FAST ION CONFINEMENT STUDIES ON HSX

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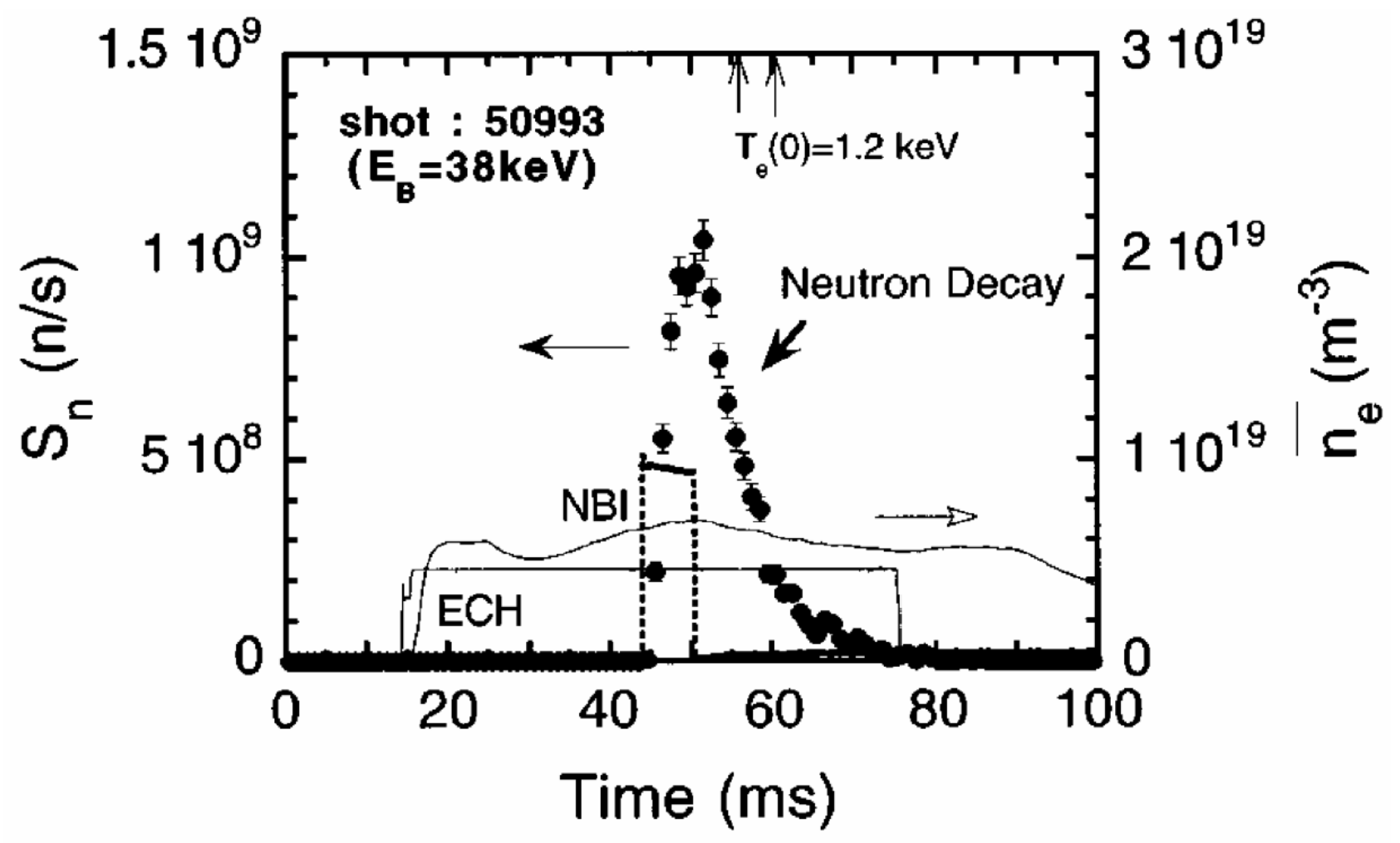
MOTIVATION

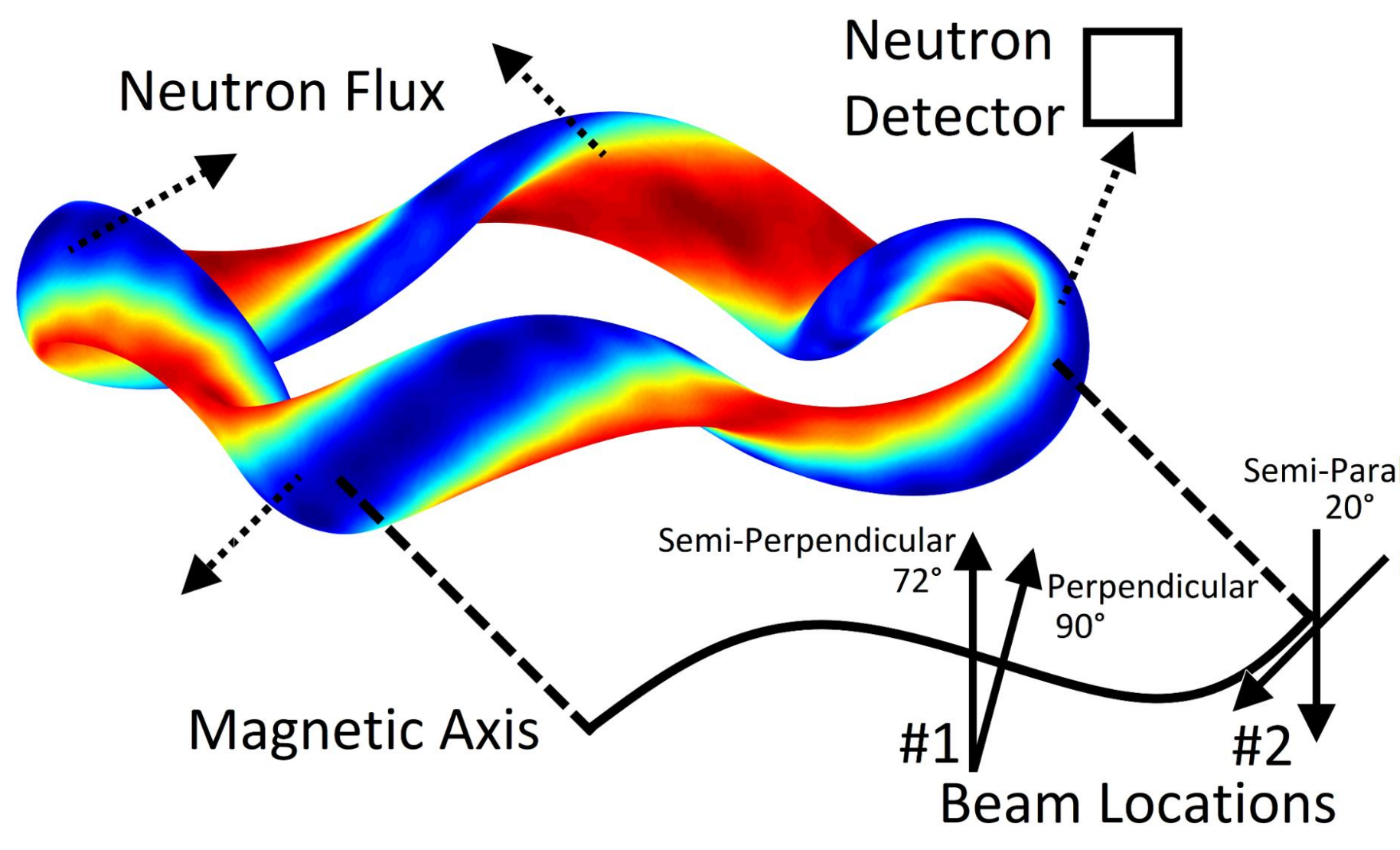
- Fast Ion confinement is critical to any fusion reactor concept
- Stellarators optimized for quasi-helical symmetry are predicted to have very good fast ion confinement, but this has not yet been shown experimentally
- The effect of quasi-helical symmetry on fast ions will be studied on HSX using a neutral beam injector and fast neutron detector
- A 20kV, 25A, 1.2ms deuterium beam and fast neutron diagnostics have been acquired and are now being installed and commissioned
- Several computational suites are being used to predict fast ion behavior and motivate beam injection geometry
- Similar experiments have been performed on CHS [1] and MST [2] showing D-D neutron flux from confined fast ions



CHS Neutron Flux Measurements [1]

METHODS

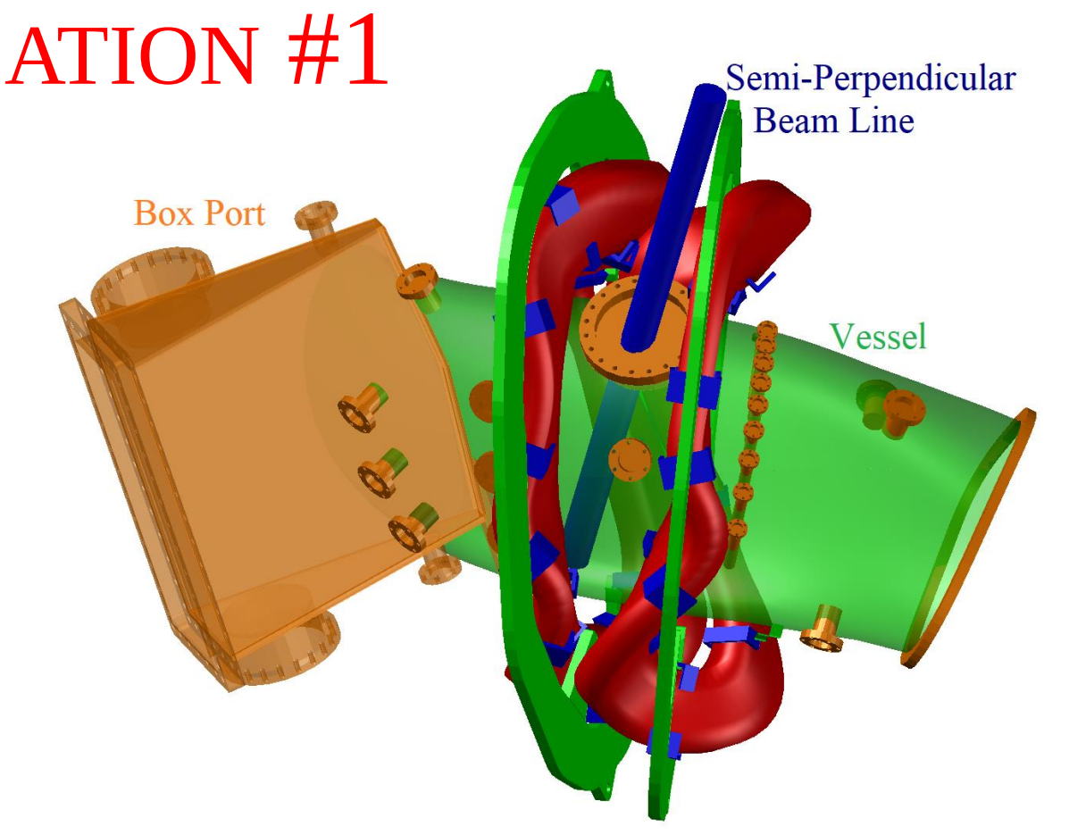
BEAM LOCATIONS

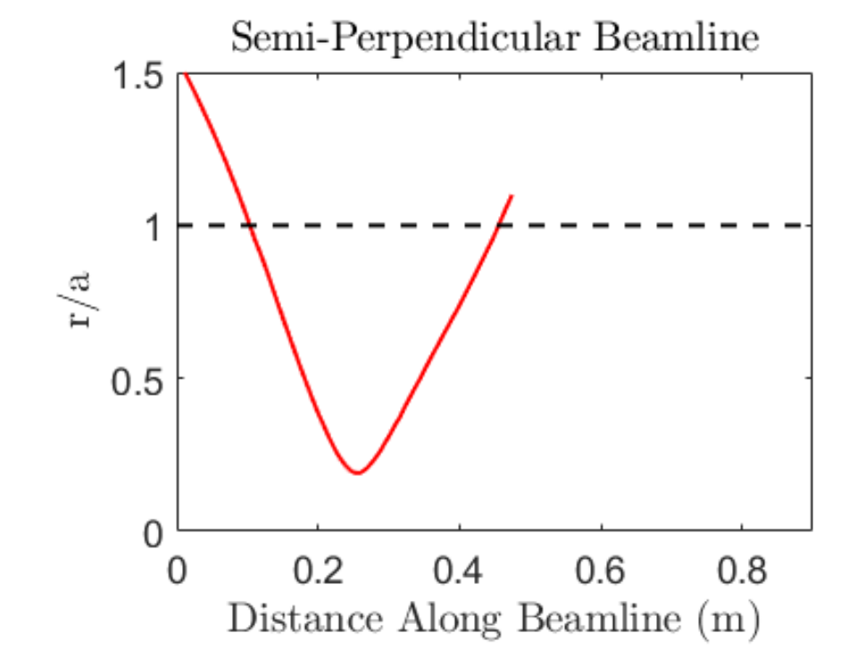


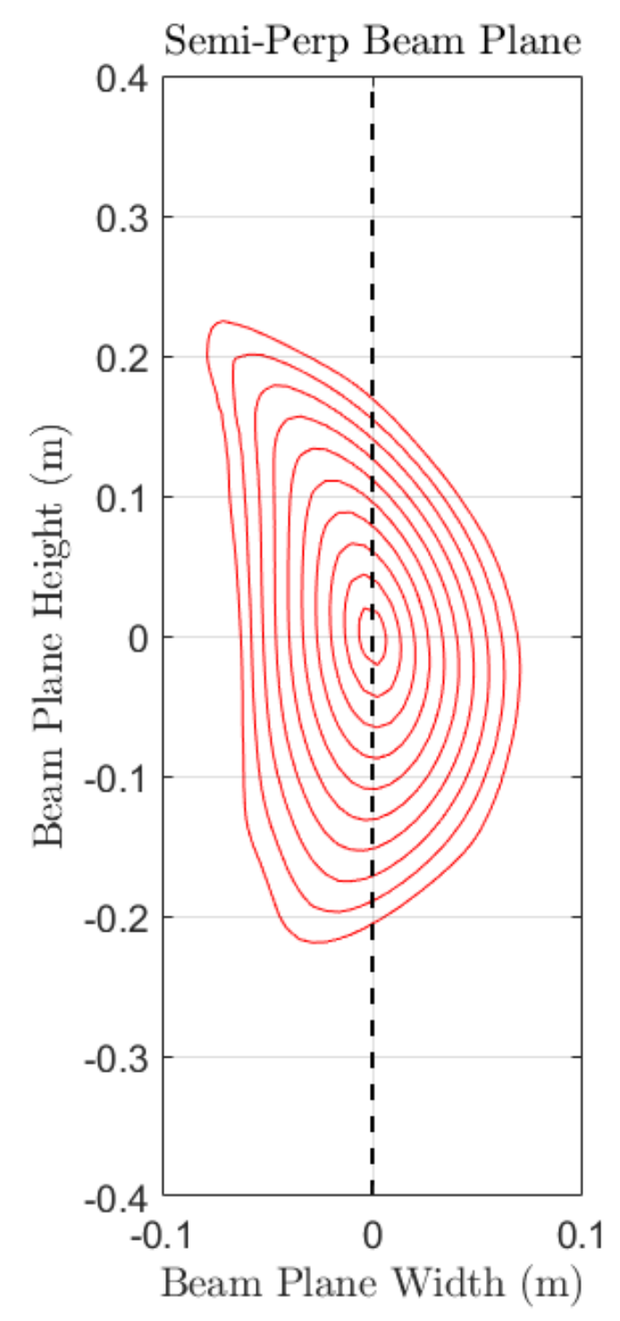
BEAM PARAMETERS

Energy	20keV
Current	25A
Diameter/Divergence	5.4cm / 1.2°
Pulse Time	1.2ms
Injection Angle #1	72°-90°
Injection Angle #2	~0°-20°
Interaction Length	35-66cm
Manufacturer	Budker

LOCATION #1

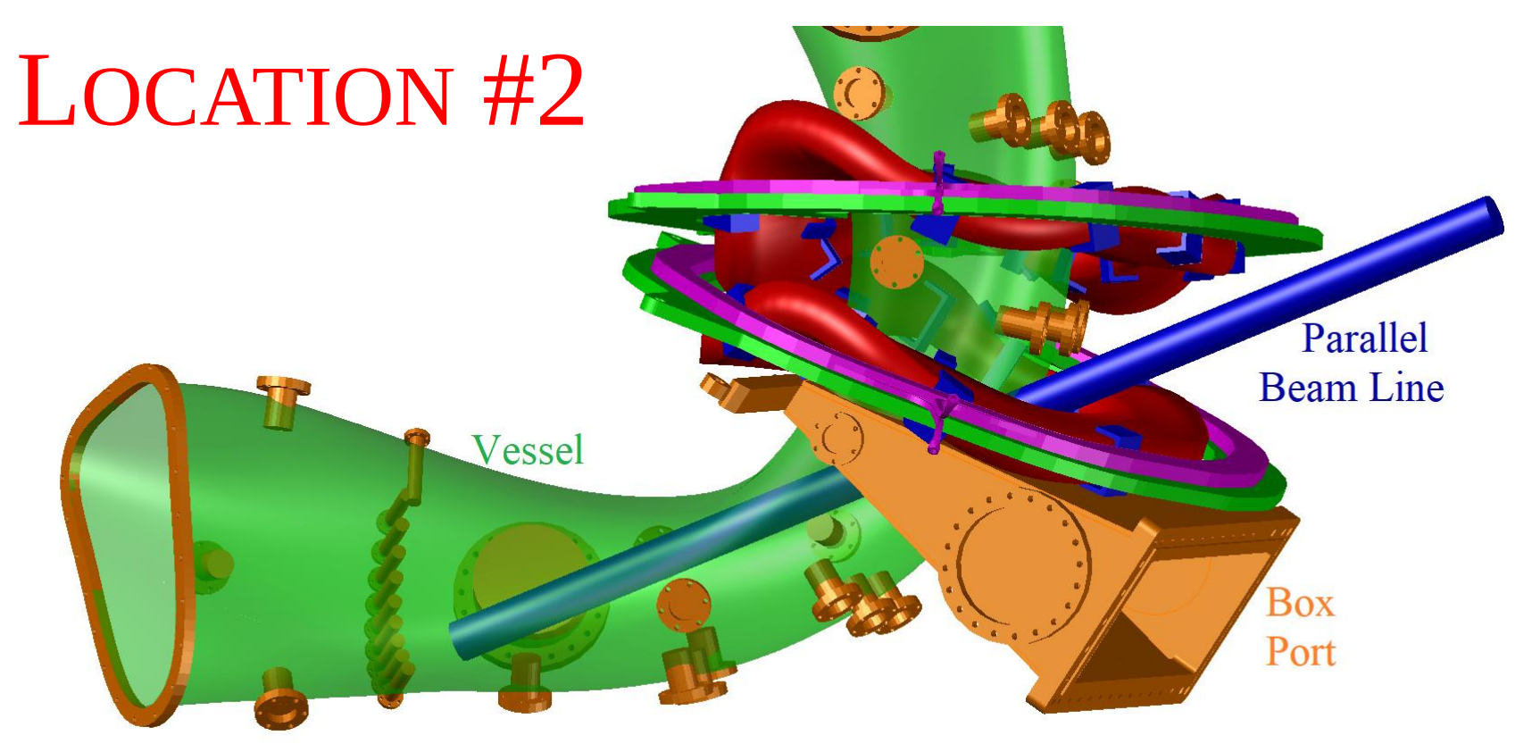


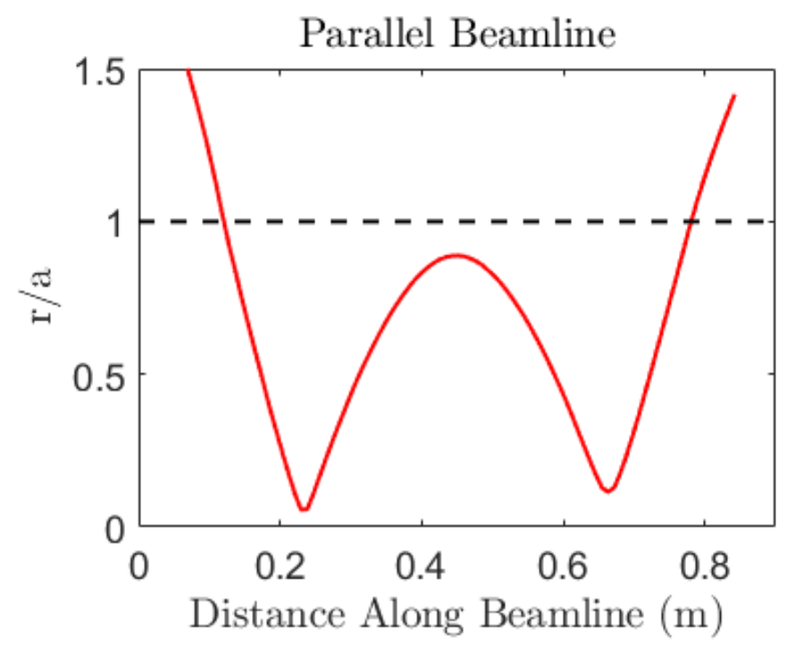


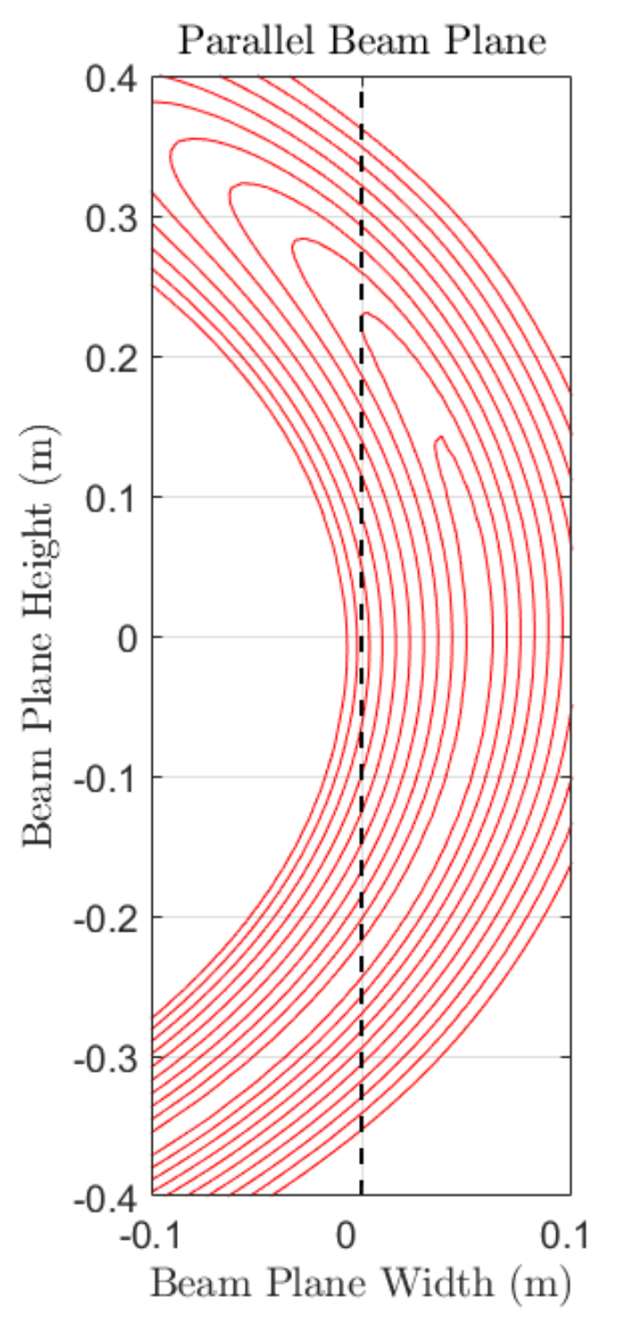


The highest injection angle available from Location #1 is 72° from the magnetic axis, with a plasma-beam interaction length of ~35cm

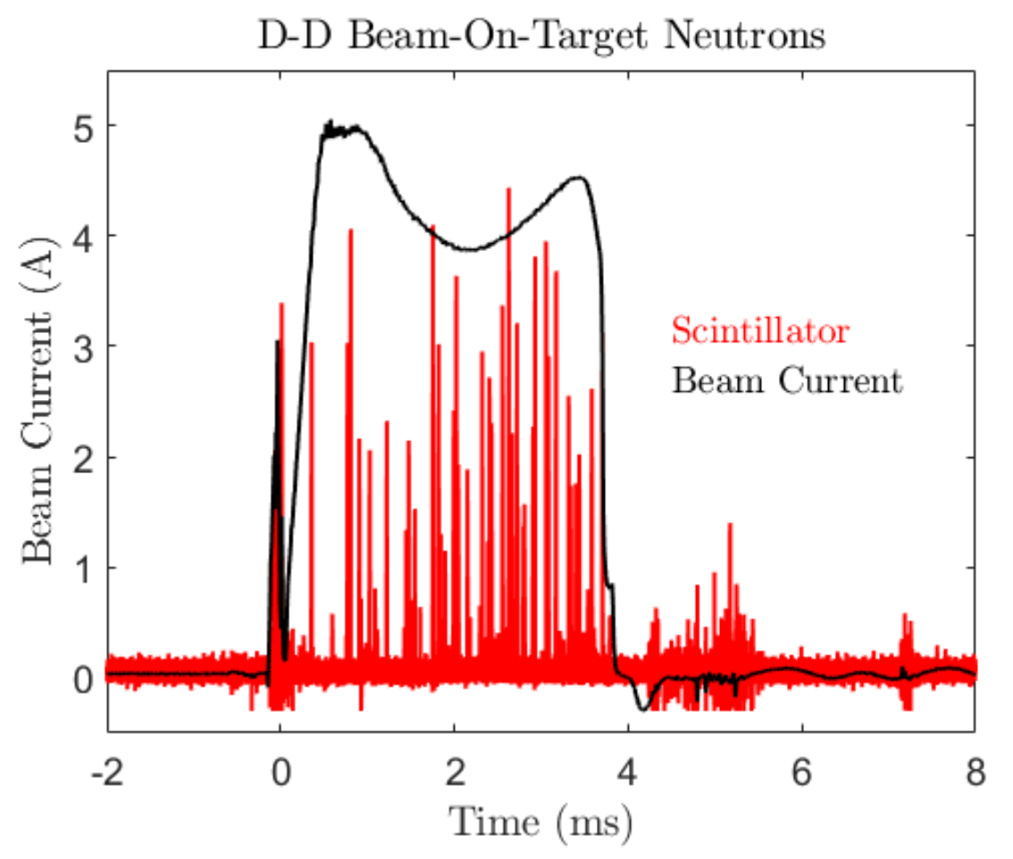
LOCATION #2







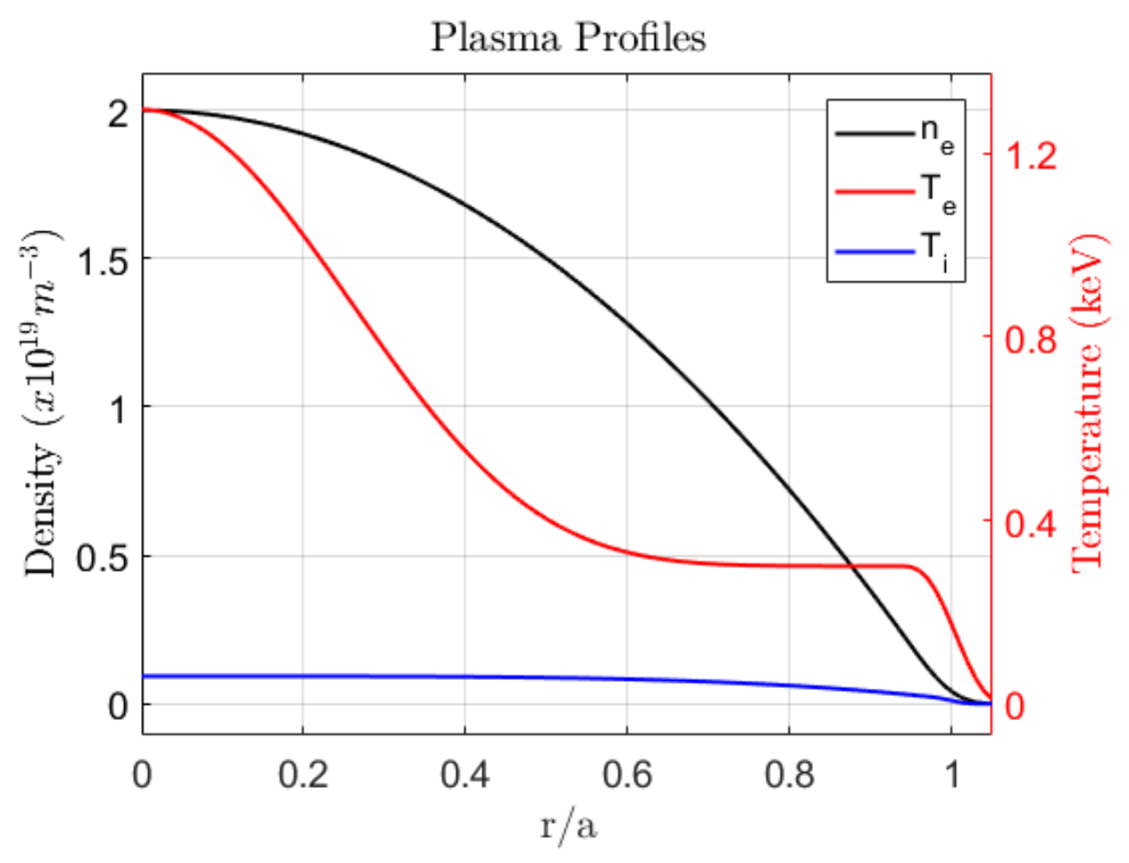
Location #2 allows for very low angle injection near parallel to the magnetic field, with a plasma-beam interaction length of ~66cm

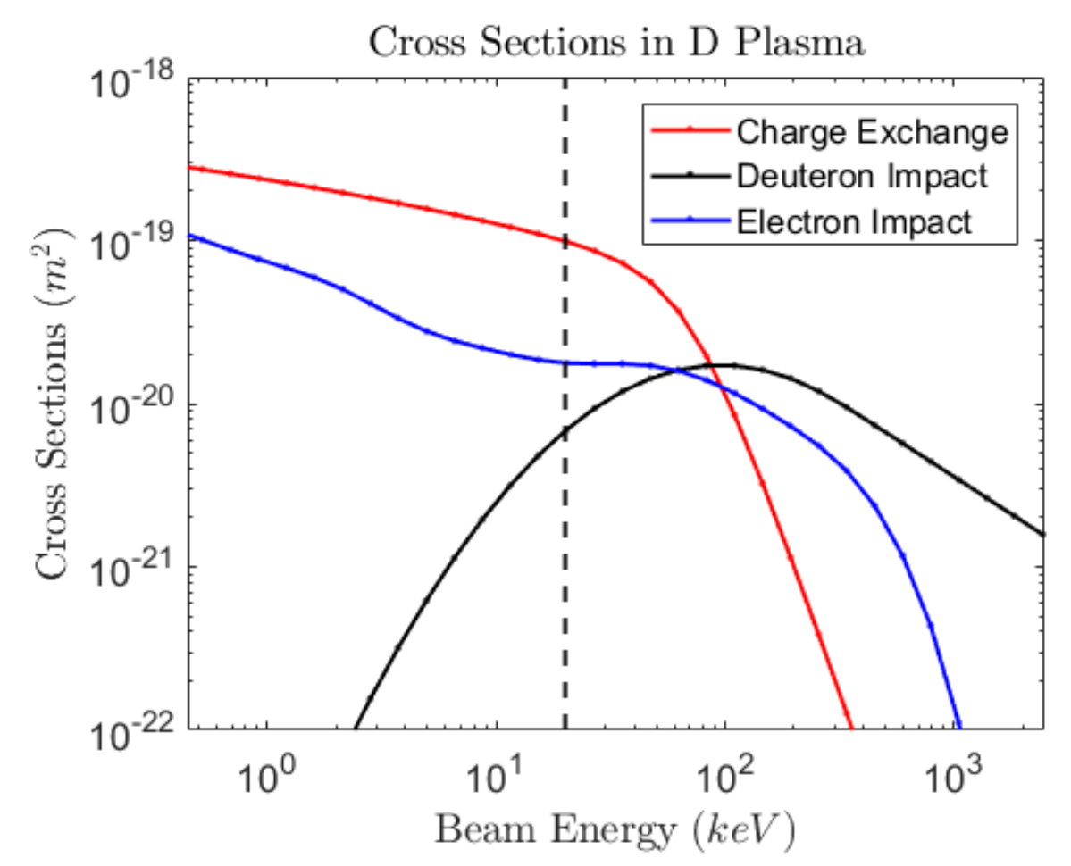


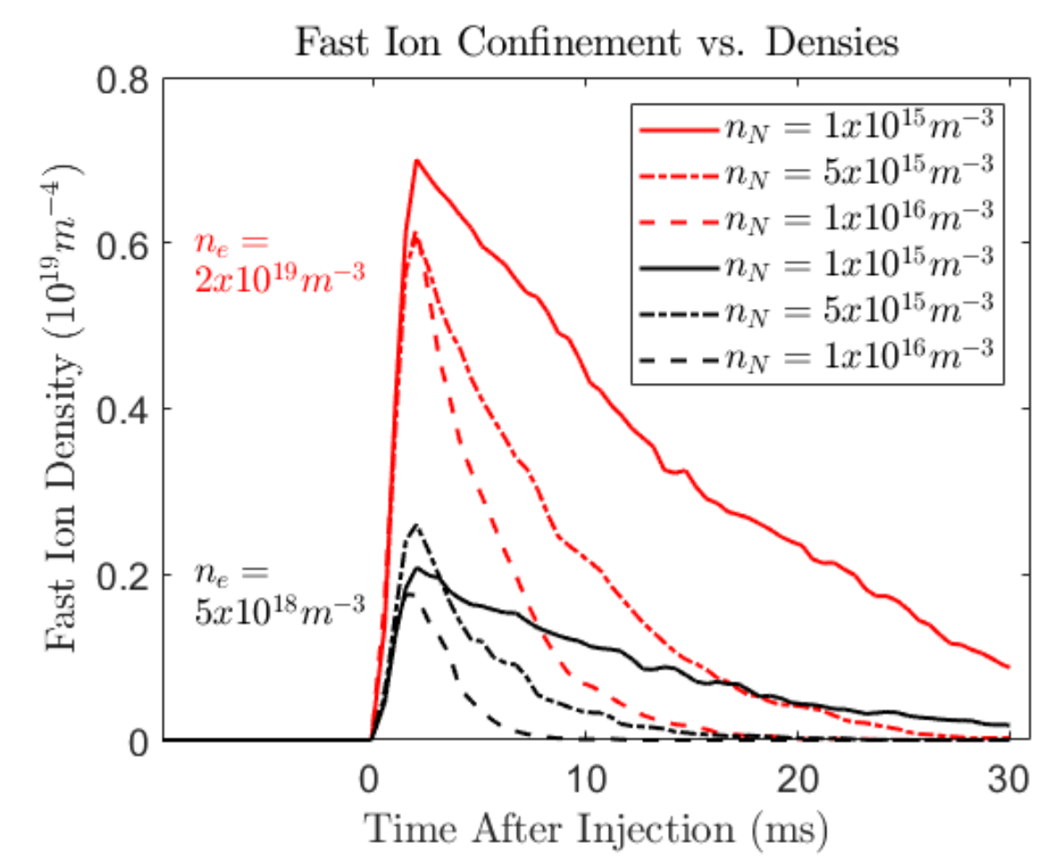
- Bicron 501A liquid scintillator can reliably count single neutron collisions and allows neutron counts to be distinguished from gamma counts via pulse shape discrimination
- A 2 in diameter, 6 inch long scintillator cylinder with a photomultiplier tube was used to observe neutrons from D-D fusion of a 20keV diagnostic neutral beam onto a deuterated stainless steel target in HSX, shown here
- Using this diagnostic, neutrons produced by fast deuterium collisions with the background deuterium plasma will be observed and decay rates will be used to determine gross ion confinement times

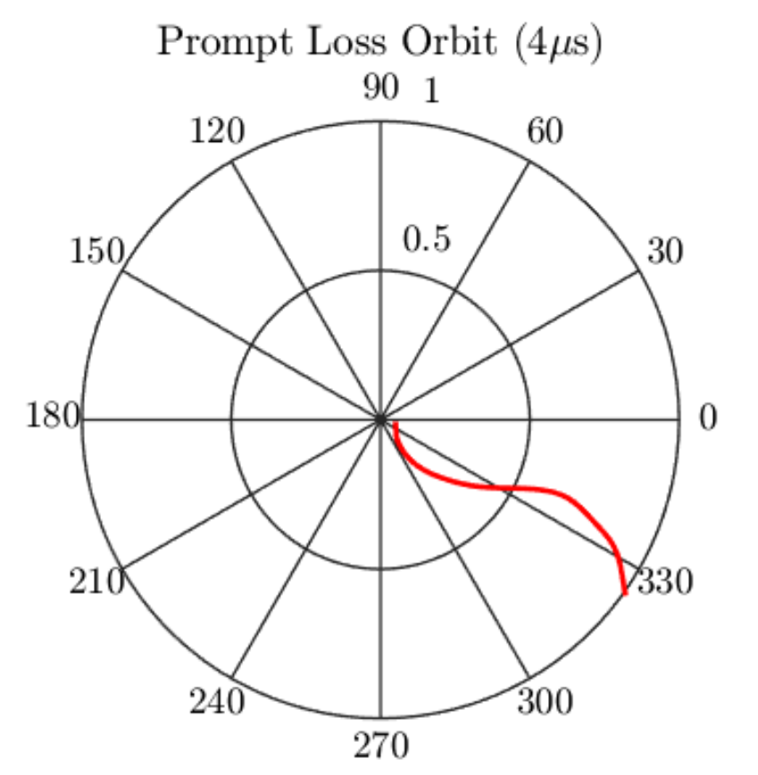
INITIAL MODELING RESULTS

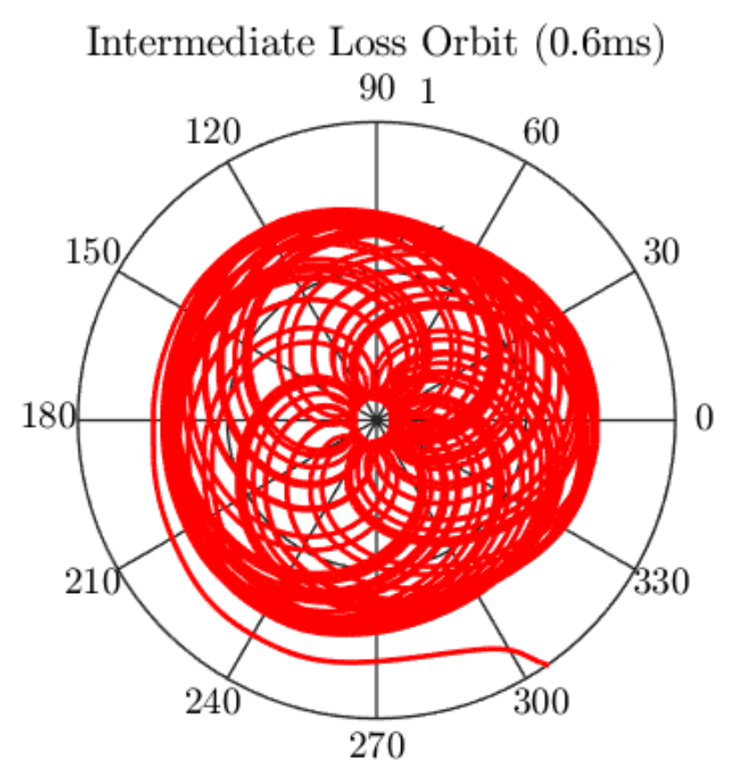
- Plasma density and temperature profiles are estimated for HSX performance with upgraded ECRH heating source - see B. Geiger’s poster, #59
- Cross sections are from Kotch [3] and Riviere [4]
- Simplified calculations show that fast ion confinement times will be dominated by charge exchange losses under current high neutral densities of ~$10^{15}m^{-3}$
- Upgrade plasma density profiles and a neutral density reduction of ~10x are expected to allow fast ion confinement times to reach ~30ms

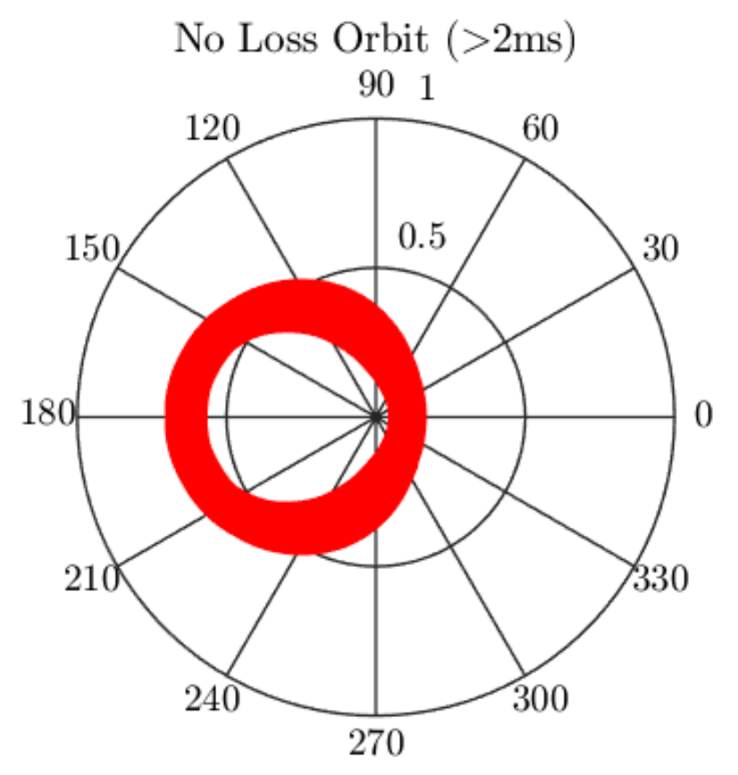






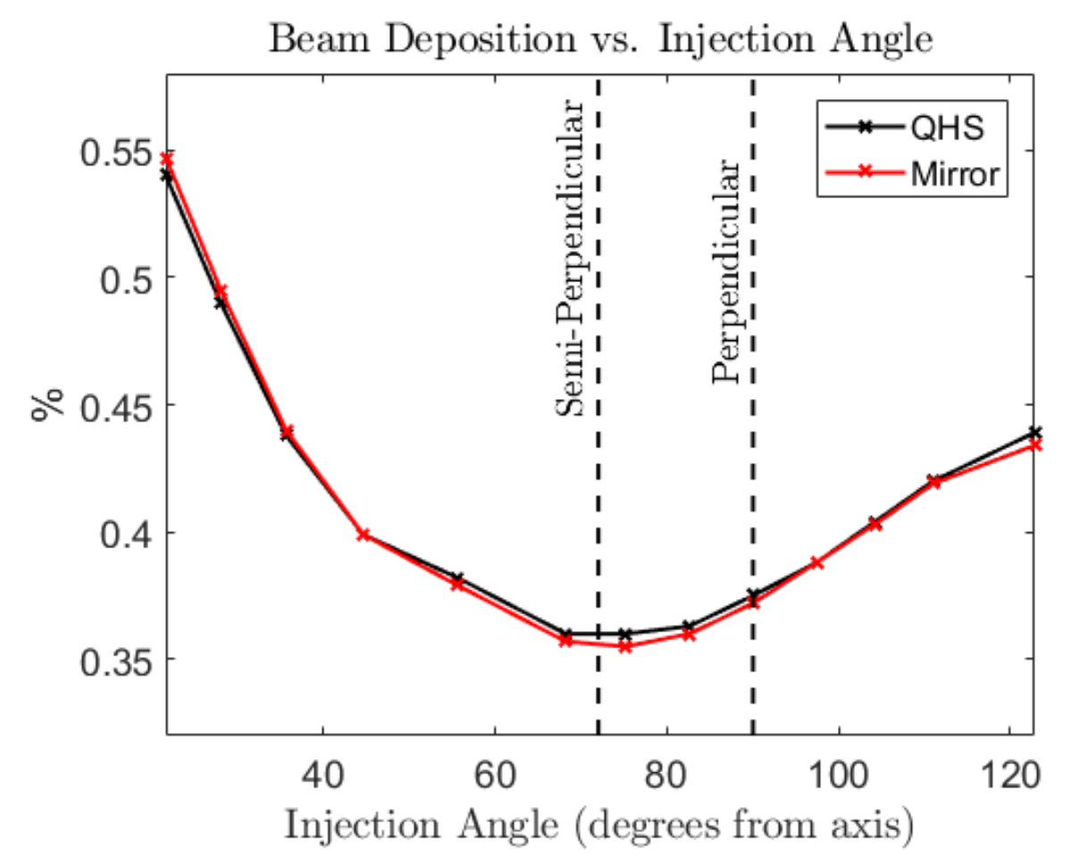


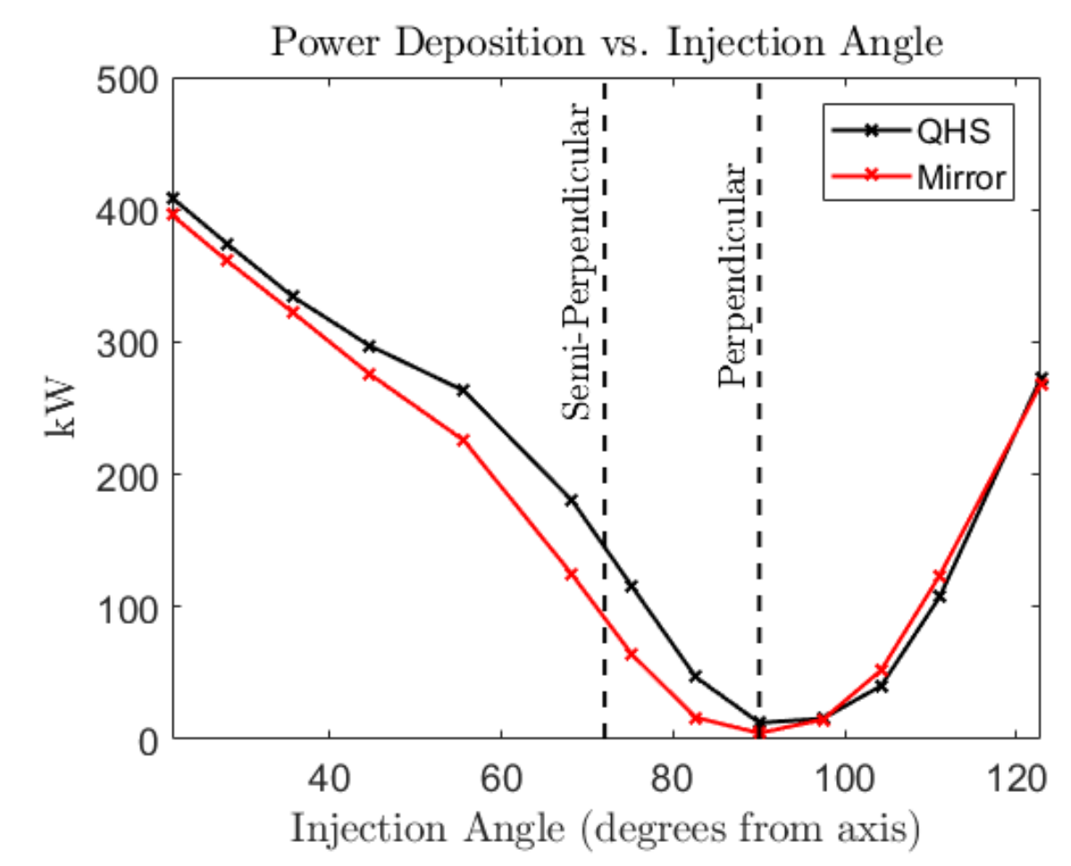


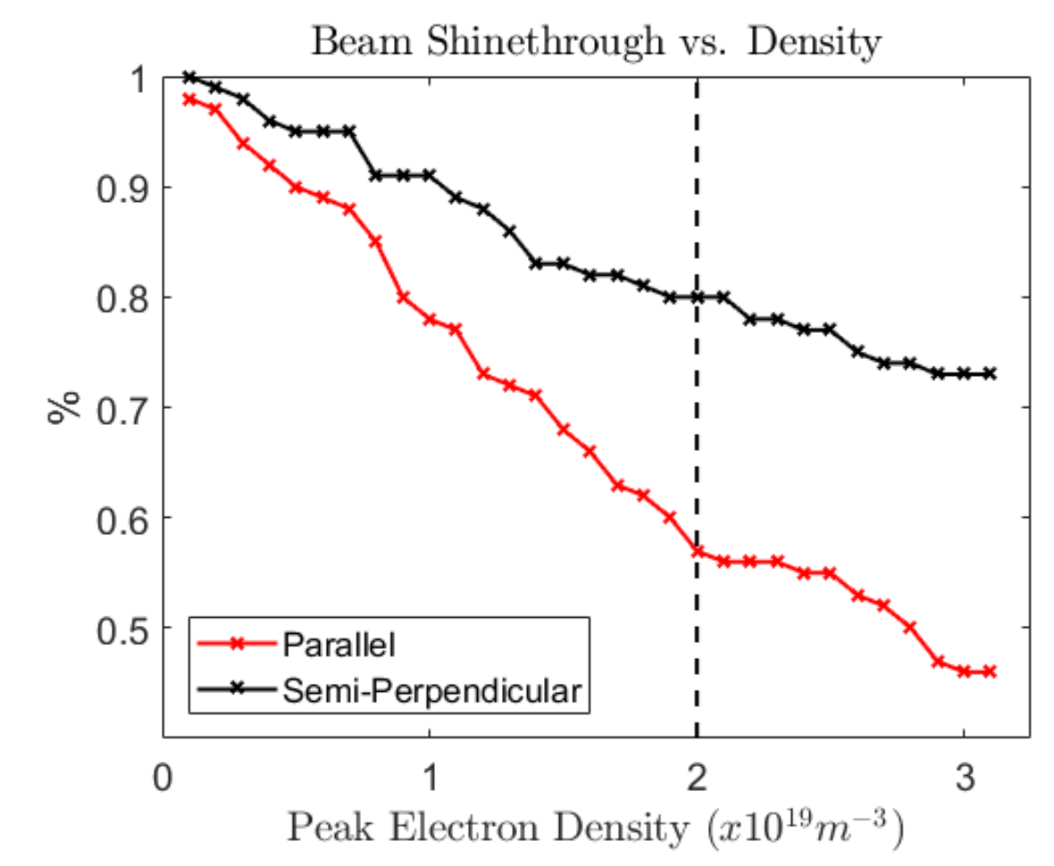


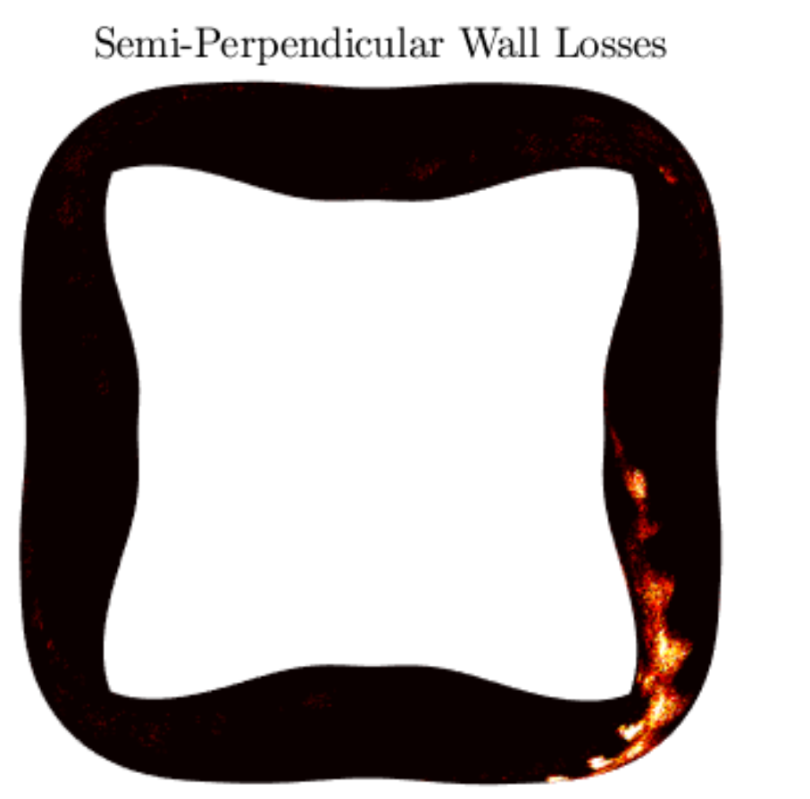
- Guiding center orbit following code OFBZ calculates fast ion losses due to magnetic configuration alone
- Orbit losses due to symmetry breaking [5] are simulated for large populations, generated by the beam deposition code FIDASIM, which models the potential injection geometries in order to motivate beam installation and experimental design
- Trapped ions near the trapped-passing boundary show large poloidal drifts and intermediate loss times, whereas passing ions show low poloidal drifts and no losses

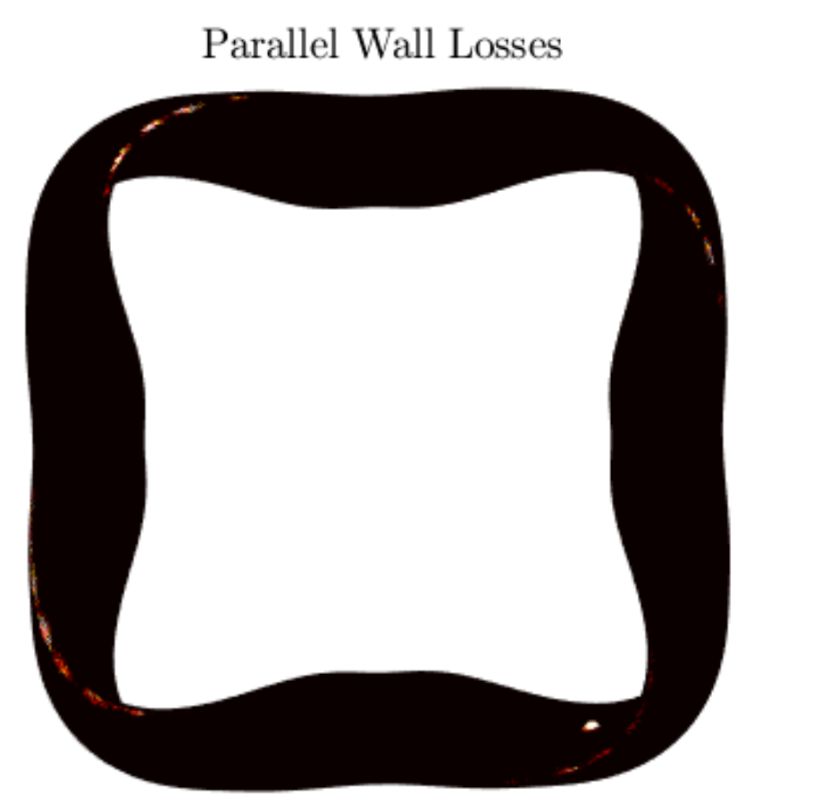
- GNET [6] and Beams3D [7] are drift kinetic particle following codes which simulate beam injection, ionization, and fast ion behavior, including collisions in fully 3D plasma equilibria
- Preliminary modeling predicts ionization rates and power deposition as a function of injection angle
- Power deposition is asymmetric in injection angle between QHS and mirror configurations, possibly due to phase shifting of symmetry breaking modes
- Inconsistencies in beam shinethrough / beam deposition predictions need to be resolved

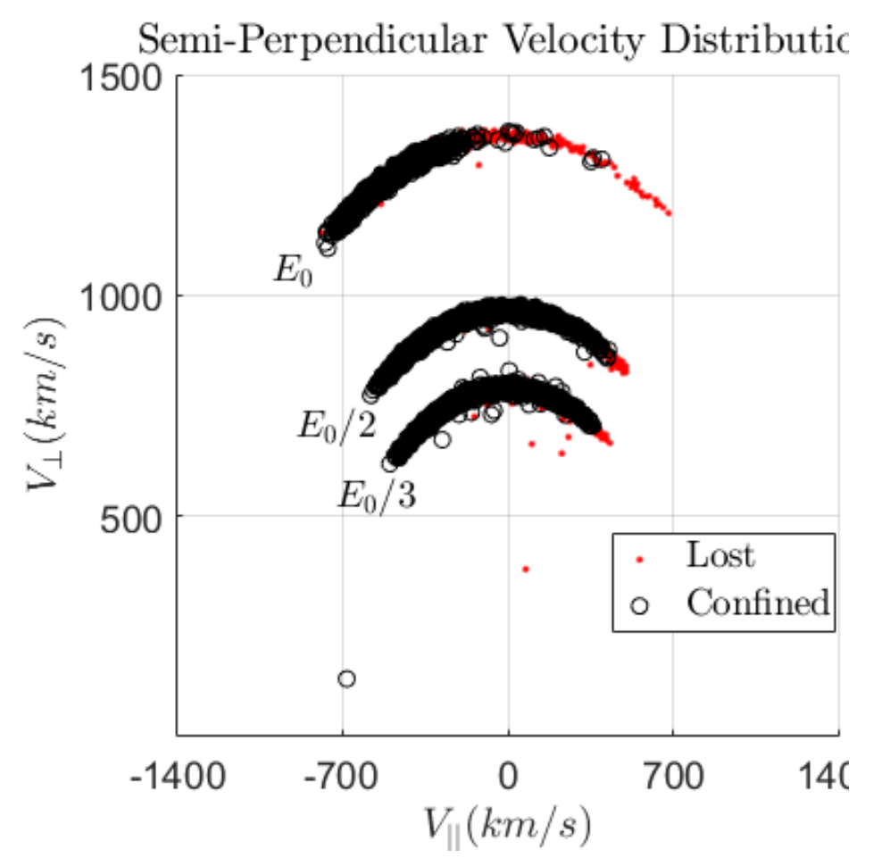


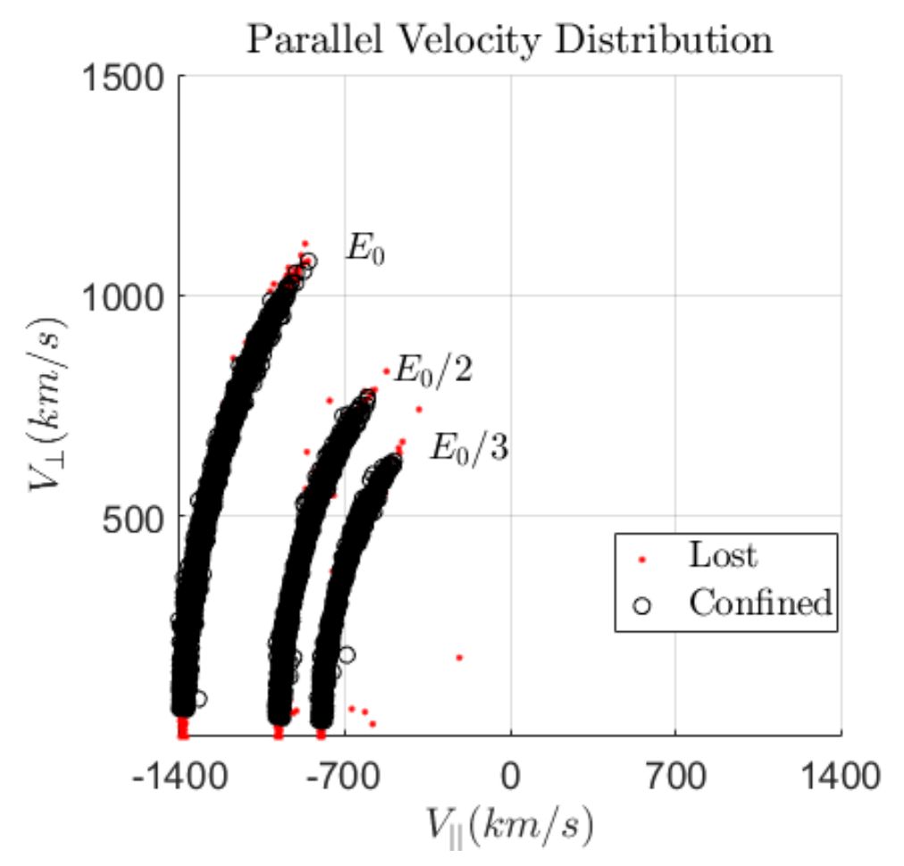












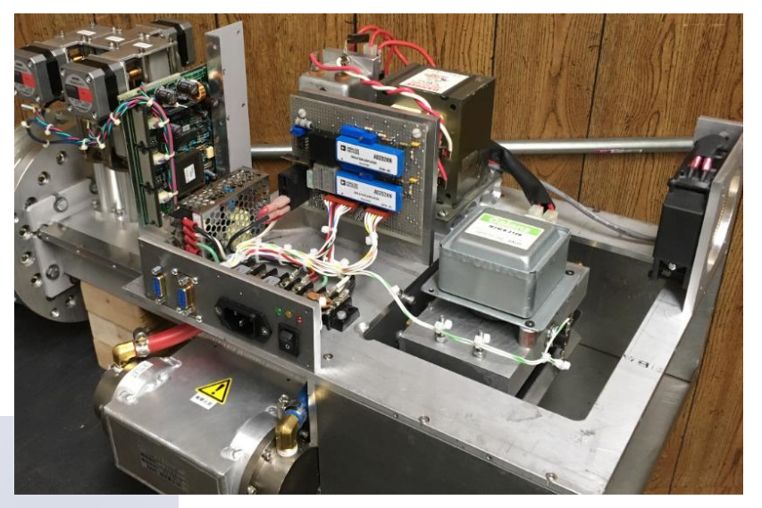
- Beams 3D demonstrates loading behavior of promptly lost (<1ms) ions on the wall
- Beam location #1 is predicted to only populate ions with high pitch angle, which are lost to the wall quickly and locally
- Ions from Beam location #2 are well confined and only load the wall equally in each field period at strike points
- For these reasons, beam location #2 will be used to demonstrate good ion confinement

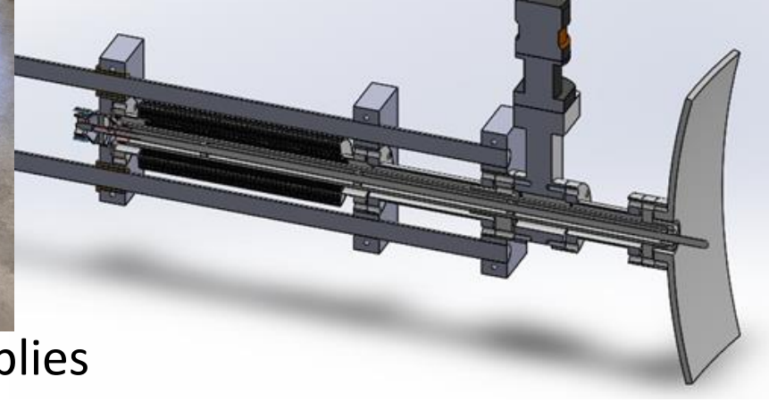
FUTURE WORK

- More detailed beam injection simulations are currently in progress which will demonstrate expected behaviors for various available beam installation geometries and motivate a final experimental design
- An upgrade to HSX is currently in progress which will increase the ECRH frequency from 28GHz to 70GHz, allowing higher plasma density and therefore lower neutral density and better energy coupling to ions - see B. Geiger’s poster, #59
- Neutral Particle Analyzers are being considered for investigating the change to fast ion distribution functions with changes in magnetic configuration
- For additional neutral density reduction, two new techniques are being considered:
  - Strike point protection, including carbon tiles and gettering materials
  - Advanced wall conditioning techniques, including steady state 2.45GHz ECRH strike point cleaning, fast penning gauges, and enhanced Hα measurements

70GHz ECRH Gyrotron with Supplies

2.45GHz 2kW Magnetron Source





2.45GHz ECRH Antenna Via DN35CF Port

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