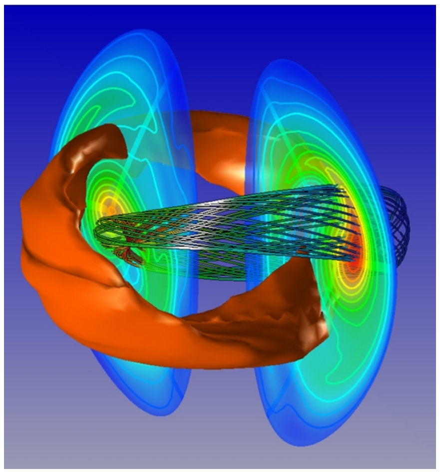
Past, Present and Future of the US-KSTAR Collaboration



Hyeon K. Park

POSTECH

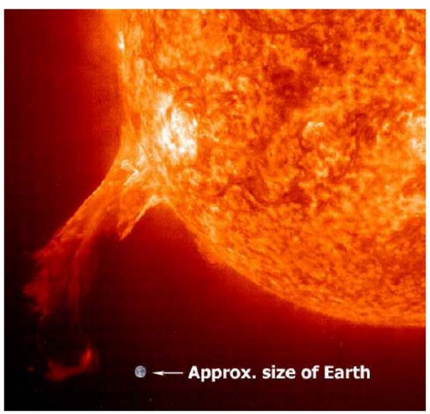
at

2009 US-KSTAR Workshop

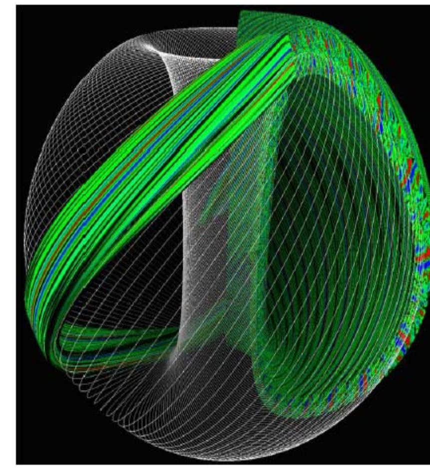
GA.SanDiego, CA

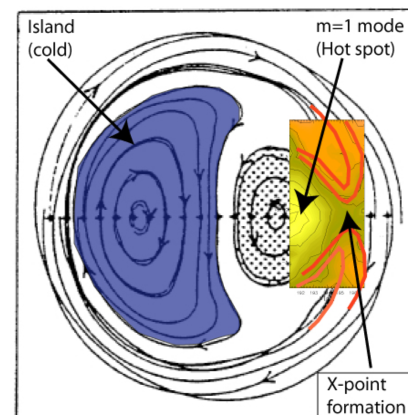
On

April 15-16, 2009



SOHO UV (He)

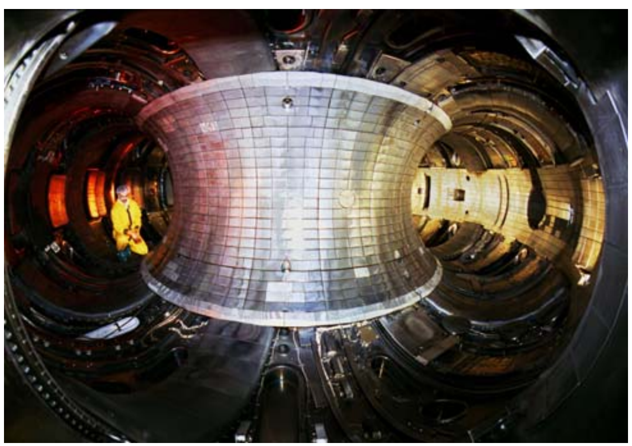




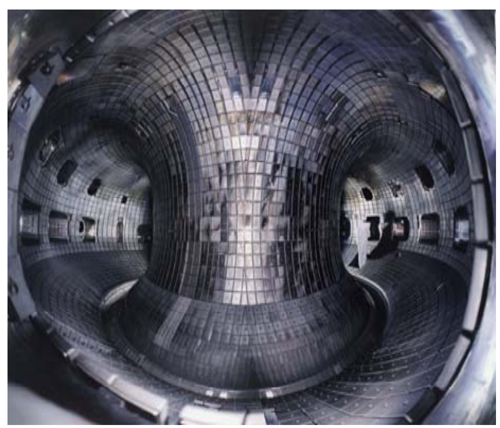
Comparison with the full reconnection model simulation result at the low field side

Past of the international fusion effort

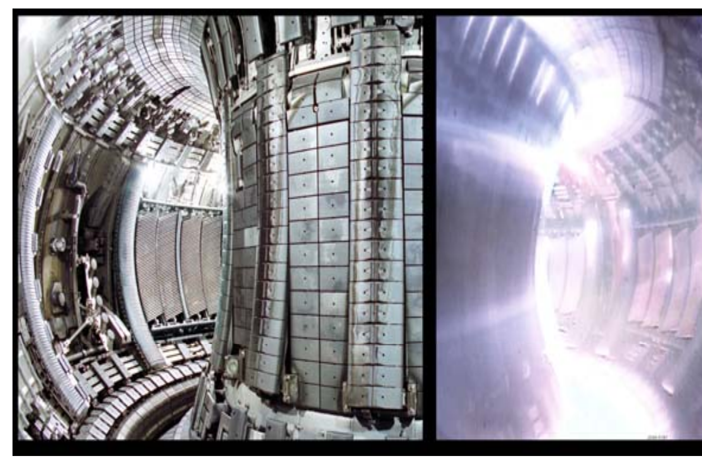
- Three large tokamak era: non-steady state device based on Cu coils (pulse length is limited by the cooling system < ~ 20 sec.)
  - Tokamak Fusion Test Reactor (USA) 1982–1997, Princeton Plasma Physics Laboratory, USA
    - **Fusion power yield: Q ~ 0.3 from D-T experiment**
  - Joint European Tokamak (EU):1983 – present, Culham, Oxfordshore, UK
    - **Fusion power yield: Q ~ 0.7 from D-T experiment**
  - JT–60U (Japan):1985 – present, Japan Atomic Energy Agency (JAEA), Japan
    - **Q~1.25 extrapolated from D-D experiment**



Internal view of TFTR



Internal view of JT60-U



Internal view of JET/plasma discharge

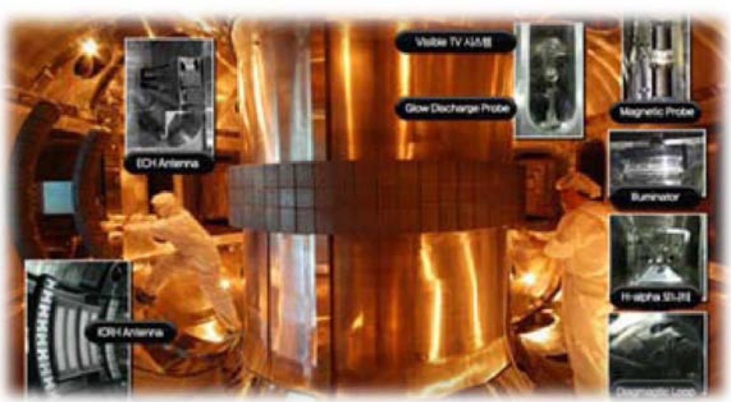
Present new fusion research

- Steady state capable devices are critical for the physics and engineering basis for the fusion plasma research
  - New superconducting tokamak devices are merging to Asian countries – Japan (LHD, JT-60SA), China (EAST), Korea (KSTAR) and India (SST)

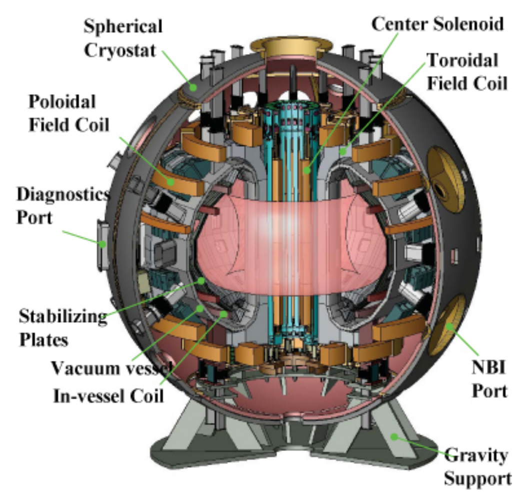
LHD, NIFS, Japan

SST-1, India

EAST, Hefei, China



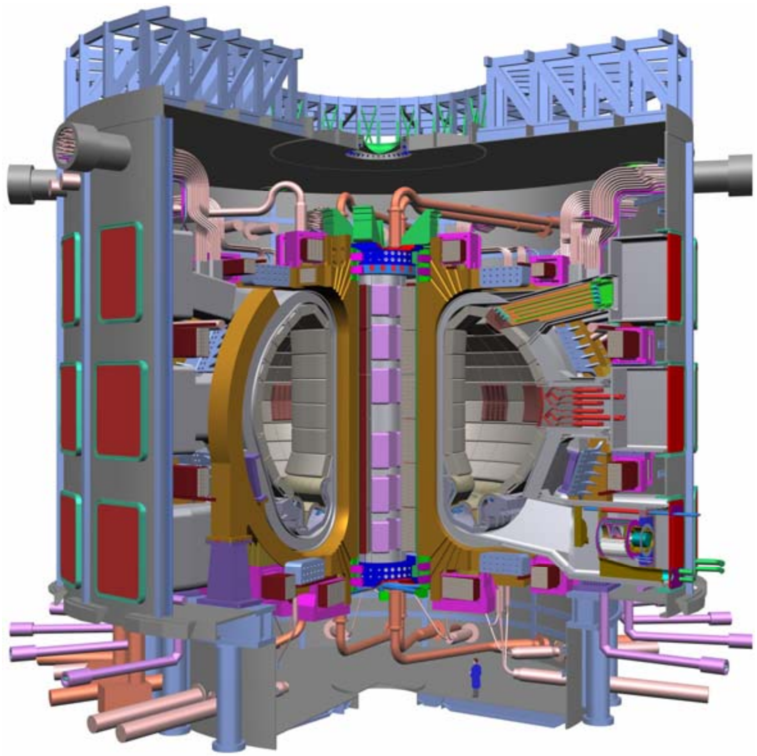
KSTAR, NFRI, Korea

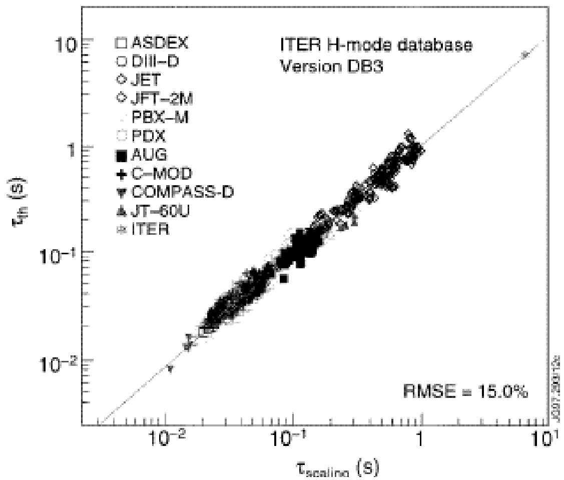


JT-60SA, JAEA, Japan

Future (ITER)

- The goal is "to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes".
  - Demonstration of fusion power yield; Q (output power/input power) ~10
  - International consortium (Europe, Japan, USA, Russia, Korea, China, and India)
  - Total cost ~ $10 B for ~10 year





$$\tau_{th} = 0.029\, I^{0.99}\, B^{-0.06}\, P^{-0.69}\, n^{0.61}\, R^{2.11}\, \varepsilon^{0.22}\, \kappa^{0.7}\, M^{0.11}$$

$$B\tau_{th} \propto \rho^{*-3.21}\, \beta^{-0.41}\, \nu^{*0.13}.$$

Physics basis is empirical energy confinement scaling

KSTAR-US collaboration (past)

- US-KSTAR workshop at GA on May 2004
- Areas of interest (first priority of KSTAR)~$1.62M
  - Steady-state Technology ($14.3M) ($0.37M)
  - Control, Stability and AT modes($1.48M) ($0.35M)
  - Conventional Diagnostics ($ 6.5M) ($0.45M)
  - Advanced Diagnostics ($2.8M) ($0.2M)
  - Collaboratory ($1.25M)($0.25M)
- US-KSTAR workshop 2005 at Daejeon (active work)
- US-KSTAR workshop 2006 at Princeton
  - FY06 International Collaboration to prepare for KSTAR operation (Finals 04/06; $1352K total)
  - Total allocation for Institution: PPPL (~500k), GA (~400k), ORNL (~200k), LLNL (~20k), MIT(~40k) Columbia (~100k),

Escalated KSTAR progress

- US-KSTAR workshop (Sept, 2007), Dajeon, Korea
  - Korean National Assembly passed the Fusion Energy Development Promotion Act on November 30, 2006.
  - DoE Secretary with the Korean Minister of Science and Technology in Dec. 13 in Seoul. The primary subjects of discussion were KSTAR, ITER and fusion collaboration.
  - Secretary Bodman strongly supported the US-Korea Fusion Collaboration using KSTAR.

Steering of US-KSTAR program

- Changes in focus
  - Steady State Current Drive system and Fueling:
    - PPPL (LHCD; steady state heat load for LHCD system and CW ECCD launc her)
    - GA (ECCD; Ray tracing & steady state waveguide system for 170 GHz)
    - NFRC will develop a contract with ORNL for the pellet fueling system
  - Advanced imaging diagnostic systems.
    - PPPL/UCD/Colorado will develop (ECEI&MIR) for KSTAR. Wide range of op eration scenario (2T - 3.5 T) will be considered.
    - Wisconsin with continue the design effort and R&D of the critical path of the BES system as the KSTAR NBI system is progressing.
  - Control, stability and AT physics
    - GA/KSTAR (Control system),
    - Columbia (Stability limit based on passive plate and IC coils),
    - AT physics (PPPL)
  - Fusion Grid collaboratory
    - MIT will explore this subject (MDS)

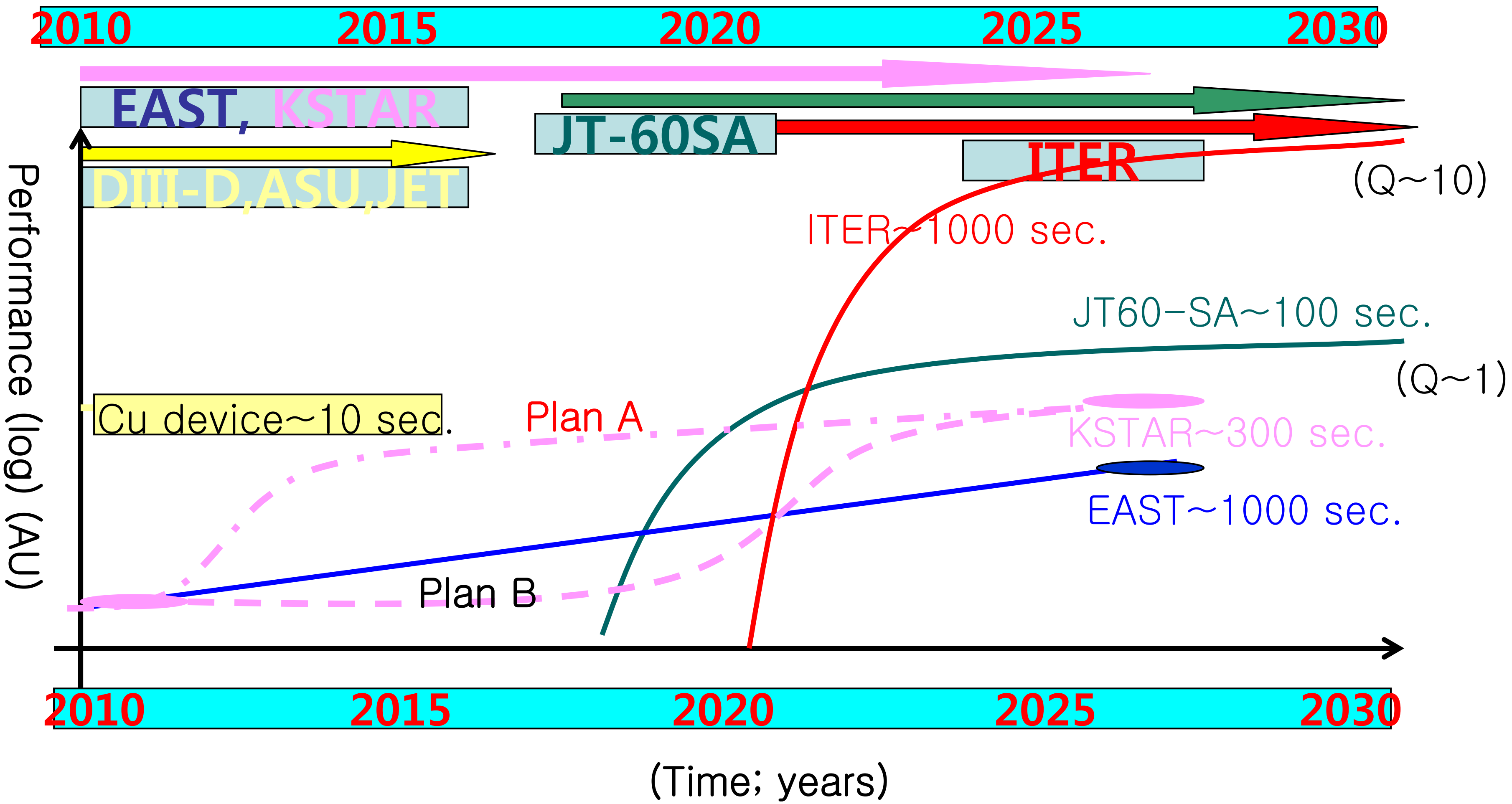
Fruitful outcome of the US-KSTAR collaboration

- Strong US team (GA/ORNL/PPPL) support for the first plasma
- ECH launcher (KSTAR/PPPL fund) – essential for the first plasma
  - 170 GHz launcher program– POSTECH/PPPL fund
- KSTAR control system (KSTAR/GA) – essential for the success of the first plasma
- Diagnostic cassette design (PPPL) – essential for the first plasma
- Equilibrium analysis (Columbia) – first KSTAR related IAEA paper
- Diagnostic system design – likely to lead to further collaboration
  - Thomson scattering (POSTECH/NFRI)
  - ECEI/MIR (POSTECH/UCD/Colorado)

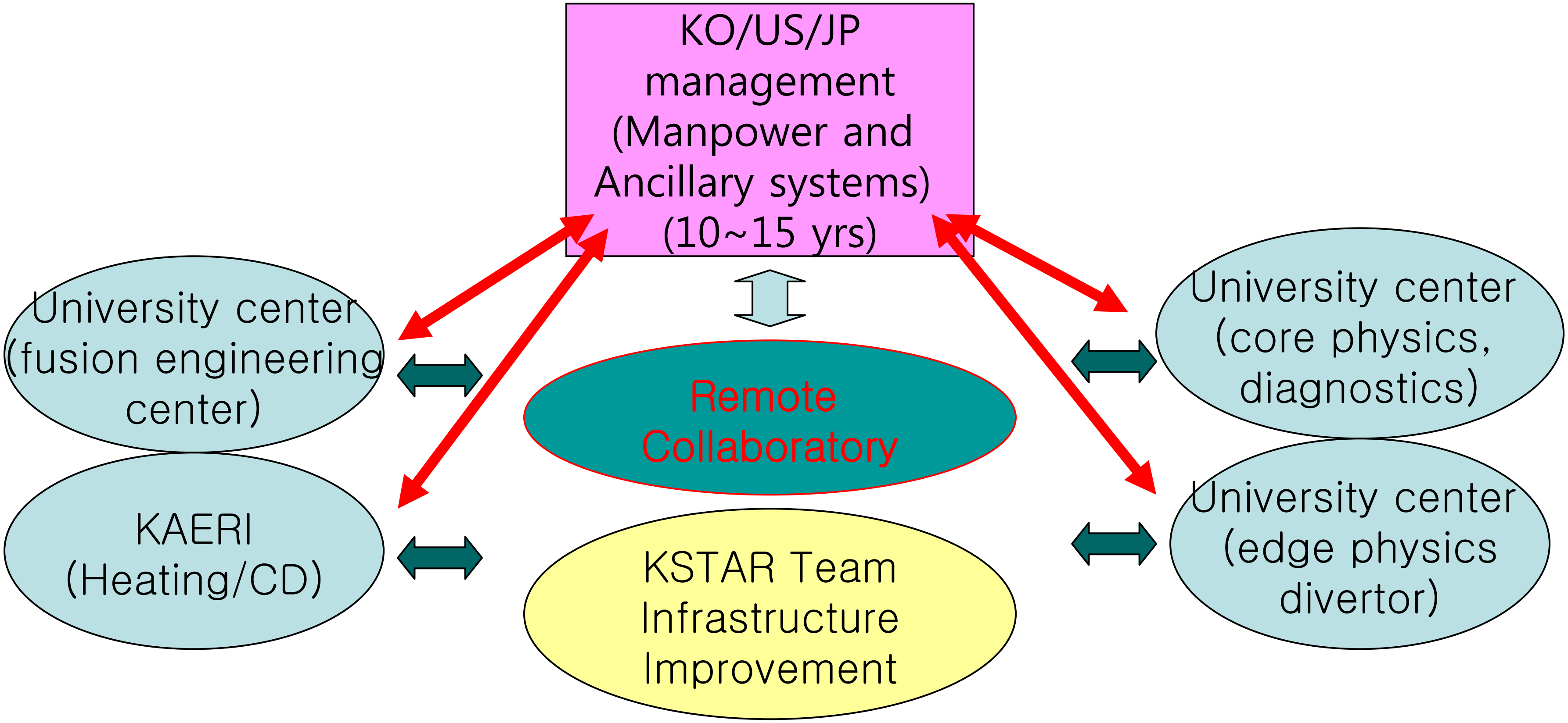
KSTAR Operation Plan (future)

Plan A : Aggressive int.-collab. plan led by KO/US/JP team

Plan B : Current plan (KO only w/ low level int-collab.)



Plan A



KSTAR operation (10~15 year initial contract): KO/US/JP management team **can play a key role in developing "steady state tokamak physics" of US and JP**

University center: work with KSTAR management to support manpower and specific programs indicated above

Remote Collaboratory: fully deployed for two phase operation of KSTAR (Day shift: JP/KO and Evening shift: US/KO)

Implementation of Plan A

First Step: Proposals from US and JP for Int. Collab.

Second Step: Form three way task forces

KO task force: **Plan for infrastructure upgrade to implement Plan A**

US task force: "**US plan on steady state tokamak physics**" based on KSTAR for 10~15 years

JP task force: **Physics plan for continuing JT-60U work toward JT60-SA on KSTAR** for ~10 years

KSTAR Strategy (short term)

KSTAR plan: demonstration of major milstones

2008 IAEA: Successful device performance and first Plasma

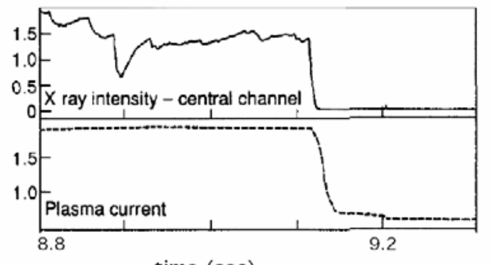
2010 IAEA: Delivery of significant new physics

New physics – strategically invest in unique measurements of key phenomena with unprecedented resolution in both time and space

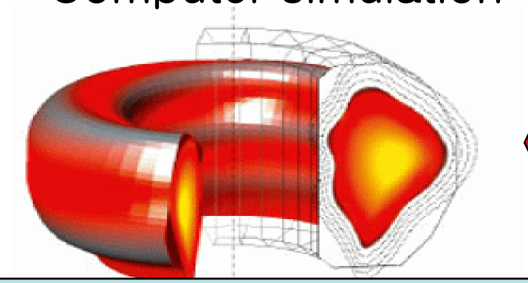
Positive results will help motivate timely investment for needed KSTAR performance upgrades

KSTAR Physics Study (short term)

Conventional Diagnostics



Computer simulation



2D/3D imaging

?

3-D imaging to provide new insights on underlying physics of Disruptions

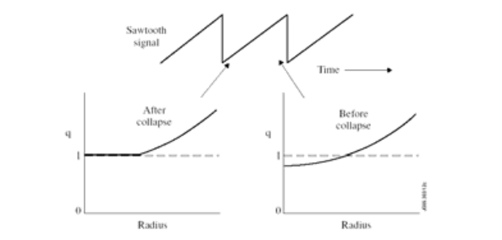
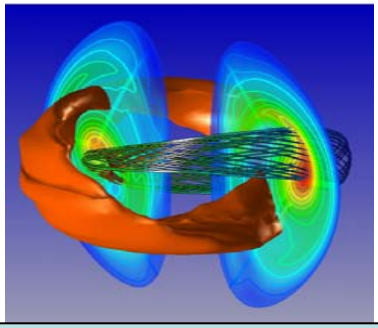
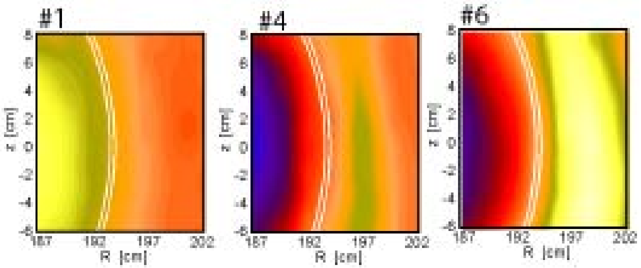


Figure 10.12. Kadomtsev's model predicts a flattening of the q-profile at the sawtooth collapse and the development of an unstable profile with $q < 1$ during the ramp phase.





Improve predictive capability of MHD physics (Sawtooth, NTM, and RWM)

Analogous to evolution of diagnostic capabilities from Stethoscope to MRI

Common Interest in R&D

Control and Stability

Steady state operation: for JT-60SA/LHD/KSTAR/EAST

Ancillary Systems

NBI and CD system: for JT-60SA/LHD/KSTAR/EAST

1) CW NBI, CD system (over ~100 sec.)
2) Cost effective accelerated program

Advanced Diagnostics

Visualization diagnostics for MHDs and Turbulence

1) to extract precise physics of stability and Transport issues
2) to impact on other areas of science (solar and astrophysics)