The ESS and the challenge of designing its cryomodules

2011-10-06, Thomas Jefferson Lab
ESS in general
Neutrons
Organisation
Schedule
Linac
Cryogenics
Cryomodules
Hybrid design
European Spallation Source – a pan-European research centre

- a world-leading facility for **materials research** and **life science**
- scientists will use neutrons to **study the materials** of tomorrow – from plastics and proteins to motors and molecules
- spallation uses a high-power **proton beam** to extract neutrons from a heavy metal target

- average beam power 5 MW
- proton energy 2.5 GeV
- 2.86 ms pulses @ 14 Hz
- length: 500 m
- 1 target station
- 22 instruments
ESS in Lund

- Neutron Source and Synchrotron Light Source on same site: ESS & MAX-IV
- World leading cluster of science facilities: XFEL, PETRA at 200 miles
- Excellent communications:
  - 35 minutes to CPH airport
  - 125 destinations
  - high speed rail link to Stockholm & Hamburg
  - a crossroads for 10 european countries
- Öresund region: an intellectual capital
  - 10’000 scientists
  - 140’000 students
  - Lund university is 3rd largest attractor of EU R&D funds
The ESS site

Experimental halls
Instruments
Neutron guides
Labs
User offices
Meeting rooms

Office
Users
Labs
Meeting rooms
Canteen
Security
Ctrl room
Library
Auditorium
Exhibition

Waste handling
Storage
Transfer

Klystron hall
Cryogenics
Workshops
Switchrooms
Test facilities
Waste facilities
Logistics
Deliveries

Front end
Accelerator

Target
Hot cells
Highbay
Pond

Guesthouses
Labs shared with MAX-lab
Walkway / biking
Why neutrons?

Diffractometers measure structures where atoms and molecules are

\[ 10^{-9} \ldots 10^{-10} \text{ m} \]

Spectrometers measure dynamics (what atoms and molecules do)

\[ 1 - 80 \text{ meV} \]
Science with neutrons

- Neutrons can provide unique and information on almost all materials.

- Information on both structure and dynamics simultaneously. "Where are the atoms and what are they doing?"

- 5000 users in Europe today
  Access based on peer review.

- Science with neutrons is limited by the intensity of today’s sources
High time average and peak flux

Evolution of the performance of neutron sources

Long Pulse and cold neutrons

• Many research reactors in Europe are aging and will be closed before 2020
• There is a urgent need for a new high flux cold neutron source in Europe

“Pulsed cold neutrons will always be long pulsed as a result of the moderation process”

F. Mezei, NIM A, 2006
ESS Organisation

- ESS AB Board
- Steering Comm (STC)
- Adm Financial Comm
- CEO C. Carlile
- Administration Director
- Machine Director
- Science Director
- Collaboration Partners
- Programme Office
- Programme Director
- Accelerator
- Target
- Conventional Facilities
- Instruments
- Neutron Science
- Data Management

- Preconstruction
- Construction
- Operation Phase

ESS Organisation
International collaboration

Sweden, Denmark and Norway cover 50% of cost

The remaining ESS members states together with EIB cover the rest!

17 Partners today
Technical R&D in global research networks

- Helmholtz Zentrum Berlin
- FZ Jülich (Target)
- DESY / X-FEL, Hamburg
- KIT, Karlsruhe (Neutronenlinien)
- Uni Rostock (HOMs)
- Uni Darmstadt (FAIR)
- HZ Rossendorf (Dresden)
- TU München (FRM2 Reaktor)
- GKSS, Geesthacht
- Fraunhofer Institut (ISE)
A sustainable research facility

Renewable Carbon dioxide:
- 120 000 ton/year

Recyclable Carbon dioxide:
- 15 000 ton/year

Responsible Carbon dioxide:
- 30 000 ton/year

⇓

Energy efficiency

Responsible Carbon dioxide:
- 30 000 ton/year

Recyclable Carbon dioxide:
- 15 000 ton/year
ESS construction cost estimates

Investment: 1478 M€ / ~10y
Operations: 106 M€ / y
Decomm.: 346 M€
(Prices per 2008)
ESS personnel
<table>
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<tr>
<th>ESS Master Milestone Plan</th>
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<tr>
<td><strong>ESS Programme Phases, Gates and Milestones</strong></td>
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<tr>
<td>---</td>
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<tr>
<td>“Day One”</td>
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<tr>
<td>Licensing</td>
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<tr>
<td>Accelerator</td>
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<tr>
<td>Target</td>
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<tr>
<td>DMSC</td>
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<td>Conventional Facilities</td>
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<td>Energy</td>
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<td>Project and Design</td>
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<td>Integrated Controls System</td>
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<td>Pre-Operations</td>
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ESS project strategy

P2B projects: prototypes

Design Update → Construction project

- Design: Prototype
- Series Design
- Manufacturing
- Inst.

- 2011: DU
- 2012: DU
- 2013: P2B
- 2014: Const.
- 2015: Const.
- 2016: P2B
- 2017: P2B
- 2018: P2B

International convention signed
TDR with cost and Schedule
Cryomodule production starts
First neutrons
First protons
## LINAC layout

### Table

<table>
<thead>
<tr>
<th>Section</th>
<th>Length (m)</th>
<th>Input Energy (MeV)</th>
<th>Frequency (MHz)</th>
<th>Geometric β</th>
<th># of Sections</th>
<th>Temp (K)</th>
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<tbody>
<tr>
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<td>5</td>
<td>$75 \times 10^{-3}$</td>
<td>352.2</td>
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<td>1</td>
<td>≈ 300</td>
</tr>
<tr>
<td>DTL</td>
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<td>3</td>
<td>352.2</td>
<td>--</td>
<td>3</td>
<td>≈ 300</td>
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<tr>
<td>Spoke</td>
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<td>50</td>
<td>352.2</td>
<td>0.50</td>
<td>14 (2c)</td>
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<tr>
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<td>200</td>
<td>704.4</td>
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<tr>
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<tr>
<td>HEBT</td>
<td>100</td>
<td>2500</td>
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<td>--</td>
<td>--</td>
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</table>
The Cryogenic Systems of ESS

• **linac:**
  extrapolation estimate: 14 kW @4.5K equiv.
  supplied at 2 K + screen temps.

• **target:**
  TD heat load calculations: 68 kW @20K
  (15 kW @4.5K equiv.) supplied at < 20K

• **instruments:**
  interpolated from ILL:
  17 l/h LHe (35 l/h peak) → liquefier cap. 45 l/h
  200 l/h LN2 (delivery based solution)

• **labs, test stands etc ...**
Cryogenics Infrastructure

ESS Cryogenics and Vacuum - Space Requirements - First Draft Estimate
2011-02-18, W. Hees, ESS-AD

- Cryo & Vacuum Storage
- Vacuum Workshop Building
- Cryogenics Workshop Building
- Linac Coldbox Building
- Linac Compressor Building
- T&E Compressor Building
- T&E Coldbox Building
- Gas Storage GHe
- LN2 Dewar
- HEBT
- Target
- Access Road

Plan View

Cross Section A:A

Metal Structure Buildings: 2000 m²
Concrete Buildings: 1000 m²
Gas Storage Area: 1000 m²
Cryomodules’ boundary conditions

Physical boundaries, tunnel geometry etc ...

ESS linac tunnel:
• cross section: 5 x 3.5 m² TBC
• length: 492 m
  (360 m cold linac)
• slope: none
• space for external cryoline, valveboxes and jumper connections
• space for CM with diameter ~ 1000 mm
Specification

- temperature: 2 K
- 8 cavities, 2 sc quads
- alignment: 0.5 mm
- possibility to service individually
- reduced heat load
- transportable (<12.3 m)
open questions:

- **assess advantages** - heat load gains vs cooling load & cost
- **cryogenic design** - cooling of utility module
- **mechanical design** - vacuum jacket bellows etc...
Reducing heat load

Hybrid design (proposal)

open questions:
- assess advantages - heat load gains vs cooling load & cost
- cryogenic design - cooling of utility module
- mechanical design - vacuum jacket, bellows etc ...
XFEL type cryomodule
Cryomodule Design Strategy

Design of spoke CMs

- IPNO (Duthil et al) preliminary work has started

Who will design the elliptical CMs?

- limited options: JLab, FNAL, IPNO
- decision to be taken before end of 2011 (workshop in November 2011)

Where to do manufacturing and testing?

- assumption: re-use of XFEL line Saclay/DESY
- other options to be studied
- industry involvement at different levels
### Cryomodule Prototypes

<table>
<thead>
<tr>
<th>AP2B WP</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.5</td>
<td>CMS: Cryomodule, Spoke</td>
</tr>
<tr>
<td>20.6</td>
<td>CMH: Cryomodule, high-beta</td>
</tr>
<tr>
<td>20.7</td>
<td>CML: Cryomodule, low beta</td>
</tr>
<tr>
<td>20.8</td>
<td>CMT: Cryo design test, continuous/segmented/hybrid</td>
</tr>
<tr>
<td>20.9</td>
<td>CMT: Cryomodule CERN-SPL</td>
</tr>
</tbody>
</table>
Next steps

• Improve cryomodule concept & requirements!

• Find someone to design the elliptical cryomodules!
Conclusion

It’s a challenge!

Because:

a) aggressive schedule
b) ambitious spec.
c) no designer (yet)