TCV
Machine news and program for 2025

S. Coda

WPTE programme meeting, 18.11.2024

EPFL Swiss Plasma Center

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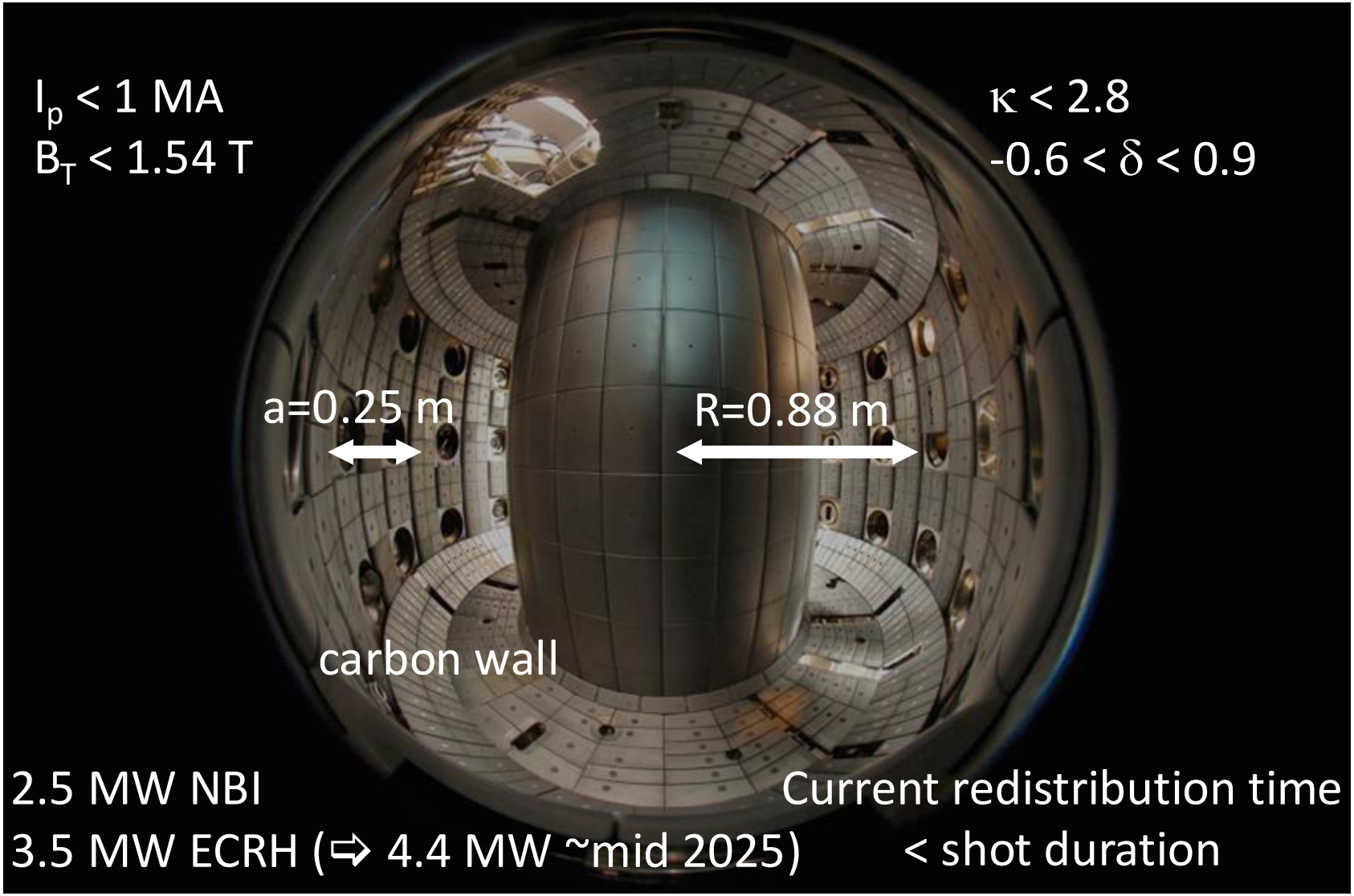
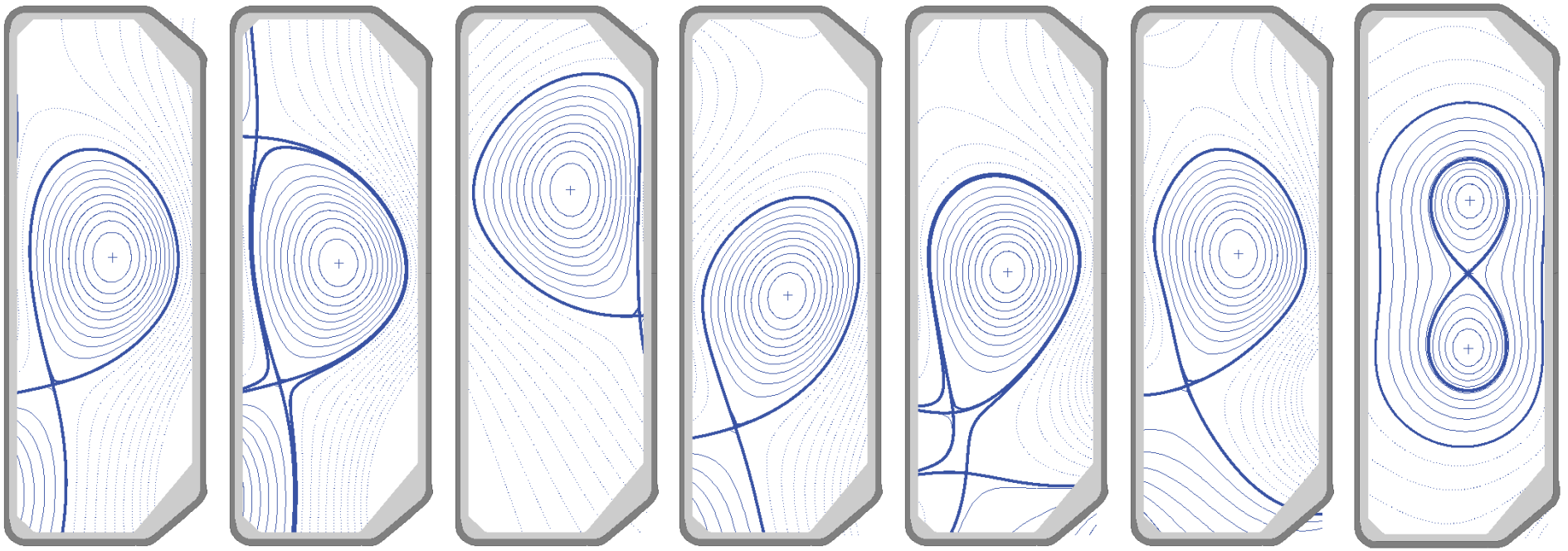
The TCV Tokamak

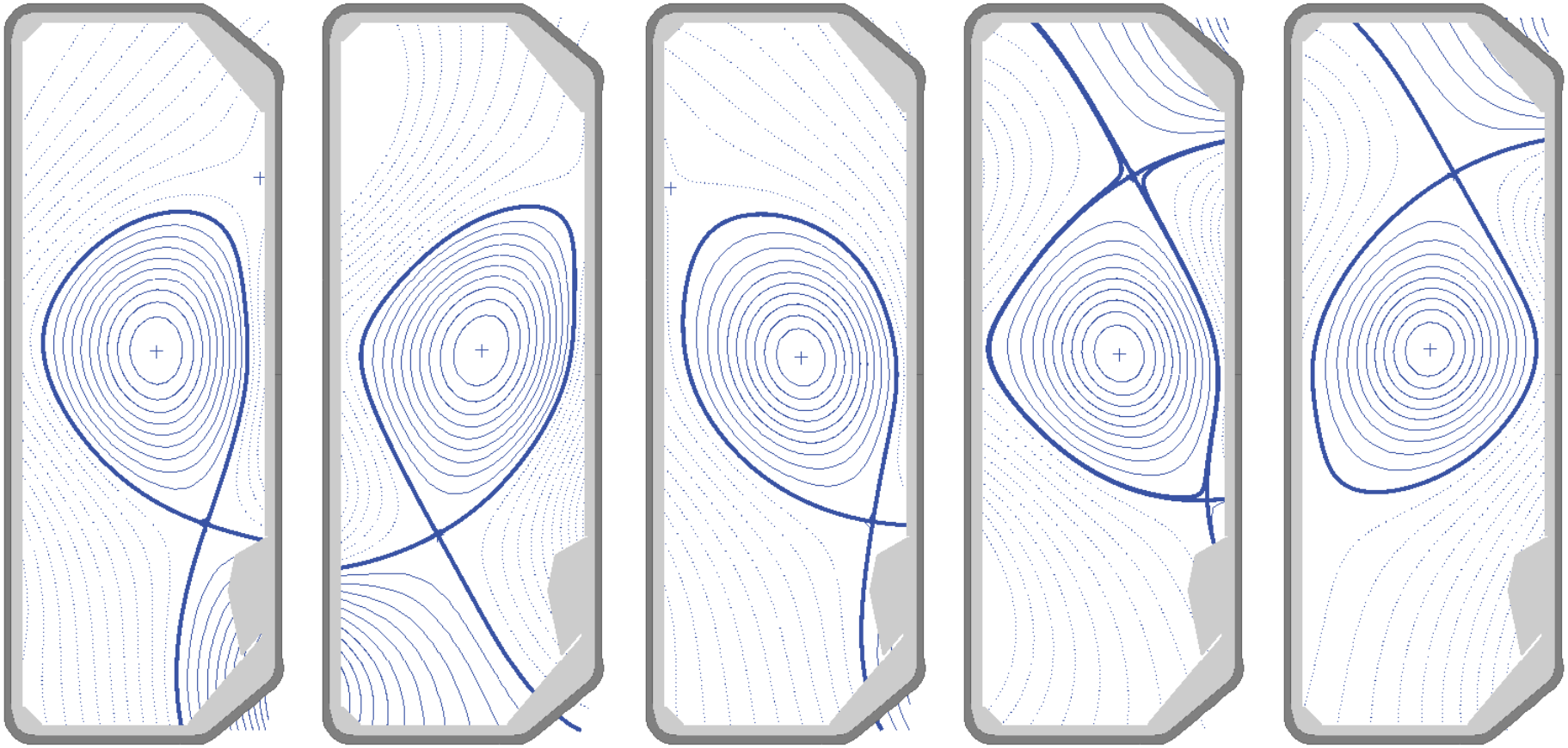


Device information

TCV is defined by flexible shaping...



…including a large variety of NT shapes

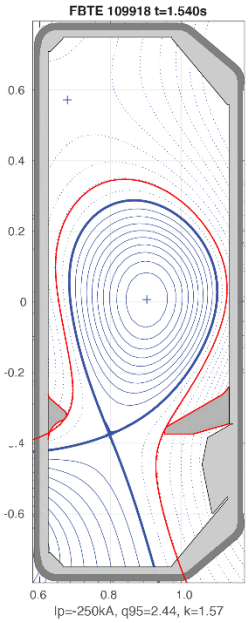


PEX baffles

Nomenclature: N/S/L (no/short/long) I/O (inner/outer) baffles

SILO baffles

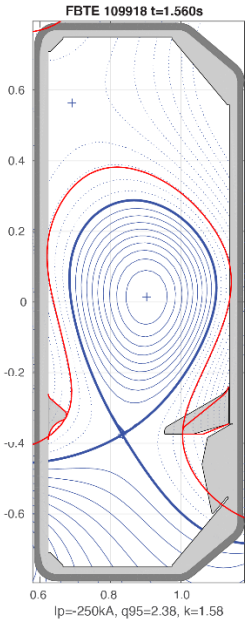
$\Delta R_u^{\text{baffle}} \sim 25mm$



100% 100%

SISO baffles

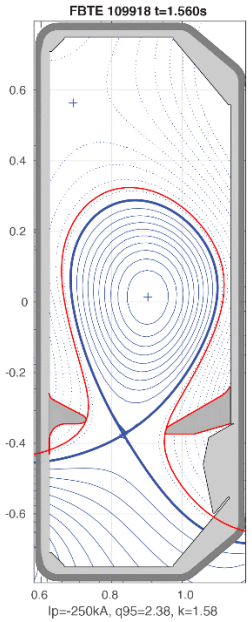
$\Delta R_u^{\text{baffle}} \sim 39mm$



100% 72%

LILO baffles

$\Delta R_u^{\text{baffle}} \sim 19mm$



200% 100%

Baffles can be swapped or removed in a 3-week vent

Several unbaffled phases have occurred

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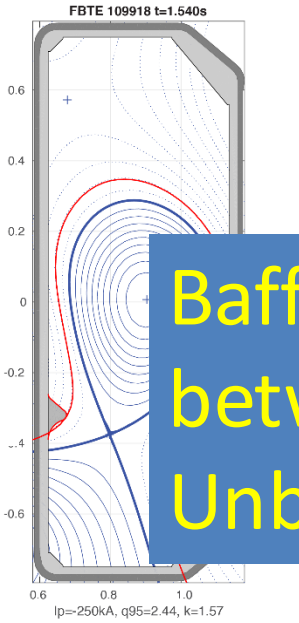

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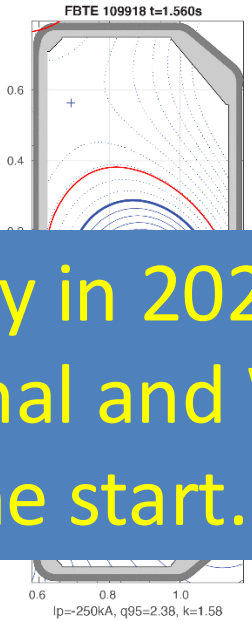


LILO baffles

$\Delta R_u^{\text{baffle}} \sim 19mm$

100%

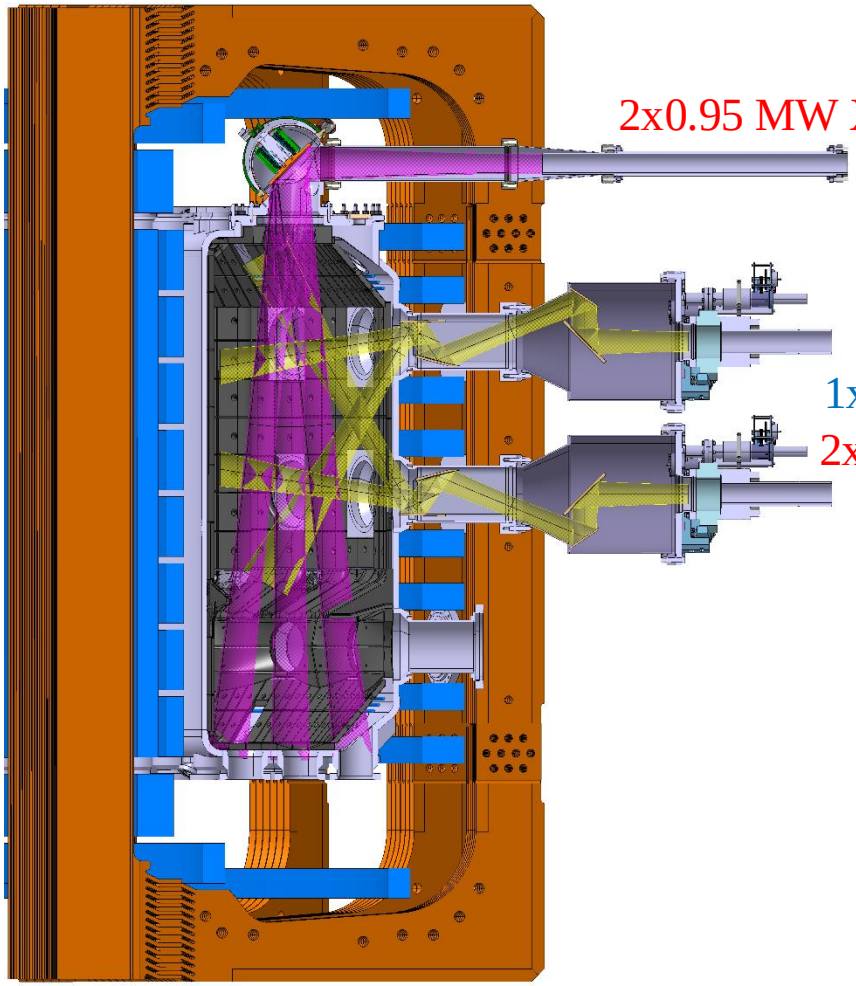
100%

Baffle geometry in 2025 to be decided between internal and WPTE programs. Unbaffled at the start.

Baffles can be swapped or removed in a 3-week vent

Several unbaffled phases have occurred

Auxiliary heating: ECRH

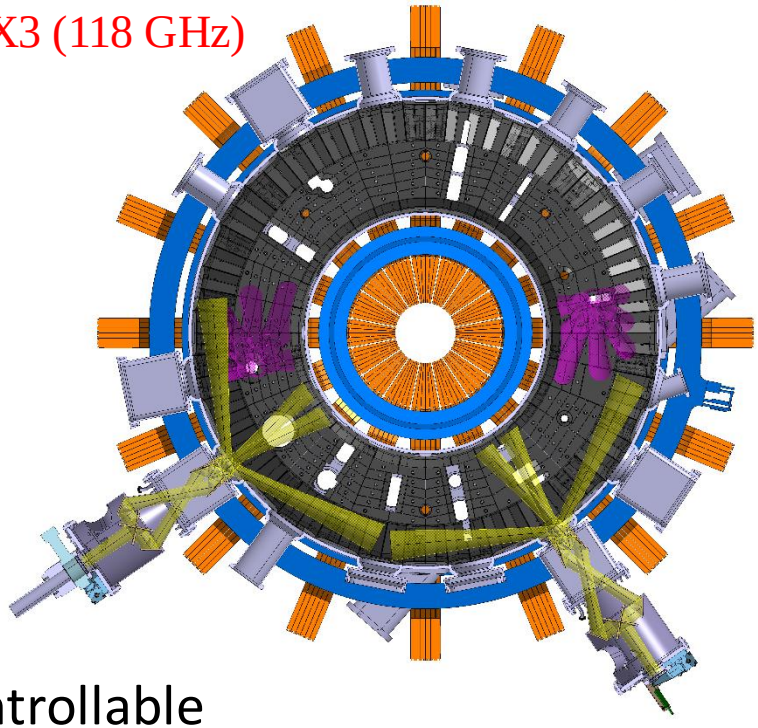


2x0.95 MW X3 (126 GHz)

Dual-frequency gyrotrons

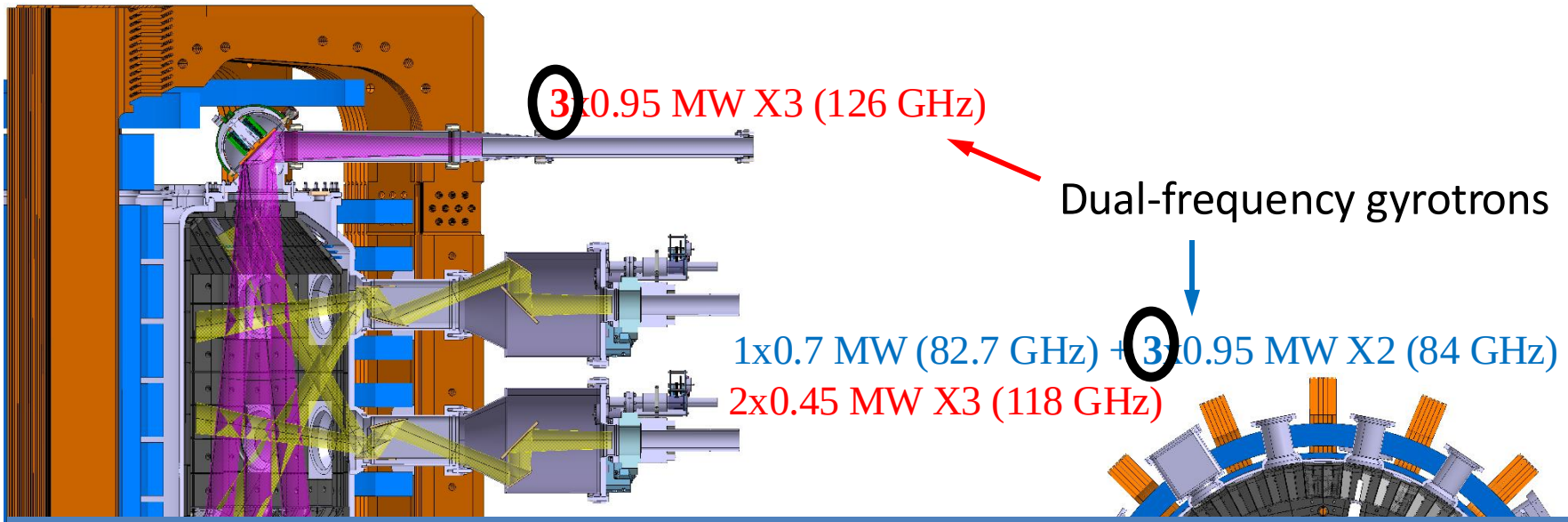
1x0.7 MW (82.7 GHz) + 2x0.95 MW X2 (84 GHz)

2x0.45 MW X3 (118 GHz)



Power and launcher angles are r/t controllable

Auxiliary heating: ECRH (~July 2025)



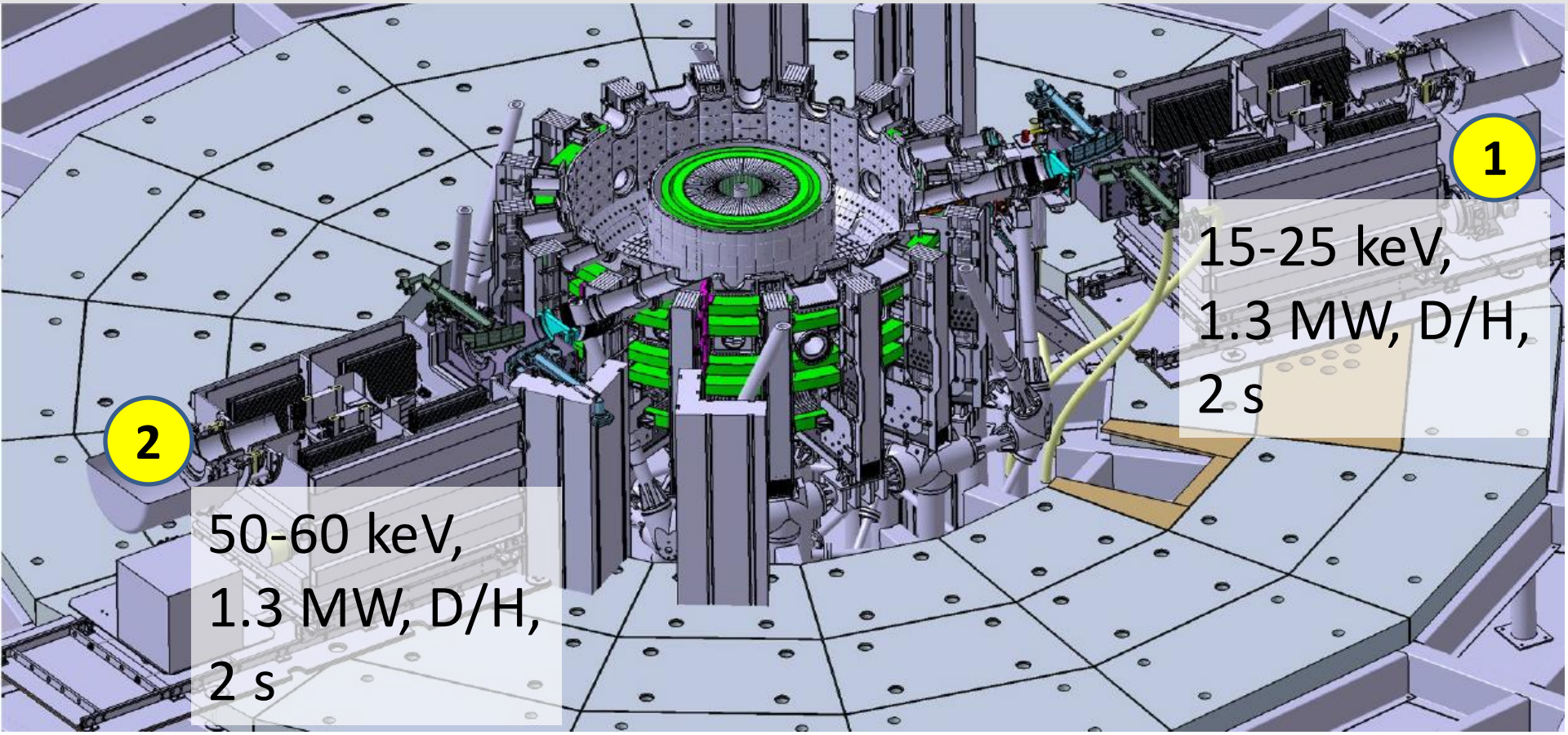
One more 1-MW dual-frequency gyrotron is expected for mid-2025.
A second one is planned for late 2026, pending final funding approval.

Power and launcher angles are r/t controllable

Auxiliary heating: ECRH

- The main following combinations will be possible in the first half of 2025:
  - 2.6 MW X2
  - 1.65 MW X2, 0.95 MW top X3, 0.45 MW lateral X3
  - 0.7 MW X2, 1.9 MW top X3, 0.9 MW lateral X3
- The main following combinations will be possible in the second half of 2025:
  - 3.55 MW X2
  - 2.6 MW X2, 0.95 MW top X3, 0.45 MW lateral X3
  - 1.65 MW X2, 1.9 MW top X3, 0.9 MW lateral X3
  - 0.7 MW X2, 2.85 MW top X3, 0.9 MW lateral X3
- R/t control possible, algorithms continually developed (discuss w. control team)

Auxiliary heating: NBI



Limitations are currently in place: only 1.1 MW for NBI-2, max injected energy 1.7 MJ for NBI-1 and 2 MJ for NBI-2. Work is underway to permit relaxing these limitations.

TCV diagnostics

Check for available systems and diagnostics and learn which are nonstandard and need to be requested

Diagnostic Groups	Short name, link	Diagnostic	Responsible Officer	Email RO	Organization	Need of suppo	Availability (default=yes)	Needs to be requested	Deputy Officer	Email DO
Magnetics	Magnetic probes	Mirnov coils: dBtheta/dt; 4 poloidal arrays of 38 coils, 3 toroidal arrays of 8 coils on the HFS, 3 toroidal arrays of 16 coils on the LFS	Jean-Marc Moret	jean-marc.moret@epfl.ch	SPC				Duccio Testa	duccio.testa@epfl.ch
	Flux loops	Flux loops (39): loop voltage								
	DML	Diamagnetic loop: stored energy								
	Saddle Flux Loops	Saddle loops (24): radial magnetic field						yes		
	Coil currents	Current in PCM modules: currents in all TF and PF coils								
Interferometry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				Yanis Andrebe	yanis.andrebe@epfl.ch
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
Thomson scattering	Thomson	Thomson scattering: core and edge Te and ne profiles, 30 points	Patrick Blanchard	patrick.blanchard@epfl.ch	SPC				Yanis Andrebe	yanis.andrebe@epfl.ch
Electron cyclotron emission (ECE)	ECE	LFS ECE: Te profile, 24 points (two possible chords, z=0 and z=23 cm, non-simultaneous)	Laurie Porte	laurie.porte@epfl.ch	SPC			yes	Arsène Tema Biwole	arsene.temabiwole@epfl.ch
		[illegible]					not operational	yes		
		Correlation ECE: electron temperature fluctuations, 6 channels					unexplained signals	yes		
	Vertical ECE	Vertical ECE: suprathermal electrons, 36 channels						yes		
Visible monitoring	RTCAM	Framing 1 kHz cameras (2): survey and real-time plasma position determination	Basil Duval	basil.duval@epfl.ch	DIFFER		currently not operational			
	FastCam	Fast framing tangential camera with intensifier	Benoit Labit	benoit.labit@epfl.ch	SPC			yes	Basil Duval	basil.duval@epfl.ch
Spectroscopy	MANTIS	Multi-spectral imaging camera system with tangential view	Artur Perek	artur.perek@epfl.ch	DIFFER			yes	Basil Duval	basil.duval@epfl.ch
	MSI	Multi-spectral imaging camera system with tangential view	Mirko Wensing	mirko.wensing@epfl.ch	MIT			yes	Basil Duval	basil.duval@epfl.ch
	CXRS	Charge-exchange recombination spectroscopy: vpol (20-40 points), vtor (20-80 points), Ti, ni of carbon or boron impurities, using 80-kW DNBI. One view on NBH available.	Basil Duval	basil.duval@epfl.ch	SPC			yes	Filippo Bagnato	filippo.bagnato@epfl.ch
	FIDA	Fast ion D-alpha (FIDA) spectroscopy: 2 views on heating NBI						yes	Marcelo Baquero	marcelo.baquero@epfl.ch
	PD	Photodiodes: Dalpha (6 horizontal), Dalpha + various other lines (9 vertical)							Umar Sheikh	umar.sheikh@epfl.ch
	Ocean	Survey broadband spectrometers (6)								
	Spred	SPRED VUV spectrometer: 2048 channels	Umar Sheikh	umar.sheikh@epfl.ch				yes	Basil Duval	basil.duval@epfl.ch
	DSS	Divertor spectrometer: impurity lines, spatially resolved (side, top views)	Kevin Verhaegh	kevin.verhaegh@epfl.ch	U.York/CCFE	yes		yes	Basil Duval	basil.duval@epfl.ch
	Zeff	Visible bremsstrahlung: Zeff	Basil Duval	basil.duval@epfl.ch	SPC					
Infrared thermography	VIR	Vertical IR camera	Holger Reimerdes	holger.reimerdes@epfl.ch	SPC			yes	Roberto Maurizio	roberto.maurizio@epfl.ch
	HIR	Horizontal IR camera						yes		
Langmuir probes	Langmuir	Langmuir probes: 96, tile-embedded (HFS+LFS walls, floor)	Christian Theiler	christian.theiler@epfl.ch	SPC			yes	Benoit Labit	benoit.labit@epfl.ch
	RPTCV	Fast reciprocating probe: Langmuir, Mach, magnetic-field heads	Cedric Tsui	cedric.tsui@epfl.ch	SPC			yes	Benoit Labit	benoit.labit@epfl.ch
	RDPA	Reciprocating probe detector array	Hugo de Oliveira	hugo.deoliveira@epfl.ch	SPC		under commissioning	yes	Christian Theiler	christian.theiler@epfl.ch
Thermocouples	TC	Thermocouples: 23 in HFS wall and floor	Benoit Labit	benoit.labit@epfl.ch	SPC				Holger Reimerdes	holger.reimerdes@epfl.ch
Bolometry	BOLO	Tomographic foil bolometer system (8x8)	Umar Sheikh	umar.sheikh@epfl.ch	SPC		not compatible with ECRH (strong pickup)		Benoit Labit	benoit.labit@epfl.ch
	AXUV	Tomographic AXUV cameras (6x20 pseudo-bolometers)	Benoit Labit	benoit.labit@epfl.ch				yes	Basil Duval	basil.duval@epfl.ch
Gas imaging	GPI	Gas puff imaging	Nicola Offeddu	nicola.offeddu@epfl.ch	SPC		under commissioning	yes	Christian Theiler	christian.theiler@epfl.ch
Pressure gauges	Baratron gauges	Two fast pressure gauges (baratrons)	Christian Theiler	christian.theiler@epfl.ch	SPC			yes	Basil Duval	basil.duval@epfl.ch
	Optical Penning gauge	Optical Penning gauge						yes	Hugo de Oliveira	hugo.deoliveira@epfl.ch
Soft X-rays	XTOMO	Tomographic SXR system (10x20)	Benoit Labit	benoit.labit@epfl.ch	SPC					
	DMPX	Wire counter SXR system: single view, 64 channels, dual layers (two energy ranges)								
	XTe	SXR system with different thicknesses (4 diodes): fast core Te estimate								
	Xtepro	Multi-chord SXR system with different thicknesses: fast Te profile estimate					commissioning - Te profile inversion to be tested	yes		
	Xmodes	Toroidally spaced dual-filter SXR detectors (4): estimation of toroidal MHD number								
	PHAV	Pulse-height analyser: heavy impurity spectra, single view	Basil Duval	basil.duval@epfl.ch	SPC		currently not operational		Umar Sheikh	umar.sheikh@epfl.ch
Hard X-rays	HXRS	Tomographic spectrometer (4x25): 2D HXR emission vs energy	Stefano Coda	stefano.coda@epfl.ch	SPC			yes	Dahye Choi	dahye.choi@epfl.ch
	TXDA	Tangential HXR detector array (6): HXR flux					recommissioning, planned for 2019	yes		
	PMTX	Scintillator + photomultiplier: runaway monitoring	Basil Duval	basil.duval@epfl.ch	SPC				Umar Sheikh	umar.sheikh@epfl.ch
Synchrotron emission	REIS	Runaway electron imaging and spectrometry system	Basilio Esposito	basilio.esposito@enea.it	ENEA		temporary – currently not on TCV	yes	Stefano Coda	stefano.coda@epfl.ch
Runaway electrons	CHEP	Cherenkov detector array	Marek Rabiński	Marek.Rabinski@ncbj.gov.pl	NCBJ			yes	Stefano Coda	stefano.coda@epfl.ch
Neutral particle analysers	CNPA	Tangential compact NPA: 32 channels, viewing NBI, 0.5-50 keV with mass discrimination	Alexander Karpushov	alexander.karpushov@epfl.ch	SPC			yes		
	NPA	Vertical NPA: 5 channels, 0.6-8 keV, no mass discrimination					not in 2018 campaign	yes		
Neutrons	NEUT	Neutron detector: 1 He3 tube	Basil Duval	basil.duval@epfl.ch	SPC				Umar Sheikh	umar.sheikh@epfl.ch
		Neutron detector: liquid scintillator	Massimo Nocente	massimo.nocente@unimib.it	U. Milano				Basil Duval	basil.duval@epfl.ch
Phase contrast imaging	TPCI	Local density fluctuation	Stefano Coda	stefano.coda@epfl.ch	SPC		currently not available, planned to be recommissioned for 2019	yes	Aylwin Iantchenko	aylwin.iantchenko@epfl.ch
Reflectometry and Doppler backscattering	PREF	Homodyne reflectometer/DBS: 78 or 92 GHz, on steerable antenna	Stefano Coda	stefano.coda@epfl.ch	SPC		currently not in use	yes	Pedro Molina	pedro.molina@epfl.ch
		Pulsed reflectometer for density profile and fluctuations: 50-76 GHz on steerable antenna	Pedro Molina	pedro.molina@epfl.ch	SPC			yes	Laurie Porte	laurie.porte@epfl.ch
		Heterodyne reflectometer/DBS: 50-76 GHz tunable/sweepable on steerable antenna	Pedro Molina	pedro.molina@epfl.ch	SPC			yes	Laurie Porte	laurie.porte@epfl.ch
		Heterodyne reflectometer/DBS: 45 GHz on steerable antenna	Andreas Kraemer-Flecken	a.kraemer-flecken@fz-juelich.de	FZJ		currently not in use	yes	Stefano Coda	stefano.coda@epfl.ch
Stray ECRH radiation	Stray	Stray diodes: non-absorbed ECRH	Tim Goodman	timothy.goodman@epfl.ch	SPC				Laurie Porte	laurie.porte@epfl.ch
	ECTM	Stray diodes: non-absorbed ECRH	Tim Goodman	timothy.goodman@epfl.ch	SPC				Oulfa Chellai	oulfa.chellai@epfl.ch
Lower-hybrid antenna	LHPI	Lower-hybrid antenna: PDI LH waves	Duccio Testa	duccio.testa@epfl.ch	SPC		currently not operational			

The diagnostic neutral beam

- The dNBI constitutes a special problem: the injector and power supplies are aging and poorly documented, and recent campaigns have been plagued by failure upon failure
- NBI-2 can be used for charge-exchange measurements, although not as complete (no toroidal rotation)
- Nonetheless, the non-perturbative nature of dNBI has been a great asset for TCV
- The dNBI power supplies are being replaced by home-grown units – this is expected to be finalized by mid-2025

Reminder of recent changes

- New diagnostics:
  - new 2D X-ray camera for monitoring of heavy impurities (Pilatus3)
  - SPR (short-pulse reflectometry) mostly commissioned
  - DBS (temporary: contribution of LPP, France)
- Gas valves: went from 3 to 10 (toroidally and poloidally distributed) fueling and seeding valves + 3 GPI valves + MGI valve
- Retired diagnostics:
  - horizontal reciprocating Langmuir probe
- Radiation shielding:
  - extra shielding (major infrastructure upgrade) around TCV means no further neutron or γ-ray concerns in TCV building: **no limitations on NBI operation**

Reminder of recent changes

Visits to SPC

- Visits are encouraged but make sure to plan ahead to comply with Swiss regulations

Operational flexibility

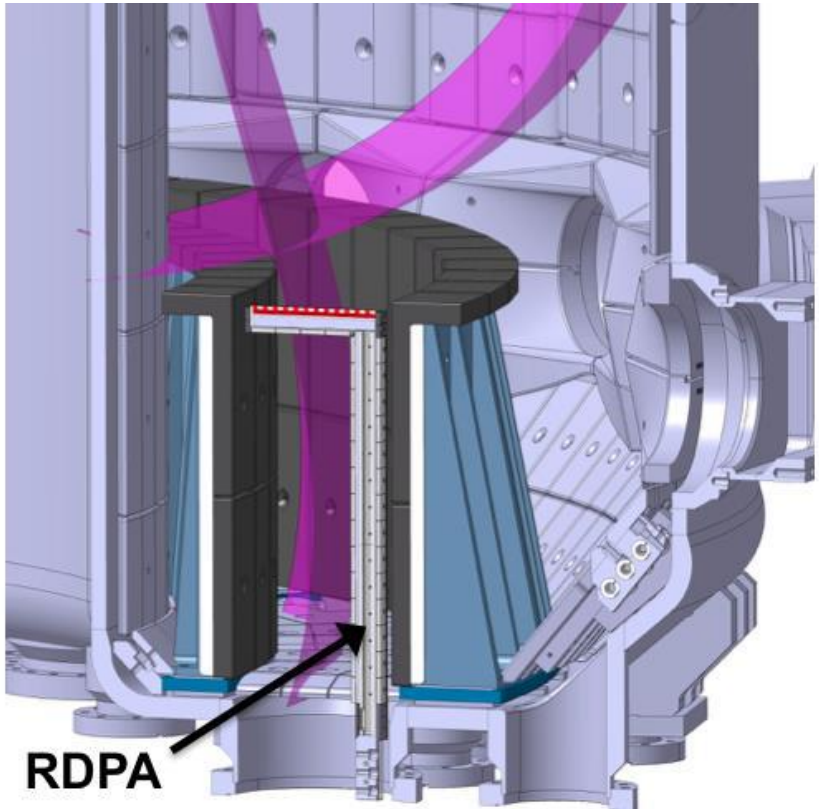
- Both toroidal field and plasma current directions can be reversed between shots
- Switchover between primary species (D, H, He) usually takes <10 shots ⇨ a H or He experiment (including beams) does not require a lot of planning
- Glow discharge cleaning between shots (typ. 5', increasing to 10' usually reverses any effects of high-density operation)
- Boronisation: performed periodically – not systematically – when plasma conditions deteriorate; near-obligatory after a vacuum break

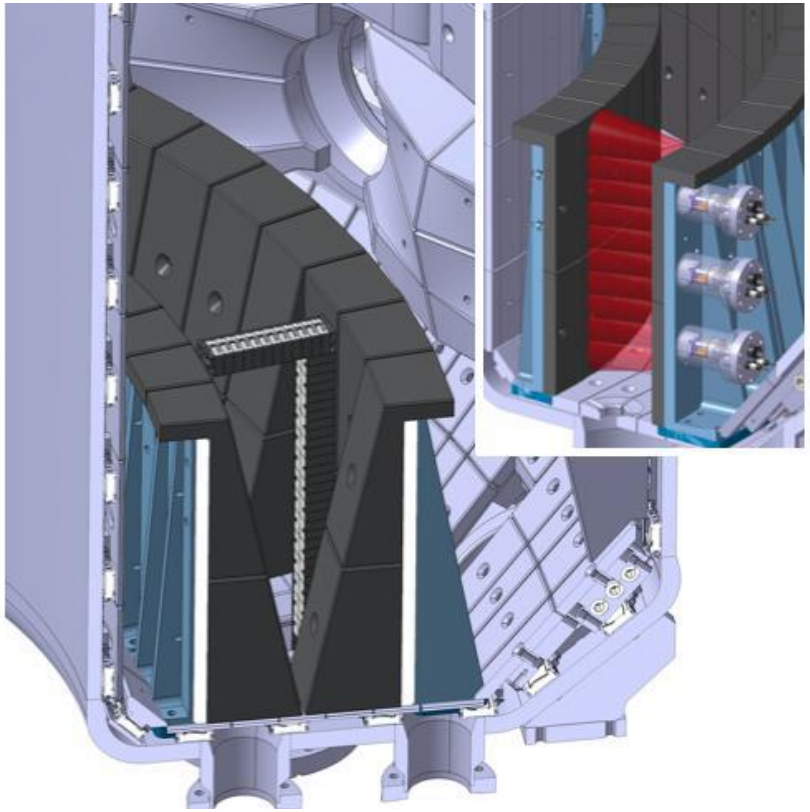
2025 calendar

- Semi-continuous operation with possible 3-week breaks to install or remove baffles, plus occasional small breaks esp. in vacation periods
  - ~3300 good shots
- The majority of the internal program (although not yet in place) is likely to be indifferent to baffles or to prefer an unbaffled machine

Beyond 2025

- Very likely (pending final funding approval) installation of a *tightly baffled long-legged divertor*, a promising reactor option for increased power handling that currently has no real-world physics validation





Beyond 2025

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- This would probably occupy a short dedicated campaign (a few to several months in the first half of 2026), as many experiments are precluded by it
- Beyond this phase, the usual shot rate can be expected to continue