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AUDITORIO ALFREDO KRAUS LAS PALMAS DE GRAN CANARIA, SPAIN

JSI

EUROfusion

Characterization of the neutron field for streaming analyses in TT operations at JET

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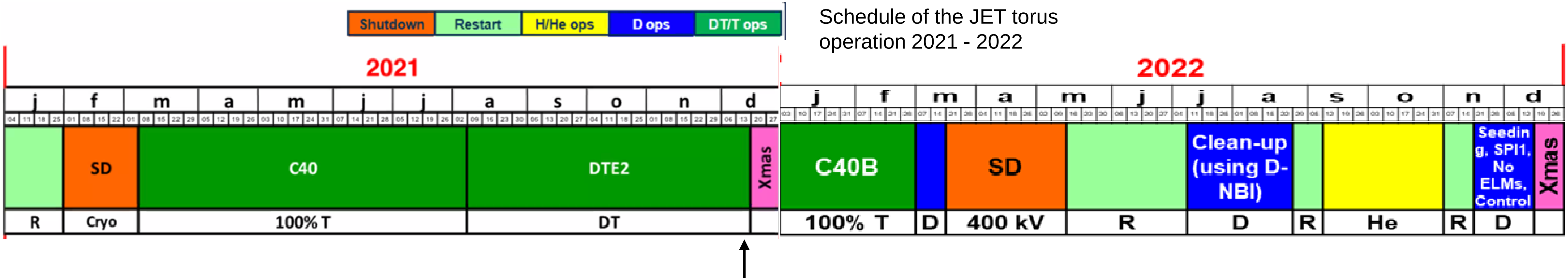
Unique tritium campaign at JET

- **Joint European Torus (JET) operated with a deuterium-tritium (DT) plasma in 2021/2022 - campaign DTE2**
  - Only JET (1997, 2021) and TFTR (1994-96) capable of operation with deuterium/tritium



Schedule of the JET torus operation 2021 - 2022

59 MJ pulse (Dec. 21. 2021)

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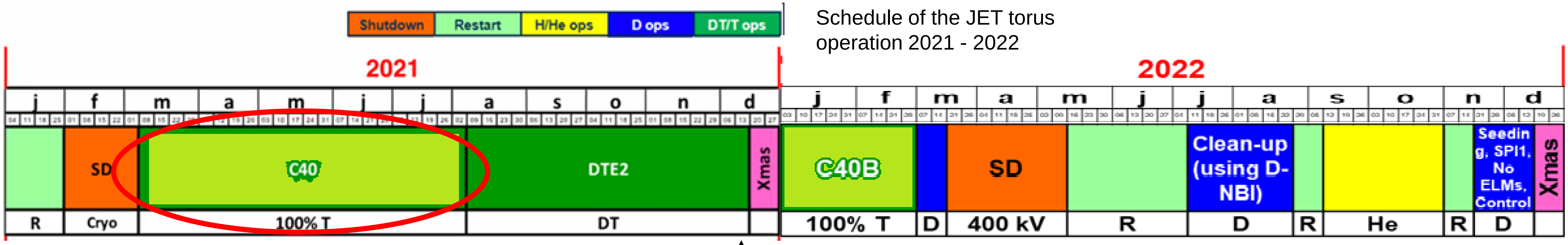


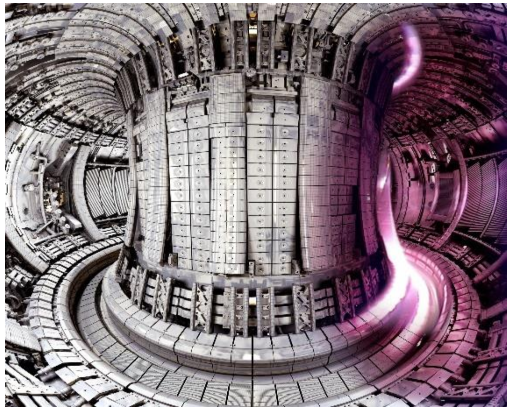
Schedule of the JET torus operation 2021 - 2022

1st part of TT campaign: December 2020 – July 2021

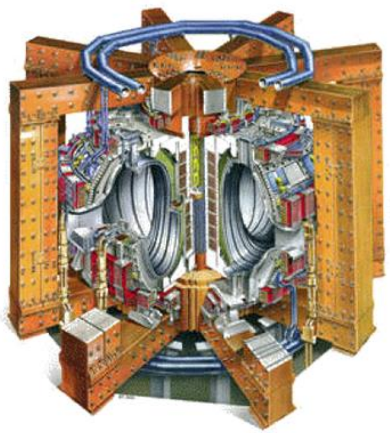
59 MJ pulse (Dec. 21. 2021)

- **The campaign included also longer periods of operation with a tritium (TT) plasma**
  - DT plasma – **T:D ~ 50:50**, large neutron yields
  - T plasma – **T:D ~ 99:1**, very interesting from physics point of view

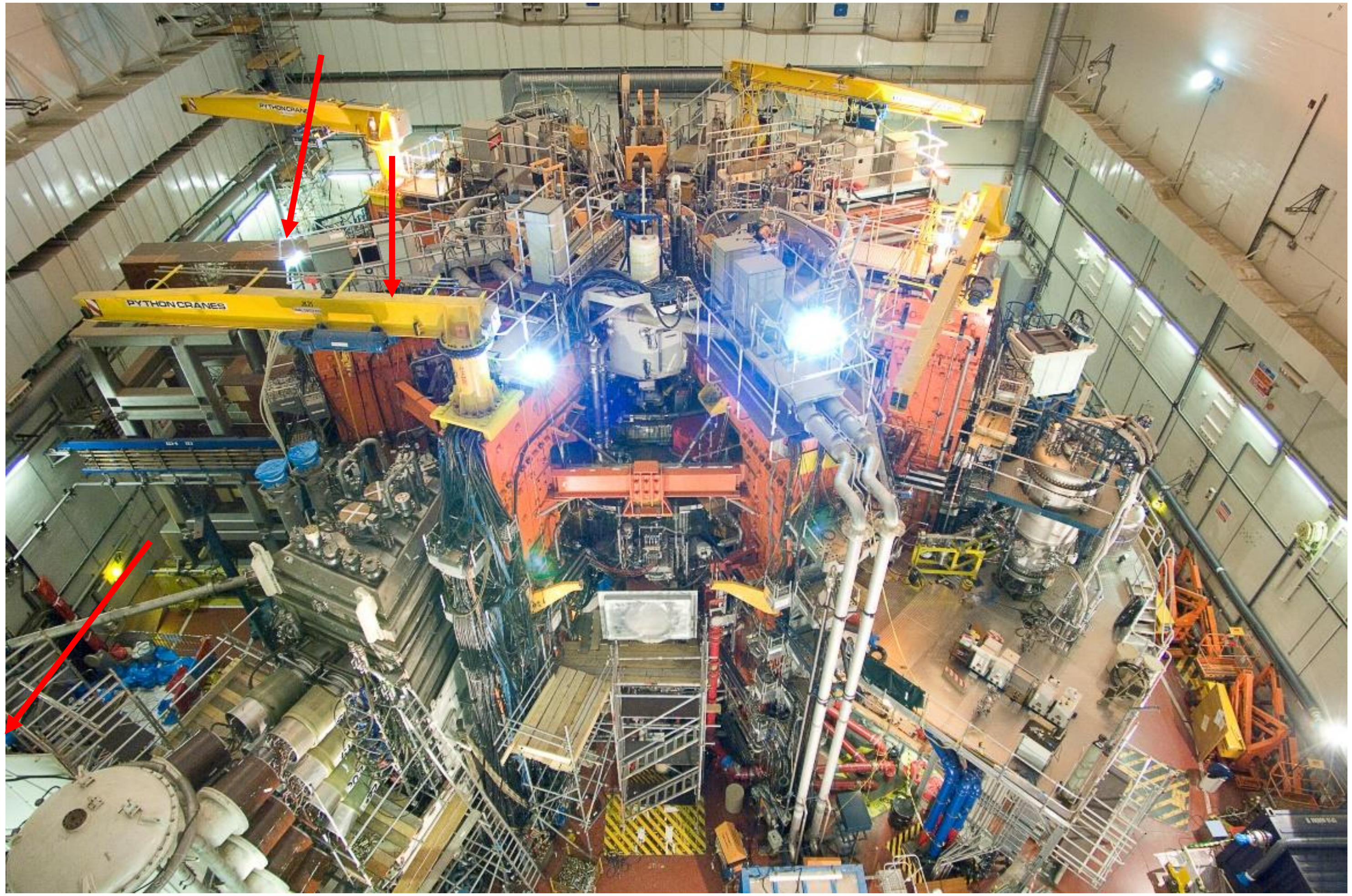
Neutron streaming



Interior of JET
Origin of neutrons



JET machine



Exterior of JET

- Complex paths for neutrons when streaming to exterior of the torus
- **Benchmark evaluation** – comparison of calculations with experiments

Detectors

- Detectors inside polyethylene moderators

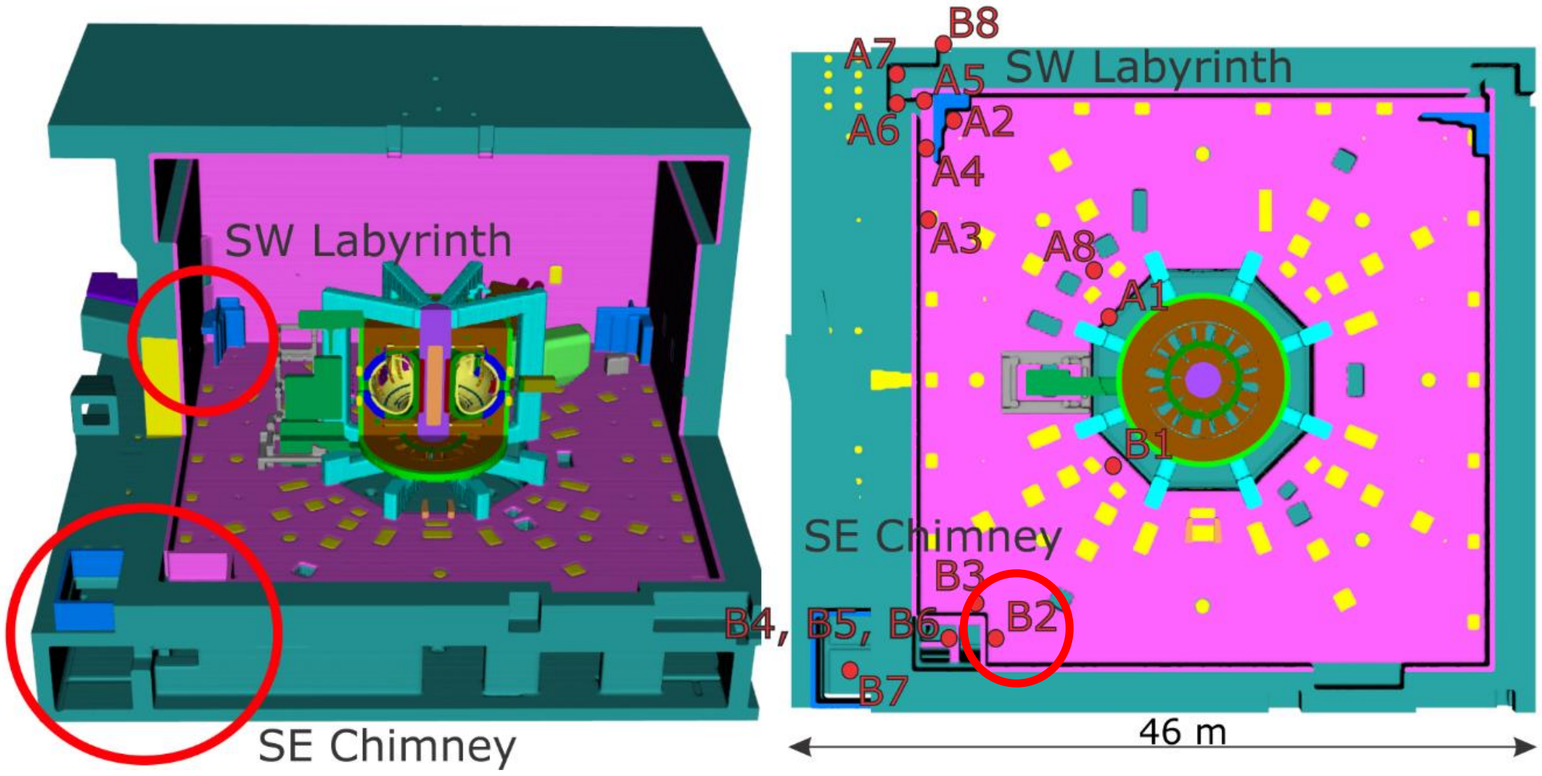
- Thermoluminescent detectors (MCP-N and MCP-7)
  - measurements by IFJ Kraków, Poland
  - 11 detector positions

- Activation foils (Co, Ta, Ag)
  - measurements by NCSR Demokritos, Greece
  - 6 detector positions

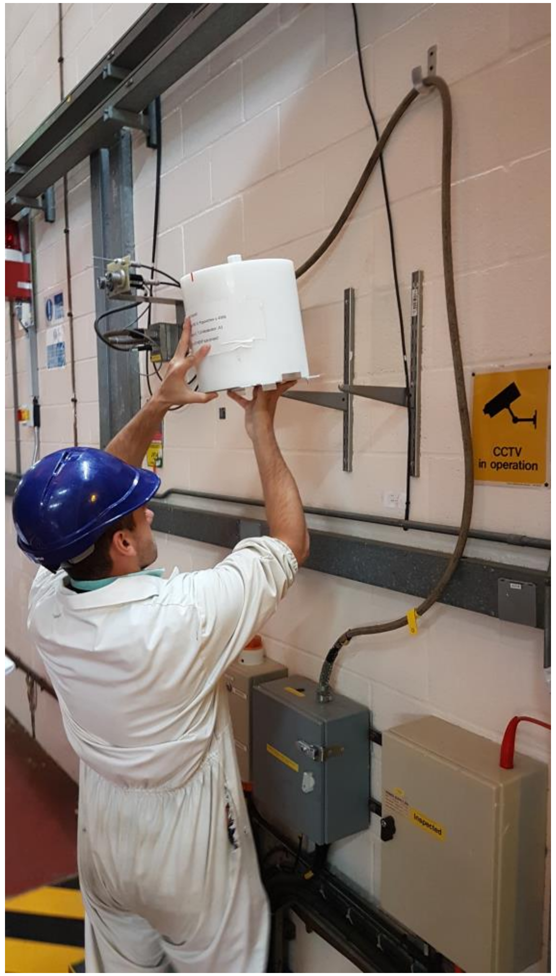
- Calculations performed by JSI, ORNL, UKAEA

Positions of detectors

- Detector positions up to 40 m from plasma
- Some behind torus hall walls



Positions of detectors



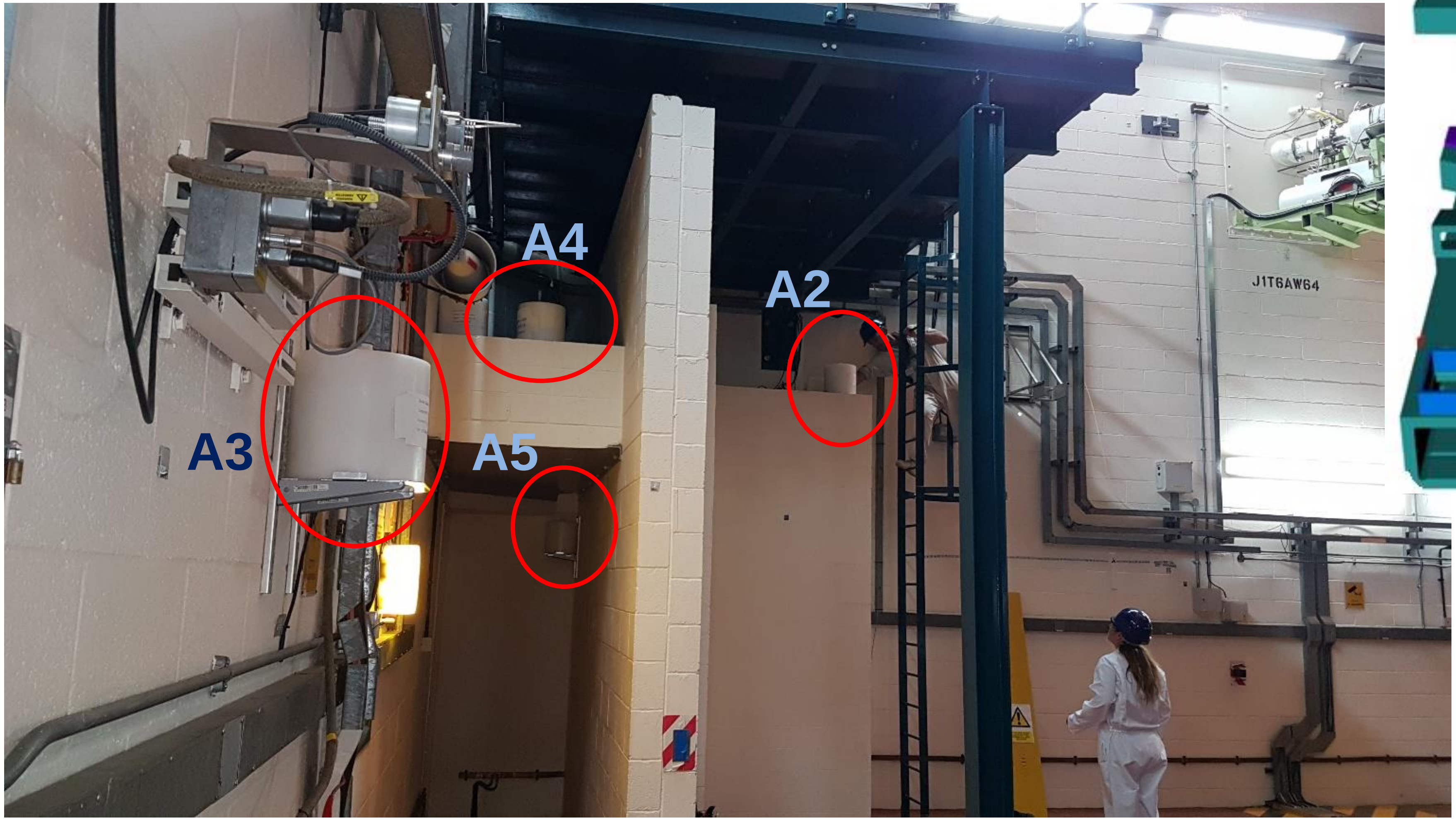
Torus hall wall

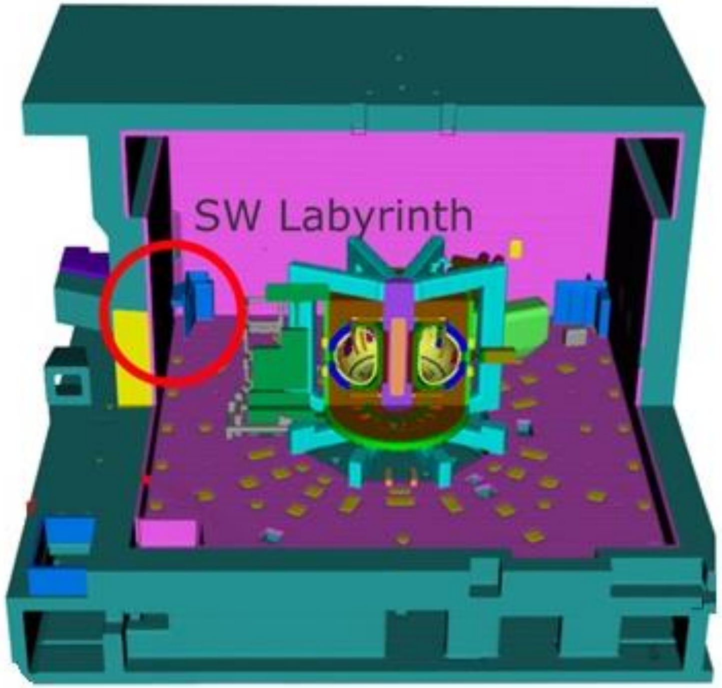
Shielded labyrinth

Basement, level below torus

Close to
vacuum vessel

Positions of detectors

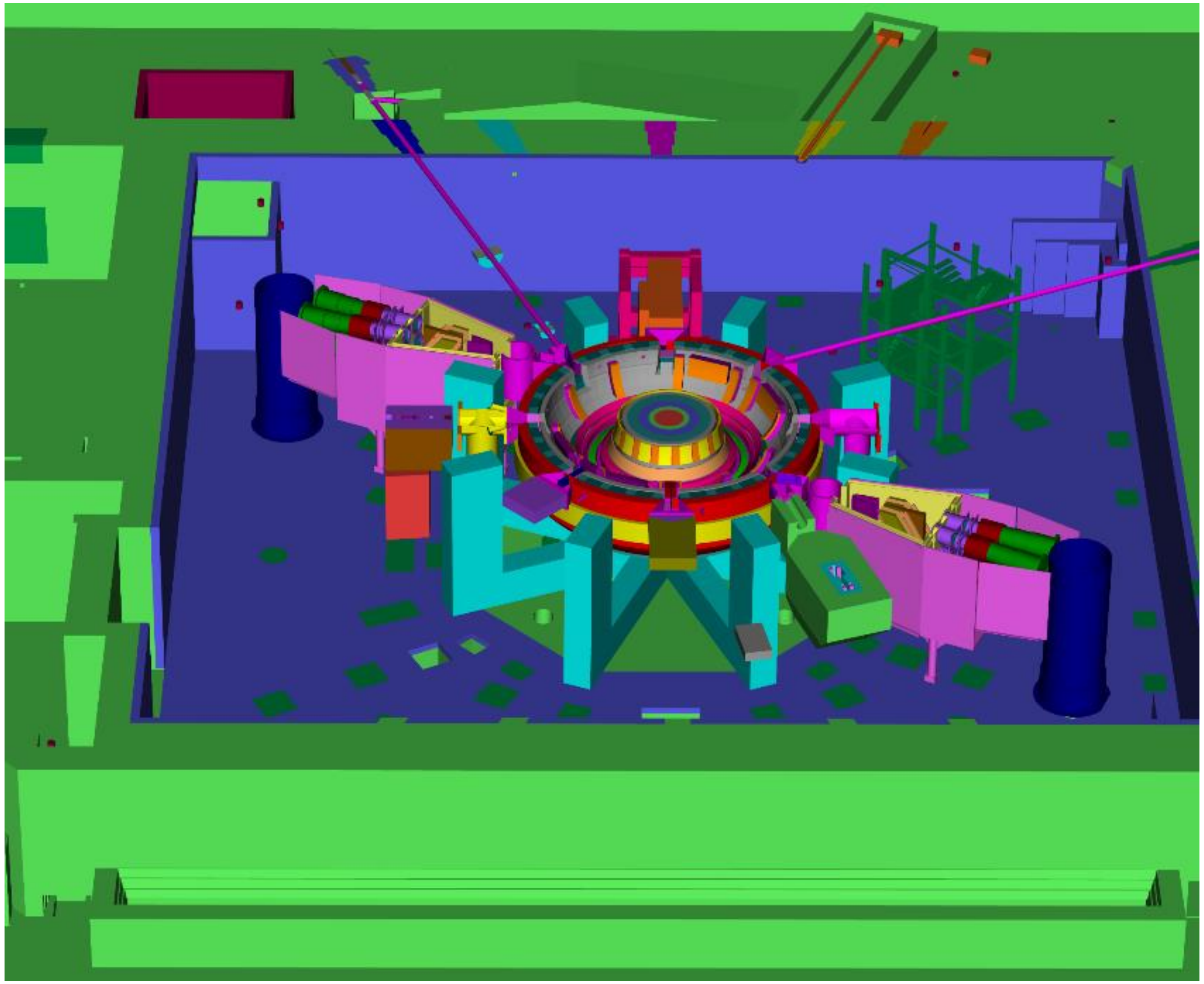


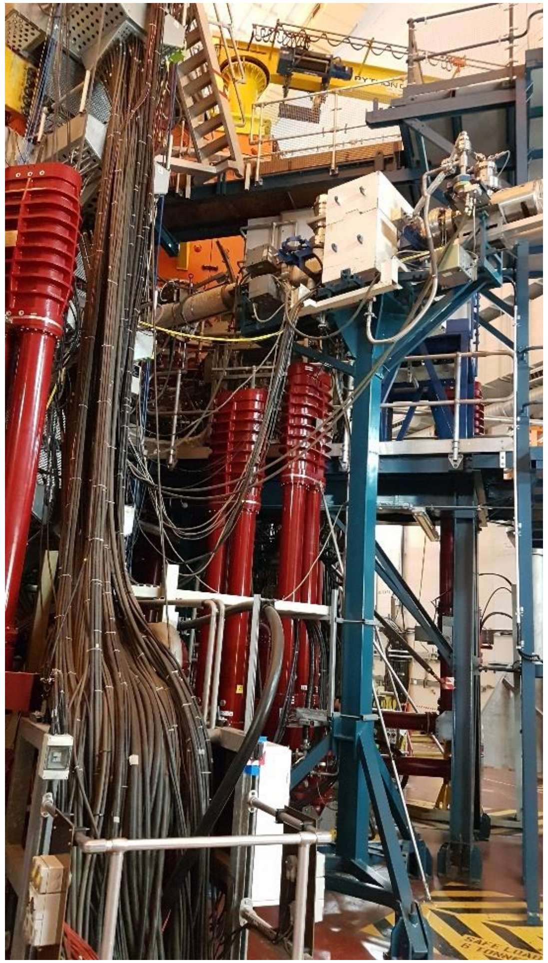


Computational model

JET models constantly developed and upgraded

Cross section through computational (MCNP) model





All details not explicitly modelled

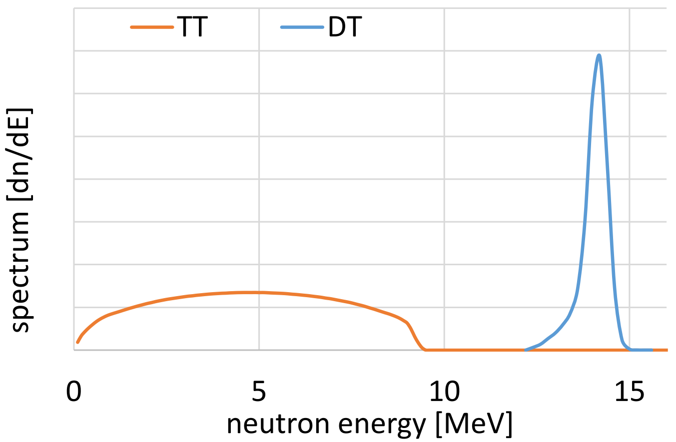
Approximation and homogenisation of small components

Plasma neutron source in tritium campain

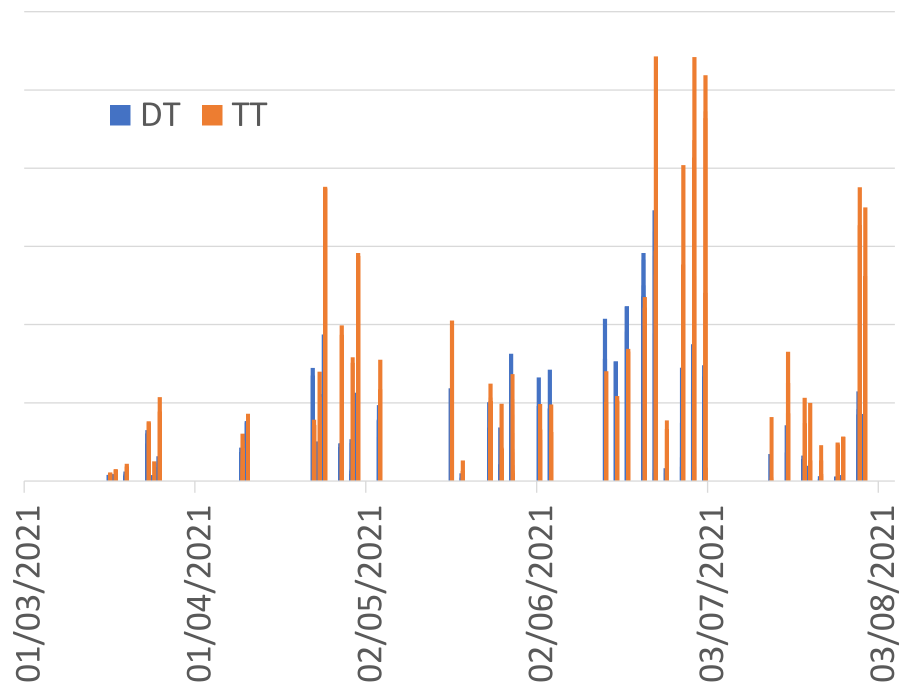
Source during tritium campaign a combination from neutrons

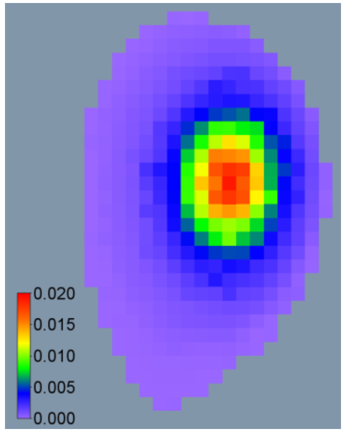
- **T + T** $\rightarrow$ ^{4}He + **2·n**
- **D + T** $\rightarrow$ ^{4}He + **n**

Source spectrum in TT operation
presence of ~1% D neutrons in plasma



Neutron yields during the JET 2021 TT campaign



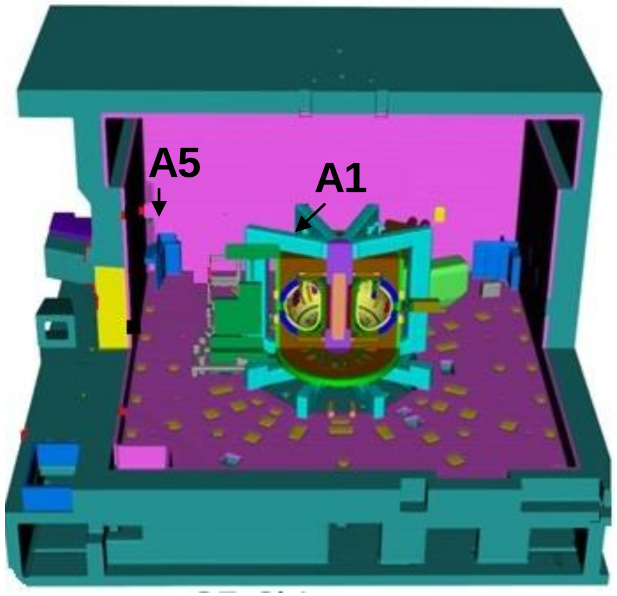


spatial source distribution
The same for TT and DT
Circular symmetric

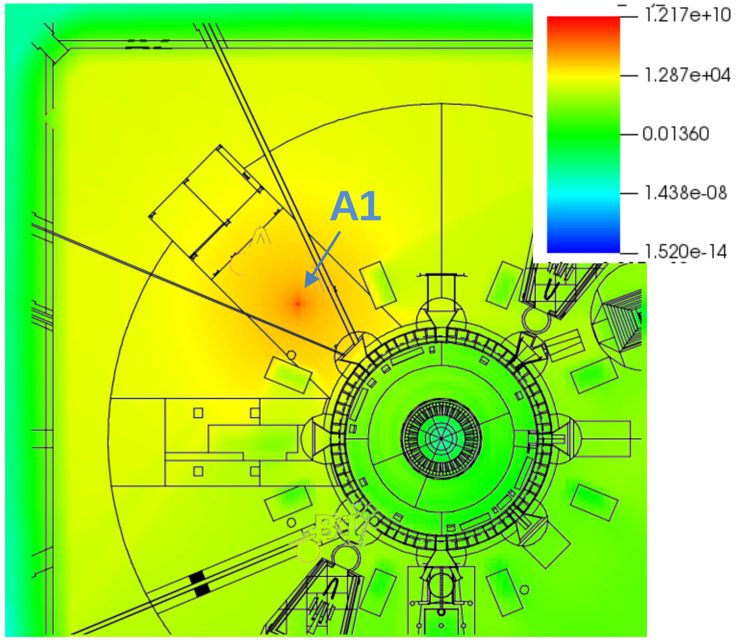
Neutron yield

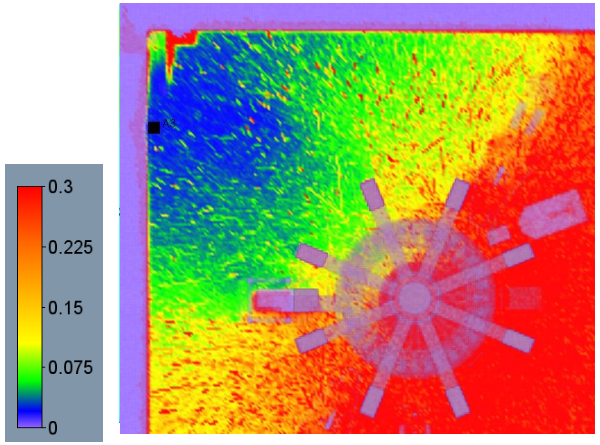
TT	DT
59,6 %	40,4 %
5,1E+18 neutrons	3,4E+18 neutrons
Emean = 5 MeV	Emean = 14.1 MeV

Two step calculations



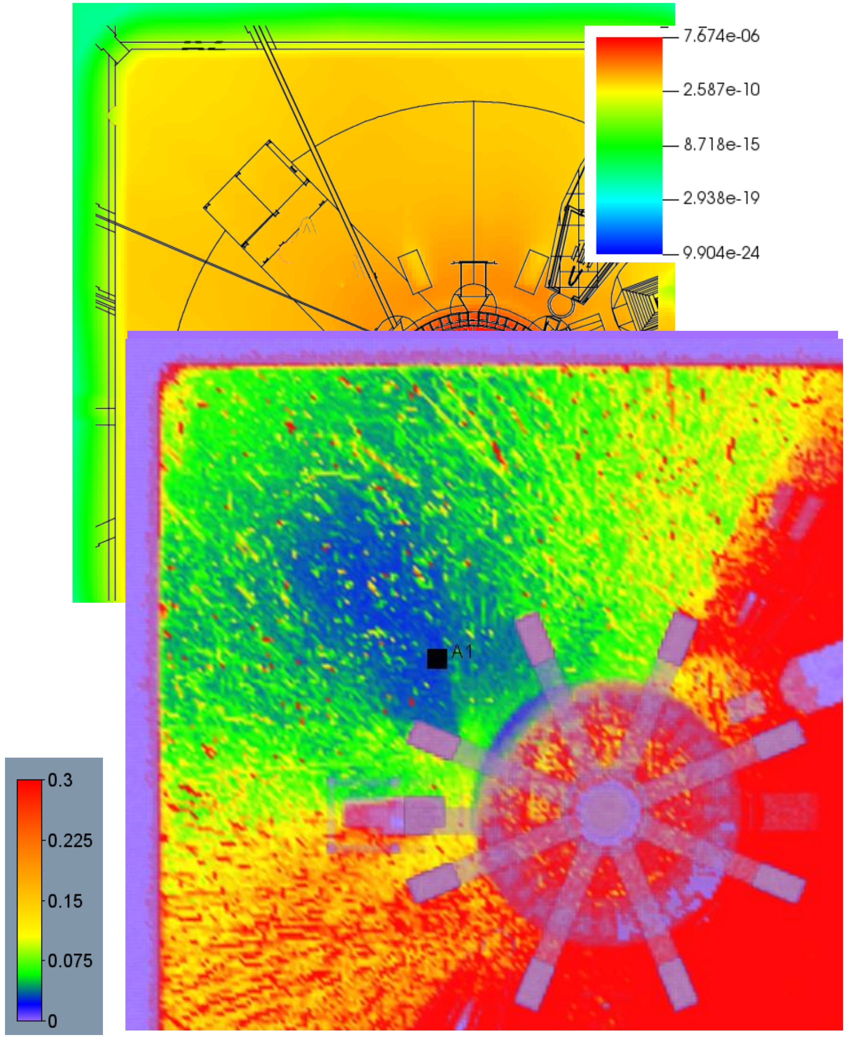
ADVANTG – deterministic calculation of variance reduction parameters





Relative error

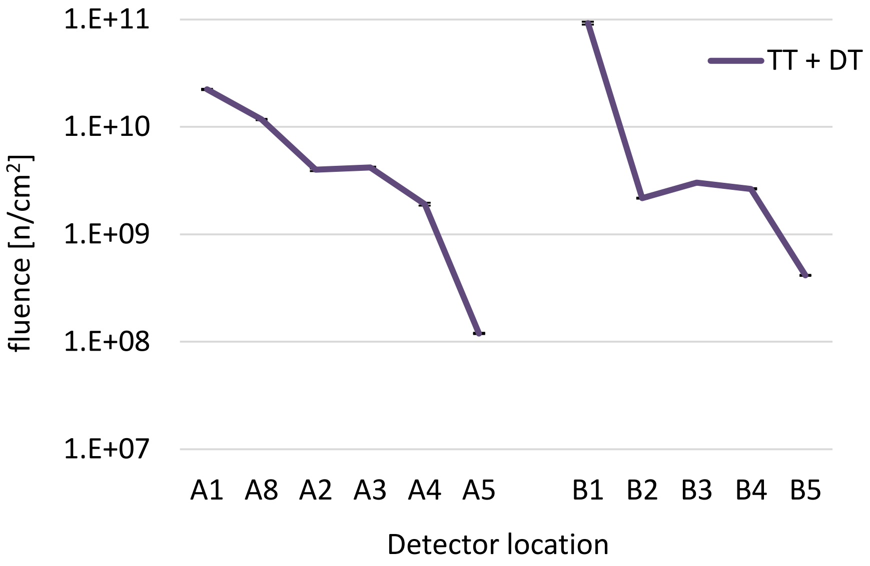
Secondary flux calculation with Monte Carlo

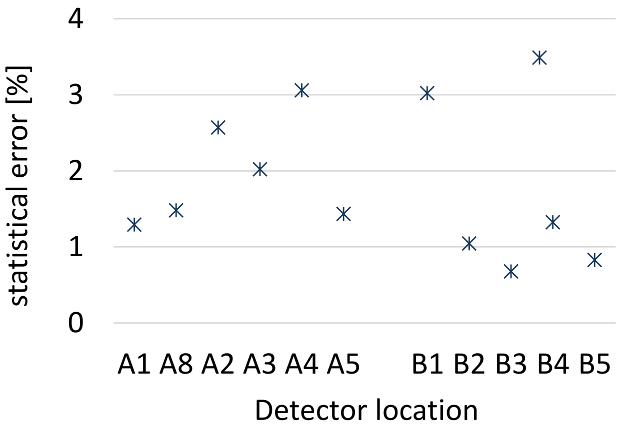


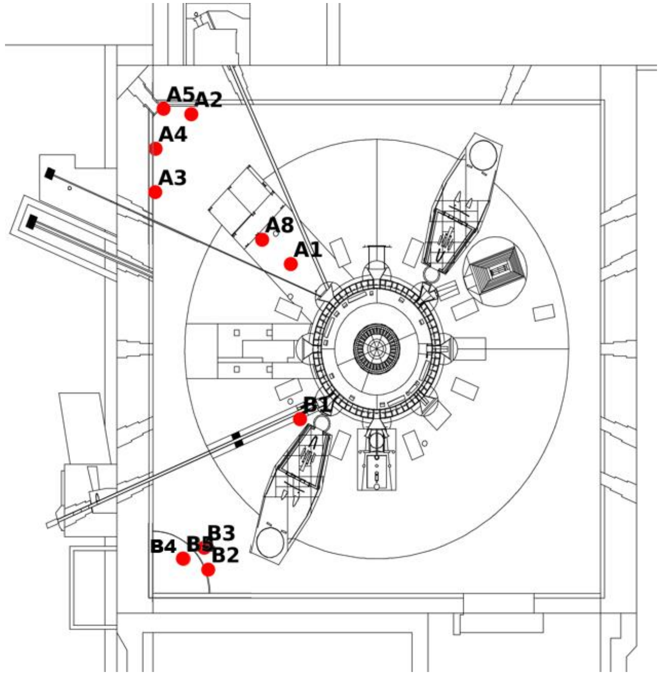
Relative error of results

Neutron fluxes – TLD detectors

Results of calculations for neutron fluxes





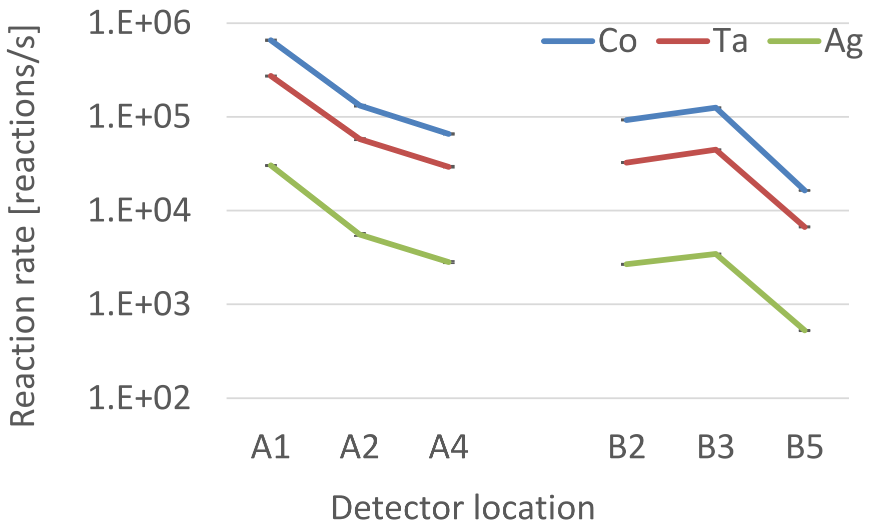


A2 location

Statistical uncertainties below 4% for all positions

Reaction rates – activation detectors

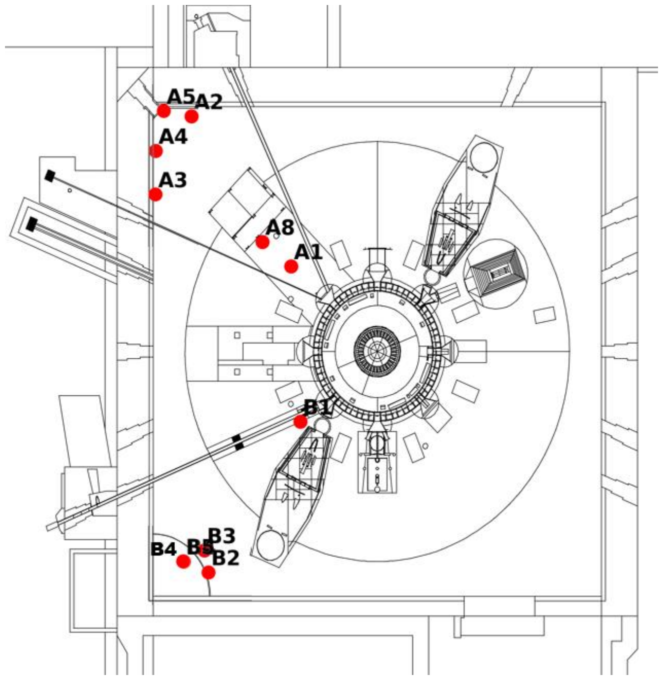
Calculations of reaction rates for selected activation materials and neutron fluxes

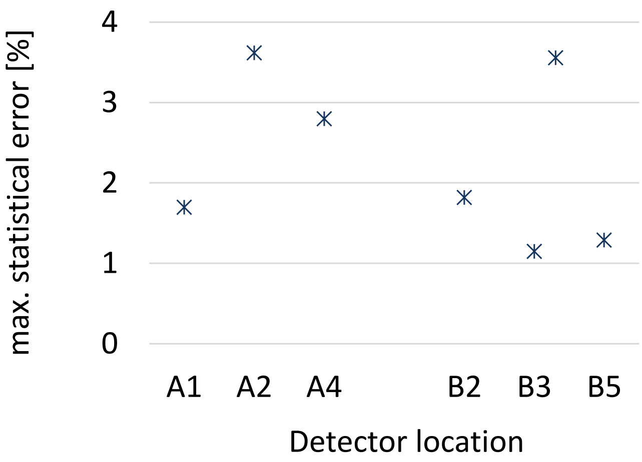


$^{59}Co(n,\gamma)\,^{60}Co$

$^{181}Ta(n,\gamma)\,^{181}Ta$

$^{109}Ag(n,\gamma)^{110m}Ag$



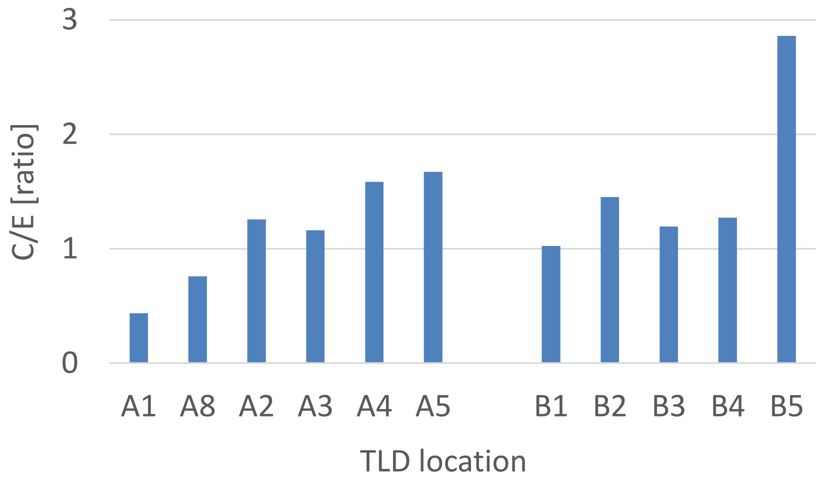


Statistical uncertainties below 4% for all positions

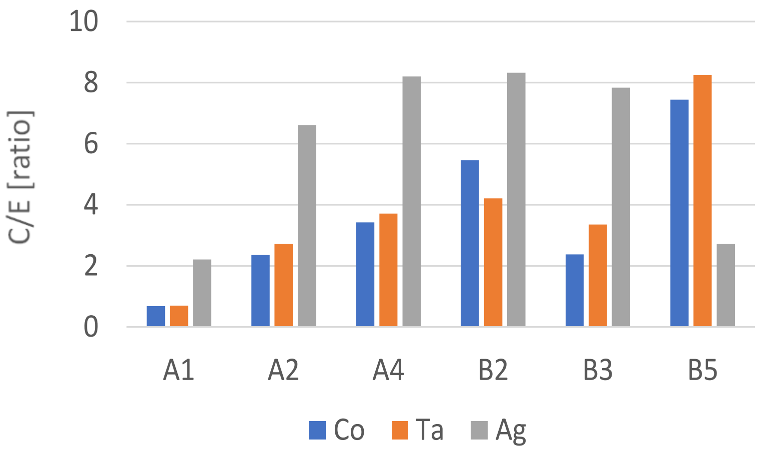
Comparison with experimental results

Experimental results provided in frame of another work
Details are presented separately

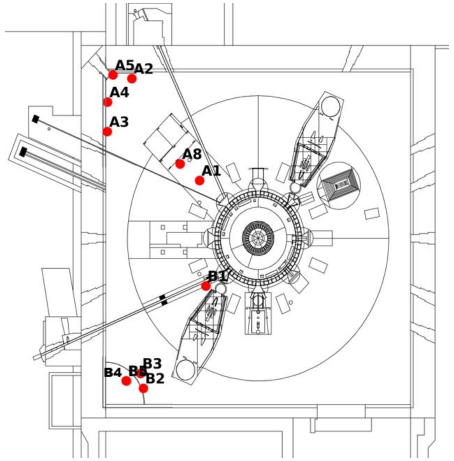
Comparison of **C/E (calculations / experiment)** for available data

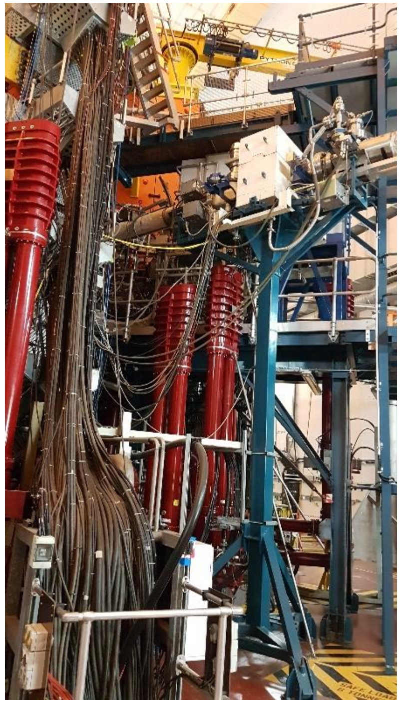


Thermoluminescent detectors - TLDs



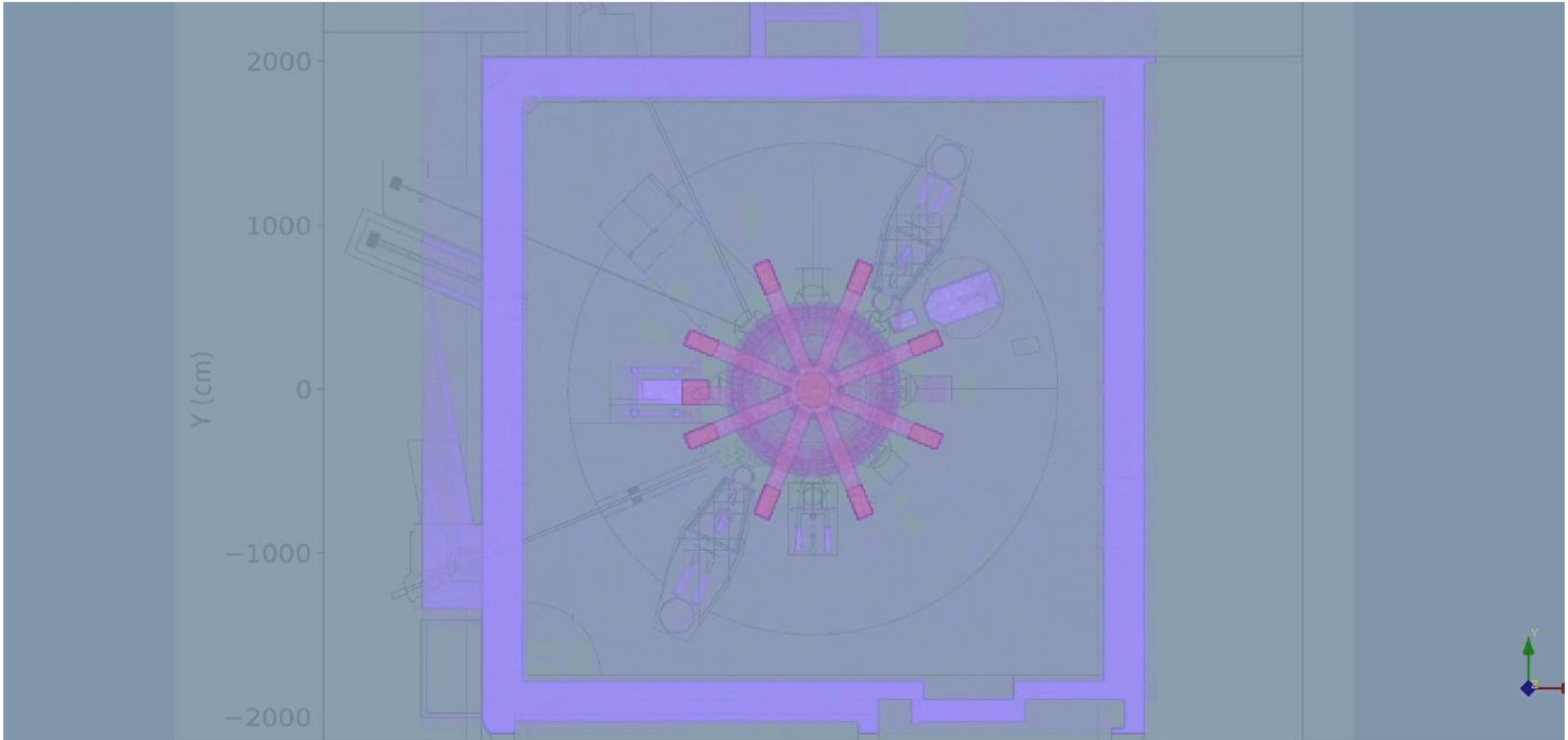
Activation foils reaction rates for reactions on Co, Ta, Ag





The TT results in better agreement with experiments as the 2020 DD campaign results

Analyses of neutron paths



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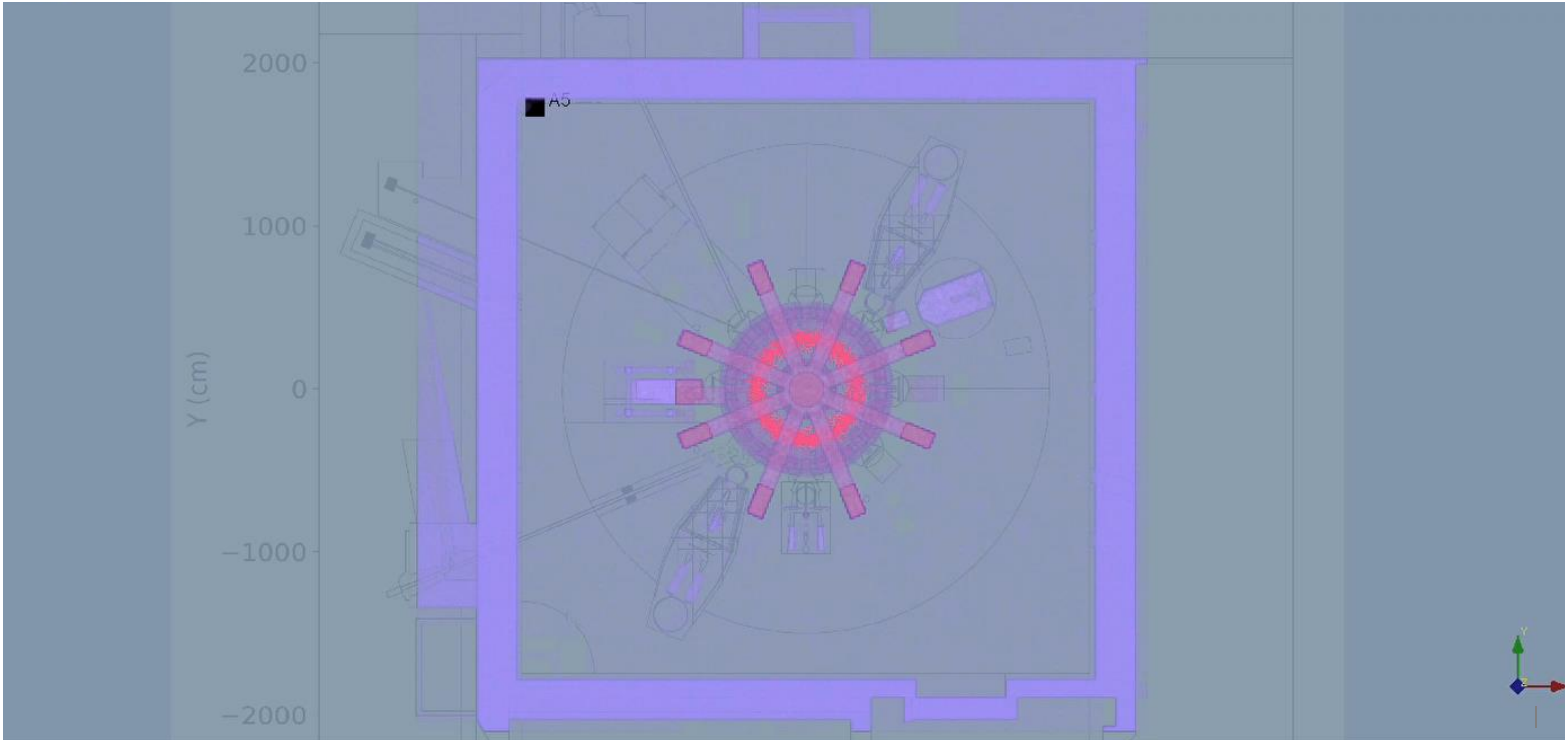
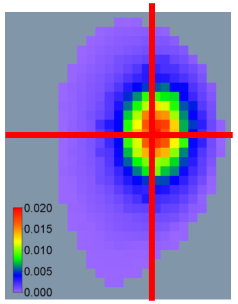


Sensitivity to plasma source distribution

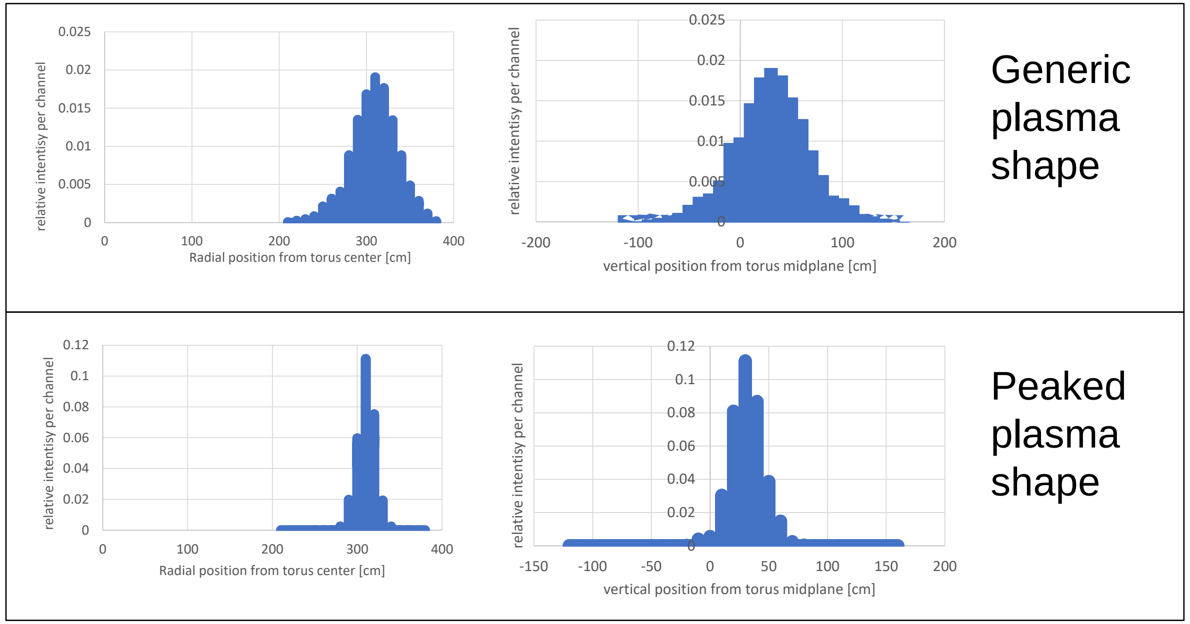


Horizontal x-section

Vertical x-section

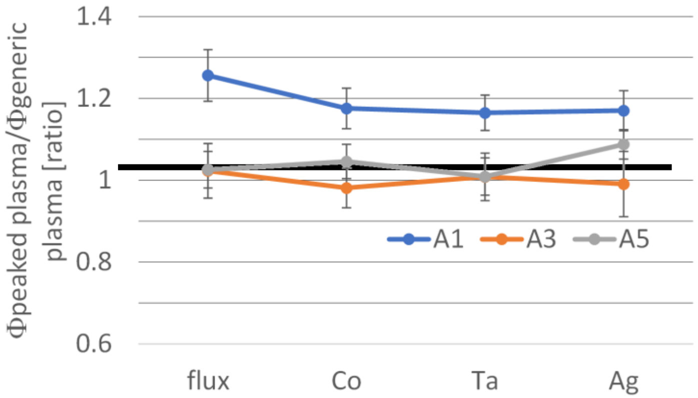
Horizontal x-section

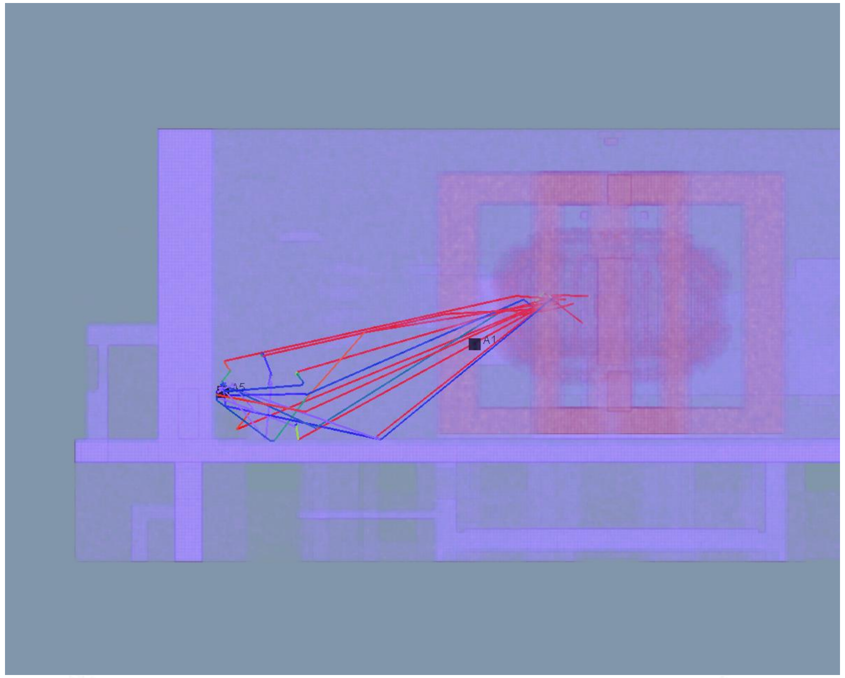
Vertical x-section



Different plasma scenarios result in different plasma shapes

Study of plasma shape on response





Detectors at locations close to plasma sensitive to plasma shape, remote locations not

Conclusions

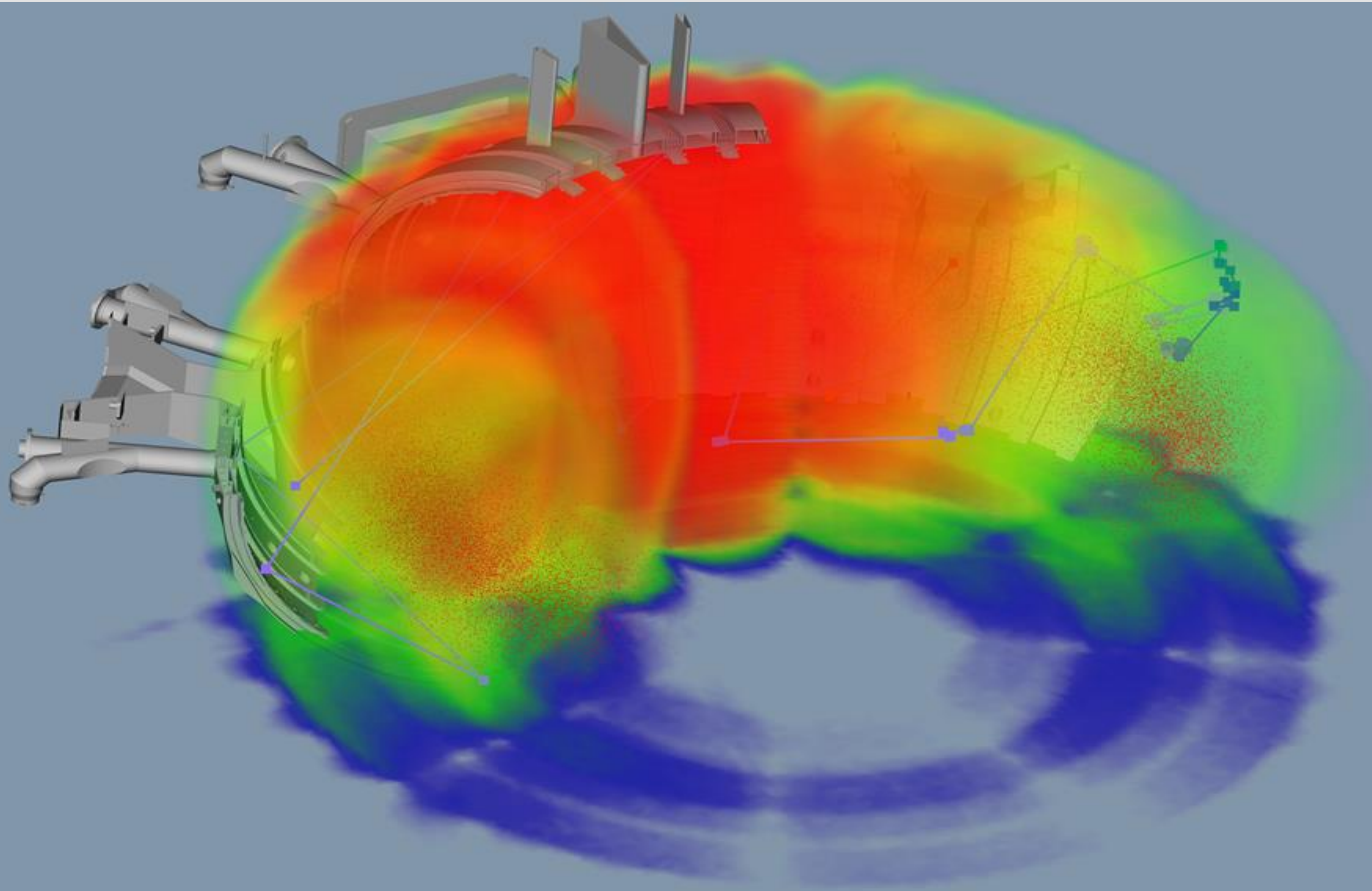
JET is a very valuable machine to compare calculations to experimental results in DD, DT and TT plasmas

Experimental data gathered during unique Tritium campaign in 2021, part of the DTE2 campaign

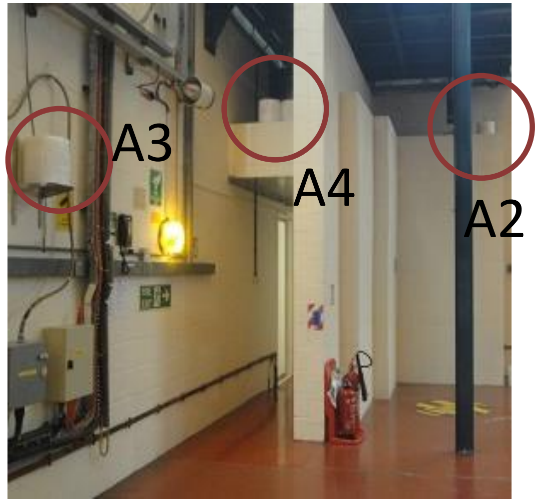
Benchmark evaluation of neutron fluxes has been performed along streaming paths at remote locations of the JET torus hall

Low statistical uncertainty of calculations, C/E values below factor of 3 for TLDs and below a factor of 8 for Activation detectors at all positions

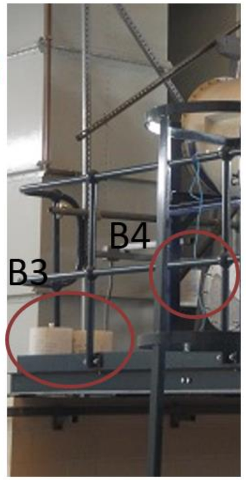
THANK YOU



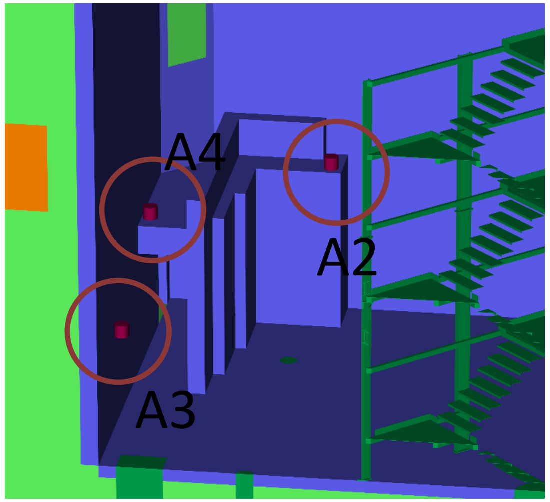
Detector locations

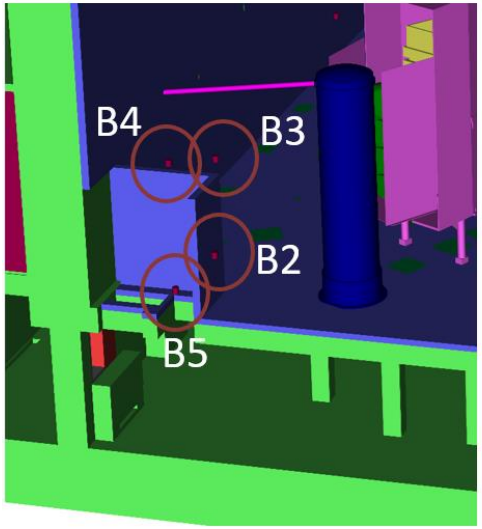


Location of detectors



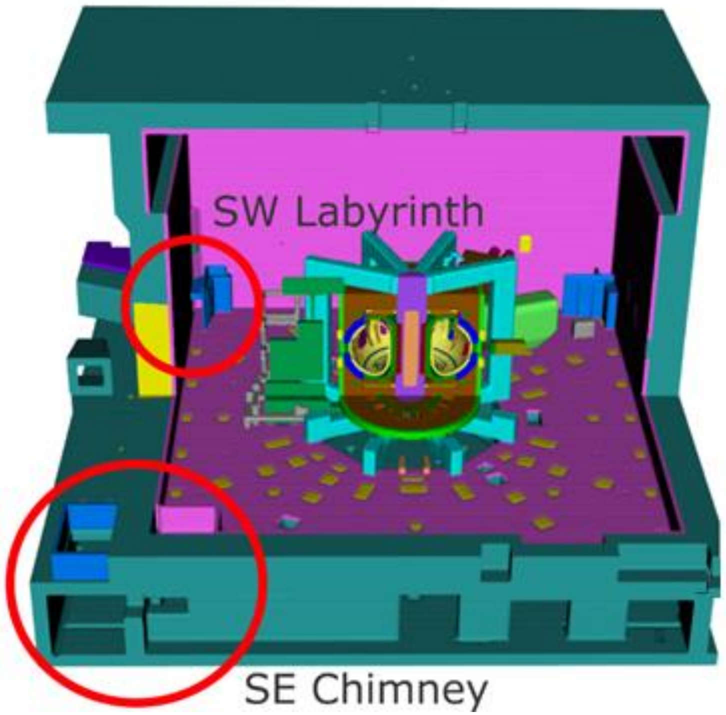
MCNP models

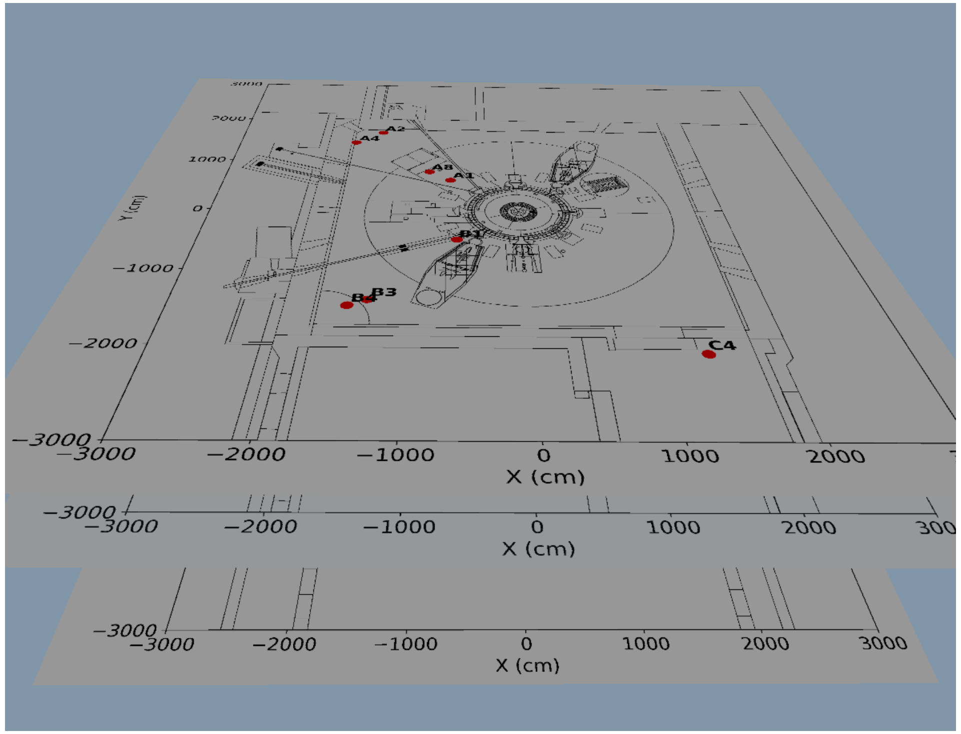




Detector locations

- **Experiments at JET for validating the neutronics codes and tools used for nuclear analyses to predict quantities such as the neutron flux along streaming paths.**
- **Several positions chosen for detectors**
  - Outside the torus
  - Along streaming paths

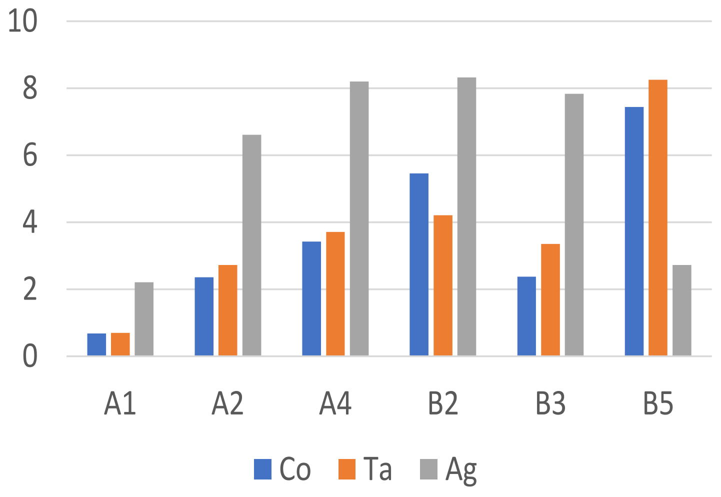


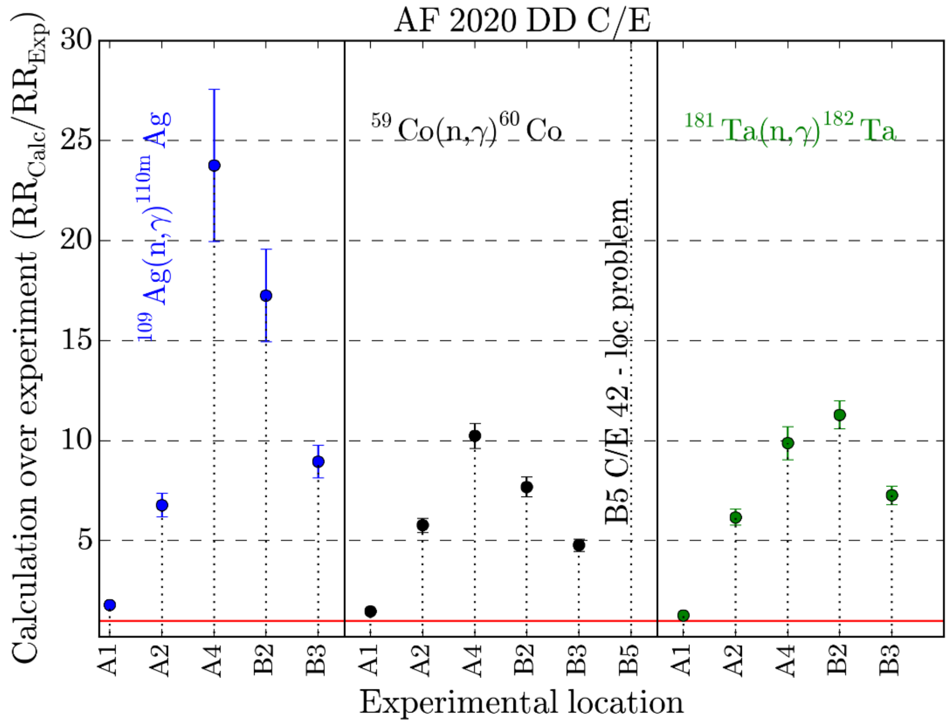


Results C/E

AFs

	C/E values		
Position	Co	Ta	Ag
A1	0.7	0.7	2.2
A2	2.4	2.7	6.6
A4	3.4	3.7	8.2
B2	5.5	4.2	8.3
B3	2.4	3.4	7.8
B5	7.4	8.3	2.7





Comparison to NEXP results – DD, 2020
(Bor Kos)

Analyses of neutron paths