OP2.1-2.2 proposals: subgroup fueling and exhaust

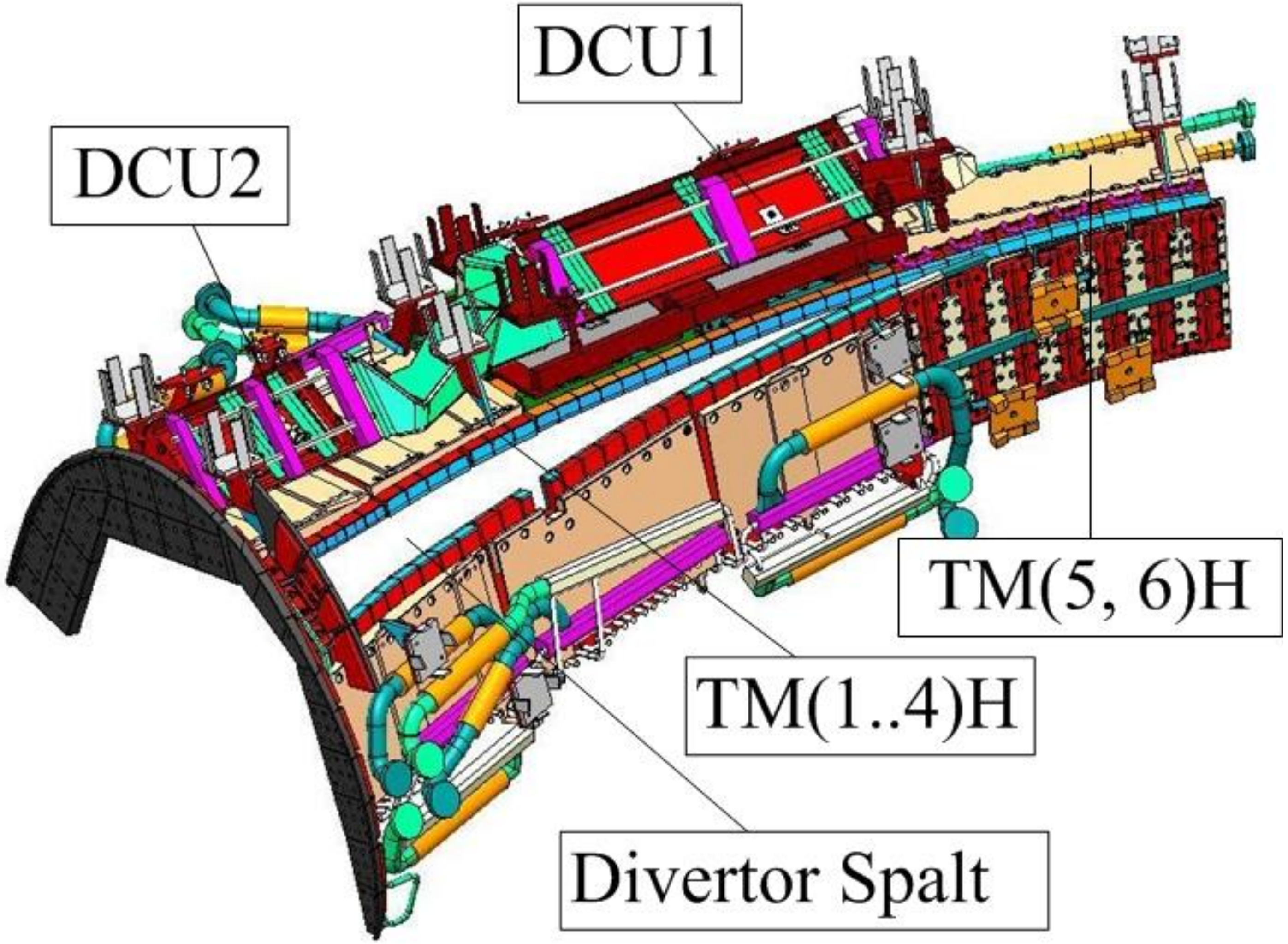
OP2.1-2.2 PWI proposals

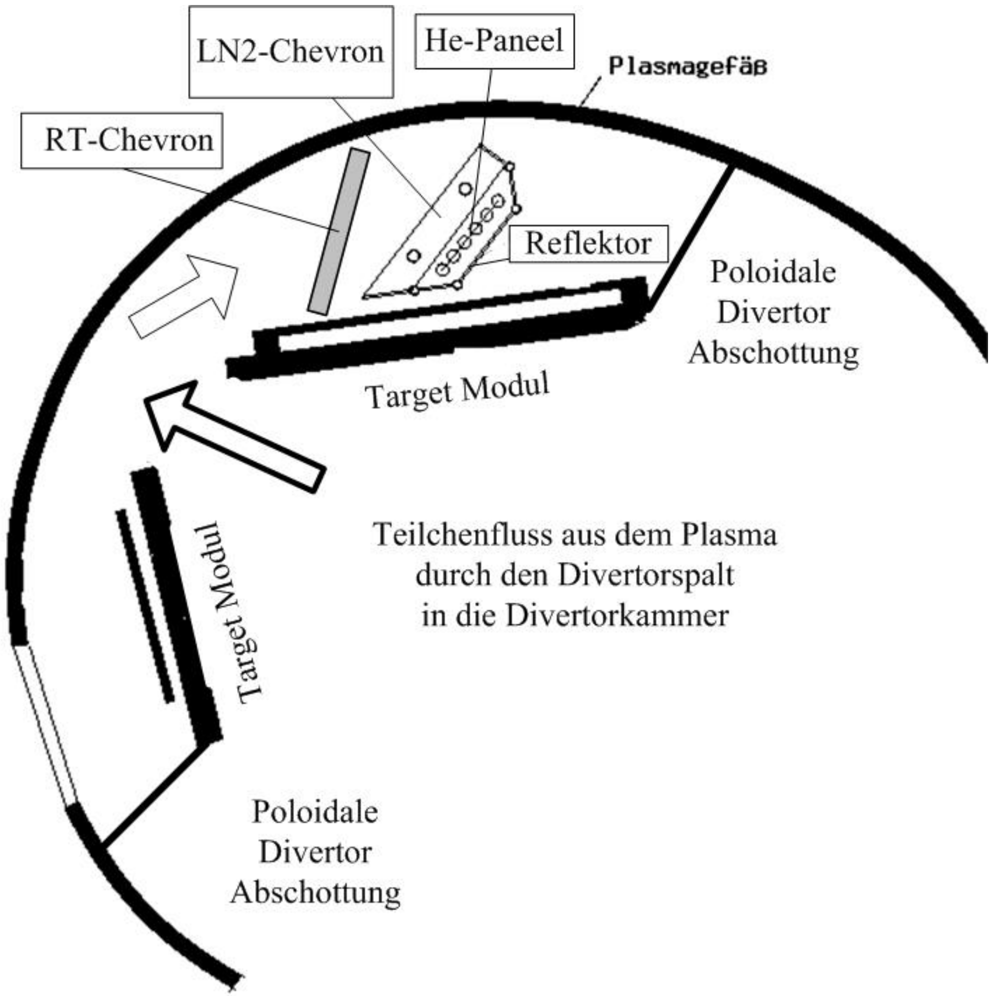
I. During commissioning
   1. Characterizing the divertor cryo-vacuum pumps (CVP): All ten together and individual pump

II. During plasma operation
   1. Characterizing the divertor cryo-vacuum pumps (CVP): Different configurations
   2. Test of He pumping using CVPs with Ar-getters
   3. Characterizing the exhaust capabilities on the low /high iota side pumpings due to, changed pumping gap cross-sections at high iota (due to installing new collars on high iota side target modules on the outboard side)
   4. Comparing the fuel retention and recycling in modules 1 and 5 with metal (tungsten) inner-wall and other modules with graphite wall
   5. Investigating the carbon and boron balance by comparing the estimated source amounts by plasma-wall interaction measurements and the measured exhaust amounts of different gases by the DRGA/QMS analyzers

III. Collaboration: IPP Garching, Uni. Wisconsin, KIT, NIFS and IPP Greifswald (other collaborators are welcome). CVP proposals are required to support Victoria Haak's doctoral work.

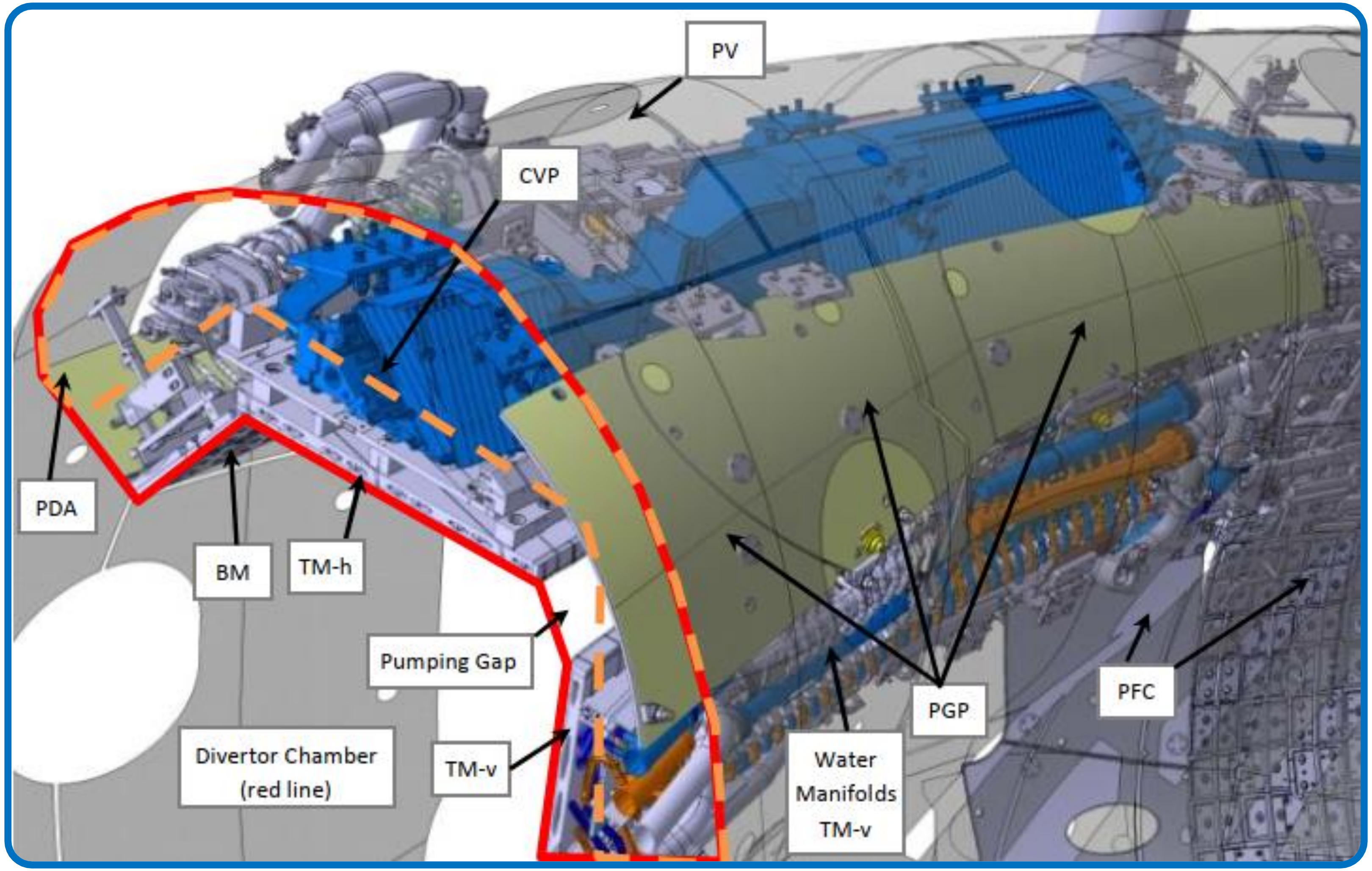
Details of CVP





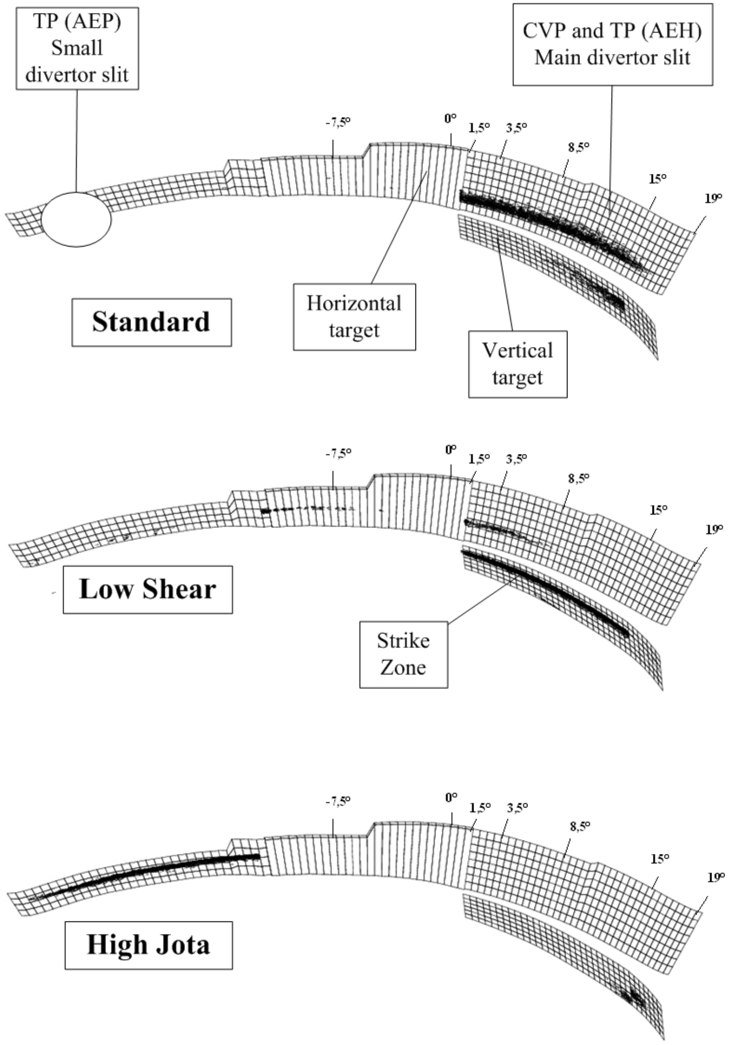
Ref.: B Streible 1-ACF-R0001.1

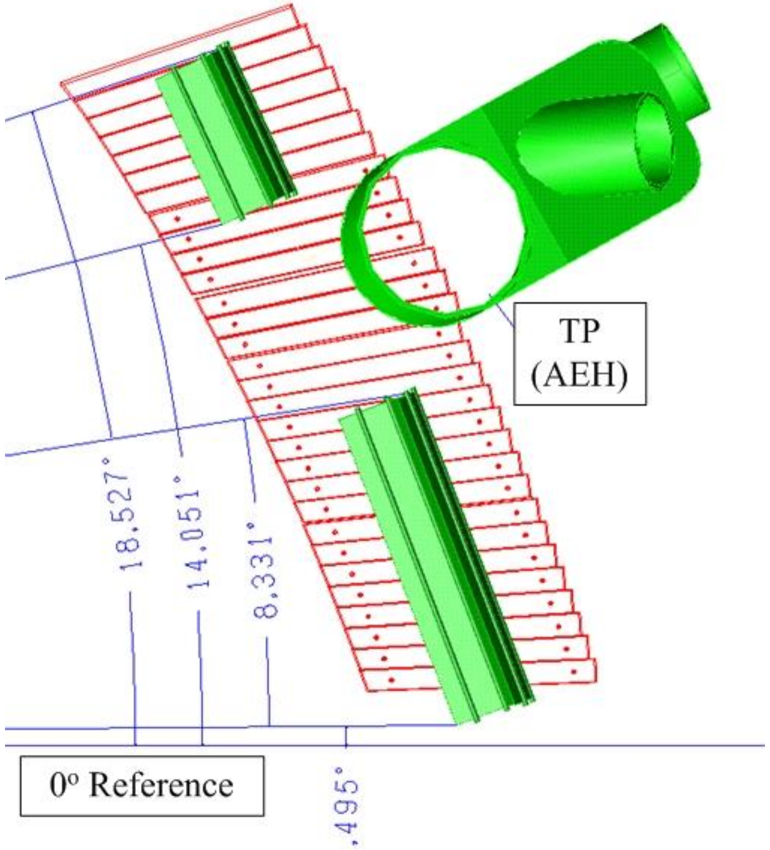
Details of CVP



Ref.: G Ehrke 1-ACF-Y0015.0

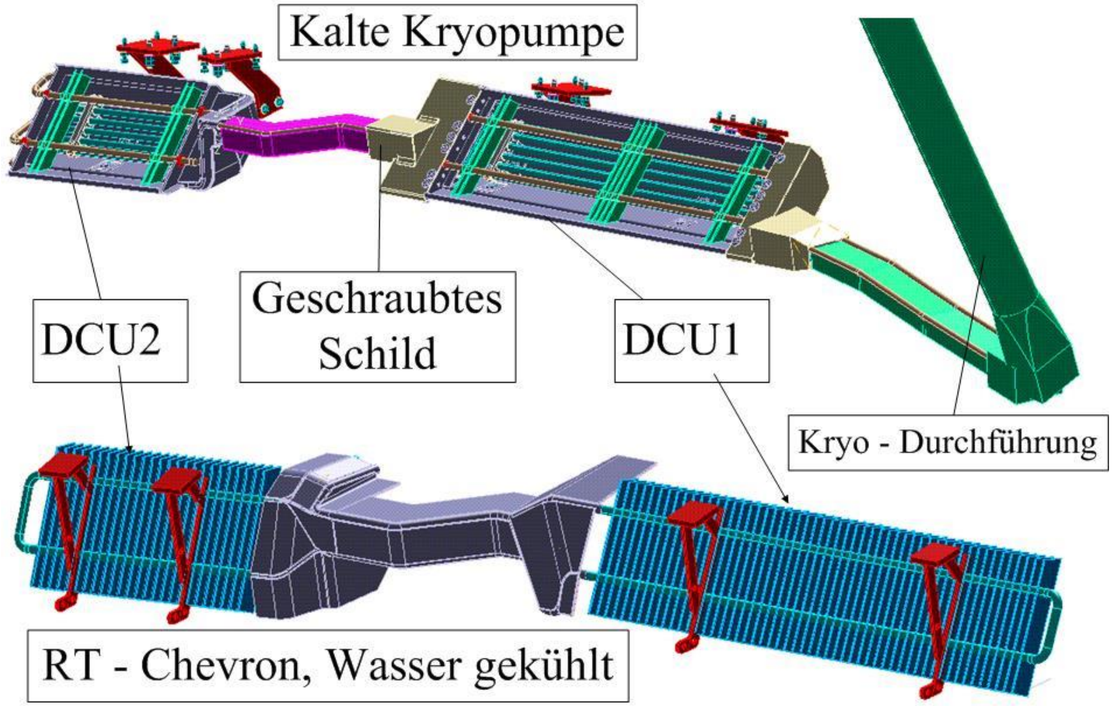
Details of CVP

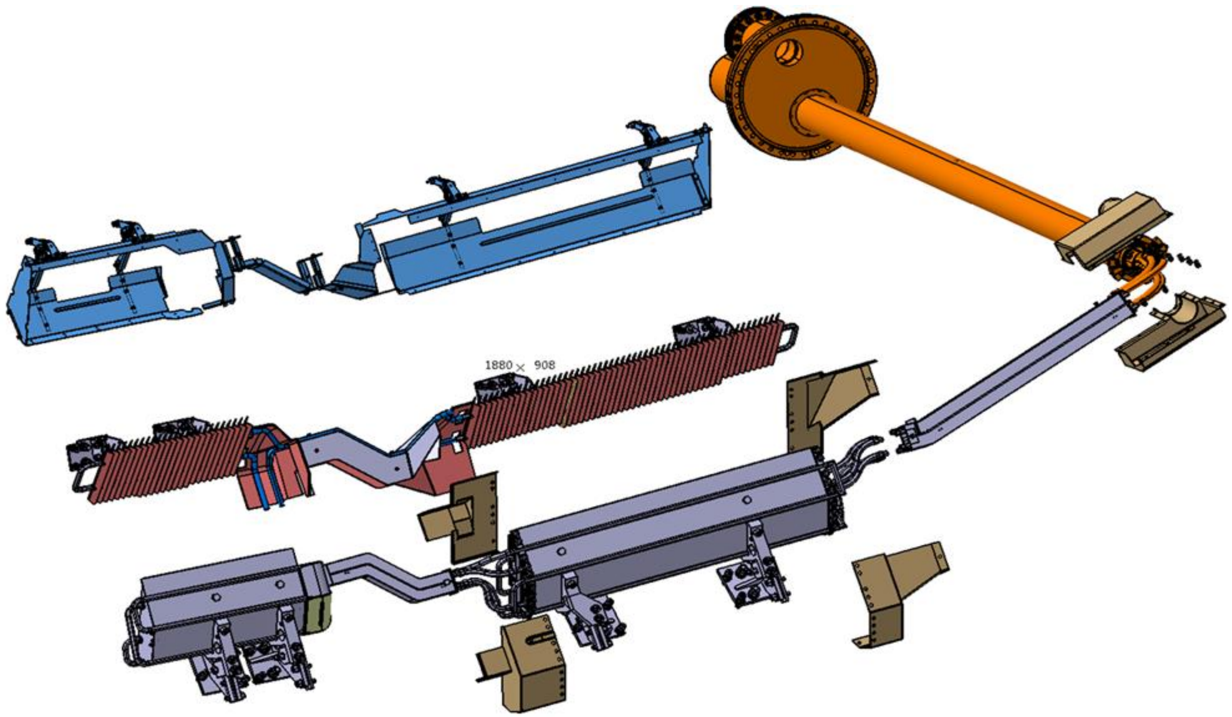




Ref.: B Streible 1-ACF-R0001.1

Details of CVP



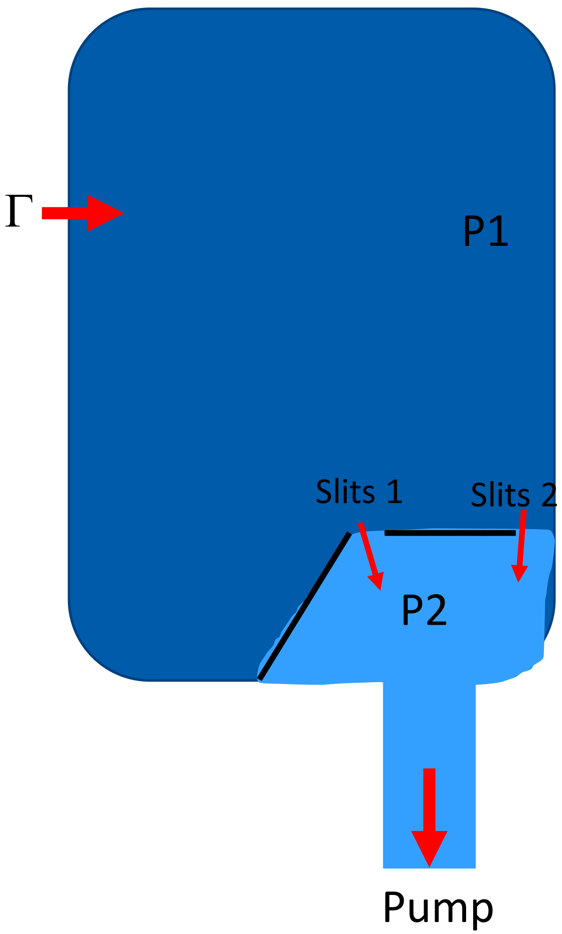


Ref.: G Ehrke 1-ACF-Y0015.0

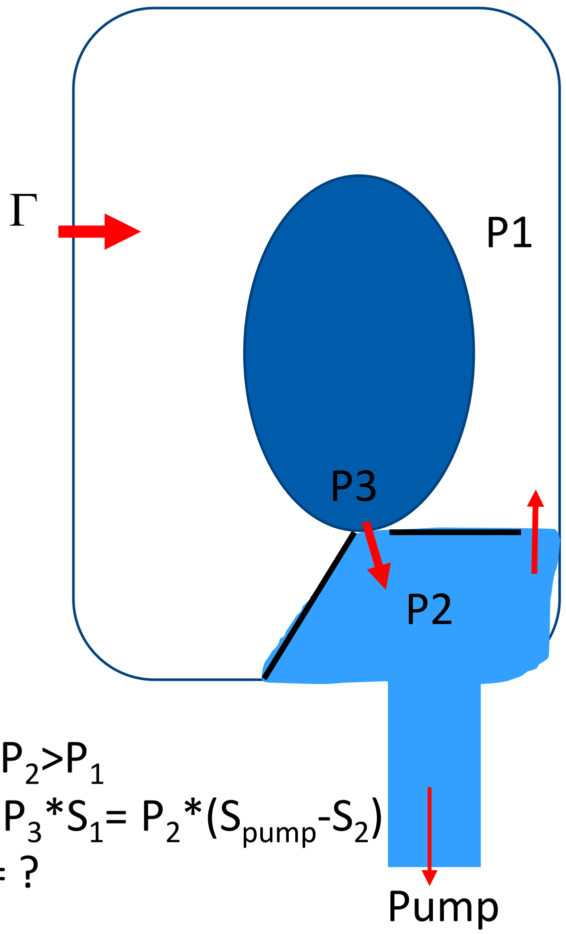
Details of CVP: Pumping capacity

Ref: V Rohde 16.3.2022

Calibration w/o Plasma



Calibration w Plasma

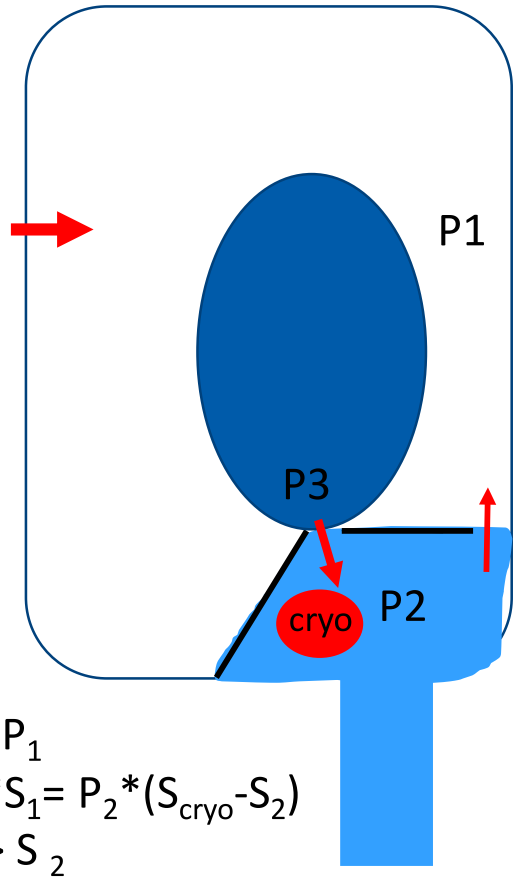


$P_3 > P_2 > P_1$

$\Gamma = P_3 * S_1 = P_2 * (S_{pump} - S_2)$

$P_3 = ?$

Calibration w Plasma & cryo



$P_3 > P_2 > P_1$

$\Gamma = P_3 * S_1 = P_2 * (S_{cryo} - S_2)$

$S_{cryo} >> S_2$

Proposal: Estimation of the plasma vessel (gas) volume

Objectives:

- Estimation of plasma vessel (PV) volume (110 m^3 during OP1.2) after installation of new in-vessel components such as CVPs, Water pipings etc.
- This is required to estimate the amount of H during CVP regeneration, to keep it well below the explosove limits

Approach:

- Pump down the plasma vessel to ca. 1×10^{-7} mbar → Close the valves to PV pumping system
- Inject a known amount of He gas, monitor the pressure rise, wait until the pressure stabilizes (thermal effects) and measure the pressure
- Estimate the plasma vessel volume

Specific requirements:

  - Diagnostics: Pressure measurements in the plasma vessel
  - Amount of gas injected

Proposal: Characterization of CVP (during commissioning)

Objectives:

- Verification of the CVPs operation and regeneration, operation of vacuum systems concerning the safety and explosive hazards
- Estimate the pumping speed of all ten CVPs together (estimated ca. 106 m^3/s at He panel)
- Initial estimations of the amount of pumped H
- Estimate the pumping speeds of individual CVP

Approach:

- Cool-down and stabilize the CVPs → Close the valves to PV pumping system
- H injection: ≤ 0.5 bar m^3 (explosive limit: 2.2 bar m^3 with a safety margin of 2) keeping the PV pressure ca. 1×10^{-3} mbar. Actual amount of H to be decided based on the vacuum system‘s H_2 dilution with N_2 limits
- Regenerate all the CVPs up to 30 K → Follow the defined procedures
- Recool-down individual CVP → H injection ≤ 0.05 bar m^3 → Regeneration of individual CVP.
- Follow this individual CVP operation one by one for all the ten CVPs

Specific requirements:

- Diagnostics: Pressure measurements in the plasma vessel
- Amount of gas injected
- QMS measurements

Proposal: Characterization of CVPs (during plasma operation)

Objectives:

- Estimate the effective pumping speed of all ten CVPs together during plasma shots in different configurations (ca. 10^{-5} - 10^{-4} mbar (OP1.2) rather low pressure for a reasonable pumping, divertor plugging to be achieved)
- Accurate knowledge of the effective pumping speed is needed as input for the divertor neutral gas simulation

Approach:

- CVP in operation → First five shots of the day with same configuration and plasma parameters (H-fuel), attached
- CVP regeneration and recool down
- Close gate valve for one of the low iota side pumping port (AEH port) and repeat the five plasma shots (gas injection control with density feedback)
- Close gate valves for both the low iota side pumping port (AEH port) and repeat the five plasma shots (gas injection control with density feedback)
- Close gate valves for both the low iota side pumping port (AEH port) and one on high iota side (AEP port) and repeat the five plasma shots (gas injection control?)
- Repeat the above steps at different pressures at pumping gap (gas puff, strike line shift) and all again with He plasma (**Detached plasma**)

Specific requirements:

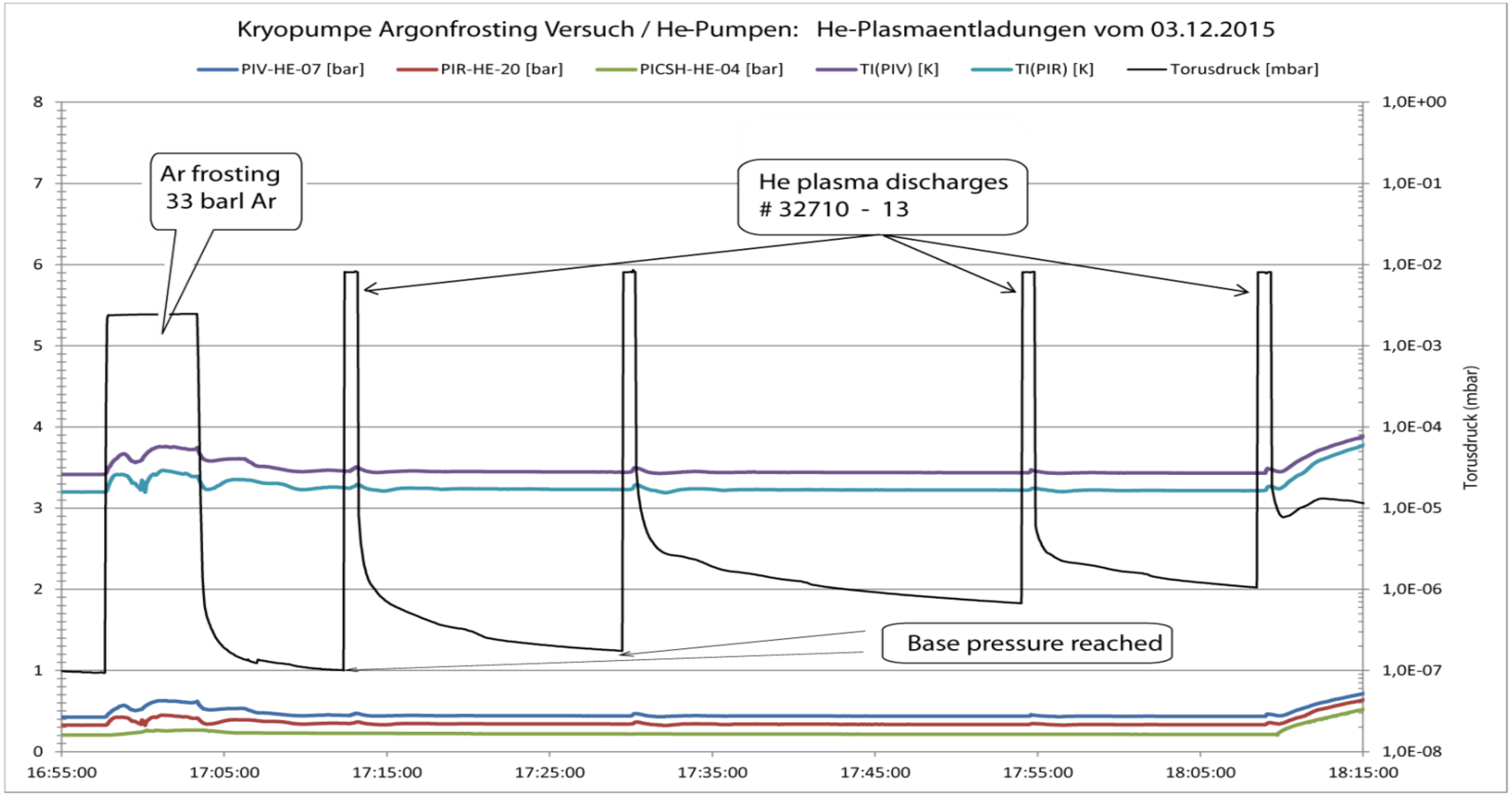
- Diagnostics: Neutral pressure measurements in PV and sub-divertor
- QMS/DRGA measurements, Amount of gas injected

Task Force(s)	II
Mag. Configurations	EJM, FTM, KJM
No. of programs for each configuration	4x5 (H) 4x5 (He)
No. of programs for different PGP press.	2x5 (H) 2x5 (He)

Requested Parameters	
Heating [MW] (ECRH)	5 MW (ECRH)
Density (feed-back) [10^{19} m^{-3}]	5

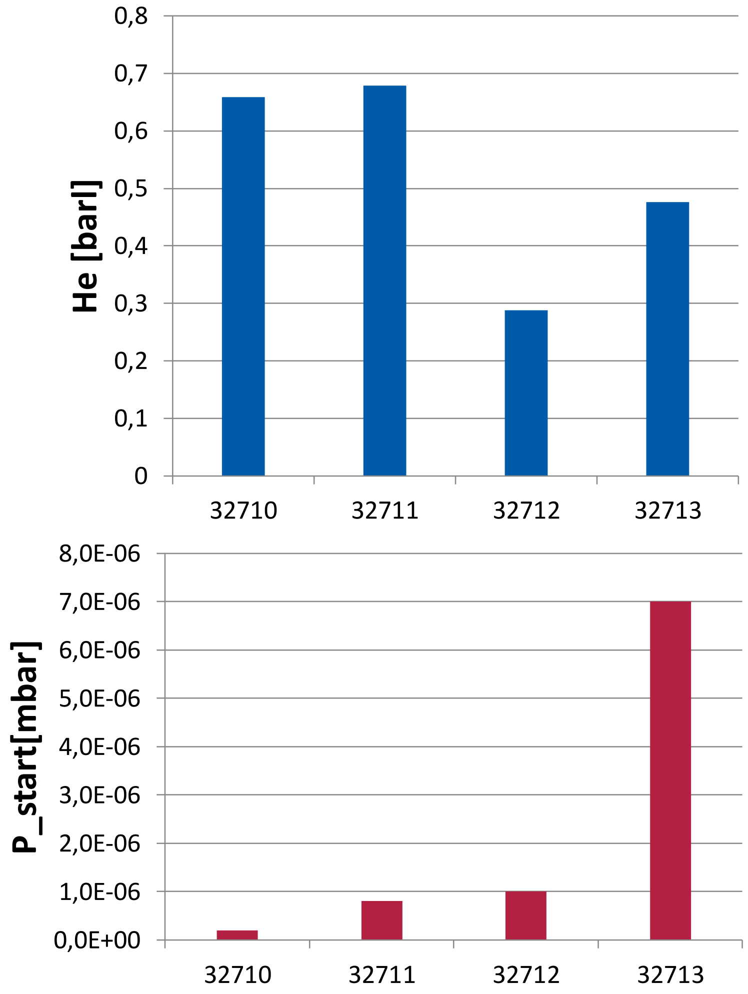
He pumping (CVP) by Ar-getters: AUG experience

Several experiments on Ar frosting. 2015 including plasma operation: works..



Ref. V Rohde, AUG upper Div review, March 2019

He pumping (CVP) by Ar-getters: AUG experience



33 barl Ar
He plasm discharges
After 4 shots:
base pressure not sufficient
He pumping 2,1 barl
He/Ar 6,4 %

Typical AUG discharge:
0,1-10 barl
Lasts for some shots

Discharges contaminated by
Ar radiation

Works but
Another technique needed

Ref. V Rohde, AUG upper Div review, March 2019

Proposal: Test of He pumping (CVP) by Ar-getters

Objectives:

- Initial tests of He pumping by Ar-getters (all CPs together)
- First test during the W7-X commissioning, if successful then at the end of plasma operation

Approach:

- CVP in operation (beginning of the day) → Inject Ar via main/divertor gas injection (amount?)
- During commissioning: Close the gate valves to PV vacuum system → inject He and monitor the PV pressures (amount?) → Regeneration of CVPs
- During plasma operation: Five shots with same configuration and plasma parameters (He-fuel), attached → Regeneration of CVPs

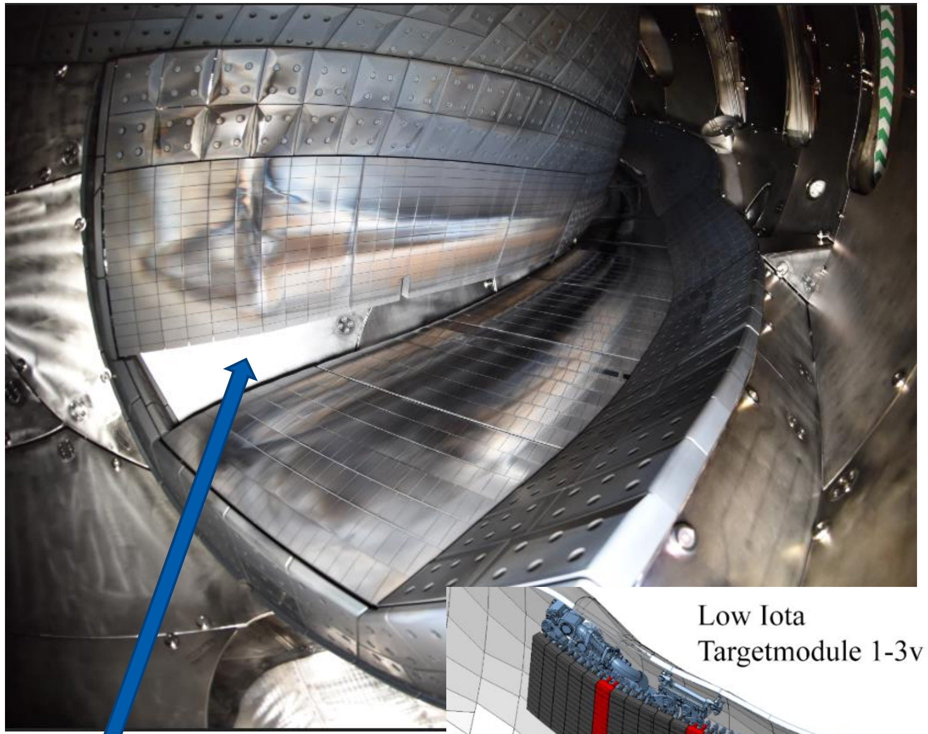
Specific requirements:

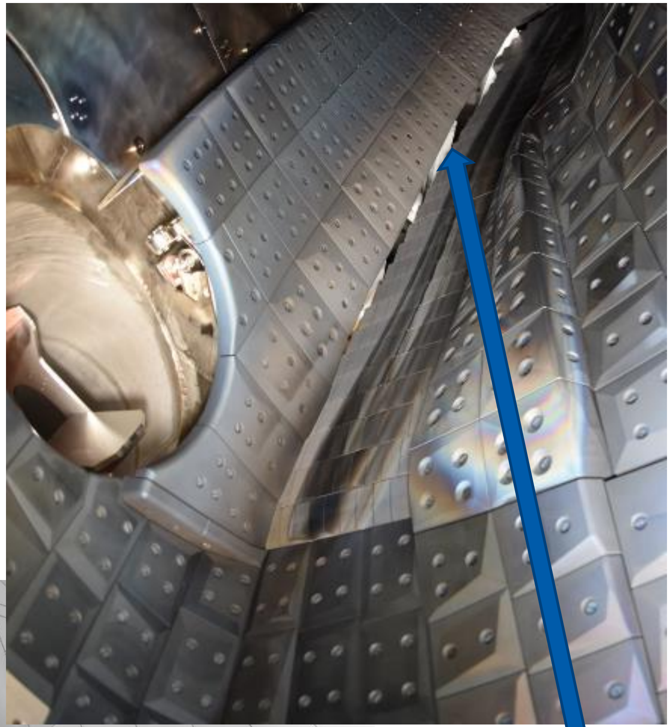
- Diagnostics: Neutral pressure measurements in PV and sub-divertor
- QMS/DRGA measurements, Amount of gas injected

Task Force(s)	II
Mag. Configurations	EJM
No. of programs	5

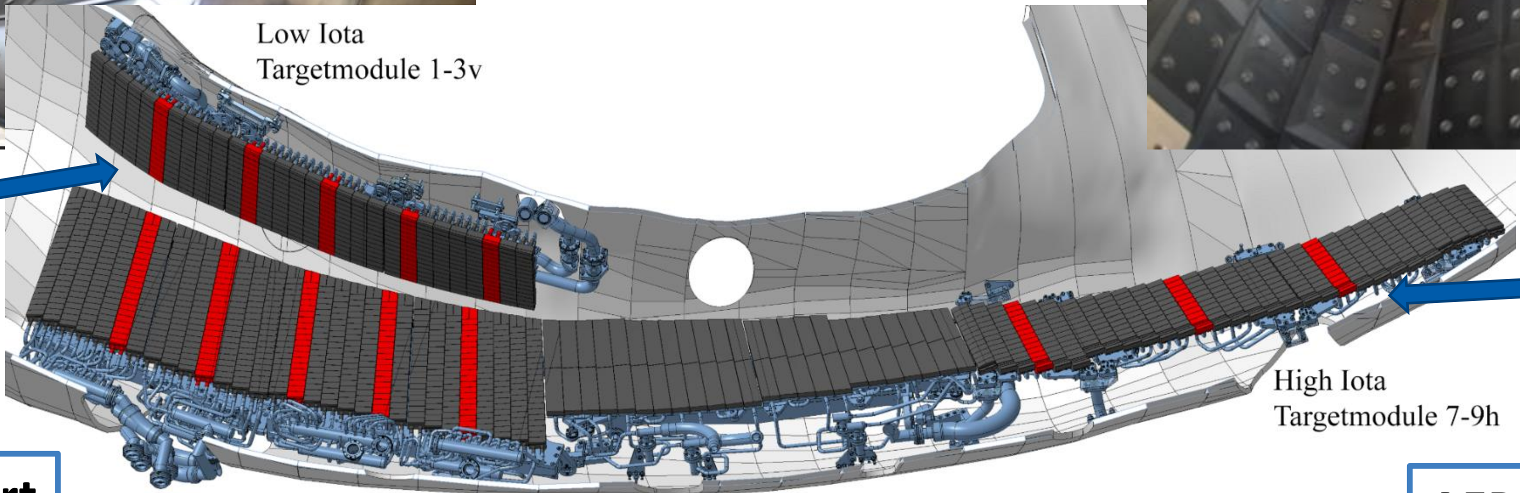
Requested Parameters	
Heating [MW] (ECRH)	5 MW (ECRH)
Density (feed-back) [10^{19} m^{-3}]	5

Pumping gaps at low / high iota side (OP1.2)





Ref. D Naujoks



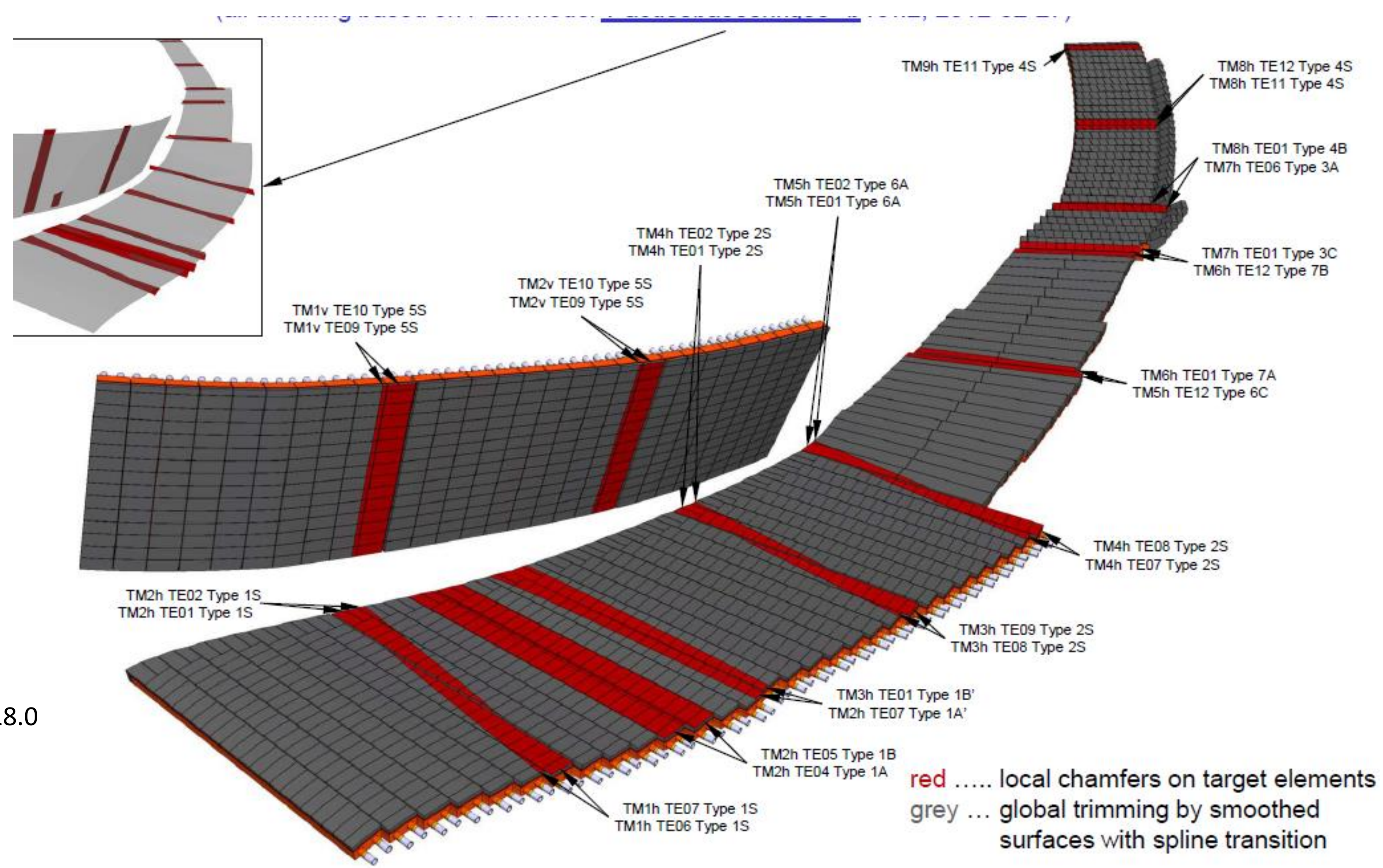
large pumping gap

small pumping gap

AEH port

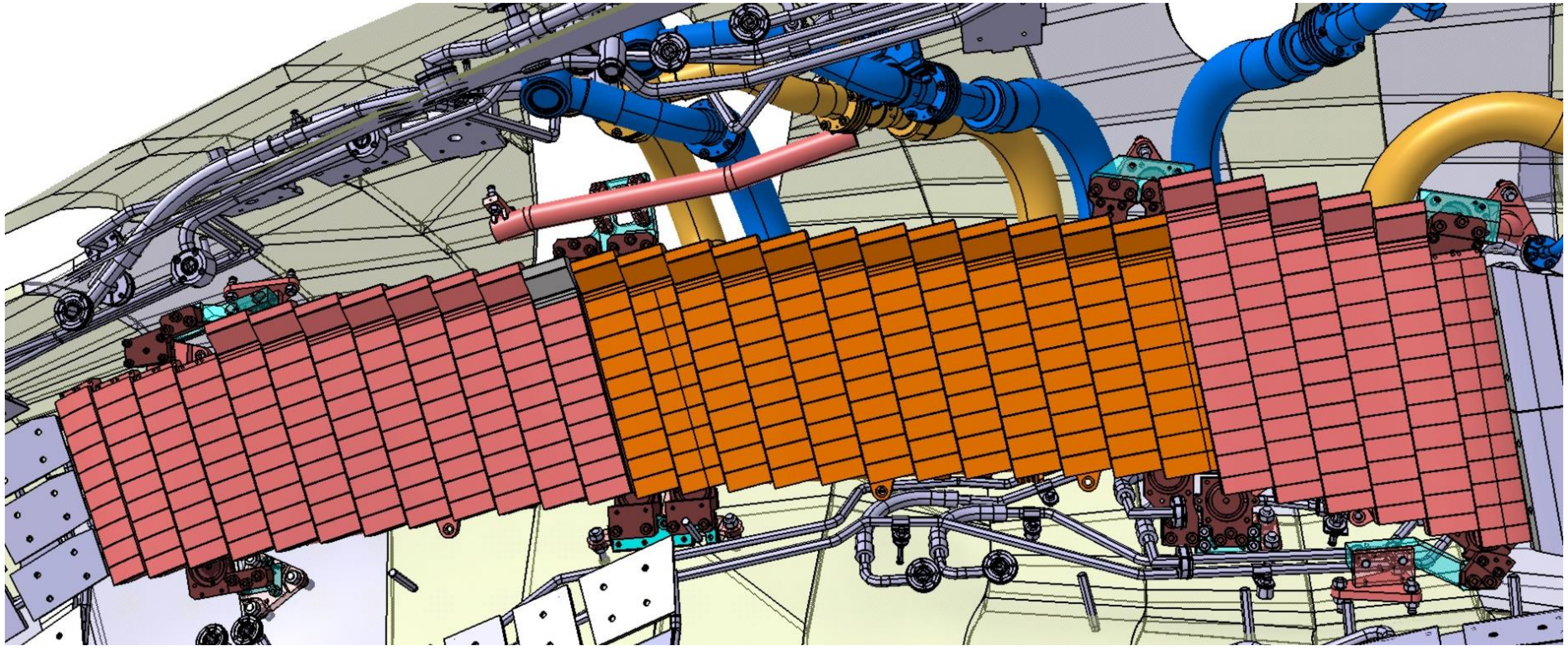
AEP port

TM7-9, collars at high iota side pumping gap



Ref. J Tretter 1-ACD-Y0018.0

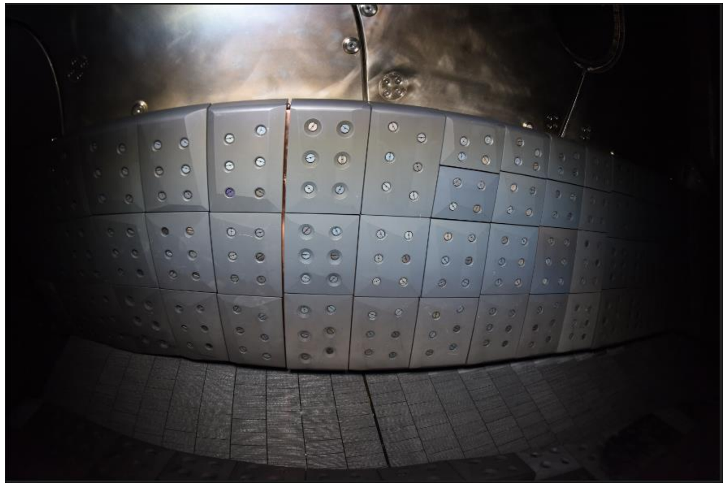
TM7-9, collars at high iota side pumping gap



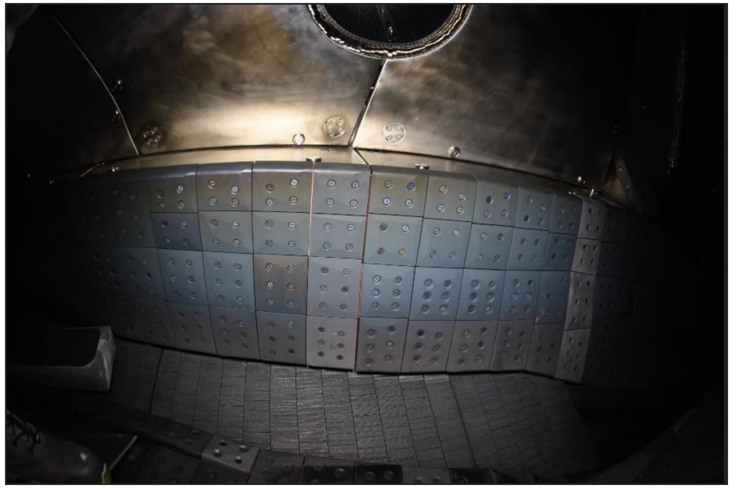
Ref. H Tittes 1-ACD-Y0015.1

Ref. Dirk Naujoks

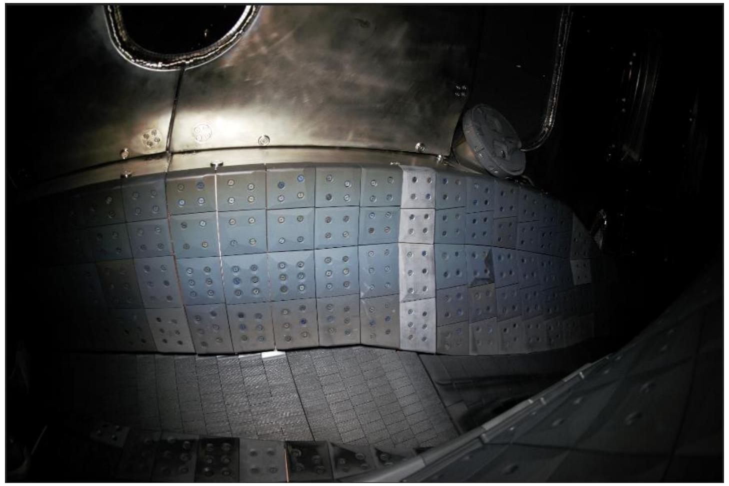
High iota side pumping gap



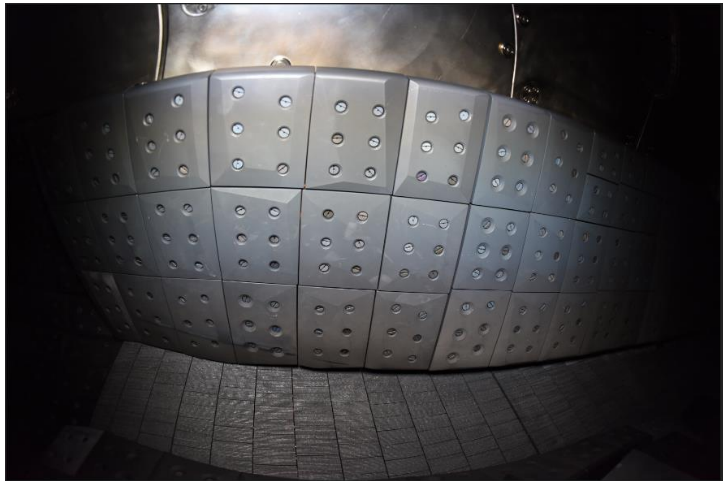
DSC_9445.jpg



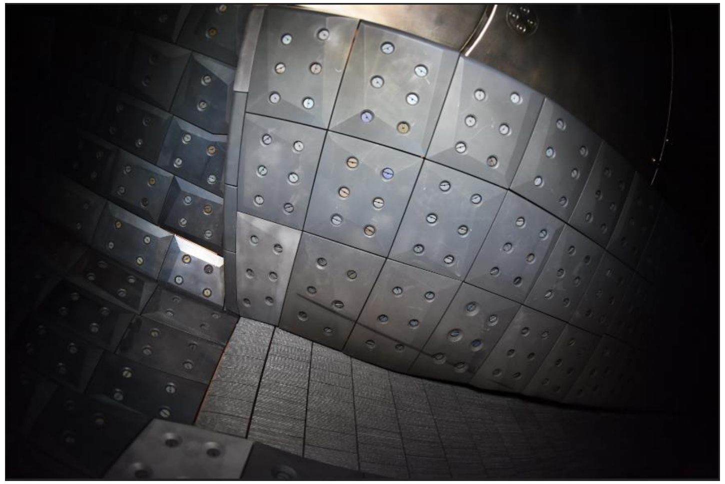
DSC_9443.jpg



DSC_9447.jpg



DSC_9446.jpg



DSC_9447.jpg

Ref: Photo documentation after CP2.1 from AS

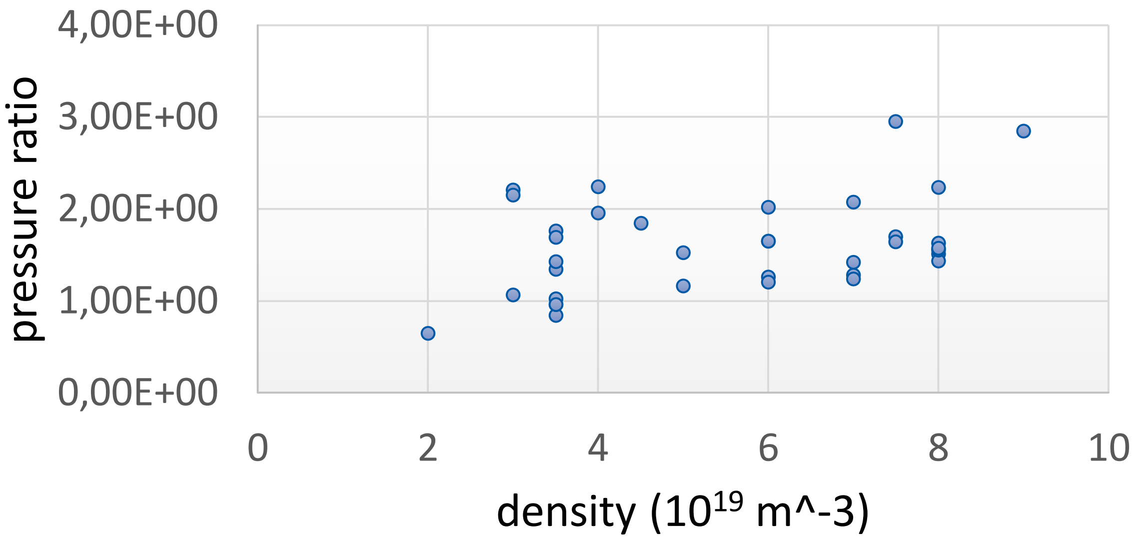
Pumping efficiency (AEH/AEP) OP1.2

Source: D Naujoks

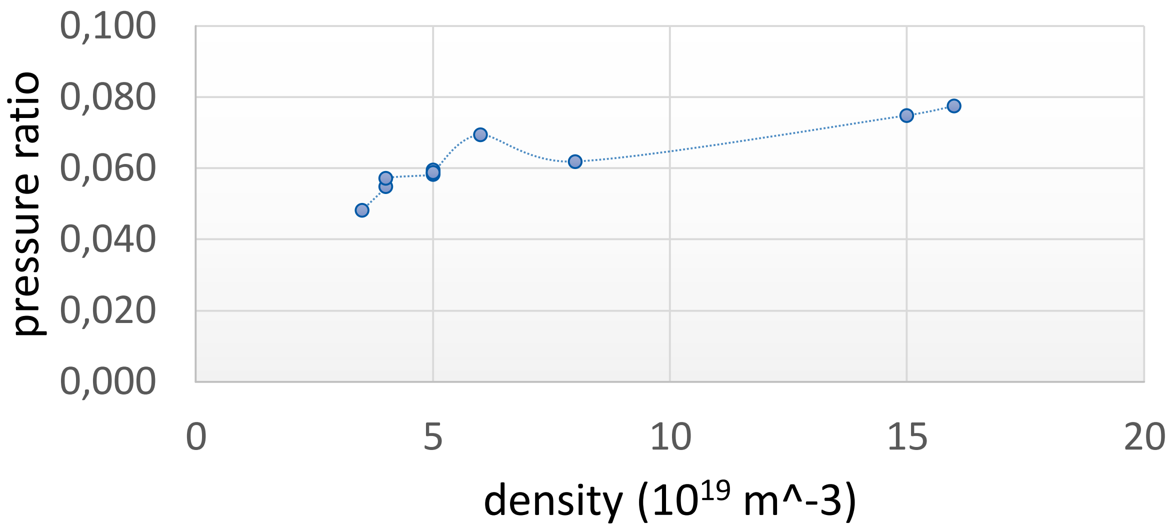
Standard configuration (EJM) up to P_{div} = **4*10^-4 mbar** (AEH port)

High-iota configuration (FTM) up to P_{div}= **1*10^-3 mbar** (AEP port)

EJM: pressure ratio AEH/AEP=2 (???)



FTM: pressure ratio AEH/AEP=0.06 (ok)



Source: V. Haak [high_low_iota_liste_18_01_2022.xlsx]

Proposal: Pumping efficiency (AEH/AEP) in OP2.1/2.2

Objectives:

- Estimate the pumping efficiency at AEP port with new collars
- Comparison of efficiencies at AEP: OP1.2 vs OP2.1
- Comparison of pumping efficiencies AEH/AEP for OP1.2 and OP2.1
- Provide inputs for the pumping gap panels for OP3

Approach:

- Repeat selected OP1.2b plasma shots with and without CVP
- Use the measurements from other plasma shots (other configurations, strike lines shift, gas puffs etc.) → ANSYS/DIVGAS analysis
-

Task Force(s)	II
Mag. Configurations	EJM, FTM
No. of programs	5 + 5

Specific requirements:

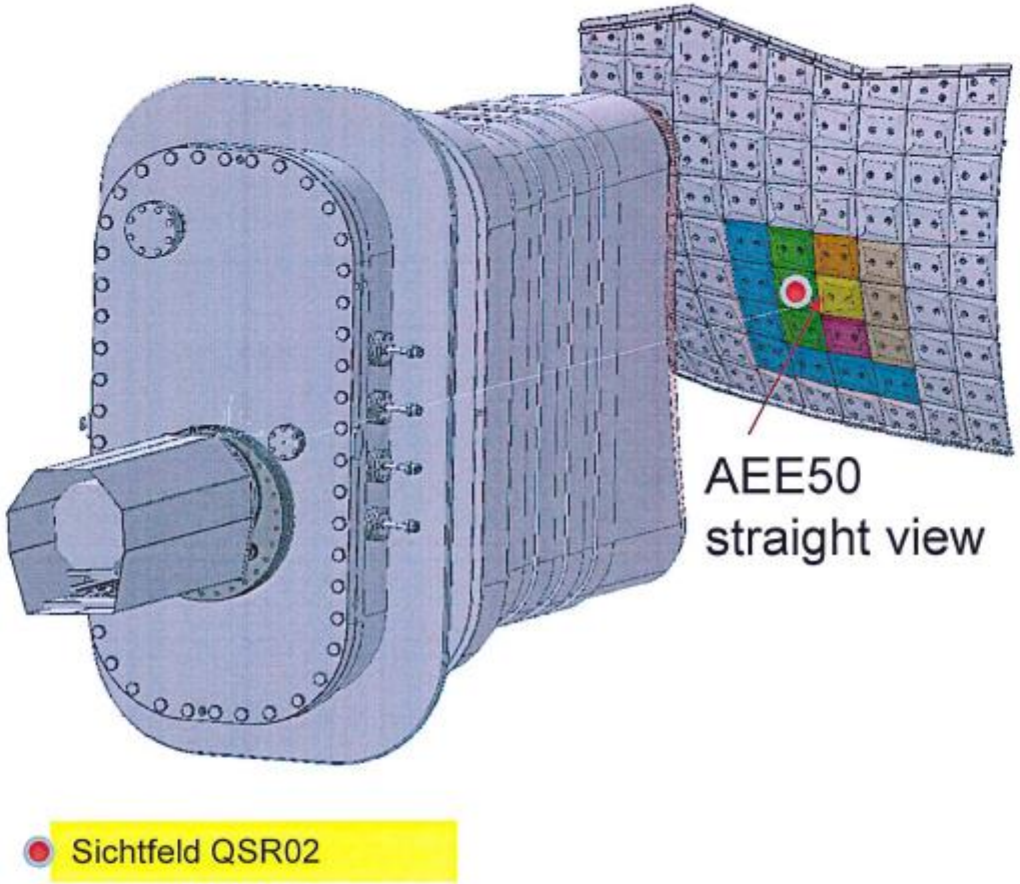
- Diagnostics: Neutral pressure measurements in PV and sub-divertor
- QMS/DRGA measurements, Amount of gas injected

Proposal-5

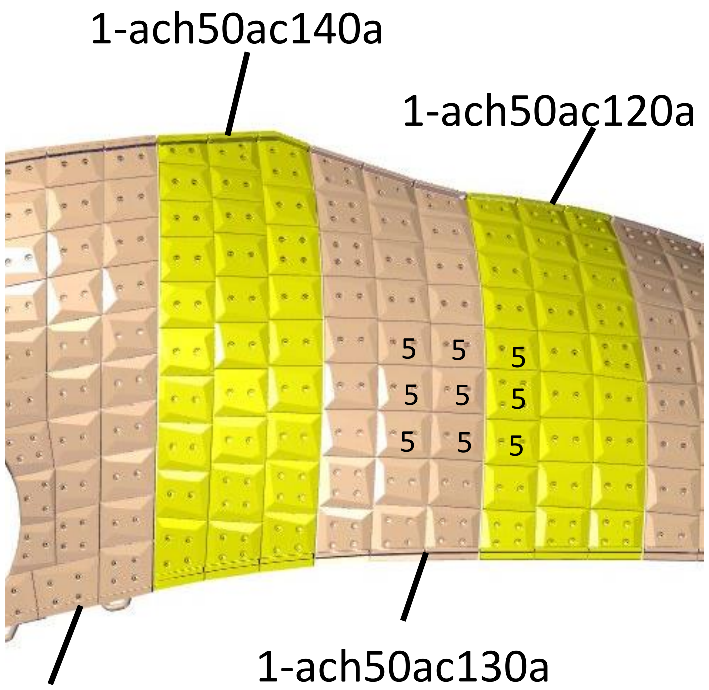
Module-5

Module-1

Proposal-4



Source: P. Kornejew



Source: Photo documentation (AS)
DSC_7089.jpg

Proposal: Comparing the fuel retention and recycling in M1 & 5

Objectives:

- Comparing the fuel retention and recycling in modules 1 and 5 with metal (tungsten) inner-wall and other modules with graphite wall

Approach:

- Monitoring the neutral pressures, effect of gas puffing etc. in various modules
- Spectroscopy measurements on tiles in M5
- Post-mortem measurements on the marker tiles (ca. 18 pcs.) installed at selected locations in M1 and M5: fuel retention
-

Task Force(s)	II
Mag. Configurations	various
No. of programs	-

Specific requirements:

- Diagnostics: Neutral pressure measurements in PV and sub-divertor
- QSR spectroscopy
- QMS/DRGA measurements, Amount of gas injected

Proposal: Carbon and boron balance during OP2.1/2.2

Objectives:

- Investigating the carbon and boron balance by comparing the estimated source amounts by plasma-wall interaction measurements and the measured exhaust amounts of different gases by the DRGA/QMS analyzers.

Approach:

- Estimated source amounts by plasma-wall interaction measurements and spectroscopy measurements
- Measure exhaust amounts of different gases by the DRGA/QMS analyzers
- Analyze the reference discharges and cumulative analysis over whole OP2.1 and 2.2 campaigns

Specific requirements:

- Diagnostics: Neutral pressure measurements in PV and sub-divertor
- QMS/DRGA measurements, Amount of gas injected

Proposal-1

Investigating the performance of bulk W/W-alloy baffle tiles under different heat load conditions in high mirror / standard configurations

- Dedicated exposures: Piggy-back
- Configurations: High mirror / Standard
- Diagnostics: IR-camera, HEXOS, XICS, quadrupole mass, spectrometer, density, temperature