



EUROPEAN
SPALLATION
SOURCE



The European Spallation Source design impact for the EURISOL facility

Christine Darve
Mats Lindroos
18th Oct, 2012

Outline

- The ESS project: From dreams to reality
- ESS for EURISOL: the actors and the sceneries
 - Target design
 - Accelerator design
- ESS radiological safety culture

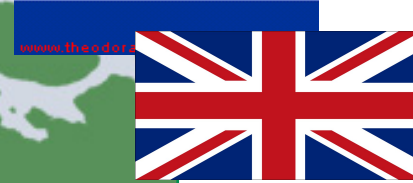
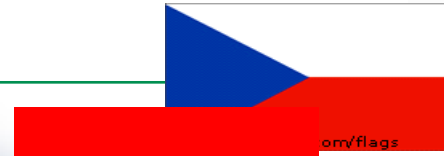
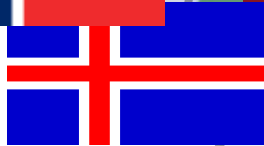
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The ESS Partners

Sweden, Denmark and Norway
50% of construction costs – 1479 M€

17 Partners
today

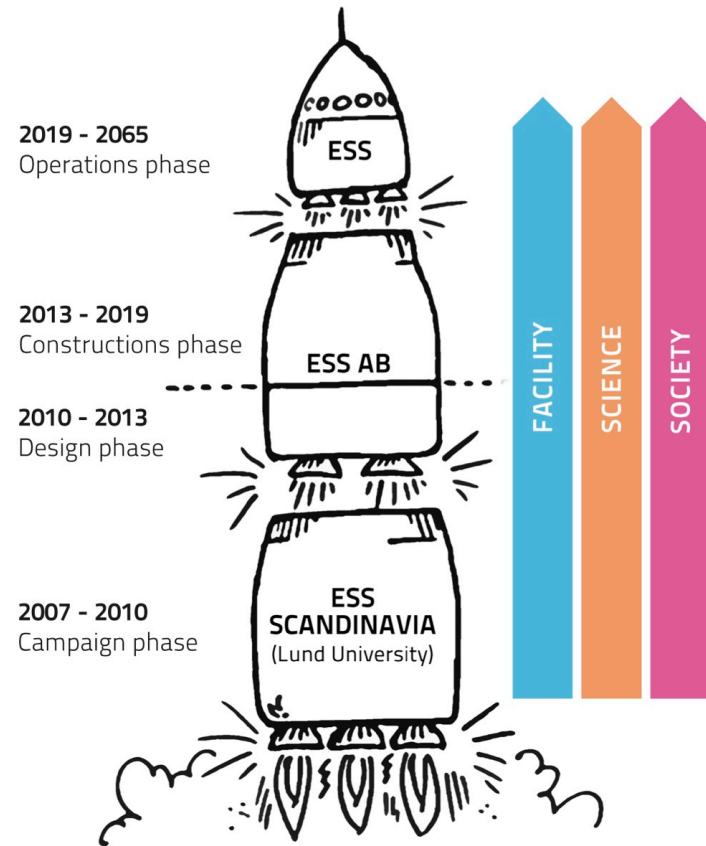


The remaining 50%: Spain, France, Germany, Italy, Switzerland, Hungary, Czech Republic, Poland, Netherlands, Estonia, Latvia, Lithuania, Iceland & UK

The ESS project strategy

- Vision & Raison d'être: Science for Society
- Mission:
 - Design, construct and operate the worlds-leading neutron source
 - Manage the company business
- Core Values:
 - Excellence
 - Openness
 - Sustainability
- ESS philosophy:
 - “Greenfield thinking on a greenfield site”

Goal: to deliver first neutrons before this decade is out
→ Goal oriented project



ESS phases and themes of communication

The ESS project



What keeps us awake at night ?

The management of In-kind contributions

The capacity of our owners and Partners to deliver funding

Complex governance and slow decision-making

Inevitable growing pains

What is a source of joy ?

The project is going like a train

We are a wholly committed team

Our partner labs are delivering

The user community is highly active

The support & commitment of the local & regional community is immense

ESS is emerging from the fog of Skåne as in a Wallander novel

ESS Review, Lund, 30th May 2012

C J Carlile

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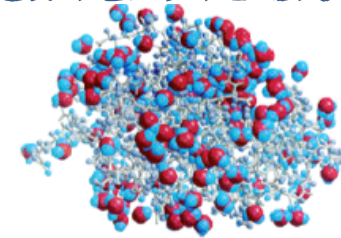
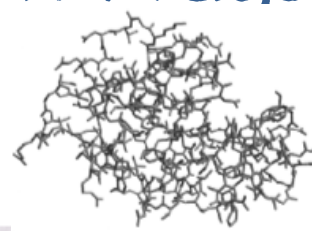
ESS – some numbers

- Superconducting Proton Linear Accelerator (500 m)
 - 2.5 GeV Proton Energy
- 50mA (2mA) peak (average) proton current
 - 357 kJ/pulse
- 2.86 msec pulse length
 - 14 Hz pulse frequency
- 71.4 msec periods between pulses
 - 5MW proton beam power
- Single Target Station
 - Rotating Tungsten, helium cooled
- 22 instruments
 - High reliability, low losses

- **Operating: 2019**
- **450 employees**
- **≈ 2500 researchers / y**
- **Constr. Cost: ≈ 1.4 B. Euro**
- **Study materials with neutrons**

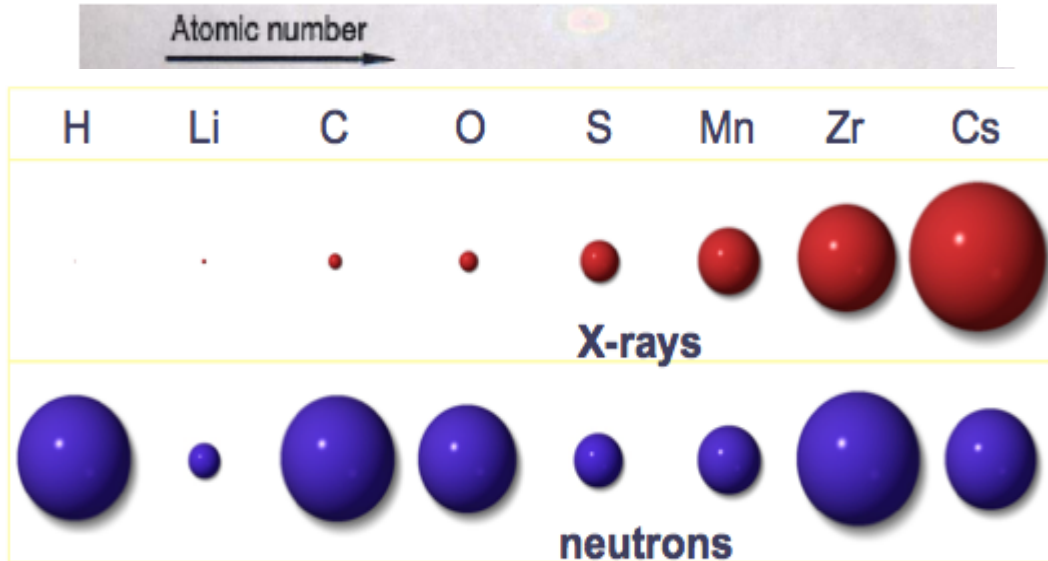


Complementarity between X-rays and Neutrons



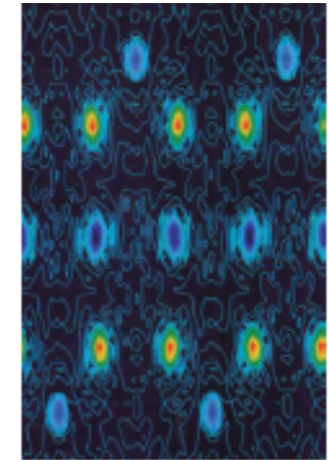
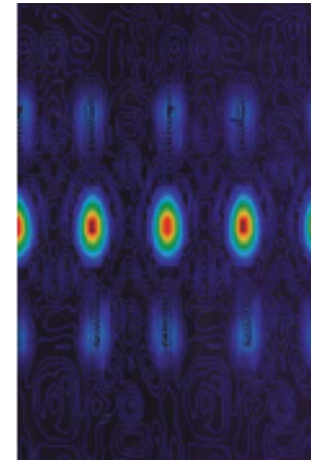
Water molecules
Observed with
neutrons

N. Niimura, et al.



X-rays

Neutrons



- Li
- O
- Mn
- O
- Li

Material for Li-battery seen by
X rays (left) and
Neutrons (right)

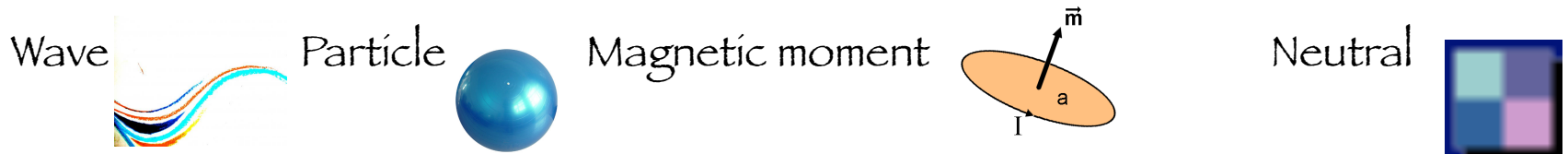
T. Kamiyama, et al.

X-rays interact with electrons.
→ X-rays see high-Z atoms.
Neutrons interact with nuclei.
→ Neutrons see low-Z atoms.

Why neutrons?

- Wavelengths comparable to interatomic spacings (1-5 Å)
- Energies comparable to structural and magnetic excitations (1-100 meV)
- Neutrons interact only weakly with matter
- Neutrons are deeply penetrating (bulk samples can be studied)
- Neutrons are scattered with a strength that varies randomly from element to element (and isotope to isotope)

→ *Neutron scattering is an ideal probe of magnetic, atomic structures and excitations*

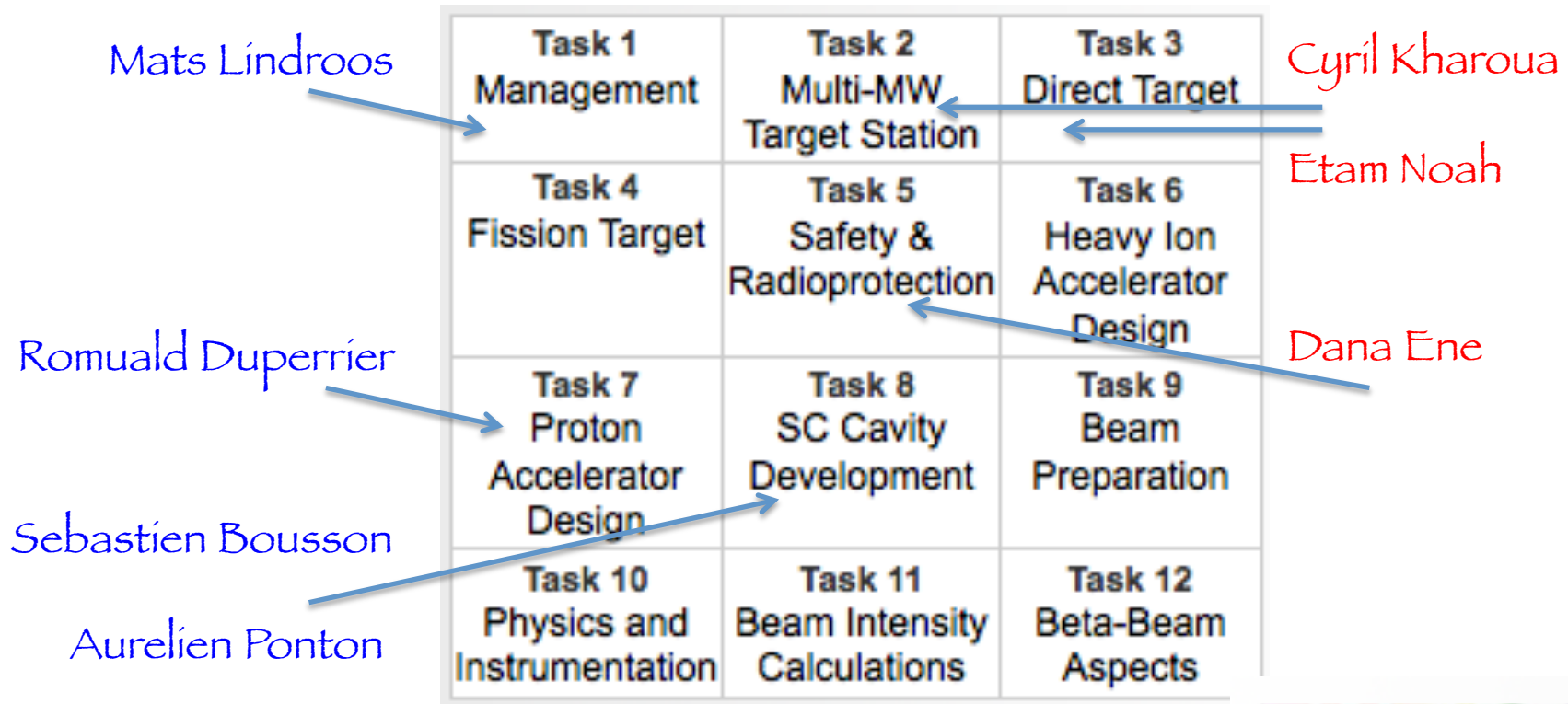


Neutron properties are used to understand the nature of the solid and liquid states of matter, as an analytical tool to aid the development of materials and as a tool to examine curiosity-driven research that spans from cosmology, superconductivity to the dynamics of the molecules of life.

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ESS / EURISOL: the actors



EURISOL
Design Study

From EURISOL to ESS: direct transfer of knowledge

Mats Lindross – ESS accelerator division head

Cyril Kharoua – ESS target division/ TS engineering

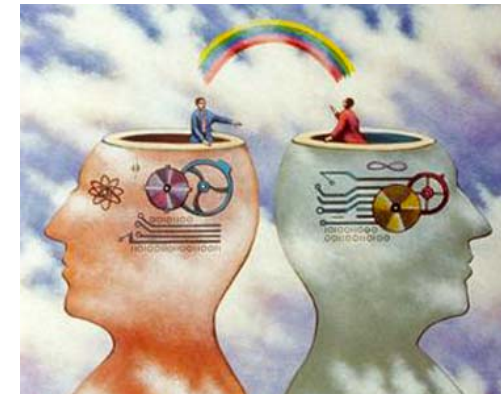
Etam Noah – ESS target division/ Materials (PT)

Romuald Duperrier – ESS system engineering

Sebastien Bousson – ESS spoke cavity work package leader

Aurelien Ponton – ESS normal conducting linac liaison

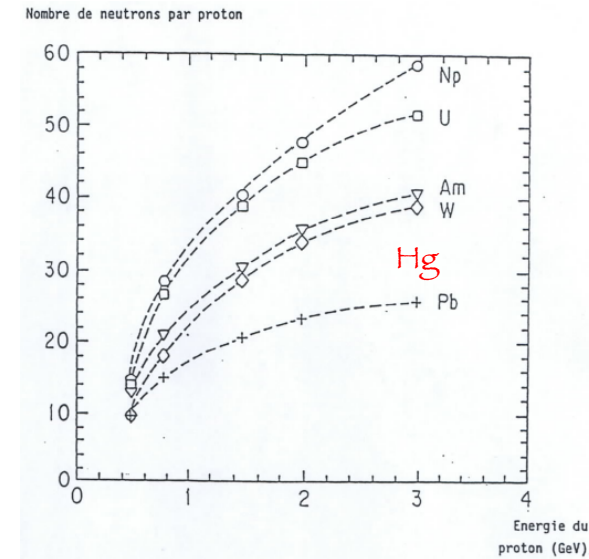
Dana Ene – ESS shielding and waste management WP leader



The fractality and entanglement ...

ESS/EURISOL: Common tools development for Multi-Megawatt Target Station

	EURISOL	ESS
Beam quality	H ⁻ , D ⁺ , ³ He ²⁺	H ⁺
Beam quantity	CW	2.86 ms; 14 Hz; 50 mA
Beam power (MW)	4	5
Energy (GeV)	1	2.5
Target Material	Liquid - Hg	Solid - W



EURISOL: Multi-users facilities

Include 3 direct targets 100 kW TS using oxides, carbides, metal foils, liquid metals

ESS: : Multi-users facilities 22 instruments

Long pulse → unique in the world !

ESS/EURISOL: Activation and Shielding

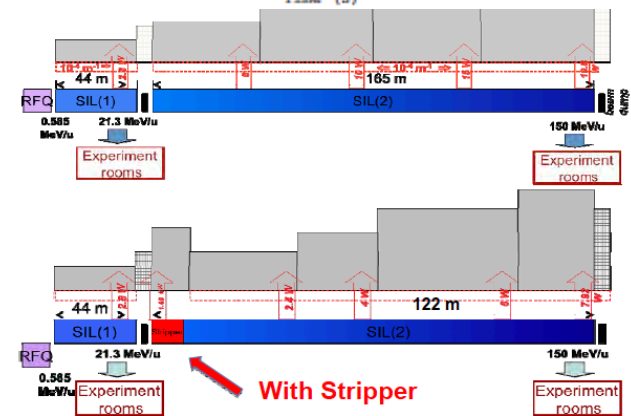
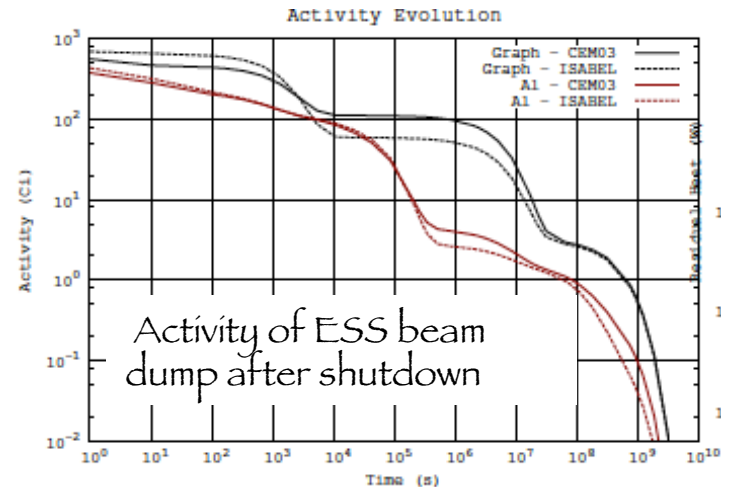
Computing irradiation using
FLUKA (high energy),

MCNPX (wide range), PHITS (w/ heavy ion)

- Dose equivalent
- Energy deposition
- Activation calculations
- Classification of waste

Knowledge transfer:

- Cooling time after shutdown (shielding, cable, electronics)
- Radiological materials handling
- Risk in tritium generating
- Risk Analysis

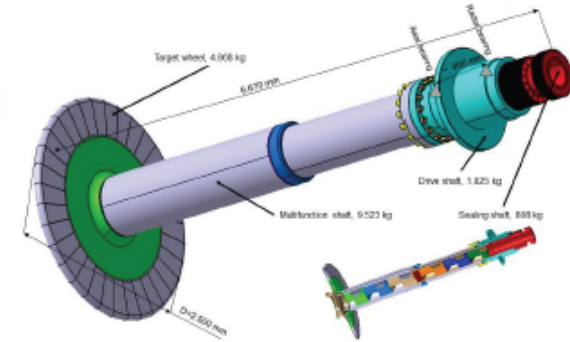
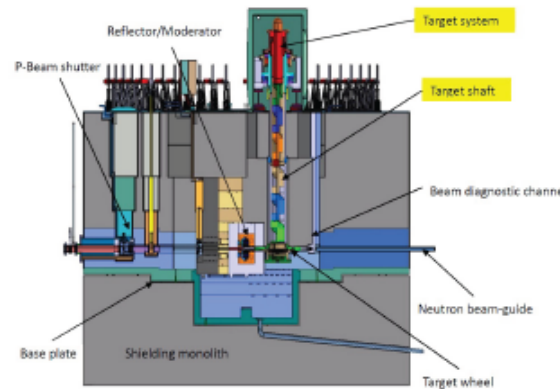


EURISOL: shield thickness calculated for the post accelerator

ESS/EURISOL: Choice of the target

Computing fluid dynamics:

- EURISOL parameters
→ Choice of Hg target
- Modeling ESS parameters
→ Discover the limit using Hg (exclusion principle...)



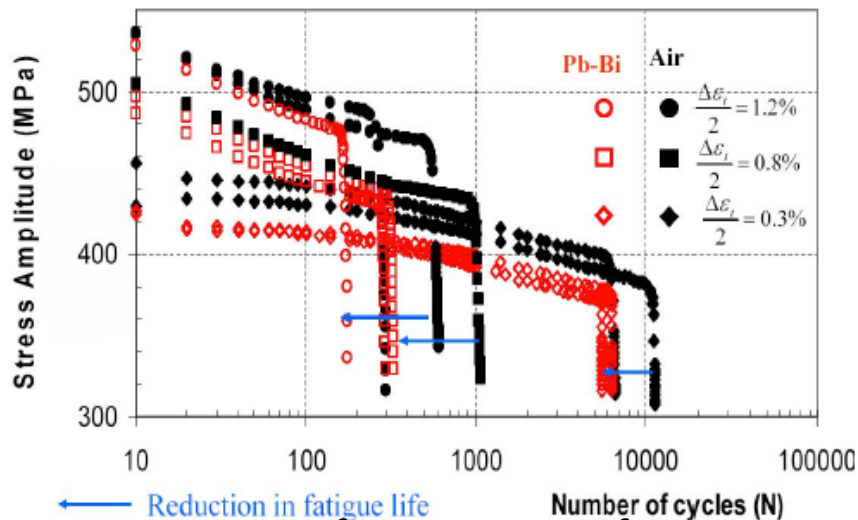
- 5 MW power level of ESS → distributing the heat over a large volume instantaneously irradiated by the proton beam
- Sufficient cooling achieved by rotating a 2.5 m diameter W target wheel and volume enhanced compared to the proton beam irradiation (ratio 33:1)

Additional motivation to prefer tungsten: No licensing available in Sweden nor in Europe for disposal of irradiated mercury !

ESS/EURISOL: Irradiation damage

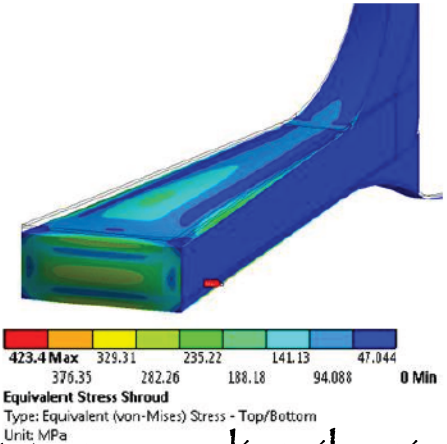
Material properties:

- Irradiated data for structural materials
- Assessment of fatigue
 - wheel
 - proton beam window



EURISOL: fatigue curve of T91 in LBE

→ Tested under beam irradiation



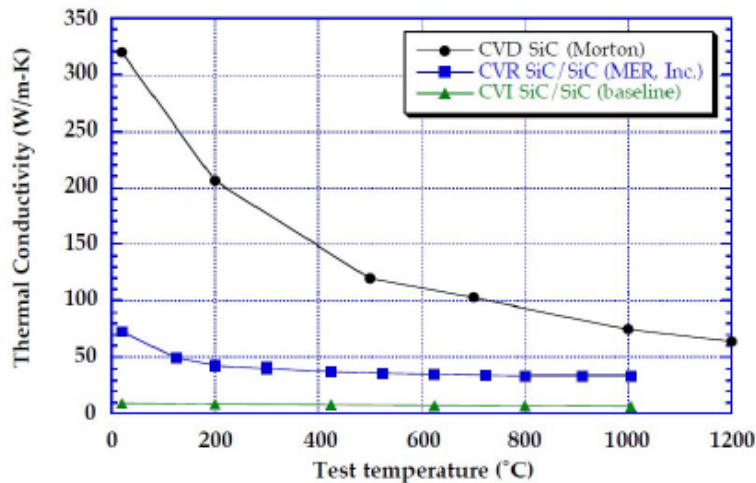
ESS VM stress distribution

- Associated areas of expertise:
- Handling of radioactive gases and cover gas purification
 - Waste management

ESS/EURISOL: Irradiation damage

TARPIPE: Irradiation program funded by EURISOL
Took place at PSI between 2006 and 2009.

- Large range of materials irradiated (non-structural, for direct targets) test their properties post-irradiation
- Generate database (measurements of radioactive inventory of these irradiated tungsten foils of varying thicknesses)
- ESS structural calculation using RCC-MRx

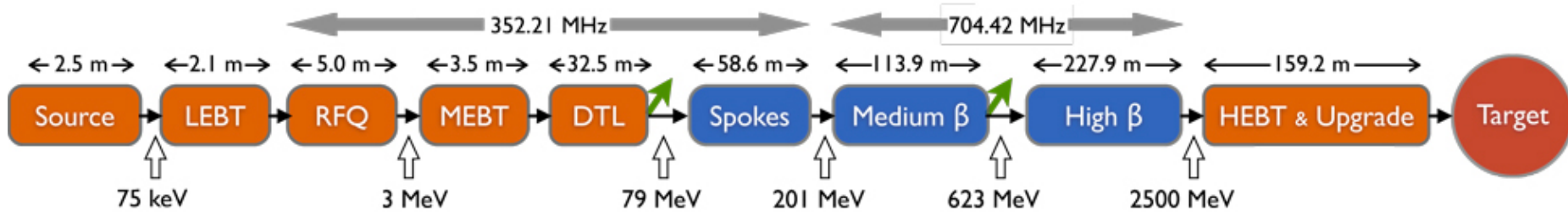


Thermal properties of un-irradiated SiC

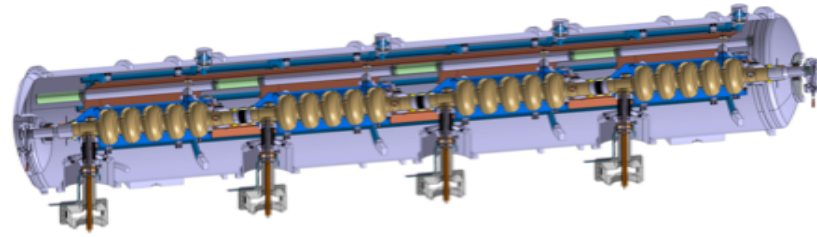
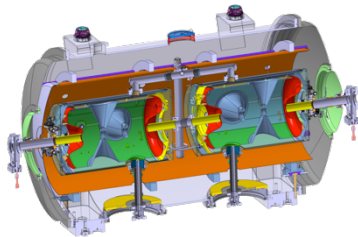
	Ø [µm] Fibre diameter	α [10 ⁻⁶ /K] Thermal expansion	All SiC	T [°C] Temperature	Cp [J/kgK] Thermal capacity
cg-Nicalon	14	3.2		20	630
Hi-Nicalon	12-14	3.5		500	1130
Type S Dow	12	5.4		700	1180
Sylramic	10	4.0		1 000	1225

ESS Accelerator

FDSL_2012_05_15



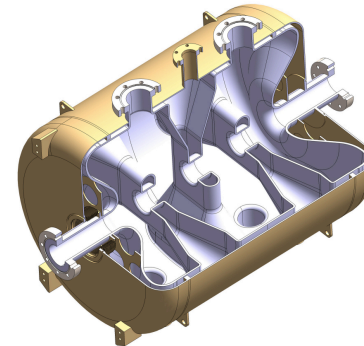
Section	Beta_geo Tech. Dem.	Cavity frequency (MHz)	Total number of modules	Cavity count per module	Cavity count per sector	Cryo-module length (m)	Sector length (m)
Spoke	0.5	352.21	14	2	28	~ 2.9	58.46
Medium-beta	0.67	704.42	15	4	60	~ 5.7	113.84
High-beta	0.86	704.42	30	4	120	~ 6.7	227.86
Total			59		208		400.16



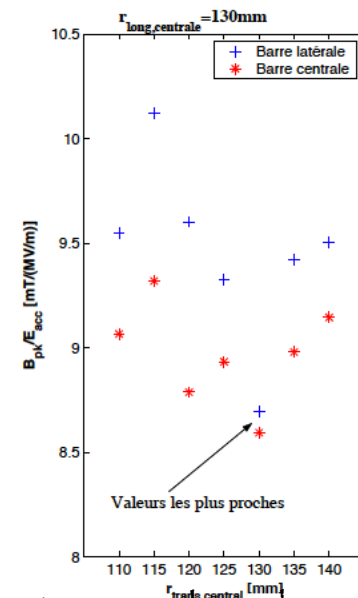
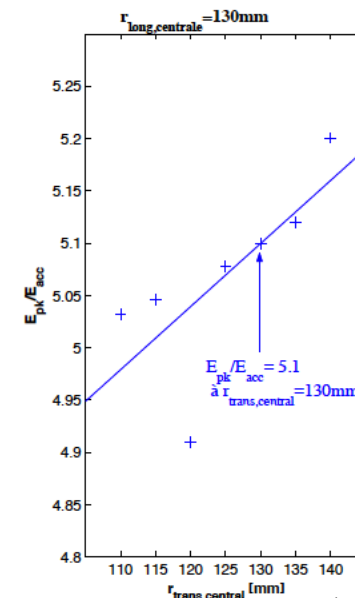
ESS/EURISOL: Design of the spoke cavity

EURISOL: Triple spoke design

- To achieve an efficient acceleration
- Development state of the art technology
- Never implemented in accelerator yet !



Lab	Type	Freq. [MHz]	Optimal β	E_{acc} max [MV/m]	V_{max} [MV]	E_{pk}/E_{acc}	B_{pk}/E_{acc} [mT/(MV/m)]
IPN Orsay	Single	352	0.20	4.8	0.8	6.7	14.5
	Single	352	0.36	8.1	2.5	4.7	12.8
ANL	Single	855	0.28	4.4	0.3	5.5	12.7
	Single	345	0.29	8.7	2.2	4.6	12.1
	Single	345	0.40	7.0	2.4	6.3	16.7
	Double	345	0.40	8.6	4.5	4.7	9.1
	Triple	345	0.50	7.6	6.6	3.7	11.5
	Triple	345	0.62	7.9	8.7	3.9	12.0
FZ-Juelich	Triple	760	0.20	8.6	1.4	5.1	13.3
LANL	Single	350	0.21	7.5	1.3	5.1	13.3
	Single	350	0.21	7.2	1.3	5.0	10.1
FNAL	Single	325	0.21	12.0	2.4	3.6	5.8
	Single	325	0.21	16.7	3.4	3.6	5.8
	at 2K	Single	325		21		



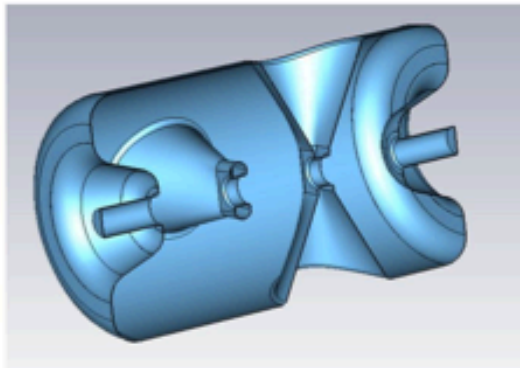
Geometric optimization to reduce the surface peak field (Microwave studio)

See Sébastien Bousson's Talk



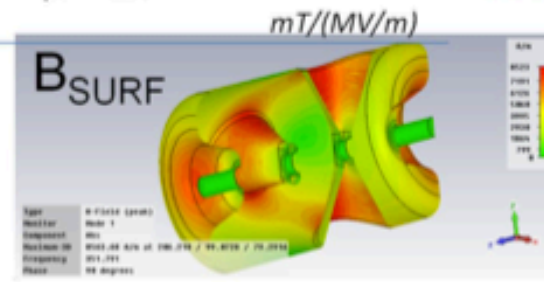
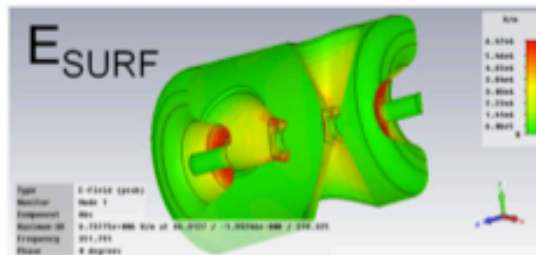
Spoke development for ESS (IPNO)

The RF Design of the spoke cavity is performed using CST Microwave Studio code.



Cavity RF parameters

R/Q	426 Ω	
G	130 Ω	
Q _o at 4K (with R _{res} = 10 n Ω)	2.6 10 ⁹	Peak fields @ 8 MV/m
Q _o at 2K (with R _{res} = 10 n Ω)	1.2 10 ¹⁰	
E _{pk} / E _{acc}	4.43	→ 35 MV/m
B _{pk} / E _{acc}	7.08	→ 56 mT



S. Bousson – EURISOL Town Meeting– 17 to 18 Oct. 2012- Lisbon

- 35 -

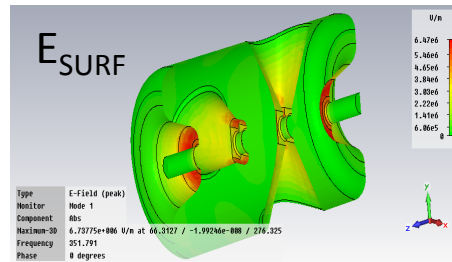
ESS/EURISOL: Design of the spoke cavity

See Sébastien Bousson's presentation

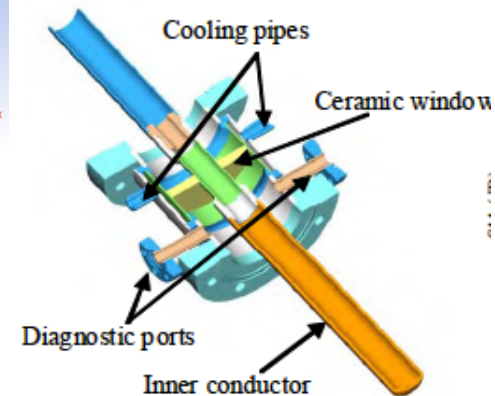
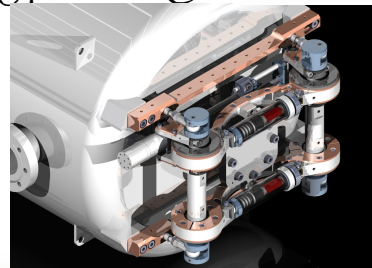
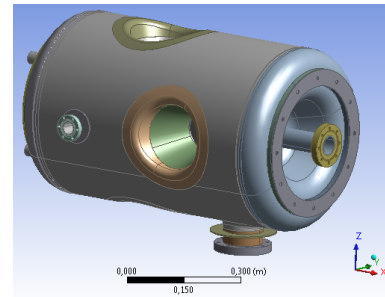
→ EURISOL: First use of spoke technology

→ ESS: the one risk ?

- Spoke cavity RF design:
 - Double spoke beta 0.5



- Spoke cavity mechanical design
- Power coupler: EURISOL type design
- Spoke cold tuning system



ESS/EURISOL: Model development and computing capacity development

Each run can be performed on a single PC but a lot of runs is necessary to get a good statistic.



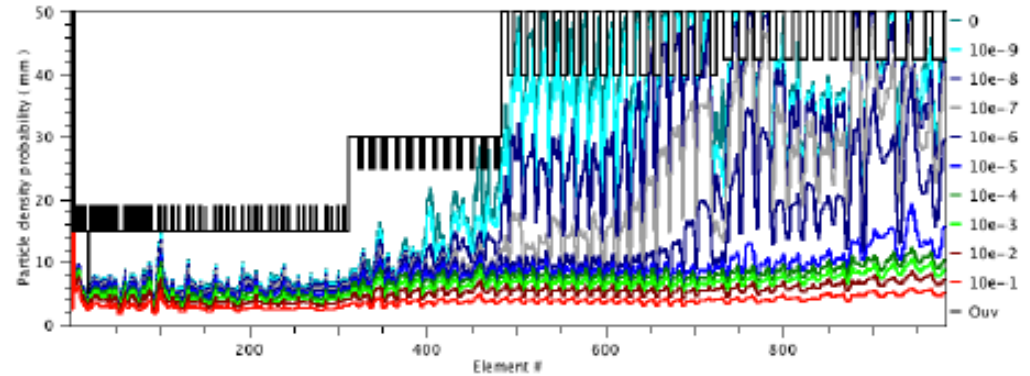
Client/Server
architecture



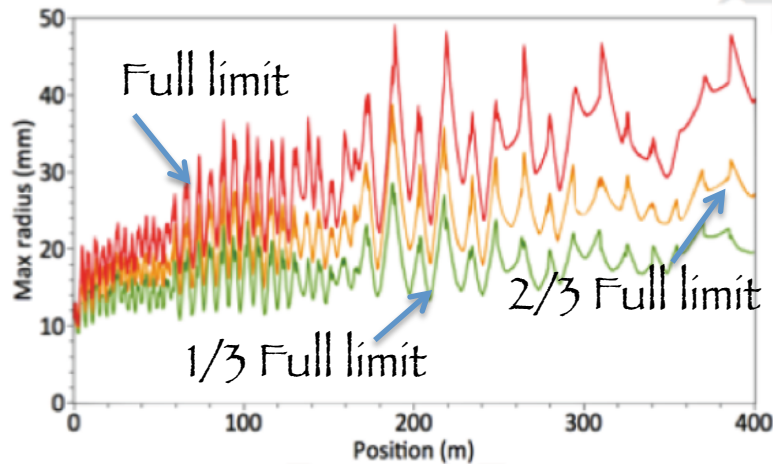
Multi parameters scheme is matched for beam dynamics errors studies
(≠ parallel computations)

ESS/EURISOL: beam losses parameterization

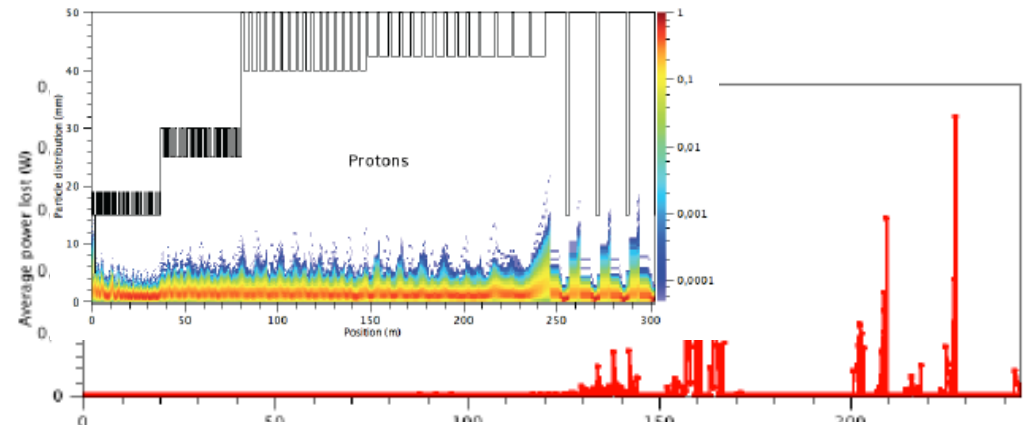
- Influence to the linac element design and corrected error



EURISOL Deuteron beam size radii along the linac



ESS maximum beam radius with errors



Loss repartition along the structure

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ESS Radiation Safety - Safety Principles

- As low as reasonable achievable (ALARA)
- Defence-in-depth (incl. engineering design, development in compliance with RCC-MRx)
- Passive and active safety measures (safety barrier)
- Review and assessment of safety issues
- Quality Assurance
- Safety Culture

ESS Radiation Safety - Functions/IAEA

“...shall be performed in operational states, in and following a design basis accident and, to the extent practicable, on the occurrence of those selected accident conditions that are beyond the design basis accidents:

Courtesy of Peter Jacobsson

- control of the reactivity;*
- removal of heat from the core; and*
- confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases”*

→ Stop the spallation process, i.e. stop the proton beam

→ Removal of the heat from the target

→ Confinement of radioactive materials

ESS Radiation Safety - Licensing processes

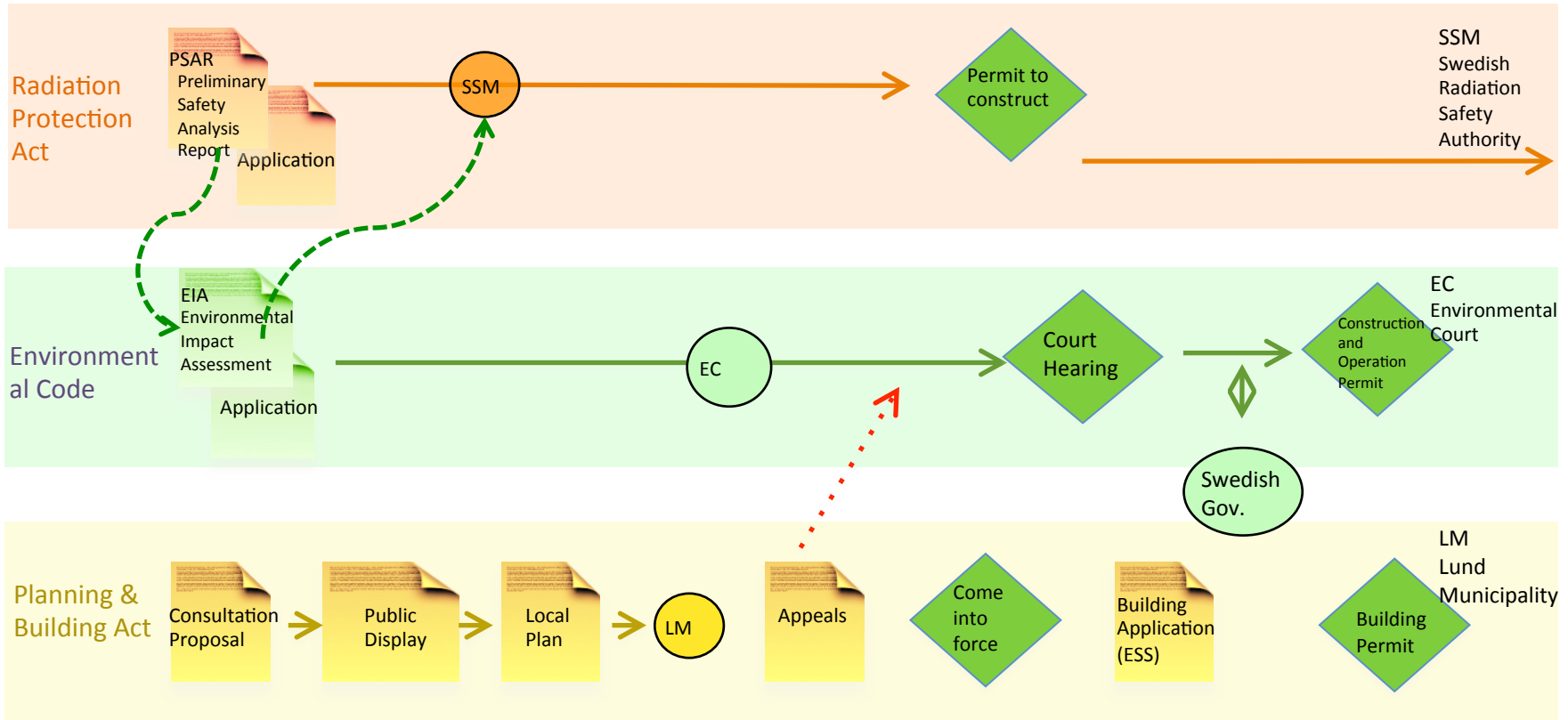
- Radiation Protection Act (Strålskyddslagen, SFS 1988:220).
The responsible authority is the Swedish Radiation Safety Authority (SSM).
- Environmental Code (Miljöbalken, SFS 1998:808).
The responsible authority is the Environmental Court.
- Planning & Building Act (Plan- & bygglagen, SFS 2010:900).
The responsible authority is the municipality of Lund.

Courtesy of Peter Jacobsson - Head of ESS safety

ESS Radiation Safety - Time Schedule

Courtesy of Peter Jacobsson - Head of ESS safety

2012-04-01 2012-07-01 2013-01-01 2013-07-01 2014-01-01



ESS Radiation Protection Act

- All facilities that generate ionization radiation needs a permit/ license for operation. Decision by SSM
- SSM specify the requirements in legislations (SSMFS).
- The Swedish legislation does not include a spallation process/ facility, i.e. SSM will do a graded approach process for the licensing of ESS
- As a first step, ESS has produced an application for receiving a permit for construction. The technical document in the application is a Preliminary Safety Analysis Report (in English)

Courtesy of Peter Jacobsson - Head of ESS safety

Conclusion

The ESS has greatly benefitted from EURISOL studies:

- Target design
- Beam dynamics statistics
- field error to influence feasibility of the linac design
- Spoke cavities
- Shielding and waste management



➔ The ESS team is extremely happy for the flying start EURISOL gave ESS into the "new ESS design" and the design update project.