Boundary Physics Topical Science Group meeting

September 23rd, 2008

Charles Skinner

- "Group discussion of NSTX contributions to the DSOL and PEP ITPA groups, and ITER high-priority research. (DSOL = Divertor and scrape-off layer, PEP = Pedestal and Edge Physics)."

  - Introduction - brief history of ITPA

  - List of topics proposed by Div/SOL ITPA and requested by IO.

  - Discussion of potential areas NSTX can contribute to:
    1. MAPP (Charles)
    2. Diagnostics (Charles)
    3. RF erosion (Joel / Charles)
    4. ELMs, SOL width (Rajesh)
    5. SOL width (Stewart)
    6. Blobs (DSOL-15) Ricky
    7. Modeling (Daren)
    8. All…..

What is the ITPA ?

- Genesis is ITER Expert Groups during ITER EDA.
- After US left ITER it was renamed "International Tokamak Physics Activity" to permit US participation without Congressional opposition.
- With ITER construction it has now moved back to the auspices of the ITER IO and is more directly coupled to ITER R&D needs.
- From preamble to new ITPA Charter:
  - "The International Tokamak Physics Activity (ITPA) provides a framework for internationally coordinated fusion research activities. The ITPA continues the tokamak physics R&D activities that have been conducted on an international level for many years resulting in the achievement of a broad physics basis essential for the ITER design and useful for all fusion programs and for progress toward fusion energy generally."
  - "The ITPA will provide support to ITER in the fulfillment of its mission by helping to create a common international research programme organized around scientific issues and will facilitate the participation of the ITER Members in the ITER scientific programme."

What does Div/SOL ITPA do ?

- Meets every 6 months. Met last week in Nagasaki September 15-18, 2008. Chaired by Lipschultz and Tsitrone.

- Sessions are organized on high priority topics.
  For Nagasaki mtg last week these are:
  - Fuel Retention:
    - Ongoing work for ITER predictions - talks & discussion
    - H level in today's tokamaks - talks & discussion
    - Fuel retention in carbon - talks & discussion
    - Fuel retention in metals - talks & discussion
    - Campaign integrated dust production and corresponding erosion - talks & discussion
  - Dust mechanism, effects and dynamics - talks & discussion
  - Wall transient thermal loads - talks & discussion
  - Material migration - talks & discussion
  - Discussion of new IEA/ITPA proposals

- Joint multi-machine experiments proposed and reported at Div/SOL mtg.

Current NSTX involvement in Div/SOL area

	ID No	Topical Group	Proposal Title	Keypersons 1	Devices 2	2005 Ext	Type	NSTX Lead / Actions	NSTX input at meeting
15	DSOL-3	Divertor & SOL	Scaling of radial transport	Bruce Lipschultz, Tony Leonard, S. Lisgo, A. Kallenbach	C-mod, ,MAST, DIII-D,JET, AUG, JT-60U	YES	E	High priority for NHTX; Maingi to discuss with Lipschultz to determine appropriate NSTX contribution, and present XP at Forum	No
16	DSOL-8	Divertor & SOL	ICRF Conditioning	Naoko Ashikawa (LHD), Jiansheng Hu (HT-7 and EAST), Volker Philipps (TEXTOR), Volker Rohde (ASDEX-Upgrade)	LHD, HT-7, EAST, TEXTOR, AUG	NEW	E	No	No
17	DSOL-13	Divertor & SOL	Deuterium codeposition with carbon in gaps of plasma facing components	K. Krieger, A. Litnovsky, K. Krieger, C. Wong,Ch. Brousset,B. Lipschultz, G. Counsell	ASDEX Upgrade, TEXTOR, DIII-D, Tore-Supra, C-MOD, MAST	YES	E	No	No
18	DSOL-15	Divertor & SOL	Inter-machine comparison of blob characteristics	J. Terry (C-Mod), G. Antar (PISCES), N. Asakura (JT-60U), J. Boedo/D. Rudakov (DIII-D), J. Egedal (VTF), W. Fundamenski (JET), O. Grulke (IPP-Griefswald), Albrecht Herrmann (AUG), C. Hidalgo (JET and TJ-II), R. Maqueda/S. Zweben (NSTX), ? (TEXTOR)	C-Mod, PISCES, TEXTOR, VTF, NSTX, TJ-II,JET, TCV, HT-7, Tore-Supra, AUG, JT-60U, DIII-D	YES	P	Zweben / broad worldwide participation; Maqueda will present XP at Forum	Yes
19	DSOL-17	Divertor & SOL	Cross-machine comparisons of pulse-by-pulse deposition	C. Skinner, V. Rohde, A Kreter	NSTX, AUG, JET		E	Skinner / congrats for making it after 2-year effort; will present XP at Forum (piggyback)	Yes, Add A Krater from JET to list
20	DSOL-19	Divertor & SOL	Impurity generation mechanism and transport during ELMs for comparable ELMs across devices	A. Loarte, W. Fundamenski, R. Pitts, M. Fenstermacher, M. Groth, A. Herrmann, V. Rohde, D. Whyte, T. Nakano and G. Counsell.	AUG, JET, DIII-D, C-mod, JT-60U, MAST, ?NSTX?			Vlad and Kevin Tritz will discuss with Loarte to determine appropriate NSTX contribution, and possibly present XP at Forum	Considering

What is goal of this meeting ?

Menard Email Sept 4th:

- "For each ITPA topical group, the corresponding NSTX ITPA members and TSG leaders are asked to work together to determine which areas NSTX can make strong contributions to - focusing on the top 2-3.
- You are also asked to discuss and determine the theory & modelling needed to support NSTX contributions, to include/invite the ITPA 'modellers' below, members of the PPPL theory group, and other theorists.
- Any additional diagnostic needs should also be noted.
- Once this information is prepared, we will hold an inclusive meeting to discuss the results from all the groups in mid to late September……
- Draft meeting agenda (TBD):
- 1. Rich will give a 15-20min overview presentation on ITER needs
- 2. Stan can comment on ITPA coordinating committee process/needs (or other)
- 3. NSTX ITPA members present summaries of proposed NSTX contributions (top 2-3) - no more than 3 VGs each - with ample time for discussion."

Candidate areas ?

Clear focus on non carbon materials makes JET-ILW most relevant.

High Priority Research Tasks 2008-2009 (DRAFT for discussion at ITPA CC 2008)

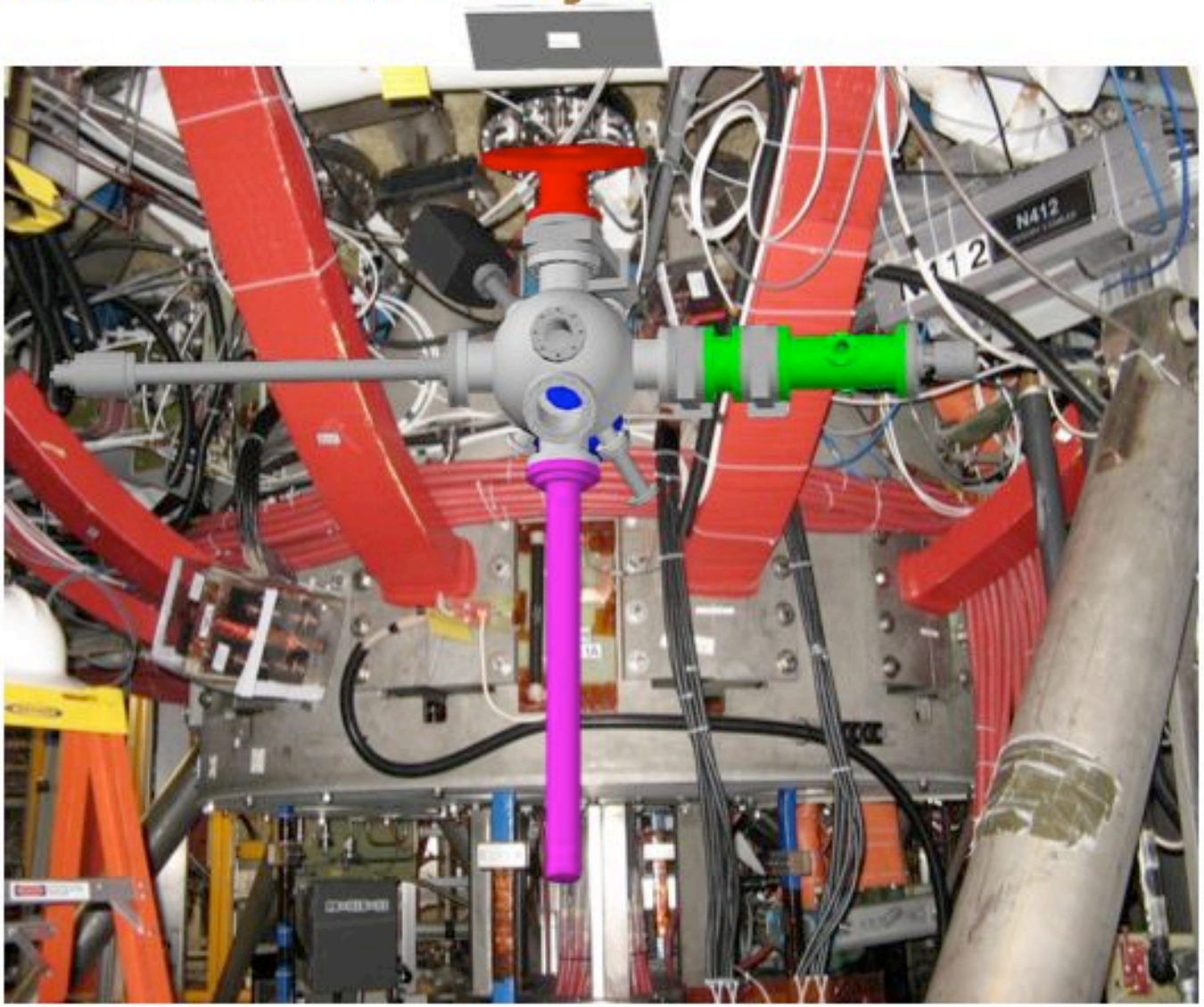
Proposed by SOLDIV TG	Requested by IO
• **Improve understanding of Tritium retention and development of efficient T removal methods.** Compile high-Z experience regarding hydrogenic retention in tokamaks and laboratory studies (new) Initiate studies on neutron damage and how that leads to T retention (new) 1. MAPP possibilities…	• A range of PWI issues will need to be resolved to build confidence that reliable operation can be sustained: • establishment of requirements for carbon/ carbidic compound removal at divertor changeout (eg need to identify distribution of redeposited material) • T-retention in W/ Be and their compounds, including neutron irradiation effects • tungsten/ beryllium material damage and dust production rates (steady-state, transients) • performance of Be-coated tungsten PFCs • development of modelling capability for beryllium and tungsten PWI simulation • When are results required? • early quantitative information on key safety-related questions (T-retention, dust production) would be important - ie 2-3 years 1. MAPP possibilities • should aim for a complete picture of W/ Be PWI issues on 5 year timescale
• **High-Z operational experience (compatibility with core)** Exposure of tungsten to He fluence and effects on surface properties (new) Characterize the level and processes involved in RF enhancement of erosion (new) 2. Joel result…	
• **Understand the effect of ELMs/disruptions on divertor and first wall structures** Exploration of the effect on the SOL and power loadings of ELM mitigation (ongoing) Study runaway effects in disruptions and how to nullify them (new) 3. Rajesh	• a validated modelling capability for runaway generation and loss to allow an improved assessment of first wall energy deposition • An improved assessment of SOL width and local power deposition during disruptions/ VDEs, including limiter plasmas • improved data and analysis within the next 12 months would be valuable 3. Rajesh, 4. Stewart, 5. Ricky
• **Improve measurements & understanding of plasma transport to targets and walls to better predict heat loads and effects on the core** Code-code comparisons including impurities - specifically carbon (underway) Identify discrepancies between codes and experiment for SOL and divertor (new) 6. Daren ?	
• **High-Z operational experience (compatibility with core)** Exposure of tungsten to He fluence and effects on surface properties (new) Characterize the level and processes involved in RF enhancement of erosion (new)	

MAPP = Materials Analysis Particle Probe
New collaboration with JP Allain - Purdue.

- Validation of safe levels of dust in the vacuum vessel required for machine operation

Compile high-Z experience regarding hydrogenic retention in tokamaks and laboratory studies (new)

Probe Location – Bay J



Proposed by Diagnostics TG	Requested by IO
Development of methods of measuring the energy and density distribution of confined and escaping α's.	
Assessment of the calibration strategy for the neutron diagnostics and the calibration source strength needed.	
Determination of life-time of plasma facing mirrors used in optical systems.	▪ Plasma facing mirrors and optical elements in divertor: – these components will likely have a finite lifetime, which will impact on reliability of optical diagnostics – several developments are needed, including • models of erosion and deposition process • mitigation of erosion and deposition by design • development of shutters and baffles • in-situ calibration techniques – deliverable: recommendation on most rugged first mirror arrangement for ITER, based on experiment and modelling – timescale: several years
Development of measurement requirements for measurements of dust, and assessment of techniques for measurement of dust and erosion. Roquemore / Pigarov ? Skinner ?	▪ Dust: Timescale: 2-3 years (by end-2011) • Validation of safe levels of dust in the vacuum vessel required for machine operation • Need to test most promising diagnostic approach, a dust microbalance, in a tokamak • Deliverable: develop, install, exploit and report on prototype ▪ Hot Dust: Timescale: 1.5 years (end-2009) • Be dust on PFCs with T > 600°C must be limited to <6kg for safety • Need to evaluate feasibility of significant quantities of dust being able to survive in regions of high heat flux using modelling and survey data from existing tokamaks • Deliverable: provide an estimate of the quantity of hot dust in ITER, including quantitative evaluation of uncertainties ▪ Divertor Erosion: timescale: 2-3 years (by end-2011) • divertor erosion is expected to be the major source of impurities and dust, as well as limiting the divertor lifetime • need to test most promising diagnostic approach to remote divertor erosion measurements, based on laser ranging techniques • deliverable: develop, install, exploit and report on prototype remote divertor erosion measurement diagnostic using laser ranging
	▪ Hydrogen background: o In non-active phase, outgassing and DNB will affect base level of hydrogen, influencing fuel retention studies o need to assess evolution of hydrogen levels in existing devices and develop an appropriate model o deliverable: estimates of hydrogen background in initial phase of ITER operation and assessment of required accuracy of gas balance measurements to permit analysis of fuel retention in non-active phase o timescale: 2-3 years
	▪ Retained tritium: o require validated techniques for assessing level of retained tritium in vacuum vessel o need to select and prototype candidate diagnostic techniques, including extrapolation from local to global measurements; also need to determine accuracy in estimate of T-burnup o deliverable: validated technique for estimation of retained tritium in vacuum vessel o timescale: 2-3 years

Laser mirror cleaning proposed.

Continue to develop dust detector / remover

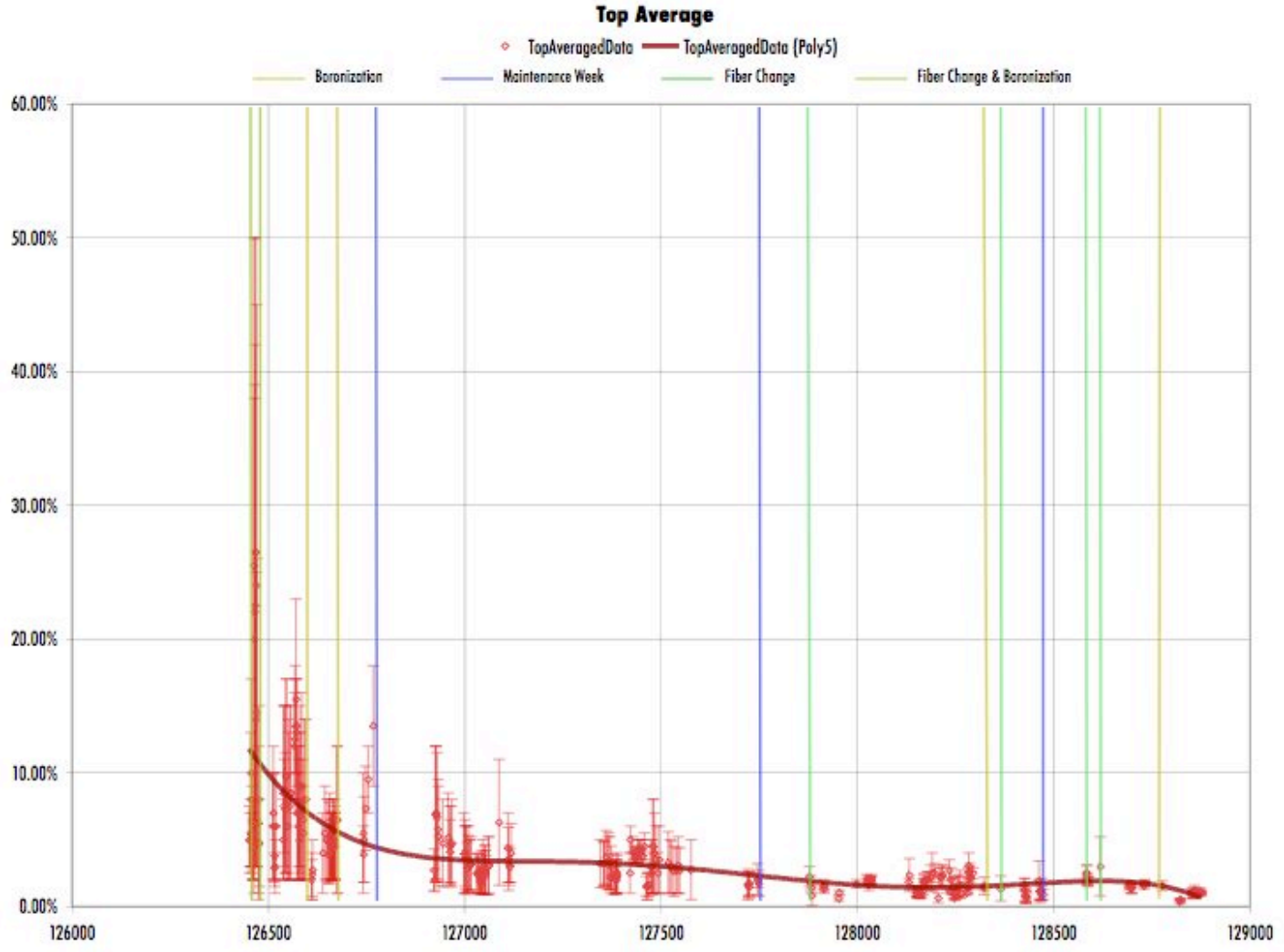
Report NSTX H/D ratio

Diagnostics request by IO:

- Hydrogen background:
  - In non-active phase, outgassing and DNB will affect base level of hydrogen, influencing fuel retention studies
  - need to assess evolution of hydrogen levels in existing devices and develop an appropriate model
  - deliverable: estimates of hydrogen background in initial

Preliminary NSTX 2008 data

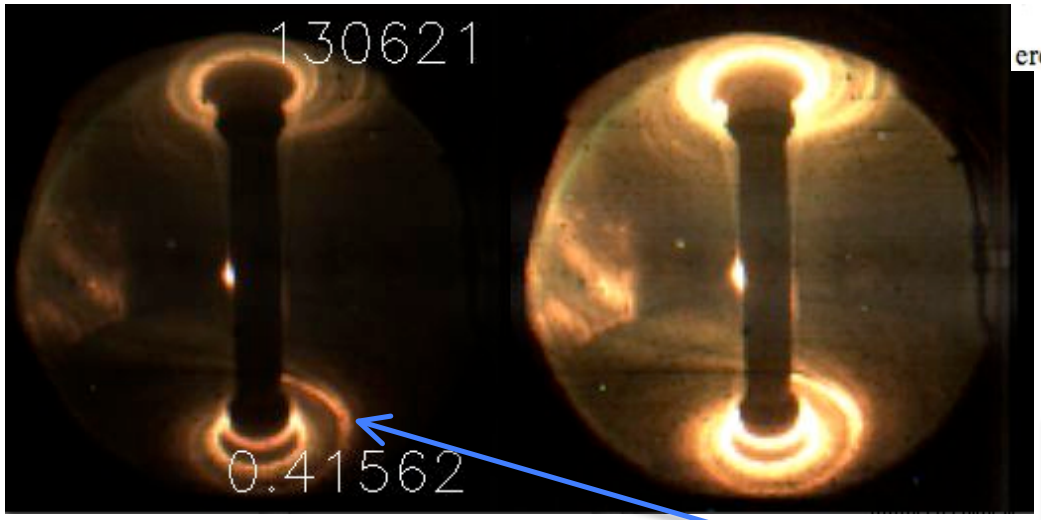
(John Robinson)



RF Effect Seen Outside Divertor Strike-point

J. Hosea

Phase = - 90° just prior to arc before elm



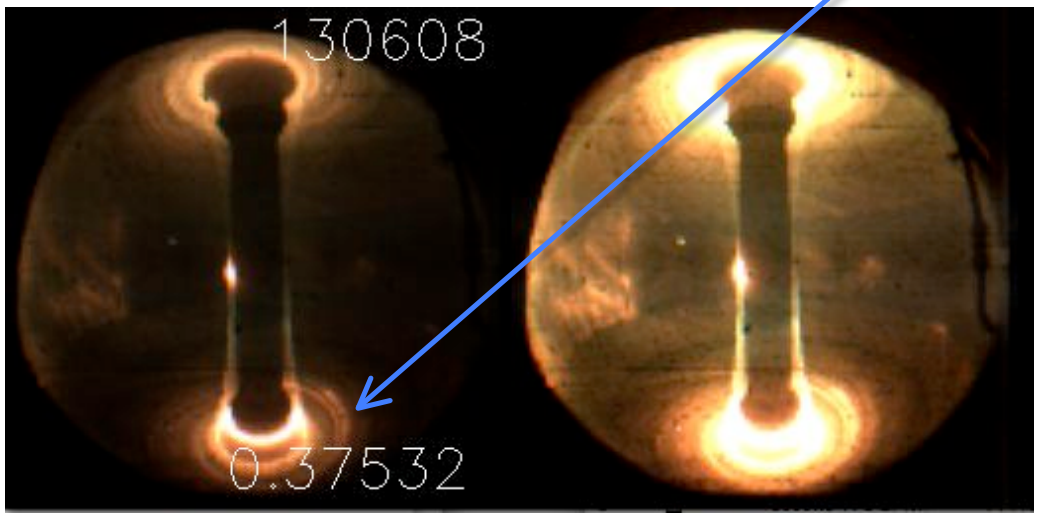
P_{RF} ~ 1.8 MW, I_P = 1 MA

Characterize the level and processes involved in RF enhancement of erosion (new)

Searching for edge RF power loss processes

- RF interaction is localized toroidally
- Appears to be linked with antenna along field lines
- Intensity may be dependent on phase
- Dies away after RF is removed
  - ➢ decay in 15 – 20 msec

Phase = - 150° just prior to arc before elm



Next campaign

- Need to measure heating with infrared camera and thermocouples to deduce RF power lost
- Need RF power and phase scans to see if power lost correlates with observed heating efficiency

Physics Questions on the SOL Width

S.J. Zweben, R.J. Maqueda, D.P. Stotler, et al

For FY10 Joule Milestone to “improve understanding of the heat transport in the tokamak scrape-off layer (SOL) plasma”, and for SOL physics experiments or theory aimed at ITER:

1) What are the possible mechanisms which could affect the divertor heat flux SOL width ?
   - SOL turbulence (both ES and EM)
   - MHD (e.g. ELMs) and magnetic error fields
   - convective cells (e.g. with RF SOL fields),
   - neoclassical transport and parallel flows

SOL Physics Questions…cont…

2) What models will be useful to explain the experimental results on the heat flux SOL width ?
   - BOUT, SOLT, XGC computational models
   - blob models, i.e. nonlinear analytic models
   - quasilinear / marginal stability estimates

3) What are the potential methods to control the this SOL heat flux width ?
   - modified magnetic divertors (e.g. ergodic, super-X)
   - convective cell generation (electrodes or RF)
   - radial electric field generation (e.g. as in TdeV)
   - radiative / detached divertors (via atomic physics).

SOL Physics Questions…cont…

4) More specifically, we need to understand from theory:

- what is the relationship between the SOL width for density and temperature (both ion and electrons) ?

- what is the relationship between the SOL widths at the midplane to those at the divertor plate ?

- how do these widths scale with the dimensionless parameters of the SOL (e.g. C, β, ρ, M, etc) ?

- does the SOL width also depend on the plasma inside the separatrix, e.g. through blob formation ?

Things that are probably NOT useful

- "Empirical scaling" of SOL widths from existing machines to ITER, since there is no physics basis for them, and they will be highly unreliable and misleading

- Applying existing theory and/or simulation to predict the ITER SOL, unless these have been validated using data on SOL turbulence and transport from existing machines (not yet done in any case !)

- Applying validated theory or models to situations in which they are NOT valid, e.g. collisional SOL models from present experiments to a collisionless ITER SOL

ITPA DSOL-15: Inter-machine comparison of blob characteristics

R. J. Maqueda, S. J. Zweben

Understanding will only be gained through comparison with theoretical/numerical modeling

Numerical/theoretical models:

- **BOUT (LLNL)**: code development has been carried out for very many years, yet results for NSTX are very limited ...if any.
- **SOLT (Lodestar)**: new effort, considerable recent progress. Incorporates "synthetic GPI" using atomic emission tables from D. Stotler.
- **Blob model (Lodestar)**: model for radial blob propagation in SOL. Good initial match with NSTX experimental data. Nevertheless, "comparison space" is limited -> "blob regime" physics still unchallenged by experimental data.
- **Other models** (B. Scott, etc): "good physics" but limited scope yield limited direct applicability to experimental data.

Model – experiment comparison based on "statistical" characterization and not "event" characterization

Possible blob measurements and characterization

- **Blob velocities:** blob radial and poloidal components.
  Are different blob regimes seen?
- **Blob sizes**: both radial and poloidal size.
- **Blob shape:** how to compare statistically?
- **Packing fraction**.
- **PDF distribution**: skewness and kurtosis – “holes”?
- **Poloidal extension of blobs**: correlation with measurements in divertor region.
- **I_{sat} characteristics** (reciprocating probe), flows within blobs?
- **n_e, T_e characteristics**: diagnostic set?

Possible blob measurements and characterization (cont.)

- **Connection to edge turbulence** ($\tilde{n}$, $\tilde{\phi}$, S(k,w), etc) -> origin of blobs.
- **Connection to SOL flows:** zonal flows?
- **Connection to:** MHD modes, interchange/ballooning?
- **Connection to "near edge" turbulence**: BES.

NSTX can provide valuable "challenging" data points for benchmark of modeling codes

Experiments with full range of NSTX's parameter space will be of additional value for this effort

Improve understanding of plasma transport: SOL & Divertor Discrepancies

- Referring to PSI 2008 presentations?
- E.g., talk by Chankin & Coster:
  - Connected simulations of SOL flow to problems in matching divertor T_e & n_e profiles,
  - And to discrepancies in E_r profiles.
  - Related by Pfirsch-Schluter formula.
  - Main conclusion: codes may be getting parallel electron transport wrong.

Applicable NSTX Modeling / Theory

- Lodestar simulation of turbulence
- Pigarov / UCSD,
  - WallPSI simulation of retention experiments?
  - UEDGE modeling of LLD & lithium behavior.
  - Dust modeling?
- BOUT?
  - Is it applicable? C-Mod is a better target.
  - Who would run it?
- XGC-0
  - Now being applied to NSTX.
  - Is not yet comprehensive (i.e., not a UEDGE replacement).
- DEGAS 2
  - Being coupled into XGC-0,
    - Will address “role of neutral penetration length on pedestal density width”,
    - And “incorporate comprehensive neoclassical and turbulence transport models into pedestal simulation codes”.
  - And will be preparing for LLD.

Big Picture Comments

- ITPA tasks loaded with V&V related concepts,
  - Discussion of validation tools & nomenclature from a fusion perspective: P. W. Terry et al., *Phys. Plasmas* **15**, 062503 (2008).
- Use the ECC to coordinate theory / modeling related to these ITPA tasks?
  - As well as the FY10 Joule milestone.
- What's the role of the BPO here?
  - Rognlien envisions an ECC / BPO meeting to focus on FY10 milestone.

Discussion: Need to pick 2-3 areas for Jon

Selection criteria - as discussed with Stan K. :

1 Outstanding science
2 Can collaborate with other institutions
3 Requested by IO

- DSOL-15: Inter-machine comparison of blob characteristics ?
  (*modelling needed to get science out of comparisons)*
- DSOL-17:Cross-machine comparisons of pulse-by-pulse deposition,
  (*modelling needed to get science out of comparisons, carbon not relevant for ITER-DT)*

- Materials probes: MAPP (NSTX)/ DiMES- MiMES (DIII-D) / S^3 (C-mod) / TEXTOR….
- Dust ingress: MAPP / fast cameras (NSTX); DiMES fast cameras (DIII-D)
- Dust detection: NSTX / Tore Supra ….
- RF enhanced erosion. NSTX / C-mod…
  - *(ready for prime time ?)*

- SOL width

- Blobs

- Others…….

Theory and Modeling needed in support ?

Additional diagnostics needed ?