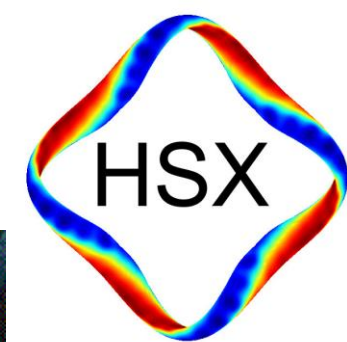




HIBP Designs for Measurement of the Electric Field in HSX

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Overview

- A feasibility study has shown that it is practical to measure the radial electric field in the Helically Symmetric eXperiment, HSX, using ion beams.
- Two options have been explored, a standard Heavy Ion Beam Probe, HIBP, and a system that measures the deflection of an ion beam due to the plasma electric field.
 - The standard HIBP measures the local space potential at multiple points, allowing a calculation of the radial electric field. Estimated signal levels are similar to some previous systems, most notably the EBT HIBP. It is also capable of measuring fluctuations in potential and density.
 - The second option studied measures the change in a probing ion beam trajectory due to the electric field. HSX vacuum magnetic fields are virtually unchanged by the plasma, therefore changes in the beam trajectory due to plasma would be dominated the plasma electric field. The changes are path integrated and the local electric field is determined by running multiple trajectories and inverting. A beam deflection system is simpler and needs a lower ion accelerator voltage than a HIBP, but it provides less information.

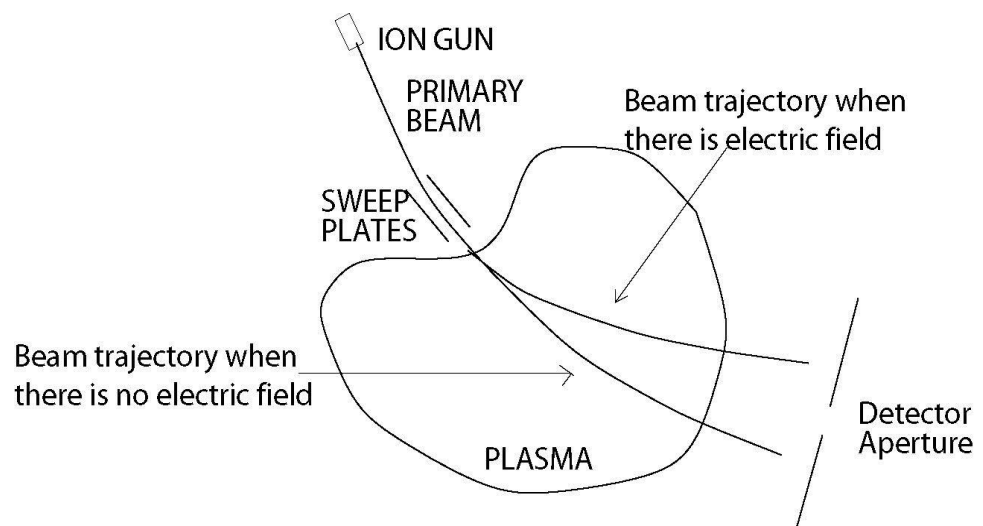
Motivations for a Heavy Ion Beam Probe Diagnostic

- Understanding the relative roles of neoclassical and anomalous transport in advanced stellarators is critically dependent on knowledge of the radial electric field.
 - Neoclassical transport depends strongly on the ambipolar radial electric field; potential measurements would resolve whether HSX is operating in the ion or electron root
 - Understanding of the anomalous transport present in devices with low effective ripple requires a detailed understanding of the neoclassical predictions
 - The CHERS system presently being installed on HSX infers the electric field through plasma flow measurements
 - An HIBP system would provide direct measurements of the potential and have better spatial, temporal, and potential resolution
- Simultaneous measurements of density and potential fluctuations would provide estimates of the electrostatic fluctuation induced particle flux and data for turbulent anomalous transport models
- RPI has a 200 keV accelerator which could be made available for HSX if it would provide the needed information at a reasonable cost

Trajectory Calculations

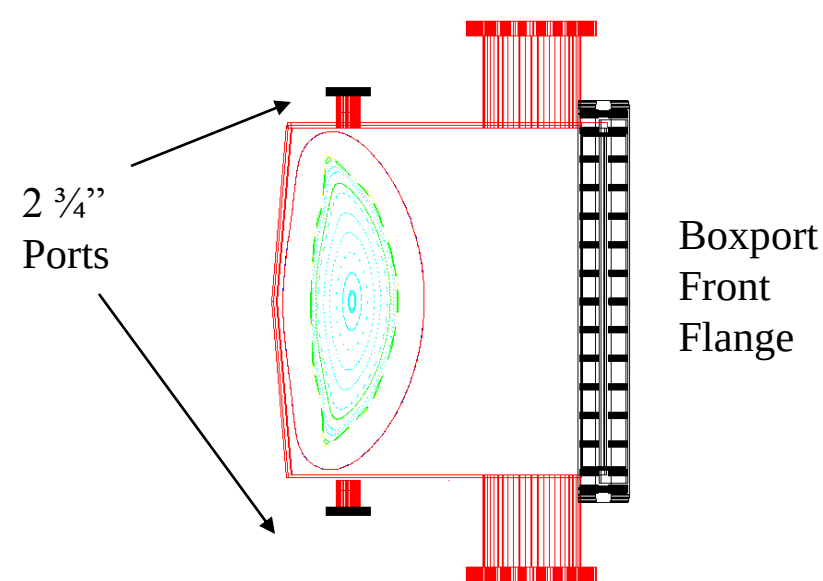
- Particle trajectories have been calculated to investigate the feasibility of a HIBP system for HSX. A number of factors have been considered:
 - Entry and exit locations
 - Beam energy
 - Ion mass
 - Magnetic field strength (all trajectories are in QHS mode)
 - Radial electric field estimates
- Beam deflection system considered as a simpler, less costly alternative to a full HIBP detector system

Experiment Geometry Outline

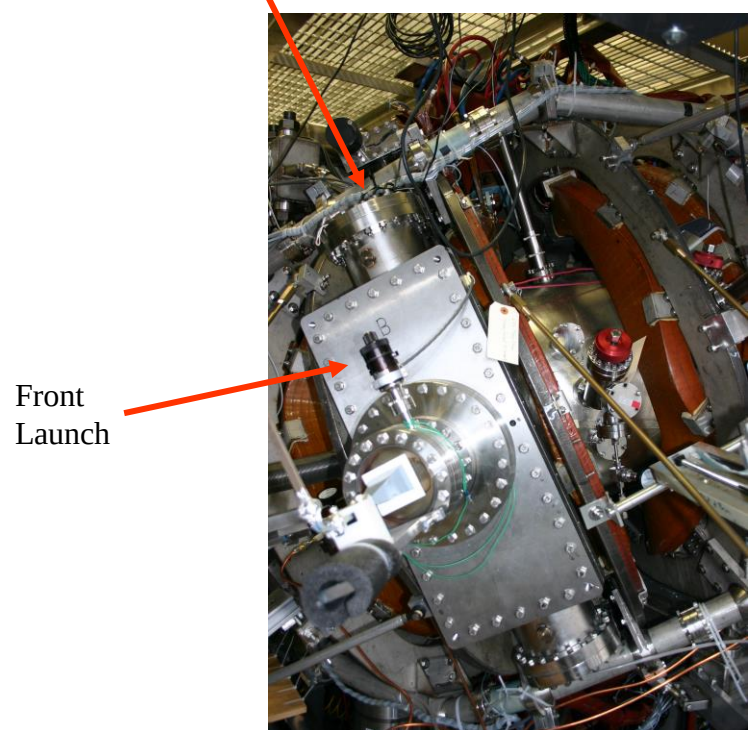


HSX Ports for HIBP

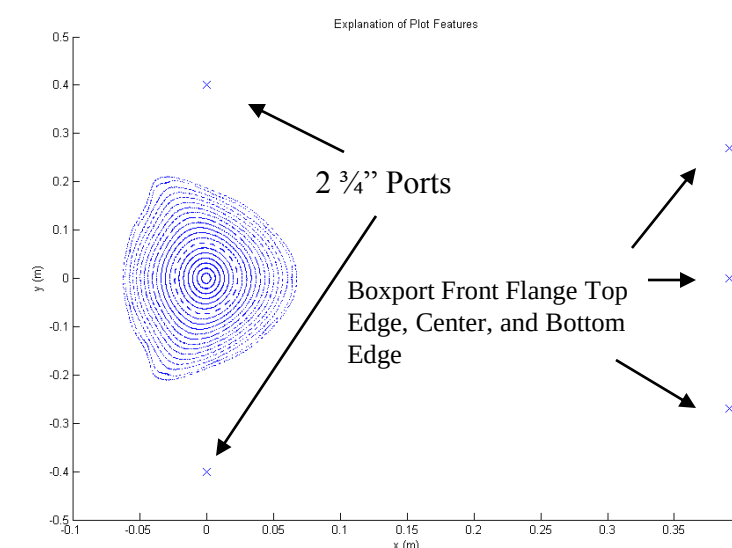
CAD Picture of HSX Boxport Cross Section



Top Launch Point (2 3/4" Port not visible)



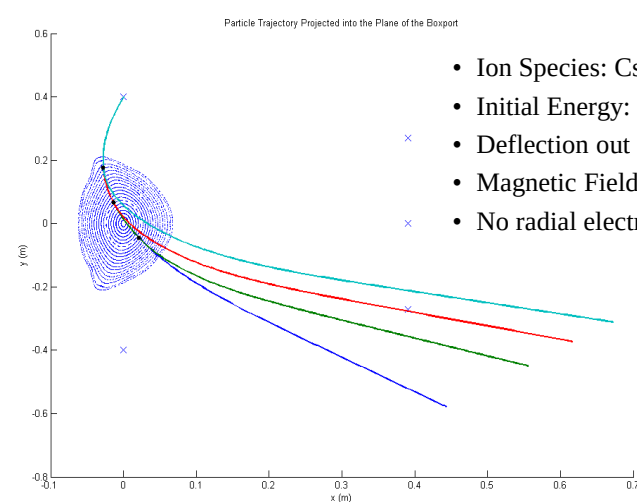
Front Launch



- Two MATLAB routines were developed independently and generated corroborating results
 - Three dimensional particle trajectories calculated first, trajectories then projected into the plane of the boxport
 - Magnetic field projected into the plane of the boxport, two dimensional trajectories then calculated

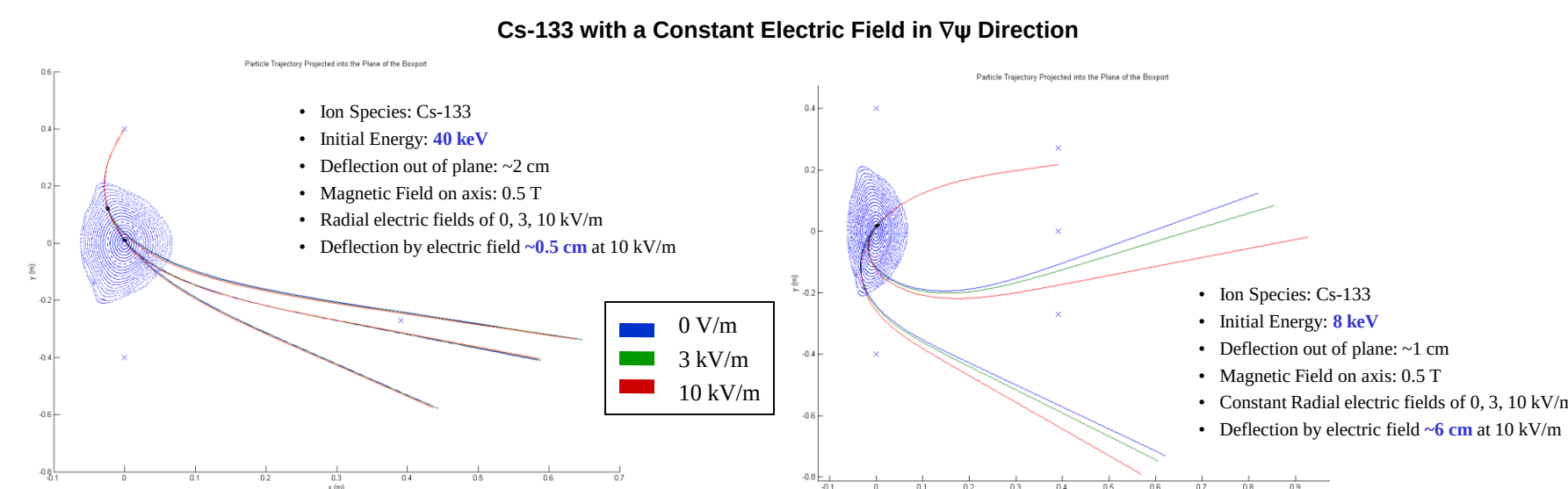
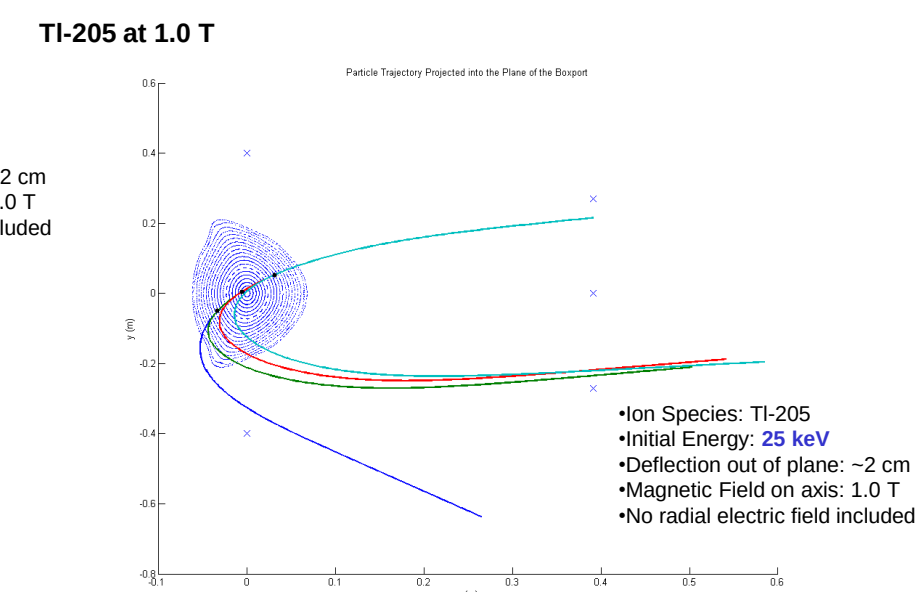
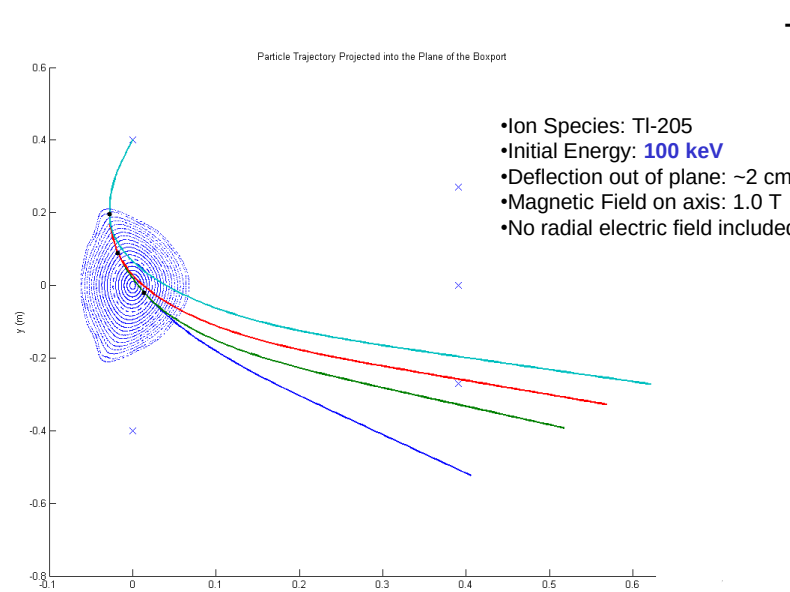
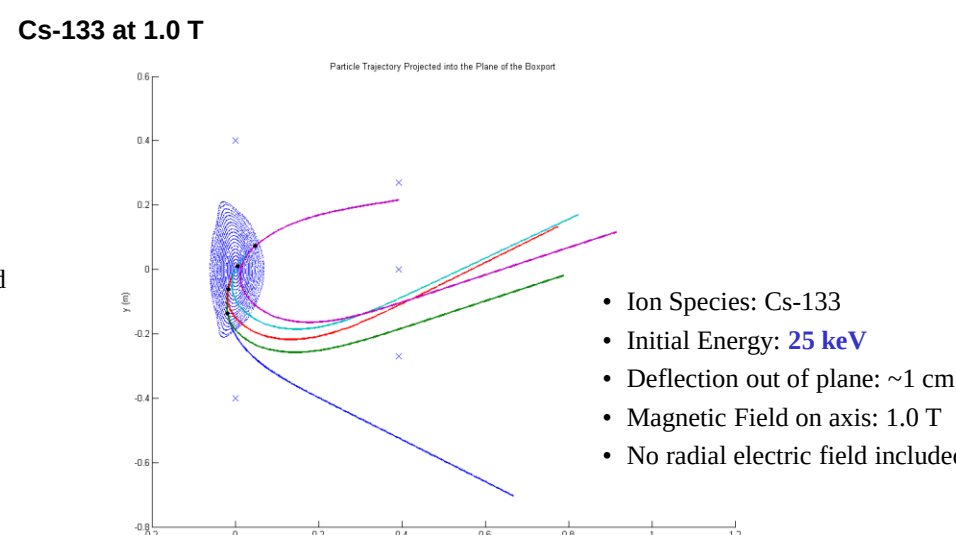
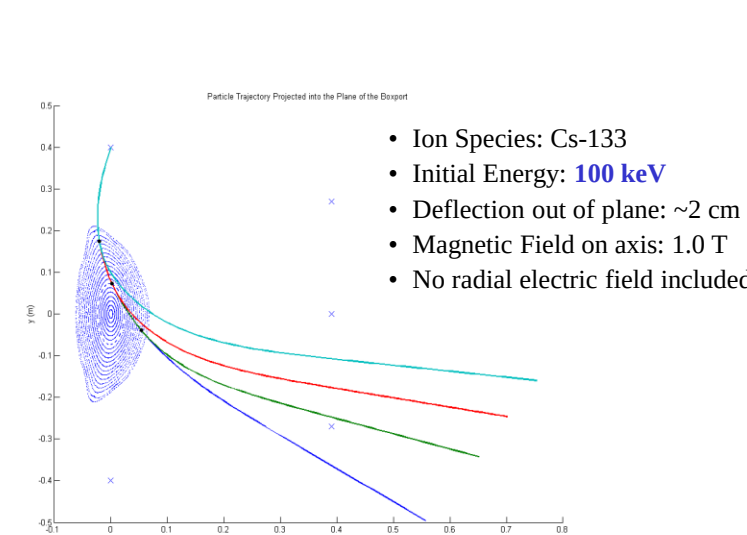
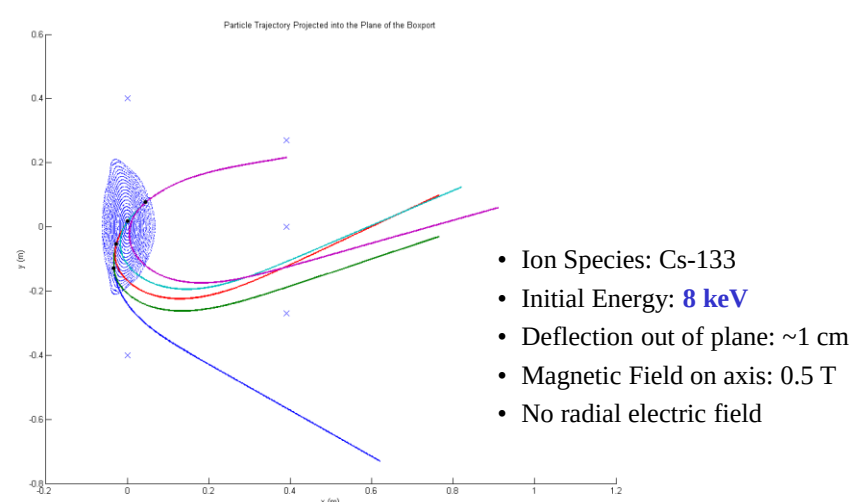
Comparison of Launch Geometries

Top Launch

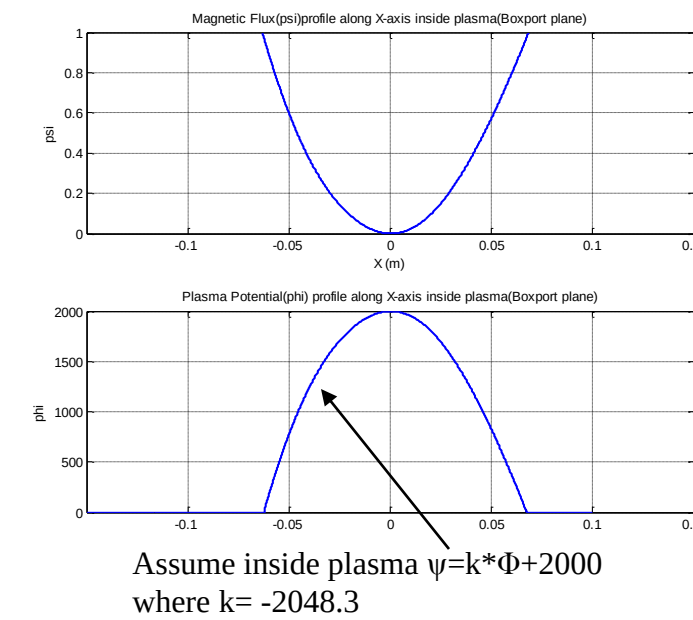


Front Launch

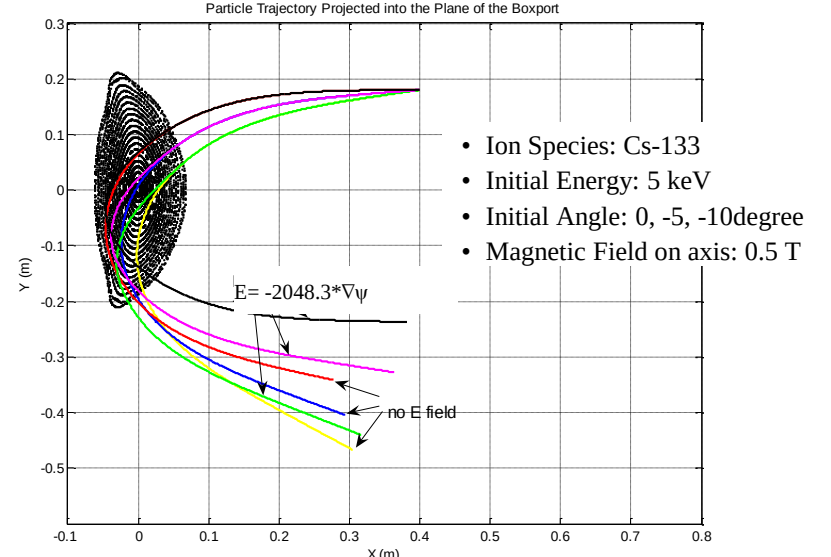
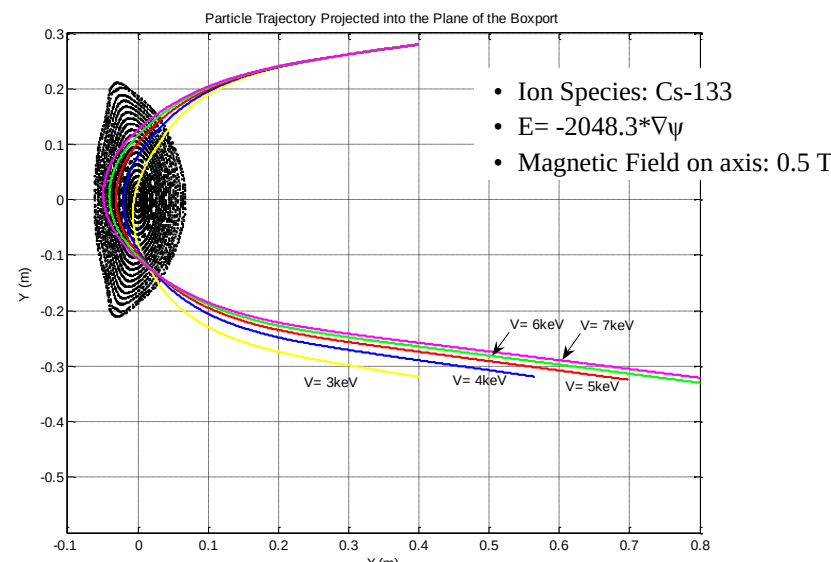
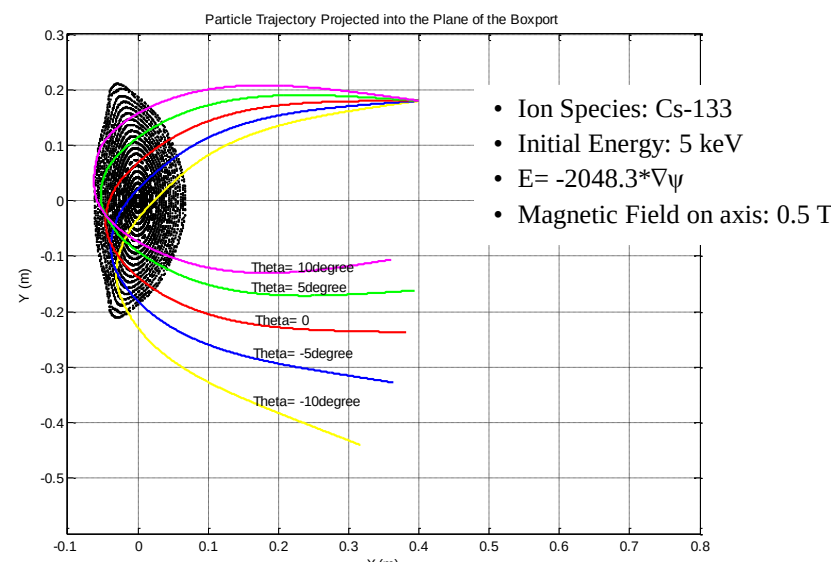
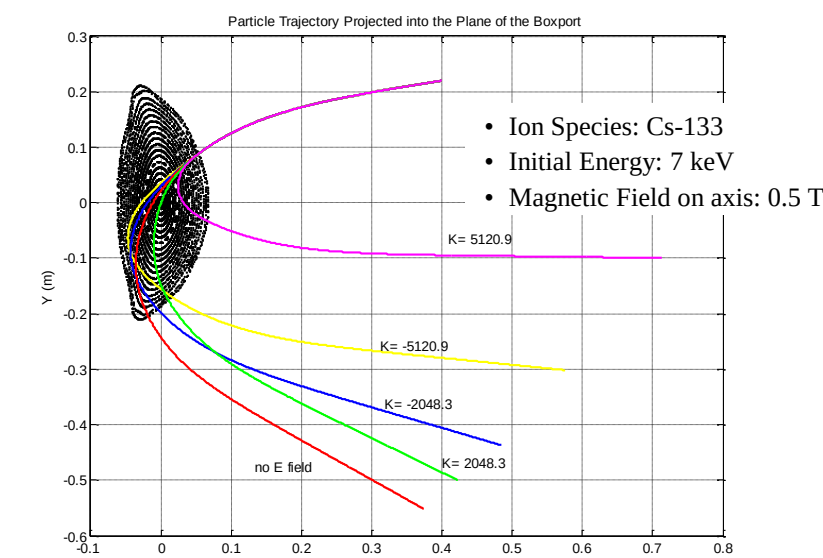
Cs-133 at 0.5 T



Launch Trajectory Scaling



Assume inside plasma $\psi = k \cdot \Phi + 2000$ where $k = -2048.3$



Implementation of an HIBP System on HSX looks Feasible

- Orbits followed in detailed magnetic field structure
- Electric fields incorporated with flux surface geometry
- Both types of launching geometries exhibit reasonable orbits
- Top launch orbits at ~100 keV exit the front of the boxport at B=1.0 T; Front launch only requires ~25 keV
- Top launch might require a detector inside the vacuum vessel to recover all secondary electrons
- Low dispersion with E~T/a imply energy analysis may be necessary for top launch
- Deflections out of the boxport plane <2 cm and not an issue
- Lower energy beam (at B=0.5 T) gives good coverage of the plasma cross-section with small variations in injection angle (assumption of electrostatic beam steering)
- Additional flexibility in coverage through variation of beam energy and calculations with Thallium and Cesium beams

Tasks Yet to Accomplished for Assessment

- Electric field and fluctuation measurement sensitivity estimates
- Secondary signal strength forecasts
- Beam divergence appraisal using finite beam calculations
- Determination of RPI hardware applicable to the HSX system
- Consideration of analyzer (full HIBP)/no-analyzer (beam deflection) options with respect to cost; quantity and quality of obtainable data with each option
- Cost and schedule estimates for the selected system