correction terms to describe the distortion due to the deflector field.



Example of an ion trajectory in Simion

Results

- Characterize distortions in the
  1. x - direction
  2. z - direction (TOF)
  3. y - direction

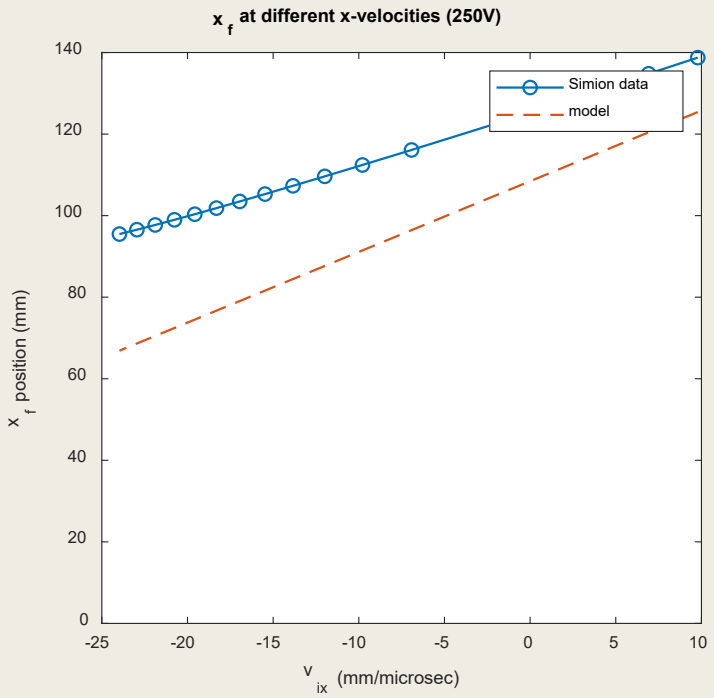


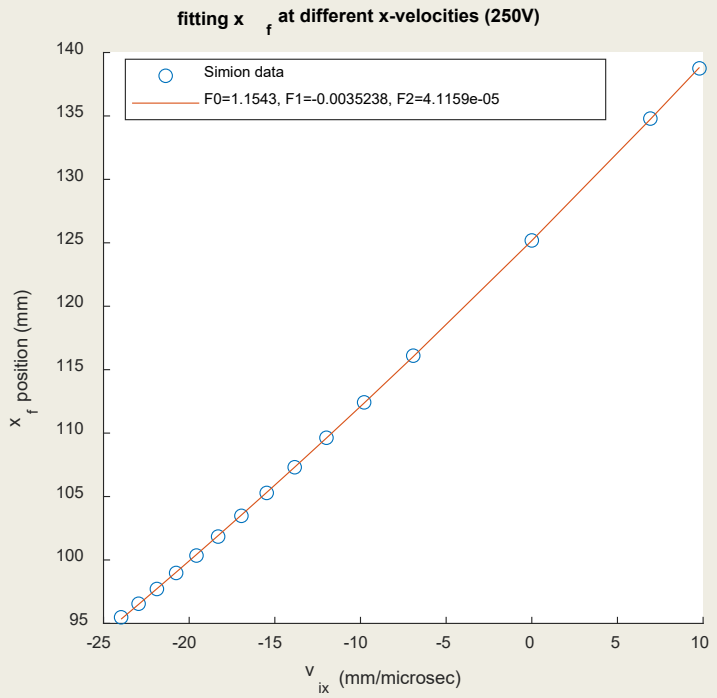
Position resolution of imaging setup: 0.25 mm

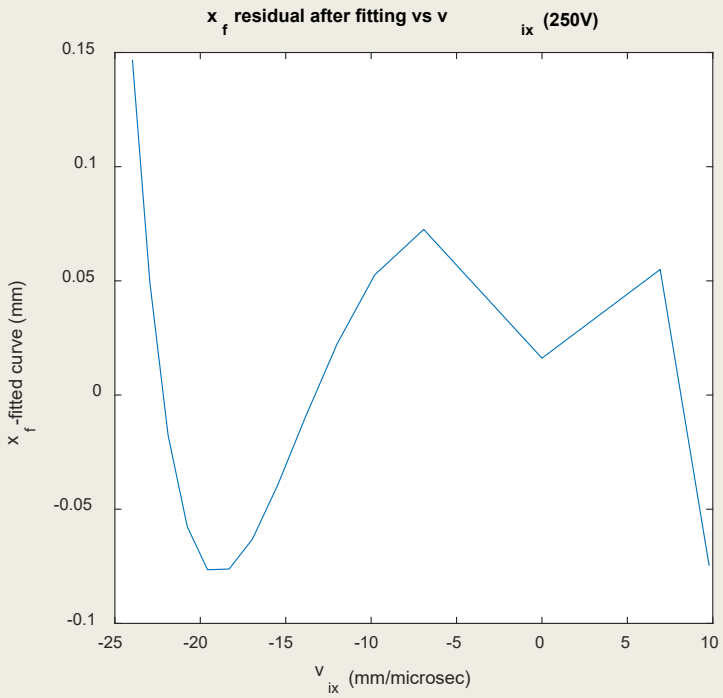
Correcting x-position model

$$x_f = \frac{qVl_1}{E_z d}\left(L - \frac{l_1}{2}\right) + v_{ix}TOF$$

- Compared simulation results to model results, corrected model







2nd order correction

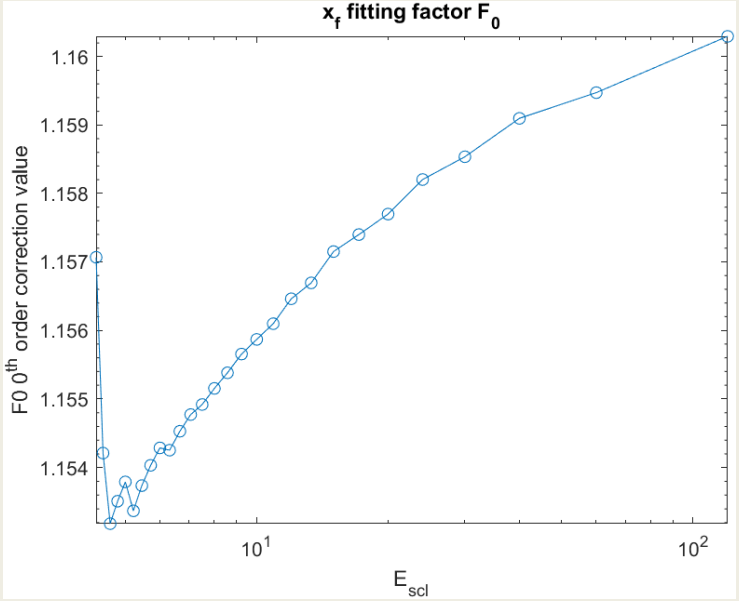
$$x_f = \frac{qVl_1(\boldsymbol{F_0 + F_1 v_{ix} + F_2 v_{ix}^2})}{Ed}\left[L - \frac{l_1}{2}\right] + v_{ix}TOF_m$$

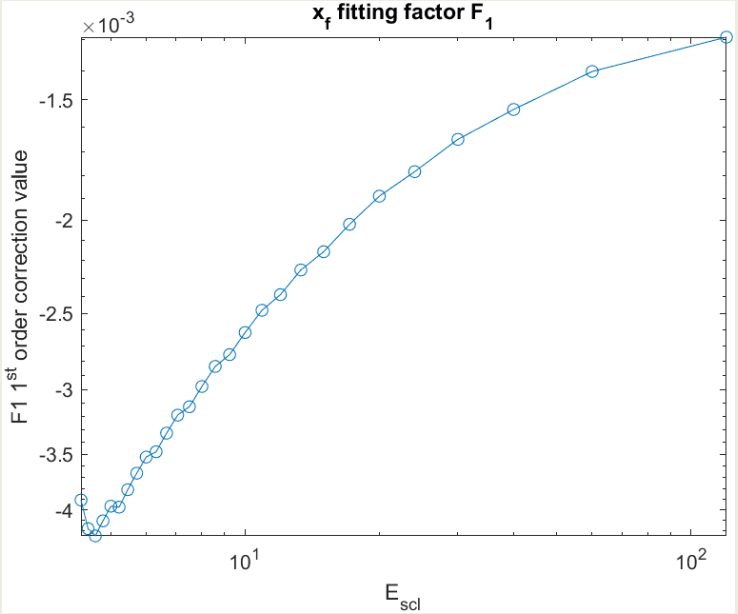
x-position correction coefficients

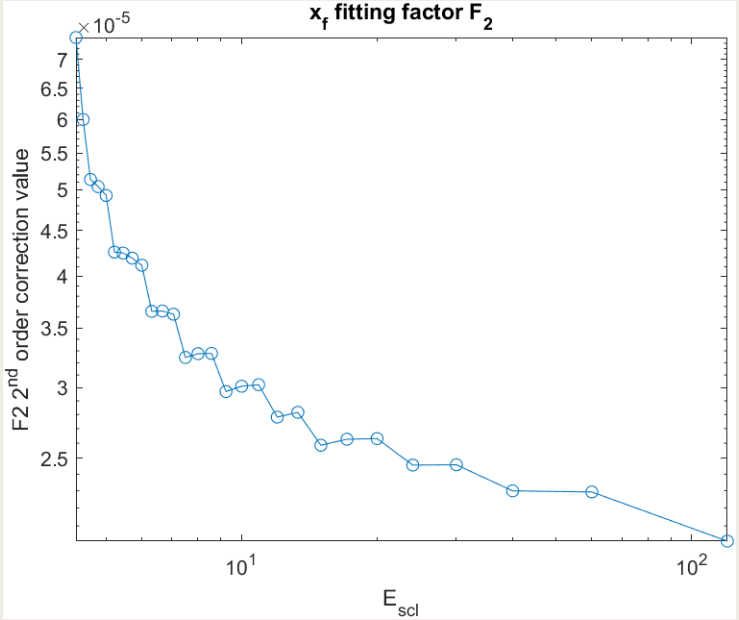
$$x_f = \frac{qVl_1(\boldsymbol{F_0 + F_1 v_{ix} + F_2 v_{ix}^2})}{Ed}[L - \frac{l_1}{2}] + v_{ix}TOF_m$$

$$x\ deflection \propto \frac{qV}{E_z} \qquad E_{scl} = \frac{E_z}{qV}$$

- Plotting F vs E_{scl} allows us to remove deflector distortions in position under a variety of initial conditions
- Fit curves to find functional form of each coefficient





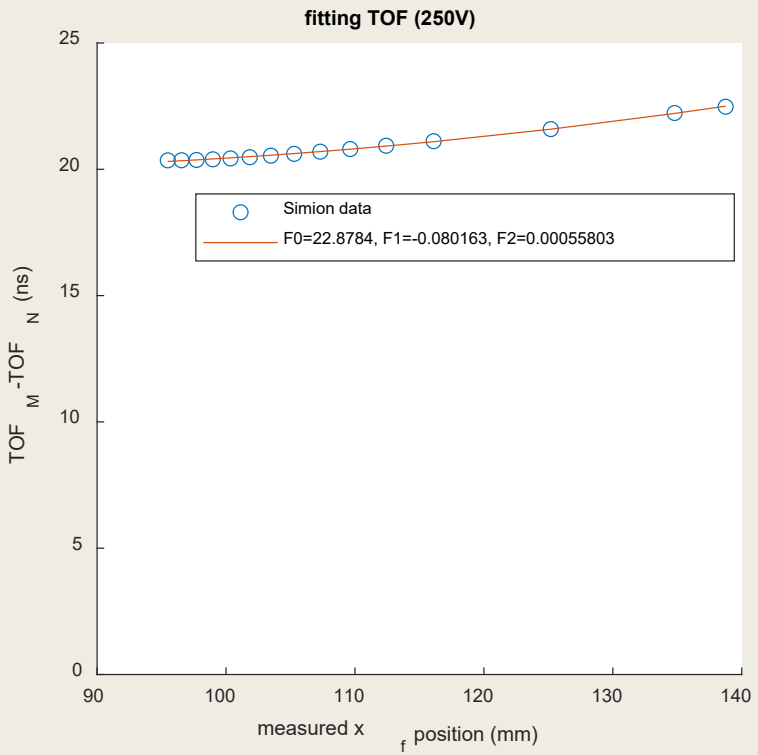


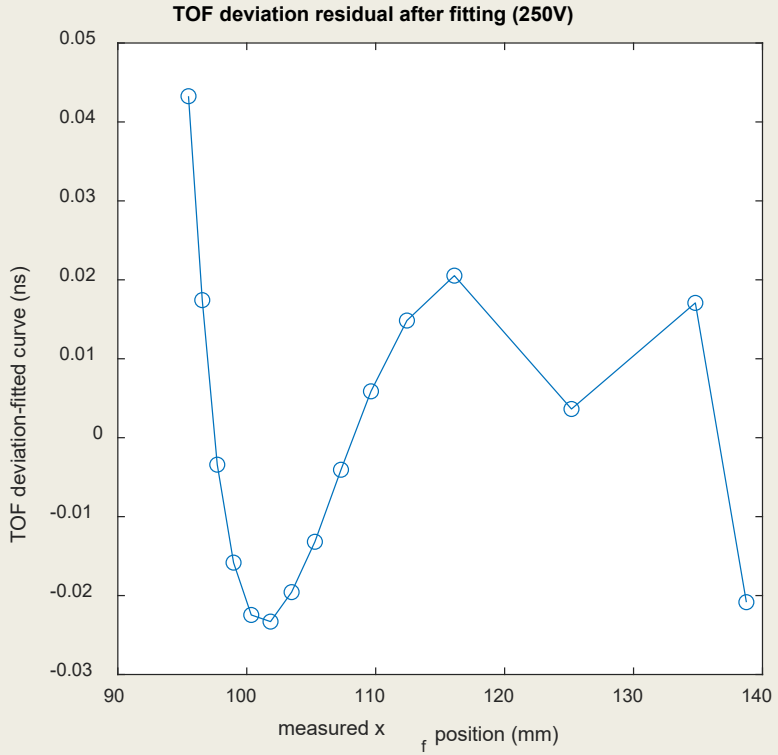
Modeling distortions in TOF

- Fit time delay
- Residual is smaller than time resolution (0.2 ns) with second order fit

$TOF_{ND} = TOF\ with\ no\ distortion$
$TOF_S = Simulated\ TOF$

$$\boldsymbol{F_0 + F_1 x_f + F_2 x_f^2} = TOF_S - TOF_{ND}$$





TOF model coefficients for different conditions

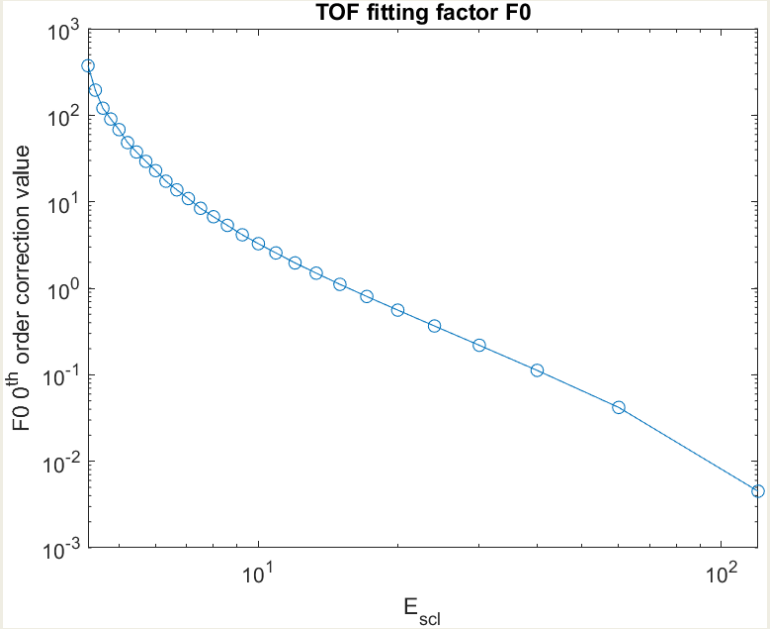
$TOF_{ND} = TOF\ with\ no\ distortion\ ('ideal')$

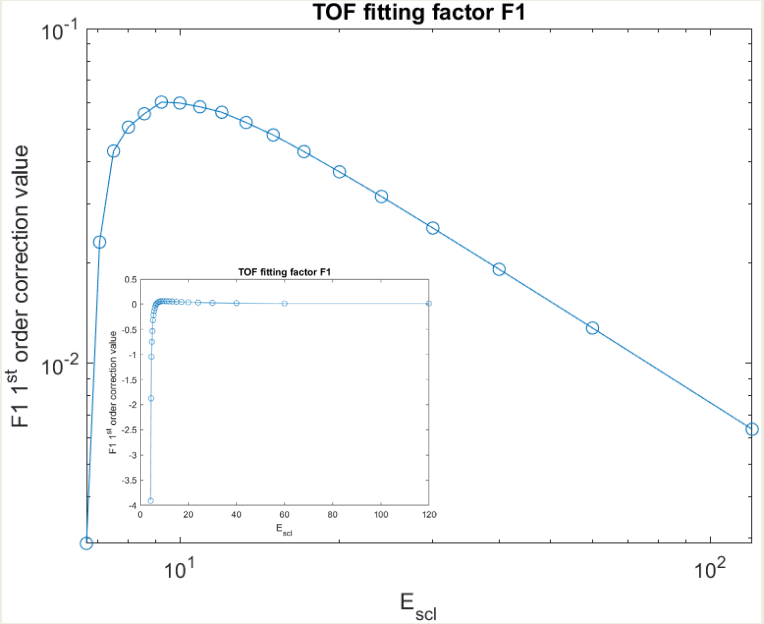
$TOF_S = Simulated\ TOF$

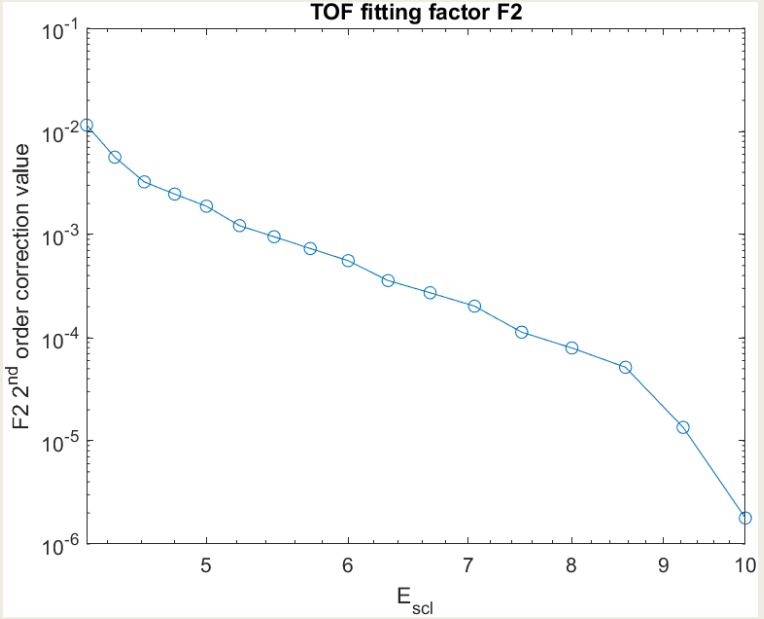
$$\boldsymbol{F_0 + F_1 x_f + F_2 x_f^2} = TOF_S - TOF_{ND}$$

$$E_{scl} = \frac{E}{qV}$$

- Fit curves to find functional form of each coefficient
- Use analytic expression to remove distortions in TOF for a variety of initial conditions.







*Some negative values omitted in middle plot. See inset graph

Summary

- Corrected x-position model, allowing us to remove distortions in x-direction.
- Determined an analytic expression for TOF delay to remove distortions in TOF.
- Distortions in the y-direction are small enough to neglect for now.

Future Work

- Fit F vs. E_{scl} curves to describe corrections for different initial conditions
- Compare fitted model to simulation results to ensure its accuracy. Test in x, y, and z directions.
- Use fitting expressions to recover fragment momentum information from experimental data

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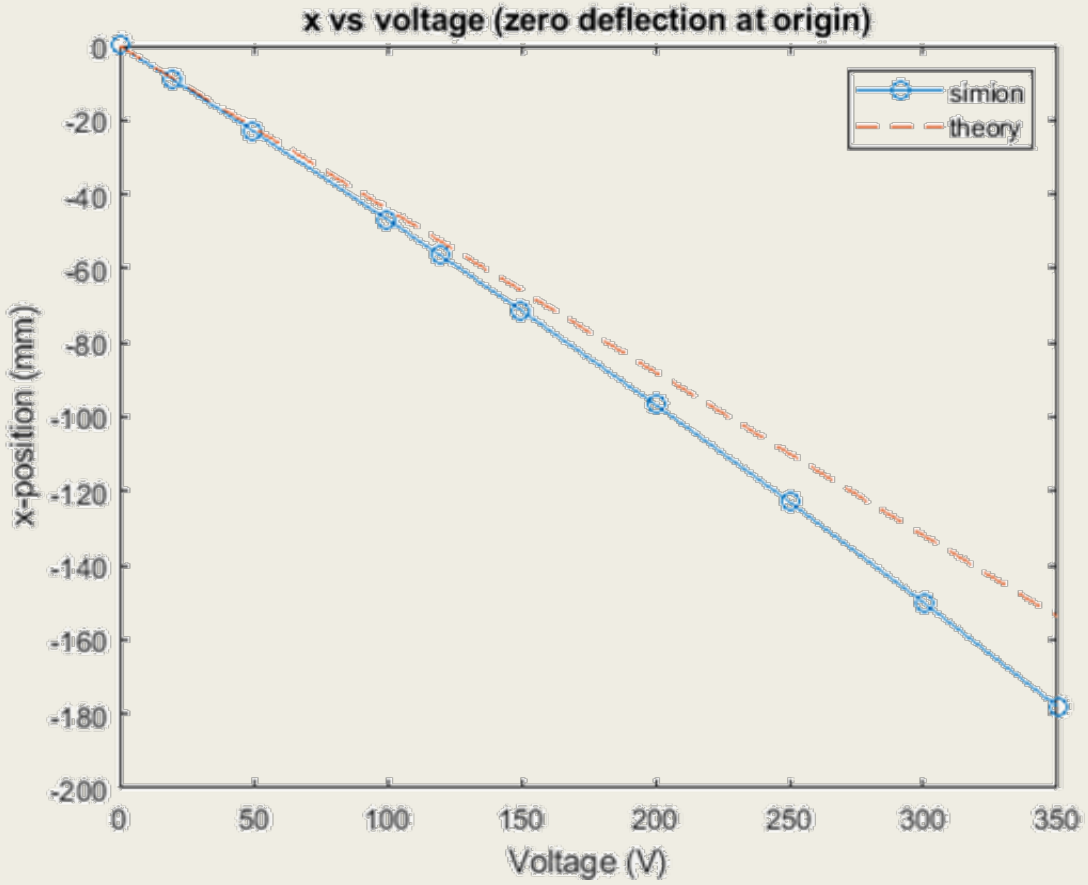
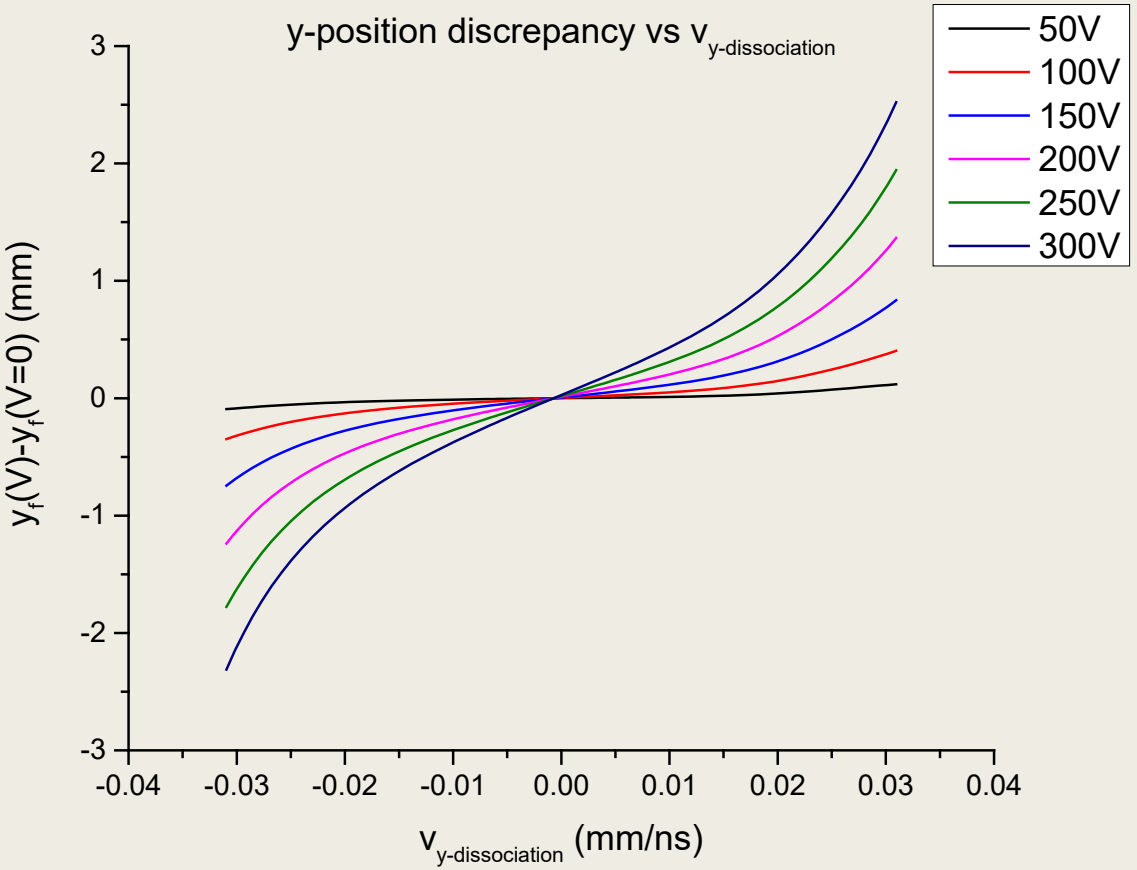
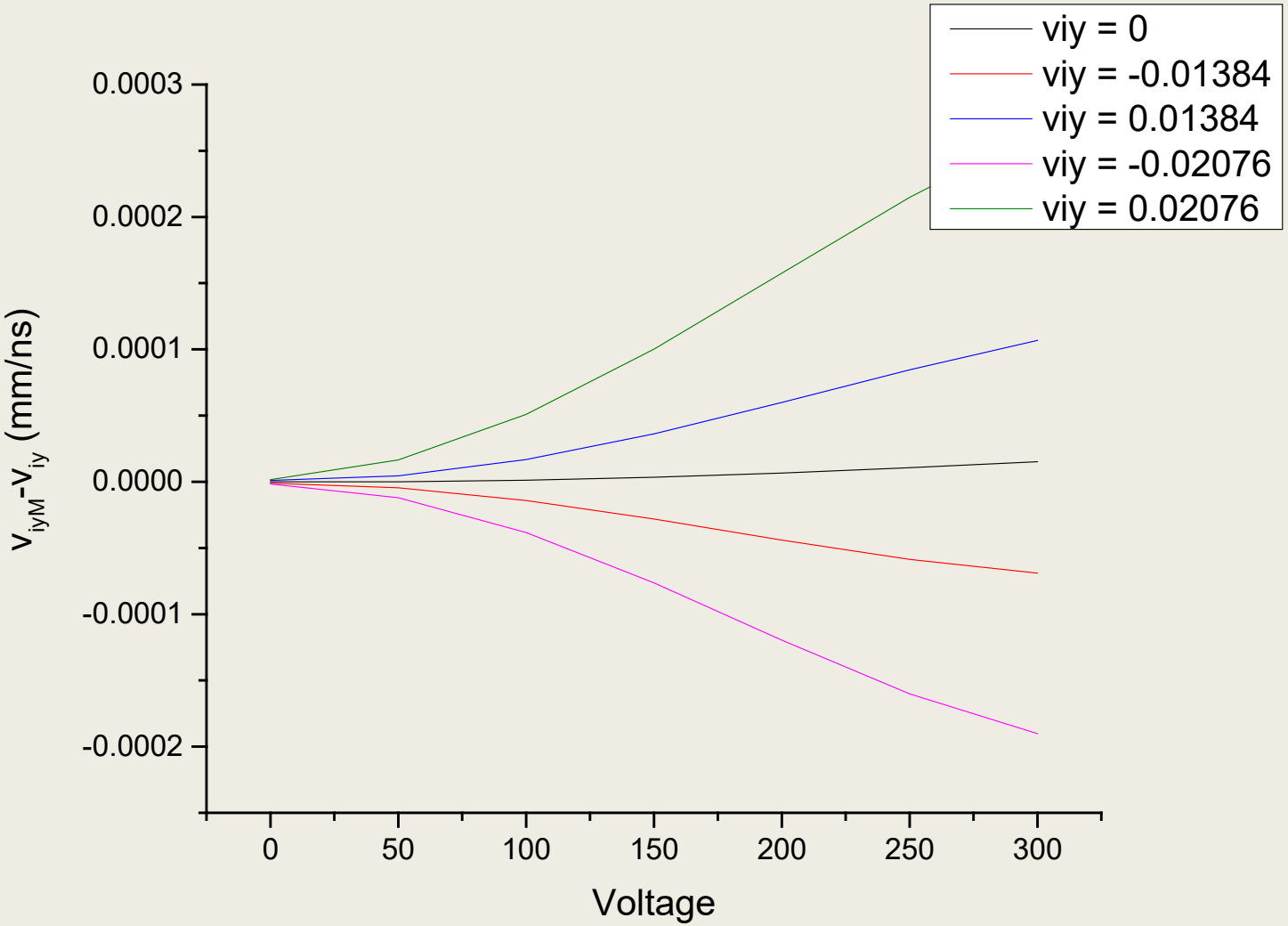
Discrepancies between model and Simion results





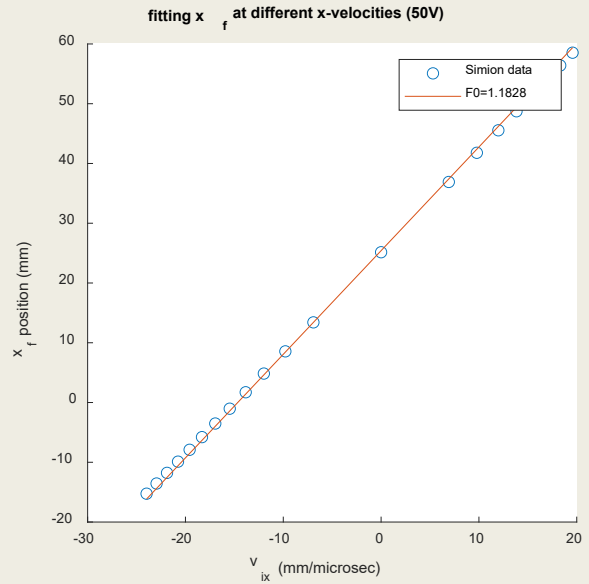
Characterizing motion in y

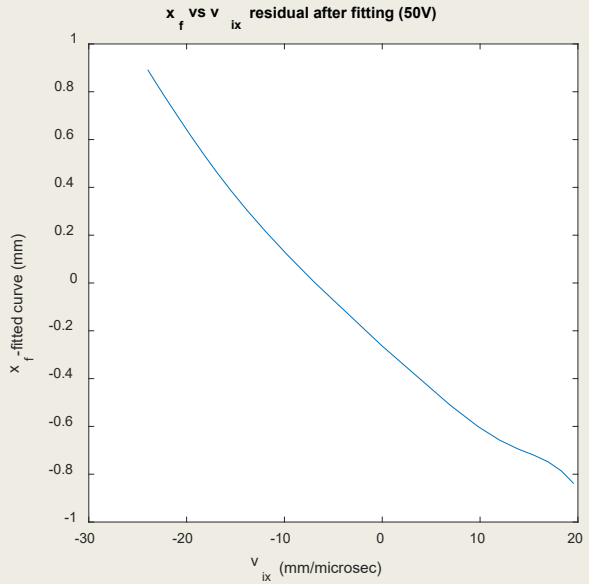


Defining terms

- y_f – measured final y-position
- TOF – measured time of flight
- v_{iy} – initial velocity in the y-direction that was input into Simion.
- v_{iyM} – y-velocity calculated using y_f/TOF
- V –volts
- v_y –instantaneous y-direction velocity as ion flies

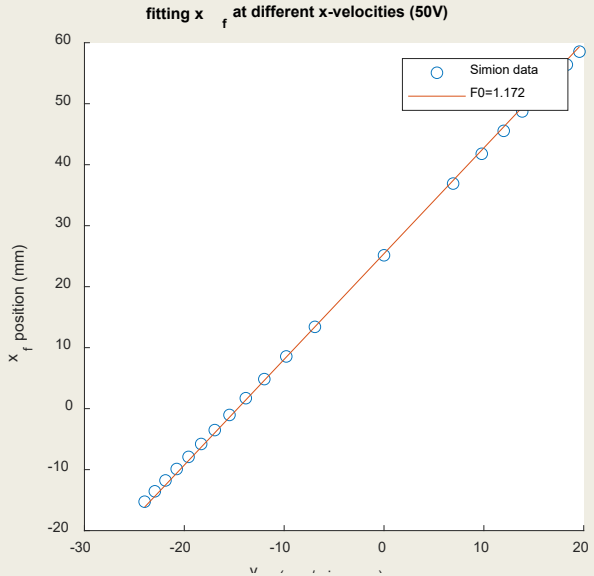
- v_{iy} was varied from -5 → +5 eV (±0.0309497 mm/ns)
- Total KE varied from 1500→1505 eV.

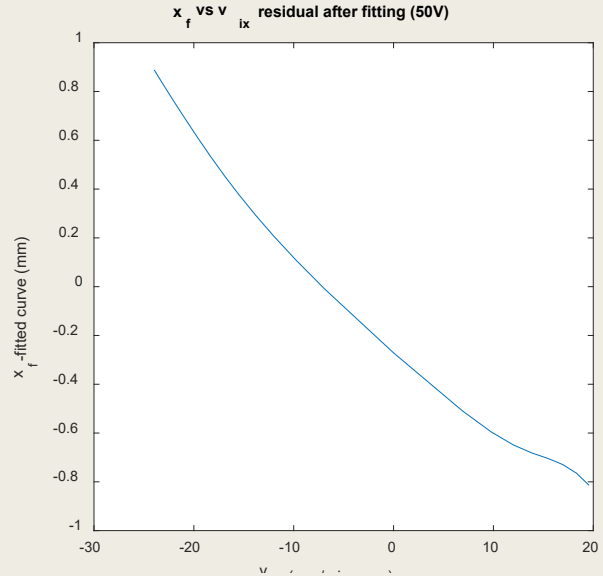




Correcting deflector length (l_1)

$$x_f = \frac{qVl_1\boldsymbol{F_0}}{Ed}\left[L - \boldsymbol{F_0}\frac{l_1}{2}\right] + v_{ix}TOF_m$$





Multiplying equation by correction factor

$$x_f = \frac{qVl_1\boldsymbol{F_0}}{Ed}\left[L - \frac{l_1}{2}\right] + v_{ix}TOF_m$$

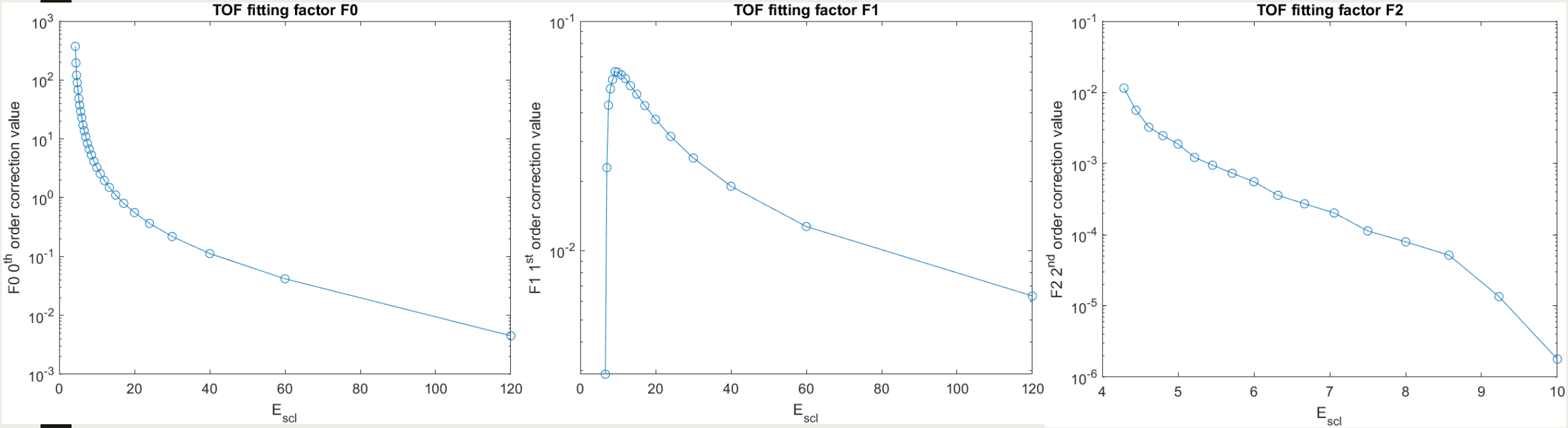
Both corrections fit the data equally well, but adding the correction factor in one place is much simpler.

$TOF_{ND} = No\ deflection\ TOF$

$TOF_s = Simulated\ TOF$

Semi-log (y) Fitting Factor vs E_{scl}

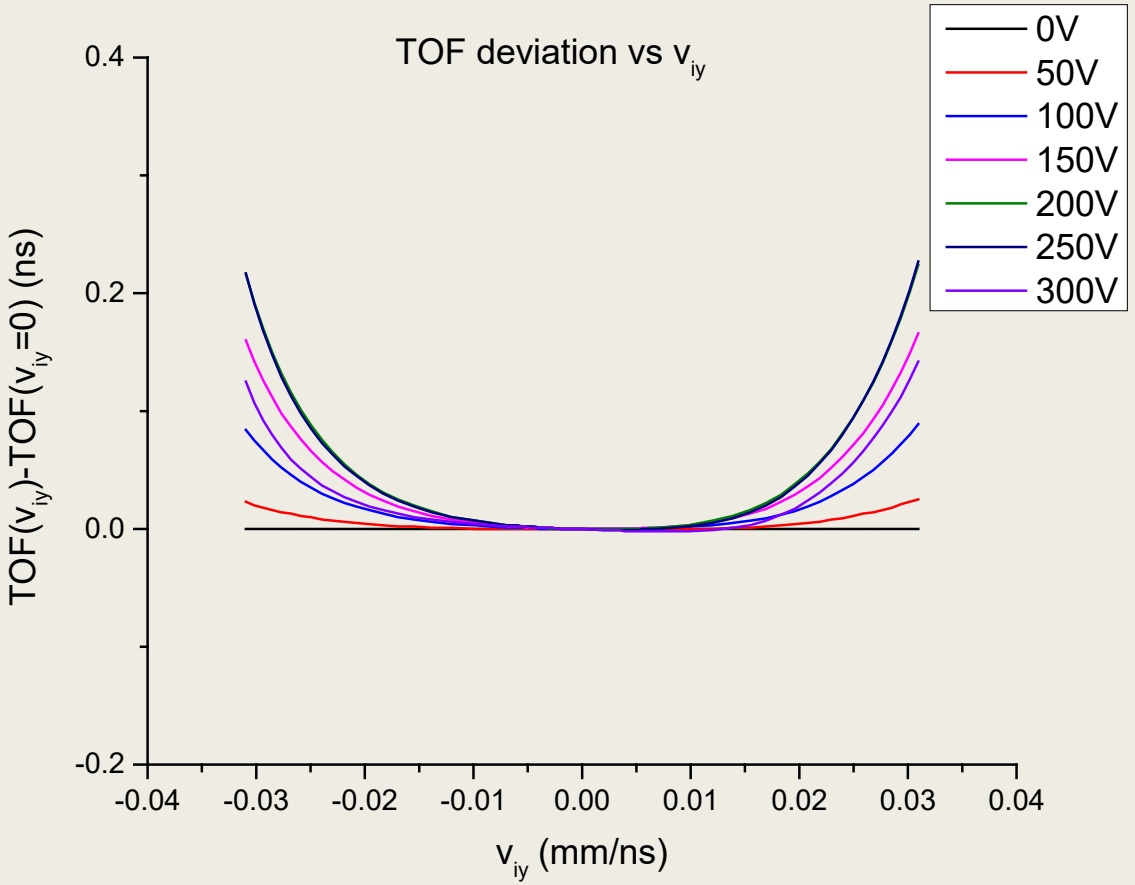
$$F_0 + F_1 x_f + F_2 x_f^2 = TOF_S - TOF_{ND}$$

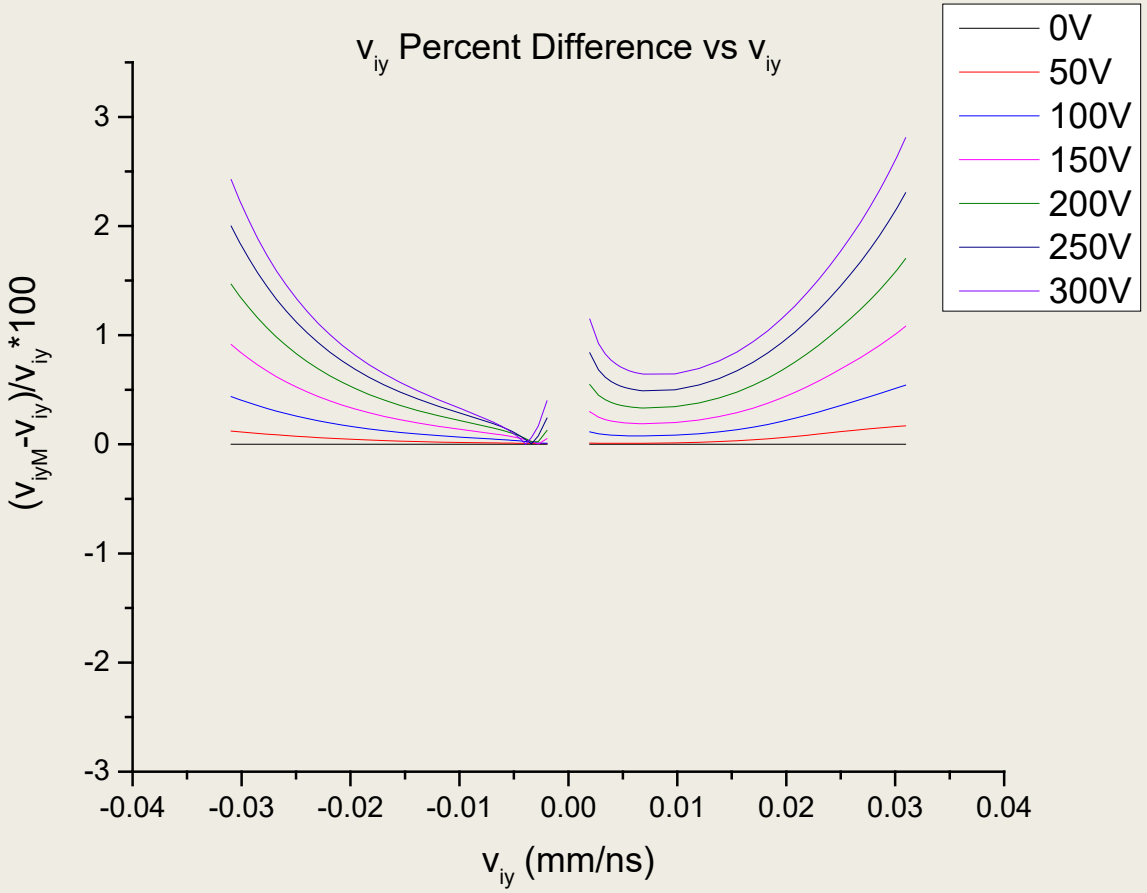


*negative data ignored in F1 graph

$$E_{scl} = \frac{E}{qV}$$

Characterizing effects of motion in y





For v_{iy} less than 5 eV, TOF deviation is less than 0.2 ns. The time resolution of our setup is 0.2 ns.

Percent error in velocity is around 2%.