Radionuclides and Radioactive Waste Characterisation at the European Spallation Source ESS

9. RCA Workshop 08 June 2021
VKTA, Dresden, Germany
Webex Meeting

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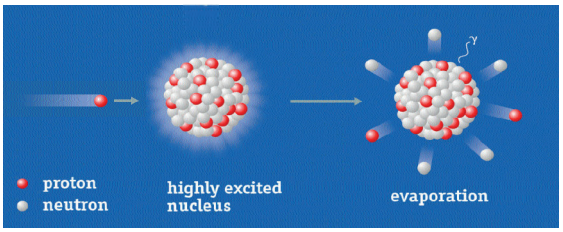
HOLGER TIETZE-JAENSCH | RADIOACTIVE WASTE MANAGER AT ESS, LUND, SWEDEN

2021-06-08, 12:50-13:10

Topics

Exciting Science with Pulsed Neutrons

From a hydrogen bottle → fast protons → pulsed neutrons → data → knowledge



Spallation: A nuclear process in which a high energy proton (particle) excites a neutron rich nucleus which decays by sending (steaming) out neutrons (~1 µs)

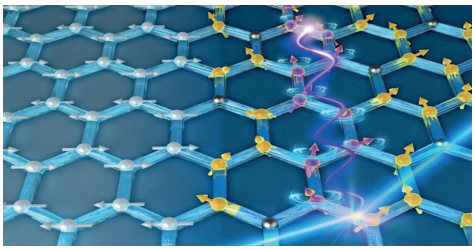
(and other particles such as gammas, protons, muons, pions, neutrinos…)

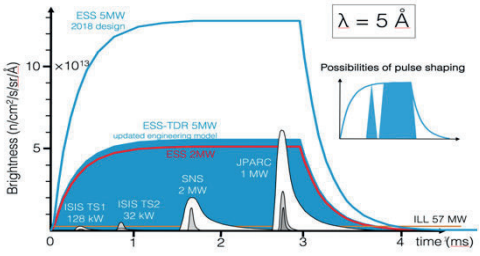
Exciting Science with Pulsed Neutrons

From a hydrogen bottle to fast protons to pulsed neutrons to data

Neutrons for Science:

1. Condensed matter and life science
2. Physics and chemistry of materials, magnetic and electronic phenomena, structural and dynamic properties, kinetics and coherent phenomena, soft matter and large scale problems
3. Particle physics, fundamental properties of quarks and co., fast neutron science
4. Engineering and geoscience, cultural heritage

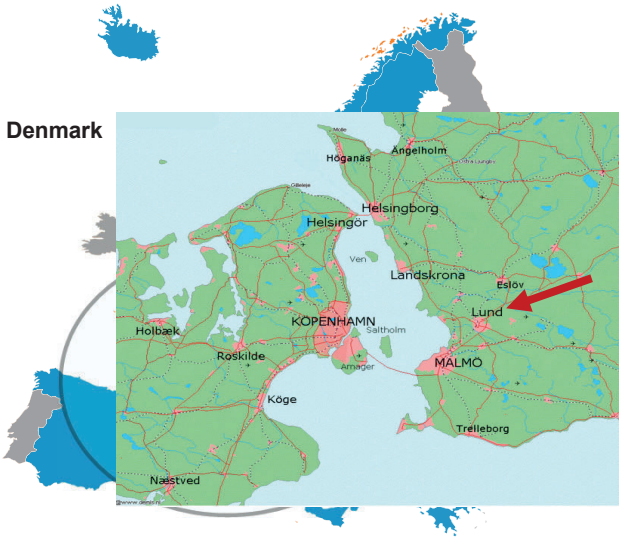




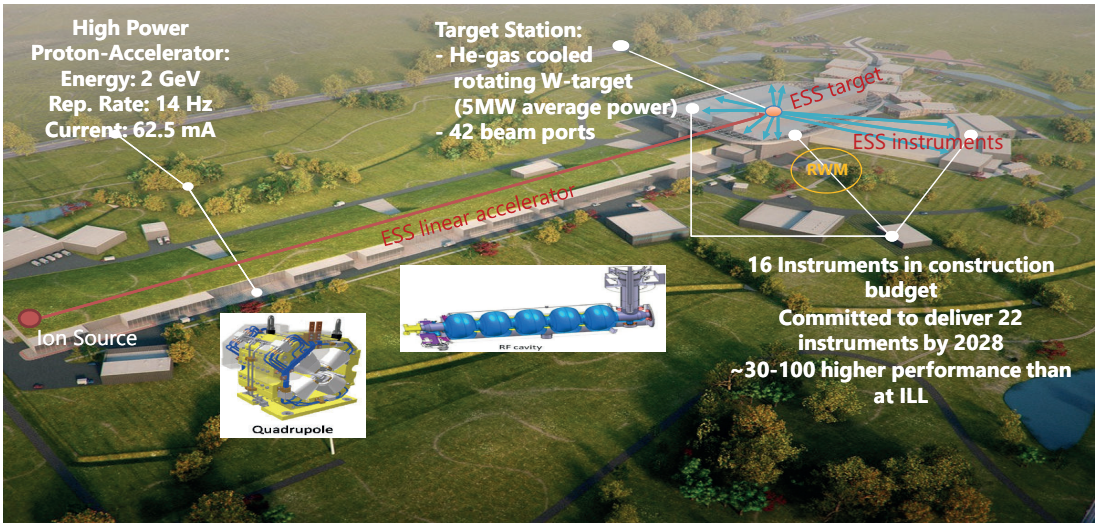
European Consortium ESS

Host Countries of Sweden and Denmark
47,5% Construction
15% Operations
In-kind Deliverables ~3%
Cash Investment ~97%

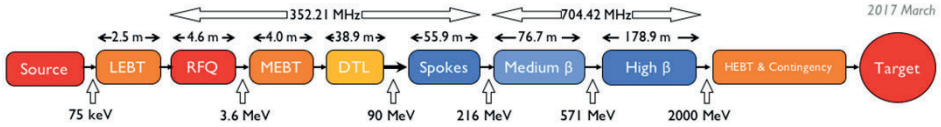
Non Host Member Countries
52,5% Construction
85% Operations
In-kind Deliverables ~ 70%
Cash Investment ~ 30%



ESS Design and Layout

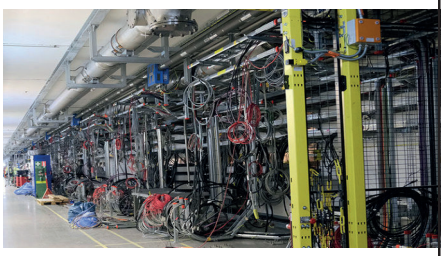


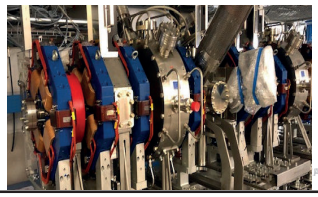
ESS Accelerator

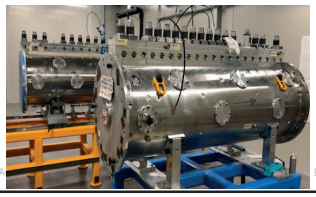


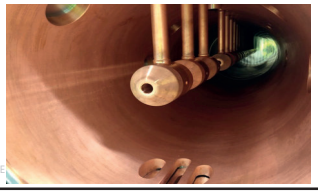
1. Prompt radiation 2. Residual radiation 3. Contamination

- Activation of components, air, coolants: **H-3, Be-7**, C-14, (Be-10) + SL
- Steady state beam loss: 1W/m: Fe-55, Co-60, Co-58, Co-57, Co-56, Mn-54, Zr-88, Sr-85, Y-88, Rb-83, Se-75, Ni-63, V-49, Sc-46, + SL
- Full point beam loss: local spallation source, short exposure time
- Nasty specialist: Gd-148 (LL alpha emitter, spallation product)







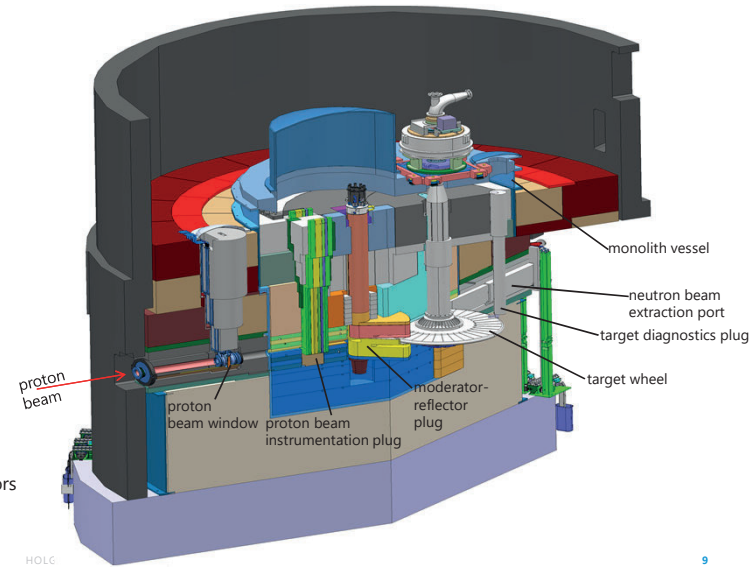


ESS Target Station

Monolith, target wheel, He-gas cooling, moderator/reflector

Main components:

- Monolith:
  - Vessel (6 m diameter x 8 m height)
  - Steel shielding (6000 tons)
  - Instrumentation plugs
  - Proton beam window
  - Neutron shutters
  - Neutron beam extraction system
- Rotating Tungsten target
  - 2.5 m diameter x 10 cm height
  - 7500 Tungsten bricks (3.5 tons)
  - 0.39 rev./s
- Target He gas-cooling
  - 3 MW capacity
  - 3 kg/s flow rate
  - ΔT = 200 °C
- High brightness moderators
  - 2 liquid H_2 moderators
  - Water premoderators and moderators
  - He cryoplant (35 kW – 16 K)



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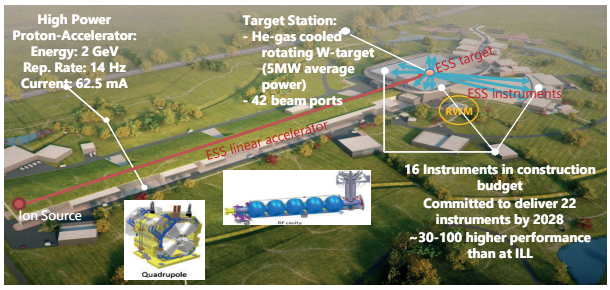
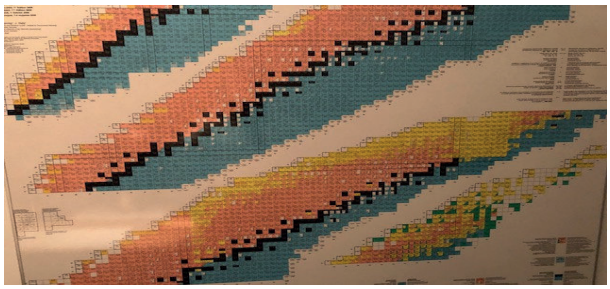
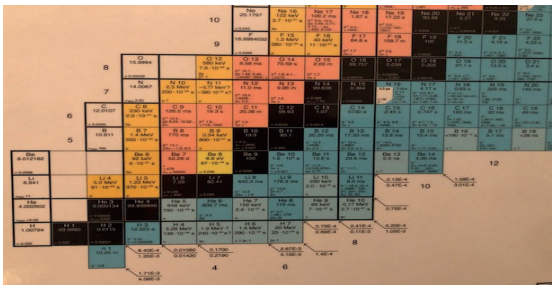






ESS Construction

Sep 2014

June 2018

May 2019

Oct 2020

ESS under construction:

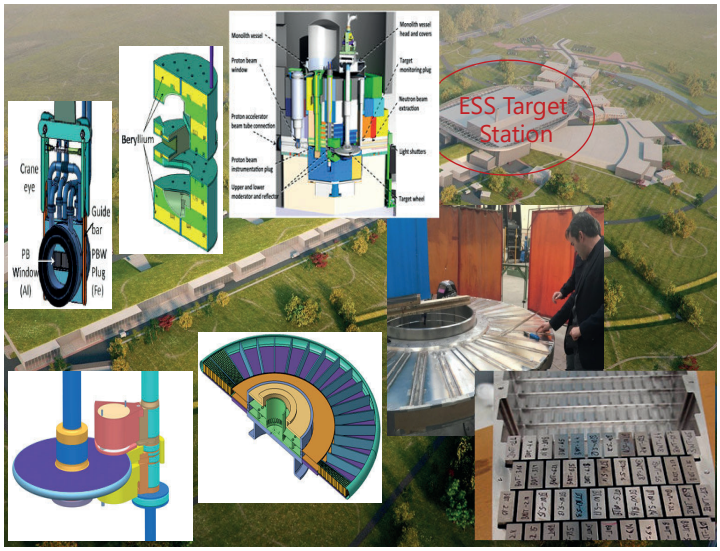
- Sep 2014 ground breaking
- 2021 accelerator commissioning
- 2022 first instrument commissioning
- 2023 SOUP: start of user program

http://www.ess.eu/

ESS Radioactive Waste

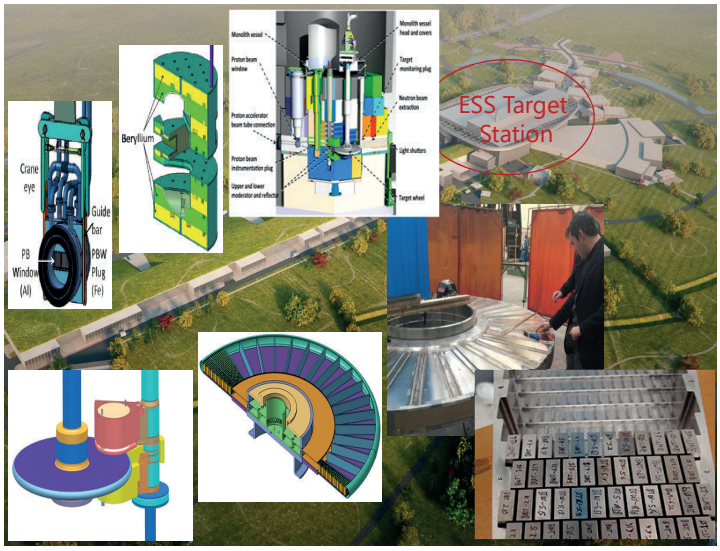
Operational Residues
Exempt waste (EW)
H-3 discharge
Short-lived low level waste (SL-LLW)
Short-lived intermediate level waste (SL-ILW)
Long-lived low level waste (LL-LLW)
Long-lived intermediate level waste (LL-ILW)

Waste forms:
1. Gaseous / aerosols
2. Liquids
3. Solids:
   - Metal
   - Concrete / rubble
   - Organic
   - Combustable
   - Other



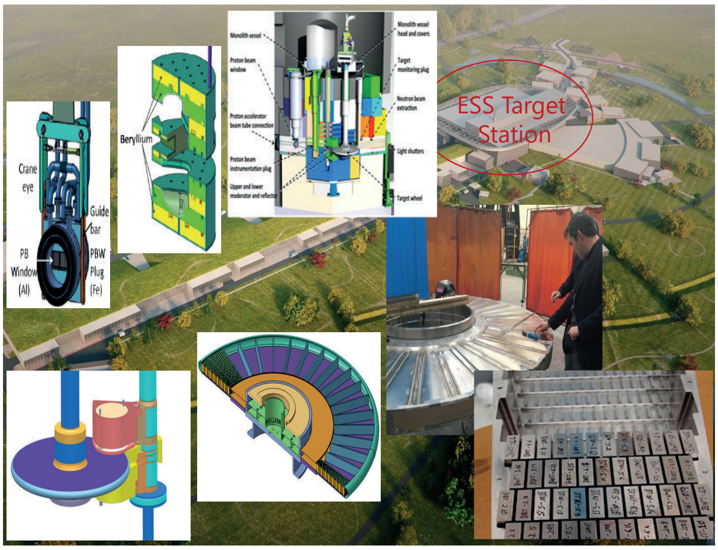
ESS Radioactive Waste

Target Wheel, 1 W-wedge (5 years)				
5 lead RN	Activity Bq (ct:5a)	Fraction (%)	T-1/2	Spec. activity per item TBq/g
Hf-172	2.2 E14	42	1.9a β+	4.3E-05
Ta-179	1.3 E14	26	1.8a, β+	2.7E-05
Lu-173	9.6 E13	19	1.4a, β+	1.9E-05
Pm-145	3.0 E13	6	17.7a, β+	6.0E-06
Cd-109	5.9 E12	1	1.3a, β+	1.2E-06
Proton Beam Window Plug (6 months)				
5 lead RN	Activity Bq (ct:5a)	Fraction (%)	T-1/2	Spec. activity per item TBq/g
Fe-55	3.5 E13	92	2.7a, β+	6.8E-05
Co-60	1.5 E12	4	5.3a, β-	3.0E-06
Co-57	6.1 E11	1.6	0.7a, β+	1.2E-06
Mn-54	5.1 E11	1.4	0.9a, β+	1.0E-06
Ni-63	1.1 E11	0.3	101a, β-	2.1E-07



ESS Radioactive Waste

He-Filter (TS, 6 months, no decay time)				
5 lead RN	Activity Bq (ct:0)	Fraction (%)	T-1/2	Spec. activity per item TBq/g
Ta-182	2,4 E10	14	0,5a β-	
Lu-172	4,5 E9	2	7d, β+	
Y-88	3.6 E9	2	1.4a, β+	
Eu-145	2.7 E9	2	6d, β+	
Tb-160	1.6 E11	80	73d, β-	
Water cooling SIER, 6 months, no decay time)				
5 lead RN	Activity Bq (ct:0)	Fraction (%)	T-1/2	Spec. activity per item TBq/g
Eu-154	1.2 E9	36	2.8a, β-	
Nb-92m	1.1 e9	34	10d, β+	
Sc-46	5 E8	15	84d, β-	
Eu-152	4 E8	12	13a, β+	
Co-56	1 E8	3	77d, β+	



Metrology to Ease Conditioning / Packaging & Containment
(no legacy waste at ESS)

Metrology:
waste stream characterisation, campaign classification
sampling and scaling → easy to measure key nuclides
rad-chem. analysis on samples → scaling / nuclide vectors → declarable RN
other declarable parameters: total activity and decay time, mass, chem.-/material composition

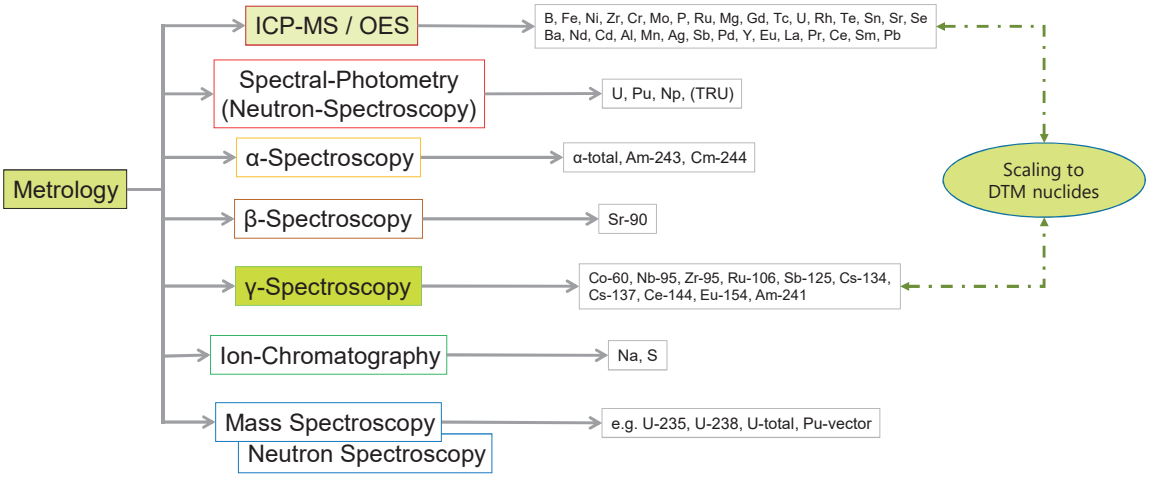
material classification: sorting & separation
identify, select and set aside difficult RW-parts (for later)
prevent / avoid exclusion criteria or show stopper content:
→ no corrosion, no gases, no liquids, no explosives / reactive mat.
all defined my max. acceptance levels (activity, life-time, toxicity)

Waste types:
waste types classification: classes with basic + supplementary properties
waste type defines → conditioning requirements
waste type defines → package/container requirements

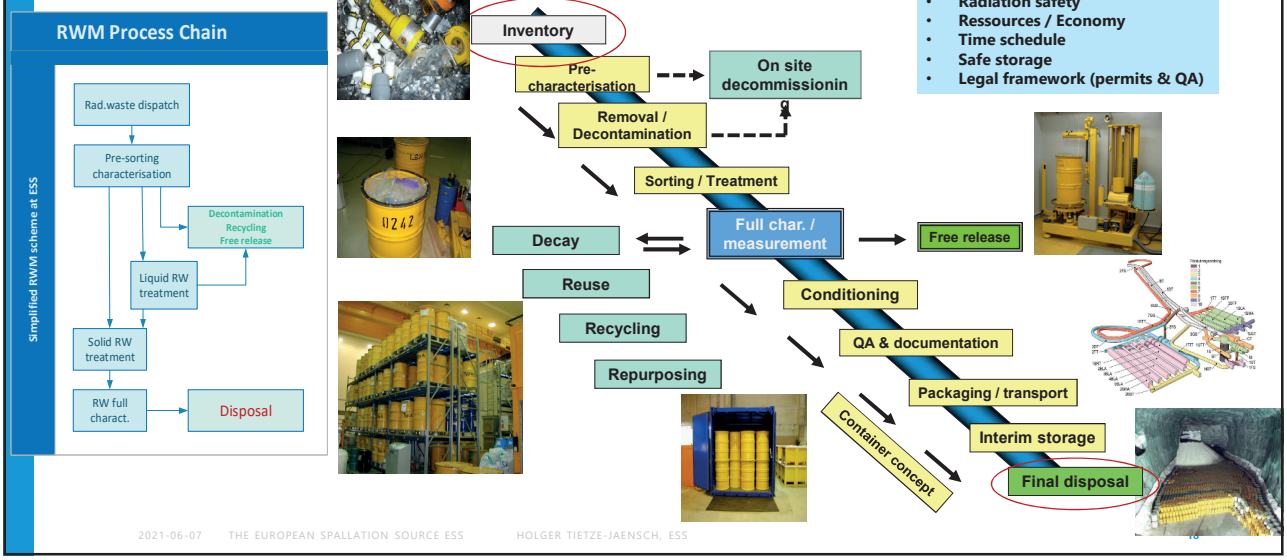
Containers:
standardised for approval, safety assessment, handling, transport

Measuring Radionuclides

RN characterisation tools



ESS Radioactive Waste Management



Summary and Outlook

Radioactive waste from an accelerator based facility conforms

Much H-3 / HTO (not a disposal issue)

Fairly Be-7 (not a disposal issue, but RP issue / large radio-toxicity)

Some Be-10 (long-lived radio-toxic disposal issue, small quantities)

Some Beta_+ metallic nuclides (treatment & disposal as usual)

Little long-lived (T1/2> 30a) rad.waste: Co-60, C-14, I-129, Be-10, Ni-59, Ni-63, Nb-94, Ho-166m, Sm-151, Sm-146, Dy-154, Tb-158, Tb-157, Eu-150, Pm-145, Hf-174m, Hf-178m, Re-186m, Gd-150, Gd-148, Cs-137, Cs-135, Ag-108m, and many more in very small quantities and doses

Decay storage before disposal into repository? Longest dose*life: C-14, Co-60, Ni-63, Be-10 + primordials (Ni-59, Mn-53, Fe-60, V-50)

Thank you for your attention

Questions