EUROPEAN SPALLATION SOURCE

Development of detectors for reflectometry at the ESS

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on behalf of the ESS Detector Group

www.europeanspallationsource.se
SINE2020 General Assembly meeting, September 7-8, 2016

News from the ESS

- The new ESS Director General John Womersley will start on November 1. JW is the current CEO of the UK's Science and Technology Facilities Council (STFC).

- The Science Directorate focus in 2016 is to align the instrument budgets with the allocated budget ("scope-setting meetings"), develop a realistic schedule for all instruments ensuring early science success, and propose which instruments are to be operational first (~2021).

- Beamport allocations made and the design and schedule of some of the key technical components about to be finalized (common shielding bunker, monolith beam extraction inserts, light shutters, civil engineering, etc.).

- ESS construction site: 24% complete. The target for this year is to reach 30%.

The Installation Galleries in Experimental Hall 2 and concrete pilings in the Beamline Gallery

Detectors for the ESS instruments

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Instrument class	Instrument sub-class	Instrument	Key requirements for detectors	Preferred detector technology	Ongoing developments (funding source)
Large-scale structures	Small Angle Scattering	SKADI	Pixel size, count-rate	Scintillators	SonDe (EU SonDe)
		LOKI		10B-based	BandGem
	Reflectometry	FREIA	Pixel size, count-rate	10B-based	MultiBlade (EU BrightnESS)
		ESTIA			
Diffraction	Powder diffraction	DREAM	Pixel size, count-rate	10B-based	Jalousie
		HEIMDAL		~~Scintillators~~/10B-based	Jalousie ?
	Single-crystal diffraction	MAGIC	Pixel size, count-rate	10B-based	Jalousie
		NMX (ESS)	Pixel size, large area	Gd-based	GdGEM uTPC(EU BrightnESS)
Engineering	Strain scanning	BEER	Pixel size, count-rate	10B-based	AmCLD, A1CLD
	Imaging and tomography	ODIN	Pixel size	Scintillators, MCP, wire chambers	
Spectroscopy	Direct geometry	C-SPEC	Large area (^{3}He-gas unaffordable)	10B-based	MultiGrid (EU BrightnESS)
		T-REX			
		VOR			
	Indirect geometry	BIFROST	Count-rate	3He-based	
		MIRACLES			
		VESPA	Count-rate	3He-based	
SPIN-ECHO	Spin-echo	tbd	tbd	3He-based/10B-based	

Reflectometry at ESS

	FREIA	ESTIA
Proposed by:	ESS + Denmark Technical University	PSI + University of Copenhagen
Applications	Liquids, soft condensed matter, kinetics	Hard condensed matter
Type	Horizontal sample geometry	Vertical sample geometry
Status	In Phase 1* Scope-setting meeting planned for October 2016	In Phase 1* Scope-setting meeting held in July 2016
IK partner prime-contractor	ISIS	PSI
Requested budget in initial proposal	15.85 M€	12.255 M€
Target budget (cost category)	A (9 M€) + 3 M€ Non-NSS contribution	A (9 M€) + 3 M€ Non-NSS contribution
Funding	UK, 100%	CH, 100%
Hot commissioning	2023?	2021?

Phase 1*: agree upon the scope, budget, schedule, resourcing.
Scope-setting meeting: present the scope within assigned cost category, determine minimum scope&budget.

Detector requirements for the ESS reflectometers

	FREIA	ESTIA	State-of-the-art
Sample-to-detector distance	1 to 8 m, mostly 3 m	6.2 m	1 - 10 m
Detector area	50 x 30 cm^2	2 x 40 x 10 cm^2	40 x 40 cm^2
Position resolution	4 mm x 0.5 mm	0.5 mm x 1 mm	2 mm x 2 mm
White flux on sample	~2*10^8 n/cm^2/s	~10^8 n/cm^2/s	~10^9 n/cm^2/s
Detector global rate	several MHz	several MHz	several MHz
Instantaneous local rate	> 100 kHz/mm^2	> 100 kHz/mm^2	<1 kHz/mm^2
Background	10^{-7}	< 10^{-7}	10^{-7}
Uniformity (%)	<5	<5	5
Detector technology	^{10}B-based counters in inclined geometry (MultiBlade)		^{3}He-based wire chamber + delay line Tubes with charge division

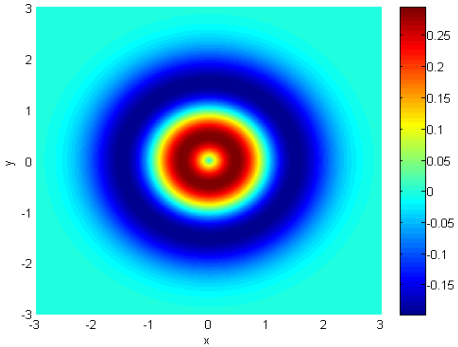
ESS DG contact person for reflectometers: Francesco Piscitelli.

EU funding for detector development

- MultiBlade: stack of MWPCs with Boron-coated cathodes in inclined geometry.
- Proof-of-concept of MultiBlade constructed and tested by ILL in 2012.
  F. Piscitelli et al., JINST 9 P03007, 2014.
- In 2015 the MultiBlade development led by Francesco Piscitelli received funds through the project BrightnESS / Task 4.2: *The intensity frontier*, ~2 Meuros.
- BrightnESS: 2015-2018, ~19 Meuros, 18 partners from 11 countries.

brightness

Task 4.2: The intensity frontier

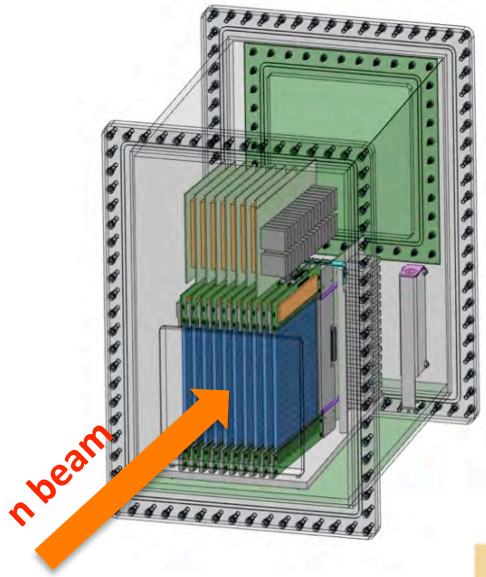


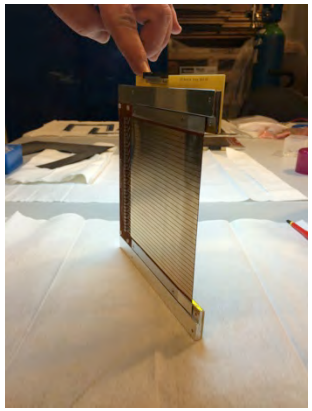
Budapest Neutron Centre

Wigner Research Institute

The ESS MultiBlade detector (MB2015)

Designed and assembled at ESS Lund during June 2015 and February 2016.





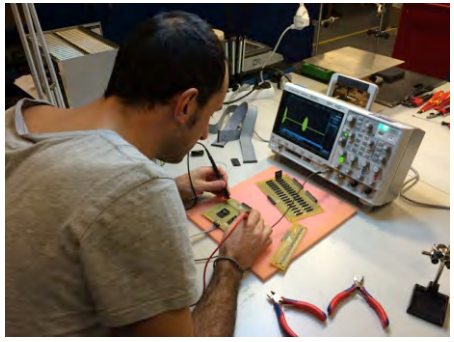
10 cm X 10 cm active area

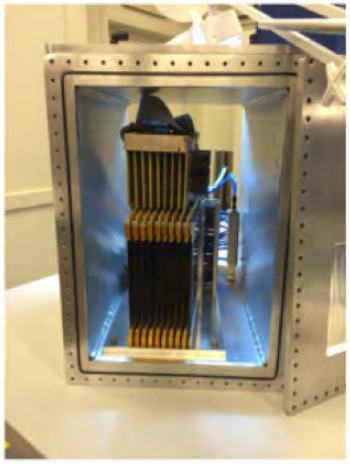
9 cassettes @ η =5° , 7.5 μ m $^{10}B_4C$ coatings

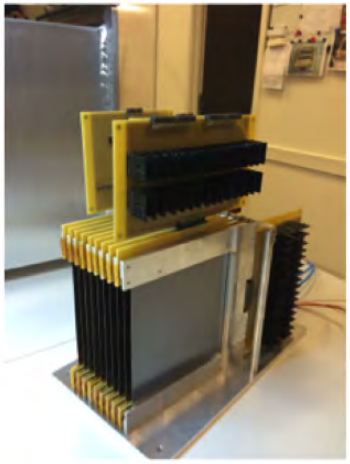
Each cassette will feature 32 anode wires and 32 cathode strips.

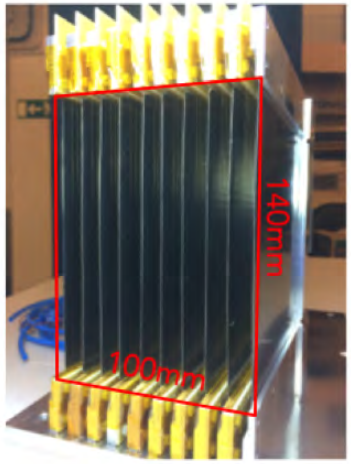
Wire pitch=4 mm / Strip pitch=4 mm

➔ spatial resolution ~wire pitch*sin(η) = 0.34 mm

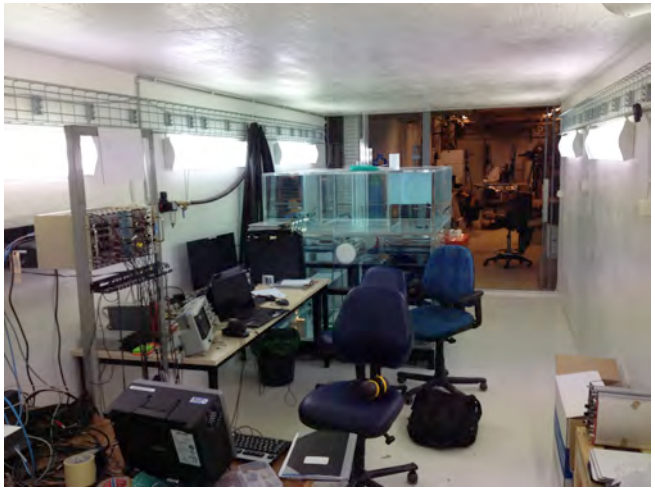




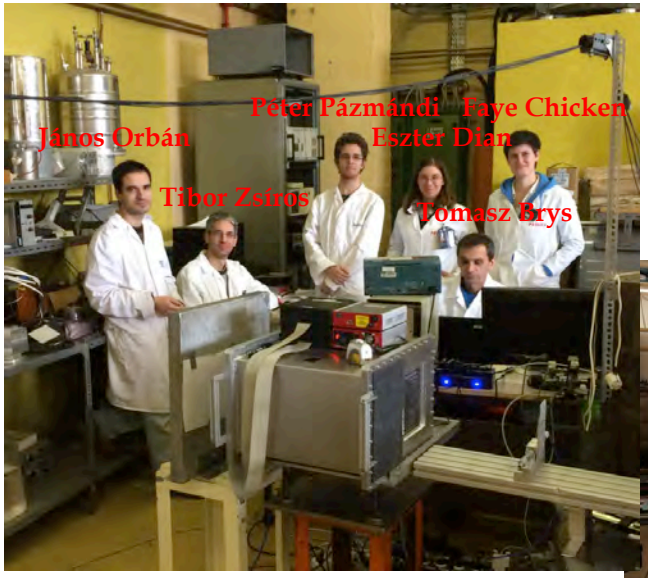




Testing MB2015



Preliminary testing with the moderated AmBe source at the ESS Source Facility (Lund University).



First testing with beam performed in March 2016 at the ATHOS beam line at BNC (Budapest).

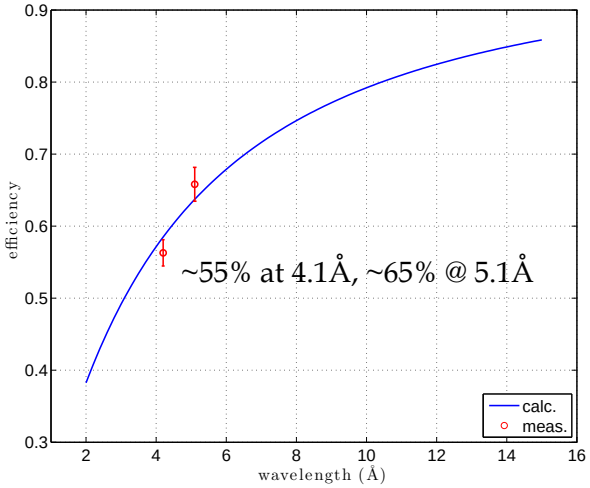
ATHOS: triple axis spectrometer, ~10^6 n/s/cm^2 at the sample position.

Francesco Messi (FraMe) joined the Nuclear Physics Group at Lund University as a BrigthnESS post-doc in April 2016.

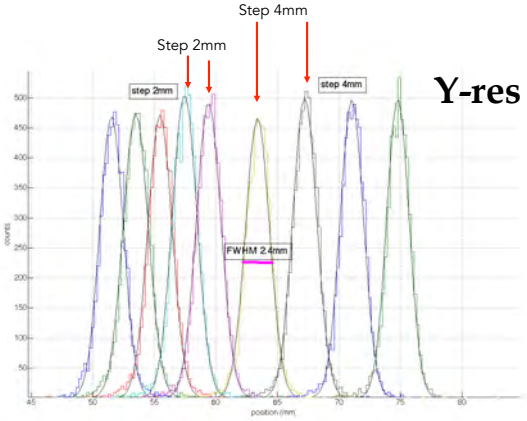
Second testing of the MB2015 at BNC performed in June 2016, data is being analysed.

Testing of MB2015 at BNC

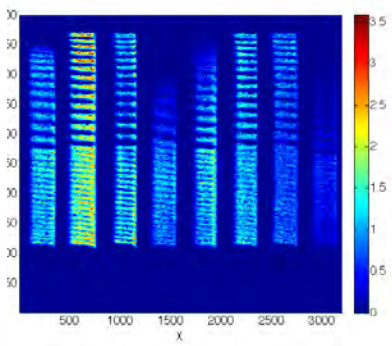
- Efficiency

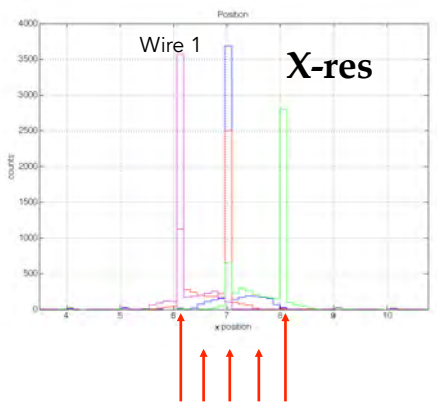


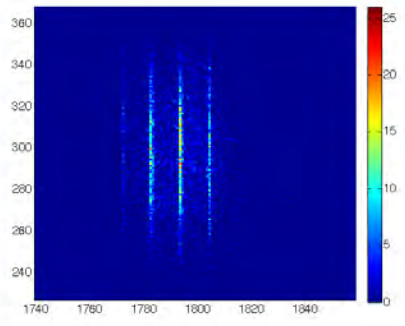
- Spatial resolution (wire and strip pitch = 4 mm)



FWHM ~ 2.4mm

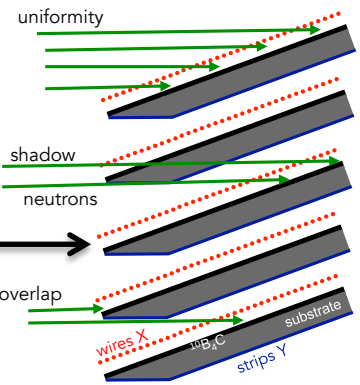






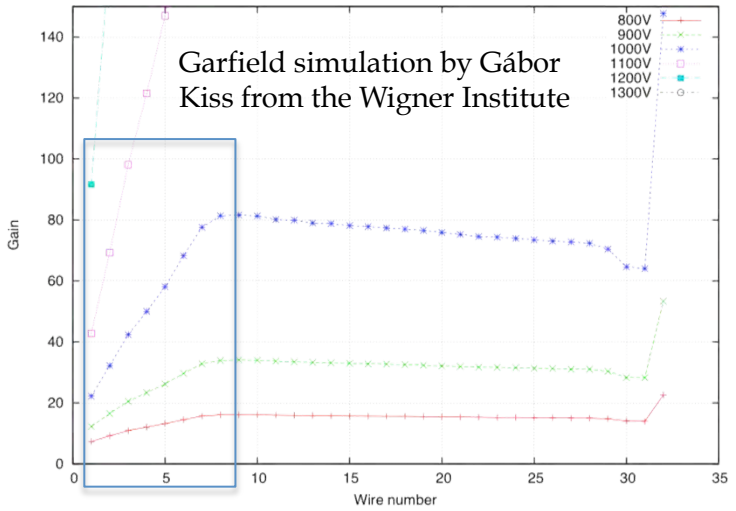
Testing of MB2015 at BNC

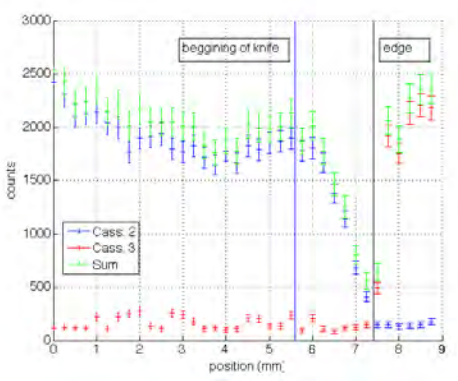
- Uniformity and overlap (must be < 5%).

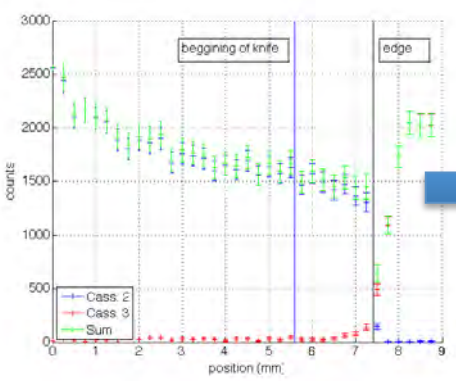


"knife" (chisel)

Experimental

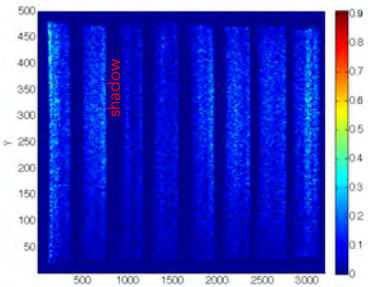


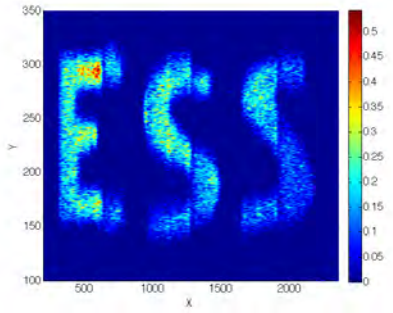




Not corrected for gain difference

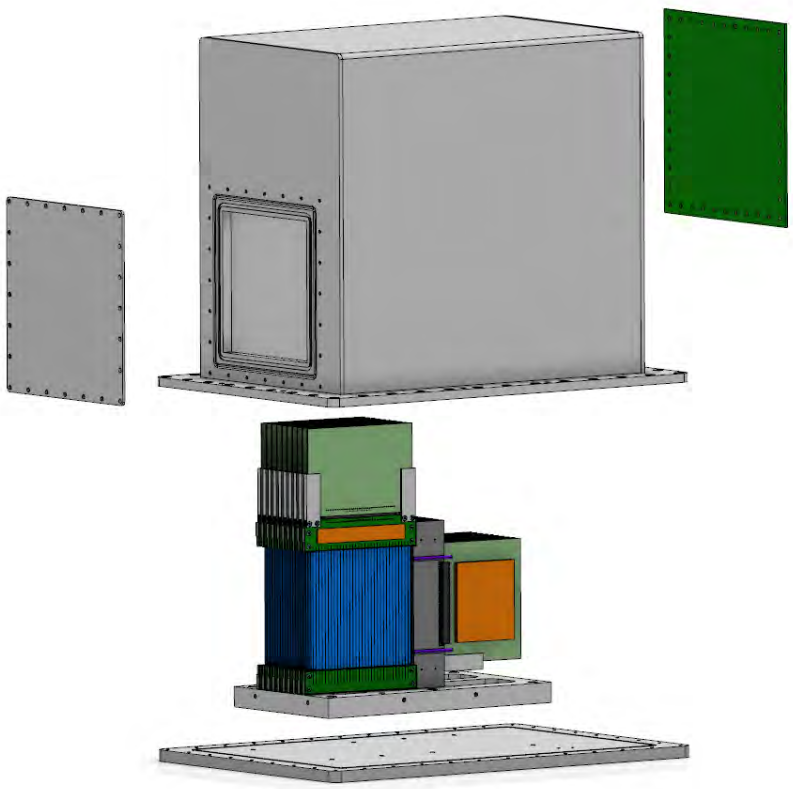
Corrected for gain difference





The next MultiBlade detector (MB2016)

- New design of the vessel (detector stack on a back plate and a hat) for easier access to the stack.
- New front-end/readout electronics designed by the partners from the Wigner Research Institute.



Objectives:

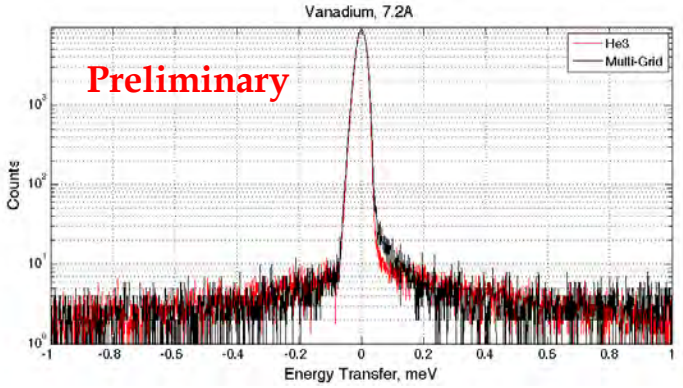
- Improve the mechanics, coplanarity of the blades, test various substrates for the coatings, add internal shielding.
- Test the new electronics.

BrightnESS Task 4.3 "Large area detectors": Technology demonstrators for scientific performance

A MultiGrid demonstrator with realistic size is currently taking data at the CNSC spectrometer at the SNS, side-by-side with the ^{3}He-tubes.

- The demonstrator was assembled this Spring at the ESS Mechanical Workshop (Embla) by recycling grids made for the IN5 demonstrator.
- 2 columns of 48 grids each plus lods of other components (detector vessel, PCBs, etc.) designed at ESS.
- 1.15 m x 19 cm active area, 128 wires and 96 grid channels individual readout.

- Successful installation at the SNS in June 2016.
- Data taking between June and Dec 2016. Data analysis ongoing.



Comparison between the He-3 and MultiGrid TOF peak recorded with the V sample at the CNSC.

Conclusions and outlook

brightness
Horizon2020/676548.
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- 2 reflectometers (FREIA, ESTIA) will be build at ESS as part of the baseline suite of 16 instruments. The lead laboratories for the two instruments are ISIS and PSI.

- The proposed detector technology for reflectometry at ESS is based on the MultiBlade concept.

- The design and testing of the MultiBlade/MultiGrid physics demonstrators is funded by the BrigthnESS EU project. BrightnESS/WP4 funds work on final detector designs, implementation and integration and activities that take developmental results and engineer them into fully functional detectors.

- Testing of the first version of the MultiBlade detector built in Lund successfully performed at the BNC. A second, improved version of the demonstrator is currently being built at ESS. Testing at BNC and scientific demonstration on reflectometry instruments planned for the upcoming months.

- This work led to the identification of design/build teams and local manufacturers, it helped establishing local contacts and initiated collaborative work with the European partners that are important IK-partners.

BrightnESS

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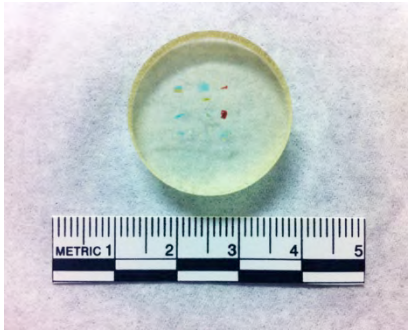
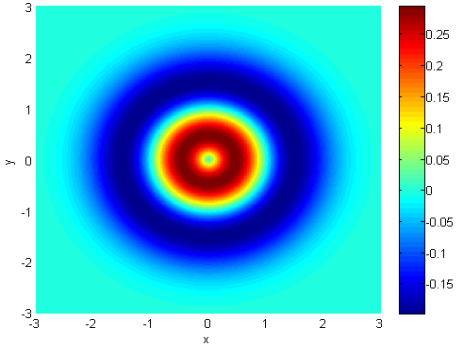
- WP4: “Innovation of Key Neutron Technologies: Detectors and Moderators”.
- ESS + 6 partners: IEAP CTU, ILL, BNC Wigner, LU, MiUN, CERN.



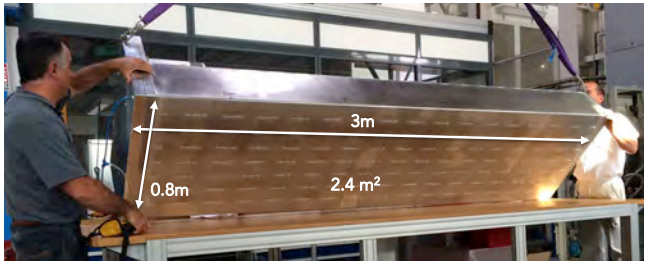
Task 4.1: The resolution challenge

macromolecular crystallography



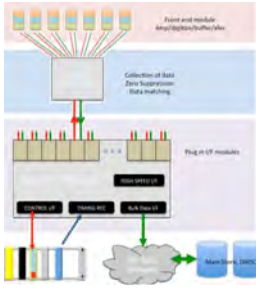
Task 4.2: The intensity frontier

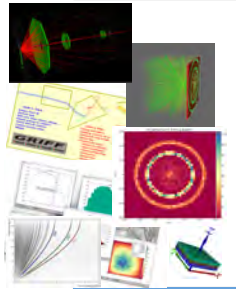
reflectometry

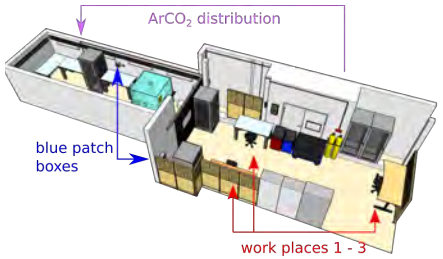


Task 4.3: Large-area detectors

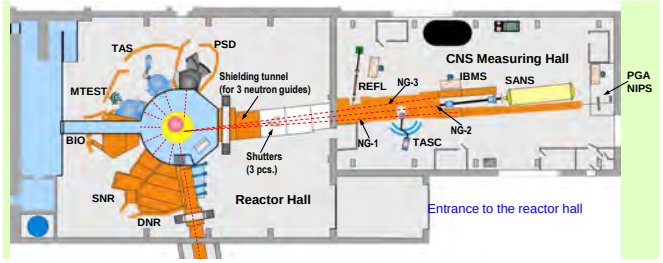
TOF spectroscopy



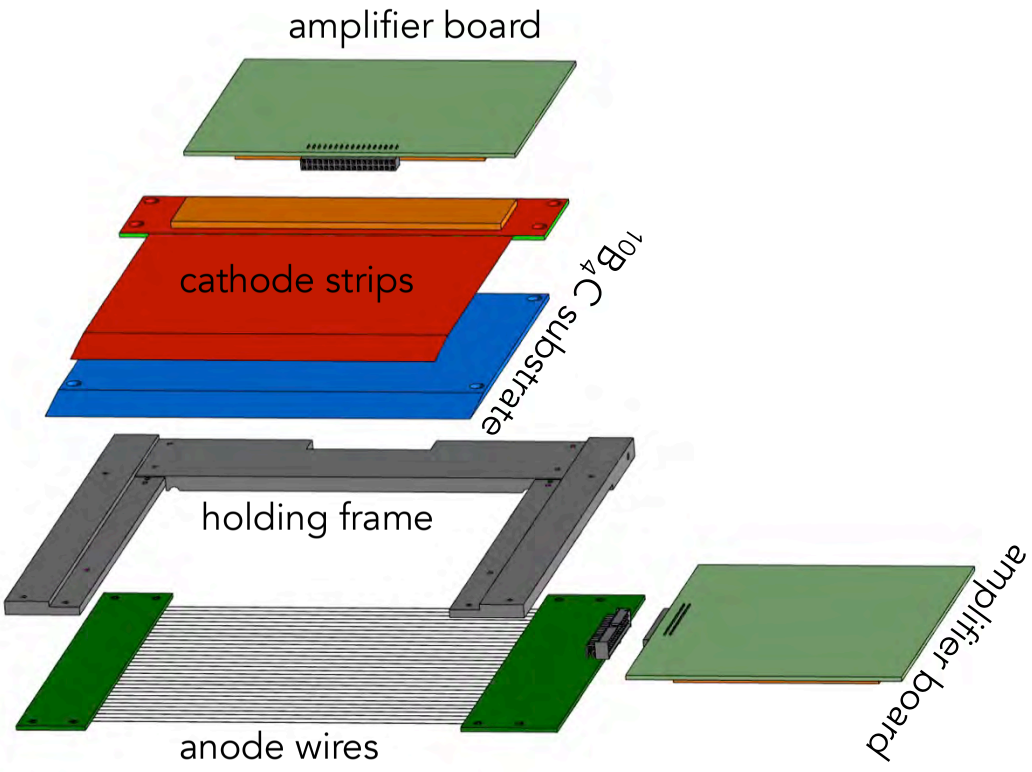


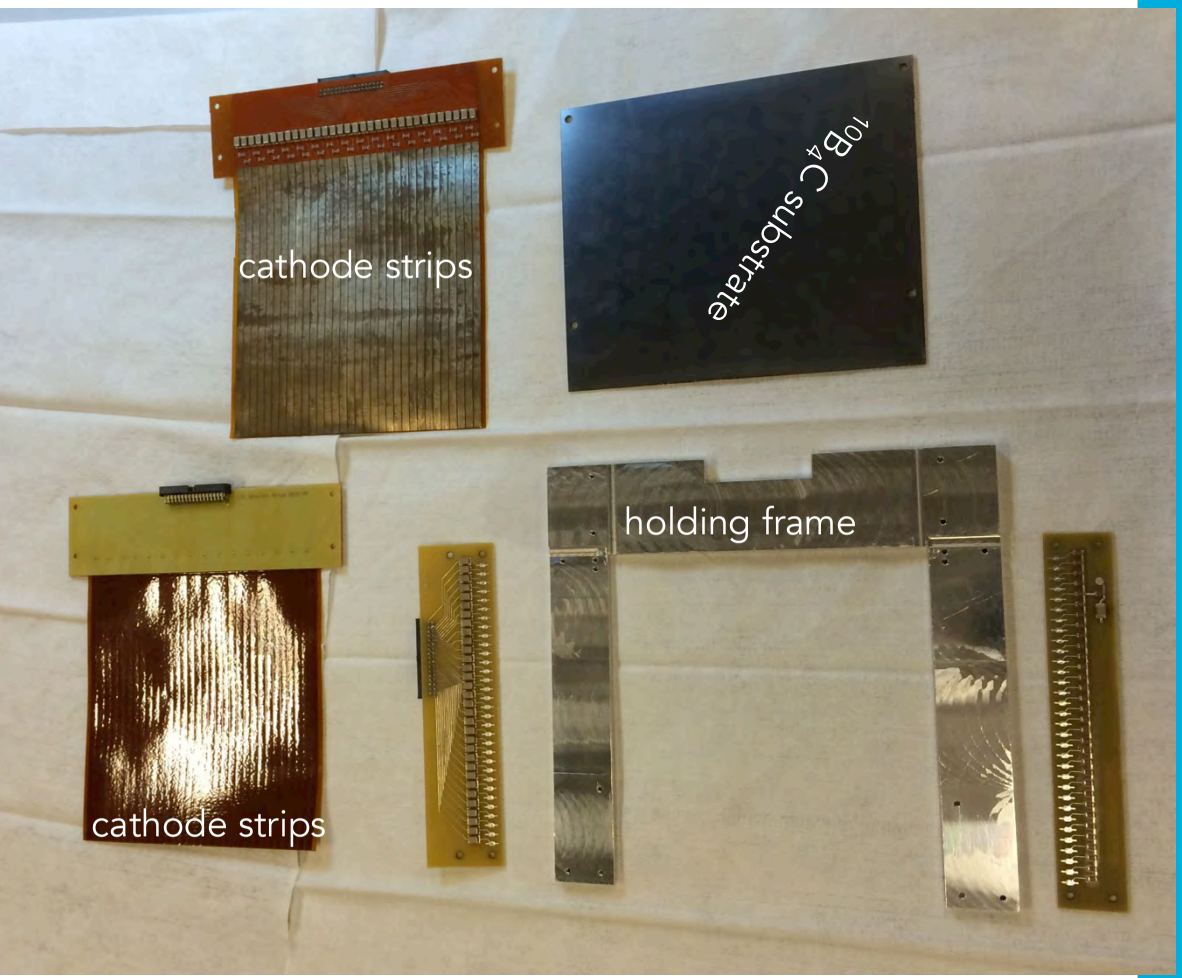


Task 4.4: Detector realization: electronics, simulations, source facility development



Task 4.5: Moderator testing and development beamline (BNC)





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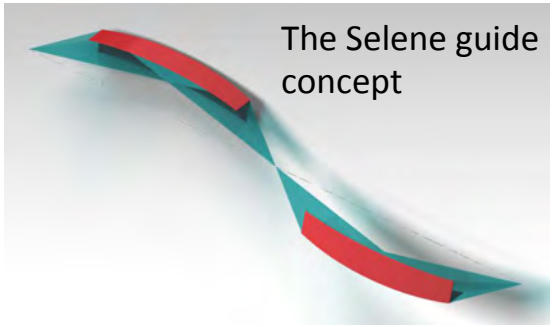
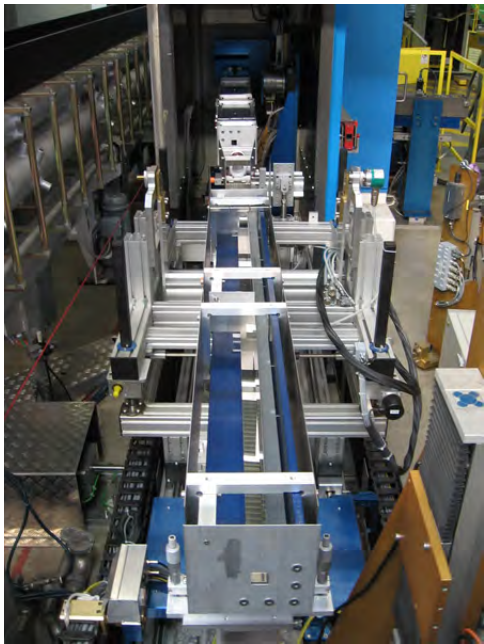
ESTIA

- The name of the instrument is given by a Greek goddess of hearth, family and architecture.
- Proposed by a collaboration between PSI and University of Copenhagen.
- A very innovative instrument design based on the Selene guide concept. Only neutrons that will hit the sample will be transported by the guide system, which ensures low instrumental background.
- Aims for the study of small samples (<< 1 cm^2), with vertical geometry.



The Selene guide concept

The instrument concept is higher risk than a more traditional design as it relies on a number of high precision optical components that have not yet been manufactured on the scale required.
A prototype instrument was constructed and tested at AMOR@PSI. More tests to follow.

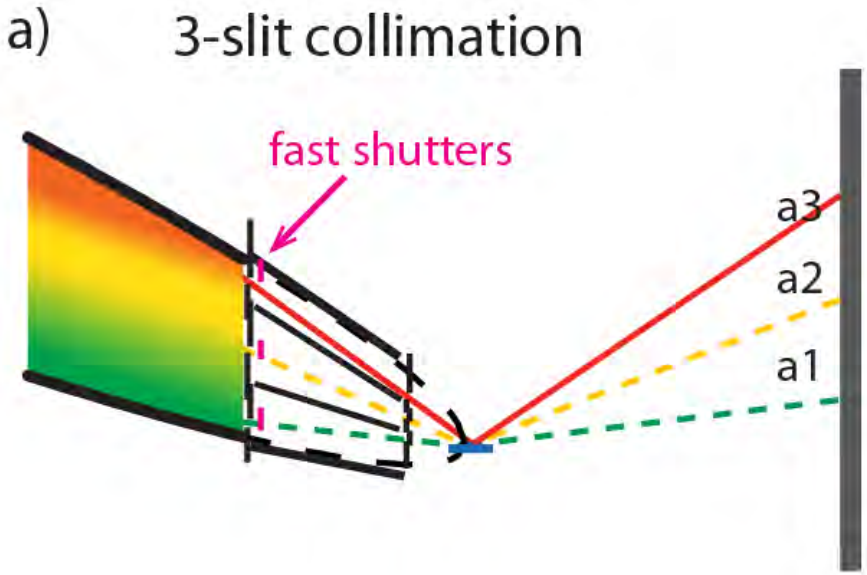


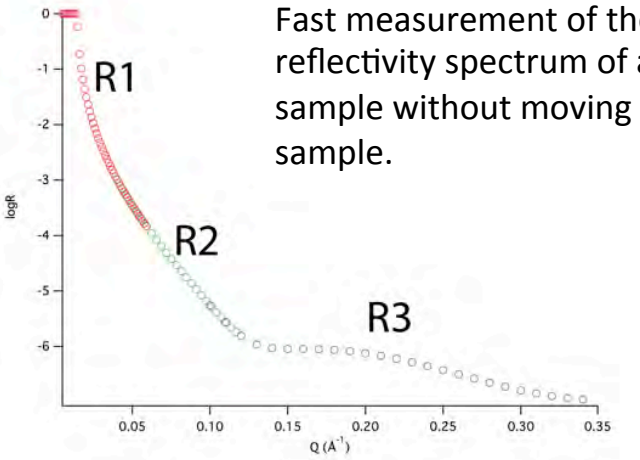
Reflectometry at ESS

	FREIA	ESTIA
Proposed by:	ESS + Denmark Technical University	PSI + University of Copenhagen
Applications	Liquids, soft condensed matter, kinetics	Hard condensed matter
Type	Horizontal sample geometry	Vertical sample geometry
Status	Ready to enter Phase 1	Phase 1 started July 2015
IK partner prime-contractor	ISIS	PSI
Requested budget in initial proposal	15.85 M€	12.255 M€
Target budget (cost category)	A (9 M€) + 3 M€ Non-ESS contribution	A (9 M€) + 3 M€ Non-ESS contribution
Funding	UK, 100%	CH, 100%
Hot commissioning	~2023	~2023

FREIA

- Proposed by a collaboration between ESS and Denmark Technical University.
- Horizontal reflectometer that will be used to study kinetics and free liquid surfaces.
- FREIA has an inclined elliptical guide design (-2°) focusing a neutron beam with 4° of vertical divergence onto a sample surface. It will have 3 modes of operation: kinetic, stroboscopic and angle-dispersive.
- In the kinetic mode, 3 angles (with good overlap) will be selected by moving 3 pairs of precision slits. Each angle will use the neutrons from every third neutron pulse.





Fast measurement of the full reflectivity spectrum of a sample without moving the sample.

Detectors for the ESS reflectometers

- Task 4.2 in Brightness was allocated funds for 122 PM effort, enough to recruit one post-doc and one PhD student (LU-PHY/ESS), and one post-doc at BNC.

- The Hungarian partners will provide electric field calculations (GARFIELD, etc.) and detailed GEANT4 simulations. Beam time at BNC for testing.

- Status project as of today: mounting finished, electronics debugging in progress, first field calculations made available by the Hungarian partners, plans for tests at the ESS SF at LU.