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EX/P8-30

Plasma Termination by Excess Pellet Fueling and Impurity Injection in TJ-II, LHD and Wendelstein 7-X

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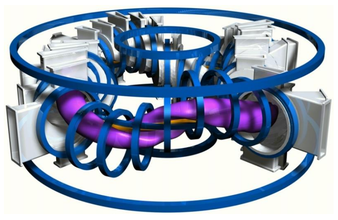
Motivation and Outline

- First survey on plasma termination due to excessive fueling and impurity injection in stellarators and heliotrons (TJ-II, LHD, W7-X)
- Time scales of plasma termination appear to be relevant for operational limits and licensing on larger scale devices
- Study impact of *inherent confinement* of helical devices

Methods

- Characterize plasma termination in TJ-II, LHD and W7-X.
- Study of plasma terminating events induced by fueling pellets and impurity injection (LBO, TESPEL) to derive time-scales and common mechanisms: **core cooling by induced impurity radiation**



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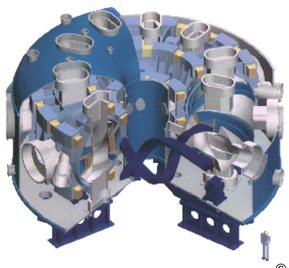
TJ-II (>1997)

Heliac (copper coils)
N=4, R=1.5m, a~0.2m, V ~1m^3
B ~ 1 T, ι ~ 1.6
P_{ECRH} ~0.6 MW, P_{NBI} ~2MW
τ_{pulse} ~ 0.2 s



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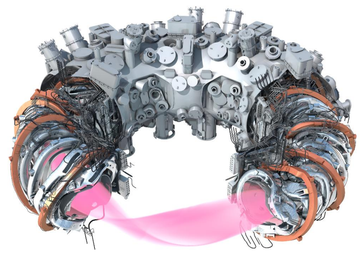
LHD (>1998)

superconducting heliotron
N=10, R=3.75m, a=0.6m, V = 30 m^3
B < 2.9 T, ι ~ 1
P_{ECRH} ~5.3 MW, P_{NBI}~ 23MW



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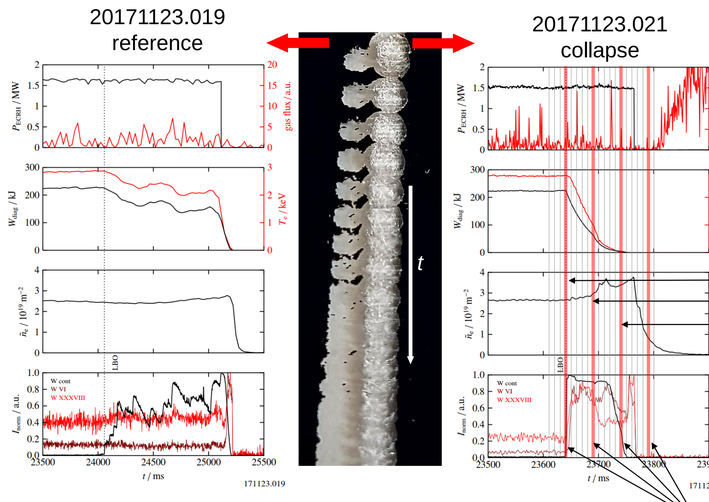
Wendelstein 7-X (>2015)

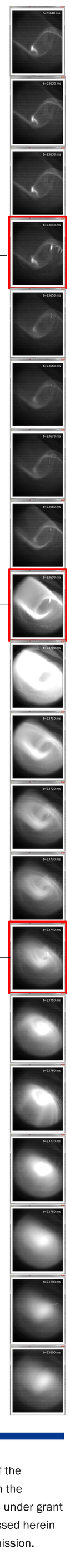
low-shear superconducting HELIAS
N=5, R ~ 5.5m, a ~0.5m, V ~ 30m^3
B ~ 2.5 T, ι ~ 5/6, 5/5, 5/4
P_{ECRH} ~6.5 MW, P_{NBI}~ 3.5MW

Plasma Collapse after Excess Impurity Injection in W7-X

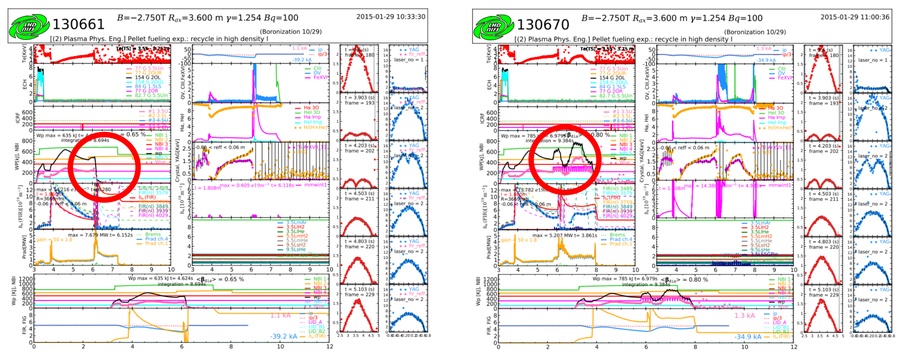


Waveforms of W-LBO experiments (T. Wegner).

LBO pulses

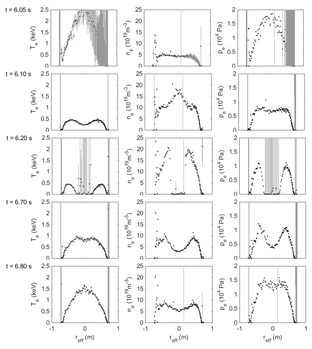


Plasma Termination / Recovery after Excess Fuelling in LHD



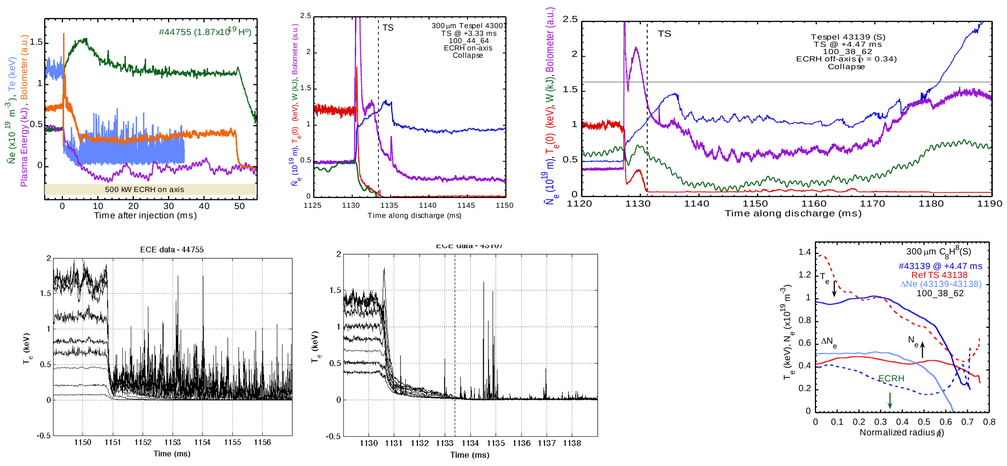
Waveforms of LHD discharges.
Left: #130661 N = 4 x 10^{21}
Right: #130670 N = 3 x 10^{21}

Evolution of T_e, n_e and p_e during plasma recovery in #130670

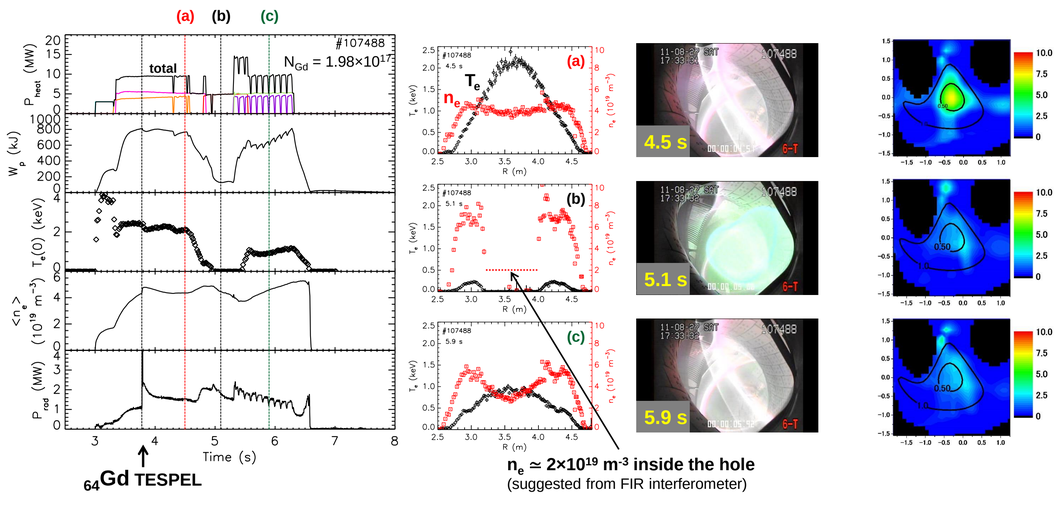


	TJ-II	W7-X	LHD
Termination by	TESPEL	LBO	Fuelling pellets, TESPEL
W/P	<10ms	80 … 100 ms	~ 100ms
$\mathcal{O}(\tau_{TERMINATION})$	2 … 10 ms	50 ms	~150 ms
Recovery observed	x		x
Radiation Source	S	W	Fe, O, Gd

Plasma Termination and Recovery by TESPEL in TJ-II



Plasma Termination and Recovery by TESPEL in LHD



^{64}Gd TESPEL

$n_e \simeq 2\times10^{19}$ m^{-3} inside the hole
(suggested from FIR interferometer)

C. Suzuki et al., J. *Phys. B: At. Mol. Opt. Phys.* **45**, 135002 (2012).

Conclusion

- Multi-machine study (TJ-II, LHD, W7-X) on plasma terminating events in stellarators/heliotrons
- Time scales are in the order of confinement times set by radiative losses from (P_{rad}/P_{heat})
- Core cooling → robust *temperature holes*
- Capabiltiy for plasma recovery in TJ-II and LHD demonstrated
- Shorter time scales (and characteristics – not shown) for broad co-ECCD in W7-X
  - **Vacuum confinement of Stellarators/Heliotrons: benign response to investigated terminating events**
  - **Robust operation: plasma recovery after massive perturbations observed**

Under auspicies of
Stellarator-Heliotron Concept

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