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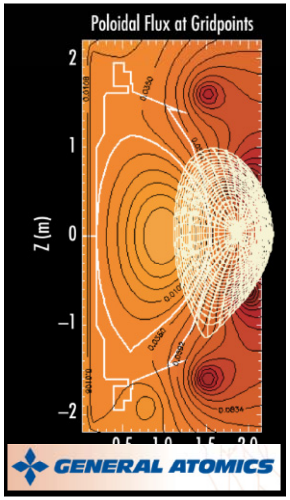
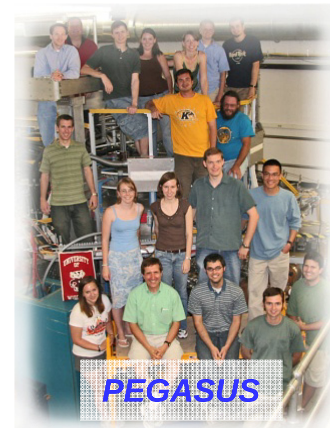
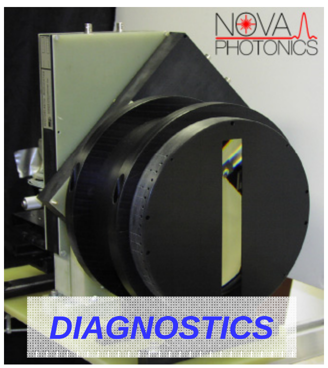
National Spherical Torus Program



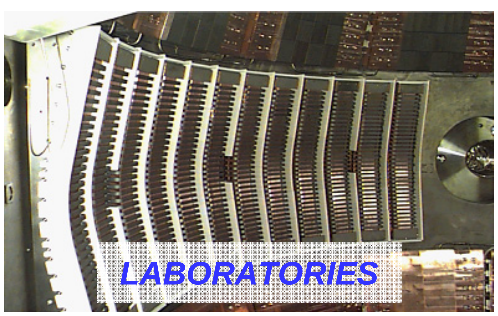


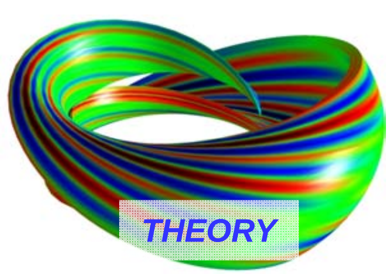
<u>Spherical Torus Coordinating Committee</u>

Bill Dorland (U Maryland)
Don Hillis (ORNL)
Rob LaHaye (GA)
Fred Levinton (Nova)
Dick Majeski (PPPL)
Jon Menard (PPPL)
<u>Martin Peng</u> (Chair, ORNL)
Steve Sabbagh (Columbia U)
Aaron Sontag (U Wisc)



OFES FY10 Budget Planning Meeting
Gaithersburg, Maryland
March 11-12, 2008





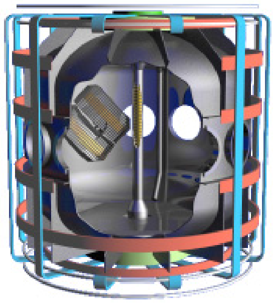
U.S. ST Coordinating Committee (STCC) charge

- Organized by OFES and report to ST Program Manager (Steve Eckstrand)
- Develop, support and promote the evolving roles of ST in the U.S. fusion program
- Coordinate milestones, plans, and longer term goals
- Review and report progress relative to funded R&D
- Represent and advocate ST Program nationally, and internationally through the IEA ST Executive Committee
- Membership selected to represent major R&D components

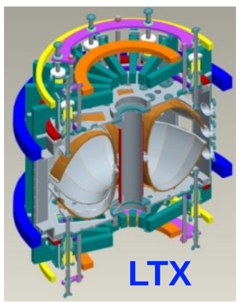
Content of talk

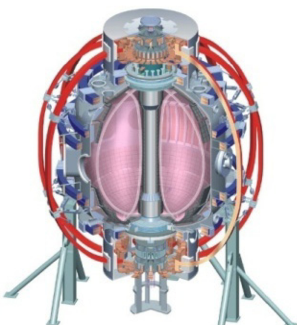
- ST R&D Mission in ITER era
- Pegasus opportunities and proposal
- LTX opportunities and proposal
- Critical research on NSTX resolvable in 3 years
- International collaboration
- Proposed STCC effort for FY09-FY10
- ST R&D Advocacy

Mission: Develop compact, high beta ST burning plasma capability for use-inspired research and development



PEGASUS



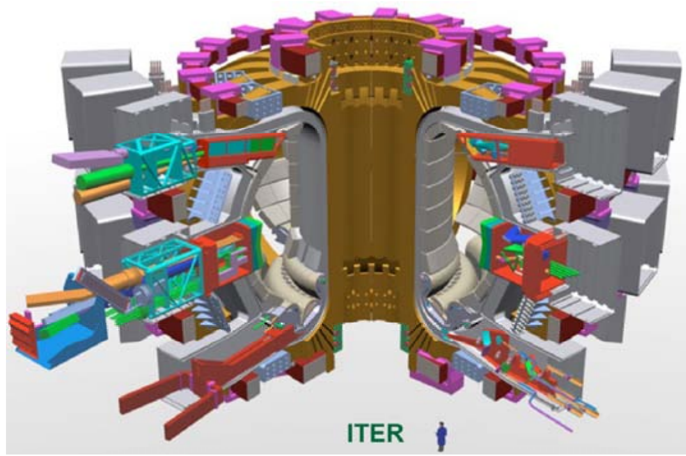


NSTX

International Research Collaboration

The ITER Era

ITER for **Burning Plasma Science**



ST burning plasma capability
for
use-inspired R&D

Work to develop the supporting ST strategy has just begun

ST & Other Fusion Energy Source(s)

Pegasus Research Program has 3 Thrusts Addressing Critical Issues for the ST & AT

Non-solenoidal startup, ramp-up

(Theme C)

- Develop scalable plasma gun arrays
  - *demonstrate high I_p with high TF*
  - *0.1 - 0.3 MA in FY08-10*
- Ramp-up via HHFW
  - *FY 09-11*
- Ramp-up via EBW
  - *collab. w/PPPL & ORNL?*

Edge stability at high $(j_{||}/B)_{edge}$

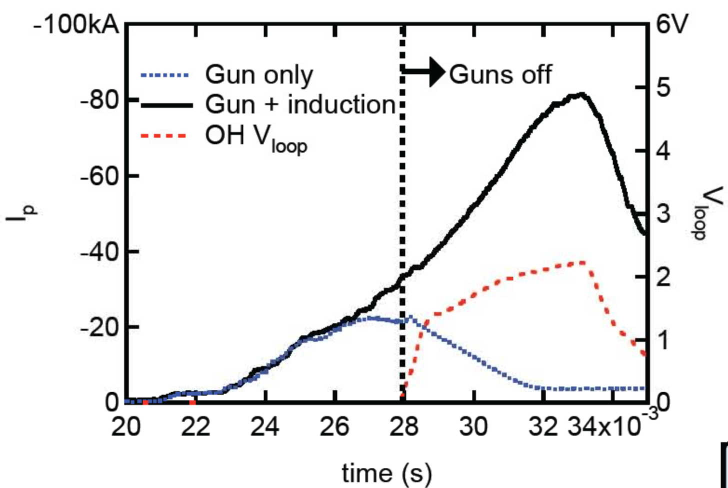
(Theme B)

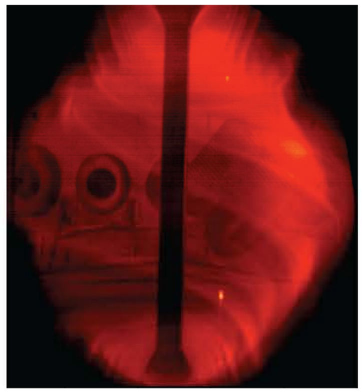
- High density magnetic probe arrays
  - *determine m & n in FY08-09*
- Edge probes: directly measure $j_{||}/B$, p(R)
  - *FY 08-10*
- Divertor coils for edge stability mod.

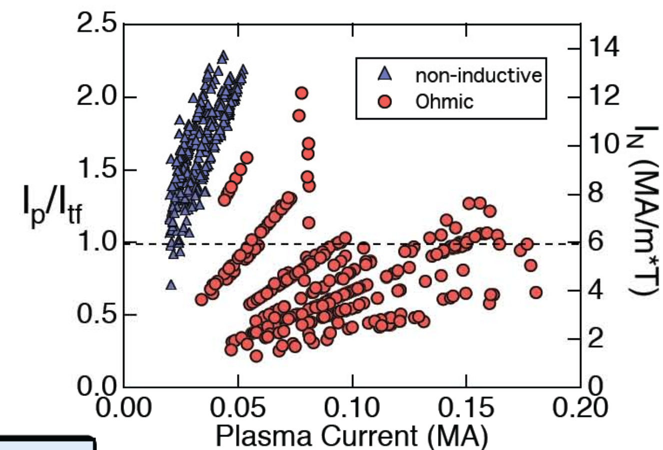
j(R) mod. for high-I_N, β_t

(Theme C)

- Edge current drive via guns
  - *broad j(R)*
  - *0.1 - 0.3 MA in FY08-10*
- New centerstack
  - *access high I_p, β_t*
  - *FY 10-12*





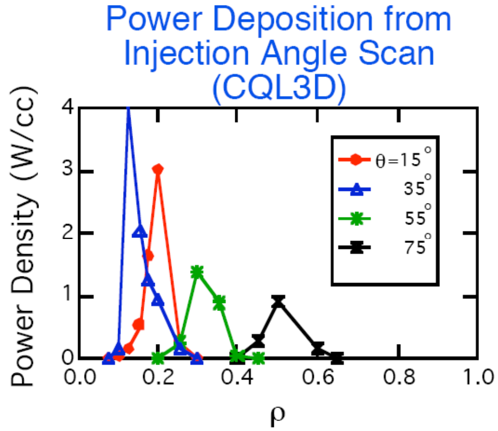


Experimental Parameters

Parameter	Achieved	Goals
A	1.15-1.3	1.12-1.3
I_p (MA)	≤0.18	≤0.30
I_N (MA/m-T)	6-12	6-20
$I_{non-inductive}$ (MA)	0.05	0.3
β_t (%)	≤25	>40
τ_{shot}	≤0.02	≤0.1

Full-Use Budget Supports Upgrades for Addressing 3 Main Thrusts of Program

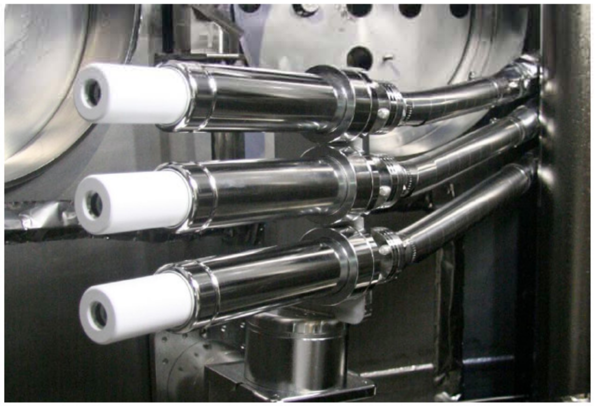
- Full-Use: +~$500K/yr
  - Optimize centerstack upgrade (+$75 K/year for FY09-10)
  - Refurbish HHFW to 1 MW (+$25 K/year for FY09-10)
  - Post-doc for Thomson Scattering (+$100 K/year)
  - **EBW: 1 MW current ramp-up tests in an ST** (+$300 K/year)
    - Collaboration with PPPL/ORNL?



- FY08 baseline = $954K
  - Support staff and students
  - Scalable, high-power gun array development

- Reduced case: -10%
  - Personnel reduction: staff or grad students
  - Downgrade or eliminate one of the High-I_p test gun arrays

- Major Facility Activities - baseline funding
  - **Plasma gun injector systems development and testing**
    - Power supplies; Scalable high-current midplane arrays
  - Divertor coil upgrade for edge stability
  - SXR imaging for j(r,t)
  - Upgrade centerstack for high TF and $I_{non\text{-}inductive} \geq 0.2$ MA



LTX focus in FY08-10: Electron transport

- FY08 - First plasma
- FY09 - Lithium wall operations
  - ∇T_e as a function of recycling
    - » Thomson scattering + Lyman-alpha + DEGAS 2
  - Effect of lowered ∇T_e on confinement
- FY10 - Operation with long current flattop
  - $> \tau_E$, > current diffusion time
  - $T_e(r)$ with relaxed current profile

Design parameters for LTX:

$R_0 = 0.4$ m
$a = 0.26$ m
$\kappa < 1.6$
$B_T < 3.4$ kG
$I_p < 400$ kA
$\tau_{discharge} < 0.25$ s

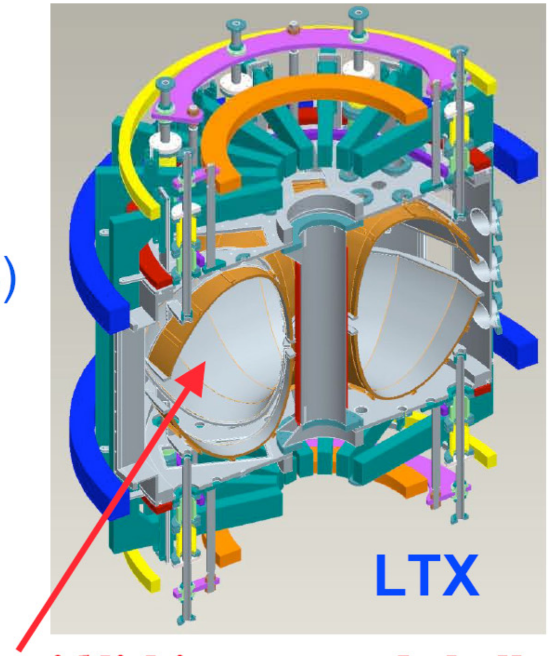
LTX research fits within theme B of the Greenwald panel:

⇒Understand *and control* plasma material interactions (GW-8)

⇒Design *replaceable* components without degrading performance (GW-9)

LTX liquid lithium wall development supports LLD implementation in NSTX

3 graduate students, 1.5 post-docs



Liquid **lithium coated shell**

Full use of LTX: Core fueling via NBI

- Full use case: baseline +700k/year incremental
  - FY09: OH supply upgrade to design capability.
    - Add edge Thomson channels
  - FY10: Install short-pulse NBI for tests of core fueling in very low recycling regime (UW-Pegasus collaboration)
    - Installation of lithium coated porous molybdenum shell
    - 3.4 kG operation
    - Begin CHERS install
  - FY11: Full NB fueling, CHERS for T_i

- Baseline funding: 970k, flat FY08-10
  - First plasma in FY08 (but OH power supply at 1/4 design, no feedback)
  - First lithium wall experiments in FY09
  - Confinement results with long flattops in FY10

- Reduced case: baseline -10%
  - Abandon Thomson scattering system in mid FY09
    - Cannot replace postdoc presently working on system
  - No OH upgrade, no long flattops in FY10

PPPL
PRINCETON PLASMA PHYSICS LABORATORY

STCC asked to assess 3-year critical research on NSTX

- Identified and organized 39 research topics
- Developed and used Measures of Criticality (MOCs) to down-select
  - Physics Regime?
  - Scientific Gap?
  - Future Design Benefit?
  - World-leading?
  - PoP Research Maturity?
  - 3-Year Progress?

3-Year, NSTX Only

  - Benefit to ITER R&D?
  - Benefit from ITER R&D?
  - Unique Contributions to Toroidal Plasma Science?

Broader, Longer Term

- Results submitted to OFES and shared with NSTX leadership

The most critical research topics identified by STCC

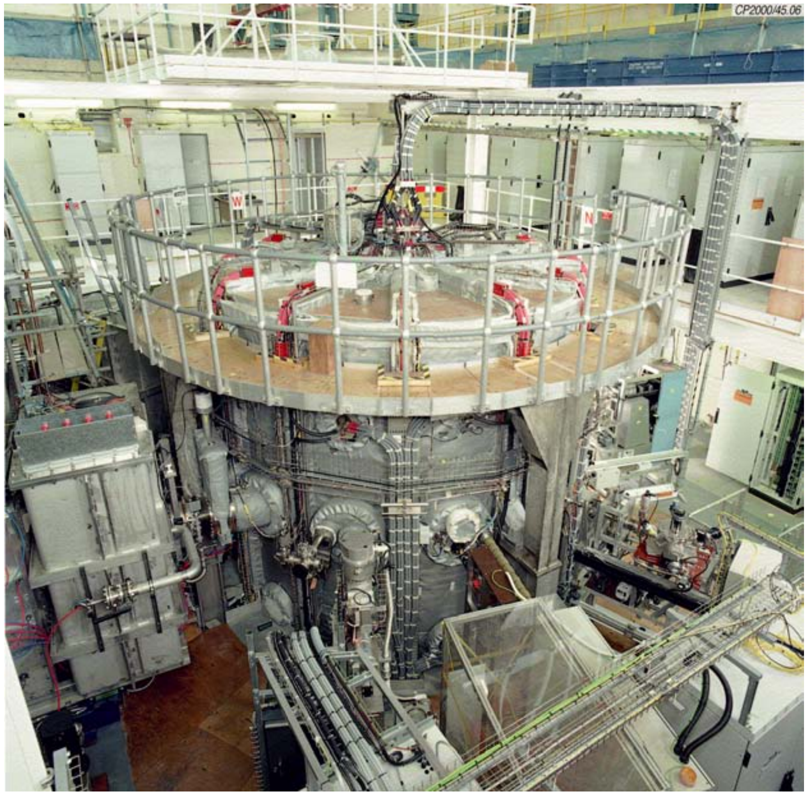
1. Impact of reduced collisionality on high-performance integrated scenarios (Themes A,B,C)
2. JNBI predictability in sustained beta ~ no-wall, fBS ~ 0.5, high-confinement plasma (Themes B,C)
3. Predictive capability in electron turbulence and transport (Themes A,B,C)
4. Multiple harmonic fast wave for ramp-up and sustainment assist (Theme C)

- **With focus and adequate theory support, these 4 critical topics can be resolved in 3 years on NSTX.**
- **Additional critical topics can be identified if the 3-year constraint is removed.**

MAST/MAST-U offers opportunities for collaboration

Two equal goals:

- Explore the potential of ST as a Component Test Facility (CTF) and/or ST Power Plant
- Advance key tokamak physics issues for ITER and DEMO



UKAEA Fusion Working in Europe

MAST-U received provisional commitment for 2/3 funding (of 36M BP total)

- Focus first on 5-s magnets, 12.5MW NBI, divertor, ELM control

Collaboration opportunities:

- PoP (1-MW) level EBW startup tests
  - 350-kW test to start in May-June 2008
- Microwave high-k scattering
- MSE upgrade
- Pellet fueling and ELM pacing upgrade
- SXR tomography
- Long-pulse rotating plasma stability control near no-wall limit

IEA ST Agreement ready to provide international framework

Present work assignment for STCC

Support FES Strategic Planning, working broadly within the community,

- Four “Approaches, Options, Initiatives” workshops for Tokamak/AT
- FESAC Panel on Magnetic Alternates (Stellarator, ST, RFP, CT)
- Assess leverage on “Strengths, Weaknesses, Opportunities, Threats” of initiatives (i.e., Future Design Benefit) to guide ST strategy and research priorities

Substantial efforts and travel will be required

- Meetings: ~30 person-trips/year, 15 for members funded by grants ($75k/year)
- Dedicated efforts (from 10% to 50% time) to be arranged directly with DOE
- Apply community (including ORNL) expertise in engineering, nuclear, material sciences to assess high-leverage impacts across major candidate initiatives (1.3 FTE/year)
- Joint work with fusion plasma science experts in such assessments

STCC advocacy

The spherical torus (ST) is an experimentally-proven magnetic fusion configuration that

(1) has advanced, and is poised to continue to advance, critical fusion energy science knowledge by leveraging its unique geometry and high beta operational space, and

(2) is envisioned to evolve into potentially cost-effective fusion energy systems.

Rapid progress has been made in devices worldwide with currents up to mega-Ampere, with the U.S. being a leader.

The DOE-formed ST Coordinating Committee (STCC) is committed to advancing world-leading ST research in support of the Fusion Energy Sciences Program, and advocates that this research path be continued during the ITER era by establishing facilities/upgrades (*in U.S. and abroad*) that will take it to the next-step. The committee suggests that the importance of continued U.S. leadership in this research surpasses specific institutional considerations, and calls for a national approach to research planning and management to energize community participation and support.