Ideas for the DNS-IV moderators and beam extraction, inspired by the ESS design

Workshop on Advanced ideas and experiments for the new Dubna Neutron Source DNS-IV,
Dubna, 6th December 2018

Ken Andersen, Neutron Instruments Division, European Spallation Source ERIC
ESS Overview

5MW proton accelerator
2 GeV, 62.5 mA
14Hz repetition rate
2.86ms pulse length
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Helium-cooled rotating W target
Hydrogen & water moderators
Peak brightness ~ J-PARC @ 1MW
Time-averaged brightness ~ ILL @ 57MW
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15 world-leading instruments under construction
First beam on target in 2022
Start of user programme in 2023
22 instruments complete by 2030
Site Photos

https://europeanspallationsource.se/site-weekly-updates
Long-pulse performance

\[ \lambda = 5 \, \text{Å} \]

Possibilities of pulse shaping

Brightness (n/cm\(^2\)/s/sr/Å) \times 10^{13}

- ESS 2016 design: 5 MW
- ESS 2013 design (TDR): 2 MW
- ISIS TS1: 128 kW
- ISIS TS2: 32 kW
- SNS: 2 MW
- JPARC: 1 MW
- ESS 2016 design: 2 MW
- ILL: 57 MW

Time (ms)
ESS Moderator Design: Butterfly

Above target:
3cm tall butterfly moderator assembly
ESS Moderator Design: Butterfly

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3cm tall butterfly moderator assembly

Below target:
Space for future upgrade

Guide: > 2 m
Above target: 3cm tall butterfly moderator assembly

Below target: space for future upgrade

 moderator

> 2 m
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• Fully coupled moderators
  – No compromise
  – Time structure determined mainly by proton pulse length
• Hydrogen for cold spectrum
• Water for thermal spectrum
• All beamports can view both
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SNS

water

para-H₂
Adapting the pulse width

Short-Pulse Source
- set pulse width by choosing moderator

ESS
- set pulse width using pulse-shaping chopper

Intensity

0 100μs 200μs

coupled
decoupled
poisoned
Impact on bandwidth of pulse-shaping chopper
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\[ \frac{T}{\tau} = 25 \implies \frac{L_2}{L_1} = 25 \]
Impact on bandwidth of pulse-shaping chopper

\[
\frac{T}{\tau} = 25 \Rightarrow \frac{L_2}{L_1} = 25
\]
\[
L_1 = 6.3 \text{ m} \Rightarrow L_2 = 157.5 \text{ m}
\]
Impact on bandwidth of pulse-shaping chopper

\[ \frac{T}{\tau} = 25 \implies \frac{L_2}{L_1} = 25 \]
\[ L_1 = 6.3 \text{ m} \implies L_2 = 157.5 \text{ m} \]
\[ \implies \Delta \lambda = 1.8 \text{ Å} \]

Longer pulse gives broader bandwidth: $\Delta \lambda \propto \frac{\tau}{L_1}$
Hall Layout

West

North

South

East

165 m
Hall Layout

ESS

J-PARC MLF

ISIS-TS2

Hall 1

Hall 2

scale

0 100 m 200 m 300 m 400 m
Low-dimensional moderators

L. Zanini et al., in preparation
Low-dimensional moderators

- 2-dimensional geometry
  - “pancake”, “butterfly”, “flat box”
  - Gain factor ~4 at H=2cm
- 1-dimensional geometry
  - “tube”, “rod”
  - Gain factor ~10 at HxW=2x2cm²
- Non-isotropic emission

Figure 16. Angular distribution of propagation direction with respect to the horizontal plane of cold neutrons (E<20 meV) emitted from the surface of the parahydrogen moderator.

Angular variation of intensity
For H=3cm
Low-dimensional moderators
Combination with pulse-shaping chopper
Why a superbooster

At present, the highest neutron flux is produced on sources of three types. The figure below shows the evolution of neutron sources.

1. Continuous flux reactors: HFR (ILL) at present and PIK reactor (NRC “Kurchatov Institute” – PNPI) in the future.
2. Spallation neutron sources: SNS (Oak Ridge) at present and ESS (Lund) in the future.

All three types of sources have reached their technological limits. Therefore, to achieve higher neutron fluxes, new solutions must be sought. We propose to develop the fourth type of neutron sources – Superbooster (E.P. Shabalin, V.L. Aksenov, G.G. Komyshev, A.D. Rogov, Atomic Energy, 2018, in print).

Superbooster is an accelerator driven multiplying neutron-producing target with periodic modulation of reactivity. Reactivity modulation allows working with a high neutron multiplication factor of a source.

Adjustable width = adjustable resolution

Suppression of secondary peak

Suppression of time-independent background
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\[ \Delta t = \text{opening time} \]

\[ \tau = \text{pulse length} \]
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\[ \Delta L = \text{chopper separation} \]
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\[ \Delta t = \text{opening time: proportional to wavelength} \]
Combination with pulse-shaping chopper

\[ \Delta \lambda = 5 \text{ Å for } \tau = 250 \mu s \]

⇒ good guide illumination

\[ \sim 50 \text{ cm} \]

\[ \sim 20 \text{ cm} \]
Summary

• ESS will be a big step forwards
  – High source brightness thanks to 2D moderators
  – Bispectral flexibility
  – Resolution flexibility thanks to pulse-shaping choppers

• Possible further evolution at DNS-IV?
  – Further increase in brightness with 2D or 1D moderators
  – Better guide illumination by starting closer
  – More resolution flexibility with compact pulse-shaping choppers

• ESS gave up on having choppers inside bulk shielding
  – Maybe a possibility at DNS-IV?
  – Longer pulse length would allow choppers to be moved further away
  – Time-independent background of booster or pulsed reactor increases importance of pulse-shaping choppers
Thank you!

ESS site 2016