Summary of theory talks at Results review and Theory Forum

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PPPL

Overview

- Theory and modeling talks fall into two categories
  - Results review : Specific shot analysis
  - Updates and plans : Generic equilibrium
- This was not a comprehensive forum

Results Review talks

- CHI – Schaffer
- MHD – Bialek
- Energetic particles – Gorelenkov, White
- Confinement and transport – Redi
- RF – Bonoli, Mau
- Boundary – Rensink, Stotler

Theory and modeling talks

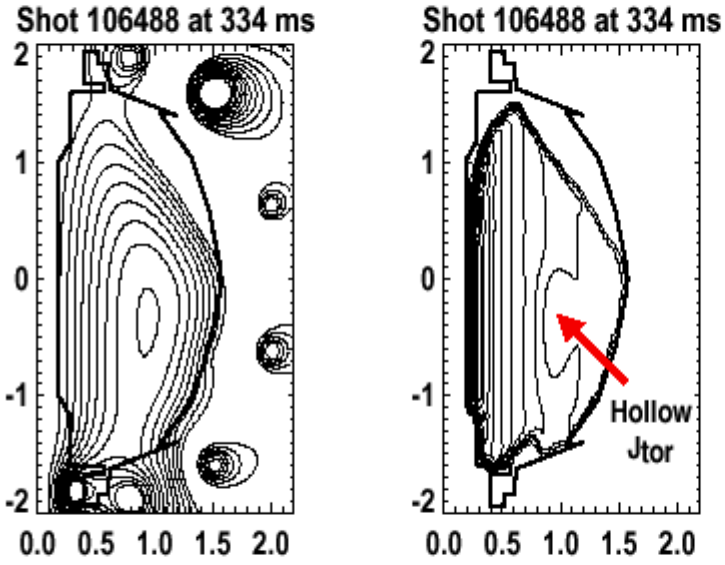
- CHI – Tang
- MHD – Guazzotto, Park
- Energetic particles – Belova
- Confinement and transport – Houlberg
- Boundary – D'Ippolito

CHI

Issues Modeling of experiment, helicity transport and physics of closed surfaces

EFIT run with SOL Current Finds a Small Closed-Flux Region. It Has a Hollow J_{tor} Distribution.

NSTX



Flux Surfaces Current Contours

- EFIT finds a small closed-flux region, even though a hollow current profile makes less flux than a peaked one.
- Hollow J is qualitatively consistent with theoretical helicity transport concepts.
- EFIT cannot fit low-current CHI shots (no closed surfaces).

- SOL current out to 2nd X–pt.
- Fit indicators are quite poor in both E-and MFIT.

4 NSTX Results Review 2002

GENERAL ATOMICS

Schaffer

CHI

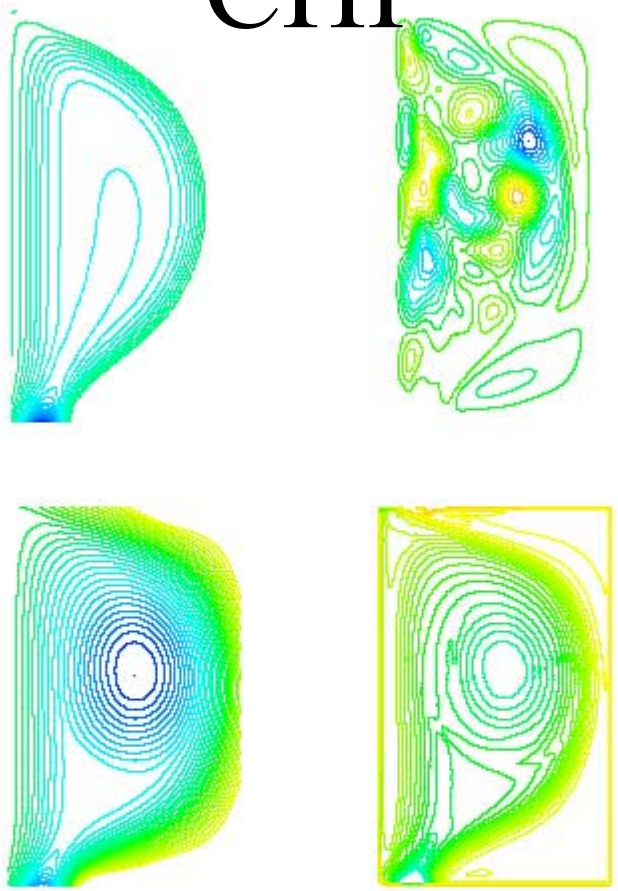
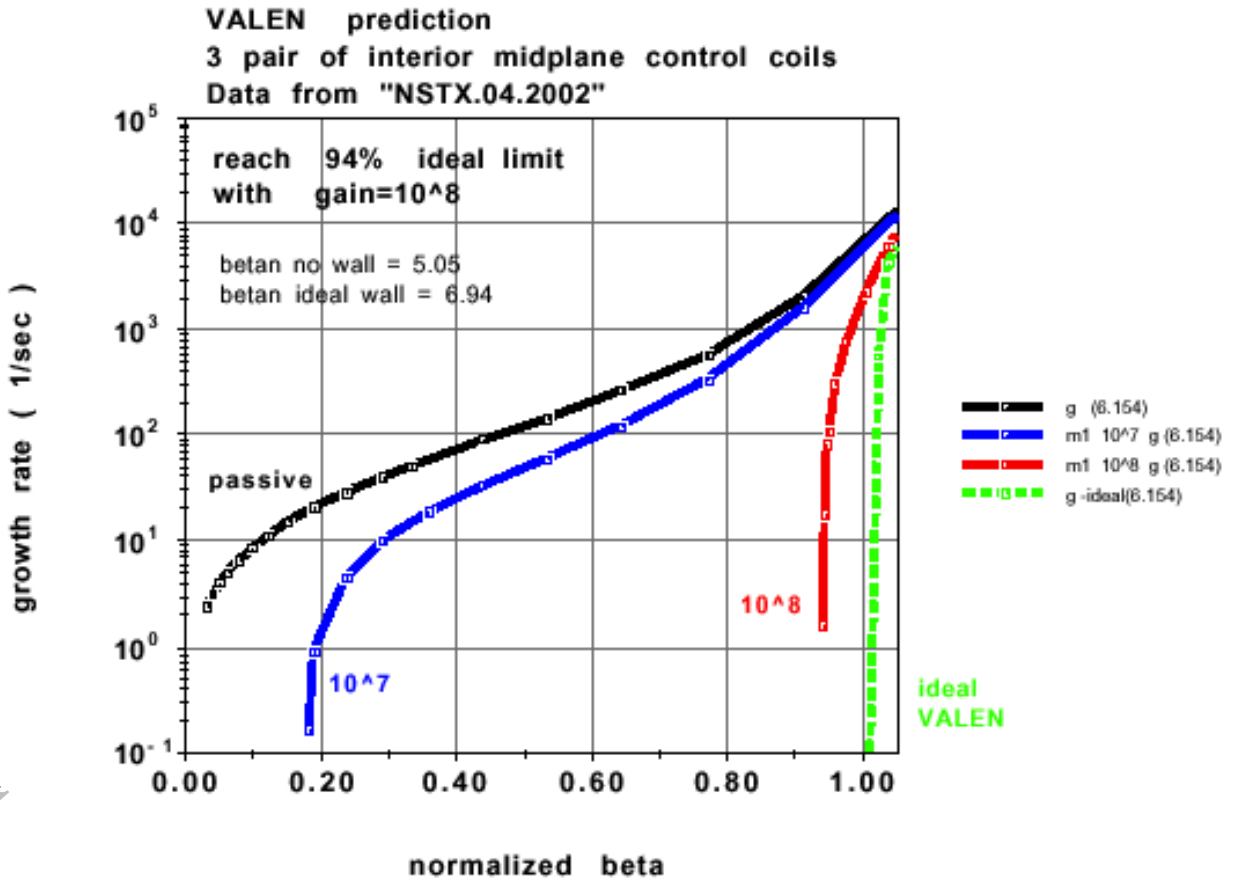


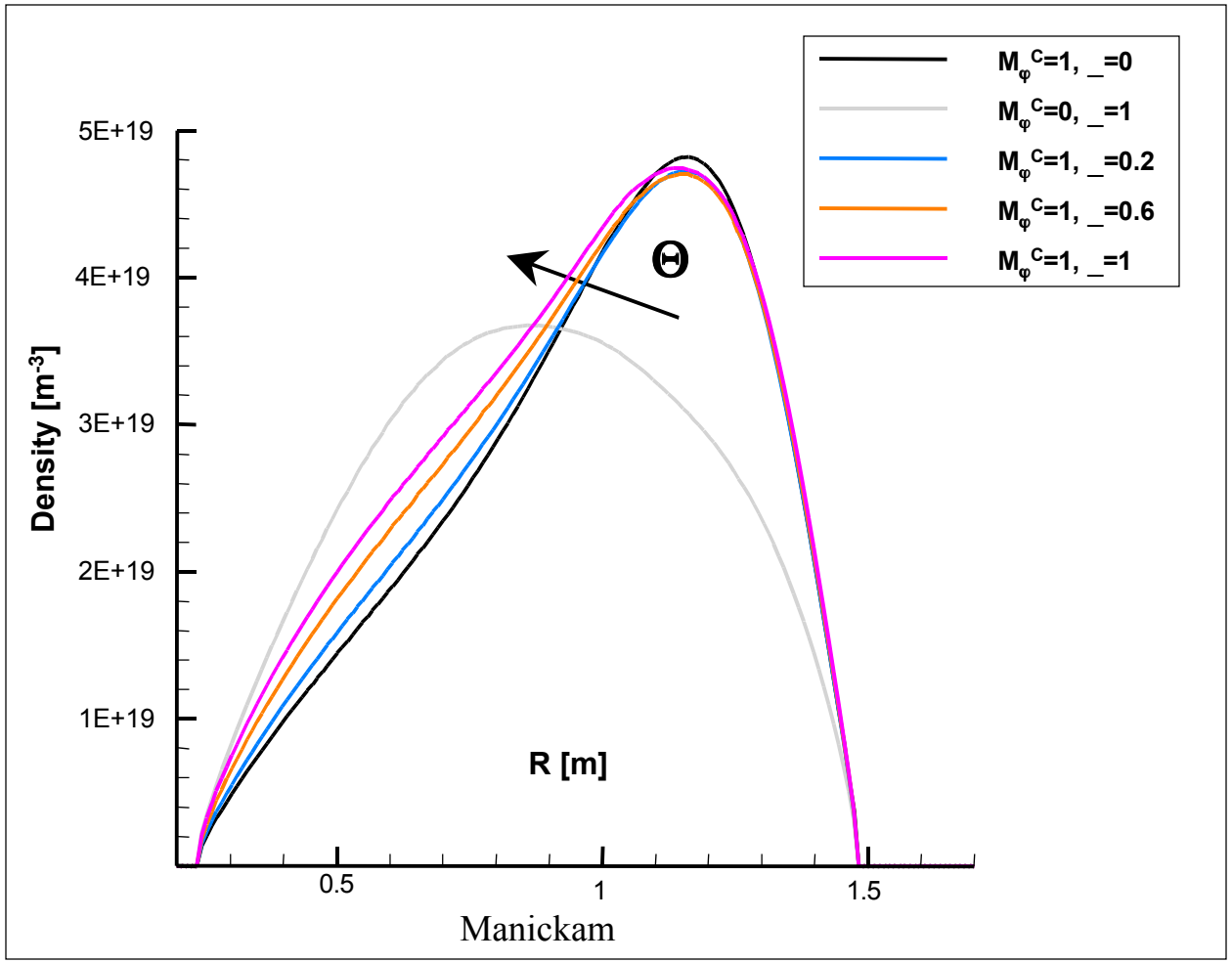
Figure 4: Top left: Axisymmetric steady state χ; Top right: n=1 component of 3D χ; Bottom left: $n = 0$ component of 3D χ; Bottom right: $n = 0$ component of 3D RB_φ.

MHD


VALEN prediction
3 pair of interior midplane control coils
Data from "NSTX.04.2002"
reach 94% ideal limit
with gain=10^8
betan no wall = 5.05
betan ideal wall = 6.94
passive
10^7
10^8
ideal
VALEN
growth rate (1/sec)
normalized beta
g (6.154)
m1 10^7 g (6.154)
m1 10^8 g (6.154)
g -ideal(6.154)

Bialek

Flow and parallel anisotropy have opposite effect



Guazzotto

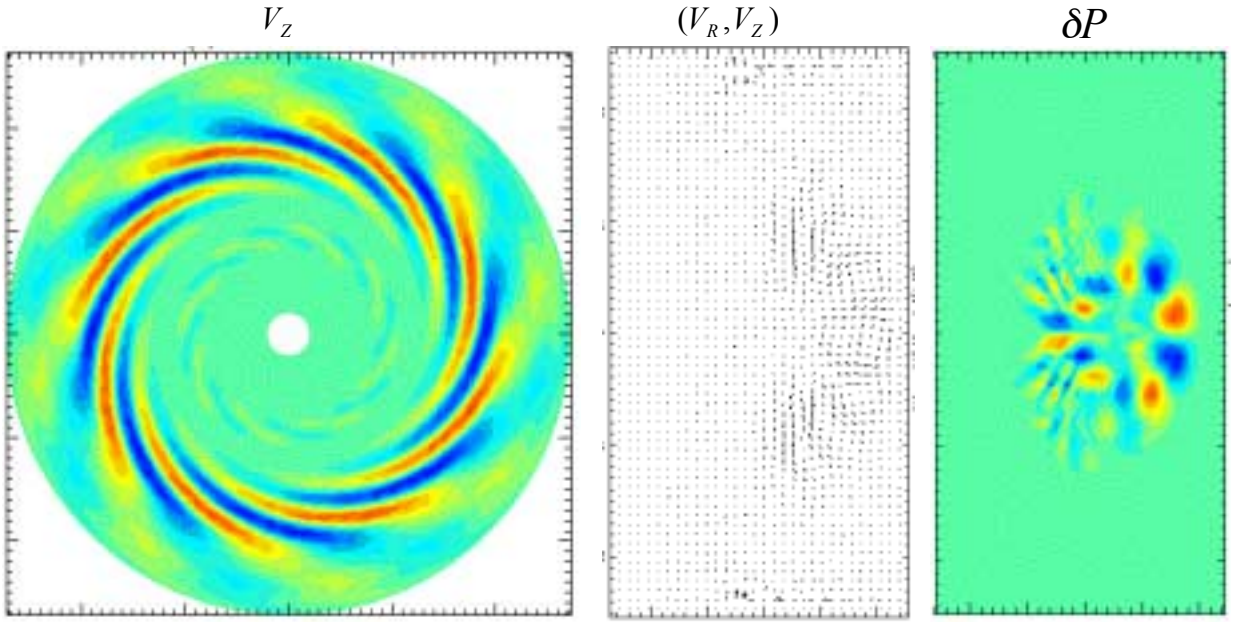
MHD

- M3D code with MHD, Two-fluids, and Particle/Fluid Hybrid levels is used to study NSTX.
- The relative density shift relation holds both in the simulation and experiment, with the centrifugal force of the hot component included.
- Toroidal sheared rotation reduces linear growth and can saturate internal kink.
- IRE:Disruption can occur in at least in two ways; due to stochasticity, and due to localized steepening of pressure driven modes.
- BAE mode is found which may explain experimental data.
- Resistive wall, vacuum region, and external coils are being added to M3D code to expand the regime of applicability.

W. Park

Simulations for n>7 show localized modes with large compressional component (CAE?)

Hybrid simulation with n=8 show weakly unstable mode with m=8-10, $\omega = 0.4\omega_{ci}$, and $\delta B_{\|} > \delta B_{\perp}$



Contour plot of z-component of fluid velocity at equatorial plane

Vector plot of poloidal fluid velocity.

Contour plot of perturbed pressure.

Belova

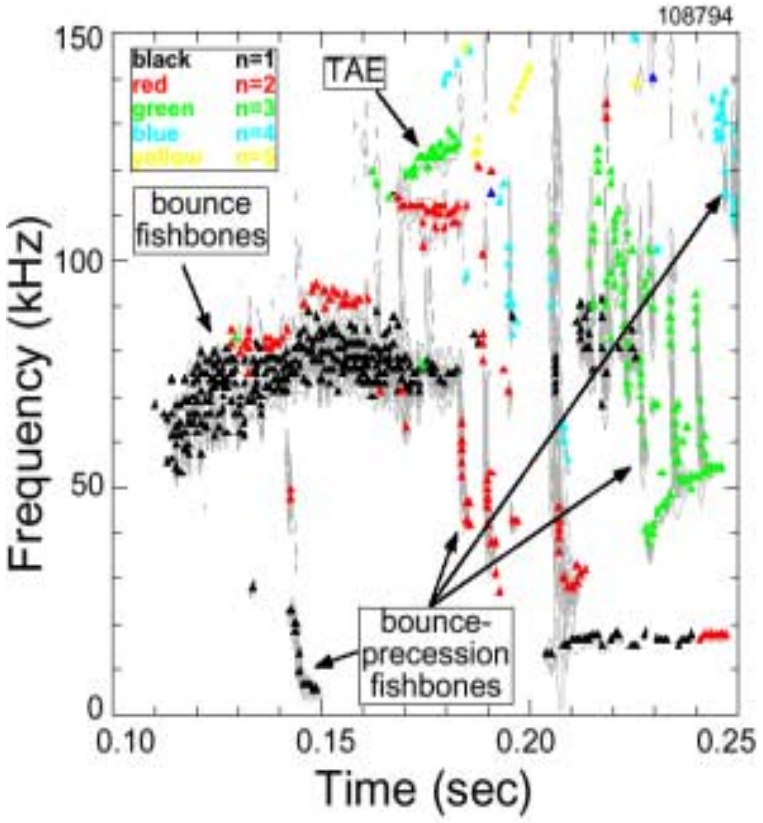
Identification of Alfven eigenmodes

- Observed sub-cyclotron oscillations are likely to be Compressional and/or Global Alfven eigenmodes driven by NBI ions
- Experimental spectral analysis yields qualitative agreement with theory
- Finite aspect-ratio analysis give correct frequency spacing
- More accurate analysis including realistic distribution functions for growth-rate using HYM code in progress
- Accurate mode charactersitics information required – polarization
- Damping mechanism to be studied – continuum , stochastic

Gorelenkov

Bounce frequence fishbones

- Large amplitude bursting modes identified as bounce frequency fishbones
- Important when there are many trapped particles and bounce angle is large
- Stable to precession resonance fishbone
- Could be important in ignited plasmas



White

Fast Ion Transport Calculations

- Benchmarking of EIGOL and GYROXY
  confirms results of both codes and
  are in good agreement with CONBEAM - can extend GYROXY
  to long time orbit calculations

- CONBEAM provides fast estimates of confinement
  without details of ion orbit paths (minutes).
  Confirmed good confinement with high I_p, B_t, $1/\rho_L$, high r_{tan}
  15 EFIT NSTX equilibria : ρ_L best guarantor of good confinement
  A possible between-shots analysis code
  Recently upgraded to calculate nonadiabatic losses (small)

- GYROXY calculations
  - long integration time calculations of collisionless confinement (days)
  - can address nonadiabatic and collisional losses

Neoclassical theory developments

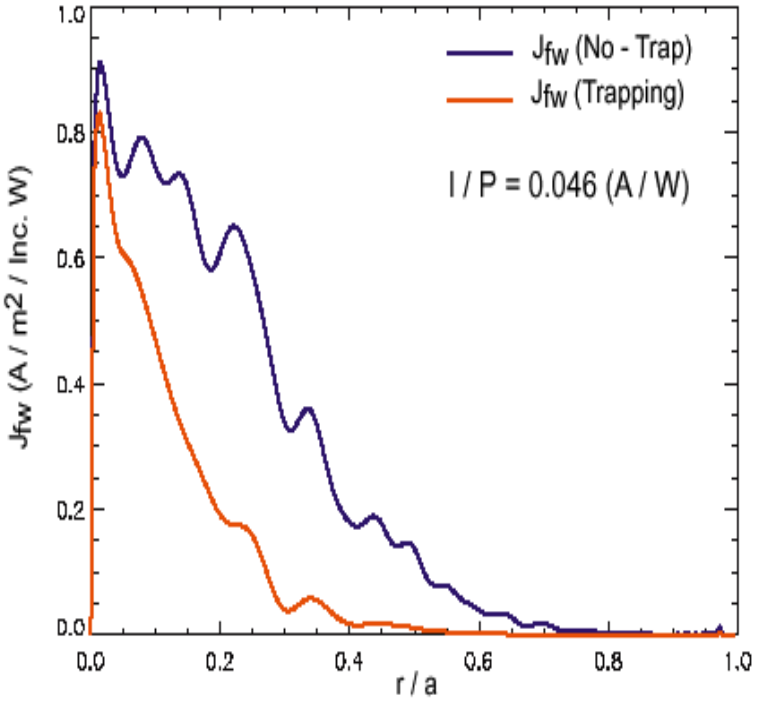
- The ion energy balance anomaly in NSTX has caused us to re-examine NBI driven energy fluxes as a possible explanation:
  - Work by Callen, et al (1974), Stacey, et al (1984-1993), and Hinton and Kim (1993) all have noted that an inward inward ion heat flux is driven by co-injection
- The expressions in the literature use limiting assumptions that are not readily applicable to NSTX:
  - Thermal ions deep in the banana regime (not true in the outer half of NSTX where the anomaly is strongest)
  - Large aspect ratio approximations (same reason)
  - Stacey, et al, and Hinton and Kim evaluated only the part driven by the NBI parallel momentum force (parallel heat force effect is likely the more dominant effect in NSTX, see next comment)
  - Expressions from Callen, et al, show the effect from NBI parallel heat force scales as Eb/Ti and can be dominant for NSTX (simple circular plasma approximation and NBI distribution)
- We are reworking the theory to remove the most questionable assumptions for NSTX, for incorporation into NCLASS using the fast ion distribution from the TRANSP NBI package

Houlberg

Modeling of HHFW current drive using TORIC

- Full wave solver coupled to an adjoint solution of the Fokker-Planck equation
- Modeling predicts $I_{co} > I_{ctr}$

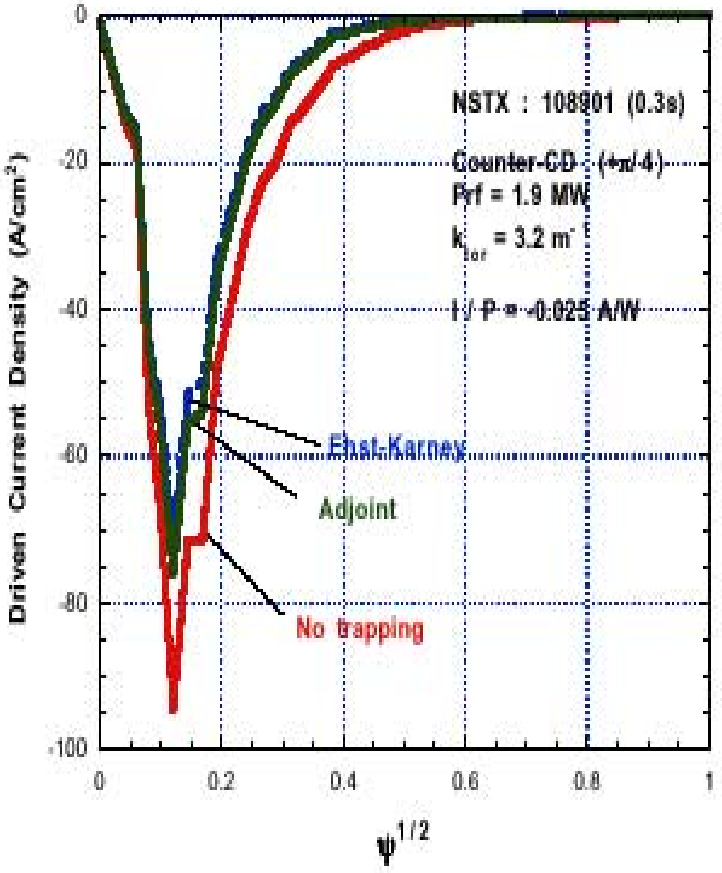
- Reduction in J(r) due to trapping is significant
- Need to include poloidal field variation

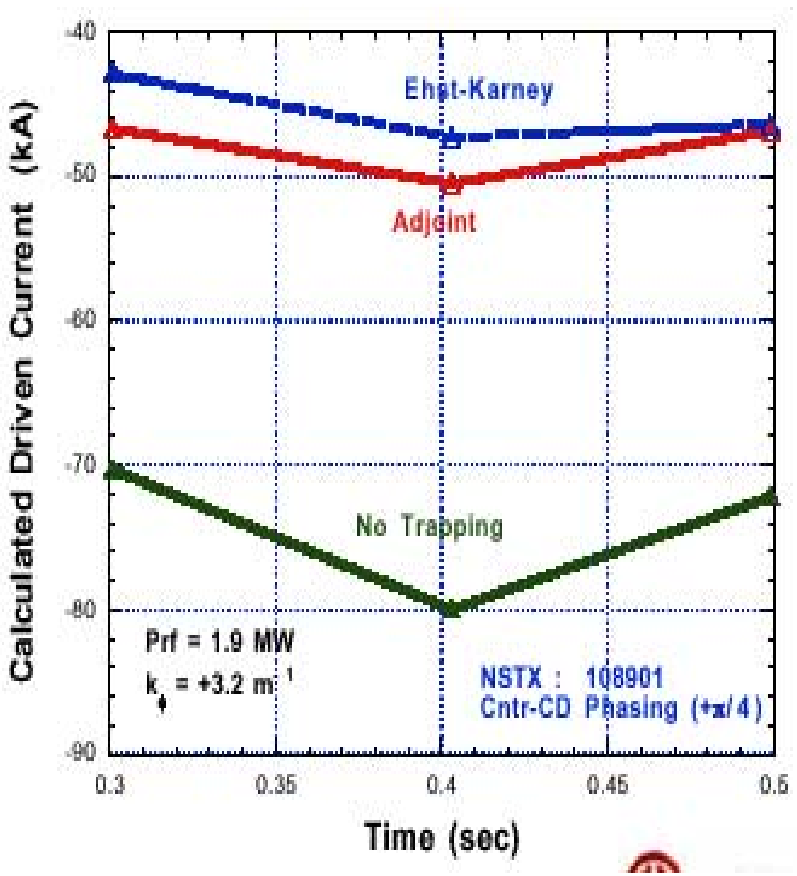


Bonoli

Modeling of HHFW current drive using CURRAY

- Ray tracing coupled to an adjoint solution of the Fokker-Planck equation
- Reduction in J(r) due to trapping is significant
- Coupling to TRANSP near completion

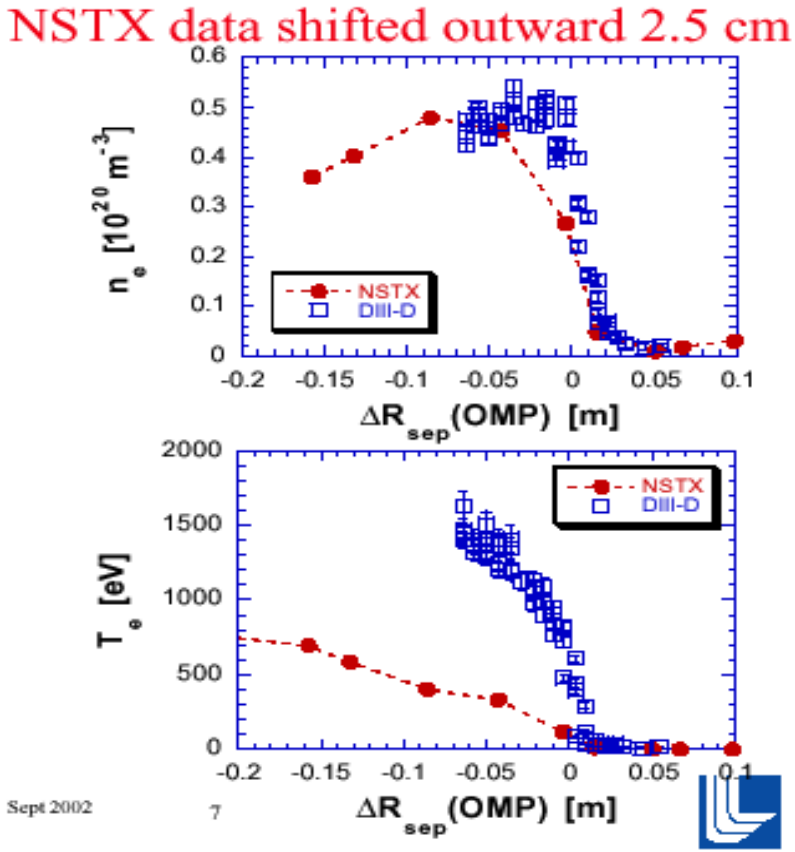




Mau

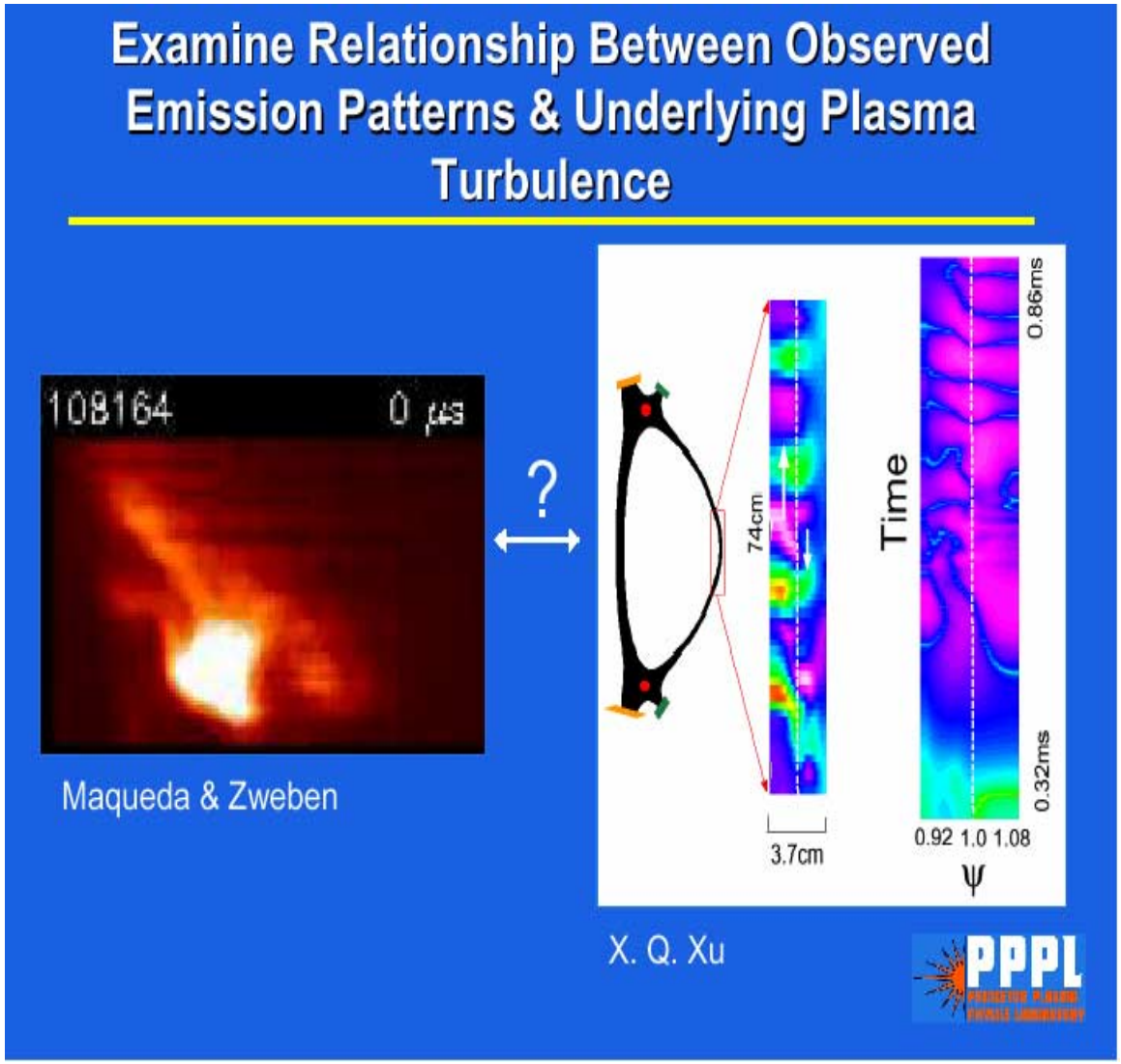
Modeling of boundary with UEDGE

- Initial analysis of boundary characterization
- Separatrix position from EFIT inconsistent with edge data
- H-mode transport coefficients appear to be 10 times DIII-D
- Divertor heating power and impurity content from simulation don't agree with experiment



Simulation of gas puff imaging

- DEGAS-2
- Realistic 2-d geometry
- Input n(r), T(r) and compare with observed cloud, or
- Use ad-hoc 2-d perturbation and compare spatial structure



SOL transport theory and modeling

Comparison of blob model to GPI data on NSTX

- initial kinematic analysis of blob motion, sizes and lifetimes (A. Keesee et al.)
  - blobs propagate radially and poloidally
  - blob size distribution was obtained
  - theoretical relation between v_x and blob size not confirmed

- we will extend the above work by carrying out a physics-based analysis of GPI and probe data to see which physical effects are important to understand the data.
  - infer potential φ from the GPI data, compute $\mathbf{v} = (c/B)\,\mathbf{b} \times \nabla\varphi$, and compare with observed blob motion and with predictions of theory.
  - is observed motion due to $\mathbf{E} \times \mathbf{B}$ drift?
  - what is relative importance of vorticity, sheath, and curvature drift physics?

D'Ippolito