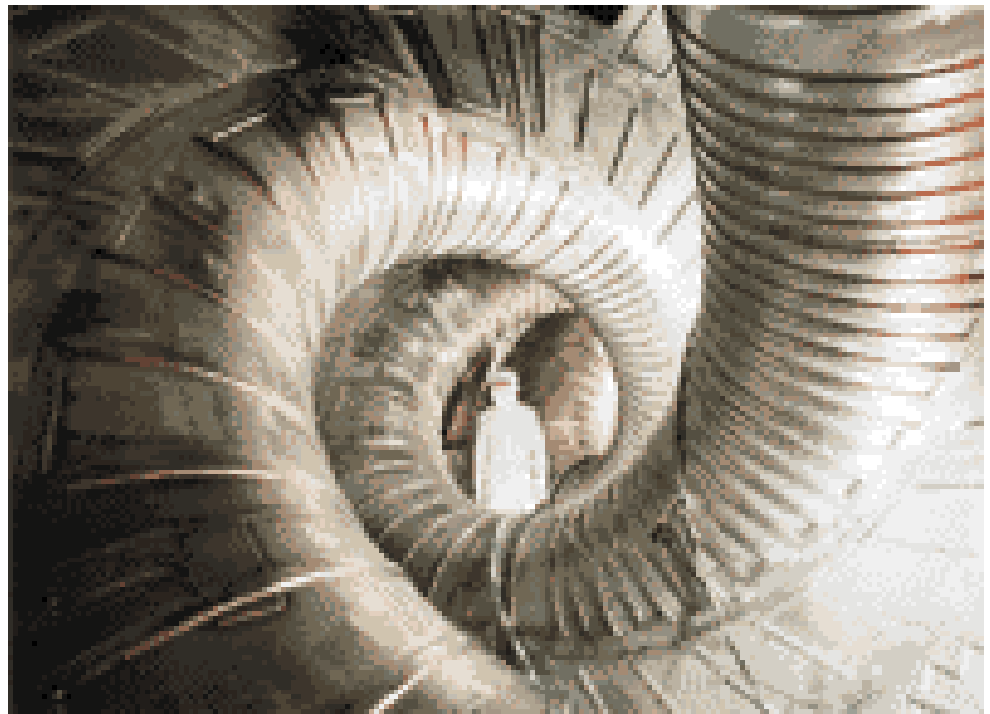


# ***What have we achieved in stellarator/heliotron - from highlights in Large Helical Device project -***



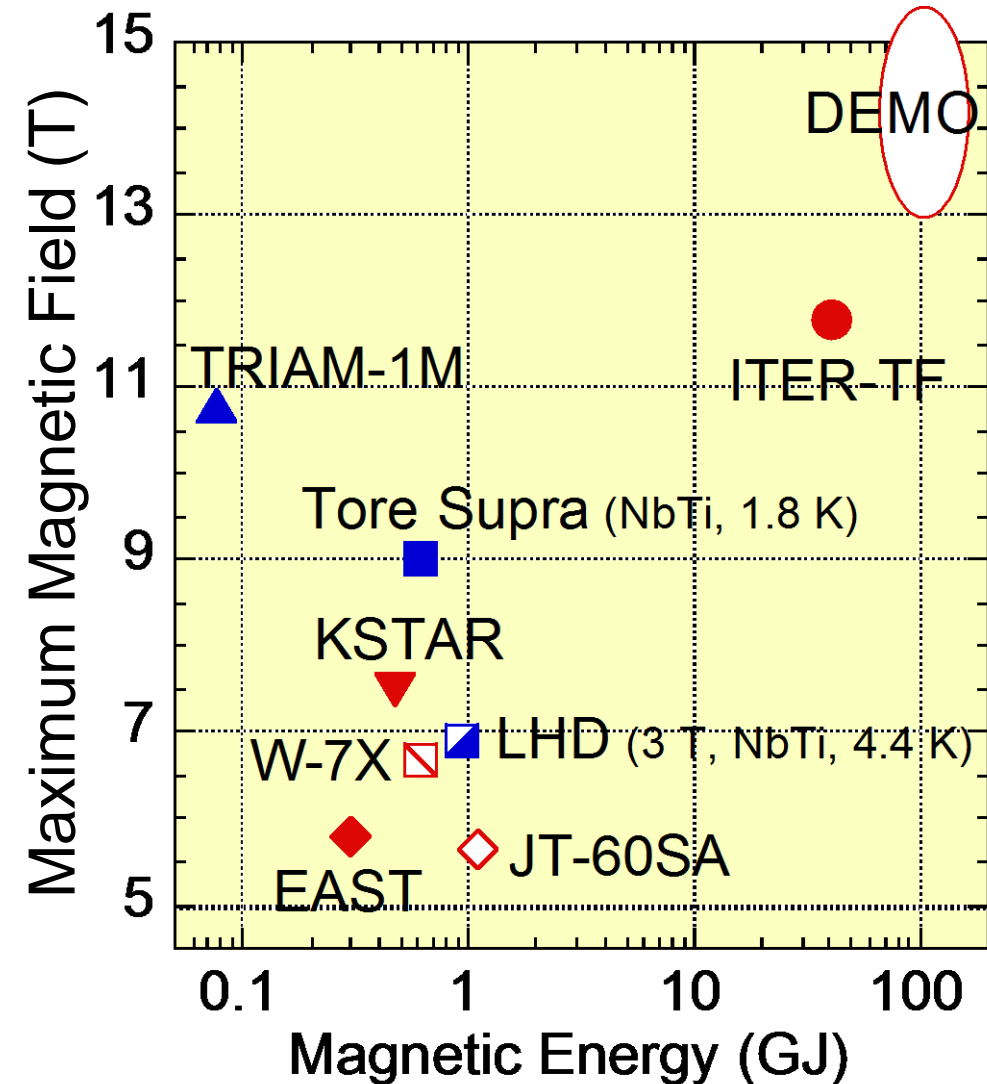
# ***Science, 1998*** **“Japan Readies Helical Device to Probe Steady-State Plasmas”**



ITER is not the last word in fusion reactors. While ITER plans to operate only in pulses of up to about 1000 seconds, the Japanese and German machines will confine the plasma for hours or even days. “We will be able to investigate parameters of steady-state plasma physics in ways that tokamaks can't,” Iiyoshi says.

Helical device proponents hope to make more than just a contribution. Iiyoshi predicts that the performance of the LHD and the Wendelstein 7X will put helical devices back in the running by 2015, when it's time to design a demonstration reactor. “It could be the choice if we have great success with the LHD experiments,”

# Large superconducting systems



LHD is the world-largest superconducting fusion device and demonstrate long-term stable operations.

**LHD** (Japan) (1998)

On-site winding

30 kA-NbTi **CICC**,

$B_{\max} = 6.9$  T,  $W = 0.9$  GJ

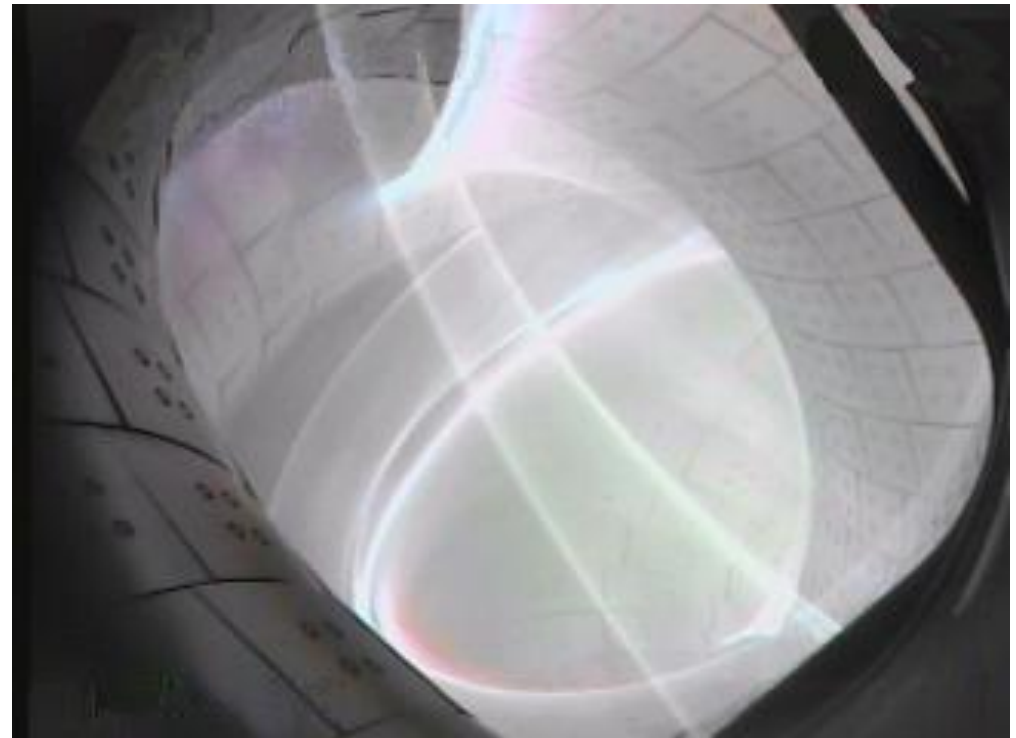


# LHD has worked very well for 15 years and provided encouraging results

→ Engineering base of a large-scale superconducting and cryogenic system for fusion reactor development

## Basic parameters

- Cold mass 820 ton
- Total weight 1500 ton
- Magnetic field 3 T
- Plasma volume 30 m<sup>3</sup>
- Heating power 36 MW
- Operational time of He compressor : 75,000 hours with duty > 99 %
- Coil excitation number : 1,540 times
- Plasma discharges : 121,500 shots



**One-hour long plasma operation**  
**A large number of opportunities**  
**for diversified collaboration**



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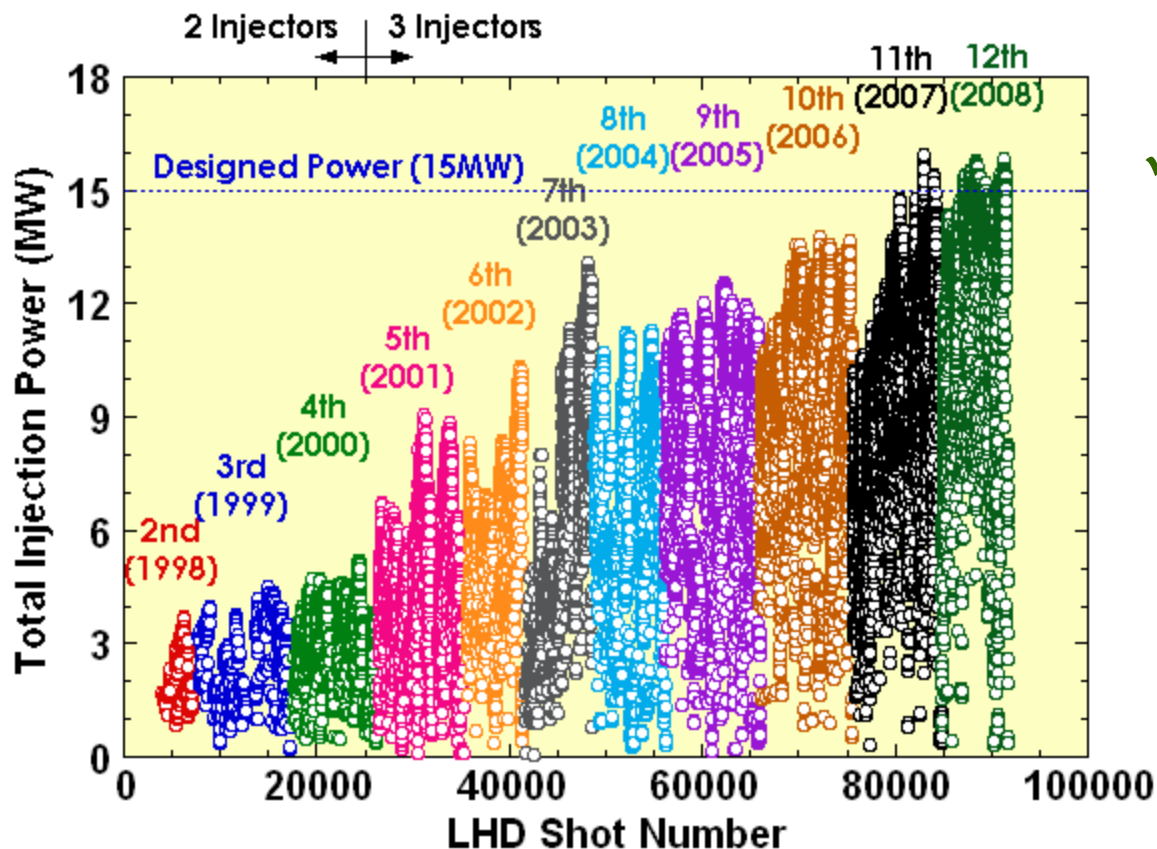


**One-hour long plasma operation**  
**A large number of opportunities**  
**for diversified collaboration**



# Negative-ion-source based neutral beam injectors work well even with heavy duty

- ✓ 189 keV - 37 A of **hydrogen negative ions**
- ✓ 16 MW of heating power to plasmas
- ✓ Available every 3 min. (up to 10 sec.)
  - ➔ > 100 shots a day



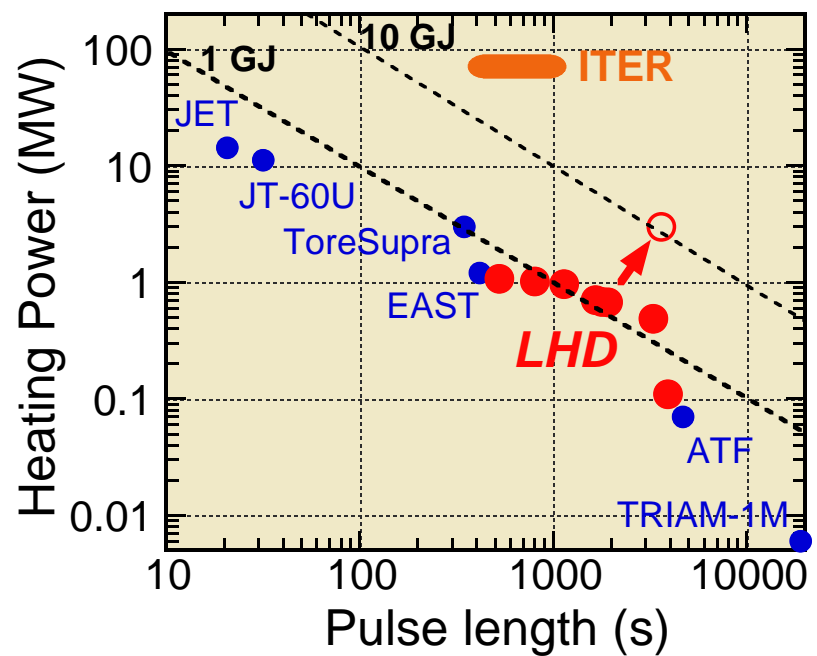
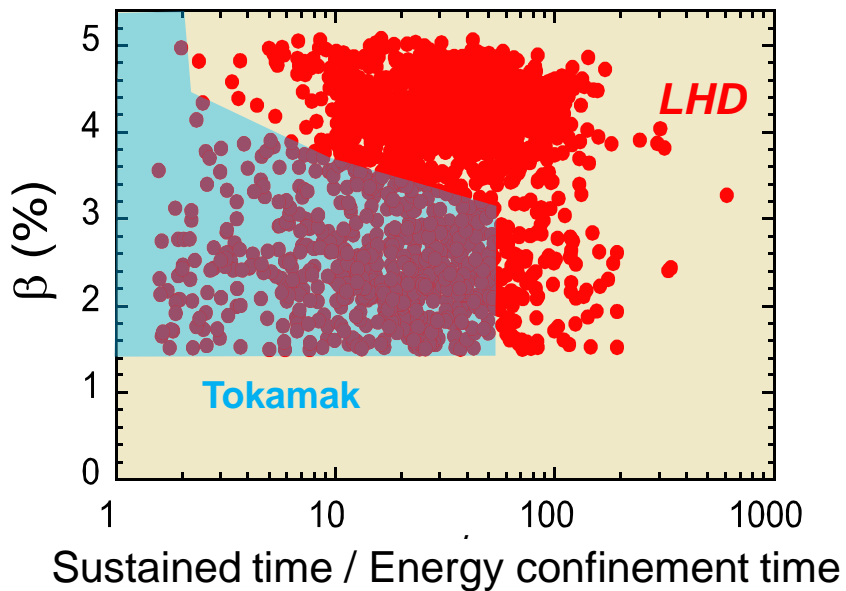
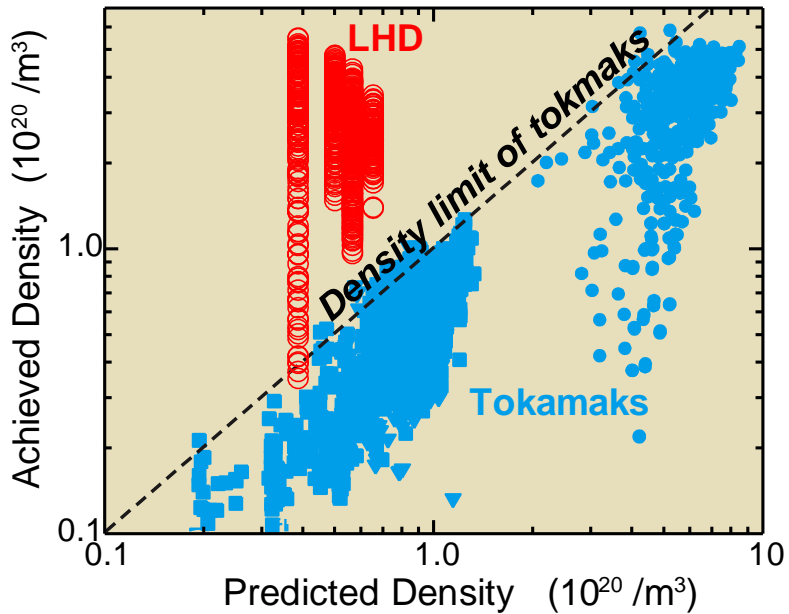
- ✓ Performance improvement by continuing the R&D in parallel with the operation.  
ex. multi-slot grid



# Stellarator/Heliotron plasmas are robust and stable

can be operated

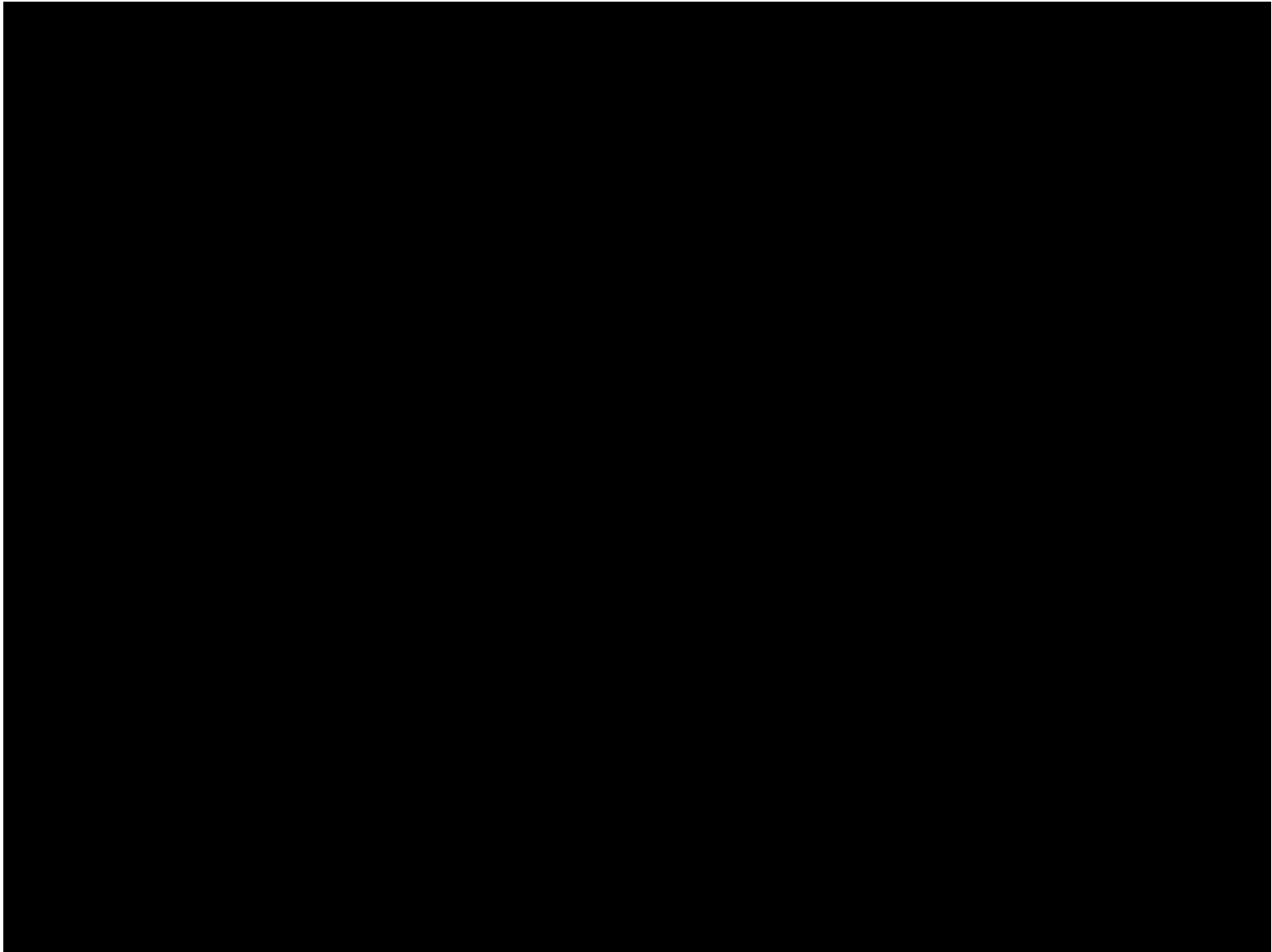
- much beyond the density limit of tokamaks
- with high pressure (beta) stably
- in extended steady-state regime



$$\beta = \frac{\text{plasma pressure}}{\text{magnetic field pressure}}$$



# Simulation of turbulence in plasma







## LHD in Japan

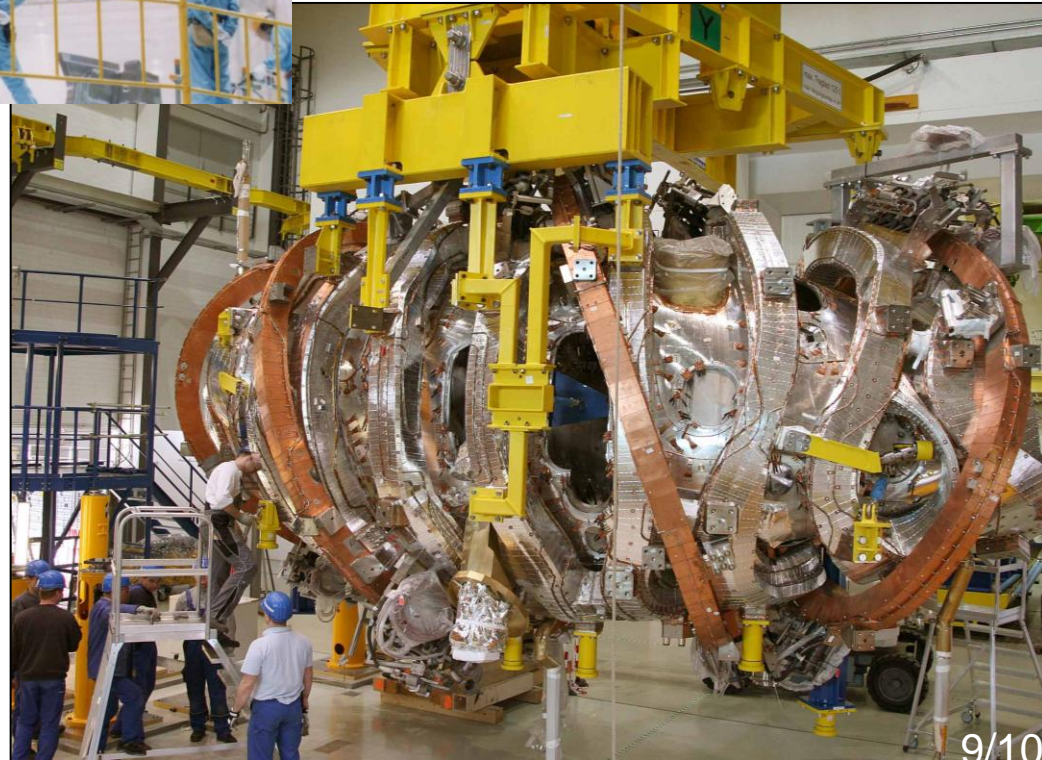
Diameter 7.5 m  
Magnetic Field 3 T

## W7-X in Germany

Diameter 11 m  
Magnetic Field 3 T

Both machines employ fully superconducting coil system: Remarkable engineering achievements

**Reactor will have 4-times larger size and doubled magnetic field**



# Summary

1. **A flagship experimental project: Large Helical Device has been exploring cutting-edge technology and physics, which demonstrates that stellarator / heliotron is a promising concept alternative / complementary to tokamaks**
2. **Steady-state, stable and robust plasma operation has been achieved.**
  - ✓ **Much higher operational density than in tokamaks**
  - ✓ **Benign and not harmful instabilities in even high pressure**
  - ✓ **1-hour long plasma operation**
  - ➔ **Pronounced and attractive nature : no disruption and steady-state operation without current drive**