XP 1511: Multi-Machine Studies of the L-H Power Threshold Dependence on Aspect Ratio

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NSTX-U

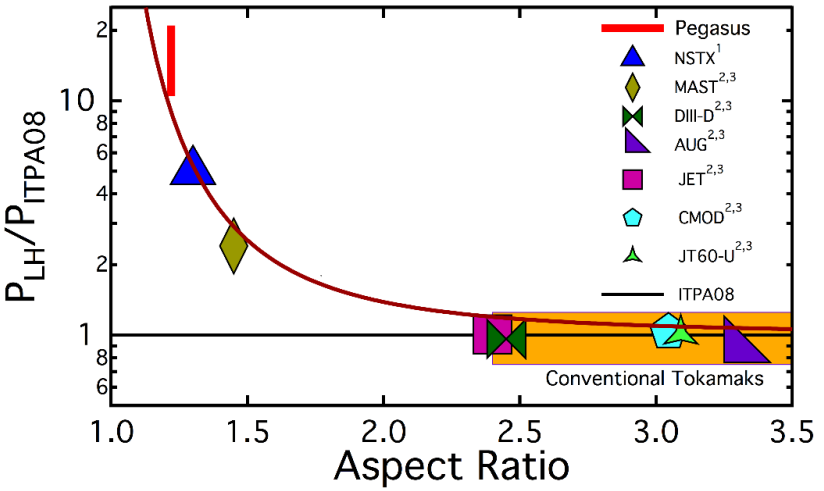
DIII-D
NATIONAL FUSION FACILITY

PEGASUS

L-H Power Threshold Diverges From Multi-Machine Scalings as A → 1

- L-H transition has aspect ratio dependent effects[1-4]
  - Magnitude of transition power
    - P_{LH}/P_{ITPA08} ~ 1 at conventional A
    - $P_{LH}/P_{ITPA08} \geq 10$ in Pegasus
  - Magnetic topology for minimum P_{LH}
    - Conventional A ~ 3: SN, favorable ∇B
    - Low-A ~ 1.5: CDN
    - A ~ 1 (Pegasus): None observed to date
  - ITPA calls for P_{LH} studies at low A

P_{LH} (A) for Favorable Single Null Diverted D Plasmas [4]

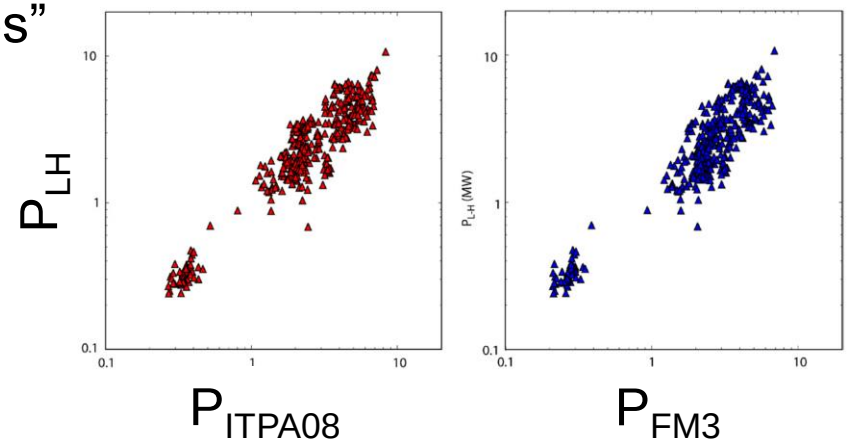


[1] R. Maingi *et al.*, Nucl. Fusion **50**, 064010 (2010)
[2] Y.R. Martin *et al.*, J. Phys.: Conf. Ser. **123**, 012033 (2008)
[3] J. Wesson, Tokamaks (4th ed.), Oxford Univ. Press (2011), p. 630
[4] K.E. Thome *et al.*, EPR 2014

Multi-Machine Experiments Necessary to Characterize $P_{LH}(A)$ Over Appropriate Range

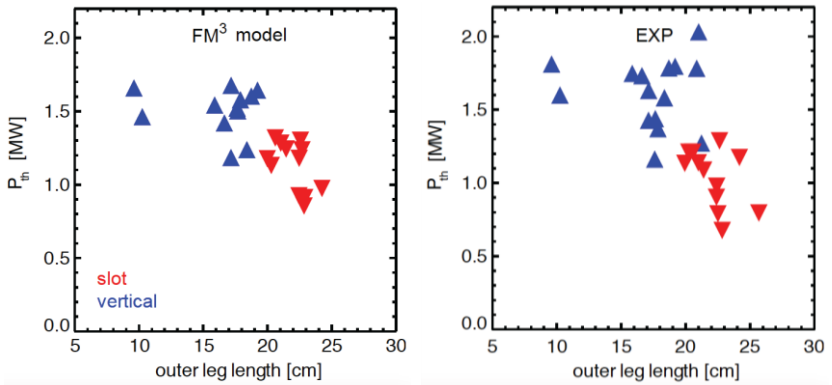
- Recent analytic P_{LH} model[5] (FM3) may explain other observed "hidden variables"
  - Captures ITPA08 scaling in: B, n_e, S
  - $P_{LH,limited}$ / $P_{LH,diverted}$ related to edge q
  - Links P_{LH} $n_{e,min}$ to edge collisionality
  - Favorable experimental comparisons on C-Mod, TCV, and Pegasus

FM3 P_{LH} Model Captures ITPA08 Scaling Behavior [5]



- Multi-machine experiments in US facilities can collectively span wide range of A
  - Low A (NSTX-U)
  - Conventional A (DIII-D)
  - Near-unity A (Pegasus)

Alcator C-Mod $P_{LH}(L_{||})$ compared to FM3 scaling.[6]



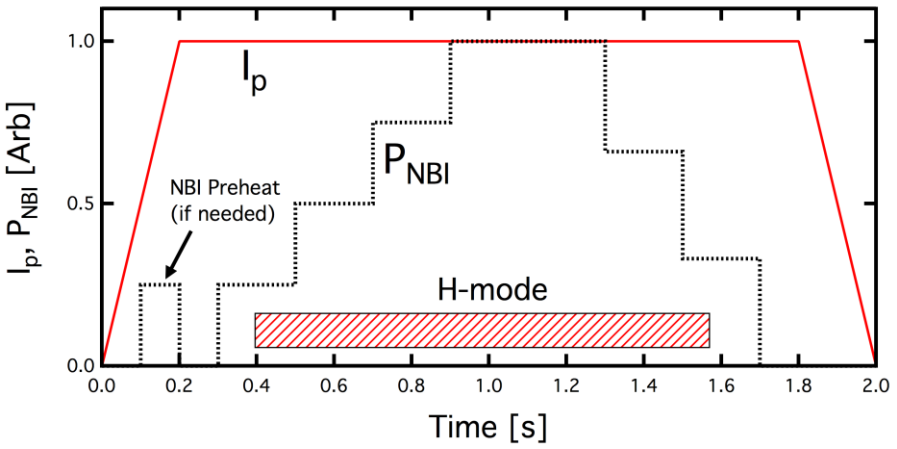
5 W. Fundamenski *et al.*, Nucl. Fusion **52**, 062003 (2012)
6 Y. Ma *et al.*, 24th IAEA FEC, San Diego, No. EX/P2-04 (2012)

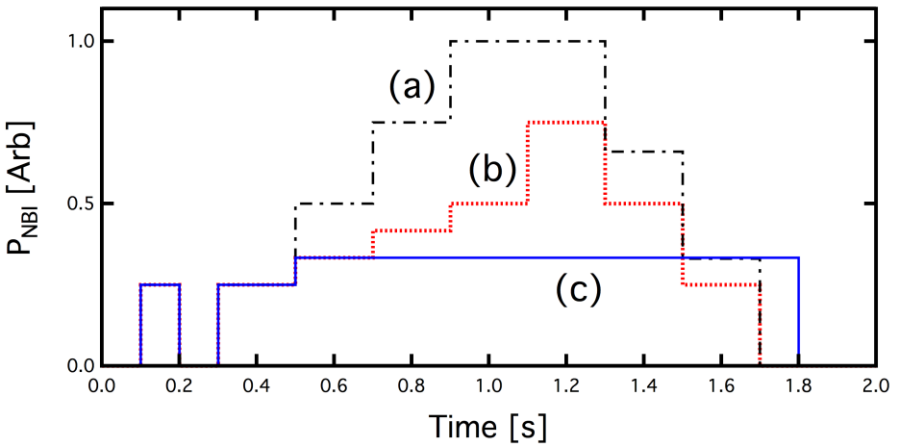
XP 1511 Objectives: Measure P_{LH} in Scenarios Relevant to FM^3 Model

- NSTX-U to provide low-A (~ 1.6) portion of multi-machine study
  - Pegasus: (A ~ 1.2); DIII-D (A ~ 2.5) proposed
- Elements
  - Magnetic geometry scan
    - Favorable SN, Limited, DN
  - Edge q scan
    - NSTX-U q_{95} ~ 10
    - Pegasus-like: $q_{95} > 15$
    - DIII-D-like: low $q_{95} < 10$
  - Document edge profile evolution over L-H, H-L transitions
  - Vary NBI tangency radius mix
- Document edge parameters, dynamics with 2D BES, TS

Methodology: P_{LH} Measured with P_{NBI} Scans

- Nominal discharge phases
  - I_p ramp over ~0.2 s
    - Remaining in L-mode
  - L-mode quiescent phase
    - Ends at latter of 100 ms post I_p flattop or terminating NBI preheat
  - NBI power ramp for L-H
    - 4 power levels, 200 ms duration
  - NBI power reduction for H-L
    - 2 power levels, 200 ms duration
- P_{LH} refined via P_{NBI} level scans
  - Coarse (a): $\Delta P_{coarse} = P_{max}/4$
  - Fine (b): $\Delta P_{fine} = P_{coarse}/3$
  - Confirmation (c): no L-H





P_{LH} Scenarios and Prioritizations

B_T [T] \ I_p [MA]	0.6	1.2	1.4
0.4			*DIII-D-like low q_{95}* *LSN [6]*
0.65	*Pegasus-like, high q_{95}* LSN + R_{tan} [2] *DN [5]*	*NSTX-U nominal q_{95}* LSN + R_{tan} [1] LIM [3] DN [4]	

Table 1: Operating scenarios for P_{LH} evaluation. Scenarios are numbered by their prioritization.

- Scenarios 1–4: P_{LH} in NSTX-U, Pegasus-like configurations
  - High-R_{tan} beam mix scans at high, low I_p in favorable LSN topology
  - 21 shots [incl. 6 contingency/development]

- Scenarios 5–6: Time/success permitting
  - q_{edge} topology effects in high, low q configurations [8 shots, incl. development]

Required Machine / Diagnostic Capabilities

- MPTS, CHERS, MSE profile diagnostics required
- Edge turbulence diagnostics strongly preferred
  - 2D BES
  - GPI
  - Reflectometry
- Availability of NBI source 2A [R_{tan} = 130 cm] required for beam tangency scan
- XP1511 should be scheduled after several X(M)Ps:
  - XP1522: intends to develop stable L-mode targets; minimizes development efforts
  - XMP for MPTS outer gap alignment
  - XMP for CHERS compatibility with 2nd NBI line