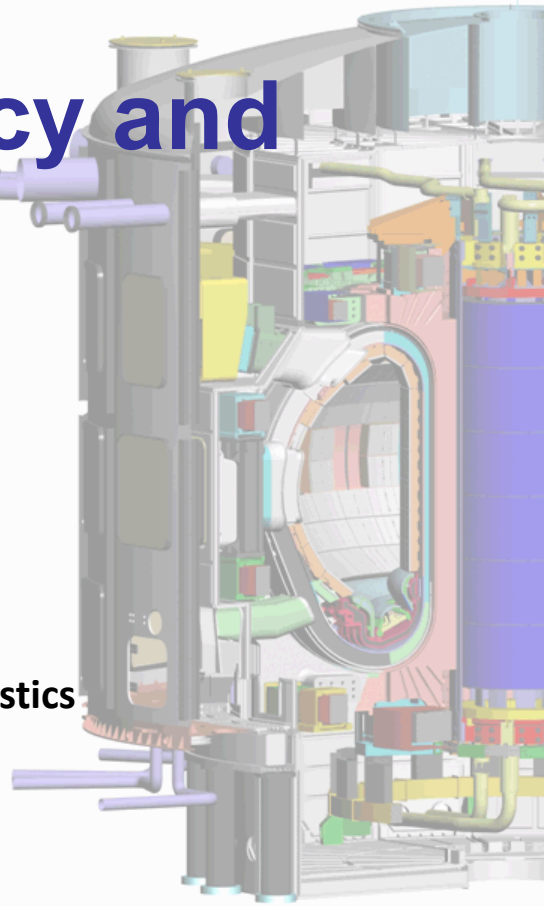
ITER NAS target accuracy and error sources



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3rd Workshop on calibration of ITER neutron diagnostics

5th - 7th Oct. 2022

KOREA DOMESTIC AGENCY

Topics

- Session II related: Accuracy of the NAS, plans for calibration and characterization procedures of NAS prior to delivery at ITER
- Session VI related: Quantification of measurement errors and strategies for reducing the errors

Contents

- Accuracy requirements in PA
- ITER NAS: schematic layout, operation sequence and measurement principle
- Error sources and reducing strategies
- Characterization of NAS prior to delivery at ITER

PA requirements

- **Role**
  - **First wall neutron fluence**
  - **Total neutron flux**

4.3.1.2 Measured parameters

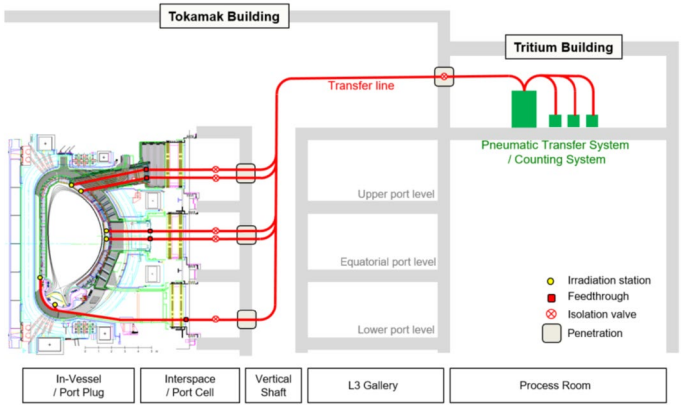
The Table 9 lists and describes the parameters to be measured by 55B8 NAS.

MEASUREMENT	PARAMETER	CONDITION	RANGE or COVERAGE	RESOLUTION (irradiation time)		ACCURACY
07. Neutron flux and emissivity	Total neutron flux		1×10^{14}-7.5×10^{20} n/s	10 s(*)	Several poloidal points	10 %
07.1.In-situ calibration-Neutron flux and emissivity	Total neutron flux	Before DD and DT phases	TBD(**)	TBD(**)	Several poloidal points	TBD(**)
34. Neutron fluence	Neutron fluence on the first wall		0.1-1 MWy/m^2	Integral	Several poloidal points	10 %

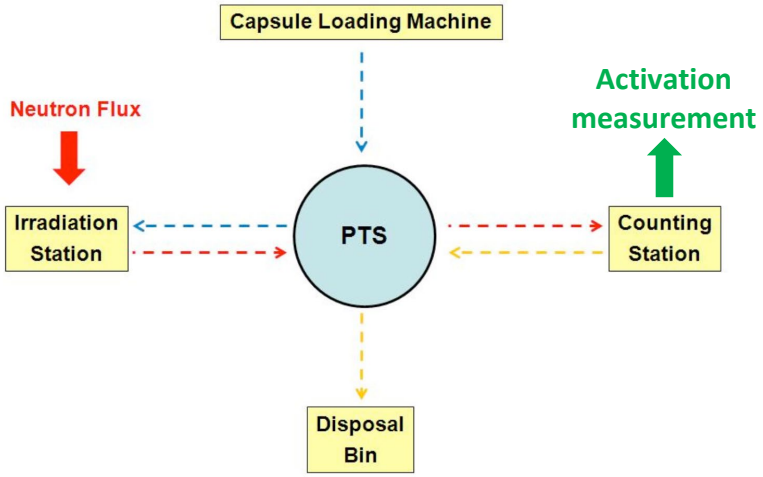
Table 9: Measurement parameters and requirements

ITER NAS

➢ Schematic layout



➢ Operation sequence



➢ Measurement principle

$$Y_n = S_n \cdot t_0$$

Sample reaction rate / V = target # density $\cdot \int \sigma(E) \cdot \phi(E) dE$

Sample reaction rate = (# of target nuclei) $\cdot S_n \cdot f \int \sigma(E) \cdot \phi'(E) dE$

S_n = (Sample reaction rate) / (# of target nuclei) / $(f \int \sigma(E) \cdot \phi'(E) dE)$

Gamma counting *Sample mass* *In-situ calibration and neutronics calculation*

Measurement errors

S_n = (Sample reaction rate) / (# of target nuclei) / $(f \int \sigma(\mathrm{E}) \cdot \phi'(E) dE)$

Gamma counting | *Sample mass* | *In-situ calibration and neutronics calculation*

$$Reaction\ rate = \frac{\lambda C}{\alpha_\gamma \varepsilon e^{-\lambda t_1}(1 - e^{-\lambda \Delta t})(1 - e^{-\lambda t_0})}$$

- λ: Decay const.
- C: gamma counts
- α_γ: gamma abundance
- ε: gamma measurement efficiency
- t_1: cooling time
- Δt: measurement time
- t_0: irradiation time

✓ Gamma counting statistical error → σ_C ~ 7%

✓ Detector efficiency error → σ_γ ~ 1%, σ_ε ~ 7%

✓ Experimental error during the in-situ calibration

✓ Statistical and systematic errors in the neutronics calculation

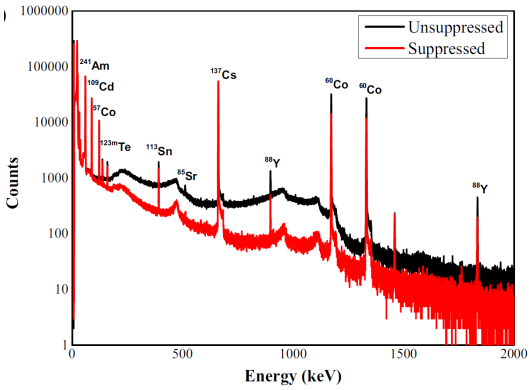
✓ Errors in the cross-section

→ 9.95% in total

Reducing strategies

✓ **Gamma counting statistical error**

- Appropriate cooling time to minimize unwanted gamma signal
- Enough measurement time
- Compton suppression gamma-ray spectrometer; select full energy peak signal only



✓ **Detector efficiency error**

- Radiation transport calculation to compensate geometry and self absorption effects

✓ **Experimental error during the in-situ calibration**

- Well characterized source, reaction cross-section, etc.

✓ **Statistical and systematic errors in the neutronics calculation**

- Well established neutronics model and low error in calculation

Characterization of NAS prior to delivery at ITER

✓ **Gamma counting statistical error**

- Appropriate cooling time to minimize unwanted gamma signal
- Enough measurement time
- Compton suppression gamma-ray spectrometer; select full energy peak signal only

✓ **Detector efficiency error**

- Radiation transport calculation to compensate geometry and self absorption effects

✓ Experimental error during the in-situ calibration

- Well characterized source, reaction cross-section, etc.

✓ Statistical and systematic errors in the neutronics calculation

- Well established neutronics model and low error in calculation

NAS measurement during in-situ calibration

- Capsule size: 8 mm in diameter, 20 mm in length
- Available space inside the capsule is very limited
- Sample activity during the in-situ calibration may be very low