Theory and Modeling in support of NSTX Five Year Plan

J. Manickam

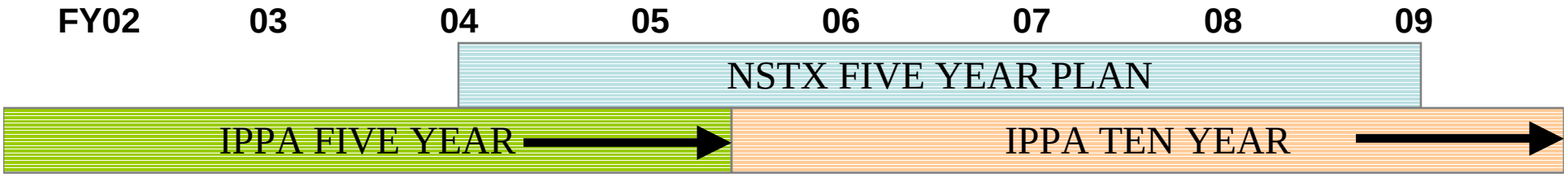
Princeton Plasma Physics Laboratory

Thanks to

N. Gorelenkov, S. Kaye, R. Maingi, J. Menard, C.K. Phillips and R. Raman

Theory supports the IPPA goals for determining the attractiveness of the ST concept

- 5 YEAR GOALS
  - Assessment of confinement, stability at high-beta
  - Non-inductive operation
- 10 YEAR GOALS
  - Long pulse – Performance extension
- SCIENCE GOALS
  - Advance fundamental understanding of plasma
  - Predictive capability

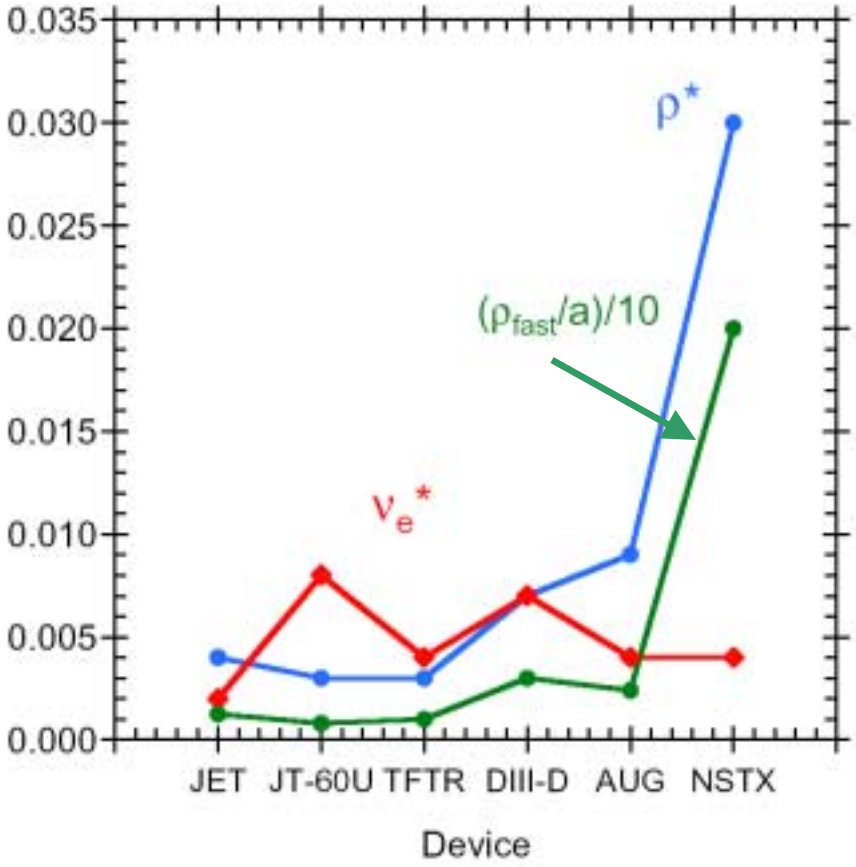


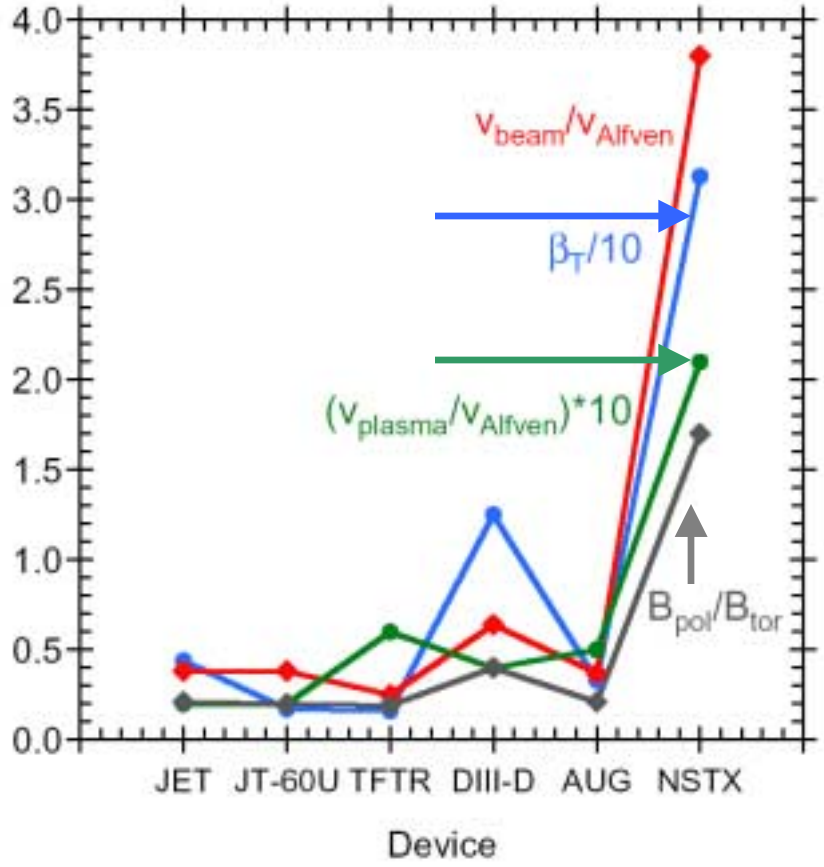
Progress has been made towards the IPPA 5 year goals

- MHD
  - Identification of RWM in high-β regimes
- Turbulence and transport
  - Shear stabilization of ITG modes
- Non-inductive current drive – CHI; RF
  - Identification of closed flux region; HHFW, CD
- Fast particle physics
  - Identification of CAE modes
- Plasma-boundary physics
  - Gas puff imaging simulation

NSTX Accesses Different Parameter Regimes Than Conventional Aspect Ratio Devices

Major differences result from lower B_T, higher relative rotation velocity





The modeling challenge is being met

Many existing codes have been adapted and benchmarked for use on NSTX

Codes are being developed to address new challenges posed by the ST

Theoretical developments are also needed

MHD topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

RWM, NTM, Locked modes, IREs

IPPA - ST 10 YEAR

Feedback, Bootstrap current, diffusion

IPPA – ST Science goal

Sheared flow, dissipation of rotation, reconnection physics

Ideal MHD EQUILIBRIUM and LINEAR STABILITY

TOPICS

- High beta limiting instabilities
- Resistive wall modes – feedback design
- Introduction of plasma flow in equilibrium and stability
- Real time stability analysis
- RWM Feedback stabilization

THEORY PLANS

- DCON, PEST – ideal, single fluid stability (FY'03 +)
- VALEN - 3D EM wall+plasma+coils (FY'03 +)
- VALEN - flow and multi-mode (FY'04 +)
- MARS – ideal, initial value with flow (FY'03 +)
- FLOW - equilibrium with flow (FY'03 +)
- NOVA-F linear stability with flow (FY'04 +)

RESISTIVE MHD AND NON-LINEAR STABILITY

TOPICS

- Resistive plasma + resistive wall
- Error fields and rotation - Dissipative mechanisms
- Internal reconnection events
- Real time stability analysis
- RWM, NTM Feedback stabilization

THEORY PLANS

- M3D - resistive, non-linear, resistive walls (FY'03 +)
- PEST-3 - Δ' - Modified Rutherford equation (FY'03 +)
- M3D + hybrid, kinetic (FY'04 +)
- HYM - resistive, non-linear, two-fluid δF (FY'04 +)
- PIES - 3-D equilibrium with error fields (FY'03 +)

Transport topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

Electron and ion thermal transport, power balance

IPPA - ST 10 YEAR

Predictive scaling based on understanding of local transport

IPPA – ST Science goal

Low and high-k turbulence dynamics

Turbulence and Transport

TOPICS

- Momentum and Power balance – Ti / Te ,- anomalous heating ? Heat pinch ?
- Confinement scaling $-V_\phi$, ρ^*, β
- Local transport and turbulence – k-spectra, Non-linear ITG
- High rotational shear, E_r
- Importance of ETG modes
- High- β --- Electro-magnetic effects
- Fast ion confinement
- Large Trapped Particle Fraction

Turbulence and Transport

THEORY PLANS

- NCLASS – modifications for ST – ρ*/ L, orbit etc (FY'03+)
- TRANSP, GLF23, Multi-mode – predictive modeling (FY'03+)
- GS2 - linear and non-linear EM μ-turbulence (FY'03+)
- GTC - linear and non-linear EM μ-turbulence (FY'03+)
- GYRO - linear and non-linear EM μ-turbulence(FY'03+)
- HYM -Non-linear CAE (FY'05+)

CHI topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

Plasma Startup

IPPA - ST 10 YEAR

Optimized non-inductive current drive

IPPA – ST Science goal

Flux closure and reconnection physics

Coaxial Helicity Injection

TOPICS

- Equilibrium reconstruction - current on open field lines
- Discharge simulation - flux penetration and closure
- Feedback control - control coils
- Empirical Optimization
- Flux closure and reconnection - Theory advances

THEORY PLANS

- EFIT - Free boundary equilibrium (FY'03+)
- ESC - Free boundary equilibrium (FY'03+)
- TSC - Tokamak plasma evolution (FY'03+)
- M3D – Non-linear resistive MHD (FY'04+)
- *CHIP - 2D – Non-linear resistive MHD (FY'04+)
- *CHIP - 3D – Non-linear resistive MHD (FY'04+)

*Funding

RF topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

Heating and current drive for HHFW and EBW in low aspect-ratio, high-β plasmas

IPPA - ST 10 YEAR

Sustained heating and CD; total current and local CD for MHD mode stabilization

IPPA – ST Science goal

Self-consistent wave-plasma interactions, large ρ* FLR treatment, WKB vs. full-wave, adjoint vs Fokker-Planck models and role of trapped particles

High Harmonic Fast Waves

TOPICS

- Finite Larmor radius approximation and WKB
- magnetic shear
- non-Maxwellian f_0
- Self-consistent Fokker-Planck models
- Particle trapping effects
- resonance overlap

High Harmonic Fast Waves

THEORY PLANS

- Wave propagation
  - HPRT, CURRAY, GENRAY – 2D WKB (FY'03 +)
  - TORIC, AORSA – 2D Full wave (FY'03 +)
  - METS – 1D Full wave(FY'03 +)
- Fast Particles and non-Maxwellian effects
  - METS (FY'04 +)
  - CQL3D, adjoint, Ehst-Karney (FY'04)
- Time dependent
  - CURRAY + Adjoint/Ehst-Karney + TRANSP (FY'03)
  - TORIC + Ehst/Karney + TRANSP (FY'03)
  - TORIC + CQL3D + TRANSP(??)

Energetic particle topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

Fast particle confinement, low-frequency wave-particle interactions

IPPA - ST 10 YEAR

Non-linear physics, high frequencey wave-particle interactions

IPPA – ST SCIENCE GOAL

Role of trapped particles and collective wave-particle interactions

Plasma boundary topics in the NSTX 5-Year plan

IPPA - ST 5 YEAR

H-mode threshold model, fuelling model

IPPA - ST 10 YEAR

SOL physics, ELMs and kinetic effects

IPPA – ST SCIENCE GOAL

Kinetic effects in edge codes

Summary

- Theory supports the IPPA goals of determining the attractiveness of the ST concept
- Theory supports the data analysis and interpretation of NSTX
- Theory advances the fundamental understanding of plasma science