Challenges in operating fusion power plant vacuum systems

OLAVIII Workshop, Oak Ridge, TN, USA

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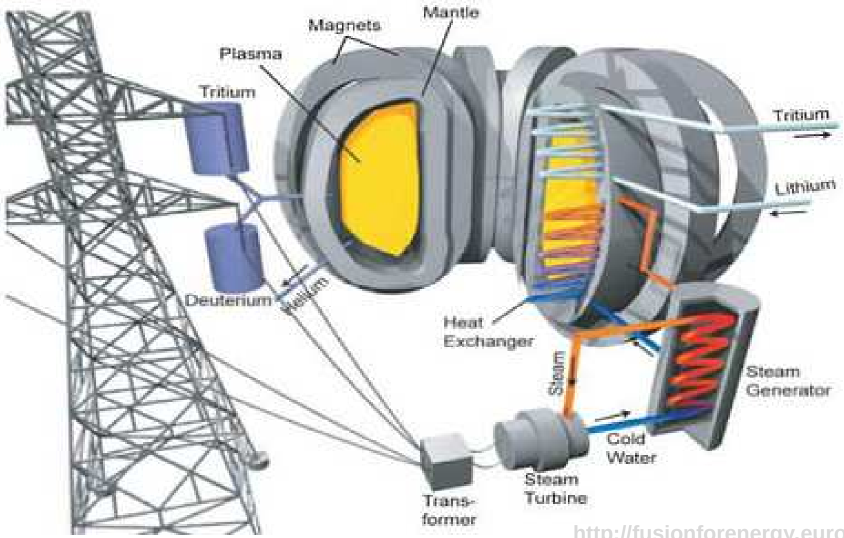
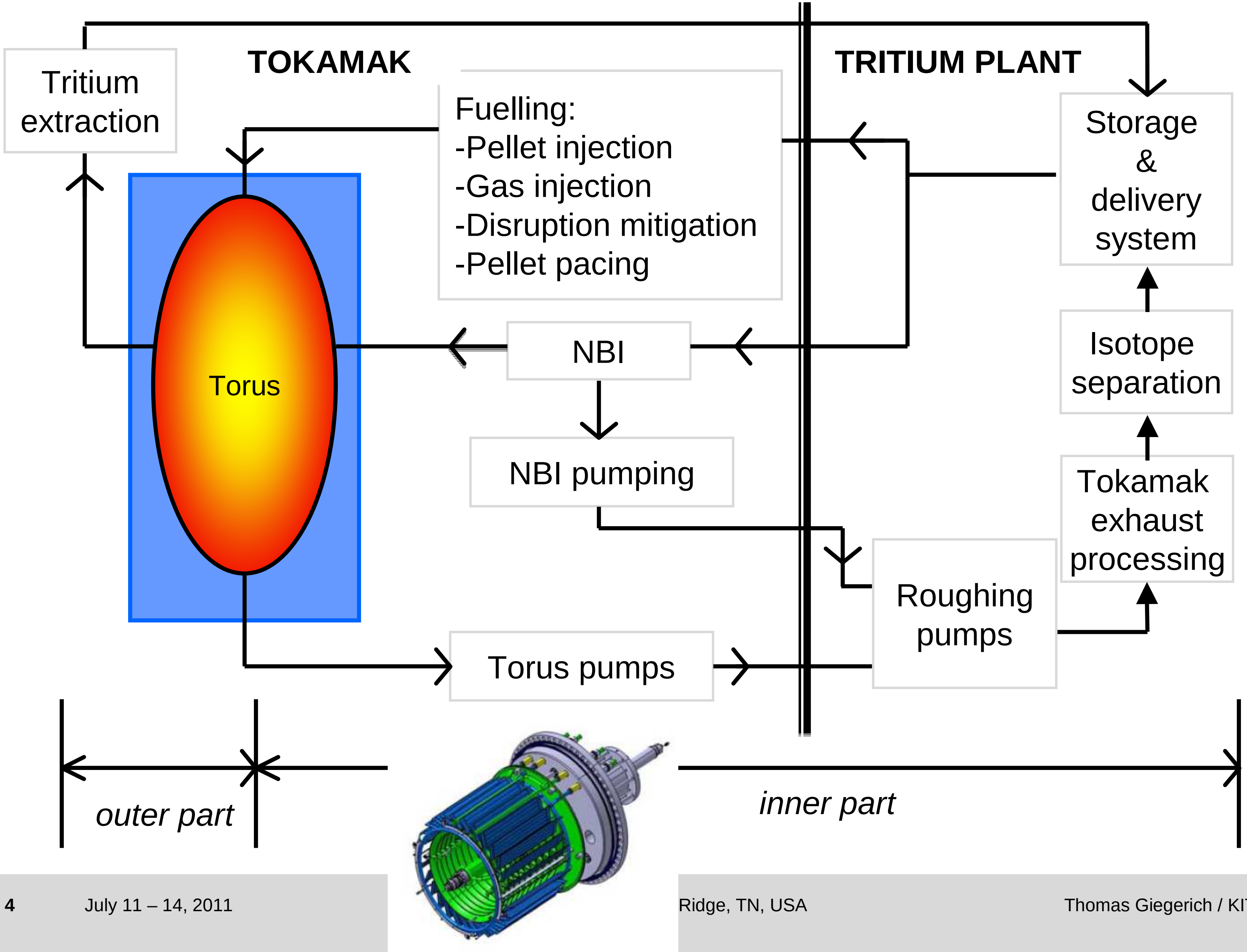


http://fusionforenergy.europa.eu/

- KIT (Karlsruhe Institute of Technology) was crated in 2010 as a merger of the University of Karlsruhe and the National Laboratory of the Helmholtz Association (the former „Forschungszentrum Karlsruhe“ FZK)
- The Vacuum Group of the “Institute of Technical Physics” (ITEP) has developed the ITER cryopumps and works in the field of nuclear fusion
- I am working in a European Trainee Programme on Vacuum (VACU-TEC) as a PhD student, supported by EFDA (European Fusion Programme)

- Introduction to a fusion reactor vacuum system
- Problems that need to be solved
- RAMI Requirements
  - Reliability
  - Availability
  - Maintainability
  - Inspectability
- Conclusions and Outlook

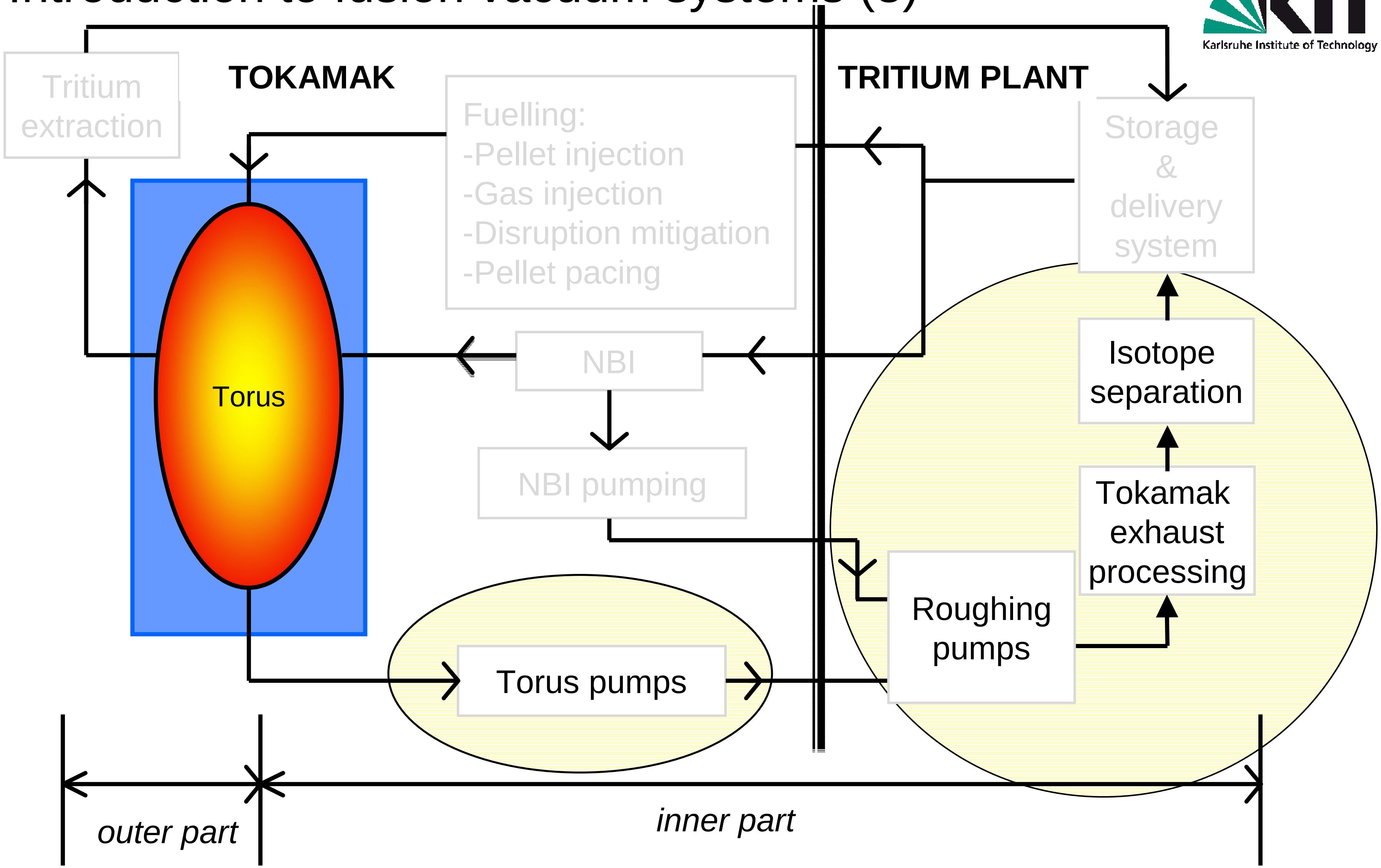
Introduction to a fusion reactor vacuum system



Introduction to fusion vacuum systems (2)

	EXPERIMENTAL REACTOR (ITER)	POWER PLANT (DEMO)
Torus vacuum system		
Pressure during plasma operation	1 - 10 Pa	1 - 10 Pa (?)
Gas load during plasma operation	153 Pa m^3/s (= 90 slm)	300 Pa m^3/s (?)
Pressure before plasma injection	10^{-6} Pa	?
Outgasing before plasma injection	?	?
Pump type high vacuum (HV) pump	Cryo	Cryo
Pump type roughing pump	Cryo	Cryo
Number of Pumps for HV	4 x 2 (4 in service, 4 regeneration)	8 x 2 (8 in service, 8 regeneration)
Pumping speed S for HV pumps	80 m^3/s	80 m^3/s
Cryopower consumtion	880 W @ 4.5 K + cool down of regeneration pumps High peak load	1760 W @ 4.5 K + cool down of regeneration pumps High peak load
Power Consumption	approx. 1.5 MW	approx. 3 MW

Introduction to fusion vacuum systems (3)



Scale-Up problem: Large high vacuum pumps, large roughing pumps and large tritium plant necessary.

Problems that need to be solved

HV-Pumps (cryopumps):

- Large 4.5 K cryo plant necessary!
- Pumps may have problems with dust (≈ 2 kg/d) and the strong microwave heating systems
- Lifetime limited through valve cycles ⇒ Big effort for replacing and/or maintenance
- Not economic

Roughing pump:

- Additional cryo power necessary
- High tritium inventory

Fuel Cycle:

- The ITER reactor will have several different types of breeding blankets for testing but will not produce its own fuel ⇒ Tritium flow in a commercial power reactor will be approx. 4 orders of magnitude higher in the outer part
- Up to now, no economic pumping solution for these high flows available
- About 100 kg tritium inventory ⇒ Needs to be reduced!

Problems that need to be solved (2)

Requirements:

Reliability
Availability
Maintainability
Inspectability
Safety, no leakage
Tritium resistant

Reliability, Availability ⇒ Pump must work when necessary and without failure. Simple and robust construction favourable!

Maintainability, Inspectability ⇒ All components have to be reached easily and service/repairs must be done remotely. No sophisticated and complicated pumps!

Safety, no leakage ⇒ No labyrinth or floating ring seals, no seal gas (may fail, charges tritium plant). Magnetic coupling and levitating required. Pump should be pressure resistant.

Tritium resistant ⇒ No elastomers or organic substances (oil, lubricant)!

Conclusion and Outlook

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A new pumping and fuelling concept is needed for commercial, economic fusion power plants.

Thank you!