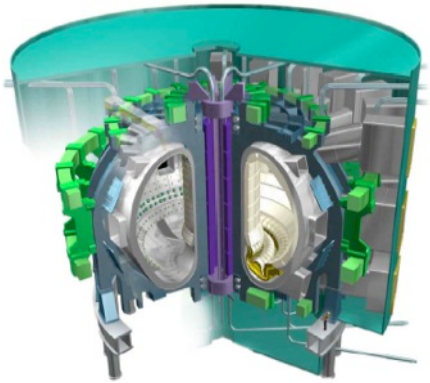
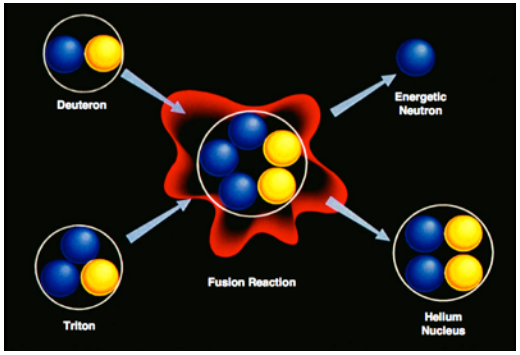
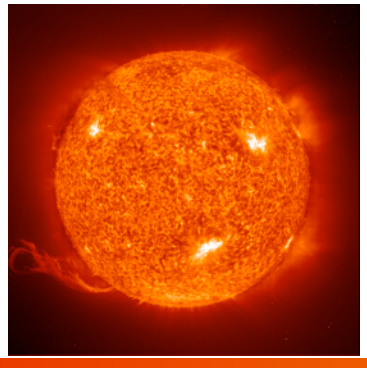
USBPO

United States
Burning Plasma Organization



# Activities of the US Burning Plasma Organization



**Charles M. Greenfield**

*Director, US Burning Plasma Organization*

*Chief Scientist, US ITER Project Office*

**Fusion Power Associates**
**33rd Annual Meeting and Symposium**

December 6, 2012

GENERAL ATOMICS

# Preparing for "burning plasma era"

- **U.S. Burning Plasma Organization (USBPO) was created in 2005 as a community-based entity**
  - Mission: *Advance the scientific understanding of burning plasmas and ensure the greatest benefit from burning plasma experiments by coordinating relevant U.S. fusion research with broad community participation*

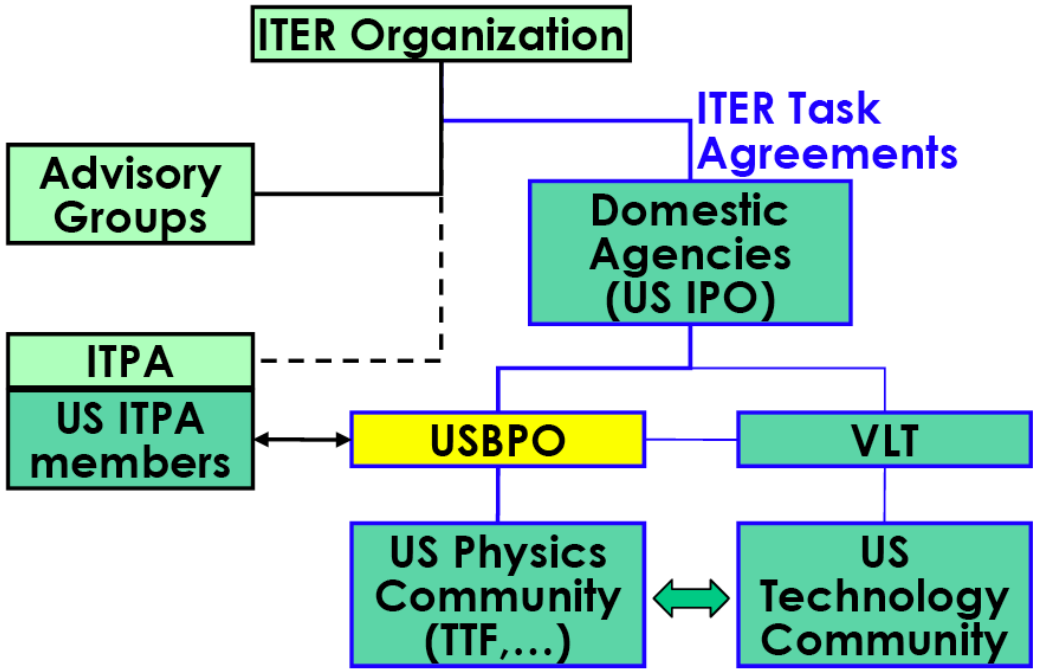
- **Broad community participation:**
  - Regular members (363 from 58 institutions)
  - Associate members (23 from 18 non-US institutions)
  - Council (12 members)
  - Research Committee (20) = leaders/deputy leaders of 10 Topical Groups
  - Directorate (5)
  - International Tokamak Physics Activity (ITPA): 49 Topical Group members + 3 Coordinating Committee members from the US

# Goals of the USBPO

- **Coordinate and advocate US burning plasma (BP) research**
- **Provide organizational structure to participate in BP program**
- **Optimize US participation in ITER and address post-ITER issues**
  - Promote and coordinate activities on existing experiments, theory & simulation, diagnostics, etc.
  - Identify and develop US areas of interest and excellence in BP science
- **Educate and advocate BP science to wider science community**
- **Coordinate US activities with US ITER Project Office**
  - ITER physics R&D
- **Facilitate strong interactions with international partners**

# USBPO Role in ITER Support

- **US ITER Project Office**
  - US Domestic Agency for ITER
  - Provides hardware & technical contributions
- **USBPO**
  - Coordinates US burning plasma research, to advance scientific understanding & ensure greatest benefit from ITER
  - USBPO Director is also the US ITER Project Office Chief Scientist



# The USBPO organizes the US Fusion Energy Science community to support burning plasma research

Charles Greenfield (Director)
Amanda Hubbard (Deputy Director)
Nermin Uckan (Asst. Dir. for ITER Liaison)

USBPO Council:
Jon Menard (Chair)
Mark Koepke (Vice Chair)
10 at-large members+
US ITER Chief Technologist

Research Committee made up of leaders and deputies of 10 Topical Groups

| | |
|---|---|
| MHD & Macroscopic Plasma Physics | Integrated Scenarios |
| Pedestal and Divertor/SOL | Operations and Control |
| Fusion Engineering Science | Modeling and Simulation |
| Diagnostics | Confinement and Transport |
| Plasma-Wave Interactions | Energetic Particles |

MEMBERS:
363 (regular)
23 (associate)

***USBPO membership is open to any fusion researcher who joins one or more topical groups***

# USBPO-ITPA Integration

- **USBPO is national base for US international activities in ITPA**
  - Acts as community arm of US ITPA representation
- **Coordination role**
  - Publicize ITPA meetings
  - Reports back to US community via eNews and web seminars
  - Recommend US members for ITPA topical groups
- **But… US ITPA participants have strong ties to individual research programs – broader coordination is not always needed**

ITPA

# The USBPO Topical Groups are strongly linked to ITPA Topical Groups and other burning plasma stakeholders


**USBPO Topical Groups and leaders (ITPA members)**

- **Energetic Particles** — Eric Fredrickson, David Pace
- **Pedestal and Divertor/SOL** — Tony Leonard (DSOL), Rajesh Maingi (PEP)
- **Integrated Scenarios** — Stefan Gerhardt, Chris Holcomb
- **Plasma-Wave Interactions** — Gary Taylor, David Green
- **Operations and Control** — Michael Walker, Egemen Kolemen
- **MHD & Macroscopic Plasma Physics** — François Waelbroek, Bob Granetz
- **Confinement and Transport** — George McKee, Gary Staebler
- **Diagnostics** — David Brower, Matt Reinke
- **Modeling and Simulation** — David Mikkelsen (T&C), Xianzhu Tang
- **Fusion Engineering Science** — Larry Baylor, Russ Doerner (DSOL)

**ITPA Topical Groups**

- **Energetic Particle Physics (EP)**
- **Pedestal and Edge Physics (PED)**
- **Divertor and Scrape-off Layer (DSOL)**
- **Integrated Operational Scenarios (IOS)**
- **ITER and ITPA Working Groups on Plasma Control**
- **MHD, Disruption, and Control (MHD)**
- **Transport and Confinement (T&C)**
- **Diagnostics (DIA)**
- **ITER Working Group on Integrated Modeling**
- **US and International Technology Communities**

# We are working to increase the role of the USBPO in advancing burning plasma science

- **From the USBPO charter: "Task Groups focused on very specific BP issues that cut across the Topical Group boundaries may be formed to carry out work to address those issues"**
- **During the past year, we have been working to increase the use of task groups, with important selection criteria:**
  - The task group must address an important issue for burning plasma science
  - We concentrate on areas where USBPO involvement can make a positive contribution – if the community is already doing a good job addressing something, we don't need a task group
    - Example 1: ELM control has been well covered and we felt it would not benefit from a task group even though it's extremely important
    - Example 2: There was some sentiment in the community that disruption mitigation would benefit from the coordination of a task group

# Task Groups have been formed to address issues of special importance to the USBPO membership

- **Disruption Task Group (Bob Granetz, John Wesley)**
  - Near term: Coordinating US research supporting ITER DMS specification
  - Longer term: Address disruption prediction and avoidance
- **Community Outreach (David Pace)**
  - Collecting material for presentations outside Fusion Energy Science community: Scientists in other fields, the public,…
- **Virtual Forum (Mike Mauel)**
  - Completed – Provided opportunities for US community input toward prioritization within Fusion Energy Science program
- **Modes of collaboration with ITER (Rajesh Maingi, Mike Walker)**
  - Starting now – Develop a US community vision of how we would like to work with ITER; anticipates later discussions among all ITER parties
- **We are seeking further opportunities to contribute**
  - Many areas (e.g. ELM control) already have broad community support, and we have decided USBPO coordination is not needed

# The US Burning Plasma Community is addressing many ITER R&D issues

**Some key examples:**

- **Disruption avoidance and mitigation**
  - Focus of new USBPO task group
  - US responsible for providing ITER DMS, which is not specified yet – current experiments determining requirements and evaluating different particle delivery methods
- **ELM control – several techniques demonstrated, working on physics basis**
  - Mitigation or suppression via 3D fields (RMP ELM control) or pellet pacing
  - Naturally ELM-free operating scenarios (I-mode, QH-mode,…)
- **Divertor and SOL issues at high heat flux, high Z vs C PFCs**
- **RF H&CD - Reduction of impurity generation, validating simulations**
- **Operating scenario development, especially high gain long-pulse and steady state**
  - Also includes preparation for low-activation phase of ITER, e.g. L-H threshold in helium plasmas
- **Predictive capabilities**
- **Plasma control**

***Not always explicitly coordinated by the USBPO – here I am speaking as a representative of the US Burning Plasma Science community***

# The US Burning Plasma Community is addressing many ITER R&D issues

**Some key examples:**

- **Disruption avoidance and mitigation**
  - Focus of new USBPO task group
  - US responsible for providing ITER DMS, which is not specified yet – current experiments determining requirements and evaluating different particle delivery methods
- **ELM control – several techniques demonstrated, working on physics basis**
  - Mitigation or suppression via 3D fields (RMP ELM control) or pellet pacing
  - Naturally ELM-free operating scenarios (I-mode, QH-mode,…)
- **Divertor and SOL issues at high heat flux, high Z vs C PFCs**
- **RF H&CD - Reduction of impurity generation, validating simulations**
- **Operating scenar… …g-pulse and steady state**
  - Also includes preparation for low-activation phase of ITER, e.g. L-H threshold in helium plasmas
- **Predictive capabilities**
- **Plasma control**

**Examples of recent work to follow…**

***Not always explicitly coordinated by the USBPO – here I am speaking as a representative of the US Burning Plasma Science community***

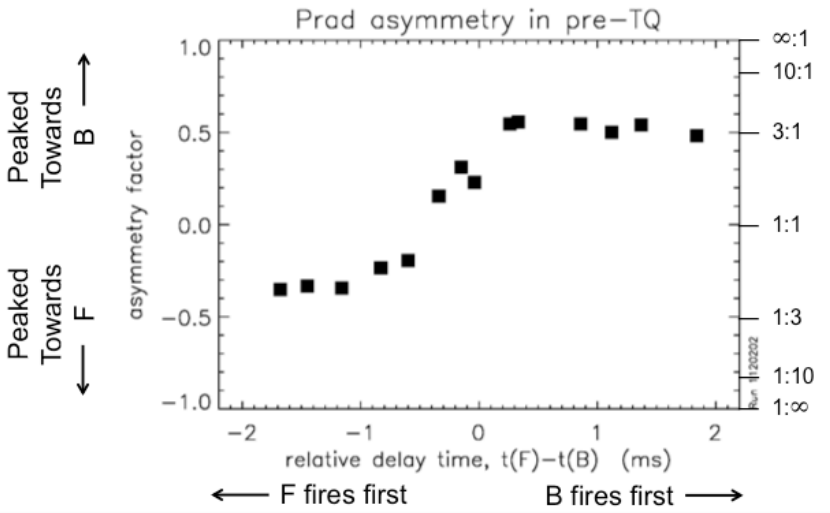
# Effective disruption + runaway electron mitigation are *essential* for ITER

- **DMS has 5 critical functions:**
  ①Limit $W_{th}$ deposit on divertor and first wall surfaces
  ②Prevent "hot plasma VDEs" and FW energy deposit
  ③Limit halo current forces in blanket/shield modules
  ④Control eddy current forces in B/S modules
  ⑤Control and dissipate runaway electron currents
- **MGI (massive gas injection) identified as primary approach**
  - MPI (massive pellet injection) as alternate
- **ITER current and energy introduce R&D needs**
  - **Control** thermal and magnetic energy radiation
  - **Avoid** and **mitigate** runaway electrons
  - **Provide adaptive control**, with high reliability and nuclear compatibility

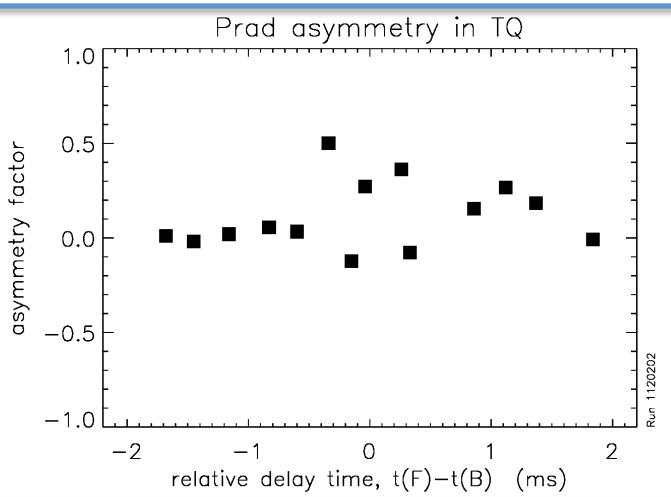
J. Wesley, APS 2012

# Multiple gas jet experiments in C-Mod address radiation asymmetries during disruptions

- **During pre-TQ, $P_{rad}$ asymmetry is controllable with two gas jets**



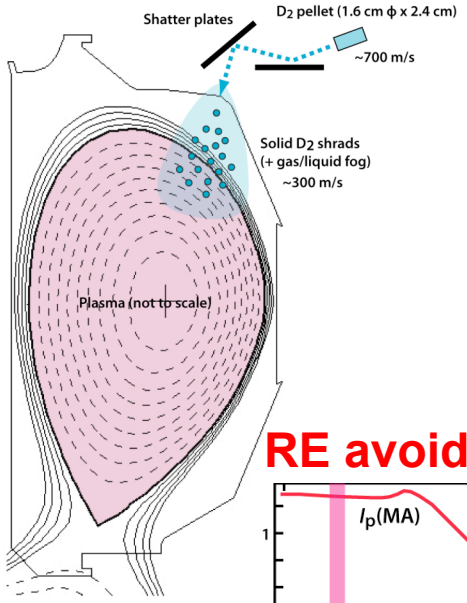

- **During TQ, $P_{rad}$ asymmetry is not controllable or reproducible with two gas jets**
  - Seems to be more symmetric with "single" jet



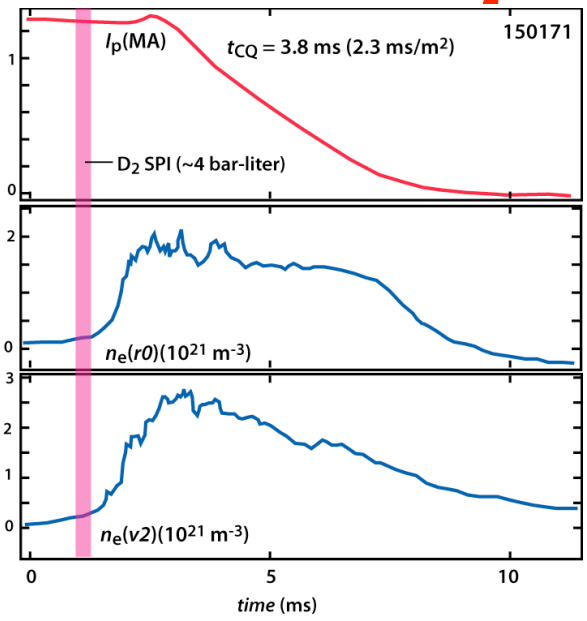

R. Granetz

- **To date, only C-Mod has performed experiments with multiple sources**
- **Possible theoretical explanation (V. Izzo, APS 2012): MHD instabilities**

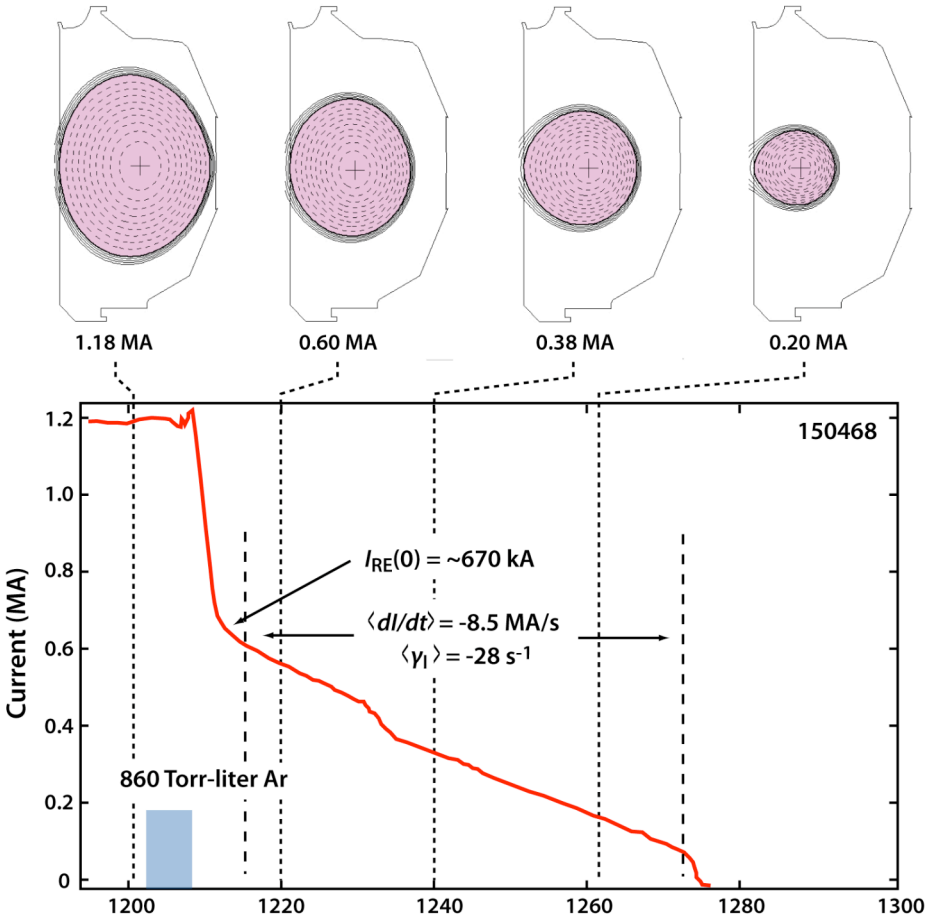
# Tests of candidate ITER RE avoidance and mitigation strategies and technologies are in progress




## RE avoidance with $D_2$ SPI




## RE mitigation with Ar MGI




J. Wesley, APS 2012

# More research is needed to specify the ITER DMS

- USIPO to provide DMS, but…
- The responsibility for determining what the physics requirements are and how they should be addressed has not been specifically assigned to the US
- Physics and technology R&D, experiments, and modeling are critical for meeting milestones (CDR now, PDR, FDR in 2016,…)
  - Will rely on results from DIII-D, C-Mod, JET, ASDEX-U, Tore Supra, KSTAR, EAST,…
  - Dedicated disruption research may be limited or nonexistent in some of these devices
- USBPO has mobilized a task group to address these issues, led by Bob Granetz (MIT) and John Wesley (GA)
  - Kickoff at US Disruption Mitigation Workshop in 2012; second workshop may take place in 2013
  - Joint planning of research in the US and a point of contact with our international partners

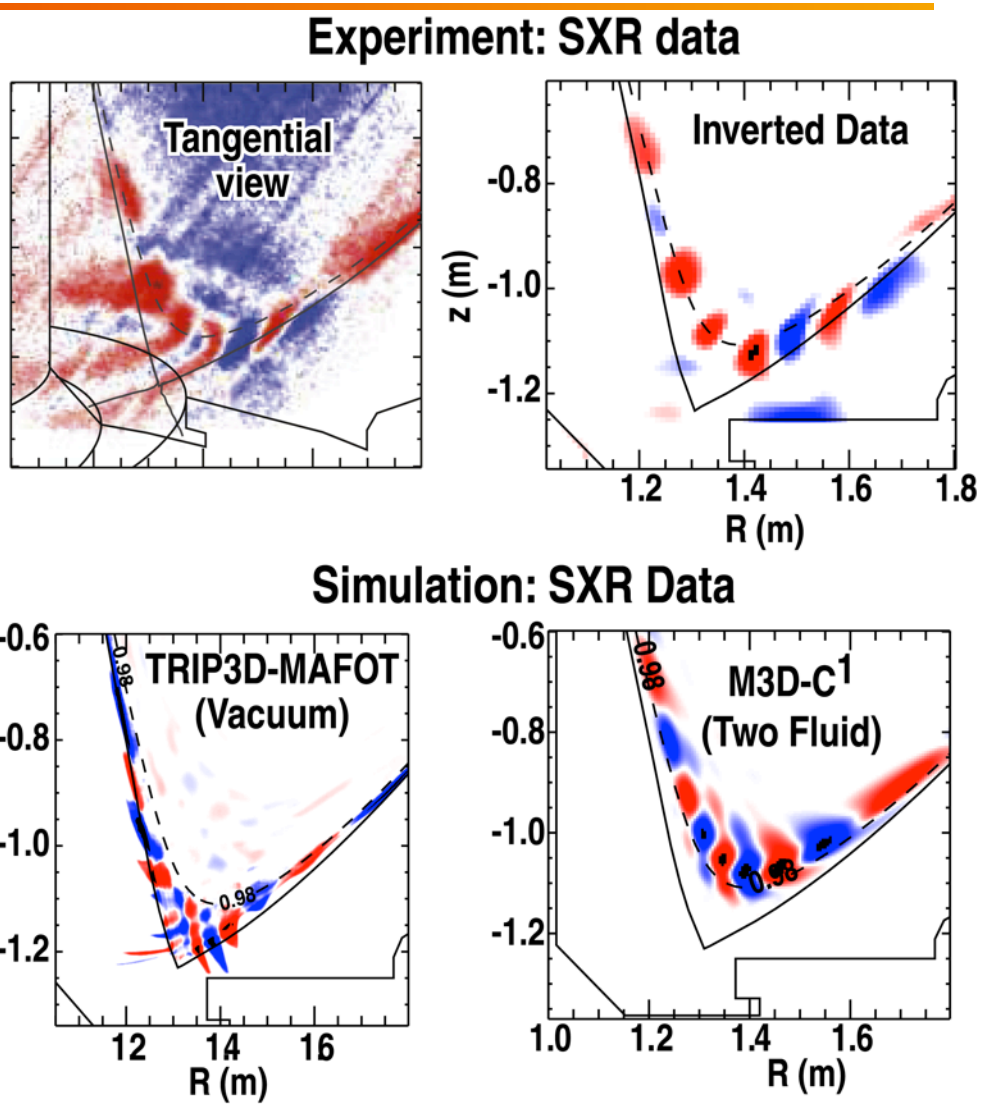
# US research is developing solutions for ITER's ELM challenge

- **DIII-D is developing a physics basis for RMP ELM control**
- **ELM pellet pacing demonstrated in ITER baseline scenario in DIII-D**
- **High performance alternative operating scenarios being developed that are naturally ELM free and may be accessible in ITER**
  ***Focus of the 2013 FES Joint Research Target***
  - C-Mod: I-mode
  - DIII-D: QH-mode

# Modulated phase RMP experiments point to island at top of pedestal inhibiting pedestal growth and ELMs

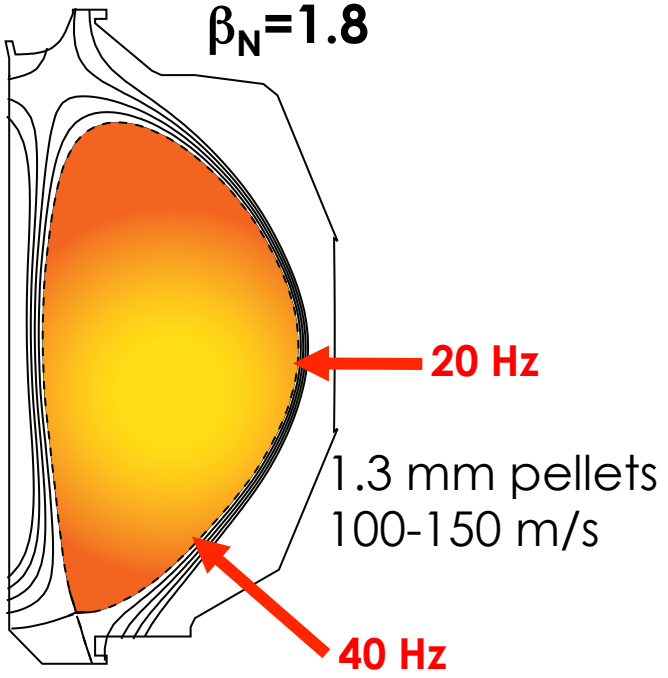
- **RMP phase flips reveal MHD structure**
  - Helical displacements seen in X-point SXR (difference imaging)
  - Compared with vacuum field and two-fluid MHD simulation

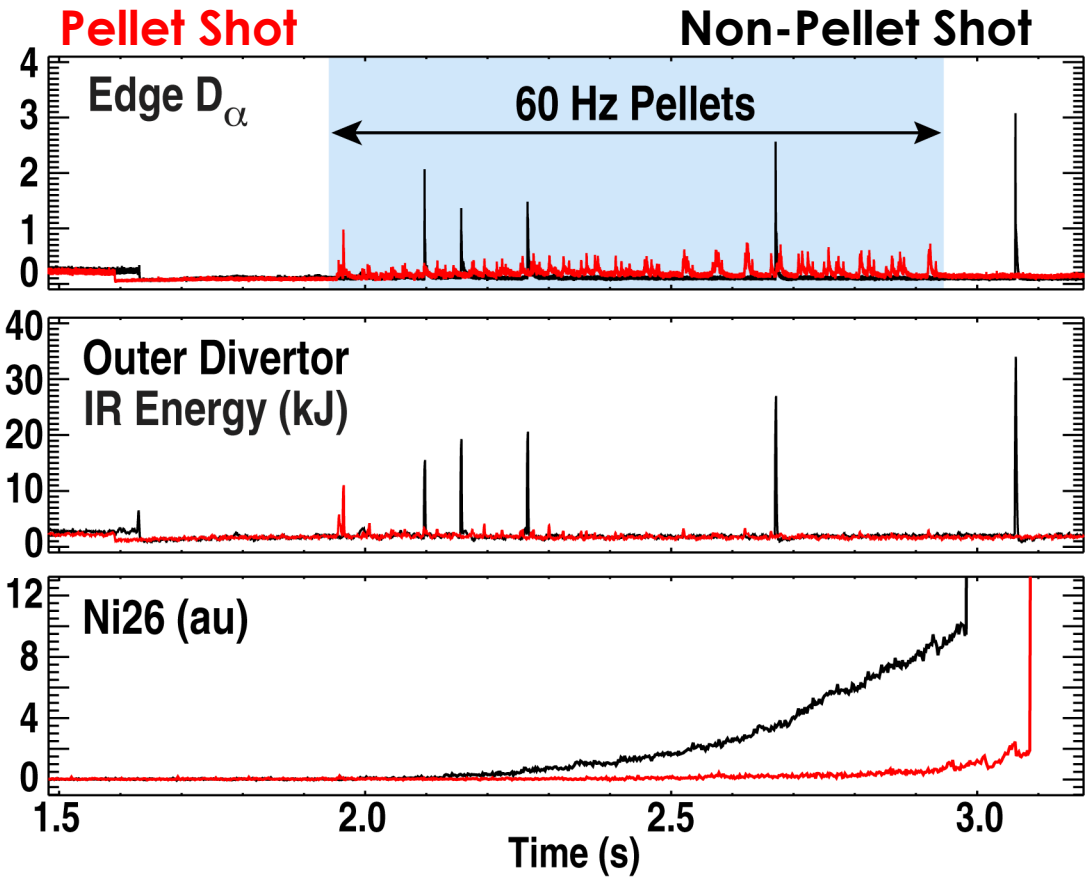
- **Mechanism: RMP limits width of pedestal**
  - RMP field resonant near top of pedestal
  - Island growth where $\omega_{e,\perp} \sim 0$
  - Island limits inward expansion of high-gradient pedestal




M. Wade, IAEA 2012

# Pellet Pacing in ITER Baseline Scenario Yields 12x Higher ELM Frequency



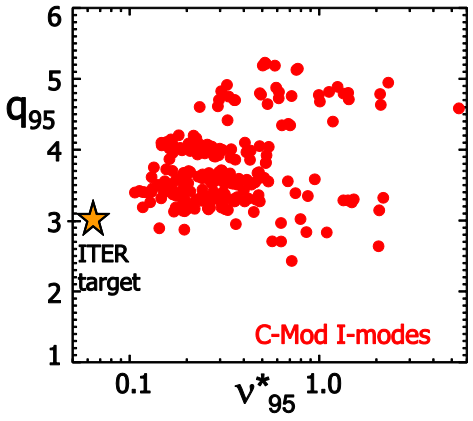

- Reduced ELM energy loss
- Minimal change in confinement
- No fueling increase
- Effective impurity screening

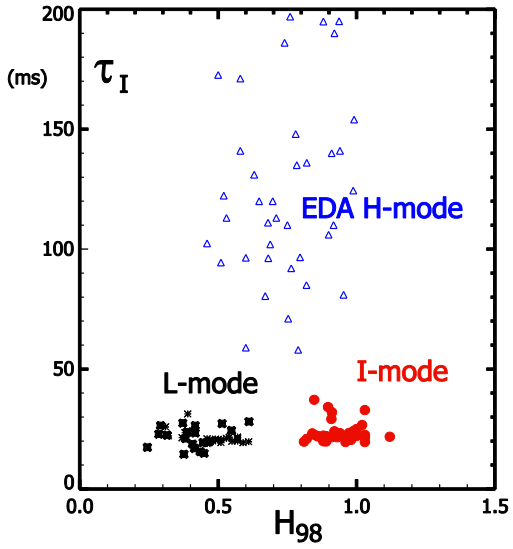
$f_{pellet} \times q_{div} = const$

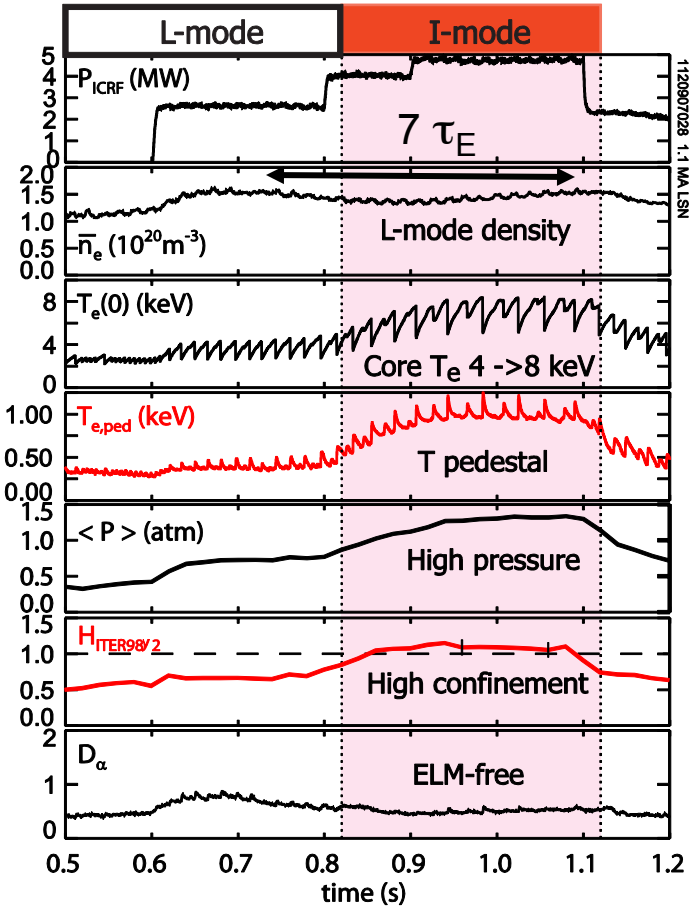
L. Baylor, IAEA 2012

# I-mode: Stationary, high energy confinement ELM-free regime *without* an edge particle barrier

- **L-mode impurity confinement makes the regime highly compatible with high Z PFCs, and with impurity seeding, as planned on ITER.**



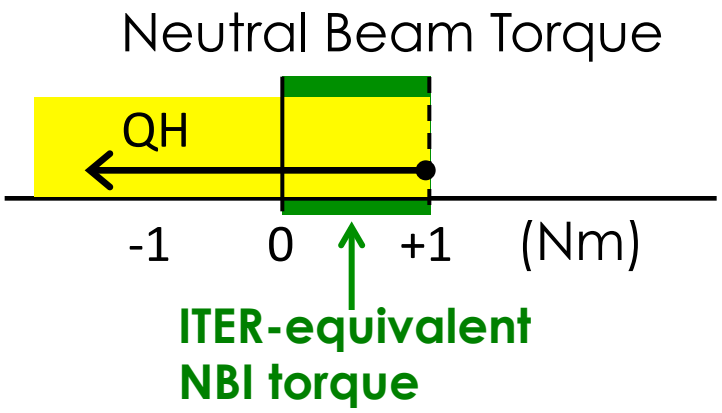




**C-Mod:** 1.1 MA, 5.8T, $q_{95}$=3.4

A. Hubbard, IAEA 2012

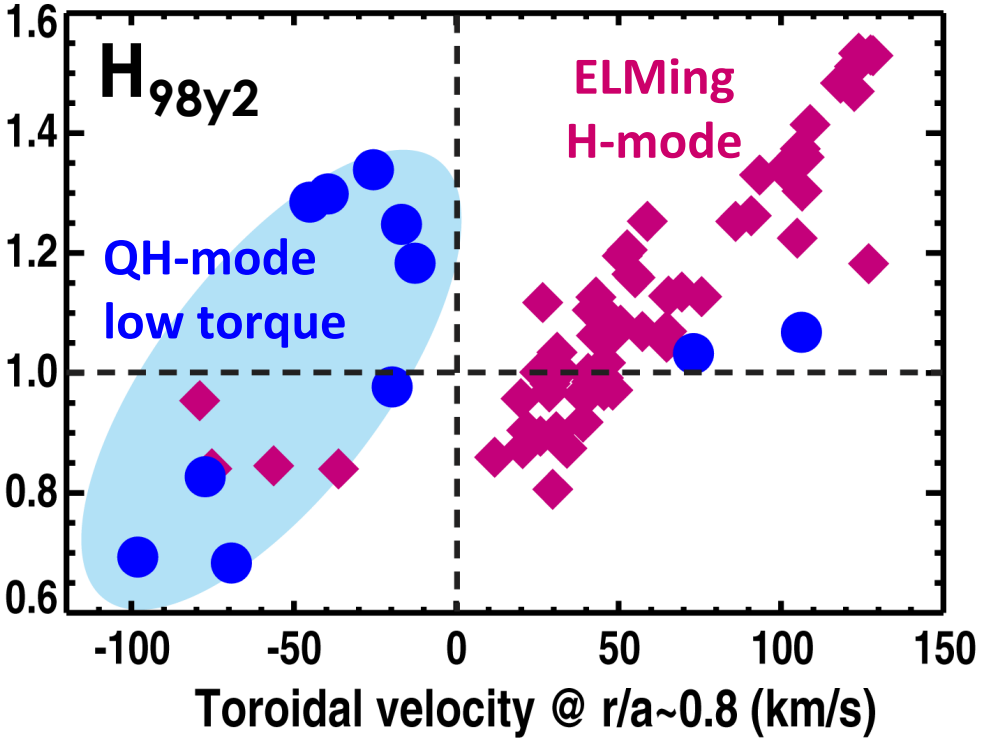
# Operating range for ELM-free QH-mode extended to ITER relevant torque using external 3D coils




- Achieved using external n=3 coils to drive edge rotation shear

**QH-mode is an attractive candidate ELM-free scenario for ITER**

**Excellent energy confinement quality at low rotation: $H_{98y2}$=1.3**




K. Burrell, APS 2012

# USBPO Communication Role

- **USBPO web site (www.burningplasma.org)**
  - All presentations, white papers, progress reports are publicly available
  - Limited-access areas for US STAC, Council, Topical Groups, …
- **USBPO *eNews***
  - 568 subscribers (from 126 institutions)
  - Includes "Director's Corner" column, feature articles, ITPA meeting reports, calendar of fusion events, research highlights
- **IT capabilities**
  - Regularly scheduled videoconferences (Research Committee, Council,…)
  - Technical briefings for US STAC members
  - Community web seminars
    - Our most recent seminar had over 70 unique connections (no way to tell how many people at each site)

# Communication within and outside the BP community

- **Web seminars**
  - Used for ITPA reports and Virtual Forum with very broad participation
- **Tuesday evening town meeting during 2012 IAEA FEC**
- **Events at APS Division of Plasma Physics Meeting**
  - Contributed oral session on ITER-related research – 2012 is fifth year
    - Usually attracts a full room
  - Evening Town Meeting on ITER (~every other year)
  - Tutorial talk: "The Scientific Challenges of Burning Plasmas" (2007)
- **Preparing presentation material for outreach**
  - Task group targeting mainly other scientific communities
  - May seek to partner with other similar and complementary efforts, e.g. Fusion Communication Committee, APS Distinguished Lecturer program, …

# Our mission will continue, but the specifics will evolve

**USBPO Mission**

***Advance the scientific understanding of burning plasmas and ensure the greatest benefit from burning plasma experiments by coordinating relevant U.S. fusion research with broad community participation***

- **Supporting successful completion of the ITER project (defined as providing a facility that is ready and able to carry out a successful research program) is our highest priority**
  - Operational issues (e.g. operating scenarios) will eventually displace design issues (e.g. DMS) as we get closer to the transition to experimental operations
- **Fusion Nuclear Science Facility may be a consideration for USBPO in the future**
- **Roles of the USBPO**
  - Use topical groups or form task groups to organize specific tasks
  - Facilitate the flow of information both to each other and outside the community
  - When USBPO involvement won't make things better, stay out of the way (e.g. ELM control and mitigation)
- **The US FES community has been enthusiastic and effective in supporting ITER and the transition of our field to burning plasma science in general**

# Backup material

# USBPO Council Members (2012-13)

| Council Member | Institution |
|---|---|
| Jon Menard – Chair | PPPL |
| Mark Koepke – Vice Chair | West Virginia |
| Richard Buttery | GA |
| Troy Carter | PPPL |
| Jerry Hughes | MIT |
| Steve Knowlton | Auburn |
| Cynthia Phillips | PPPL |
| Tom Rognlien | LLNL |
| Don Spong | ORNL |
| Anne White | MIT |
| Clement Wong | GA |
| Stan Milora (VLT), Charles Greenfield, Amanda Hubbard, Nermin Uckan, five DOE representatives | Ex officio |

# USBPO Topical Group Leaders (2012-13)

| Topical Group | Leader | Deputy Leader |
|---|---|---|
| Confinement & Transport | George McKee (Wisconsin) | Gary Staebler (GA) |
| Diagnostics | David Brower (UCLA) | Matt Reinke (MIT) |
| Energetic Particles | Eric Fredrickson (PPPL) | David Pace (GA) |
| Fusion Engineering Science | Larry Baylor (ORNL) | Russ Doerner (UCSD) |
| Integrated Scenarios | Stefan Gerhardt (PPPL) | Chris Holcomb (LLNL) |
| MHD | François Waelbroeck (Texas) | Bob Granetz (MIT) |
| Modeling & Simulation | David Mikkelsen (PPPL) | Xianzhu Tang (LANL) |
| Operations & Control | Michael Walker (GA) | Egemen Kolemen (PPPL) |
| Pedestal & Divertor/SOL | Tony Leonard (GA) | Rajesh Maingi (ORNL) |
| Plasma-Wave Interactions | Gary Taylor (PPPL) | David Green (ORNL) |

# US ITPA Topical Group Coordinators

| Topical Group | US Coordinator | US Deputy Coordinator |
|---|---|---|
| Diagnostics | Réjean Boivin | David Brower |
| Divertor & SOL | Bruce Lipschultz | Tony Leonard |
| Energetic Particles | Eric Fredrickson | David Pace |
| Integrated Operational Scenarios | Chuck Kessel | Tim Luce [2] |
| MHD Stability | Ted Strait [1] | Bob Granetz |
| Pedestal | Rajesh Maingi [2] | C.S. Chang |
| Transport & Confinement | Stan Kaye | George McKee |
| ********** | ********** | ********** |
| Coordinating Committee | Steve Eckstrand | Randy Wilson<br>Charles Greenfield |

[1] Also: Topical Group international leader
[2] Also: Topical Group international deputy leader