ESS detector activities II

Kalliopi Kanaki
Detector Systems Design Section Leader

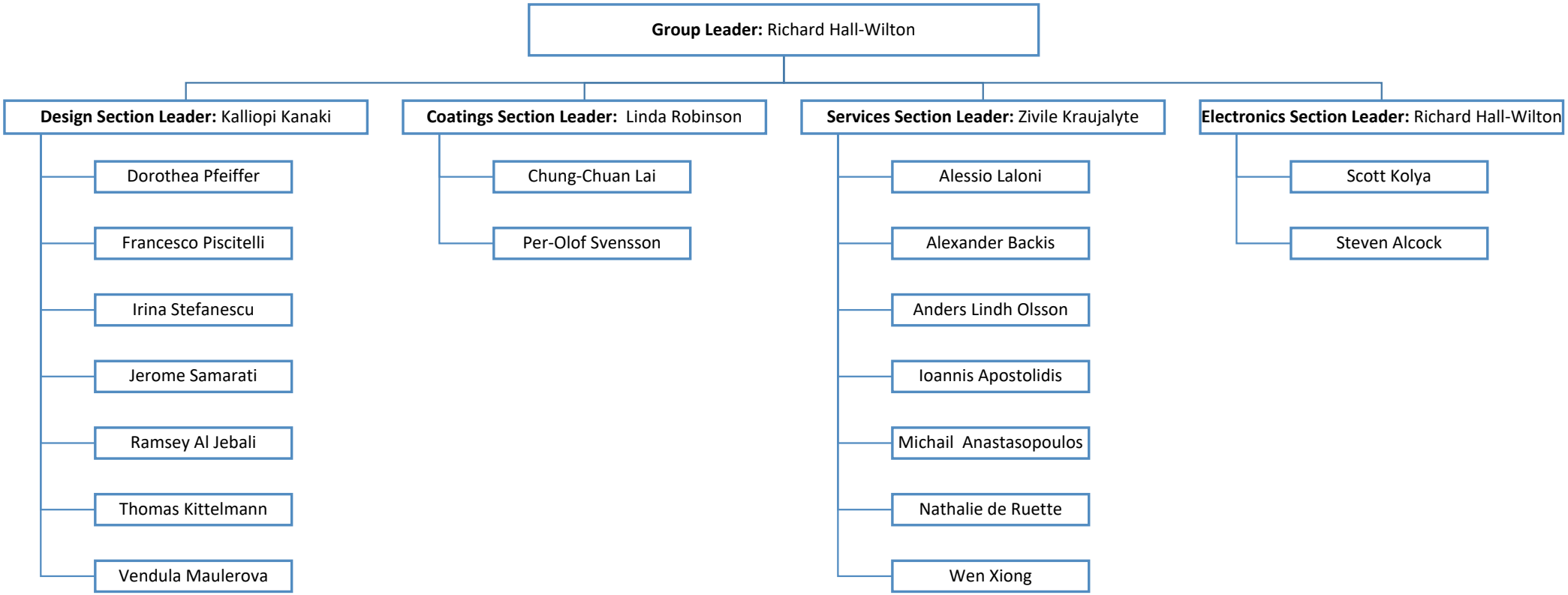
ICND meeting, Manchester, 27.10.2019

Outline

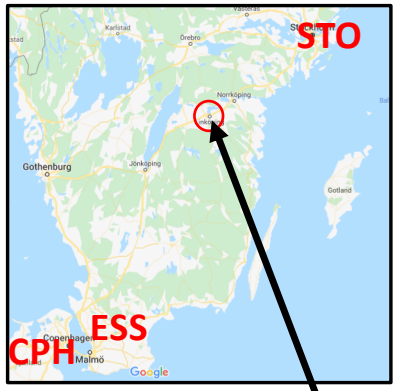
- Updates in the DG organigram
- Coating activities
- Engineering on MultiGrid, MultiBlade and GdGEM
- Workshop status
- Beam monitors common project
- Simulation activities

Lots of it covered during IKON17: 2 detector sessions and 1 beam monitor session (URL)

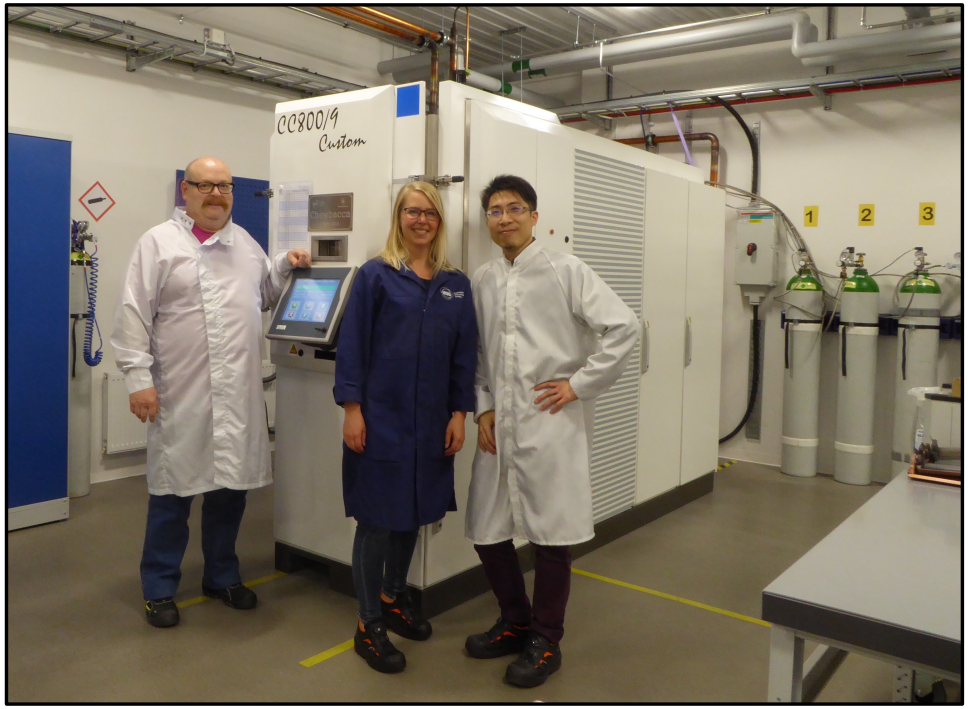
Detector Group Organigram



Neutronic coatings Section at ESS Detector Coatings Workshop in Linköping



ESS Detector Coatings Workshop in Linköping, established 2014



Linda Robinson
Neutronic Detector Coatings Section Leader

Chung-Chuan Lai
Coatings Scientist

Per-Olof Svensson
Production Technician

Futher contact:
linkoping@esss.se

Contact us if you want coatings!

Process development for ^{10}B thin films

EUROPEAN SPALLATION SOURCE

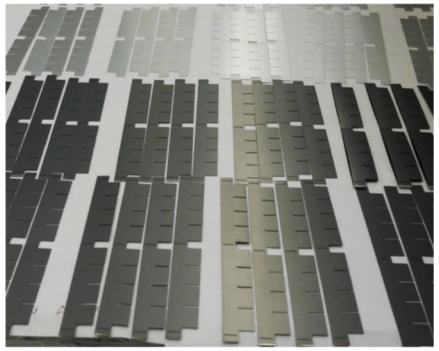
DC magnetron sputtering of B_4C coatings

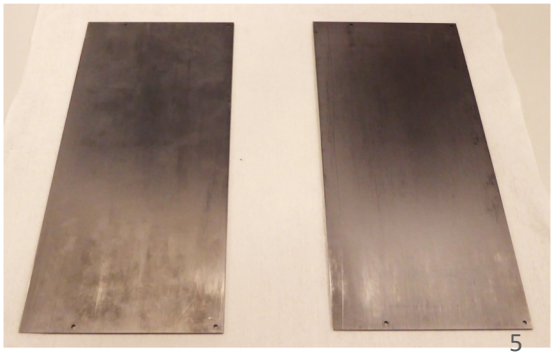
- Chemically stable compound
- Commercially available targets
- Well-established deposition technique
- Low-temperature process possible

Thin film with maximized neutron detection efficiency:

- Good adhesion to substrates
- 1- or 2-side coating possible
- Large area possible
- High density
- Low impurity level
- Controllable thickness and uniformity
- Neutron radiation hard

Al





Ti

Detector production

Receive and iteration of deposition requests


Deposition requests

Send to linkoping@esss.se
Please answer the questions that are applicable to your request

Date 13/12/2017
Name Ioannis Apostolidis
Shipping address ESS Office
Phone number 0721792068

Affiliation ESS
Project MG.24.I
Type of collaboration with ESS -
Short description of project (background, status so far, other useful information) Similar to MG.24.T

Single or repeated coating request Single, blades are enough for a demonstrator
When would the depositions to be done Second week of January

Receive samples and holders

Batch production of B4C coated samples

Sample characterization and documentation

Packing and shipment

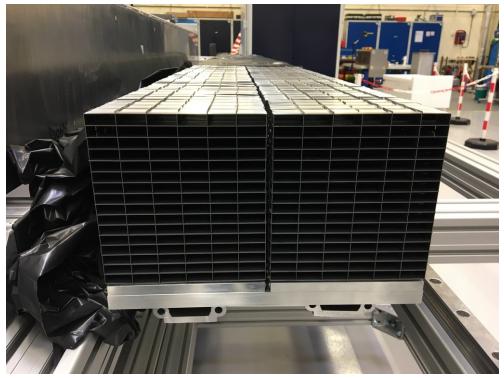
Continuous optimization of our production flow and quality!

Multigrid and Multiblade

Our main focus detectors in Linköping

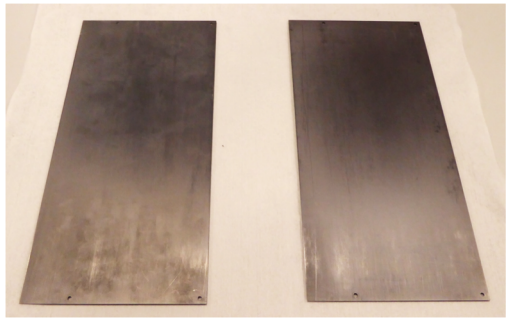
Multigrid - MG

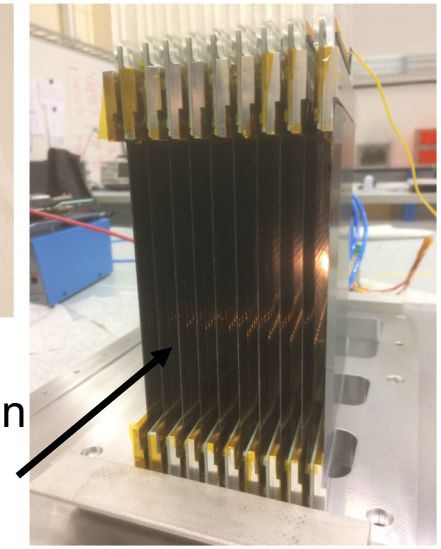
- CSPEC and T-REX
- Estimated time to produce coatings for multigrid instruments 1-2 years / instrument



Multiblade - MB

- ESTIA and FREIA
- Estimated time to produce coatings for multiblade detectors 1-2 months / instrument





Production capacity for Multi Grid

Production capacity for MG

- Production speed expected to be around 400 runs/year
- 2 runs/day
- 360 Normal Blades (NB)/run, 240 Radial Blades (RB)/run
- 2.6 m^2/run for MG, NB
- Approximately 1000 m^2 per year in full production
- Production cost below 1000€ per coated m^2

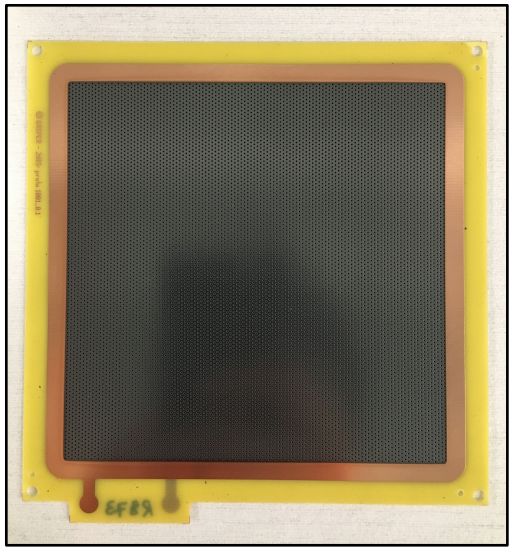
QA and QC procedures and documentation in place
Operation as a production line

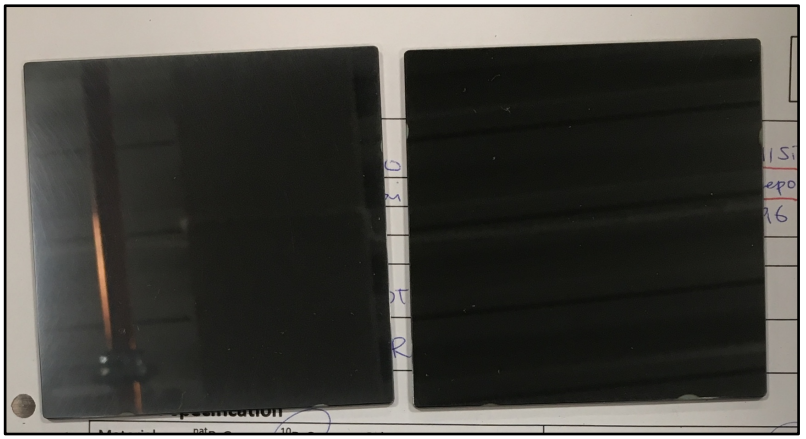
Coatings for latest demonstrator

- Coatings for 300 grids were produced this summer with both NB and RB
- All runs were done in less than a month with 2 runs/day
- Production went smoothly with no bigger concerns

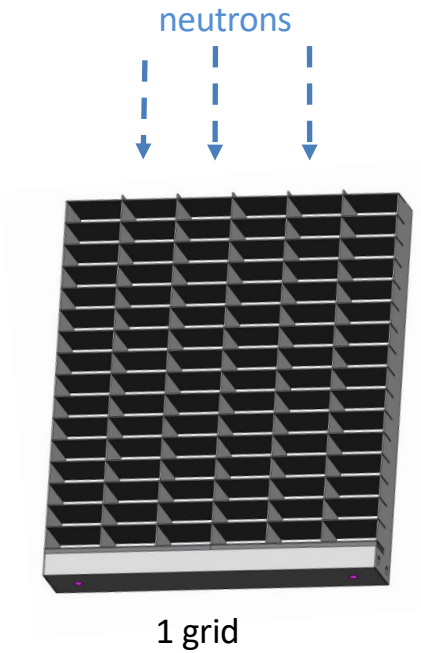
Process development done for our collaborators

- Coatings for temperature sensitive substrates or other more difficult substrates, such as Cu coated Kapton, soda-lime glass, SiN-SiC composite has been made

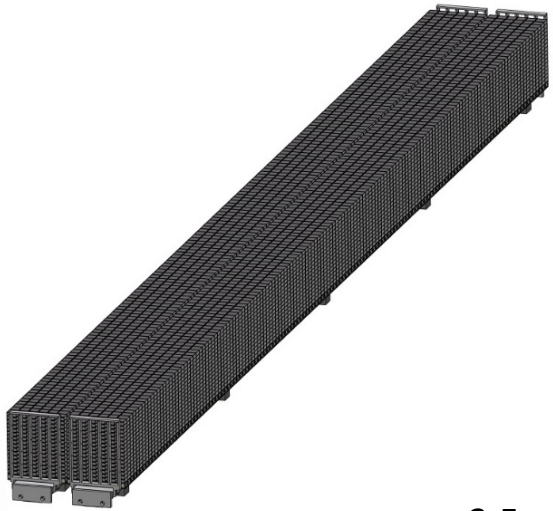




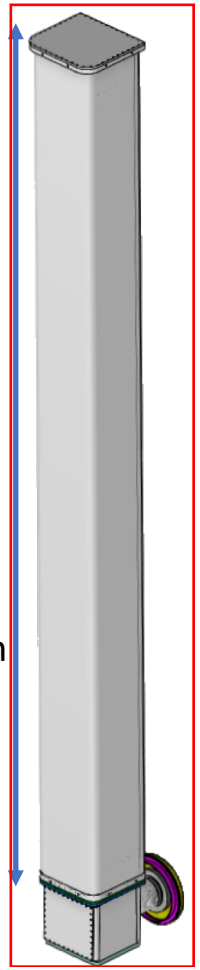
Engineering - MultiGrid



1 grid

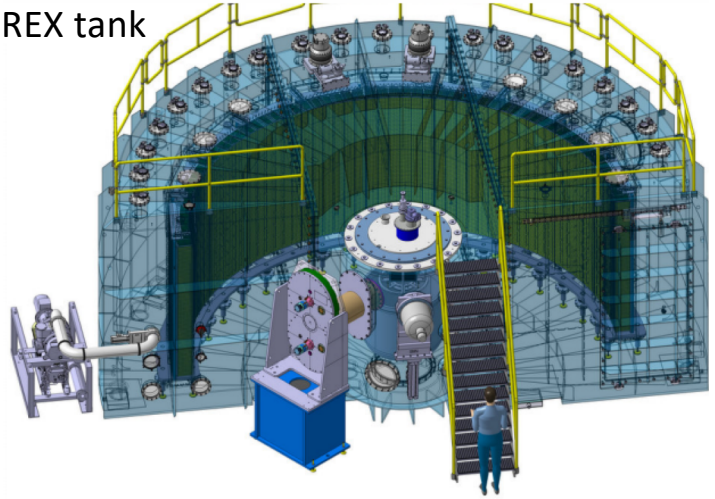


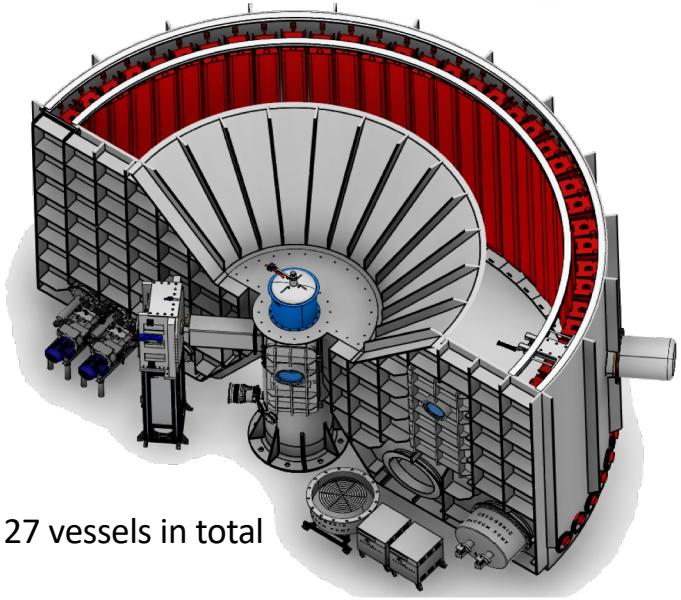
140 grids x 2modules/vessel



Frontend electronics
Sensors

One detector every 5.349°
27 starting detectors, 135° coverage

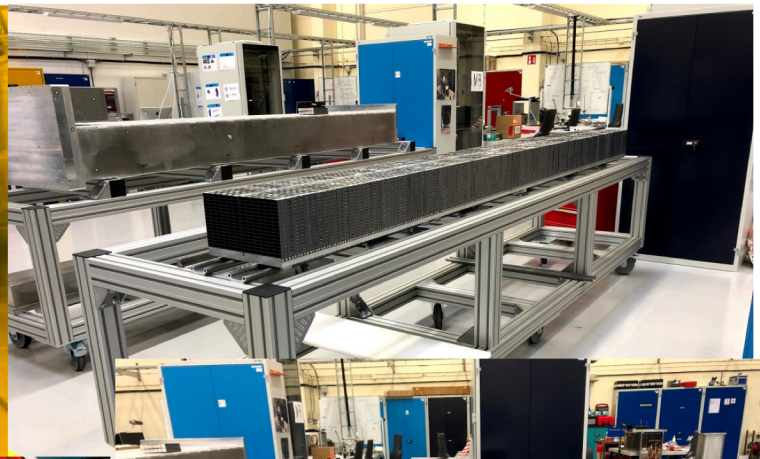


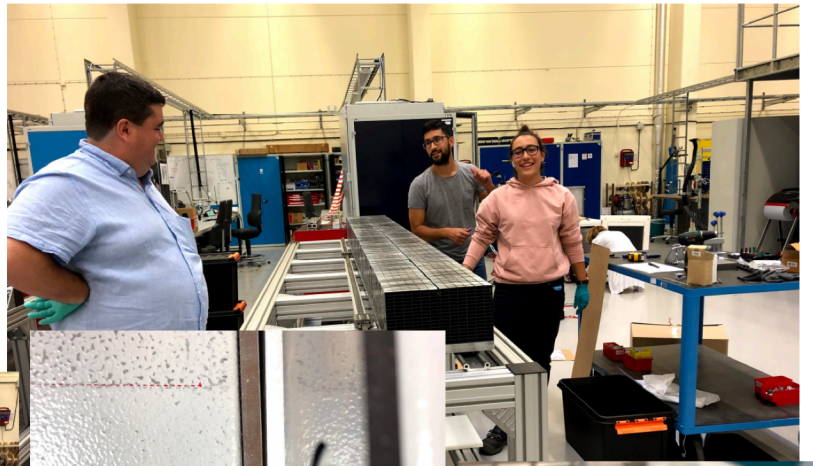


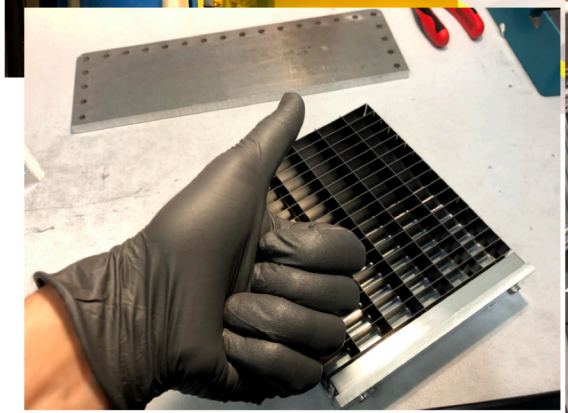
27 vessels in total

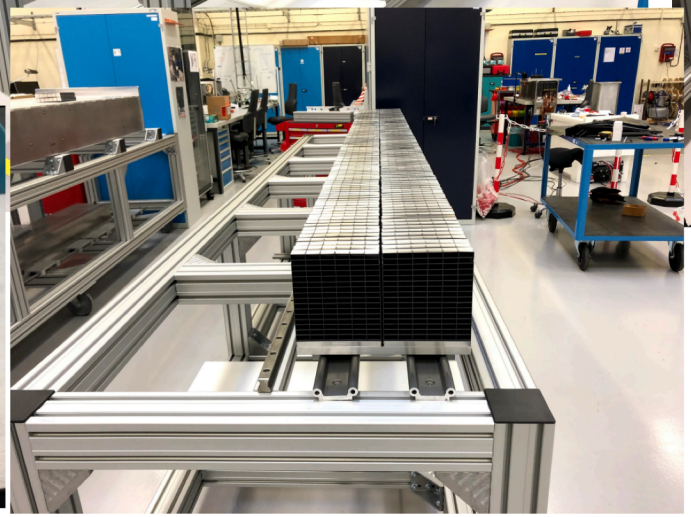
CSPEC tank

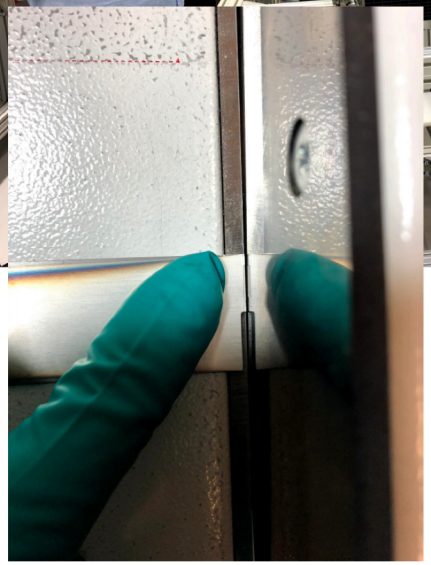
Engineering - MultiGrid

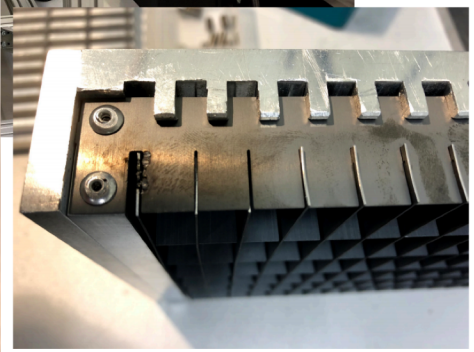








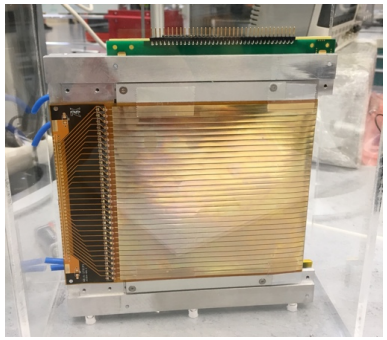


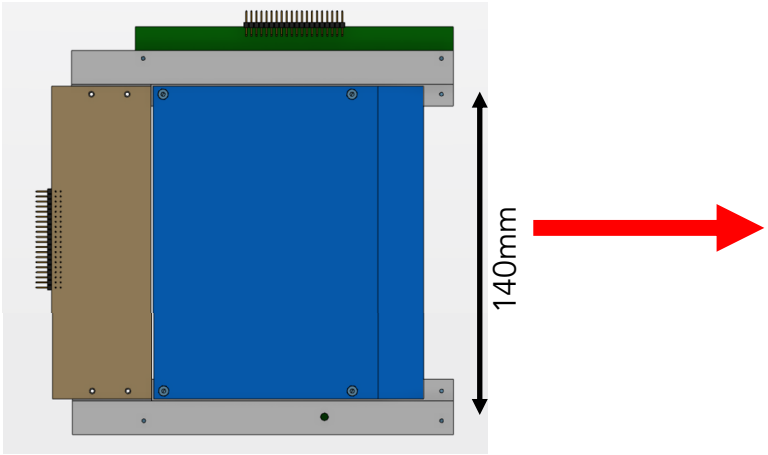


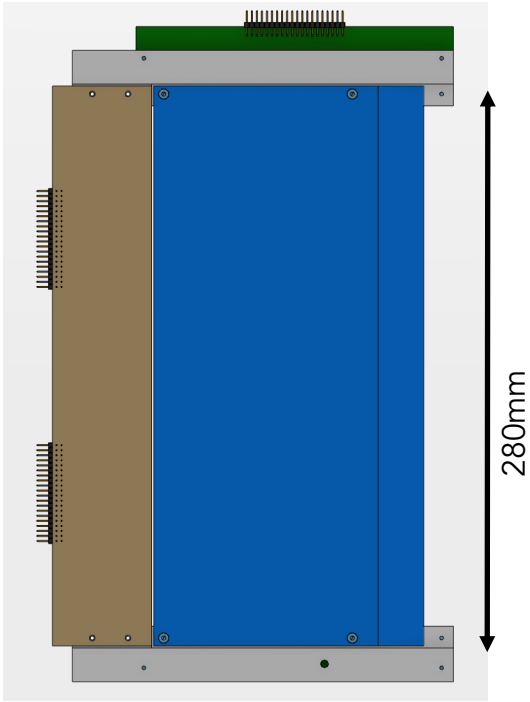
Engineering - MultiGrid

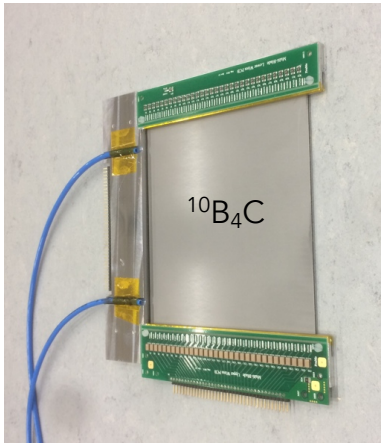
- MG.CSPEC 300 grids assembled as a dry run for production
- 5% of CSPEC grids built over 1.5 months this summer
- QC in place for: blade cutting, grid assembly, welding, training, blade traceability protocols integrated.
- Lessons learned have been fed back to the process
- About to receive a prototype vessel for a column

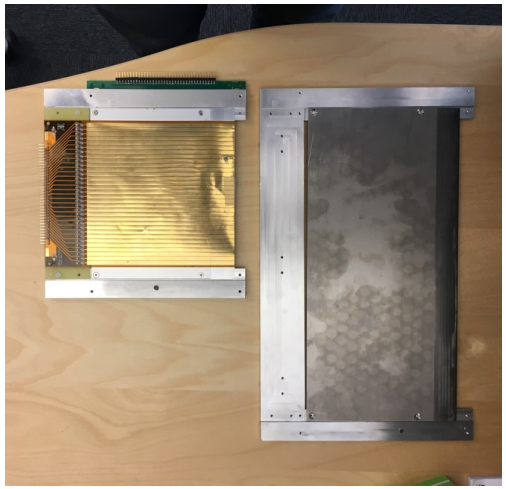
Engineering
Multi-Blade for ESTIA & FREIA: MB300





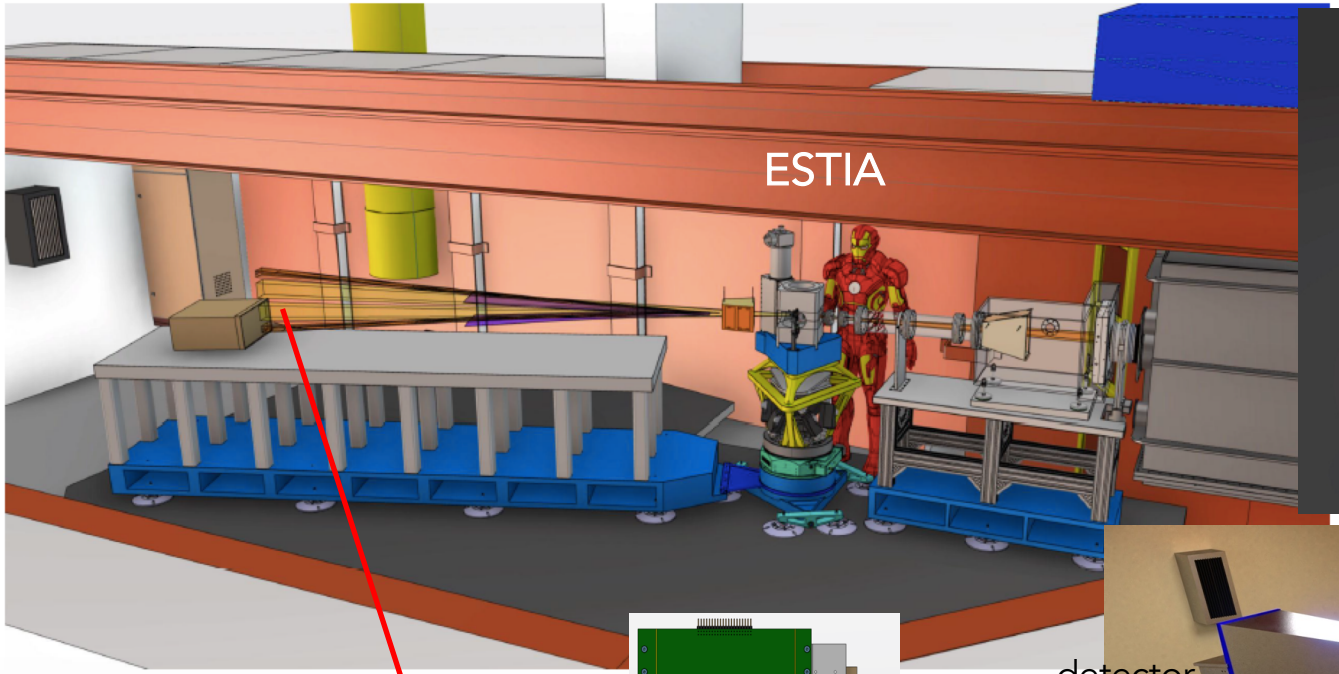


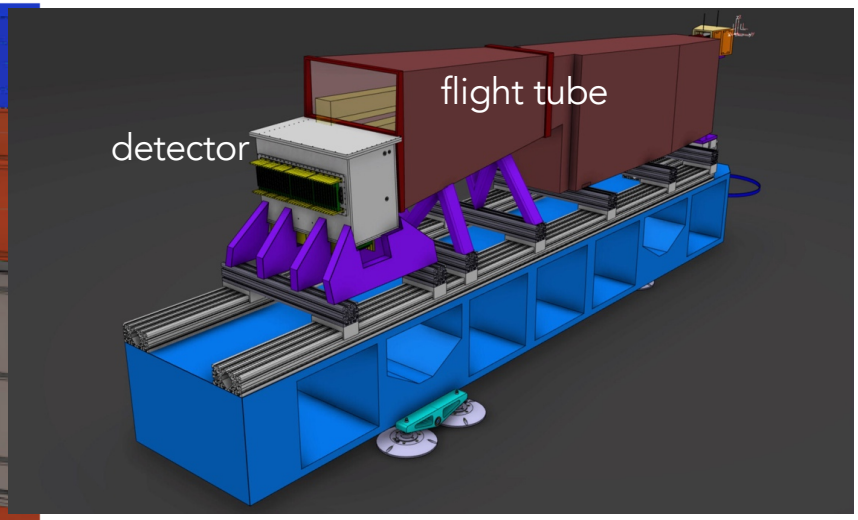


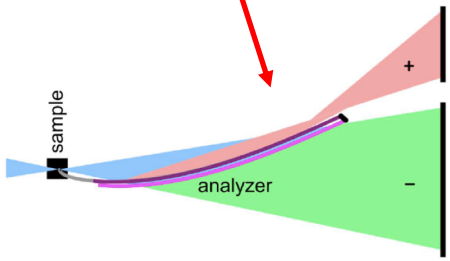


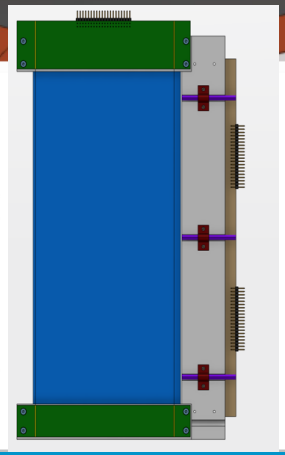
FINAL DESIGN

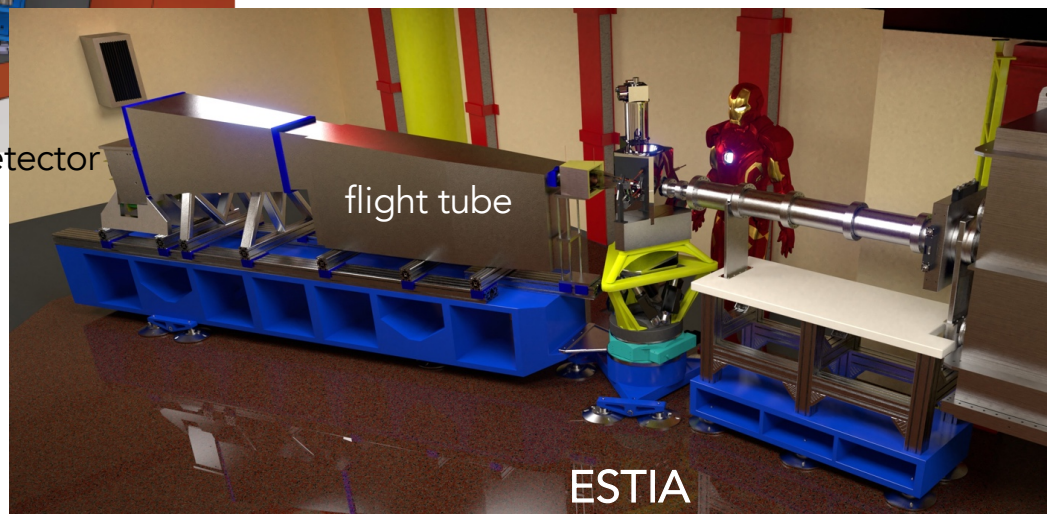
Multi-Blade 300 for ESTIA



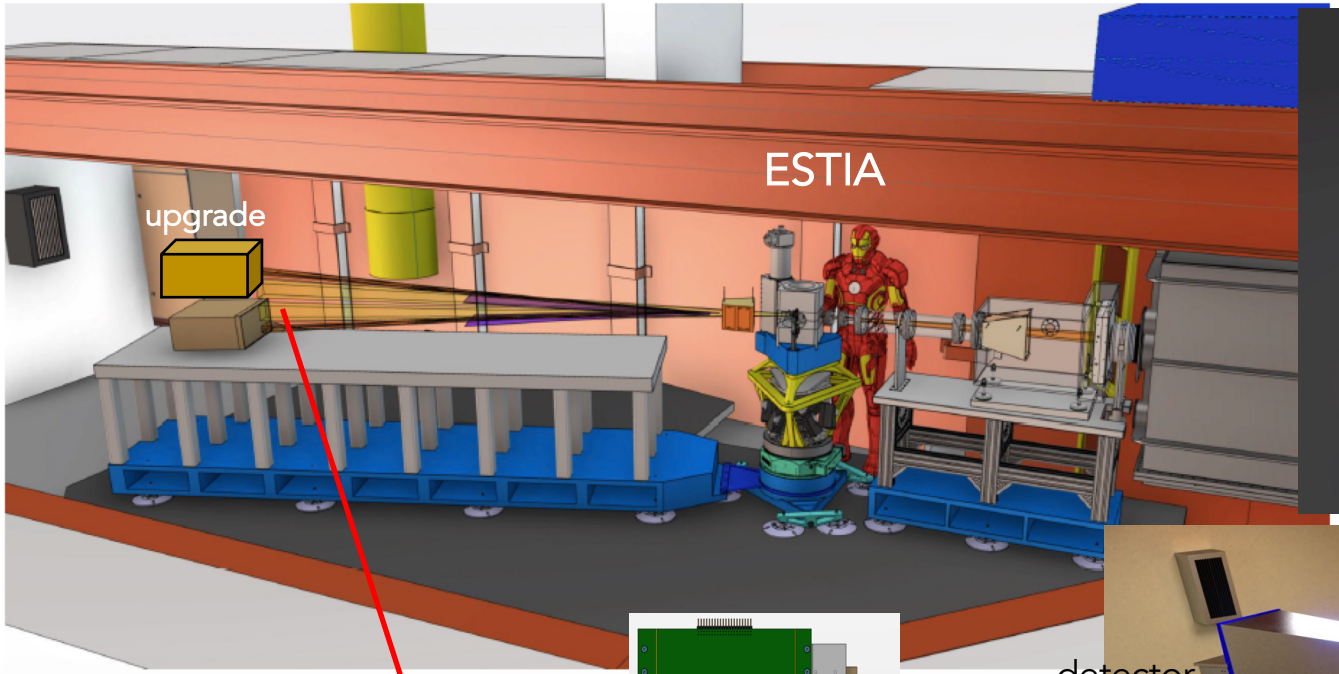


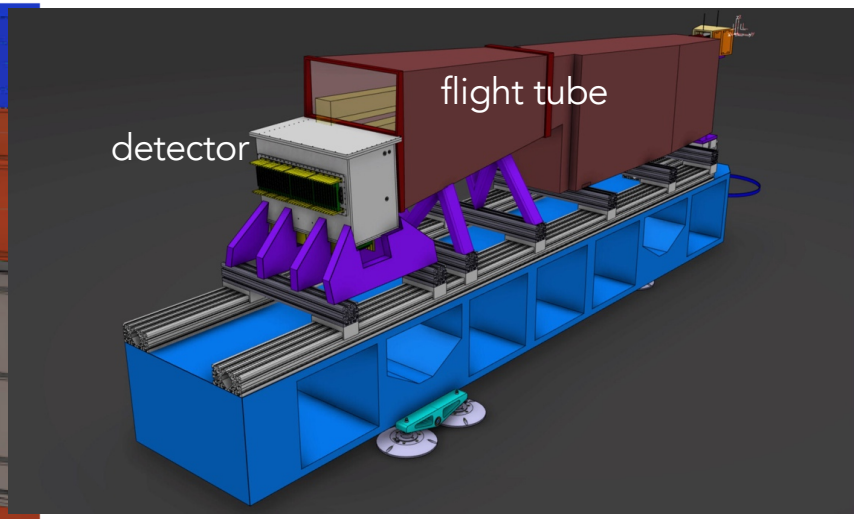


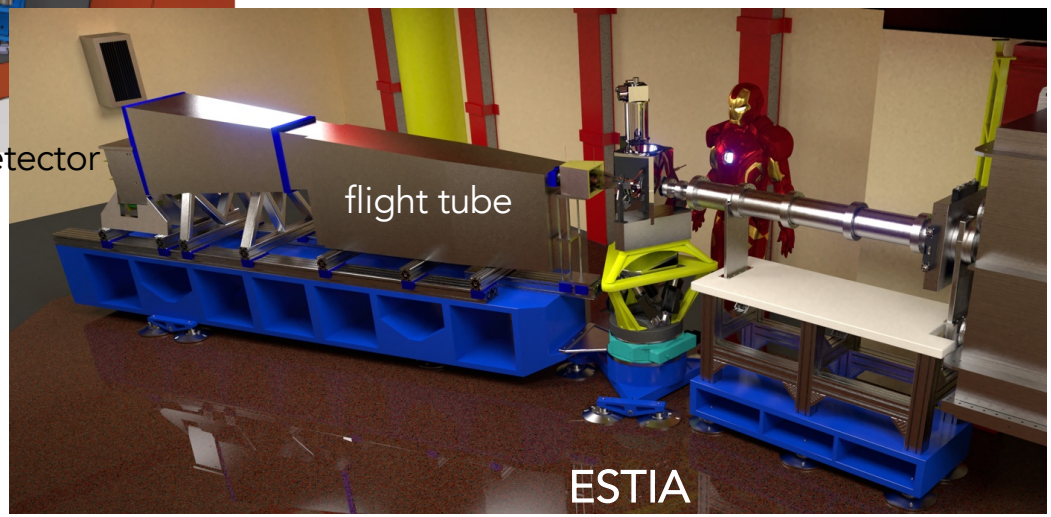


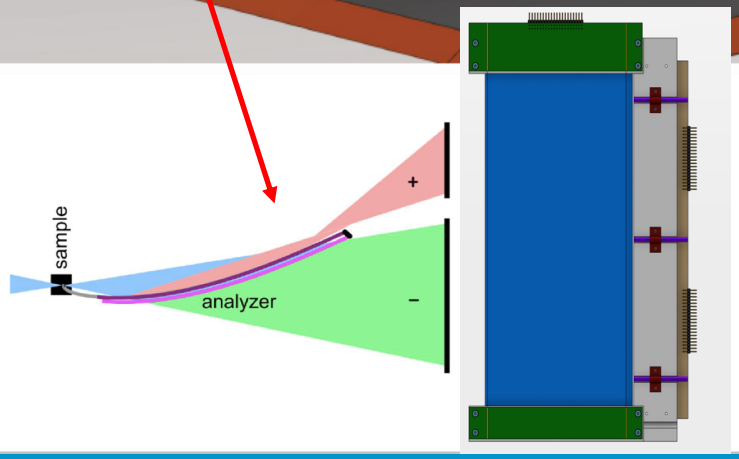


Multi-Blade 300 for ESTIA

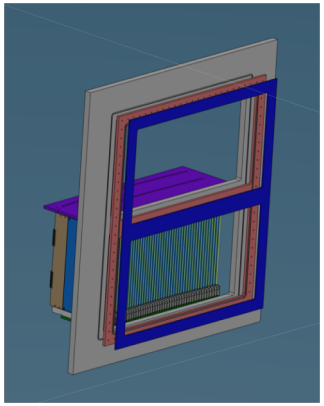


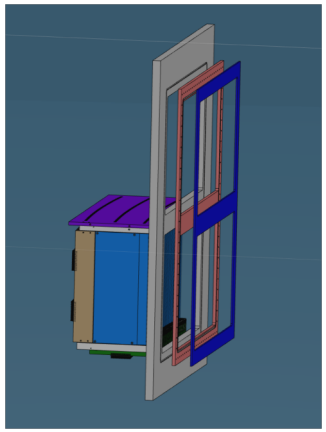


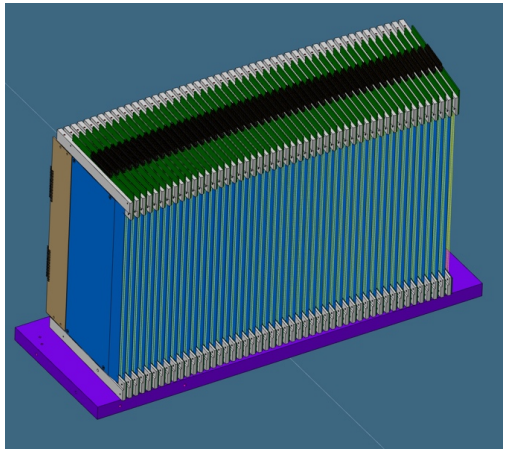


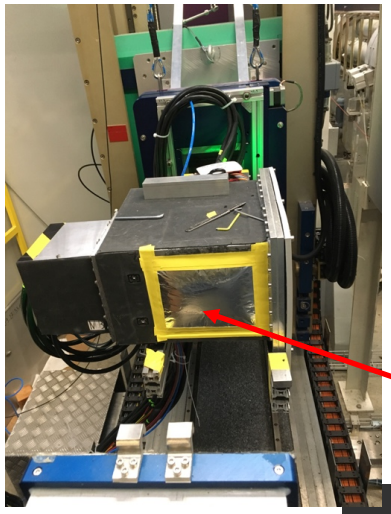


Multi-Blade 300 for ESTIA

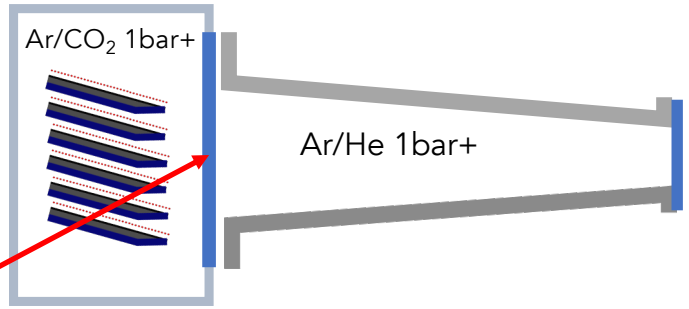








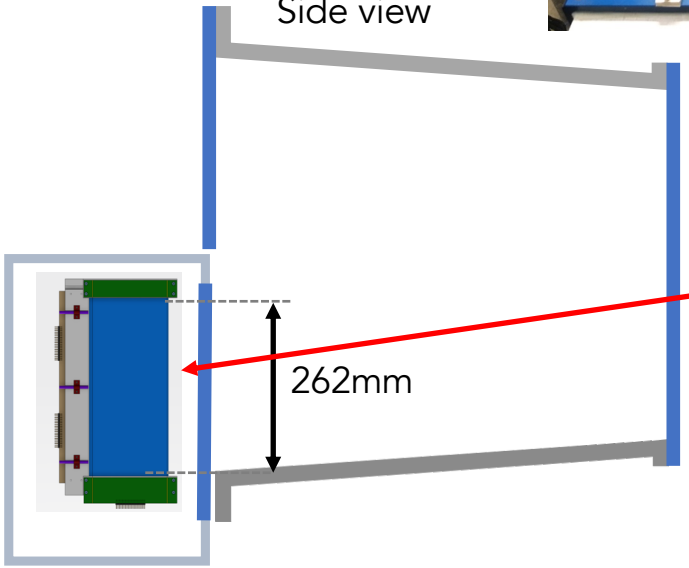
Top view

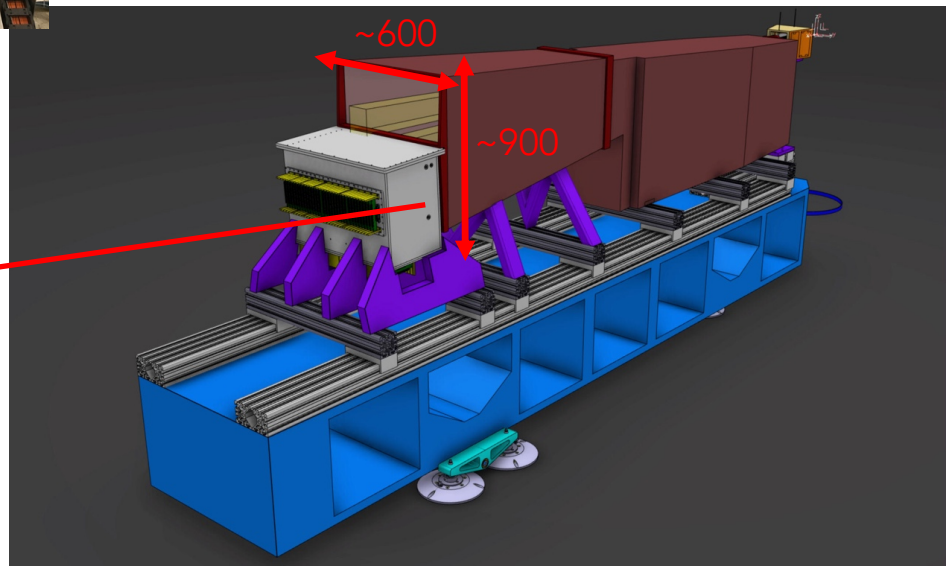


Al foil

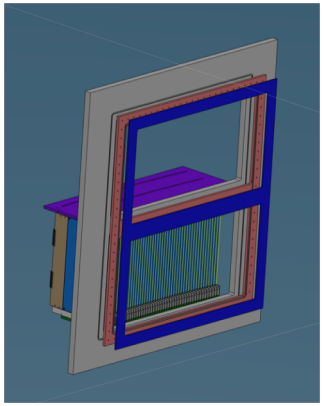
Multi-Blade

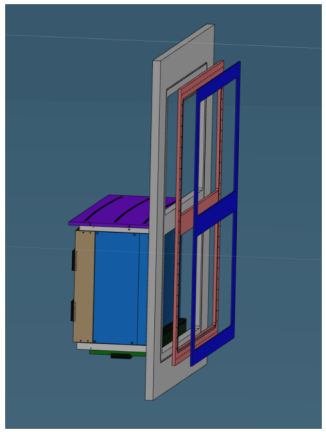
Side view

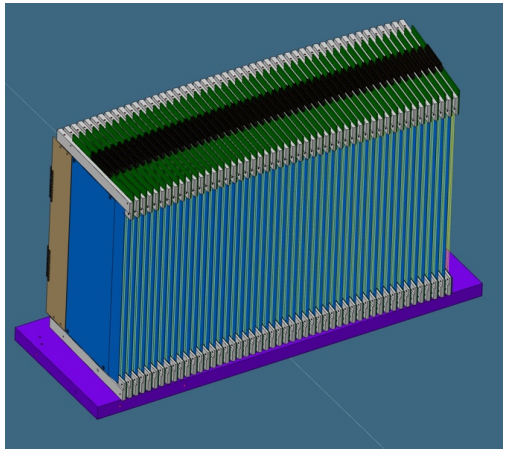




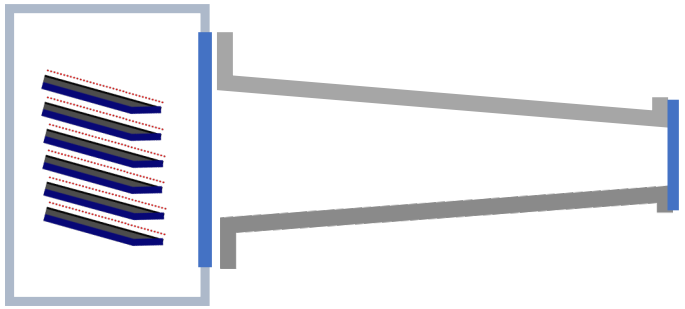
Multi-Blade 300 for ESTIA



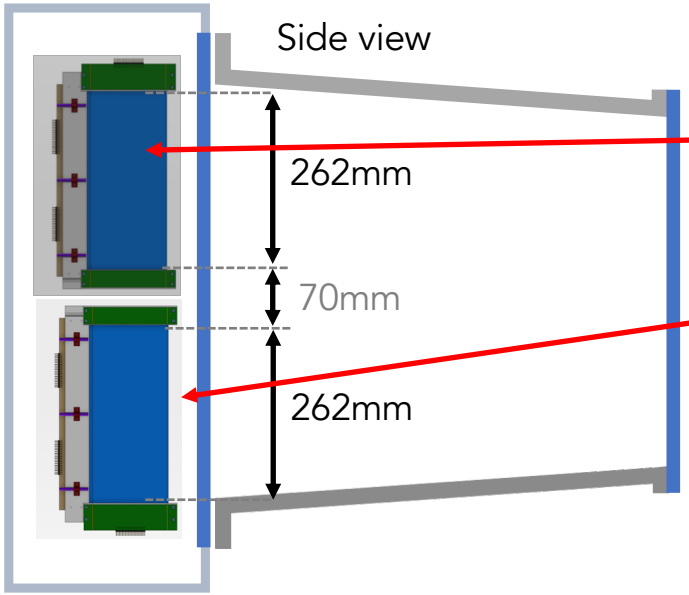




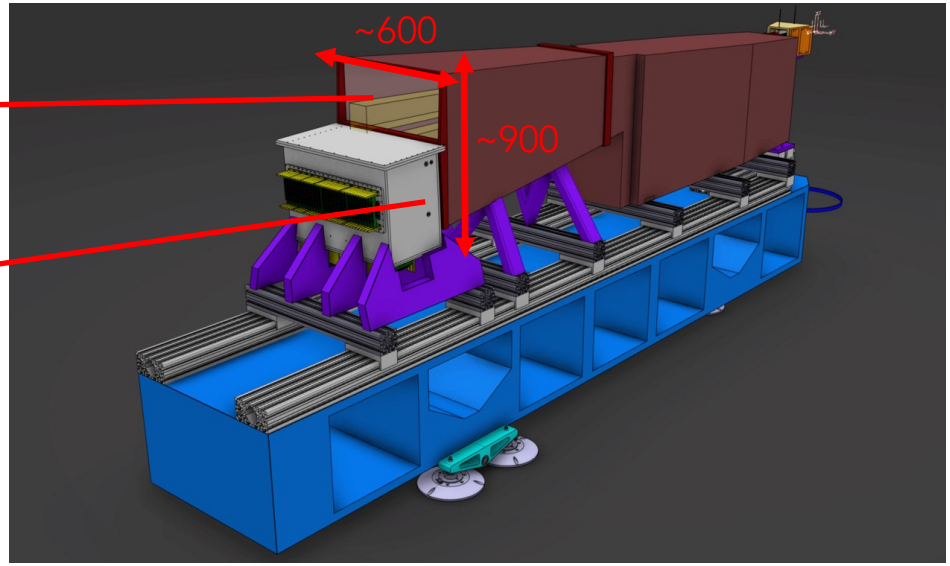
Top view



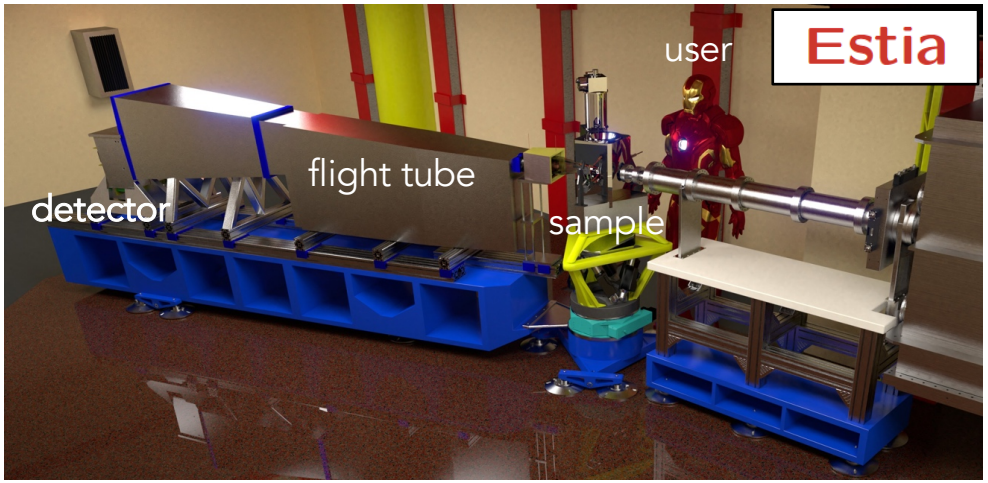
Multi-Blade



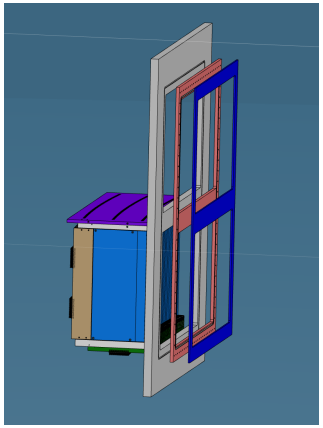
upgrade

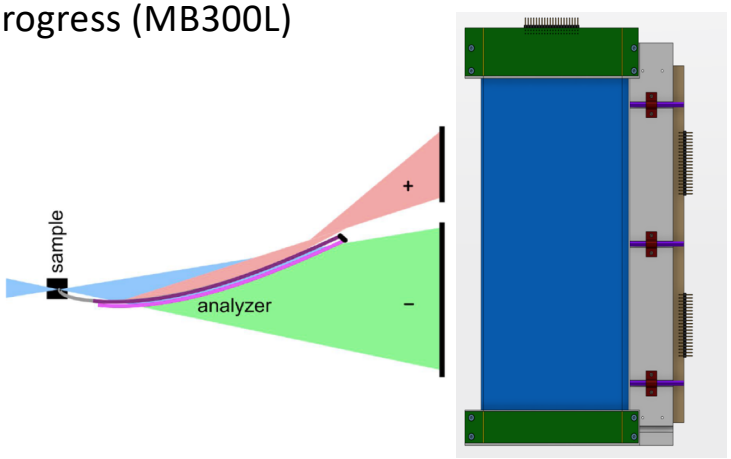


Multi-Blade 300 for ESTIA



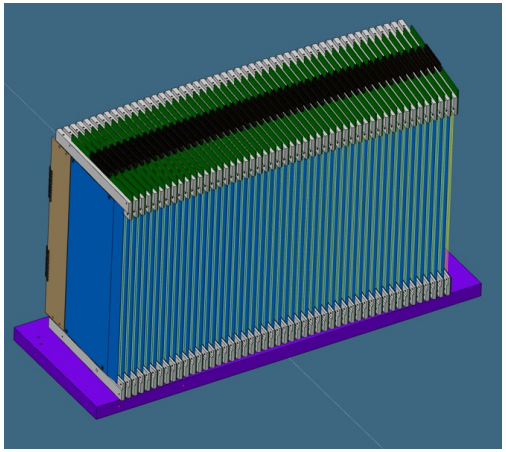
Last prototype in progress (MB300L)
to test long blades

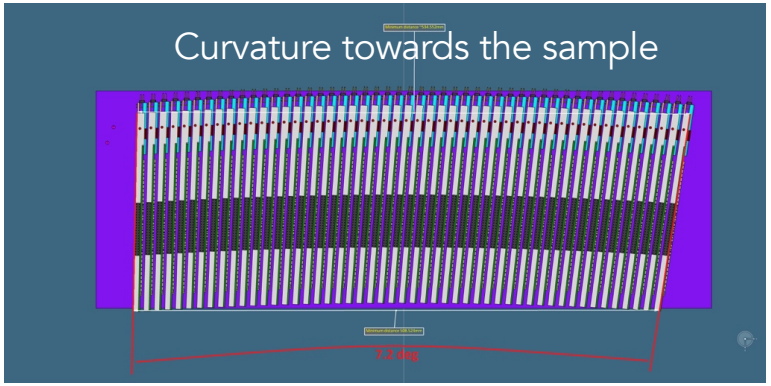


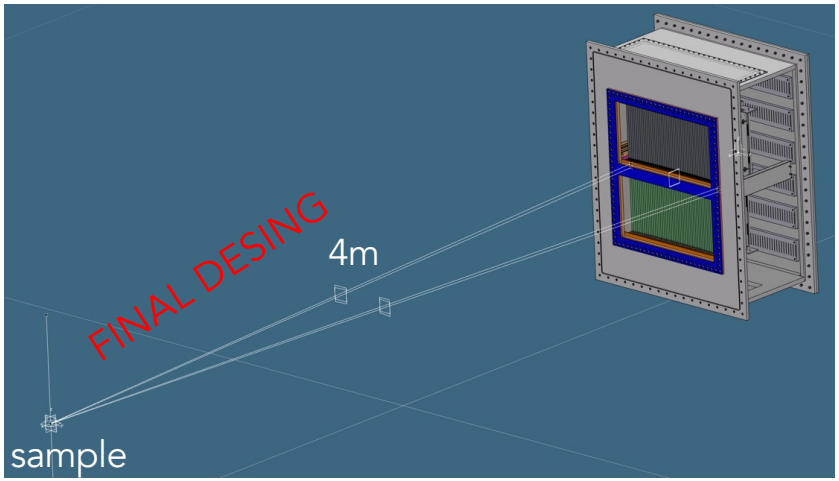


1 blade

50 blades

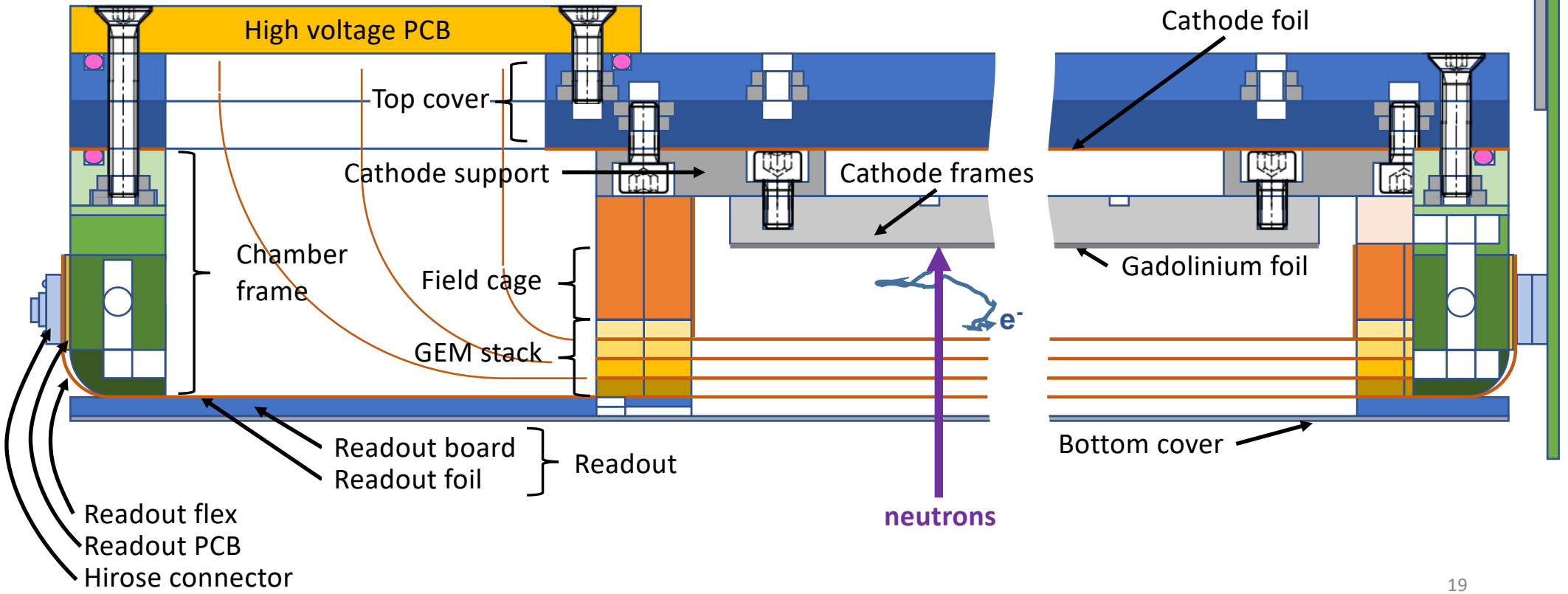




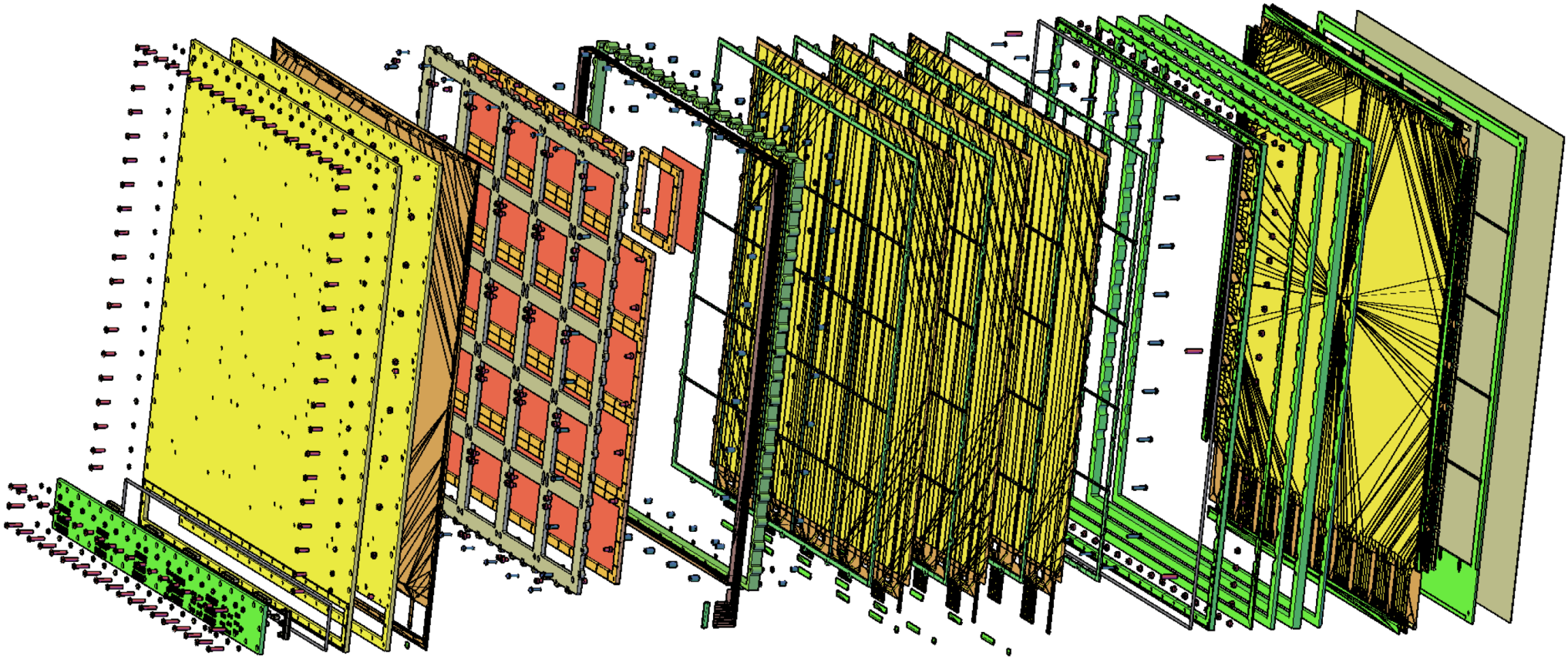


The NMX GdGEM demonstrator cross-section

Detector prototype v0 “Zita”

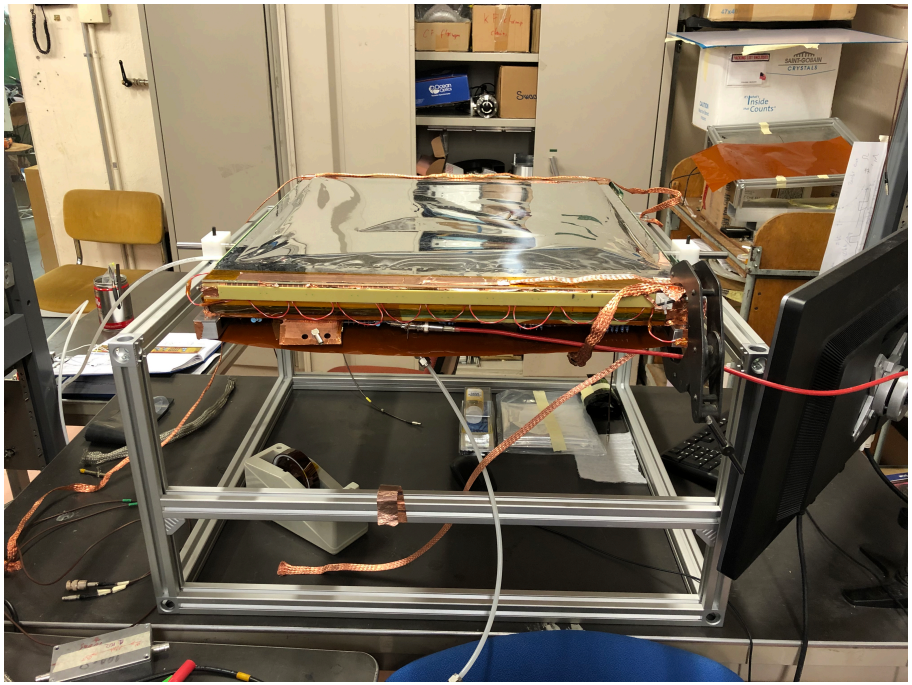


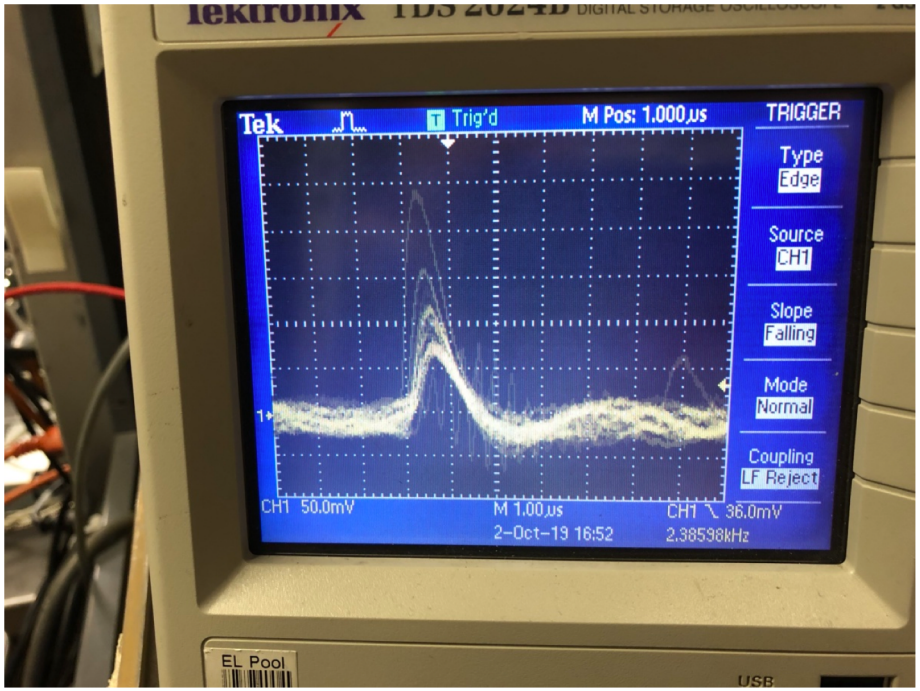
Engineering - GdGEM



Engineering - GdGEM

- Full scale demonstrator gives signals
- To be tested next year
- Ready for production
- IKEA-like manual for assembly: URL, page 12





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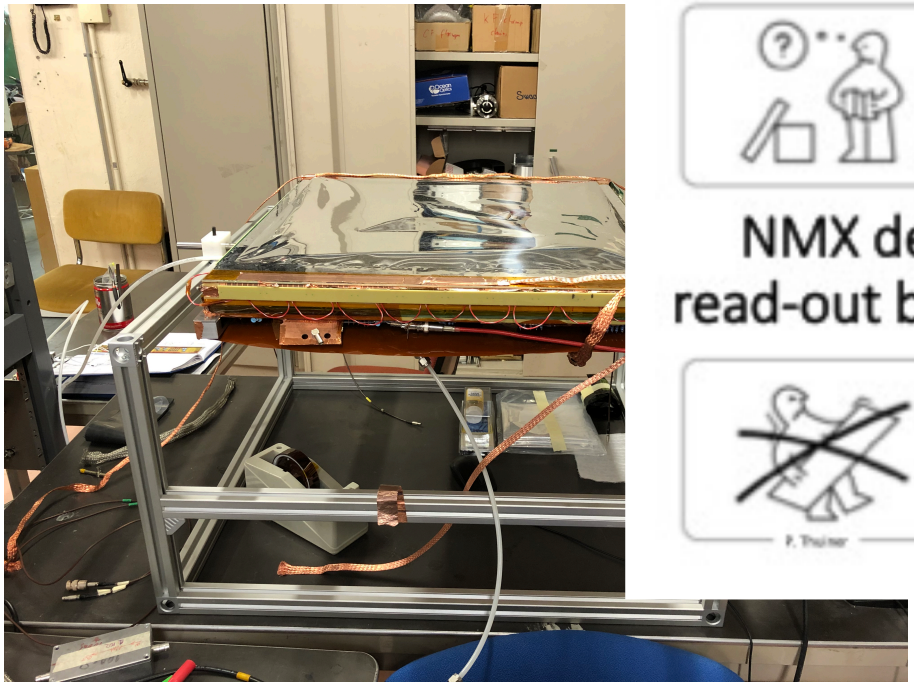
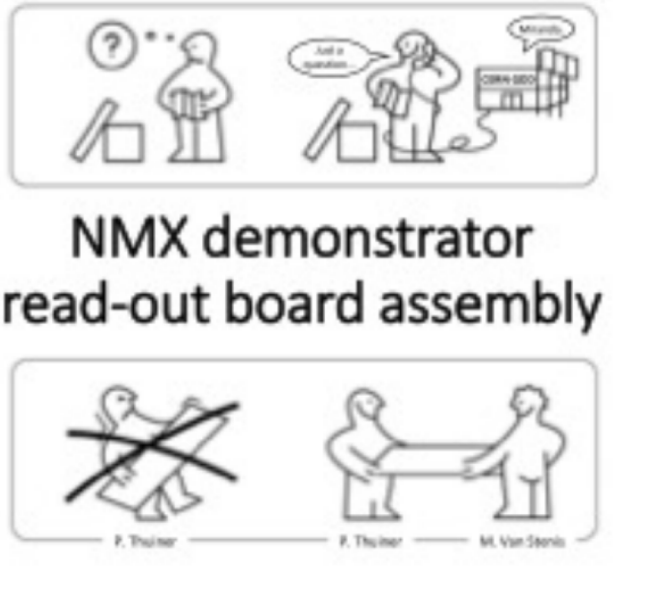
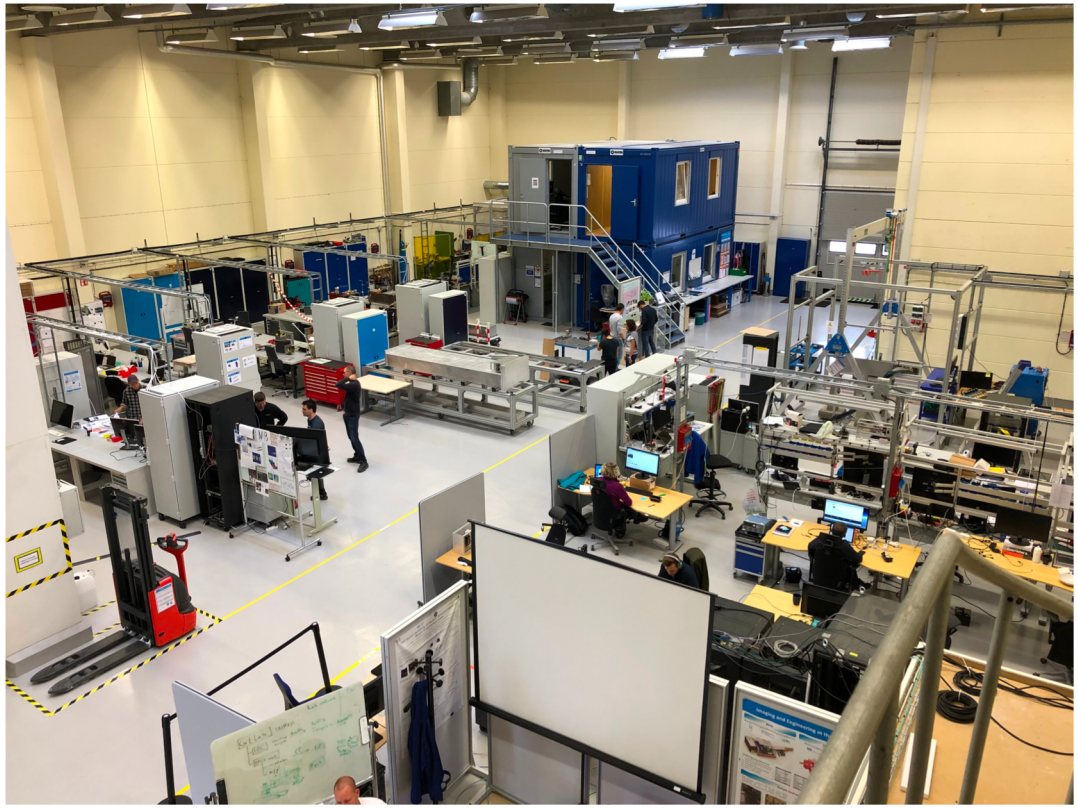




Workshops – Utgård and Mimir's well

> 1000 m^2
700 m^2 for DG



Workshops – Utgård and Mimir’s well

> 1000 m^2
700 m^2 for DG

Workshops – Utgård and Mimir's well

> 1000 m^2
700 m^2 for DG

- 2 mechanical engineers in the ESS DG
- 1 workshop coordinator
- 1 technician
- To expand significantly in the near future

E04: first workshop at site (long instrument hall E01)

Beam monitors common project

- Ensure provision of monitors to enable science case of instruments and in particular early science success
- Allow efficient commissioning and long term facility monitoring
- Design, procurement, installation and cold commissioning of ~50 beam monitors for the ESS instruments from a few kW to 2 MW
- People involved:
  - Steven Alcock – electronics engineer (15%-20%)
  - Ioannis Apostolidis – mechanical engineer (50%)
  - Kalliopi Kanaki – neutron scientist (50%)
  - Vendula Maulerová – workshop assistant (50%)
  - Anders Lindh Olsson – integration coordinator
  - Alessio Laloni – detector technician
- Joint ILL-ESS researcher on BM with Bruno starting 1 December

Current BM locations

	Bunker			Guides-Choppers		Sample	
1. ESTIA	10.7m	11.1m				23m – Pre sample	
2. SKADI	Before HS			After bunker wall		Pre sample	Transmission
3. VESPA	7.38m	10.02m		20.02m		58.37m - Pre sample	59.6m – Transmission
4. ODIN	8.42m			23.7m		53m - pre sample	
5. DREAM						Pre sample	Transmission
6. NMX	BBG					Sample incident	
7. BEER	6.44m	9.875m				Pre sample (out of scope – HZG will build)	
8. CSPEC				28m	105.6m	160m – Pre sample	
9. BIFROST	6.9m			27.9m	80.1m	Pre sample	Transmission
10.MIRACLES	8.3m			54.6m		162.2m – Pre sample	163m – Transmission
11.MAGIC	6.7m					Pre sample (0.5-1.5m from sample)	
12.TREX	6m			108m		162m – Pre sample	Transmission
13.HEIMDAL	8.1m			20m		Pre sample	
14.FREIA	7m	8.3m	10.3m (or 14m)	16.25m		Pre sample	
15.LOKI	6.5m			15.5m (TBD)		Pre sample	Transmission (Snout) Transmission (Beam stop)

50+ monitors

Beam monitors per location and function

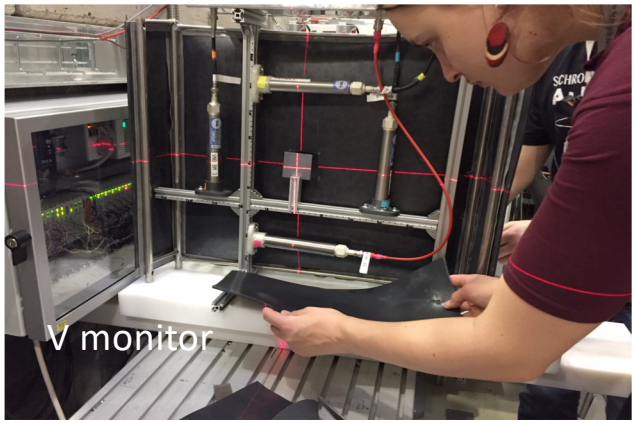
Location	BM options (✓: qualified, ?: work in progress)	Desired functionality
Bunker	Fission chamber (flux × eff ≤ 10^{12} n/cm^2/s) ✓	• Flux • Timing • Discrimination of thermal n vs. fast n vs. γ
	Ionisation chamber (flux × eff ≤ 10^{12} n/cm^2/s) ✓	
	GEM (flux × eff ≤ 10^{8} n/cm^2/s) ?	
Guides/choppers	Semi-parasitic V monitor (10^{9} n/cm^2/s) ✓	• Flux • Timing (to be investigated further for V- and γ-monitors)
	GEM (flux × eff ≤ 10^{8} n/cm^2/s) ?	
	Parasitic γ-monitor ?	
Pre- and post-sample	MWPC (flux × eff ≤ 10^{5} n/cm^2/s) ✓ GEM (flux × eff ≤ 10^{8} n/cm^2/s) ?	• Flux • Timing

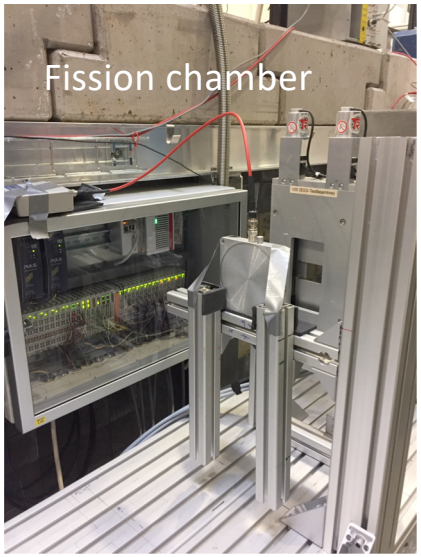
Instrument participation status

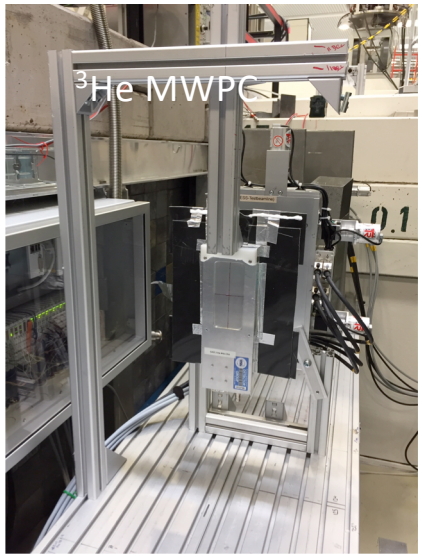
#	Instrument / BM partner	Spatial envelope status	Indicative participation status
1	**ESTIA / PSI**	Design in CAD	Interested in utilities and services
2	**ODIN / PSI**	Reservations in CAD	Waiting for response from PSI
3	**DREAM / FZJ**	Reservations in CAD	Not interested for now
4	**BEER / HZG**	Reservations in CAD	Positive for bunker BMs / remaining BMs from HZG
5	**CSPEC / TUM**	Reservations in CAD	Waiting for response from TUM
6	**BIFROST / DTU**	Reservations in CAD	Positive / expecting offer from ESS
7	**MAGIC / FZJ**	Reservations in CAD	Waiting for response from FZJ
8	**LoKI / ISIS**	Reservations in CAD	NitroGEM option
9	SKADI / JCNS	Reservations in CAD	Positive / first offer sent from ESS to JCNS
10	VESPA / CNR, ISIS	Reservations in CAD	Waiting for response from CNR/ISIS
11	NMX / ESS	Reservations in CAD	positive
12	MIRACLES / ESS Bilbao	Reservations in CAD	positive
13	T-REX / CNR	Waiting: contacted	Waiting for response from CNR
14	HEIMDAL / AU	Meeting at IKON16: Waiting on information	Waiting for response from AU
15	FREIA / ISIS	Reservations in CAD	positive

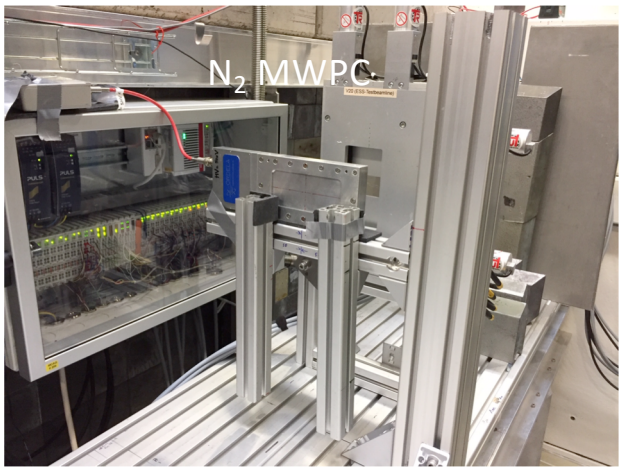
Beam tests & devices tested at HZB

- 3 runs at V20 & 1 at V17 (>20 days of beam time)
  - February 2019: focus on V-based monitor
  - May 2019: focus on DAQ integration and timing
  - July 2019 (parasitic): focus on the CDT ionization chamber
- 2 MWPC (^{3}He, N_2), V monitor, fission chamber, ionisation chamber

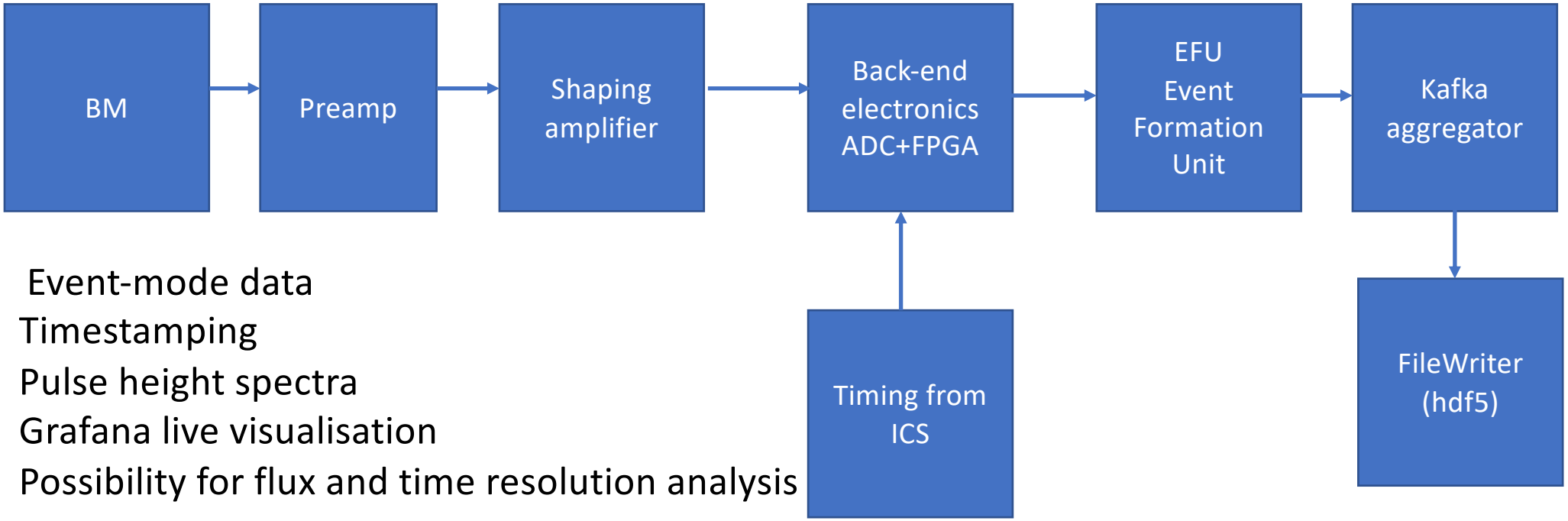








Setup with official ESS DAQ readout



- Event-mode data
- Timestamping
- Pulse height spectra
- Grafana live visualisation
- Possibility for flux and time resolution analysis

V. Maulerová et al., arXiv:1908.08041 submitted to EPL

Setup with

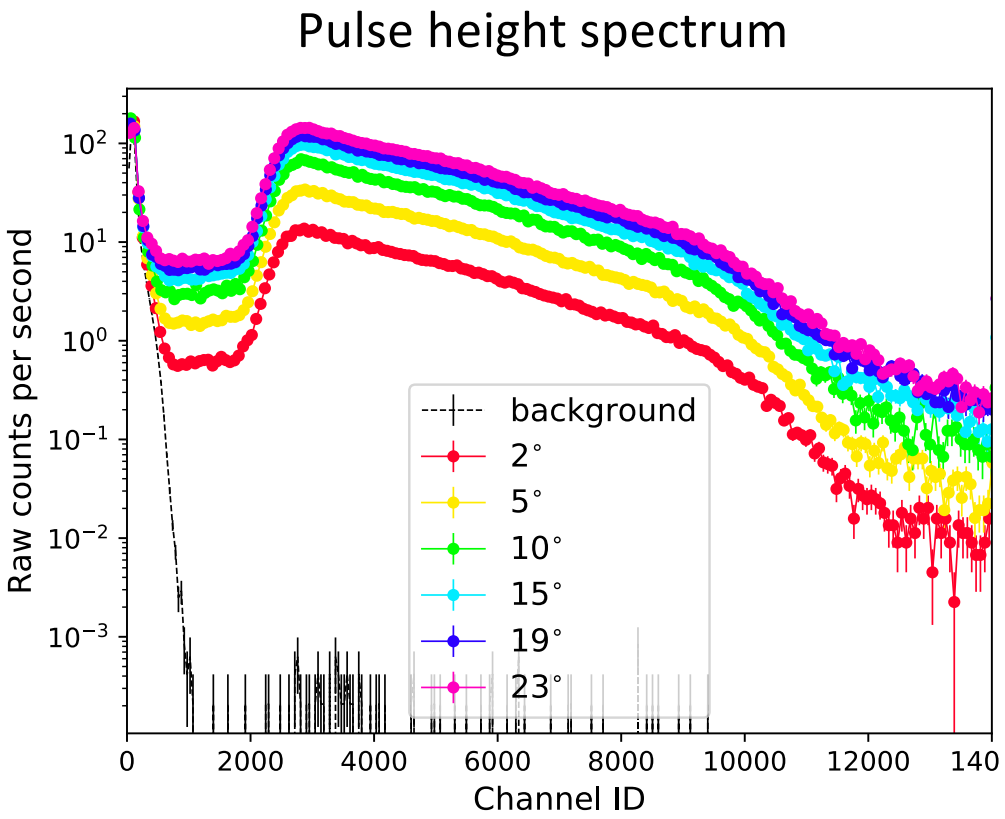
V20 setup @HZB

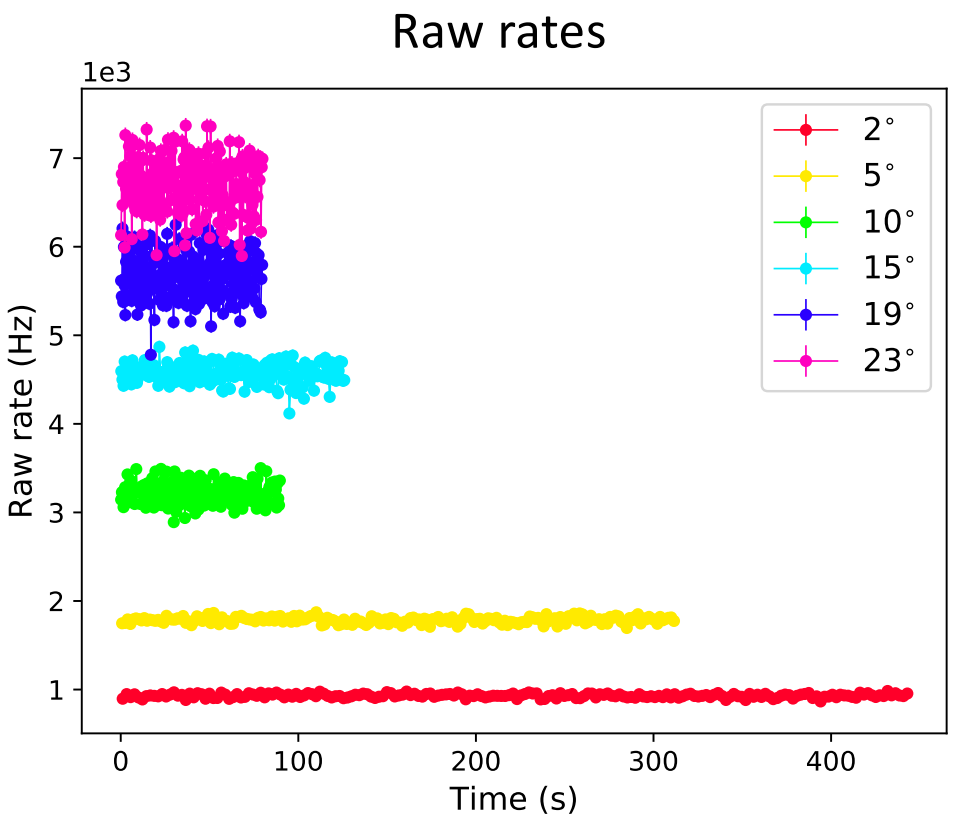
BM → Preamp → EFU Event Formation Unit → Kafka aggregator → FileWriter (hdf5)

- Event-mode data
- Timestamping
- Pulse height spectra
- Grafana live visualisati
- Possibility for flux and

V. Maulerová et al., arXiv:1908.08041 submitted to EPL

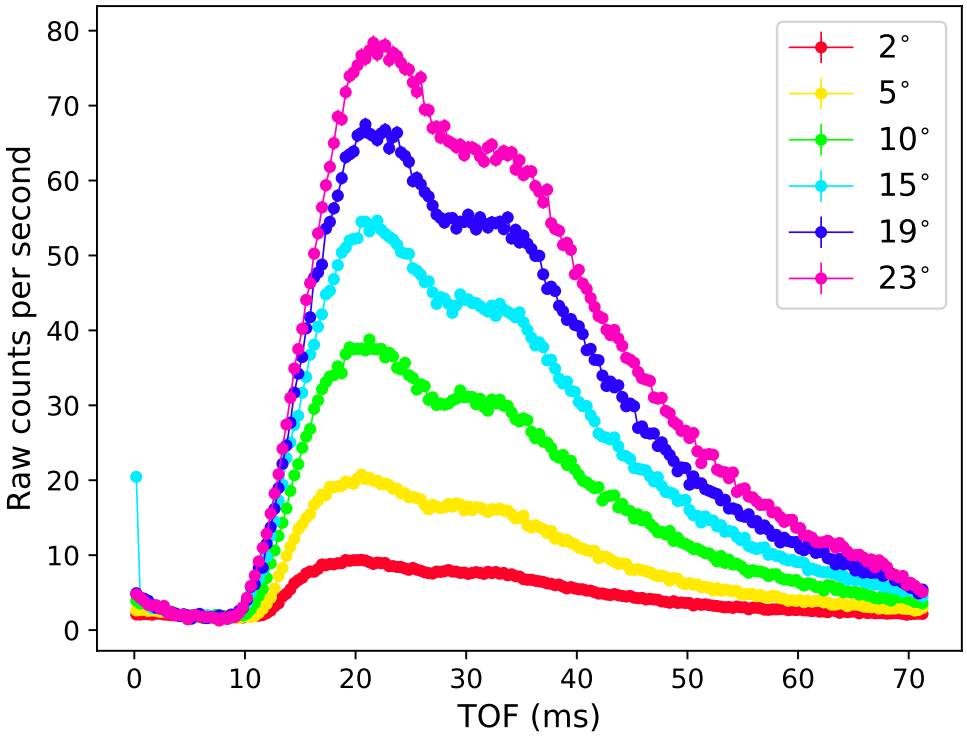
Fission chamber (LND 3054)



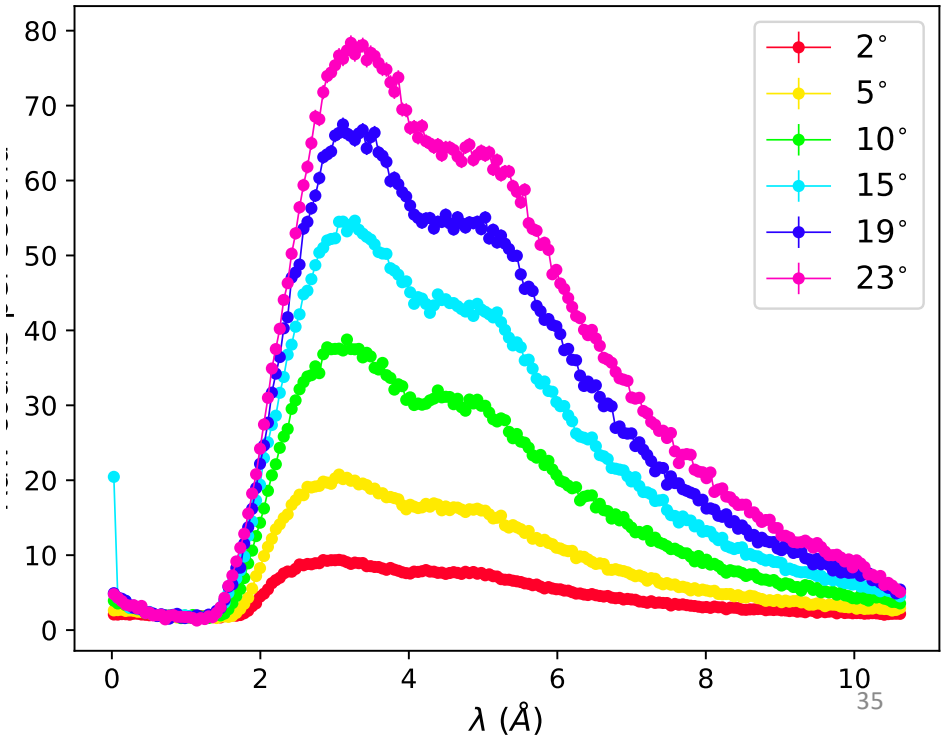


Fission chamber (LND 3054)

TOF

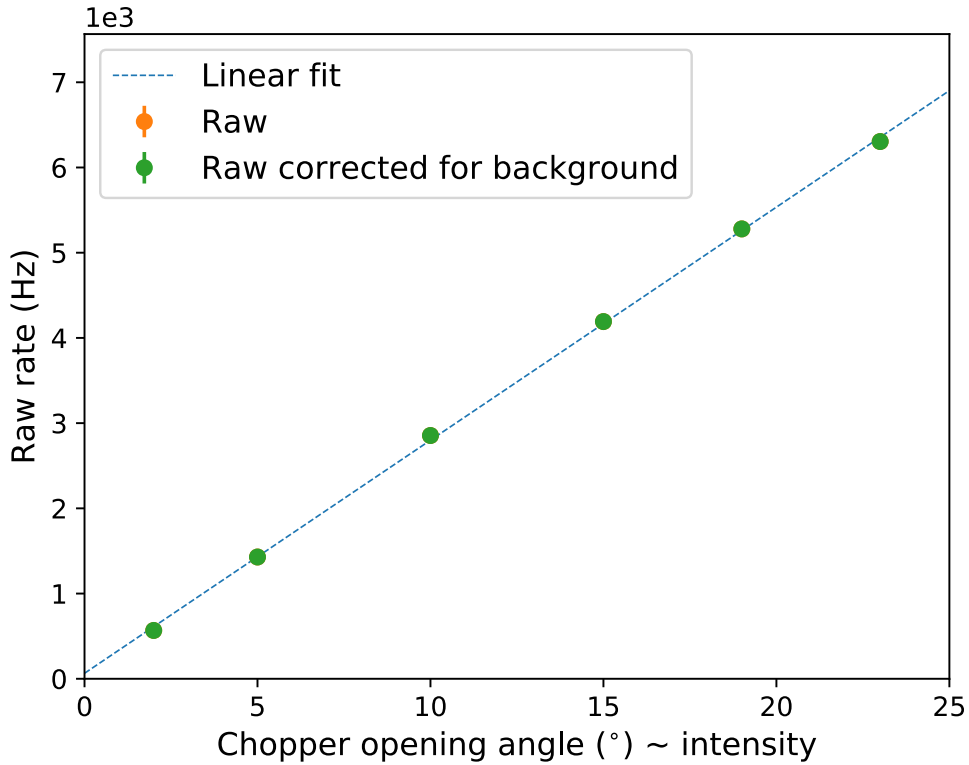


λ = 3.956*TOF/L,
L: distance from source



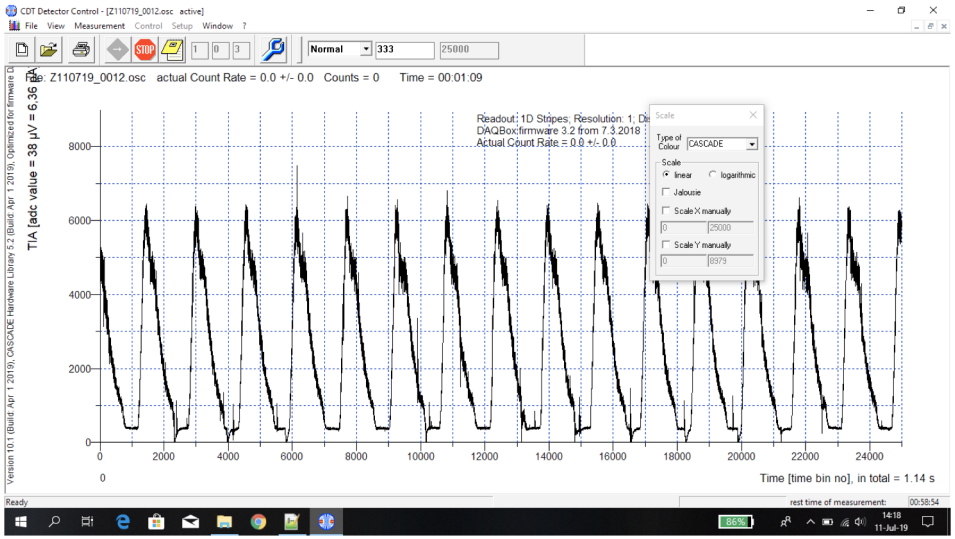
Fission chamber (LND 3054)

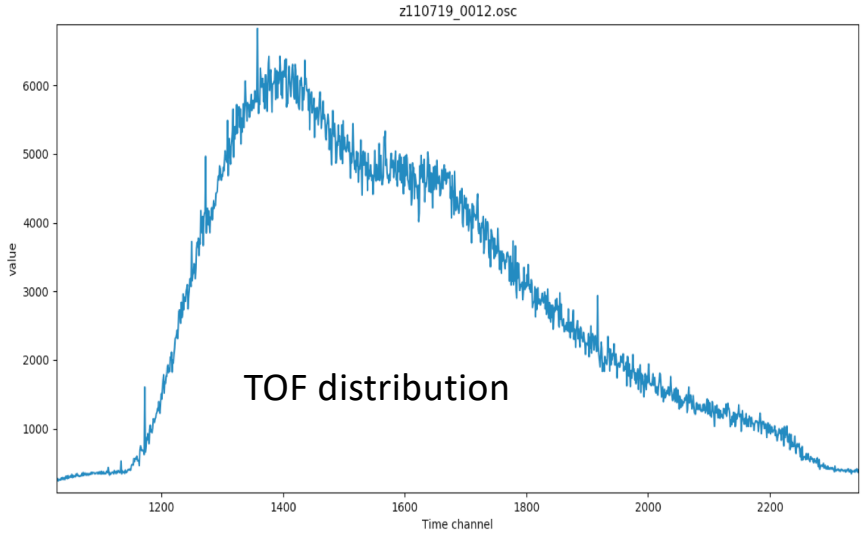
- Points are derived with threshold applied and background subtracted.
- Input to efficiency correction for absolute flux determination.
- Linear response up to 6 x 10^6 n/cm^2/s



Ionisation chamber (I-BM CDT)

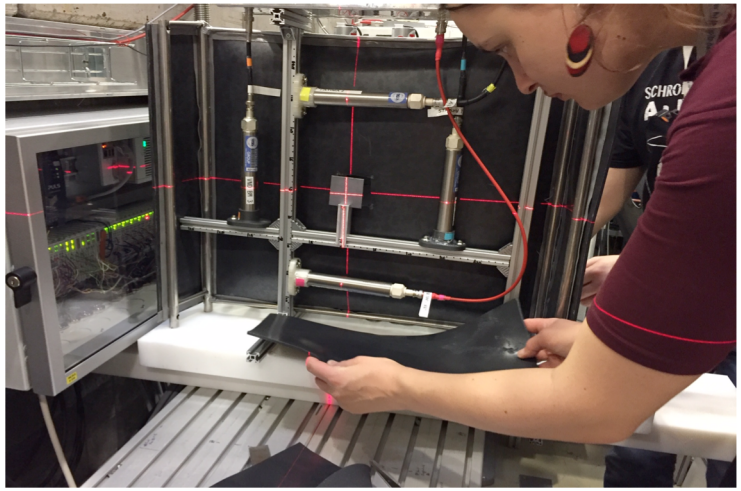
- The I-BM CDT has an inherent method for rejecting γ background by design.
- Flux for the specific model is calculated as $\Phi = 3.9*10^{14}\ I_{monitor} = 1.3*10^{8}\ V_{out}$
- Increased confidence for high flux use

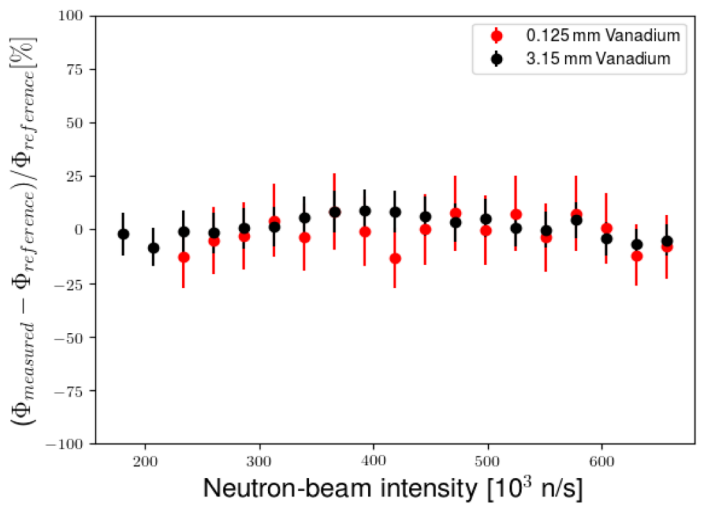


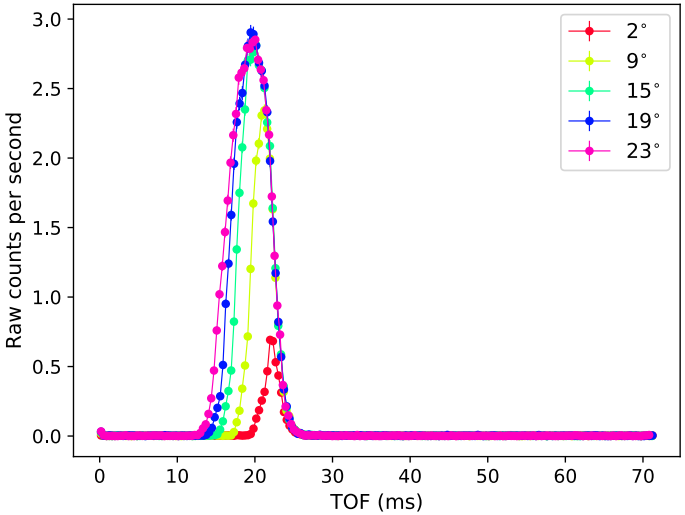


V monitor

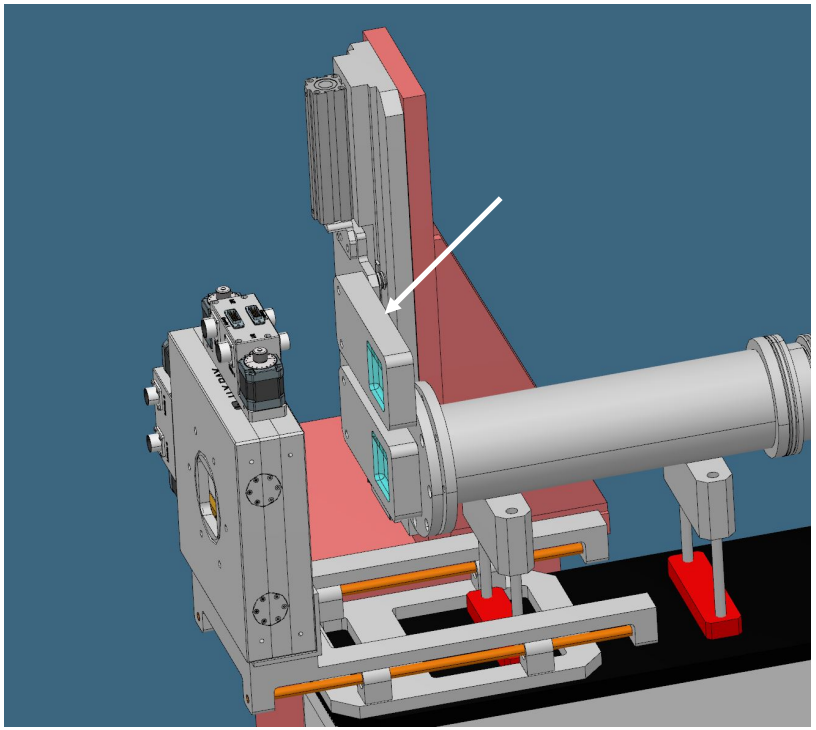
- Performance understood
- Absolute flux correction achieved
- Linear response up to 700 kHz incoming beam intensity
- Can reach 1 GHz
- Time-stamped data taken with 2 active detector lengths
- Parameter optimisation in progress
- Paper ready by December
- See my IEEE talk: Thu, 31 Oct, 16:35, N-38-03
- https://jinst.sissa.it/jinst/theses/2019_JINST_TH_004.js



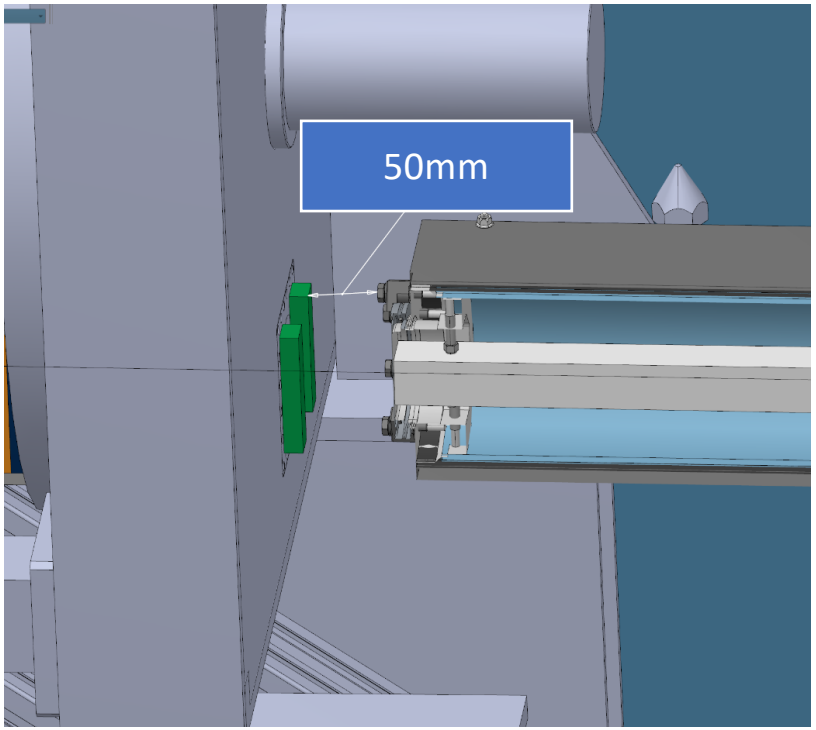




Spatial envelopes

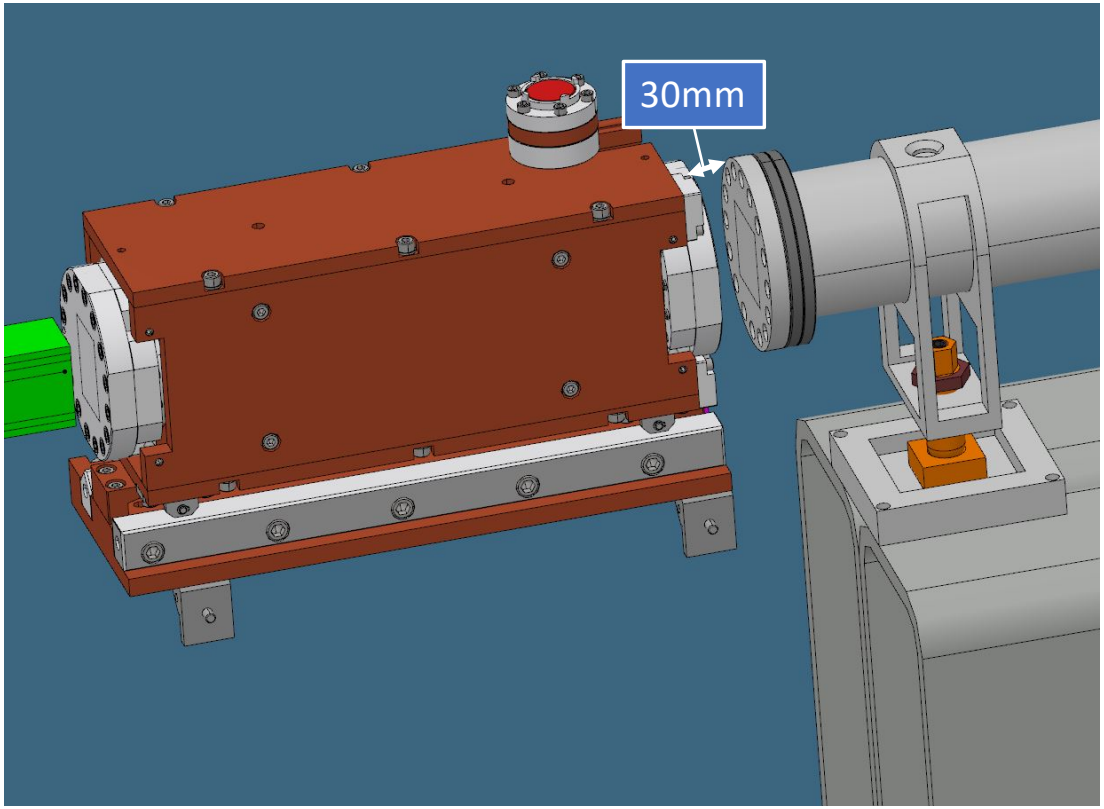


BIFROST
Liam Whitelegg



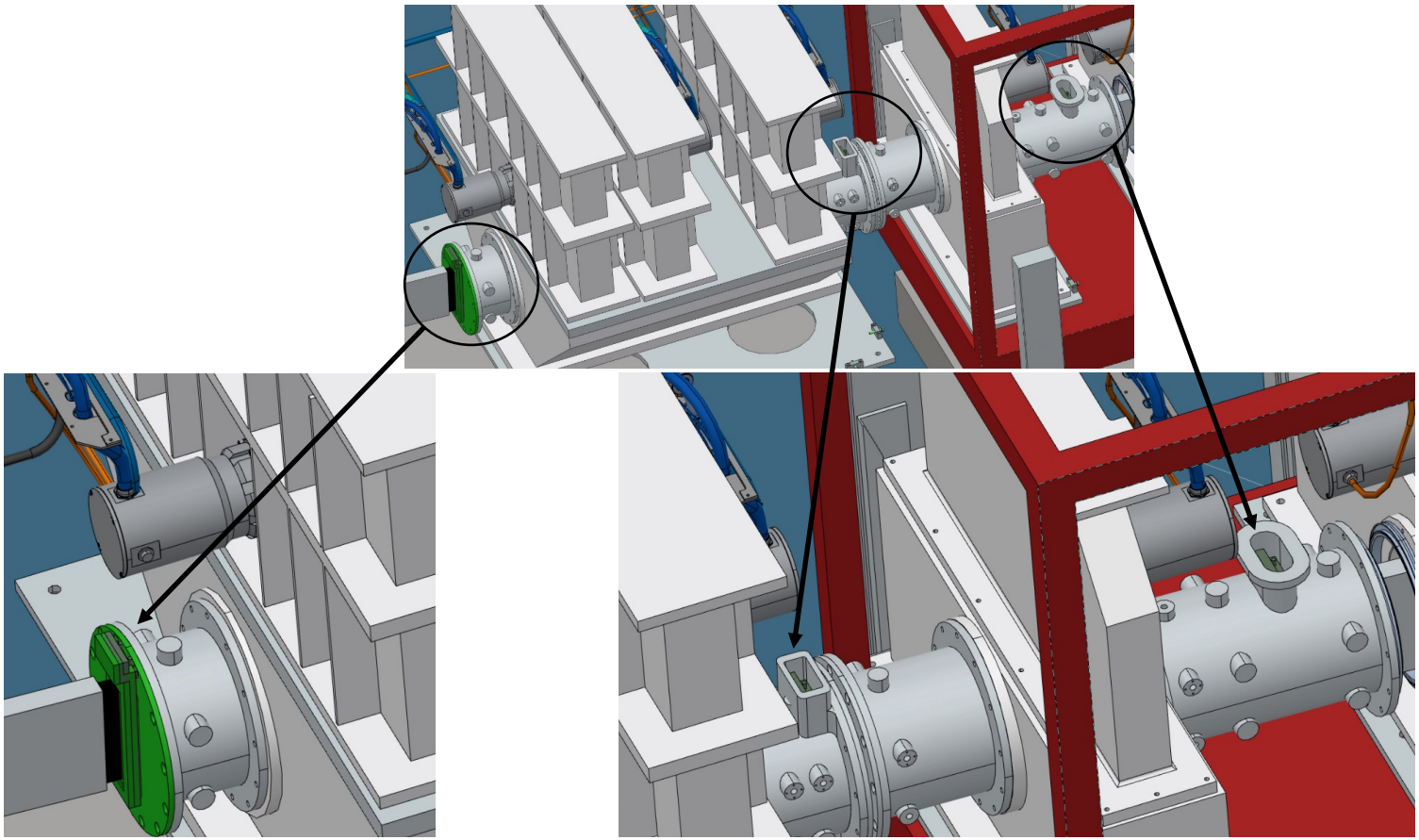
MAGIC
Sergey Klimko

Spatial envelopes



NMX
Giuseppe Aprigliano

Spatial envelopes



FREIA – Jon Elmer

Simulation tools & projects

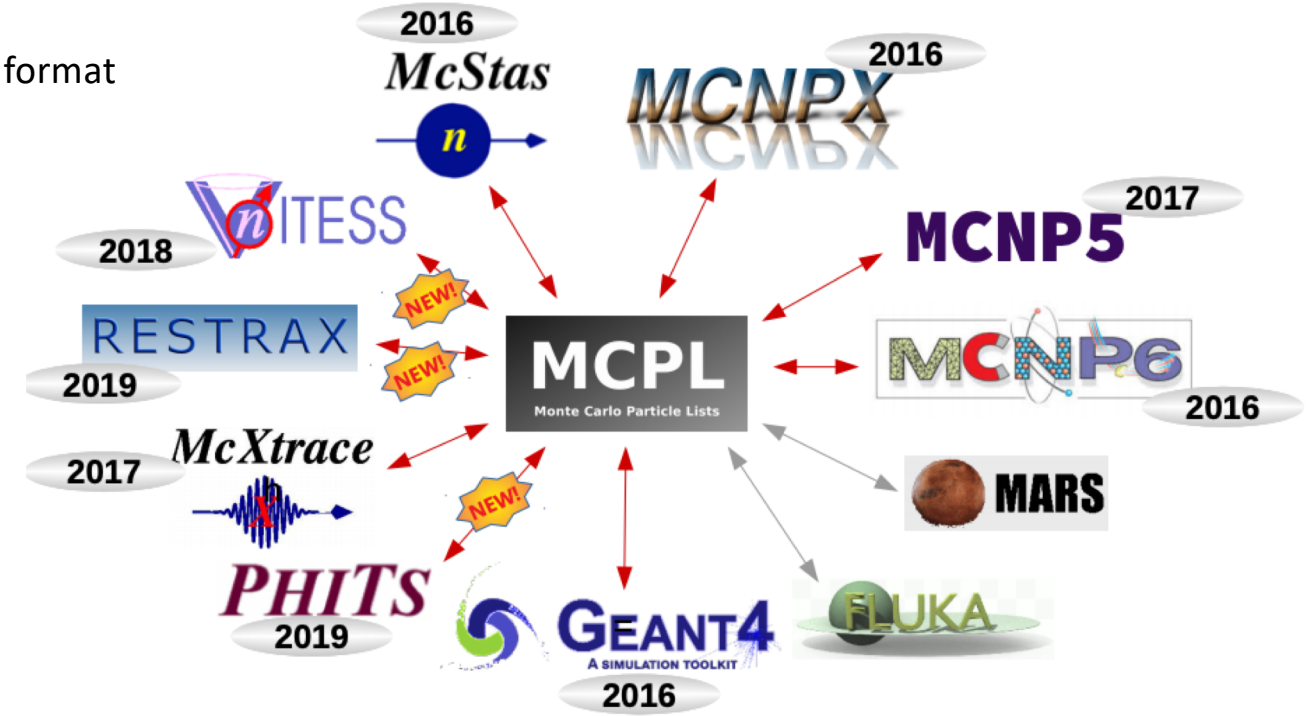
- MCPL: Monte Carlo Particle Lists [1]
- NCrystal [2]: thermal neutron transport library
- ESS Detector Group simulation framework [3]

- Beam monitors: efficiency, scattering, transmission [4]
- MultiGrid: backgrounds from scattering and shielding
- Jalousie spatial resolution for diffractometers HEIMDAL and MAGiC
- Boron Coated Straws: absorption, scattering, activation, efficiency
- BIFROST: incident detector rates (signal and background)

[1] X. X. Cai, T. Kittelmann, "NCrystal : a library for thermal neutron transport", Computer Physics Communications (2019), https://doi.org/10.1016/j.cpc.2019.07.015
[2] T. Kittelmann et al., "Geant4 Based Simulations for Novel Neutron Detector Development", CHEP 2013, doi:10.1088/1742-6596/513/2/022017
[3] T. Kittelmann et al., Monte Carlo Particle Lists: MCPL, Computer Physics Communications, Volume 218, September 2017, Pages 17-42, ISSN 0010-4655, https://doi.org/10.1016/j.cpc.2017.04.012
[4] F. Issa et al., "Characterization of thermal neutron beam monitors", Phys. Rev. Accel. Beams 20, 092801, (2017)

Codes with MCPL support

Binary exchange file format



https://mctools.github.io/mcpl/
http://ecns2019.essworkshop.org/talks/05.pdf

The NCrystal project

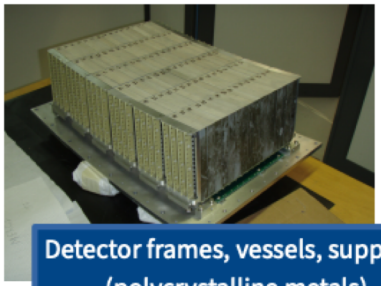
https://mctools.github.io/ncrystal/

NCrystal

X. X. Cai & T. Kittelmann

Original motivation:

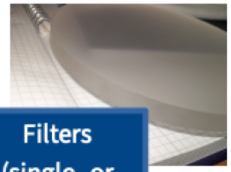
Augment Geant4 with proper modelling of thermalised neutrons in crystalline materials (and avoid the usual free-gas treatment)



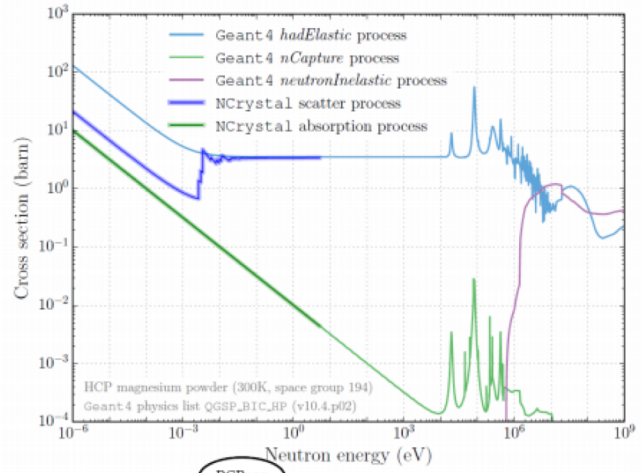
Crystalline samples

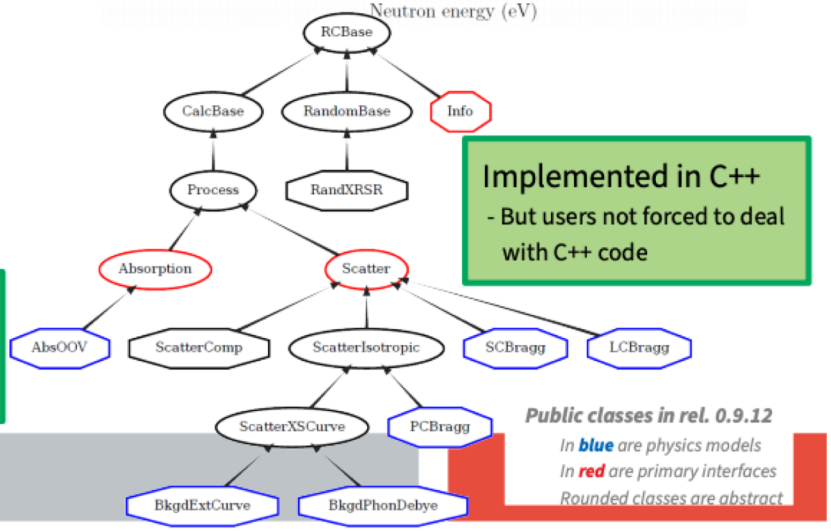
Detector frames, vessels, supports (polycrystalline metals)

Monochromators, analysers (single crystals. layered crystals)



Filters (single- or poly-crystals)





Implemented in C++

- But users not forced to deal with C++ code

Scope has expanded beyond Geant4

- We can reach a wider and more relevant community
- We also have use-cases outside Geant4 ourselves
- As a service to the community in general

Public classes in rel. 0.9.12

*In **blue** are physics models*
*In **red** are primary interfaces*
Rounded classes are abstract

8

Advances earlier efforts in older "NXSG4" plugin

- T Kittelmann and M Boin 2015 *Comput. Phys. Commun.* **189**, 114-118
- Geant4-specific plugin for polycrystals, no proper bkgd, no tools/bindings
- Thin wrapper around nxslib by M. Boin.

Many available interfaces

Can share configurations and data files across them all

NCrystal
X. X. Cai & T. Kittelmann

NCrystal

Direct/standalone usage

- *Command-line tools*
- *Programmatic access from C++/C/Python*

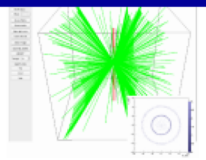
NCrystal aims to be hassle-free:

- *Robust modelling over large range of setups*
- *No required dependencies.*
- *Linux, OSX, Windows*
- *C++98, C++03, C++11, C++14, C++17*
- *C89, C99 or C11; Python2.7+, Python3.3+*
- *Unrestrictive Apache 2.0 license*
- *RNG streams, error reporting etc. can be controlled by calling code.*
- *In the pipeline: MT safety.*

McStas

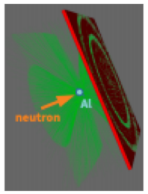
- *Plugin (component) ships with NCrystal release.*
- *Supports multiple scattering + a few basic sample shapes*
- *Available out-of-the box (thanks to P. Willendrup)*

ANTS2



- *Available out-of-the-box (thanks to A. Morozov)*

GEANT4
A SIMULATION TOOLKIT



- *Plugin ships with NCrystal release.*
- *ESS-DG's Geant4 framework has NCrystal built in.*
- *Goal is availability out-of-the-box for all Geant4 users.*

OpenMC

- *Plugin is work in progress (thanks to J. I. Márquez Damián)*

NJOY

- *Can use NCrystal results when generating ENDF files for various MC applications (like MCNP).*
- *(thanks to J. I. Márquez Damián)*

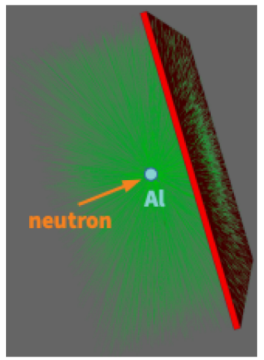
Bragg diffraction in polycrystals and powders

NCrystal

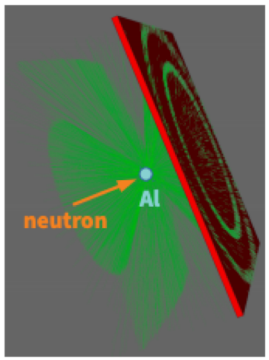
X. X. Cai & T. Kittelmann

Based on provided HKL planes with d-spacings and structure factors, the implementation is straight-forward.

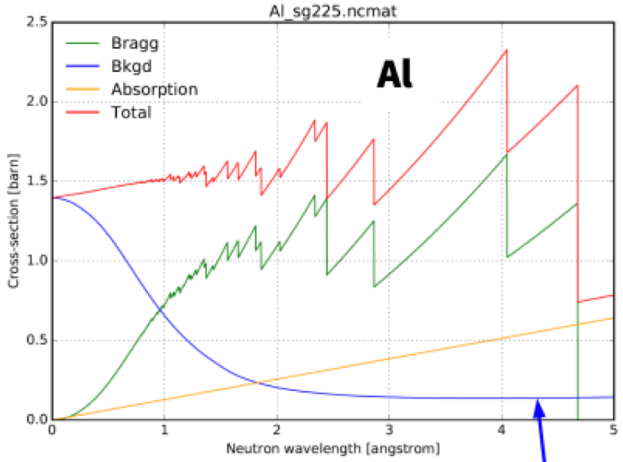
Care is taken to be extremely fast O(ns/call), even in case of huge number of planes.



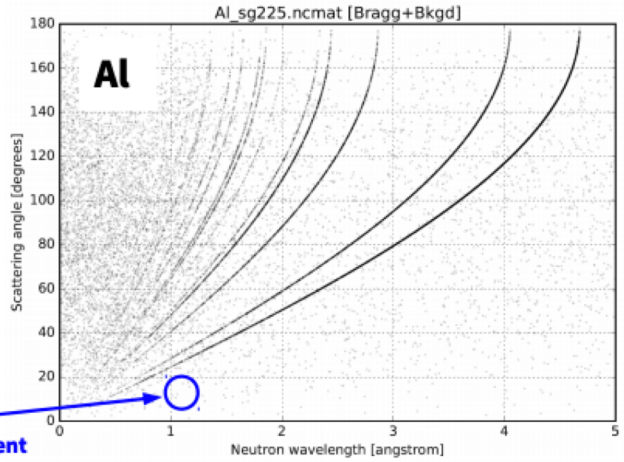
Geant4 free-gas model
(wrong MFP, wrong scatter)



Geant4 with NCrystal
⇒Debye-Scherrer cones



Provides cross-sections



And scatter angles

Non-Bragg "Bkgd" component
discussed on later slide

Special anisotropic model for Pyrolytic Graphite

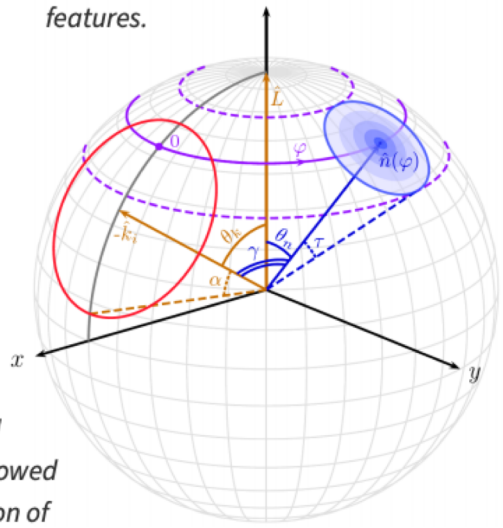
PG often used as filters, monochromator, analyser

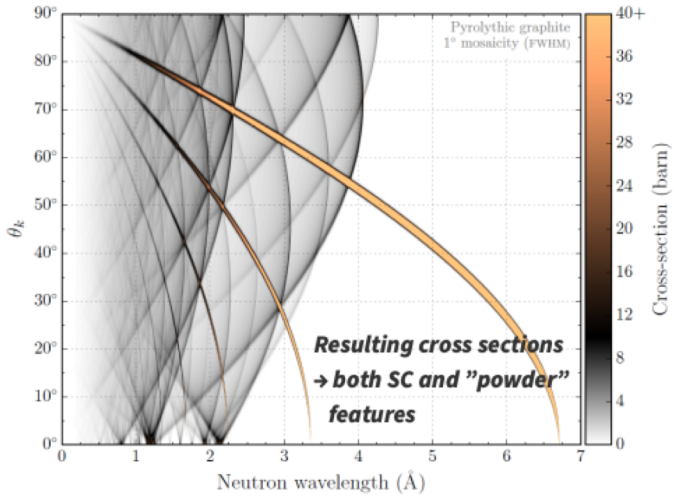
NCrystal

X. X. Cai & T. Kittelmann

Layered crystal model:

- *Usual Gaussian mosaic distribution is "smeared out" by rotation*
- *Exhibits both single-crystal and powder features.*

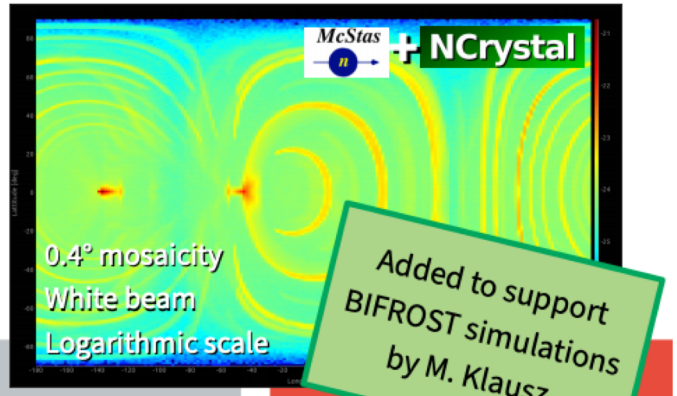




Features:

- *Cross-sections determined by efficient pre-search followed by fast Romberg integration of SC Gaussian mosaicity code.*
- *Features realistic transmission probabilities and multiple-scattering effects (incl. "zig-zag walk")*

→ World-leading realism in PG modelling!!!



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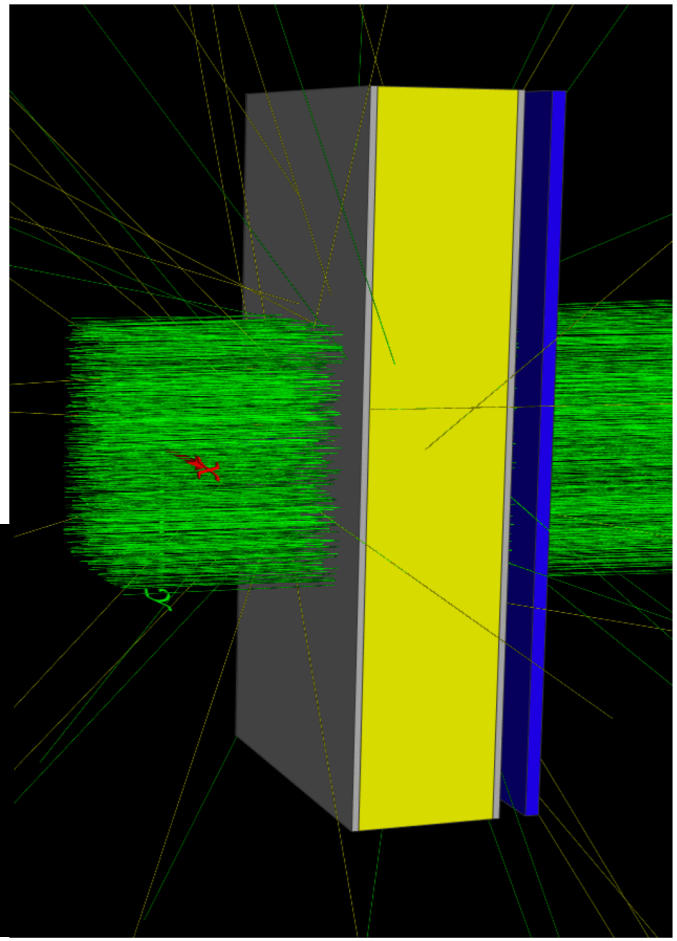
https://github.com/mctools/ncrystal/wiki

BM Geant4 simulations

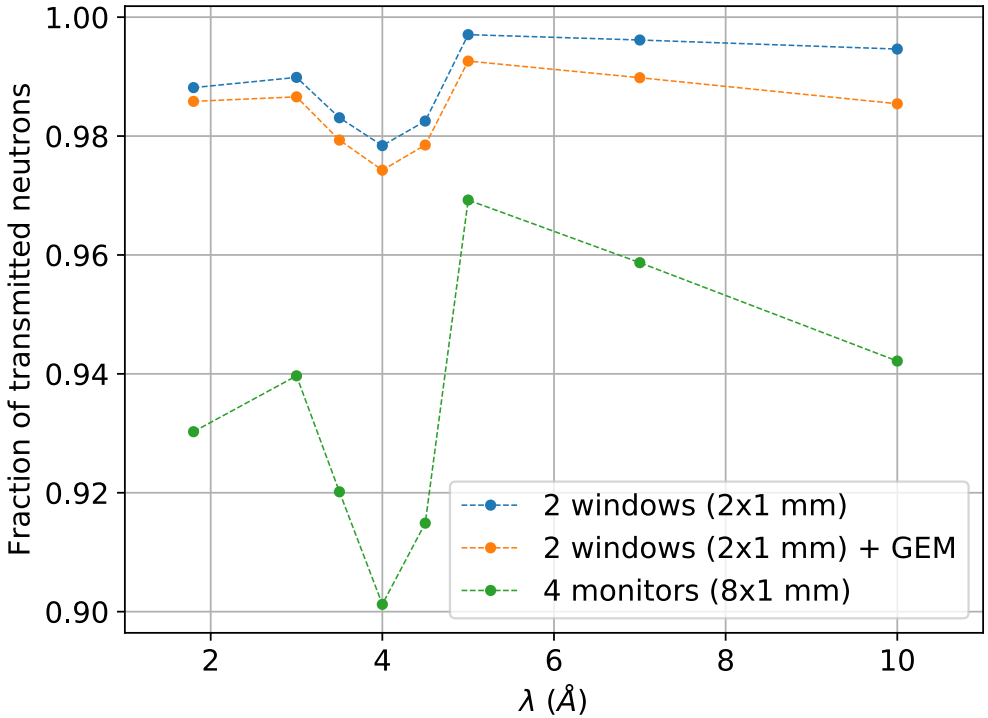
- Impact of BM materials on
  - Transmission
  - Scattering
  - Efficiency
- Means for efficiency corrections
- Means for parameter optimisation



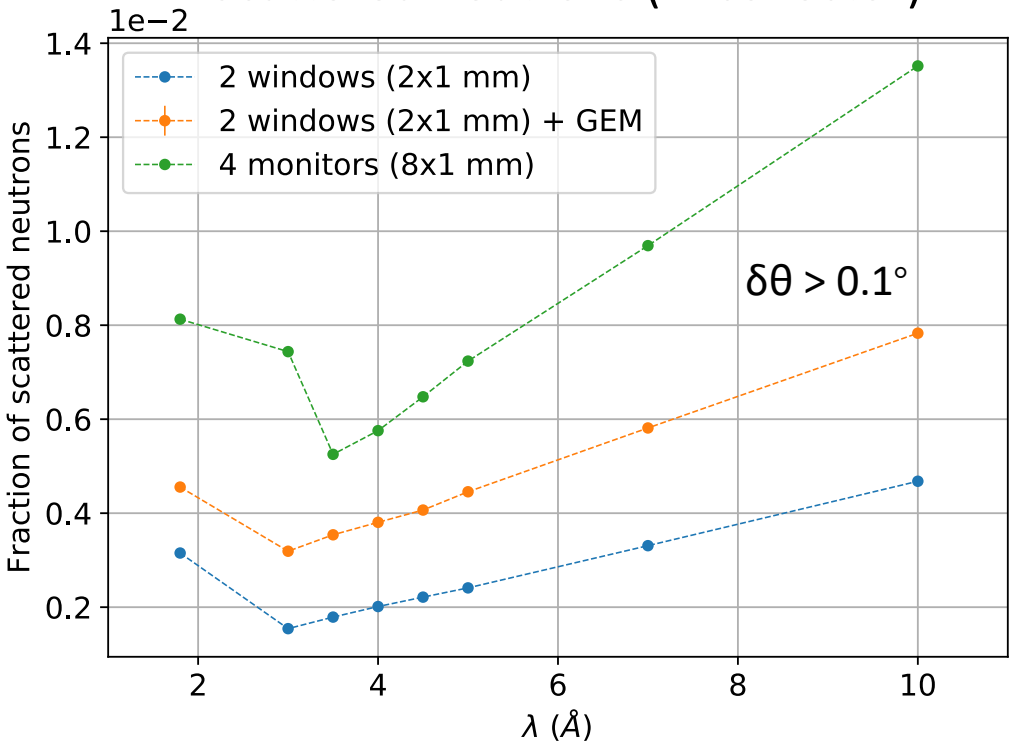
Green: neutrons
Gray: BM windows
Yellow: gas
Blue: collector volume for analysis
Optionally contains
- GEM foil
- solid converter
- Cu

Impact of multiple BM windows

Transmission = (all) neutrons in collector / initial neutrons

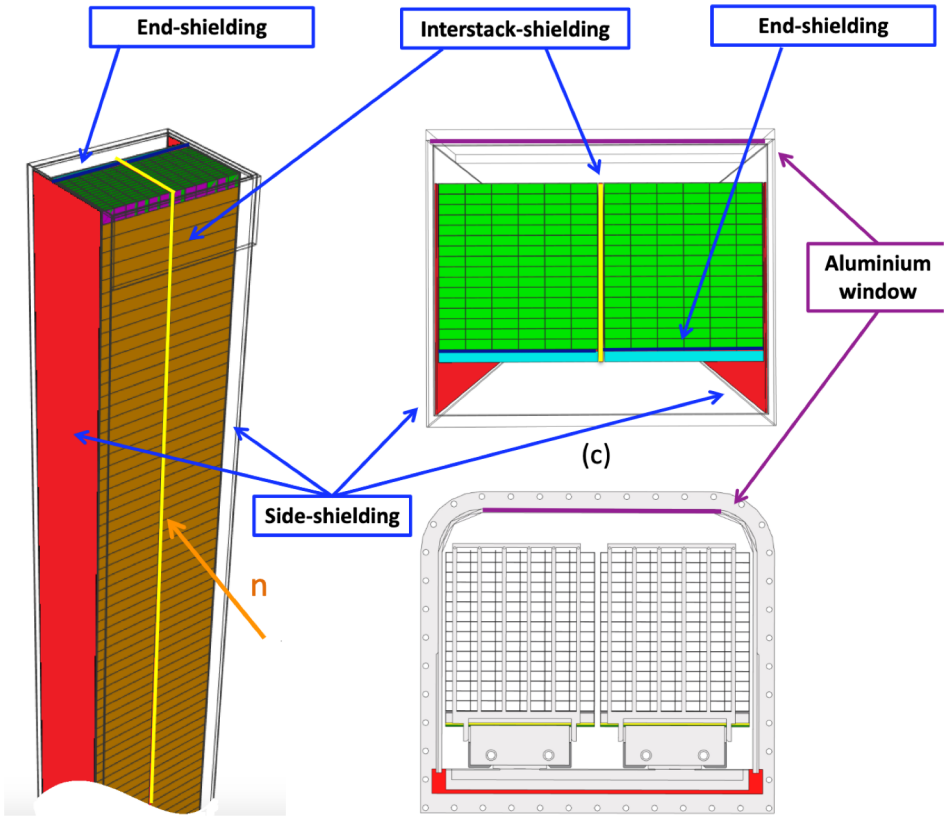


Scattered neutrons (in collector)



Need a definition for scattering that serves instrument purposes.

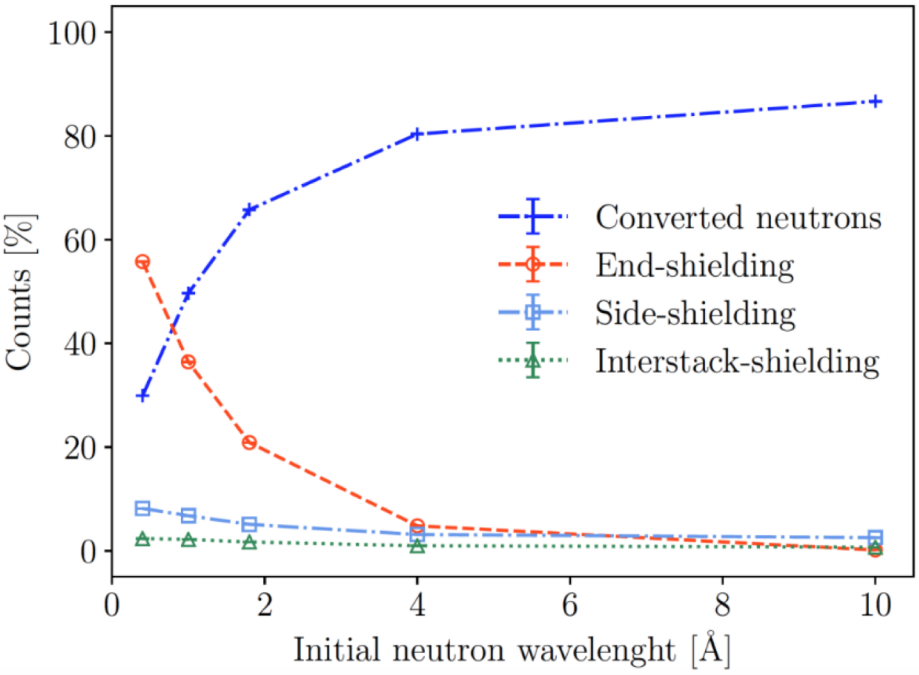
MultiGrid Geant4 simulations

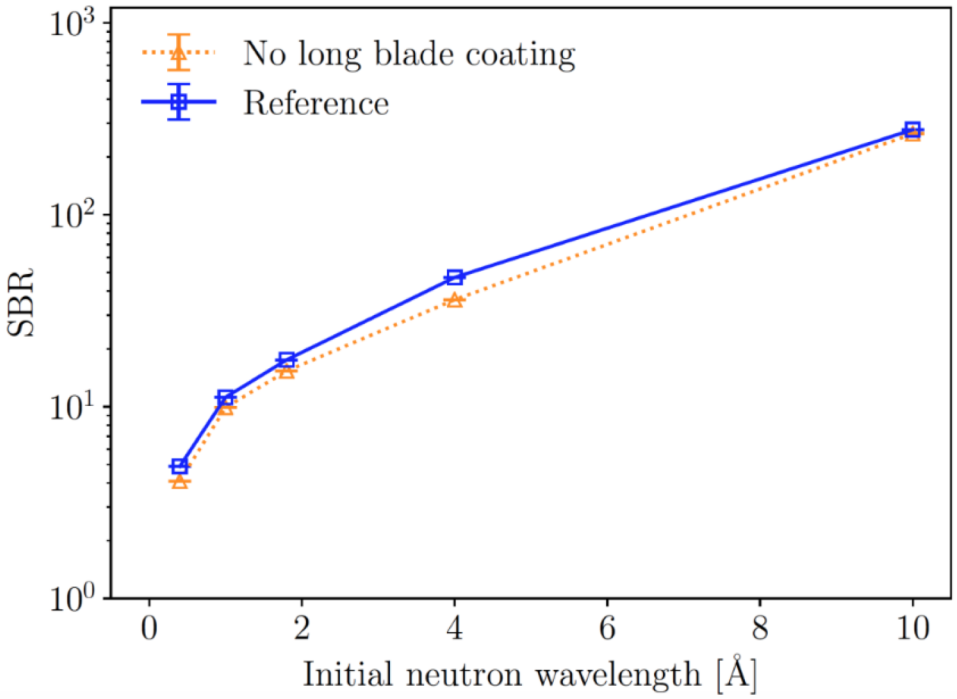


- Studies of background from scattering
  - Impact of entrance window thickness
  - Impact of local internal shielding
  - Impact of radial blade coating
- Ph.D. thesis published by Eszter Dian
- See Eszter's talk on Monday 2:52 PM, N-03-05

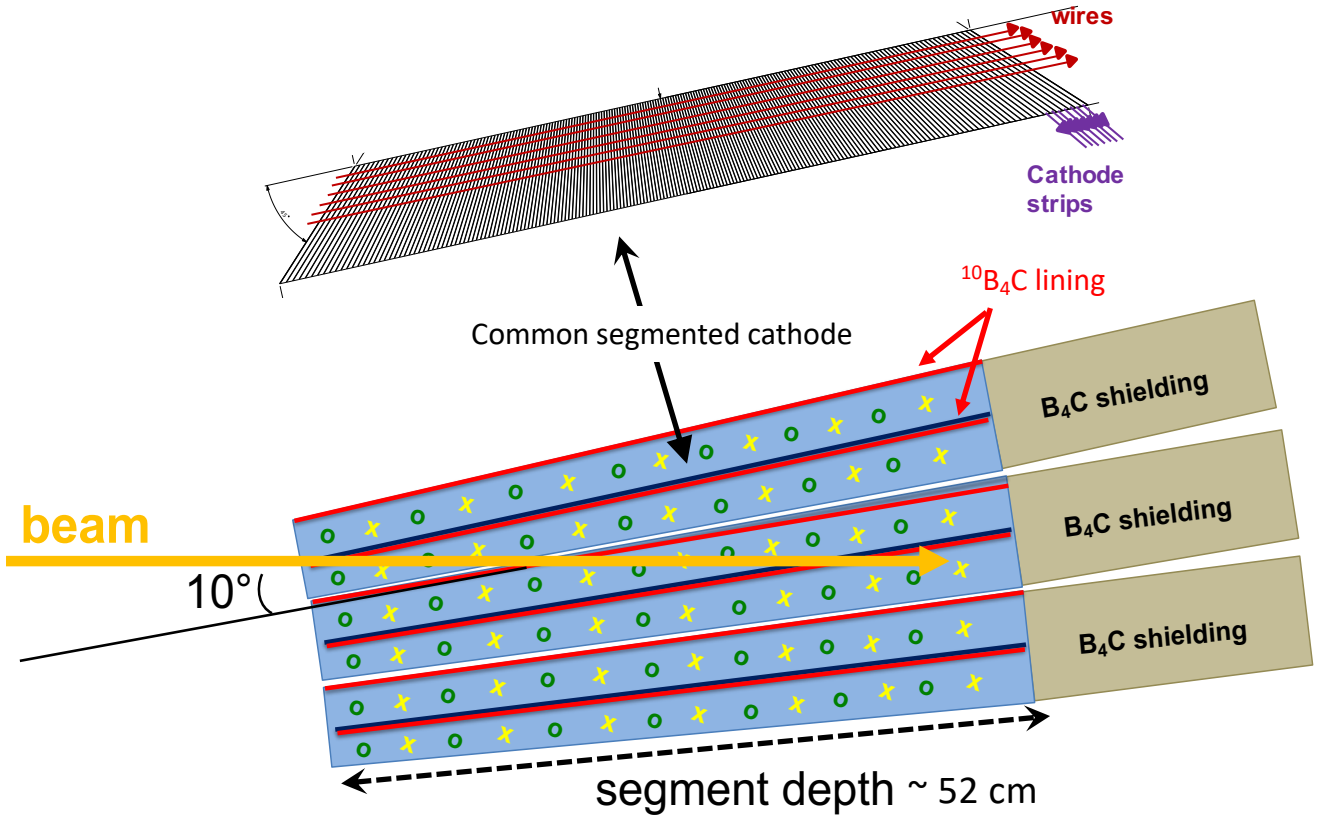
E. Dian et al., "Suppression of intrinsic neutron background in the Multi-Grid detector", JINST 14 (2019) P01021, DOI:10.1088/1748-0221/14/01/P01021
E. Dian et al., "Scattered neutron background in thermal neutron detectors", Nuclear Inst. and Methods in Physics Research, A 902 (2018) 173–183. DOI: 10.1016/j.nima.2018.04.055

MultiGrid Geant4 simulations



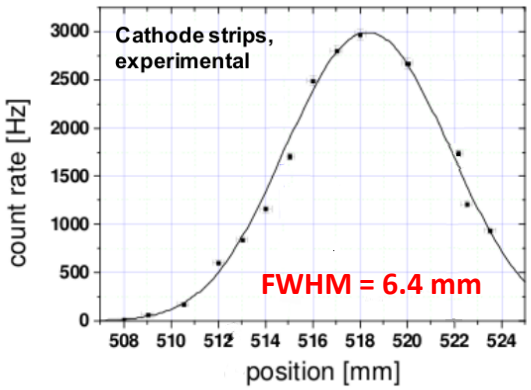


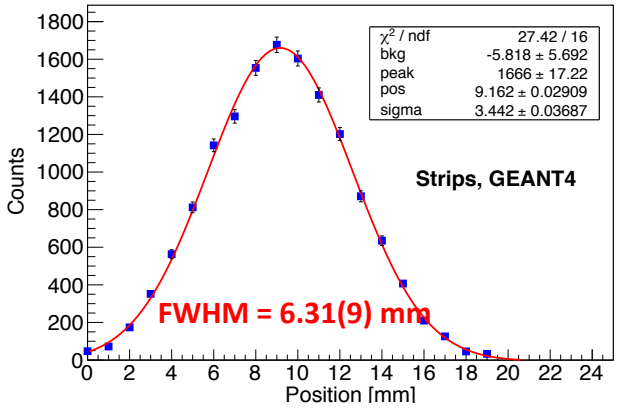
The HEIMDAL Jalousie detector

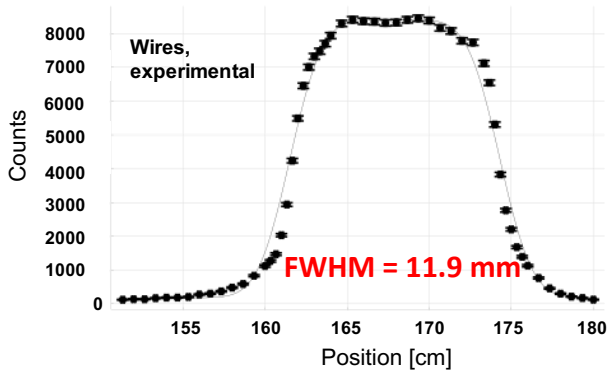


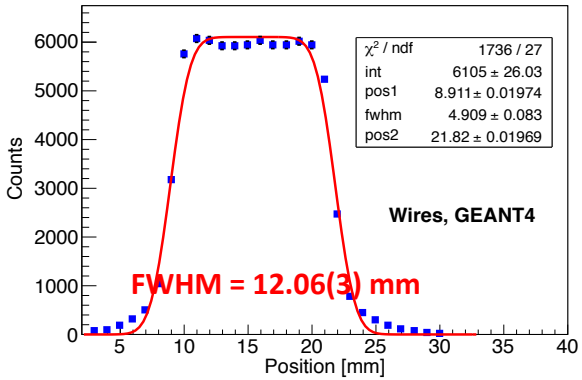
10 nominal interactions of the incoming neutron with the $^{10}B_4C$ layer ➔ ε>50% at 1.8 Å.

Validation of the simulation strategy





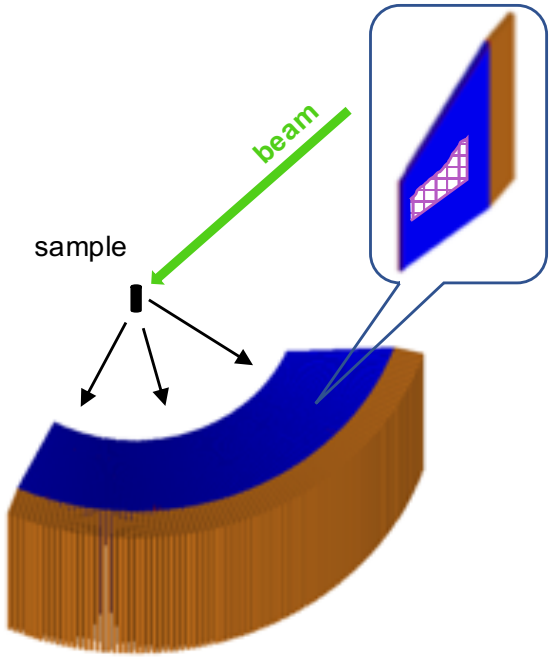




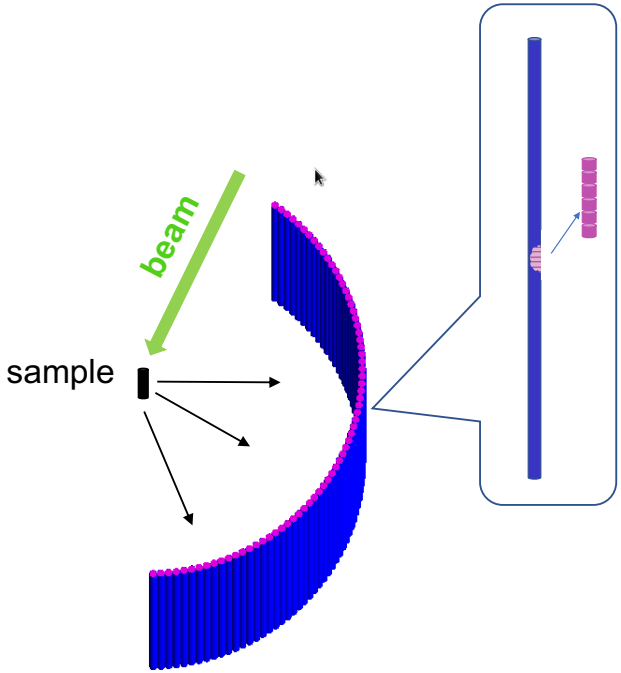
Experimental data from G. Modzel, PhD thesis, Univ. of Heidelberg, 2014, and M. Henske et al., NIMA 686(2012) 151.

Investigation of the detector contribution to the resolution function

sample = Vitess trajectories for NaCaAlF



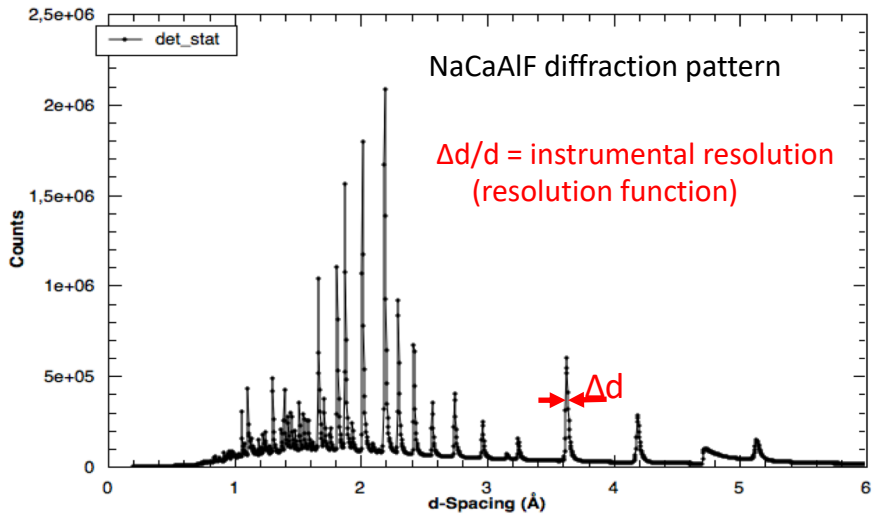
GEANT4 for the HEIMDAL-Jalousie detector



GEANT4 for the WISH-like detector

GEANT4 simulations for the Jalousie detector for HEIMDAL

- Goal of this simulation work is to create the detector model that can be used to investigate the performance of the detector in a virtual physics experiment and understand the detector contribution to the instrumental resolution function.

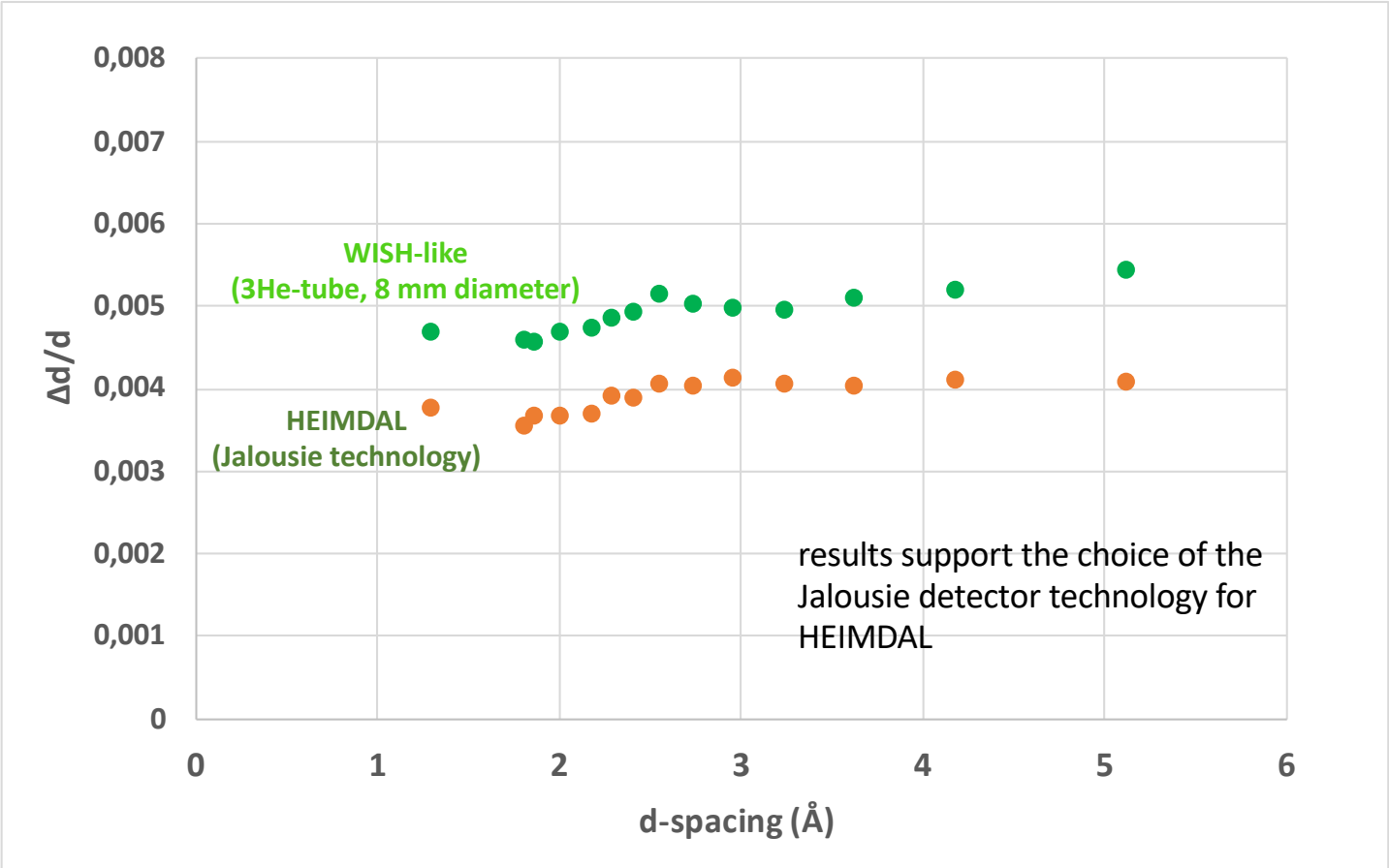


$$\frac{\Delta d}{d} = \sqrt{\left(\frac{\Delta tof}{tof}\right)^2 + \left(\frac{\Delta L}{L}\right)^2 + (\Delta\theta \cot\theta)^2}$$

At spallation sources: Δd/d = Sample ⊗ Instrumentation

↳ moderator, beamline components, **size of the detector pixel**

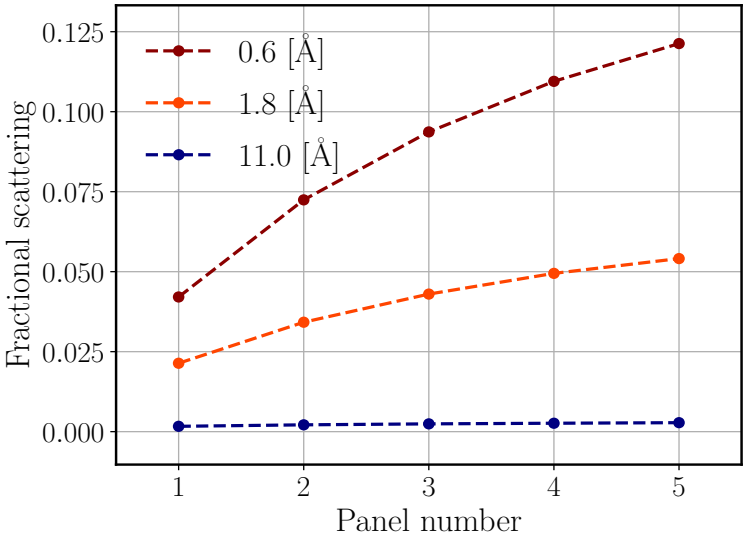
Resolution results

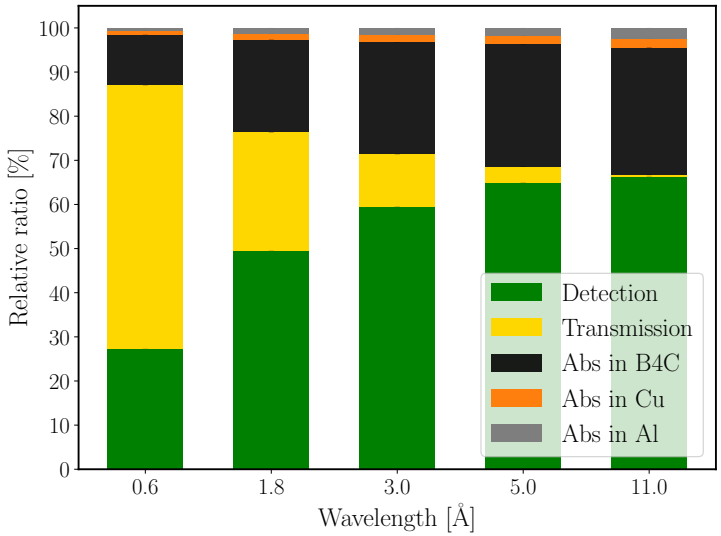


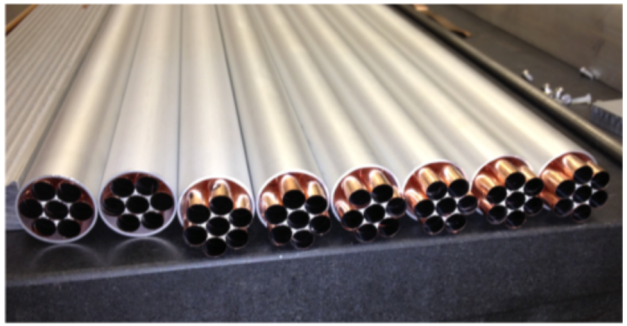
I. Stefanescu et al., "Performance study of the Jalousie detector baseline design for the ESS thermal powder diffractometer HEIMDAL through GEANT4 simulations", 2019 JINST 14 P10020
I. Stefanescu et al., "Neutron Detectors for the ESS diffractometers", 2017 JINST 12 P01019

BCS Geant4 simulations

- Scattering at acceptable levels for SANS and diffraction
- Scattering considerable for applications which are highly sensitive to it such as spectroscopy
- High transmission for small λ (60% at 0.6 Å) -> absorbent shielding
- Absorption is B4C is 6.5–8 times more than in Al and Cu combined
- Absorption in Al and Cu together is less than 5% even for highest λ
- Use of the model for LoKI detector calibration and large geometry studies

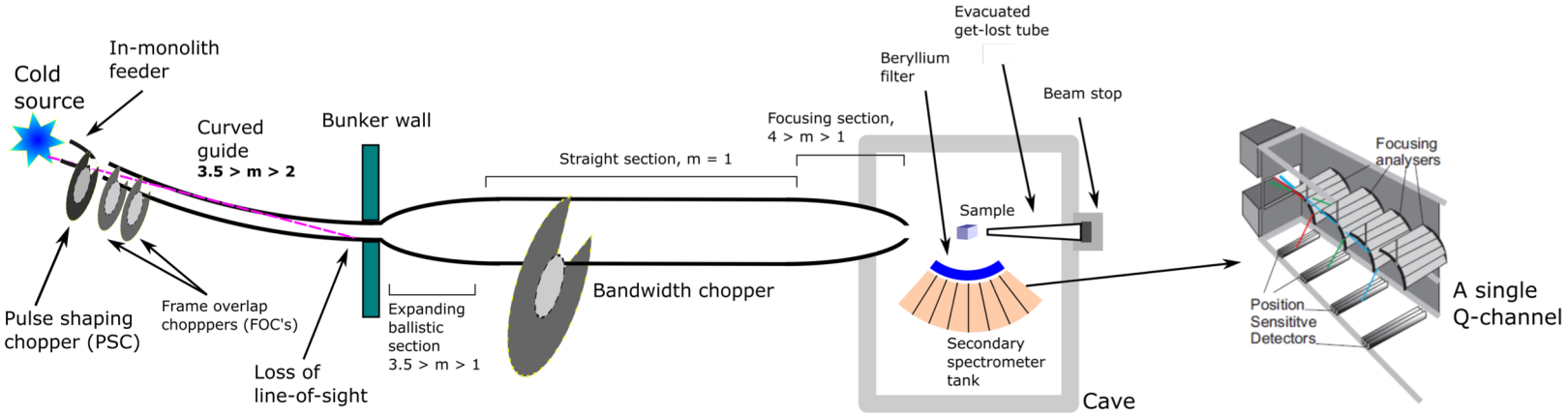






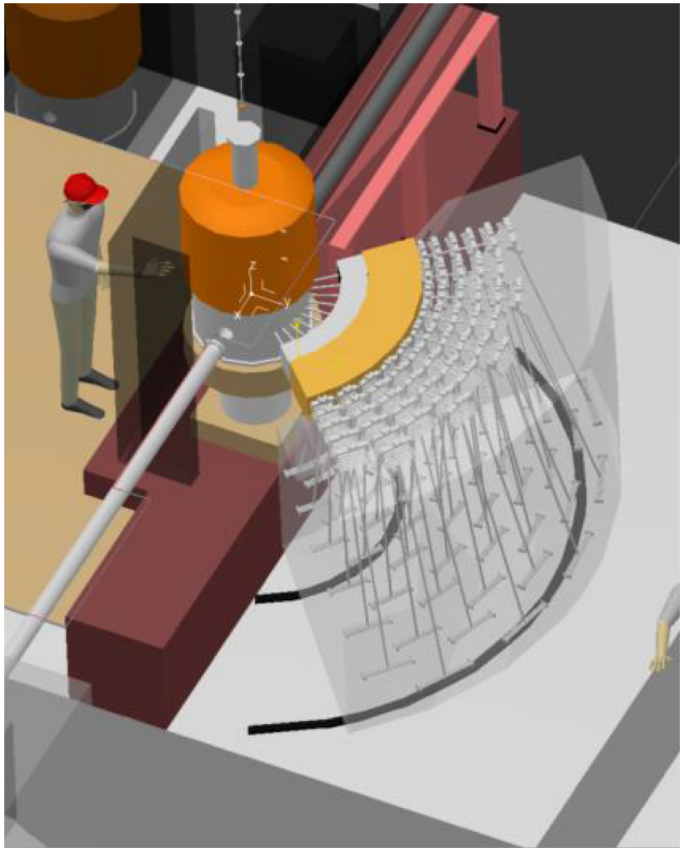
M. Klausz et al., "Performance evaluation of the Boron Coated Straws detector with Geant4", NIM A 943 (2019), 162463, doi: https://doi.org/10.1016/j.nima.2019.162463

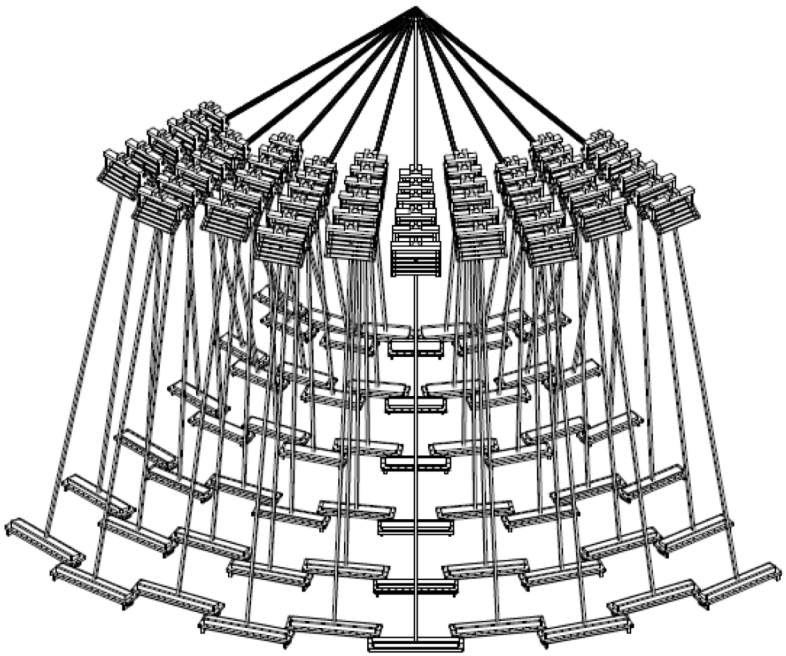
BIFROST@ESS



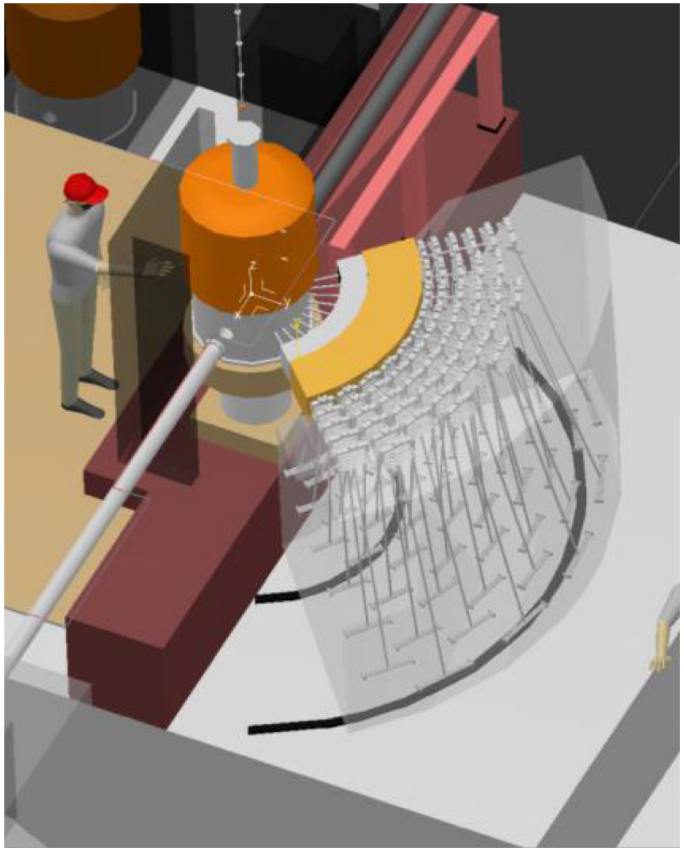
- High flux indirect geometry cold spectrometer
- Small sample (1 mm^3) in extreme environment
- Relatively simple beam transport and conditioning system
- Option to use full ESS pulse in low resolution mode

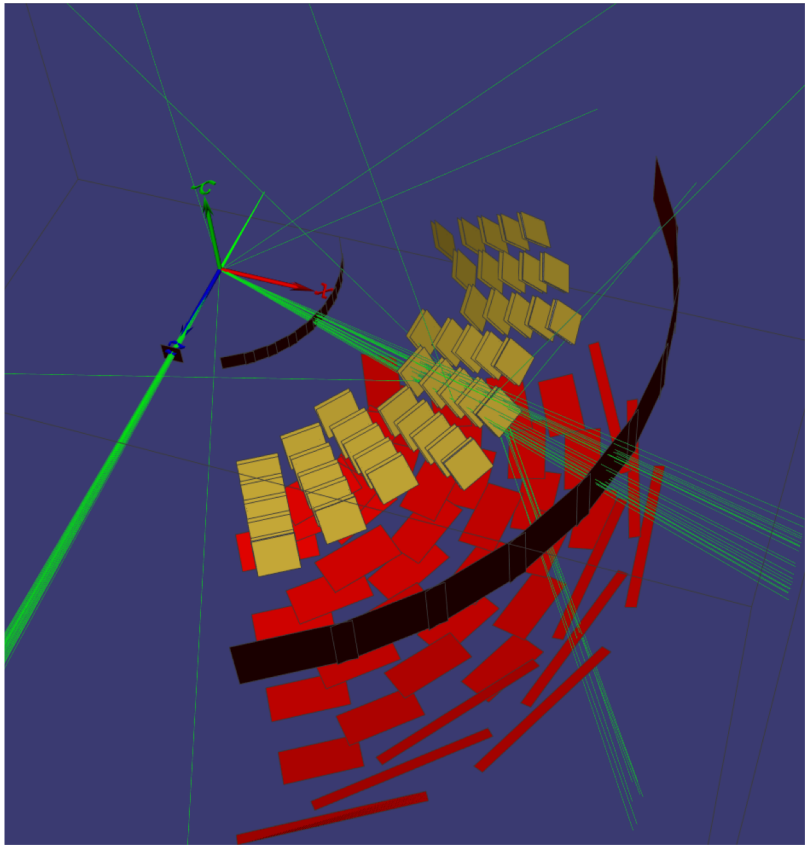
BIFROST Scattering Characterisation System





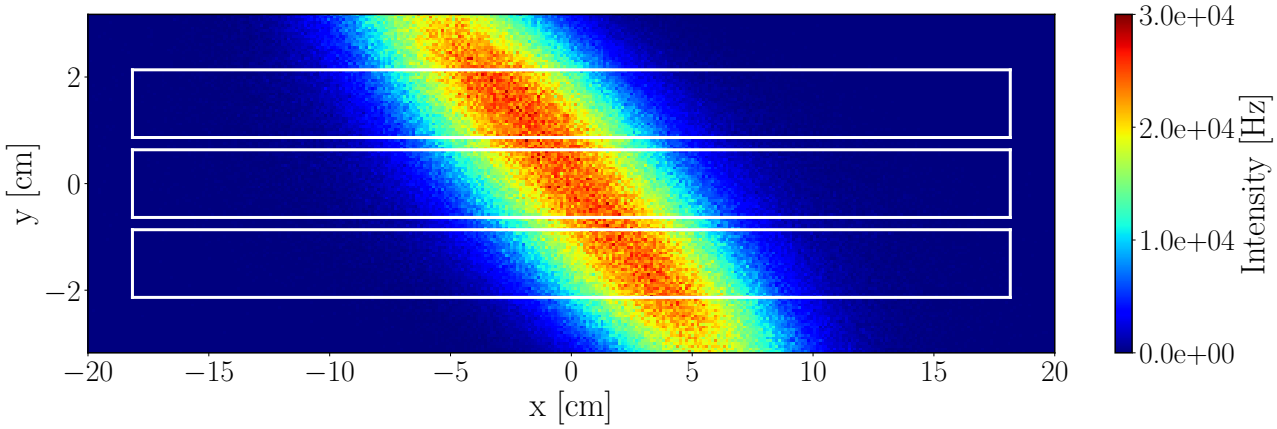
Geant4 model with all Q channels



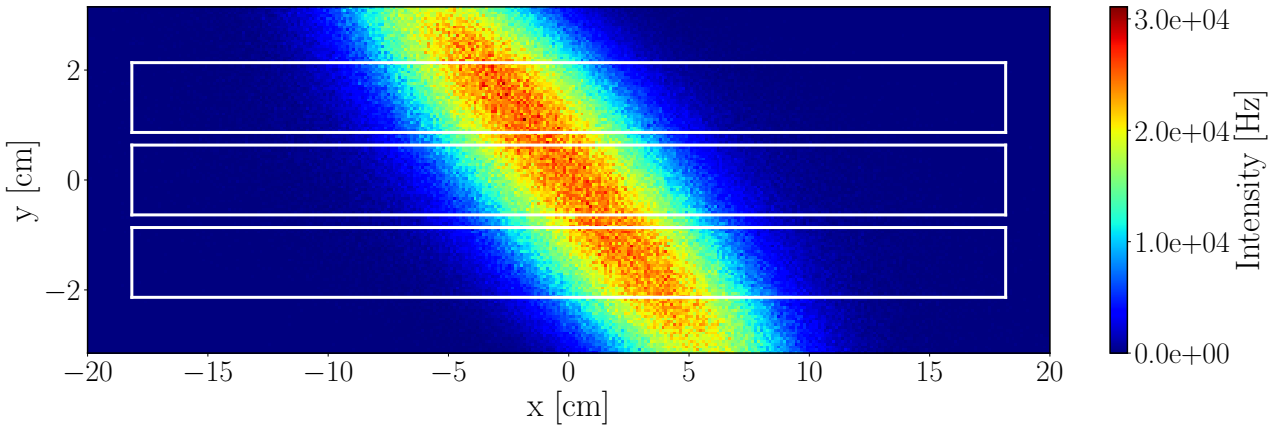


Neutron intensity on the ^{3}He triplets

McStas

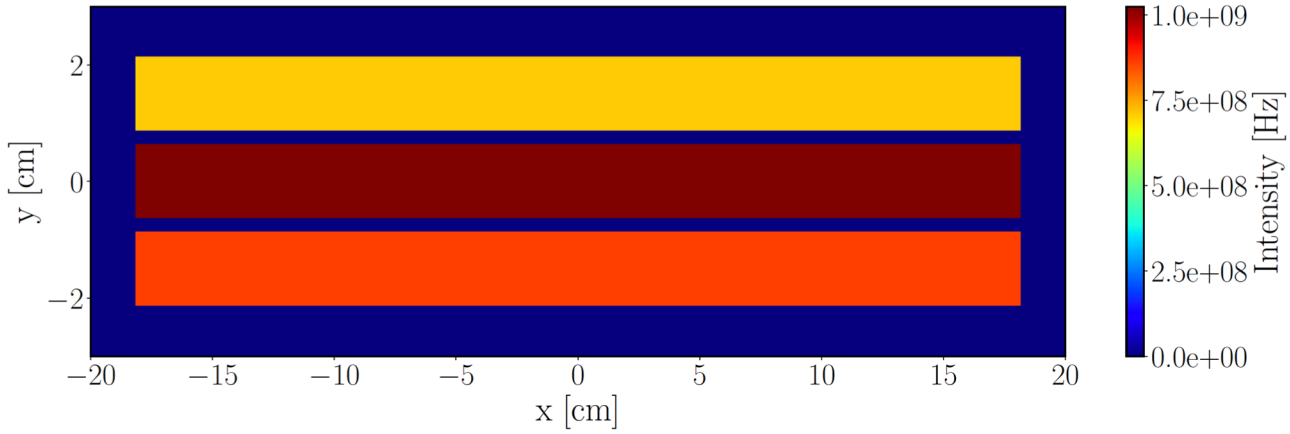


Geant4

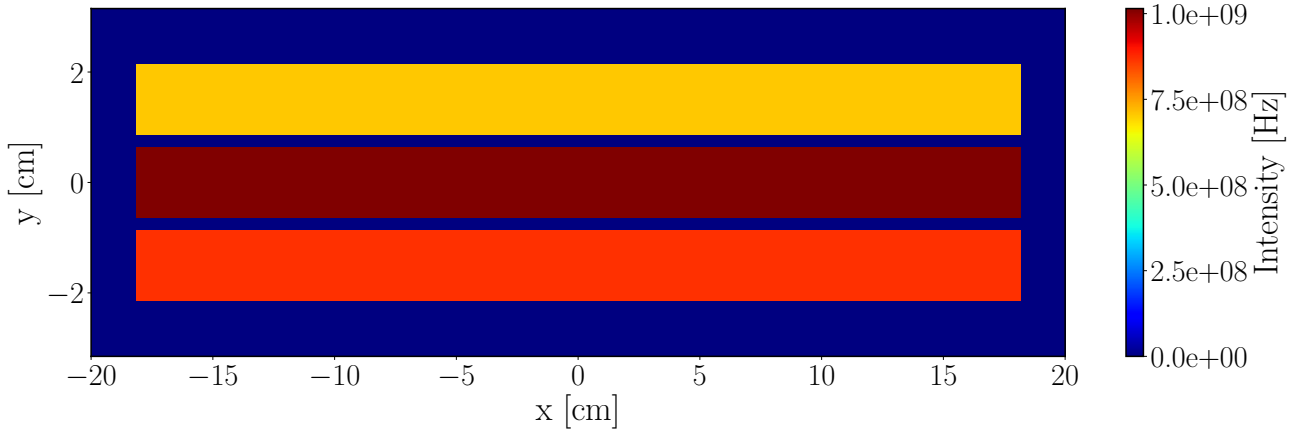


Peak instantaneous incident detector rate

McStas



Geant4



BIFROST conclusions

- Parameters:
  - Sample: Y_2O_3 single-crystal, hkl=2,-2,-2 (d_{hkl} = 3.0724 Å)
    cylindrical h=d=15 mm, mosaicity = 60 arcmin
  - Analyzer: thickness = 1 mm, mosaicity = 60 arcmin
  - Source power = 5 MW
  - PSC opening time = 5 ms (full ESS pulse)

- Time averaged incident rate on one ^{3}He tube: 4e7 Hz
- **Peak instantaneous incident rate on one tube: 1e9 Hz**
- Paper ready for submission by December

Summary

- We are getting ready for detector construction
  - Engineering detector design is mature
  - Workshops are ready to host construction
  - Last issues are being ”ironed out”
- Beam monitors activities are ramping up
- Simulation projects successful with addressing design issues