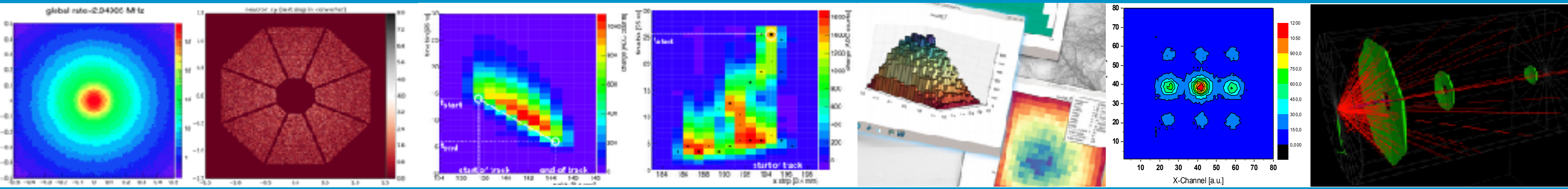
Realising the Detector Baseline for the ESS Instrument Suite

Richard Hall-Wilton

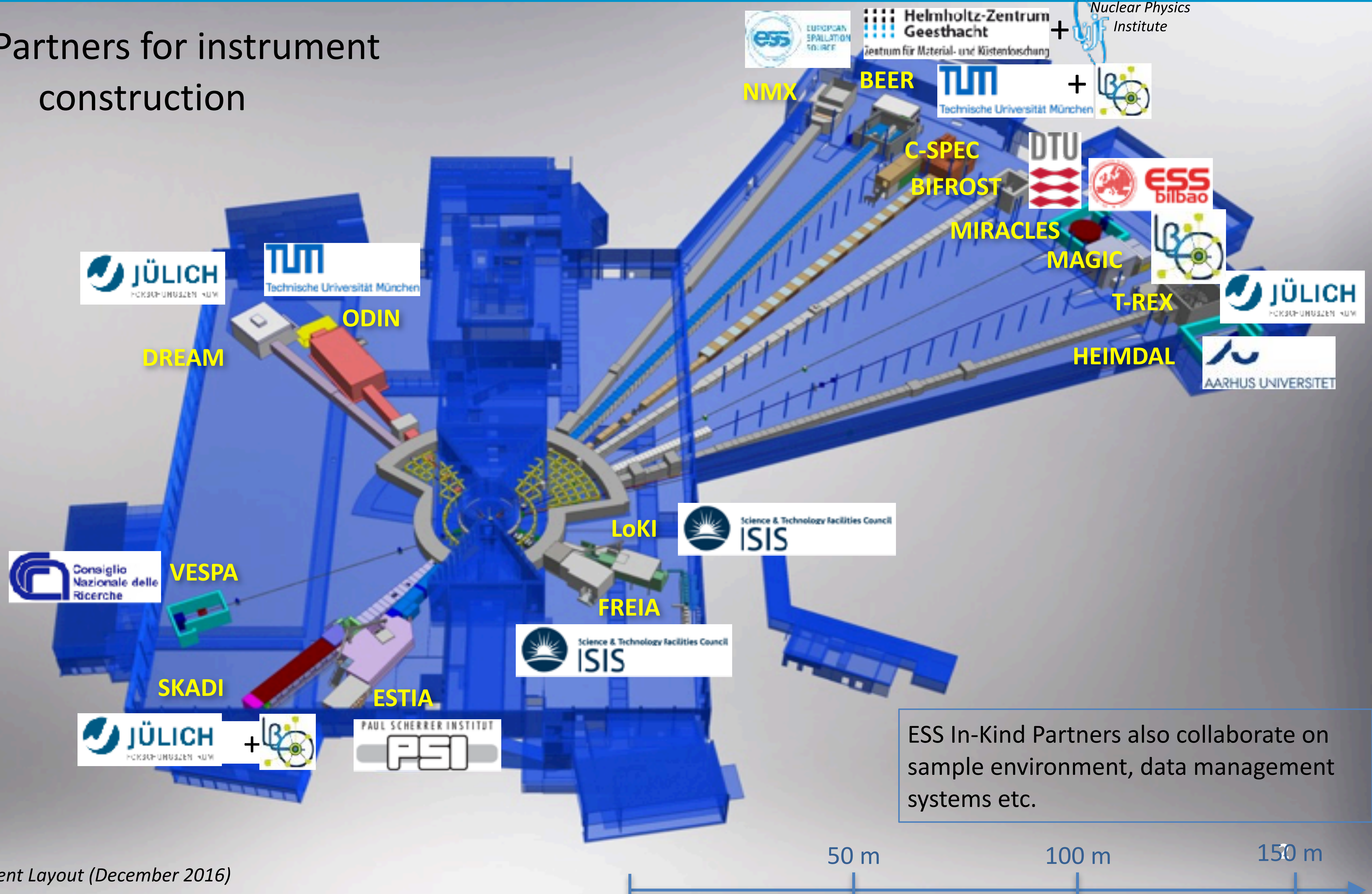
Leader of Detector Group
Deputy Division Head of Instrument Technologies

On Behalf of the ESS Detector Group and Partners



ESS Neutron Instrument positions: December 2016

Lead Partners for instrument construction

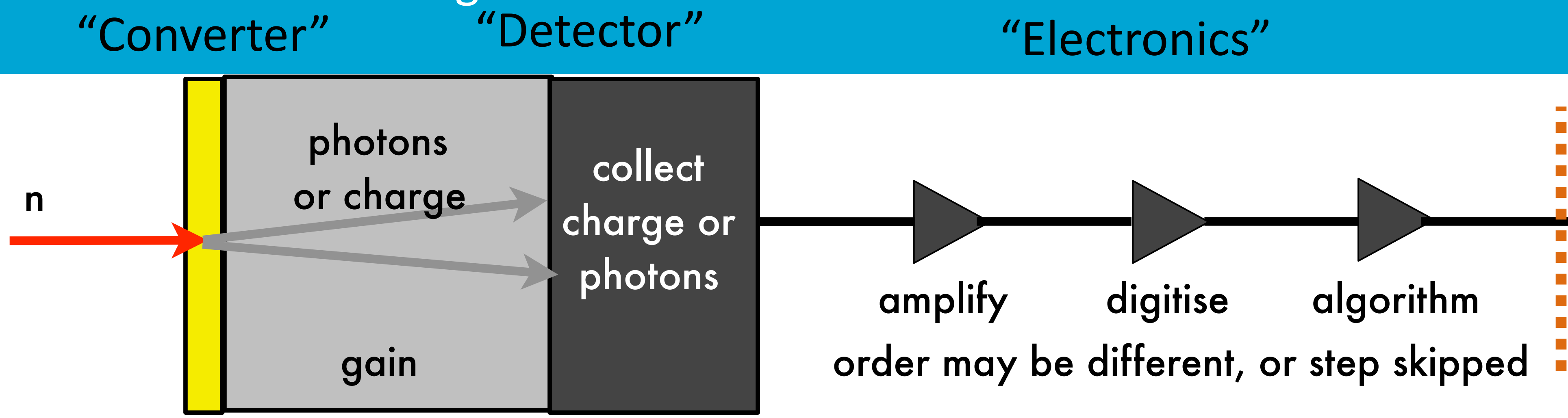


ESS In-Kind Partners also collaborate on sample environment, data management systems etc.

ESS Instrument Layout (December 2016)

Schedule: Where are we for detectors?

Detector schedule is longer than the instrument build schedule



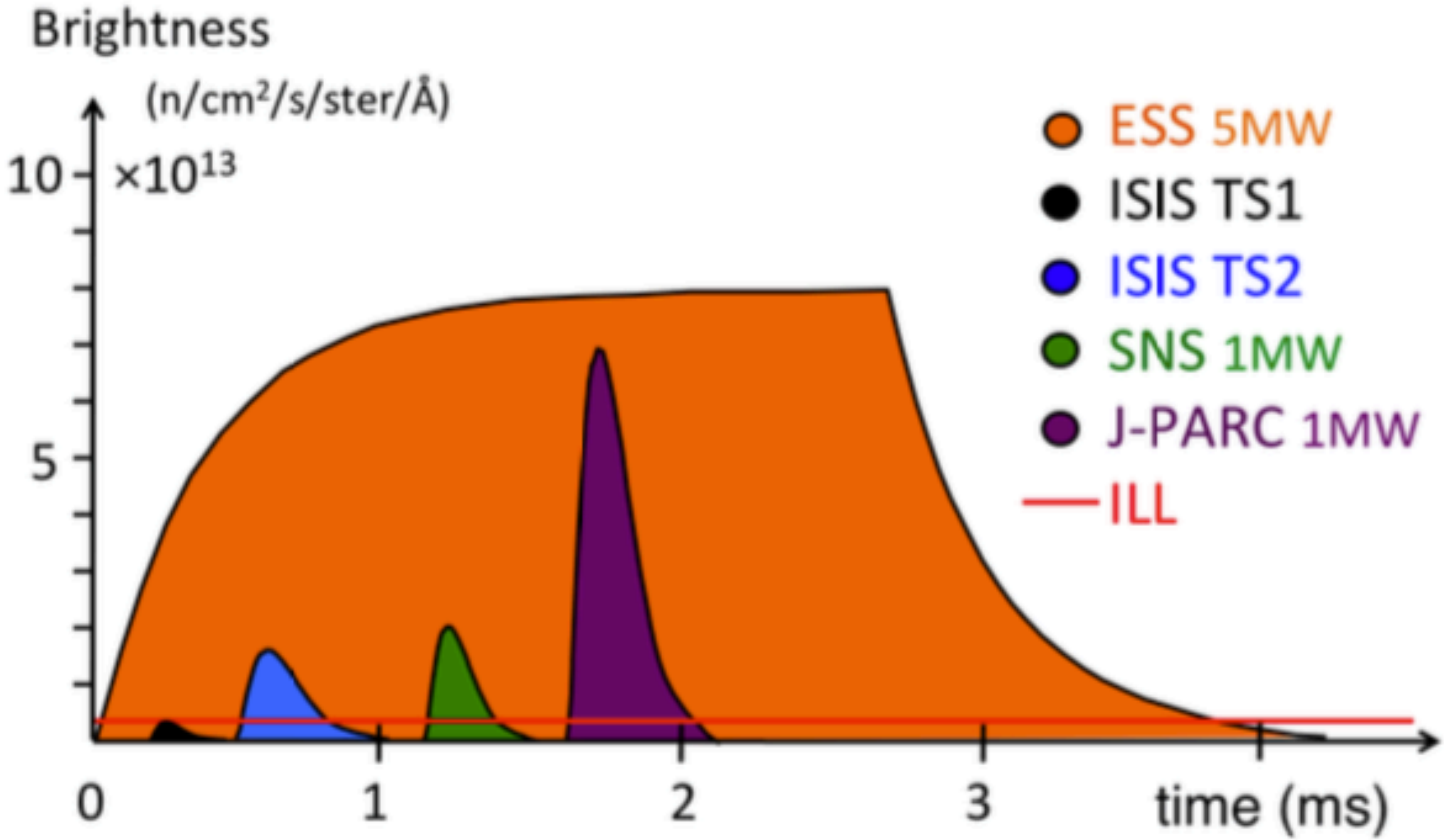
"DMSC-land"

See Tobias Richter's and Thomas Gahl's talks

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 interface	Electronics
					Instrument conceptual design	ICS/DMSC interface
						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

Challenge for Rate



What can be done with this brightness

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

Also: scarcity of Helium-3 …

Developments required for detectors for new Instruments

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

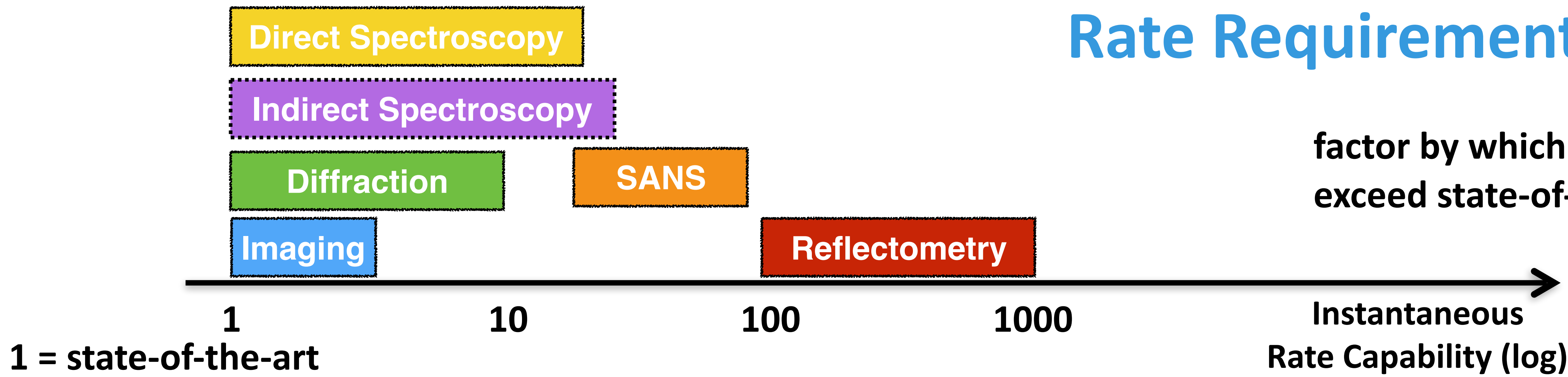
Developments required for detectors for new Instruments

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

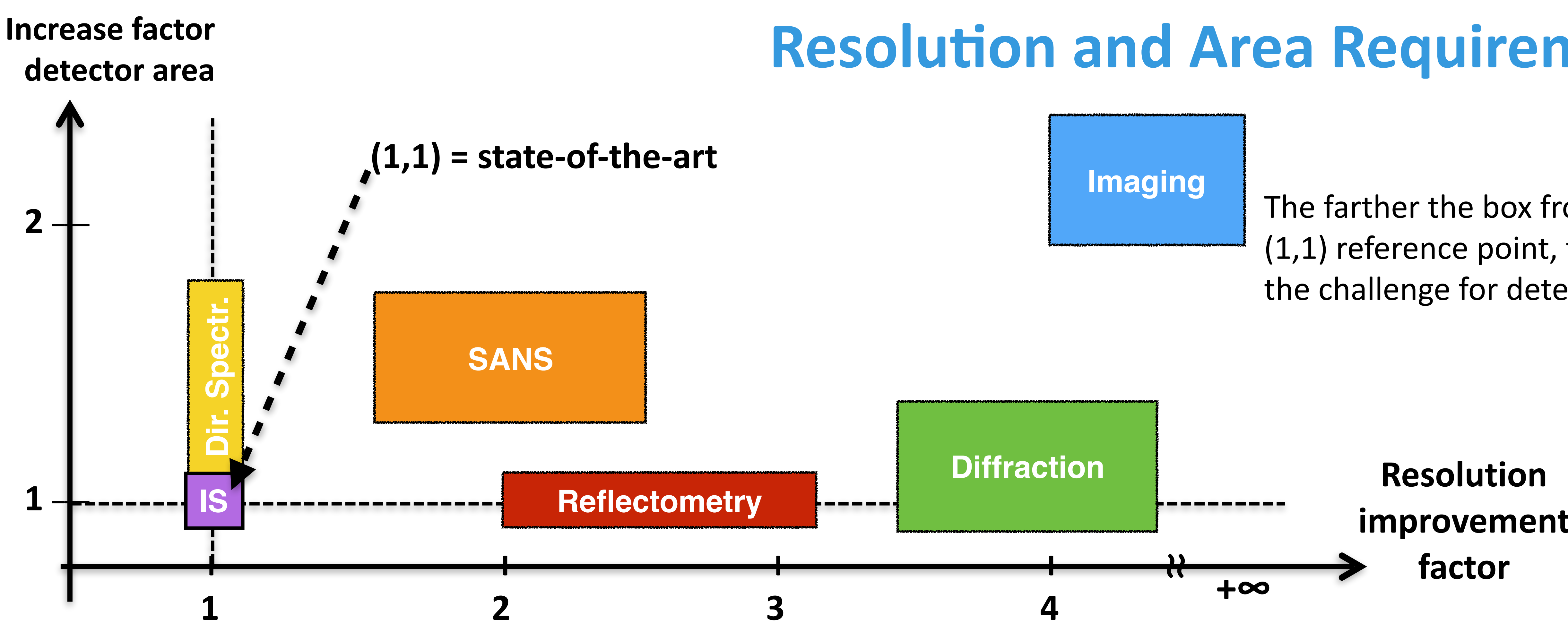
EUROPEAN SPALLATION SOURCE

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.

Challenge by Instrument Class

Instrument Class	Challenge which dominates detector design on instrument	
Reflectometry	Rate, Resolution	*See Francesco Piscitelli this afternoon*
SANS	Rate, Resolution, Area (cost)	
Imaging	Resolution, Rate	
Diffraction	Resolution	*I. Stefanescu et al, JINST 12 (2017) P01019*
Direct Spectroscopy	Area (Cost), Rate	*See Anton Khaplanov this morning*
Indirect Spectroscopy	Rate	

Varied Challenges

use SANS as example, as complicated with parameters improved at the same time

SANS: State-of-the-art

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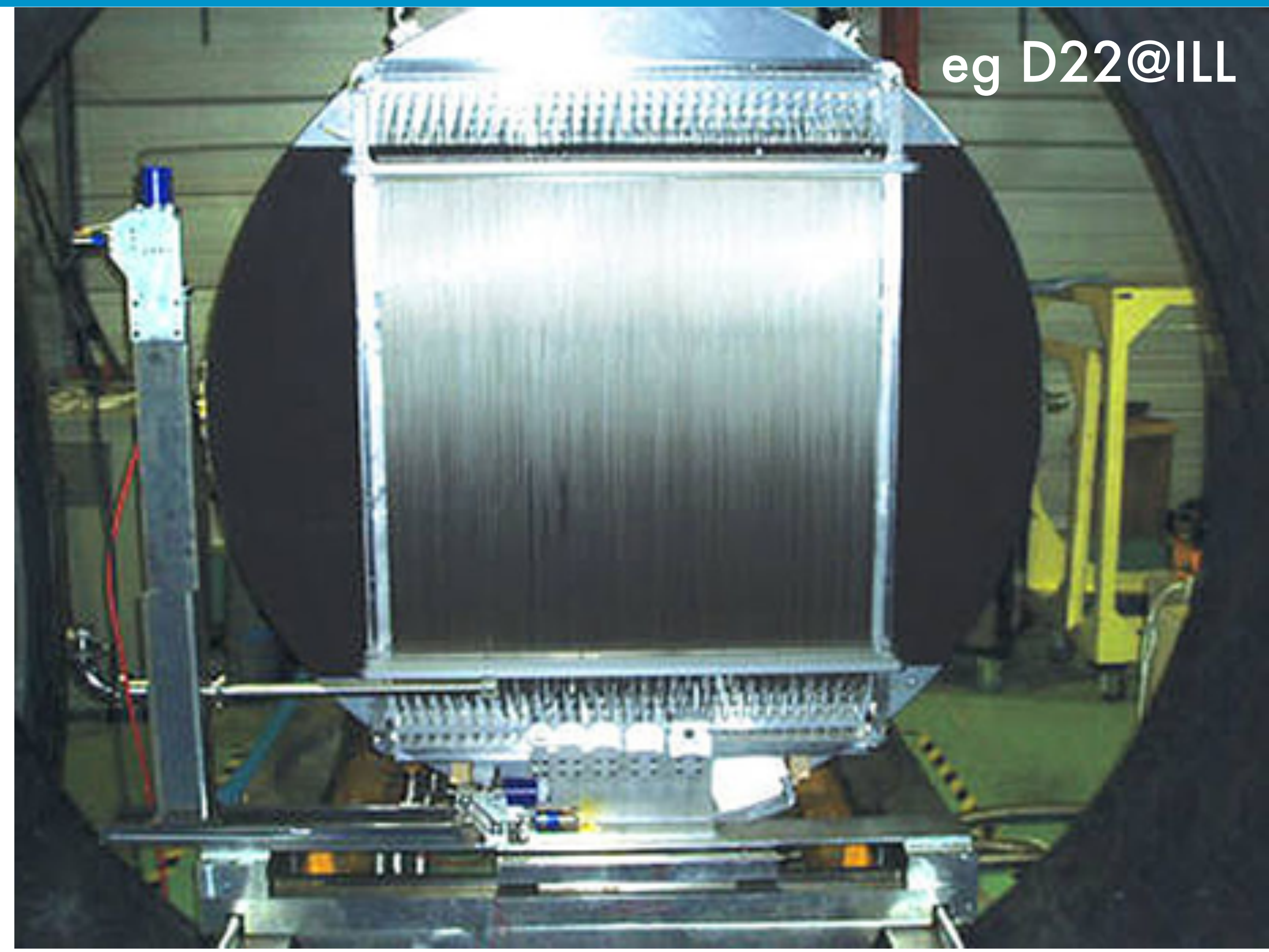
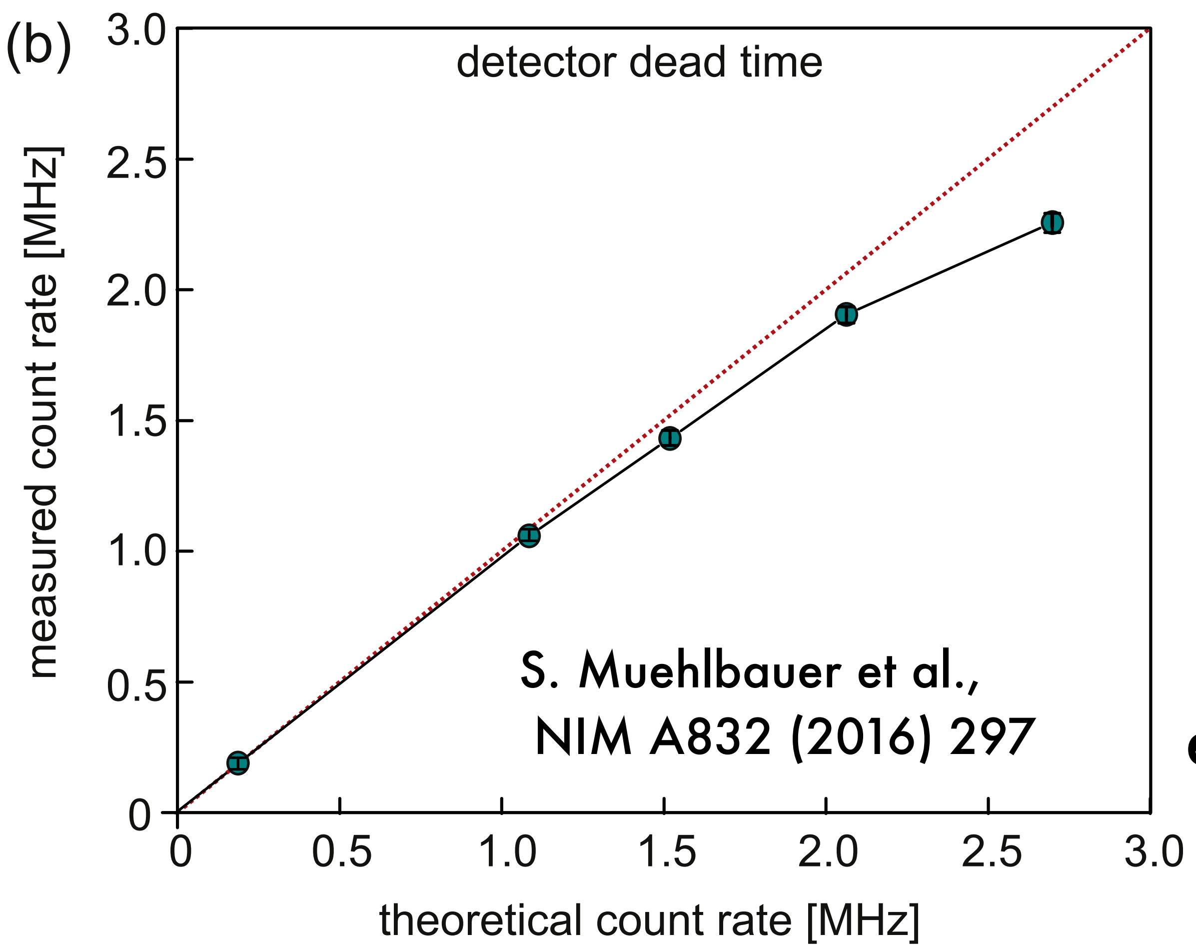
- Typically stacks of 1m long 8mm He-3 tubes
- Rate limitation few MHz for 10% dead time
- Resolution defined by tube dimensions

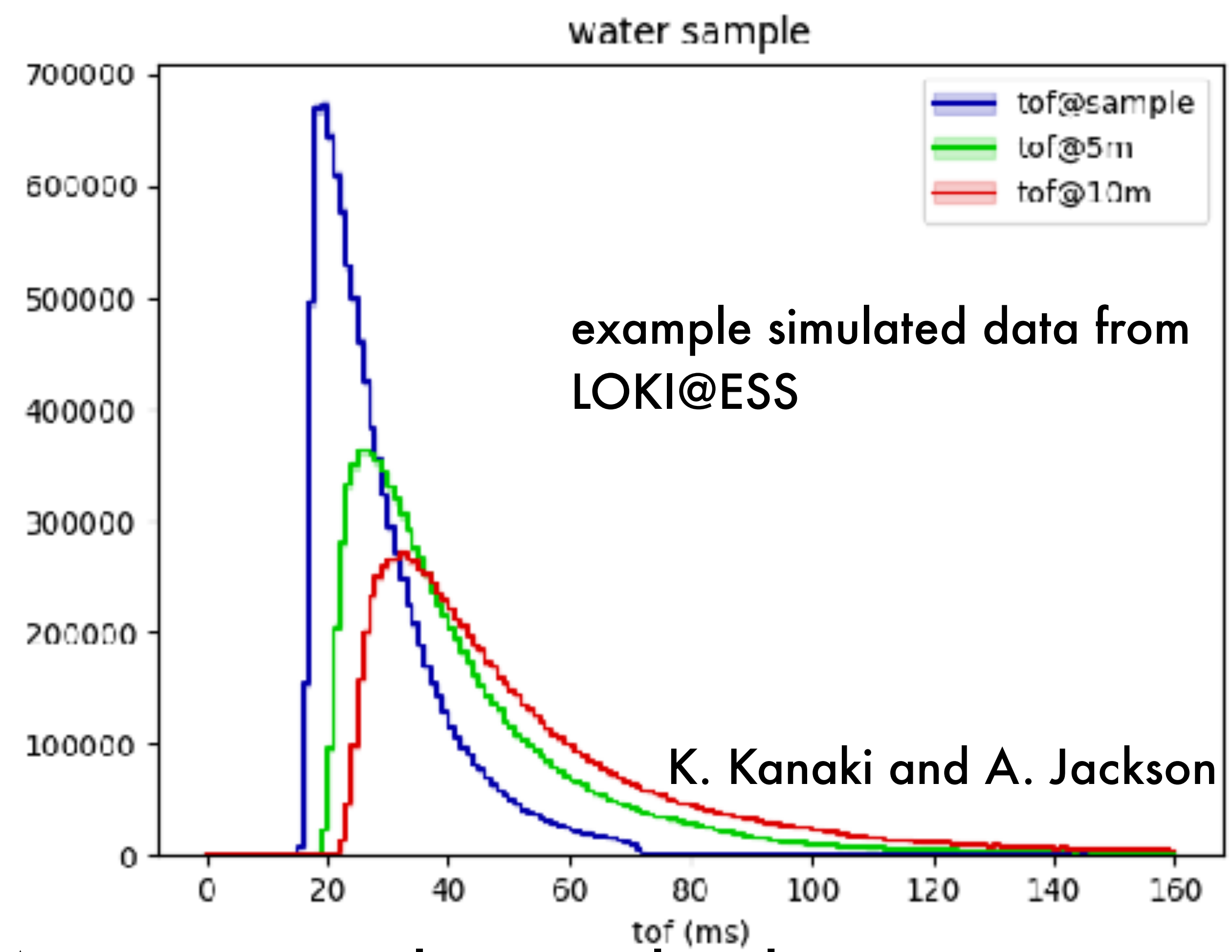




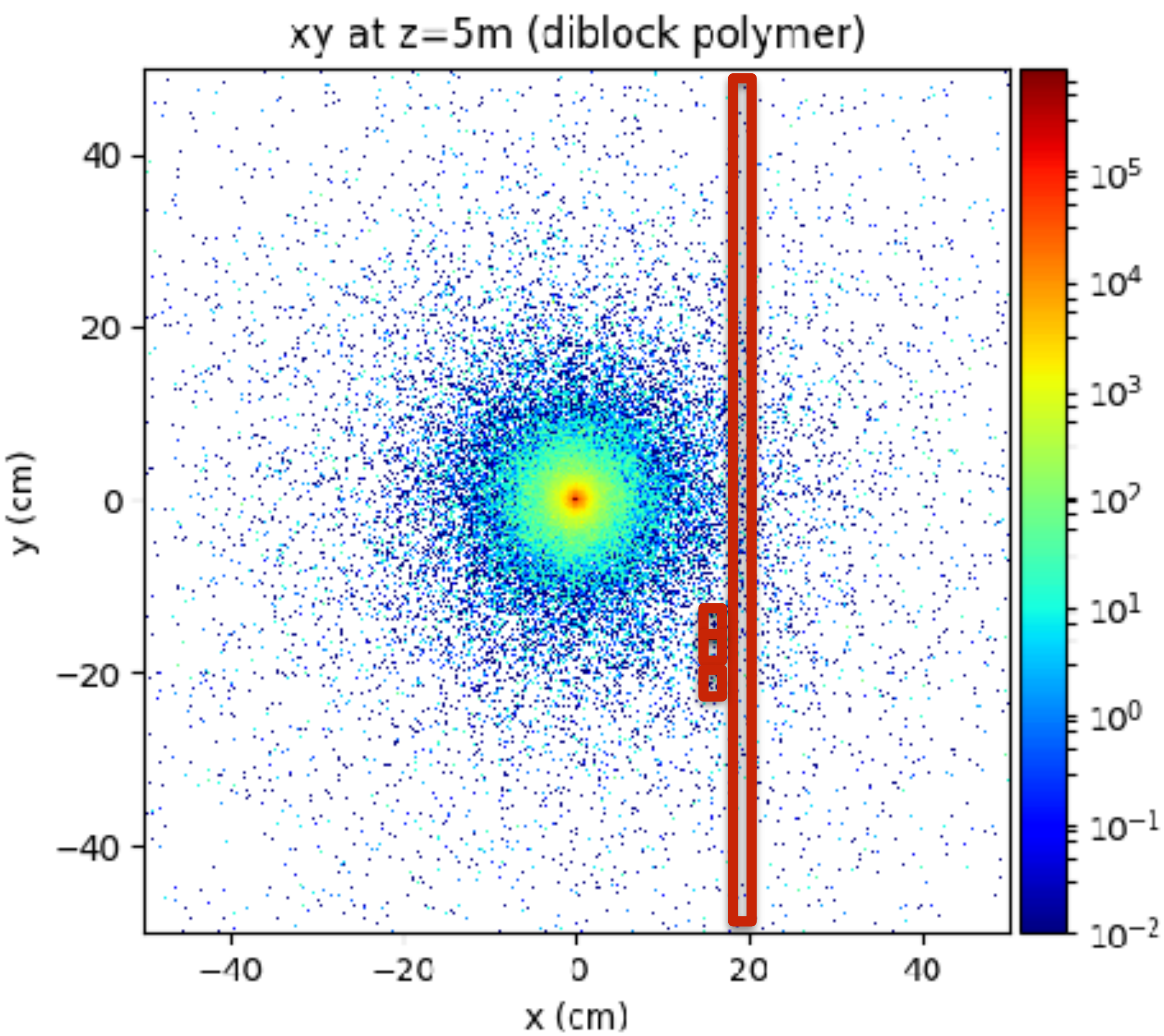
eg SANS-1 at FRM-II

Rates in SANS Data

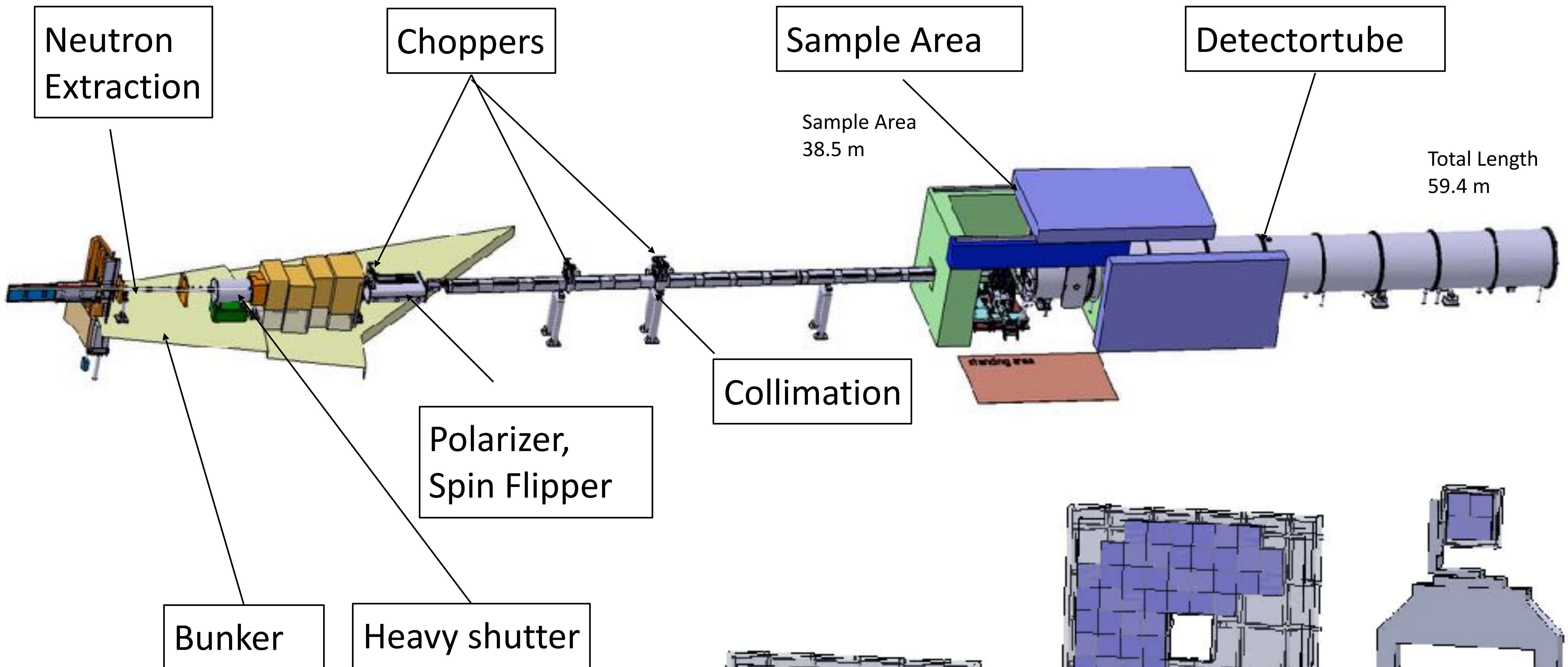
- At spallation sources, data is highly peaked in time
- Additional challenge for the detector rate requirements



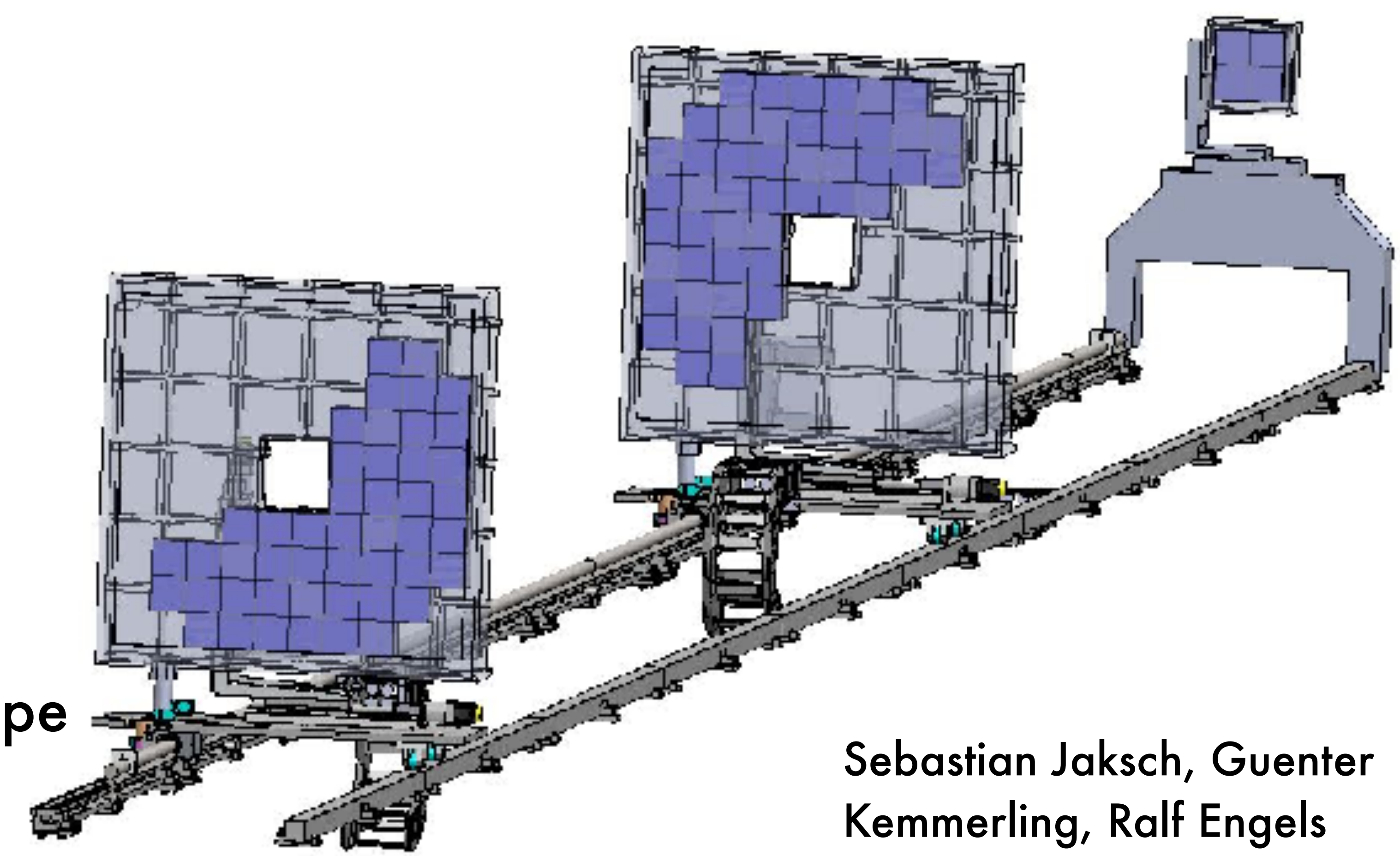
- A 1m 8mm psd He-3 tube detects across ca. 80cm2
- To improve rate capability need to reduce this area:
  - Pixelate
  - Multiple layers in depth (see Davide Raspino, next talk)



SKADI layout



- 2 moving detectors
  - $1m^2$ – pixel 6 mm
  - 400 modules / detector
- 1 fixed detector @20 m
  - $20x20\ cm^2$ – pixel 3 mm



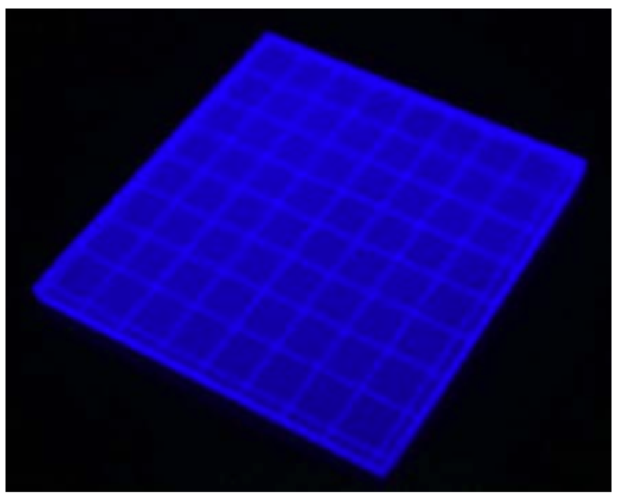
- **about half detector area in initial scope**
- **half in later upgrade**

Sebastian Jaksch, Guenter Kemmerling, Ralf Engels

SoNDe Detector

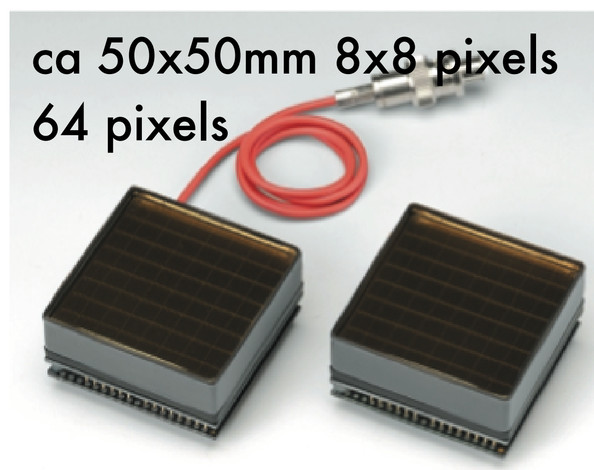
Develop a high-resolution neutron detector technique for enabling the construction of position-sensitive neutron detectors for high flux sources.

- high-flux capability for handling the peak-flux of up-to-date spallation sources (x 20 over current detectors)
- high-resolution of 6 or 3 mm by single-pixel technique
- high detection efficiency of up to 80 %



Grooved Li glass (GS20)

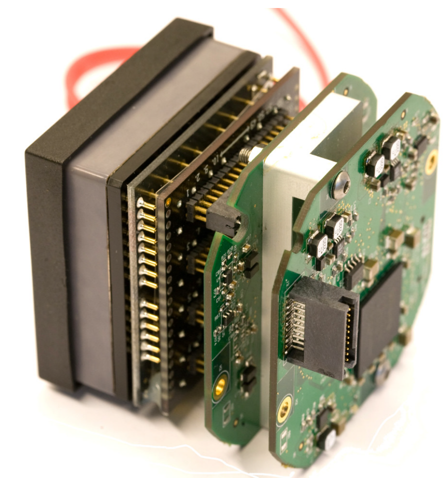
+



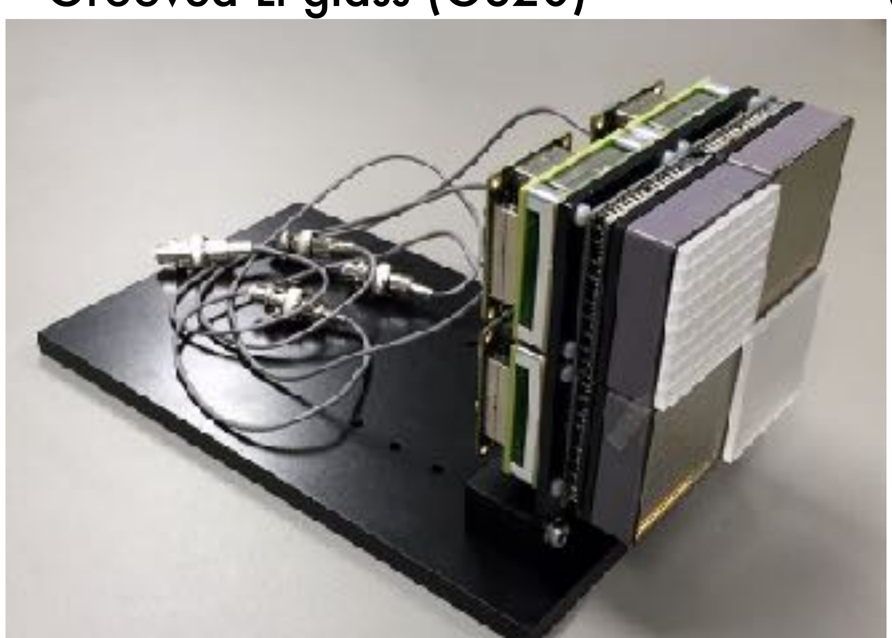
ca 50x50mm 8x8 pixels
64 pixels

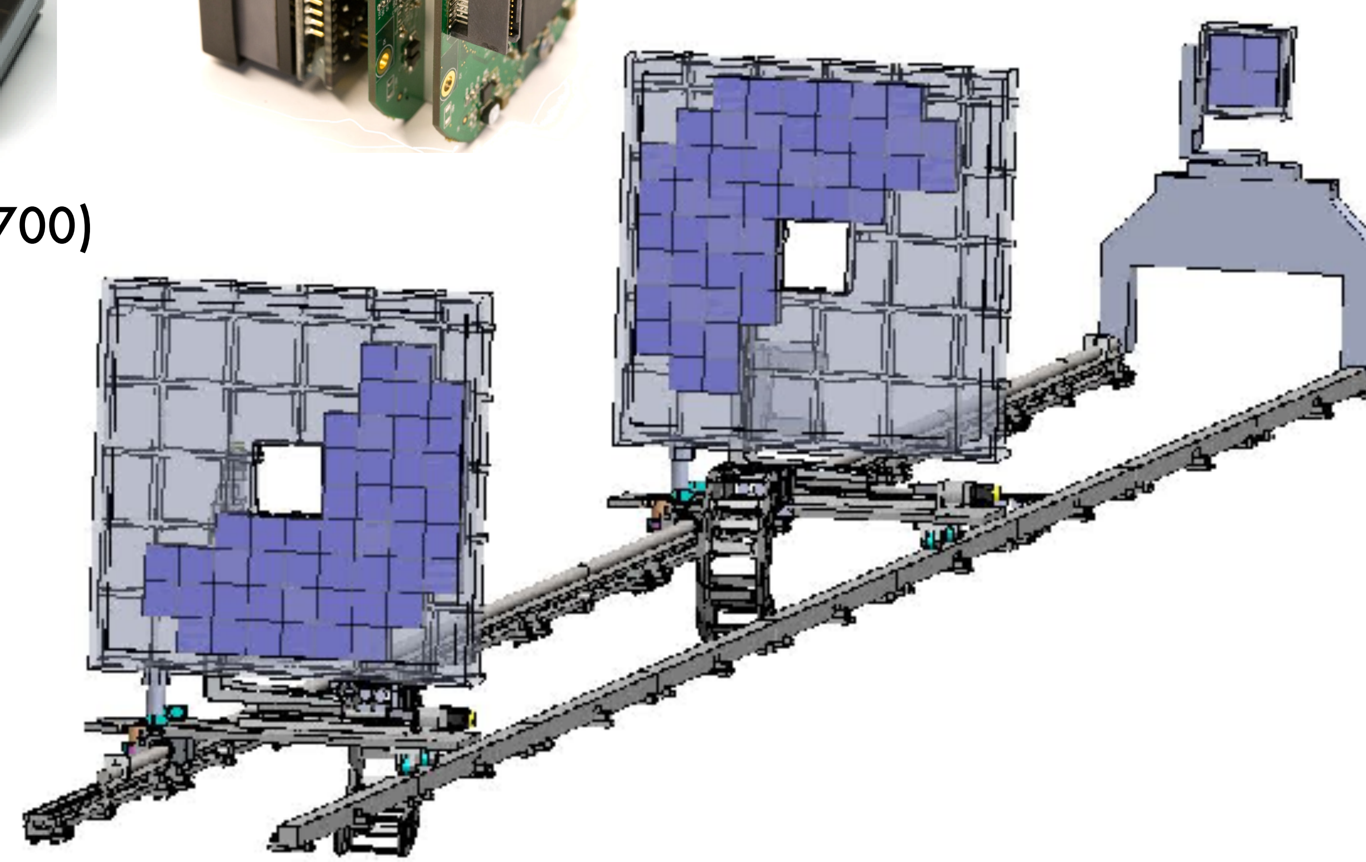
MA-PMT (H9500 or H12700)

+

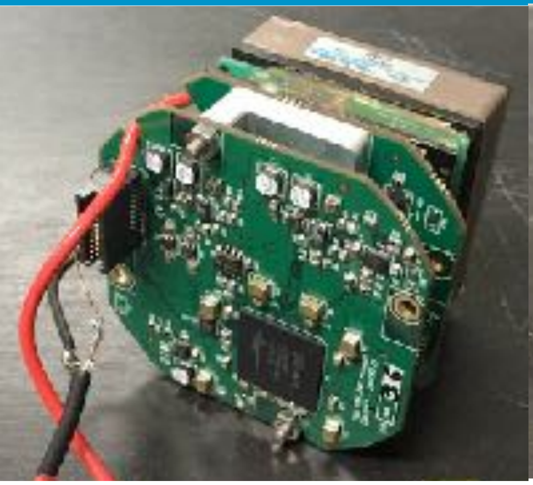


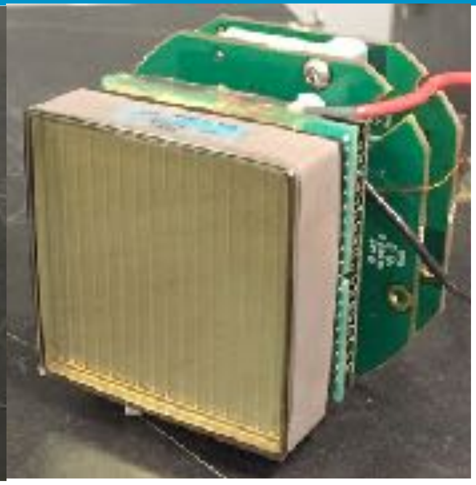
IDEAS IDE3465
+FPGA



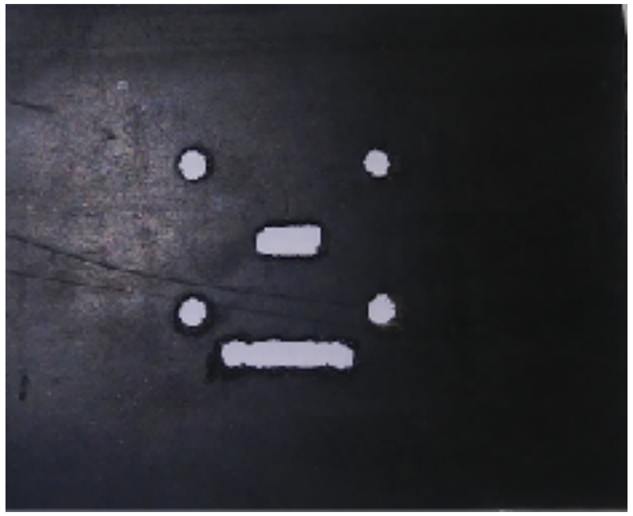


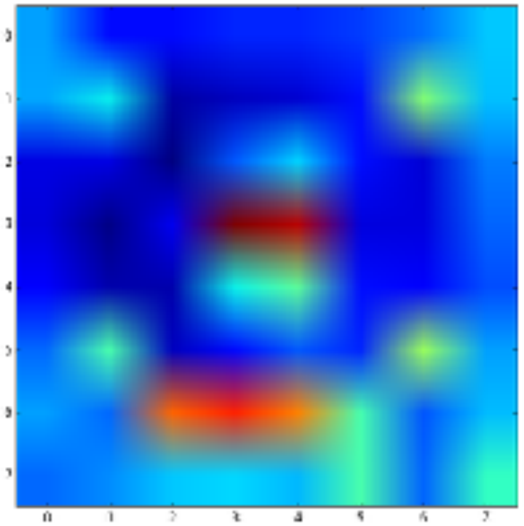
SoNDe Detector

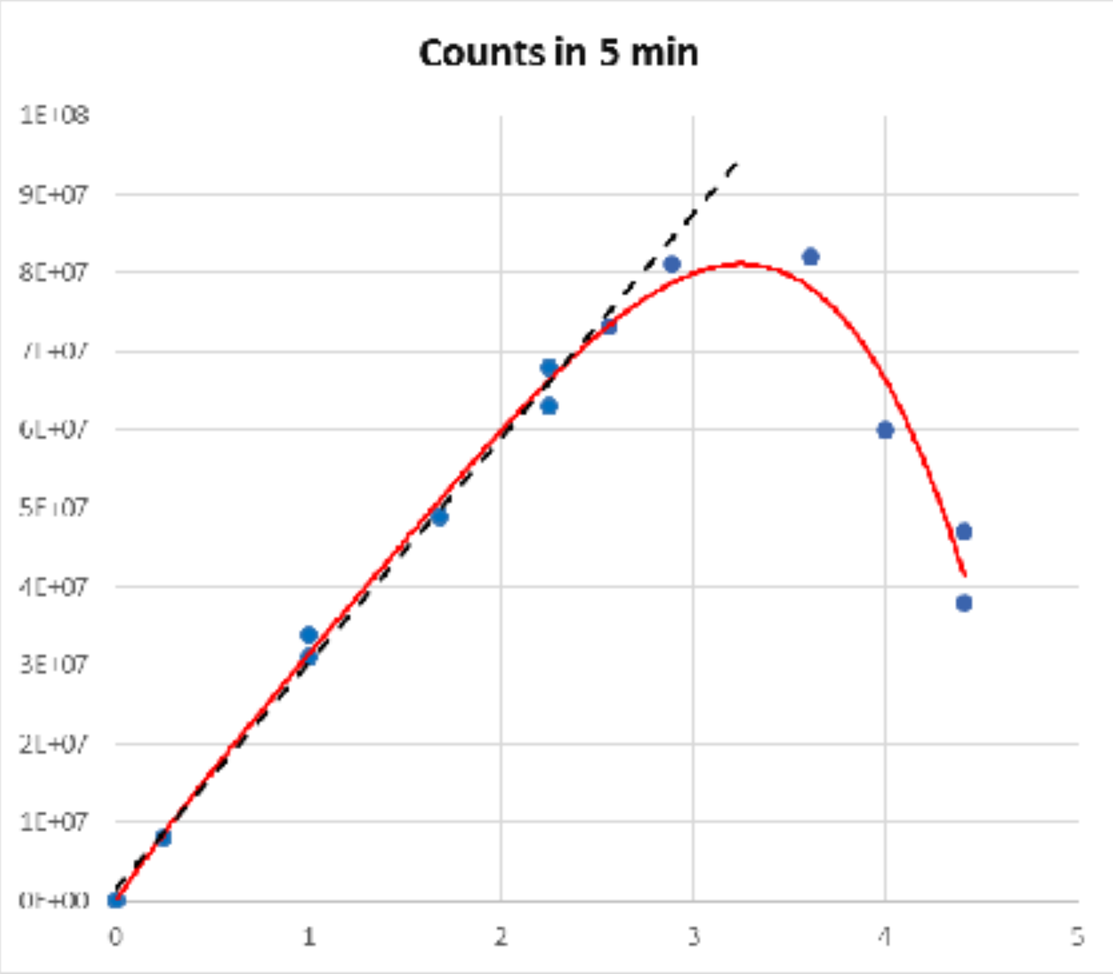




• Results from initial evaluation system

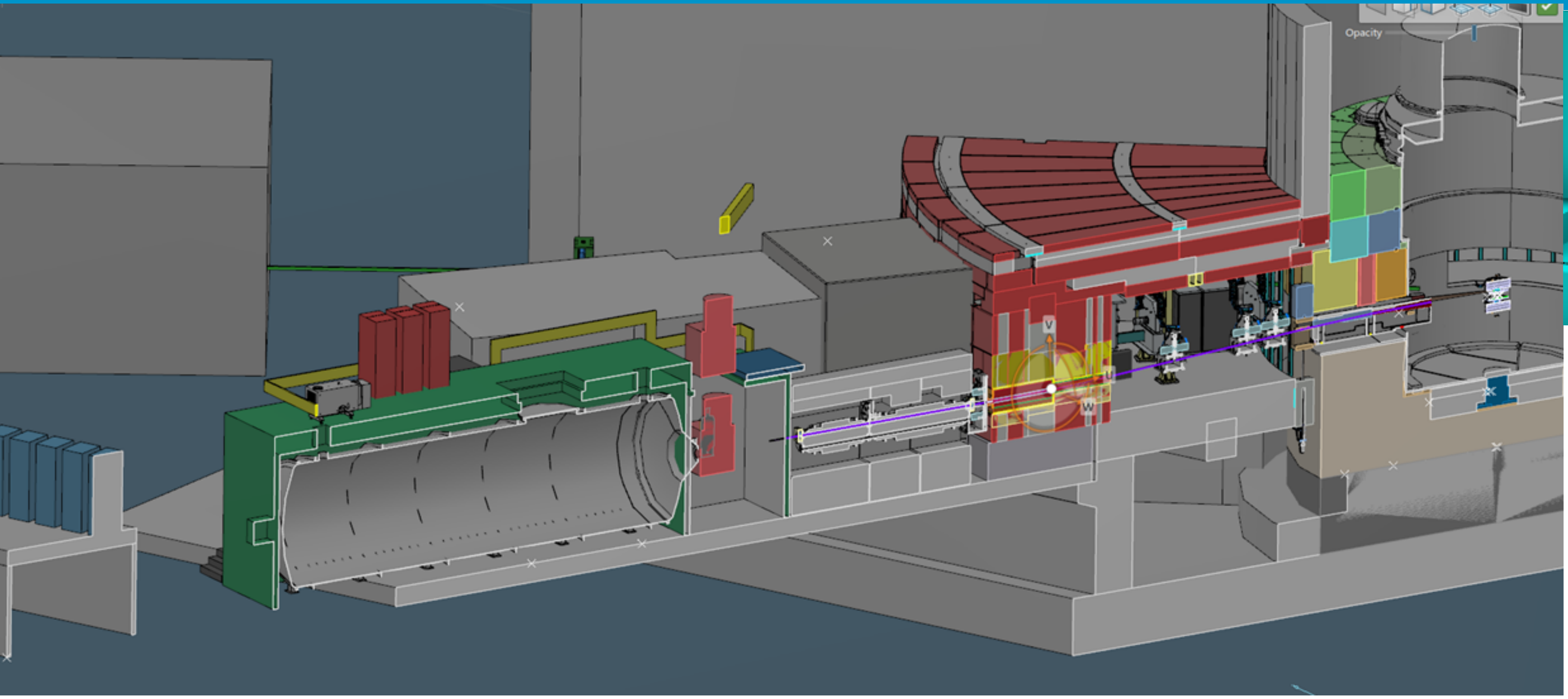


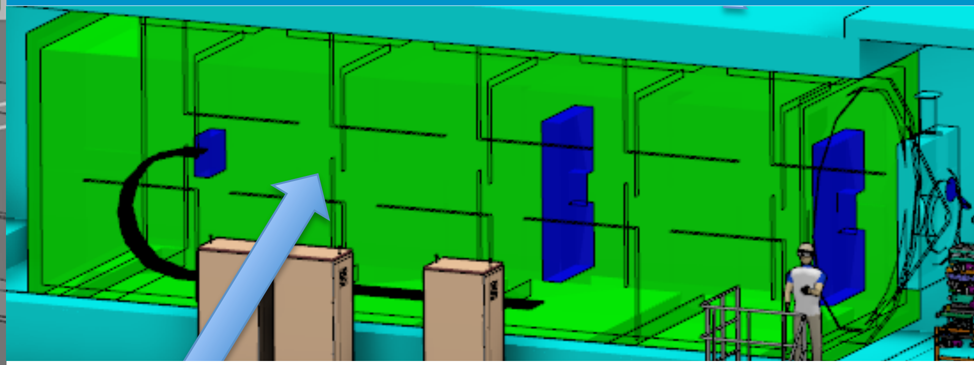




• Count rates on a module up to 250 kHz, linear to 200 kHz
• Corresponds to >20 MHz @10% deadtime for full 1m^2
• No degradation up to 5E14 neutrons integrated flux

LOKI Detector Requirements





- Short instrument
- Wide angle detector coverage up to 45 deg
- Arranged in 3 banks
- total 9m^2

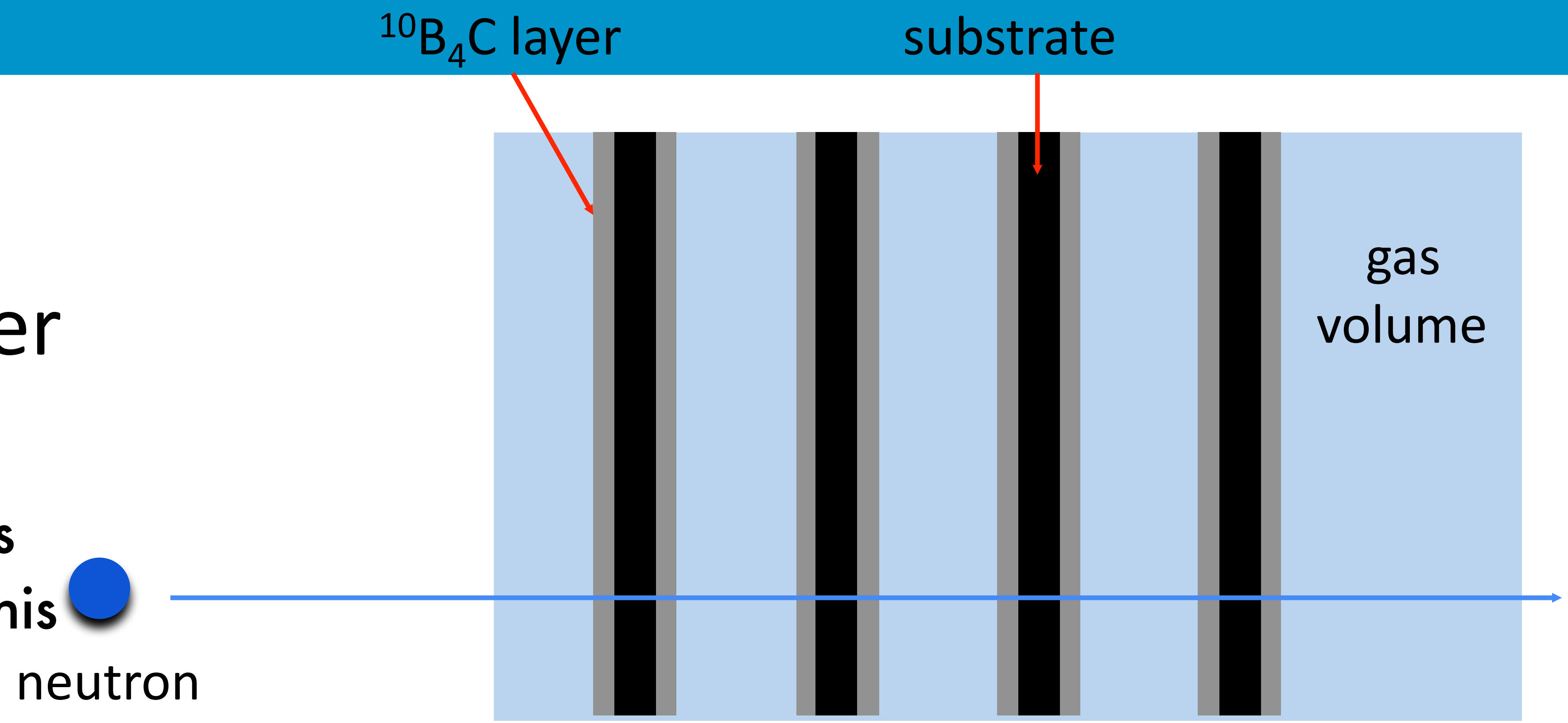
- Rearmost bank ca. 1x1m, movable
- 6mm resolution
- Other banks 2x2m fixed. Relaxed resolution requirements

- about half detector area in initial scope
- half in later upgrade

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

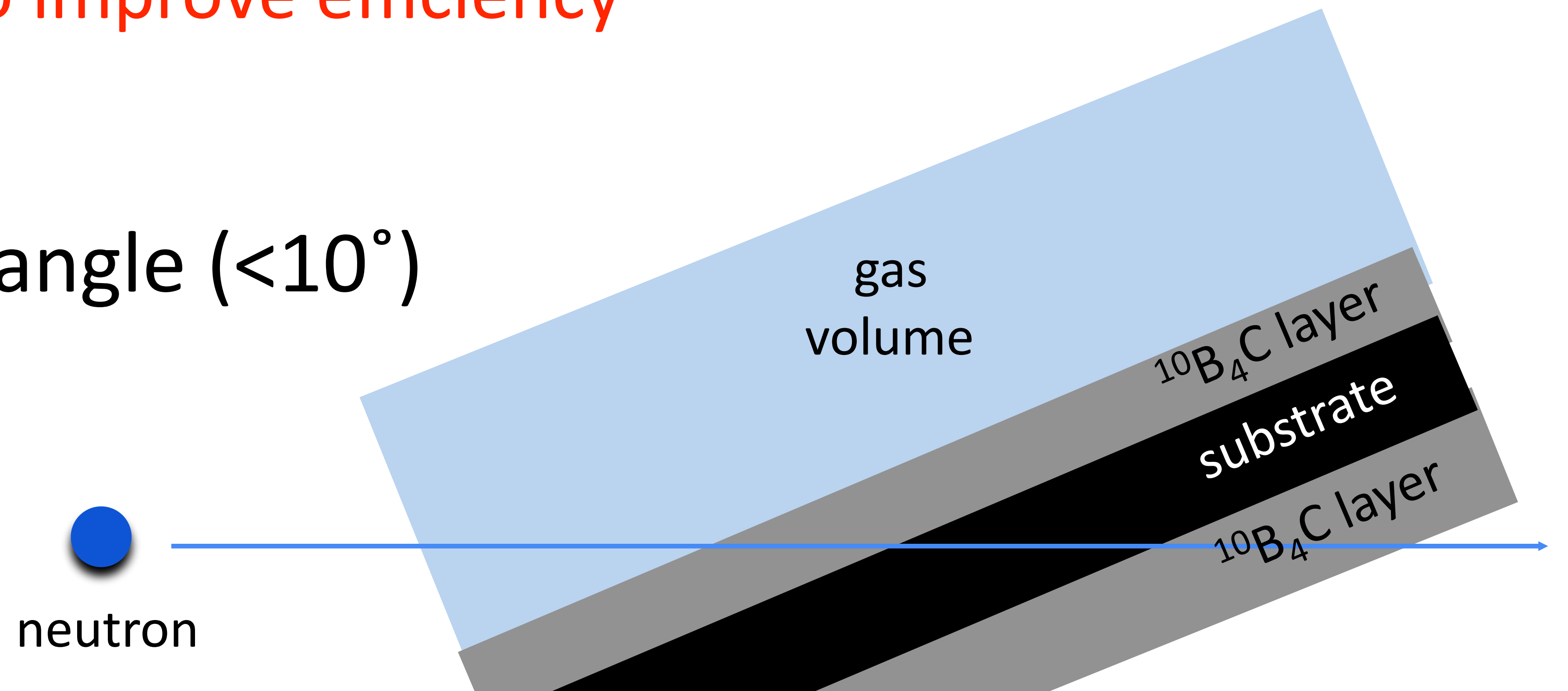
Generic approaches to improve efficiency

1 Multi layer



See Anton Khaplanov's talk this morning for an application of this

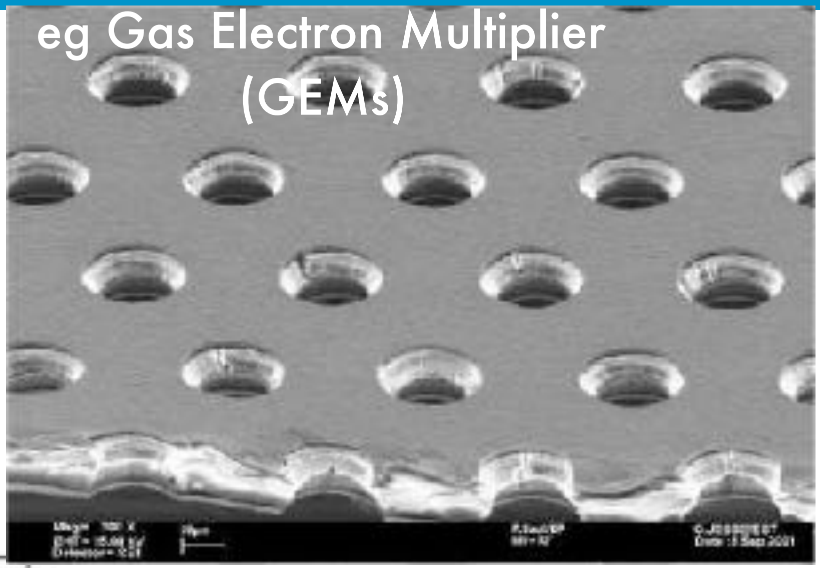
2 Grazing angle (<10˚)

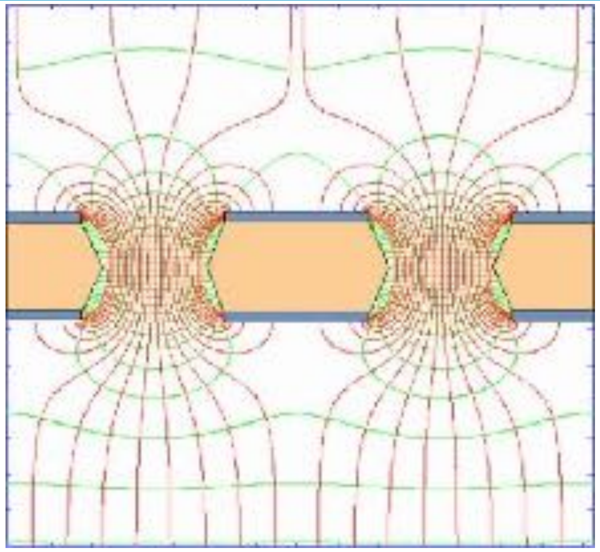


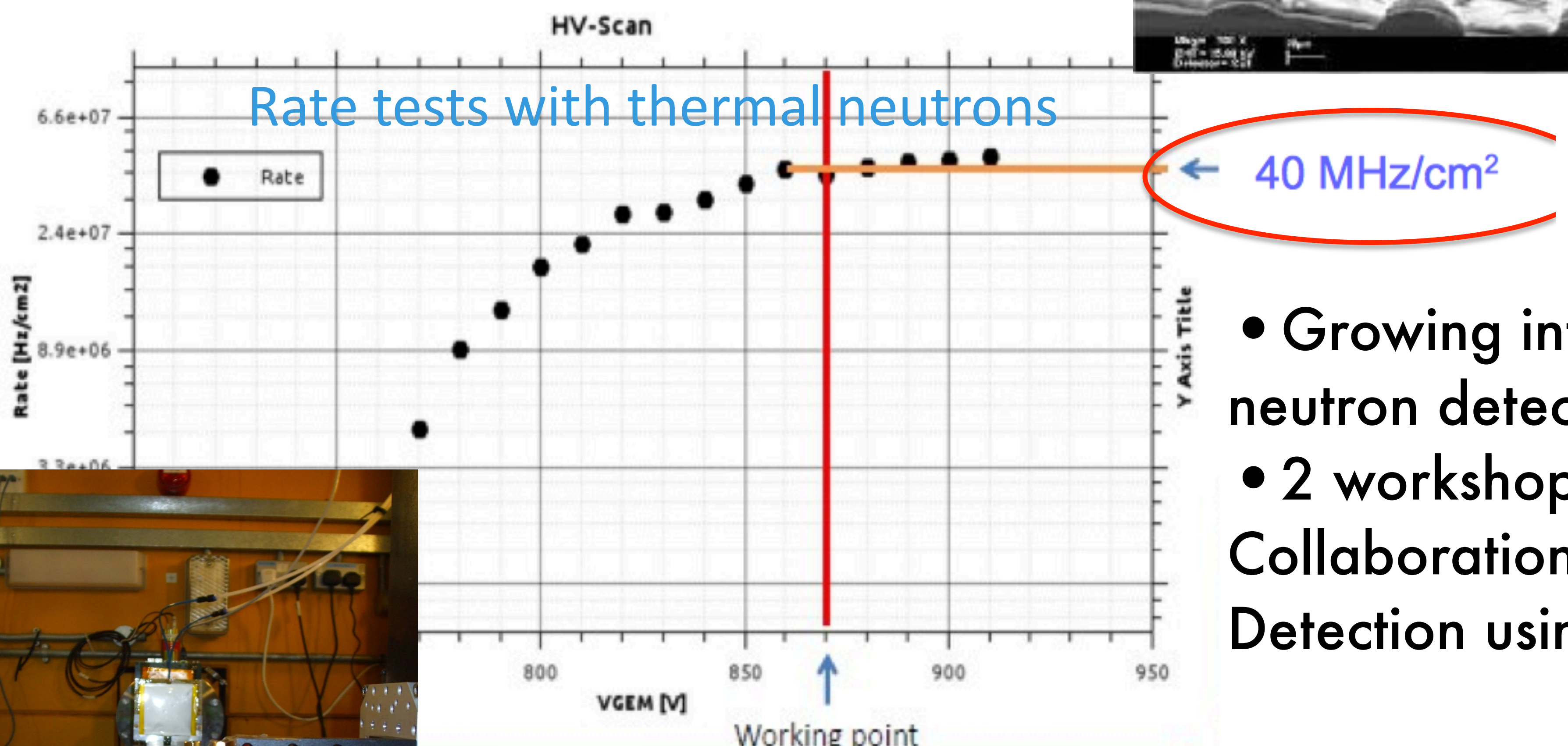
See Francesco Piscitelli's talk this afternoon for an application of this

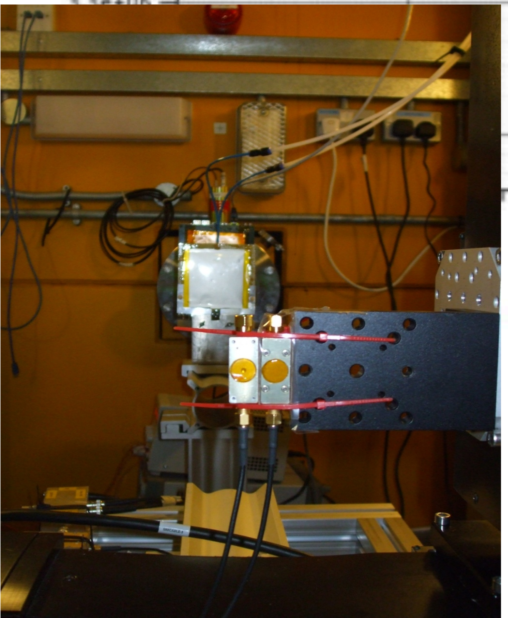
Micropattern Gaseous Detectors

- Field started by A Oed at the ILL with the micro-strip gas chamber (MSGC) in 1988
- Now widespread: many variants
- Potentially very good resolution and very high rate capability









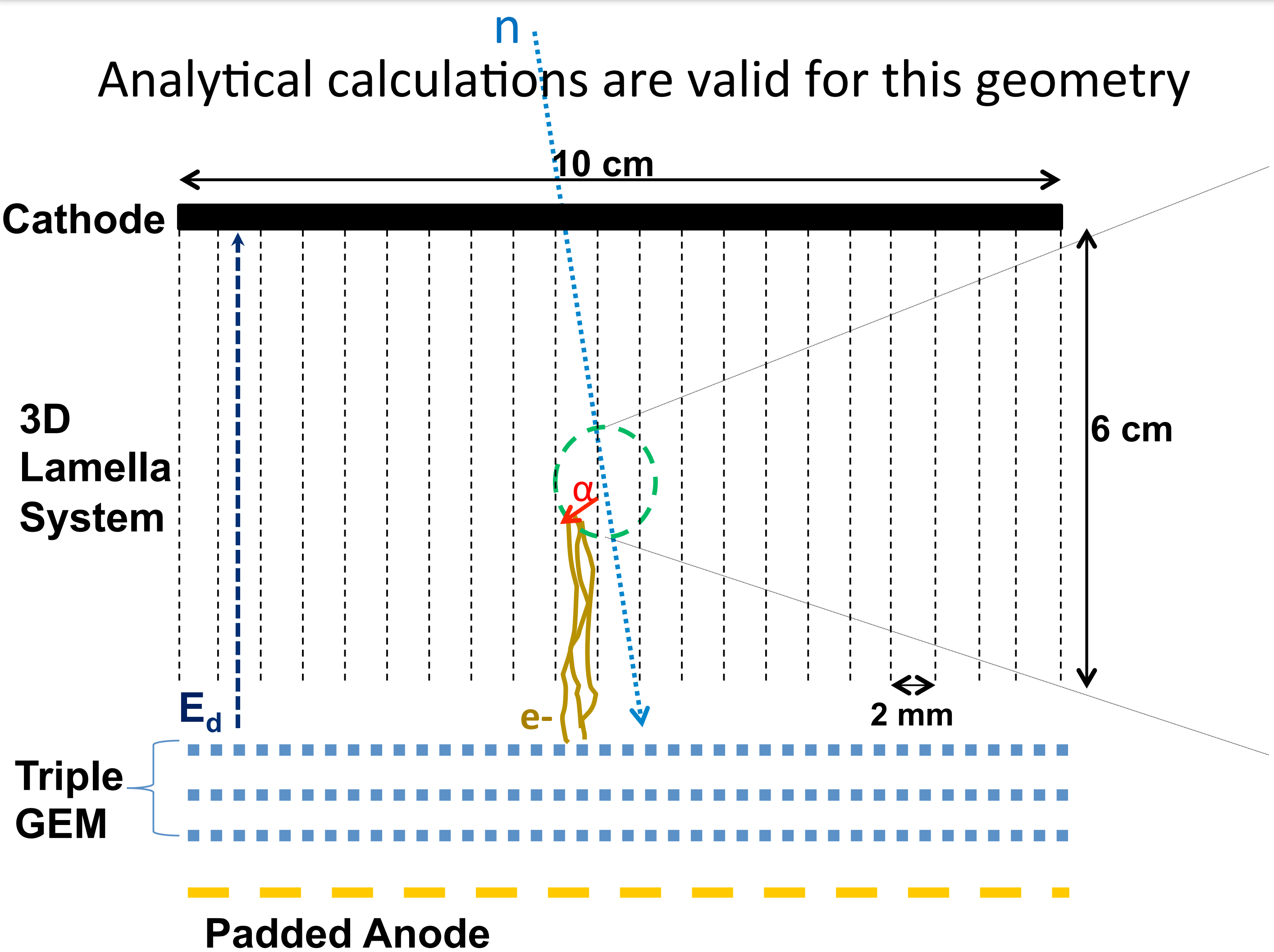
- Growing interest for applications for neutron detection
- 2 workshops organised by CERN RD51 Collaboration (with HEPTECH) on Neutron Detection using MPGDs

Summary of 1st workshop for MPGDs for neutron detection: arXiv:1410.0107

2nd Workshop: https://indico.cern.ch/event/365380/ arXiv:1601.01534

BANDGEM Detector

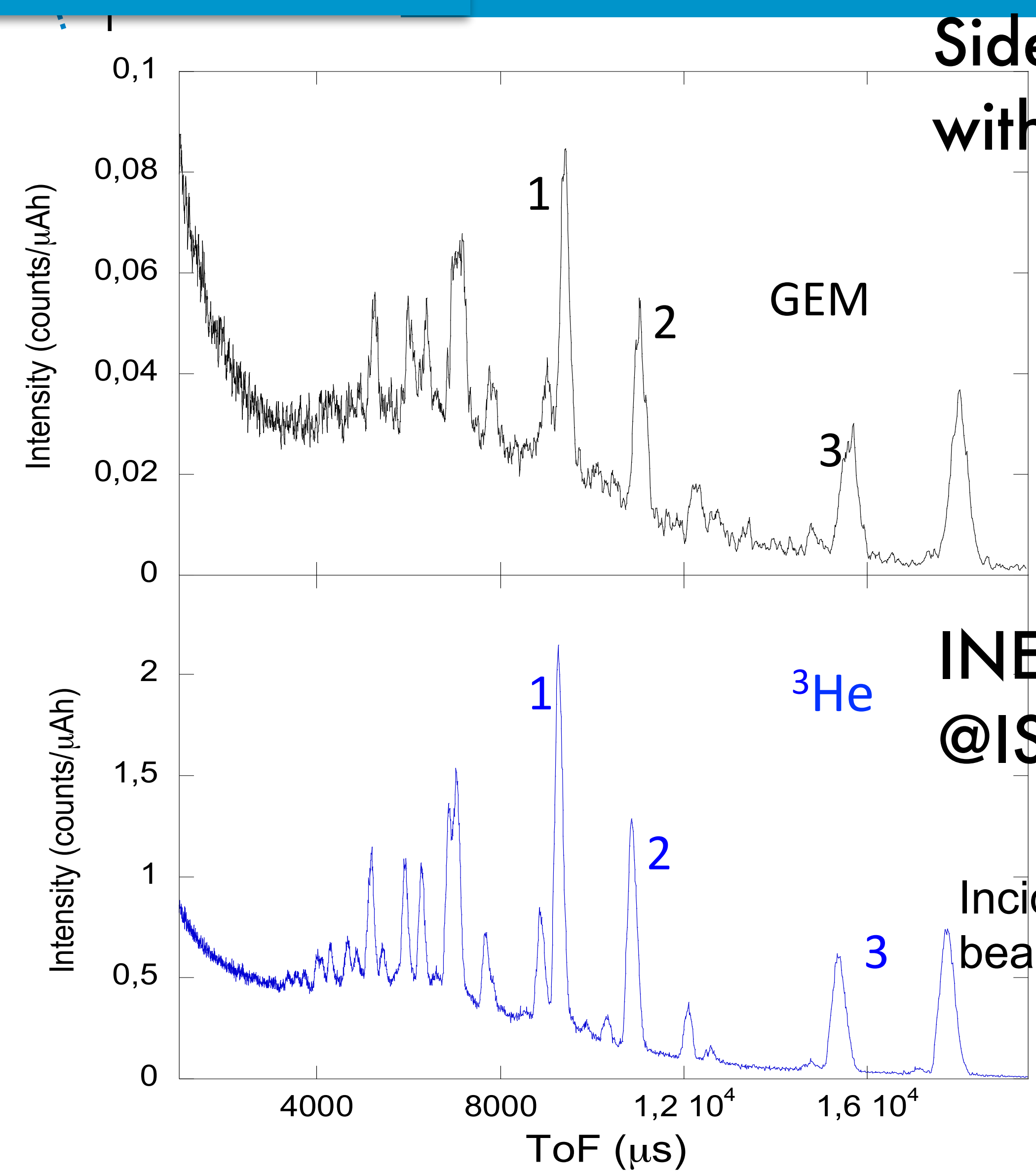
Analytical calculations are valid for this geometry



Alumina lamellae coated on both sides with $^{10}B_4C$

Using low θ values (few degs) the path of the neutron inside tl
B_4C is increased → Higher efficiency when detector is inclined

Side-by-side
with He-3



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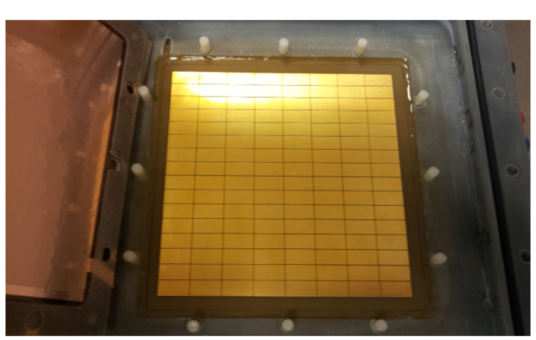
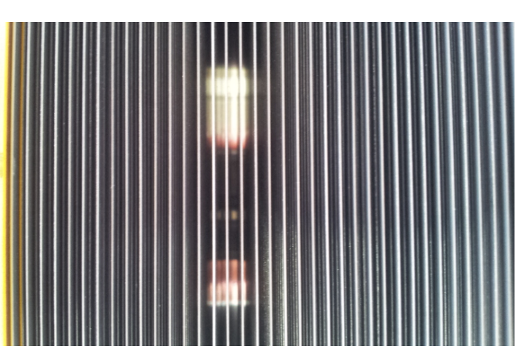
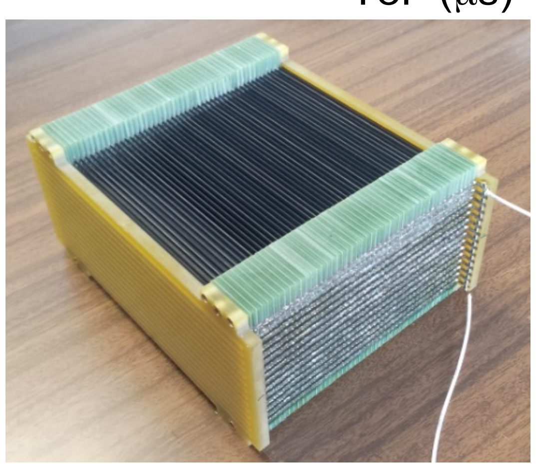
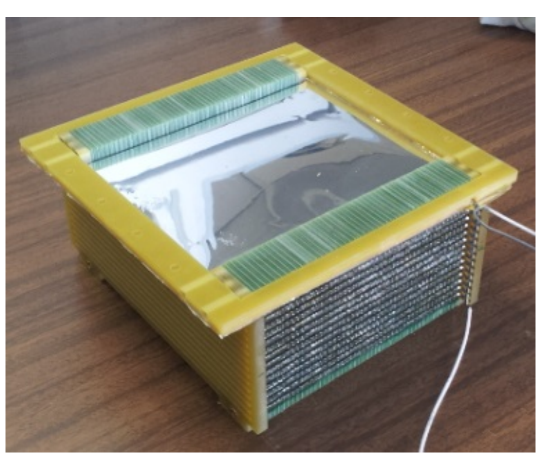


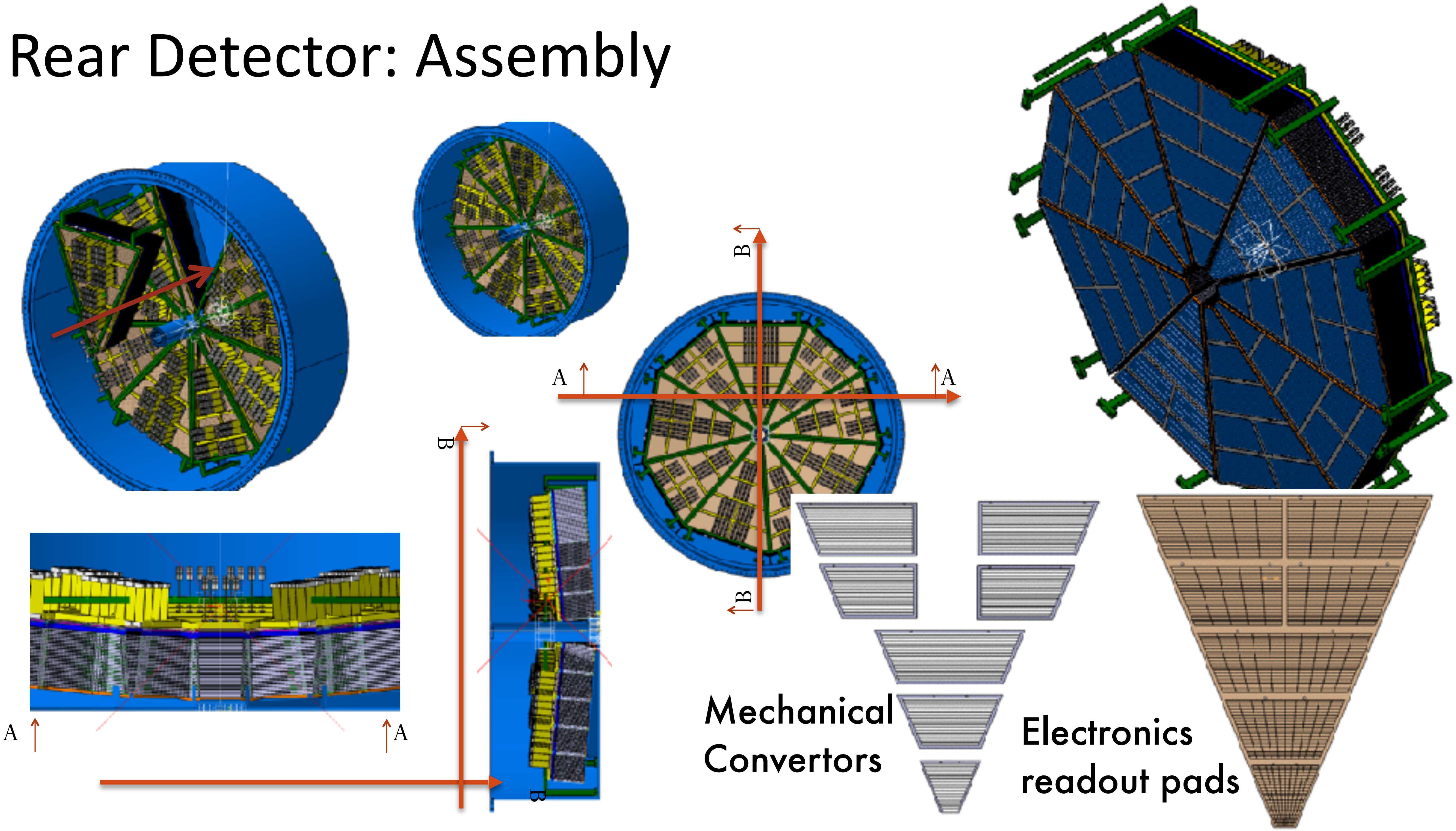






BANDGEM Detector for LOKI

Rear Detector: Assembly



BANDGEM Detector for LOKI

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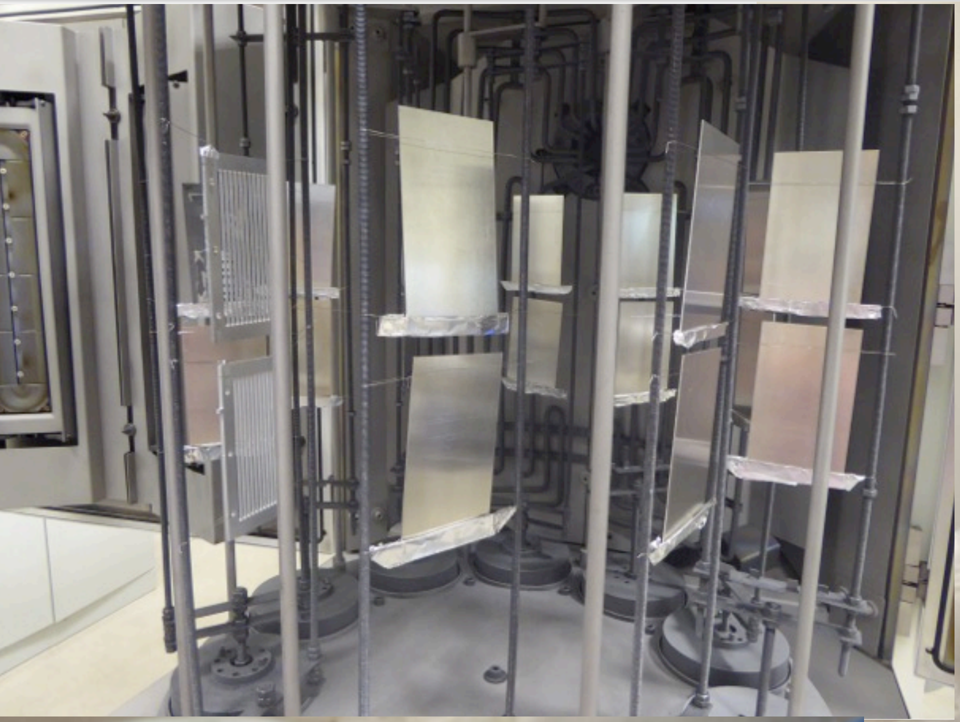
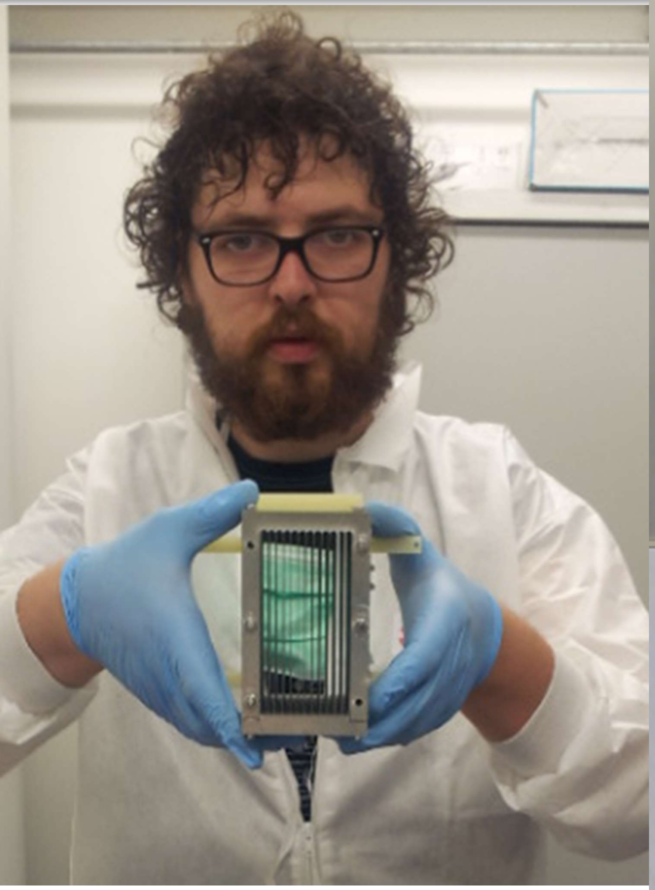
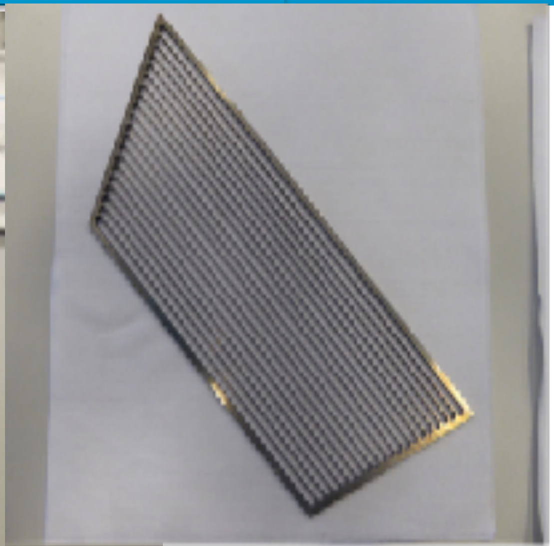
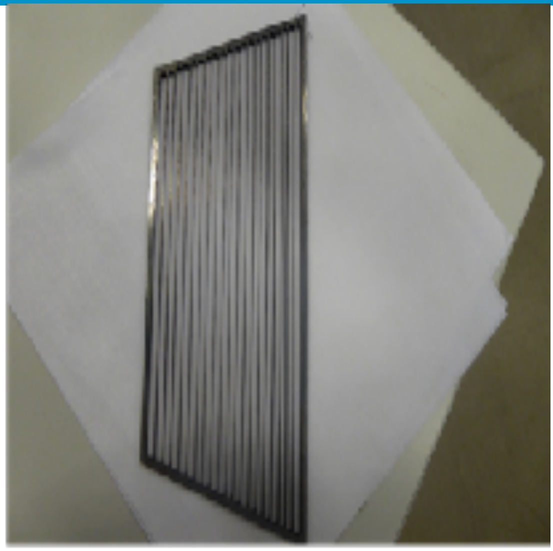
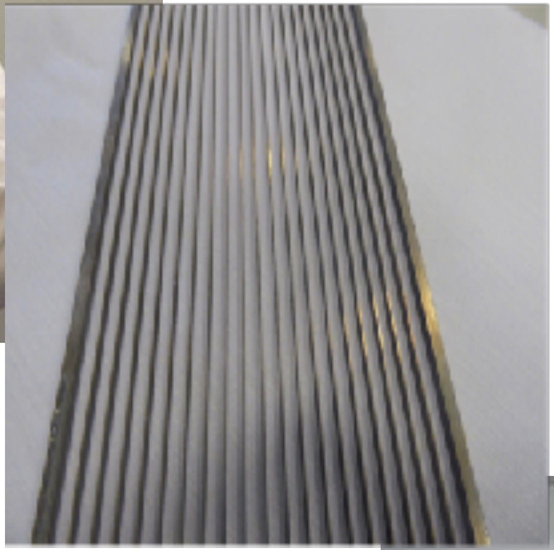
Consiglio Nazionale delle Ricerche
INFN Istituto Nazionale di Fisica Nucleare
Linköping University
ess EUROPEAN SPALLATION SOURCE

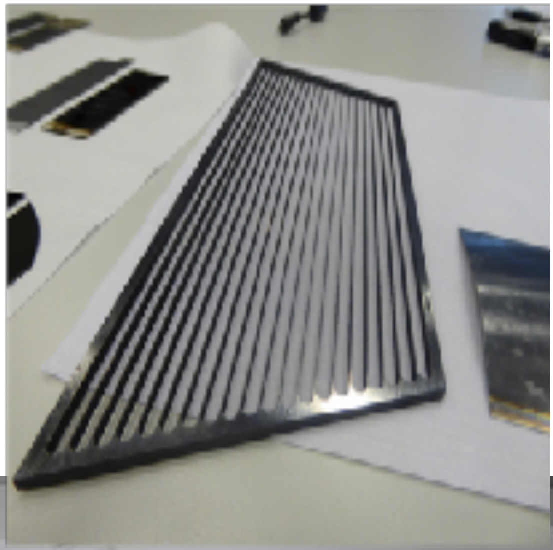


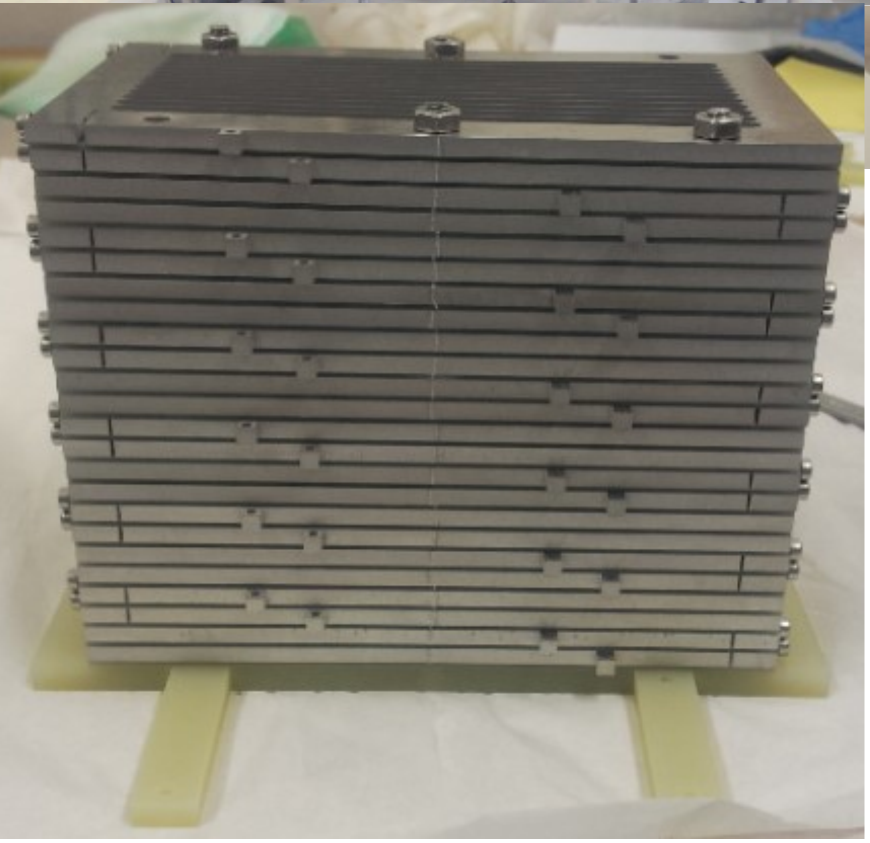






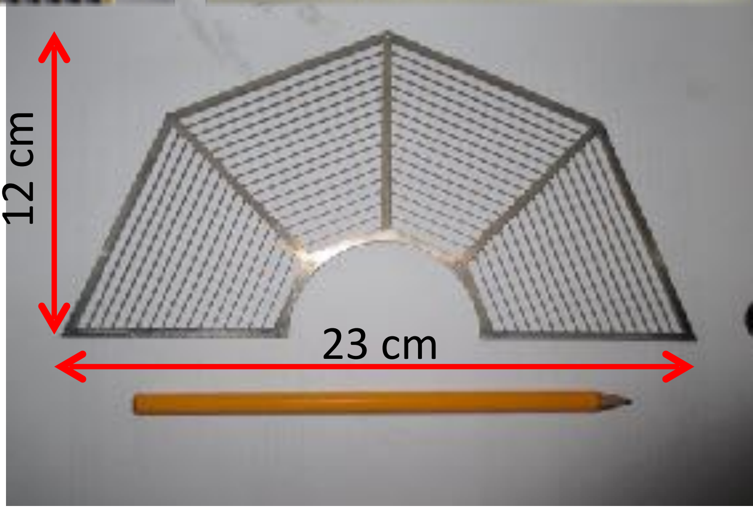






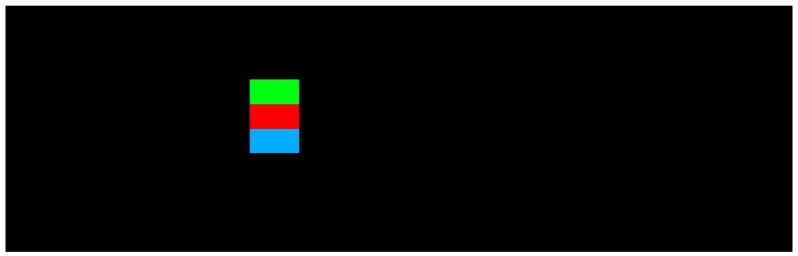
Stack of Conversion elements can be produced and coated

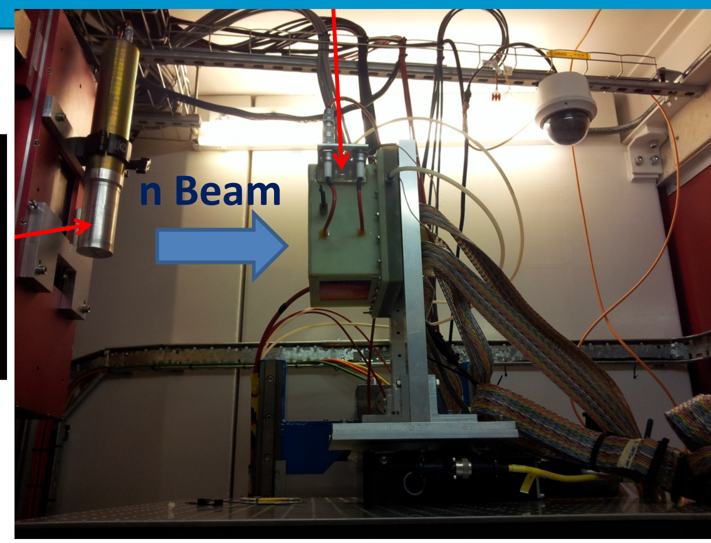
Precision waterjet cutting (Watajet, Milan)



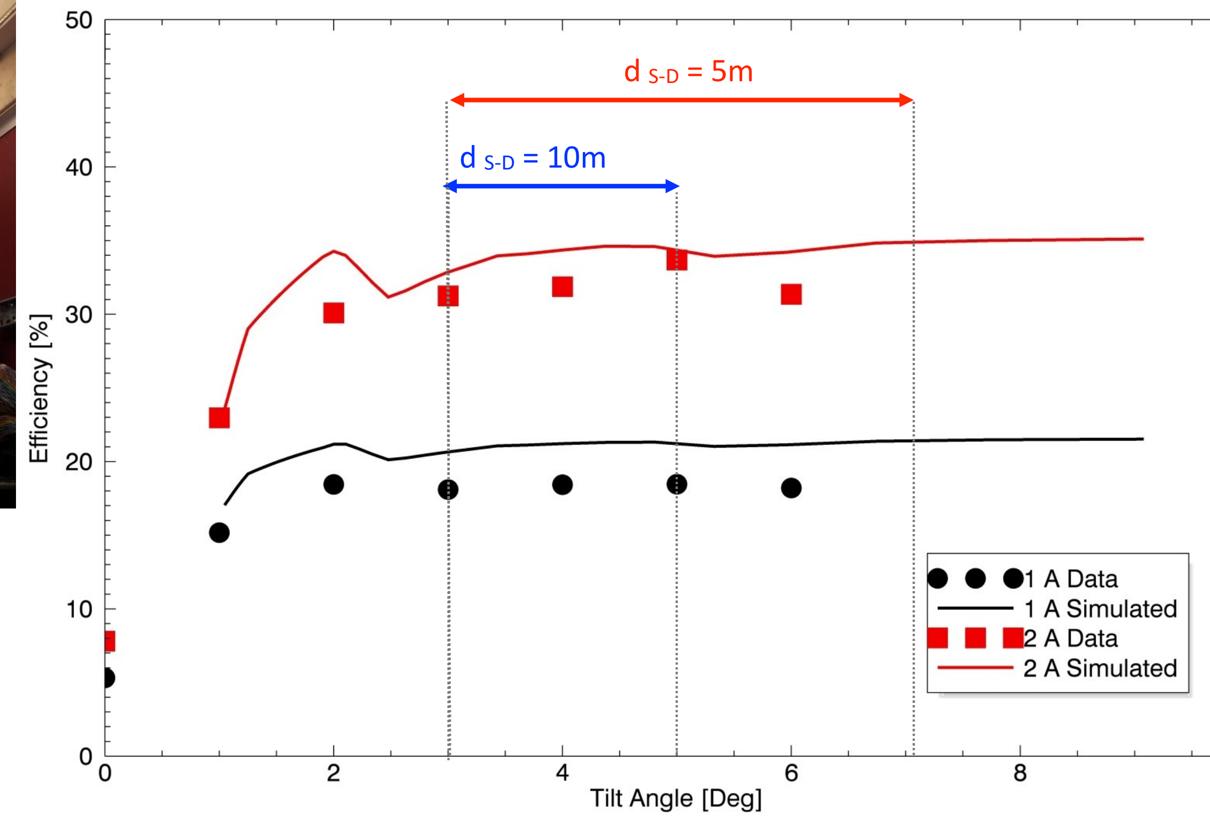
BANDGEM Detector Results

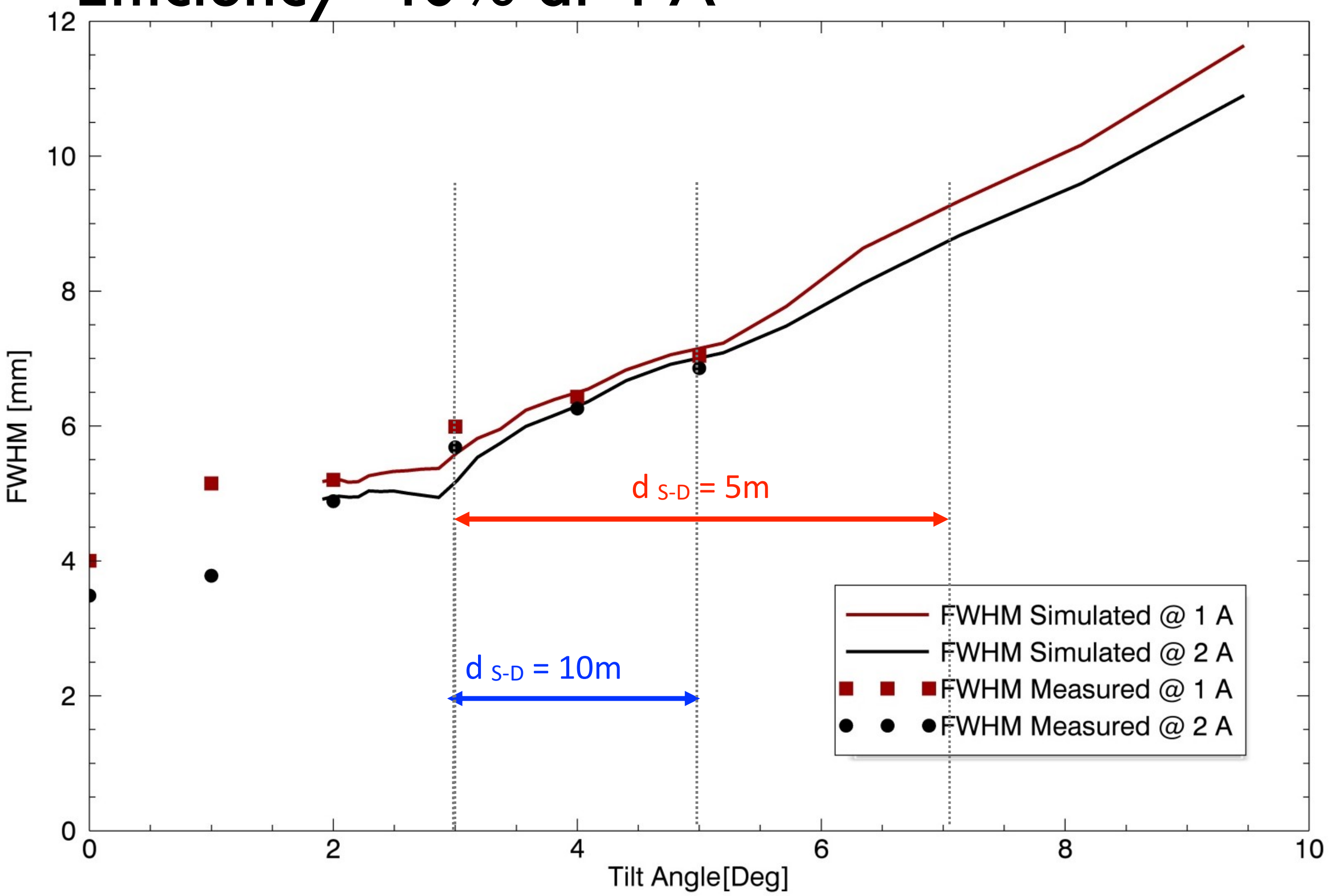
on EMMA@ISIS

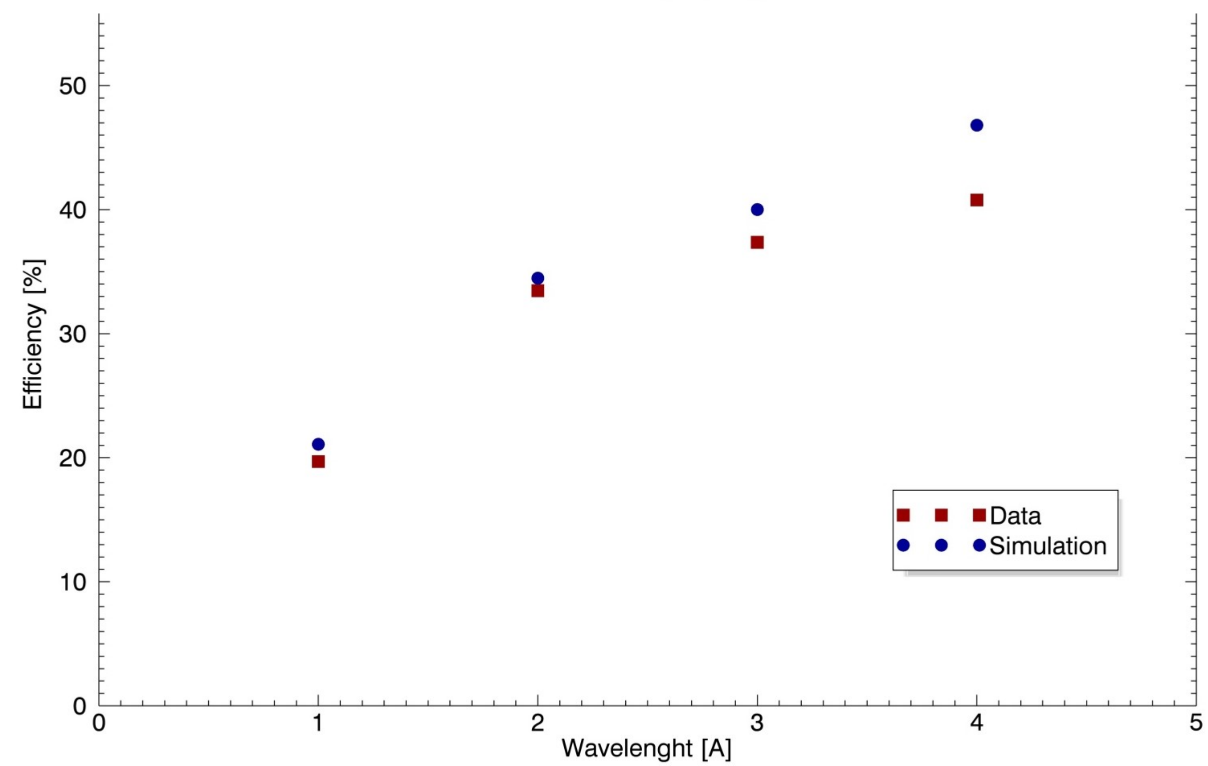




- Resolution as expected
- Efficiency with tilt angle as expected
- Efficiency>40% at 4 A







Detectors for ESS: strategy update for 16 instruments

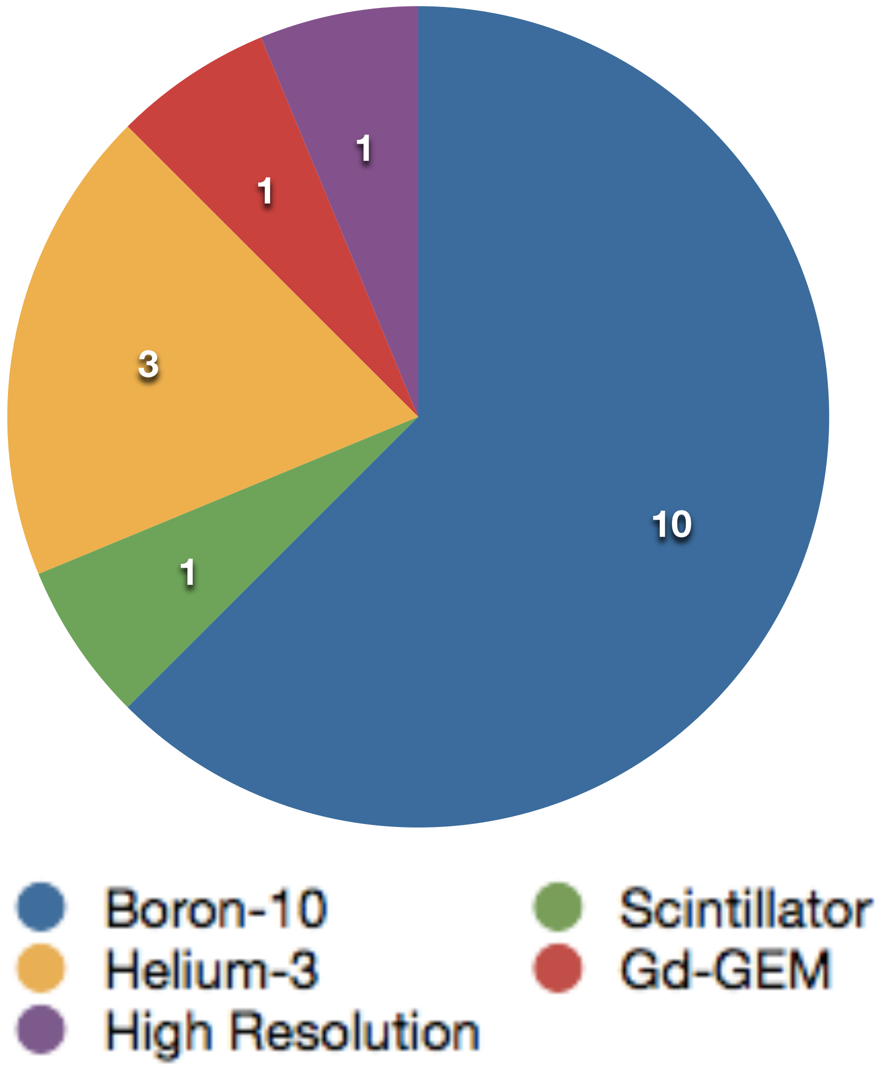
Instrument class	Instrument sub-class	Instrument	Key requirements for detectors	Preferred detector technology	Ongoing developments (funding source)
Large-scale structures	Small Angle Scattering	SKADI	Pixel size, count-rate, area	Scintillators	SonDe (EU SonDe)
		LOKI		10B-based	BandGem
	Reflectometry	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 BrightnESS)
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	
		MIRACLES			
		VESPA	Count-rate	3He-based	
SPIN-ECHO	Spin-echo	tbd	tbd	3He-based/10B-based	

Good dialogue and close collaboration needed for successful delivery and integration

Preferred Detector Technologies for Baseline Suite

Detectors for ESS will comprise many different technologies

Best-Guess at Detector Technologies for 16 Instruments:



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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

Laboratoire Léon Brillouin

BNC
Budapest Neutron Centre

wigner

Consiglio Nazionale Ricerche

IFP

UNIVERSITÀ 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) 4131/249032

IEAP

CDT GmbH
CASCADE
Detector
Technologies

FZÚ

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

UNIVERSITY OF MALTA
L-Università ta' Malta

Risø DTU
National Laboratory for Sustainable Energy

ideas

COSYLAB

IFE
Institute for Energy Technology

JÜLICH
FORSCHUNGSZENTRUM

FLNP

Mittuniversitetet
MID SWEDEN UNIVERSITY

icnd.org {

FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

HZB Helmholtz Zentrum Berlin

ISIS

J-PARC

NEUTRON SCIENCES

INTERNATIONAL COLLABORATION FOR THE DEVELOPMENT OF NEUTRON DETECTORS }

Summary

- ESS will provide increased neutron brightness
- Novel instrument designs push requirements for detectors well beyond current day state-of-the-art

- Detector systems project in good shape, and running at full speed
- Baseline detector designs exist
- Set of design and build partners identified and available
- Very much an open collaboration of groups across (mostly) Europe
- Having a capable build group and set of willing expertsise is as important as the details of the design

- Detector work now very much design, and not R&D
- Schedule and budget: make the detectors affordable and on time
- Enable partners

brightness

SoNDe Solid-State Neutron Detector