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The study of edge transport and turbulence on NSTX - an integrated measurements and modeling approach

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NSTX

Outline

- **Thoughts on administrative and organizational issues**

- **Areas where LLNL could make contributions in NSTX Boundary Physics efforts in FY2009 - FY2013**

  - ✓ **Boundary Physics physics topics**
    - Particle and density control with lithium
    - Fueling
    - Divertor physics
    - Edge transport - will be addressed in Umansky's talk

  - ✓ **Diagnostics ideas**

- **Disclaimer: Due to lack of time for preparation this presentation is not inclusive**

Some thoughts on organizational and administrative issues

- NSTX Boundary Physics group - unique in that many efforts are done by national labs (ANL, LANL, LLNL, ORNL, SNL, …)

- Need to diversify? - either bring more effort by universities for physics and diagnostics, or increase budget for national labs. Otherwise national labs compete with each other for the same money…

- How to address "sharing" issues with NCSX ?

Particle and density control by lithium will be one of the main thrusts

- **Running NSTX with a lithium divertor module will bring the need for a new edge characterization**

- **Characterize particle balance**
  - Particle flux measurements - source and sink of neutrals and impurities
  - Particle balance using integrated edge and core modeling (e.g. DEGAS 2, UEDGE + TRANSP)
- **Characterize impact on transport regimes**
- **Characterize divertor properties**
  - Divertor regimes
  - Divertor heat flux handling
  - Divertor pumping, neutral pressures
  - MARFE formation
  - Role of molecular fluxes (D_2, hydrocarbons, Li and C dimers)

Further development of advanced fueling techniques will be needed

- **Fueling techniques in NSTX research plan**
  - Gas fueling, including SGI
  - Compact toroid - unique, interesting, high promise - should be strongly endorsed
  - Cryogenic pellet injection - "conventional" but may be necessary with lithium

- **Further supersonic gas injection studies**
  - Develop SGI-fueled high-performance regimes
  - Develop new supersonic gas injectors (higher pressure, cryogenic gas temperature, molecular clusters, various poloidal locations)
  - Develop advanced nozzles (fully optimized Laval nozzles, aerospike nozzles)
  - Further develop analytic or numerical model of supersonic gas jet penetration and fueling
  - Use SGI for diagnostic applications - helium line ratio, impurity transport studies

Study of SOL parallel transport, divertor heat flux mitigation are important for next generation STs

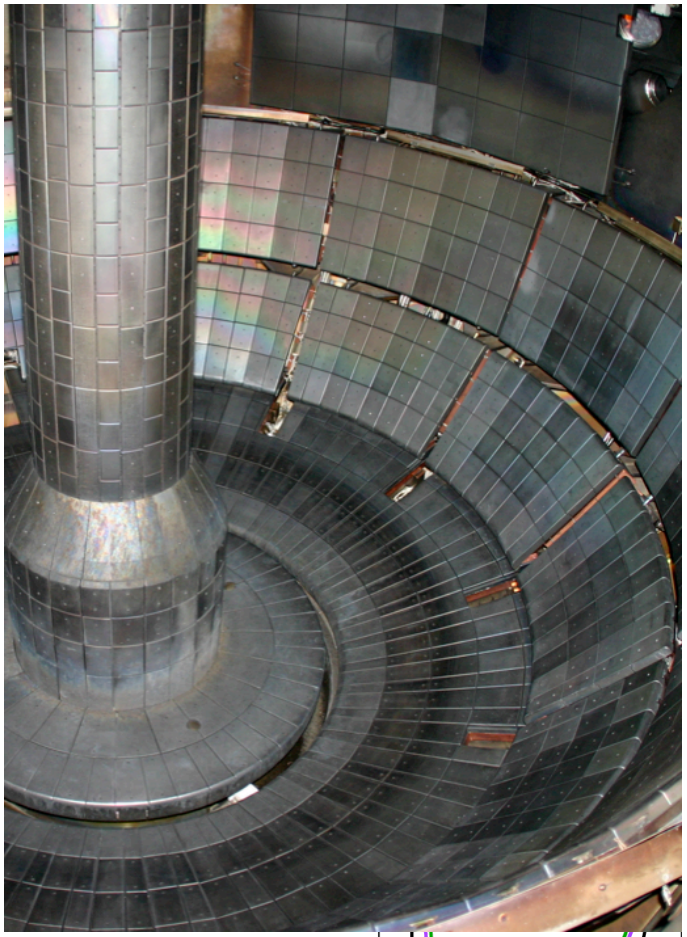
- **Study heat flux reduction techniques in ST geometry**
  - Need to characterize and understand **"baseline" techniques**
  - Radiative divertor
  - Detached or partially detached divertor
  - Flux expansion
  - Multiple divertors
  - Strike-point sweeping
  - Radiative mantle
  - Liquid lithium divertor module

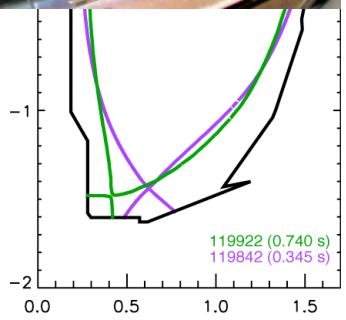
- **Modeling**
  - Two point models
  - 1D models (e.g. onion-skin model)
  - UEDGE multi-fluid edge transport models
  - BOUT turbulence modeling

Present NSTX divertor geometry is not optimized for heat flux mitigation

- **Low aspect ratio magnetic configuration leads to**
  - small divertor volume
  - small plasma wetted area
  - high $q_{||}$
  - short connection length $L_{||}$
  - High SOL mirror ratio $M = |B_{min}| \ / \ |B_{max}|$
  - SOL area factor: $A_{out} > A_{in}$

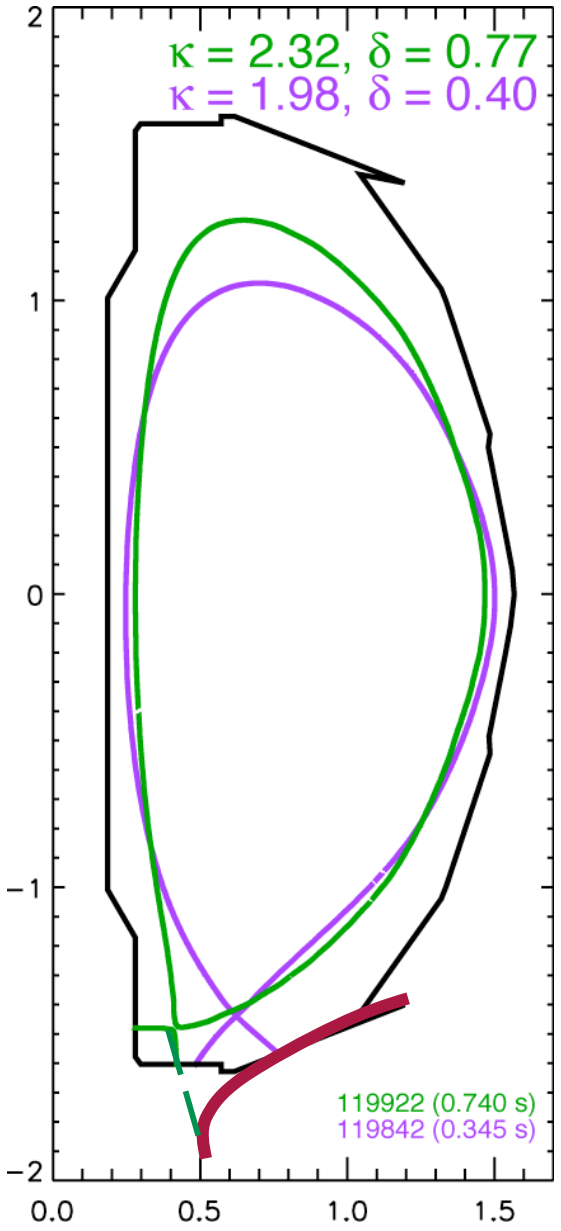
- **NSTX divertor**
  - open
  - horizontal targets
  - graphite tiles
  - no active pumping





Advanced ST research on NSTX would benefit from a new divertor geometry

- **Present NSTX divertor geometry has allowed much flexibility in plasma shaping**
- **Advanced ST will utilize highly shaped plasmas**
- **Possible modifications to divertor during lithium module installations may be able to accommodate new divertor plates**
- **Divertor geometry can be changed toward**
  - More closed geometry
  - Dome
  - Vertical targets
  - High Z PFC



Divertor private flux region studies may become the next hot topic in tokamak research

- **PFR studies are motivated by experiment and theory**
  - PFR heat and particle fluxes and scaling are poorly characterized
  - Clearly important for divertor regimes, MARFEs
  - ITER is still debating the role and need for divertor dome
  - Proposed by Prof. S. Krasheninnikov (UCSD) as a BPO topic

- **NSTX can make an important contribution…**
  - Measure heat, particle fluxes and scaling
  - Measure role of PFR size
  - Measure role of PFR heat flux diffusion, drift flows, …
  - Measure impact of ELMs on PFR
  - Measure turbulence in PFR
  - Compare with theory, models (UEDGE, BOUT, …)

Boundary Physics research on NSTX should be integrated with core plasma studies

- The integration is done mainly in ISD group
- Boundary Physics program should be consistent with core energetic particles, transport, MHD research
- Areas where more integration can help
  - Pedestal stability
  - Pedestal transport and turbulence
  - ELMs
  - Fueling and particle transport

Diagnostic ideas (1)
Diagnostics for Lithium age on NSTX

- **Diagnostic issues**
  - Degradation of **window** transmission and **mirror** reflectivity
  - **Reflections** from lithium-coated surfaces complicate interpretation of IR and visible camera measurements
  - Lithium **coatings** may be a problem for flush-mounted Langmuir probes, SXR array foil filters, exposed detectors

- **Should be a funded item!**
- **Diagnostics for lithium age on NSTX**
  - **Ly-alpha** arrays (instead of D_α arrays)
    - Reflections at 1216 A negligible
    - AXUV diode + filter technology - well developed, robust
    - Presently being tested on LTX
  - Divertor heat flux measurements using thermocouples or divertor tile **IR fiber-based thermography**
  - **Imaging spectrometer** for edge and divertor atomic and molecular impurity profiles

Diagnostic ideas (2)
Neutral 1D and 2D core, pedestal, edge profiles

- **Edge 2D neutral profiles from existing filtered cameras**
  - LLNL-developed inversion algorithm can be used for 2D emissivities from 2D line-integrated brightnesses

- **Laser-induced ionization (LII) diagnostic for 1D core, pedestal and edge neutral profiles**
  - Developed at Ioffe Institute in the 90-s (Nuclear Fusion 35, 1385 (1995)
  - Feasibility study for NSTX by Dr. S. Tolstyakov in 2001
  - Based on optical measurements of neutral deuterium atom upper level populations using laser photoionization
  - May be possible to use present MPTS laser, same APD detectors
  - Possible to use same optical channels (?)

Diagnostic ideas (3)
Divertor profiles

- **Many man-year LLNL expertise**
- **Divertor Thomson scattering system**
- **Divertor heat flux profiles**
  - Inexpensive **fast IR arrays** (instead of expensive cameras) for ELM studies
    - Well-developed 1D detector technology
    - Available commercially, with some in-house integration
  - Divertor **tile-embedded fiber** measurements of IR emission
    - Independent of divertor surface
    - Presently used on Tore Supra with success

- **Imaging spectroscopy of divertor plasma - *Ti, n_e, T_e, v, Γ_i***
  - Line and continuum profiles
  - Spectral line Doppler broadening for T_i profiles
  - Spectral line Doppler shift measurements for flow velocities
  - Balmer or Paschen series line broadening for n_e profiles, line intensities *for* T_e profiles in recombining divertor
  - Particle influx profiles - molecular, neutral, impurity ions