# KSTAR and US collaboration

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KSTAR

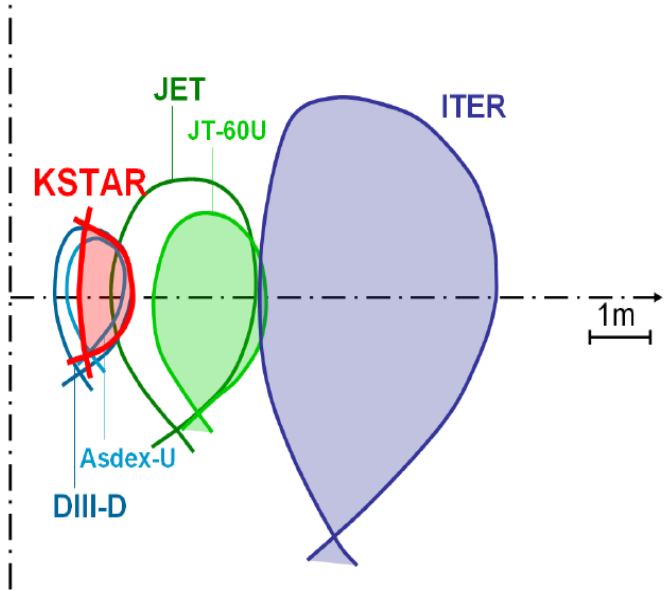
NFRI 국가핵융합연구소 National Fusion Research Institute

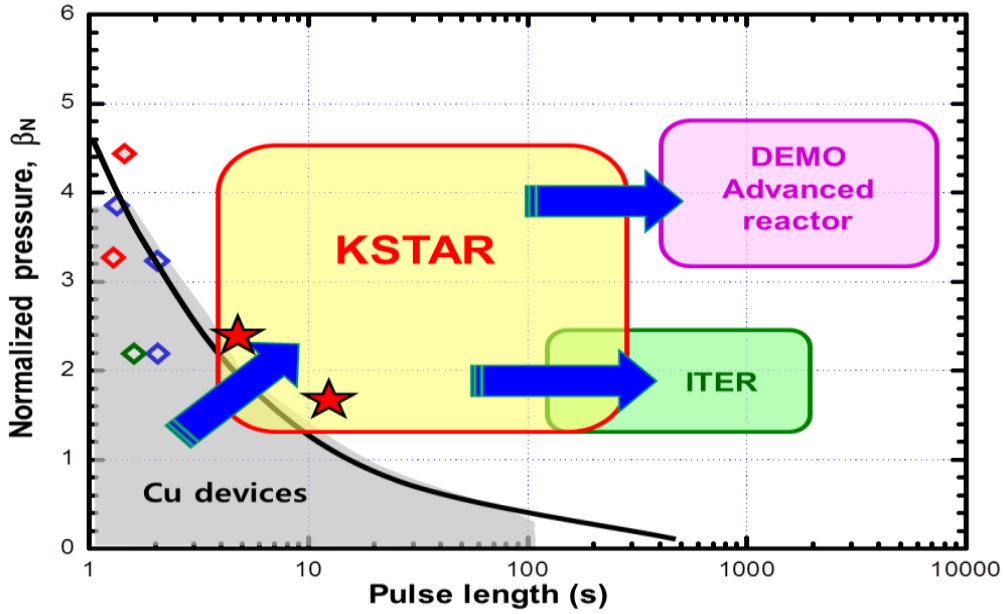
# KSTAR is dedicated to the study of long pulse, steady State, Advanced tokamak



## KSTAR Missions are

- To obtain the superconducting tokamak construction and operation experience
- To explore the physics and technologies of high performance steady state operation that are essential for ITER and fusion reactors

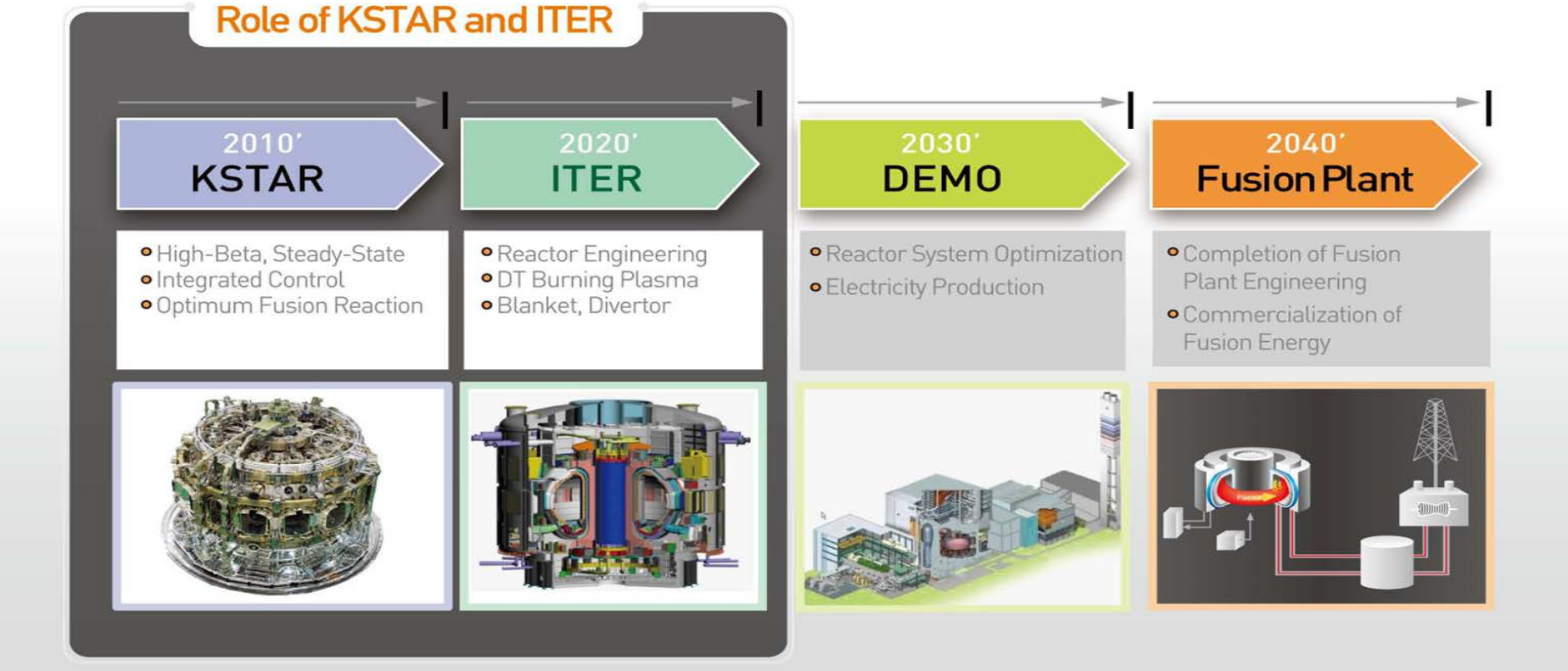



Machine design is optimized for advanced target operation
Strong plasma shaping, Passive stabilizing plates, low TF ripple..

# Korean Fusion Energy Development Plan






**Vision : Secure sustainable new energy source by technological development and commercialization of fusion energy**

**"Nuclear Fusion Energy Promotion Law" was established by the Korean National Assembly in 2007**

**→ KSTAR(also ITER) is a key program in KO fusion development**

# KSTAR was the product of US-KO collaboration program and it showed long pulse capability of SC machine via five year operation

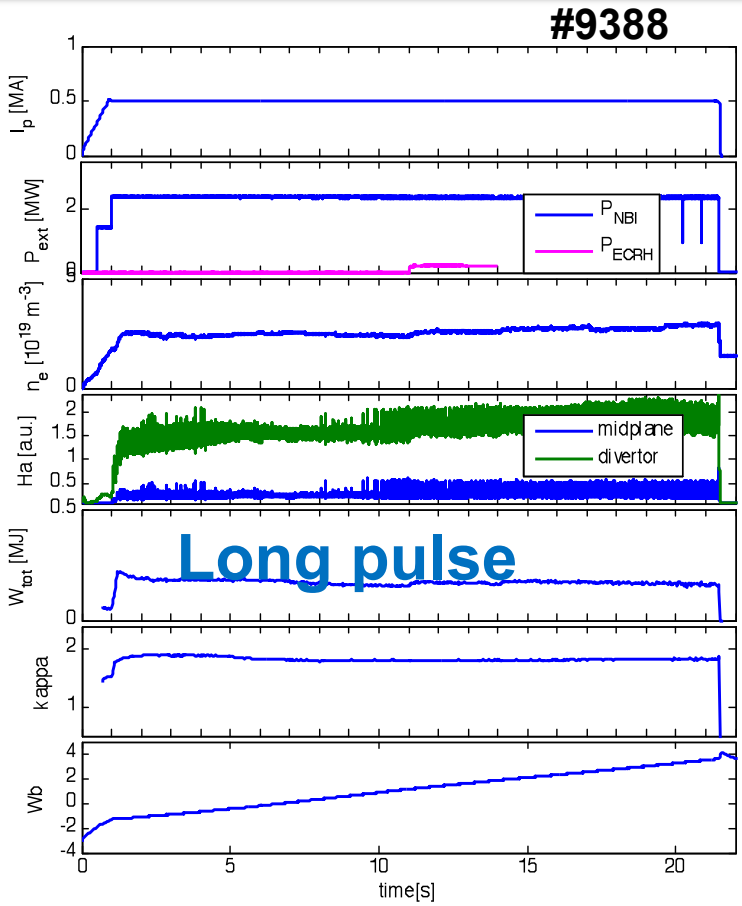


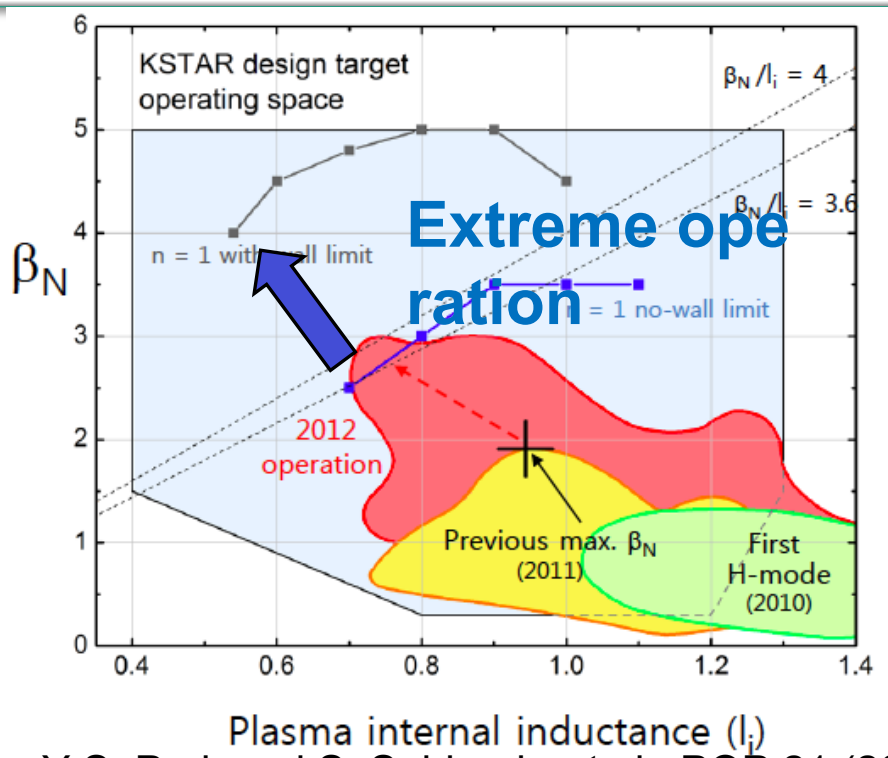
- **TPX (US-born idea for burning plasma) was the original design ba sis for KSTAR**
  - Deuterium/Tritium to Deuterium/Deuterium machine
  - 1000s to 300s
  - Added the more advanced concepts such as in-vessel control coil
- **Enhanced the engineering capability of KO industry**
- **US contribution to the successful first plasma and H-mode achieve ment was essential and** is working with GA and PPPL
- **Via 1st phase of operation(08-12), KSTAR showed the capability of high performance/long pulse and unique features**
  - 22s H-mode, n=1 ELM suppression, low error field, etc.
- **KO's jump-start(so called mid-entry) strategy by utilizing the inte rnational collaboration has been successful**

KSTAR GENERAL ATOMICS PPPL PRINCETON PLASMA PHYSICS LABORATORY COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK UCDAVIS OAK RIDGE National Laboratory

# The steady progress has been made in addressing long-pulse and high beta operation






Y.S. Park and S. Sabbagh, et al., POP 21 (2014)

- With better control logics of magnet and motor-generator
  → **longer pulse operation is ready to test**

**- Note1 : tangential neutral beam in KSTAR similar to DIII-D**
**→ Providing strong stability with high rotation for advanced operation**
**- Note2 : Heating upgrade is necessary**

**In 2014, we will demonstrate not only 50s at 0.5MA but also 10 s at 1MA H-mode as an operational milestone**

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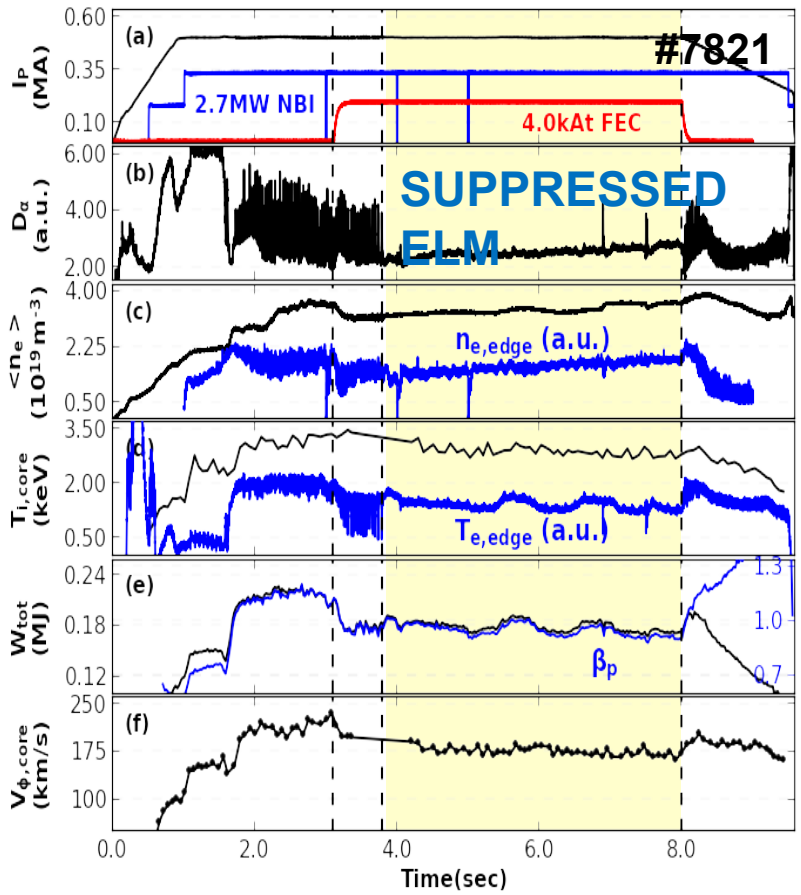
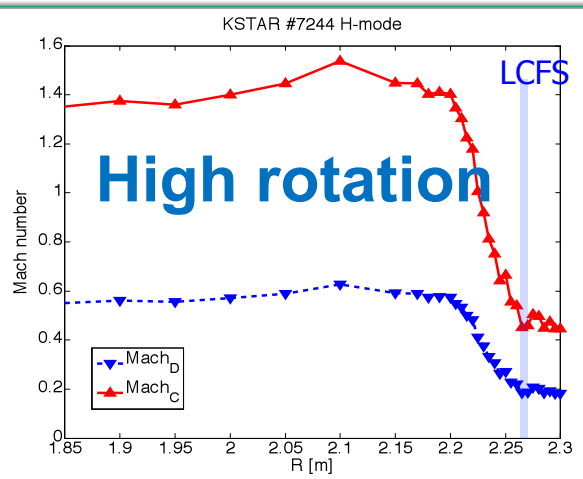
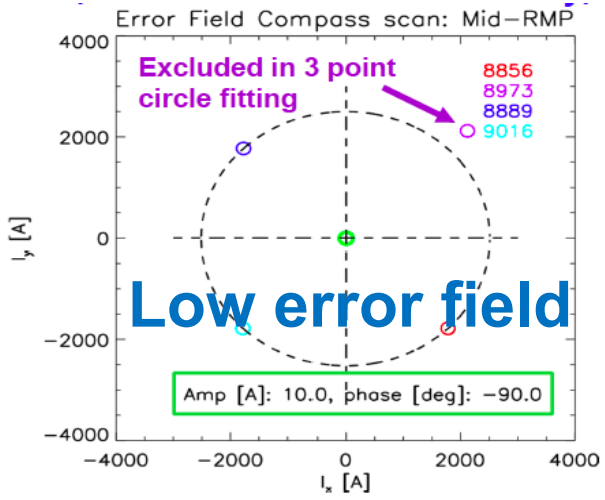
# Low-n RMP driven ELM-suppressions is one of unique features in KSTAR along with low error field and high rotation at the pedestal






- **n=1 driven ELM-suppression (unique in the world)**
  → Potentially allowable for RMP coils outside vessels (**reactor-relevant**)




**δB/B0 = $10^{-5}$ (lower than conventional $10^{-4}$)**

**Note KSTAR outperforms conventional tokamaks suitable for the advanced researches and is supported by advanced diagnostics such as ECEi**

# KSTAR's 2nd phase(13-17) has world-leading goals

- **Securing high performance core and edge plasma in long pulse(or iginal goal of KSTAR) using well designed machine**
  - Presently uncertain about the ELM suppression capability which is successful for a short period(~10s) if pulse length is extended and at the reactor level of extreme operation condition
  - reliable long pulse demonstration
- **Expecting for new dataset of world records beyond what we have now, but the analysis has not been satisfactory with KO efforts alo ne**
  - How to connect unique features of KSTAR to the theoretical base
- **Connecting experimental data with modeling efforts**
  - Paths to extrapolate of the present operating regime to reactor relevant conditions
- **So, KSTAR could play a bigger role if supported by international analysis effort and it is essential.**

**Heating upgrade up to 18 MW is being negotiating for completi ng missions of 2nd phase(13-17) [presently, ~10MW]**

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# What specifics from US the most influential?



- **Supporting to achieve the original mission of KSTAR and to solve ITER urgent issues.**

  - High performance core and edge plasma for long pulse
  - Can KSTAR operate disruption free at such high $\beta_N$ values over long pulse?
  - Scenario developments for advanced and hybrid operations
  - Validation of the present control methods to solve ITER issues for long pulse and at ITER relevant plasma conditions

- **Connecting with the theoretical analysis on the unique experimental data**

  - Why is n=1 RMP ELM suppression demonstrated at KSTAR only?
  - Is there any connection between the low error field with the n=1 ELM suppression physics?
  - How to connect the n=2 ELM suppression achieved in the DIII-D to n=1 and n=2 suppression in KSTAR?

# What benefits may US get from KSTAR?



- **Benchmarking and improving theoretical modeling tools to unique experimental conditions (i.e.steady state operation)**
- **Validating/predicting the codes to extrapolate to reactor conditions**
- **Extension of the short pulse US physics data to long pulse to gain more reliable insight into steady state operation**
- **Accessing to gaining valuable experience from a long pulse superconducting tokamak without making a major investment**
- **Education of young scientists on a world-leading long-pulse superconducting tokamak**

# Summary



- **KSTAR has made a significant progress over the last 6 years of o peration and entering into the its 2nd phase**
- Via 1st phase of operation, **KSTAR demonstrated its the capability of high performance/long pulse and unique features**
- **To achieve its original mission (high beta for 300s),**

  **an upgrade plan has been established**
- **To augment and substantiate its output**, collaboration with internat ional community, especially **with US will be essential**
- **It also would help to strengthen US leadership in the area of fusio n by extending the short pulse US physics data to the long pulse KSTAR to gain more reliable insight into the reactor level conditi on(i.e.steady state operation)**


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Thank you for your attention !
에너지강국
핵융합이 답입니다
바닷물로 만드는 해
핵융합에너지가 에너지 문제 해결의 답입니다
태양에너지의 원리인 핵융합은 바닷물을 연료로 하는 안전한 미래에너지원입니다
국가핵융합연구소는 핵융합에너지 개발로 에너지문제의 궁극적인 답을 찾습니다
'The sun made from the sea'
is the solution of energy problem.

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