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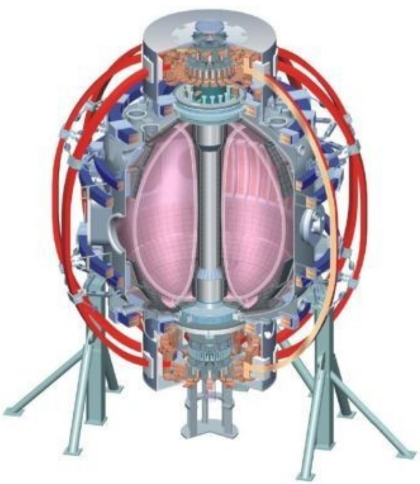
Plasma Electron Spectroscopy (PLES) for Deuterium, Lithium and Impurity Monitoring

M.A. Jaworski (PPPL), *et al.*

NSTX 2011 Research Forum LRTSG Session
LSB-252 – 1:30-5:30pm, March 16, 2011



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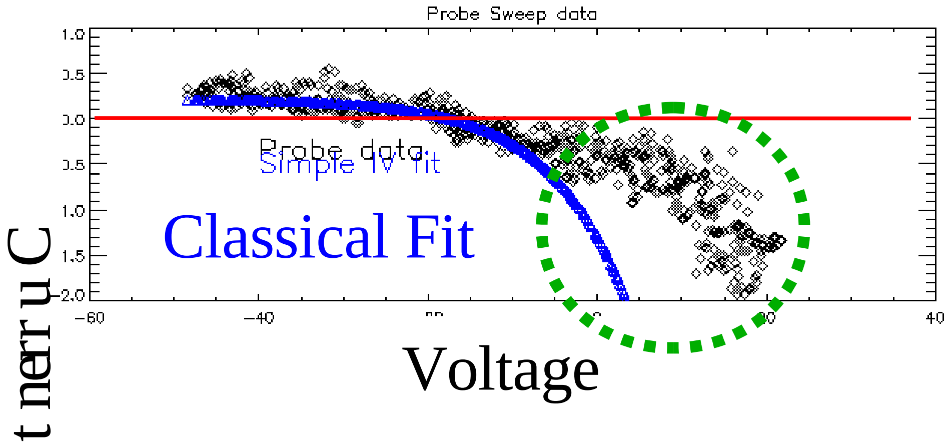
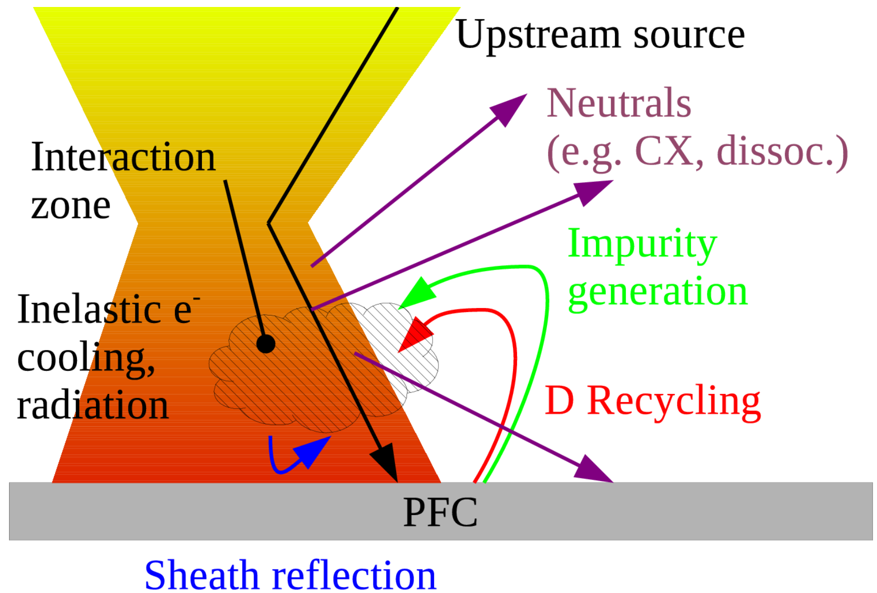
Electron energy distribution function (EEDF) provides insight into SOL processes

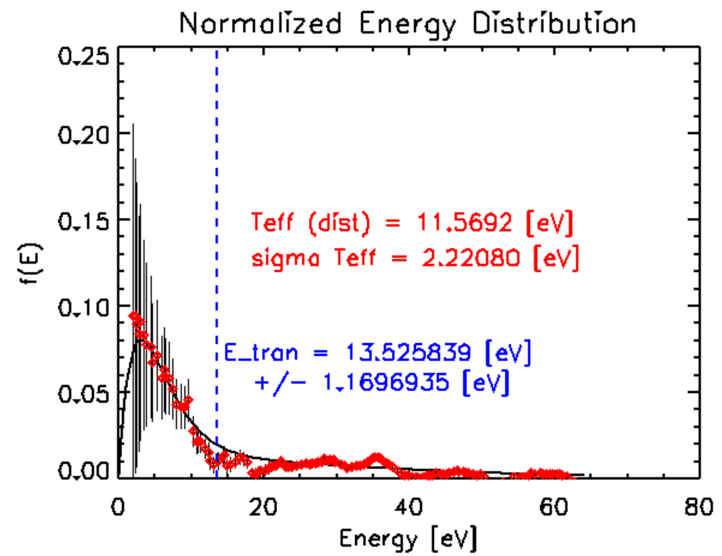
- Classical interpretation “throws away” data above floating potential
- First derivative method (Popov, 2009, PPCF; Arslanbekov, 1995, PSST) provides interpretation of complete characteristic
- In principle, EEDF contains resulting distribution of electrons after numerous interactions in the SOL
  - e.g. inelastic interactions increase low energy population (D or different impurities, diff. energies)
  - Plasma potential can be evaluated for sputter yield estimation

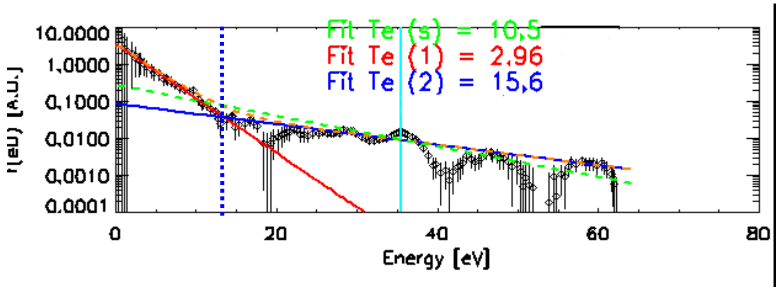


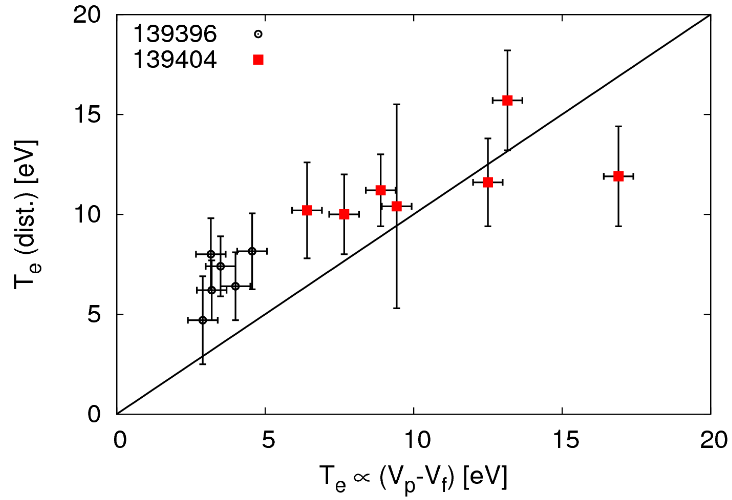


First results are encouraging

- In general, lower Te obtained than classical interpretation, consistent with divertor Thomson comparisons on DIII-D (Watkins, 2001, JNM)
- Bi-modal distribution found to be typical (predicted by kinetic codes of Chodura and Batischev)
- Transition energy in bi-modal distribution typical of deuterium inelastic interactions (many examples of ~13eV transition)
- Suspected deuterium-absorbing LLD shot (e.g. high gas fueling but similar total deuteron content) shows transition to higher temperatures via larger hot fraction

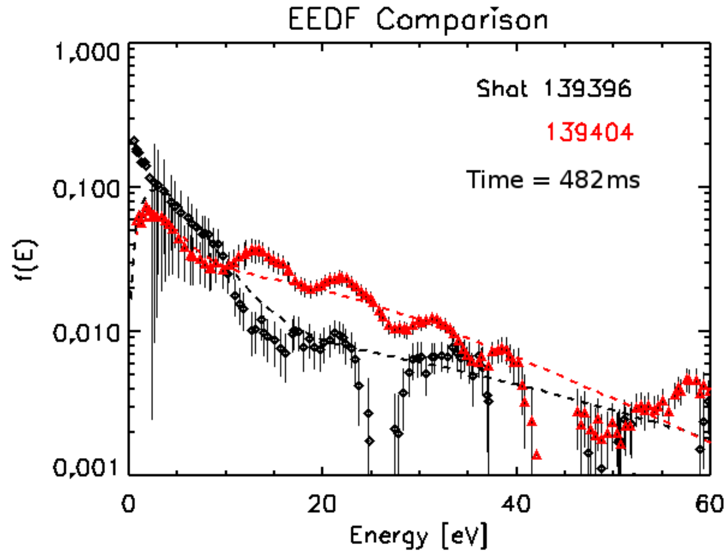




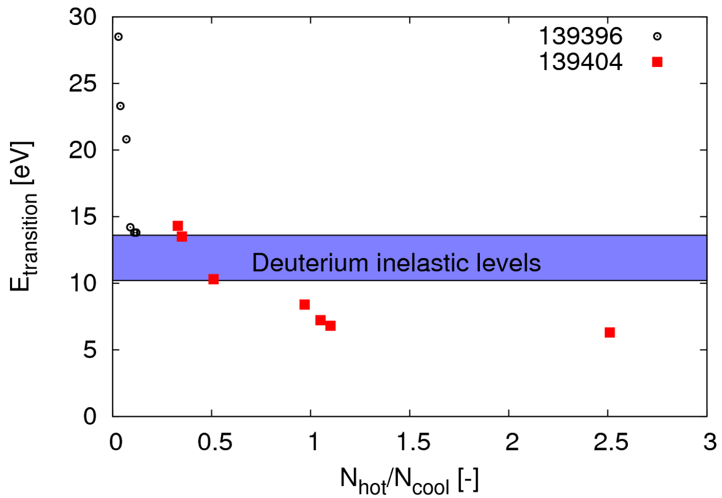


EEDF comparison with active(?) LLD

- Similar times in discharge, similar magnetic locations in SOL
- Higher gas fueling in 139404, yet similar core density
- Reduction in bi-modal character (statistical similarity with single temperature fit indicated by Goodness-of-Fit metric)
- Shifts in EEDF consistent with reduced recycling:
  - Transition to single Maxwellian distribution (Chodura, 1992, CPP)
  - Increase in plasma temperature indicates reduction in energy loss terms (e.g. inelastic collisions)
  - Change in transition energy to below hydrogen excitation energy
- Indicates that the Langmuir probe may be a power diagnostic of the **PMI** processes in the divertor



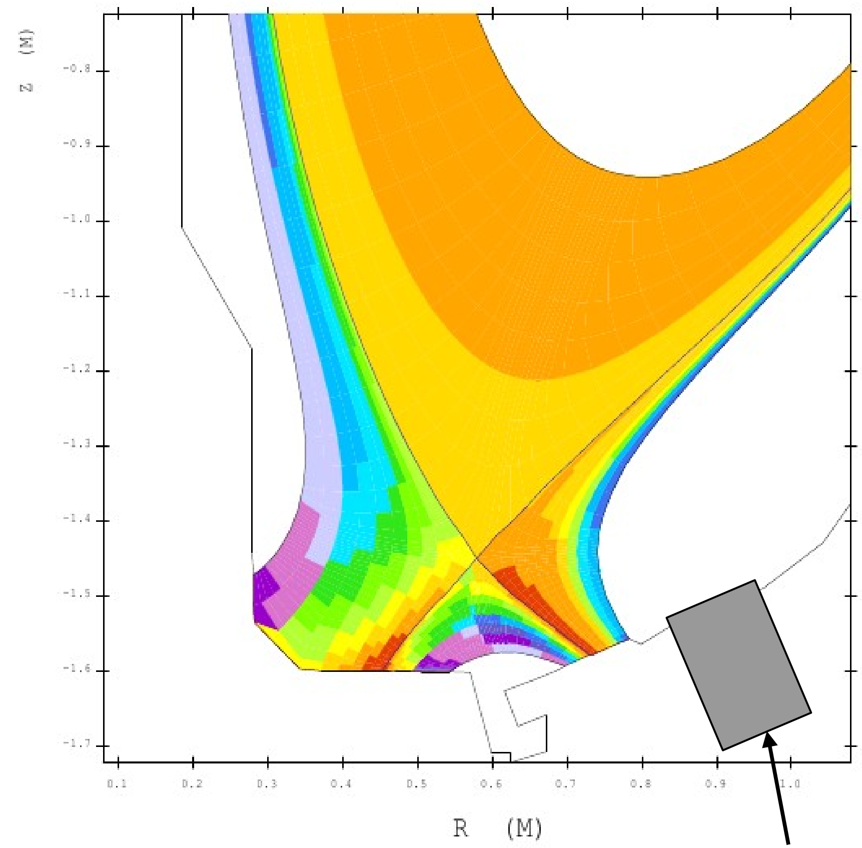
5 eV, 2e20 vs. 16eV, 5e19



XP A: PLES aims to confirm Langmuir probe interpretation and test MAPP for independent neutral detection

- Previous impurity or D2 injection shots in high-triangularity shape – not optimal for HDLP data acquisition
- This XP will place strike-points on probes and actively inject impurities into the divertor region
  - D2, CD4, He, Ne, Ar
  - Monitor changes in HDLP and look for changes in EEDFs
- Will confirm and aid development of Langmuir probe interpretation and usage as deuterium and/or impurity detector
- This XP will also determine MAPP sensitivity to neutral deuterium content during D2 injection shots as an additional means for monitoring of neutrals

OEDGE Plasma Reconstruction



MAPP

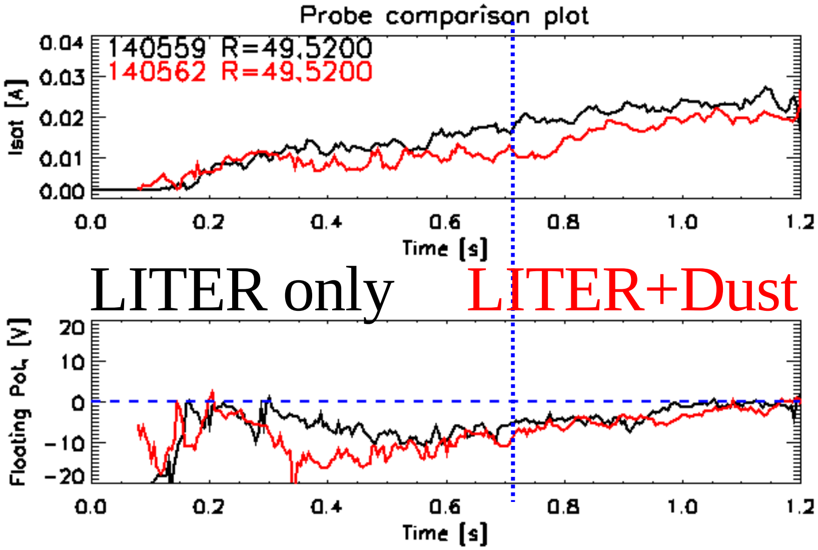
OEDGE will provide a modeling link between HDLP and MAPP

XP A: PLES shot listing

- Establish reference discharge (similar to LLD shots with SP control)
- Perform MAPP exposure in reference discharge, retract, perform TDS.
- Determine optimal injection location (lower divertor vs. outboard injector)
- Perform gas injections (He, CD_4, Ne, Ar) at multiple (3) rates saving D_2 injection for last
- On final discharge with D_2 injection, insert MAPP, expose to discharge, retract and perform TDS.
- Some other time, perform reference MAPP exposure: insert into torus, inject D_2 without discharge, retract and perform TDS.
- 1.5 days requested, 0.75 days minimum
- Establishes HDLP response to impurities and deuterium content – aids interpretation of suspected reductions in local recycling via EEDF changes
- Establishes MAPP response to increased neutral deuterium content in the edge of NSTX – provides measure of neutral deuterium uptake (i.e. wall pumping)
- Attempts to start understanding: significance of wall pumping effects in lithiated machine vs. pumping in the divertor region itself

XP B: SOL and PFC modification during in-situ lithiumization via dust injection and diffusive evaporation

- XP1056 last year attempted to quantify additional benefit of dust injection:
  - LITER at 30 mg/min
  - LITER (30mg/min)+dust 200mg/s
- Observed reductions in metal content, but overall radiation did not change
- However, high-triangularity shape placed outer strike-point near inboard Langmuir probe at 50cm
  - Indicated reduction in Isat by about 40%
  - Evaluation of Ne at ~700ms indicates density reduced by ~50%
  - i.e. addition of large quantity of particles results in reduced density at outboard target(?)
- Density reduction indicates LP is viable diagnostic for evaluating the quality of wall conditioning on a given flux tube (i.e. even though SOL flow sent dust toward inboard)



Parameters at 700ms

Shot	Te [eV]	Ne [m-3]
140559	~11	4.8e19
140562	~12	2.4e19

Isat ratio = 1.6

Ne ratio (Isat) = 2.0

Ne ratio (EEDF) = 1.8

Characterize effectiveness in LSN and DN

- Dust injection may provide means of “refreshing” the lithium layer during a discharge (c.f. EAST long-pulse operation)
- Double-null operation planned as part of high-power NSTX-U scenarios
  - If Li is “standard” for NSTX-U, how do we coat upper PFCs?
  - Evaluate coating effectiveness by density change at other flux-tube end in DN discharges
- Redepositing Li used on TFTR and on CPS based Li machines like FTU
  - Is the co-deposited coating different than evaporation + bombardment?
  - Utilize MAPP to compare in-situ co-deposited layers for D content with TDS
- Measure target density during LSN and DN operation with diffusive evaporation and powder injection (separately)
  - Compare change in density, look for saturation by “turning off” application technique and repeating discharges
  - Expose MAPP during dust injection, expose MAPP during diffusive evap – analyze with TDS to determine absorbed D in films – compare with LITER reference discharge
- Significant difference between co-deposited and evaporated films may indicate improved Li delivery systems for the upgrade
- 1 day requested, 0.5 minimum

XP C: Comparison of local plasma parameters between Li and de-conditioned Li-wall conditions

- Depends on the development of de-conditioning procedure in XMP
- Utilize medium triangularity shape (outer strike on HDLP/LLD, inner strike on inboard probe)
- Expose MAPP to de-conditioning procedure, but no discharge – retract and perform full analysis
- Obtain plasma characteristics with HDLP during discharge
- Repeat de-conditioning procedure with MAPP exposed AND expose MAPP to full discharge (repeat HDLP data collection) – retract and perform full analysis
- If not obtained, perform similar exposure and analyses with LITER wall conditioning
- 0.5 days requested, 0.5 days minimum

Conditioning	Local Plasma	MAPP TDS	MAPP XPS	MAPP DRS
LITER	Higher Te? Lower Ne?	Low D quant.	Less C due to Li coverage?	Li coverage?
LITER+disch.		Medium D?	More C due to Li removal/redep?	Less Li coverage, more C?
De-cond.	Lower Te? Higher Ne?	High D?	?	More D coverage?
De-cond.+disch.		No change in D from before?	More C due to redep?	Same D coverage?

XP D: Comparison of local plasma parameters between Li and boronized wall conditions

- Depends on whether a boronization campaign is conducted
- During TMB – expose MAPP, retract and perform full analysis on deposited coatings
- Obtain HDLP signals for comparison
- Repeat before/after discharge analysis as in XP C, except for “typical” boronized wall conditioning (i.e. He-GDC)
- Compare resulting Langmuir probe signals and MAPP measurements of absorbed D, near-surface chemical content and surface composition
- 0.5 days requested, 0.5 days minimum

Conditioning	Local Plasma	MAPP TDS	MAPP XPS	MAPP DRS
Boron+He-GDC	Te and Ne compared to de-conditioned Li?	Lower D quant.	Less C due to B coverage?	B coverage?
post-discharge		Medium D?	More C due to B removal/redep?	More C than B?

BACKUP

Heuristic explanation for a bi-modal distribution

- Original Maxwellian is convolved with an inelastic cross-section
- Reaction generates new electron with low energy and original electron loses ionization energy
- Result is a non-Maxwellian distribution that will relax toward a bi-modal distribution
- Only a fraction of high-energy electrons react, though, and a hot tail population still appears at the target