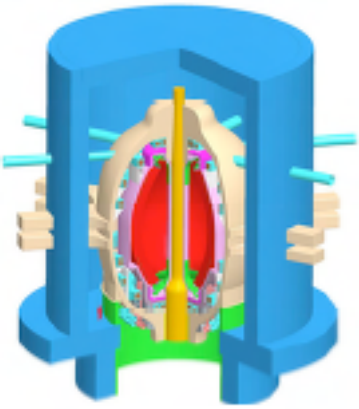
Spherical Torus Fusion Development Path
Realistic Steps Toward Attractive DEMO

ST is a low-aspect-ratio tokamak (R/a ~ 1.5)

Attractive physics features:

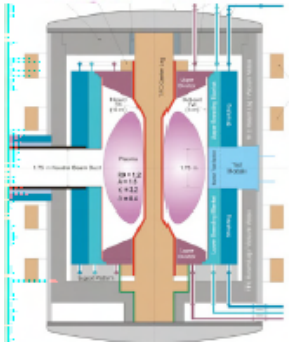
- Naturally high elongation
- High beta
- High shape-factor

ST-DEMO



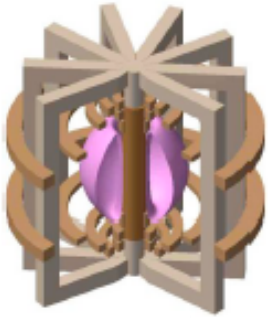
ARIES-ST

ST-CTF



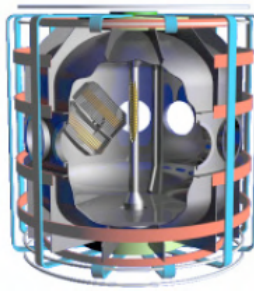
Compact CTF

ST-PE

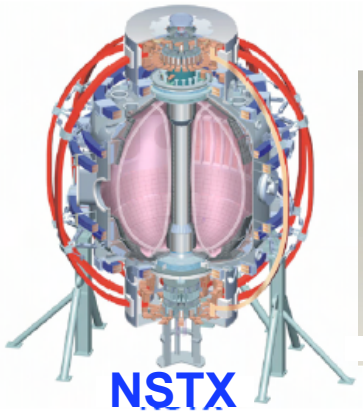


NHTX

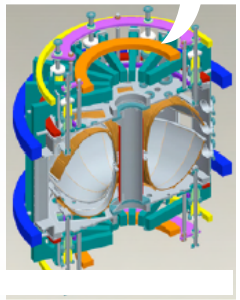
ST-PoP



PEGASUS



NSTX



LTX

Attractive reactor features:

- A simple inexpensive demountable TF Coil.
- Allowing radically simplified maintenance.

U.S. is Leading the Vibrant World ST Research Program

- **Active world wide ST research during the past 10 years in the U.S., U.K., Japan, R.F., Brazil, Italy, and PRC with 12 operating ST experiments and three new facilities are under construction.**
- **NSTX (US) and MAST (UK) are mega-ampere class ST facilities.**
- **US ST program is leading the world in science and innovation:**

  NSTX - The most powerful ST facility in the world with state-of-the-art diagnostic systems, addressing the full range of scientific topics, including ST-specific integration issues.

  HIT-II - Developed CHI to start the plasma non-inductively; Applied on NSTX.

  PEGASUS - the lowest R/a ~ 1.1 to explore the benefit of this regime including very high beta operations. Also investigating an innovative start-up technique based on plasma guns which can be also applied to NSTX.

  LTX (CDX-U) - the lowest particle recycling (~30%), and improved confinement with liquid lithium based approach. To be applied on NSTX.

ST is a part of the world fusion research portfolio of concepts to maximize the chance of successful DEMO

International ST Research Activities

- **Operating International STs:**

  MAST, Culham, UK - A mega-ampere class ST with many complementary features to NSTX. Large vacuum vessel, no stabilizing plates, excellent set of profile and boundary diagnostics. NBI and EBW heating. Confinement, H-mode, and boundary physics. Innovative start-up utilizing internal PFs.

  GLOBUS-M, Ioffe Physico, RF - Medium size ST with R/a = 1.5, Ip ~ 300 kA. ICRF, NBI, Plasma Jet .

  TST-2, Tokyo University, Japan - Small size ST with Ip ~ 140 kA . HHFW and EBW physics.

  TS3 and 4, Tokyo University, Japan - Small size STs. Spheromak merging to obtain high beta STs with internal coils. Short pulse with Ip < 300 kA.

  LATE, Kyoto University, Japan - Small size ST. ECH/EBW for start-up without OH with Ip ~ 10 kA.

  There are a number other small STs in China, Brazil, and Japan.

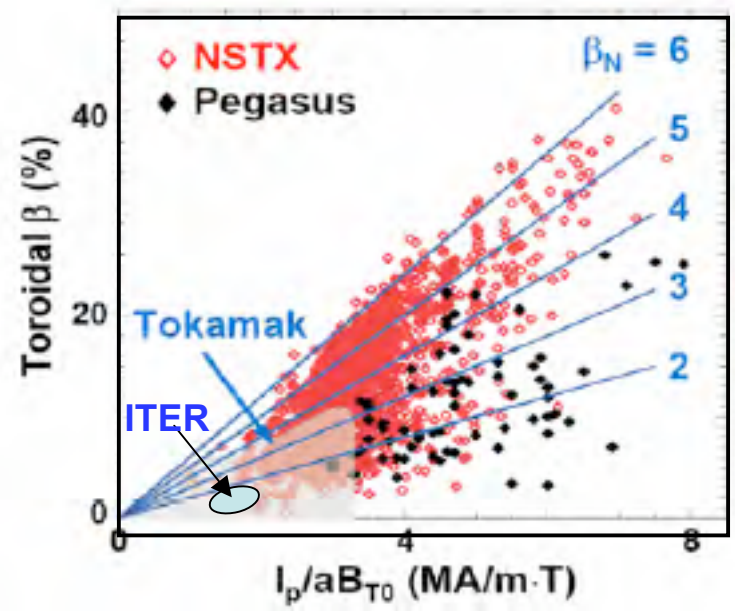
- **STs under construction:**

  QUEST, Kyushu University, Japan - Follow-on device of TRIAM. Medium size, long-pulse, non-inductive operations. First stage to start in ~ 2008 with Ip < 100 kA.

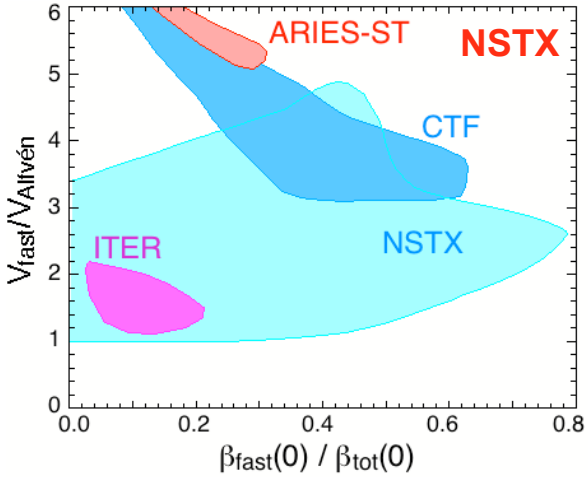
  UTST, Tokyo University, Japan - Follow-on device to TS3/4 and TST-2. Double null formation with more reactor relevant external PF coils. Aim to achieve very high beta with merging. First Plasma in 2007.

ST Offers Access to Wide Tokamak Plasma Regimes

Wide range of β_T up to ~ 40 %.

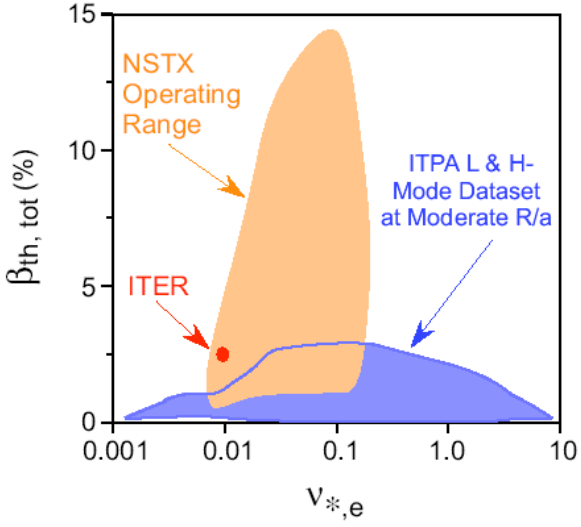


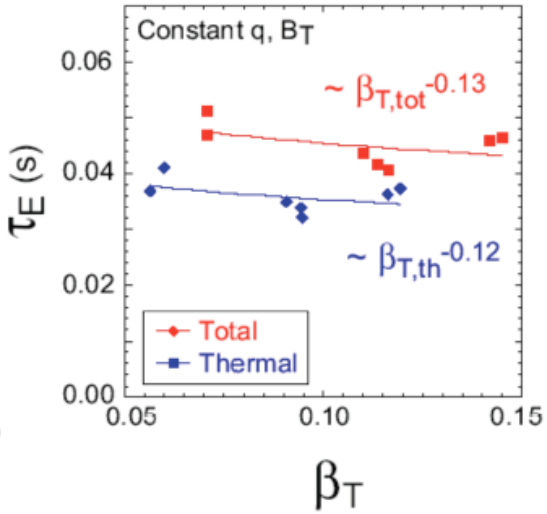
Unique Energetic Particle Physics

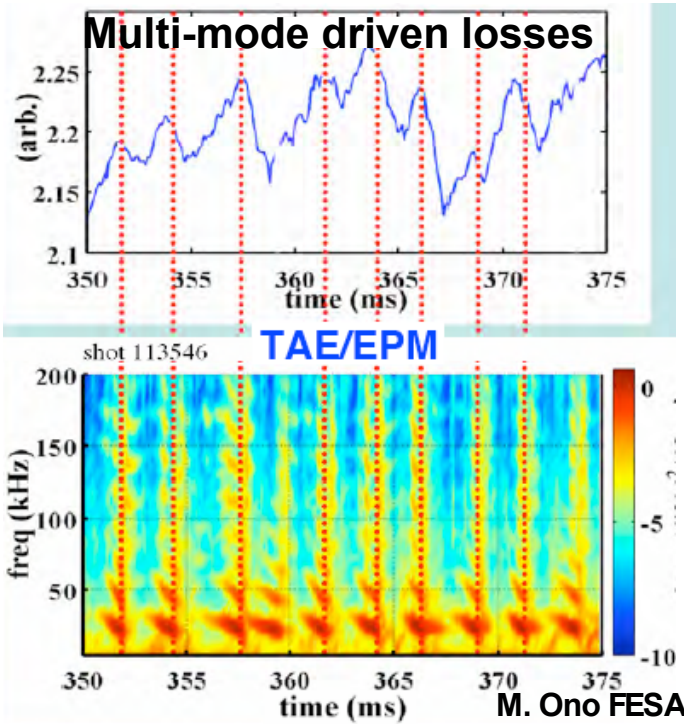


β Confinement Scaling, Electron Transport

Weak beta degradation observed

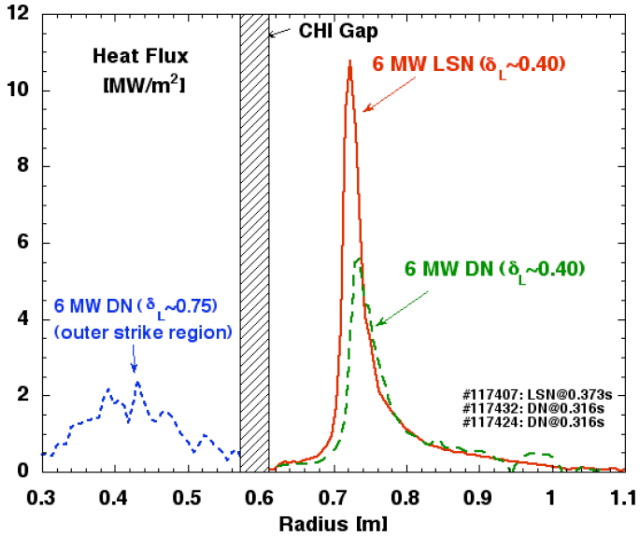




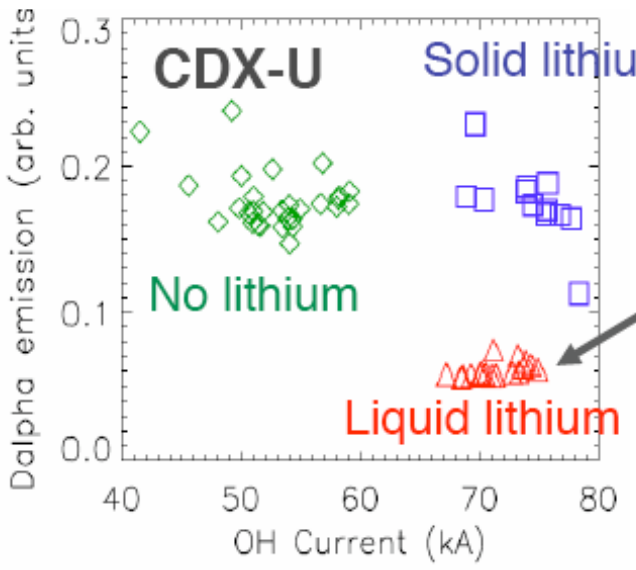


Investigating Innovative Solutions for NHTX/CTF and DEMO

NSTX with ITER-level heat flux

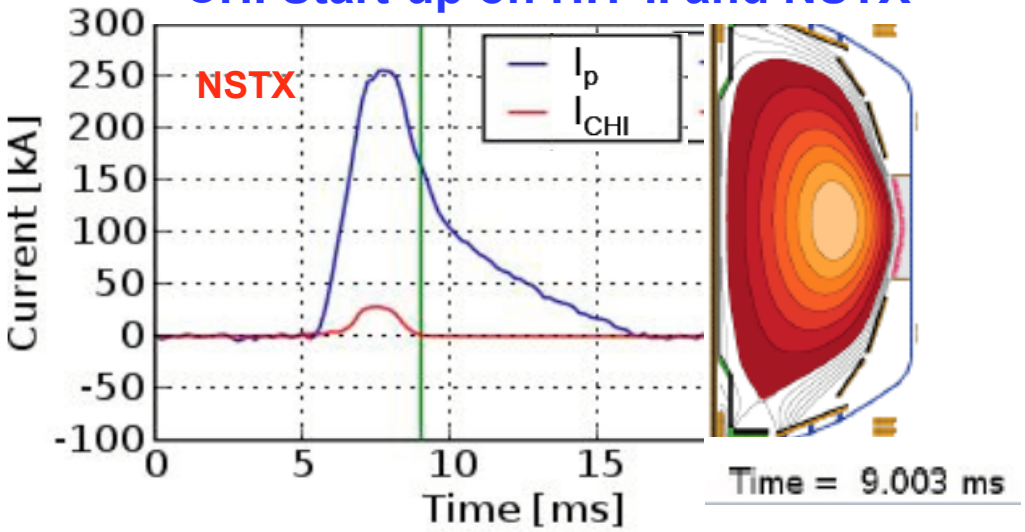


Lithium on CDX-U/LTX and NSTX

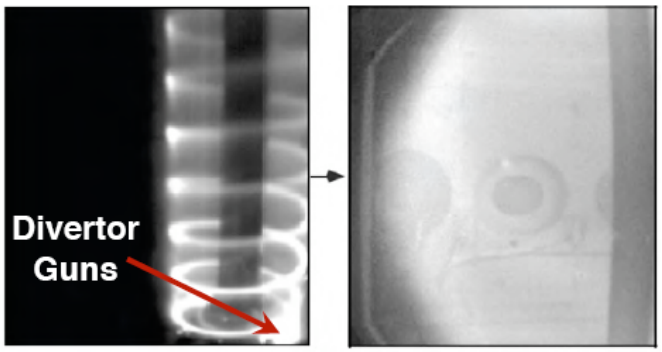


Record low recycling achieved with improved confinement!

CHI Start-up on HIT-II and NSTX



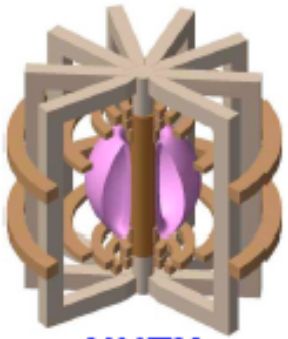
PEGASUS Gun Start-up



Ip ~ 30 kA achieved

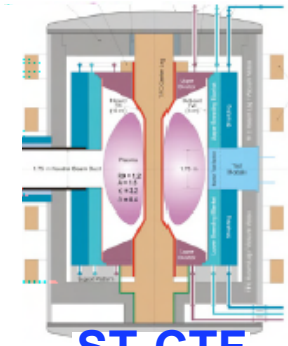
Next Steps in ST Development Path

Present ST program contributes physics basis for the crucial next step ST devices



NHTX

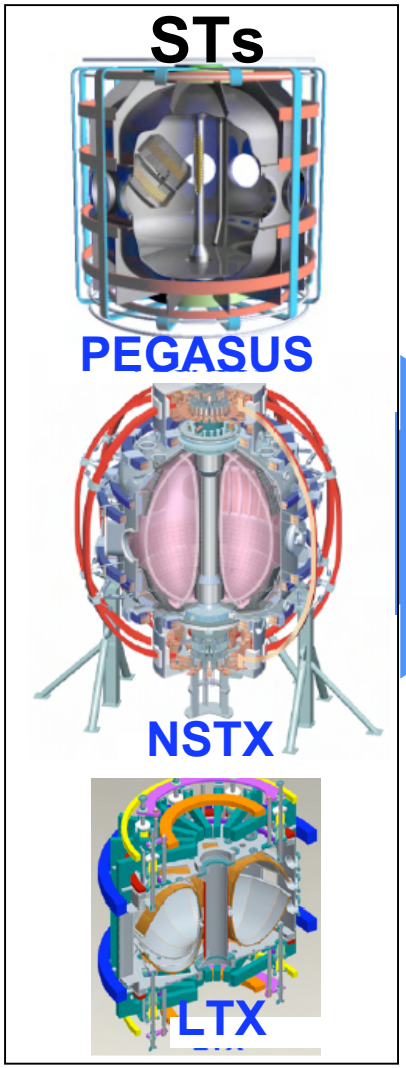
NHTX (PE-ST) at 3 - 4 MA range provides cost effective physics / technology basis in support for CTF and DEMO: Demonstrate stable continuous high-performance operation with very high heat flux and acceptable hydrogen isotope retention.



ST-CTF

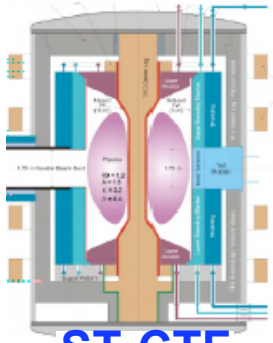
Compact ST-CTF at ~ 10 MA range provide a compact nuclear component test facility to support DEMO: Provide ~ 6 Mwyr/m2 neutron over ~ 10 m^2 with acceptable level of tritium consumption

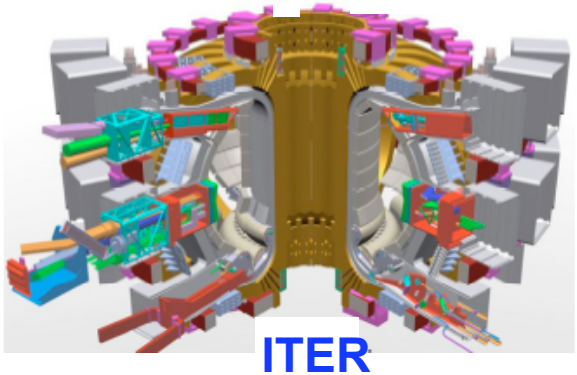
Broad Contributions of ST Research Program



Advanced Physics, Plasma-Materials Interactions

Nuclear Component Testing





Burning Plasma Physics