Wigner Research Institute

EUROPEAN SPALLATION SOURCE

LUND UNIVERSITY

LINKÖPINGS UNIVERSITET

Linköping University

The **Multi-Blade** ^{10}B-based neutron detector for high intensity neutron **reflectometry** at **ESS**

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

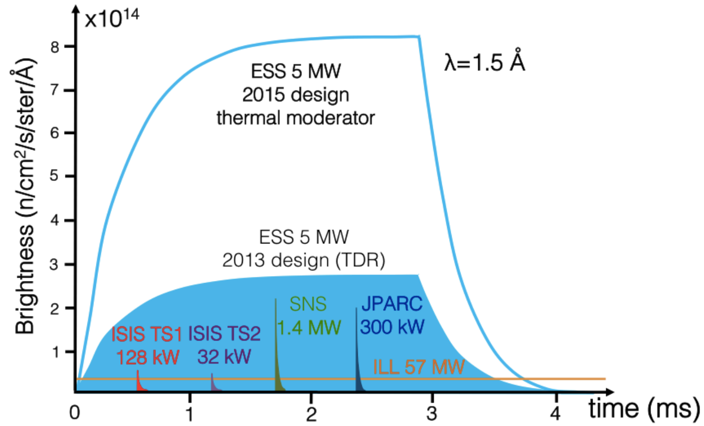
DMSC workshop

2016/11/09

brightness

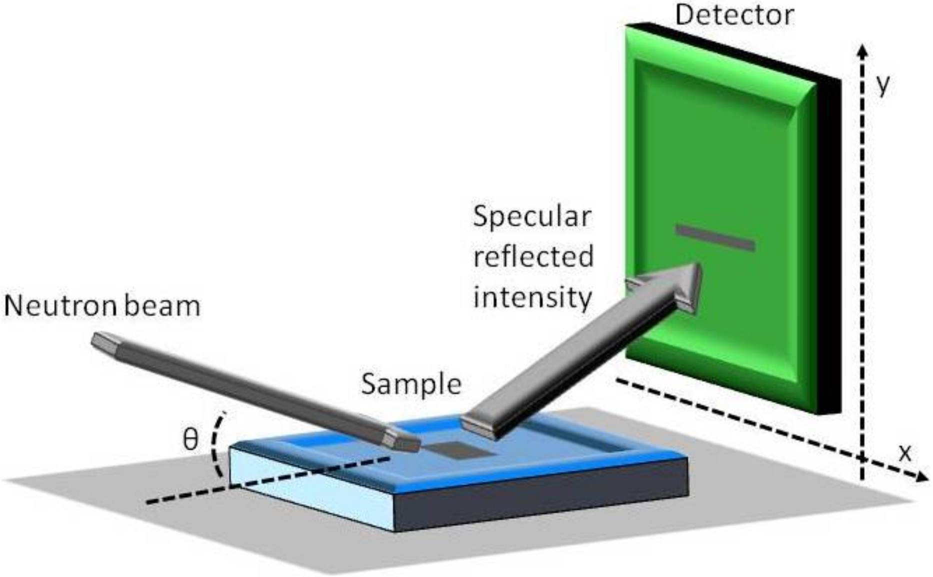
Building research infrastructure and synergies for highest scientific impact on ESS

ESS will be several times brighter than existing facilities

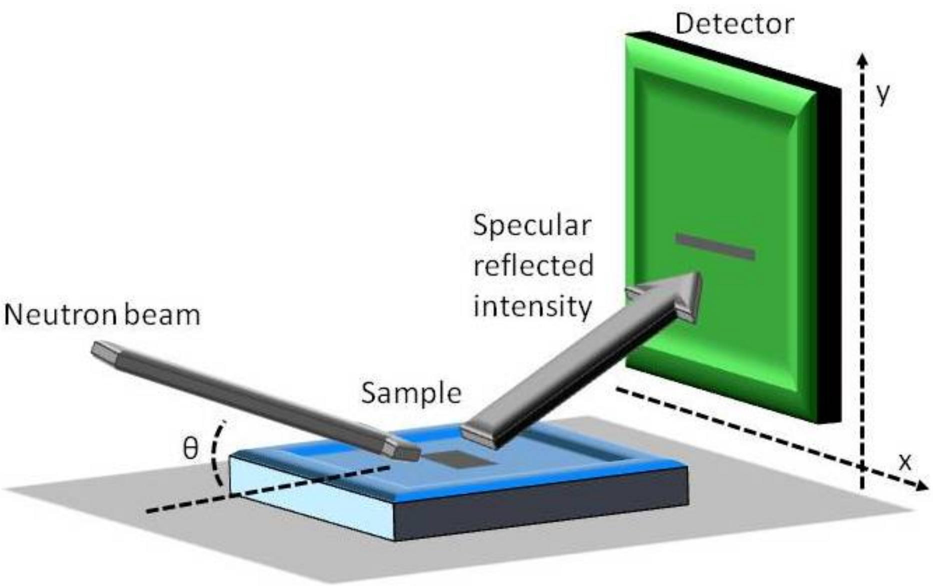


More powerful neutron instruments

Very High detector requirements

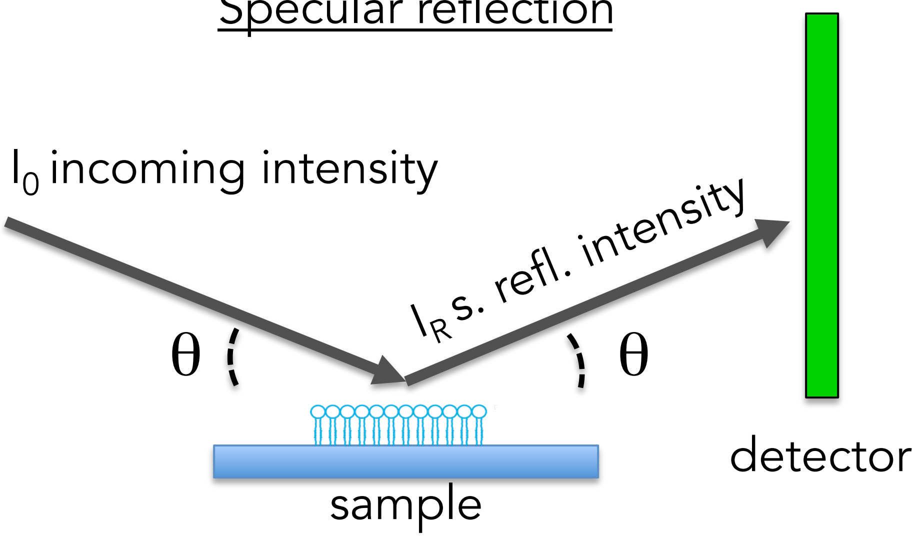


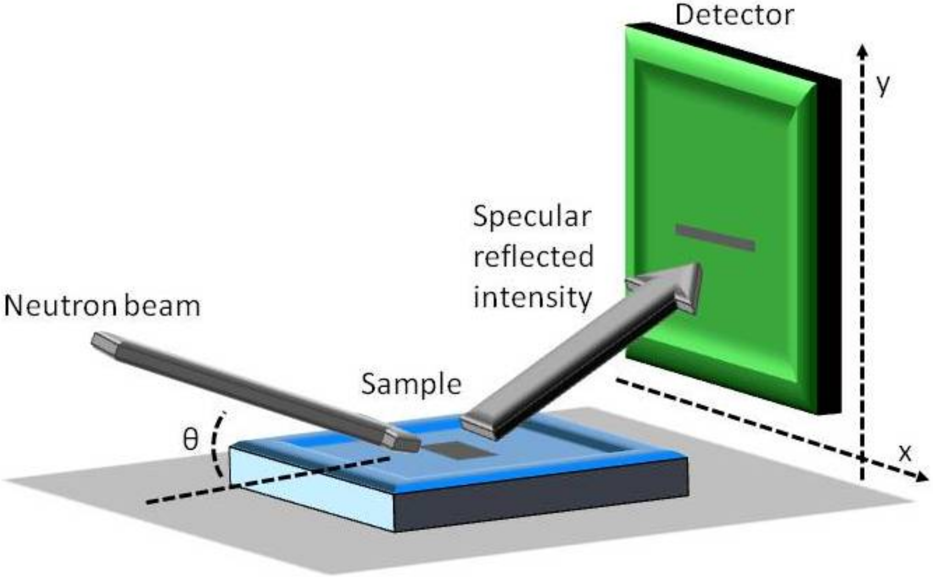
Reflectometry is a technique to study
SURFACES AND INTERFACES



Reflectometry is a technique to study SURFACES AND INTERFACES

Specular reflection

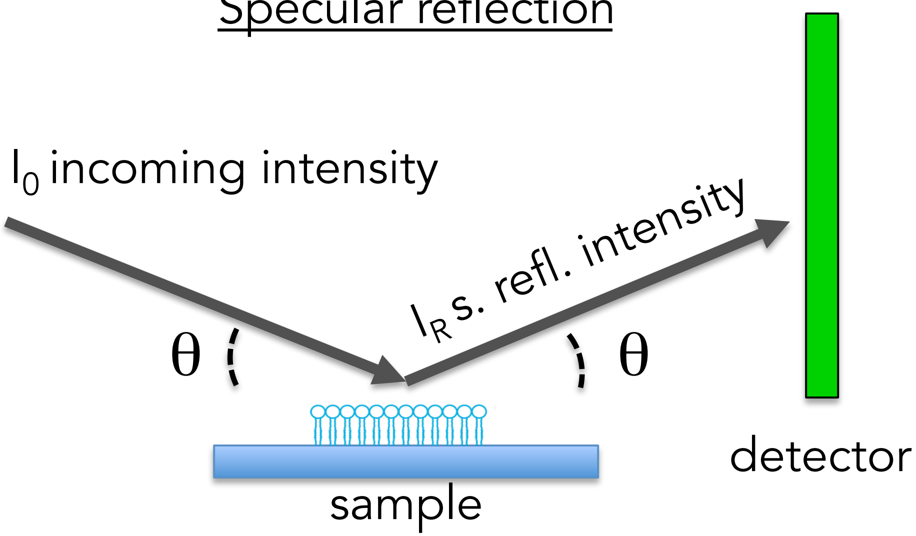




Reflectometry is a technique to study SURFACES AND INTERFACES

To measure the reflected neutrons as a function of q

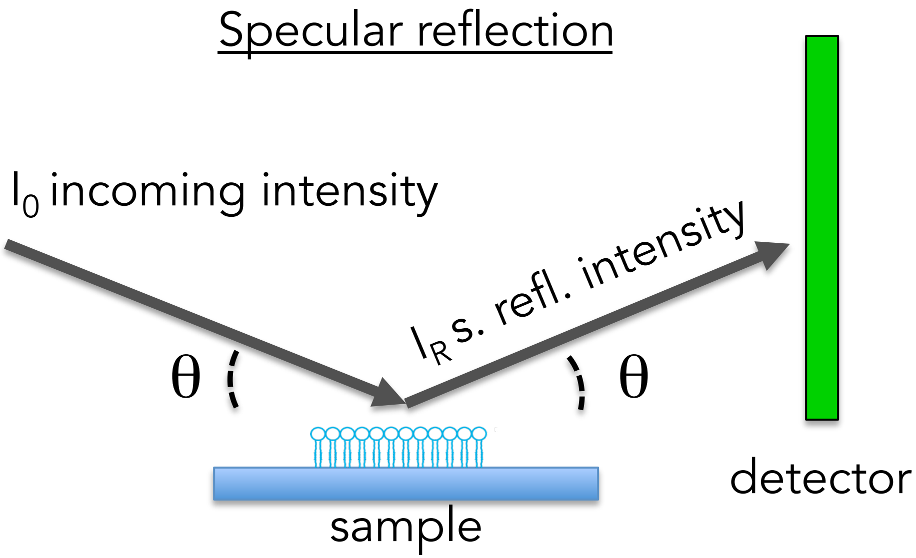
Specular reflection



Neutron wavelength

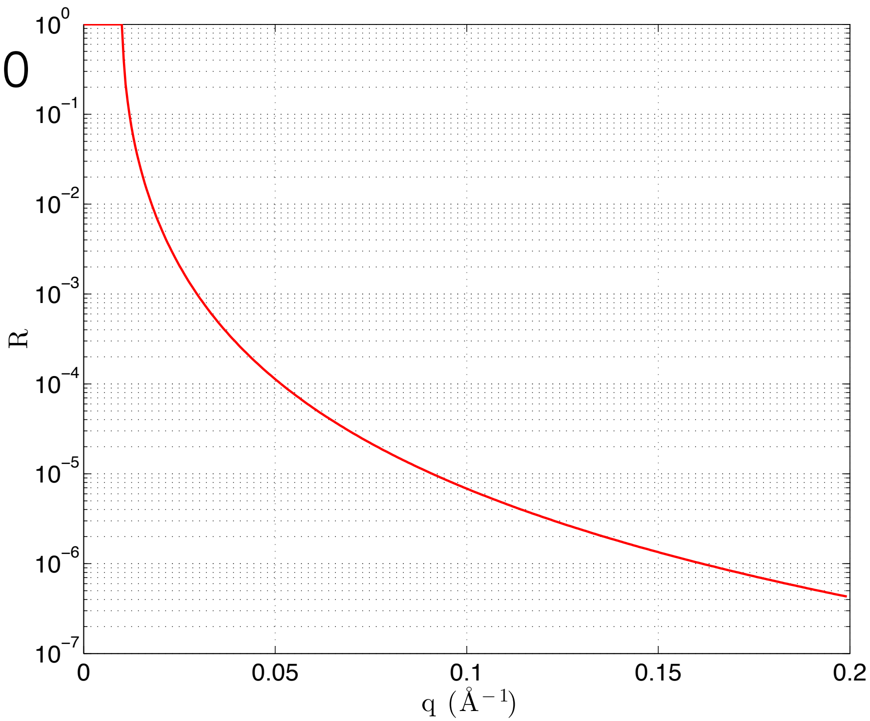
$$q = (4\pi/\lambda)\sin(\theta)$$

Incidence angle

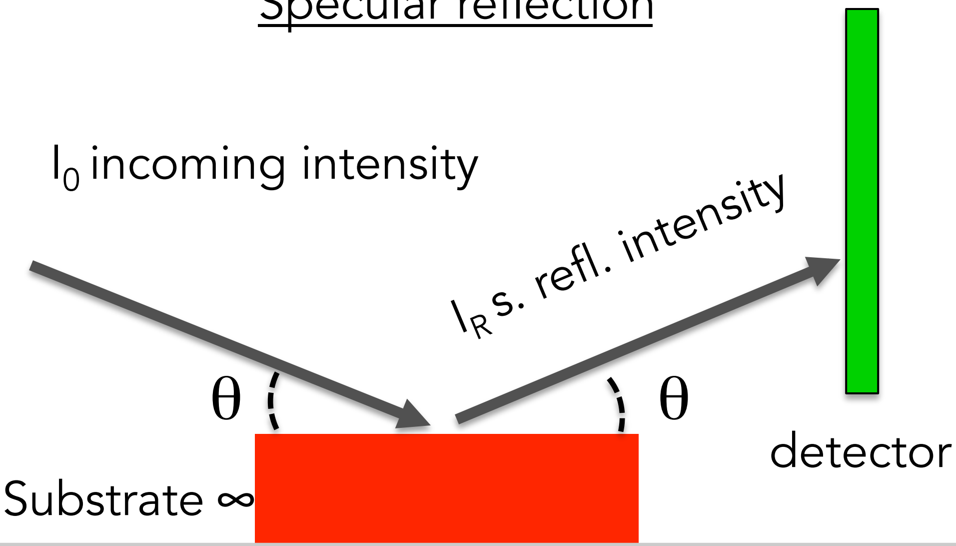


$$q = (4\pi/\lambda)\sin(\theta)$$

$R = I_R/I_0$



Specular reflection



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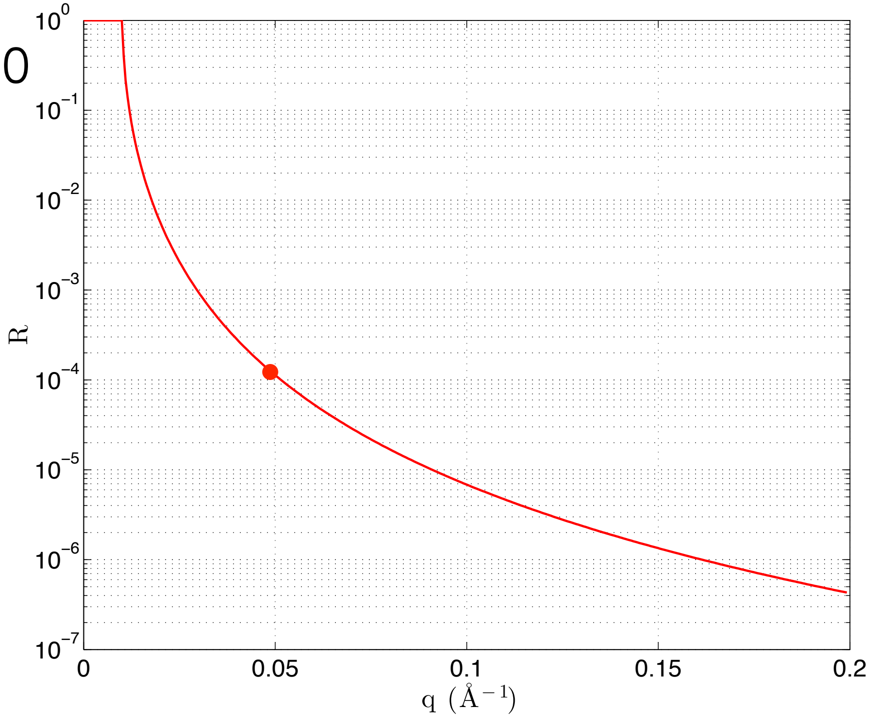

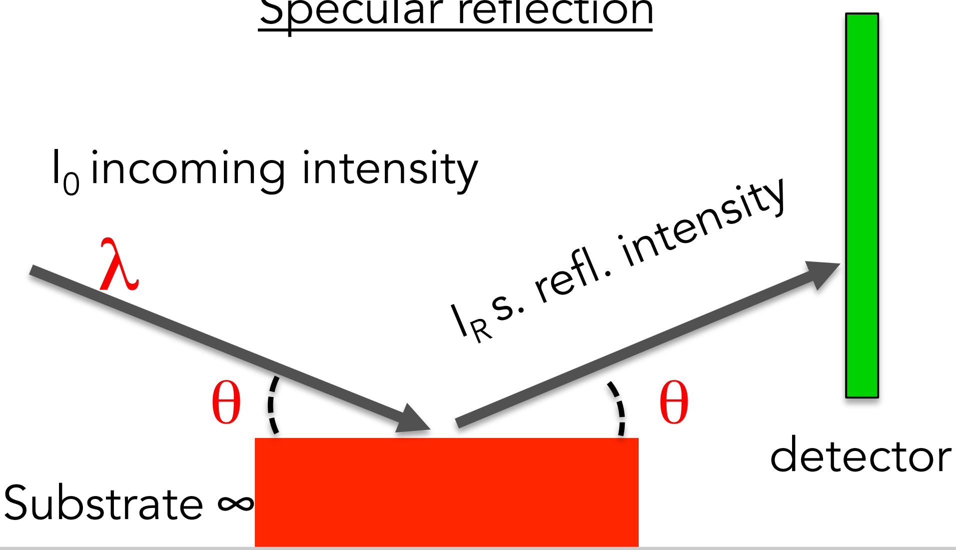

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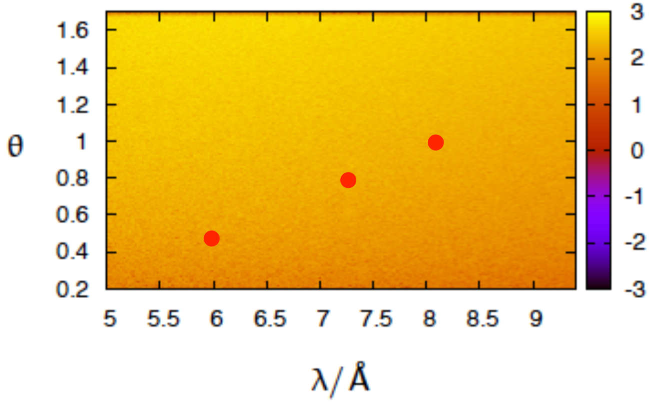
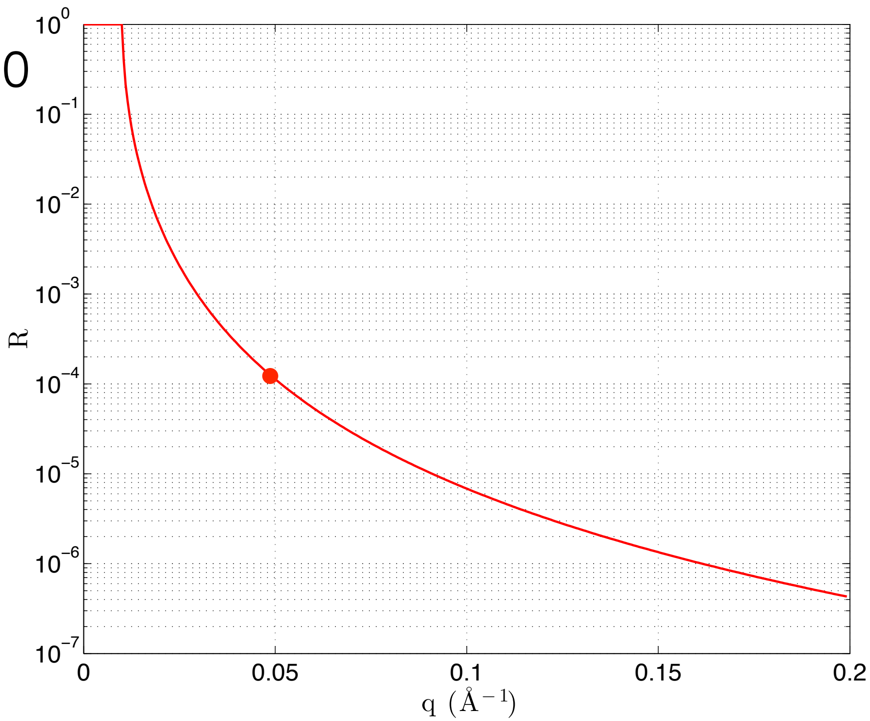
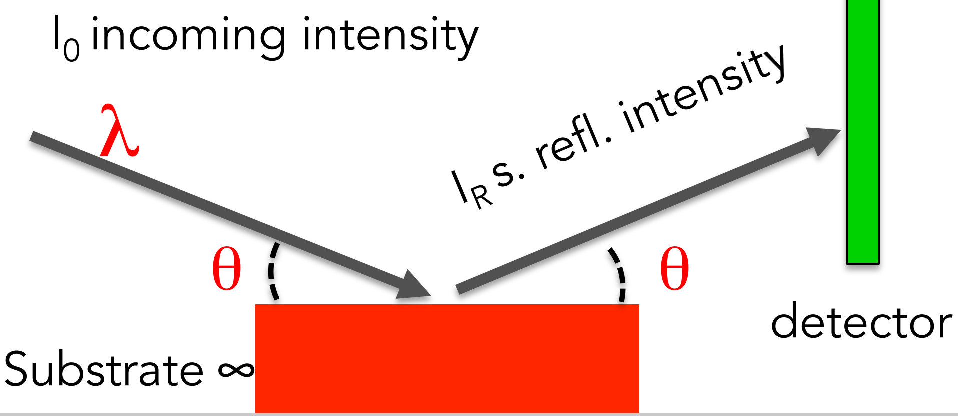




<u>Specular reflection</u>



$$q = (4\pi/\lambda)\sin(\theta)$$

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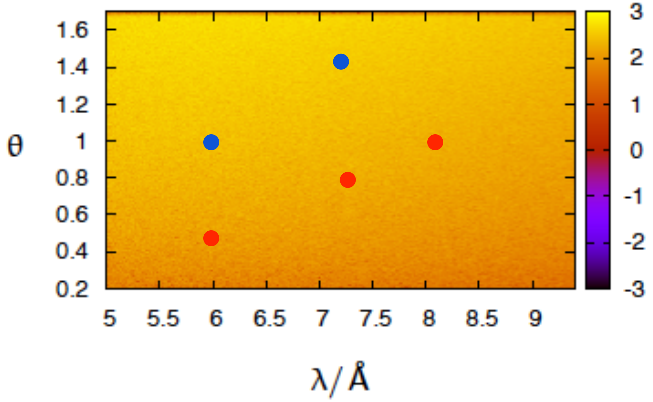
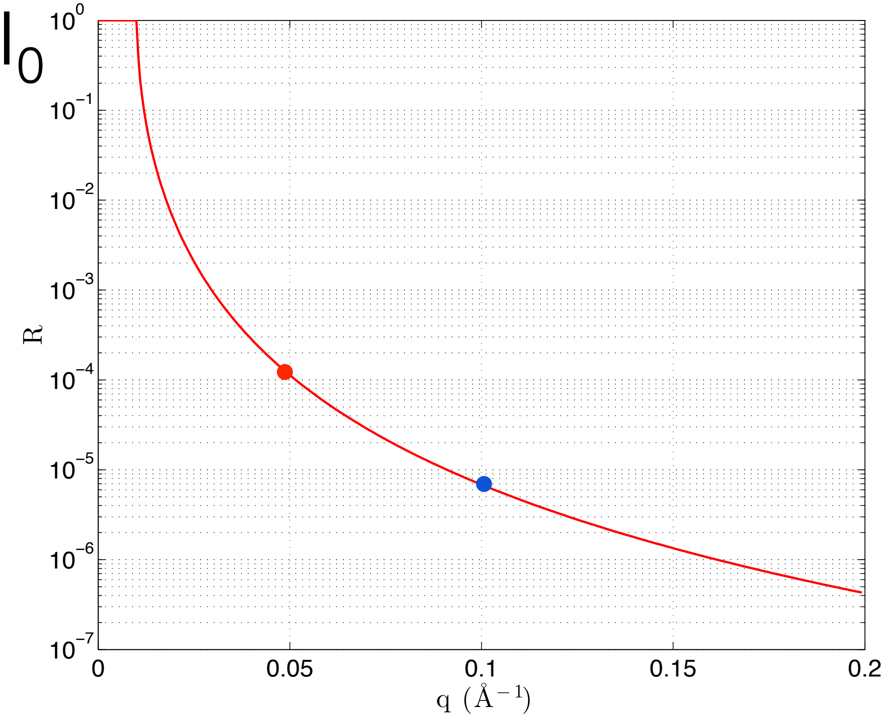
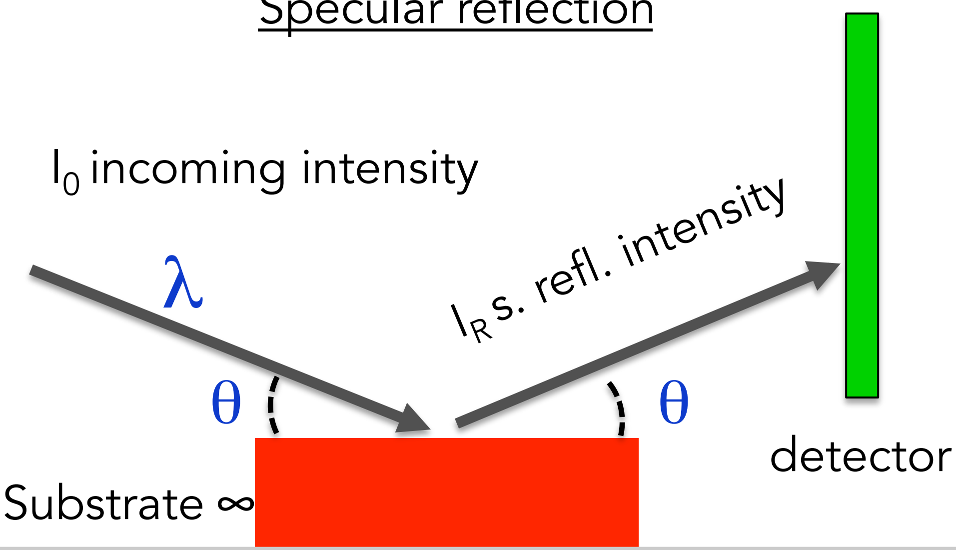




Specular reflection



$$q = (4\pi/\lambda)\sin(\theta)$$

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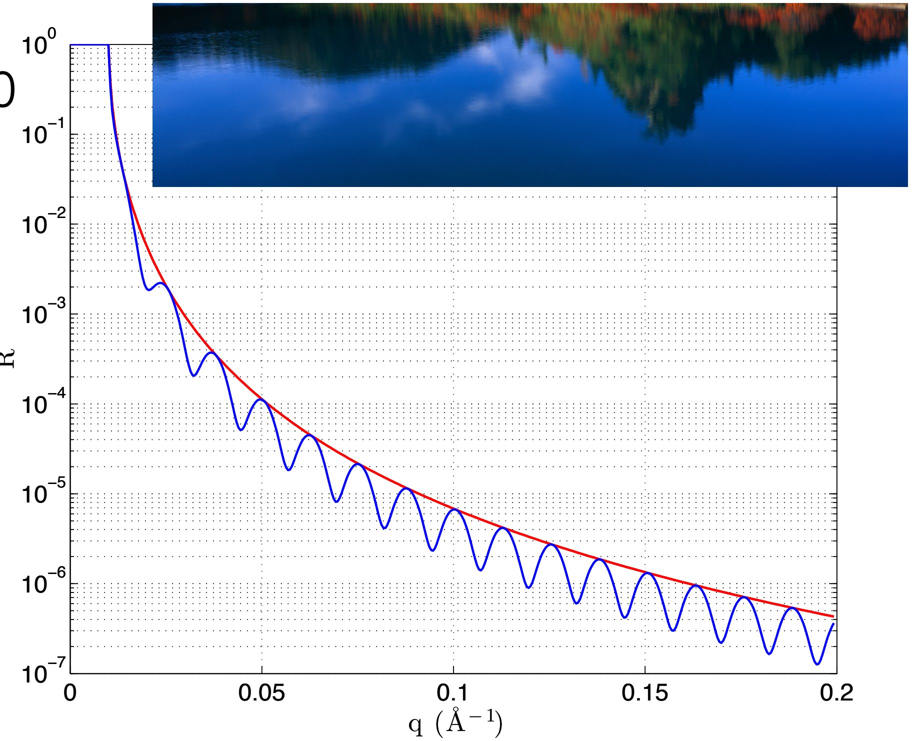
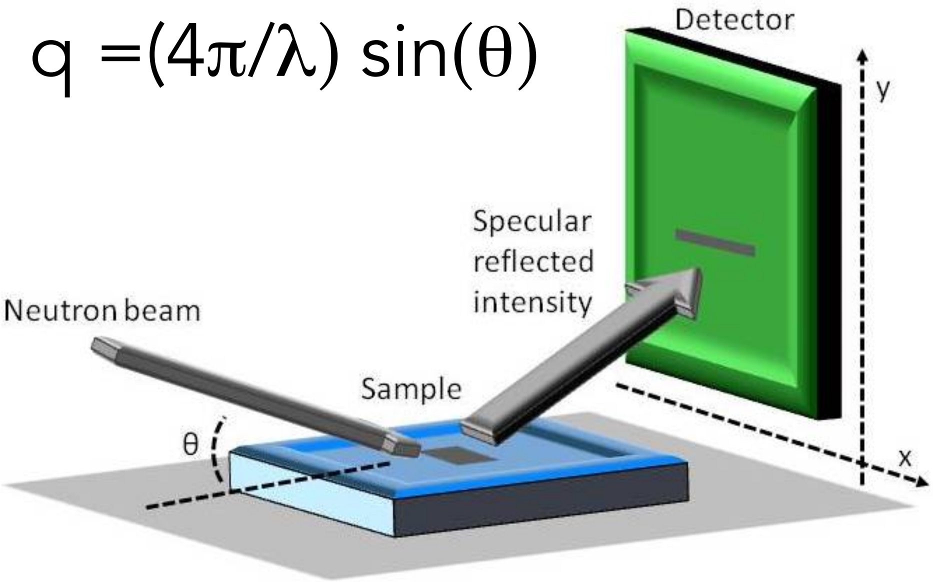
FITTING & INVERSION

R PROFILE

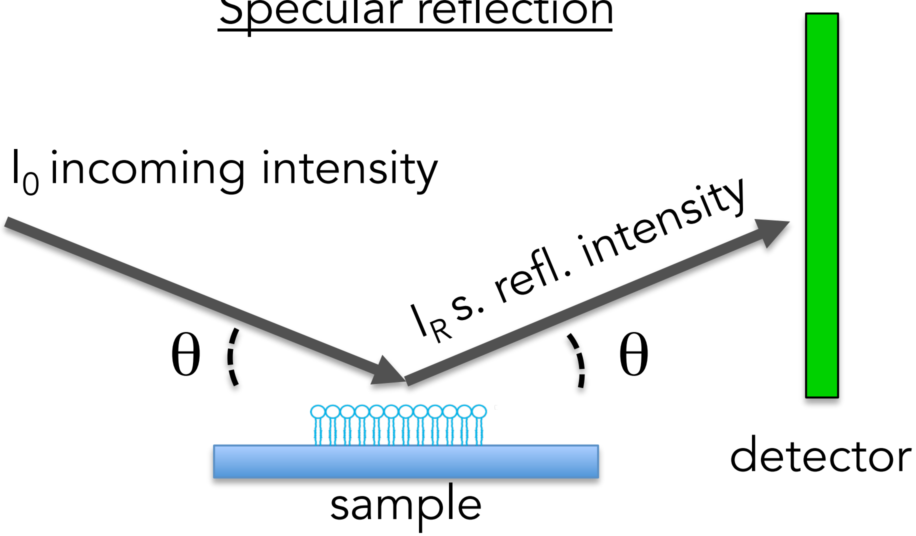


SAMPLE (SLD profile)

$$q = (4\pi/\lambda)\sin(\theta)$$



Specular reflection



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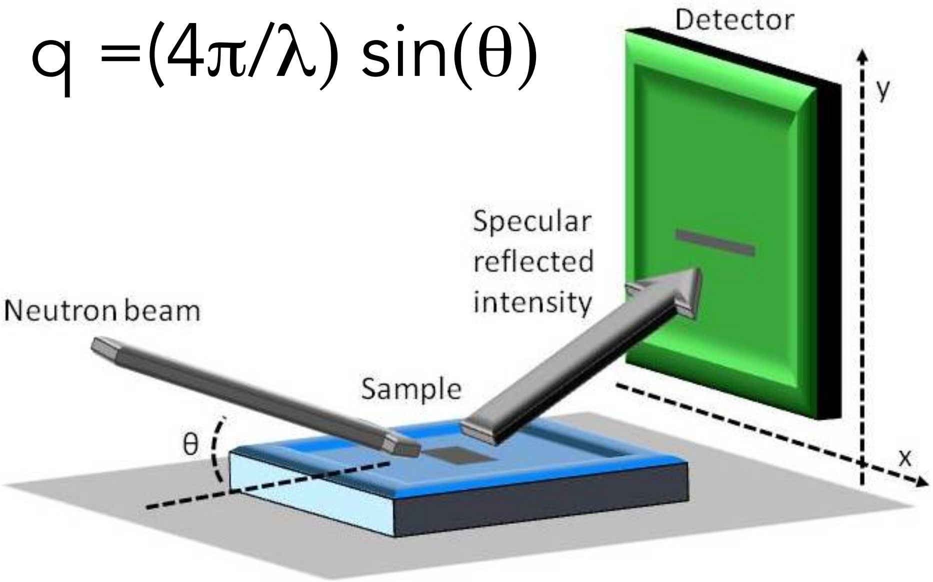

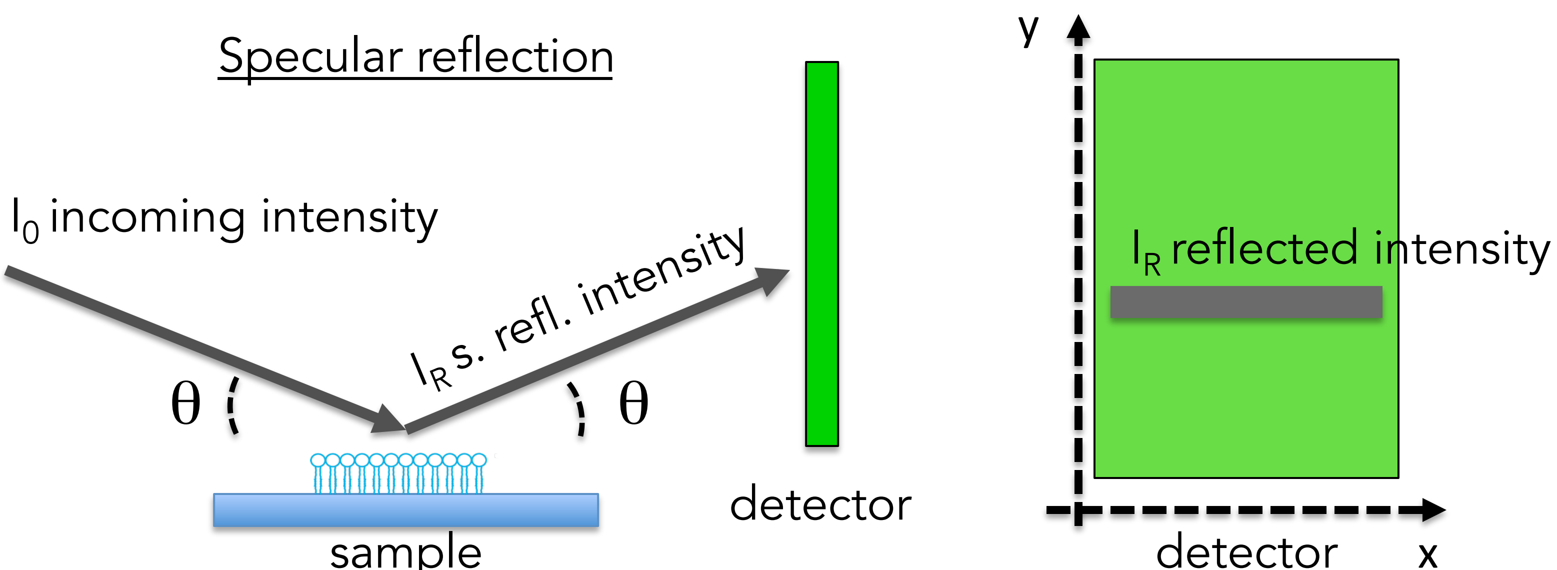

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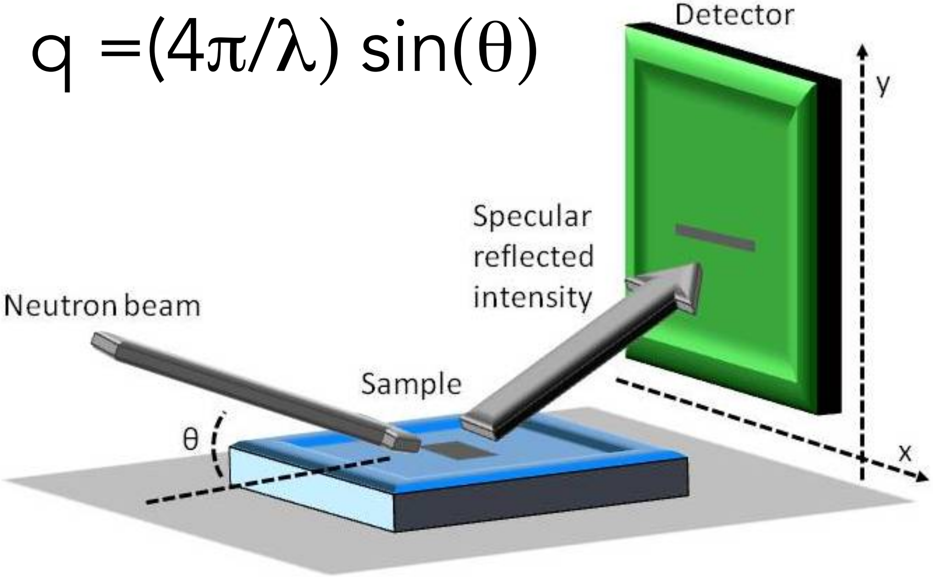
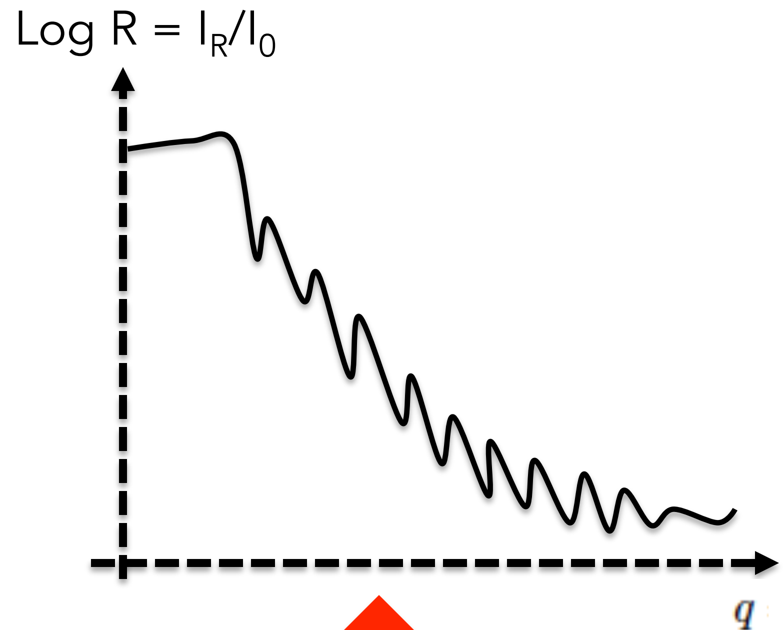
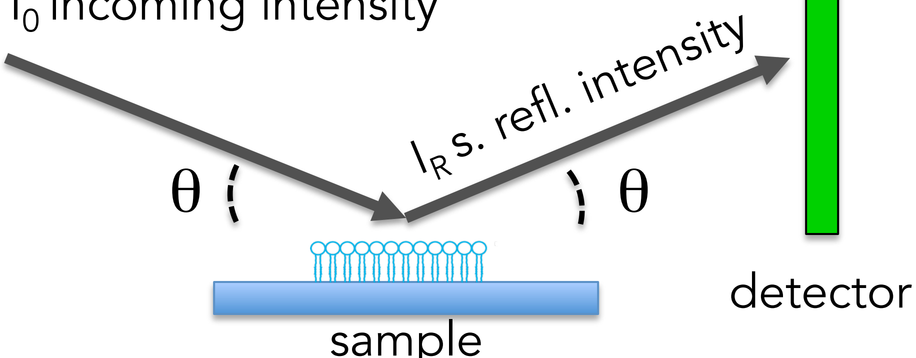
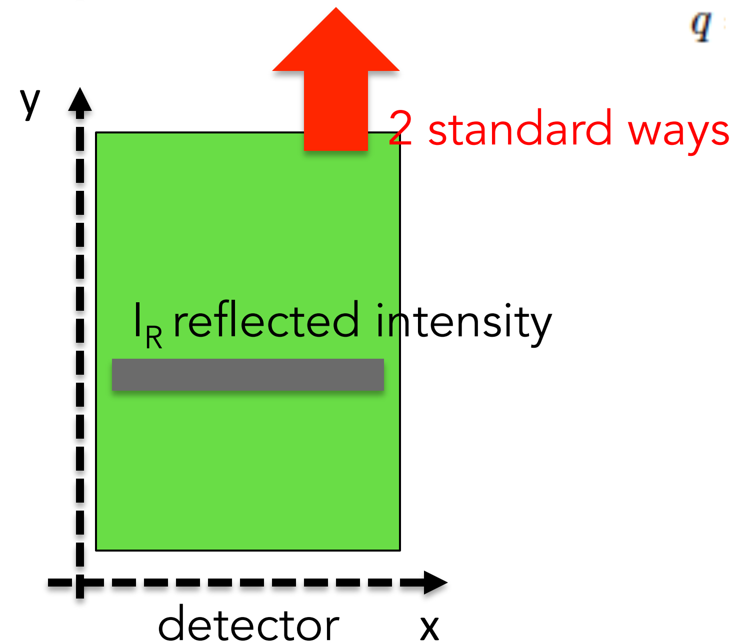




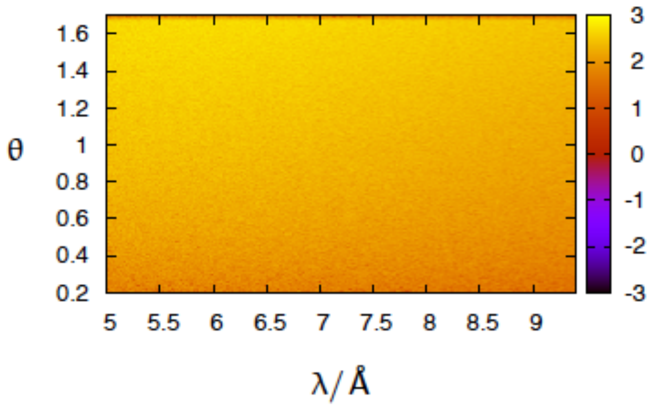
Specular reflection

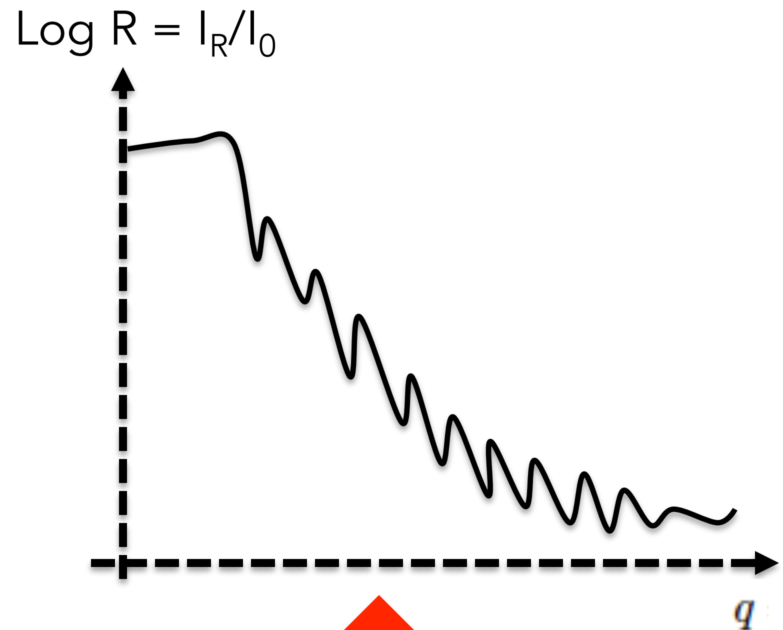




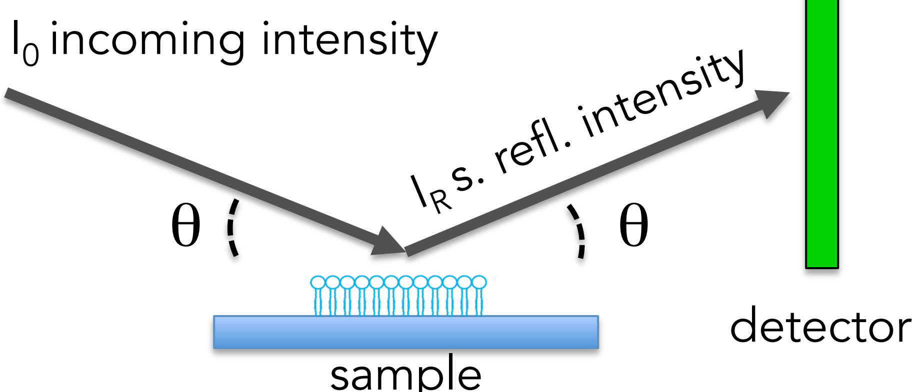
$$q = (4\pi/\lambda)\sin(\theta)$$

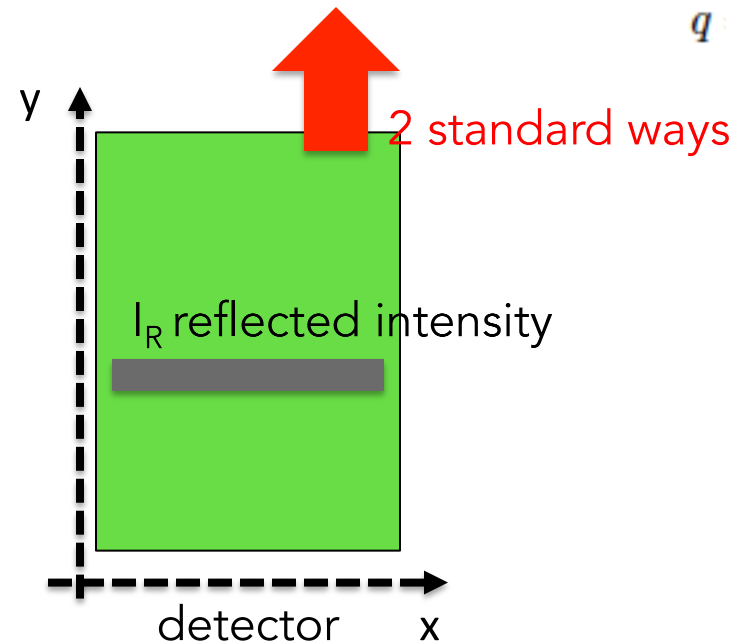
1. ToF (λ scan, θ fixed)
2. Monochromatic (λ fixed, θ scan)





Specular reflection





$$q = (4\pi/\lambda)\sin(\theta)$$

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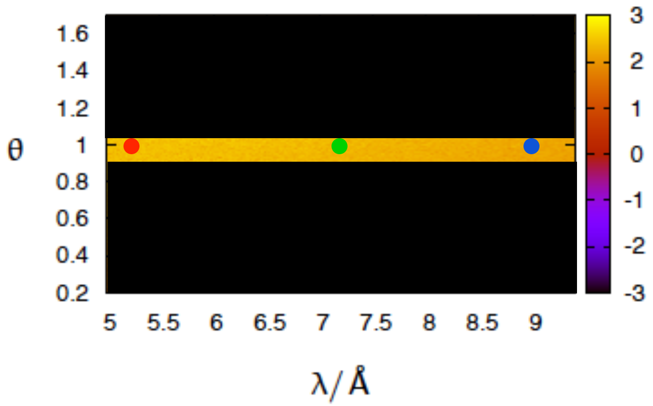
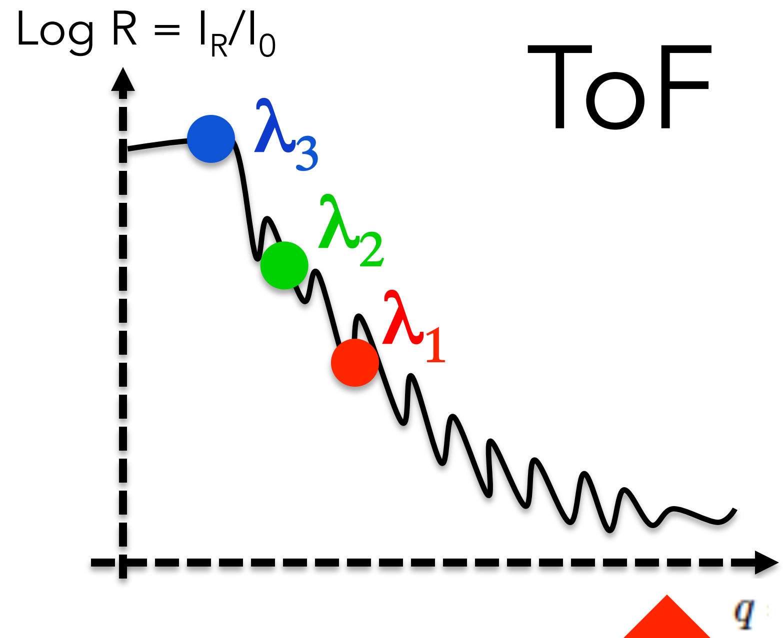
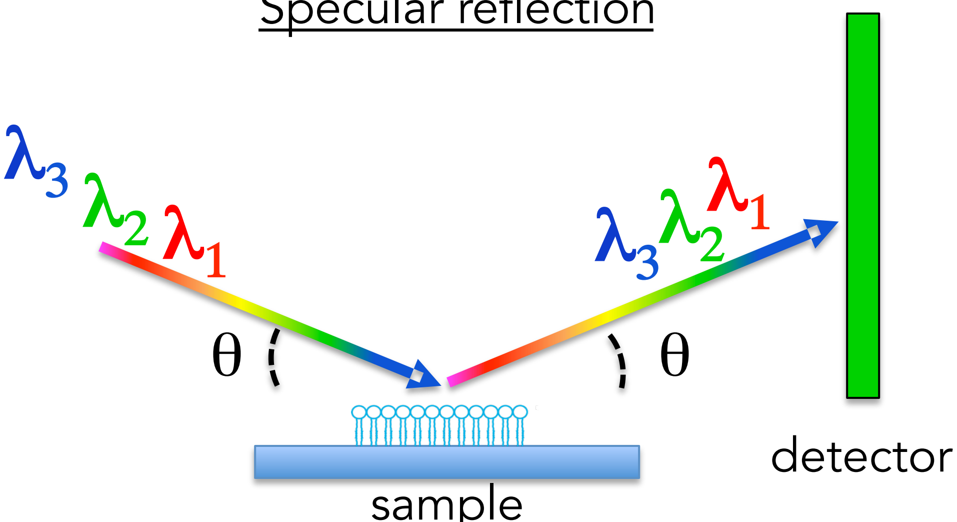
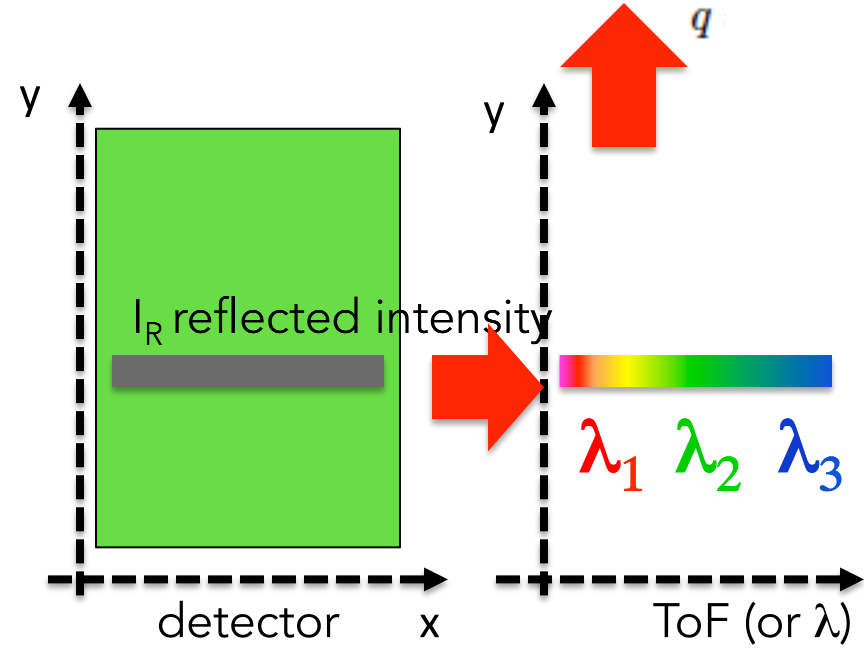


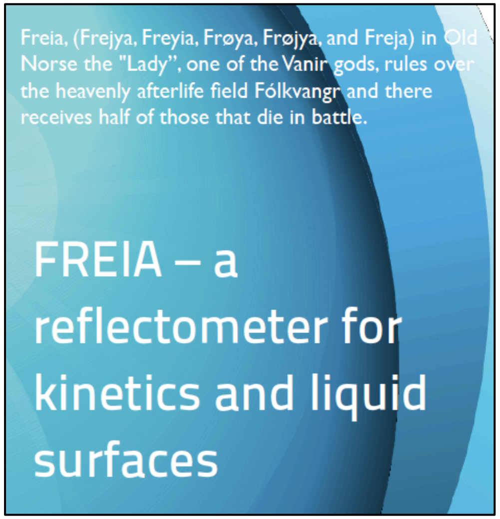
ToF

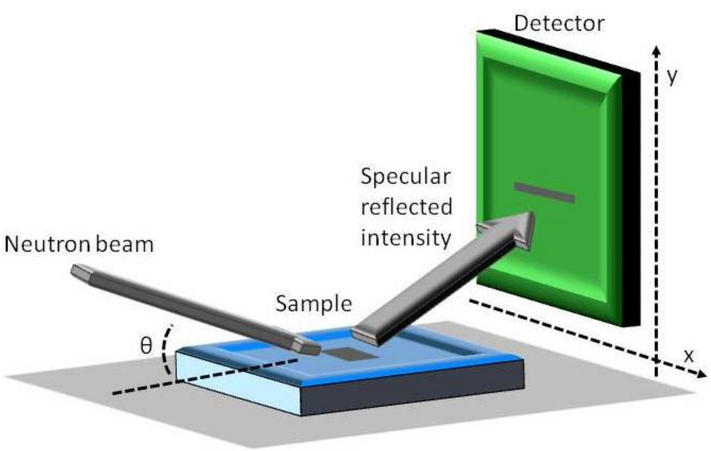


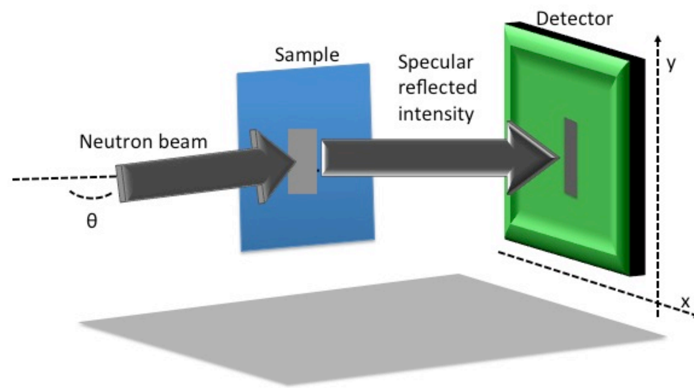
Specular reflection







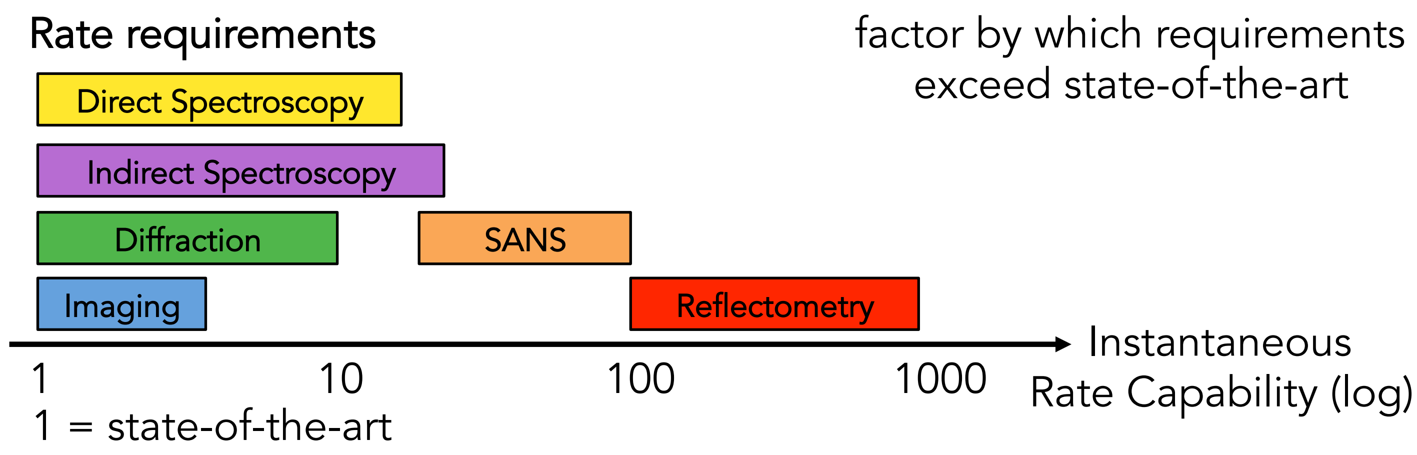




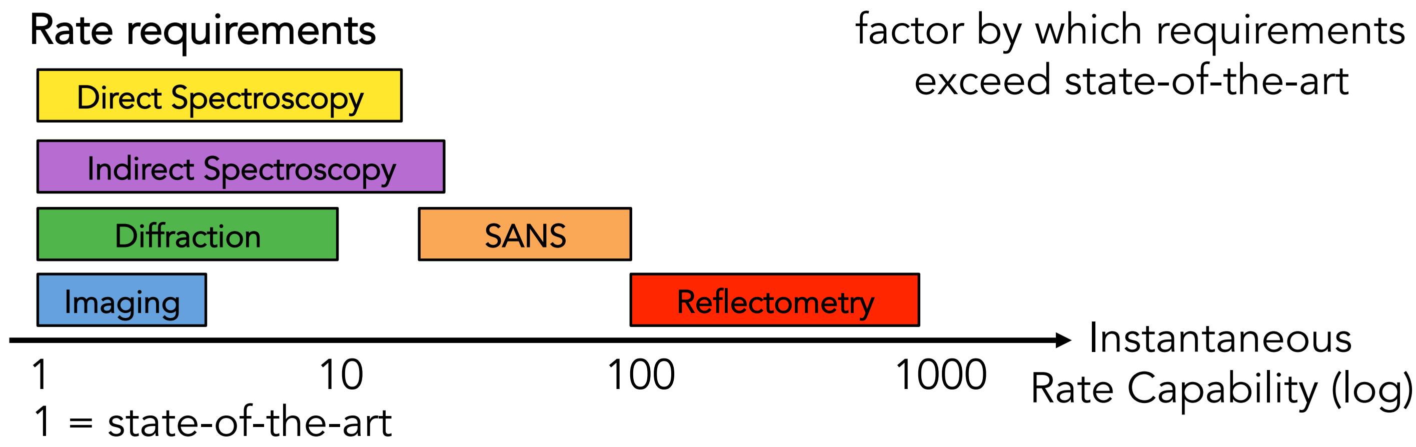
Horizontal ToF Reflectometer

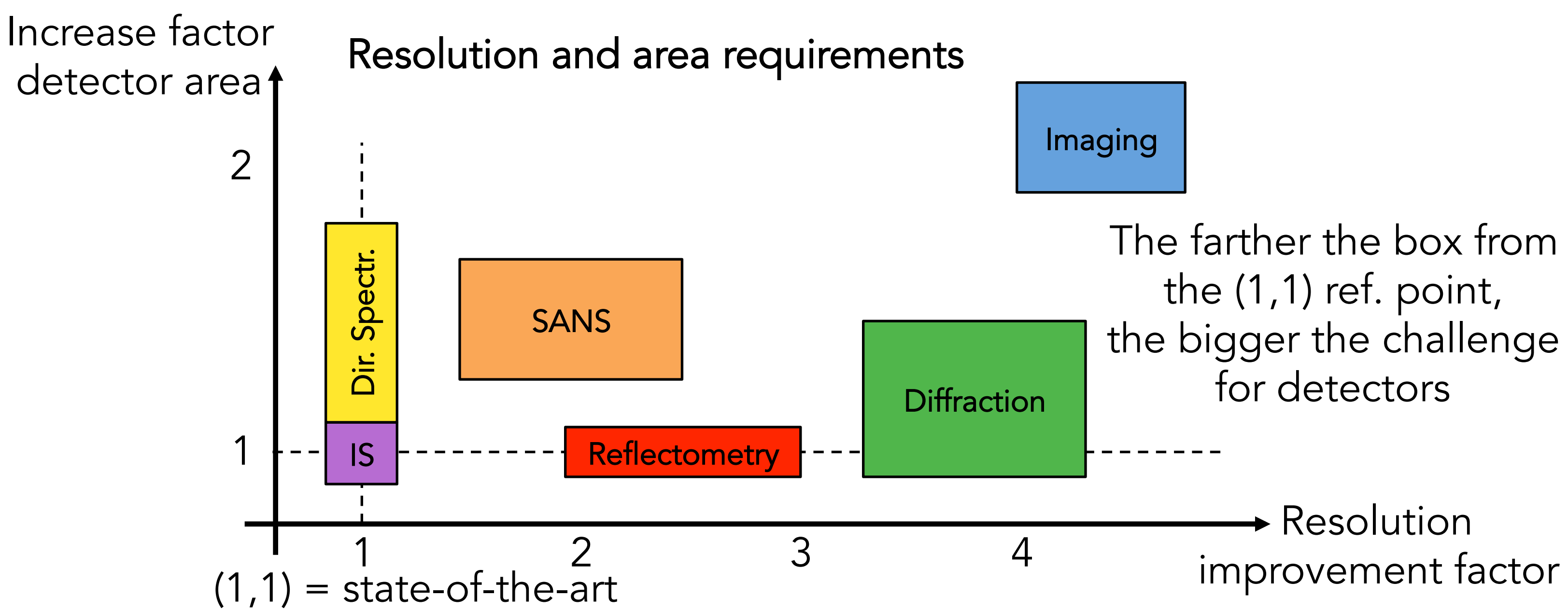
Vertical ToF Reflectometer

Detector requirements



Detector requirements

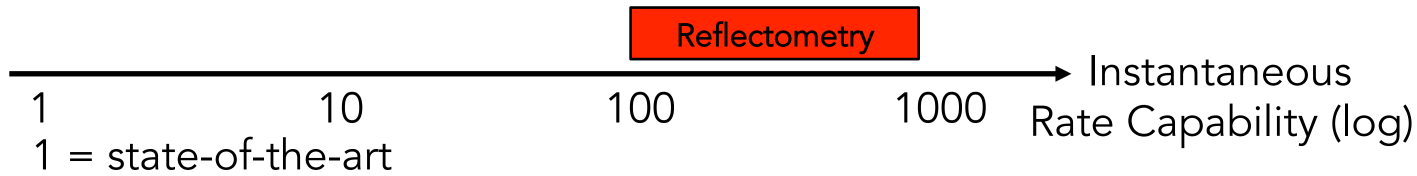




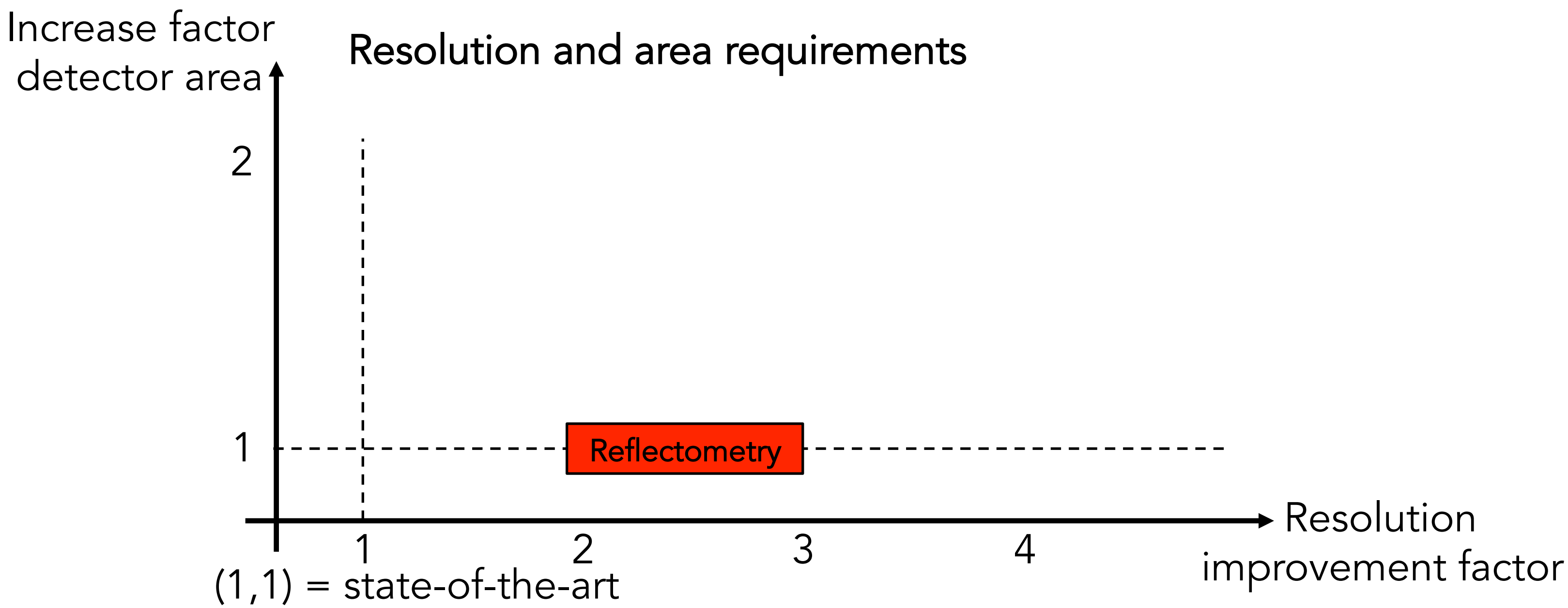
Detector requirements: Neutron Reflectometry

Rate requirements

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



Resolution and area requirements

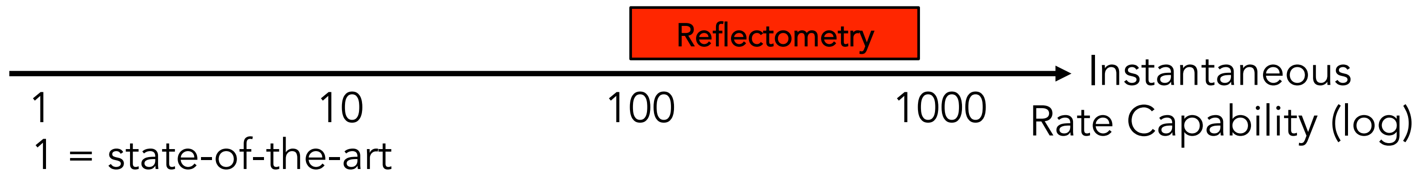


Detector requirements: Neutron Reflectometry

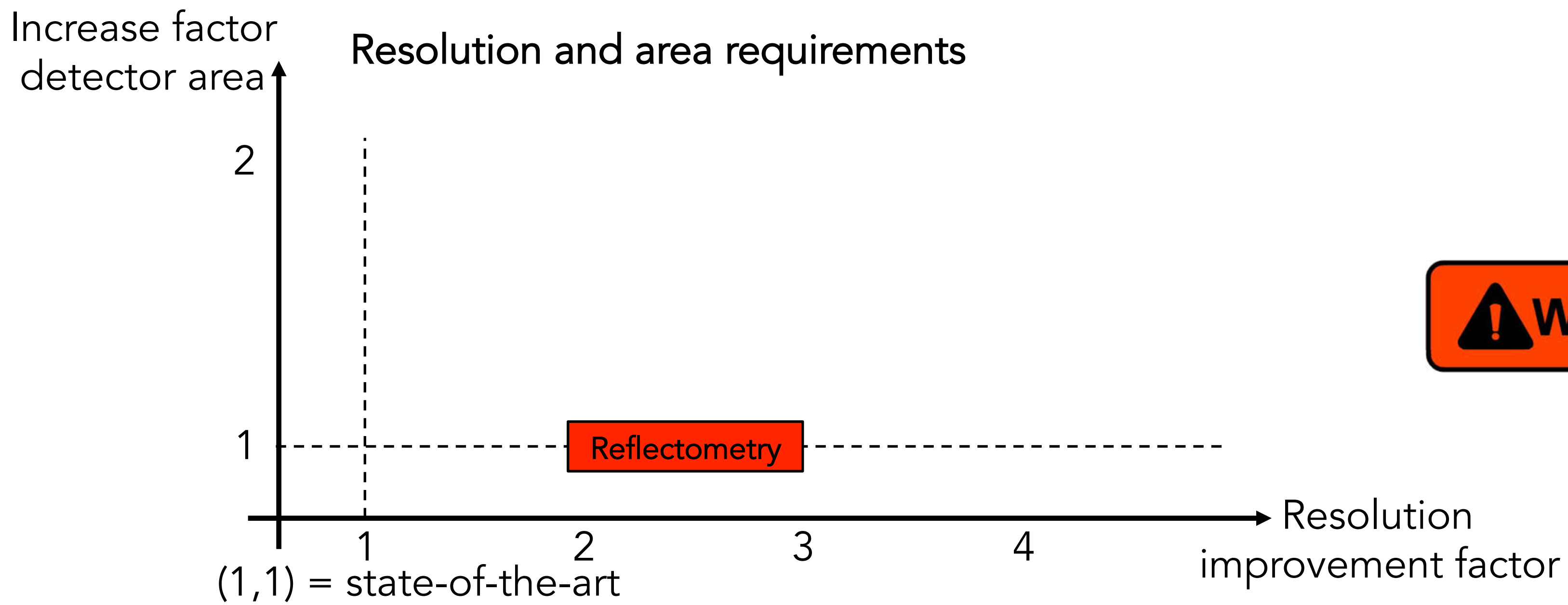
Rate requirements

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

WARNING **NO TECHNOLOGY EXISTS TODAY!** WARNING



Resolution and area requirements

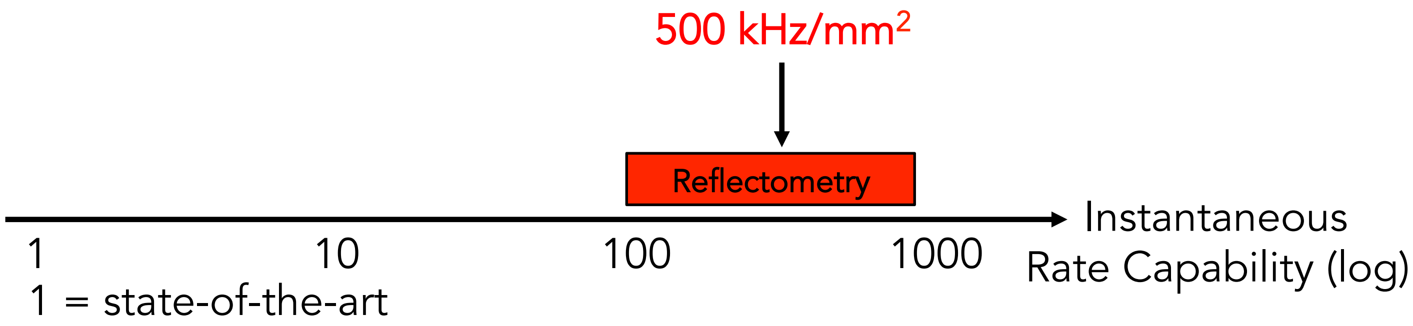


WARNING

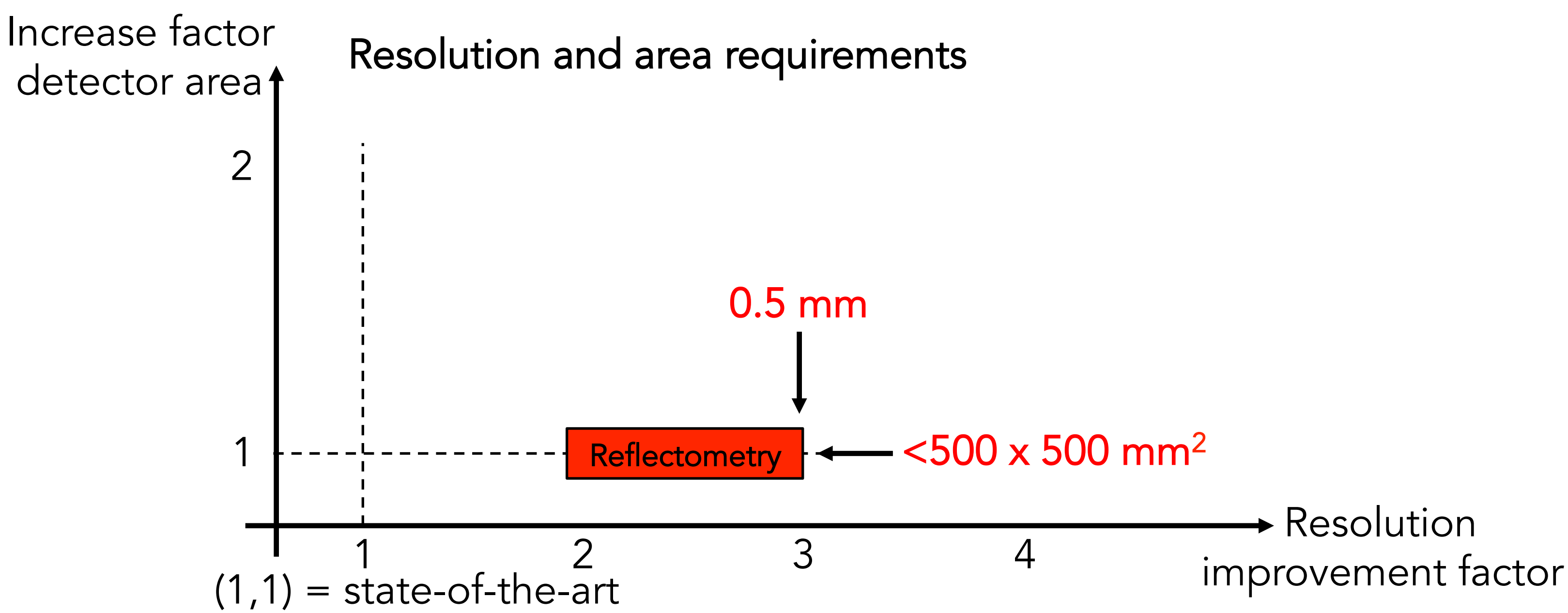
Detector requirements: Neutron Reflectometry

Rate requirements

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

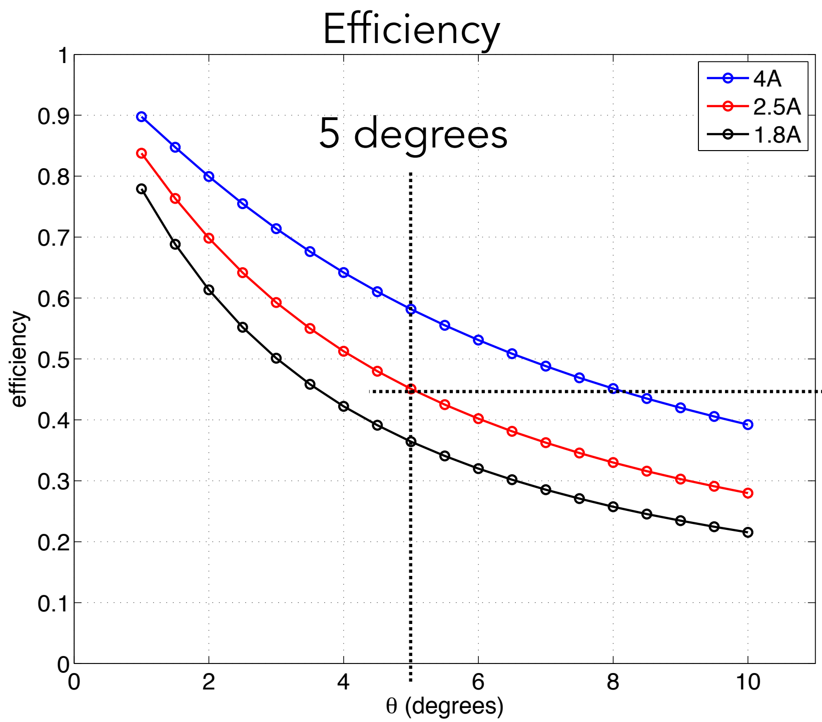


Resolution and area requirements

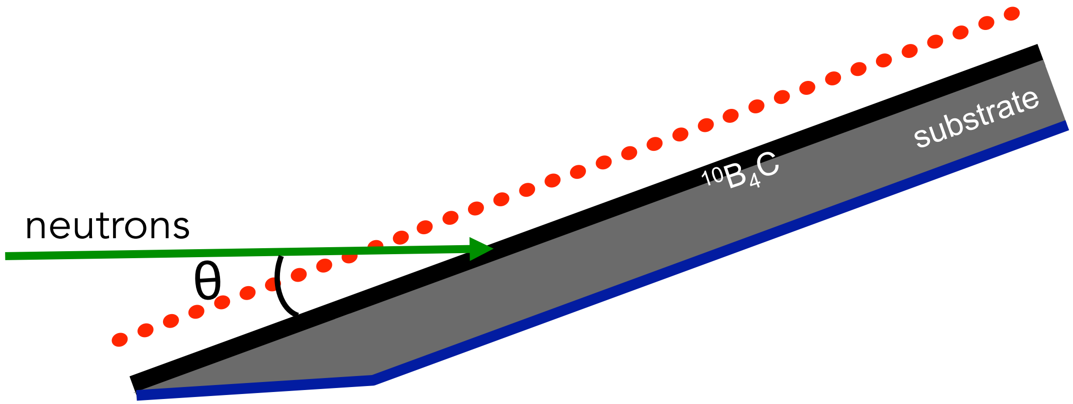


The Multi-Blade project

The Multi-Blade project

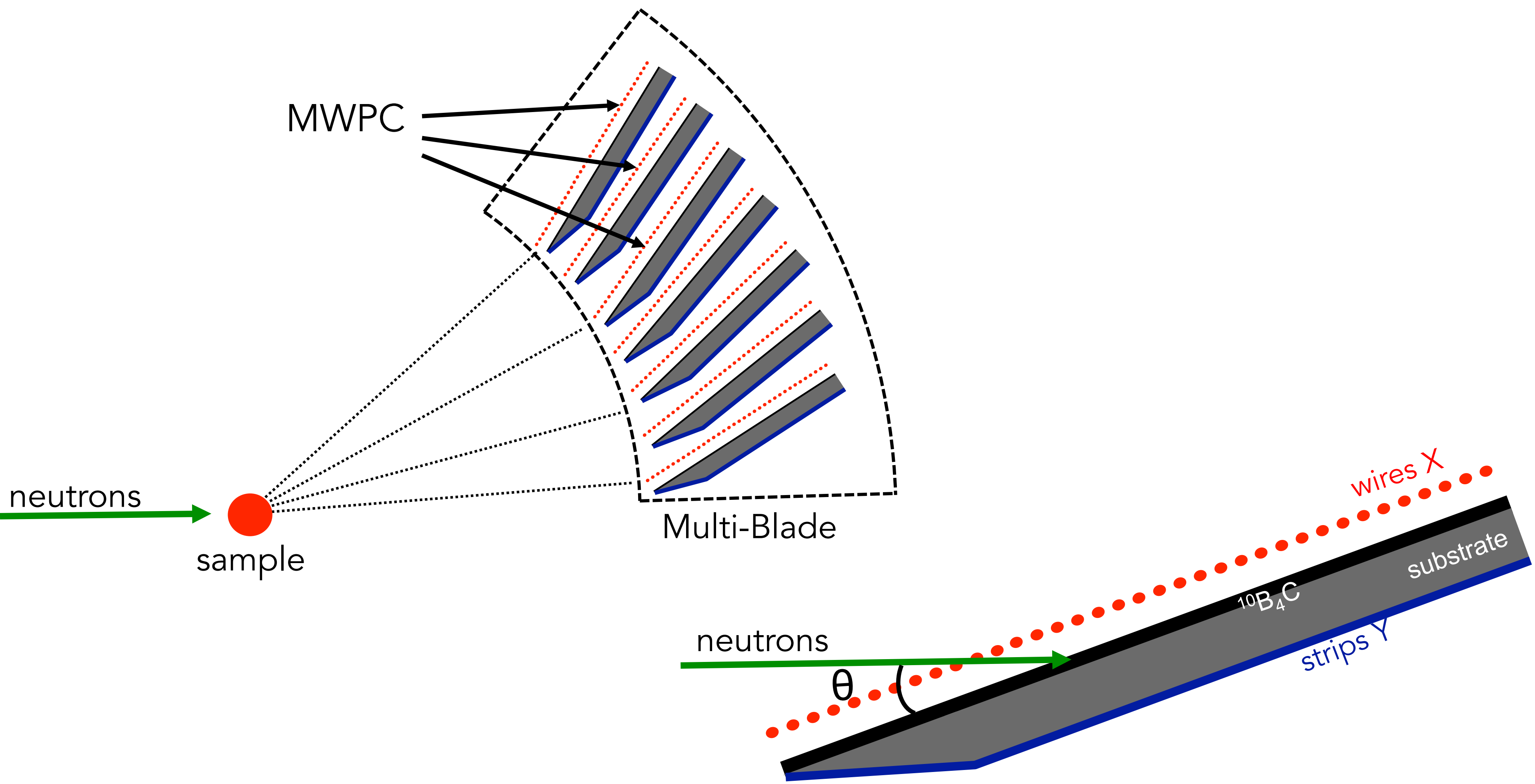


Efficiency 45% at 2.5Å
A single Boron layer inclined at 5 degrees



θ = 5 degrees

The Multi-Blade project

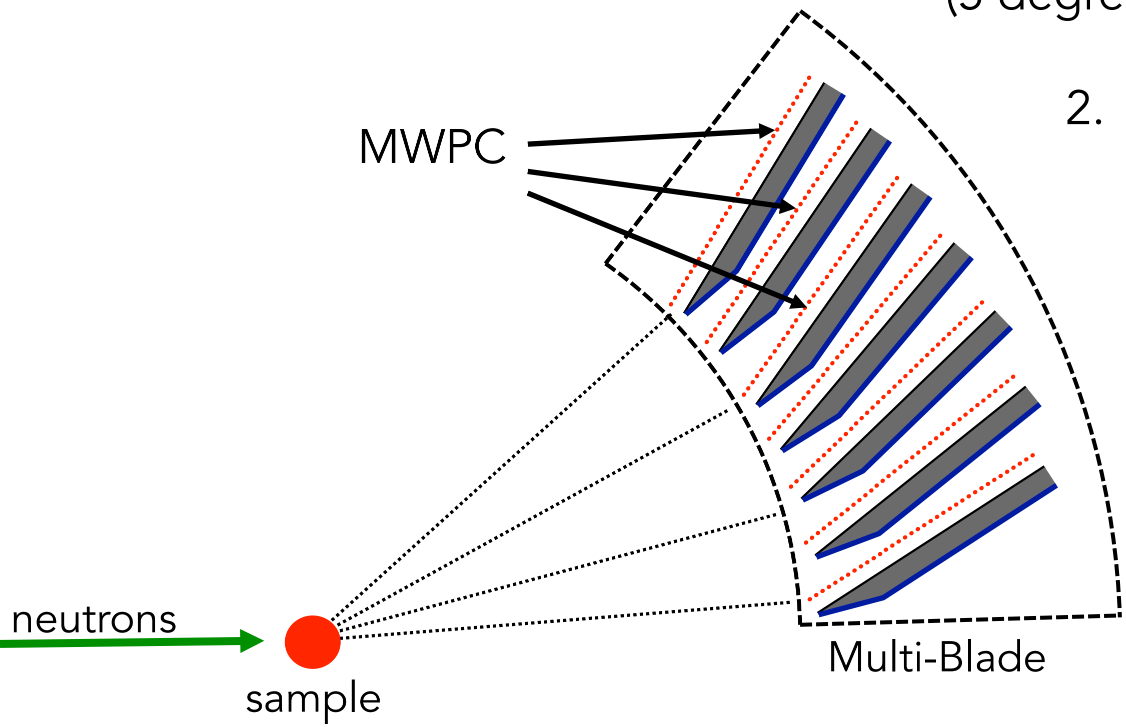


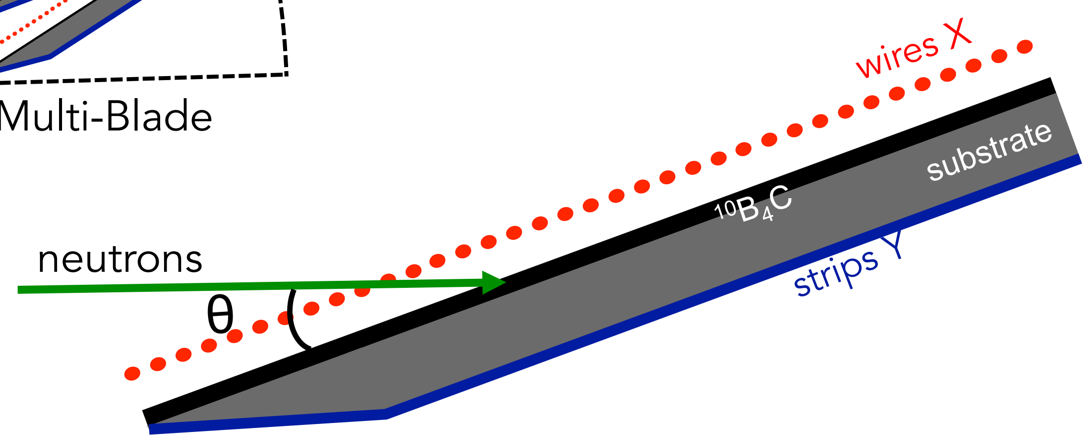
$\theta = 5$ degrees

The Multi-Blade project

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)



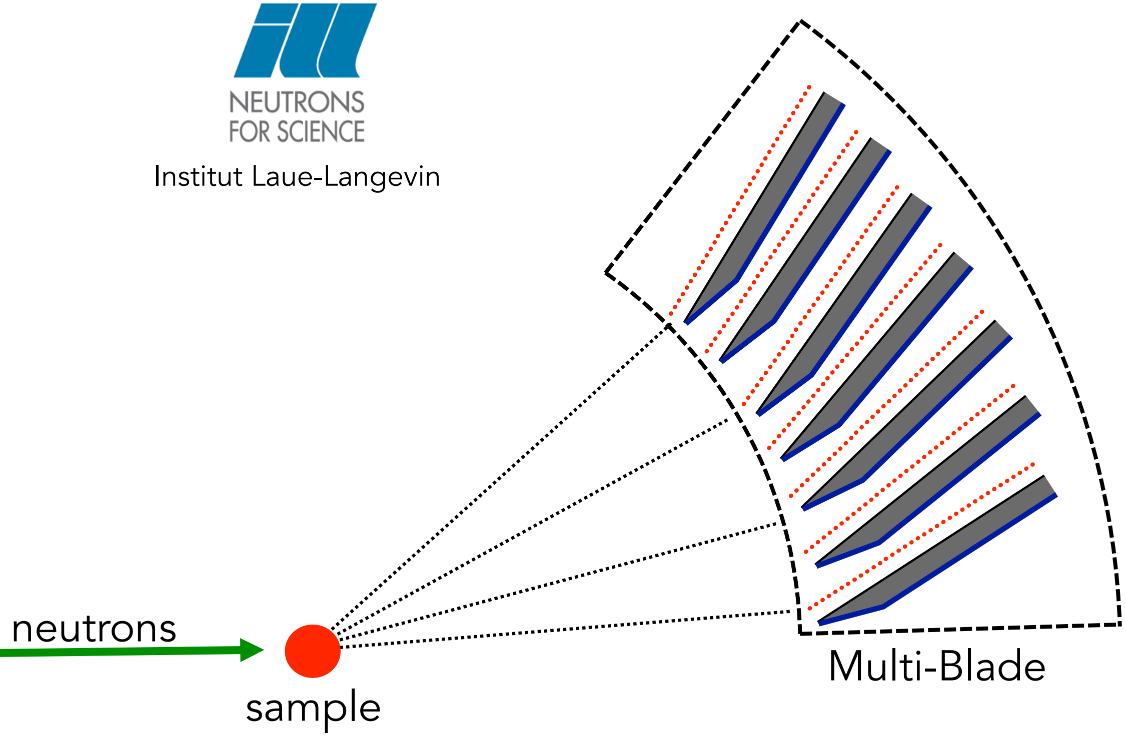


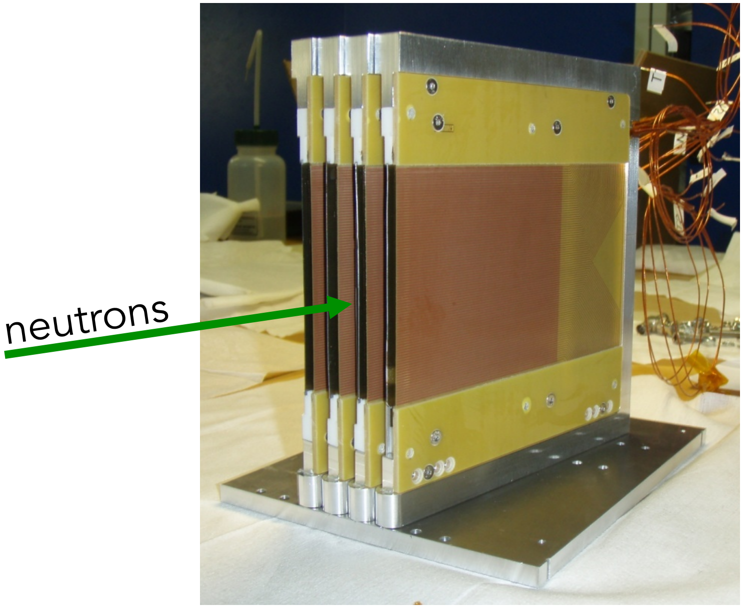
θ = 5 degrees

The Multi-Blade project

concept introduced in 2005

Institut Laue-Langevin





4 cassette demonstrator

proof of concept in 2012

Institut Laue-Langevin

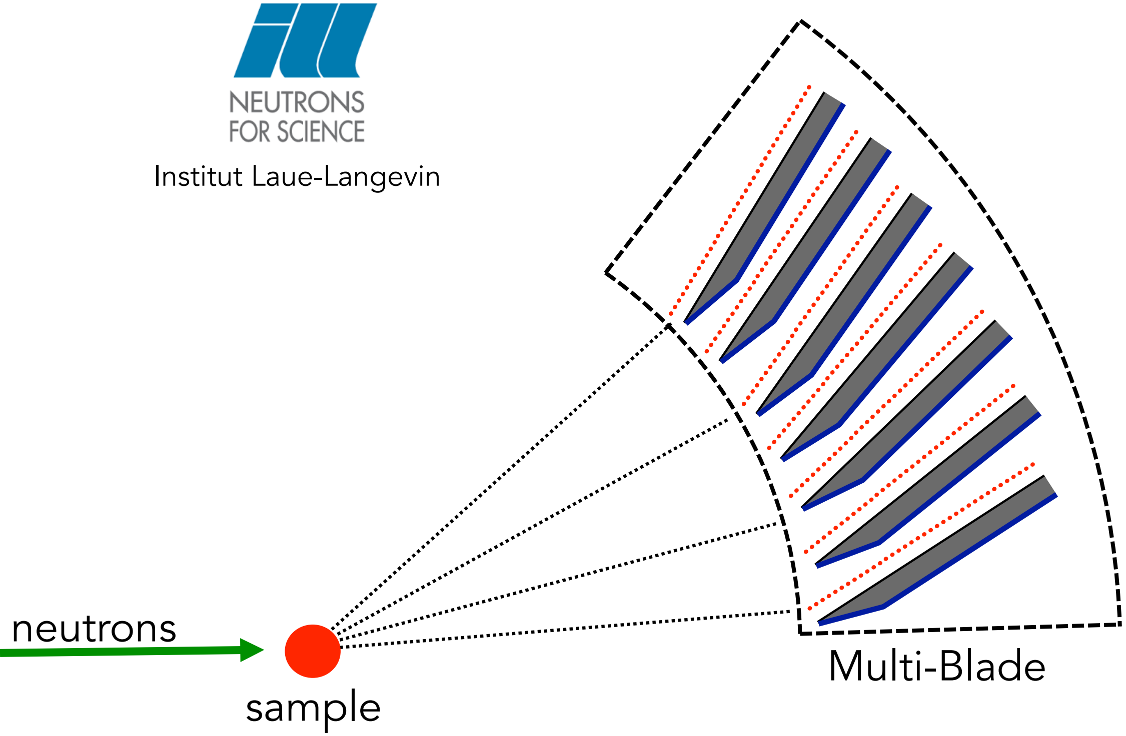
University of Perugia

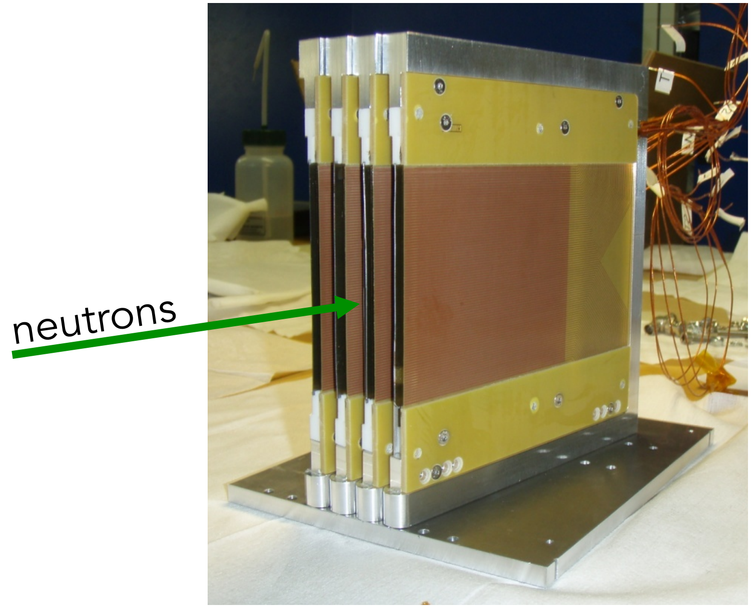
The Multi-Blade project

concept introduced in 2005

NEUTRONS FOR SCIENCE

Institut Laue-Langevin





4 cassette demonstrator

proof of concept in 2012

NEUTRONS FOR SCIENCE

Institut Laue-Langevin

University of Perugia

Promising Results!

The Multi-Blade project

EUROPEAN SPALLATION SOURCE

LUND UNIVERSITY

Wigner Research Institute

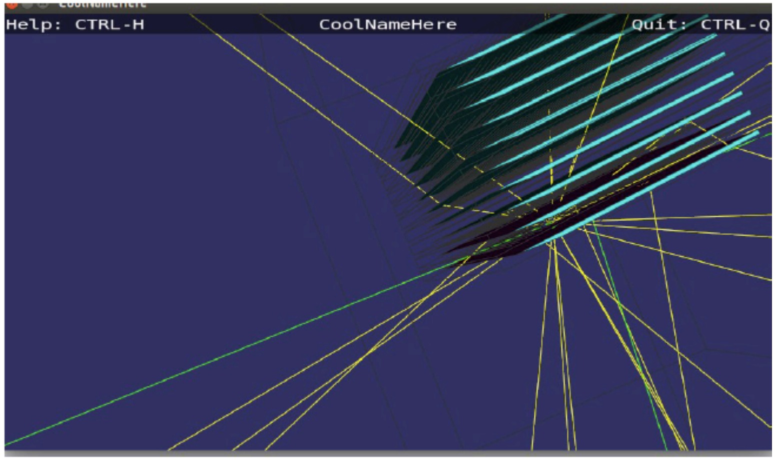
Linköping University

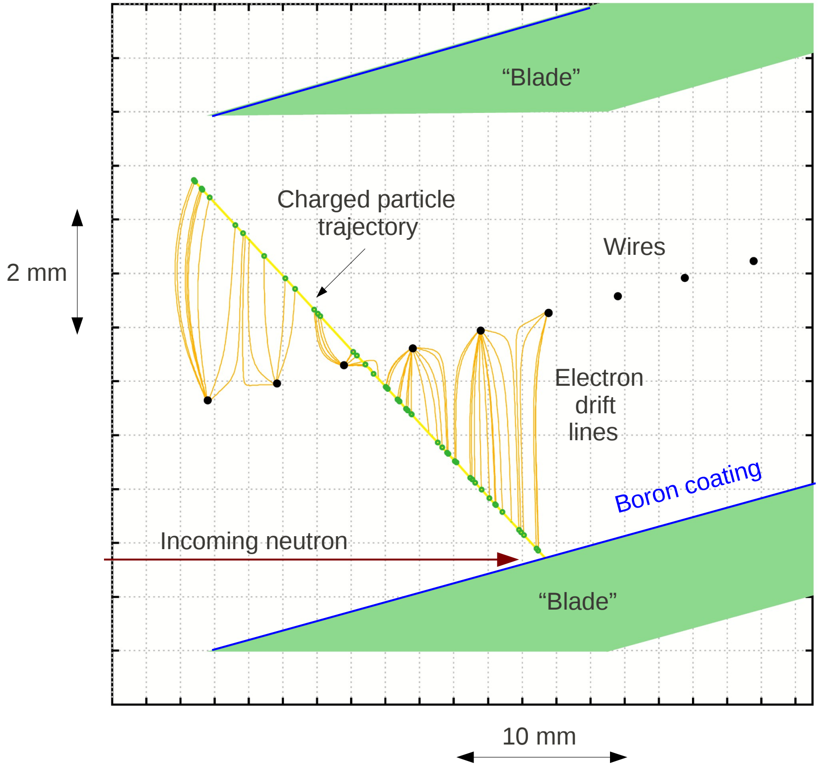
3 years

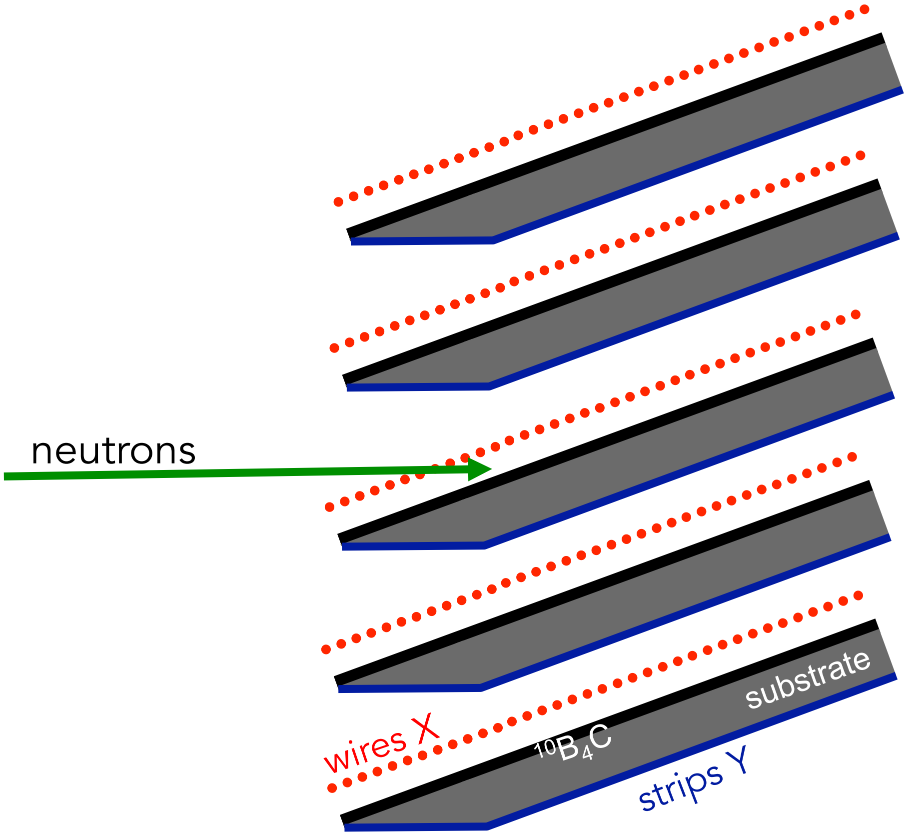
The key objective of WP4 is the technological evolution of neutron detectors in terms of resolution, intensity and dimensions.

Task 4.2 Neutron Detectors – The Intensity Frontier

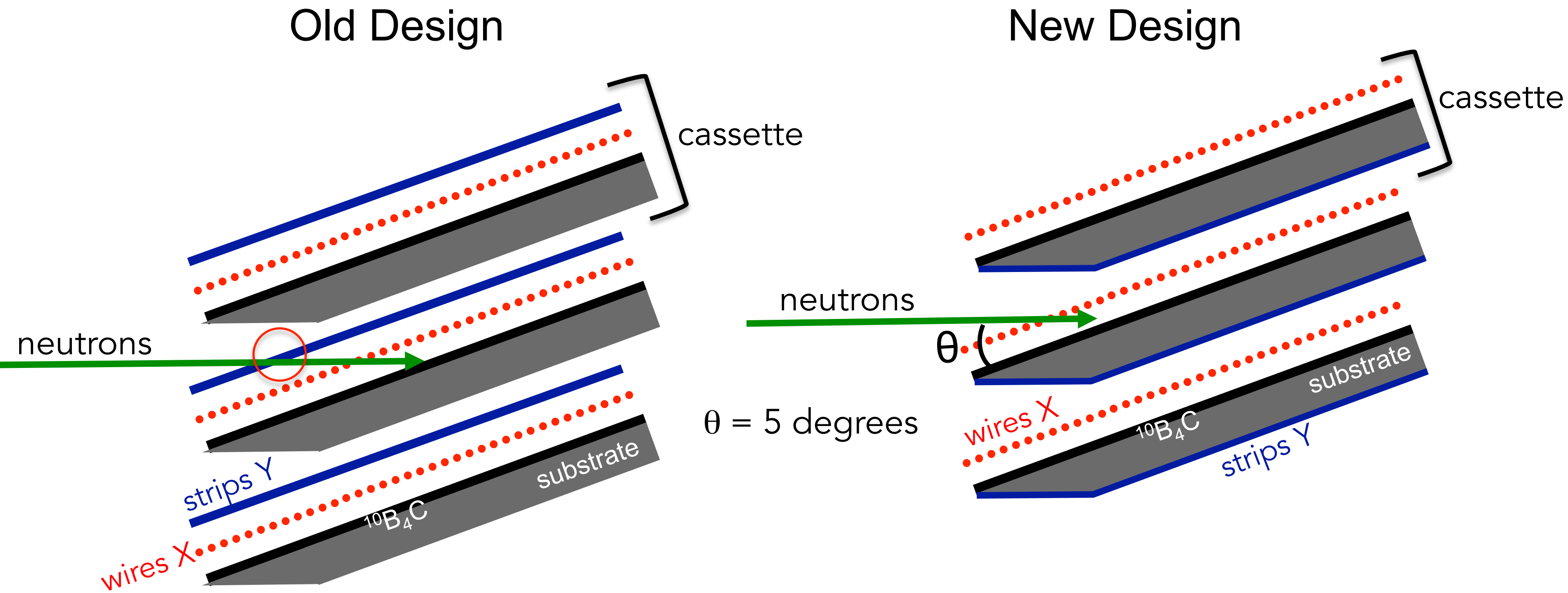
GARFIELD and GEANT4 simulations







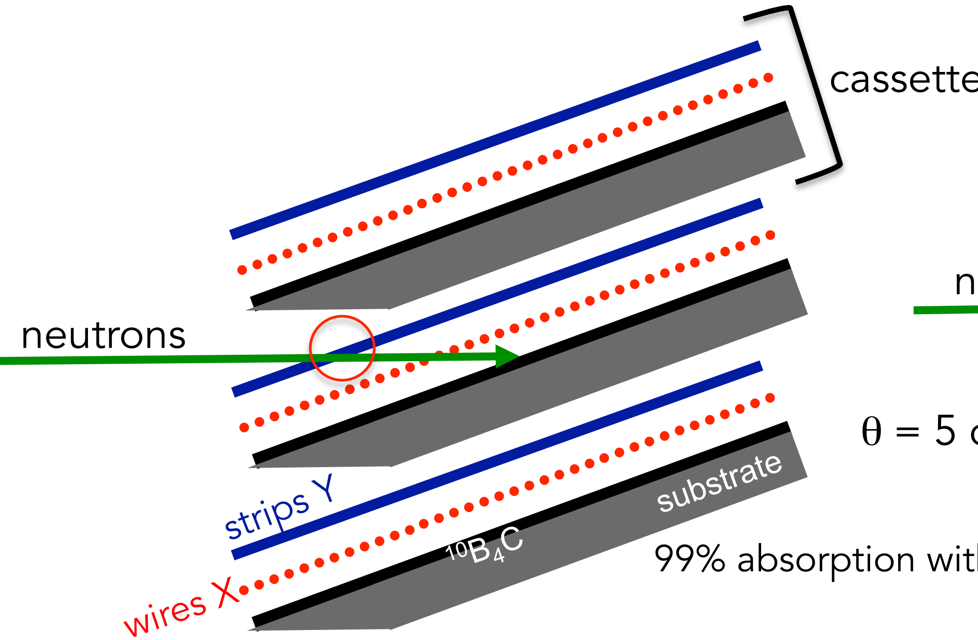
Materials evaluation



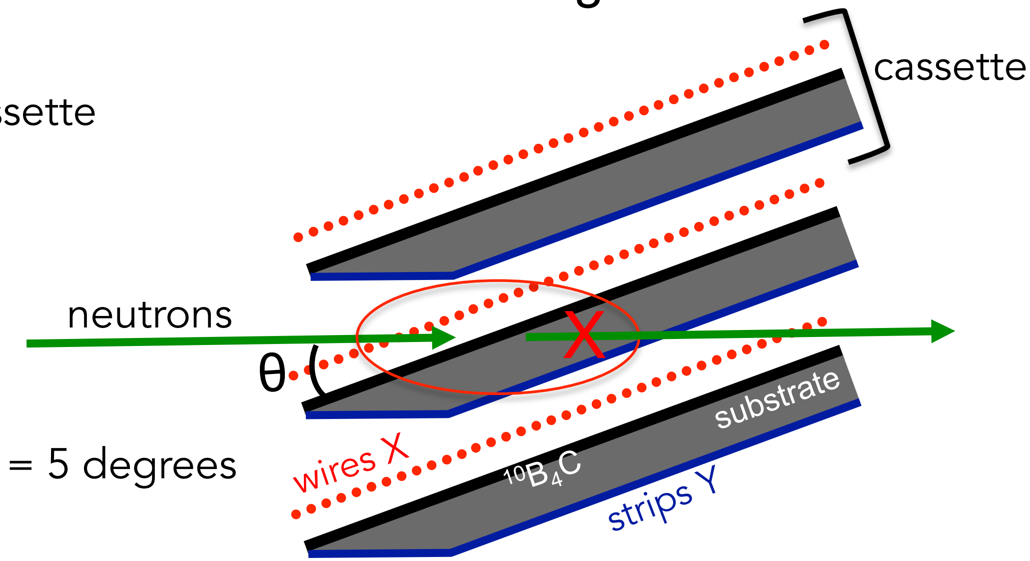
Reduce the scattering

Materials evaluation

Old Design

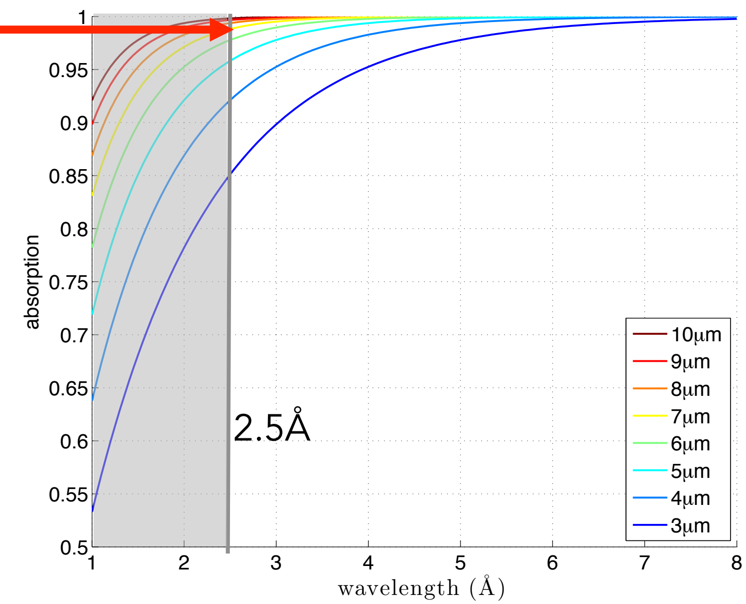


New Design



θ = 5 degrees

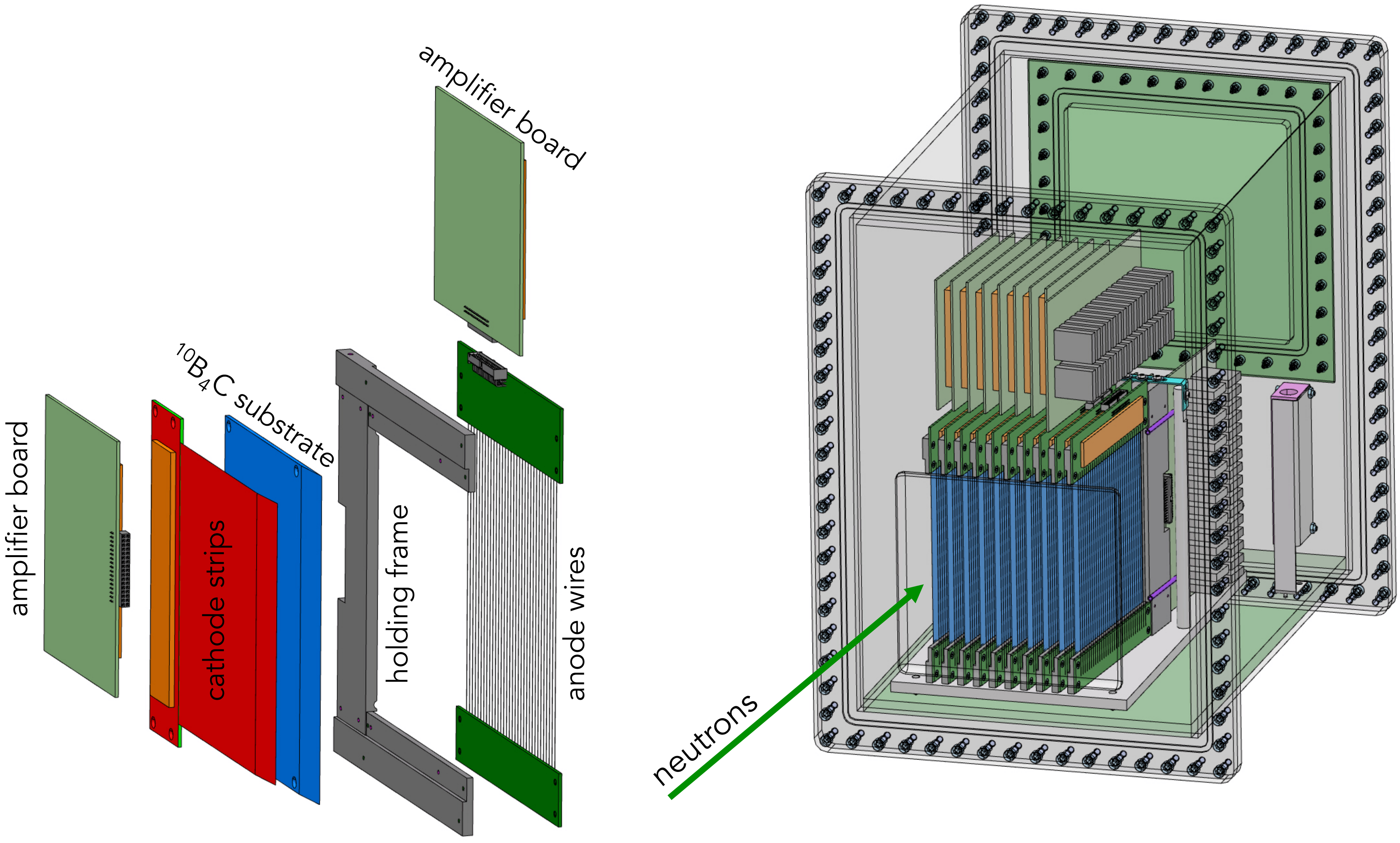
99% absorption with 7μm



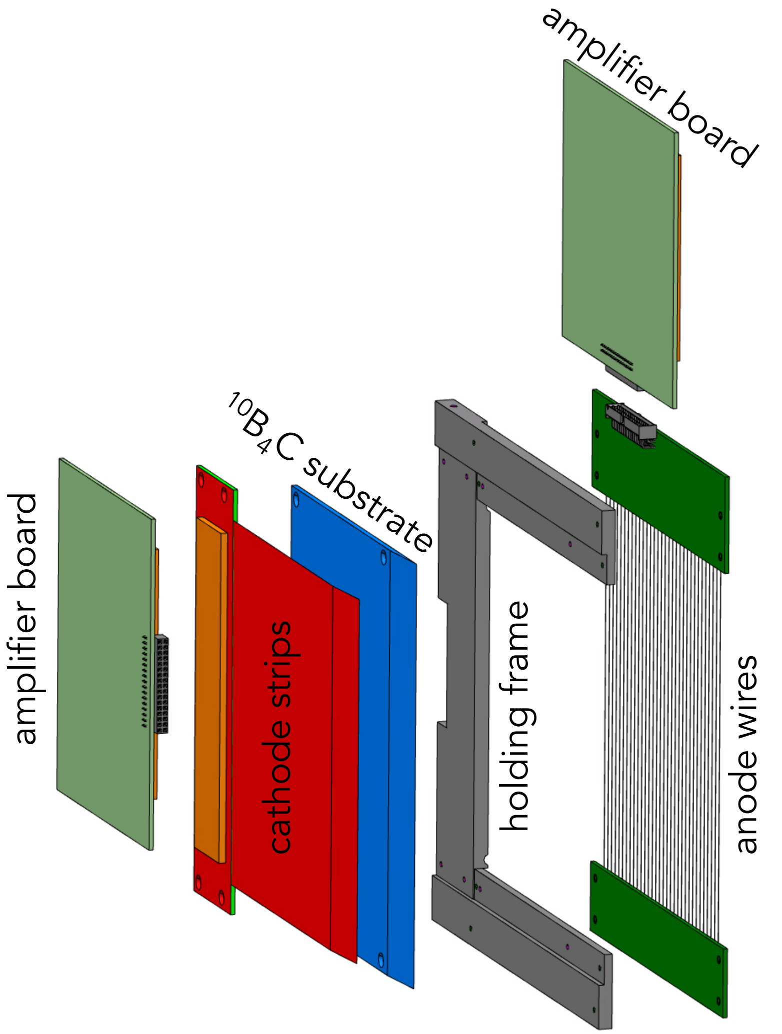
Reduce the scattering

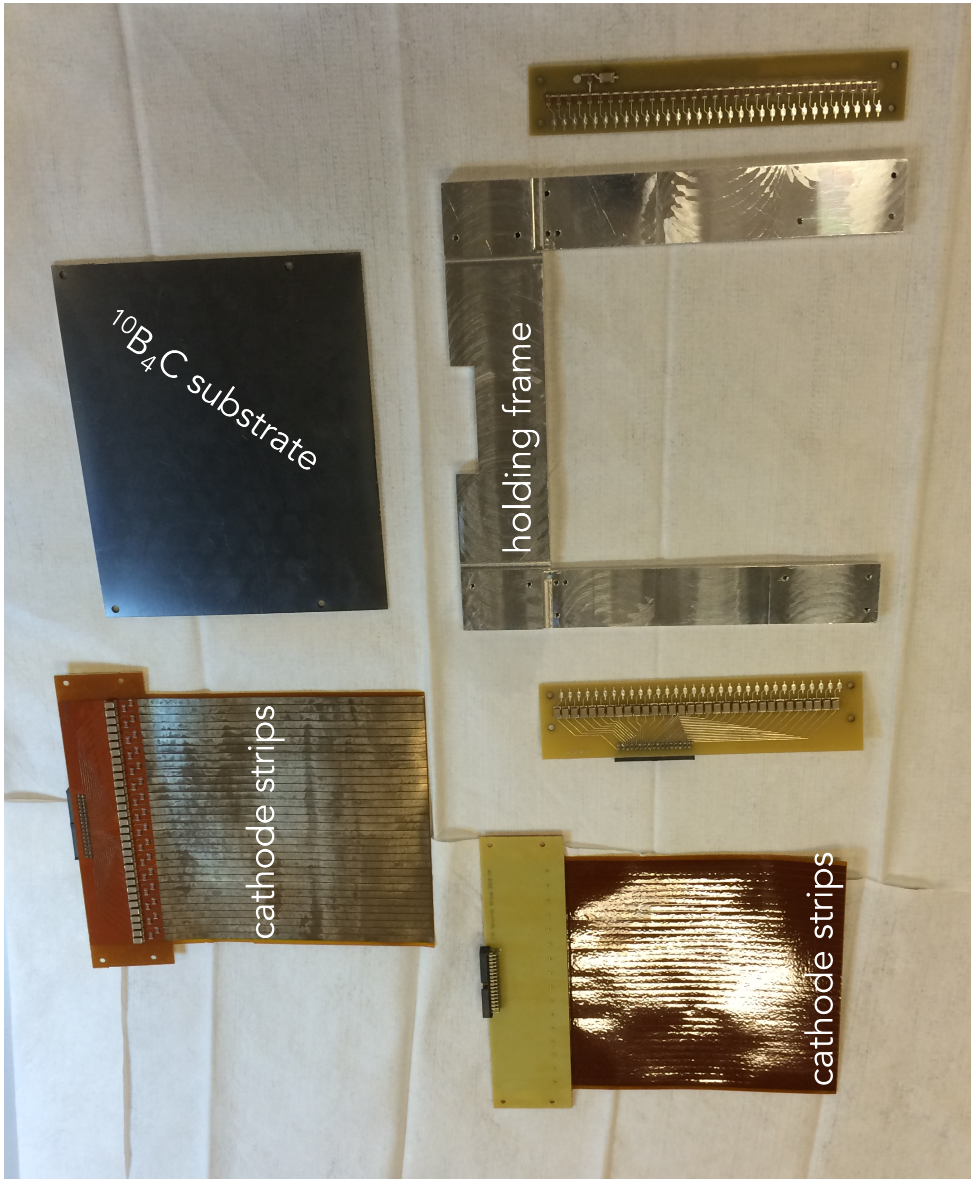
Mechanical design

100x140mm^2 active area demonstrator

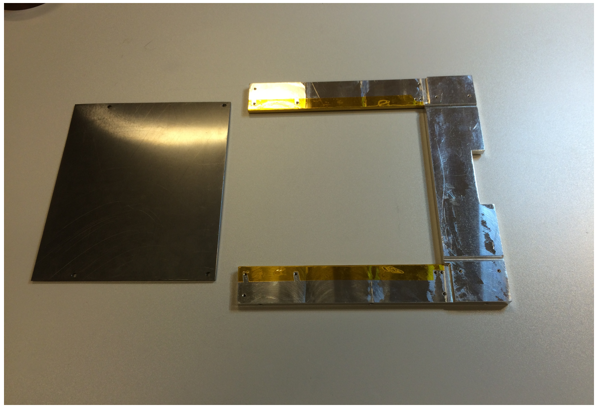


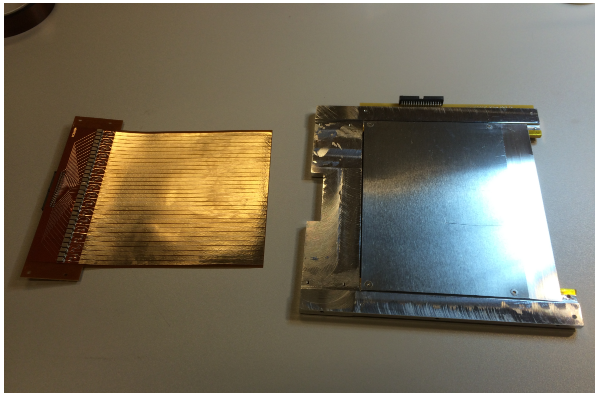
The Multi-Blade detector

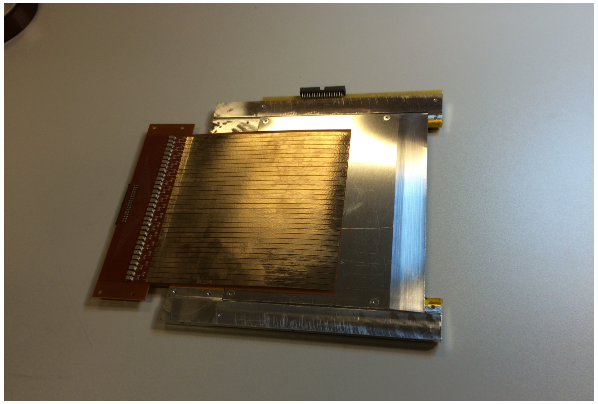


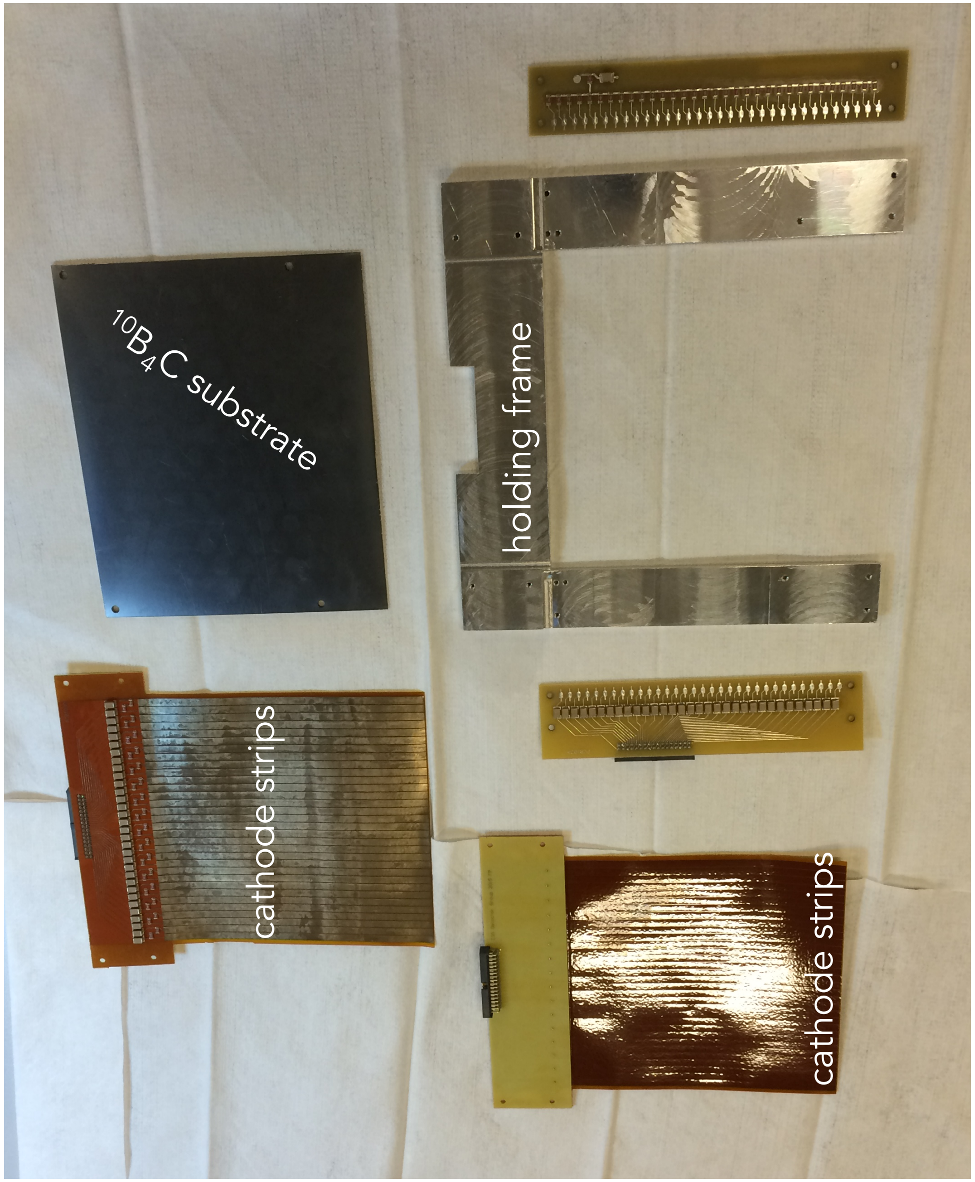


The Multi-Blade detector

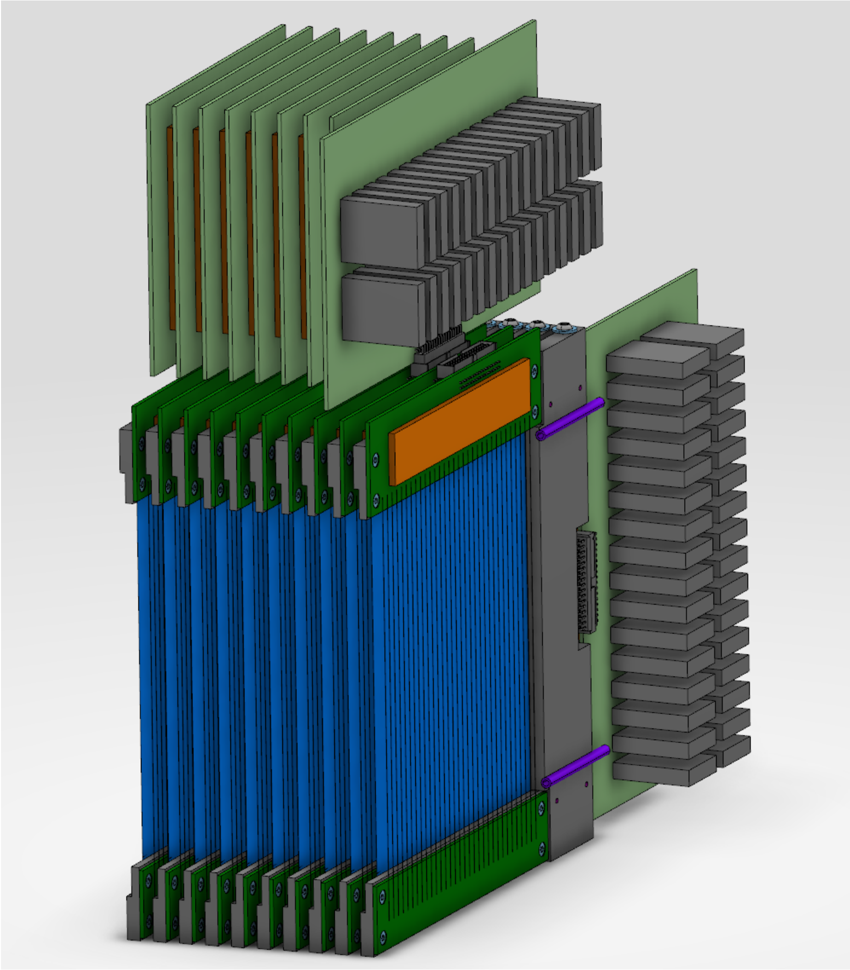


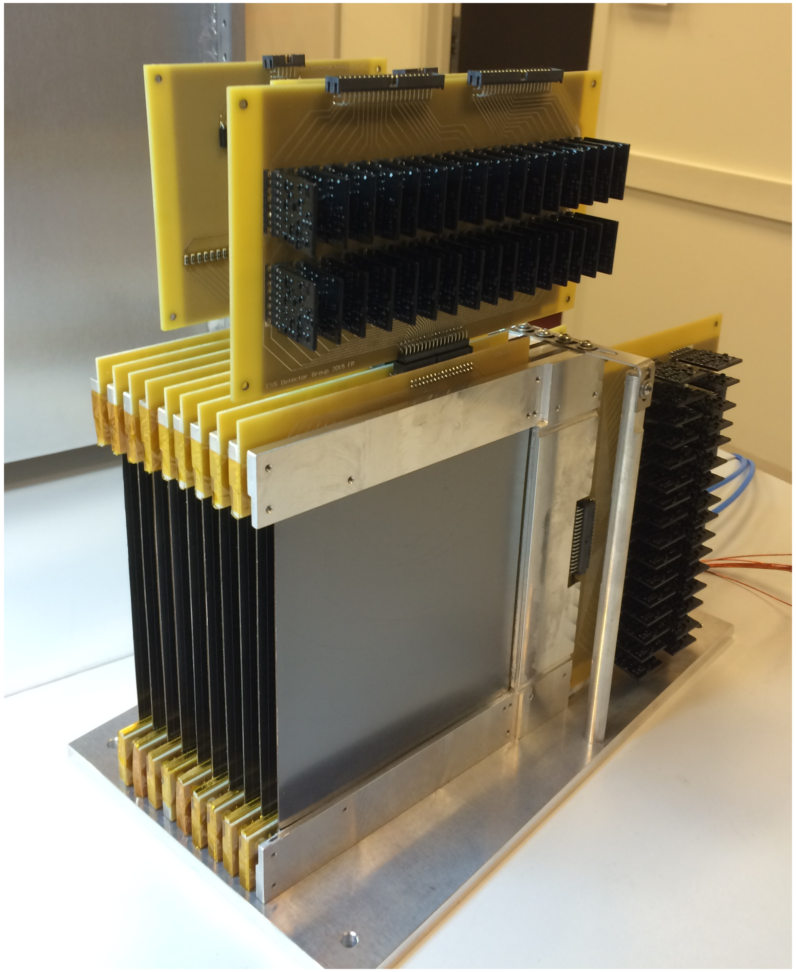




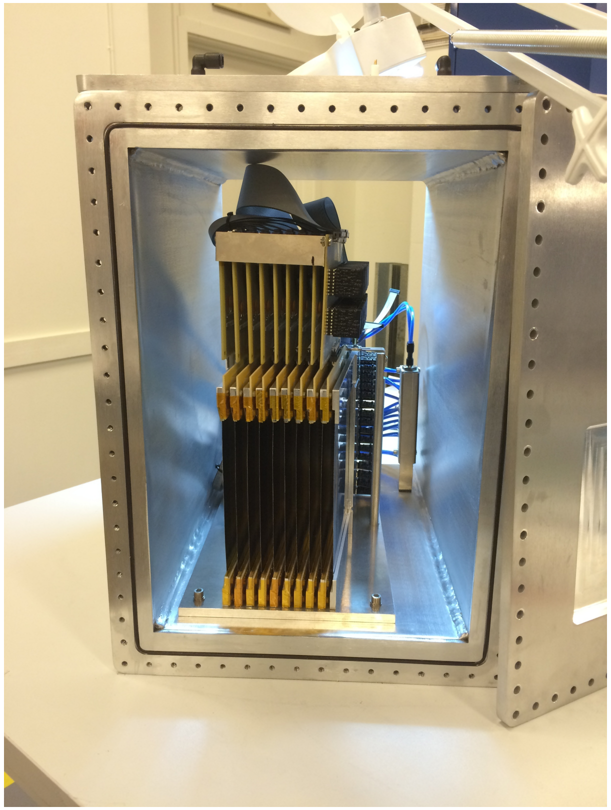


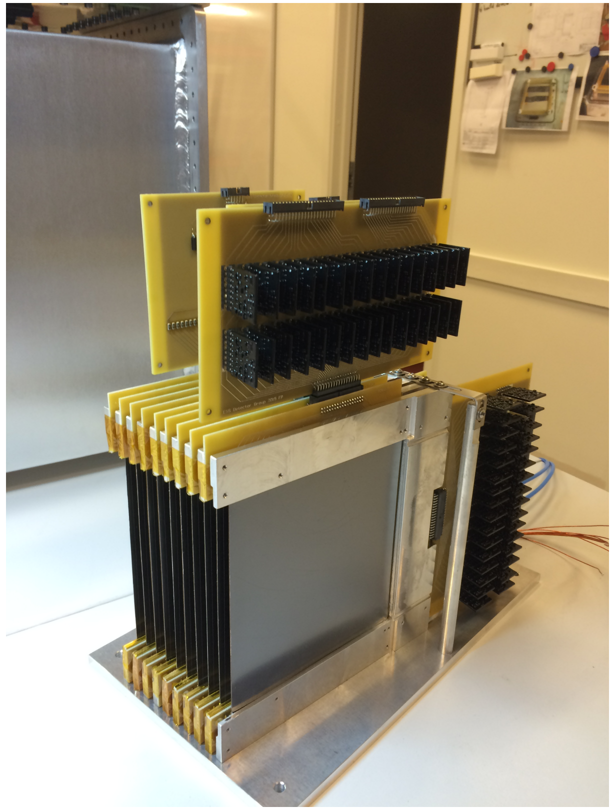
The Multi-Blade detector

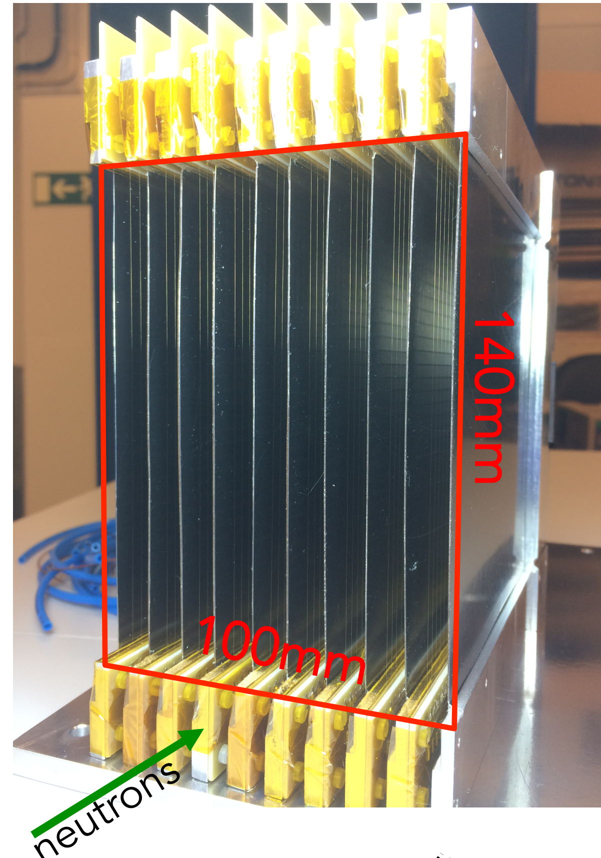




The Multi-Blade detector

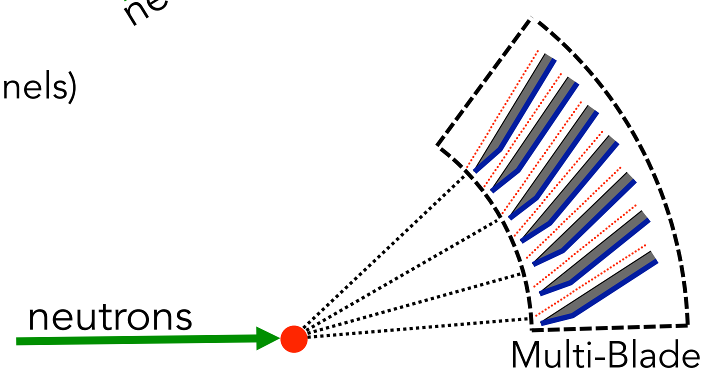




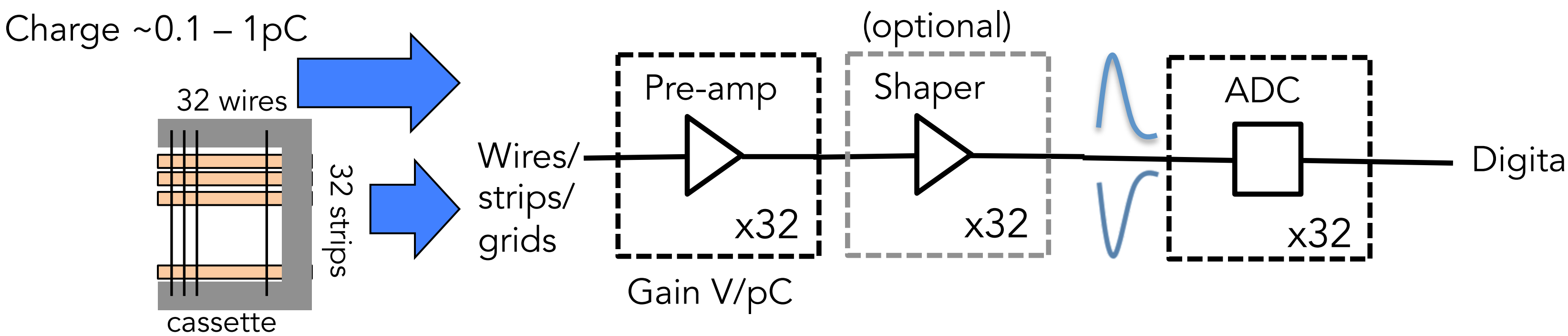


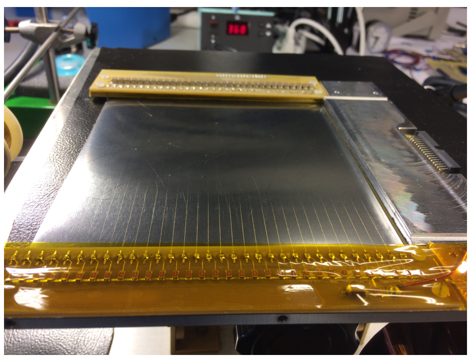
9 Cassettes inclined at 5 degrees with respect to the neutron beam
1 Individual readout (32 wires+32 strips) + 8 charge division (32 channels)

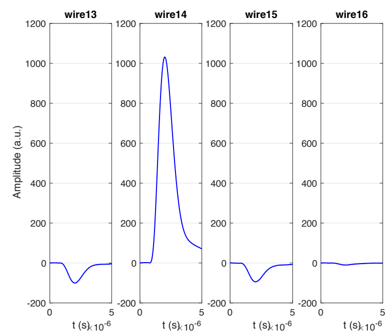
Individual Readout for the final detector

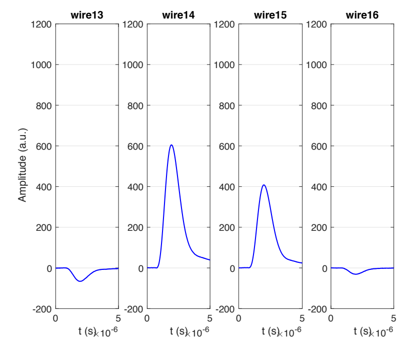


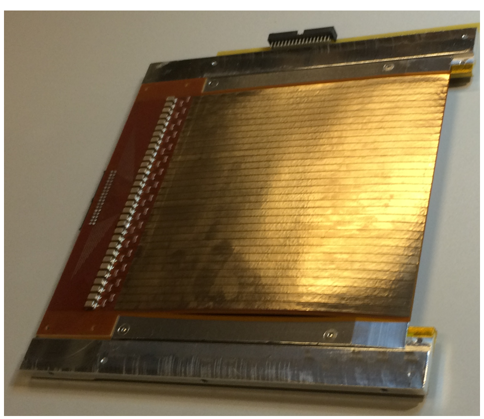
Electronics

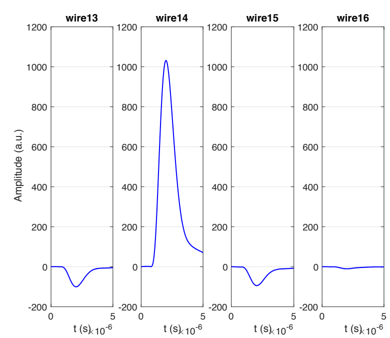




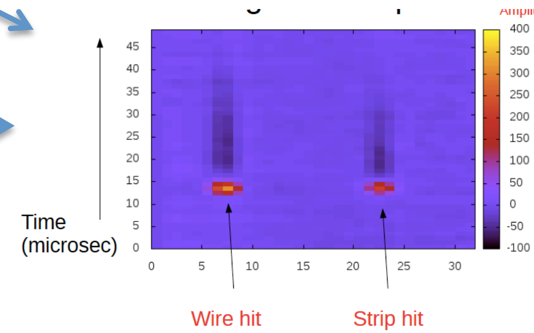






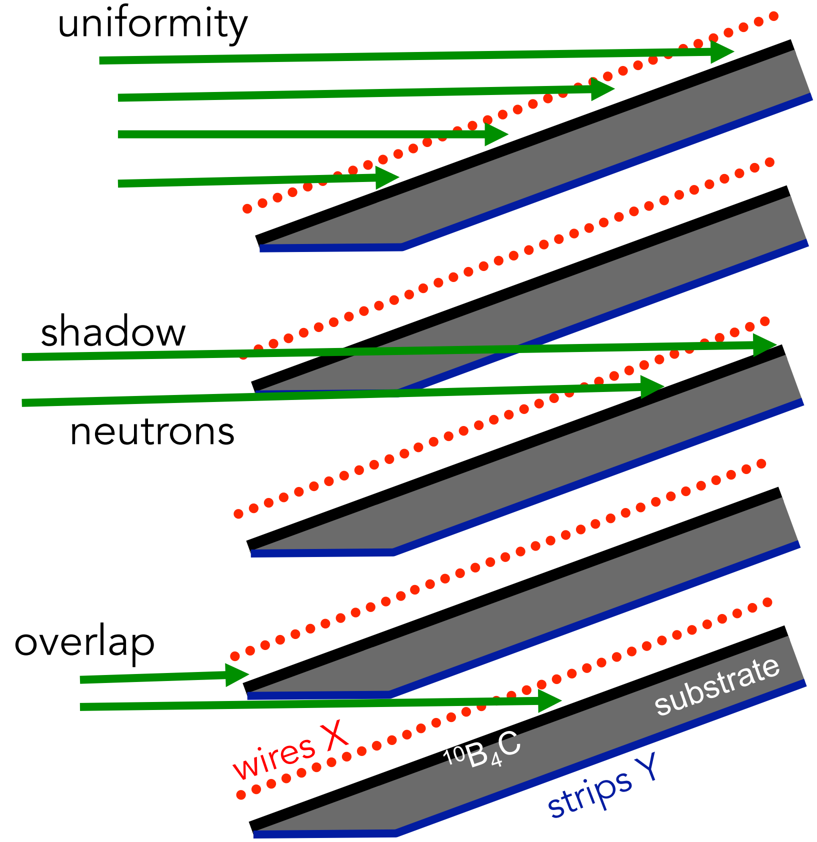


Cluster reconstruction (X,Y)
+time stamp

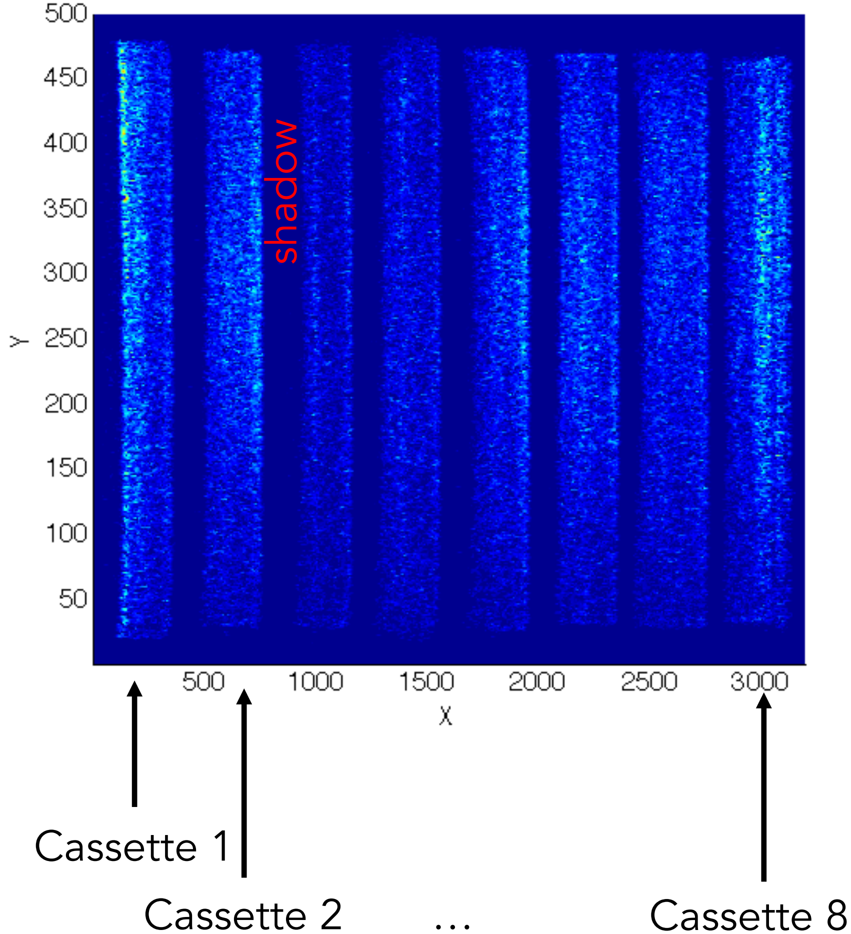


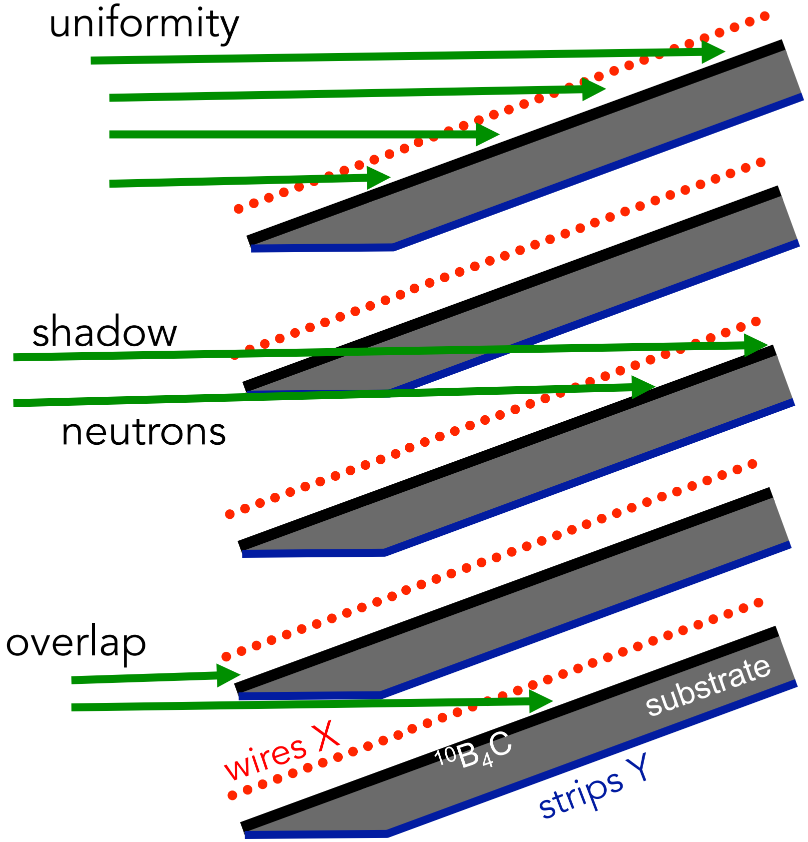
Results

Uniformity and overlap

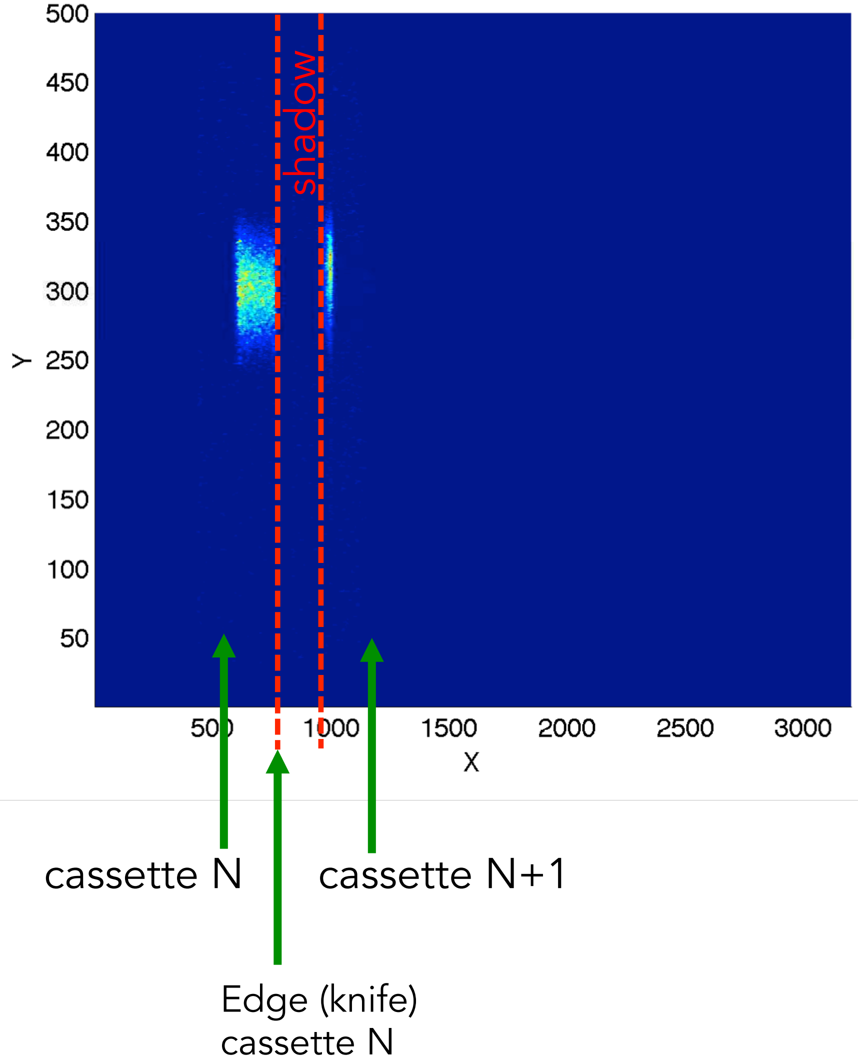


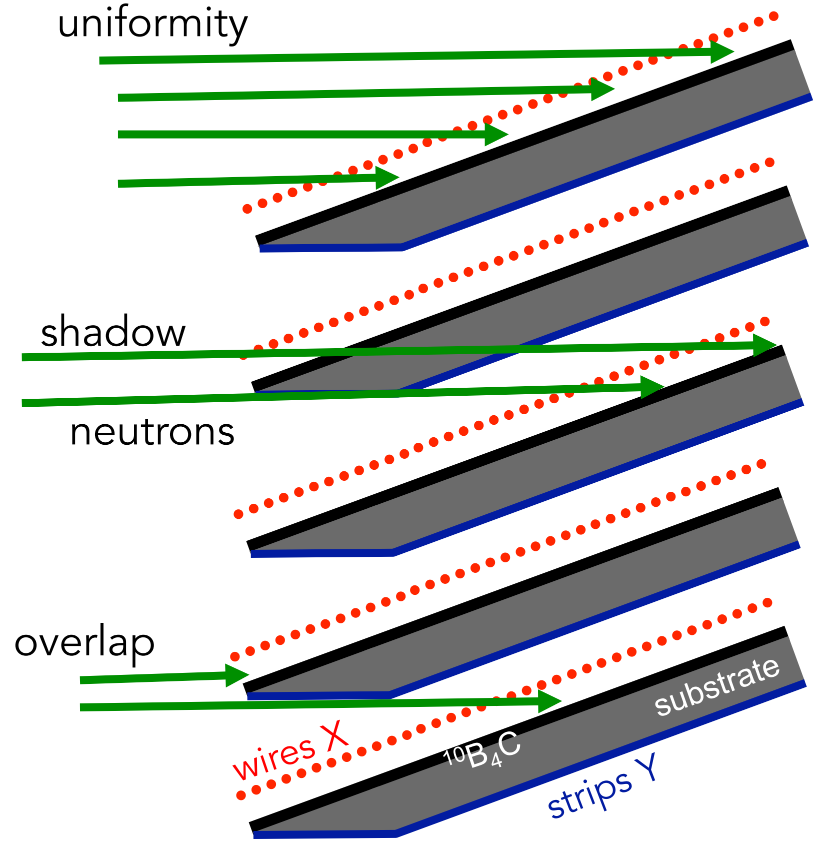
Uniformity and overlap



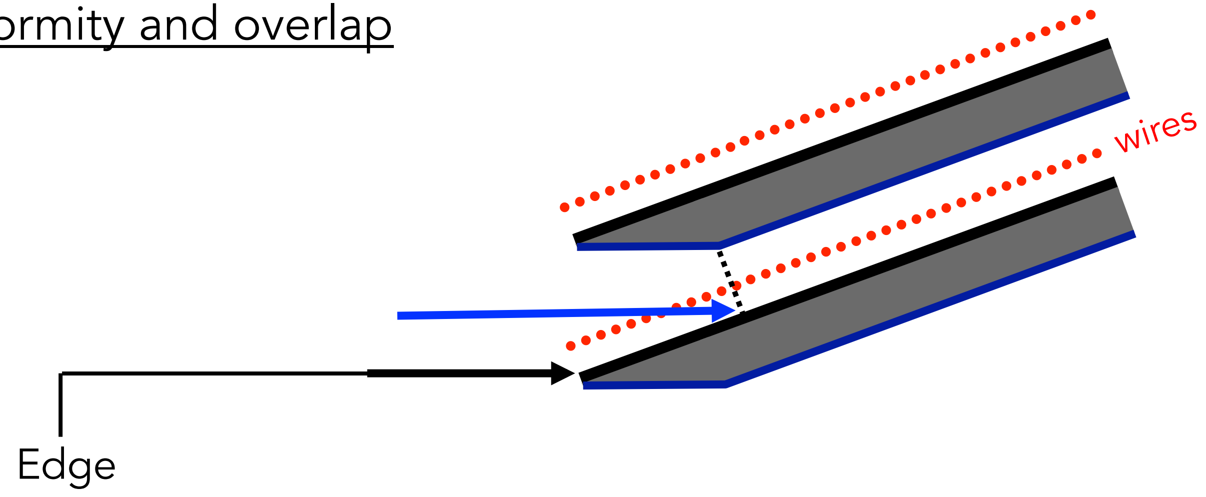


Uniformity and overlap

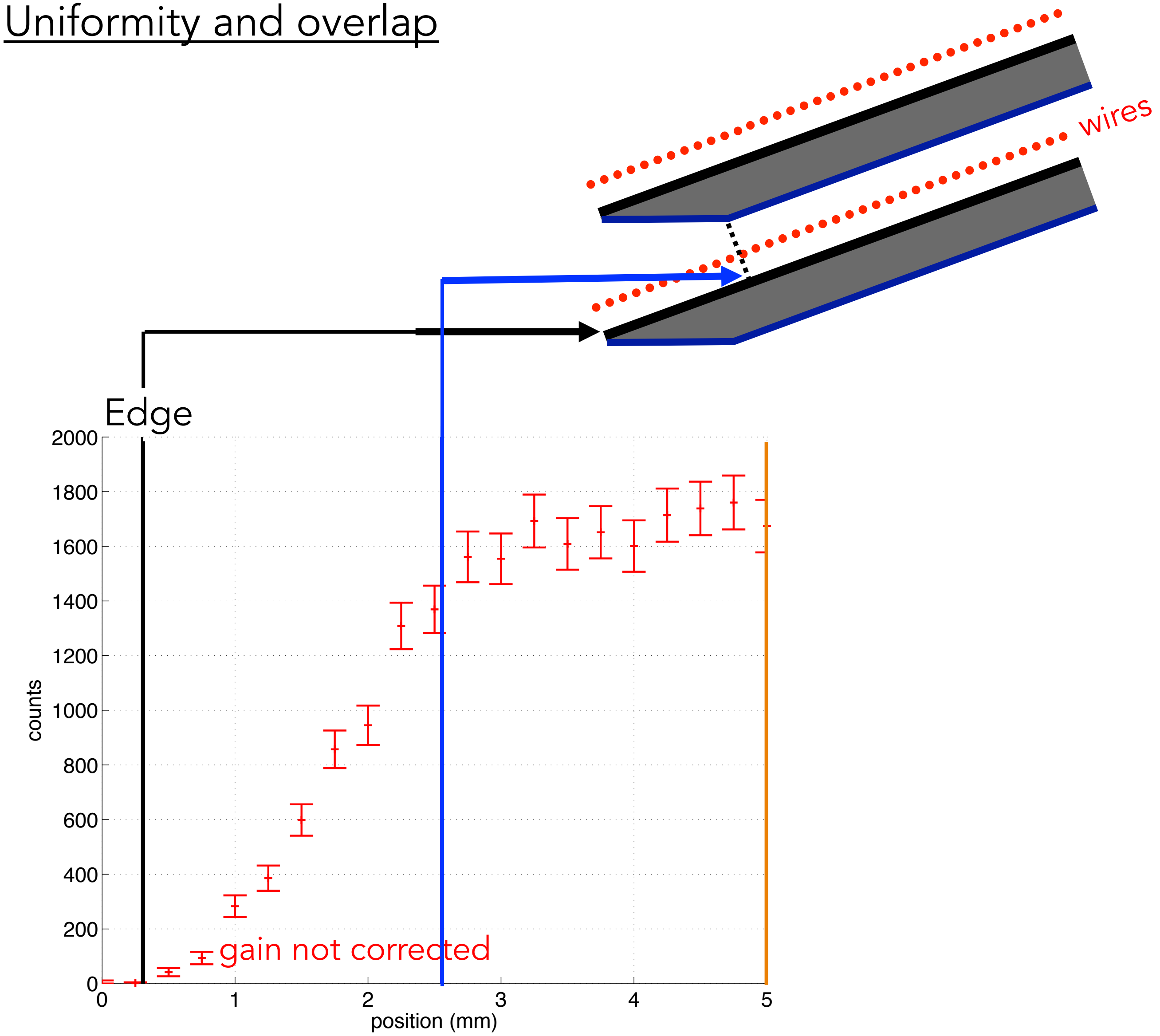




Uniformity and overlap

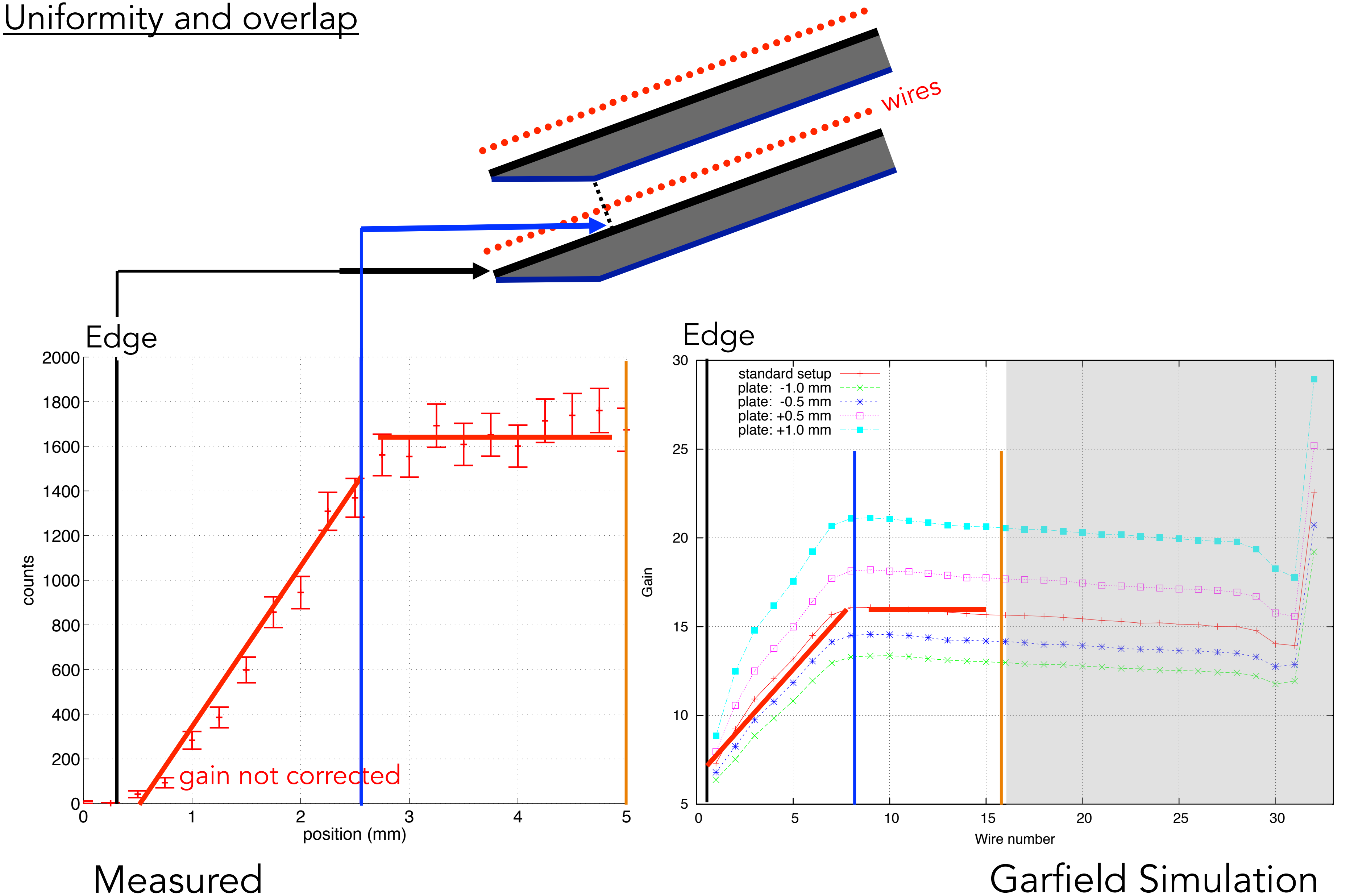


Uniformity and overlap

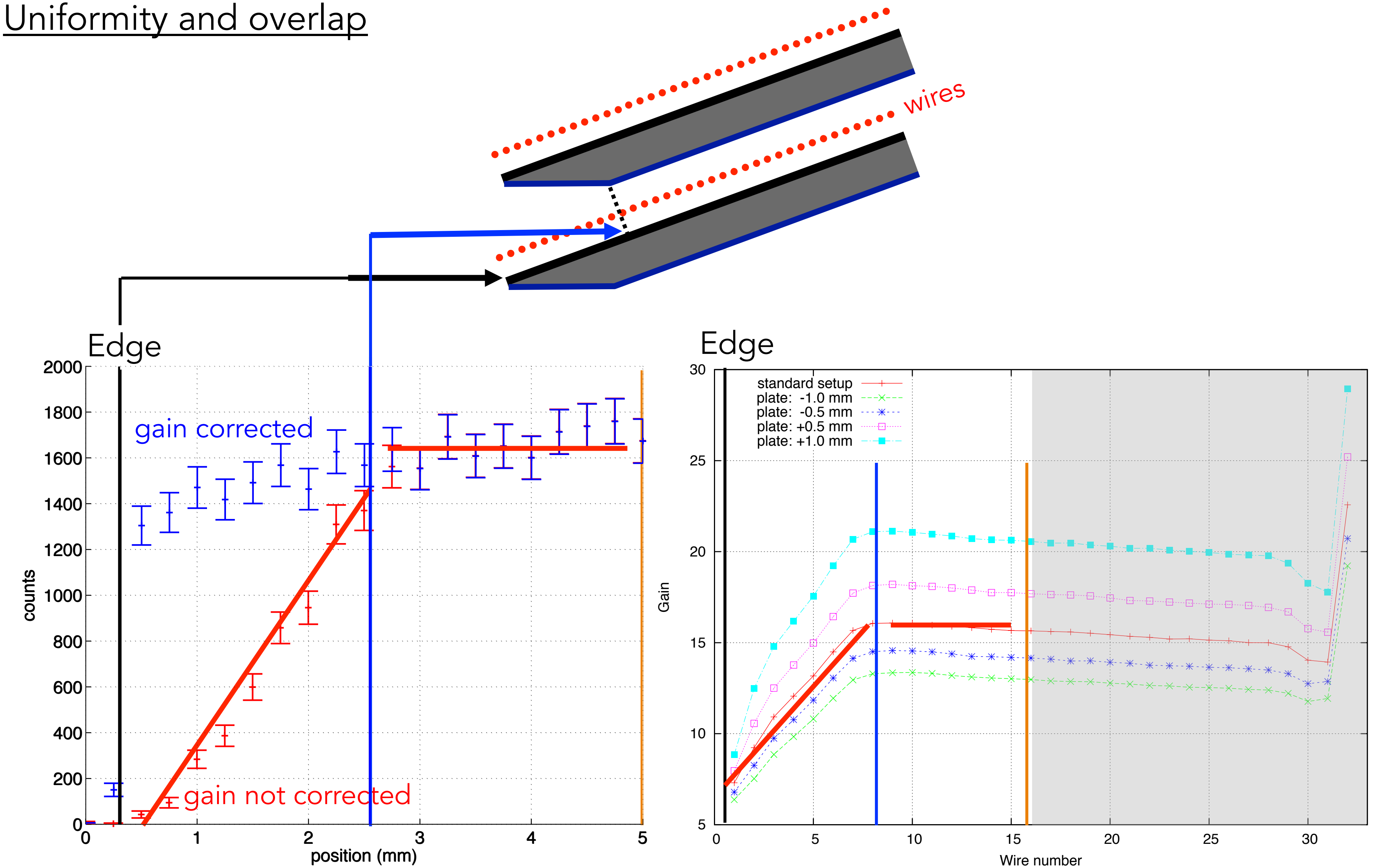


Measured

Uniformity and overlap



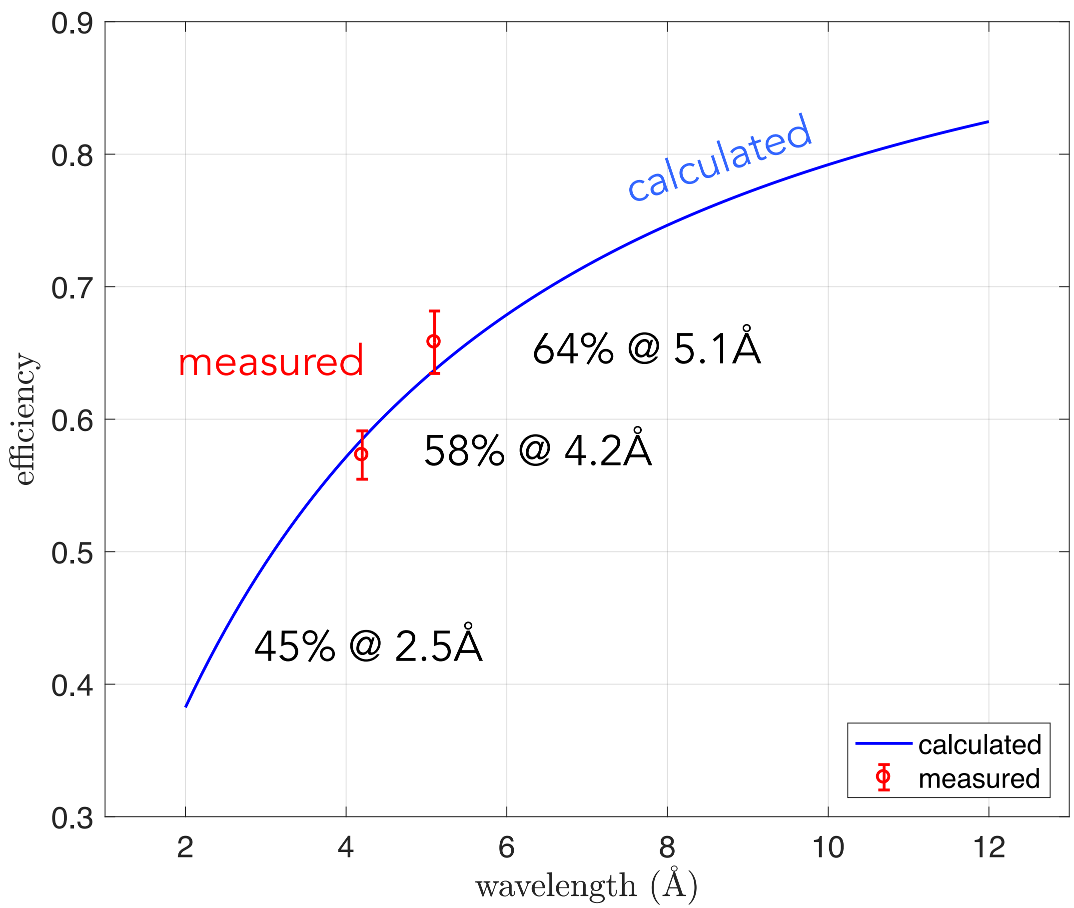
Uniformity and overlap



Measured

Garfield Simulation

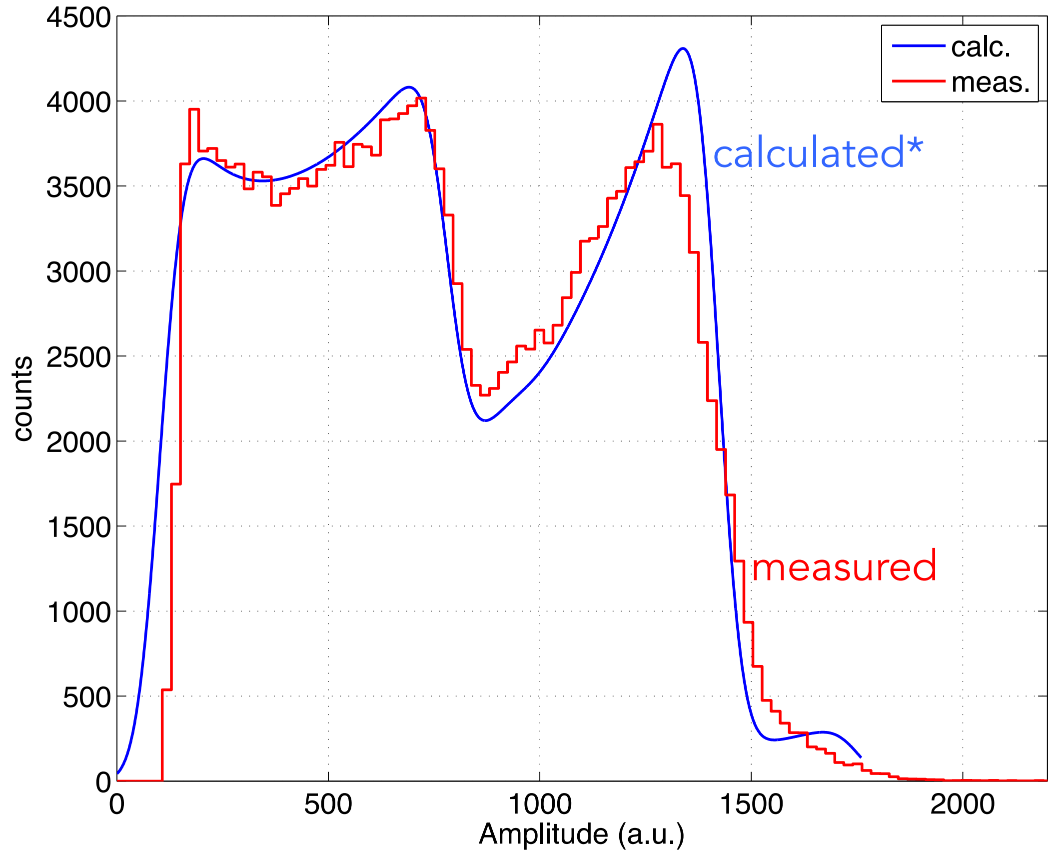
Efficiency



calculated
measured
64% @ 5.1Å
58% @ 4.2Å
45% @ 2.5Å
efficiency
wavelength (Å)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
2
4
6
8
10
12
calculated
measured

PHS and Gain

*F. Piscitelli and P. van Esch,
Analytical modeling of thin film neutron converters and its application to thermal neutron gas detectors
J. Instrum. 8, P04020 (2013)
arXiv:1302.3153

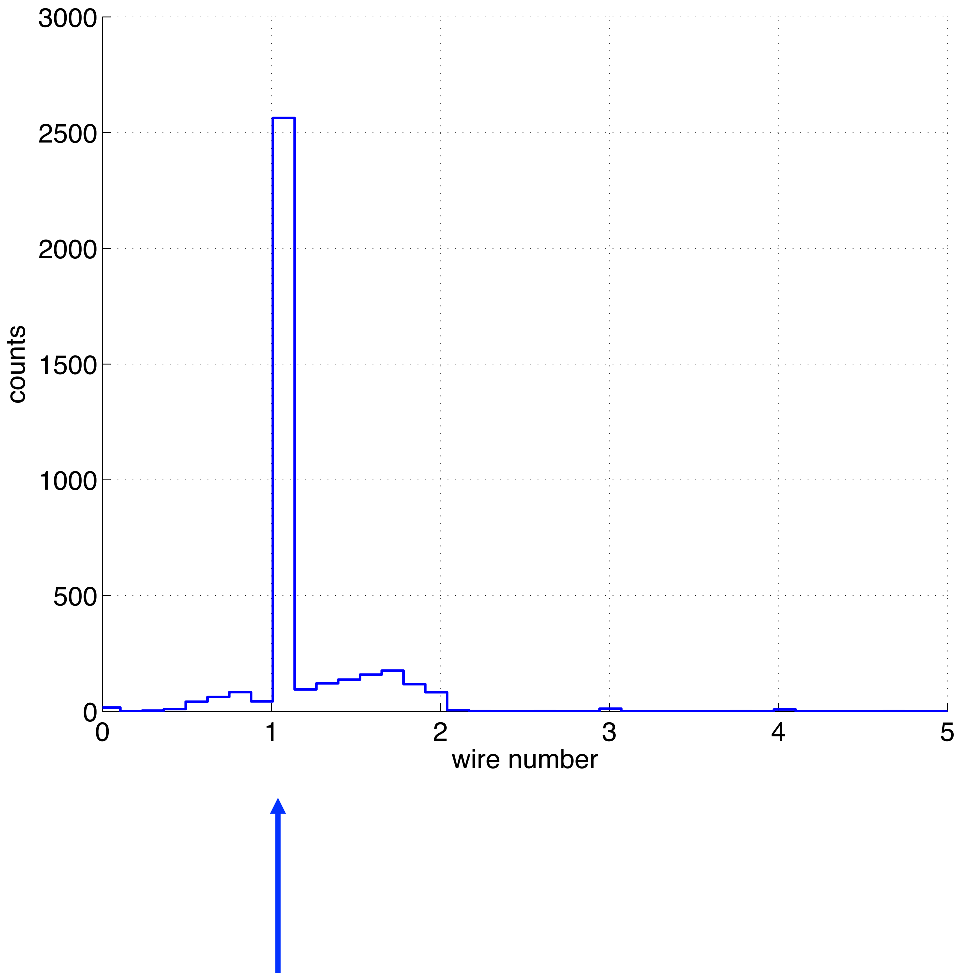


Measured @ 4.1Å 5 degrees

Energy Resolution ~50 KeV
Energy Threshold ~100 KeV

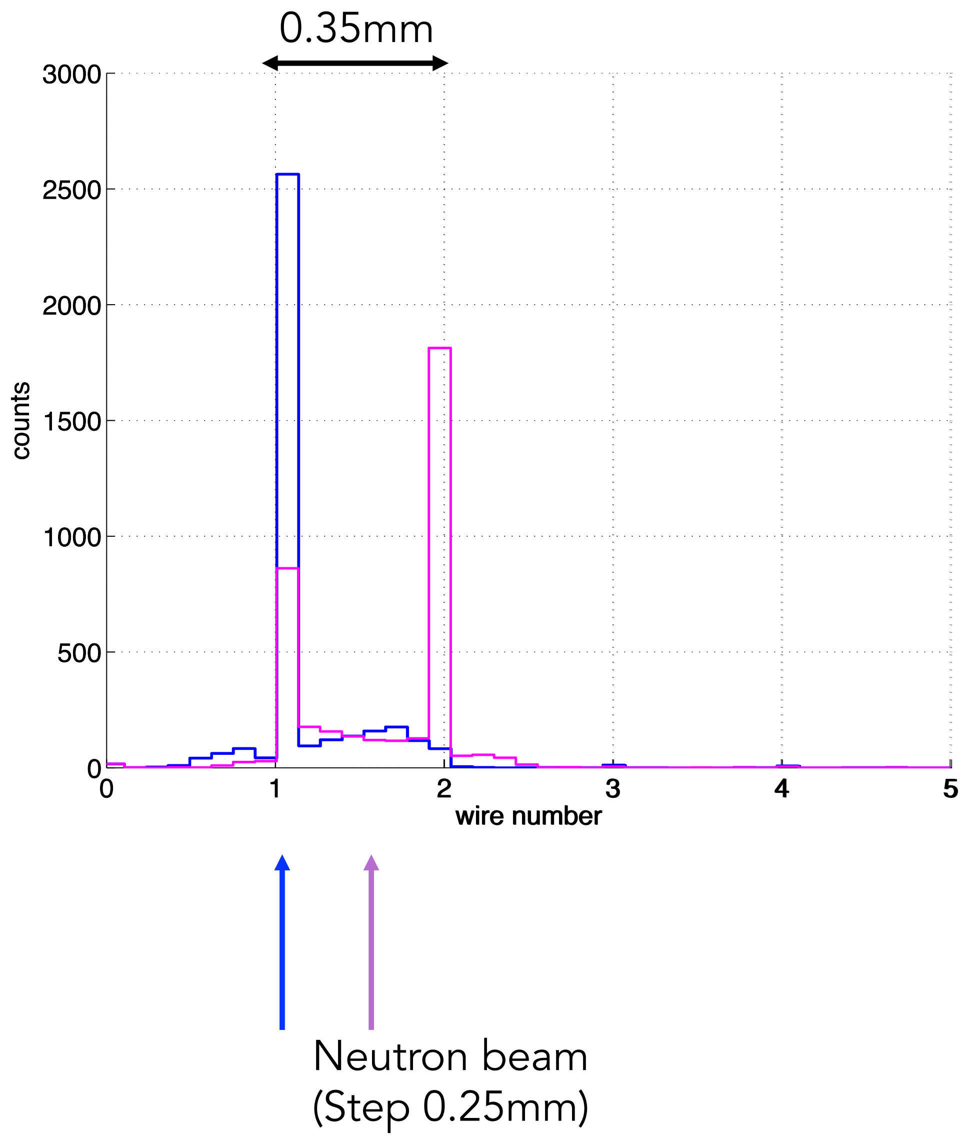
Gas Gain ~ 20 (max 0.2pC avalanche charge)
(contributes to improve the counting rate capability)

Spatial resolution X – wires

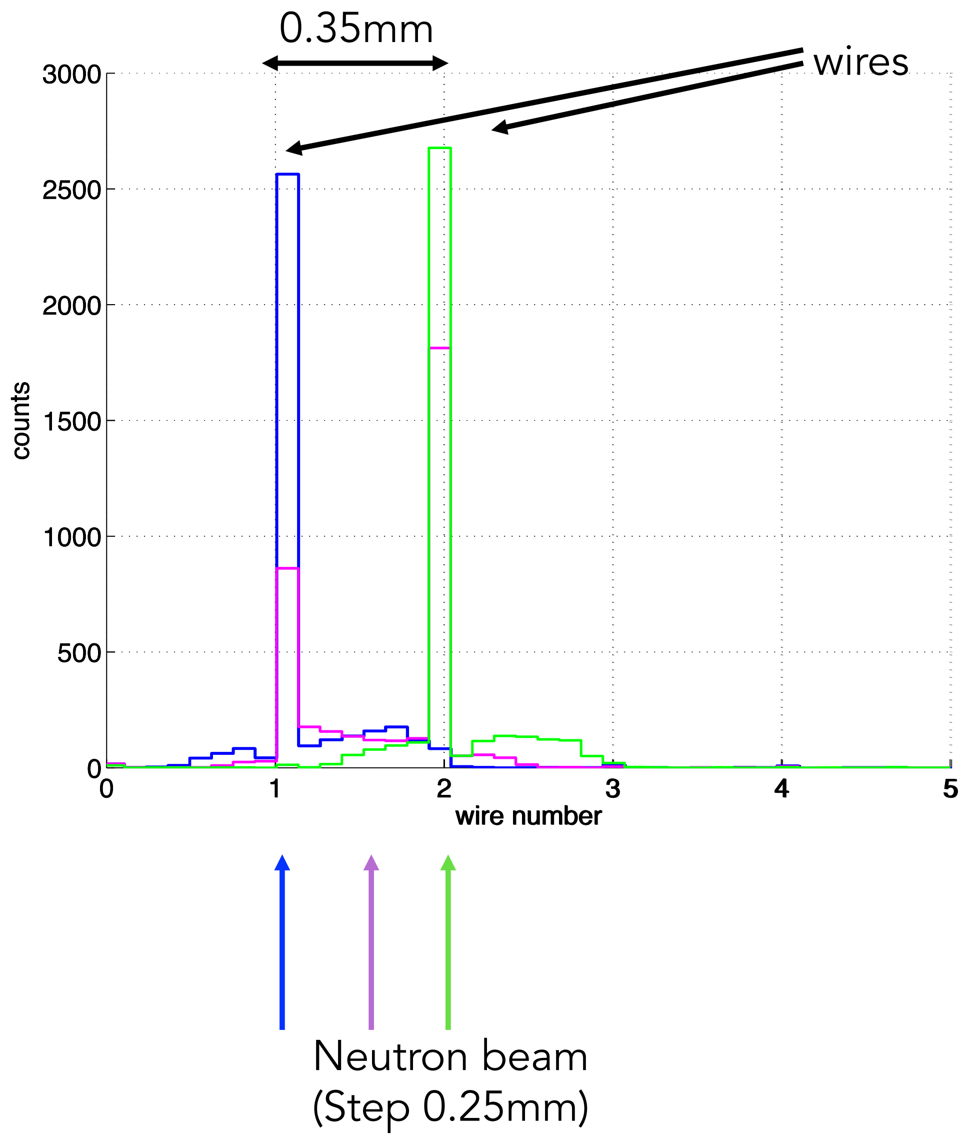


Neutron beam
(Step 0.25mm)

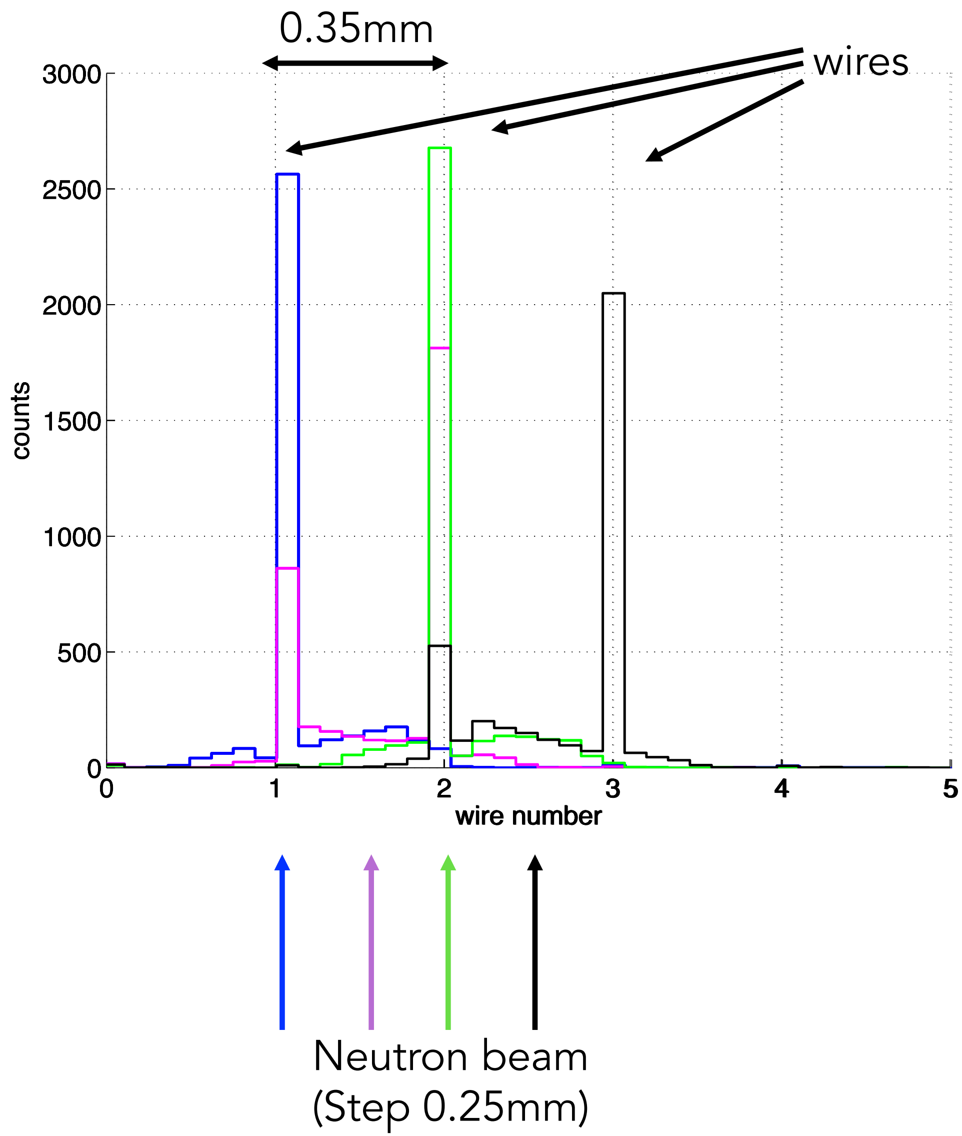
Spatial resolution X – wires



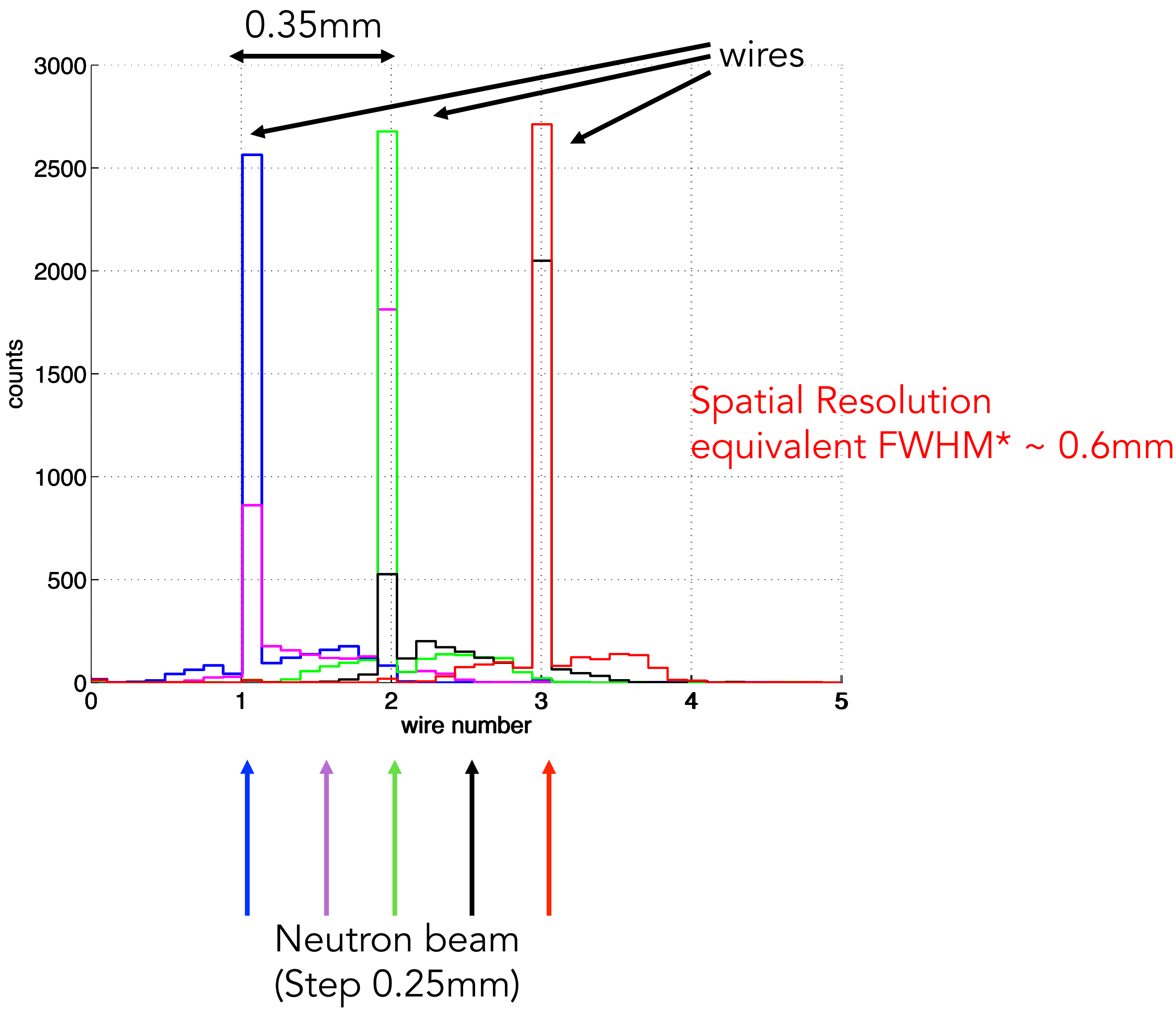
Spatial resolution X – wires



Spatial resolution X – wires

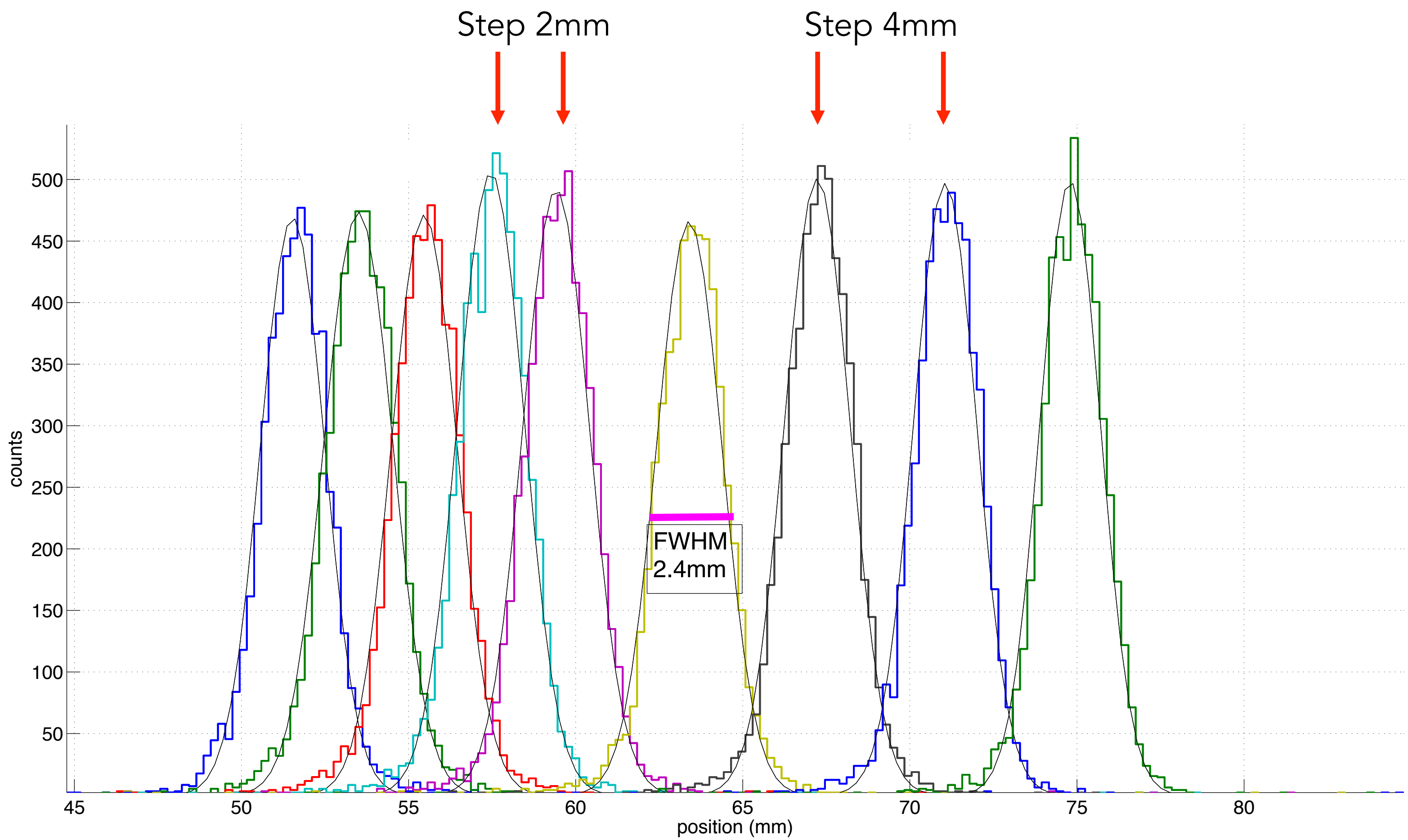


Spatial resolution X – wires



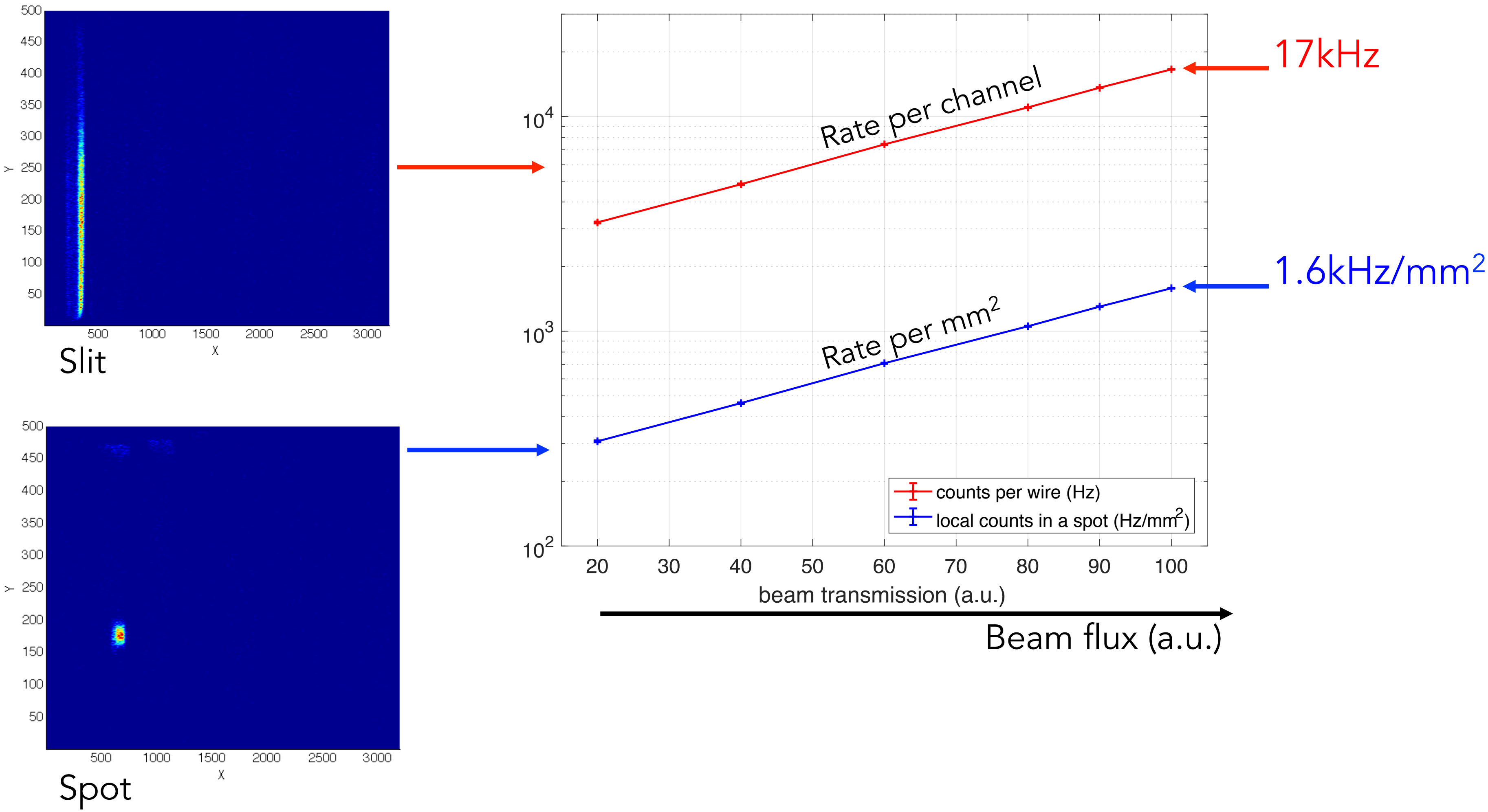
*P. Van Esch et al.,
An information-theoretical approach to image resolution applied to neutron imaging detectors based upon discriminator signals
in Proceedings of ANNIMA conference, Marseille 2013
arXiv:1307.7507

Spatial resolution Y – strips



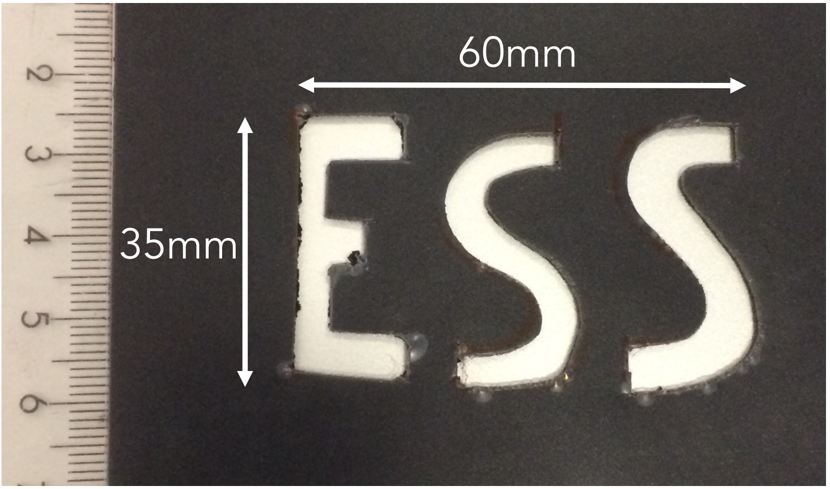
Spatial Resolution FWHM ~ 2.4mm

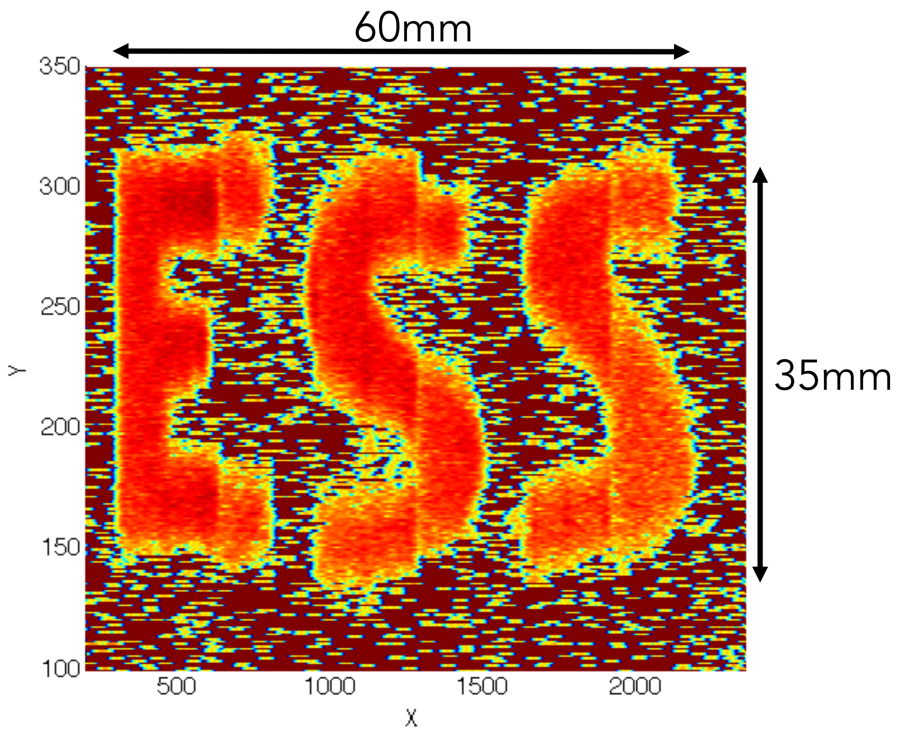
Counting rate capability



No saturation observed up to ~ 1.6kHz/mm^2

Images

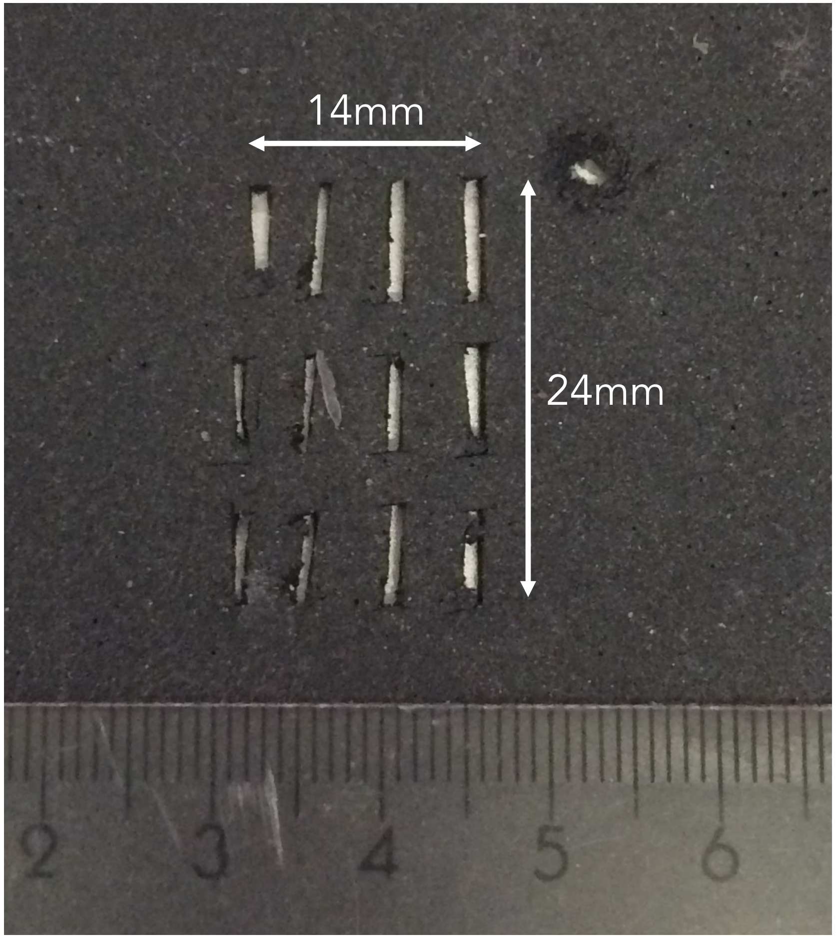




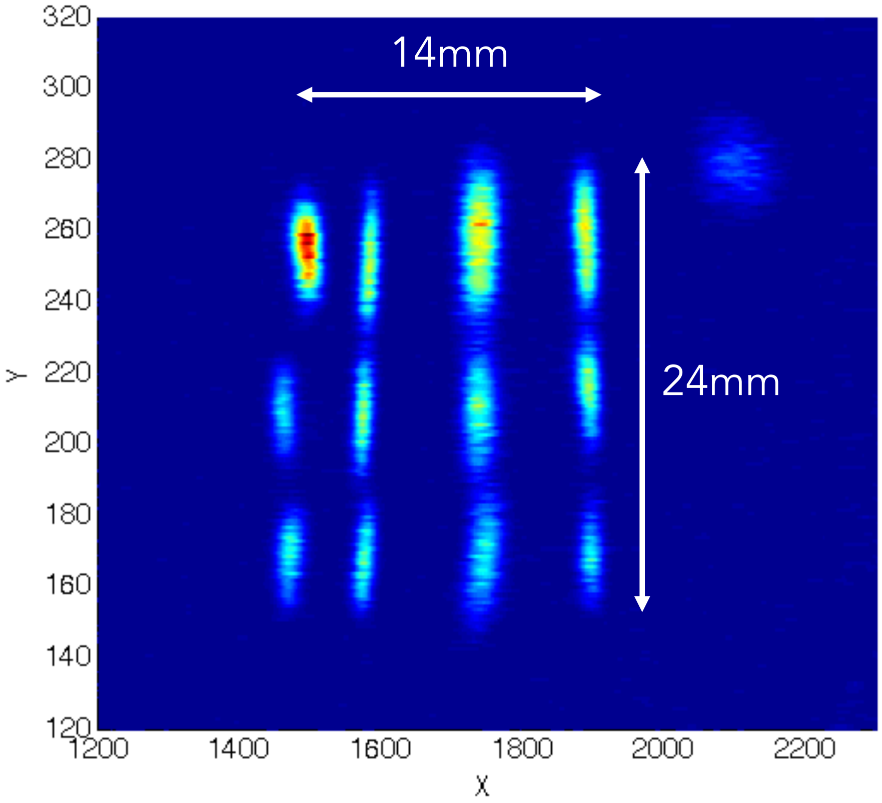
Mask

Raw image from the detector (log scale)

Images

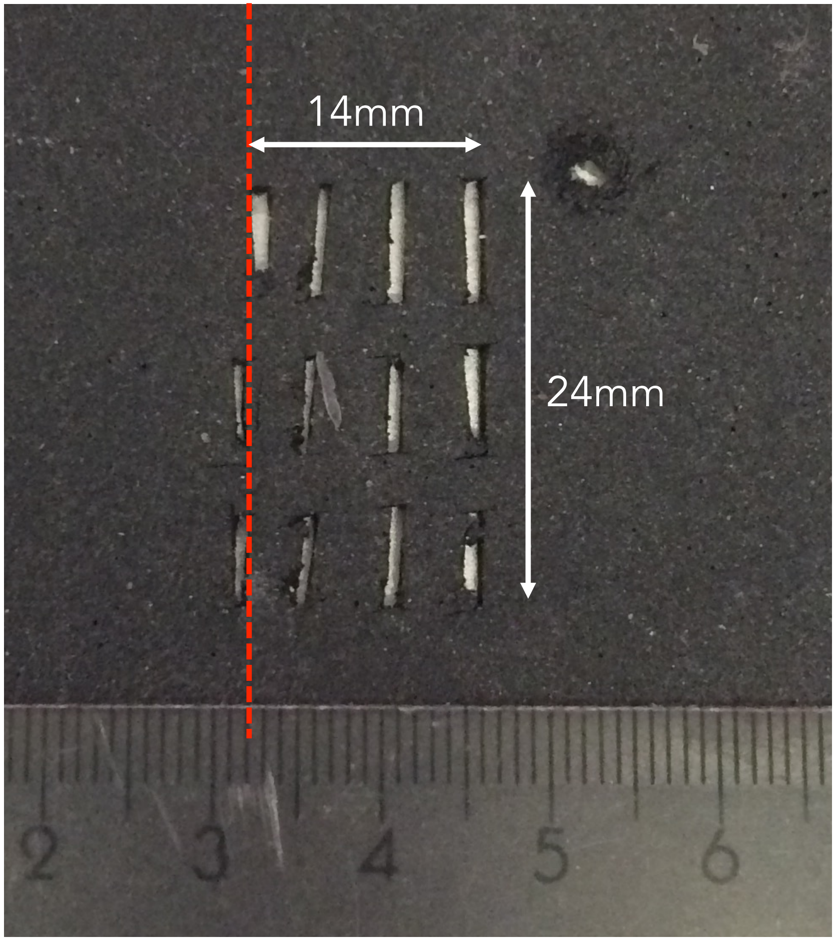


Mask

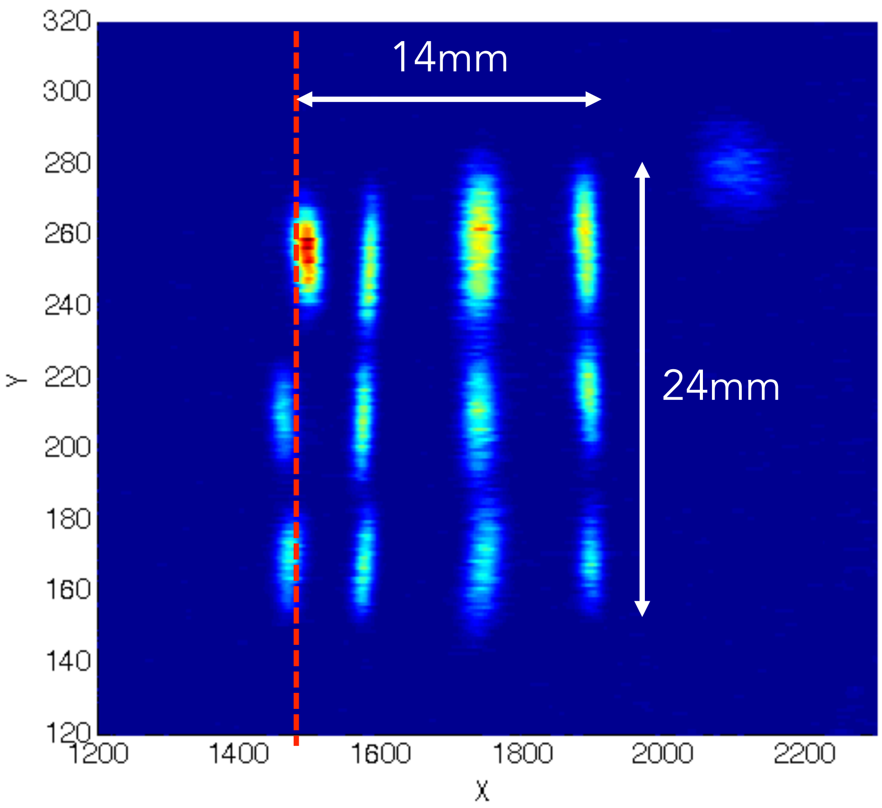


Raw image from the detector

Images



Mask



Raw image from the detector

Summary

	Multi-Blade 2013	Multi-Blade 2016 (actual status)		Goal	What to do next
Spatial Res. X	0.3mm	0.6mm (wire pitch can be adjusted)	✚	0.5mm	Nothing – Matches the goal
Spatial Res. Y	4mm	2.4mm	✚	2 - 3mm	Nothing – Matches the goal
Stability	Not measured	~1% (over 12h)	✚	1% (over days)	Longer tests
Efficiency	Measured 26% @ 10deg 2.5Å	Measured 58% @ 5deg 4.2Å Measured 64% @ 5deg 5.1Å	✚	>45% @ 2.5Å	Nothing – Matches the goal
Low gain operation	Gain ~60	Gain ~20	✚	--	Nothing – Matches the goal
Counting Rate Capability	Not measured	1.6 kHz/mm^2 (>17kHz extrapolated)	➡	500 KHz/mm^2	Needs to be measured
Uniformity X	15%	20% (measured in Charge Div. 1350V)	➡	5%	Mechanical Improvements
Uniformity Y	15%	20% (measured in Charge Div. 1350V)	➡	5%	Mechanical Improvements
Overlap	2mm gap 50% loss	0.7mm gap 50% loss	➡	≤1xResoltution (≤0.5mm)	Mechanical Improvements

Summary

	Multi-Blade 2013	Multi-Blade 2016 (actual status)		Goal	What to do next
Spatial Res. X	0.3mm	0.6mm (wire pitch can be adjusted)	+	0.5mm	Nothing – Matches the goal
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Counting Rate Capability	Not measured	1.6 kHz/mm^2 (>17kHz extrapolated)	→	500 KHz/mm^2	Needs to be measured
Uniformity X	15%	20% (measured in Charge Div. 1350V)	→	5%	Mechanical Improvements
Uniformity Y	15%	20% (measured in Charge Div. 1350V)	→	5%	Mechanical Improvements
Overlap	2mm gap 50% loss	0.7mm gap 50% loss	→	≤1xResoltution (≤0.5mm)	Mechanical Improvements

We are building a new prototype …

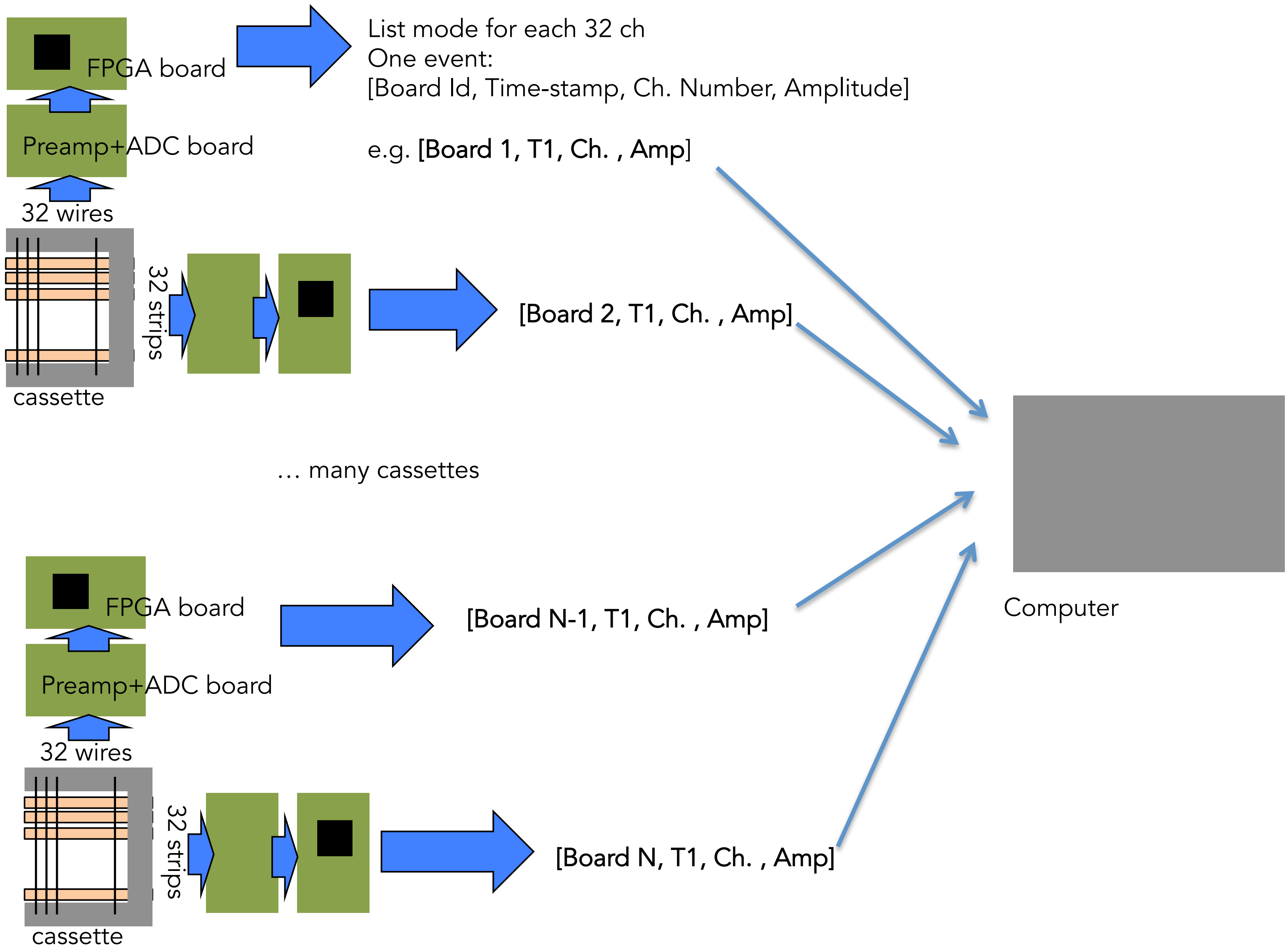
The final goal is to reproduce a Reflectivity measurements at an existing Reflectometer.

We are building a new prototype …

The final goal is to reproduce a Reflectivity measurements at an existing Reflectometer.

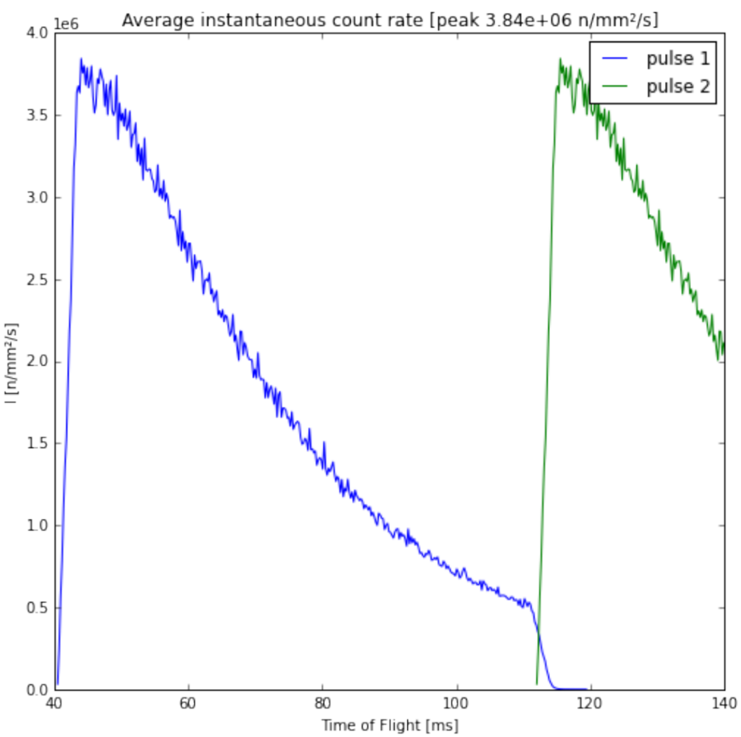
Backup slides

Readout Wigner electronics for the MB16 - FIRMWARE

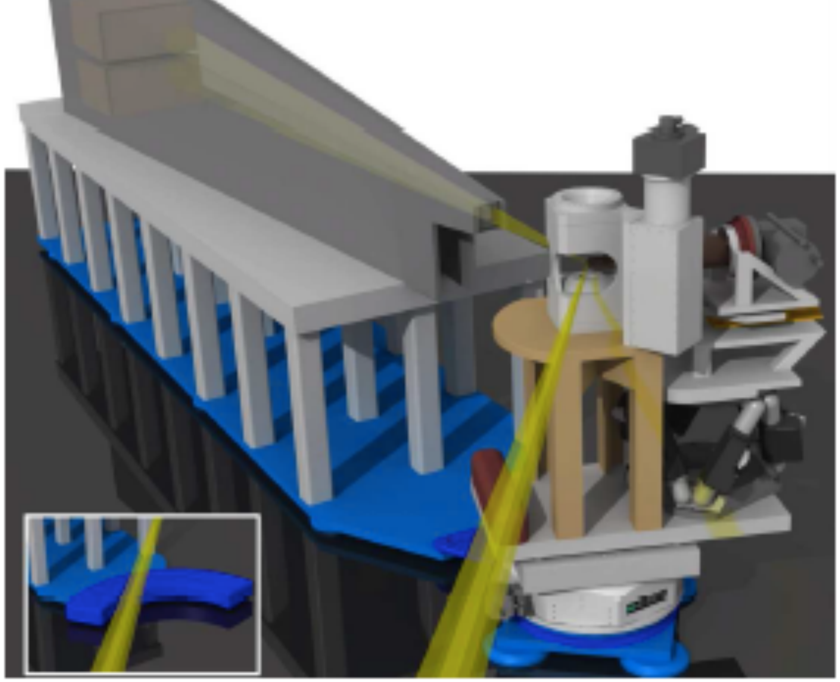


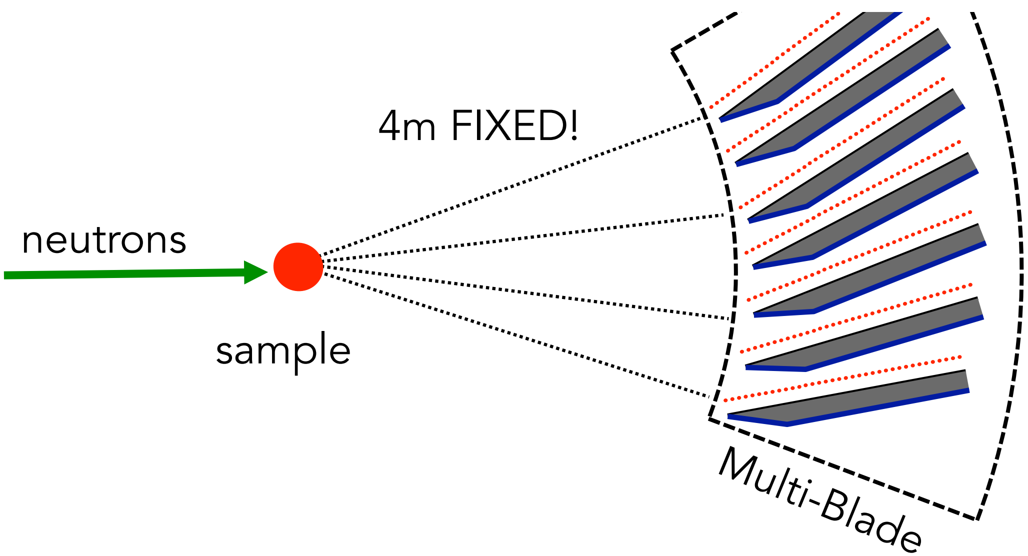
ESTIA

Req. #	Parameter	Description	Value/Error
13.6.9.3r7	L_D	Distance sample to detector	± 0.5 mm
13.6.9.3r8	$2\Theta_{range}$	Rotation range around Z-axis (scattered beam angle)	-10° - +120°
13.6.9.3r9	$\delta 2\Theta$	Rotation accuracy for 2Θ	0.005°
13.6.9.3r10	δX	Horizontal detector resolution	± 0.5 mm
13.6.9.3r11	δZ	Vertical detector resolution	± 4 mm
13.6.9.3r12	D_X	Horizontal detector size	500 mm
13.6.9.3r13	D_Z	Vertical detector size	250 mm
13.6.9.3r14	f_{CR}	Maximum expected count rate	4 MHz/ mm^2
13.6.9.3r15	δt_{ToF}	Detector time resolution	1 ms
13.6.9.3r16	$\epsilon_{4Å}$	Detector efficiency at 4Å	45%
13.6.9.3r17	ϵ_{γ}	Detector sensitivity to gamma radiation	10^{-6}



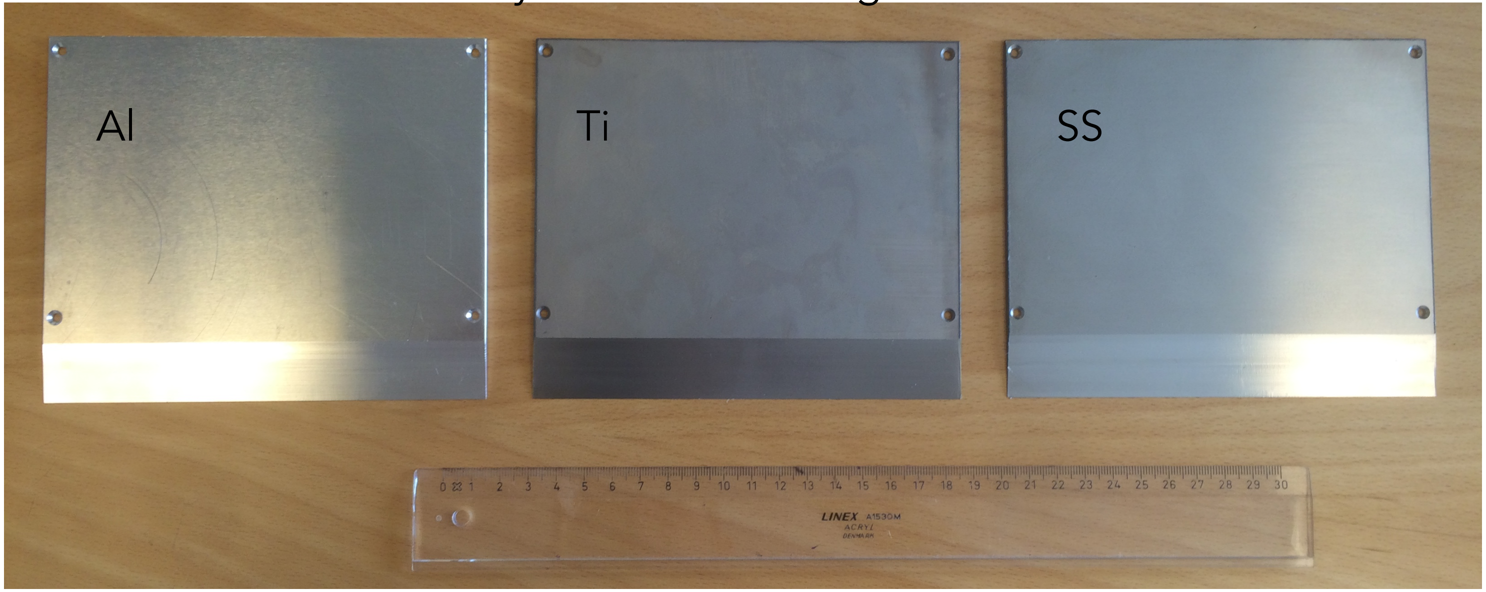
2 twin detectors



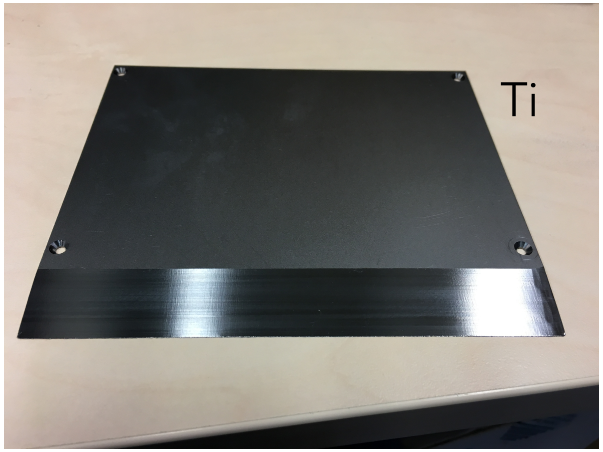


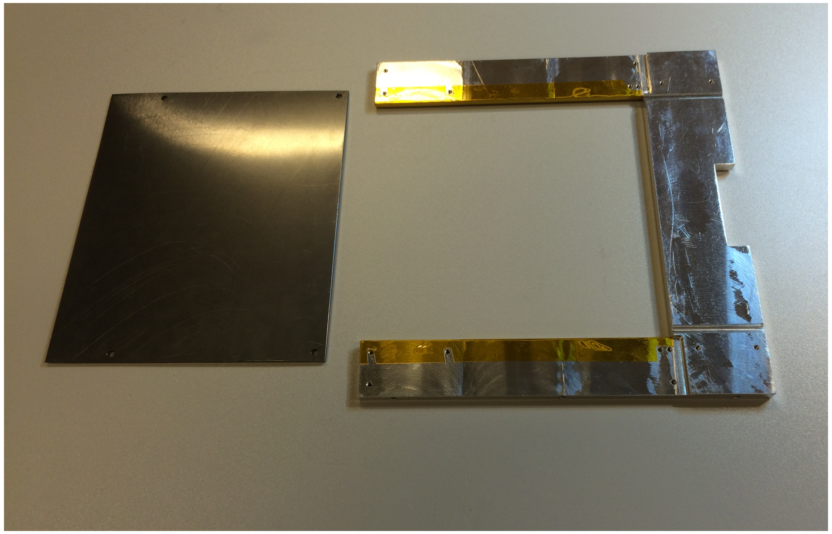
MB-16

Planarity is an issue on large surfaces



Preparing the samples for 2-side coating that can turn in the chamber,
What happens to the knife?

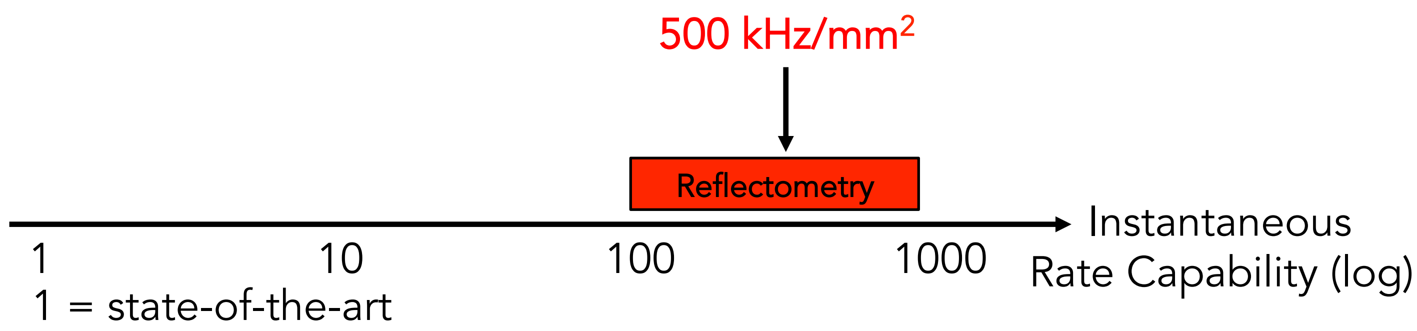


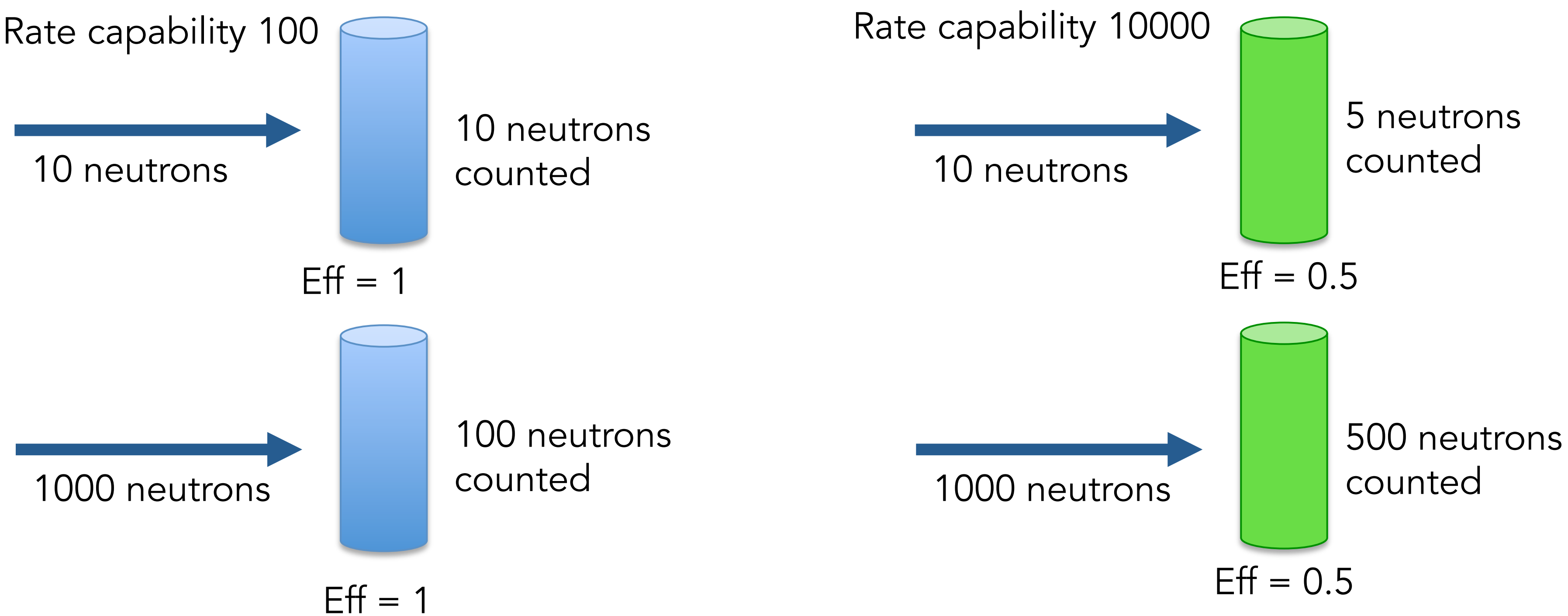


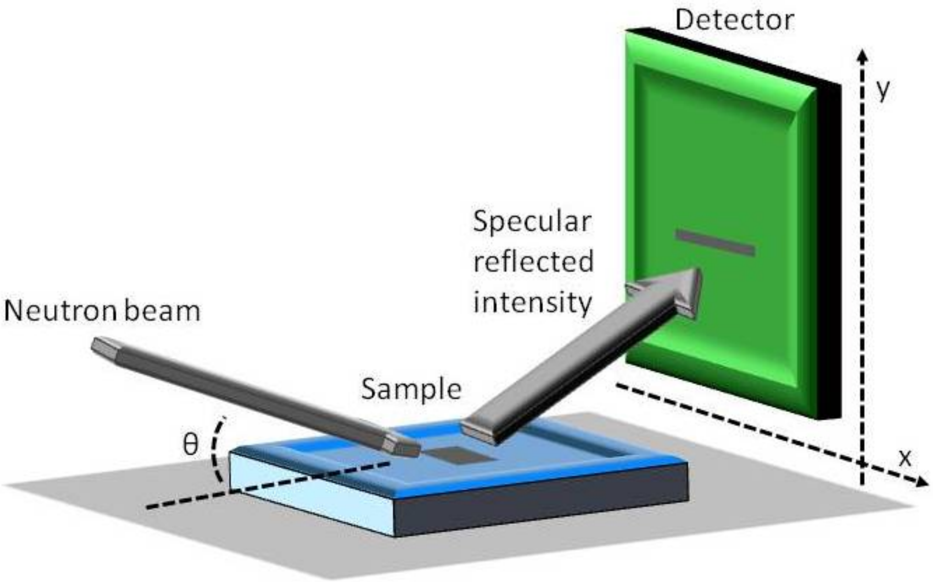
Detector requirements: Neutron Reflectometry

Rate requirements

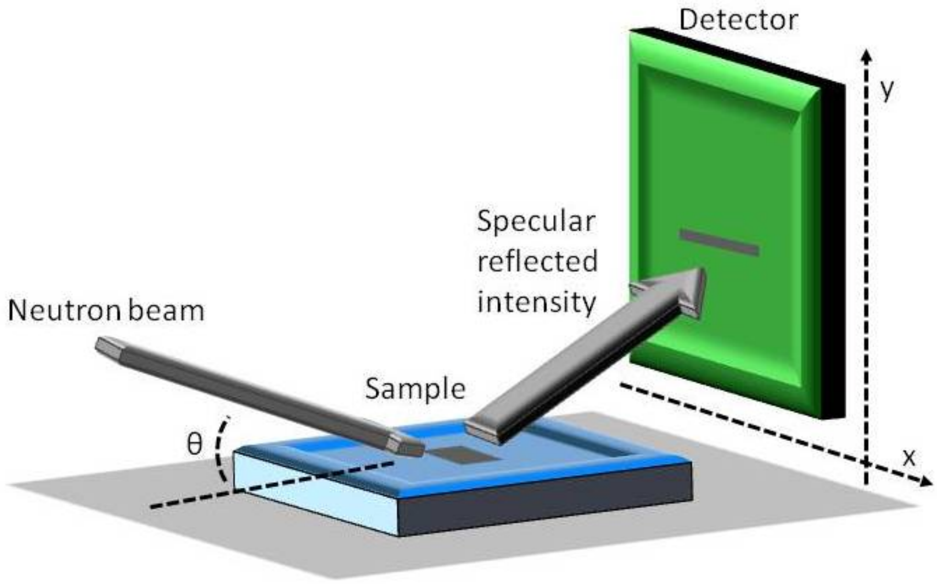
factor by which requirements exceed state-of-the-art





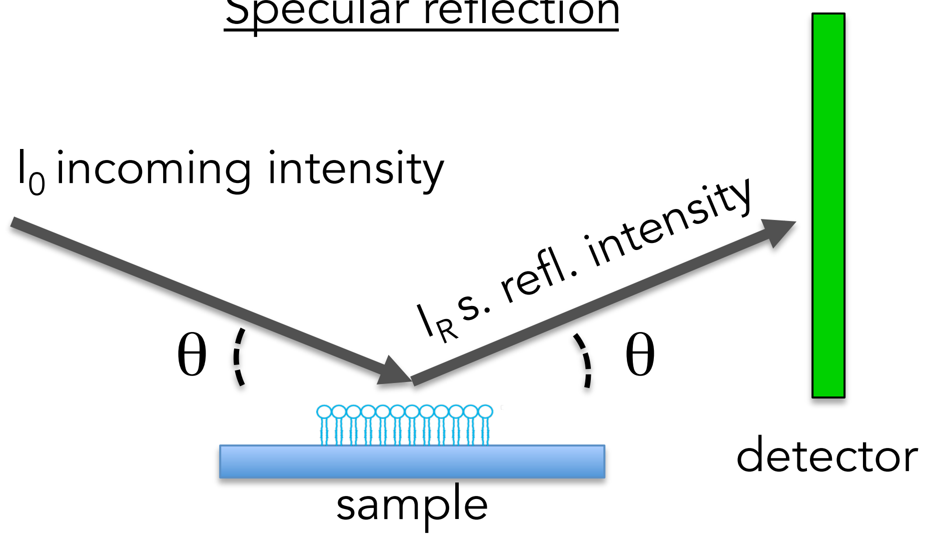


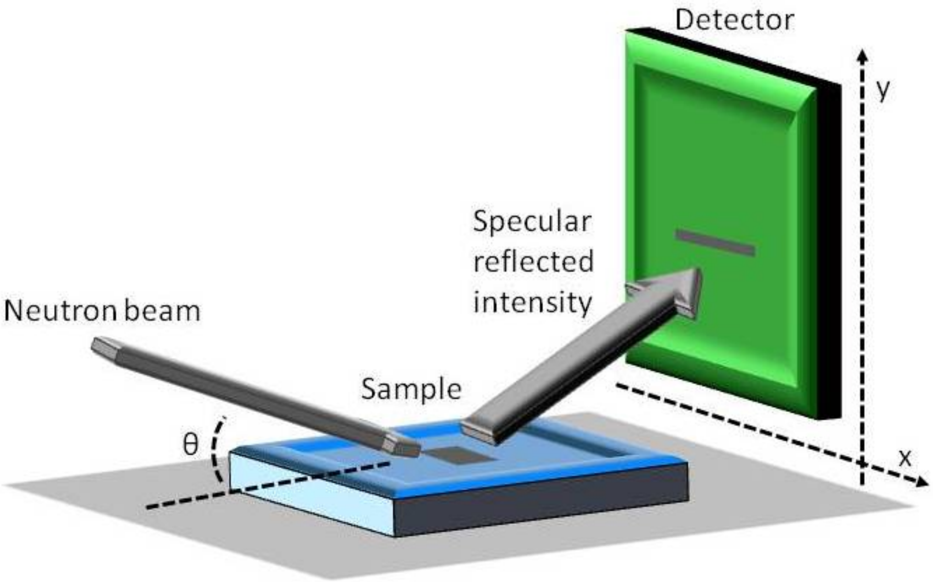
Reflectometry is a technique to study
SURFACES AND INTERFACES



Reflectometry is a technique to study
SURFACES AND INTERFACES

Specular reflection

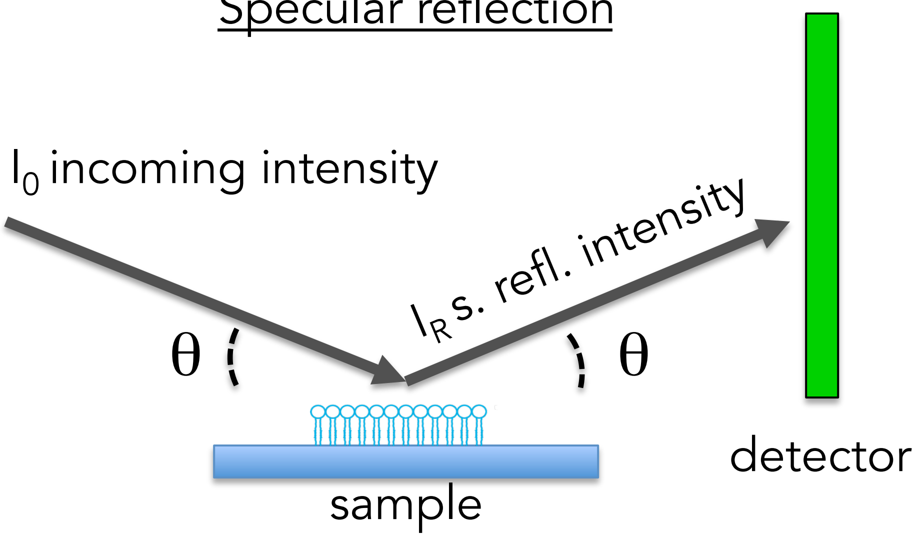




Reflectometry is a technique to study SURFACES AND INTERFACES

To measure the reflected neutrons as a function of q

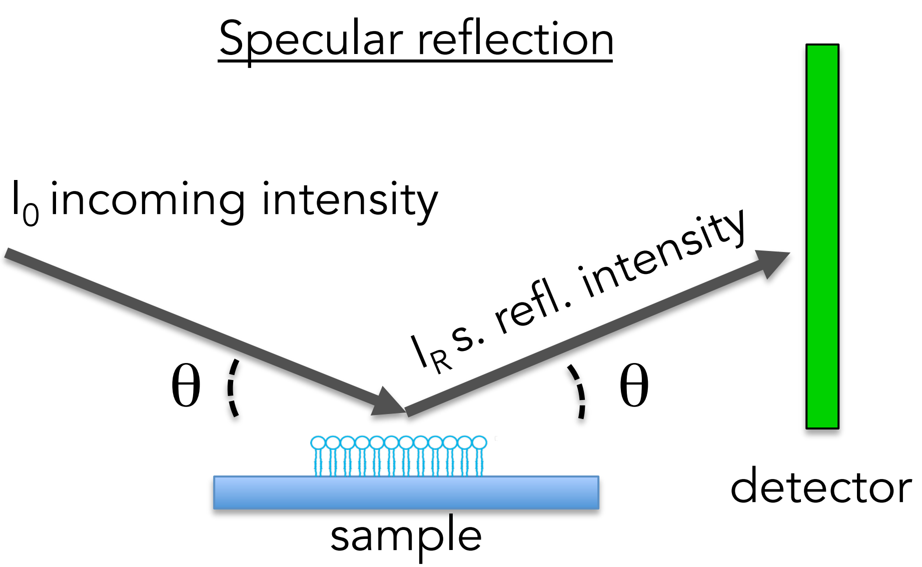
Specular reflection



Neutron wavelength

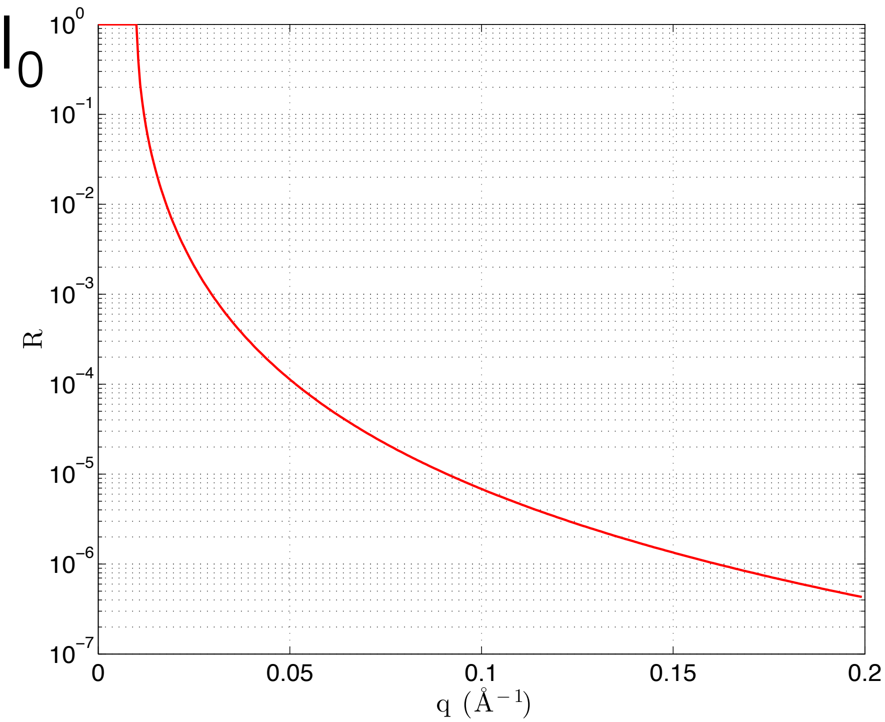
$$q = (4\pi/\lambda)\sin(\theta)$$

Incidence angle

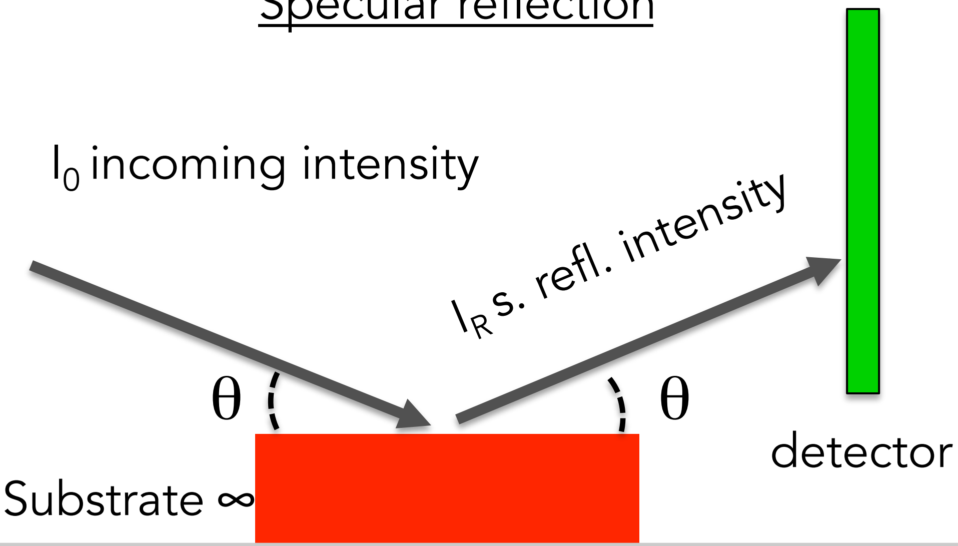


$$q = (4\pi/\lambda)\sin(\theta)$$

$$R = I_R / I_0$$



Specular reflection



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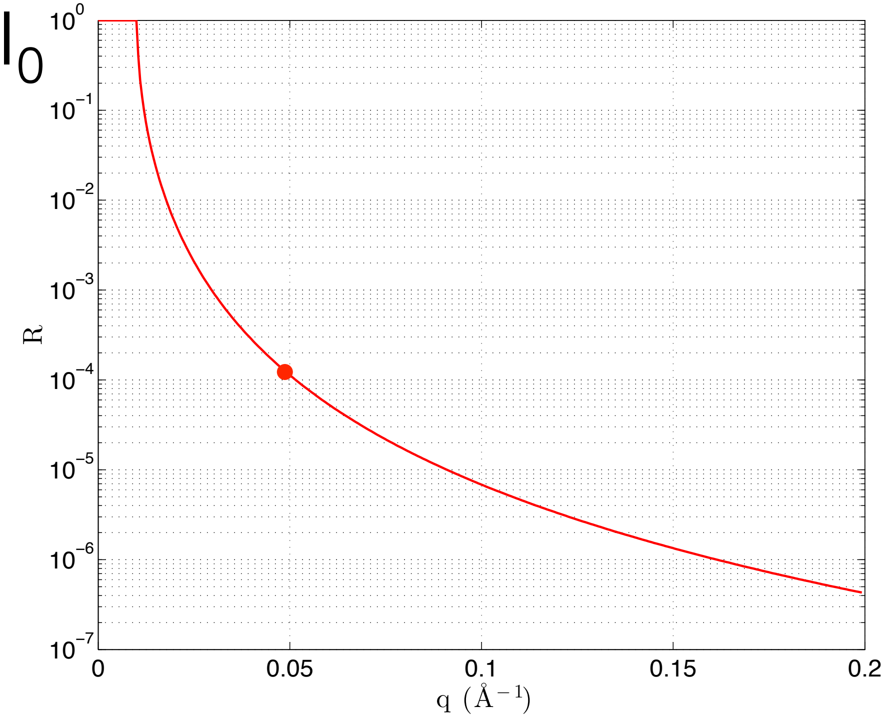
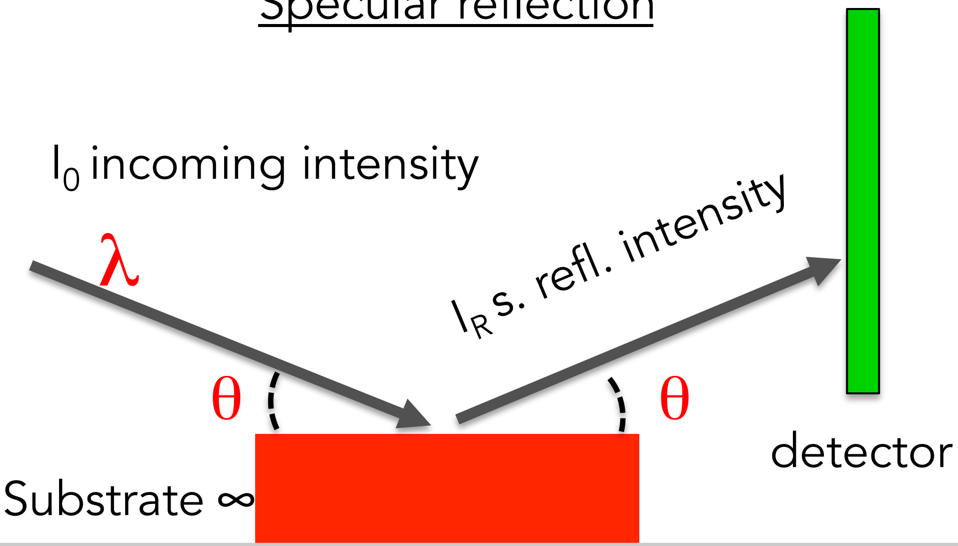
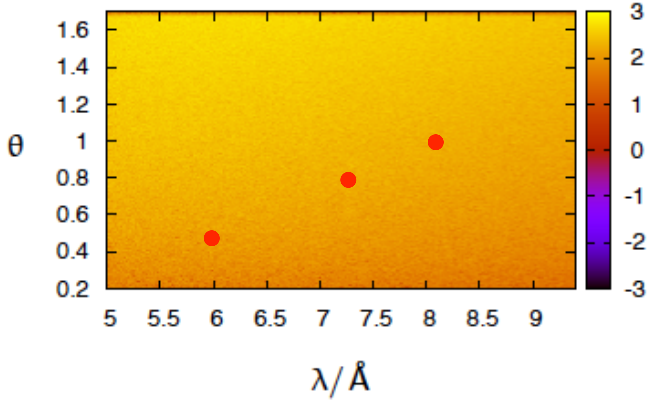


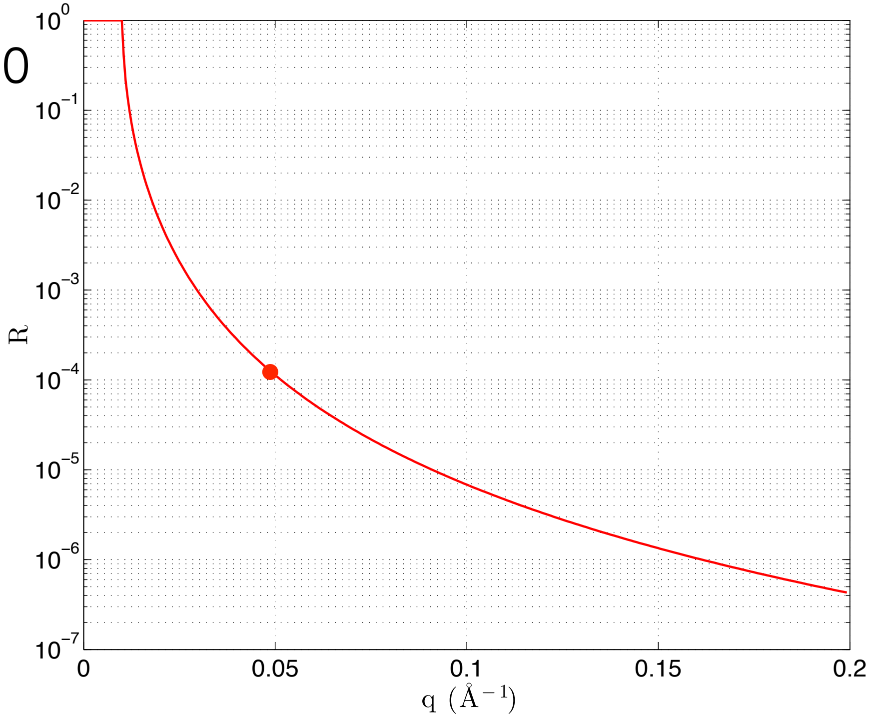
Specular reflection



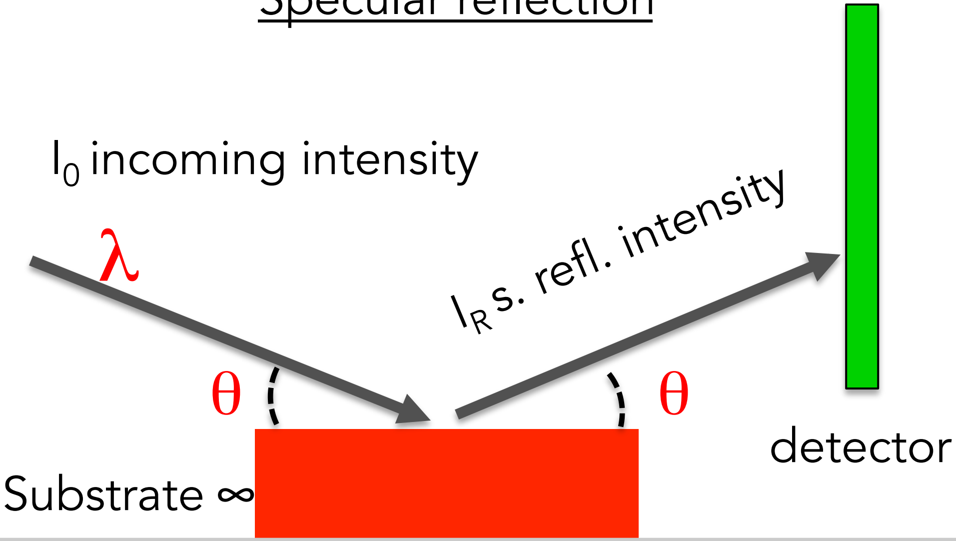
$$q = (4\pi/\lambda) \sin(\theta)$$

$$R = I_R/I_0$$



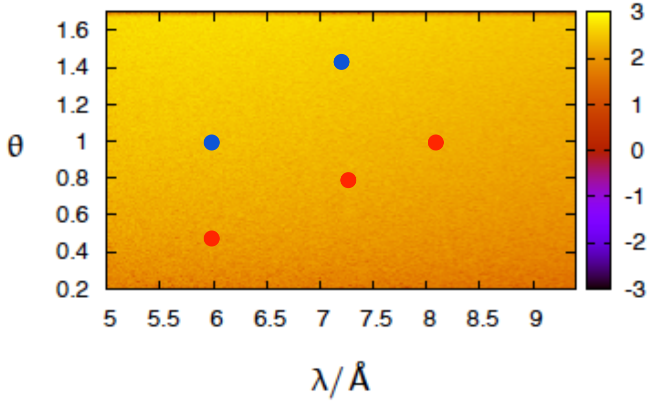


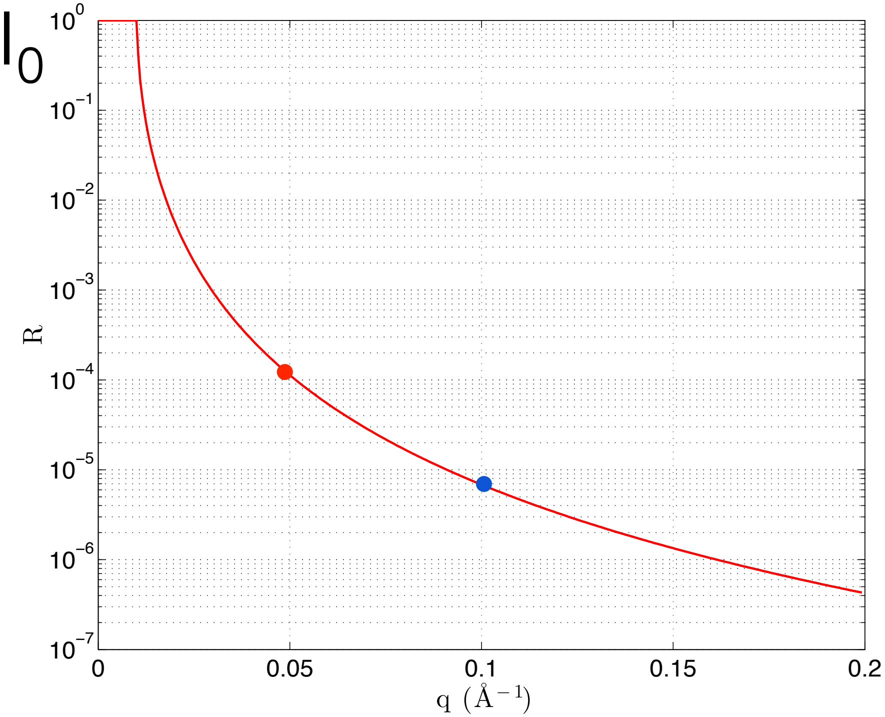
Specular reflection



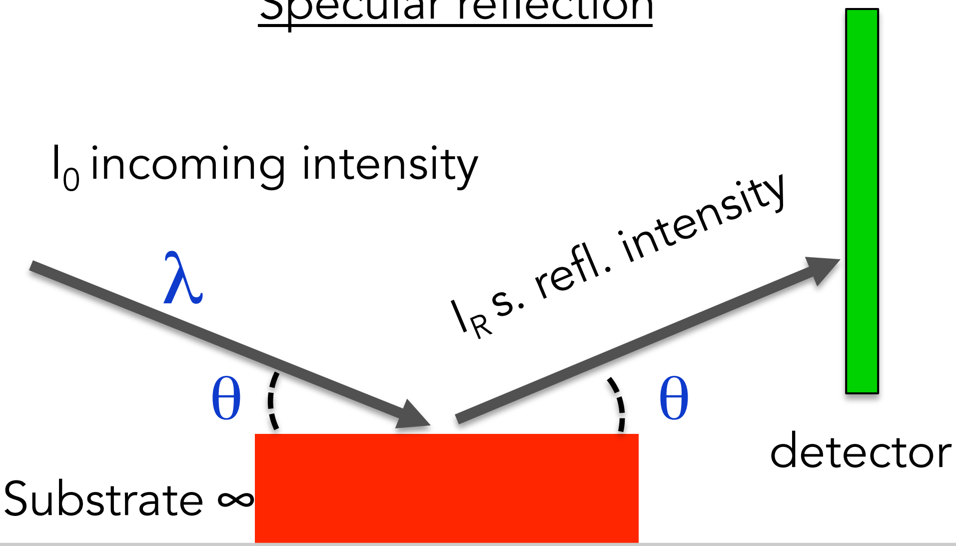
$$q = (4\pi/\lambda) \sin(\theta)$$

$$R = I_R / I_0$$



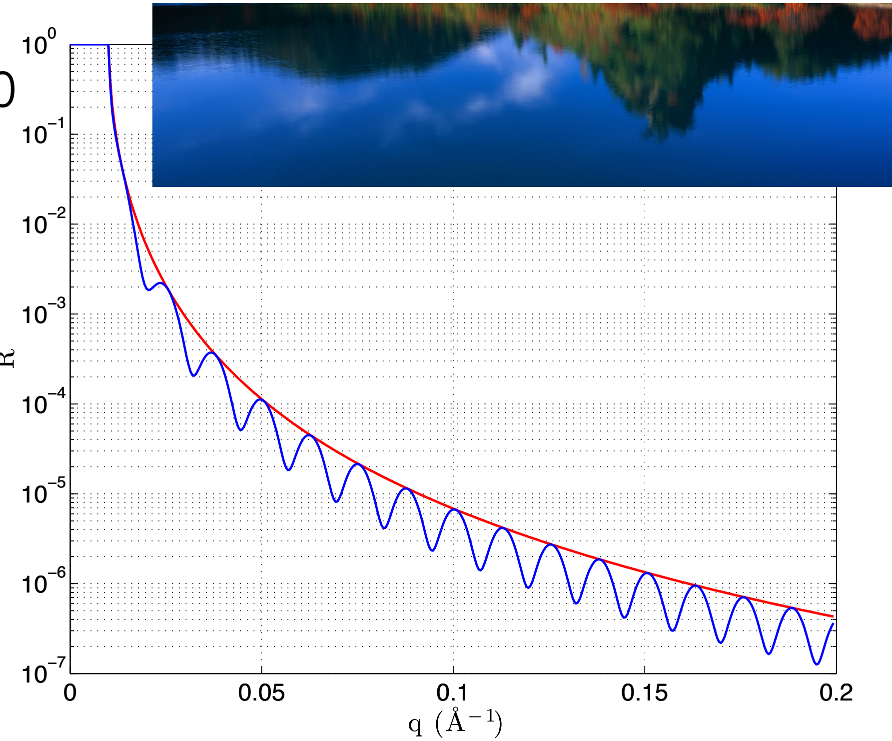


Specular reflection



$$q = (4\pi/\lambda)\sin(\theta)$$

$R = I_R/I_0$

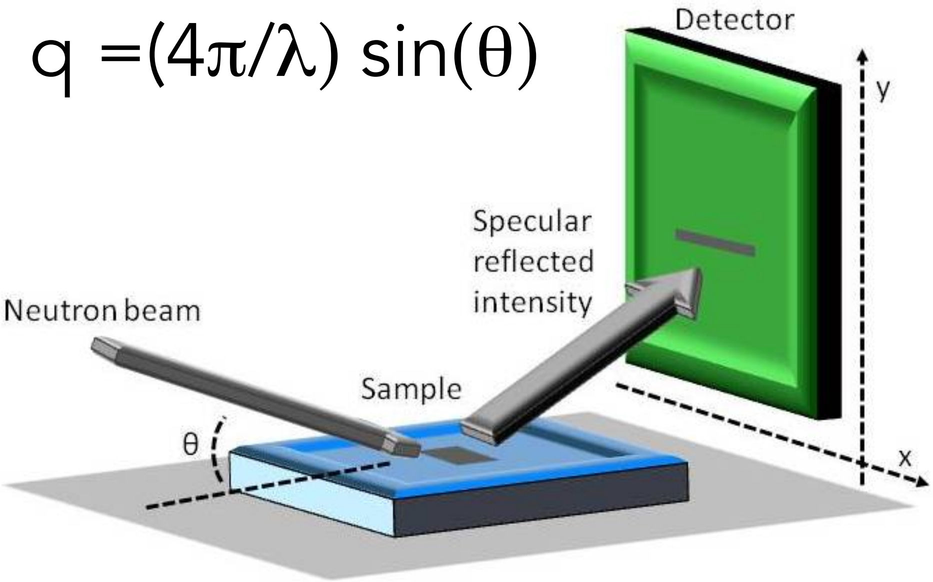


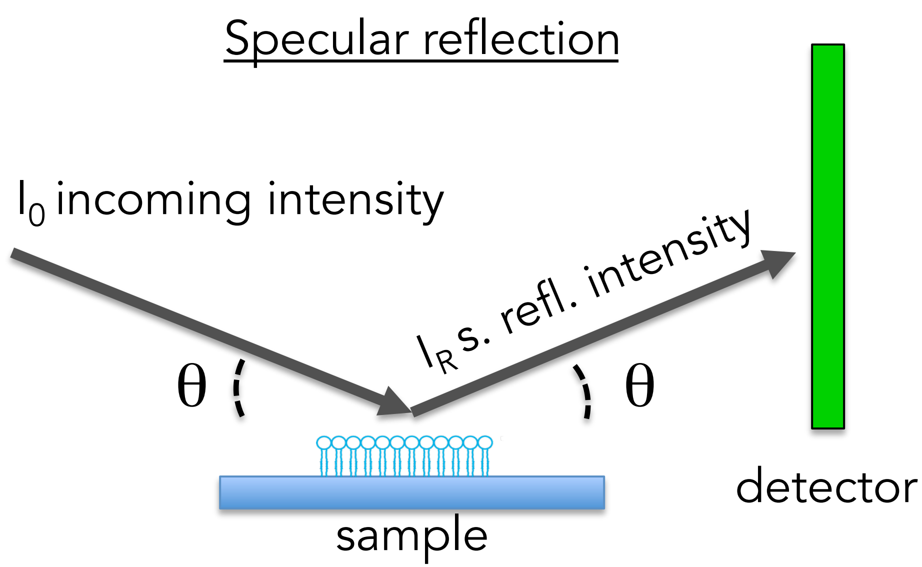
FITTING & INVERSION

R PROFILE

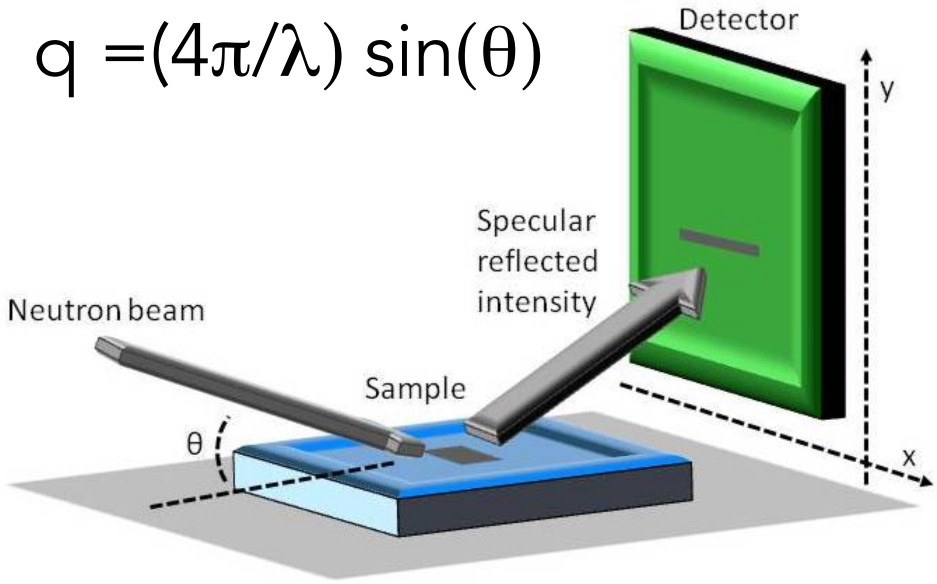
SAMPLE
(SLD profile)

$$q = (4\pi/\lambda)\sin(\theta)$$

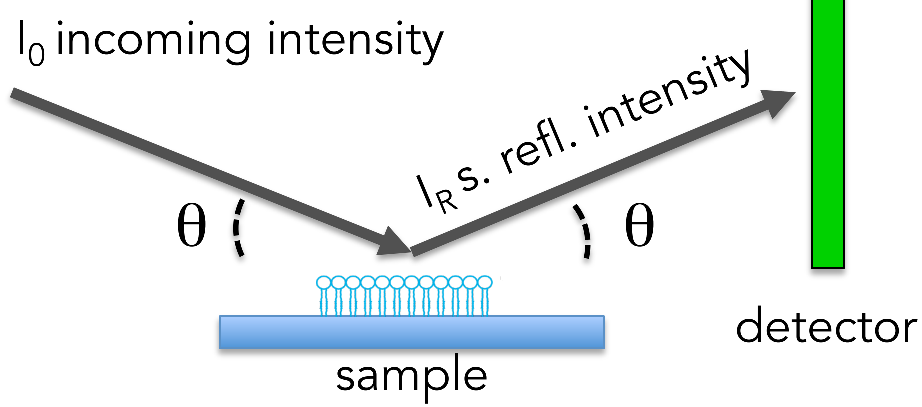


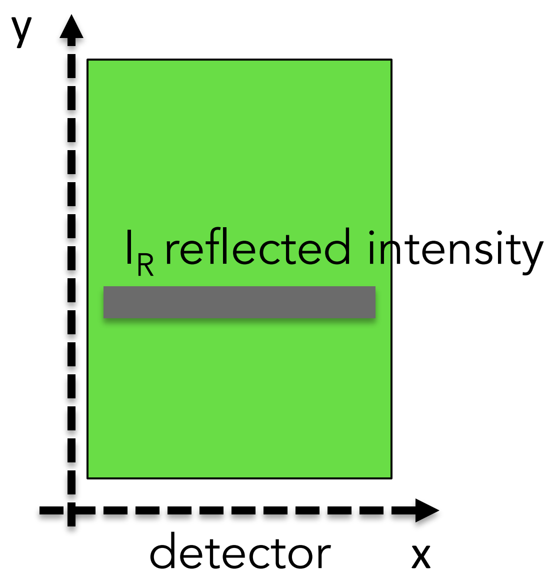


$$q = (4\pi/\lambda)\sin(\theta)$$

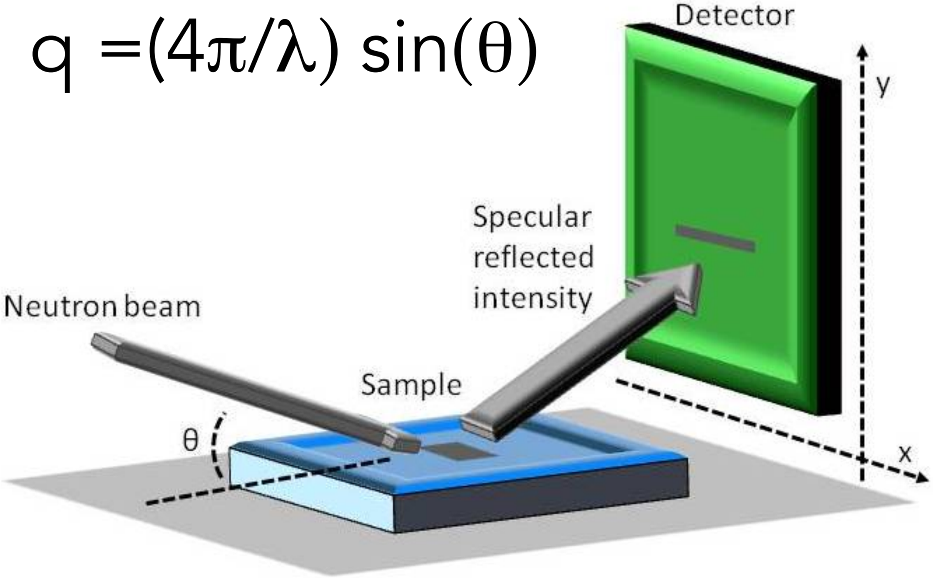


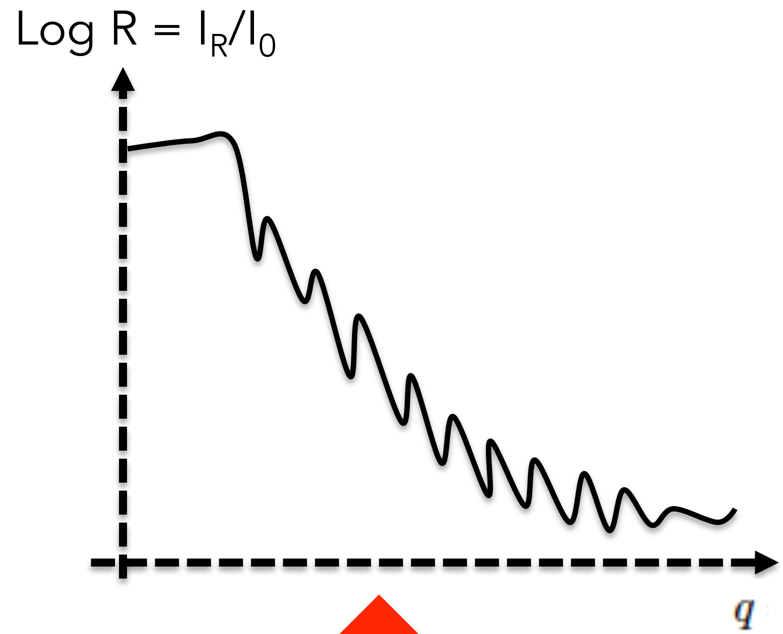
Specular reflection



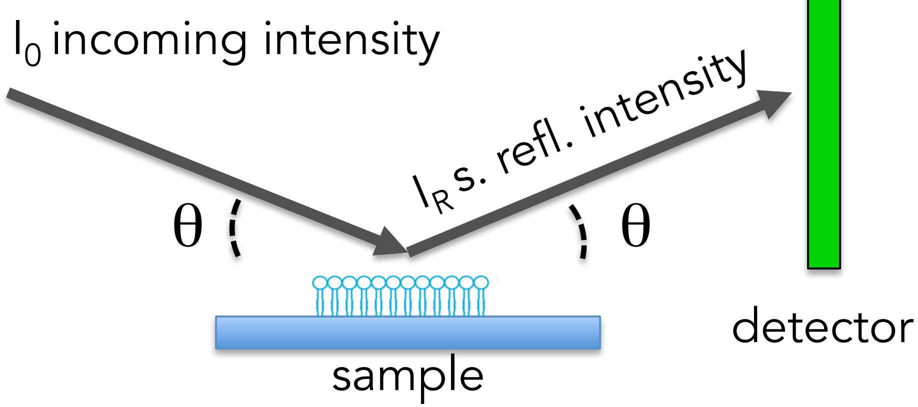


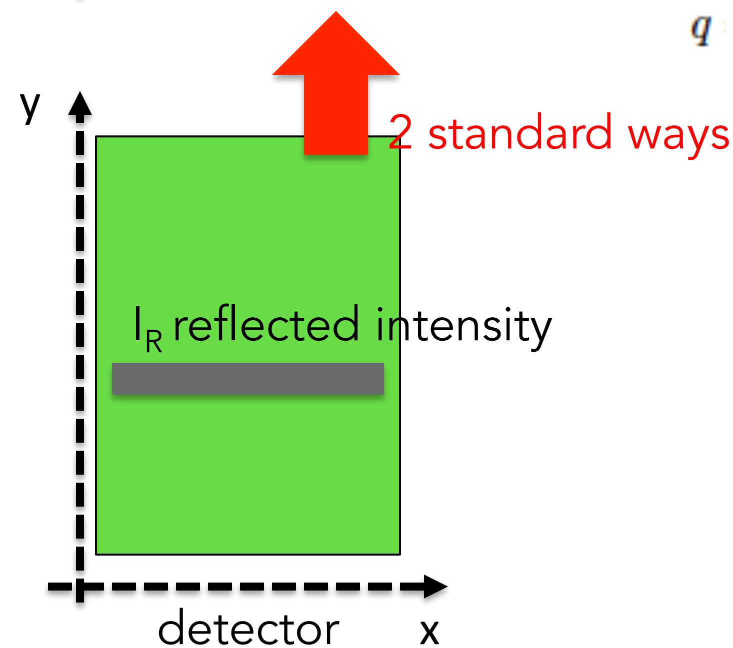
$q = (4\pi/\lambda)\sin(\theta)$





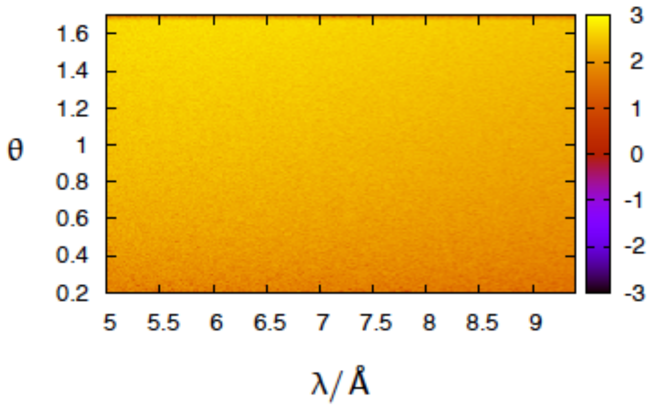
Specular reflection

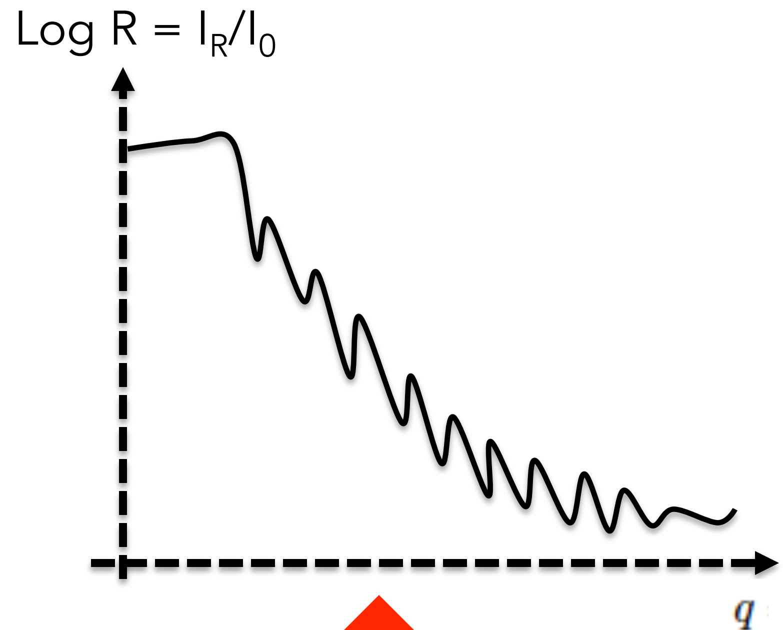


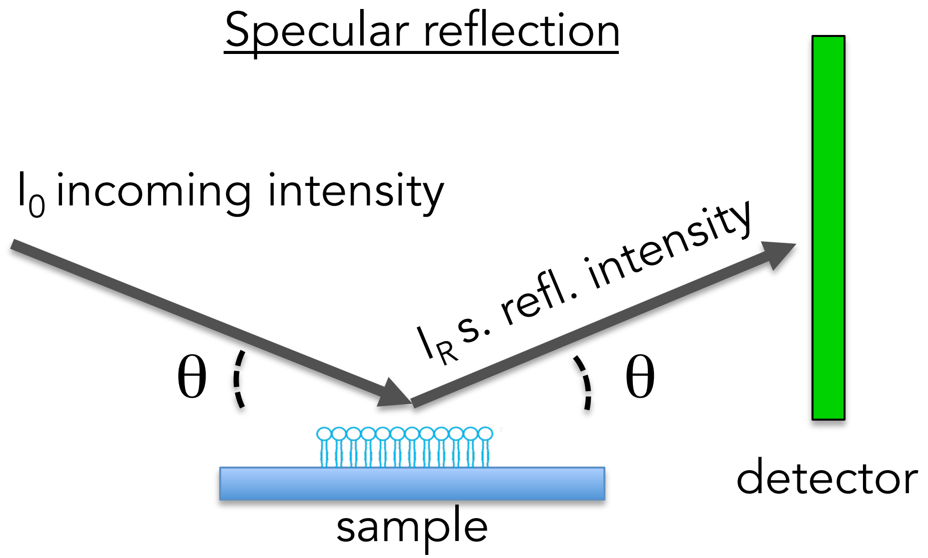


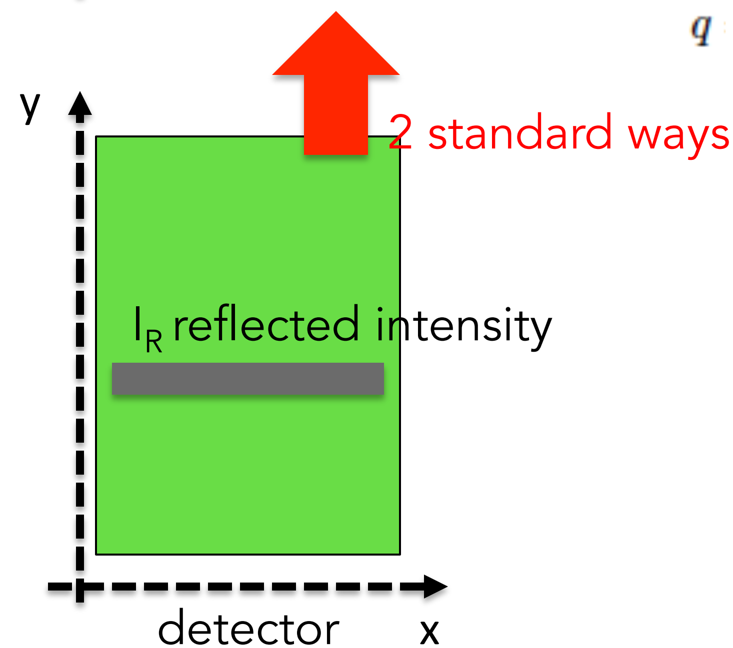
$q = (4\pi/\lambda) \sin(\theta)$

1. ToF (λ scan, θ fixed)
2. Monochromatic (λ fixed, θ scan)









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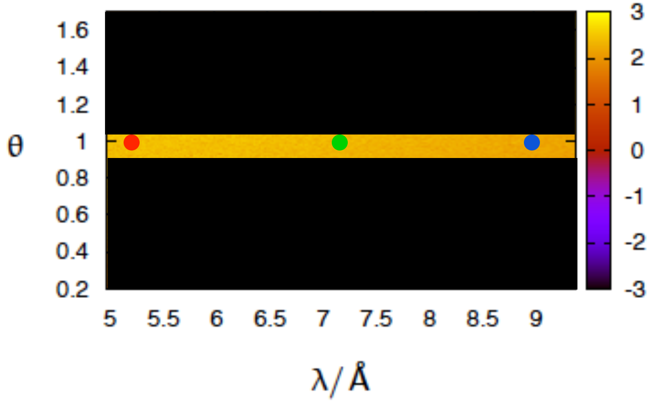
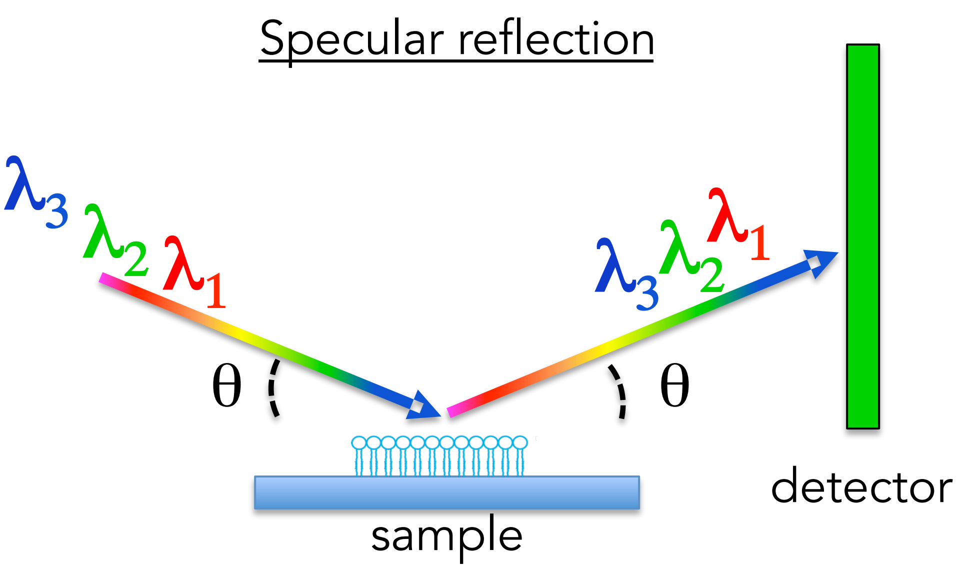
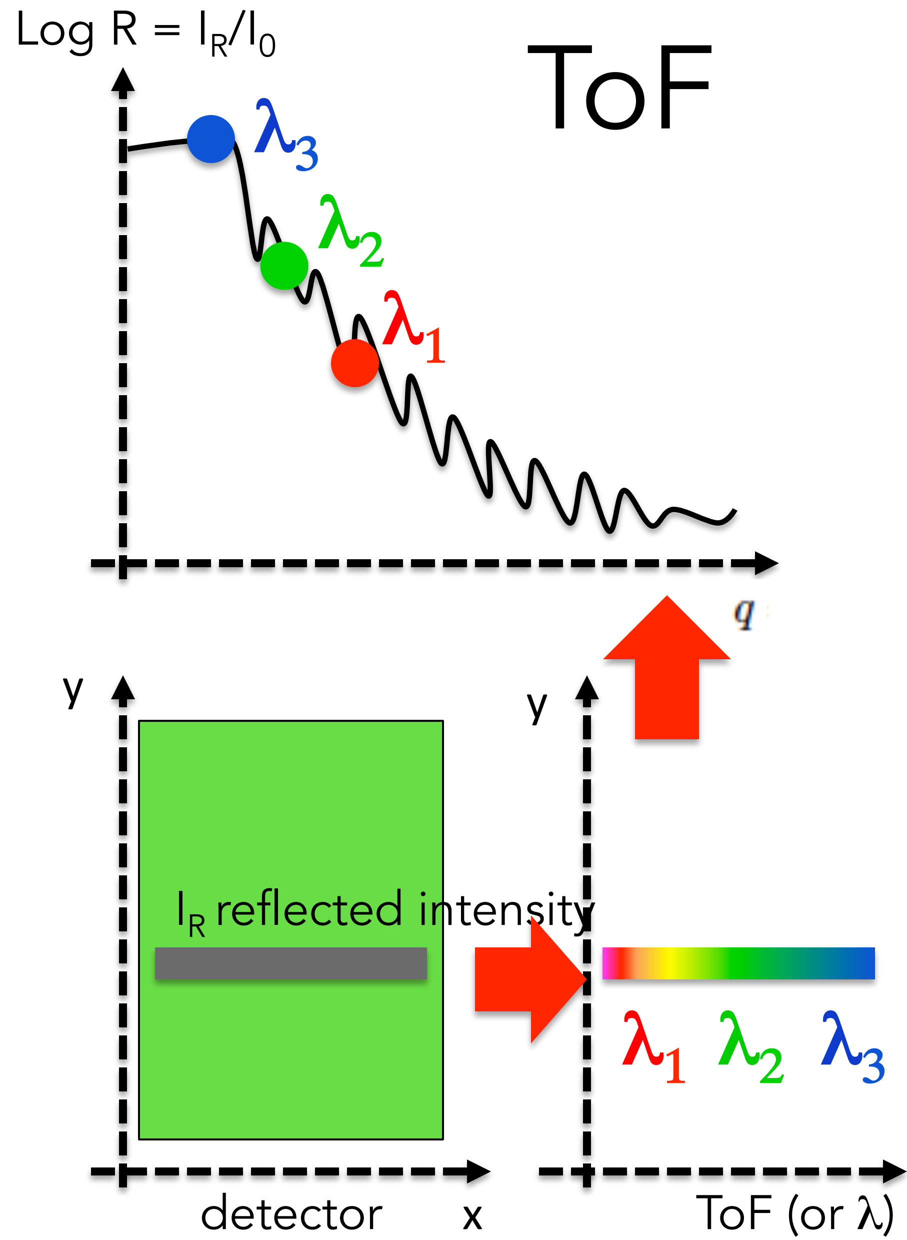
2. Monochromatic (λ fixed, θ scan)

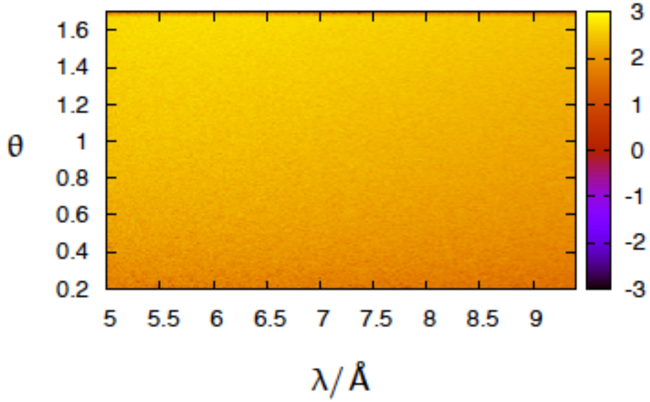


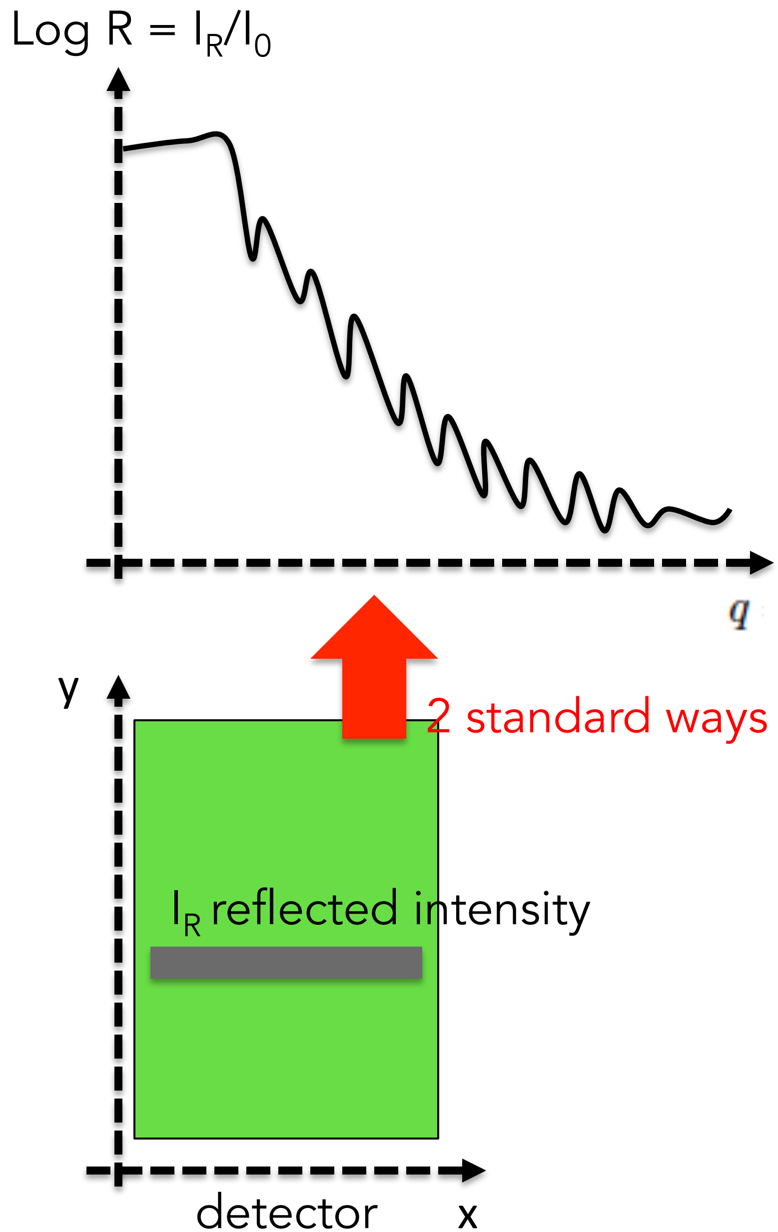




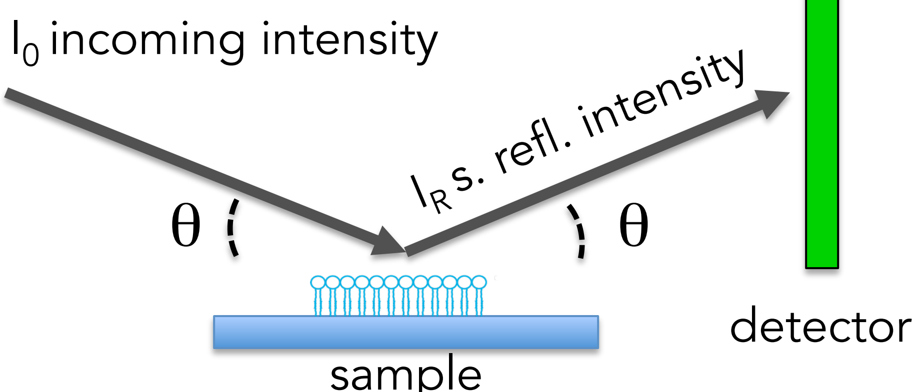
$q = (4\pi/\lambda)\sin(\theta)$

1. ToF (λ scan, θ fixed)
2. Monochromatic (λ fixed, θ scan)





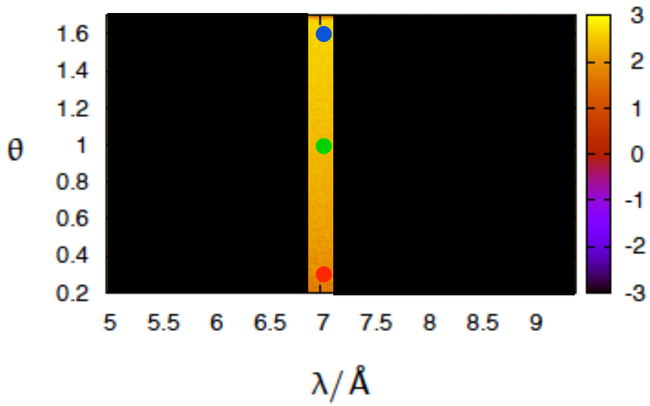
Specular reflection

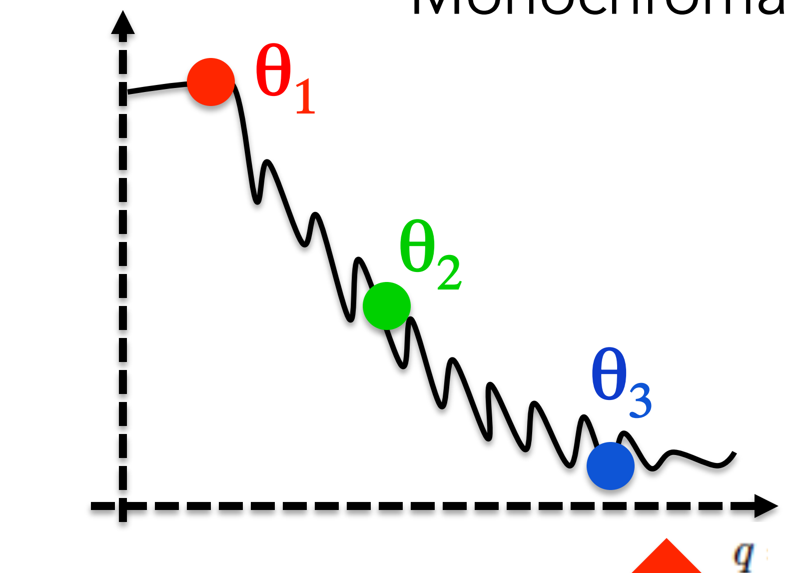


$q = (4\pi/\lambda)\sin(\theta)$

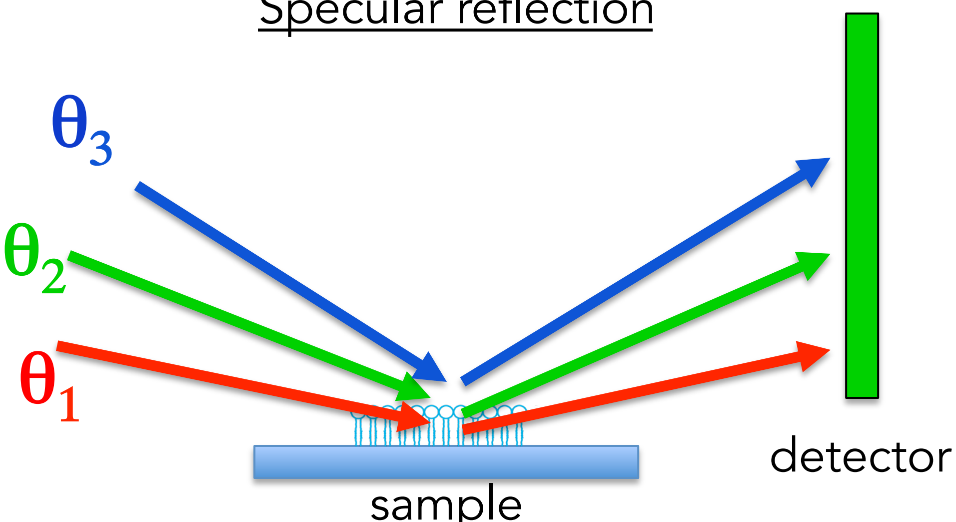
1. ToF (λ scan, θ fixed)
2. Monochromatic (λ fixed, θ scan)

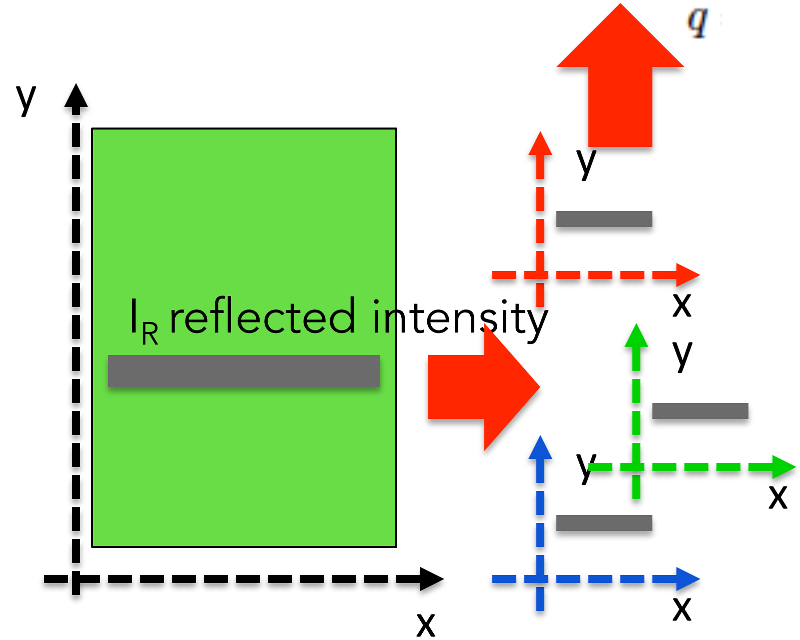
Monochromatic





Specular reflection

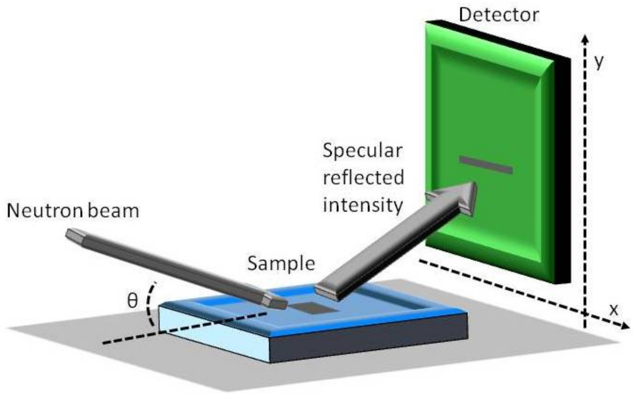




Reflectometry at ESS: FREIA and ESTIA

Reflectometry at ESS: FREIA and ESTIA

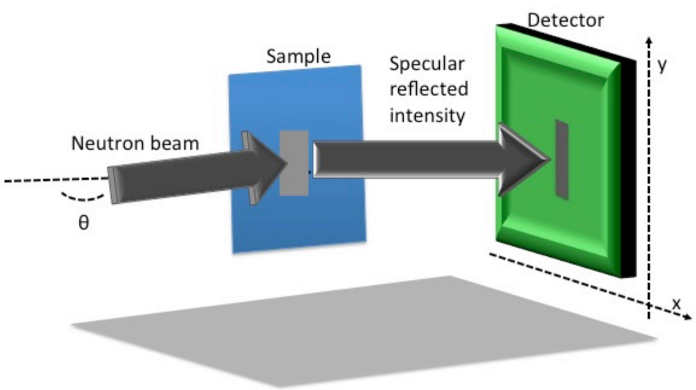
FREIA



<u>Horizontal Reflectometer</u>
(FREIA)

Suitable for liquids
(limited angular range)

Estia



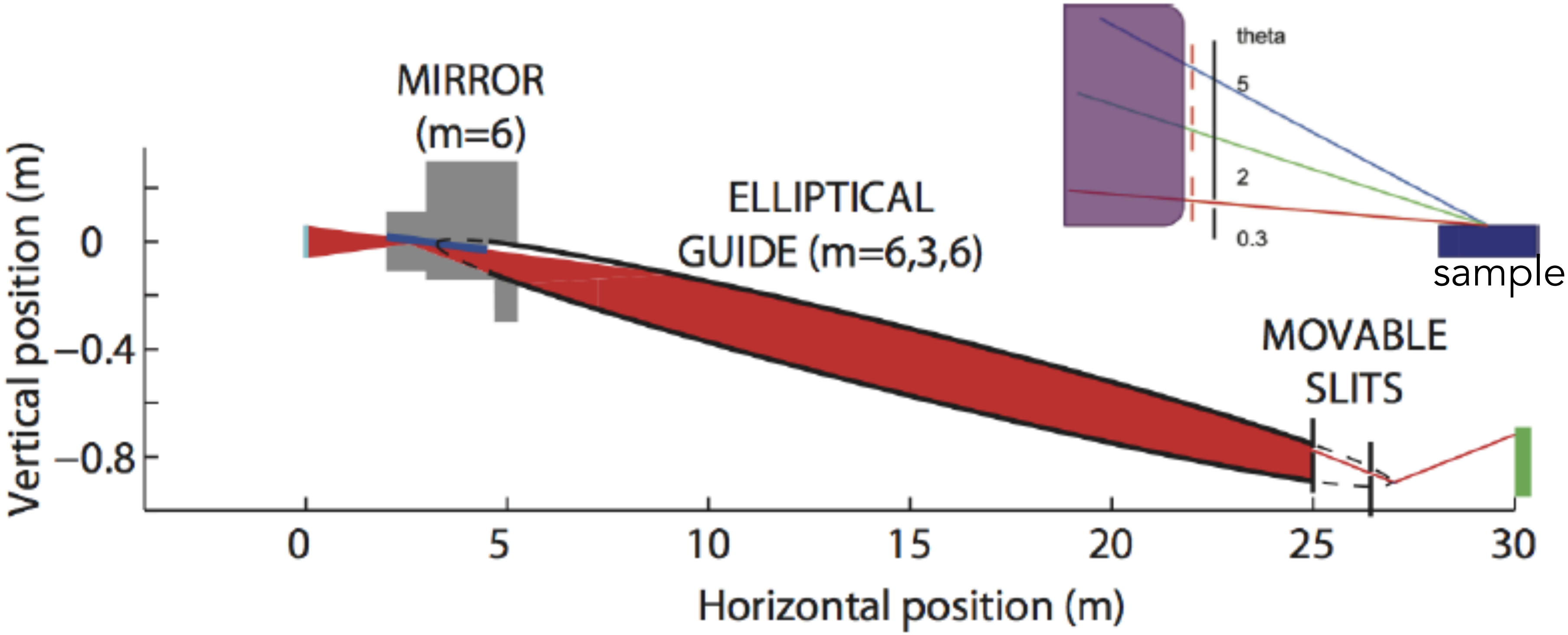
<u>Vertical Reflectometer</u>
(ESTIA)

Not suitable for liquids
More versatile
(wide angle range)

Freia, (Frejya, Freyia, Frøya, Frøjya, and Freja) in Old Norse the "Lady", one of the Vanir gods, rules over the heavenly afterlife field Fólkvangr and there receives half of those that die in battle.

FREIA – a reflectometer for kinetics and liquid surfaces

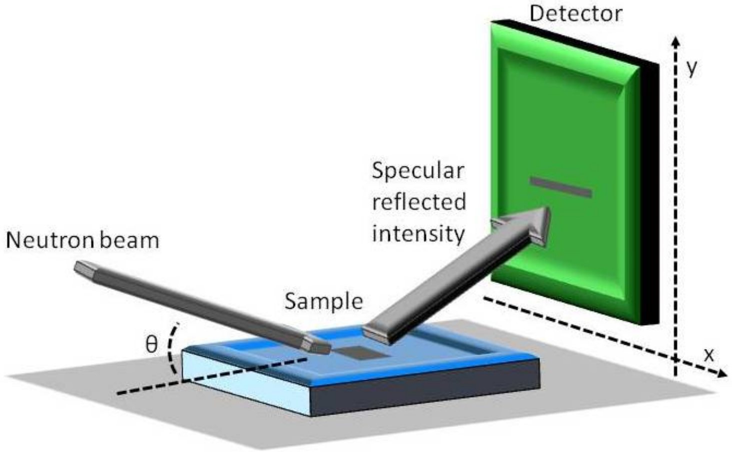
FREIA

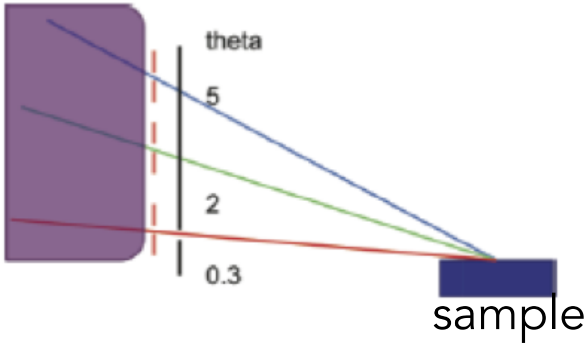


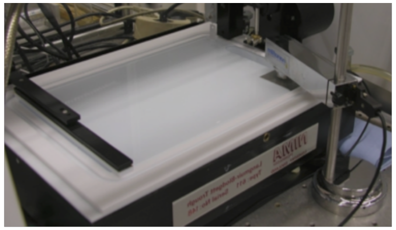
MIRROR
(m=6)
ELLIPTICAL
GUIDE (m=6,3,6)
MOVABLE
SLITS
theta
5
2
0.3
sample
Vertical position (m)
0
−0.4
−0.8
Horizontal position (m)
0
5
10
15
20
25
30

FREIA

$$q = (4\pi/\lambda)\sin(\theta)$$

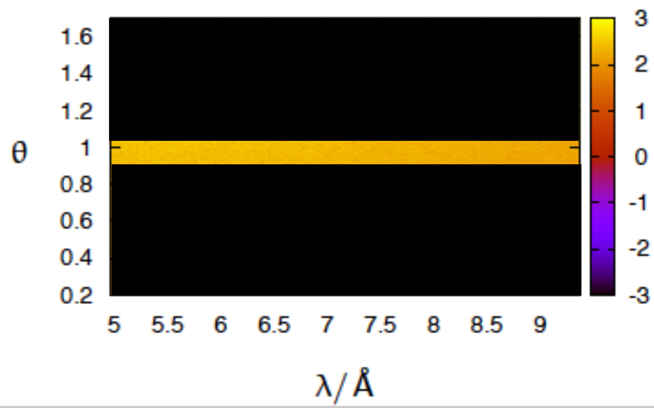




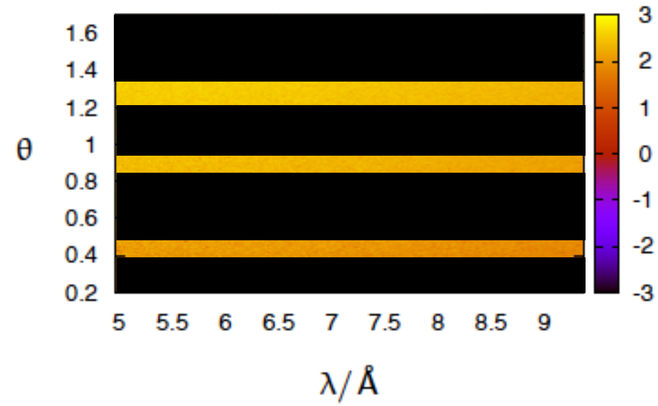


Langmuir–Blodgett trough

Conventional ToF refl.



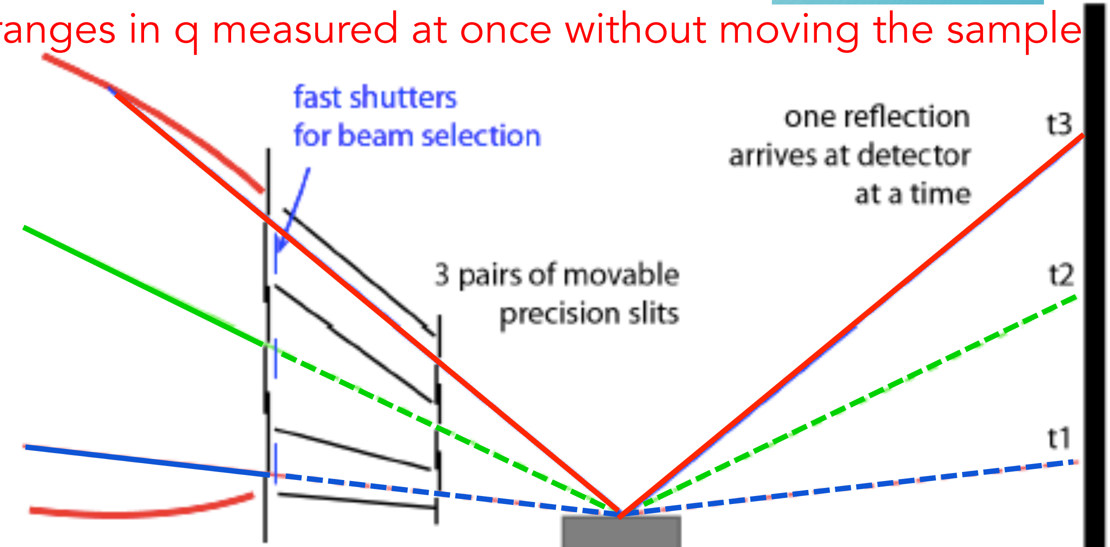
FREIA



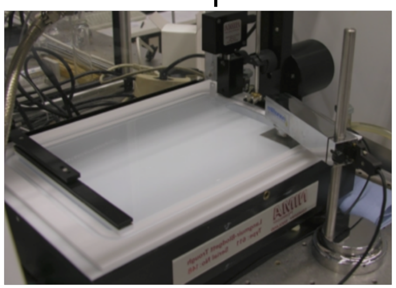
FREIA

$$q = (4\pi/\lambda)\sin(\theta)$$

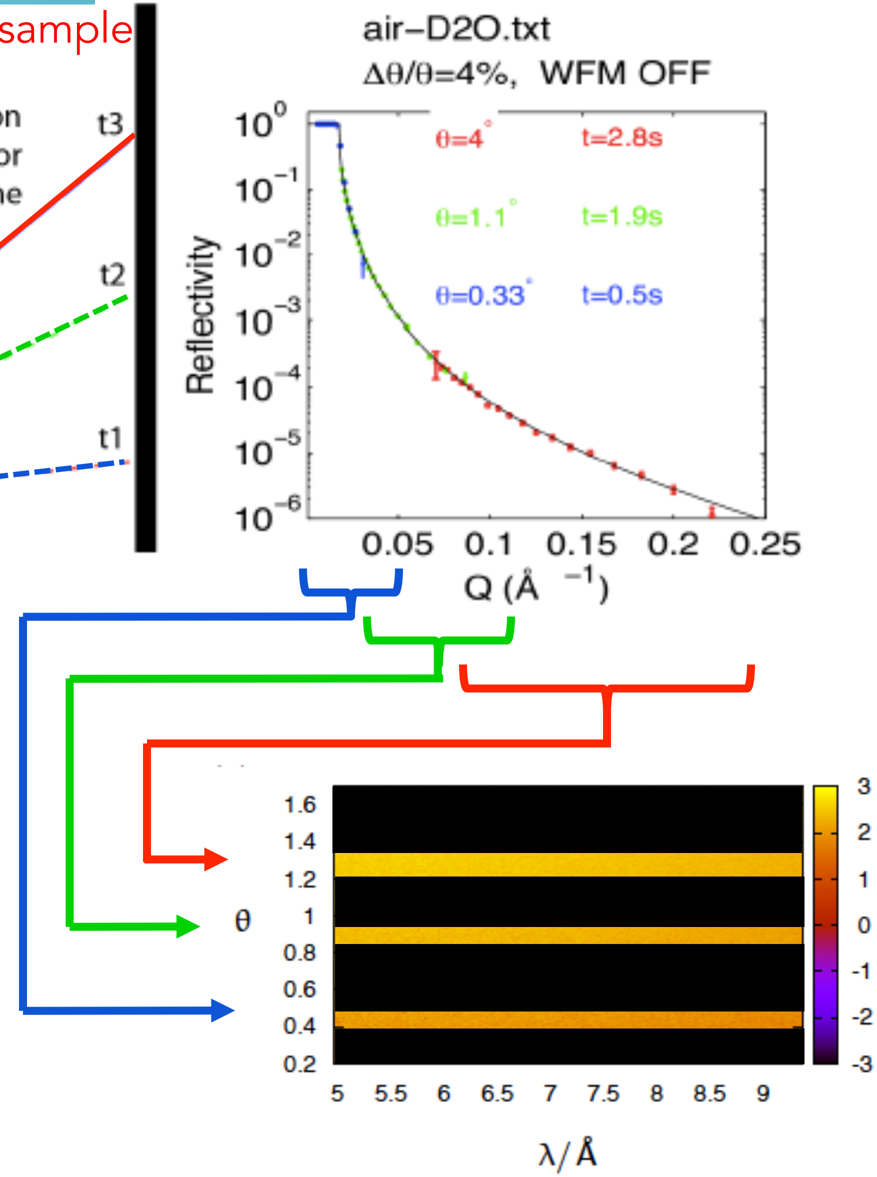
3 ranges in q measured at once without moving the sample



sample



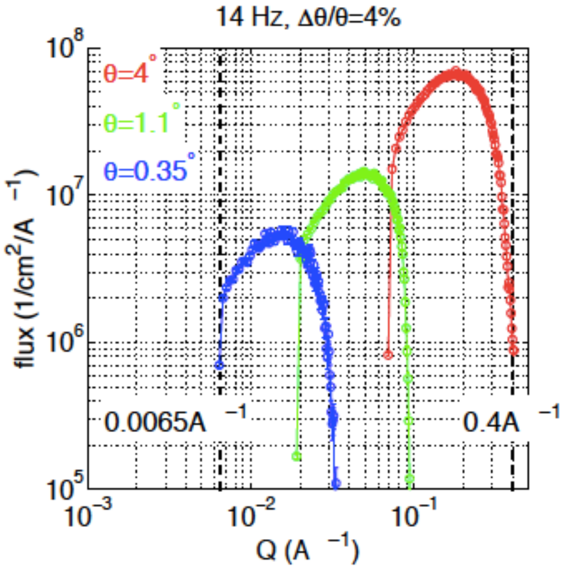
Langmuir–Blodgett trough



FREIA

$q = (4\pi/\lambda)\sin(\theta)$

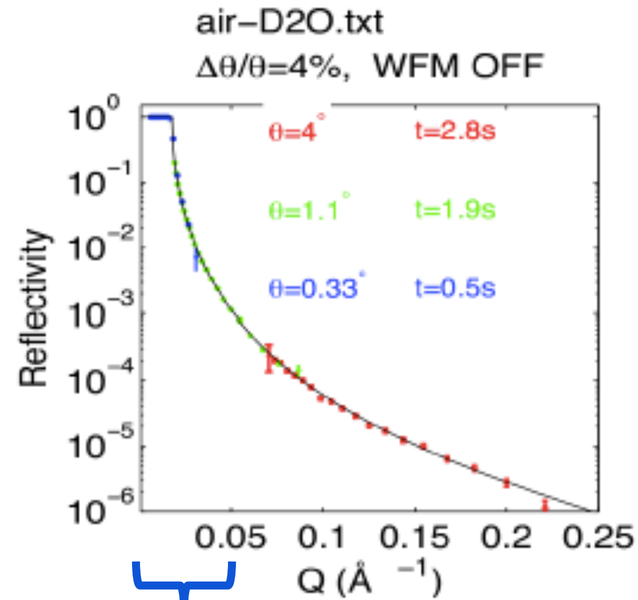
Flux at sample



$5 \bullet 10^6$

10^7

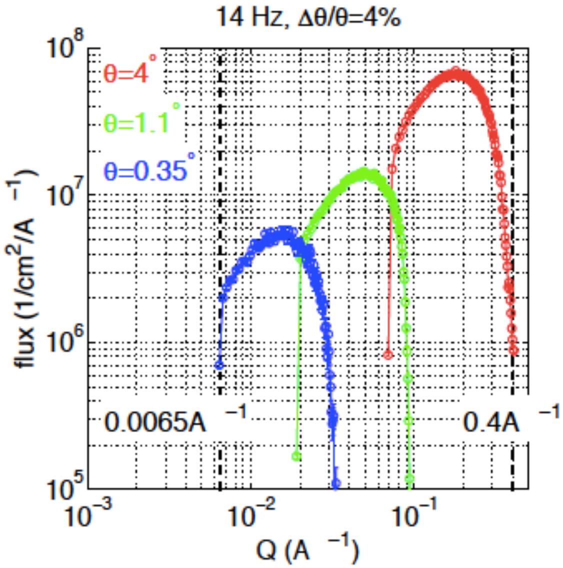
$5 \bullet 10^8$ n/s/Å/cm²
(at λ peak)

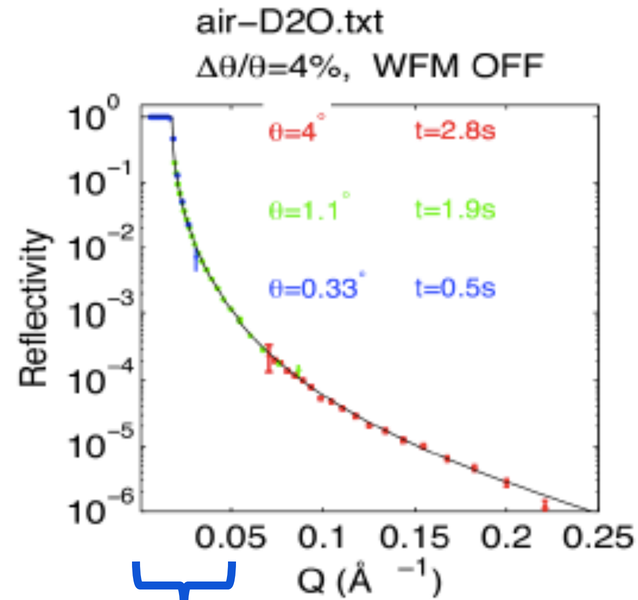


FREIA

$$q = (4\pi/\lambda)\sin(\theta)$$

Flux at sample





$5 \bullet 10^6$ → $R=10^0$

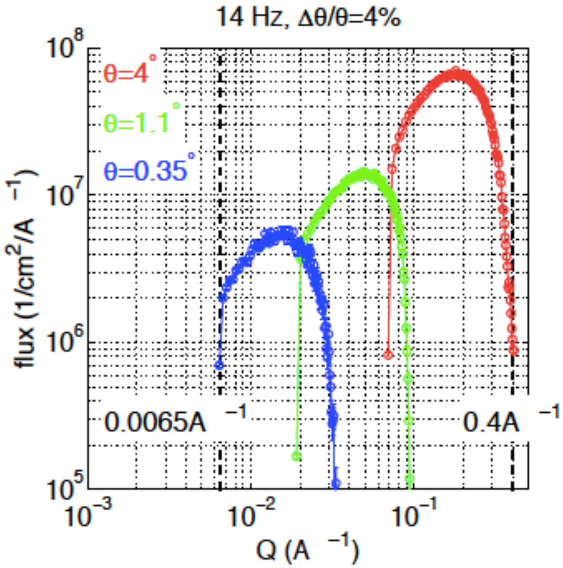
10^7 → $R<10^{-1}$

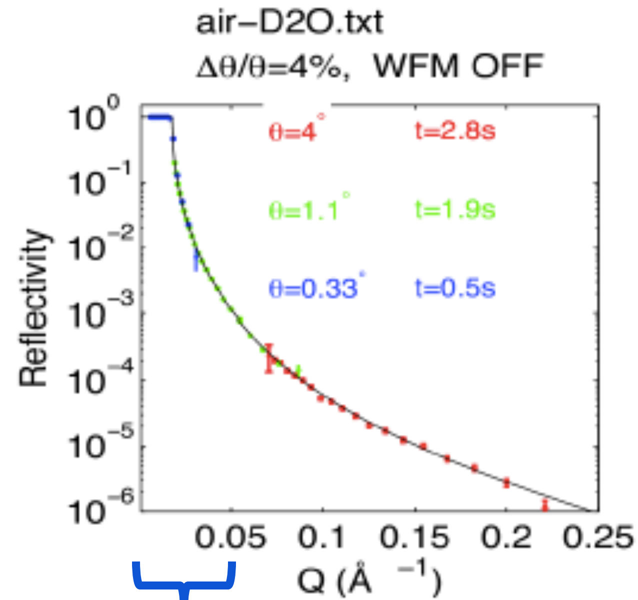
$5 \bullet 10^8$ n/s/Å/cm^2 (at λ peak) → $R<10^{-4}$

FREIA

$q = (4\pi/\lambda)\sin(\theta)$

Flux at sample





$5 \bullet 10^6$

10^7

$5 \bullet 10^8$ n/s/Å/cm²

(at λ peak)

$R = 10^0$

$R < 10^{-1}$

$R < 10^{-4}$

$< 10^2$ n/s/Å/mm²

$< 10^4$ n/s/Å/mm²

Flux at detector

$10^0 \bullet 5 \bullet 10^6 =$

$5 \bullet 10^6$ n/s/Å/cm² =

= 10^5 n/s/Å/mm²

The state of the art

Instrument	Facility	techn.	area $(mm \times mm)$	spatial res. $(mm \times mm)$	efficiency	global rate (s^{-1})	local rate $(s^{-1}mm^{-2})$
FIGARO [9]	ILL	^{3}He	512×256	$\sim 2 \times 7.5$	$\sim 63\%$ @ 2.5Å $\sim 90\%$ @ 10Å $\sim 80\%$ @ 30Å	$3 \cdot 10^7$	230
SuperADAM [11]	ILL	^{3}He	300×300	2.8×2.8	76% @ 4.4Å	$2 \cdot 10^5$	-
REFSANS [12]	FRM2	^{3}He	500×500	$\sim 2 \times 2$	58% @ 10Å $\geq 50\% \in [5, 18]$Å	$2.2 \cdot 10^5$	300
INTER [13]	ISIS	^{3}He,^{6}Li	200×200	$\sim 1 \times 1$	-	-	-
POLREF [14, 15]	ISIS	^{3}He	200×200	$\lesssim 1 \times 1$	-	-	-
BIOREF [16]	HZB	^{3}He	300×300	2×3	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
MR	SNS	^{3}He	210×180	1.5×1.5	-	-	-
Platypus [17]	OPAL	^{3}He	500×250	1.2×1.2	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
SOFIA [18, 19]	J-PARC	^{3}He ^{6}Li	128×128 256×256	2×2 4×4	- -	- -	300 300

The state of the art

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BIOREF [16]	HZB	^{3}He	300×300	2×3	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
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SOFIA [18, 19]	J-PARC	^{3}He ^{6}Li	128×128 256×256	2×2 4×4	- -	- -	300 300

FREIA

Max rate on detector (at peak)	10^5 n/s/Å/mm^2
Max global rate	12 MHz (1.2x100mm^2 footprint*) 12 MHz (detector area*)
Wavelength range	2.5 – 12 Å (optional up to 25Å)
Efficiency	>60% (above 4Å)
Max detector size	500x500mm^2
Spatial resolution	4mm x 1mm
Sample-Detector distance	Not fixed (mostly 3m)
Window scattering	$<10^{-4}$

x300

Flux at detector

The state of the art

Instrument	Facility	techn.	area ($mm \times mm$)	spatial res. ($mm \times mm$)	efficiency	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
FIGARO [9]	ILL	^{3}He	512×256	$\sim 2 \times 7.5$	$\sim 63\%$ @ 2.5Å $\sim 90\%$ @ 10Å $\sim 80\%$ @ 30Å	$3 \cdot 10^7$	230
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LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
MR	SNS	^{3}He	210×180	1.5×1.5	-	-	-
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FREIA

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Max detector size	500x500mm^2
Spatial resolution	4mm x 1mm
Sample-Detector distance	Not fixed (mostly 3m)
Window scattering	$<10^{-4}$

x300

Flux at detector

Swiss-Danish ESS
instrumentation consortium

Jochen Stahn
Marité Cardenas
Ursula B. Hansen

ESS SAC Meeting
21. 05. 2014, Lund

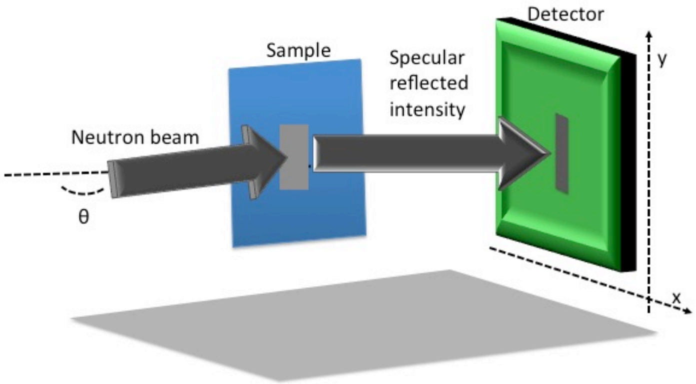
Estia

a

focusing reflectometer for small samples

based on the

Selene guide concept

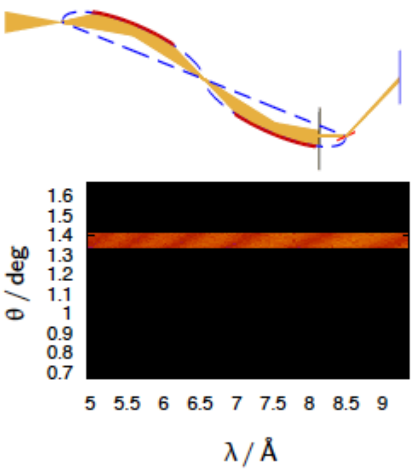


Vertical ToF Reflectometer

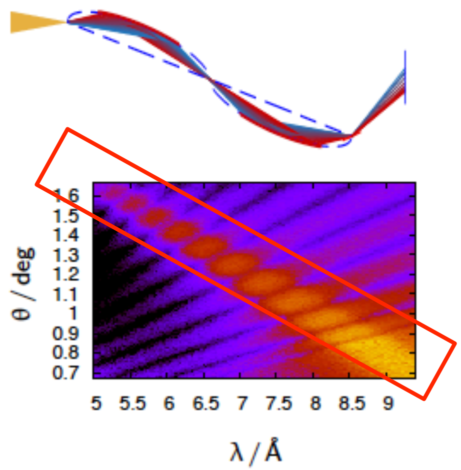
$$q = (4\pi/\lambda)\sin(\theta)$$

It can work in 3 different modes:

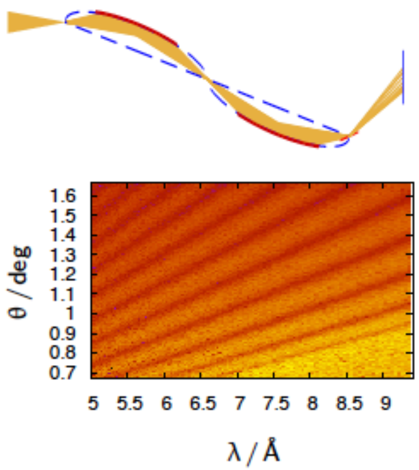
almost conventional reflectivity [→2.8.1]



λ-θ-encoding [→2.8.2]



high-intensity specular reflectivity [→2.8.3]



The state of the art

Instrument	Facility	techn.	area ($mm \times mm$)	spatial res. ($mm \times mm$)	efficiency	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
FIGARO [9]	ILL	^{3}He	512×256	$\sim 2 \times 7.5$	$\sim 63\%$ @ 2.5Å $\sim 90\%$ @ 10Å $\sim 80\%$ @ 30Å	$3 \cdot 10^7$	230
SuperADAM [11]	ILL	^{3}He	300×300	2.8×2.8	76% @ 4.4Å	$2 \cdot 10^5$	-
REFSANS [12]	FRM2	^{3}He	500×500	$\sim 2 \times 2$	58% @ 10Å $\geq 50\% \in [5, 18]$Å	$2.2 \cdot 10^5$	300
INTER [13]	ISIS	^{3}He, ^{6}Li	200×200	$\sim 1 \times 1$	-	-	-
POLREF [14, 15]	ISIS	^{3}He	200×200	$\lesssim 1 \times 1$	-	-	-
BIOREF [16]	HZB	^{3}He	300×300	2×3	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
MR	SNS	^{3}He	210×180	1.5×1.5	-	-	-
Platypus [17]	OPAL	^{3}He	500×250	1.2×1.2	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
SOFIA [18, 19]	J-PARC	^{3}He ^{6}Li	128×128 256×256	2×2 4×4	- -	- -	300 300

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Estia

Max rate on detector (at peak)	• Conventional refl. 10^5 n/s/Å/mm^2 • High intensity mode 10^4 n/s/Å/mm^2
Max global rate	• Conventional refl. 12MHz (2x60mm^2 footprint or on whole detect. area) • High intensity mode 100MHz ** (105x105mm^2 footprint or on whole detect. area)
Wavelength range	4 – 12 Å
Efficiency	>60% (above 4Å)
Max detector size	300x500mm^2
Spatial resolution	4mm x 0.5mm
Sample-Detector distance	Fixed ~4m

x300

Flux at detector

The state of the art

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x3 Resolution

x300 Flux at detector

The ESS requirements

	FREIA	Estia
Max local rate	10^5 n/s/Å/mm^2	• Conventional refl. 10^5 n/s/Å/mm^2 • High intensity mode 10^4 n/s/Å/mm^2
Spatial resolution	3mm x 1mm	3mm x 0.5mm