



WPW7X: Preparation and Exploitation of W7-X Campaigns Project Execution Plan 2021

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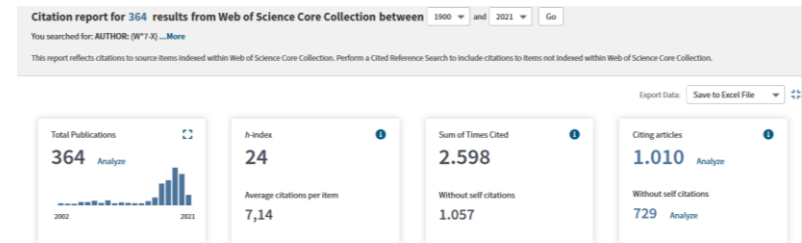


This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

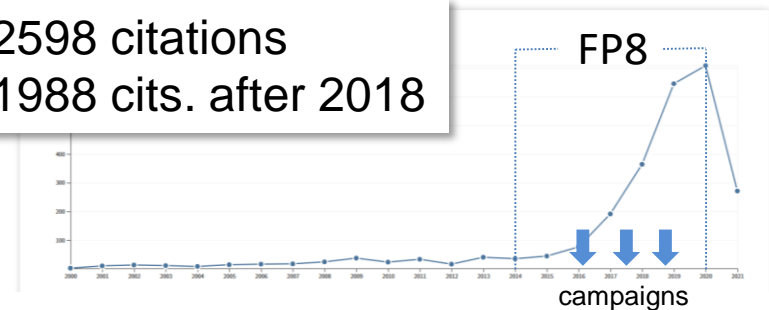
- Optimized magnetic fields can be engineered and built [1]
- The bootstrap current is small and controllable [2]
- Stellarator optimization reduces the neoclassical transport [3]
- Long-pulse operation is feasible in W7-X: detached plasmas [4]
- **NEW PHYSICS ahead:**
3D turbulence? fast-ions?
impurities? PWI in long-pulse ...

- [1] Sunn-Pedersen et al., Nat. Comm. 7, 13493 (2016)
 [2] Dinklage et al., Nat. Physics 14, 855 (2018)
 [3] Beidler et al., Nature (2021, accepted/under embargo)
 [4] Zhang et al., Phys. Rev. Lett. 123, 025002 (2019)
 + 360 articles from the W7-X Team

Community Recognition



2598 citations
1988 cits. after 2018



Bringing stellarators to maturity – OP2: the next step

Higher performance and towards steady-state

- ECRH upgrade: 12 gyrotrons, 1.5MW upgrades
- ICRH: < 2MW
- NBI upgrade: 6.8MW (10MW w/D)
- actively, water-cooled PFCs
- cryo-pumps
- cw pellet injection (ITER prototype from ORNL)
- trustable scenario proposals for HELIAS
- theory & predictive modelling for next steps
- infrastructure, safe-operation, diagnostics developments/upgrades and hardening



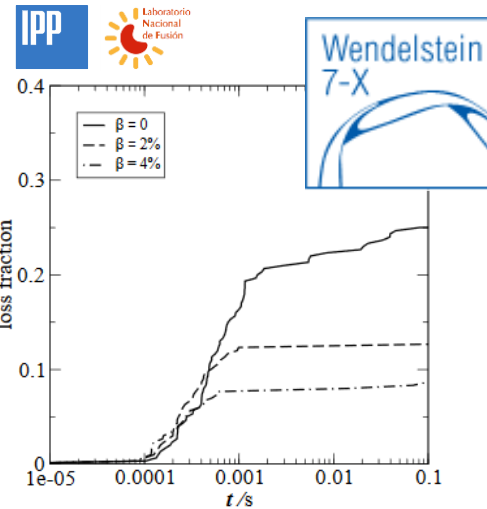
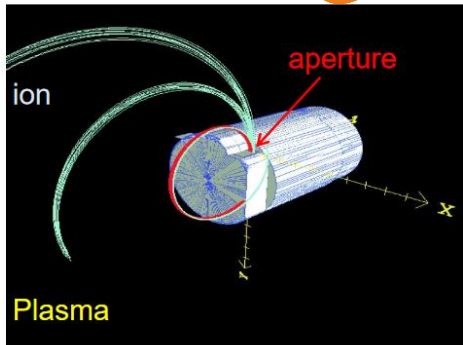
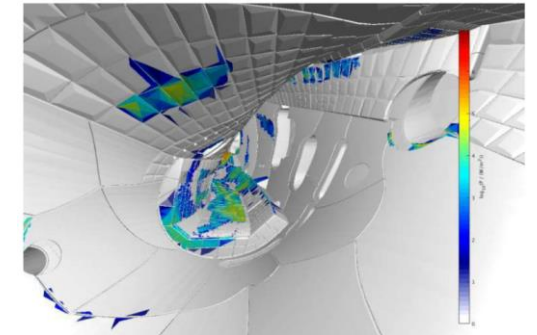
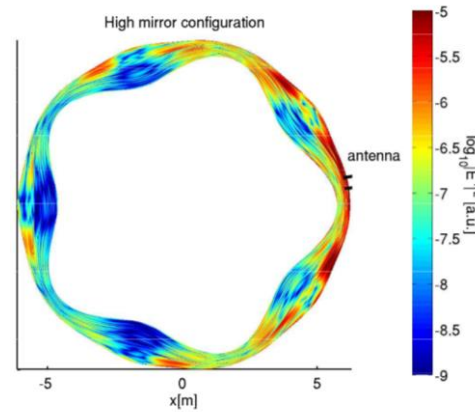
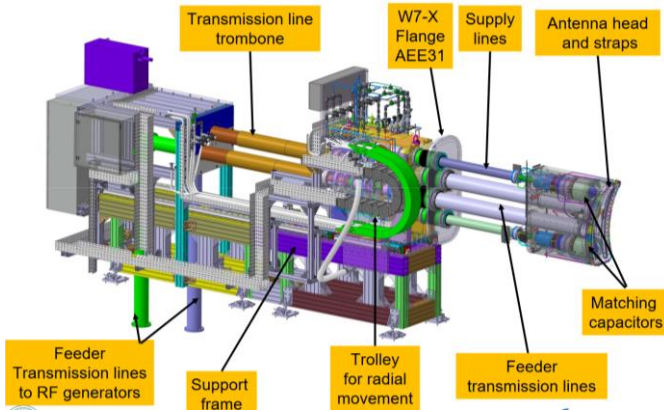
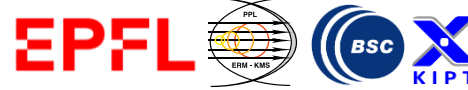
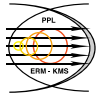
Status W7-X/C: progress as planned (after COVID)

→ program FP9: go to low v^* (fusion), high- β (stability, optimization)
at high densities (fast-ions, economy/operation)

Not covered in Horizon Europe (FP9) for the Mission-8-Roadmap vision - reactor assessment:
tungsten divertor/pure metallic wall operation to be prepared

**EUROfusion leads crucial elements and contributes to the W7-X experiment program
focusing on the objectives from the Roadmap to Fusion Electricity (Mission 8)**

Show-case for our *One-Team-Approach*: open, goal-oriented cooperation





Approval of the Project Execution Plan 2021

Part I

- WPW7X in FP9
- W7-X: status and campaign planning

Part II

- Workplan 2021 – towards OP2: Budget, Risks and Opportunities
- PEP 2021

- Change requests
- Approval of the PEP and additional decision proposals

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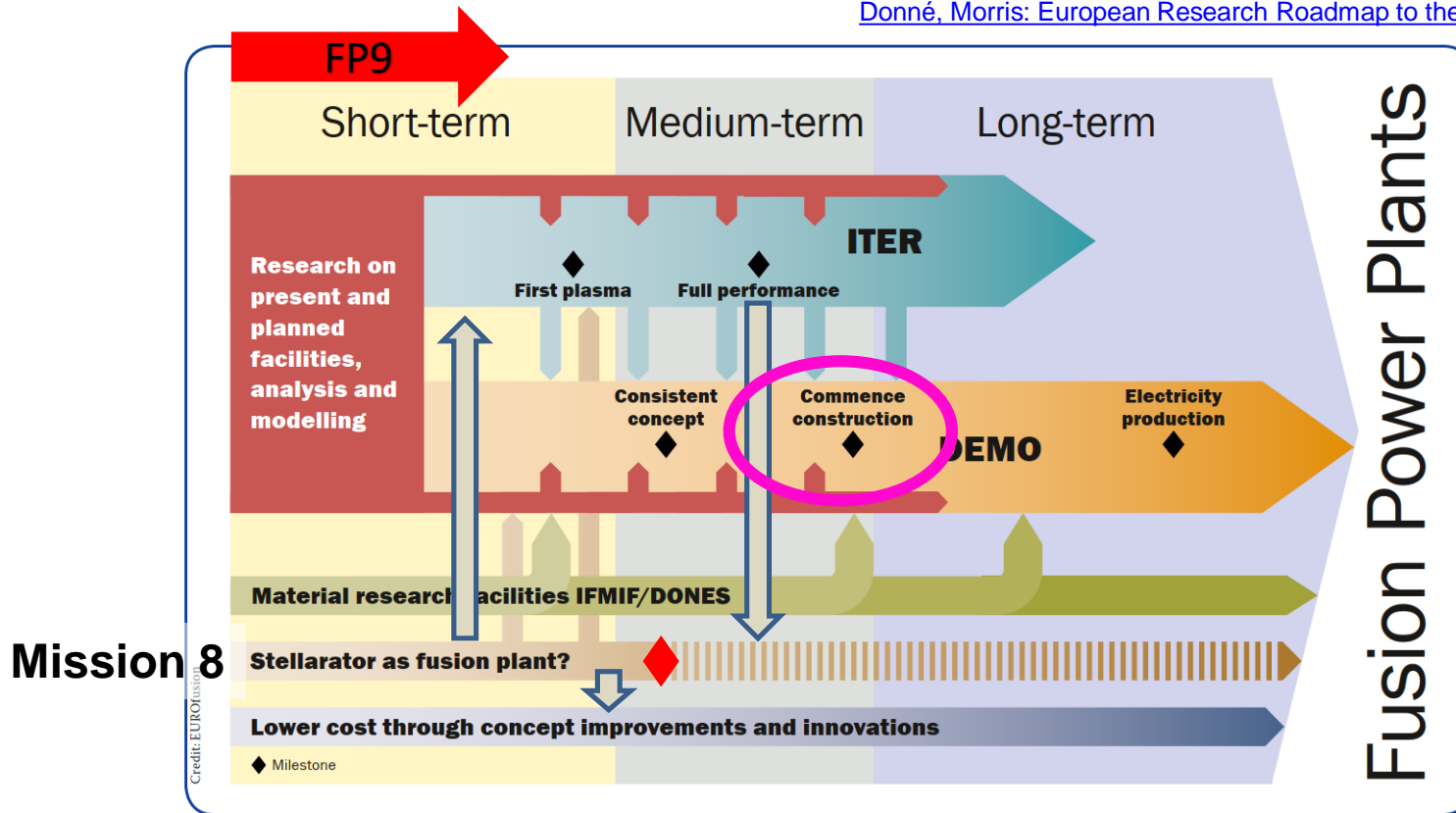
WPW7X implements Mission 8 of the
European Roadmap to Fusion Electricity in Horizon Europe:
Bring Stellarators to Maturity

(with TSVV-12, -13, WPPRD; International Collaborations, ...)

Mission 8: bring stellarators to maturity



Donné, Morris: European Research Roadmap to the Realisation of Fusion Energy



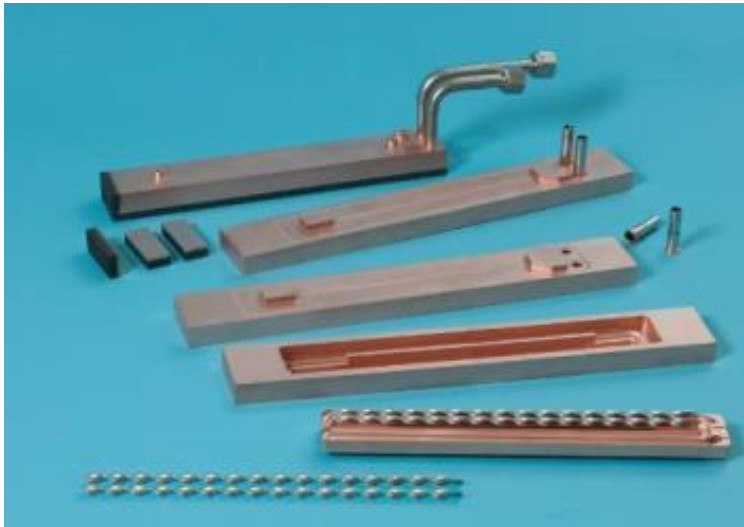
Clear long-term deliverable: optimized-stellarators as Fusion Power Plants

Additional benefit for the Roadmap: strategic risk mitigation, innovation, specific support to ITER and DEMO + 3D-expertise to complete the EU fusion asset and to foster European leadership in fusion

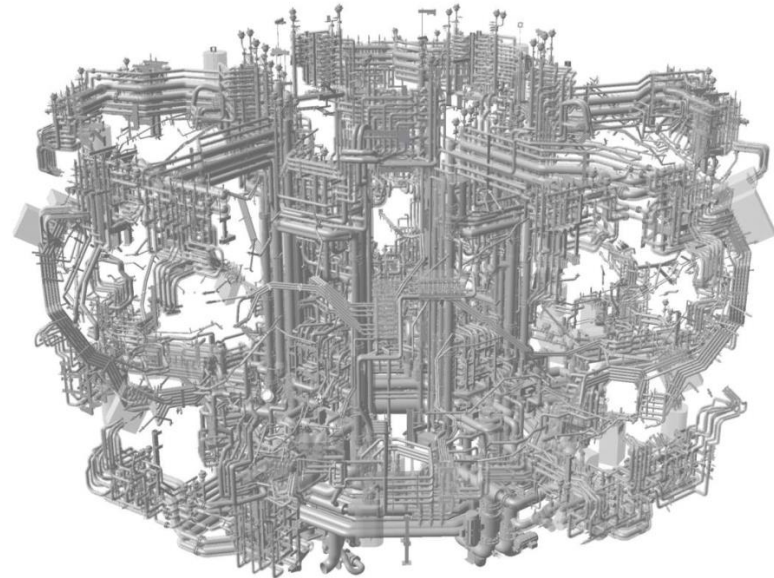
Our vision: stellarators as an alternative line to fusion electricity

HELIAS reactor relevant plasmas

- high-performance/long pulse
- high density and $T_i \sim T_e$,
- high beta (nT), low ν^*



Water-cooled PFCs:
the high-heat-flux divertor

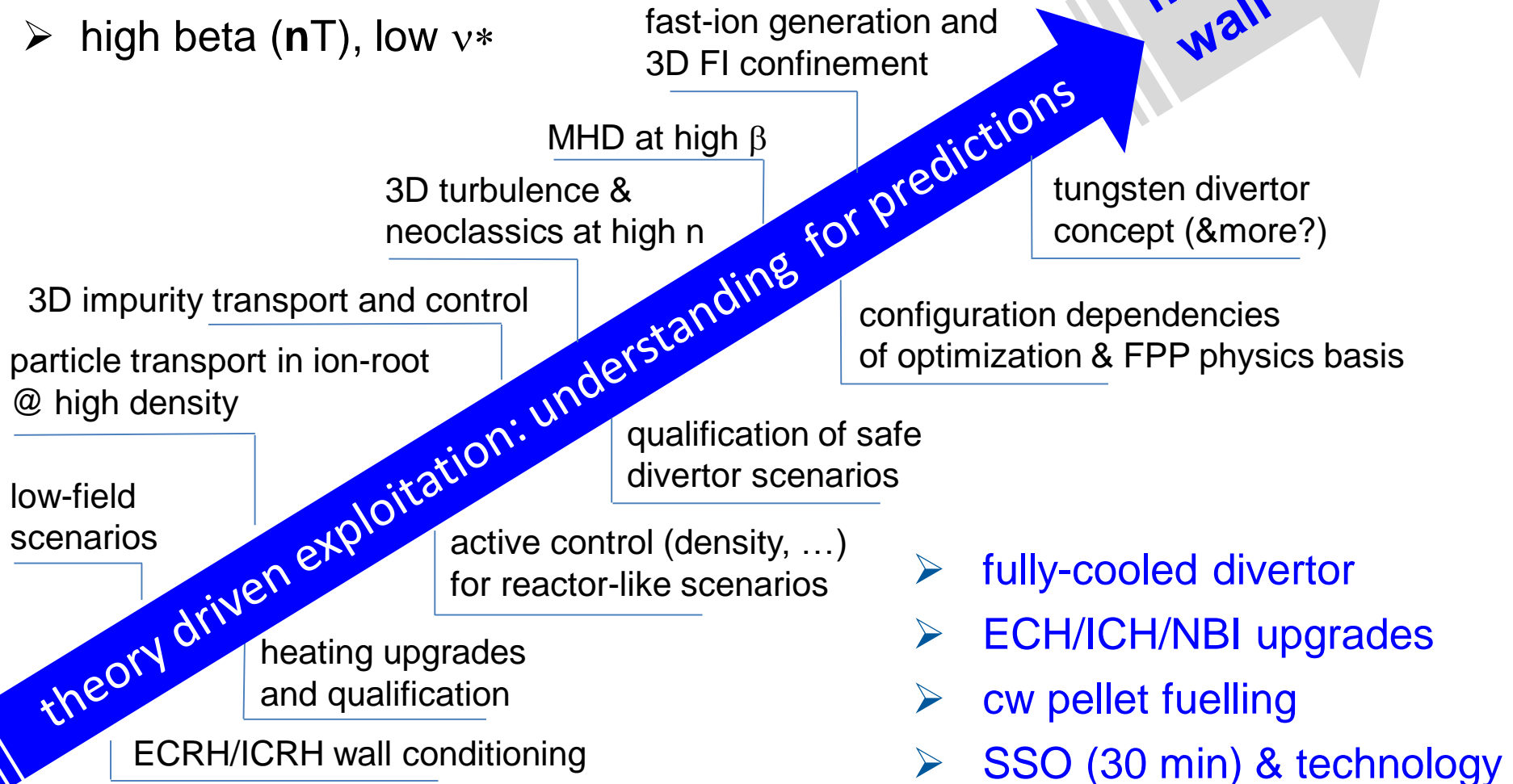


W7-X completion (W7-X/C): 2018 ~ 22
actively cooled PFCs/commissioning of water-cooling

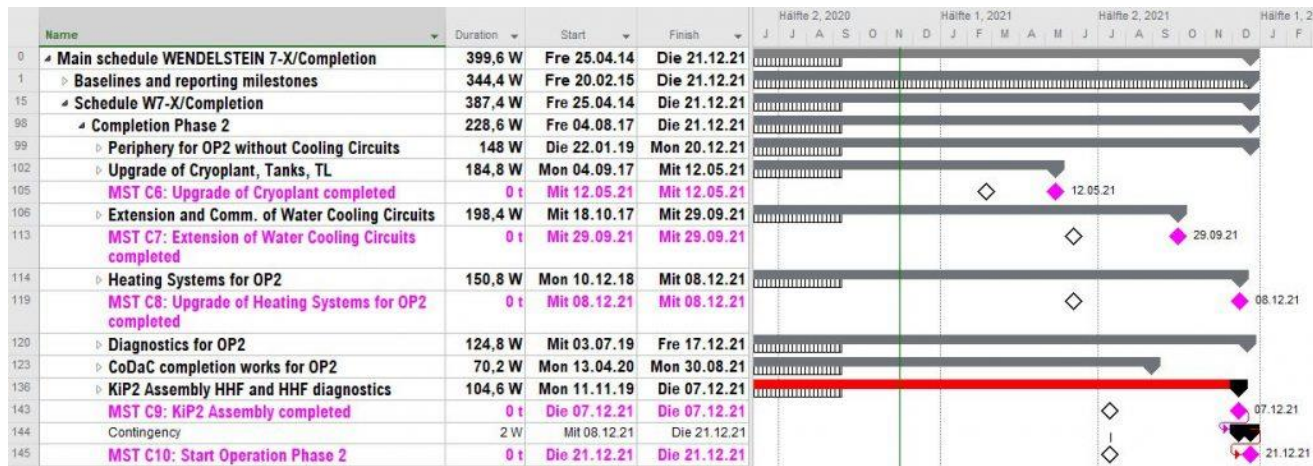


HELIA S reactor relevant plasmas

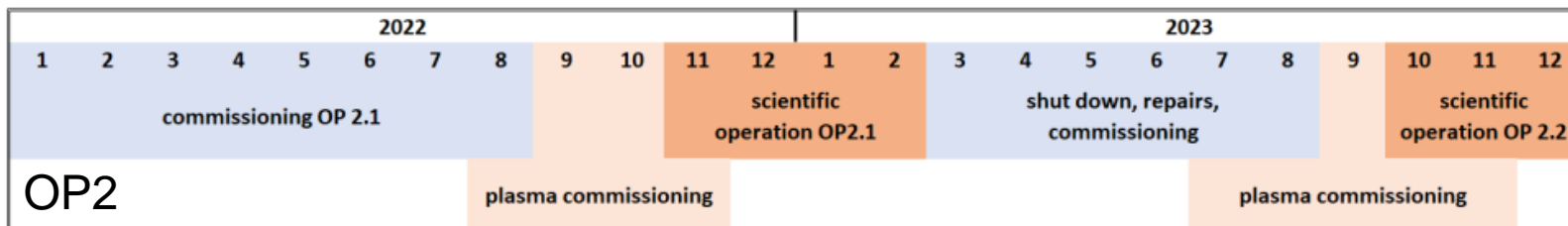
- high-performance/long pulse
- high density and $T_i \sim T_e$,
- high beta (nT), low ν^*



Project Plan W7-X/C: milestone C10 – stays at 21.12.2021



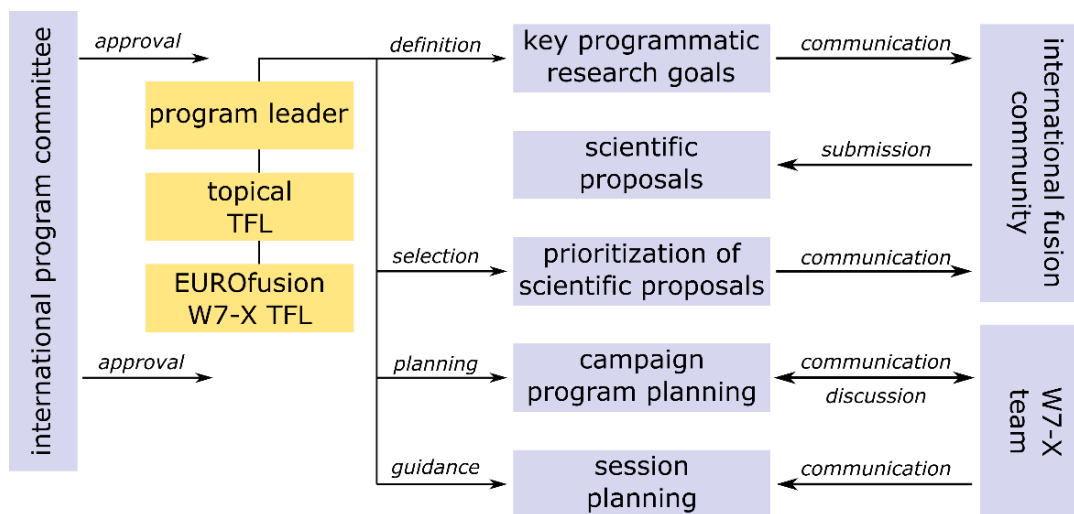
Proposed campaign planning (IPC endorsed, to be approved by W7-X Project Board)



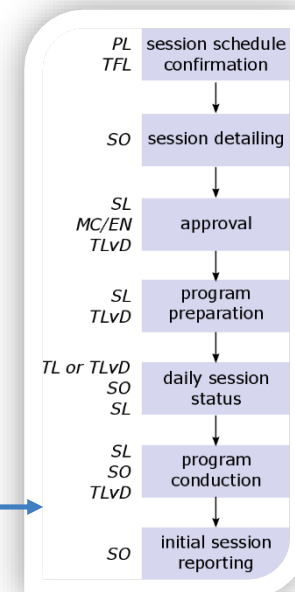
Participation of EUROfusion in commissioning important in 2022

- from 2022: yearly campaigns of 14 wks scientific operation (+ plasma commissioning)
- call for proposals to the W7-X Team in due course (2022) – synchronized to EUROfusion calls

Workflow of Scientific Proposals



- definition of key programmatic goals of a campaign form basis of prioritization
- open call for proposals, which (after evaluation) form the basis for the program planning
- post-deadline proposals need to be channeled through the task force leaders
- session planning and conduction as in OP 1.2b
- **proposal: program presentation to IPC via the W7-X program workshop**





Proposal for Research Task Forces on W7-X and programmatic goals (evolving)

TF I - Core scenario development

- Integrated scenarios for long pulse operation approaching 2GJ energy turnaround.
- Stationary ECRH and NBI heating scenarios with improved energy confinement and plasma profile control.
- Assessment of fast ion confinement approaching operation at high plasma-beta.
- ...

TF II - Edge scenario development

- Integrated scenarios for long pulse operation with PFC heat load control, efficient particle exhaust and impurity screening.
- Development of long stationary divertor detachment scenarios with and without impurity seeding.
- Preparation of carbon-free operation with tungsten PFC.
- ...

TF III – stellarator optimization

- Assessment of operational limits with respect to heat/particle transport and radiation
- MHD stability and optimization exploitation
- NBI and ICRH qualification and plasma operation at reduced magnetic field
- Edge plasma exploitation and validation of numerical tools.
- ...

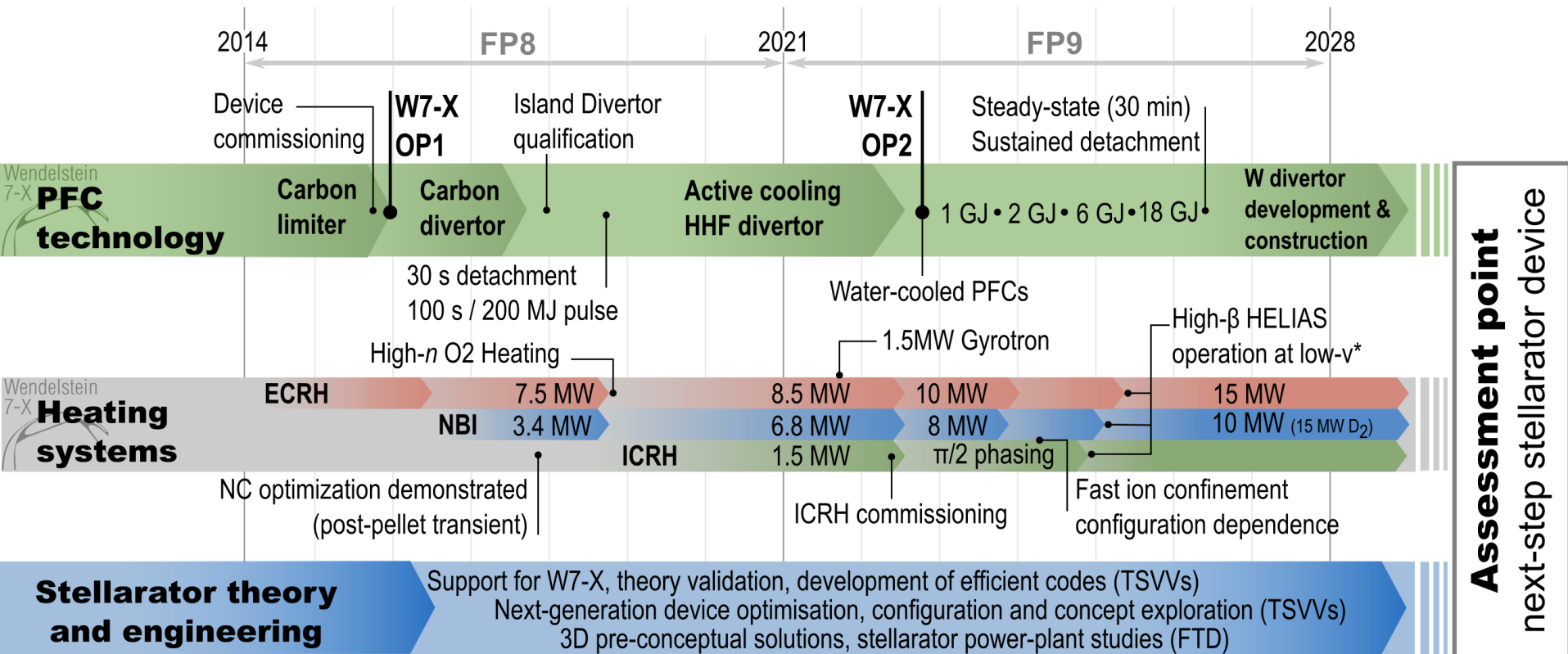
- topics are interlinked (individual physics aspects / integrated scenario) and close interaction between research TFs on W7-X and W7-X topical groups is required (one-team-approach)
- approved by W7-X International Program Committee (IPC)



to support conceptual studies for a next-step, optimized helical device (short-term)
to prepare the assessment of optimized stellarators (mid-term)
and to deliver the physics basis for a stellarator Fusion Power Plant (long-term)

WPW7X exploits W7-X campaigns to bring optimized stellarators to maturity.

W7-X in FP8 and FP9



Assessment point
next-step stellarator device

EUROfusion Machine Time W7-X				
2021	2022	2023	2024	2025
0%	18%	23%	30%	30%

Level-1: Horizon Europe Milestones and Deliverables broken down in Annual Work Program

Level-2: **Annual Work Program** formulated in terms of objectives

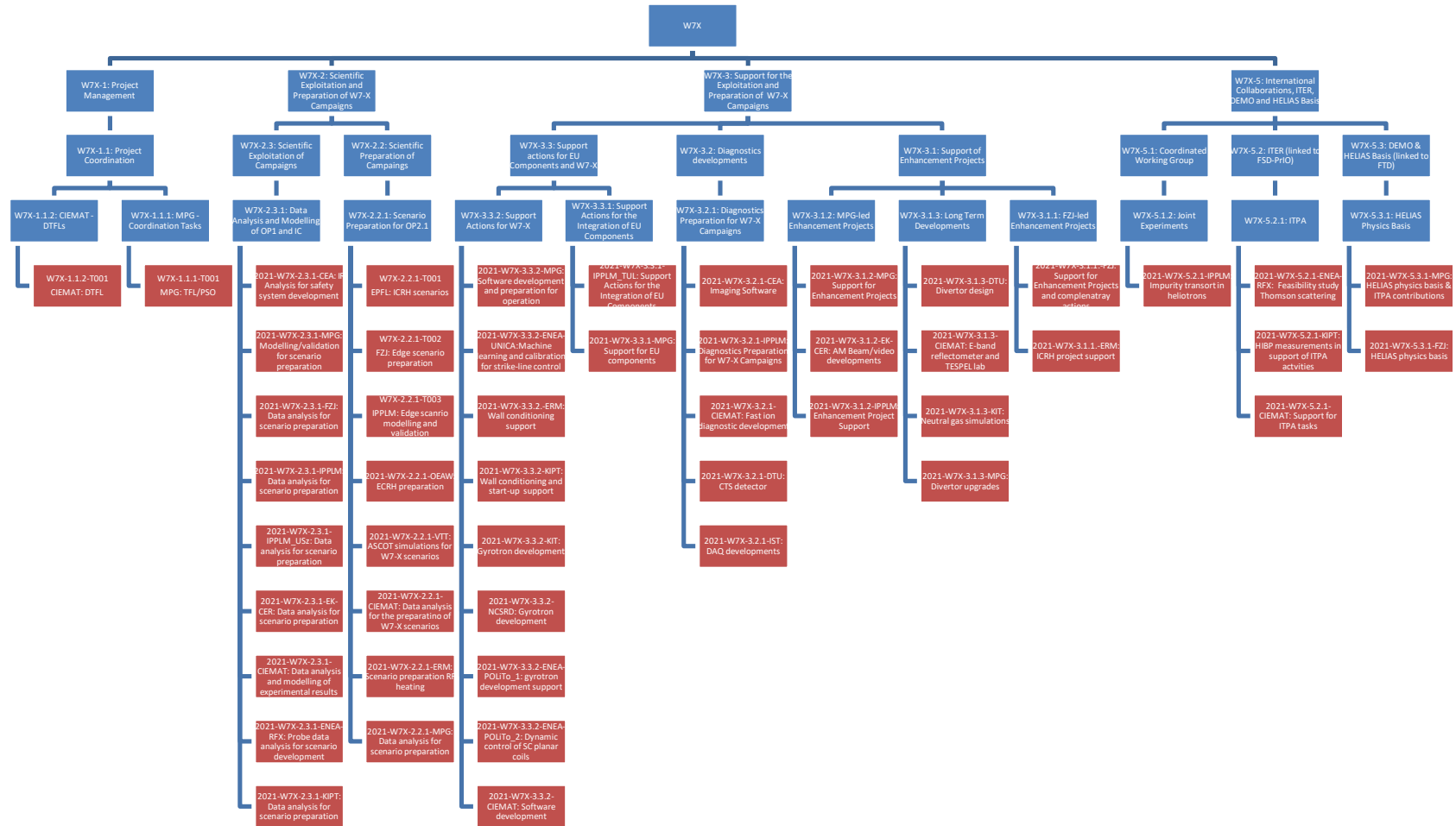
Level-3: Project Execution Plan defines task to resolve objectives, metrics of success: deliverables

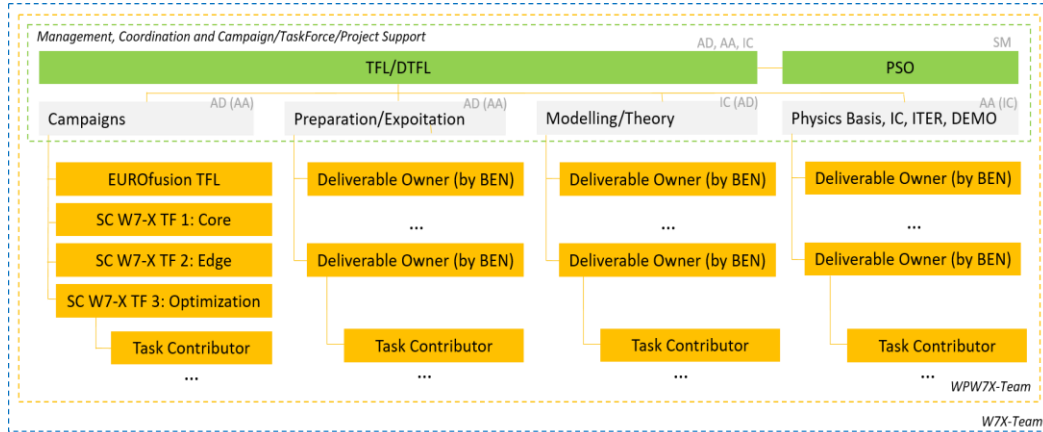
WPW7X-2021.01	Continue the development of heating and fueling system upgrades and prepare their installation on the device.
WPW7X-2021.02*	Initiate collaborations with TSVV-12 on stellarator optimization and lay out plans for the project with the goal of producing highly optimized designs by 2025.
WPW7X-2021.03*	In collaborations with TSVV-13 , enhance the capabilities of micro-turbulence modelling in W7-X via development of the currently available gyrokinetic codes, their verification and their application to specific transport problems.
WPW7X-2021.04	Prepare safe long-pulse, high-power operation by implementing safety interlocks and developing strategies for wall conditioning .
WPW7X-2021.05	Continue to develop and implement diagnostic systems and upgrades in support of the scientific objectives of Mission 8 in OP2.
WPW7X-2021.06	Advance the analysis of OP1 experimental data, develop and validate physics models and codes to (a) prepare OP2 experimental scenarios and (b) continue to construct the physics basis and the design and simulation tools for next-step devices.
WPW7X-2021.07	Prepare longer-term upgrades of the W7-X divertor and plasma facing components in collaboration with other EUROfusion work packages (WPPWIE, WPDIV).
WPW7X-2021.08	Support the preparation of the HELIAS physics basis, ITER first plasmas, ensure information exchange with the EUROfusion FTD and continue international collaborations in support of the Mission 8 objectives.

PEP-2021: Preparation of OP2

FP8 Enhancements, diagnostics, support, experiment proposals

Small activities: Metallic wall, HELIAS physics basis, ITER/ITPA, International Collaborations

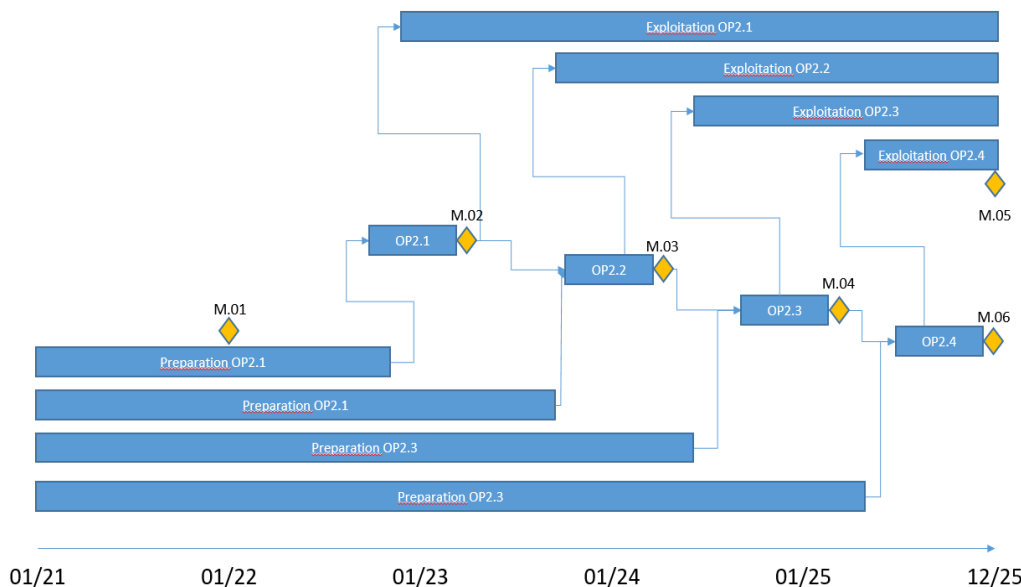




Structure

- flat hierarchies
- full integration into the W7-X Team

One-Team: leverage of resources



Simple overall workflows: format follows function

- ❖ Preparation
- ❖ Campaigns
- ❖ Exploitation

Exceptions:

- support HELIAS/ITER/DEMO
- International Collaborations

- Fusion Technology Department (FTD) – WPDIV: dedicated development of target technology
 - Supports the metallic wall/divertor **target developments** for W7-X taking benefit from simultaneous developments for JT60-SA

→ hardware

- FTD – WPPRD implements HELIAS engineering activities
 - Support by **HELIAS physics basis** and experiments on W7-X

→ requirements for divertors/first-wall of next –step devices.

- Fusion Science Department (FSD) – PWIE, WPTE, JT60SA, JET: fostering European leadership in fields of key expertise
 - **metallic wall** operation, wall conditioning,
 - **exhaust/fueling**
 - safe steady-state operation: surveillance and fast control for metallic wall operation
 - steady-state technology: hardening
 - 3D modelling

→ software, expertise

- International Collaborations
 - IEA TCP-SH: participation in LHD
 - **Physics Basis**

→ specific support, expertise

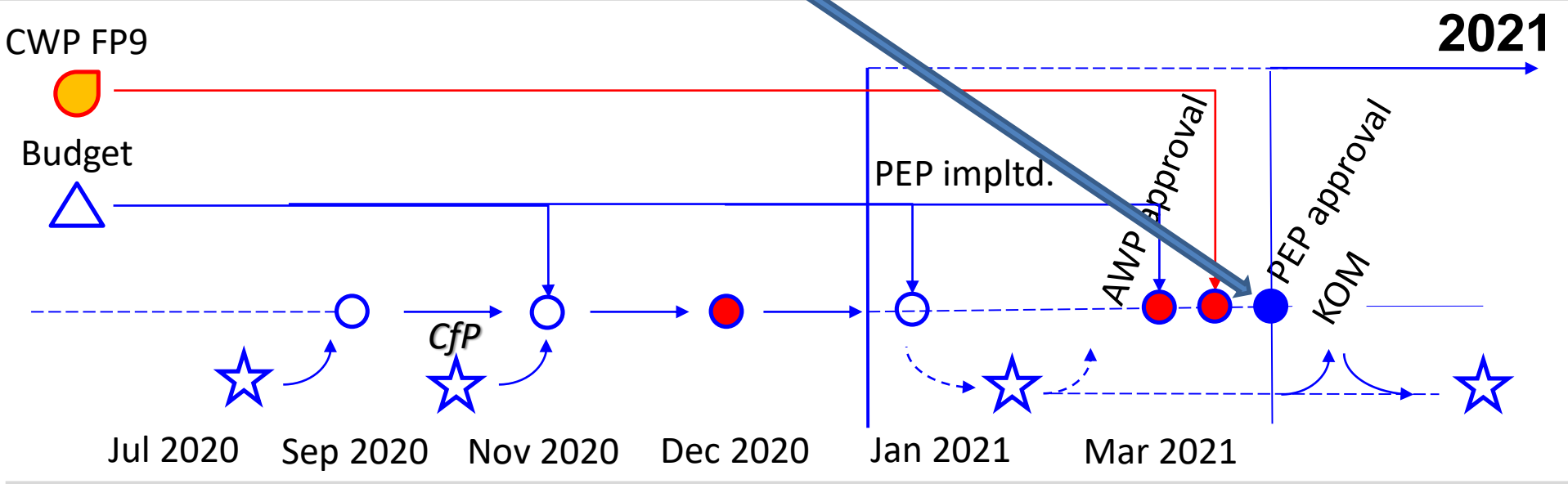
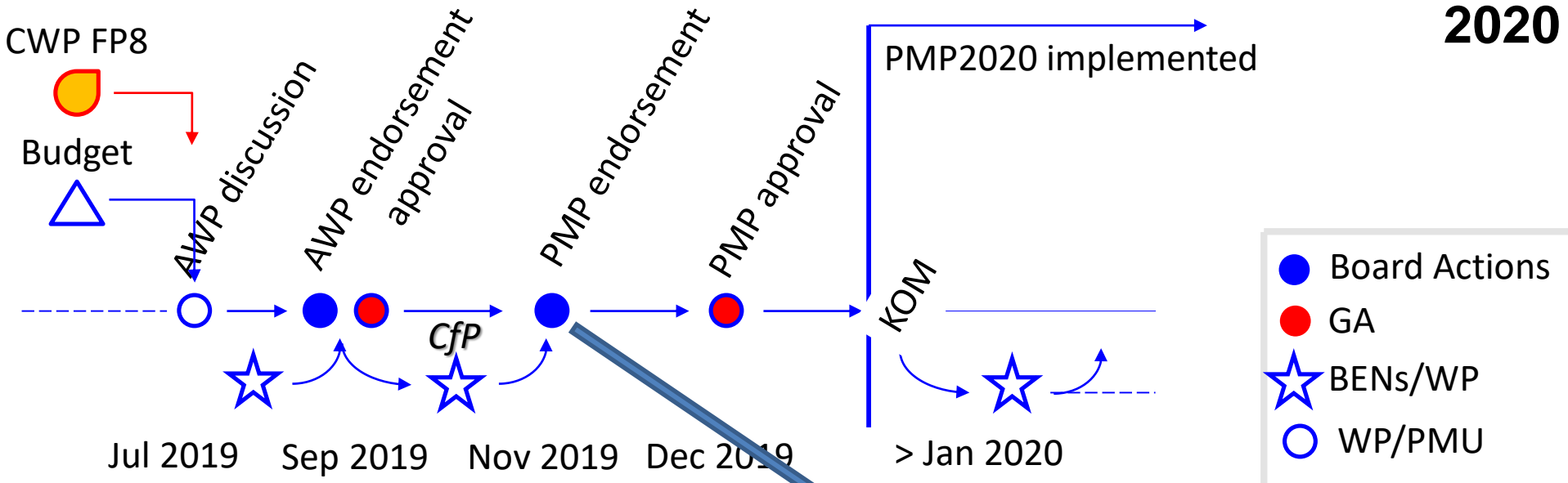
Common goals:

- **Metallic divertor**
(WPDIV, WPW7X, WPPWIE, MPG)
- **High-performance SSO**
(WPW7X, WPPWIE, MPG, WPPRD)
- **Coordination meetings**
held w/ PWIE, DIV, PRD

The plan comes with risks

Time, Resources, Scientific and technical risk
Risk register see PEP

Risk Identification			Rating Pre-Mitigation				Strategy / Mitigation		Notes	
Risk-ID	Date (added/ modified) [dd/mm/ yy]	Risk Title, Category, Owner, Description & Details (a) "As a result of..." (b) "There is the risk that..." (c) "Resulting in..."	Likelihood ¹	Impact ²			Risk Level ³	Treatment Strategy & Risk Mitigation Actions (Comments, Details, Due Dates, etc.)	Resp.	Status, Comments, ...
				Tech	Cost	Sched.				
WPR-01	01/01/2021	<p>Assembly of actively cooled in-vessel components (WCIVC) are late or W7-X is unavailable</p> <p>Category: Technical, Project Management</p> <p>Owned by: Project W7-X</p> <p>As a result of unavailability of resources (due to COVID) or unforeseen technical issues, there is the risk that the assembly of the actively cooled in-vessel components are late. This may results in a shift of the campaigns.</p>	1			4	4 medium	Reduce effects: shift of machine time, bring forward preparatory actions, enforce international cooperation - monitoring	Regular participation of the Project Sponsor in weekly status meetings	
WPR-02	01/01/2021	<p>Delays in the commissioning of WCIVC</p> <p>Category: Technical, Project</p>	1			3	3 low	Reduce effects: shift of machine time, bring forward preparatory actions	Regular participation of the Project Sponsor in weekly status meetings	





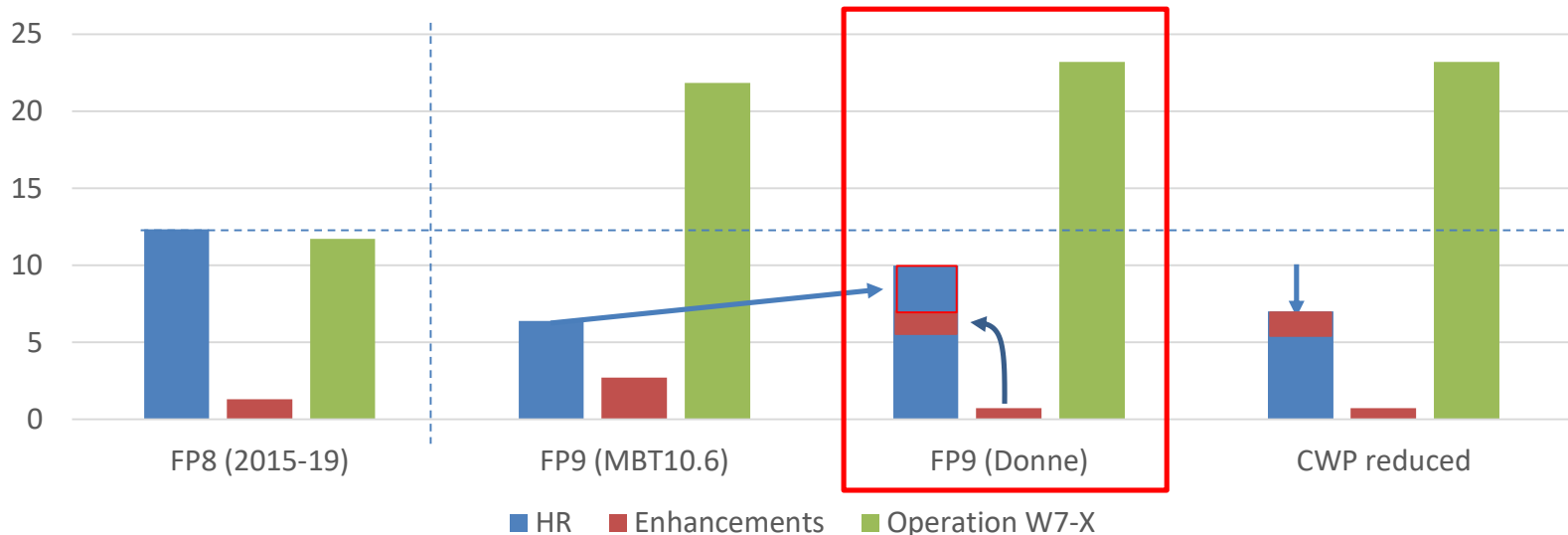
The stellarator gets more money in FP9

FP8 (2015-19): 25.63 M€-CC total
3 campaigns/38wks
→ 7.6 weeks @ EUROfusion funding rate

FP9 (2021-25): 33.91 M€-CC total
4 campaigns/56wks
→ 14.14 weeks @ EUROfusion funding rate

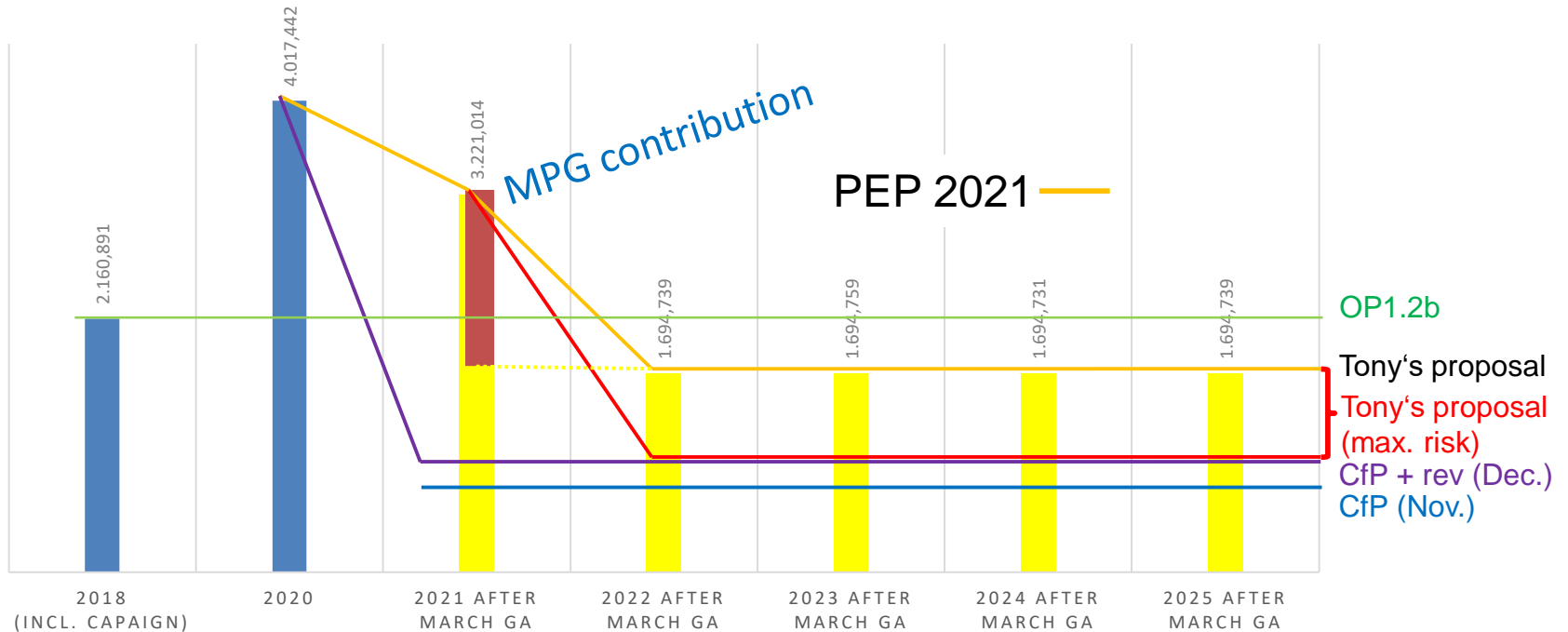
FP9: More EU scientific commitments. More EU machine time. More EU enhancements.

Risk in different Budget Scenarios





DEVELOPMENT OF MANPOWER BUDGET INCLUDING MISSIONS (VALUES IN K€ CC)



The overall (FP9) HR budget bears a risk for 2022 and thereafter.



- **EEGs**
 - The call for EEG grants starting in 2022 is being prepared
 - Discussion involved proposals from 2021, PRD proposal high-lighted
 - Call: end of June, submission by Sep.
 - Scorecard and proposals from WPW7X submitted to PMU
 - Discussion with PMU Jun. 9th
- **Secondments: vital to exploit long-term investments**
 - secondments (> 3 months, unit costs) should go through a selection process (PMU-Admin).
 - launch a call for an ICRH expert for the preparation and commissioning of the ICRH system in Greifswald for 2021 (subject to selection, retroactively from Jan. 1st, 2021)?

K. Avramidis	2021-W7X-3.3.2-KIT: Gyrotron development (request via IMS Task Review Process): Removal of bullet point: Advances in critical key components and operating modes	21.05.2021
M. Kubkowska/A. Winter/A Dinklage (Change request that will be decided by the PB)	<p>Shift of resources from IPPLM-U-Lodz to MPG in 2021</p> <ul style="list-style-type: none"> • Removal of Task 2021-W7X-3.3.1-IPPLM_TUL: Support Actions for the Integration of EU Components (25,17 PM, 46,538 k€ CC) → the Budget IPPLM 2021 WBS Level 3 reduces from 87,2153646 k€ CC to 40,6773646k€ CC (87,2153646 k€ CC - 46,538 k€ CC = 40,6773646k€ CC) • Reduction of IPPLM Travel Budget by 5,112 k€ CC from 18,105 k€ CC to 12,983 k€ CC (51,65 k€ CC - 46,538 k€ CC = 5,112 k€ CC). <p>→ Reduction of the WPW7X Travel budget by 5,122 k€ CC von 277,95775 k€ CC auf 272,8358 k€ CC</p> <ul style="list-style-type: none"> • Increase of budget for Task 2021-W7X-3.3.2-MPG: Software development and preparation for operation (97 PM, 430,438 k€ CC) by 11,63 PM to 108,63 PM (430,438 k€ CC + 51.608 k€ CC = 482,046 k€ CC) • Addition of Task Description 2021-W7X-3.3.1-IPPLM_TUL to 2021-W7X-3.3.2-MPG • Increase of Indicative Resources for IPPLM in 2022 by 51,65 k€ CC (from 96,49229167 k€ to 148,1423 k€ CC • Reduction of Indicative Resources for MPG in 2022 by 51,65 k€ CC (from 152,0958333 k€ CC to 100,445833 k€ CC) 	05.05.2021
A. Alonso	Update of CIEMAT Deliverable Descriptions (harmonization of task descriptions) → Changes in ANNEX II	26.05.2021



- LHD is going to have the final two campaigns
- Contact: Brezinsek, Alonso, Thomsen and Dinklage are appointed as International Program Advisors in the LHD Topical groups

Planned period(s) of engagement	Beneficiary
1 month* 1 person	KIPT

- Request for 2021 InCo plans (PEP section 6.6) sent on 28/05: only one response received.
 - Please check/confirm requirements for InCo asap
- InCo missions in FP9 will still be reimbursed at 100% rate.
- InCo mission requests will be approved on a yearly basis under the constraints of (i) priority and (ii) budget availability.



Focus on wall conditioning & RF start-up support (W7X-3.3.2-T004)

- 1) Development of scenarios for ICWC at U-2M in support of W7-X, including a scenario at low magnetic field,
- 2) Improvements and developments for ICWC related diagnostics,
- 3) ICRH start-up scenarios in support of W7-X,
- 4) Analysis of ICRH start-up experiments at LHD,
- 5) Start-up ICRH / ECRH modeling for W7-X and U-2M.

1. Two regimes are planned to be studied experimentally with W7-X-like antenna on Uragan-2M: wall conditioning discharge at high (minority regime) and low magnetic field (high neutral gas pressure in both cases, execution of the item 1);
2. Detailed study of target plasma production in minority regime (regular gas pressure, carrying out the item 3).
3. Developing and improving the procedure of measurements with the set of the thermo-desorption probes (execution of the item 2).
4. Analysis of ICRH start-up experiments at LHD.
5. ICWC / ECWC code for stellarator applied for wall conditioning (carrying out the items 3 and 5).

The developed scenarios should be studied in more details with all the diagnostics involved. The operation at the magnetic field 0.7 T should be mastered. The ECE measurements should be introduced. Proposal for W7-X should be formulated.

Emphasize on data processing for thermo-desorption probes,

New proposal should be formulated for LHD ICRH experiment ,

Modeling should be applied to low magnetic field ICWC discharges.

Progress is affected by infrastructure issues. Loss of key personnel leads to risks. Request by the WPL: the beneficiaries of WPW7X are kindly requested to consider potential in-kind support.



- The WPW7X Board approves the PEP 2021 including all change requests.