Theoretical Research for NSTX

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Outline

Goal; Tool upgrade and analysis of data,
Active involvement in the future experiments

1. MHD Stability
2. Neoclassical and Turbulent Transport
3. Energetic Particle Physics
4. Boundary Physics

MHD Stability in NSTX

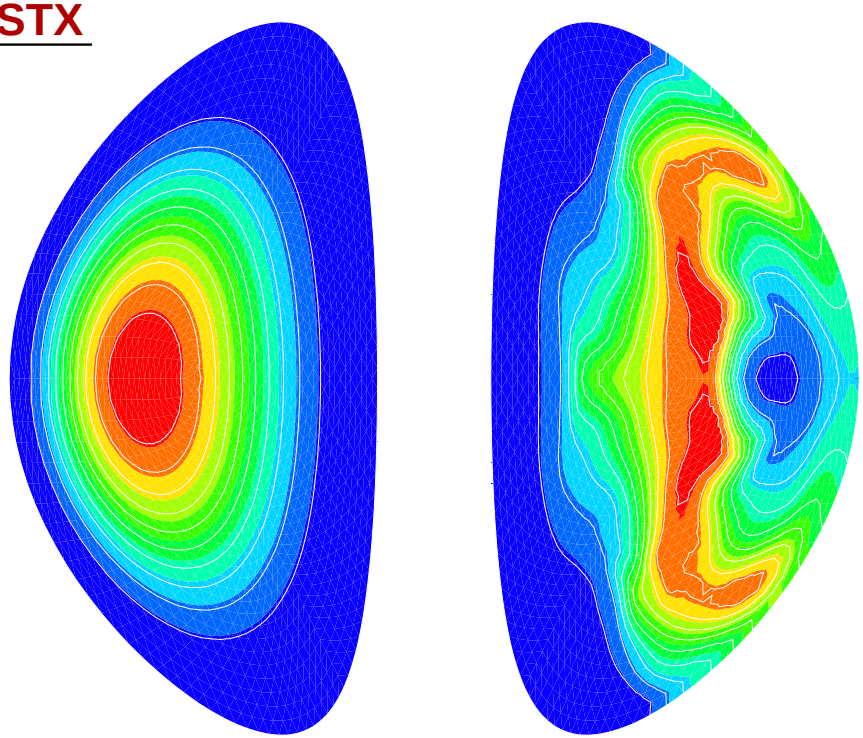
- Low Aspect Ratio, Shaping, Large Orbits $\rightarrow$
  Strong Poloidal Coupling $\rightarrow$
  Demand on Computation,
  Unexplored Regime for Neoclassical MHD
- Support MHD analysis of NSTX discharges
  throughout operation: (CODES-ON-LINE)
- Improve userfriendliness of Codes $\rightarrow$
  Implement limited between shot analysis using stability database and/or fast analysis techniques [FY00+]
- Study Resistive Wall Mode (RWM) stability,
  determine need for feedback [FY01+]

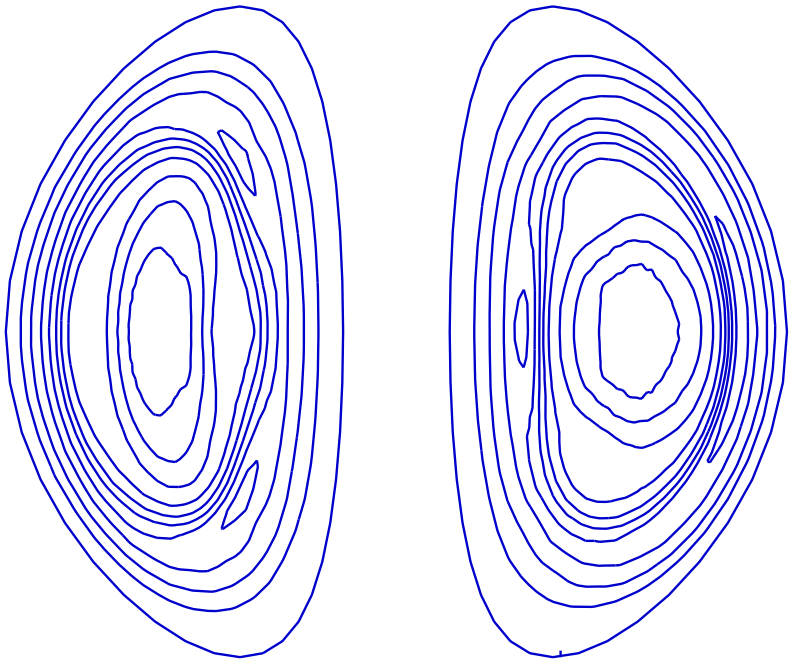
MHD Stability in NSTX cont'd

- Provide stability analysis to help develop steady state high-β operation scenario [FY01+]
- Simulate internal reconnection event (IRE) using nonlinear MHD codes [FY01+]
- Develop physics basis for modeling Coaxial Helicity Injection (CHI) [FY01+]
- Perform profile optimization analysis in high-β regime, determine parametric stability boundaries [FY02+]
- Nonlinear resistive MHD disruption simulation [FY03+]

M3D studies of NSTX

Pressure profiles:
Initial and during
a high-β disruption





Pressure contours
showing
saturated double
tearing islands in
a low-β plasma

Transport Studies in NSTX

Neoclassical Physics

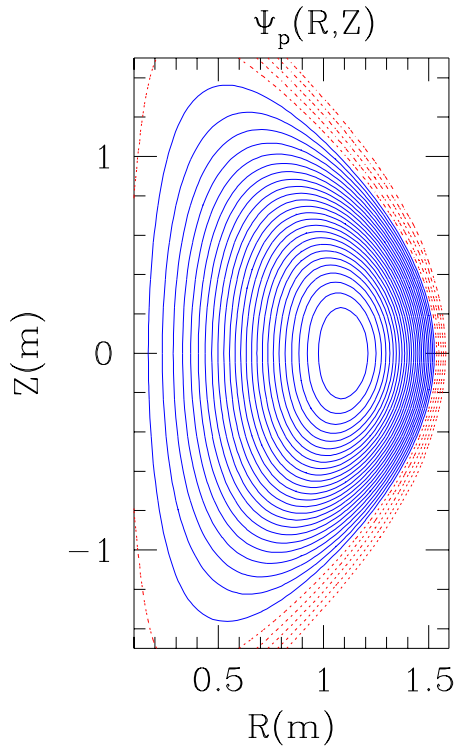
- Use Gyrokinetic (GTC) code to calculate neoclassical ion thermal and particle transport, as well as bootstrap current for NSTX equilibria [FY00]
- Calculate poloidal flow damping at low aspect ratio [FY01]

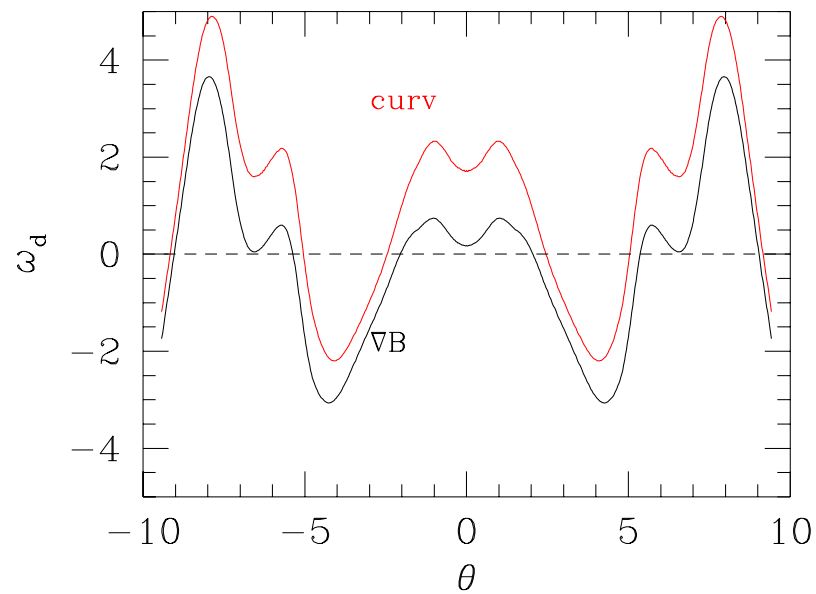
Participate in Diagnostics Development

- Determine range of $\mathbf{k}$ which contributes most to transport, and which survives $\mathbf{E} \times \mathbf{B}$ shear from Gyrofluid and GTC codes[FY00]
- Fluctuation diagnostics looking at high B side where $\mathbf{E} \times \mathbf{B}$ shearing rate is lower
- Theory support for Reynolds and Maxwell stress measurements[FY01]

NSTX: Gyrofluid Code in Realistic Geometry

$\mathbf{E} \times \mathbf{B}$ effects are included in realistic geometry.





We calculate equilibria using with JSOLVER, and numerically calculate $\omega_d(\theta)$ using JSOLVER output:

The difference between the curvature and ∇B drifts is an important feature of high-β NSTX plasmas.

Transport Studies in NSTX cont'd

Theory-Experiment Comparison

- Inclusion of external $\mathbf{E} \times \mathbf{B}$ flows, the electrostatic turbulence driven ion thermal transport calculation by Gyrofluid and GTC codes for model profiles [FY00+]
- Use measured profiles ($n, T, U_\phi, ...$) to determine neoclassical and turbulent ion thermal transport with the availability of fine resolution profile diagnostics[FY01+]
- Compare experimentally measured parametric dependencies of transport with GK and GF calculations [FY02+]
- Employ electromagnetic GF/GK codes for NSTX and DIII-D similarity experiments (similar cross-sectional shape) [FY02+]

Transport Studies in NSTX cont'd

- Linear stability theory possibly too optimistic

Extend Zonal Flow Generation Theory to High-β Plasmas

$$\epsilon^{3/2}\rho_{pi}^2\frac{\partial[\partial_r^2\Phi]}{\partial t} = \frac{1}{\Omega_i}\partial_r^2\{< U_r U_\theta > - V_A^2 < b_r b_\theta >\}...$$

- Reynolds stress drives zonal flows in electrostatic turbulence
- Maxwell Stress cancels Reynolds stress in Alfvenic state
  $\rightarrow$ Weaker zonal flows lead to soft-β limit?
- Simulation and covariant theory of electromagnetic ITG[FY03]
- Collaboration with experts in energetic particle physics[FY03]

Energetic Particle Physics in NSTX

Strong poloidal coupling, Wide gap in Alfven continuum, $v_h/v_A > 1$ for high-β $\rightarrow$
Nonperturbative stability calculation capabilities required including Nova-K upgrades

- TAEs expected to be unstable $\rightarrow$
  Continue TAE scoping studies, initiate sawteeth and fishbone stability [FY00]

- Extend stability studies of TAEs, Sawteeth, and fishbones for high-β plasmas with the availability of high frequency fluctuation and fast ion diagnostics [FY01+]

Energetic Particle Physics in NSTX cont'd

- Initiate the development of simulation capability for TAE and fishbone nonlinear saturation in collaboration with the University of Texas[FY03]
  Calculate associated ion beam losses[FY03]
- Address role of compressional Alfven waves in high-β plasma transport[FY03]
- Continue development of the theoretical and numerical models for wave-induced flow shear generation
  Predict requirements to control turbulence [FY04]

Boundary Physics Studies in NSTX

High $\delta, q_{95} \rightarrow$ Edge Localized Modes may be benign (Grassy ELMs in JT60-U, EDA in C-mod)

- Theoretical understanding of edge turbulence:
  Collaboration between DEGAS-2 (PPPL) and BOUT (LLNL)
  Comparison to observed filaments by turbulence imaging diagnostics [FY01+]
- Theoretical understanding of H-mode power threshold in collaboration with LLNL (BOUT) [FY02]
- Study of pedestal width scaling:
  Large orbit size, high $q_{95} \rightarrow$ Test possible ρ_{pi}, magnetic shear dependence and implications of bootstrap current
  Neutral density dependence with DEGAS-2 [FY04]

Conclusions

- PPPL theory work has identified crucial issues, and motivated some experiments in NSTX
- Physics in new parameter regime expected in NSTX require extension of theories and code upgrades
- Active participation in the future experiments through data analysis, theory development, and experimental proposal for comparison