National Spherical Torus Experiment Research Program

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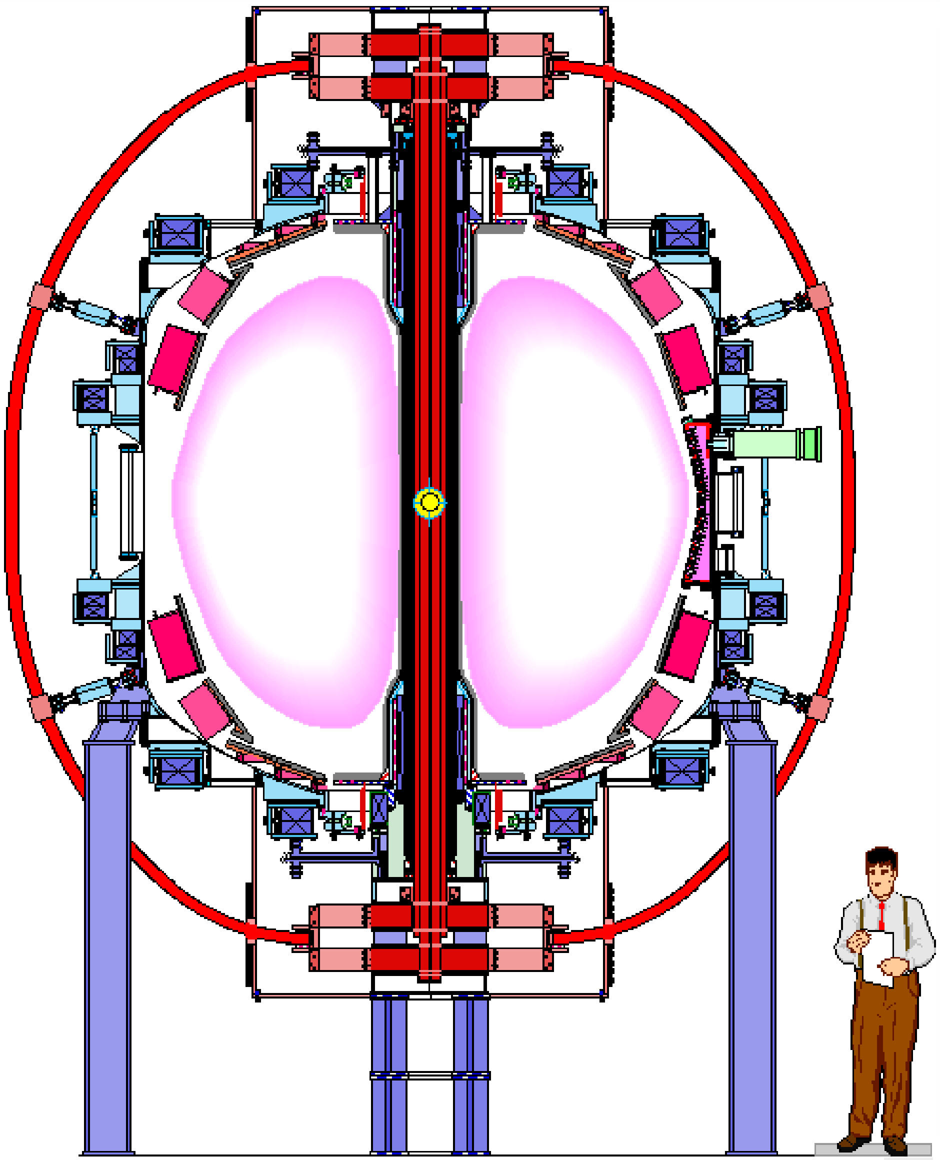
NSTX is a World-Class Innovative Fusion Experiment



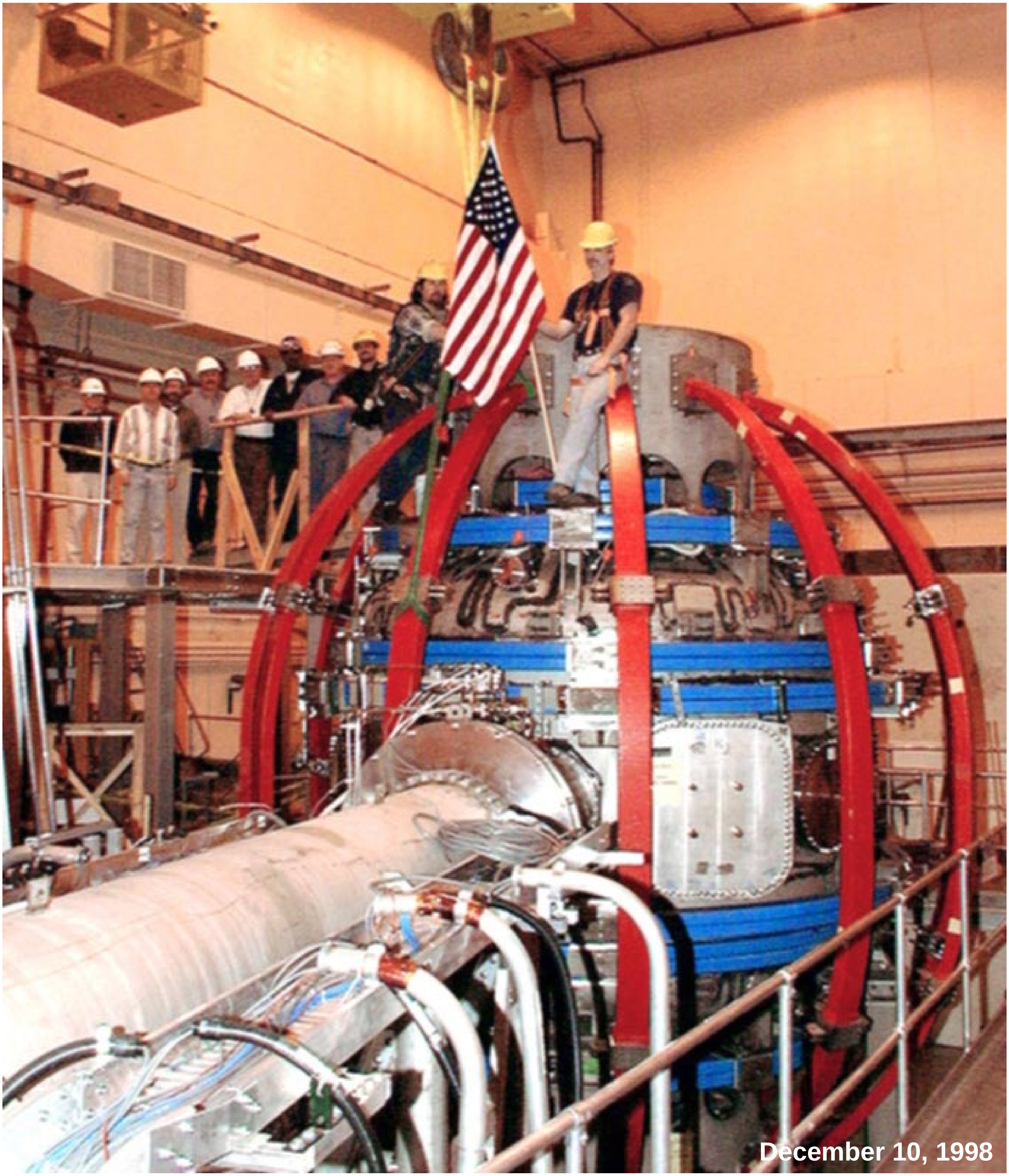
Baseline Parameters

- Major radius
  ≤ 85 cm
- Minor radius
  ≤ 68 cm
- Plasma current
  1 MA
- Toroidal field
  0.3–0.6 T
- Heating and current drive
  6–11 MW
- Flat-top time
  5–1.6 s

Joint Project of: Columbia University, ornl, PPPL Princeton Plasma Physics Laboratory, UW

NSTX Construction is Approaching Completion

NSTX



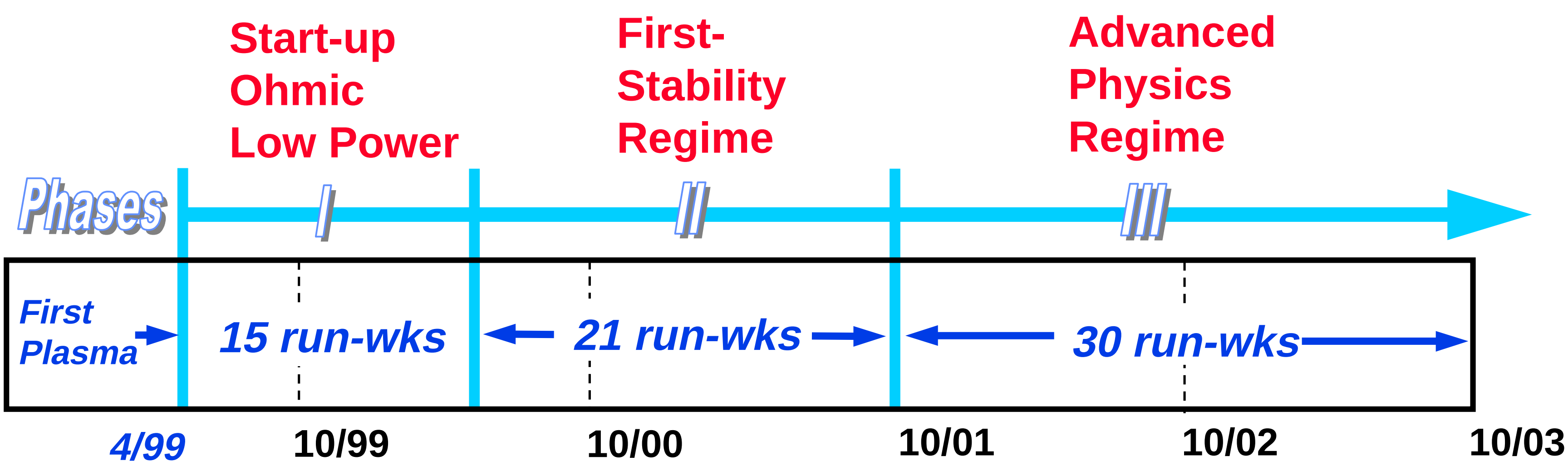
A National Research Team Will Investigate Fusion Science Principles of Spherical Torus

- High plasma pressure in low magnetic field ($\beta_T \leq 45\%$) for high fusion power density at low cost
- Good energy confinement in a small-size plasma (τ_{NC} for ions?)
- Nearly fully self-driven (bootstrap) plasma current (~ 80%) for economy
- Dispersed heat and particle fluxes for feasible power handling (double-null vs inboard limited plasmas)
- Plasma startup without induction magnet for compactness

NSTX is a member of a growing ST fusion research community

- HIT-II (U. Wash.), Pegasus (U. Wisc.), CDX-U (PPPL)
- MAST (U.K.), Globus-M (Russia), TS-3/4, HIST, TST-M, etc. (Japan), ETE (Brazil), etc.

We Envision Three Phases of NSTX Research for the Initial Five Years



- HHFW → 4 MW
- Current → 1 MA
- Pulse → 0.5 s
- CHI start-up
- Measure $T_e(r)$, $n_e(r)$

- HHFW ~ 6 MW
- NBI → 5 MW
- Current ~ 1 MA
- Avg. $\beta_T \rightarrow 30\%$
- Noninductive startup
- Pulse → 1 s
- Measure $J(r)$, $T_i(r)$

- HHFW ~ 6 MW
- NBI ~ 5 MW
- Current ~ 1 MA
- Avg. $\beta_T \sim 45\%$
- Bootstrap ~ 80%
- Pulse → 5 s
- Measure fluctuations

Phase-I (5/99 - 4/00): Explore and Establish Startup and Ohmic/Low Auxiliary Power Operational Space

Research Goals

- Initial characterization of Ohmic/low power confinement and operational limits (including shaping, divertors)
- Test and develop HHFW heating scenarios
- Test and develop CHI current initiation scenarios

Key Questions for ET discussion

- What are the scientific goals for key experimental runs?
- How to characterize or quantify these goals?

Six Research Run-Weeks for FY99 (July-September)

- Establish initial Ohmic plasmas, develop HHFW and CHI
- Check out diagnostics, etc.

Phase-II (5/00 - 9/01): Explore Noninductive Startup Operation and Strong Heating in First-Stability Regime

Research Goals

- Establish CHI non-inductive startup techniques
- Introduce and test ECH and EBW startup techniques
- Establish confinement scaling of ST plasmas heated to moderately high beta (~25%)
- Study local transport and turbulence properties and investigate transport barrier formation under power heating
- Investigate plasma SOL properties for divertor and inboard-limited (naturally diverted) configurations
- Study approach to MHD limits at moderate edge q and moderate betas
- Explore and characterize current drive during sustainment phase (HHFW, NBI, CHI, Bootstrap)

Key Questions for WG discussion

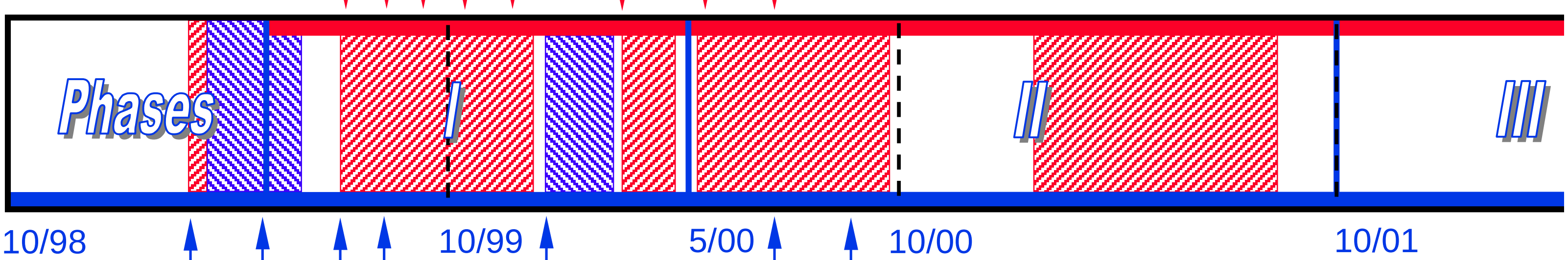
- What are the scientific goals for key research elements?
- How to characterize or quantify these goals?

The Phase-I Research is to Establish the Basis for High Power Investigations in Phase II

NSTX

Scientific Investigation

- 7/99 - Begin ohmic plasma tests with significant current
- 8/99 - Begin CHI startup tests
- 9/99 - Begin HHFW plasma heating tests
- 10/99 - Begin tests of divertor and currents toward ~1 MA
- 11/99 - Begin CHI startup tests to significant current
- 3/00 - Begin HHFW tests up to ~4 MW
- 5/00 - Begin HHFW tests up to ~6 MW
- 7/00 - Begin high-power NBI/HHFW experiments



Facility Capability

- 9/00 - Fluctuations diagnostics
- 7/00 - NBI, J(r) diagnostics ready
- 1/00 - NBI installation
- 8/99 - Multi-time point Thomson scattering
- 7/99 - NSTX ready for experimental research runs
- 4/30/99 - TPC Complete
- 2/99 - First Plasma

Major Events of FY99 NSTX National Program

FY99 NSTX Experimental Run Planning and FY00-01 Priorities

- 1/12-14/98: FY99 NSTX **Research Forum**
- 2/99: Organize Phase-I Experimental Task teams and leaders, develop initial run plans
- 3/99: Issue Update NSTX Research Program Outline
- 7/99: Begin experimental research runs

Program Advisory Committee (PAC) and Fusion Facilities Coordinating Committee (FFCC)

- 2/11-12/99: PAC6 - Phase-I experimental plan and FY00-01 priorities
- 2/99: FFCC - Update coordinated research plan of C-Mod, DIII-D, NSTX
- 9/99: PAC7 - FY00 experimental plan and FY01-02 priorities

DOE Review and Approval

- 2-4/99: ?Solicit and receive FY00 enhanced collaboration proposals
- 4/7-9/99: Budget and Planning Meeting
- 9/99: ?Decision on FY00 enhanced collaboration proposals

National NSTX Facility and Research Team Are Readying to Make Major Contributions to MFES

- NSTX is a world-class innovative fusion experiment, and is approaching completion
- NSTX National Research Team is in place to investigate the scientific principles of Spherical Torus plasmas

We look forward to working with the excellent Team in this exciting research program

Backup

At 1-MA Current, NSTX Plasmas Are Expected to Expand the Scientific Domain of Toroidal Plasmas

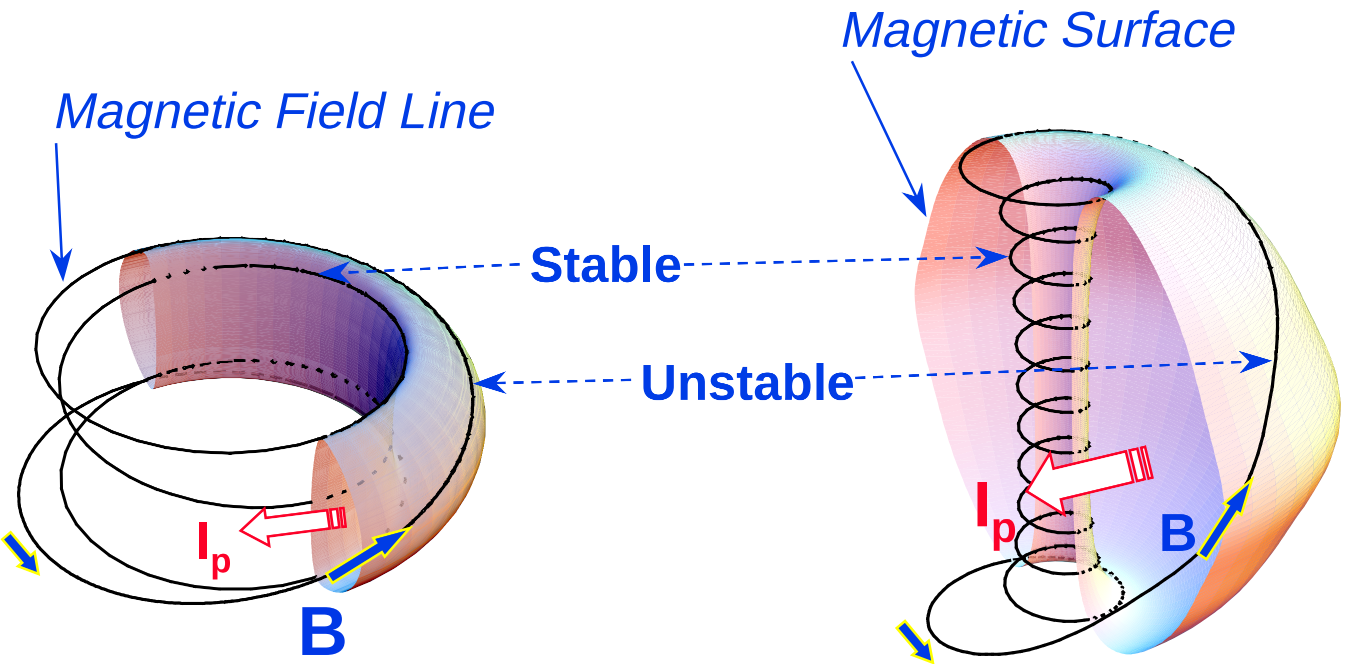
Physics	Parameters of Interest	NSTX
Confinement	– Inverse aspect ratio ε (= a/R)	0.8
	– Edge safety factor q_{edge}	~10
	– Magnetic well depth: $\Delta\|B\|/\|B\|$	0.3
	– Normalized ion gyroradius ρ_i*	0.03
	– Diamagnetic flow shear rate (ω_I*)	$\sim 10^6$
Stability	– Stable avg. toroidal β	0.45
	– Ideal wall stabilization ($\beta_{N\text{-wall}}/\beta_{N\text{-no wall}}$)	~2
	– Flow speed for stabilizing wall mode (~0.1v_A)	$\ll c_S$
	– Neoclassical tearing mode ($\beta_{NCT}/\beta_{N\text{-wall}}$)	~1
H-Mode	– Edge T_i pedestal (large edge heat flux and ρ_i)	large
	– Power threshold ($\propto$ nB at edge)	low
	– Inner-wall limiter operation (VH-mode)	likely

At 1-MA Current, NSTX Plasmas Are Expected to Expand the Scientific Domain of Toroidal Plasmas (cont.)

Physics	Parameters of Interest	NSTX
Edge-Divertor	**Outboard SOL in ND* plasma**	
	– Mirror ratio	~4
	– Flux tube expansion	≥10
	– Connection length compared to DN plasma	~2×
Noninductive Startup	– Plasma helicity/I_p (~ $1.6\ell_i\kappa a^2 I_{TF}$) [H·Wb]	0.5
	– Plasma poloidal flux/I_p (~ $\mu_0\ell_i R$) [H]	0.3×10^{-6}
	– Bootstrap current overdrive (stable $I_{bs} > I_p$ at high q)	yes
Current Maintenance	– NBI: guiding-center orbit containment in low poloidal flux	~100kV D^+ (co-inj.)
	– Energetic particle driven instability	$v_{NB}>v_A$
	– RF: plasma dielectric constant $\sim(\omega_p/\omega_{ce})^2$	~40
	– Stable pressure-driven current alignment (assuming potato orbit)	~100%

* ND = Inboard limited with Naturally Diverted outboard SOL

ST Maximizes the Stable Field Line Length over the Unstable Field Line



TPX-Like Tokamak
(A = 4, κ = 2, q = 4)

Spherical Torus
(A = 1.25, κ = 2, q = 12)

This leads to many unique ST plasma parameters and properties