^{10}Boron-film-based detectors for ESS

Irina Stefanescu

Detector scientist, ESS Detector Group

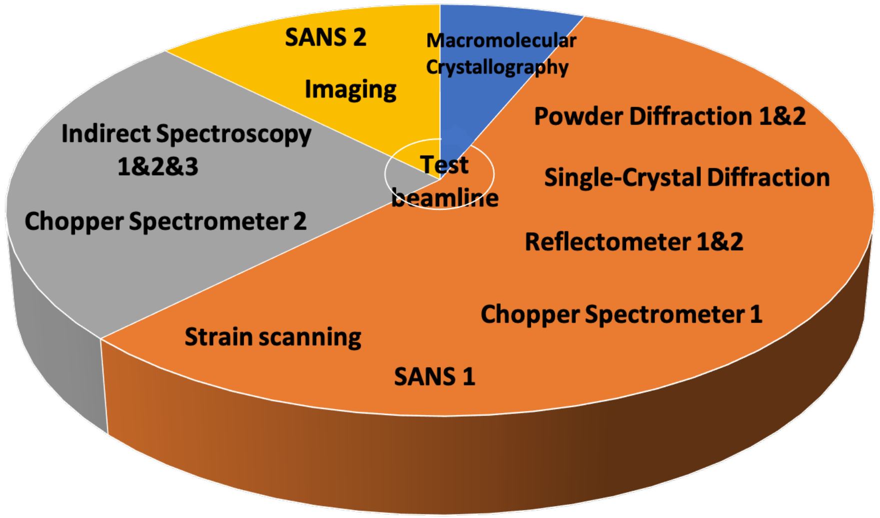
2023-10-30

THE 24TH MEETING OF THE INTERNATIONAL COLLABORATION OF ADVANCED NEUTRON SOURCES (ICANS XXIV)

Outline

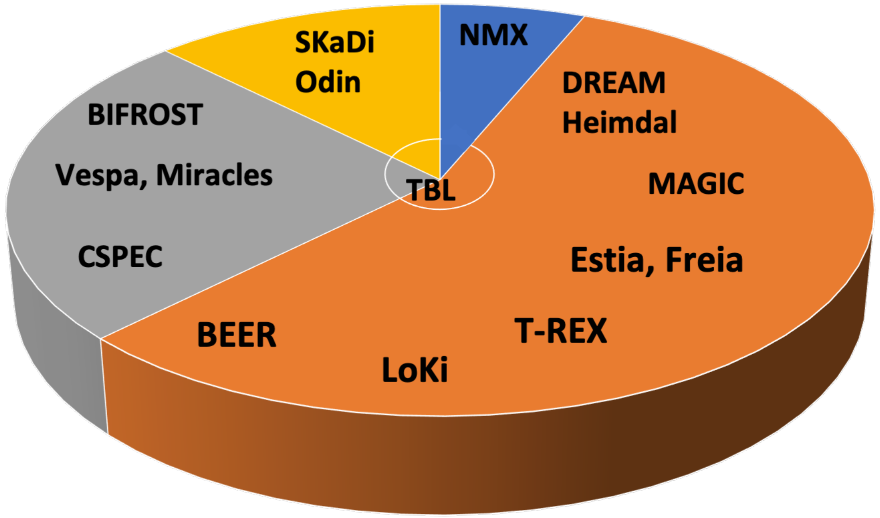
The initial ESS instrument suite

- **16 instruments including the Test beamline ➔ plenary talk by Pascale Dean, tomorrow 9 am**
- **9 instruments will use gas detectors based on the Boron-10 solid converter developed as an alternative technology to the ^{3}He gas counters.**



^{10}B
^{157}Gd
^{6}Li
^{3}He

Initial ESS instrument suite by instrument class



Initial ESS instrument suite by instrument name

^{10}Boron vs. ^{3}He

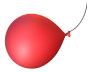
σ = 3838 b for E_n = 25 meV

$n + {}^{10}B \rightarrow {}^{7}Li + \alpha + Q\ (2.79\ MeV)$

solid form 

σ = 5330 b for E_n = 25 meV

$n + {}^{3}He \rightarrow t + \alpha + Q\ (0.764\ MeV)$

gaseous form 

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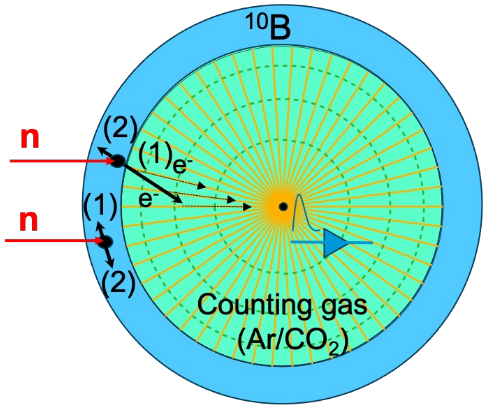

$\varepsilon_{detection} = \varepsilon_{capture} * \varepsilon_{escape} * \varepsilon_{collection}$

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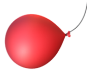

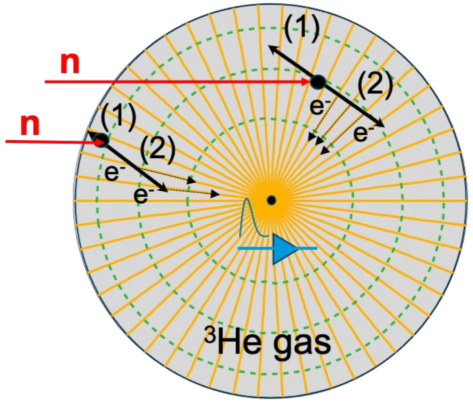

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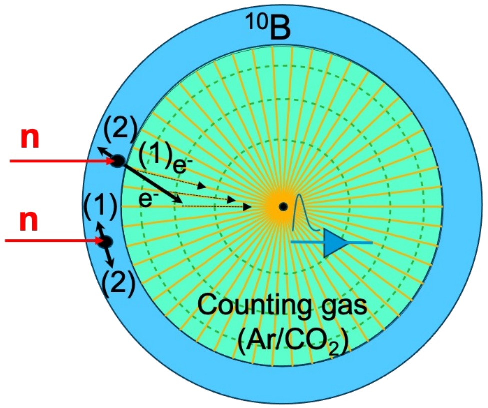

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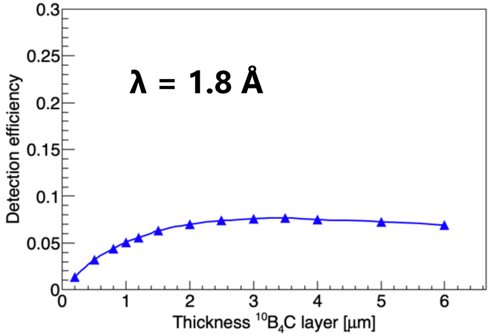
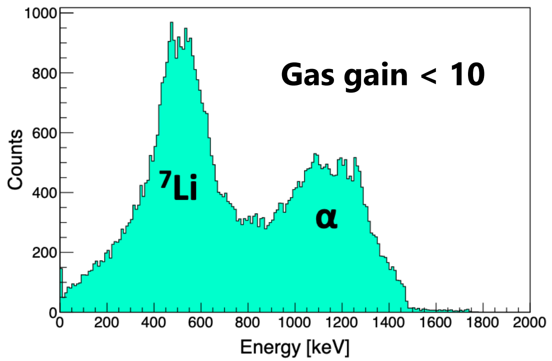


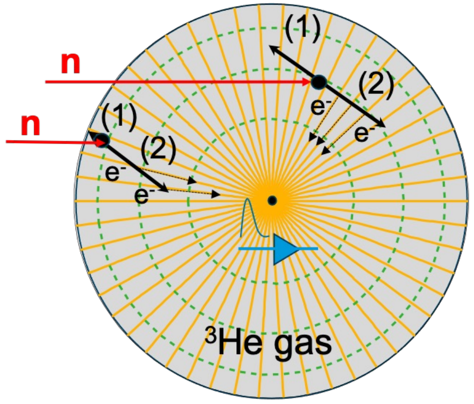


10Boron vs. 3He

σ = 5330 b for E_n = 25 meV

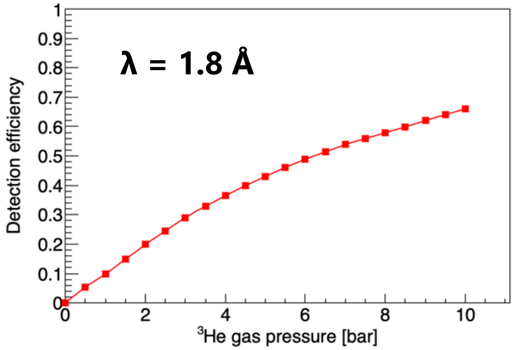
n + $^{3}He \rightarrow$ t + α + Q (0.764 MeV)

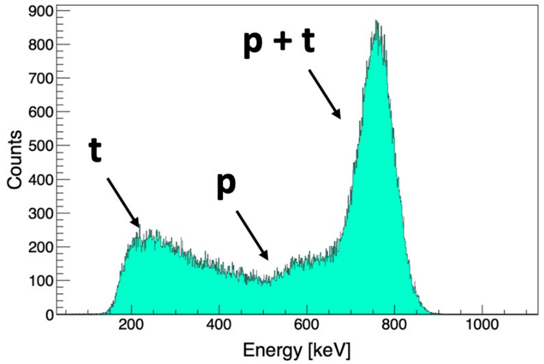
gaseous form



$\varepsilon_{detection} = \varepsilon_{capture} * \varepsilon_{collection}$

Gas gain < 10





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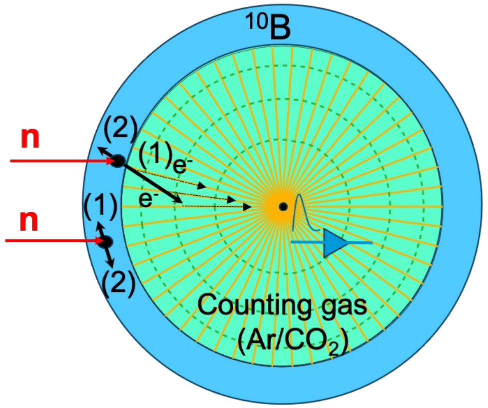

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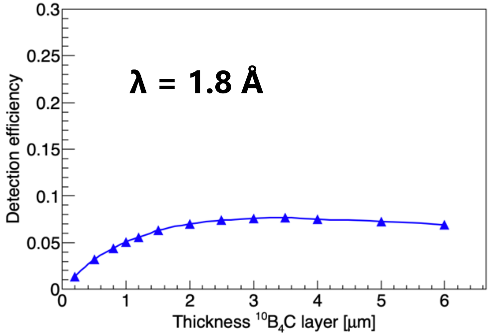

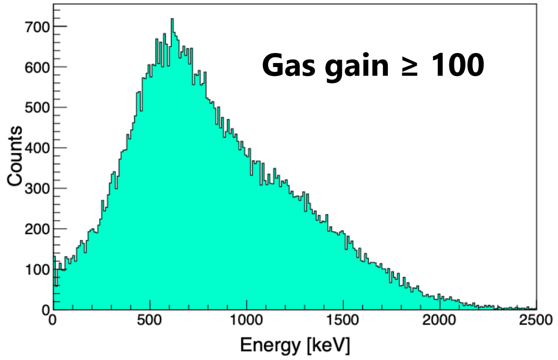

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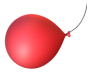

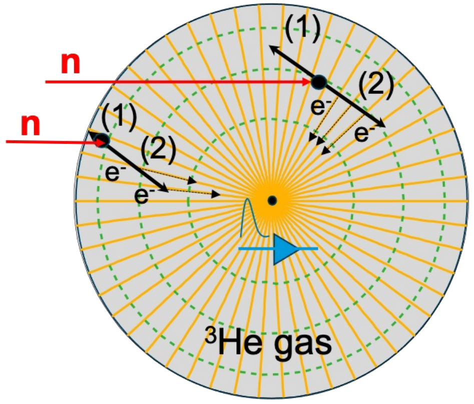

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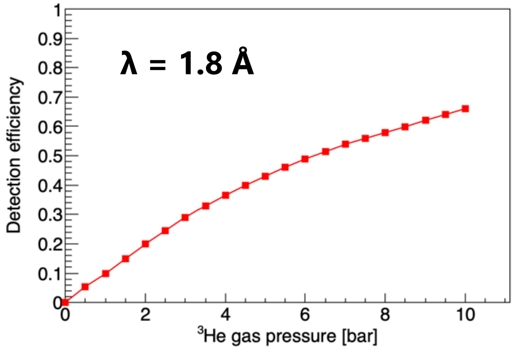
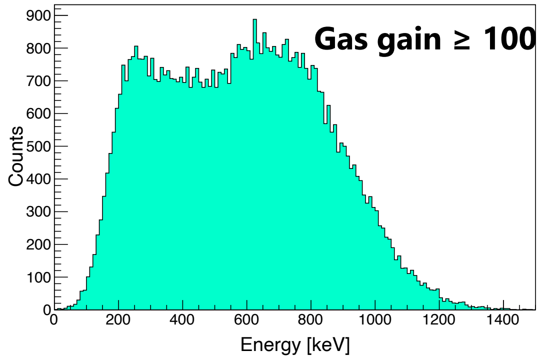
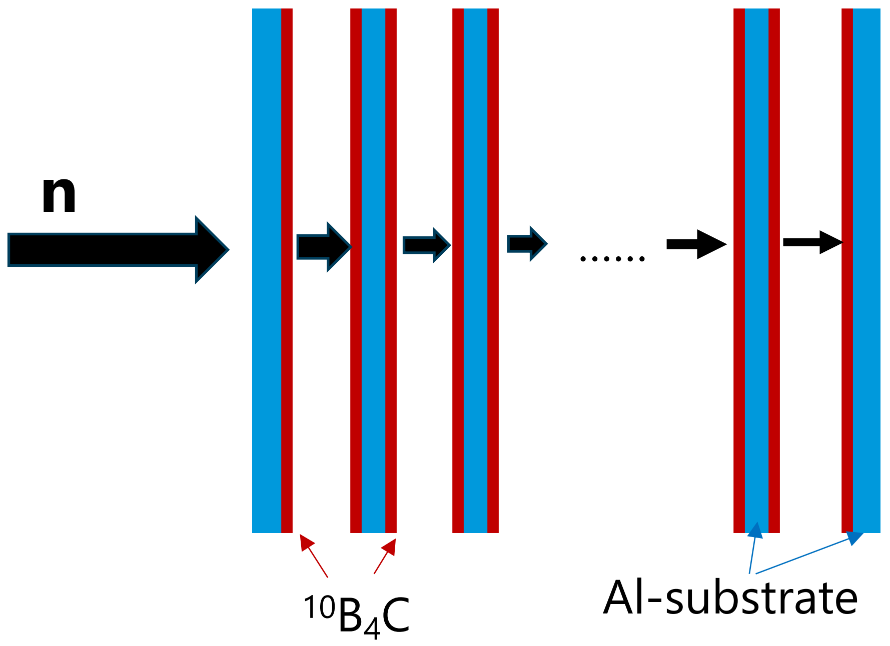
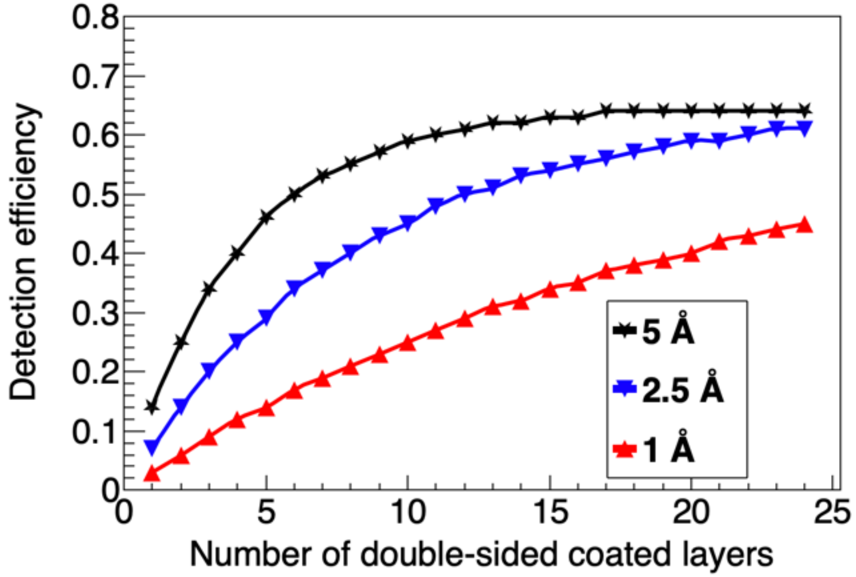




Multilayering. Orthogonal vs. inclined geometry





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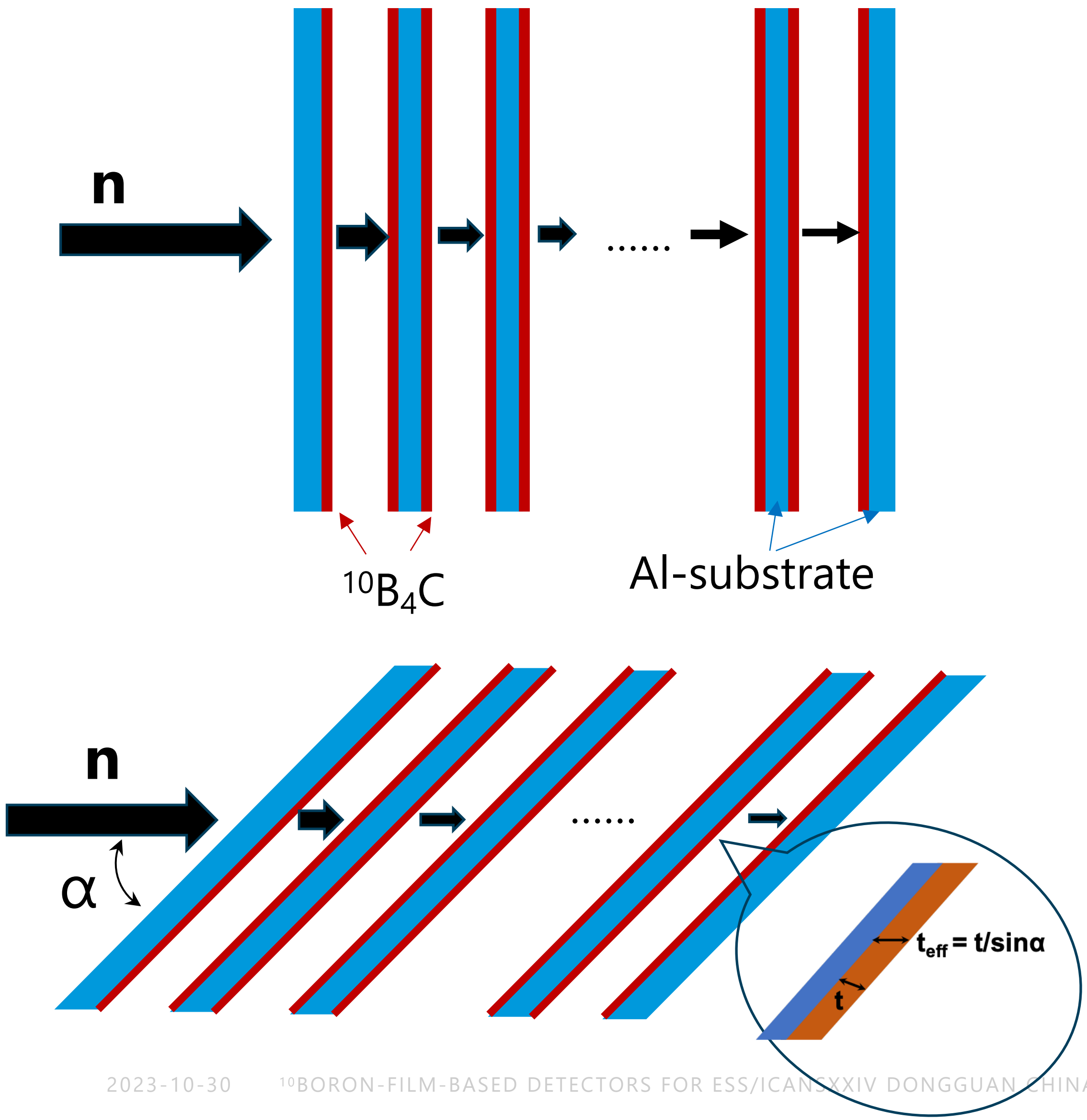
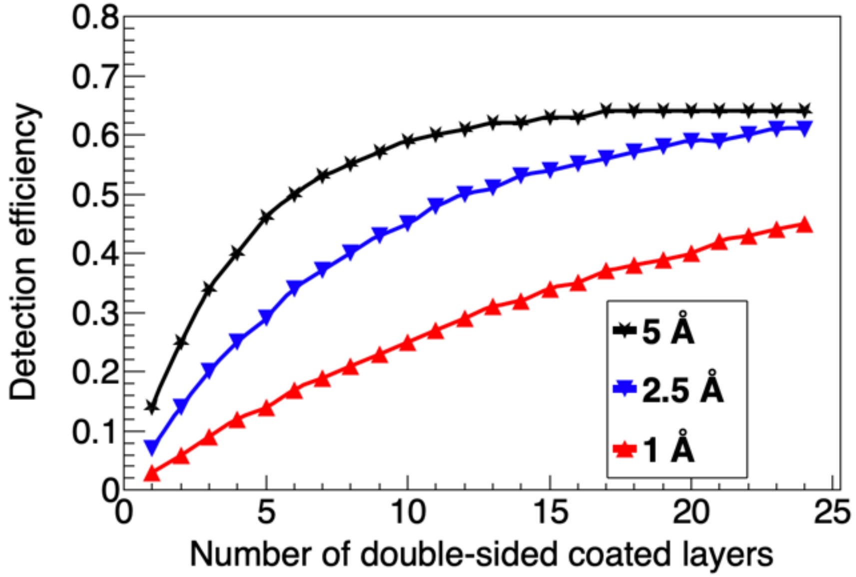
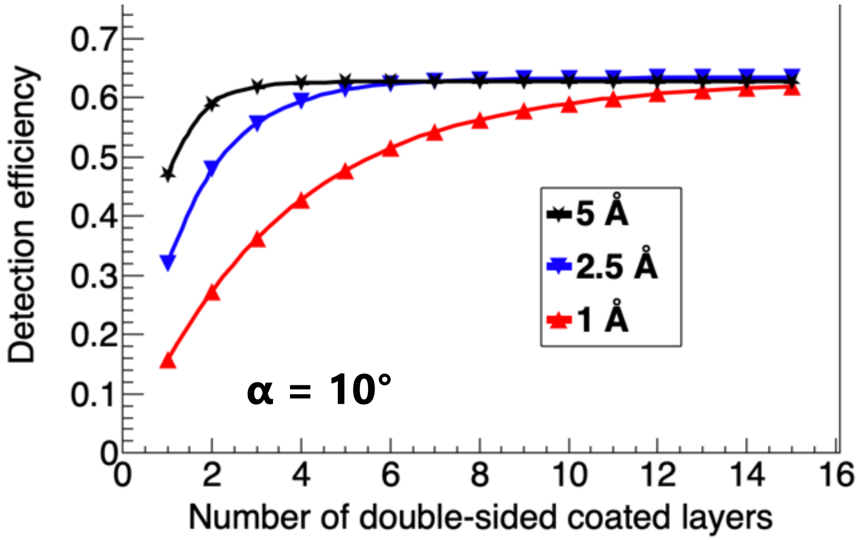
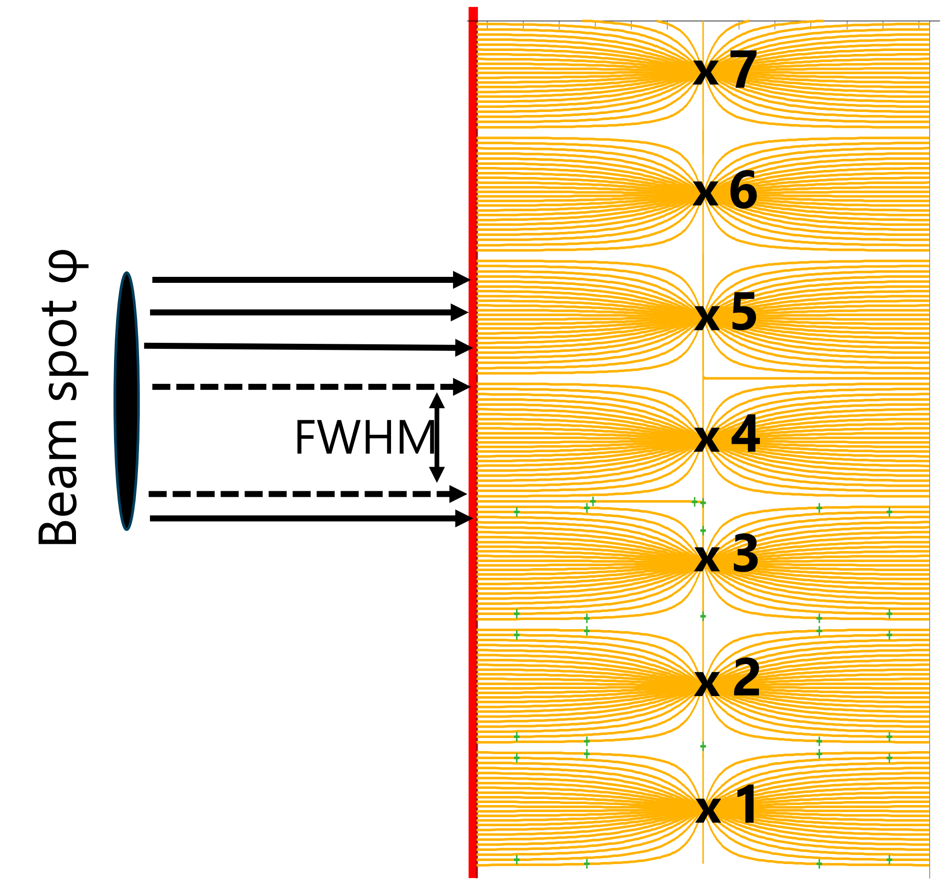






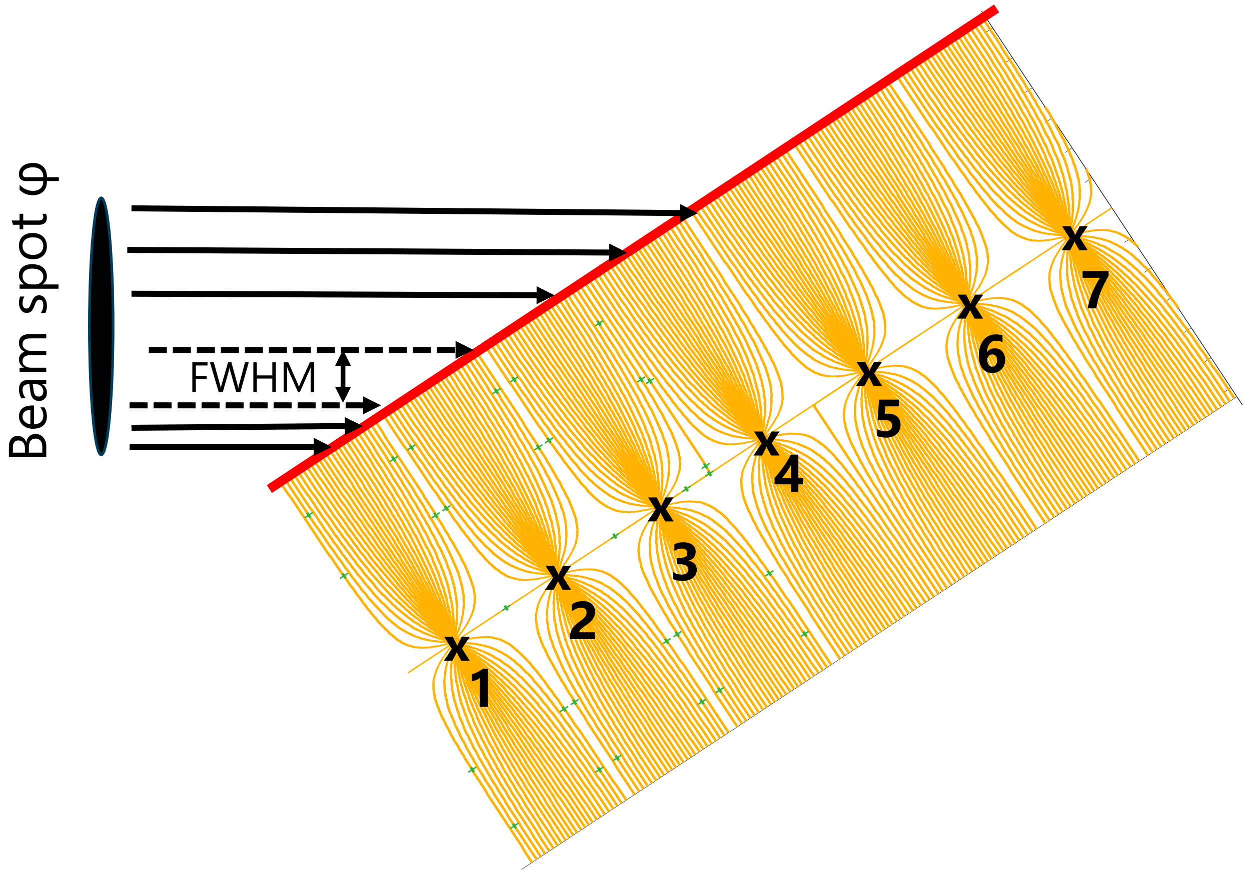
Multilayering. Orthogonal vs. inclined geometry

FWHM ~ wire pitch

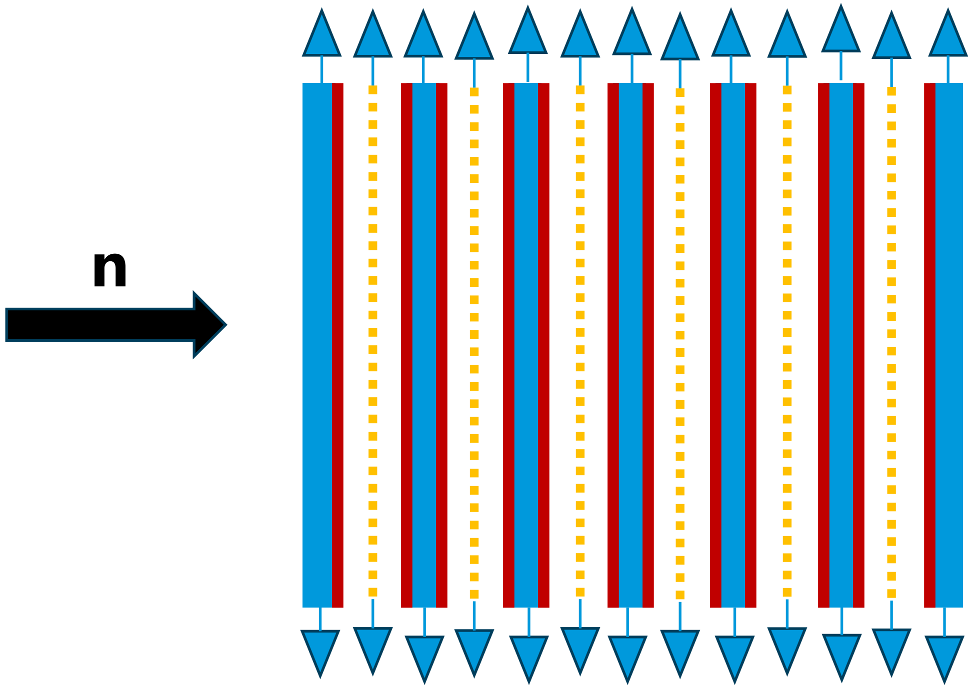


improved spatial resolution if single-coated layers are used

FWHM ~ wire pitch x tan(α)

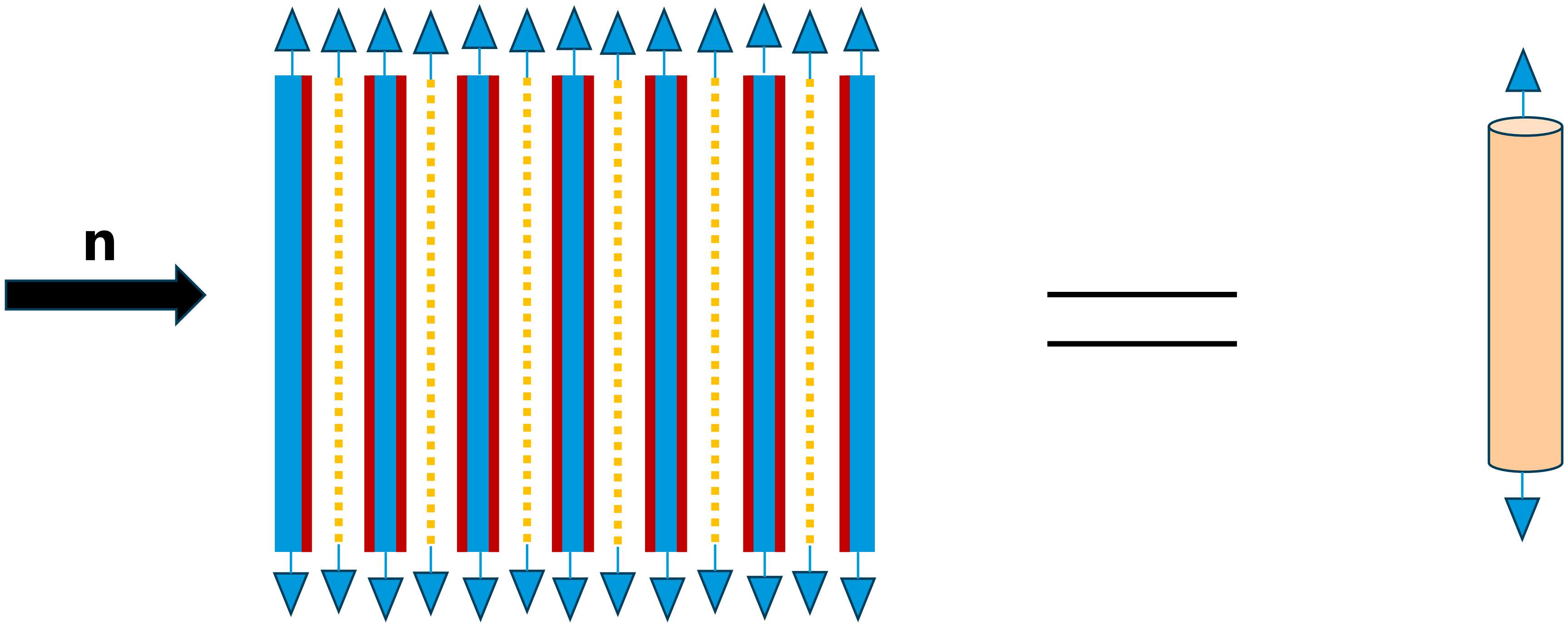


- Multilayering helps increase the count rate capability of the detector provided signals generated by each layer are collected by wires/strips readout individually



- Multilayering helps increase the count rate capability of the detector provided signals generated by each layer are collected by wires/strips readout individually

- It leads to a dramatic increase in the number of readout channels, require increased computing capabilities

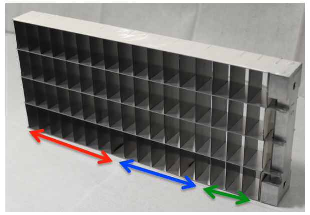


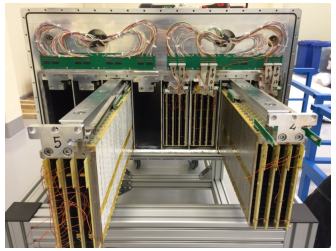
Boron-10 based detectors for ESS

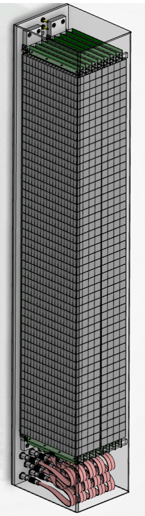
Multi-Grid for direct spectroscopy (ESS, SE)

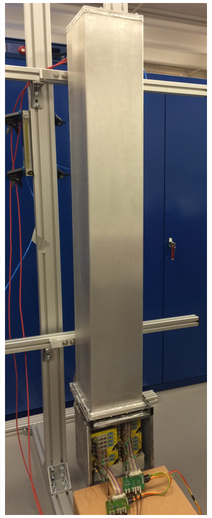
T-REX

ESSDetector Group





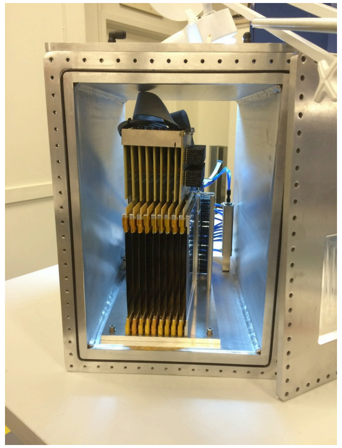


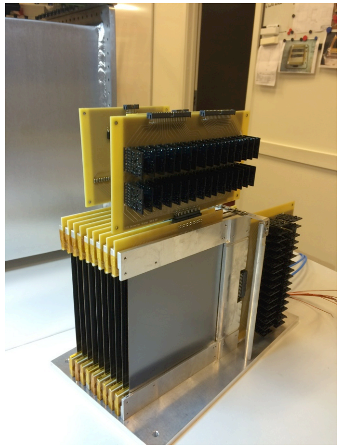


Multi-Blade for reflectometry (ESS, SE)

FREIA, ESTIA, TBL

ESSDetector Group



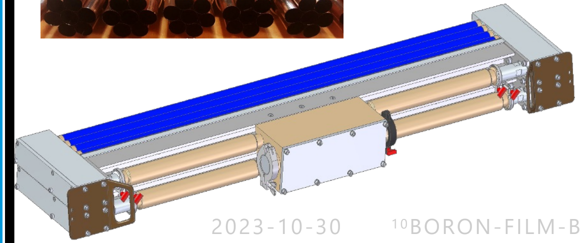


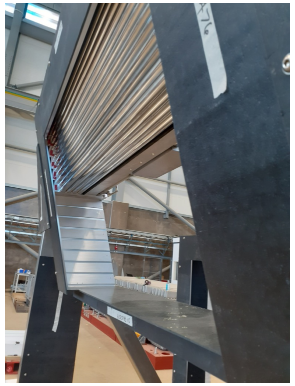
Boron-coated straws for SANS (STFC, UK/PTI, USA)

LoKi

UKRI Science and Technology Facilities Council

ISIS Neutron and Muon Source

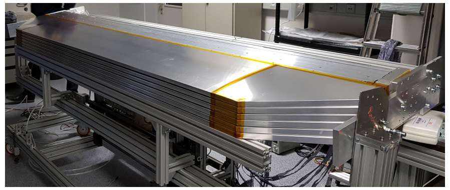


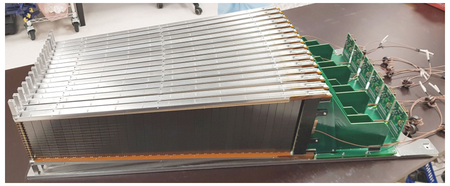


JALOUSIE for diffraction studies (CDT/FZJ, Germany)

DREAM, MAGIC, HEIMDAL

CDT





Boron-10 based detectors for ESS

Multi-Grid for direct spectroscopy (ESS, SE)

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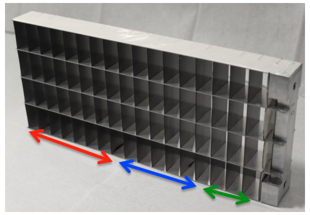
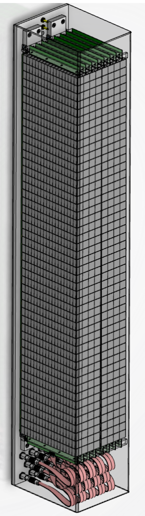
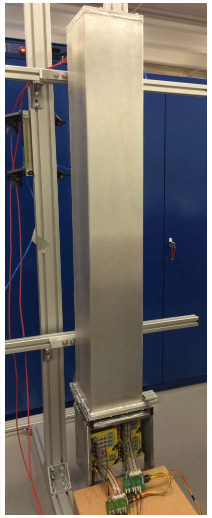
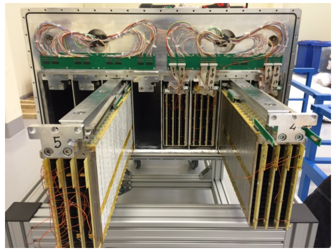


ESSDetector Group







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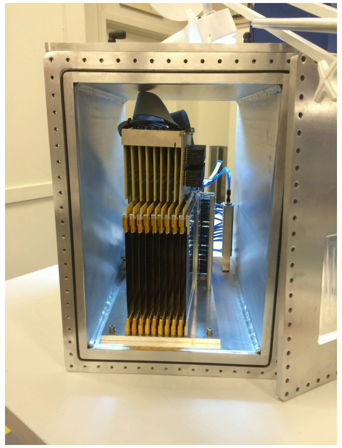

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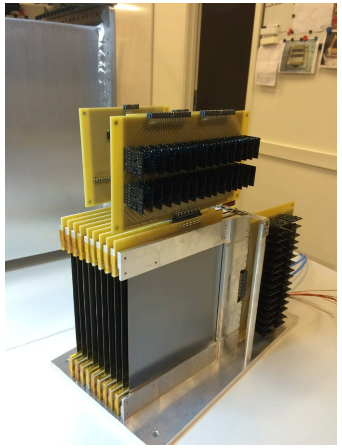

Boron-coated straws for SANS (STFC, UK/PTI, USA)

LoKi

UKRI Science and Technology Facilities Council

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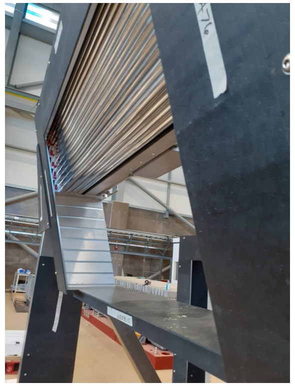

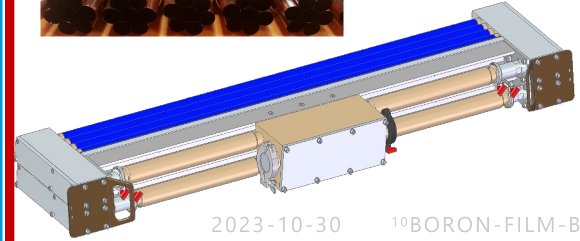

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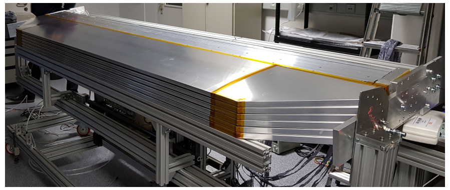
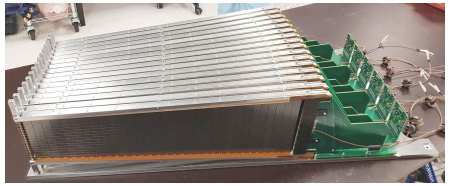
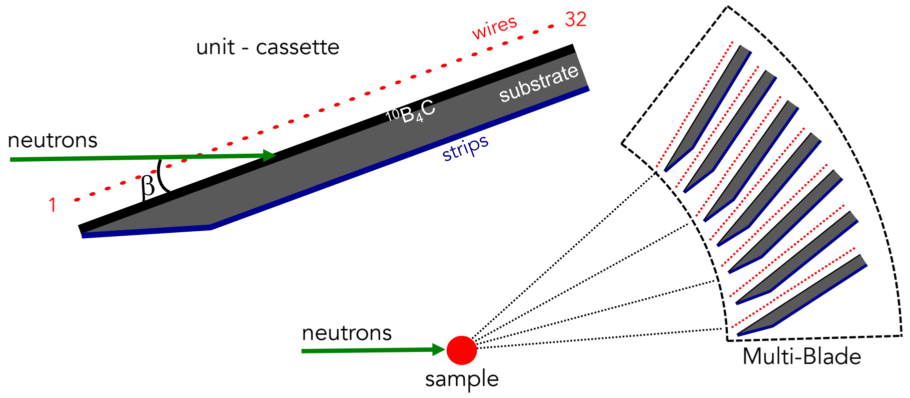


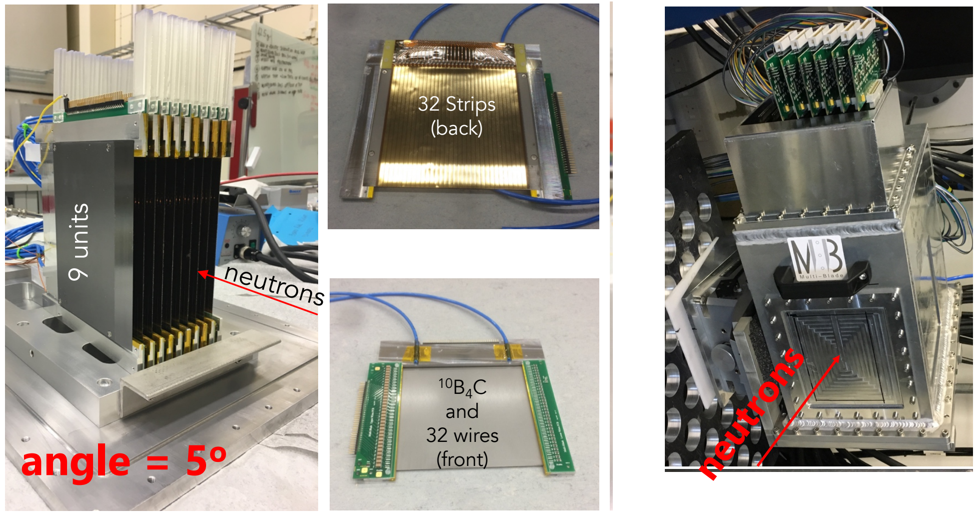
CDT

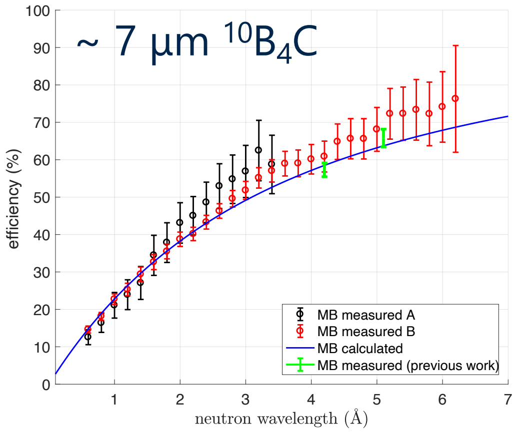


The Multi-Blade detector concept for reflectometry

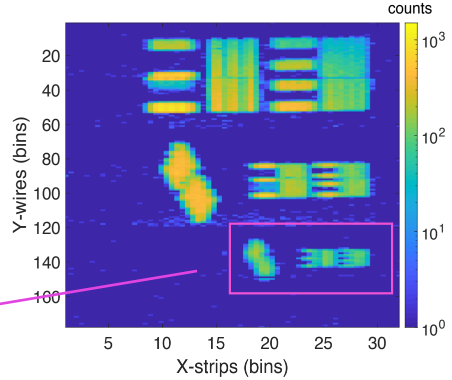
- Requirements for reflectometry detectors: high-count rate capability, sub-millimeter position resolution

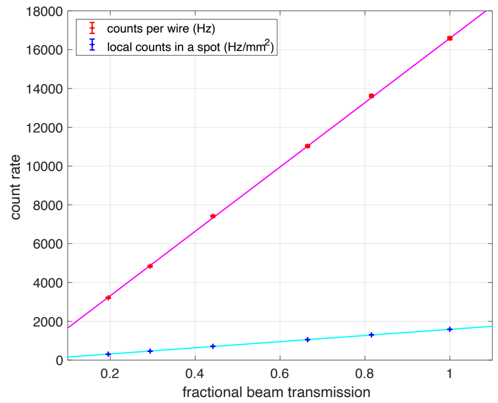






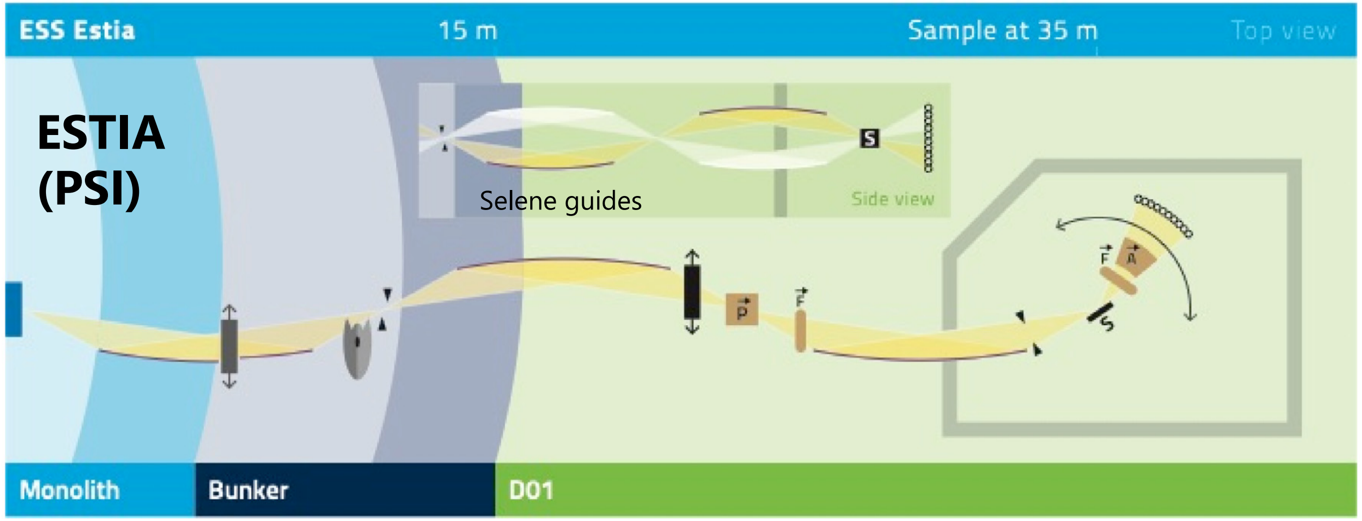
Spatial resolution (FWHM)
0.35 mm (H) x 4 mm (V)

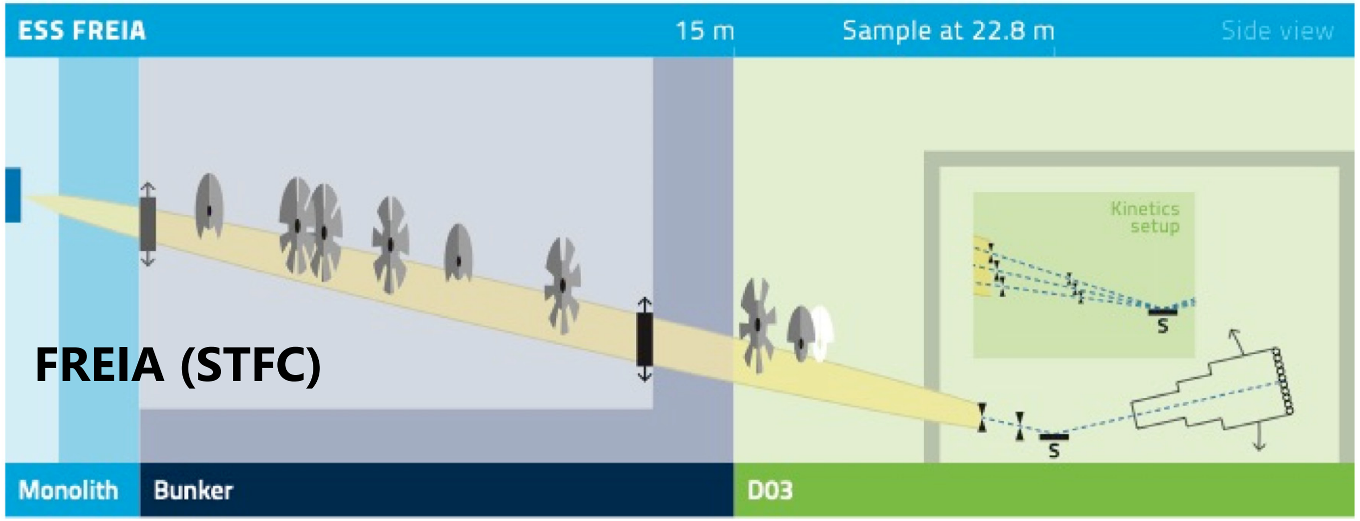




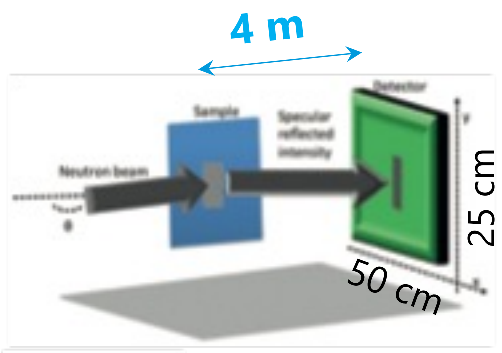
F. Piscitelli et al., JINST12 (2017) P03013 * F. Piscitelli et al., JINST13 (2018) P05009 *** G. Mauri et al., JINST15 (2020) P03010**

The Multi-Blade detector concept for reflectometry





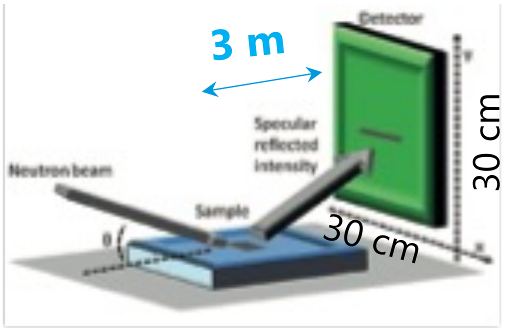
K.H. Andersen et al., NIMA 957 (2020) 163402



Vertical sample geometry
Option for polarization analysis

Spatial resolution (FWHM)
0.5 mm (H) x 4 mm (V)

48 cassettes with a width of 25 cm each mounted horizontally



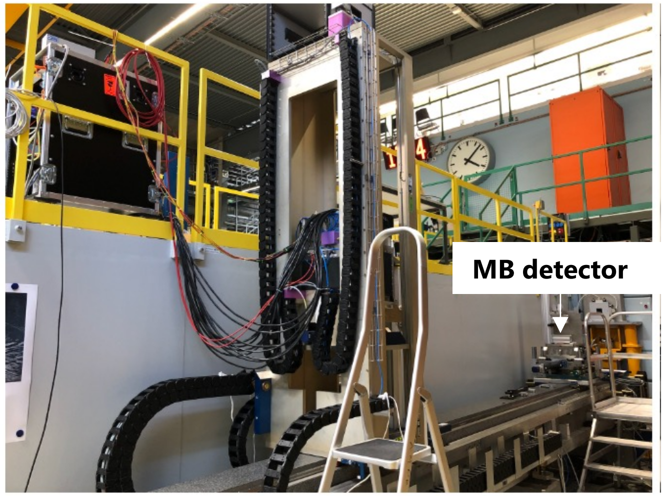
Horizontal sample geometry
Broad simultaneous Q-range for structural and time-resolved studies

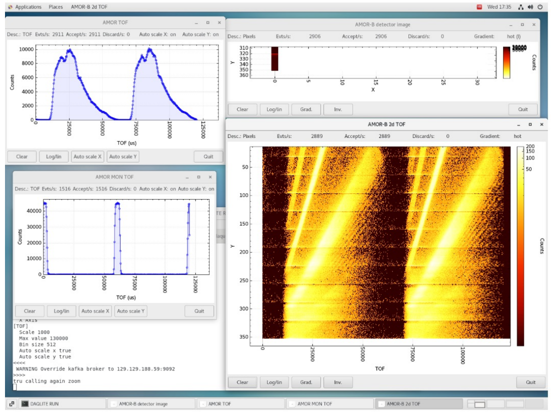
Spatial resolution (FWHM)
2.5 mm (H) x 0.5 mm (V)

32 cassettes with a width of 30 cm each mounted vertically

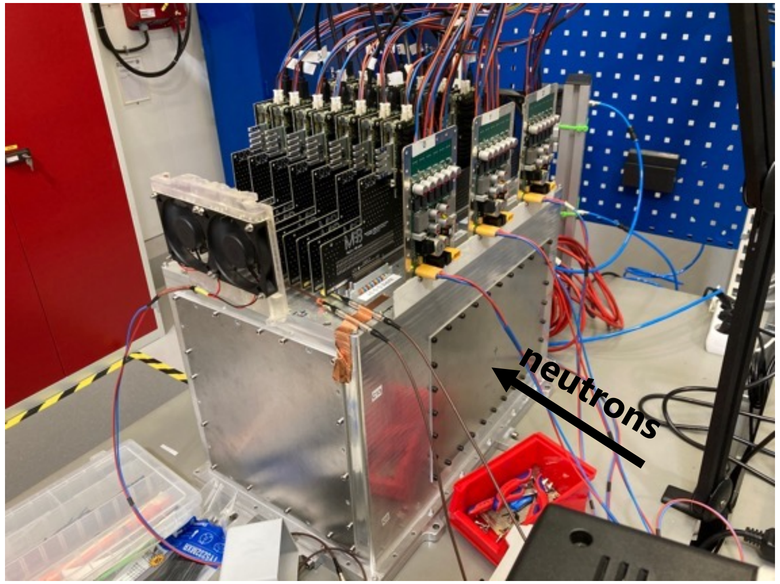
The Multi-Blade detector for AMOR@PSI

MB2020 @ AMOR, PSI

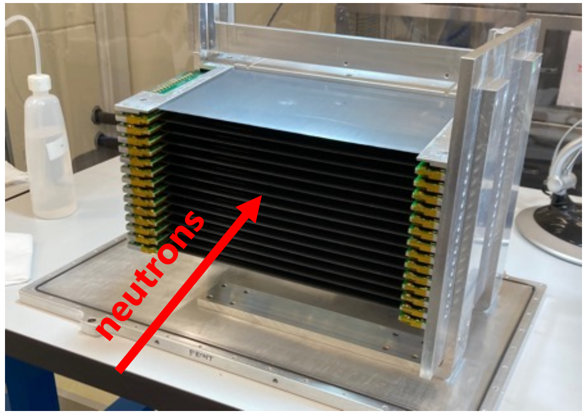




MB2023 @ ESS Detector Lab

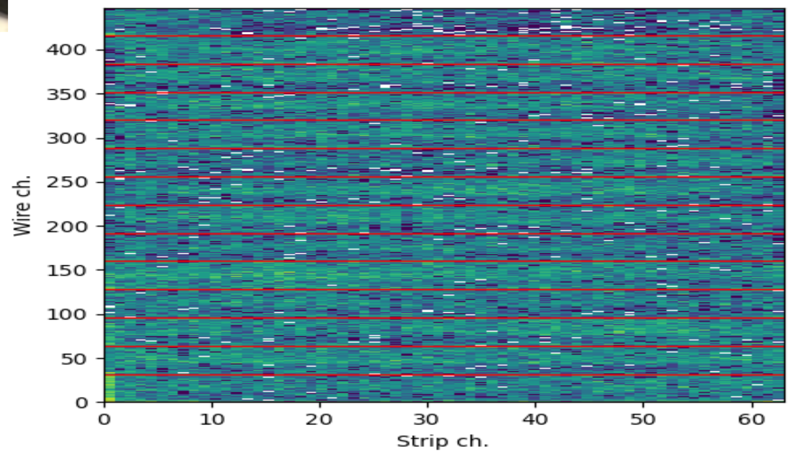


The MB detector assembled for AMOR@PSI



14 cassettes each consisting of 64 strips and 32 wires

A 1:1 copy of the MB for AMOR will be built for use by the ESS Test beamline, joining the ESTIA and FREIA detectors



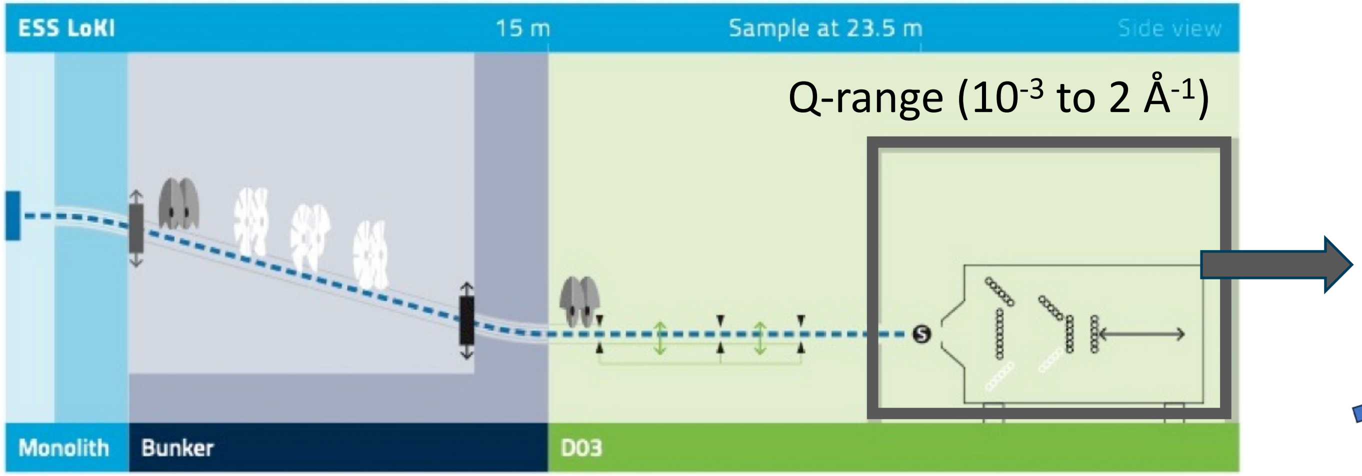
Muon image collected with the MB for AMOR

Boron-coated straws (BSC) for LoKi (SANS)

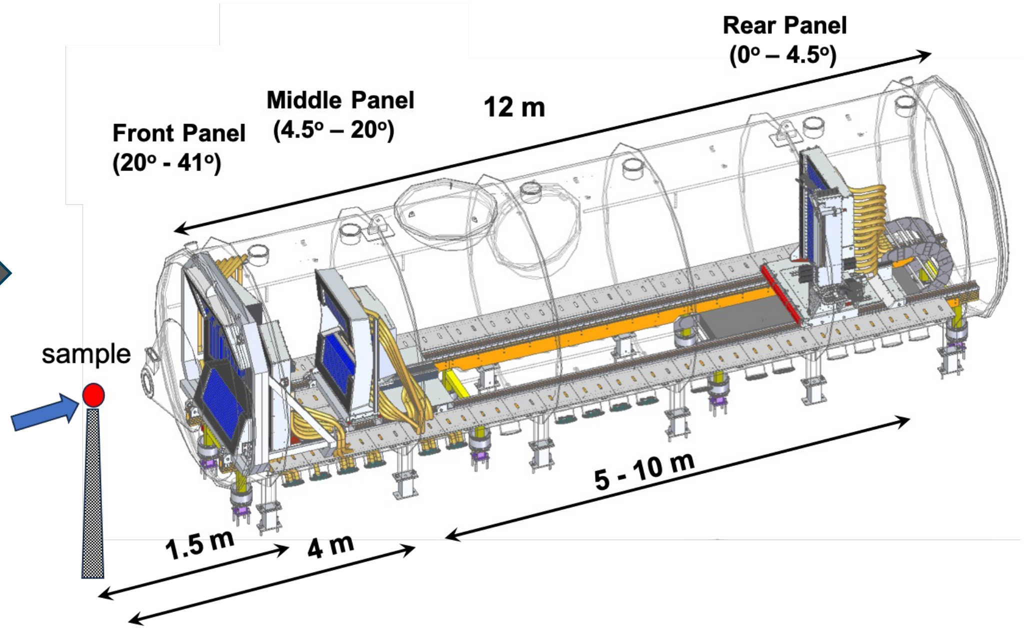
Science and Technology Facilities Council

ISIS Neutron and Muon Source

Broad-band high-intensity SANS instrument built by STFC, UK



K.H. Andersen et al., NIMA 957 (2020) 163402



The detector array covers up to 42° (~6 m^2)

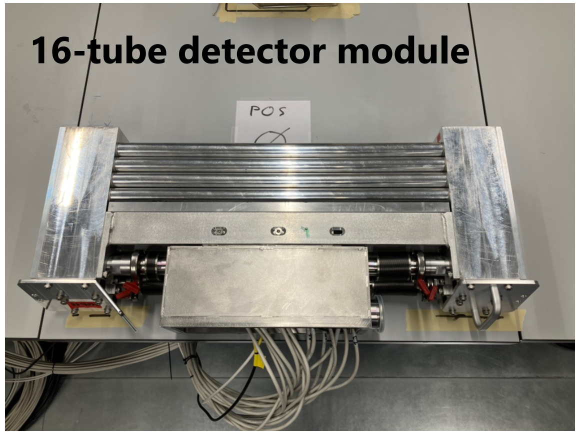
Expected flux at the sample position ~10^8 n/s/cm^2 (2 MW)

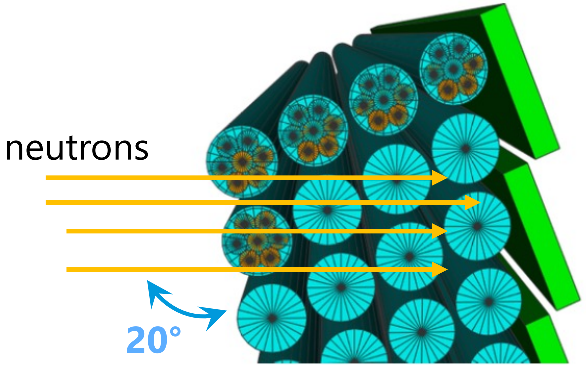
Detectors designed and built by STFC, UK

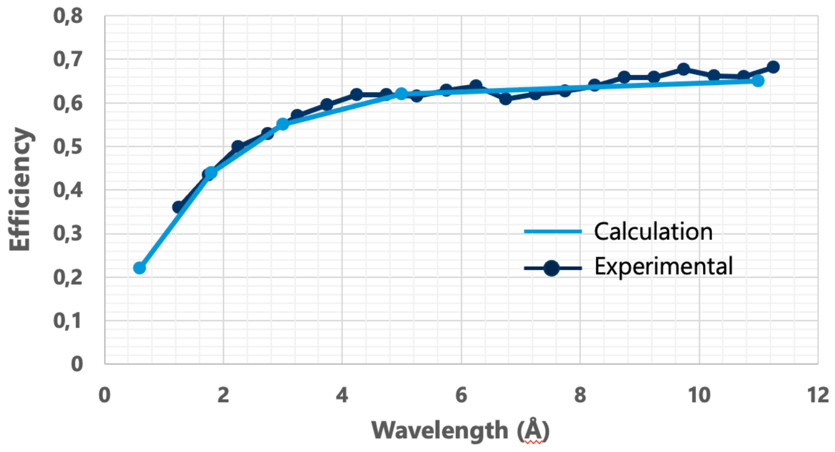
Boron-coated straws (BSC) for LoKi (SANS)

Detector based on the Boron-coated straw technology developed by Proportional Technologies Inc, TX, USA

Multi-tubes coated with ~1 µm of $^{10}B_4C$
Sealed, 0.7 atm of Ar/CO_2 (90-10)







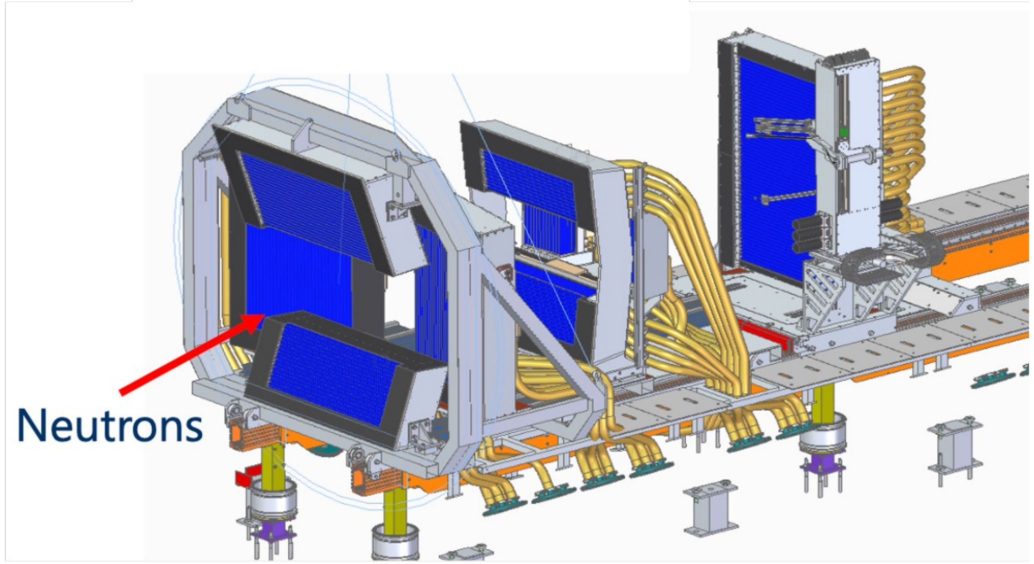
Calculation by M.Klausz et al., NIMA, 943 (2019), 162463
Measurement by D. Raspino, STFC, to be published

Boron-coated straws (BSC) for LoKi (SANS)

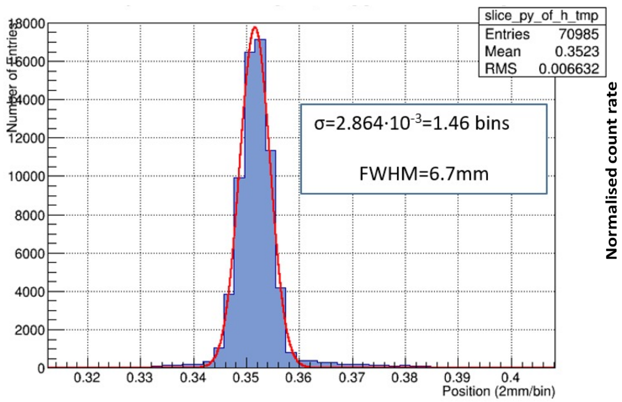
9 detector banks (56 detector modules)

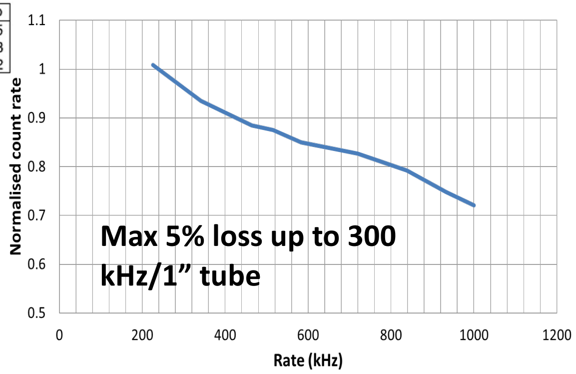
Only 5 banks for Day 1 (36 modules)

- **18 modules – 1000 mm long**
- **3 modules – 500 mm long**
- **15 modules – 1200 mm long**

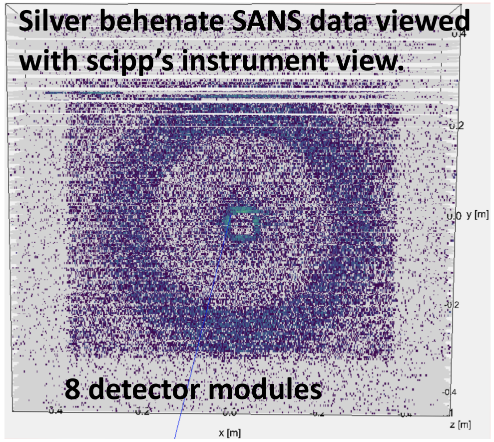


Detector modules intensely tested at Larmour@ISIS during the R&D and manufacturing phases





Measurements by D. Raspino, STFC, to be published



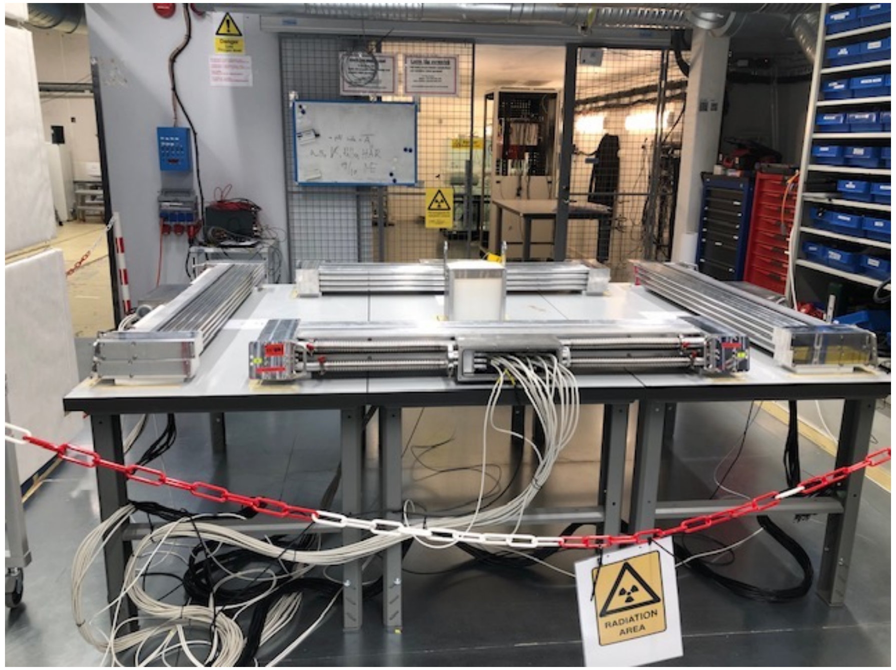
3584 readout channels processed by 29 CAEN R5560 ADCs (125 MHz)

J. Walker et al., 13th Int. Workshop Emerging Technol. Sci. Facil. Controls, doi:10.18429/JACoW-PCaPAC2022-FRO22

Boron-coated straws (BSC) for LoKi (SANS)

Science and Technology Facilities Council

ISIS Neutron and Muon Source



Site inspection tests of the Day-1 Loki detector modules

Installation of the front and middle panel detectors at ESS

Start of LoKi cold-commissioning planned for Q2-Q3 2024

Conclusions, outlook

- The scientific performance of most of the ESS instruments relies heavily on gas counters employing the ^{10}B-solid converter developed as an alternative to the ^{3}He-based detectors.

- LoKi (SANS), Test beamline, DREAM (powder diffraction), MAGiC (single-crystal diffraction), ESTIA, FREIA (reflectometry), BEER (strain scanning) will employ this technology.

- LoKi, Test beamline and DREAM are expected to start cold commissioning in Q2-Q3 of 2024. These will be the first instruments in the world to operate with large-area Boron-based gas detectors. Installation of detectors started, integration ongoing in the lab.

Finish presentation

2023-10-30

Loki detector readout (1)

Science and Technology Facilities Council

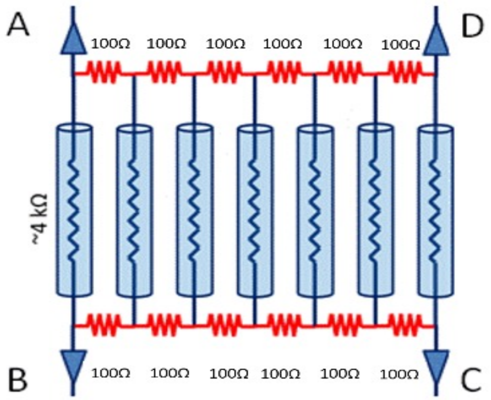
ISIS Neutron and Muon Source

4032 straws

Would require 8064 electronics channels (preamp+ADC)

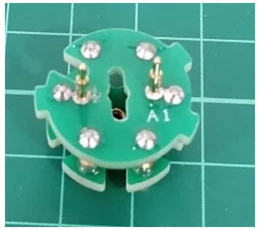
Multiplexing required

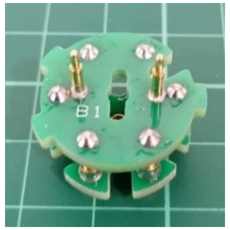
3.5 reduction→ 2304 channels

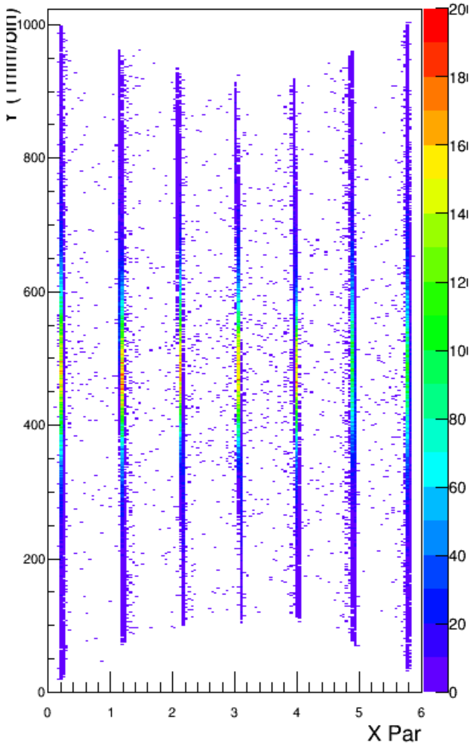


$$x = \frac{A+B}{A+B+C+D}$$

$$y = \frac{A+D}{A+B+C+D}$$







Loki detector readout (2)

ISIS Neutron and Muon Source

16 channels board preamp (Erik Schooneveld)

- One at each side of a module
- Twisted paired signals on a Ethernet cable to the ADC

128 Chs ADC R5560 by CAEN

- 125 MHz sample rate
- 14 bits
- Open FPGA
- Firmware developed on SCI-Compiler by Nuclear Instrument
- DSP/Amplitude Calculation/ γ/n / Time stamp
- Interface with the ESS DAQ via 10 Gbe fibres
- Effort from STFC-ISIS, STFC-TD, ESS-DG, NI
- Diagnostic Tools