Theory Contributions to Tokamak Concept Innovation at PPPL

C-MOD (MIT)

JET (Europe)

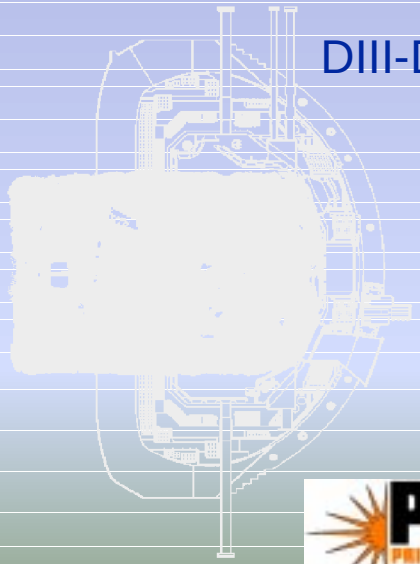
R. Nazikian

For the Theory Review

June 1-2, 2000

Princeton Plasma Physics Lab.

DIII-D (GA)



JT-60U (Japan)

PPPL
PRINCETON PLASMA PHYSICS LABORATORY

Approach to Addressing Advanced Tokamak Issues inline with FESAC Goals

Develop predictive first principles understanding of turbulence, transport and plasma profiles

Understand and control stability of long wavelength modes

Develop methods for profile, transport and particle control

Flexible teams of PPPL theorists, experimentalists and engineers bring an integrated approach to key tokamak issues

Theory Contributions to Understanding and Control of MHD

Demonstrated capability of modeling experiment in TFTR

Some Highlights:

- High-n ballooning modes: (M3D)

(W. Park et al., PRL 95)

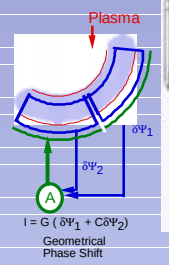
- Infernal modes in ERS (PEST)

Challenge:
Enhance performance through profile and MHD control

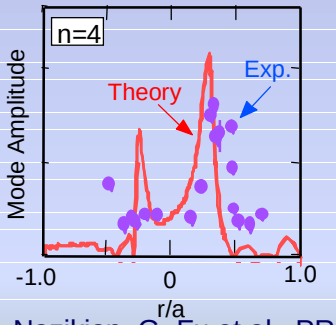
Feedback stabilization of resistive wall modes (DIII-D, Columbia):

- Theory role central to feedback initiative

(M. Okabayashi, N. Pomphrey, R.E. Hatcher NF 98)



Theory prediction led to observation of alpha-driven modes in TFTR



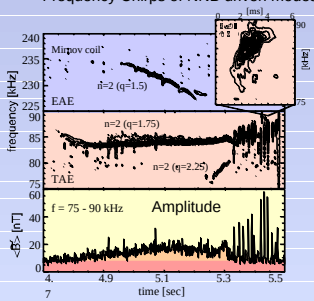
(R. Nazikian, G. Fu et al., PRL 97)

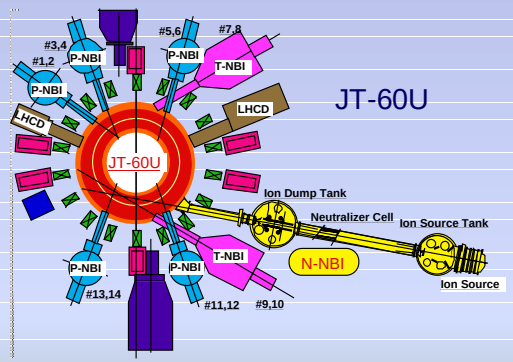
Challenges:

- non-perturbative fast ions (NOVA-2)
- non-linear saturation and loss (M3D)

Alpha physics and simulation experiments on JET and JT-60U

Transition to Bursting Enhances Mode Amplitude:
Frequency Chirps of NNB driven modes





JT-60U

- simulation of alpha driven modes with 500 keV D beams
- Explanation of chirp mode using HINST (high-n code)

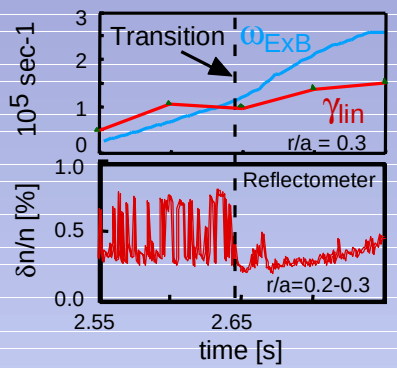
JET

- NOVA-2 analysis of sawtooth stabilization by alphas (low-n non-perturbative: Gorelenkov et al., EPS 00)

Theory Contributions to the Study of Turbulence Suppression and ExB Shear in Transport Barriers

PPPL/GA collaboration reveals key role of ExB shear in transport barrier physics

$$\omega_{ExB} = \left| \frac{(RB_\theta)^2}{B} \frac{\partial}{\partial \psi} \frac{E_r}{RB_\theta} \right|$$ (Hahm and Burrell, Phys. Plasmas (1995))



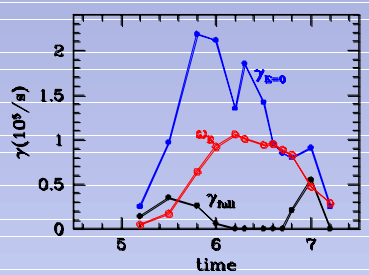
E. Mazzucato et al., PRL 1996.

Challenges for AT physics:

- Transport barrier formation: onset and scaling
- Anomalous (large) electron transport, except in barrier
- Turbulence simulation with large scale ExB shear: comparison to experiment

Extension to international collaborations:

JET



JET:

- ExB shear sufficient to stabilize turbulence in OS regime

(M. Beer et al., EPS 1999)

- suppression of fluctuation level observed, similar to TFTR

JT-60U:

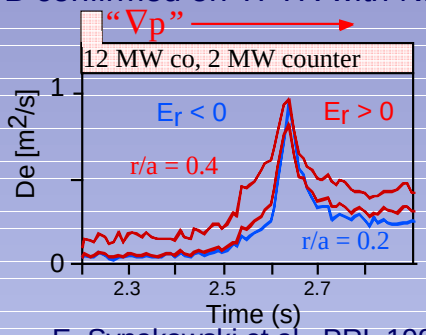
- ExB shear insufficient to stabilize turbulence

(G. Rewoldt et al., Phys. Plas. 98)

- radial decorrelation observed on reflectometer, no clear sign of suppression
- Next step: non-linear simulation of decorrelation

Core Transport and Edge Particle Control

ExB Shear control of
ITB confirmed on TFTR with NBI



E. Synakowski et al., PRL 1997

Challenge:

- Develop reactor relevant control tools

ICRF methods for flow control in AT regimes

C-MOD

ICRF

C-MOD:

- MC-IBW and V_{pol}
- ICRF and V_{tor}

(F. Perkins, R. White, IAEA 00)

- LHCD for q-profile control

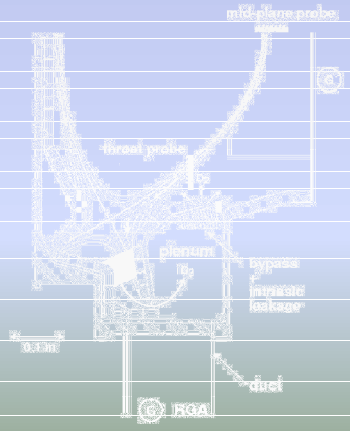
Control of impurity influx, neutral fueling and recycling in the plasma edge

Challenge:

- Control of impurity accumulation and edge density essential for advanced tokamak operation

Collaborations:

- DEGAS 2 code applied to C-MOD bypass experiments (D. Stotler et al., PSI 2000)
- Bypass experiments designed to test divertor control of neutral density

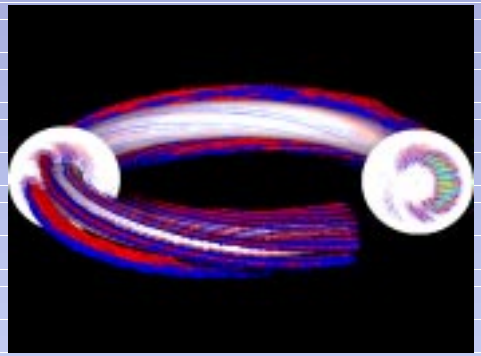


C-MOD Divertor baffling experiments

Advances in Simulation and Visualization Create New Opportunities for Enhanced Theory Experiment Integration

GTC simulation:

Z. Lin



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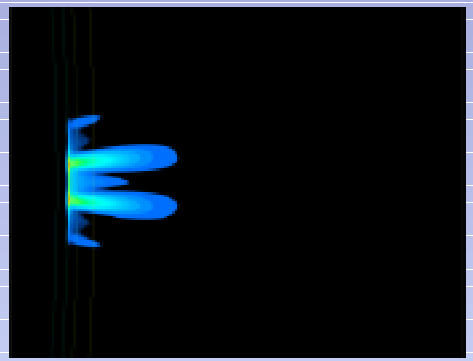
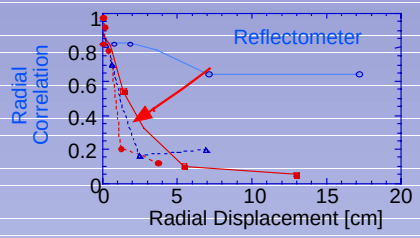
Parallelized simulation of μ-wave reflection:

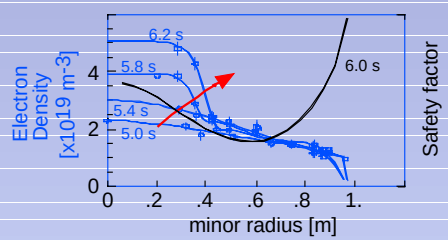
E. Valeo



• System size ~ 200 λ x 100 λ

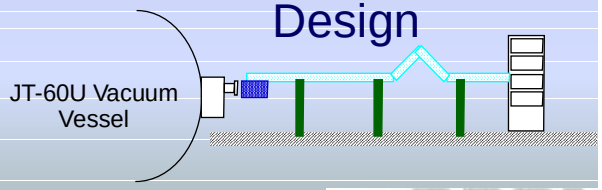
Data Interpretation (JT-60U)

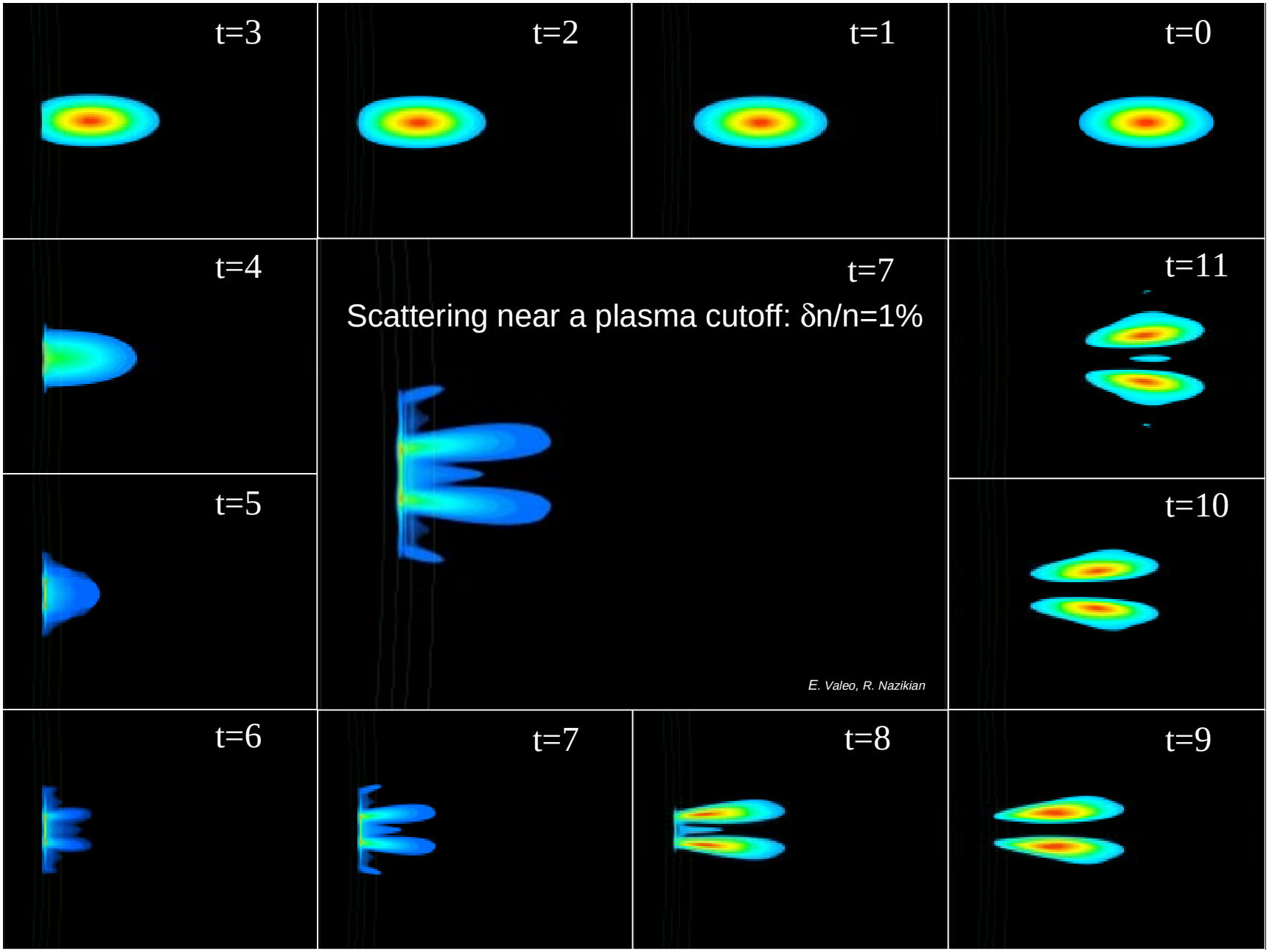




R. Nazikian et al., IAEA 1998

Experimental Design

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t=2
t=1
t=0
t=4
t=7
Scattering near a plasma cutoff: δn/n=1%
t=11
t=5
t=10
E. Valeo, R. Nazikian
t=6
t=7
t=8
t=9

PPPL Theory Strongly Contributes to Tokamak Concept Innovation

• Flexible teams of PPPL theorists, experimentalists and engineers bring an integrated approach to key tokamak issues

• Involvement of theory in the design of control systems, experiments, and data interpretation will continue to increase with

- improvements in computation and simulation capability
- advances in scientific visualization and diagnostics