# Neutron diagnostics for JT-60SA

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ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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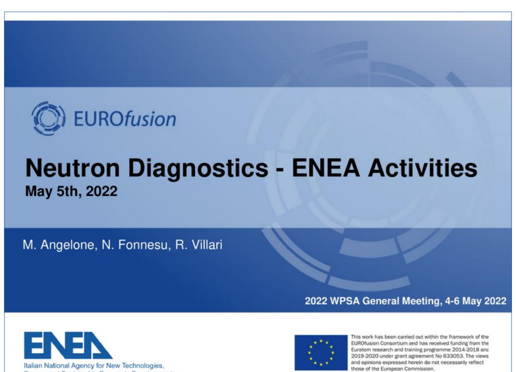
# Scoping and feasibility studies up to the level of conceptual design


- Scenarios
- Neutron emissivity profiles
- Neutron spectrometry


- Time integrated measurement of the total neutron yield
- Neutron emission spectroscopy via unfolding
- Study of the different materials behaviour in the fusion reactor environment




- Diamond detectors for triton burn-up
- Measurement of dose rate due to neutron activation

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# Neutron spectrometers and collimated neutron flux monitors for real time control


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# Fast particle physics

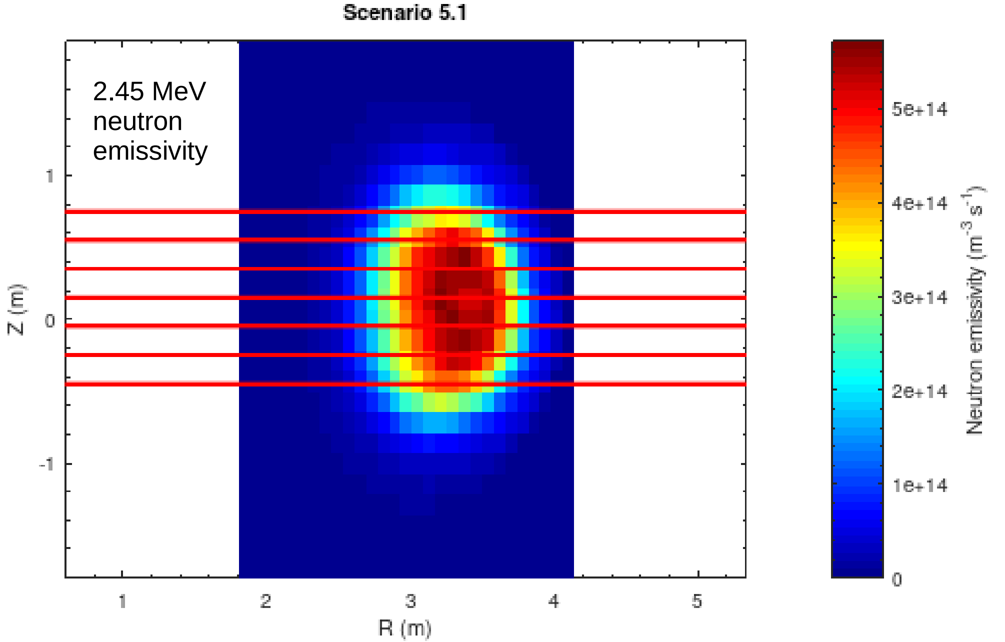
- NBIs & N-NBIs (85/500 keV) resulting in FI populations with different E and λ driving EPs (FBs), BAEs, TAEs, GAEs and CAEs;
- Super-Alfvénic velocity of the N-NBI driving TAEs, , GAEs and CAEs; impact on current drive efficency.
- Orbits of MeV D comparable to αs orbits in ITER and DEMO;

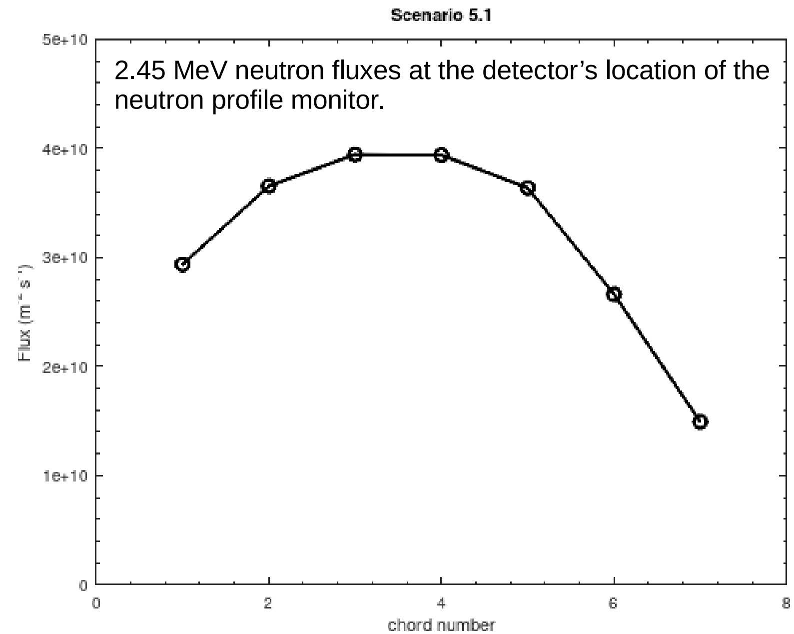
| Tokamak | TFTR | JET | JET | JT-60U | ITER | Slim CS | JT-60SA Scen#1-#5-1 |
|---|---|---|---|---|---|---|---|
| Fast ion | Alpha | Alpha | Alpha | Deuterium | Alpha | Alpha | Deuterium |
| Source | Fusion | Fusion | ICRF tail | Co NBI | Fusion | Fusion | Co NBI |
| $\tau_s$ [s] | 0.5 | 1.0 | 0.4 | 0.085 | 0.8 | ~2 | 0.5 - 1.6 |
| $n_f$ _max / $n_e(0)$ [%][a] | 0.3 | 0.44 | 1.5 | 2 | 0.85 | | 0.35 - 2.2 |
| $\beta_f$ _max [%][a] | 0.26 | 0.7 | 3 | 0.6 | 1.2 | | 0.54 – 2.3 |
| $<\beta>$ [%] | 0.03 | 0.12 | 0.3 | 0.15 | 0.3 | ~1.2 | 0.2 – 0.9 |
| $\beta_f$ _max / $<\beta>$ | 8.7 | 5.8 | 10 | 4 | 4 | | 2.5 – 3.2 |
| max $\vert R\nabla\beta_f\vert$ [%] | 2.0 | 3.5 | 5 | 6 | 3.8 | | 5.2 – 65 |
| $v_f$_max / $v_A$ | 1.6 | 1.6 | 1.3 | 1.9 | 1.9 | ~2 | 1.0 – 1.26 |

- Coupling of anomalous transport of FI to micro turbulence: neutron emissivity profiles to assess diffusion coefficients.
- Verification & validation (V&V) activities of theory-based transport codes for FI through neutron experimental measurements
- T burn-up as a proxy for (DT neutrons) to study the transport of 1 MeV T which have $r_L$ similar to that of 3.5 MeV αs.
- ELMs and RMPs impact on FI confinement (neutron emissivity profiles).

# Neutron emissivity

- Simulations based on ASCOT FI distribution provided by Ph. Lauber and R. Coelho for scenario 5.1 based on L. Garzotti et al 2018 Nucl. Fusion 58 026029 and geometry from S. Sumida et al. Rev. Sci. Instrum. 91, 113504 (2020).



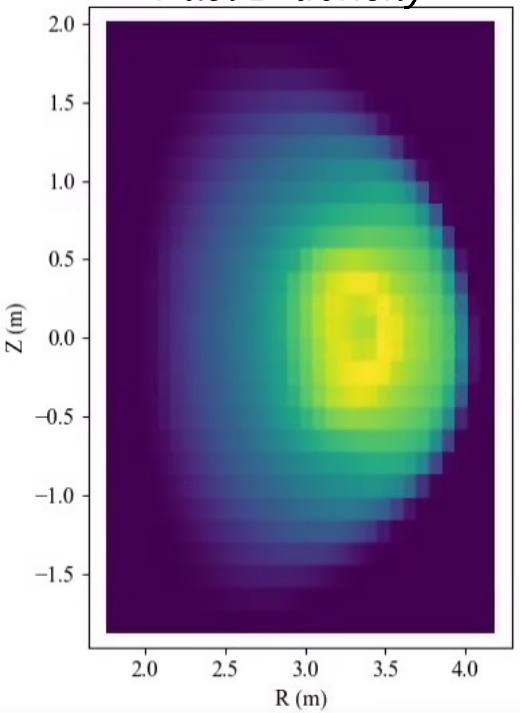




- Off-axis NBCD efficacy and optimization via neutron emission profiles: the behaviour of fast-ions during their slowing-down processes is also a key issue to understand the physics of off-axis NBCD since the current drive is dominated by these fast-ions.
- Scenario development via fuel ion density and temperature profiles.
- Triton-burn up contribution (not insignificant).

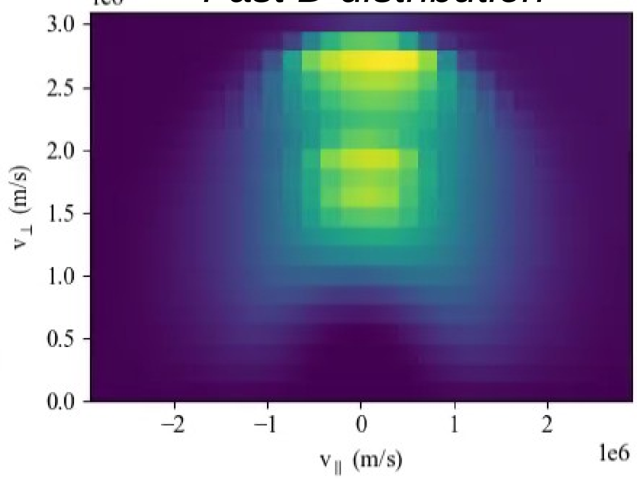
# Neutron spectrum calculation

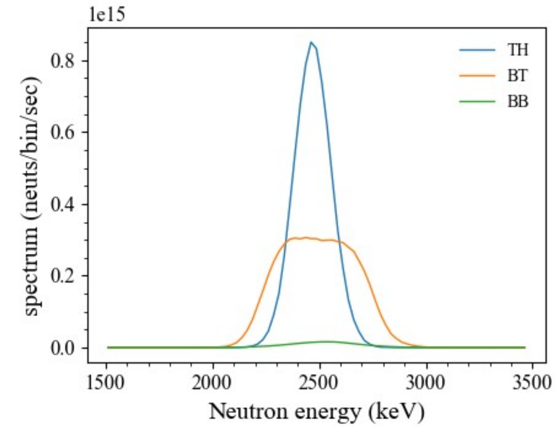
- Simulations based on ASCOT FI distribution provided by Ph. Lauber and R. Coelho for scenario 5.1 based on L. Garzotti et al 2018 Nucl. Fusion 58 026029.
- FI distribution input to DRESS code for neutron emissivity and spectra calculations (2.45 MeV component only).

*Fast D density*




*Fast D distribution*

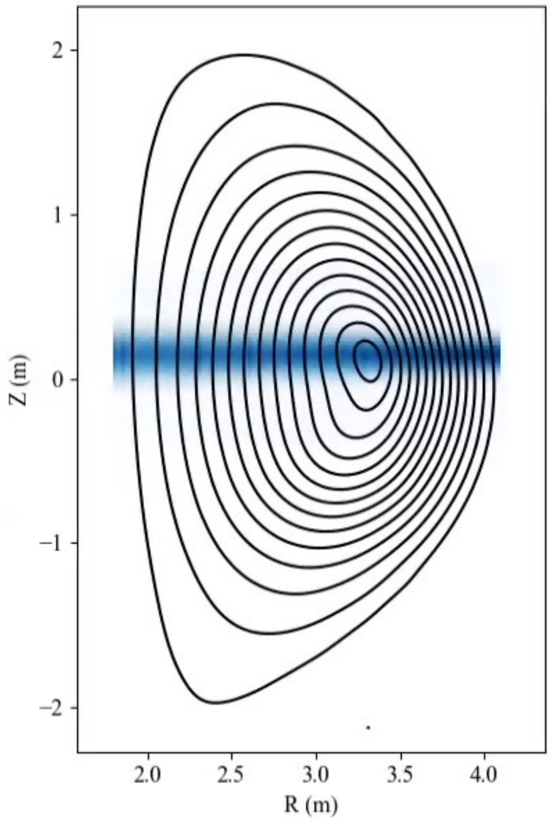


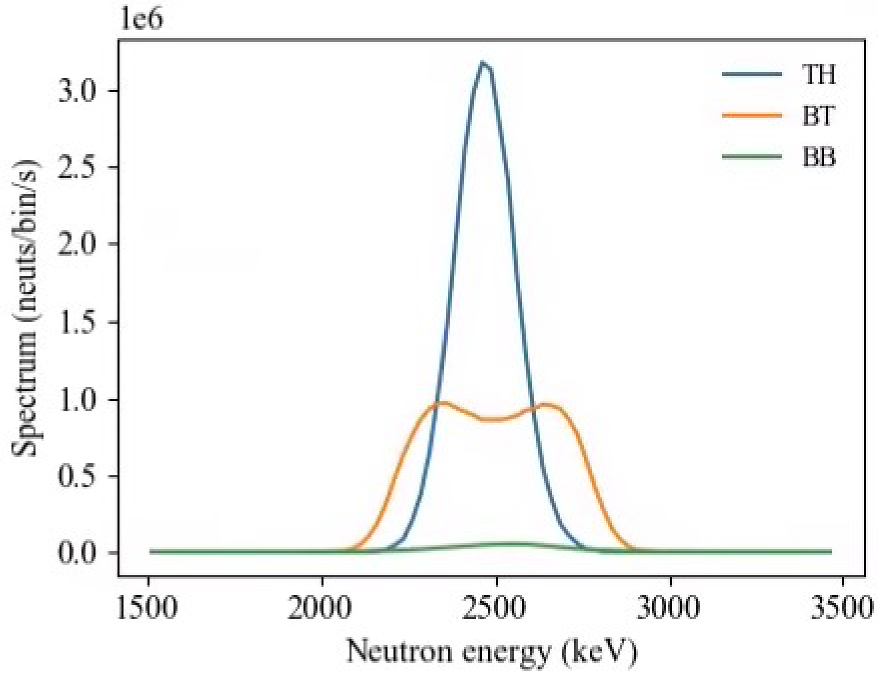

Integrated the neutron emission over the entire plasma volume and over all emission directions.

# Neutron spectrum for collimated view

**Viewing cone weight map (solid angles)**




**Neutron spectra at the detector position**



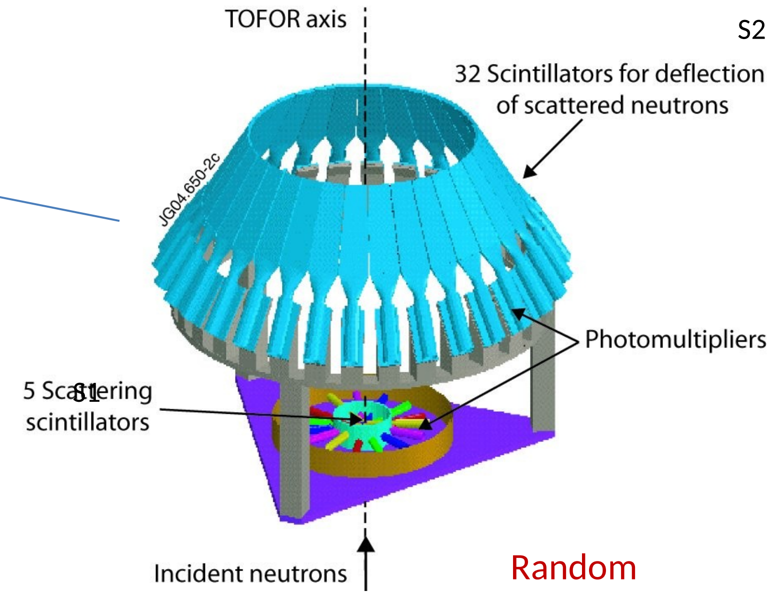

Rate at the detector: 5 x $10^{7}$ $s^{-1}$

Flux at the detector: 4 x $10^{10}$ $m^{-2}s^{-1}$

# Neutron emission spectrometers

2.45 MeV DD neutrons:

- TOFOR-like system at JT-60SA
- Time-of-flight spectrometer
- Digital data acquisition
- Recording time and energy of neutron events in scintillators allows for better background discrimination.

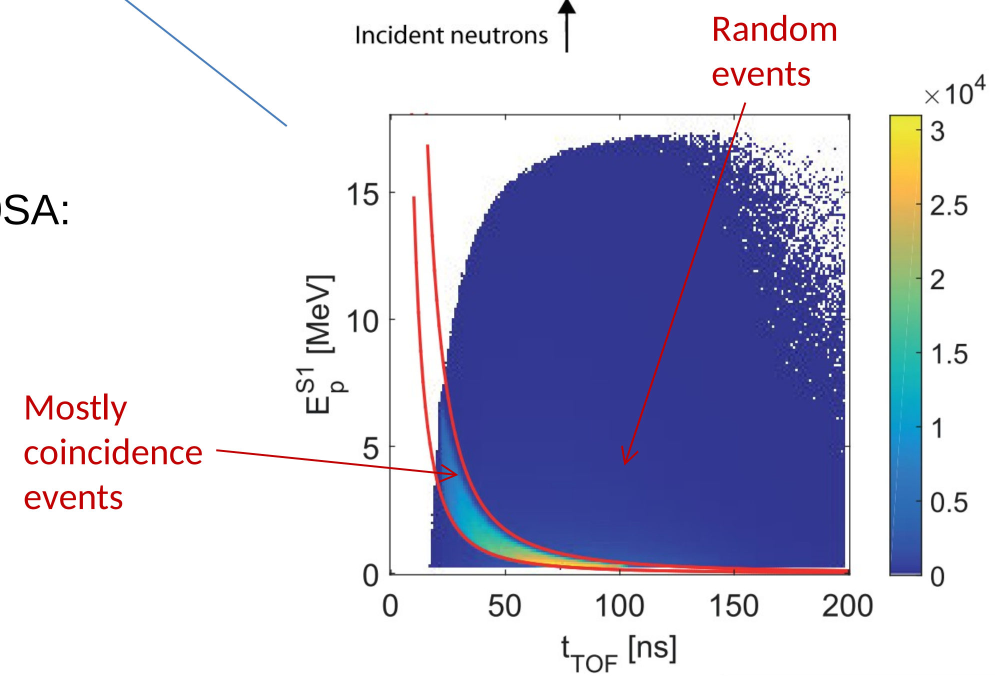



14 MeV DT burn-up neutrons:

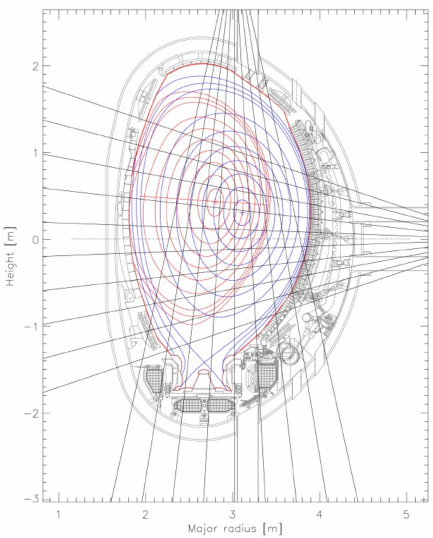
- Diamonds
- Liquid scintillators

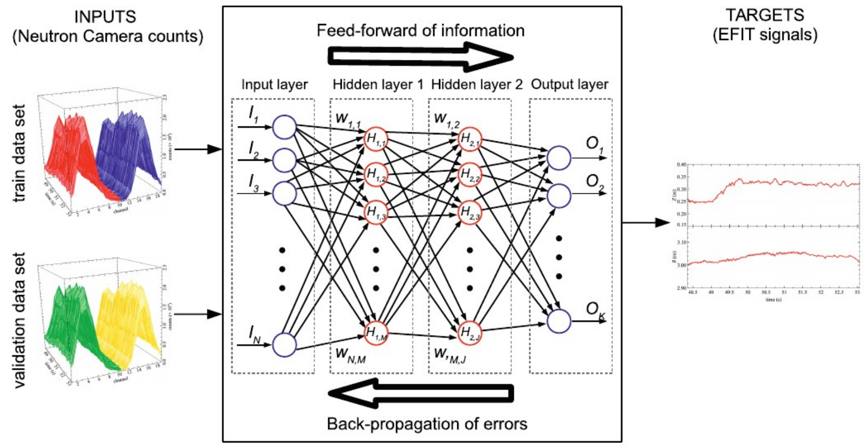
Modelling tools to be geared towards JT-60SA:

- Neutron spectrum calculator code
- Line-of-sight code
- Detector response function simulations
- Backscatter neutron simulations
- Neutron shielding simulation

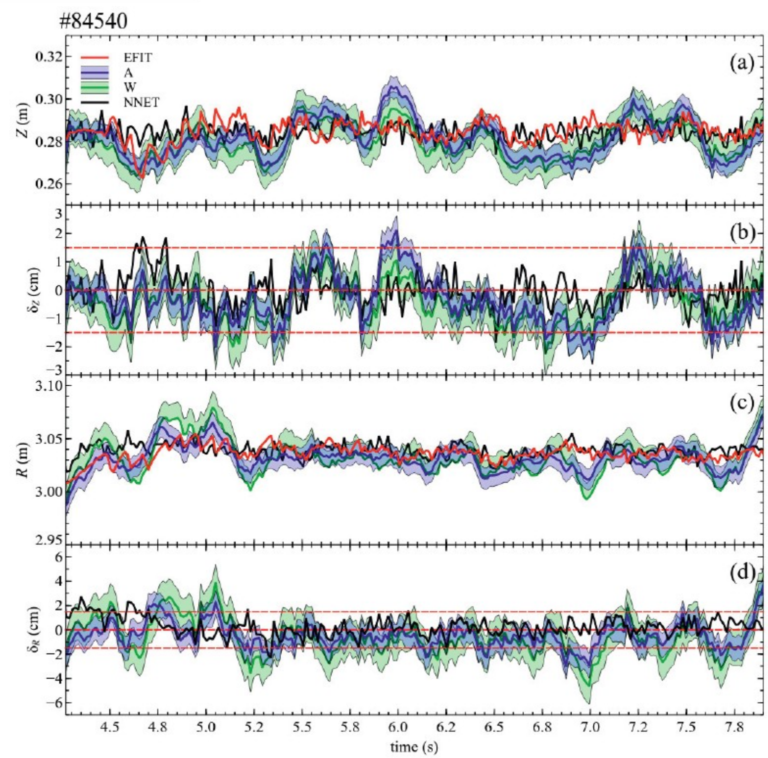


# Collimated neutron flux monitors for plasma position real time control



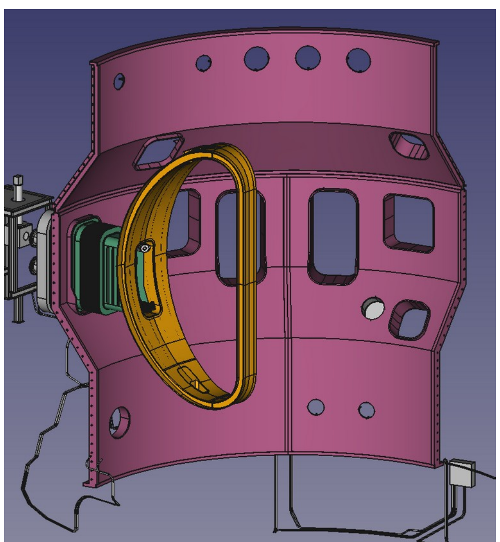

- Neural network able to follow centroid position in presence of VDE and 1 or 2 missing channels
- Trained on magnetic diagnostics but replaces them in the long run (DEMO relevant)
- Once trained, works on a time scale compatible with real time control

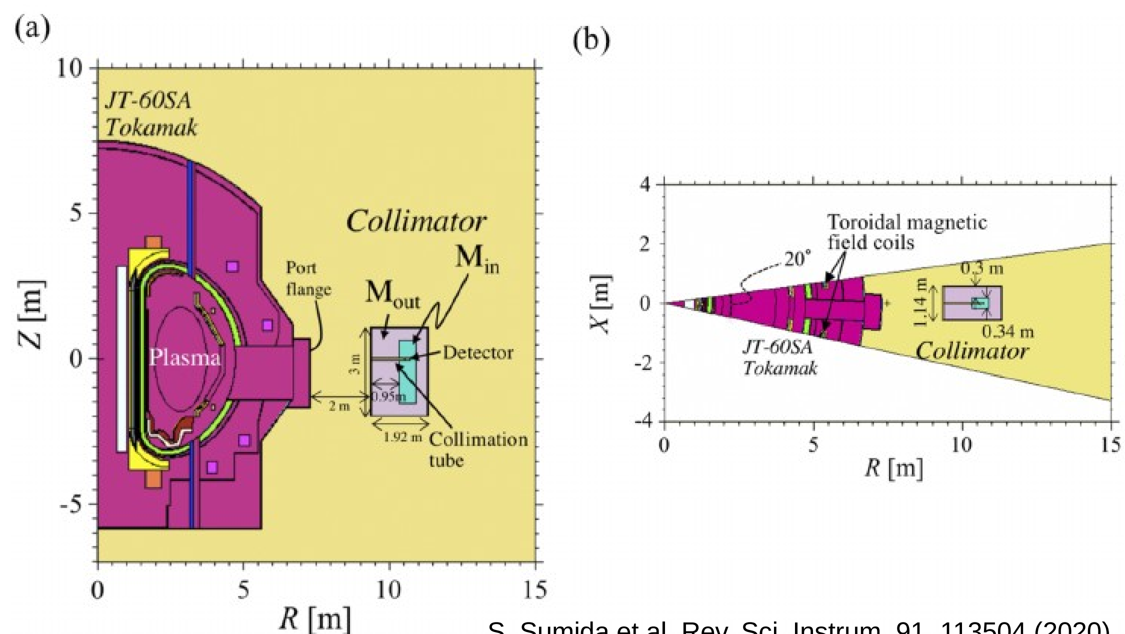



A. Sperduti, Plasma position measurement with collimated neutron flux monitor diagnostics on JET, Fusion Engineering and Design 168 (2021) 112597

# 2022 Activity plan

1. replicate some of the most relevant scenarios (4-1 and 5-1) within the TRANSP/NUBEAM framework including also the NNBI;
2. a more systematic analysis of the performances of compact and TOFOR-like spectrometer on JT-60SA;
3. preliminary study for the integration of the spectrometer(s);
4. retrieve MCNP model for shielding and scattered neutron estimates;
5. establish contact with OST partner.






S. Sumida et al. Rev. Sci. Instrum. 91, 113504 (2020)