Multi-Blade

Wigner Research Institute

EUROPEAN SPALLATION SOURCE

LUND UNIVERSITY

Linköping University

Multi-Blade Detector for **Neutron Reflectometry** at ESS: results obtained at the CRISP reflectometer at ISIS and current status

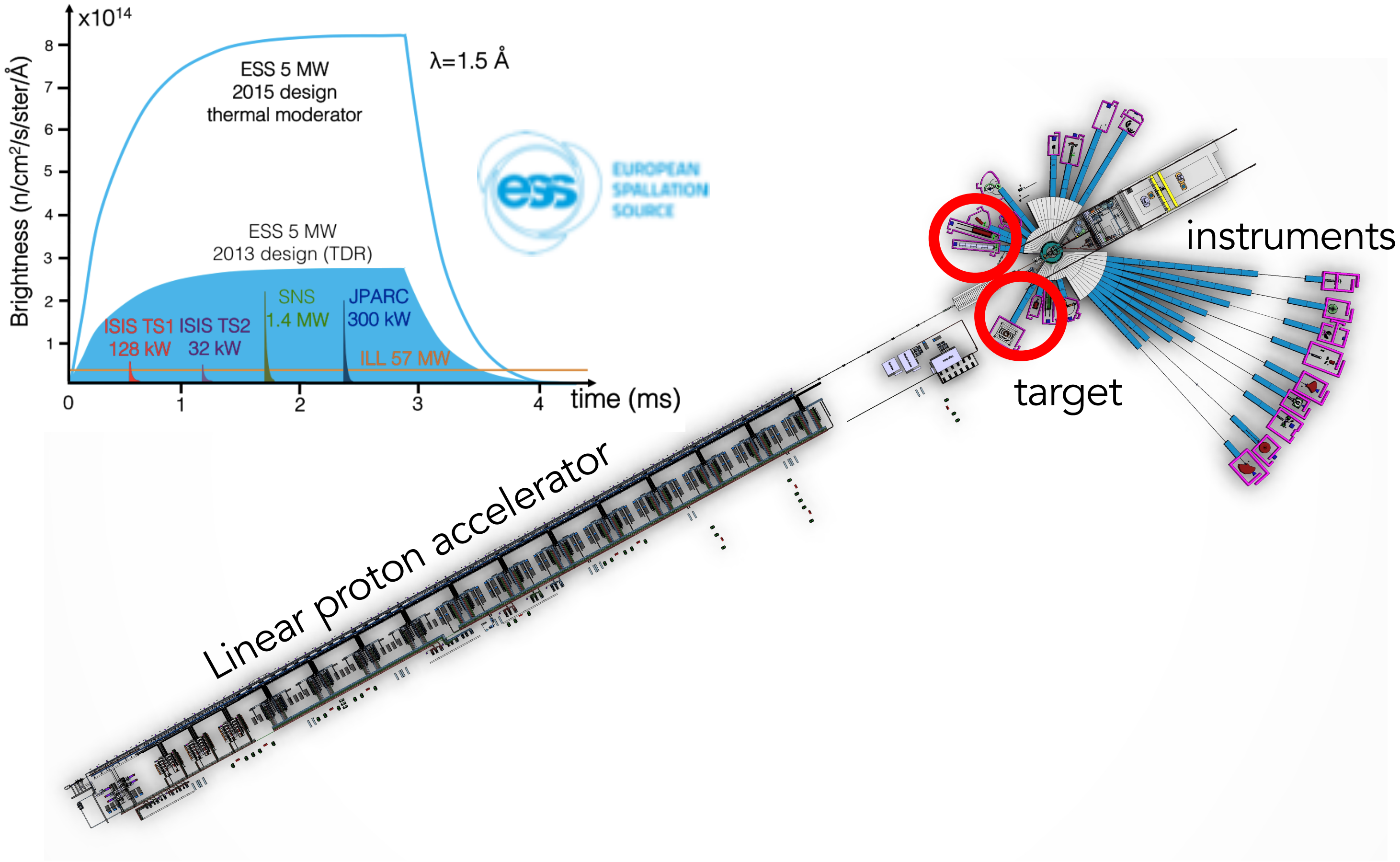
Francesco Piscitelli
on behalf of
ESS / Wigner / Lund University / Linköping University collaboration

IKON15 Lund

2018/09/11

brightness

Building research infrastructure and synergies for highest scientific impact on ESS

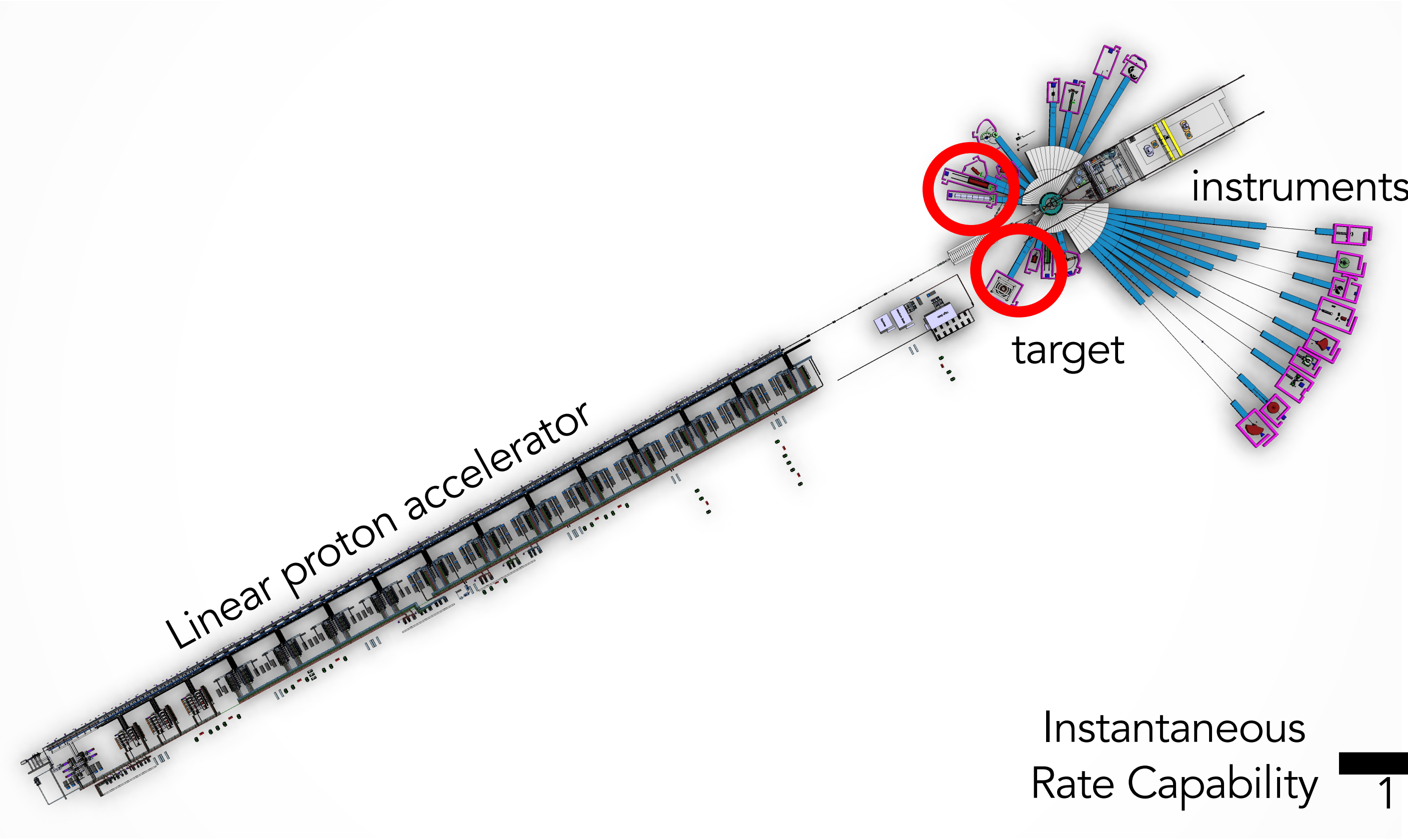


2 Reflectometers:

FREIA horizontal refl.

Estia vertical refl.

Introduction

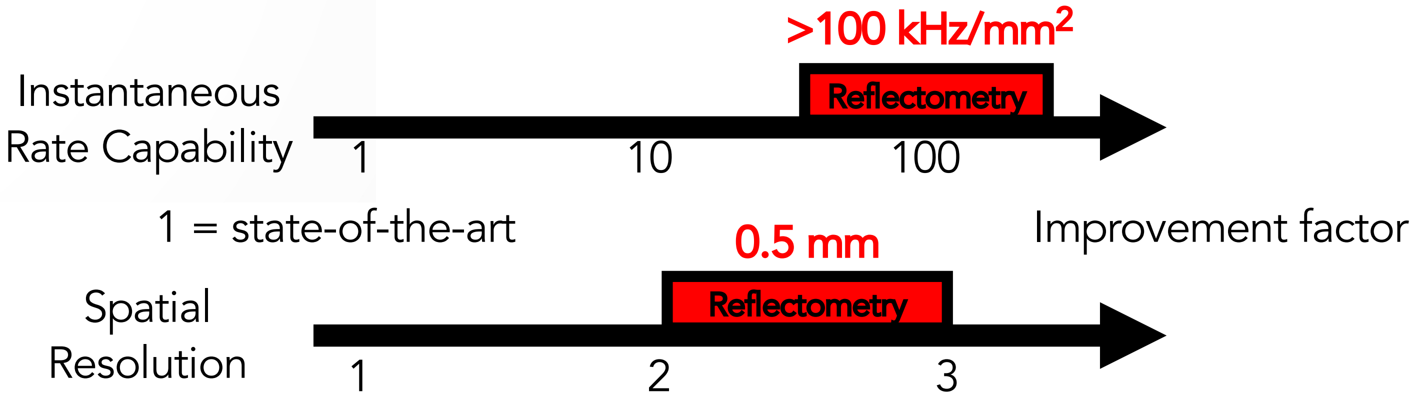


2 Reflectometers:

FREIA horizontal refl.

Estia vertical refl.

High detector requirements



Multi–Blade

^{10}B-detector for reflectometers

Introduction: the Multi-Blade project

Multi–Blade

^{10}B-detector for reflectometers

BrightnESS

European Spallation Source

Lund University

Wigner Research Institute

Linköping University

3 years

The key objective of WP4 is the technological evolution of neutron detectors in terms of resolution, intensity and dimensions.

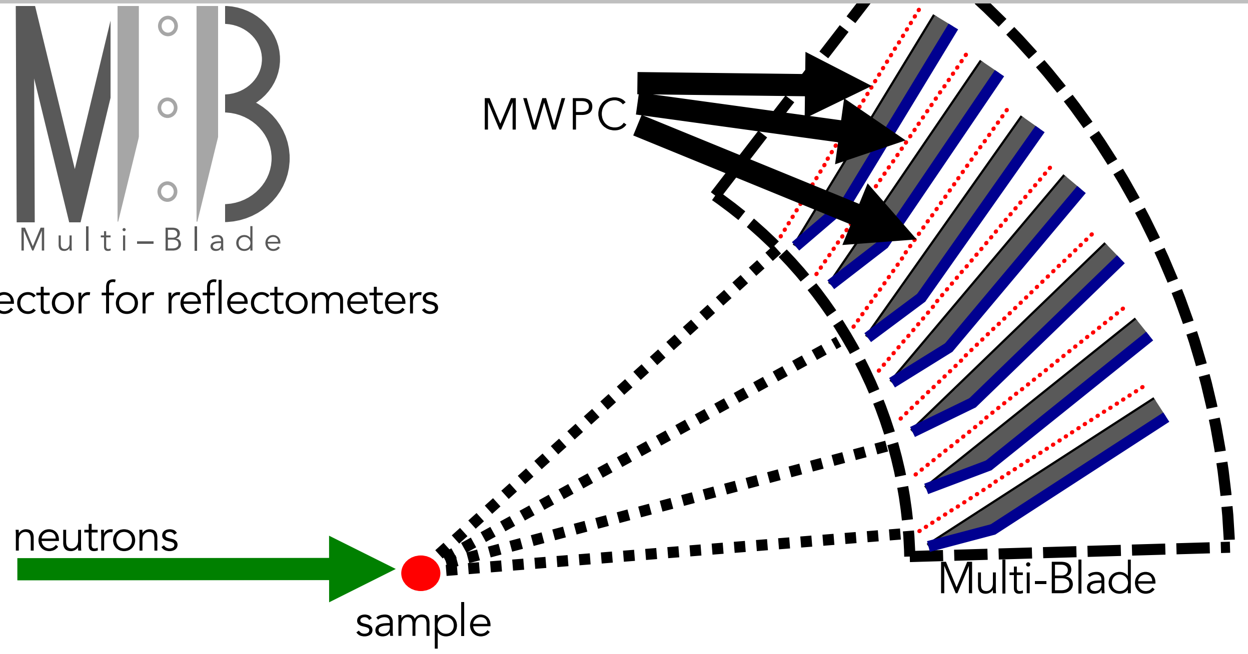
Task 4.2 Neutron Detectors – The Intensity Frontier

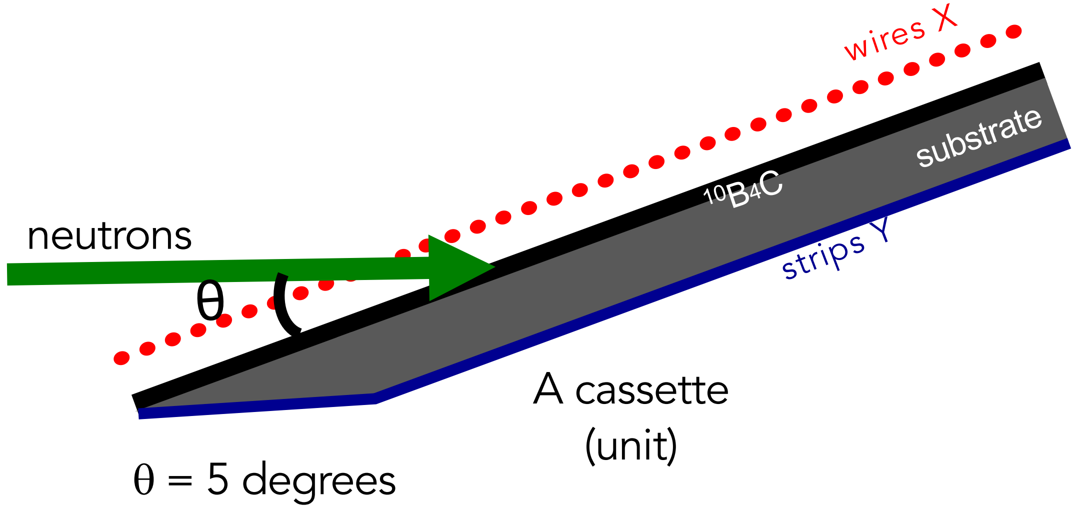
High counting rate capability

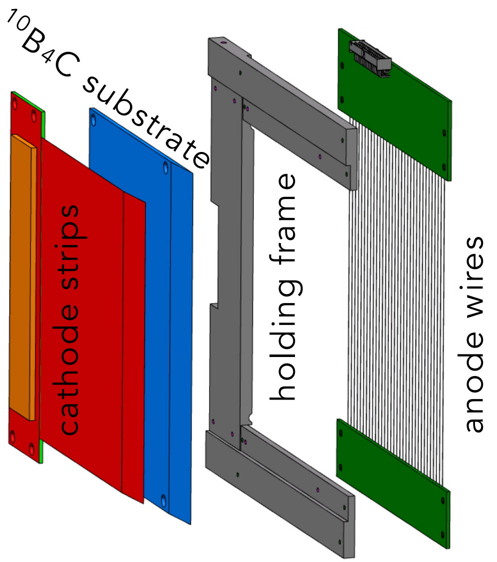
High spatial resolution

Multi–Blade

^{10}B-detector for reflectometers

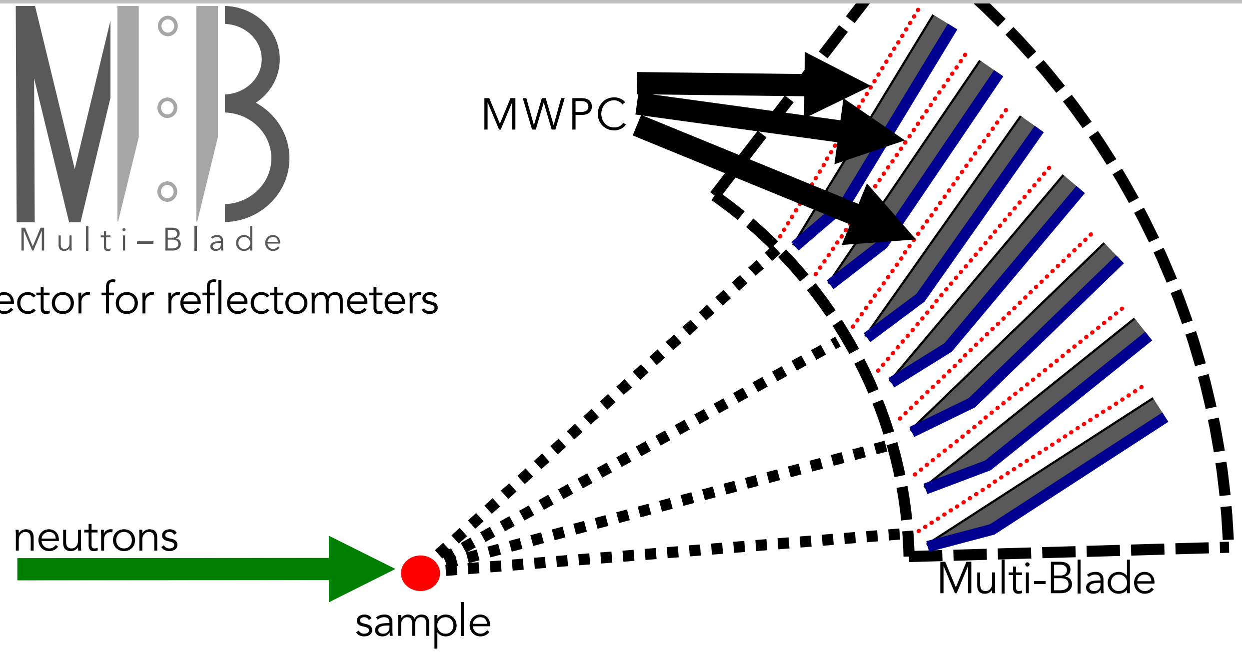


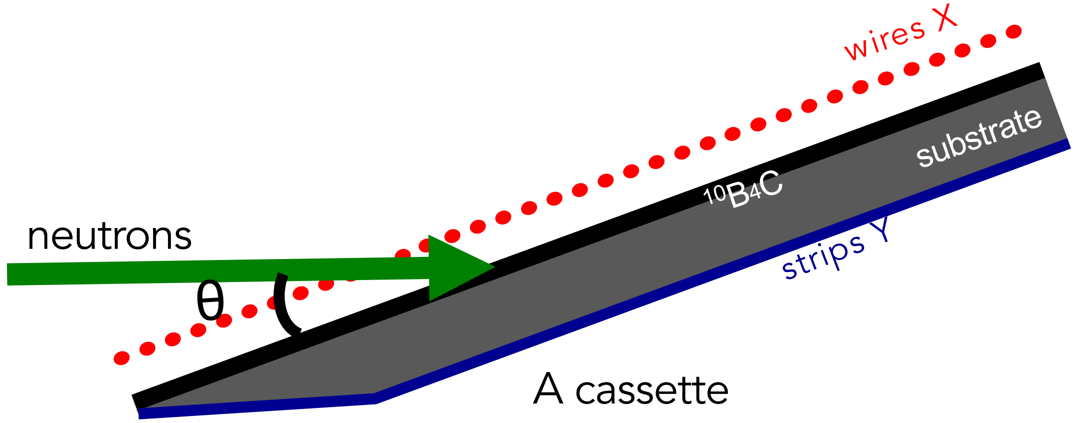


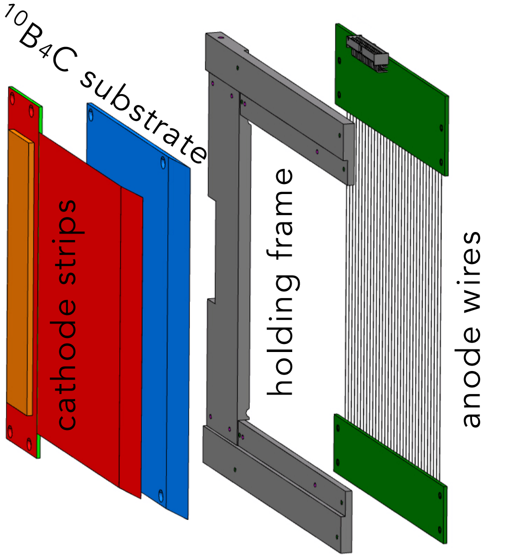


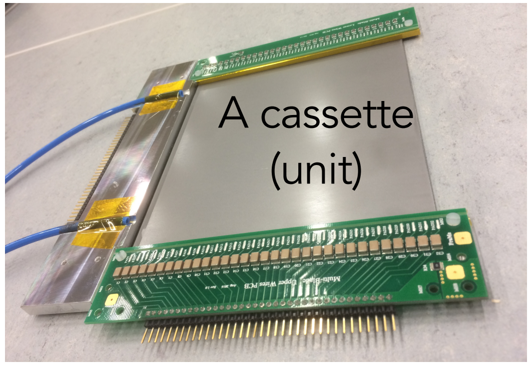
Multi-Blade

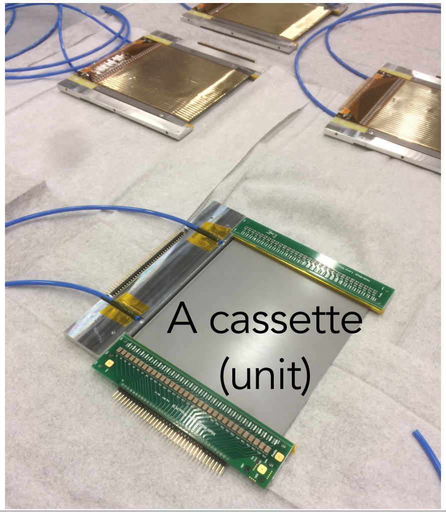
^{10}B-detector for reflectometers





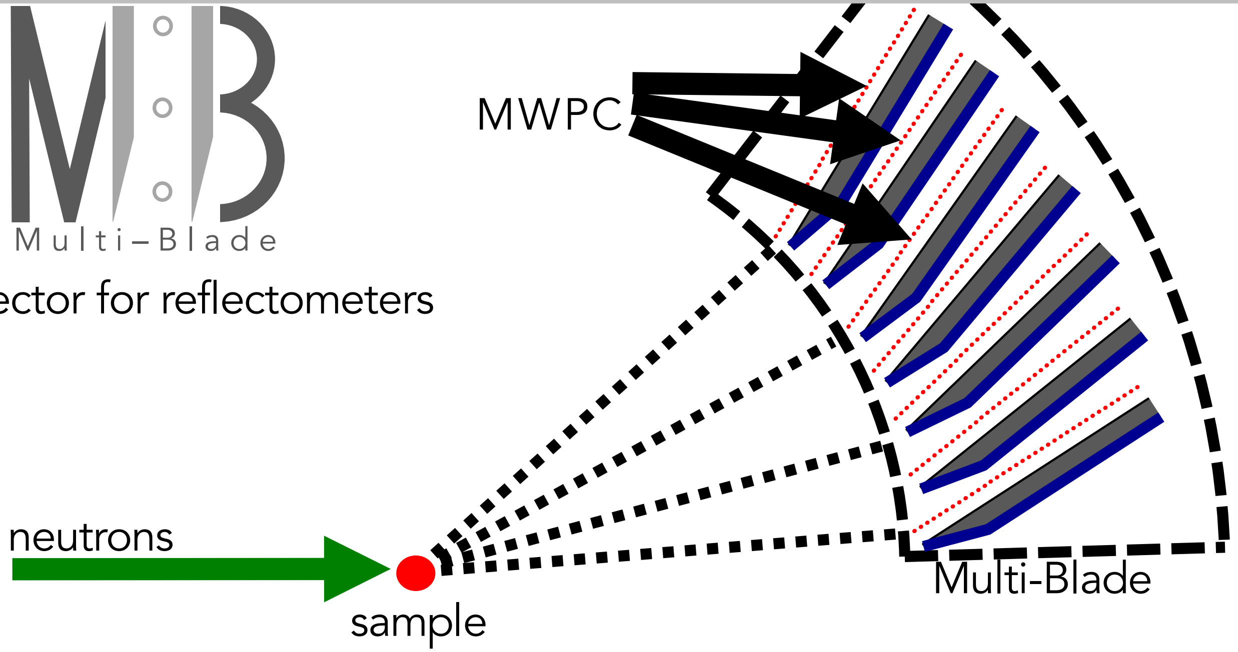


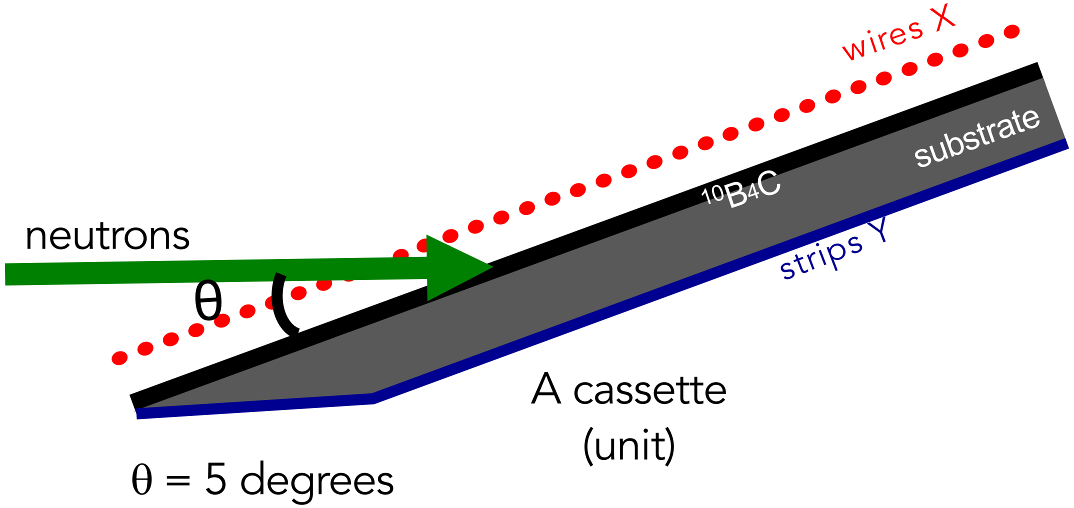


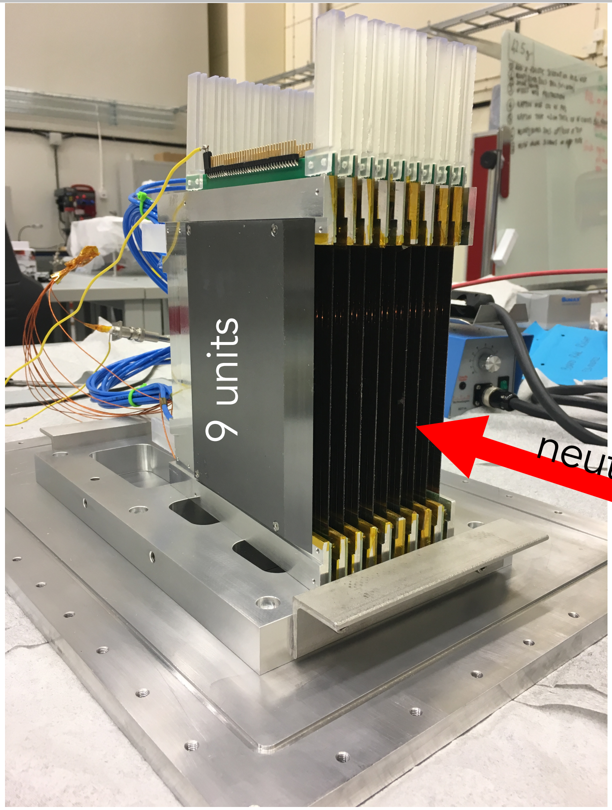


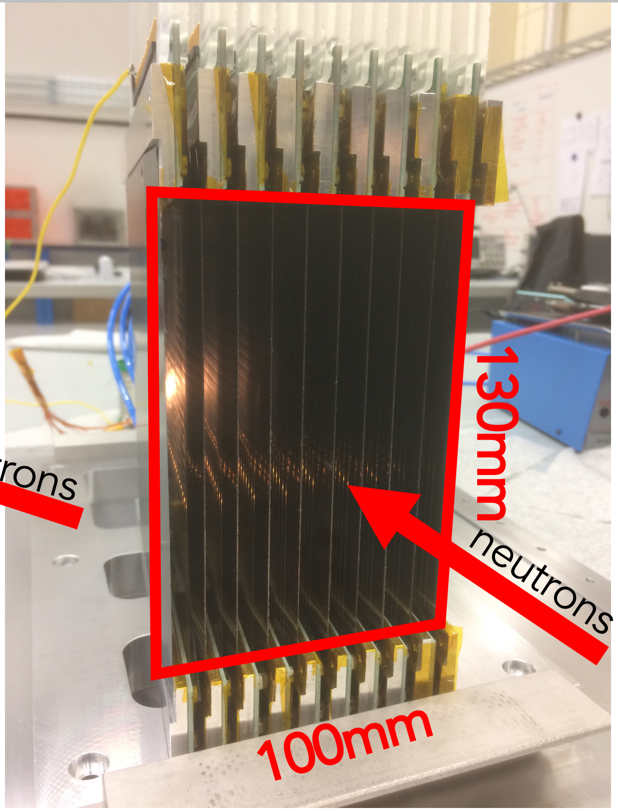
Multi-Blade

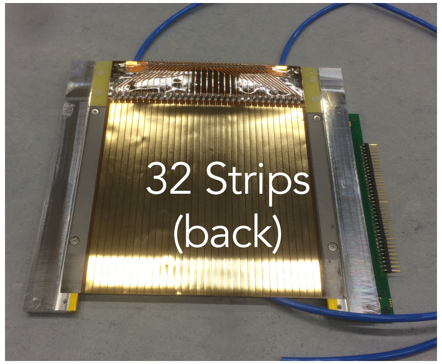
^{10}B-detector for reflectometers

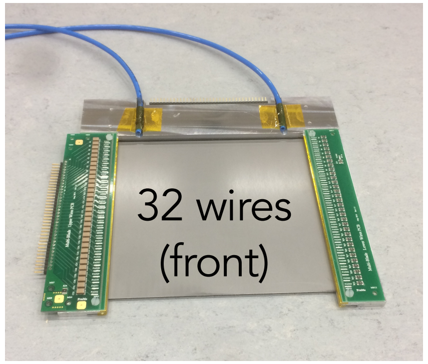




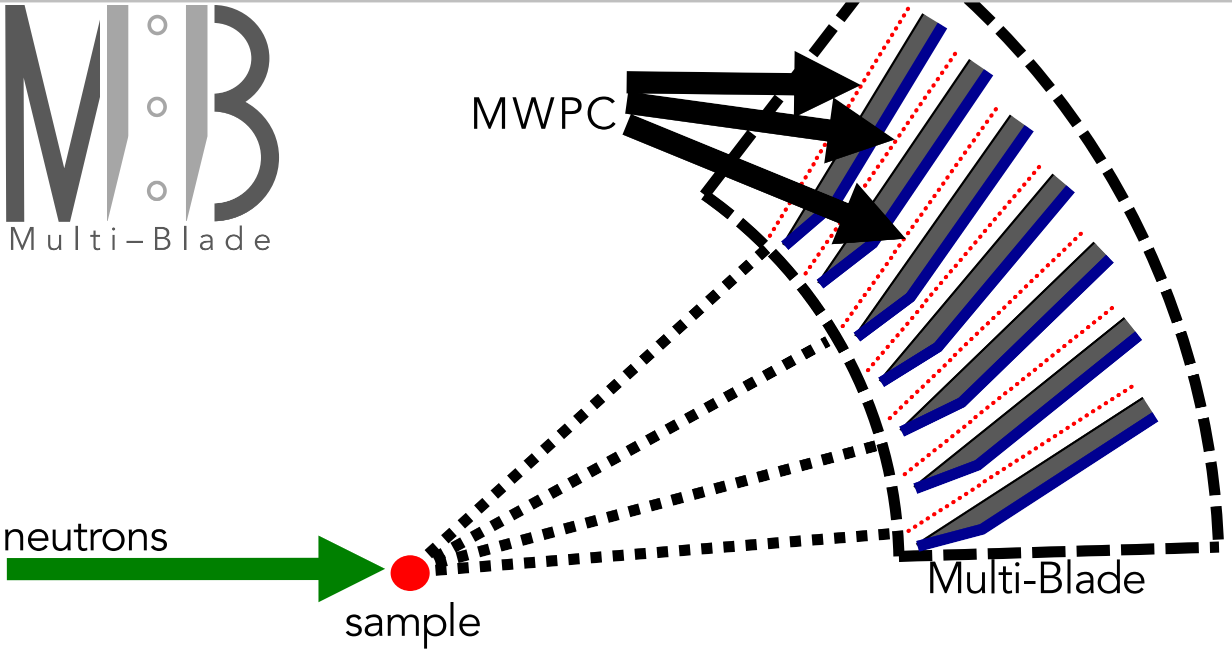

9 units
neutrons

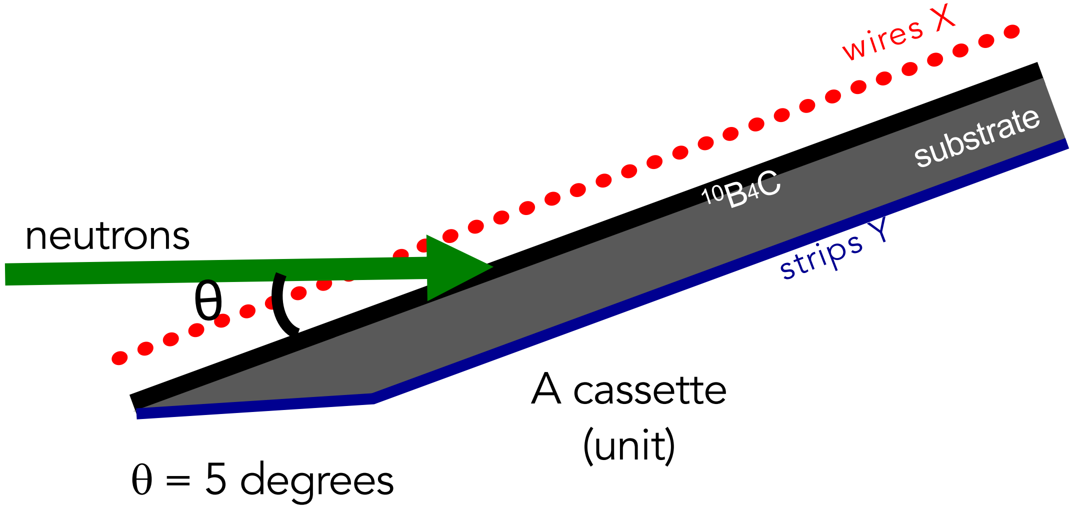

130mm
neutrons
100mm


32 Strips
(back)

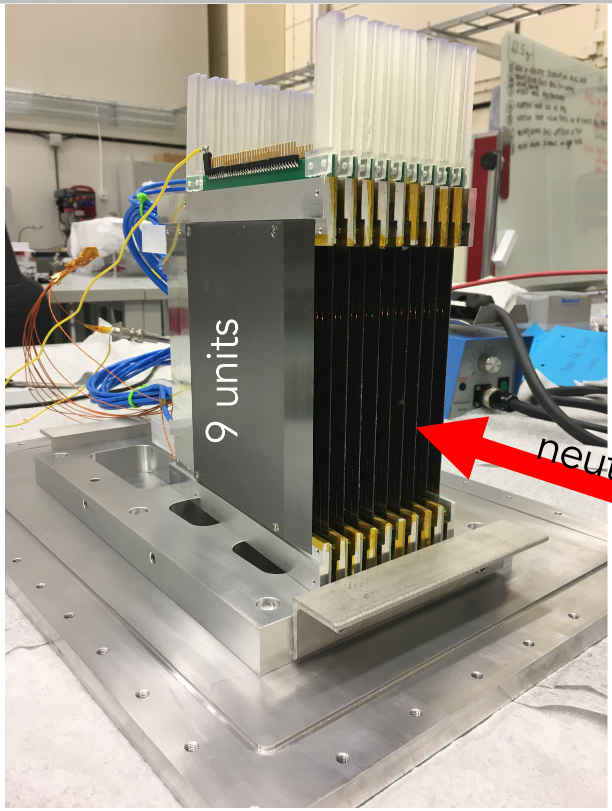

32 wires
(front)

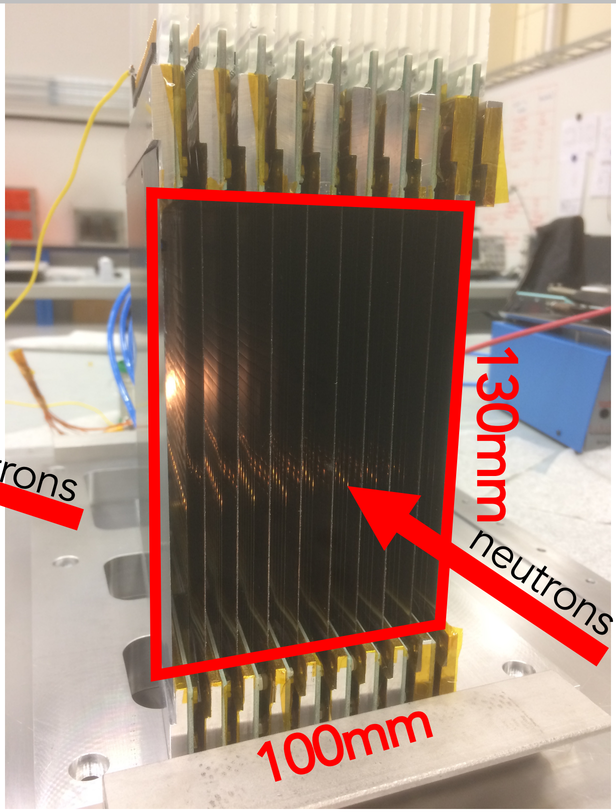
Multi–Blade

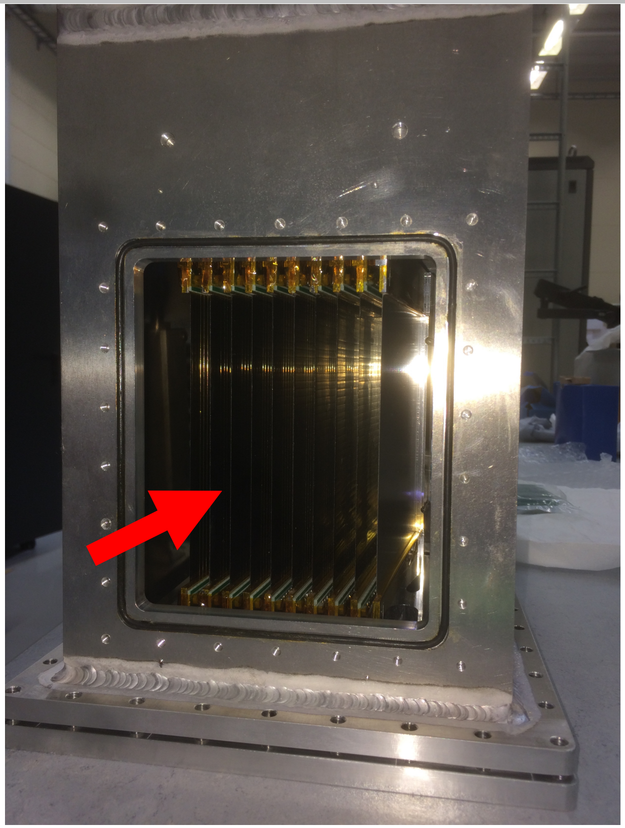

MWPC
neutrons
sample
Multi-Blade

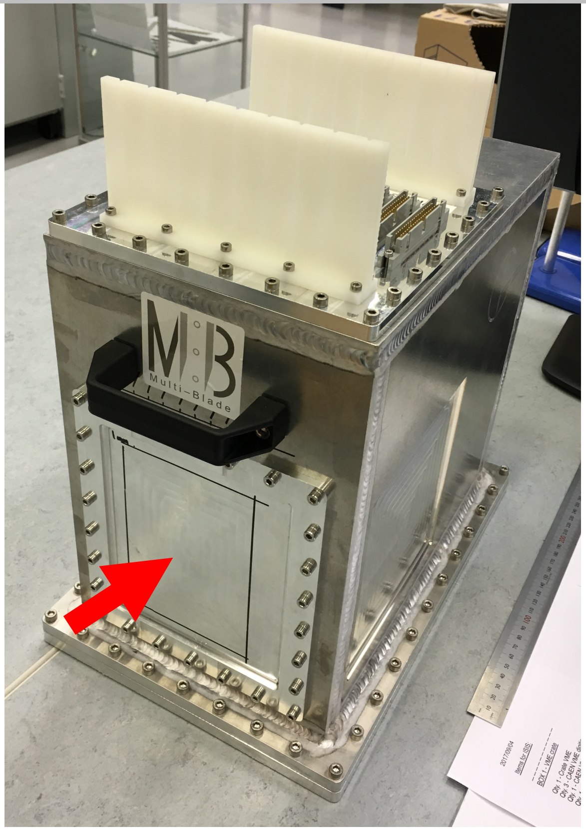

wires X
substrate
$^{10}B_4C$
strips Y
neutrons
θ
A cassette
(unit)
θ = 5 degrees

Introduction: the Multi-Blade project

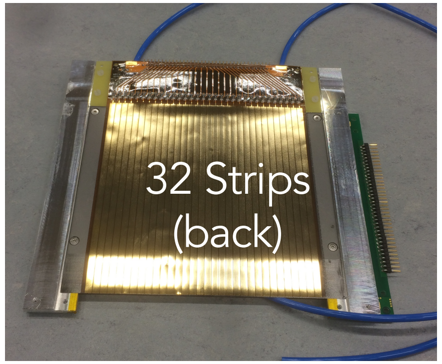


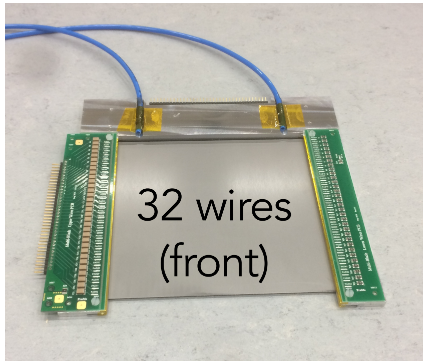




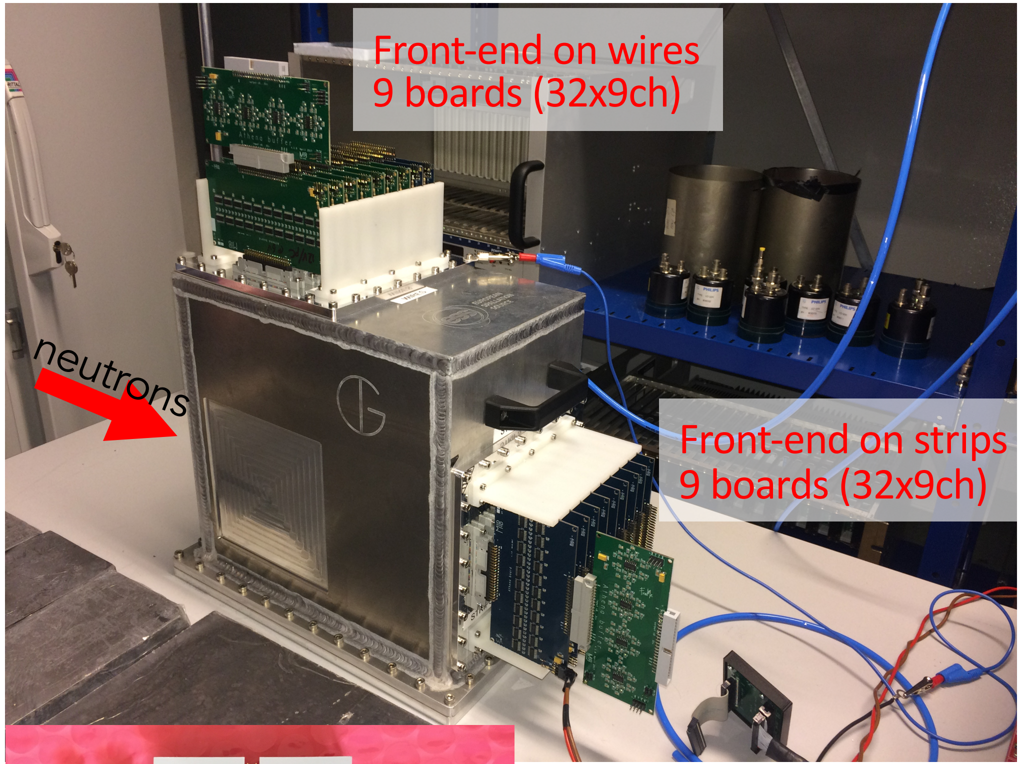


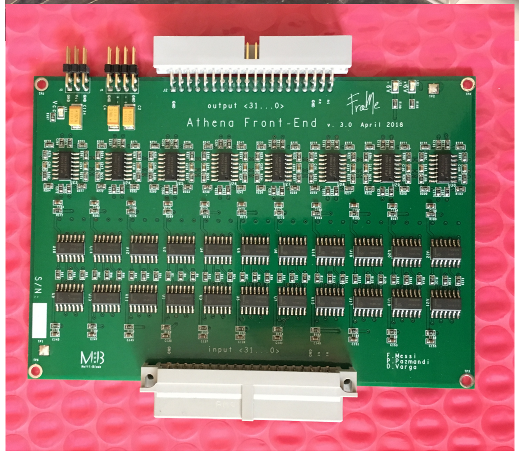
vessel

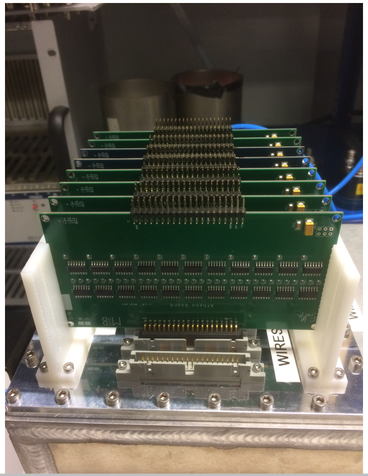


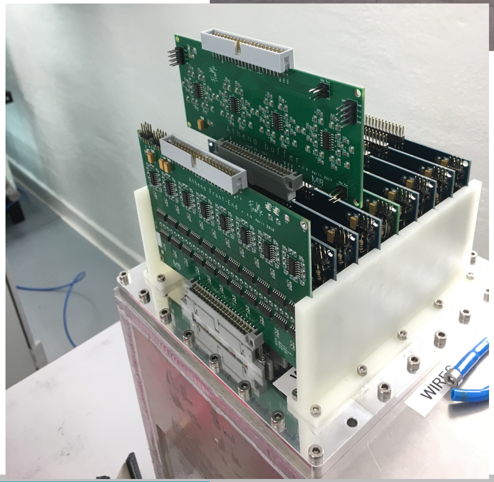


Readout electronics

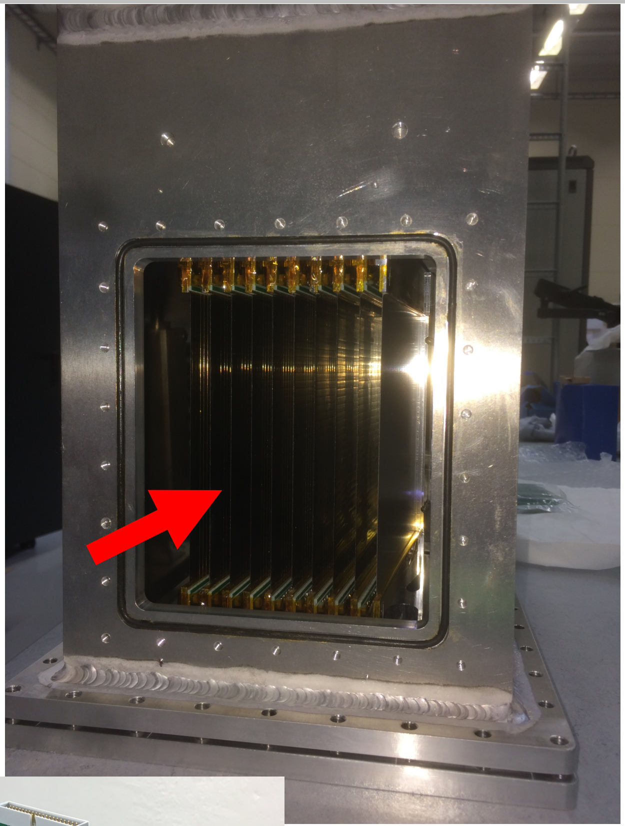


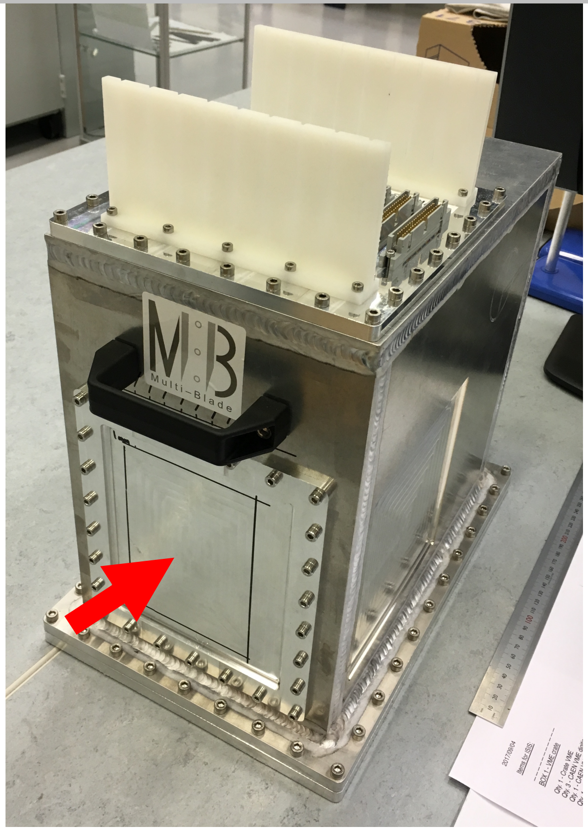






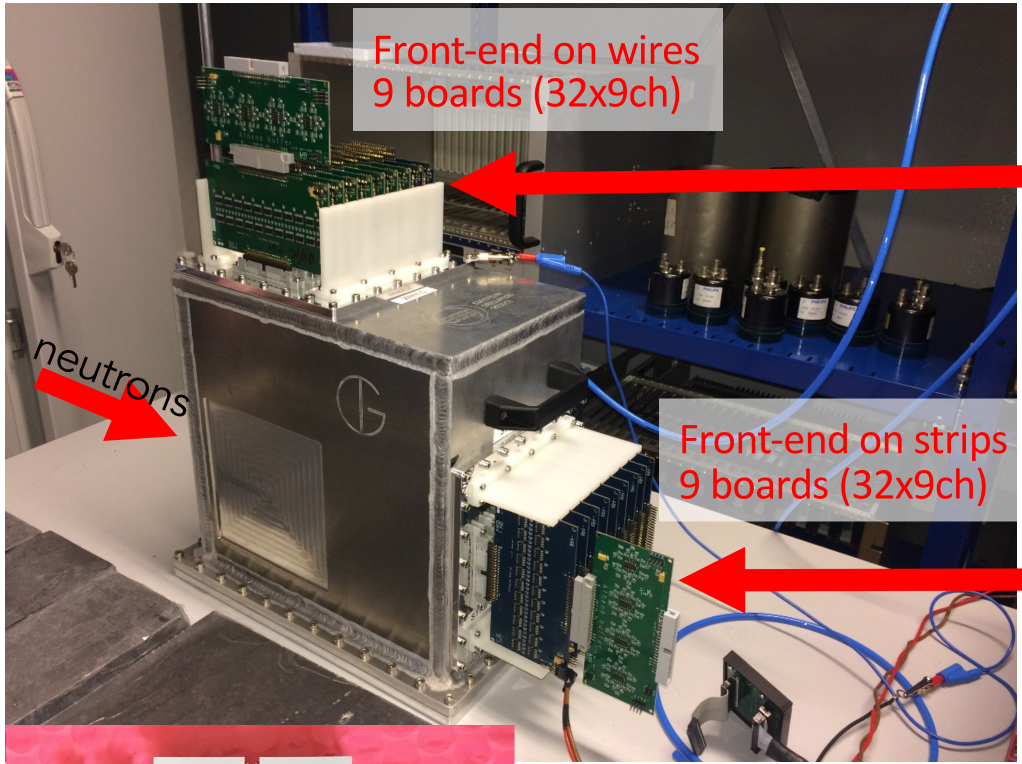
32ch front-end boards



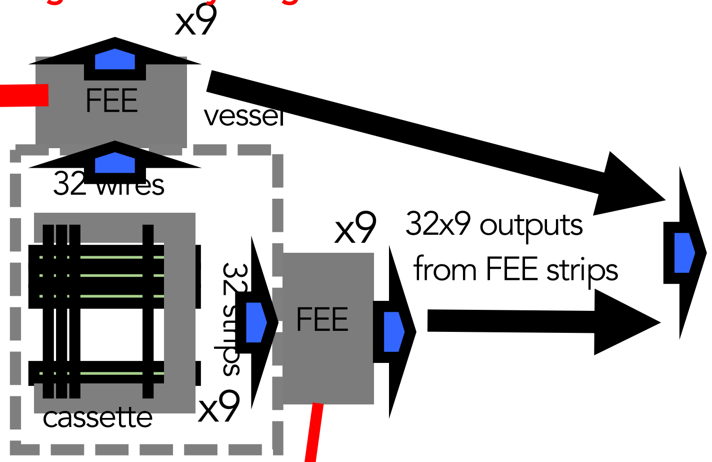


vessel

Readout electronics



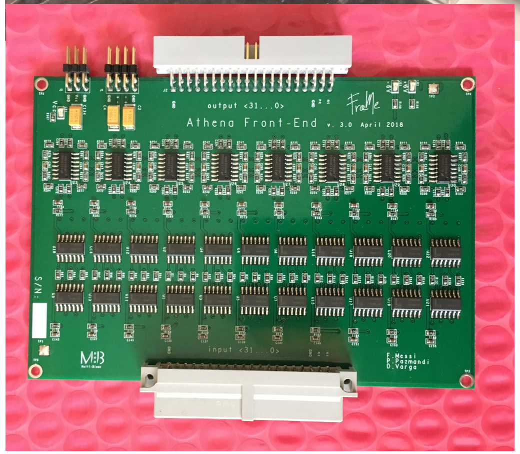
~600 ch electronics
Significantly large number of ch.



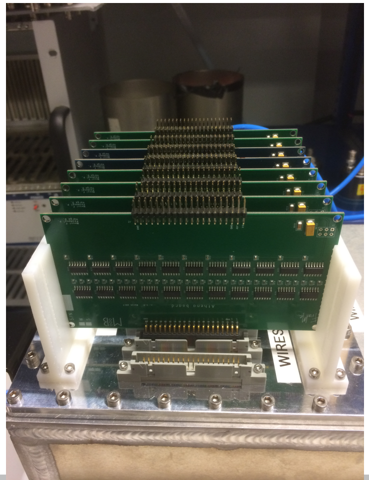
TTL for time stamp reset

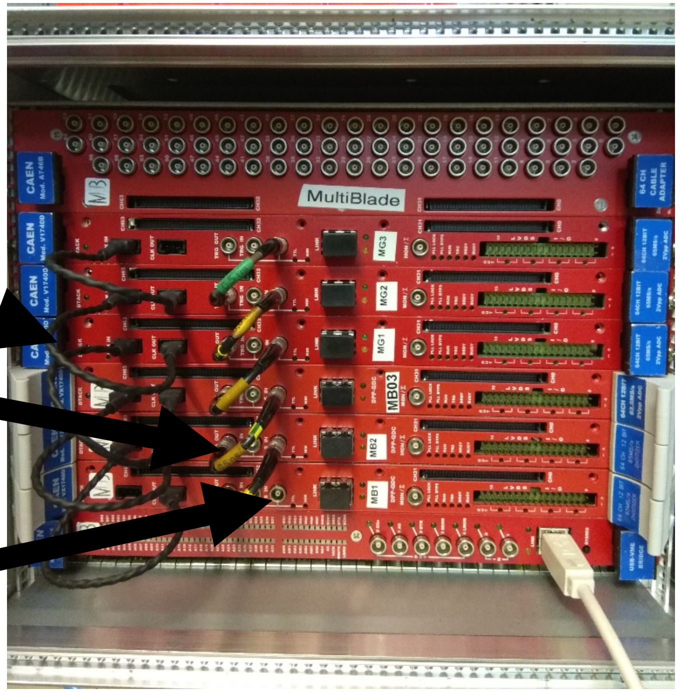
CAEN
V1740D

One Digitser (64ch is 1 cassette)



32ch front-end boards



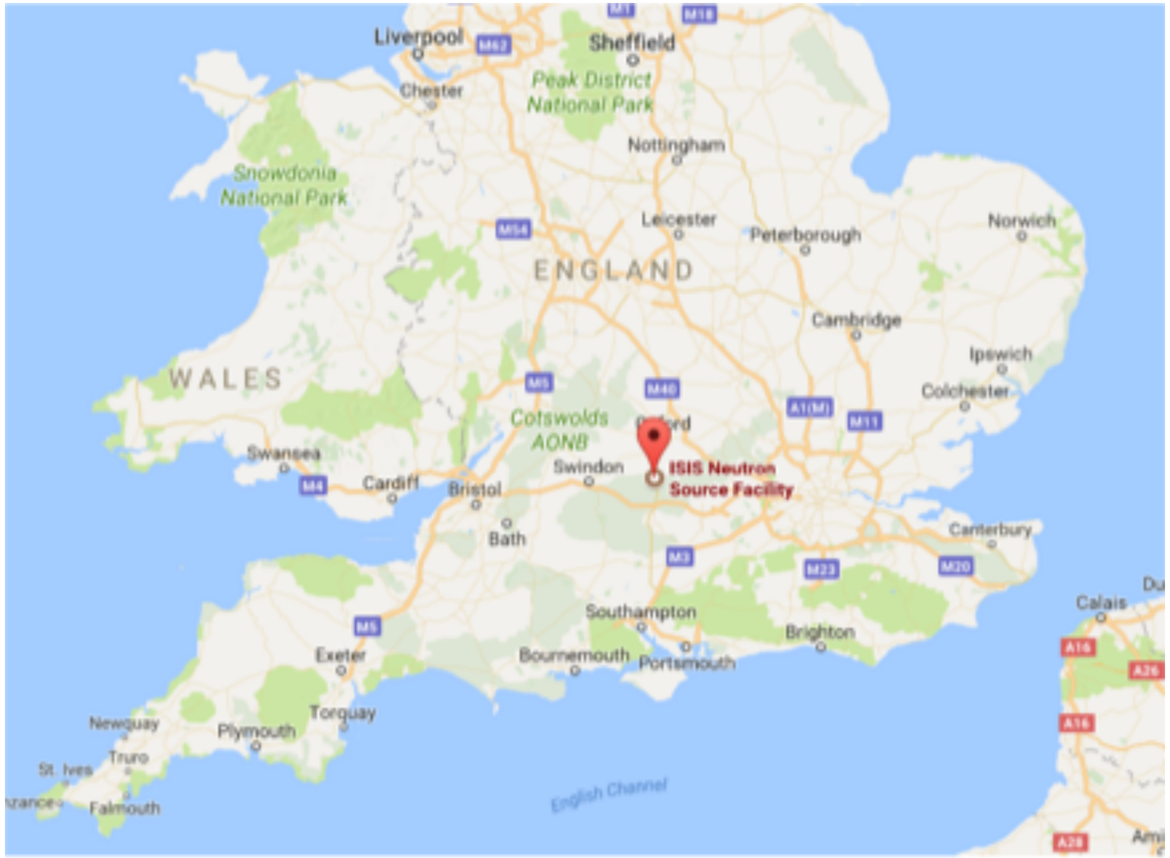


All digitisers (cassettes) share the same clock

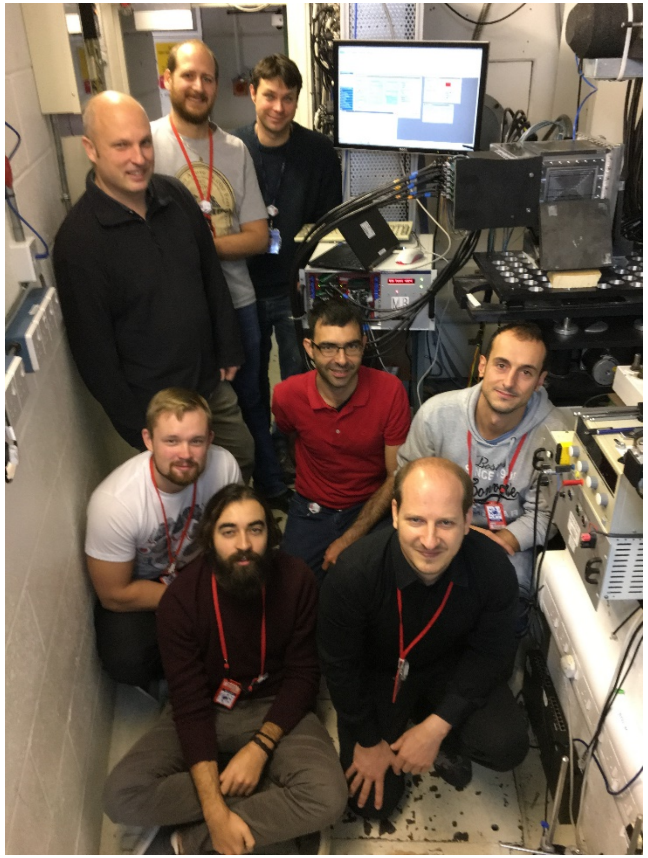
Sin-TRGout propagation, All units get the same time stamp reset

Time stamp reset according to an external TTL signal, i.e. chopper or proton pulse

Beam time on CRISP



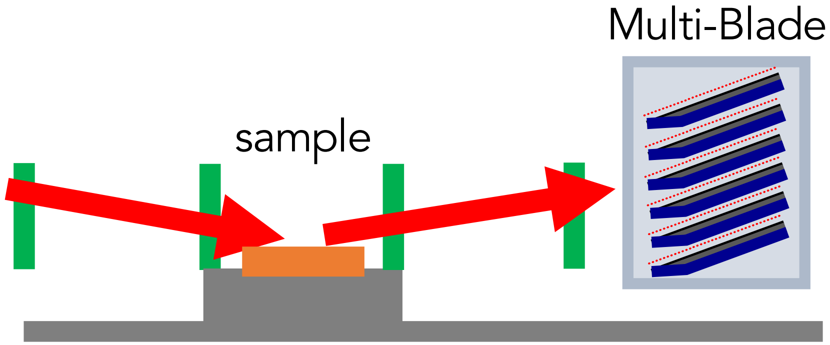
Science & Technology Facilities Council
ISIS



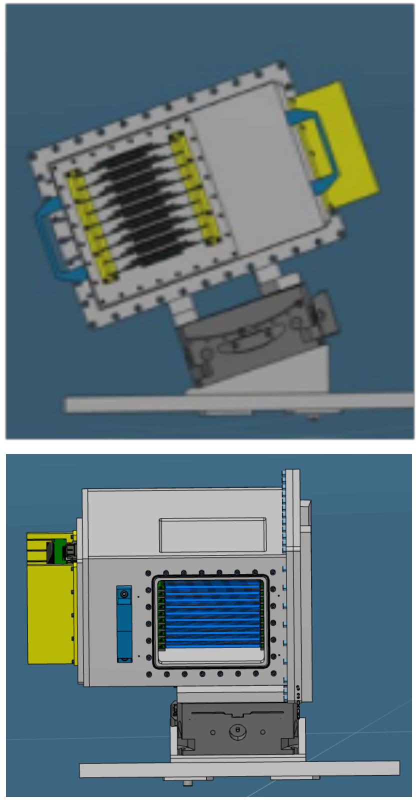
Artur Glavic (ESTIA)
And
Tom Arnold (FREIA)
with us during the tests

Tests performed 1st week of October 2017 on the CRISP reflectometer at ISIS

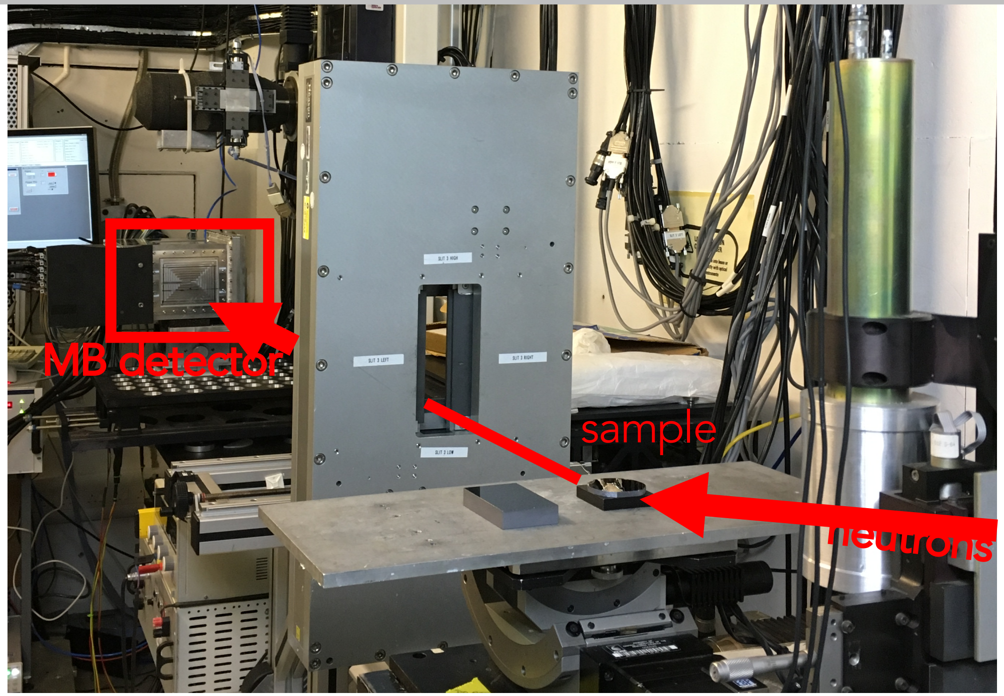
F. Piscitelli et al., Characterization of the Multi-Blade 10B-based detector at the CRISP reflectometer, JINST 13 P05009 (2018).

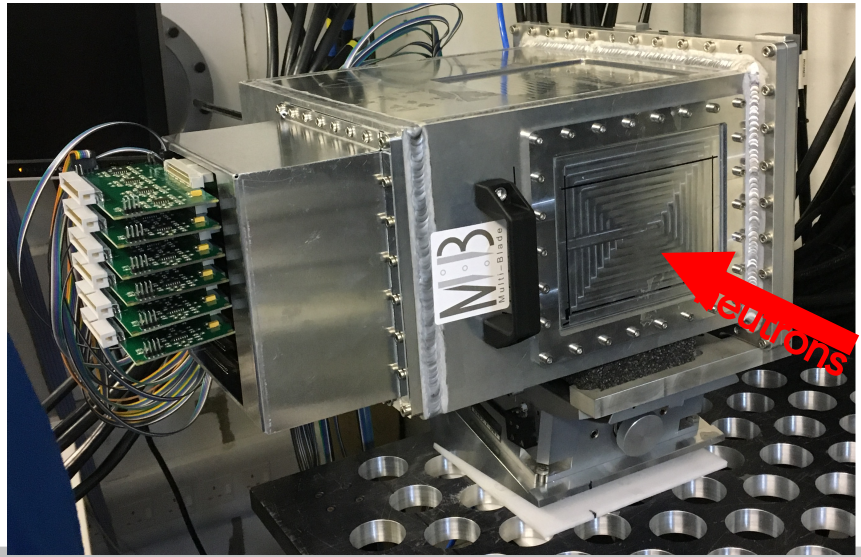


Thermal Neutron Reflectometer	@ TS1
Neutron wavelength	0.5 – 6.5 Å @ 50Hz (0.5 – 13 Å @ 25Hz)
q range	0.005 – 1.1 $Å^{-1}$
Moderator - sample distance	10.25m
Sample - Detector distance	1.87m
Sample - MB Detector distance	2.33m



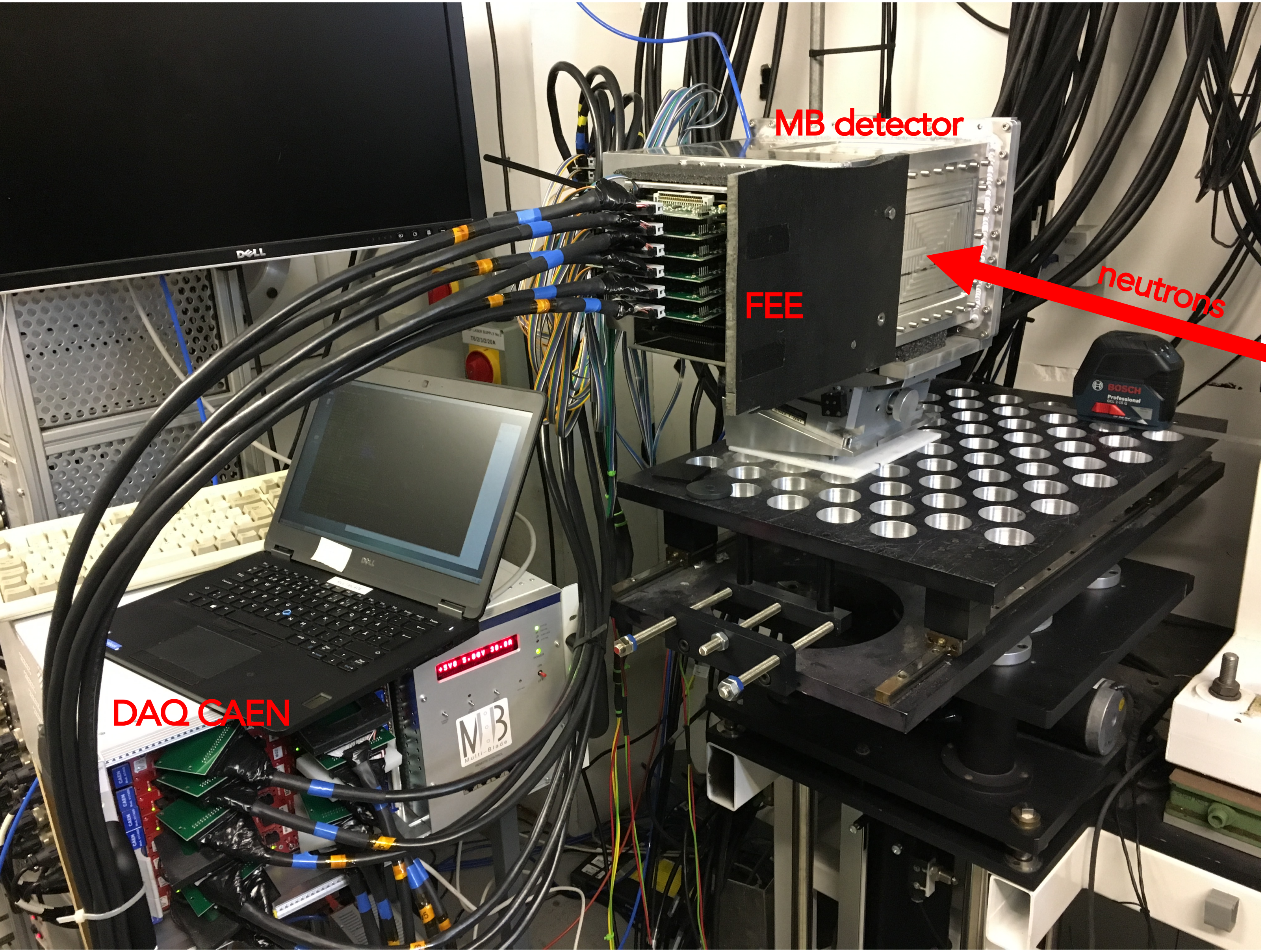
The cassette (units) are placed horizontally

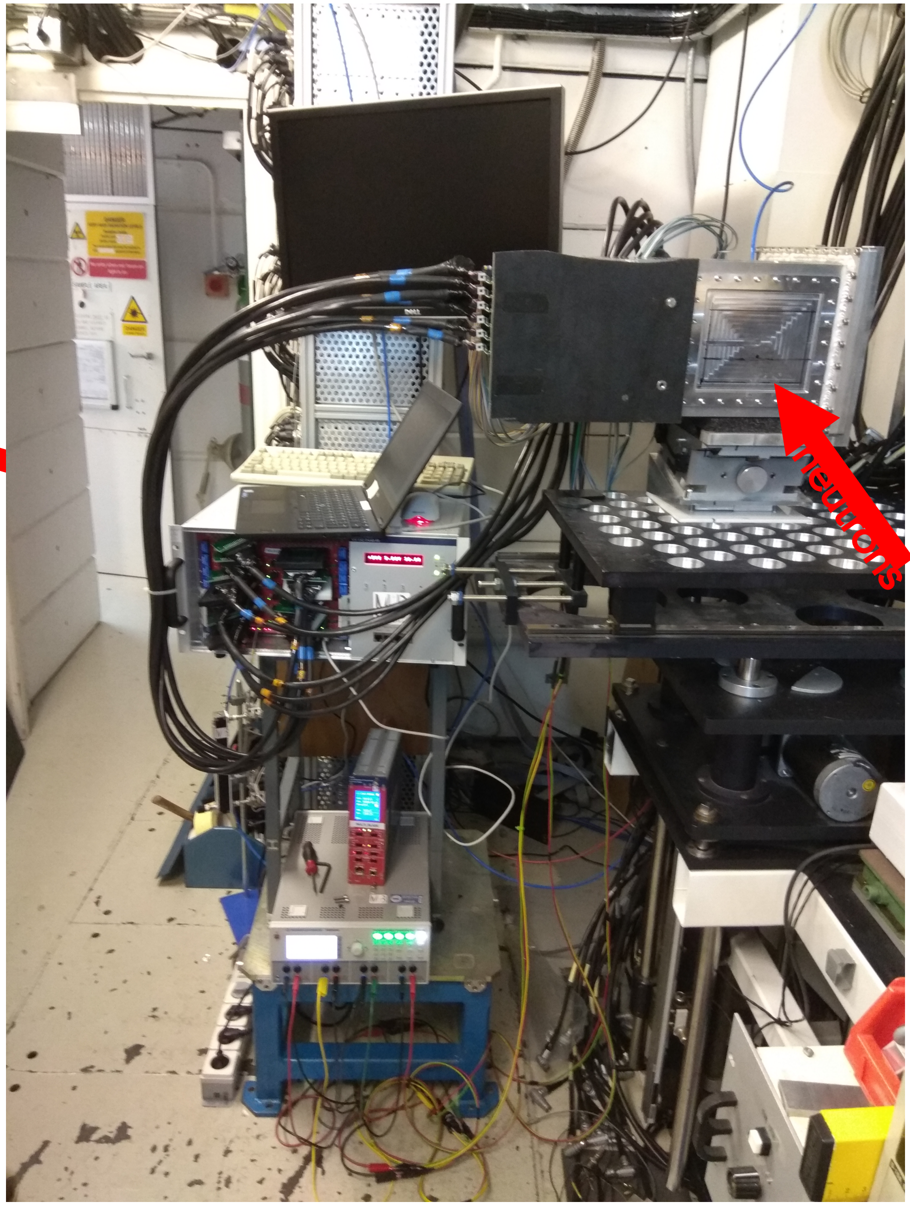




Beam time on CRISP

F. Piscitelli et al., Characterization of the Multi-Blade 10B-based detector at the CRISP reflectometer, JINST 13 P05009 (2018).





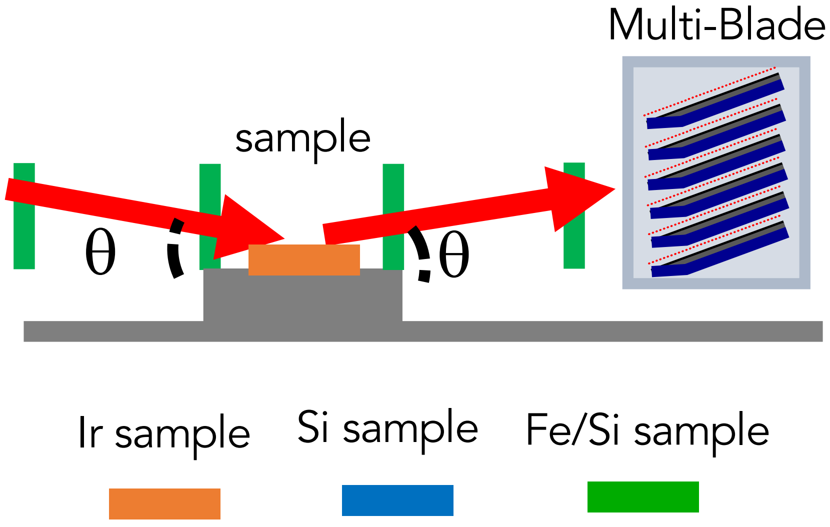
Multi-Blade

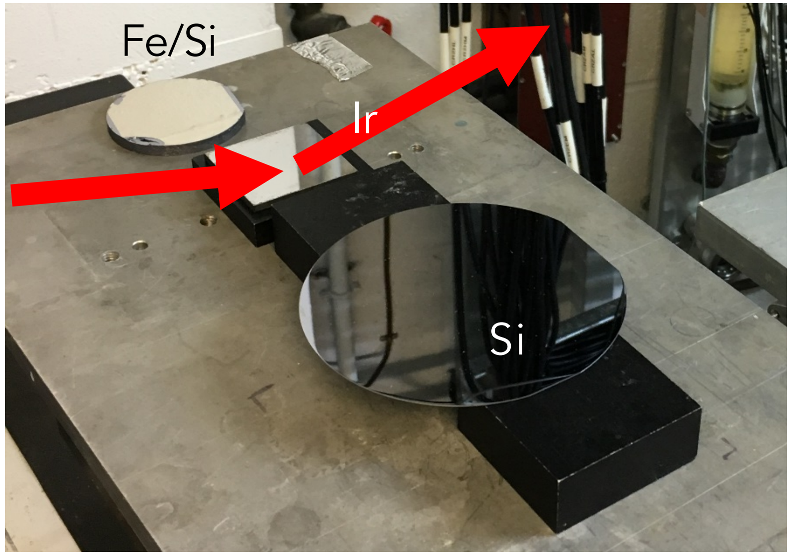
Matching ESS requirements

efficiency	45% @ 2.5Å 56% @ 4.2Å 65% @ 5.1Å	
spatial resolution	0.5 x 3.5 mm^2	x3 better than state-of-the-art
uniformity	10%	
stability	2%	
counting rate capability	>1.6 kHz/mm2 (lower limit) >17kHz / channel (lower limit)	x10 better than state-of-the-art
gamma-ray sensitivity	< 10^{-7} (with 100keV threshold)	as good as state-of-the-art
fast neutron sensitivity	< 10^{-5}	x100 better than state-of-the-art
gas gain	20	
overlap	50% eff. drop in 0.5mm gap	

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., 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. Study of a high spatial resolution ^{10}B-based thermal neutron detector for neutron reflectometry: the Multi-Blade prototype, JINST 9 P03007 (2014).

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).





- Iridium

Dependance of the q-resolution on detector spatial resolution

- Silicon

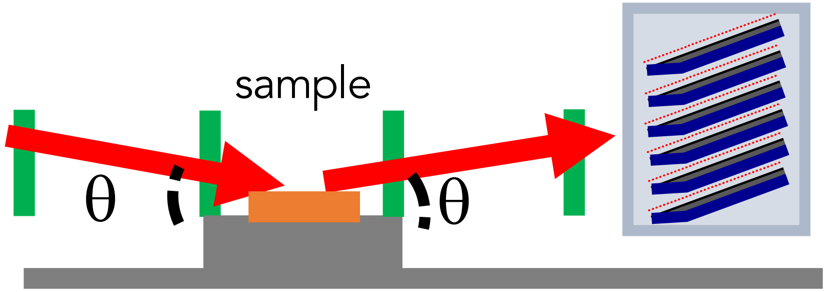
Collimated vs divergent mode (uniformity & spatial resolution)

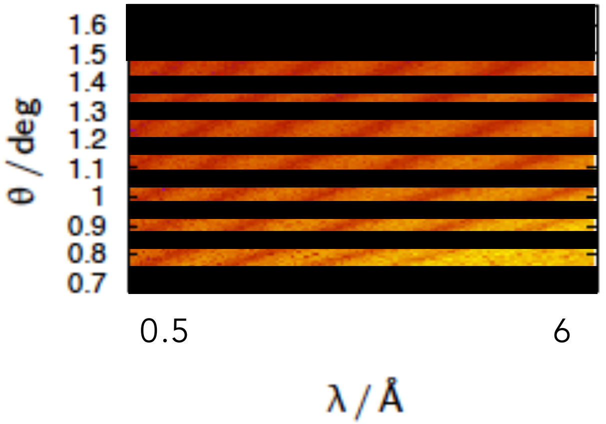
- Fe/Si supermirror

Off-specular (counting rate & uniformity & spatial resolution)

Scientific results from CRISP: Iridium

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

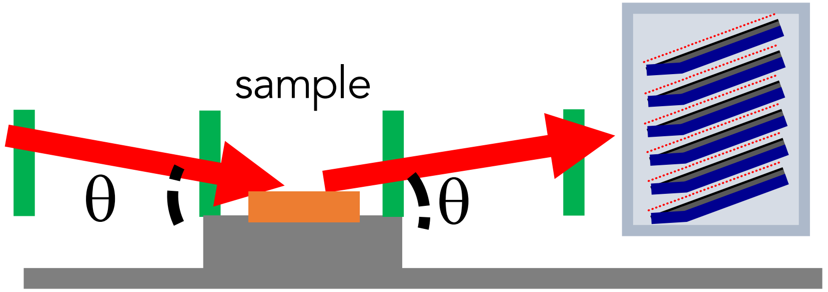




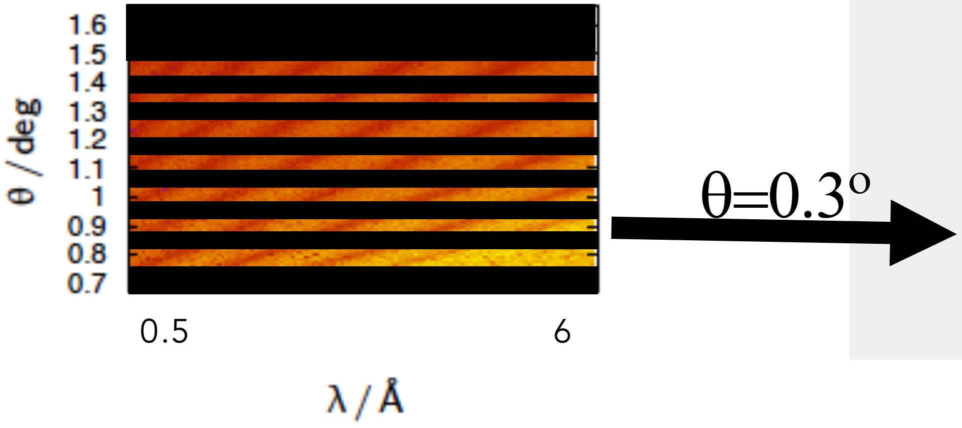
Scan in angle 0.2-0.8 deg

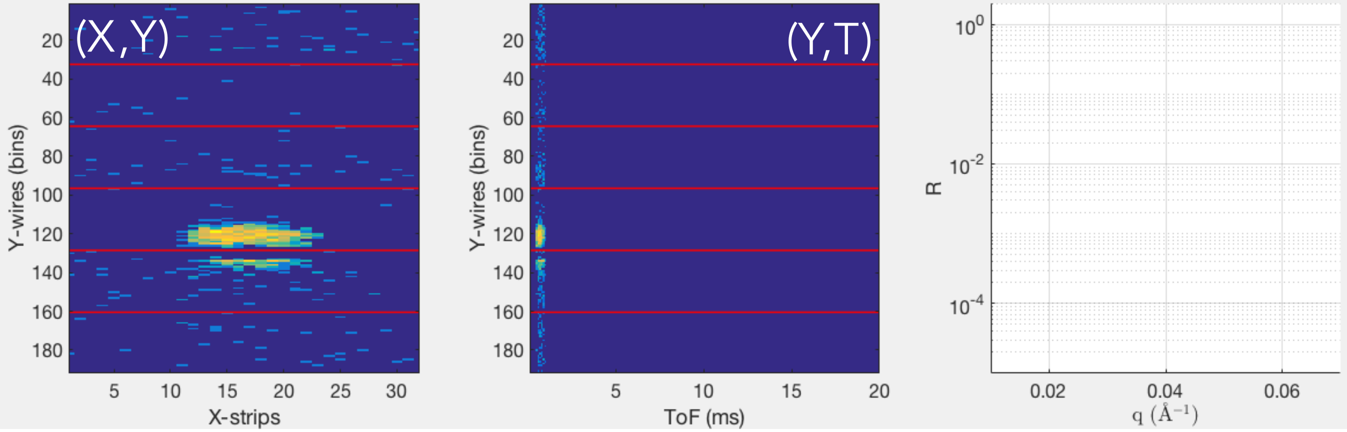
Scientific results from CRISP: Iridium

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



Ir sample
Si sample
Fe/Si sample

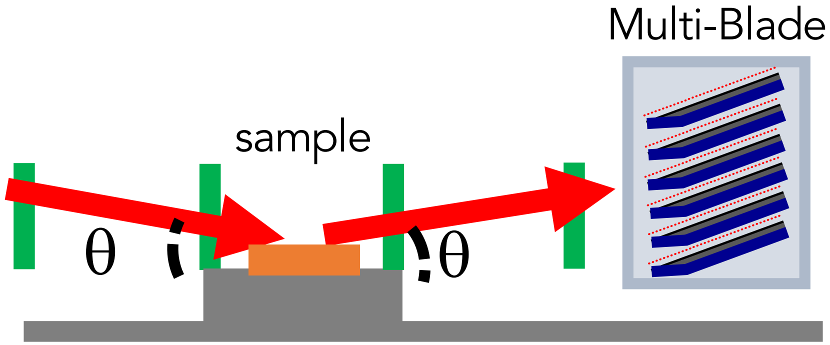




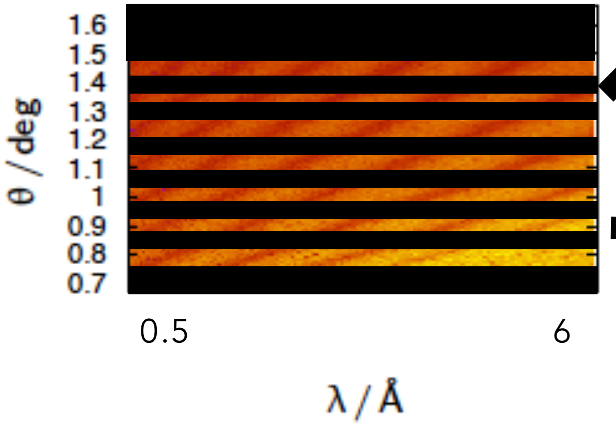
Scan in angle 0.2-0.8 deg

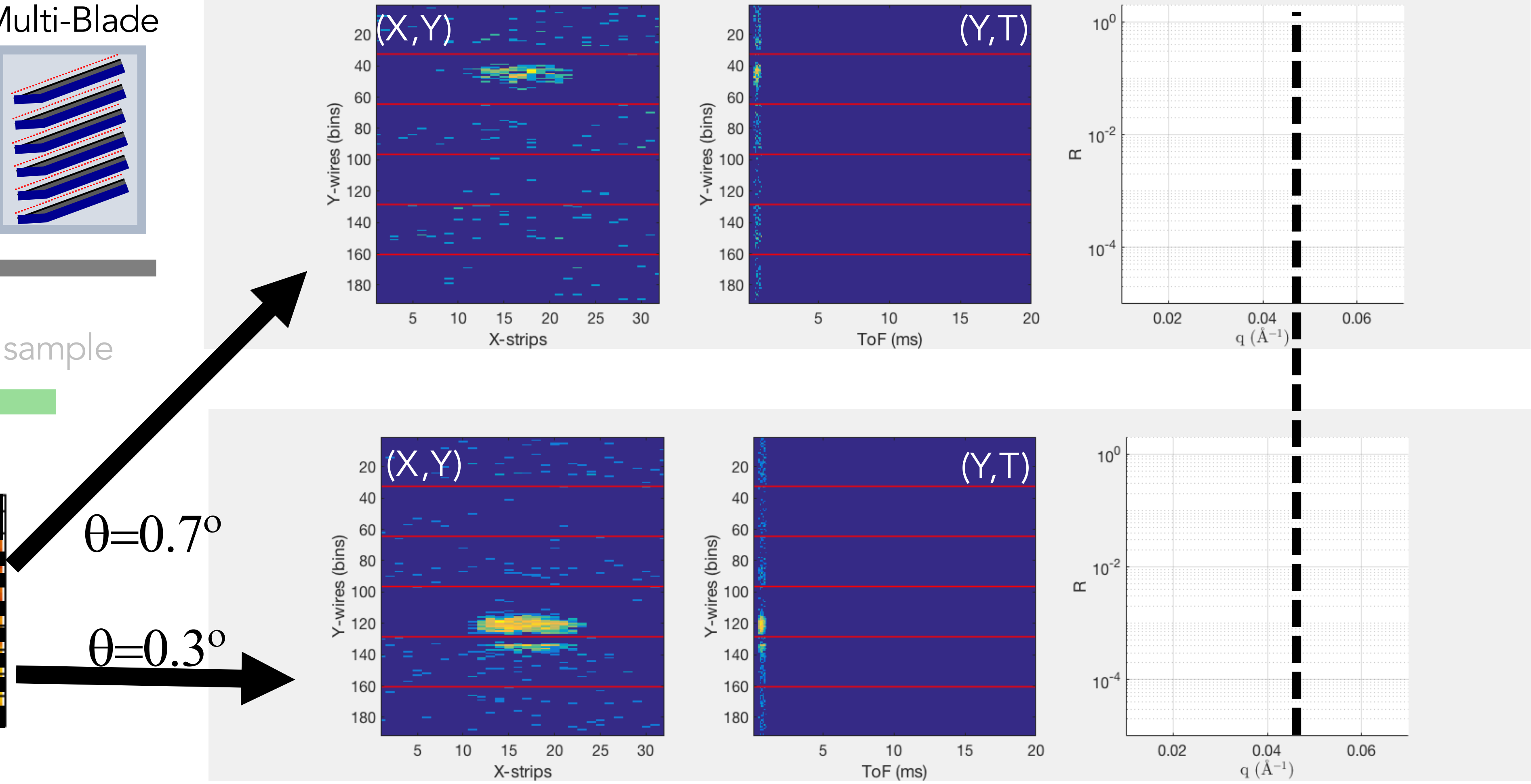
Scientific results from CRISP: Iridium

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



Ir sample
Si sample
Fe/Si sample

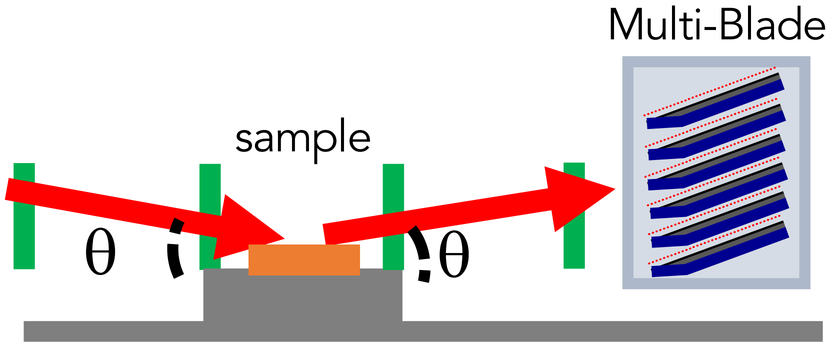


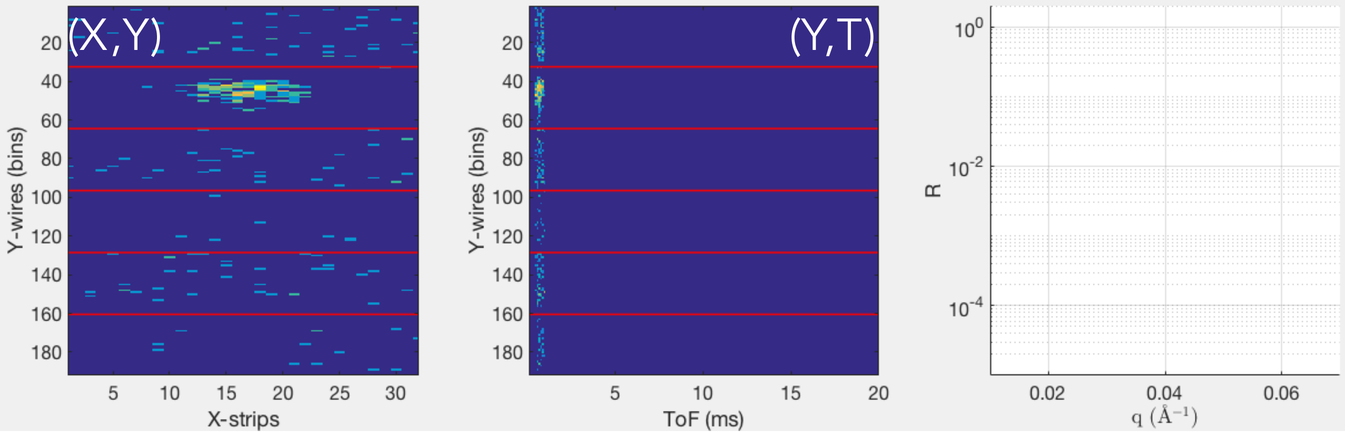


Scan in angle 0.2-0.8 deg

Scientific results from CRISP: Iridium

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

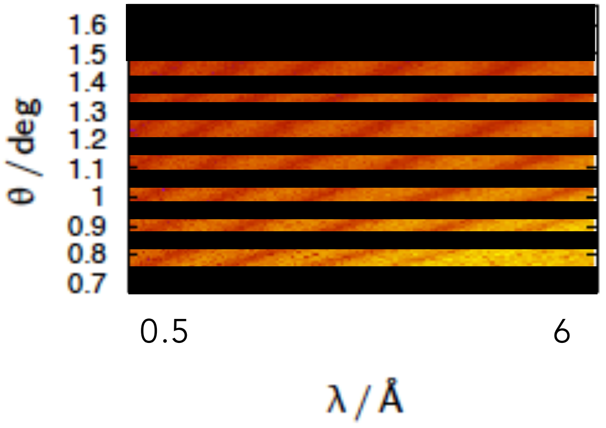




Ir sample

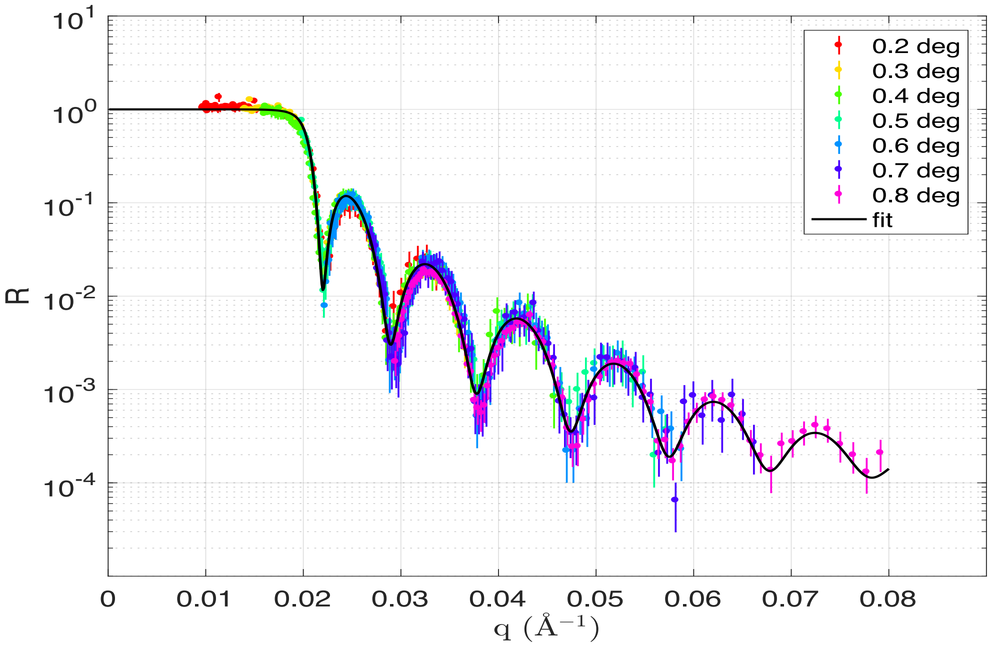
Si sample

Fe/Si sample



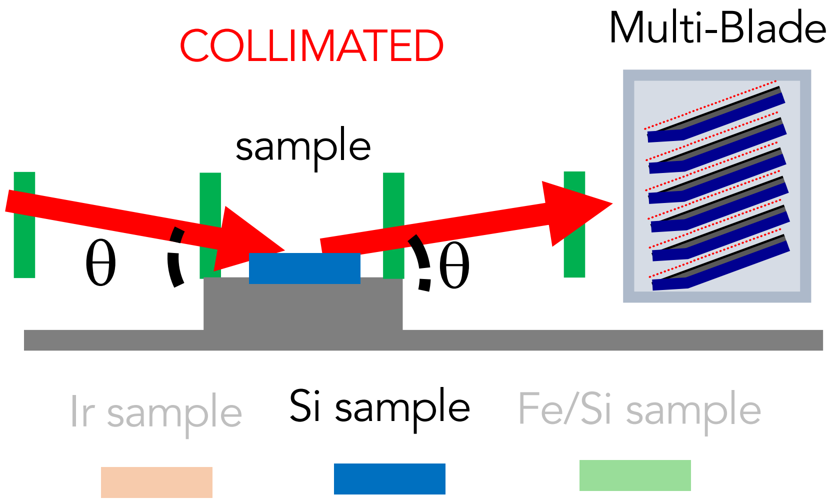
Scan in angle 0.2-0.8 deg

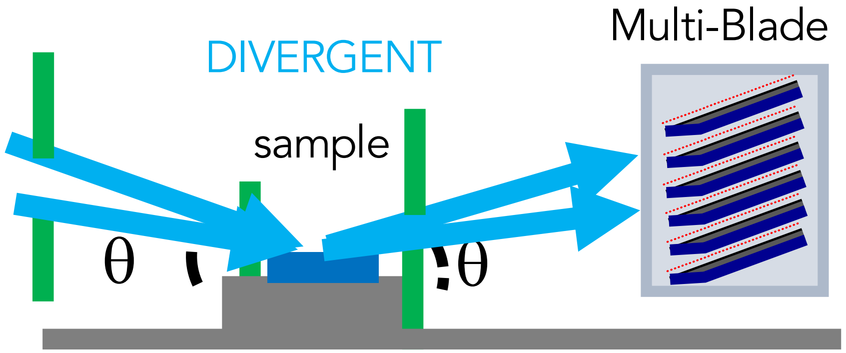
Thickness	550 Å
Roughness	15 Å
N_b	$7.3\cdot10^{-6}$ Å^{-2}



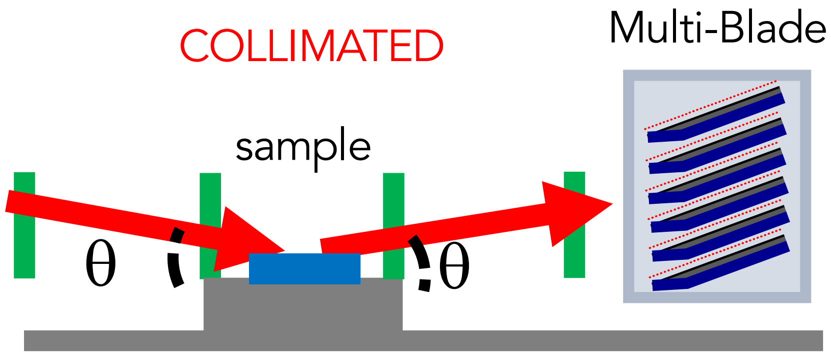
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

Working modes on CRISP

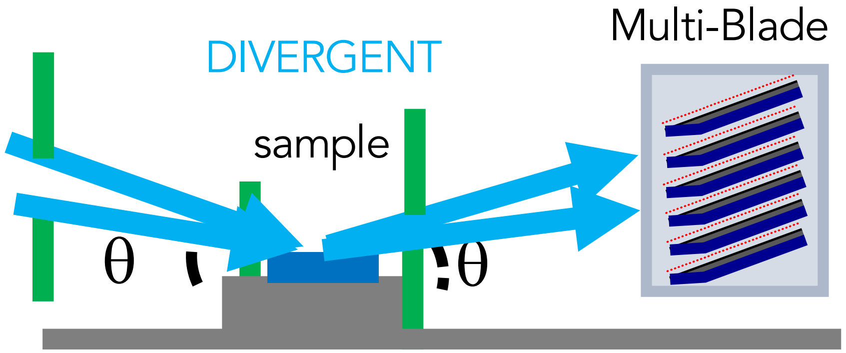




G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

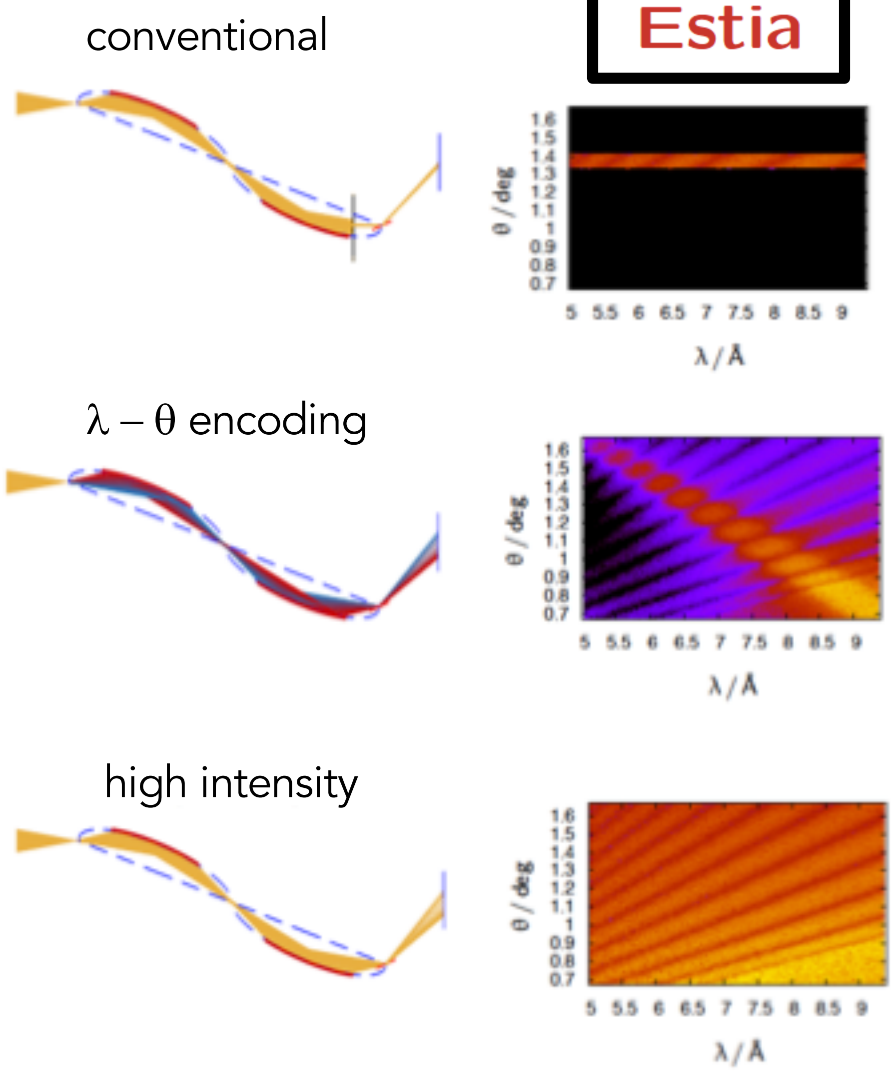


Ir sample Si sample Fe/Si sample

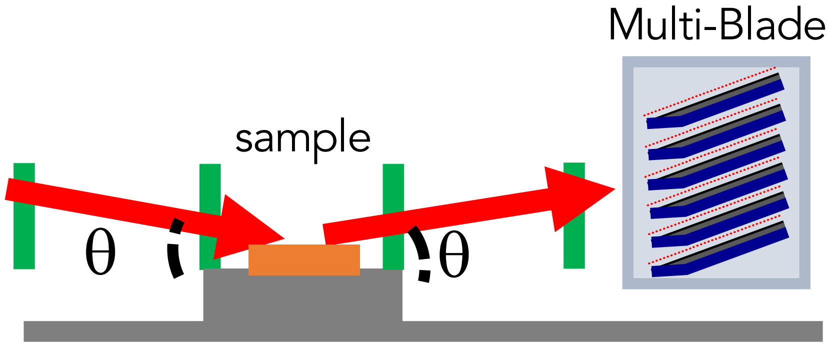


Working modes on CRISP

Estia



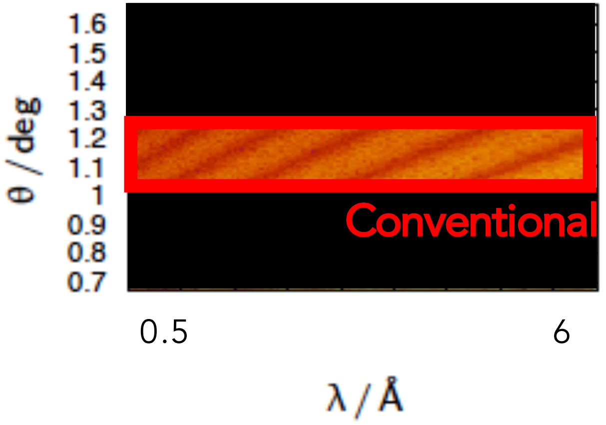
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

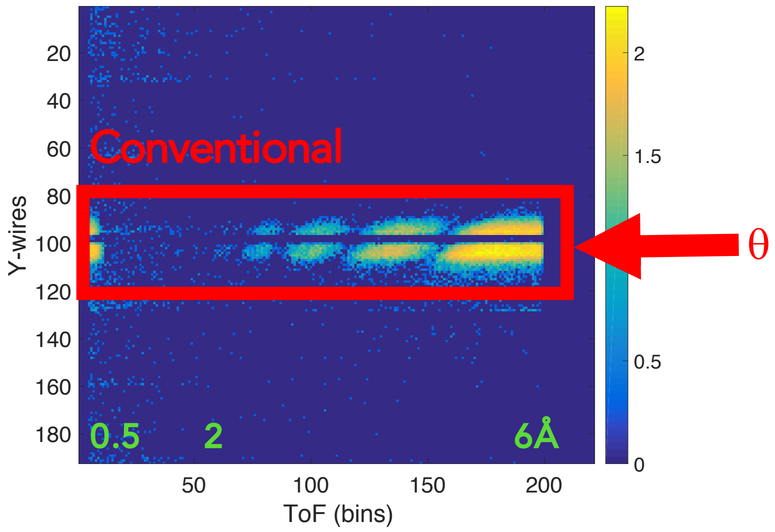


Dependence of the q-resolution on detector spatial resolution

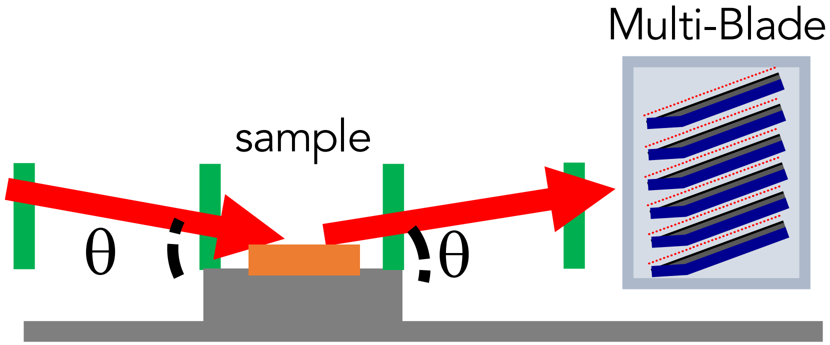
$$q = \frac{4\pi}{\lambda} \sin\theta$$

Conventional data reduction





G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



Dependence of the q-resolution on detector spatial resolution

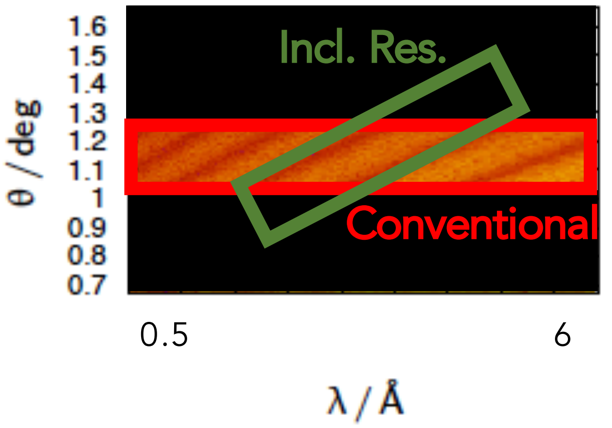
$$q = \frac{4\pi}{\lambda}\sin\theta$$ Conventional data reduction

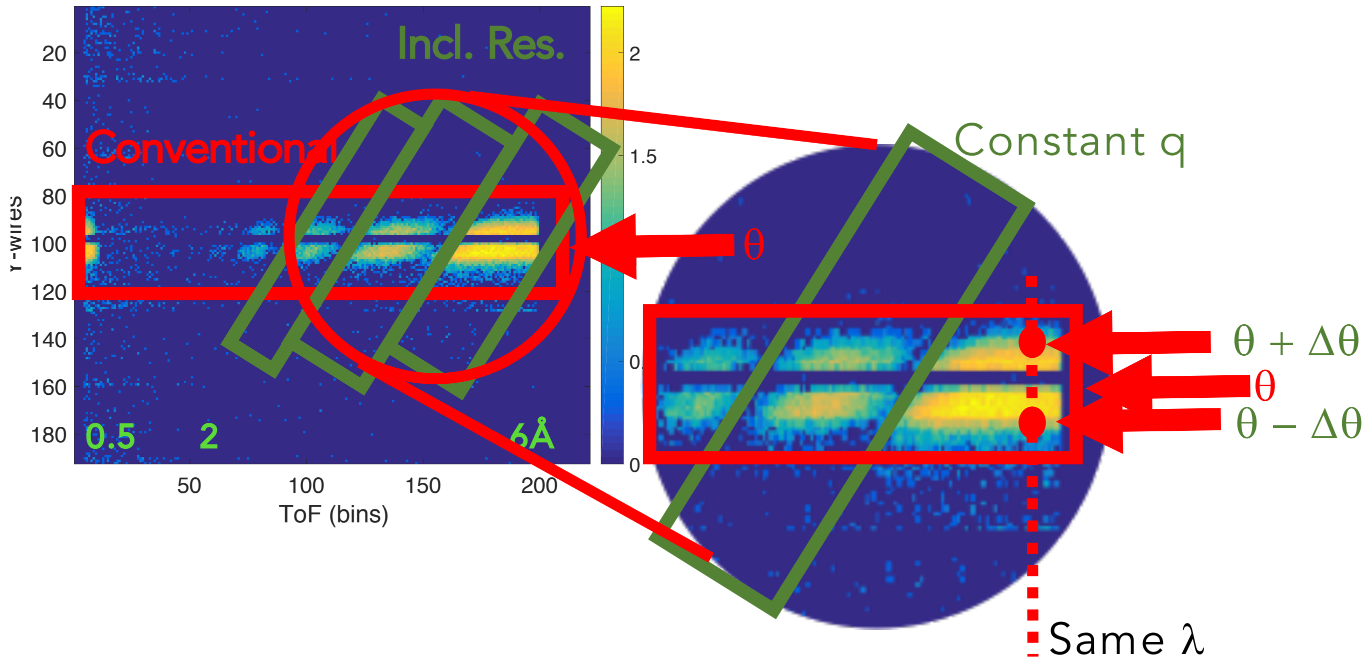
$$q = \frac{4\pi}{\lambda}\sin(\theta \pm \Delta\theta)$$ θ-correction

Including detector resolution

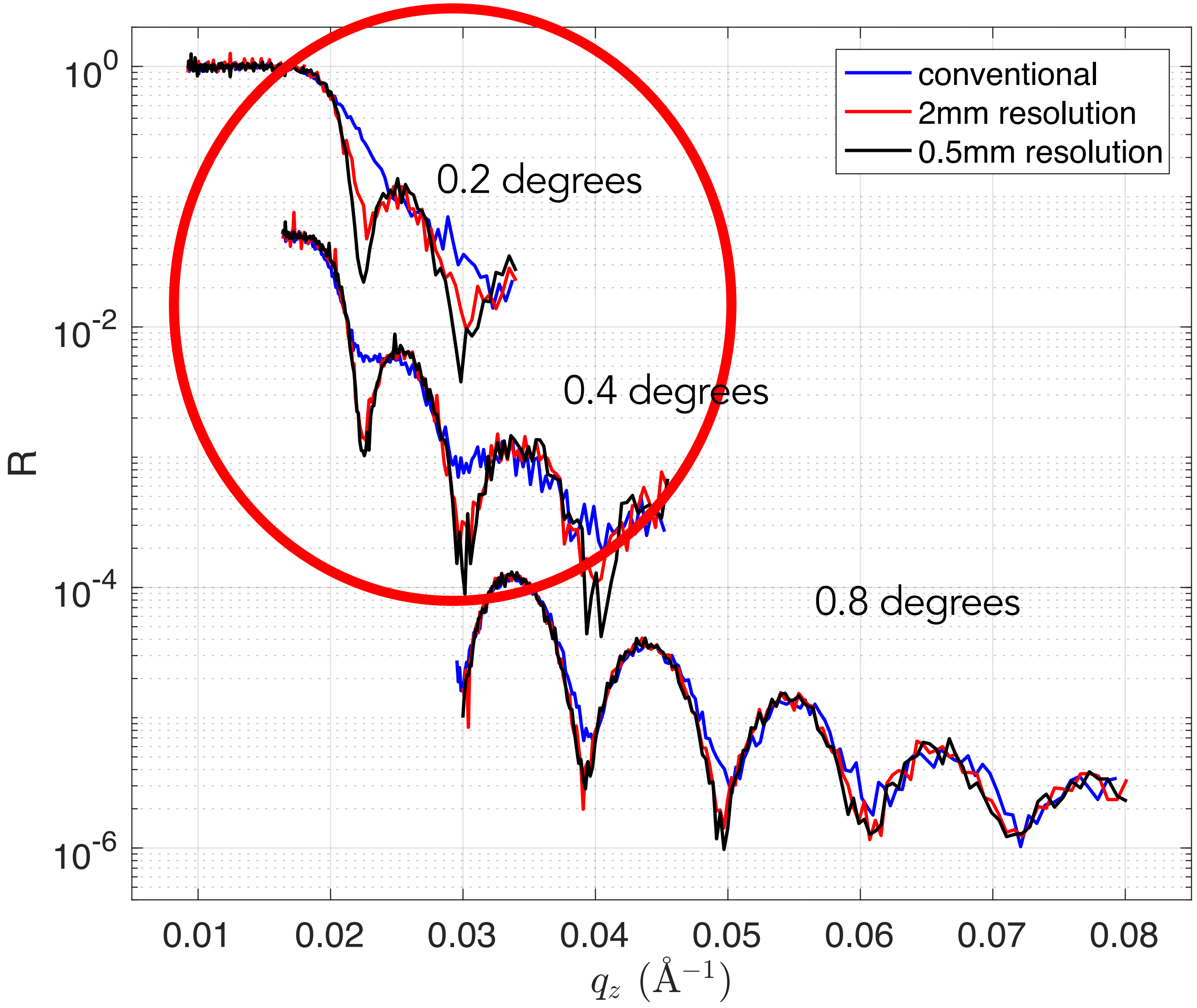
Ir sample   Si sample   Fe/Si sample

Integration at constant q, correcting θ with the position on the detector

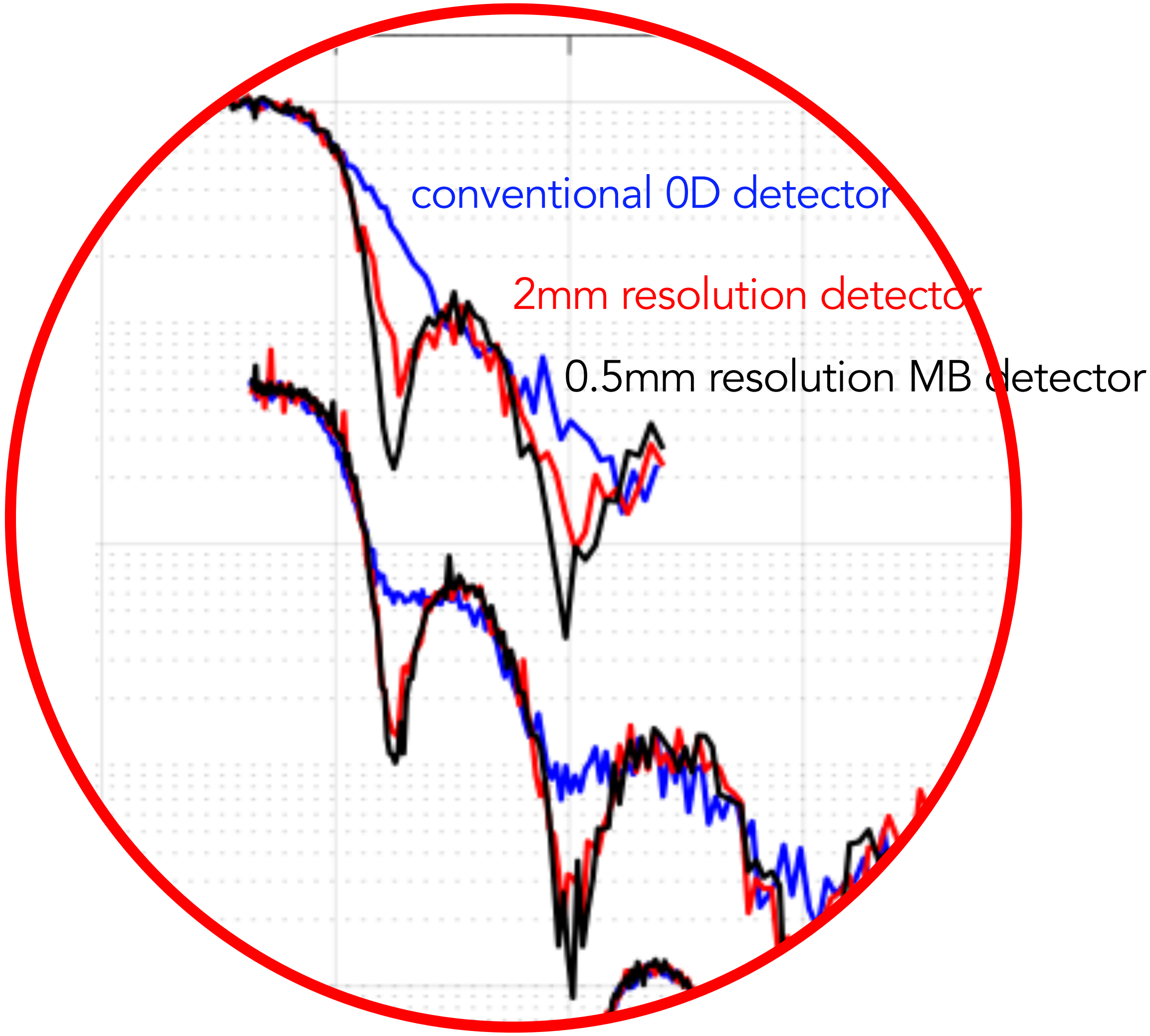




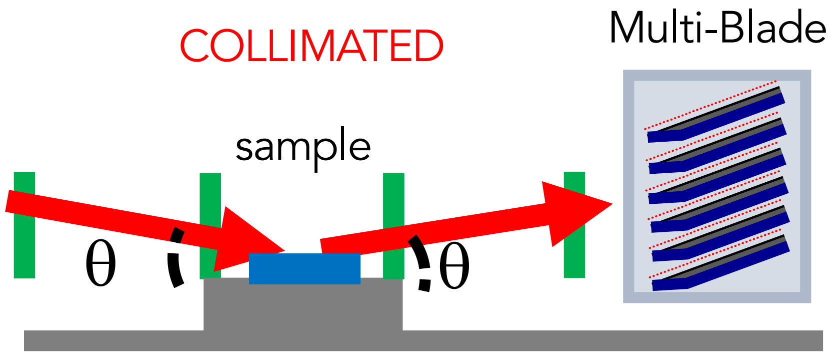
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



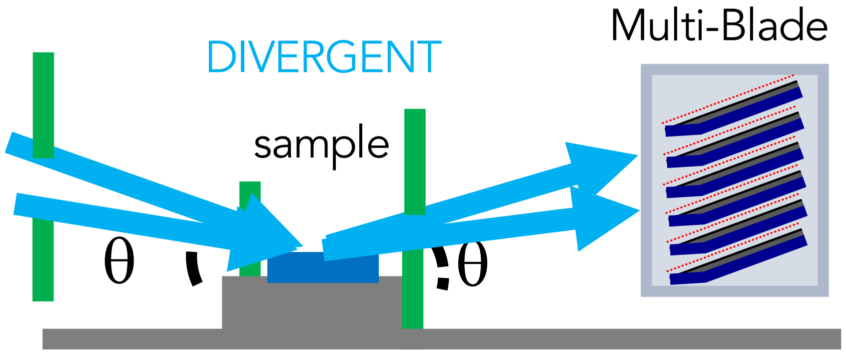
Dependence of the q-resolution on detector spatial resolution



G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

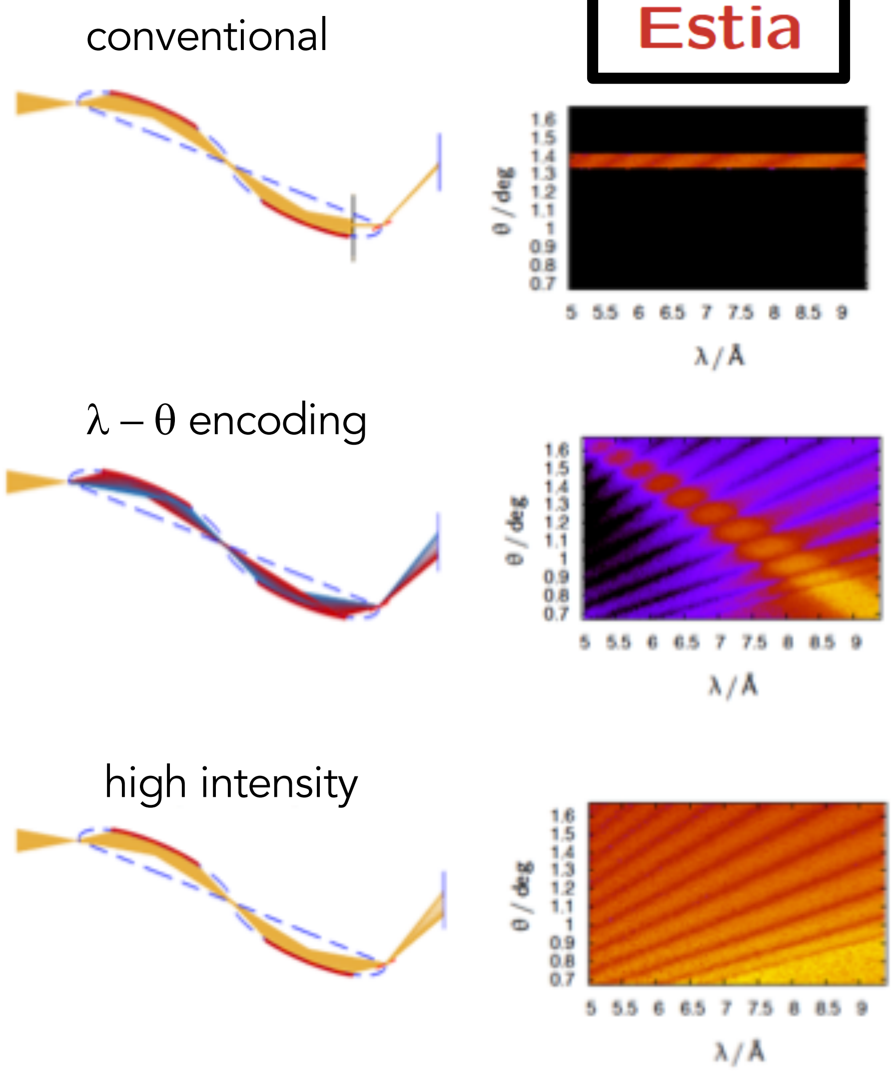


Ir sample Si sample Fe/Si sample

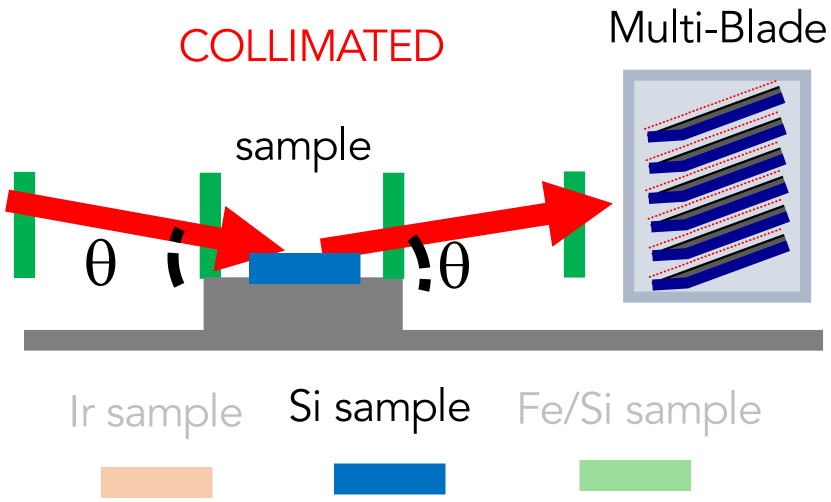


Working modes on CRISP

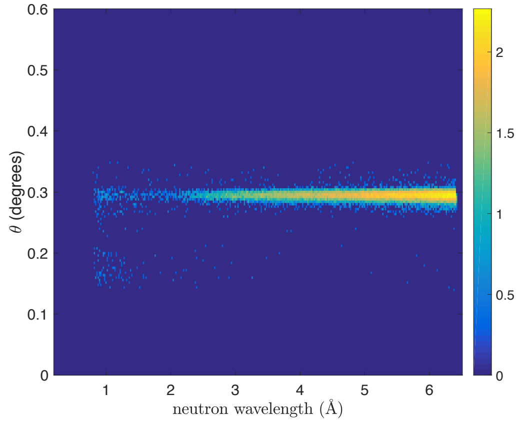
Estia

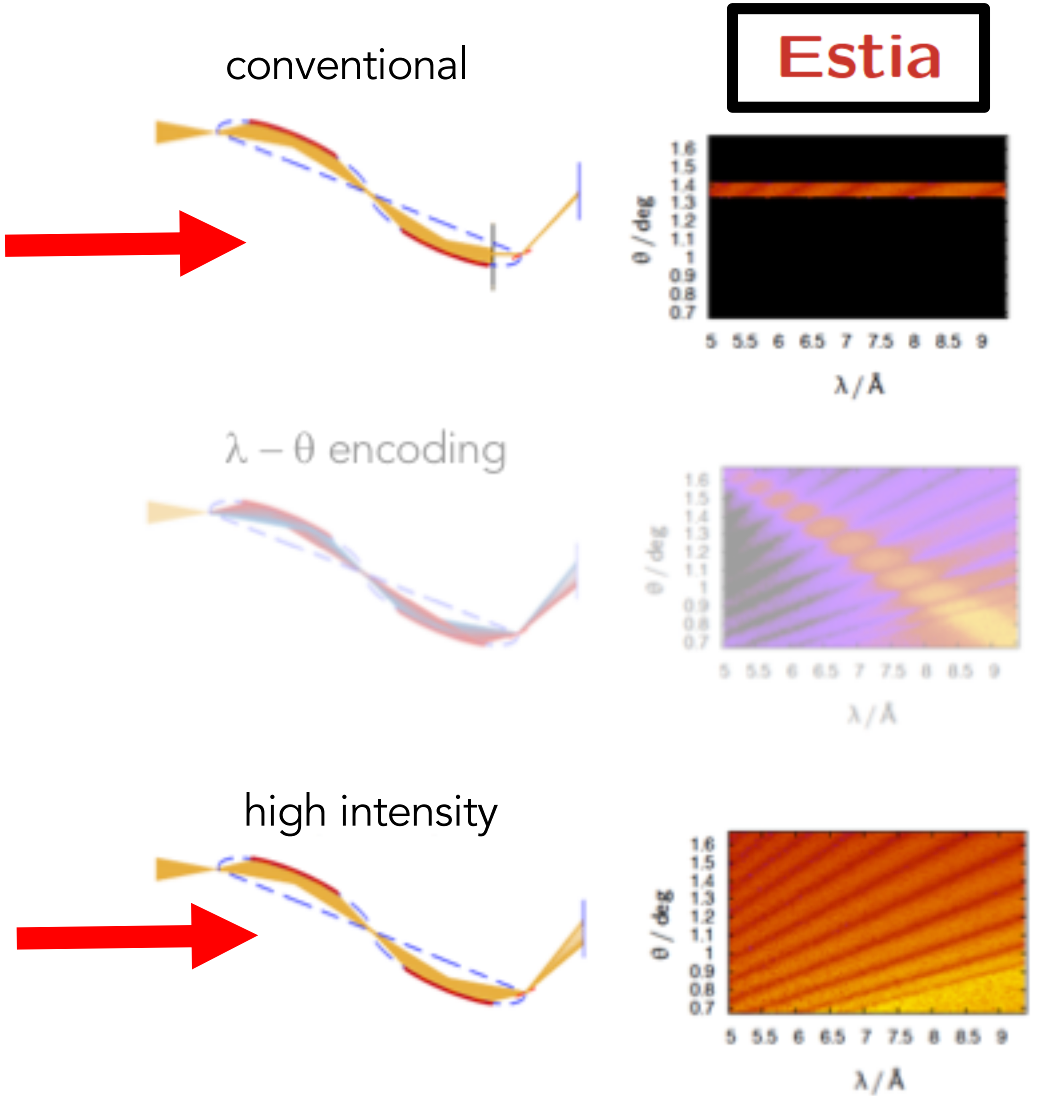


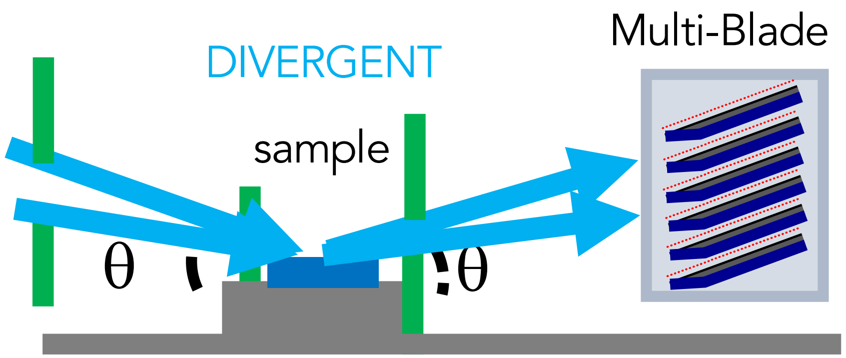
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



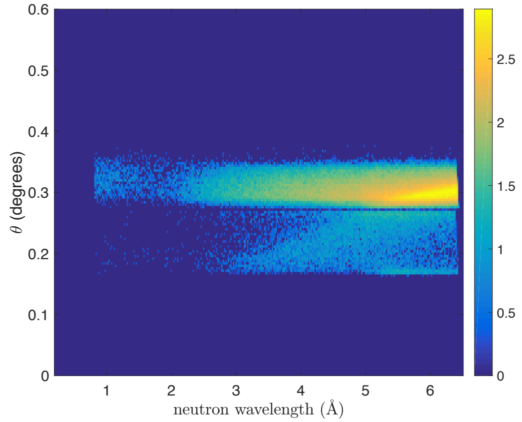
LOWER RATE



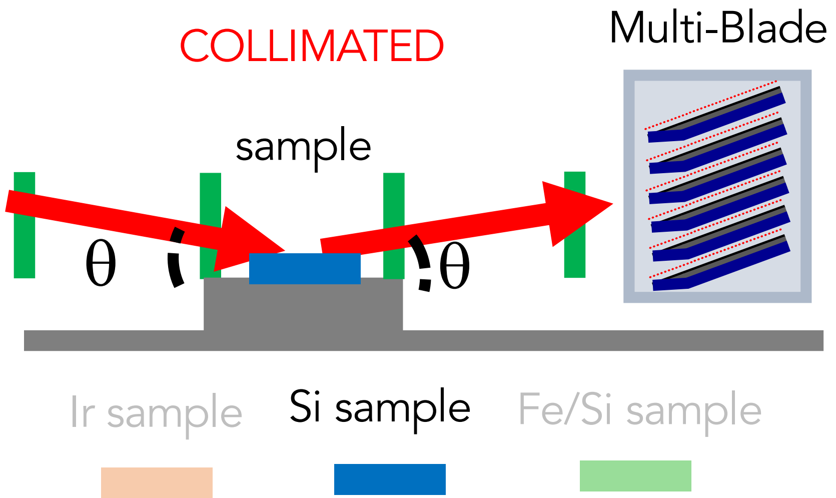


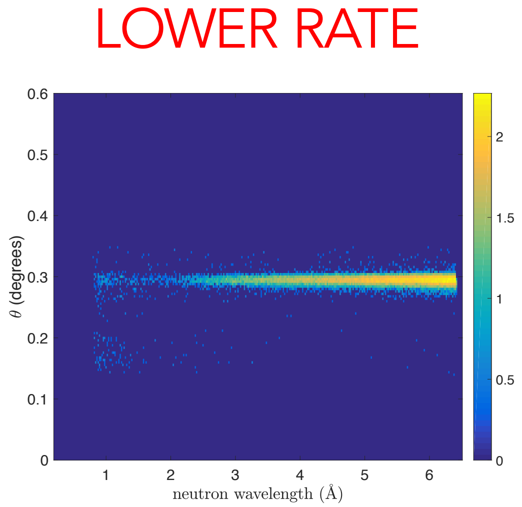


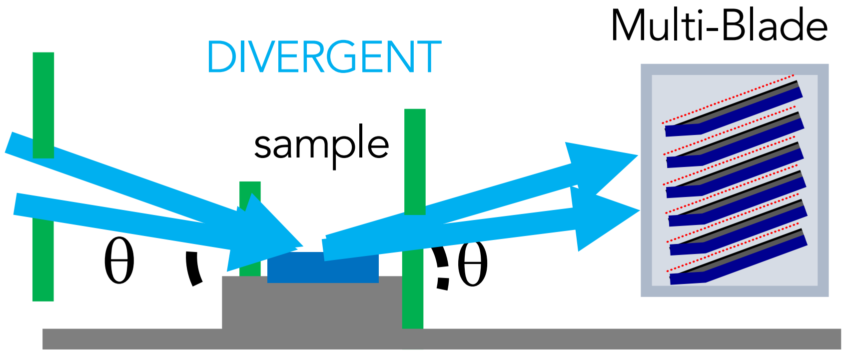
HIGHER RATE

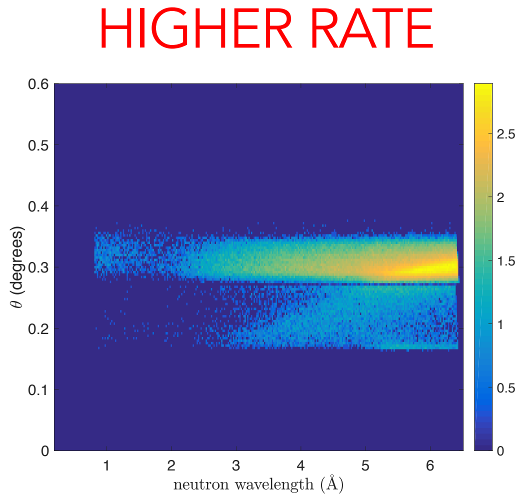


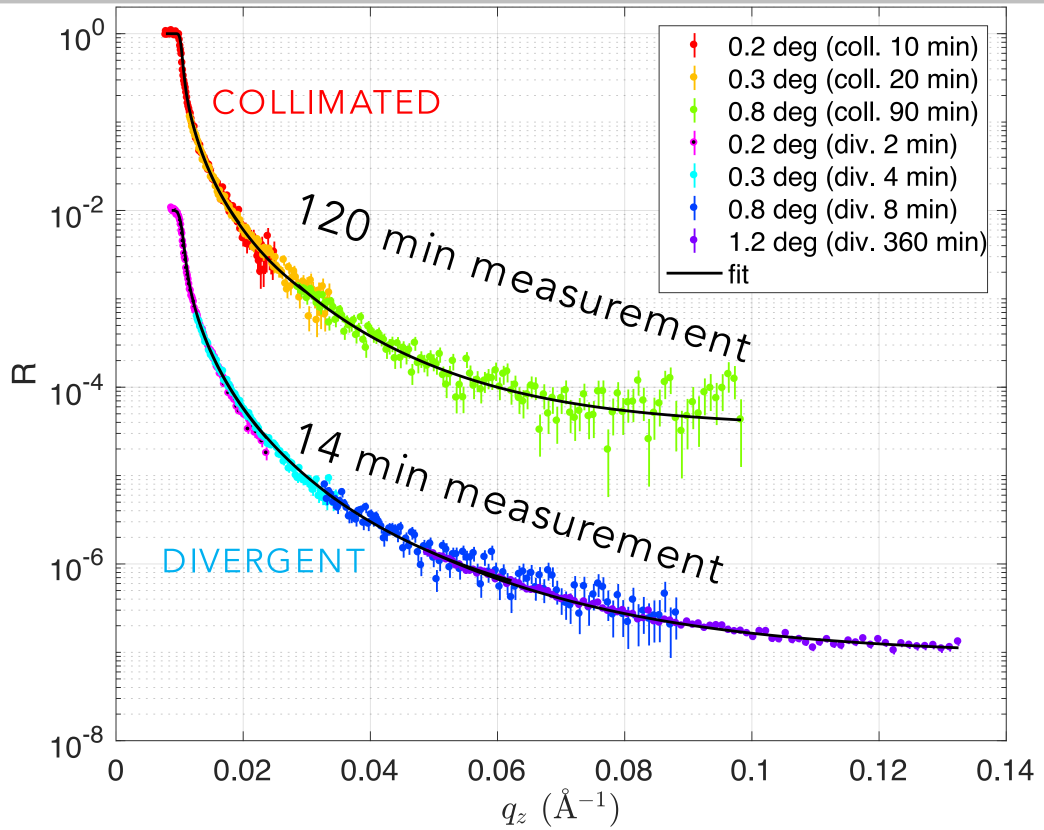
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).









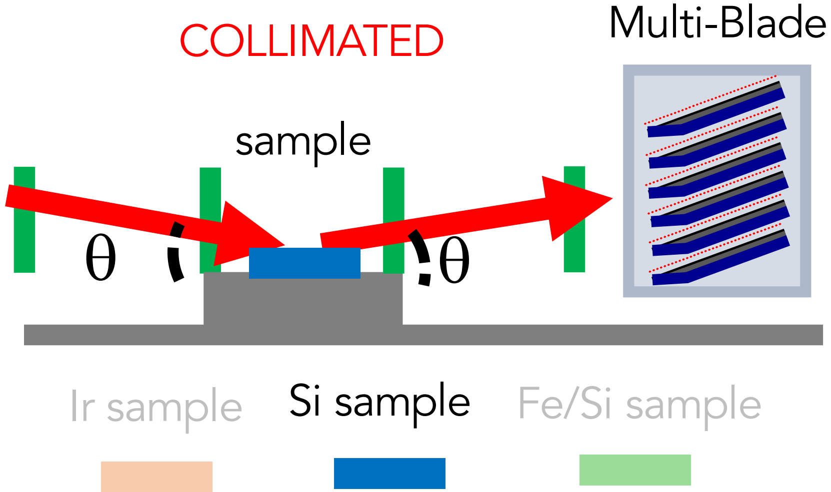


The spatial resolution and the counting rate capability of the detector is needed to measure in divergent mode

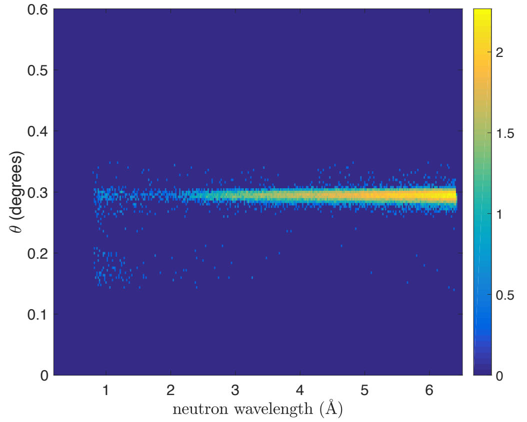
COLLIMATED: 120 min measurement

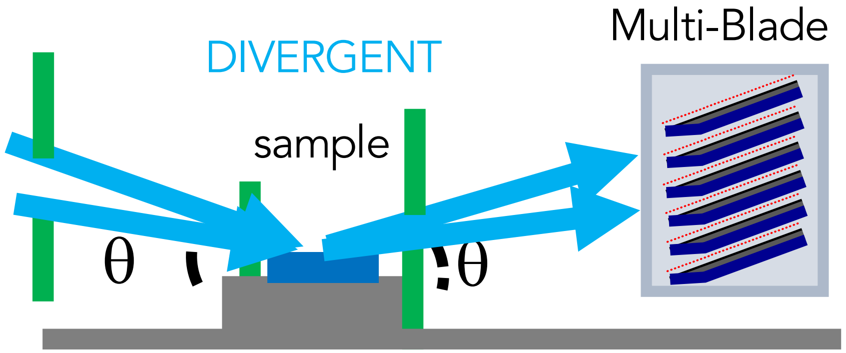
DIVERGENT: 14 min measurement

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

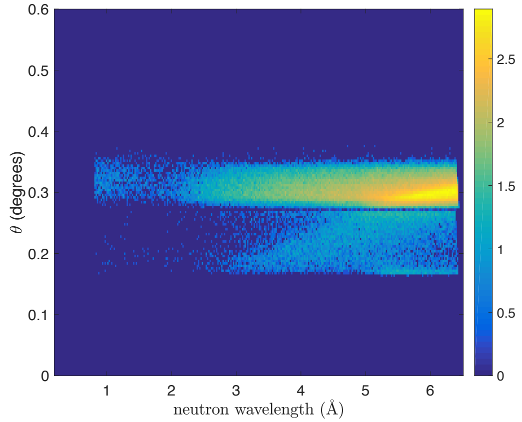


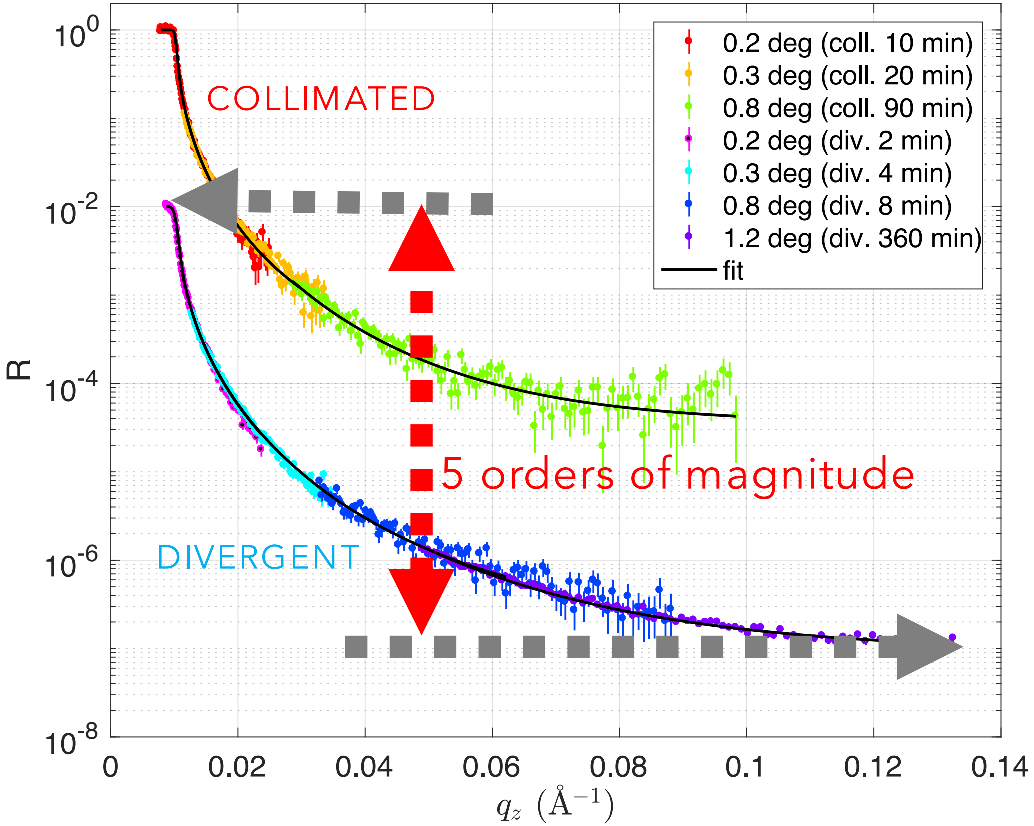
LOWER RATE





HIGHER RATE



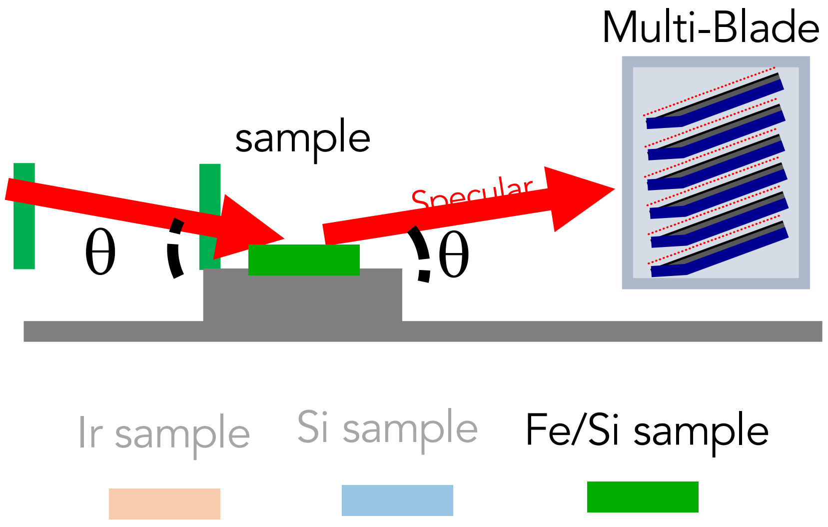


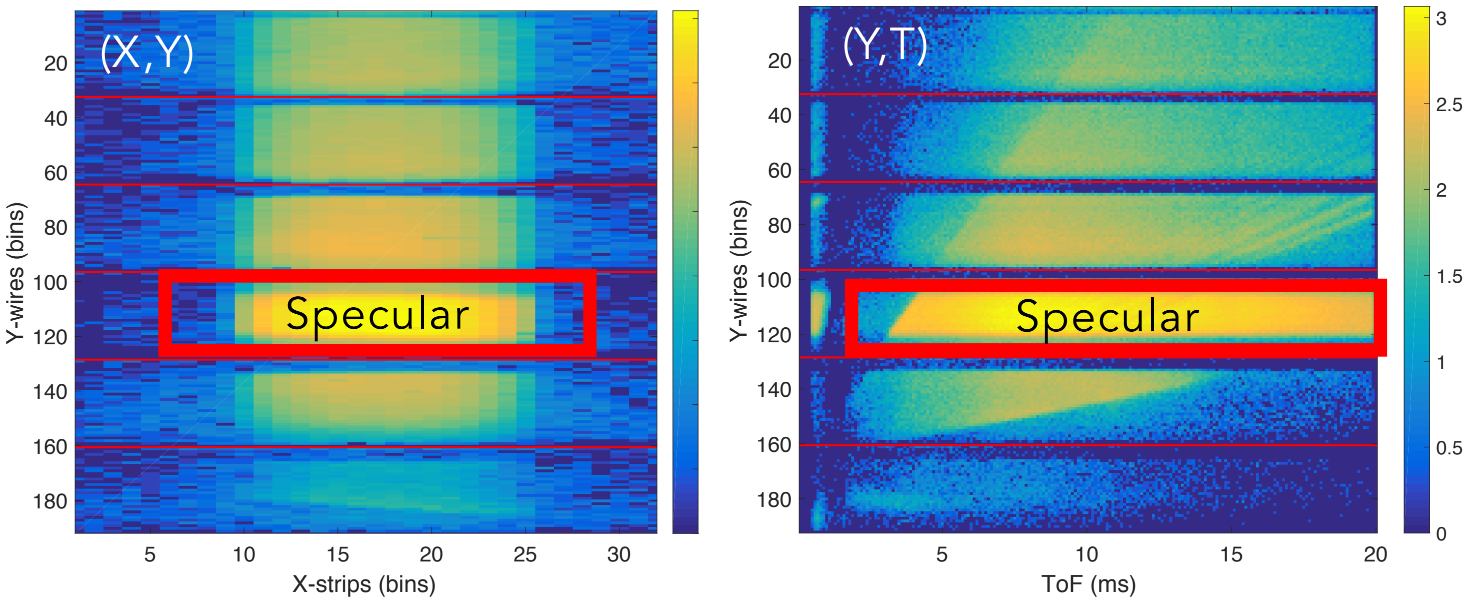
The spatial resolution and the counting rate capability of the detector is needed to measure in divergent mode

COLLIMATED: 120 min measurement

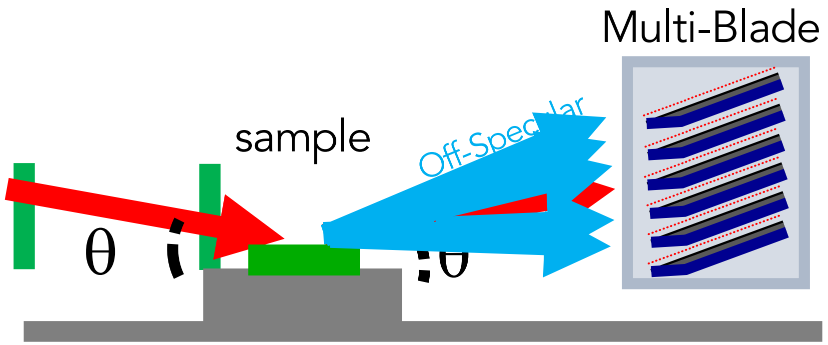
DIVERGENT: 14 min measurement

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

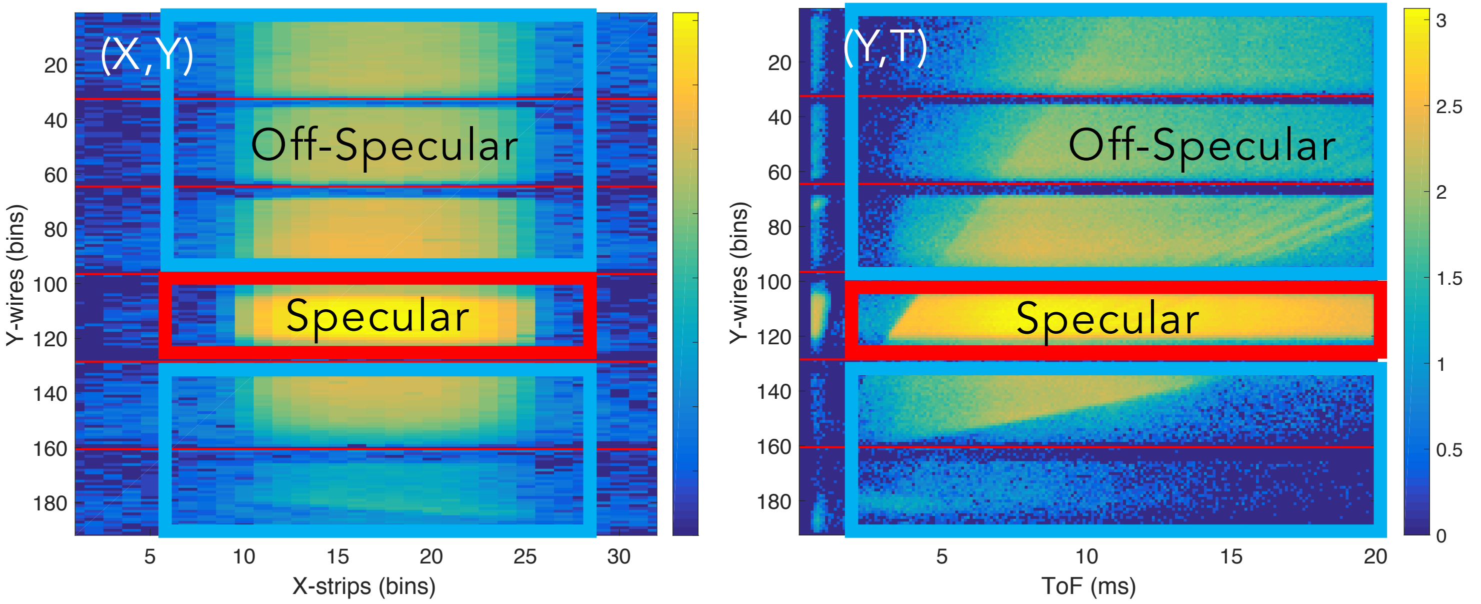


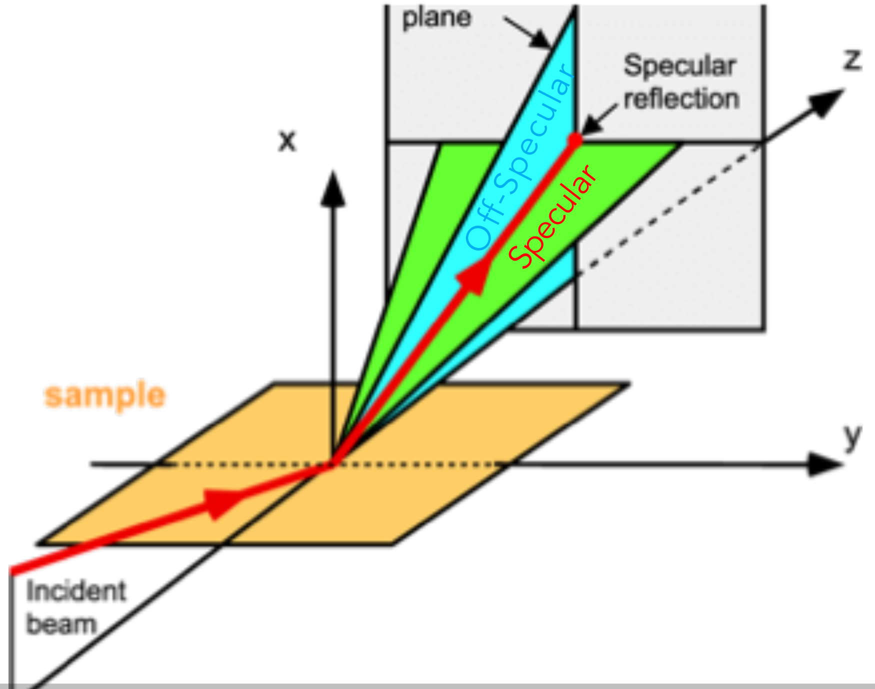


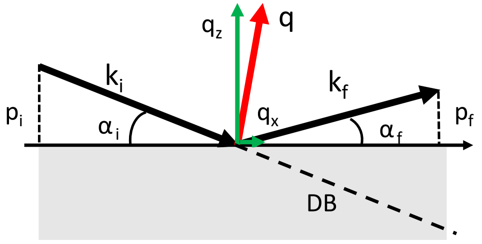
G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).



Ir sample   Si sample   Fe/Si sample







Parallel component of the scattering vector q.

Investigation of in-plane structures.

$$p_i = \frac{2\pi}{\lambda}\sin\alpha_i$$

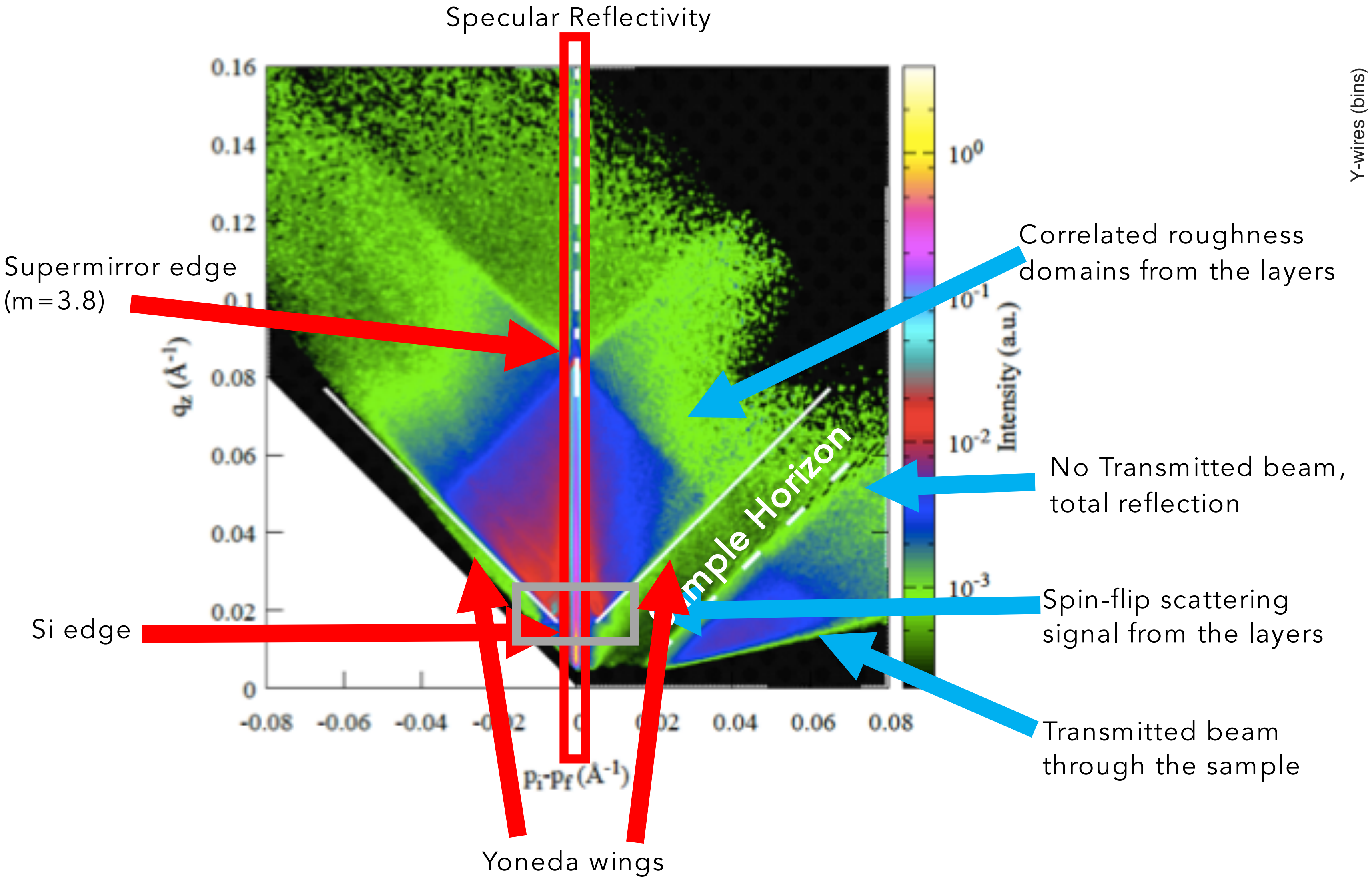
$$p_f = \frac{2\pi}{\lambda}\sin\alpha_f$$

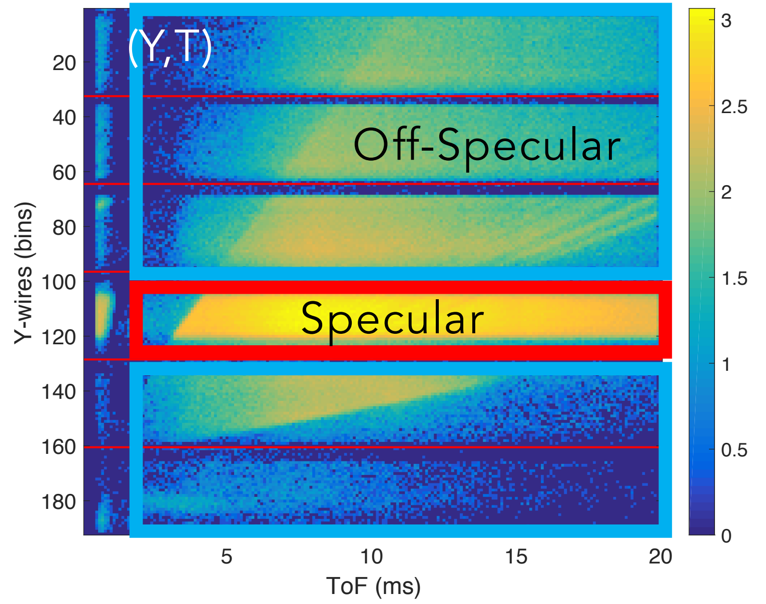
$$q_x = \frac{2\pi}{\lambda}(\cos\alpha_f - \cos\alpha_i)$$

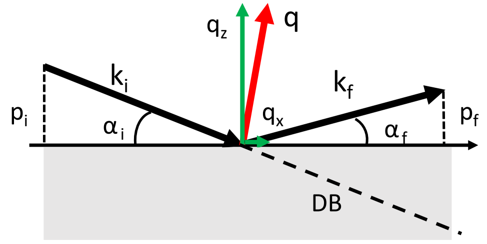
$$q_z = \frac{2\pi}{\lambda}(\sin\alpha_f + \sin\alpha_i)$$

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

Off-specular scattering from Fe/Si neutron supermirror







$$p_i = \frac{2\pi}{\lambda}\sin\alpha_i$$

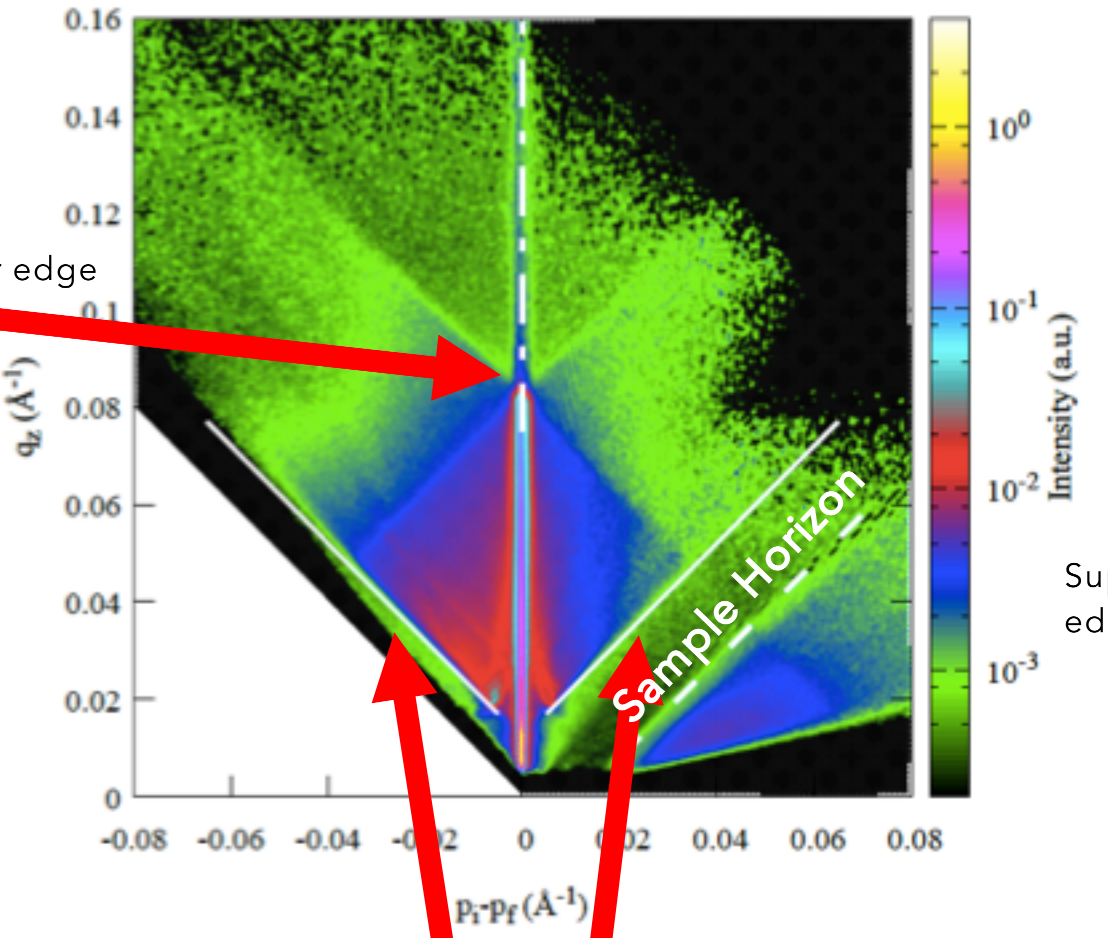
$$p_f = \frac{2\pi}{\lambda}\sin\alpha_f$$

$$q_x = \frac{2\pi}{\lambda}(\cos\alpha_f - \cos\alpha_i)$$

$$q_z = \frac{2\pi}{\lambda}(\sin\alpha_f + \sin\alpha_i)$$

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, Proc. R. Soc. A 474: 20180266 (2018).

Off-specular scattering from Fe/Si neutron supermirror




Nuclear Instruments and Methods in Physics Research A 840 (2016) 181–185

Contents lists available at ScienceDirect

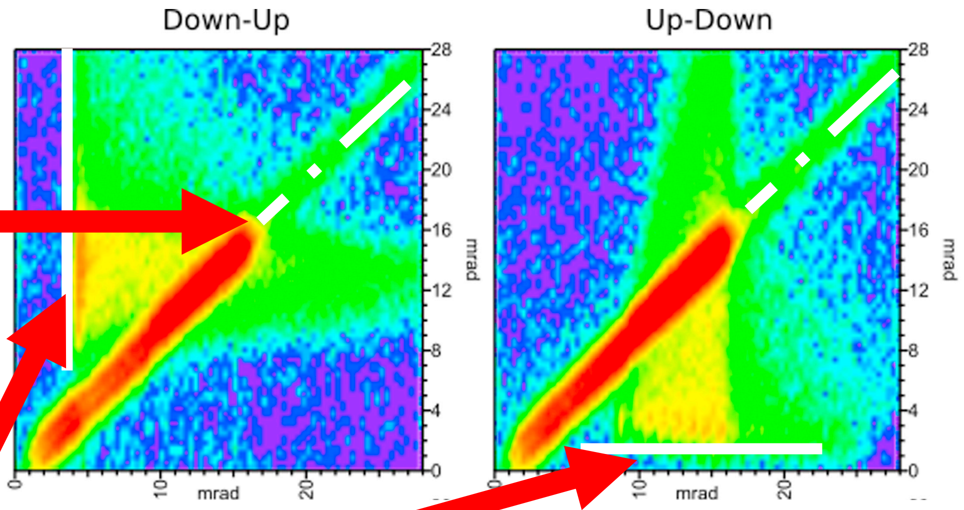
Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Depolarization in polarizing supermirrors

Christine Klauser, Thierry Bigault, Peter Böni, Pierre Courtois, Anton Devishvili, Nataliya Rebrova, Michael Schneider, Torsten Soldner

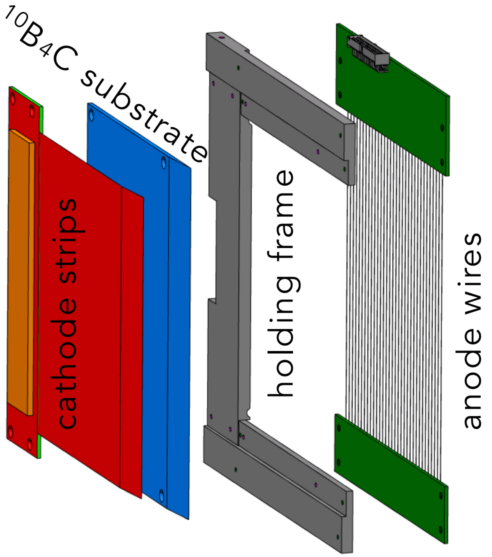


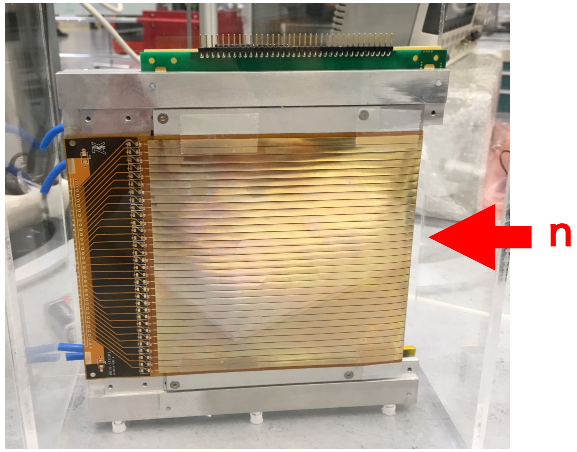
(from SuperADAM at ILL)

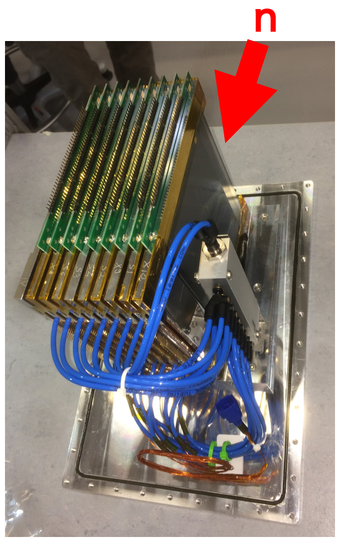
MB300 for ESTIA & FREIA

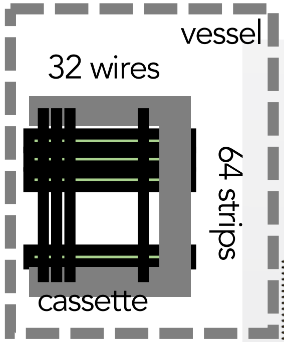
Multi-Blade 300

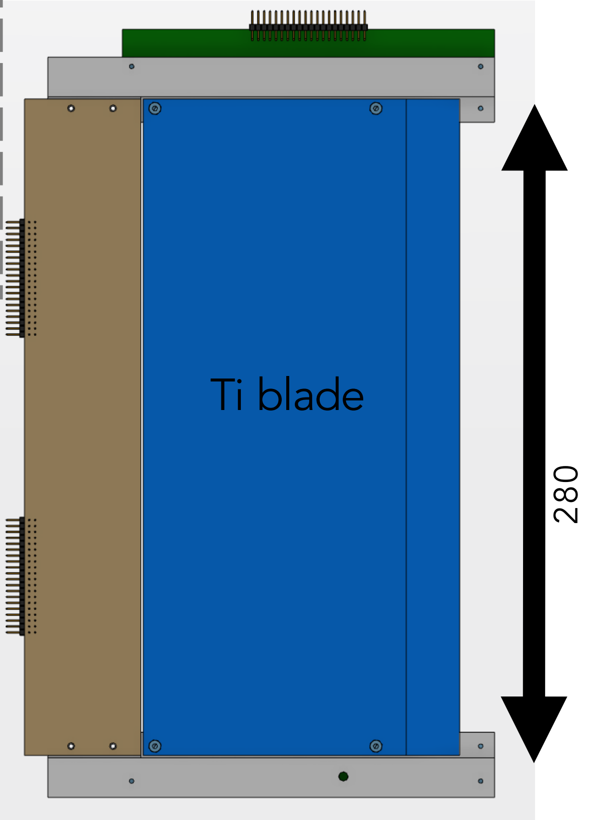
	N blades	Blade height (mm)	N wires	N strips	N tot ch	N pixels
ESTIA	50	280	1600	3200	4800	5 M
FREIA	30	280	960	1920	2880	1.8 M



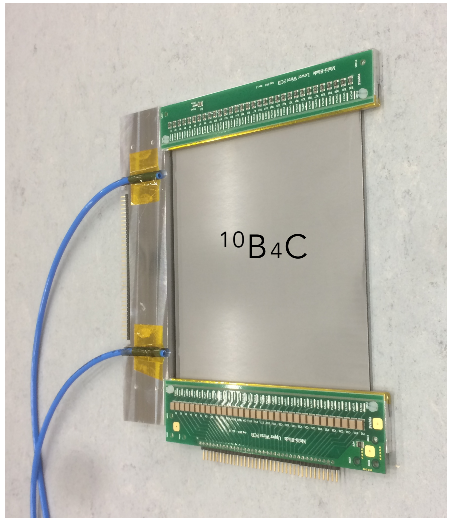


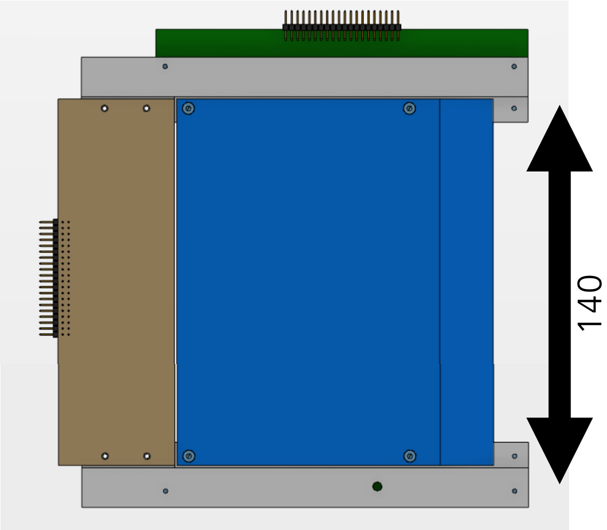




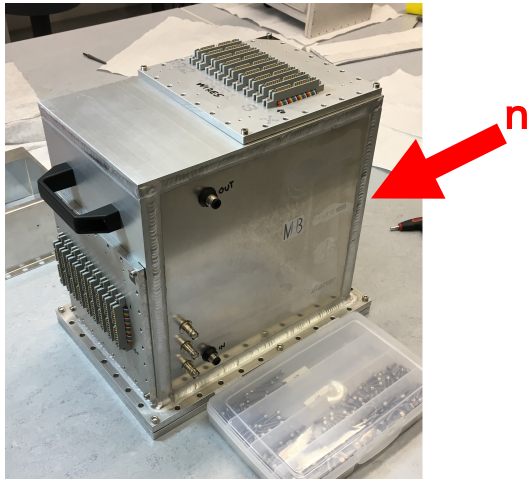


32 wires x 64 strips



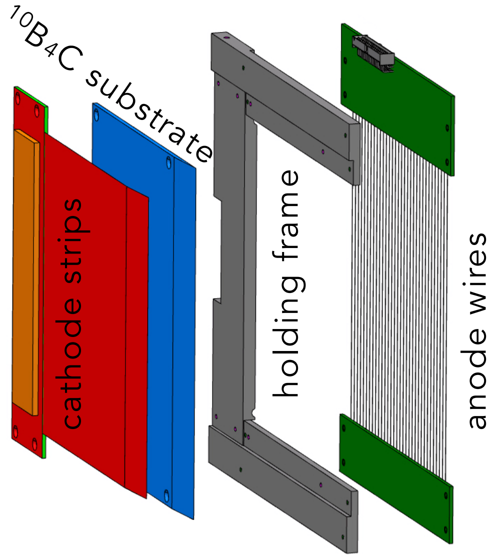


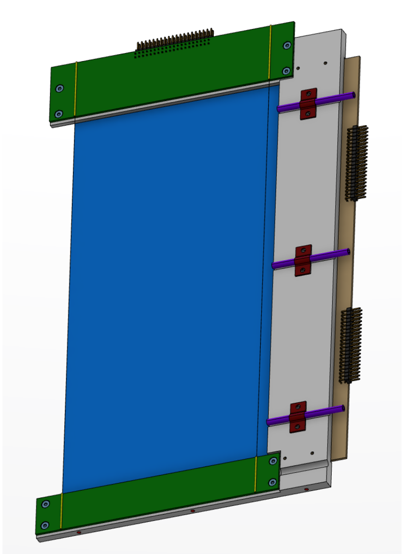
32 wires x 32 strips

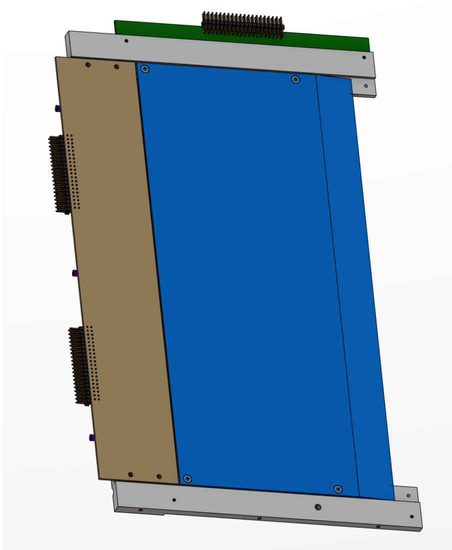


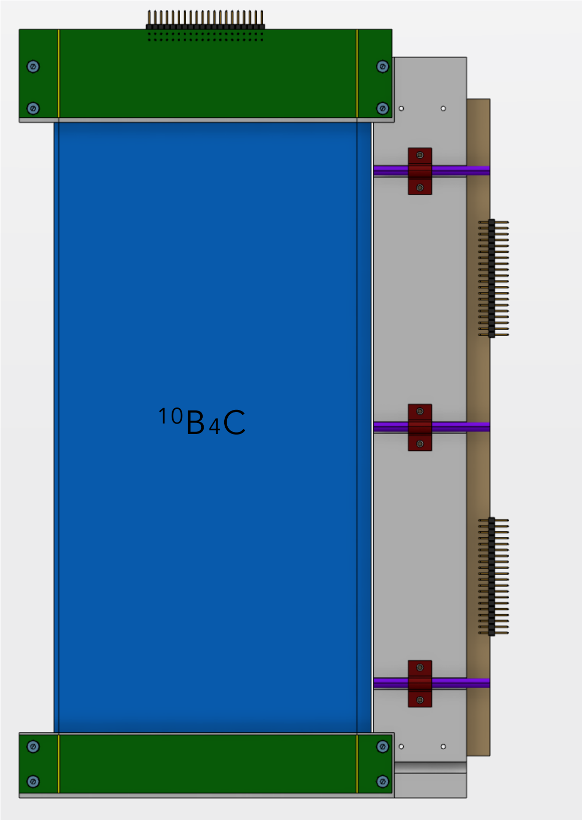
Multi-Blade 300

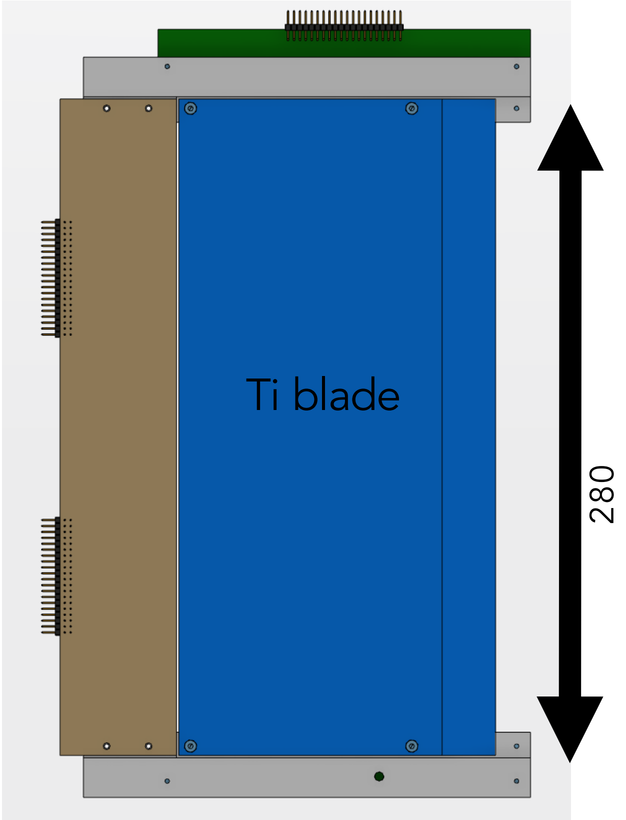
	N blades	Blade height (mm)	N wires	N strips	N tot ch	N pixels
ESTIA	50	280	1600	3200	4800	5 M
FREIA	30	280	960	1920	2880	1.8 M





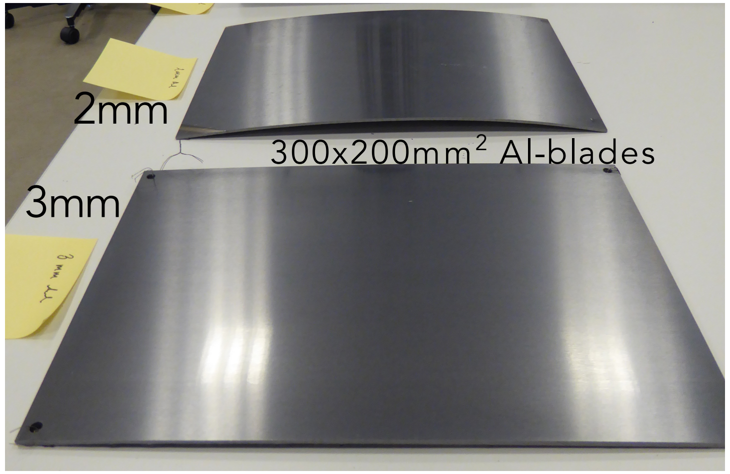


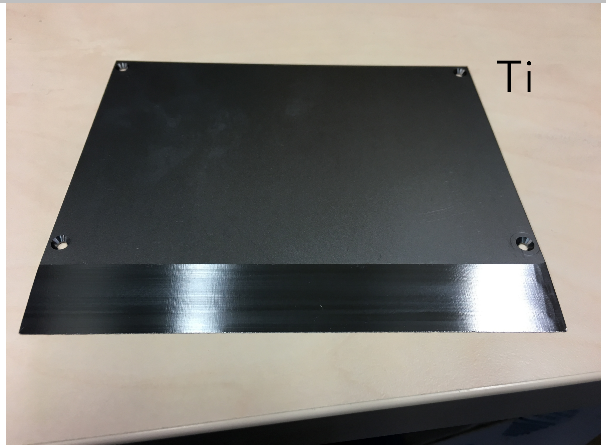


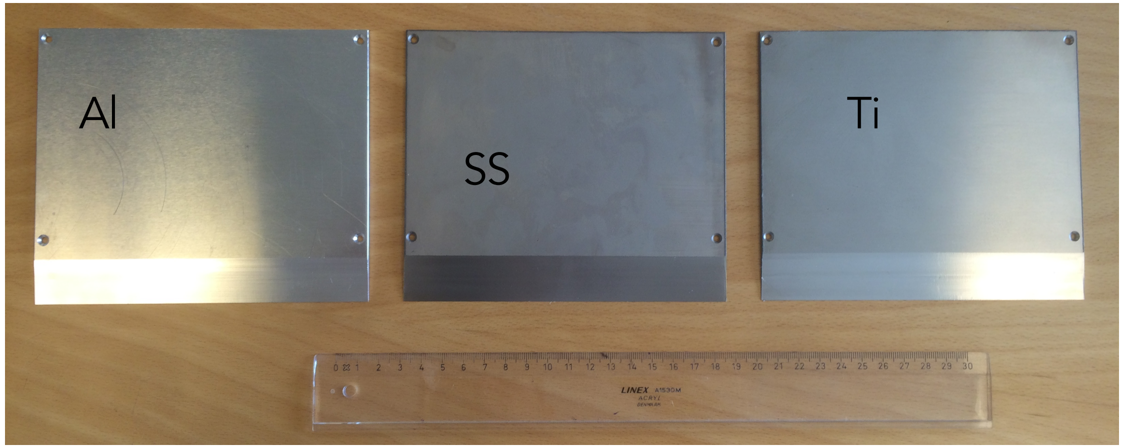


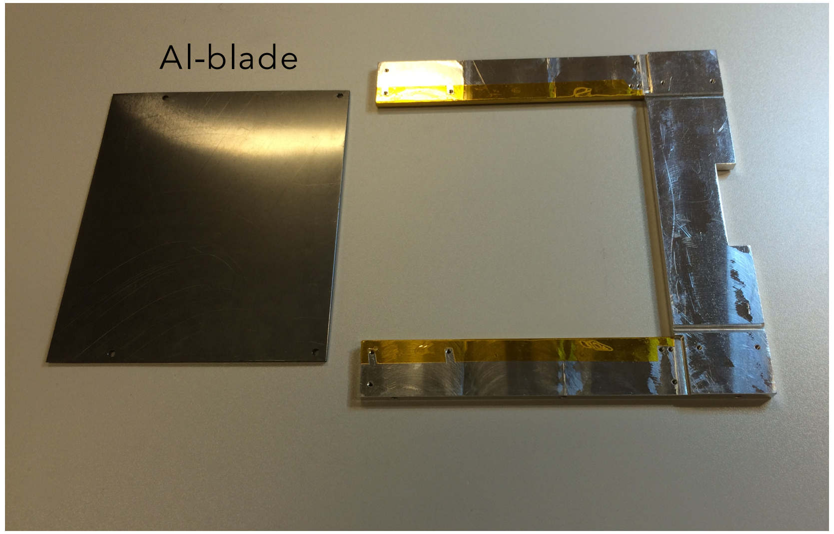
32 wires x 64 strips

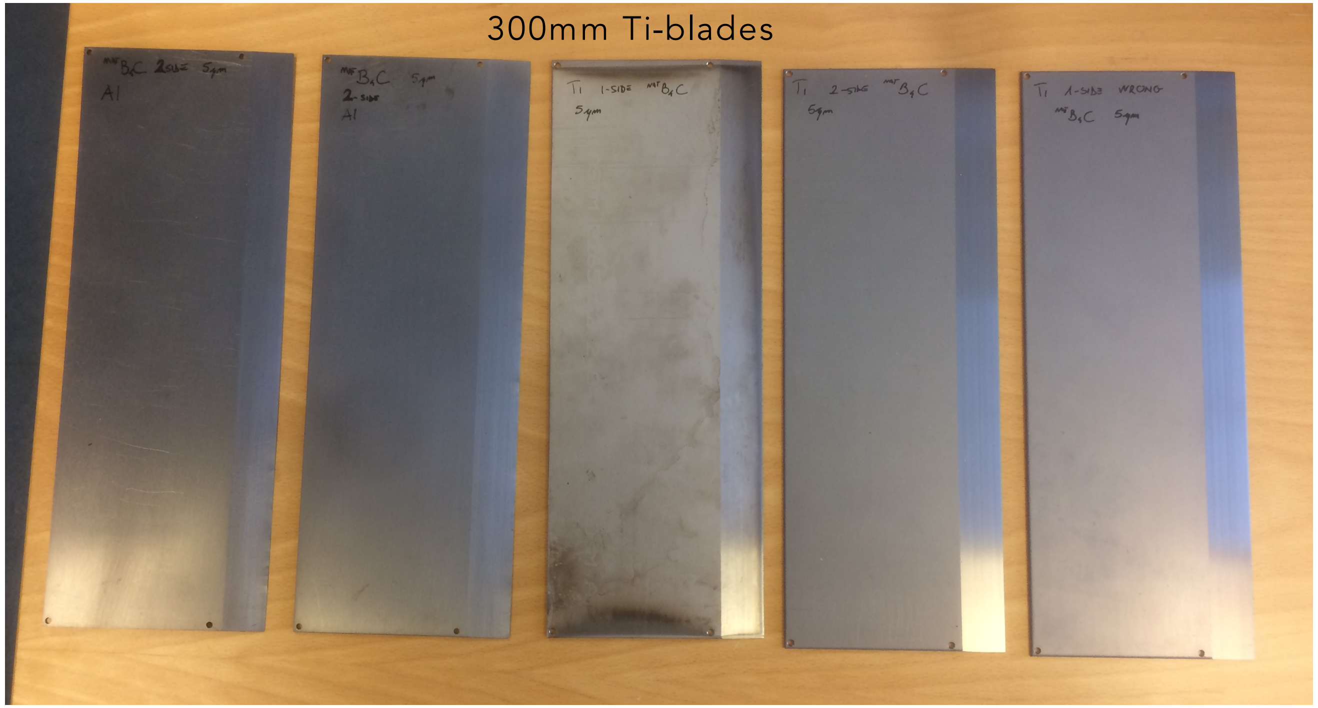
Multi-Blade 300



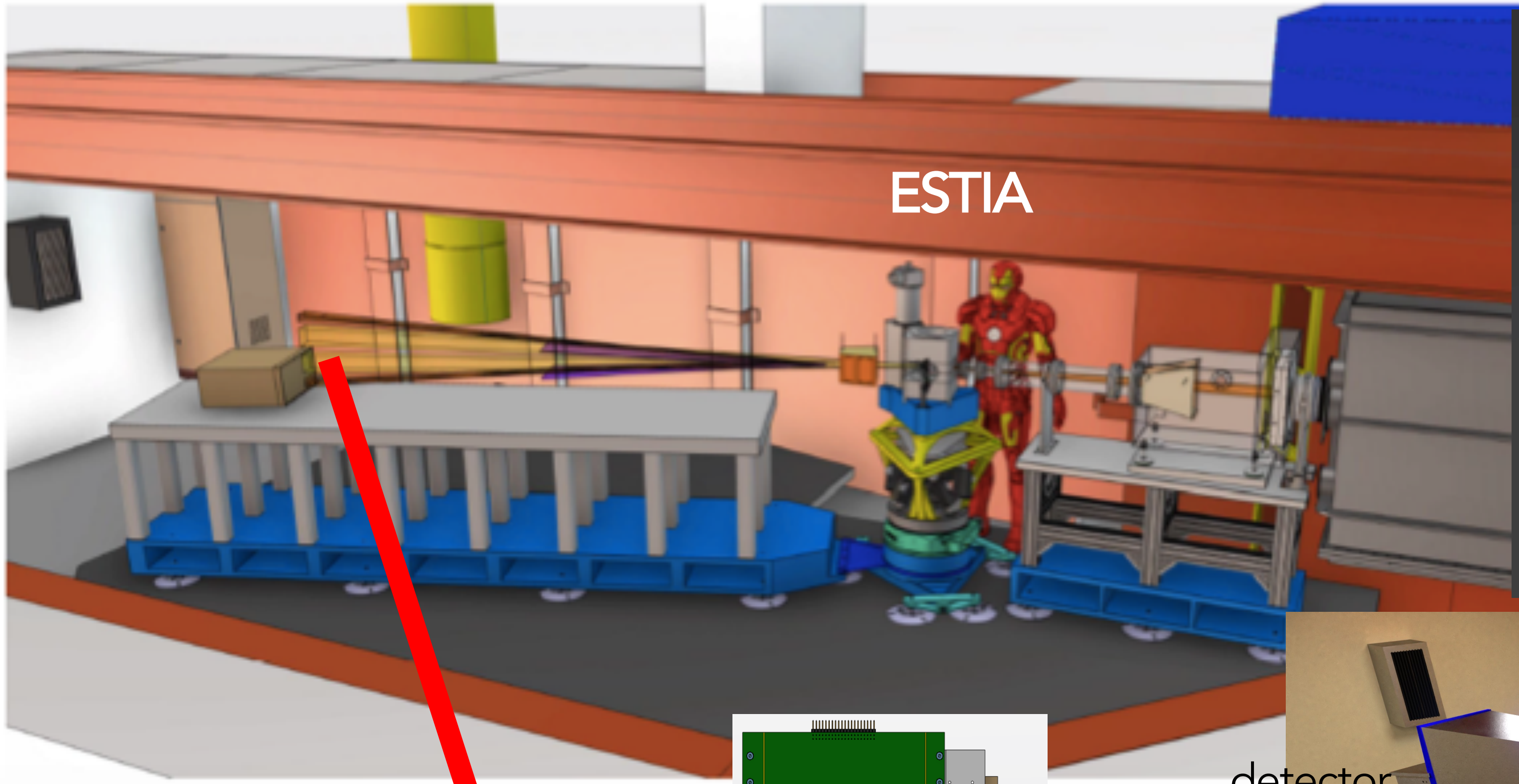


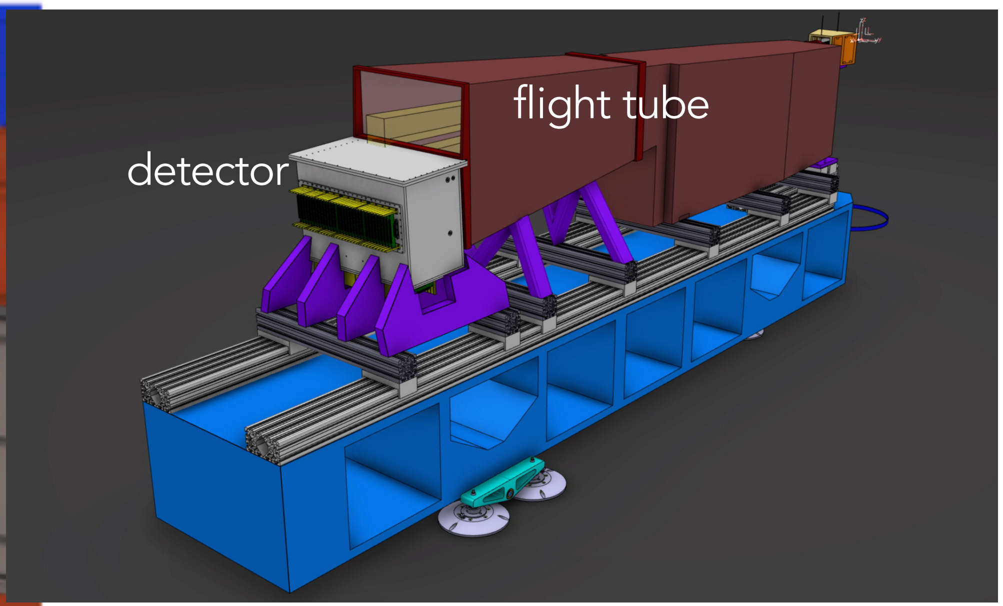


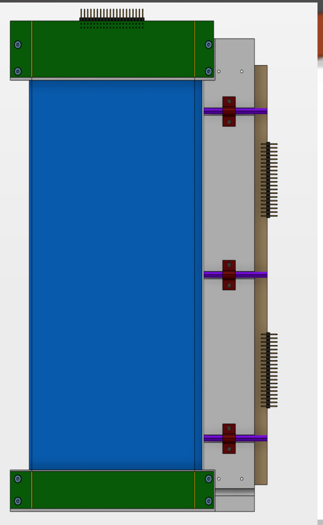


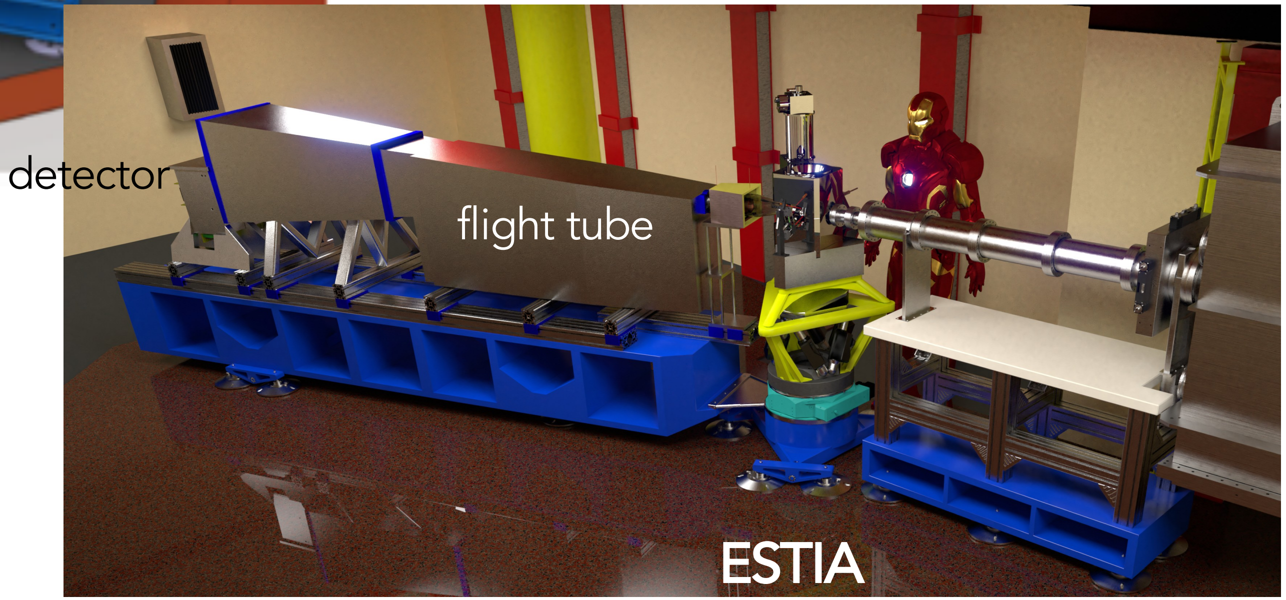


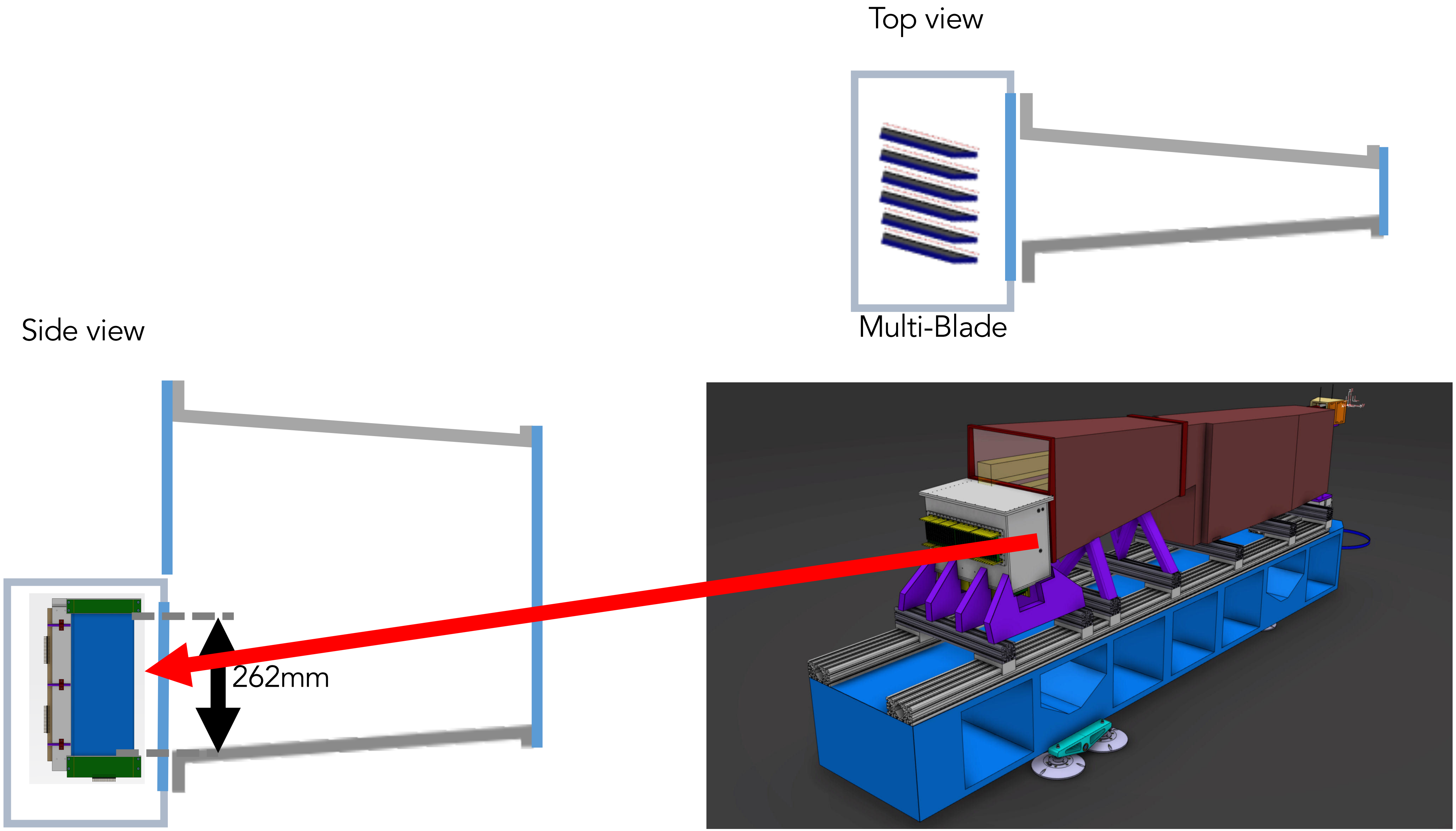
Multi-Blade 300

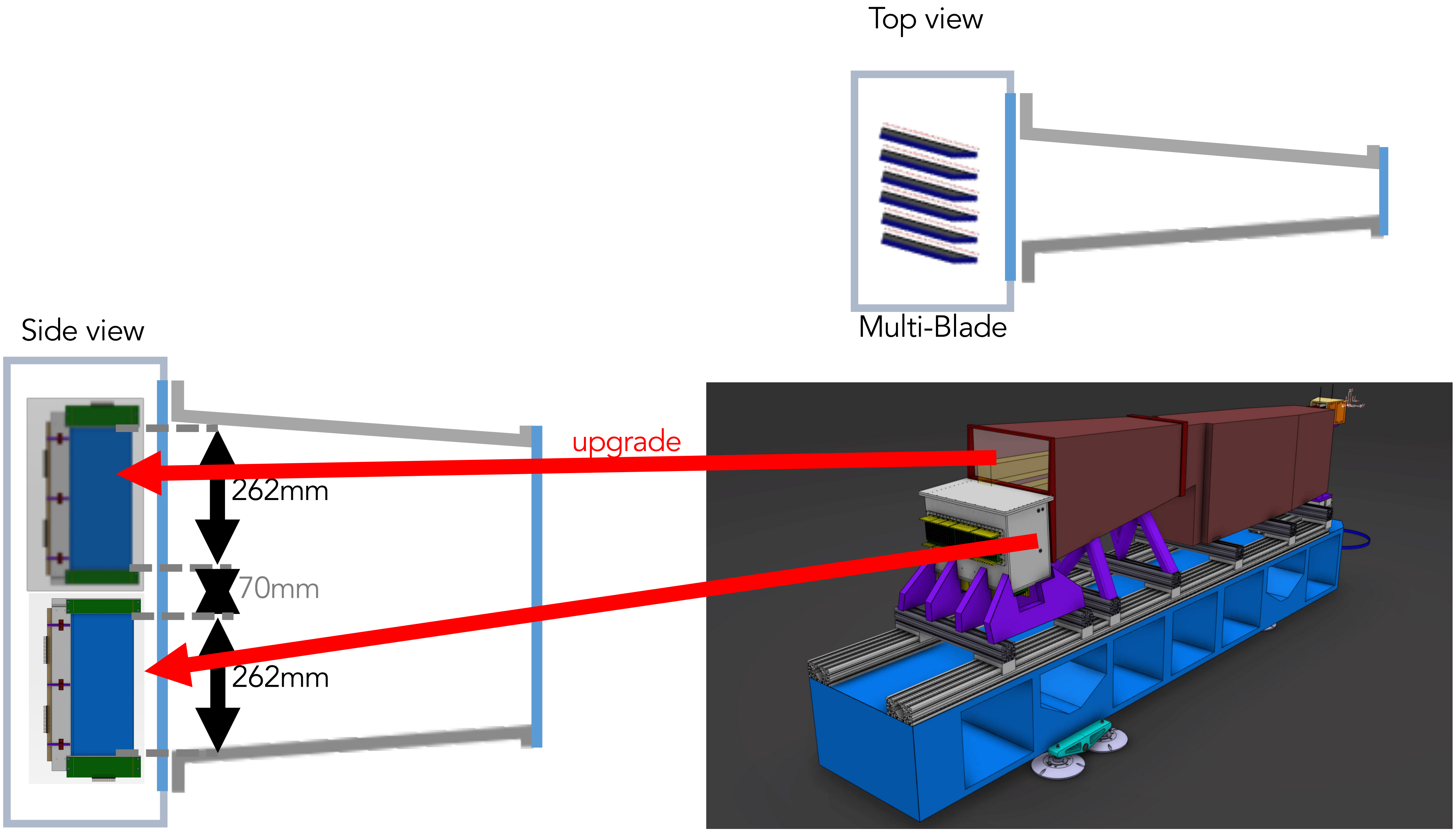




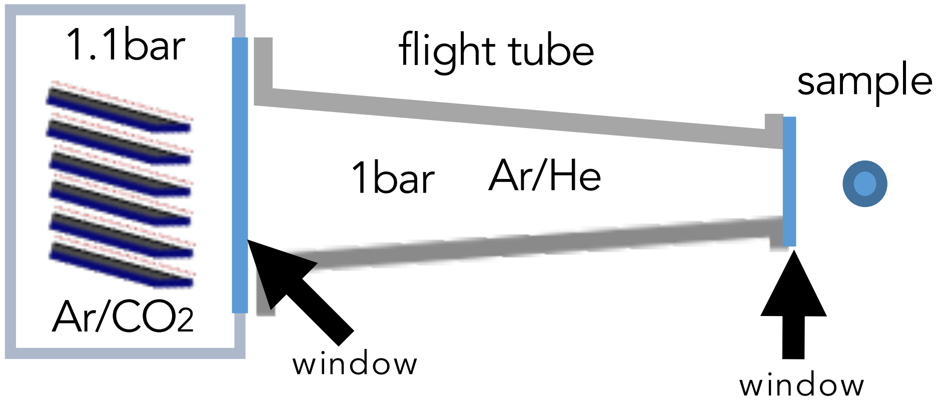





Top view
Multi-Blade
Side view
262mm


Top view
Multi-Blade
Side view
upgrade
262mm
70mm
262mm

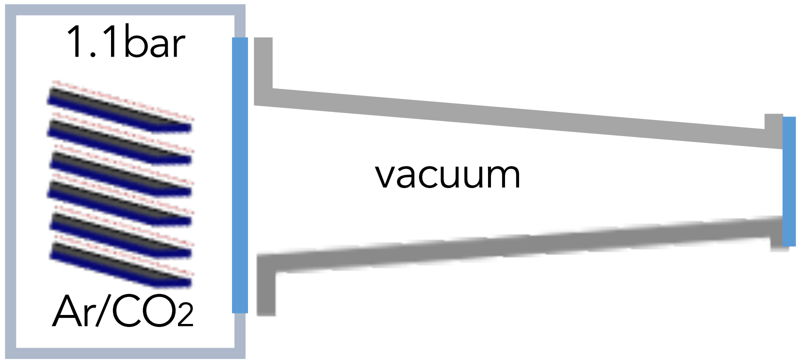
ESTIA/FREIA option



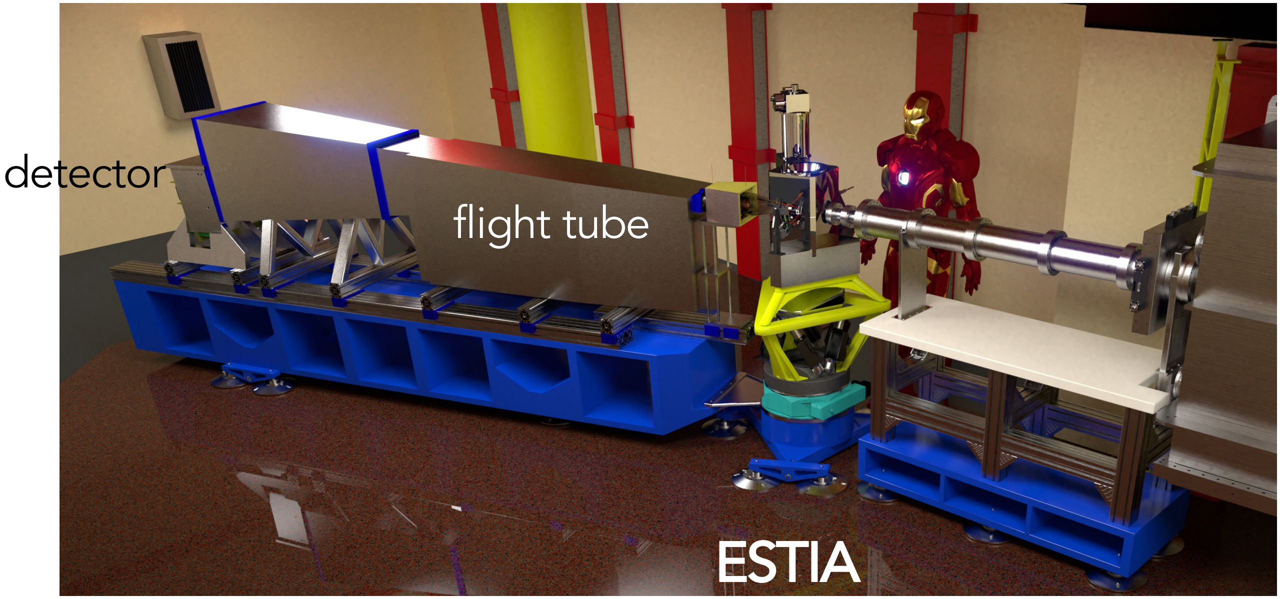
ΔP ~ 100mbar

Al foil or single crystal Silicon/Al_2O_3 can be used

FREIA option

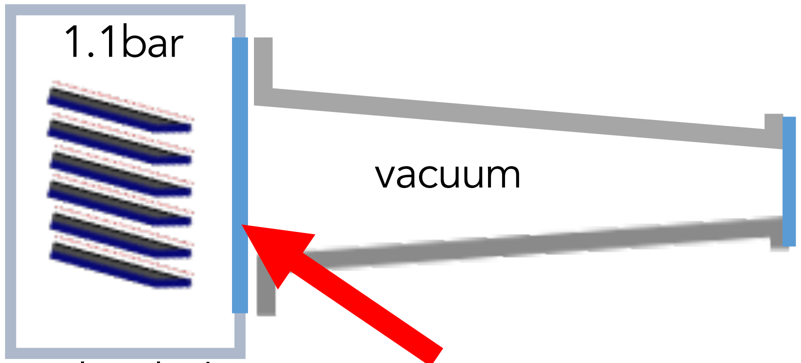


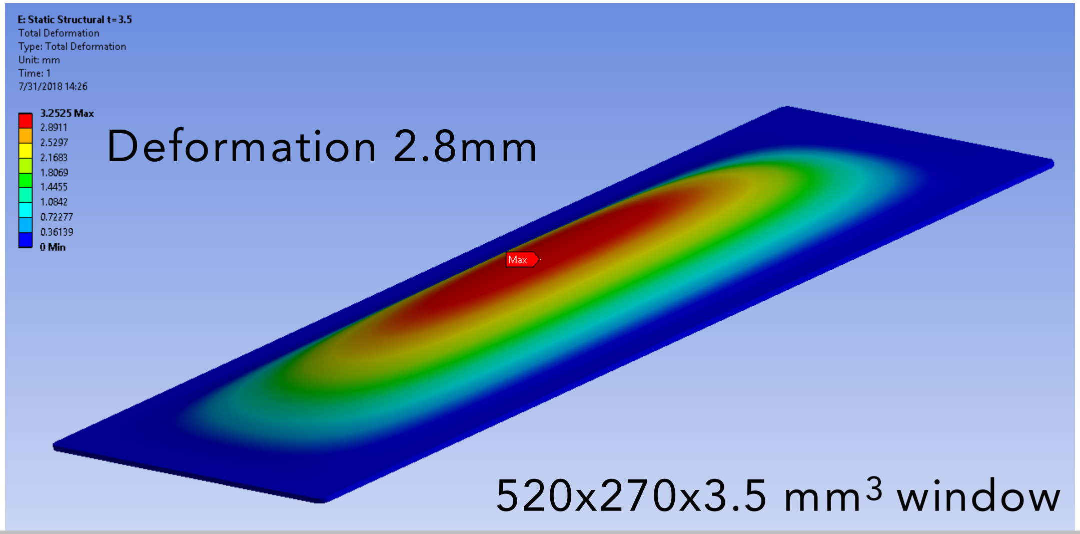
ΔP ~ 1bar

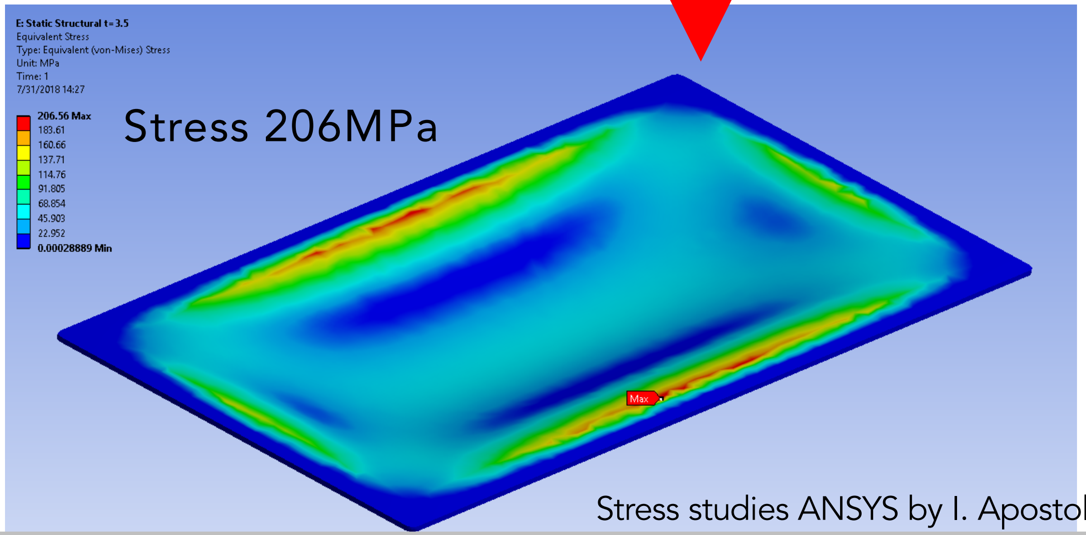


	Al 6000 series	Al 7000 series
Yield Strength	~240 MPa	~500 MPa
Composition	Al (96%) Mn (1%) Mg (1%) Si (1%) others (1%)	Al (90%), Cu (1.5%) Mg (2.5%) Zn (5%) others (1%)

Window Thickness	Stress
2 mm	290 MPa
3 mm	230 MPa
3.5 mm	206 MPa
5 mm	125 MPa



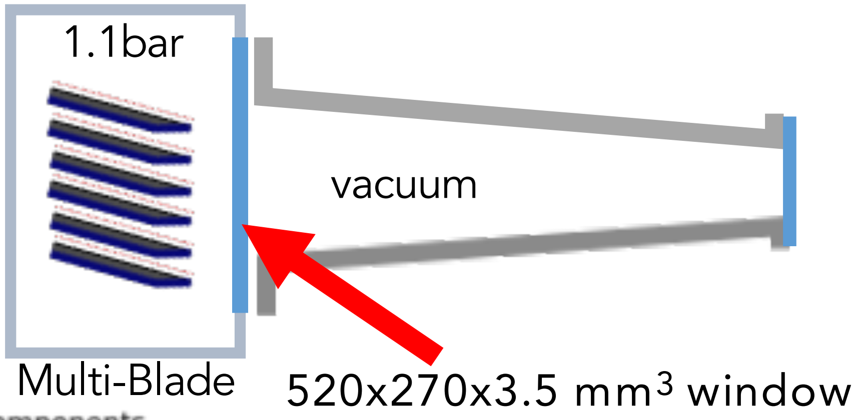


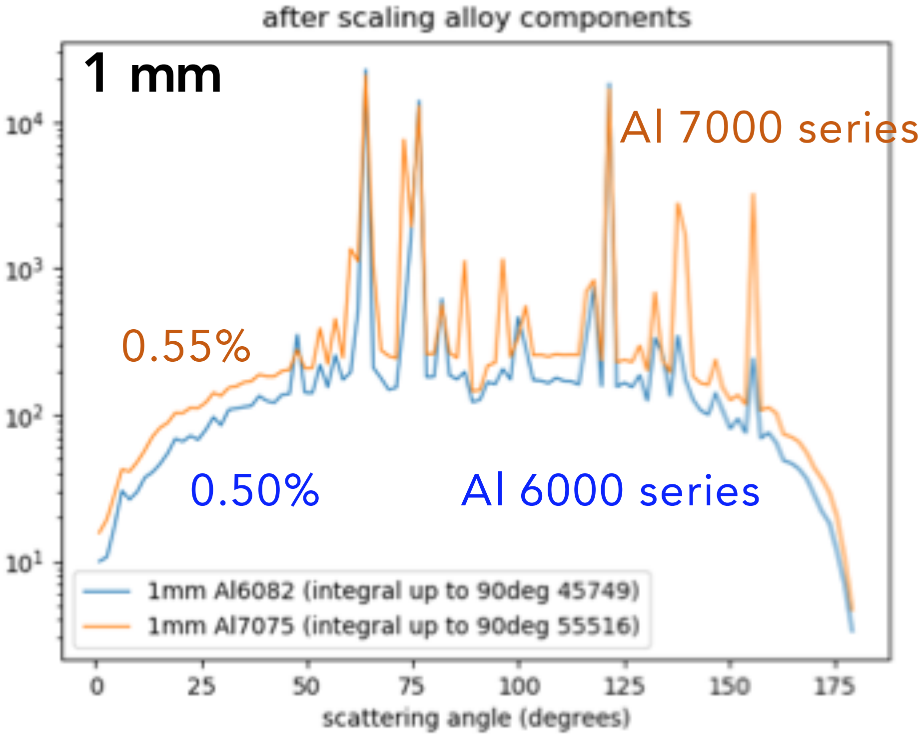


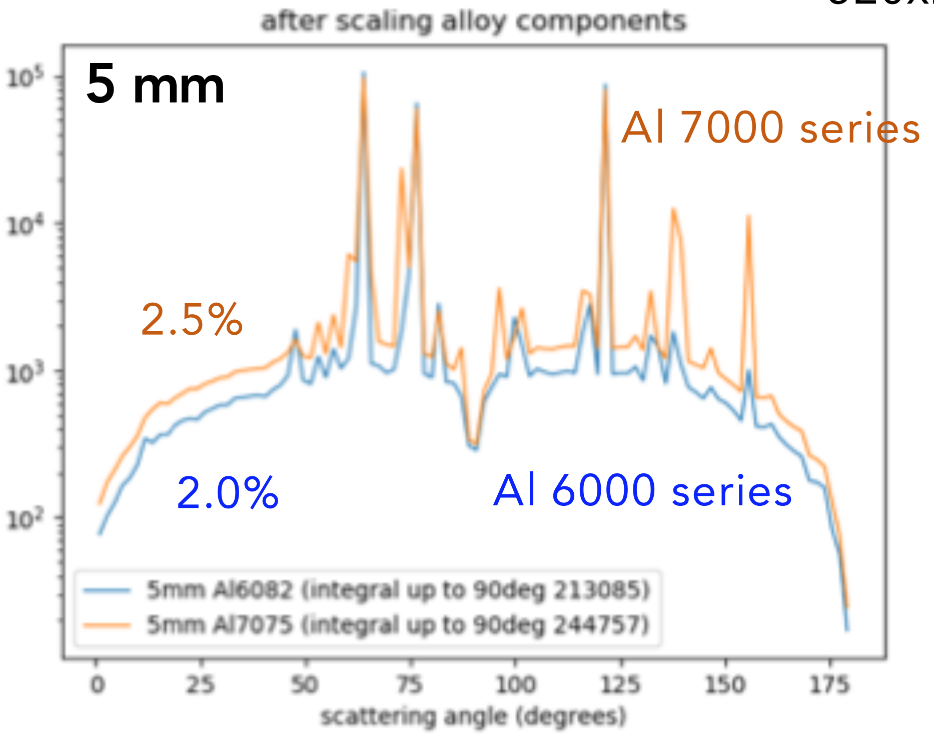
Stress studies ANSYS by I. Apostolidis

	Al 6000 series	Al 7000 series
Yield Strength	~240 MPa	~500 MPa
Composition	Al (96%) Mn (1%) Mg (1%) Si (1%) others (1%)	Al (90%), Cu (1.5%) Mg (2.5%) Zn (5%) others (1%)

Window Thickness	Stress
2 mm	290 MPa
3 mm	230 MPa
3.5 mm	206 MPa
5 mm	125 MPa





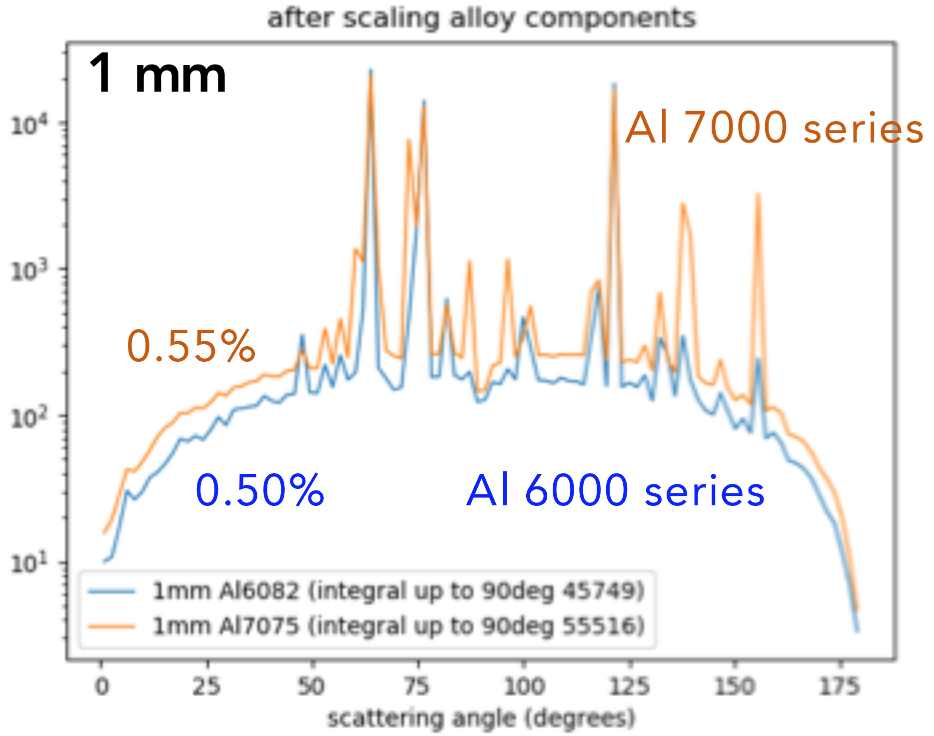


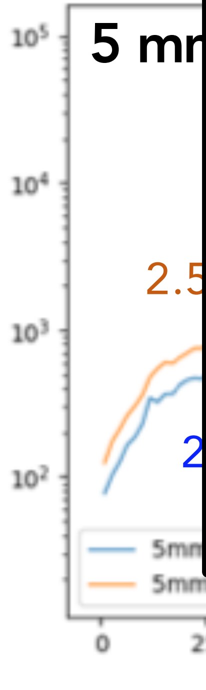
5mm Al 6000
can be reduced
to 2mm of Al 7000

Simulations GEANT4 by K. Kanaki

	Al 6000 series	Al 7000 series
Yield Strength	~240 MPa	~500 MPa
Composition	Al (96%) Mn (1%) Mg (1%) Si (1%) others (1%)	Al (90%), Cu (1.5%) Mg (2.5%) Zn (5%) others (1%)

Window Thickness	Stress
2 mm	290 MPa
3 mm	
3.5 mm	
5 mm	






PREPARED FOR SUBMISSION TO JINST

Geant4 based simulation of the Multi-Blade detector for investigation of spurious neutron scattering

G. Galgóczi[a,b,1] R. Hall-Wilton[c,d] K. Kanaki[c] T. Kittelmann[c] F. Piscitelli[c] D. Varga[b]

[a] Eötvös Loránd University, 1053 Budapest, Egyetem tér 1-3.
[b] Hungarian Academy of Sciences, Wigner Research Centre for Physics, 1525 Budapest 114., P.O. Box 49., Hungary
[c] European Spallation Source ESS AB, P.O Box 176, SE-221 00 Lund, Sweden
[d] Mid-Sweden University, SE-851 70 Sundsvall, Sweden

E-mail: galgoczi.gabor@wigner.mta.hu

ABSTRACT: Abstract...

KEYWORDS: Only keywords from JINST's keywords list please

Simulations GEANT4 by K. Kanaki

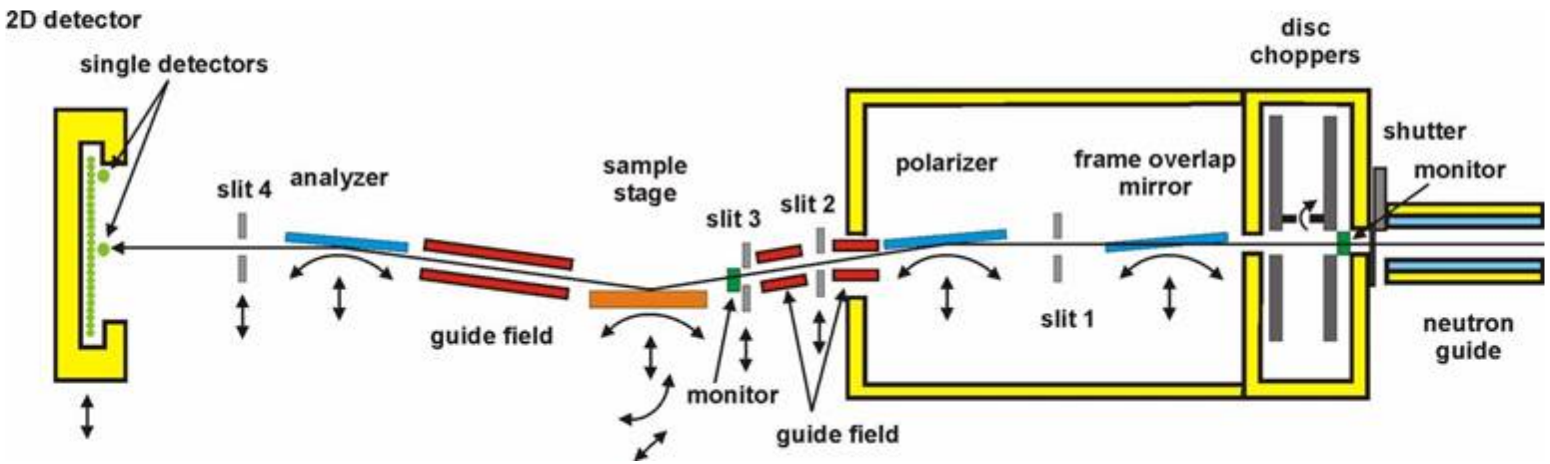
TEST on AMOR (PSI)

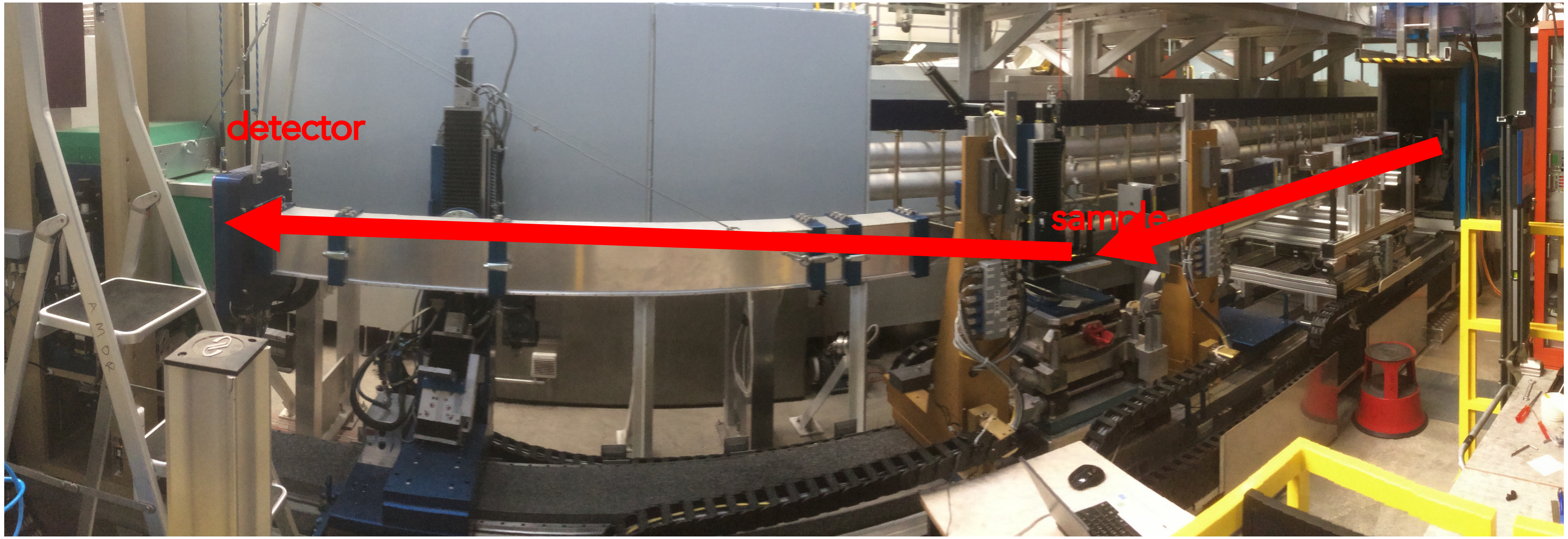
13-18 Nov 2018

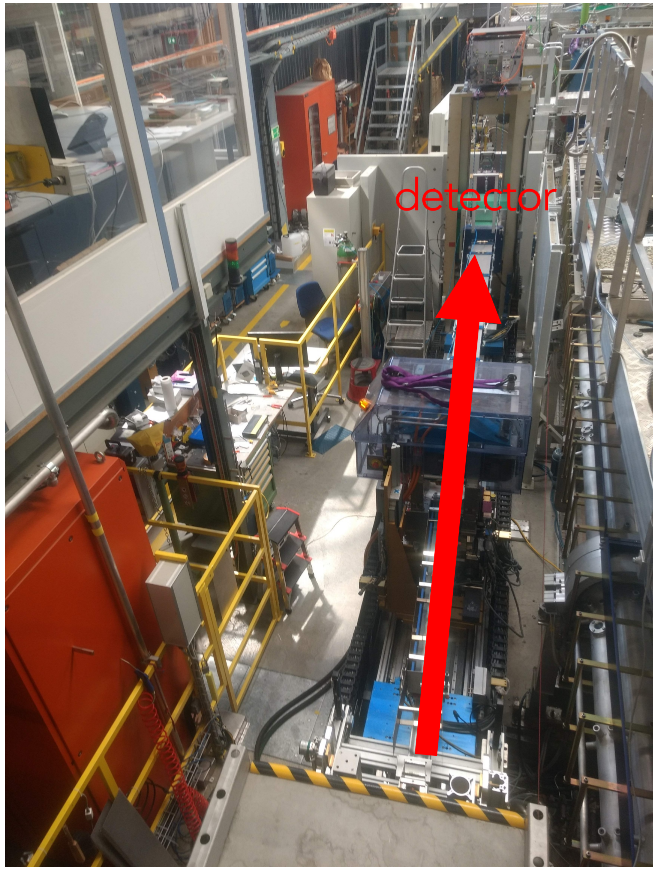
WHY: AMOR setup similar to the ESTIA setup (SELENE guides and focused beam)

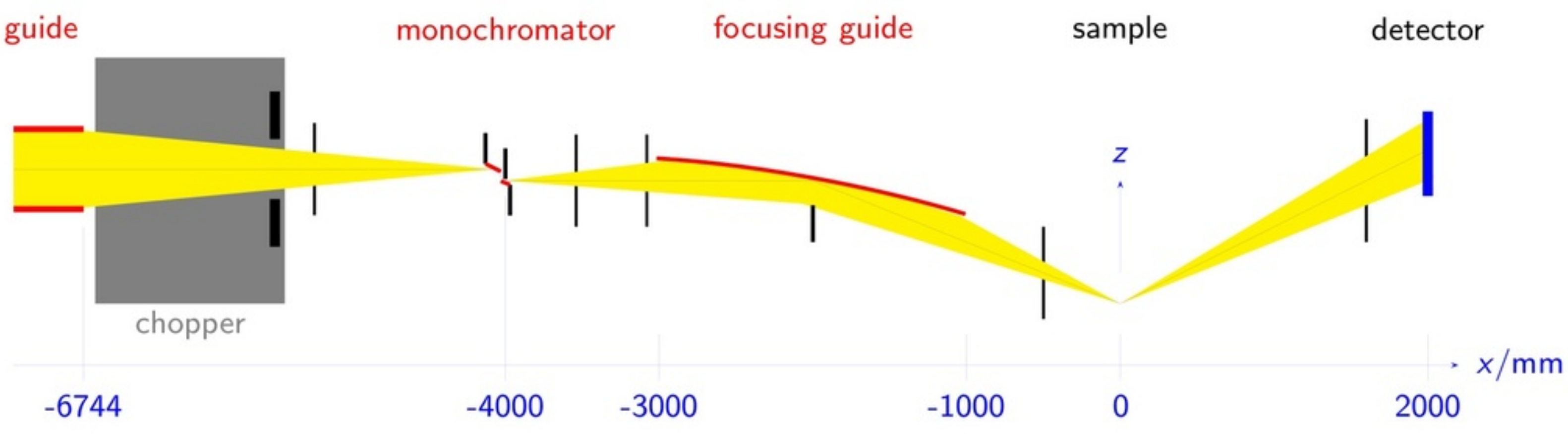
WHAT: MB18 same size of the demonstrator tested on CRISP, but with all the improvements that will be implemented on the MB300 for the instruments

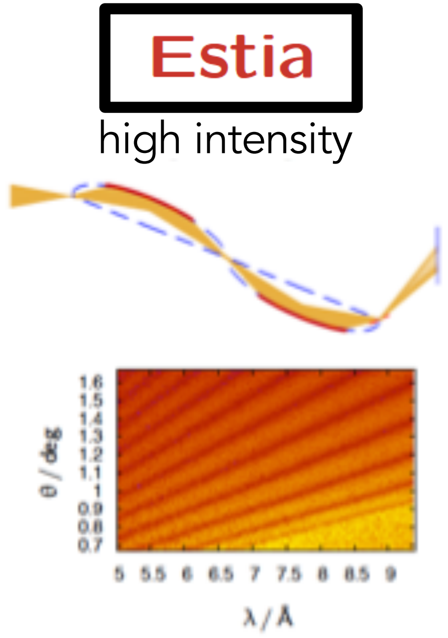
Test on AMOR (PSI)

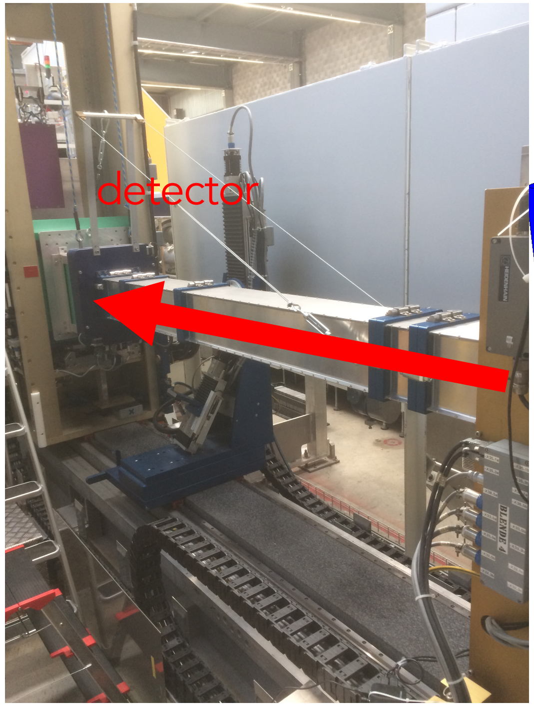


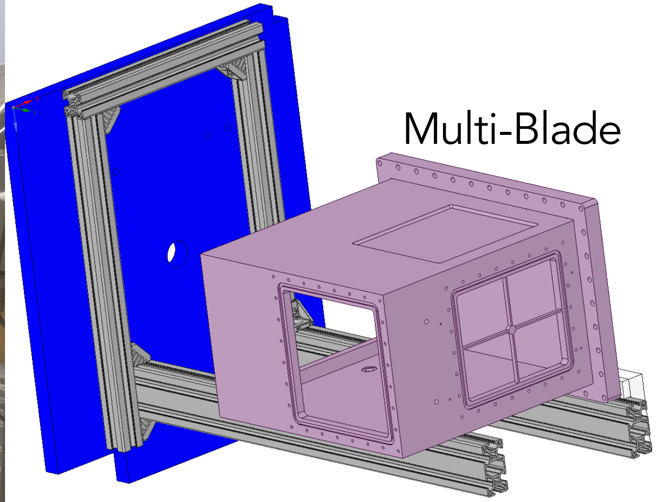


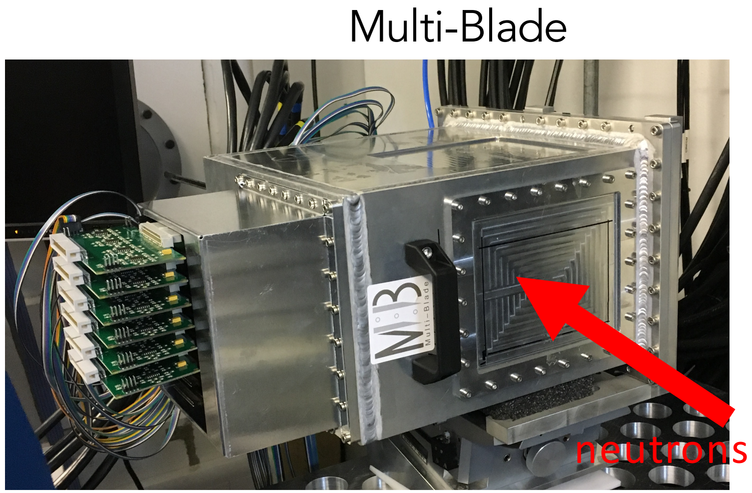












MB18 same size of the demonstrator of CRISP,
but with all the improvements that will be implemented on the MB300 for the instruments

Conclusions

✓ *MB concept*

Design is ready to build for ESS instruments

Design completed

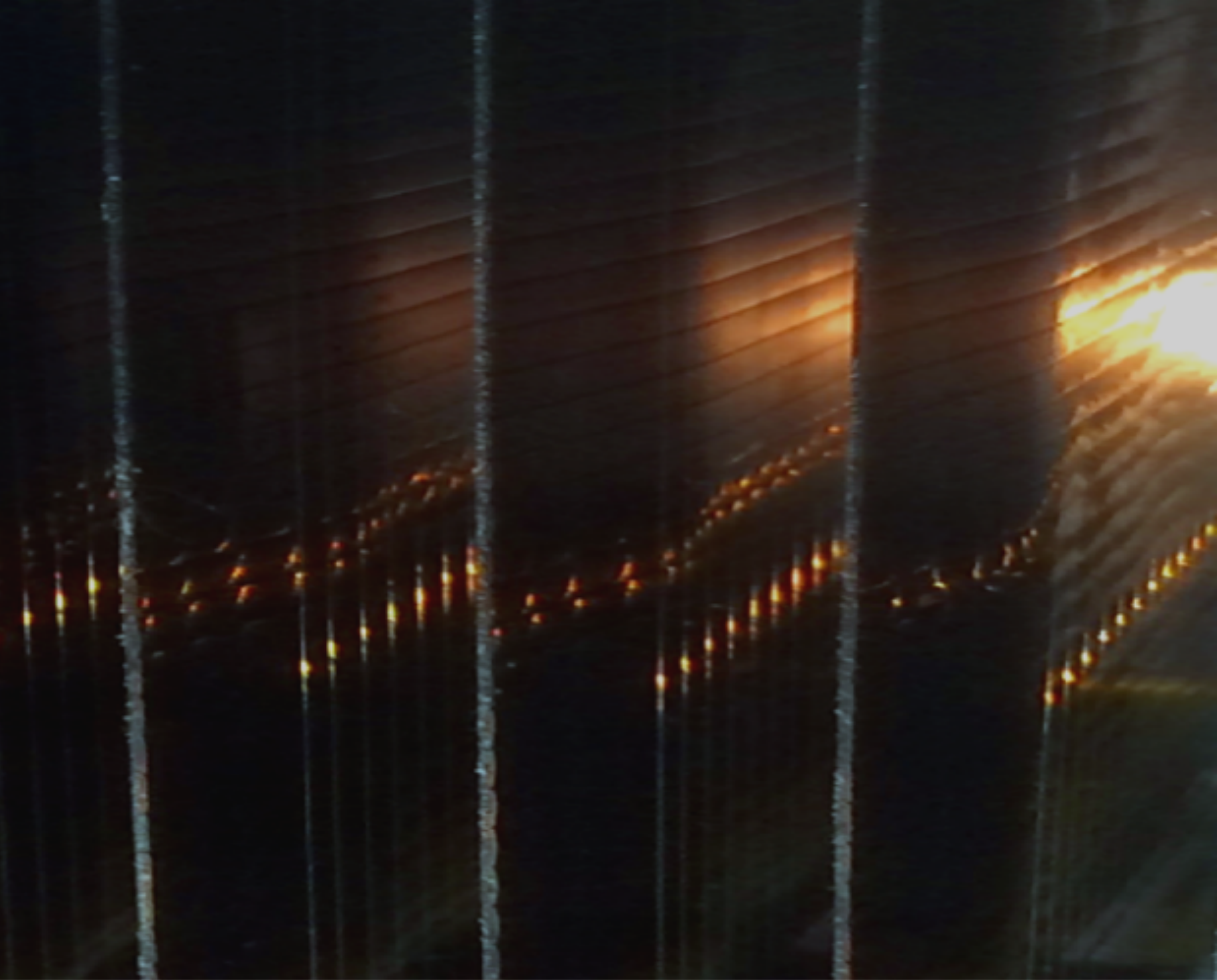
Blades ordered

✓ *MB fast neutron - gamma sensitivity*

The sensitivity to background has been characterized
Thermal n bg > fast n bg > gamma bg

✓ *CRISP TEST*

The Multi-Blade detector can be considered a mature technology for neutron reflectometry



Conclusions

- ✓ *MB concept*

Design is ready to build for ESS instruments

Design completed

Blades ordered

- ✓ *MB fast neutron - gamma sensitivity*

The sensitivity to background has been characterized

Thermal n bg > fast n bg > gamma bg

- ✓ *CRISP TEST*

The Multi-Blade detector can be considered a mature technology for neutron reflectometry

Future plans

- ➢ *Upcoming tests*

Beam time offered at PSI on AMOR (ESTIA concept)

Beam time offered at ISIS for rate tests

Beam time offered at ILL (2019, rainbow concept on D50)

Multi-Blade detector suggested for IFE new reflectometer

- ➢ *Next MB detector*

Build scaled up detector for ESTIA and FREIA

Thank you for your attention

F. Piscitelli et al., Characterization of the Multi-Blade 10B-based detector at the CRISP reflectometer at ISIS, ArXiv:1803.09589, JINST 13 P05009 (2018).

G. Mauri et al., Neutron reflectometry with the Multi-Blade 10B-based detector, ArXiv:1804.03962, Proc. R. Soc A 474: 20180266 (2018).

G. Mauri et al., Fast neutron sensitivity of neutron detectors based on boron-10 converter layers, ArXiv:1712.05614, JINST 13 P03004 (2018).

F. Piscitelli et al., The Multi-Blade Boron-10-based Neutron Detector for high intensity Neutron Reflectometry at ESS, ArXiv:1701.07623, JINST 12 P03013 (2017).

A. Carmona Besañez et al., Python tool for eff calculations of B10 detectors, ArXiv:1801.07124, submitted to Computer Physics Communications (2018).

F. Piscitelli et al., Neutron reflectometry on highly absorbing films and its application to $^{10}B_4C$-based neutron detectors, ArXiv:1510.01085v1, Proc. R. Soc. A 472, Issue 2185 (2016).

F. Piscitelli et al. Study of a high spatial resolution ^{10}B-based thermal neutron detector for neutron reflectometry: the Multi-Blade prototype, ArXiv1312.2473, JINST 9 P03007 (2014).

F. Piscitelli and P. Van Esch, Analytical modeling of thin film neutron converters and its application to thermal neutron gas detectors, ArXiv:1302.3153, JINST 8 P04020 (2013).