Water Activation Experiment in the JET DTE3 campaign: Recovery of Saturated Gamma Signals in Support of ITER

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CHALLENGE

- Water activation in DT tokamak
- Signal saturation above ≈1.3×10^{16} DT neutrons

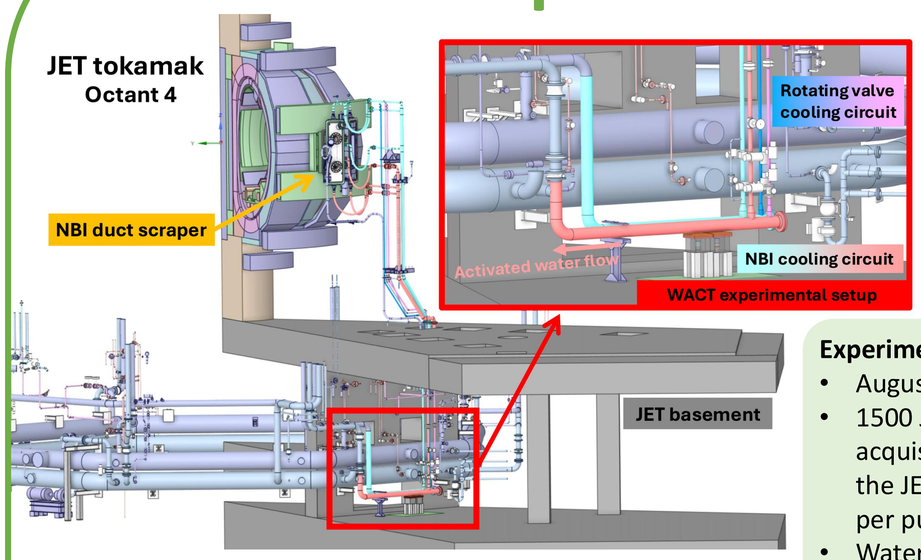
METHOD

- BGO gamma spectrometry
- Recovery of saturated pulses using pulse **104225**

CONCLUSION

- ^{16}N activity linear with DT yield
- Usable detection range extended by two orders of magnitude

JET WACT experiment



Experiment in numbers:
- August - December 2023
- 1500 JET pulses recorded; acquisition triggered by the JET pulse start, 300 s per pulse
- Water transit time to the detector ≈ 9.5 s

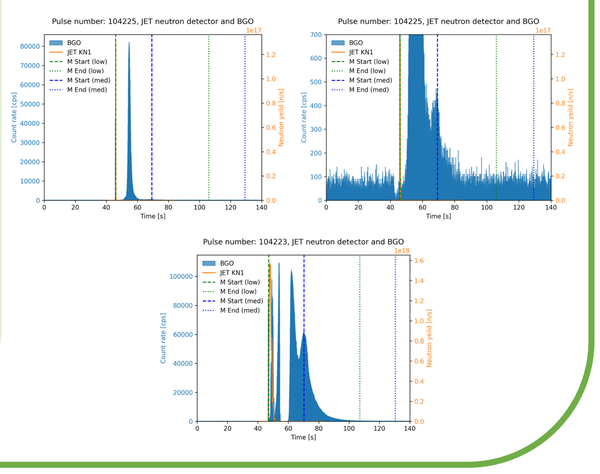
DT neutrons primarily activate the cooling water through ^{16}O(n,p)^{16}N. ^{16}N decays with a 7.13 s half-life, emitting 6 and 7 MeV gamma rays.
A BGO scintillation spectrometer was installed in the JET basement, Octant 4, directly beneath the NBI water cooling pipe, inside a 5 cm thick lead chevron enclosure with four 1.3 cm lead collimator plates (2x 5 mm and 2x 30 mm apertures).

Saturated signal processing

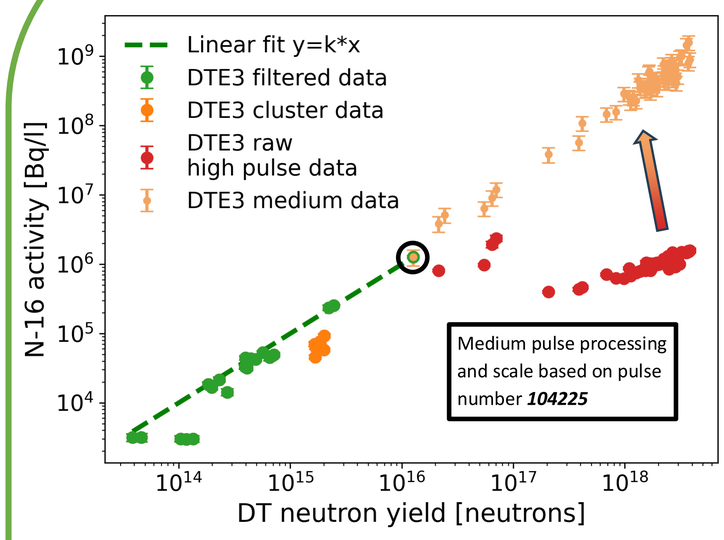
For $Y_n > 1.3\times10^{16}$ the count rate exceeds 100 kcps, saturating the DAQ.
The recorded signal drops to zero until most of the activated water volume has passed.
A secondary peak follows at t ≈ 25 s → the same activated water returning via the rotating-valve path, attenuated only by ^{16}N decay over the longer transit, hence proportional to the primary activation.

Pulse analysis with **two acquisition gates**:
- **low-pulse gate**, opened at the plasma start, capturing the full primary signal
- **medium-pulse gate**, delayed ≈ 25 s, capturing only the post-recovery signal

104225 is the only pulse where both are valid: $\boldsymbol{K_{med} = 423}$.
- Primary transit: t_0, 46543 counts
- Delayed tail: t_0 + 25 s, 110 counts



Results



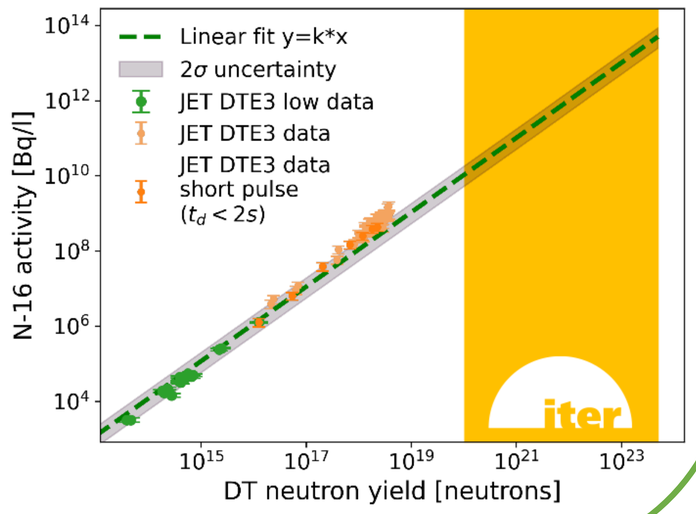
^{16}N activity concentration:

$$A(^{16}N) = \frac{N}{t_{meas} \cdot \varepsilon \cdot I_\gamma}$$

N = fitted 6.13 MeV peak area,
t_{meas} = 60 s live time,
ε = extended-source efficiency,
I_γ = 6.13 MeV emission intensity.

Low-pulse gate: green, orange and red color data.
Medium-pulse gate + $\boldsymbol{K_{Med}}$: sand color data

Extrapolation to ITER-relevant yields
Linear fit ($k = 9.96\times10^{-11} Bq/l/n$) extrapolated over eight orders of magnitude.
Reconstructed data lie within the 2σ band; short pulses ($t_d < 2s$) agree best, longer pulses are biased high by continued activation during the recovery window.
ITER range: ≈10^{12}–10^{13} Bq/l.



Conclusions

- **First and only experimental dataset of neutron-induced water activation in a DT tokamak cooling circuit.**
- **^{16}N activity scales linearly with DT neutron yield.**
- **The recovery method extends the usable dynamic range to 3.8×10^{18} neutrons; reconstructed activities fall within the 2σ band of the extrapolated linear trend.**
- **The dataset provides benchmark data for ITER water-activation modelling and supports activation-based coolant diagnostics.**

Acknowledgement

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