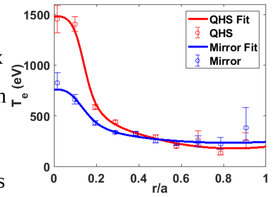
Plans for Neutral Beam Injection on HSX

D.T. Anderson, F.S.B. Anderson, K.M. Likin, S. Murakami[1], E.M. Schilling, A.L.F. Thornton
HSX Plasma Laboratory, University of Wisconsin, Madison, WI, USA; [1] Kyoto University, Kyoto, Japan

Project Goals

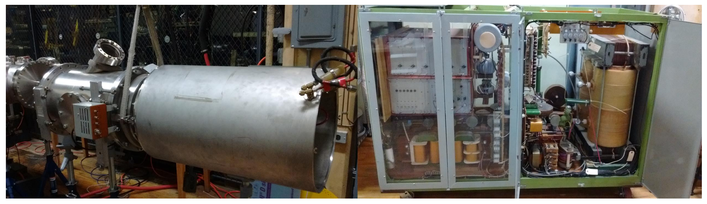
- Study energetic ion confinement in a Quasi-Symmetric Stellarator
  - Use Neutral Beam Injection (NBI) to inject 20 keV deuterium neutrals into deuterium plasma and measure resulting neutron flux from D-D fusion events
  - Infer presence and confinement of fast ions from decaying neutron flux
- Identify / Test metrics for energetic ion confinement
  - Effect of symmetry breaking, effective ripple
  - Use to assess / optimize potential configurations for future devices



Previous studies on effects of symmetry breaking on electron confinement (ECH)

NBI System

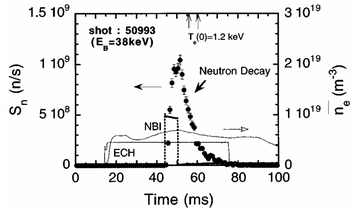
Acceleration Voltage	20 kV
Emitted Current	40 A (0.8 MW)
Estimated Current into Plasma	25 A (0.5 MW)
Gaussian Beam Diameter / Divergence	5.4 cm / 1.2 degs.
Pulse Time	1.2 msec
Injection Angle	90 – 72 degs.
Length along Beam Axis into Plasma	31 – 38 cm

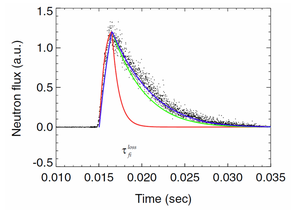


Beam Head and Neutralizer

High Voltage Power Supply Rack

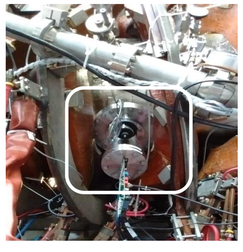
- Similar experiment carried out successfully on other HSX-scale devices, namely, the Compact Helical System (CHS)
- Also performed on Madison Symmetric Torus (MST); beam donated by MST Group

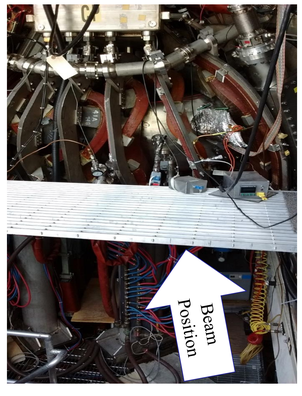




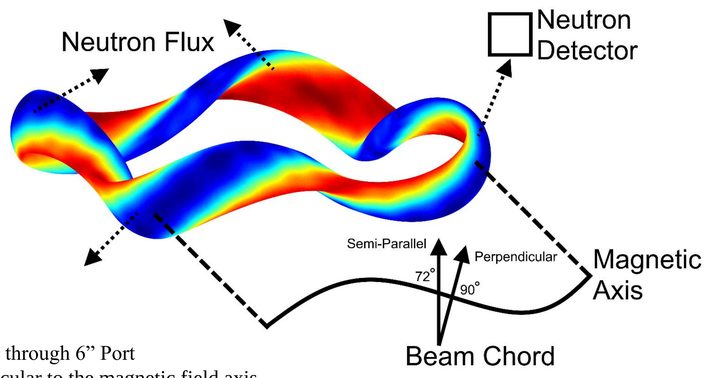
Installation on HSX

Proposed mount location:
NBI → Upwards into vessel from mezzanine
Neutron Detector →15 cm port on C' between coils 3 and 4

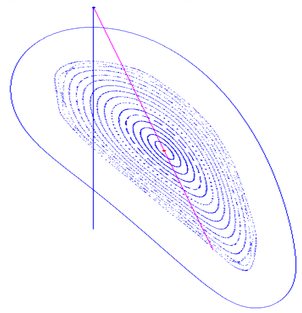




Launching Geometry

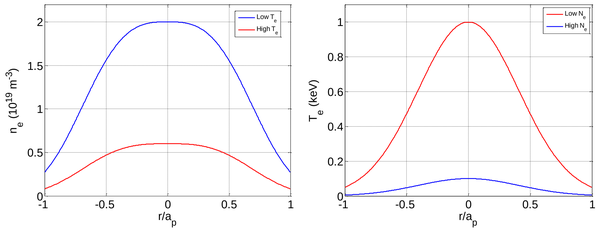


Injection through 6" Port
Perpendicular to the magnetic field axis



- Three different cases have been examined, namely, (1) perpendicular launch through a box port or (2) 6" port and (3) a tangential launch through 6" port → 72º to the magnetic field axis

Plasma Density and Electron Temperature Profiles



70 GHz ECRH System

- Major hardware components donated by W7-X Group (IPP)
  - 500 kW / 70 GHz depressed collector gyrotron/magnet capable of 3 s operation
  - Collector power supply, transmission line components
- New beam power supply requested from FES
- Will expand experimental capabilities:
  - Operation at B = 1.25 T
  - Triple attainable density (2X cutoff $n_e = 3 \times 10^{13}$ cm^{-3})
  - Longer pulse operation
- Will provide a better target plasma for the injection studies
  (and better shielding of core from neutrals with reduced CX: n*a goes from 0.075 => 0.3)

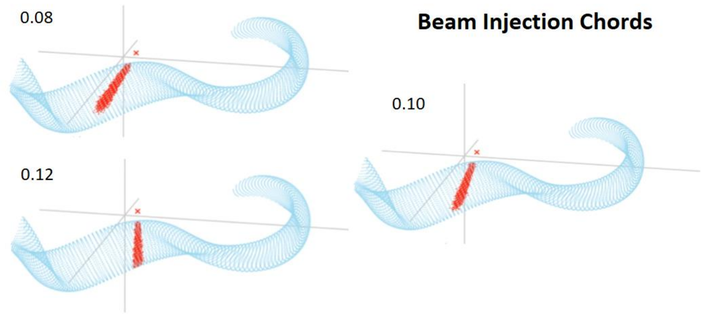
Collector Power Supply

Polarizers

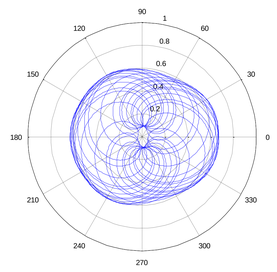
Corrugated waveguide

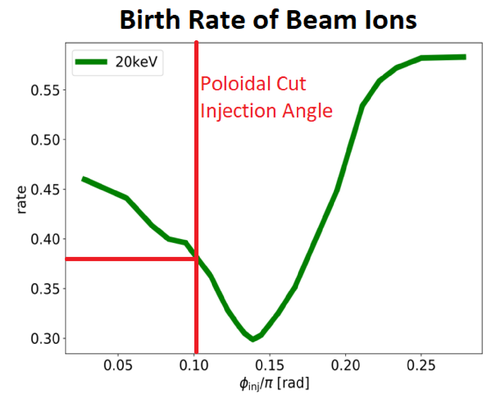
Torus window

Simulations by GNET

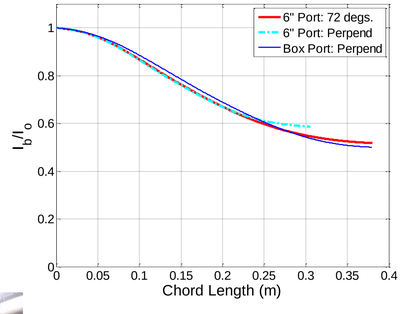


Drift orbit of 20 keV ions in HSX

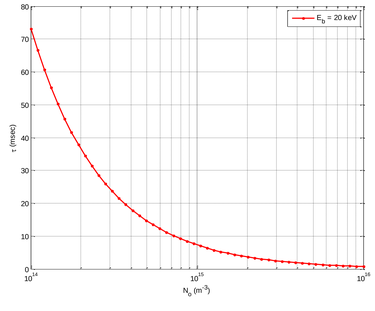




Attenuation along the beam axis



Charge Exchange Time in D plasmas



Estimates

- Fast Ion Birth Rate (beam attenuation) along chord
  - GNET = 36-38%
  - 1-D estimate = 41-48%
- Best-Case (perfect confinement) neutron rate
  - 1-D estimate = ~5×10^8 n/s
  - CHS measurement = 1×10^8 – 1×10^9 n/s

Next Steps

- Test NBI system on test stand; install on HSX
- Use GNET to model slowing down and charge exchange; energy deposition and efficiency
- Model neutron production and fluxes for comparison to measurements
- Contrast confinement of energetic ions in QHS and mirror magnetic configurations

Acknowledgments

This work is supported by US DOE Grant DE-FG02-93ER54222

60th Annual Meeting of the APS Division of Plasma Physics, November 5-9, 2018, Portland, Oregon