Technological Innovation and BrightnESS

Work Package 4: Innovation of key neutronic technologies: Detectors, Moderators and Testbeamline

Work Package 5: Real-Time Management of ESS Data

Richard Hall-Wilton, Work Package 4 Manager & Detector Group Leader
Tobias Richter, Work Package 5 Manager & Data Management Group Leader

- The goal of BrightnESS was risk reduction for ESS
- "Detectors, Moderators and Data" were just under half of BrightnESS
- Timeline: September 2015 – August 2018

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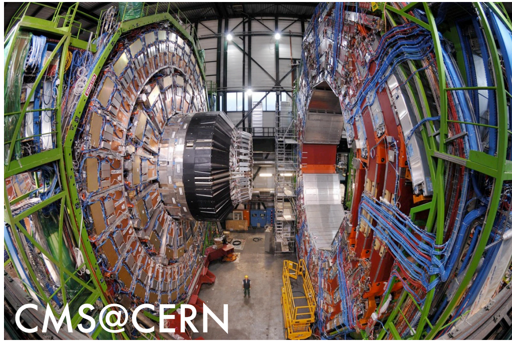
Instrumentation

EUROPEAN SPALLATION SOURCE

What camera you use has a big impact on the quality of photos that you get out of it …


GTC@La Palma


IN5@ILL


CMS@CERN

Bleeding edge Instrumentation enables novels and future science

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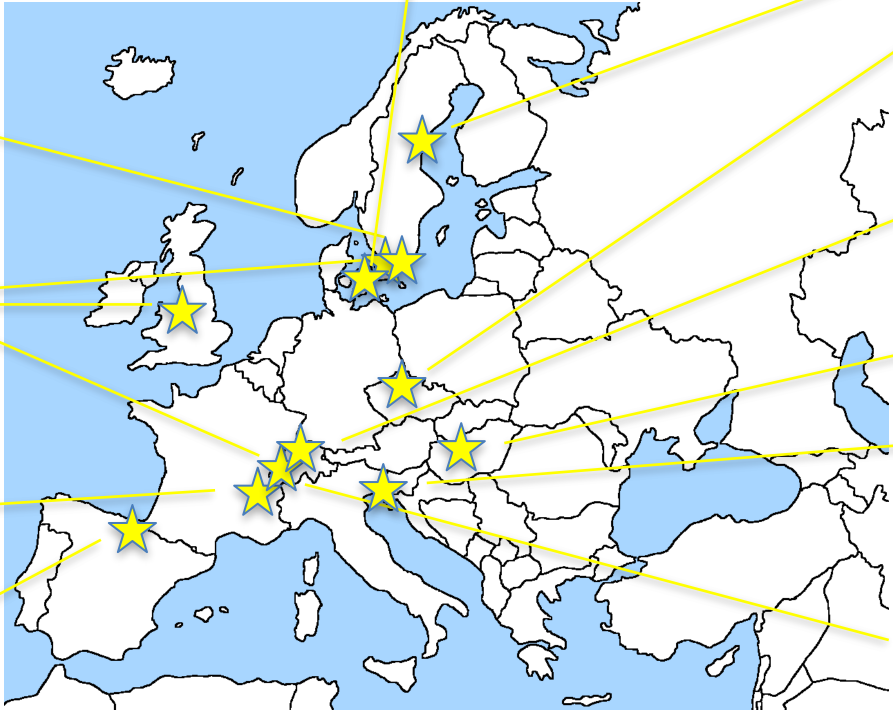
WP4 & 5 Partners

EUROPEAN SPALLATION SOURCE



Københavns Universitet (Sigillum Universitatis Hafniensis)

Mittuniversitetet – MID SWEDEN UNIVERSITY

IEAP

CZECH TECHNICAL UNIVERSITY IN PRAGUE

LUND UNIVERSITY

PAUL SCHERRER INSTITUT PSI

EUROPEAN SPALLATION SOURCE

WIGNER

ILL NEUTRONS FOR SCIENCE®

Elettra Sincrotrone Trieste

ESS bilbao

CERN

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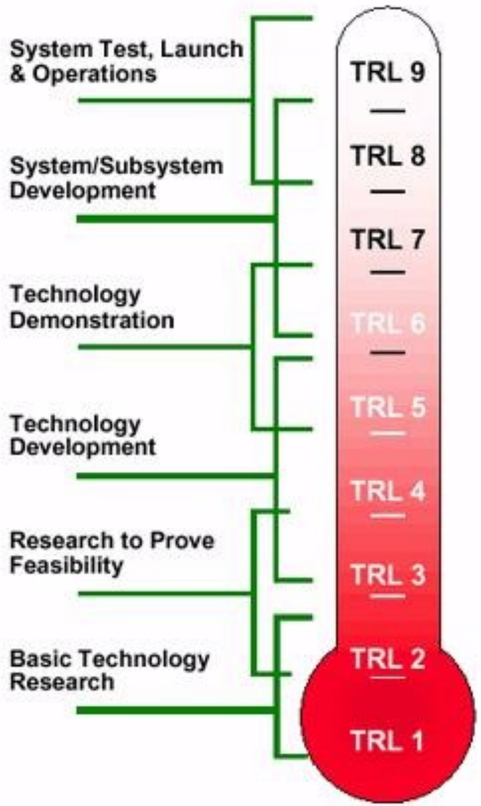
Technological Risk Reduction



- WP 4 is a technical task focussed on challenges in neutronic technologies
- It is about validating and realising these technologies, which includes data challenges (WP 5)
- It is about taking novel technologies selected for ESS from "Technological Readiness Level" 3-5 to 8-9
- Aim: helping a smooth start for ESS scientific output
- Fundamentally in-kind and collaborative tasks, relying on the expertise of partner institutes involved

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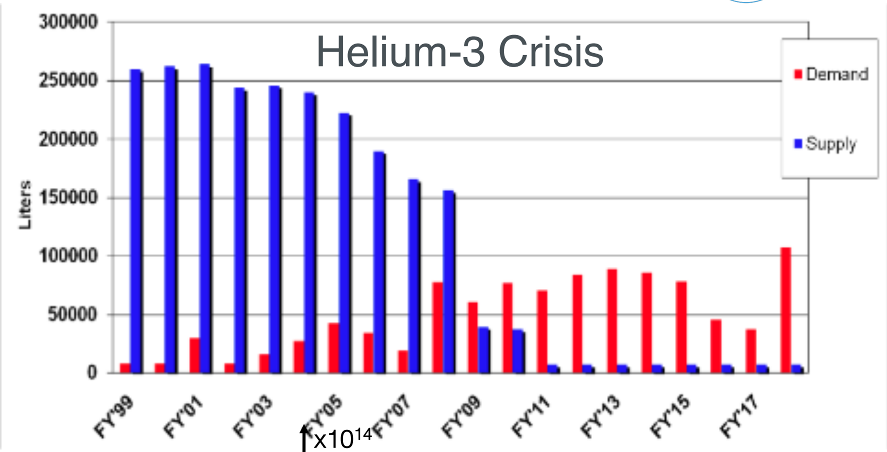
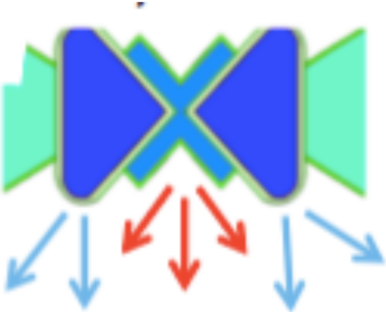
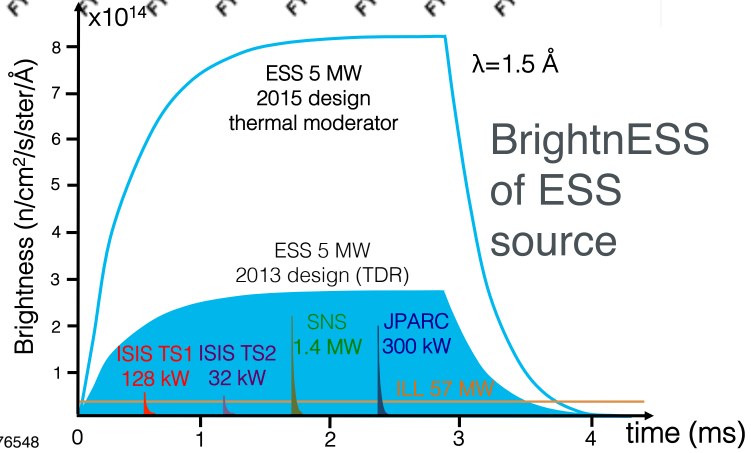
The Technical Challenge





Engineering Low Dimensional Moderators



BrightnESS of ESS source

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Requirements Challenge for Detectors for ESS: beyond detector present state-of-the art

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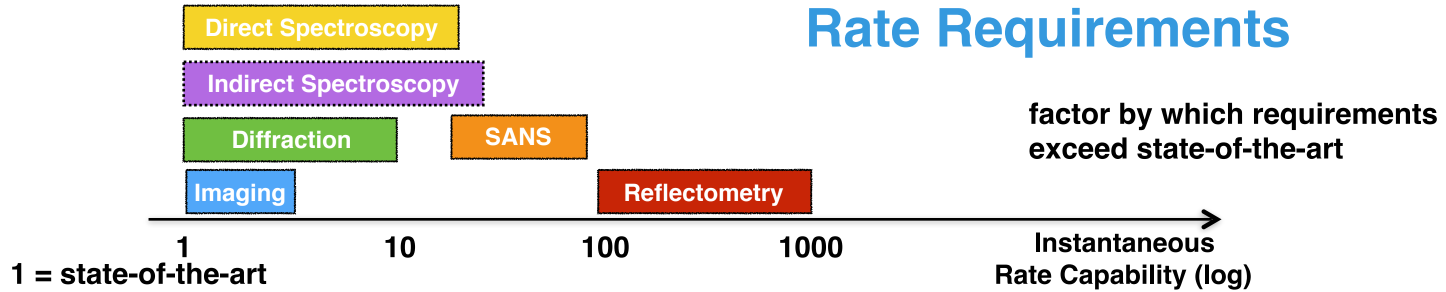
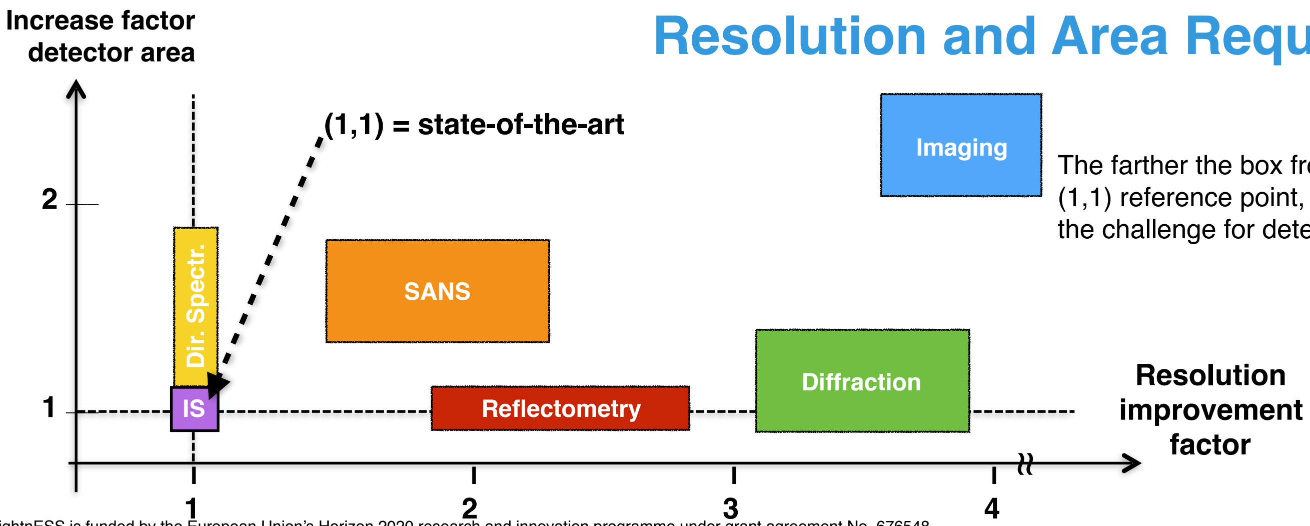
Rate Requirements



Resolution and Area Requirements



The farther the box from the (1,1) reference point, the bigger the challenge for detectors.

This is the level of aspiration that we should have every decade

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brightness Technical Challenge for Detectors

EUROPEAN SPALLATION SOURCE

Instrument Design	Implications for Detectors
Smaller samples	Better Resolution (position and time) Channel count
Higher flux, shorter experiments	Rate capability and data volume
More detailed studies	Lower background, lower S:B Larger dynamic range
Multiple methods on 1 instrument Larger solid angle coverage	Larger area coverage Lower cost of detectors

Task 4.1
"The Resolution Challenge"
Task 5.1

NMX, ODIN

Task 4.2:
"The Intensity Frontier"
Task 5.1 & 5.3

ESTIA, FREIA, Beam Monitors

Task 4.4:
"Detector Realisation"

All instruments:
Electronics, testing, simulation, quality

Task 4.3:
"Realising Large Area Detectors"

CSPEC, TREX, VOR

Developments required for detectors for ESS

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WP4 Status

- 11 (of 15) deliverables complete
- 18 (out of 20) milestones achieved
- Budget will be spent according to consortium agreement
- On track: expected to complete by 31.8.2018

Status of KPIs from WP4

KPI	Planned number (project)	Actual number (@M32) (Detectors)
Number of publications on neutronic technologies	7	23 (will be >30 by end of BrightnESS)
Number of participation in conferences related to neutronic technologies	23 (3 Data + 20 Detectors)	54
Number of developed open source software packages	6 (2 Data + 4 Detectors)	7
Number of successful simulations	6	16

The biggest impact to ESS:

Detectors are now a “normal” risk item

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Results

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Task4.2: The Intensity Frontier

The Multi-Blade project

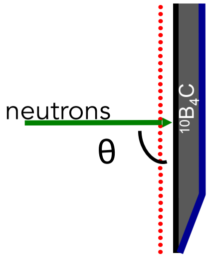
High counting rate capability

High spatial resolution

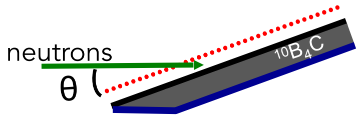
A single Boron layer inclined at 5 degrees

^{10}B-detector for reflectometers

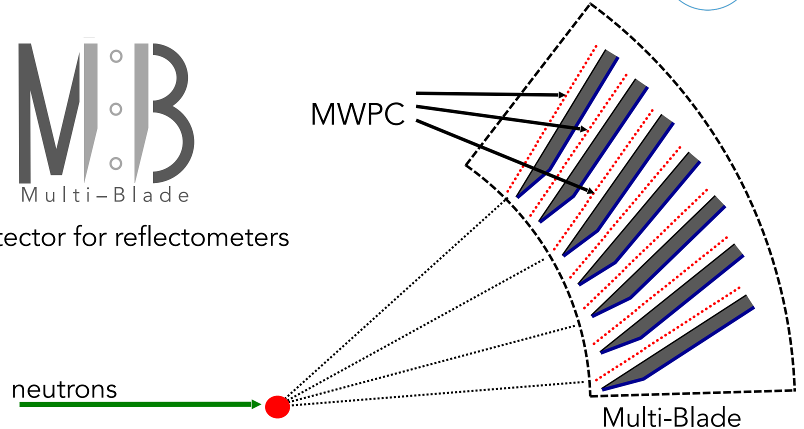
Efficiency <5% at 2.5Å   Efficiency 45% at 2.5Å

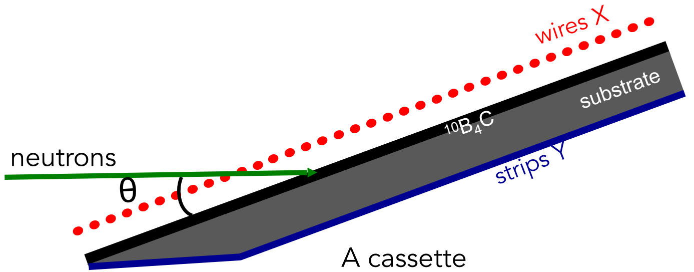


θ = 90 degrees



θ = 5 degrees





A cassette (unit)

θ = 5 degrees

F. Piscitelli et al, Journal of Instrumentation 12, P03013 (2017) - doi: 10.1088/1748-0221/12/03/P03013 , arXiv:1701.07623

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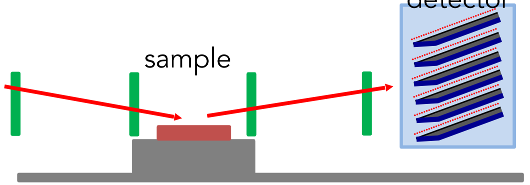
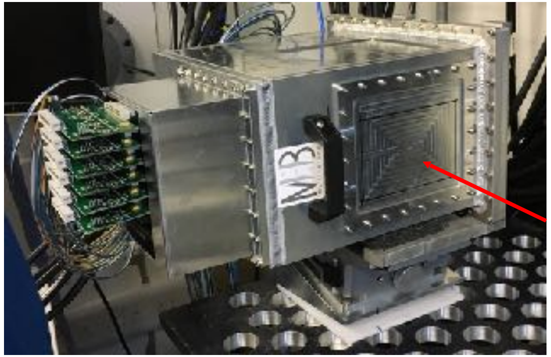
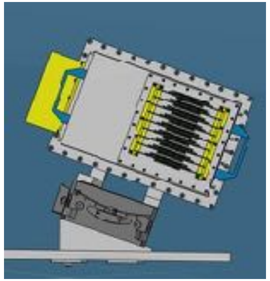
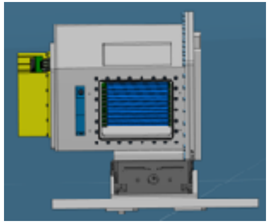
Task4.2: The Intensity Frontier

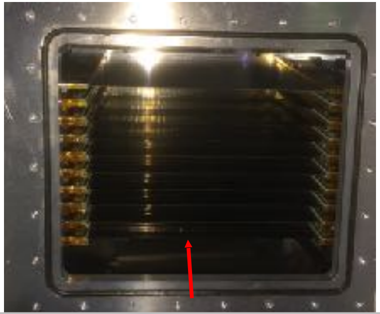
CRISP reflectometer at ISIS

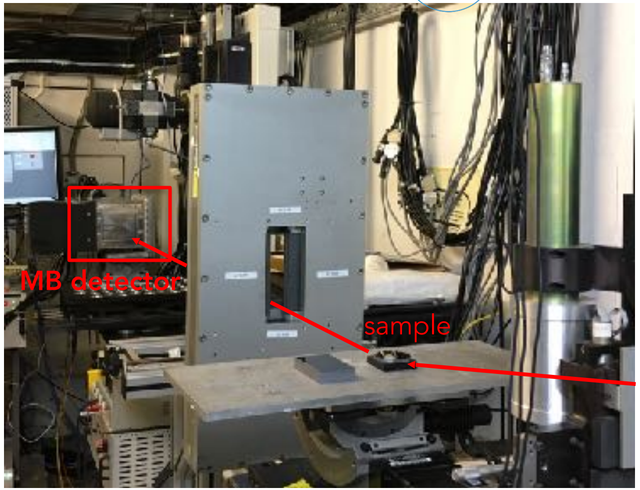


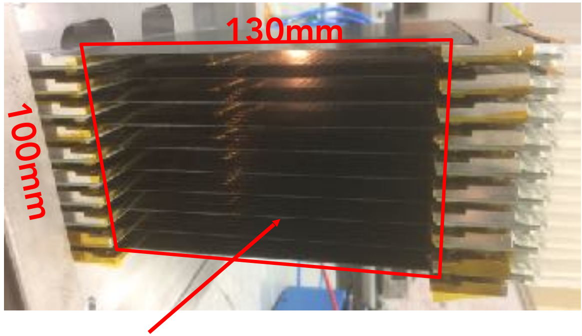












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Task4.2: The Intensity Frontier

Results

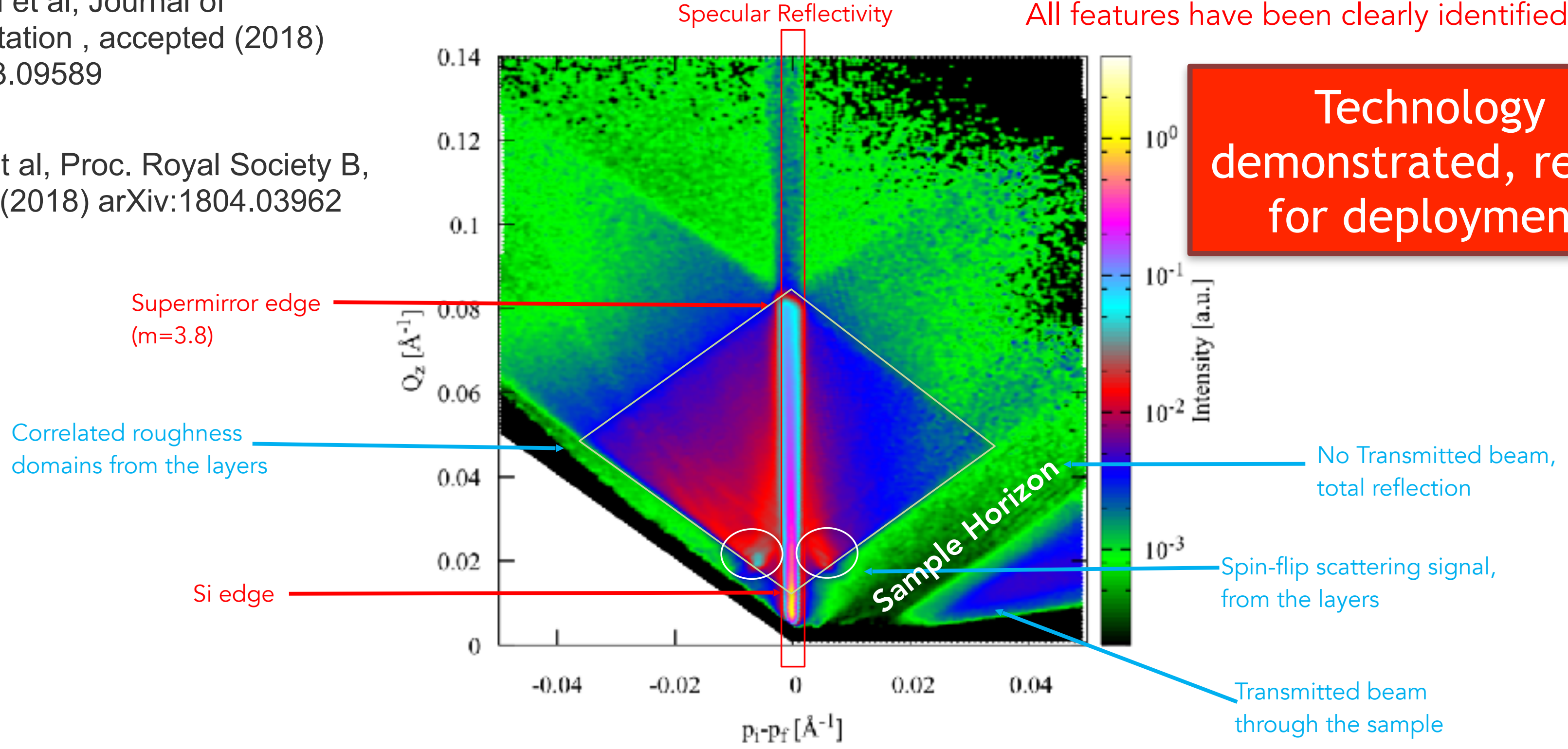
F. Piscitelli et al, Journal of Instrumentation , accepted (2018) arXiv:1803.09589

G. Mauri et al, Proc. Royal Society B, submitted (2018) arXiv:1804.03962

All features have been clearly identified

Technology demonstrated, ready for deployment

Off-specular scattering from Fe/Si supermirror



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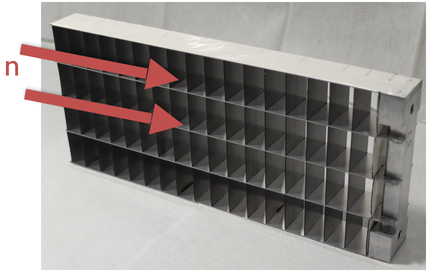
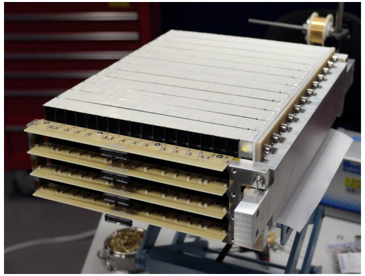
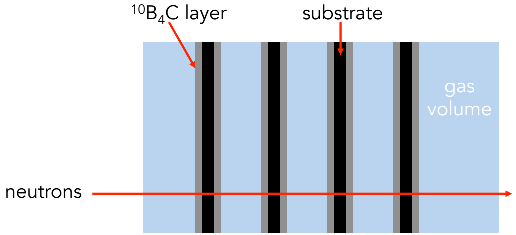
Task4.3: Realising Large Area Detectors

EUROPEAN SPALLATION SOURCE



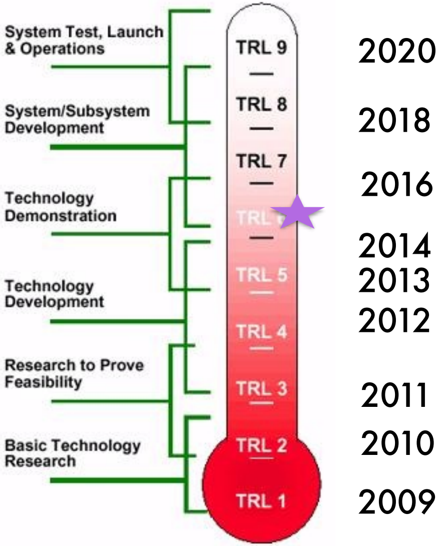




Technology Demonstrators of Scientific Performance at:
CNCS@SNS and SEQUOIA@SNS

Multi-Grid Design

Invented by ILL, co-developed ILL&ESS



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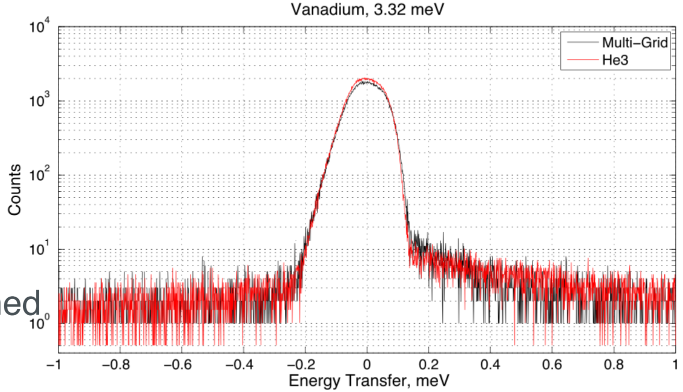
brightness Task4.3: Realising Large Area Detectors

EUROPEAN SPALLATION SOURCE

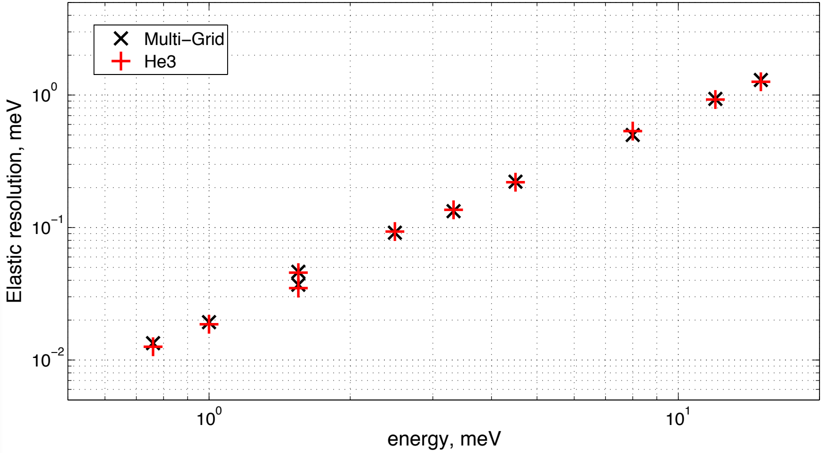
B10 Multi-Grid Detector Performance is equivalent to that of He-3 detectors

Similar test for thermally optimised detector planned for August on SEQUOIA



A.Khaplanov et al. *"Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS"* https://arxiv.org/abs/1703.03626 2017 JINST 12 P04030

Technology demonstrated, ready for deployment



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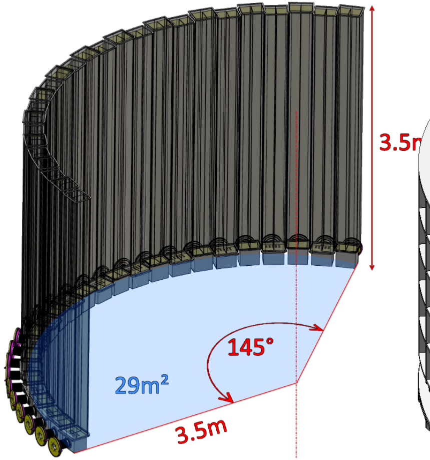
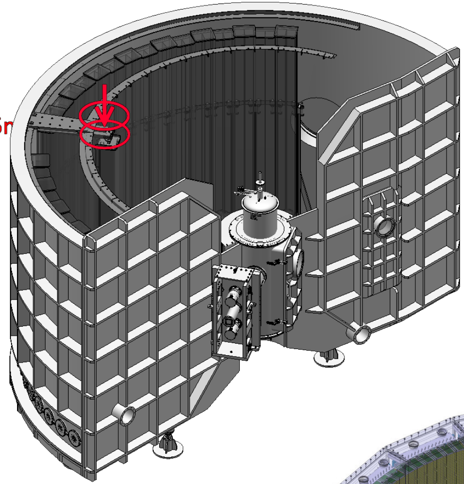
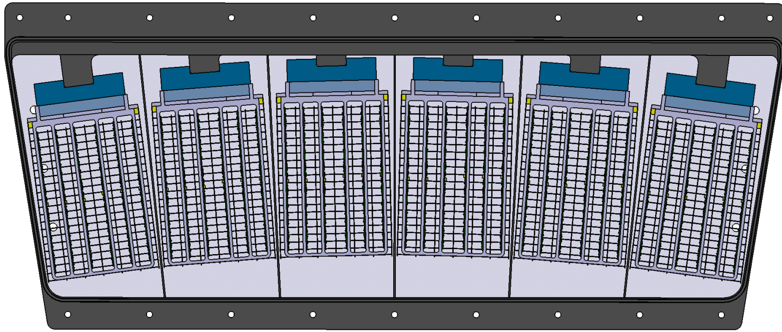
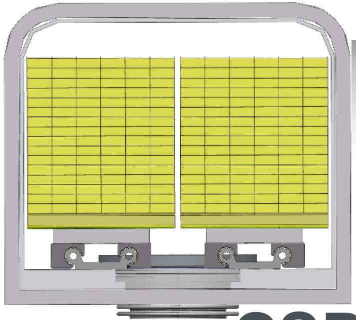
Task4.3: Realising Large Area Detectors

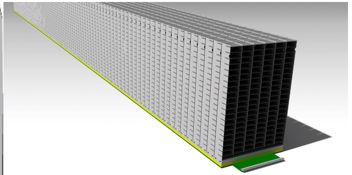
EUROPEAN SPALLATION SOURCE

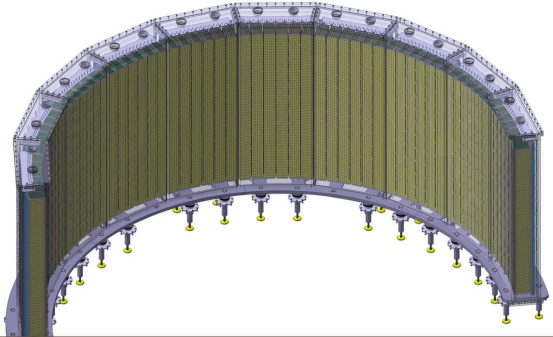


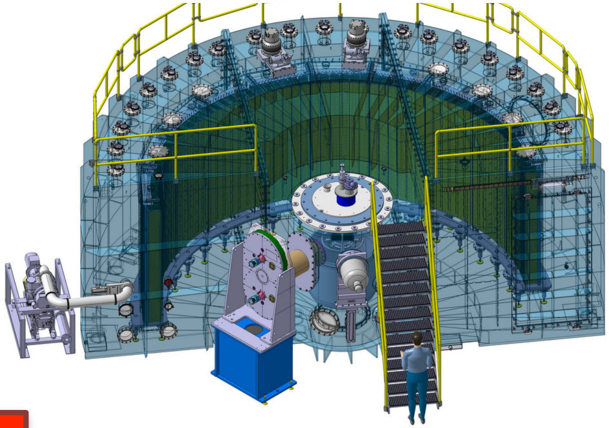












CSPEC

Detailed Engineering Design Started

TREX

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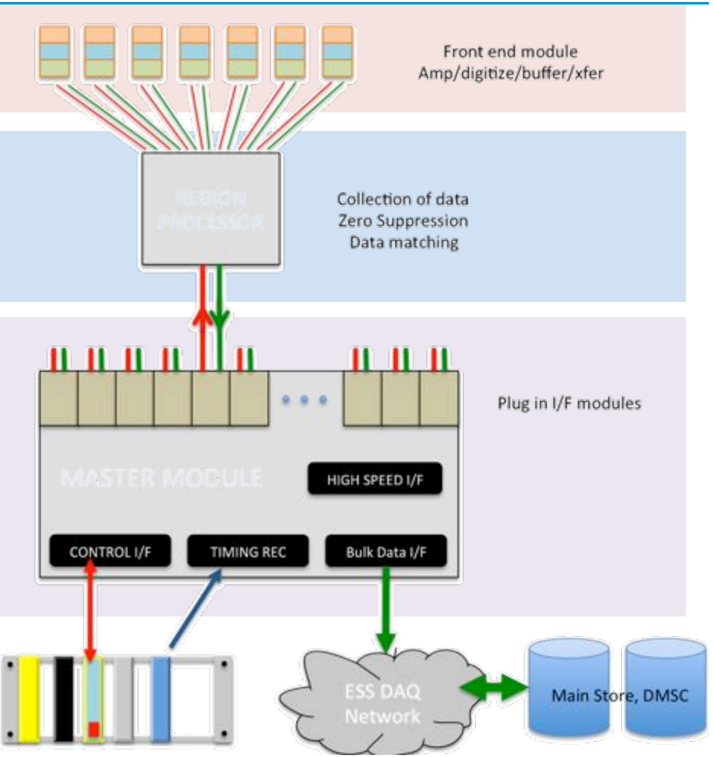
Task4.4: Detector Realisation



- An integrated plan for integrated detector readout
- For all parts of system, prototype hardware exists

- Interface between WP4 and WP5 a key interface for ESS instruments
- The sum of this interface defines the data acquisition path for neutron detector data at ESS

Interface shared, understood, manned and demonstrated

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WORK PACKAGE 5
Real time management of ESS data

Innovative Software Infrastructure

- ✓ Creating innovative software infrastructure to make the experimental data available as a live stream to which data reduction, and analysis, software can subscribe to process and visualize the data

Overview of WP5

- Ties in neatly to detector development in WP4
- Funded early prototyping of the detector data interface, helping that development
- Captures technical scope not covered by ESS TDR
- Reduces risk in the ESS construction phase through collaboration with existing facilities, offering expertise and the ability to test under real conditions
- Helps project partners and ESS in kind by kick starting a common data acquisition platform that is modern and maintainable

Task 5.1	Creating a standard neutron event data stream for different detector types	ESS, KU
Task 5.2	Creating a standard method for streaming meta-data for fast applied fields	ESS, PSI
Task 5.3	Software to aggregate and make available neutron event data and sample meta-data	ESS, PSI, Elettra

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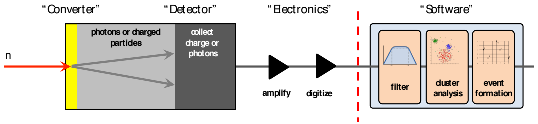
What does it do?

Task 5.1

- Convert digitized raw detector signals to **pixel ID & timestamp** per event
- Processing is highly specific for the detector type and readout chain
- Enables the neutron count rates and detector capabilities of ESS
- Reduces technical risks associated with custom hardware or FPGA code



Task 5.2

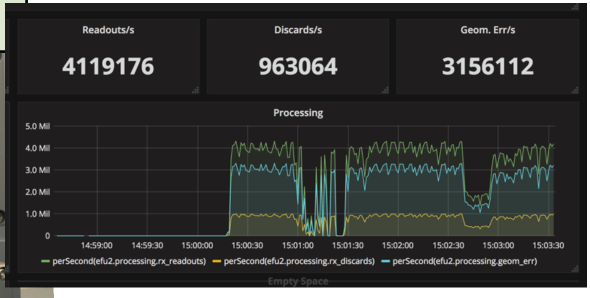
- Acquire and timestamp ADC data from "fast" sample environments equipment
- No turn key solution available with absolute timestamping and continuous operations

Max sample rate	1 M/s
Timing resolution and accuracy	10 ns
ADC resolution	12 bit or better

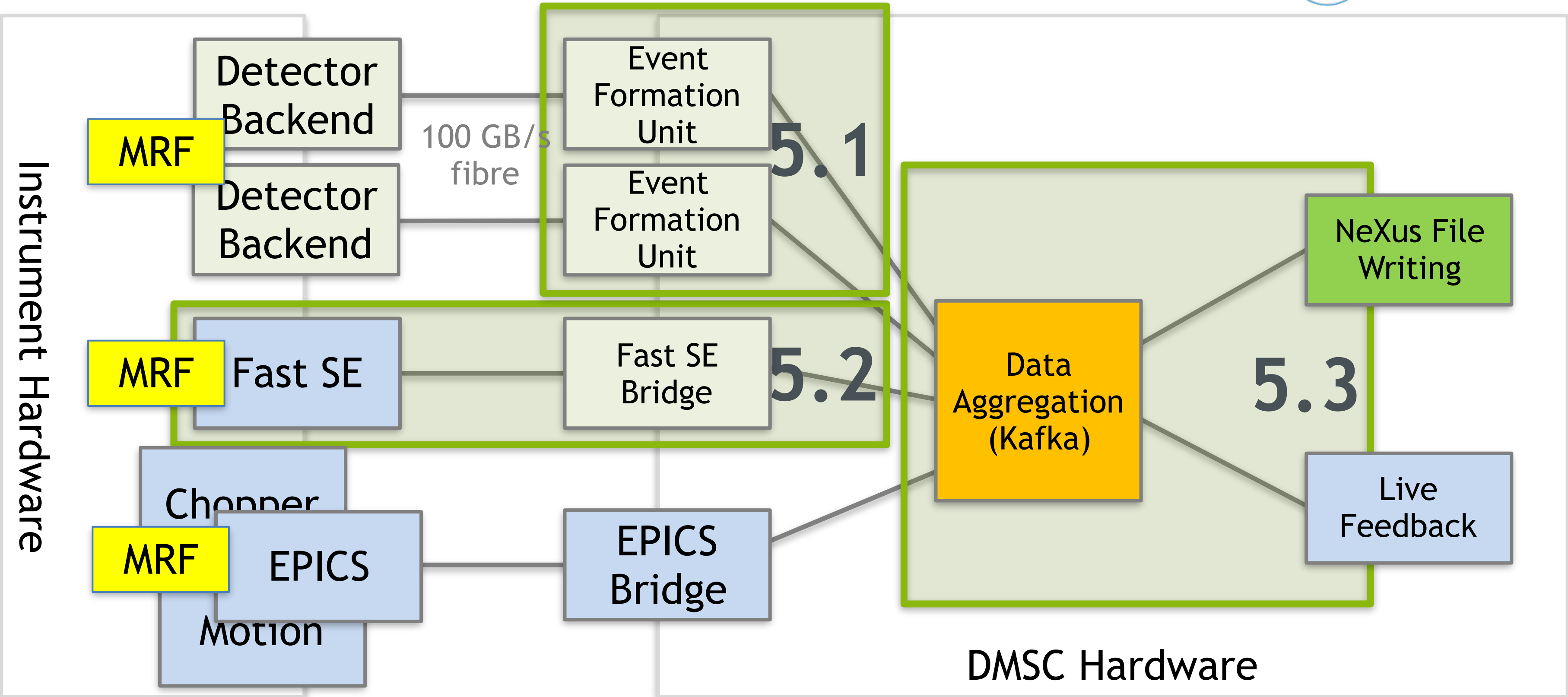
Task 5.3

- Aggregate data (neutron event information and metadata) and publish for file writing and visualization
- Integrate controls information from general EPICS devices

APACHE kafka® A distributed streaming platform



Instrument Readout Architecture



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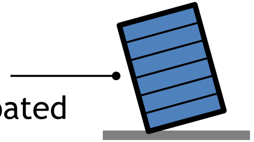
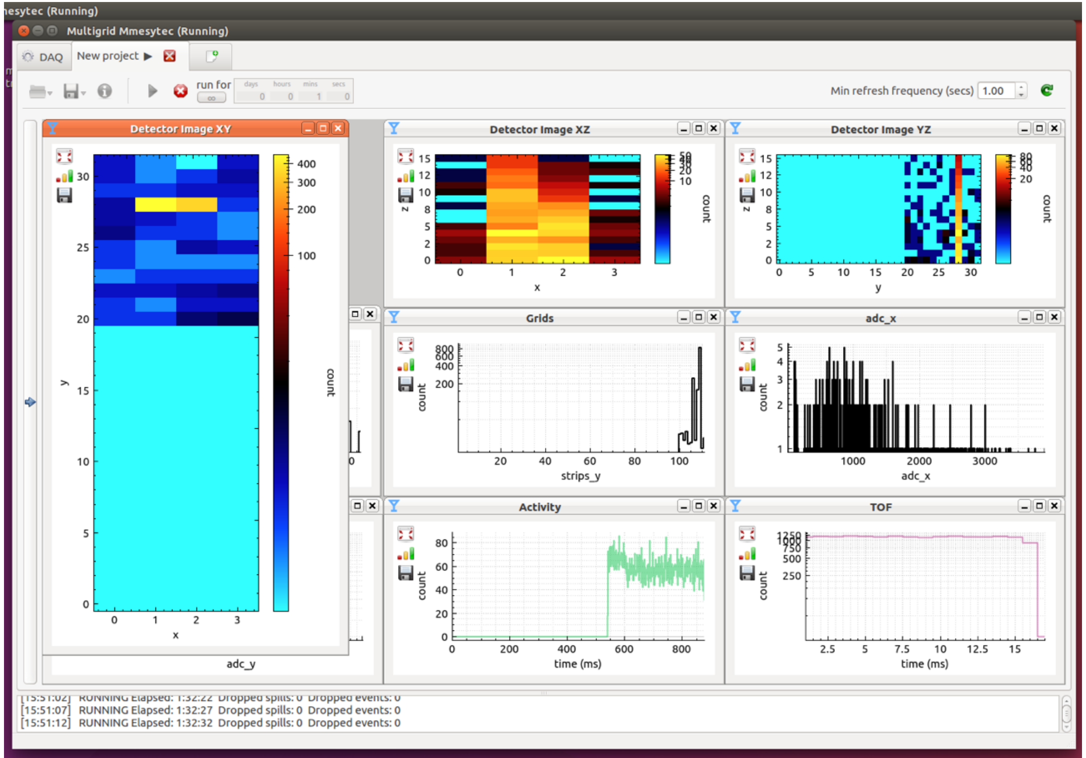
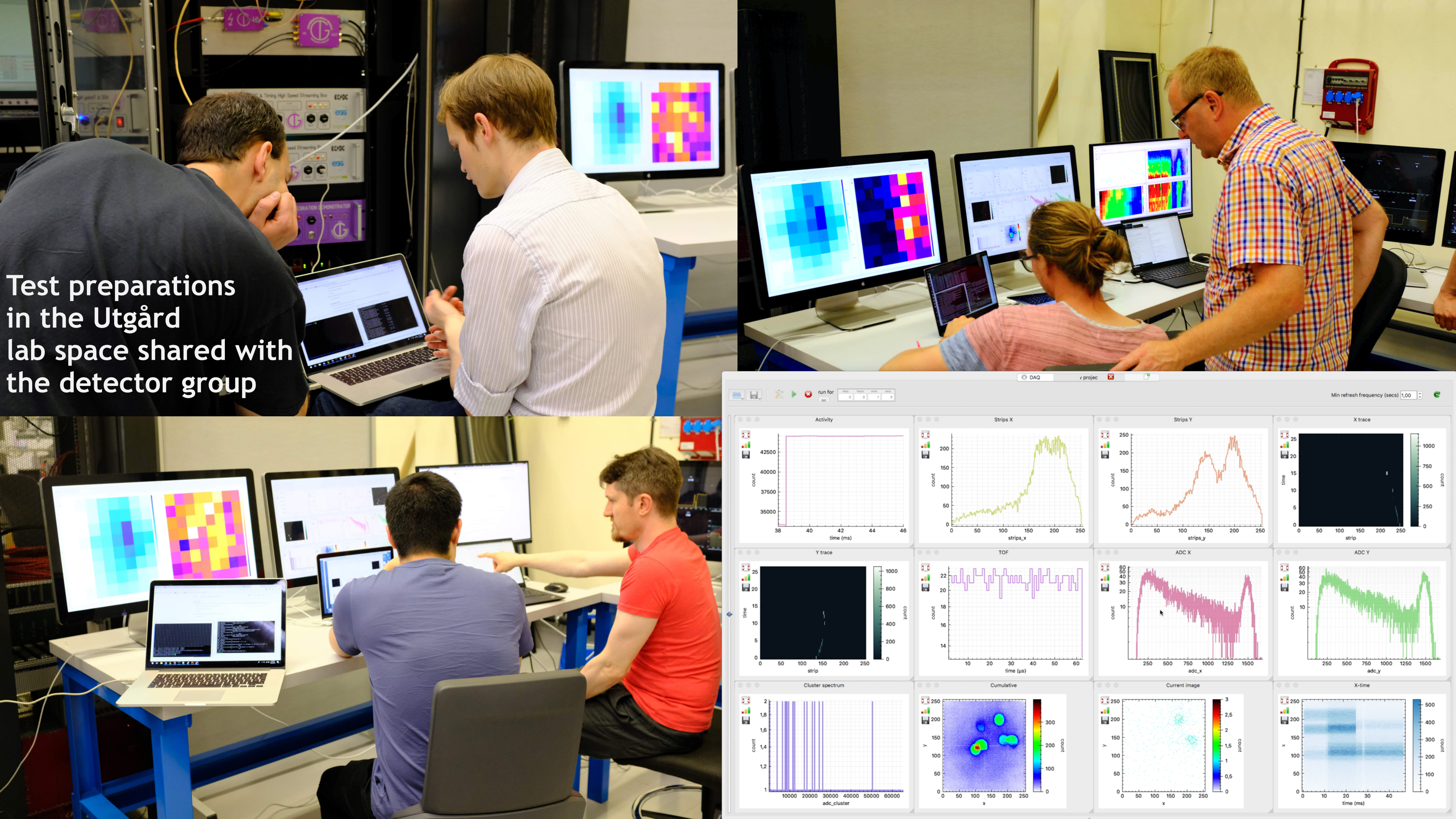
Live Event Formation

- Multi-Grid, Multi-Blade, Gd-GEM and SonDE prototypes have been tested under realistic conditions, covering the full range of processing complexity for future ESS
- Participated in a number of field tests (Lund test facility, ILL, IFE, Utgard), more are in the pipeline
  - Using prototype third-party readout electronics
  - Commissioning tool is welcome and accelerates development (DAQIRI, right)
  - EFU processing generally works
  - No unexpected problems
- Real ESS readout hardware prototypes are available now and are being integrated

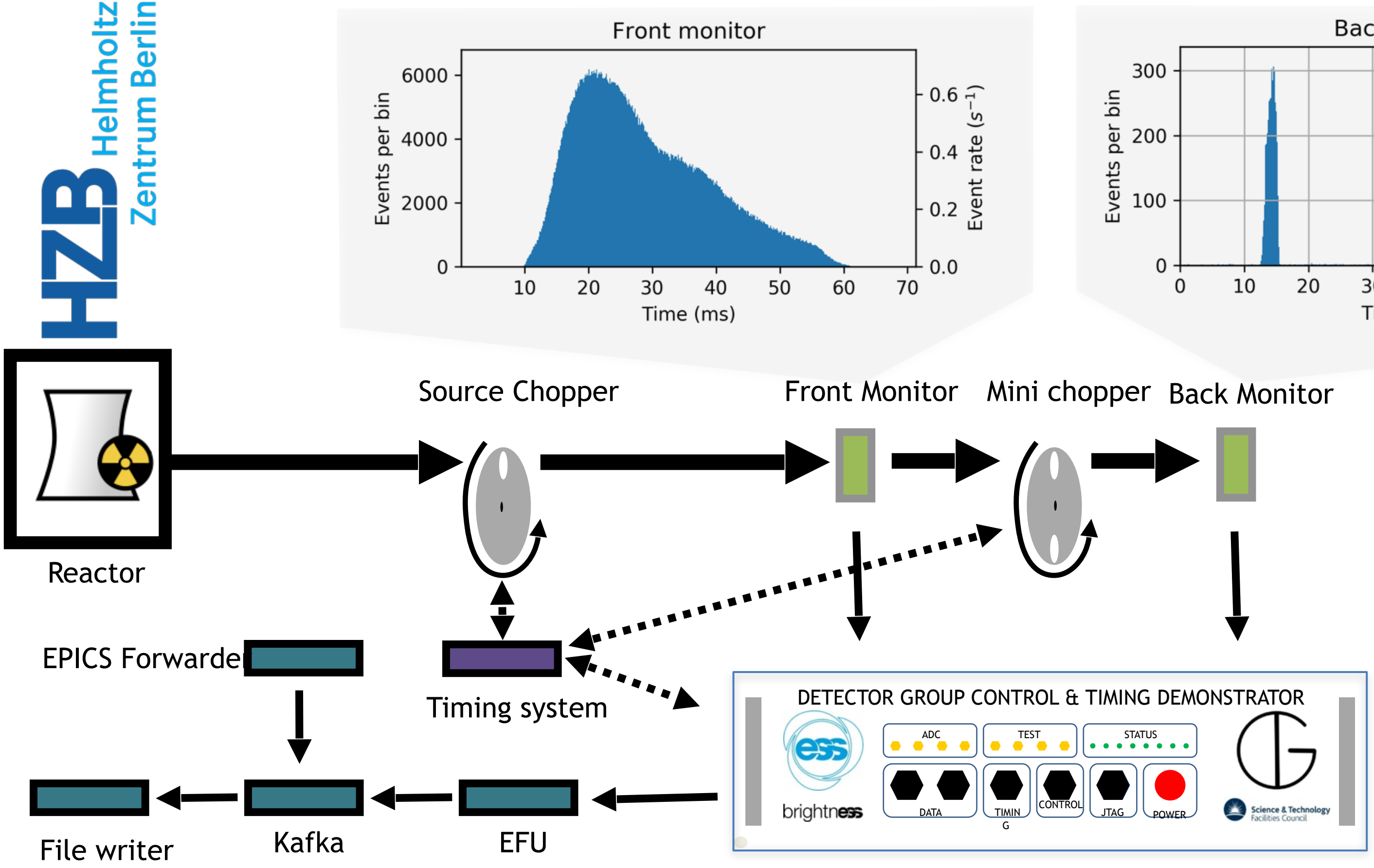
Example: Multi-Grid Detector Tilt Shadow – Blade Sides Coated

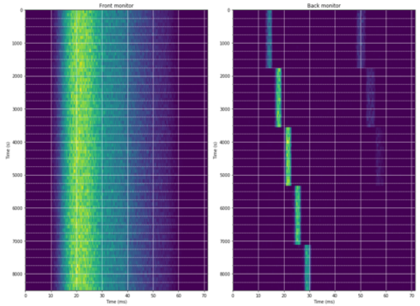





Test preparations
in the Utgård
lab space shared with
the detector group
DAQ
run for
Min refresh frequency (secs)
Activity
Strips X
Strips Y
X trace
Y trace
TOF
ADC X
ADC Y
Cluster spectrum
Cumulative
Current image
X-time

“Full” Prototype Test at HZB V20

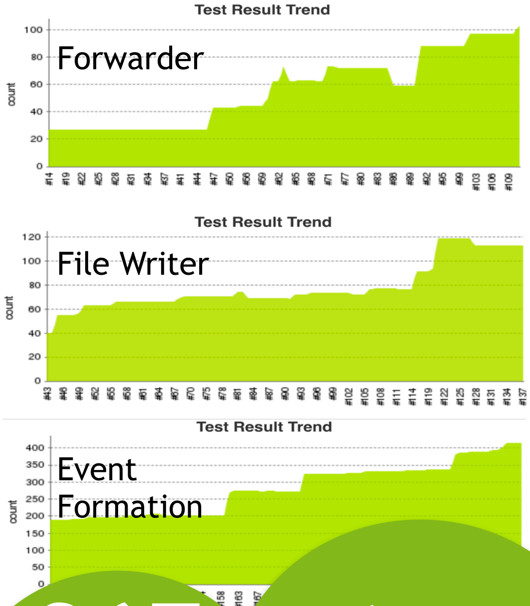




Readout from Monitors
Jan 2018

brightness Testing, Diagnostics and Scalability

EUROPEAN SPALLATION SOURCE

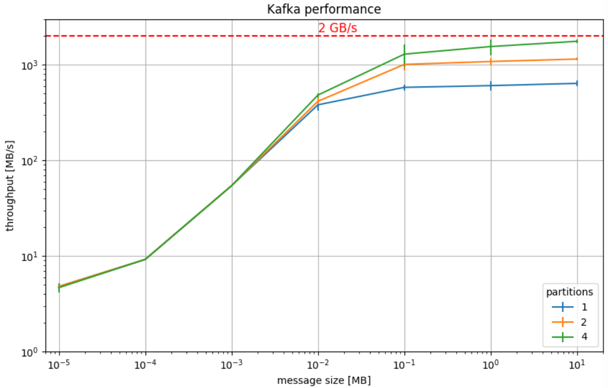


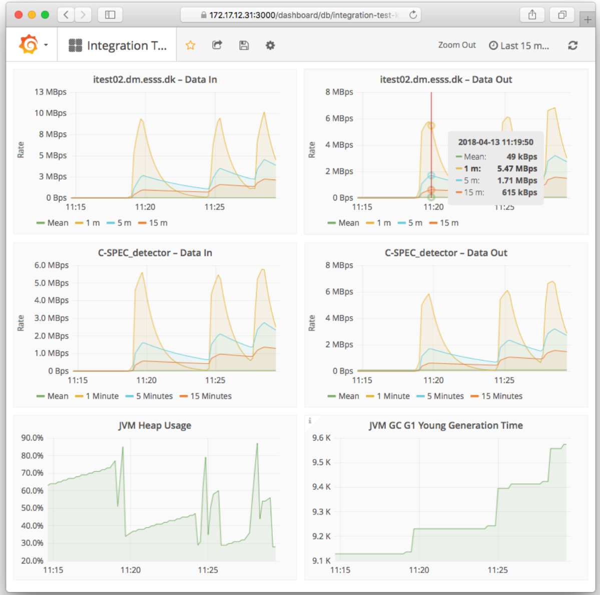
The software suite needs to be ready for operations at ESS (and other facilities). To that end there was a campaign to:

- Increase and improve test coverage
- Enhance or build in logging and diagnostics facilities
- Test and measure scalability of components

267 C++ Code Files

611 automated tests





Summary

- ✓ Technological advances in instrumentation and data handling enable new and novel future scientific capabilities. BrightnESS represents such a step forward & will have a great future impact on the scientific output of ESS.
- ✓ Risk mitigation through early integration and verification of the feasibility.
- ✓ Coordination with European neutron facilities.
- ✓ Jointly developed neutron data acquisition platform with partners: more developers to maintain the software stack long term
- ✓ Allowed scientists, engineers and technologists to develop and mature in their careers and well as allowing junior researchers to get their first experience of technological innovation

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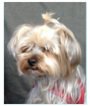
EUROPEAN SPALLATION SOURCE

Richard Hall-Wilton
Detector Group Leader
Tobias Richter
Data Management Group Leader
European Spallation Source ERIC



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In terms of ESS project risk, impact of BrightnESS is to move detectors, novel moderators, and data management from being high risk technical items into a normal level of risk

BrightnESS reduces the level of risk for the delivery of the ESS project

A big thank you to all our partners for the success!

Extra Material

BrightnESS is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 676548