MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Superconducting magnet system of W7-X fusion experiment – Design and Operation experiences

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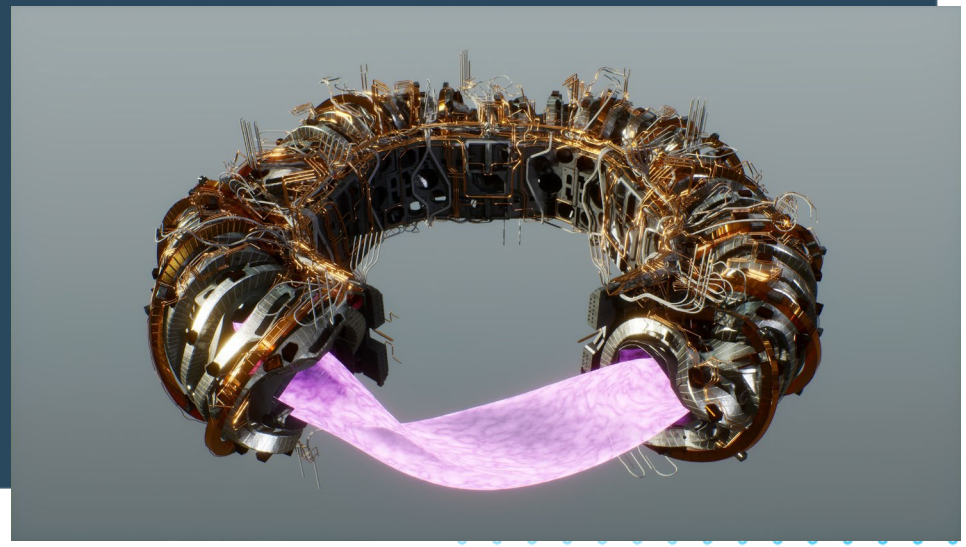
Wendelstein 7-X Magnetsystem



EUROfusion

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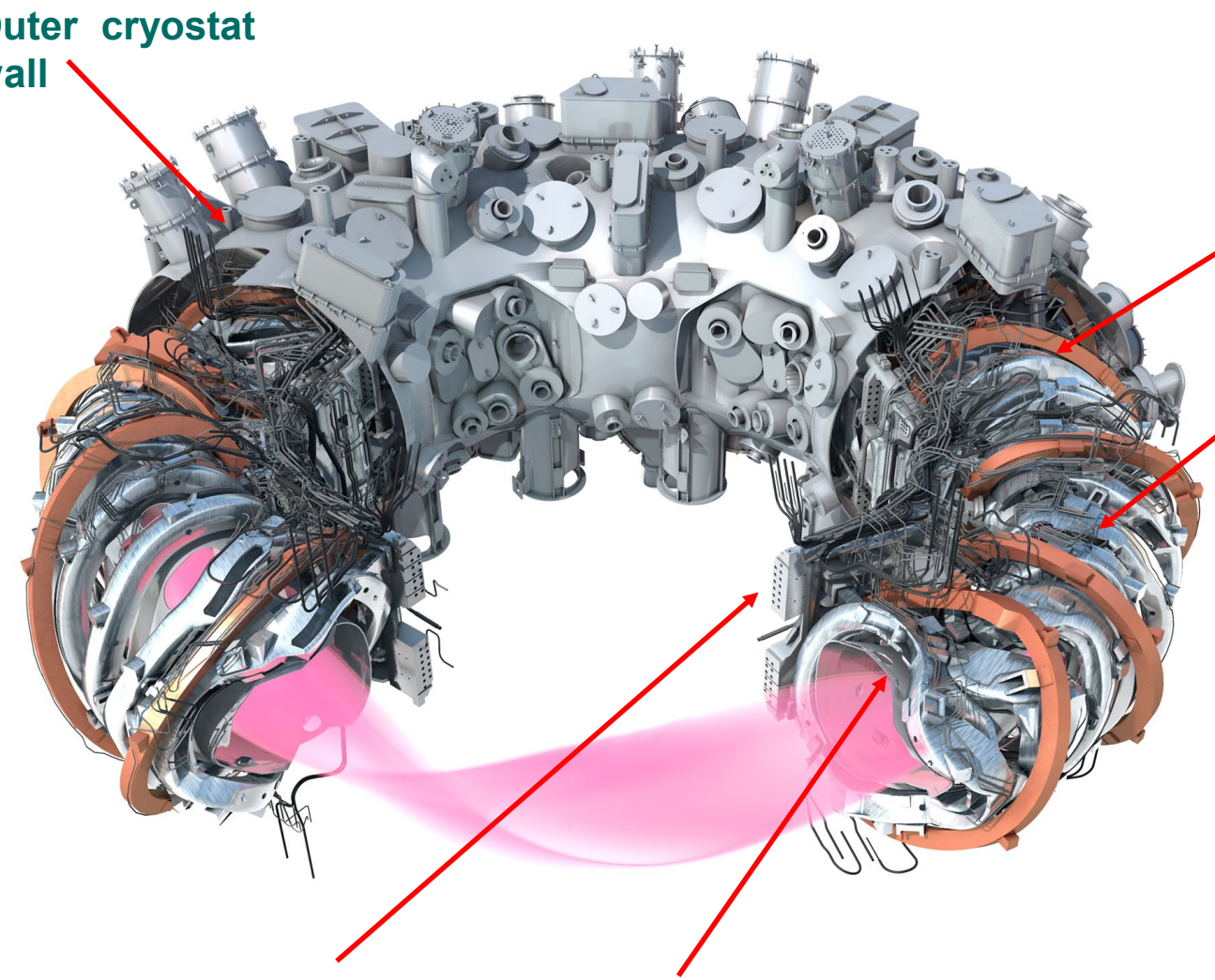
Wendelstein 7-X is a nuclear fusion experiment with magnetic confinement.

Source: IPP W7-X
Flux surface measurement

W7-X Superconducting magnet system



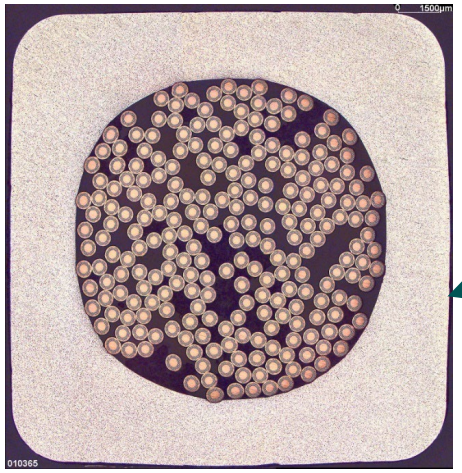
20 planar coils
nominal current of 16 kA at 4 K

50 non-planar coils
nominal current 17.6 kA at 4 K

7 electrical circuits
5 non-planar coil circuits
2 planar coil circuits
with 10 coils each in series

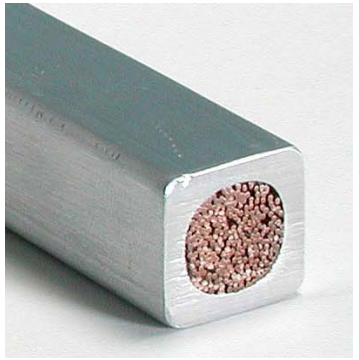
characteristic values
Magnetic field energy: 620 MJ
Magnetic peak field: 6.7 T
(on plasma axis 3 T)

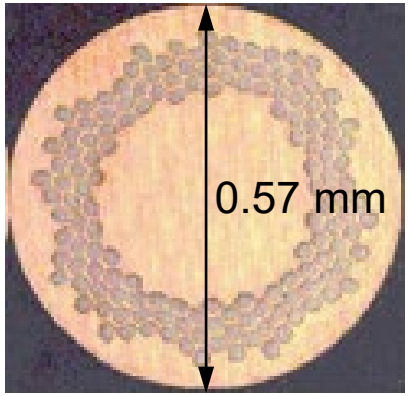
W7-X Superconductor



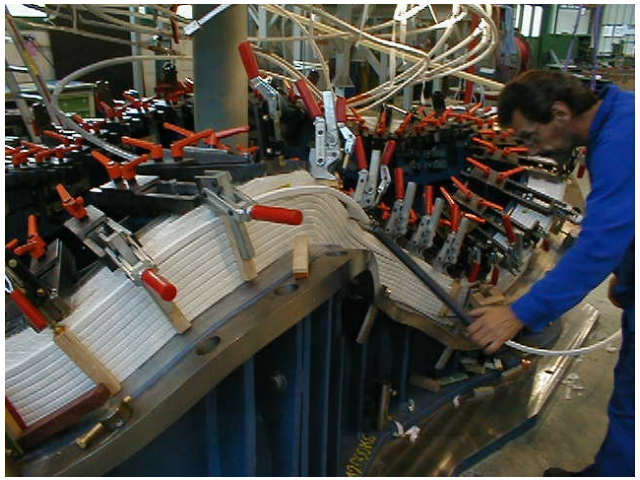
W7-X conductor cross section

W7-X superconductor with NbTi
Cable **i**n **C**onduit **C**onductor (CICC)



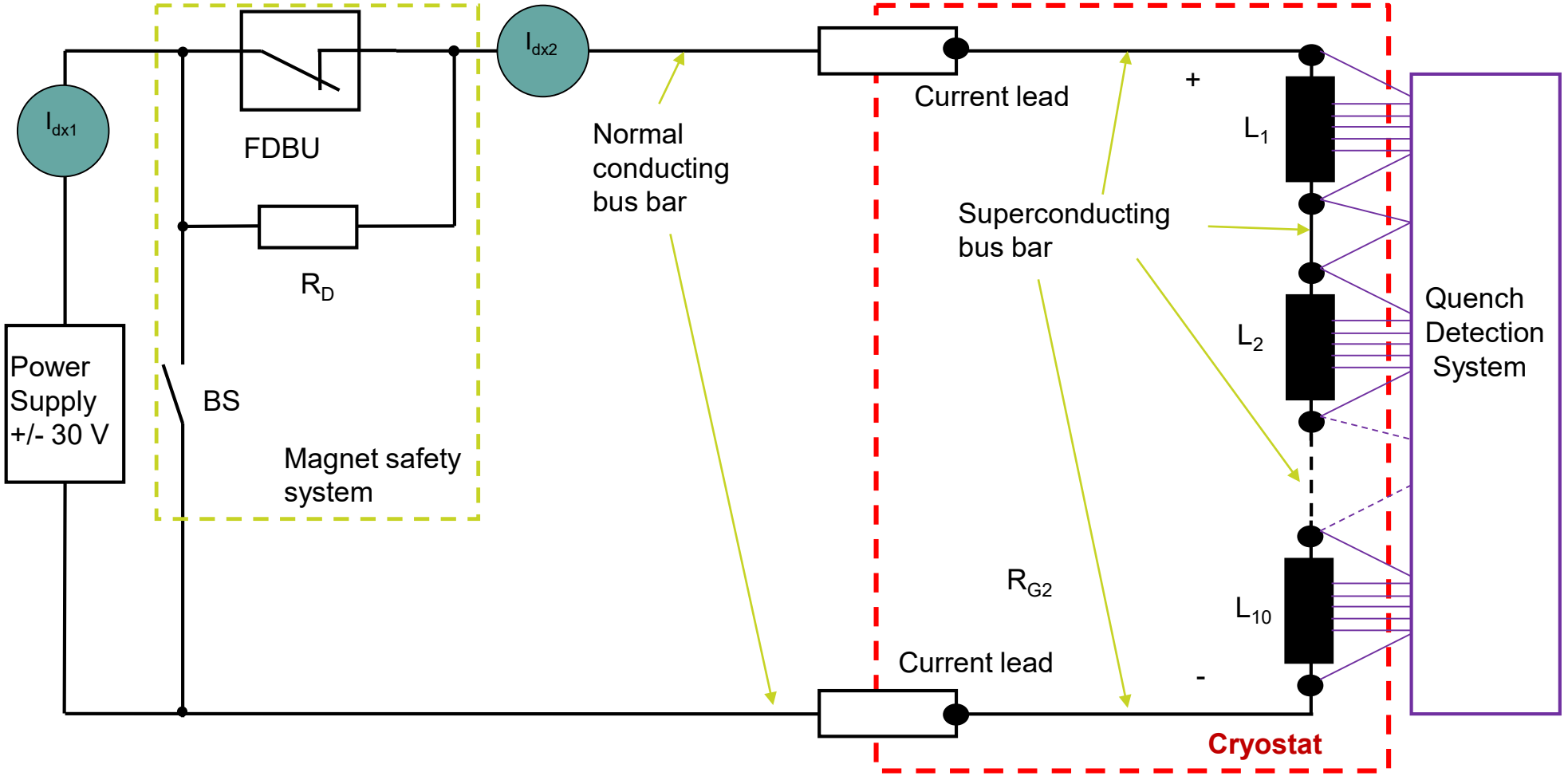


strand cross section



Strand diameter	0.57 mm
Ic (6 T/4,2 K)	> 150 A
Cu:NbTi	2.6 +/- 0.2
Cabling law	3x3x3x3x3
Number of strands	243
Jacket	AlMgSi (6063)
Wall thickness	> 2 mm
Outer dimension	16 x 16 mm^2
Al jacket yield strength Rp0.2	<150MPa soft cond. at room temperature >285MPa hard cond. at 4K
Void fraction	37 +2/-1%
Mass flow rate tolerance	+/-10%

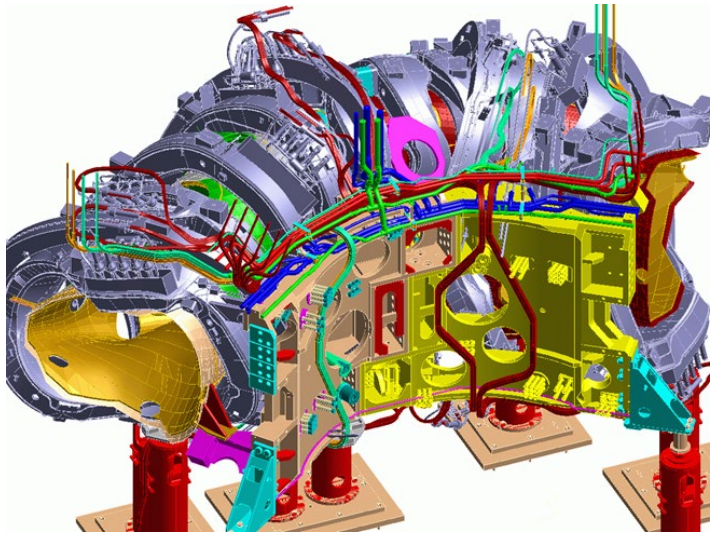
Superconducting magnet system

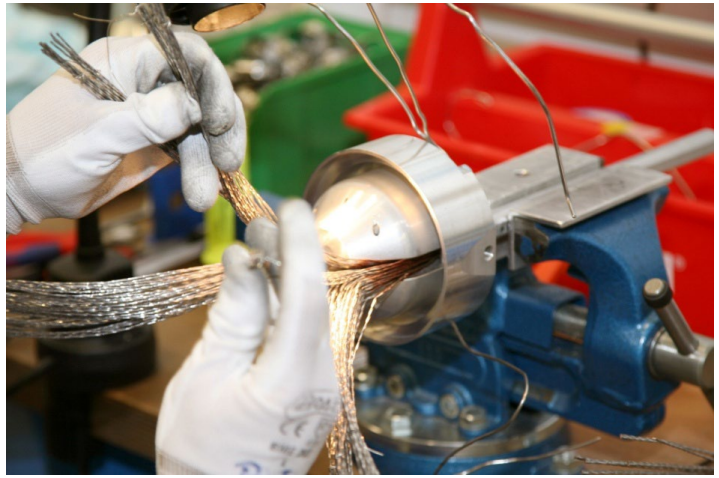


BS = bypass switch;
FDBU = fast discharge breaker unit (two bypass switches, two DC breakers and one explosive fuse)
R_D = discharge resistor

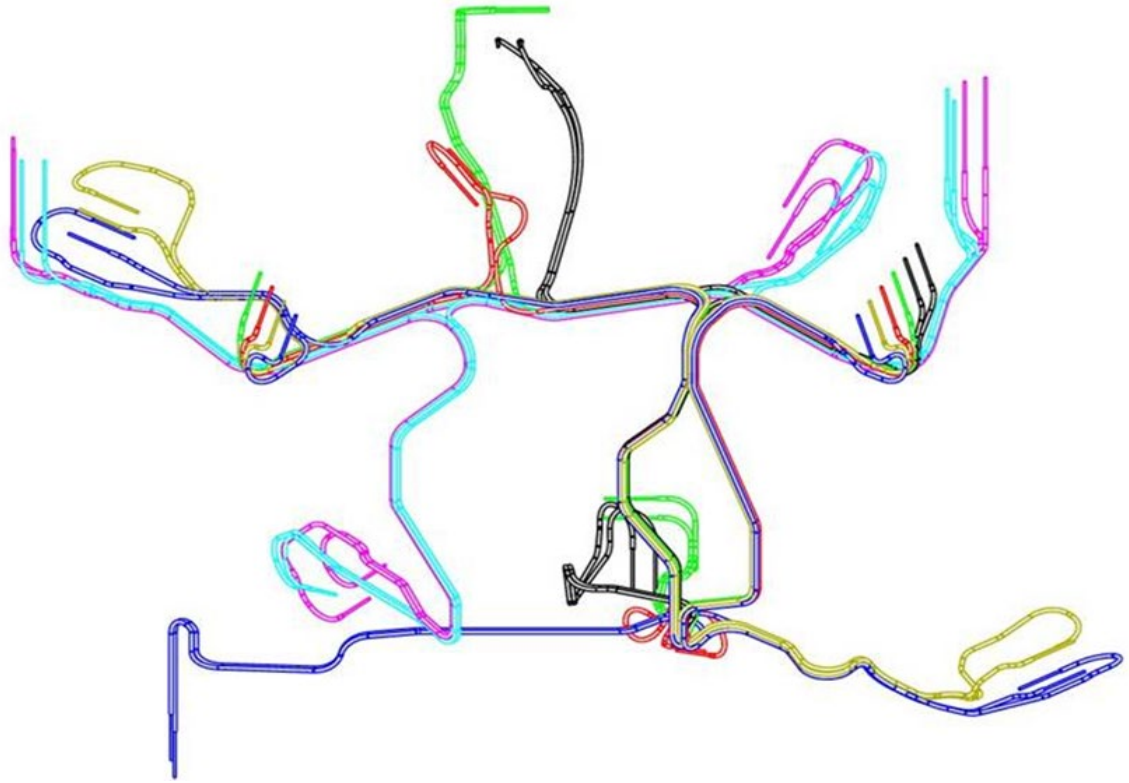
L_1 , L_2 …L_{10} : ten coils of the same type in series (1 H per circuit)
● Joint
QD Quench detection system

Bus system



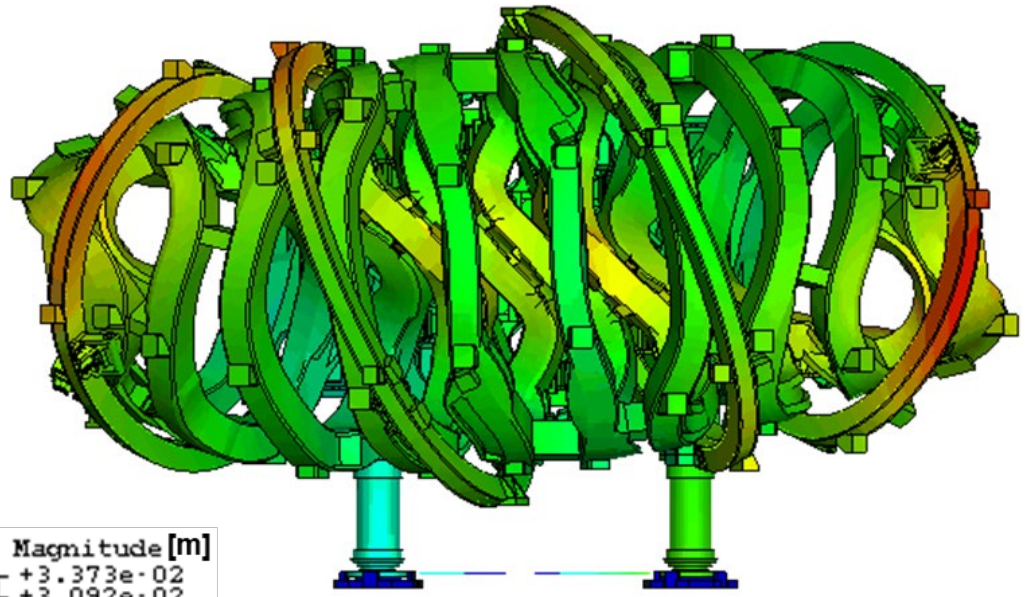


test joint manufacturing



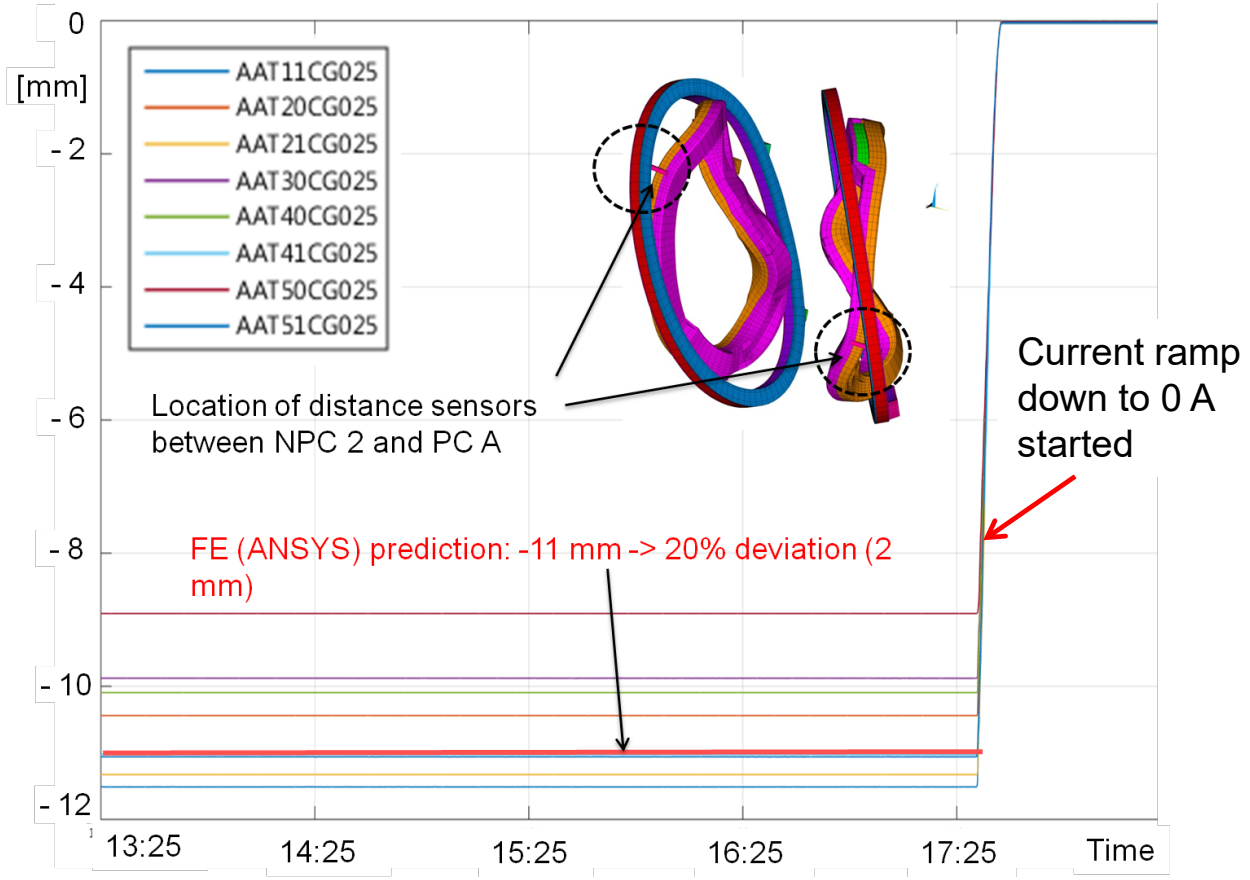
Bus bar system – manufacured at FZ Jülich, assembled by team from Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences.

Monitoring of mechanical behaviour



View on global FE model

Mechanical sensors:
- 510 strain gauges
- 58 distance sensors
- 88 contact sensors



Maximum measured relative displacements between NPC 2 coils and PLCA coils

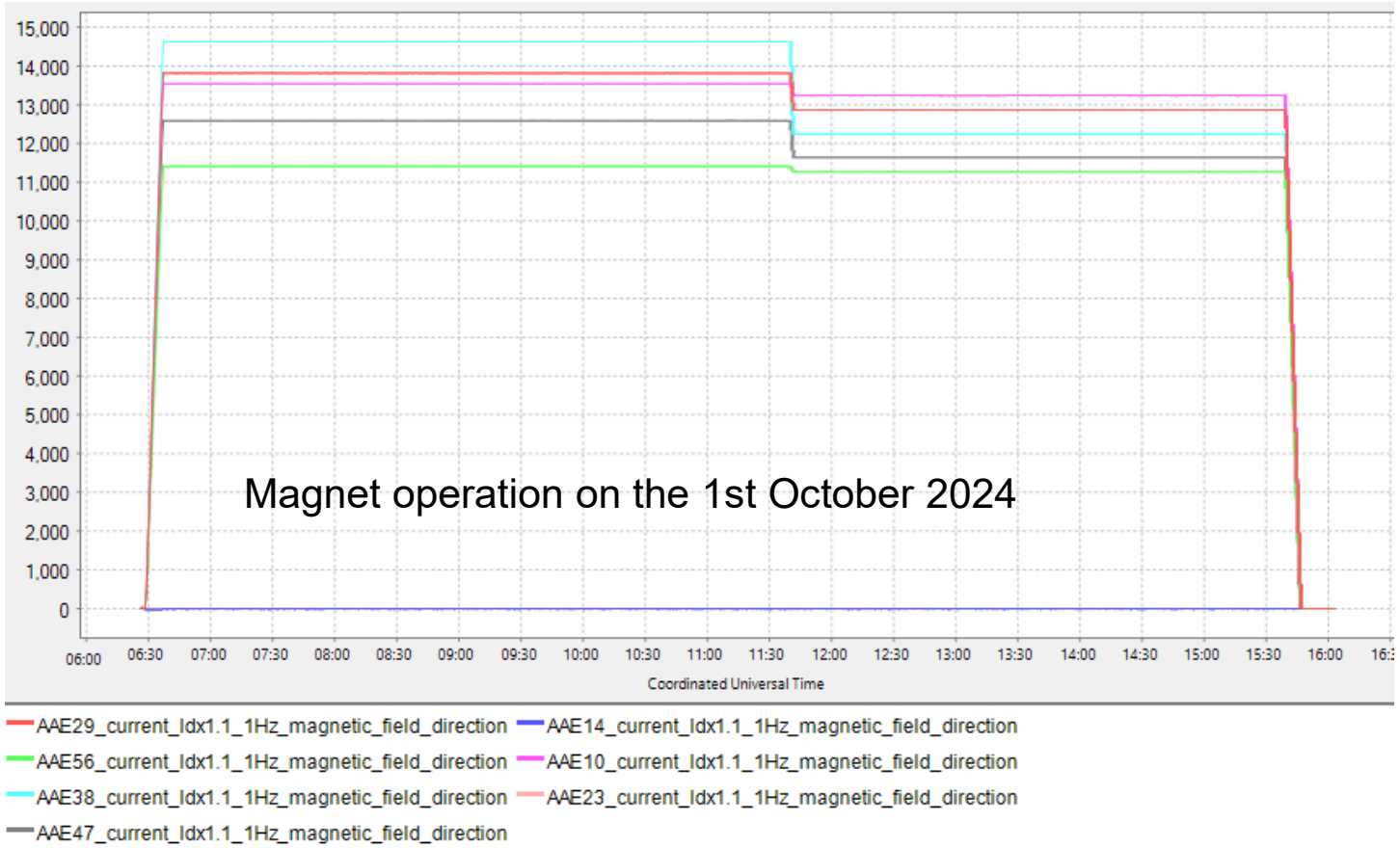
Operation experiences

W7-X is in operation since 2015, we are now in the fifth operational phase called OP2.2.

To operate a steady state Stellarator looks like simple but it requests:

- cryoplant operation
- DC power supply operation
- intermediate high voltage tests
- permanent structural monitoring

No quench, no structural problems.



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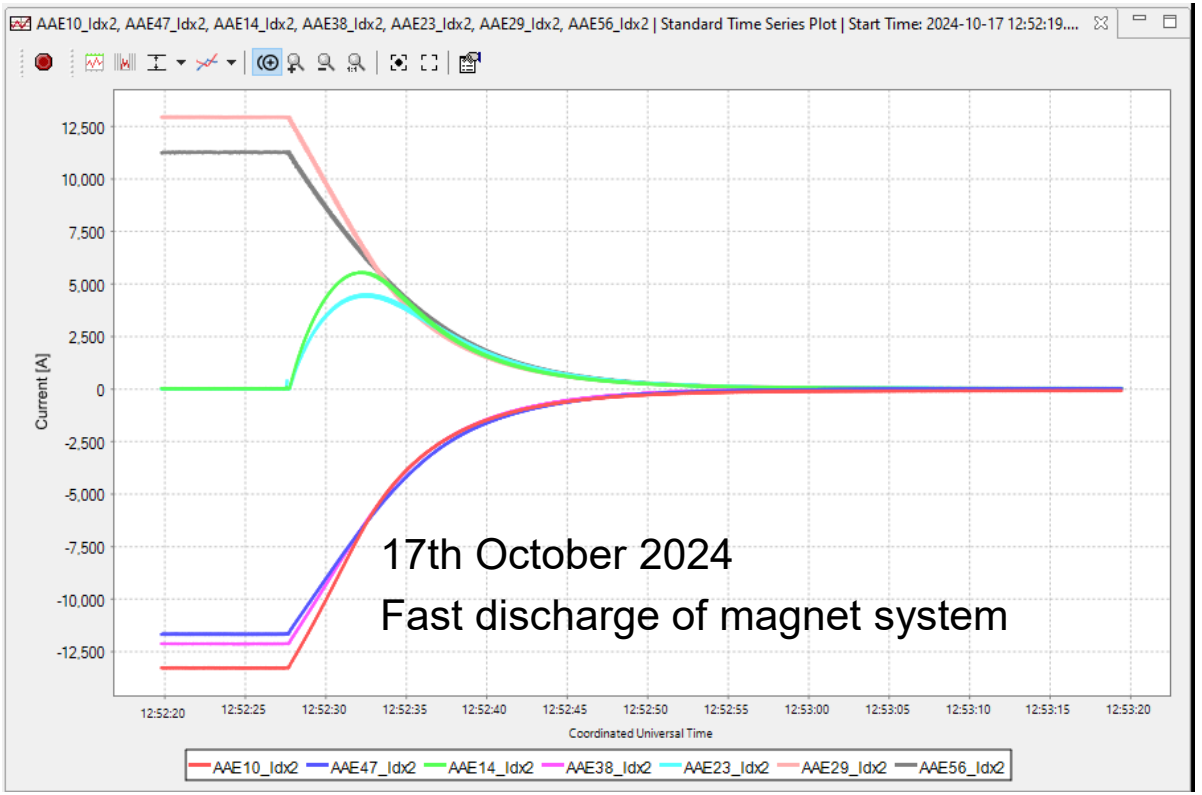
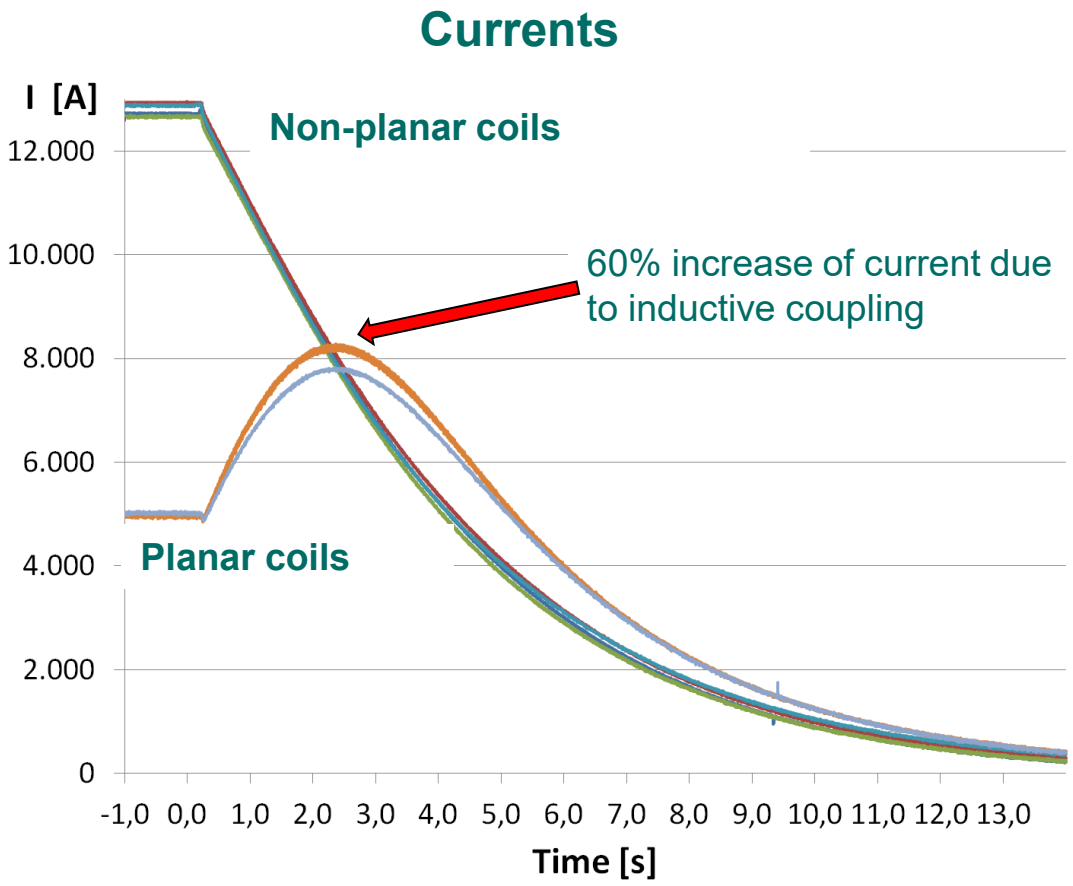
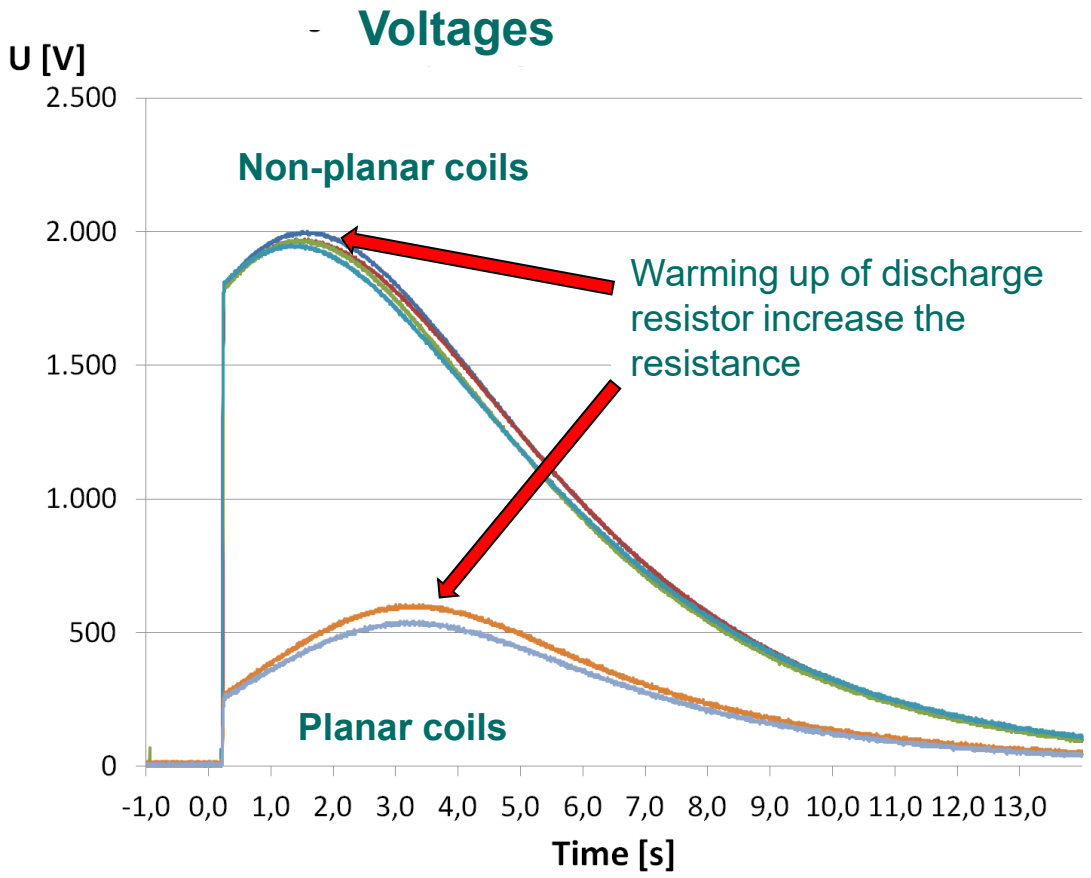


Fast discharge of superconducting magnet system

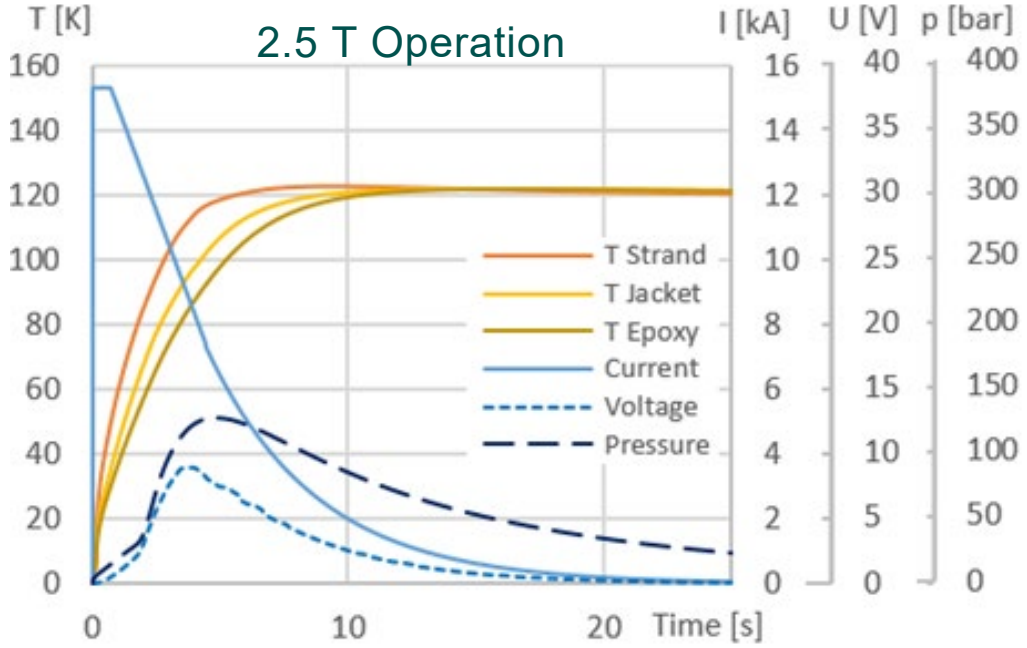


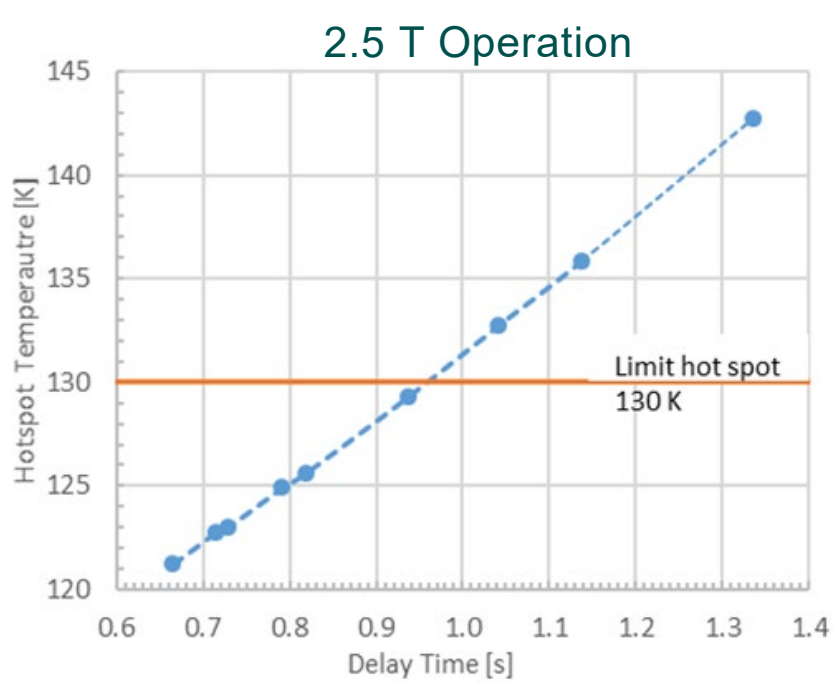


Thermohydraulic analysis for quench case

W7-X operation required updates of the thermohydraulic calculations:

- 2017 for a change on the discharge resistors performed by Swiss Plasma center [1]
- 2023 for a change on the Quench Detection system parameters for 2.5 T operation, performed by IFJ PAN Krakow and West Pomeranian University of Technology Szczecin [2]
- 2024 for 1.8 T operation (verified and analyzed by IFJ PAN Krakow)





[1] K. Sedlak et al., “Study of the hot-spot temperature during quench in the nonplanar coils of W7-X”, doi: 10.1109/TASC.2017.2779147.
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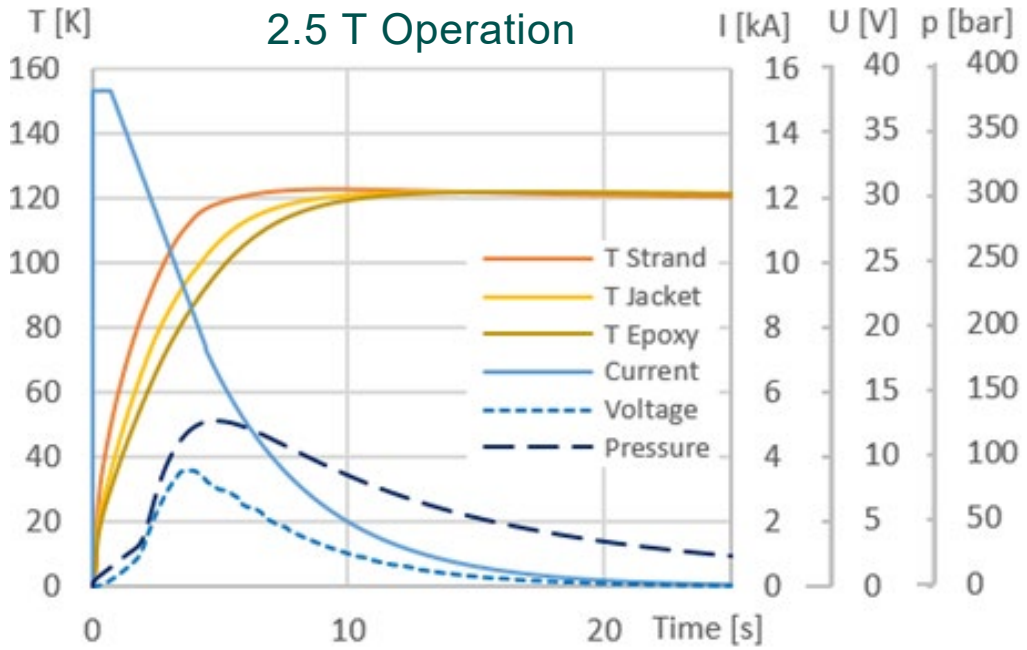
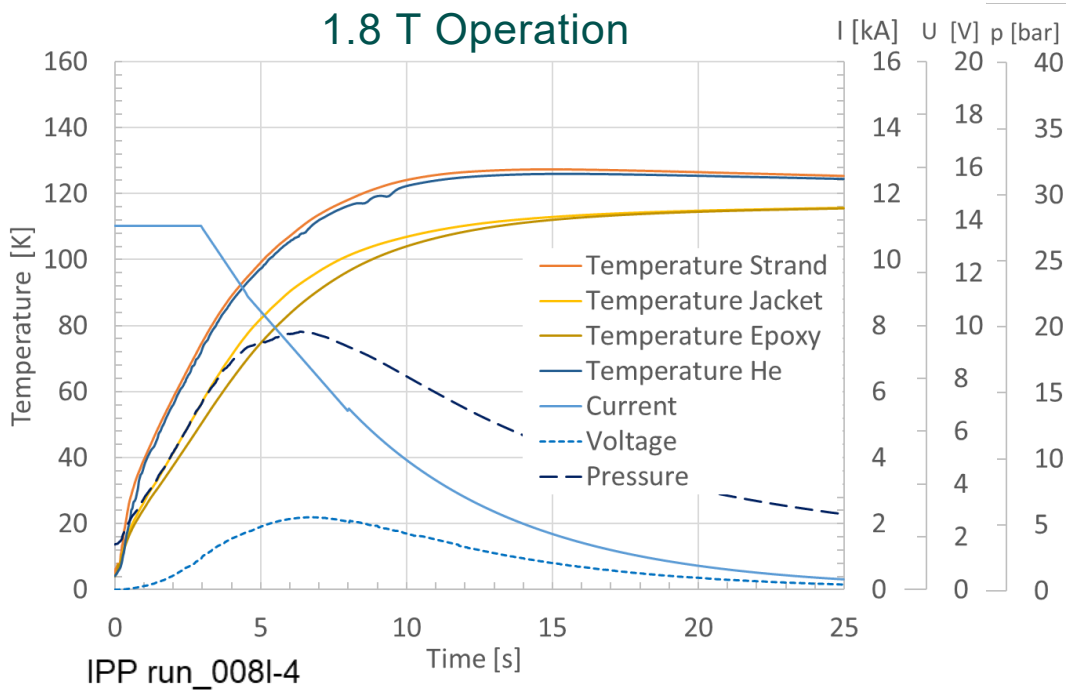


run W7X0551 for 2.5 T from [2]



IPP run_008l-4

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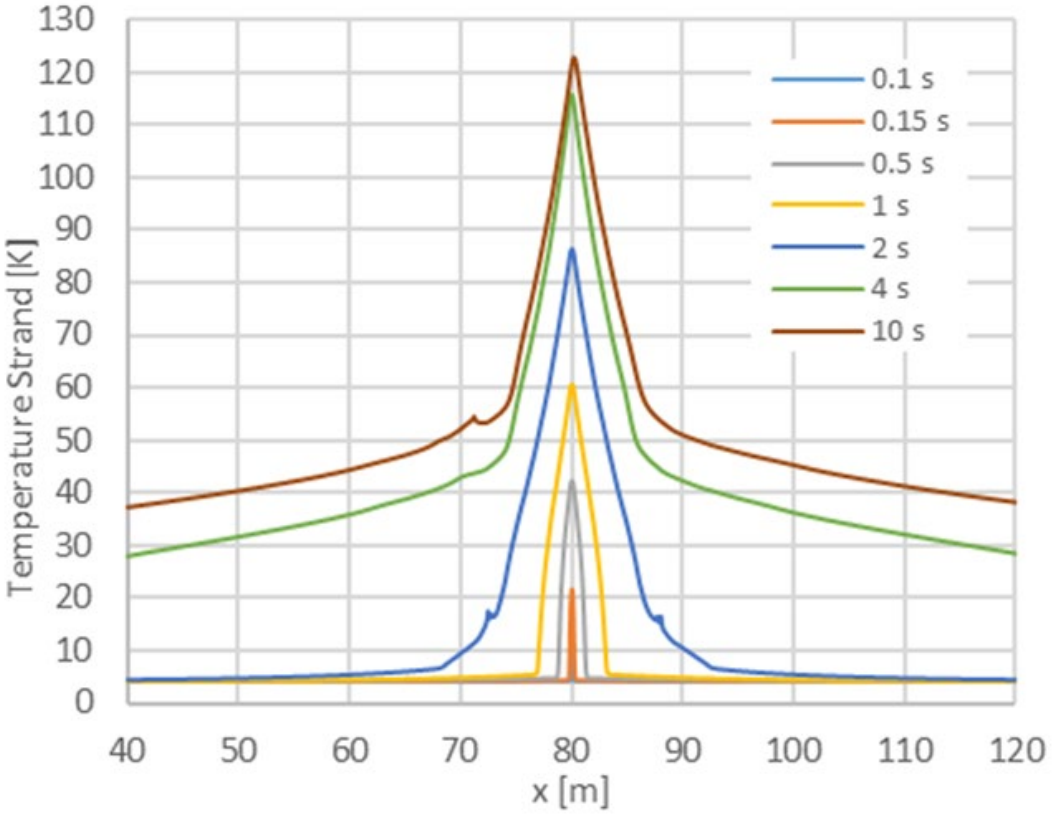
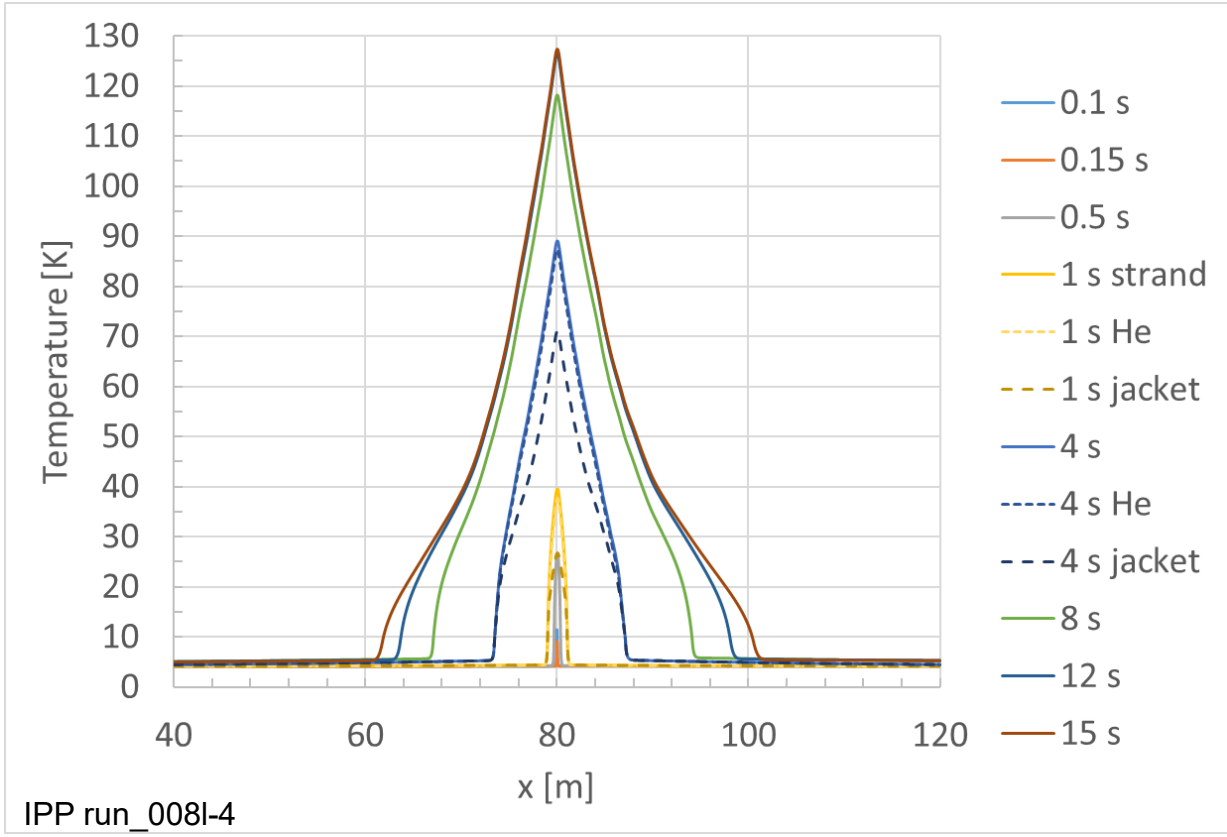
Thermohydraulic analysis for quench case

2.5 T Operation



run W7X0551 for 2.5 T from [2]

1.8 T Operation



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Thermohydraulic analysis for quench case

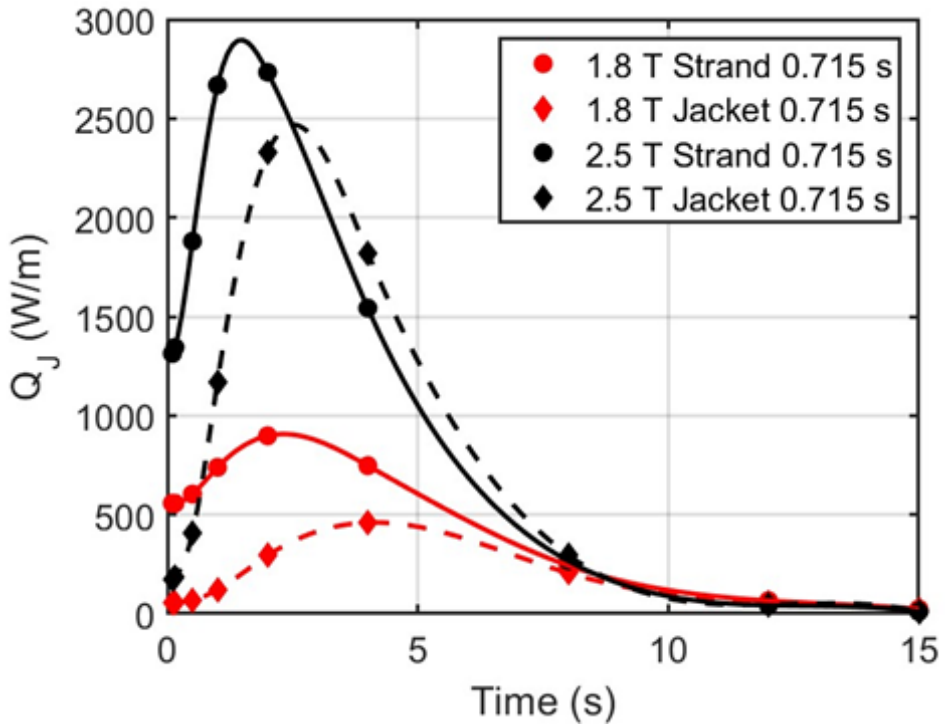

Diagram taken from IFJ PAN report M. Lewandowska, A. Dembkowska
Hotspot Temperature Calculation in a W7-X Non-Planar Coil (operation at 1.8 T)

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W7-X record for long pulse operation – 8 min discharge >1GJ

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Short summary