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OPAL CNS Moderator Performance

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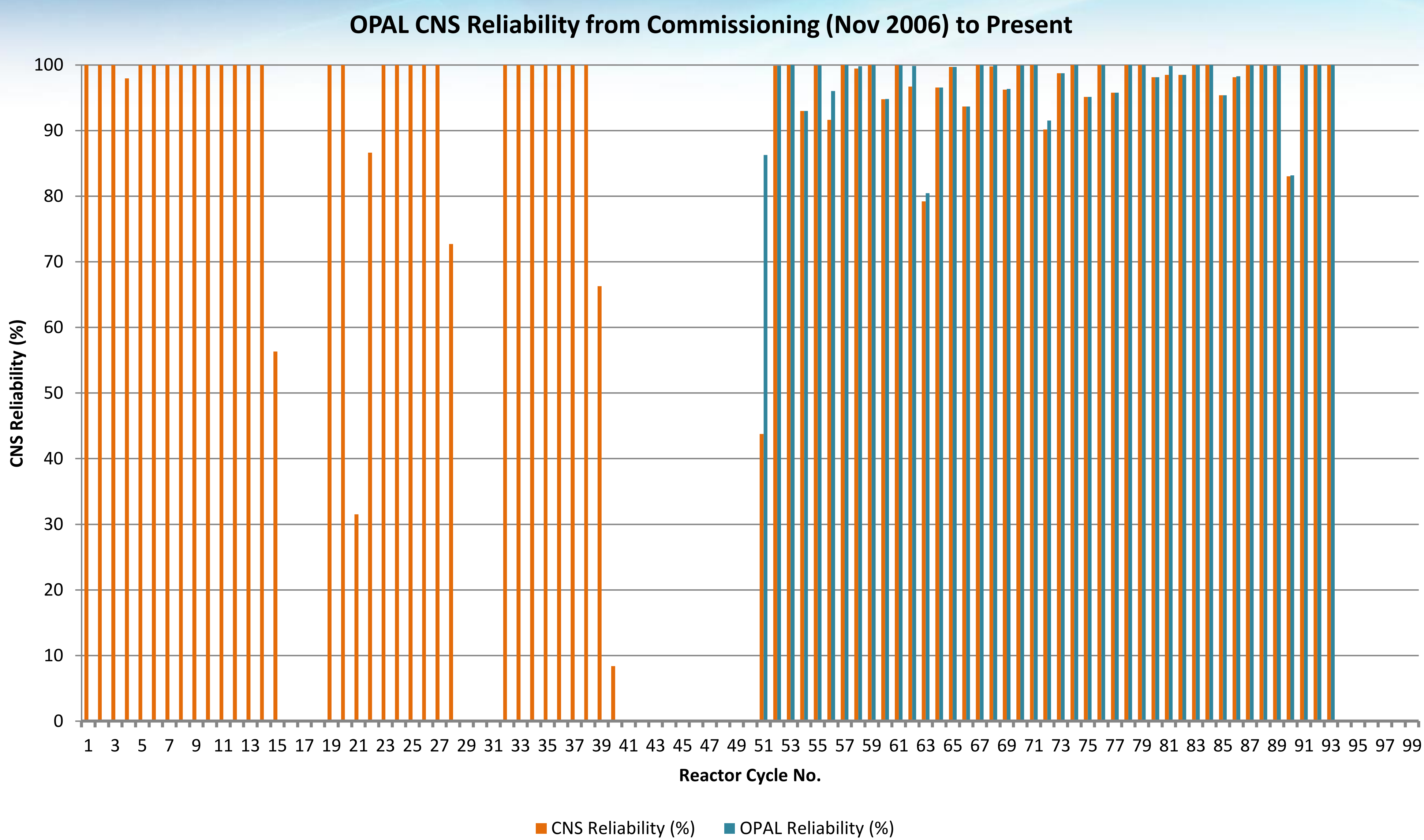
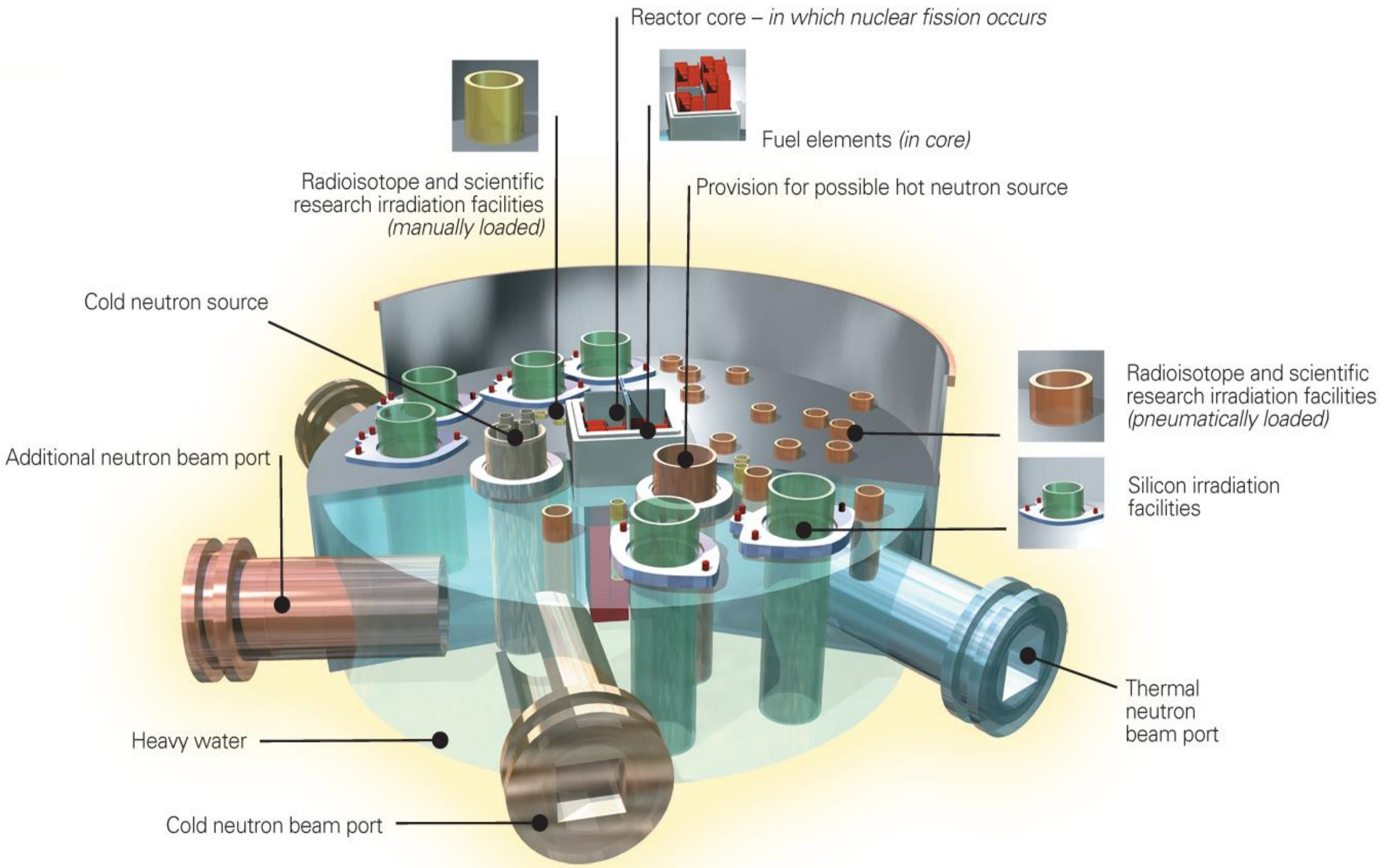

OPAL CNS Reliability from Commissioning (Nov 2006) to Present
CNS Reliability (%)
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Reactor Cycle No.
CNS Reliability (%)
OPAL Reliability (%)

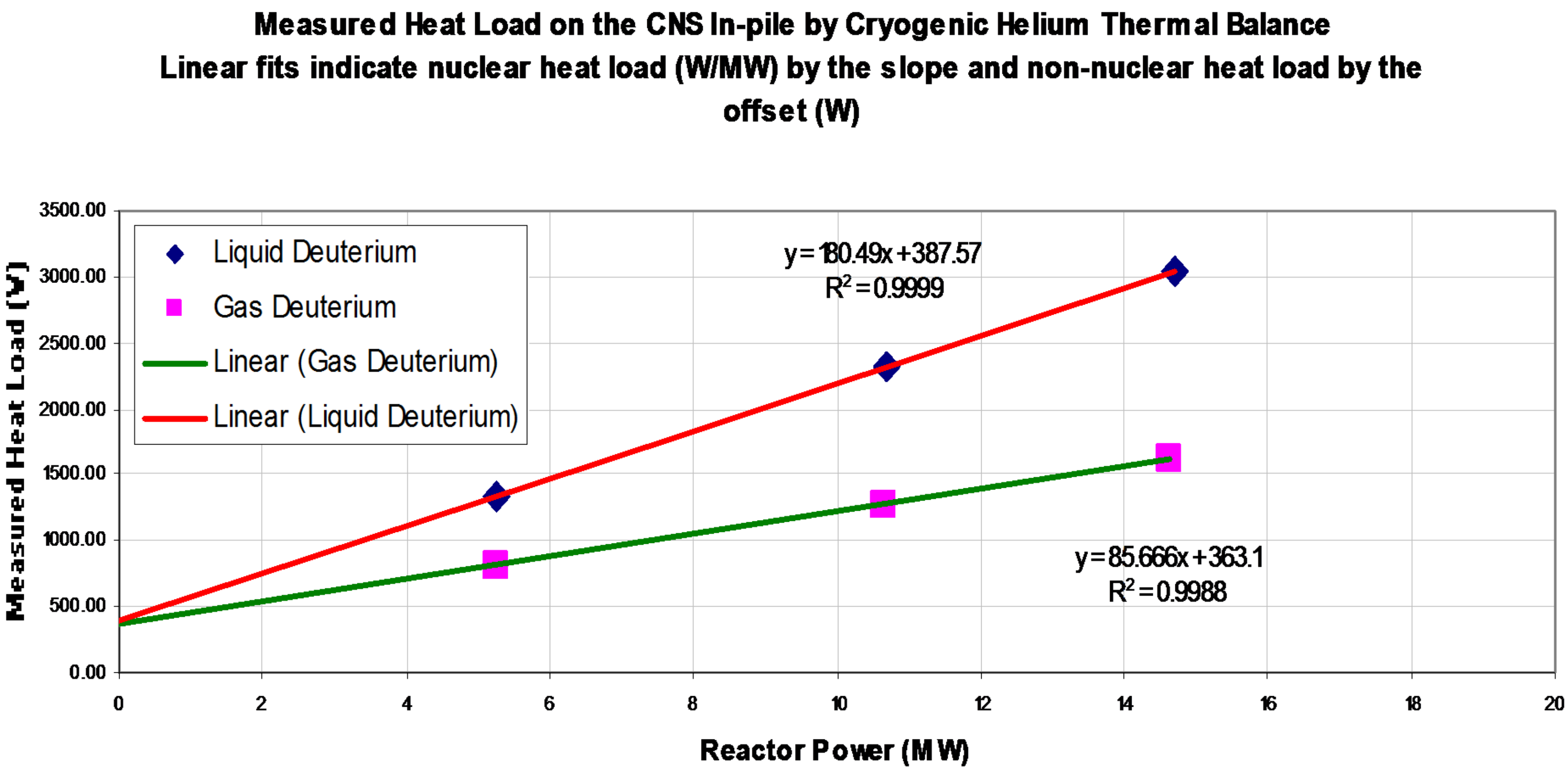
OPAL Reactor Facilities



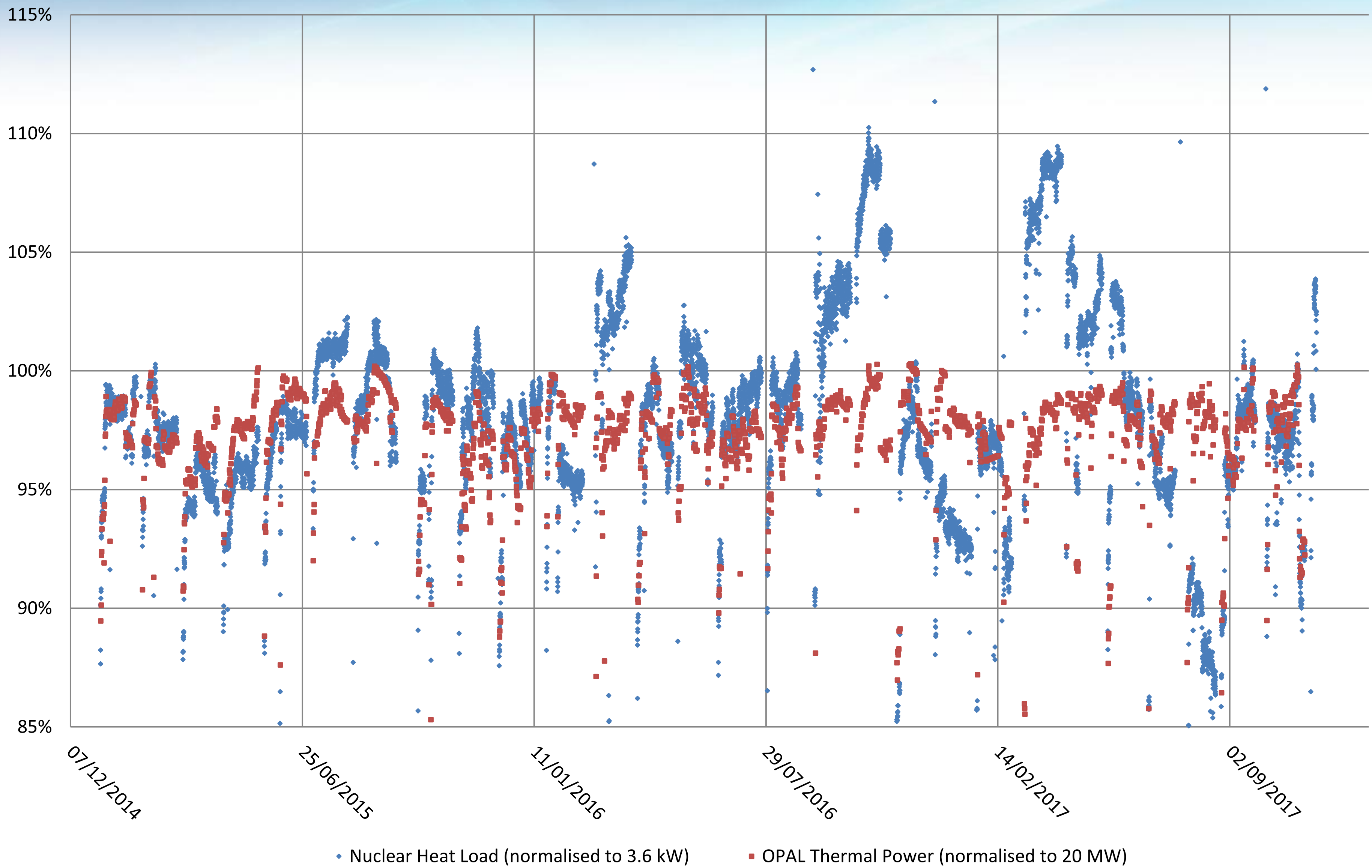
What Happened to CNS Flux?

- In early 2017, neutron users have noticed a significant drop in cold neutron flux ~ -20%
- Possible causes
  - Neutron guides (fault discovered in 2011)
  - Source flux

Heat Load vs Reactor Power



CNS Heat Load vs Reactor Power

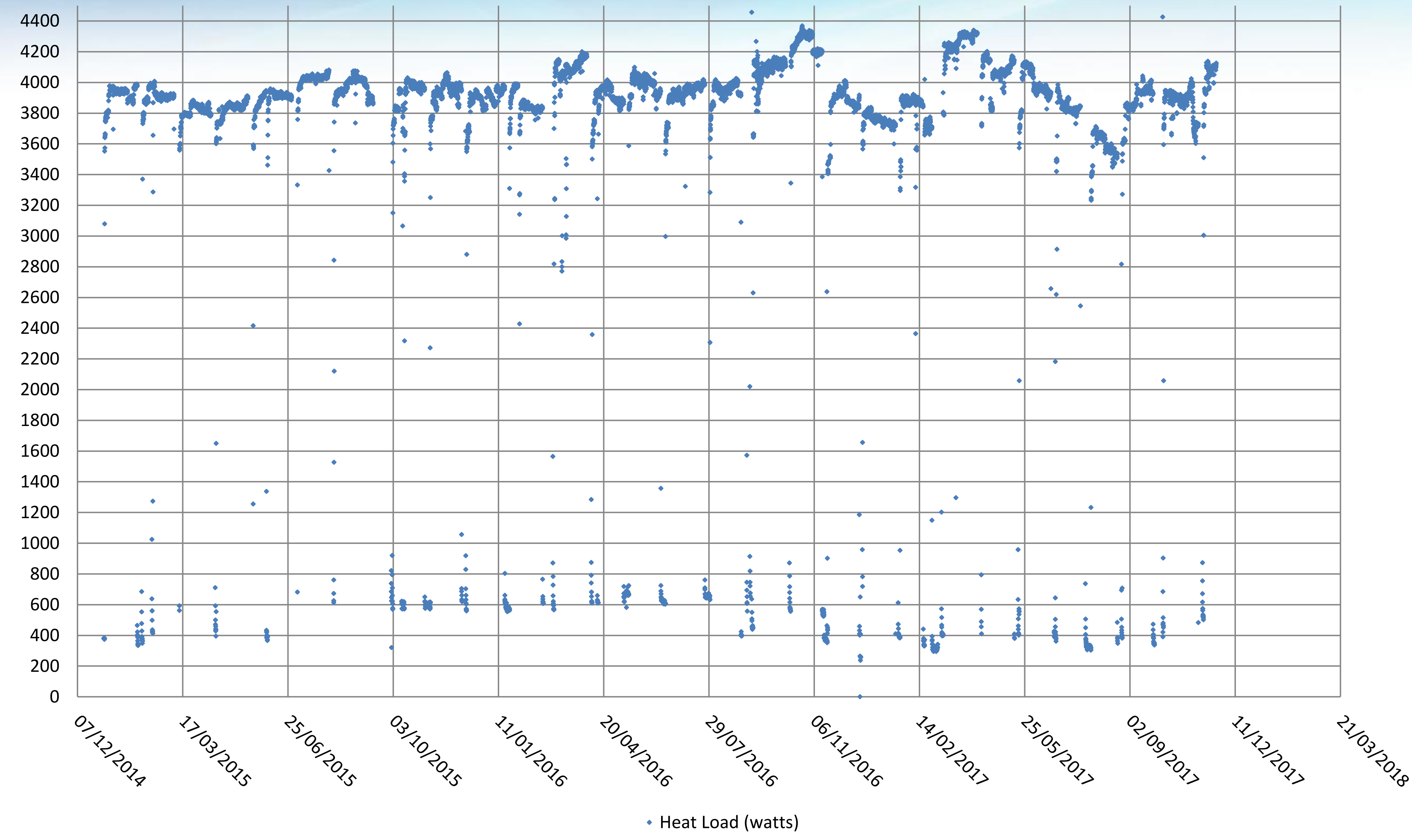


Helium Temperature Sensor Drift

Process Conditions (nominal)	Sensitivity	Typical Operational Variation by Conservative Estimation	Resultant CNS Flux Variation
Helium temp. sensor drift	15%/K	~ -1 K	-15%

- Sensors had recently been checked
- Measured a stable bias of ~1 K subject to slow drift (years), but no evidence for cycle-to-cycle "oscillation"

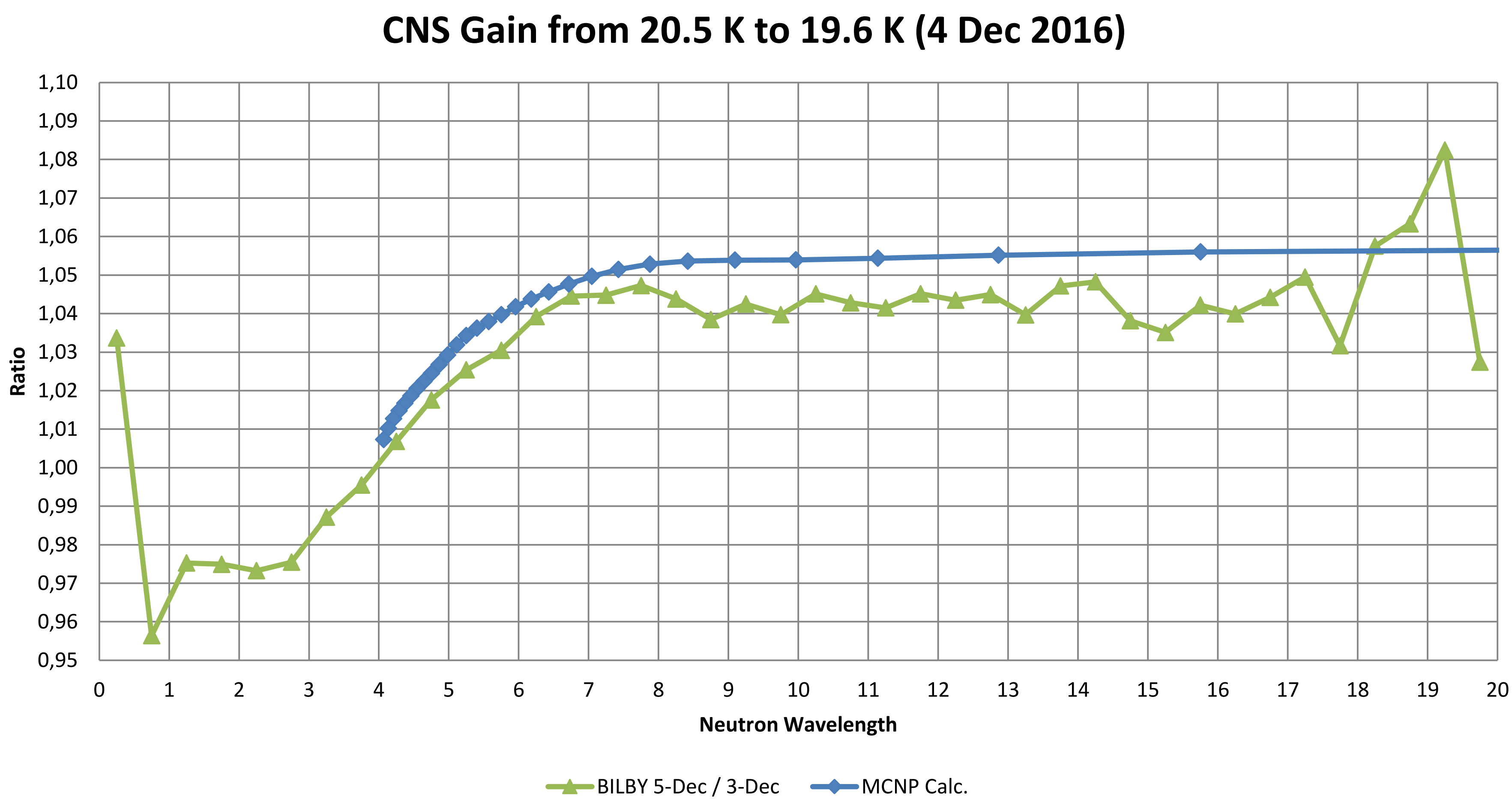
CNS Heat Load (watts)



CNS Flux Sensitivity (1)

Process Conditions (nominal)	Sensitivity	Typical Operational Variation by Conservative Estimation	Resultant CNS Flux Variation
D_2O purity (99.5%)	6.66%/%	±0.5%	±3.33%
D_2O temp. (35 °C)	-0.0228%/°C	±1 °C	±0.0228%
D_2O gap between CNS thimble and beam tube (1 mm)	-5.52%/mm	negligible	negligible
LD2 temp. (24.5 K)	-4.38%/K	±0.5 K	±2.2%
LD2 ortho/para ratio (3:1)	0.288%/%	Unknown but expected to be small	±1% (order of magnitude estimation)

MCNP Calculation vs Measurement



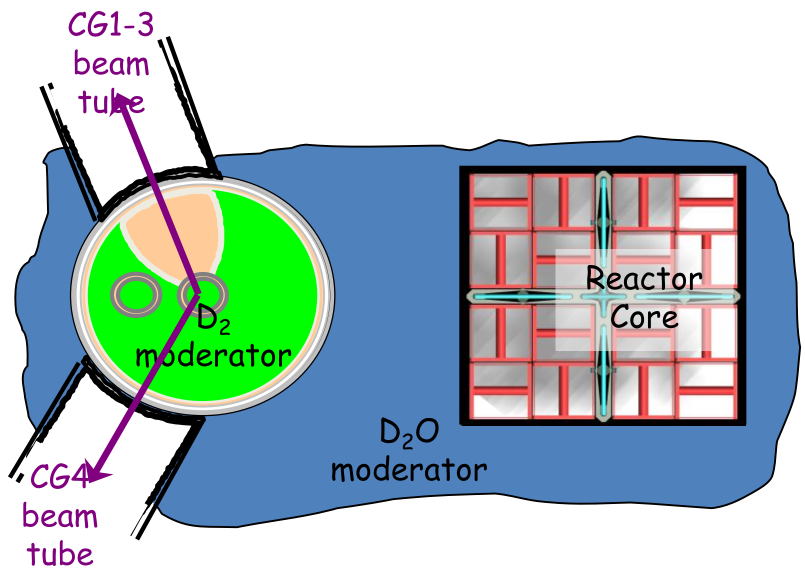
CNS Flux Sensitivity (2)

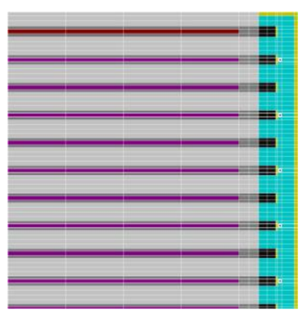
Process Conditions (nominal)	Sensitivity	Typical Operational Variation by Conservative Estimation	Resultant CNS Flux Variation
Control rod positions (critical positions for the first core)	5.58% between actual configuration and that after 180° rotation	Control rod movement pattern is repeated in every reactor cycle	N/A
Reactor core (first core and equilibrium core)	4.56% between the two cores	Fuel management strategy	To be assessed further

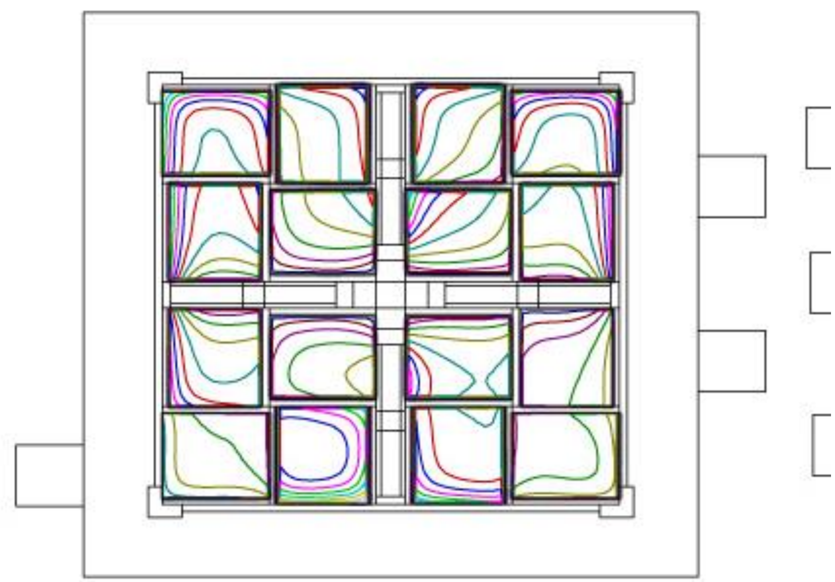
Fuel Management Programs

- Cell code: CONDOR
- Diffusion code: CITVAP
  – Flux and power density
  – Reactivity
  – Poison transients
  – Adjoint flux
  – Kinetic parameters

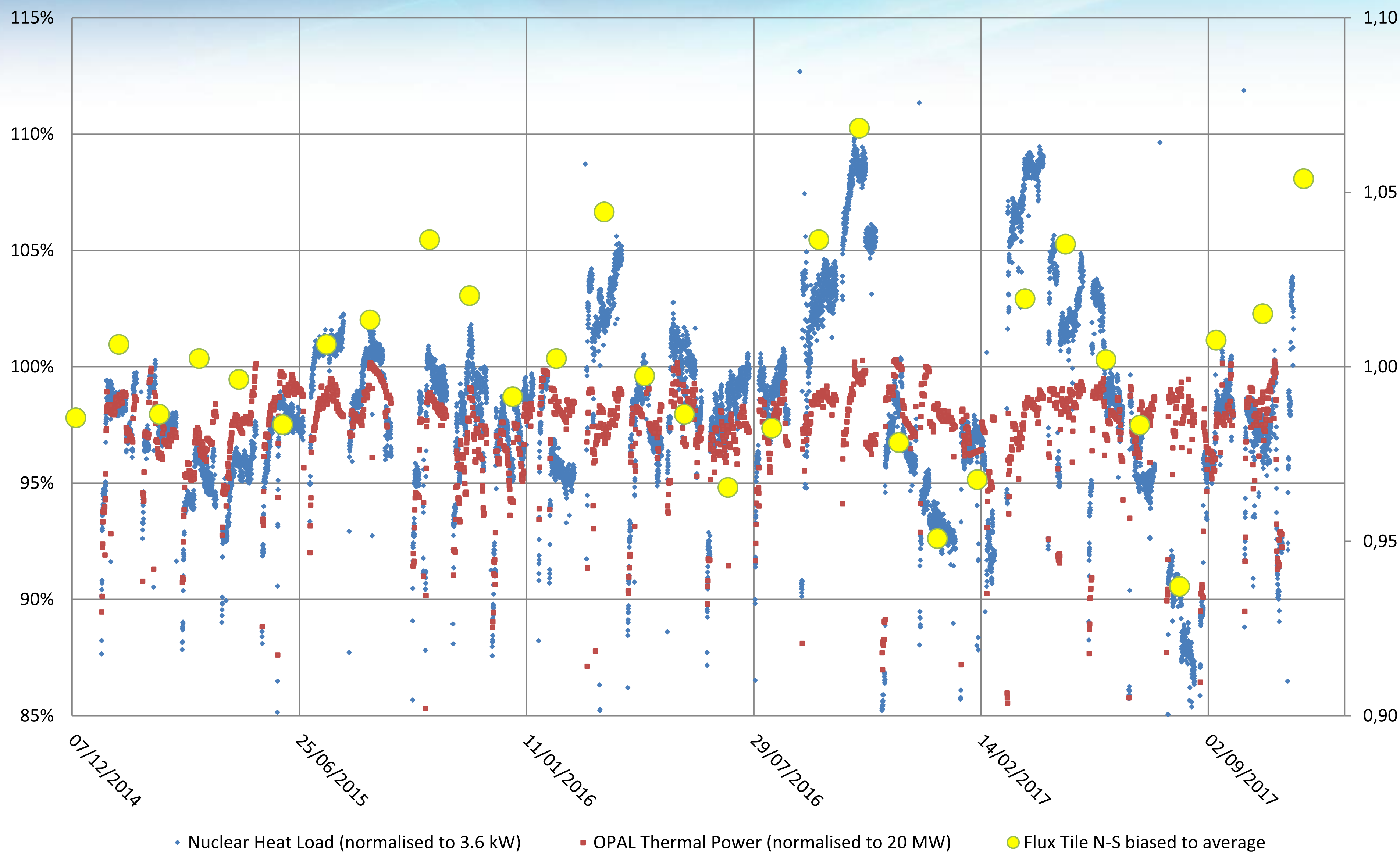
Core Power Density – Flux Tilt







CNS Heat Load vs Reactor Power



Conclusions

- CNS heat load is an excellent indicator of source flux
- Core configuration can have a significant impact on the CNS flux
- Can be predicted by numerical calculations

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