Initial ideas for LLD experiments

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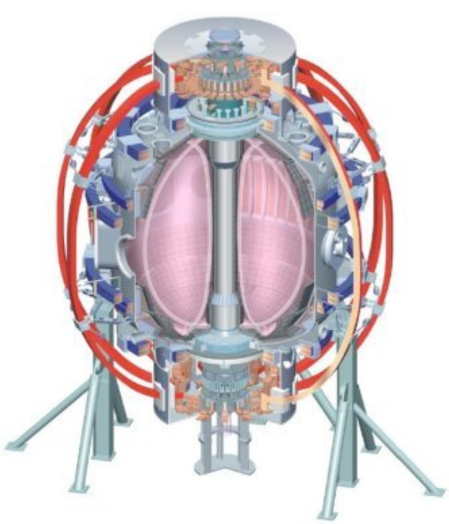
NSTX Lithium Thrust Meeting
Princeton, NJ
23 November 2009



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Plan for LLD start-up experiments

- Focus on four main thrusts
  - LLD pumping capability
  - Effect on pedestal and core performance
  - Effect on SOL / divertor transport
  - Divertor heat flux handling

- Start LLD experiments in a controlled manner
  - High-triangularity (δ~0.7-0.8, R_{OSP} ~ 0.4-0.5 m) fiducial 2-4 MW NBI
    - little heating / heat flux on LLD
  - Use LLD at controlled temperature using heaters
    - scan temperature between 150 and 350-400 C
  - Obtain data to address the four point above
  - Then proceed to medium triangularity shape (δ~0.5-0.6, R_{OSP} ~ 0.5-0.65 m) but start with cold LLD

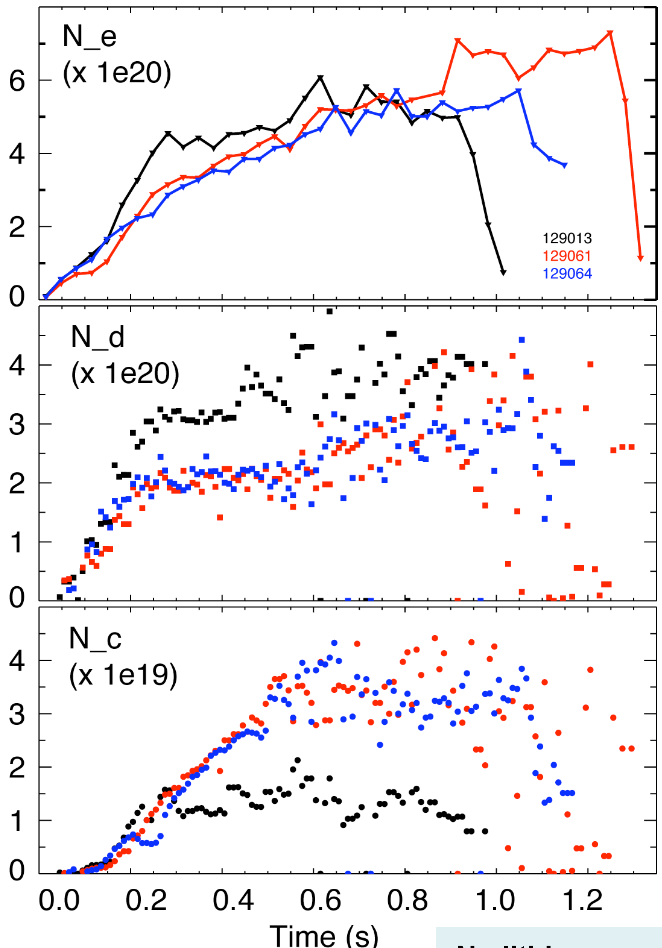
LLD commissioning and initial XPs should be planned as self-inclusive one day segments

- Avoid breaking experiments by thermal cycling and overnight pauses
- LLD pumping capability
  - Use SGI scenario for constant N_i discharges, vary LLD temperature
  - Particle balance models can show "wall" inventory and τ_p^* essentially characterizing pumping
  - If FireTip channel 7 operational, can measure SOL density response to SGI pulses ("pumpout")
  - Use Ly-alpha array and probes to measure local recycling coefficients

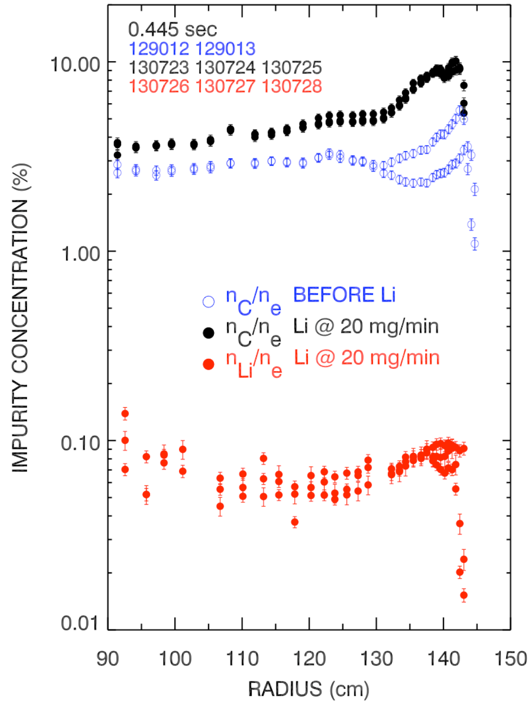
- Effect on SOL / divertor transport
  - Measure impurity source profiles (Li, C, molecular) simultaneously
  - To reduce edge impurity sources, use partially detached divertor (either using "snowflake" configuration or divertor gas injection) and explore synergy with LLD pumping

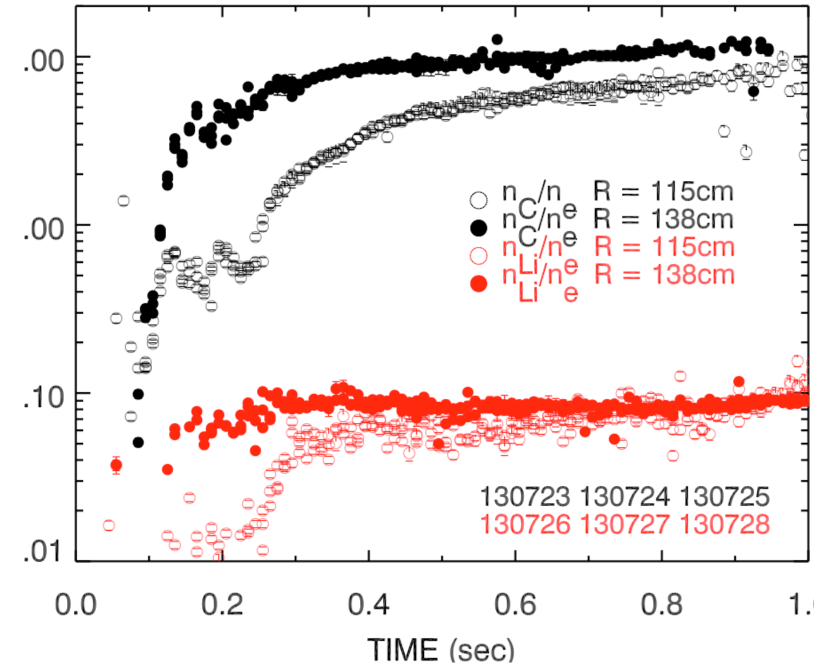
- Effect on pedestal and core performance
  - Need core lithium density measurements in LLD experiments

Ion inventory is well controlled in discharges with lithium, core carbon accumulates, lithium is screened out



No lithium (129013)
190 mg Lithium (129061)
600 mg lithium (129064)





- Impurity density profiles from CHERS
  - C VI, n = 8-7 transition, 529.1 nm
  - Li III, n = 7-5 transition, 516.7 nm
- Lithium concentration much lower than carbon concentration
  - n_C/n_{Li} ~ 100
- Carbon increases with Li evaporation

Dynamic particle balance model indicates strong pumping by lithium

$$\frac{dN_p}{dt} = \Gamma_{gas} + \Gamma_{NBI} + \Gamma_{NBI\_cold} + \Gamma_{NBI\_cryo} + \Gamma_{wall} + \Gamma_{pump} + \frac{dN_n}{dt}$$

Change of particle inventory — *Gas feed rate* — *NBI fueling rate* — *NBI cryopump rate*

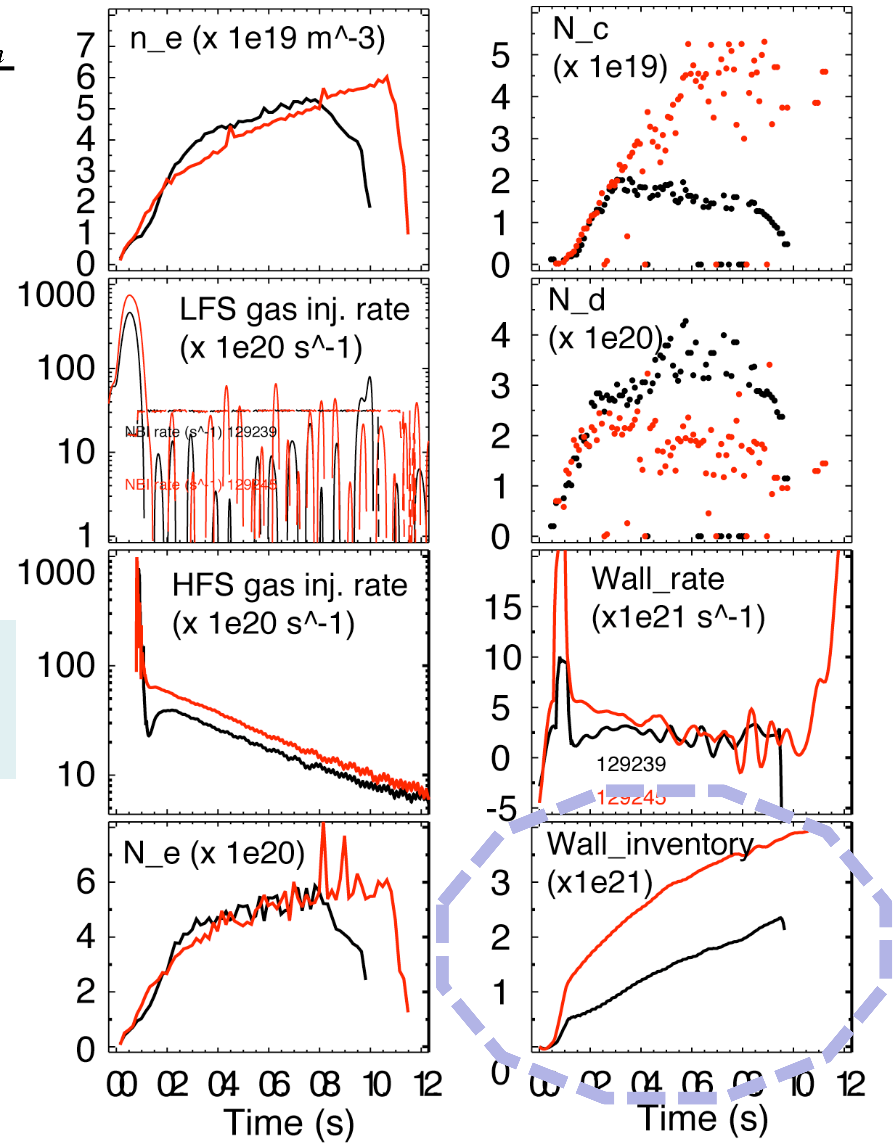
Ion density $$n_i = n_e \frac{Z - Z_{eff}}{Z - 1}$$

Fueling efficiency $$\eta = \frac{N_p(t)}{N_{src}(t)}$$

No lithium (129013)
190 mg Lithium (129061)

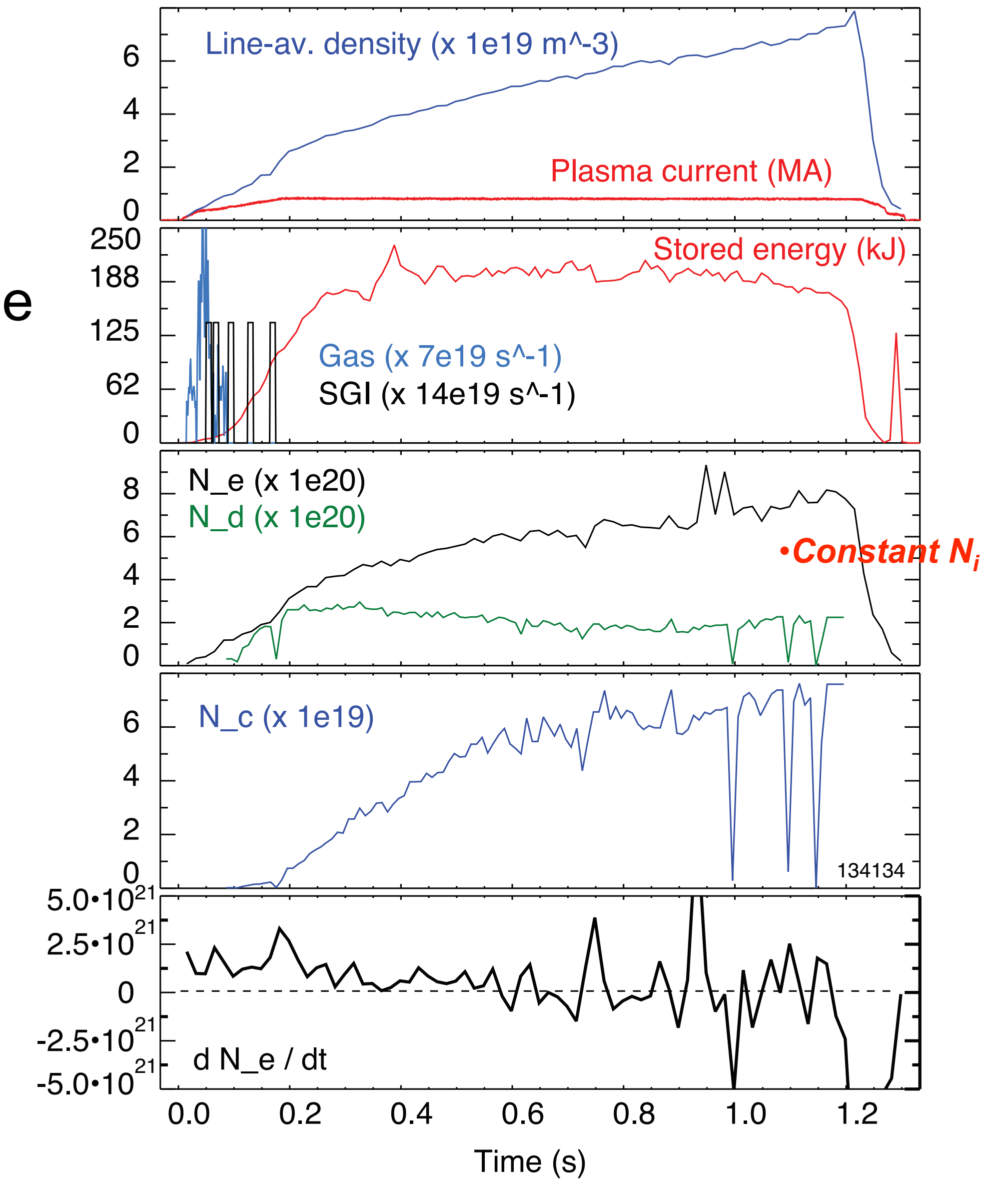
Rewrite global particle balance equation as:

$$\frac{dN_p}{dt} = \eta_{gas} S_{gas} + \eta_{NBI} S_{NBI} + S_{recy} - \frac{N_p}{\tau_p}$$



A long pulse H-mode discharge scenario with SGI fueling and controlled N_i was developed

- Used SGI-only fueling
- LITER rate 6-9 mg/min
- Ion density control
- N_i constant, while N_e is rising due to carbon



Summary from APS poster "Modifications in SOL and divertor conditions with lithium coatings…"

- Evaporative lithium coatings on carbon PFCs modify divertor and SOL sources
  - Lower divertor, upper divertor and inner wall recycling was reduced by up to 50 %
  - Local recycling coefficients reduced on inner wall and far SOL, remained similar in the outer strike point region
  - Lower divertor carbon source from physical sputtering also reduced
  - Divertor lithium influx increased, however, lithium was retained in divertor

- SOL transport regime changes from high-recycling to sheath-limited
  - Apparently small parallel T_e gradient
  - Detached inner divertor re-attaches, X-point MARFEs disappear

- Pedestal and core confinement improvement leads to
  - Surface pumping reduces ion inventory (density) by up to 50 %
  - Lithium is effectively screened from plasma
  - Carbon accumulation observed
  - P_{rad} increases in the core, P_{SOL} significantly reduces

Comparison with cryo-pumps

- Cryo-pumping (e.g., DIII-D experience)
  - Significant in-vessel hardware modifications
  - Inflexibility in plasma shaping due to the need of proximity to strike point
  - Calibrated pumping rate
  - Demonstrated density control
  - Compatibility with radiative divertor

- Lithium coatings on graphite PFCs (NSTX LITER experience)
  - Flexibility in plasma shaping
  - Need for operational scenario development for each pumping and fueling rate
  - Multiple side effects (good and bad) on plasma core and edge