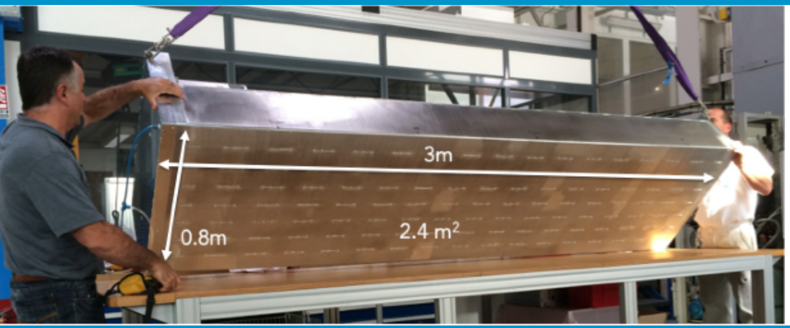
Neutron Detector Choices for the Initial Instrument Suite at the European Spallation Source

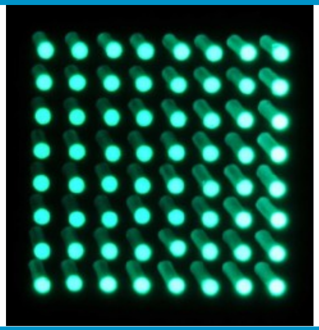
Richard Hall-Wilton

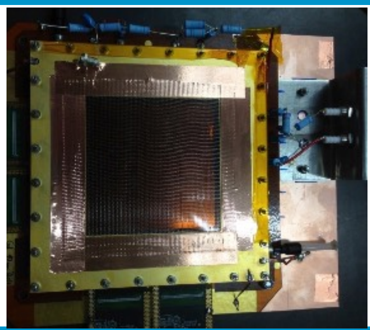
Leader of Detector Group

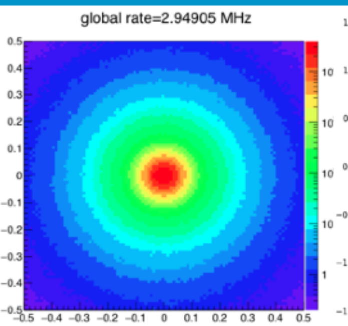
SNS Seminar, 20th October 2017

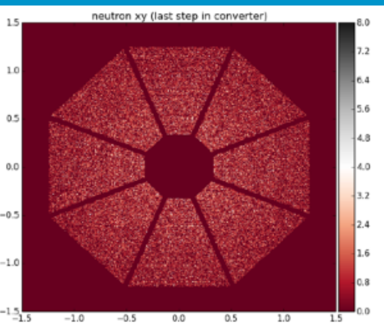
www.europeanspallationsource.se

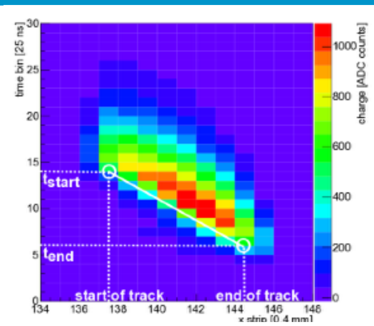


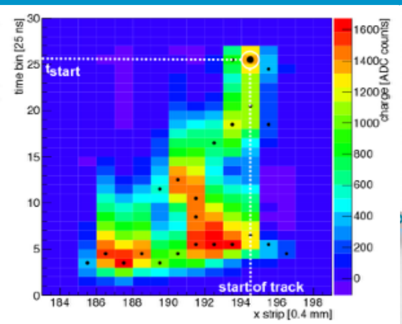


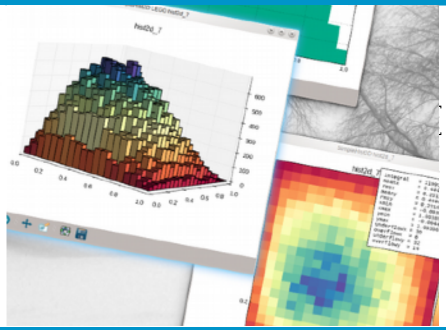


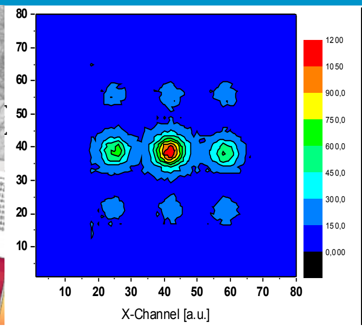


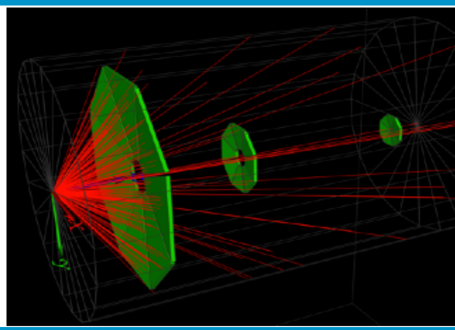












Mittuniversitetet
MID SWEDEN UNIVERSITY

ESS Partners on Detectors

EUROPEAN SPALLATION SOURCE

CERN

SNS SPALLATION NEUTRON SOURCE

LINKÖPING UNIVERSITY

ESS bilbao

LUNDS UNIVERSITET

UNIVERSITAS BERGENSIS

Science & Technology Facilities Council

Science & Technology Facilities Council ISIS

BNC Budapest Neutron Centre

wigner

Consiglio Nazionale Ricerche

IFP

UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

INFN Istituto Nazionale di Fisica Nucleare

JCNS Jülich Centre for Neutron Science

DENEX
Detektoren für Neutronen GmbH
Stöteroggestraße 71 | 21339 Lüneburg
Tel.: +49 (0) 4131/248932

IEAP

CDT GmbH
CASCADE Detector Technologies

FZÚ

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

mta EK

Risø DTU
National Laboratory for Sustainable Energy

ideas

COSYLAB

IFE
Institute for Energy Technology

JÜLICH
FORSCHUNGSZENTRUM

Mittuniversitetet
MID SWEDEN UNIVERSITY

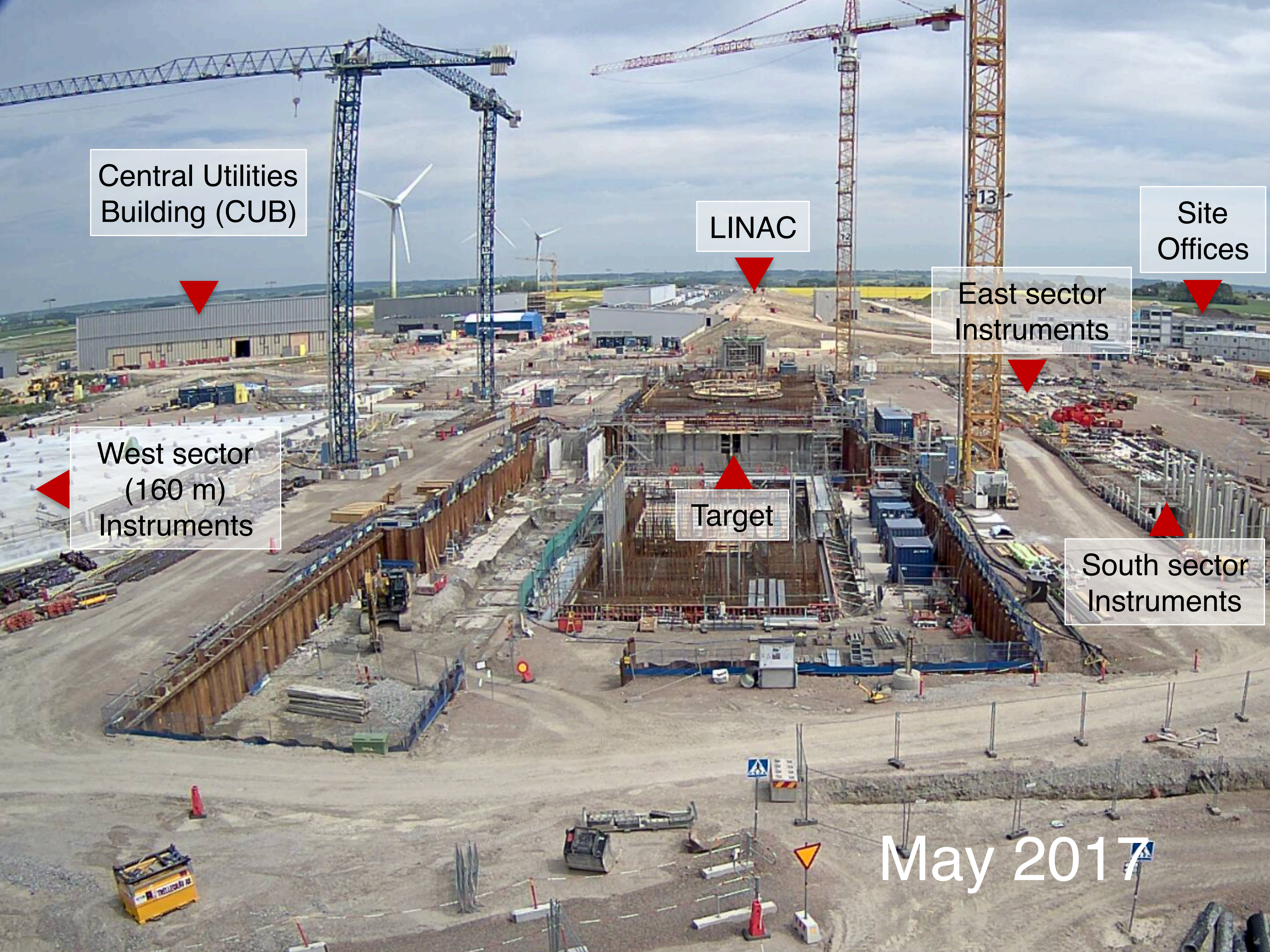
icnd.org { ILL ess FRM II Forschungs-Neutronenquelle Heinz Maier-Leibnitz HZB Helmholtz Zentrum Berlin ISIS J-PARC NEUTRON SCIENCES }

INTERNATIONAL COLLABORATION FOR THE DEVELOPMENT OF NEUTRON DETECTORS

Update on Status of ESS


webbkameror.se
EUROPEAN
SPALLATION
SOURCE
The ESS site
2011


ESS construction
18 May 2017


Central Utilities Building (CUB)
LINAC
Site Offices
East sector Instruments
West sector (160 m) Instruments
Target
South sector Instruments
May 2017


ESS construction
August 2017

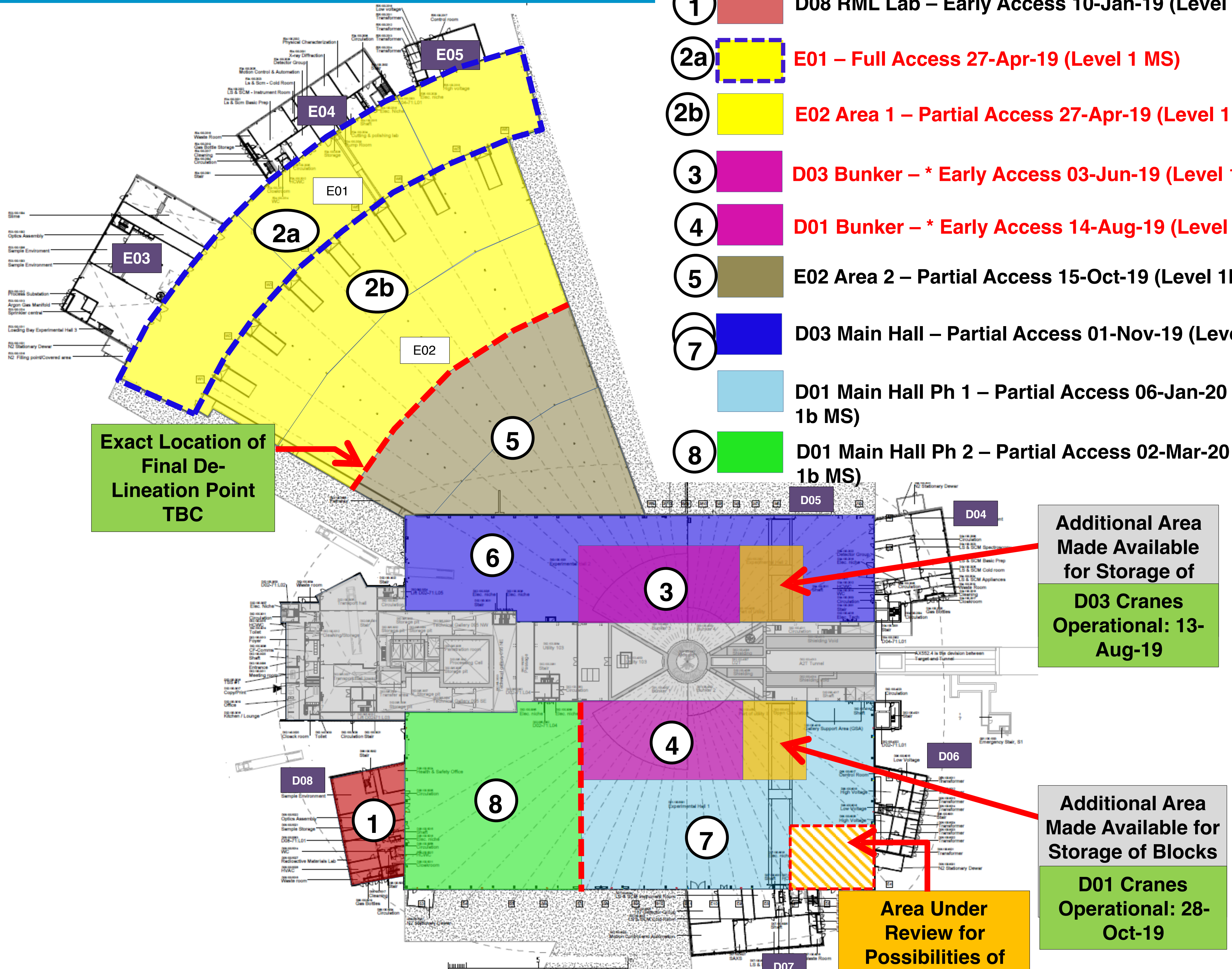

ESS construction
August 2017


ESS construction
August 2017

2019/2020: NSS Proposed Access Dates (Excludes Full Access Dates)

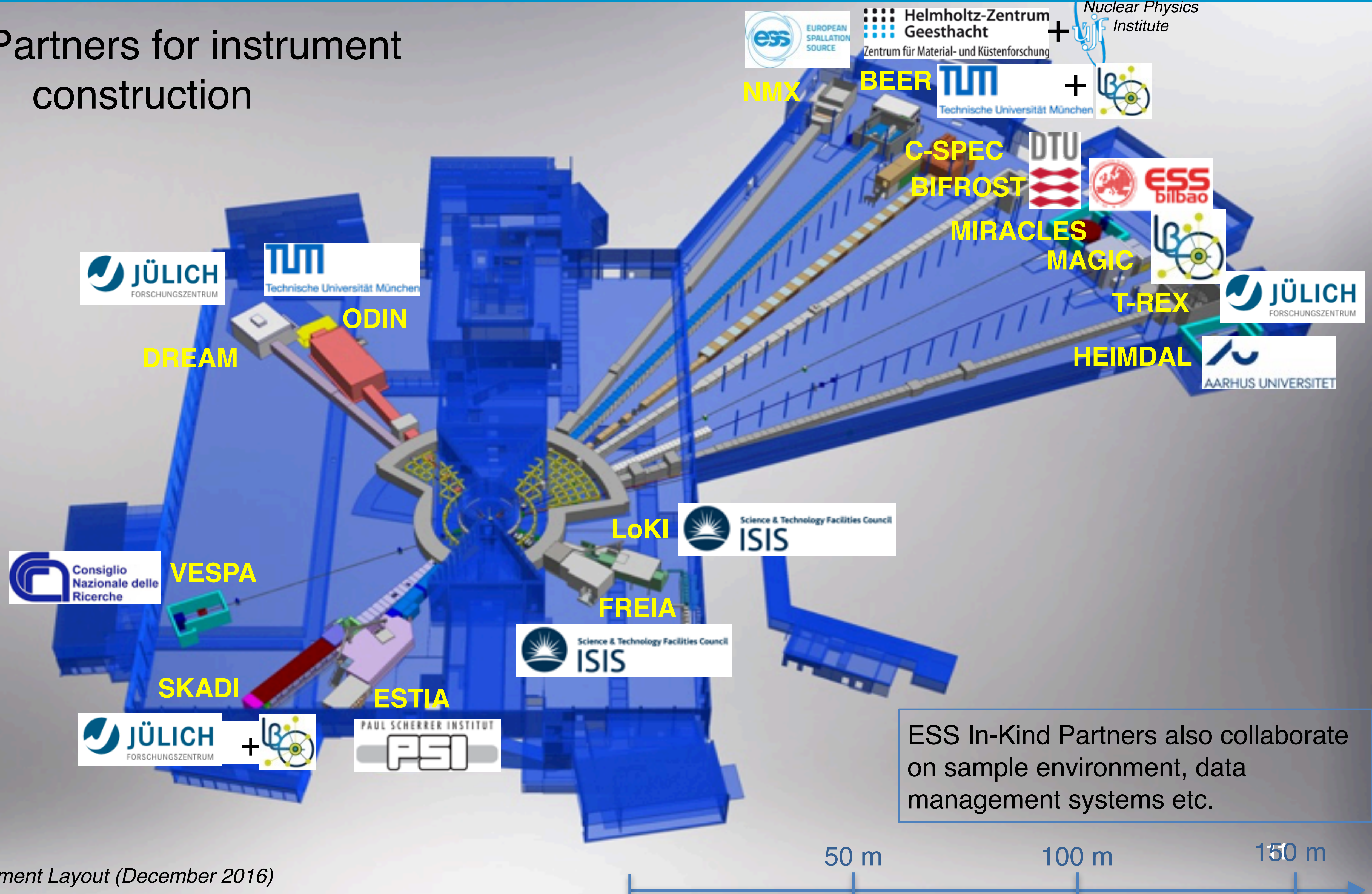
SKANSKA ESS CONSTRUCTION

- 1 — D08 RML Lab – Early Access 10-Jan-19 (Level 1b MS)
- 2a — E01 – Full Access 27-Apr-19 (Level 1 MS)
- 2b — E02 Area 1 – Partial Access 27-Apr-19 (Level 1 MS)
- 3 — D03 Bunker – * Early Access 03-Jun-19 (Level 1 MS)
- 4 — D01 Bunker – * Early Access 14-Aug-19 (Level 1 MS)
- 5 — E02 Area 2 – Partial Access 15-Oct-19 (Level 1b MS)
- 6 — D03 Main Hall – Partial Access 01-Nov-19 (Level 1b MS)
- 7 — D01 Main Hall Ph 1 – Partial Access 06-Jan-20 (Level 1b MS)
- 8 — D01 Main Hall Ph 2 – Partial Access 02-Mar-20 (Level 1b MS)



ESS Neutron Instrument positions: December 2016

Lead Partners for instrument construction



ESS In-Kind Partners also collaborate on sample environment, data management systems etc.

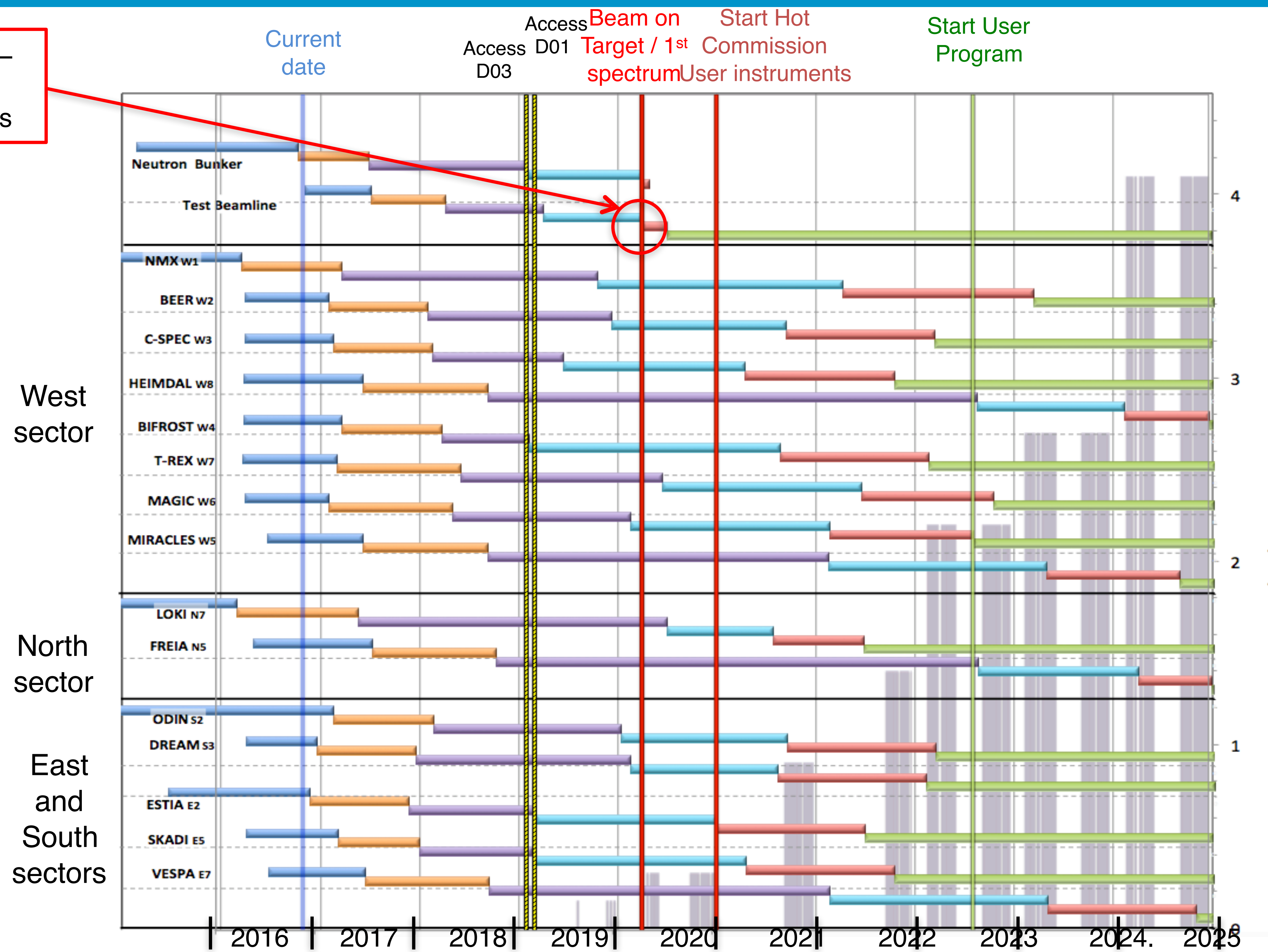
ESS Instrument Layout (December 2016)

Council.07.14.a

Neutron Beam Instrument Draft Schedule

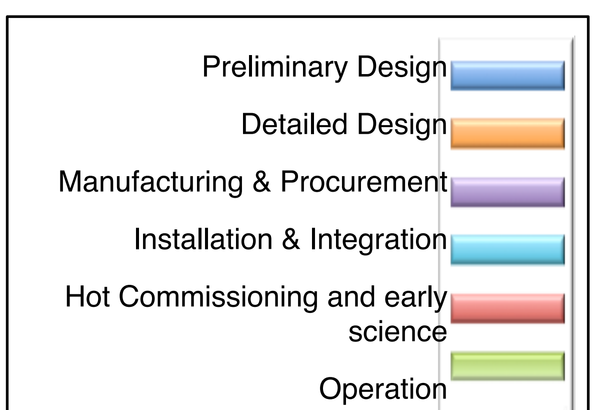
V2.0, 2nd November 2016

Commissioning of test beam – to demonstrate performance and inform instrument projects

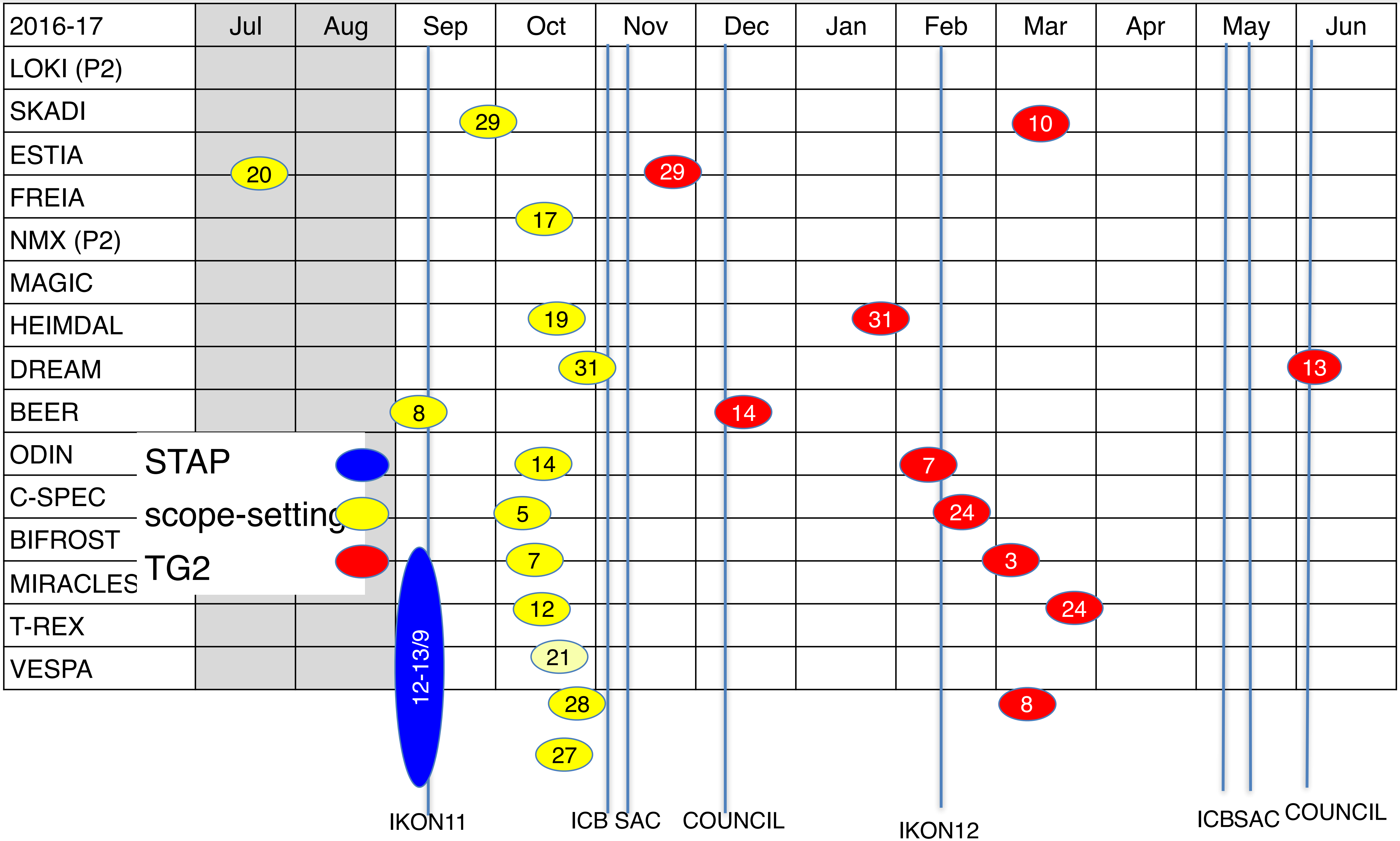


Notes;

- Access & B.O..T dates yet to be confirmed
- Instrument dates from scope setting
- HC start;
  - E ≥ 200 MeV
  - P ≥ 200 kW
  - January 2021

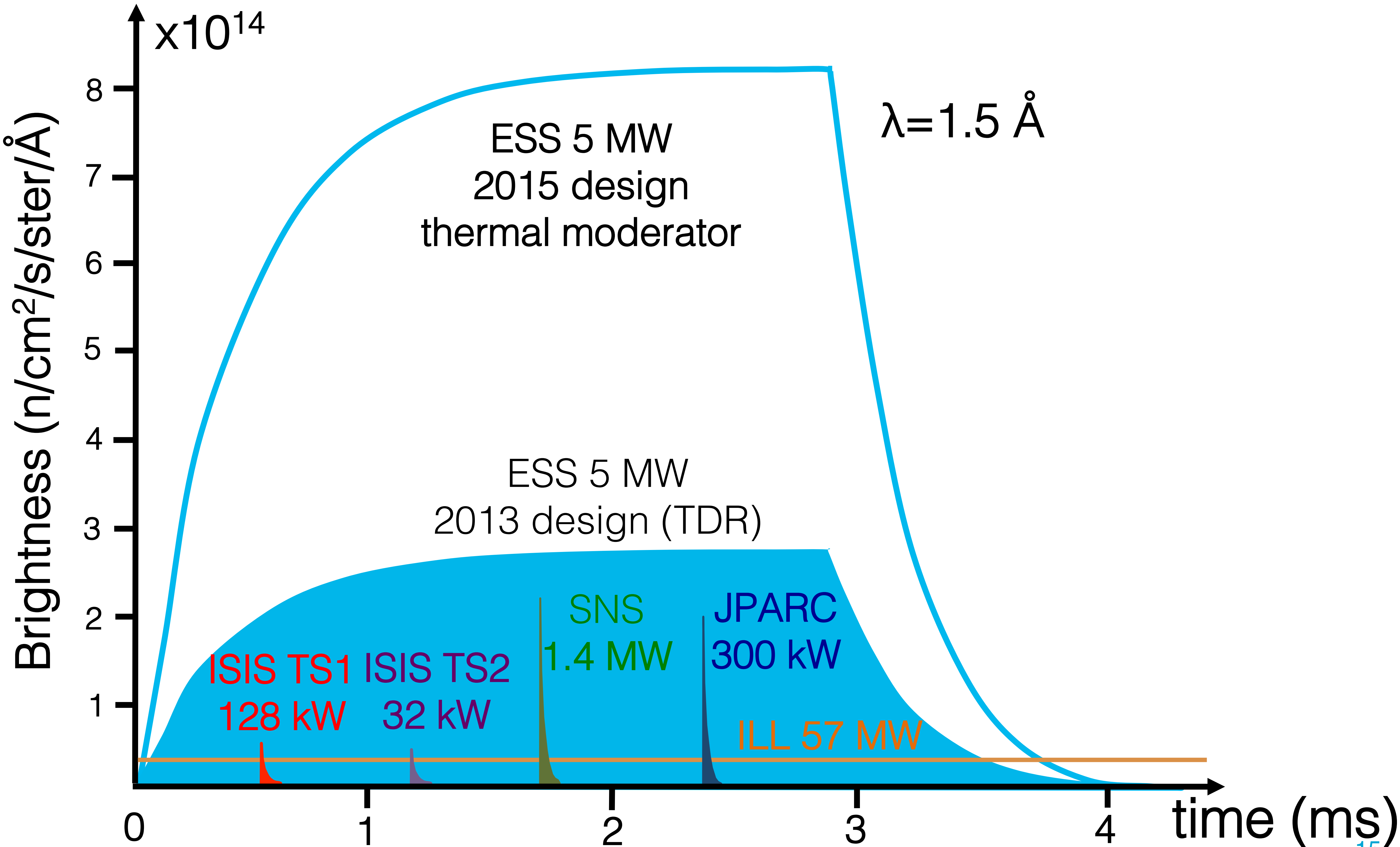


Neutron Instruments: Phase 1 schedule



Update on Status of ESS Detectors

Challenge for Rate



What can be done with this brightness?

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

Developments required for detectors for new Instruments

Also: scarcity of Helium-3 ...

What can be done with this brightness?

What does a factor 10 improvement imply for the detectors?

Implications for Detectors	Implications for Detectors
Better Resolution (position and time)	sqrt(10)
Channel count	pixelated: factor 10 x-y coincidence:sqrt(10)
Rate capability and data volume	factor 10
Lower background, lower S:B Larger dynamic range	Keep constant implies: factor 10 smaller B per neutron
Larger area coverage Lower cost of detectors	Factor of a few

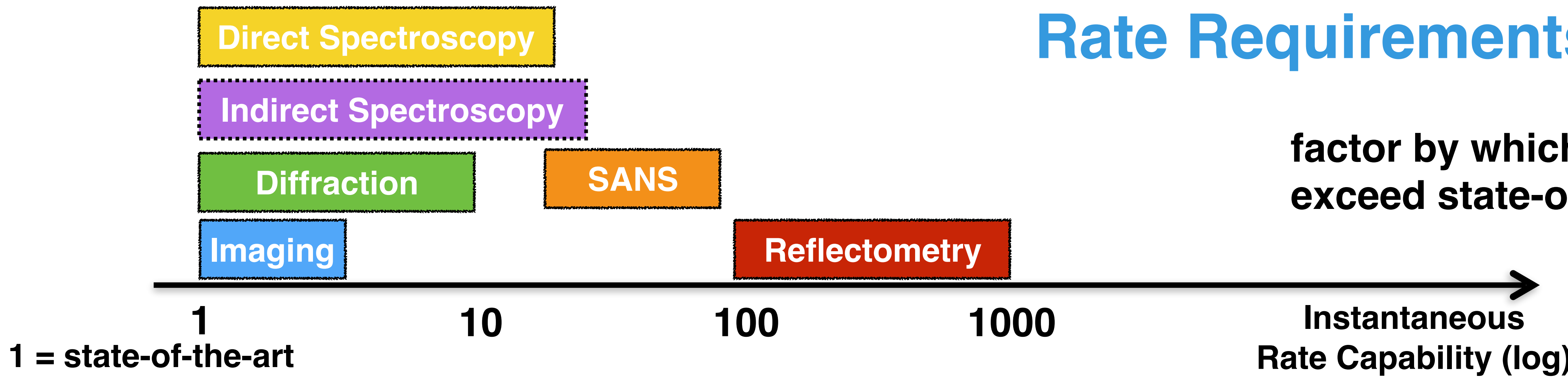
Developments required for detectors for new Instruments

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

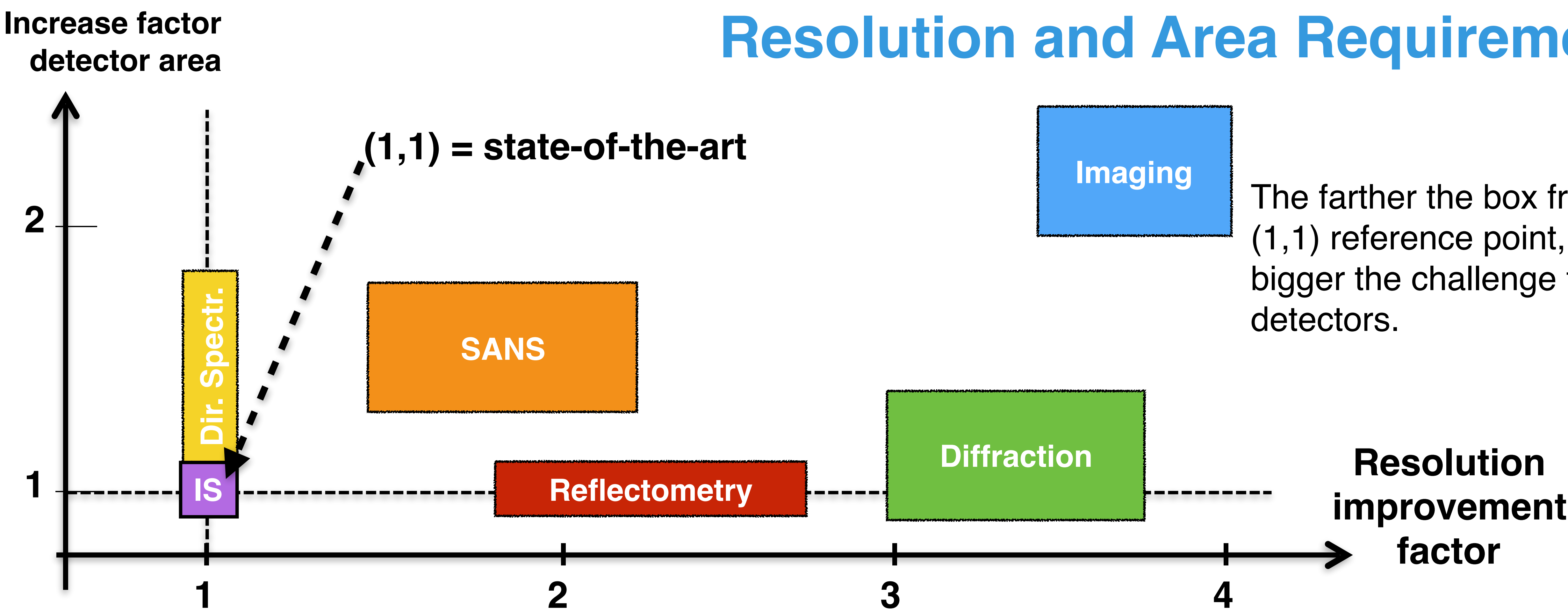
EUROPEAN SPALLATION SOURCE

Rate Requirements

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



Resolution and Area Requirements



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

Detectors for ESS: baseline for selected instruments

EUROPEAN SPALLATION SOURCE

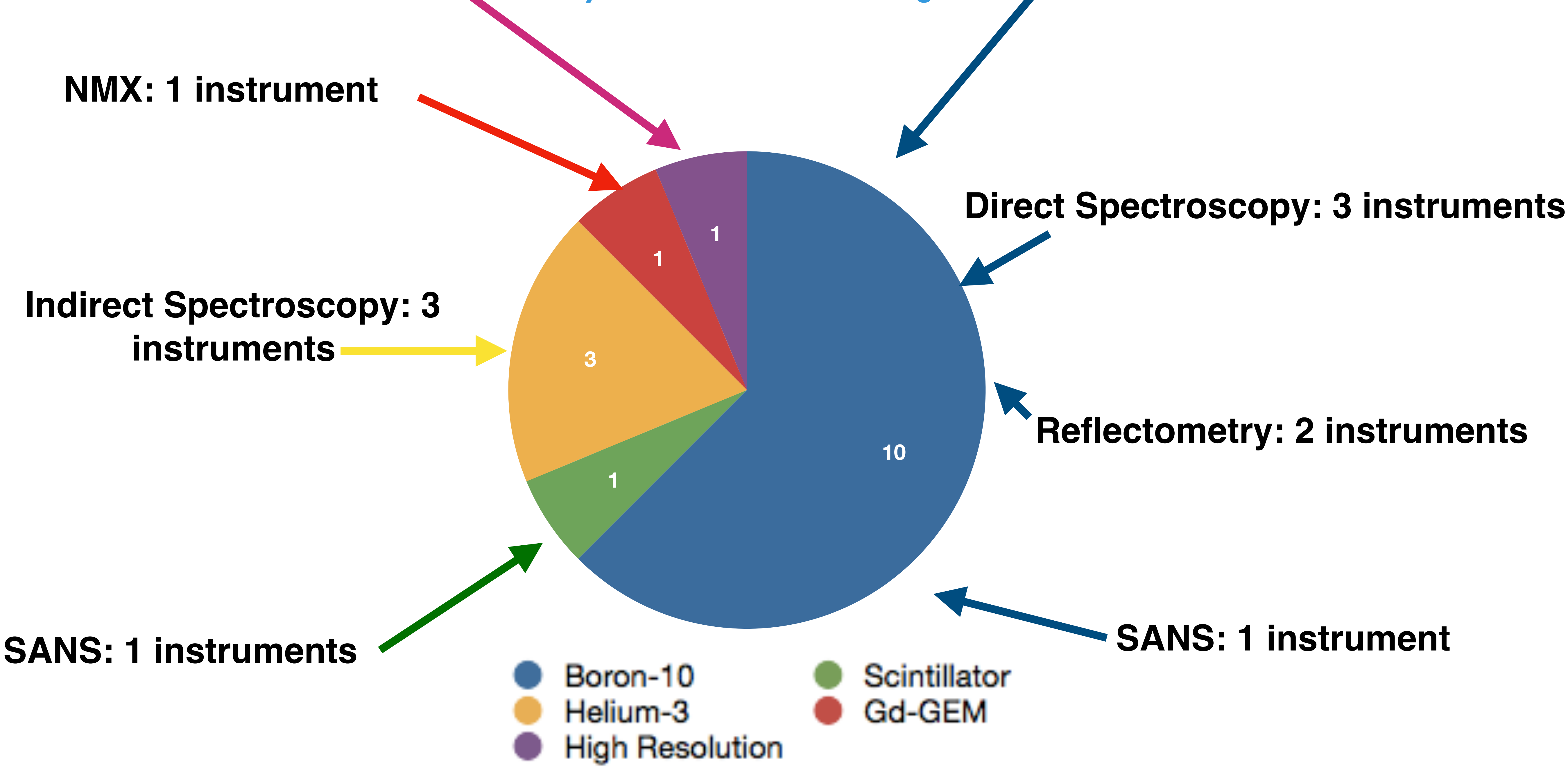
Instrument class	Instrument sub-class	Instrume nt	Key requirements for detectors	Preferred detector technology	Ongoing developments
Large-scale structures	Small Angle Scattering	SKADI	Pixel size, count-rate, area	Pixellated Scintillator	SonDe (EU SonDe)
		LOKI		10B-based	BandGem
	Reflectometry	FREIA	Pixel size, count-rate	10B-based	MultiBlade (EU BrightnESS)
		ESTIA			
Diffraction	Powder diffraction	DREAM	Pixel size, count-rate	10B-based	Jalousie
		HEIMDAL		10B-based	Jalousie
	Single-crystal diffraction	MAGIC	Pixel size, count-rate	10B-based	Jalousie
		NMX	Pixel size, large area	Gd-based	GdGEM uTPC(EU
Engineering	Strain scanning	BEER	Pixel size, count-rate	10B-based	AmCLD, A1CLD
	Imaging and tomography	ODIN	Pixel size	Scintillators, MCP, wire chambers	
Spectroscopy	Direct geometry	C-SPEC	Large area (^{3}He-gas unaffordable)	10B-based	MultiGrid (EU BrightnESS)
		T-REX			
		VOR			
	Indirect geometry	BIFROST	Count-rate	3He-based	He-3 PSD Tubes
		MIRACLES			He-3 PSD Tubes
		VESPA	Count-rate	3He-based	He-3 PSD Tubes
SPIN-ECHO	Spin-echo	tbd	tbd	3He-based/10B-based	

arXiv:1411.6194

Good dialogue and close collaboration needed for successful delivery and integration

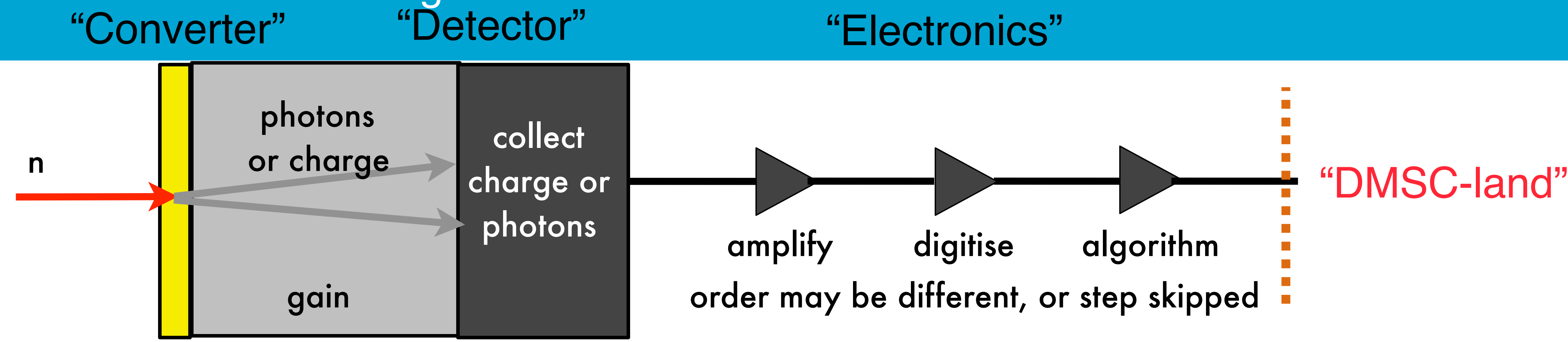
Baseline Detector Technologies for Initial Suite

Detectors for ESS will comprise many different technologies



Schedule: Where are we for detectors?

Detector schedule is longer than the instrument build schedule



2011	2012	2013	2014	2015	2016	2017
Coatings	Detector Conceptual Designs	Detector Prototype Designs	Strategy for Instruments, Instrument Designs	People, workshops and facilities, Instrument Designs	Electronics	Instrument Detector Design
					ICS/DMSC	Electronics
					Instrument conceptual design	ICS/DMSC
						Construction

2018	2019	2020	2021	2022	2023	2024	2025
Electronics /ICS/DMSC	Design	Construction	Construction	Construction	Installation	Installation	Installation
Design	Construction	Installation	Installation	Installation	Commissioning	Commissioning	Commissioning
Construction	Installation	Commissioning	Commissioning	Commissioning	Operation	Operation	Operation

Facilities

Thin Films Workshop

Mittuniversitetet MID SWEDEN UNIVERSITY

LINKÖPING UNIVERSITY

EUROPEAN SPALLATION SOURCE

- ESS Facility, co-located with Linkoping University for synergies in expertise and facilities
- Just moved across the road to location available until 2025
- Industrial coatings machine and production line setup
- Capacity: several times ESS needs
- Capacity: >1000m2/year coated with 10B4C
- If interested in coatings: **contact us**
- **Please give feedback!**

Detector Workshop

Up and running in Lund

Also:
- Mechanical workshop
- Source Facility

Some examples of detector technology

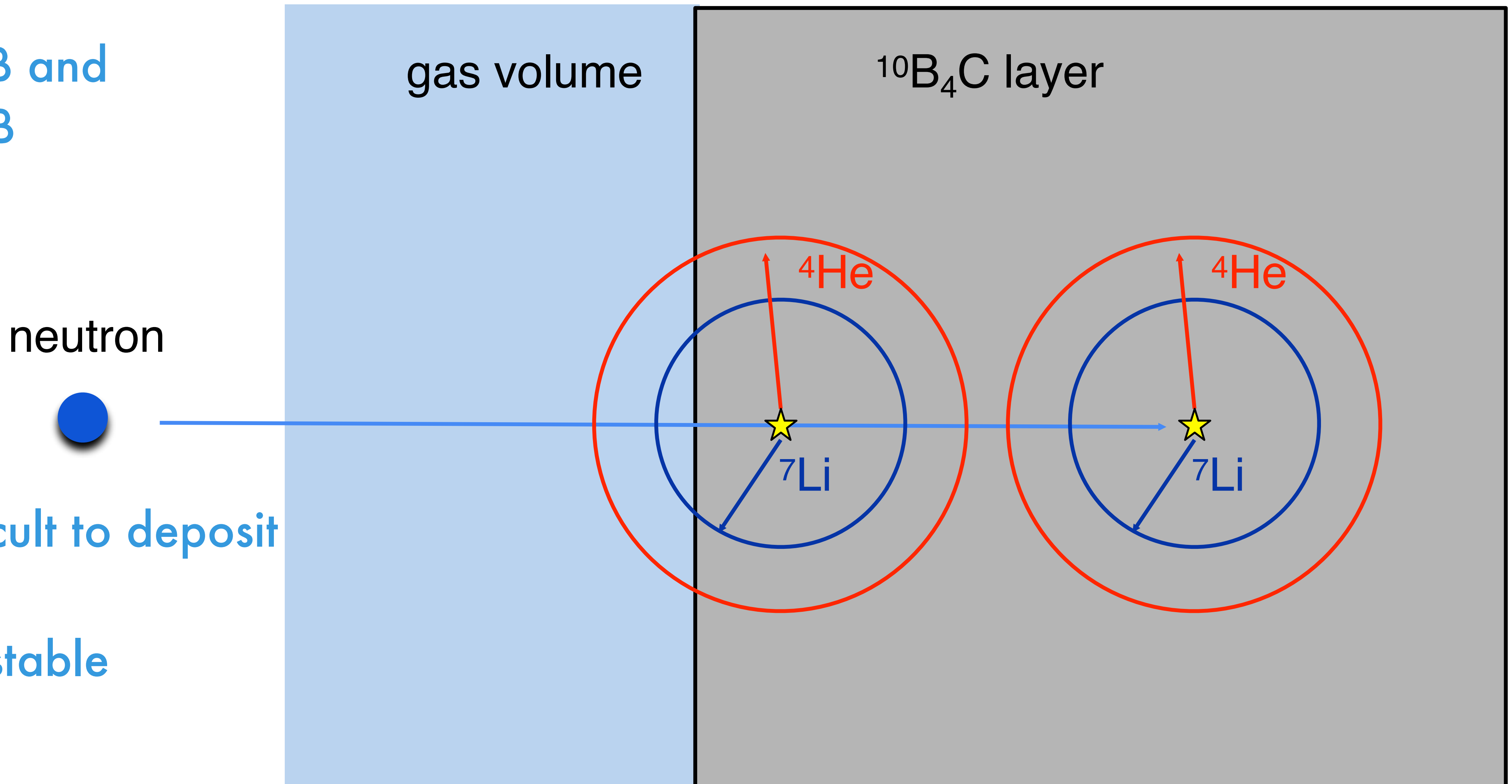
MultiGrid and Multiblade

^{10}Boron-based Thin Film Gaseous Detectors

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

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

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



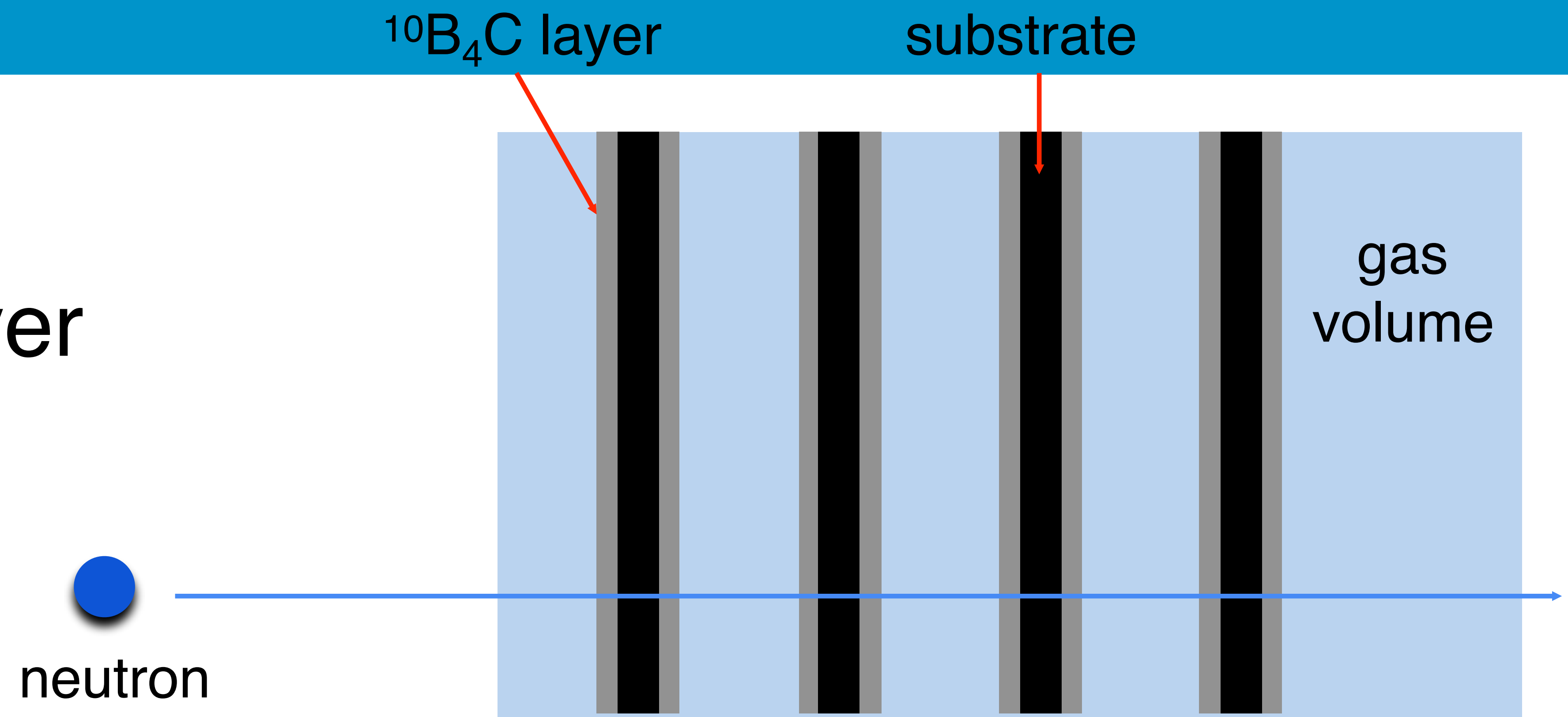
- Boron is difficult to deposit
- Use $^{10}B_4C$
- Conductive, stable

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

Mittuniversitetet
MID SWEDEN UNIVERSITY

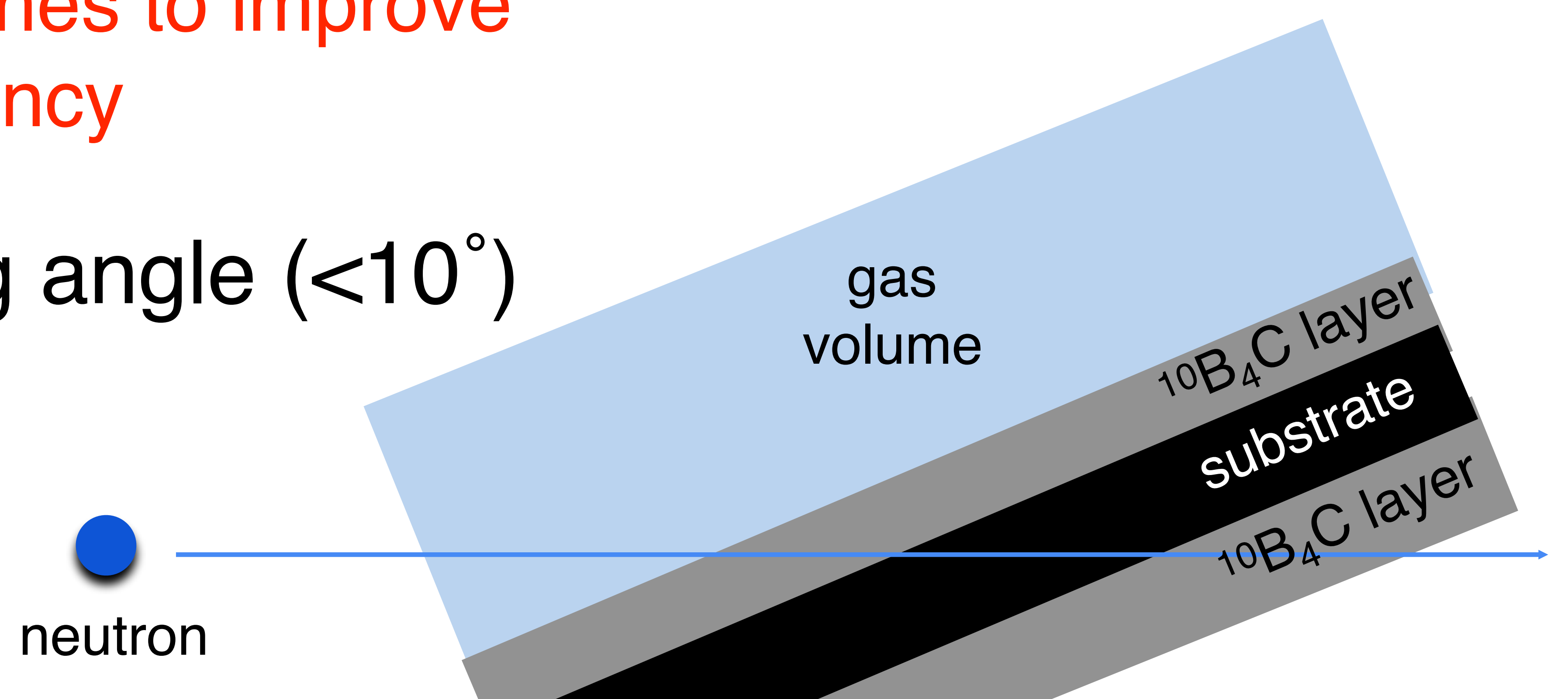
ess EUROPEAN SPALLATION SOURCE

1 Multi layer



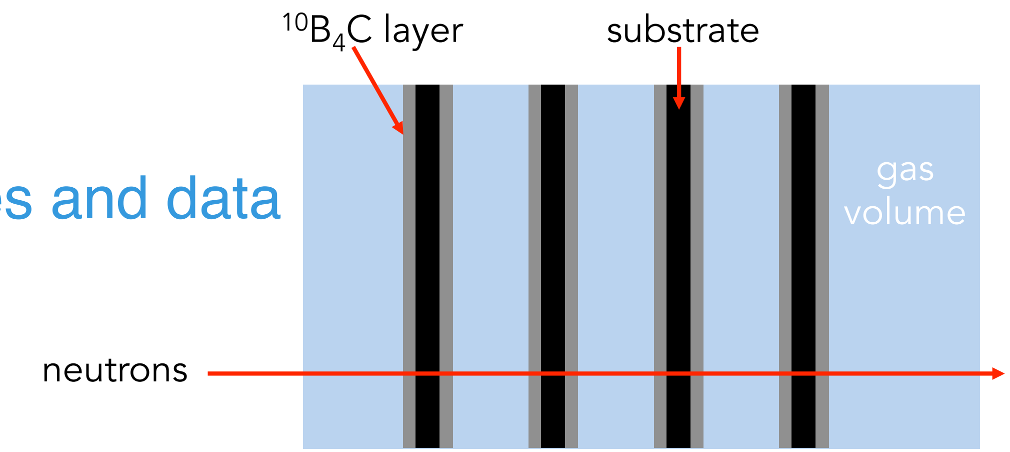
Generic approaches to improve efficiency

2 Grazing angle (<10˚)



Efficiency of ^{10}B Detectors: Perpendicular Geometry

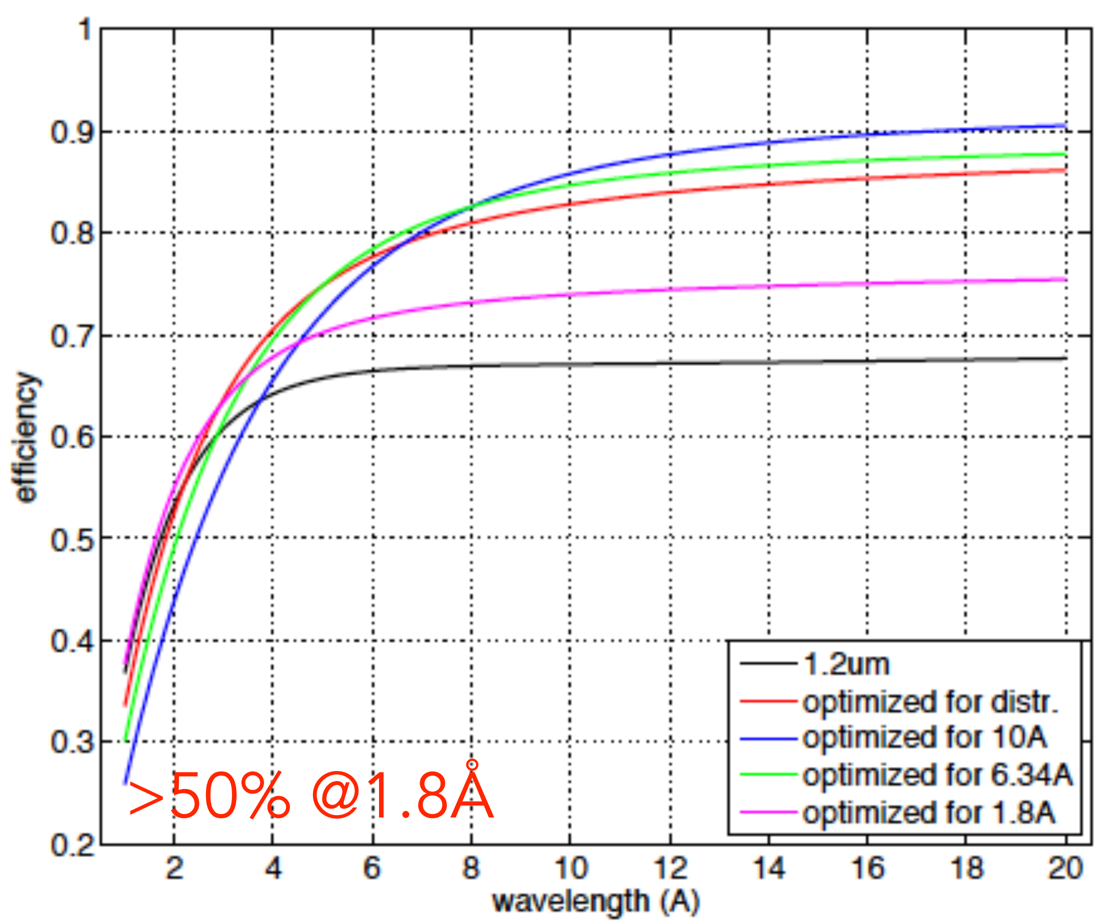
- Single layer is only ca.5%
- Calculations done by many groups
- Analytical calculations extensively verified with prototypes and data
- Details matter: just like for ^3He



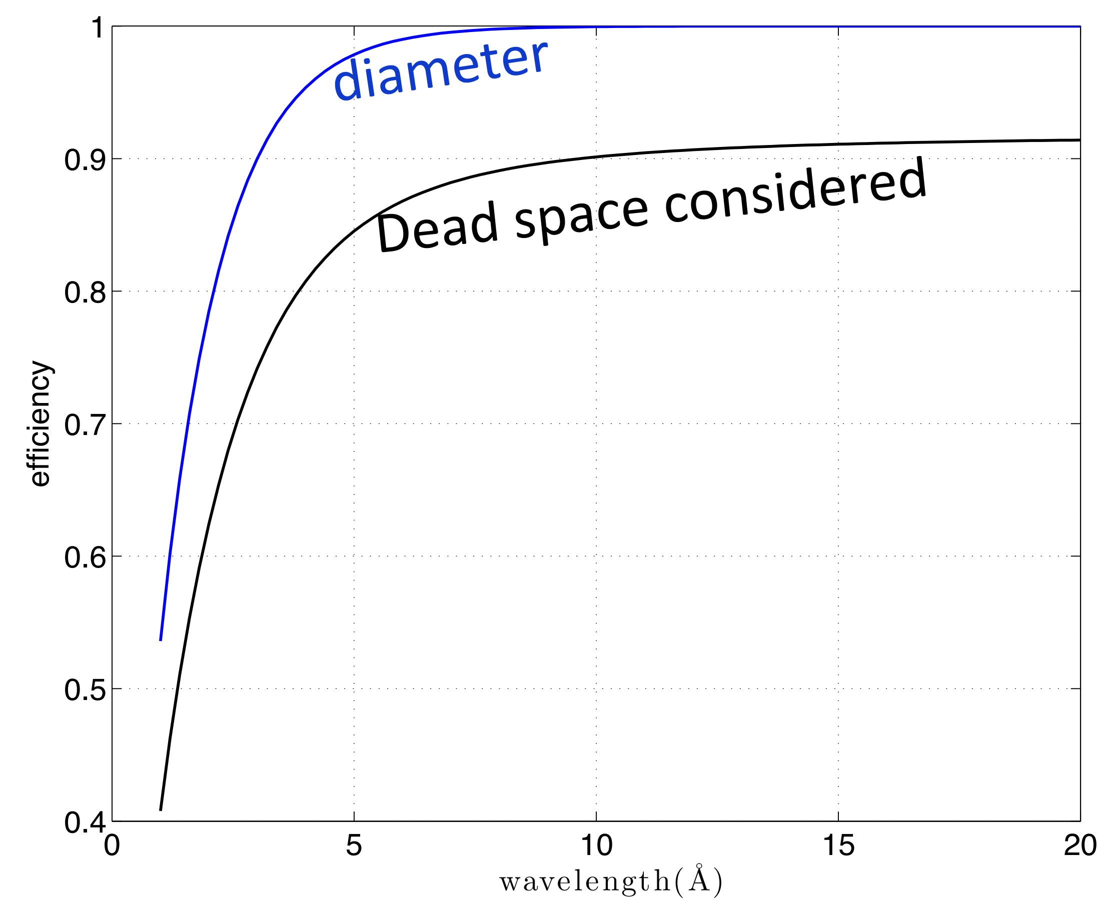
- Multilayer configuration (example):

JINST 8 (2013) P04020

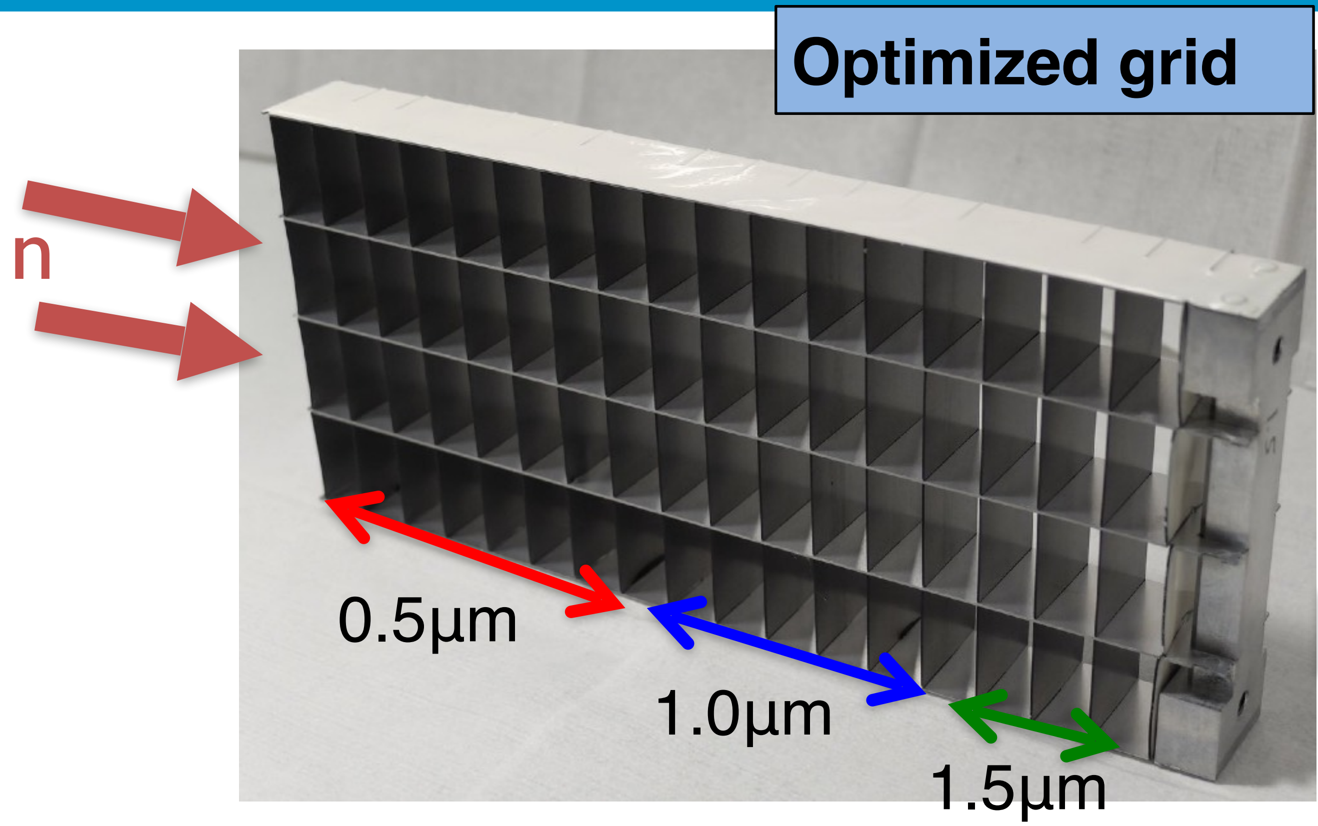
Multi-Grid



^3He tubes – 1 inch – 4.75 bar



Efficiency Optimizations

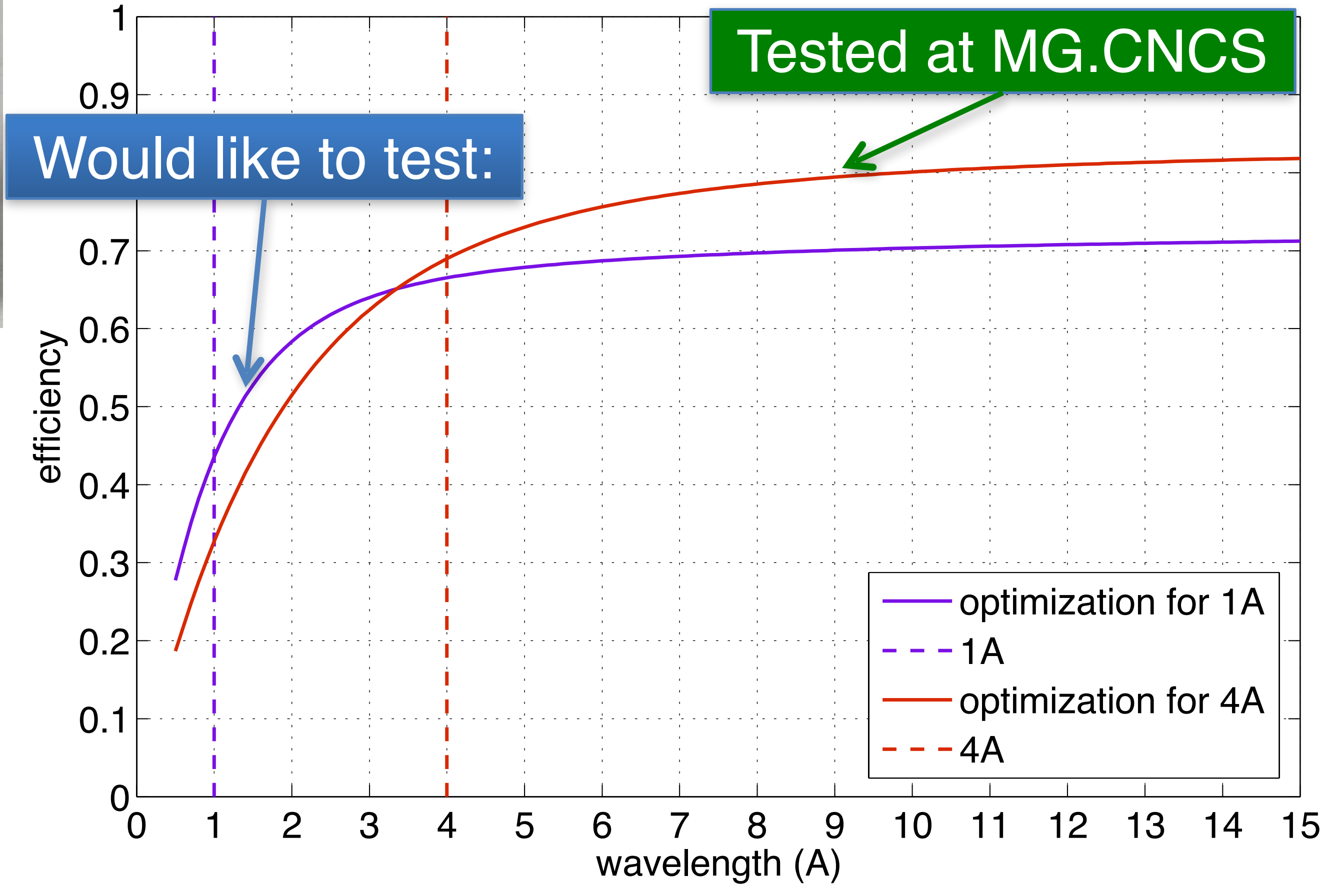


Layer thicknesses in MG.CNCS (16 blades):
7 blades 0.5µm,
7 blades 1.0µm,
3 blades 1.5µm

Would like to test:

Proposed for a thermal detector (20 blades):
4 blades 1.0µm,
10 blades 1.25µm,
6 blades 2.0µm.

Efficiency as a function of wavelength for MG optimized for cold vs. thermal spectrum



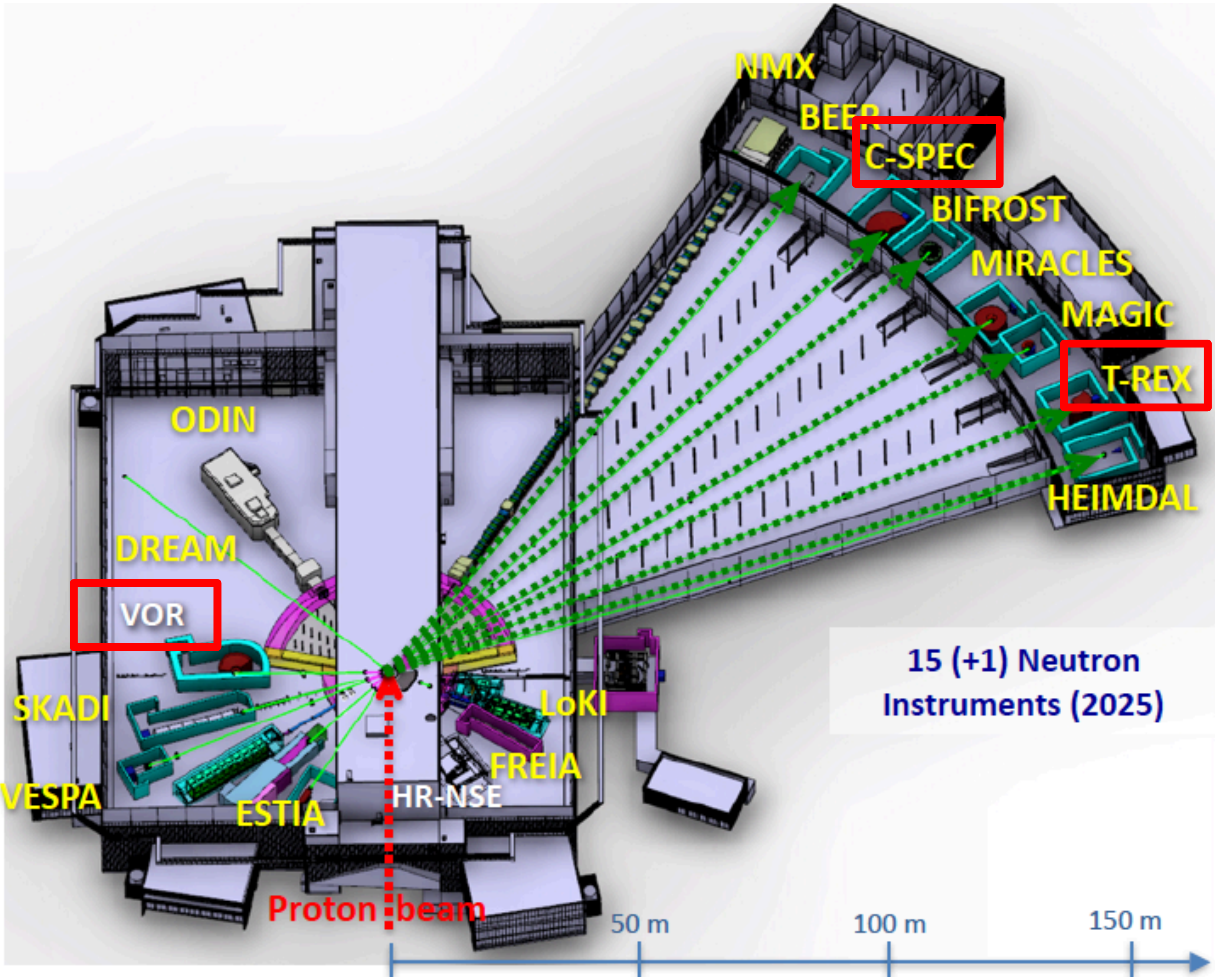
- Cold – optimization centered on 4Å
- Thermal – optimization centered on 1Å

Time-of-Flight Spectrometers at ESS

- First 16 instruments chosen
- 3 ToF spectrometers for ESS
- CSPEC and T-REX – design phase
- VOR – accepted proposal
- **Multi-Grid** as **baseline** detector technology

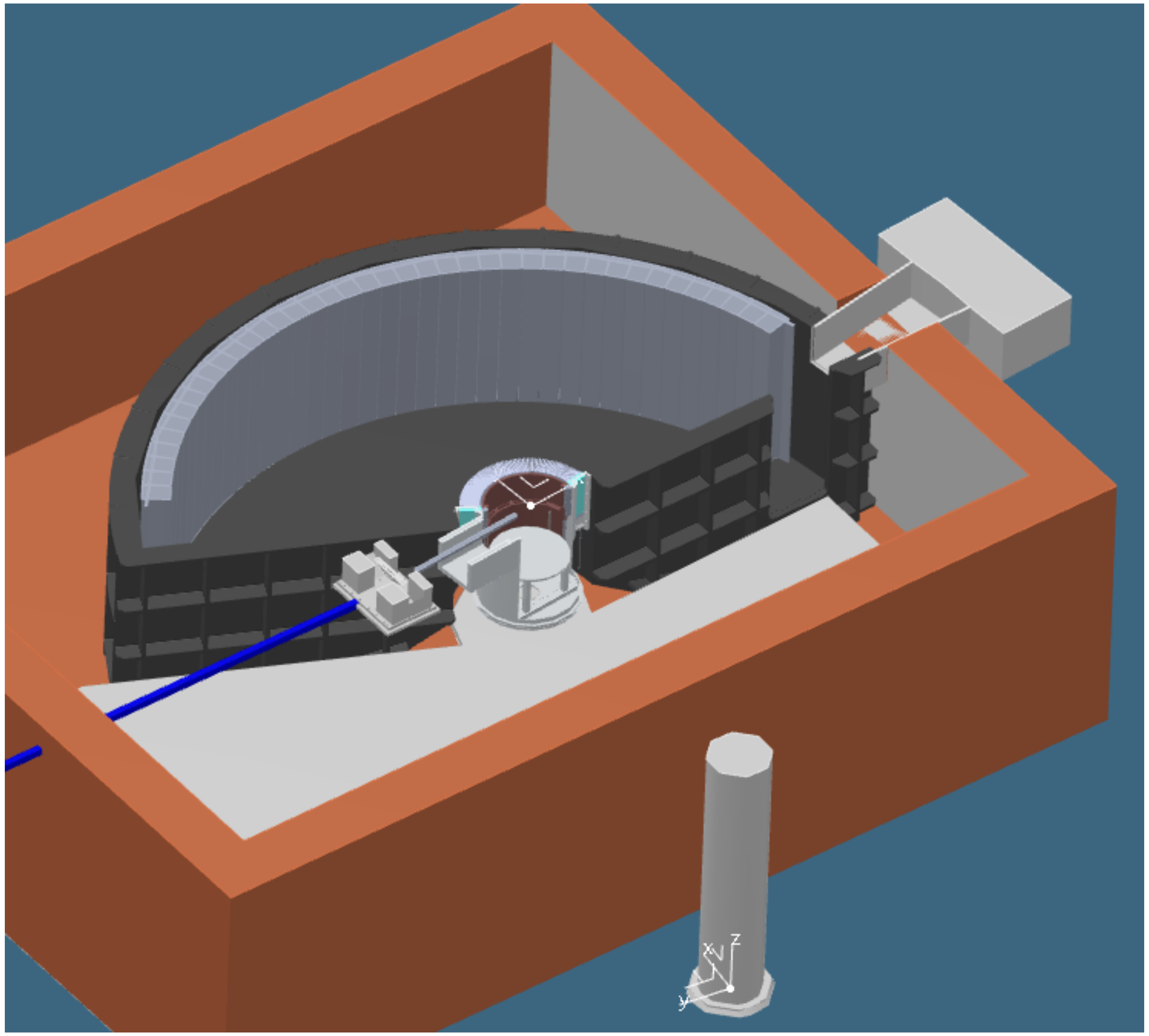
Instrument	C-SPEC	T-REX	VOR
Sample – detector	3.5 m	3 m	3 m *
Detector height	3.5 m	2.2 m	3 m *
Detector area	29 m²	21 m²	37 m² *

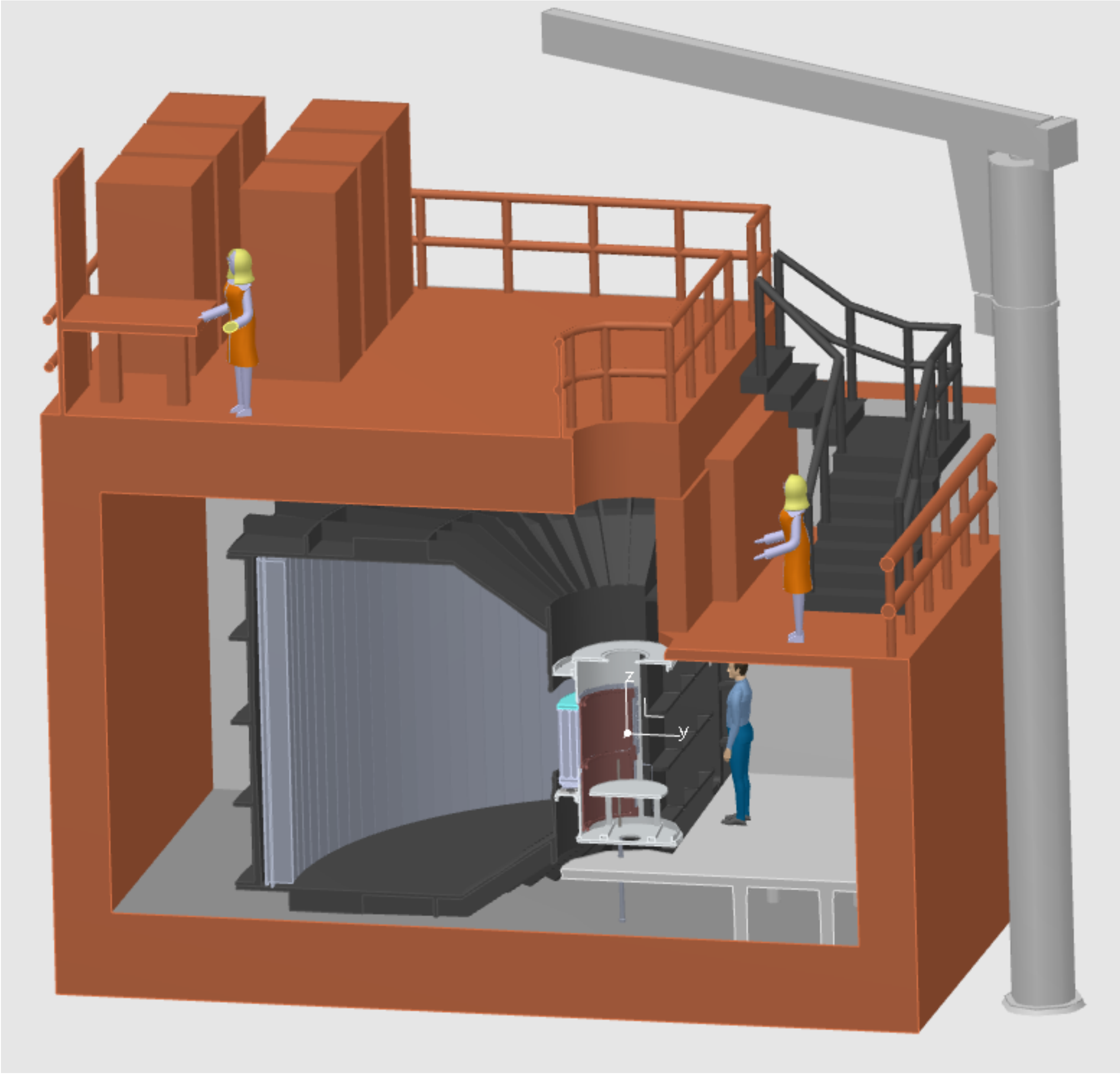
*preliminary



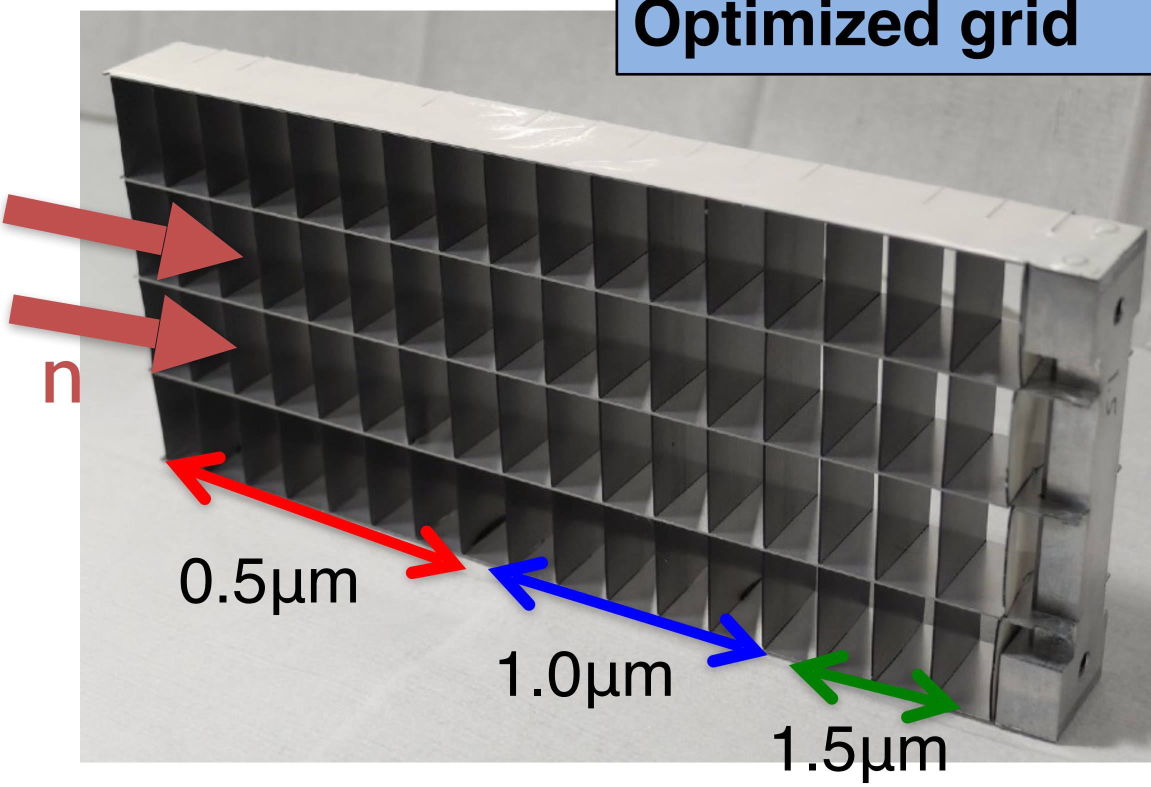
CSPEC at ESS

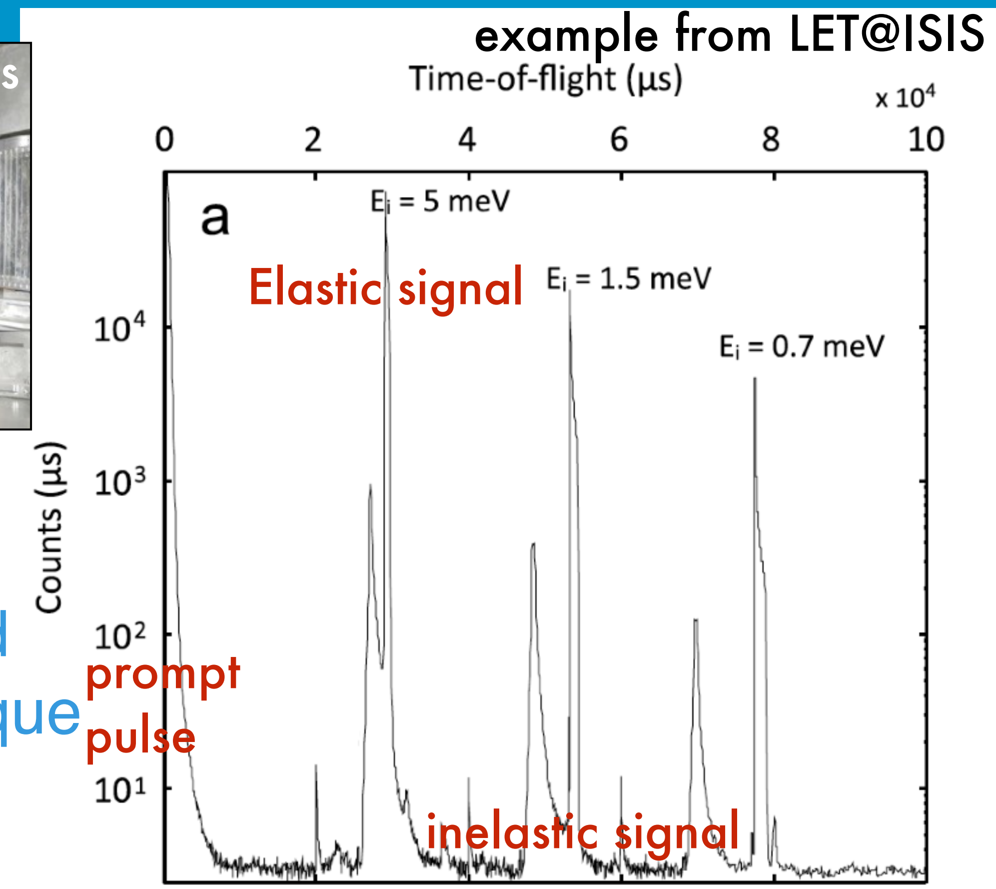
Cold spectrometer
0.2 meV < E_i < 20 meV
29m² detector
Horizontal coverage 5° to 135°
Vertical coverage -25° to 25°





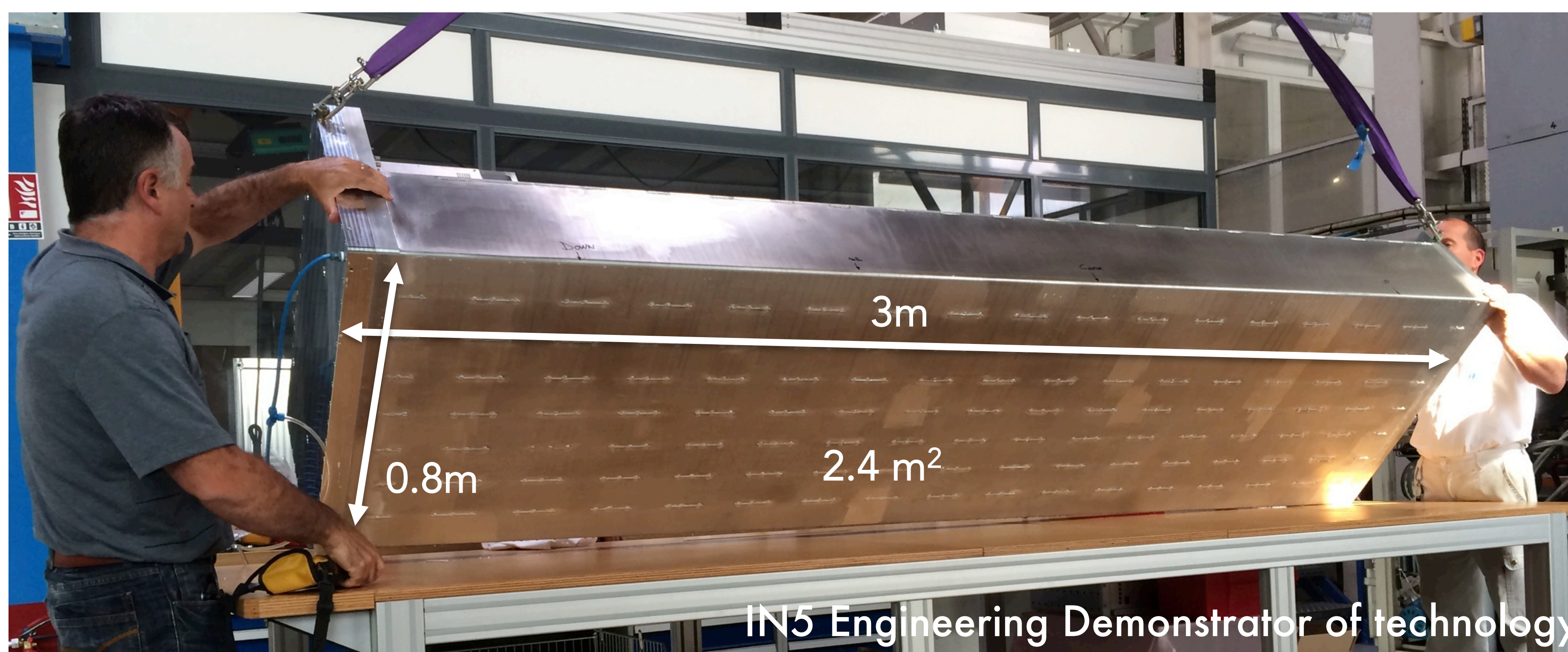
Multi-Grid Detector Design





- Very background sensitive technique

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



Demonstrator Test at SNS on CNCS

EUROPEAN SPALLATION SOURCE

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

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

Centre for Energy Research (Hungary):
Eszter Dian

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

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

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

brightness
Horizon 2020 grant agreement 676548

WP 4.3: Large-Area Detectors

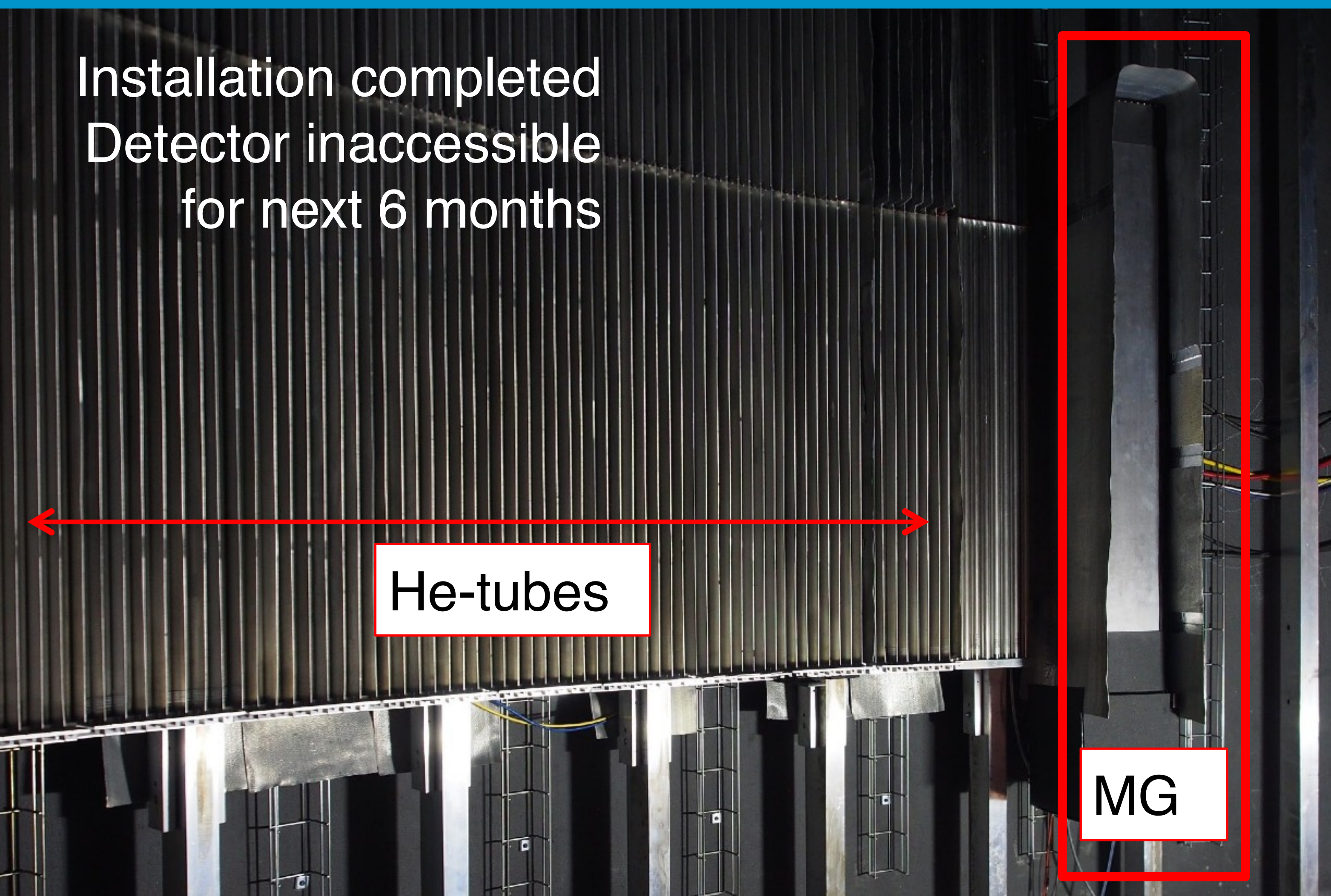
Previous publications:

B4C layers:
*C. Höglund et al, J of Appl. Phys. 111, 104908 (2012)
Characterization:
*A. Khaplanov et al., arXiv:1209.0566 (2012)
*B Guerard et al., NIMA, 720, 116-121 (2013), http://dx.doi.org/10.1016/j.nima.2012.12.021iJ
*J. Correa et al., Trans. Nucl. Sc. (2013), DOI: 10.1109/TNS.2012.2227798
*A. Khaplanov et al., (2014) *J. Phys.: Conf. Ser.* **528** 012040 doi:10.1088/1742-6596/528/1/012040
Gamma sensitivity:
*A. Khaplanov et al., JINST 8, P10025 (2013), arXiv:1306.6247
Alpha background:
*A. Khaplanov et al., JINST 10, P10019 (2015); doi:10.1088/1748-0221/10/10/P10019

Current work:

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

Multi-Grid test at CNCS



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

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

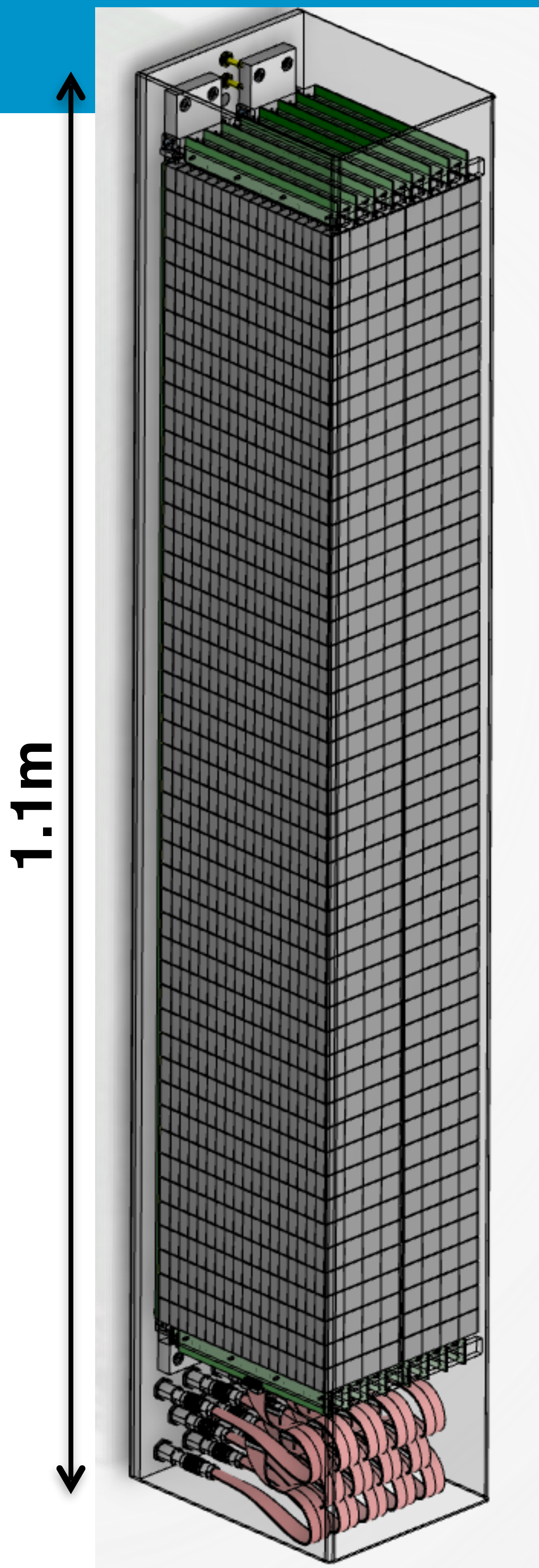
- Test side-by-side with existing technology in world leading instrument
- Realistic conditions. Long term test.
- "Science" or application performance
- 2 different technologies on the same instrument

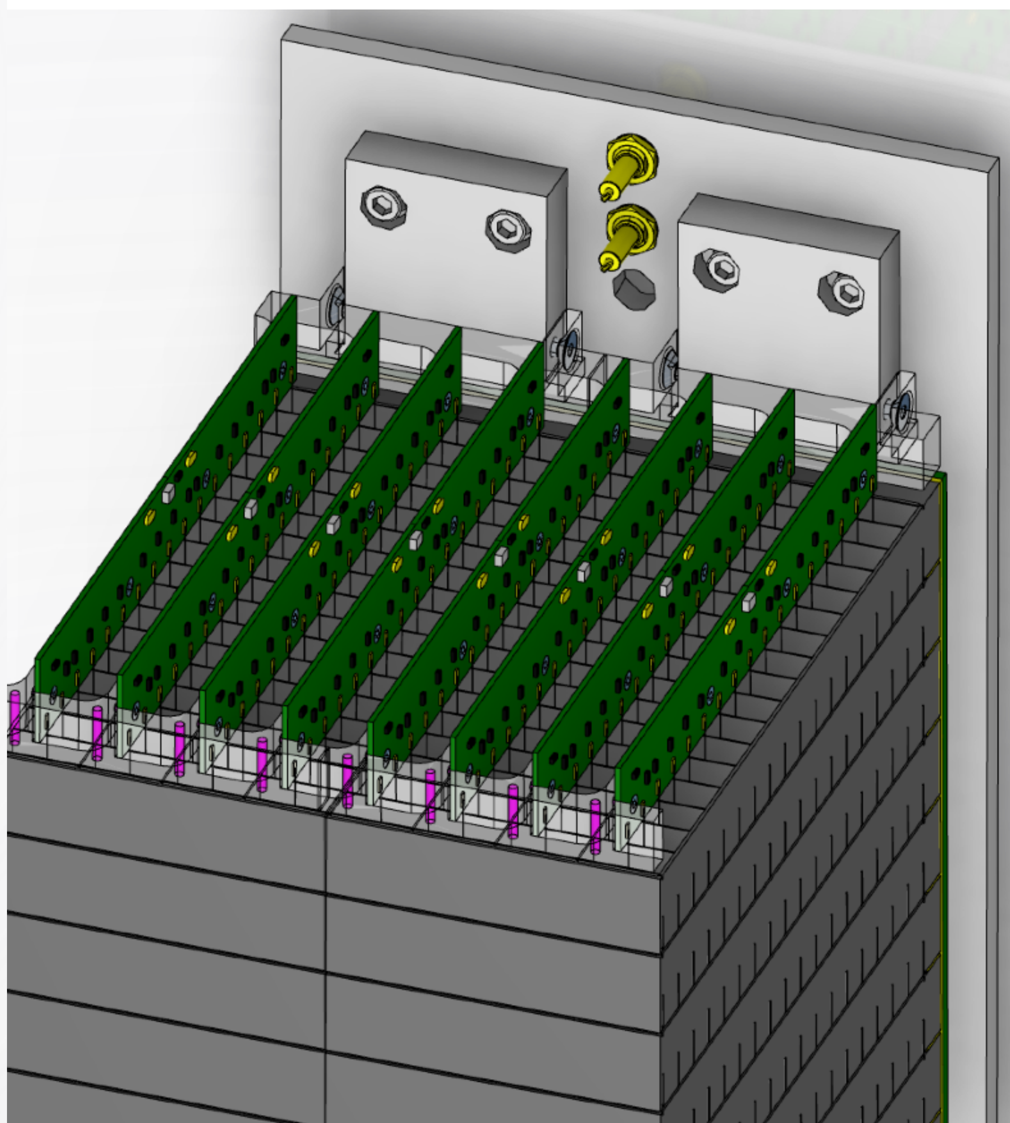
Construction of MG.CNCS in Lund

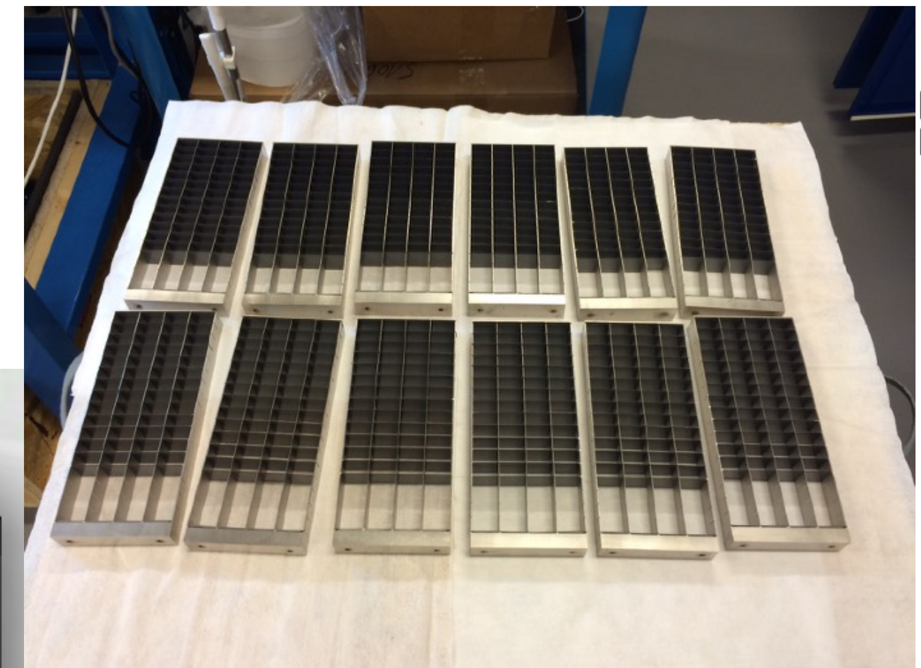
EUROPEAN SPALLATION SOURCE

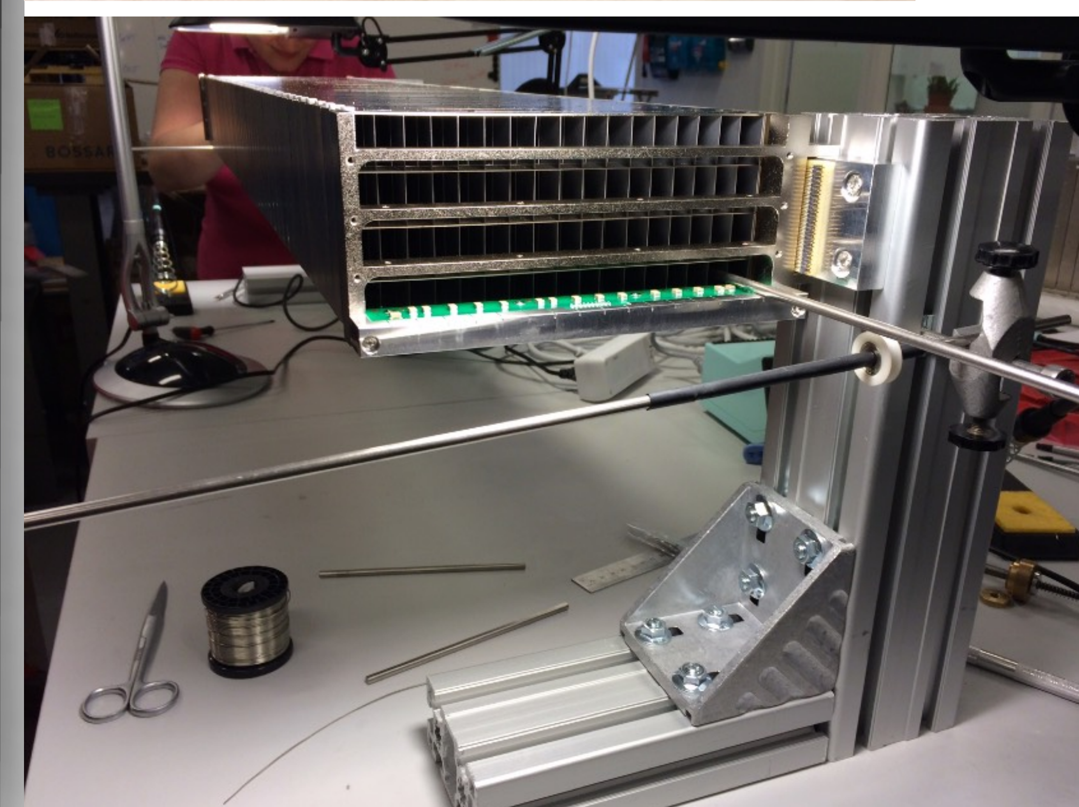
brightness

NEUTRONS FOR SCIENCE®

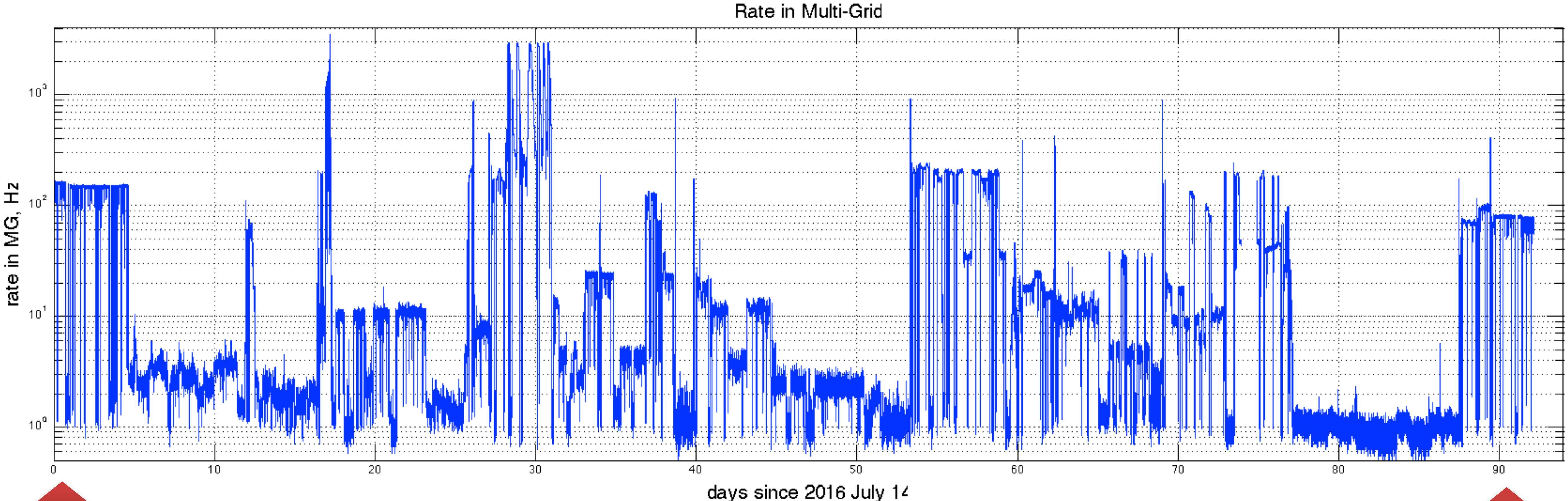








Operation since 2016-07-14



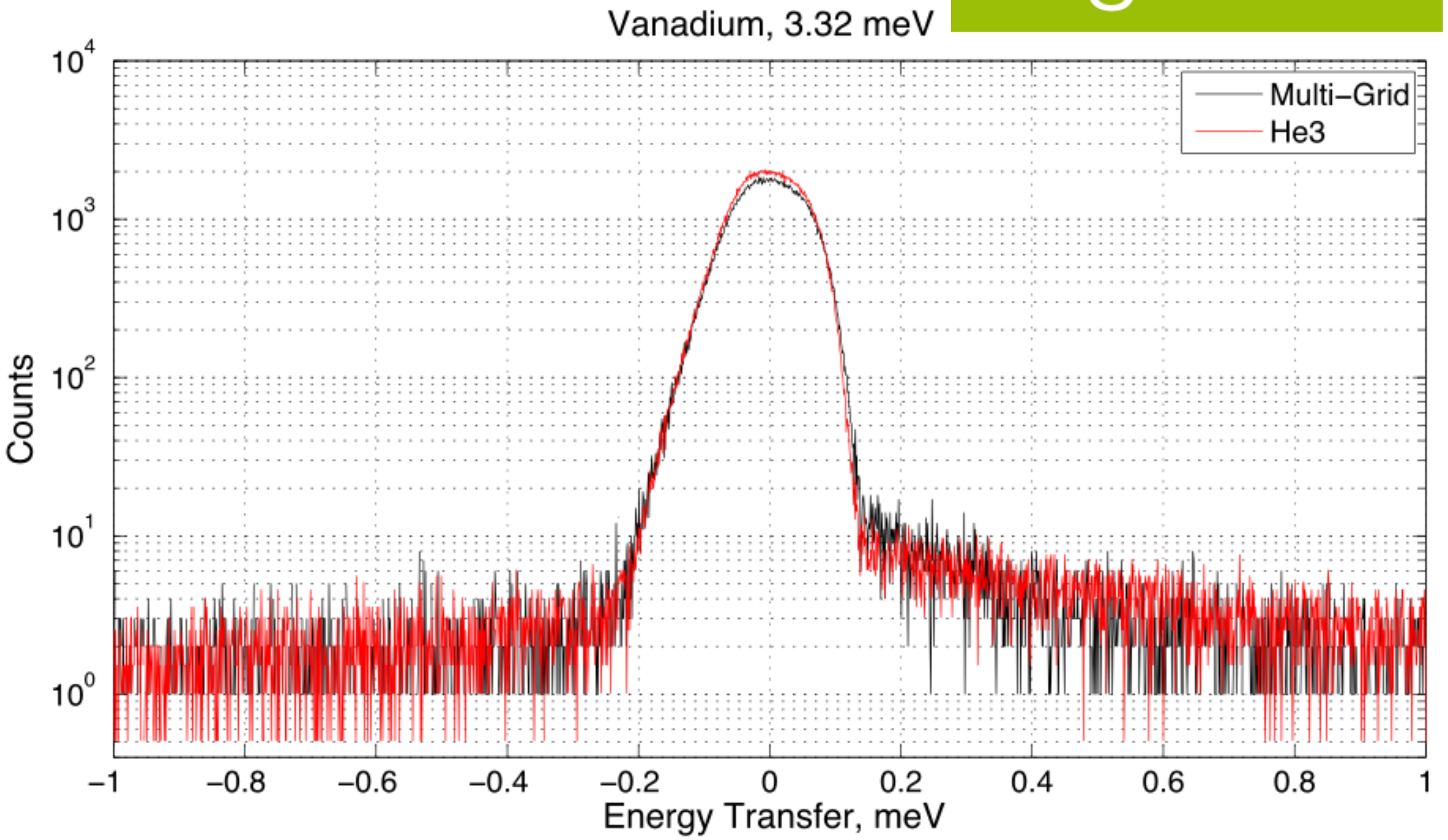
First day

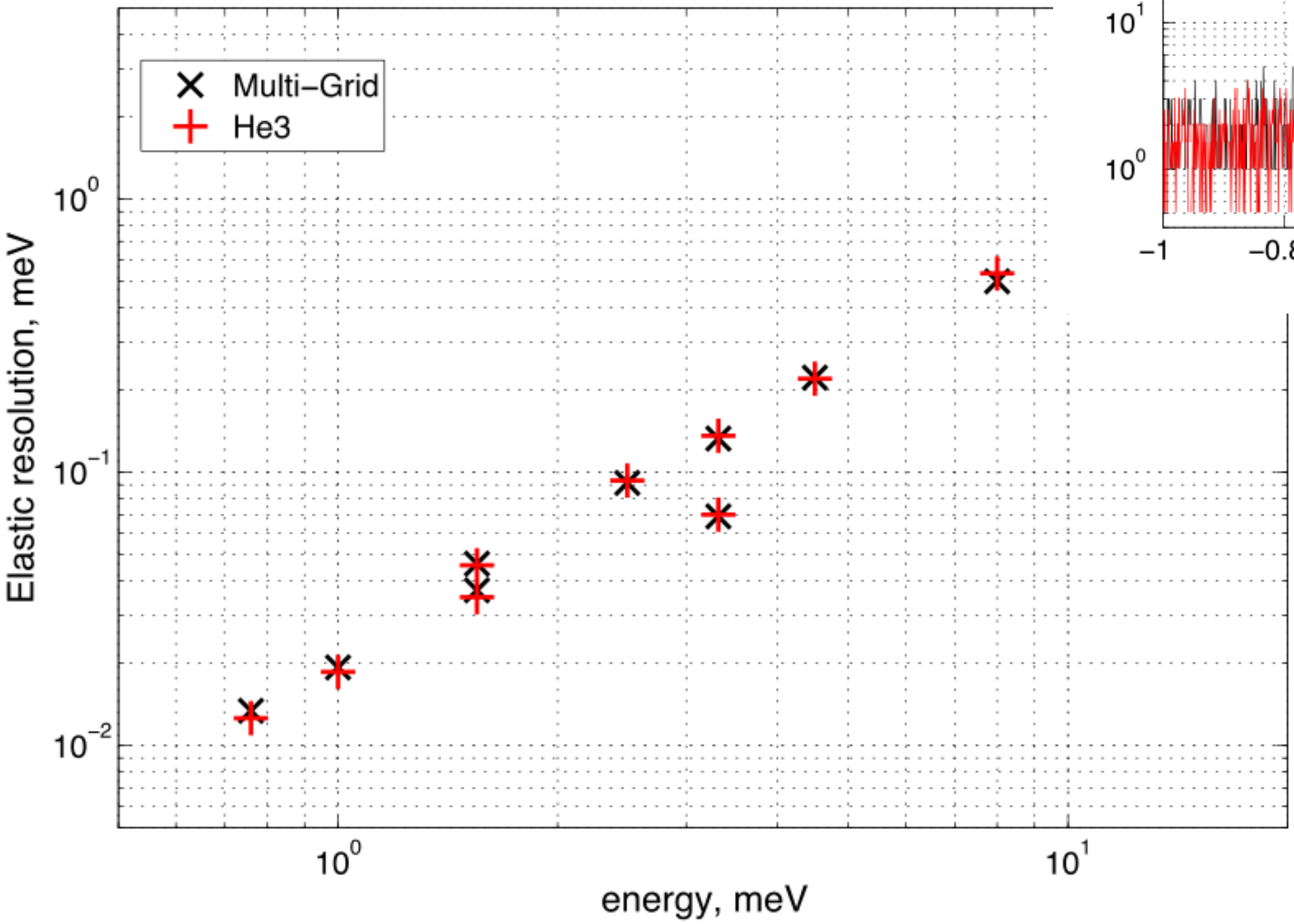
90 days

Operating without possibility of access since installation

Count rate stable to within 1-2% for a constant setting

Multi-Grid test at CNCS





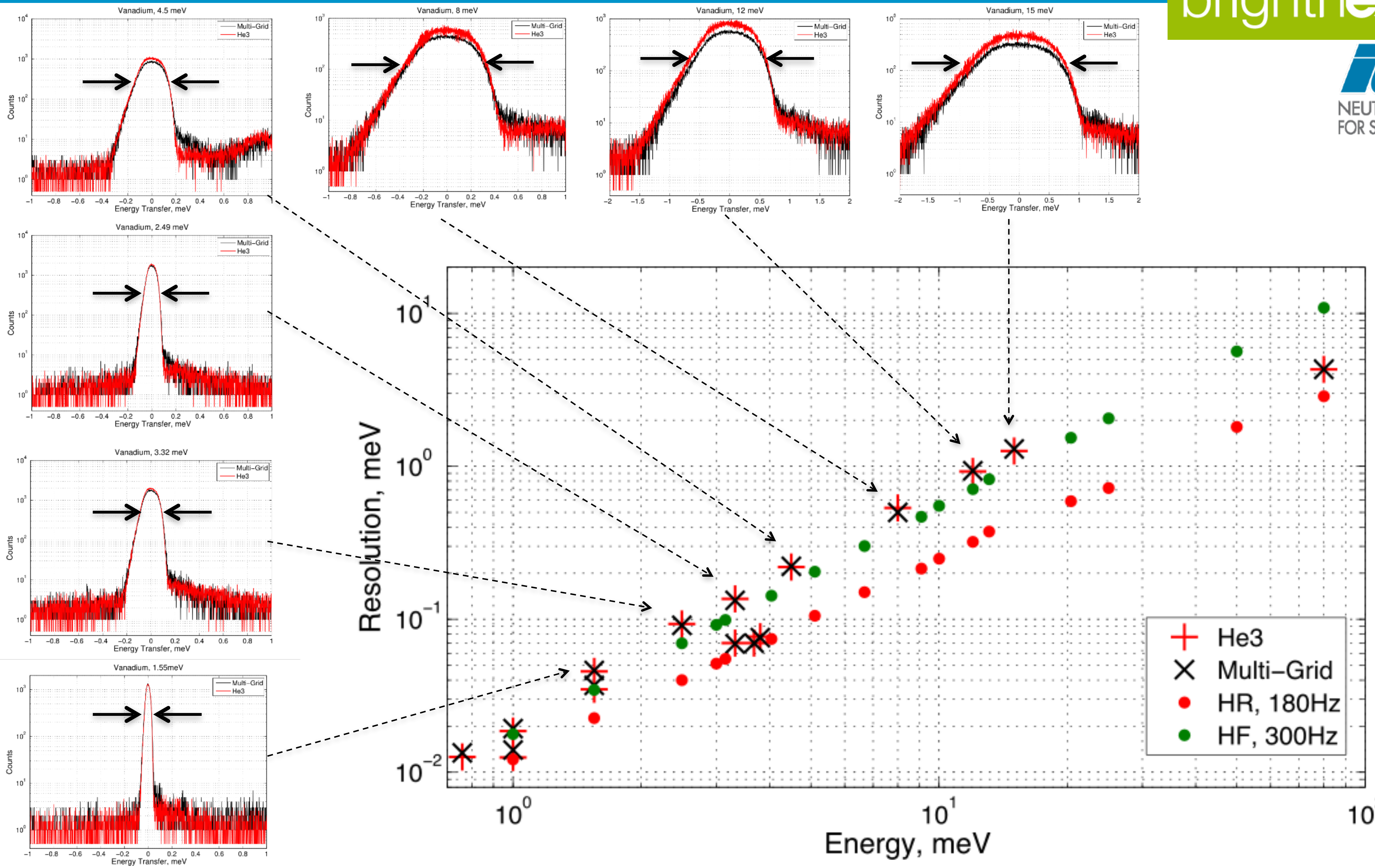
- Data and instrument resolution identical
- Technology suitable for ESS instruments

Elastic Energy Resolution

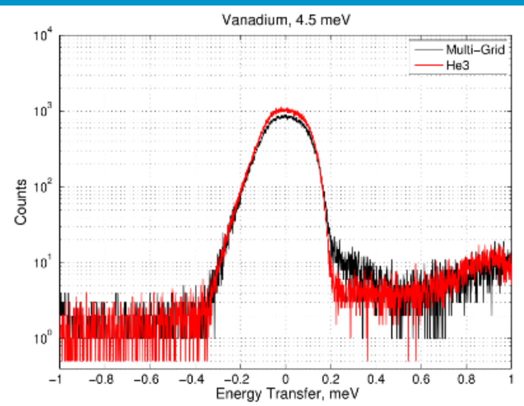
EUROPEAN SPALLATION SOURCE

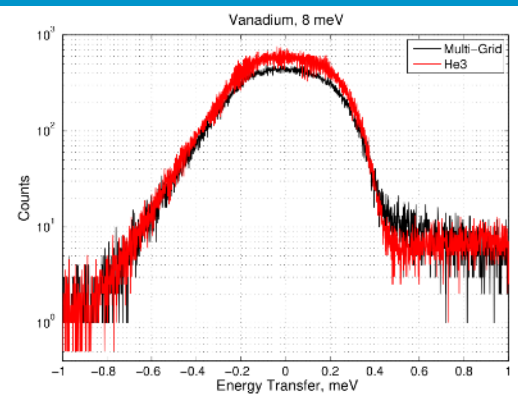
brightness

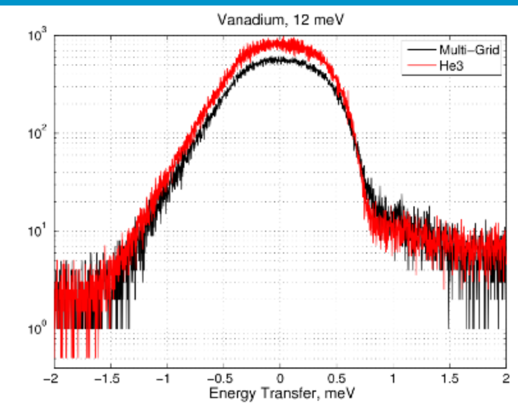
NEUTRONS FOR SCIENCE

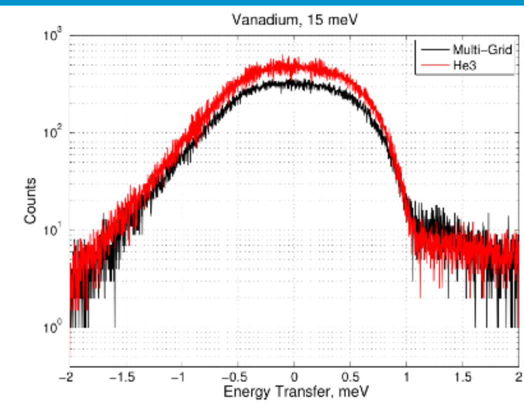


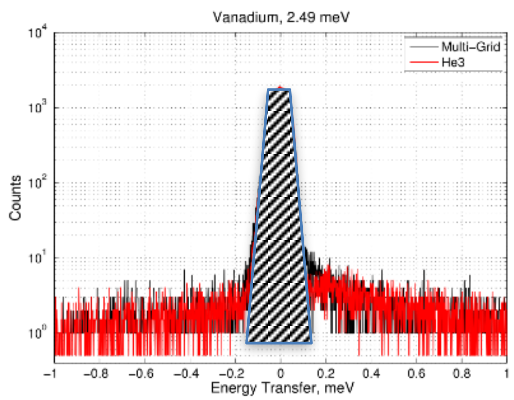
Efficiency

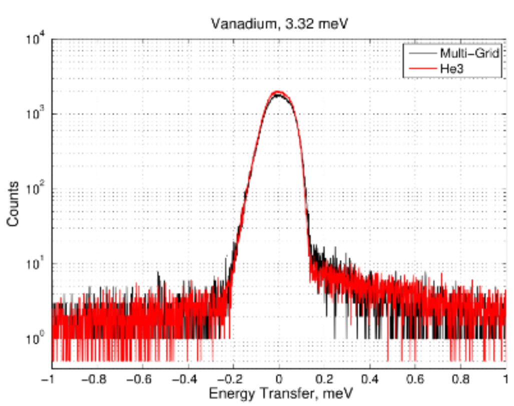


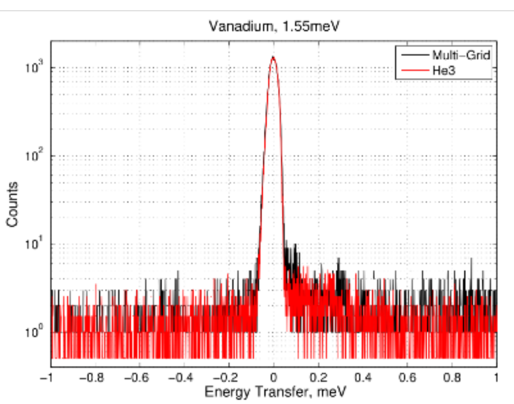


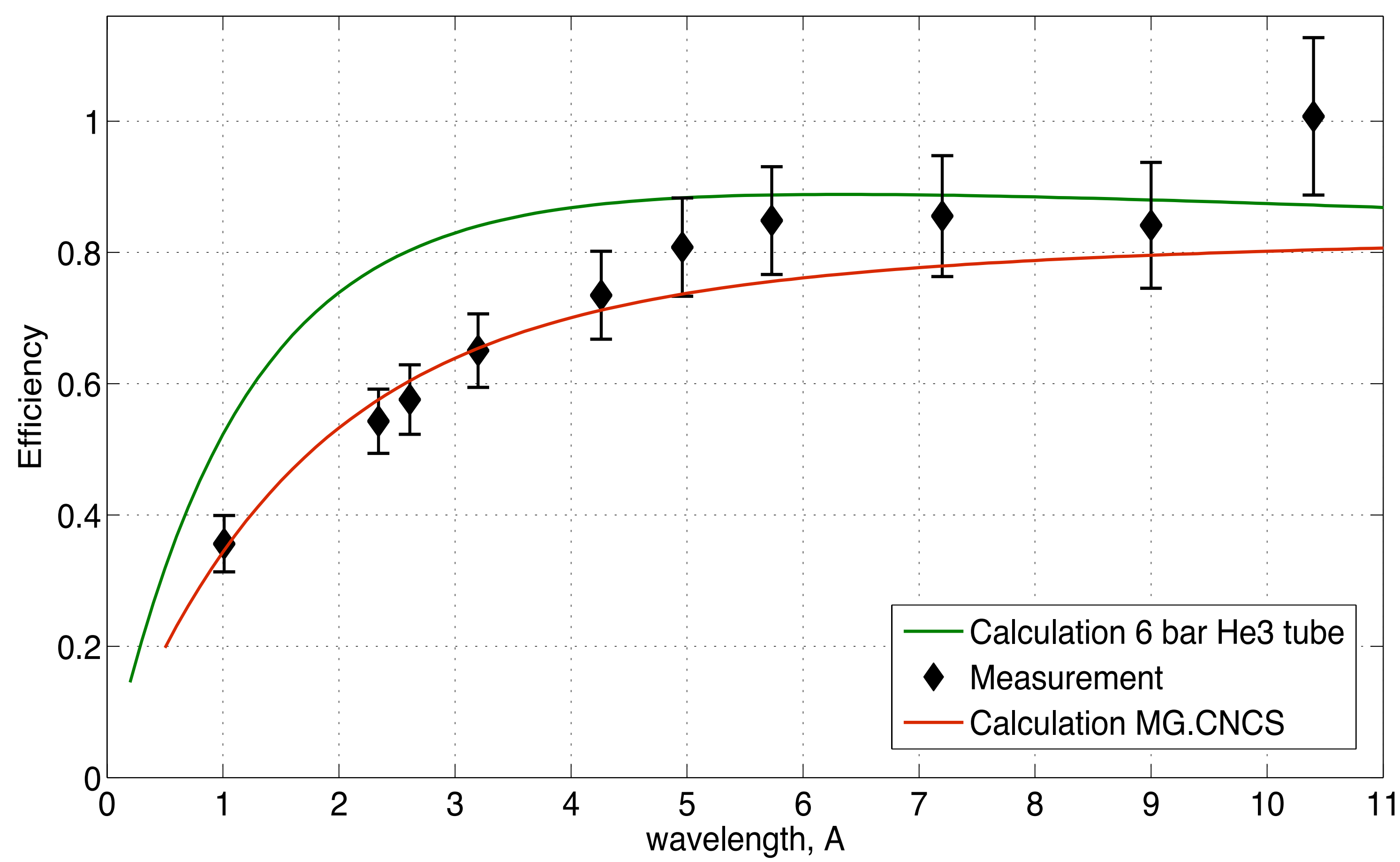












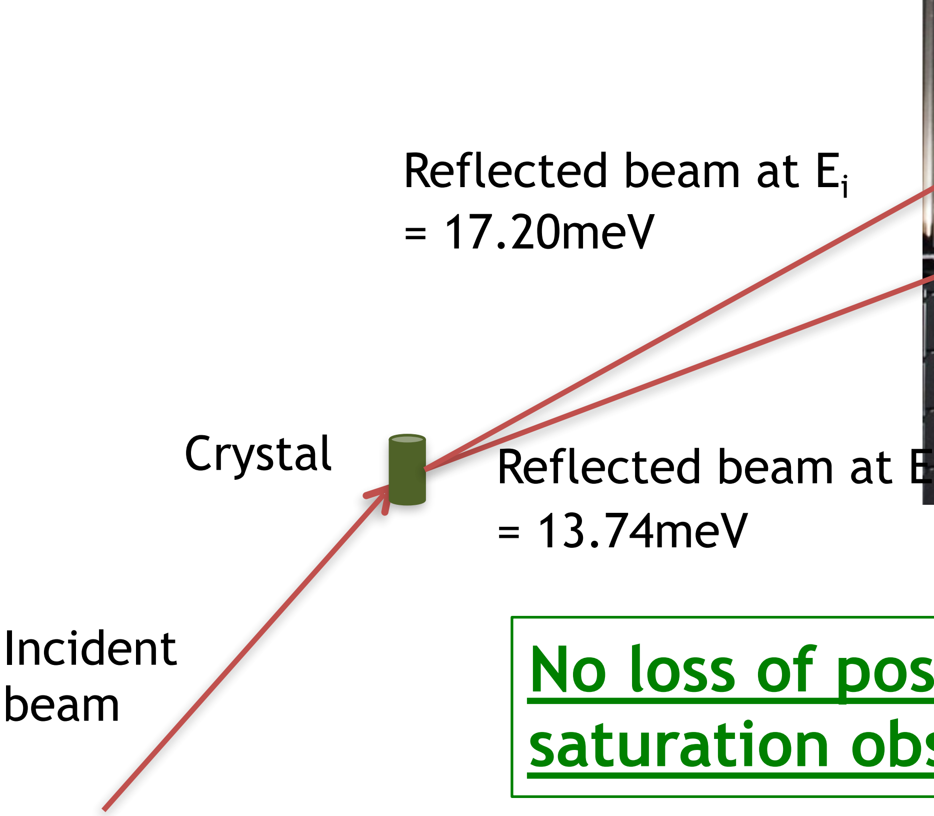
Counts from integral of the elastic peak in dE
Efficiency measured relative to the nearest He3 tubes
Error bars: 5-8%, agrees with prediction

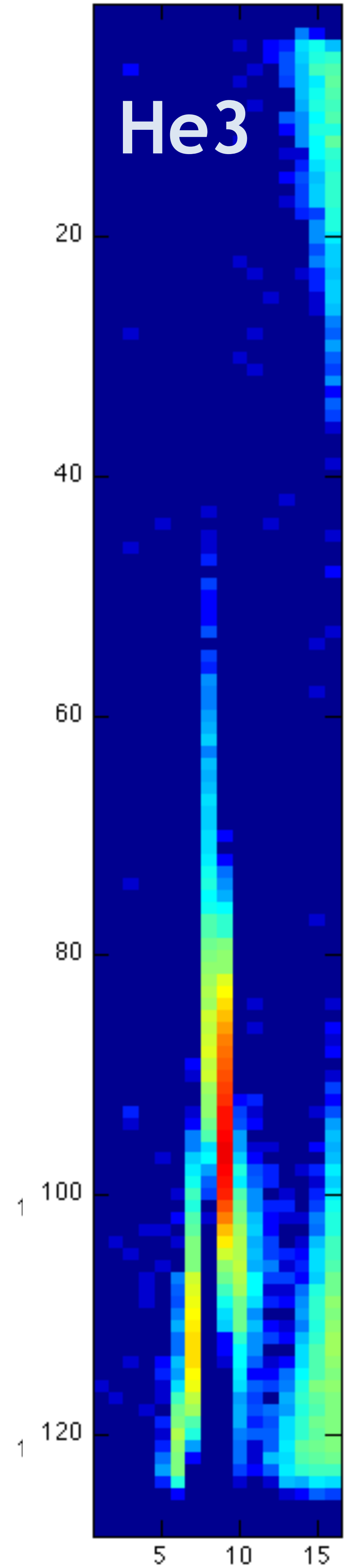
Single Crystal Reflection

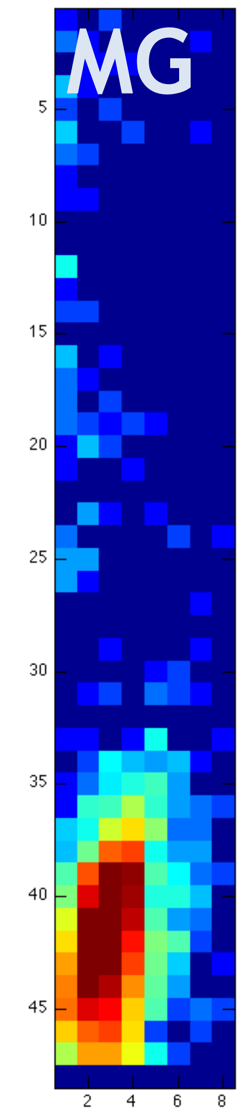
A single crystal reflects neutrons according to Bragg's law:

$$n\lambda = 2d\sin(\theta / 2)$$

Resulting in an intense spot seen by detector



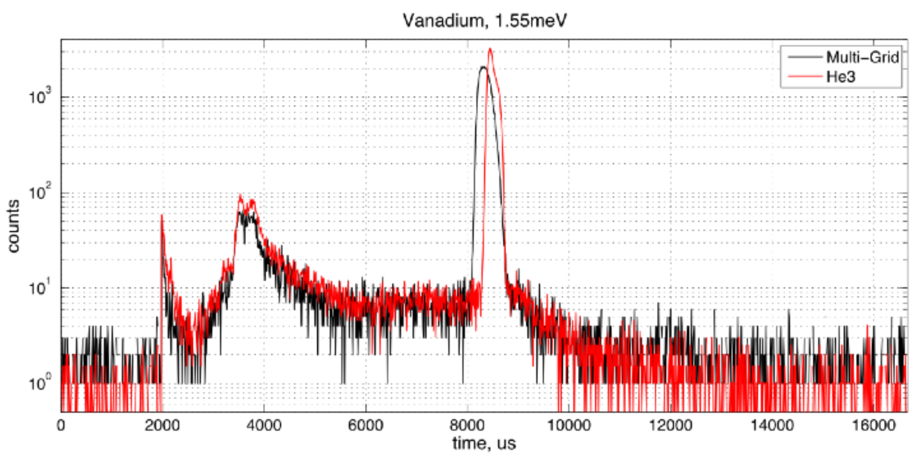




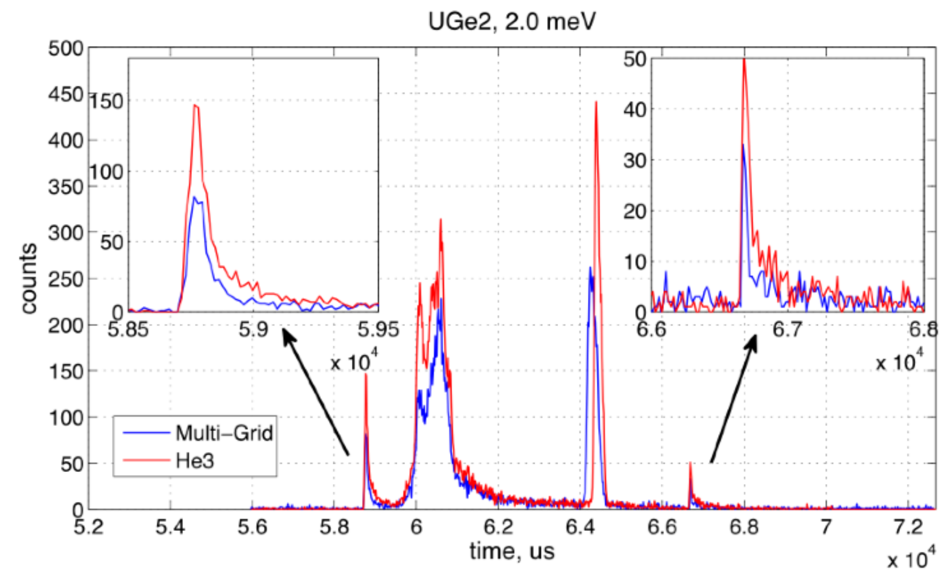
No loss of position resolution or saturation observed in Multi-Grid

Methods Used for Tests

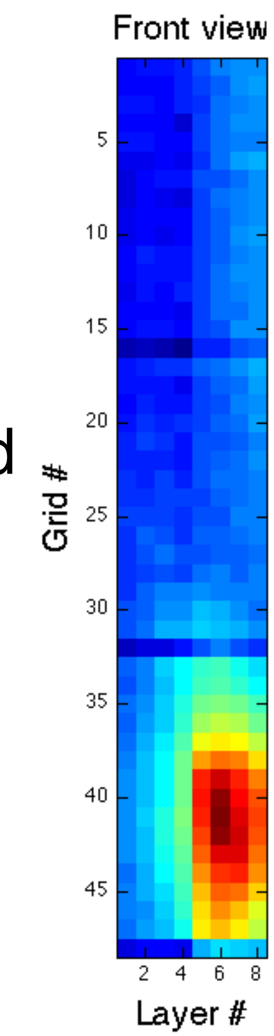
Vanadium



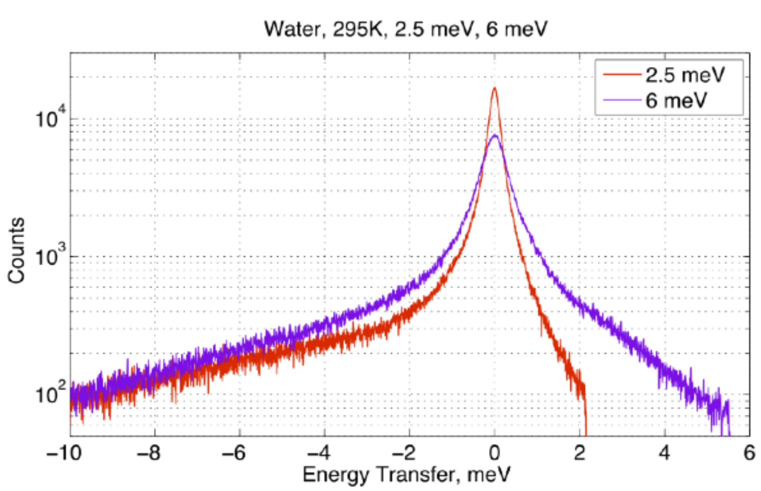
Fast neutrons (fission, prompt)



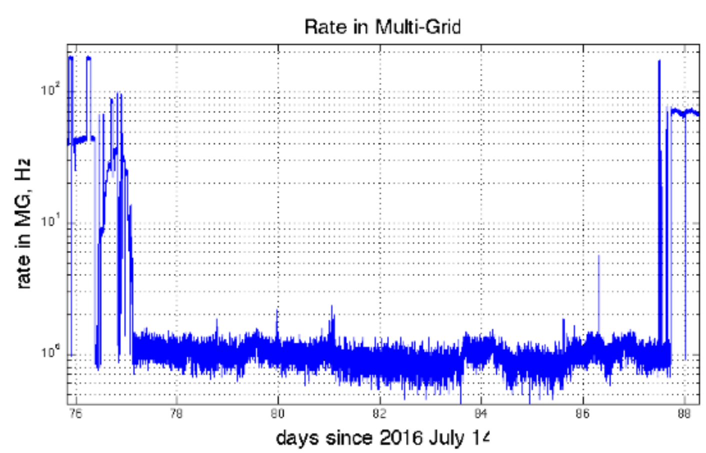
Single crystal



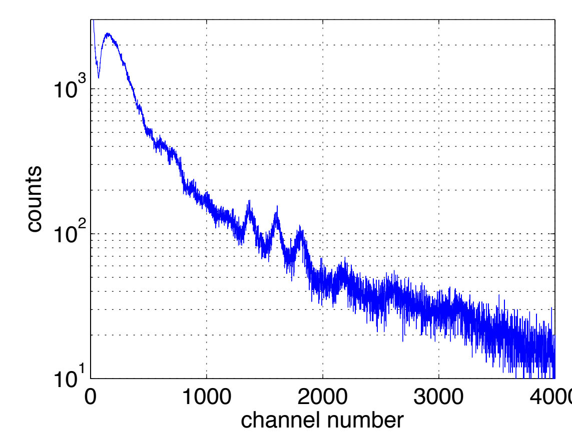
Water, Ice



Background



Gamma background (NaI detector)



Allowing to measure:

Energy resolution, efficiency, scattering, background sensitivity, saturation

Results of CNCS Test

EUROPEAN SPALLATION SOURCE

brightness

NEUTRONS FOR SCIENCE®

- **Operation with no access for 11 months, until end May.**
- **Essential demonstration. MG is now the baseline detector for CSPEC & T-REX**
- **Energy resolution, efficiency, backgrounds**
  shown to be comparable between MG and He3.
- **Better performance at high rate in Multi-Grid**
- **JINST paper, 2017 JINST 12 P04030 https://arxiv.org/abs/1703.03626 for all results**

Thanks to the colleagues at SNS for this opportunity and cooperation!
These results would not be possible without you!

Prepared for submission to JINST

Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS

M. Anastasopoulos,[a] R. Bebb,[a] K. Berry,[b] J. Birch,[c] T. Bryś,[a] J.-C. Buffet,[d] J.-F. Clergeau,[d] P. P. Deen,[a] G. Ehlers,[e] P. van Esch,[d] S. M. Everett,[b] B. Guerard,[d] R. Hall-Wilton,[a,f] K. Herwig,[g] L. Hultman,[c] C. Höglund,[a,c] I. Iruretagoiena,[a] F. Issa,[a] J. Jensen,[c] A. Khaplanov,[a,1] O. Kirstein,[a,h] I. Lopez Higuera,[a] L. Robinson,[a] S. Schmidt,[a,c] I. Stefanescu,[a]

[a]European Spallation Source, P.O Box 176, SE-22100 Lund, Sweden
[b]Instrument and Source Division, Spallation Neutron Source, 1 Bethel Valley Road, Oak Ridge, TN 37831-6476, USA
[c]Linköping University, Thin Film Physics division, IFM, SE-581 83 Linköping, Sweden
[d]Institute Laue Langevin, 71 avenue des Martyrs, FR-38042 Grenoble, France
[e]Quantum Condensed Matter Division, Spallation Neutron Source, 1 Bethel Valley Road, Oak Ridge, TN 37831-6475, USA
[f]Mid-Sweden University, SE-85170 Sundsvall, Sweden
[g]Instrument and Source Division, Spallation Neutron Source, 1 Bethel Valley Road, Oak Ridge, TN 37831-6466, USA
[h]School of Mechanical Engineering, University of Newcastle, Callaghan, Australia

E-mail: Anton.Khaplanov@esss.se

Abstract: The Multi-Grid detector technology has evolved from the proof-of-principle and characterisation stages. Here we report on the performance of the Multi-Grid detector, the MG.CNCS prototype, which has been installed and tested at the Cold Neutron Chopper Spectrometer, CNCS at SNS. This has allowed a side-by-side comparison to the performance of He-3 detectors on an operational instrument. The demonstrator has an active area of $0.2 m^2$. It is specifically tailored to the specifications of CNCS. The detector was installed in June 2016 and has operated since

Multi-Grid test at CNCS

Next Steps:

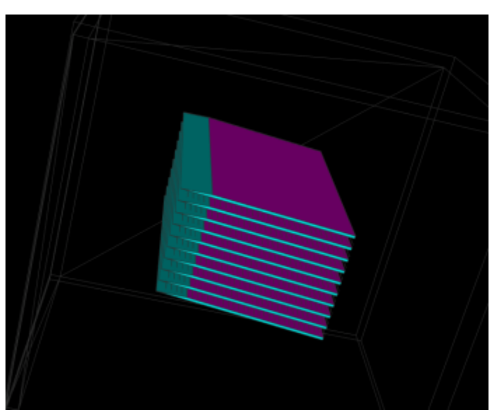
- Data analysis still ongoing
- “Thermal” instrument demonstrator planned
- In past couple months, have visited 4SEASONS@JPARC, DIN-2PI@IBR2 and SEQUOIA@SNS to investigate feasibility and interest
- Services, vacuum, etc under design
- Integration into instrument design
- Design for CSPEC and TREX started

Simulation

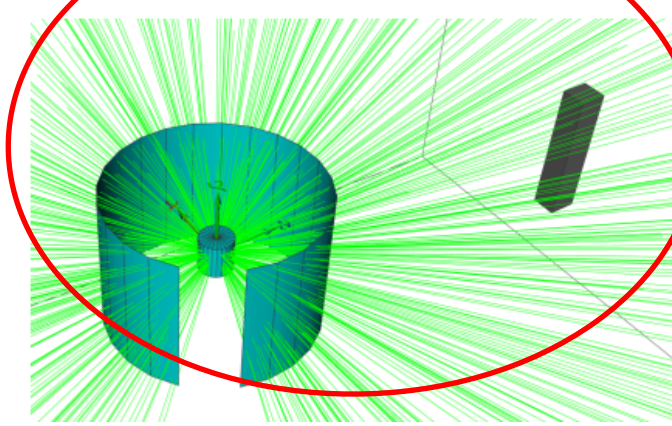
The ESS DG simulation projects

- Several projects, the majority of detector demonstrators have been modeled (E. Dian, G. Galgóczi, K. Kanaki, M. Klausz, D. Lucsányi, V. Maulerova, D. Pfeiffer, I. Stefanescu, C. Sørgaard)
  - Multi-Grid
  - Multi-Blade
  - He-3
  - BAND-GEM
  - macro-structured MWPC
  - flat MWPC
  - plastic scintillators
  - Source Testing Facility@LU
  - B/Gd-GEM
  - Jalousie
  - Si sensors
  - boron-coated straws

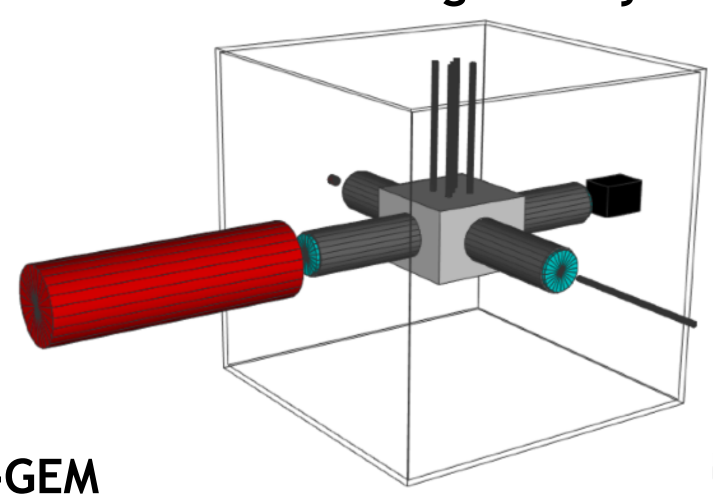
Multi-Blade



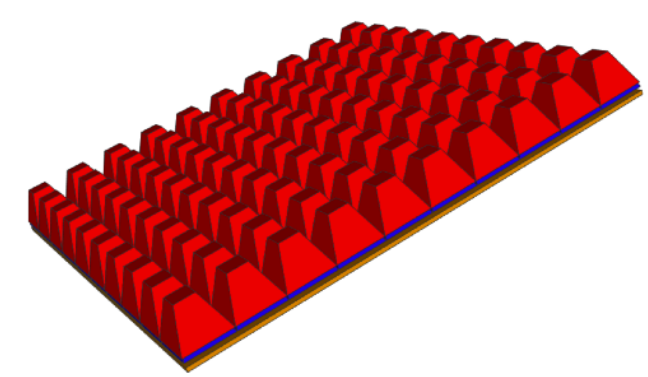
Multi-Grid



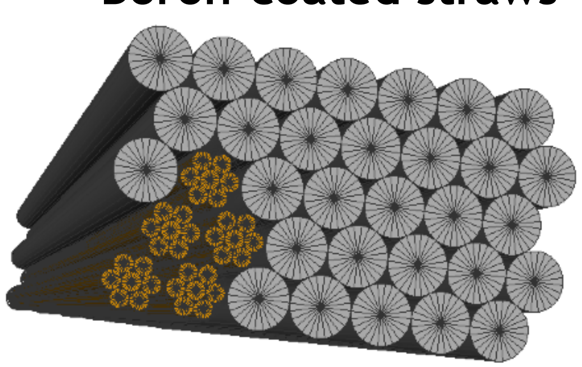
Source Testing Facility



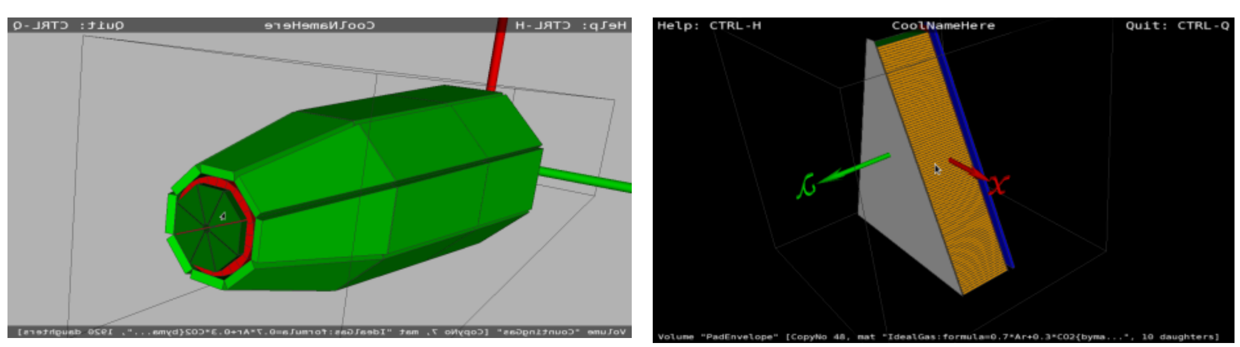
Si sensors



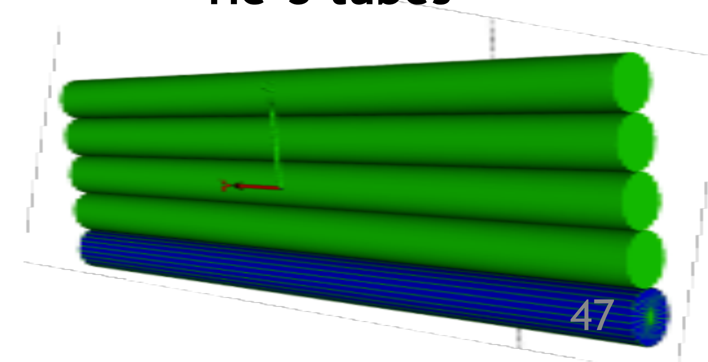
Boron-coated straws



BAND-GEM



He-3 tubes



Simulation tools

- New tools & utilities are recently developed for neutron studies
  - Physics
    - Coherent scattering
    - Inelastic scattering
    - Single- and poly-crystals…
  - And more
    - Communication
    - Visualisation
    - Ready-to use…

NXSG4
doi:10.1016/j.cpc.2014.11.009
http://nxsg4.web.cern.ch/nxsg4/

NCrystal
https://github.com/mctools/ncrystal/wi

MCPL -
Monte Carlo Particle List
https://mctools.github.io/mcpl/

ESS Coding Framework -
Geant4 simulation framework Developed by ESS Detector Group
doi:10.1016/S0168-9002(03)01368-8
doi:10.1088/1742-6596/513/2/022017

19 Sept. NSS Seminar
K. Kanaki, X X. Cai, E. Dian: Optimization of detector design for instruments with simulations: Tools and applications

Scattered neutron background

- Neutron scattering on detector and environment
- Study and distinguish background effects

↓

- Guidelines for detector design

Realistic simulation

Prototype

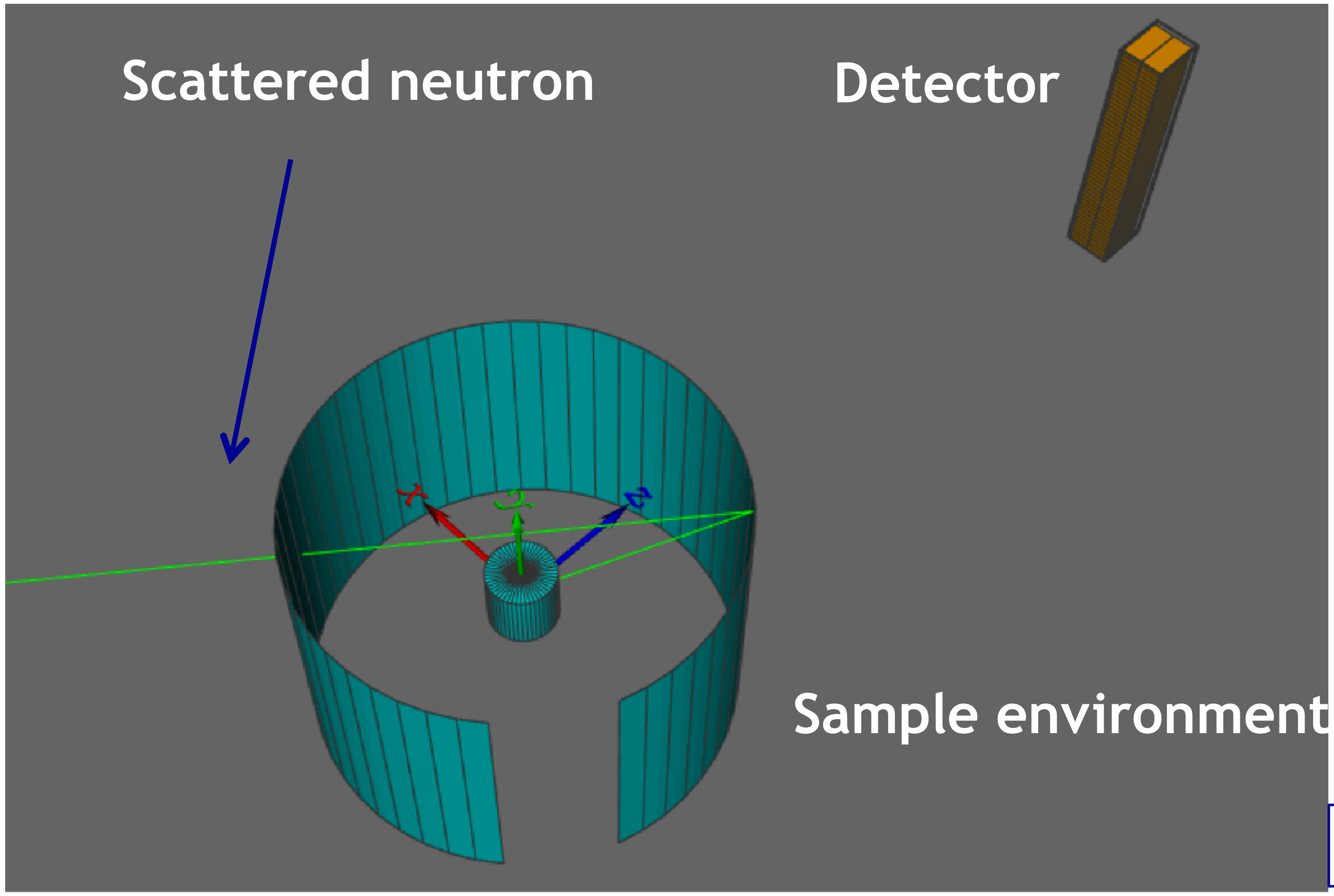
↓

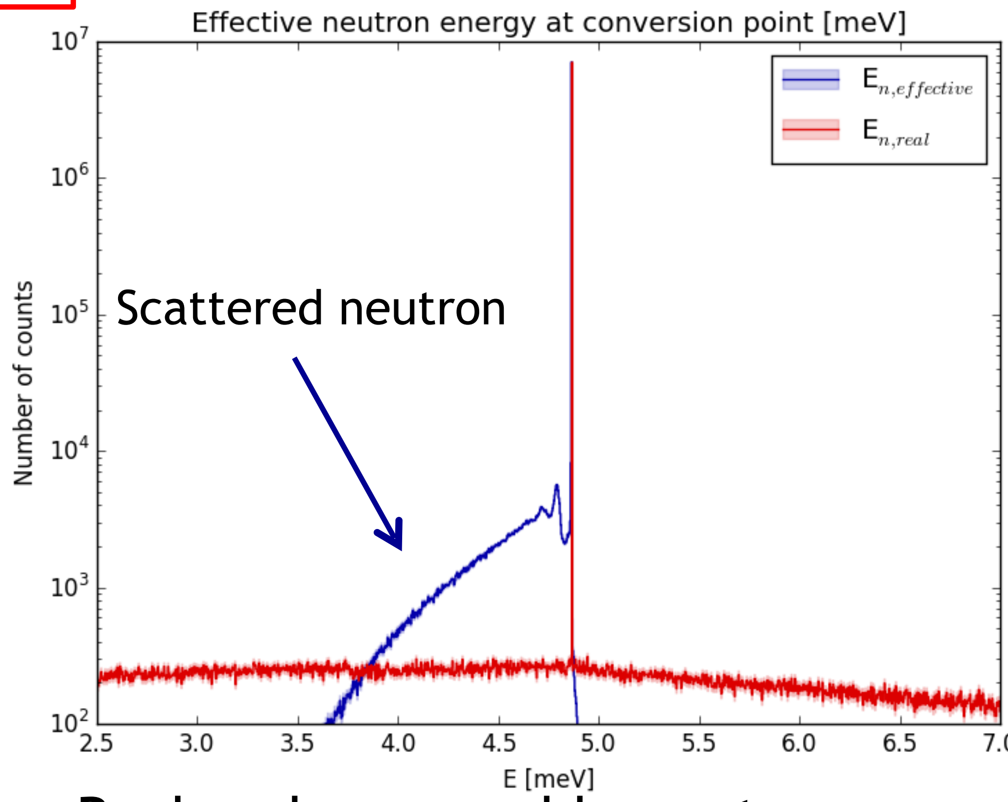
Full-scale detector model

Validation

↓

Optimization



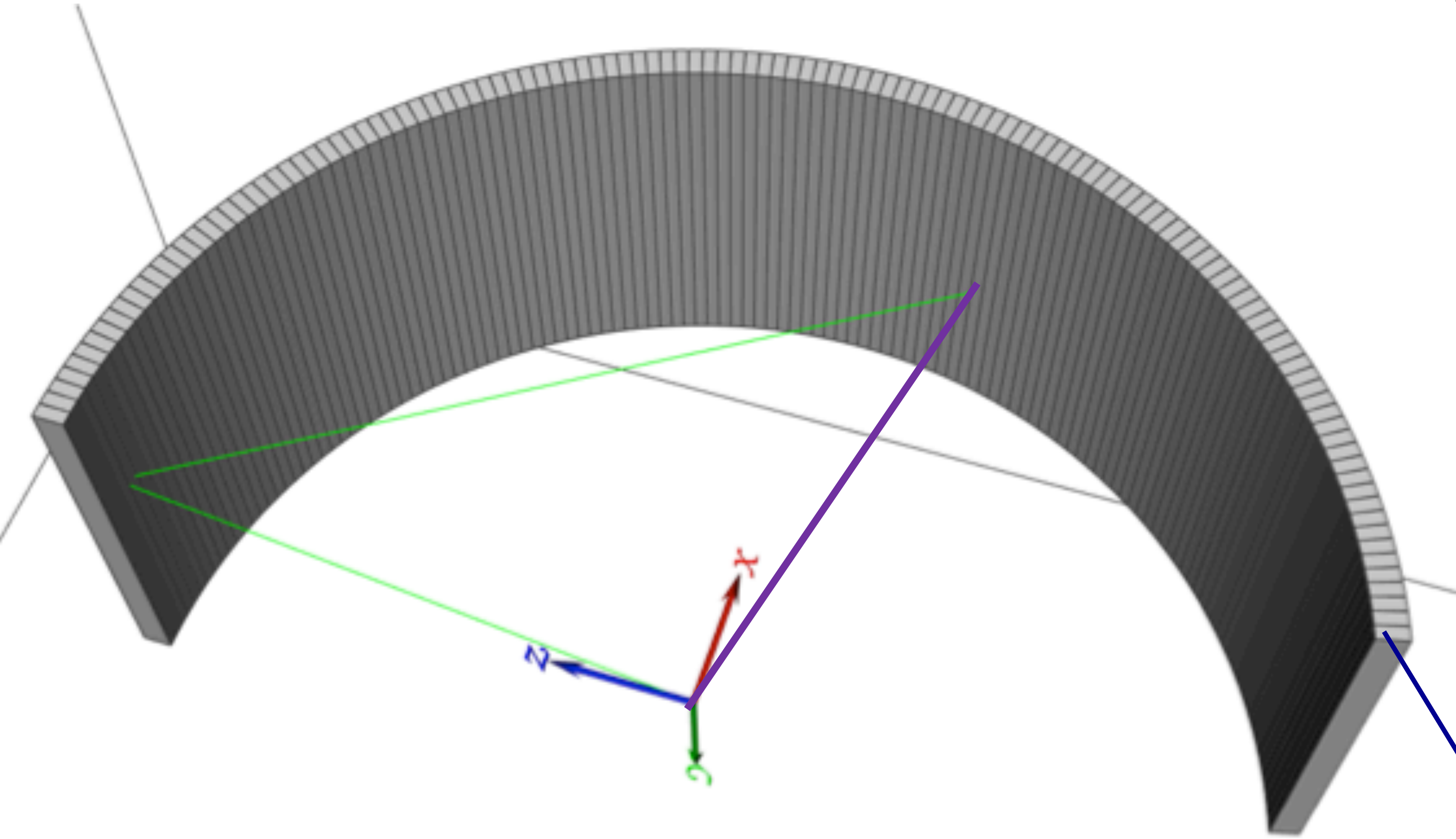


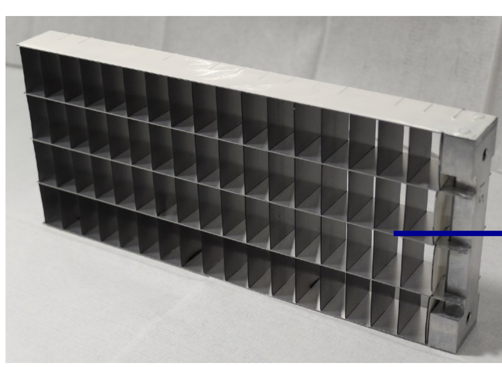
Real and measurable neutron energy

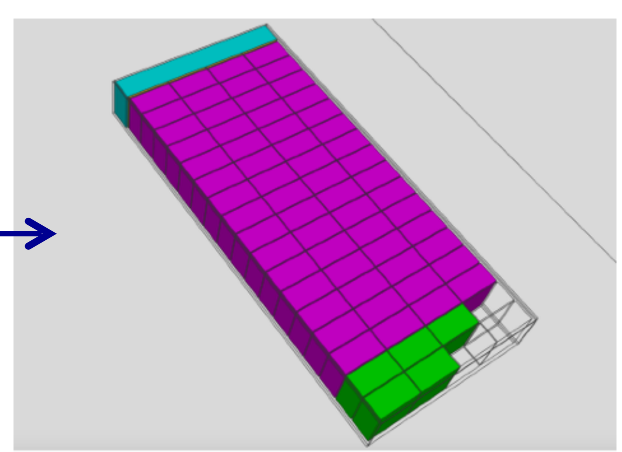
Geant4 @Coding Framework

Large area detector for chopper spectroscopy – Multi-Grid

Geant4 @Coding Framework







Multi-Grid

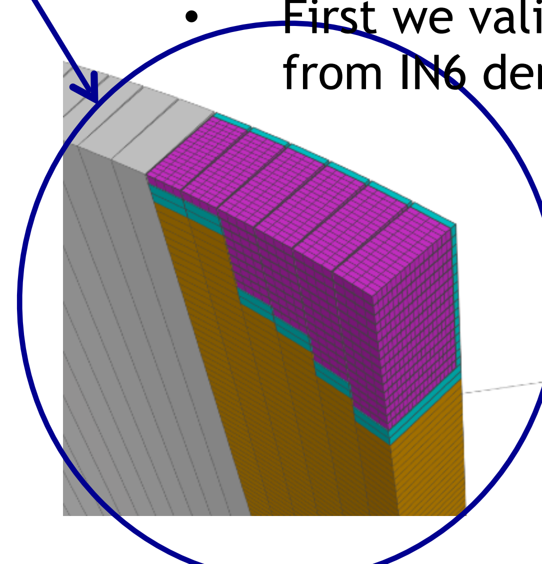
- Large area detector
- Inelastic instrument, chopper spectroscopy

Low background is essential

- Solid B_4C converter + Ar/CO_2
- Aluminium frame – **crystalline Al**

Scattered neutron background induced in detector

- First we validated simulation with data from IN6 demonstrator detector



A. Khaplanov et al.

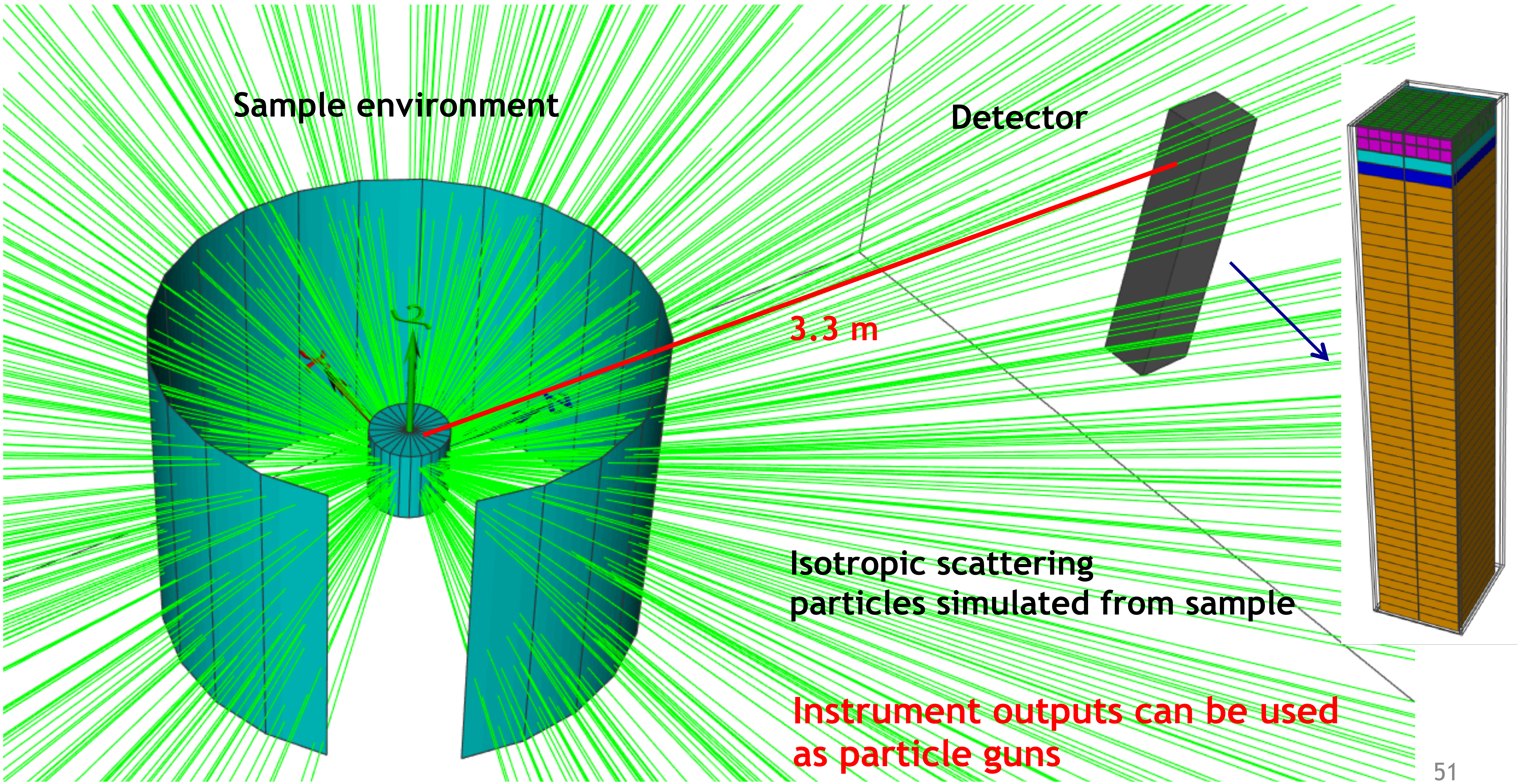
http://dx.doi.org/10.1016/j.nima.2012.12.021

Multi-Grid detector test at CNCS, SNS

EUROPEAN SPALLATION SOURCE

Geant4 @Coding Framework

NXSG4

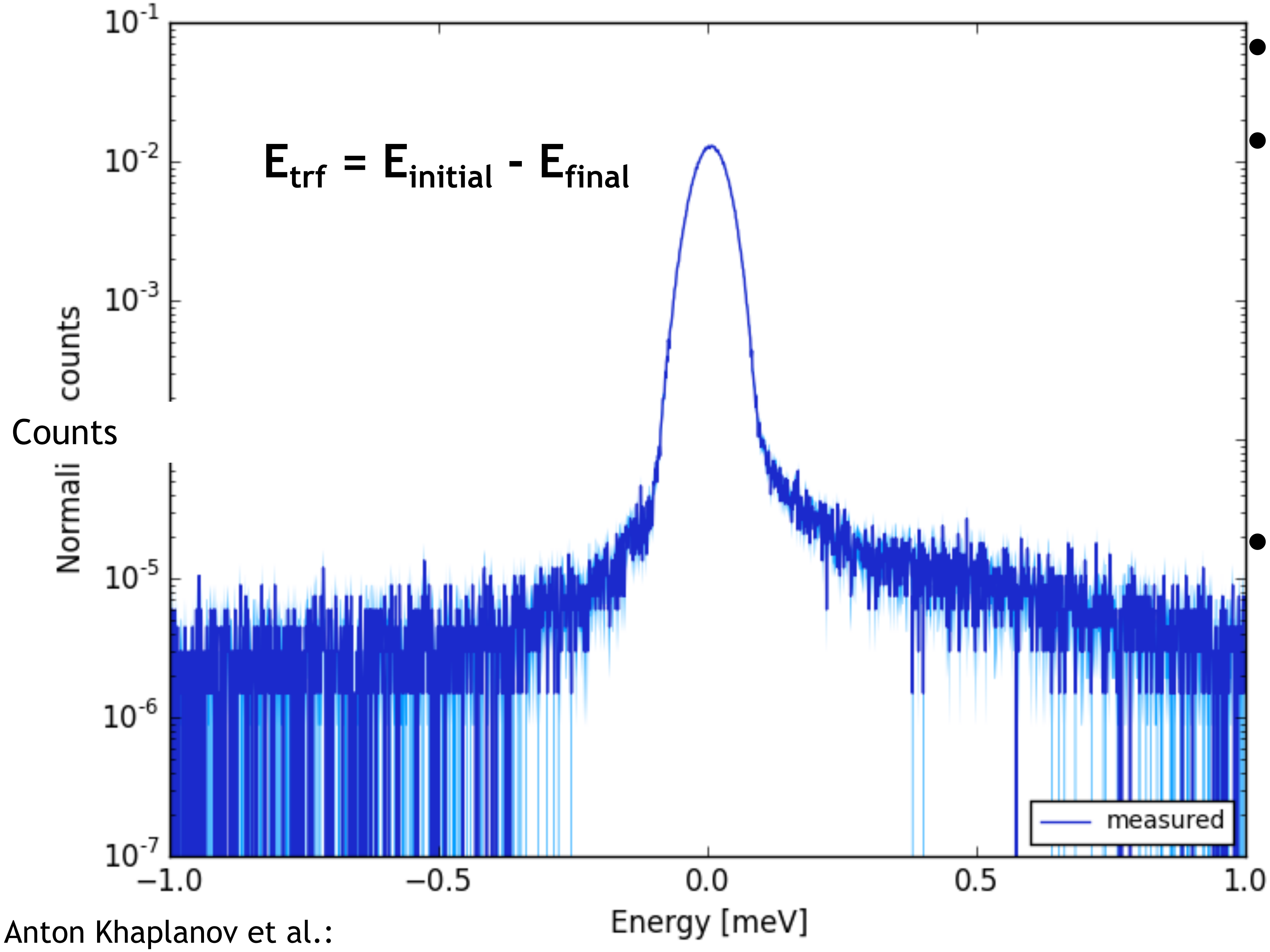


Isotropic scattering particles simulated from sample

Instrument outputs can be used as particle guns

MultiGrid detector test at CNCS, SNS

Derived energy transfer at 3.678 meV from measurement



- Chopper spectroscopy
- Measured quantities:
  - ToF
  - detection-coordinates

↓

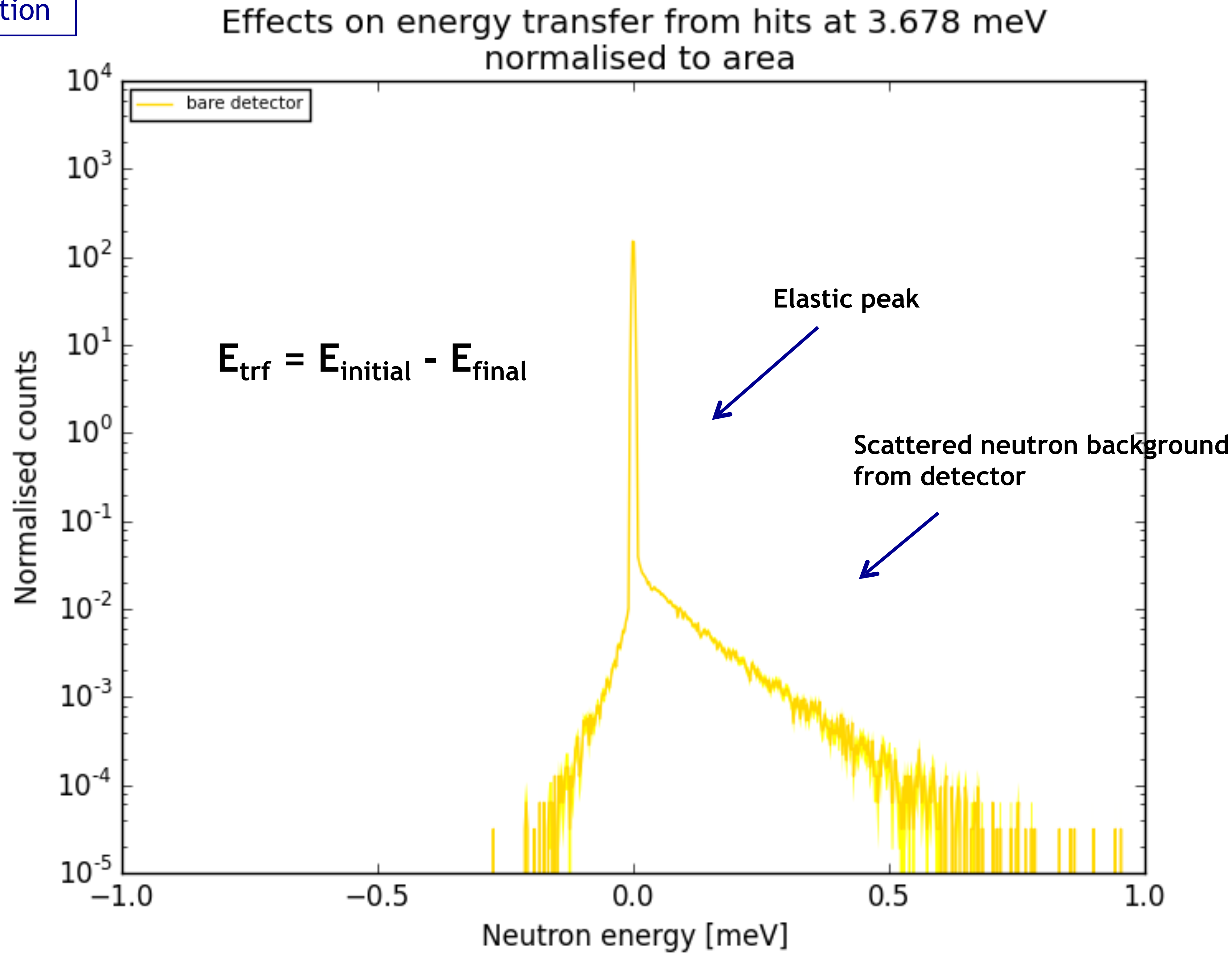
- Energy transfer:
  $E_{trf} = E_{initial} - E_{final}$

Anton Khaplanov et al.:
Multi-Grid Detector for Neutron Spectroscopy: Results Obtained on Time-of-Flight Spectrometer CNCS
doi:10.1088/1748-0221/12/04/P04030, https://arxiv.org/abs/1703.03626

MultiGrid detector test at CNCS, SNS

Geant4 simulation

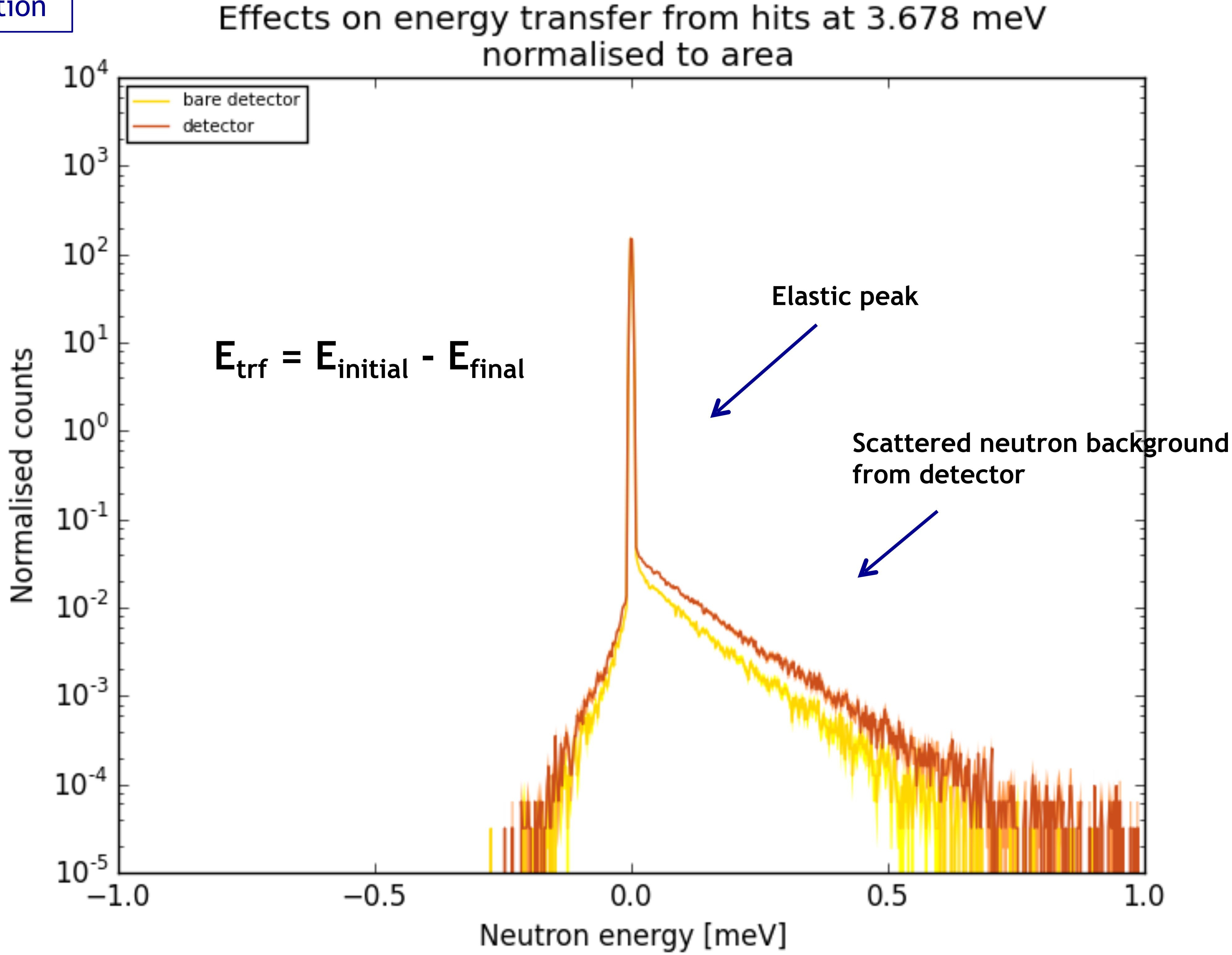
NXSG4



MultiGrid detector test at CNCS, SNS

Geant4 simulation

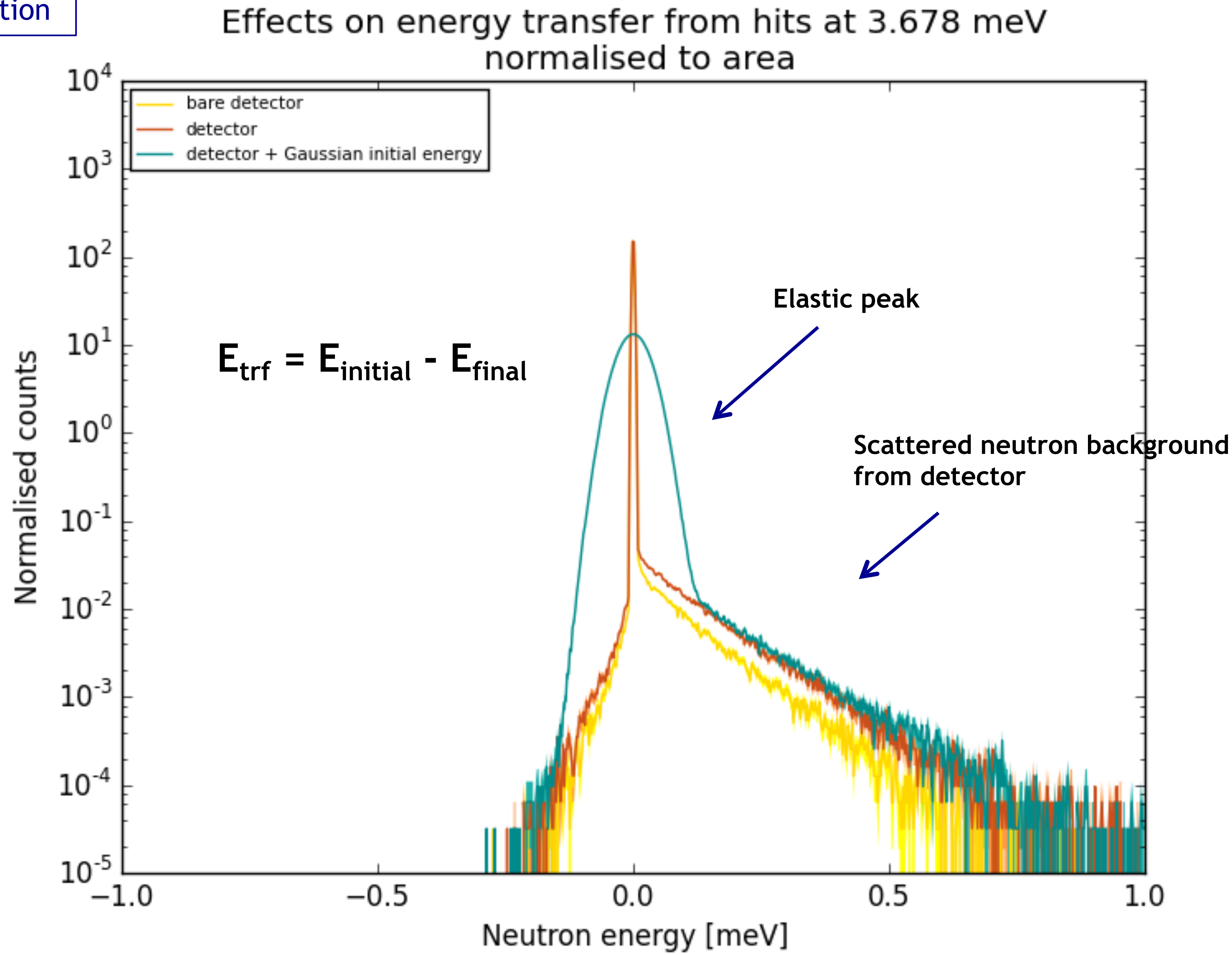
NXSG4



MultiGrid detector test at CNCS, SNS

Geant4 simulation

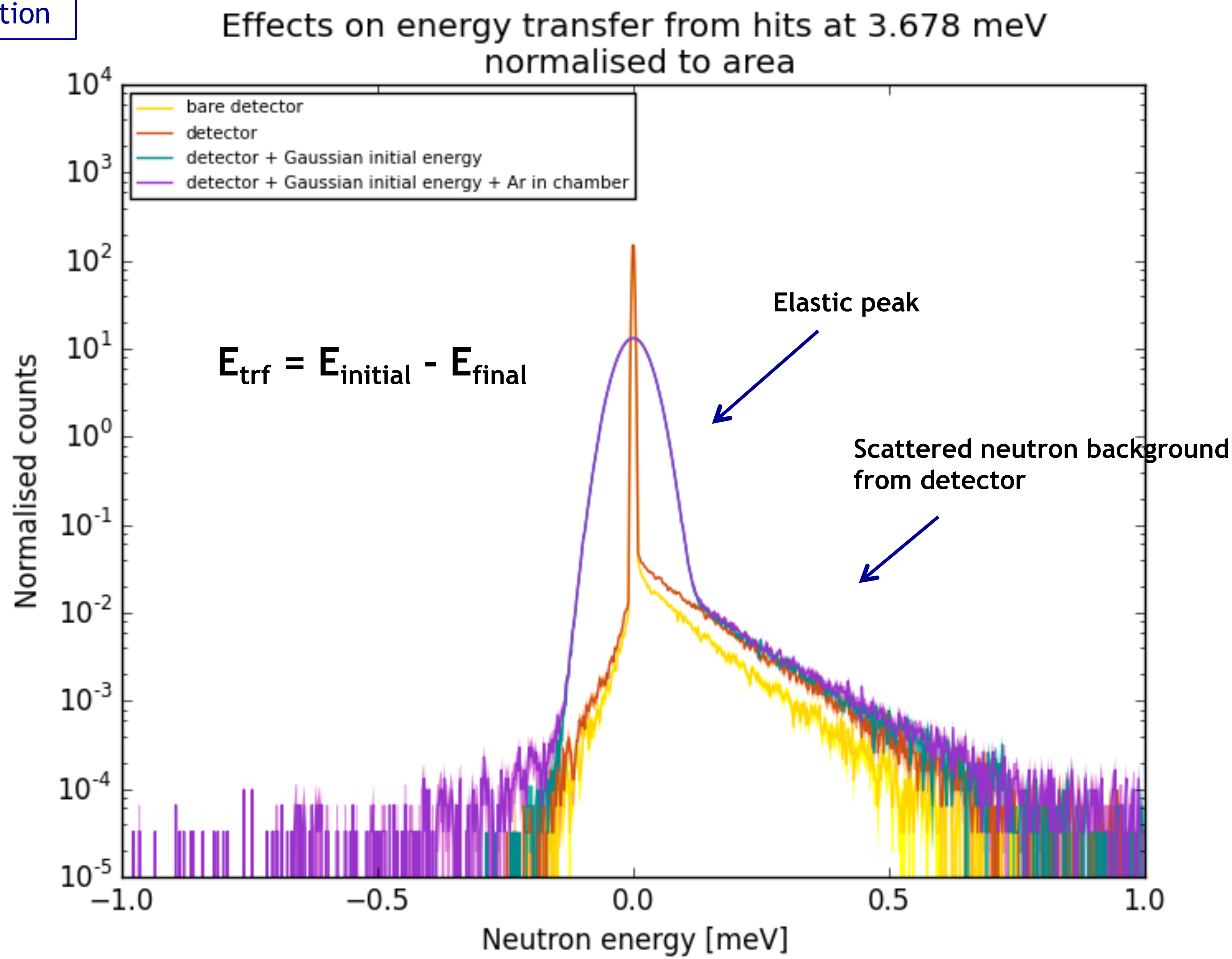
NXSG4



MultiGrid detector test at CNCS, SNS

Geant4 simulation

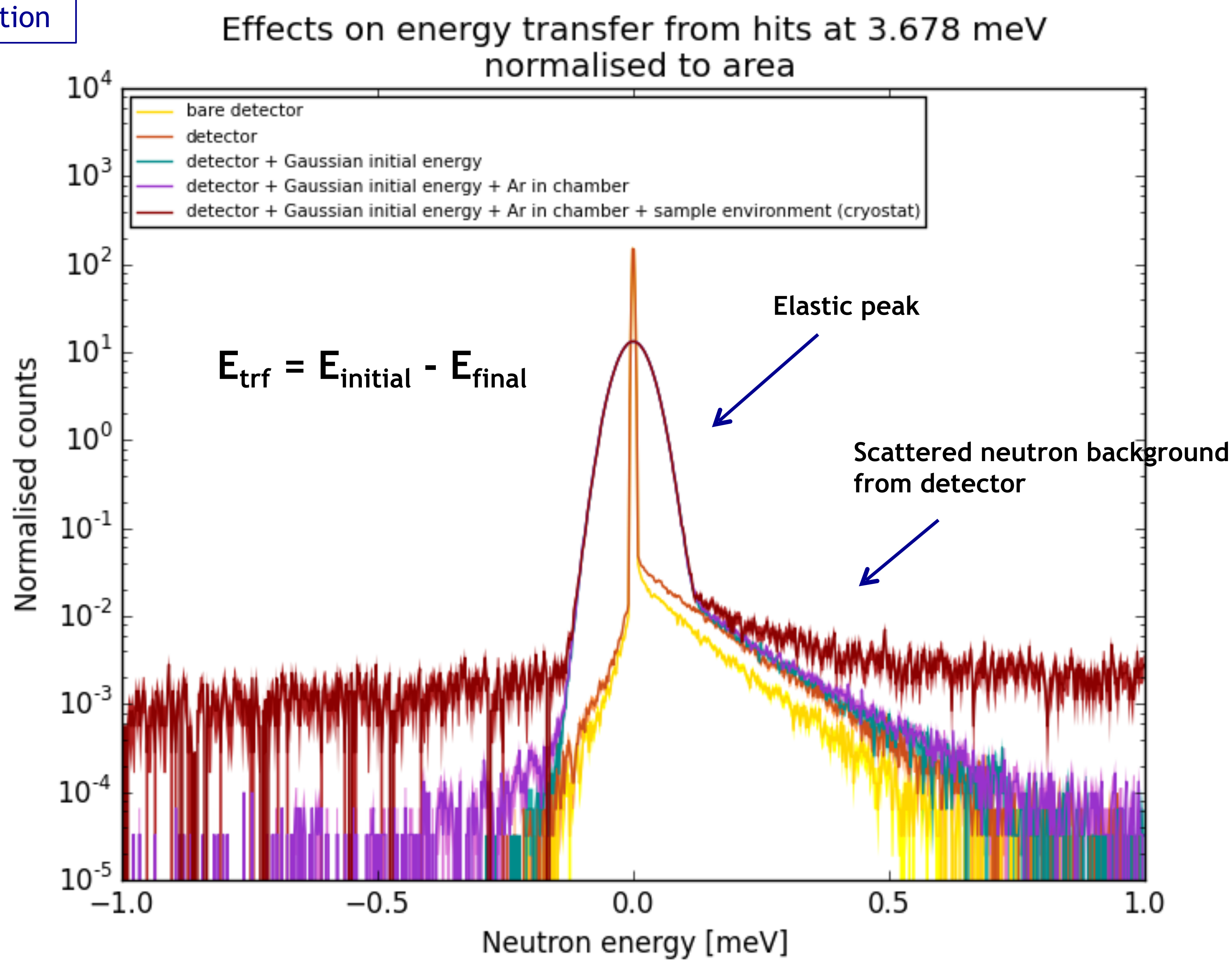
NXSG4



MultiGrid detector test at CNCS, SNS

Geant4 simulation

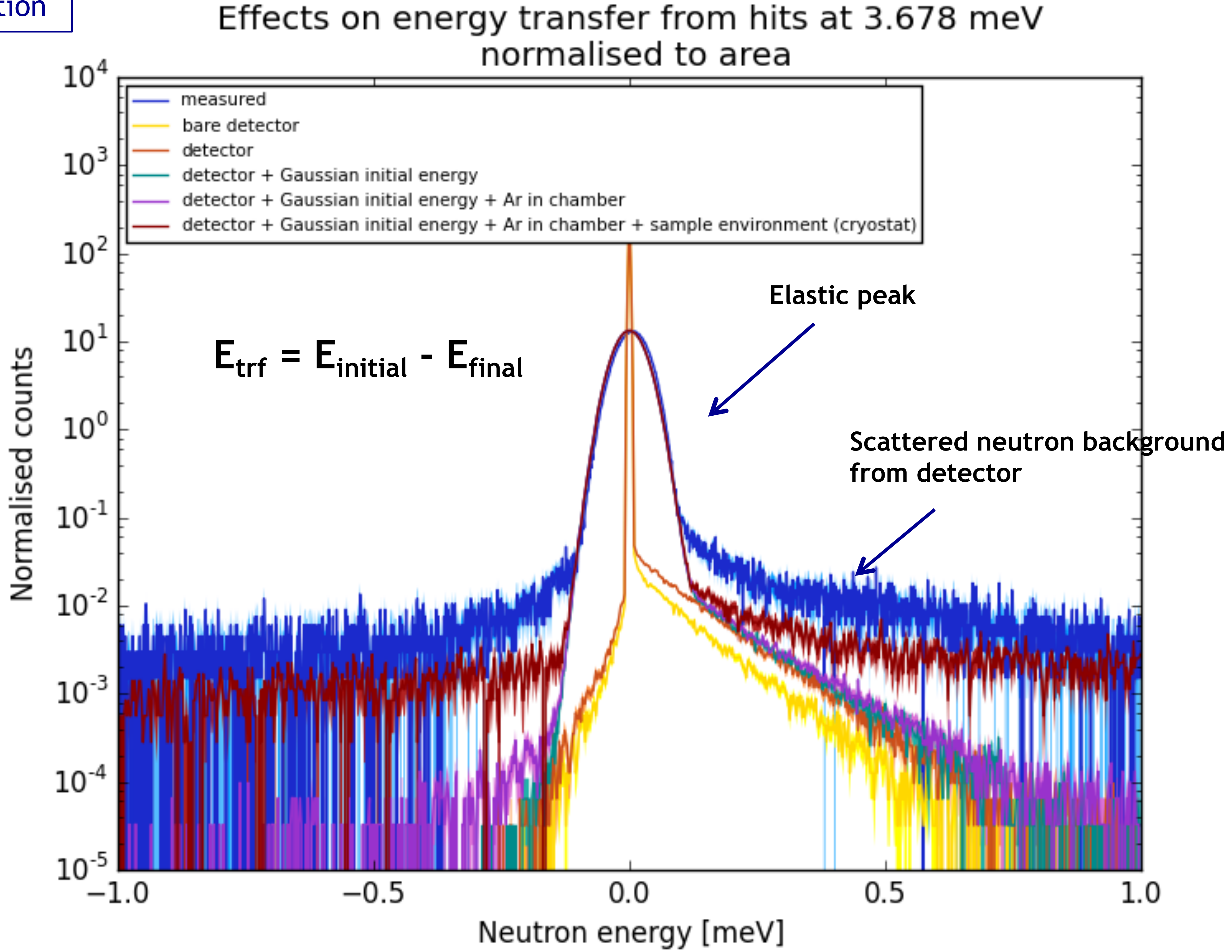
NXSG4



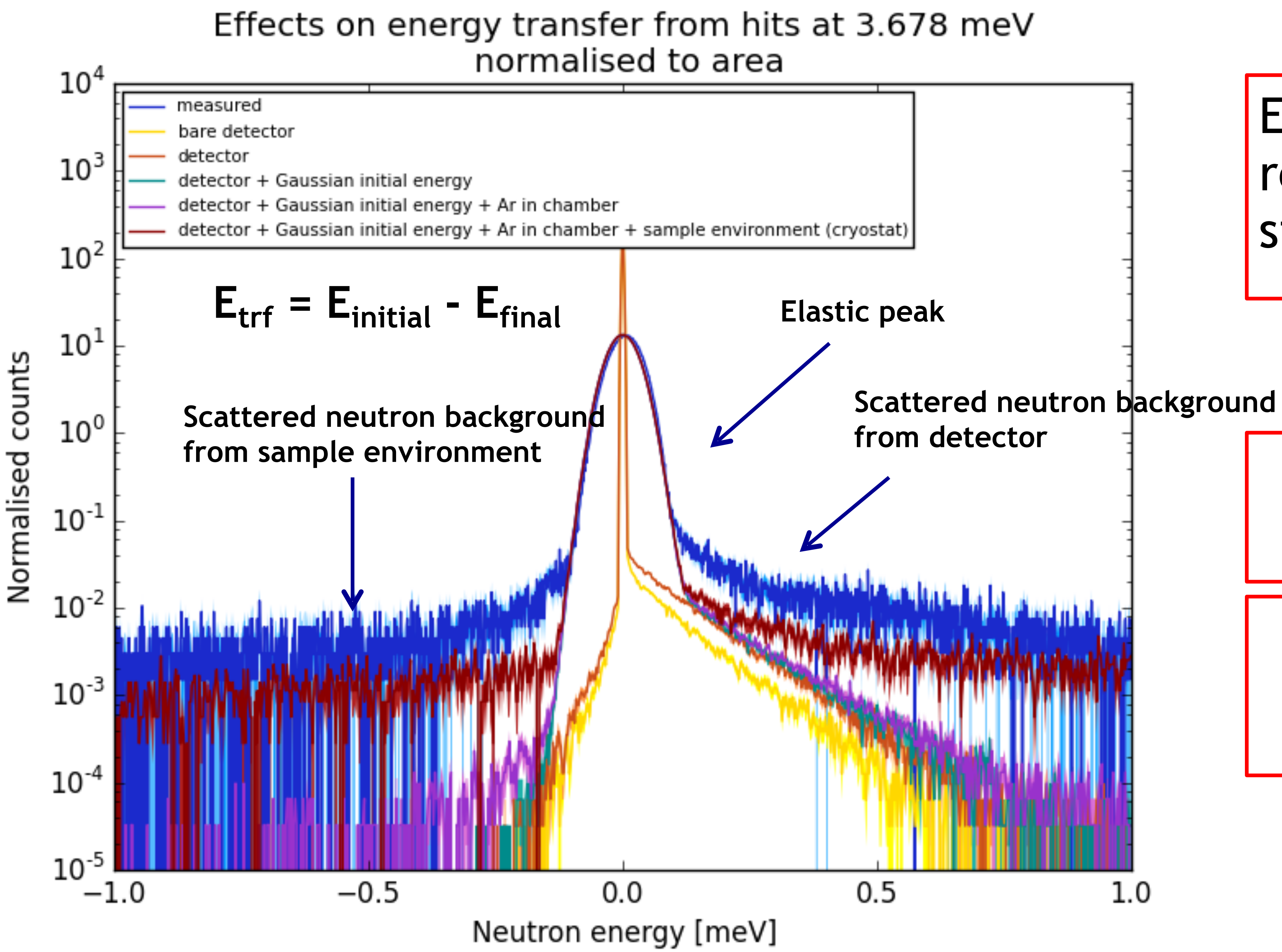
MultiGrid detector test at CNCS, SNS

Geant4 simulation

NXSG4



MultiGrid detector test at CNCS, SNS



Validation

Energy transfer reproduced with simulation at 3.678 meV ✓

Distinguish different sources of background

Detailed analysis and quantification of background effects

↓

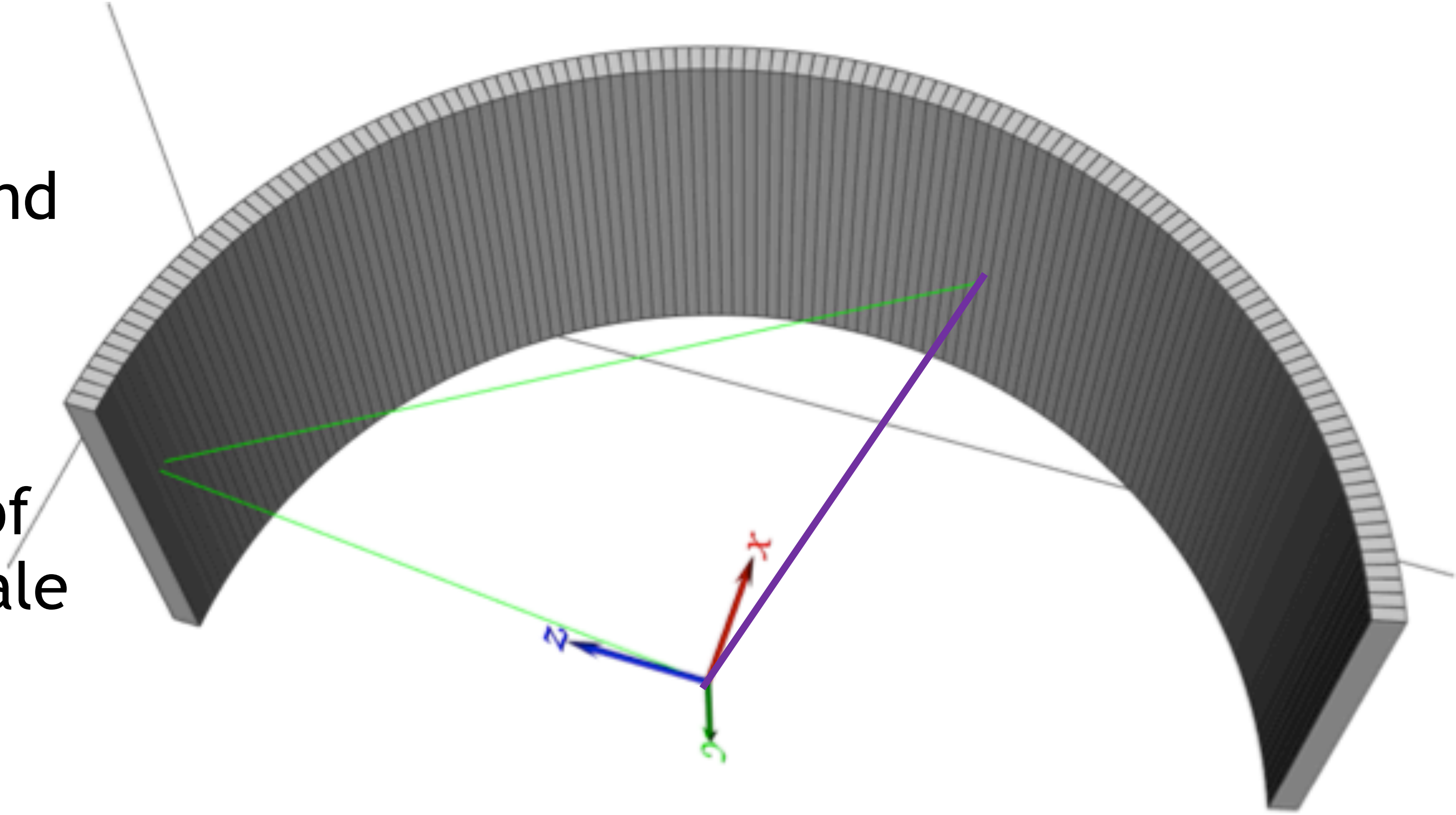
Optimization

Simulation: Conclusion

- Realistic Multi-Grid model built
  - reproduced measured results from IN6 and CNCS experiments
- Ready to use for optimization

Instruments with better signal-to-background ratio by design

- Predicament for background sources and levels in full-scale detector
- Shielding and design optimization in the level of grids, columns and full-scale detector



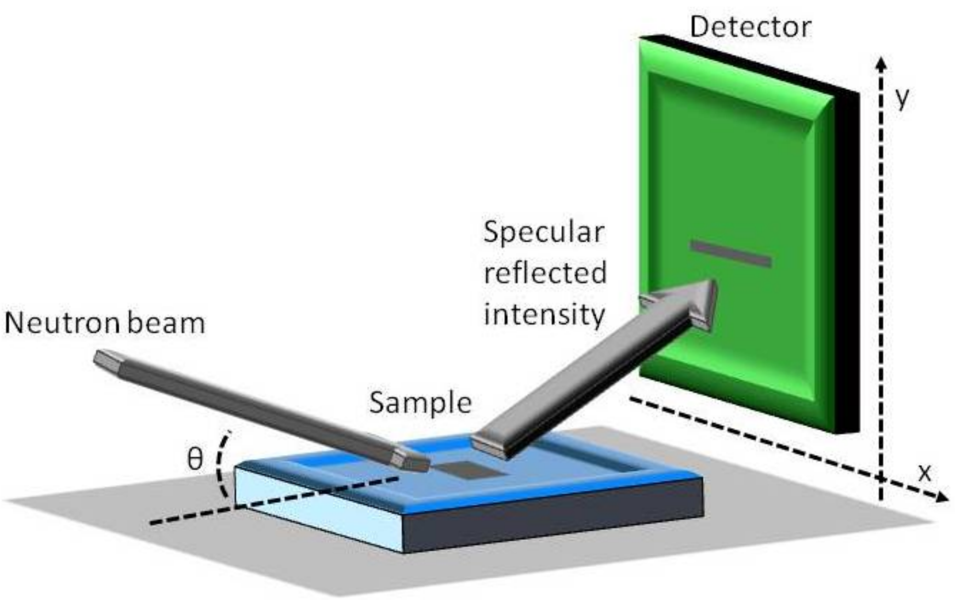
Neutron Reflectometry: A Rate Challenge

brightness

NEUTRONS FOR SCIENCE

EUROPEAN SPALLATION SOURCE

- Rate requirements is high:
  - Intensity of new sources
  - Time structure of pulse
  - Advanced design instruments



ESS requirements

area $(mm \times mm)$	spatial resolution $(mm \times mm)$	global rate (s^{-1})	local rate $(s^{-1}mm^{-2})$
500×500	$[\leq 0.5, 2] \times 2$	$[5, 100] \cdot 10^5$	$[5, 300] \cdot 10^2$

x10 x100

The state of the art

area $(mm \times mm)$	spatial resolution $(mm \times mm)$	global rate (s^{-1})	local rate $(s^{-1}mm^{-2})$
500×500	1×2	$100 \cdot 10^5$	300

^{3}He technology

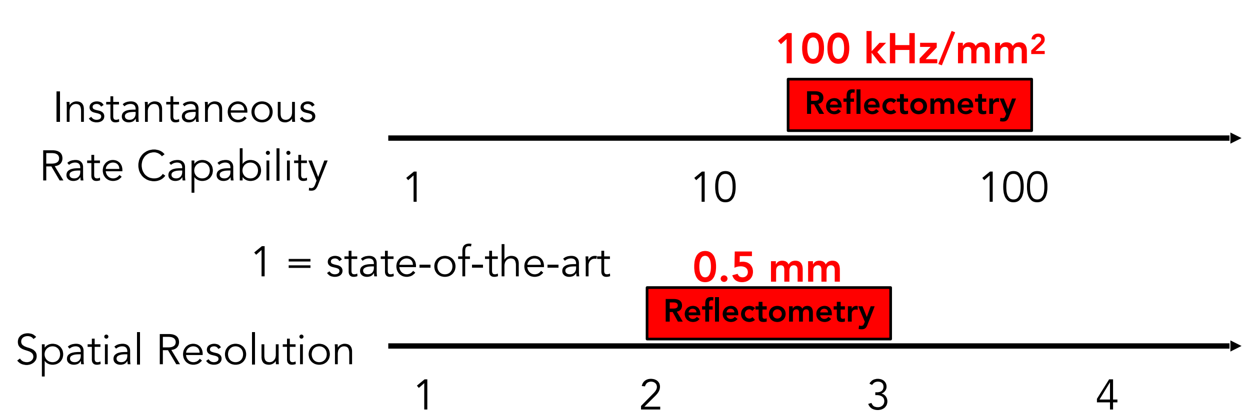
x1 x10

Multi-Blade

area $(mm \times mm)$	spatial resolution $(mm \times mm)$	global rate (s^{-1})	local rate $(s^{-1}mm^{-2})$
	0.3 x 4		>1000

^{10}B technology

High detector requirements



Multi-blade design:
- High rate capability
- Sum-mm resolution

The Multi-Blade project

High counting rate capability

High spatial resolution

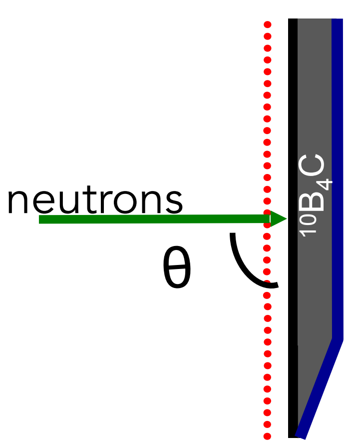
A single Boron layer inclined at 5 degrees

Multi–Blade

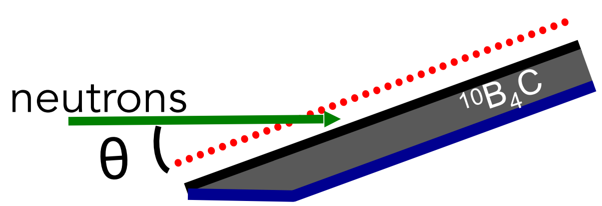
^{10}B-detector for reflectometers

Efficiency <5% at 2.5Å

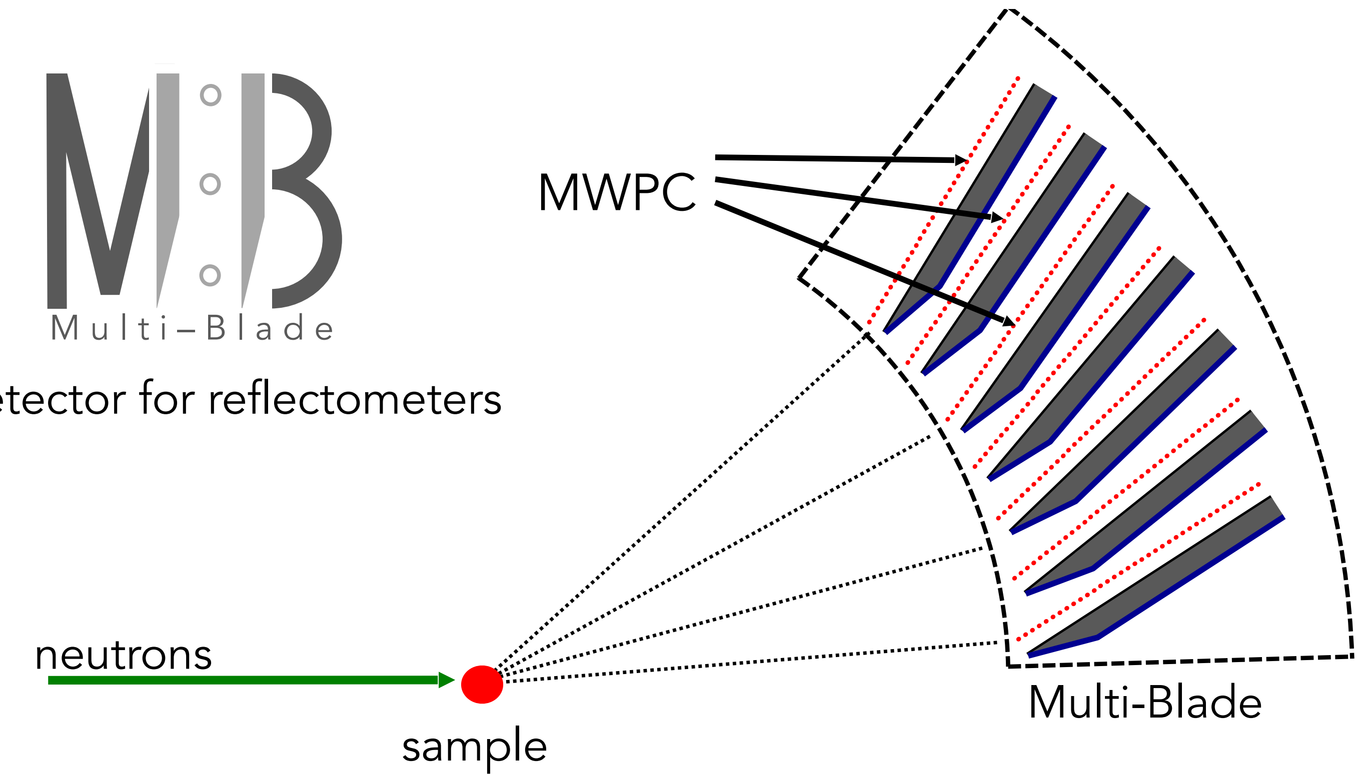
Efficiency 45% at 2.5Å

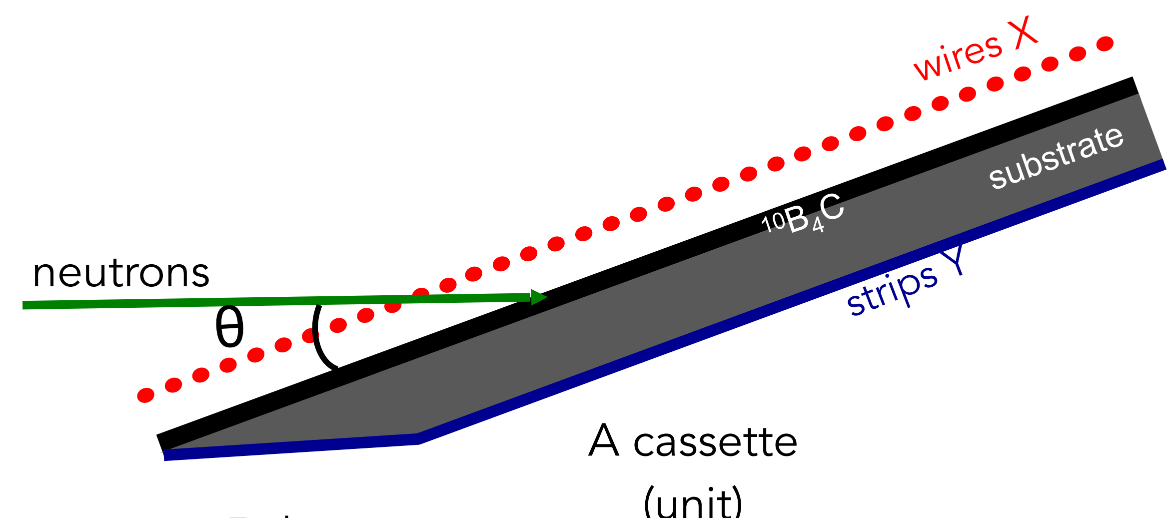


θ = 90 degrees



θ = 5 degrees





θ = 5 degrees

The Multi-Blade project

High counting rate capability

High spatial resolution

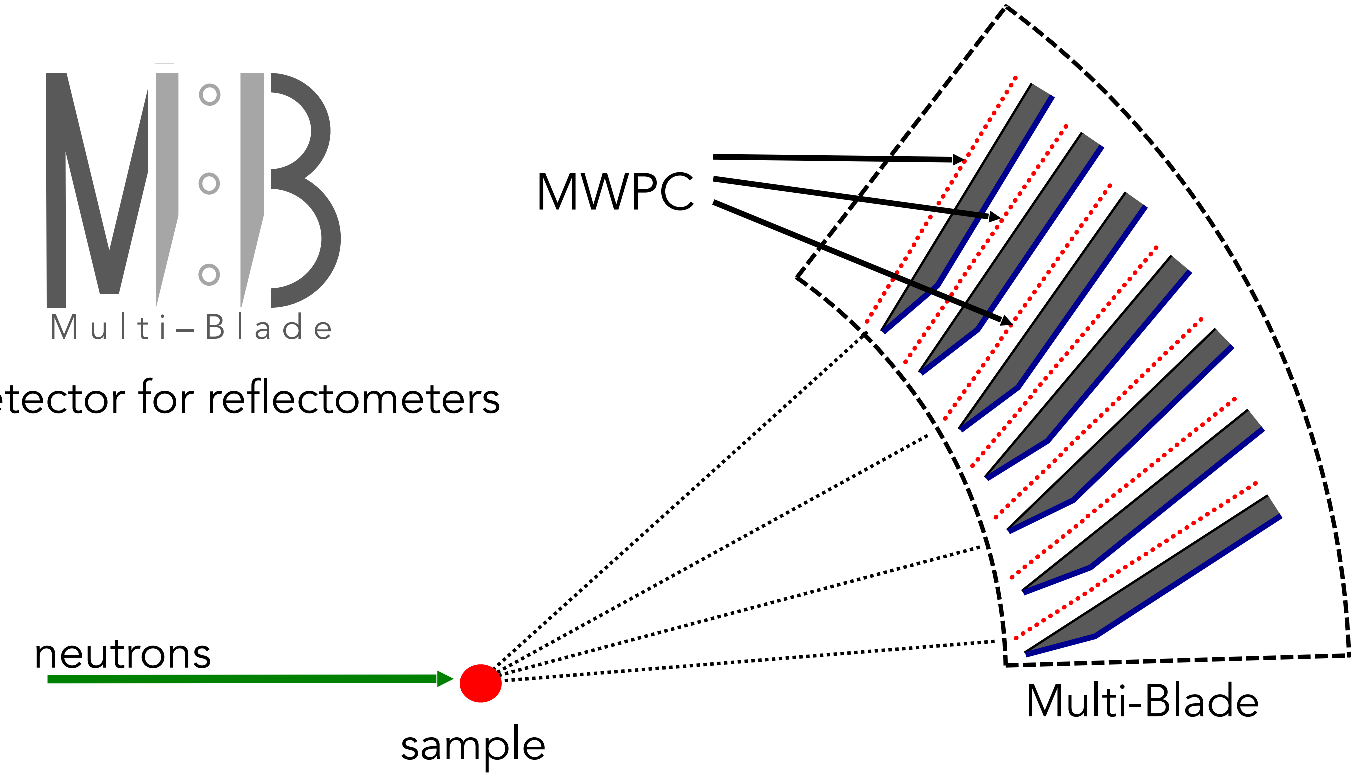
Why the counting rate capability is improved?

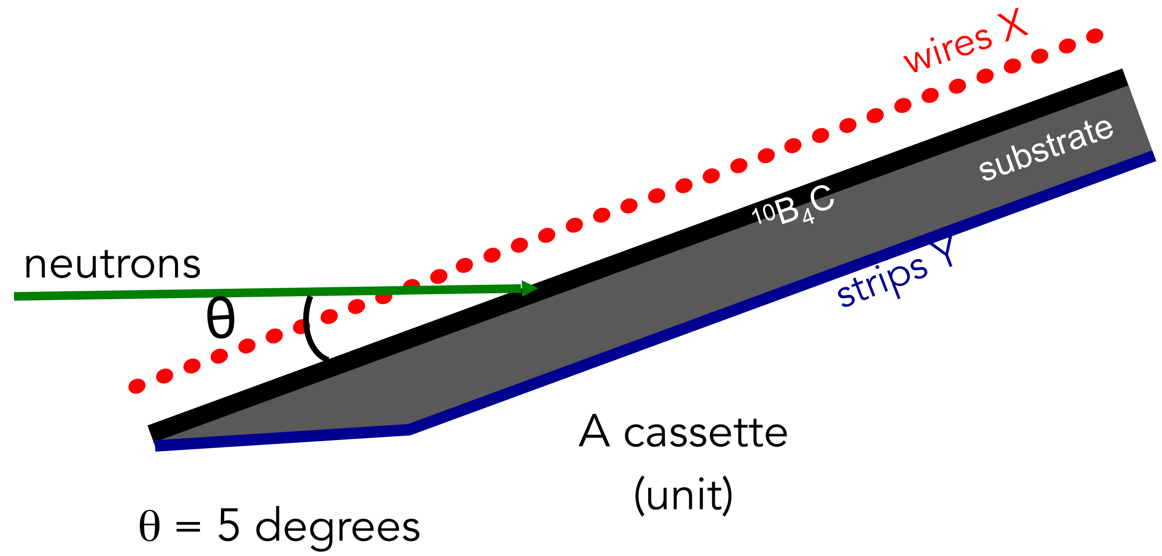
^{10}B-detector for reflectometers

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

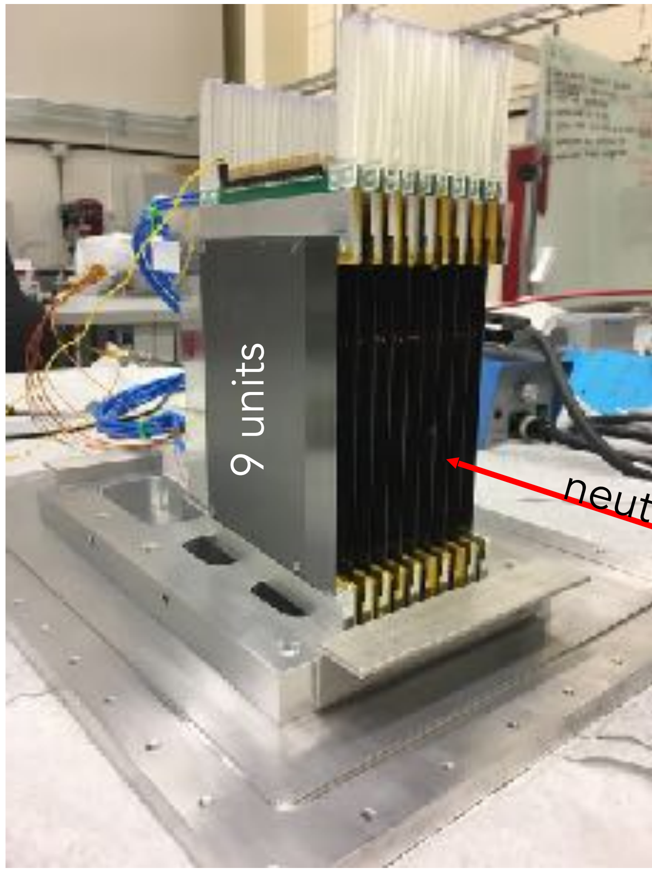
2. Thin gap MWPC (4mm)

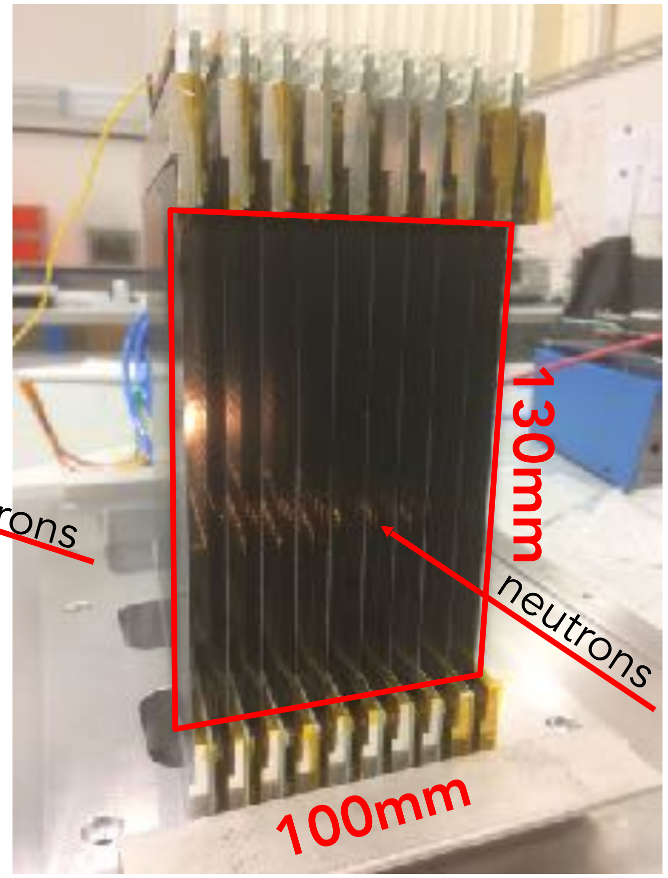
3. Low gas gain operation G~20 (max 0.2pC avalanches)

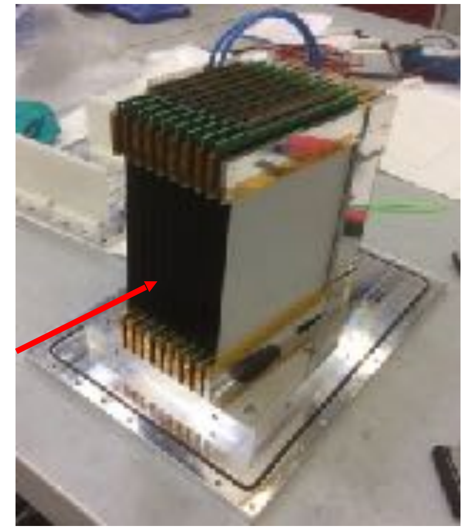




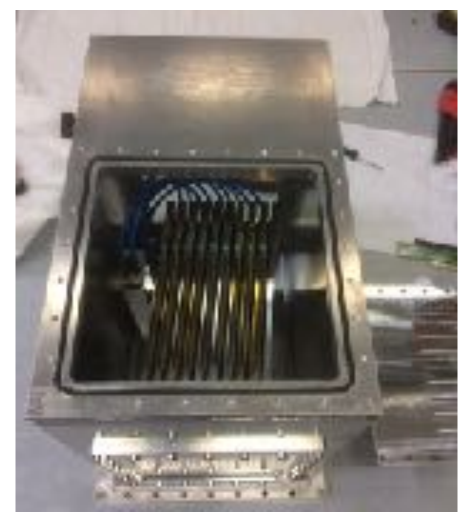
The Multi-Blade project



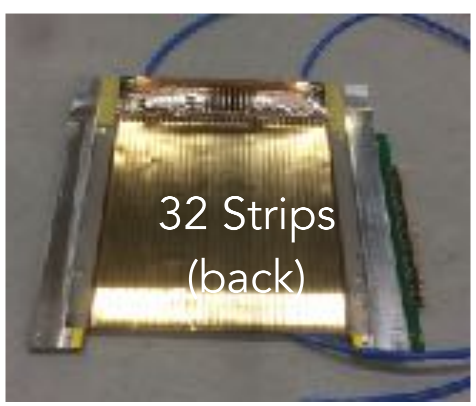


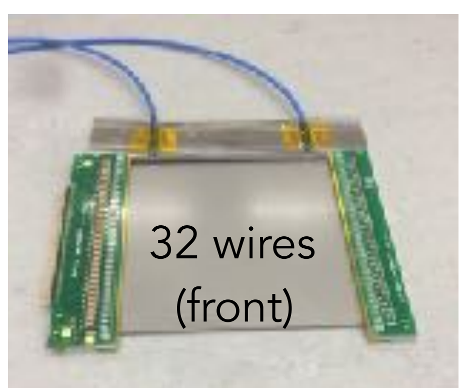


vessel



32 ch
front-end board





Summary

	Multi-Blade
gas gain	20
efficiency	45% @ 2.5Å 56% @ 4.2Å 65% @ 5.1Å
spatial resolution	0.5 x 2.5 mm^2
uniformity	10%
overlap	50% eff. drop in 0.75mm gap
stability	<1% in 12h
counting rate capability	>1.6 kHz/mm2 (lower limit) >17kHz / channel (lower limit)
gamma-ray sensitivity	< 10^{-7} (with 100keV threshold)

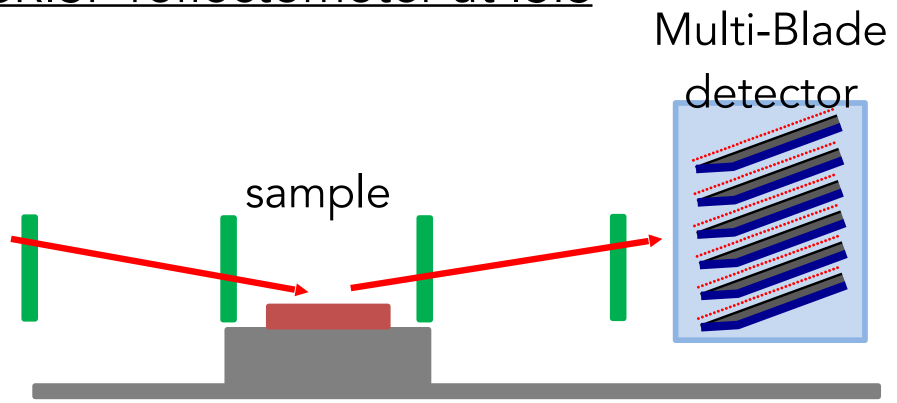
Matching ESS requirements

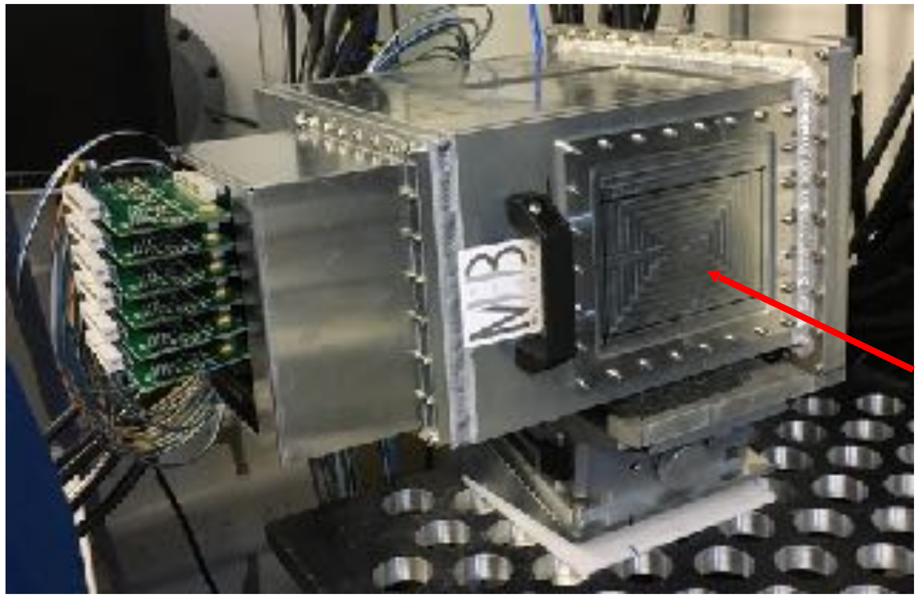
x3 better than state-of-the-art

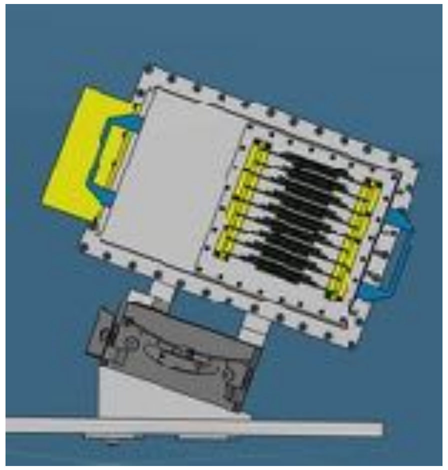
x10 better than state-of-the-art

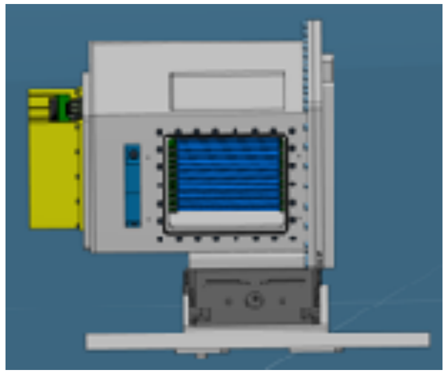
F. Piscitelli et al., The Multi-Blade Boron-10-based Neutron Detector for high intensity Neutron Reflectometry at ESS, JINST 12 (3) P03013 (2017).

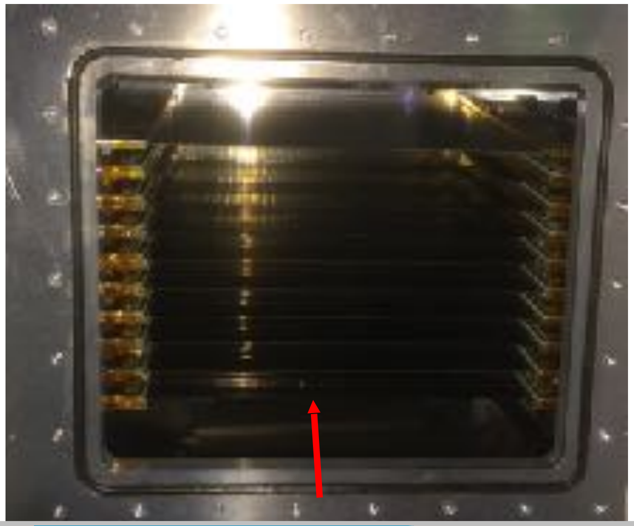
CRISP reflectometer at ISIS

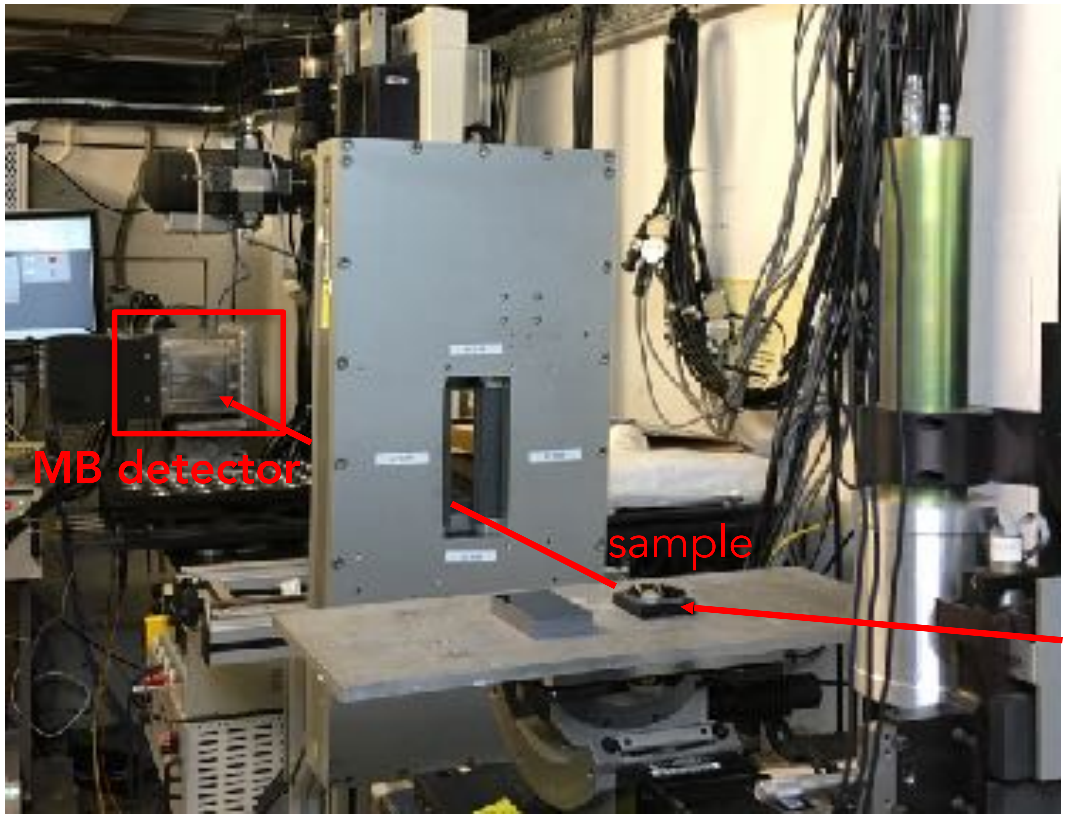


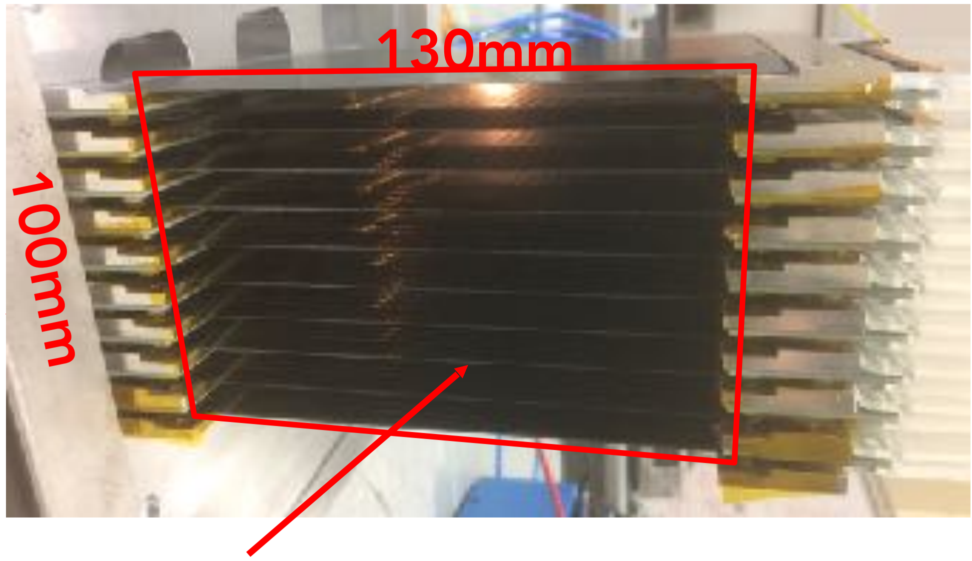




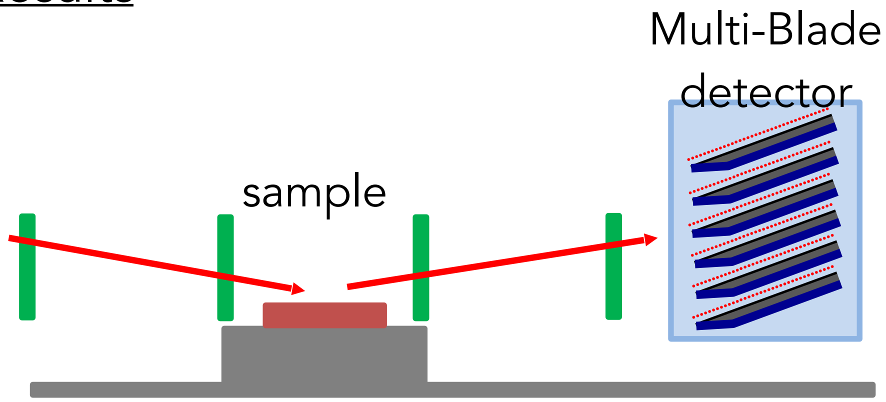


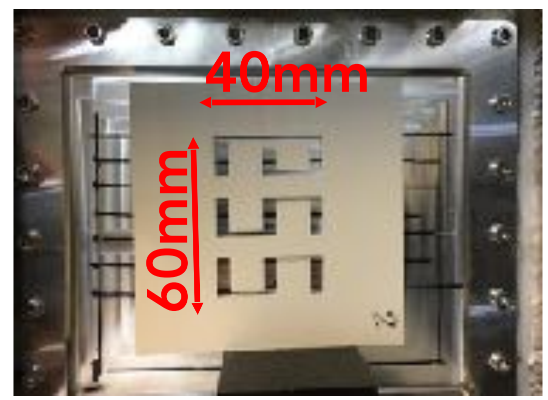


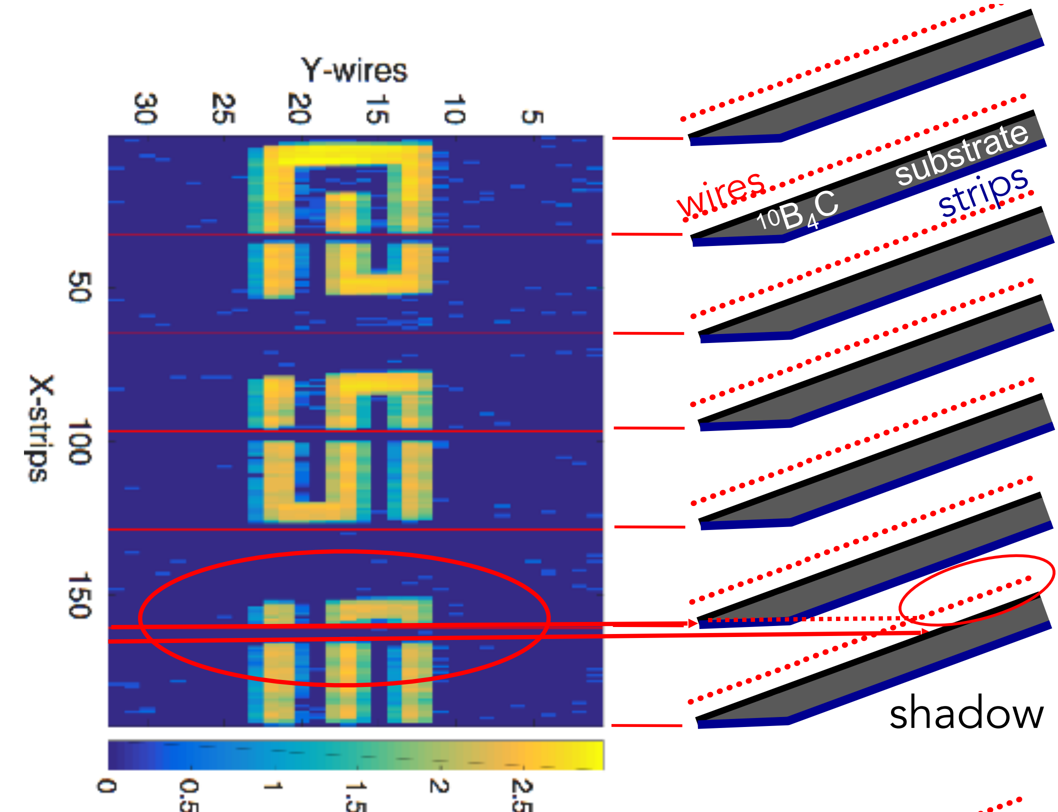


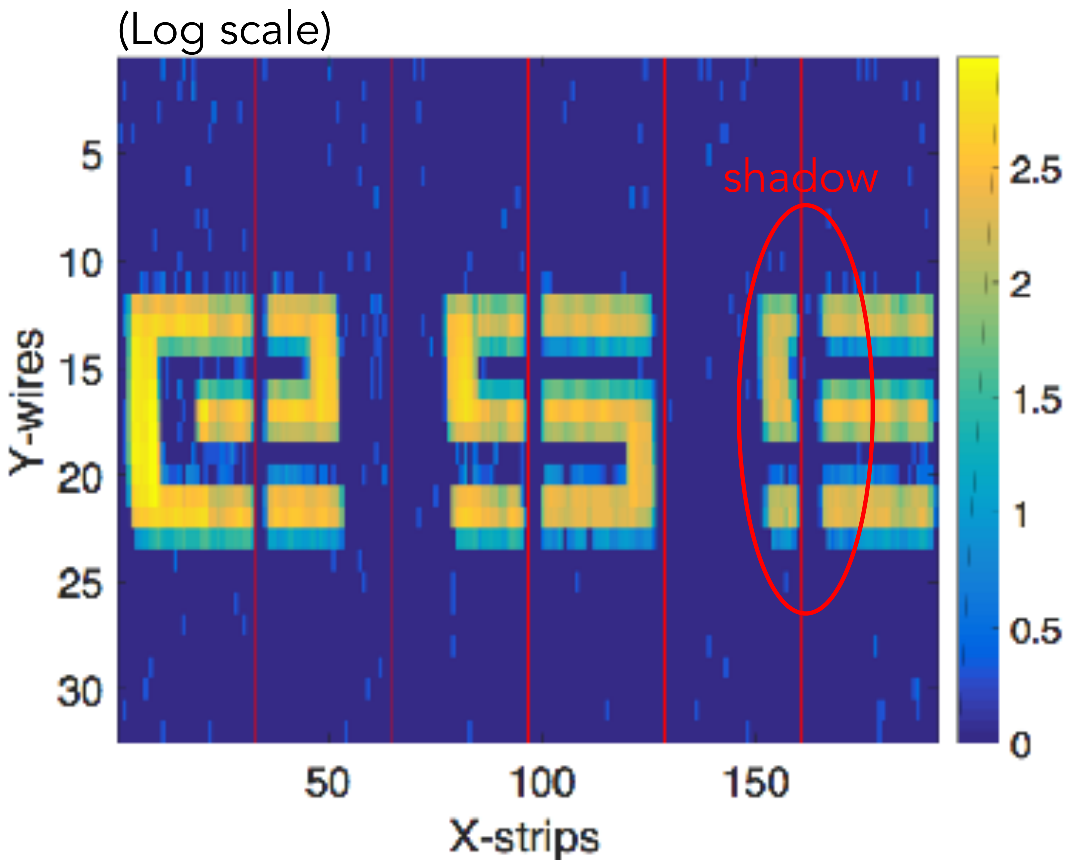


Results

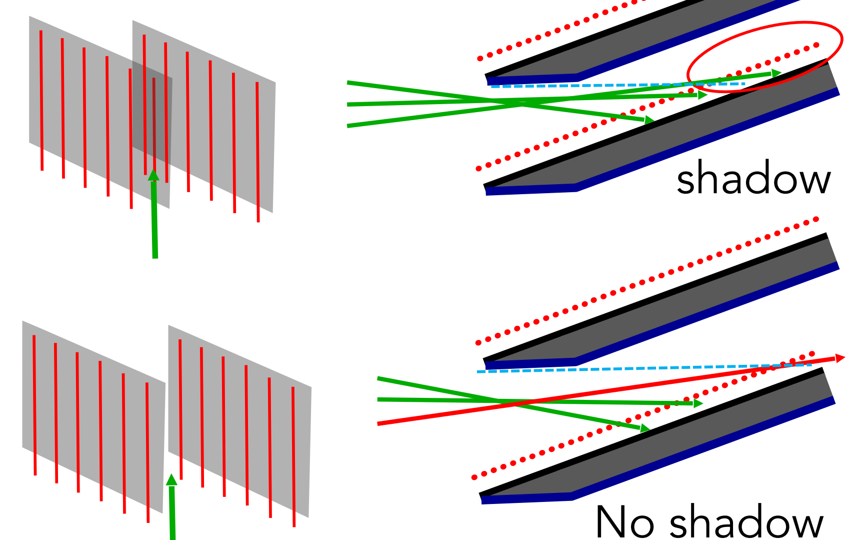




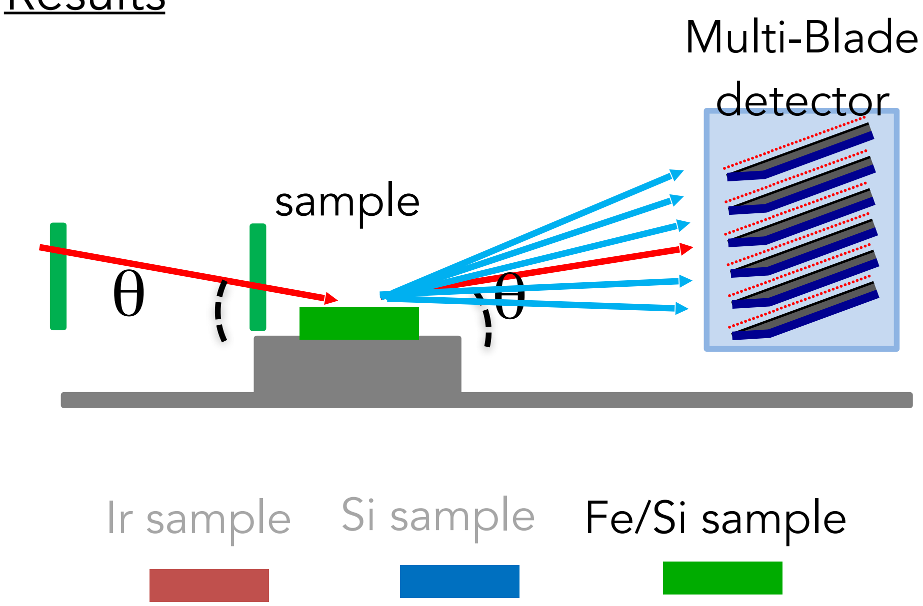


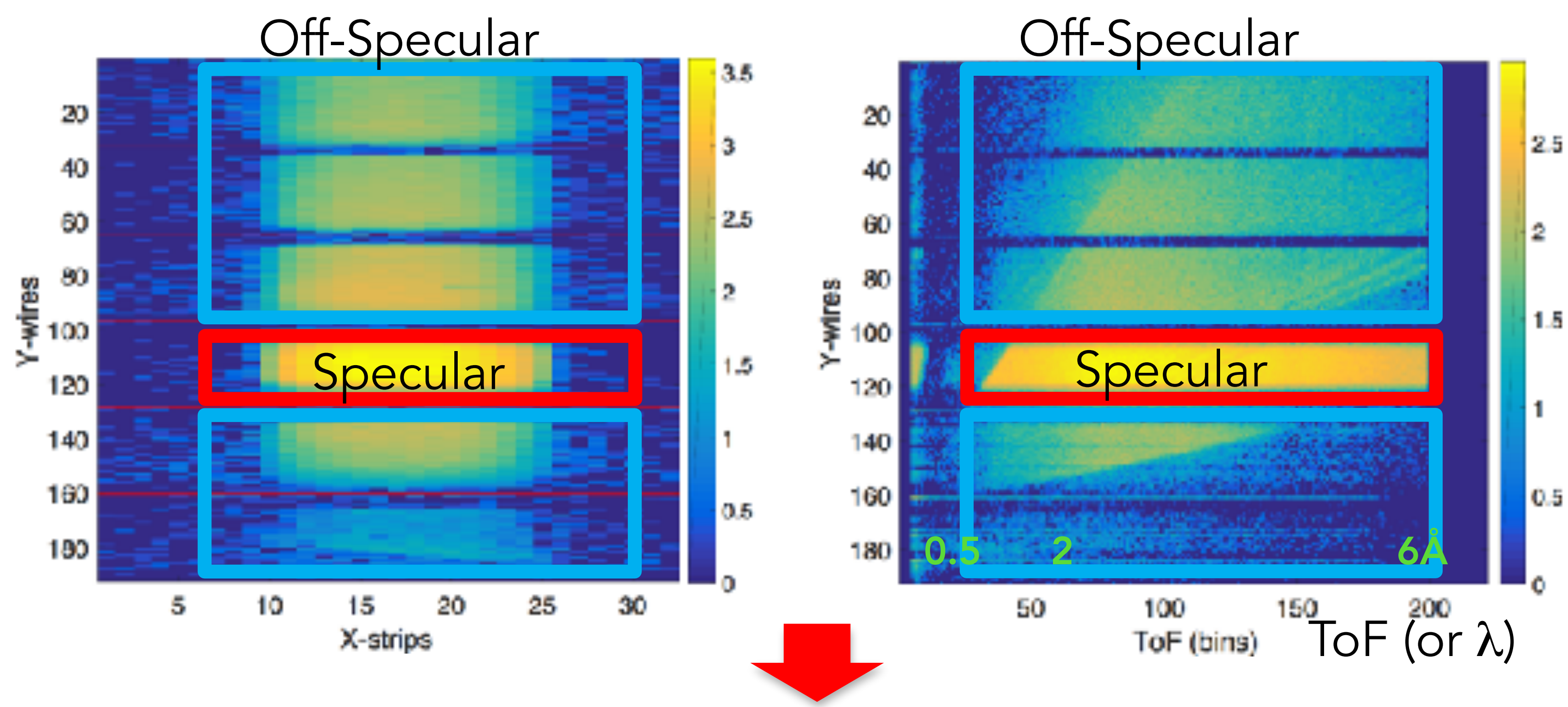


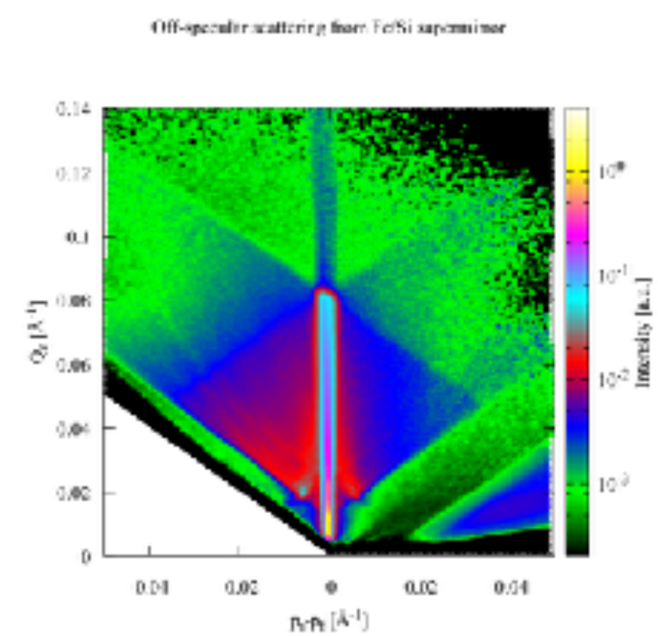
Not a dead area but the overlap avoids dead zones



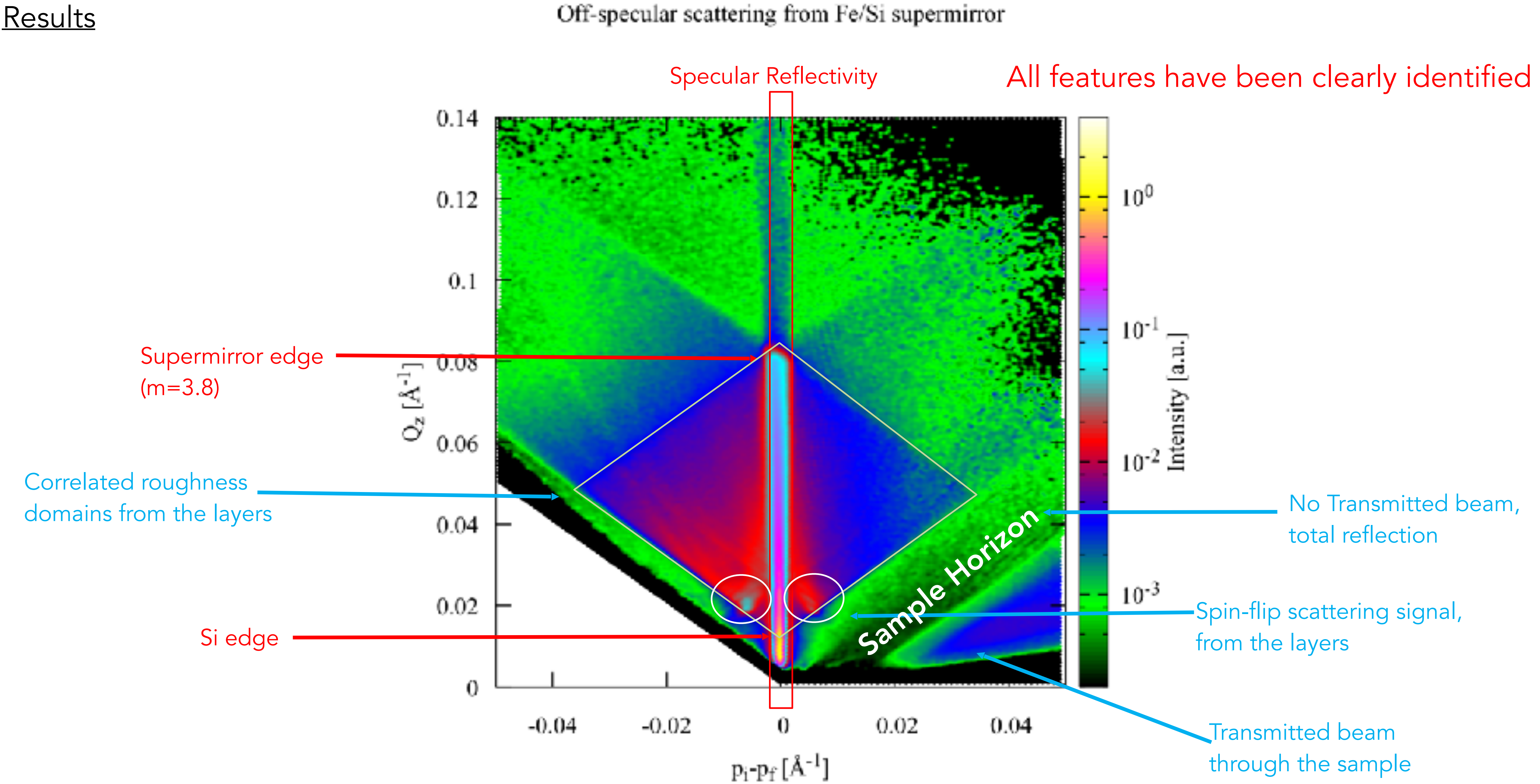
Results


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


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



Results



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

Why are we here?

Summary

****Need to be > x100 better on rate capability****

Matching ESS requirements

	Multi-Blade
gas gain	20
efficiency	45% @ 2.5Å 56% @ 4.2Å 65% @ 5.1Å
spatial resolution	0.5 x 2.5 mm^2
uniformity	10%
overlap	50% eff. drop in 0.75mm gap
stability	<1% in 12h
counting rate capability	>1.6 kHz/mm2 (lower limit) >17kHz / channel (lower limit)
gamma-ray sensitivity	< 10^{-7} (with 100keV threshold)

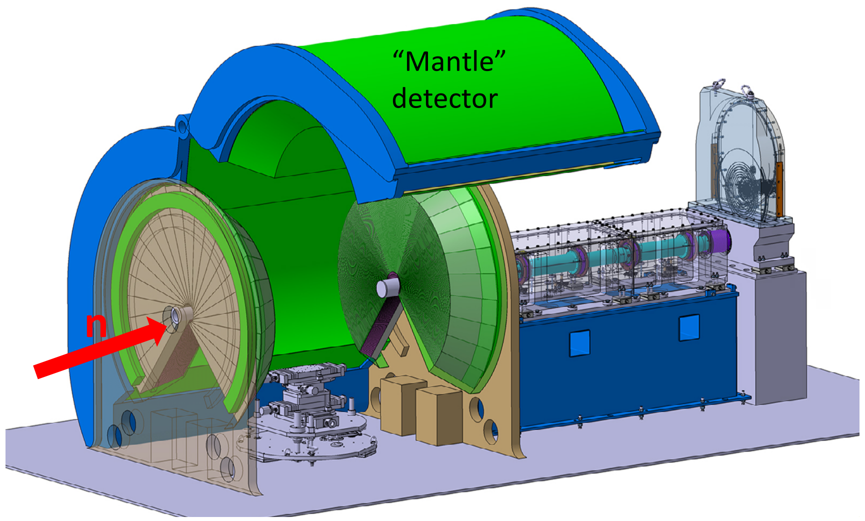
x3 better than state-of-the-art (spatial resolution)

x10 better than state-of-the-art (counting rate capability)

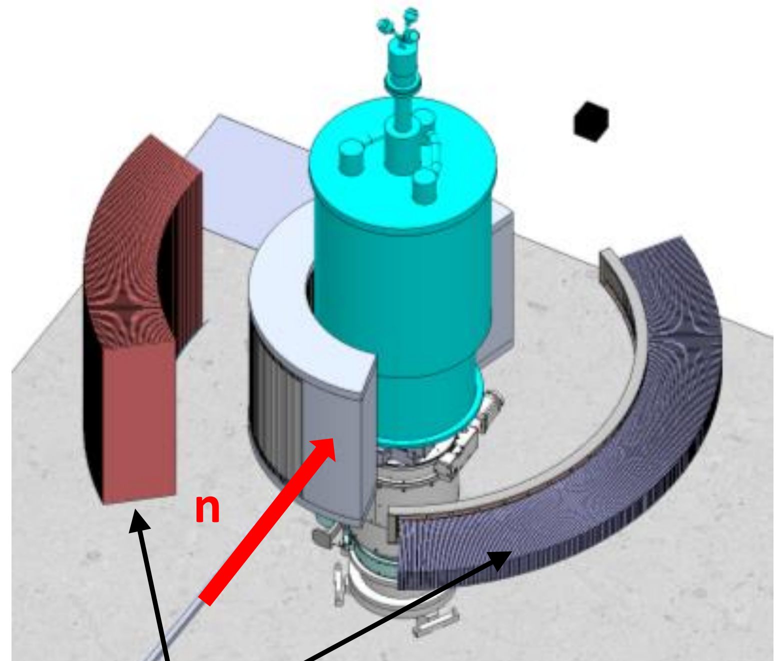
F. Piscitelli et al., The Multi-Blade Boron-10-based Neutron Detector for high intensity Neutron Reflectometry at ESS, JINST 12 (3) P03013 (2017).

The Jalousie detector

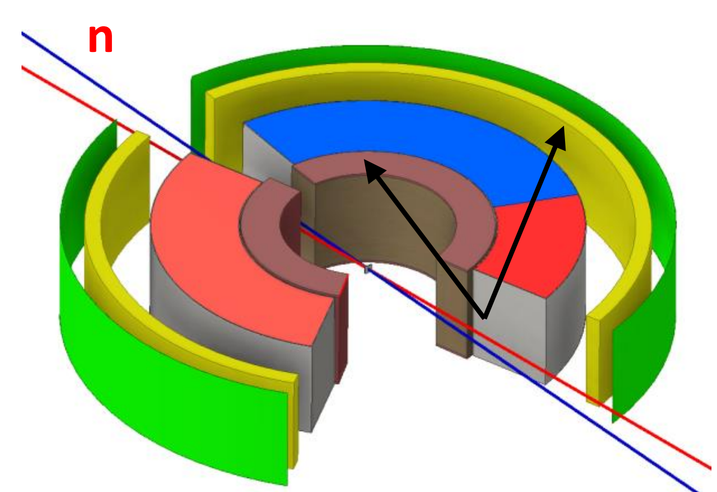
The Jalousie detector concept was developed by the company CDT in Heidelberg. The detector is based on the ^{10}B-technology.



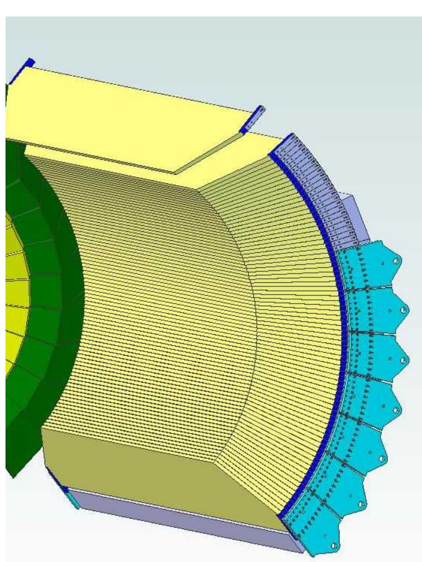
POWTEX (FRM2)/DREAM (ESS) Jalousie detector

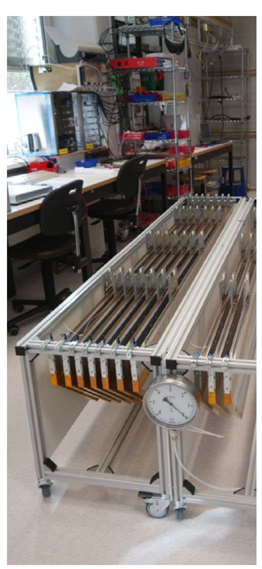


MAGIC-Jalousie detector (ESS)



HEIMDAL-Jalousie detector (ESS)





The POWTEX-Jalousie is currently under construction for the POWTEX instrument at the FRM2 research reactor (Garching).

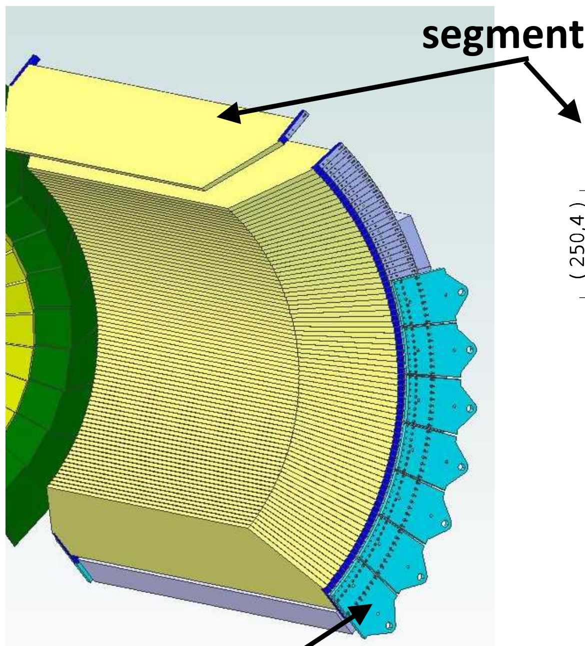
Design and construction of DREAM-Jalousie (ESS) scheduled to start in 2018.

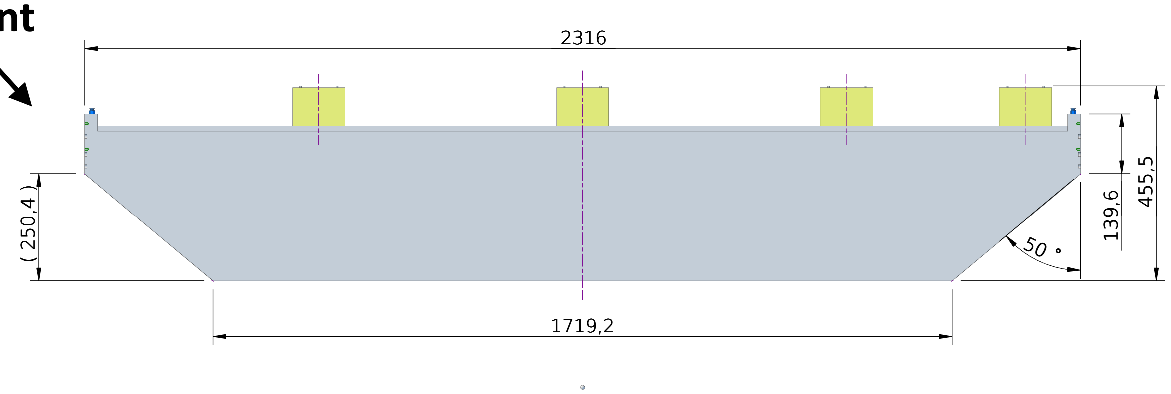
M. Henske et al., The ^{10}B-based Jalousie neutron detector – An alternative for ^{3}He-filled position sensitive counter tubes, NIMA 686 (2012) 151.

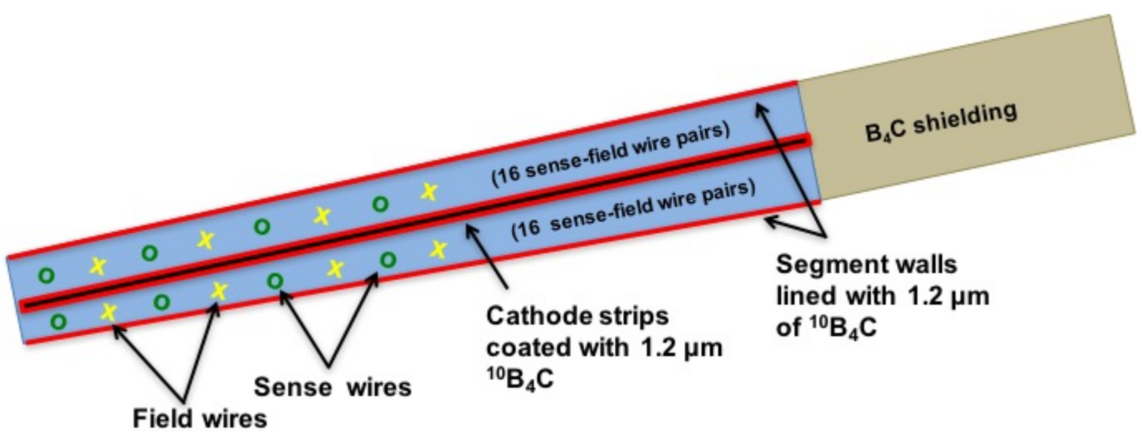
The POWTEX-Jalousie detector

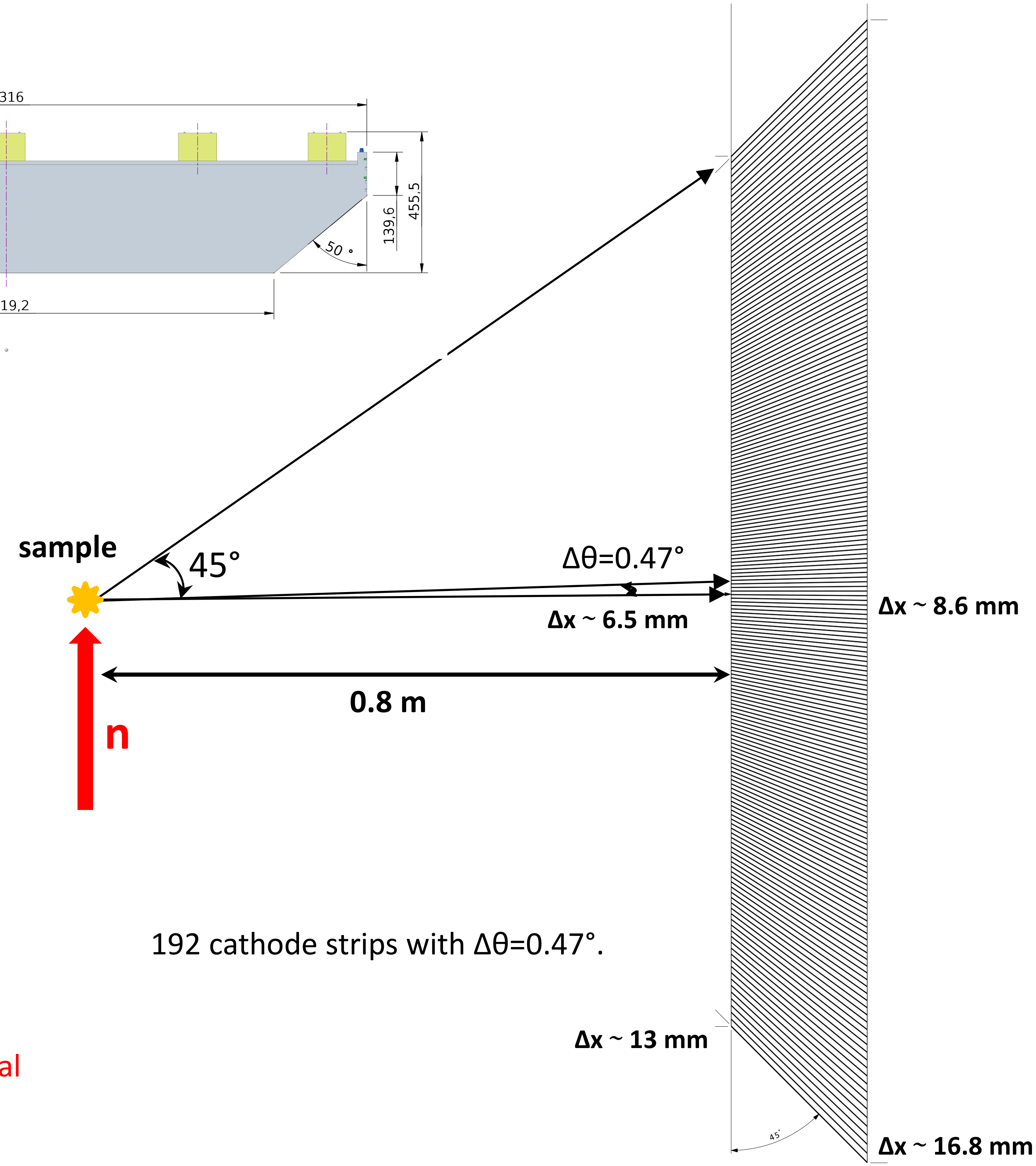
CDT

EUROPEAN SPALLATION SOURCE



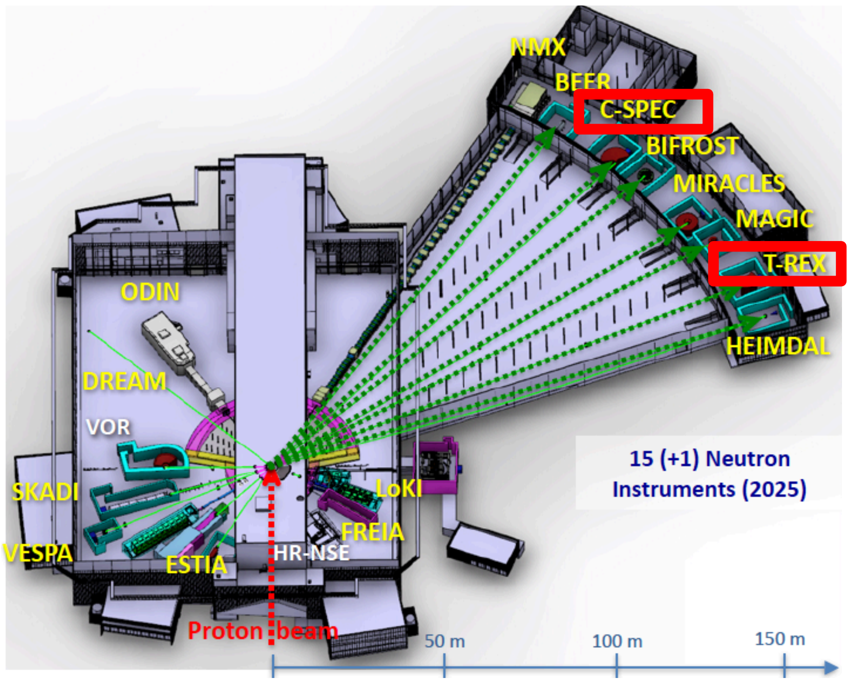






3D matrix of 16 (wires) x 192 (cathode strips) = 10240 non-identical sensitive elements (voxels).

Energy Ranges for ESS Spectrometers

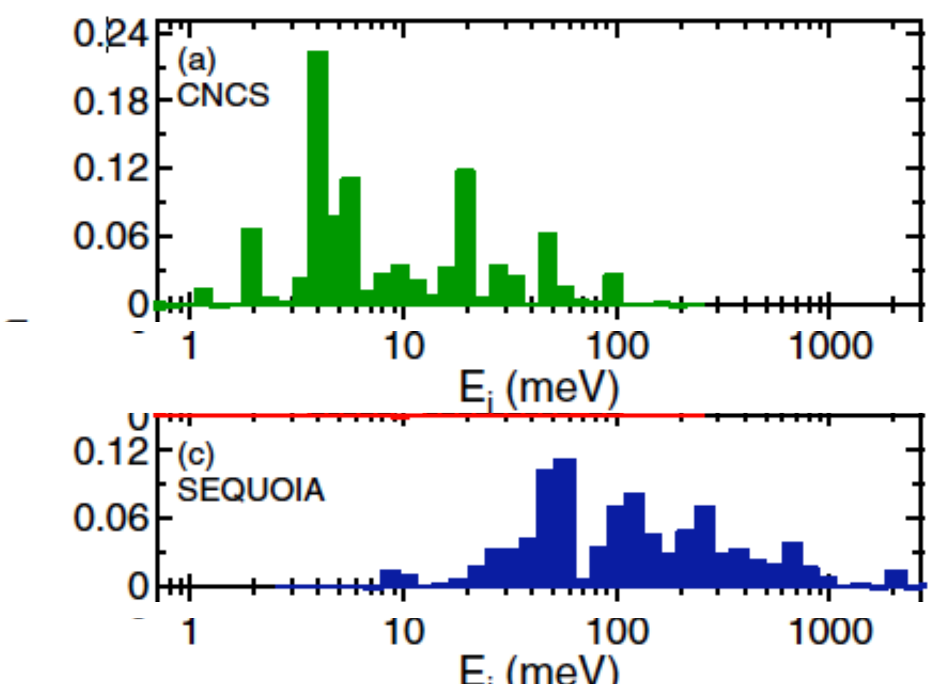


Energy ranges of the first ESS ToF spectrometers

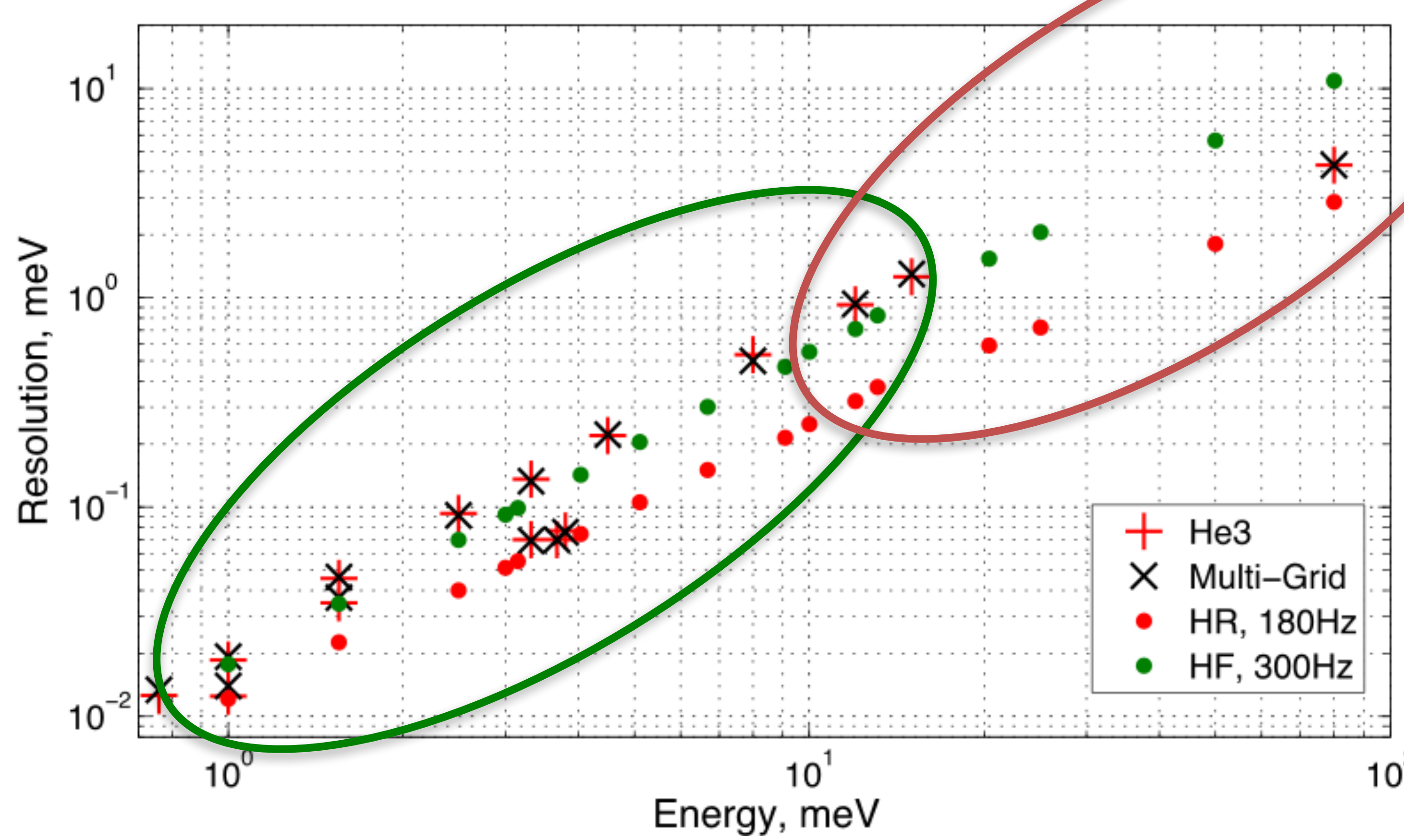
	CSPEC	T-REX
Typical initial λ, Å (meV)	2 to 15 Å (20 to 0.36 meV)	0.7 to 6.4 Å (160 to 2 meV)

Cold range, 0.76 to 15 meV measured

Measurements needed for thermal range, up to 160 meV



Incident energies used at CNCS and SEQUOIA (M. Stone et al.)



Summary

- Construction is proceeding rapidly
- 15 instruments are entering construction for ESS
- There is a baseline detector design for these instruments
- Detectors are in detailed design

brightness

SoNDe Solid-State Neutron Detector

SINE2020