Low Background Neutron Monitor

Adaptation of n_TOF SiMoN Monitor to ESS

M. Mosconi [1] P. Mastinu [2] R. Martinez [1] J. Ortega [1]
M. Huerta [1] A. Zugazaga [1] F. Issa [3] R. Hall-Wilton [3] E. Abad [1]

[1]ESS Bilbao, Zamudio, Spain

[2]INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy

[3]European Spallation Source, Lund, Sweden

Financed by brightnESS: WP4 detectors
H2020-INFRADEV-2014-2015/H2020-INFRADEV-1-2015-1

12th February 2018

Motivations

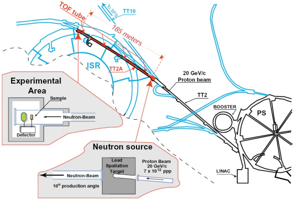
1. Lack of commercial monitors fulfilling ESS requirements in order of count rate
2. Commercial monitors perturbate the neutron propagation to a large extent

Development of a low interaction, low background monitor able to be coupled to a fast readout

The CERN experiment n_TOF uses since 20 years monitors based on a thin layer of neutron converter in beam and ion detection on silicon detectors placed outside the neutron beam.

Is this approach exportable to ESS?

n_TOF Approach to Neutron Monitoring



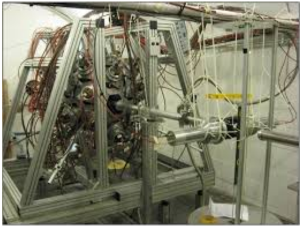
Development of a low background monitor to be close to main detectors

n_TOF experiment

White beam (0.025 eV - 20 GeV)

Measurements of (n,γ), (n,f) cross sections

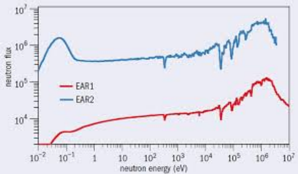
n, γ-rays flying directly from the target to the sample



Silicon Detector Monitor SiMoN

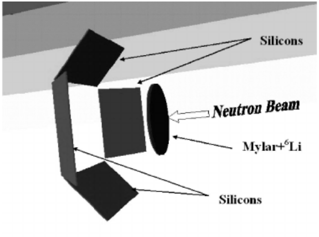
low γ-ray background monitor

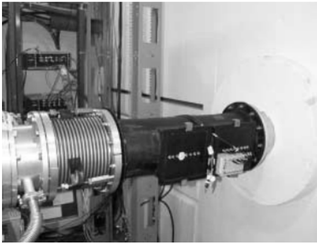
$\epsilon \sim 10{-}4$



SiMoN implementation

- Ion detection in 4 Si detectors
  - 300 μm thick 6x4 cm^2, energy resolution 150 keV
  - Detection at 45° to reduce ion struggling
- ^{6}Li(n,α)T: 3.7 μm metallic ^{6}Li embedded in C
- Aluminium content reduced:
  - Plastic as substrate
  - Carbon fiber scattering chamber





S. Marrone et al, Nucl. Inst. Meth. A, 517, 2004

P. Mastinu et al, Braz. J. Phys., 34-3A, 2004

ESS requirements and our assumptions

1. Different locations to be monitored:
    - Bunker, if possible
    - Choppers
    - Proximity of the sample environment
2. Different levels of radiation (none negligible)
3. Low interaction monitor:
    - Reduced attenuation
    - Reduced perturbation of the neutron spectrum
4. High count rate: Monitor up to 10^9 n/cm^2/s
5. $\epsilon \sim 10^{-5}$

1. Different kind of monitors
    - Extreme radiation conditions
    - Vibration
    - Smallest possible background
2. Special attention on radiation hardness
3.
    - Low mass
    - Short interruption of the beam guides
4. Usage of fast detectors

Present Development: Simulations & Considerations

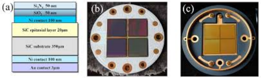
- Considerations on materials
- Considerations on possible ion detectors (radiation hardness and price)
- Considerations on background and scattering chamber design
- **MCNP simulations:**
  1. Effect of the vacuum level on ion propagation (TRIMM & MCNP)
  2. Validation of the model
  3. Possible detector positions
  4. Perturbation of the neutron spectrum
  5. Possible amounts of converter
  6. γ-yield of the device

Ion detectors

Si detector radiation hardness

- From PIPS® commercial information:
  demage after 10^9 α/cm^2 , 10^{12} fast neutrons/cm^2
- Developments to improve them (Hamamatsu and others)

⇨ Too radiation soft for ESS



SiC detector radiation hardness

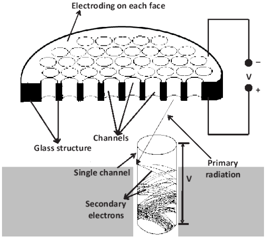
Possibly, demage after many order of magnitude more

⇨ Possibly OK

Micro Channel Plates

- Radiation Hard
- Ultra fast response
- Insensitive to γ-rays, sensitive to βs
- No energy resolution → charge particles counter

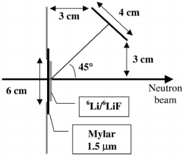
⇨ A viable option, a 6x4 cm^2 → 4000 - 5000 €

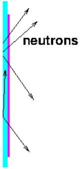


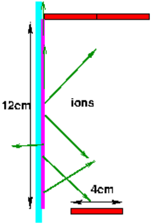
MCNP Simulations of the Monitor Design

1. MCNP6 modeling:

   Ion transport decoupled by neutron trasport
2. Reproduction of n_TOF setup for validation
3. Ion emission from thick $^{10}B_4C$ layers for validation
4. Test geometry of a neutron guide 12x12 cm^2
5. Neutron transmission
6. Different positions for the ion detector
7. Possible converter thicknesses
8. γ emission







Assumptions:

- Worse scenario for substrate thicknesses:

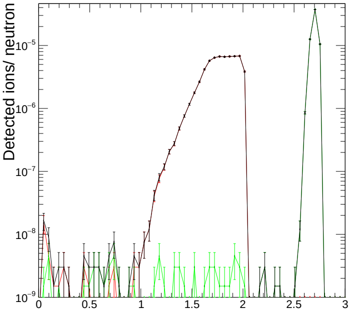
  0.3 mm Al; 40 μm kapton

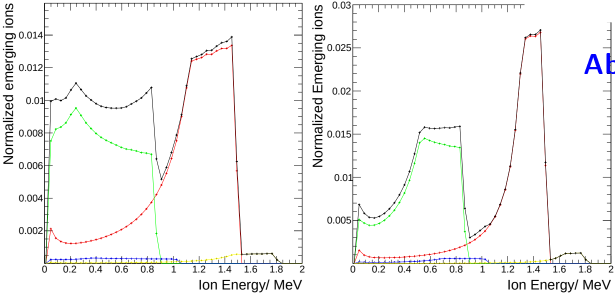
  Note: Kapton change its flexibility after 10^8 Gy

Validation

- n_TOF efficiency reproduced at 1 eV (them: 6 10^{-4} , us: 5 10^{-4})
- Emerging ions/neutron for common B_4C layers

	thickness	Ions/n	Ions/ion
$^{10}B_4C$	1 μm	5.2 %	39 %
$^{10}B_4C$	0.5 μm	3.4 %	45 %
$^{nat}B_4C$	0.5 μm	0.8 %	45 %





Above: Ions detected in the SiMoN replica

Left: Ions emerging from 1 μm $^{10}B_4C$ & 0.5 μm $^{10}B_4C$

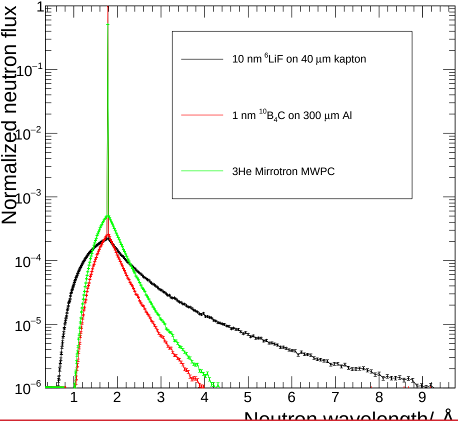
Neutron Transmission through in-beam materials

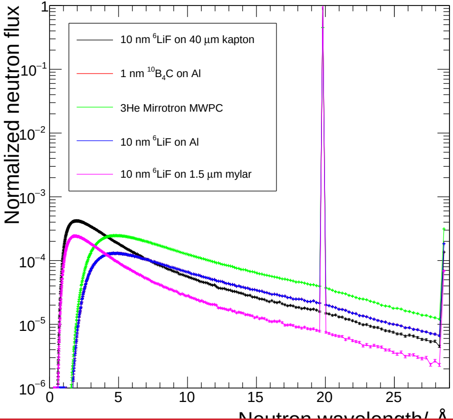
Thermal neutrons

		not interacting	perturbed
^{6}Li/^{nat}Li ^{6}LiF/^{nat}LiF	40 μm kapton	97.4 %	1.23 %
^{10}B$_4$C / ^{nat}B$_4$C	0.3 mm Al	96.6 %	0.679 %
^{6}Li/^{6}LiF	0.3 mm Al	96.6 %	0.679 %
Mirrotron **MWPC**		51.1 %	1.35 %

Cold neutrons

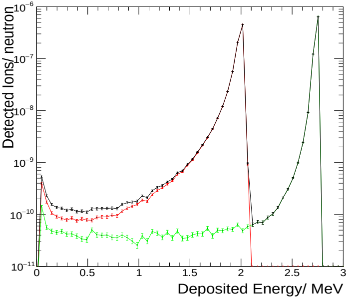
		not interacting	perturbed
^{6}Li/^{nat}Li ^{6}LiF/^{nat}LiF	40 μm kapton	88.3 %	5.58 %
^{10}B$_4$C / ^{nat}B$_4$C	0.3 mm Al	93.1 %	1.53 %
^{6}Li/^{6}LiF	0.3 mm Al	93.0 %	1.53 %
^{6}LiF	1.5 μm mylar	93.5 %	3 %
Mirrotron		45.2 %	2.89 %

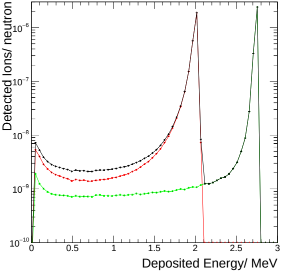




Detector position

- Si detector of the n_TOF size
- 4 positions tested at the reflector of the beam guide level:
  - 45° (soon neglected)
  - perpedicular to the deposits: attached at the converter, 2 cm away, 4 cm away
- 0.2 % diff. MCNP vacuum and 10^{-1} mbar

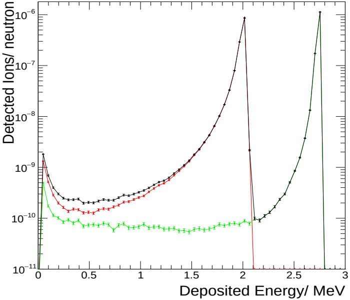




4 nm ^{6}LiF
(left) detector in contact
(right up) detector 4 cm away

(right) detector 2 cm

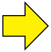
away



Thicknesses of converters for $\epsilon \sim 10^{-5}$

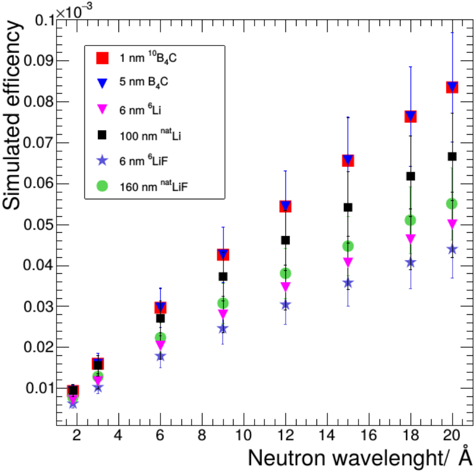
Results for 4 detectors at 4 cm from the converter

- Thickness of converter dependent on substrate thickness
- Thickness of converter dependent on number and position of detectors

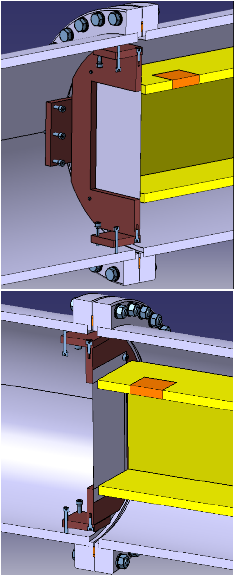


Nanometric deposits!

$$\frac{0.3 \text{ mm Al} + B_4C}{40\ \mu\text{m kapton} + \text{Li}} \gamma\text{-yield} \sim 100$$



Conclusions & Future Workplan



Conclusions

- Best substrate Al: possible to use μmetric foils → update the calculations
- Kapton + ^{6}Li can be an option when a reduced γ-yield is a requirement (e.g. big solid angle on detectors)
- No drawbacks from using ^{6}LiF
- Detector/s embedded in the neutron beam guides
- MCPs proposed, SiC under study

Proposed Workplan

- Experimental tests on MCPs
- Demo with Si detectors to compare with MCPs (no energy definition)
- Prototype

The end