International Activities Update

Burning Plasmas
International Collaborations

FY2005 OFES Budget Planning Meeting
Gaithersburg, MD
March 19, 2003

Ned Sauthoff

Outline

Burning Plasma Activities

- ITER, FIRE and the FESAC strategy
- Ranges of expected ITER project and program activities/costs in FY04-05
- FIRE plans

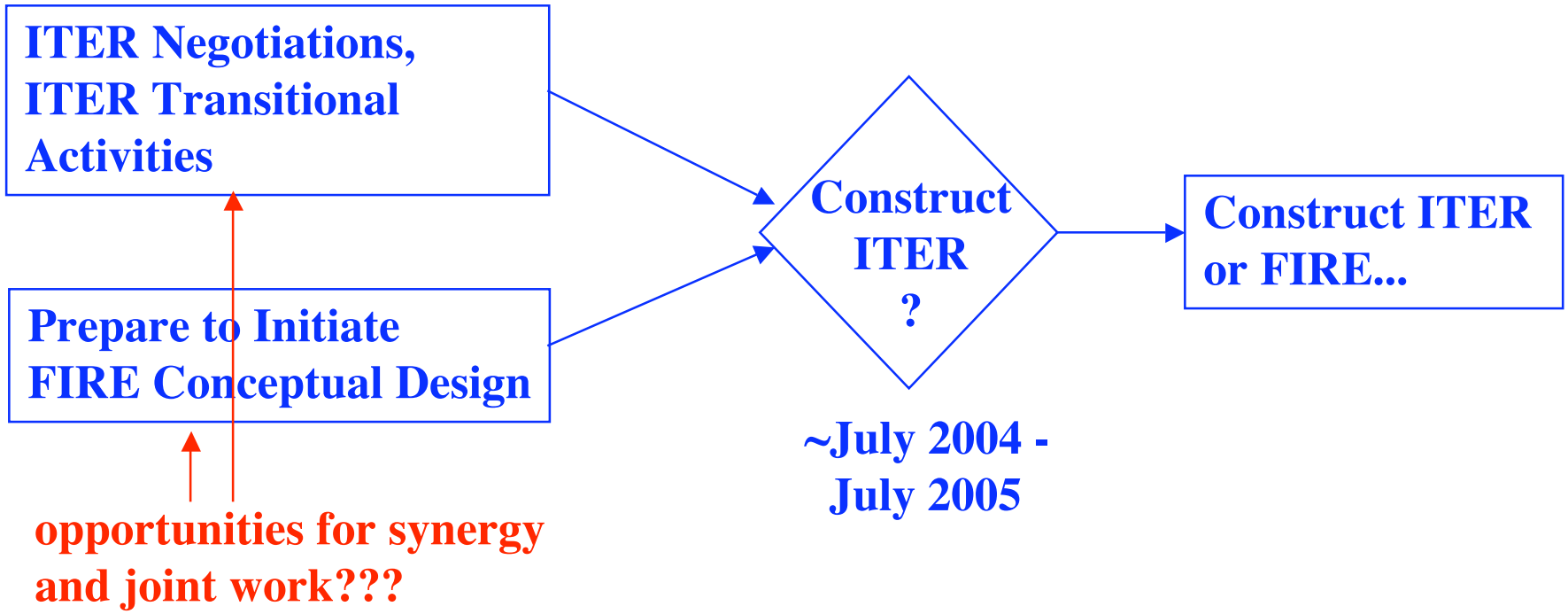
International Collaborations

- Overview of Accomplishments, Plans and Issues
- Specific Reports
  - Tokamaks (JET, JT-60U, ASDEX-U, Tore Supra, TEXTOR, Chinese, KSTAR)
  - Stellarators (Wendelstein and LHD) (J. Lyon)

ITER, FIRE, and FESAC's strategy

- "ITER and FIRE are each attractive options for the study of burning plasma science. Each could serve as the primary burning plasma facility, although they lead to different fusion energy development paths." (FESAC)

- "Because additional steps are needed for the approval of construction of ITER or FIRE, a strategy that allows for the possibility of either burning plasma option is appropriate." (FESAC)



Upcoming ITER activities in FY03-05

Support of US ITER Negotiations

- **Cost Estimation of possible "in-kind contributions"**
  - introduction of US rates into the ITER Costing
  - assessment of the technical aspects of select ITER cost-packages
  - US industrial estimates

- **"Levels of Interest" in packages for "in-kind contributions"**
  - identifying the programmatic interest (FESAC, BPPAC, US ITER Forum 5/8-9, ...)
  - assessing possible US strategies for prioritization of possible "in-kind contributions"
  - providing compelling arguments to motivate other parties to accept the US offers

- **Contributing input to discussions**
  - management
  - procurement and cost-risk control, ...
  - staffing
  - research-phase activities (*** US focus area ***)

- **Providing general technical support for the US Negotiators**

US Preparations for ITER Construction

- **Participation in on-going ITER Project Management**
- **Development of the US ITER Project Management Plan**
  - comply with the ITER management plan
  - comply with the US DOE Program and Project Management Manual (DOE M 413.3-X)
- **Performance of long-lead-time work on Critical Path Tasks, US reviews**
  - finalizing the design of magnets and other early procurements
  - qualifying US superconducting-strand/cable suppliers
  - technical discussions on task-sharing
- **Positioning the US to perform agreed procurements**
  - work with the ITER Team to finalize procurement packages with US interest (essential to cost-control)
  - begin procurement process for early US components

ITER Transitional Activities

- **Types of Participation**
  - "Secondees" to Garching and Naka and later to the ITER Site and in the Field
  - Performance of "Tasks"

- **Near-term opportunites for US secondees, suggested by the IT Leader**
  - "in Naka
    - participation in the writing of technical specifications for the CS manufacturing;
    - completion of the design and specification of the coil winding instrumentation
    - participation in the writing of specifications for the water cooling systems
    - diagnostics definition
    - RH transfer casks: design review and analysis
    - Tritium plant, and cryogenic distribution: layout review

  - in Garching
    - participation in the writing of specifications for the procurement of all conductors, the Divertor High Heat flux components
    - review of the detailed design of blanket (shield and FW) and start of definition of specifications
    - the same for the cryostat, and the vacuum system
    - (some) diagnostics integration
    - taking over of the design for IC, EC and CODAC systems."

ITER Supporting Program Activities (outside the ITER Project Scope and Budget)

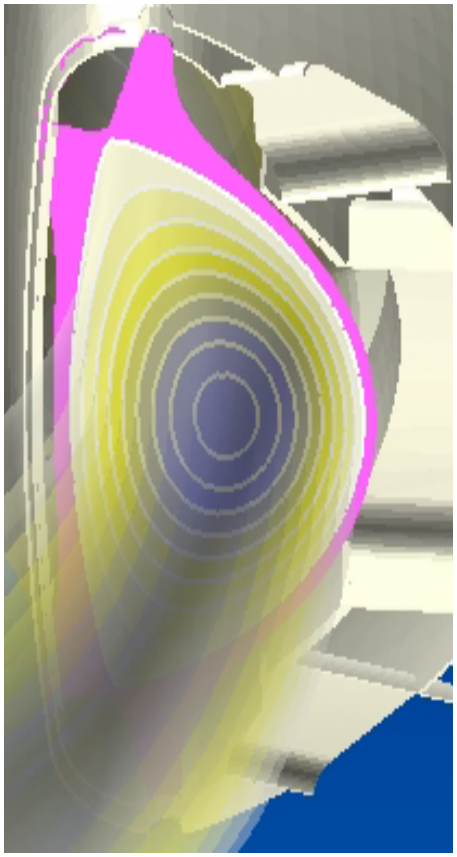
- **Experiments, theory and modeling aimed at key questions for burning plasmas (design and operation)**
  - Participation in the ITPA
  - Joint Experiments
- **R&D and Design on Diagnostics, Heating and Current Drive Systems**
  - enablers of research, as well as opportunities for R&D
  - a focus and process for burning plasma diagnostic R&D and design is needed
  - (this activity is outside the ITER project and cost estimate)
- **Re-establish US participation in the ITER Test Blanket Program**
- **Planning for the ITER Research Phase**
  - scenario development
  - determination of advanced enabling tools (plasma control and diagnostics)
  - building tools for simulation-based experiment-design, control, monitoring, and analysis,

Ranges of expected US ITER project activity-costs ($M)

	FY03	FY04 for 10/06 Start of Construction	FY04 for 10/05 Start of Construction	FY05 for 10/06 Start of Construction	FY05 for 10/05 Start of Construction
support of ITER negotiations (cost-estimation, interests, management, procurement...)	0.5	2.0 (B)	2.0 (B)	1.0	1.0
preparations for ITER construction		1.0 (I)	2.0 (I)	2.0	3.0
in-kind contributions for early components		0.5 (I)	7.5 (I)	7.5	13.0
ITA secondees		1.0 (I)	2.0 (I)	2.0	4.0
ITA tasks		1.0 (I)	2.0 (I)	2.0	4.0
TOTAL	0.5	2.0(B) + 3.5 (I)	2.0(B) + 13.5(I)	14.5	24.0

Supporting Burning Plasma program (diagnostic R&D and design, heating and current drive R&D and design, simulation and analysis tool-building, scenario development, ...)

Major FIRE Accomplishments (Feb 02 - Feb 03)



FIRE Simulation

- Snowmass Assessment confirmed FIRE design basis.
- FESAC found FIRE to be attractive option for BP experiment , and recommended Dual Path Strategy.
- Design space expanded for ARIES-like AT mode with Q = 5, β_N ~4, f_{bs}~80% and > 95% J(r) equilibration.
- FIRE-Based Development Path presented at Snowmass, FESAC and NRC.
- FIRE design point being updated in response to community input.
- Community reviews identified additional technical work required.

FIRE Mission and Scope for FY 2004/2005

- **Advance the design of FIRE as part of the FESAC Dual Path Strategy, and be prepared to initiate a conceptual design by the time of the U.S. decision on participation in ITER construction.**
  - respond to PVR chits and recommendations
  - extend “advanced capability” – physics and technology
- **Support both the ITER and FIRE paths of the FESAC Strategy:**
  - continue the development of advanced tokamak scenarios and advanced technologies needed for an attractive tokamak power plant in coordination with ARIES design activities.
  - address generic burning plasma R&D activities (e.g., PFC, disruption mitigation, plasma engineering, insulation development)

FIRE FY2004 Activities

- **Proposed Budget: $1.9M (Incremental)**
- **Principal Milestone: September 2004**
  - Demonstrate feasibility of an ARIES-like AT Scenario for FIRE (and ITER)
    - RWM stability and feasibility analysis with compatible PFCs
- **Other activities**
  - Optimize PFCs to extend performance of FIRE and ITER ARIES
  - Develop RWM technology (insulation, feedback control,..) for FIRE and ITER ARIES
  - Disruption Mitigation Development for FIRE and ITER ARIES
  - Plasma Engineering (ICRF, LHCD, Pellets, ..) with aim to FIRE and ITER ARIES
  - Diagnostic Development for FIRE and ITER (AT Physics parameters)
  - Collaborate with SCIDAC Fusion Plasma Simulator on BP simulations.

FIRE FY 2005 Activities

- **Proposed Budget: $1.91 M (Incremental)**

- **Principal Milestone (September 2005)**
  - Join ITER Construction Projector or begin FIRE Conceptual design
  - National Structure for US Burning Plasma Initiative in place
    - (Note: ITER Construction Authorization scheduled for July 2005)

- **Other Activities**
  - Demonstrate a viable disruption mitigation technique suitable for FIRE or ITER ARIES-RS
  - Demonstrate a PFC configuration design with suitable heat loads and tritium inventory for FIRE or ITER ARIES-RS
  - Plasma Engineering (ICRF, LHCD, Pellets, ..) with aim to FIRE or ITER ARIES
  - Diagnostic Development for Burning Plasmas

Areas for possible synergy/joint work (FIRE, ITER)

- **Plasma Facing Components (Divertor and First Wall)**
  - high power density
  - long pulse capability
  - low tritium retention
  - elm erosion and disruption survivability
  - maintainability

- **Vacuum Vessel (blanket modules and shielding port plugs)**
  - low activation ?
  - nuclear heating ---- blanket module test assemblies
  - disruptions
  - integrate with closely coupled control/stabilization coils and diagnostics

- **Plasma Heating, Current Drive and Fueling**
  - development/design of ICRF, LHCD systems for BP scenarios
  - interface with fusion environment (esp. launchers)

- **Diagnostics Development and Design Integration**
  - new diagnostics for J(r), E(r), fluctuations, alpha particles
  - integration with fusion environment (e.g., radiation-induced conductivity)

Summary

- **We must stick with the FESAC strategy**

- **We have lots of work to do in preparations for Burning Plasmas**
  - BOTH ITER and FIRE:
    - develop scenarios and advanced technology relevant to FIRE and ITER
    - identify research opportunities on FIRE and ITER (science and technology)
    - address generic burning plasma R&D activities (e.g., AT, PFC, disruption mitigation, plasma engineering, insulation development)
  - ITER: negotiations, preparation for construction, secondees, tasks, exploring research potentials and positioning the US for the research phase
  - FIRE: address “chits”, extend AT capability, ...

- **We should look for opportunities for synergy in an integrated ITER/FIRE burning plasma activity**

- **“NOW is the time!”**

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International Collaborations

- Overview of Accomplishments, Plans and Issues
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  - Stellarators (Wendelstein and LHD) (J. Lyon)

Significant Accomplishments in International Collaborations

- **Tokamaks (JET, JT-60U, ASDEX-U, Tore Supra, TEXTOR, Chinese, KSTAR)**
  - JET physics: □-modes, NTMs, current hole, j(r)-control, core/pedestal transport, divertor
  - JET technology: HPP ICRF antenna testing, laser-based tritium removal prototype
  - ASDEX-U: QH, NTM, edge identity, ITBs, ICRF/LHRF modeling
  - Tore Supra: CIEL (long pulse, co-deposition, erosion; transport (MM, IFS)
  - TEXTOR: Dynamic Ergodic Divertor constructed
  - Chinese: 1st plasma in HL-2A (ASDEX); HT-7U under construction
  - KSTAR: buildings complete; coils in construction/test; first plasma ~2005; research planning underway with KSTAR as an international science facility

- **Stellarators (Wendelstein and LHD) (J. Lyon)**
  - Unique US analysis tools applied to 3D high-beta configurations (LHD, W7-AS)

International Collaborations Plans

- **Tokamaks**
  - JET physics: (04) trace tritium, □-simulation;
    (05) EP-{shaping, FW antenna, diagnostics}
  - JET technology: ITER-like ICRF antenna
  - ASDEX-U: QH, NTM, edge identity, ITBs, ICRF/LHRF modeling
  - Tore Supra: long pulse, co-deposition, erosion; transport (MM, IFS)
  - TEXTOR: impurity/He transport/exhaust, ELMs
  - Chinese: 1st plasma in HL-2A (ASDEX), HT-7U under construction
  - KSTAR: diagnostics, LHRF/ECRF, plasma control, data acquisition/control, cryopump, in-vessel design, AT issues, research planning

- **Stellarators (Wendelstein and LHD) (J. Lyon)**
  - 2-D fast ion distributions and soft X-rays in LHD
  - application of the M3D code for analysis of high beta equilibria and stability in W7-AS in FY04 (incremental)

Significant Issues in International Collaborations

- **JET**
  - 3 EP-diagnostics (GA, ORNL, PPPL) with reduced budget are imposing significant stress
    - ORNL requests incremental funding to both deliver and staff the diagnostic
    - PPPL research team falls from 4.85 FTEs to 1.45 FTEs to <1.0 FTE in order to afford the diagnostics
  - US activity on the HPP ICRF prototype antenna reduced or terminated
- **Stellarators**
  - funding reduction jeopardizes the milestone
    "Explore MHD equilibrium and stability in ... international stellarators...."

Specific device material

New Opportunities Exist for Burning Plasma Science on JET (R. Nazikian)

FY04

- **Trace Tritium campaign in the Fall**
  - **particle transport in both ELMy H-Mode and AT**

- **Alpha simulation studies with He-beam accelerated by high harmonic waves**
  - **fusion alpha particle simulation of *AE**

FY05-06

- **Modified divertor permits high triangularity at high current and high field (4 MA, 4T), with increased RF and NBI heating**
  - **transport, energetic particles, pedestal physics**

- **ITER-like FW antenna**

- **Major diagnostic enhancements**

Broad Based US Participation in JET Scientific Program

- Alpha simulation studies (IFS, PPPL, UC Irvine, MIT,…)

- MHD stability, NTMs, current hole, current profile control (PPPL, Wisconsin, GA, ORNL,…)

- Predictive transport modeling, microstability analysis, pedestal physics, trace tritium (LeHigh, MIT, PPPL, GA,…)

- Divertor physics and plasma wall interactions, tritium (LLNL, PPPL, GA,MIT,…)

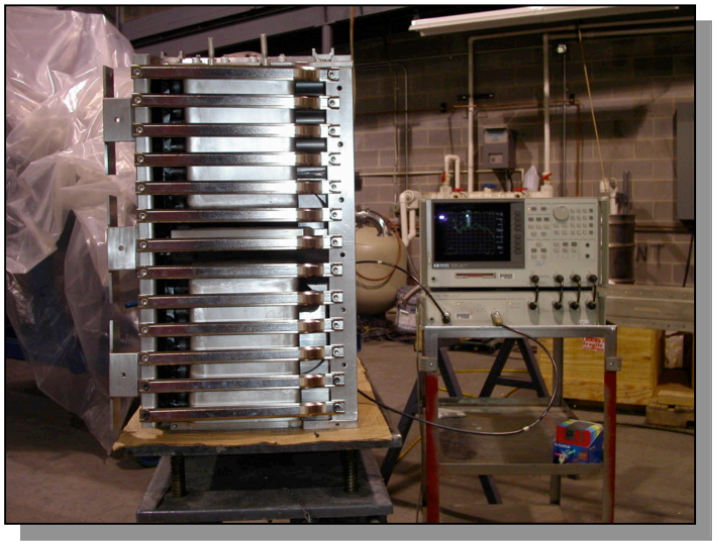
- RF technology development, ELM resilience, coupling and reliability, ITER-like antenna (ORNL, PPPL,…)

In addition PPPL provides physics operator support and TRANSP analysis support for the JET program

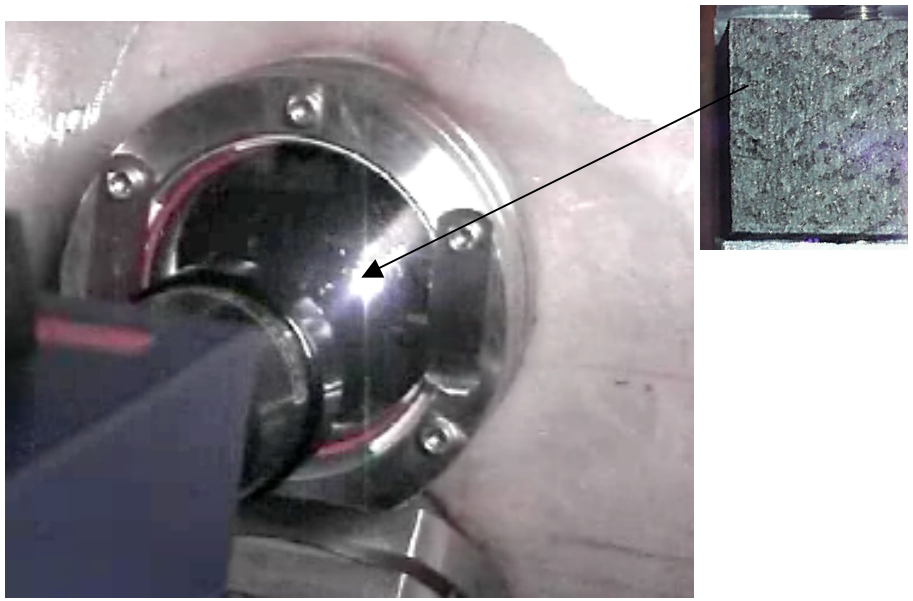
- This US support is eliminated under current budget guidance

A Few Successes of US-JET Collaboration in Technology FY02-03

- **Assembly of the JET ITER-Like ICRF Antenna High Power Prototype is Nearing Completion (Collaboration between PPPL, ORNL)**
- **Discussions initiated by EFDA-JET to extend testing program on HPP**
  - **Requires additional funds for FY04**
- **The HPP terminates in FY03.**



Antenna box and current straps during low power RF tests



Incandescence from laser/tile interaction

- Exciting results in Nd laser detritiation from carbon tiles.
- Under the FY04-05 guidance level, Tritium technology development will no longer be supported.

Three Diagnostics for JET-EP Approved by DOE in FY02

- Faraday cup and scintillator detectors
  (Col. School of Mines, IPP Garching, PPPL)

- CXRS Helium Ash Diagnostic for JET-EP
  (ORNL, IPP)

- High Resolution Thomson Scattering
  (General Atomics, UKAEA)

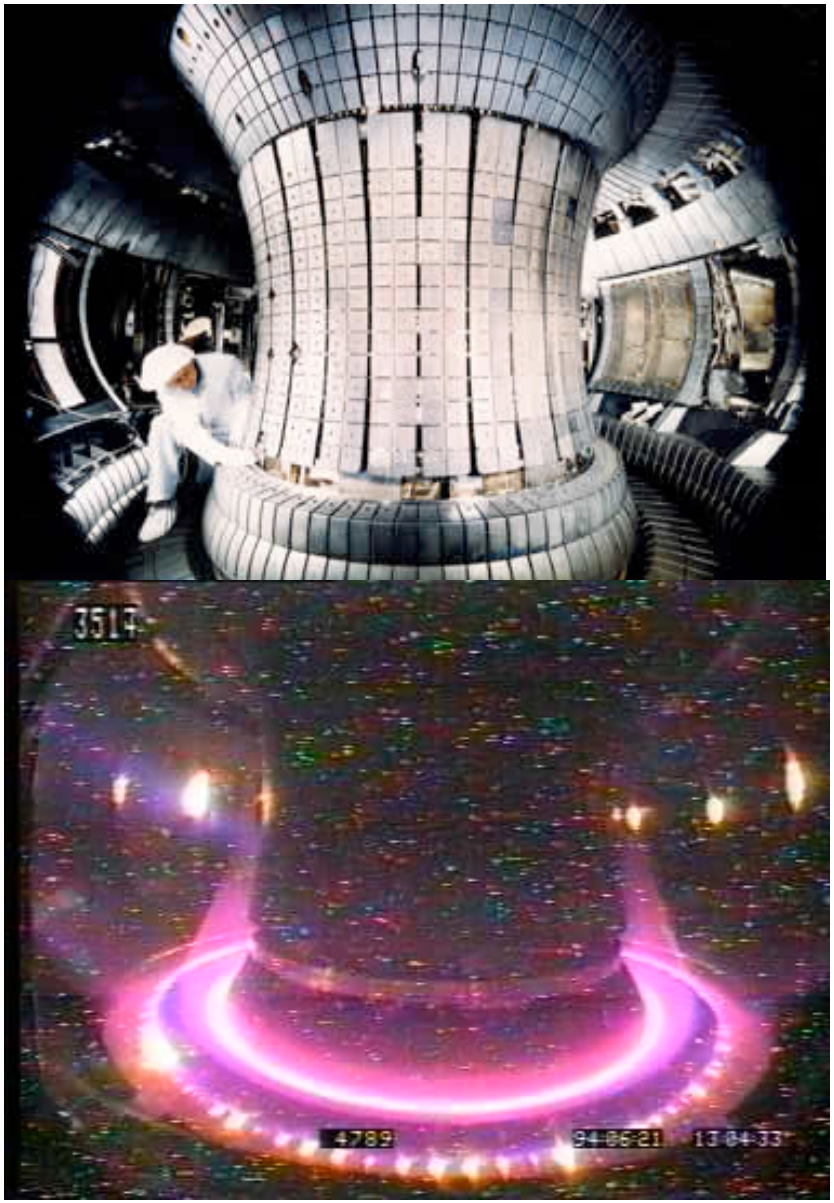
- PPPL and GA will deliver on commitment within base budget. However, this will reduce the PPPL research manpower on JET from 4.85 to 1.45 FTEs. If in addition PPPL provides planned support of ORNL on the CXRS, then PPPL research manpower drops below one FTE.

- ORNL requires incremental support to deliver the diagnostic.

JT-60U (R. Nazikian)

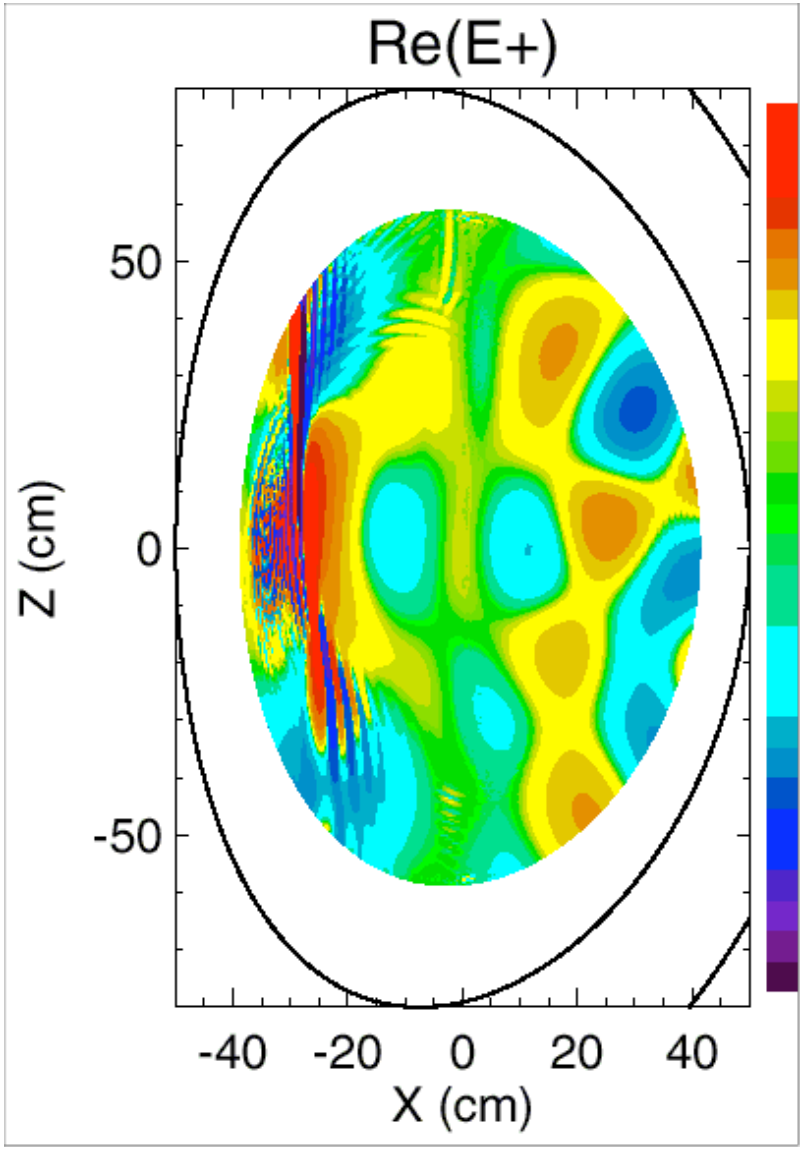
US Collaborations with ASDEX-Upgrade (E. Marmar)

- QH-Mode/counter-NBI (with DIII-D)
- NTM studies (DIII-D, JET)
- H-Mode threshold comparisons (C-Mod)
- Edge dimensionless identity experiments, EDA H-Mode (C-Mod, DIII-D)
- Density peaking and ITB physics with off-axis heating (C-Mod)
- ICRF and LHRF code development and analysis (MIT, ORNL)
- Collaborations expected to continue through FY05; funded through Sci-Dac and tokamak programs



ASDEX-U Collaborations: RF Modeling Activities

- ICRF and LHRF code development and analysis
- Bonoli and Wright (MIT), D'Azevedo (ORNL), Brambilla and Meo (IPP)
  - Implementation of TORIC ICRF field solver at IPP
- *Figure shows first fully converged full-wave simulation for ICRF mode-conversion on ASDEX-U
  - requires 511 poloidal modes



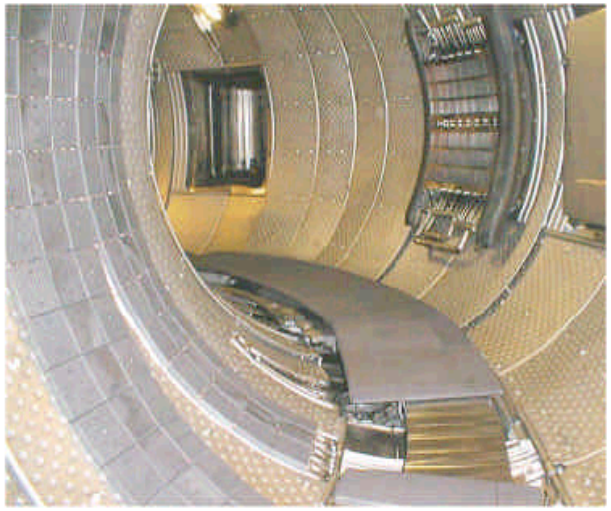
* J. Wright, P. Bonoli, E. D'Azevedo, M. Brambilla, F. Meo, APS-DPP 2002 Conference, Orlando, FL

Tore Supra (P. Mioduszewski)*

Long-pulse particle and impurity control (CIEL)

GJ campaign **achieved t_{pulse} > 4 minutes, $P_{extracted}$ > 0.6 GJ, and found rapid build-up of co-deposited layers: >150 □m after 2 hours 20 minutes accumulated time (~10 ITER pulses), with potentially serious consequences for *tritium retention in ITER.***

An analysis effort has been launched, focussing on the role of intense local heating from fast electrons due to LHCD (EPS). Work is based on previous validation of a detailed CIEL model, and development of more detailed information on chemical erosion: equal contributions from C-, C_2-, and C_3-based sources.



Intérieur de Tore Supra équipé de nombreux composants activement refroidis

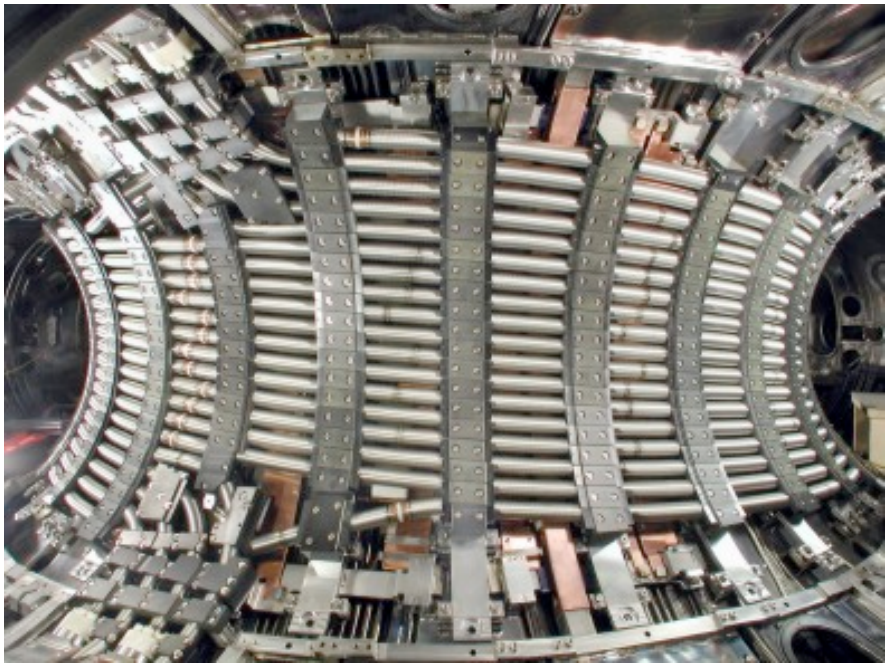
The effect of the TS ergodic layer on impurity expulsion was documented, leading to a proposal to use impurities for ELM heat flux mitigation, now being exploited at JET. (ORNL: J. Hogan et al.)

Transport studies

Multi-Mode transport simulations (BALDUR) showed that the Trapped Electron Mode dominated over the Ion Temperature Gradient mode, driving most of the transport. (Lehigh Univ.: G. Bateman, A.Kritz, I. Voitsekovich et al.)

Collaboration of IFS transport group with Cadarache continues:
an initiative on electron transport. **(IFS: W.Horton et al.)**

TEXTOR with Dynamic Ergodic Divertor(DED) (D. Hillis)



- DED has been installed and TEXTOR Vacuum Pump-down is underway
- First Plasma Operation with the DED is expected in late March 2003

ORNL/TEXTOR Collaboration

Activities 2003-2004

ORNL activities with TEXTOR Team are focused on joint participation in JET Experiments via Trilateral-Euregio cluster

- Impurity Seeding Experiments at JET (contacts: J. Ongena, A. Messiaen, A. Pospieszczyk)
  - Impurity Exhaust, Ar/Ne recycling, improved confinement, ELM control
  - Joint participation in JET, DIII-D, Tore Supra, and TEXTOR Impurity Seeding Experiments
- He Transport and exhaust at JET (K-H Finken, T. Loarer [Tore Supra])
  - Experiments planned for May 2003
- He and H wall changeover experiments at JET (A. Pospieszczyk, V. Phillips, T. Loarer [Tore Supra])
- Participation in DED Experiments
  - Impurity transport (including He) in plasmas with ergodic edges
- Planning for joint "International IEA Workshop on Stochasticity in Fusion Edge Plasmas" Oct 6-8, 2003 - Jülich, Germany

DIII-D/UCSD (T. Evans, R. Moyer) activity focuses on:

- Mitigation of ELMs with Ergodization

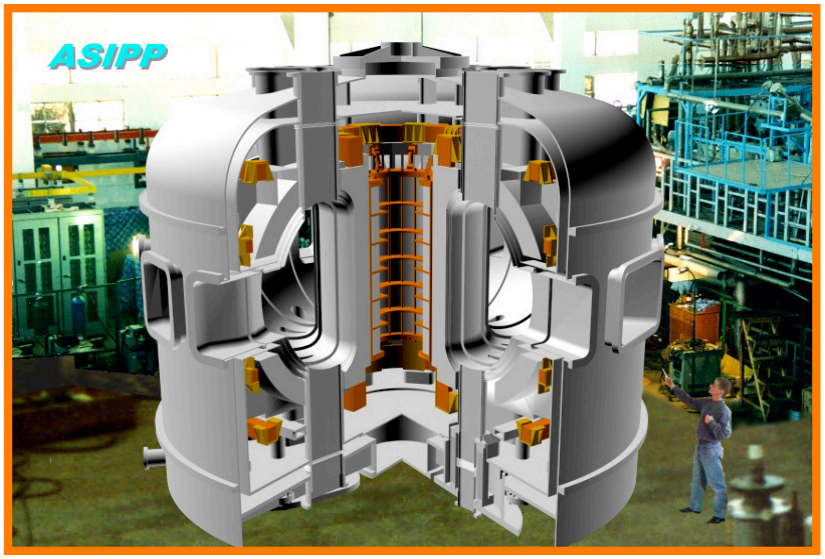
ORNL/TEXTOR Collaborative Experiments at JET

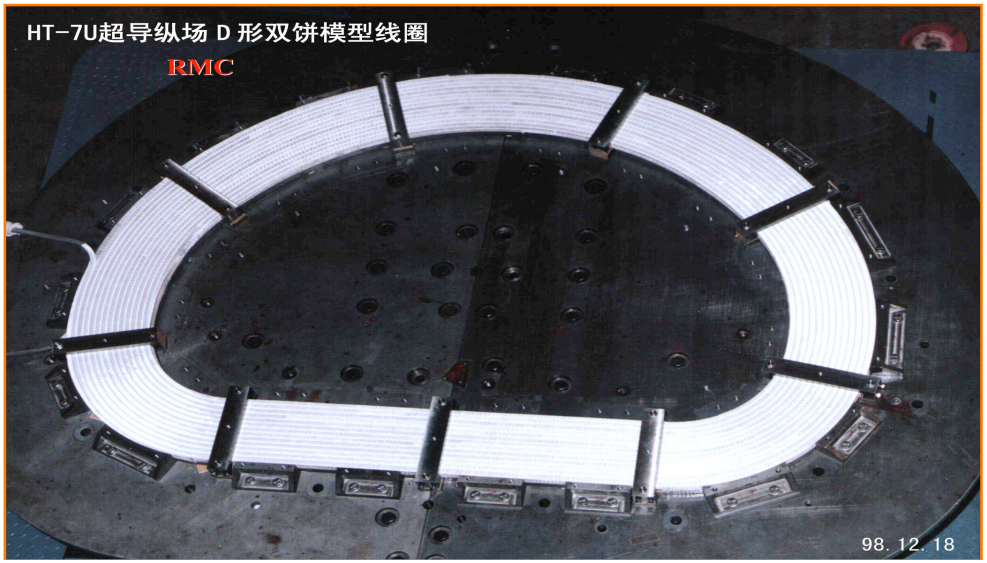
- Influence of Ar recycling and divertor Configuration on Confinement in Impurity Seeded Discharges - Hillis, Onjena, et al. - Feb. 2003
- Comparison of Helium Ash simulation studies for ELMing H-mode and ITB discharges (Finken, Hillis - April 2003)
- Helium transport in reversed B discharges - (Hillis, Finken, Hogan - May 2003)
- Influence of wall on Trace Tritium discharges - (Hillis, V. Phillips, et al. - Oct. 2003)

US-PRC COLLABORATION
HIGHLIGHTS OF PRC FUSION PROGRAM (V. Chan)

- **The HL-2A tokamak at the Southwest Institute of Physics (SWIP), which utilizes the ASDEX magnet and vacuum vessel, achieved first plasma and a dedication ceremony was held on December 2, 2002.**

- **The HT-7U superconducting tokamak is under construction at the Institute of Plasma Physics - Chinese Academy of Science (ASIPP), to be completed within 2 years. The superconducting magnet is being built at the institute, and the vacuum vessel is being manufactured by Chinese industry**





US-PRC COLLABORATION ACTIVITIES

- **UT-FRC successfully completed the Helimak fabrication project with ASIPP and Chinese industry**
- **UT-FRC continued experimental collaboration with ASIPP on HT-7**

  An 8-channel heterodyne ECE system has been installed on HT-7 and a diagnostic neutral beam is being provided. Further diagnostics contributions are planned
- **Discussions were completed with Huazhong University of Science and Technology to transfer the TEXT tokamak from FRC to HUST. A joint institute for TEXT study will be formed**
- **DIII-D and ASIPP scientists jointly carried out equilibrium, stability and transport analyses of long pulse enhanced confinement discharges in the HT-7 tokamak that were presented by ASIPP in an APS invited paper**
- **DIII-D scientists visited ASIPP to consult on the modeling and design of the HT-7U double null divertor; an ASIPP scientist visited GA for 5 months to collaborate on improvement of the magnetic reconstruction code EFIT**
- **PPPL scientists collaborated with SWIP in transport modeling of HL-2A plasmas and the study of ECH driven MHD effects on HL-1M**
- **A LLNL theorist has installed the BOUT edge turbulence code on the ASIPP Linux cluster and a short course was given on using the code**

SUGGESTED TOPICS FOR FUTURE ACTIVITIES

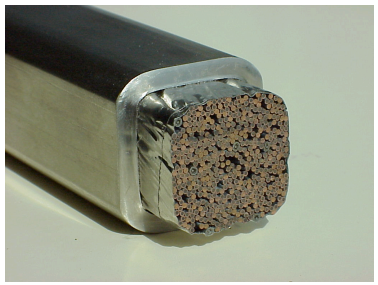
- Joint study with SWIP on plasma fueling with supersonic molecular beam injection that can penetrate deeper into the plasma. This technique was first developed on HL-1M and has now been extended to HT-7, W7-AS, LHD and Tore-Supra

- Continue joint development of analysis codes. The EFIT equilibrium reconstruction code improvement is a good example of a collaboration that benefits both U.S. and PRC. PRC in particular would benefit from the availability of analysis codes to extract scientific understanding from experimental data

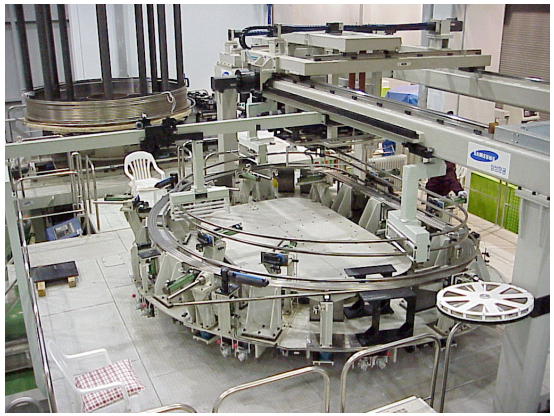
- Both HL-2A and HT-7 have available significant run time for collaboration. Both tokamaks are heated by RF sources only and would be suitable for plasma studies with no momentum input. Collaboration in RF technology development is also mutually beneficial

- For their future programs, PRC scientists are interested in gaining experience in tokamak operation with shaped plasmas, extending diagnostics capabilities, and collaborating on divertor and in-vessel component design

KSTAR International Collaboration Status: March 2003 (J. Wesley)

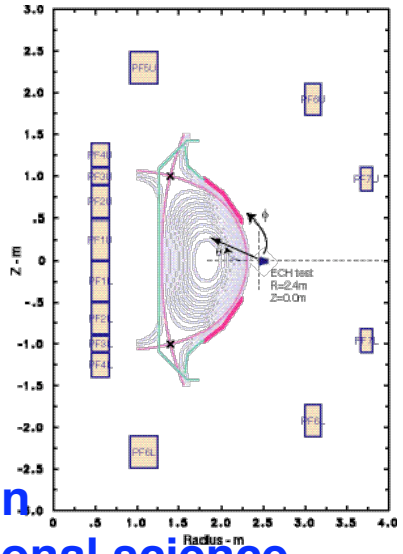


- KSTAR (Korea Superconducting Tokamak Advanced Research) Project is on track planned to achieve 'first-plasma' by the end of CY2005
- KSTAR plasma size and configuration capabilities will be comparable to those of DIII-D: 'ITER-like' plasma configuration, SN and DN, superconducting TF and PF coils (Nb3Sn TF and inner PF; NbTi outer PF). KSTAR is presently the largest all-SC 'advanced tokamak' project authorized for construction, and the Koreans have developed the SC technology infrastructure needed
- Operational capabilities by 2011: 2 MA, 20-s with NBI, LH and IC H/CD; EC and 300-s pulse length upgrade proposed, starting in 2012; full capability available ~2016
- Status: torus hall and facility construction complete, TF and PF coil production in progress at SAIT; first TF coil now in cryotest at SAIT; vacuum vessel in fabrication at HHI; NBI and IC systems in development at KAERI; LH systems development at POSTECH
- US-KSTAR collaborations are in place at $500K/yr level; targeted to support initial KSTAR plasma operation in 2005 and experiments beginning in 2006



KSTAR International Collaboration: History and Present Status

- Pre-1998: Korea-funded collaborations with US labs (primarily PPPL and ORNL) focused on finalization of the KSTAR design (derived from US TPX design) and science planning
- 1998-2003: OFES-funded collaborations at PPPL, GA, ORNL, LLNL and MIT: finalization of specific KSTAR design details, preparation for KSTAR commissioning and initial operations (commencing in 2005) and, most recently, exploratory planning for 'international' collaboration in subsequent KSTAR operation and plasma experiments



- KSTAR Director General (G-S Lee) has indicated the Korean Government's intent to operate KSTAR as an international fusion facility, with Korean-funded operations and joint Korea-international science and experiment planning and staffing
- Studies by US fusion science and technology development staff have identified a wide range of possibilities for collaborating with the KSTAR team on preparations for initial operation and subsequent experiments. Topics of mutual interest include: heating and current drive technologies and experimentation in long-pulse 'advanced-tokamak' regimes; advanced 2-D and 3-D plasma turbulence-viewing diagnostics and modeling and simulation of 'conventional' and advanced tokamak operation regimes

FY03 International Research Collaborations: KSTAR

Institution	Funding ($K)	Approximate FTEs	Work Scope/Intent
PPPL	352	1.4	• Diagnostic port cassette designs • LHRF launcher and system design • ECRF launcher design
GA	96	0.4	• Plasma control system design and software • 'Advanced' control science and systems • In-vessel cryopump design consultation
LLNL	25	0.1	• EC and scenario modeling • Application of CORSICA/CALTRANS simulation code
MIT	0	0	• No FY03 scope/inten
ORNL	13	0.05	• H-alpha 'filterscope' diagnostic

- [red text and data are for FY02]
- FTEs are approximate/generic and do not include allowance for travel, ODC, etc. The intent of the presentation here is to indicate approximate funding level and task scopes for specifically-funded KSTAR collaboration activities

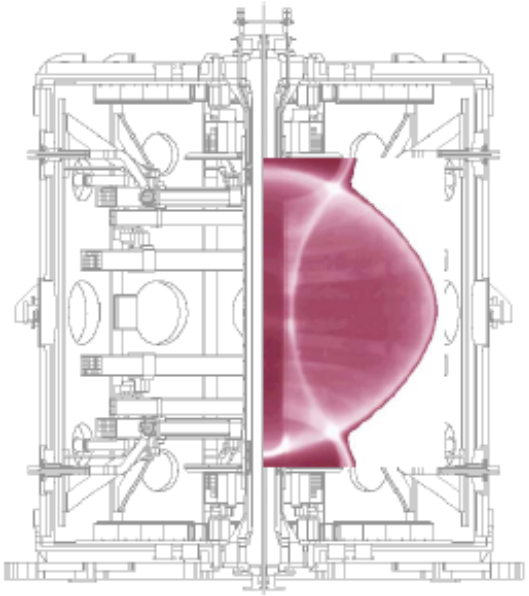
- **This Table does not show KSTAR-applicable 'base-program-funded' generic plasma simulation/modelling development, advanced diagnostic concept and hardware development and national laboratory and university base-program staff participation in the on-going series of US-KSTAR Bilateral Science Meetings and Workshops. Significant contributions to the last (August 2003) KSTAR 'Advanced Physics'/Transport Workshop by university-based modeling and diagnostic concept development staff (eg. Pedestal modeling by G Bateman et al, at Lehigh University) are to be noted**

KSTAR International Collaboration at GA/DIII-D

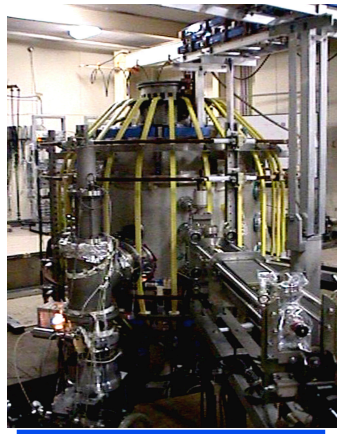
- **The rationale for the development and expansion of long-term collaboration between GA/DIII-D and KSTAR lies in the similar size, mission objectives and operation and science study capabilities of DIII-D and KSTAR**
- **Past GA-KSTAR exchanges have identified high-priority topics for future (FY03 and thereafter) GA/DIII-D collaborations:**
  - conceptual and software designs for the KSTAR plasma control, data acquisition and analysis systems and real-time plasma equilibrium reconstruction and current/safety-factor (q) profile measurement,
  - engineering consultation on in-vessel component design and operation and,
  - timely communication of GA/DIII-D findings on advanced plasma control science (neoclassical tearing mode and resistive wall mode control science and technology basis, active EC and/or IC current and q-profile control, active plasma boundary and edge-localized-mode control, etc.)
- **FY03 KSTAR International Collaboration funding ($96K) presently supports funding-limited efforts on plasma control software transfer and in-vessel engineering consultation**
- **DIII-D National Program staff have also identified opportunities for medium-term to long-term visits by KBSI/KSTAR staff to participate in DIII-D experiments, data analysis and/or facility and diagnostics system operation activities. Such visits will provide training and experience to the Korean staff that will be directly applicable to future KSTAR operation and science experimentation**

NSTX physics relevance to IPPA Thrusts (including Burning Plasmas) has led to broadened international collaborations

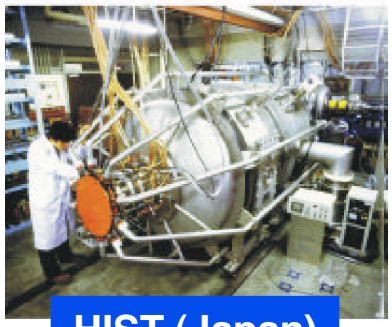
- **Merging database with MAST, U.K.**
  - NBI H-mode, transport, □E
  - EBW H&CD (1 MW, 60 GHz), FY03
  - Divertor heat flux studies, FY03-04
  - NTM, ELM characterization
- **Exploratory ST's in Japan**
  - **TST-2**: ECW-EBW initiation
  - **TS-3,4**: FRC-like □~1 ST plasmas
  - **HIST**: helicity injection physics
  - **LATE**: solenoid-free physics
- **Began participation in ITPA (ITER) – Aspect Ratio & □ effects**
  - □ scaling on H-mode confinement
  - □ limits for ITB operation
  - ELM impact on pedestal & SOL
  - RWM & NTM



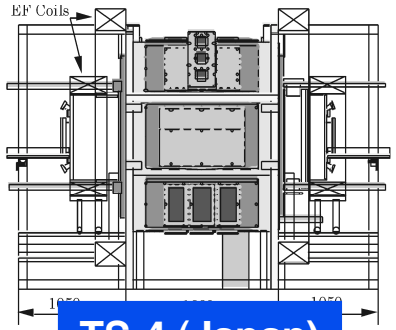
MAST (U.K.)



TST-2 (Japan)



HIST (Japan)



TS-4 (Japan)

Opportunities for Advancing 3-D High Beta Physics on International Stellarators (J. Lyon)

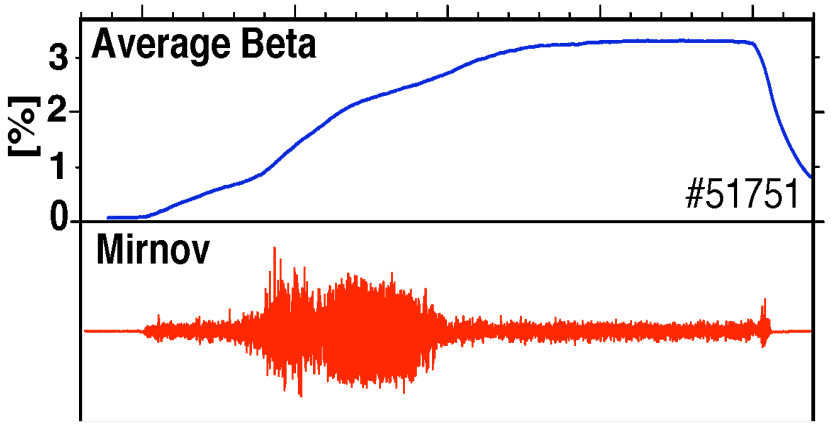
- **Unique US analysis tools can be used to understand 3-D high beta configurations in LHD and W7-AS.**

FY04 Presidential (Level 1) Milestone:

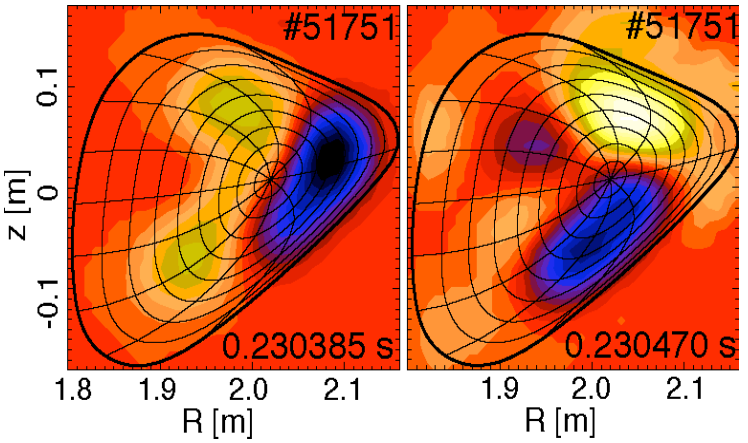
"Explore MHD equilibrium and stability in…international stellarators in preparation for the operation of NCSX"

- **Overall funding for international stellarator collaboration has been reduced, jeopardizing the achievement of the milestone.**

MHD quiescent high beta (3.2%) in W7-AS
(M. Zarnstorff and the W7-AS team, 2002 IAEA)



X-Ray Tomograms



Support for Stellarator Collaborations Has Been Severely Reduced

Collaboration	Activity	Budgets (k$)			
		FY 03	FY 04	FY 04(I)	FY 05
PPPL on W 7-AS and LHD	analysis of 3-D high beta configurations in LHD and W7-AS	518	0*	415*	405
ORNL on LHD (funded separately)	measurement & analysis of 2-D fast ion distributions and soft X-rays in LHD	265	256		265

* **No funding in FY 2004 jeopardizes a FY04 Presidential (Level 1) Milestone:**

"Explore MHD equilibrium and stability in…international stellarators in preparation for the operation of NCSX"

Application of the M3D code had been planned for analysis of high beta equilibria and stability in W7-AS in FY04

RFP (S. Prager)