Activities of the US Burning Plasma Organization

M.G. Bell

Vice-Chair of Council,
U.S. Burning Plasma Organization*

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* I wish to acknowledge the major contribution of Chuck Greenfield, Director, USBPO to this talk

The USBPO is the principal coordinating body for MFE burning plasma research

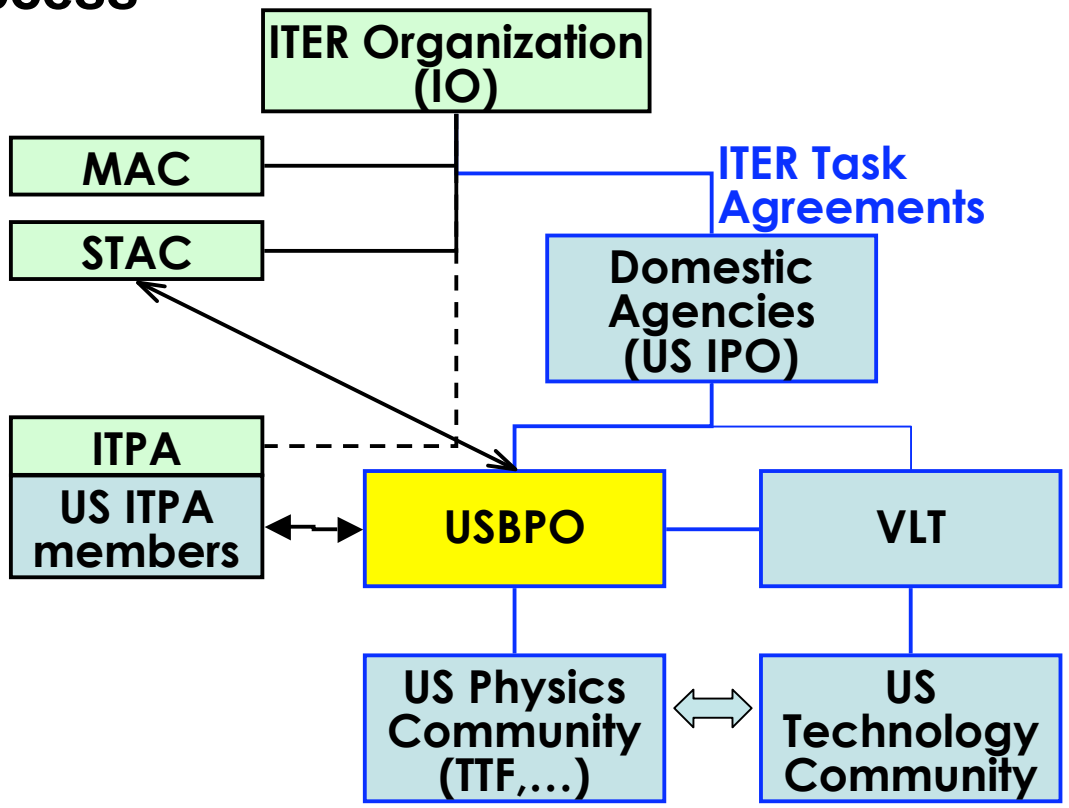
- **It exists to *advance the scientific understanding of burning plasmas and ensure the greatest benefit from a burning plasma experiment by coordinating relevant U.S. fusion research with broad community participation***
- **Works with laboratories, universities, ITPA, TTF, ITER Organization, US ITER Project Office (IPO), DOE, ...**
- **Membership is open to researchers and graduate students active in burning plasma science and technology research, and whose home institution lies within the U.S.**
  - 372 current members represent a cross-section of the community
  - We particularly encourage students to join: *they will be the ITER generation*
  - http://burningplasma.org

The USBPO acts as the science arm of US ITER

- **Most US research in MFE is now focused on making ITER a reality and ensuring its success**

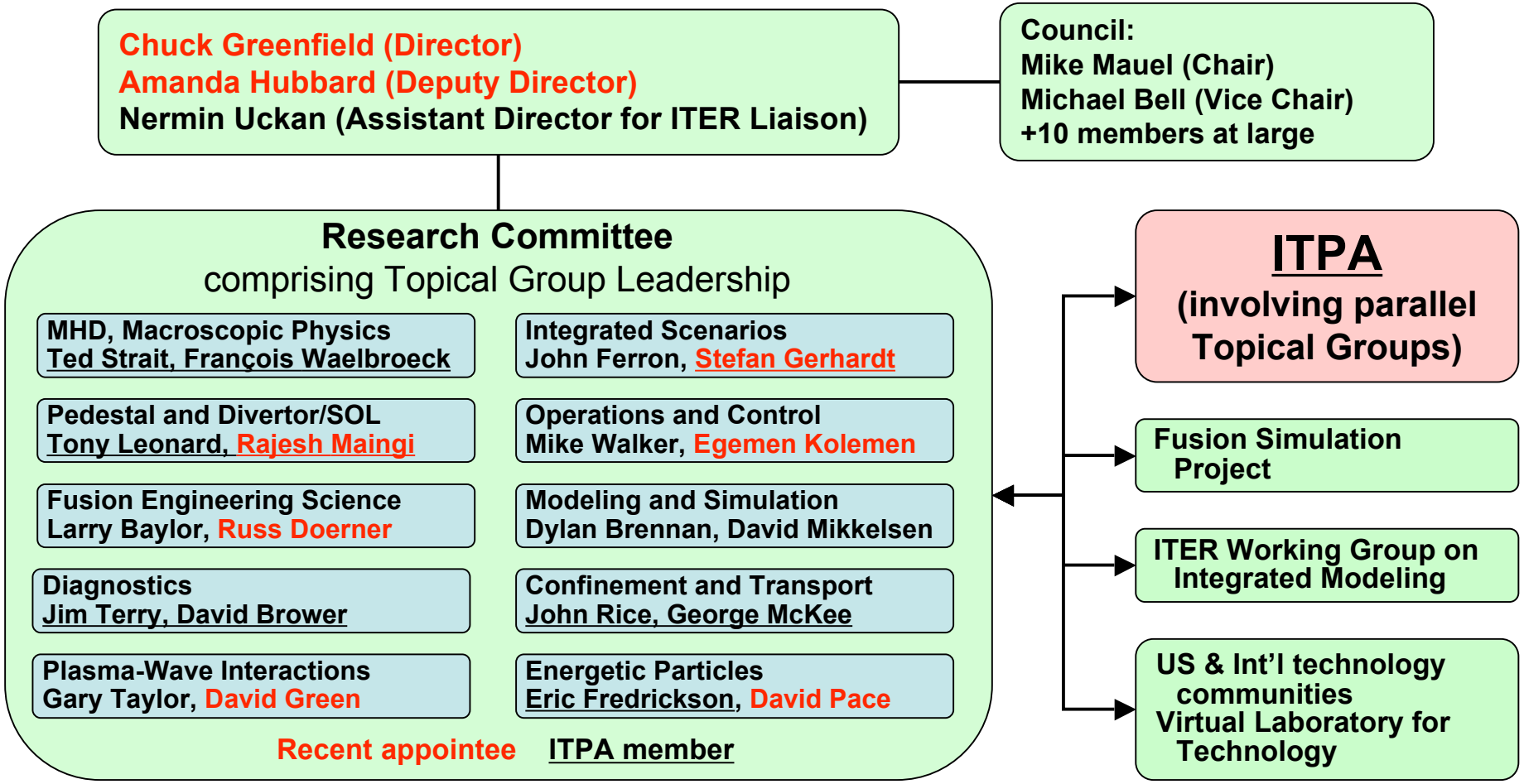
- **ITER research tasks come to the community**

  1. From the IO through the US domestic agency (US IPO)
  2. Through the ITPA (now under ITER auspices) e.g. joint experiments, etc.
  3. Self-generated BPO tasks



The US was a leader in establishing domestic frameworks for ITER support

The USBPO is well integrated with the US ITPA involvement and other research communities



- USBPO directorate takes lead role in identifying and recommending US ITPA members to DOE
- Director participates in annual ITPA Coordinating Committee and Joint Experiments meeting

USBPO continues to organize activities to advance burning plasma research

- **Began with the 2006-7 ITER Design Review**
  - US MFE community contributed strongly in identifying design issues
- **Addressed several urgent issues that have arisen since**
  - ELM control, disruptions, control, etc.
- **Conducted briefings by experts in the community for the US delegates to the ITER Science and Technology Advisory Committee (STAC) prior to each of its meetings**
- **Support for US-based students to attend ITER Summer Schools**
  - **8 scholarships awarded for June 2011 school in Aix-en-Provence**
- **Organized a rapid response from the US community to the proposed ITER deferrals (August, 2011)**
- **Completed a study on "International Collaboration Opportunities for the US Fusion Sciences Program" (July 2011)**
  - This report has become an input for a FESAC subpanel on this topic

Dissemination of information to the community has become an important function of the USBPO

- **Monthly BPO eNews newsletter (542 subscribers!)**
  - Received by all members
  - Others are welcome: http://burningplasma.org/enews_signup
- **Community video/web seminars**
  - Typically, about 20 sites participate via ESnet H.323 and ReadyTalk
  - To date, we have used these seminars to report on ITPA matters
  - Plan to expand scope, *e.g.* more introductory topics geared toward students and early-career scientists
- **Presence at annual APS-DPP conference**
  - Town Meeting with speakers from IO, USIPO, ITPA, USBPO
  - Contributed oral session "Research in Support of ITER" (15 talks)

Highlights of community-wide research in support of ITER

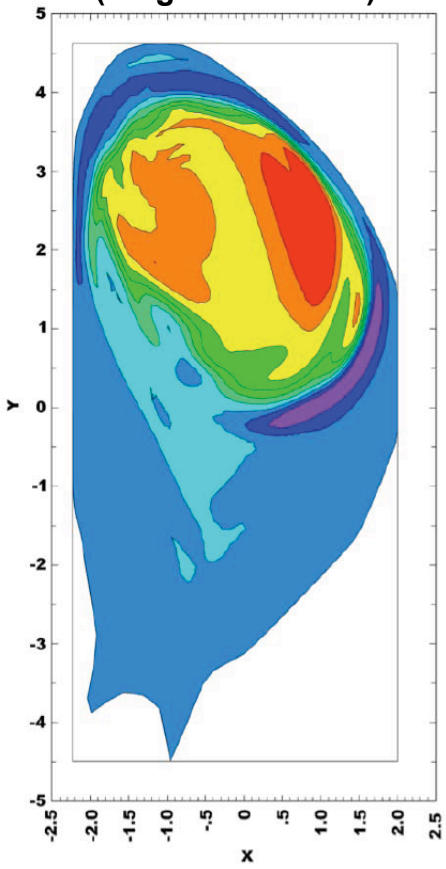
- **Organization of this summary**
  - Topical areas with explicit needs identified by the ITER Organization listed first
    - Items in red provided by D. Campbell, Director for Plasma Operation, IO
  - Other topical areas are important for predicting ITER performance
    - Some reflect US community strengths and priorities

This summary is in no way exhaustive: there is too much to cover in the time available

Avoidance and mitigation of disruptions: minimizing the risk of damage

- **ITER needs**
  - Reliable mitigation systems
  - Improved database for thermal loads
  - Energy deposited by runaway electrons (RE)
  - Improving disruption prediction success rates
  - Extending RE physics to ITER
- **Recent and current research**
  - Rapid shutdown with gas and pellet injection
  - Stabilizing locked tearing mode
  - Runaway electron physics
  - Demonstration of controlled RE dissipation
  - RE confinement increases with machine size
  - Experiment and modeling show low-κ limiter plasmas retain REs more than high-κ divertors
  - More comprehensive disruption simulations

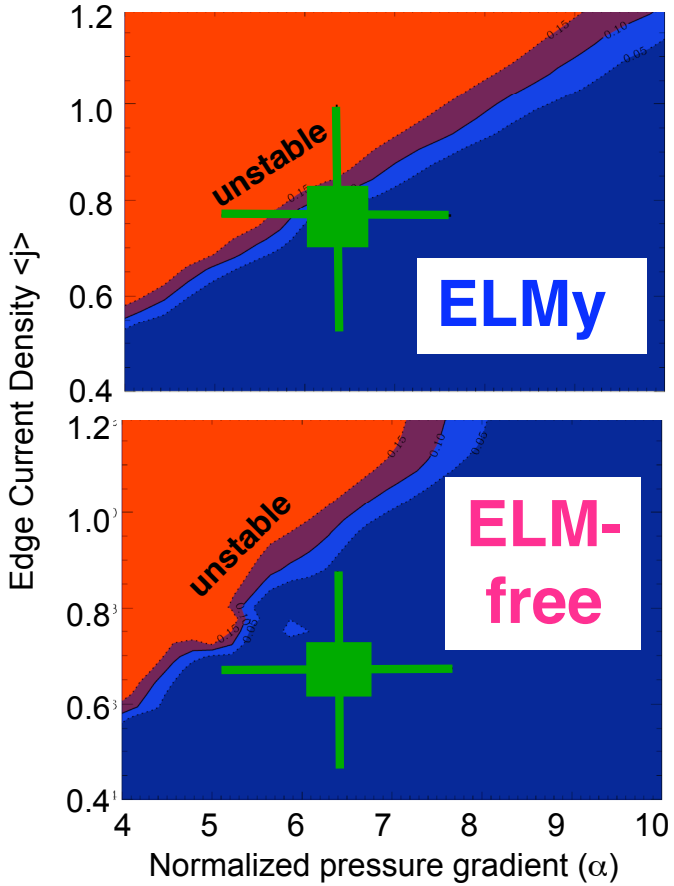
Toroidal current density at t = 46τ_A (range: -1.1 – +3.2)



M3D modeling of an ITER VDE-triggered disruption (H. Strauss, 2011)

Limiting the potentially damaging effect of ELMs: Avoidance, suppression, or mitigation

- **ITER needs**
  - Improved understanding of ELM physics (scaling, footprint, ...)
  - Physics of RMP ELM suppression
  - Extend naturally ELM-free scenarios and pacing to ITER conditions
- **Recent and current research**
  - ELM-free operating scenarios: QH-mode, I-mode, lithium coating
  - ELM pacing via vertical jogs, pellet injection, pulsed RMP
  - Progress in understanding physics of RMP ELM suppression

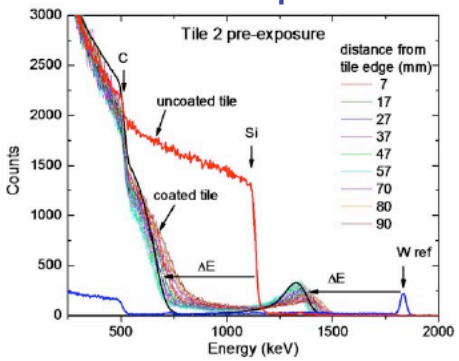


Edge stability space and experimental data for ELMy (non-lithium) and ELM-free (with-lithium) NSTX discharges (D. Boyle, 2011)

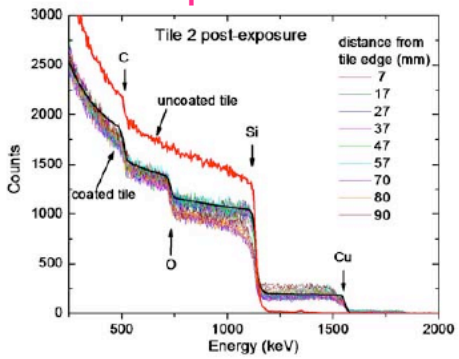
Protecting the first wall: Thermal loads, erosion,…

- **ITER needs**
  - Physics and scaling of heat flux width
  - SOL heat and particle transport
  - Characterization of secondary divertor
  - Divertor detachment at high performance
  - Operation with Be wall and W divertor
  - Effects of damage to tungsten surfaces
  - Fuel recovery techniques
- **Recent and current research**
  - 2010 FES Joint Research Target
    - Divertor heat flux width $\propto I_p^{-1} B_T^{0} P_{loss}^{0}$
  - PFC erosion, redeposition and migration
    - PISCES investigating beryllium
    - DIII-D investigating tungsten
    - SNL analysis of exposed/eroded PFCs
- ***If carbon divertor is reconsidered, US will provide new data***

Before exposure



After exposure in EAST

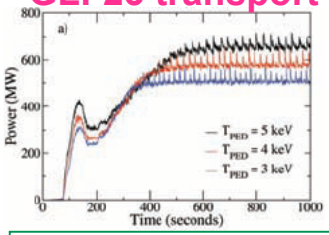


Rutherford backscattering analysis of a tile with a 1μm C layer following erosion by >10hr plasma exposure in EAST tokamak (W. Wampler, 2011)

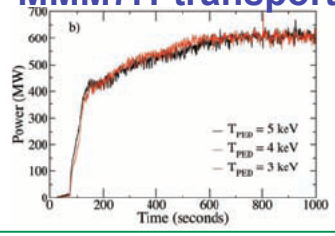
Developing and qualifying operating scenarios to fulfill ITER's mission

- **ITER needs**
  - Evaluate impact of possible deferrals:
    - Heating and current drive systems
    - Reduced central solenoid capability
  - Transport at low rotation with electron heating
  - Transport during ramp-up and ramp-down
  - H-mode access in various phases and He
  - Fuelling with high neutral opacity of SOL
  - H&CD requirements for advanced regimes
- **Recent and current research**
  - Demonstration discharges in baseline, hybrid, steady-state scenarios
  - Ramp-up and ramp-down scenarios
  - ITPA modeling task on current ramp
  - Modeling of ICRH heating scenarios

GLF23 transport

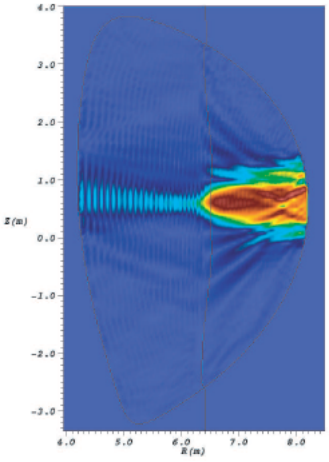


MMM7.1 transport

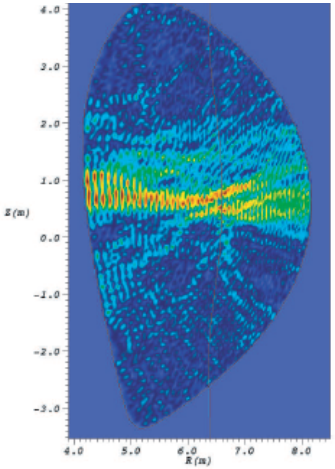


TSC/PTRANSP simulation of ITER 15MA fusion performance for two transport models (T. Rafiq et al., 2011)

Full-field (5.3T)



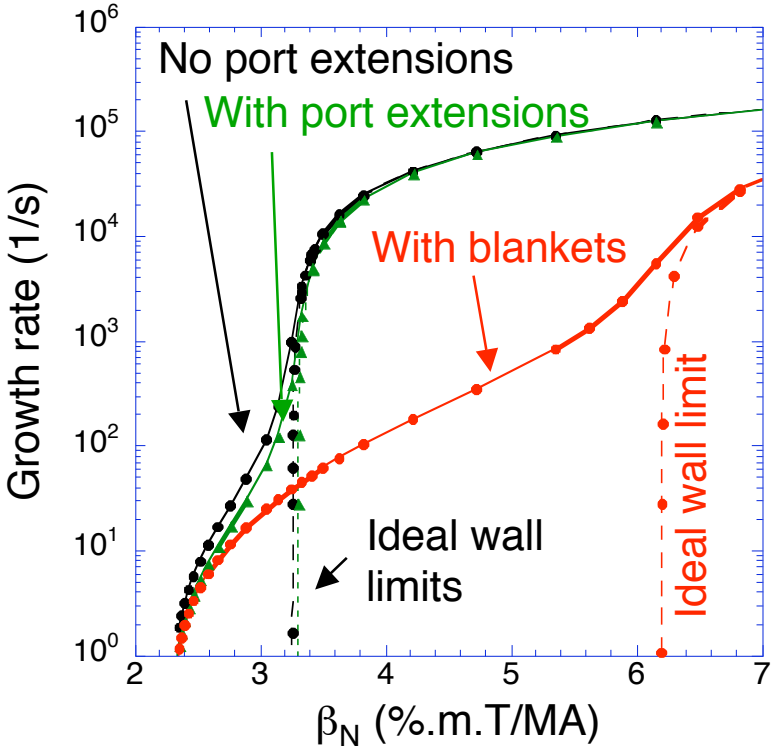
Half-field (2.65T)



AORSA code modeling of RF wave-fields for ITER reference scenarios (R. Budny et al., 2011)

Robust control will be needed for operation of high performance fusion plasmas

- **ITER needs – Plasma Control System conceptual design review in 2012**
  - Define diagnostic/actuator/control requirements for ITER
    - Divertor detachment; first wall heat load; ICRH coupling; fuelling pellets
  - Handling and control of disturbances
  - Profile control for maintaining stability
  - Development of operations infrastructure
  - Experimental operations procedure
- **Recent and current research**
  - Scenario control development and controllability analysis
  - PCS development for ITER (heating, fueling, error-fields, RWM, NTM)
  - Requirements analysis and preliminary design of control related systems
  - Test of Common Bonding Network grounding scheme (C-Mod)

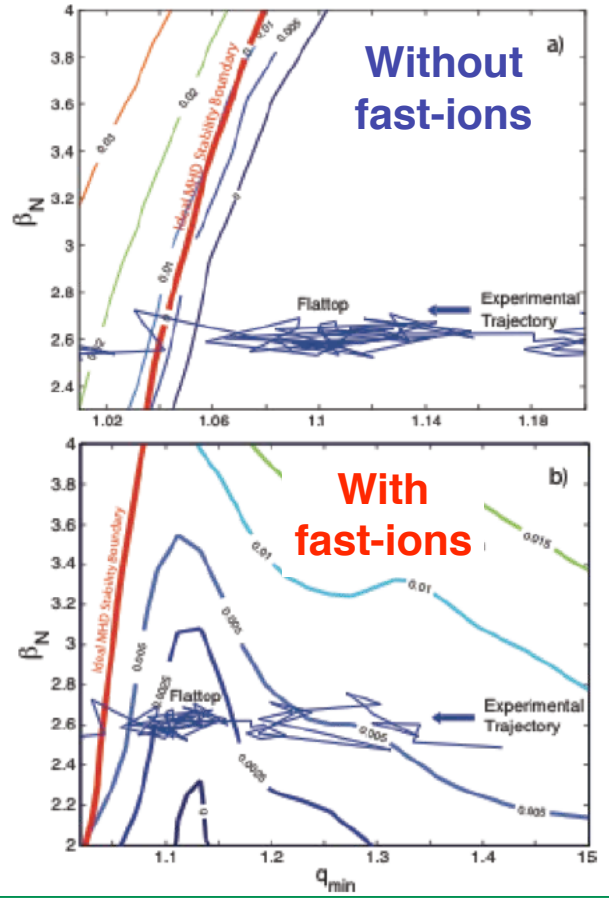


VALEN modeling of RWM growth rate in ITER showing effects of structural elements (J. Bialek, 2011)

Understanding and control of other MHD phenomena

- **ITER needs**
  - Stability in high beta advanced scenarios
- **Recent and current research**
  - NTM stability: joint DIII-D/NSTX experiment shows roles of aspect ratio, curvature stabilization, and Δ'
  - NTM control: assessment of actuators
  - EF/RWM: adequacy of ITER control coils
  - RWM physics: Validation and verification of codes and models
  - "State space" controller for high beta regime
  - MHD stability in H-mode plasmas with energetic ions
  - Field errors
    - Measurement techniques for ITER
    - Impacts on low-torque H-modes

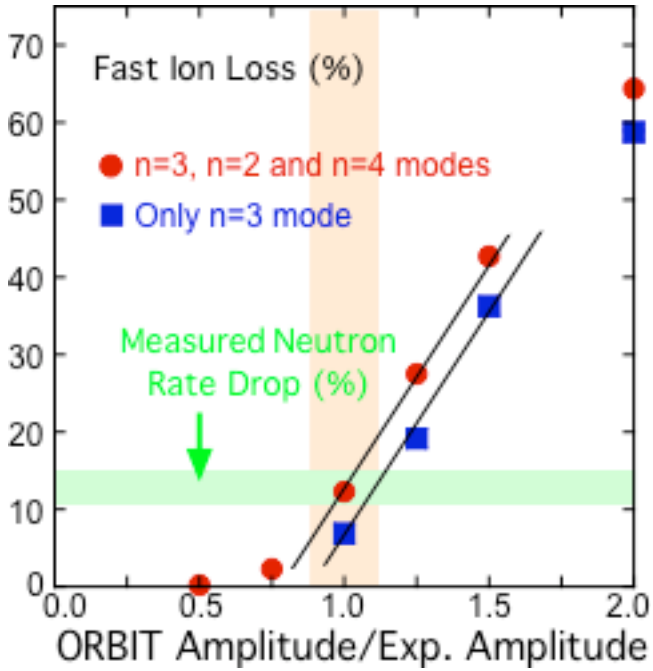
Contours of $\gamma\tau_A$ and experimental trajectory



NIMROD modeling for DIII-D showing fast-ion (β_h/β_{tot} = 0.16) **destabilization** *of the 2/1 resistive mode (D. Brennan, 2011)*

Energetic particle confinement and stability

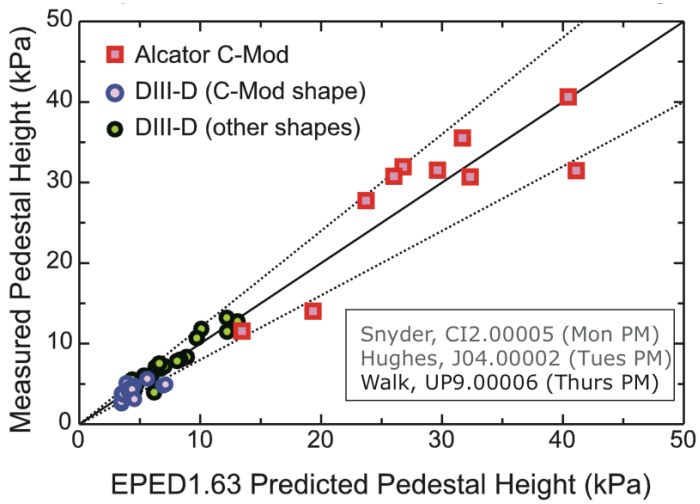
- **ITER needs**
  - Predictive capability for non-linear fast ion driven mode stability and transport
  - Physics of non-linear phenomena
    - saturation, mode interactions, chirping, avalanching, transport
  - Role in stability of ideal/resistive MHD
  - Effect on beta limits, triggering disruptions
  - Fate of fast ions in disruptions
- **Recent and current research**
  - Fast ion transport in NSTX dominated by large, multi-TAE bursts or avalanches
  - Experiments and modeling of fast ion transport from Alfvénic modes and MHD



Fast ion transport modeled in ORBIT using linear NOVA eigenmodes, empirical amplitude and frequency evolution. The sharp threshold for loss onset is consistent with the avalanche model. (E. Fredrickson et al. 2011)

Other active topics

- **ITER needs**
  - Assess the potential impact of Test Blanket Modules on performance
  - Understanding the H-mode pedestal for operational scenario design
- **Recent and current research**
  - Mockup in DIII-D of TBM magnetic perturbation used to study effects on confinement, rotation, stability, energetic particles
  - 2011 FES Joint Research Target on pedestal structure
    - Data collected to test many models
    - NSTX shows strong I_p scaling of pressure at pedestal top
    - EPED model validated for C-Mod, DIII-D



Comparison of EPED (v1.63) model for the H-mode pressure pedestal height with data from Alcator C-Mod and DIII-D. (J. Hughes et al. 2011)

Looking forward…

- **The US MFE community as a whole has been very proactive, and very engaged in efforts to make ITER successful**
- **Effort is underway internally to develop USBPO role**
  - Looking for areas where the USBPO can "add value"
- **Aim to be more effective in identifying tasks where coordination of the US community may be beneficial**
  - In process of forming BPO Task Groups to
    - Support ITPA joint modeling tasks
    - Investigate disruption mitigation and avoidance strategies
    - Develop a *modus operandi* for collaborative research on ITER
- **Now considering a second Burning Plasma Workshop**
  - Probably in 2013, location and exact time TBD
  - Last community BP workshop was in 2005 – a lot has changed