

Neutron Detector Activities at ESS – the Multi-Blade

Eszter Dian, Giacomo Mauri, Francesco Piscitelli
on behalf of ESS Detector Group

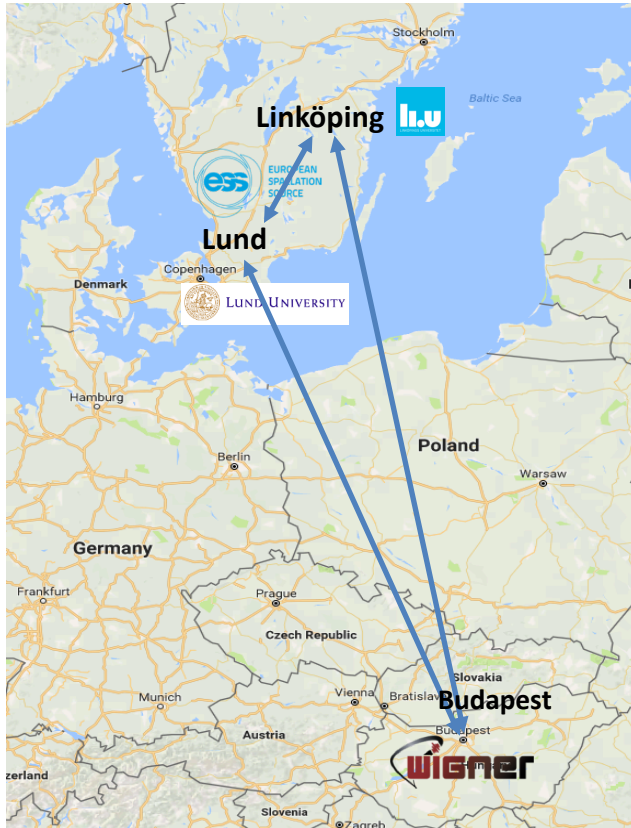
European Spallation Source ESS ERIC

4 September 2020, CREMLINPlus WP7 kick-off

The Multi-Blade detector



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LUND UNIVERSITY



Linköping University



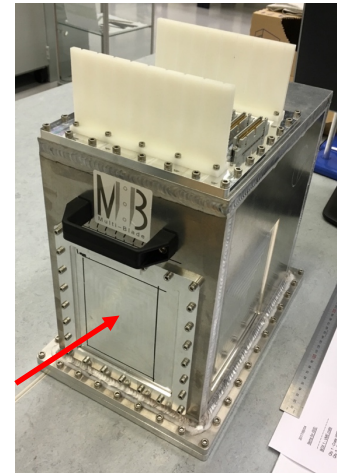
Wigner RCP

- Multi-wire proportional chamber
- Solid $^{10}\text{B}_4\text{C}$ neutron converter
- Ar/CO₂ counting gas
- Reflectometers of ESS (ESTIA, FREIA)

Challenge:

- High count rate capability
- High spatial resolution

Aim beyond
State-of-the-Art



History of the Multi-Blade detector



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brightness



June 2013

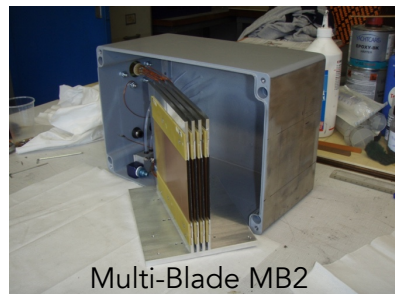
November 2015

March 2017

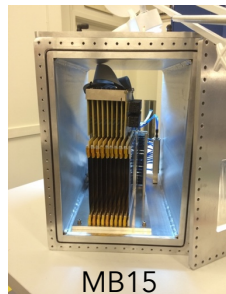
September 2018

August 2020

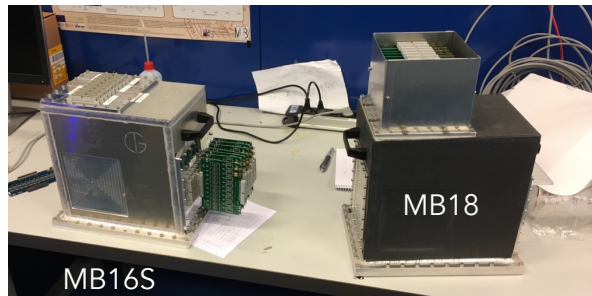
And the future?



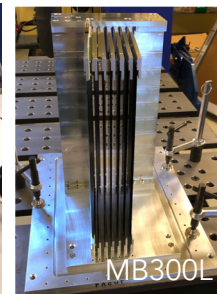
Multi-Blade MB2



MB15



MB16S



MB300L



MB0 MB1 MB2



2012

2013

MB15



2015

MB16T MB16S



2017

MB18



2018

MB300L



2020

Already tested at
reflectometers:
- CRISP at ISIS
- AMOR at PSI

(Introduced at ILL, developed by ESS under BrightnESS)

History of the Multi-Blade detector



brightness



June 2013

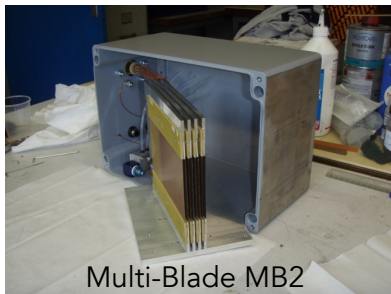
November 2015

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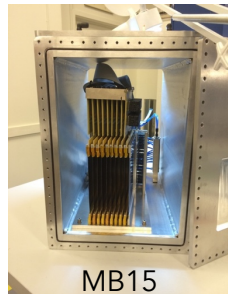
September 2018

August 2020

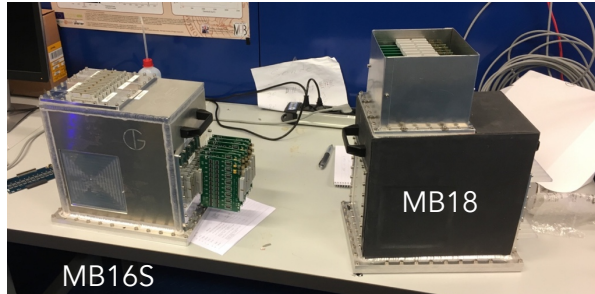
The first instruments with MB set the new State-of-the-Art



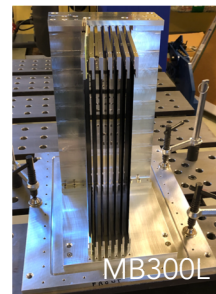
Multi-Blade MB2



MB15



MB16S



MB300L

Instruments using the MB:

Next week!

- 1st ARMOR at PSI
- 2nd ESTIA at ESS
- 3rd SONATA at PIK...?

MB0 MB1 MB2
2012 2013

MB15 MB16T MB16S
2015 2017

MB18
2018

MB300L
2020

Already tested at reflectometers:
- CRISP at ISIS
- AMOR at PSI₄

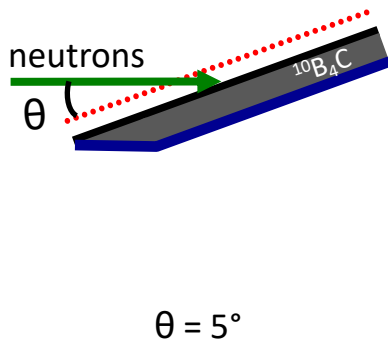
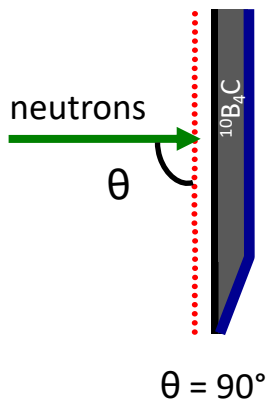
(Introduced at ILL, developed by ESS under BrightnESS)

The Multi-Blade concept

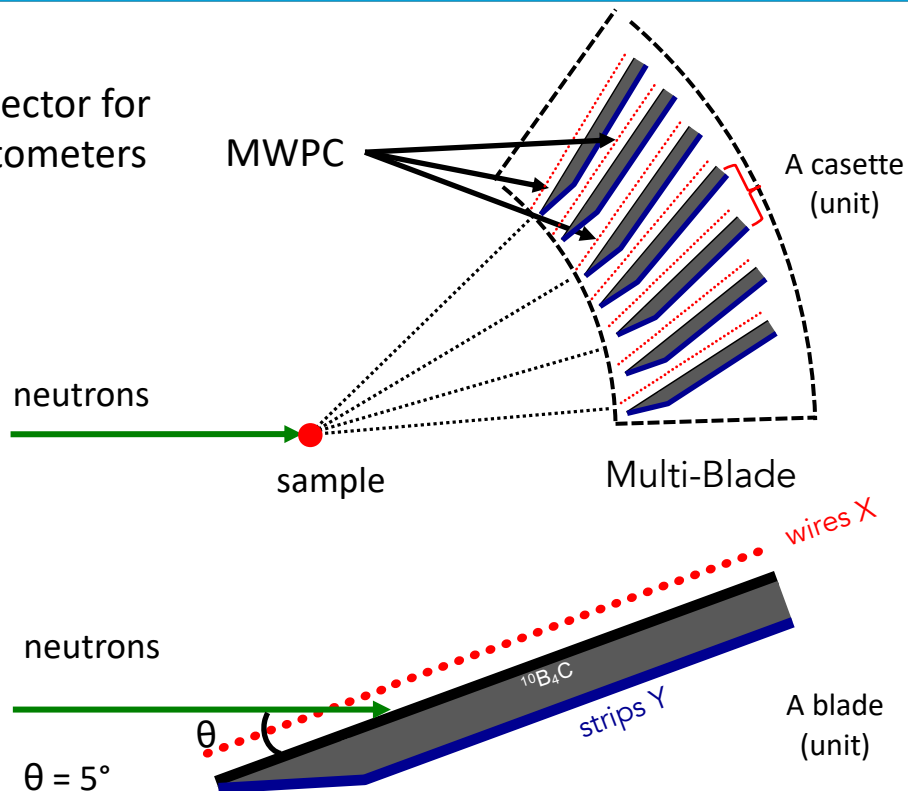
High counting rate capability
High spatial resolution

A single boron layer inclined at 5 degrees

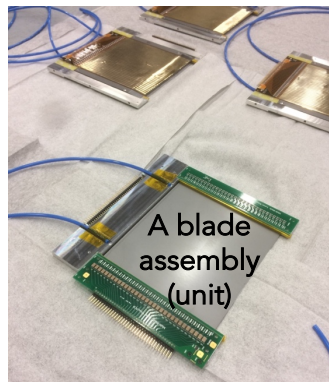
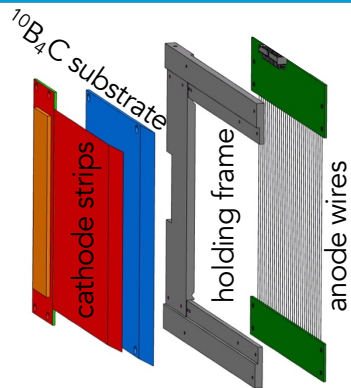
- Efficiency **<5%** at 2.5Å
- Efficiency **45%** at 2.5Å



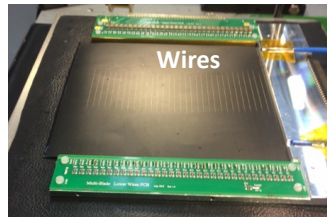
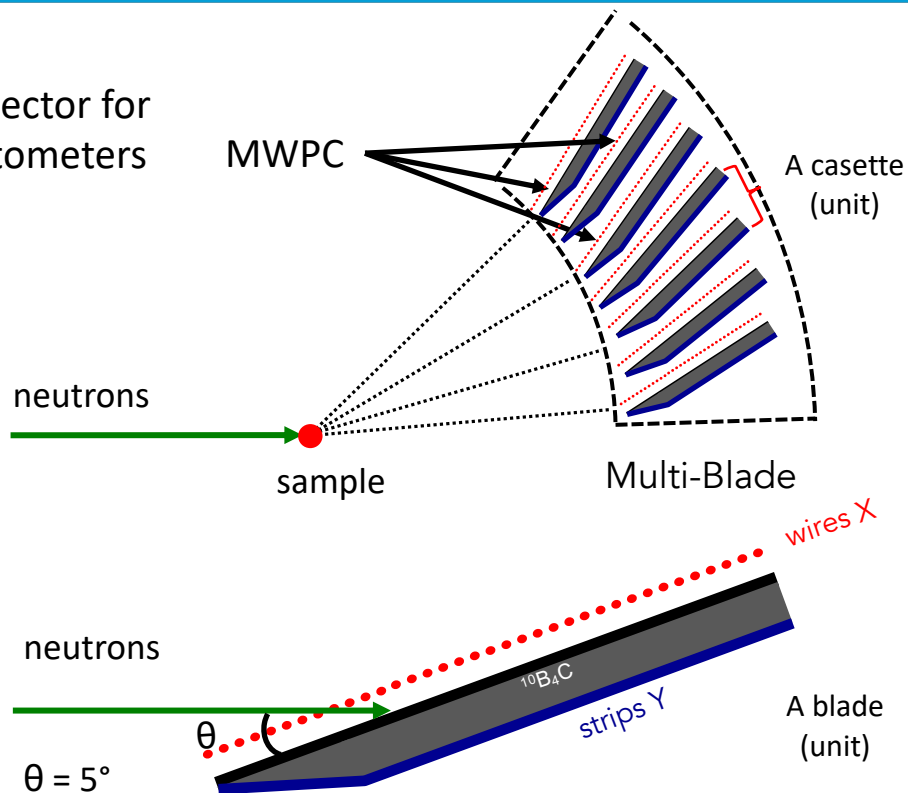
^{10}B -detector for
reflectometers



The Multi-Blade detector



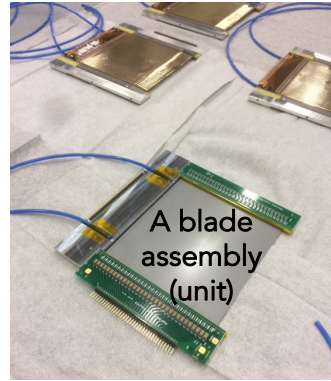
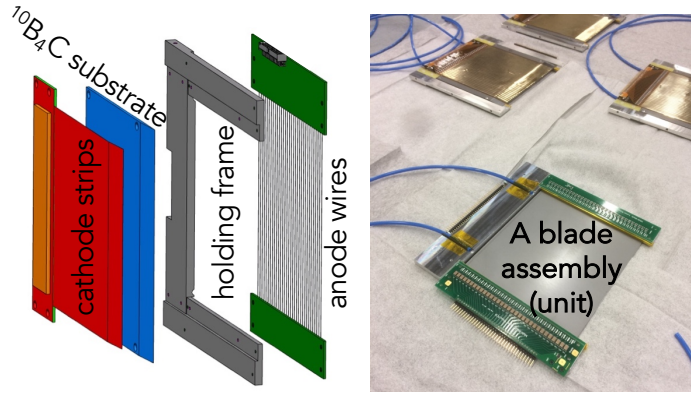
^{10}B -detector for reflectometers



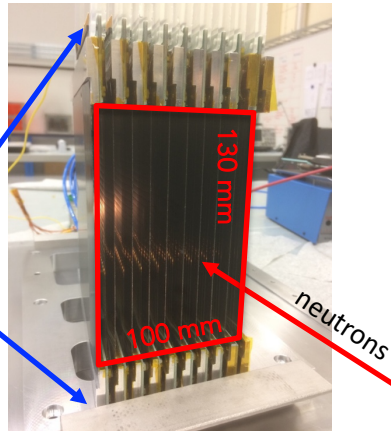
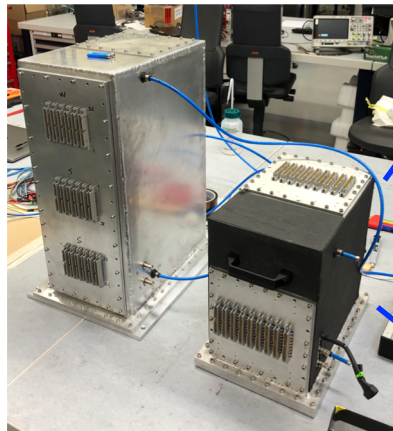
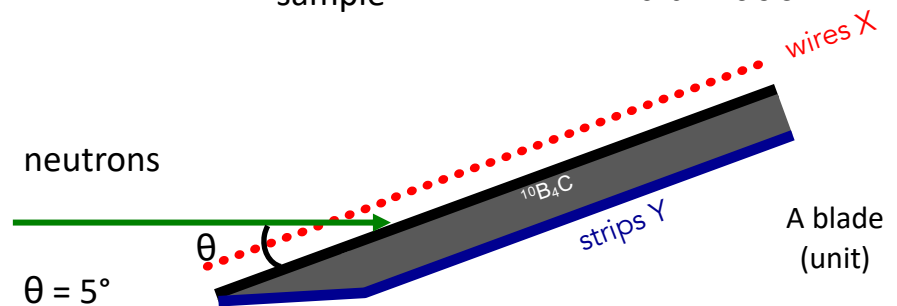
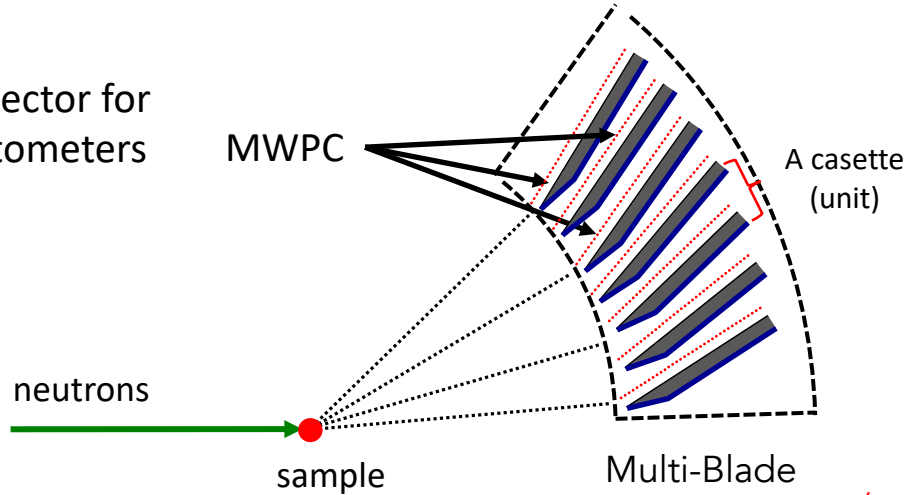
The Multi-Blade detector

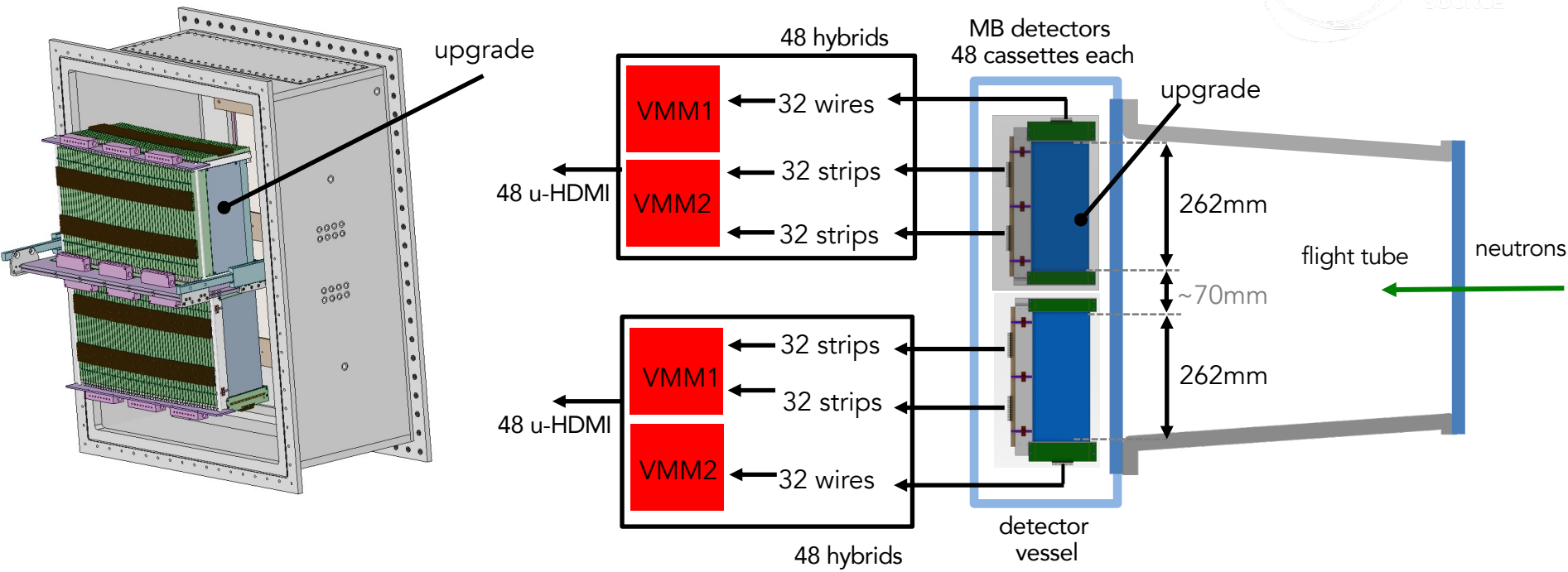


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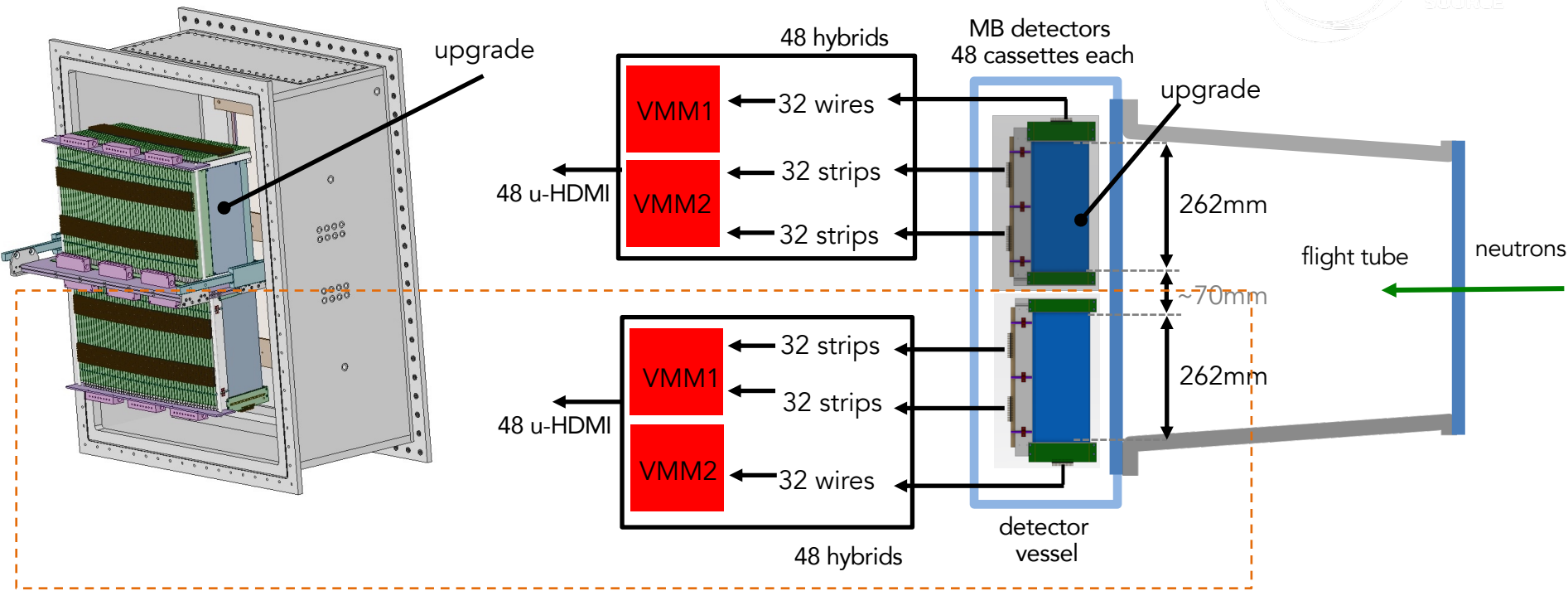


^{10}B -detector for
reflectometers





The Multi-Blade detector for the ESTIA@ESS



The Multi-Blade detector for the ESTIA@ESS

Multi-Blade performance



Matching ESS requirements

✓	efficiency	44% @ 2.5 Å 57% @ 4 Å 82% @ 12 Å
✓	spatial resolution	0.5 x 3.5 mm ²
✓	uniformity	±2%
✓	stability	2% (over days)
✓	counting rate capability (peak rate)	>3.5 kHz/mm ² (lower limit) >60kHz / 30mm ² (lower limit)
✓	gamma-ray sensitivity	< 10 ⁻⁷ (with 100keV threshold)
✓	fast neutron sensitivity	< 10 ⁻⁵ (with 100keV threshold)
✓	gas gain	60-100
✓	overlap	50% eff. drop in 0.5mm gap

x3 better than state-of-the-art

>20 better than state-of-the-art

as good as state-of-the-art

x100 better than state-of-the-art

The Multi-Blade detector for the ESTIA@ESS

Requirements for reflectometry at PIK - SONATA instrument



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	Required design*	MB version 1 (including readout system)	MB version 2 (detector only)
Sensitive area	400 × 400 mm ²	100 × 130 mm ²	400 × 260 mm ²
Spatial resolution	2 × 2 mm ²	0.5 × 3.5 mm ²	
Overall count rate	1 MHz	> 100 MHz (depending n scattering pattern)	
Count rate per pixel	50 kHz	13 kHz/mm ² @10% deadtime 50 kHz/px _{equivalent}	
Efficiency (@ 2 Å)	40%	~ 44% (measured @ 2.5Å)	

- ✓ x3-4 better than state-of-the-art
- ✓ x20 better than state-of-the-art
- ✓
- ✓

* Communication with Evgeniy Altyntbaev

Requirements for radiography at PIK



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	Required design*	MB version 1 (including readout system)	MB version 2 (detector only)
Sensitive area	100 × 100 mm ²	100 × 130 mm ²	400 × 260 mm ²
Spatial resolution	0.1 × 0.1 mm ²	0.5 × 3.5 mm ²	
Overall count rate	1 MHz	> 100 MHz (depending n scattering pattern)	
Count rate per pixel	100 kHz	13 kHz/mm ² @10% deadtime 50 kHz/px _{equivalent}	
Efficiency (@ 2 Å)	40%	~ 44% (measured @ 2.5Å)	
Gamma sensitivity	10 ⁻⁷	< 10 ⁻⁷ (with 100 keV threshold)	



x3-4 better than
state-of-the-art



x20 better than
state-of-the-art



as good as
state-of-the-art

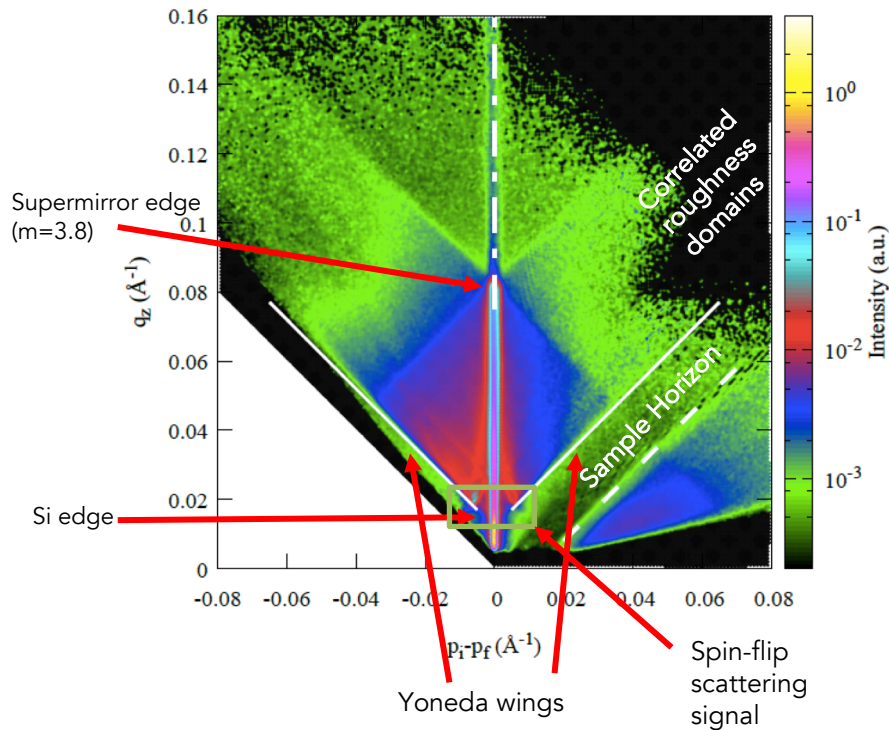


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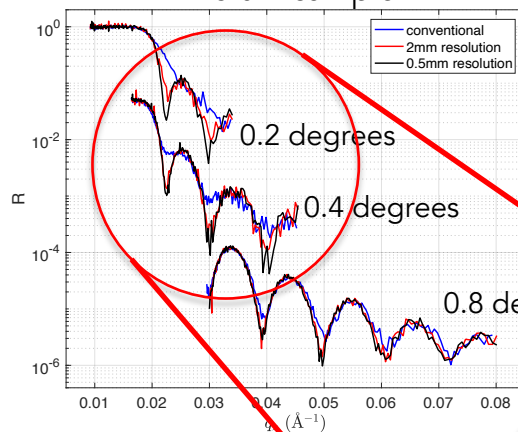
We could look at how much we can increase the resolution, maybe 0.2 mm × 1 mm ...?

Some scientific results

Off-specular scattering from Fe/Si neutron supermirror
Measure with the MB detector



Iridium sample

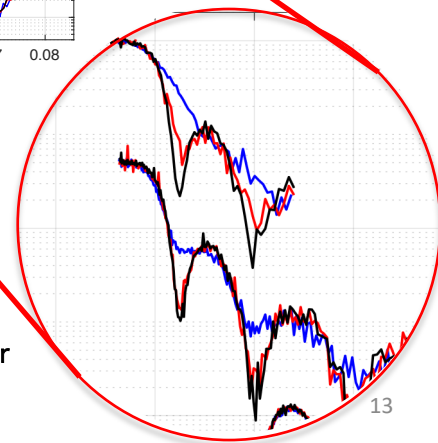


CRISP@ISIS

conventional 0D detector

2mm resolution detector

0.5mm resolution MB detector



The Multi-Blade detector:

- A well-understood Ar/CO₂-filled MWPC with solid ¹⁰B₄C converter
- Detector design with a decade worth of optimisation
- Already tested at reflectometers at ISIS and PSI
 - Already produced scientific data
 - Will be installed at AMOR next week

- Ready to set the new State-of-the-Art in reflectometry
- Ready to support world leading science

- G. Mauri et al., The Multi-Blade Boron-10-based neutron detector performance using a focusing reectometer, JINST 15 P03010 (2020).
- F. Piscitelli et al., Characterization of the Multi-Blade 10B-based detector at the CRISP reflectometer at ISIS, JINST 13 P05009 (2018).
- G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).
- G. Mauri et al., Fast neutron sensitivity of neutron detectors based on boron-10 converter layers. JINST 13 P03004 (2018).
- F. Piscitelli et al., The Multi-Blade Boron-10-based Neutron Detector for high intensity Neutron Reflectometry at ESS, JINST 12 P03013 (2017).
- F. Piscitelli et al. Study of a high spatial resolution ^{10}B -based thermal neutron detector for neutron reflectometry: the Multi-Blade prototype, JINST 9 P03007 (2014).

Thank you for your
attention!

