EUROfusion

DTT and the Subproject WPDIV-IDDT

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MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

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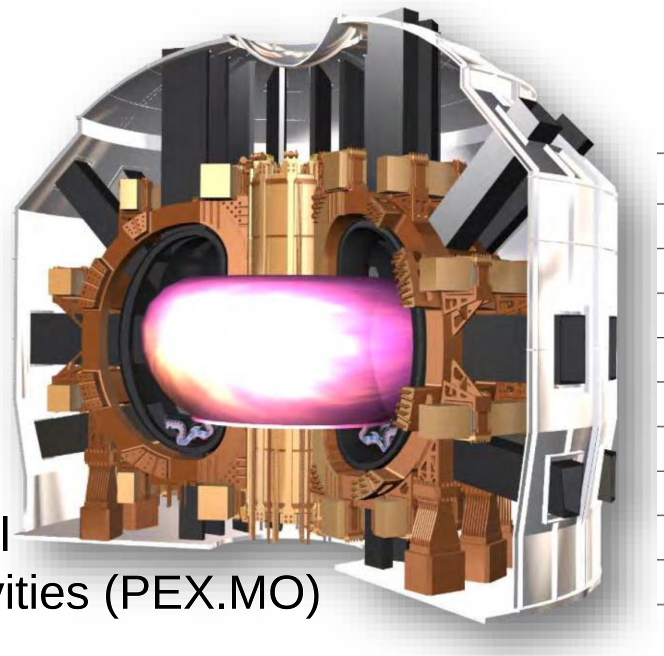
Scope of WPDIV-IDTT Subproject

WPDIV-IDTT supports the
design, qualification R&D, fabrication, assembly and installation of
- the DTT **divertor** (PFC+cassette body) and
- the DTT **subsystems which have an interface with the divertor**

DTT shall install a divertor which allows to test advanced divertor solution(s) for DEMO

The (substantial) EU financial contribution is subject to milestones to be achieved by the DTT project (DTT.M0) as well as by the EUROfusion PEX activities (PEX.MO)

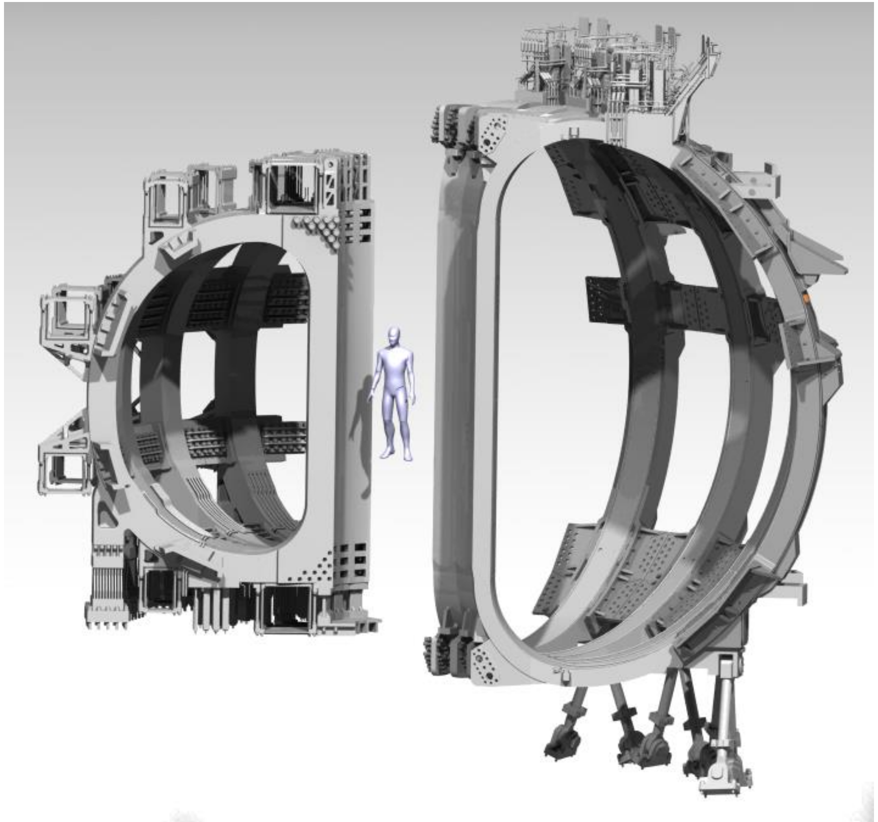


DTT Design Parameters

Parameter	Value
R (m)	2.19
a (m)	0.70
R/a	3.3
Volume (m^3)	29
q_{95}	3
I_p (MA)	5.5
B_T (T)	6.0
H_{98}	1.0
Pulse length @EOF (s)	90

DTT vs JT-60SA: Complementary Devices

DTT JT-60SA



high field: 6.0 T
(Nb$_3$Sn)
high current: 5.5 MA
high density: > 1e20/m³
high auxiliary power: ~40 MW
„small“ radius: 0.70 m

⇒ **„exhaust physics“**

low field: 2.3 T
(NbTi)
high current: 5.5 MA
„low“ density: < 1e20/m³
high auxiliary power: ~40 MW
„large“ radius: 1.18 m

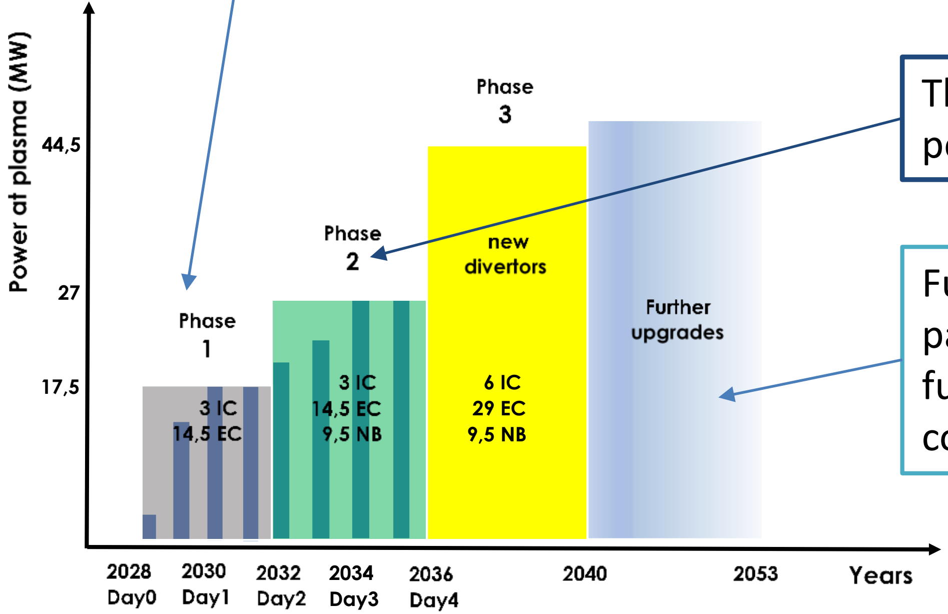
⇒ **„core physics“**

Planned Evolution of DTT Experimental Programme

In the first phase all the possible plasma scenarios will be tested to identify the most promising following divertors

The amount of additional heating power to be increased in three steps

Further upgrades dictated by the parallel development of the nuclear fusion facility under design and needs coming from the fusion community



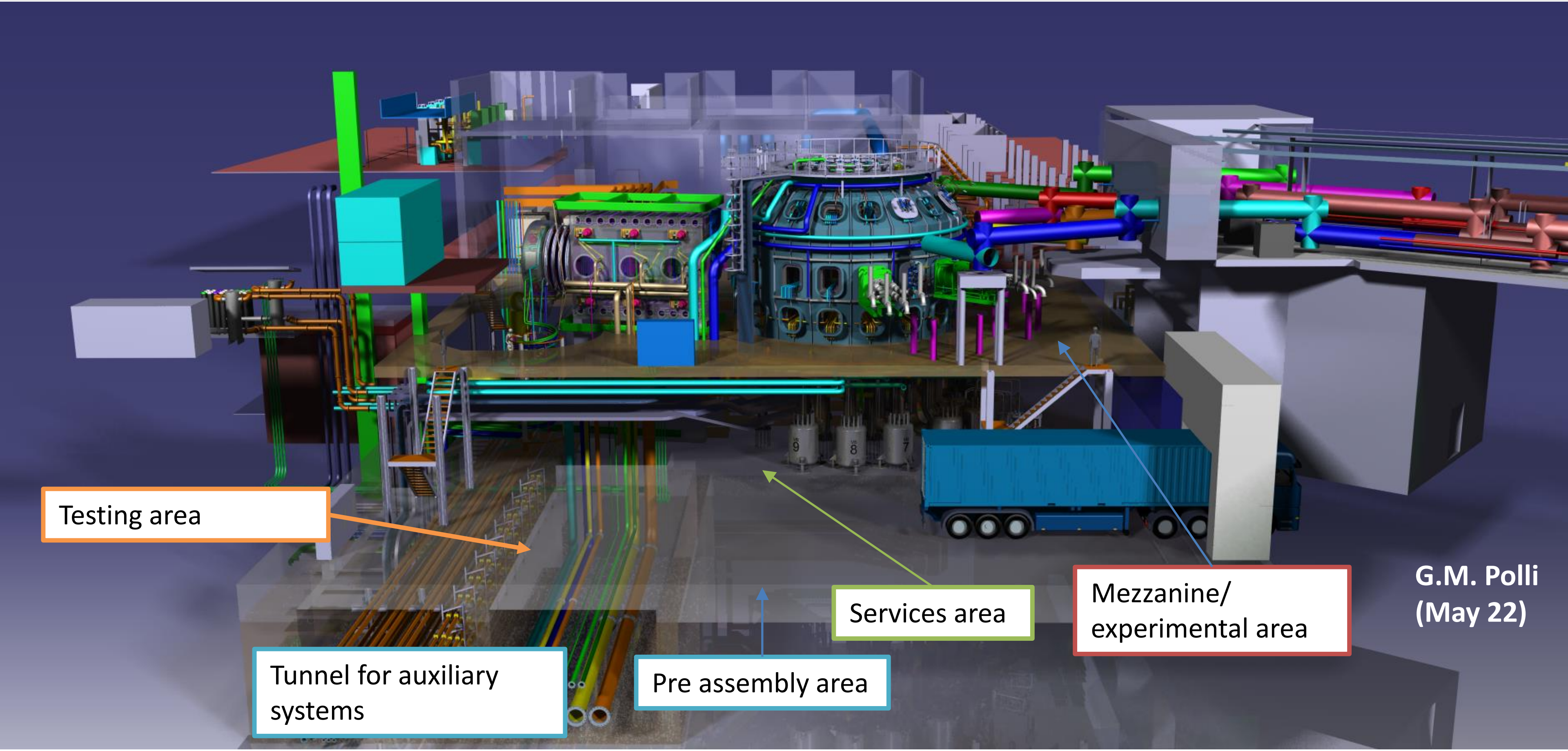
G.M. Polli (May 22)

Status of the DTT Project: Site Layout

G.M. Polli (May 22)

Status of the DTT Project: Site Layout (close-up)

Layout of DTT Torus Hall

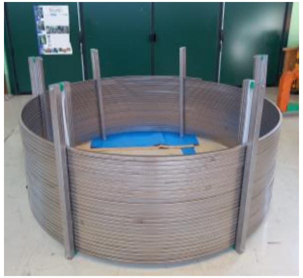


DTT Project: Status of Procurement (Example)

TF coils call for tender has been awarded, some components have been already delivered

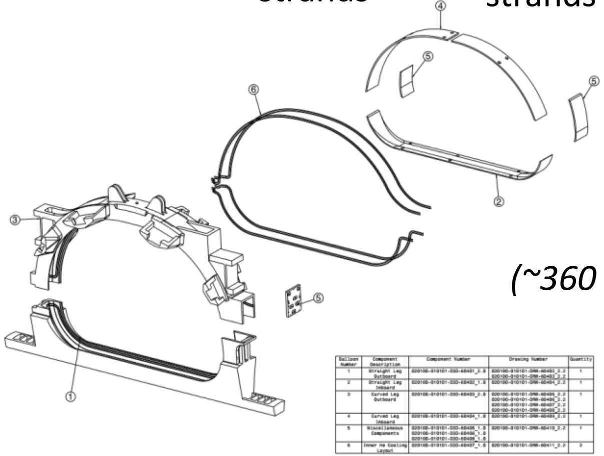
55 tons Nb_3Sn strands

31 tons Cr coated Cu strands



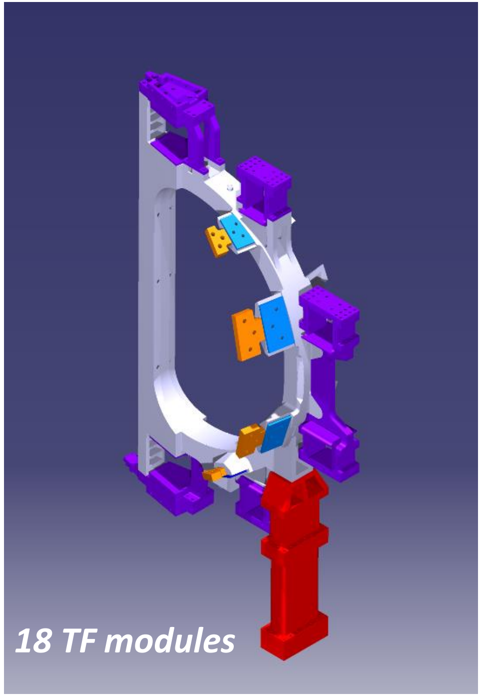
icas

20,4 km of conductors (95 unit lengths)



18 Casing components
(~360 tons of 316LN material delivered)
contract to be signed

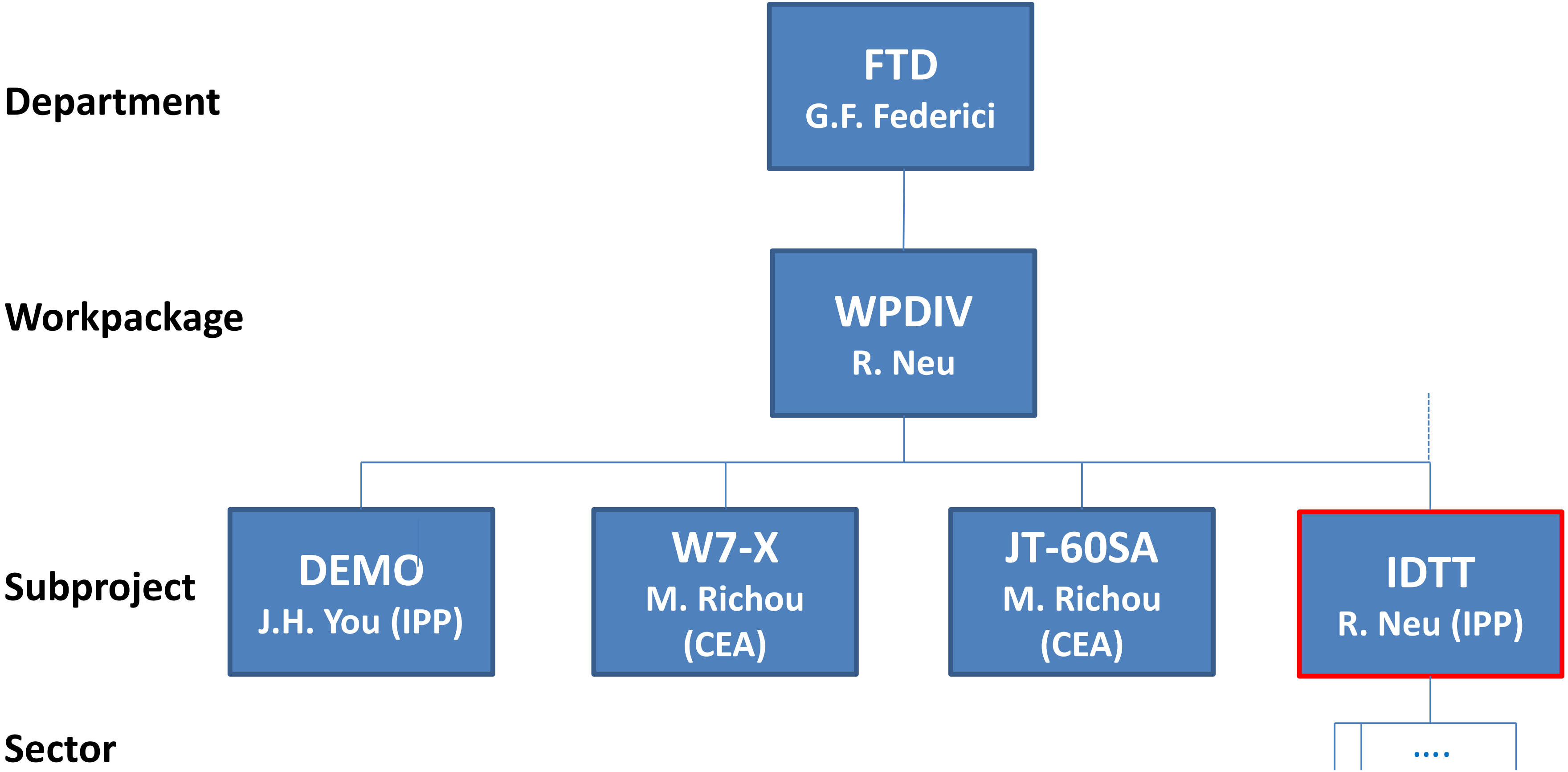
SIMIC Spa



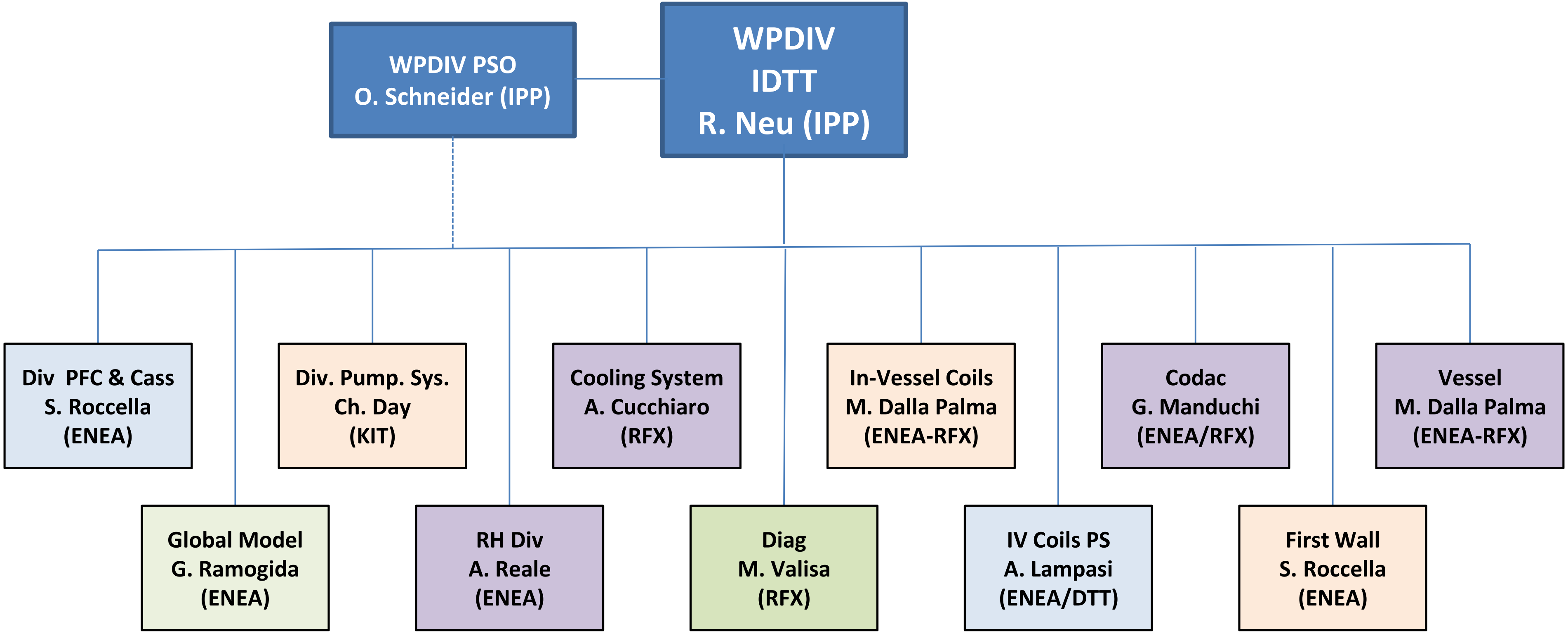
ASG SUPERCONDUCTORS

G.M. Polli (May 22)

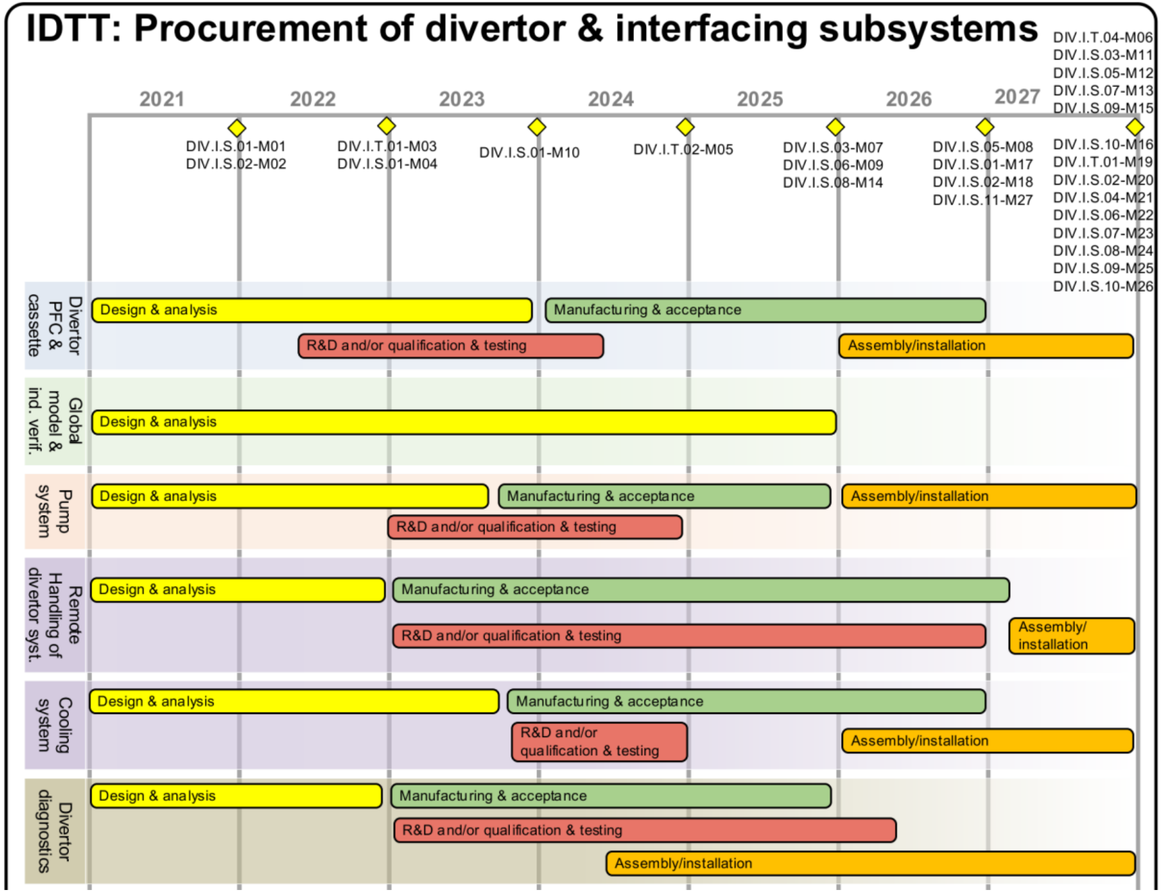
Structure of WPDIV



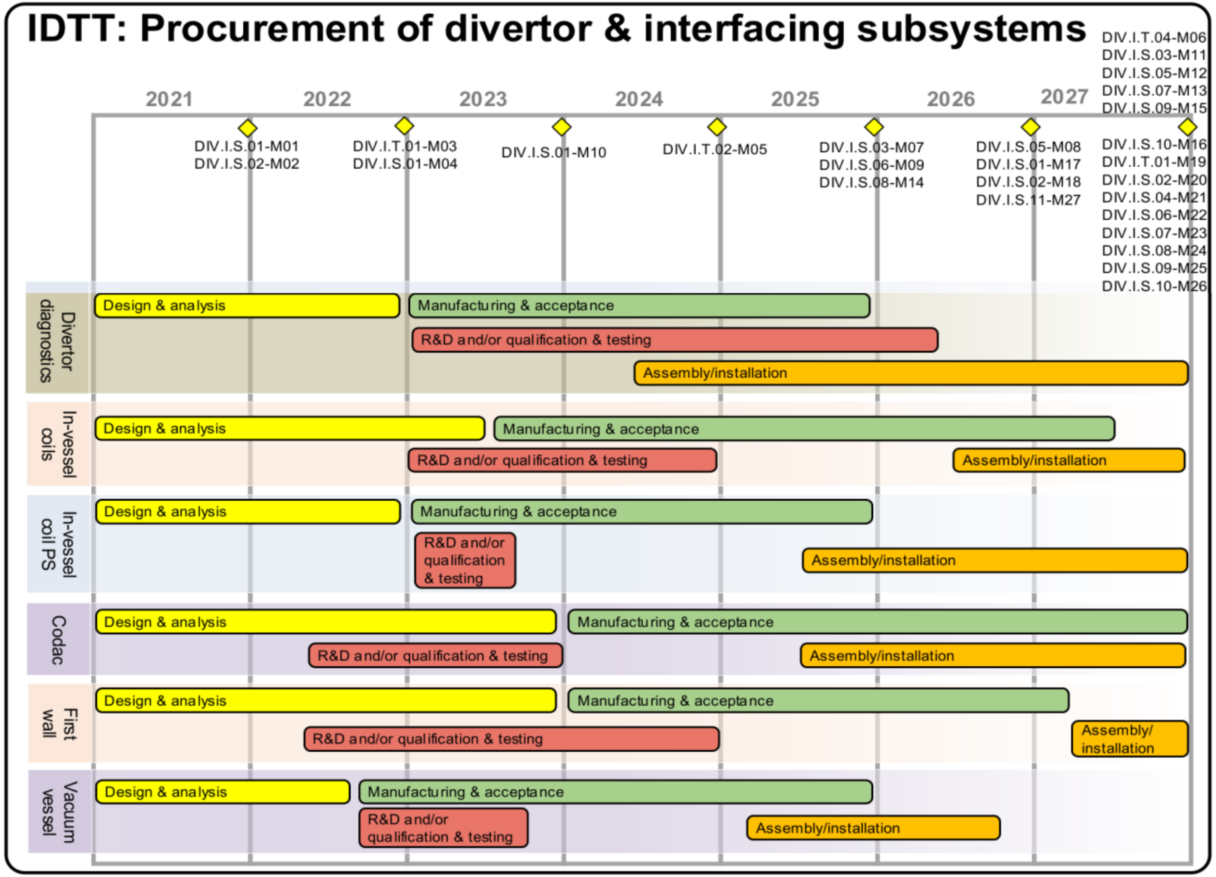
Structure of WPDIV-IDTT



DTT Gantt Chart



DTT Gantt Chart



Identification of the DTT Divertor Layout

Original DTT schedule/milestones and PEX milestones were not compatible (assuming an actively cooled divertor, capable of admitting alternative configs.)

⇒ review of (DEMO/DTT) ADC investigations performed during FP8 within WPDTT ADC and PMI

⇒ agreement (FTD / FST) to launch dedicated modelling efforts: identifying a possible DTT divertor solution until the end of 2021, capable of running alternative configurations without compromising their specific features

Early 2022:

⇒ proposal for flexible actively cooled divertor with adequate power handling capability for a range of (alternative) divertor configurations

⇒ solidified timeline for divertor design/development/manufacturing

⇒ updated (and consolidated) timeline for milestones and deliverable

WPDIV / WPPWIE Investigations on Divertor Shape

Conceptual design of a DTT divertor has been carried out (cassette + PFUs)

Design choices:

- qualified technologies (ITER): W mono-blocks (hot radial pressing (HRP))
- steel as structural material for cassette
- high flexibility for multiple magnetic configuration (SN, XD, NT, (SF))

Design constraints identified and quantified:

- maximum volume compatible with remote handling
- geometry constraints for welding and pipe shielding
- manufacturing constraints: target curvature, integrated flat tile curve with HRP (limited R&D needed)
- hydraulics compatible with plant (mass flow rate, pressure drop, temperature)

Constraints and Fundamental Choices for Divertor PFUs

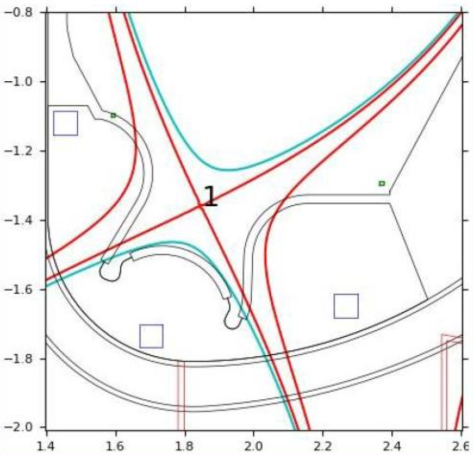
- **all plasma facing units** (PFUs: IVT,OVT & DOME) consist of **actively cooled W**, to withstand maximum heat loads
- **divertor cassettes** compatible remote handling
- **minimum bending radius** of the plasma facing surface **~190 mm** (manufacturing constraint when using W mono-blocks)
- **cooling pipes must be shielded** from parallel plasma heat flux
- inner board and outer board plasma **grazing angle 2°** for reference SN configuration, smaller angle possible for XD configuration
- **dome** must be able to accommodate strike points
- **pumping slots** between vertical targets and “central dome” (pumping speed ~100 m^3/s at cryo pumps in lower vertical ports)

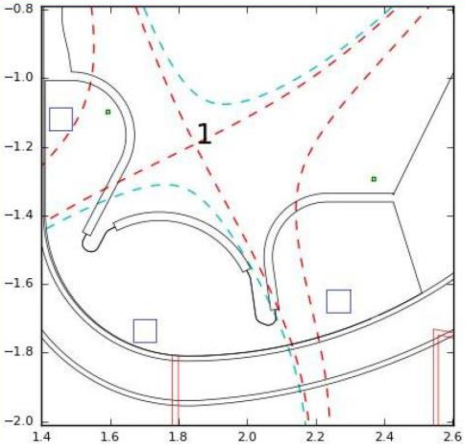
From Divertor Shape Definition to Optimization

1. Definition of different divertor shapes compatible with constraints and fundamental choices
2. Definition of reference (and additional) magnetic configurations
3. Selection by comparison between shapes and a reference shape
4. Divertor shape optimization

P. Innocente
R. Ambrosino,
PSI 2022

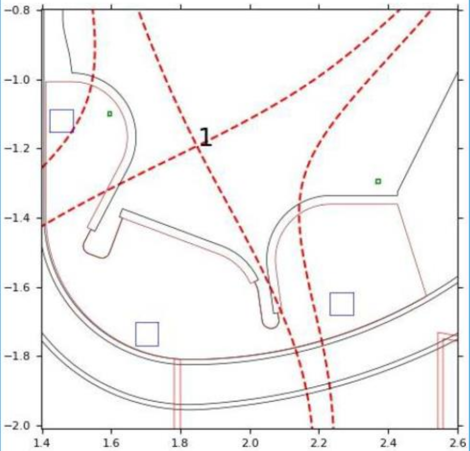
Narrow divertor



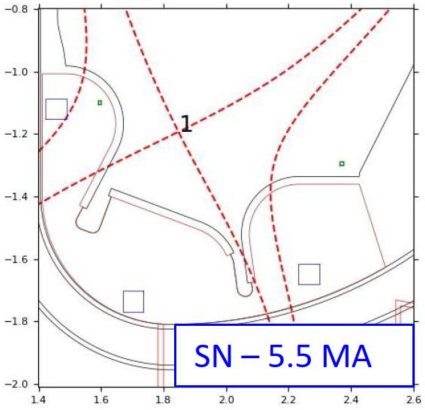


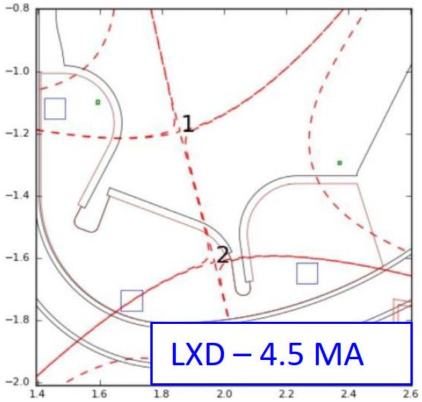
Wide divertor

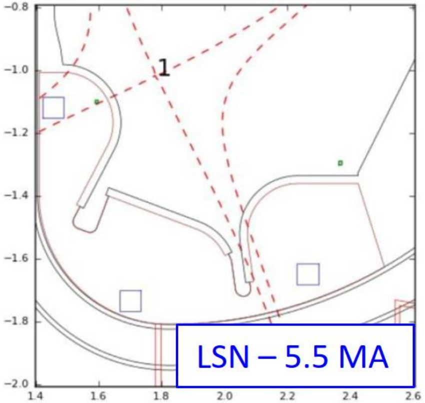
Wide divertor with flat-dome

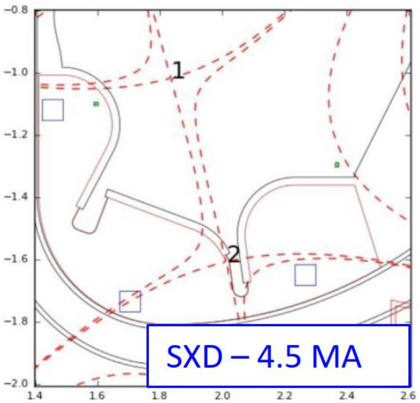


Magnetic Configurations with “Wide” Divertor and Flat Dome





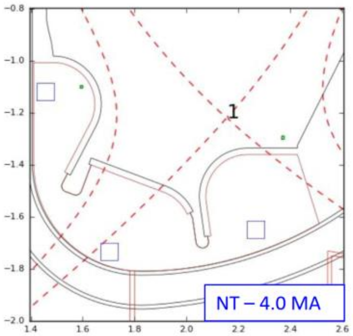


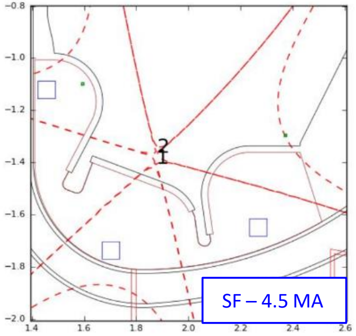


Edge modeling with different divertors:

- SN in pure D power scan with P_{SOL}=4÷25 MW
- XD, NT in pure D power scan with P_{SOL}=4÷8 MW
- SN, XD, NT scan with Ne/Ar seeding @ P_{IN}=30 MW

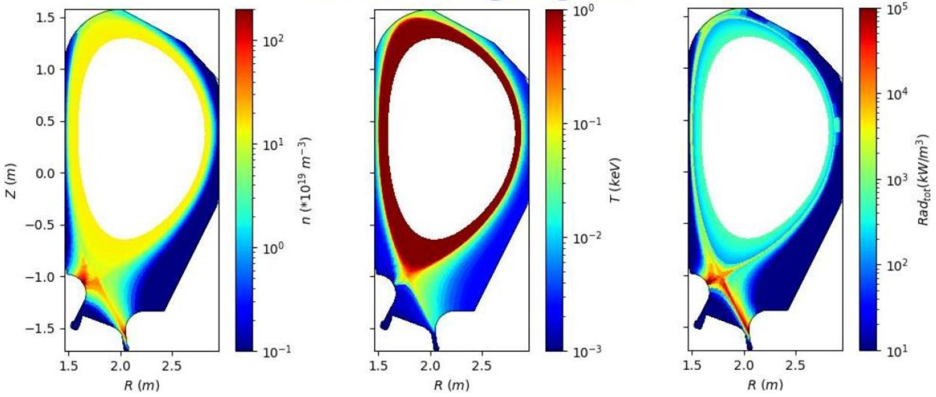
P. Innocente, R. Ambrosino, PSI 2022





Seeding with Wide Flat Divertor (SOLEDGE)

Neon Long leg SN



$< Z_{eff} >_{sep} = 2.8$

$P_{rad,tot} = 25.3$ MW

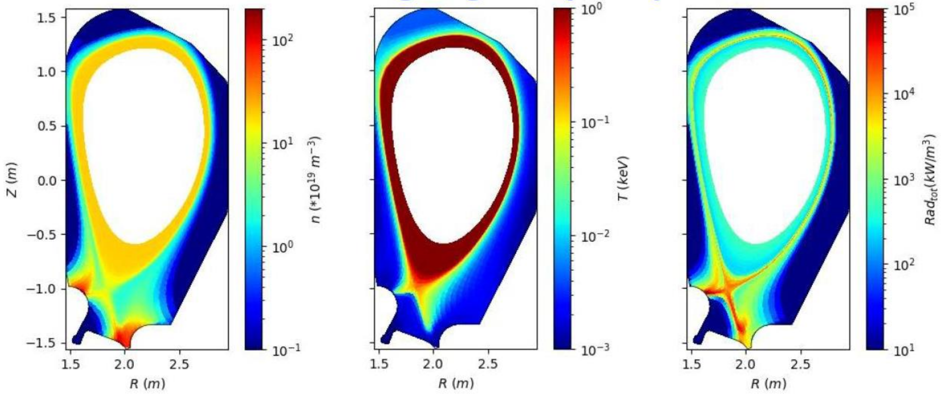
$P_{SOL} = 24.5$ MW

$C_{imp} = 3.0\%$

Long external legs provide a bigger radiative volume reducing request on impurity

P. Innocente
R. Ambrosino

Neon Long leg XD (SXD)



$< Z_{eff} >_{sep} = 3.6$

$P_{rad,tot} = 25.7$ MW

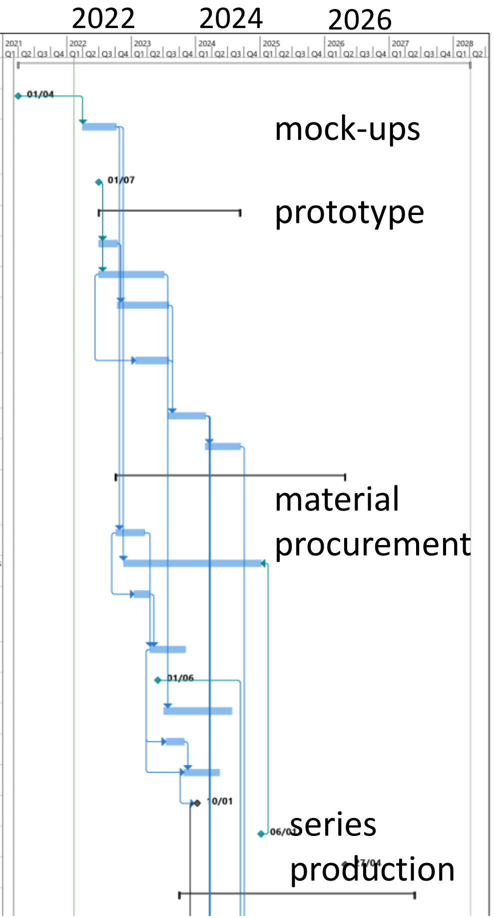
$P_{SOL} = 19.4$ MW

$C_{imp} = 2.3\%$

SXD provides less impurity content in the core thanks to a higher top pedestal density

Detailed Planning for Divertor Design / Manufacturing / Installation

ID		Task Mode	Task Name	Duration	Start	Finish	Free Slack
0			**divertor_espanso_10-02-22**	**1672 days**	**Thu 01/04/21**	**Fri 07/04/28**	**0 days**
1			1 start	0 days	Thu 01/04/21	Thu 01/04/21	239 days
2			2 Material procurement, manufacturing and testing of small mock-up	6 mo	Fri 01/04/22	Wed 05/10/22	0 mo
3			3 Freezing FW shaping	0 days	Fri 01/07/22	Fri 01/07/22	0 days
4			**4 Prototype activity**	**516 days**	**Fri 01/07/22**	**Wed 11/09/24**	**42.5 days**
5			4.1 Design of ovens	64 days	Fri 01/07/22	Thu 13/10/22	0 days
10			4.6 divertor design and analyses	240 days	Fri 01/07/22	Thu 06/07/23	0 days
6			4.2 3 prototype ovens (including tender)	193.5 days	Thu 13/10/22	Mon 31/07/23	0.5 days
7			4.3 procurement of the material for the prototype (including tender)	129 days	Thu 26/01/23	Tue 01/08/23	0 days
8			4.4 prototype manufacturing	129 days	Tue 01/08/23	Mon 26/02/24	0 days
9			4.5 prototype qualification	129 days	Mon 26/02/24	Wed 11/09/24	0 days
11			**5 Material procurement (including tender)**	**848 days**	**Wed 05/10/22**	**Mon 27/04/26**	**158 days**
12			5.1 Procurement of tubes	107.5 days	Wed 05/10/22	Fri 17/03/23	0 days
19			5.8 monoblock procurement	500 days	Fri 18/11/22	Mon 06/01/25	781.13 days
17			5.6 call for tender tube/SS terminals joints	64.5 days	Tue 17/01/23	Tue 18/04/23	0 days
13			5.2 tube/SS terminals joints	129 days	Tue 18/04/23	Fri 03/11/23	0 days
20			5.9 first batch monoclock delivery	0 days	Thu 01/06/23	Thu 01/06/23	278.5 days
16			5.5 procurement swirl tapes	250 days	Thu 06/07/23	Tue 23/07/24	881 days
14			5.3 call for tender for tube bending	64.5 days	Mon 17/07/23	Fri 27/10/23	0 days
18			5.7 tube bending	129 days	Fri 27/10/23	Tue 14/05/24	0 days
15			5.4 start Ni coating of tubes	0 days	Wed 10/01/24	Wed 10/01/24	140 days
21			5.10 last batch monoblock procuren	0 days	Mon 06/01/25	Mon 06/01/25	0 days
22			5.11 finish Ni coating of tubes	0 days	Mon 27/04/26	Mon 27/04/26	465 days
23			**6 series production**	**874 days**	**Mon 02/10/23**	**Thu 27/05/27**	**0 days**

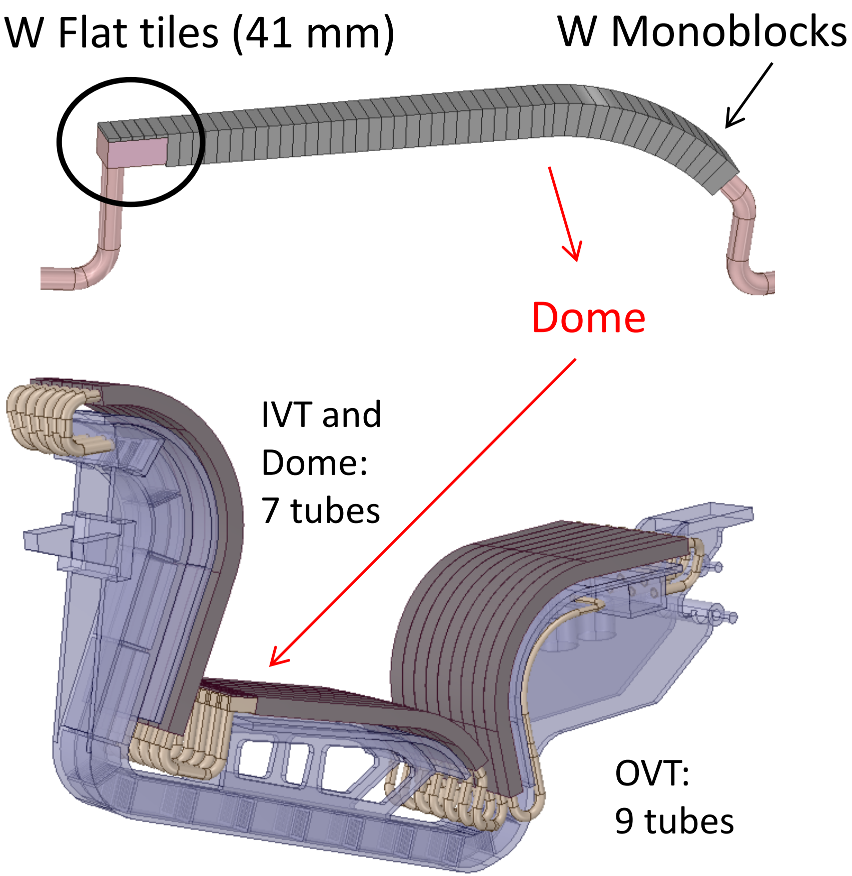


detailed planning available

start date: 01/04/22
end date: 10/06/27

GM Polli, Mar 2022

Layout of the Full-W DTT Divertor

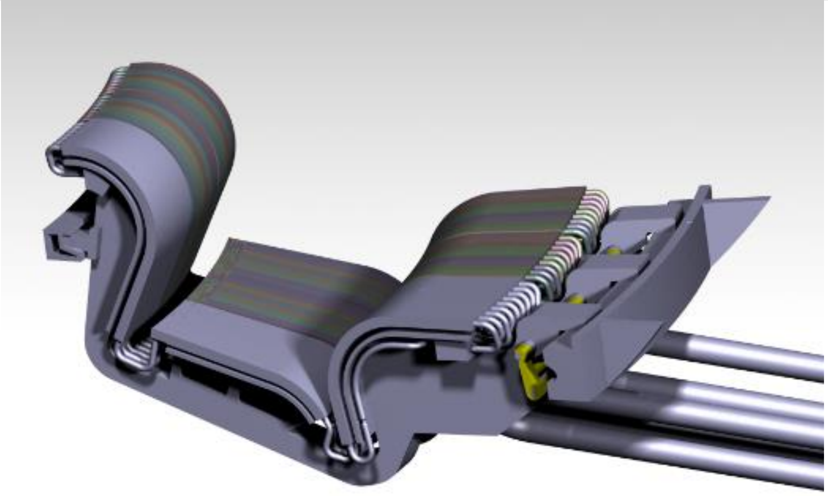


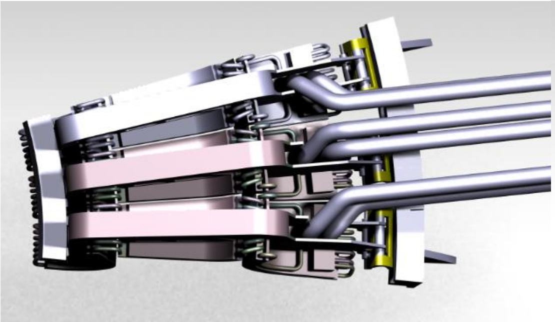
- **no showstoppers** identified in preliminary thermohydraulic and mechanic analysis
- **optimization** is required to withstand **electromagnetic loads**

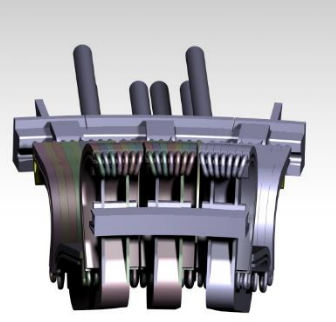
- (limited) R&D is required for:
  - **investigating CHF** limit for small plasma footprints/without swirled tape/other turbulence promoters
  - **flat tile design** integrated with the HRP process needs to be validated through small-scale experiments
- design and verification of the **fixation systems** (PFUs to cassette + cassette to VV) ongoing

S. Roccella, Apr 2022

Technical Layout and Schedule of the DTT Divertor







Properties of DTT divertor
- 54 cassettes
- > 20 MW/m^2 steady state
- M< 400 kg (max allowed weight)
- Hot Radial Pressing HRP with W monoblocks (ITER-like technology)
- Compatibility with SN – XD – NT
- RH compatibility checked
- Wide range of cooling water parameters (30°-130° C, up to 5 MPa)
- Pumping preliminarily verified
- 4 modules with additional flexiblity

Procurement strategy:
- R&D on small mock-up
- Prototype for manufacturing qualification
- 3 parallel lines for PFU prod. (IVT, Dome, OVT)

Summary and Conclusions

- flexible divertor to accommodate large range of (alternative) divertor plasma configuration agreed
- optimized ITER-like W mono-block targets to be used for all surfaces in the divertor to guarantee highest flexibility even at full performance
(efficient use of target development for DEMO during FP8)
- engineering design to be started now to allow manufacturing in time for start of operation in 2028