



Measurement of Pfirsch-Schluter flows and radial electric field in HSX



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Overview

- Inboard-outboard asymmetry in the parallel C^{+6} ion flow has been measured using the Charge Exchange Recombination Spectroscopy in the HSX stellarator, indicating the presence of counter-streaming Pfirsch-Schluter (PS) ion flows.
- Measurements are made for the helically symmetric (QHS) and the mirror configurations.
- Similar level of PS flows is observed for all cases studied.
- The mean carbon flow is larger for the mirror configuration (by a factor of ~ 2) compared to that in QHS.
- PS flows are observed to be parallel to B in low field side and anti-parallel to B in high field side. This observation is opposite to what is previously calculated.
- The radial electric field, which is proportional to the magnitude of the PS flow, is larger than the previous measurements (from radial force-balance) but still significantly less than the neoclassically calculated value for QHS.

Pfirsch-Schluter flows

Pfirsch-Schluter (PS) parallel flows arise due to the flow incompressibility,

$$\nabla \cdot (V_{\parallel} + V_{\perp}) = 0$$

PS flow is a local parallel flow that compensates for the compression of perpendicular flows.

Therefore, the total parallel flow (local) = flux-surface-averaged flow + PS flow.

PS flow can be written as

$$V_{PS} = V_{\perp} h \vec{B} = \left(\frac{\nabla P_i}{en_i Z_i} + E_r \right) h \vec{B}$$

Where h is an integration constant satisfying

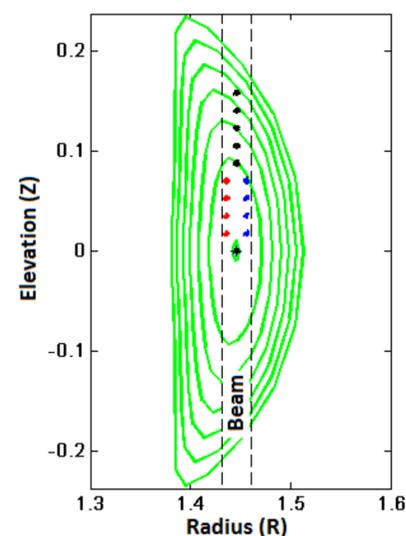
$$\vec{B} \cdot \nabla h = -2 \frac{(\vec{B} \times \nabla B) \cdot \nabla \psi}{B^3}, \langle h B^2 \rangle = 0$$

When pressure gradient is negligible, radial electric field can be calculated from the PS flow

$$E_r = \frac{V_{PS}}{hB}$$

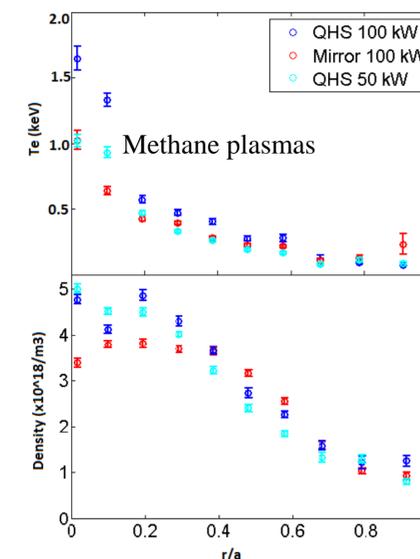
Measurement of inboard-outboard V_{\parallel} asymmetry

HSX CHERS PS views

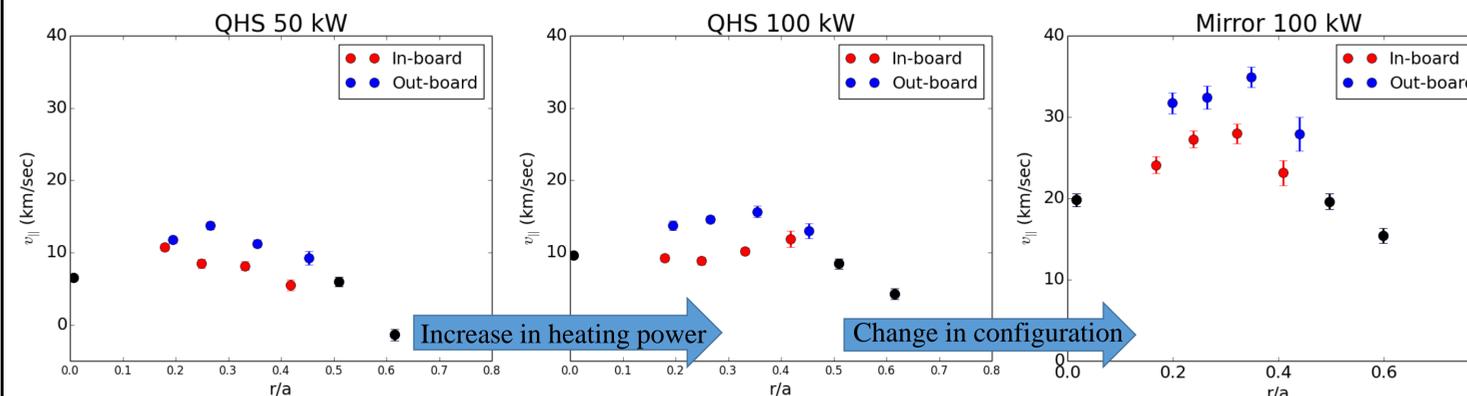


- 30 keV, 3 ms, ~ 4 A Hydrogen diagnostic neutral beam.
- CVI emission at 529.1 nm is collected.
- Focused optics, measurement spot size ~ 1.4 mm.
- PS views are positioned in-board and out-board sides of the beam.

Plasma parameters (T_e and n_e)

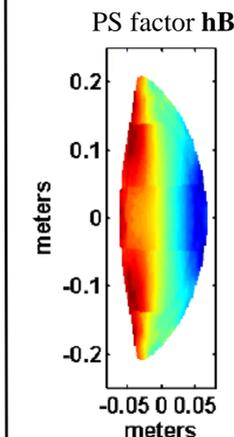


Experimental Results

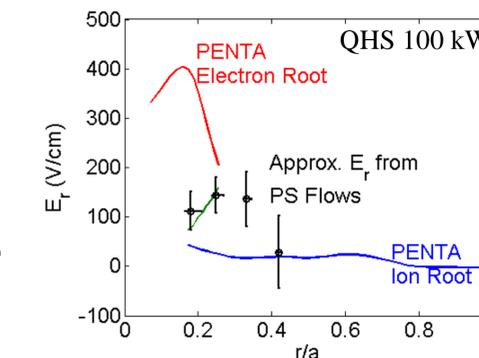


- Similar PS flows in all cases studied.
- Large mean flows in mirror geometry compared to that in QHS
- Measured PS flow direction is opposite to the calculation. (See the PS factor 'hB' calculation)

Radial electric field



Comparison with neoclassical calculations



Radial electric field higher than previous measurements (of ~ 40 - 50 V/cm), still less than the PENTA electron-root estimate

Summary

- Counter-streaming parallel ion flows (Pfirsch-Schluter flows) has been observed in the HSX stellarator for the first time.
- Magnitude of the PS flow is similar in all cases studied.
- The mean flow is nearly doubled in the mirror configuration compared to that in QHS.
- Direction of the measured PS flow is opposite to what is previously calculated.
- Preliminary calculation indicates higher than previously measured radial electric field, but lower than the electron-root estimates.