Status of the ITER Project and Neutronics Activities

Mohamed Sawan

Fusion Technology Institute
The University of Wisconsin-Madison

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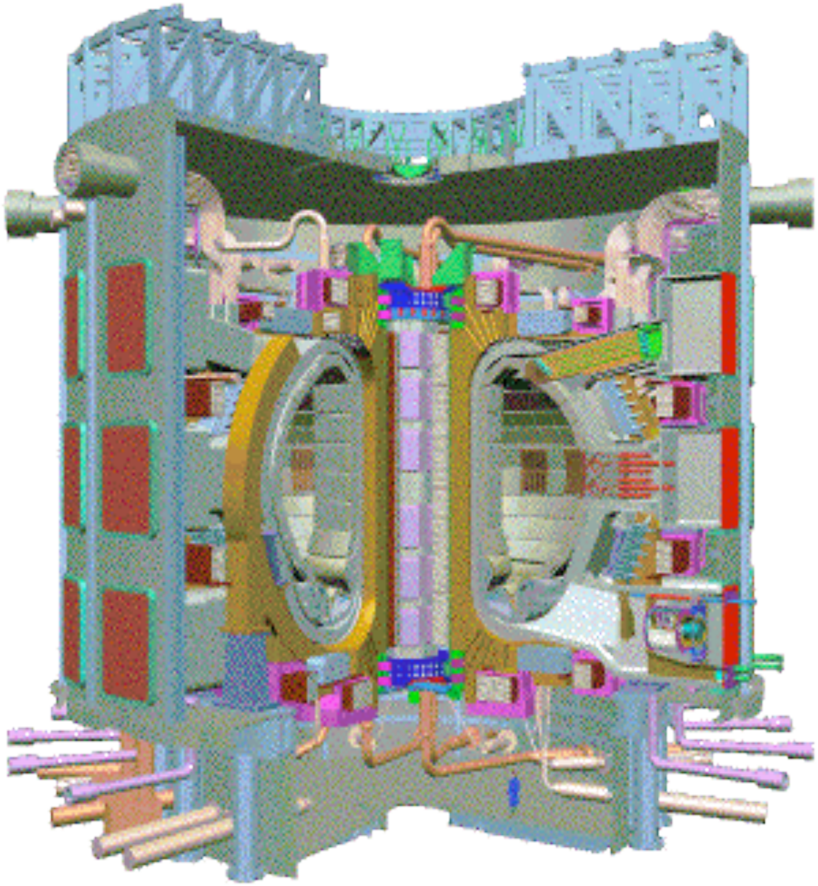
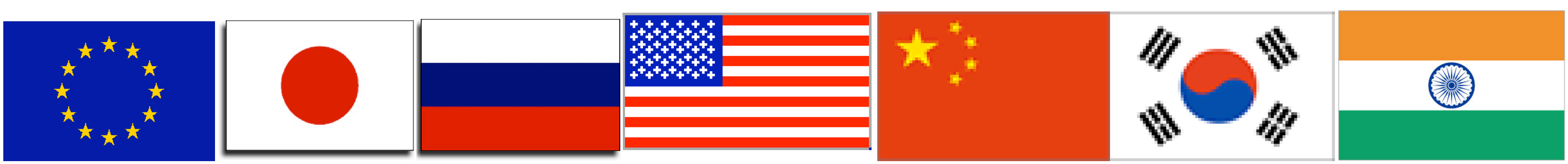
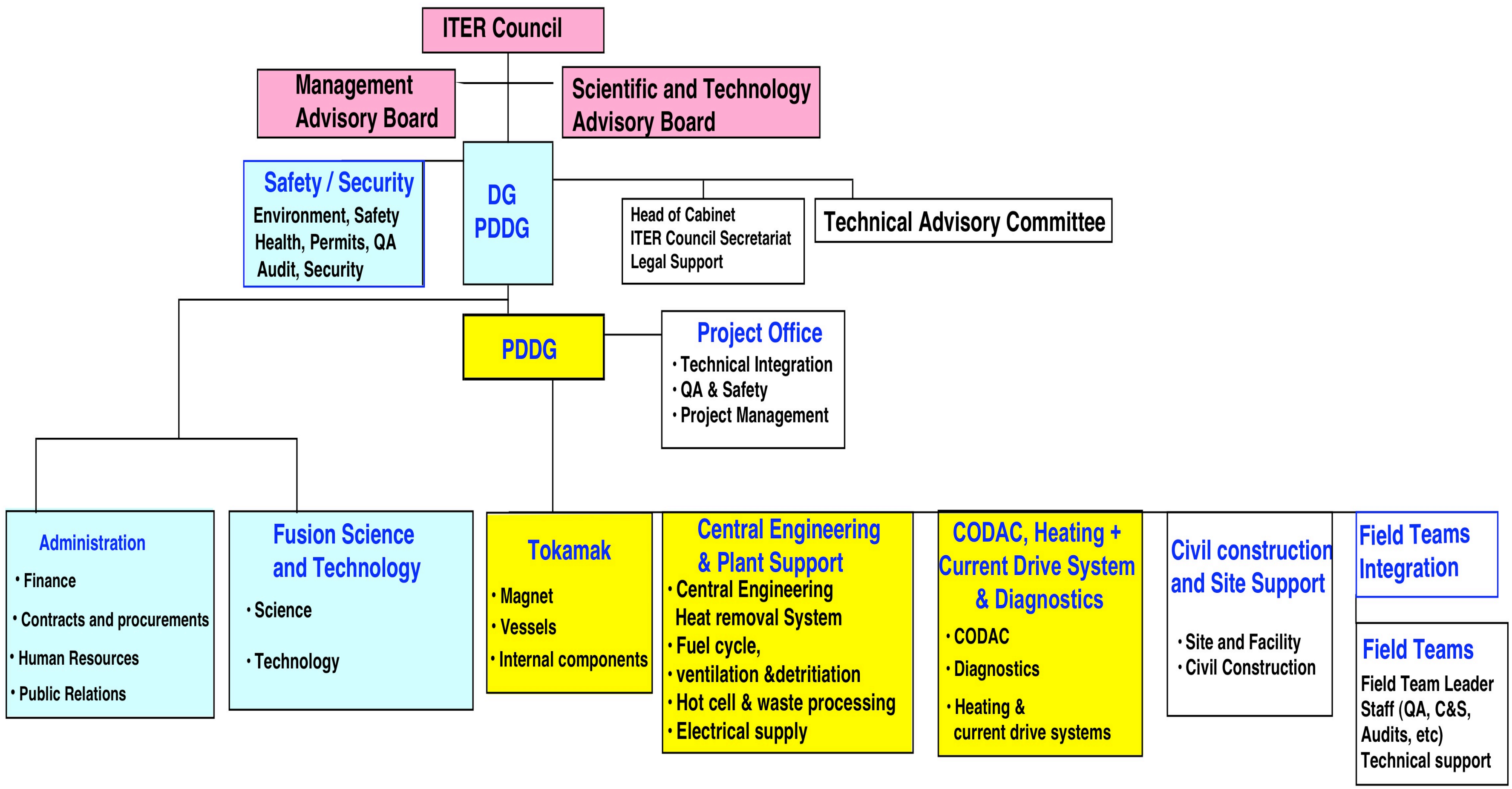
On May 24, 2006, the ITER International Agreement was initialed in Brussels by the Seven ITER Parties

- **The seven Parties**:
  - **Have judged sufficient scientific and technological readiness and benefits**
  - **Are committing 110% of the ITER value for construction (including reserve)**
  - **Have agreed on the hardware responsibilities of each party**
  - **Have developed organizational and legal arrangements for the ITER Legal Entity**

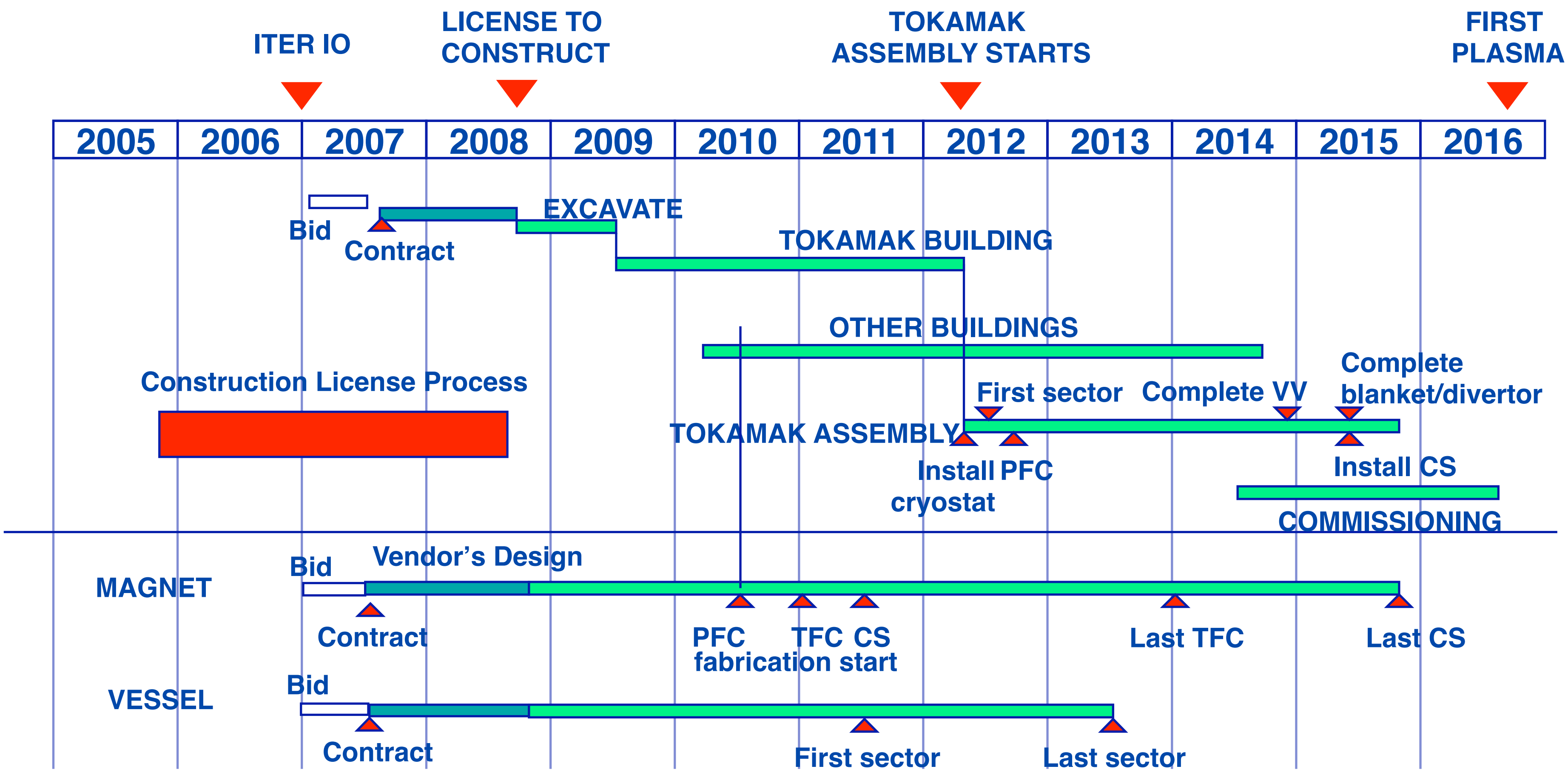




ITER Organizational Structure



Integrated Project Schedule



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ITER Collaboration

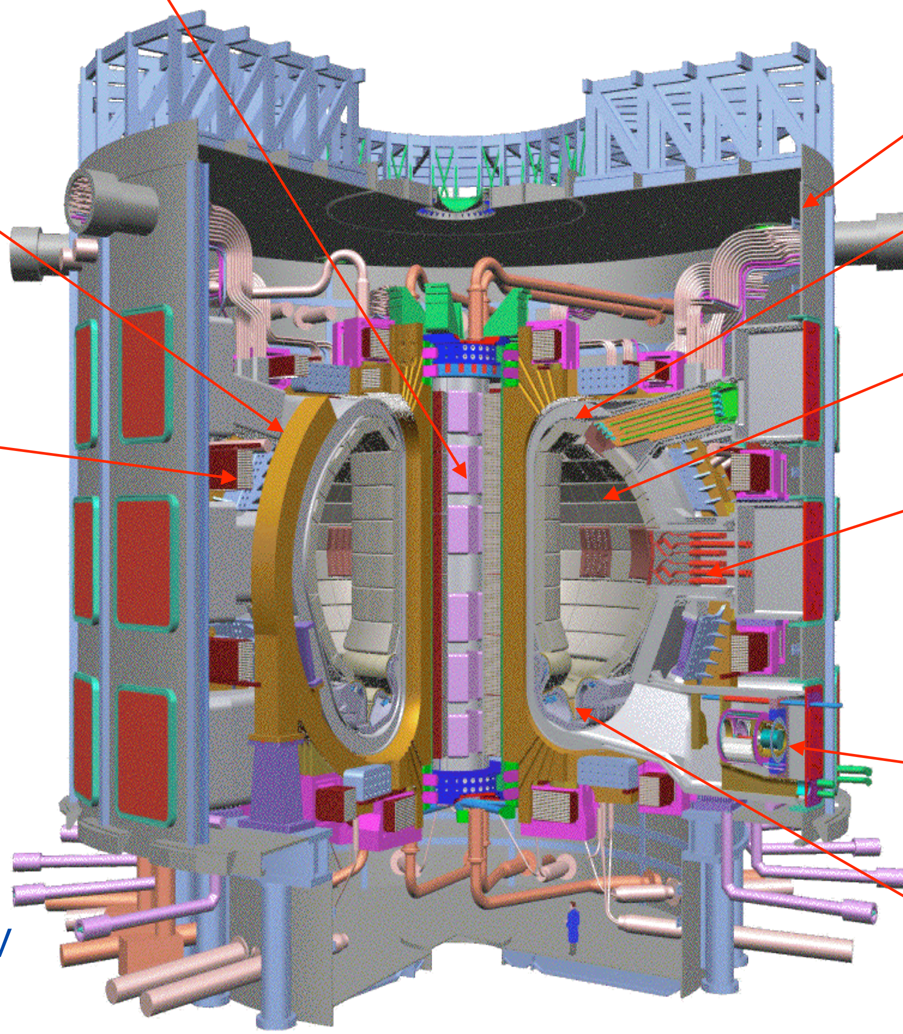
- For its size and cost and the involvement of virtually all the most developed countries, representing over half of today world's population ITER will become a new reference term for big science projects.
- The ITER project is one of the world's biggest scientific collaboration.

The core of ITER

Central Solenoid
Nb_3Sn, 6 modules

Toroidal Field Coil
Nb_3Sn, 18, wedged

Poloidal Field Coil
Nb-Ti, 6



Cryostat
24 m high x 28 m dia.

Vacuum Vessel
9 sectors

Blanket
440 modules

Port Plug
heating/current drive, test blankets limiters/RH diagnostics

Torus Cryopumps, 8

Divertor
54 cassettes

Major plasma radius 6.2 m

Plasma Volume: 840 m^3

Plasma Current: 15 MA

Typical Density: 10^{20} m^{-3}

Typical Temperature: 20 keV

Fusion Power: 500 MW

Machine mass: 23350 t (cryostat + VV + magnets)
- shielding, divertor and manifolds: 7945 t + 1060 port plugs
- magnet systems: 10150 t; cryostat: 820 t

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US ITER Scope

Central solenoid windings

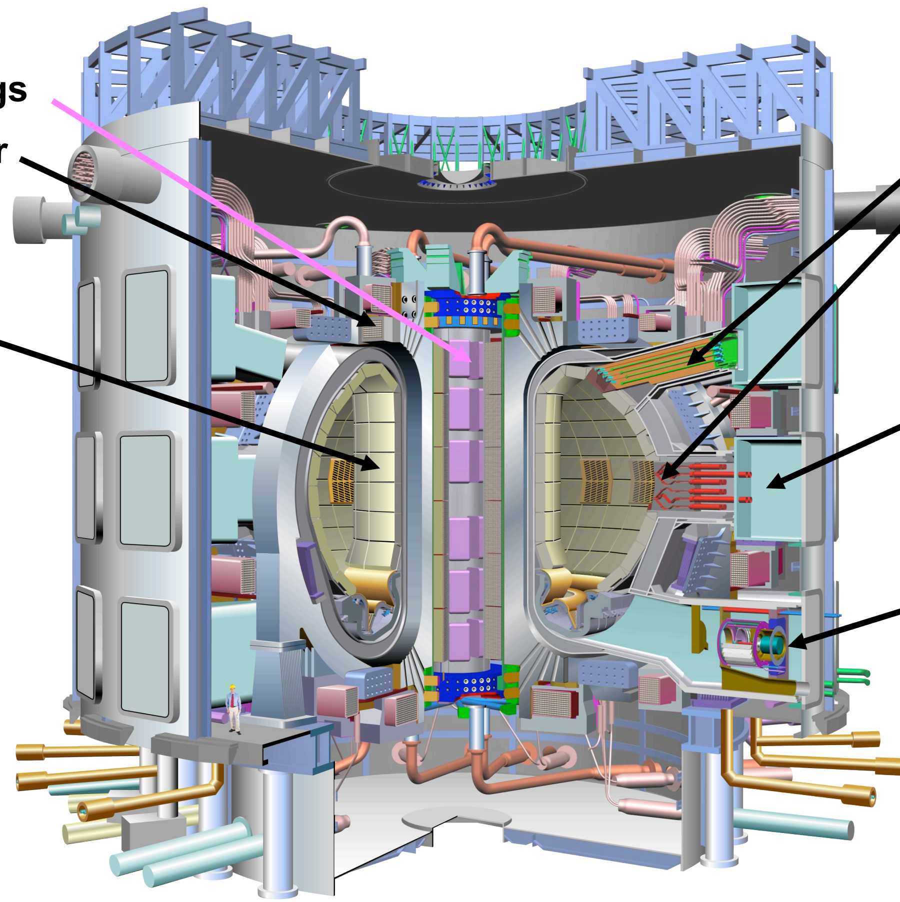
8% of TF coil conductor

20% of FW/shield

Moveable port limiters

Steady state electrical power

Tokamak cooling water system



16% of port based diagnostics

All ICH transmission lines

All ECH transmission lines

Standard vac. components, roughing pumps
Pellet fueling

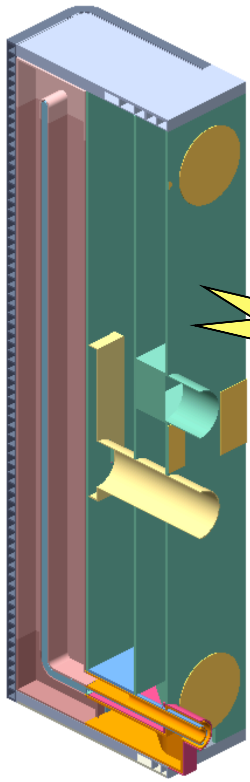
Tokamak exhaust processing (tritium separation) system

Neutronics analyses are critical to design effort *(M. Sawan is US lead)*

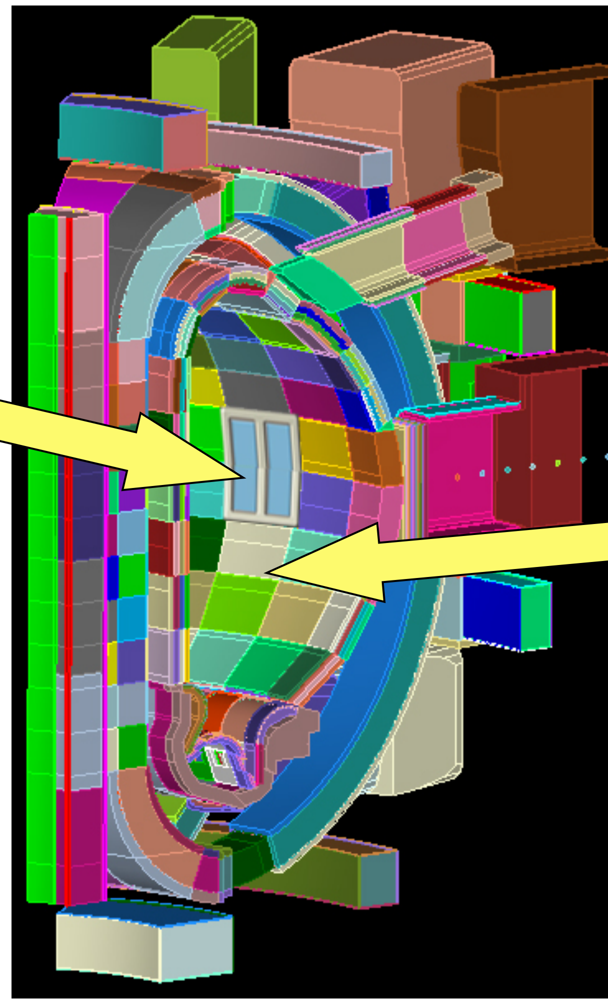
- *ITER is a nuclear device*
- Analysis must be kept up to date during design, construction, and operation
- Analysis of ITER basic machine
  - Computation of radiation field, radiation shielding, nuclear heating, activation, materials radiation damage, absorbed dose to insulators, other sensitive components
- Analysis of US contributions
  - Port mounted equipment (diagnostics, port limiters, test blanket modules)
  - FW/Shield modules
  - Other?
- Efficient integration of CAD models in MCNP neutronics calculations and use of complementary codes (e.g. Attila) for checking, design development

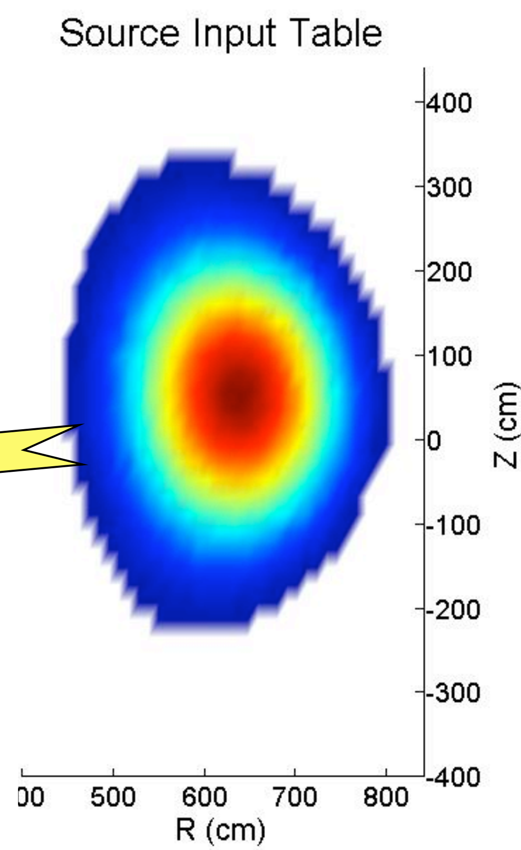
Detailed ITER TBM 3D Nuclear Analysis Approach

A full ITER CAD model has been tested for 3D MCNP-CGM calculation
Actual neutron source sampled in calculation
TBM CAD model will be integrated with full ITER model for detailed TBM nuclear analysis



DCLL TBM





QA Procedures for ITER neutronic analyses

The objective is the preparation of the "Quality Procedure for Neutronics Analysis Management System", that shall be used in ITER Project to regulate from the quality assurance requirements the whole process that goes from the definition of a need for neutronics analysis to the documentation of the results, in particular defining how a Neutronics Task Order must be specified, performed, reviewed and filed.

Draft Report "**ITER Project Management and Quality Program for the Neutronic Analyses System**" was issued by P. Batistoni, ENEA, Frascati in March 2006.
document ITER_D_23H9A4 (Rev. 0)

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Verified and validated codes to be used in the ITER calculations

ITER IT develops, maintains and provides the neutron source reference and the geometrical/material model to be used with reference code MCNP

Other codes in table can be used for specific purposes, upon approval

Code / version	Comments
MCNP – version 4b/4c/5	Reference code
TRIPOLI – version 4.3	Limited application (upon approval)
DOORS – version 3.3	Limited application (upon approval)
DANTSYS – version 3.0	Limited application (upon approval)
FISPACT – version 2005	Reference code
ATTILA	Validation in progress
MCNP – CAD	Validation in progress
MCNP – FISPACT STEP 1&2	Validation in progress
SUSD3D	Sensitivity uncertainty analysis
MCSEN	Sensitivity uncertainty analysis

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Verified and validated nuclear data to be used in the ITER calculations

Nuclear data libraries verified and validated in the development of the ITER project and that can be used in the ITER neutronic analyses and calculations.

Nuclear data library / version	Comments
FENDL /MC - 2.1	Validation in progress
FENDL / MG - 2.1 GENDF or FENDL / MG - 2.1 MATXS	Validation should be performed
FENDL /A– 2.1 (=EAF-2003)	Validation in progress
EAF - 2005	Validation in progress

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FENDL-2.1 Background

- FENDL-2.1
  - Revision to FENDL-2.0 (1995/96)
  - Compiled November 2003, see report INDC(NDS)-451
  - 71 elements/isotopes
  - Working libraries prepared by IAEA/NDS, see INDC(NDS)-467 (2004)
  - Processing performed using NJOY-99.90 at IAEA-NDS and resulting processed files are available in ACE format for MCNP and in MATXS format for multi-group transport calculations (175n-42g)
  - New reference data library for ITER neutronics calculations
- Ongoing qualification and validation
  - Qualification ⇒ benchmark analyses
  - Validation ⇒ fusion benchmark experiments

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Data Source for FENDL-2.1

No.	Library	NMAT	Materials
1	ENDF/B-VI.8 (E6)	40	^{2}H, ^{3}H, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{16}O, ^{19}F, $^{28-30}$Si, ^{31}P, S, ^{35,37}Cl, K, $^{50,52-54}$Cr, ^{54,57,58}Fe, ^{59}Co, ^{61,62,64}Ni, ^{63,65}Cu, ^{197}Au, $^{206-208}$Pb, ^{209}Bi, $^{182-184,186}$W
2	JENDL-3.3 (J33)	18	^{1}H, ^{3}He, ^{23}Na, $^{46-50}$Ti, , ^{55}Mn, $^{92,94-98,100}$Mo, ^{181}Ta,V
3	JENDL-3.2 (J32)	3	Mg, Ca, Ga
4	JENDL-FF (JFF)	4	^{12}C, ^{14}N, Zr, ^{93}Nb
5	JEFF-3 (EFF) JEFF3	4	^{27}Al, ^{56}Fe, ^{58}Ni, ^{60}Ni
6	BROND-2.1 (BR2)	2	^{15}N, Sn

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ITER Calculational Benchmark

- ITER 1D blanket/shield/VV/TF-coil configuration
  - Set up as part of the FENDL-1 benchmarking efforts

    Reference: M. Sawan, FENDL Neutronics Benchmark: Specifications for the calculational and shielding benchmark, INDC(NDS)-316, December 1994
  - Applied for benchmarking of FENDL-1.0 multigroup data against ENDF/B-V data using ONEDANT discrete ordinates code

    Reference: M. Sawan, Results of the neutronics and shielding calculational benchmark, IAEA Advisory Group Meeting on Completion of FENDL-1, Del Mar, CA, December 5-9, 1995
  - Suitable computational benchmark for ITER neutronics calculations
- FENDL-2.1 vs. 2.0 (U. Fischer, FZK)
  - No significant differences of calculated neutron fluxes except for region of TF coil (deep penetration) where FENDL-2.1 results are 10-12 % higher
  - Similar trend is observed for photon fluxes and nuclear heating
  - Significant discrepancies found for He and H production data
    - FENDL-2.0 total gas production cross-sections missing some important contributors

FENDL-2.1 Validation

- Extensive work of validation and verification of computer codes and nuclear data libraries for neutronic calculations has been performed during the ITER EDA R&D (e.g. FENDL-1.0/2.0)

- New data can be validated using available fusion benchmark experiments performed during the ITER EDA R&D (FENDL-2.1)

- Validation of FENDL-2.1/MC data has been started using the available fusion benchmark experiments performed during the ITER R&D activity.

- Validation of FENDL-2.1/MG data should also be done

- Validation of FENDL-2.1/A (EAF-2003) is performed within the EFF/EAF project

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Integral Experiments for Validating FENDL-2.1

Benchmark experiments performed at FNG and used for FENDL-2.1 /MC validation :

- **Bulk shield experiment** (inboard shield, stainless steel & water)
- **Streaming experiment** (shield with streaming channel, stainless steel & water)
- **Silicon Carbide (SiC) block**
- **Tungsten block**
- **Breeder blanket (Be / Li_2CO_3) experiment**

  including JEFF-3.1 analysis
- **Shutdown dose rate** (to be done)

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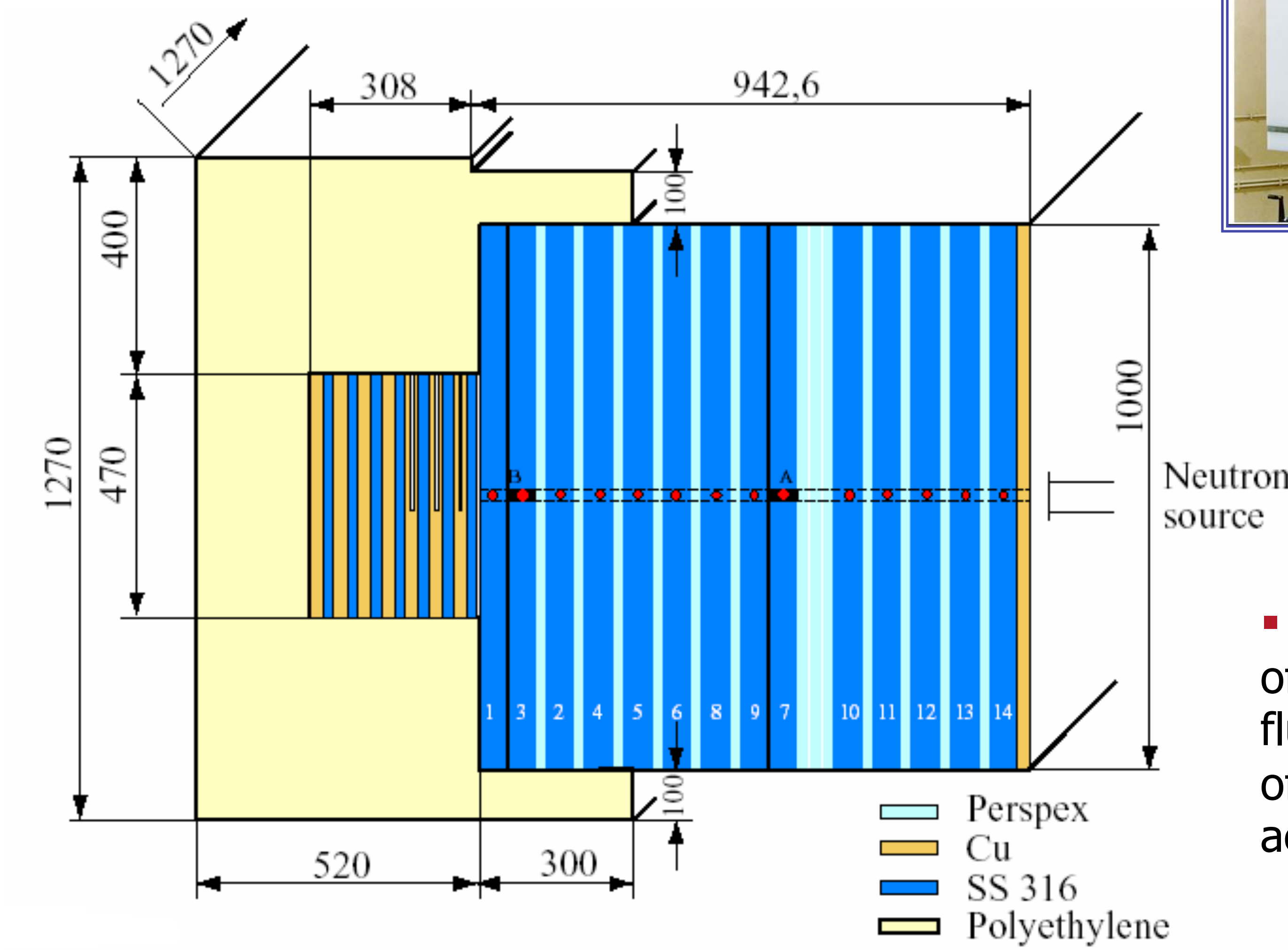
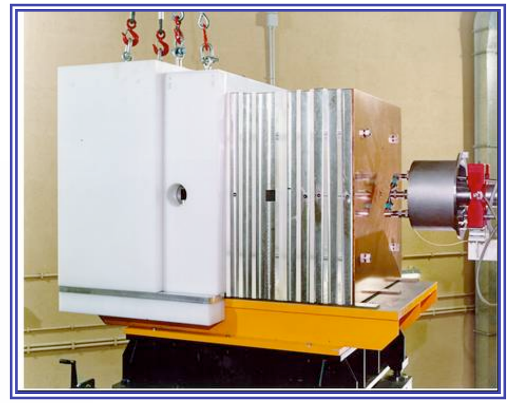
Mock-up of the ITER inboard first wall/shielding blanket/ vacuum vessel/toroidal magnet





- Measurements of the neutron flux as a function of depth by activation foils

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ITER Benchmark Experiments at FNS/ JAEA

- **Bulk shielding experiments**
  - (Iron Experiment)
  - SS316 Experiment
  - SS316/water Experiment
  - SS316/water with Superconducting Magnet simulation Experiment
- **Streaming Experiments**
  - Gap Streaming Experiments
  - Duct Streaming Experiments

etc.

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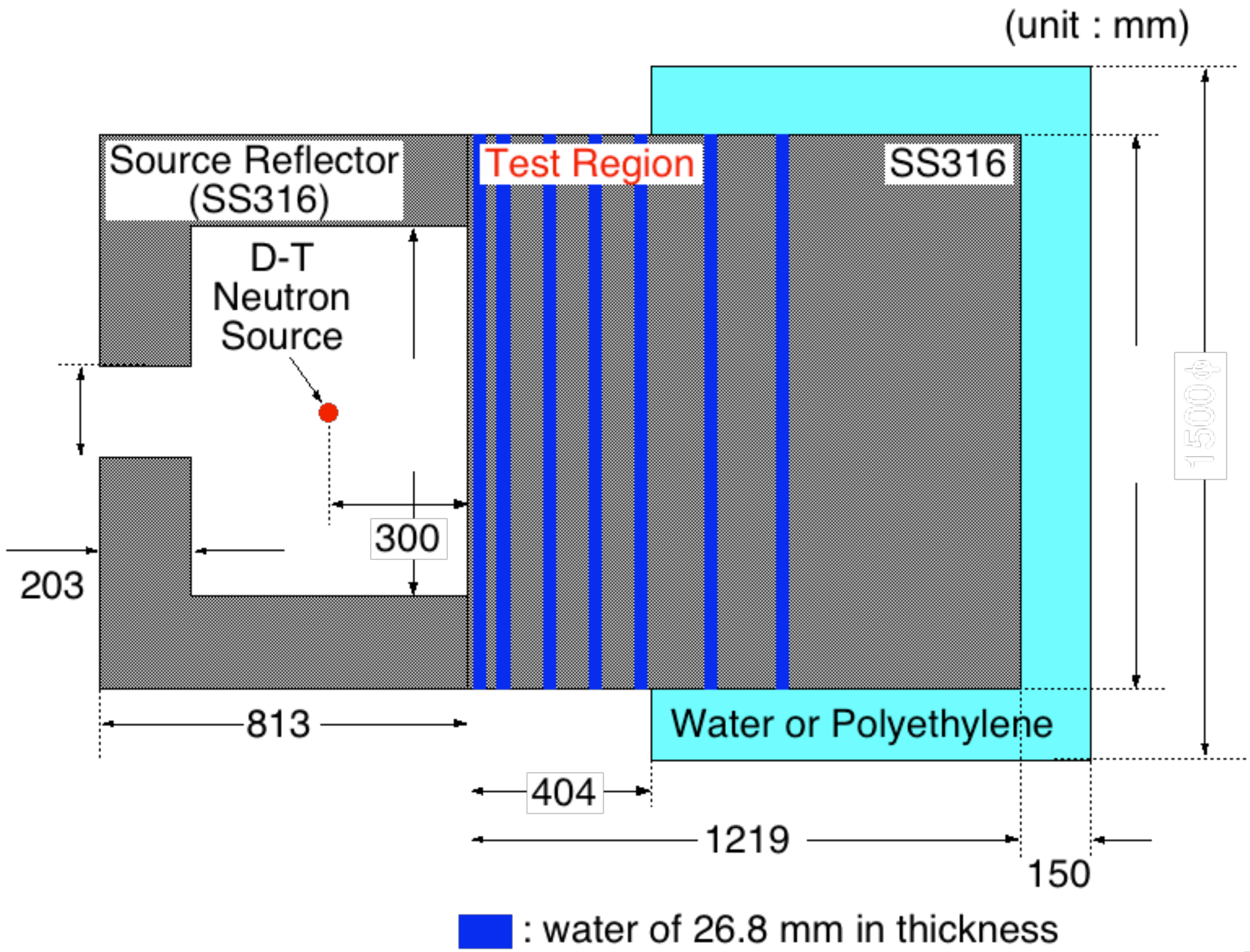
SS316/water Assembly



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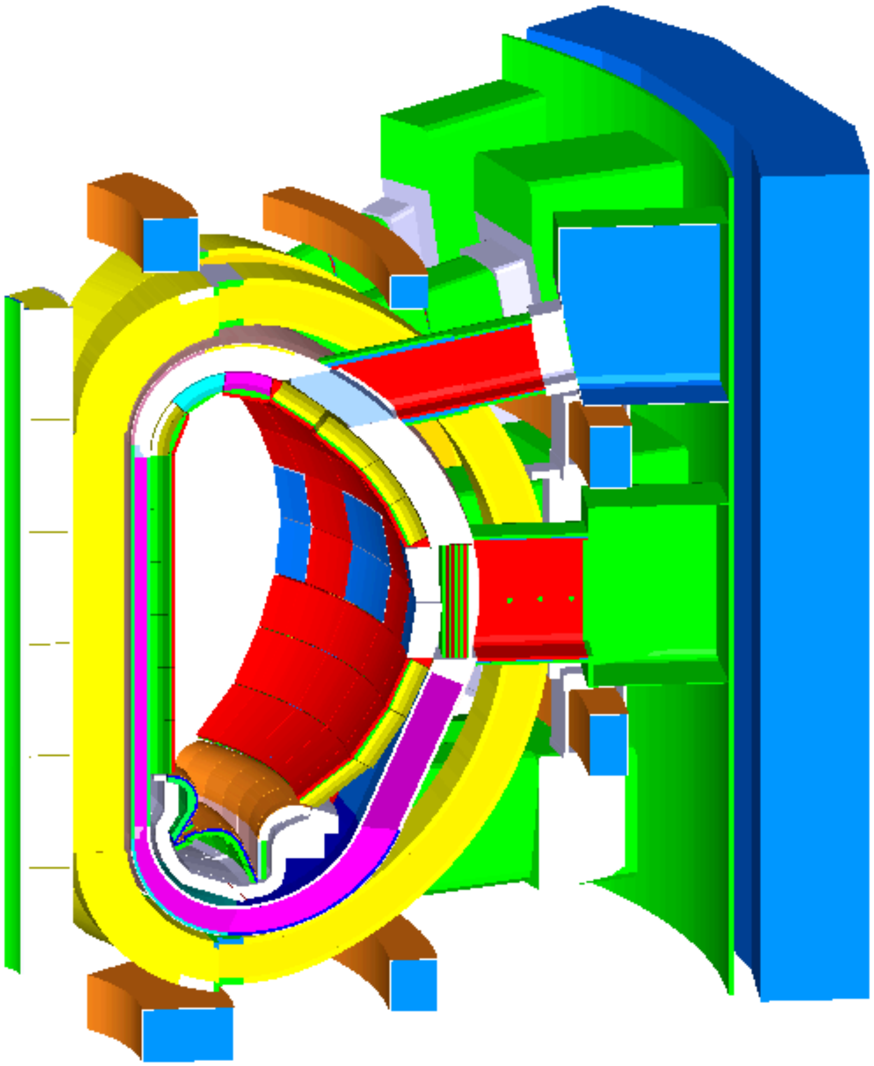
ITER benchmark model for code validation



- CATIA v5.R12 model
- Room temperature
- ~1000 solids
- Made by Curt Gliss (JWS Garching)
- No splines
- 40 degree machine sector
- 17 material specifications
- Used for validation of MCNP/CAD and Attila codes

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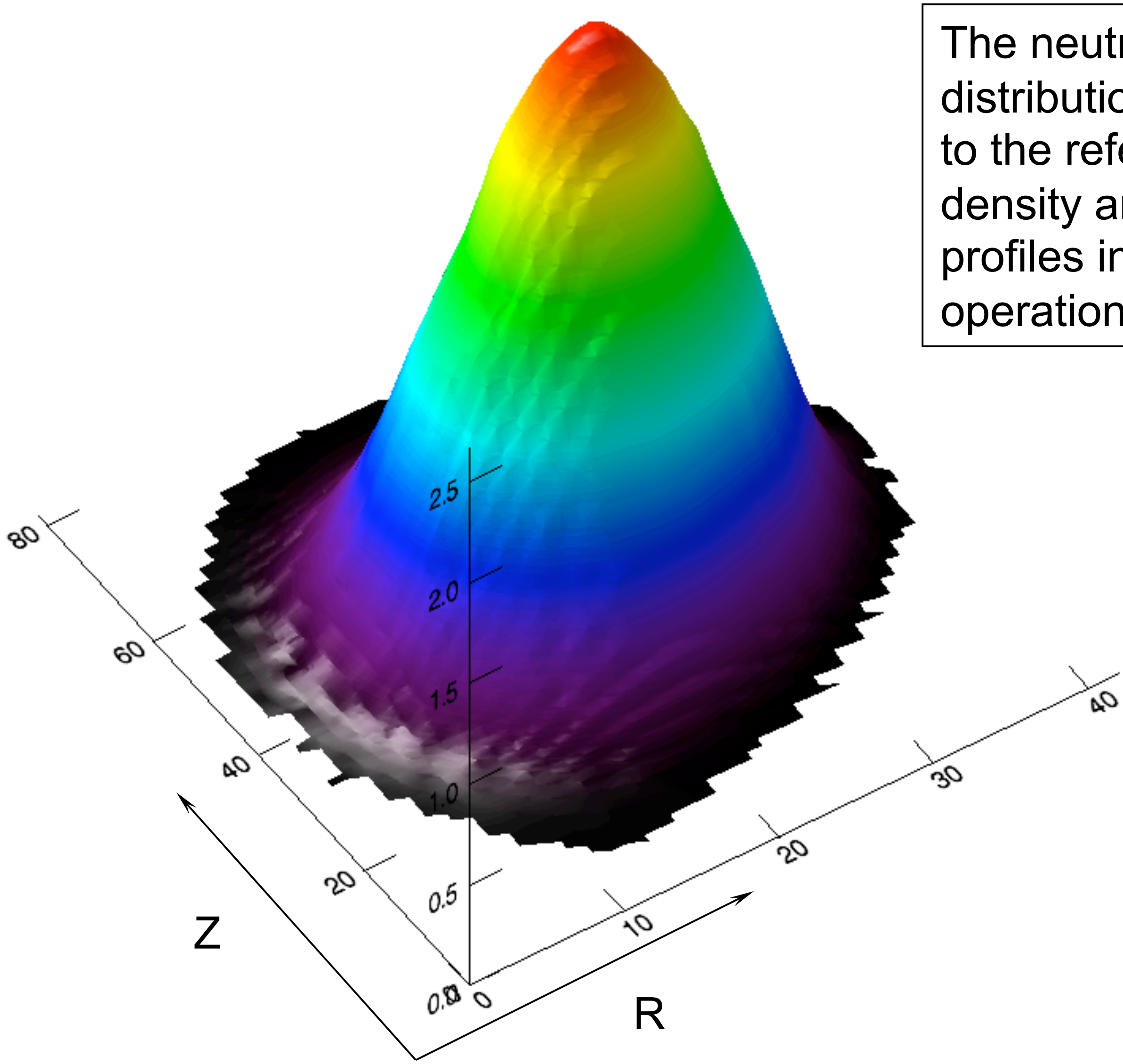
ITER neutron source



The neutron born probability distribution is corresponding to the reference DT plasma density and temperature profiles in the inductive operational regime.

SUMMARY

- ITER project is proceeding with construction in Cadarache scheduled in 2008 with first plasma expected in 2016

- Nuclear analysis is essential activity for ITER design, construction, and operation

- QA Procedures for ITER neutronics analyses have been developed

- MCNP is the reference code and FENDL-2.1 is the reference data library

- Extensive qualification and validation for codes and data is ongoing