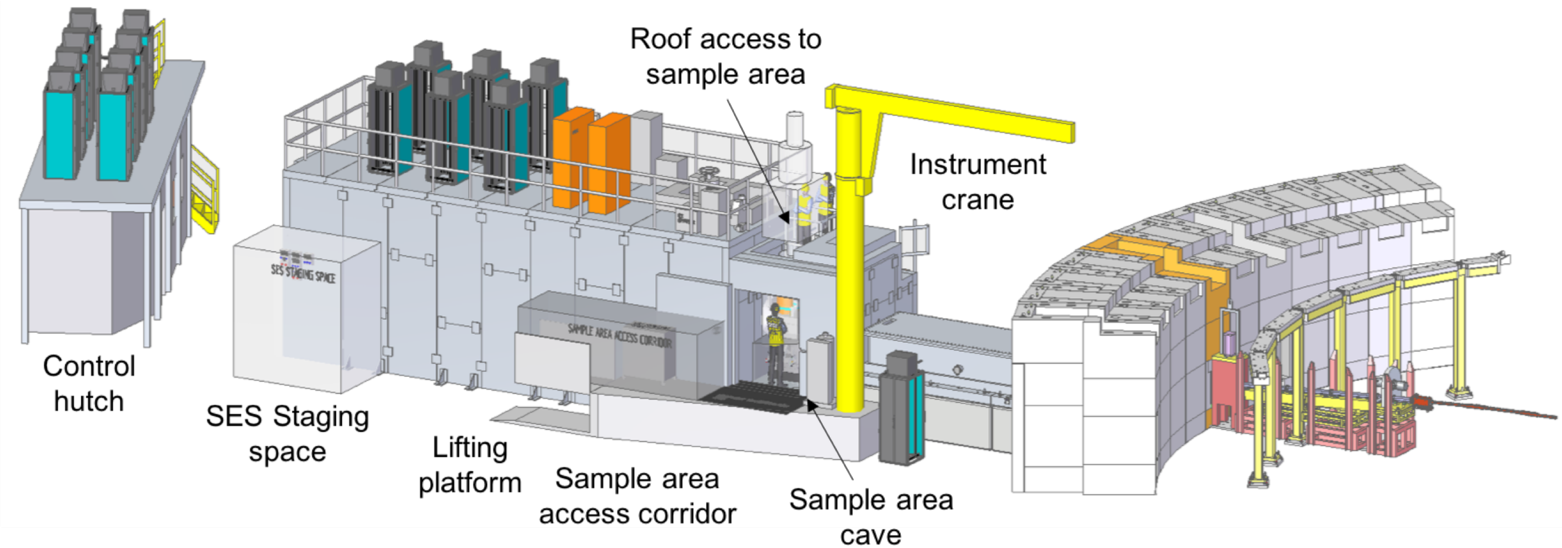
Simulation & Calibration of LoKI's Boron-Coated Straw Detectors

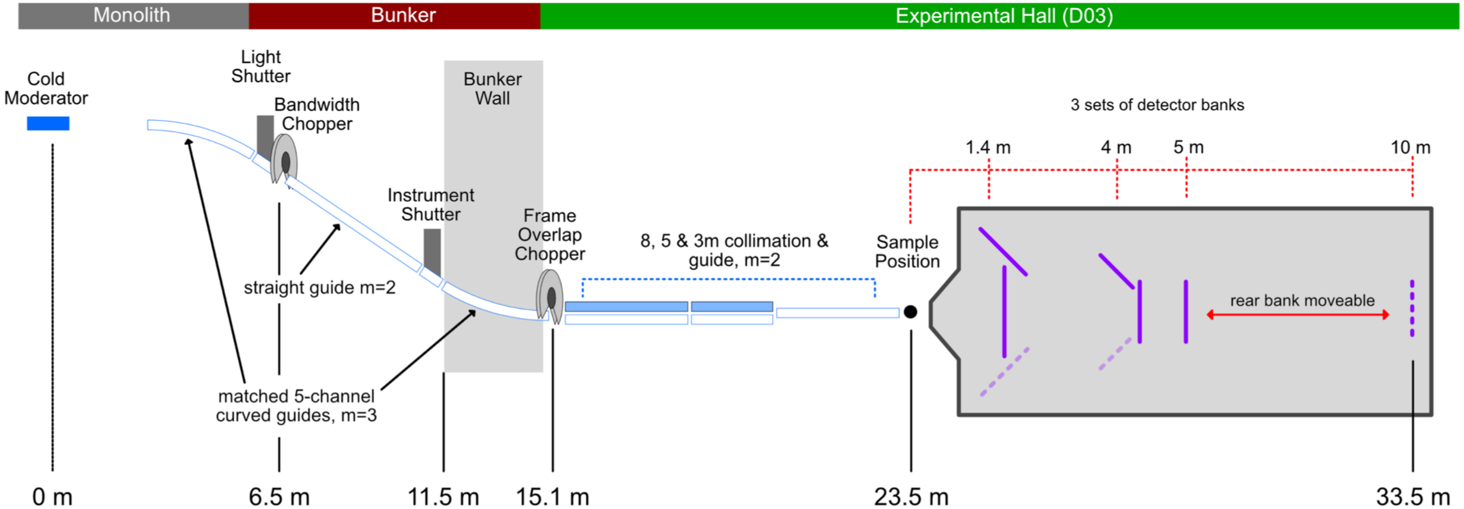
CanSAS 2019

Freising, Germany

LoKI



Roof access to sample area
Instrument crane
Control hutch
SES Staging space
Lifting platform
Sample area access corridor
Sample area cave

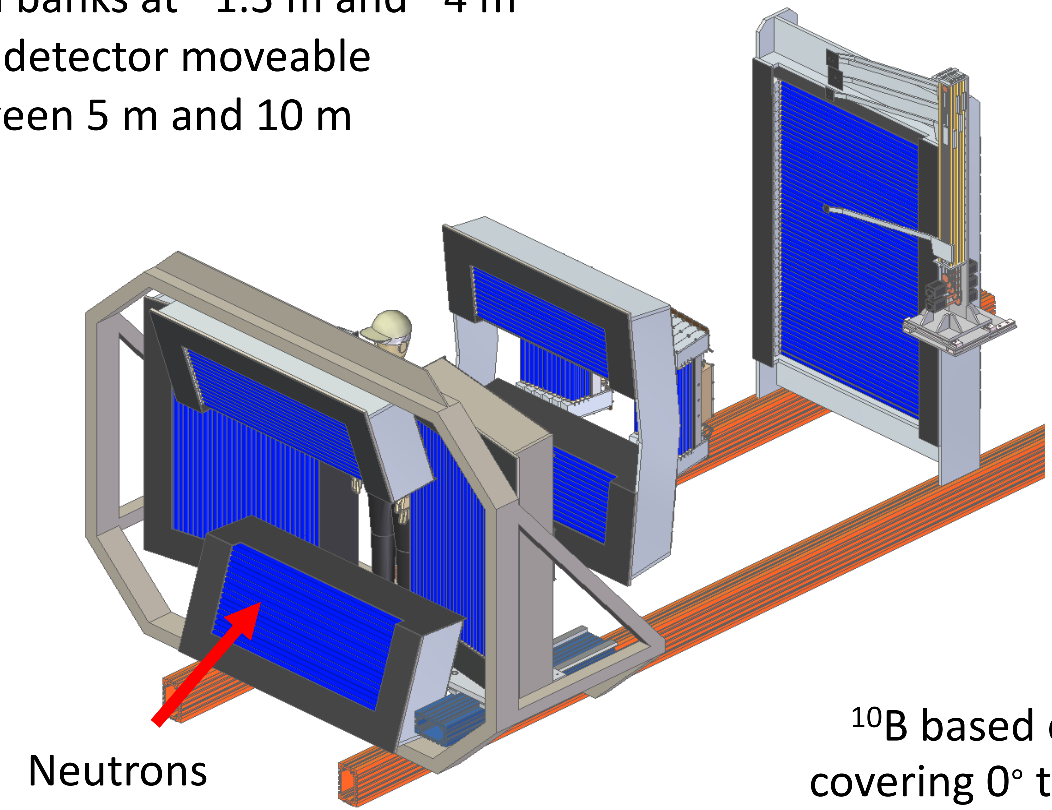


Monolith
Bunker
Experimental Hall (D03)
Cold Moderator
Light Shutter
Bandwidth Chopper
Bunker Wall
Instrument Shutter
Frame Overlap Chopper
straight guide m=2
matched 5-channel curved guides, m=3
8, 5 & 3m collimation & guide, m=2
Sample Position
3 sets of detector banks
1.4 m
4 m
5 m
10 m
rear bank moveable
0 m
6.5 m
11.5 m
15.1 m
23.5 m
33.5 m

Detector Layout

Large detector array:

- Fixed banks at ~1.3 m and ~4 m
- Rear detector moveable between 5 m and 10 m

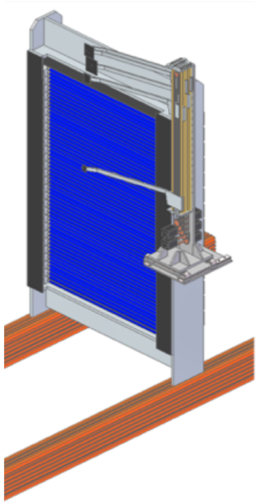


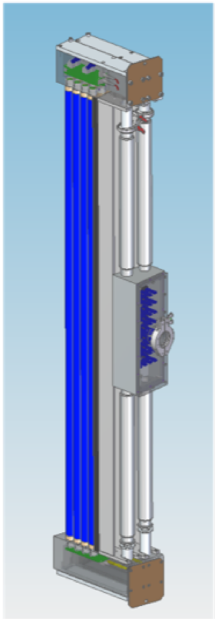
^{10}B based detector system covering 0° to 45° in scattering angle and 360° in azimuthal angle (180° Day 1).

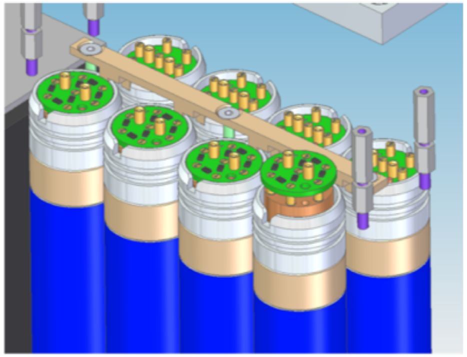
Technology: Boron-Coated Straws
- Proportional Technologies

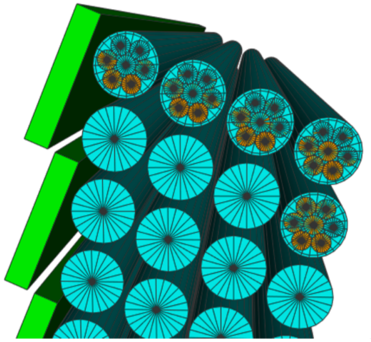
Detector banks have:

- 4 layers of 1” diameter tubes, each containing seven 7 mm diameter straws (in 3 layers, but slightly rotated) = effectively 12 layers.
- 2 columns of four tubes in an “8 pack” sub-module





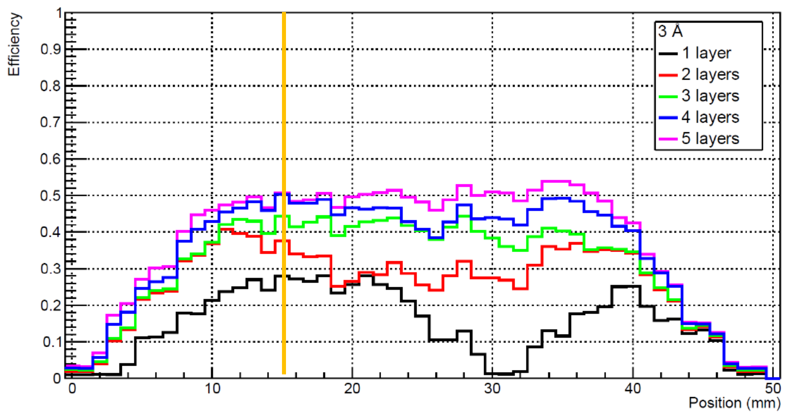


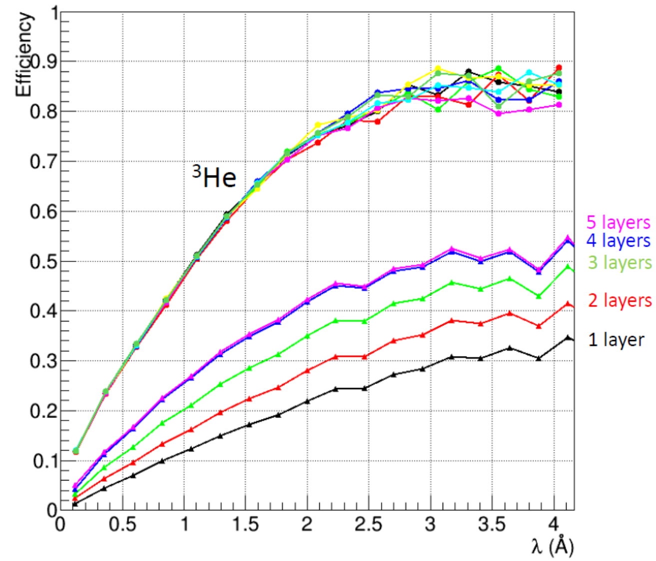


- Horizontal offset 0.4”
- Rotation 20°
- The rotation and the staggering help to have uniform efficiency

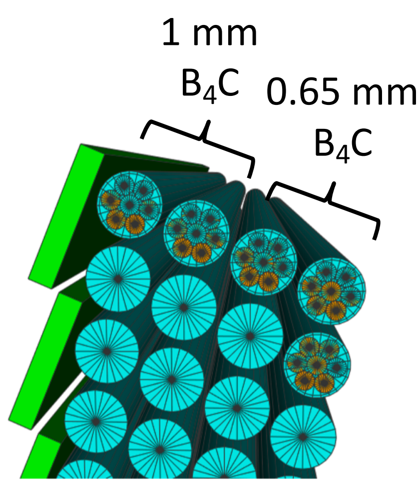
Technology: Boron-Coated Straws - Proportional Technologies

Efficiency vs. Position @ 3 Å



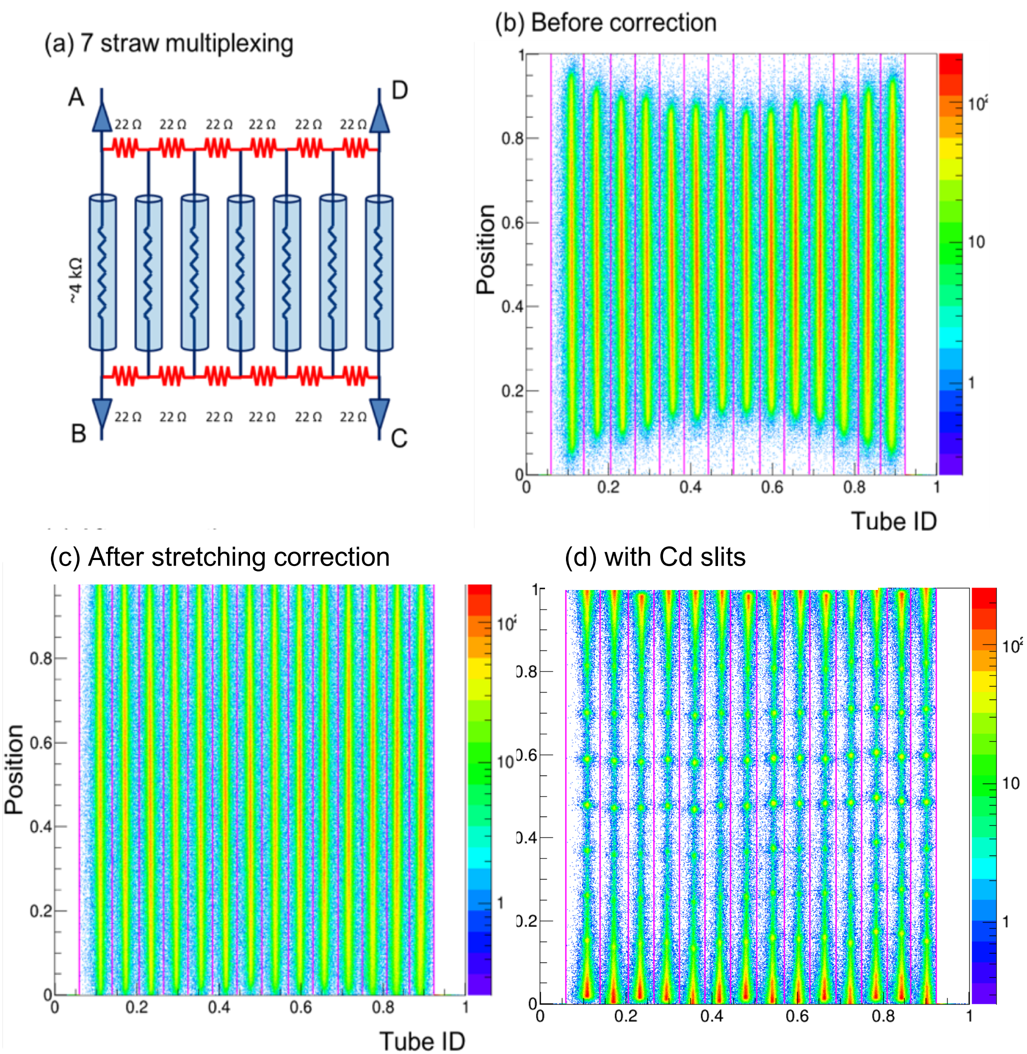


Efficiency: ~50%-60% at LoKI wavelength
Position resolution: FWHM is ~6 mm up to 350 kHz
Rate capability: 15% rate lost at 2.3 MHz



→ spread count rates throughout the detector

Straw Tube Multiplexing

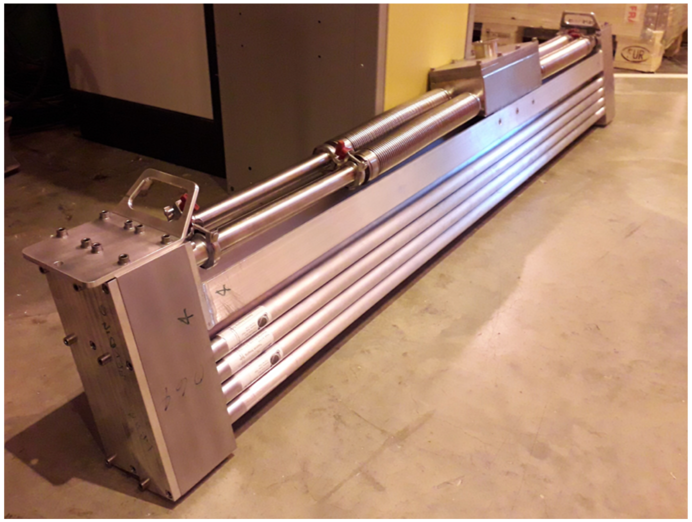


- To reduce the number of signals coming from so many straws
- Resistive chain between both ends of the BCSs
- 7 BCSs in 1 tube are readout by four preamps connected at the corners (A, B, C, and D) of the circuit.
- x axis is used to identify in which BCS a neutron was absorbed
- Y axis is used to calculate where a neutron interacts along the length of the BCS

$$x = \frac{A+B}{A+B+C+D}$$

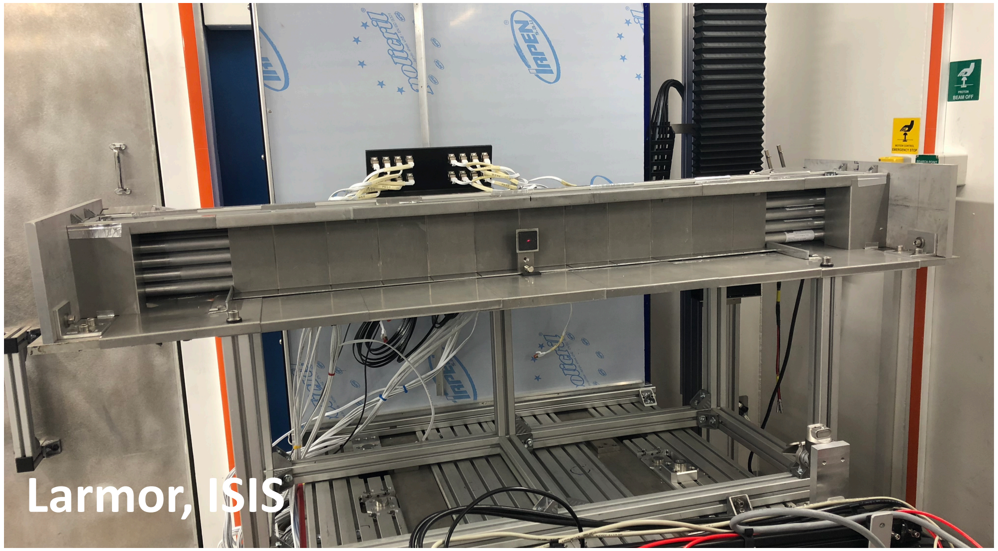
$$y = \frac{A+D}{A+B+C+D}$$

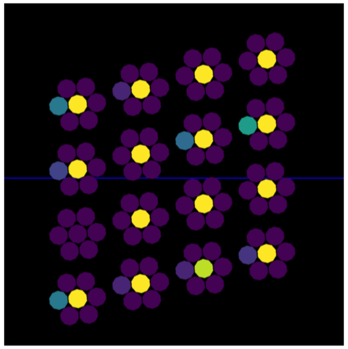
First Tests at ISIS - June 2019



- Tube stretching corrections determined using Cd mask
- Measured Vanadium, glassy carbon, empty beam, AgBe4, SDS powder, polymer blend

Currently working on:
→ Displaying data corrected for stretching in Mantid





Simulations

McStas simulation of instrument → **Geant4** simulation of full detectors → **Mantid** reduction and analysis of simulated data

Simulate and visualise the expected readout of the real detector modules:

→ Help analyse and debug the early detector tests

→ to develop and test data processing and calibration methods for individual detector panels and, eventually, the full detector array

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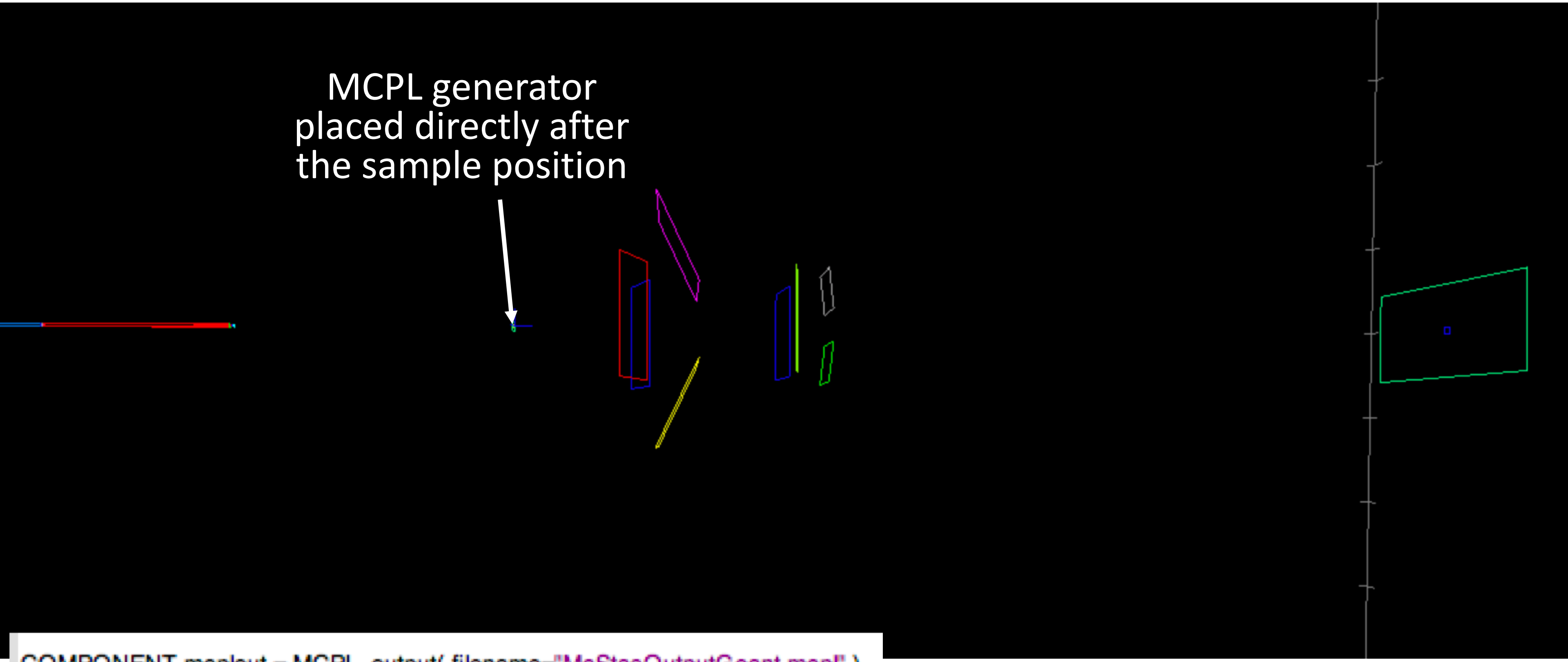


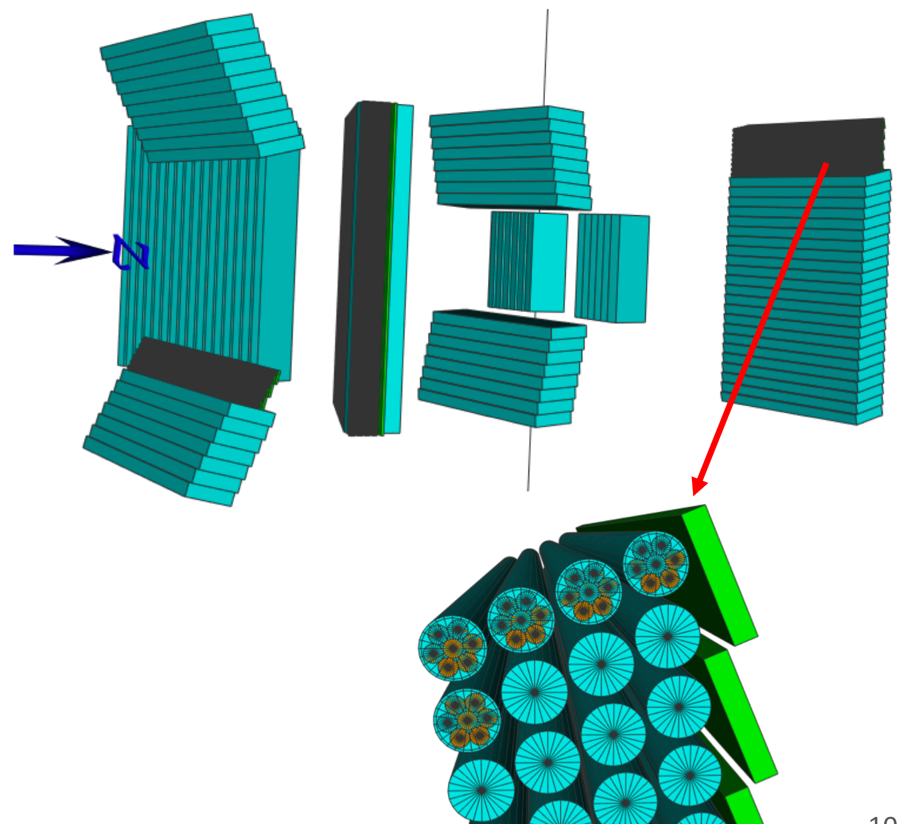

```
COMPONENT mcplout = MCPL_output( filename="McStasOutputGeant.mcpl" )
AT(0,0,0.1) RELATIVE PREVIOUS
```

Simulations

McStas simulation of instrument → **Geant4** simulation of full detectors → **Mantid** reduction and analysis of simulated data

Geant4 is a powerful Monte Carlo simulation toolkit for describing the passage of particles through matter.

It provides step-based particle simulation in arbitrarily complex geometrical layouts, and with physics modelling capabilities.



Simulations

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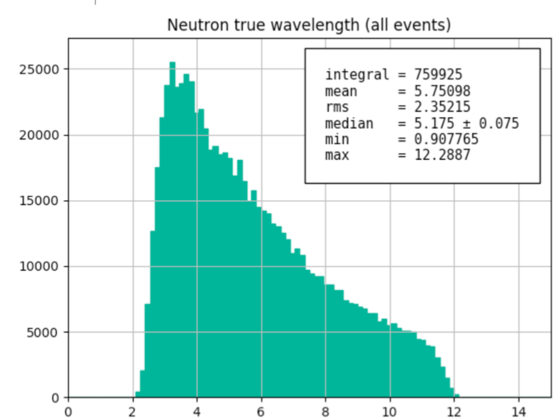
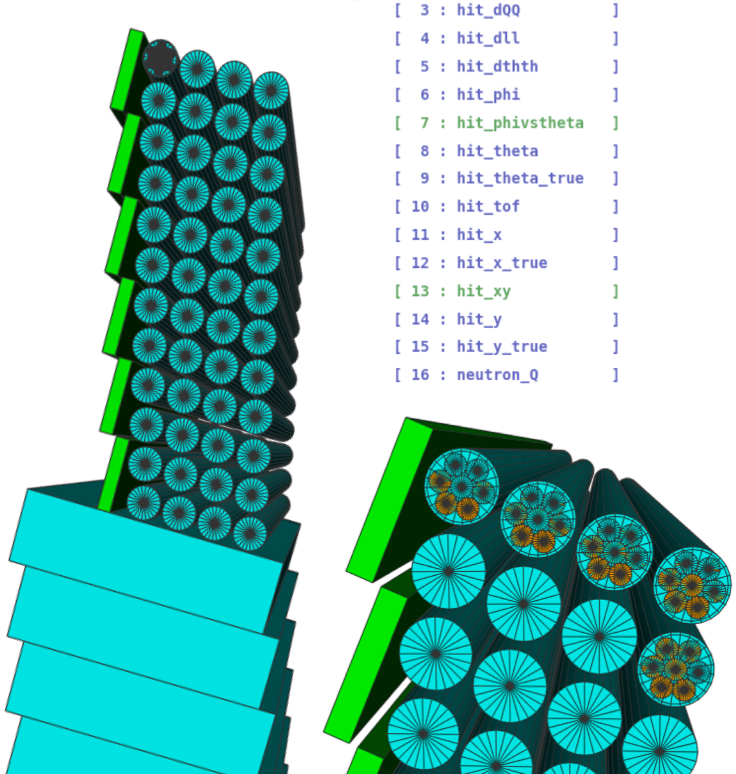
McStas simulation of instrument → **Geant4** simulation of full detectors → **Mantid** reduction and analysis of simulated data

```
[  0 : energyDeposition ]    [ 17 : neutron_Q_FP                 ][ 34 : neutron_x          ]
[  1 : hit_Q            ]    [ 18 : neutron_Q_conv               ][ 35 : neutron_x_FP       ]
[  2 : hit_Q_true       ]    [ 19 : neutron_ekin                 ][ 36 : neutron_x_FP_cut   ]
[  3 : hit_dQQ          ]    [ 20 : neutron_ekin_FP              ][ 37 : neutron_x_conv     ]
[  4 : hit_dll          ]    [ 21 : neutron_ekin_conv            ][ 38 : neutron_x_conv_cut ]
[  5 : hit_dthth        ]    [ 22 : neutron_ekin_eff             ][ 39 : neutron_x_step     ]
[  6 : hit_phi          ]    [ 23 : neutron_lambda               ][ 40 : neutron_xy         ]
[  7 : hit_phivstheta   ]    [ 24 : neutron_nsegments            ][ 41 : neutron_xy_FP      ]
[  8 : hit_theta        ]    [ 25 : neutron_phi                  ][ 42 : neutron_xy_conv    ]
[  9 : hit_theta_true   ]    [ 26 : neutron_steel                ][ 43 : neutron_y          ]
[ 10 : hit_tof          ]    [ 27 : neutron_steel_morethanonestep][ 44 : neutron_y_FP       ]
[ 11 : hit_x            ]    [ 28 : neutron_theta                ][ 45 : neutron_y_FP_cut   ]
[ 12 : hit_x_true       ]    [ 29 : neutron_theta_FP             ][ 46 : neutron_y_conv     ]
[ 13 : hit_xy           ]    [ 30 : neutron_theta_FP_cut         ][ 47 : neutron_y_conv_cut ]
[ 14 : hit_y            ]    [ 31 : neutron_theta_conv           ][ 48 : neutron_y_step     ]
[ 15 : hit_y_true       ]    [ 32 : neutron_theta_conv_cut       ]
[ 16 : neutron_Q        ]    [ 33 : neutron_tof                  ]
```

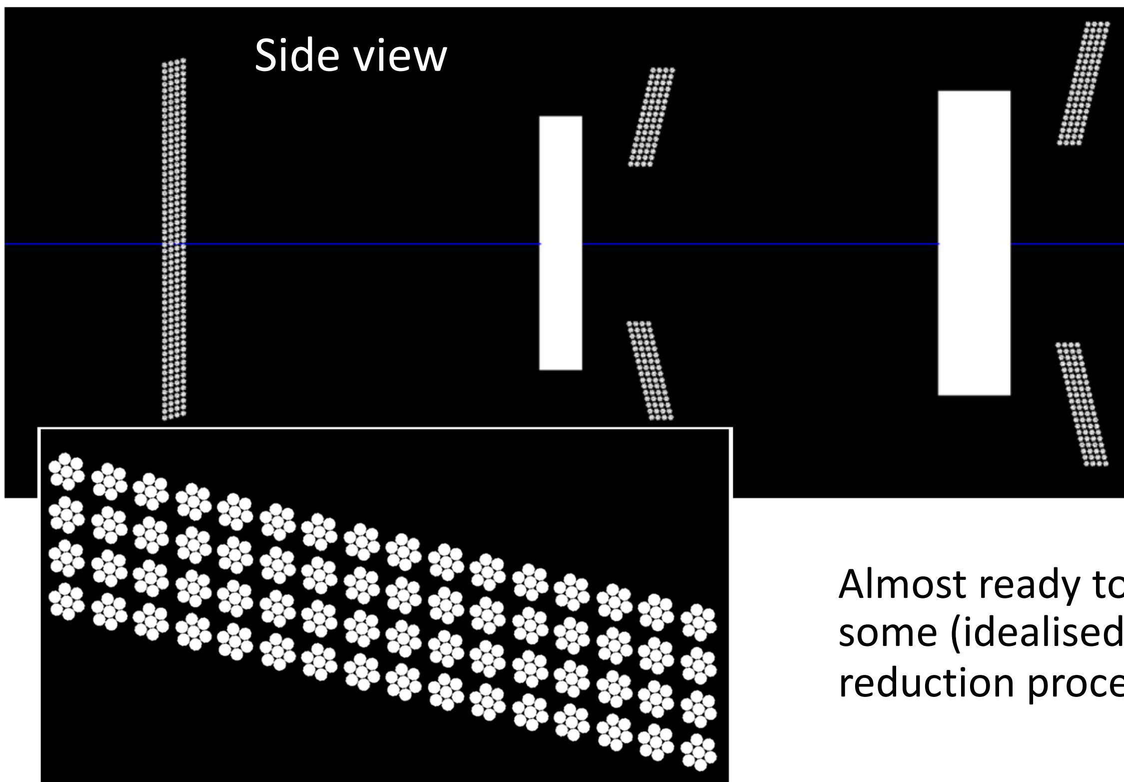


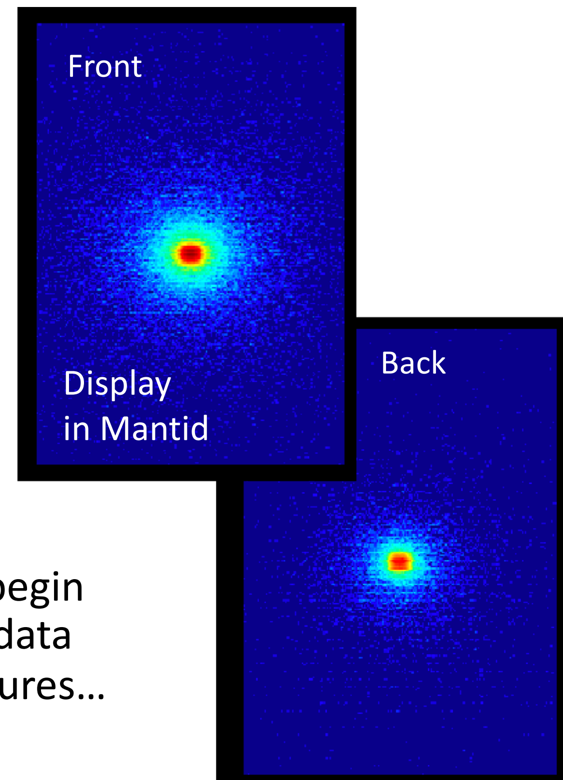


Investigate various aspects of the detector performance: efficiency, absorption and the impact of scattering on the measured signal (background effects), multiple scattering effect from the layers of detector panels, λ-dependant transmission of neutrons through the straws

Simulations

McStas simulation of instrument → **Geant4** simulation of full detectors → **Mantid** reduction and analysis of simulated data





Almost ready to begin some (idealised) data reduction procedures…

Big questions… tackling TOF & 3D detectors

Challenges for data processing:

- Detector position calibration

→ We can't simply survey in the pixel positions

→ Need to use surveyed masks in front of the tubes

- *Solid angle corrections:*

→ Issues with parallax in the quite deep detectors

→ …also as detector moves from 5 to 10 m, or changes in the sample position

→ Calibrating wide angle banks (longer pathlengths in samples? And detectors?)

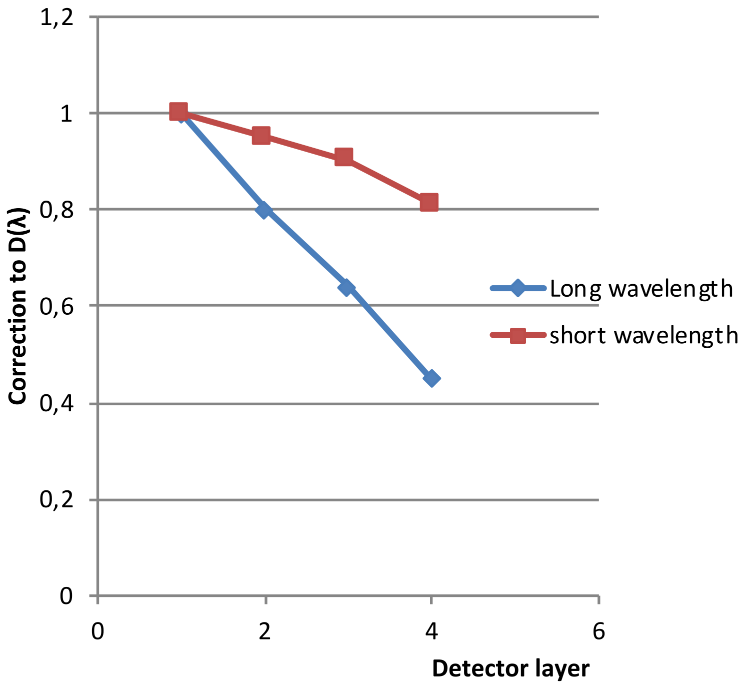
- Relative efficiency of the detectors

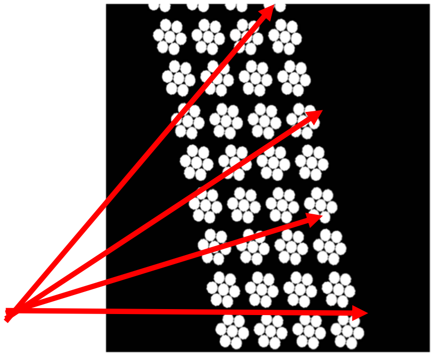
→ Self-screening in layers

- *Wavelength calibrations*

Quest for standards:

- Samples which scatter over wide q
- For intensity calibrations

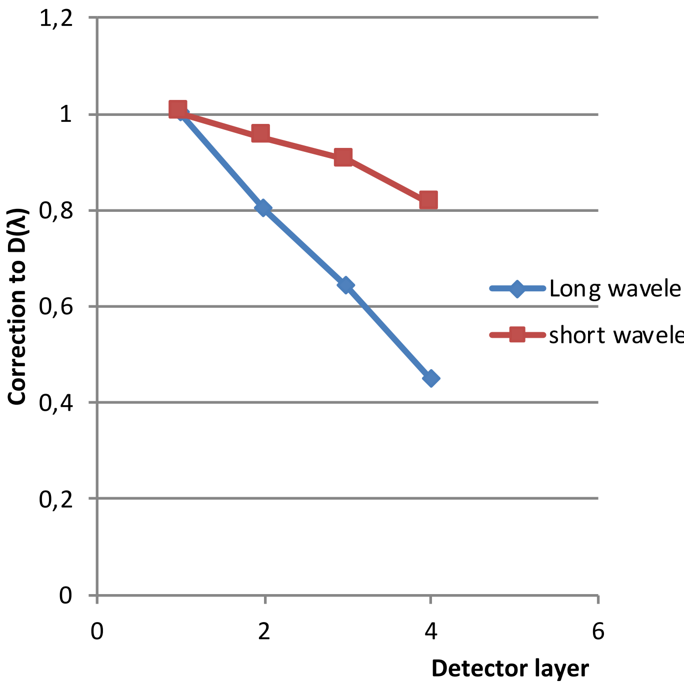




Big Questions: Self-Screening in the 4 (or more) Layers

(Note in real detector the tubes are not exactly in line, so this is just an example, simulations will show more detail variability)

Layer =	1	2	3	4
Long wavelength				
real local efficiency %	**20**	**20**	**30**	**30**
neutrons	**1000**	800	640	448
detected	200	160	192	134.4
effective efficiency %	20	16	19.2	13.44
correction to D(lambda)	1	0.8	0.64	0.448
Short wavelength				
real local efficiency %	**5**	**5**	**10**	**10**
neutrons	**1000**	950	902.5	812.25
detected	50	47.5	90.25	81.225
effective efficiency %	5	4.75	9.025	8.1225
correction to D(lambda)	1	0.95	0.9025	0.81225



- The shape of D(λ) will have to change as neutrons go deeper into the ~10 layer of straws.
- GEANT simulations will provide initial estimates of this self screening.
- We could split D(λ) into a product of monitor and detector parts,
- or store the relative corrections for say each layer of straws and then final corrections for individual straw.
- Note – the first two layers of tubes have a lower efficiency in order to spread count rates.

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Extra figures