NSTX-U

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Introduction to the:
National Spherical Torus eXperiment - Upgrade (NSTX-U)

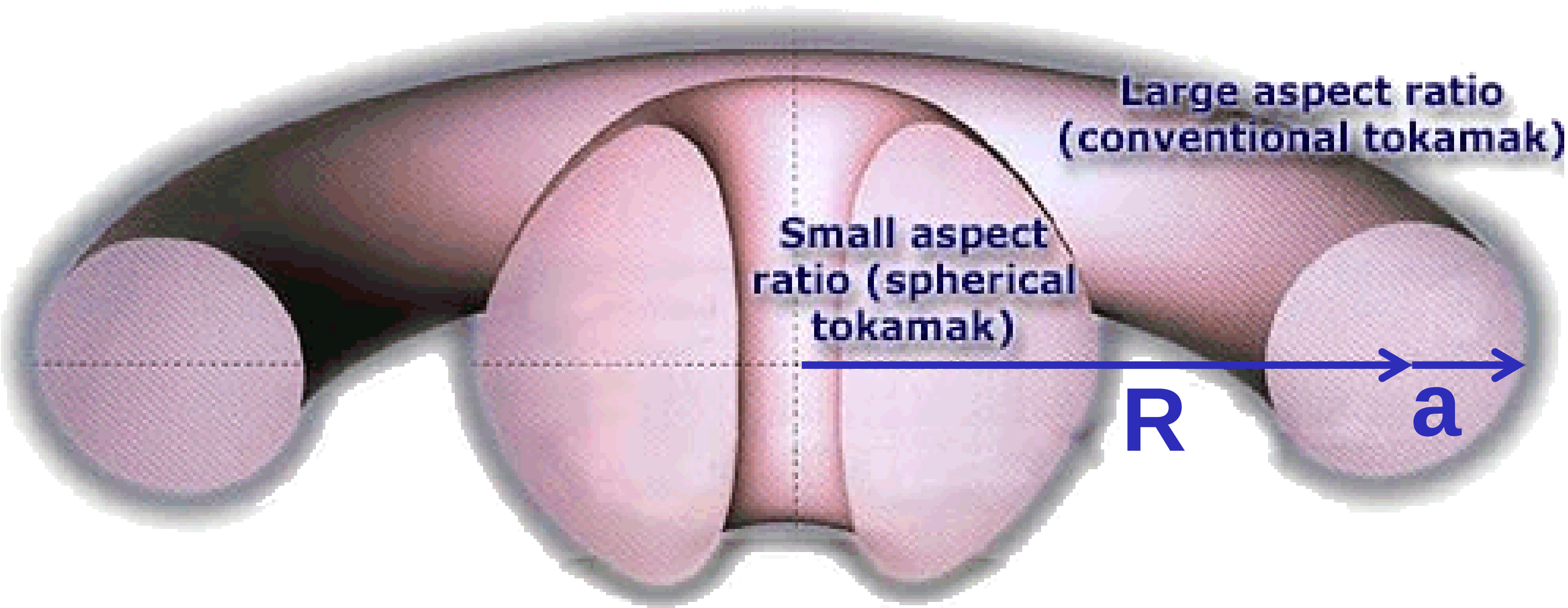
Jon Menard, PPPL
NSTX-U Program Director

March 27, 2015

Aspect ratio is important geometric parameter for toroidal fusion devices

Aspect ratio A = R / a

R = major radius   a = minor radius



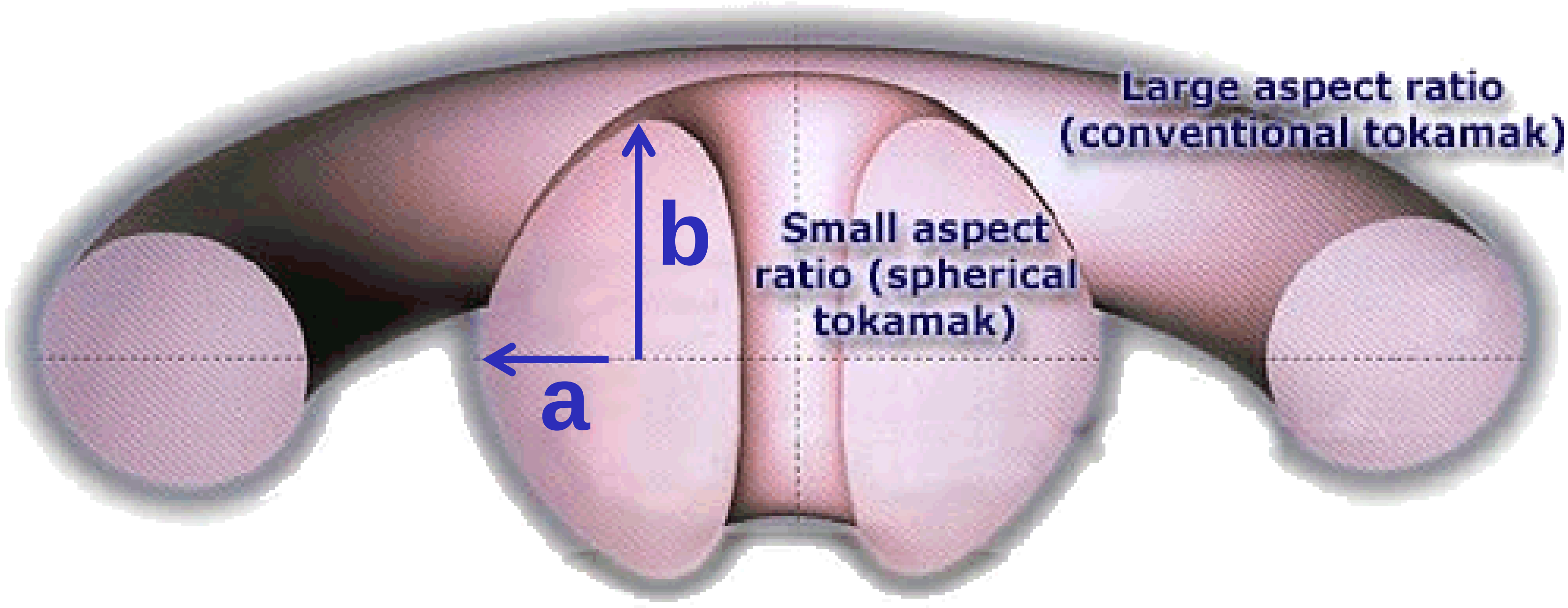
Spherical torus/tokamak (ST) has A = 1.1 - 2

Conventional tokamak typically A = 3 - 4

STs have higher natural "elongation"

Elongation κ = b / a

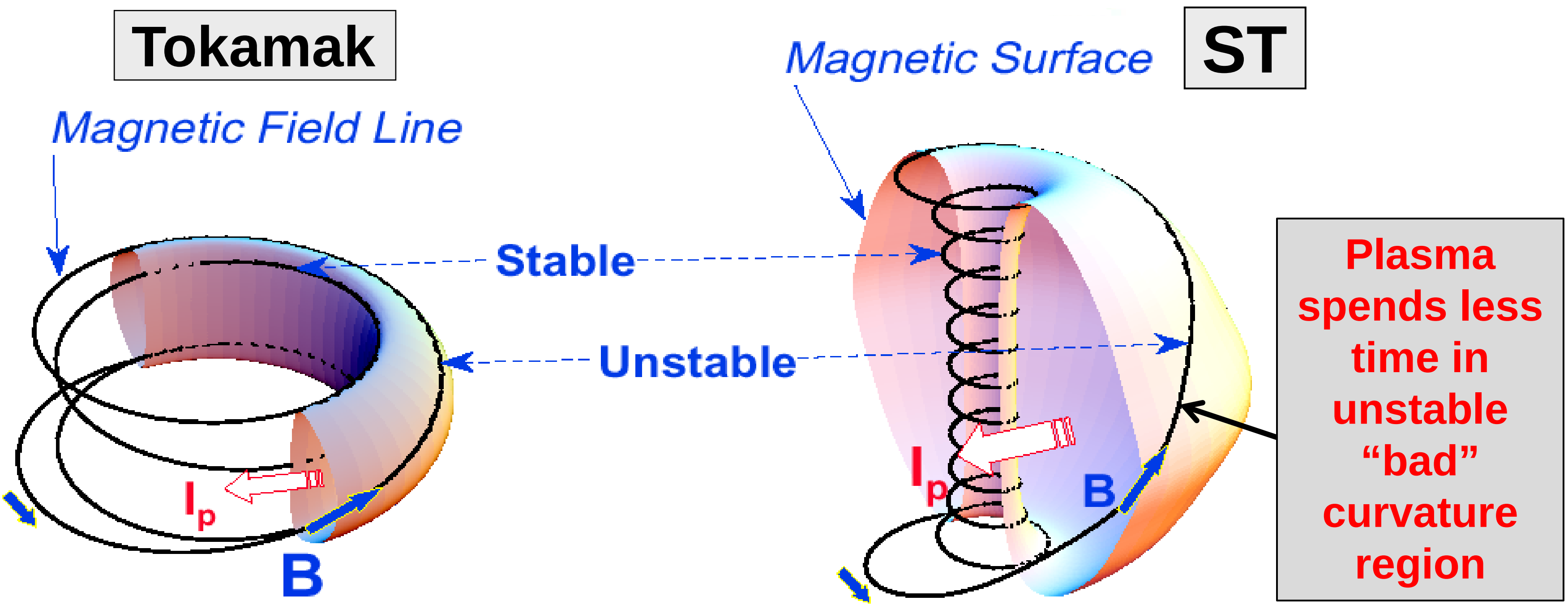
b = vertical ½ height   a = minor radius



Higher elongation improves stability & confinement

Magnetic field structure of ST increases normalized pressure by factor of 3-4×

Normalized pressure: $\beta = p / (B^2/2\mu_0)$ $P_{fusion} \propto \beta^2 B^4$

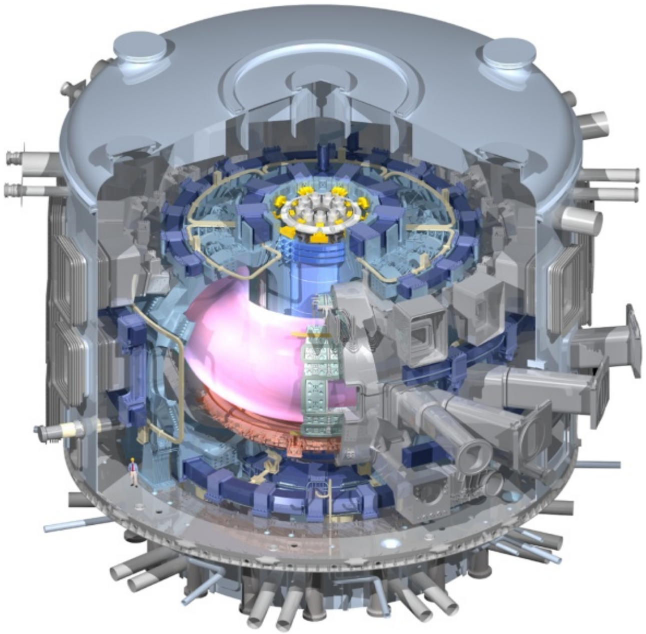


Tokamak	ST
A ~ 3	A ~ 1.5
κ = 1.5-2	κ = 2-3
β_T = 3-10%	β_T = 10-40%

Low aspect ratio / ST extends predictive capability for ITER and toroidal science

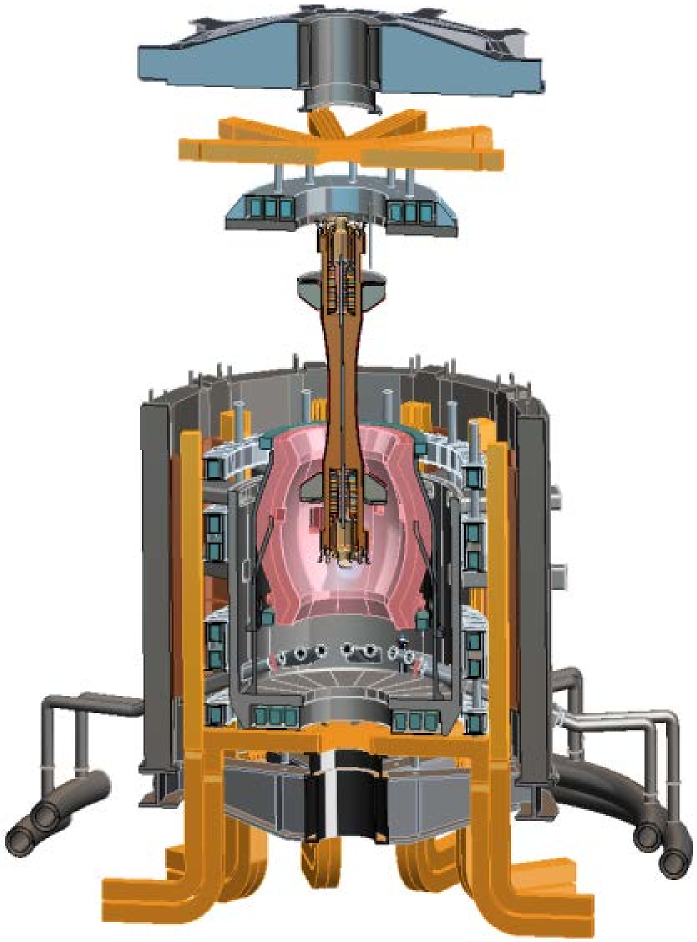
- High β, shaping, rotation extend stability, transport knowledge
- NBI fast-ions in present STs mimic ITER DT fusion products → study burning plasma science
- STs can more easily study electron-scale turbulence at high temperature → important for all toroidal configurations

Burning Plasma Physics - ITER



Design studies show ST potentially attractive as “Fusion Nuclear Science Facility” (FNSF)

PPPL ST-FNSF concept



- FNSF: Qualify fusion reactor components in device much smaller than reactor
- High neutron wall loading
- Modular, maintainable
- Can be tritium self-sufficient
  – Requires sufficiently large size

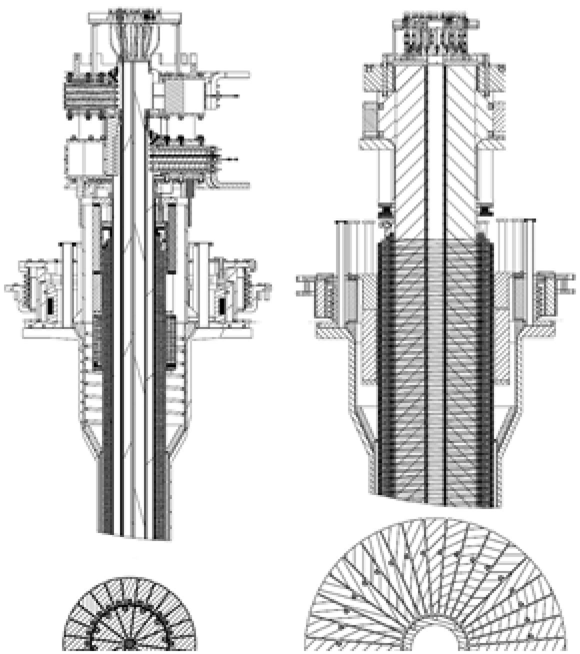
NSTX Upgrade: Two major new components
Will be most capable ST in world program

- **New center-stack:**
  – 2 × toroidal field (0.5→1T)
  – 2 × plasma current (1→2MA)
  – 5 × pulse-length (1→5s)

- **2nd more tangential neutral beam injector (NBI):**
  – 2 × current drive efficiency
  – 2 × heating power (5→10MW)

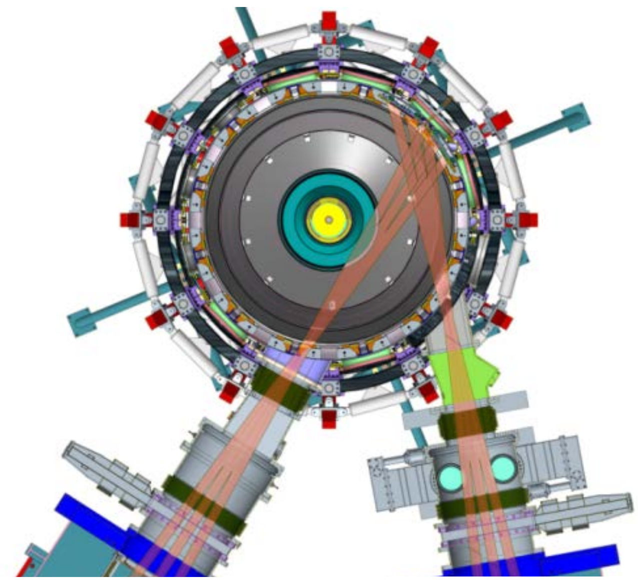
Previous center-stack

New center-stack



TF OD = 20cm

TF OD = 40cm



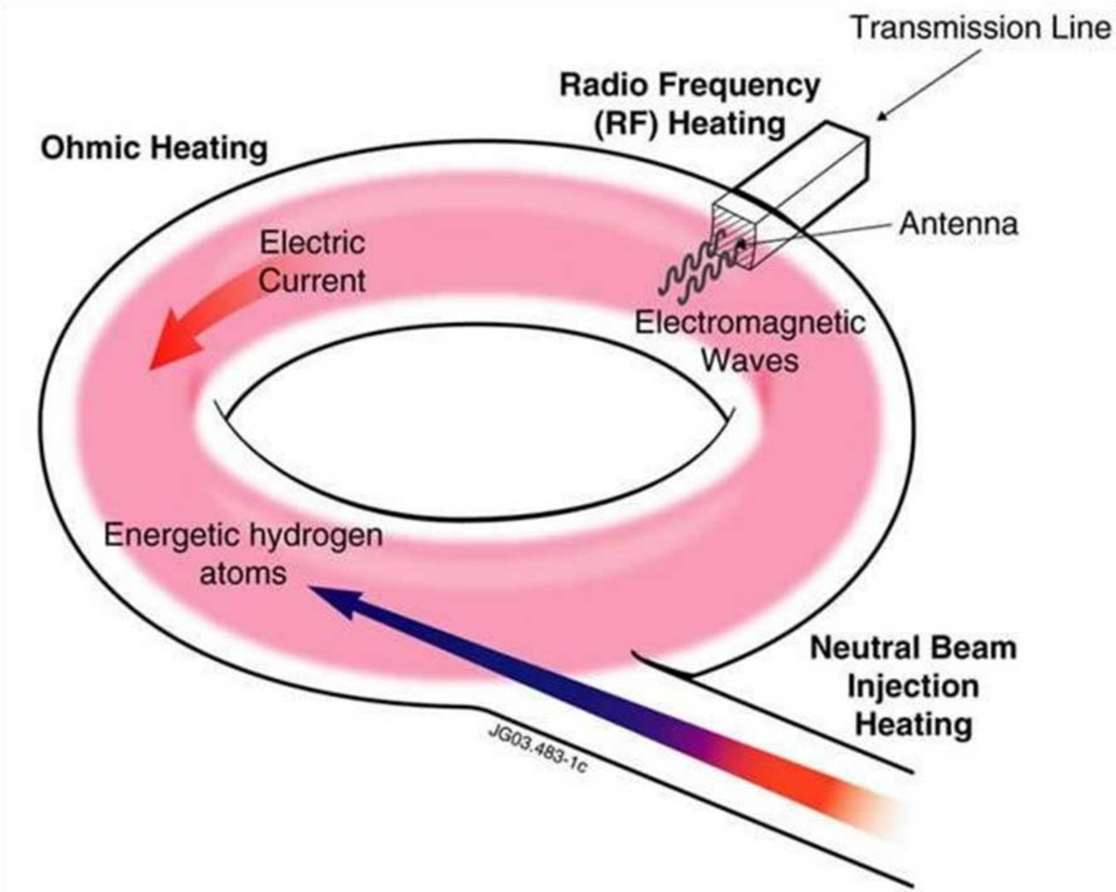
Present NBI

New 2nd NBI

~5-10× increase in nTτ

NSTX-U average plasma pressure ~ tokamaks

Steady-state tokamak / ST must drive plasma current without transformer



- External: wave and beam current drive
- Self-generated: high pressure plasmas make "bootstrap" current
- Efficient tokamak power plant will need 70-90% self-generated current

NSTX: 70% transformer-less current drive NSTX-U: project 100%

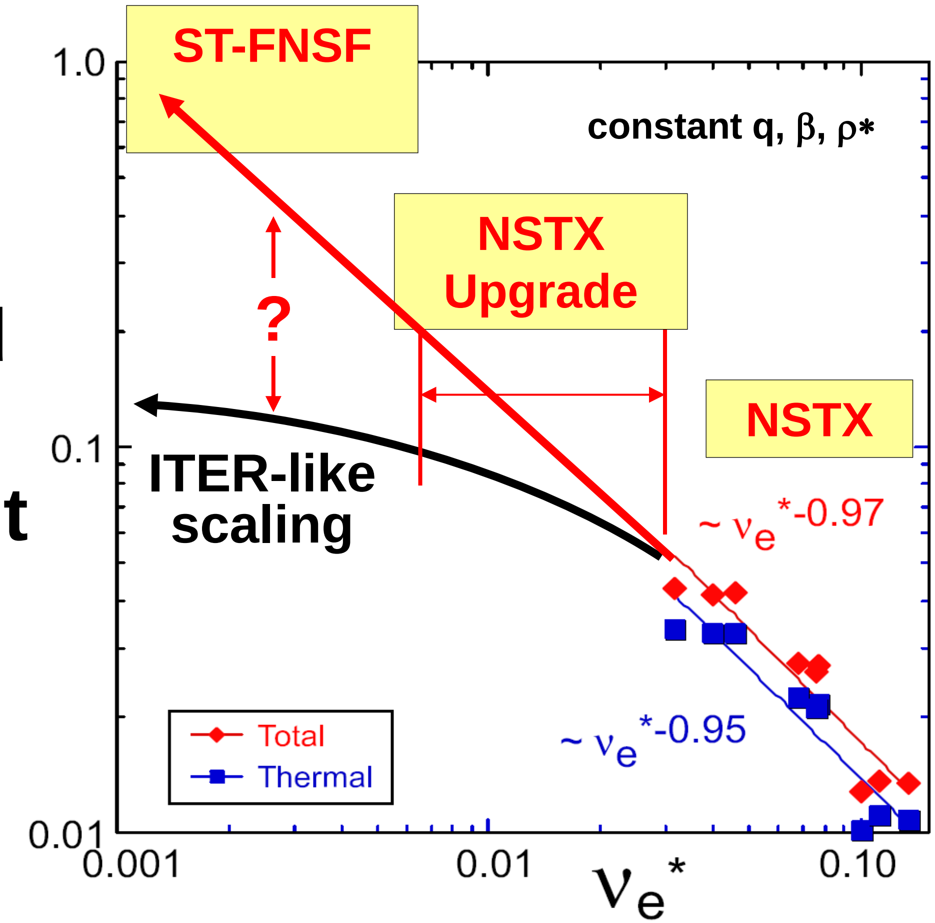
Question: Can NSTX-U operate without using transformer?

STs observe confinement increases at higher T_e (!)

Will confinement trend continue, or look like conventional A?

Normalized energy confinement

$B\tau_E$ [T-s]



Normalized electron collisionality $\nu_e^* \propto n_e / T_e^2$

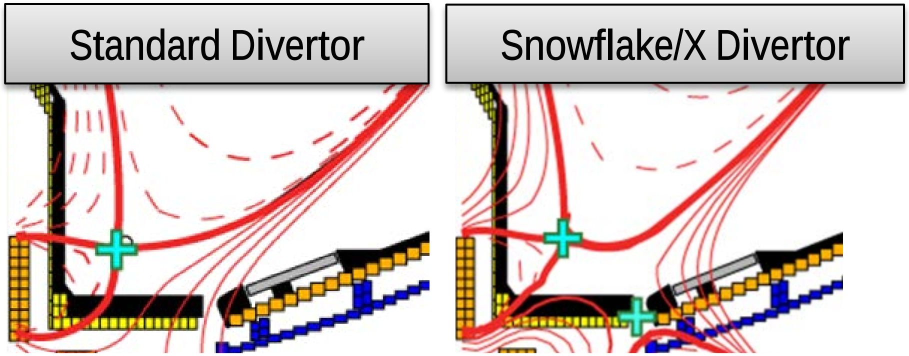
Question: Which instabilities cause electron energy transport?

NSTX-U wall heat fluxes ~4× higher than NSTX

Near/above ITER values (40MW/m^2 unmitigated – 4× engineering limits)

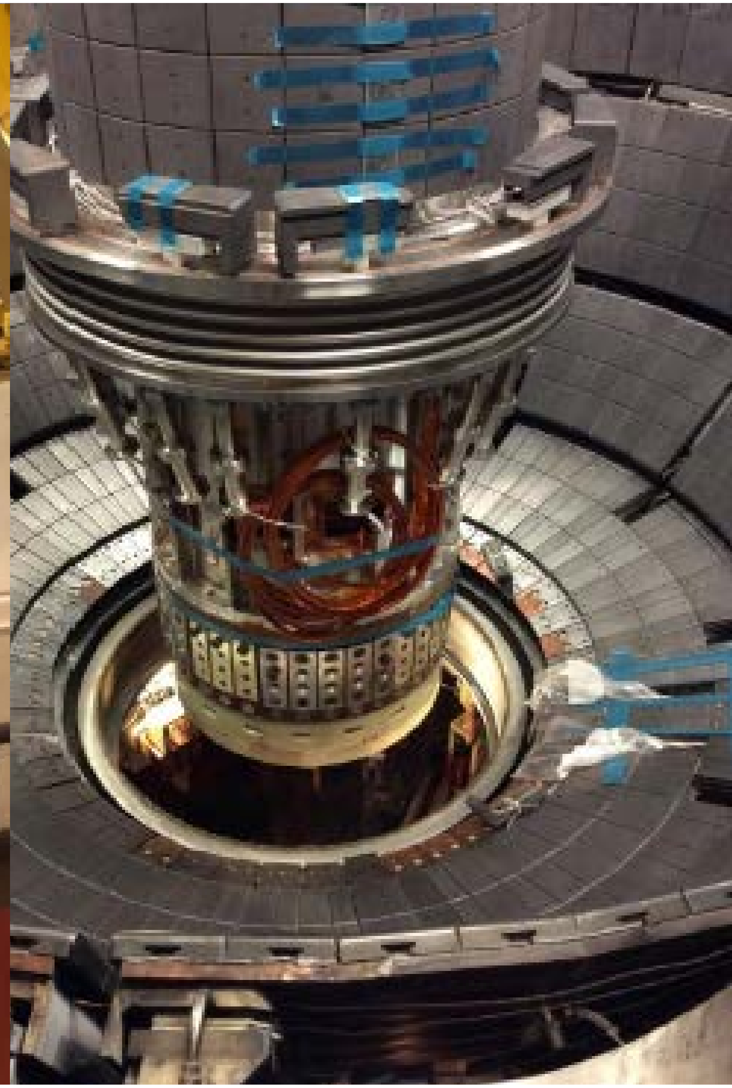
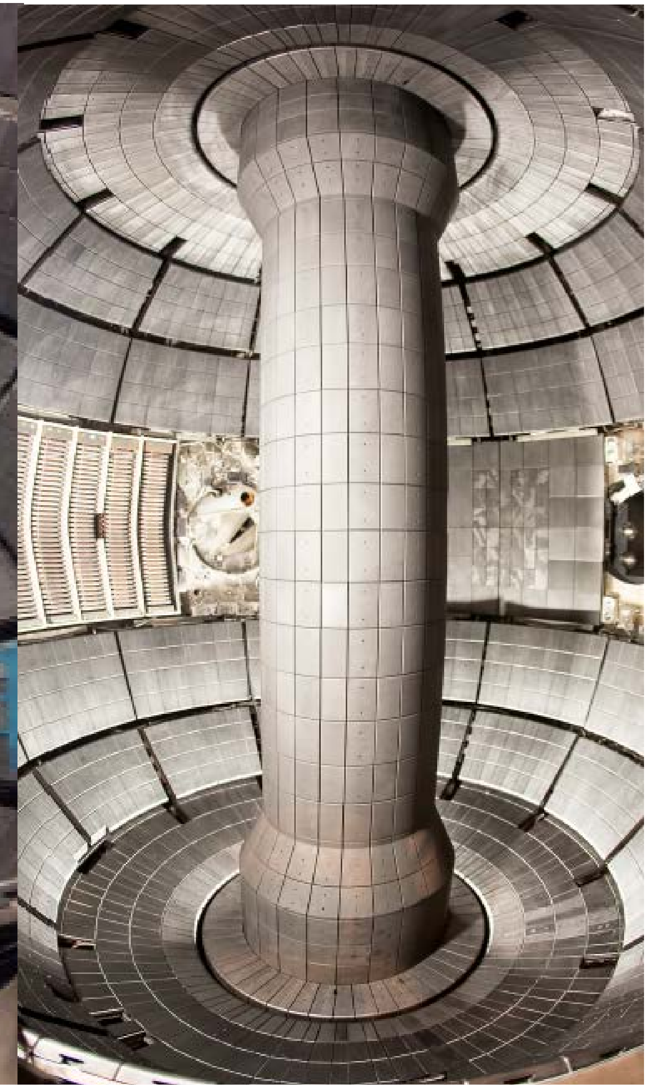
Question: What are viable ways to protect reactor walls?

- Expand / lengthen exhaust channel
- Spread heat using radiative “cushion”
- Liquid metal walls
- Combinations?



New Center-Stack installed in NSTX-U (!)

Vacuum pump-down achieved in January, 2015

Relocated 2nd NBI beam line box from TFTR

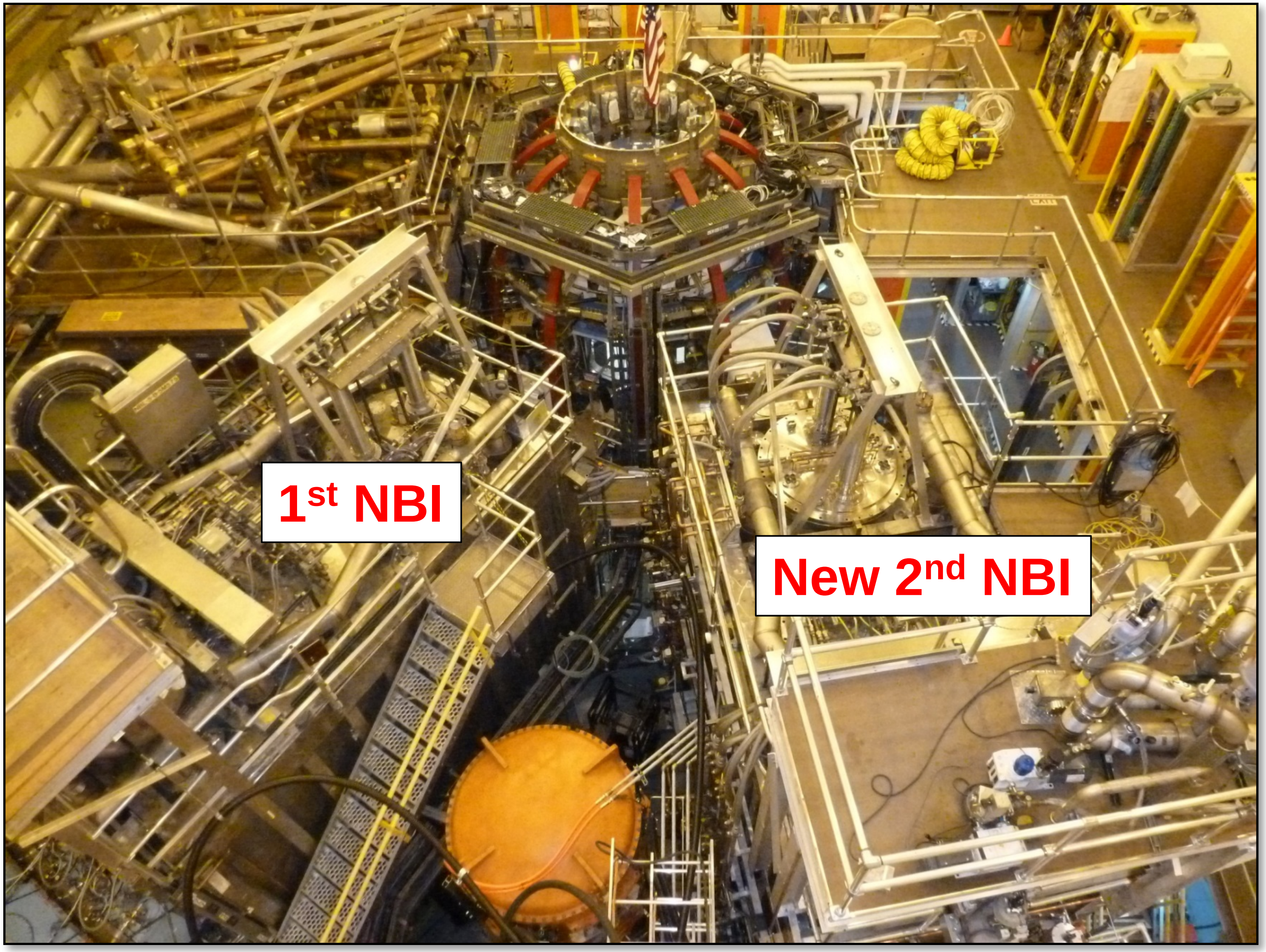
Beam Box being lifted over NSTX-U

Beam Box placed in its final location & aligned

Beam Box being populated with components

NSTX Upgrade Project nearly complete

Test plasmas expected in April, research plasmas in June



There are many great research opportunities on NSTX-U!

Thank you!

Any questions?