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Divertor heat flux reduction and detachment in lower δ, κ LSN plasmas

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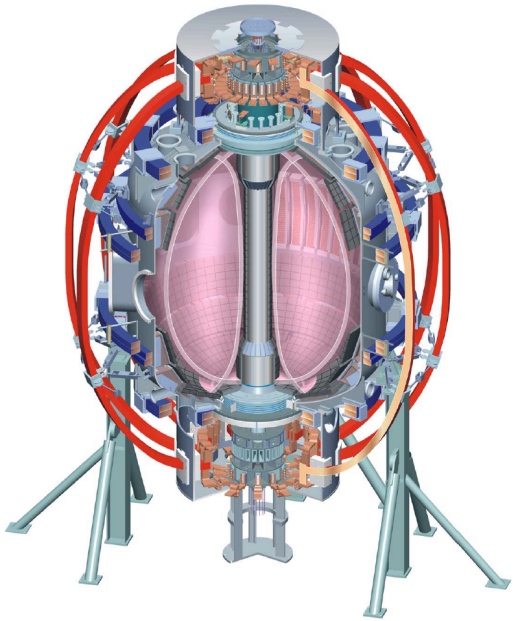


ORNL PPPL NSTX

Motivation - understand and control divertor heat and particle fluxes at low aspect ratio

Motivation

- Develop divertor heat flux mitigation scenarios for NSTX
- Understand physics of divertor regimes, including detachment, at low aspect ratio
- Basis for CTF divertor scaling and predictive capability
- Contribution to ITER divertor database with high flux expansion divertor
- Study divertor regimes with low recycling surfaces - any surprises? (lithium)
- Unique NSTX contribution in all these topics
- NSTX XP goals: study divertor regimes (heat and particle parallel and perpendicular transport) in NBI-heated H-mode plasmas, determine plasma geometry effects on divertor, develop radiative and/or dissipative divertor scenario with reduced divertor peak heat flux and good core confinement

NSTX results demonstrate heat flux reduction with dissipative divertor in lower δ, κ LSN plasmas

- Proposed for NSTX in 2003, ran 1/3 day in FY04, ran 1.5 days in FY05
- C. J. Lasnier (LLNL staff at DIII-D) participated in 2005 experiment

- NSTX results to date (from XP 438, XP 520)
  - Inner divertor heat flux < 1 MW/m^2, outer divertor heat flux~ 4-7 MW/m^2
  - OSP does not detach at high densities ($n_e \sim n_G$) as a result of short $L_{//}$ and open divertor geometry (?). ISP detaches at low n_e, P_{in}
  - Tried midplane D_2 puffing in 2-4 MW NBI L- and H-mode LSN plasmas to raise edge collisionality from 5-20 to 10-80. Result: outer peak heat flux *x 2-4*, but no volume recombination signs - no detachment, radiative mantle or radiative divertor?
  - Midplane neon puffing - similar result, radiative mantle or radiative divertor?
  - Lower divertor *semi-steady-state* D_2 puffing - got OSP partial detachment (reduced outer peak heat flux *x 4-5*, shift of heat flux profile peak, signs of volume recombination)

Plan is to study routes to detachment in long pulse LSN scenario with D_2 and CD_4 puffing

- Study OSP detachment with steady-state divertor D_2 puffing (~ 0.5 day)
  - Target plasma - 4 MW H-mode LSN plasma, 4.5-5 kG, $\delta \sim 0.45$, $\kappa = 1.85$
  - Will use Branch 5 Injector for long continuous gas puffing (similar to HFS injector)
- Comprehensive diagnostic set is ready

- Study OSP detachment with extrinsic impurity - CD_4 puffing (~ 0.5 day)
  - SOL and divertor temperature in NSTX is too low for neon to radiate efficiently, but expect carbon and deuterium to radiate well
  - Have a bottle of CD_4 committed to the experiment
  - Study carbon screening

- In both parts focus not only on detachment but also on impurity source characterization and core performance

- Outstanding tasks
  - Develop UEDGE analysis for the experiment
  - Evaluate divertor regimes with low-recycling edge (lithium)

Detailed shot plan

• Setup an rt-EFIT-controlled LSN (with PF2L coil) HFS-fueled plasma and perform gas injection rate scan (10 shots)

• Setup a 0.8-1.0 MA 0.45-0.55 T shot with 2 NBI sources B, C at 90 kV, adjust the X-point height so that the inner strike point remains at 1-2 cm from the inner wall throughout discharge. Example shots: 116097, 116098, 116099, 116111, 116485, …

• Vary Branch 5 injector rate from 0 to 200 Tl/s, HFS 1200-1300 Torr

• In one high density discharge, turn off NBI at the time when n_e is high (> 5 x 10^{19} m^{-3}) to obtain high density low input power condition for about 50 ms

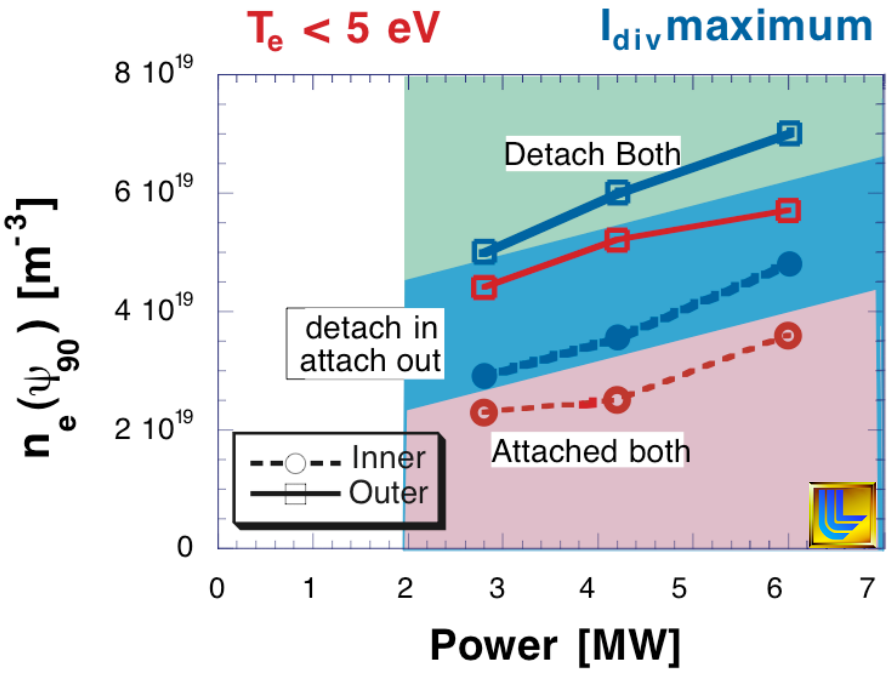
• Greenwald density for I_p=0.7 MA is n_G = 4.8 x 10^{19} m^{-3}

• Use 7-12 min He GDC as appropriate, (conditional) add modulated and full beam A

• Perform CD_4 injection in increasing quantities (0.05 – 0.2 s duration pulses at a rate from 1 to 20 Torr l / s) into intermediate density two NBI source shot from 1. Monitor radiated power (10 shots).

• Use Injector 3 for CD_4. CD_4 pulse start time 0.30 - 0.35 s

Backup slides



G. Porter, N. Wolf

Attempt to change parallel momentum and power balance:

$$\frac{d}{ds}(m_i n v^2 + p_i + p_e) = -m_i(v_i - v_n)S_{i-n} + m_i v S_R$$

$$\frac{d}{ds}((-\kappa T_e^{5/2}\frac{dT_e}{ds}) + n v_{||}(\frac{5}{2}(T_i + T_e) + \frac{1}{2}m_i v_{||}^2 + I_0)) = S_E$$

Publications and collaborations

- Publications
  - One JNM paper (2005)
  - Posters at APS 2004, PSI 2004
  - Oral talk at APS 2005
  - PSI-17 poster abstract accepted
  - Paper in preparation to be submitted to NF

- Collaboration potential
  - Discussed possible collaboration with DIII-D (through LLNL program)
  - Possible collaboration with MAST