MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

Wendelstein 7-X on the path to a Helias Reactor

Samuel Aaron Lazerson
on behalf of the W7-X Team

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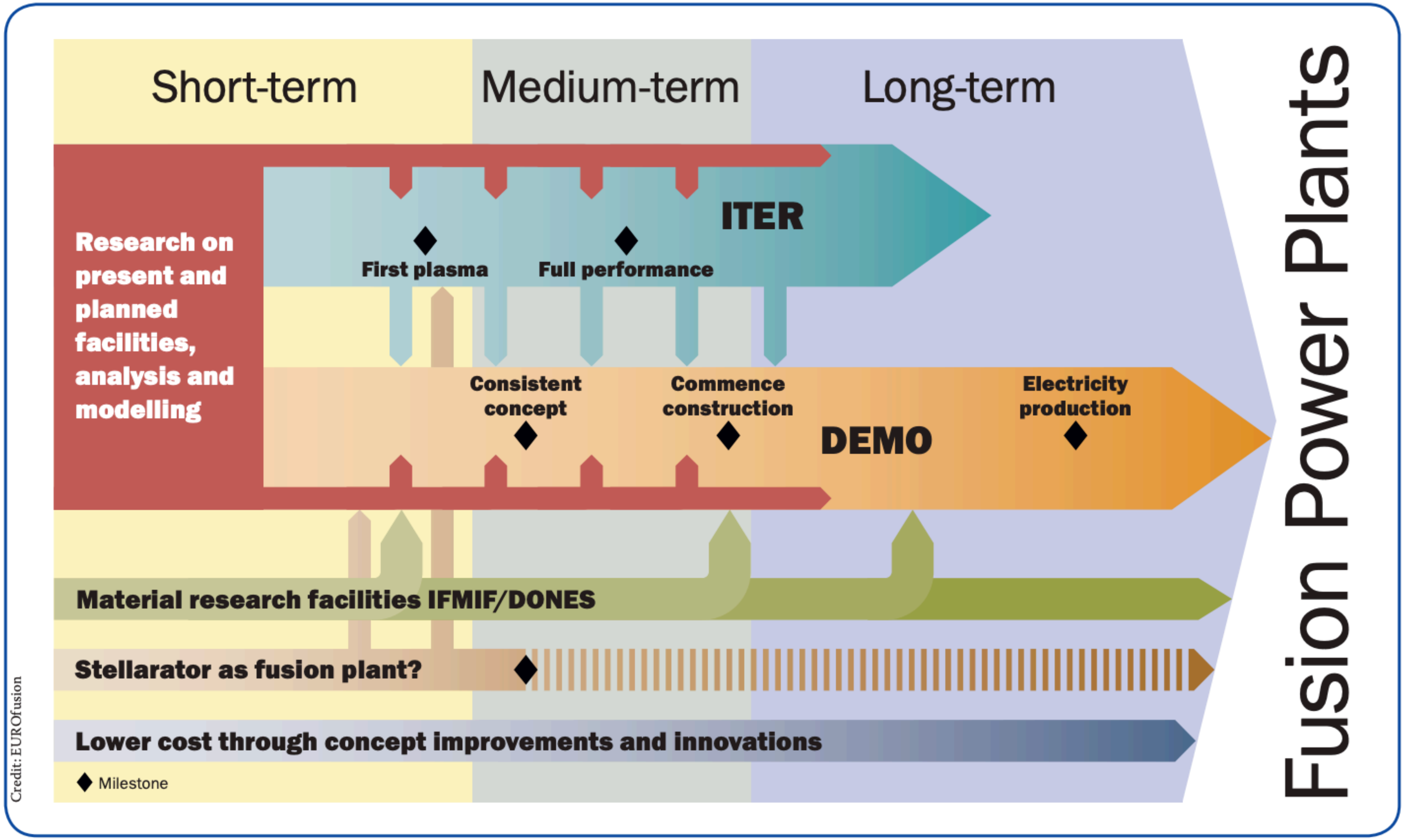
Stellarators contribute to the EU fusion energy roadmap



Donné, Morris: European Research Roadmap to the Realization of Fusion Energy
https://www.euro-fusion.org/fileadmin/user_upload/EUROfusion/Documents/2018_Research_roadmap_long_version_01.pdf

Stellarators solve the challenge of steady state operation

Transient Free - No need for ELM control

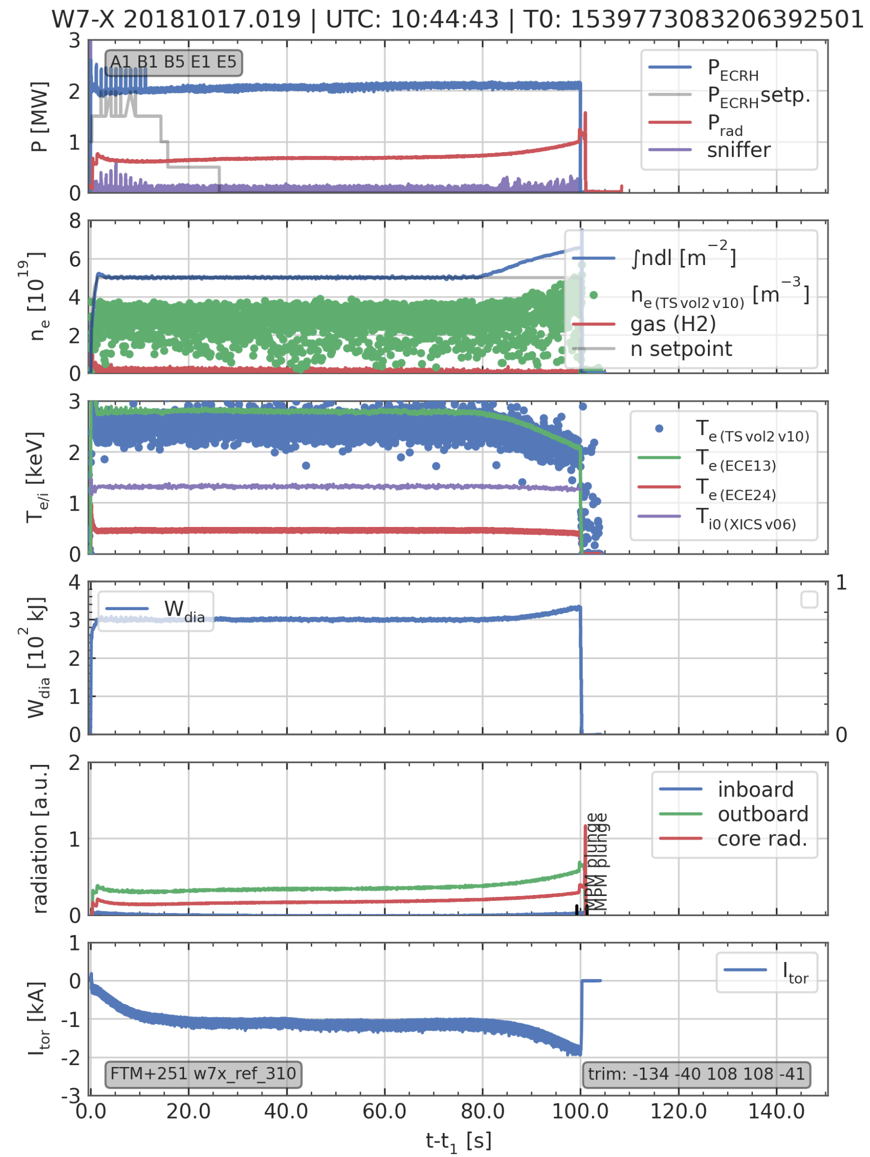
Inherently Non-Inductive - No need for current drive

Disruption Free - No need for disruption mitigation schemes

Physics is baked-in - Costs are in the design not the operation

No Greenwald Density Limit - High density lower temperature operation is possible

Stable power detachment demonstrated - minimal control systems needed



Wendelstein 7-X is the worlds most advanced stellarator

Located in Greifswald Germany, W7-X began operation in 2015 and is now in its fourth experimental campaign.

Design criteria

R_{major}= 5.5 m

a_{minor} = 0.5 m

Volume = 27 m^3

P_{ECRH} = 10 MW, P_{NBI}=20 MW, P_{ICRH}=1.5 MW

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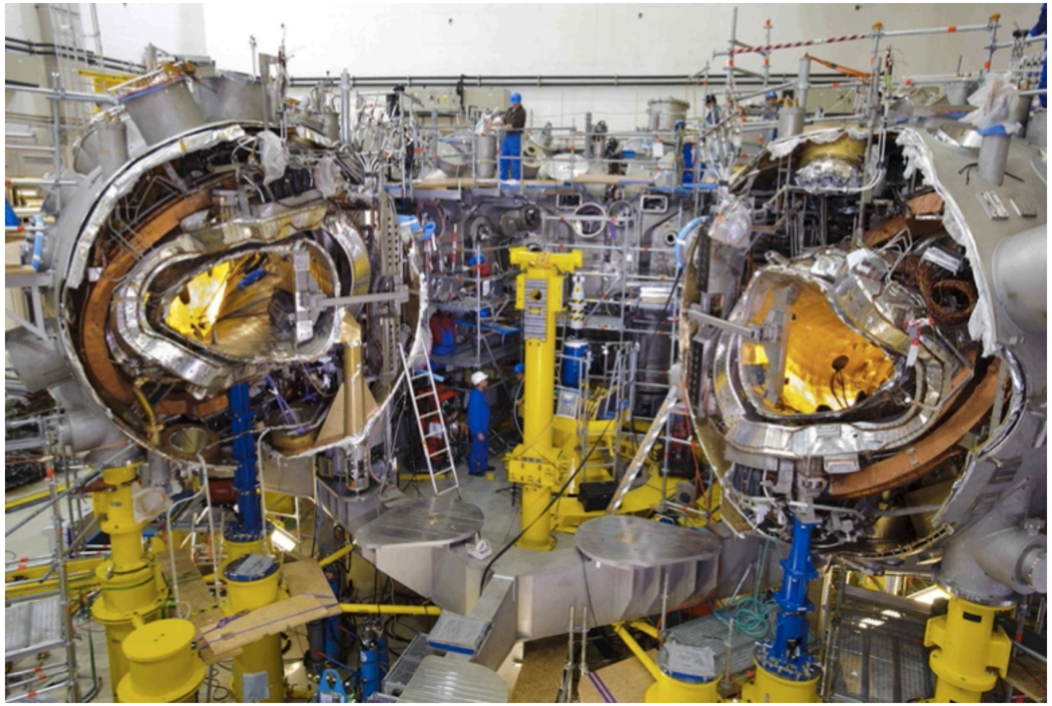

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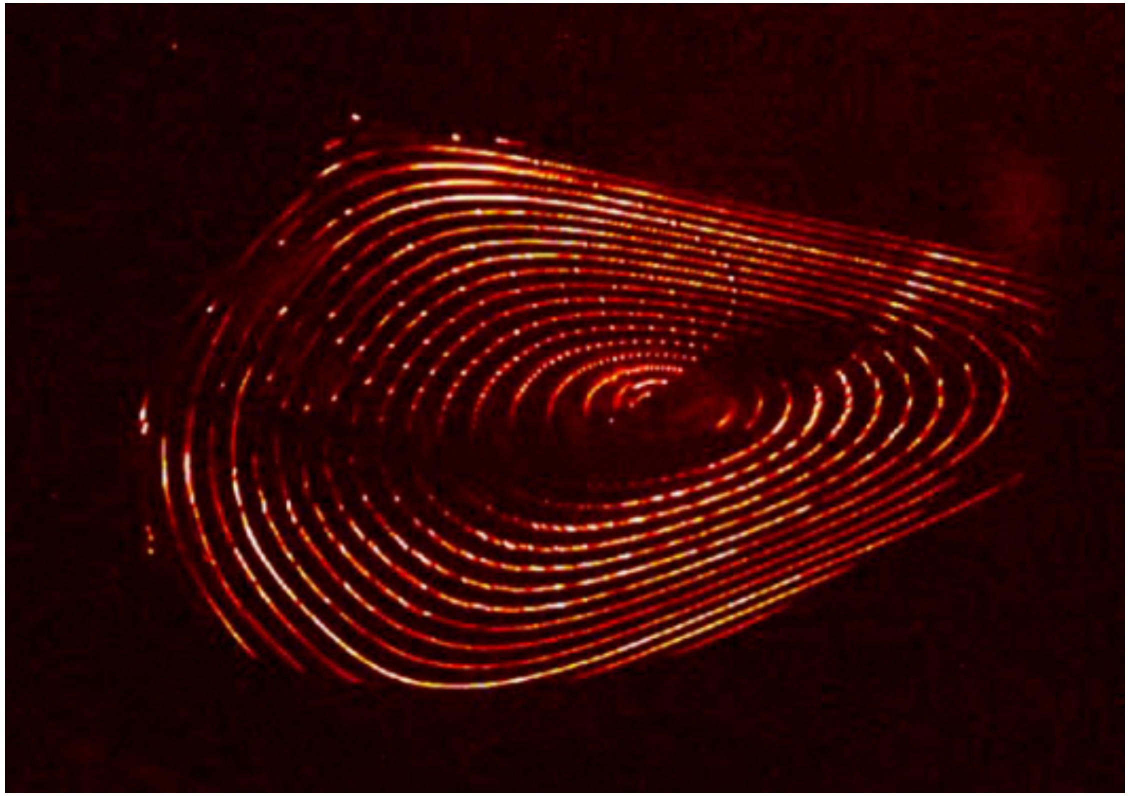

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1. Module coil design feasibility - ✓
2. Good magnetic flux surfaces - ✓

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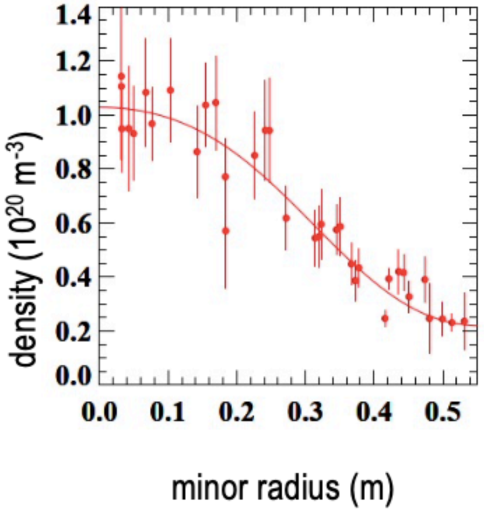

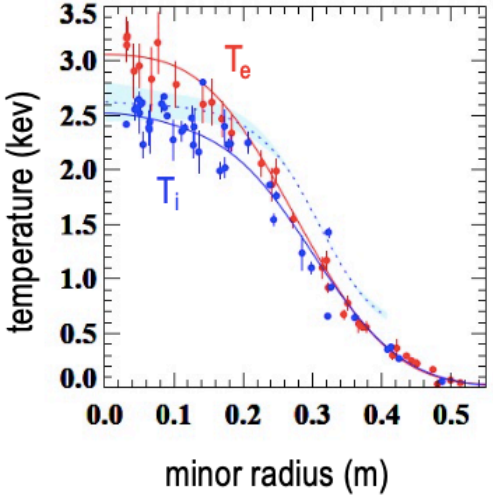

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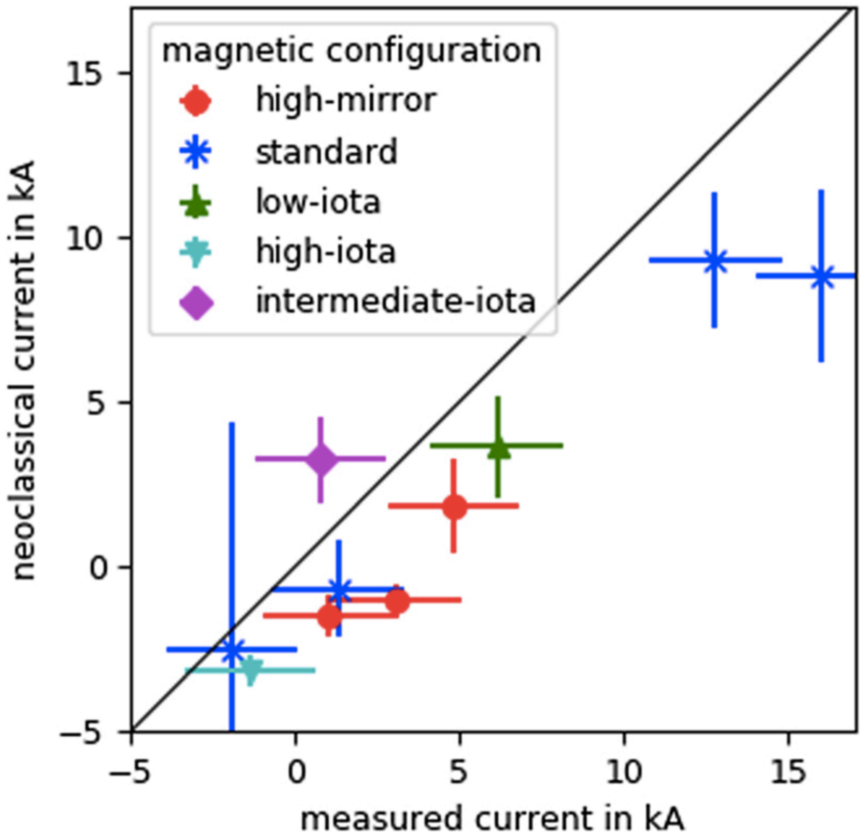
4. Small bootstrap current - ✓



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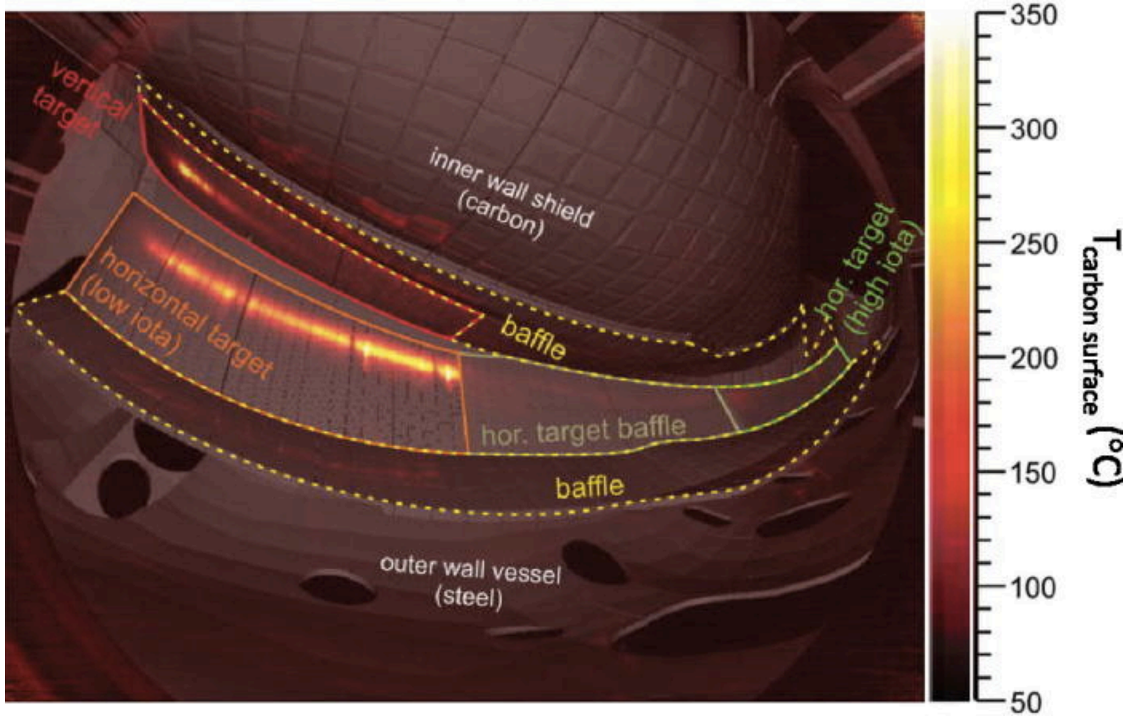

Design criteria

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2. Good magnetic flux surfaces - ✓
3. Reduced neoclassical transport (1/nu-regime) -✓
4. Small bootstrap current - ✓
5. Island divertor for steady-state exhaust - ✓

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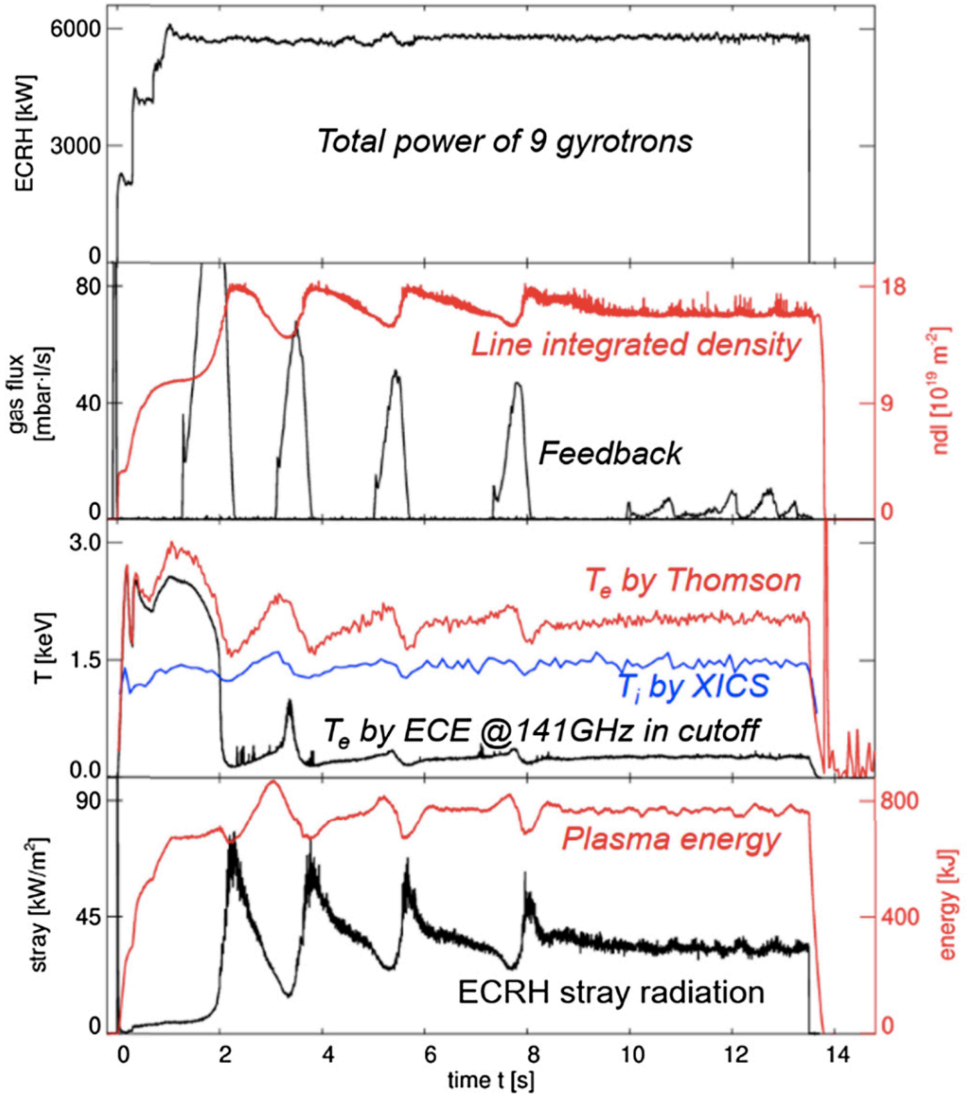

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6. Finite <ß>~5% stability

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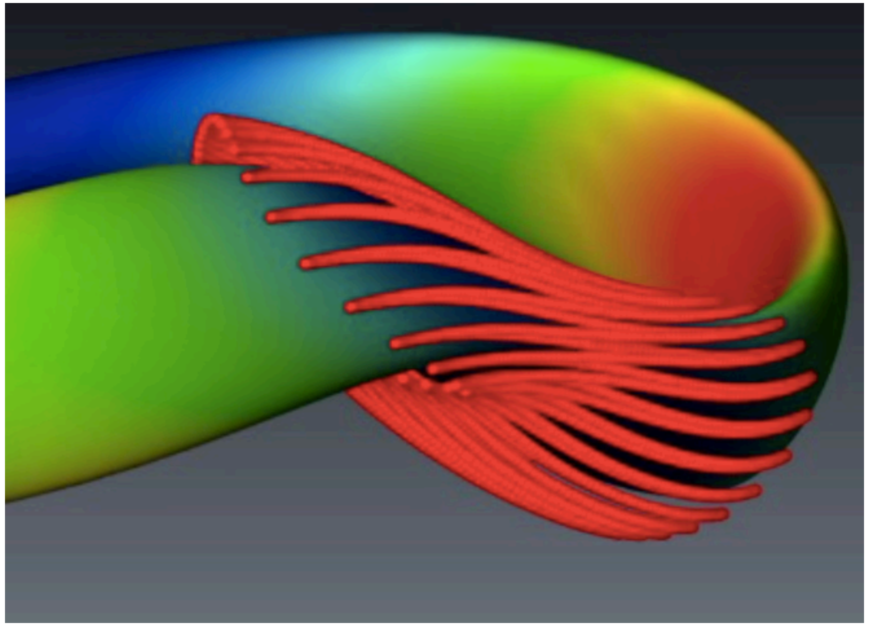
4. Small bootstrap current - ✓
5. Island divertor for steady-state exhaust - ✓
6. Finite <ß>~5% stability
7. Improved fast ion confinement



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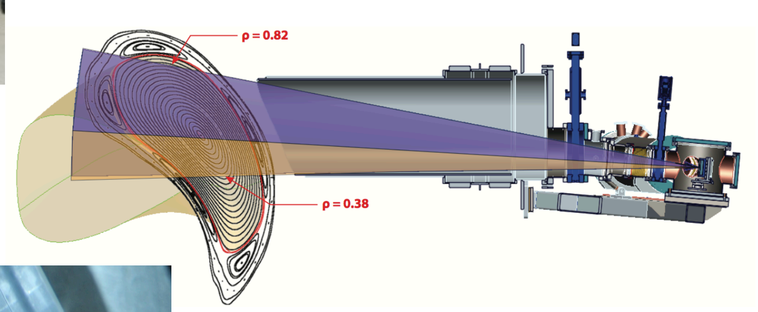
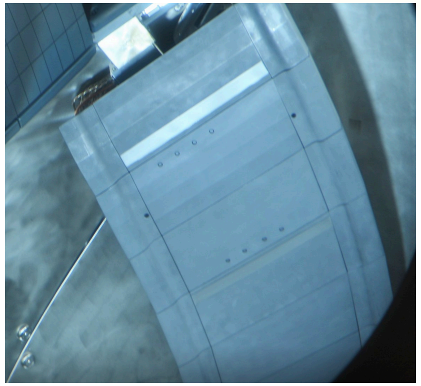
Technology development has been key to the success of W7-X

- Plant-like system data acquisition
  - Continuous along with pulsed data
- Long pulse diagnostic development
  - Active cooling, ECRH stray radiation, activation
- Long pulse heating and fueling technology
  - 1 MW Gyrotrons (1.5 MW in development)
  - Steady-state pellet injector
  - Divertor gas valves for steady-state detachment
- Neural networks for fast analysis
  - Equilibrium, fast profile inference, divertor safety

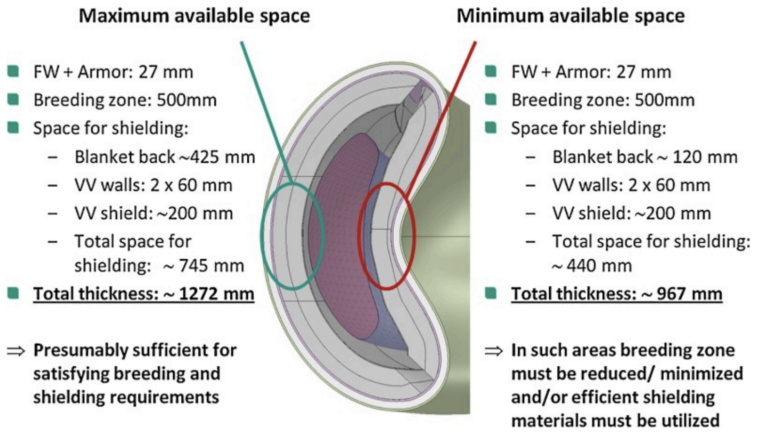




US contributions to W7-X play a large role in both achieving the goals of W7-X along with furthering technological development for future US based long-pulse machines.

W7-X research is brining the stellarator reactor concept to maturity

- **Confinement scalings are being expanded through experimentation**
- **The PROCESS systems code allows for costing of stellarator reactors**
- **Technologies for steady state operation are being developed and tested on W7-X**
- **Predictive codes are being validated against data on W7-X**



Stellarators provide a risk-averse approach to reactor design

Warmer et al. Fusion Engineer. and Design, 2017. https://doi.org/10.1016/j.fusengdes.2017.05.034