Dependence of Profiles and Edge Stability on NSTX Neutral Beam Power

PPPL · GENERAL ATOMICS
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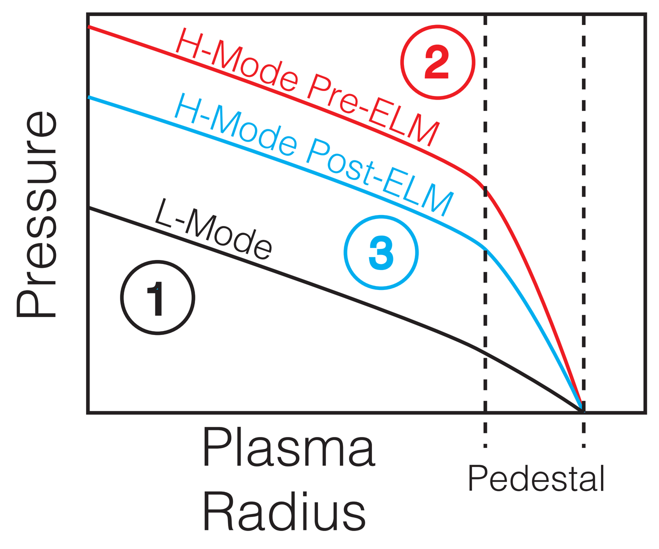
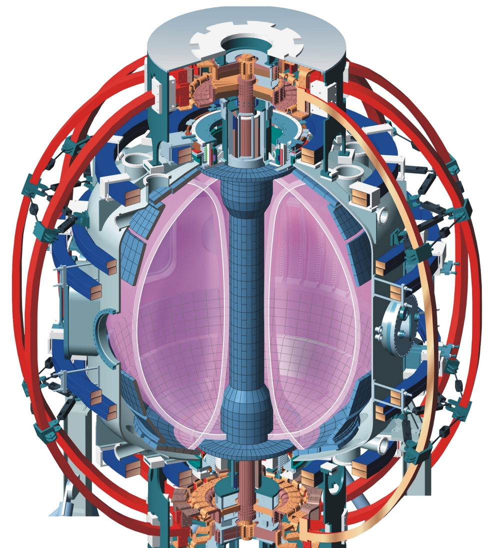
The NSTX and instabilities

L-mode vs H-mode



1. L-mode has low energy confinement.
2. More input power causes a transition to H-mode (high energy confinement).
   H-mode plasmas have **larger currents and pressure gradients in the edge**.
3. Edge localized modes (ELMs) cause a transitory decrease in energy confinement.

The NSTX [1]



Machine Parameters

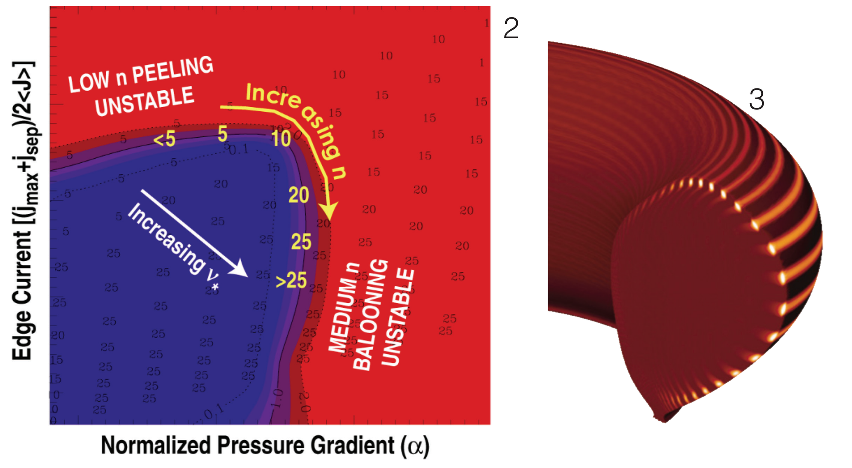
R_0	0.86	m
a	0.67	m
I	1.5	MA
B_0	0.55	T
NBI	7.4	MW
RF	6.0	MW
t	1.8	sec

- NSTX was a spherical tokamak (ST).
- STs have small aspect ratios and lend themselves to stability.
- Power of the neutral beam injector (**PNBI**) is varied for this study, which is called a **power scan**.

Edge-Localized Modes (ELMs)

What causes ELMs?

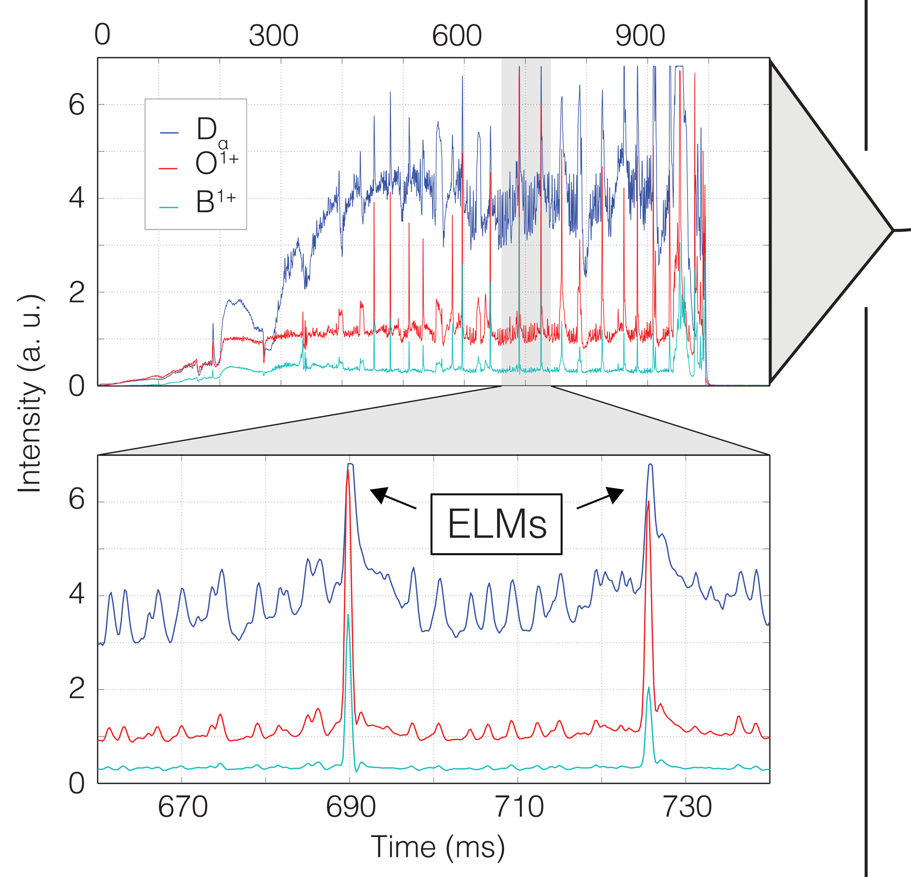
- **Steep pressure gradients** and **current densities** in the pedestal region.



ELMs:

- Eject plasma, impurities, and heat when the stability boundary is reached.
- Occur frequently in H-mode.
- Are accurately described by MHD as peeling-ballooning modes (above images).
- Cause filaments.

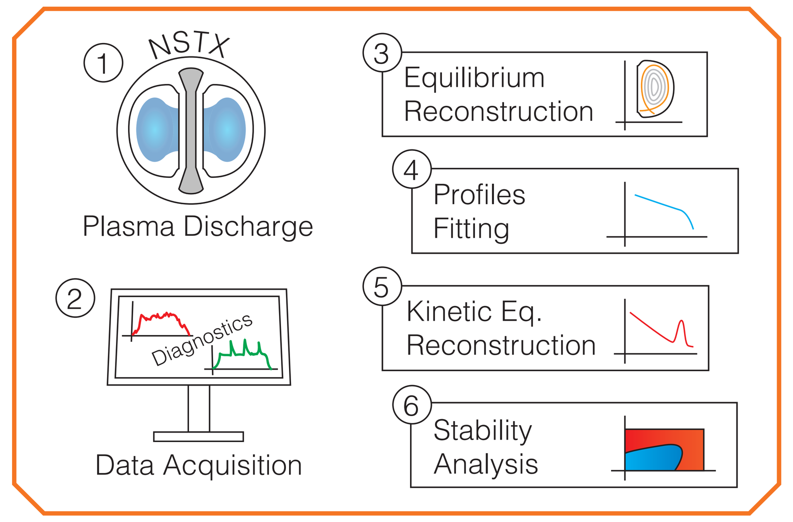
The Filterscope



- Detected visible light that ELM filaments emit.
- Easier to see ELMs in O^{1+} and B^{1+} spectral lines.

How is a power scan performed?

The Analysis Process (I did ③-⑤)



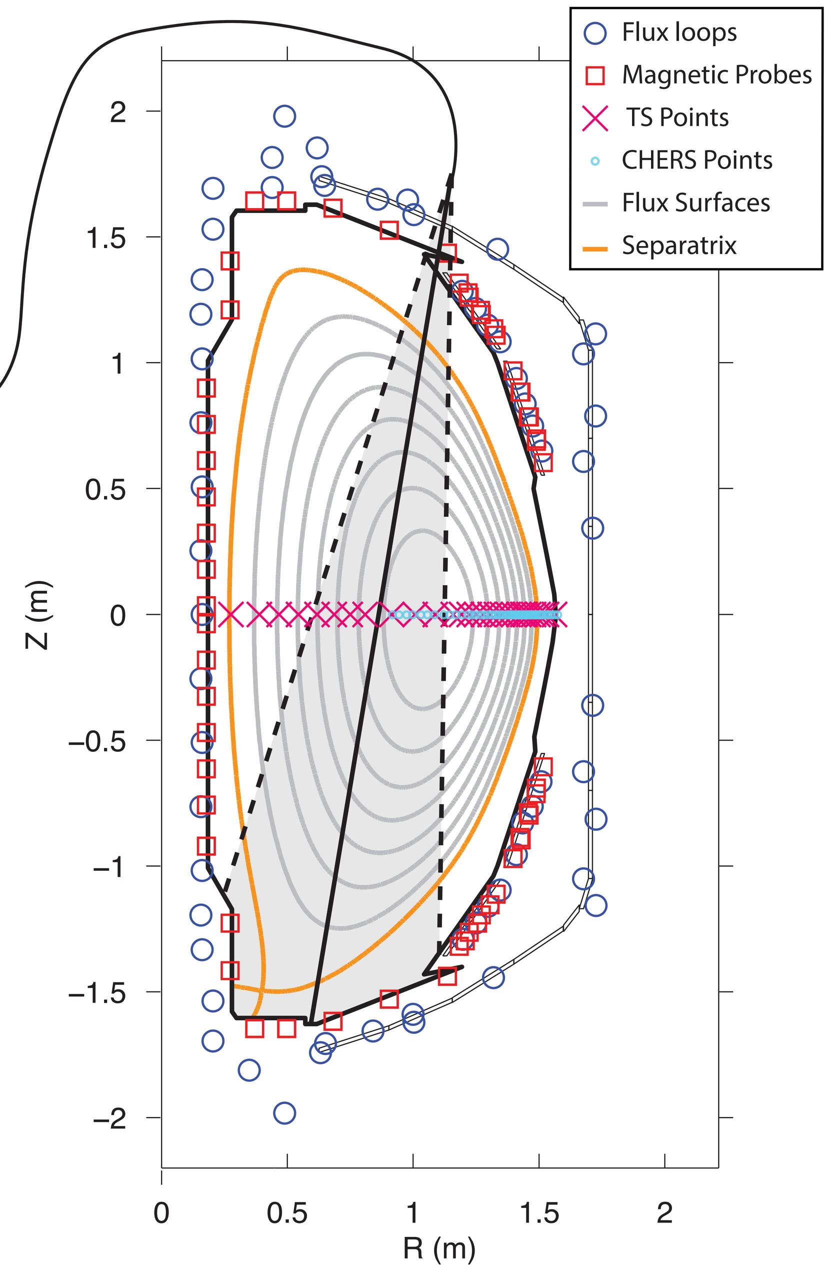
Expectations

- NSTX was capable of 7.4 MW of NBI power.
- $P_{e,i}$, $T_{e,i}$, and other parameters were calculated as a function of PNBI.
- Increased PNBI is expected to **increase** core $T_{e,i}$, $P_{e,i}$, $n_{e,i}$, and **edge J and ∇P**.
- ELMs are more prone to be destabilized in plasmas with more PNBI.

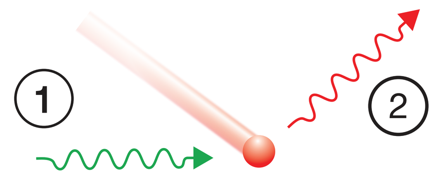
Diagnostics

Magnetics: Flux loops, Probes [4]

- Used to reconstruct MHD equilibria.
- ELMs were visible in the data.



Thomson Scattering (TS) [5]

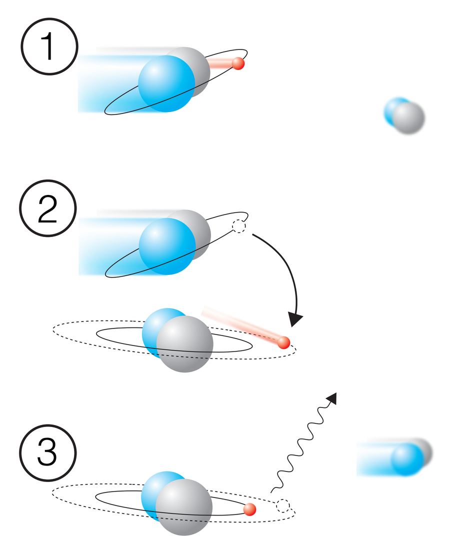


- Provides information on electron density and temperature.
- Acquired at 60 Hz.

1. A photon is emitted by a laser.
2. The photon is scattered by the electron, blueshifting or redshifting it.
   The scattered photon is collected and analyzed

Charge Exchange Recombination Spectroscopy (CHERS) [6]

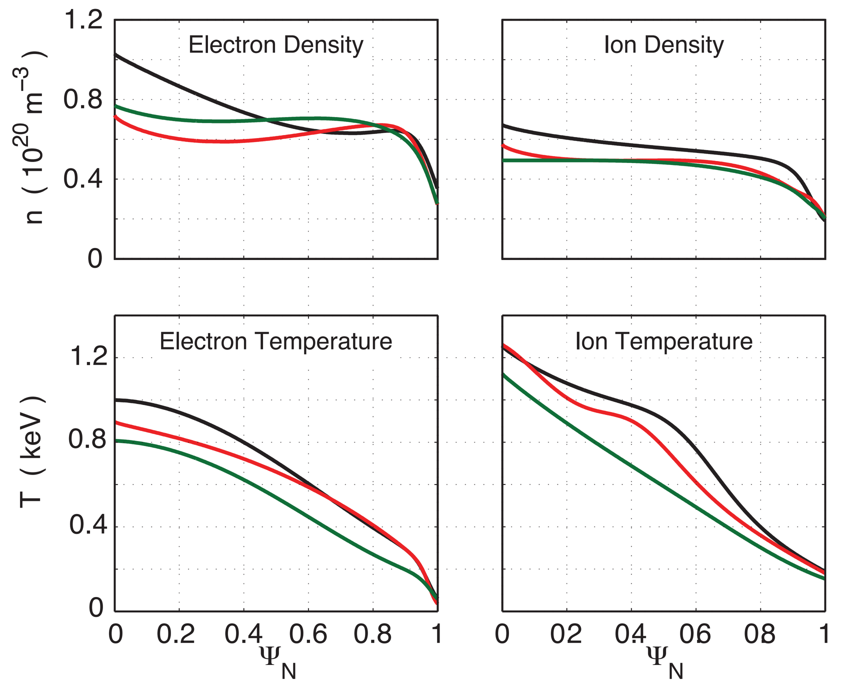
- Provides information on ion density, temperature, and rotation.
- Acquired at 100 Hz with a 10 ms integration time.

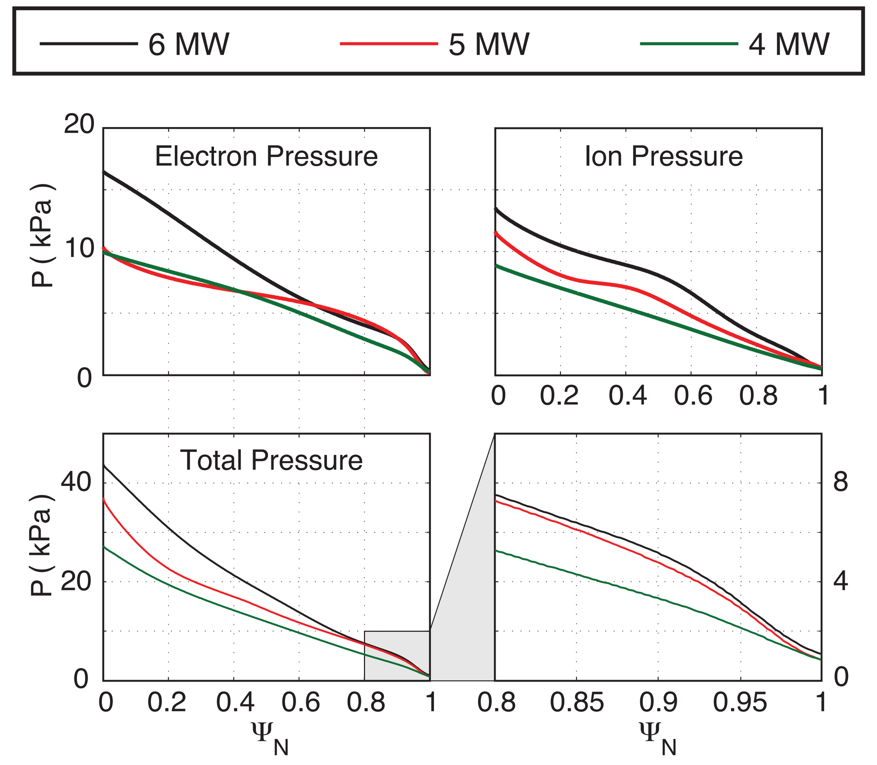


1. A fast neutral atom passes by a slow ion.
2. The slow ion captures the electron from the fast neutral atom.
3. The captured electron drops down to lower energy levels and emits photons.
   The emitted photons are collected and analyzed.

Power scan results and inferences

Kinetic Profiles



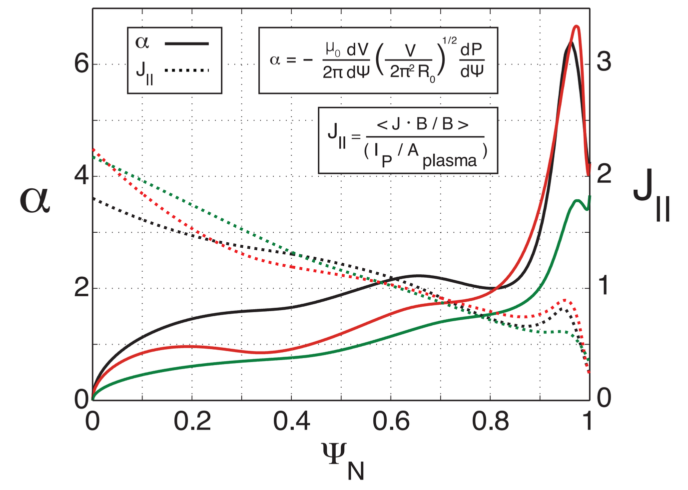


- $n_{e,ped}$ is comparable for all three discharges.
- $T_{e,ped}$ for 5-MW and 6-MW discharges are comparable and higher than the 4-MW discharge.
- $T_{i,e}$ increases with PNBI.

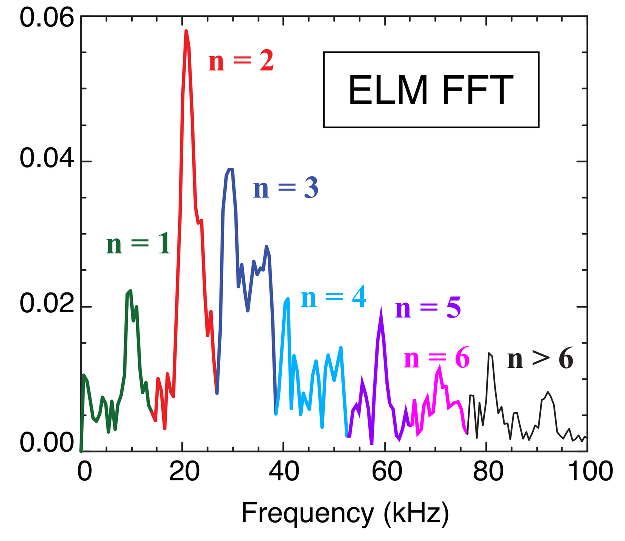
- P_{tot}, P_{fast}, and P_{ion} increase with PNBI.
- $P_{e,ped}$ for 5-MW and 6-MW discharges are comparable and higher than the 4-MW discharge.

Stability Analysis

- The 5-MW and 6-MW discharges have similar α and $J_{||}$ in the pedestal.
  - This similarity indicates that they **both reach the stability boundary**.
- The 4-MW discharge has lower α and $J_{||}$ which indicates that
  - transport may be removing energy faster than the NBI can provide.
  - it **does not reach the stability boundary.**
- Greater pressure gradients lead to larger bootstrap currents.



- Two codes used for stability analysis:
  - ELITE (ideal MHD)
  - M3D-C[1] (two-fluid resistive MHD)
- Ideal MHD calculations using ELITE indicate that all ideal modes are stable.
- Instability growth rates are much higher in M3D-C[1] than ELITE.
- ELMs are dominated by **resistive low n modes**



[1]: J. E. Menard et al., "Overview of the physics and engineering design of NSTX upgrade," Nucl. Fusion **52**, 083015 (2012).
[2]: T. H. Osborne et al., "Edge stability of stationary ELM-suppressed regimes on DIII–D," JPCS **123**, 012014 (2008).
[3]: N. M. Ferraro, S. C. Jardin, and P. B. Snyder, "Ideal and resistive edge stability calculations with M 3 D- C 1," Phys. Plasmas **17**, 102508 (2010).
[4]: E.J. Strait, E.D. Fredrikson, J.-M. Moret, M. Takechi, "Magnetic Diagnostics", Fusion. Sci. Technol. **53**, 304-334 (2008).
[5]: B. P. LeBlanc et al., "Operation of the NSTX Thomson scattering system," Rev. Sci. Instrum. **74**, 3 (2002).
[6]: R. E. Bell et al., "Comparison of poloidal velocity measurements to neoclassical theory on the National Spherical Torus Experiment," Phys. Plasmas **17**, 082507 (2010).

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