Transport and MHD Research on NSTX Through 2003 and How it Serves the ST PoP Mission

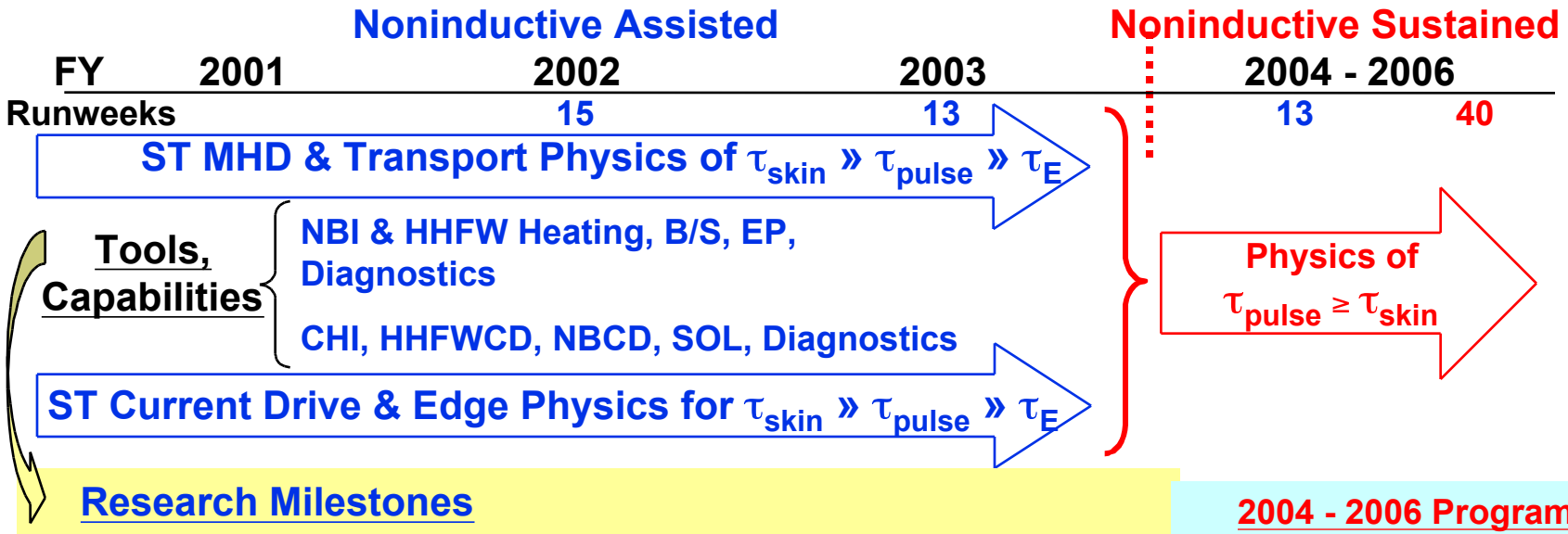
E.J. Synakowski
Princeton Plasma Physics Laboratory
For the National NSTX Research Team

Office of Fusion Energy Science
Gaithersburg, MD
March 14, 2001

The NSTX Research Program is poised to explore physics unique to high beta and low aspect ratio

- Promising baseline plasmas for research have been developed
  - ~ 20% β_T achieved (EFIT; Columbia)
  - High confinement
- Diagnostic and heating capability already reveal exciting new physics
- Research Program structured around Annual Milestones
  - Milestones consistent with IPPA goals
  - Entry points to deeper scientific understanding

FY01-03 Topical Research and Tool Development Support Long-Pulse Goals



Research Milestones

- **Study τ_E**
- Heat with HHFW
- **MHD stability**
- **Assess high β_T & flow effects on χ**
- Demonstrate CHI
- Assess HHFW CD efficiency
- SOL fluxes
- **Integrate hi β_T & hi τ_E for ~5τ_E (wall stabilization)**
- Extend startup & sustainment to ~1s

Bold milestone in this talk

2004 - 2006 Program Areas

- Noninductive startup & sustainment
- Heating, CD, fueling control
- MHD mode control
- Turbulence suppression
- Energetic ion effects
- Multi-state interface control

Fundamental and unique science is key to assessing the attractiveness of the ST

IPPA Goal 2.1: Assess the attractiveness of the ST concept (FY'04)

Unique topical science is directly relevant to this practical goal

- Transport Science — ST Attractiveness
  - Strong p- or V_φ-driven E×B shear vs. increased electromagnetic effects

    High β P(r) compatible with long pulse?
  - Anomalously high edge rotation (new)

    Favorable wall mode stabilization?
- MHD Science — ST Attractiveness
  - High stability from field line geometry

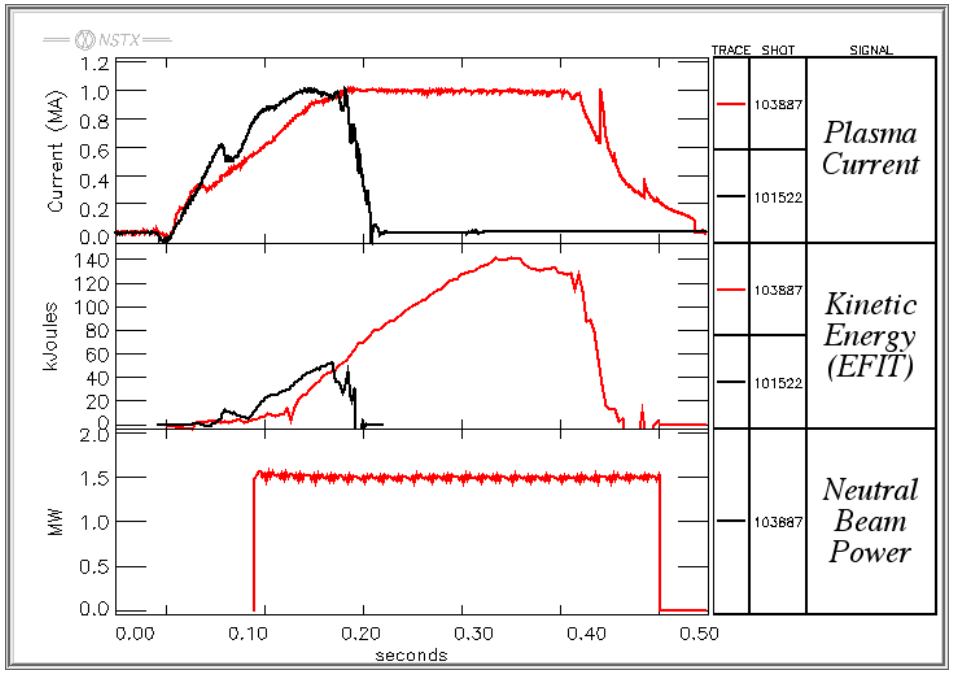
    Stability margin at high pressures?
  - $V_{beam} >> V_{Alfven}$; $V_{th} \sim V_{Alfven}$

    Alphas well confined?
  - 3-D MHD and reconnection physics (Maingi)

    Will CHI extrapolate?

The NSTX Program has a good baseline scenario, and is developing tools to extend it

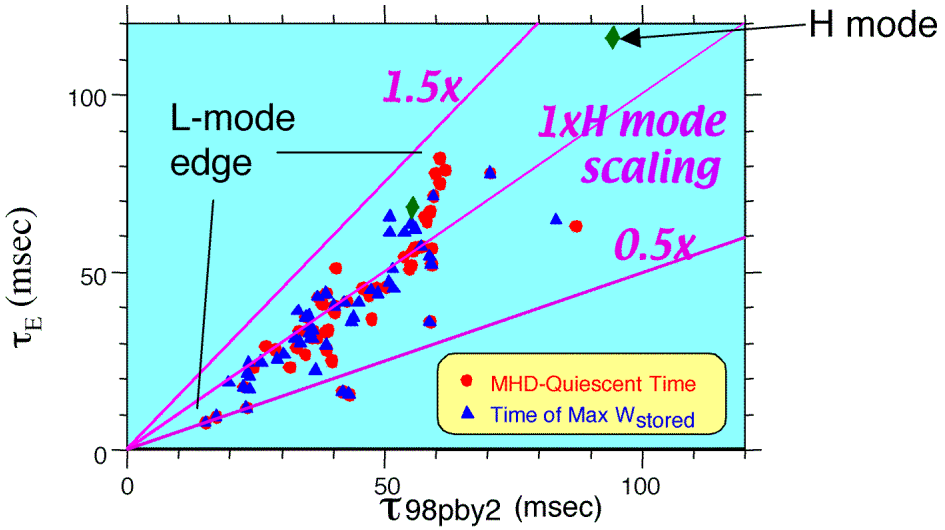
- Significant progress in pulse length and reproducibility
  - 1 MA routine; design rating
  - Tools in place: NBI (5 MW), HHFW heating (ORNL; 4 MW), shape control (GA), boronization (MAST), HeGDC
- Longer pulse more control, current, and heating tools
  - Being developed: CHI (UWash), HHFW CD (ORNL), real-time EFIT (GA), high temperature bakeout
  - To be assessed: active mode stabilization (Columbia, GA)



Early transport studies reveal exciting trends and different operating regimes

IPPA Goal 2.1: Assess attractiveness of ST

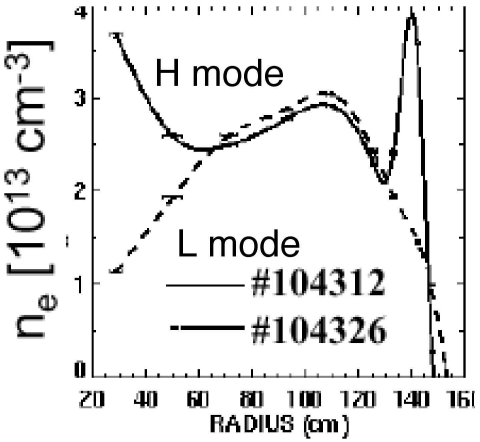
FY '01 Milestone: Initial confinement assessment

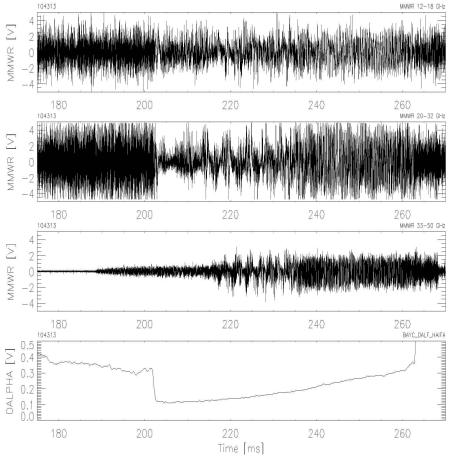


- τ_E with L-mode edge ~ H-mode scaling

- H mode
  - Broad pressure profile for long-term?
  - Transport science: large ρ* (ORNL)

- First edge fluctuation measurements (UCLA, LANL)

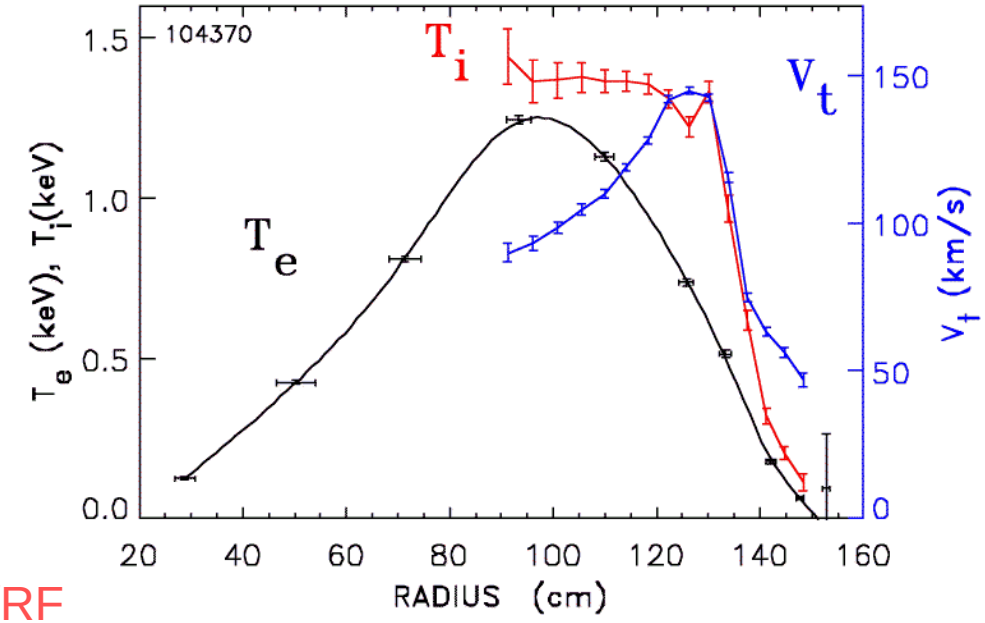




FY ‘02 transport studies focus on unique ST physics

FY ‘02 Transport Milestone: Unique local ST transport physics

- Large edge V_φ not seen at moderate A
  - Favorable for wall mode stabilization?
- In FY ‘02
  - Scan beta. Trends in χ_e, χ_i
  - Strong/weaker ExB: Compare NBI/RF plasmas
  - Compare to gyrokinetic theory

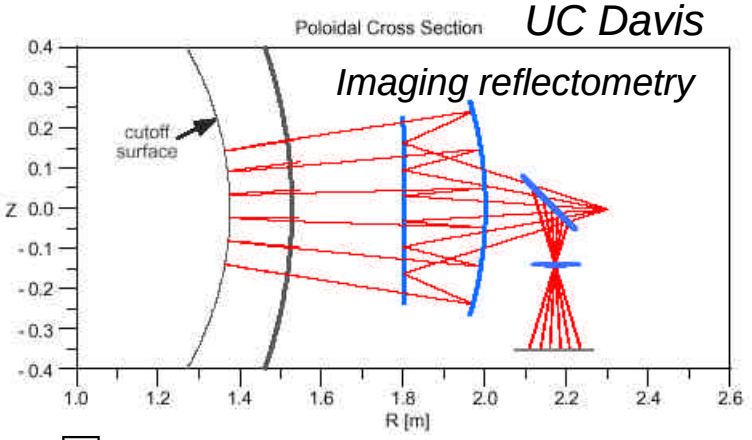


FY ‘03 gives opportunity for start of unique core turbulence studies

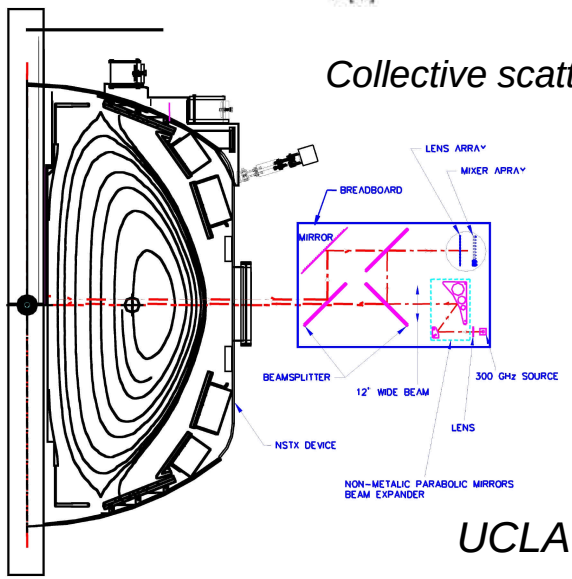
IPPA Goal 1.1: Advance transport based on turbulence understanding

- Core fluctuation diagnostics late FY ‘03
  - Turbulence Diagnostics Workshop last January
  - Contributions: JHU, Kurchatov, PPPL, RPI, UC Davis,UCLA
- Much-anticipated: strong ExB shear
- Electron thermal transport: unique opportunity
  - Electromagnetic effects
  - High beta + smaller B mode size larger, more easily detected?

UC Davis



Collective scattering



UCLA

NSTX program is in a position to make unique contributions to MHD science in FY '02, 03

IPPA Goal 2.1:

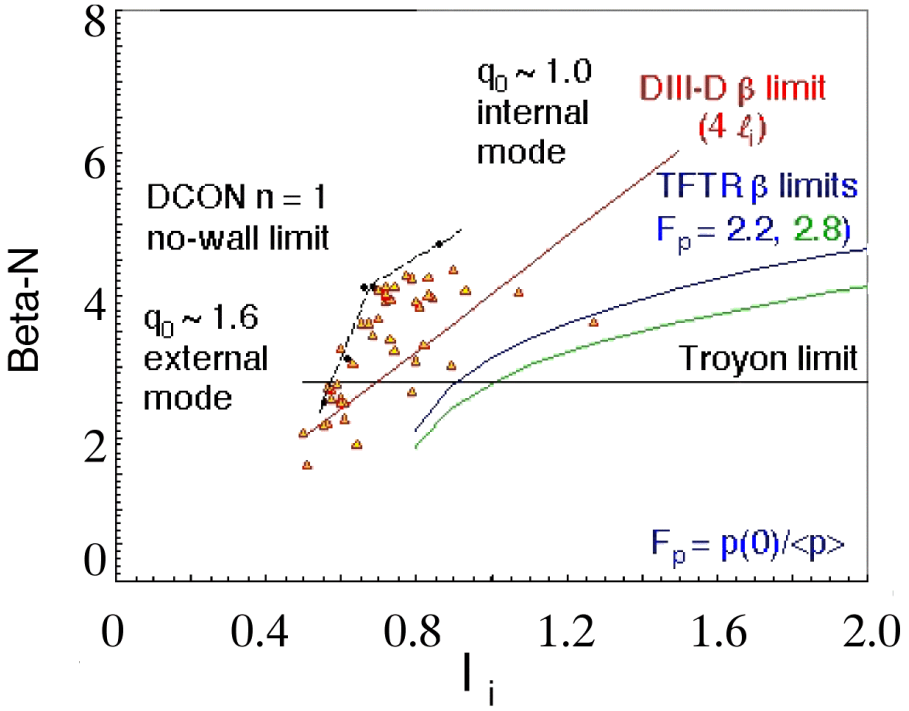
Assess attractiveness of ST

IPPA Goal 1.2: Develop predictive MHD capability including resistive and kinetic effects

FY '02 MHD Milestone:

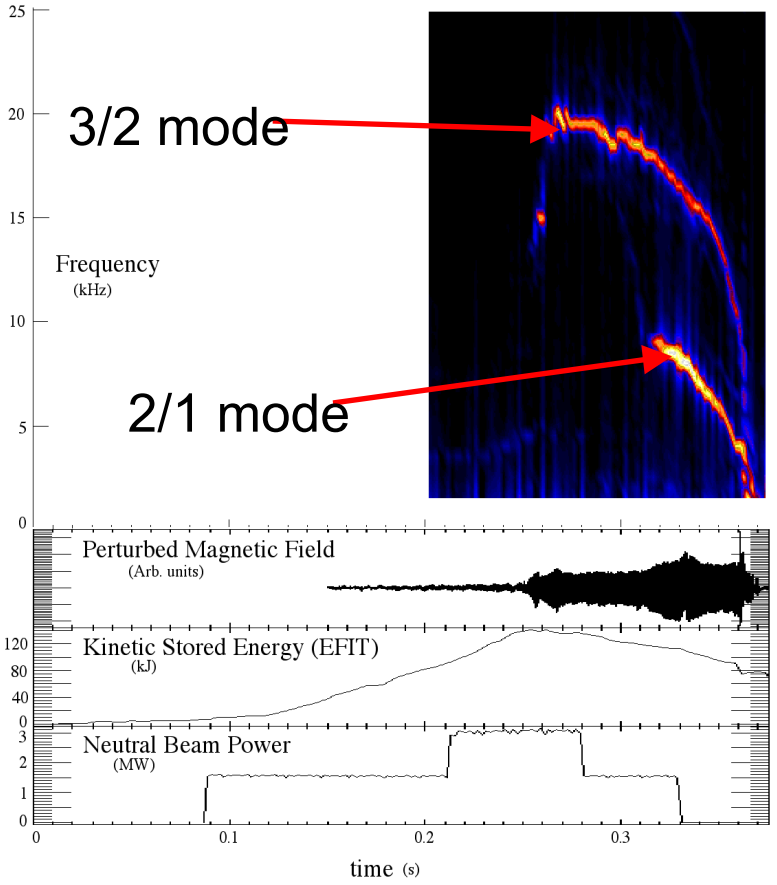
Assess global stability

- Beyond the Milestone: Detailed experiment-theory comparison requires
  - excellent profile diagnostics
  - advanced plasma control capability



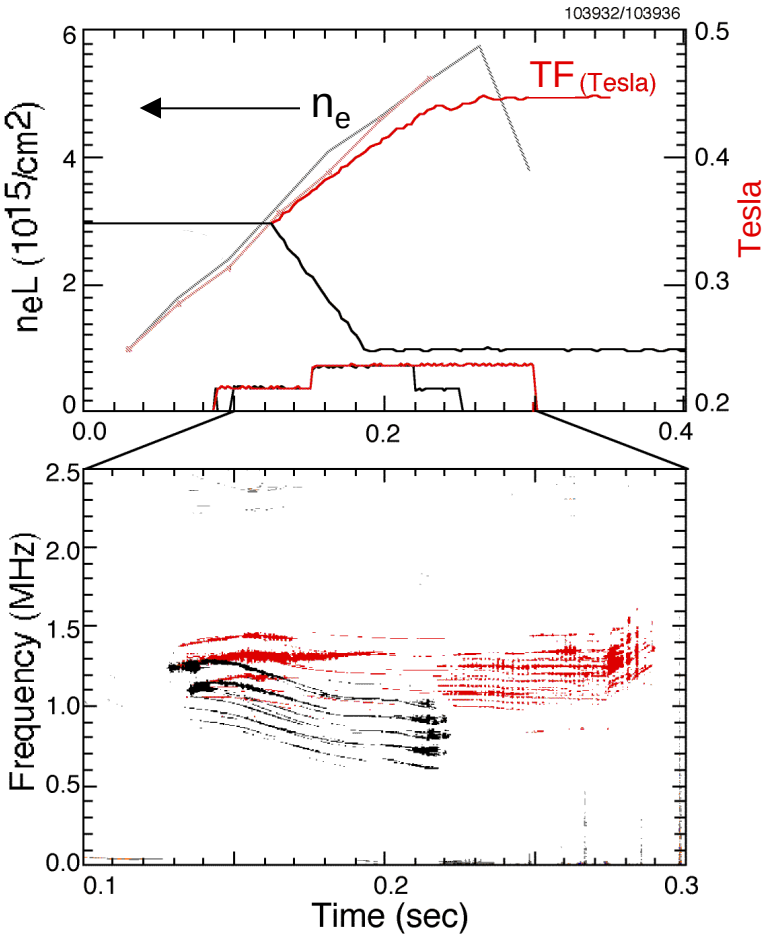
Meeting FY '02 active stabilization assessment point requires identification of beta-limiting modes

- FY '02: Scientific assessment of β-limits
  - Identify β limiting modes: RWM, neoclassical tearing,…
    - Deploy/improve magnetics, SXR diagnostics
  - End of FY '02: Start feedback system design
    - Active magnetic coils
    - EBW CD for tearing?
- FY '03: Design assessment
  - Final review of active feedback design



New fast particle-induced MHD data speaks to new science as well as practical goals

- Rich variety of modes already seen
  - Possibly Compressional AE's
  - Measure losses, '01 - '03 (Triniti)
- New physics
  - $V_{beam} >> V_{Alfven}$
  - $V_{th} \sim V_{Alfven}$ at high beta
- DIII-D/NSTX comparison proposed
  - Role of aspect ratio (UC Irvine)
  - Different gap structure at low A



Integration milestone in FY '03 draws on progress in all topical areas

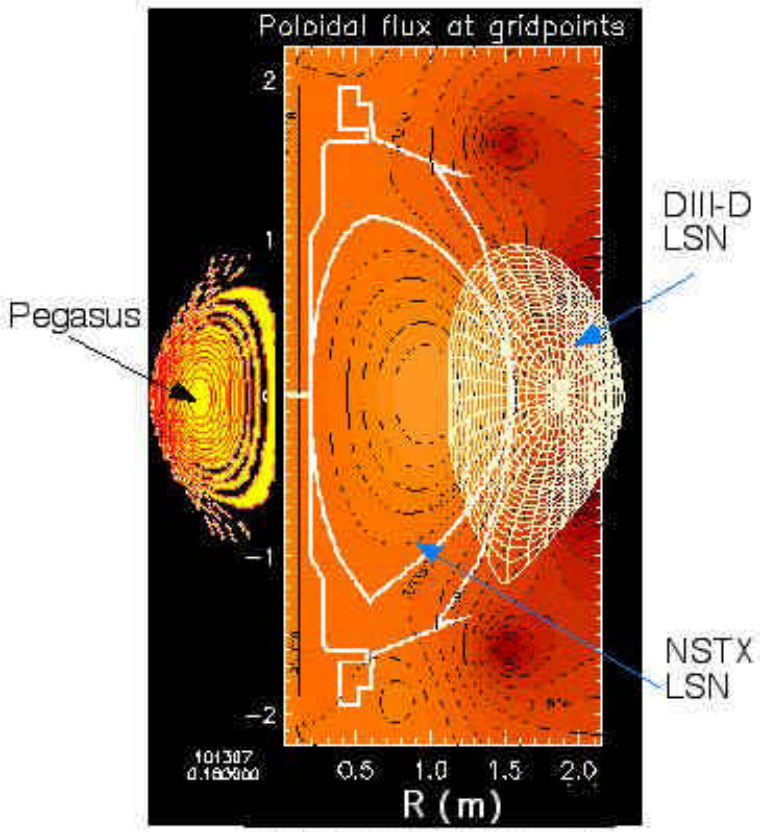
FY '03 Milestone: Test ST plasmas with simultaneously high confinement and high beta for $t_{pulse} >> \tau_E$

25% β_T; 40% J_{BS}

- Solution requires acceptable p(r,t), J(r,t)
  - Transport, MHD, wave-particle, boundary science
- Milestone will help clarify tool needs for $t_{pulse} \geq \tau_{skin}$
  - Active mode stabilization final design
  - P(r) control: test heating/fueling flexibility
  - Develop algorithms for HHFW CD feedback

Inter-machine research will help reveal the physics of beta & aspect ratio

- Amplifies scientific strength of national and international programs
- DIII-D: similar cross section shape, size
  - RWM assessment work (Columbia, GA)
  - Beam-induced MHD proposal (UC Irvine)
  - Transport proposal (GA)
- Pegasus: aspect ratio can match at 1.25
  - Logical connection for studying physics of A
  - EBW startup research (U. Wisconsin)
- MAST: similar size and A, but wall is far
  - Wall/no wall influence on neutral density and H mode thresholds



Paoletti, Sabbagh (Columbia)

Incremental funding would accelerate program checkpoints and deepen science

Example Science topic	Baseline	Increment
Technical active stabilization checkpoint - Scientific assessment in FY'02 (Columbia, GA)	end FY '03	end FY '02
Compare MHD & theory w/ measured q - LIF MSE measurements (Nova Photonics)	mid FY'03	start FY '03
Compare high β transport & theory with measured E_r (Nova Photonics)	mid FY'03	start FY '03
Turbulence dynamics at high β - Core fluctuations (Collaboration opportunity)	late FY '03	start FY '03
ρ* physics of edge pedestal - Thomson scattering, CHERS (LANL, LLNL, ORNL, UCSD)	FY ' 04	FY '03

The Proof-of-Principle mission of NSTX is in good accord with the IPPA science goals

- Assessing the attractiveness of the ST is intimately tied to the science of transport, MHD (discussed here), wave-particle interactions, and boundary physics (Maingi)
- Unique ST science already emerging
  - Program organized around new physics of high beta and low A
- Exploration/development of operating scenarios requires run time for tool and control system development
  - Development of operating space and key assessments advanced in incremental budget scenario
- Beta & aspect ratio science will emerge from studying contrasts and similarities with other devices
  - Enabled by portfolio approach