Characterization of the scrape off layer density and SOL density control tools for Local Helicity Injection design

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Feb. 25, 2015

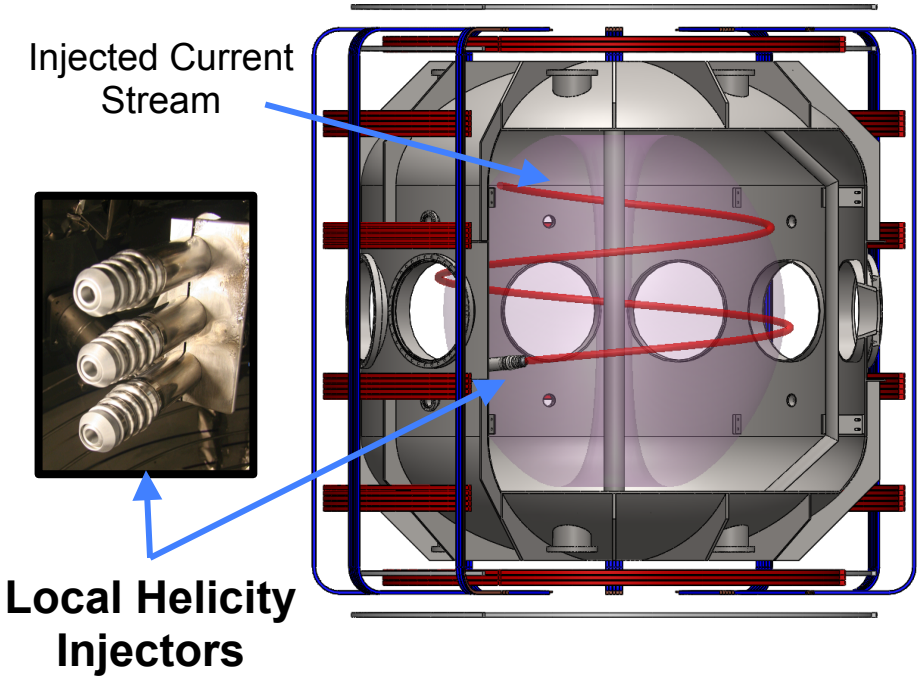
NSTX-U Research Forum, Princeton, NJ

NSTX-U

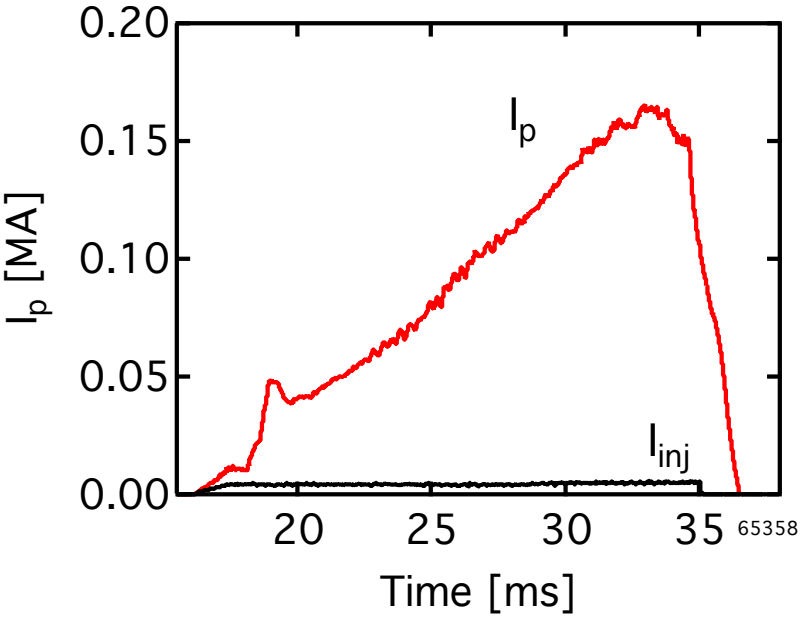
PEGASUS

Local Helicity Injection (LHI) non-solenoidal startup successfully demonstrated on Pegasus

Current injected from point source



$I_p \leq 0.18$ MA (I_{inj} = 5 kA)



- Unstable current streams form tokamak-like state via Taylor relaxation
- Appears scalable to MA-class startup

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Design of NSTX-U LHI system critically depends on realized injector impedance

- Max attainable I_p set by helicity input and Taylor relaxation

  - Helicity balance: $$I_p \le \frac{A_p}{2\pi R_0 \langle \eta \rangle}\left(V_{ind} + \frac{A_{inj} B_{\phi,inj}}{\Psi_T} V_{inj} \right)$$

  - Taylor limit: $$I_p \le f(\varepsilon, \delta, \kappa) \sqrt{\frac{\kappa A_p I_{TF} I_{inj}}{2\pi R_0 w}}$$

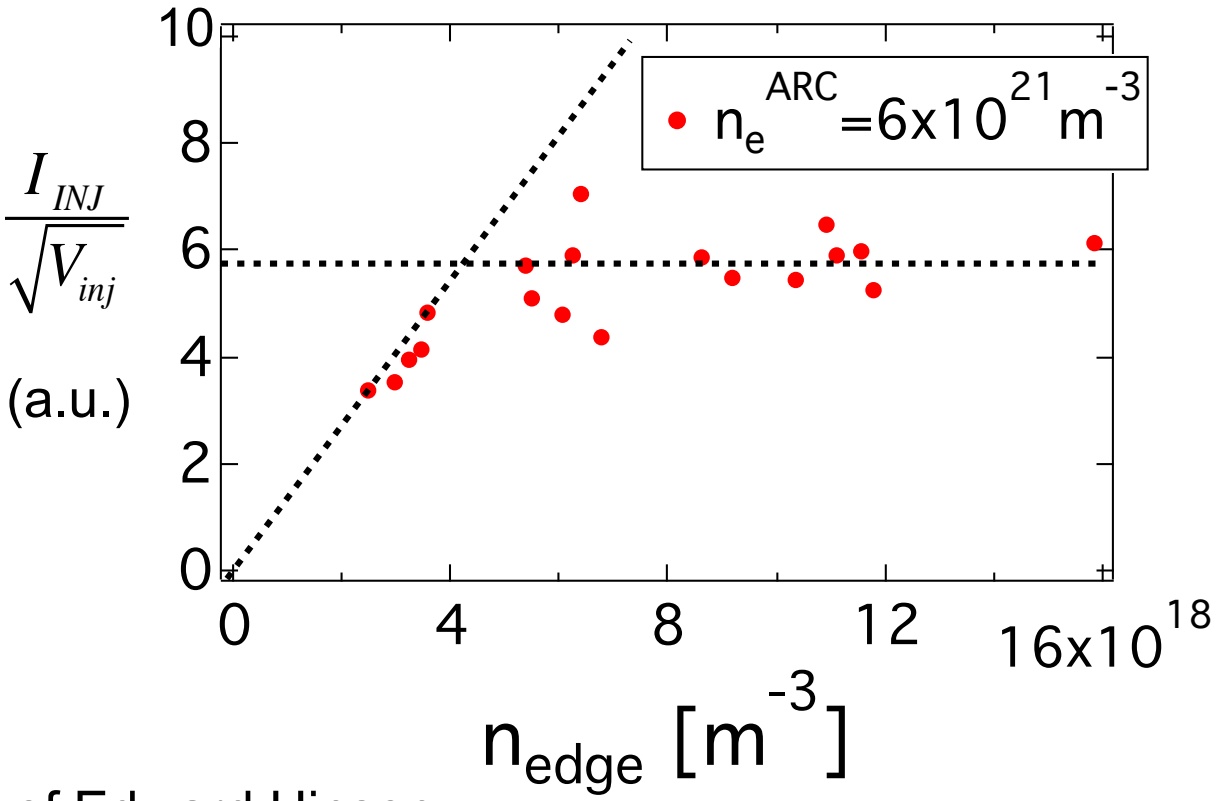
- Two physical effects govern relationship between I_{inj} and V_{inj}

  - Double layer: $$I_{DL} \sim \frac{V_{DL}^{3/2}}{\ell_{sheath}^2} \sim \frac{\lambda_{De}^2 V_{DL}^{3/2}}{V_{DL}} \sim n_{DL}\sqrt{V_{DL}} \sim n_{arc}\sqrt{V_{inj}}$$

  - Quasi-neutrality: $$I_{inj}^e \le A_{inj} n_{SOL}^i e v_e = A_{inj} n_{SOL} e \sqrt{\frac{2eV_{inj}}{m_e}} \sim n_{SOL}\sqrt{V_{inj}}$$

Scan of SOL density during LHI on Pegasus illustrate both impedance limits*

- Edge density scanned with $n_{ARC} = 6 \times 10^{21} m^{-3}$
- At low edge density, quasi-neutrality limits impedance
- At higher edge density, impedance saturates (set by n_{arc})



*Plot courtesy of Edward Hinson

NSTX-U Experimental Proposal

- Goal: Measure SOL density and document SOL density control tools for design of LHI system for future deployment on NSTX-U
  - Low and high field side gas puffing
  - Scan I_p ($\leq$ 1MA), Auxiliary power (NBI, HHFW)
  - Document dependence on magnetic geometry and wall conditions

- Document SOL/edge density with Langmuir probes, Thomson scattering, possibly reflectometer

- Runtime: ½ day boron, ½ day lithium

- Contributes to NSTX-U 5 year priority goal 2: Develop and understand non-inductive start-up and ramp-up

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