Boundary Physics Sessions Summary

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for the NSTX Boundary Physics Group

NSTX 5 Year Plan Ideas Forum
Princeton, NJ
June 24-26, 2002

Boundary Physics Sessions Summary

Four Sessions held:

- Particle control and fueling
- Edge/SOL/divertor transport and turbulence
- Pedestal and ELMs (w/Transport and MHD)
- Power handling and impurities

Group discussion at end of last session on power handling

- Inadequacy of baseline diagnostics
- Relative emphasis of above topics in boundary program

IPPA Boundary Physics Goals on Spherical Torus (3.2.1)

5-Year Objective: Make preliminary determination of the attractiveness of the spherical torus (ST), by bootstrap operation, and acceptable divertor heat flux, for pulse lengths much greater than energy confinement times.

Implementing Approaches
3.2.1.5 Disperse Edge Heat Flux at Acceptable Levels: Study the dispersion of edge heat flux over a range of externally controllable parameters and estimate the plasma facing component requirements under high heating power in the spherical torus magnetic geometry. Determine the ability for managing intense energy and particle fluxes in the edge geometry and for increasing pulse durations significantly beyond the energy confinement time. Most elements of the physics on the edge open field lines are shared between the ST and the tokamak, while the ST introduces stronger variations of the magnetic field strength along the field lines, that are closer to the magnetic mirror. The “toroidal mirror” configuration also tends to have large flux expansion in the divertor region, likely extending the physics research to new parameter regimes.

IPPA Goals on Boundary Physics (3.1.4)

What are the fundamental processes occurring near the boundary of a confined plasma and how can the interaction between the plasma and material surfaces be controlled?

***5-Year Objective*: Advance the capability to predict detailed multi-phase plasma-wall interfaces at very high power- and particle-fluxes.**

Progress will be measured by the level of agreement between models of physical processes in the edge region and experimental measurements, and by the capability to control energy and particle exhaust from a hot plasma.

- plasma edge physics
- coupling between edge and core plasmas
- plasma wall interactions

IPPA Goals on Boundary Physics – edge transport

3.1.4.1 Plasma Edge Physics : Develop physics understanding reliably to predict scrape-off layer widths and radial electric fields in the edge region. Develop theory and modeling for plasma transport along the magnetic field over regions in which the collisionality (ratio of mean-free-path to gradient scale-length) shows wide variation. Enhance diagnostics necessary to identify sources of core impurities. Determine effect of non-Maxwellian electron distributions on atomic transition rates. Extend and refine models of plasma radiation and opacity in the presence of sharp gradients.

IPPA Goals on Boundary Physics – edge/core coupling

3.1.4.2 Coupling Between Edge and Core Plasmas : Improve understanding of plasma transport across the magnetic field in the presence of steep gradients and a magnetic separatrix. Develop understanding of the role of edge profile pedestals on core confinement. Develop a coupled core/edge model and code, with radial electric fields, to simulate confinement regime transitions. Develop detailed understanding of what drives an edge localized mode, including better diagnostics such as detailed current profile measurements in the edge region.

IPPA Goals on Boundary Physics – heat flux and impurities

3.1.4.3 Plasma-wall Interaction : Understand the conditions under which the heat flux from the plasma core can be more broadly distributed on vessel walls and divertor. Develop fundamental understanding of conditions for detachment of flowing plasma from the divertor plate. Use materials-physics data to determine level of tritium retention in walls. Refine understanding of atomic and plasma physical processes in sheath regions near confining walls.

PARTICLE CONTROL AND FUELING
Parallel 3 1:30-3:15 PM Monday 6/24 B252

5 " IPPA goals in particle control", R.Maingi

5+5 "Need for Density Control", R.Maingi

5+5 “Advanced wall conditioning techniques”, H. Kugel

5+5 "Cryopump for Density Control", M. Menon

5+5 “Diagnostics for cryopump”, R. Maingi

10+5 "Liquid Surface Module for NSTX", M. Ulrickson (R. Kaita)

5+5 "LASER Radar for Li Surface Measurements", M. Menon

5+5 “'"Gas Nozzle for Fueling"'”, V. Soukhanovskii

5+5 "Deuterium Pellet Injector", L. Baylor (D. Rasmussen)

5+5 "CT Injector", R. Raman

DISCUSSION

PARTICLE CONTROL AND FUELING
Parallel 3 1:30-3:15 PM Monday 6/24 B252

"Need for Density Control", R.Maingi

- Long pulse lower-single null and most double-null discharges have density rising through high performance phase
- dN/dt between 1-2 times NBI fueling rate
- Note that most shots have inner wall gas puffing which dribbles in through end of shot -> desire to find alternate, more controllable fueling

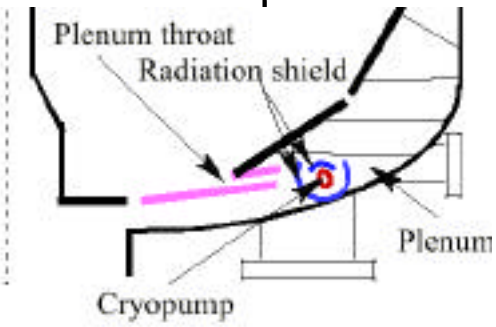
“Advanced wall conditioning techniques”, H. Kugel

- Boron: pre-run TMB, daily TMB, betweenshot TMB, during shot TMB, and pellets
- Lithium: pellets, evaporator, divertor module
- Synergy between lithium and boron?

PARTICLE CONTROL AND FUELING
Parallel 3 1:30-3:15 PM Monday 6/24 B252

"Cryopump for Density Control", M. Menon

- Cryopump design is optimized for a specific shape
- Baffle opening needs to be moved closer to controllable outer strike point locations
- Ideal pumping speed ~ 1-2 times plenum conductance
- Toroidally continuous pump difficult because of support



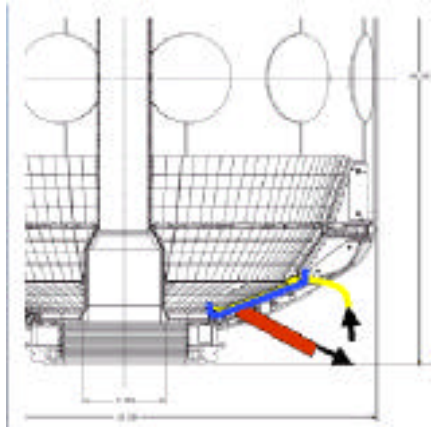
“Diagnostics for cryopump”, R. Maingi

- Important to understand role of cryopump in particle balance
- Fast pressure gauges near cryopump can be used to estimate cryopump exhaust rate
- Langmuir probes in divertor tiles can give , ne, Te, and particle flux profiles to guide (and test after cryopump installation) plenum design

PARTICLE CONTROL AND FUELING
Parallel 3 1:30-3:15 PM Monday 6/24 B252

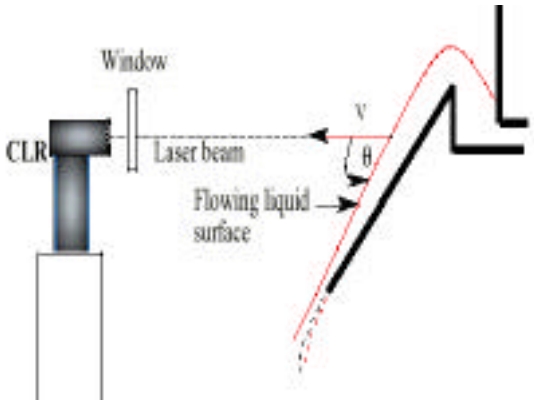
"Liquid Surface Module for NSTX", M. Ulrickson (R. Kaita)

- Liquid Lithium module in divertor designed for 10^{23} particle removal/shot
- Lithium surface area ~ 1 m^2, 10 m/s flow velocity
- Can also help with power handling capability
- Need to understand MHD effects of flowing liquid metal



"LASER Radar for Li Surface Measurements", M. Menon

- remote laser measurement of properties of liquid metal surface
  - flow velocity
  - film thickness
  - flow instabilities



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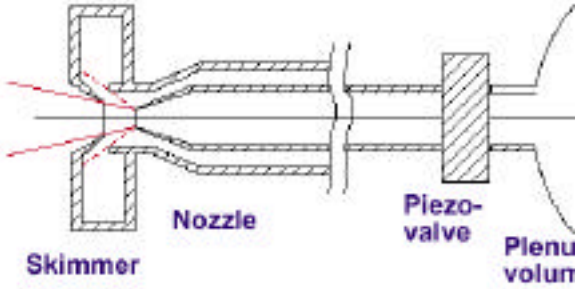


“"Gas Nozzle for Fueling"”, V. Soukhanovskii

- supersonic gas puff through nozzle
- deeper fueling than thermal gas
- can be used for gas puff imaging, impurity transport
- can also be used for Helium line emission measurements (edge n_e, T_e)

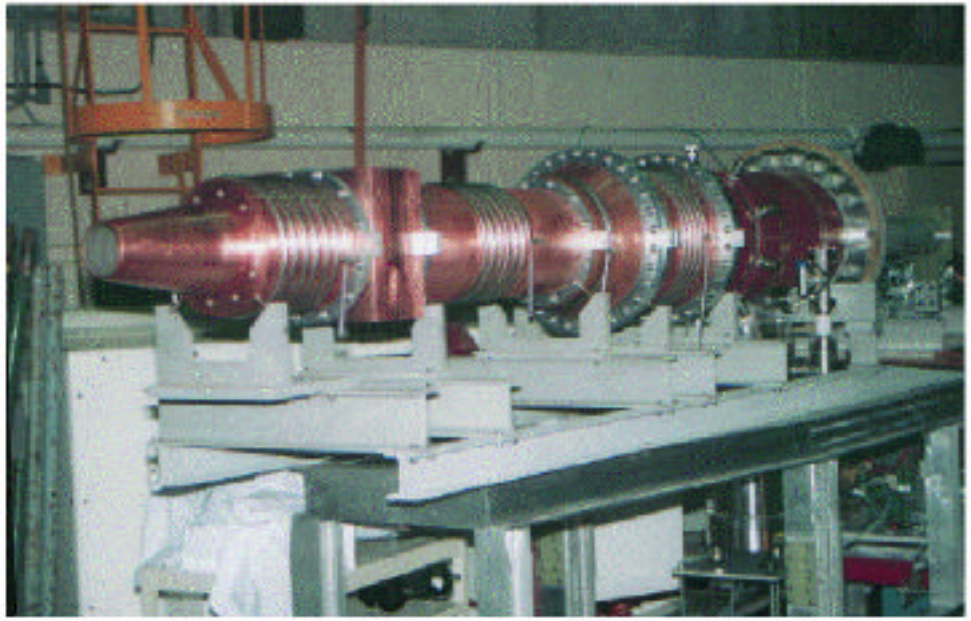
"Deuterium Pellet Injector", L. Baylor (D. Rasmussen)

- compact, “pellet injector in a suitcase”
- pellet sizes can be tailored to NSTX fueling needs
- should be able to achieve density above Greenwald limit
- magnetic field well at high beta should enhance low-field side pellet penetration due to E X B drift toward center

PARTICLE CONTROL AND FUELING
Parallel 3 1:30-3:15 PM Monday 6/24 B252

"CT Injector", R. Raman

- existing injector previously used on TdeV
- reactor relevant fueling mechanism
- deeper fueling than gas, pellets
- can be made repetitive



EDGE TRANSPORT AND TURBULENCE
Parallel 6 10:35 AM-12:15 PM Tuesday 6/25 Director's Conf. Room

5+5 “Parallel vs perpendicular transport”, R. Maingi

5+5 “Status of ChERS”, T. Biewer

5+5 "Five Year Edge Turbulence Program", S. Zweben (H. Kugel)

5+5 “Edge Turbulence Modeling”, X. Xu (remote)

10+5 "New Electromagnetic Head for Fast Probe Turbulence Measurements", “Edge Physics”, & “Divertor reciprocating probe” J. Boedo

5+5 “ Fluid Edge Modeling”, M. Rensink (M. Fenstermacher)

5+5 “Atomic Physics Effects”, D. Stotler

5+5 “Edge and Divertor diagnostics”, V. Soukhanovskii

DISCUSSION

EDGE TRANSPORT AND TURBULENCE
Parallel 6 10:35 AM-12:15 PM Tuesday 6/25 Director's Conf. Room

"Parallel vs perpendicular transport", R. Maingi

- discussion of edge transport focus in C-MOD and DIII-D
- C-MOD focusing on bursty nature of edge transport and turbulence, and balance between parallel heat conduction and perp. convection in different parts of the SOL
- DIII-D focusing on drifts in X-point region, and look into burtsy transport and location of recycling sources

"Status of CHERS", T. Biewer

- 51 spatial channels with < 5mm resolution in edge, 10ms time res.
- poloidal (6 chords) and toroidal (7 chords) rotation at edge
- installation to be completed during outage

EDGE TRANSPORT AND TURBULENCE
Parallel 6 10:35 AM-12:15 PM Tuesday 6/25 Director's Conf. Room

"Five Year Edge Turbulence Program", S. Zweben (H. Kugel)

- proposal to do a detailed characterization of edge turbulence
- ohmic and auxiliary heated discharges
- density limit
- L-H and H-L transition
- relation between edge and core turbulence
- requires close coupling to theory and modeling

“Edge Turbulence Modeling”, X. Xu (remote)

- description of the BOUT fluid turbulence code
- proposed additions to BOUT: neutrals and kinetic packages
- density limit
- L-H and H-L transition
- relation between edge and core turbulence

EDGE TRANSPORT AND TURBULENCE
Parallel 6 10:35 AM-12:15 PM Tuesday 6/25 Director's Conf. Room

"New Electromagnetic Head for Fast Probe Turbulence Measurements", &

“Divertor reciprocating probe” J. Boedo

- description of physics to be done with existing reciprocating probe
- proposal to implement T_e fluctuations capability within existing probe
- proposal to add divertor reciprocating probe for transport studies
- also help diagnose CHI physics

“Fluid Edge Modeling”, M. Rensink (M. Fenstermacher)

- description of the 2-D UEDGE fluid transport code
- comparison with data from August 2001
- UEDGE ready and awaiting data from edge characterization experiment

EDGE TRANSPORT AND TURBULENCE
Parallel 6 10:35 AM-12:15 PM Tuesday 6/25 Director's Conf. Room

"Atomic Physics Effects", D. Stotler

- need upgrade to molecular and hyrdocarbon physics in DEGAS-2, extra manpower needed
- physics puzzles: to understand physics of the private flux region and role of E X B drifts
- need experiments and codes to study SOL kinetic effects

"Edge and Divertor diagnostics", V. Soukhanovskii

- Helium line ratio technique for measuring edge n_e, T_e
- divertor SPRED XUV system
- divertor imaging spectrometer for impurity n_e, T_e, and v_{flow}

POWER HANDLING AND IMPURITIES
Parallel 8 3:35-5:30PM Tuesday 6/25 Director's Conference Room

5 " IPPA goals in power handling", R.Maingi

5+5 “Heat Flux and Pulse Length in NSTX”, R. Maingi

5+5 “Advanced PFC development for high power, long pulse operation”, H. Kugel

10+5 "Need for Fast IR Camera" + "Filter Wheel for Fast Camera Impurity Profiles" R. Maqueda (H. Kugel)

5+5 “Radiative divertor diagnostics”, S. Paul

5+5 "NSTX DIMES", C. Wong (C. Skinner)

DISCUSSION

POWER HANDLING AND IMPURITIES
Parallel 8 3:35-5:30PM Tuesday 6/25 Director's Conference Room

"Heat Flux and Pulse Length in NSTX", R. Maingi

- recent analysis shows divertor tile temp. rise of ~ 300 deg. C after 0.2s of NBI heating in lower-single null H-modes, peak heat flux ~ 10 MW/m^2
- extrapolates to pulse length limit ~ 3 sec.
- present IR cameras have too many intermittent failures
- need more reliable, research grade IR cameras

"Advanced PFC development for high power, long pulse operation", H. Kugel

- need to re-design PFCs for long pulse ~ 5s operation
- high performance CFC's, tungsten brush, B_4C coatings, and liquid metal are all advanced material candidates
- wall armor testing station?

POWER HANDLING AND IMPURITIES
Parallel 8 3:35-5:30PM Tuesday 6/25 Director's Conference Room

"Need for Fast IR Camera" + "Filter Wheel for Fast Camera Impurity Profiles" R. Maqueda (H. Kugel)

- fast IR camera (> 1 kHz) would allow investigation of fast events, e.g. ELMs, reconnections, LSN termination events, etc.
- propose video camera in mid-IR range with image transport system to remove camera from magnetic field (e.g. as designed for C-MOD)
- filter wheel on visible camera allows investigation of recycling and would add to experiments evaluation wall conditioning techniques

“Radiative divertor diagnostics”, S. Paul

- case for additional diagnostics to diagnose divertor
  - divertor Thomson
  - tile Langmuir probes: better spatial resolution than present 1 probe/tile
  - divertor spectrometer
  - additional filterscopes

POWER HANDLING AND IMPURITIES
Parallel 8 3:35-5:30PM Tuesday 6/25 Director's Conference Room

"NSTX DIMES", C. Wong (C. Skinner)

- very successful on DIII-D at highlighting new physics
- can also implement on NSTX to solve ST specific edge issues
- need good characterization of plasma near DiMES to model results

Boundary Physics Discussion

- Group discussion on baseline diagnostics needed immediately, before official start of 5 year plan
  - Research grade infrared cameras
  - Instrumented divertor tile Langmuir probes

- Above diagnostics required to design divertor for NSTX upgrades
  - In-vessel cryopump and baffle design
  - Divertor design (5 sec. pulse length) for center stack upgrade

- Discussion of emphases
  - all areas discussed in four sessions important
  - research should focus on ST specific aspects of boundary physics, which is all of BP since ST magnetic difference is largely at edge >> collaborations with higher R/a important to understand ST

NSTX 5 Year Planning Forum
Summary of Boundary Physics Sessions

Particle Control and Fueling
Parallel 3, 1:30-3:15 PM, Monday 6/24

Proposed 5 Yr Goals	IPPA Bnd Phys Goals	Major Hardware Issues	Inter-device / other fields
IPPA Goals In Particle Control, R.Maingi			
Need For Density Control R.Maingi	ST enabling	Install cryopump	
Advanced Wall Conditioning Techniques, H. Kugel	ST enabling		Applicable to other devices
Cryopump for Density Control M. Menon	ST enabling	Install cryopump	
Diagnostics for Cryopump R. Maingi	ST enabling	Langmuirs, FastPressure Gauges, Divertor Diag	Fast Neutral Pressure Gauge Innovations
Liquid Surface Module for NSTX , M. Ulrickson (R. Kaita/remote)	Disperse heat flux	Major; Suitable port	Applicable to other devices
LASER Radar for Li Surface Measurements M. Menon	ST enabling	Suitable Port	Many applications
Gas Nozzle for Fueling V. Soukanovskii	ST enabling	Install Gas Nozzle	
Deuterium Pellet Injector L. Baylor (D. Rasmussen)	ST enabling	Install Pellet Injector	
CT Injector for Fueling and Profile Control R. Raman	ST enabling	Install CT Injector	Applicable to other devices

NSTX 5 Year Planning Forum
Summary of Boundary Physics Sessions

Edge Transport And Turbulence
Parallel 6, 10:35 AM-12:15 PM Tuesday

Proposed 5 Yr Goals	IPPA Bnd Phys Goals	Major Hardware Issues	Inter-device / other fields
IPPA goals in edge transport, R.Maingi			
Parallel vs Perpendicular Transport, R. Maingi	ST Edge Edge-core coupling	X-Pt diagnostics	Inter-device comparisons
Five Year Edge Turbulence Program, S.Zweben (H.Kugel)	ST Edge Edge-core coupling		Inter-device comparisons
"Edge Turbulence Modeling" X.Q.Xu (remote)	ST edge		Inter-device comparisons
New Physics to be Addressed with the Fast Probe, J. Boedo	ST edge	New Probe Head	Inter-device comparisons
Poloidal Asymmetries, Transport, and Divertor Studies, J. Boedo	ST edge Edge-core coupling	Divertor Fast Probe	Inter-device comparisons
Fluid Edge Modeling M.Rensink (M. Fenstermacher)	Edge	IR Cameras Langmiuirs Divertor Rad	Inter-device comparisons
Atomic Physics Effects, D. Stotler	ST edge	Molecular luminosities	Inter-device comparisons
Edge and Divertor Diagnostics", V. Soukanovskii	ST divertor / edge	Dedicated spectrometers	Inter-device comparisons

NSTX 5 Year Planning Forum
Summary of Boundary Physics Sessions

Power Handling and Impurities
Parallel 6. 3:35-5:30PM Tuesday

Proposed 5 Yr Goals	IPPA Bnd Phys Goals	Major Hardware Issues	Inter-device / other fields
IPPA goals in power handling, R.Maingi			
Heat Flux and Pulse Length in NSTX, R. Maingi	Heat flux control	Fast IR Camera	Inter-device comparisons
Advanced PFC Development For High Power, Long Pulse Operation, H. Kugel	ST enabling	Upgrade tiles	
Need for Fast IR Camera R. Maqueda (H. Kugel)	ST edge	Fast IR Camera	Inter-device comparisons
Radiative Divertor Diagnostics S. Paul	ST divertor / edge	IR Cameras Bolometers Langmuirs	Inter-device comparisons
Filter Wheel for Fast Camera Impurity Profiles R.Maqueda (H. Kugel)	ST divertor / edge	Filter wheel for visible camera	Inter-device comparisons
NSTX DIMES C. Wong (C. Skinner)	ST wall	Sample Probe	Inter-device comparisons