NSTX-U Boundary Physics

Theory/Experiment Joint Research Topics

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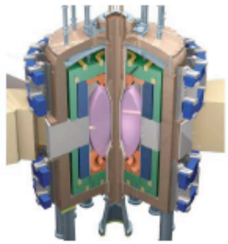
A vision for U.S. fusion research in the coming decade has emerged from OFES emphasizing 4 research themes:

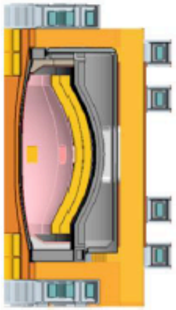
- **Plasma dynamics and control**
  - Perform detailed measurement of underlying processes, connect to theory, develop integrated understanding, demonstrate advanced scenarios in tokamaks
- **Materials in a fusion environment, harnessing fusion power**
  - Understand and control processes beyond the last closed flux surface, including open field line physics, plasma-surface interactions, coupling between SOL & PSI
  - Determine the fusion nuclear science facility (FNSF) geometry
  - Determine the materials the FNSF will be made from and should test
- **Validated predictive capability**
  - Increase emphasis on validation of physics models incorporated in simulation
  - Increase confidence in extrapolating tokamak/ST in support of ITER, next-steps
- **3-D magnetic fields**
  - Determine the optimum level of 3D field in toroidal magnetic configuration accounting for both physics and engineering complexity in the optimization
    - Enhance the theory of 3-D equilibria, stability, and transport research
    - Increase emphasis in 3-D fields near-term on domestic facilities

NSTX-U research targets predictive physics understanding needed for fusion energy development facilities

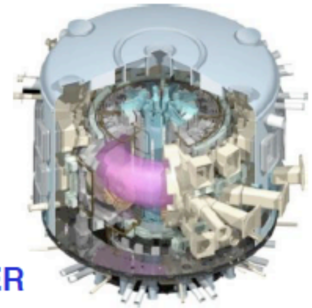
- Enable key ST applications
  - Move toward steady-state ST FNSF, pilot plant
  - Close key gaps to DEMO
- Extend understanding to tokamak / ITER
  - Leverage ST to develop predictive capability



Fusion Nuclear Science Facility (FNSF)



ST Pilot Plant

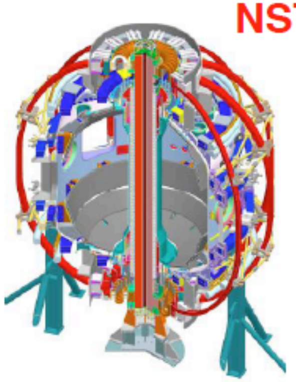


ITER

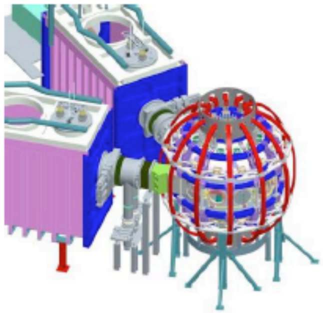
Research Goals:

- Develop key physics understanding to be tested in unexplored, hotter ST plasmas
  - Study high beta plasma transport and stability at reduced collisionality, extended pulse
  - Prototype methods to mitigate very high heat/particle flux
  - Move toward fully non-inductive operation with profile control (current and rotation profiles)

NSTX-U



New center-stack



2^{nd} Neutral Beam

Close coupling with theory and modeling needed in the areas of NSTX and NSTX-U Boundary Research

- Edge transport and plasma-surface interactions
  – Thermal heat transport in the SOL
  – SOL turbulence studies
  – Divertor transport and heat flux mitigation
  – Impurity sources, PFC development
  – Fueling optimization

- H-mode physics
  – Pedestal physics studies
  – ELM characterization and control

Goal: Identity Key Theory and Modeling Needed to address the Boundary Physics Research

- Provide initial guidance for Theory/Experiment joint research topics on Boundary Physics in preparation for:
  - next NSTX-U Brainstorming Meeting (March 2012)
    - Identify theory and modeling needs in support of NSTX-U research program
  - and 5-year Plan:
    - Theory/modeling needs presented above are to be folded in the 5-year plans

- This meeting will focus on <u>the topics for the upcoming brainstorming meeting</u>.

List of Potential Topics for Boundary Physics Research

Topics Ideas - Tentative	Goals	Notes
Edge Physics and Turbulence Simulation (SOL and Pedestal)	Clarify the role of edge turbulence vs. neoclassical effects in setting the SOL power width. [Lodestar] Effects of Li on the SOL width (some overlap with LiRTSG).[Lodestar] How does this fundamental physics affect PFC wear/ damage, recycling, L-H transition, density limit? [Lodestar] Relation between Blobs and edge flows [Lodestar] XGC0 and XGC1 [w./ Battaglia, C-S Chang, S-H Ku] Role of Lithium in suppressing ELMs (overlap with LiRTSG) [TBD] Physics of Collisionless SOL [Zakharov,Granstedt] More Ideas?	GPI- Blob Tracking, probes, BES, high spatial resolution edge fluctuation diagnostics Important for understanding the SOL width scalings
Snowflake divertor	theory and modeling of steady-state and transient (ELM) transport in snowflake configurations	
Divertor Transport and Radiation	Validate existing plasma transport models (fluid, kinetic, gyro-kinetic) Validate and extend PSI models	
Synthetic diagnostics	Enable realistic coupling between simulation codes results and experimental observations	

More Ideas….

Collisionless Scrape off Layer

Leonid E. Zakharov, Erik Granstedt

Plasma particle absorption by the liquid lithium surface (LiWF regime) creates unique plasma edge situation:

- $T_{edge} \simeq T_{core}$;
- $n_{edge} \ll n_{core}$;
- ***The SoL becomes collisionless;***
- ***Thermal force in the SoL is eliminated;***
- ***Thermo-electric currents in the SoL are eliminated;***
- ***Instead the mirror-ratio can drive the SoL currents;***
- ***The sheath potential becomes sensitive to the mirror-ratio in the SoL:***
  (a) in its absence $\phi^{sheath} \propto 1/T_{edge} \ll T_{edge}/e$
  (b) with a finite mirror-ration $\phi^{sheath} \simeq T_{edge}/e$
- ***Plasma edge cooling by the secondary electrons from PFC is affected by the mirror confined ions.***

The physics of the Collisionless SoL should be one of the key topics of the Theory in incoming years.

Flux tube equilibria at the plasma edge

The Theory should extend its treatment of the plasma edge stability.

1. ***There is no basic principle justification of the "ideal" MHD plasma model for edge stability;***
2. ***ELM stabilization by the Li-conditioning has been robustly predicted based on perturbed equilibrium theory, rather than on the ideal MHD (and its so-called "peeling ballooning" model).***
3. ***Plasma edge (including the pedestal region) is always perturbed with magnetic field lines striking the PFC***
4. ***The equilibrium situation at the plasma edge does not corresponds to conventional equilibrium models.***
5. ***Flux tubes with the local current densities different from the bulk plasma are possible in the case of RMP and potentially in the quasi-stationary situation.***

The theory of the flux tube equilibria can be done and is necessary for understanding of the plasma edge MHD phenomena