# Initial Decommissioning Plan for European Spallation Source Facility

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EUROPEAN SPALLATION SOURCE

ARIA 2015,

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Knoxville, USA

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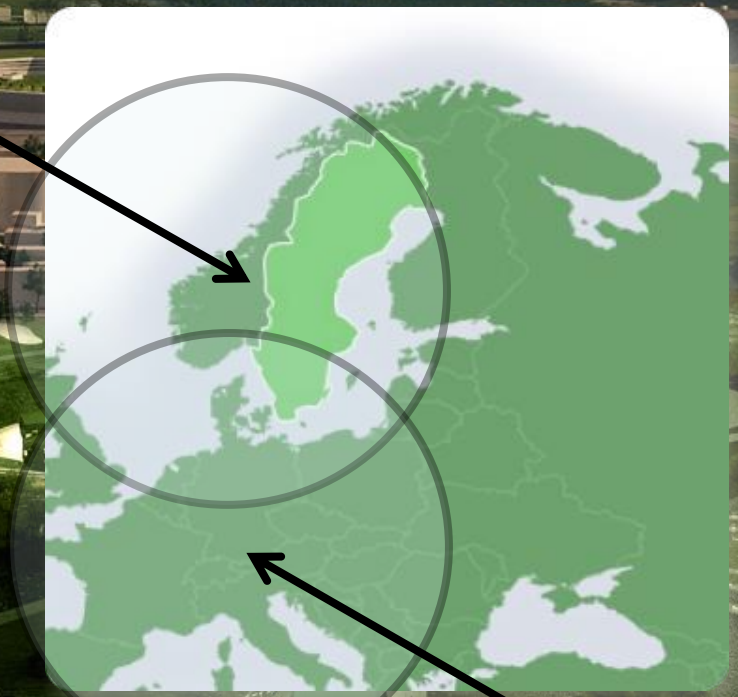
# A European Science Project

- ESS – an international research facility
- Budget 1843 M€

Sweden,
Denmark and Norway:
50% of construction and
20% of operations costs

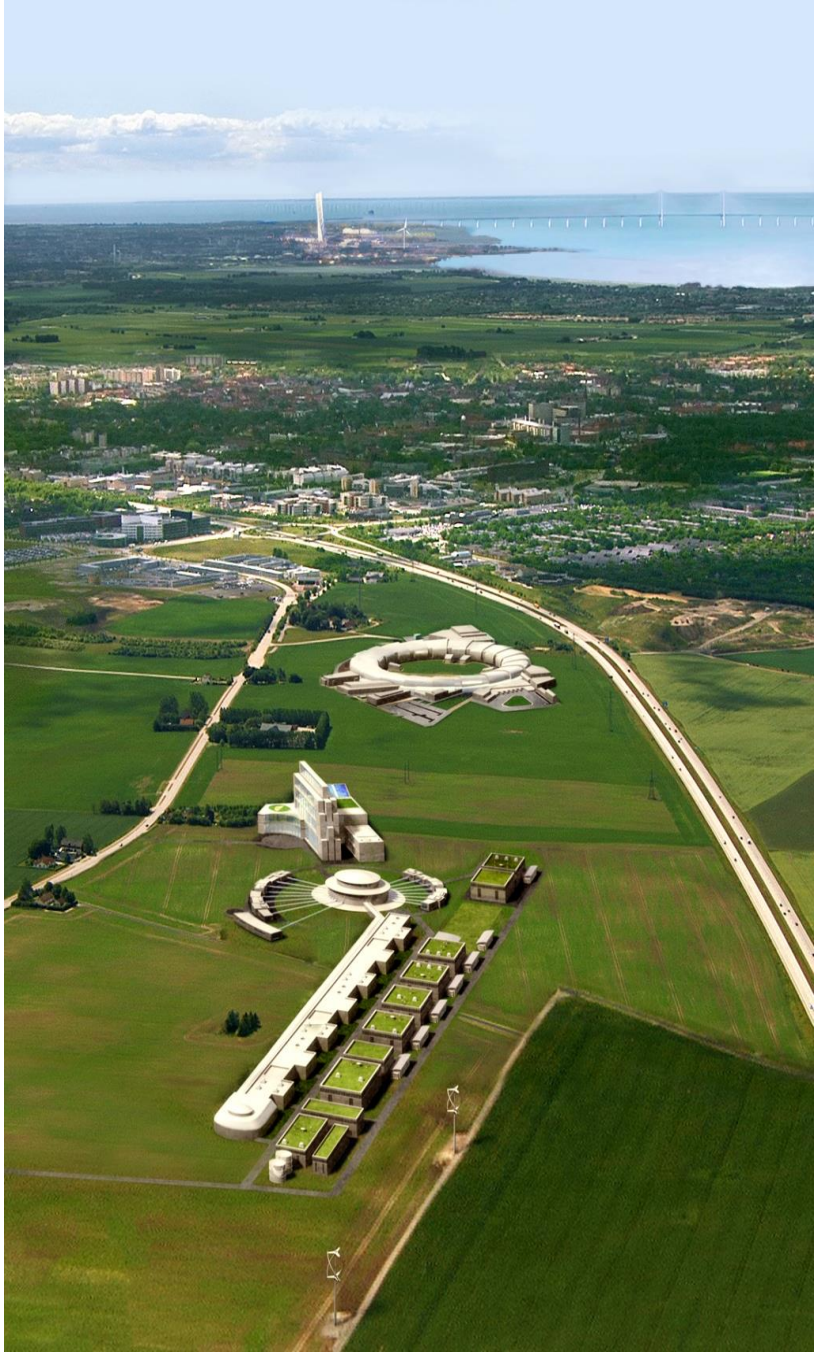


European partners
pay the rest

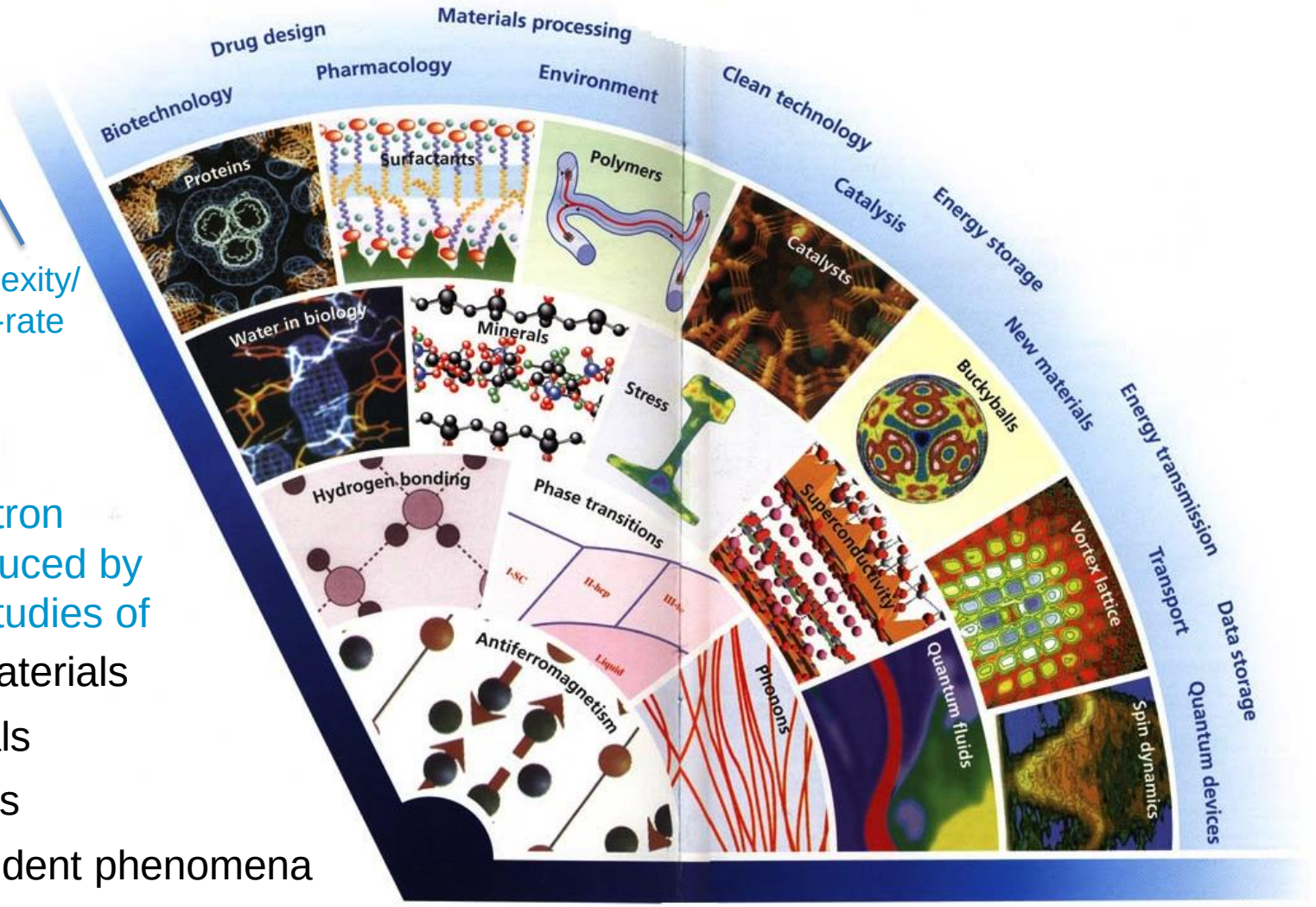
# ESS

## Future site view
## &
## Main parameters

| INPUT | unit | NOMINAL | UPGRADE |
|---|---|---|---|
| Average beam power | MW | 5 | 7.5-15 |
| Macro-pulse length | ms | 2.86 | 2.86 |
| Pulse repetition rate | Hz | 14 | 14 |
| Proton kinetic energy | GeV | 2 | 2 |
| Target type | He cooled solid W rotating | | |
| Moderators (reference concept 2) | Liquid Hydrogen at 20K coupled | | |
| Reflector (reference case) | Be water cooled | | |
| Number of instruments in construction budget | | 22 | |
| Number of neutron beam ports | | 48 | |



# ESS is an *applied* science facility benefiting high-technology industries, medicine,




Complexity/
Count-rate

Resolution

The high neutron intensity produced by ESS allows studies of

- Complex materials
- Weak signals
- Small details
- Time dependent phenomena

# Time Plan and Recourses

Today:

- 350 employees
- 40 nationalities

2019:

- 400-500 employees

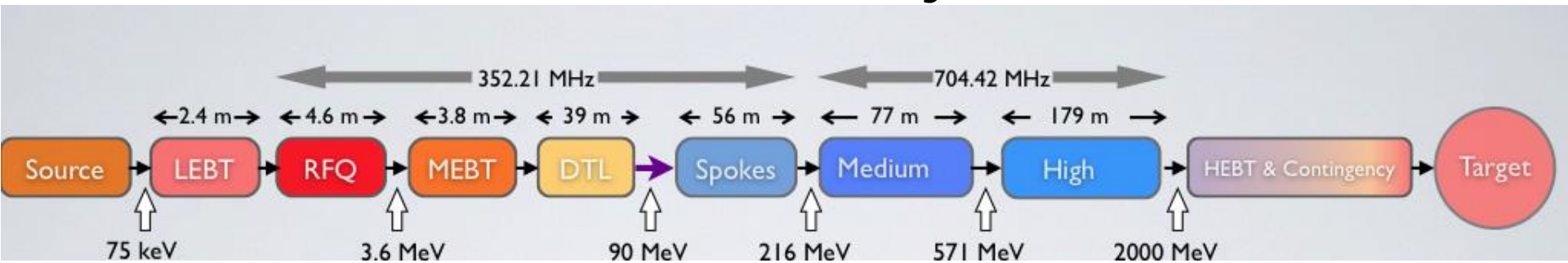
- 2007 – 2009 **Campaign phase**
- 2010 **ESS company set up**
- 2010 - 2012 **The Design Update phase**
- 2013 - 2018 **Construction Phase**
- 2019 - 2025 **Completion Phase – 7 to 22 instruments**
- 2026 - 2066 **The Operations Phase**
- 2067 – 2071 **Decommissioning Phase**

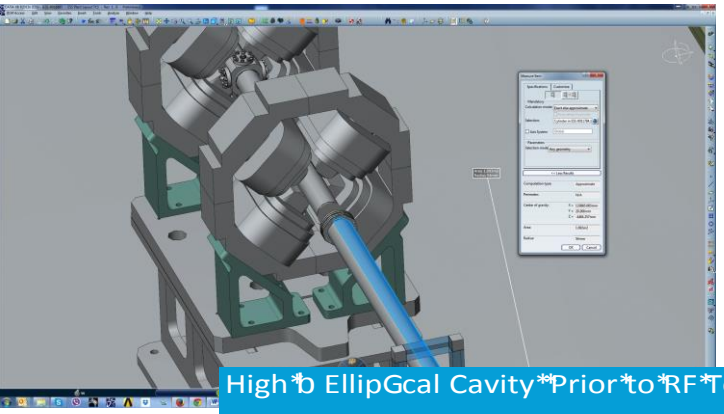
# European Spallation Source in Lund, Sweden

**December 2014**

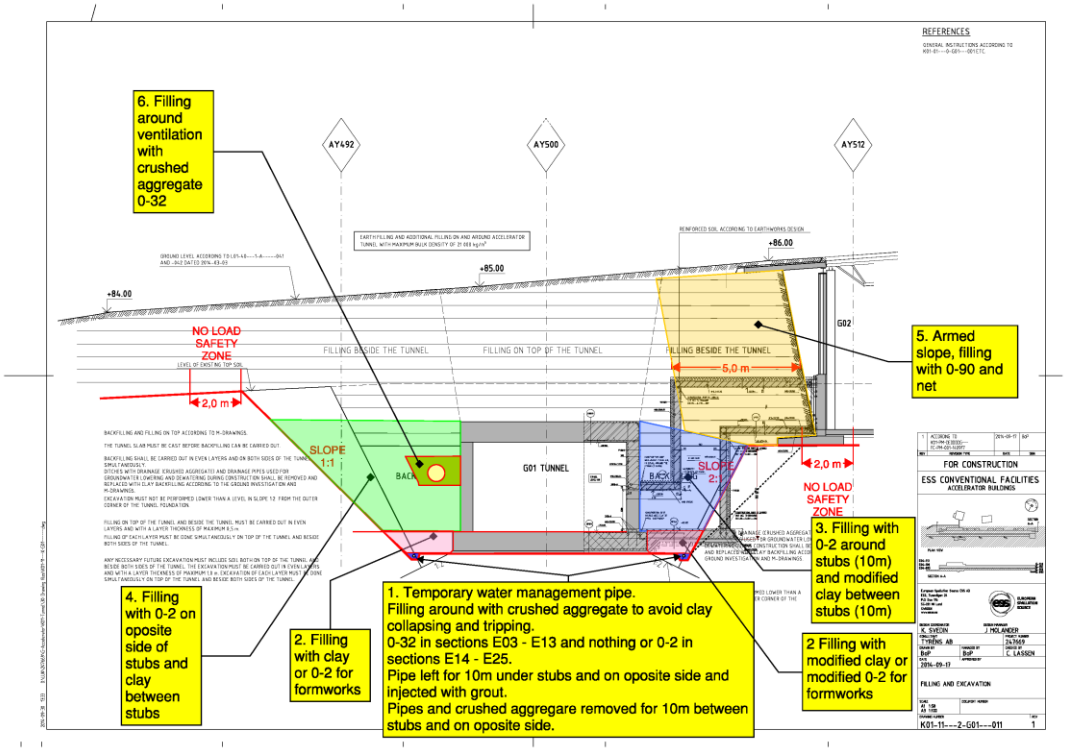
**2019**

# Accelerator lay-out

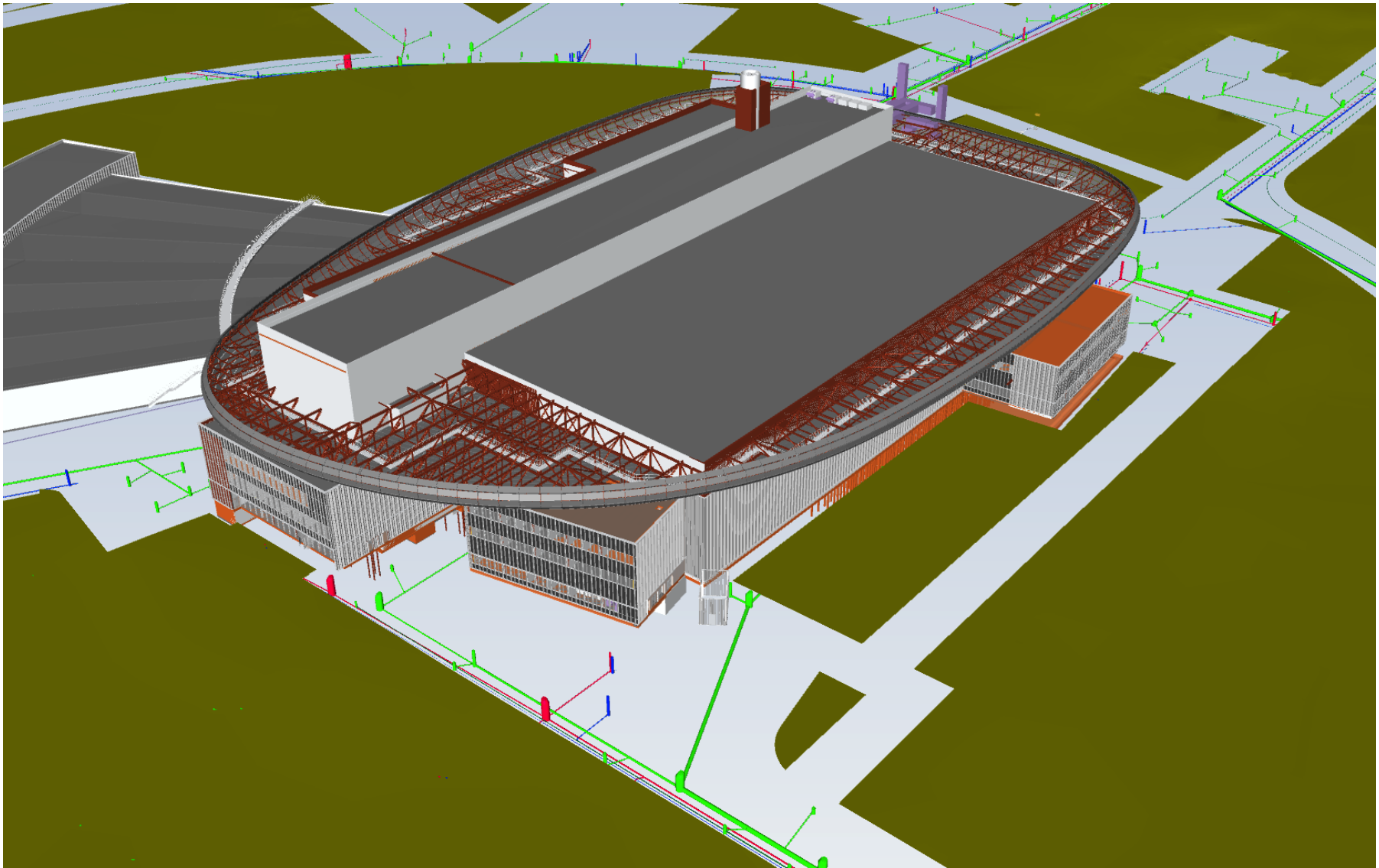


High*b EllipGcal Cavity**Prior*to*RF*TesGng*

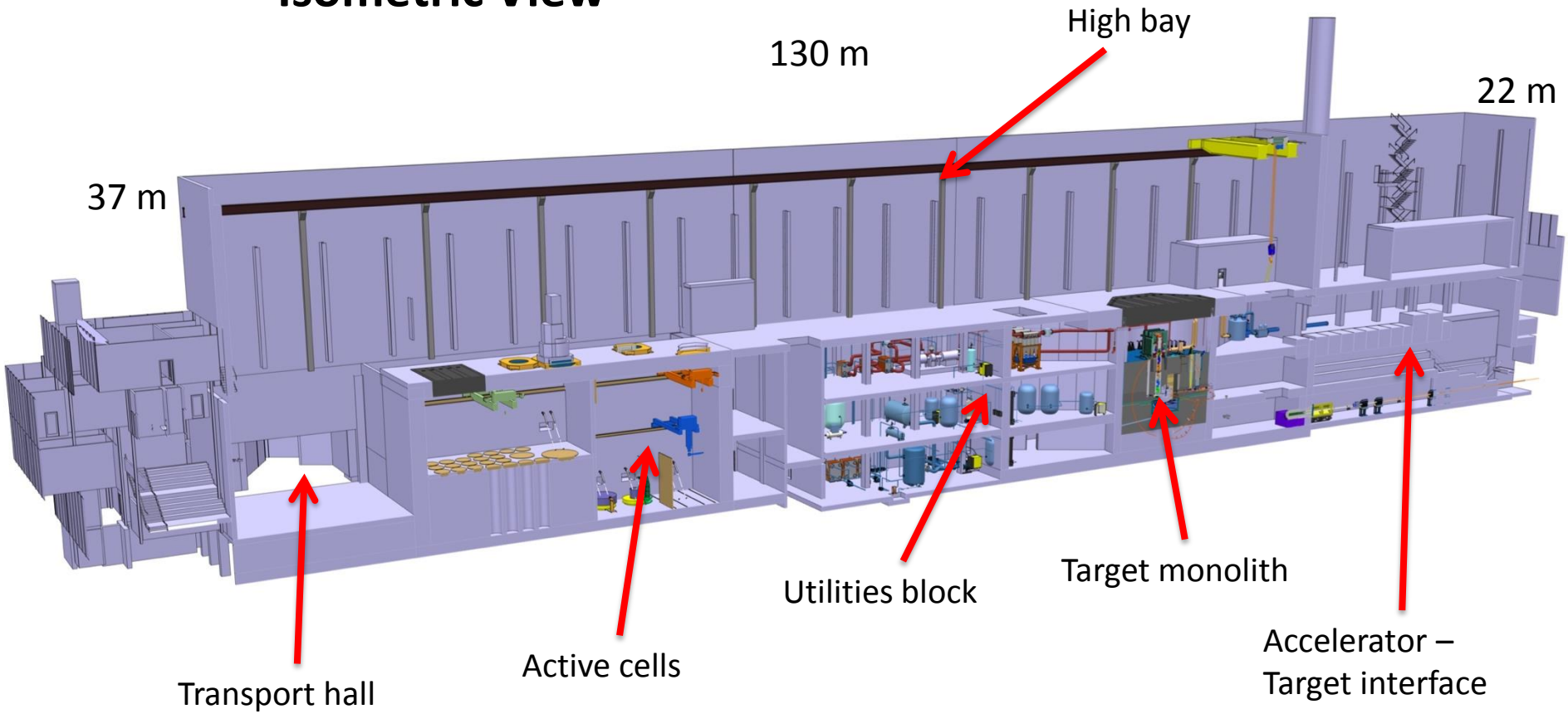


# Target Station and Instrument Hall overview

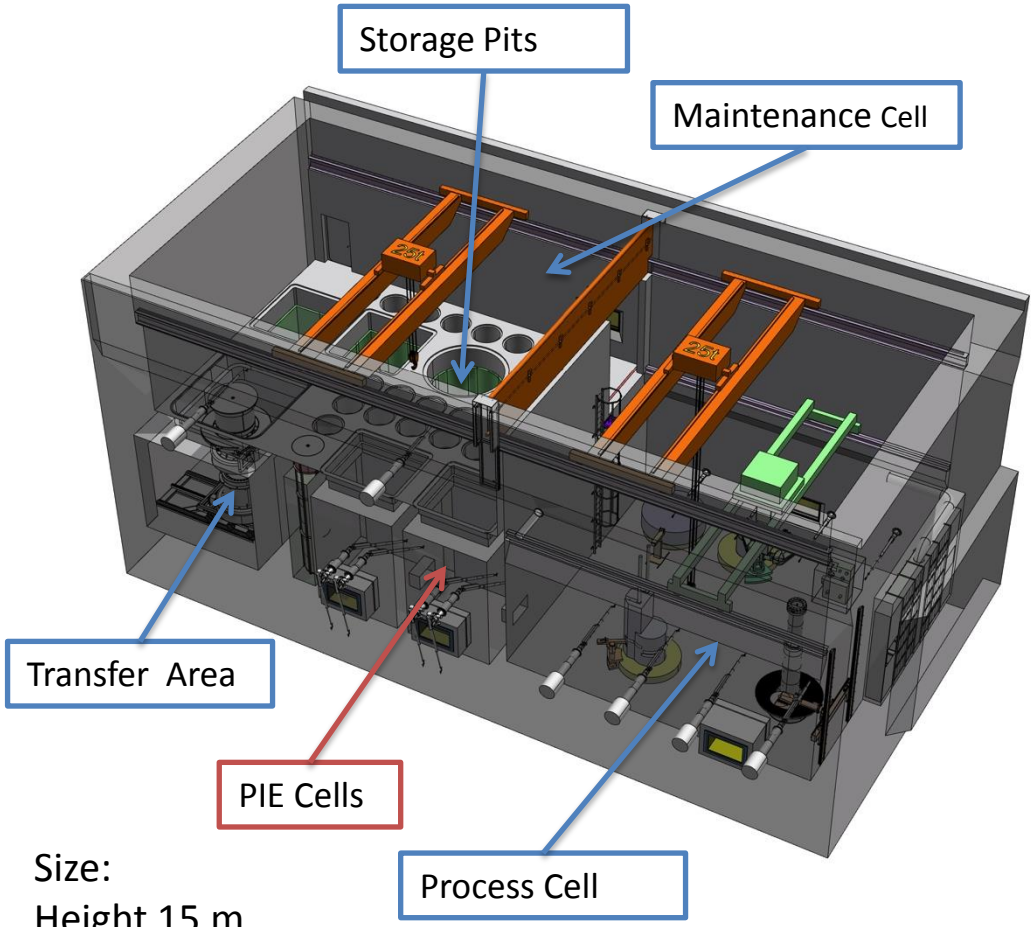


# The ESS Target Station Layout

**Isometric View**



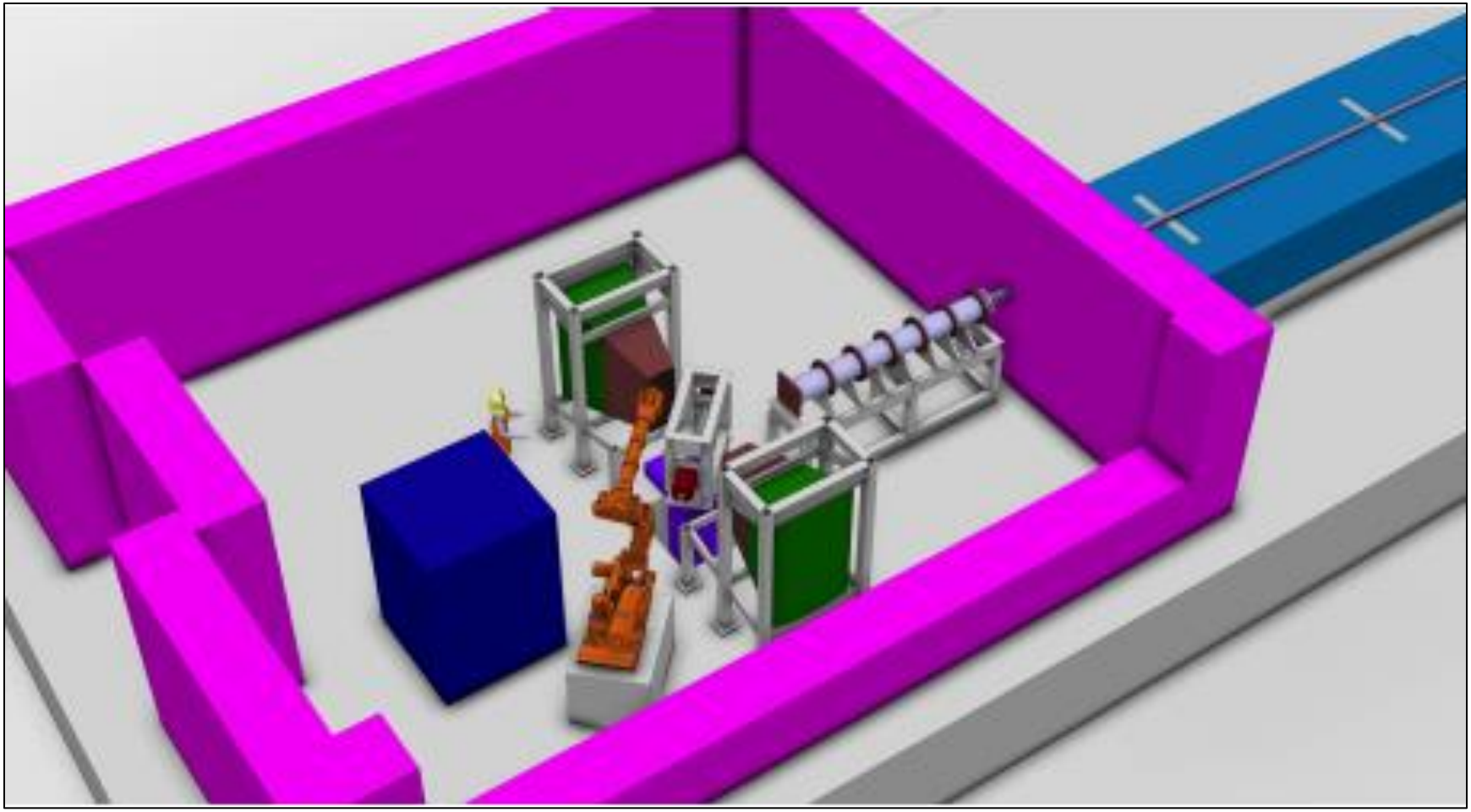
# Hot Cells Layout




Size:
Height 15 m
Length 30 m
Width 12 m

- **Process cell** – Introduction of radiated components from the high bay, processing of components and preparation for interim storage and shipment as well as refurbishment in specific cases.
- **Maintenance cell** – Maintenance of equipment and logistical hub for transfer inside the active cells.
- **Storage pits** – Intermediate storage of vessels awaiting off-site shipment.
- **Technical galleries** – Contains the remote handling interfaces for active cell operations, component storage, PIE activities, human logistics around the cells and air locks for entrance into the maintenance cells.
- **Transfer area** – For off-site shipment of casks, control and decontamination of shipment cask surfaces.

# Diffractometer. Conceptual model



# Main goals:

**Swedish Authority (SSM) requested for supplementary information to ESS's application PSAR in 2012:**

- *a description of the presence of radioactive materials (nuclides and quantities) at the facility after final shutdown;*
- *an overview of the planned timing for the start and finish of the various stages of decommissioning;*
- *a summary of experiences from other similar decommissioning projects.*

**Mainly status of the ESS-project as given in TDR 2013 =>**

**Content:**

- APPLICABLE REQUIREMENTS
- DECOMMISSIONING STRATEGY
- BASE LINE PLAN FOR DECOMMISSIONING
- **RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN**
- **RADWASTE MANAGEMENT**
- OTHER TYPE OF WASTE EXPECTED AT SHUT-DOWN
- KEY ELEMENTS OF DECOMMISSIONING PLAN
- ENGINEERING DESIGN FOR EFFICIENT DISMANTLING AND DISPOSAL



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# Requirements

Regulations affecting decommissioning fall into three categories:

1. those that directly affect decommissioning (e.g., the removal of radioactive materials as needed to reduce future risk);
2. those that protect the workers and the public during decommissioning operations; and
3. those that apply if hazardous or toxic materials that require remediation are present in the facility

- Swedish low states that the operating organization shall ensure that there is a current and documented **decommissioning plan for the facility.**

- According to the Environmental Code, ESS also has responsibilities to **investigate and remediate the contaminated areas as a result of the operation**. Before dismantling and demolition may begin a new Environmental Impact Assessment, **(EIA)** "Miljökonsekvensbeskrivning" for the ESS facility has to be prepared.

- Additionally, according to the Act on Planning and Building, a **demolition application including a detail plan** showing how the demolition materials to be managed will be assessed and approved by the Lund County. The plan should also include an inspection of the environmental and health hazardous substances in the buildings. Whether some clean materials will be used for remediation needs to be clearly stated as well.

# DECOMMISSIONING STRATEGY

- **Immediate dismantling (ID)** option selected as referenced decommissioning strategy

Compliance with the recommendations of the (IAEA NW-T-2.3 , 2011) and (IAEA TRS-446, 2006) & ESS project time schedule (2067 to 2071)

| Parameter | Immediate dismantling (ID) | | Deferred dismantling with one lengthy safe enclosure period (DD-SE) | |
|---|---|---|---|---|
| Planning | ID needs stepwise planning; the decommissioning plan (DP) is updated and extended periodically throughout the lifetime of the facility. If any disorder occurs during the operation of the facility an appropriate DP is at hand. | + | Stepwise planning goes on in the same manner as with ID. As the safe enclosure period obviously precedes the dismantling of the most active parts planning for this work phase is not required in full details | - |
| Licensing process | If ID strategy is accomplished licences should be obtained simultaneously for all components of decommissioning work (dismantling technology, radioactive waste processing and disposal, environmental impact etc.) | + | In the "final shutdown" phase licences are required only for the envisaged steps reaching safe enclosure status. Operations following the SE period (minimum length according to IAEA guidance: 20 years) should be licensed in due course | - |
| Cost estimates, funding | ID cost estimates shall become more and more accurate in the updated DP's. Funding has to be managed within a relatively short period of time (envisaged duration of the decommissioning of a medium-size research facility is 5 – 7 years if all means are at hand) but no major discrepancies are expected from the estimates as influencing factors will not change dramatically in the course of the work. Minor differences may occur between planned and real costs | + | Stepwise planning goes on in the same manner as with ID. As the safe enclosure period obviously precedes the dismantling of the most active parts planning for this work phase is not required in full details | - |
| Expertise, familiarity of staff with the site | The expertise of the operators and associated expert staff can be widely used in the decommissioning procedure. Recorded data are relatively fresh, irregularities can be identified easily. The site is familiar for most of the decommissioning staff. | + | Record keeping and data management is difficult. Expertise of operating staff is fading. He site will not be familiar for most of the staff during the crucial steps of dismantling the highly radioactive parts | - |
| Dismantling technologies | Technologies are given. | | There is more time to develop site- and case-specific dismantling technologies | |
| Radioactive wastes | The amount of non-clearable waste requiring disposal is higher for ID case than for DD-SE case. Waste management costs are higher but more precisely estimated for ID than for DD-SE. | | | |
| Reuse of equipment & reutilisation of building and site | Reuse and reutilisation can be accurately planned; however, higher radiation levels may tighten their scope. | | Most of the equipment will go out of fashion, reuse and reutilisation is very limited | |

- **Green field status** desirable endpoint: The site can be reutilised without any further restriction; buildings are either demolished or reused. This implies the unconditional release (clearance) from regulatory control


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# BASE LINE PLAN FOR DECOMMISSIONING (1)

## Main tasks and timescale

The baseline plan for decommissioning consists of removing the components in a sequence starting with the most radioactive parts and ending with the least radioactive ones.

Main tasks of the ESS decommissioning project, in their chronological order

| | | |
|---|---|---|
| Phase #1 | Remove highly activated components | Work under Operating License & permit from the decommissioning activities* |
| Phase #2 | Remove other ILW | Work under Operating License & permit from the decommissioning activities* |
| Phase #3 | Remove LLW | Work under Operating License & permit from the decommissioning activities* |
| Phase #4 | Radiological clearance of buildings and site | Work under Operating License & permit from the decommissioning activities* |

*In compliance with Swedish legislation for nuclear facilities.

Time frame described in ( IAEA R2D2 , 2009) can serve as a first rough estimate for the ESS decommissioning project.

# BASE LINE PLAN FOR DECOMMISSIONING (2)
# Methodologies and approach

*Decommissioning methodologies/techniques*

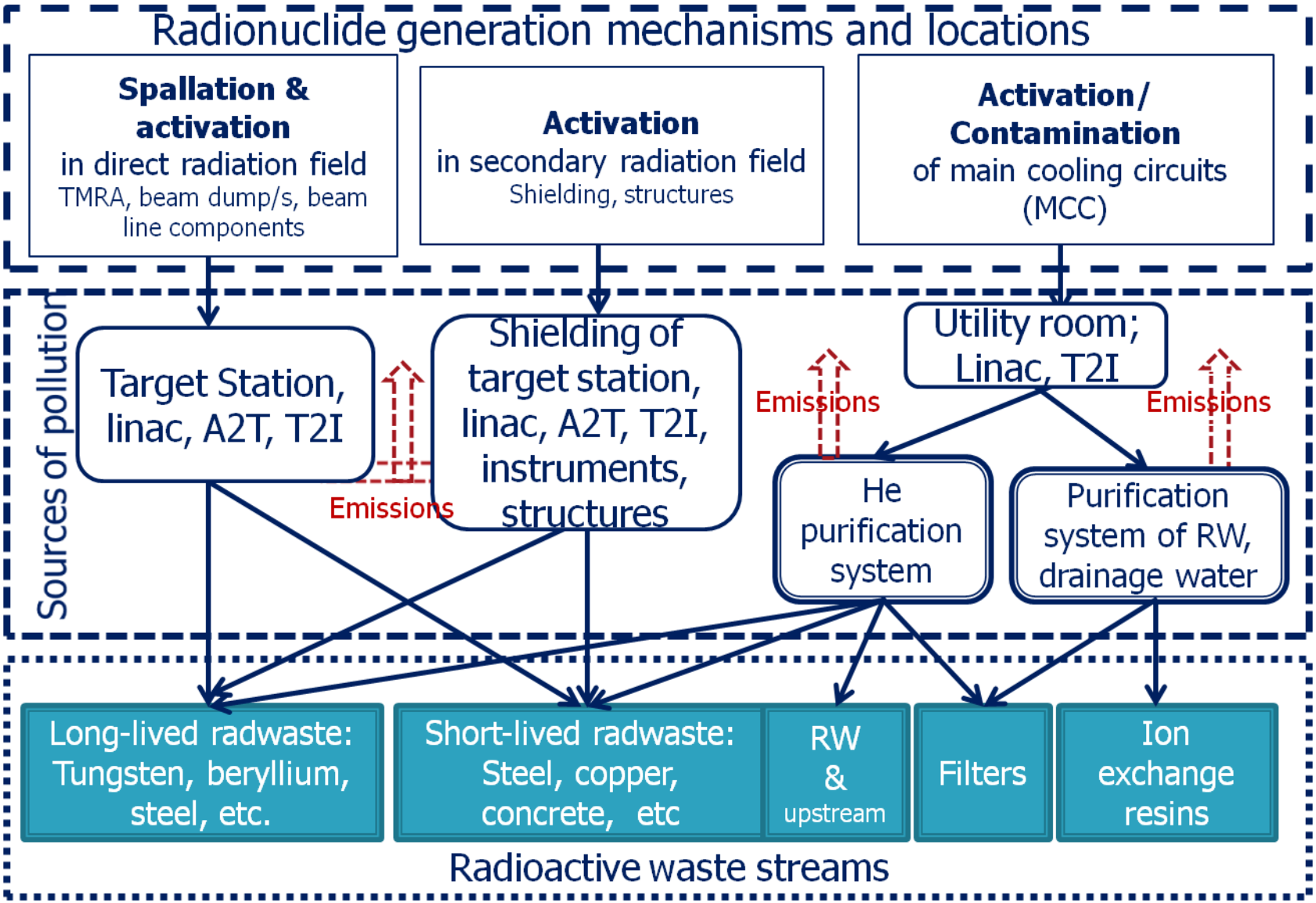
| Area | Cold cutting | Thermal cutting | Connector disassembly | RH* removal / robot | CH# removal /building crane | RH* removal /building crane | C H# rubblizing/crusher | Wire saw cutting | Cutting shares | CH# demo/heavy equipments | Decontamination /shot or $CO_2$ blusting |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Linac front end (source -> DTL) | x | x | x | | | | | x | x | x | |
| Linac SP (Spokes -> High β) | x | x | x | | | | x | x | x | x | x |
| Klystron | x | x | x | | | | | x | x | x | |
| A2T | | | | | | | | | | | |
| Target station (systems & shielding) | x | | x | x | x | x | | x | x | x | x |
| Utility rooms | x | x | x | | | | | x | x | x | x |
| Beam dump | x | x | x | | | | x | x | x | x | |
| NBLs & Experimental stations | x | x | x | | | | | x | x | x | |
| Services and support labs | x | x | x | | | | | x | x | x | x |
| Central Labs/Offices | x | x | x | | | | | x | x | x | |
| Other buildings | x | x | x | | | | | x | x | x | |

*CH = contact handling; #RH = remote handling

These methods/techniques were described and judged in detail in (SNS-D&D, 1999) and found to be the most effective and appropriate for the areas of the SNS facility. Approaches to effectively dismantle the ESS facility and keeping with ALARA principles will be further developed, in compliance with the baseline decommissioning plan

# RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN(1)

## Simplified scheme of ESS radwaste streams



# RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN (2)

## Waste radiological characterization: Principles

**ESS solutions at this stage:**

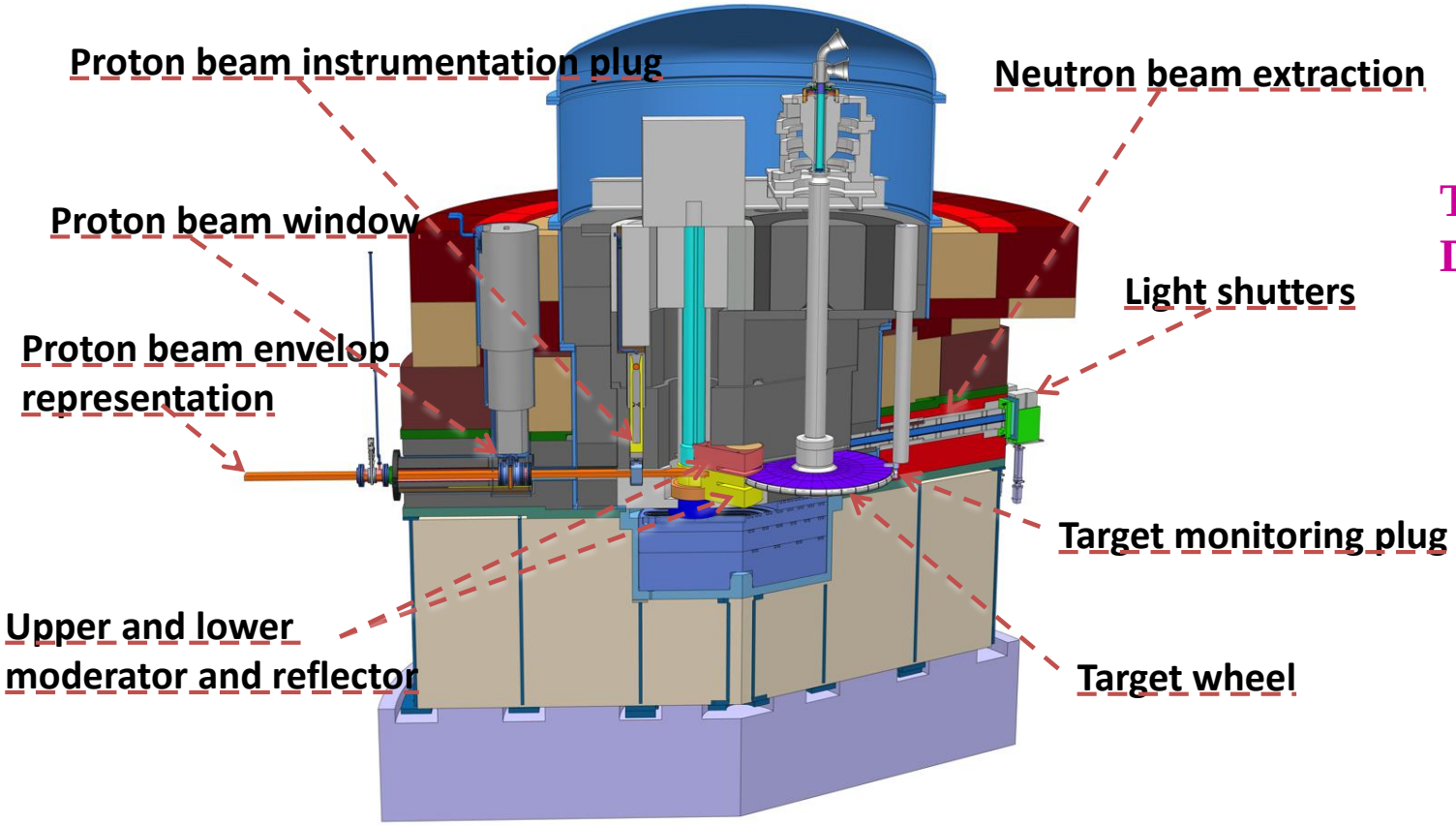
**Direct radiation**: MCNPX/PHITS + CINDER'90 (DCHAIN-SP)

**TMRA, Beam dump, Collimators, Accelerator devices: classification based on surface dose value & CI concept**

**Secondary particle field & contamination of main cooling circuits MCC**

**Other methods & BEG : Rough estimates & scaling data from the existing experience (when available) for difficult to predict activity levels or use rough assumptions**

**Vacuum Chambers, Vacuum components, Beam Diagnostic Monitors, Electrical installations, filters, ion exchangers, others**




**TS: Direct radiation**

# RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN (2)

## Waste radiological characterization: direct characterization

- **Inventory =>**

DB to SKB (disposal facility) for Source Term evaluation, Waste classification, Transportation, Operation issues

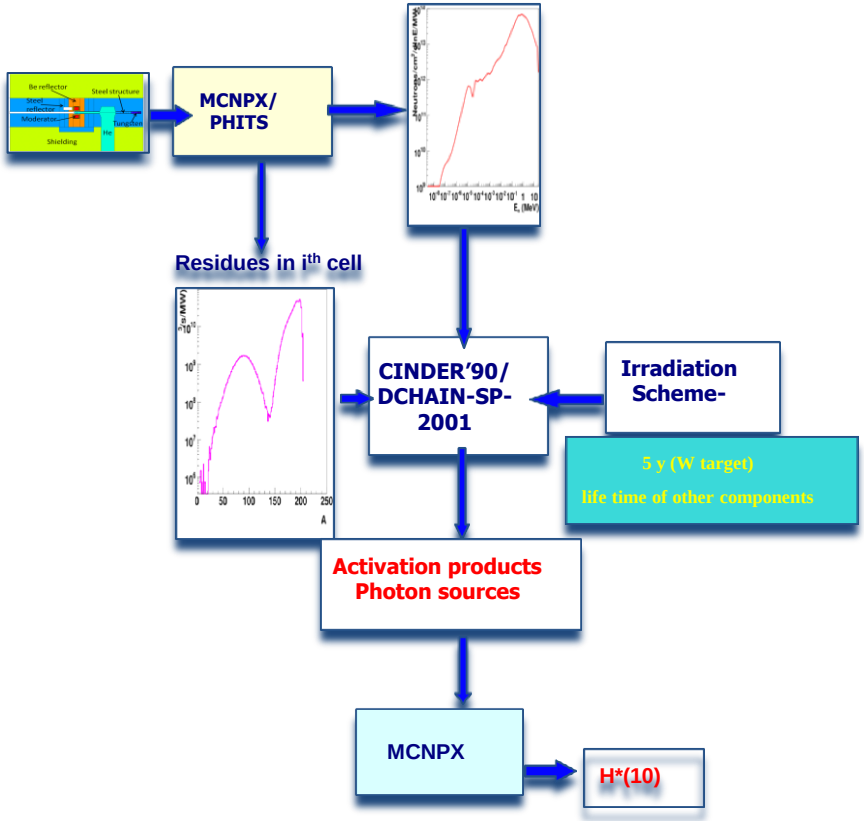
- **Alpha component**
- **Gases production | evolution =>**

design, waste rate, ST

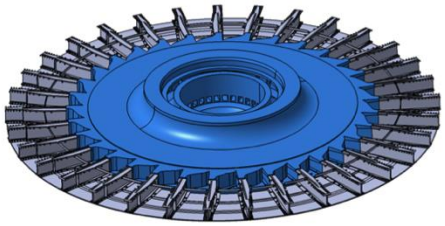
- **Decay times =>** logistics , transportation
- **Heat load =>** logistics, transportation
- **Gamma dose rate model =>**

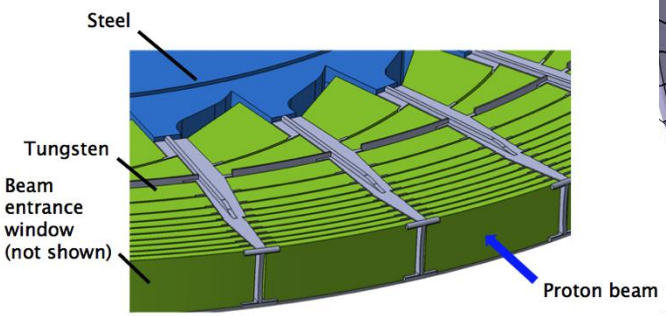
handling, transportation

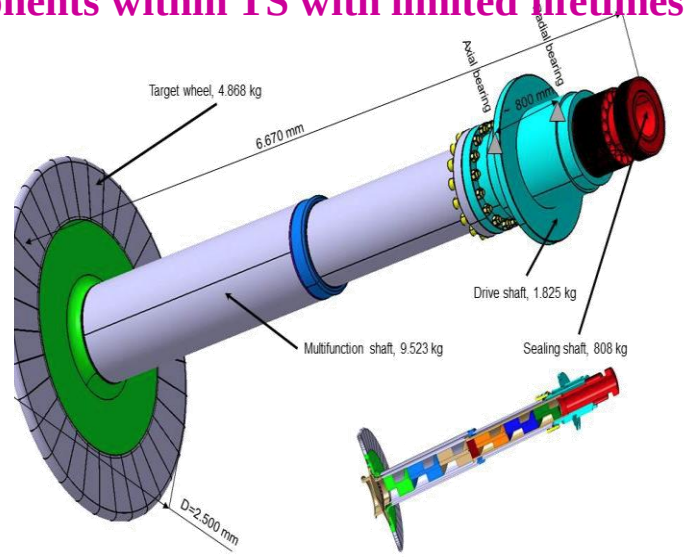
- **Model validation=>** accuracy
- **ESS radiological characterization system & traceability**



# DIRECT RADIATION: Components within TS with limited lifetimes:






Tungsten slabs sectors

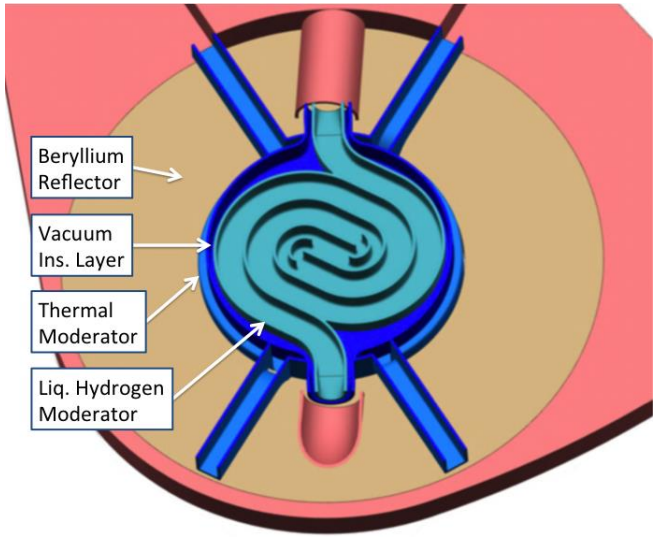
Helium coolant

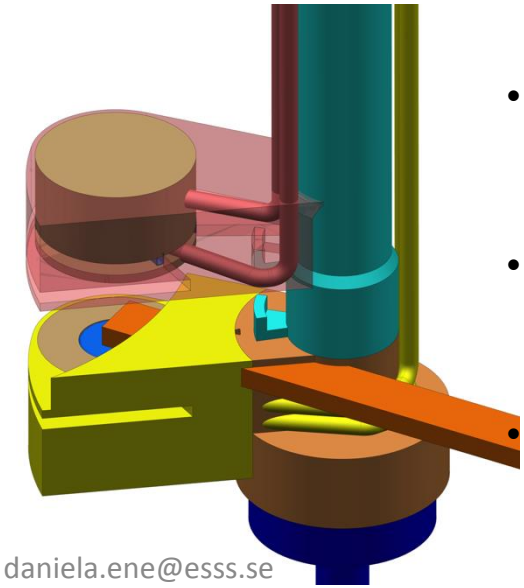
- Mass flow 3 kg/s
- Pressure 1,0 Mpa
- Inlet temperature 20 °C
- Outlet temperature 220 °C

Rotational speed 25,5 rpm

Wheel diameter 2,5 m

Shaft length > 5 m



- Inner reflector
  - Beryllium
  - Water cooled
- Outer reflector
  - Steel
  - Water cooled
- Cut-outs
  - for the view path to the beam extraction
  - For the target wheel

# RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN (3)

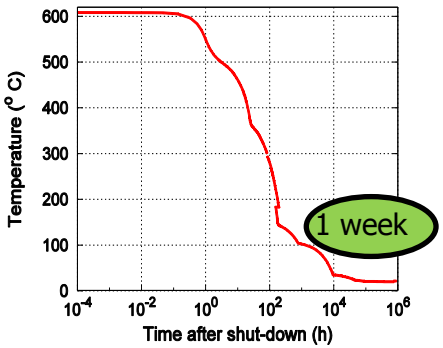
## Waste radiological characterization: highly activated components

### *Activity and Decay heat as function of decay time:* W wheel

| Time | TOTAL | | Waste level |
|---|---|---|---|
| | ACT(Bq) | ACT(TBq/m$^3$) | |
| 0 | **4.67E+17** | 2.46E+06 | HLW |
| 1week | **1.11E+17** | 5.86E+05 | |
| 1y | **1.20E+16** | 6.32E+04 | |
| 3y | **4.40E+15** | 2.28E+04 | |
| 5y | **3.03E+15** | 1.56E+04 | |
| 7y | **2.33E+15** | 1.19E+04 | ILW |
| 9y | **1.90E+15** | 9.72E+03 | |

| Time | TOTAL | | Waste level |
|---|---|---|---|
| | DH(W) | DH(kW/m$^3$) | |
| 0 | **4.28E+04** | 2.17E+02 | HLW |
| 1week | **3.28E+03** | 1.67E+01 | |
| 1y | **3.69E+02** | 1.87E+00 | |
| 3y | **1.24E+02** | 6.31E-01 | |
| 5y | **6.17E+01** | 3.14E-01 | ILW |
| 7y | **3.27E+01** | 1.66E-01 | |
| 9y | **1.86E+01** | 9.57E-02 | |

**time evolution of the maximum temperature load in the W target after shut-down**

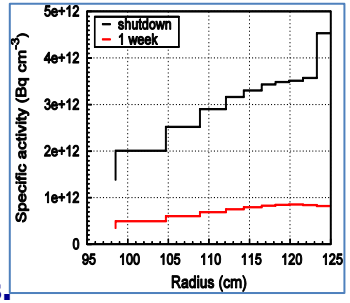


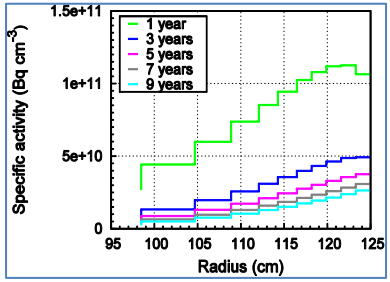

W target waste

**ILW** type: DH < 2 kW/m$^3$

A < $10^4$ Bq/m$^3$

**Radial distribution of the specific activity in W**




**Time after the final shut-down needed to handle and ship the activated items.**

| Item | Operation (ESS baseline) | Minimum waiting time | |
|---|---|---|---|
| | | Extraction | Shipping |
| Target wheel | 5 years | 1 week | < 5 years |
| Shaft | 5 years | 1 week | 1/2 - 1 year |
| PBW plug | (1/2- 1) year | 1 day | 1/2 - 1 year |
| PMR plug | (1/2- 1) year | 1 day | 1/2 - 1 year |

**Activity (Bq) of the high gamma energy nuclides within the tungsten wheel**

| Nuclide | Shut-down | 5 years |
|---|---|---|
| $^{22}$Na | 4.59E+11 | 1.21E+11 |
| $^{54}$Mn | 3.98E+12 | 6.91E+10 |
| $^{60}$Co | 6.61E+12 | 3.43E+12 |
| $^{154}$Eu | 6.61E+12 | 3.43E+12 |
| $^{172}$Lu | 8.47E+14 | 1.15E+14 |
| $^{173}$Lu | 1.15E+15 | 9.21E+13 |
| $^{182}$Ta | 9.94E+14 | 1.56E+10 |

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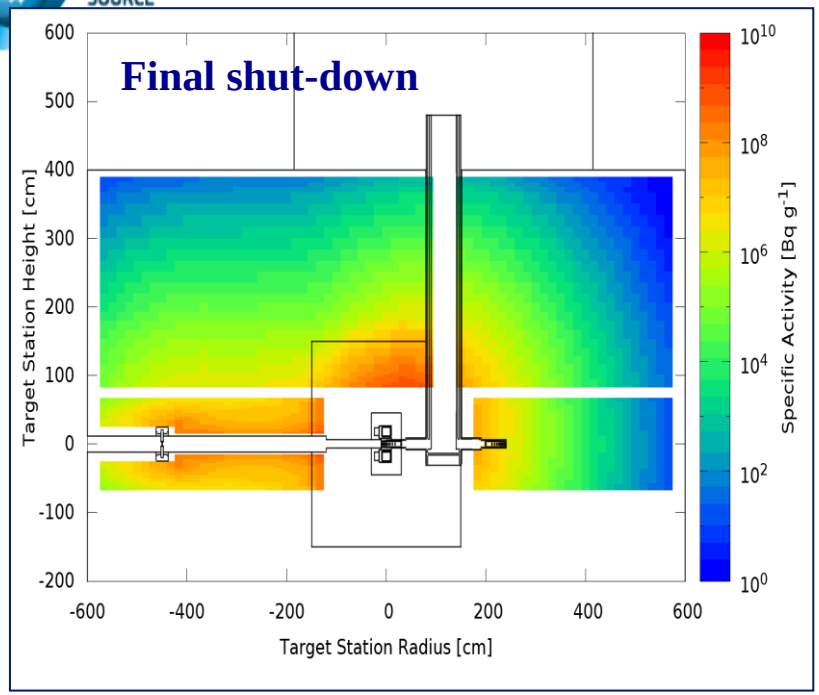
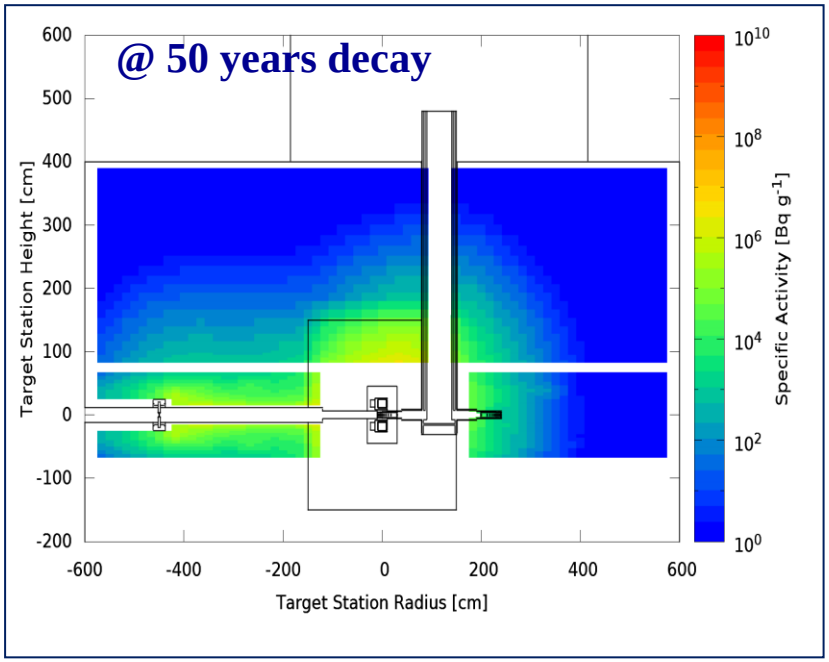
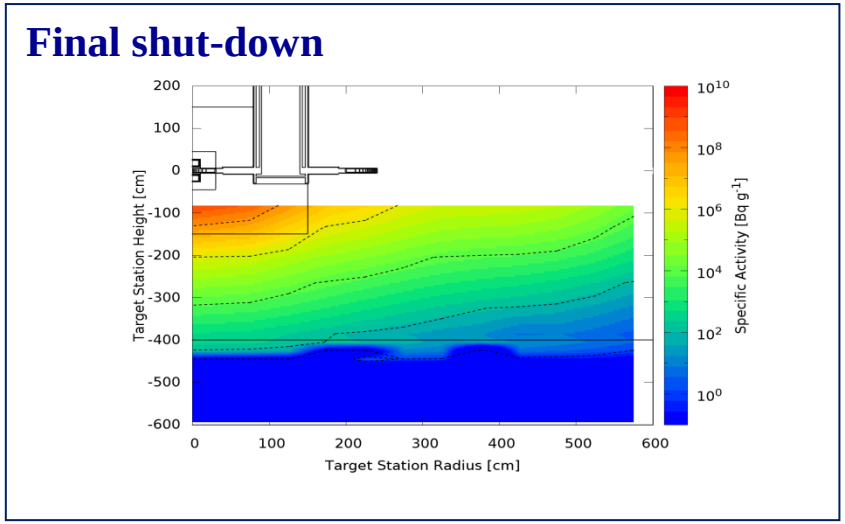
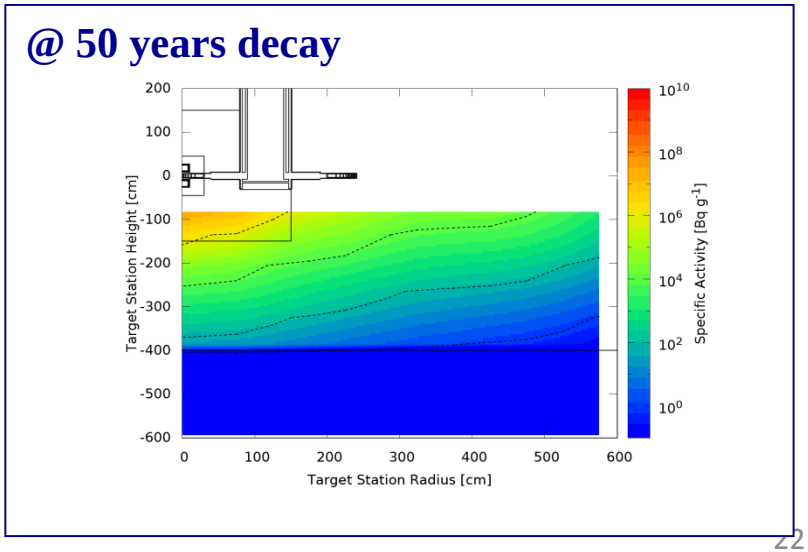
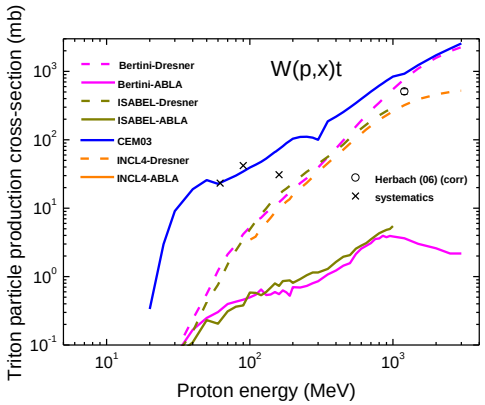
# DIRECT RADIATION: Components within TS with ESS lifetime (40 years)






# DIRECT RADIATION:

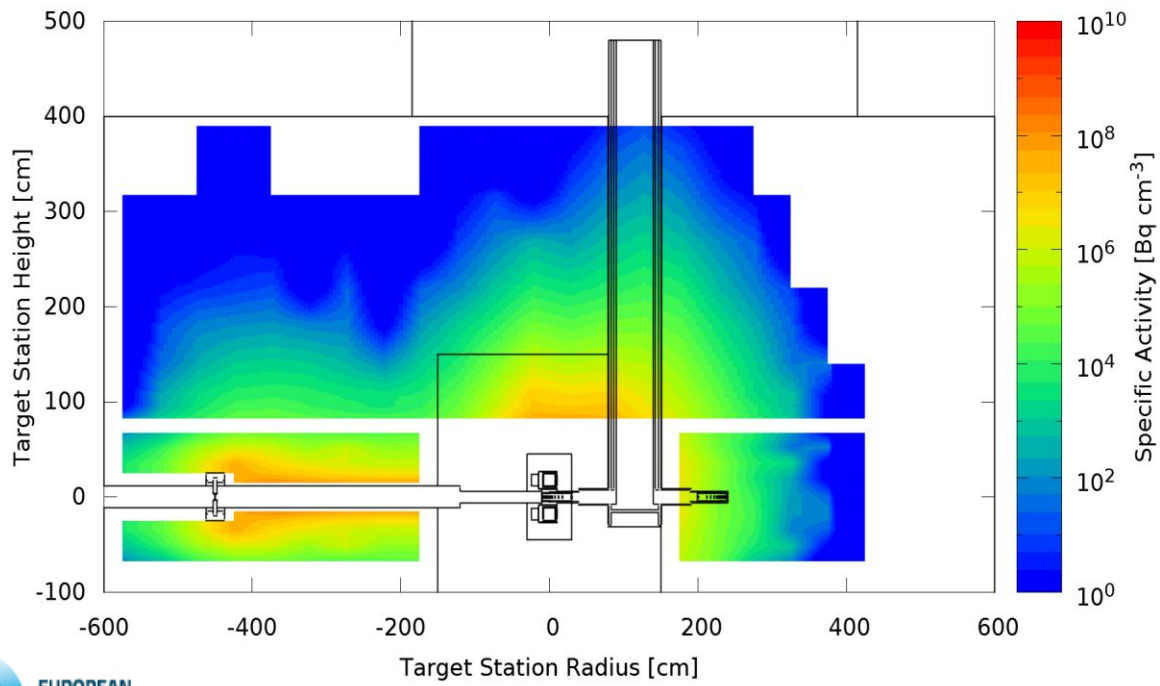
# $^3$H production

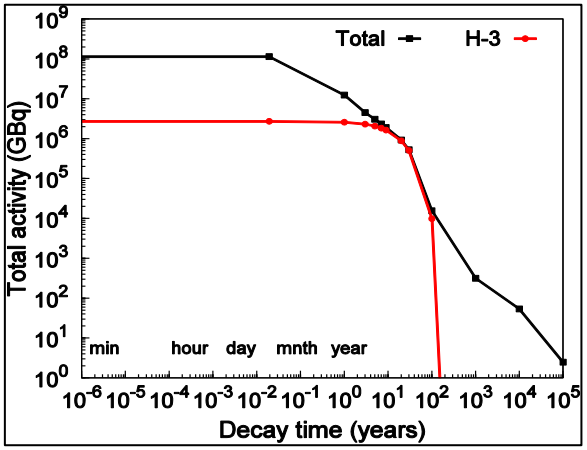
$^3$H release from the accelerator tunnel conservatively estimated of 1 GBq/year

## $^3$H activity produced in TMR in 5000 h operation

| Component | Activity (Bq) |
|---|---|
| Target | $6.13\ 10^{14}$ |
| Inner reflector (2) | $4.17\ 10^{14}$ |
| Target shroud | $2.88\ 10^{13}$ |
| Outer reflector | $9.32\ 10^{12}$ |
| Pre-moderator | $1.97\ 10^{12}$ |
| Moderator clad | $9.36\ 10^{11}$ |
| He coolant | $2.42\ 10^{10}$ |
| Moderator | $1.65\ 10^{10}$ |
| TOTAL | $1.07\ 10^{15}$ |

## Specific activity distribution of $^3$H inside target station @ final shutdown (40 years).



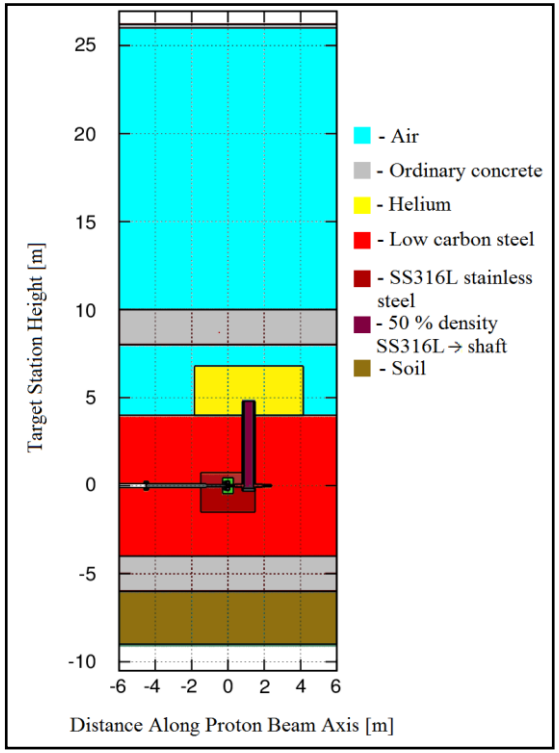



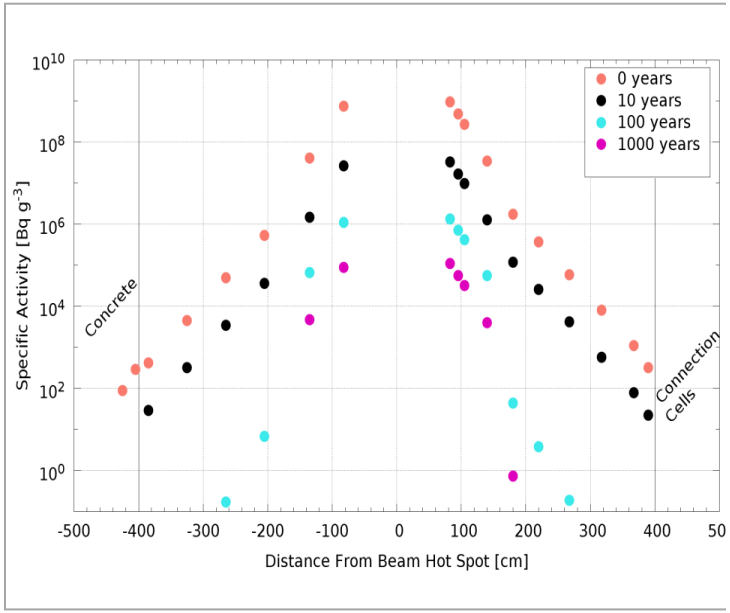

Total activity in the target and the $^3$H contribution as a function of the decay time after 5 years of irradiation.

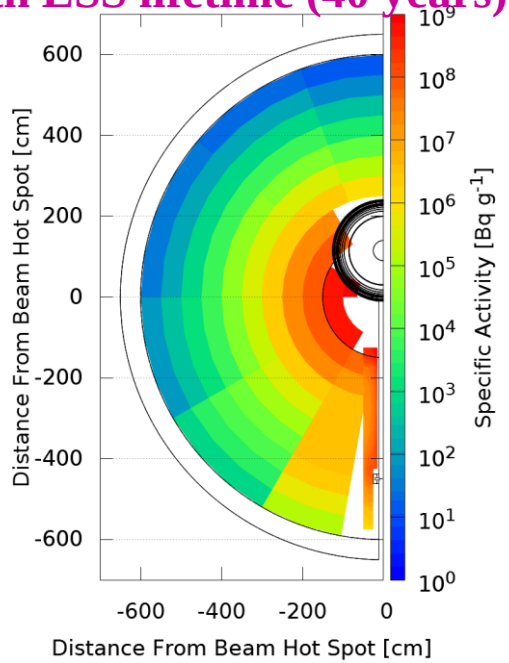
EUROPEAN SPALLATION SOURCE

# DIRECT RADIATION: Components within TS with ESS lifetime (40 years)

**@ Shut-down**



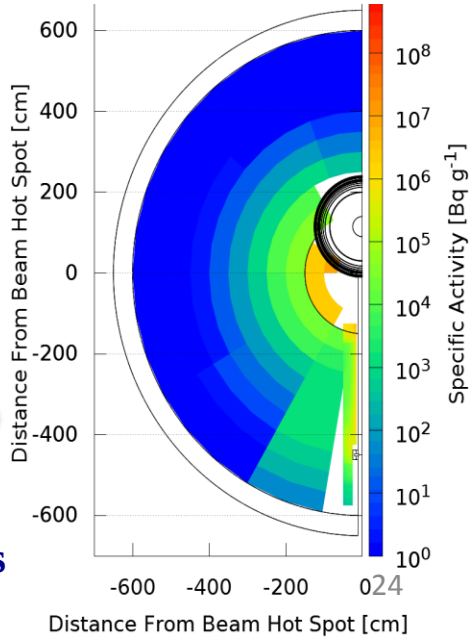




**Specific residual activity profiles along the vertical axis of the target station for different decay times. Center is at the beam hot spot .**

Specific activity distribution in a horizontal plane at the level of the target.

**@ 50 years**

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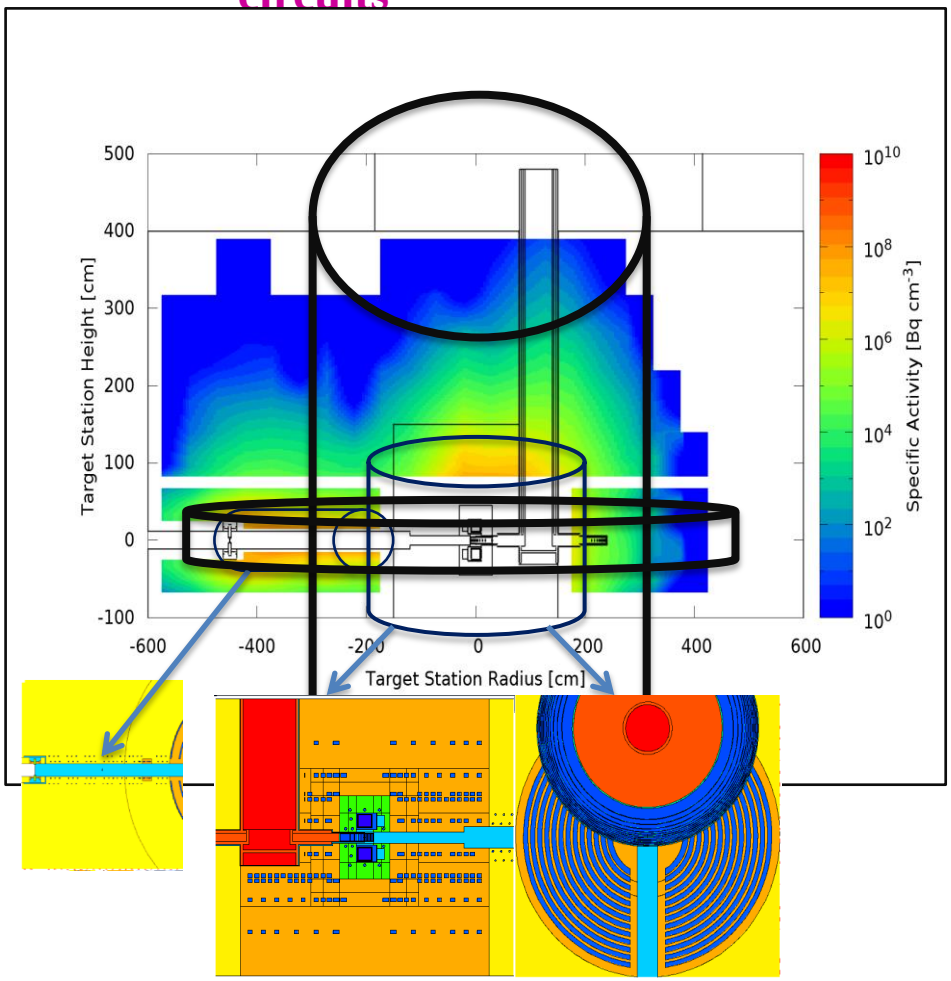
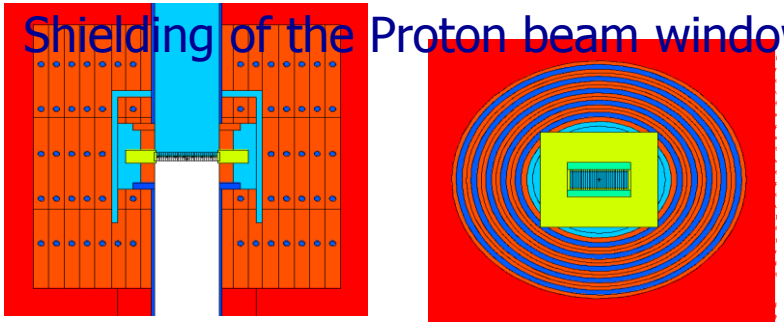
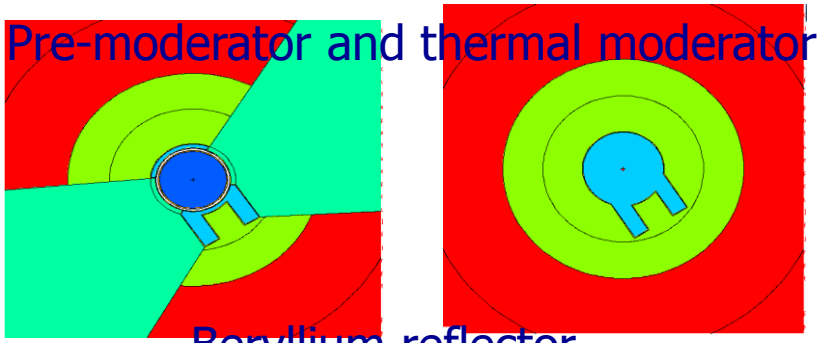
# DIRECT RADIATION: Activated water in primary circuits



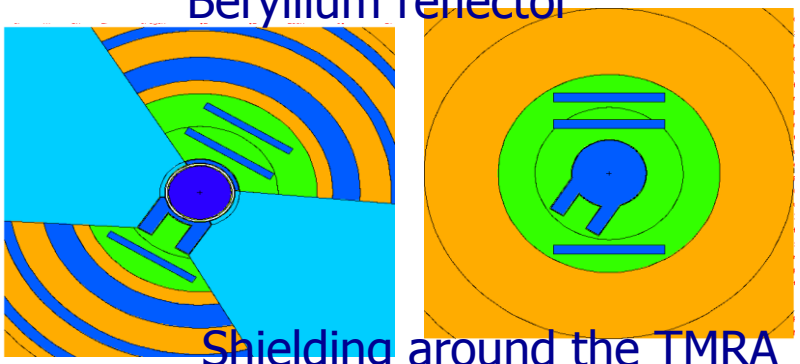

Shielding of the Proton beam window



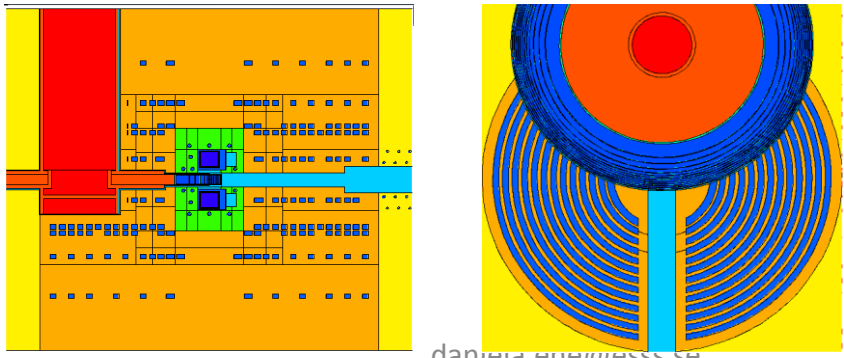
Pre-moderator and thermal moderator



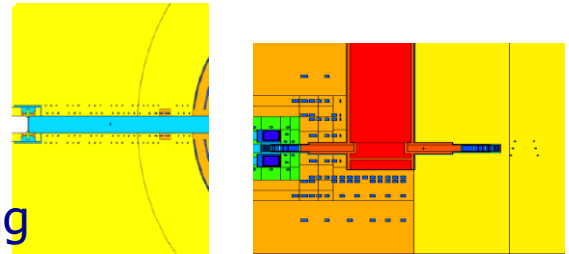
Beryllium reflector



Shielding around the TMRA

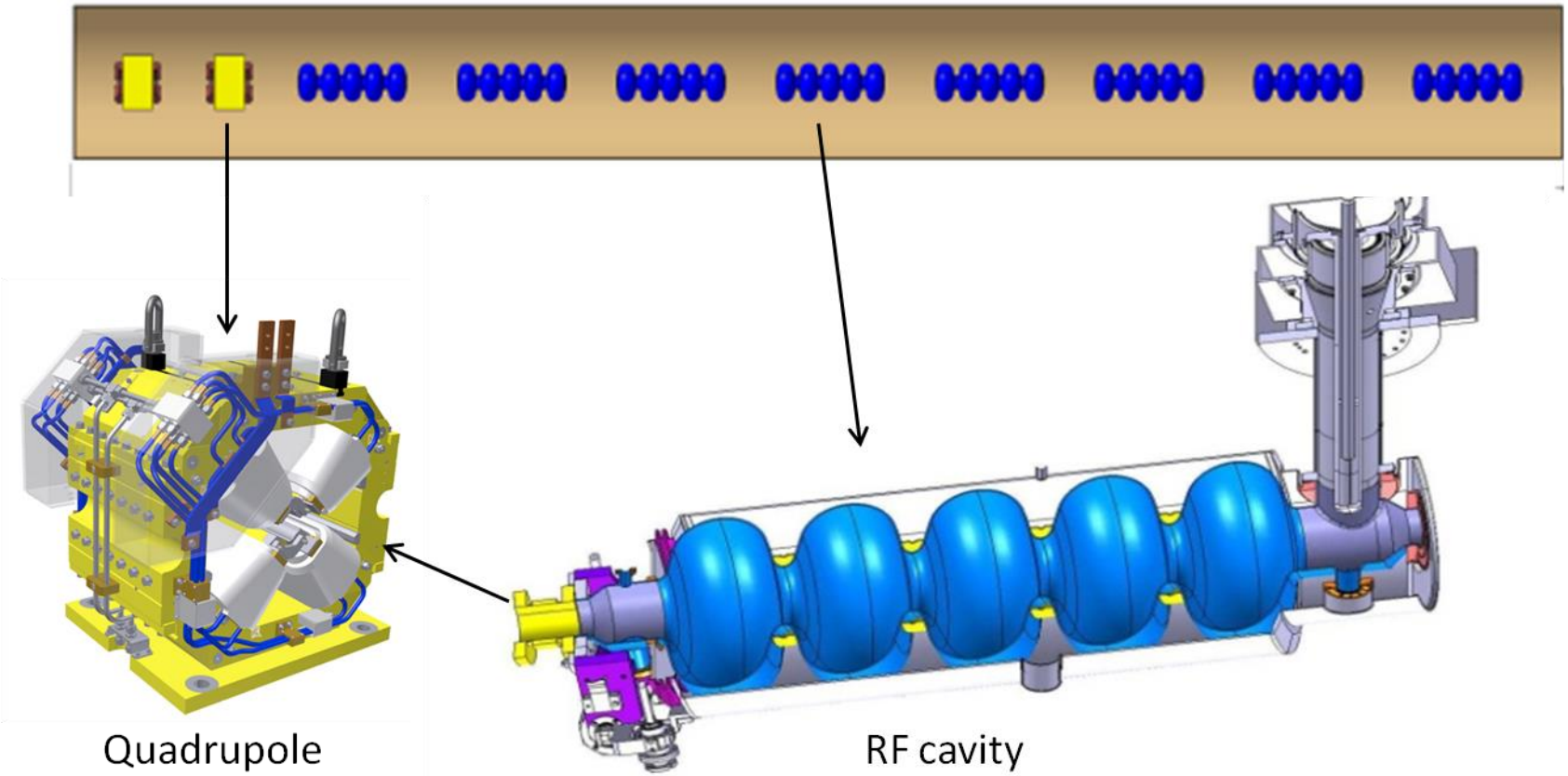


Instrument & plug & cooling around => beam guide in shielding

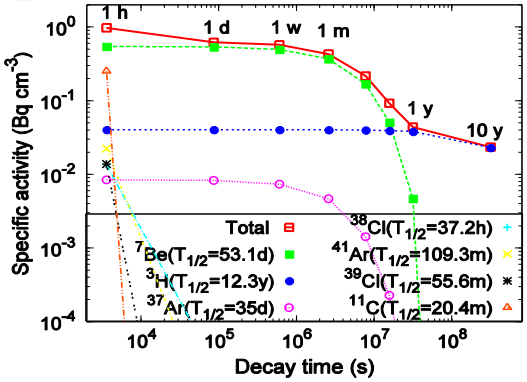


# Direct radiation: ACCELERATOR

ESS cryomodule: elliptical high beta



# Linac waste radiological characterization 1W/m loss



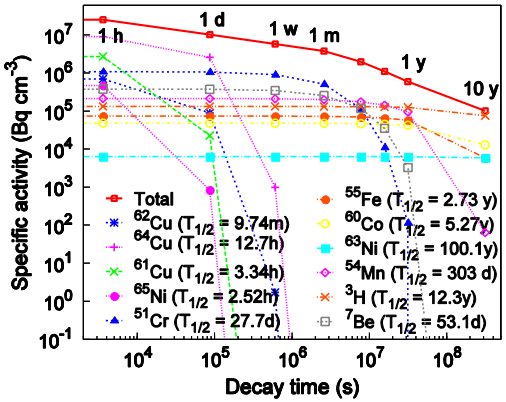

**1 m $^3$ air around the loss**

**Ventilation rate in the tunnel**

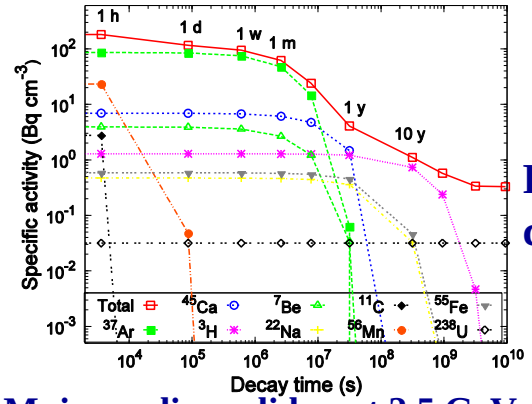
$$A_i = \lambda_i R_i \, T \frac{r}{r+\lambda i} \{1 - \exp[(\lambda_i + r)T]\} \exp(-\lambda_i t_{transit})$$

**Source Term**
**Specific activity [Bq cm$^{-3}$] in first 100 cm of soil surrounding the concrete wall** =>

| Isotope | $T_{1/2}$ | Soil |
|---|---|---|
| *$^{3}$H* | *12.33y* | 9.669E-01 |
| $^{7}$Be | 53.12d | 9.770E-02 |
| *$^{22}$Na* | *2.6y* | 1.537E-01 |
| $^{24}$Na | 14.96h | 5.348E+00 |
| $^{32}$P | 14.26d | 8.337E-02 |
| $^{35}$S | 87.32d | 5.863E-03 |
| $^{45}$Ca | 162.61d | 1.051E+00 |
| $^{46}$Sc | 83.79d | 2.022E-01 |
| $^{54}$Mn | 312.3d | 1.585E-01 |
| $^{55}$Fe | 2.73y | 1.935E+00 |
| $^{65}$Zn | 244.26d | 3.153E-04 |

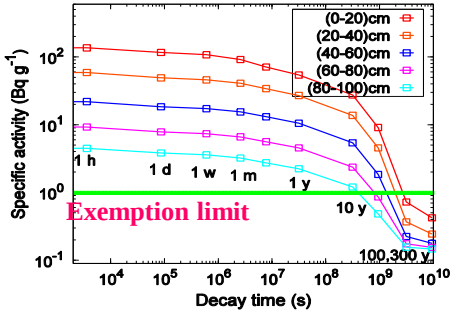


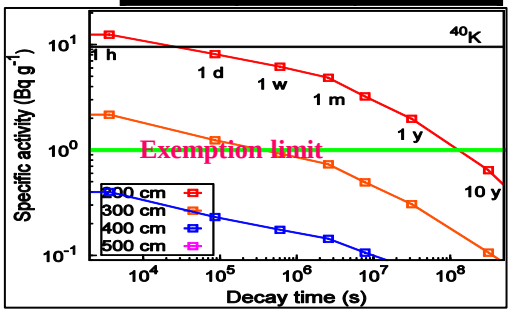

**Linac structure Cu quadrupol**



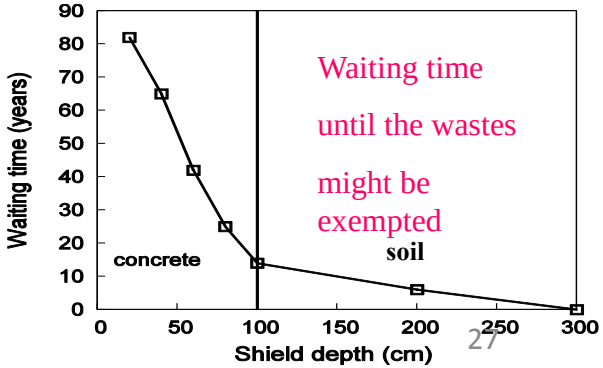

**First 20 cm concrete layer**

**Major radionuclides at 2.5 GeV**
**40 y operation @ 0.7 duty cycle**



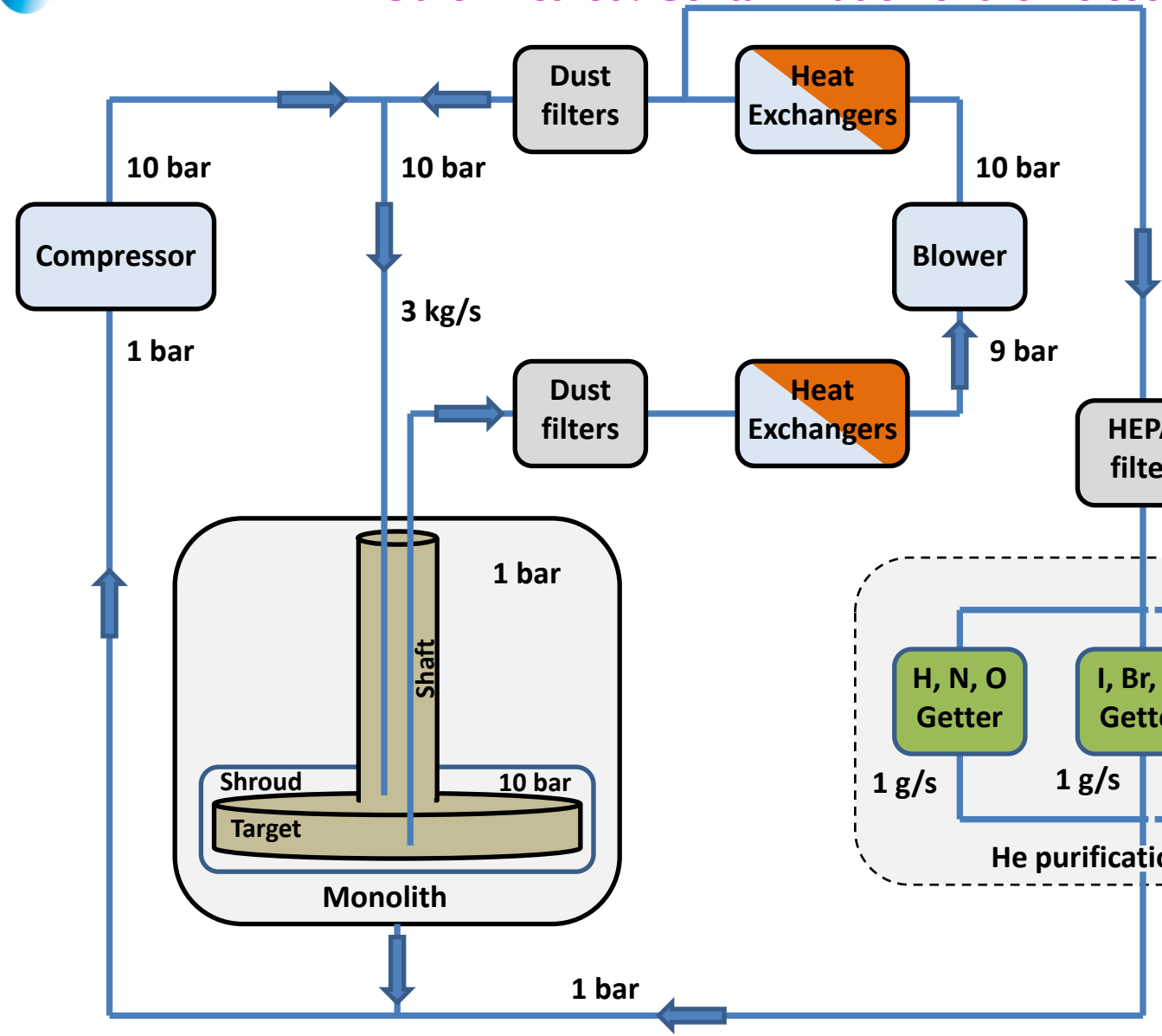




1.5E4 tones (volume of 6.4E+3 m$^3$) of concrete will require final disposal



# RADIOACTIVE WASTE EXPECTED AT SHUT-DOWN (4)

## Other method: Contamination of the He cooling circuit




-W target activation

-Release fractions of isotope within He coolant:

1 volatiles & 1/2volatiles

2 dust

Purification system based:

- Filters
- Getters

Waste

# ESS total waste amounts and types

| Waste origin | Accelerator | | | Target & Accelerator to target zone | | | Neutron Beam Lines & Instruments | | |
|---|---|---|---|---|---|---|---|---|---|
| | tones/y | tones/40y | material | tones/y | tones/40y | material | tones/y _or tones/10y =>* | tones/40y | material |
| Operation Maintenance | 15 | 600 | Fe-LLW | | 554 | Equipments-ILW-LL | 1890* | 7560 | Metal, some glass-LLW |
| | 1 | 40 | Ion exchangers | 7.1 | 288 | Cu&Fe-ILW-SL | 0.375 | 15 | samples, various-LLW |
| | | | | 6.5 | 258 | blocks, pipes-LLW-SL | | 7575 | Total -solid |
| | | | | 14 | 1096 | Total solid | 0.165 | 6.6 | L: burnable liquids |
| | | | | 4 | 160 | Ion exchangers | 0.165 | 6.6 | L: non-burnable liquids |
| | | | | | | | 1100* | 4400 | plastic-VLLW |
| | | | | | | | | | |
| Decommissioning @40y | | 1614 | metal-LLW | | 12 | Equipments | Shielding bunker | 11000# | concrete-LLW |
| | | 9345 | concrete-LLW | | 8540$ | Fe-ILW+LLW-SL | Instrument shielding | 20000# | concrete-LLW |
| | | 4000 | soil-VLLV | | 800 | concrete-VLLW | | 31156 | Total |

# CF of 0.5 $m^3$/ton was applied

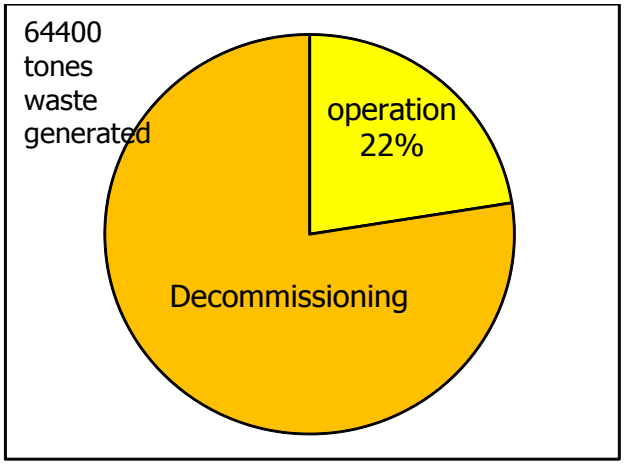
$compact shielding

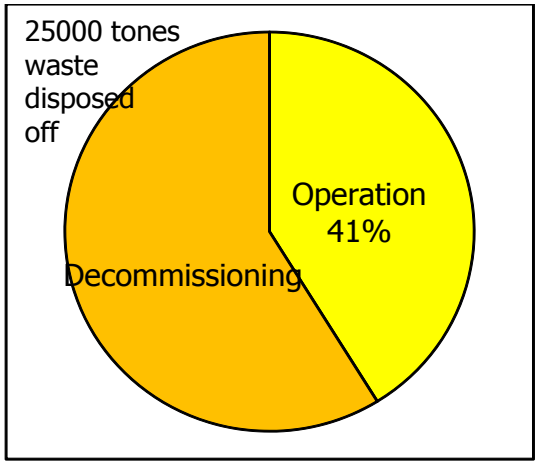
| | Operational (tones/40y) | | | | | Decommissioning (tones@40y) | |
|---|---|---|---|---|---|---|---|
| | Be | Sealed sources | solid-metal | liquids | Ion exchangers | Metal (Fe) | concrete |
| SFR | | 0.08 | 10000 | 15+180 | 200 | 10000 | 3500 |
| SFL | 13 | | 550 | | | 1000 | |
| Free released waste | 4400 | | | | | 36000 | |

- Potential to be disposed off
- Mixture : to be disposed off + free release
- Free release
- Disposal solution under analysis

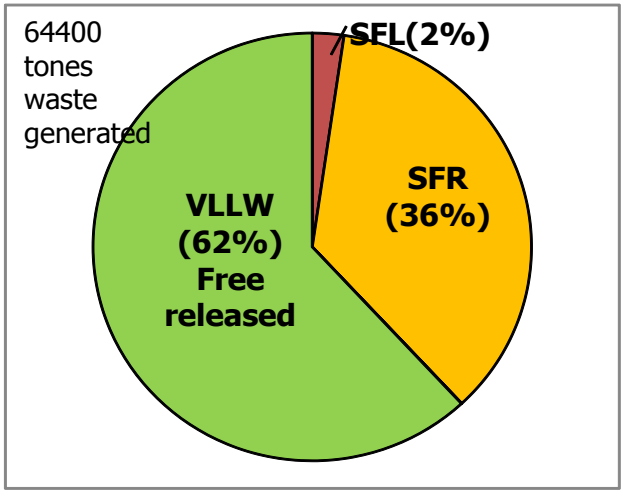
About **15000 tons of waste** is expected to be sent for final disposal from decommissioning

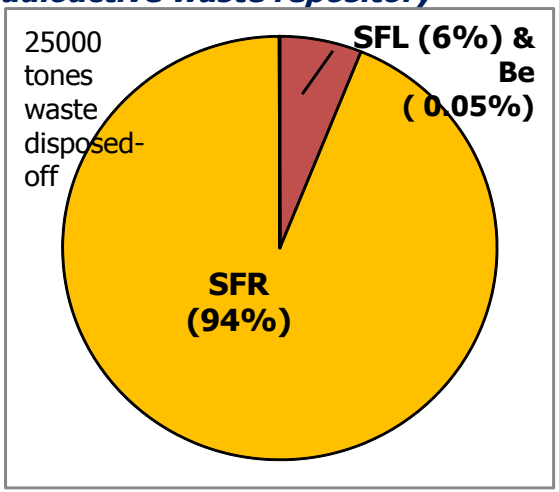
# Waste disposal | Assessment of disposal volumes needed




***Operational and decommissioning components of waste. Left: All waste generated. Right: Waste destined for a radioactive waste repository***




***Final disposition of waste. Left: All waste generated. Right: Waste destined for a radioactive waste repository.***

**Disposal capacity requested for ESS waste**

| Waste type | SFR $m^3$ | SFL $m^3$ |
|---|---|---|
| Equipments from TS & A2T | | 600 |
| Operational waste | 10000 | 10 |
| Decommissioning waste | 15000 | 1000 |
| **Total** | **25000** | **1600** |

The values for SFL also includes 13 $m^3$ of beryllium waste

Capacity of existing and planned repositories in Sweden:

SFR total volume 200 000 $m^3$
SFL total volume 10 000 $m^3$

**ESS waste < 12 %**

# RADWASTE MANAGEMENT (1)

## Waste classification

$$CI = \sum_{i}^{N_nuclides} \frac{A_i}{CL_i}$$

**Waste classification using clearance concept**

1. ***HLW = High Level Wastes, Heat generating***
2. ***LILW =Low and Intermediate Level Wastes:***
   - ***2.1 LL -LILW = Long Lived - LILW***
   - ***2.2 SL -LILW = Short Lived – LILW***
3. ***EW = Exempt Wastes***

**Examples on Clearance Levels (CL)**

| Radionuclide | Mass-specific Clearance Levels (RS-G-1.7) [Bq/g] | Surface-specific Clearance Levels (RP 113) [Bq/cm²] |
|---|---|---|
| $^{55}Fe$ | 1,000 | 10,000 |
| $^{3}H$, $^{63}Ni$ | 100 | 10,000 |
| $^{235}U$, $^{238}U$ | 1 | 1 |
| $^{60}Co$, $^{137}Cs$, $^{152}Eu$ | 0.1 | 1 |
| $^{239}Pu$ | 0.1 | 0.1 |

**ESS CI library achieved**

- ***CI < 1 =>EW;***
- ***CI > 1 :***

*1.CI _nuclides with* $T_{1/2}$ ***> 30 years <1 >SL-LILW***

*2.CI _nuclides with* $T_{1/2}$ ***> 30 years >1 &***

*Long lived alpha emitters: > 400 Bq* $g^{-1}$ *average;*

*> 4000 Bq* $g^{-1}$ *individual package*

***LL-LILW***

3. *Generated heat* ***(>2 kW*** $m^{-3}$ & $10^4$ TBq/m3 => ***HLW***

**Valuable tool for decommissioning waste classification**

# Waste classification (1)

Clearance index of the soil around the concrete wall of the linac high energy zone expected at shut-down.

| Isotope | T1/2 (y) | A (Bq/g) | L* (shut-down) (Bq/g) | A/L (shut-down) | A (Bq/g) (1y) | A/L (1y) | A (Bq/g) (15y) | A/L (15y) |
|---|---|---|---|---|---|---|---|---|
| $^{3}H$ | 1.23E+01 | 6.04E-01 | 100 | 6.04E-03 | 5.71E-01 | 5.71E-03 | 2.60E-01 | 2.60E-03 |
| $^{7}Be$ | 5.31E+01 | 6.11E-02 | 10 | 6.11E-03 | 6.03E-02 | 6.03E-03 | 5.02E-02 | 5.02E-03 |
| $^{22}Na$ | 2.60E+00 | 9.61E-02 | 0.1 | 9.61E-01 | 7.36E-02 | 7.36E-01 | 1.77E-03 | 1.77E-02 |
| $^{24}Na$ | 1.71E-03 | 3.34E+00 | 1 | 3.34E+00 | | | | |
| $^{32}P$ | 3.90E-02 | 5.21E-02 | 100 | 5.21E-04 | 1.02E-09 | 1.02E-11 | | |
| $^{35}S$ | 2.39E-01 | 3.66E-03 | 100 | 3.66E-05 | 2.02E-04 | 2.02E-06 | | |
| $^{45}Ca$ | 4.45E-01 | 6.57E-01 | 100 | 6.57E-03 | 1.38E-01 | 1.38E-03 | 4.73E-11 | 4.73E-13 |
| $^{46}Sc$ | 2.29E-01 | 1.21E-01 | 0.1 | 1.21E+00 | 6.16E-03 | 6.16E-02 | | |
| $^{54}Mn$ | 8.55E-01 | 9.91E-02 | 0.1 | 9.91E-01 | 4.40E-02 | 4.40E-01 | 5.19E-07 | 5.19E-06 |
| $^{55}Fe$ | 2.73E+00 | 1.21E+00 | 100 | 1.21E-02 | 9.38E-01 | 9.38E-03 | 2.68E-02 | 2.68E-04 |
| $^{65}Zn$ | 6.69E-01 | 1.97E-04 | 1 | 1.97E-04 | 6.99E-05 | 6.99E-05 | 3.49E-11 | 3.49E-11 |
| $^{152}Eu$ | 1.35E+01 | 2.35E-03 | 0.1 | 2.35E-02 | 2.23E-03 | 2.23E-02 | 1.09E-03 | 1.09E-02 |
| $^{154}Eu$ | 8.59E+00 | 2.86E-04 | 0.1 | 2.86E-03 | 2.64E-04 | 2.64E-03 | 8.52E-05 | 8.52E-04 |
| $^{40}K$ | 1.3E+09 | 9.53 | 100 | 9.53E-02 | 9.53 | 9.53E-02 | 9.53 | 8.52E-04 |
| SUM | | | | **7** | | **1** | | **0.04** |

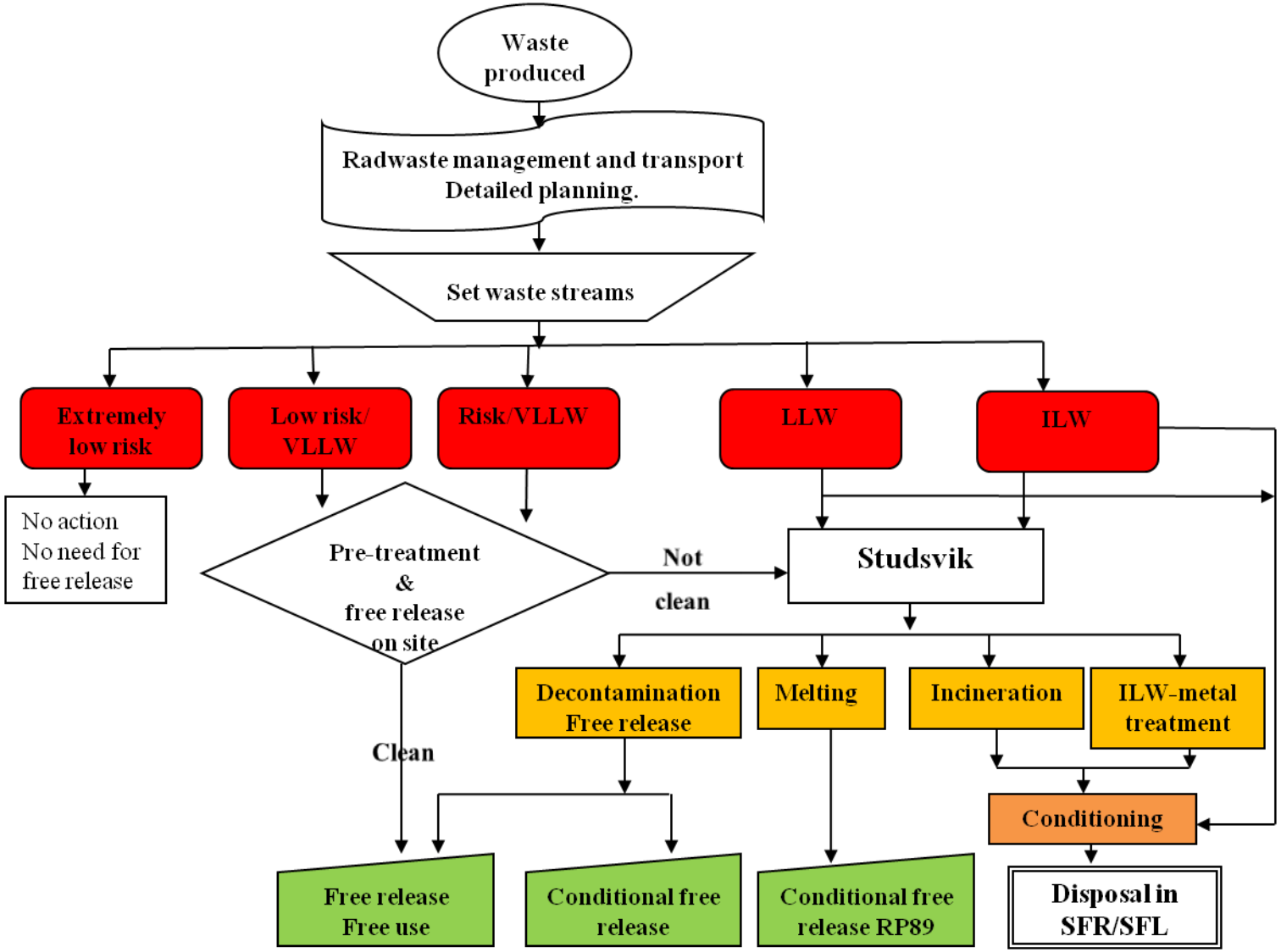
# Waste classification (2)

Clearance index of the concrete wall of the linac high energy zone expected at shut-down. The most important isotopes in the first 20 cm layer of the wall are given in the table.

| | T1/2 (y) | Specific activity (A) (Bq/g) | Clearance Index (L)*(Bq/g) | A/L (shut-down) | A/L (1y) | A/L (10y) | A/L (40 y) |
|---|---|---|---|---|---|---|---|
| H-3 | 1.23E+01 | 4.47E+01 | 100 | 4.47E-01 | 4.22E-01 | 2.55E-01 | 4.72E-02 |
| Be-7 | 5.31E+01 | 2.45E+00 | 10 | 2.45E-01 | 2.42E-01 | 2.15E-01 | 1.45E-01 |
| Na-22 | 2.60E+00 | 3.92E+00 | 0.1 | 3.92E+01 | 3.00E+01 | 2.73E+00 | 9.23E-04 |
| Na-24 | 1.71E-03 | 6.09E+00 | 1 | 6.09E+00 | | | |
| P-32 | 3.90E-02 | 1.76E+00 | 100 | 1.76E-02 | 3.45E-10 | | |
| S-35 | 2.39E-01 | 3.73E-01 | 100 | 3.73E-03 | 2.05E-04 | | |
| Ca-45 | 4.45E-01 | 1.08E+01 | 100 | 1.08E-01 | 2.28E-02 | 1.87E-08 | |
| Sc-46 | 2.29E-01 | 2.93E-01 | 0.1 | 2.93E+00 | 1.43E-01 | 2.21E-13 | |
| Mn-54 | 8.55E-01 | 1.00E+00 | 0.1 | 1.00E+01 | 4.44E+00 | 3.01E-03 | |
| Fe-55 | 2.73E+00 | 5.10E+00 | 100 | 5.10E-02 | 3.95E-02 | 4.02E-03 | 1.98E-06 |
| Zn-65 | 6.69E-01 | 6.70E-02 | 1 | 6.70E-02 | 2.38E-02 | 2.11E-06 | 0 |
| Eu-152 | 1.35E+01 | 6.95E-01 | 0.1 | 6.95E+00 | 6.61E+00 | 4.17E+00 | 8.97E-01 |
| Eu-154 | 8.59E+00 | 5.69E-02 | 0.1 | 5.69E-01 | 5.25E-01 | 2.54E-01 | 2.26E-02 |
| total | | | | **67** | **42** | **7** | **1** |

# RADWASTE MANAGEMENT (2)

Flow chart for radwaste logistics at the ESS facility during operation



# KEY ELEMENTS OF DECOMMISSIONING PLAN

- Licensing conditions
- Staffing and training
- Organization and administrative control
- Cost estimation
- Waste management
- Emergency management
- Radiation and physical protection
- On and off site monitoring
- Quality assurance

## KEY ELEMENTS OF DECOMMISSIONING PLAN: Cost estimation

- Pre-decommissioning actions (conceptual and detailed decommissioning planning, authorisation, radiological and hazardous material surveys, selection of subcontractors)
- Facility shutdown activities (termination of operation, stabilization, isolation and inspection of radiologically controlled areas, drainage and drying or blowdown of all systems not in operation, sampling for radiological inventory characterisation, removal of system fluids, spent resins, combustible materials, decontamination of surfaces)
- Procurement of general equipment and material
- Dismantling activities
- Waste processing, storage and disposal
- Site security, surveillance and maintenance
- Site restoration, clean-up and landscaping
- Project management, engineering and site support
- Research and development
- Others

The ASTRA experiences showed the following ratios:

Personnel costs: 72%

Waste processing and storage: 23%

Procurement of equipment: 5%

The total decommissioning cost of the ASTRA project was 15,2 M euro, that is approximately 130 M SEK. The total manpower requirement was 88 man×year, that is an average personnel of 18 (comprising managers, engineers and technicians) was able to accomplish the project.

**The estimated costs for the ESS decommissioning project are under investigation.**

# ENGINEERING DESIGN RECOMMENDATIONS:

- Decommissioning plans
- Site factors
- Facilities and system design
- Structural design
- Operational design
- Materials design
- Waste management

**Design principles and good practices applied to minimize the activity and the volume of radioactive waste generated from ESS facility operation and maintenance:**

- Materials are chosen with the view to minimize induced radioactivity (via consideration of neutron capture cross section and half lives of product nuclei – low cobalt and low manganese steels will be used, while aluminum alloys are preferred to the steels when possibl
- Neutron-producing target is made of the refractory metal tungsten. Radionuclides produced through proton irradiation are therefore held within the target being thus better contained than if the target was made from mercury or lead-bismuth eutectic , as occurs in other spallation sources;
- The proton beam will not be accelerated unless the machine will be set-up or run for experimental programmers. In particular when the beam will be adjusted (the proton beam losses will be unavoidable higher than in normal usage) the mean beam current will be minimized by reducing the pulse repletion frequency, minimizing therefore the irradiation of components within the machine.
- Wherever possible the beam lines and related components will be designed in a modul fashion, such that the replacement and repair of components generates the smallest reasonab volume of waste. The modular design of beam line and accelerator components encourages th re-use of irradiated components for spare parts.
- Activated solid waste from the facility operation that poses no loose contamination, wil be size-reduced through dismantling and cropping techniques, in order to minimize the volume of radioactive waste arising;
- Wherever possible, radioactive solid materials are either reincorporated in the equipment, or used for spare parts. Examples of this include magnets and shielding blocks.
- Active and non-active wastes are segregated. Waste generated in radioactive areas is segregated into radioactive and non-radioactive bins based on provenance. The segregation operation will be done with the assistance of Radiation Protection staff. Waste identified as no radioactive in this way undergoes reassurance monitoring prior to be sent to classical disposal;
- Wherever possible, solid waste are decontaminated in order to minimize, as far as reasonably practicable, radioactive waste arising;
- Wherever possible, management and/or engineering controls will be put in place to minimize the requirements to use personal and respiratory protective equipments when performing tasks. These equipments will be also reused wherever practical and safe to do so. These measures reduce the amounts of contaminated protective equipments designated as radioactive waste;
- Majority of solid radioactive waste may be compacted in order to reduce the volume of radioactive waste produced;
- Bespoke drainage system will be installed in the target station to recycle the collected cooling system water. In this way the release of tritiated water to the environment will be minimized;

# Summary

**Major achievements:**

- **Decommissioning strategy**
- **Base line plan for decommissioning**
- **Estimates of the total ESS waste volumes**
- **Management of radwaste**
- **Classification of the waste in agreement with Swedish system**;
- **Waste streams** identification; treatment lines can handle and suitable disposal facilities =>waste type descriptions (WTD);
- **problematic waste;**
- **treatment/conditioning options** appropriate for the waste streams and where they will be performed;
- **waste disposal options** & **the disposal volumes** needed

**The current data are estimations subjected to evolutions and regular updates.**

**An important outcome of the assessment made is that all ESS waste can most probably be treated and disposed of within the existing and planned Swedish waste system.**

# Thank you !

EUROPEAN
SPALLATION
SOURCE

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