Confinement measurements in the Lithium Tokamak Experiment-β

LTX-β

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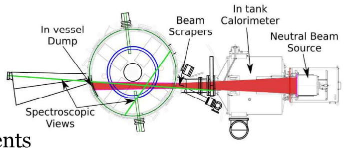
Li predicted, demonstrated to improve fusion

- Low Recycling due to chemical bonding of H/D/T
  - Improves density control
  - Improved energy confinement in TFTR, NSTX, CDX-U
  - Reduces edge thermal losses, gradients, turbulence
- Reduce impurities
  - Li relatively benign: Low-Z and low first ionization potential
  - Sputtering decreases for higher edge T_i > 200 eV
  - Getters other impurities from residual gases
  - Buries surface impurities (as solid) or dissolves (as liquid)
- Liquid metals could solve many wall issues
  - Can't break/crack, erosion not issue, so can be thinner
  - Substrate only has to handle heat & neutrons, not plasma
  - Can flow or evaporate to handle heat, remove tritium
- **All of these explored, demonstrated on LTX(-β)**

LTX-β upgrade extends new low-recycling regime

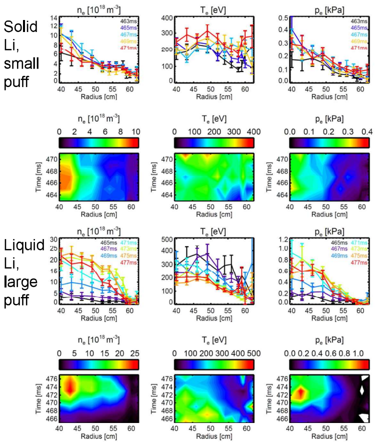
- Lithium coatings bind hydrogen, suppressing neutral recycling
- LTX: Hot edge and flat T: no ∇T loss!
- Expand regime: higher field, add NBI
- NBI goals: Fuel, Heat, Torque, CHERS
  - Steadier n_e w/o edge cooling
  - Higher, flat T_e, T_i + fast ions
  - Higher p, W_{kin}, β
  - High v_{Tor} w/ low edge drag
  - 17–23 kV, 35A, 5 ms
- Initial NBI experiments had low fast ion confinement
- Recent, mostly ohmic experiments increased I_p to 135 kA

Parameters		LTX[1]	LTX-β[2]
Major Radius	R_o	34 – 40 cm	
Minor Radius	a	20 – 26 cm	
Toroidal Field	B_T	0.18 T	0.3 T
Ohmic Bank	E_{OH}	0.4 MJ	0.8 MJ
Plasma Current	I_p	85 kA	135 kA
Beam Power	P_{NBI}	0	700 kW
Beam Duration	t_{NBI}	0	5 ms



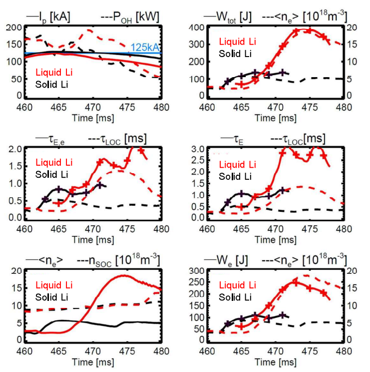
[1] D.P. Boyle et al PRL 2017
[2] D. Elliott et al IEEE Plasma 2020

Record T_e~400 eV, p_e~1 kPa values achieved



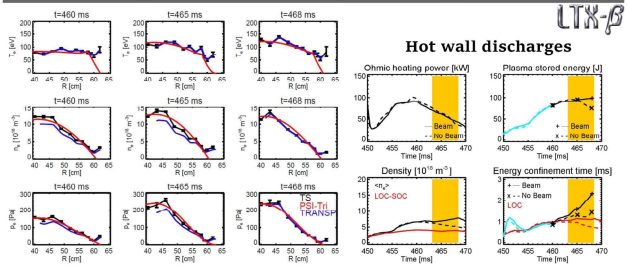
- Preliminary Thomson Scattering profiles consistent w/ ~flat T_e
- Edge cools during gas puff, but later recovers
- Regime extended to liquid Li, higher I_p, B_T
- Future analysis w/ NBI optimization
- TS upgrades will measure HFS core and LFS edge

Confinement follows, exceeds Linear Ohmic scaling



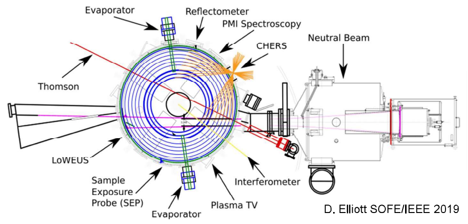
- Energy confinement increases ~ n_e
  - Linear Ohmic Confinement (LOC) or neoAlcator
- Confinement does ***not*** decrease w/ n_e
  - Seen in LTX
- n_e exceeds critical Saturated Ohmic Confinement scaling
  - No clear saturation

Earlier liquid Li similar but lower performance



- TRANSP analysis using TS profiles, CHERS core T_i, kinetic constrained Psi-Tri equilibria
  - Excludes P_{NBI} due to low coupling
  - Follows, then exceeds Linear Ohmic Confinement scaling
- ~Flat T_e profiles consistent with low-recycling regime

Enhanced diagnostics → wider, deeper, finer studies



- AXUV Lyman alpha arrays for recycling measurements
- Magnetics, Langmuir probes, AXUV bolometer
- ORNL/PPPL: CHERS, multiple visible spectrometers
- UT-K: Sample Exposure Probe for PMI study
- LLNL: Filtered fast cameras, XUV/UV spectrometers
- UCLA: Interferometer & reflectometer enhanced for $\tilde{n}_e$

Broad modeling effort for unique LTX-β physics

- PSI-Tri equilibrium reconstructions
  - Psi-Tet eddy currents
- TRANSP integrated analysis
  - NUBEAM, NCLASS
- SOL ion mirror trap
- LiWallFusion
  - 3Dorb code for fast ions
- DEGAS2 neutral recycling