EUROfusion

Feasibility study and validation of PEEK gasket for DONES STUMM module

AMICI-I.FAST Workshop on Facilities for beam test of accelerator components

Kraków, 12.10.2023

Urszula Wiącek[1], Santiago Becerril[2], Jesus Castellanos[3], Jerzy Kotuła[1], Wojciech Królas[1], Arkadiusz Kurowski[1], Agnieszka Kulińska[1], Jacek Świerblewski[1]

1 Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Kraków, Poland
2 IFMIF-DONES España, Granada, Spain
3 Universidad Castilla La Mancha (UCLM), Toledo, Spain

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

IFMIF-DONES Laboratory

IFMIF-DONES - International Fusion Materials Irradiation Facility
DEMO Oriented Neutron Source

EUROfusion Consortium WPENS Project
(Work Package Early Neutron Source)

Department of Radiation Transport Physics (NZ61)

Jan Dankowski
Barbara Gabańska
Andrzej Igielski
Wojciech Królas
Agnieszka Kulińska
Arkadiusz Kurowski
Urszula Wiącek

Division of Scientific Equipment and Infrastructure Construction (DAI)

Dariusz Bocian
Marcin Curyło
Jerzy Kotuła
Rafał Ortwein
Przemysław Wąchal
Jacek Świerblewski
Wojciech Marek

IFMIF-DONES Laboratory

IFMIF-DONES - International Fusion Materials Irradiation Facility
DEMO Oriented Neutron Source

EUROfusion Consortium WPENS Project
(Work Package Early Neutron Source)

Escúzar site (ca. 10 ha),
18 km southwest from Granada, Spain

IFMIF-DONES Laboratory

IFMIF-DONES - International Fusion Materials Irradiation Facility
DEMO Oriented Neutron Source

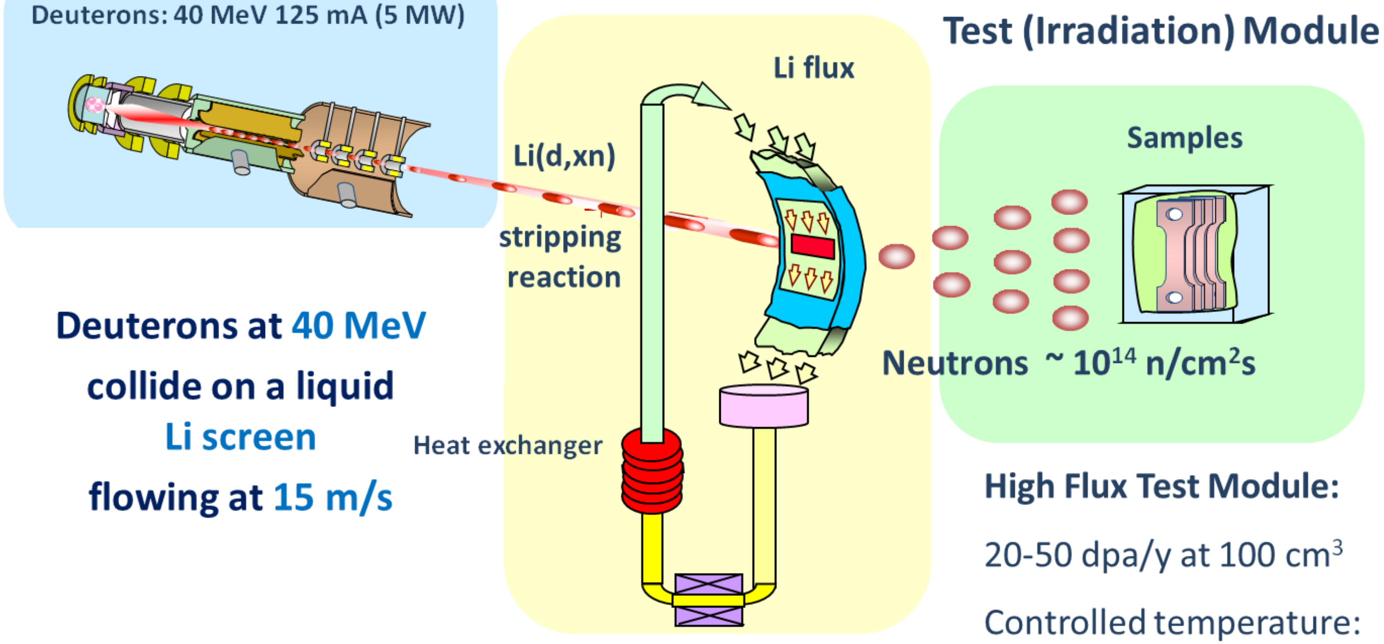
EUROfusion Consortium WPENS Project
(Work Package Early Neutron Source)

Escúzar site (ca. 10 ha),
18 km southwest from Granada, Spain

Accelerator

Lithium Loop (Target)

Test (Irradiation) Module



Deuterons at 40 MeV collide on a liquid Li screen flowing at 15 m/s

Heat removal by high velocity Li flux

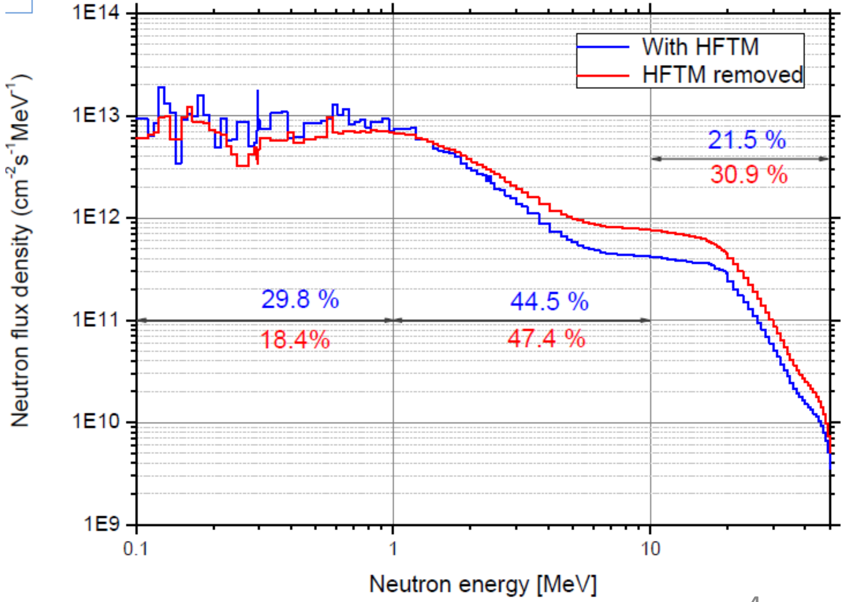
High Flux Test Module:

20-50 dpa/y at 100 cm^3

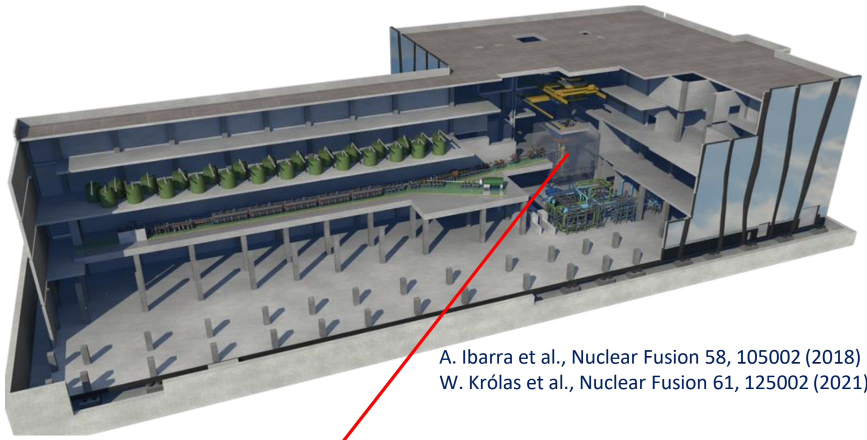
Controlled temperature:
250 < T < 1000 °C

HFTM in place
ϕ_{tot} = 2.57 10^{13} $cm^{-2}s^{-1}$

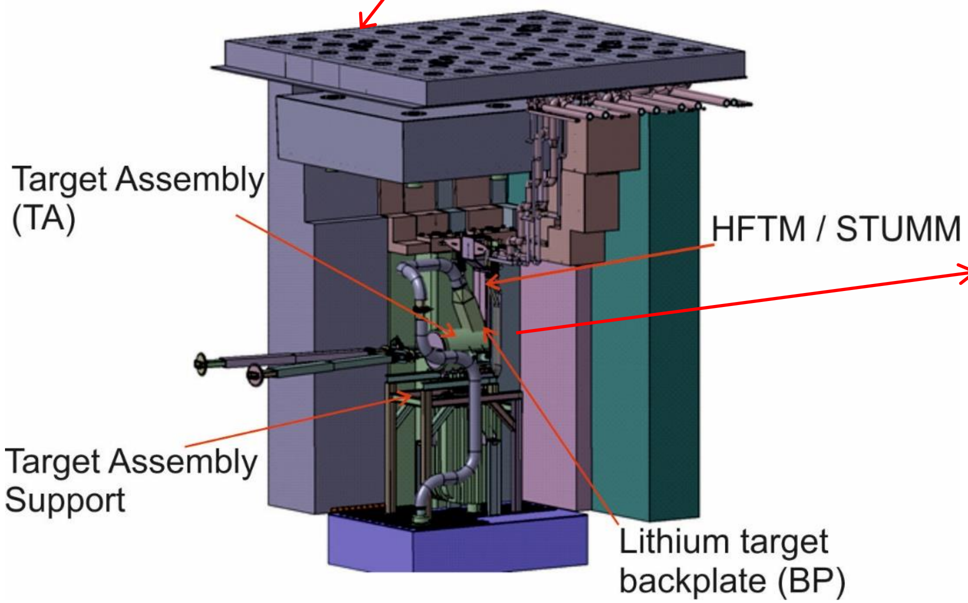
HFTM removed
ϕ_{tot} = 3.12 10^{13} $cm^{-2}s^{-1}$



IFMIF-DONES Laboratory

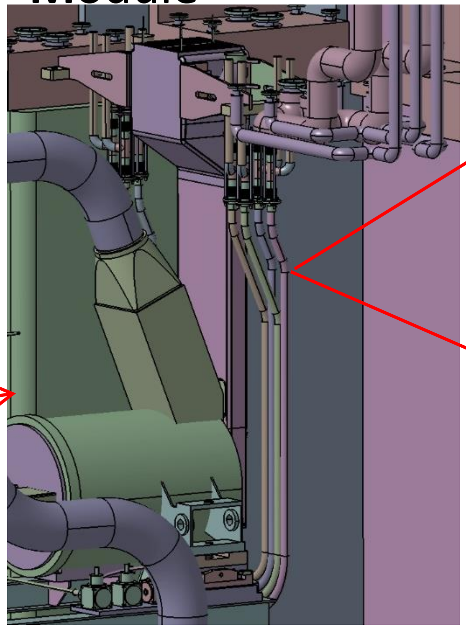


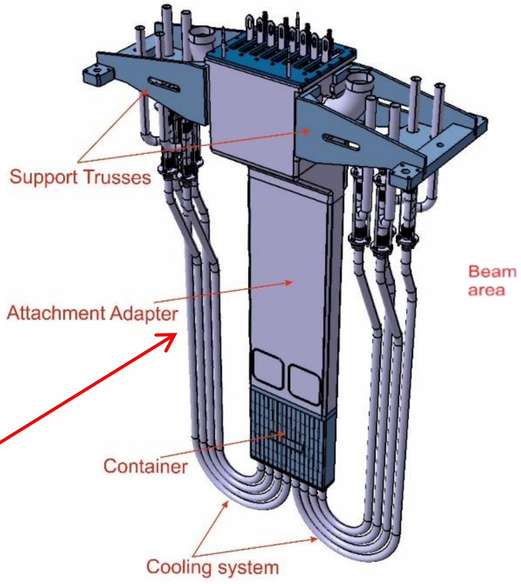
A. Ibarra et al., Nuclear Fusion 58, 105002 (2018)
W. Królas et al., Nuclear Fusion 61, 125002 (2021)

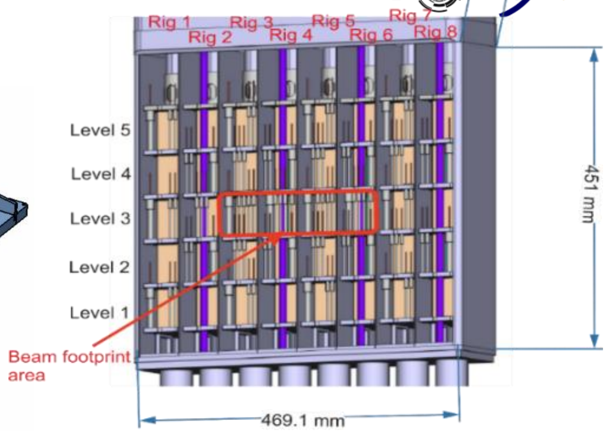


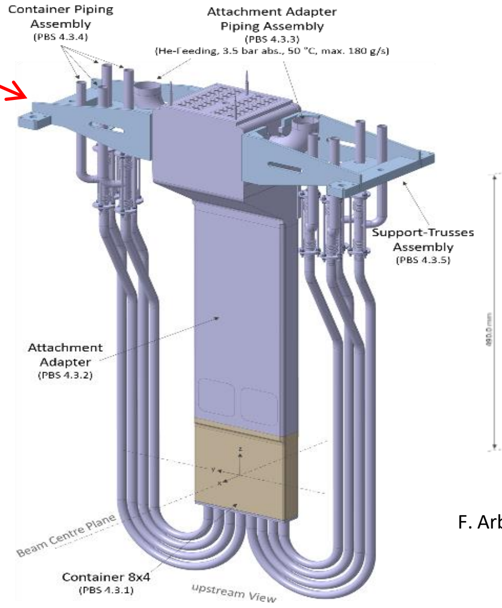
Test Cell (TC) - the space dedicated to irradiations.

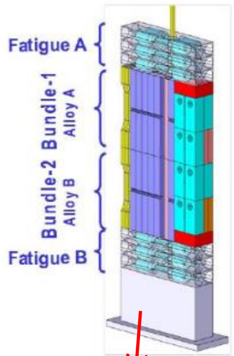
STUMM –
Start **U**p **M**onitoring **M**odule

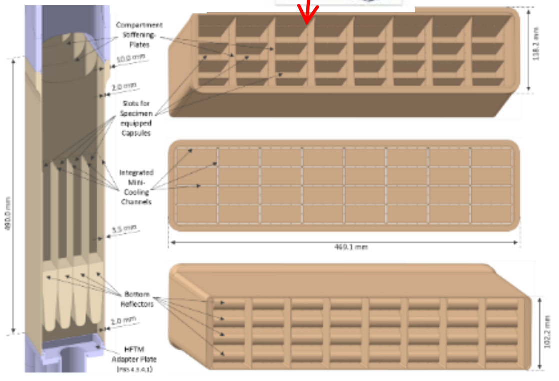








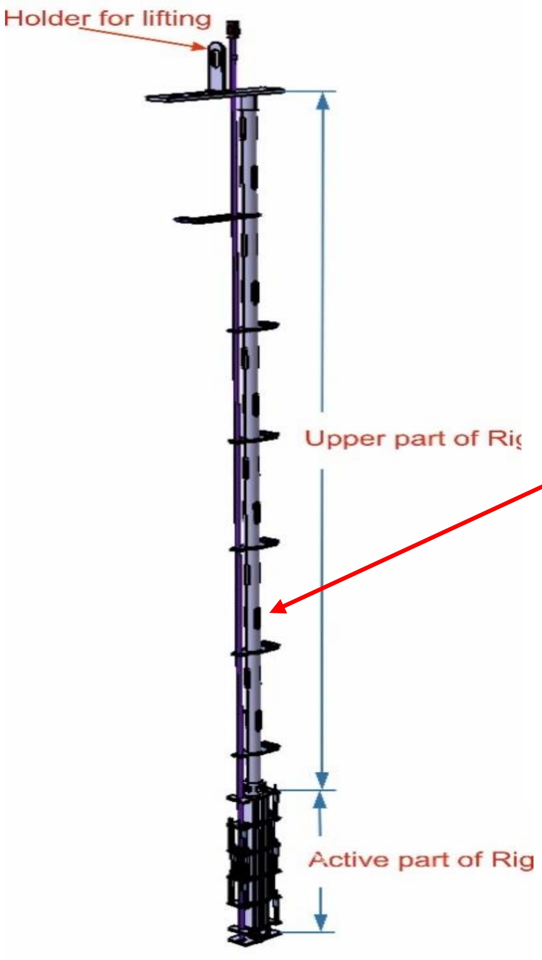




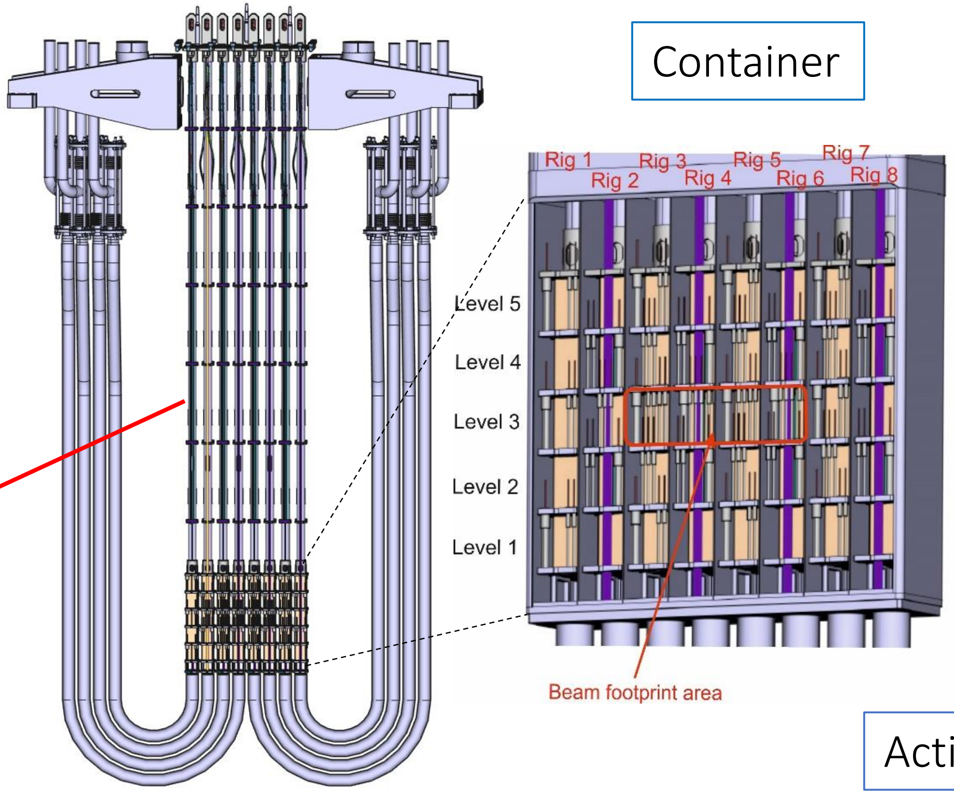
F. Arbeiter et al., Nuclear Materials and Energy (2016)

HFTM – High **F**lux **T**est **M**odule

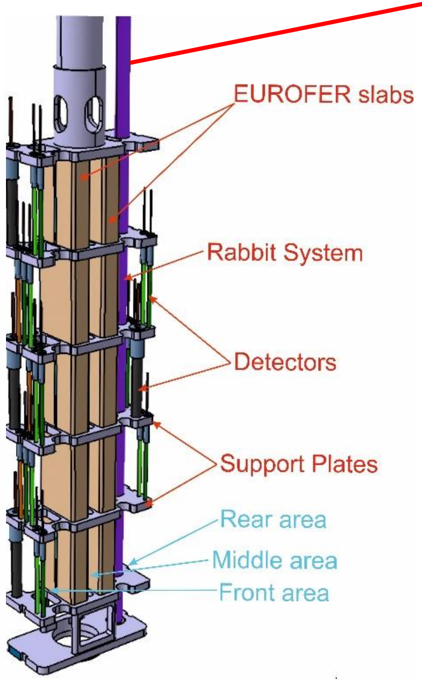
STUMM – Start Up Monitoring Module



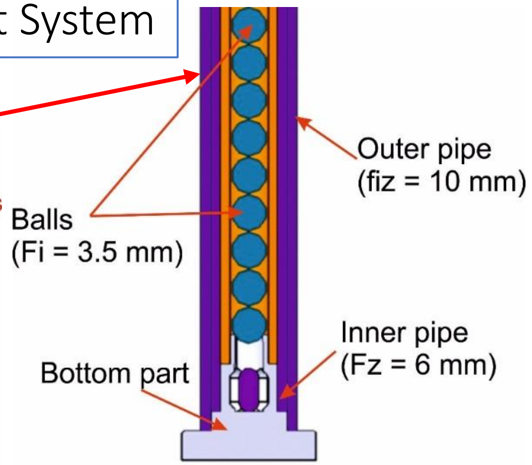
Single Rig



Container



Active part of rig



Rabbit System

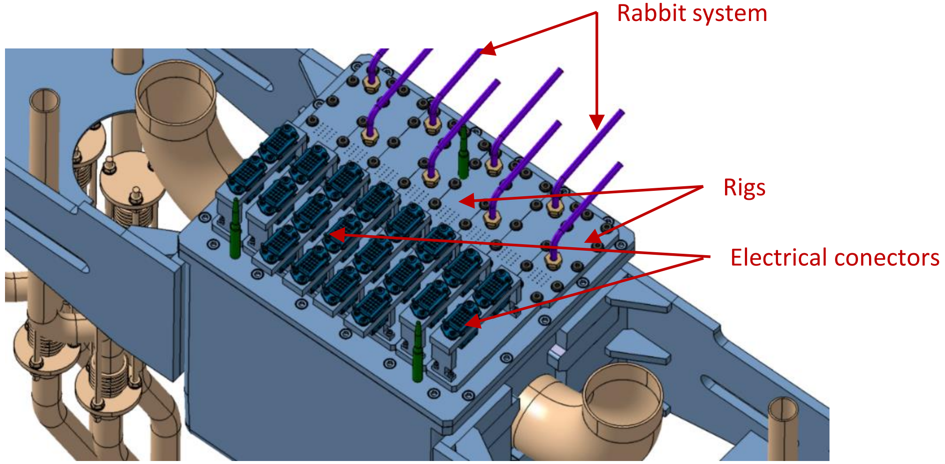
Reaction	Threshold [MeV]
In-115 (n,n') In-115m	0.4
Ni-58 (n,p) Co-58	1.0
Ti-47 (n,p) Sc-47	1.5
Ti-46 (n,p) Sc-46	3.5
Ti-48 (n,p) Sc-48	7.0
Nb-93 (n,2n) Nb-92m	8.9
Ni-58 (n,2n) Ni-57	12.4
Cu-63 (n,3n) Cu-61	20.0
Y-89 (n,3n) Y-87m	21.5
Bi-209 (n,4n) Bi-206	22.6
Tm-169 (n,4n) Tm-166	23.7

Detection systems for STUMM:

- Rabbit system (RS) (x8) (1 per rig) – thermal, epithermal and fast neutrons
- MFC (U238) & IC (max 140) - fast neutrons
- MFC (U235) or SPND detectors (max 40) – thermal and epithermal neutrons
- Gamma thermometers (max 40) – nuclear heating
- Thermocouples (max 40) – temperature

STUMM – Start Up Monitoring Module

Initial Conditions	
Gas pressure in Test Cell	0.2 bar
Gas pressure in STUMM (Helium gas)	3 – 3.5 bar
Maximum drop pressure in STUMM	0.6 – 0.8 kPa
The maximum mass flow rate of the cooling medium	0.18 kg/s
Cooling gas temperature at the inlet	max to 60°C
Maximum temperature of the cooling gas at the outlet	150°C
Maximum temperature inside Container	200°C - 250°C
Heat generation	from MCNP calculations
Neutron flux density	up to 10^{14} - 10^{15} n/cm^2/s
Gamma-ray dose	~GGy per year
Heat exchange (radiation, conduction in He-gas) with the Target Assembly at 300 °C	
The **tolerated leakage** for each flange shall be equal to **2 · 10^{-4} Pa · m^3/s** based on a total tolerated leakage from HFTM to TC of **10^{-2} Pa · m^3/s**	



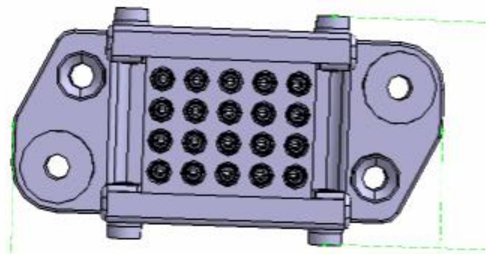
STUMM Ver. 2022

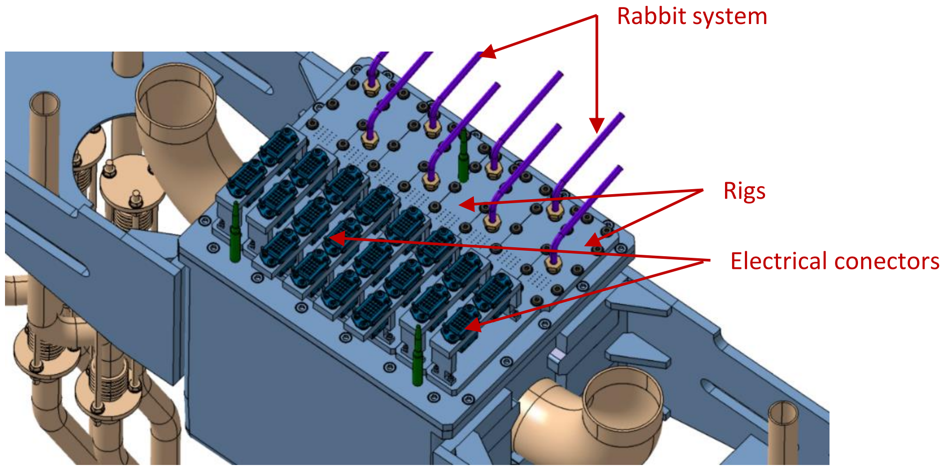
STUMM – Start Up Monitoring Module

Requirements:

- **STUMM shall be able work in more than one irradiation cycle - replaceable rigs**
- **STUMM shall be a system tightness**

It is very difficult to ensure both





STUMM Ver. 2022

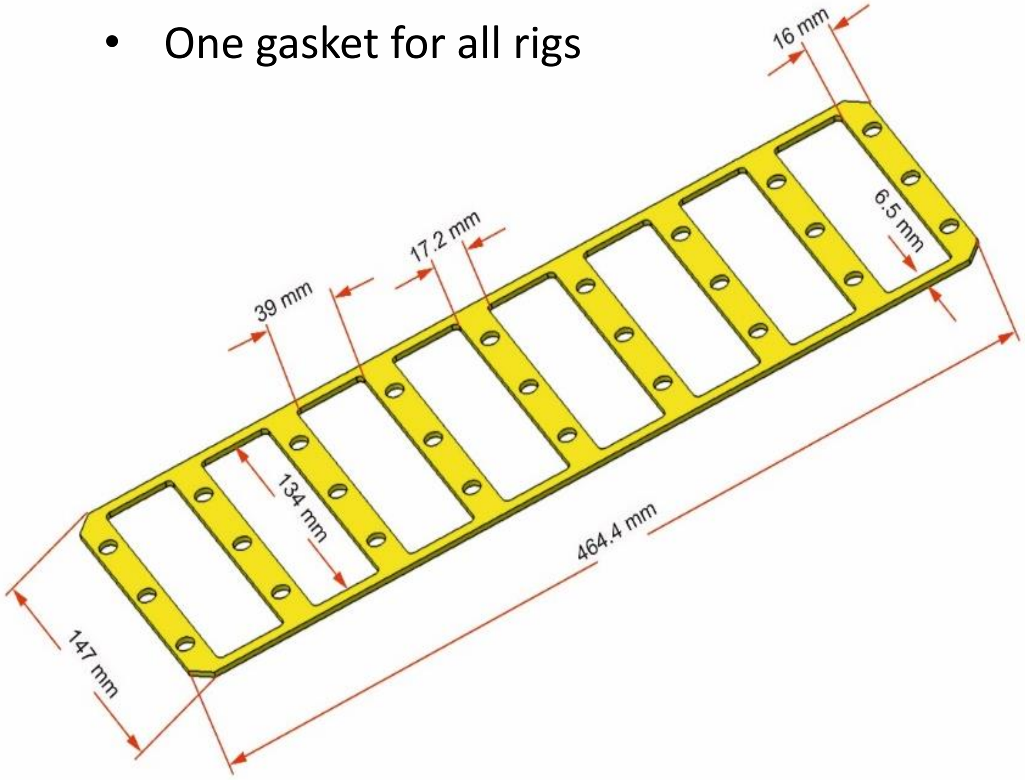
General issues:

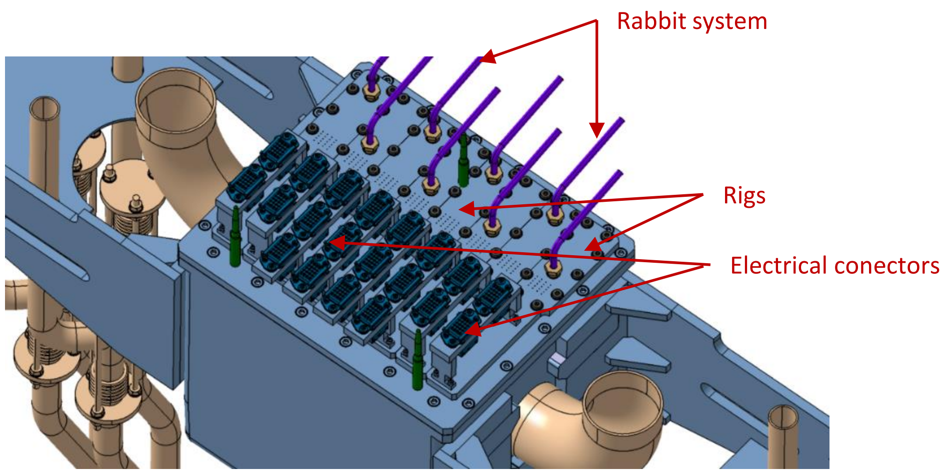
- Each rig must be sealed.
- Large amount of detectors in the current design (240).
- 2 or 3 multi-pin (20 pins) connectors per rig for the most instrumented rigs.
- Limited space for access via RH.

PEEK as a gasket for STUMM

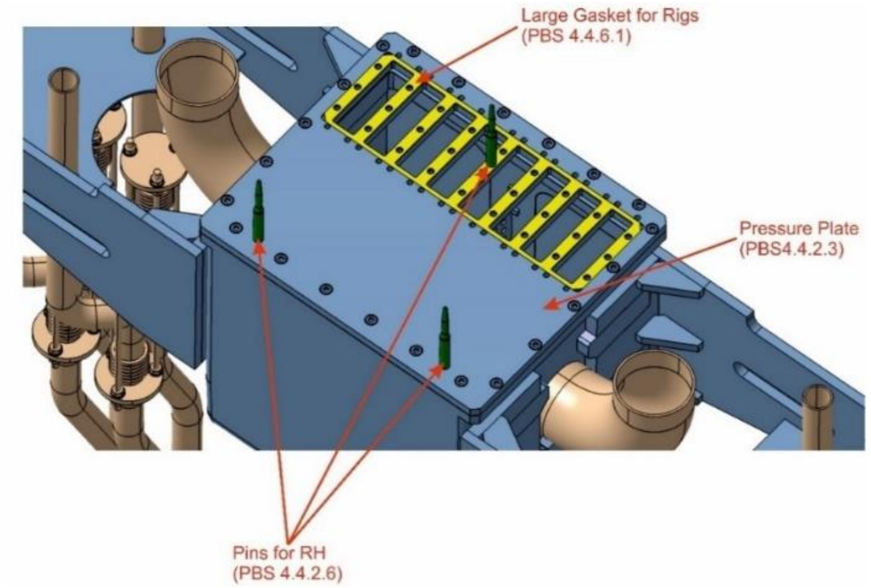
The general assumptions:

- Propose **material** for the rigs gasket – **PEEK (*Polyether ether ketone)***
  - One gasket for all rigs





STUMM Ver. 2022

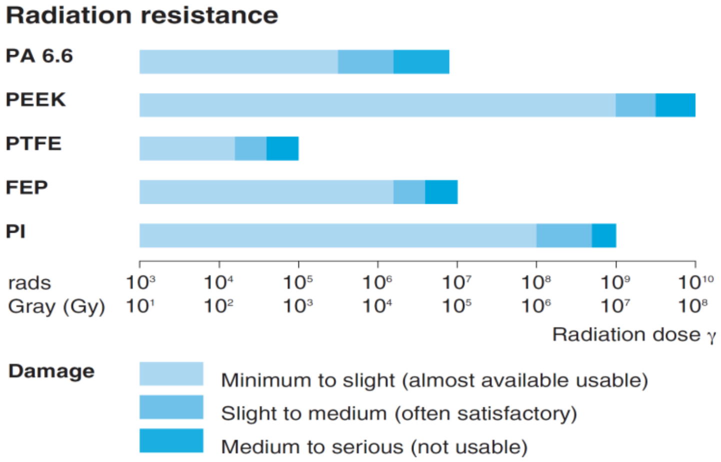


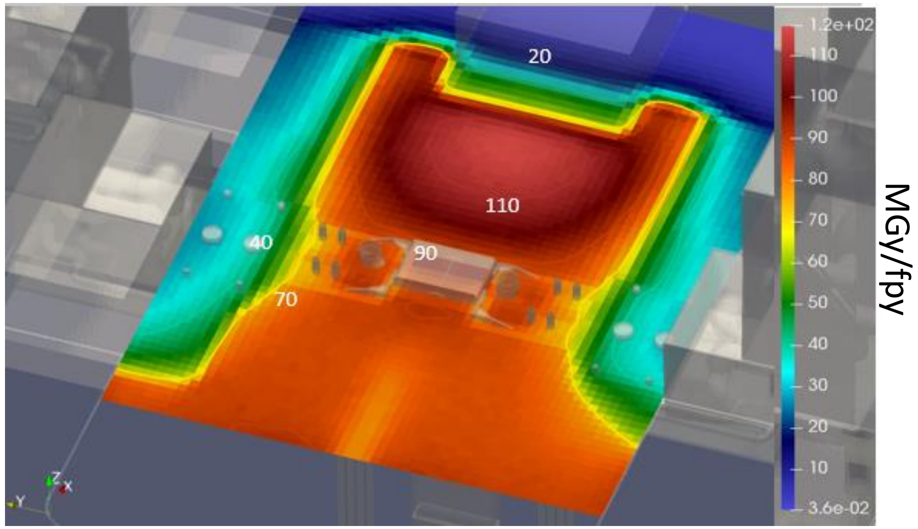
PEEK as a gasket for STUMM

Radiation resistance of PEEK:

Based on ITER Report (RHYTUK):
Radiation damage properties of Polyether ether ketone (PEEK)

- Good radiation resistance and keep its mechanical properties up to **10 – 20 MGy**
- Is recommended to use for the radiation dose up to **1.5 MGy**
- Most of the presented tests for gamma ray (or electron beam)
- For combined radiation fields (neutrons and gamma) PEEK degrades faster
- The parameters of PEEK are improved while the dose is increased





The absorbed dose (MGy/fpy) of PEEK (Rep EFDA 2NF525 v.1.4).

There is a risk that the PEEK seal will lose its properties and will not be reusable.

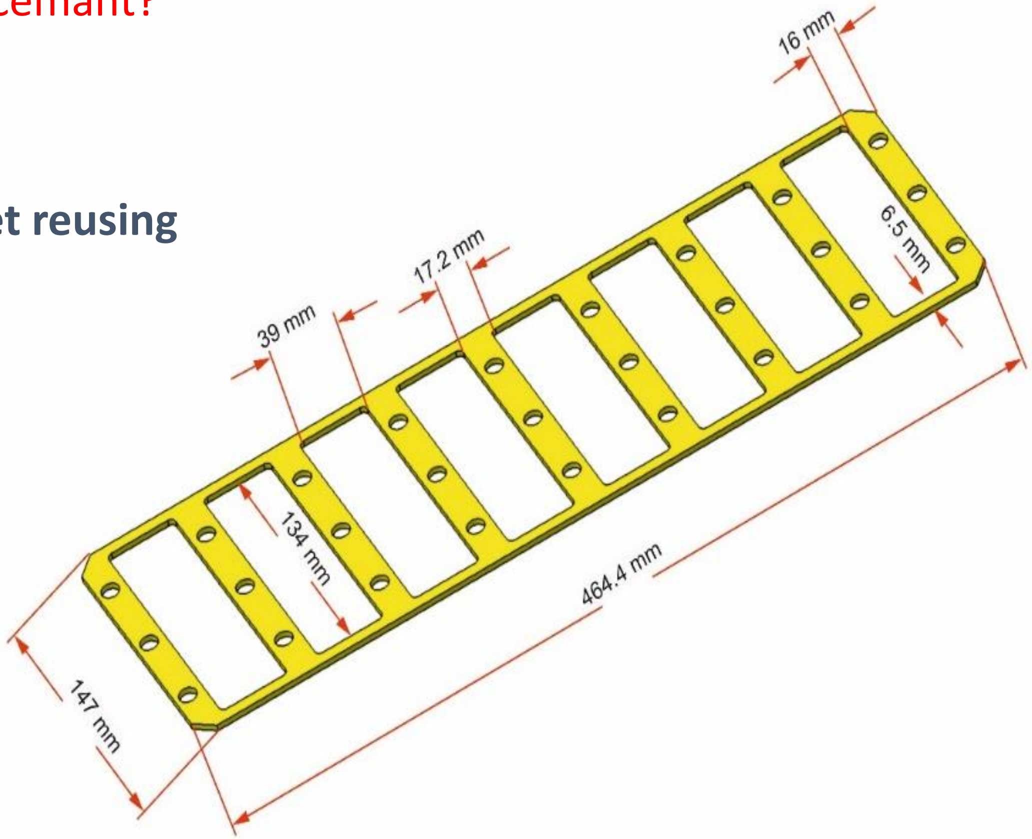
At the upper part of HFTM/STUMM is foreseen above **50 MGy / fpy.**

PEEK as a gasket for STUMM

The general questions are:

- Is this solution feasible?
- Is it possible to reuse the same gasket (PEEK) after rig replacemant?

Experimental validation of the PEEK gasket reusing

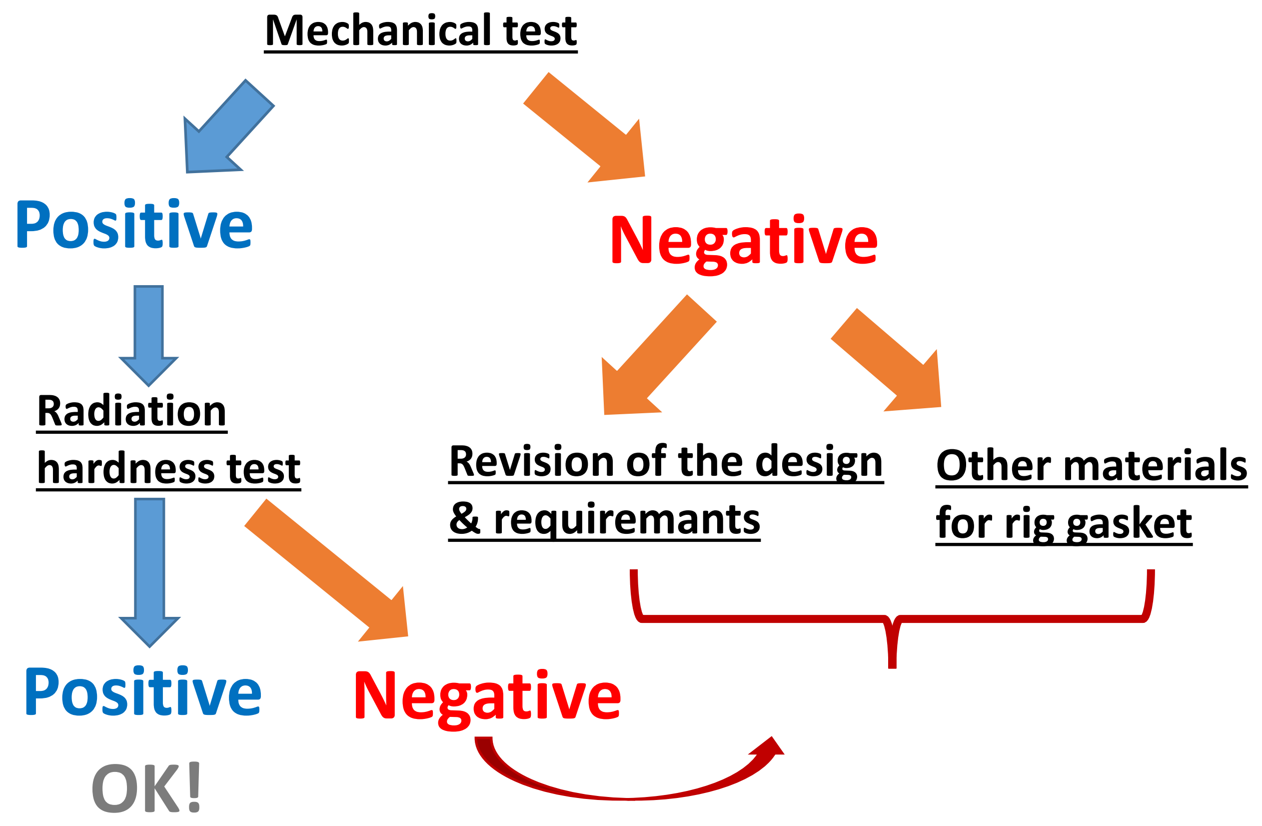


A simple system consisting of following elements:

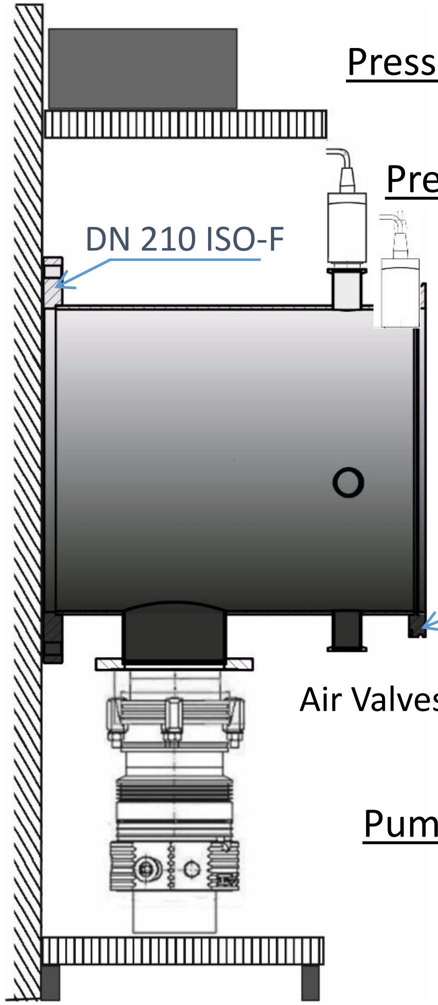
- The vacuum chamber
- PEEK o-ring seals
- He leak detector
- A set of pipes
- The vacuum pumping station

Experimental validation of the PEEK gasket reusing

Results of the tightness test of the seal made of PEEK



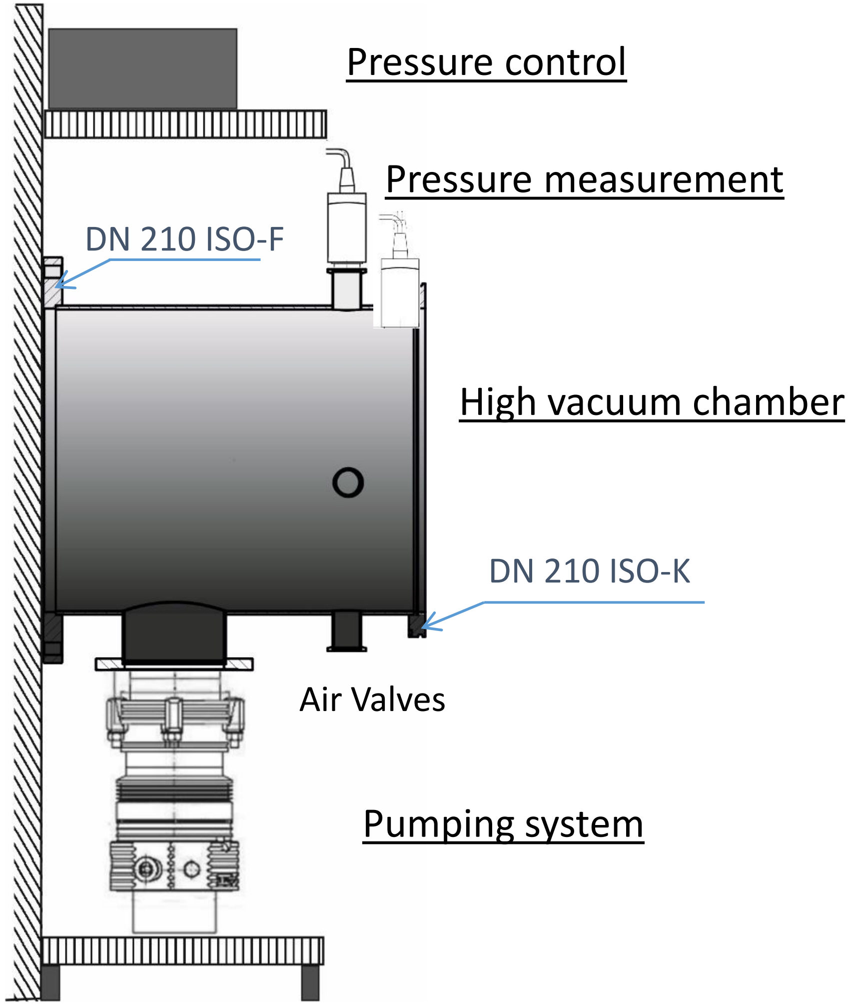
Experimental validation of the PEEK gasket reusing



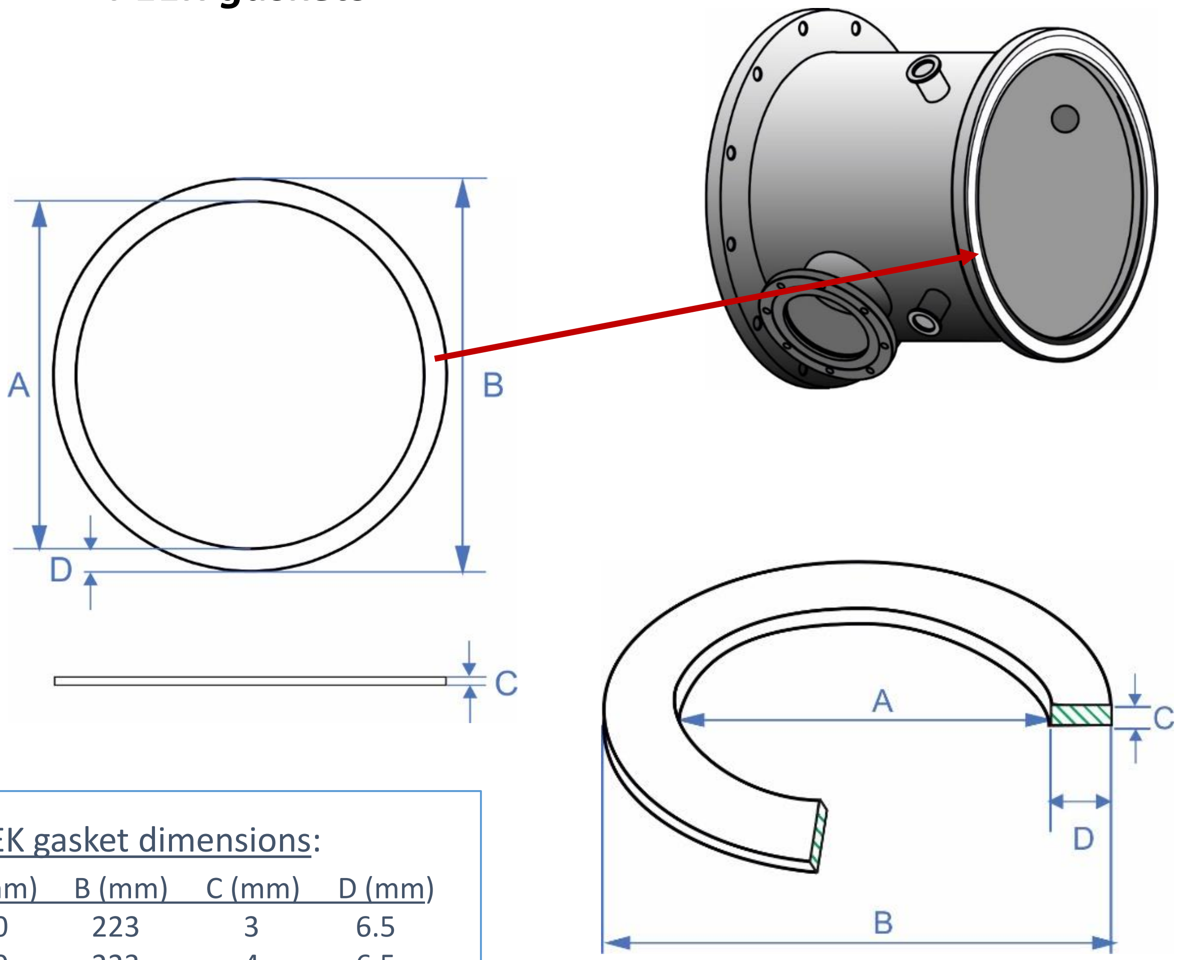
Set-up for test experiments:

- ***High vacuum chamber***
  (Pressure during typical experiments up to ~3x10^{-6} mbar)
- ***The front flange DN 210 ISO-K***
  (uses clamp fasteners)
- ***The rear flange DN 210 ISO-F***
  (uses bolt fasteners).
- ***Pumping system*** – the set of the rotary and turbo pump
- ***Pressure measurement*** - IONIVAC gauge (Cold Cathode/Pirani Combination Gauge) can measure ~10^{-10} mbar
- ***Pressure control*** - COMBIVAC gauge controller
- ***PEEK gaskets***

Experimental validation of the PEEK gasket reusing



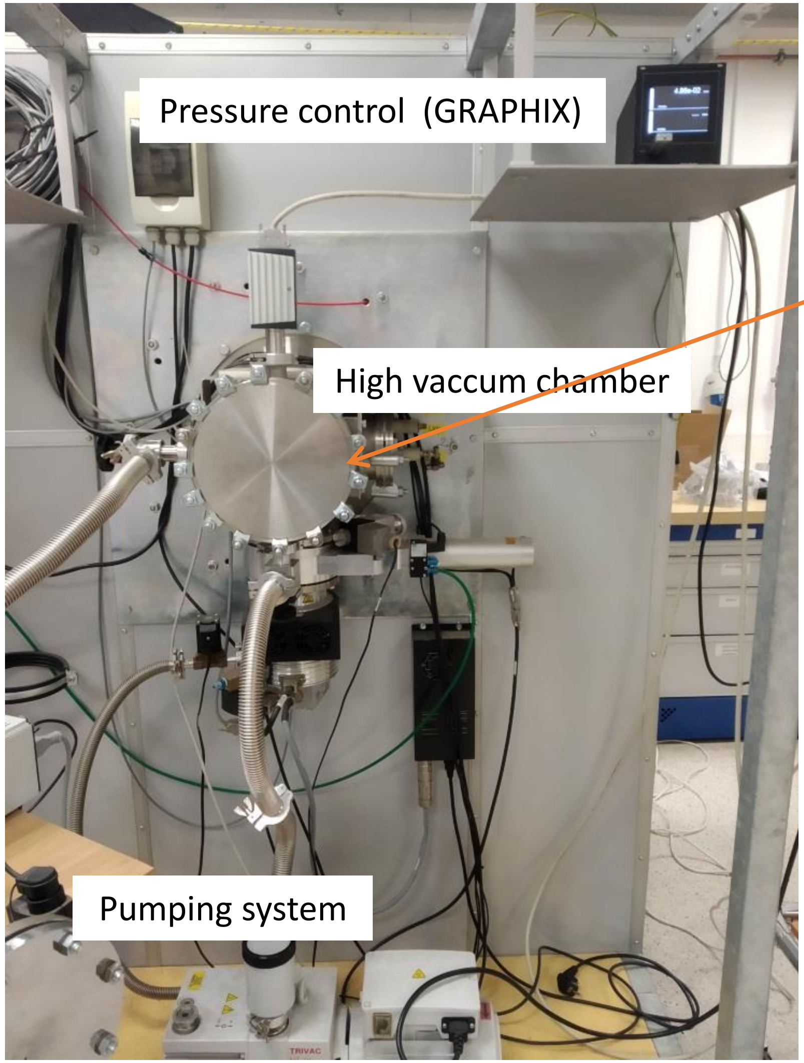
- ***PEEK gaskets***



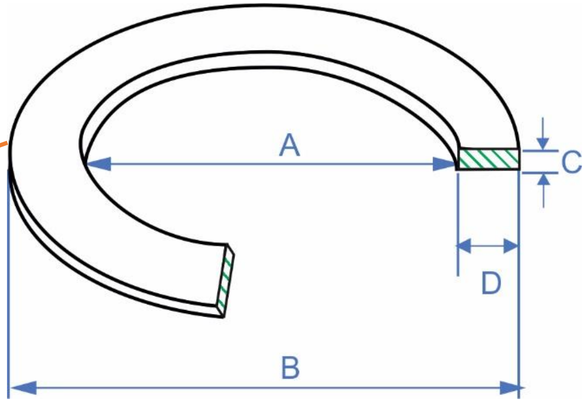
PEEK gasket dimensions:

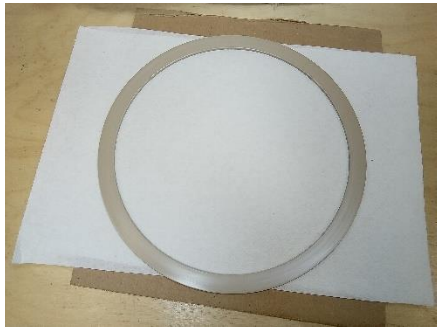
	A (mm)	B (mm)	C (mm)	D (mm)
I	210	223	3	6.5
II	210	223	4	6.5
III	210	238	3	14
IV	210	238	4	14

Experimental validation of the PEEK gasket reusing



Set-up for test experiments





PEEK gasket dimensions:

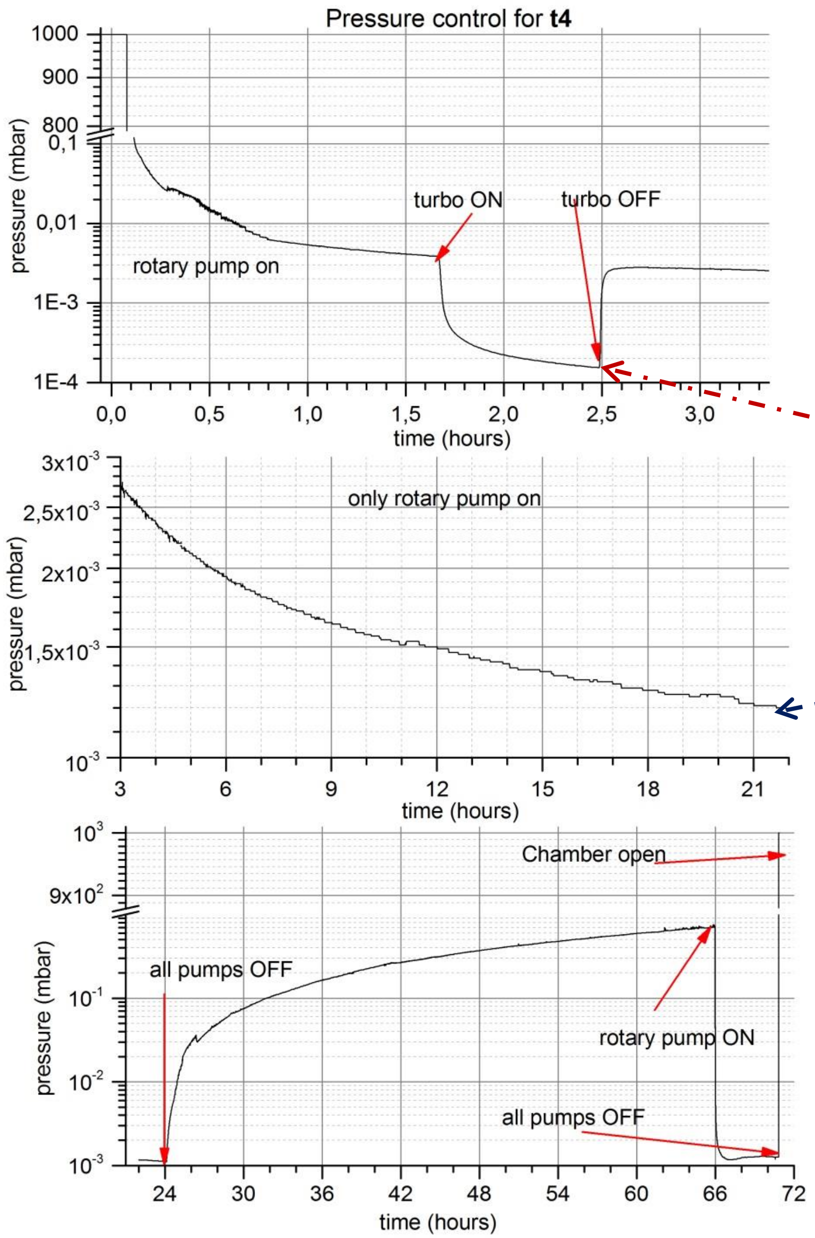
	A (mm)	B (mm)	C (mm)	D (mm)
I	210	223	3	6.5
II	210	223	4	6.5
III	210	238	3	14
IV	210	238	4	14

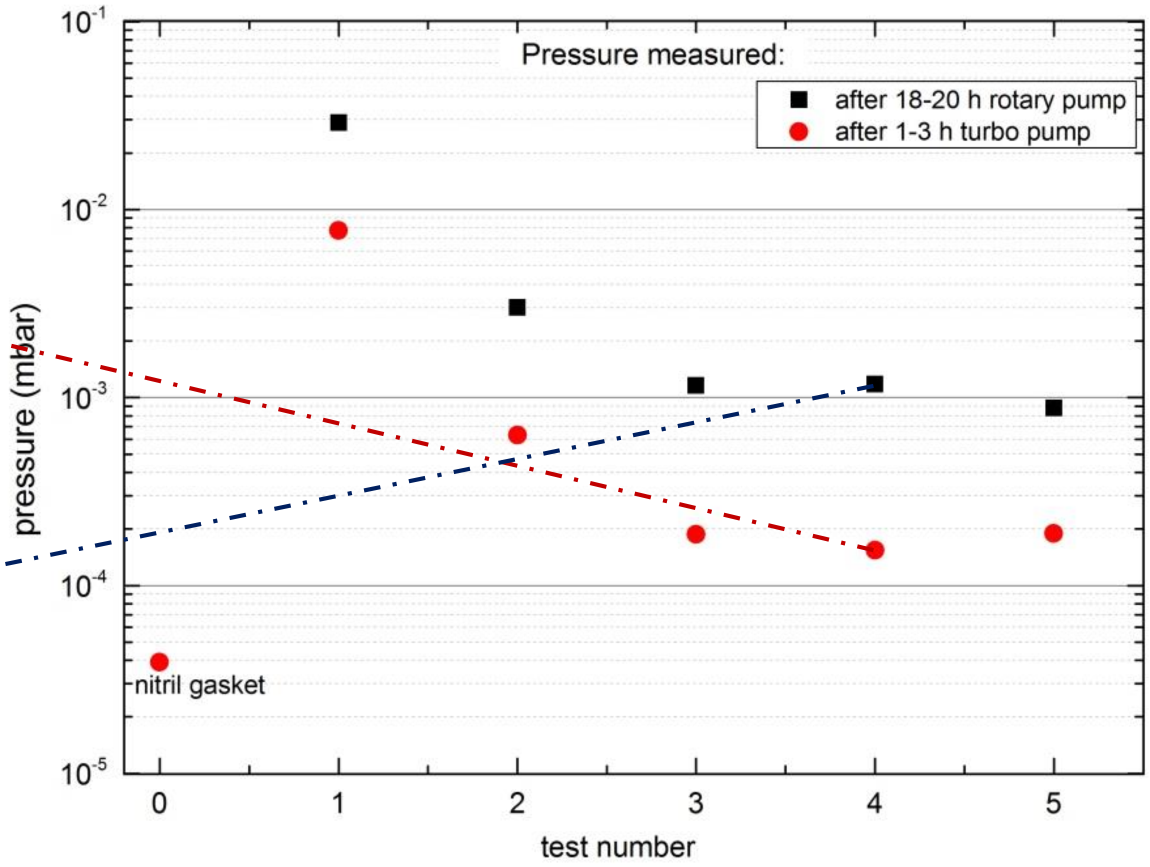
Main experimental steps:

1. PEEK gasket placed under the front flanche of the HV chamber.
2. Closing and evacuating the HV chamber (~10^{-4} mbar).
3. Pressure control continously ~24 hours.
4. Opening of the chamber, visual check of the PEEK gasket, thickness control.
5. PEEK gasket placed again under the front flanche.

Steps repeated five times.

Experimental validation of the PEEK gasket reusing

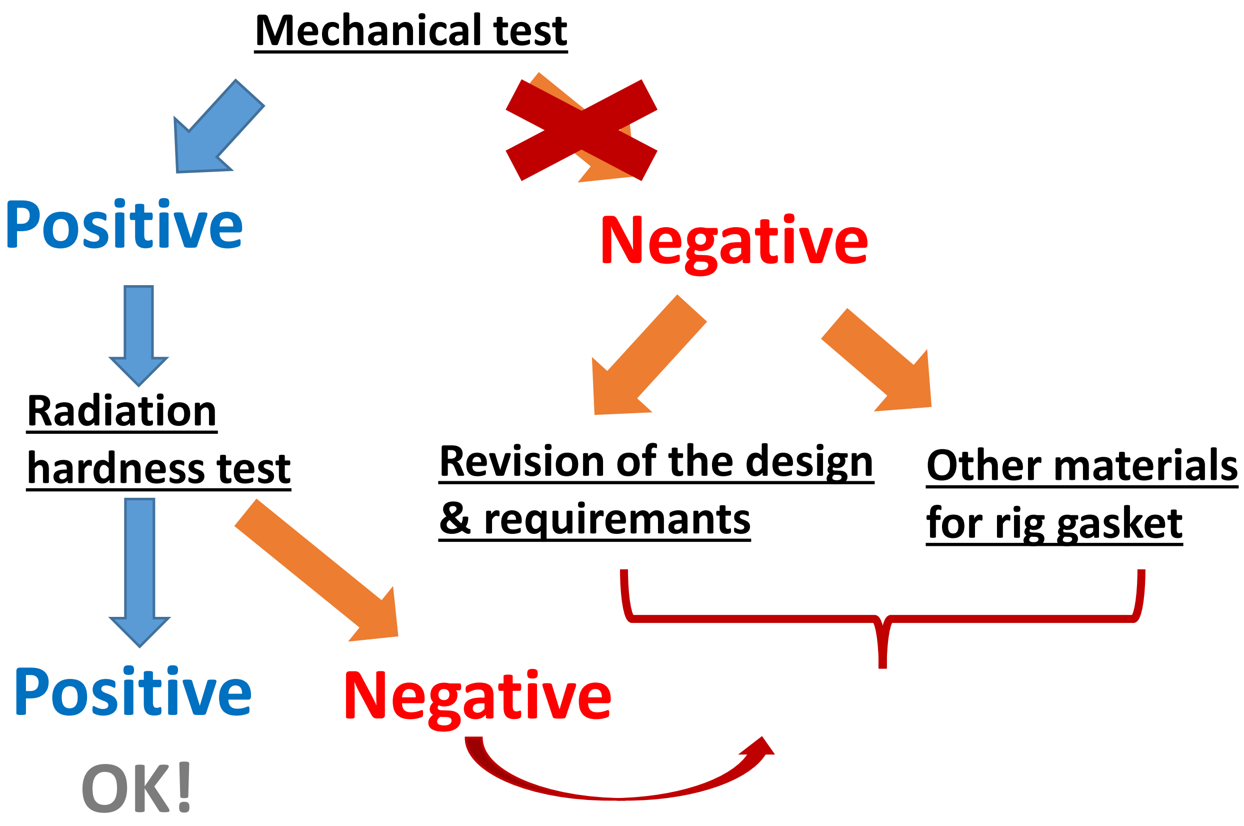




Preliminary experimental results

Experimental validation of the PEEK gasket reusing

Results of the tightness test of the seal made of PEEK



Summary

- The first results look promising!
- The next step will be a test of the PEEK gasket after irradiation
- But the question is:

Where this gasket can be irriadiated?

- MARIA Reactor
- TR24 at NPI-Rez in Czech Republic
- LIPAc

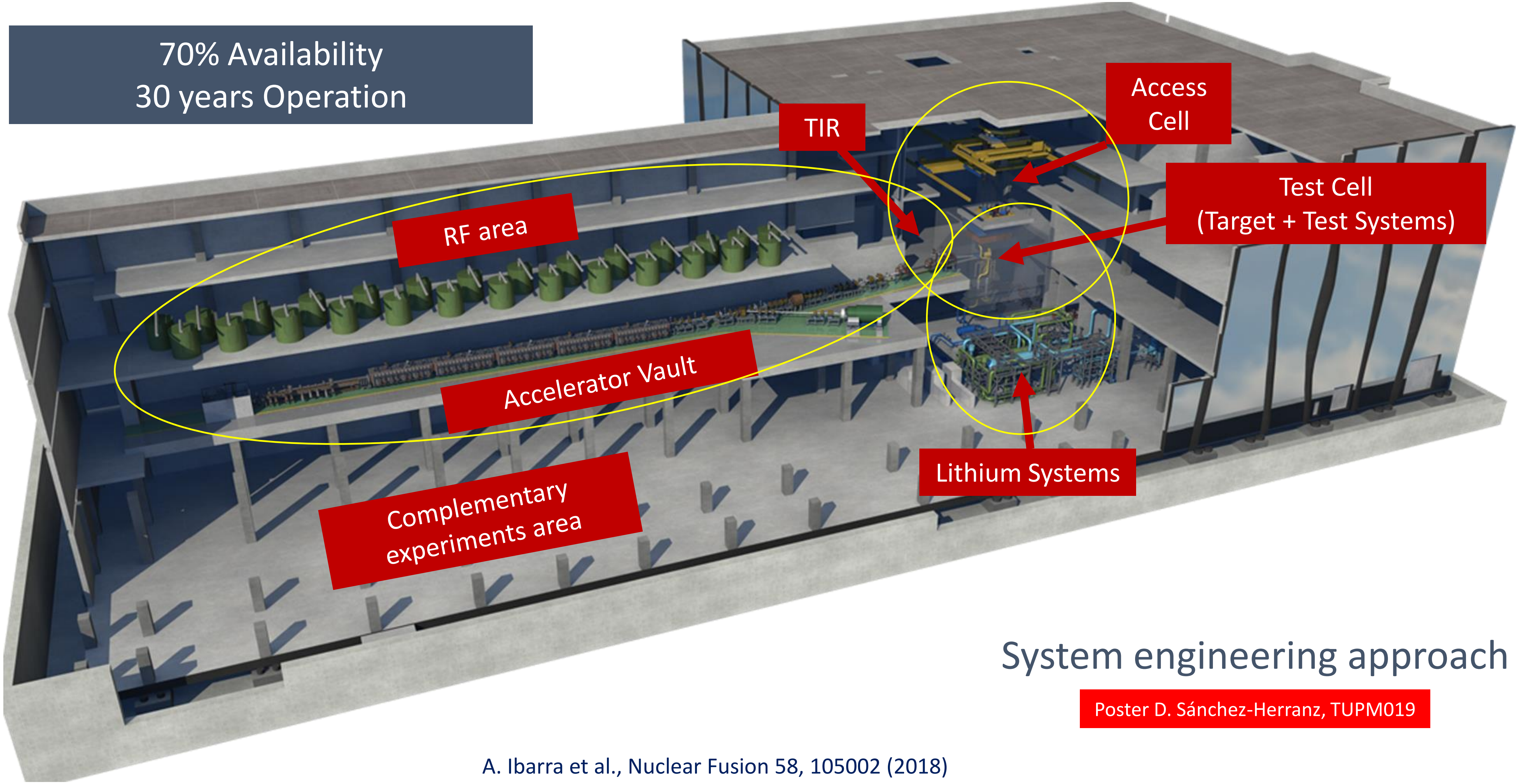
References:

1. U. Wiącek, A. Kurowski, J. Kotuła, R. Ortwein. *System Design Description Document for the IFMIF-DONES Start-Up Monitoring Module (STUMM)*; Technical Report - *EFDA_D_2MNBDB* (2023)
2. U. Wiącek, J. Kotuła, A. Kurowski, R. Ortwein "2022 Update of the STUMM Engineering Design"; Report EFDA_D_2PWFB8 (2023)
3. 3D CAD model of STUMM; EFDA_D_2N5PTM v.2.9 (2023)
4. R. Ortwein, U. Wiącek; *Conjugated heat transfer analysis of the Start-Up Monitoring Module (STUMM) for IFMIM-DONES including heat generation mapping* ; Fusion Eng. Des. 188 (2023) 113451; DOI: https://doi.org/10.1016/j.fusengdes.2023.113451
5. C. Torregrosa-Martin and all, *Overview of IFMIF-DONES diagnostics: Requirements and techniques*; Fusion Eng. Des 191 (2023) 113556
6. U. Wiącek, and all, *New approach to the conceptual design of STUMM: a module dedicated to the monitoring of neutron and gamma radiation fields generated in IFMIF-DONES*, Fusion Eng. and Design 172, 112866 (2021).
7. W. Królas, A. Ibarra and all, *The IFMIF-DONES fusion oriented neutron source: evolution of the design*, Nucl. Fusion 61, 125002 (2021).
8. R. Ortwein, J. Kotuła, U. Wiącek, J. Świerblewski, D. Bocian, *Hydraulic analysis of the start-up monitoring module (STUMM) for IFMIF-DONES*, Fusion Eng. Des., 171 (2021) 112601, doi: 10.1016/j.fusengdes.2021.112601,

- Thank you for your attention

IFMIF-DONES principal system

70% Availability
30 years Operation

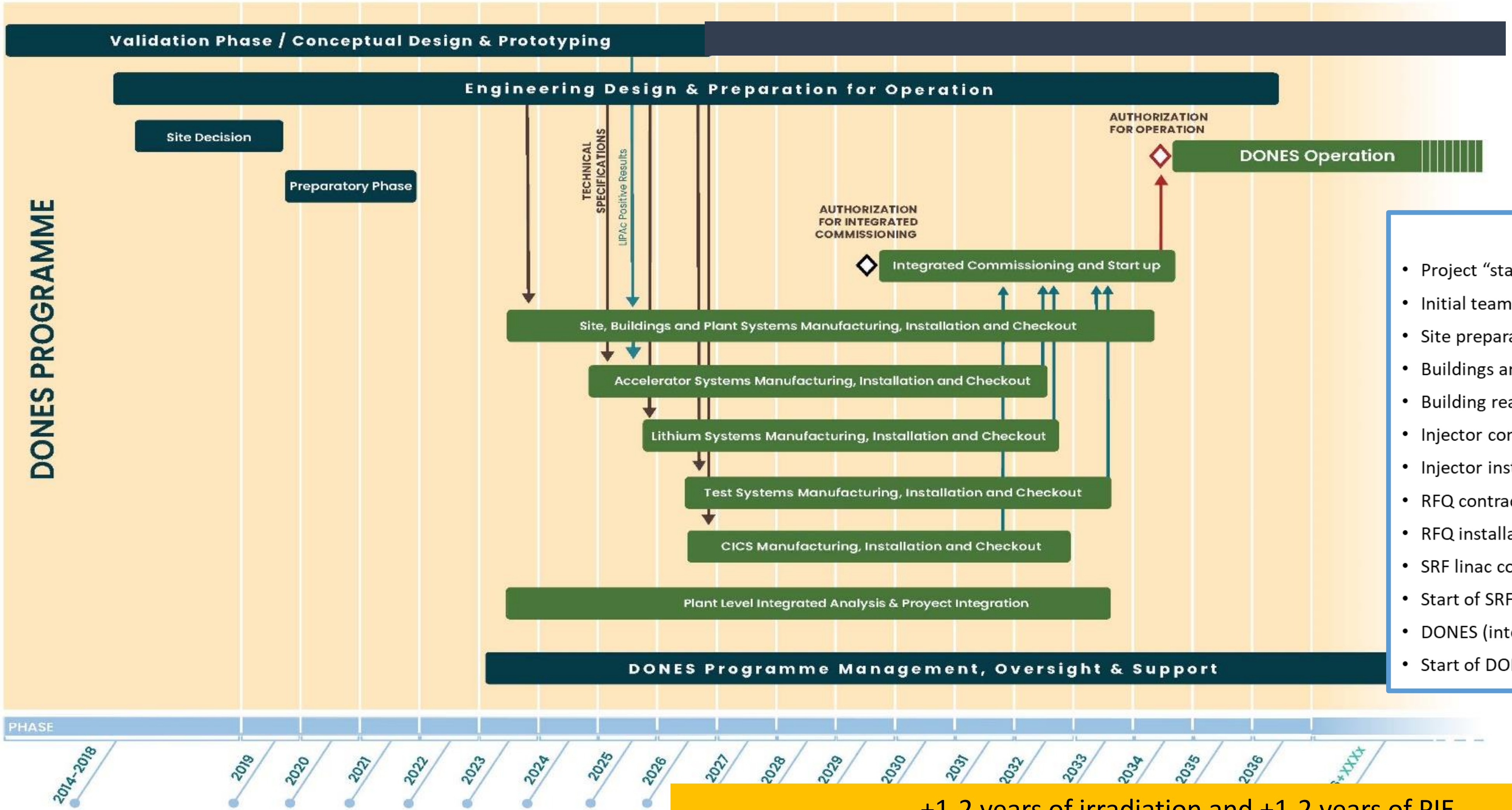


System engineering approach

Poster D. Sánchez-Herranz, TUPM019

A. Ibarra et al., Nuclear Fusion 58, 105002 (2018)
W. Królas et al., Nuclear Fusion 61, 125002 (2021)

DONES Programme Schedule



Critical path milestones

• Project "start"	T0
• Initial team build up	+1 y
• Site preparation contract	+1 y
• Buildings and Plant Systems contract	+2 y
• Building ready	+6 y
• Injector contract	+4 y
• Injector installation	+6 y
• RFQ contract	+4 y
• RFQ installation and commissioning	+7 y
• SRF linac contract	+5 y
• Start of SRF installation and commissioning	+8 y
• DONES (integrated) commissioning	+10 y
• Start of DONES operation	+11 y

Some acceleration could be possible, but not very relevant

+1-2 years of irradiation and +1-2 years of PIE

First materials data around T0+(13-15)y