Abstract
The formulation and validation of a novel quasi-one-dimensional particle-in-cell code for the simulation of magnetic nozzles is presented.

Methodology
We developed a novel quasi-one-dimensional electrostatic particle-in-cell method which focuses on studying energy exchange and thermalization in the plasma.

Validation Simulations

Quasi-one-dimensional Algorithms
Governing equations:
\[
\frac{dx}{dt} = v
\]
\[
\frac{dv}{dt} = q (E + v \times B)
\]
Particle Movers:
- Standard Boris Algorithm for Axisymmetric Coordinates
- Modified Semi-Implicit Q1D Boris Algorithm

\[
\frac{m v^2}{2} - \frac{q v \cdot B}{2} = E_0 + \frac{q v \cdot B}{2} - \frac{q v \cdot B}{2}
\]

Conclusion
The code is validated with standard one-dimensional test cases. A quasi-one-dimensional method for magnetic nozzle simulation is developed and its implementation shows promising results for magnetic mirror test cases. Further evaluation of Q1D algorithms and implementation will be done in the future.

Acknowledgements
This research is funded by a NASA Space Technology Research Fellowship. Thank you to my fellow lab mates at PEPL for their helpful discussions and support.