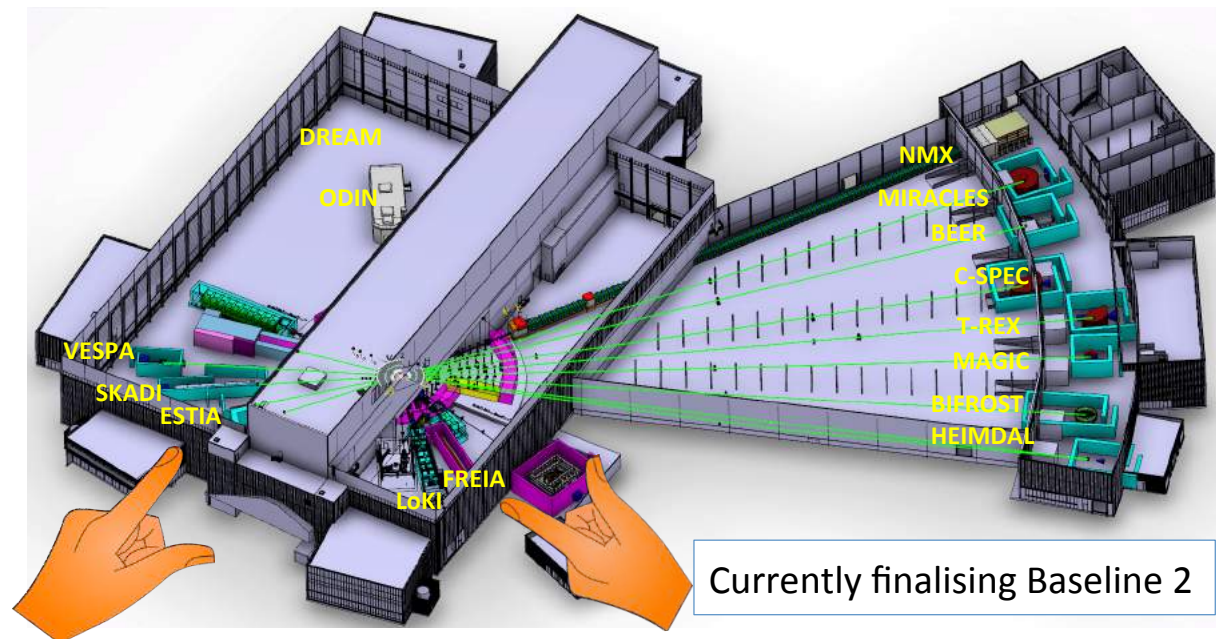


# Status report on ESS reflectometers

Irina Stefanescu  
on behalf of the ESS Detector Group

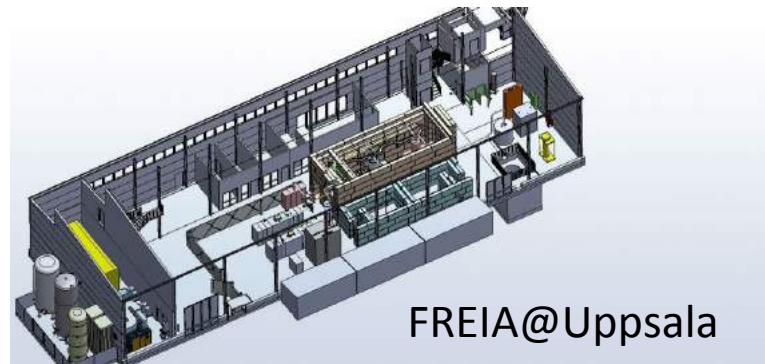
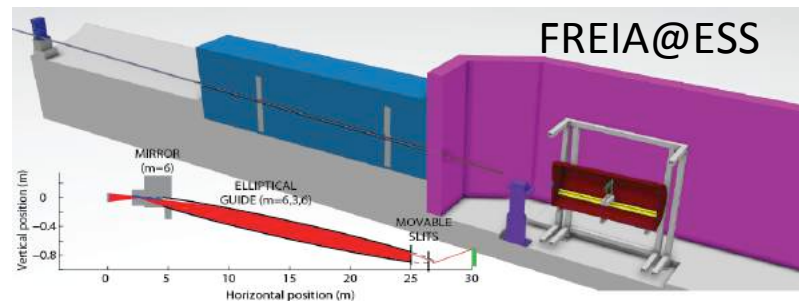
# Reflectometry at ESS

- ESS-TDR includes 2 reflectometers as part of the baseline instrument suite. Both a horizontal and vertical sample geometry instruments are needed to satisfy the requirements of a complete science program.
- Four instrument concepts submitted to relevant STAP during proposal Round 2 (FREIA, VERITAS, ESTIA, THOR) and one during Round 3 (HERITAGE).
- FREIA and ESTIA were recommended for construction as part of the baseline suite of 16 instruments. Proposals available online at <https://europeanspallationsource.se/instrument-proposals-2013-0>.
- At least one reflectometer will be available at Day-1.



# FREIA

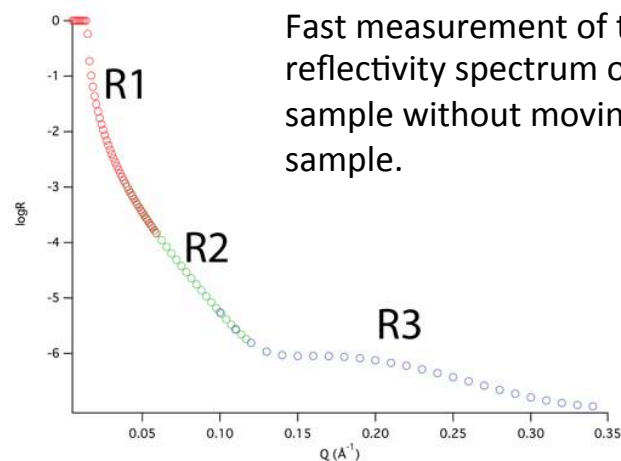
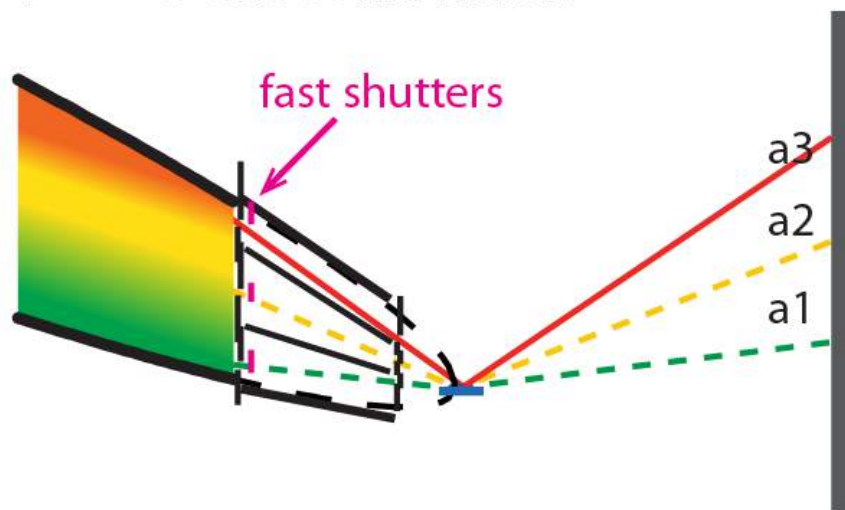
- **F**ast **R**eflectometer for **E**xtended **I**nterfacial **A**nalysis.
- ....also a Norwegian chocolate brand, a knityarn brand, an experimental physics laboratory at the Uppsala University, a Norwegian goddess (Freyja), etc. (source: google.com).



# 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 ( $-2^\circ$ ) focusing a neutron beam with  $4^\circ$  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.

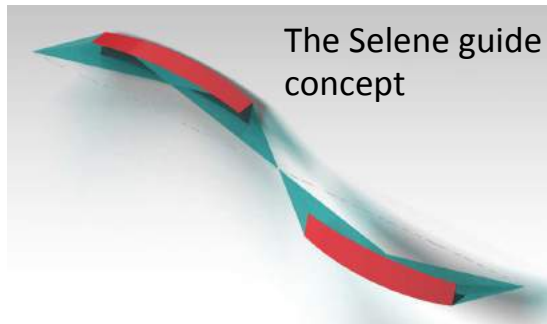
## a) 3-slit collimation



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

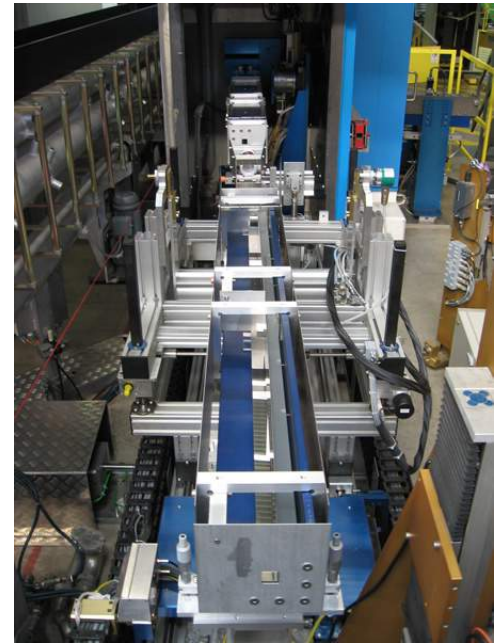
# ESTIA

- 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 ( $< 1 \text{ cm}^2$ ), with vertical geometry.



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



# Reflectometry at ESS

|                                              | FREIA                                                  | ESTIA                                        |
|----------------------------------------------|--------------------------------------------------------|----------------------------------------------|
| <b>Length</b>                                | 25 m                                                   | 58 m                                         |
| <b>Wavelength range (Å)</b>                  | 2.5 - 12 (optional up to 25)                           | 5 - 10                                       |
| <b>Uniqueness</b>                            | Capable of delivering data for 3 angles simultaneously | Small samples, low background measurements   |
| <b><math>q_{max}</math> (Å<sup>-1</sup>)</b> | 0.005 - 0.45                                           | 0.005 - 0.5, to be covered in 4 measurements |
| <b>Sample footprint</b>                      | 4 x 4 cm <sup>2</sup>                                  | 1 mm <sup>2</sup> ÷ 5 cm <sup>2</sup>        |
| <b><math>\Delta q/q</math></b>               | 4%                                                     | 5%                                           |
| <b>Performance</b>                           | Faster measurement times, higher q range               | Faster measurement times, higher q range     |

# Detector requirements for the ESS reflectometers

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

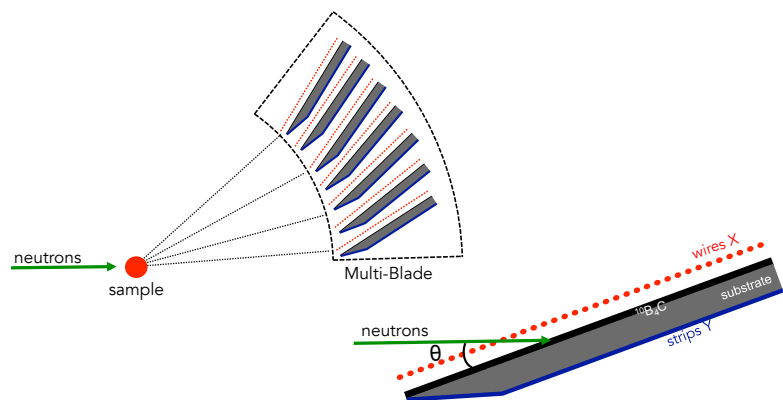


# Detectors for the ESS reflectometers

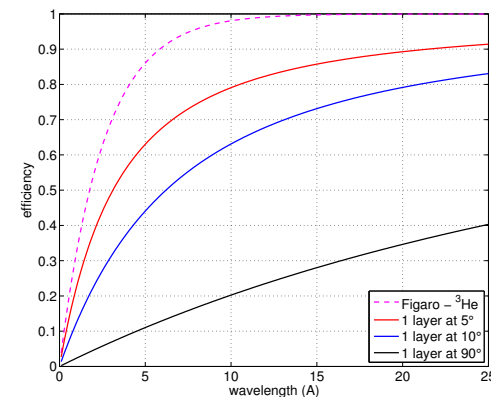
- Detector based on the MultiBlade concept preliminary tested at ILL in 2012.
- Francesco is building a second prototype in Lund.
- Work funded through the EU project BrightnESS (2015-2018).

## MultiBlade@ILL, results 2012:

- Measured Efficiency **45%** at 2.5 Å
- Spatial Resolution **280 $\mu$ m x 4mm**
- Counting rate capability  **$\sim 5$  kHz/mm<sup>2</sup>** at 2.5 Å  
(limited by the electronics)



Detector concept: achieve high-efficiency and high spatial resolution by using Boron-layers in inclined geometry.



F. Piscitelli et al., JINST 9 P03007 (2014)

F. Piscitelli, PhD Thesis, Uni. Perugia and ILL (2014) arXiv:1406.3133

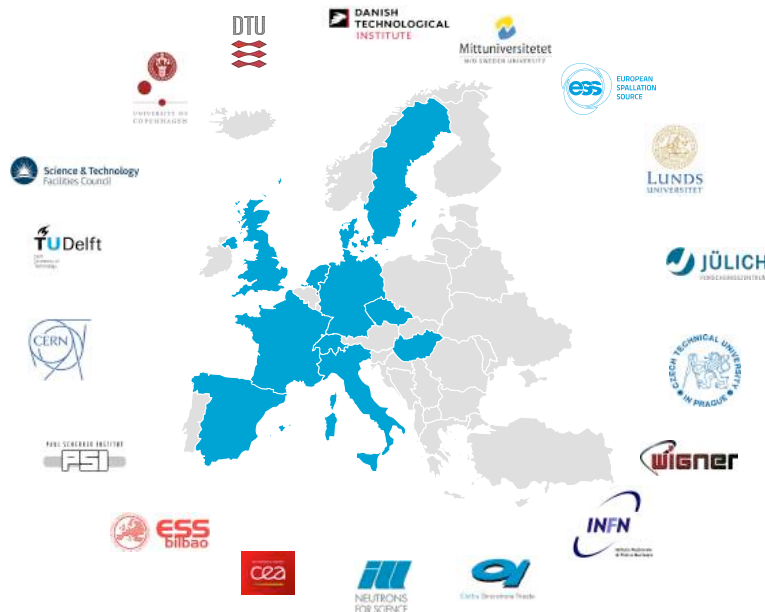


# BrightnESS

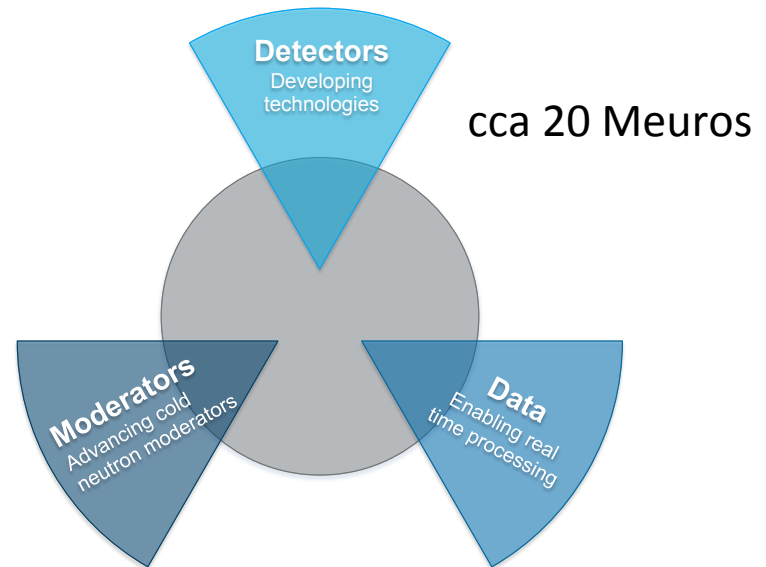


- Topic: INFRADEV-3-2015, “Individual implementation and operation of ESFRI projects”.
- 36 months (09/2015 – 09/2018), 18 Consortium Partners, ~20 Meuros.
- BrightnESS funds InKind and collaborative tasks.
- Scientific objectives: cold moderators, detectors, data handling.
- The allocated budget is shared among six Work Packages.
- WP4: “Innovation of Key Neutron Technologies: Detectors and Moderators”.

## Consortium Partners



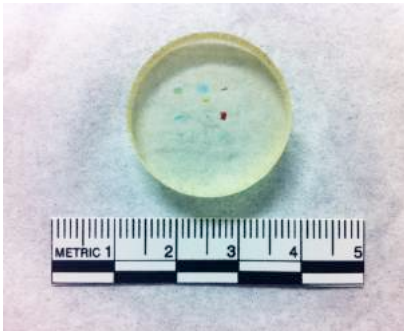
## Scientific Objectives



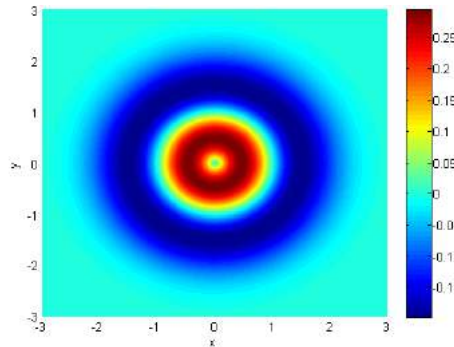


# BrightnESS

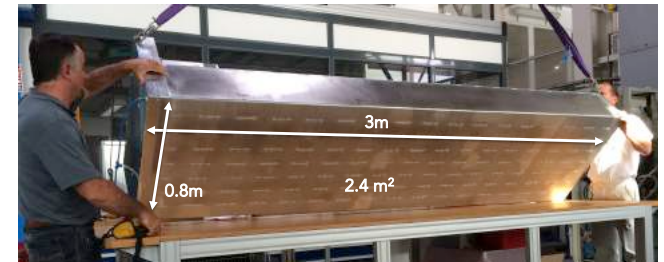
- WP4: “Innovation of Key Neutron Technologies: Detectors and Moderators”.
- ESS + 6 partners: IEAP CTU, ILL, BNC Wigner, LU, MiUN, CERN.



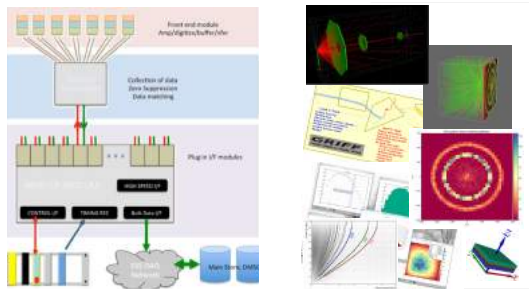
**Task 4.1: The resolution challenge**  
*macromolecular crystallography*



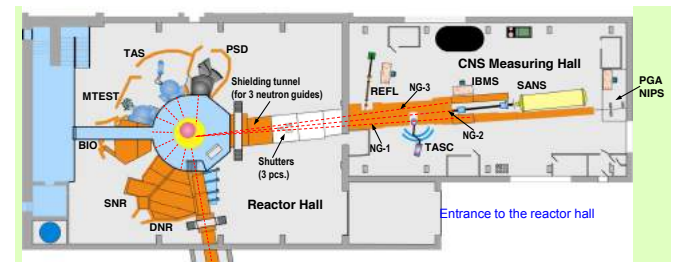
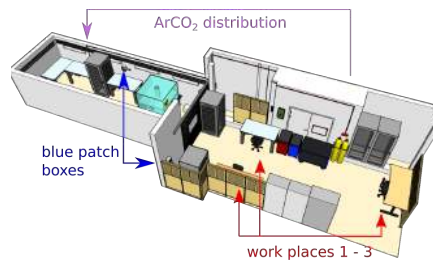
**Task 4.2: The intensity frontier**  
*reflectometry*



**Task 4.3: Large-area detectors**  
*TOF spectroscopy*



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

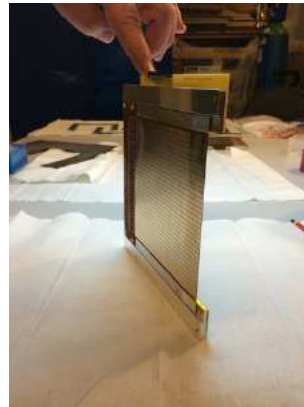
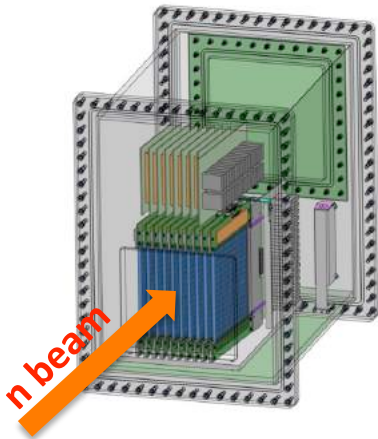


**Task 4.5: Moderator testing and development beamline (BNC)**

# Detectors for the ESS reflectometers



- Task 2: detectors for reflectometers. Funds: 2 Meuros.
- Partners involved: Wigner Research Institute and the Division of Nuclear Physics at LU.
- Detector prototype designed and assembled in Lund.



10 cm X 10 cm active area

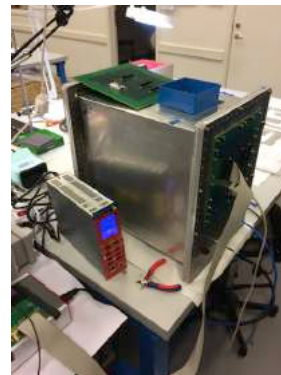
9 cassettes @  $\eta=5^\circ$

5  $\mu\text{m}$   $^{10}\text{B}_4\text{C}$  coatings

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

Wire pitch=4 mm / Strip pitch=4 mm

→ spatial resolution  $\sim \text{wire pitch} \cdot \sin(\eta) = 0.34 \text{ mm}$



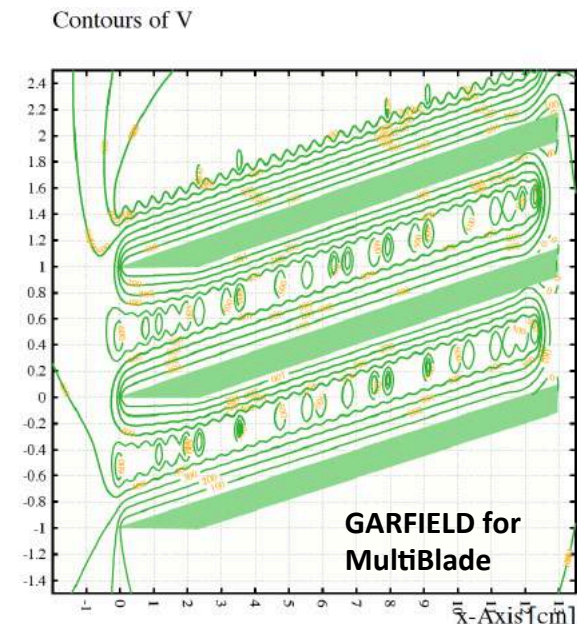
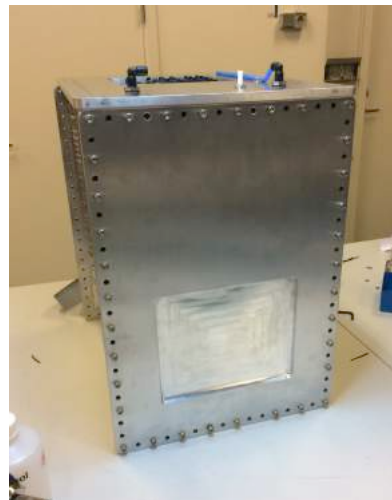
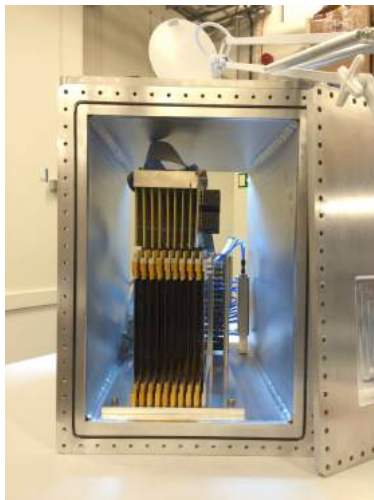
Tests at the ESS SF and BNC to characterize the prototype in terms of uniformity, efficiency, count rate capability.



# 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.



## Conclusions and perspectives

- 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.
- There is a very large gap between detector development and source advances. At ESS, all instrument classes require better detectors/new technologies. Advances are required in more than one area simultaneously (reflectometry: spatial resolution and rate capability).
- The basic detector R&D for reflectometry that started at ILL in 2011 is being now continued at ESS with EU funds.
- Unlike SINE2020/WP9, that is addressing basic R&D, BrightnESS/WP4 funds work on final detector designs, implementation and integration and activities that take developmental results and engineer them into fully functional detectors.
- Task 9.4 of SINE2020/WP9 is about exploring innovative ideas for  $^3\text{He}$ -free neutron detectors that could lead to buildable devices on the timescale of 5+ years.