Impurity and \( \alpha \)-particle transport in the W7-X using Charge Exchange Recombination Spectroscopy: An overview.

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1. W7-X (heliac) is an optimized disruption free, quasi-steady state device with no inductive current drive requirement.
2. Particles and impurities are confined within helical magnetic wells in a quasi-axisymmetric configuration.
3. Ambipolar electric field resulting from varying collisionality (and diffusivities) leads to an inward flux of impurities causing high radiative losses.
4. Neoclassical transport is higher than for tokamaks and has varying regimes when compared.
5. \( \alpha \)-particle confinement time is to be detrimental as its density and retention period is critical in a fusion device.
6. Impurity and particle transport is to be analyzed using charge exchange recombination and other diagnostics.
7. The contribution of anomalous transport in the W7-X is to be studied resulting in global transport.

Transport in Tokamaks Vs. Stellarators

<table>
<thead>
<tr>
<th>Classical Diffusion</th>
<th>P-S Diffusion (18 – 31 times ( D_0 ))</th>
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</thead>
<tbody>
<tr>
<td>( D_s \approx q^2 v_T )</td>
<td>( D_{ps} \approx q^2 v_T )</td>
</tr>
<tr>
<td>Banana Diffusion</td>
<td>Plateau Diffusion</td>
</tr>
<tr>
<td>( D_s \approx \left( \frac{q^2}{e^2 r_s^2} \right) v_T )</td>
<td>( D_{ps} \approx \left( \frac{q^2}{e^2 r_s^2} \right) v_T )</td>
</tr>
</tbody>
</table>

3. Neoclassical collisionality (showing Diffusion Vs. collisionality) regimes for tokamaks\(^{[3]} \)

5. Neoclassical confinement quality parameter \( \varepsilon_{eff} \) versus minor radius in various stellarators\(^{[2]} \)

Confinement Quality in Stellarators (\( \varepsilon_{eff} \& Z \))

\[
\varepsilon_{eff} = \frac{\int_1^{\rho_{eff}} \frac{1}{\rho} \left( \frac{1}{\rho} \frac{d\rho}{dK} \right)^{1/2} dK}{\int_1^{\rho_{eff}} \left( \frac{1}{\rho} \frac{d\rho}{dK} \right)^{1/2} dK}
\]

6. Basic Drift wave mechanism leading to anomalous transport\(^{[4]} \)

Helium Transport & CXR Spectroscopy

D-T reaction by products lead for an equation burn control parameter ‘p’ to determine helium confinement quality.

7. The plasma operating conditions (POPCON) in the \( n_t, T_e \) Vs. \( T_e \) plane for different values of \( p \)

8. W7-X NBI active CXRS system with schematic

Primary research objectives

1. To determine if transport in the W7-X follows from neoclassical theory for stellarators, if not what causes this deviation.
2. To estimate the effects of (low Z) impurities, especially \( \alpha \)-particles on density profiles and overall transport.
3. To explore the performance of CXRS and other diagnostics to evaluate such questions in the W7-X environment.

References