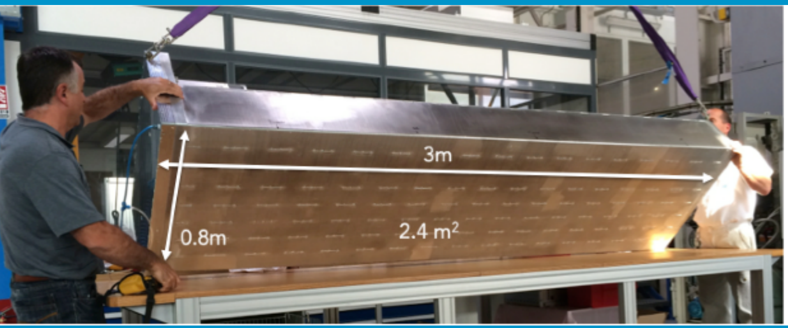
Detector Systems, Monitors and Collaboration Opportunities

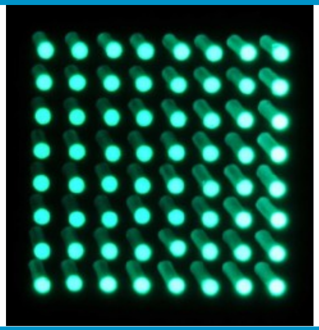
Richard Hall-Wilton

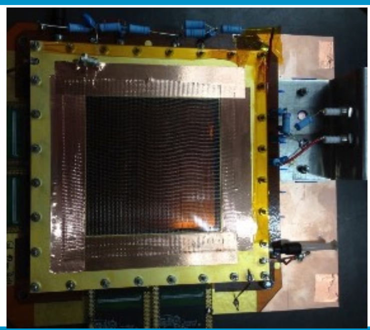
Leader of Detector Group

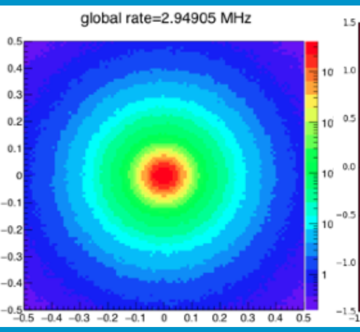
ESS-JPARC Workshop, 19th January 2018

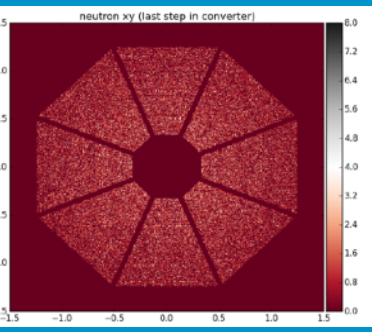
www.europeanspallationsource.se

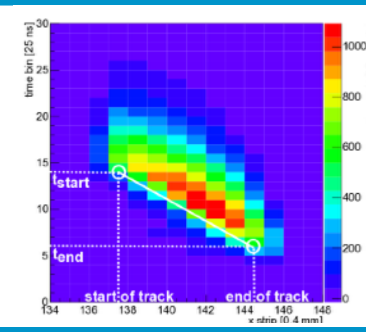


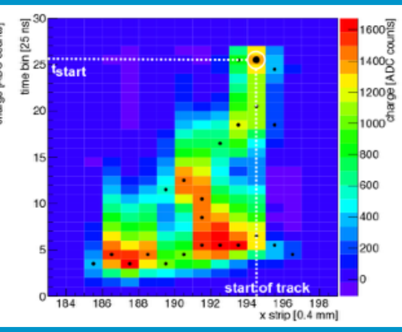


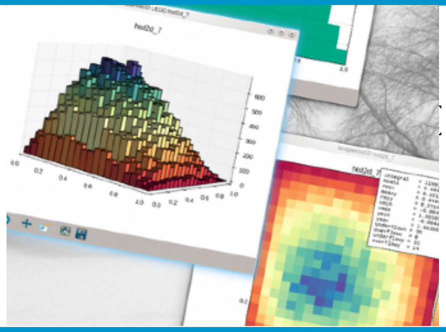


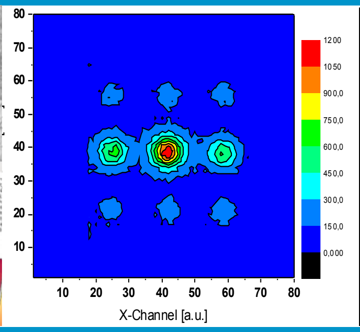


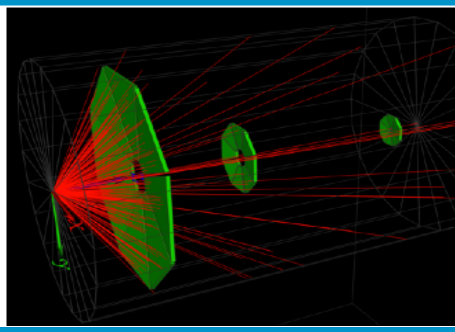












Requirements Challenge for Detectors for ESS: *beyond detector present state-of-the art*

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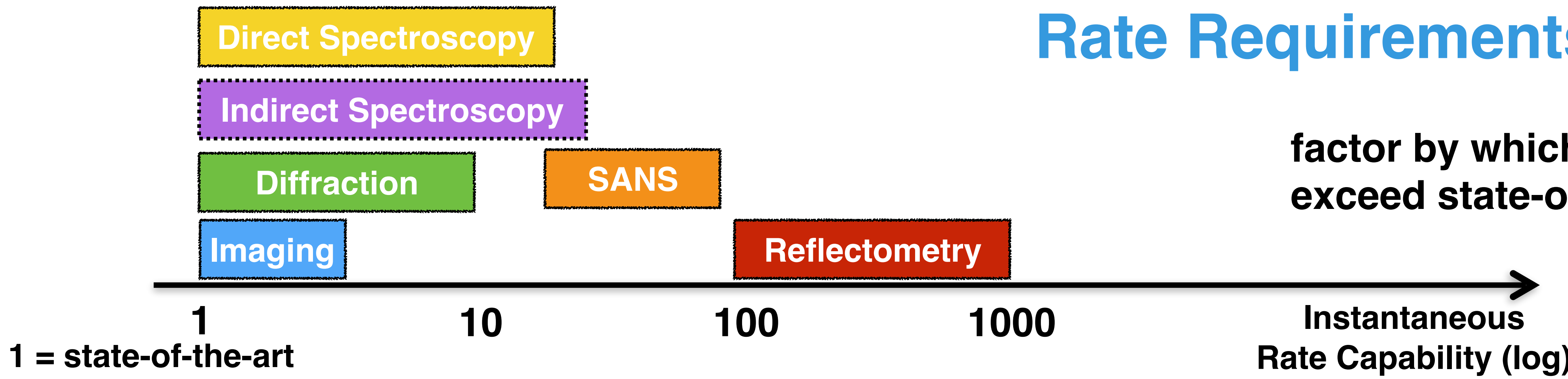
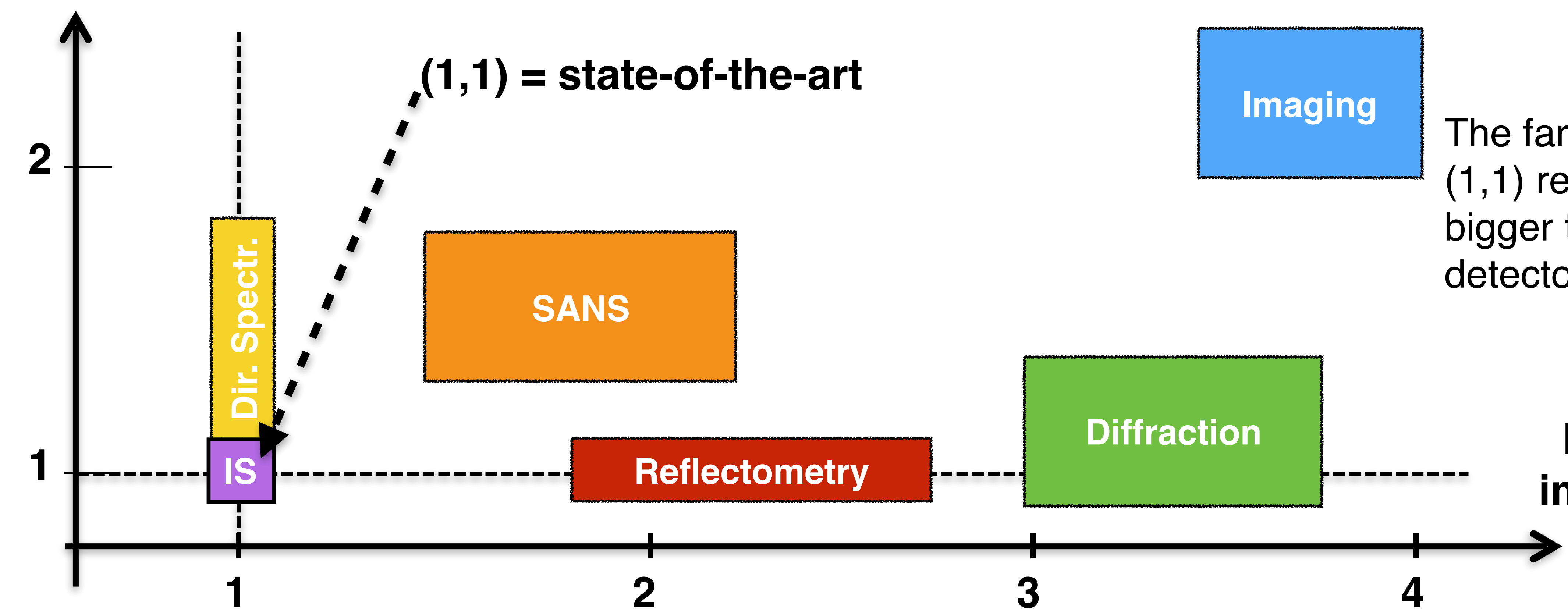
Rate Requirements



factor by which requirements exceed state-of-the-art

Resolution and Area Requirements



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

Baseline Detector Technologies for Initial Suite

Mittuniversitetet
MID SWEDEN UNIVERSITY

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Detectors for ESS will comprise many different technologies

Imaging: 1 instrument
Various

NMX: 1 instrument
Gd-GEM

Indirect Spectroscopy: 3 instruments
He-3 PSD Tubes

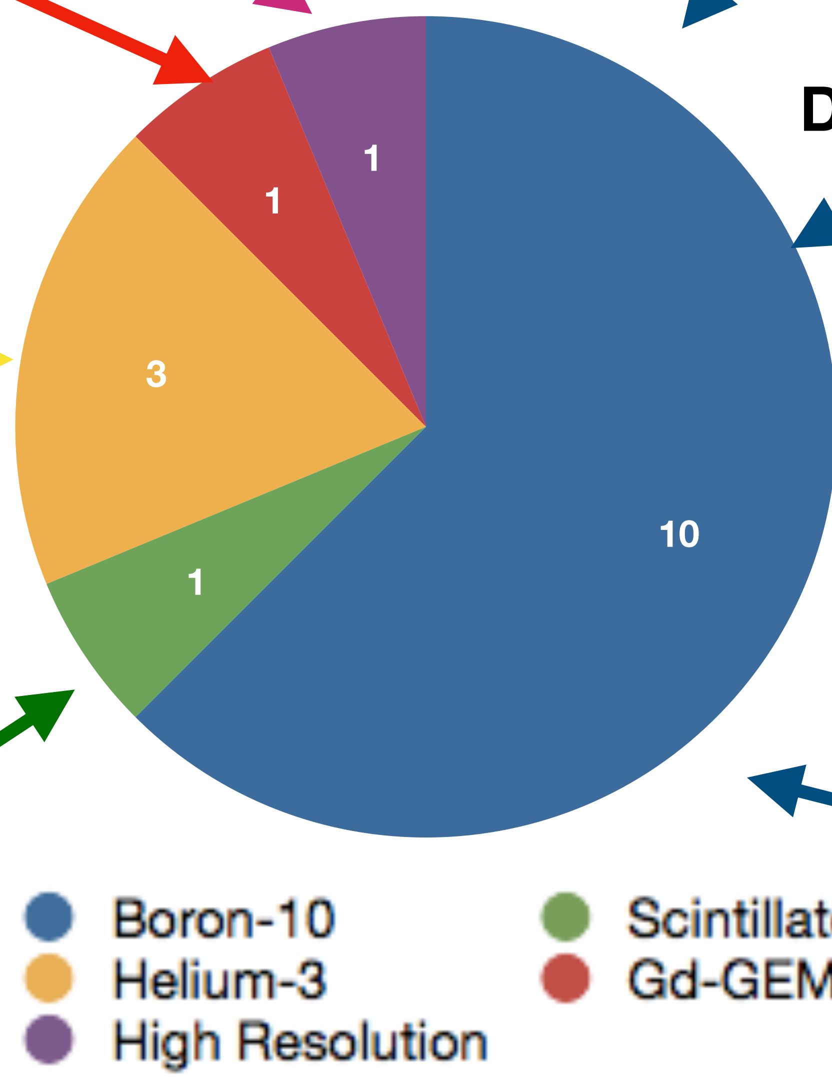
SANS: 1 instruments
SoNDe

Diffraction: 4 instruments
Jalousie (3)
Am-CLD (1): B-10 MWPC

Direct Spectroscopy: 3 instruments
Multi-Grid

Reflectometry: 2 instruments
Multi-Blade

SANS: 1 instrument
BandGEM

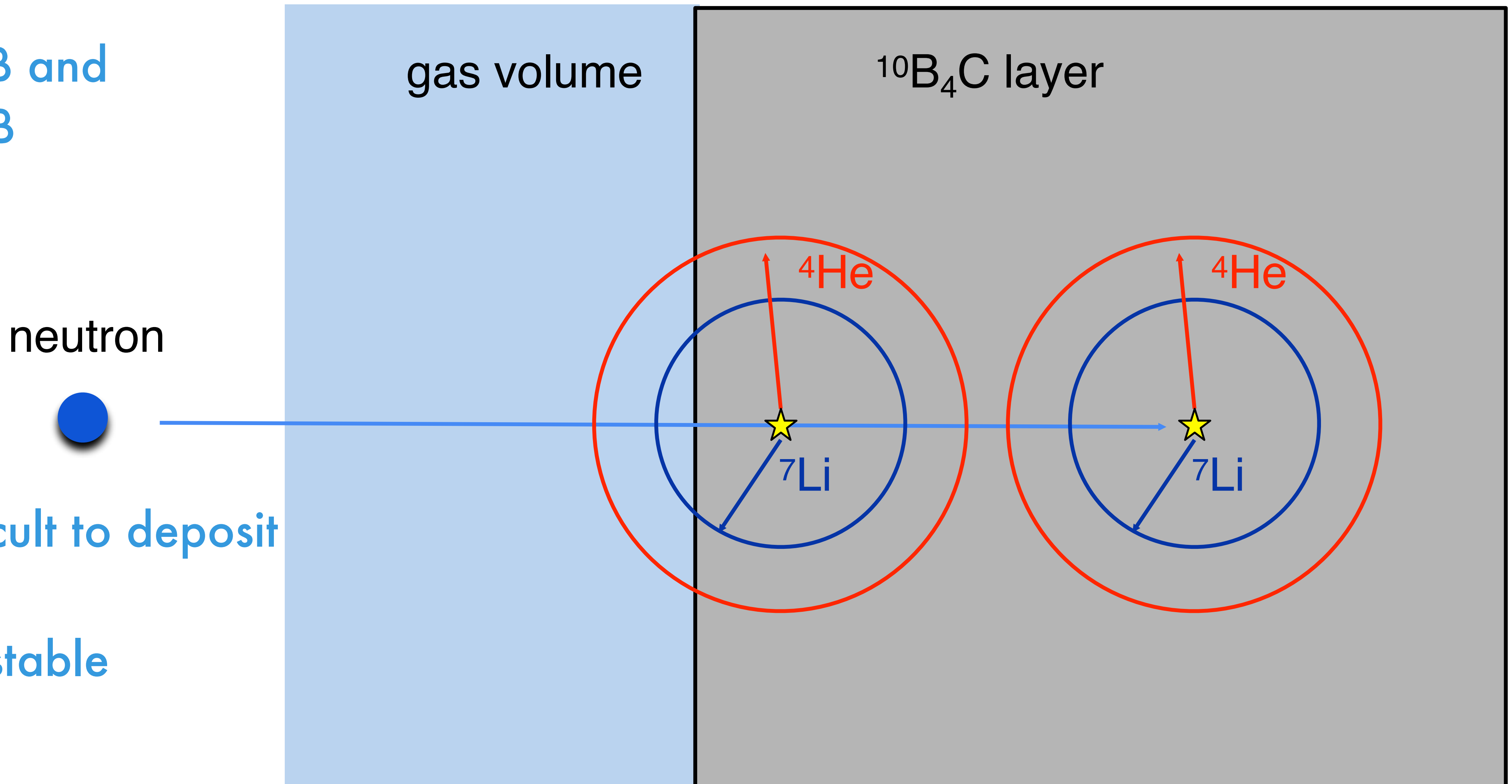


^{10}Boron-based Thin Film Gaseous Detectors

$$
\begin{aligned}
{}^{10}B + n \rightarrow {}^{7}Li^{*} + {}^{4}He \rightarrow {}^{7}Li + {}^{4}He + 0.48MeV\,\gamma\text{-ray} + 2.3\ \ MeV \quad (94\%) \\
\rightarrow {}^{7}Li + {}^{4}He \qquad\qquad\qquad\qquad + 2.79\,MeV \quad (6\%)
\end{aligned}
$$

Efficiency limited at ~5% (2.5Å) for a single layer

- ^{nat}B contains
  80 at.% ^{11}B and
  20 at.% ^{10}B

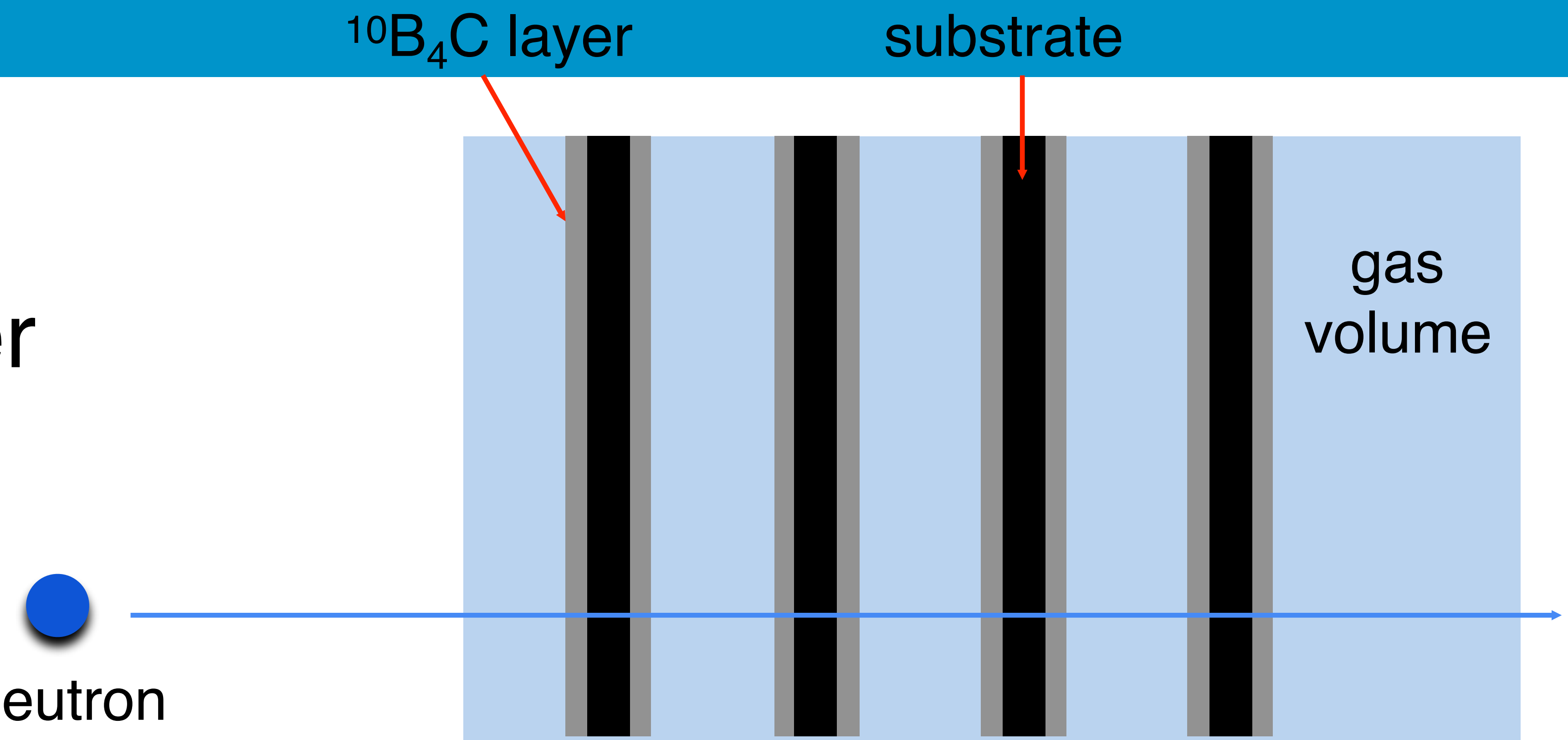


- Boron is difficult to deposit
- Use $^{10}B_4C$
- Conductive, stable

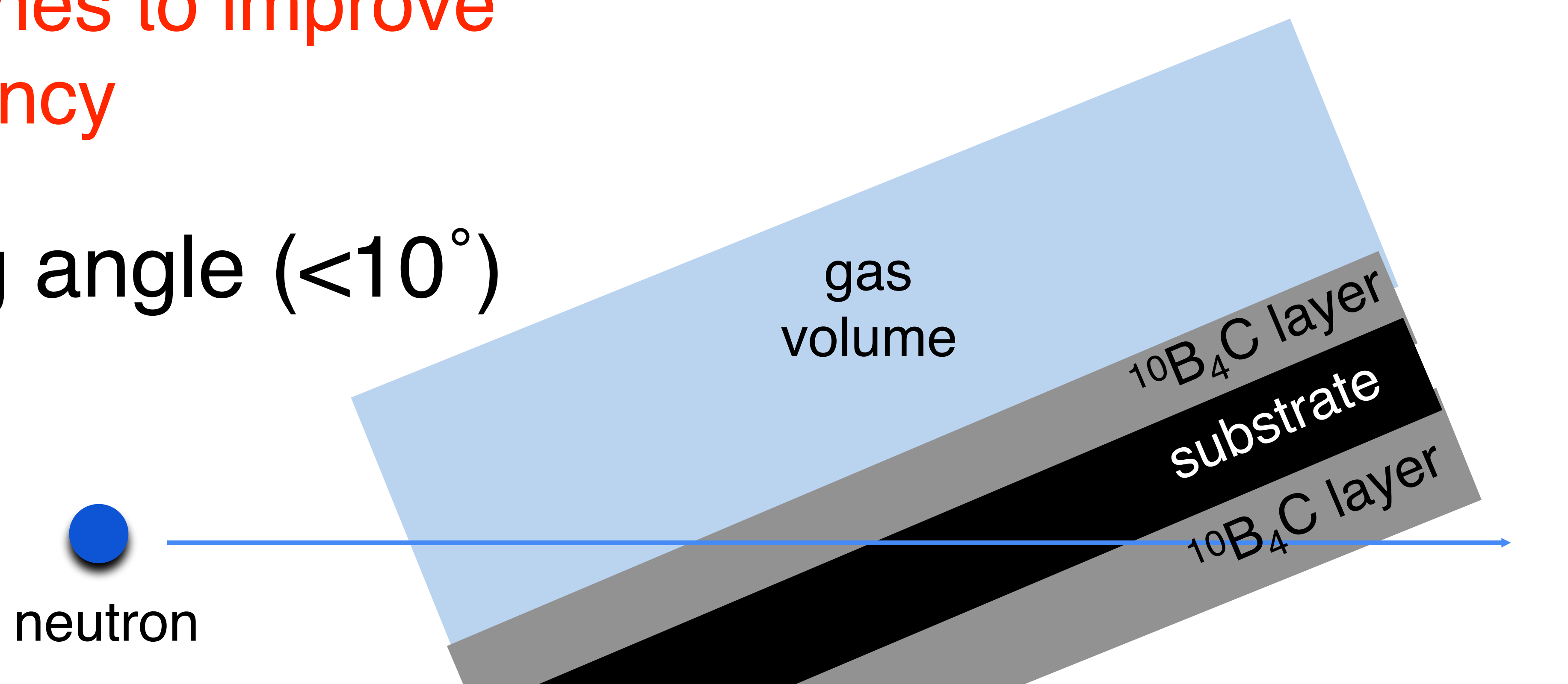
Enhancing the efficiency of ^{10}B-based Neutron Detectors

Generic approaches to improve efficiency

1 Multi layer



2 Grazing angle (<10˚)



Demonstrator Test at SNS on CNCS

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ILL:
Bruno Guerard, Jean-Claude Buffet, Jean-Francois Clergeau, Anthony Leandri

ESS:
Anton Khaplanov, Fatima Issa, Richard Hall-Wilton, Oliver Kirstein, Tomasz Brys, Michail Anastasopoulos, Isaak Lopez Higuera, Richard Bebb, Sara Arranz, Carina Höglund*, Linda Robinson*, Susan Schmidt*

Centre for Energy Research (Hungary):
Eszter Dian

Linköping University:
Jens Birch, Lars Hultman, (also *)

SNS:
Ken Herwig, Georg Ehlers, Michelle Everett, Kevin Berry

Earlier – the participants of the CRISP project on Large-Area detectors.

brightness

Horizon 2020 grant agreement 676548

WP 4.3: Large-Area Detectors

Previous publications:

B4C layers:

*C. Höglund et al, J of Appl. Phys. 111, 104908 (2012)

Characterization:

*A. Khaplanov et al., arXiv:1209.0566 (2012)

*B Guerard et al., NIMA, 720, 116-121 (2013), http://dx.doi.org/10.1016/j.nima.2012.12.021iJ

*J. Correa et al., Trans. Nucl. Sc. (2013), DOI: 10.1109/TNS.2012.2227798

*A. Khaplanov et al., (2014) *J. Phys.: Conf. Ser.* **528** 012040 doi:10.1088/1742-6596/528/1/012040

Gamma sensitivity:

*A. Khaplanov et al., JINST 8, P10025 (2013), arXiv:1306.6247

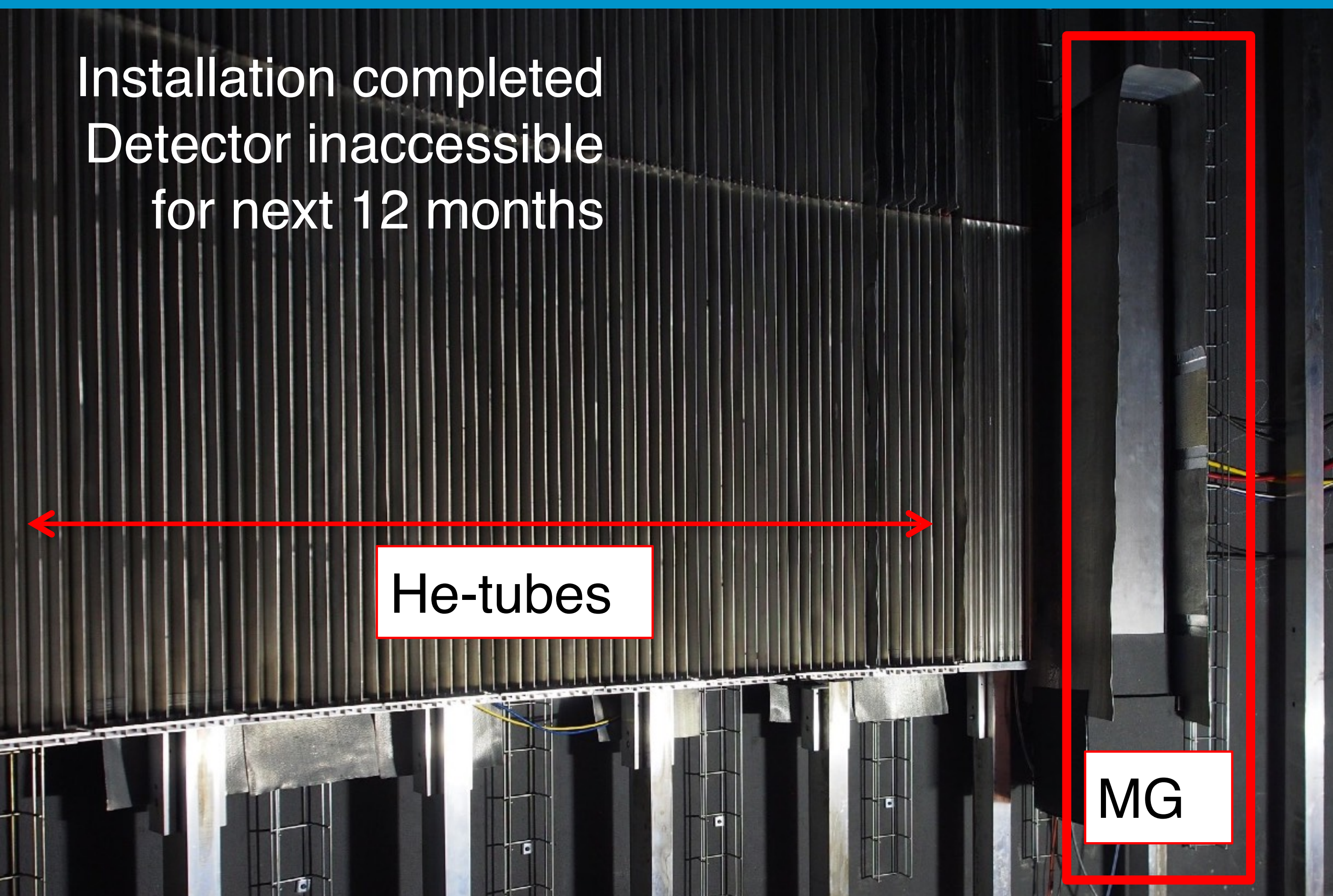
Alpha background:

*A. Khaplanov et al., JINST 10, P10019 (2015); doi:10.1088/1748-0221/10/10/P10019

Current work:

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

Multi-Grid test at CNCS



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

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

- Test side-by-side with existing technology in world leading instrument
- Realistic conditions. Long term test.
- "Science" or application performance
- 2 different technologies on the same instrument

Construction of MG.CNCS in Lund

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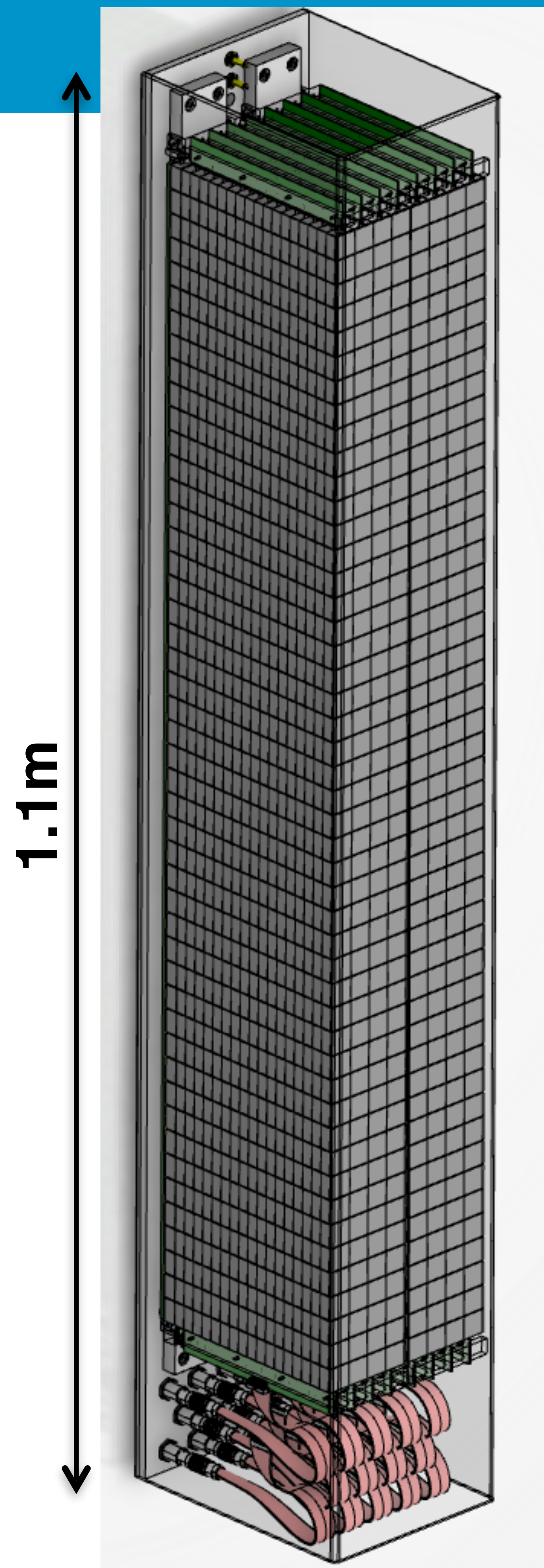
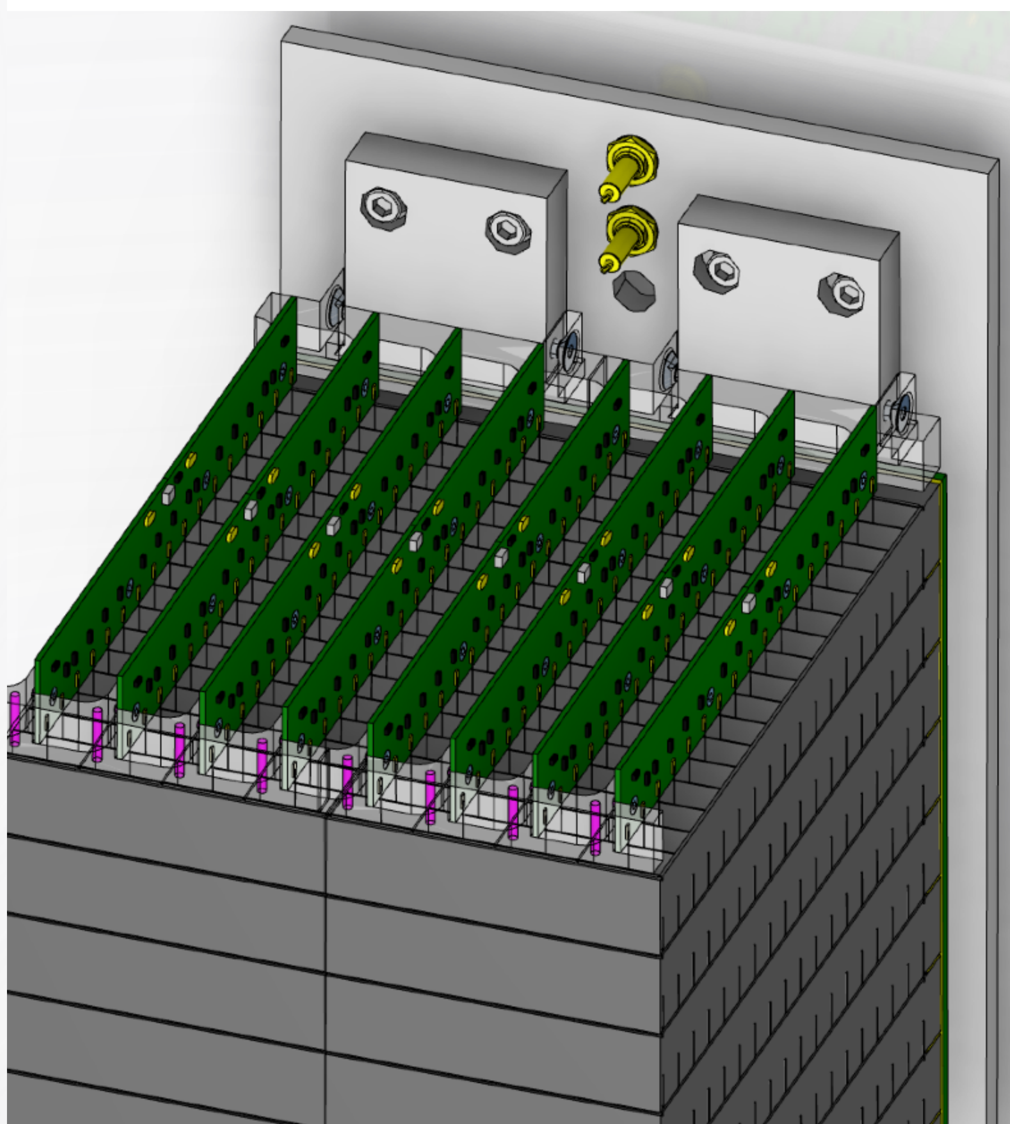
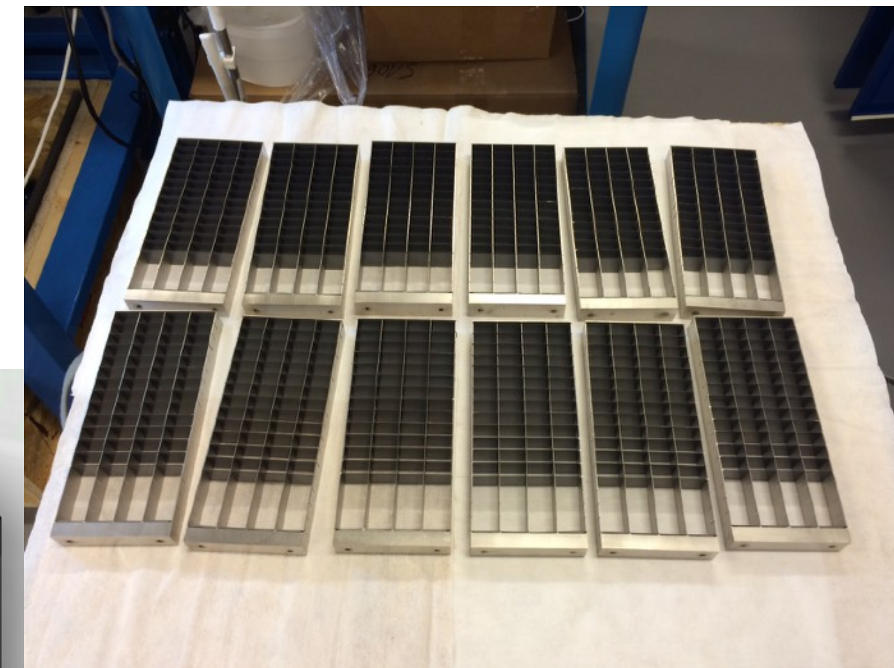
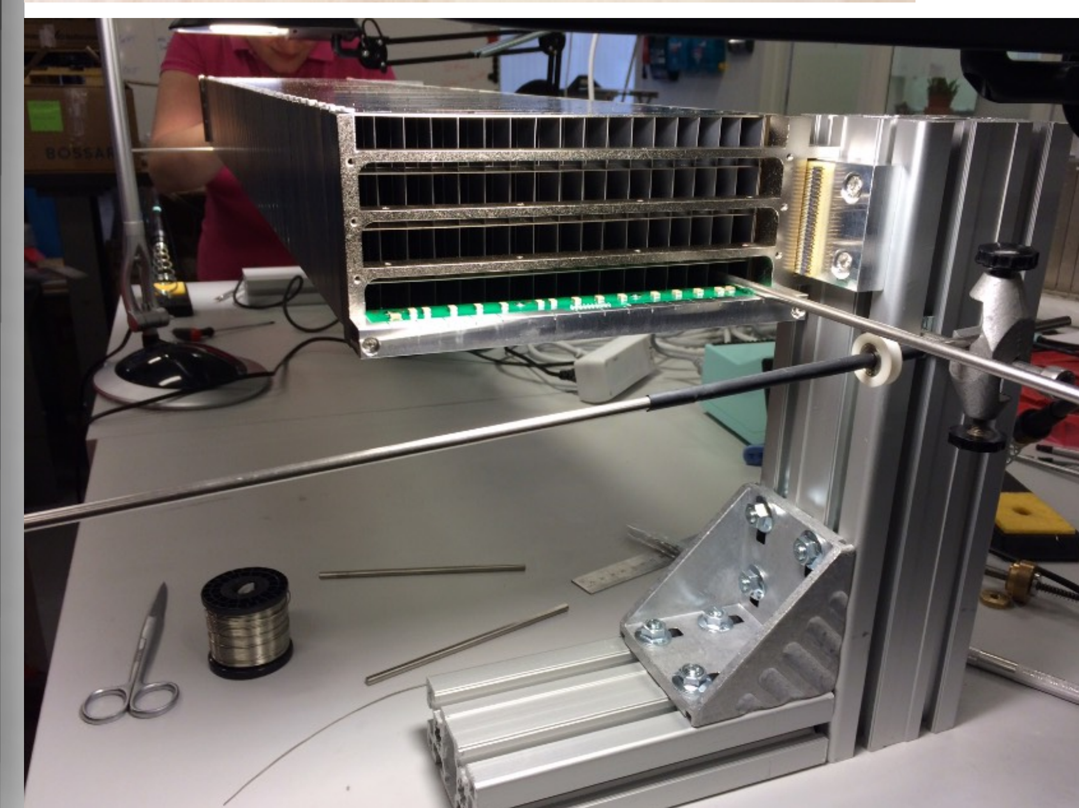
NEUTRONS FOR SCIENCE®

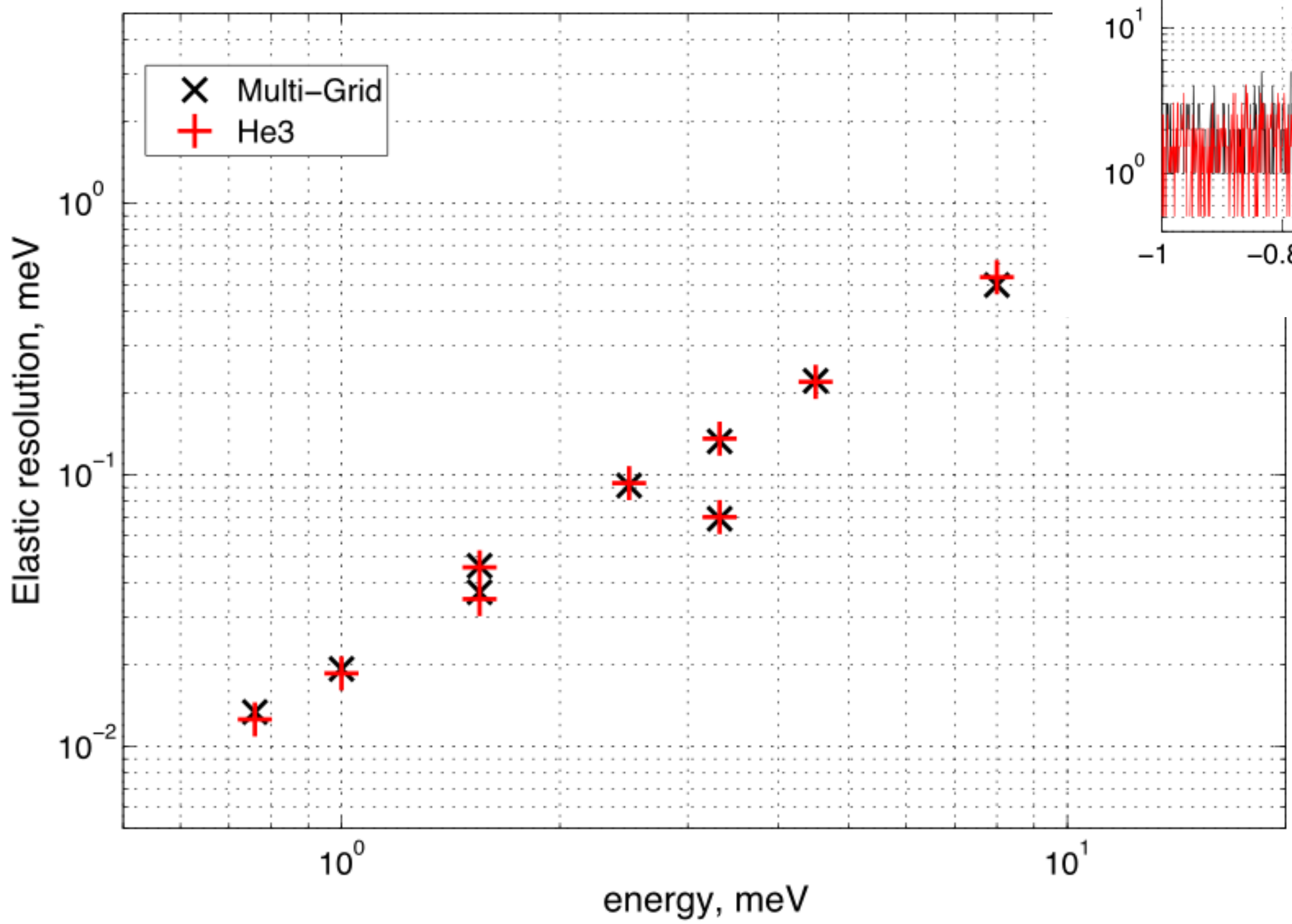


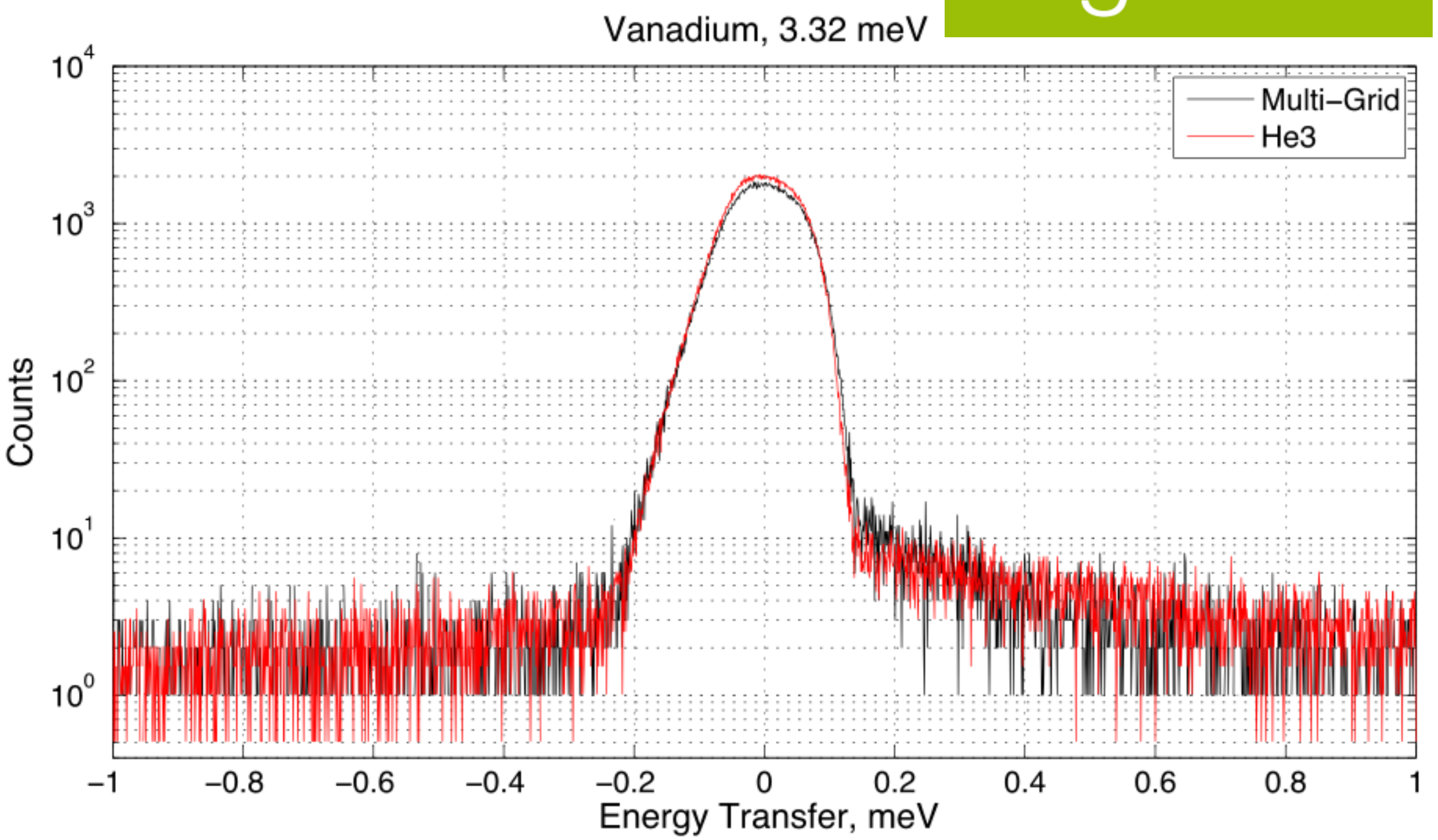






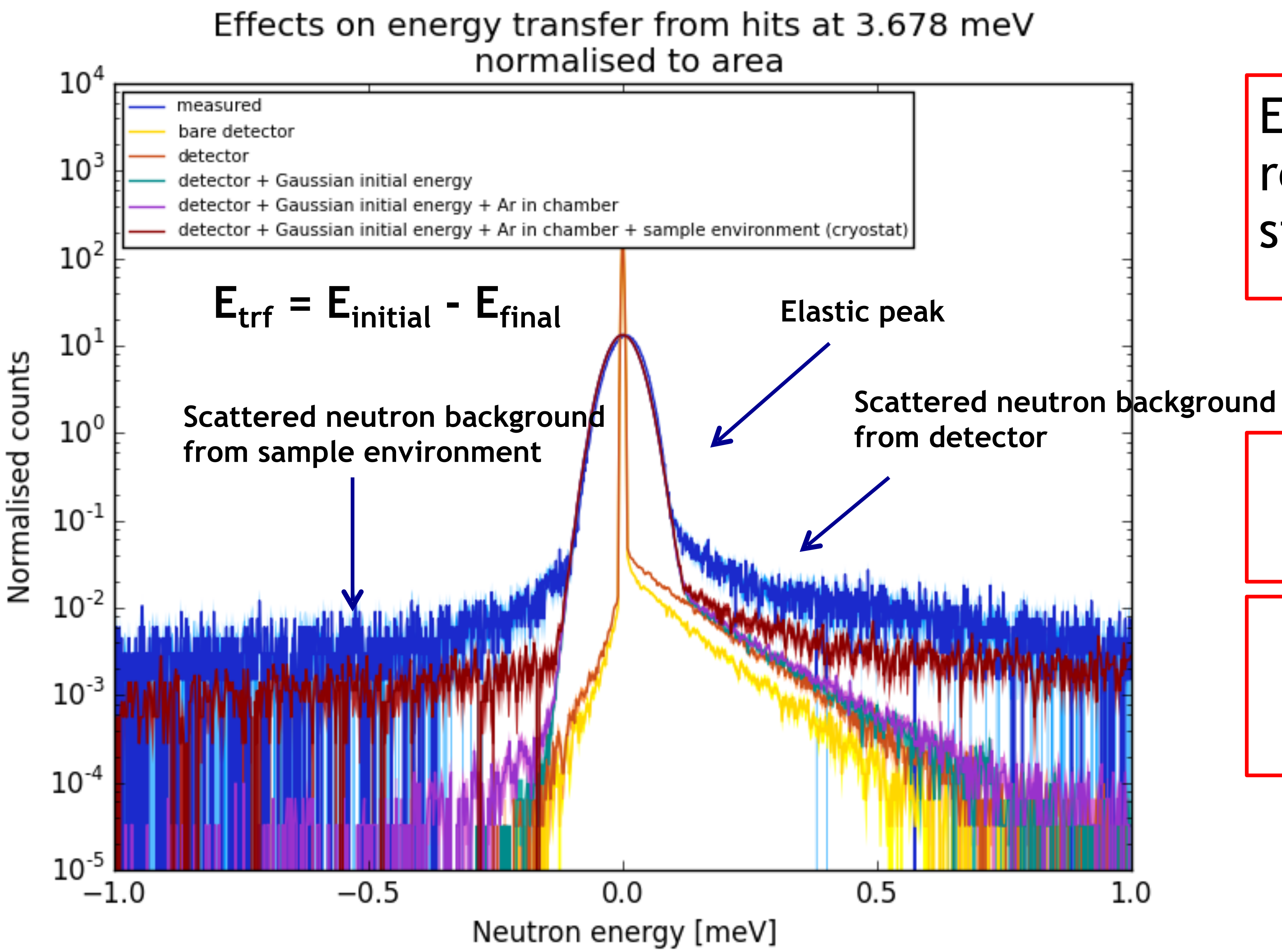
Multi-Grid test at CNCS





- Data and instrument resolution identical
- Technology suitable for ESS instruments

MultiGrid detector test at CNCS, SNS



Validation

Energy transfer reproduced with simulation at 3.678 meV ✓

Distinguish different sources of background

Detailed analysis and quantification of background effects

↓

Optimization

E.Dian et al., NIM A (subm.), arXiv:1801.05686

Multi-Blade | Wigner Research Institute | European Spallation Source | Lund University | Linköping University

The Multi-Blade project

High counting rate capability

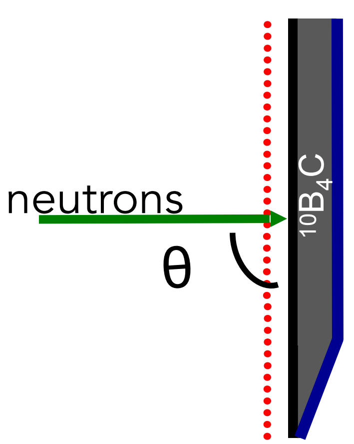
High spatial resolution

A single Boron layer inclined at 5 degrees

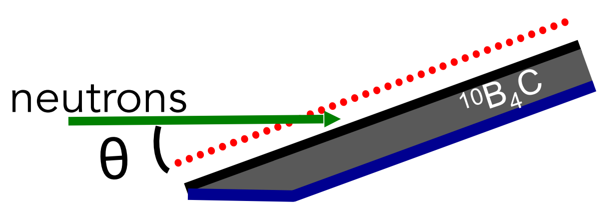
Multi-Blade

^{10}B-detector for reflectometers

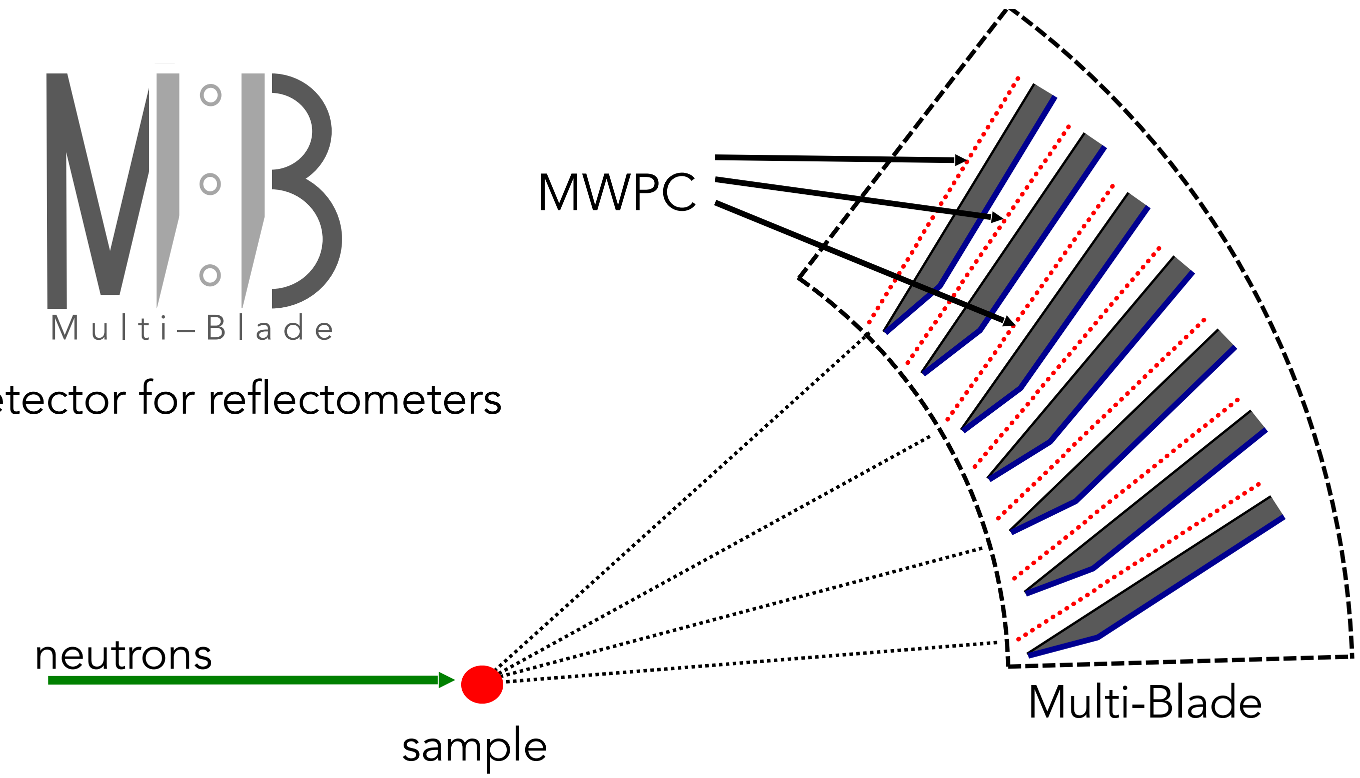
Efficiency <5% at 2.5Å | Efficiency 45% at 2.5Å

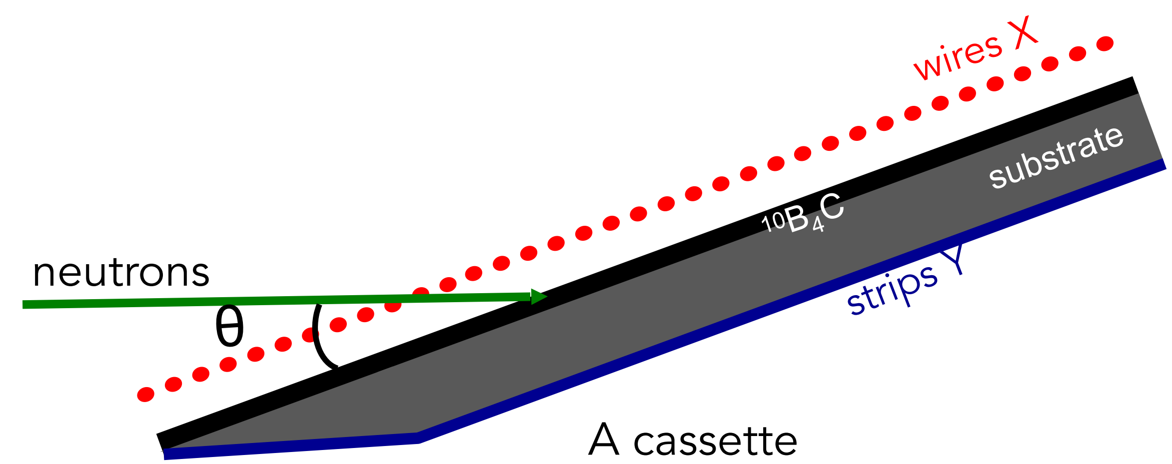


θ = 90 degrees



θ = 5 degrees





θ = 5 degrees

brightness

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

The Multi-Blade project

High counting rate capability

High spatial resolution

Why the counting rate capability is improved?

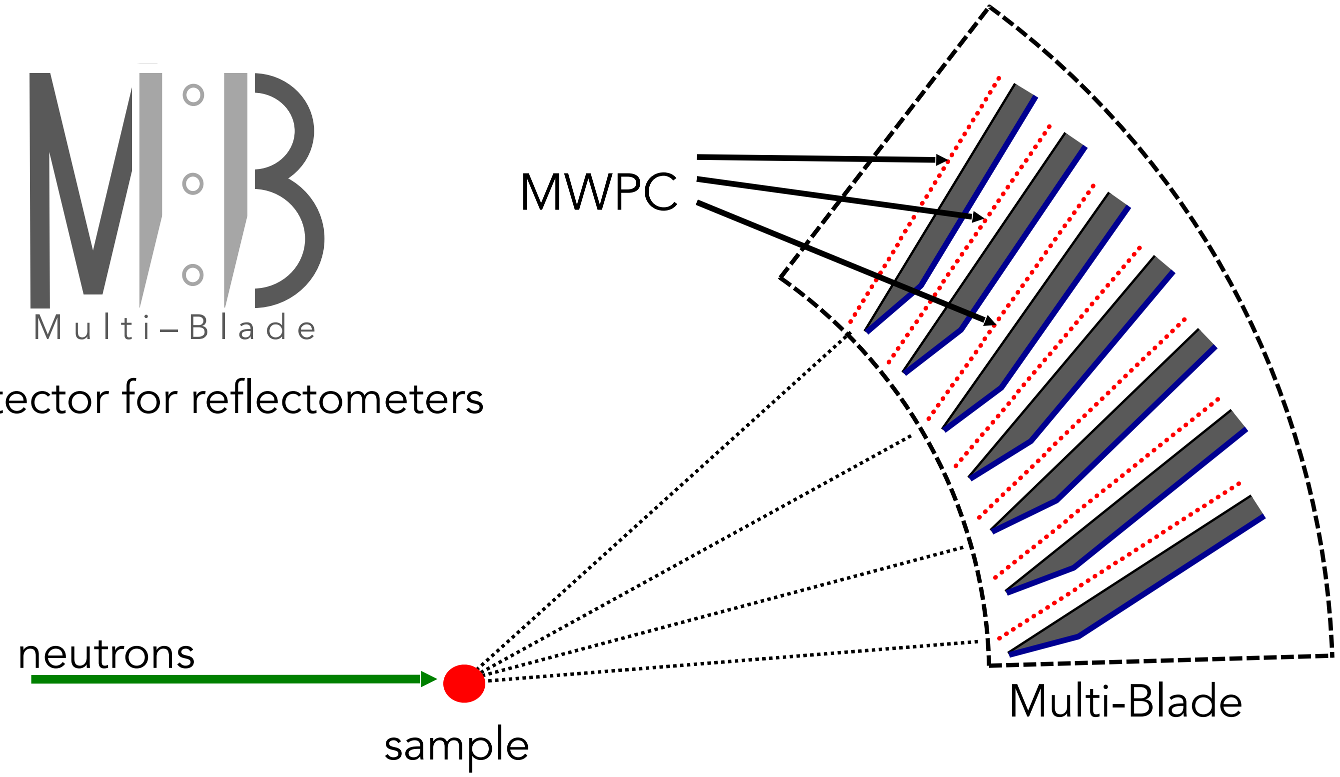
1. The intensity is spread over a wider surface (5 degrees ~ factor x10)

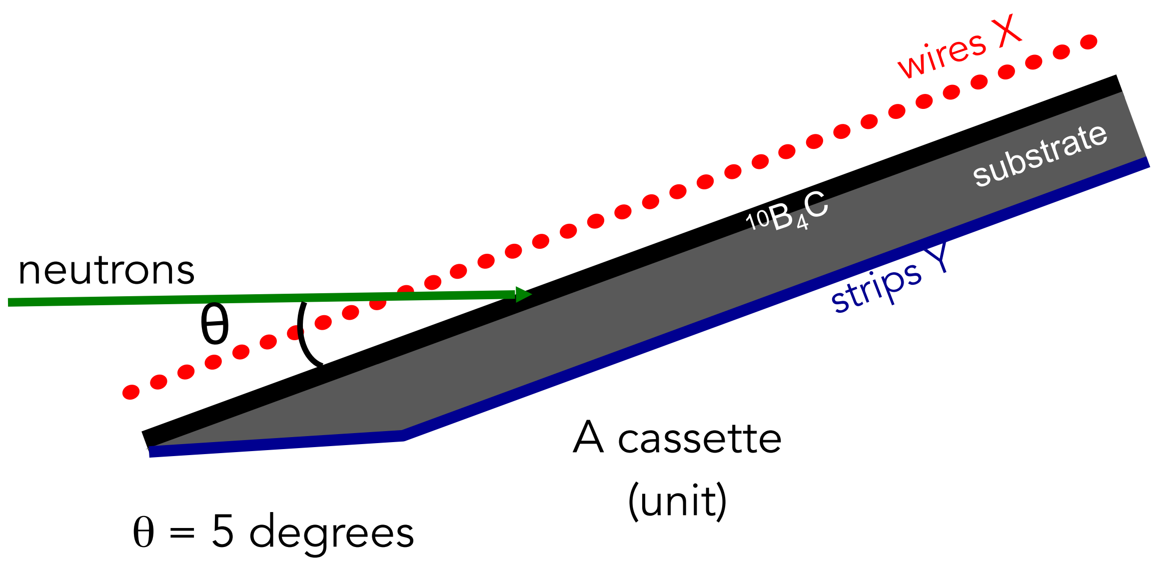
2. Thin gap MWPC (4mm)

3. Low gas gain operation G~20 (max 0.2pC avalanches)

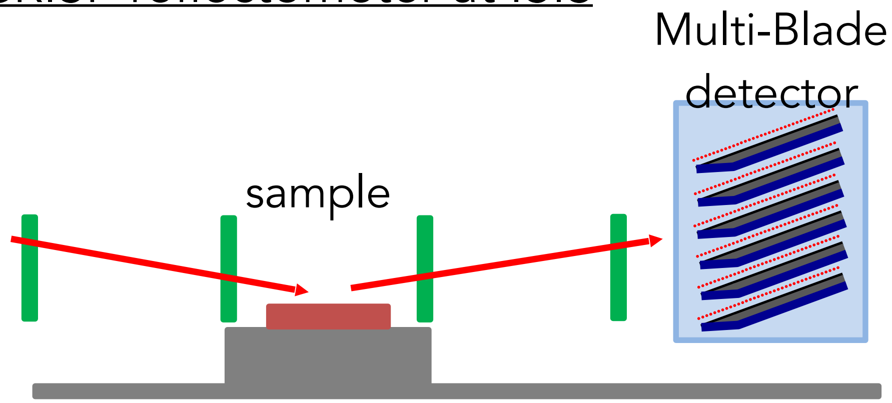
Multi–Blade

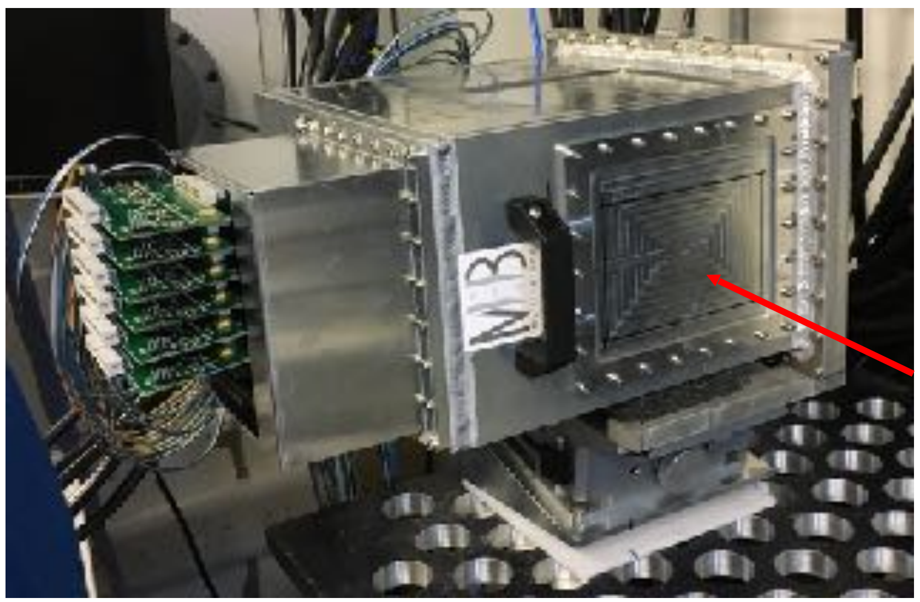
^{10}B-detector for reflectometers

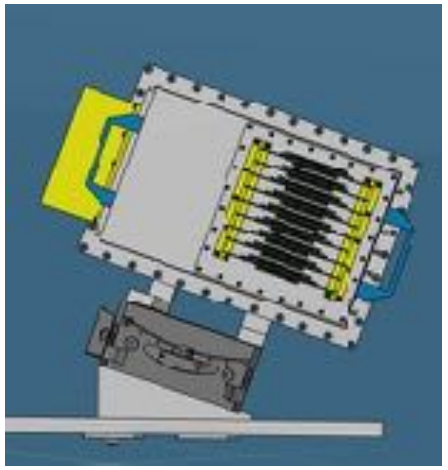


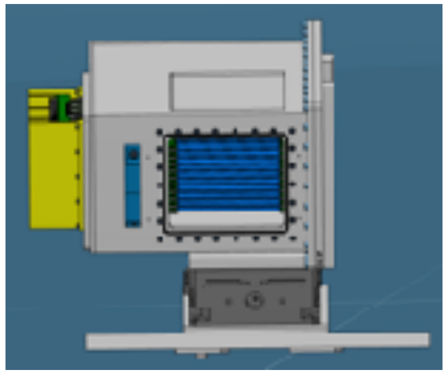


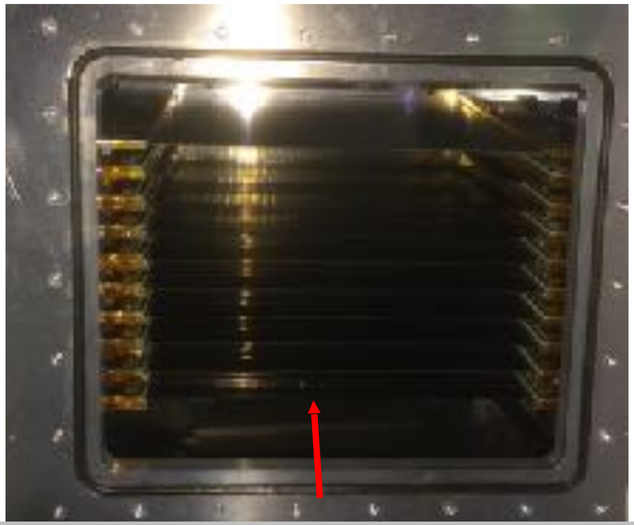
CRISP reflectometer at ISIS

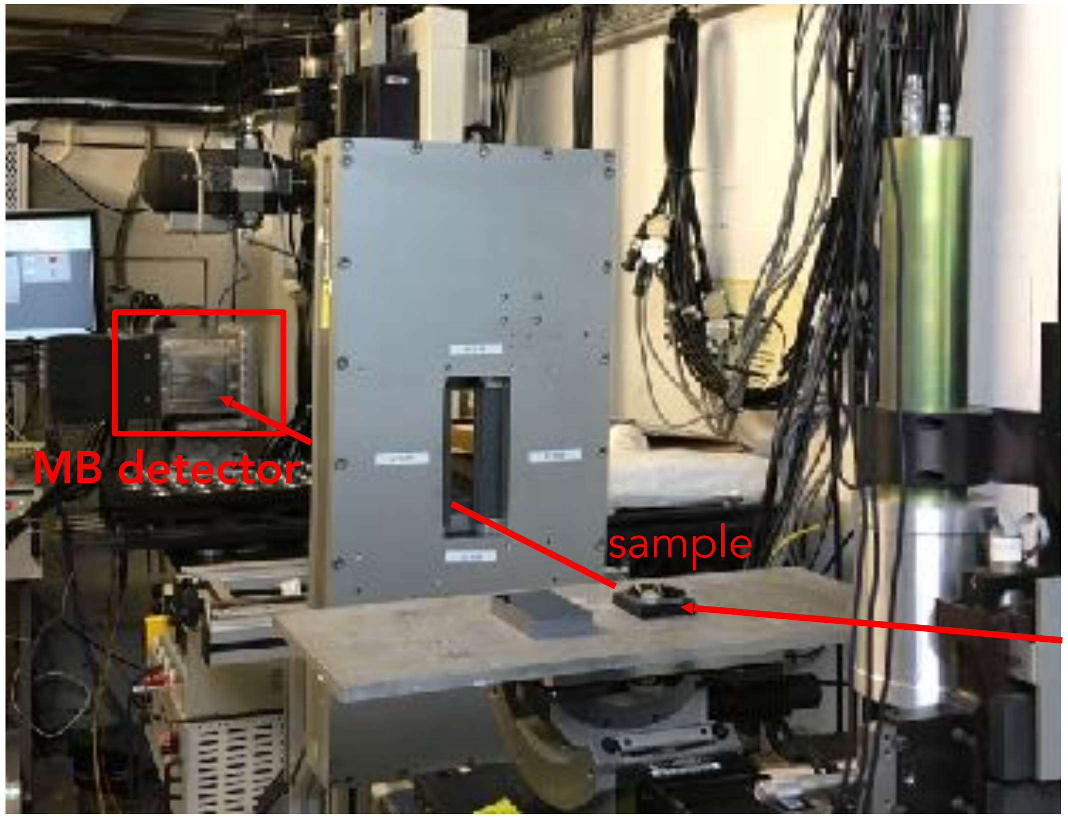


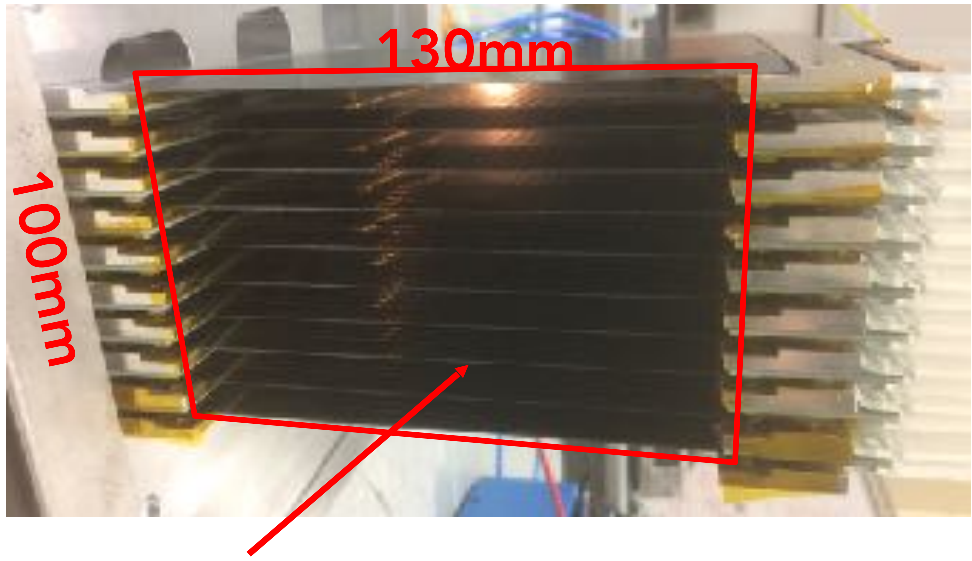




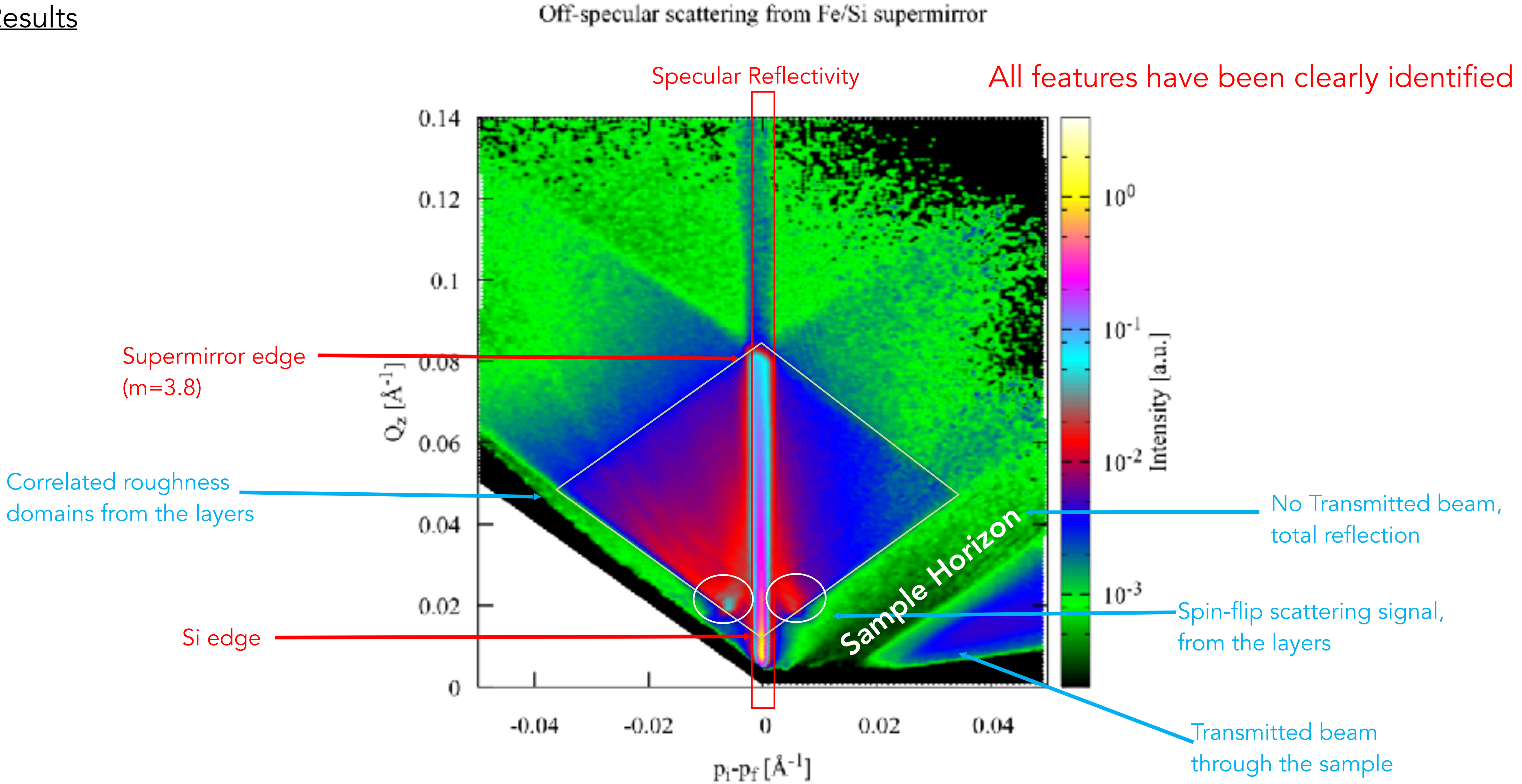








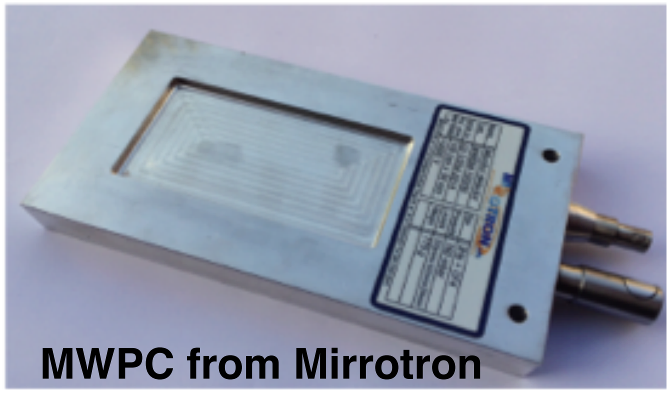
Results

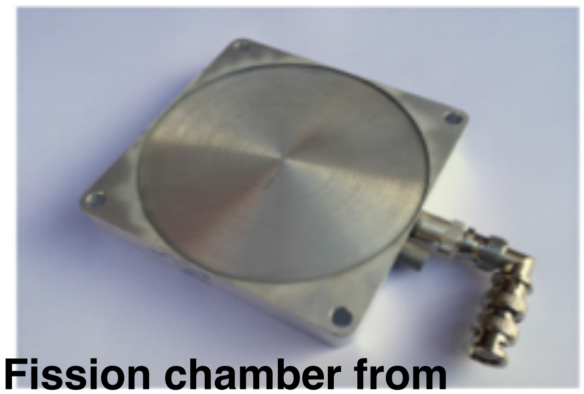


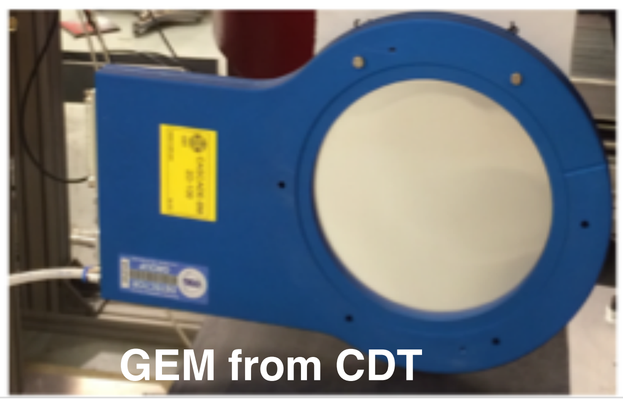
Off-specular scattering from Fe/Si supermirror
Specular Reflectivity
All features have been clearly identified
Supermirror edge
(m=3.8)
Correlated roughness
domains from the layers
Si edge
No Transmitted beam,
total reflection
Spin-flip scattering signal,
from the layers
Transmitted beam
through the sample
Sample Horizon
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.04
-0.02
0
0.02
0.04
Q_z [Å^{-1}]
p_i-p_f [Å^{-1}]
10^0
10^{-1}
10^{-2}
10^{-3}
Intensity [a.u.]

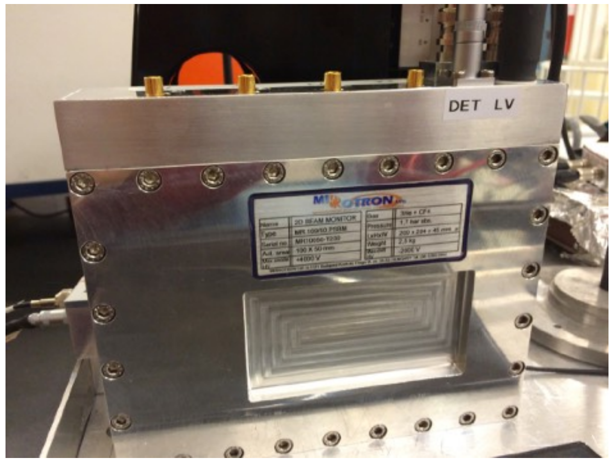
Beam Monitors


Scintillator from Detector Quantum

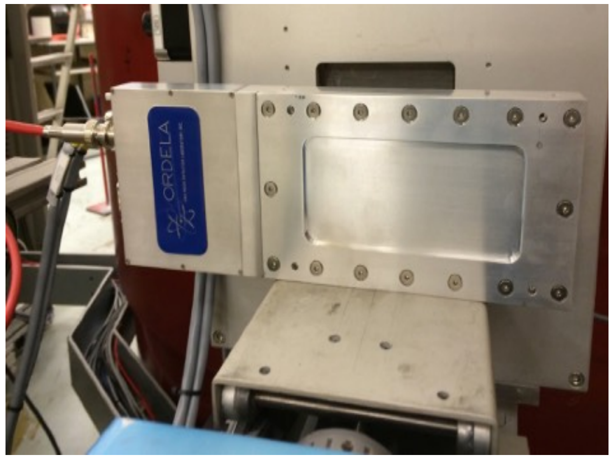

MWPC from Mirrotron


Fission chamber from LND


GEM from CDT



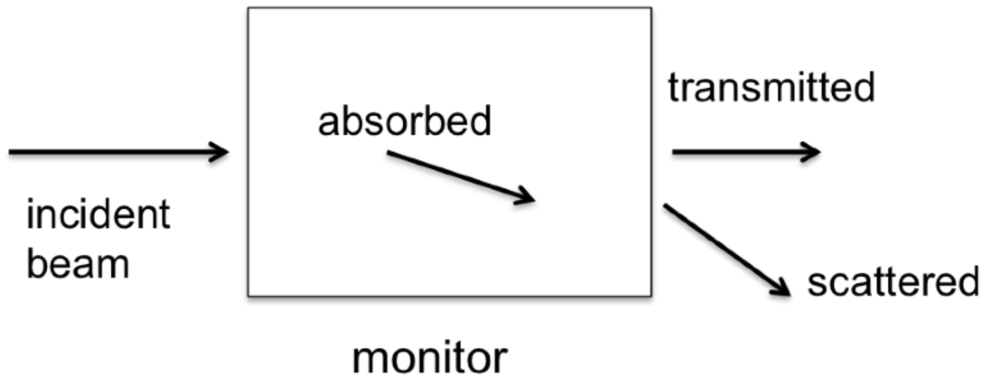
2D-MWPC from Mirrotron



Two MWPC from ORDELA ,filled with ^{3}He or ^{14}N

Type	Supplier	
MWPC (4)	Mirrotron-ORDELA	Filled with ^{3}He gas or ^{14}N
Fission chamber (1)	LND	^{235}U
GEM (1)	CDT	Coated with ^{10}B
Scintillator (1)	Detector Quantum	Li-glass beads

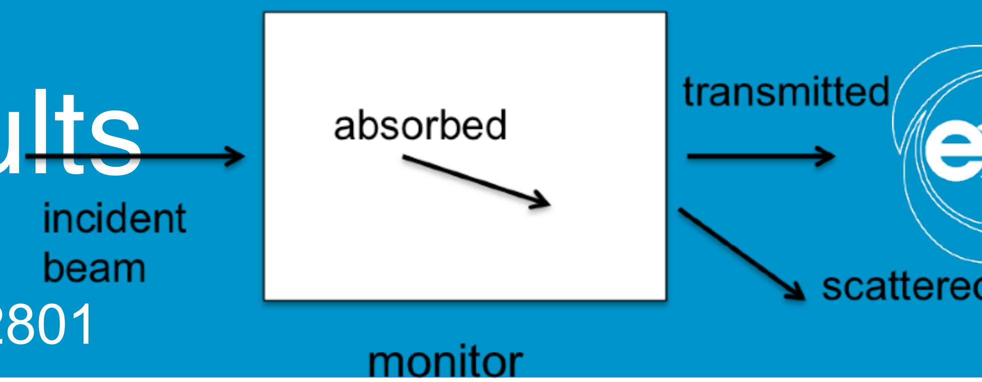
2D-GEM monitor for ESS realized by Milan-CNR
Mirrotron to be filled by Nitrogen



F. Issa et al., Phys. Rev. Accel. Beams 20 (2017) 092801

Beam monitors-main results

F. Issa et al., Phys. Rev. Accel. Beams 20 (2017) 092801



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	MWPC from ORDELA	MWPC from ORDELA	MWPC BM-100X50 from Mirrotron	2D-MWPC from Mirrotron	2D-GEM from CDT	Scintillator from Quantum Detectors, UK	Fission chamber from LND
Isotope used for neutron capture	^{3}He	^{14}N	^{3}He	^{3}He	^{10}B	^{6}Li	^{235}U
Gas pressure mbars	Partial pressure 6,0795	Partial pressure 81,06	Partial pressure 6,5	Partial pressure 0.4	Total pressure 100	------	Total pressure 1013,2
Filled gas	$^{3}He+^{4}He+CF_4$	$N+CF_4$	$^{3}He+CF_4$	$^{3}He+CF_4$	Ar/CO_2	--------	P10
Active Area (mm^2)	114 x 51	114 x 51	100 x 50	100 x 50	Diameter 100 mm	28 x 42	Diameter 108.0 mm
Applied voltage (V)	850	850	1300	Anode at -3500V Drift at 1500V	-1000	650	300
Attenuation %	4.5	4.4	2.5	7.3	11.1	0.49	3.87
Calculated attenuation %	4	4	2			0.1	2
Measured Efficiency at 2.4Å %	0.12	3.3×10^{-3}	0.11	0.01	2.7	0.052	0.01
Supplier efficiency % at 1.8Å	0.1	0.001	0.1	0.015			
Scattering %	3.9	3.8	4	9	10.3	0.74	3.8

What now?

- Updating requirements from instruments for monitors both for commissioning and operation
- Taking into account operational environments
- Draft set of recommendations
- Looking at potential of parasitic monitors


株式会社

Collaboration Opportunities

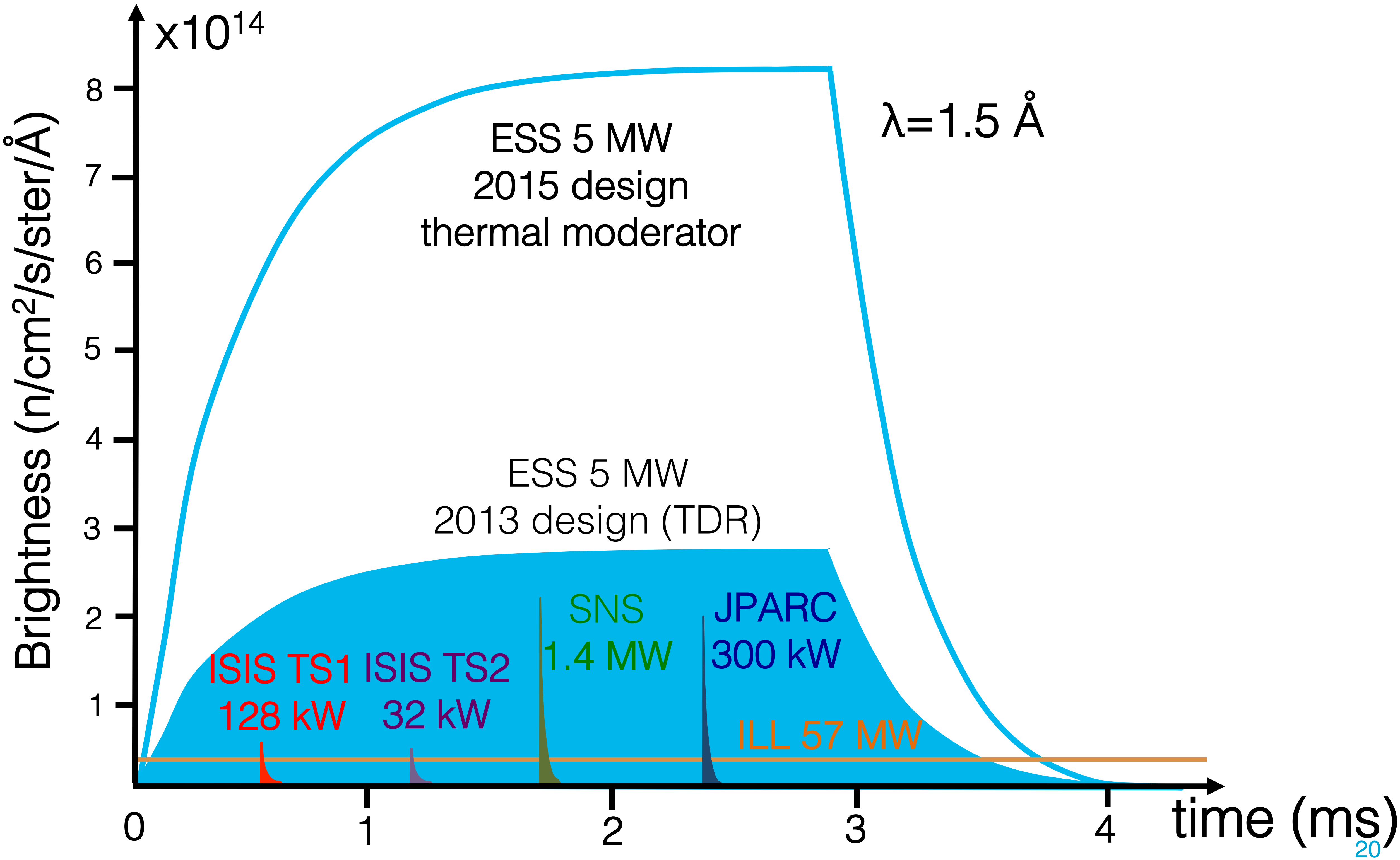
•MultiGrid: Repetition Rate Multiplication feature has only been implemented in J-PARC. Understanding the data treatment with MultiGrid

•Detector demonstration under real environments necessary to understand real world performance of new detector designs
•eg Gd-GEM detector design, need to demonstrate performance for Neutron Macromolecular Crystallography application
•However spare detector space needed, eg Nova beam line with "spare" bank

•Monitors: interested in any advice or experience to offer
•Possible testing opportunities


あせらない
急ぐ時ほど
落ち着いて
STOP
転倒災害
転倒災害の多くは「急いでいるとき」に発生しています！

Challenge for Rate



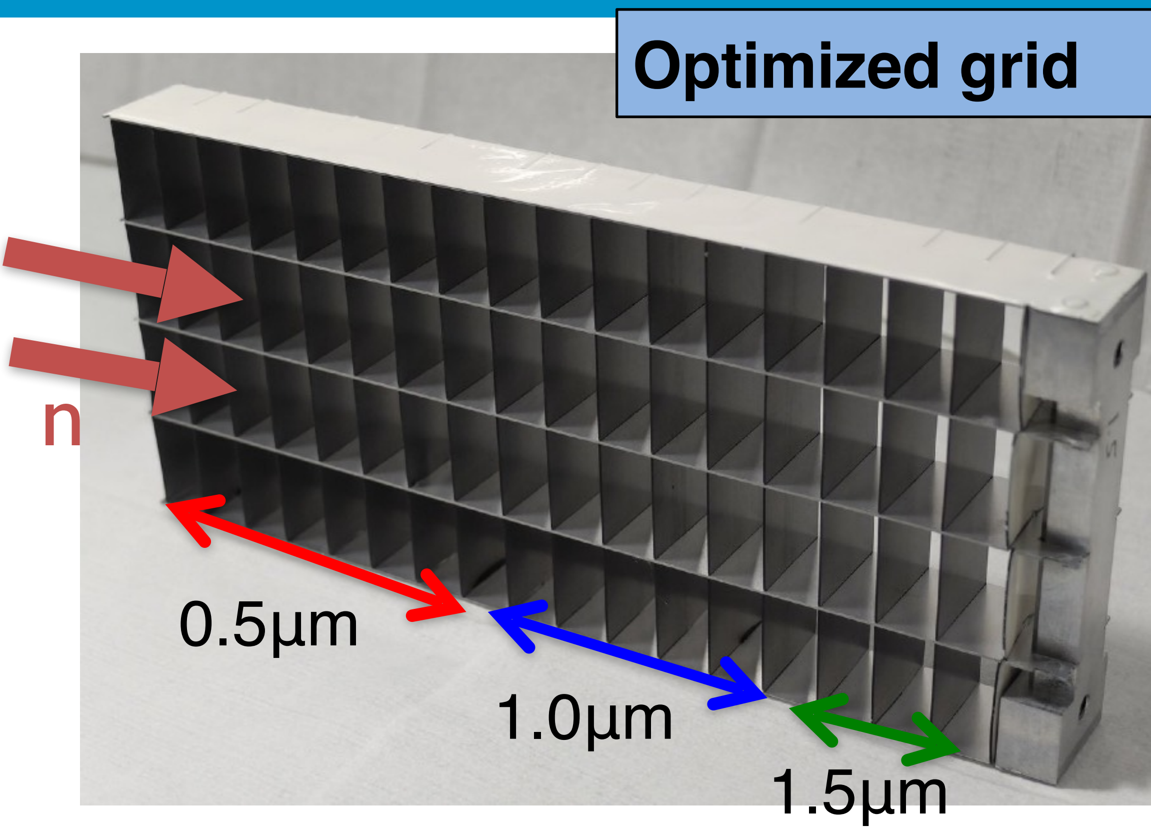
What can be done with this brightness?

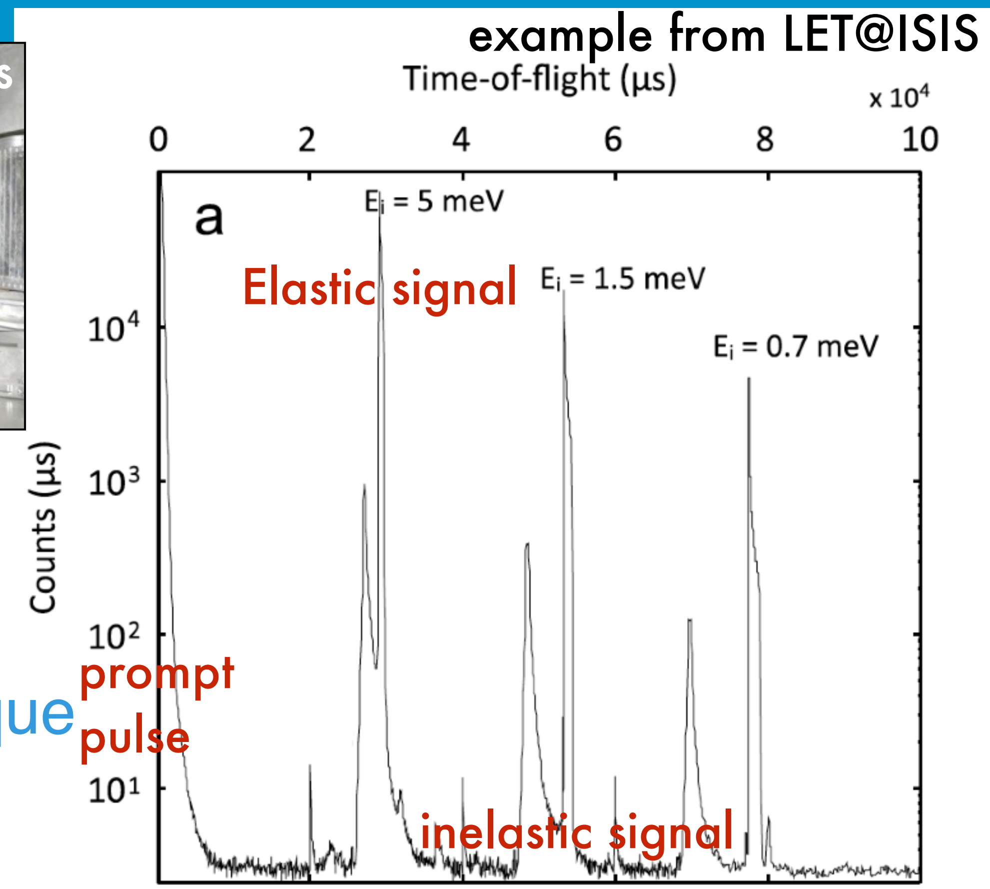
Instrument Design	Implications for Detectors
Smaller samples	Better Resolution (position and time) Channel count
Higher flux, shorter experiments	Rate capability and data volume
More detailed studies	Lower background, lower S:B Larger dynamic range
Multiple methods on 1 instrument Larger solid angle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

Also: scarcity of Helium-3 …

Developments required for detectors for new Instruments

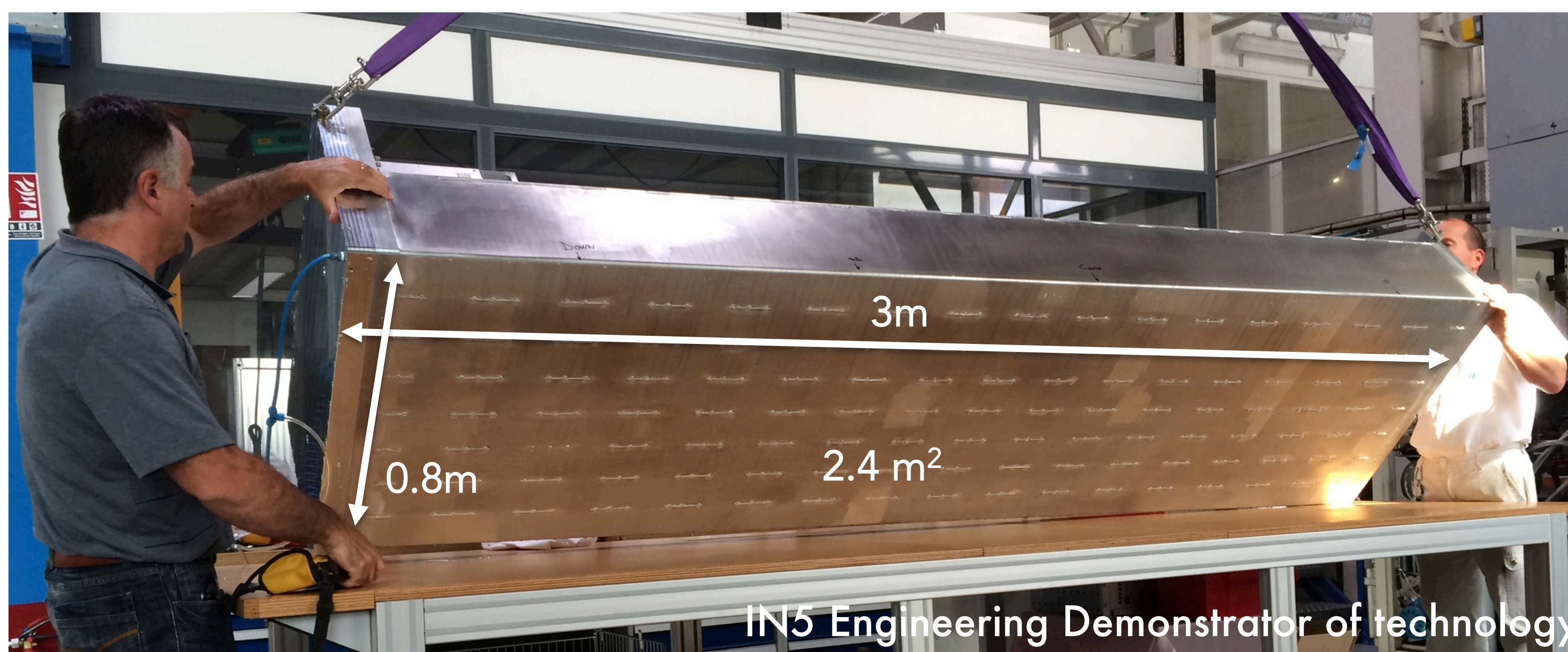
Multi-Grid Detector Design



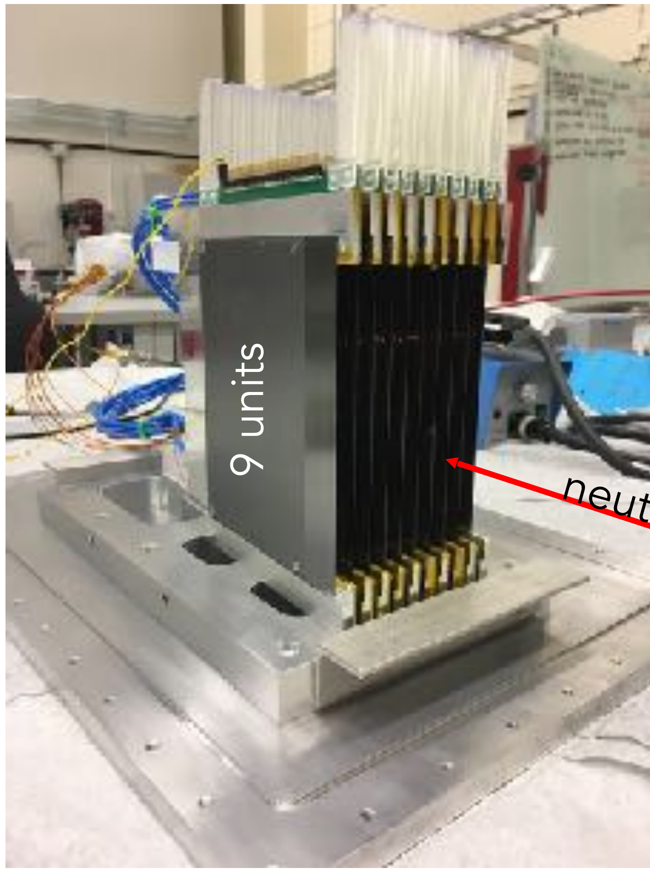


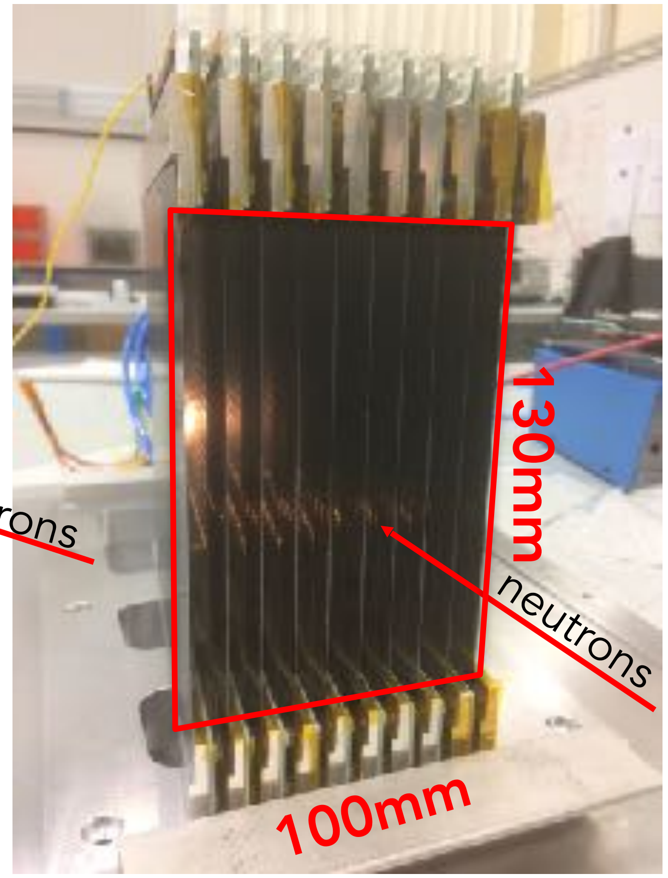
- Very background sensitive technique

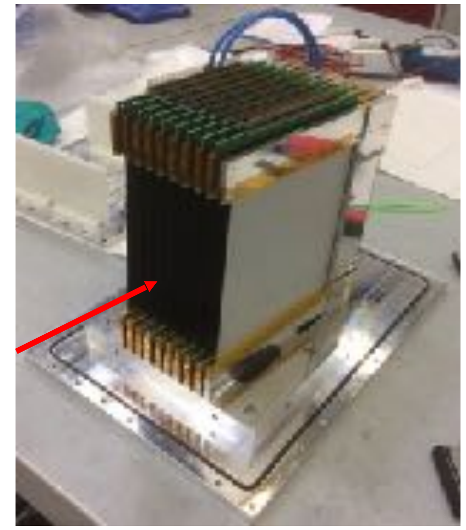
- Designed as replacement for He-3 tubes for largest area detectors
- Cheap and modular design
- Possible to build large area detectors again
- 20-50m² envisaged@ESS



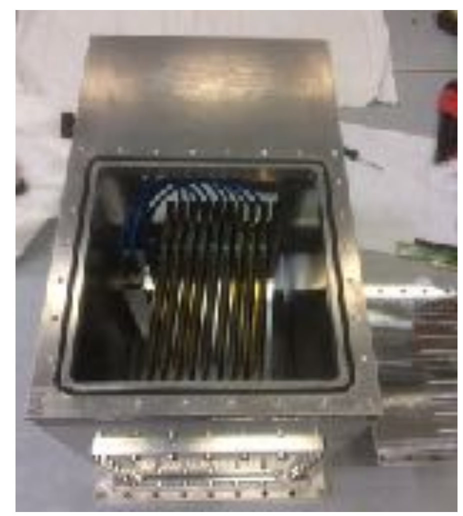
The Multi-Blade project



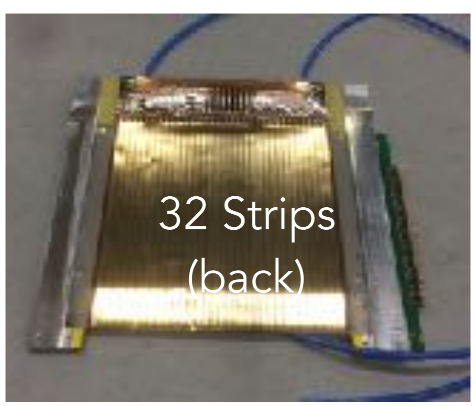


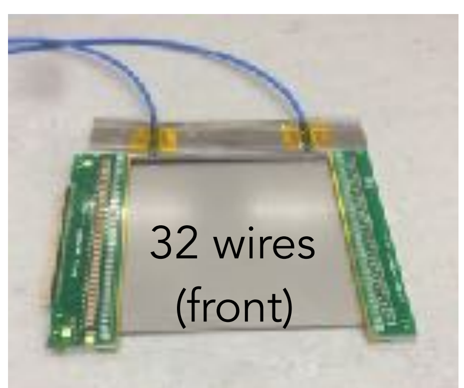


vessel

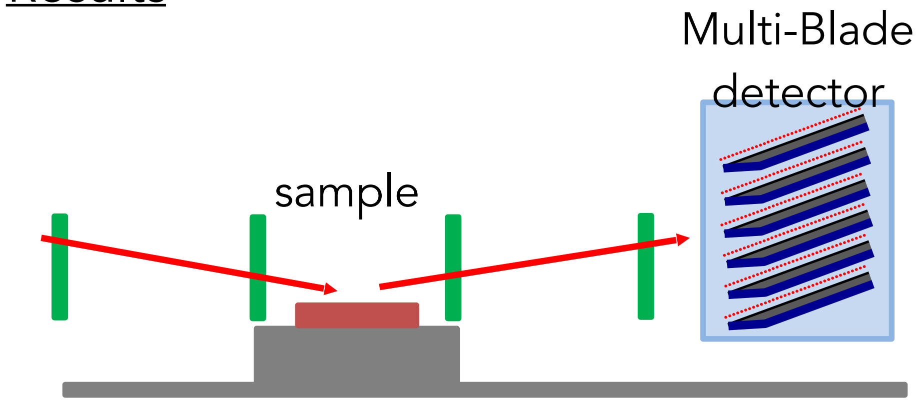


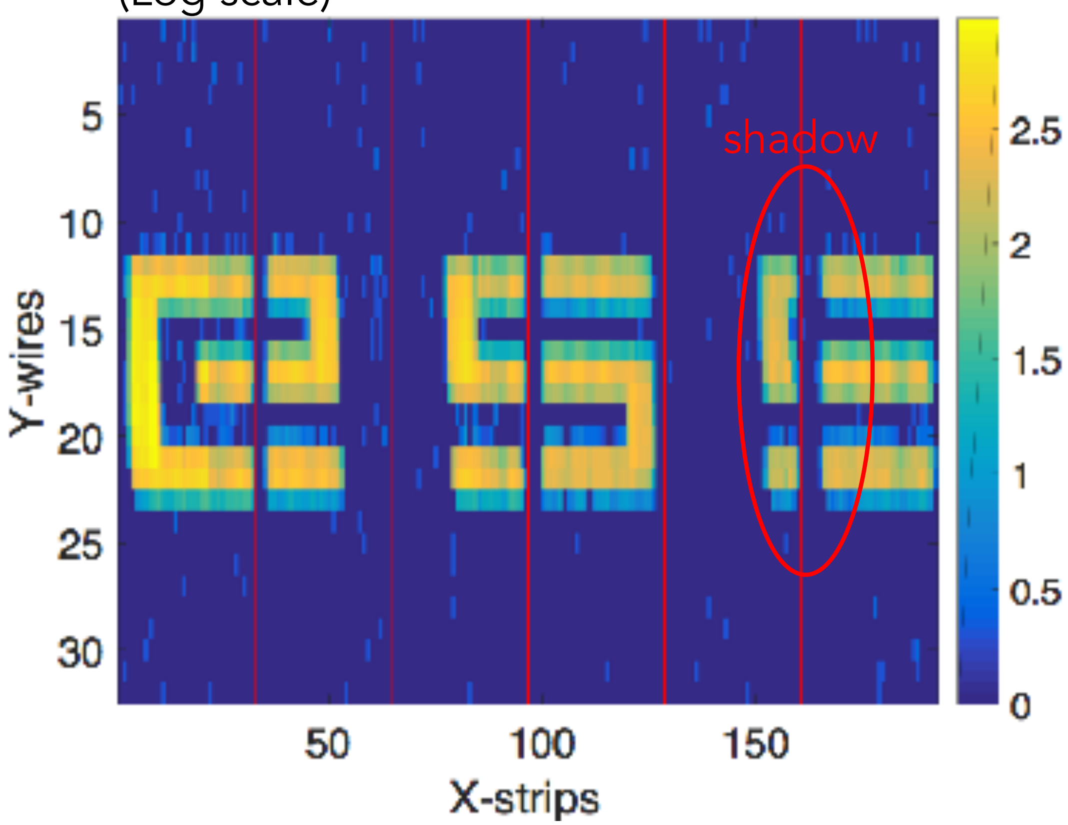
32 ch
front-end board

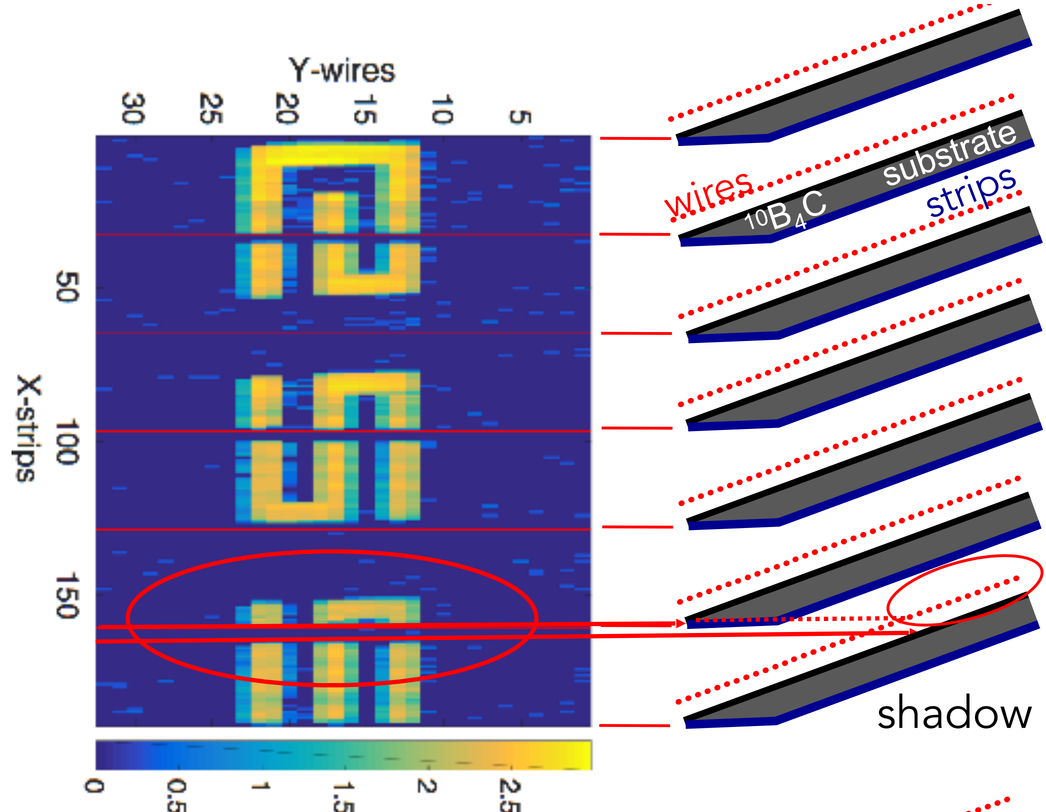




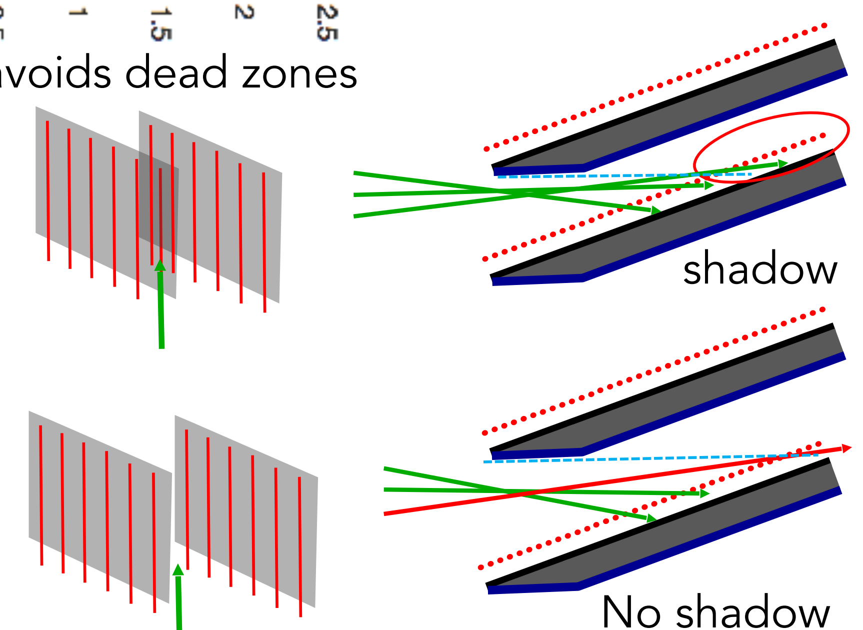
Results



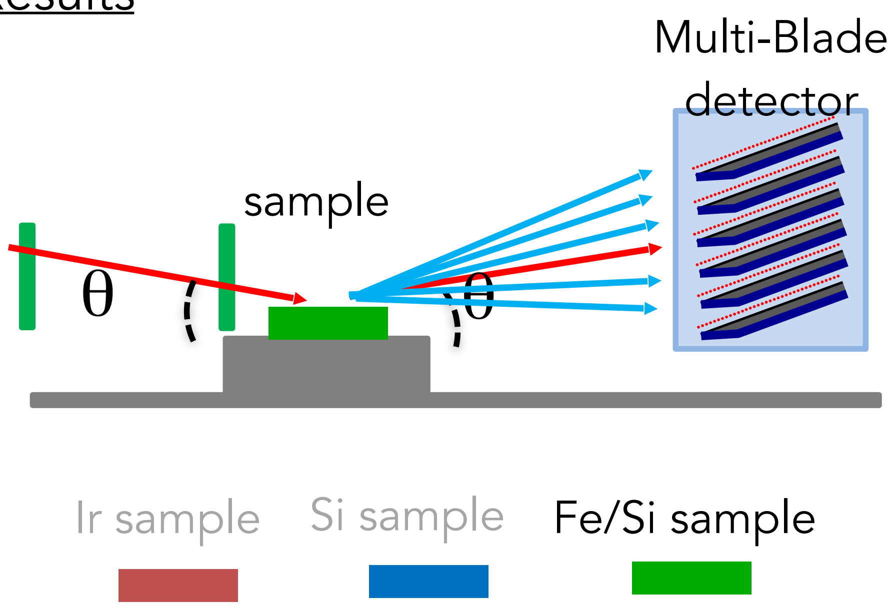


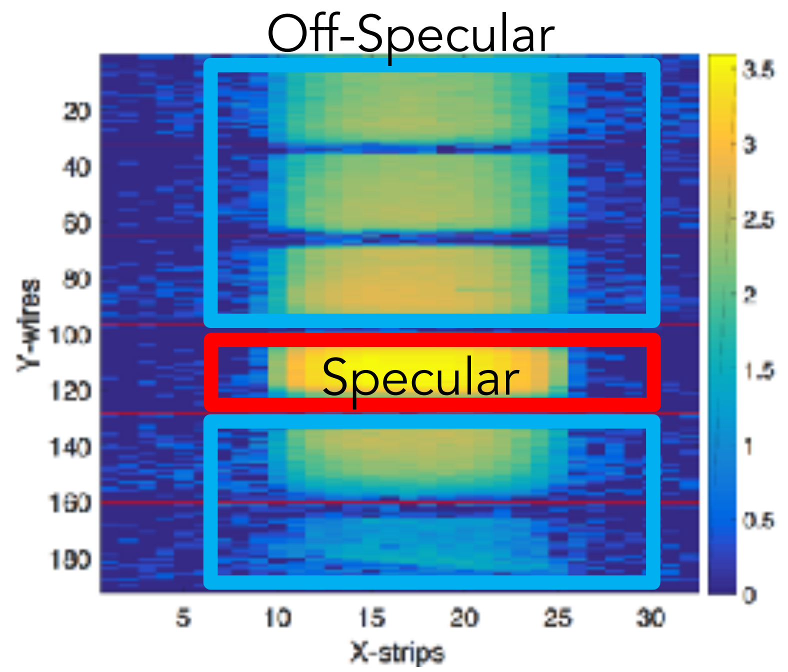


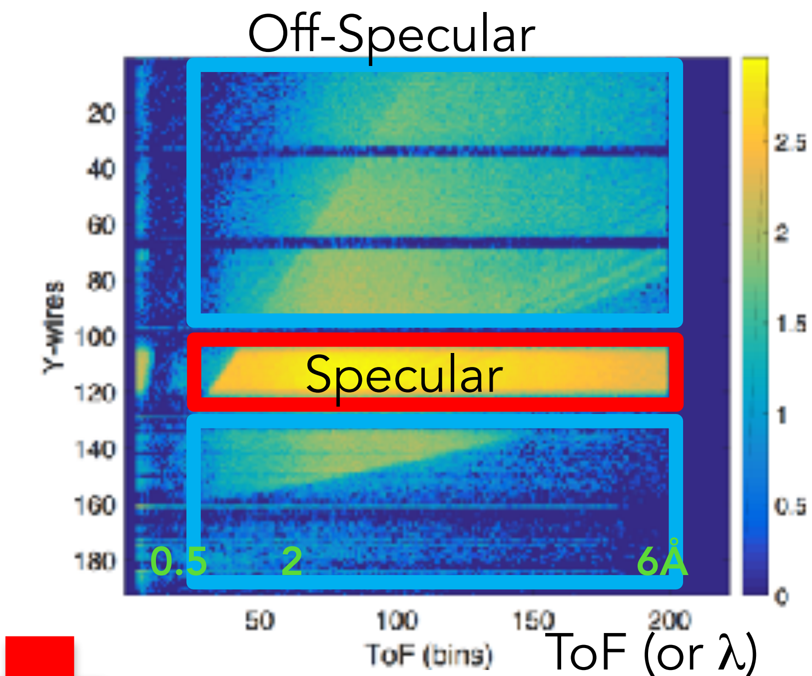
Not a dead area but the overlap avoids dead zones



Results


Multi-Blade detector
sample
θ
θ
Ir sample
Si sample
Fe/Si sample


Off-Specular
Specular
Y-wires
X-strips


Off-Specular
Specular
Y-wires
ToF (bins)
ToF (or λ)
0.5
2
6Å