Max-Planck-Institut für Plasmaphysik

Proposals for Helium Transport

V. Winters, F. Reimold, T. Romba (in no particular order)

Motivation

- Effective confinement time of Helium, ${\tau^*}_\alpha$, combination of core transport of confined sources of Helium, ($\tau_{\alpha 1}$), SOL dwell time ($\tau_{\alpha 2}$) and effective recycling (R_{eff}) [1]:

<u>With core-born source (fusion, NBI, or core penetrating gas source)</u>

$$\tau_\alpha^* = \tau_{\alpha 1} + \frac{R_{eff}}{1 - R_{eff}} \tau_{\alpha 2}$$

<u>SOL Gas Source only</u>

$$\tau_\alpha^* = \frac{1}{1 - R_{eff}} \tau_{\alpha 2}$$

- Both the core transport and the recycling/pumping properties of helium need to be quantified for W7-X and the island divertor

- Effective recycling coefficient also contains properties about pumping: as removal efficiency increases, R_{eff} goes down

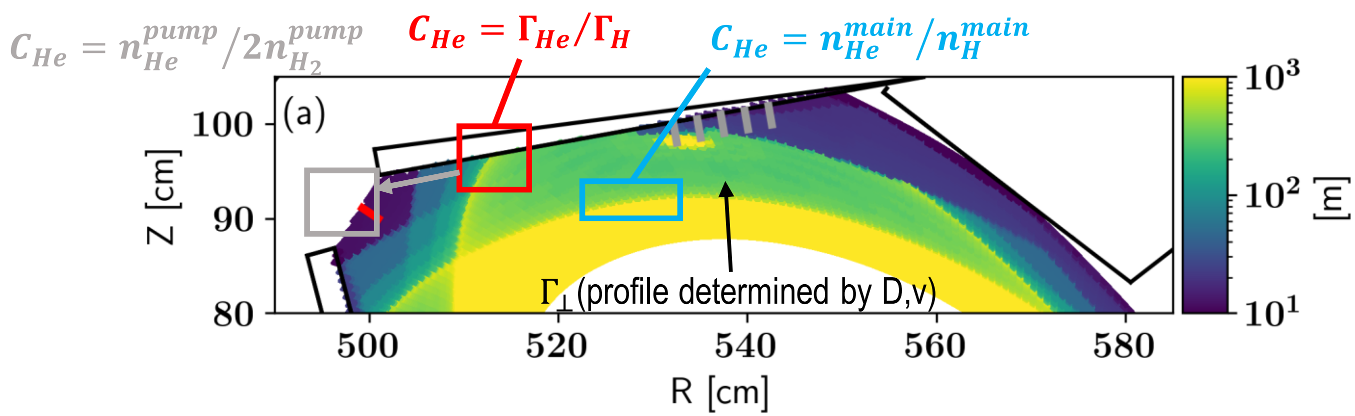
- 3 Ways of modifying removal efficiency (without changing divertor geometry):

  1. Modify total net flux (H+He) to pump
  2. Modify enrichment of Helium η_{He}
  3. Modify pumping speed (switching on/off cryo, turbopumps)

At the moment we do not know the total flux to the pump nor the enrichment of He in the divertor

[1] P. C. Stangeby, *The Plasma Boundary of Magnetic Fusion Devices* (2000)

Linking Helium Transport Together



Links in Impurity Chain

1. Core transport determines Helium profile in confined plasma
2. SOL transport determines Helium concentration at divertor/last closed flux surface
3. Neutral transport determines Helium gas concentration at the pumping gap
4. Exhaust efficiency determines effective recycling coefficient

We should get a good idea of how these parameters are varying with plasma conditions (attached -> high Prad conditions)

Proposals: Determining Helium Transport in experimental parameter space

Proposal 1: Core Transport

Main Proponent: T. Romba

- CXRS measures fully ionized Helium (He^{2+}) density in the confined region
- One can use modulated Helium puffs from divertor Helium beam to get knowledge of D, v profiles (core transport) combined with CXRS measurements [2]

Proposal 2: Quantifying Helium Enrichment (Piggy Back)

Main Proponent: V. Winters + T. Romba

- Enrichment of Helium can be defined by [1]:

SOL transport only

$$\eta_{He} = \frac{n_{He}^{div} / n_{H}^{div}}{n_{He}^{main} / n_{H}^{main}}$$

SOL + neutral transport

$$\eta_{He} = \frac{n_{He}^{pump} / 2n_{H_2}^{pump}}{n_{He}^{main} / n_{H}^{main}}$$

- We easily have the capability to measure SOL + neutral transport enrichment (+ comparison to EMC3):
  - $n_{He}^{pump} / 2n_{H_2}^{pump}$ is measured by the WISP gauges in AEI port (Sereda)
  - $n_{He}^{main} / n_{H}^{main}$ is measured by CXRS (Romba)

[2] H. Takenaga *et al* 1999 *Nucl. Fusion* **39** 1917

Proposals cont‘d

Proposal 3: Similarity of divertor concentration vs AEI gauge concentration (Piggy Back):

- One can measure ratio of influx of particles at strike line using S/XB (AEF divertor spectroscopy, Oliver Ford‘s location, + other locations) (Method 1)
- One can measure absolute concentrations if one knows plasma parameters where radiation is located (2D He-beam, He line radiation analysis) (Method 2)

Proposal 4: Estimate of Helium ionization length (Piggy Back):

- Use AEI port divertor spectroscopy to look at radial decay of neutral Helium line with plasma parameters (should check AEF port for better localization and multiple emission regions + synthetic spectroscopy)

Proposal 5: Impurity behaviour in NBI heated discharges (Presumably included somewhere else):

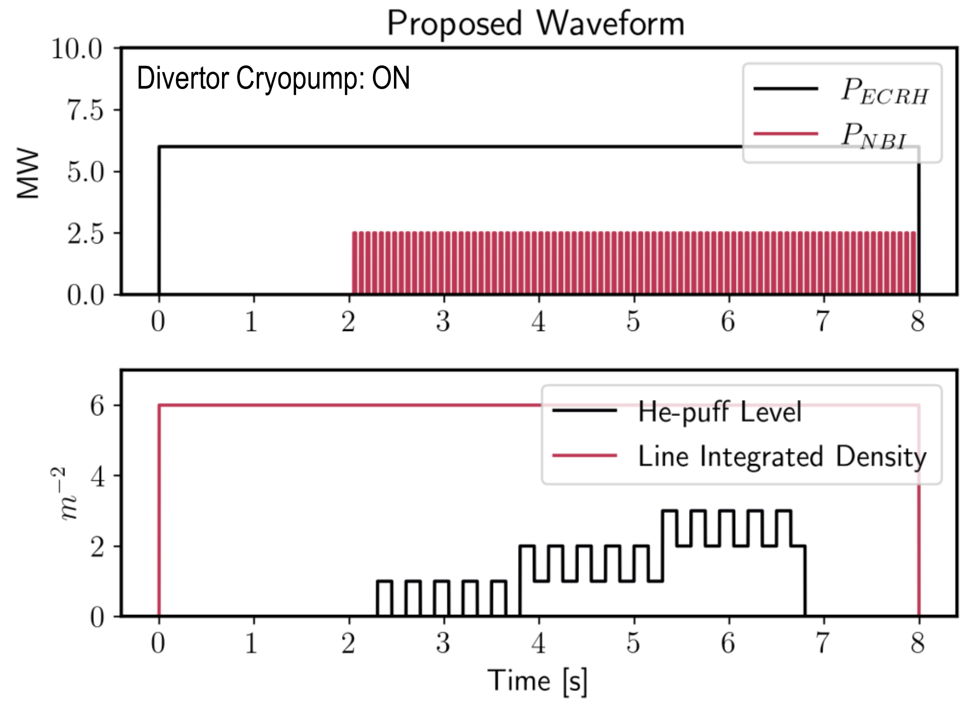
- Use CXRS spectrometers at a wide range of impurities (He, C, O, Ne, and Ar) to check for consistent impurity behaviour in accumulating cases (also NEOTRANSP validation)
- Presumably we can take some of the high performance ones and seed He, Ne, and Ar

Proposal 6: Helium plume validation (Presumably possible during NBI beam commissioning):

- If we can seed some Helium during NBI beam commisioning we should be able to gauge the strength of the plume effect – maybe even with OP1.2b data?

Proposed Experimental Waveform

- Modulated He-puffs to get time-dependent source in confined plasma (for now just one valve…)
- NBI 20ms blips for He profile measurements
- Stepwise increase of ‚background' Helium level, stop seeding and allow time for signal decay (τ_α^*, R_{eff})
- Repeat for several density/f_{rad}/P_{ecrh}
  - for f_{rad} scan – at one density, seed N to isolate radiation dependencies
- Assumes ~2s for density to stabilize at beginning of program (OP1.2b-like)



Needed (Active) Diagnostics

- He-beam (for seeding/measurement)
- CXRS

Needed (Passive) Diagnostics

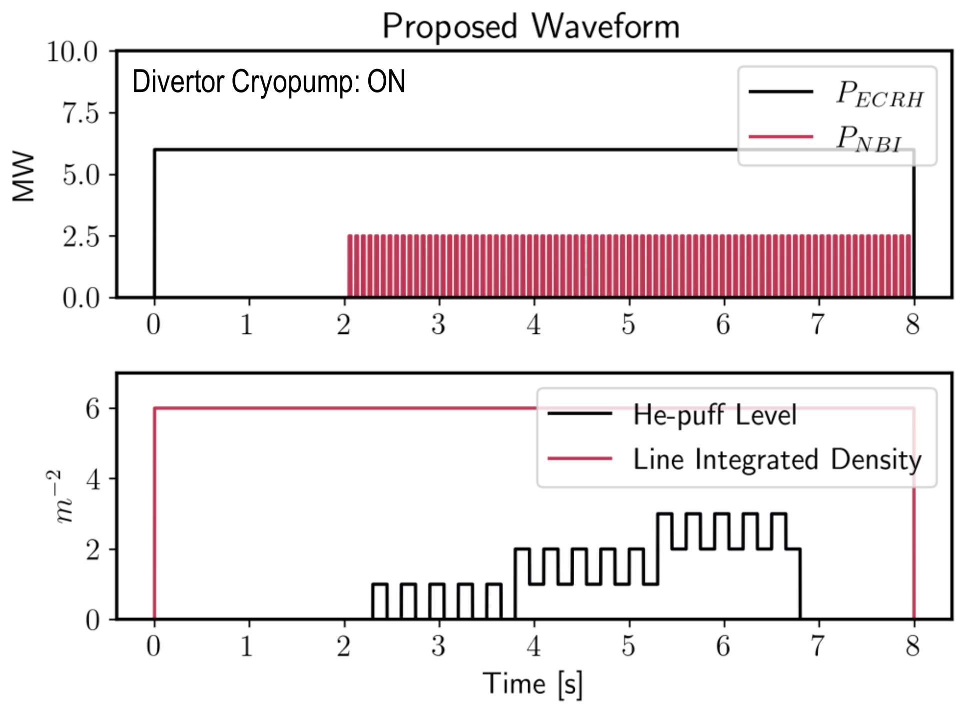
- Divertor Spectroscopy (AEF port also)
- WISP Gauges/Filterscopes
- HEXOS
- All other spectroscopy

Proposed Experimental Waveform

Proposals which can be covered under this waveform

1. Core Helium transport with CXRS (Romba)
2. Helium parallel flow measurements with CIS (using He-II filter) (Perseo)
3. Effective confinement time measurement of Helium – can be used to get effective recycling coefficient (Sereda or Kremeyer?)
4. Subdivertor enrichment (Sereda) and
5. Divertor enrichment (+ ionization length, divertor concentration measurements, and EMC3 comparison) (Winters/Romba)

Lots of physics may be covered with one set of experimental programs!



Possible example of systematic dataset:

- ❑ At medium density level – f_{rad} scan (4-5 programs)
- ❑ At medium density level – P_{ecrh} scan (4-5 programs)
- ❑ At high P_{ecrh} – density scan (4-5 programs)
  - (Thermal force dominated regime?)

Available Diagnostics

- **He-beam** (ne,te profiles, seeding) 2D measurements of profiles if using all 5 valves, possibility of varying seeding location
- **Divertor Spectroscopy** (AEI – parallel to horizontal target + AEF – perpendicular to horizontal target) for Helium radiation distribution/particle flux measurements
  - Can measure in the same divertor as He-beam
- **WISP Gauges** (AEI – pumping gap +AEH – pumping port) to measure partial pressures of Helium
- **CXRS** to measure confined He^{2+} measurements/Passive visible system looks into divertor
- **Filterscopes** – toroidal distribution of Helium line radiation (symmetries/time delays)
- **HEXOS** – He VUV spectroscopy + perpendicular visible observation
- **CIS** – He-II filter to measure parallel flows
- **Jülich endoscopes** – more visible spectroscopy in divertor
- **Divertor Cameras –** AEF40 He-I measurement, endoscopes AEA30 He-II measurement, AEA31 He-I measurement