Max-Planck-Institut für Plasmaphysik

The new stellarator Wendelstein 7-X and visions for a stellarator/heliotron power plant

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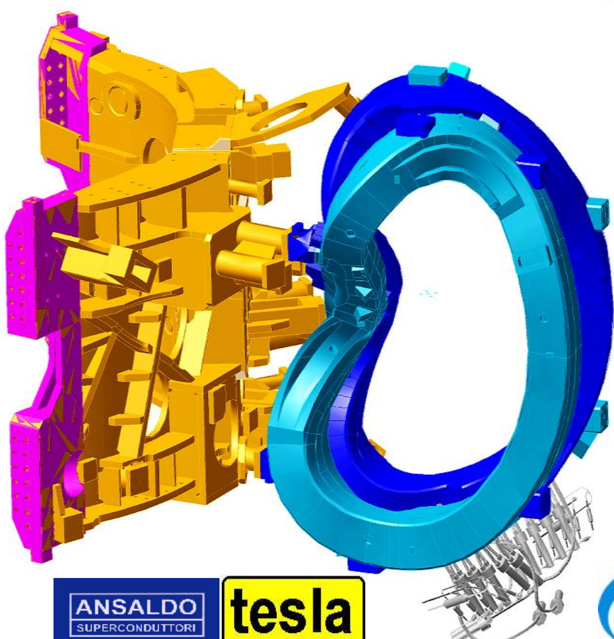
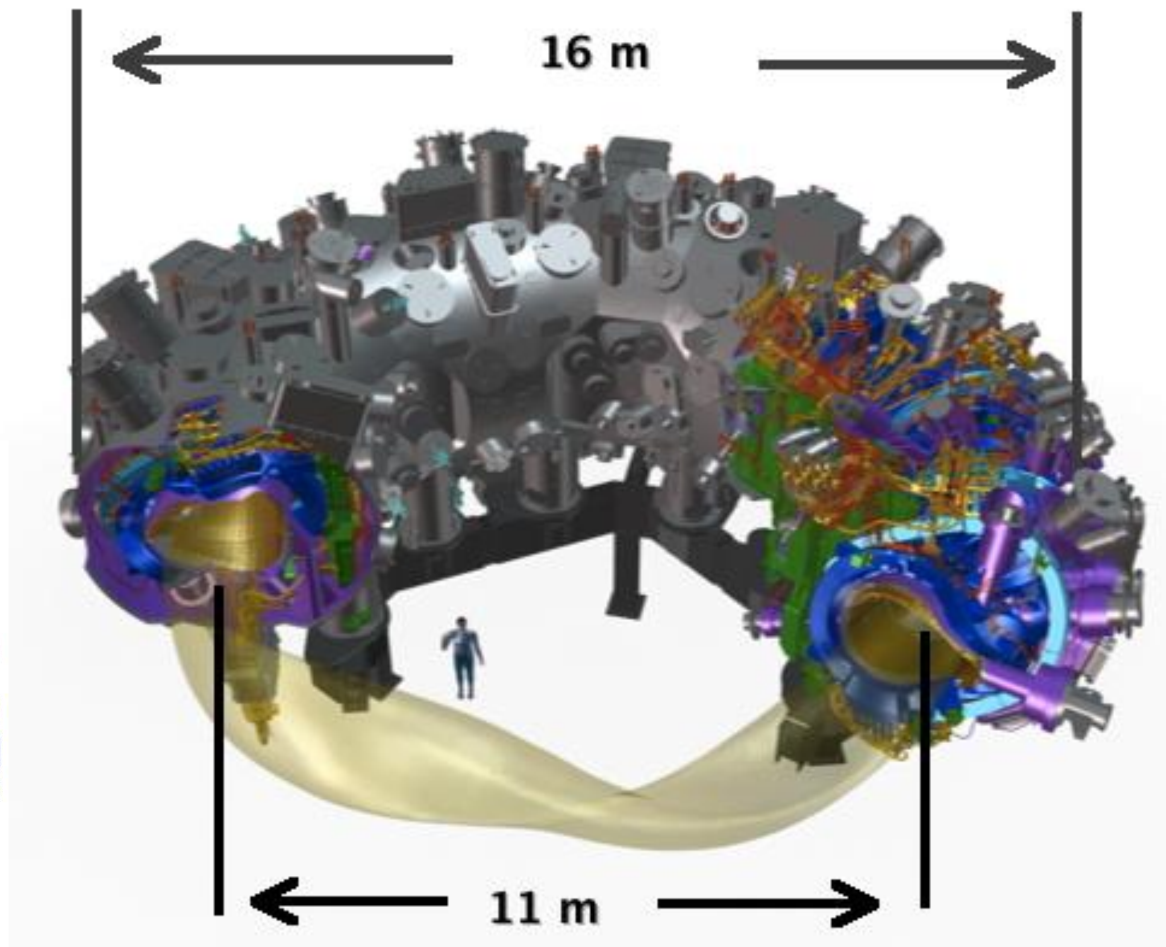
Introducing the W7-X stellarator

Hydrogen and deuterium plasma at 100 mio °C

B=2.5 T superconducting coil system, NbTi at -270°C





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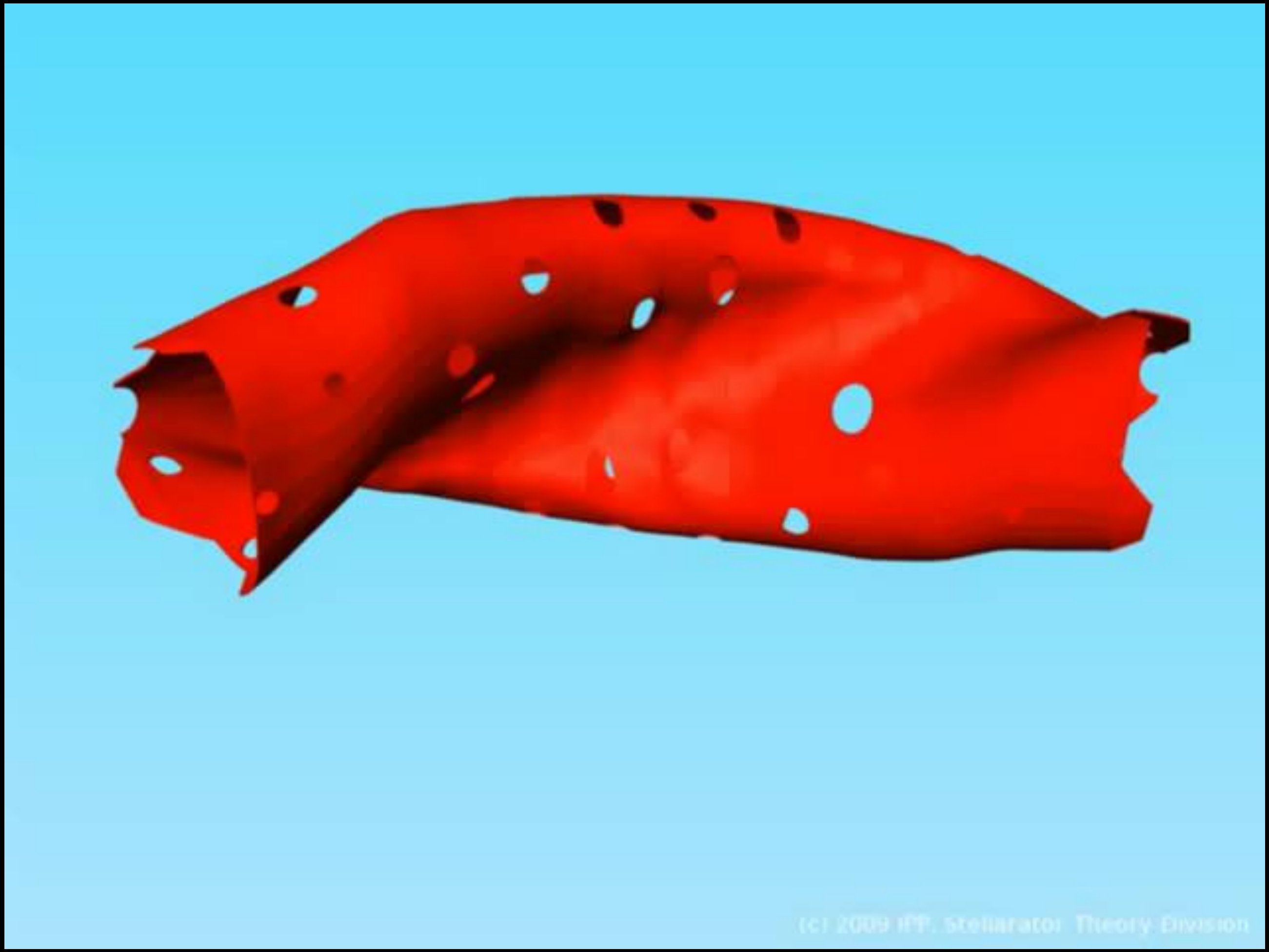
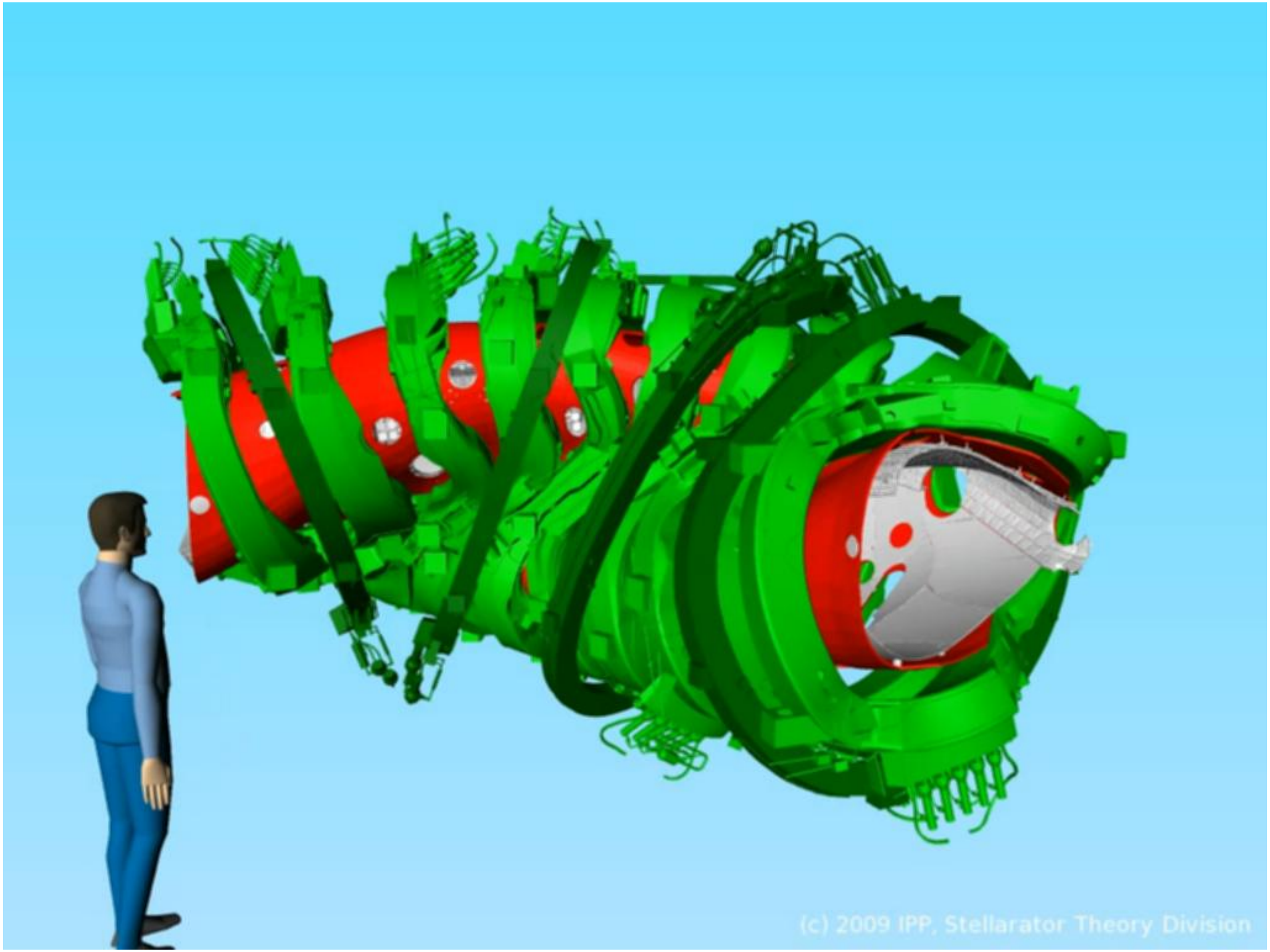
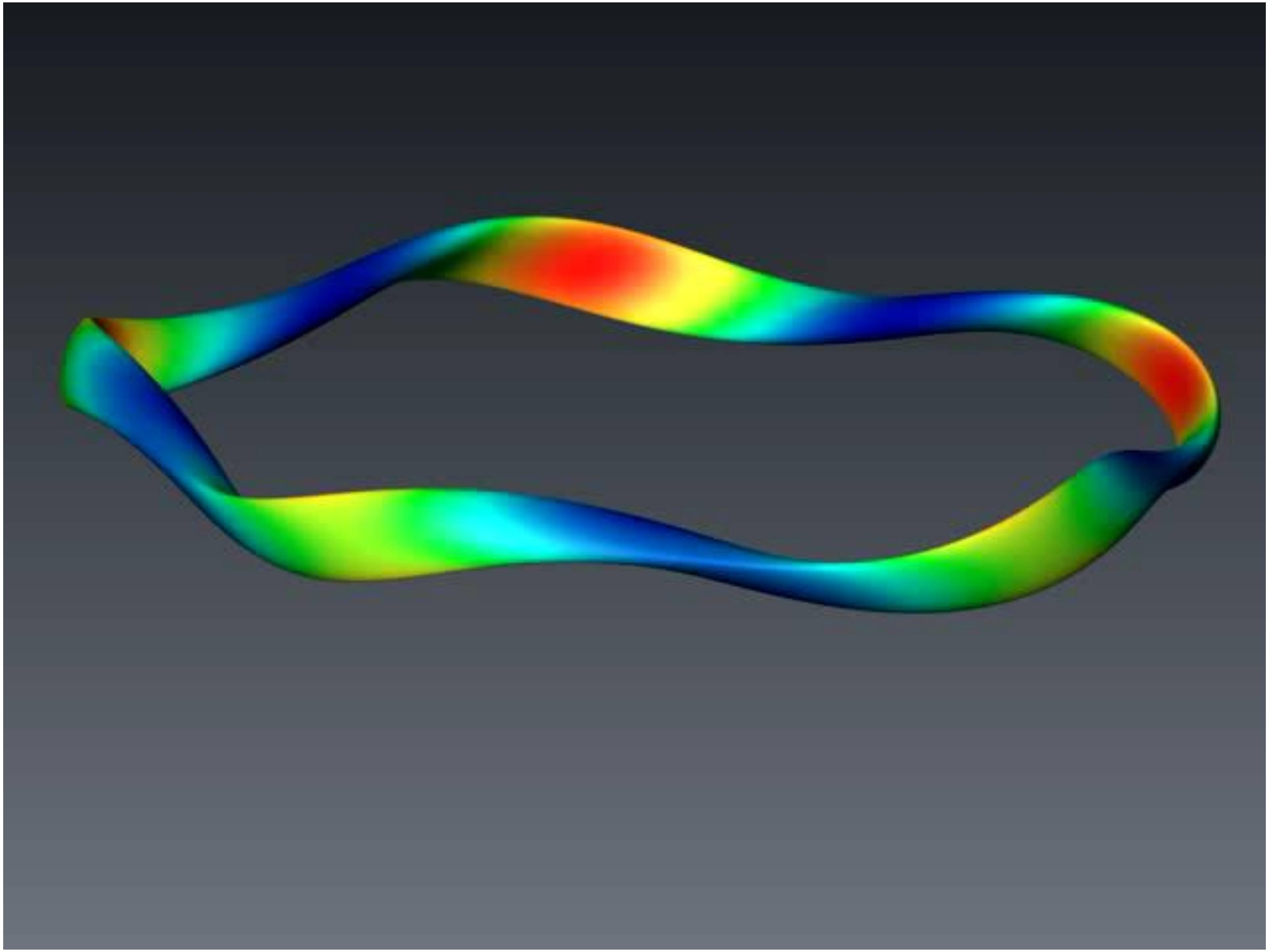
Wendelstein 7-X construction



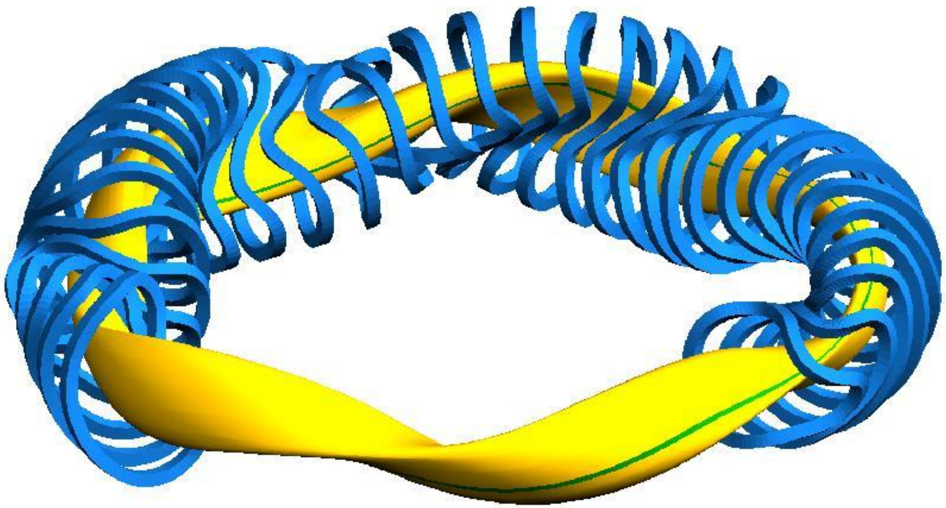
Wendelstein 7-X components



Wendelstein 7-X optimization



Wendelstein 7-X optimization



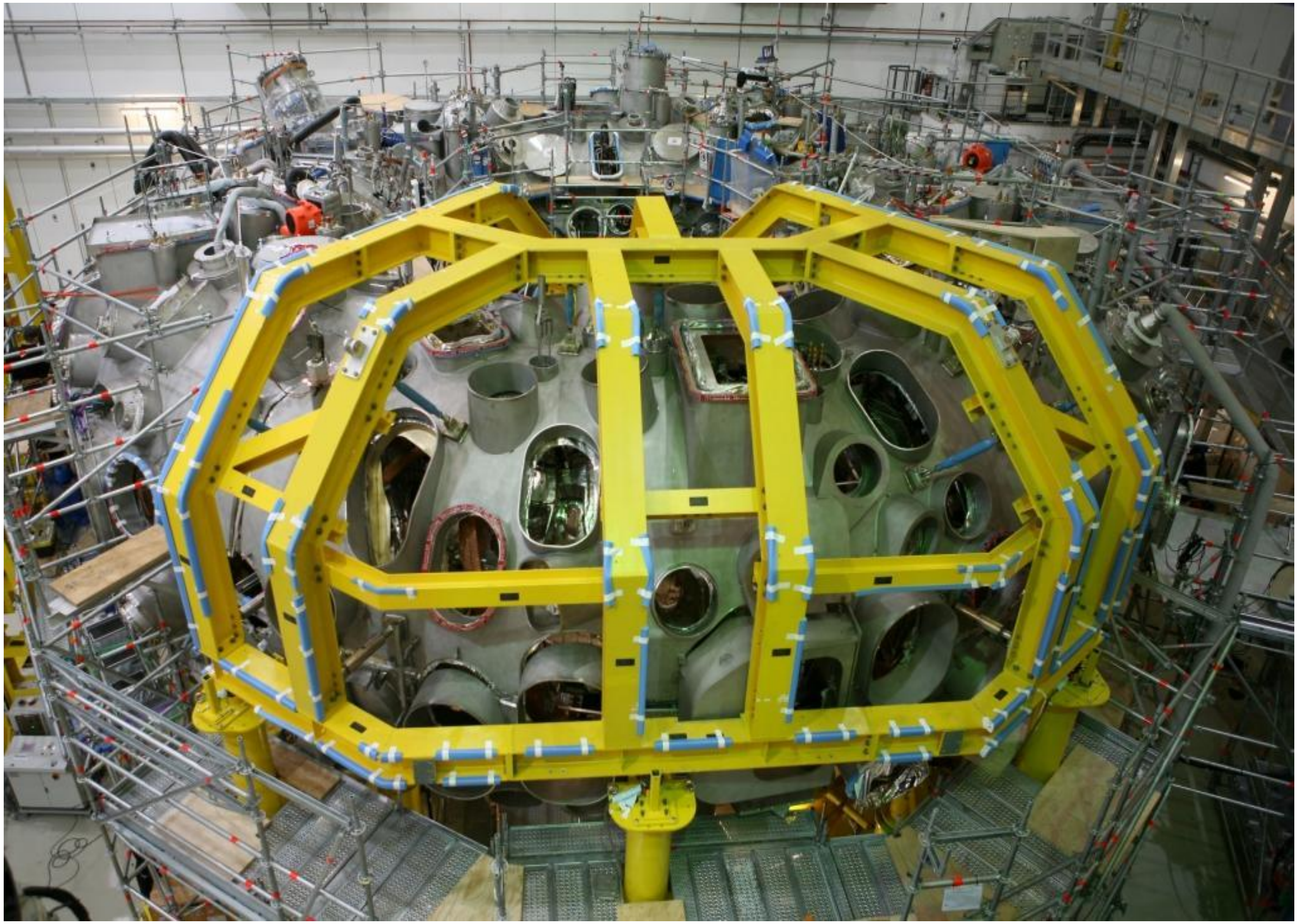
The magnetic field is optimized through analytical and computational calculations.

Some optimization goals:

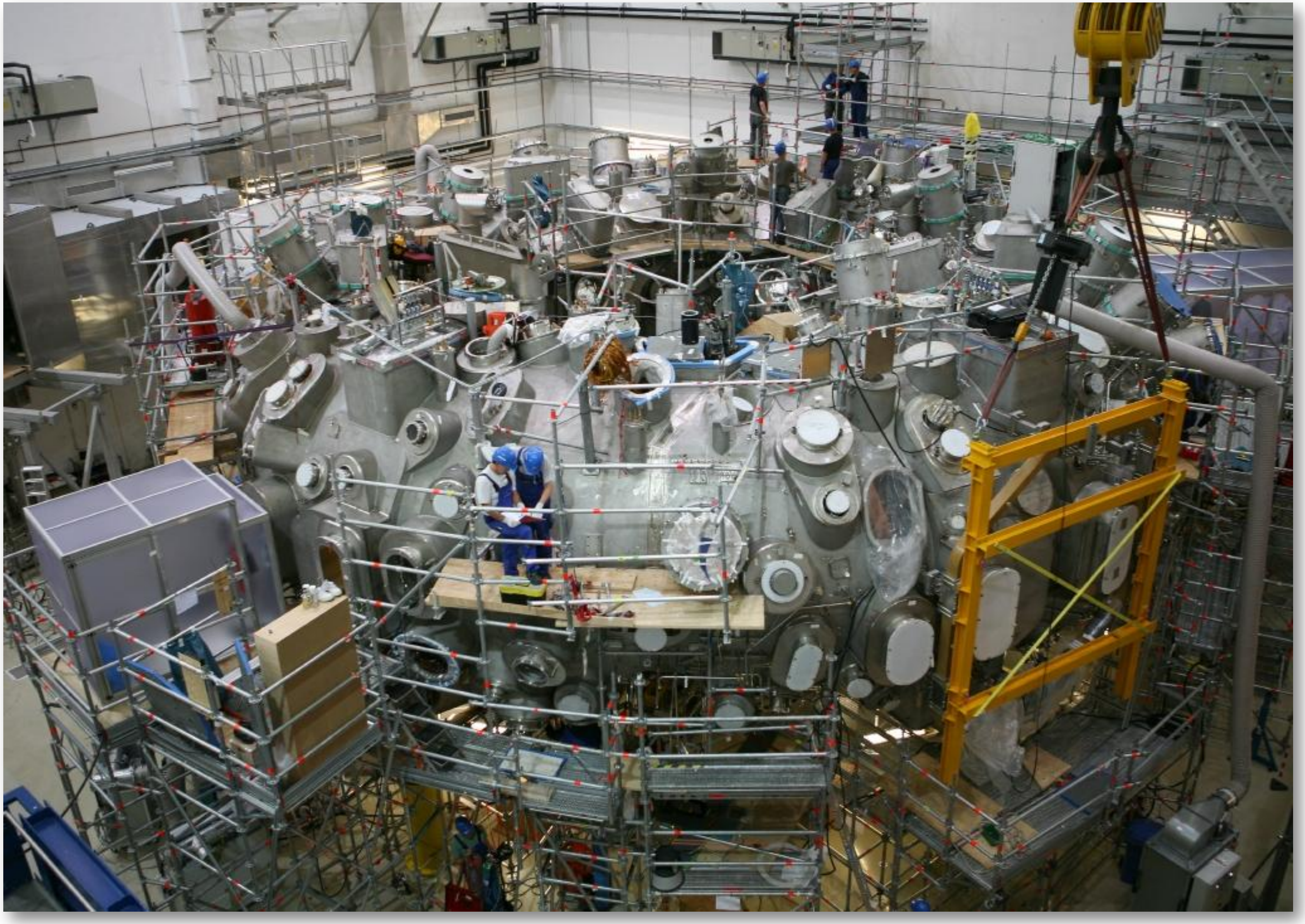
- Good plasma confinement
- Good plasma stability
- High achievable plasma pressure
- Adequate exhaust and impurity control

The coil set was designed to exactly create the magnetic field required.

The main 70 coils are installed since 2011



Infrastructure completion (1: 2012)



Infrastructure completion (2: Nov 2013)

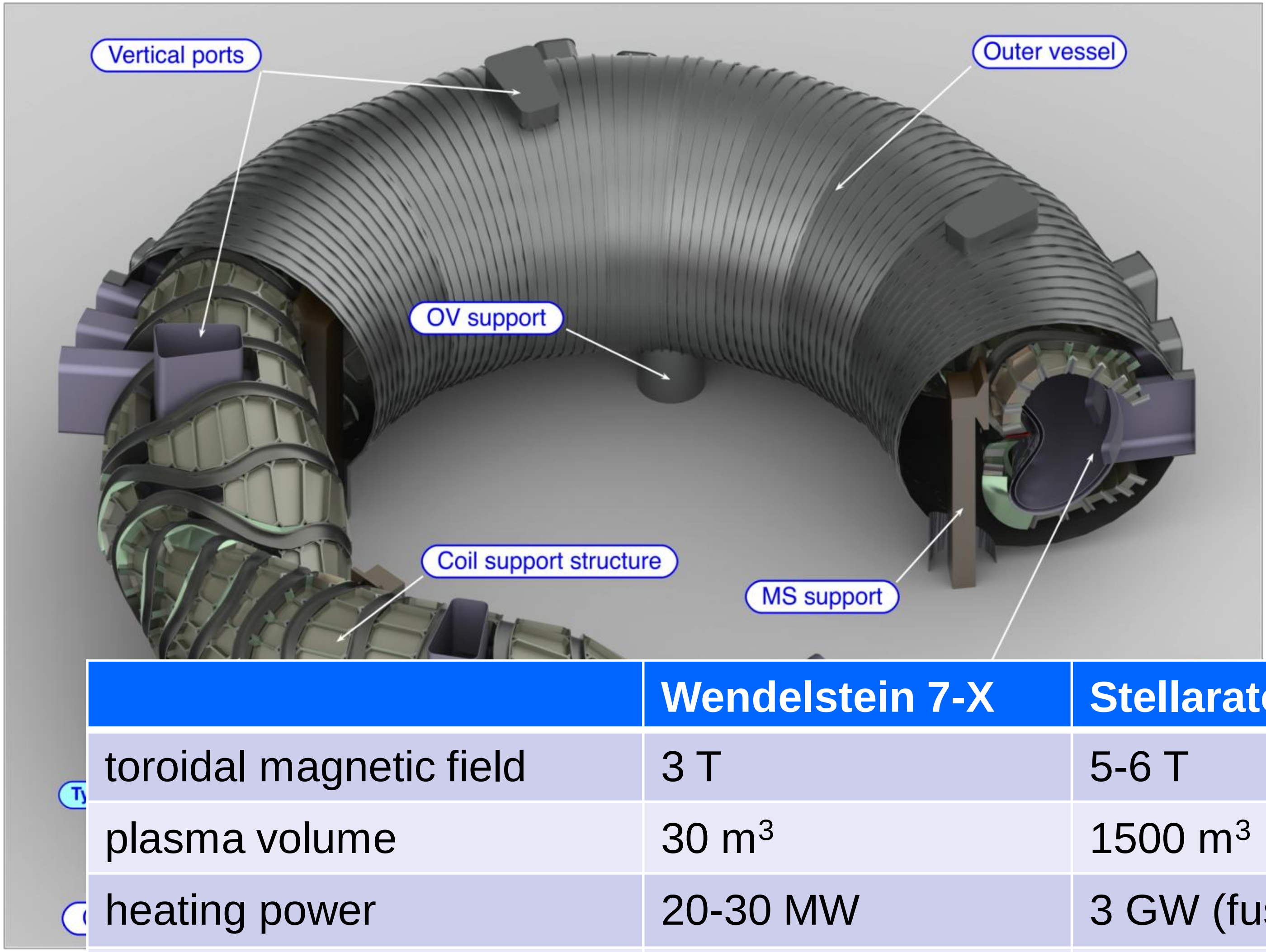
Wendelstein 7-X schedule

- May 2014: Beginning of commissioning
- Spring 2015: First plasmas
  - 1 second pulses with 2 MW of heating
- Mid 2016: First upgrade complete
  - 10 second pulses with 8 MW of heating
- Mid 2019: Second upgrade complete
  - 30 minute pulses with 10 MW of heating
  - The pulse length is only limited by the temperature rise in the cooling water (no cooling tower in the budget)
  - (10 second boosts of up to 18 MW of heating)

Wendelstein 7-X goals

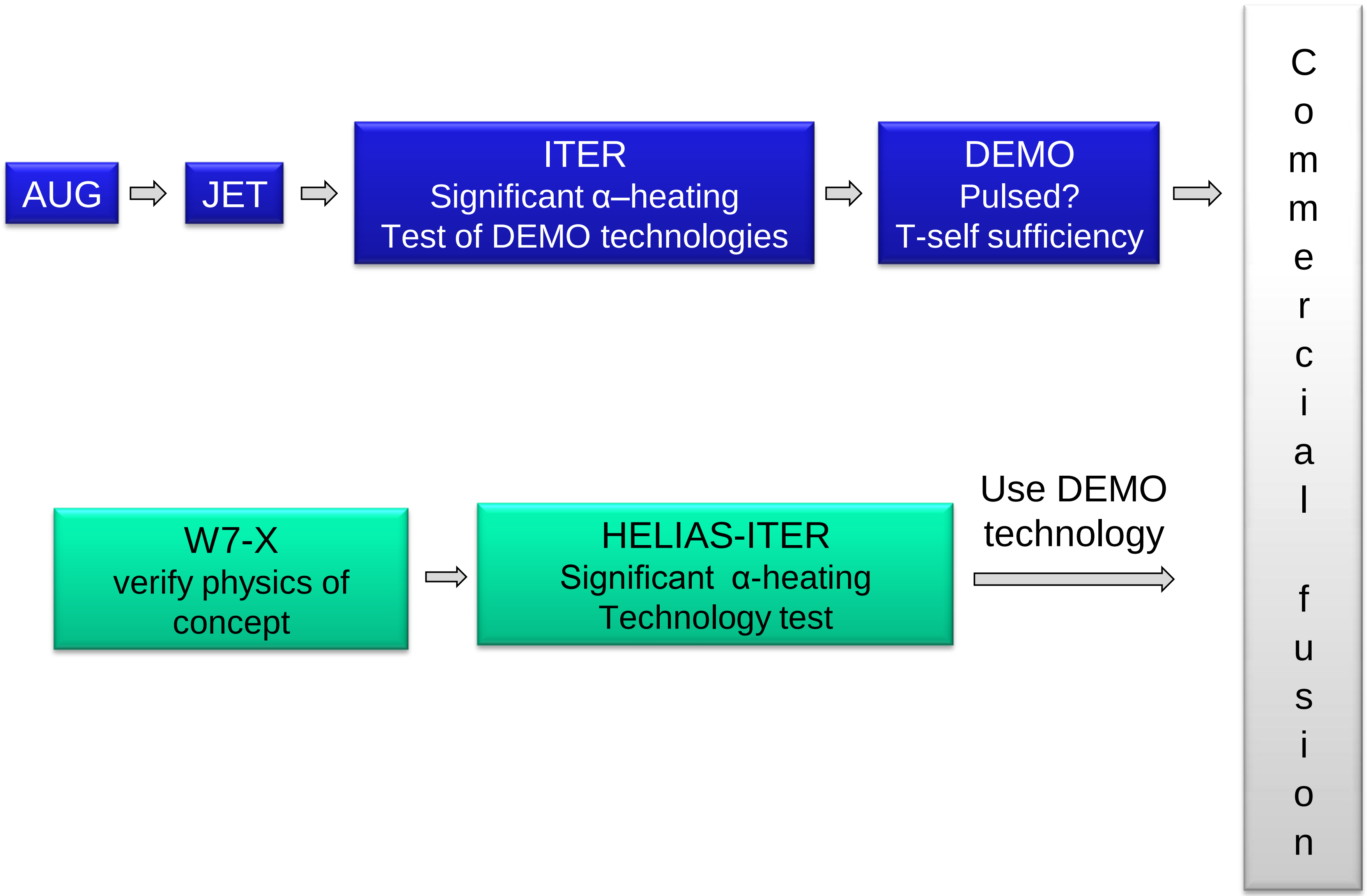
- Simultaneous achievement of:
  - High temperature (factor 2-3 below ITER)
  - High pressure relative to B-field, β (ITER range)
  - Good confinement τ (factor ~10 below ITER)
  - Acceptable impurity content (ITER range)
- 30 minute pulses (ITER range)
  - Ensures steady state for:
    - Plasma+magnetic field
    - Plasma heating/energy/pressure
    - Plasma particle fueling/exhaust/plasma density
    - Plasma-wall interactions
      - Thermal steady state for all in-vessel components

Stellarator reactor vision (Europe)



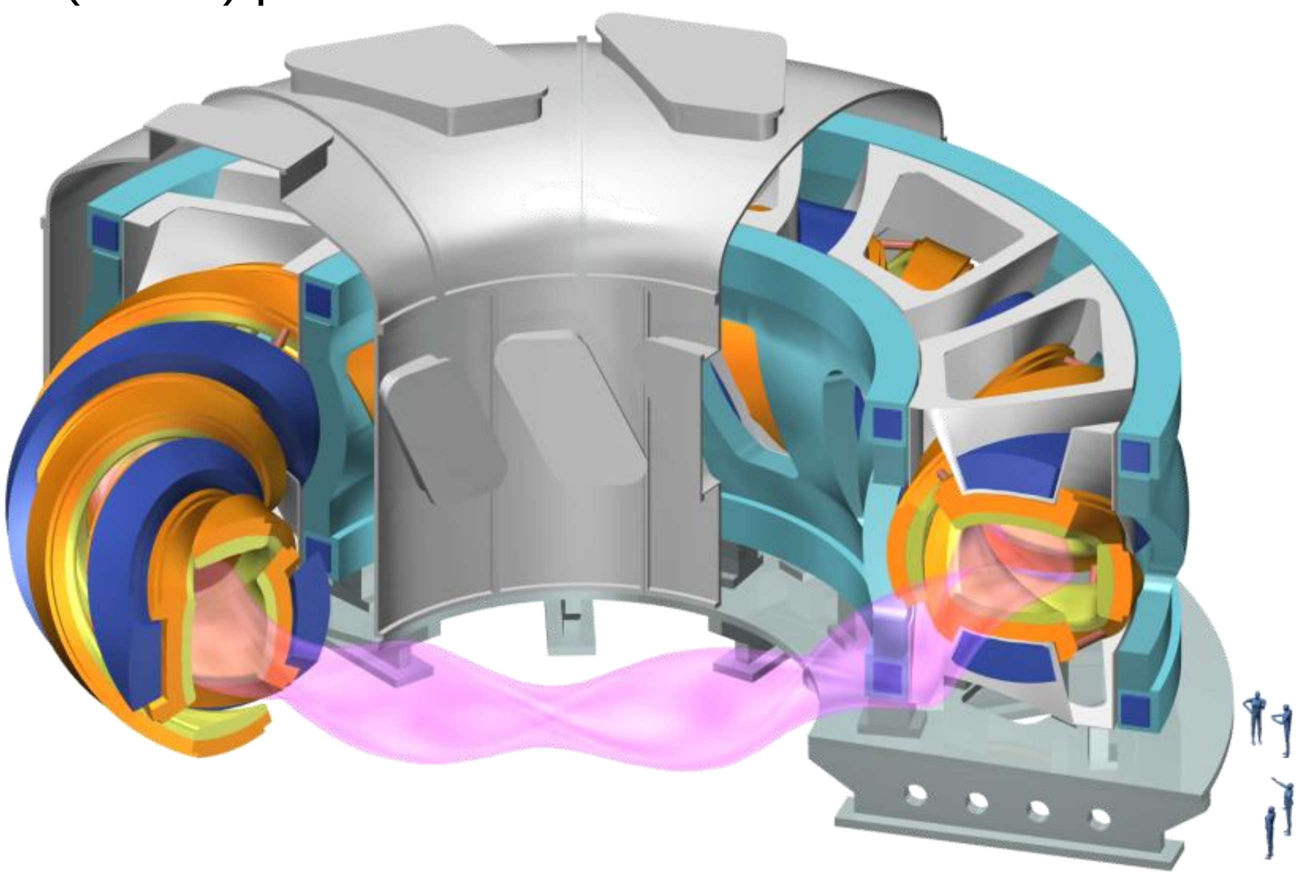
	Wendelstein 7-X	Stellarator FPP
toroidal magnetic field	3 T	5-6 T
plasma volume	30 m^3	1500 m^3
heating power	20-30 MW	3 GW (fusion power)
average neutron heat load		**1 MW/m^2**
average plasma heat load	0.1 MW/m^2	0.4 MW/m^2

European roadmap to a stellarator reactor



Stellarator/heliotron reactor vision (Japan)

Size R=17 m allows for plenty of space for blanket and radiation shield
Magnetic field will be 4.6 T, slightly smaller than ITER
Neutron loading will be low compared to tokamak reactor (2 MW/m^2)
3 GW thermal (fusion) power



A Japanese roadmap to a fusion reactor

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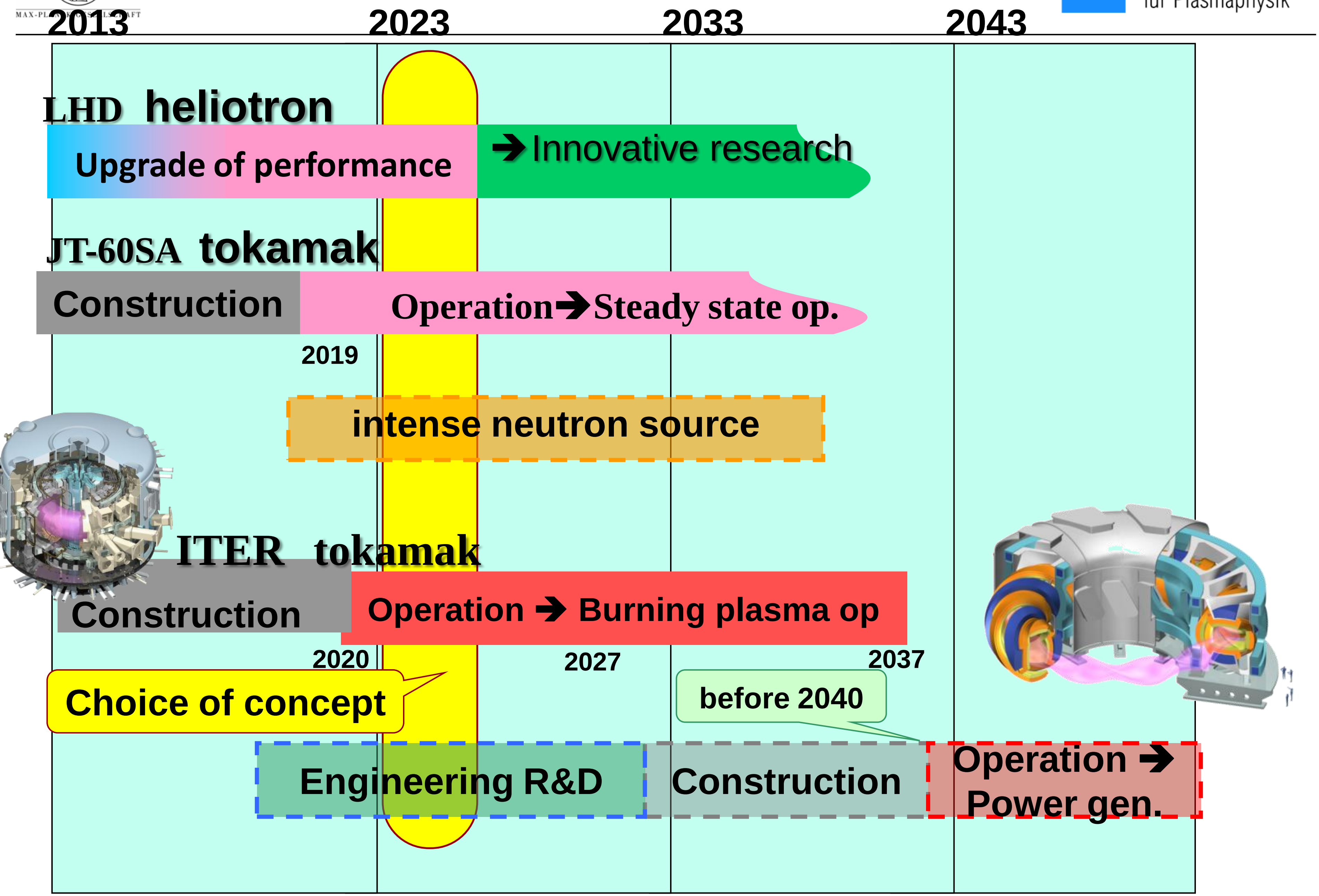

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US stellarator vision: compactness

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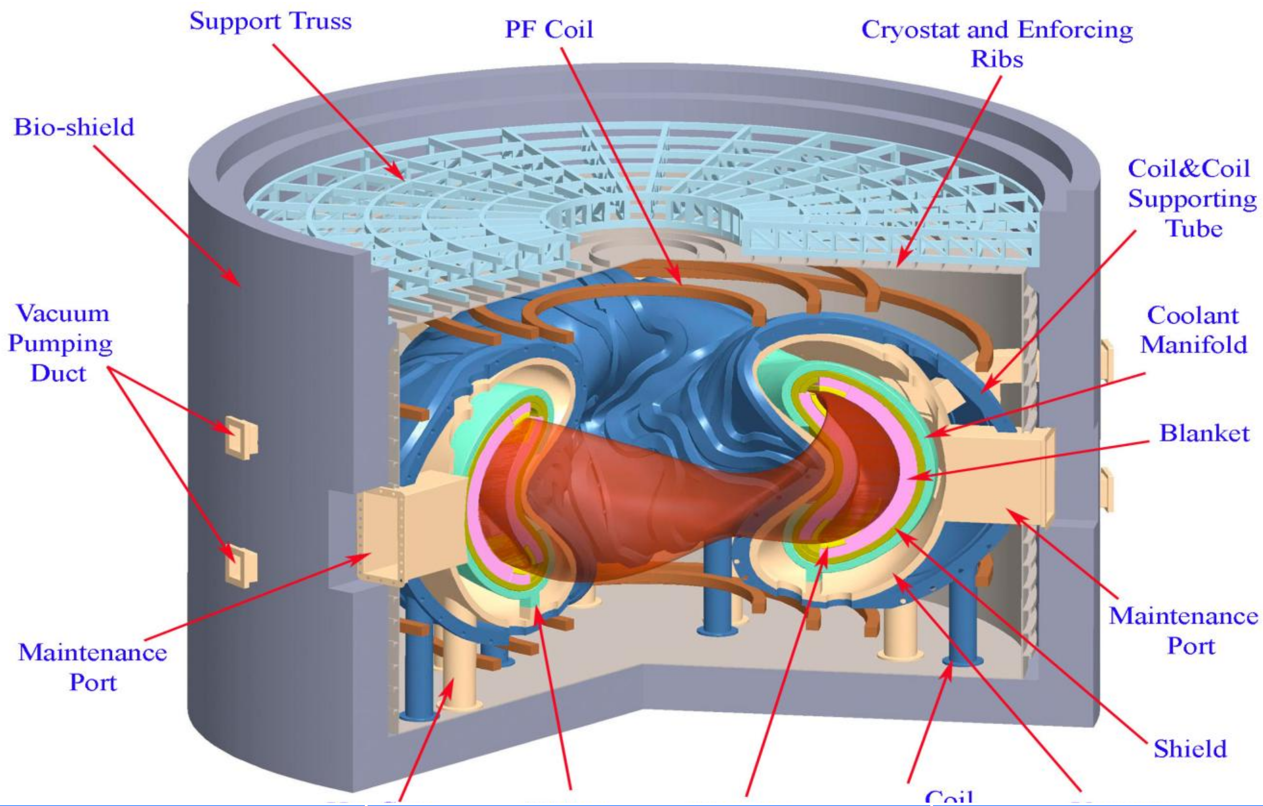

	US stellarator reactor vision	German stellarator reactor vision
toroidal magnetic field	5.7 T	5-6 T
plasma volume	500 m^3	1500 m^3
heating power Neutron wall load	2.3 GW (fusion power) 4 MW/m^2	3 GW (fusion power) 1 MW/m^2

To-do list for the stellarator/heliotron reactor

- Assume: W7-X and LHD successfully achieve their goals
  - Steady state, high performance, stable operation
    - (Also a goal for ITER)
- What then needs to be proven in a next-step stellarator?
  - Fusion burn control:
    - D-T fueling control (ITER ➔ stellarator?)
    - He exhaust removal control (ITER ➔ stellarator?)
    - Stable operating point (ITER ➔ stellarator?)
  - Tritium breeding from lithium (initial studies in ITER)
  - Long term integrity of plasma facing components (ITER, initial studies)
  - Low recirculating power/efficient electricity production
    - Should be easier to achieve in a stellarator – no need for current drive

Summary

- Stellarators/heliotrons provide an alternative path to a magnetic fusion power plant
- Advantages include better stability and easier access to steady state operation
- The stellarator/heliotron is catching up with the tokamak (e.g. LHD)
- Coming generation:
  - W7-X will begin commissioning in about 6 months and have first plasma in about 18 months
- Main goal of W7-X:
  - Steady state, high pressure, high temperature plasma at high confinement quality
- To be shown still in next-step stellarator/heliotron:
  - Fusion burn: α confinement, α heating, α exhaust
- Power plant studies are underway