EUROfusion

Overview of recent advancements in IFMIF-DONES neutronics activities

15th International Symposium on Fusion Nuclear Technology (ISFNT-15) | 10-15 Sept 2023

Y. Qiu,

M. Ansorge, I. Alvarez, K. Ambrožič, T. Berry, B. Bieńkowska, H. Chohan, A. Cufar, T. Deszi, D. Dworak, T. Eade, J. García, D. Jimenez, I. Lengar, A. Lopez, V. Lopez, E. Mendoza, F. Mota, F. Ogando, J. Park, T. Piotrowski, A. Serikov, G. Stankunas, A. Tidikas, G. Tracz, G. Žerovnik, IFMIF-DONES team

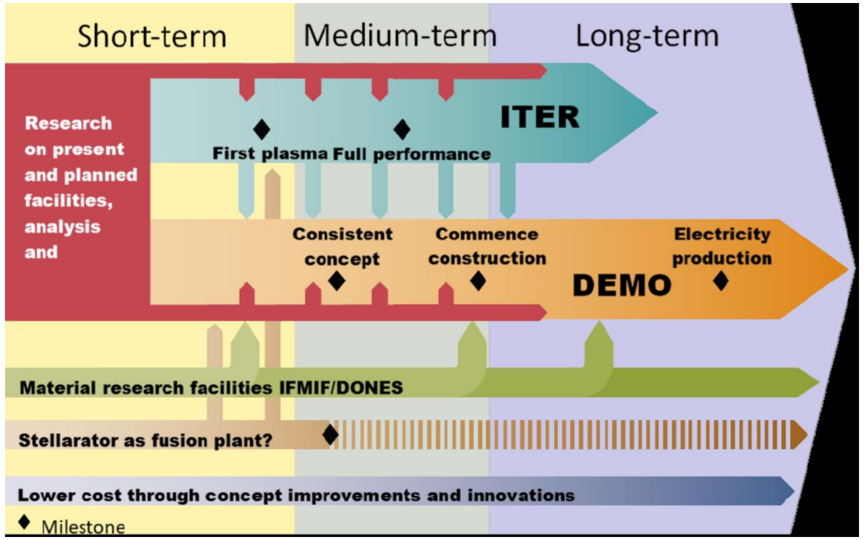
This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053. The views and opinions expressed herein do not necessarily reflect those of the European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

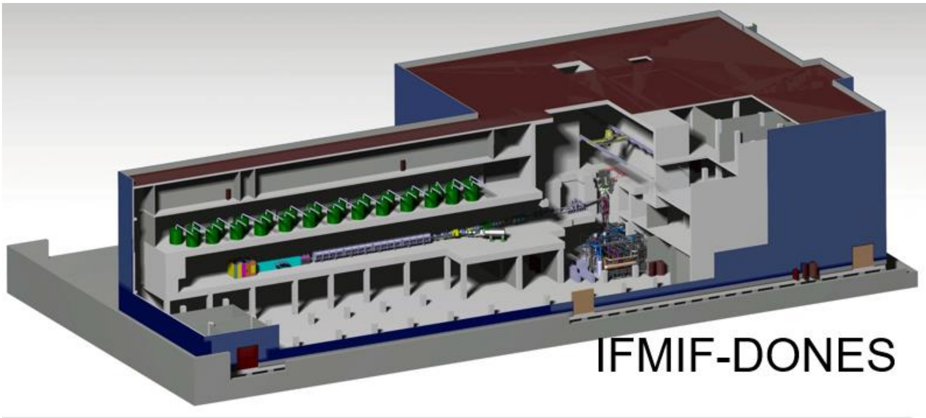
Outlines

- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

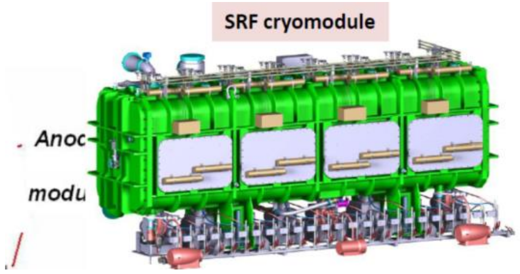
Introduction of DONES and neutronics activities

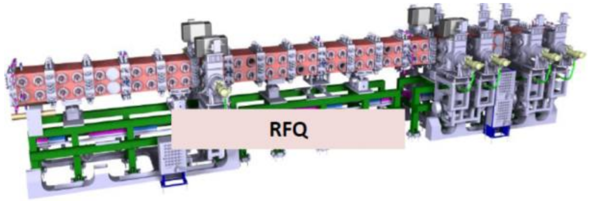
- IFMIF-DONES: International Fusion Material Irradiation Facility - DEmo Oriented Neutron Source
- Provide irradiation data for the construction of DEMO
  - Deuteron-lithium neutron source based on IFMIF using a deuteron accelerator (125 mA, 40 MeV)
  - DONES Construction phase will be started in the 2024-2025s in Granada (Spain). The first neutron is expected in early 2030
  - One of the three important facilities of the roadmap
- Work Package Early Neutron Source (WPENS)
  - Project of EUROfusion, hand-over phase to IFMIF-DONES España consortium
  - Lead by CIEMAT and contributions from 16+ research units.

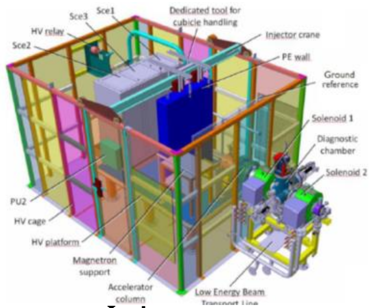




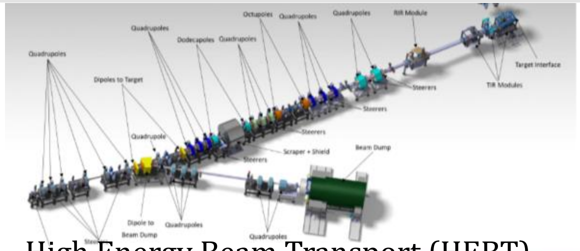
Introduction of DONES and neutronics activities



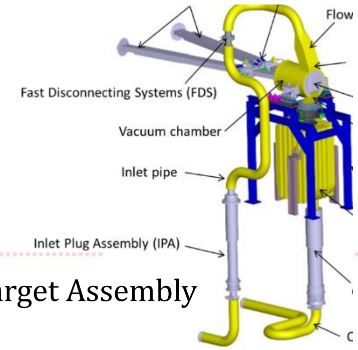




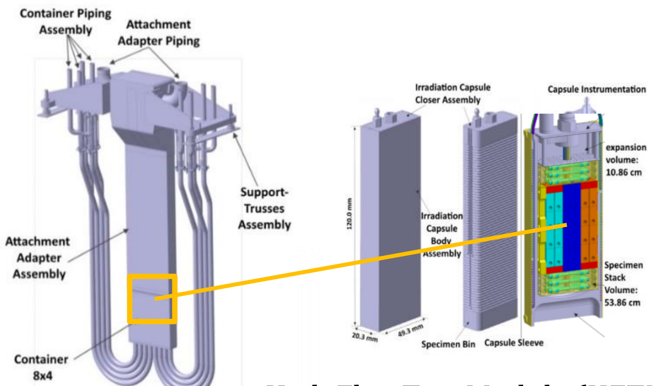
Injector



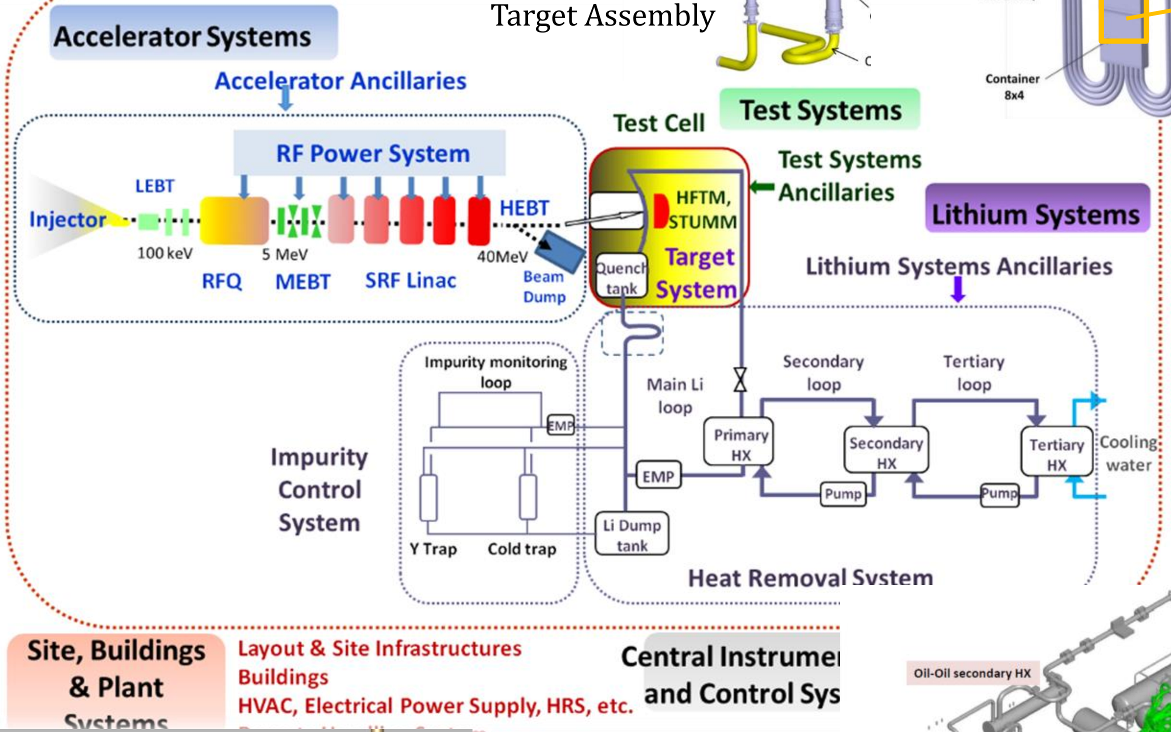
High Energy Beam Transport (HEBT)

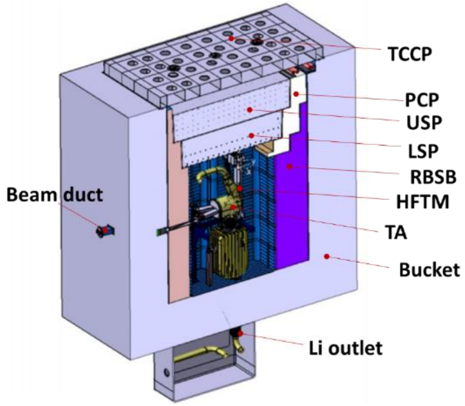


Target Assembly

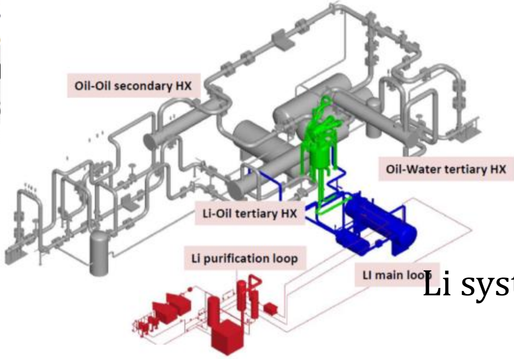


High Flux Test Module (HFTM)



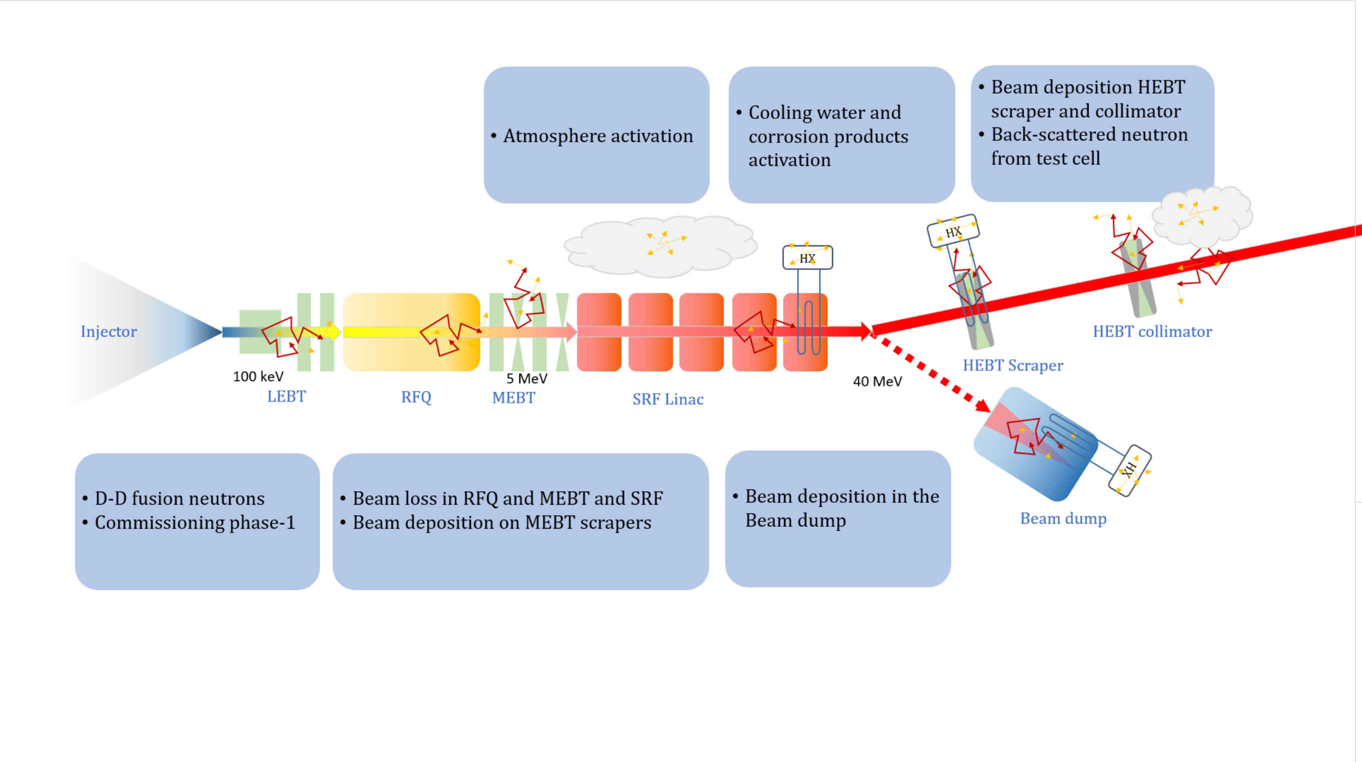


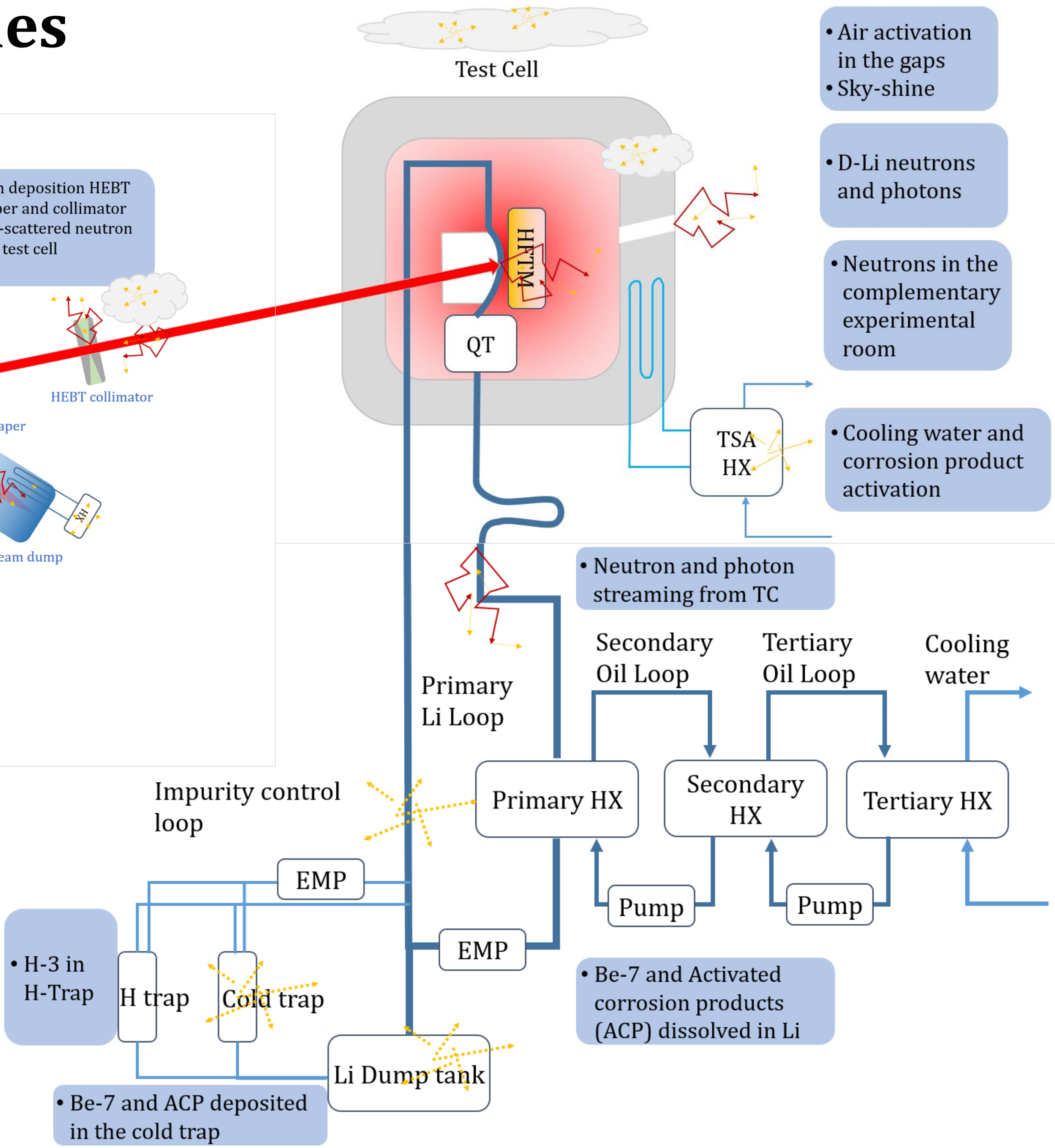
Test Cell

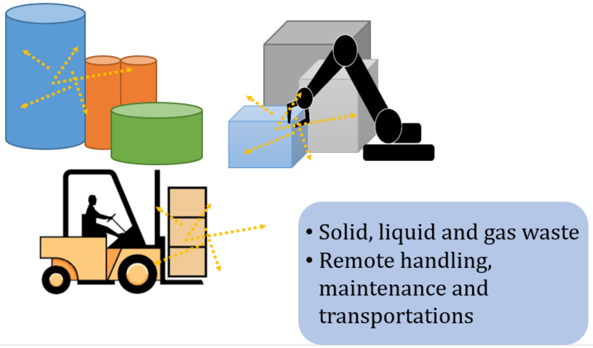


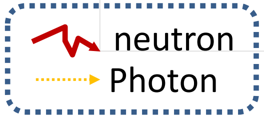
Li system

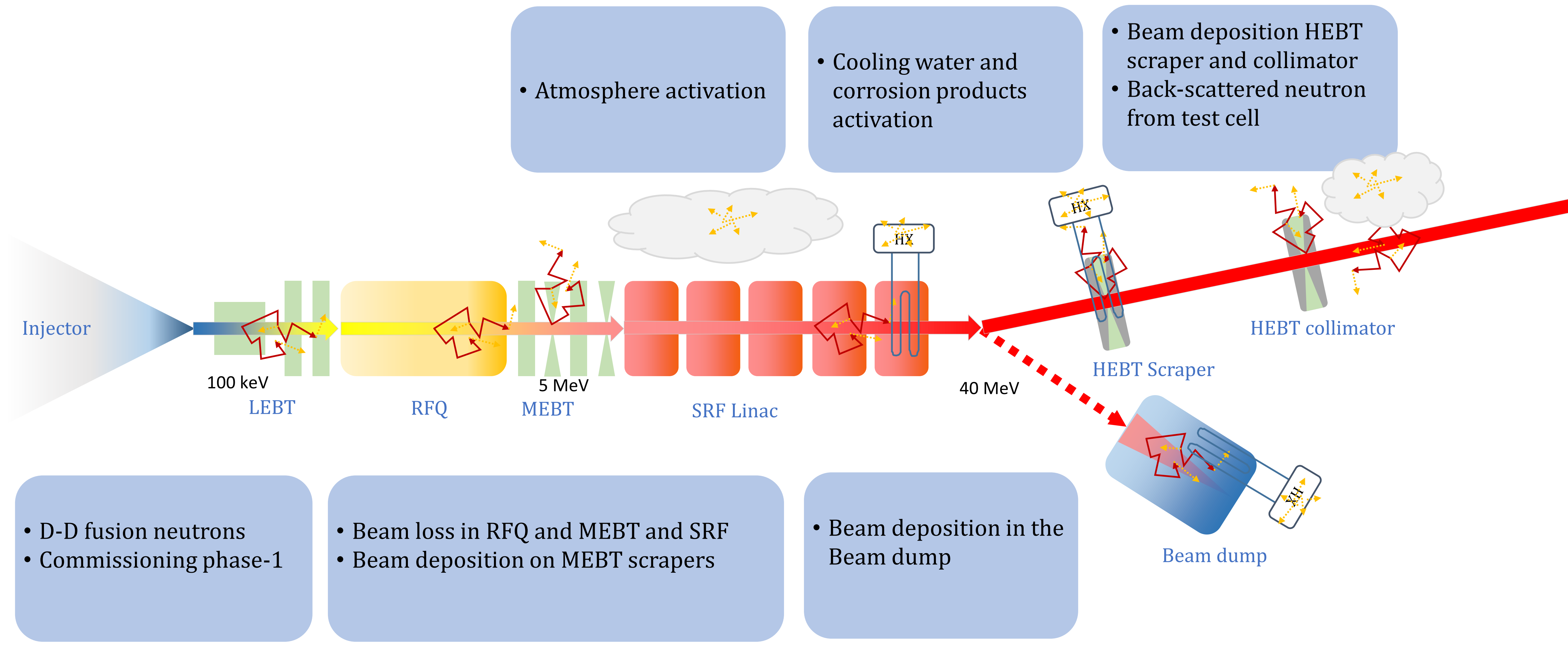
Introduction of DONES and neutronics activities



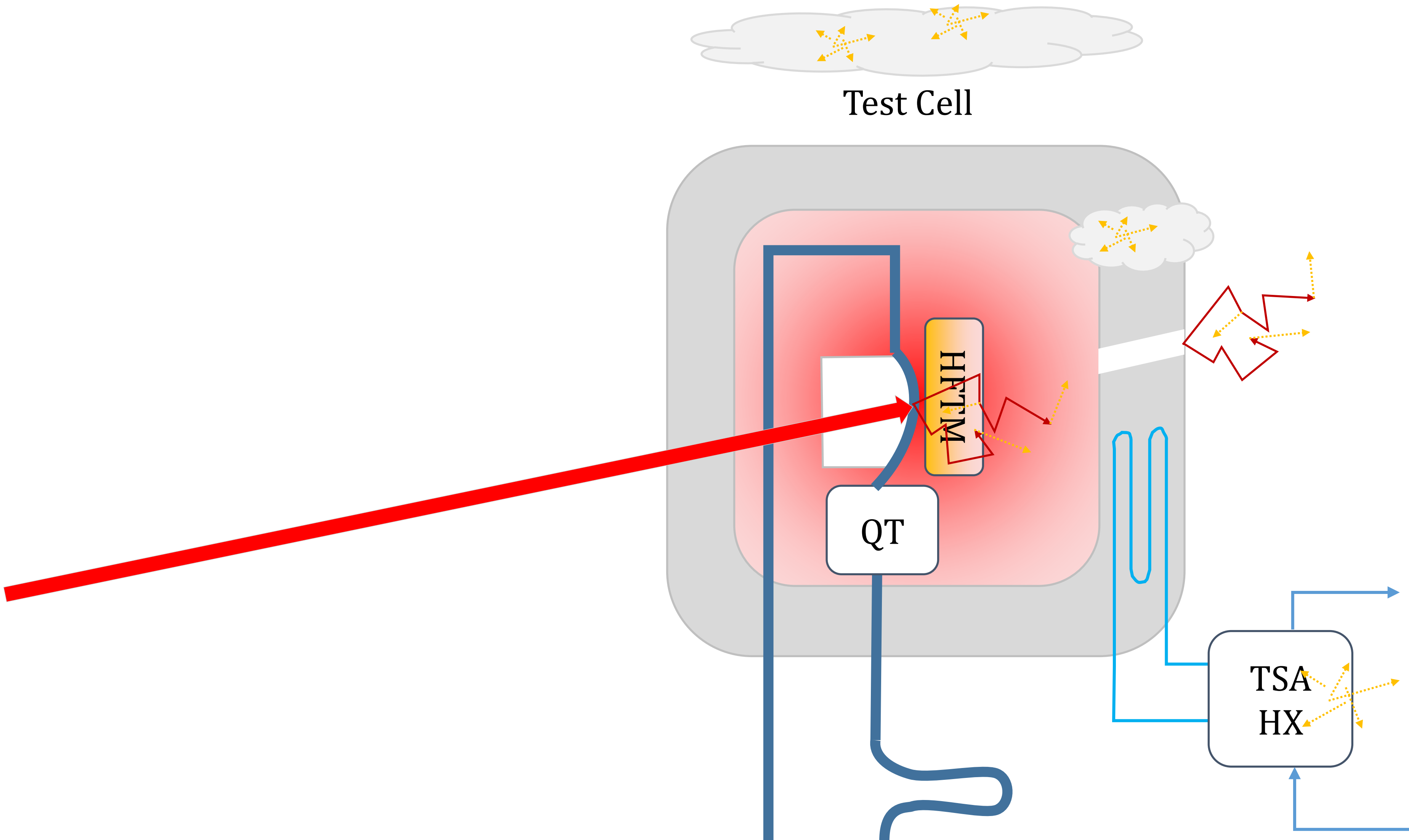








• Atmosphere activation
• Cooling water and corrosion products activation
• Beam deposition HEBT scraper and collimator
• Back-scattered neutron from test cell
Injector
100 keV
LEBT
RFQ
5 MeV
MEBT
SRF Linac
HX
40 MeV
HEBT Scraper
HEBT collimator
Beam dump
• D-D fusion neutrons
• Commissioning phase-1
• Beam loss in RFQ and MEBT and SRF
• Beam deposition on MEBT scrapers
• Beam deposition in the Beam dump

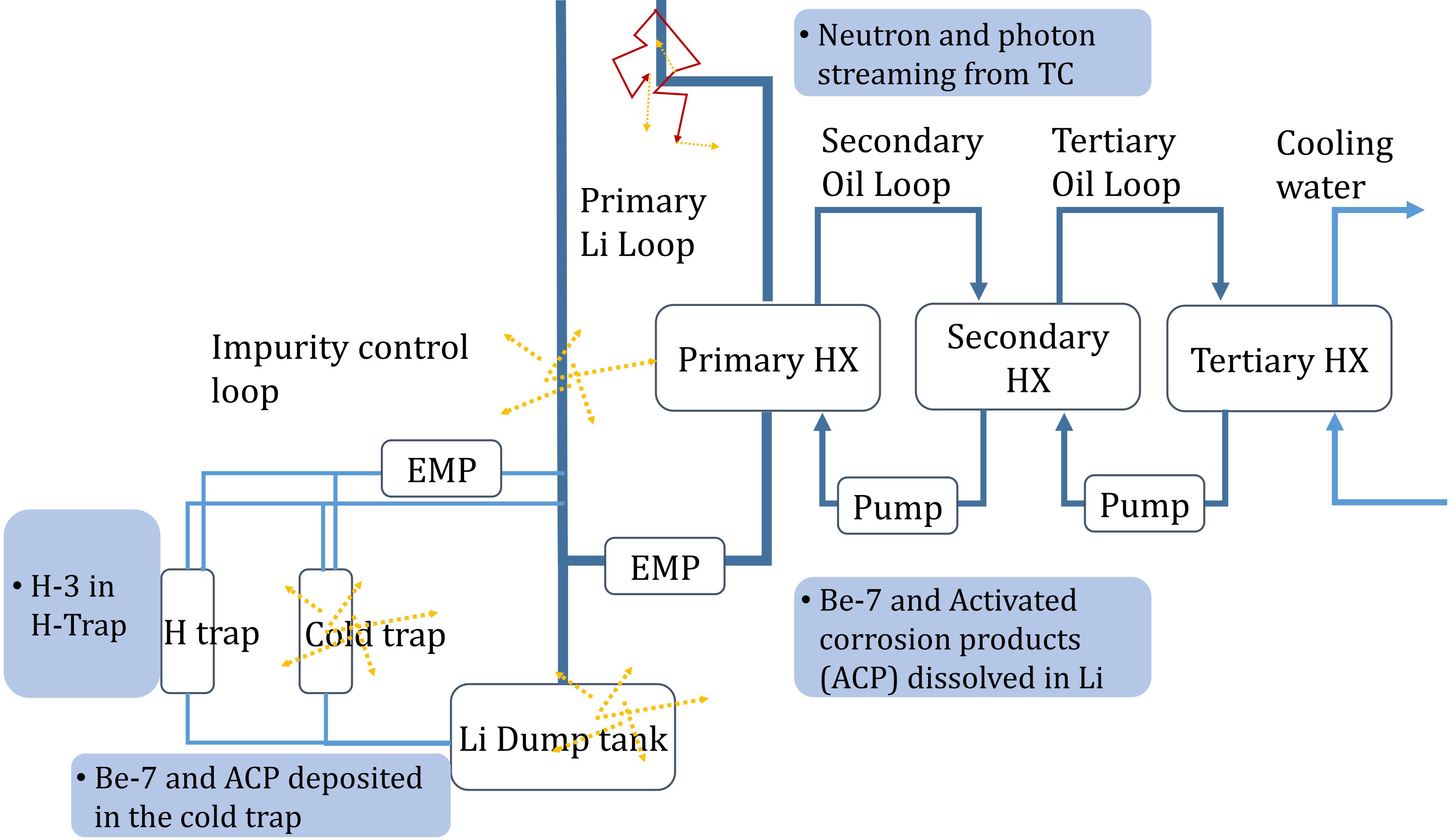


- Air activation in the gaps
- Sky-shine

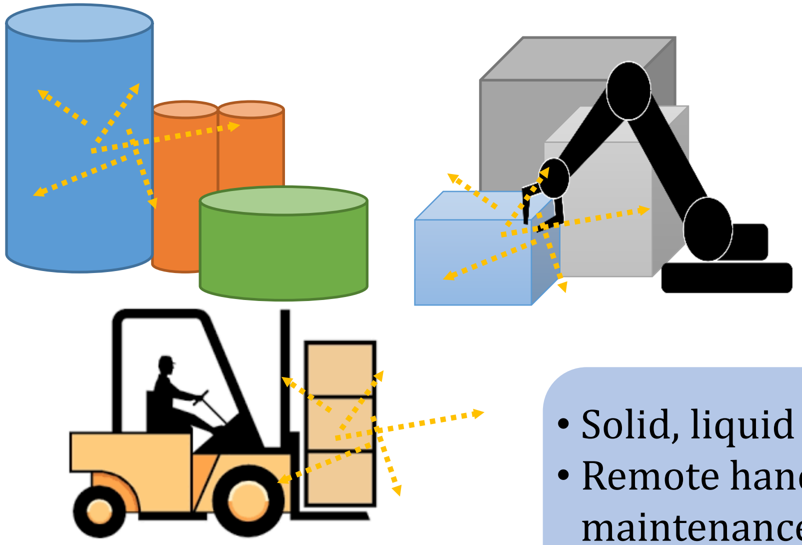
- D-Li neutrons and photons

- Neutrons in the complementary experimental room

- Cooling water and corrosion product activation

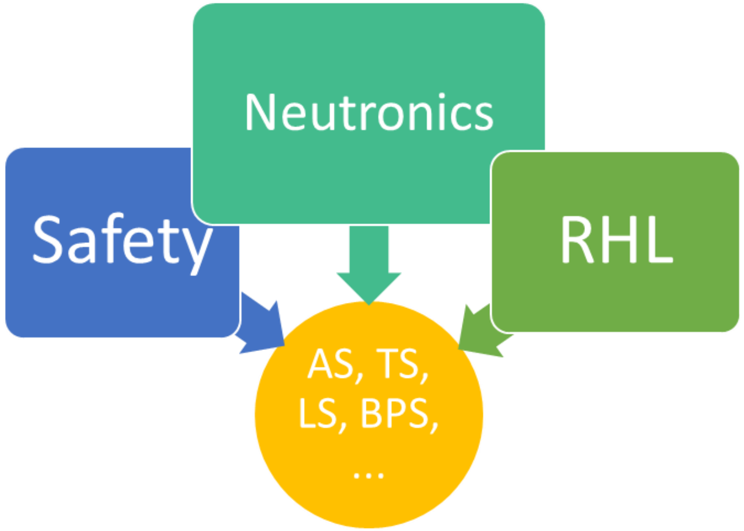


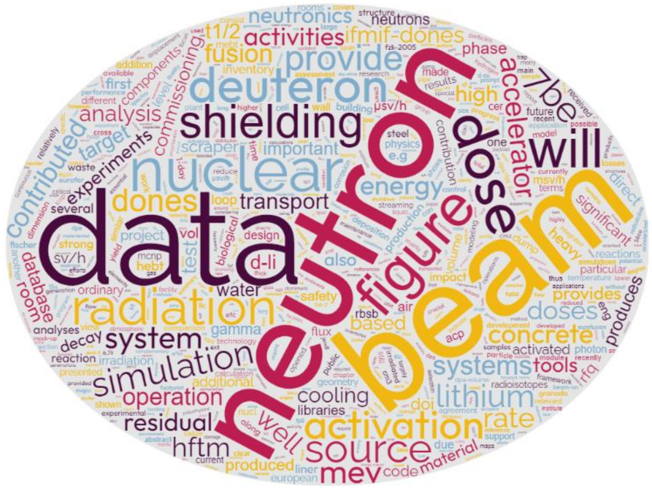
• Neutron and photon streaming from TC
Primary Li Loop
Secondary Oil Loop
Tertiary Oil Loop
Cooling water
Impurity control loop
Primary HX
Secondary HX
Tertiary HX
EMP
Pump
Pump
EMP
• H-3 in H-Trap
H trap
Cold trap
Li Dump tank
• Be-7 and Activated corrosion products (ACP) dissolved in Li
• Be-7 and ACP deposited in the cold trap



- Solid, liquid and gas waste
- Remote handling, maintenance and transportations

- Neutronics activities in WPENS
  - **Plant-level transversal activities** relevant to accelerator system(AS), test system (TS), lithium system (LS), building and plant system (BPS), safety, remote handling and logistics (RHL).
  - The analysis activities include design analyses and optimization, radiation dose maps, radiation shielding and ALARA, activation and inventory, models, tools and data developments, experimental benchmarks and validations.
- Achievements
  - Involvement of 20 scientists from 10 European research units
  - Accomplished a total of **80+ subtasks and ~240 ppm** of resources in the past 3 years



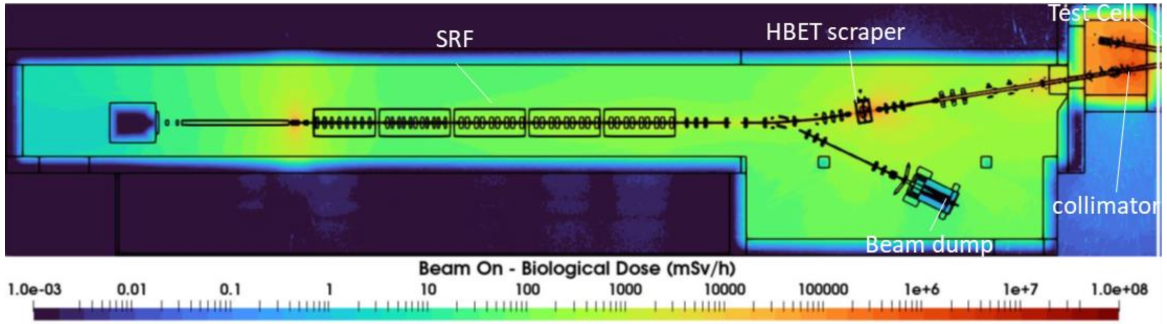


Outlines

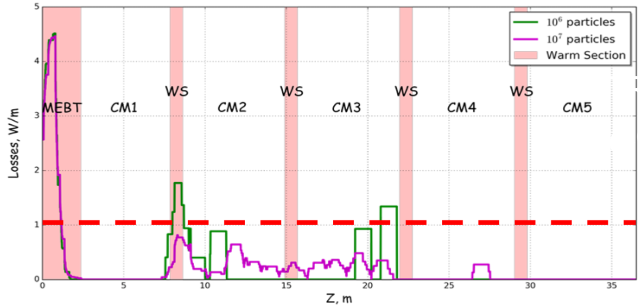
- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system (AS)
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

AS radiation source terms

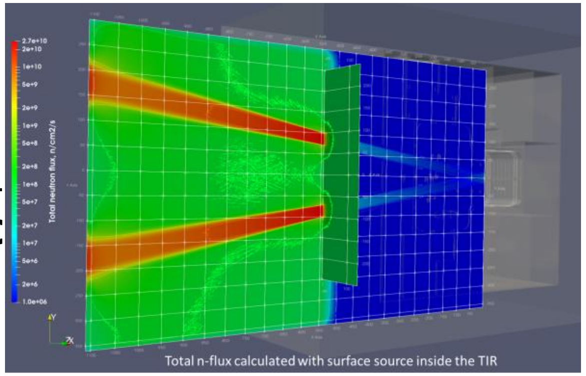
- Radiation source terms
  - Deuteron beam losses and depositions
  - Activated AS components
  - TC back-streaming neutron and gamma.
  - Activated cooling water, air and argon atmosphere
- Radiation from RFQ, MEBT and SRF
  - 1 W/m beam losses assumption for safety evaluation, while higher realistic beam losses are used for the RFQ and MEBT analyses.
  - 2x 0.6 kW beam deposition at 5 MeV in two MEBT copper scrapers.
  - 40 MeV deuteron beam, deposited power 2.4 kW at the HEBT scraper and 3.2 kW at the HEBT collimator.
  - Beam dump copper cone cartridge accepts 1% duty cycle of deuteron beam (~50 kW) at 40 MeV.
  - Radiation from TC: Neutron flux in the level of 10^{10} n/cm2/s at the TIR



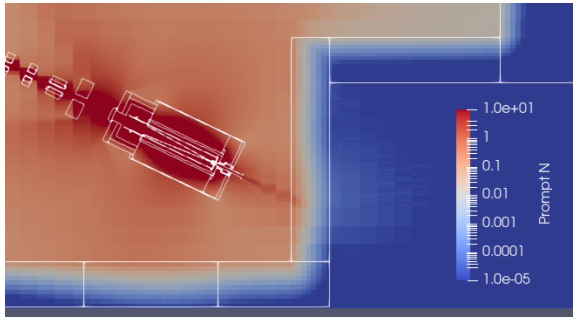
Accelerator rooms beam-on total doses maps (mSv/h)



Simulated beam losses in the SFR



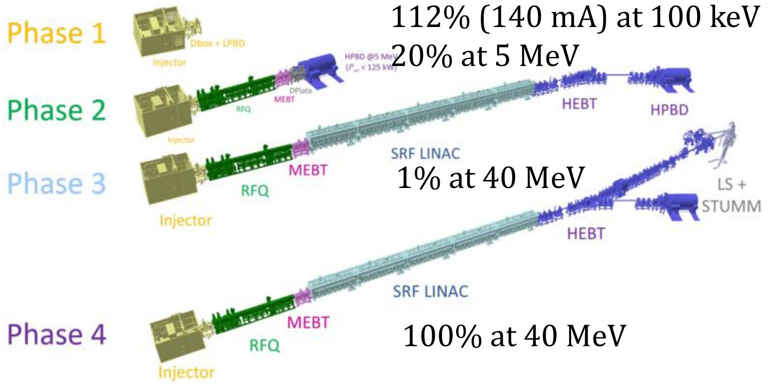
Neutron flux back-streaming from TC ($n/cm^2/s$)



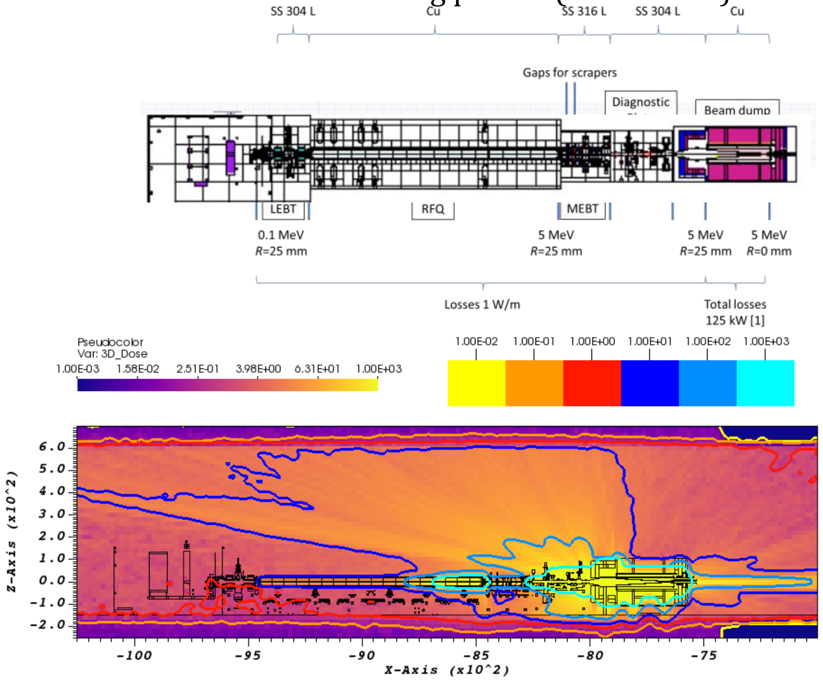
Prompt neutron dose rate (Sv/h) of BD on 1% duty cycle

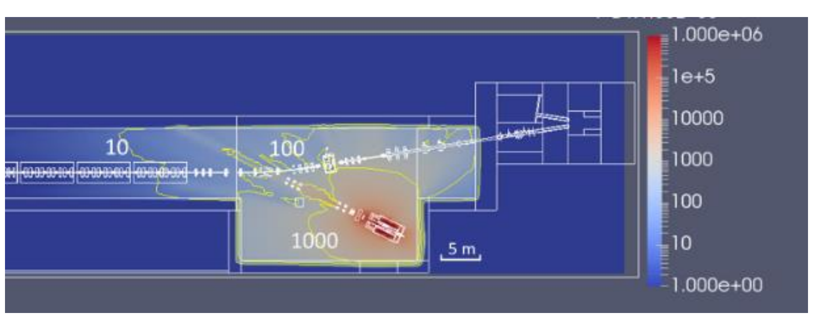
Commissioning studies

- Nuclear analysis in Phase 1
  - Deuteron energy is lower than the threshold of interaction with the Copper dump.
  - The **dominant reaction is (D, D) reactions**, and produced 2.54 MeV neutrons.
  - Neutron yield is estimated to be 1.6– 3.6 $\cdot 10^9$ n/s, the measurement performed in the LIPAc measurement is ~**9.4 $\cdot 10^8$ n/s**.
- Nuclear analysis in Phase 2
  - Detailed neutronics model consists of >9000 bodies, multiple steps of deuteron and neutron simulations
  - Two months of commissioning, 1-hour cooling: Residual dose above 100 µSv/h of biological doses close to the MEBT and HPDB entrance, above 10 µSv/h in the meters around the accelerator
- Nuclear analysis in Phase 3
  - 4 years of conservative commissioning and 1-hour cooling
  - Residual dose in several mSv/h surrounding the HPBD.
- Providing key support for obtaining the **licensing for the commissioning phases** and maintenance planning.

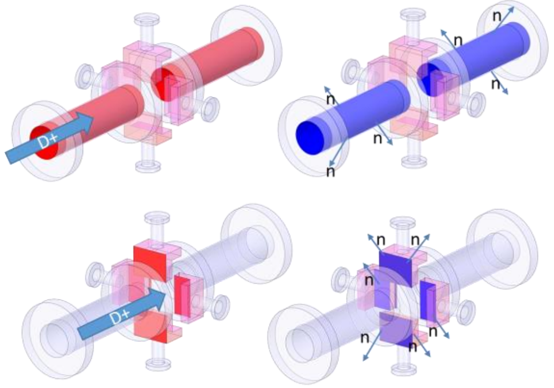


DONES accelerator commissioning phases (I. Podadera)





Total residual dose rate (µSv/h) in **Phase 3** (1-hour cooling)



Decay photon source from different contributions

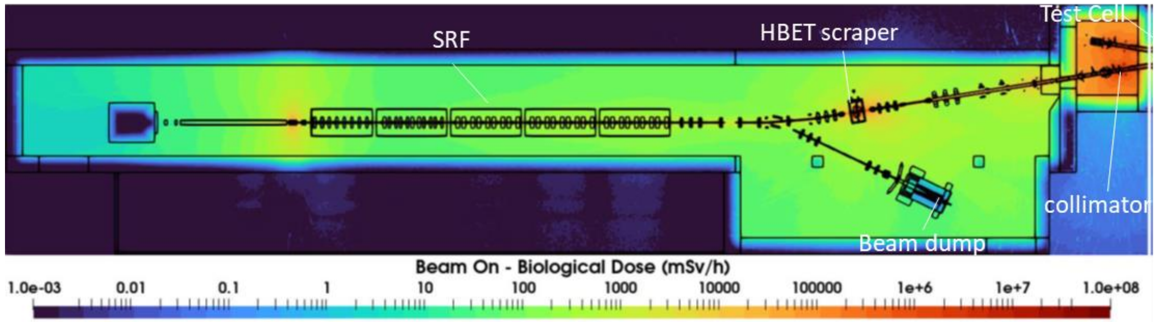
Total residual dose rate (µSv/h) in **Phase 2** (1-hour cooling)

Doses during normal operations and maintanence

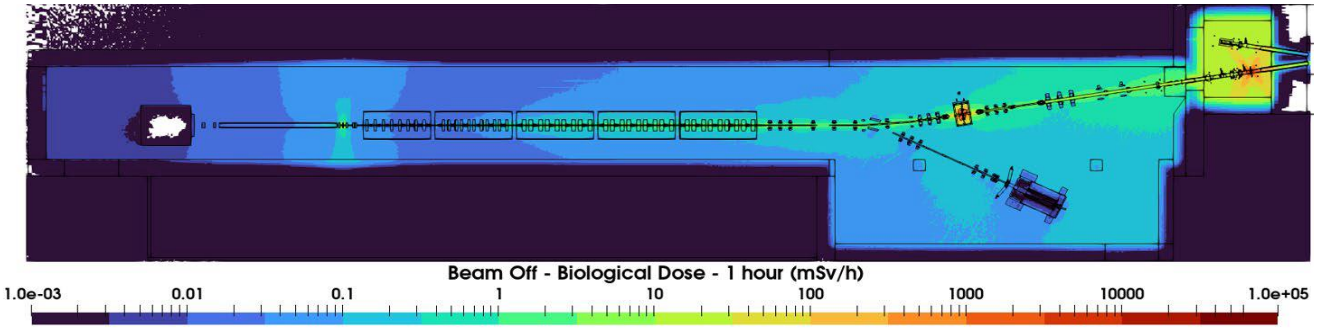
- Beam-on and beam-off analyses during normal operation
  - Full map of accelerator rooms with updated geometry and materials.
  - Taking account neutron and photon from deuteron and neutron interactions, as well as neutron/photon from TC.
  - Determination of beam-on biological dose maps and beam-off biological dose maps after 1 hour, 1 day and 1 week of cooling time
  - Dose maps updated in yearly basis

Maximum residual biological dose values (mSv/h) at 1-day after shutdown

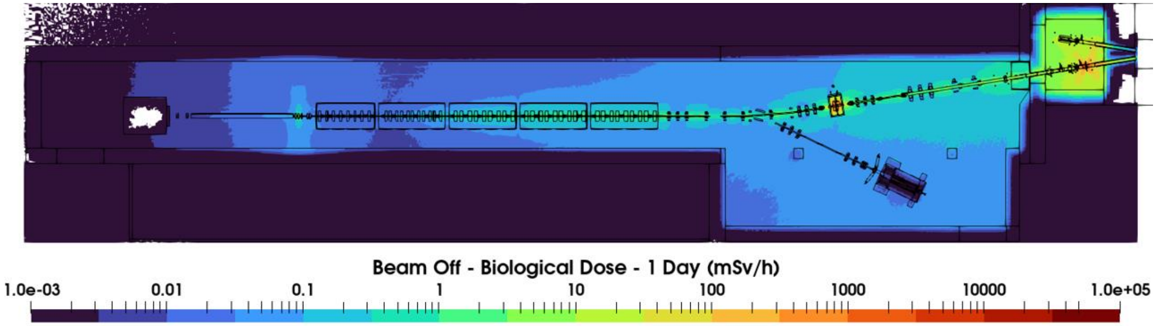
Region	Maximum dose (mSv/h)
Injector +LEBT	0.01
RFQ	0.11
MEBT	18.7
SRF-CM1	0.11
SRF-CM2	5.04
SRF-CM3	7.57
SRF-CM4	4.07
SRF-CM5	33.6
HEBT scraper	17830
RIR+IC	7.91
Beam dump	0.36



Biological dose (mSv/h) during operation of the accelerator in the AS room



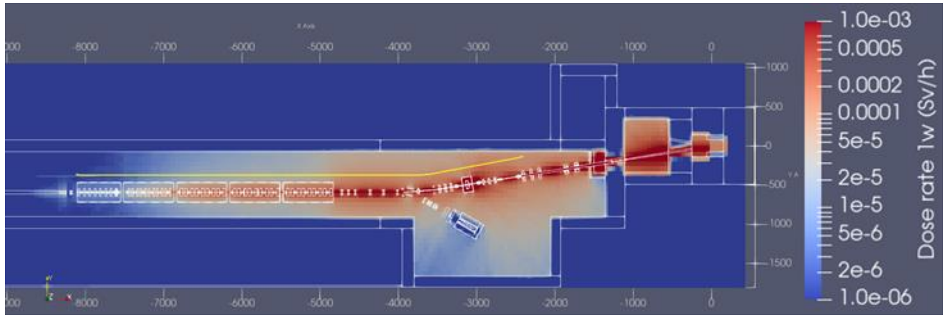
Biological dose (mSv/h) at 1-hour of cooling time in the AS room



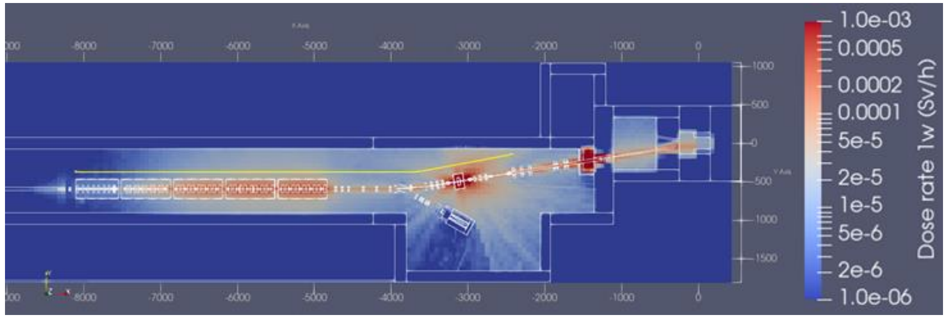
Biological dose (mSv/h) at 1-day of cooling time in the AS room

ALARA optimizations

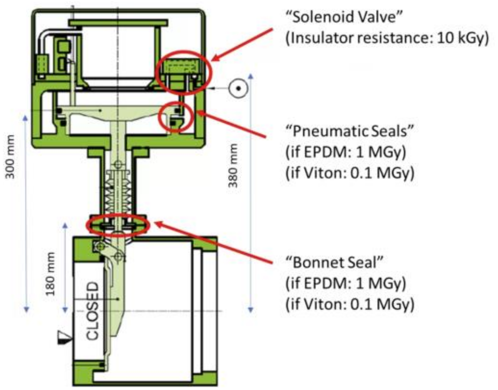
- Aluminum v.s. Stainless Steel as beam-facing material.
  - Residual dose from deuteron and neutron activation. 1 W/m beam losses assumption
  - Aluminum results in lower doses and faster decay, thus Aluminum are suggested to be beam-facing material.
- Fast isolation valve (FIV) shielding optimizations
  - FIV are safety class machine protection valves
  - With local neutron and photon shielding and additional shadows in the shielding plug, durability is **extended from 1 year to 3 year**

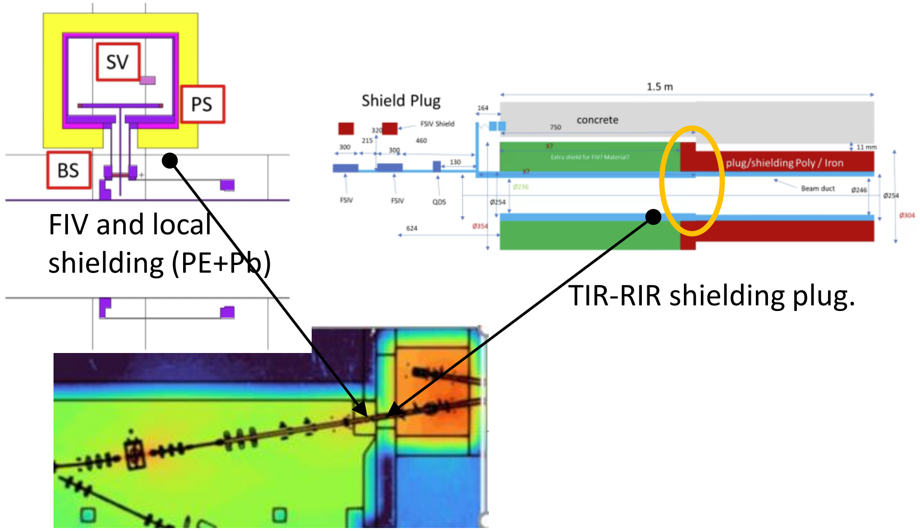


Dose rate [µSv/h] calculated using **Steel** (1-week)



Dose rate [µSv/h] calculated using **Aluminum** (1-week)





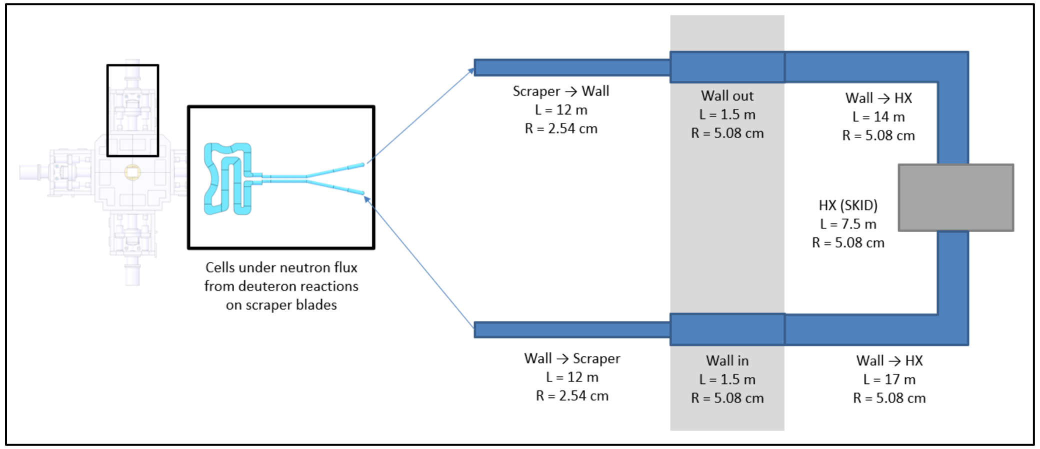
Dominant nuclei for deuteron-activated contact doses

Aluminum	Stainless steel
• Na-24 (T=12h): 1 day 86%, 1w: 0.3% • Co-56 (T=77d): 1d: 2%, 1w: CD 16% • Na-22 (T=2.6y)1d: CD 8.6%, 1w: 67%	• Co56 (CD 66-75%, T=77d) • From Fe56(d,2n) • Mn52 (CD 17-9%, T=5.6d) • Mn54 (CD 7%, T=312d)

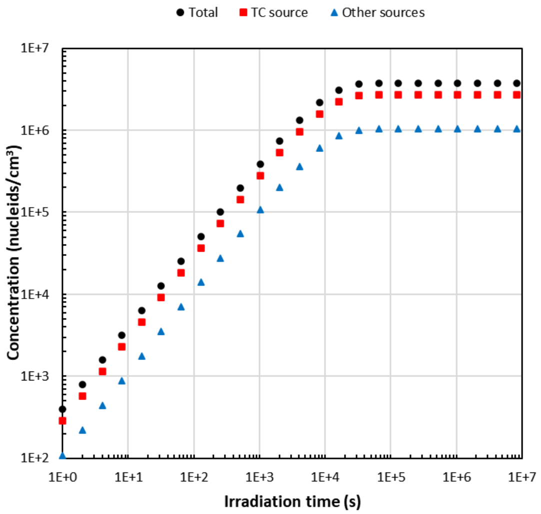
Water and air activation

- **HEBT scraper cooling water analysis**
  - Detailed models of the water flow paths and fluid activation using Actiflow code.
  - ACP is taken into account, but no significant impact due to the low corrosion rate in CuCrZr at the low temperature of 20-30 °C.
  - Total activity in range of 1E+05 Bq per kg, dose rates **<1 μSv/h per litre**
- **Airborne contamination analysis**
  - Air (1.28% of Argon) is filled in the AS rooms, and TIR will be filled with Argon.
  - ^{41}Ar Production in **TIR (target interface room)**: equilibrium ~ 19.4 hours, total activity **$8.202 \cdot 10^{10}$ Bq,** which requires decay volume or cooling time before access.
  - ^{41}Ar Production **AS rooms**: equilibrium ~ 17 minutes, total activity: $1.004 \cdot 10^7$ Bq.

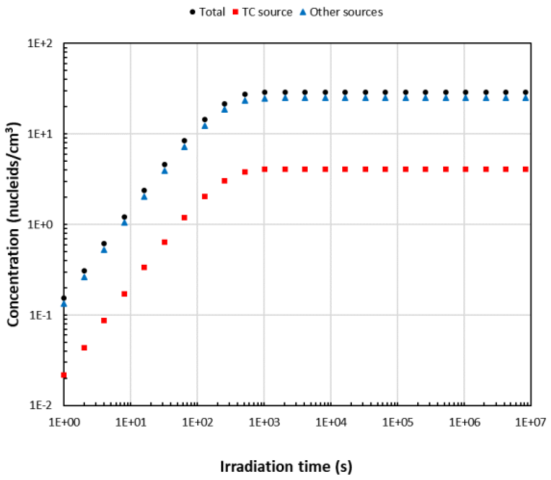
$^{40}Ar + n \rightarrow {}^{41}Ar + \gamma$ Ar-41 $\tau = 1.8\,h\,, E = 1.29\,MeV$



Geometry of water circuit for scraper water cooling system



^{41}Ar Production in **TIR**



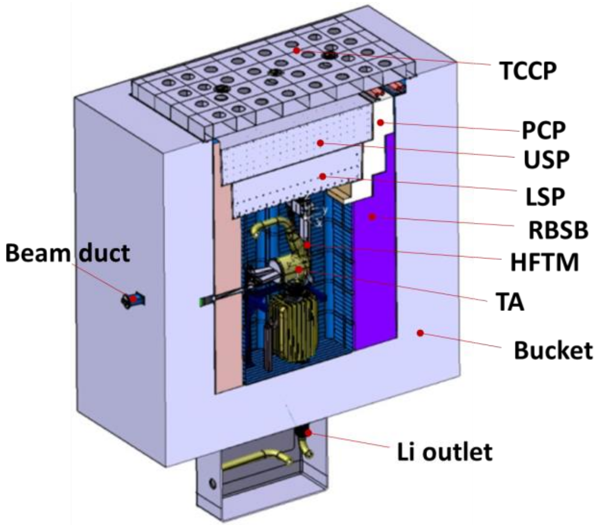
^{41}Ar Production **AS rooms**

Outlines

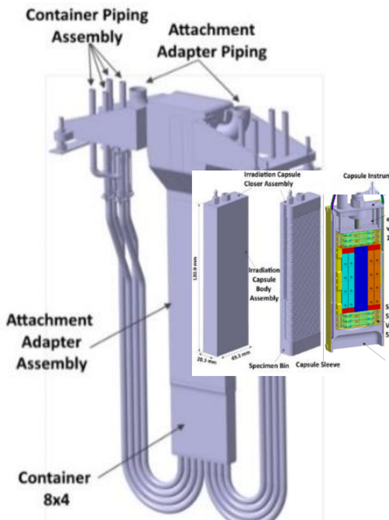
- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system (AS)
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

Test system source terms

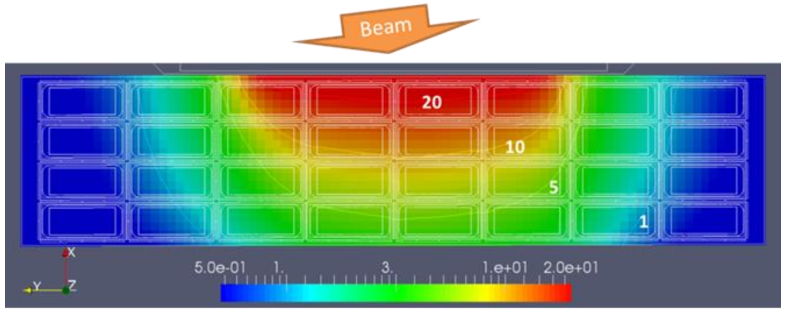
- Test cell (TC) and high flux test module (HFTM)
  - Test cell houses the target assembly (TA) and the HFTM, and provides shielding with the Removeable shielding blocks (RBSB), bucket and several shielding plugs (PCP, LSP, USP, TCCP).
  - HFTM houses the material samples and the center irradiation capsules with active temperature control.
- Neutrons production from the target
  - Total neutron yield of **6.8 10^{16} n/s**, neutron flux up to **10^{15} n/cm^2/s** at the target, and 1-5 10^{14} n/cm^2/s at the high flux test module (HFTM) region. Damage rate in the range of **5-20 dpa/fpy** in the centre capsules
  - Neutron dose rate in the TC attenuates **from 10^{12} μSv/h to < 1000 μSv/h** in beam downstream, and < 1 μSv/h in the lateral walls. Very challenging shielding analyses.



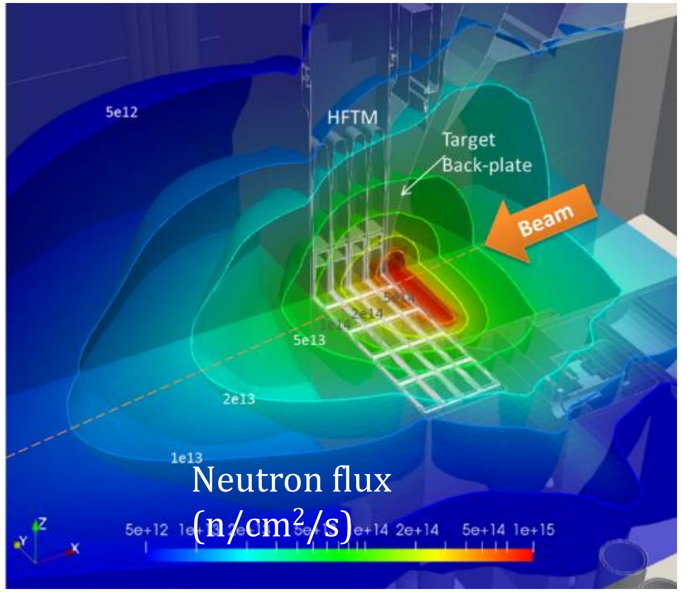
TC CAD model

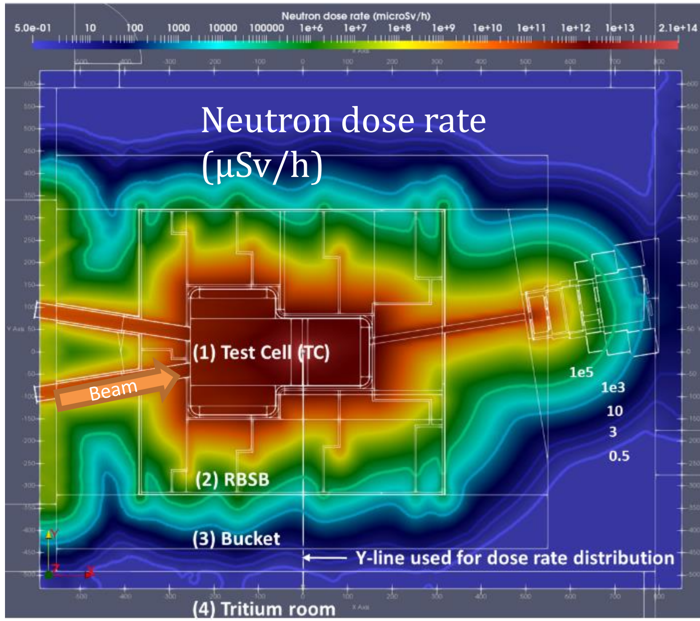


High Flux Test Module (HFTM)



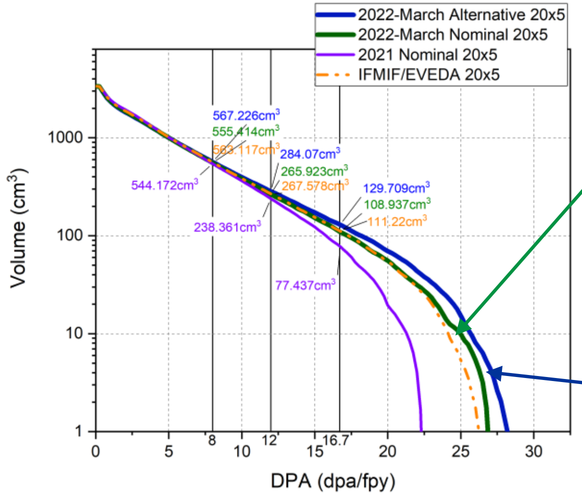
Displacement damage rate (dpa/fpy)



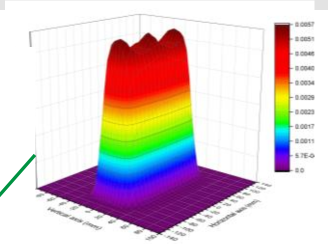


Nuclear analyses for the target and HFTM

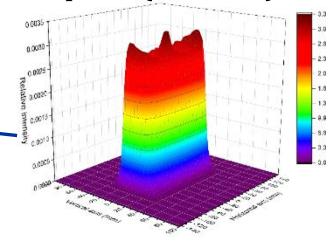
- New reference beam profiles
  - Deuteron beam impings on Li target with a semi-rectangular footprint of 20x5 cm^2 (nominal) 10x 5 cm^2 (reduced)
  - New beam profiles have been proposed to provide the balance of high damage dose and irradiation gradients.
  - The alternative beam footprint provides a higher volume at high damage rate.
- Deuteron beam heating deposition
  - Simulation of fine-resolution deuteron heating deposition on Li using charged-particle transport function of MCNP6 (coupled d, n, p and proton transport).
  - High-fidelity heating data provided for Thermal hydraulics analysis of TA.
- Updated HFTM nuclear responses with detailed sample model
  - Aiming for estimation of neutron dose uncertainty in samples the HFTM
  - Simulation shows that the DPA-volume are similar on both the homogenous model (h.m.) and detail sample model (s.m.)



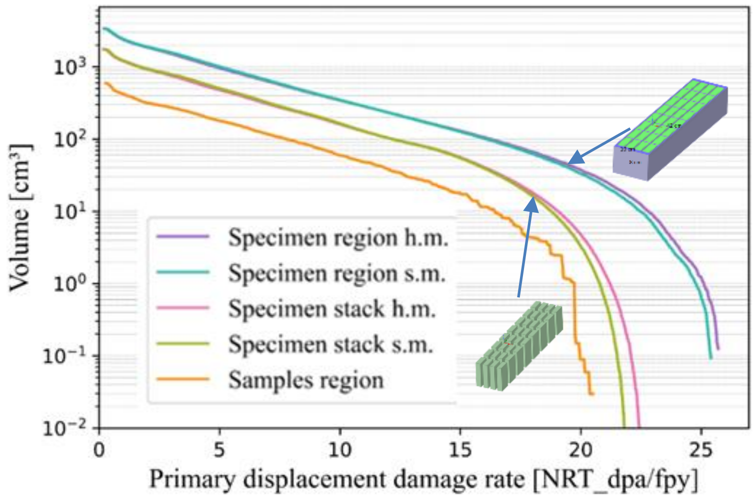
Cumulative volume v.s. damage rate



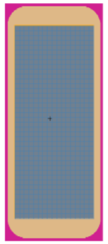
IFMIF reference beam footprint (nominal)



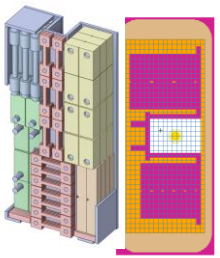
New alternative beam footprint with center peak (nominal)



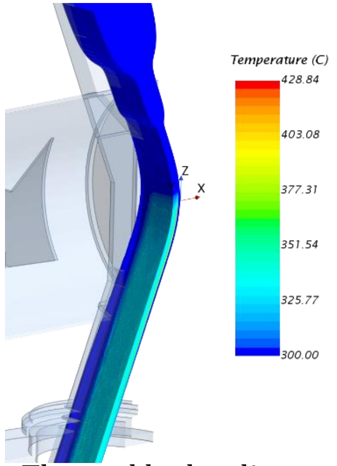
Primary displacement damage rate [dpa-NRT/fpy]



homogeneous rigs (h.m.)

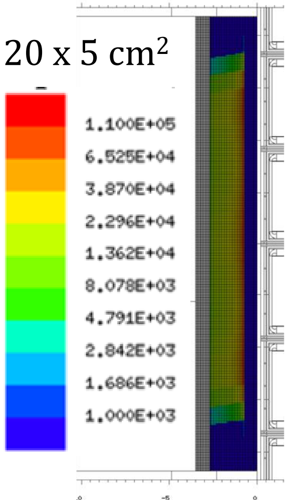


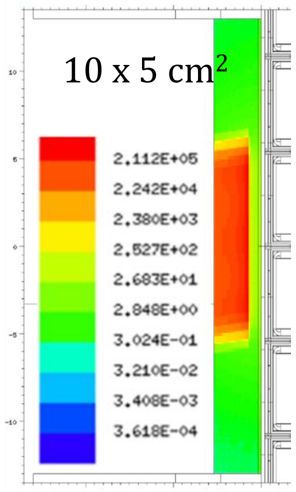
samples in rigs (s.m.)



Thermal hydraulics analyses of Li flow

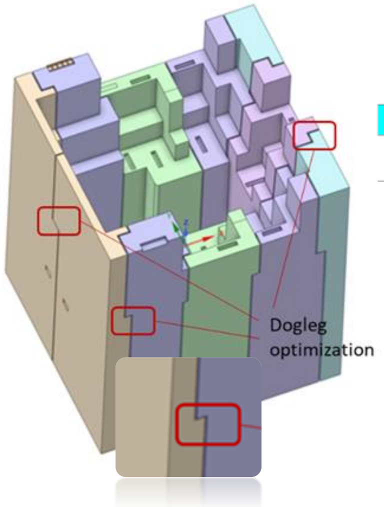
Deuteron heat deposition (W/cm^3)

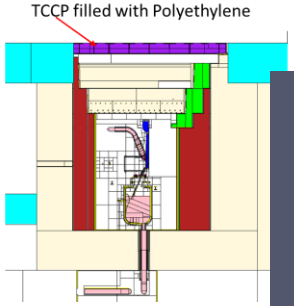


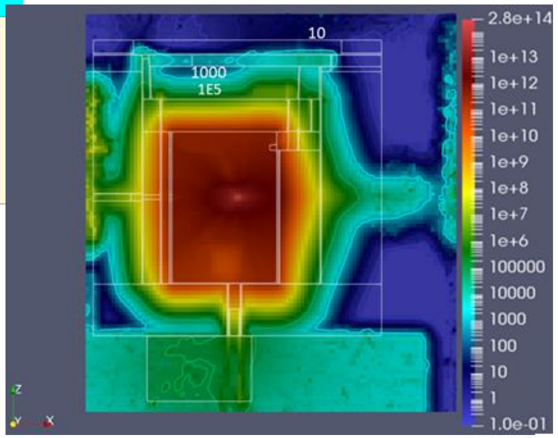


ALARA optimizations

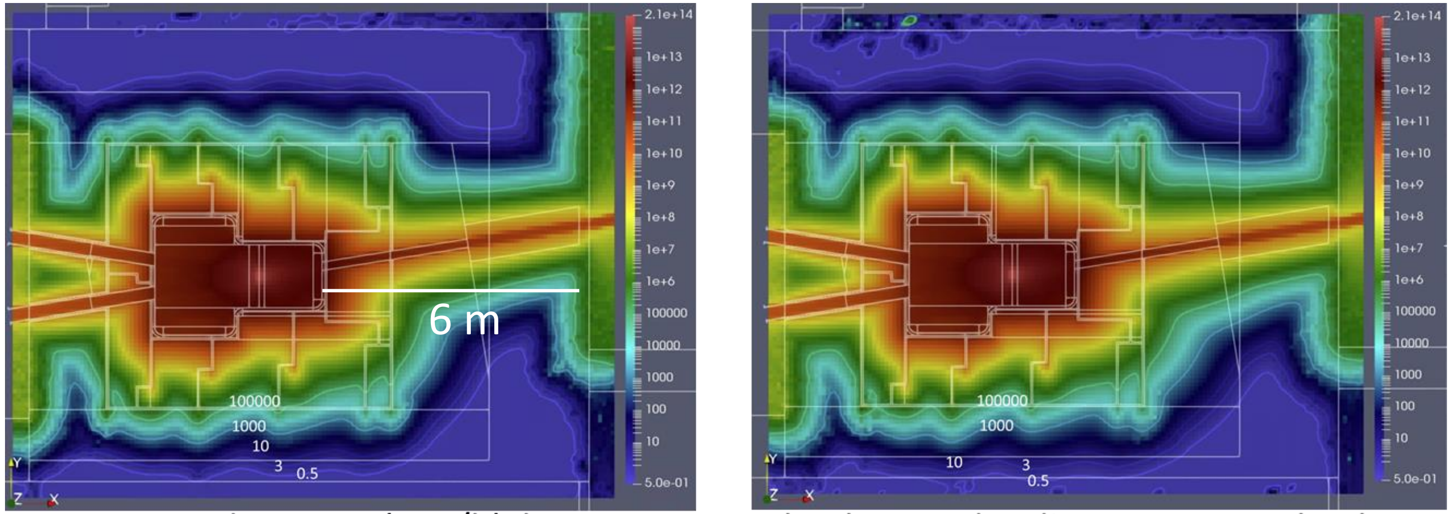
- Shielding optimization for the RBSB
  - RBSB implements dog-legs to mitigate the neutron streaming through the 40 mm gaps
  - Vertical dog-legs introduce many complexities for remote handling,
  - It was replaced by polyethene shielding in the test cell cover plate (TCCP)
- ALARA optimization for the bucket
  - The bucket was designed to use heavy concrete.
  - High fidelity shielding analyses show shielding effects are comparable.
  - **Cost reduction of 6x** , as well as weight reduction of >50%







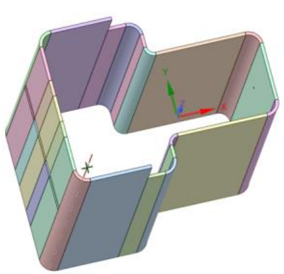
Neutron dose rate (μSv/h)



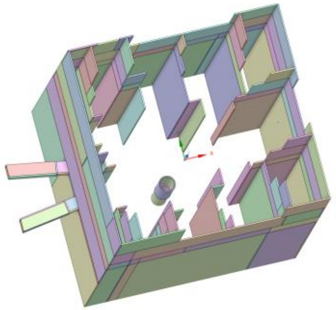
Neutron dose rate (μSv/h), heavy concrete bucket and ordinary concrete bucket

Air activation and sky-shine

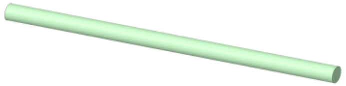
- Activation for the Air in the TC gaps
  - Air exists in the TC gaps of RBSB, liner, etc. with sizes of 40+ mm
  - Ar-41 dominates the total activity within 1 hour, and drops significantly, C-14, H-3 and Ar-37 are relevant in long cooling time
  - High residual activities require air circulation control to avoid additional contamination in the neighbouring rooms.



TC liner gaps



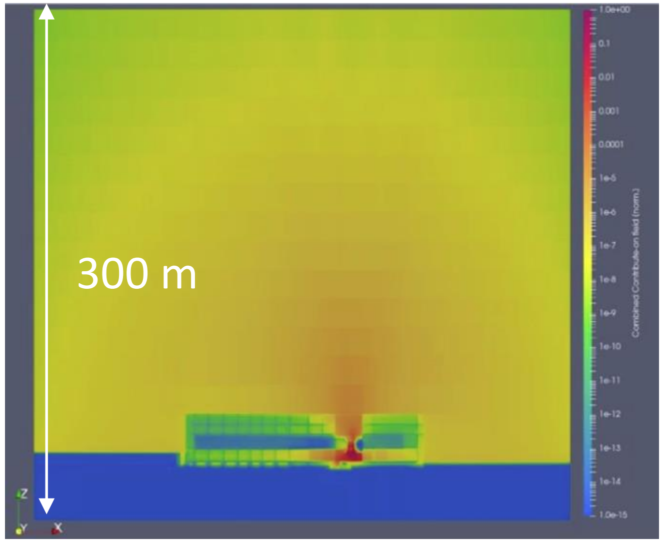
RBSB gaps



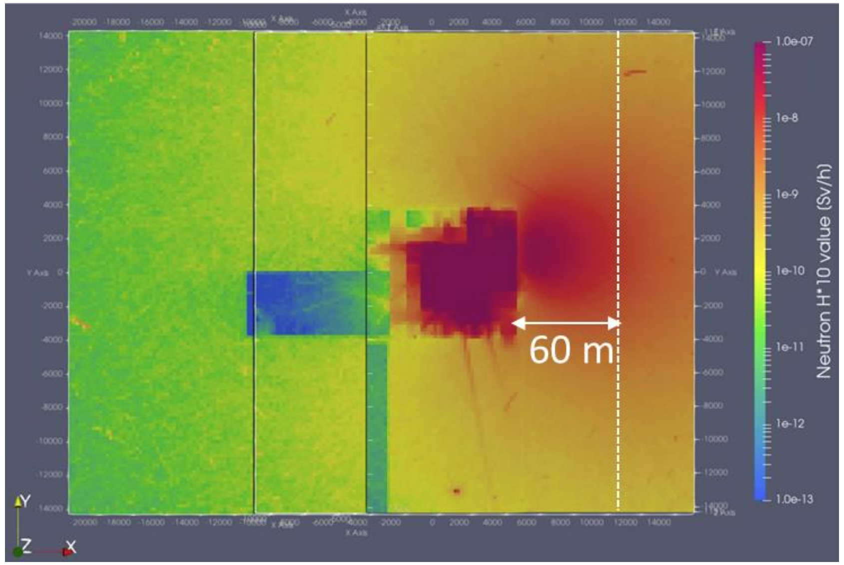
Neutron beam tube

	0-seconds	1-hour	1-day
Ar-41 Activities (Bq)	1.676E+11	1.147E+11	**1.858E+07**
Total Activities (Bq)	2.901E+11	1.419E+11	**2.560E+10**

- Sky-shine simulation of beam-on radiation from the TC
  - Dose map up to 360 m x 280 m x 300 m, using a global model with Variance reduction code ADVANTG
  - Dose rate values of 0.01-0.05 μSv/h (88 - 430 μSv/year) at 60 m downstream
  - Require additional shielding optimization to meet the safety requirements



Normalized contribution field (COF) of sky-shine to the dose at ground level



Neutron dose (Sv/h) at ground level

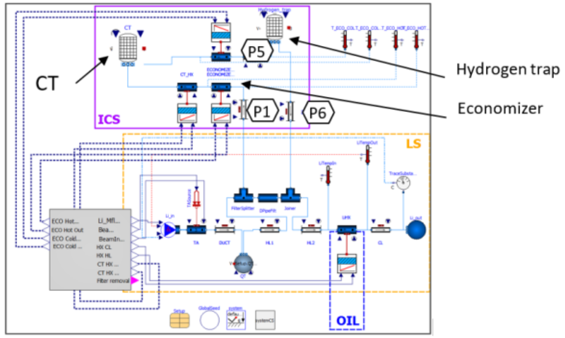
Outlines

- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system (AS)
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

Li system

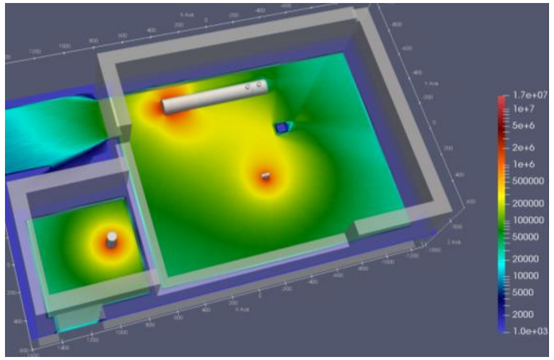
- Be-7 and H-3 production
  - Be-7: $T_{1/2}$ 53 days, γ 477 keV, most from deuteron activation: Li-6 (d, n) Be-7 (~15%) and Li-7 (d,2n) Be-7 (~83%)
  - Be-7 production rate is ~0.75g/fpy (9.7 10^{15} Bq/fpy), which reaches an equilibrium inventory of 0.15g (2.0 10^{15} Bq) at 1 fpy.
  - H-3 production rate is ~3.78 g/fpy (3.0 g/fpy from d-Li reaction and 0.78 g/fpy from the n-Li reaction)
- Be-7 dose analyses
  - Be-7 distribution depends on: Li loop operation temperature, cold trap efficiency, mass transfer coefficient, impurity control flow rate, etc.
  - Parametric studies of 108 cases provide much different dose distributions, while dose rates are mostly as high as several Sv/h.
  - Under the temperature of 300 ˚C and trap efficiency of 60%, almost 100% Be-7 can be confirmed in the cold trap except for the dissolved Be-7.

Model representation of Modelica code

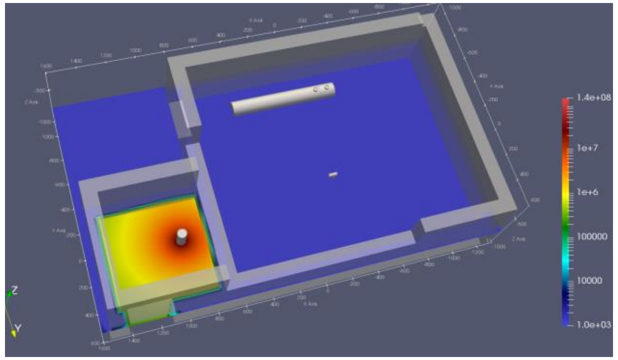


	Cold Leg Temp.	Hot Leg Temp.	ICS mass flow [%]	MTC CL	MTC HX	Trap eff. [%]	Be-7 In HX [g]	Be-7 In CL [g]	Be-7 In CT [g]
Case-1	250	274	0.5	0.000298	8.29E-05	60	0.09462	0.05253	0.00914
Case-2	300	324	1	0.000396	9.12E-06	60	0	0	0.15615
Case-3	300	324	1	0.00036	9.12E-05	40	0.01978	0.02766	0.10871
Case-4	300	324	1	0.000396	9.12E-06	0	0.00955	0.1464	0.00006

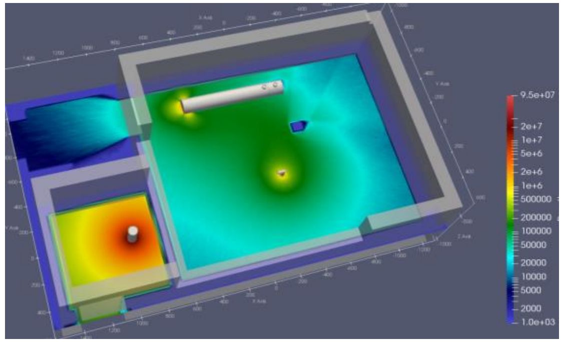
Operation condition of the Li loop and ICS



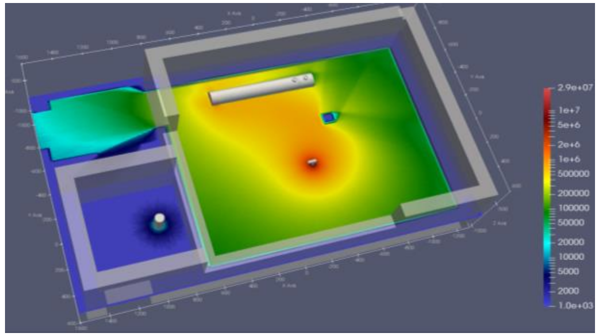
Case-1



Case-2



Case-3



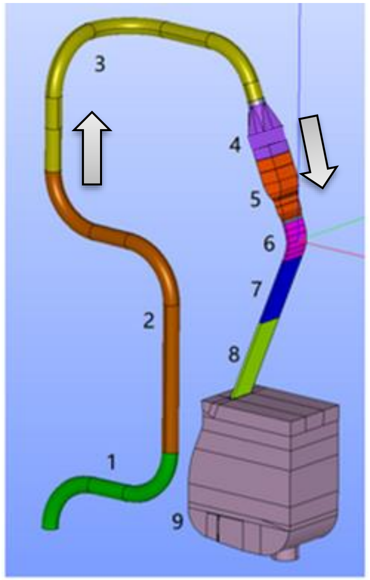
Case-4

Be-7 decay photon doses (µSv/h)

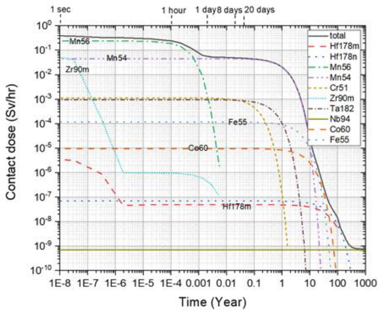
Activated corrosion products

- ACP simulations
  - Li corrosion rate of Eurofer and SS316L from experimental measurements from ENEA *Lifus 6* facility
  - The production rate of dominant isotopes simulated in different Li segments from major reaction pathways, contributed from both neutron and deuteron.
  - Mass transfer of radioisotopes simulation using Modelica based on their dissolving curves.
  - Obtained a list of radioisotopes in different Li loop components

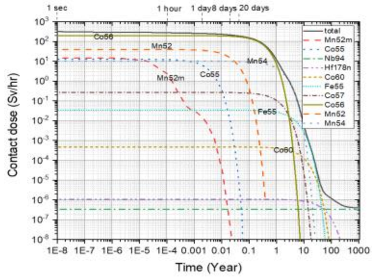
	Sum. Wall [mg]	Sum. Li [mg]	LiHX [mg]	CL [mg]	CL_TC [mg]
Fe55	0.645691	2.891645e-01	2.623453e-01	2.785806e-01	1.047651e-01
Mn51	0.000000	1.032328e-07	0.000000e+00	0.000000e+00	0.000000e+00
Mn52	0.000000	7.546957e-04	0.000000e+00	0.000000e+00	0.000000e+00
Mn52m	0.000000	8.925280e-07	0.000000e+00	0.000000e+00	0.000000e+00
Mn54	0.000000	3.303965e-01	0.000000e+00	0.000000e+00	0.000000e+00
Mn56	0.000000	8.065303e-05	0.000000e+00	0.000000e+00	0.000000e+00
Cr51	0.004553	1.127897e-04	1.152077e-03	1.223366e-03	2.175991e-03
Ni57	0.000000	1.645170e-03	0.000000e+00	0.000000e+00	0.000000e+00
Co55	0.000000	9.461301e-05	0.000000e+00	0.000000e+00	0.000000e+00
Co56	0.000000	1.32195[illegible]e-01	0.000000e+00	0.000000e+00	0.000000e+00
Co57	0.000000	1.264104e+00	0.000000e+00	0.000000e+00	0.000000e+00
Co58	0.000000	4.110067e-01	0.000000e+00	0.000000e+00	0.000000e+00
Co58m	0.000000	1.591487e-03	0.000000e+00	0.000000e+00	0.000000e+00
Co60	0.000000	6.809732e-02	0.000000e+00	0.000000e+00	0.000000e+00
Co60m	0.000000	1.621391e-06	0.000000e+00	0.000000e+00	0.000000e+00
W181	0.000005	9.339950e-10	7.119827e-07	7.357418e-07	2.375593e-07
V52	0.000000	3.650830e-03	0.000000e+00	0.000000e+00	0.000000e+00
Al28	0.000000	4.575686e-02	0.000000e+00	0.000000e+00	0.000000e+00



Li volume to calculate neutron fluxes



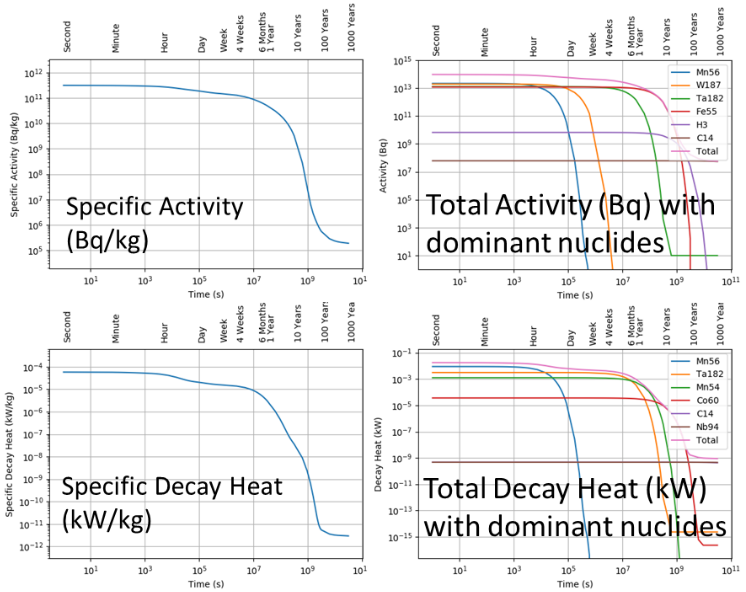
Contact dose (Sv/h) for Eurofer activated by neutron



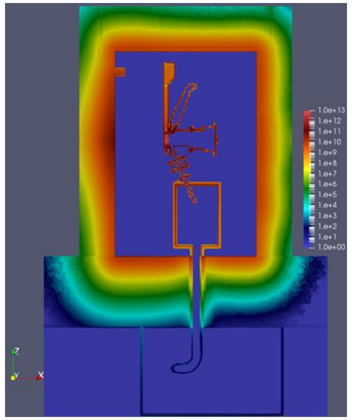
Contact dose (Sv/h) for Eurofer activated by deuteron

Radioactive Waste Treatment System (RWTS) analyses

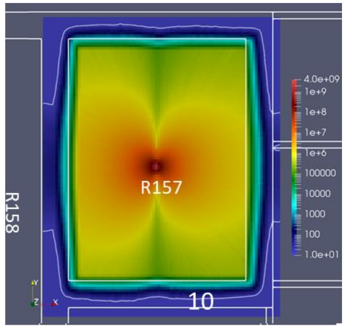
- Activation inventory database and Decay gamma source database
  - Inventory database for all the TS components, including HFTM, TA, Liner, RBSB, TSP, …
  - Collection of existing decay gamma source files for HFTM, TA, TC concrete wall, etc. using unified the cR2S (common R2S) format
- Nuclear analyses for the solid and liquid RWTS rooms
  - Residual dose of activated components transferred to RWTS rooms.
  - Radiation from liquid waste of several sources: Li, water, etc



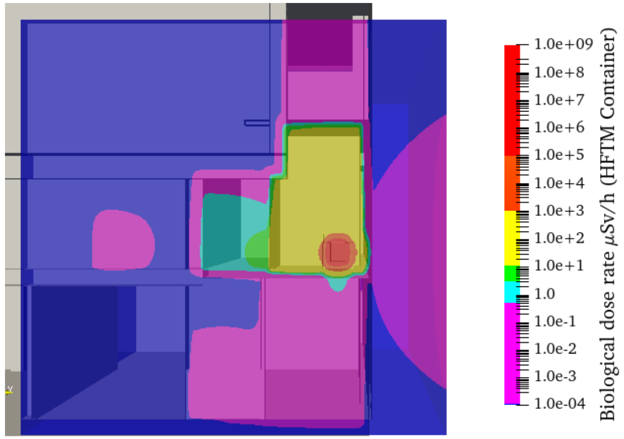
Activation inventory for the TC components



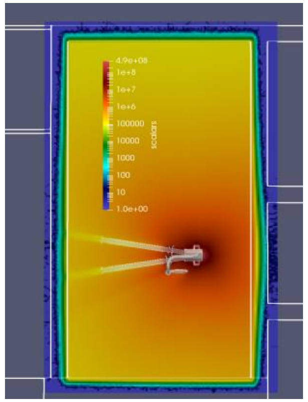
Decay gamma sources (p/s)



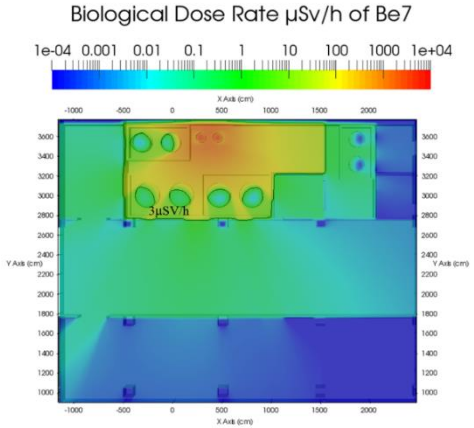
HFTM dose rate [μSv/h] in RW treatment cell at 1-day after shutdown



beam dump stopper in waste container located in solid waste storage cell.



TA dose rate [μSv/h] in irradiating RW storage cell at 1-day cooing



Radiation dose liquid waste storage cells

Outlines

- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system (AS)
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

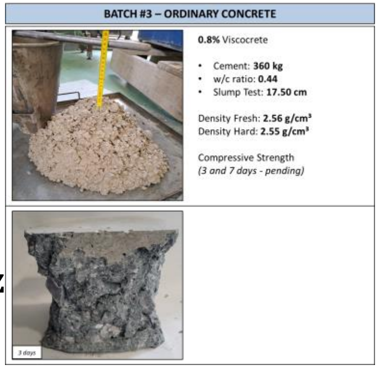
Simulation codes and data

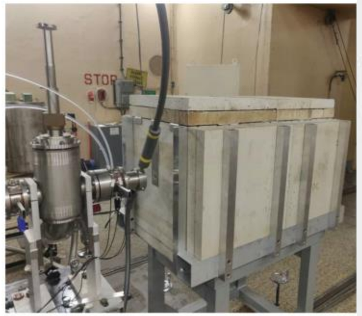
Highlights of tools and data developments

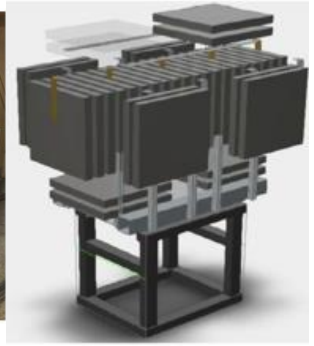
Topic	Tools	Highlights
Modeling	• SuperMC • McCad • GeoUNED	• SuperMC and McCad are common tools for producing MCNP model • New modeling program GeoUNED facilitates CAD-to-MC conversion based on FreeCAD/Python
Deuteron transport	• McUNED • McDeLicious • SrcUNED-AC	• McUNED is validated for AS simulations, and McDeLicious for d-Li neutron source simulations • SrcUNED-AC is an MCNP subroutine providing direct sampling of secondary neutrons and photons from deuteron based on double-differential spectra.
Neutron transport	• MCNP • OpenMC	• OpenMC has been benchmarked for test system simulation
Activation	• FISPACT-II • ACAB • Actiflow	• Actiflow code was recently adopted for water activation simulation of AS and TC water cooling loop
Shutdown dose	• D1SUNED • R2Smesh-3.0 • MCR2S	• Recently D1SUNED was extended to the SDR of light ion activation, and extensive validation has been done for DONES application.
Variance reduction	• ADVANTG • OTF-GVR	• In addition to ADVANTG, OTF-GVR is an effective global variance reduction method, which is intensively used for TC shielding calculations.
Data libraries	• TENDL-2021 • JENDL-5 • FENDL-3.1d/3.2	• TENDL has well-known deficiency in deuteron libraries , and recently JENDL-5 provides deuteron data for several isotopes: Cu-63, Cu-65, Al-27, Nb-93 and • Newly released FENDL-3.2 is currently under validation for the DONES application

Neutronic experiments

- The IFMIF-DONES mock-up experiment
  - Aims to characterize the shielding performances of ordinary concrete and heavy concrete.
  - Concrete mock-up prepared at **Granada using local aggregates**.
  - The first experiment on ordinary concrete was performed in an **NPI-Rez U180m cyclotron** in March 2023.
  - Five sets of foils (Fe, Al, Ti, Au In) used in five locations. Most of the foils have good statistics on the counting, except Fe/Ti at the rear position
- LIPAc prototype accelerator neutronics activities under Broach Approach phase 2 (BA-II)
  - The **LIPAc accelerator** will provide a strong deuteron beam with 125mA power and 9 MeV energy. The deuteron will deposit in the high-energy beam dump (BD) and produce neutrons up to 10^{14} n/s.
  - One concept is to utilize the neutrons produced from deuterons interacting with the beam dump materials.
  - Another proposal is benchmarking and validation of tools and libraries against experimental data.
  - Experiments and radiation survey with the 5 MeV deuteron beam commissioning campaign is ongoing.



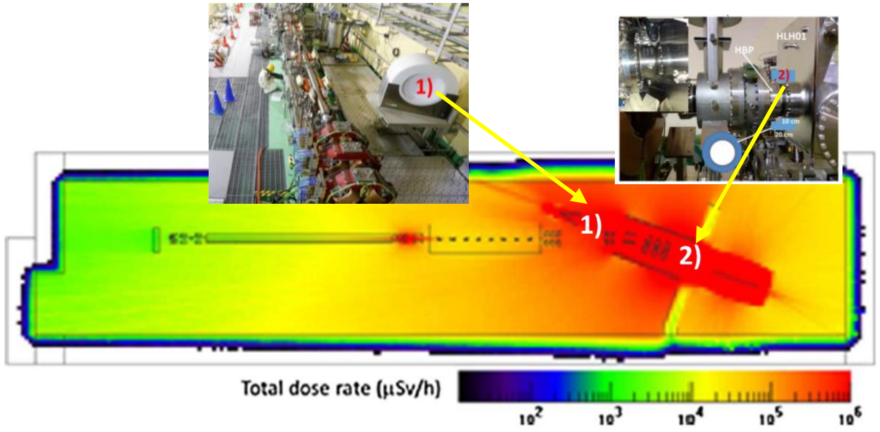




Experiment setup

Activation Foil	Depth [cm] 0	25	50	75	100
Fe	0.06%	0.52%	2.10%	2.38%	4.43%
Al	0.09%	0.82%	0.71%	0.90%	2.96%
Ti	0.04%	0.17%	0.22%	0.72%	4.15%
Au	0.03%	0.03%	0.03%	0.11%	0.17%
In	0.04%	0.09%	0.08%	0.13%	0.16%

Statistical Error
<1%
1 - 3.2%
>3.2%



Outlines

- Introduction of DONES and neutronics activities
- Neutronics activities for Accelerator system (AS)
- Neutronics activities for Test system
- Neutronics activities for Li and other systems
- Simulation tools, data and nuclear experiments
- Summary and outlook

Summary and outlook

- Summary
  - With the contributions of more than 10 research units, the neutronics activities in the framework of EUROfusion WPENS has achieved many successful outcomes in the last 3/4 years.
  - These activities include design analyses and optimization, radiation dose maps, shielding and ALARA, activation and inventory, models, tools and data developments, experimental benchmarks and validations
  - These data are key inputs for the accelerator system(AS), test system (TS), lithium system (LS), building and plant system (BPS), safety, remote handling and logistics (RHL).
  - Application-driven developments for the simulation tools, data, and nuclear experiments provide strong support and acceleration for the nuclear analysis.
- Outlooks
  - Deuteron data developed are in urgent demand for the needs of high-quality simulations.
  - Dedicated benchmarking and experiments are not sufficient for the validation and verification of tools and data
  - Systematic quality assurance is further required for the productive calculation.

Thank you!

M. Ansorge	NPI-CAS, Rež, Czech Republic
I. Álvarez	UGR, Granada, Spain
K. Ambrožič	JSI, Ljubljana, Slovenia
T. Berry	UKAEA, Abingdon, UK
B. Bienkowska	IPPLM, Warsaw, Poland
H. Chohan	UKAEA, Abingdon, UK
A. Cufar	JSI, Ljubljana, Slovenia
T. Deszi	C3D Ltd, Budapest, Hungary
D. Dworak	IFJ PAN, Cracow, Poland
T. Eade	UKAEA, Abingdon, UK
J. García	UGR, Granada, Spain
D. Jimenez	CIEMAT, Madrid, Spain
I. Lengar	JSI, Ljubljana, Slovenia
A. Lopez	UNED, Madrid, Spain
V. Lopez	UNED, Madrid, Spain
E. Mendoza	CIEMAT, Madrid, Spain
F. Mota	CIEMAT, Madrid, Spain
F. Ogando	UNED, Madrid, Spain
J. Park	KIT, Karlsruhe, Germany
T. Piotrowski	WUT, Warsaw, Poland
A. Serikov	KIT, Karlsruhe, Germany
G. Stankunas	LEI, Kaunas, Lithuania
A. Tidikas	LEI, Kaunas, Lithuania
G. Tracz	IFJ PAN, Cracow, Poland
G. Žerovnik	JSI, Ljubljana, Slovenia
DONES team	