The Divertor Tokamak Test Facility

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On behalf of the DTT Team and the DTT Board

Presented at the Meeting of the WPCD EUROfusion, Frascati February 24th, 2020

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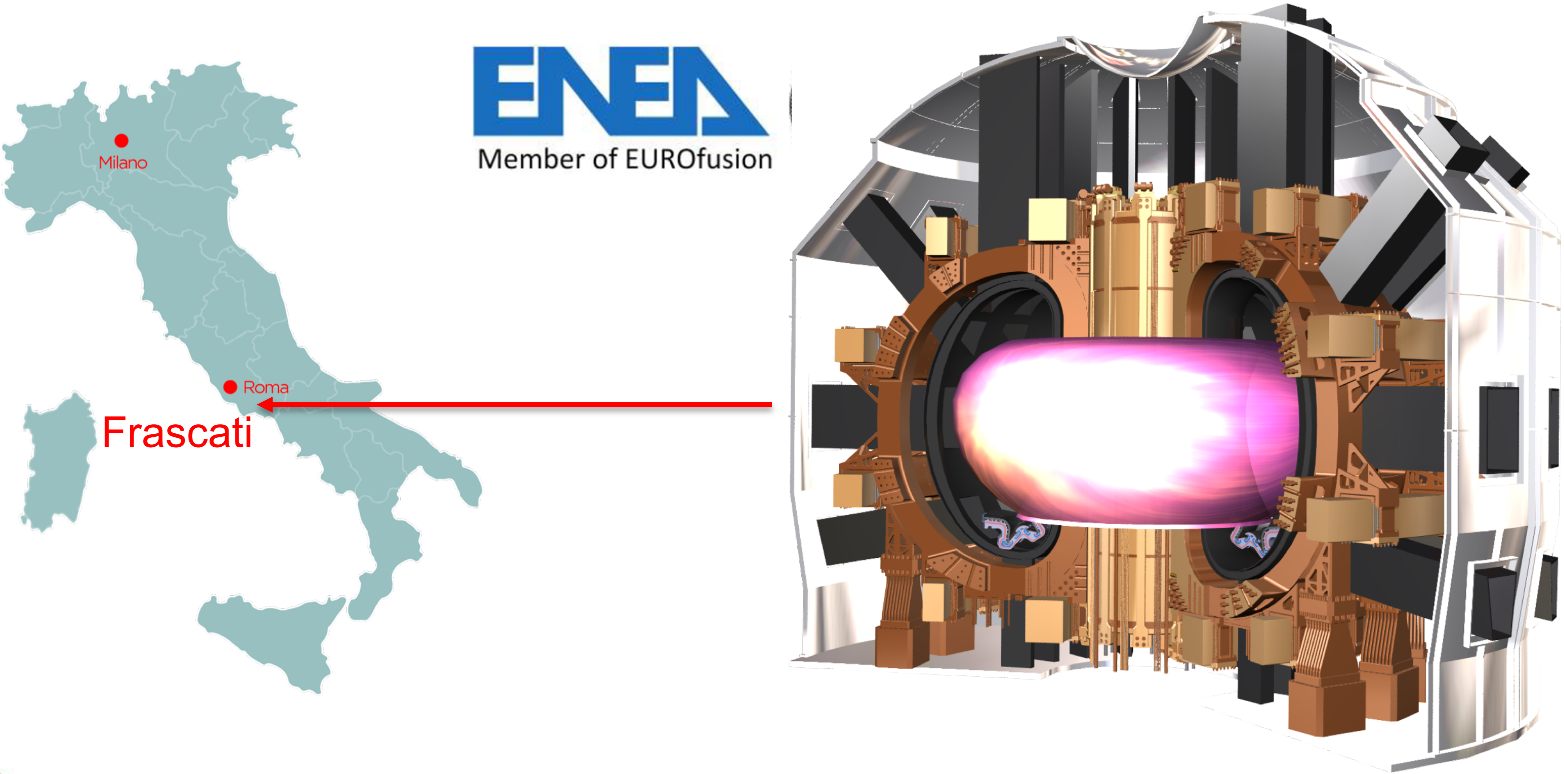
Divertor Test Tokamak facility: 5.5 MA, 6 T, 45 MW



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Italy: Juncker Plan - EIB lends EUR 250m to ENEA for research into clean fusion energy

EN FR DE IT

19 September 2019

Press release | 18 September 2019 | Rome

Juncker Plan in Italy: European Investment Bank lends €250 million to Italian agency for research into clean fusion energy

Energy: ENEA and Eni join forces for international DTT project worth 600 million euros

30/1/2020

The companies together in the scientific and technological centre for fusion for the energy of the future: unlimited, sustainable and safe

Frascati (RM), 29 January 2020 - Italy comes to the forefront of the international stage with a project in which ENEA and Eni will work together in a strategic alliance. The project, worth over 600 million euros, focuses on the energy of the future, sustainable, safe and unlimited, and it involves the establishment of a scientific and technological centre for fusion DTT (Divertor Tokamak Test) in ENEA's Research Centre in Frascati (Rome) by DDT Scarl, a joint venture owned 25% by Eni, 74% by ENEA and 1% by Consorzio CREATE.

The project will have an impact of around 2 billion euros on the national GDP and will create 1,500 new jobs, among which 500 for scientists and technical specialists.

The agreement was signed today at the Research Centre of ENEA by the president of ENEA, **Federico Testa**, and the CEO of Eni, **Claudio Descalzi**, in the presence of the Secretary to the Prime Minister, **Riccardo Fraccaro**, of the Minister for Universities and Research, **Gaetano Manfredi**, the Minister of Economic Development, **Stefano Patuanelli**, and the

DTT is here and running

- DTT is a new superconducting **tokamak** under construction in Italy (ENEA lab, Frascati)
- Main scientific goals:
  - Investigate **energy and particle exhaust systems**
  - Provide a state-of-the-art facility to accompany ITER and support DEMO design
- **Construction Budget closed**
- **Legal entity for construction established**
- **Team expanding** and for 2 positions selection is ongoing
- **Final design** started, first major **call for tender** (superconducting strand) closed, next one (TF coils) launched within few months
- Construction time: **7 years**
- Operation time: **25 years**

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Collaborations welcome!

Main motivations for DTT

ITER baseline exhaust strategy: risks exist that it cannot be extrapolated to DEMO

Risk minimization: in parallel with ITER conventional divertor develop now credible **programme** to improve high heat flux components and to develop divertor alternative solutions

Exhaust linked with core performance: need for integrated approach and therefore plasma has to be ITER relevant

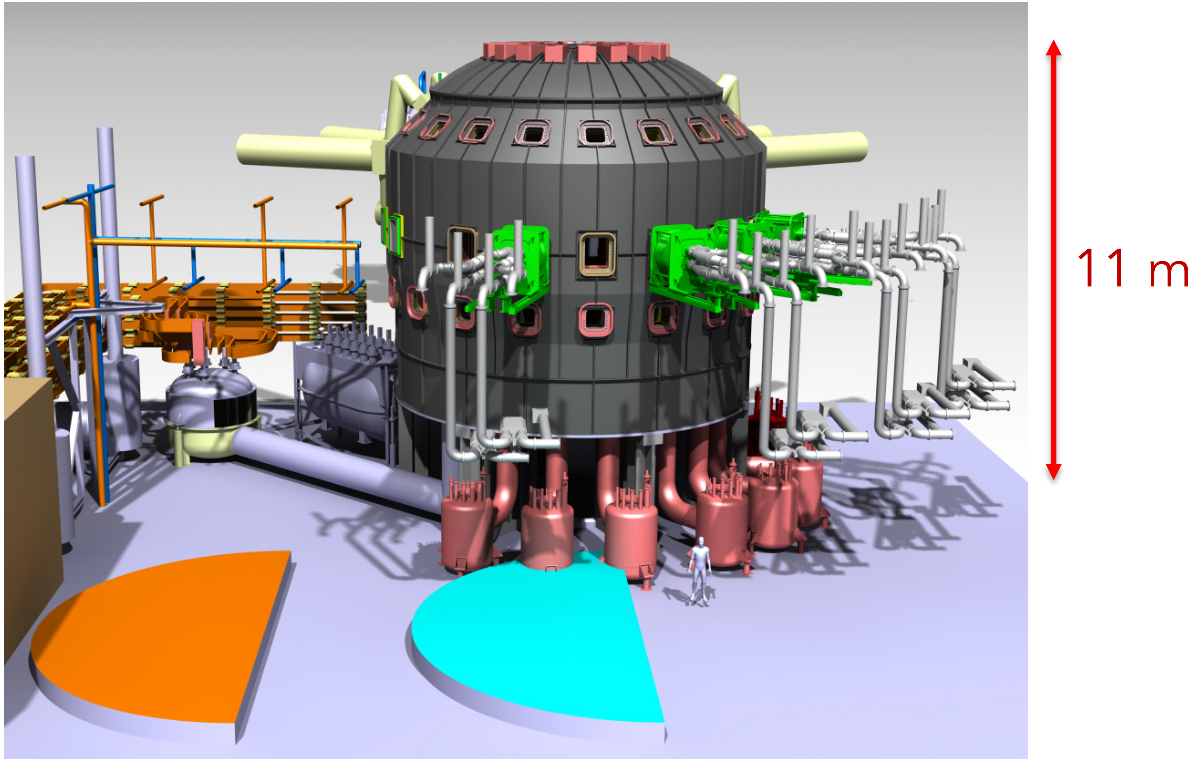
Support and complement ITER operation (e.g. disruption mitigation)

DTT design boundary conditions and key objectives

- Tackling the plasma exhaust issue
  - at power levels relevant for ITER and DEMO
  - with scenarios relevant for core – edge integration (not merely a power dump)
- Using proven technologies
- Providing a facility for:
  - Divertor concepts
  - DEMO relevant technologies
- Keeping schedule to comply with stakeholders expectations

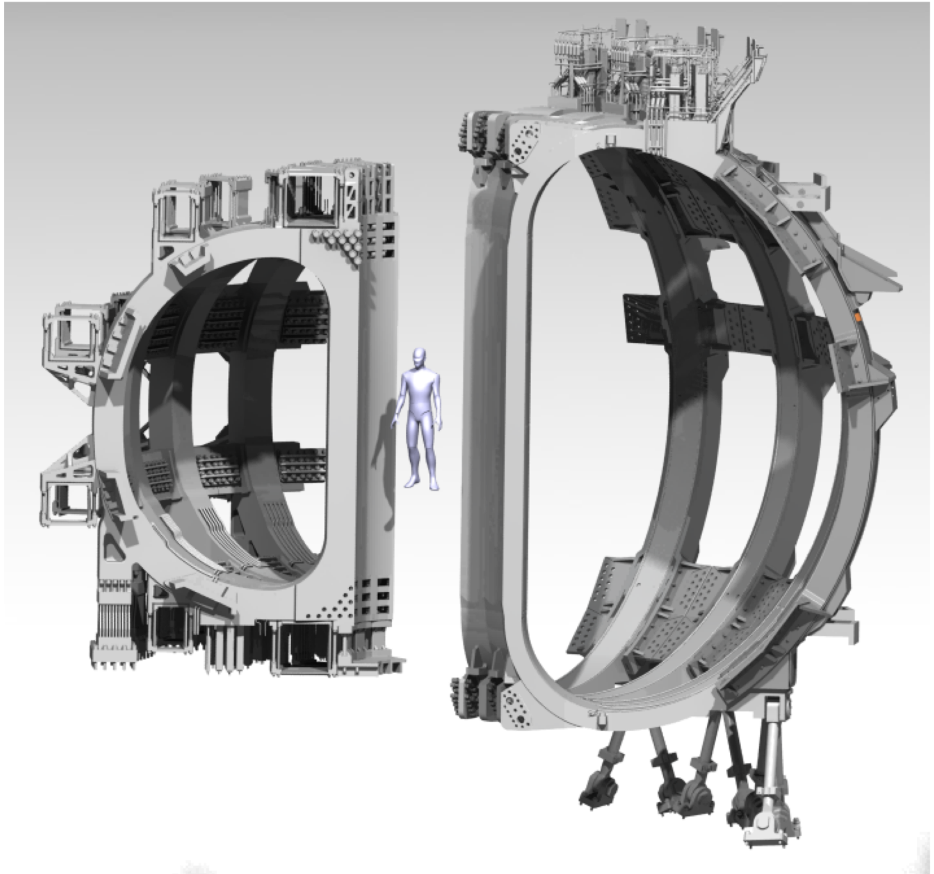
B_T (T)	I (MA)	Plasma Vol. (m^3)	Add Heating (MW)	R/a (m/m)	Pulse length (s)	Total # shots
6	5.5	~28	45	2.14 / 0.65 (0.68)	~100	25000

n/n_G	0.45
P_{sep} (MW)	32
P_{sep} /R	15
<T> (keV)	6.1
<n> ($10^{20}m^{-3}$)	1.72
k	1.89
δ	0.46
β_N	1.5
ν*	2.5
ρ*	2.8

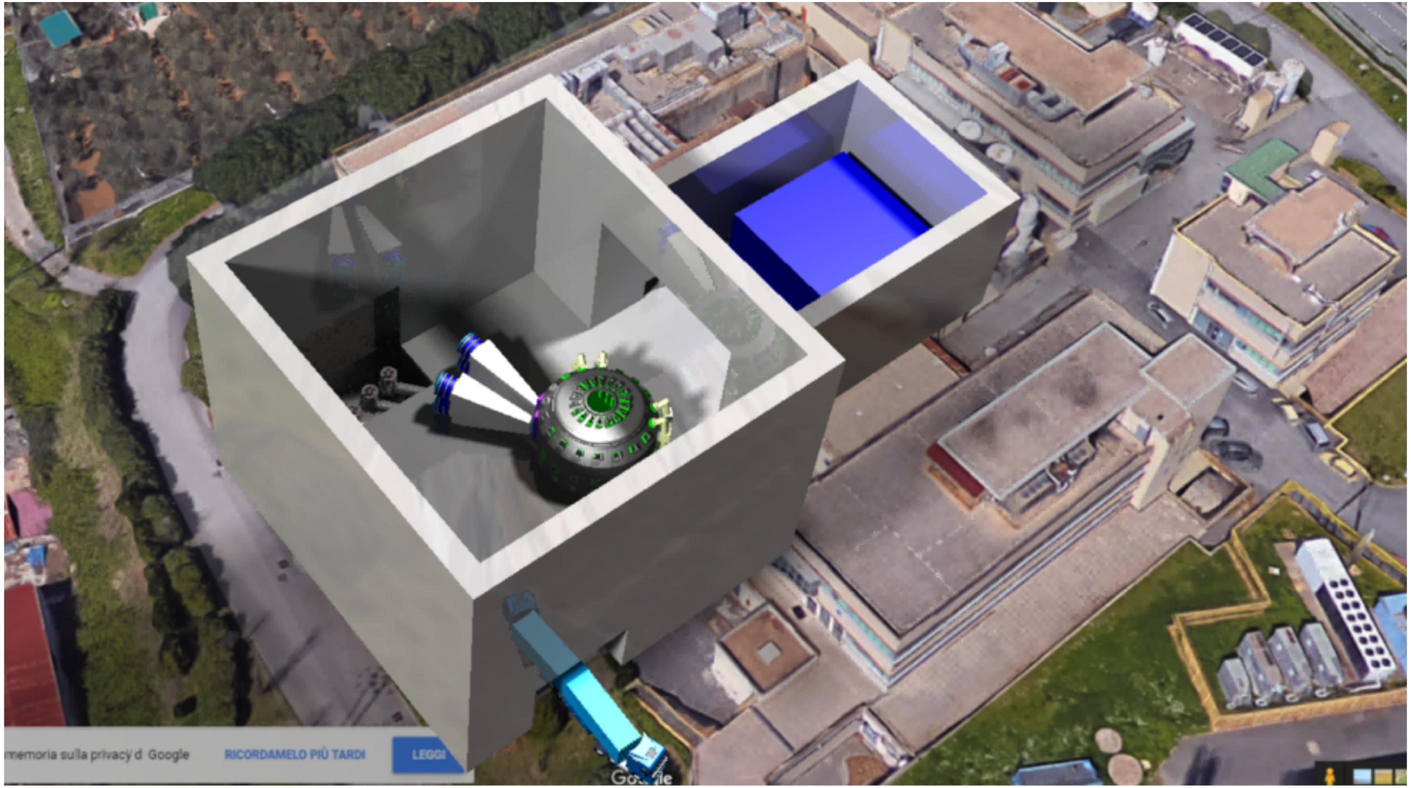


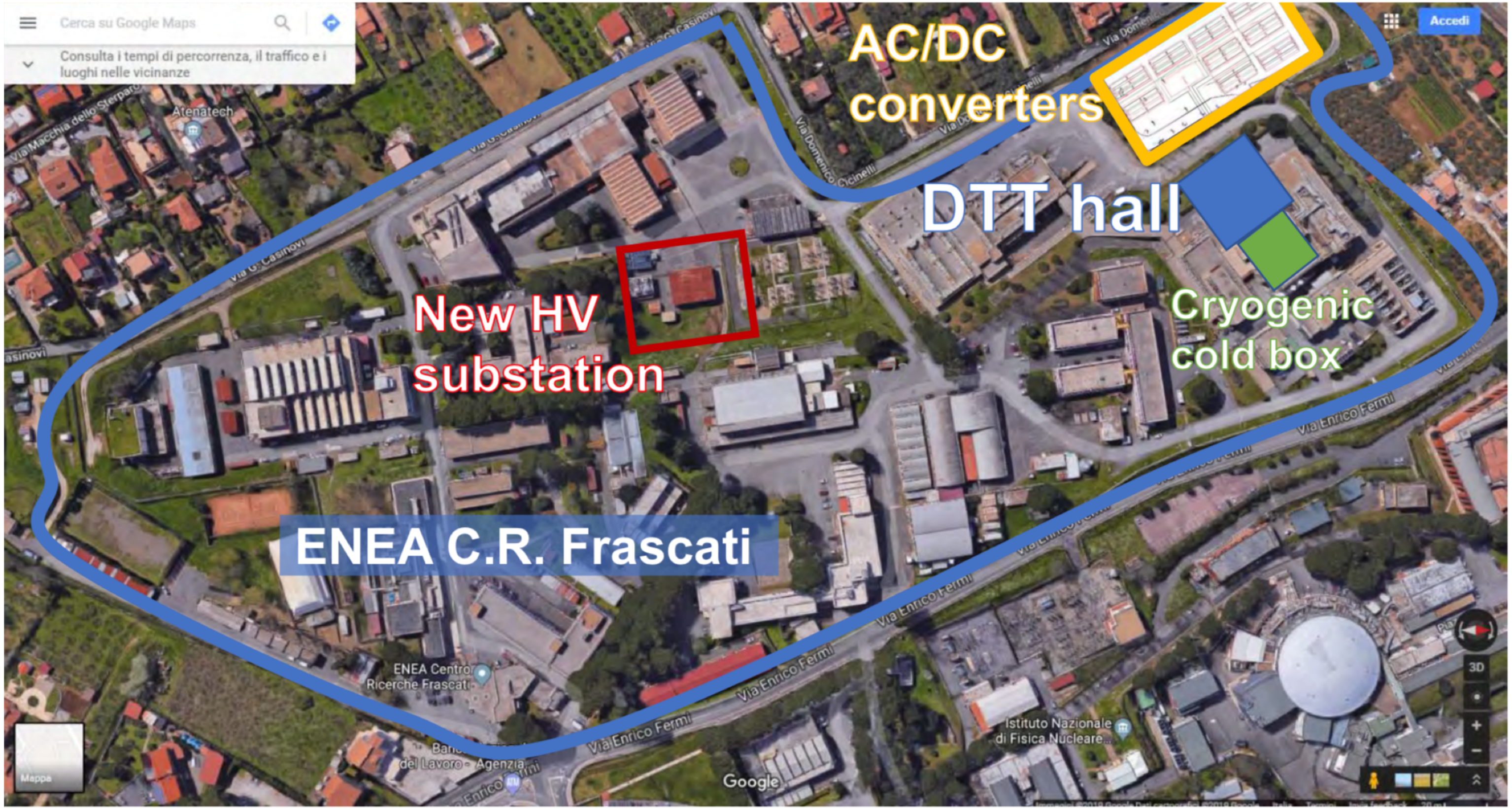
Small modification wrt. Interim design report still possible

DTT vs JT-60SA

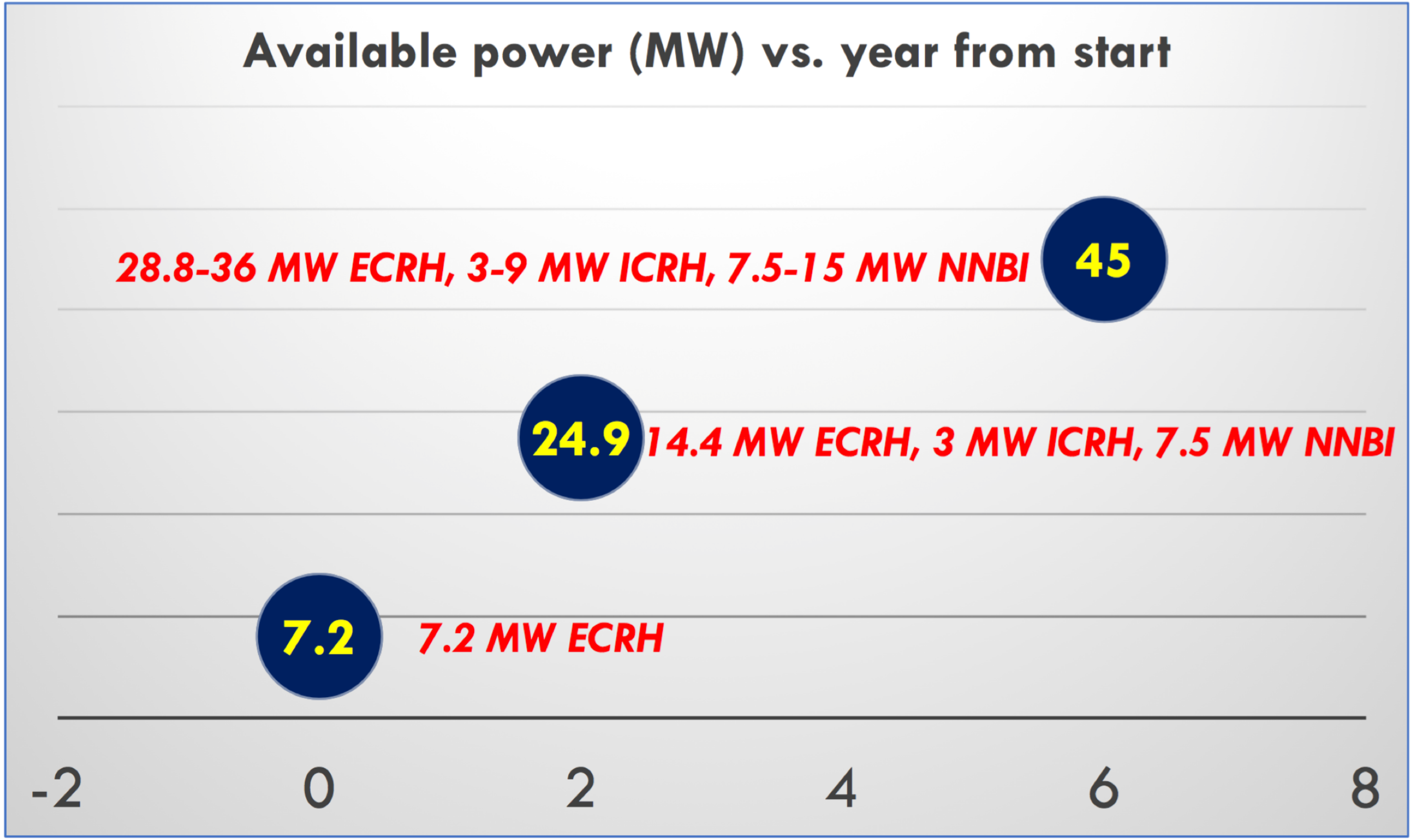


DTT site – torus hall




Cerca su Google Maps
Consulta i tempi di percorrenza, il traffico e i luoghi nelle vicinanze
Accedi
AC/DC converters
DTT hall
Cryogenic cold box
New HV substation
ENEA C.R. Frascati
Atenatech
Via Macchia dello Sterparo
Via G. Casinovi
Via Domenico Cicinelli
Via Enrico Fermi
ENEA Centro Ricerche Frascati
Istituto Nazionale di Fisica Nucleare
Google
Mappa
3D

Heating 45 MW $P_{sep}/R \sim 15$ (ITER=14 DEMO=17)



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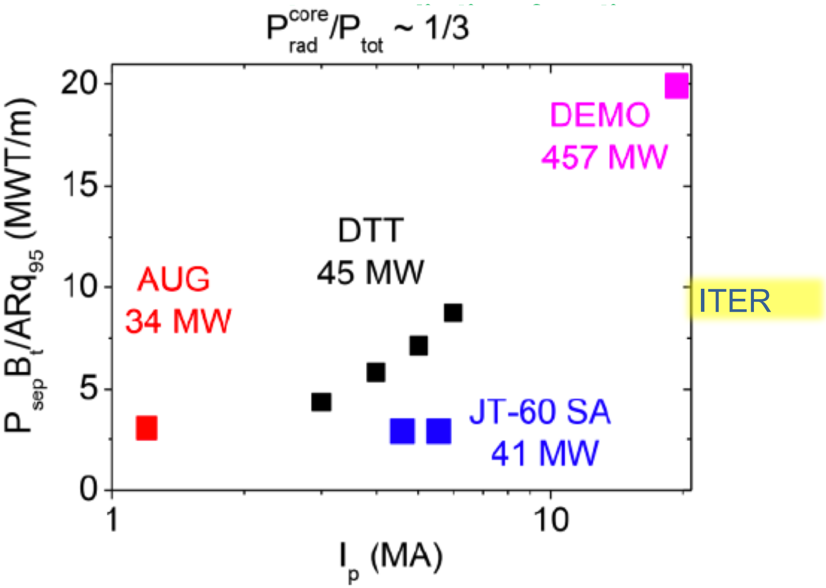
DTT comparative performance: normalized SOL power flow

DTT can reach high levels of SOL loading

Important for the study of dissipative divertor at high edge power flow levels

DTT can verify merits of high field

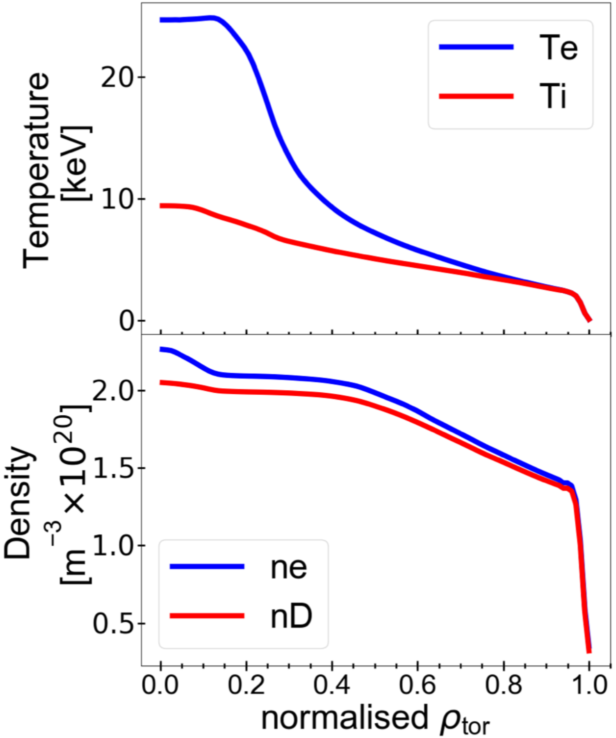
$$\lambda_q \propto A q_{95}/R$$



De Baar et al., Final Report of the Plasma Exhaust Ad Hoc Group (PEX AHG), Phase 3 (2018)

Physics based simulations of SN full power plasma profiles

B_T=6T, I_p=5.5 MA, P_{ECH}=29 MW, P_{NBI}=15 MW, P_{ICH}= 3 MW, Z_{eff}=1.7



Casiraghi, Mantica et al.)

- 1.5D simulations using JINTRAC/JETTO with TGLF and QuaLiKiz turbulent transport models
- Equilibrium and heating modelled self-consistently
- Pedestal from EPED
- Impurity radiation, rotation, sawteeth and ELMs not yet included

τ_E~ 0.28 sec

β_N~1.7

$\beta_{Nfast}/\beta_{Ntot}$~ 6-8 %

DD Neutrons~ 1.5E17 s^{-1}

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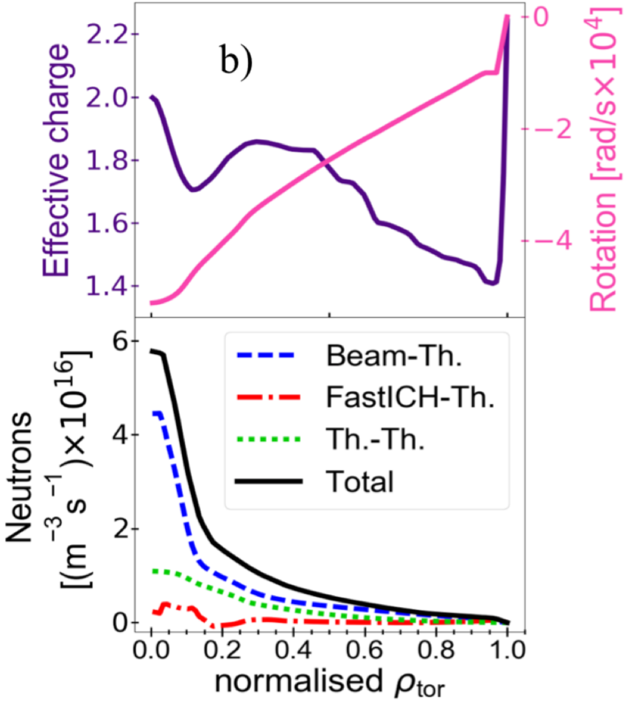

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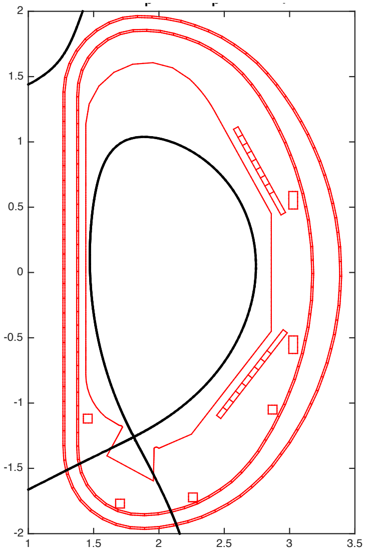
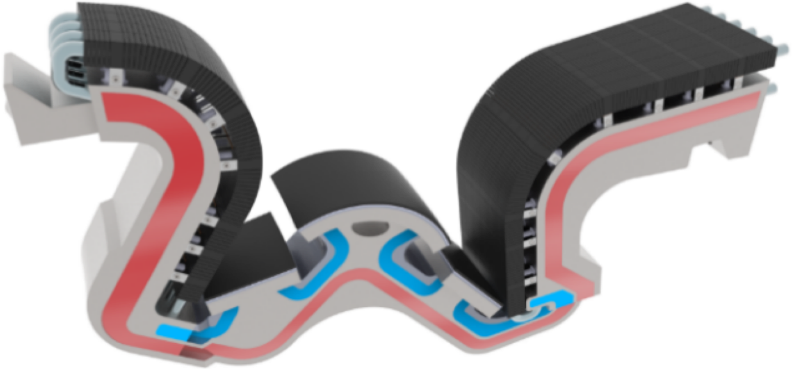
DTT divertor flexibility

The facility will offer **sufficient flexibility** to incorporate the best candidate divertor concept even at a later stage of its construction, on the basis of the studies carried out in present tokamaks involved in the PEX activities **(around 2022-2023, according to agreement with EUROfusion).**

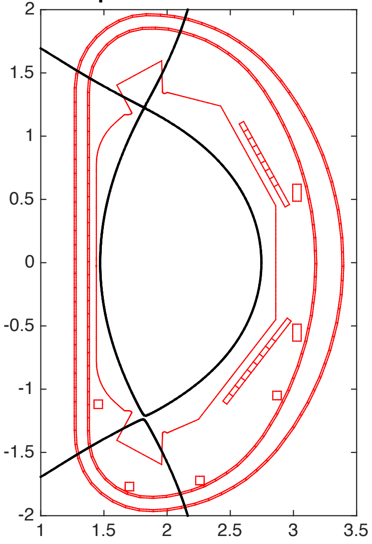


Single Null Reference configuration I_{pl}=5.5 MA

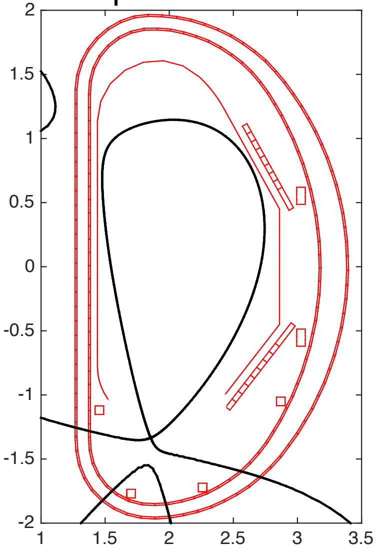


DTT divertor flexibility

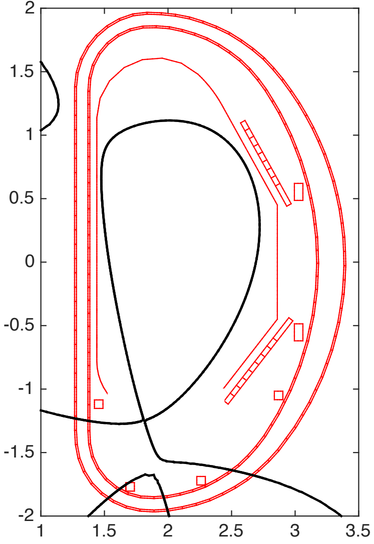
Double Null
I_{pl}=5 MA



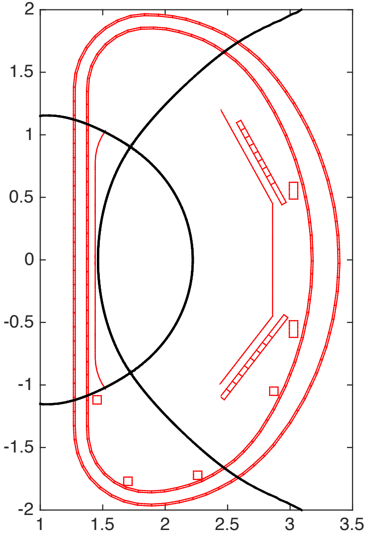
Snowflake
I_{pl}=4.5MA



X-divertor
I_{pl}=4.5MA



Double Super-X
I_{pl}=3MA



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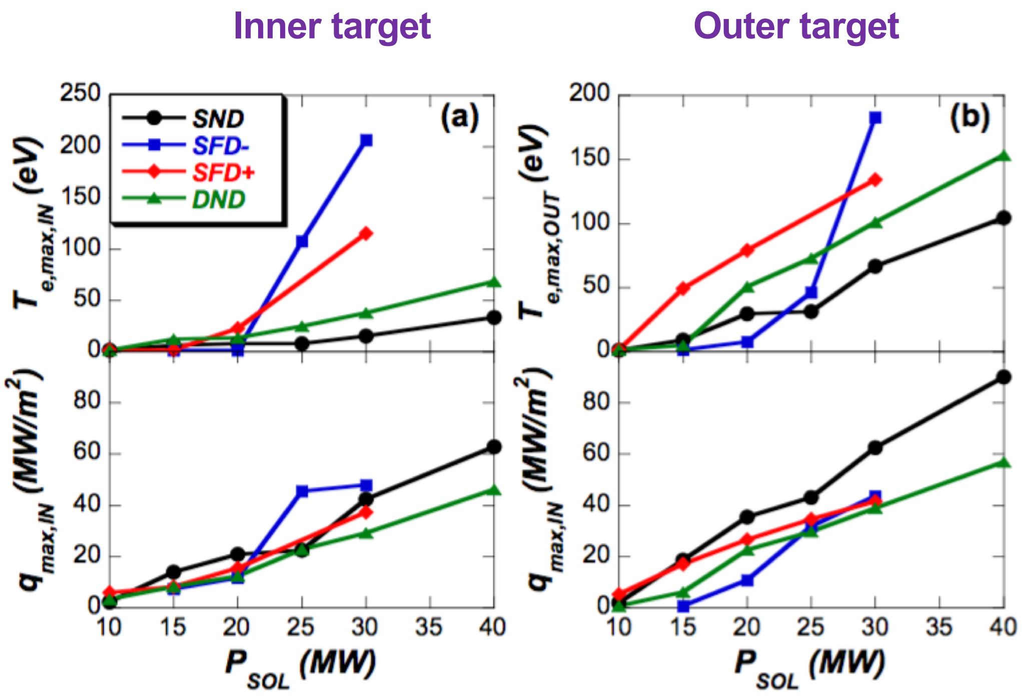
Ambrosino et al.

Fluid modeling of power exhaust: pure deuterium
High radiation fraction needed to operate DTT at maximum power



For acceptable divertor conditions (power load and detachment) in pure D need to reduce P_{SOL} at a **very low value** (~ 10 MW for SN)

SOLEDGE-EIRENE

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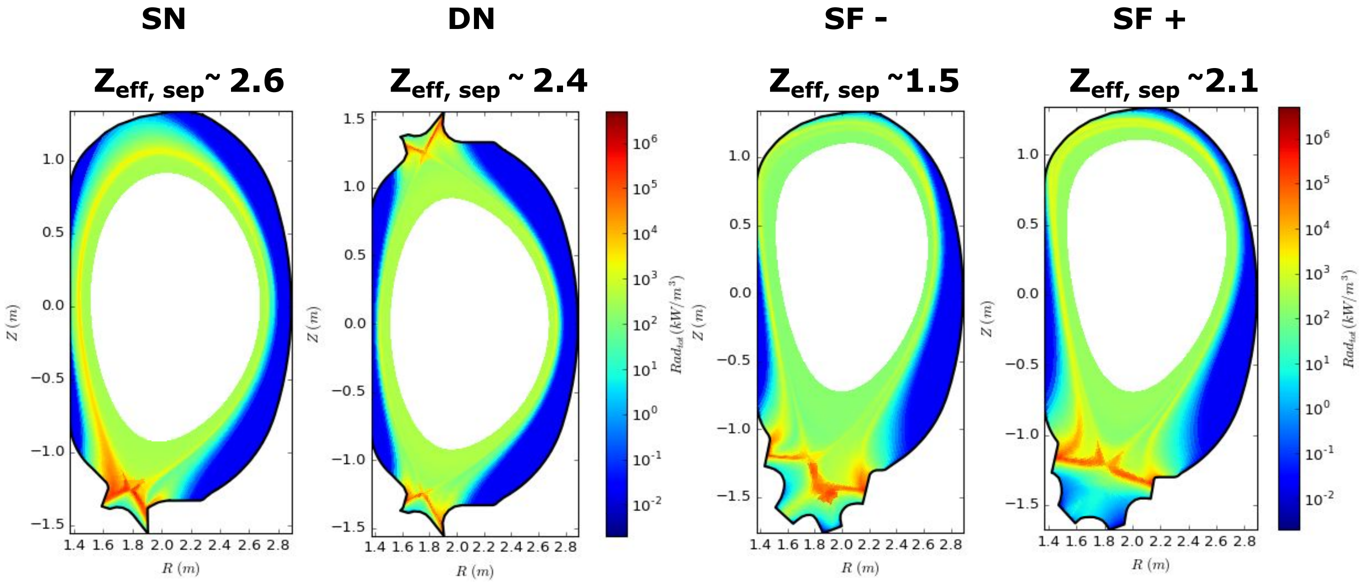
Innocente et al.

Impurity seeding: 90% radiation fraction with Ar and Ne



SN $Z_{\text{eff, sep}} \sim 2.6$

DN $Z_{\text{eff, sep}} \sim 2.4$

SF - $Z_{\text{eff, sep}} \sim 1.5$

SF + $Z_{\text{eff, sep}} \sim 2.1$

P_{SOL}=36 MW – $P_{rad}/P_{sol} \sim 90\%$

$n_{sep} = 1 \times 10^{20}\ m^{-3}$

Ne seeding requires higher Z_{eff}

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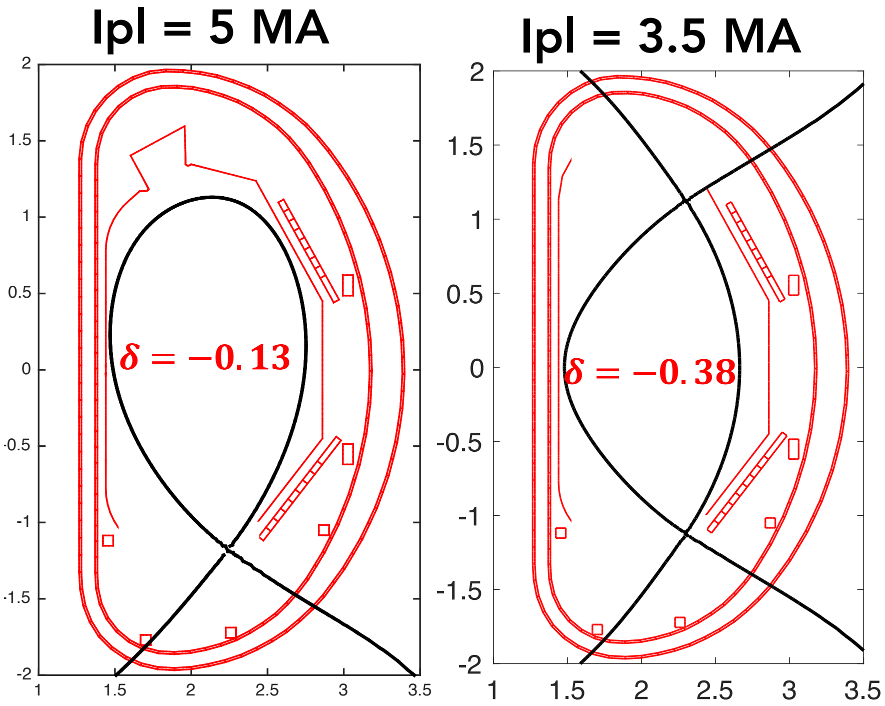
Innocente et al.

Negative Triangularity

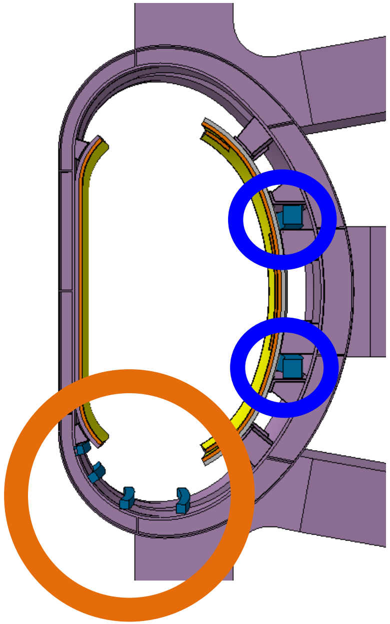

Ipl = 5 MA

Ipl = 3.5 MA

- Available space inside TF coils allows for optimization of.
  - first wall
  - stabilizing plates
  - Vessel
- Vessel being redesigned now

Ambrosino et al.

In-vessel coils and DMS



2 independent n=0 copper coils and 2 stabilizing plates for

- Vertical stabilization
- Fast radial control (breakdown, L-H & H-L transitions)
- DN wobbling

4 independent n=0 divertor coils for:

- Magnetic configuration control in the divertor region
- Strike point sweeping (DEMO option)

Internal coils for ELM/MHD control under design

DMS system (shattered pellet) to support ITER

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Physics organization: areas and coordinators

‘Plasma exhaust and divertor physics’ (Paolo Innocente)

‘Plasma scenarios and transport’ (Paola Mantica)

‘Diagnostics’ (Marco Valisa)

‘MHD stability and its control, and disruptions ’ (Gregorio Vlad)

‘Plasma theory’ (Fulvio Zonca)

Executive Board: Aldo Pizzuto (PL), Raffaele Albanese, Flavio Crisanti, Piero Martin


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DTT

Divertor Tokamak Test facility

Interim Design Report

A milestone along the roadmap
to the realisation of fusion energy

https://www.dtt-project.enea.it

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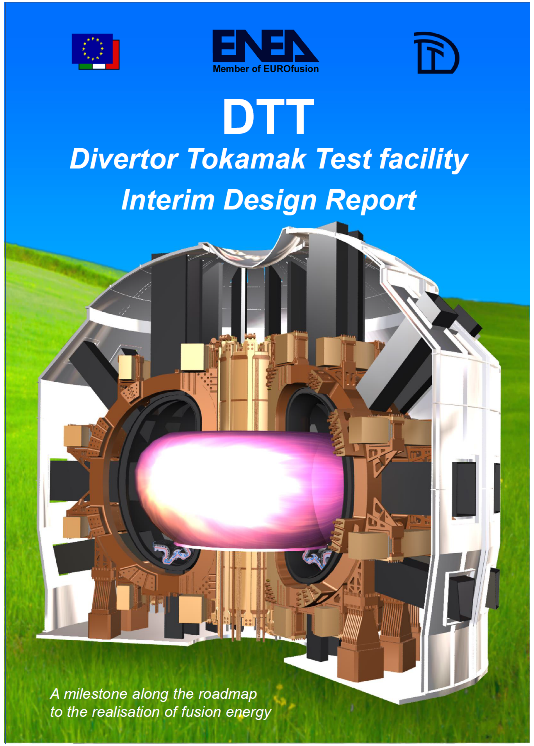
Collaborations welcome!

DTT interim design report



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Spare slides

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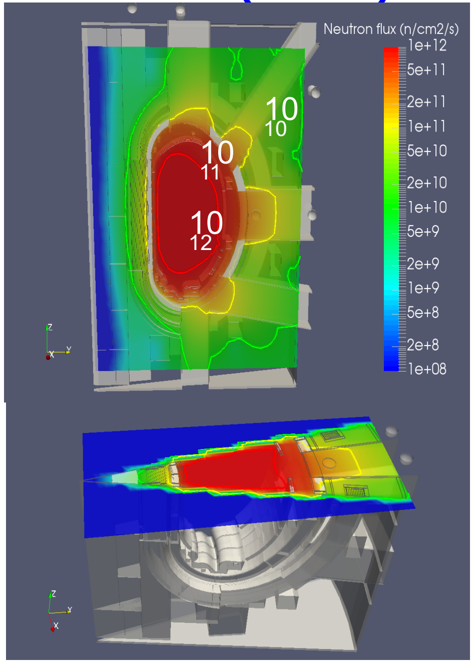
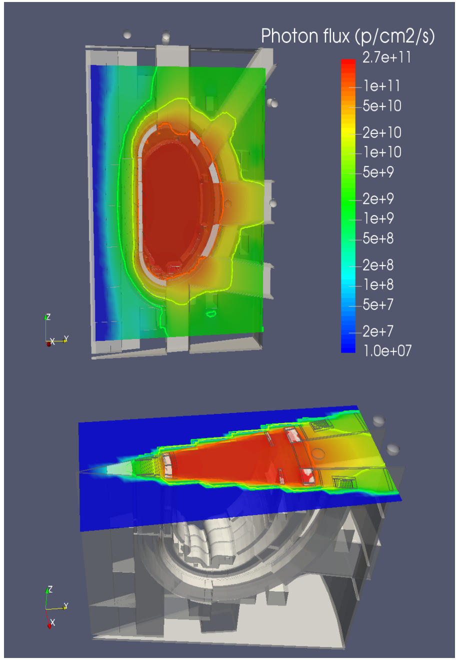
DTT Neutronics

- **DD neutron yield rate** in max performance (P_{add} 45 MW): **1 ·10^{17} n/s**
- **DT neutron yield due** to **Triton burn-up** in max performances: **1·10^{15} n/s** (1%)

Neutron (n/cm²s)



Gamma (p/cm²s)



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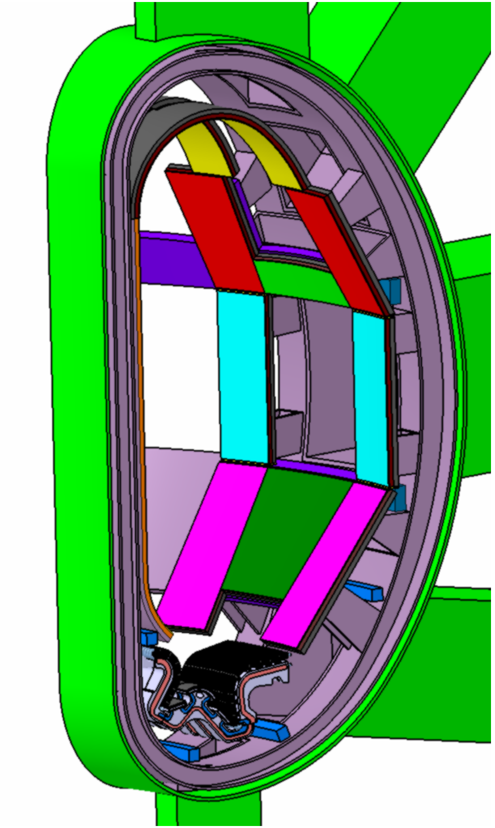
High performance shots

DTT symmetric up-down to increase flexibility



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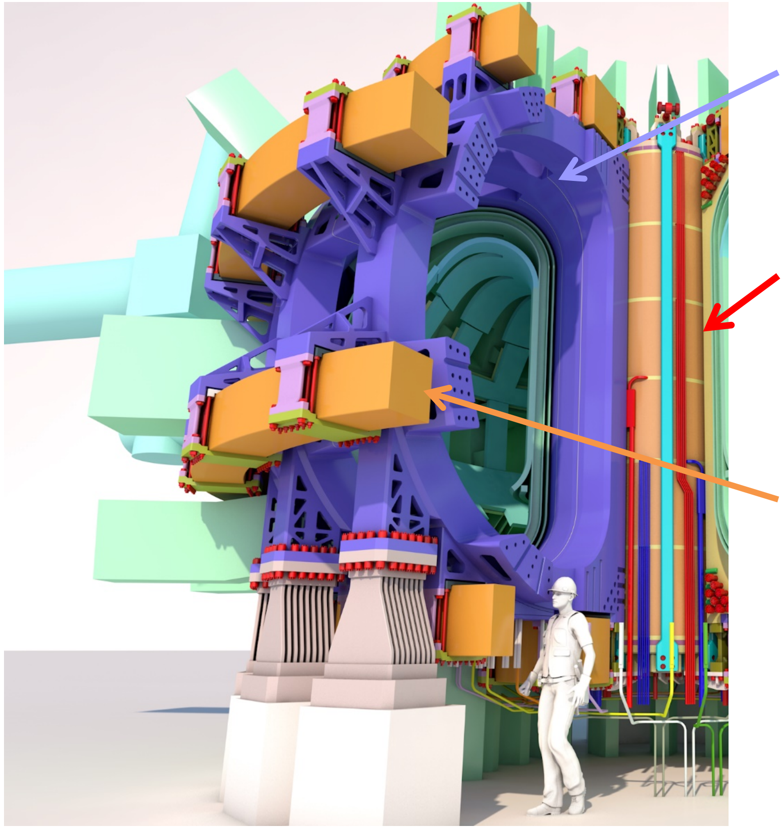
Superconducting magnet system: overview



18 Toroidal Field coils

Nb_3Sn Cable-In-Conduit Conductors
5 *Double-Pancakes* (3 regular + 2 side)

6 Central Solenoid module coils

Nb_3Sn Cable-In-Conduit Conductors
6 *independent modules*

6 Poloidal Field coils

4 NbTi Cable-In-Conduit Conductors
2 Nb_3Sn Cable-In-Conduit Conductors
6 *independent modules*

Design based on proven and reliable technologies

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ECRH System

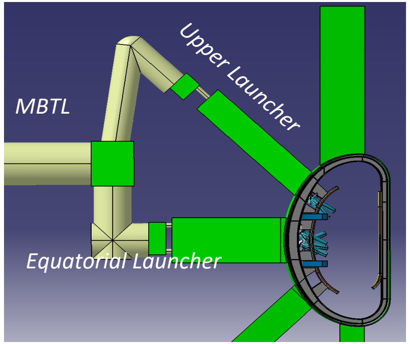
32-40 MW installed (16 MW in the first phase) exploiting existing technology:

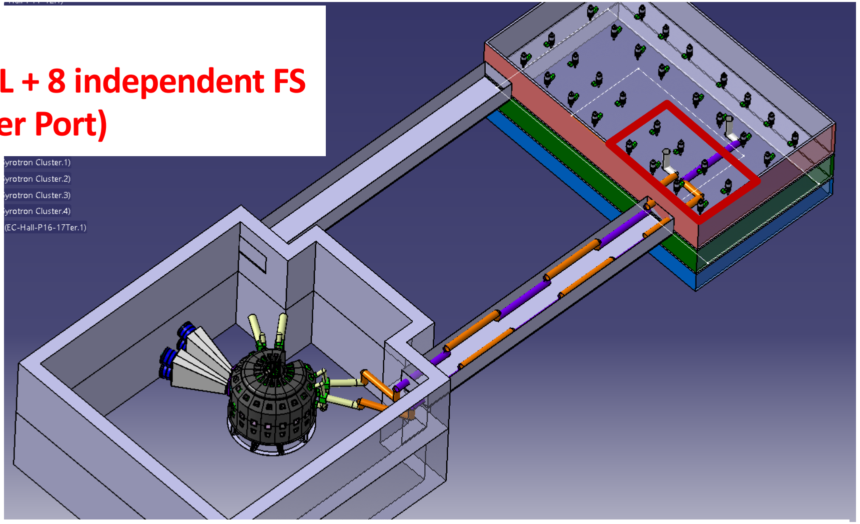
Gyrotron (170 GHz/1 MW/100 s) + High Voltage Power Supply: RoX from ITER

Quasi Optical Evacuated Transmission Line (TL): RoX from W7-X

Antenna: Front Steering Launchers fully independent

Clusters Architecture:
8 Gyrotron (feed in couple) + 1 QOTL + 8 independent FS Launcher (6 in Eq. Port and 2 in Upper Port)





Central CD (~25 kA/MW) for 0.72 MA of non inductive contribution

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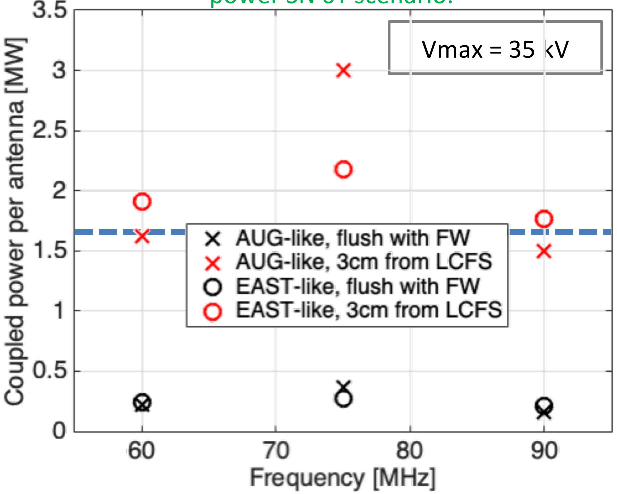
Ion Cyclotron Resonance Heating

3 MW at plasma from day-1, up to 9 MW at final stage

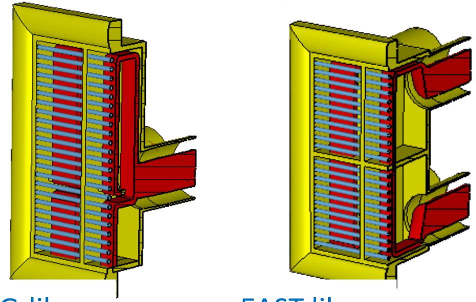
Base Module

- 2 or 4 transmitters: (60 MHz- 90 MHz) for 4 MW
- 4 coaxial TL with ECT matching scheme
- 2 Antennas (2 x Straps, movable)

TOPICA simulations for DTT full-power SN 6T scenario.



Antenna Options



AUG-like EAST-like

Antenna concept (present reference):

- 2 straps (single or double feeding)
- Port-plug radially movable: 0 – 6 cm
- Power density : 3- 3.5 MW/m^2
- Stand-off Voltage 36 kV/cm
- **Plug-in efficiency: ~40%**

DTT Additional Power

The power distribution in the 3 systems for the **day-1** will be:

ECRH: 16 Gyrotron for 14.4 MW at plasma - 170 GHz/1 MW/100 s

ICRH: 3 MW at plasma

NNBI: 1 Injector for 7.5 MW at plasma

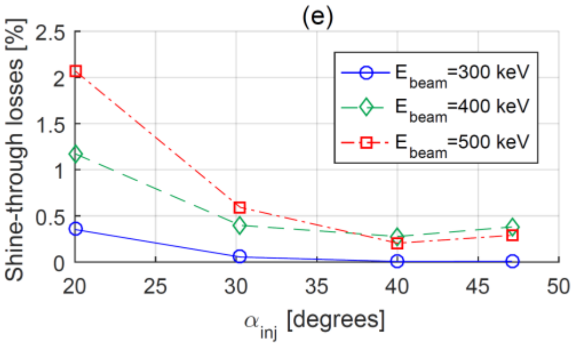
The decision for power distribution in the **final stage** still open:

	Option1	Option2	Option3
NNBI	**15 MW**	**7.5 MW**	**7.5 MW**
ECRH	**28.8 MW**	**36 MW**	**28.8 MW**
ICRH	**3 MW**	**3 MW**	**9 MW**
Power (MW)	**46.8 MW**	**46.5 MW**	**45.3 MW**

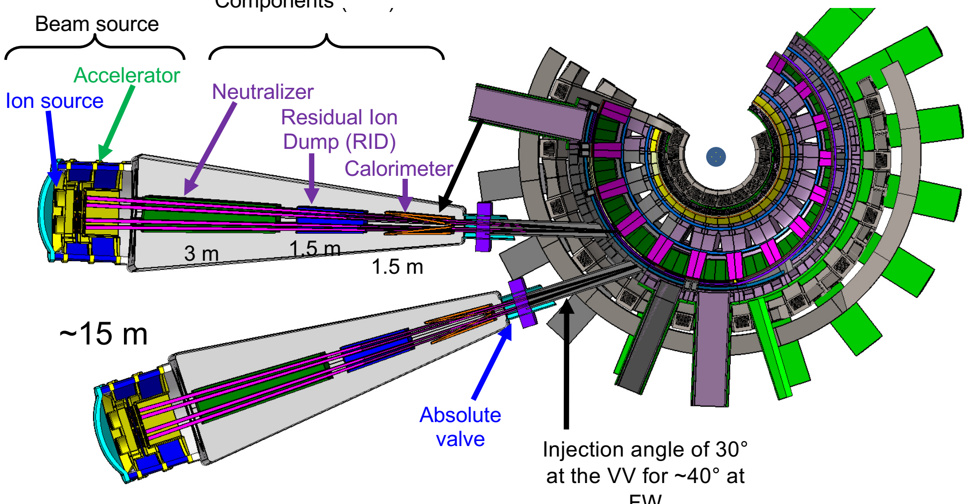
NNBI main parameters

- Power to plasma: **7.5 MW per injector**
- Beam energy: **400 keV** in 2 acc. stages
- Extracted current: **40 A** of D^-
- Target wall plug efficiency: ~45%

Shine through losses Evaluations



- *8 RF plasma sources*
- *Hybrid vacuum system (NEG + cryo)*
- *40 ° Injection at LCMS*



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