Lithium Research Topical Science Group

16 June 2009

Purpose of meeting is Preparation for mid-run assessment (MRA) 9:00 AM on Wednesday 17th (tomorrow).

MRA agenda:

- List of accomplishments
- List other remaining high-priority XPs (assuming 1-3 days of run time).
- LRTSG allocated 18 mins presentation by CS + 7 mins for discussion.

This is NOT a Group review of new XPs (insufficient time to review 5 of them)
Nor formal results review (will come later).

Remaining LR TSG XP previously prioritized by BP TSG in December:

XP913 Initial use of Li Dropper (1 day top priority, 1/2 day 2nd priority).

Need to make most compelling case for additional run time e.g. data needed for LLD, PAC requests, ITPA, 5 year plan … .

Need to identify any XPs that would like TF reversal (or say that we would prefer not to spend 1-2 days reversing TF).

Agenda:

Brief Review of past XPs (CS)

- XP837 Recovery of Lithium Wall Conditions
- XP911 Li pumping and retention in NSTX.
- XP950 Dependence of metallic impurity generation.
- XP951 Diffusive Li injection.

Future XPs for second 1/2 of campaign. '√' means already prioritized.

- XP913 (1.5d √) Mansfield Initial use of Li dropper.
- Canik / Rajesh "Dependence of energy confinement enhancement on lithium coating thickness" (0.5d)
- Joon-Wook "Measurement of SOL widths in ELM-free H-mode plasmas" (0.5d)
- Vlad: "Pumping capability of lithium coatings and LLD" (0.5 ?d)
- Stewart: "Effect of lithium coatings on edge turbulence in NSTX." (0.5 d)
- XP911 Skinner "Retention with heavy Li conditioning + Sample probe". (0.5 d)

Total 4 d (cf 1-3 day guidance).

- Is there a consensus on prioritizing 4 additional XPs ?
- Group Position on TF reversal ?
- *Need to compress to 18 min presentation.*

Overview of XP827(2009), Recovery of Lithium Wall Conditions and ELM Mitigation in High-δ Discharges
H. Kugel et al.,

- XP-827(2008) LITER Characterization and ELM Mitigation in Low-δ Discharges was rerun as Recovery of Lithium Wall Conditions and ELM Mitigation in High-δ Discharges.
- High-δ, Ip = 1 MA discharges were established, and lithium was evaporated on to the lower divertor, in increasing amounts using selected rates from 16 to 50 mg/minute, in deposition sequences applied for 10 or 8 minutes each, with the pre-deposition HeGDC gradually decreased from 10, 8, 6, 4, to 0 min.
  - the high-δ discharges, became increasingly ELM-free, relative to the pre-lithium reference discharges, and finally ELM-free.
- Then, low-δ discharges were obtained for two different conditions, and closely reproduced the same 2008 ELM-free discharges.

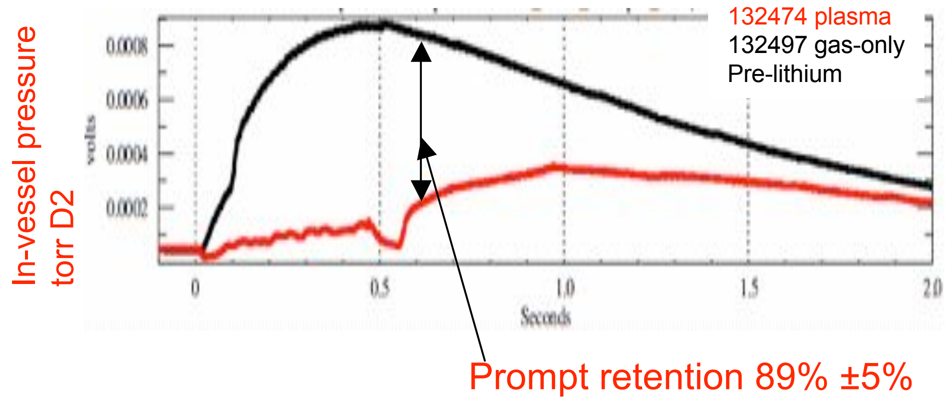
XP827 Summary and Conclusions

- Initial results found that the deposition of relatively thin coatings of lithium
  - increased the plasma current pulse length relative to the before-lithium reference discharges,
  - caused earlier H-mode transitions,
  - significant density reduction in the early part of discharges calling for more fueling,
  - increasing electron temperature, electron stored energy and confinement time,
  - reduced OV/CIII impurity ratios.
- As the net lithium deposition increased
  - the high elongation discharges, relative to the pre-lithium reference discharges, became increasingly ELM-free, and finally, became ELM-free.
  - the discharge pulse length, with lithium wall conditions and RWM applied, increased to about 1.2 sec,
  - OV and OV/CIII impurity ratios decreased below those following boronization, and approached the 2008 levels.
  - a high-δ, H-mode, discharge was obtained with 1 MW NBI (1.8 MW total) with Tau-E of about 100ms.
  - Eventually the HeGDC was reduced to 0 minutes, allowing the increased duty cycle.
- Then, low-δ discharges were obtained for two different conditions, that closely reproduced the same 2008 ELM-free discharges.

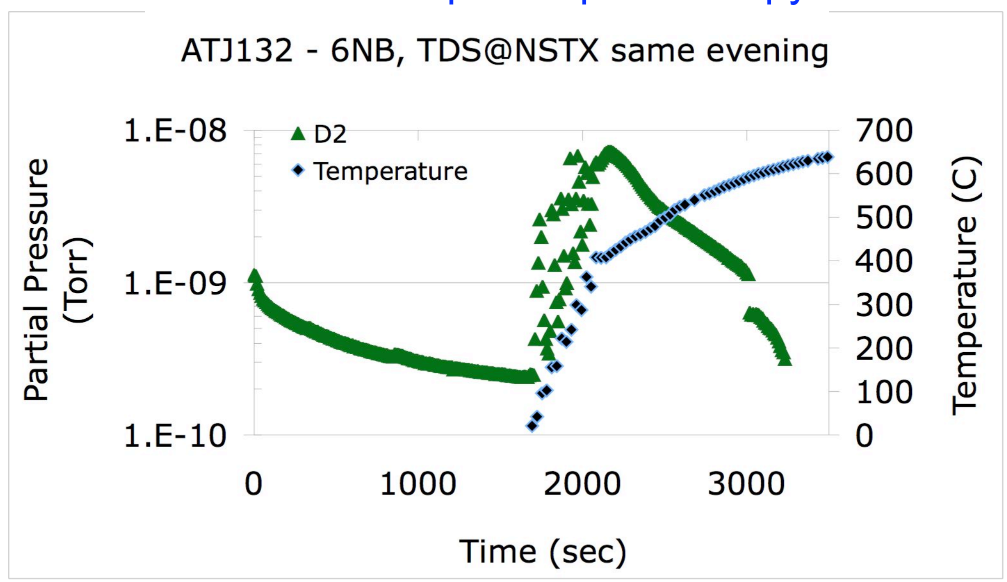
XP911 Preliminary results.

C. H. Skinner et al.,

- Gas balance measurements showed high (>90%) prompt retention, that decreased due to post-shot outgassing.
- As part of a collaboration with Purdue University ATJ graphite, Si and Pd samples were exposed to the plasmas by a sample probe at Bay J.
- After exposure, thermal desorption spectroscopy was performed on an ATJ sample. Background thermal desorption from samples unexposed to NSTX plasmas was also measured.
- Twelve samples have been shipped to Purdue University for further surface analysis



Thermal Desorption Spectroscopy



X-ray Photo-electron Spectroscopy of ATJ samples exposed on sample probe.

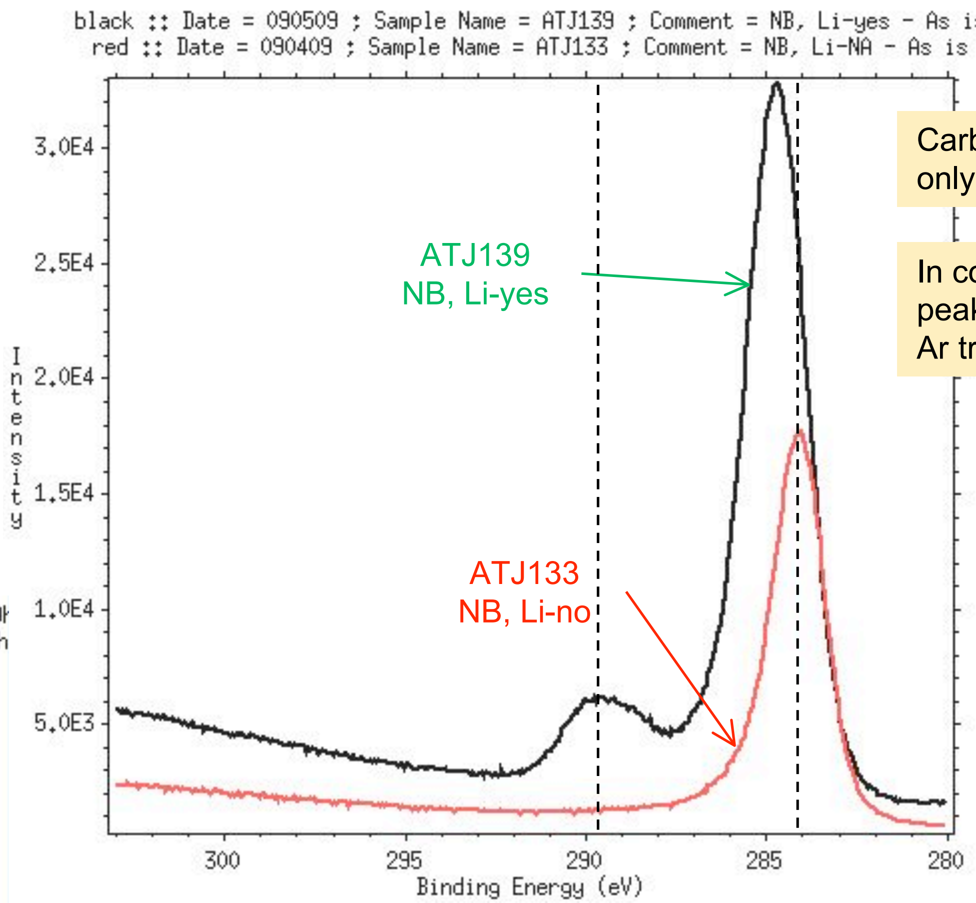
Sample of results:C1s peaks in lithiated vs. non-lithiated - NB

ATJ139

- <u>Lithium</u> conditioning
- 6 NSTX NB plasma shots
- Ar cleaning
- TDS performed at Purdue
- XPS at Purdue

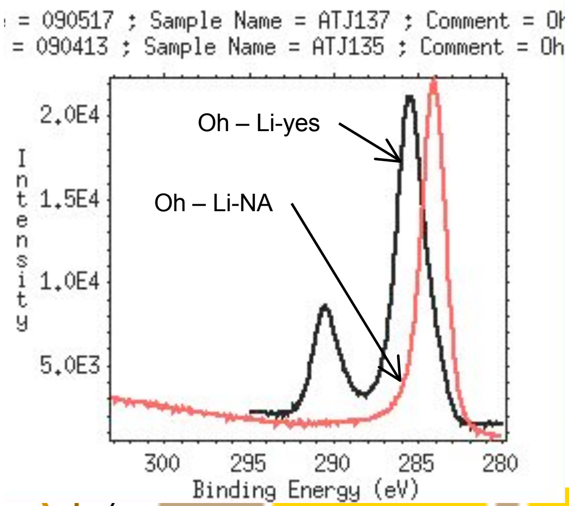
ATJ133

- <u>No lithium</u> conditioning
- 6 NSTX NB plasma shots
- Shipped to Purdue under Ar
- TDS at Purdue



Carbonate peak develops only on lithiated surfaces

In control studies, carbonate peak develops ~290eV after Ar transfer or air exposure



Graphitic peak is at a higher energy after Li conditioning for both NB and Ohmic plasmas

RSSEL

PURDUE UNIVERSITY

XP-950: Dependence of metallic impurity accumulation on I_p and the outer gap in the presence of lithium deposition

S. Gerhardt, S. Paul et al.,

Motivation:

- Li-conditioned ELM-free scenarios are known to suffer from massive radiated power if they achieve long pulse.
- Speculation/lore what that large outer gap or high I_p would limit the impurity accumulation, that source mix might matter.
  - Test this hypothesis with systematic scans.
  - Try, if possible, to diagnose the difference impurities, impurity sources, and provide operations/infrastructure guidance.

Preliminary results:

- Impurity Accumulation Reduced at large values of I_P and Outer Gap
- Carbon Increases when the Outer Gap Became Large
- Total Radiated Power Reduced with Increasing Outer Gap At I_P=700kA
- For Fixed Gap of 20 cm, high-I_P Had Less P_{rad}, but Similar Rate of Rise, but ELMs may Complicate Analysis

XP951 Improved lithium coverage with diffusive Li injection

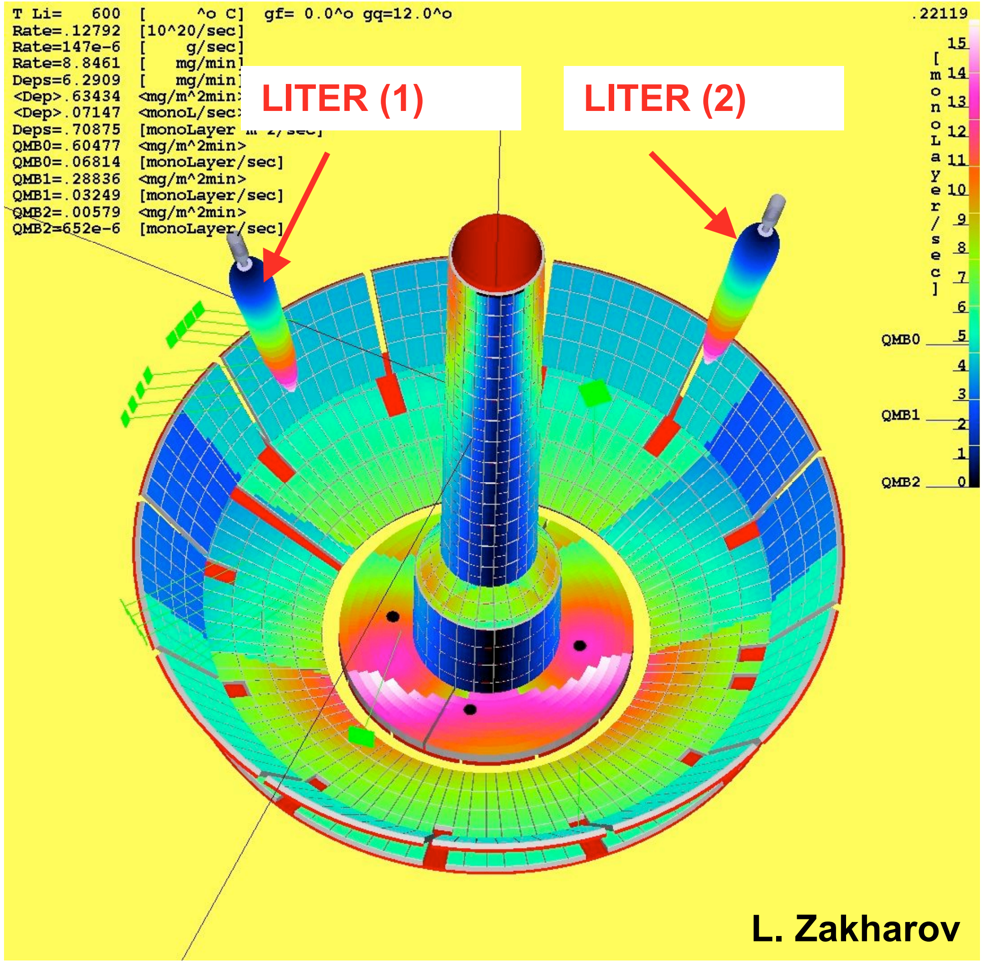
Charles Skinner and NSTX team.

Motivation:

- Density and impurity control is goal of multi-year Li program on NSTX.
- But so far elimination of ELMs by Li has caused impurity accumulation late in discharge.
- Core carbon levels actually increase with Li. (R. Bell).

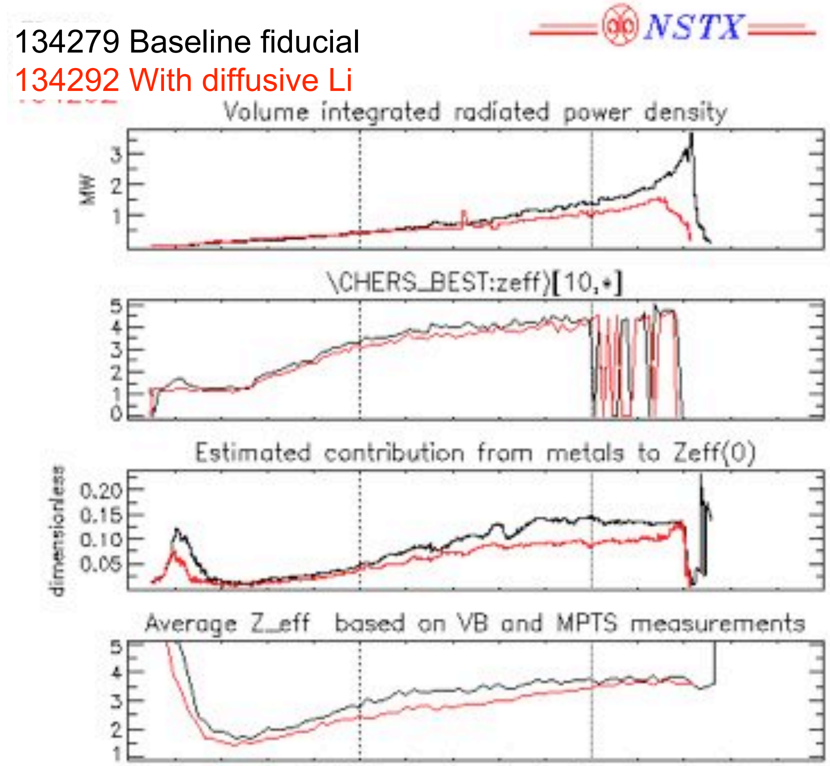
XP951 Plan:

- Inject Li into low pressure He gas.
- Collisions will scatter Li into previously shadowed areas on center stack and upper midplane.
- Vary coverage by varying He pressure and mean free path (e.g. mfp = 17 cm @ 4e-4 torr He).
- Monitor upper QMB, Prad, Zeff…

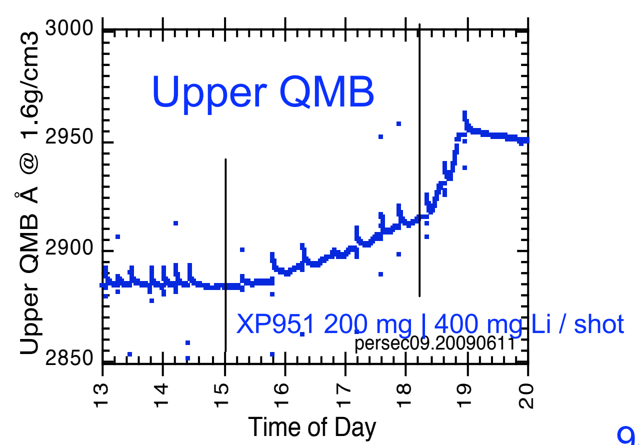


XP951 Preliminary results

- Started with good LSN H-mode fiducial with 200 mg 'regular' Li evaporation into vacuum.
- Varied He pressure in 3 stages during 200 mg LiTER evaporation
  - 1.2e-4 ± factor two (mfp= 0.56 m)
  - 4e-4 torr He ± factor two (<u>mfp= 0.17 m, *best*</u>)
- Double LiTER to 400 mg into
  - constant 25 e-4 torr He (mfp= 0.03 m)
  - constant 10 e-4 torr He (mfp= 0.07 m)
  - constant 4e-4 torr He (mfp= 0.17 m)



- Results showed more pumping (more gas needed) and up to ~20% lower Prad, lower Zeff (VB), Zeff (CHERS), Zeff (metals).
- See expected deposition on upper QMB.
- No large increase in He emission on SPRED.
- Notice 'enhanced' green emission on upper CS.
- Exception is first shot at 1.2e-4 torr He.
- Relevant 'integration time' for Li unclear.
- DEGAS modeling pending.



Potential LRTSG XPs for 2nd 1/2 of campaign

Brief Review of past XPs (CS)

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XPs for second 1/2 of campaign. '√' means already prioritized.

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Total 4 d (cf 1-3 day guidance).

- Group Position on TF reversal ?
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XP913 Initial use of Li Dropper (Mansfield)

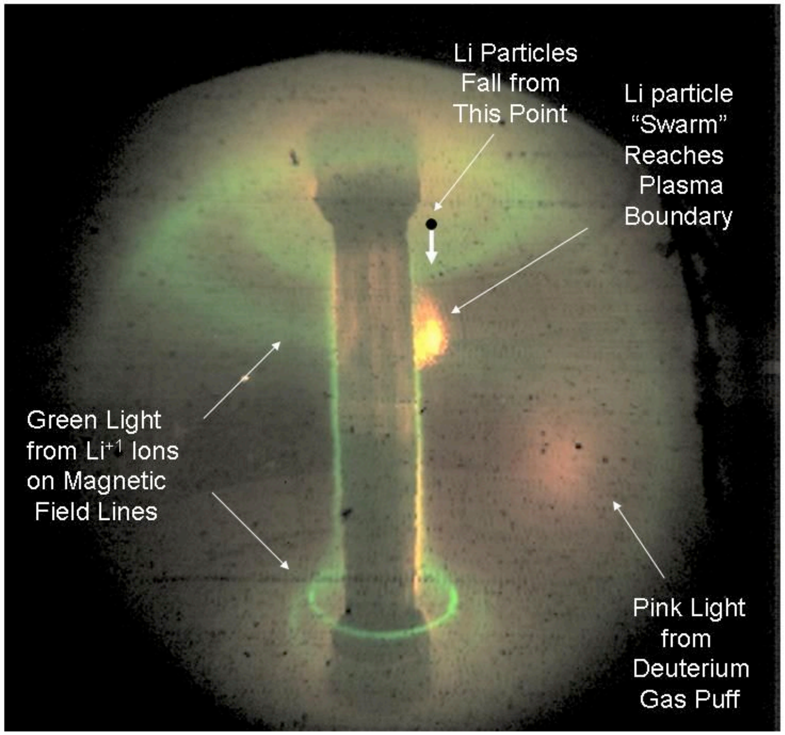
Goal(s) of the XP

- Establish whether or not the 1st aerosol experiment is reproducible.
- Fiducials: H mode by early NBI overdrive - reduced CS gas
  - Early aerosol injection - before L-to-H transition
  - 10 mg/s and higher - probe the limit of Li aerosol mass flux
- Push plasma performance

If time permits

- Investigate synergistic effects with LITER
  - Can aerosol injection suppress impurity influx?

Camera View of Early Li Aerosol Injection Taken at t ~ 60 ms



Already prioritized in BP TSG 1 day 1st priority, 1/2 day 2nd priority.

NSTX

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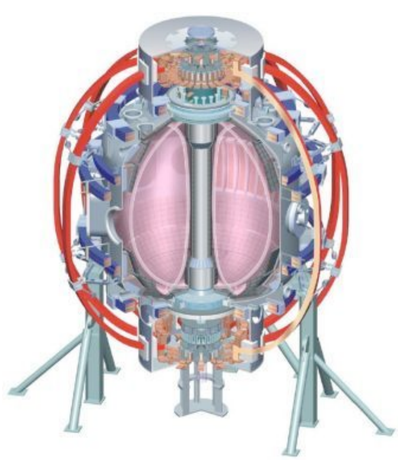
Dependence of energy confinement enhancement on lithium coating thickness

College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

J.M. Canik and R. Maingi, ORNL

NSTX Li Research TSG XP Review
Princeton, NJ
May 29, 2009



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RRC Kurchatov Inst
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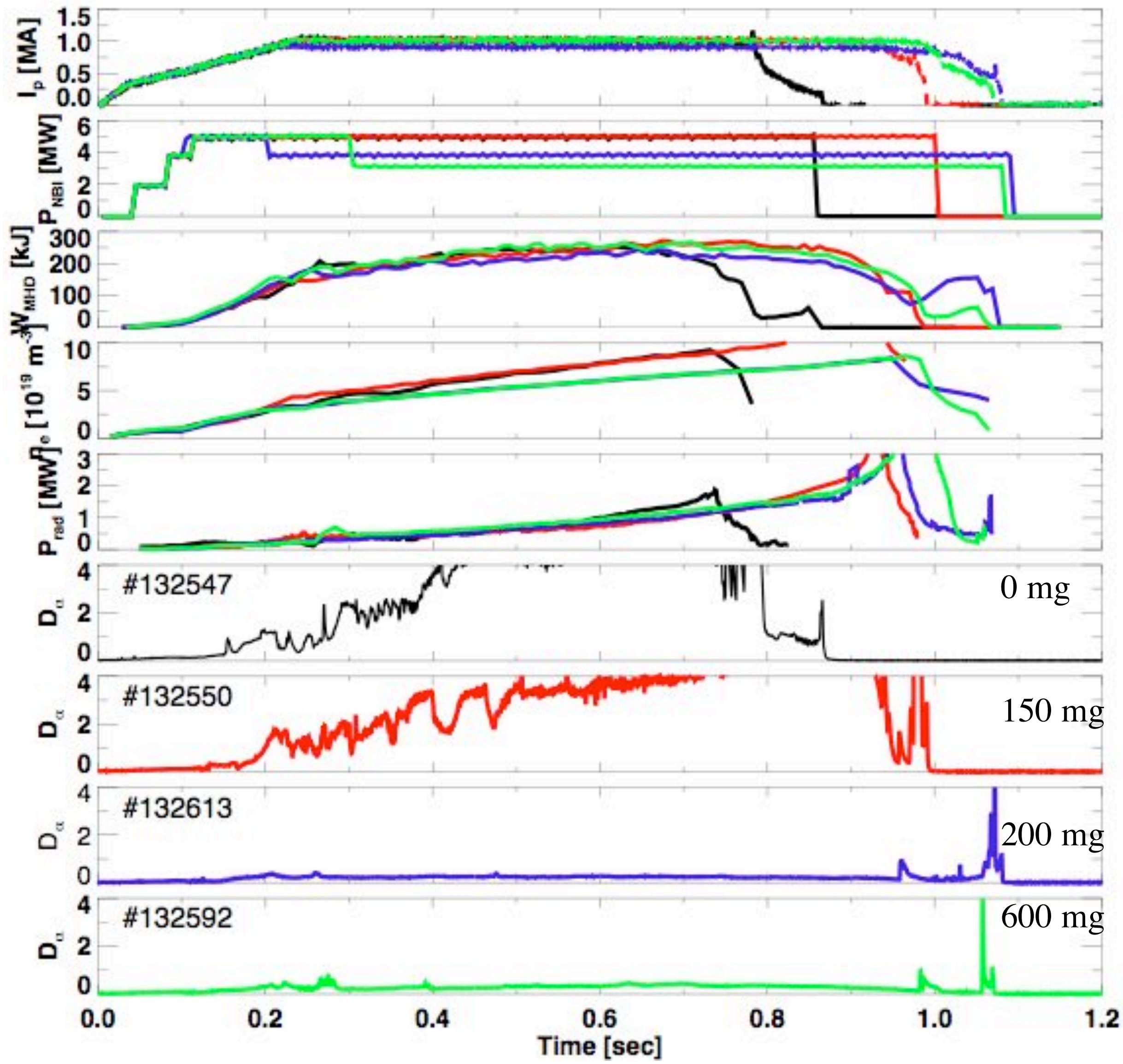
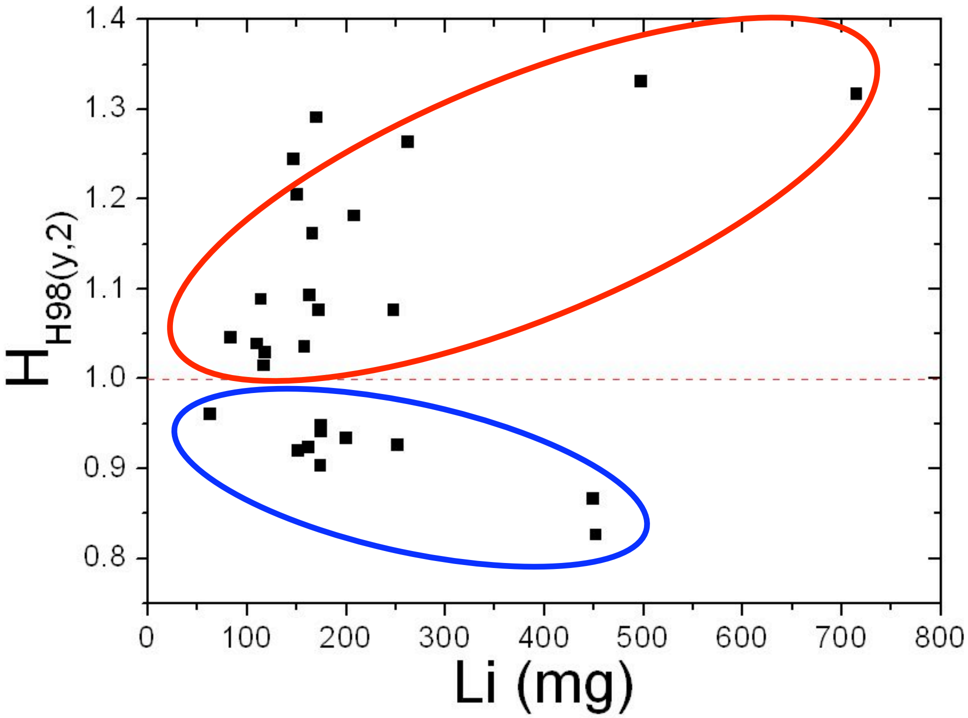
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Plasma confinement seems to increase with deposited Lithium (but…)



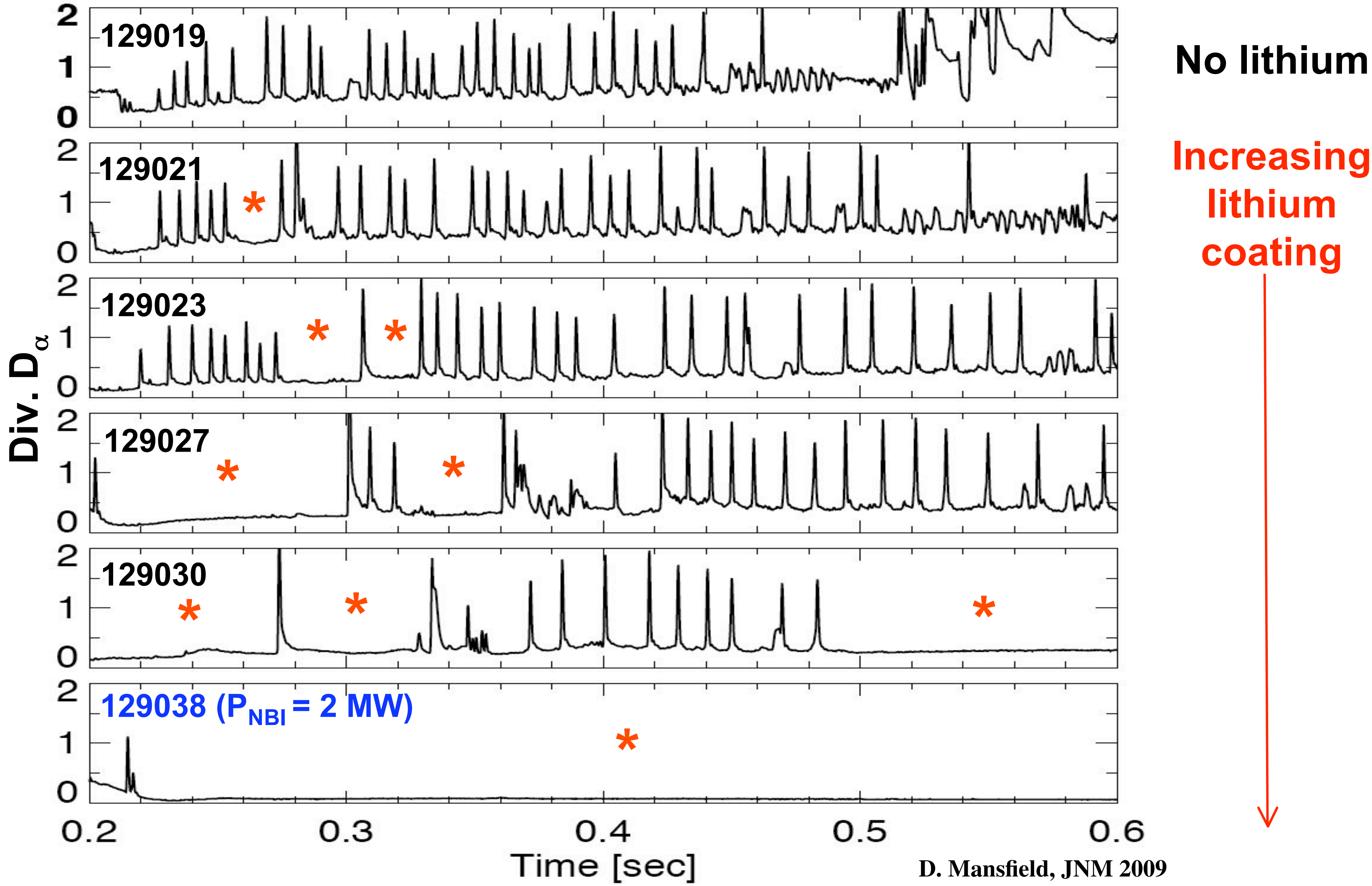
Some evidence for the enhancement of energy confinement increases with the Li layer thickness

- Transport has been analyzed for many shots by S. Ding
- Some of the data shows an increase in the H-factor at very high Li evaporation
  - …but some data shows the opposite trend
- These shots are from many days
  - Need a controlled experiment to conclusively test this



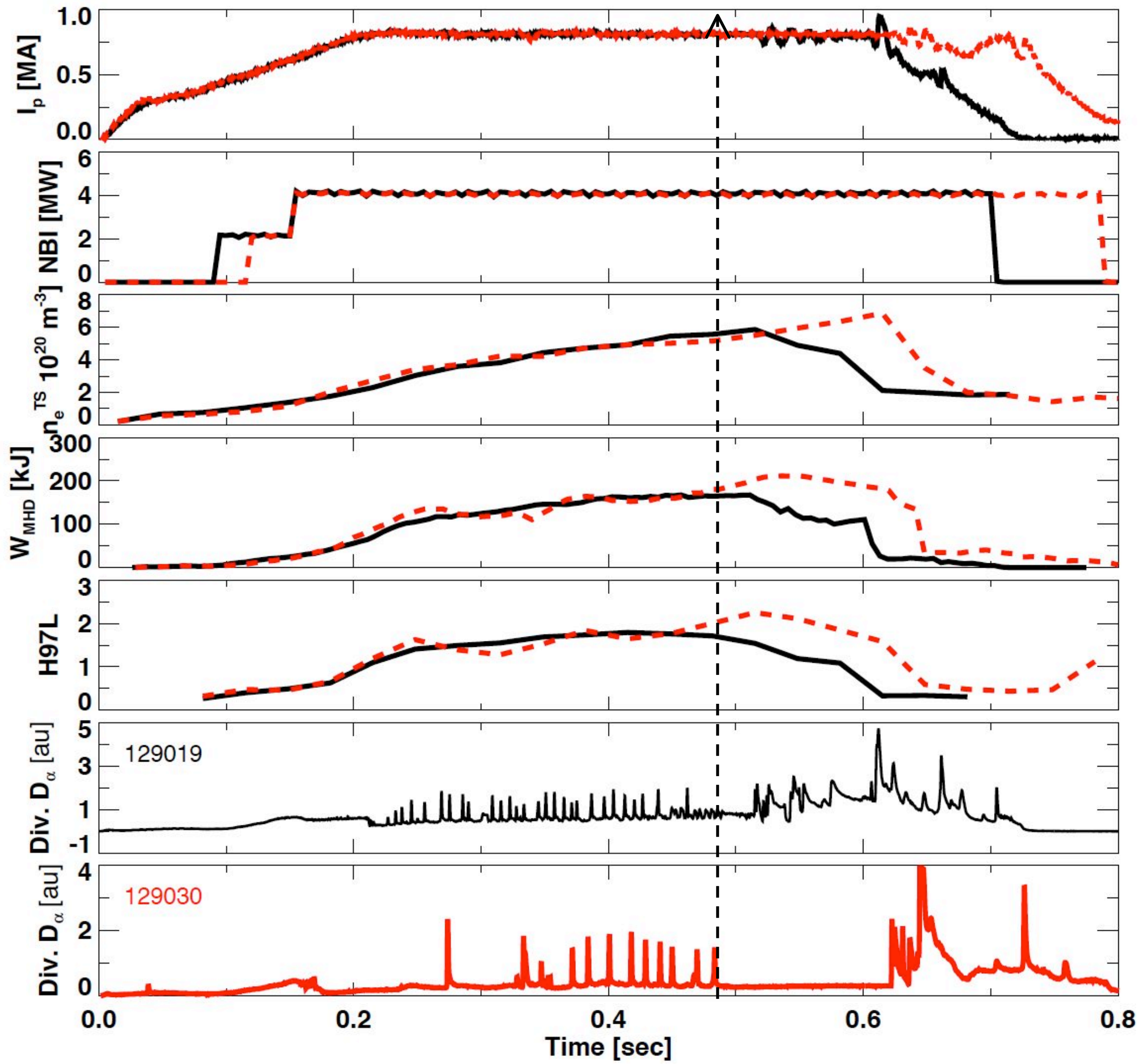
Ding, NSTX physics mtg 5/4/09

Li layer thickness clearly affects the ELM behavior



D. Mansfield, JNM 2009

Stored energy increased after ELMs disappeared



Maingi, TTF 2009

No lithium

With lithium

- ***Does stored energy continue to increase with Li beyond what is required to suppress ELMs?***

Proposed ½ day shot list

- Start with standard fiducial
- Vary amount of Li evaporated between shots
  - 0, 100, 200, 300, 400 and 500 mg/shot
  - Take three shots at each level
  - If confinement is improving with evaporation, extend to 600 mg
- 18-21 shots required, can do in solid ½ day
  - Planning for 10 minute shot cycle, requires high evaporation rate towards the end of the shot list

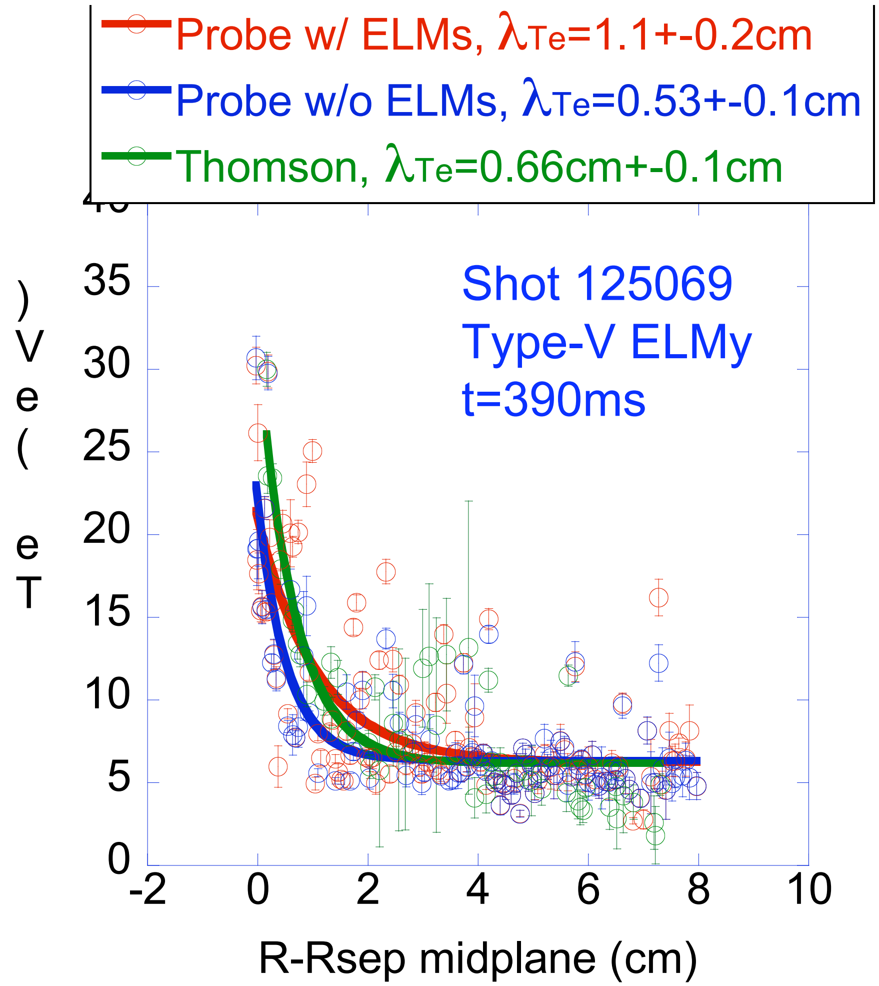
- Possible modifications for group discussion
  - Add in a shot of RMP ELM triggering (at 50 or 60 Hz) at each Li level to test ELM size vs. Li layer thickness?
    - Would start with different shot: 800 kA, kappa ~ 2.5, |drsep| < 5 mm
  - Add a series of shots in L-mode to separate confinement enhancement and ELM suppression?

Measurement of SOL widths in ELM-free H-mode plasmas

J-W. Ahn[1], R. Maingi[1], J. Boedo[2],
J. Myra[3], V. Soukhanovskii[4]

[1]Oak Ridge National Laboratory
[2]University of California – San Diego
[3]Lodestar Research Corporation
[4]Lawrence Livermore National Laboratory

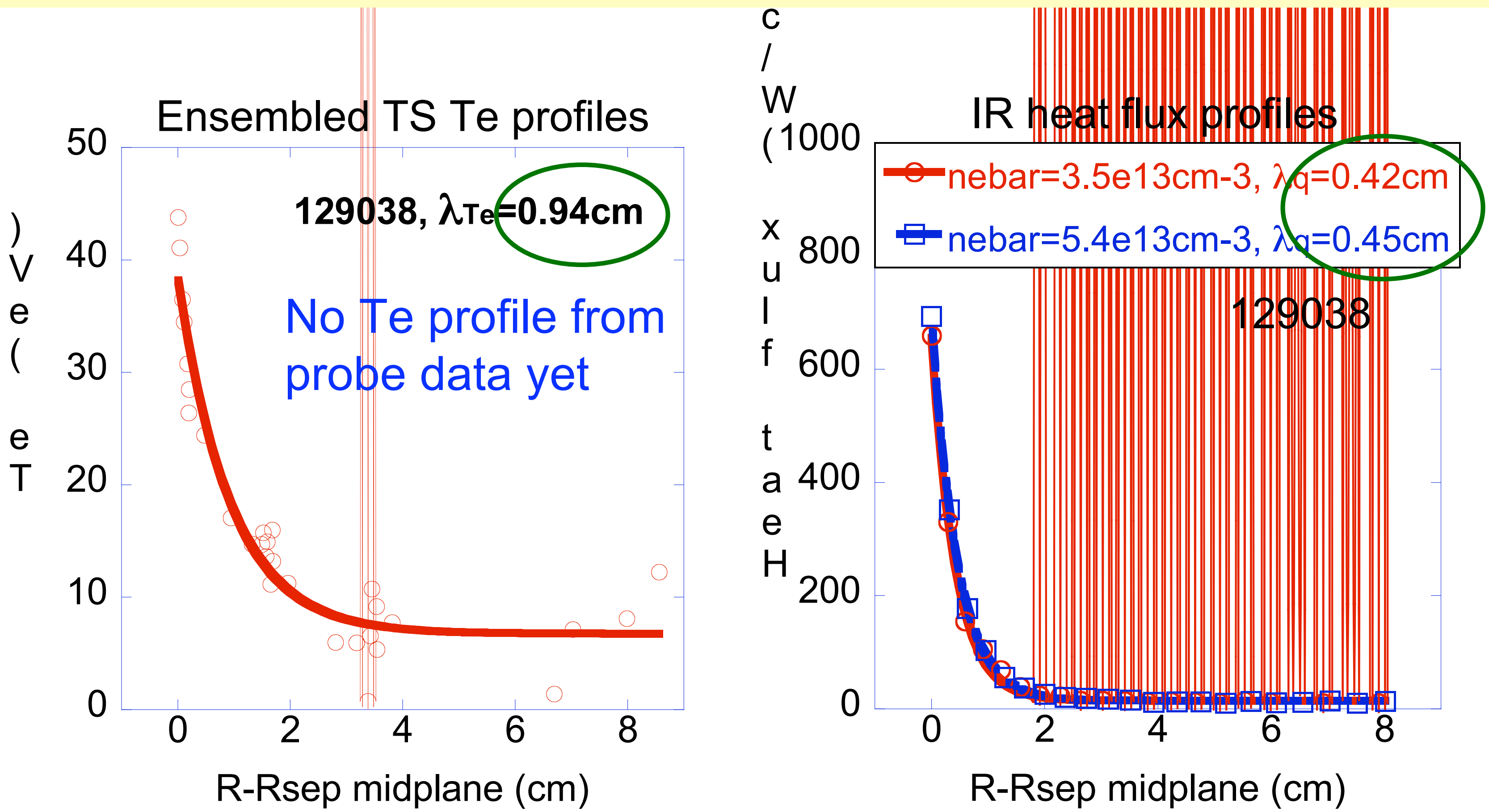
λ_{Te} is strongly affected by ELMs



- Probe measurement is continuously affected by ELMs and blobs
  - measured Te shows high scatter
  - Te SOL width broadens
- Probe I-V data with ELM affected portions removed
  - re-process probe data
  - Te SOL width becomes narrower
- TS measurement is instantaneous
  - misses many ELM filaments in the near SOL
  - effectively represents inter-ELM profile with narrower λ_{Te}

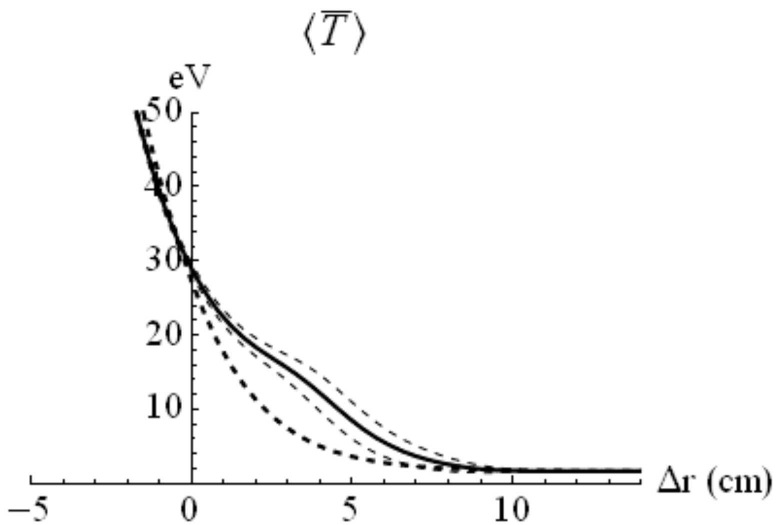
λ_{Te} is highly affected by ELMs, measured by probe

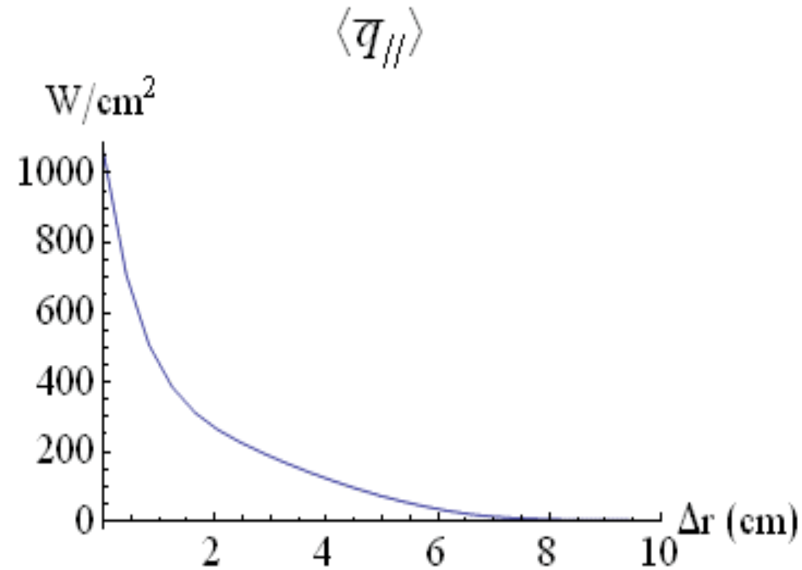
Need probe data for ELM-free H-mode



- nebar continuously rises during the H-mode, by a factor of ~2, with $n_{e,sep}$ fixed
- λ_{Te} and λ_q stays constant at ~0.4cm and ~0.9cm, respectivey
  - λ_{Te}/λ_q ~2, close to prediction from simple parallel power balance model

ELM-free H-mode is good for SOLT modeling





Simulated Te and $q_{||}$ profiles by SOLT (J. Myra, ECC 2009)

- SOLT is strongest without presence of ELMs with electrostatic terms only included at the moment
- Modeling has been focused on L-mode (eg, 112825) so far
- ELM-free H-mode will still have blobs and should be fine for modeling

Experimental Plan

- ELM-free H-mode discharges with assistance from LITER
  - Reference shot: 132601
    (δ=0.5, κ=1.8, I_p=800kA, P_{NBI}=2MW)
- Measure λ_{Te} simultaneously with TS and probe up to LCFS
- Measure λ_q with fast and slow IR cameras
- Repeat to complete measurements at 3 density points at t=300ms, 500ms, 700ms (5 shots for each)

Requested run time: 1/2 day

Summary: Joon-Wook Ahn

- I am proposing a ½ day XP for SOL measurement in Lithium assisted ELM-free H-mode plasmas.
- Titte: Measurement of SOL widths in ELM-free H-mode plasmas-
- Authors: J-W. Ahn, R. Maingi, J. Boedo, J. Myra, V. Soukhanovskii-
- Motivation: Previous SOL measurements in NSTX H-mode plasmas suggest that heat spread on the divertor tiles may be increased by ELMs. This observation was made possible by comparing Te measurements from the probe and Thomson scattering, along with heat flux decay lenghts. We propose to conduct the same experiment in ELM-free H-mode plasmas. This will enable us to directly confirm the role of ELMs in setting Te and heat flux SOL widths. A successful SOLT modeling for an ELM-free H-mode plasma will be also a great advantage for deeper understanding of blobs behavior and its relation to SOL widths.

Vlad:

- **From:** Vlad Soukhanovskii vlad@pppl.gov
- **Date:** June 15, 2009 10:24:26 AM EDT
- **To:** Charles Skinner cskinner@pppl.gov
- **Cc:** Henry Kugel <hkugel@pppl.gov>, Rajesh Maingi rmaingi@pppl.gov
- **Subject: Re: Lithium Research Topical Science Group Meeting B252 10:00 AM June 16th**
- Charles,
- I would like to discuss/propose an XP "Pumping capability of lithium coatings and LLD". We can take advantage of SGI-fueled long pulse H-modes.
- I will try to send you a few slides if I can manage to finish them today. Thank you. Vlad

Effect of lithium coatings on edge turbulence in NSTX

S.J. Zweben, R.J. Maqueda, R. Kaita, H. Kugel, D. Mansfield, L. Roquemore, C. Skinner, D. Stotler et al

Lithium Research Topical Group 6/16/09

Goal: Look for the effects of lithium on SOL turbulence using GPI diagnostic, i.e. before vs. after lithium

Motivation: SOL turbulence determines SOL transport, i.e. plasma parameters at separatrix, so an effect of lithium on SOL turbulence can be a mechanism through which lithium affects plasma as a whole

Physics Issues in this XP

- No known mechanism for lithium coatings (or any surface coatings) to *directly* affect edge turbulence or transport (i.e. not in basic equations of edge turbulence theory)
- Several possible indirect mechanisms based on theory:
  - wall boundary conditions (~ within a Debye length)
  - edge pressure profiles (i.e. ne and/or Ti or Te)
  - edge neutral density, Zeff, and/or radiated power
  - edge flows and/or electric fields

  ⇒ need to measure these other things in addition to wall coatings and SOL turbulence

Practical Issues for this XP

- To do GPI measurements, need to add 1-2 torr-liters of D2 each shot (<< normal D2 fueling rate)
- Therefore need to check effect of this gas puffing on wall conditioning / plasma performance
- Need to decide what to keep constant before / after lithium, e.g. density, egde Te, ELM behavior, etc.

=> Would like to 'piggy back' on other experiments first to get clearer idea of connection between lithium and edge turbulence, if possible

First-Cut Proposal for this XP

- Start with well conditioned lithium wall and 'de-condition' using D-GDC or other means
- Or, start with 'de-conditioned' machine and add lithium
- External parameters (B,I, shaping, etc.) kept constant
- Use GPI and all other edge diagnostics for this XP
- First attempt with simplest case:
  - OH SND plasma, B=4.5 T, I=0.8 MA
  - GPI during flat-top ~ 0.2-0.3 sec
  - use moderate constant gas puff fueling
  - every 3rd shot with no GPI puff to check effect

XP911 revisited

- XP911 was run early in the run with little difference between pre-lithium and with-lithium retention.
- The idea is to repeat for 0.5 day to see if the present heavy Li coating has changed the retention.
- Also use the sample probe to address issues with long term Li exposure …
-