ST Steady-State Issues and Opportunities

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Magnetic Fusion Concepts WG
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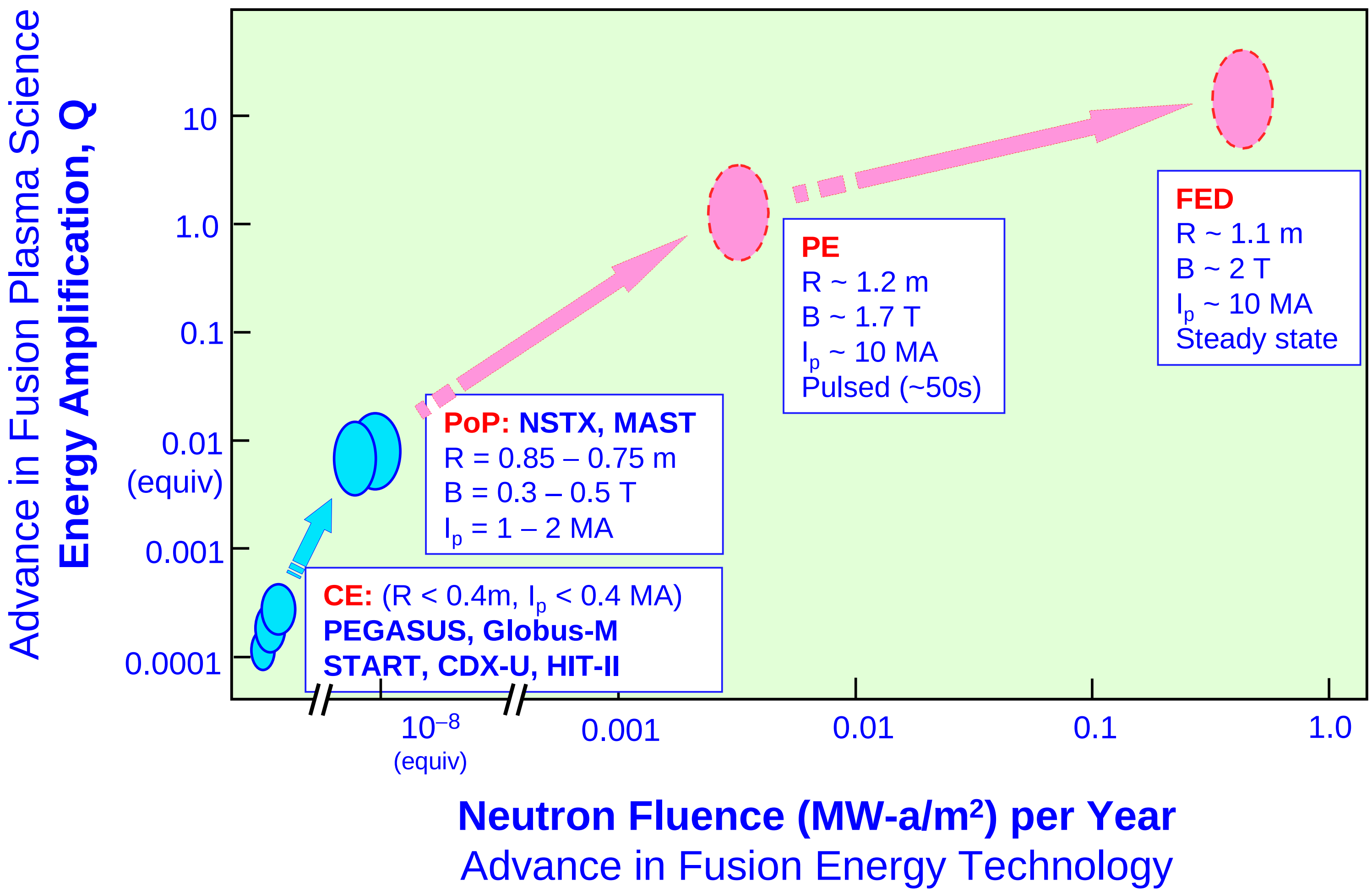
ST Can Advance Fusion Science and Technology Using Small-Size Devices

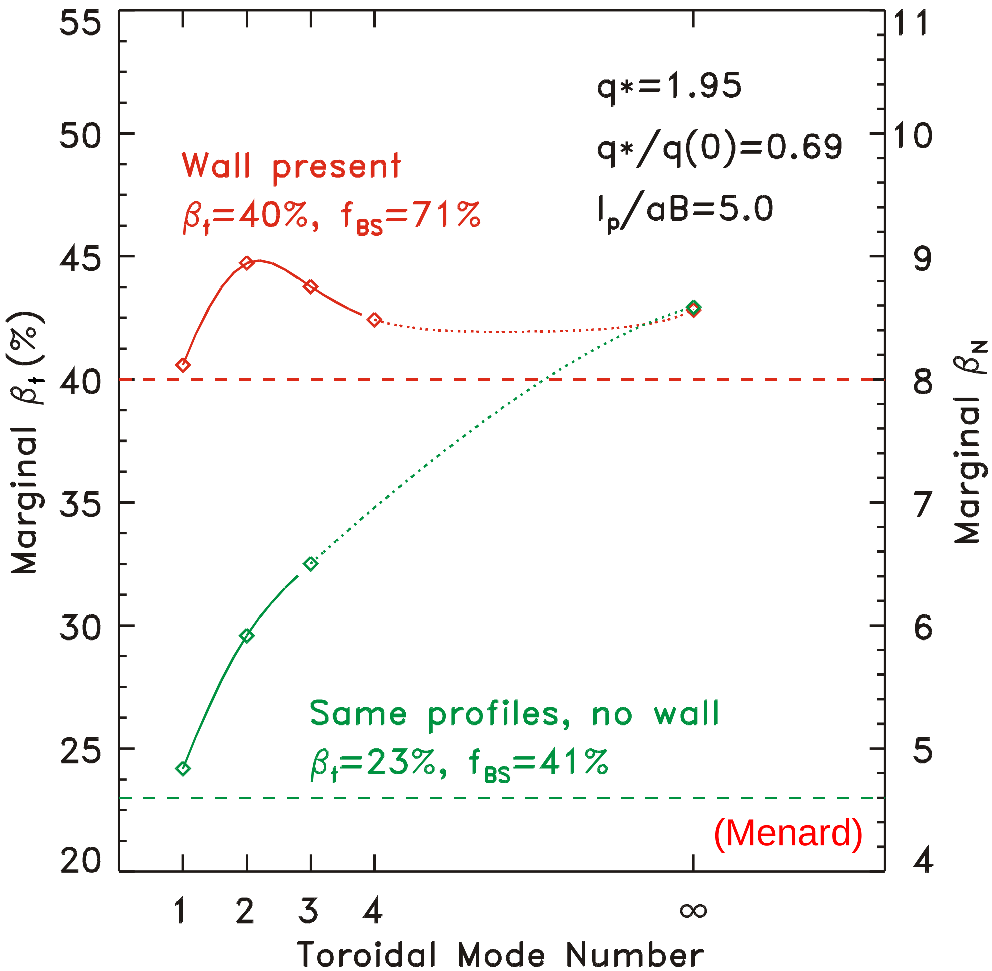


Steady State Issues of Importance to ST

- Noninductive ramp-up to full current
  - Plasma initiation via CHI, EBW
  - Small helicity ($\sim 1.6 \ell_i \kappa a^2 I_{TF} I_p$) and poloidal flux ($\sim \mu_0 \ell_i R_0 I_p$) content
  - Dictated by resistive flux diffusion time
- HHFW and EBW
  - Dielectric constant $(\omega_{pe}/\omega_{ce})^2 \sim 100 \rightarrow$ efficient HHFW absorption
  - Proximity of R-cutoff, UHR, and L-cutoff $\rightarrow$ conversion to EBW
- NBI
  - Supra-Alfvén ions $\rightarrow$ TAE, "fishbone" modes
- "No-wall" regime: $f_{\nabla p} \sim 40\%$, $q \sim 10$, $\beta_T \sim 25\%$
- "Wall-stabilized" regime: $f_{\nabla p} \sim 70\%$, $\beta_T \sim 40\%$
- CHI requirements on electrodes (divertor plates)

NSTX Will Investigate No-Wall and Wall-Stabilized MHD Beta Limits for $\kappa \sim 2$

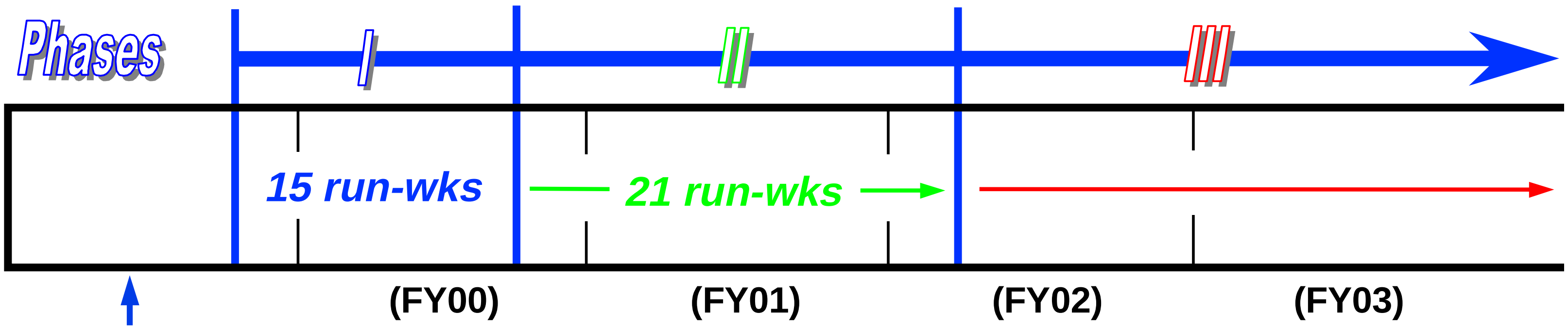
$\kappa = 2.0$, $\beta_T = 23–40\%$, $\beta_N = 4.5–8$, $f_{Bootstrap} = 41–71\%$



Tools

- High Power Heating
  - NBI
  - HHFW
- Plasma shape control
- Plasma profile measurements

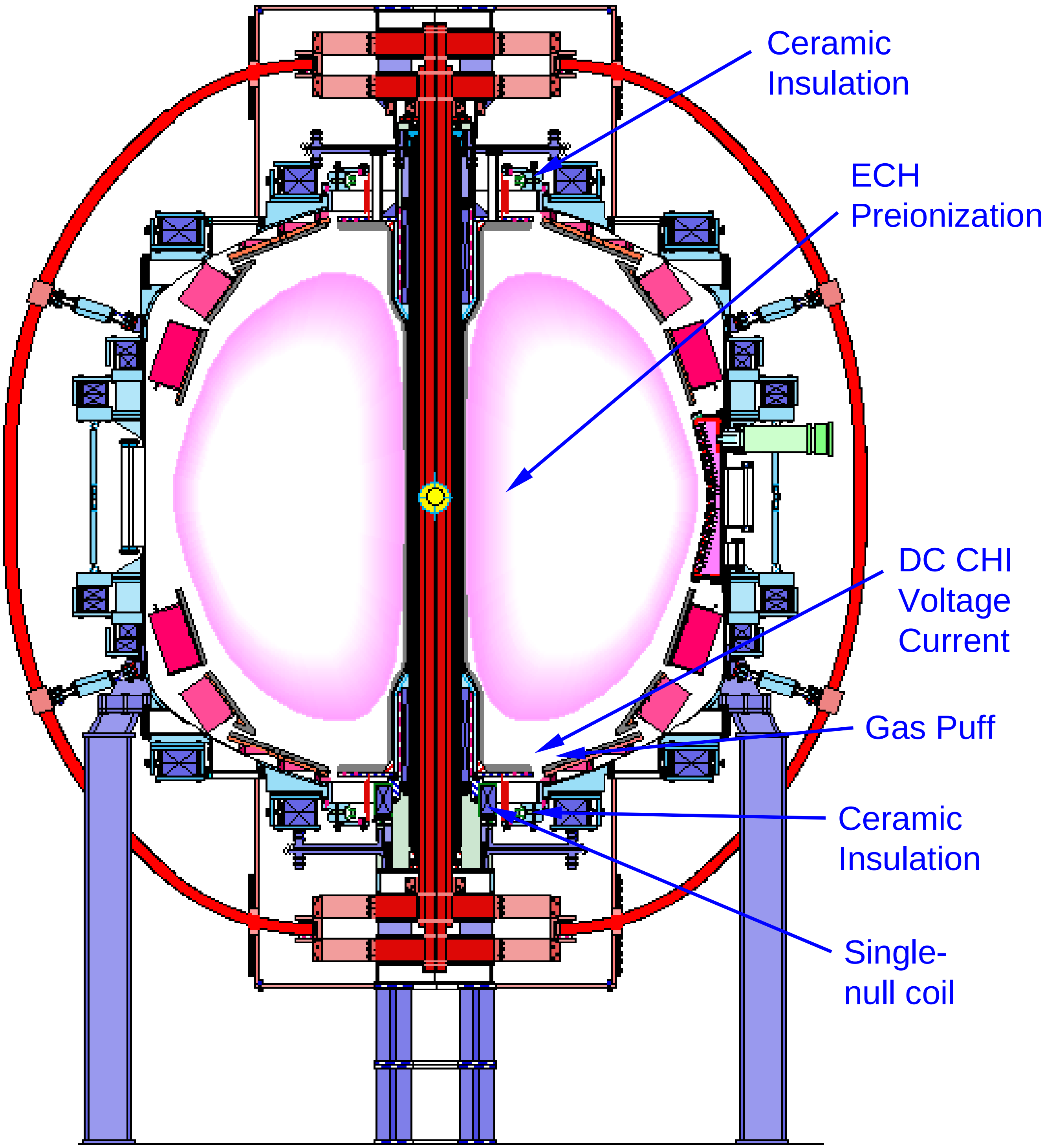
NSTX Research Plans to Investigate the Key ST Physics Issues in the Next 4-5 Years



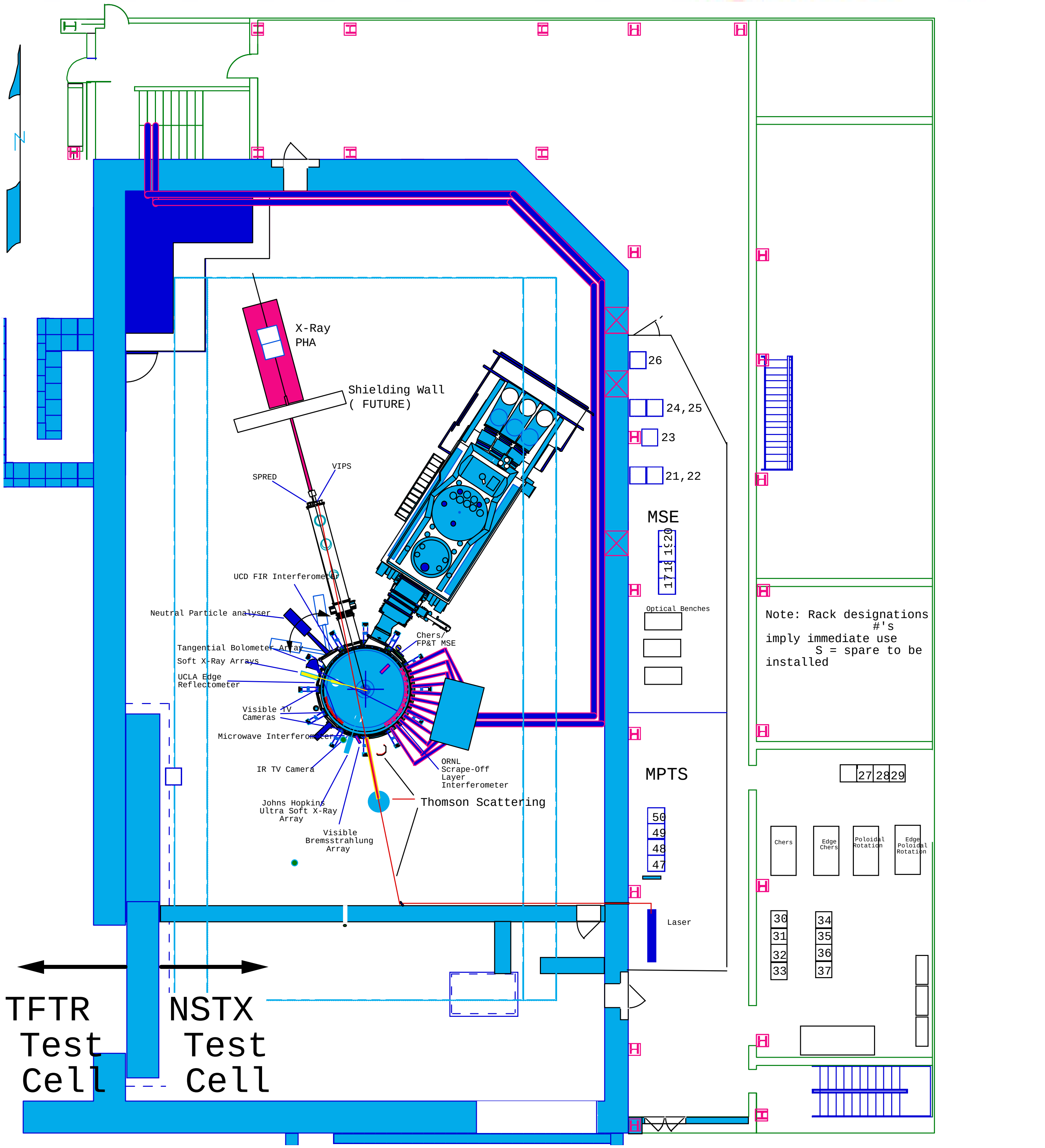
2/99 First Plasma

	Inductive	Noninductive Assisted Startup	Sustained Noninductive Operation
• **Toroidal Beta, β_T**		• $\rightarrow$ 25% (no-wall limit)	• $\rightarrow$ 40% (wall stabilized)
• **Bootstrap Current**		• $\rightarrow$ 40% (no-wall limit)	• $\rightarrow$ 70% (wall stabilized)
• **Current**	• $\rightarrow$ 0.5 MA	• $\rightarrow$ 1 MA	• ~ 1 MA
• **Pulse**	• $\rightarrow$ 0.5 s	• $\rightarrow$ 1 s	• $\rightarrow$ 5 s
• **HHFW Power**	• $\rightarrow$ 4 MW	• ~ 6 MW	• ~ 6 MW
• **NBI Power**		• $\rightarrow$ 5 MW	• ~ 5 MW
• **CHI Startup**	• $\rightarrow$ 0.2 MA	• $\rightarrow$ 0.5 MA	• ~ 0.5 MA
• **Measure**	• $T_e(r)$, $n_e(r)$	• $j(r)$, $T_i(r)$, flow	• **turbulence**

NSTX is Designed to Investigate Coaxial Helicity Injection Startup



NSTX Test Cell Arrangement



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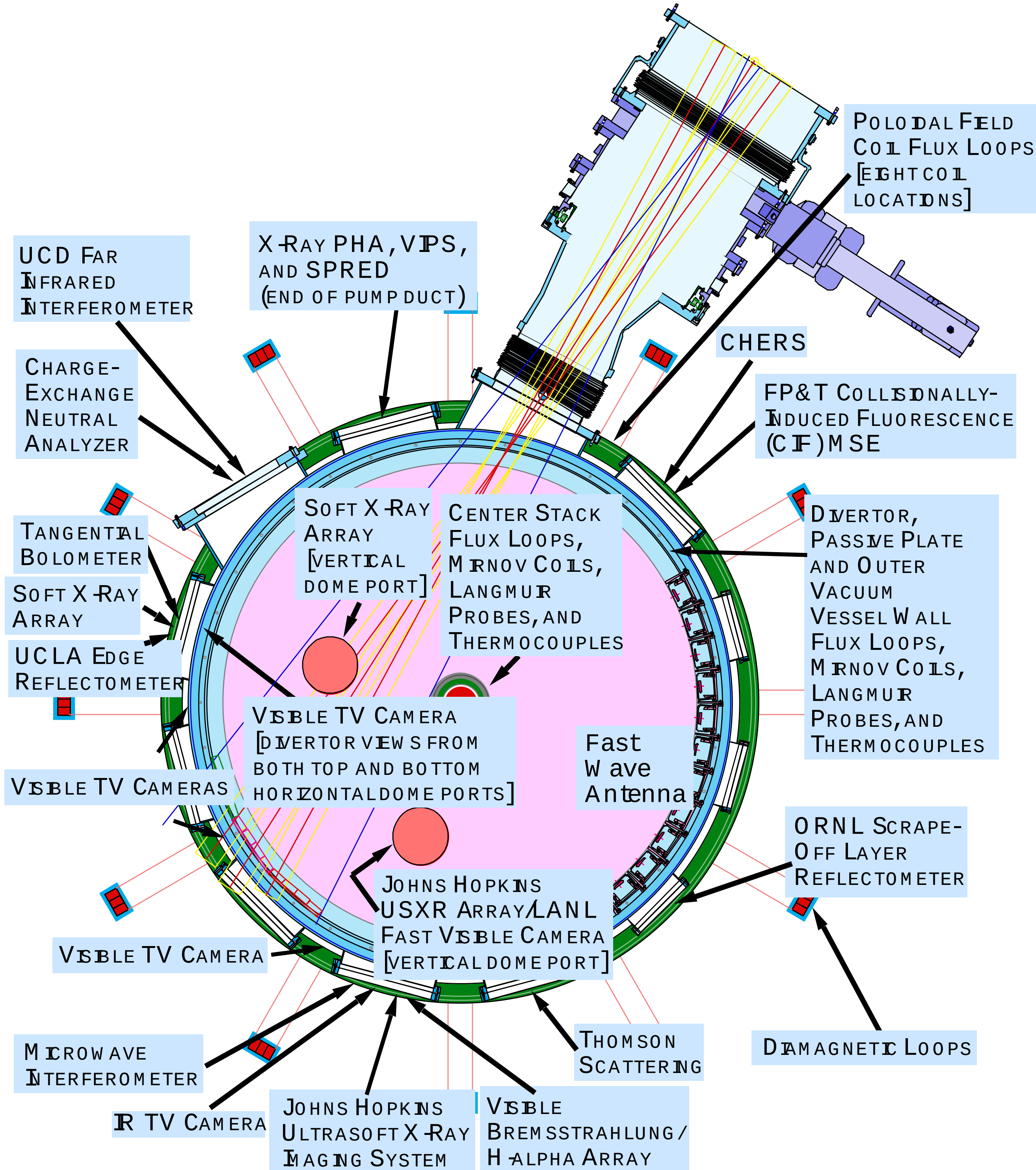
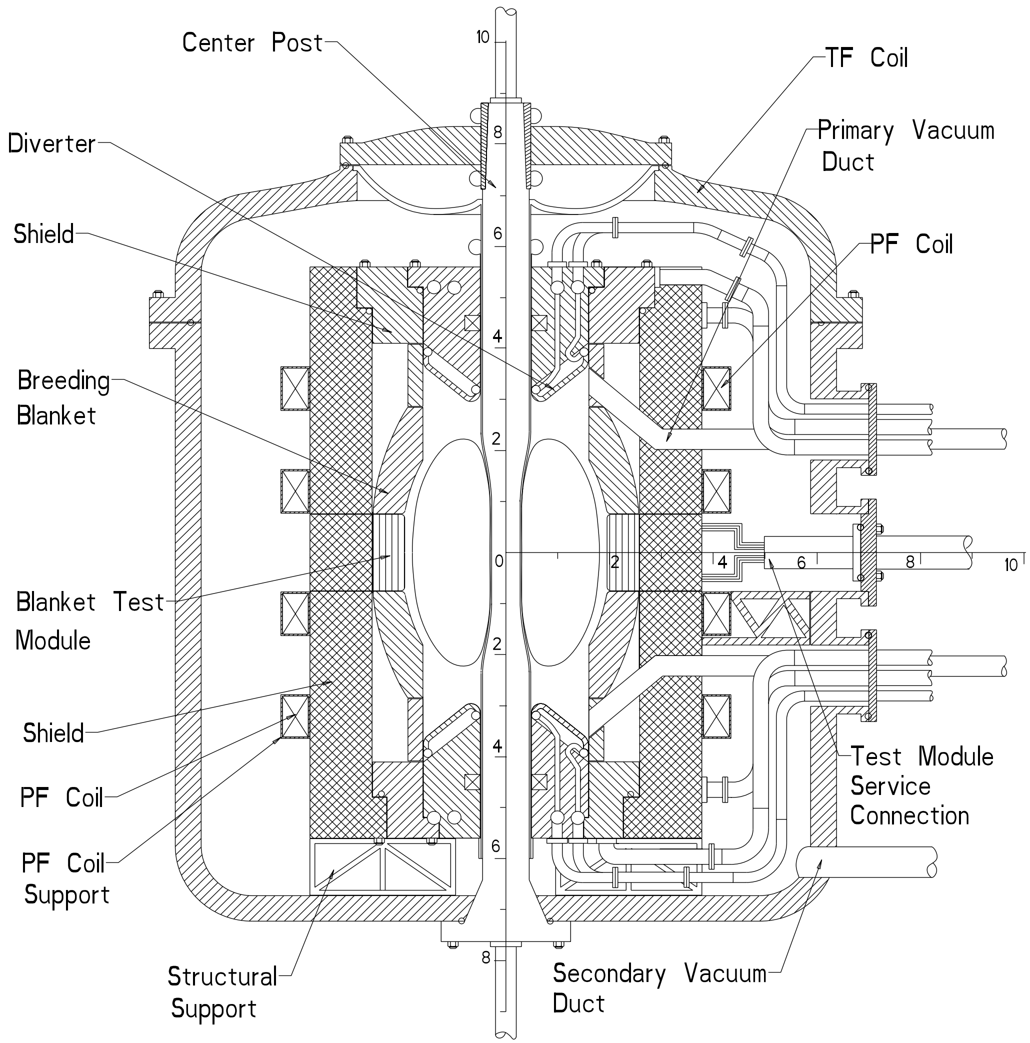
Planned Diagnostics Systems



ST Could Enable Small Fusion Energy Development Device, such as the Volume Neutron Source (VNS)

VNS



- Steady-state driven (Q~1)
- Very high neutron fluence (~5 MW-a/m^2)
- Requires Performance Extension (PE) physics data
- Tests blankets, materials
- Design feature prototypical of power plant
- Upgradable to Fusion Development Facility (FDF) to produce electricity

ST Performance Extension Device Has Potential for Testing Long-Pulse D-D, and Pulsed Q~1–10

Near-Term ST Devices	NSTX/MAST		DTST			VNS	PP-like
Development Stage	Proof of Principle		Performance Extension			Fusion Energy Development	
Mode of operation	No-Wall	Wall-Stabilized	D-D H~1	Q~1 H~1	Q~10 H~3	Q~1 Driven	Q>10 Sustained
Major radius (m)	0.85		~1.2			~1.1	
Aspect ratio	≥1.25		1.4			1.4	
Toroidal field (T) at major radius	0.3–0.6		0.9	1.7	1.7	2.1	
Plasma current (MA)	1–2		~5	~10	~10	~10	
Edge safety factor	10–5		~10			~10	
Plasma cross section elongation	2–2.5		3			3	
Normal beta β_N (%Tm/MA)	5	8	3.5	3.5	5	4	8
Average toroidal beta β_T (%)	25	40	23	23	34	27	50
Average density (10^{20} m^{-3})	0.5	0.5	0.5	1	0.7	1.1	1.2
Average temperature (keV)	1	1.6	3	7	15	9	16
∇p-driven current fraction (%)	40	70	50	50	75	50	90
Plasma drive power (MW)	6–11		25	35	4	40	25
NBI energy (keV)	70–80			110		110	400
Fusion power (MW)	–		–	36	40	66	260
H (ITER98H) [Kardaun, 1998]	1–2		1	1.2	3	1	3
Plasma flattop (burn) time (s)	1–5		~100	~10	~10	~1000	
Neutron wall load (MW/m^2)	–		0.6			1.0	4.0
Neutron fluence/year (MW/m^2)	–		~0.003			~0.3	~1.2