BIFROST – Scientific background and operation procedures

Core team:
Instrument scientist: Rasmus Toft-Petersen (DTU/ESS)
Instrument engineer: Liam Whitelegg (ESS)
Instrument data scientist: Greg Tucker (ESS)
IOE: Manon Chesneau

Partners:

Danmarks Tekniske Universitet

Laboratoire Léon Brillouin

PAUL SCHERRER INSTITUT

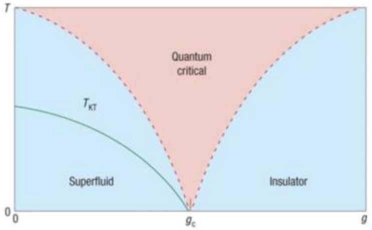
Institute for Energy Technology

Neutron spectroscopy

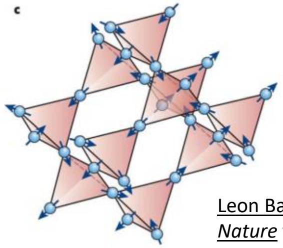
Rare earth

High-Tc superconductivity

Quantum magnetism

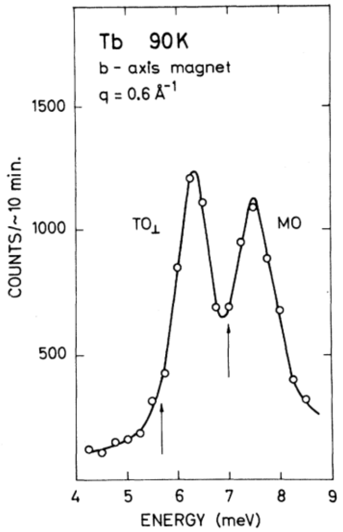


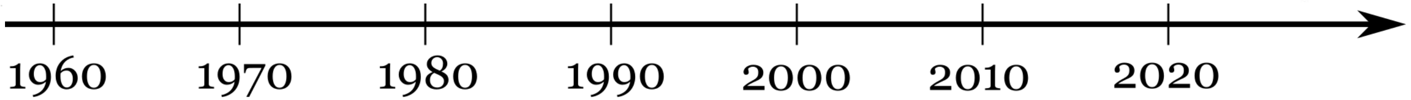
Frustrated magnetism,

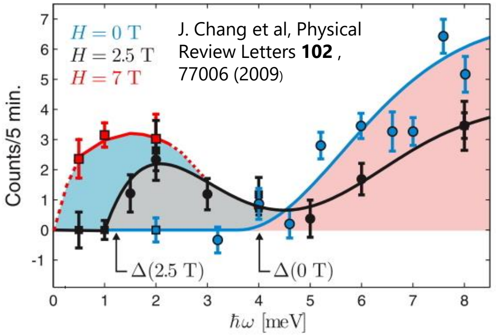


Leon Balents
Nature volume 464, pages,199–208 (2010)

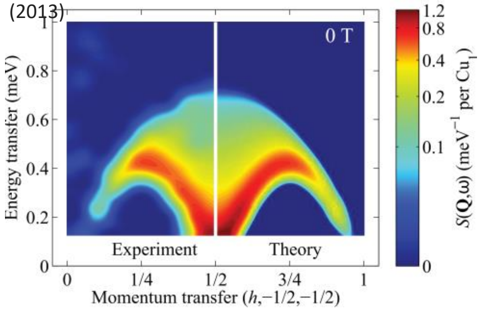
J. Jensen and J. G. Houmann
Phys. Rev. B **12**, 320 (1975)

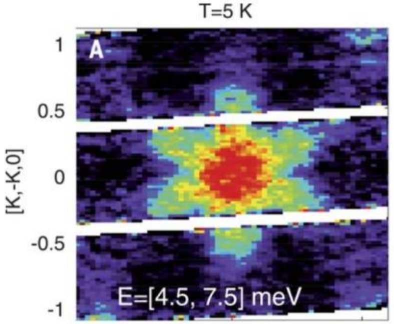




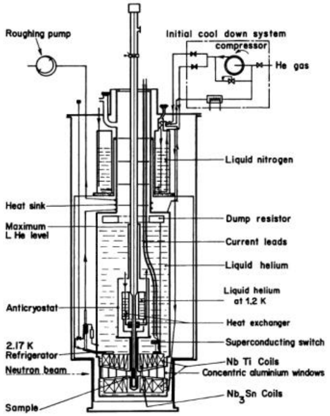


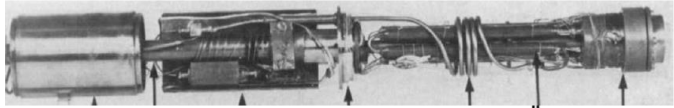
M. Mourigal et al., Nature Physics 9, pages 435–441 (2013)

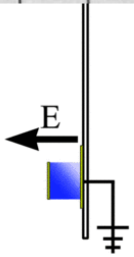




A. BANERJEE, ET AL, SCIENCE • 9 Jun 2017 Vol 356, 6342







Neutron spectroscopy

J. Jensen and
Phys. Rev. B

…magnetism,

Leon Balents
Nature volume 464, pages,199–208 (2010)

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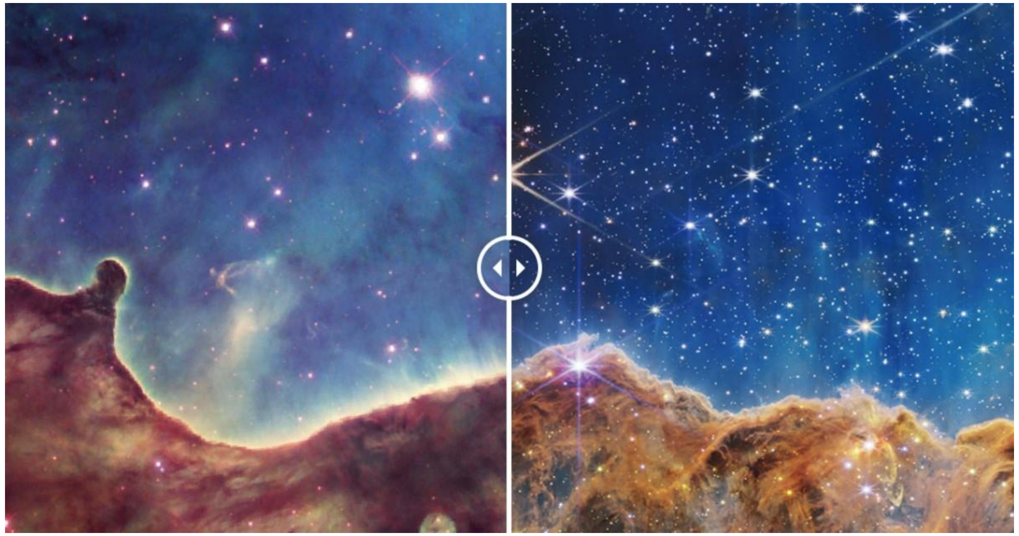
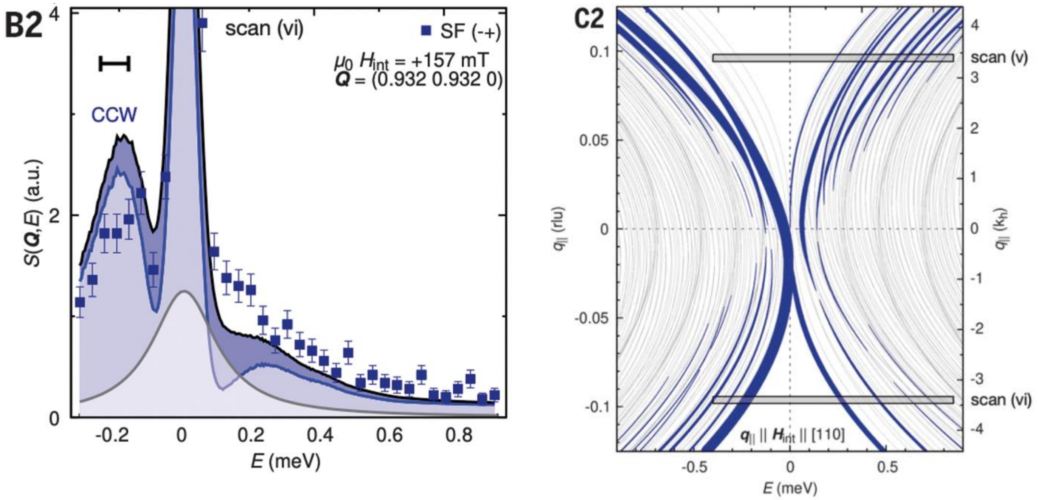
Evolution towards:

More complex phenomena
Smaller magnetic moments
Smaller samples
More complex sample environment

The easy experiments has been done

BIFROST goal: One example



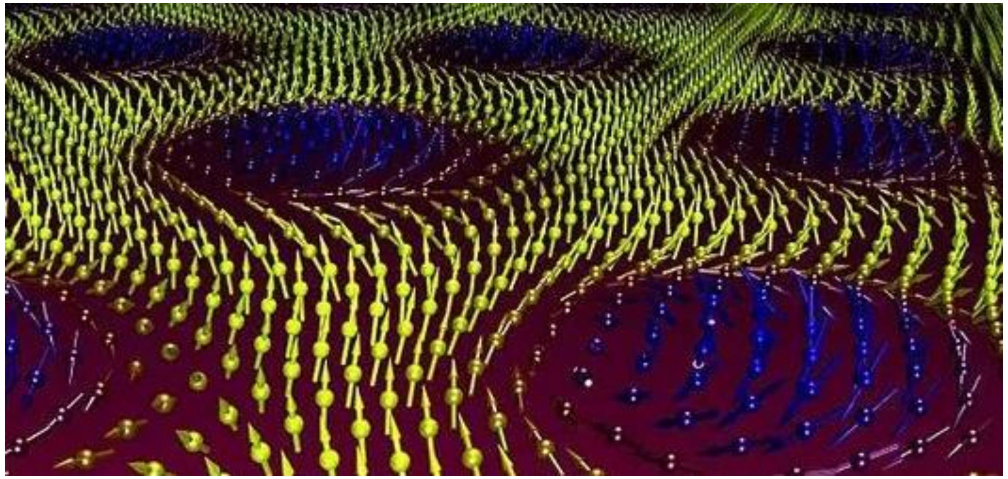


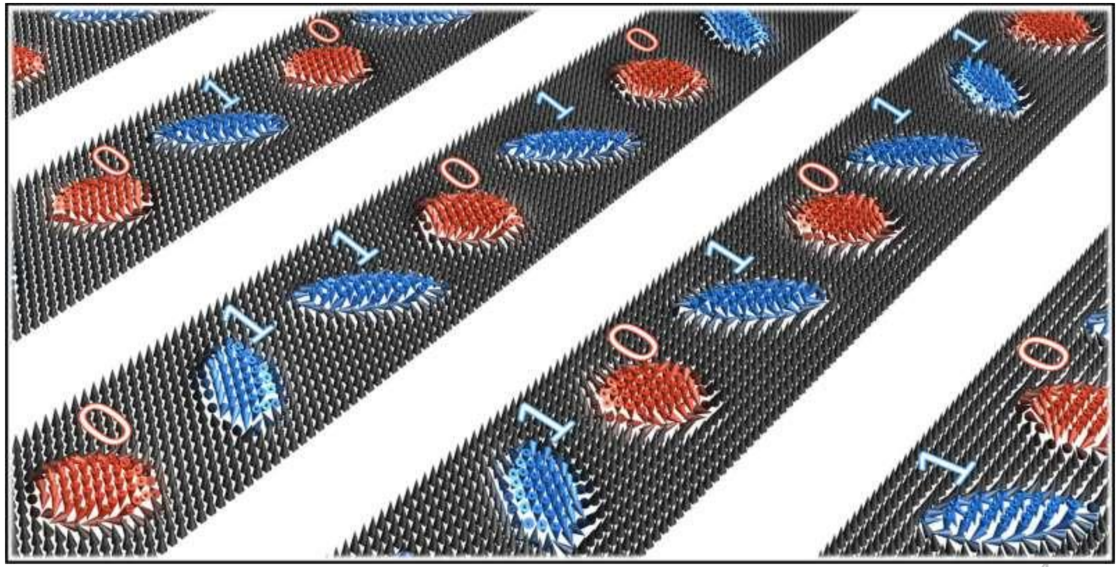
T. Weber, et. al, Science, 375, 2022

Topological magnon band structure of emergent Landau levels in a skyrmion lattice

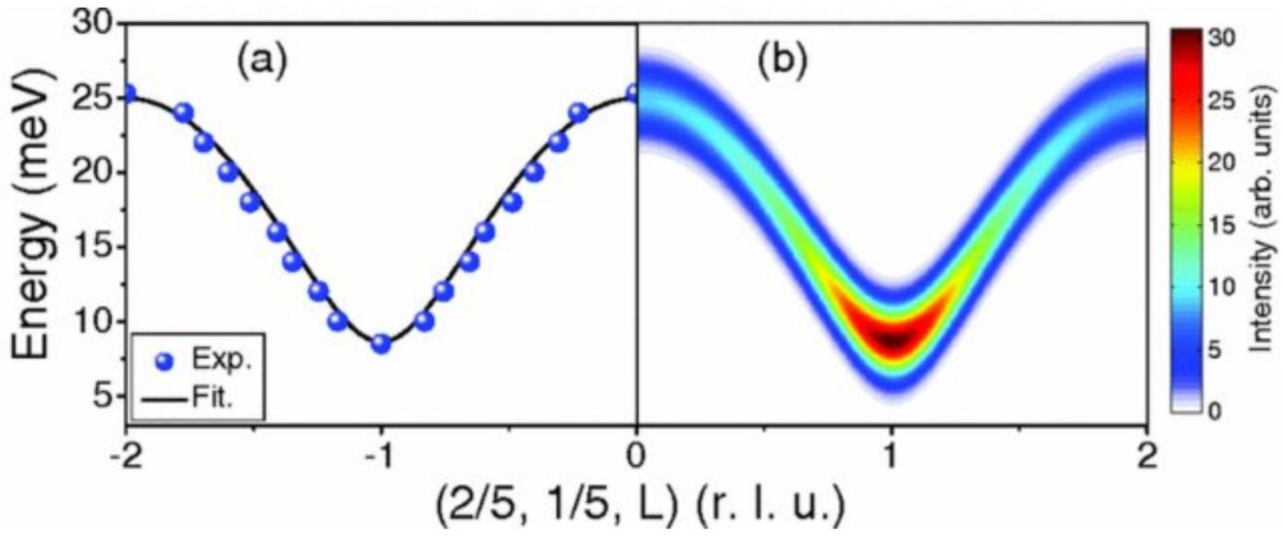
Resolution

- Resolution is often sacrificed for flux – we need the details!

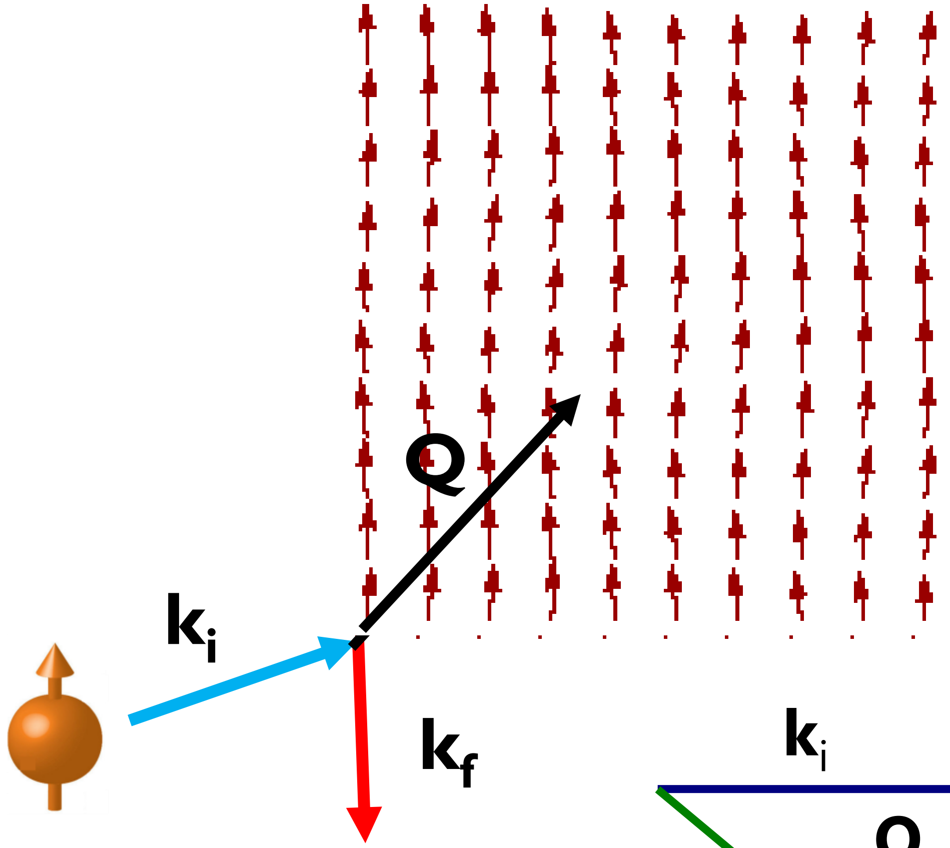




BIFROST goal: Measure propagating excitation of magnetic structures

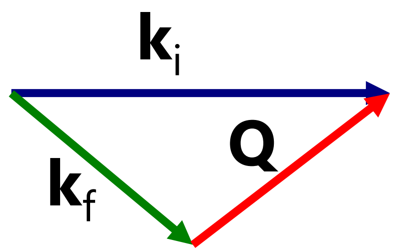


Pertubation of magnetic order behaves like a quasiparticle, that can be created and annihilated by neutrons



We can directly measure the excitation spectrum, and understand the interactions responsibe for the magnetic ground state

Incident neutron -> primary spectrometer
Scatter



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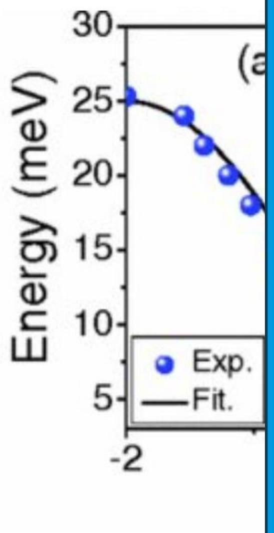

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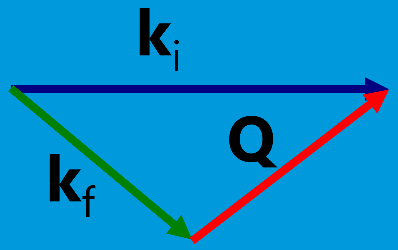
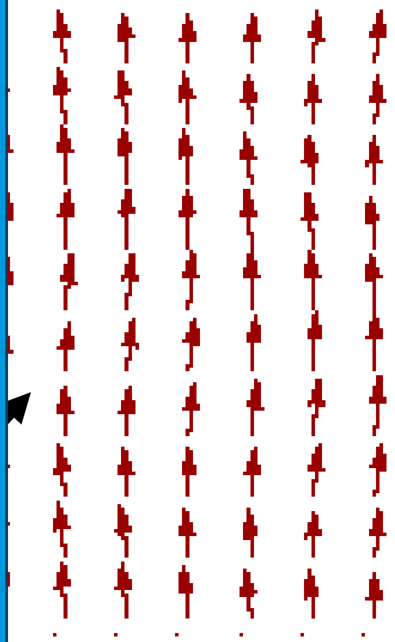


For every detected neutron, **we need to know the energies of the incident and scattered neutrons, as well as the scattering angle**

With spectroscopy, you cannot directly measure both the incident and scattered energies, you need to fix one and measure the other. On BIFROST we 'fix' the scattered neutron energy, and measure the incident neutron energy *indirectly*.

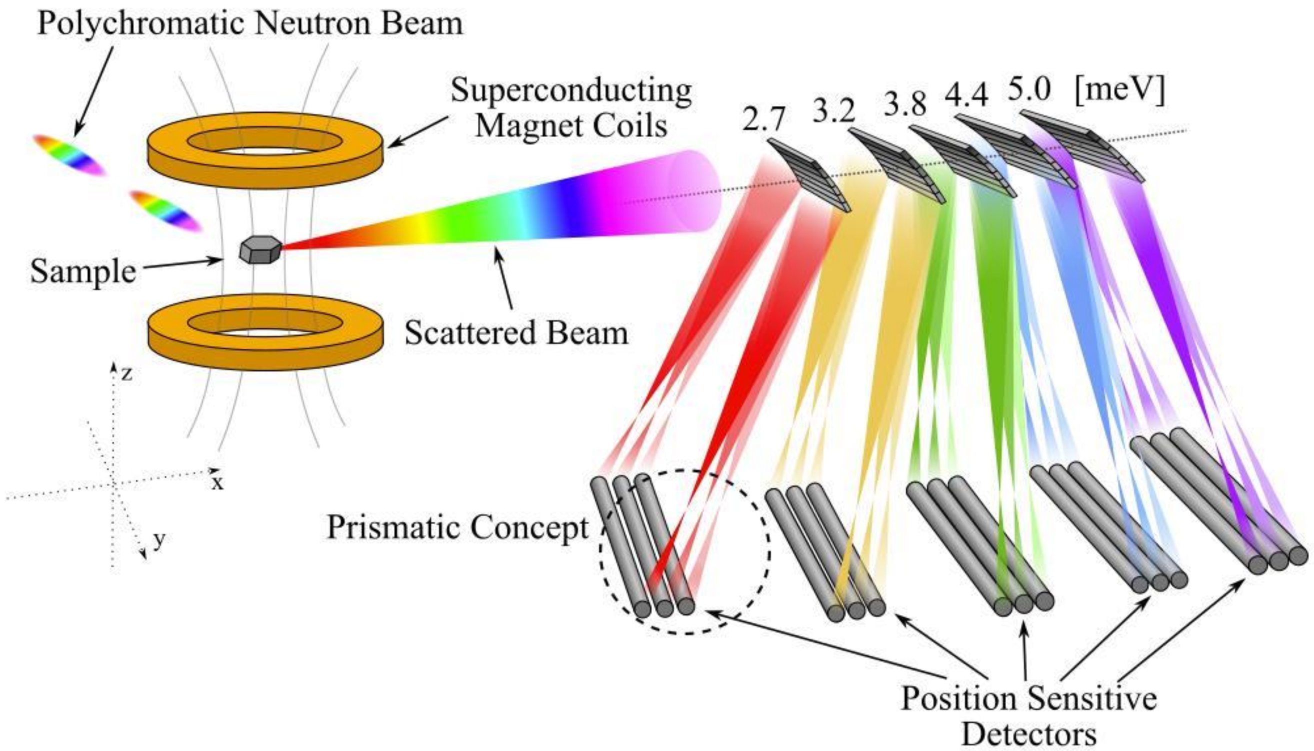


BIFROST: Methodology in time and space

Physical premise 1: The analysers reflect a known neutron energy to the detector

Physical premise 2: We know all flight paths before and after the sample

This is ensured by the design



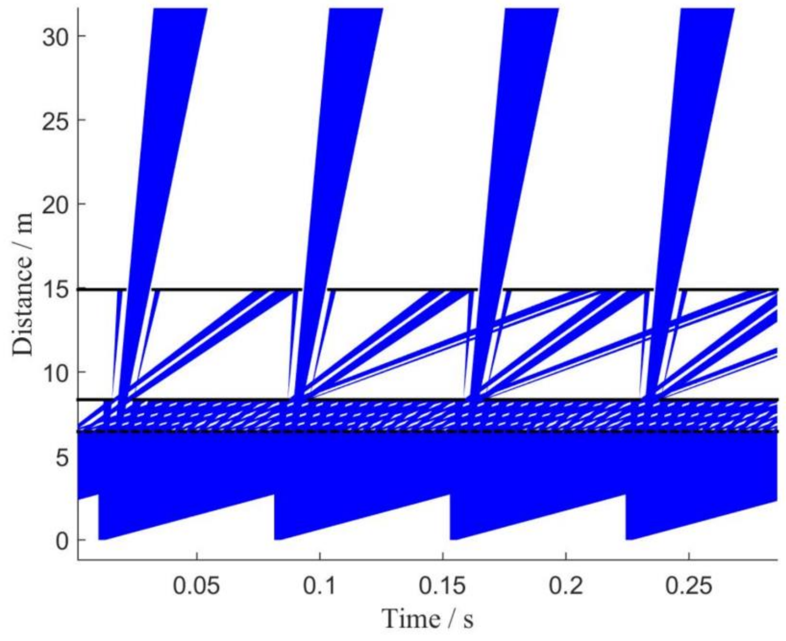
Methodology:

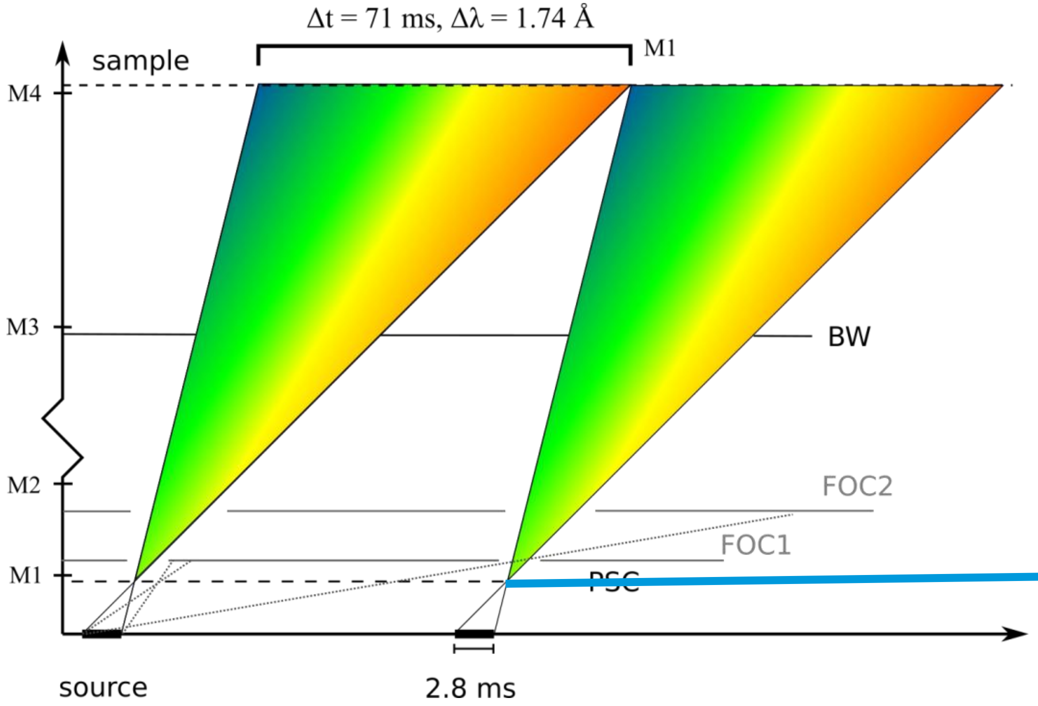
- You record a neutron detection event at detector Y, position X at time t
- Coordinates X and Y gives you the scattering angle (if you know the tank position!)
- Since you know the scattered energy (velocity) and the flight path, *we calculate the scattering time.*
- Knowing the scattering time, *we can calculate the incident velocity of neutron and hence its energy*
- ***The uncertainty of the flight time determines how well we can determine this velocity***

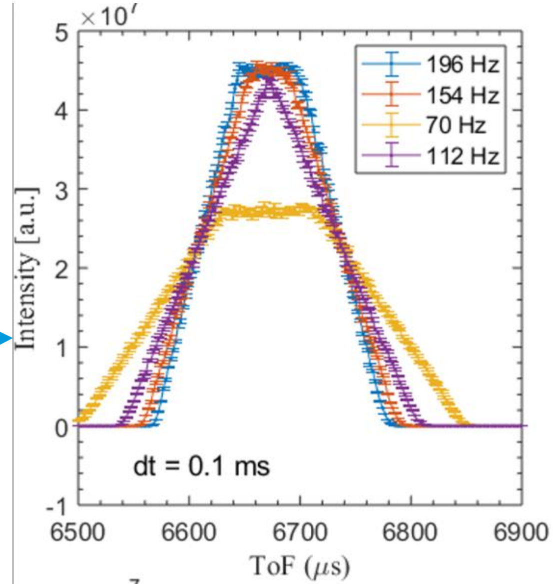
BIFROST: ToF front end – why we need the PSC

__Polychromatic beam:__

- High incident flux
- Energy resolution of primary spectrometer highly tunable via fast Pulse Shaping Chopper (PSC)







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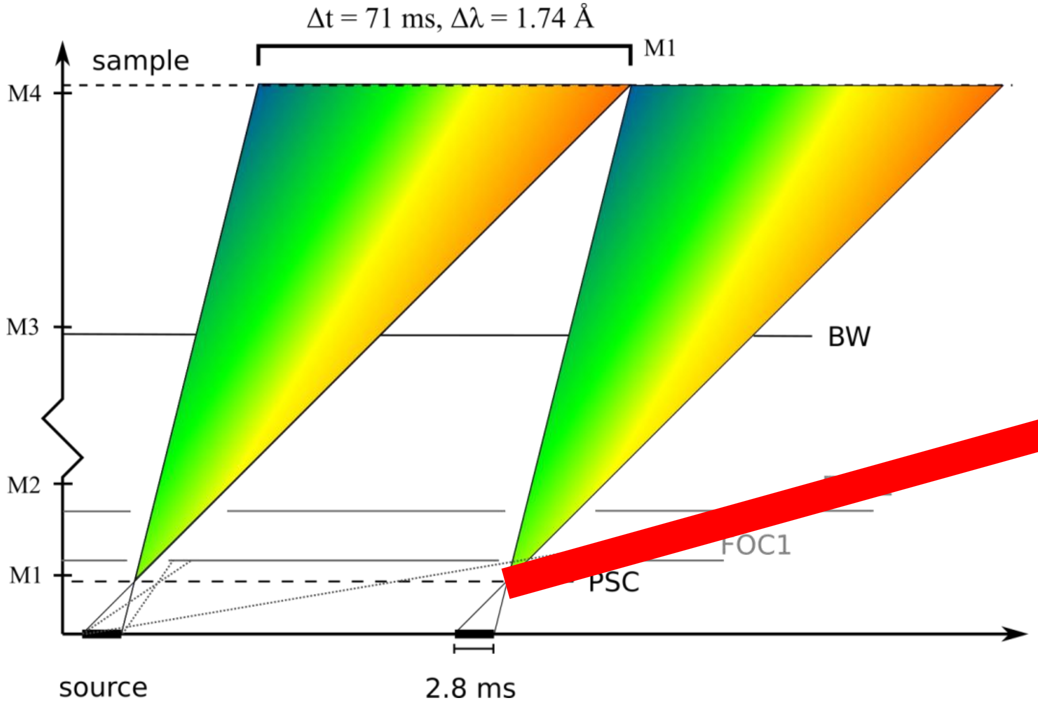

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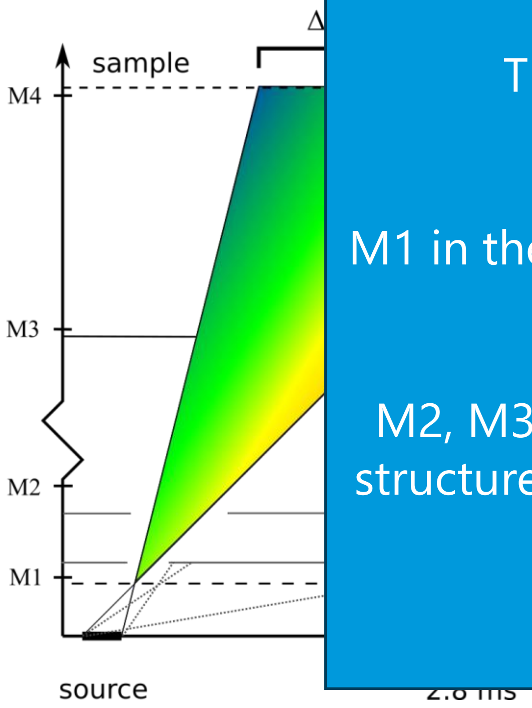
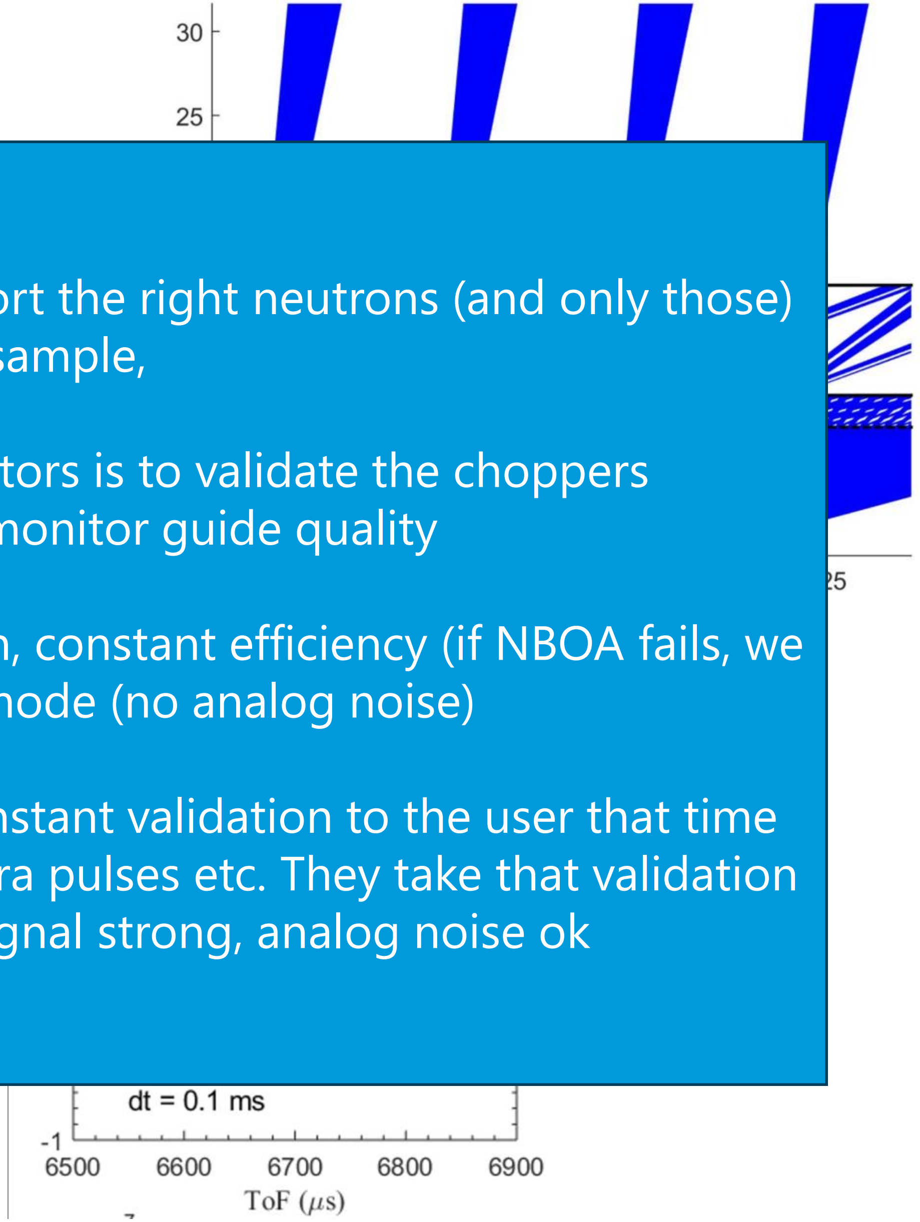




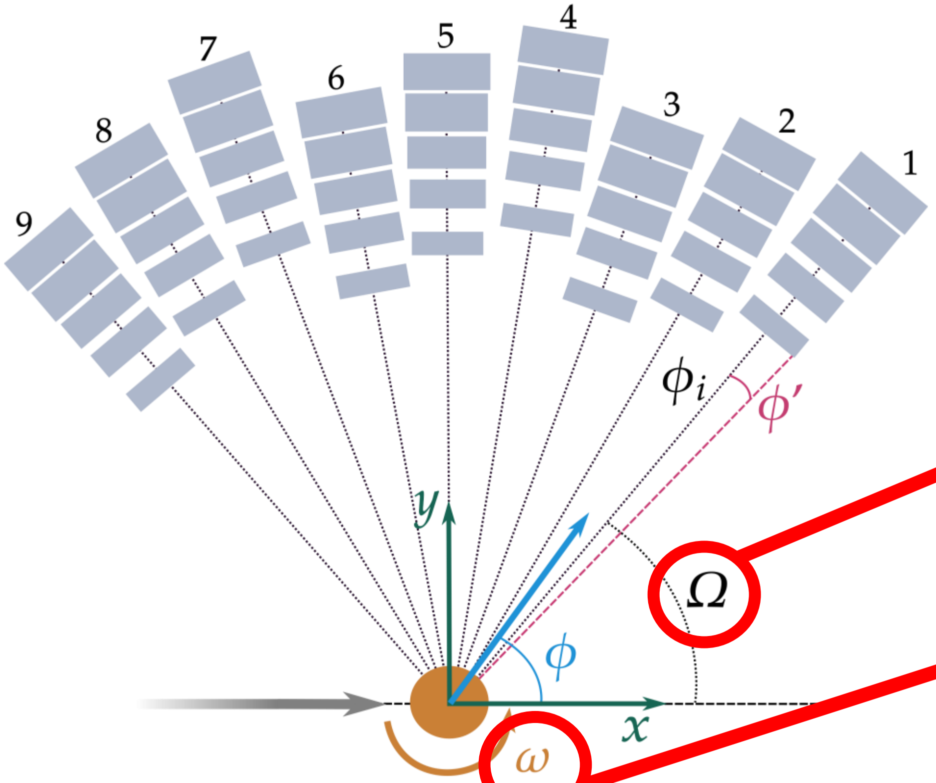
The purpose of the guide is to transport the right neutrons (and only those) to the sample,

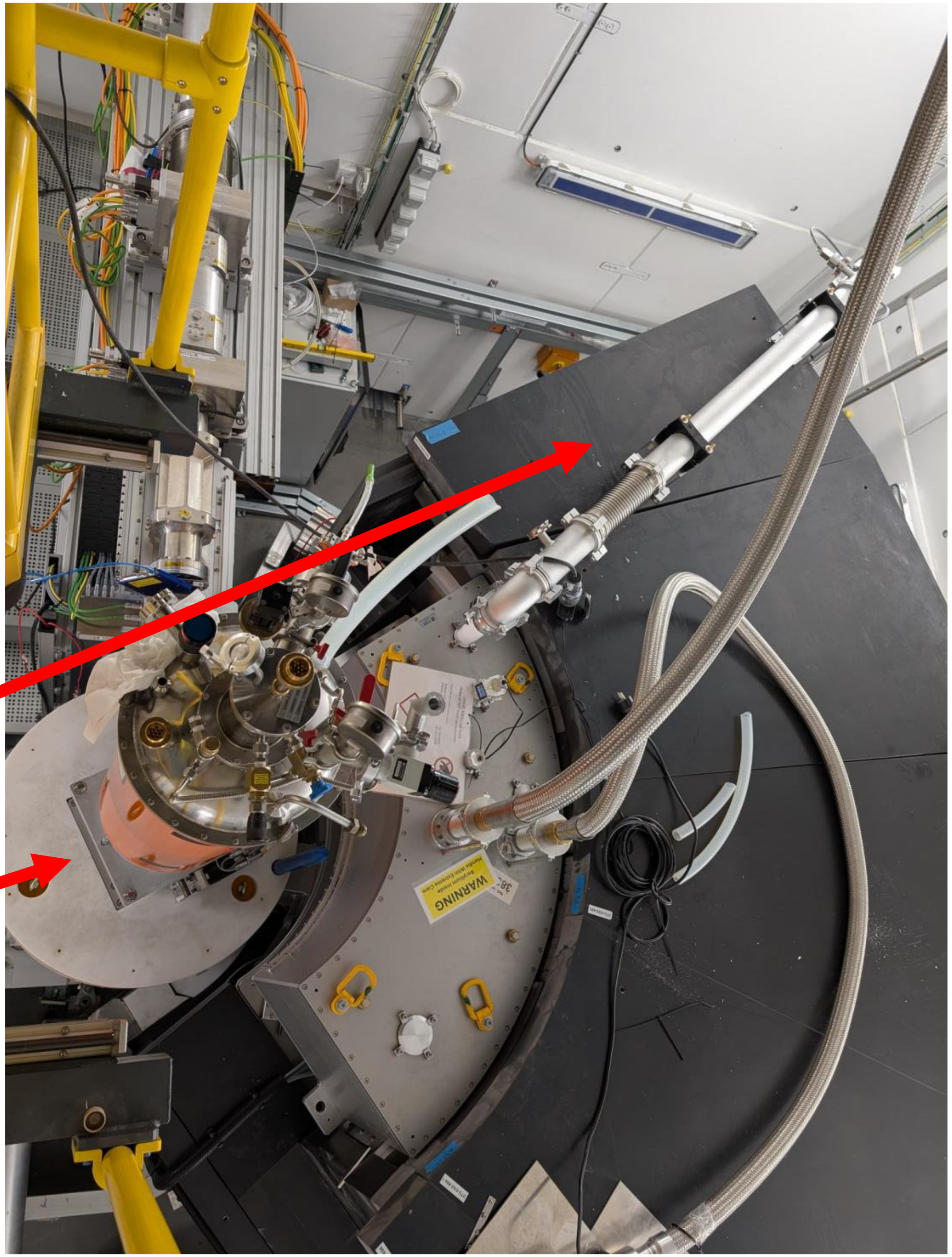
The purpose of the first 3 monitors is to validate the choppers experimentally, and monitor guide quality

M1 in the bunker: Handle the radiation, constant efficiency (if NBOA fails, we need to know). Event mode (no analog noise)

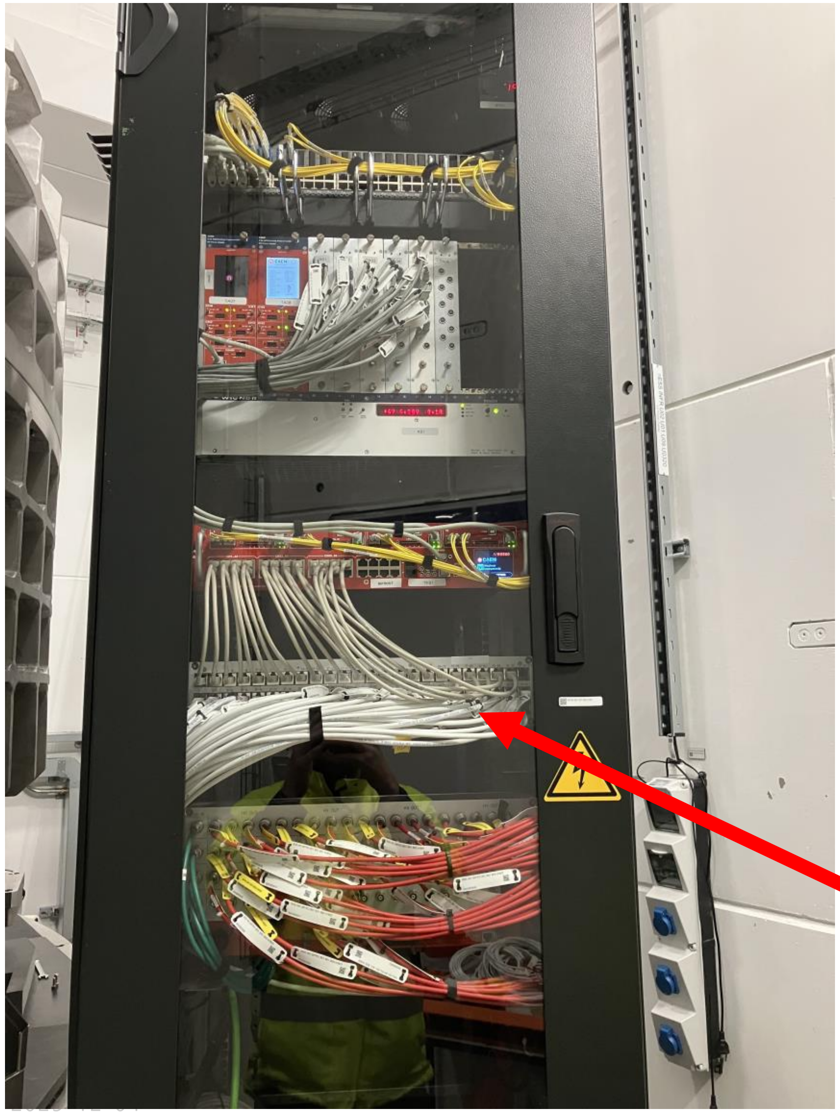
M2, M3: Not attenuate the beam, constant validation to the user that time structure is kosher, they dont have extra pulses etc. They take that validation with them in the data file. Signal strong, analog noise ok

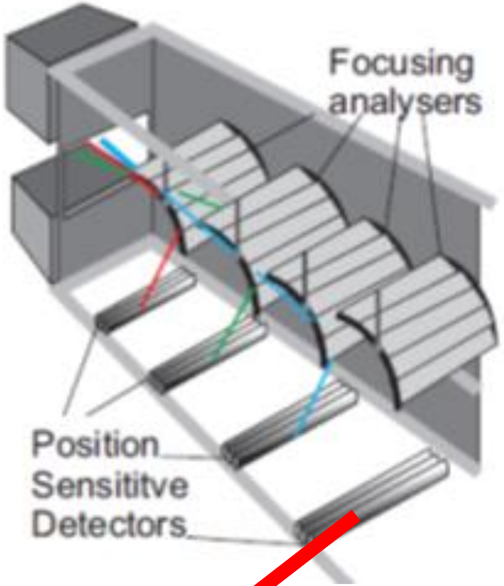
BIFROST: Analysers and angles

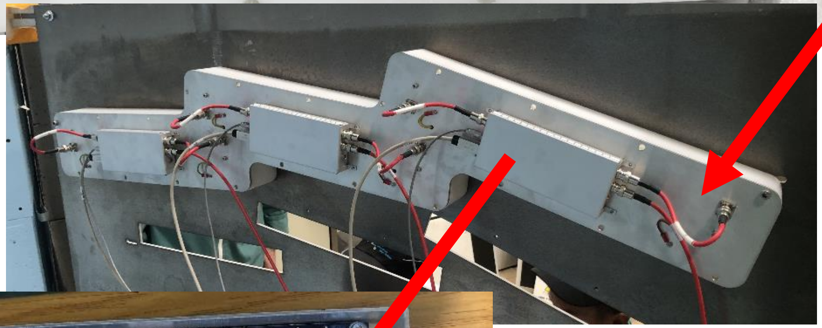




Backend principle of BIFROST – reality







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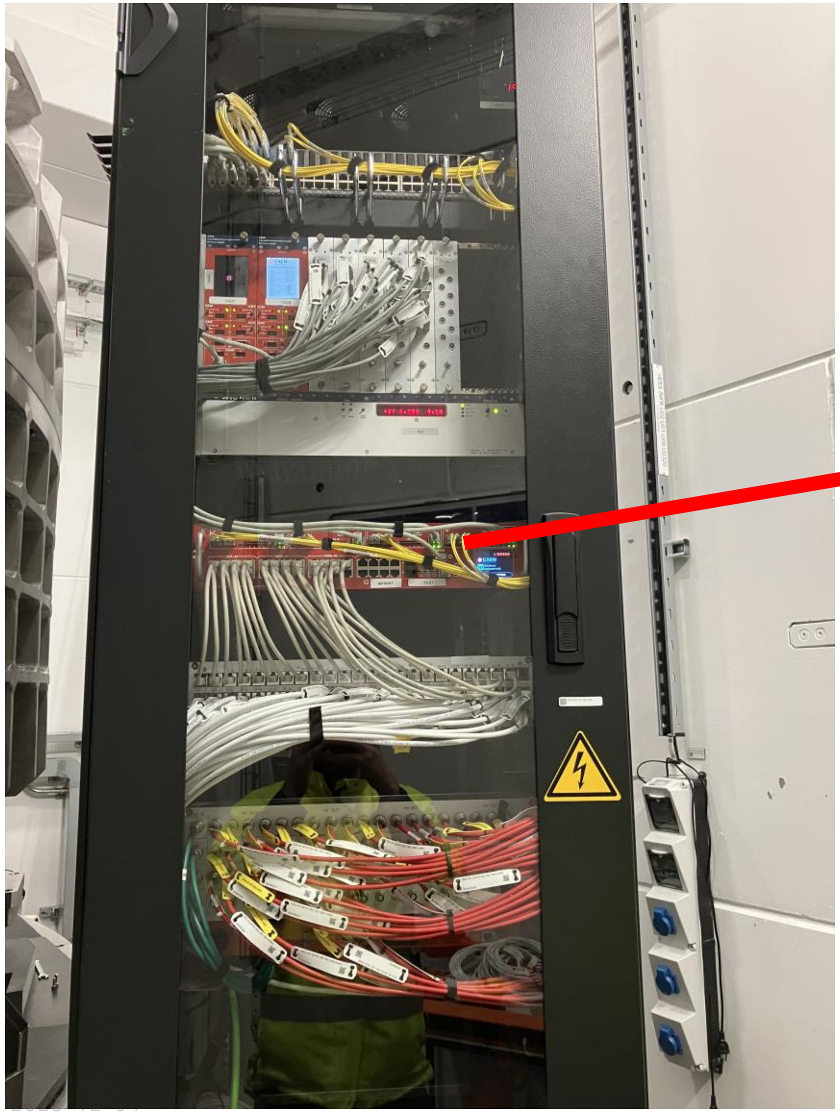

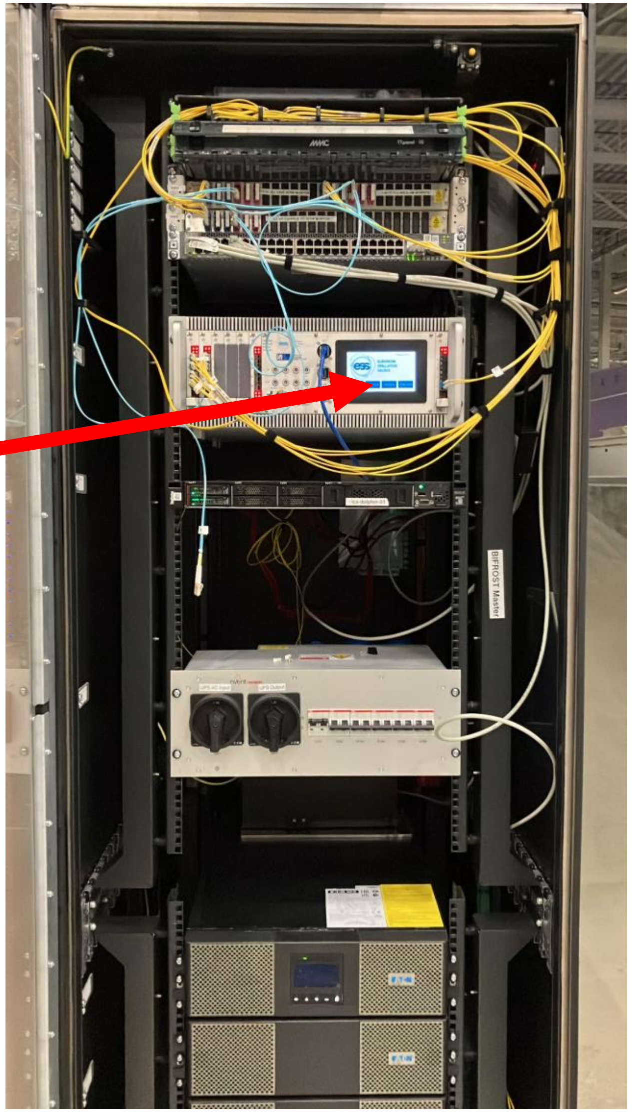

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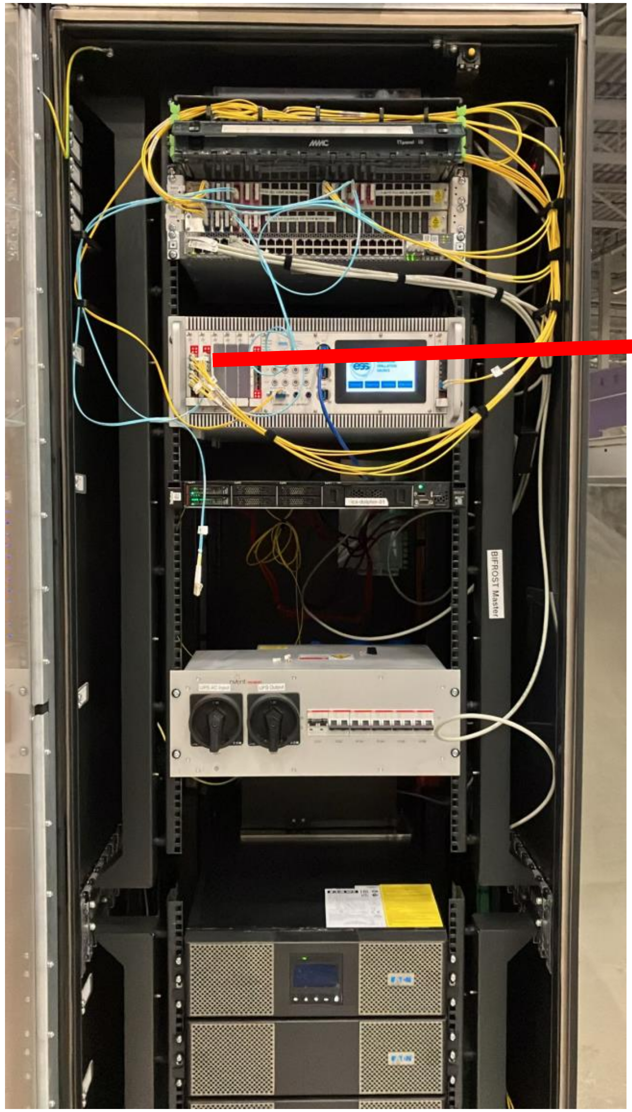

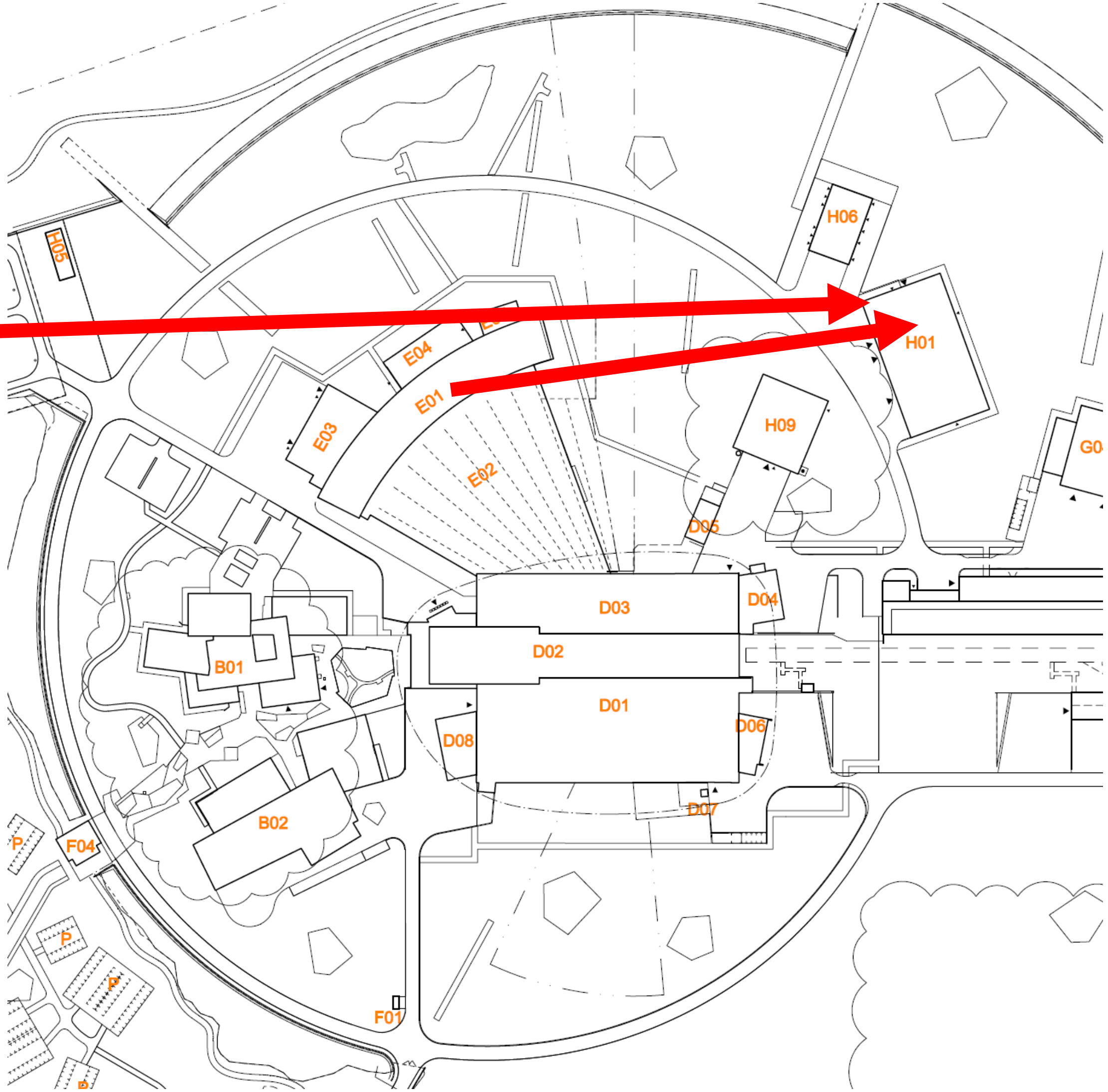

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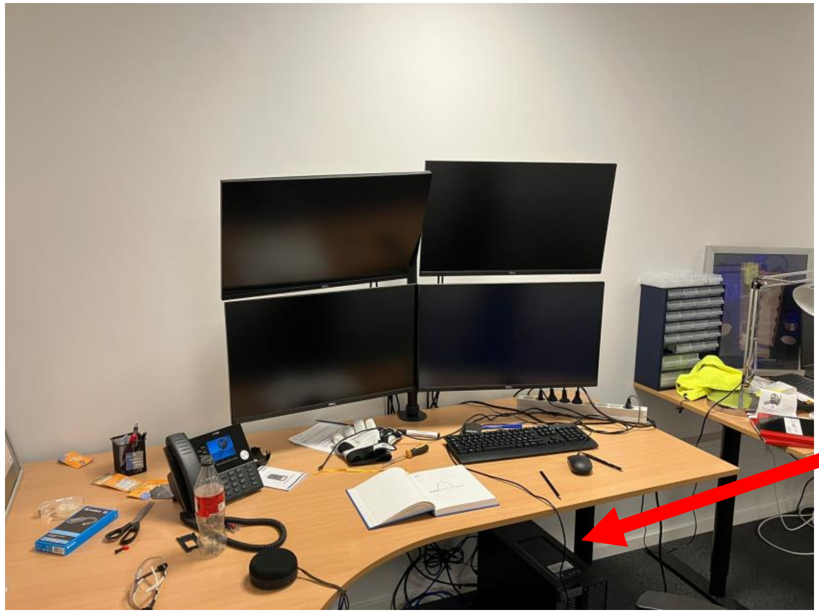
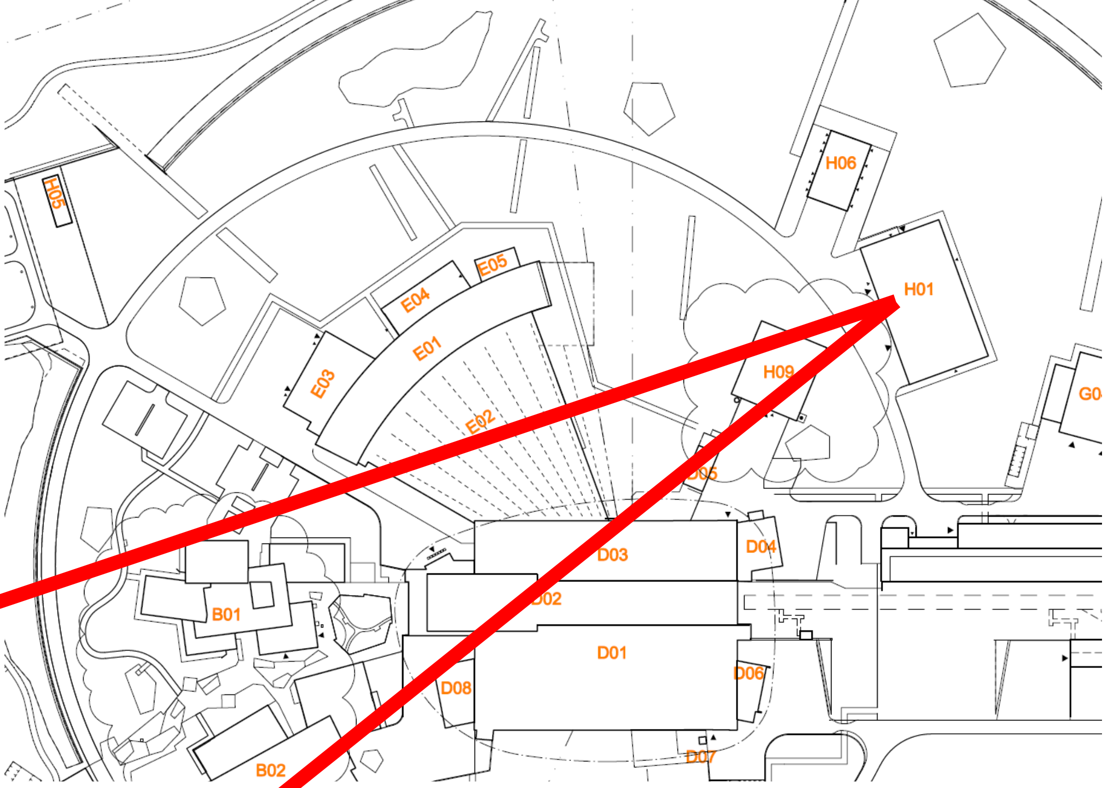




Operational modes - conops (Highlights)

Scenario 1: Sample environment installation (proton beam on or off, shutter closed, access through bottom labyrinth)

- Setting the primary instrument parameters for a specific experiment including choppers, slits, tank, attenuators etc. remotely via control computer and software
- Opening cave hatch
- Mounting the sample environment through the roof with the instrument crane, and move it onto the sample table.
- Setting up sample environment power supplies to the instrument control, checking sample rotation motor, test ramping of field, temperature or pressure
- Checking filter temperature, tank rotation and removing possible beam obstruction.
- Closing cave hatch

Required staff: instrument scientist & technician (if available), SAD scientist

Frequency: 1-3 times per cycle

Operational modes - conops (Highlights)

Scenario 6: Sample removal (proton beam on or off, cave open, shutter closed, beam off access through elevated labyrinth)

- Sample dose is measured in the minutes/hours after beam off by the instrument scientist following guide lines from the radiation protection.
- After cooling down, the sample is removed by the instrument scientist
- Upon agreement with radiation protection, very hot sample are removed by specialized staff.
- Sample is labeled and stored in a centralized lab or cabinet.
- If the sample is very active it is stored in a designated lead coffin

Required staff: user, instrument scientist, radiation protection worker

Frequency: 5-10 times per cycle

Maintenance modes – conops (Highlights)

Scenario 1: Maintaining a chopper in the bunker (accelerator off)

- At proton beam off, wait for radiation levels to drop, following radiation protection guidelines
- Dismantle bunker roof under RP supervision
- Measuring the activity near the chopper CHIM to evaluate whether extraction is possible
- Specialized technician unbolt the chopper spindle/CHIM and extract the hardware remotely
- Once extracted, the dose levels are measured again, and the component transported to the place of maintenance.

Required staff: Chopper group engineer & bunker technician (if available)

Frequency: 10-30 times in the lifetime of the instrument

Maintenance modes – conops (Highlights)

Scenario 2: Maintaining the detector system (Accelerator on /off, beam off)

- Turn off detector high voltage
- Accessing the cave via the ground level labyrinth
- Venting the tank to atmosphere pressure
- Removing polyethylene shielding elements from the tank to gain access to the detectors.
- Turn off power for the electronics racks
- Removing a detector triplet element and trolley it out of the cave for maintenance

Required staff: detector scientist & technician (if available)

Frequency: 5-15 times in the lifetime of the instrument

Maintenance modes – conops (Highlights)

Scenario 3: Maintenance inside the tank (Accelerator on /off, beam off)

- Turn off detector high voltage
- Accessing the cave via the ground level labyrinth
- Venting the tank to atmosphere pressure
- Removing all polyethylene shielding elements from the tank
- Turn off power for the electronics racks
- Removing all detector triplet elements
- Remove the cave roof
- Unbolt the two tank pieces, and use the E01 hall crane to remove the top tank piece for access

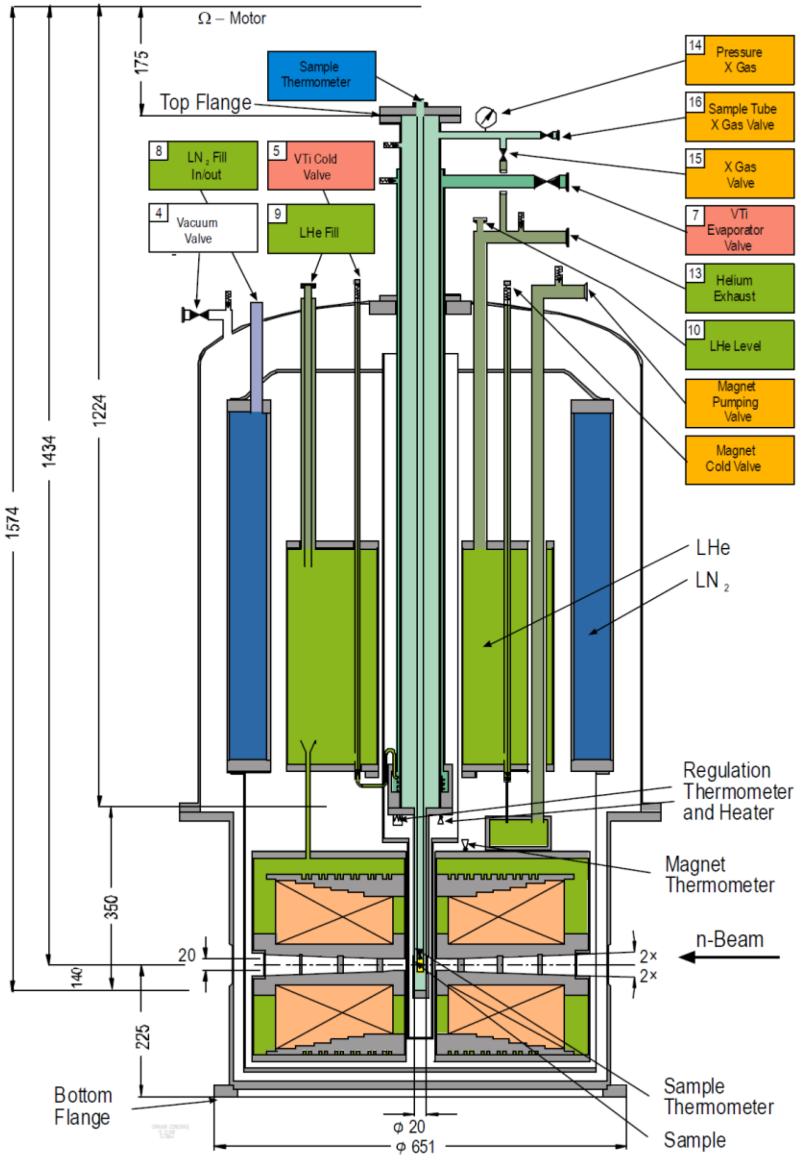
Required staff: detector scientist, instrument engineer & technician(s)

Frequency: 1-2 times in the lifetime of the instrument

Sample environment

Sample environment

- Superconducting coils. Helium cools sample & magnet coils
- Magnetize surroundings why BIFROST is built of non-magnetic materials
- User and instrument scientist needs to constantly monitor temperature, cryogen levels needle valve



Thanks for your attention

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