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Boundary Physics Topical Science Group summary

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FY 2010 NSTX Mid-run Assessment

27 August 2010
Princeton, NJ

Boundary Physics TSG priorities are defined by

- **DOE and NSTX Milestones**
  - **FY2010 DOE Joint Research Target:** Conduct experiments on major fusion facilities to improve understanding of the **heat transport in the tokamak scrape-off layer** (SOL) plasma, strengthening the basis for projecting divertor conditions in ITER.
  - **FY2010 Research Milestone R(10-3):** Assess H-mode **pedestal characteristics and ELM stability** as a function of collisionality and lithium conditioning
  - **FY2011 DOE Joint Research Target:** Conduct experiments on major fusion facilities to improve the understanding of the physics mechanisms responsible for the **structure of the pedestal** and compare with the predictive models described in the companion theory milestone.
- **NSTX-U planning needs and ST development path needs**
- **ITPA participation, ITER needs**

Three Boundary Physics TSG priorities have been defined for FY 2010 run

- Compare divertor heat flux widths to midplane density and temperature widths and edge turbulence characteristics, and determine the scaling of SOL and divertor heat transport (**FY2010 Joint Research Milestone**)

- Determine the relationship of ELM properties to discharge boundary shape, lithium conditioning, and 3D resonant magnetic perturbations (RMPs), and compare stability of pedestal / ELMs with model calculations (**Milestone R10-3**)

- Understand and develop a predictive capability for the physics mechanisms responsible for the structure of the H-mode pedestal (**FY2011 Joint Research Milestone**)

FY2010 BP TSG Experiments are to support APS DPP invited talks and IAEA FEC presentations

- APS Invited Talks:
  - J.-W. Ahn
  - J. Canik
  - A. Loarte
  - V. A. Soukhanovskii

- IAEA FEC presentations:
  - J. Canik, Oral, Optimization of Density and Radiated Power Evolution Control using Magnetic ELM Pace-making in NSTX
  - R. Maingi, Oral, Modification of Edge Profiles, Edge Transport, and ELM Stability with Lithium in NSTX
  - V. A. Soukhanovskii, Poster, Synergy between the “Snowflake” Divertor Configuration and Lithium Plasma-Facing Component Coatings in NSTX
  - J.-W. Ahn, Poster, Divertor heat and particle flux profile modification during 3-D field application in NSTX
  - J.-K. Park, Poster, Title not available

Six XPs are completed (or nearly completed)

- **XP 1043, R. Maingi, FY2010 JRT on thermal SOL transport**
  - measured divertor heat flux footprint as function of shaping (δ, drsep), P_{in}, I_p, C-Mod/DIII-D comparison shape
  - May require extra 0.25-0.5 day for additional data
- **XP 1046, J.-W. Ahn, Effect of externally applied 3D fields on divertor profiles**
  - Documented effect of n=3 perturbation on divertor as function of ν, q_{95}, I_p, P_{in}
- **XP 1048, J.-K. Park, RMP threshold of ELM modification at different q_{95}**
  - Measured threshold of the n=3 perturbation field strength and spectrum on ELM triggering
- **XP 1044, A. Diallo, Increasing the Range of Achievable Pedestal Height**
  - Measured pedestal structure scaling with I_p but not B_t
- **XP J. Boedo, SOL transport and turbulence with lithium conditioning**
  - Measured SOL profiles in low-power ELM-free H-modes as function of LITER rate
  - May require extra 0.25-0.5 day for additional data
- **XP 1045, V. A. Soukhanovskii, "Snowflake" divertor**
  - Obtained “snowflake” divertor configuration and characterized divertor heat and particle fluxes, May require extra 0.5 day for additional data

High-priority experiments reviewed (or not) but not yet executed

- XP1026, A. Loarte, Effects of ELM control with resonant magnetic perturbation on edge power fluxes between and at ELMs (1 day, ITER run time reserve)
- J. Canik, Density pumpout due to RMPs as a function of collisionality (0.5 day, ITER run time reserve)
- XP 1051, S. Zweben, Test of LLD Electrodes for SOL Control (0.25 day)
- XP 1050, V. A. Soukhanovskii, Radiative divertor with impurity seeding (0.5 day)
- D. Battaglia, ELM suppression using 3D fields from a single row off-midplane coils on NSTX (1 day, ITER run time reserve)
- R. Goldston (w/ MS and WP TSGs), Edge harmonic oscillations (1 day)

New experiments proposed to strengthen IAEA and APS talks

- J. Canik, 0.5 day: Watching ELMs disappear with optimum diagnosis of turbulence
- R. Maingi, 0.5 day: Are peeling modes responsible for ELMs in NSTX?
- V. A. Soukhanovskii, 1 day: Study of “snowflake” divertor in high-triangularity ELM-free H-mode discharges

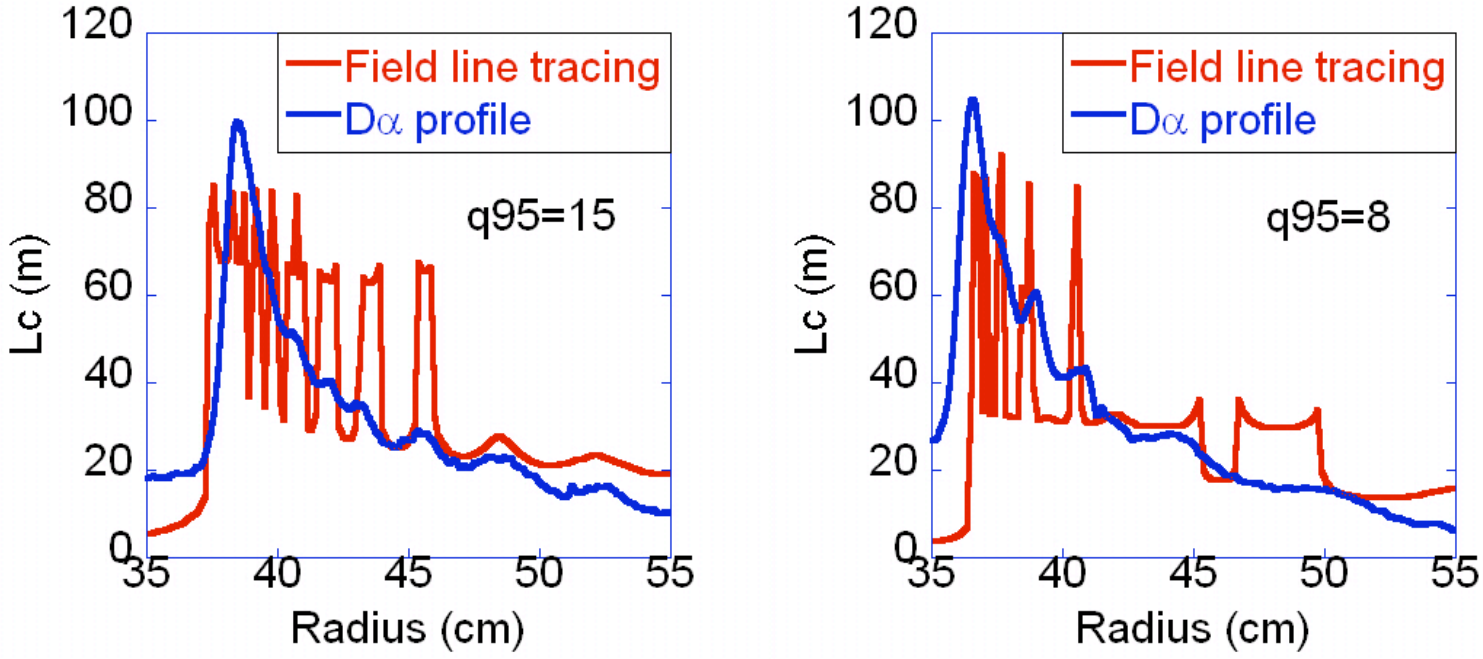
Backup

XP1043 (R. Maingi): FY2010 Joint Research Target on SOL transport is completed

- Goal 1: measure SOL heat flux footprint at high δ
  - ✓ NBI scan: 2-6 MW in 1 MW increments at 1.2, 0.8 MA
  - ✓ I_p scan 0.7 – 1.3 MA at 4 MW and B_t=0.45 T
  - ✓ B_t scan from 0.33-0.55 T at 0.8 MA, 4 MW
  - ✓ *Made a great dataset for t_E scaling analysis*
- Goal 2: measure heat flux footprint in C-Mod/DIII-D low-κ, near-DN shape
  - ✓ Got I_p between 0.72-0.8 MA, few NBI levels
- Goal 3: measure heat flux footprint as a function of d_r^{sep}
  - ✓ High δ: got data at d_r^{sep}= 0, -2.5, -5, -7.5, -1 cm
  - ✓ Low δ: got data at d_r^{sep}= -0.7, -1.3 cm; *desire d_r^{sep}=0 cm*

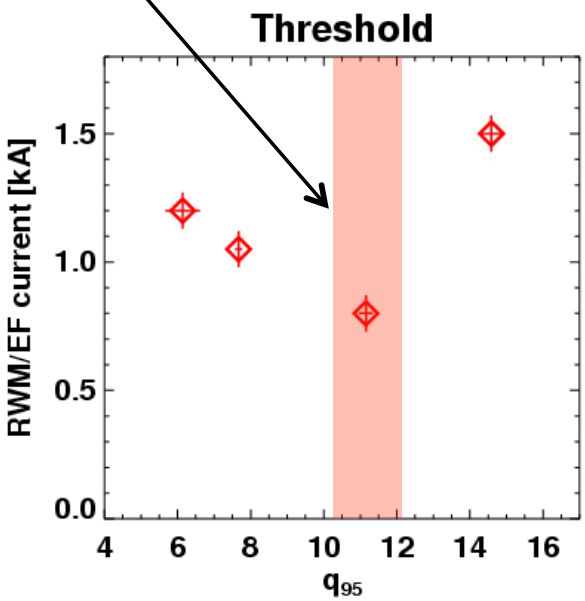
XP1046 (J.-W. Ahn): Effect of externally applied 3D fields on divertor profiles – has been completed

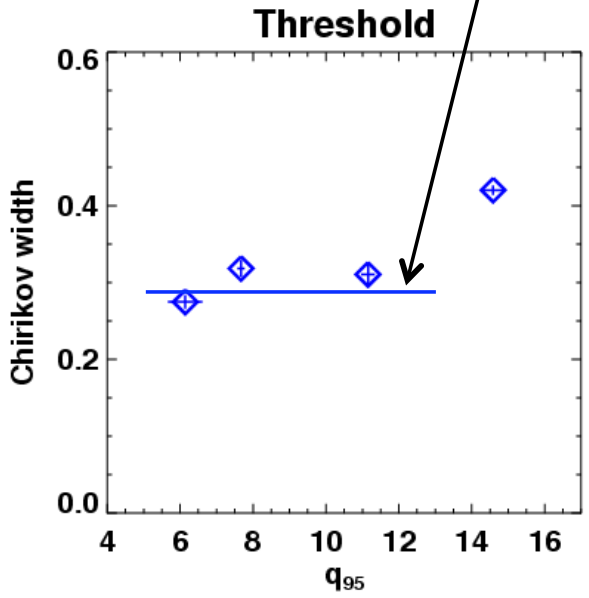
- Fine collisionality scan: 5 P_{NBI} points x 3 density points
- Stable n=1 footprint data and static phase scan – 6 points
- q95 scan in conjunction with XP1048 (Park) – 4 points
- Initial result re-confirms the usefulness of vacuum field line tracing to predict the separatrix splitting



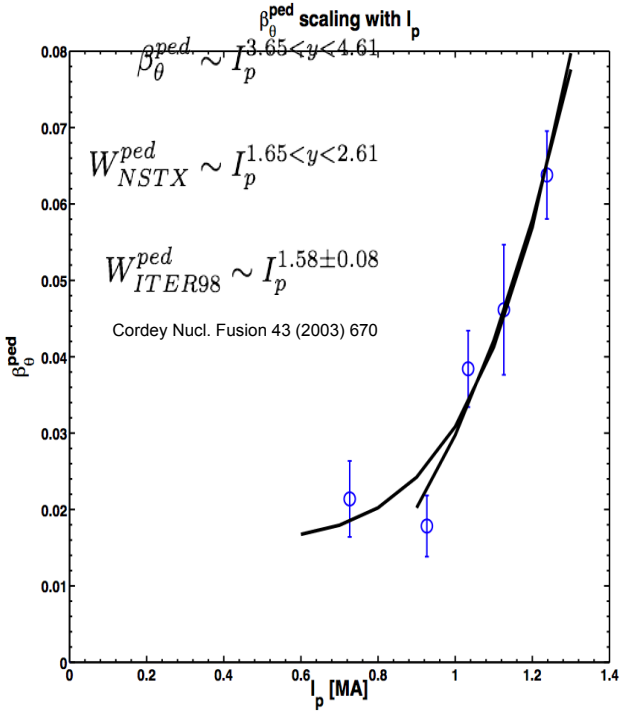
XP 1048 (J.-K. Park) successfully measured 3D-field thresholds for ELM triggering

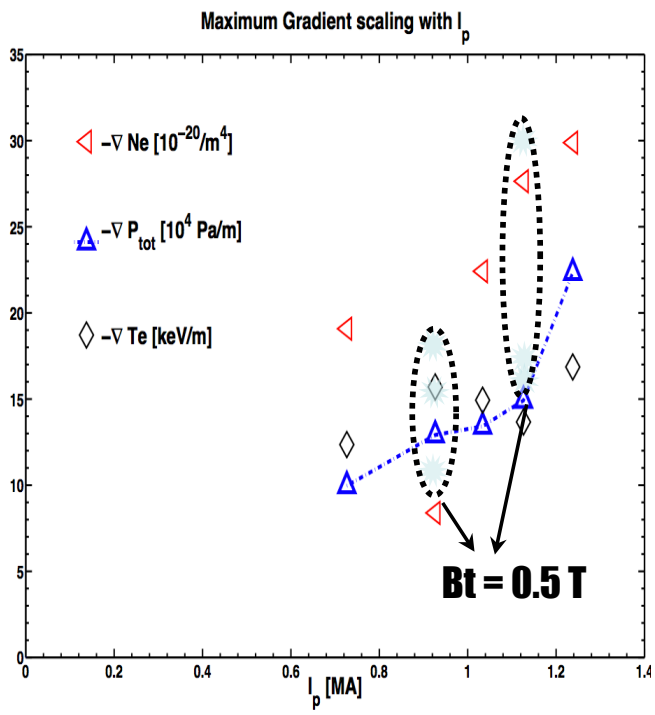
- Target plasmas : I_P=0.7~1.3MA, 3MW beam, 300mg LITER, high κ~2.5, high σ~0.8, q_{95}=6~15
- For q_{95}=6~11 : Lower threshold for higher q_{95}, stochastic layer (vacuum Chirikov > 1) width ~ 0.3
- For q_{95}>12 : Higher threshold for higher q_{95}
- Optimal q-window ~ 11 for ELM triggering?

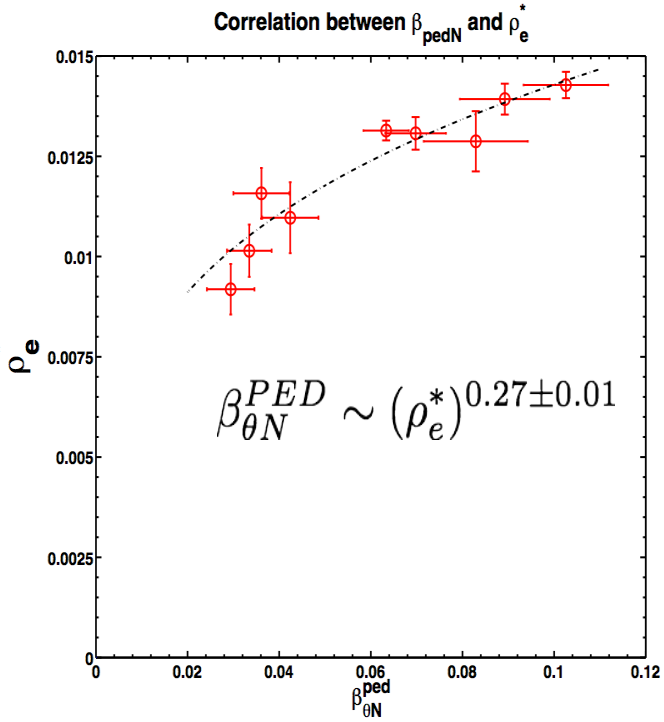




XP1044 (A. Diallo): Preliminary analysis show scaling of the pedestal height and the maximum pressure gradient with Ip.

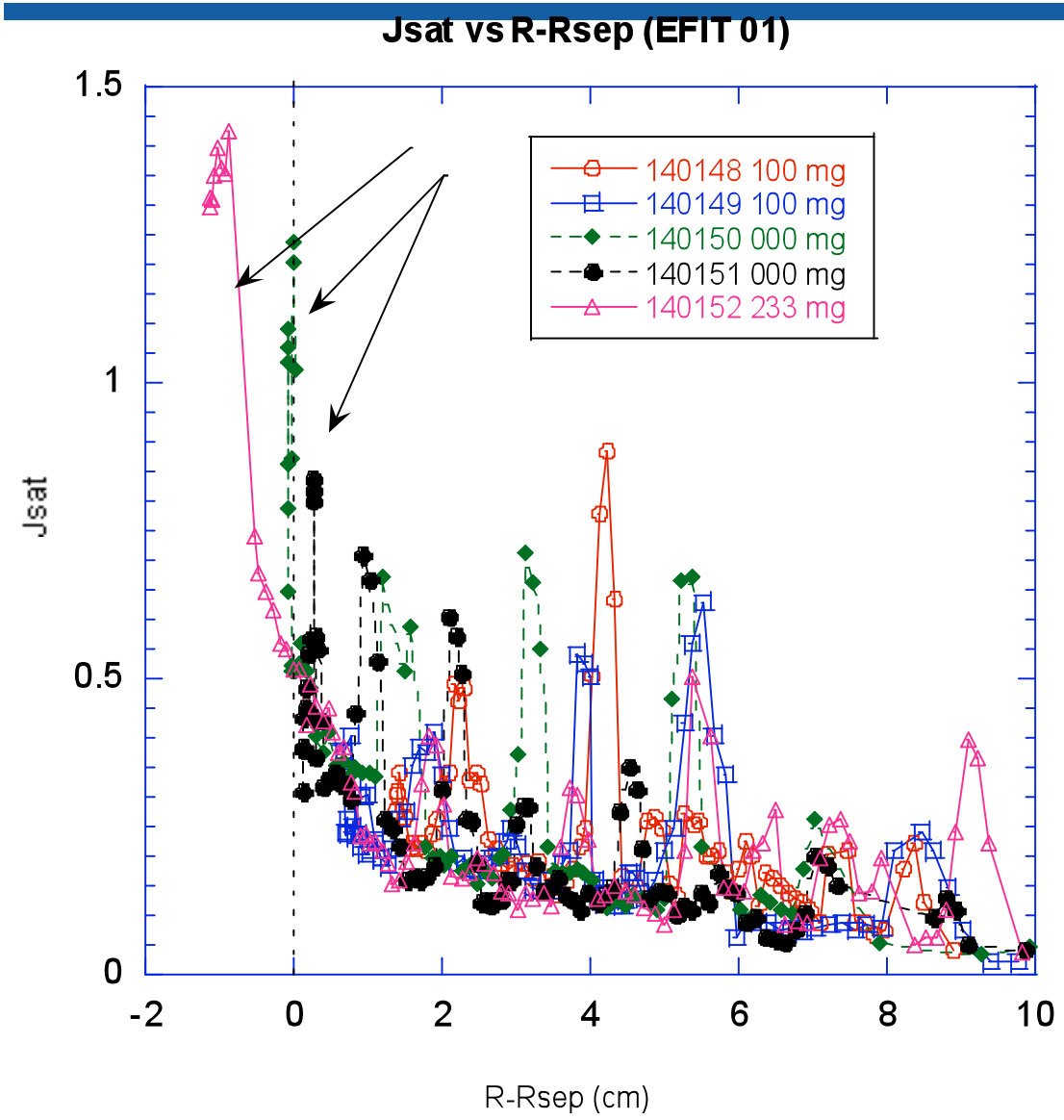






- Goal: Perform Ip and Bt scans at fixed plasma shape near the MHD stability limit to advance the predictive capability of the pedestal height for low r/a devices and correlate inter-ELM fluctuations with the pedestal structure.
- Preliminary Results:
  - Strong scaling of Ip with the pedestal poloidal beta (compared to ITPA/ITER98 scaling).
  - The pressure gradient scales with Ip at constant Bt ~ 0.45 T. Evidence that the density gradient plays a greater role (compared to the temperature gradient) in the critical pressure gradient of the pedestal.
  - No discernible pedestal height variation with Bt possibly perhaps due to the narrow range magnetic field mixed with poor reproducibility of some of the discharges of the 1/2 day Bt scan.
  - Obtained correlation between the normalized pedestal beta with rhos evaluated at electron pedestal temperature suggesting that the pedestal width (described by rhos) scaling cannot be explained with a simple beta scaling.
- Assessing correlation of fluctuations in the pedestal-SOL region with the onset of ELMs: So far no clear evidence of intermediate k fluctuations present during the last 50% of the ELM cycle - Need to be able to clearly discern inter-ELM fluctuations from intrinsic MHD activity (*ELM pacing approach could be beneficial in resolving the causality issue*).

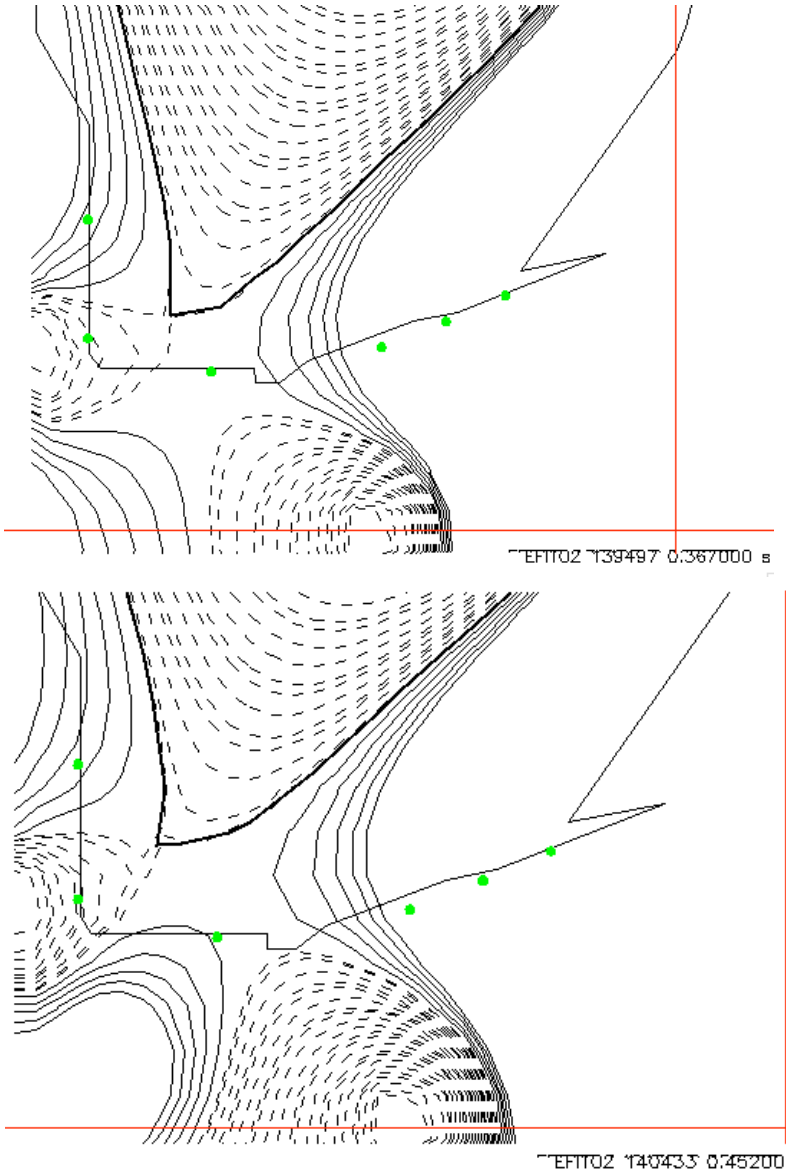
XP (J. Boedo): SOL profiles almost identical, Pedestal shows differences as lithium rate changed



- Data shows NO/LITTLE difference (aside small ELMs) in the SOL
- Only difference seems to be where the pedestal rises near R-Rsep=0
- In 140152 (233 mg li) the pedestal is~0.5-1 cm further in
- In 140150 and 140151 (0 ms lithium) the rise is closer to the nominal R-Rsep=0
- We conclude that the transport changes occur inside, or at, the LCFS.

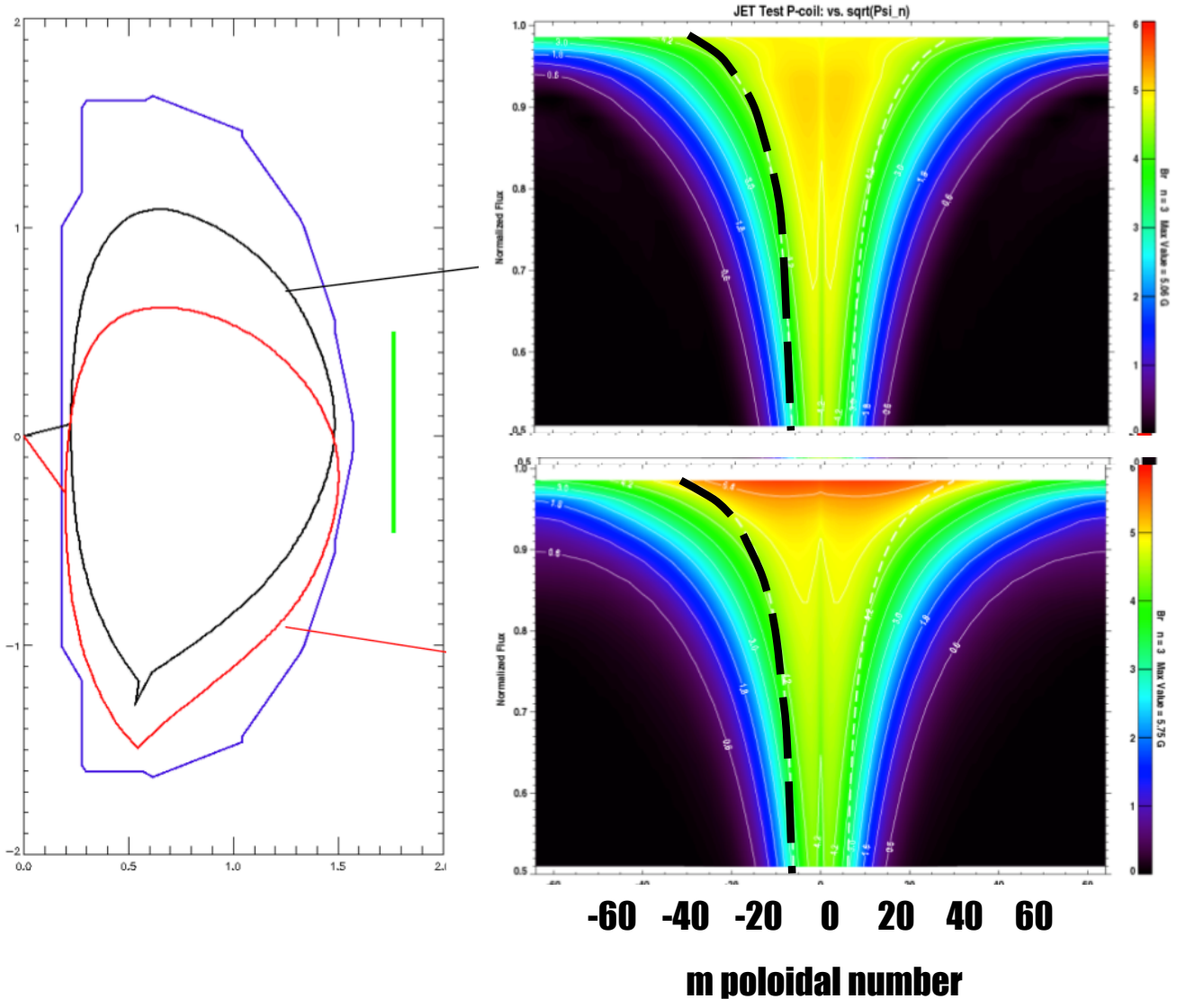
XP 1045 (V. A. Soukhanovskii): "Snowflake" divertor in NSTX

- Obtained SFD configuration with PCS SP control in medium-δ discharges (two-coil SFD)
  - Much improved control of SPs and SFD
  - Still periods of SFD for 100-200 ms
  - Few measurements for these shots
- Obtained SFD with three coils (w/ reversed PF1B)
  - Steady-state SFD for nearly discharge duration, however, all shots are ELMy
  - Obtained full divertor data for I_p=0.8-1 MA, P_{in}=3-6 MW
  - Impact of PF1B field on SFD to be clarified



XP1030 (Battaglia): ELM suppression using off-midplane resonant perturbations

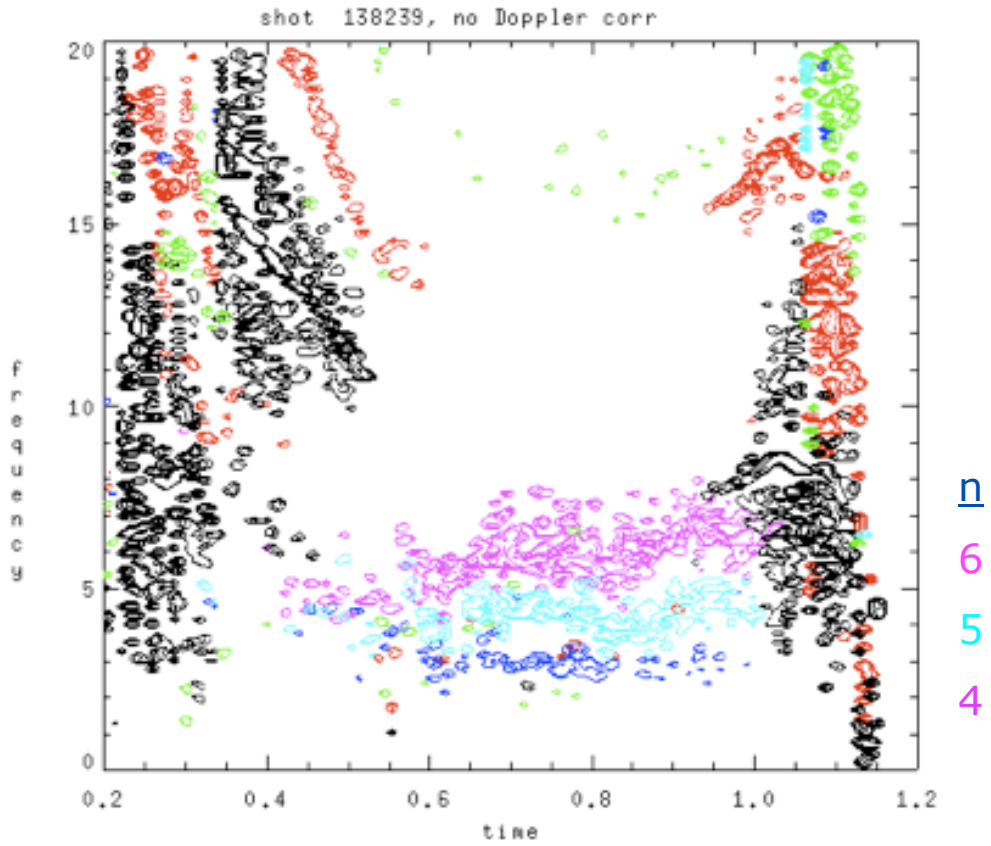
- Shift plasma down 20 cm or more
  - Improves resonant coupling
  - Reduces non-resonant amplitude (reduced braking)
  - Off-midplane NBI
- ITER relevant
  - What is needed to suppress ELMs with RMPs?



XP 1051 (Zweben): Effect of divertor electrode biasing on local SOL transport

- Motivation: learn whether the divertor plate particle flux can be controlled by local electrode biasing
- Goal of XP: bias electrodes in Bays E and K and measure effects on local probes and visible emission

XP 1068 (R. Goldston): Driving EHOs with Amplitude-Modulated HHFW

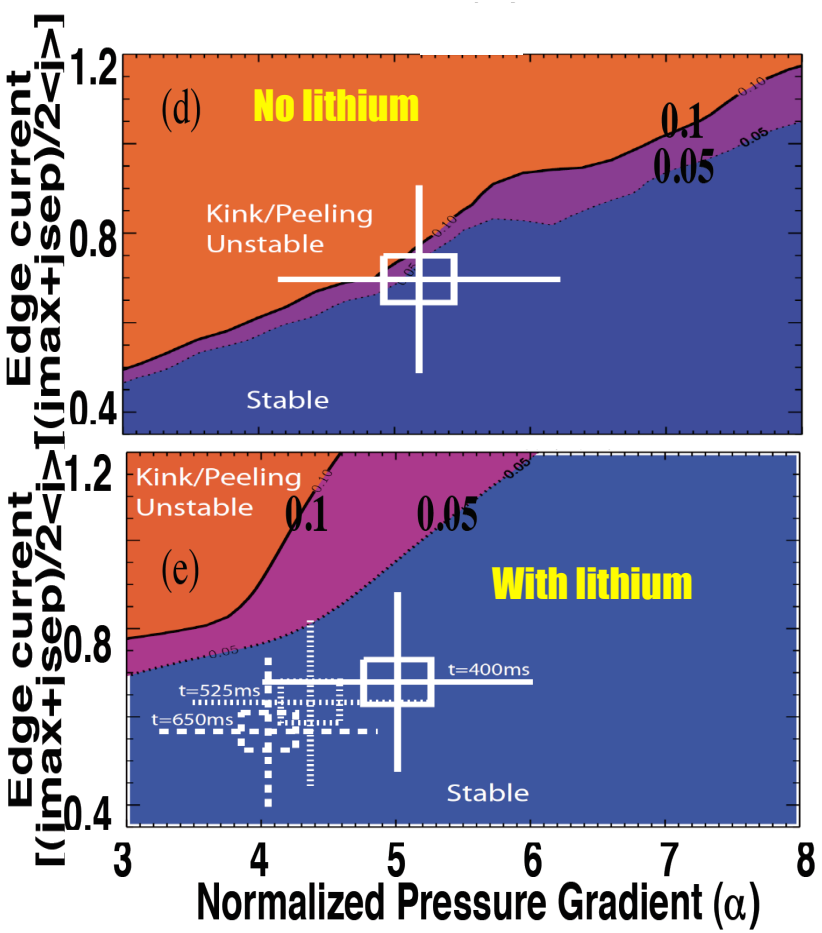


- We have observed EHO's in ELM-free shots w/o low n MHD.
- They do not clearly reduce impurity increase.
- But what if we could amplify them?

- External control of H-mode pedestal particle transport could allow long pulses in NSTX.
- Could also provide ELM control in ITER.
- Later, try audio frequency currents from SPAs?

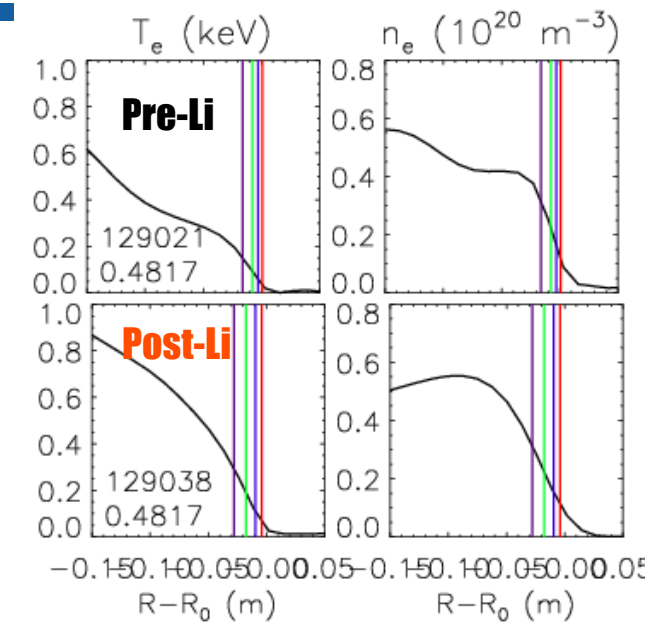
New XP (R. Maingi): Are peeling modes responsible for ELMs in NSTX?

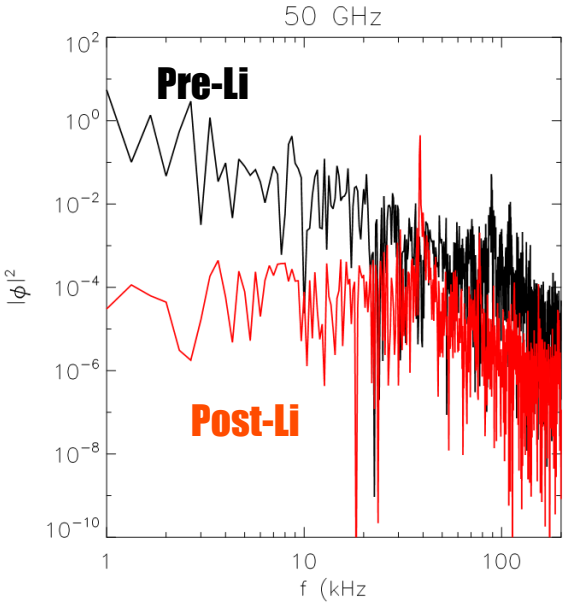
- ELMs can be suppressed with Li wall coatings
- Stability calculations suggest pre-Li discharges close to peeling stability boundary, i.e. far from ballooning
- Propose: I_p ramps to change edge j
  - Re-establish pre-lithium discharges, e.g. 129015
  - Add $+I_p$ ramp: 0.1 MA in 0.2 sec
  - Add $-I_p$ ramp: 0.1 MA in 0.2 sec
  - No Li between discharges; 7 min HeGDC
  - Request ½ day
  - Will support IAEA 2010 oral



New XP (J. Canik): Watching ELMs disappear with optimum diagnosis of turbulence

- Support of Canik's APS invited talk
- As lithium is applied…
  - ELMs disappear
  - Pedestal density profile shifts inwards, relaxes
  - Transport barrier widens, χ reduced near edge
  - Good documentation of these was obtained in 2008 and 2009
- New XP aims for more comprehensive turbulence measurements to correlate with reduced edge transport
  - Fixed frequency reflectometer data indicative of reduced fluctuation level
- ½ day XP: start with ELMy H-mode, add lithium until ELMs are suppressed
  - With improved turbulence diagnostic set: High-k scattering, addl. reflectometers, BES





New XP (V. A. Soukhanovskii) Study of "Snowflake" divertor in highly-shaped ELM-free H-mode discharges

- XP1045 used medium-δ targets with PF1AL and PF2L coils for "snowflake" divertor
  - Often had a 300 ms event due to OSP in CHI gap
  - Had Type I ELMs - unable to characterize core impurity density evolution
- Use fiducial-like high-δ, high-κ startup scenario with a transition to "snowflake" divertor in flat-top
  - Add PF1B in flattop, and later add PF2L
  - This avoids OSPjumps across CHI gap, keeps δ high at all times
  - Offers a chance of ELM-free H-modes to study the impact of "snowflake" divertor on impurity accumulation
  - Would significantly contribute to IAEA Poster and APS Invited, potentially address PAC questions and NSTX-U needs
  - XP would include shot development, I_p, P_{in} scans, LITER scan