Bifrost: A new type of cold neutron spectrometer at the ESS

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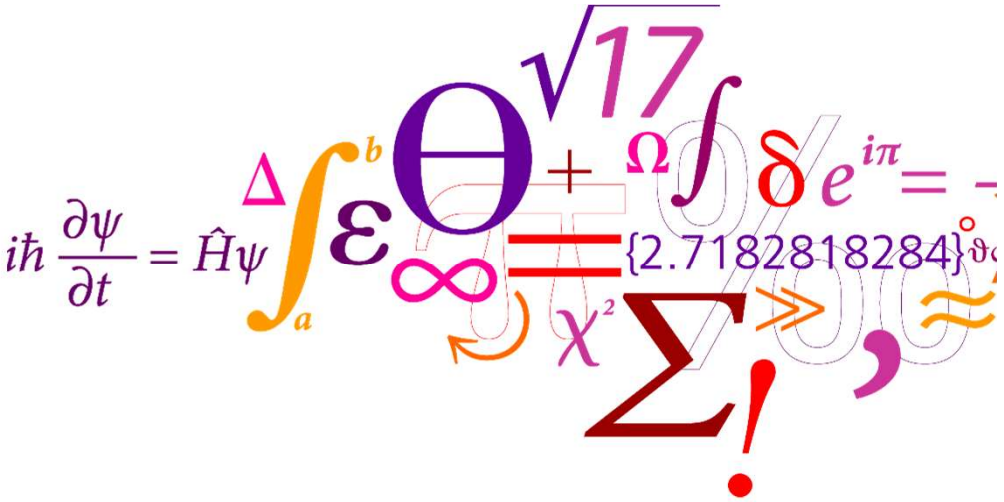
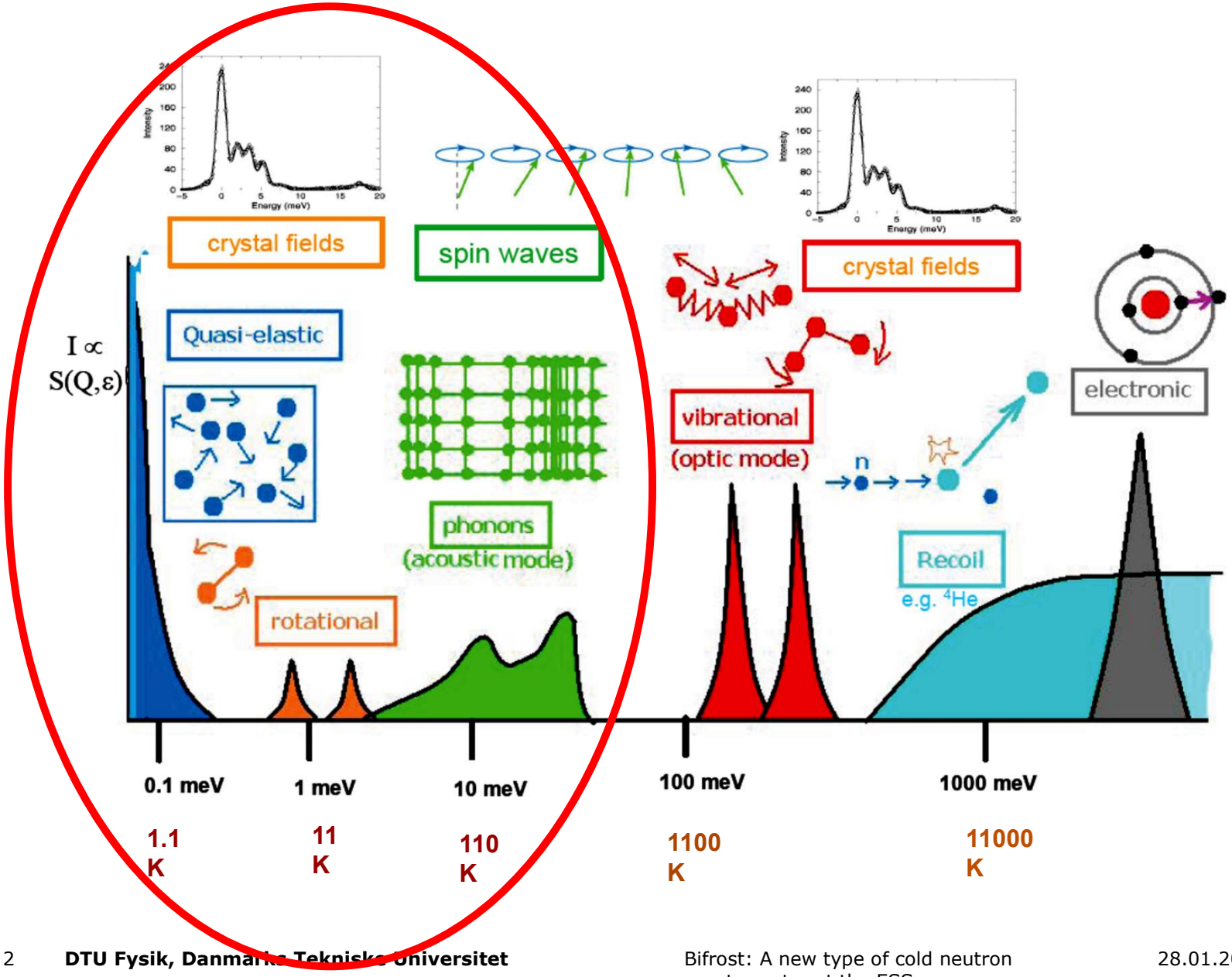
Liam Whitelegg, Lead instrument engineer (ESS)

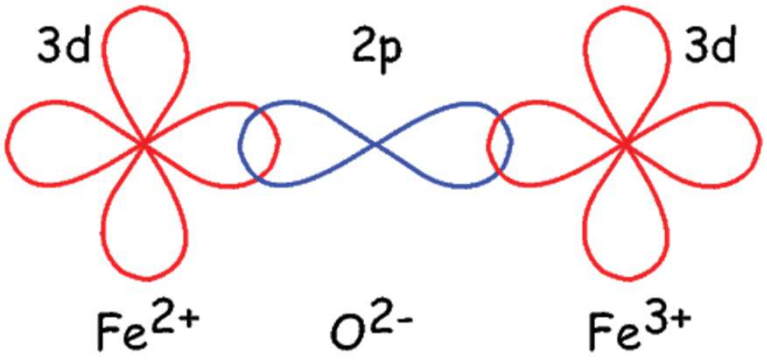


DTU Fysik
Institut for Fysik

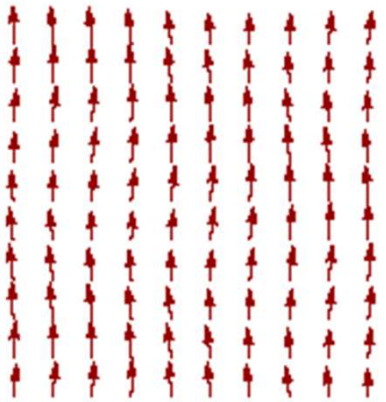
Cold neutrons are unbeatable



Example: Magnetism



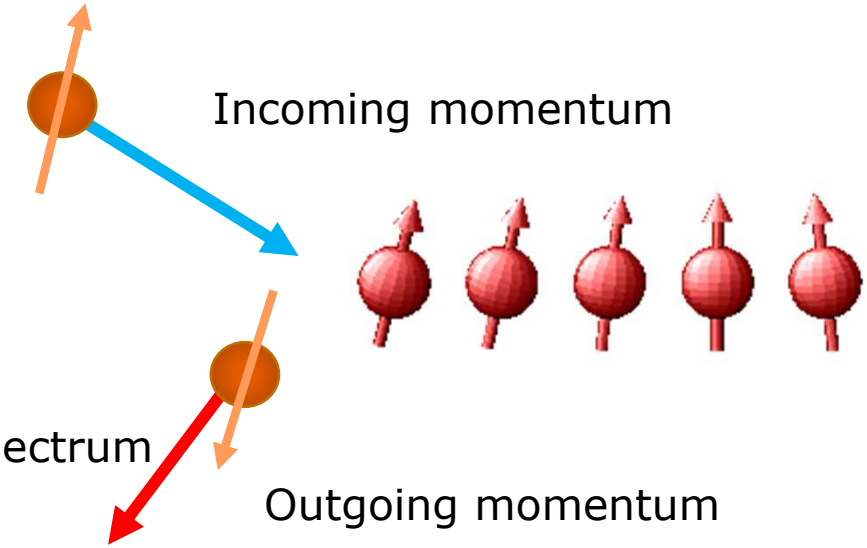
Orbital overlap mediates interaction between spins and magnetic order.



Pertubation of that order propagates like a particle. This excitation can be created by the neutron

$$\mathbf{k_i} - \mathbf{k_f} = \mathbf{Q}$$

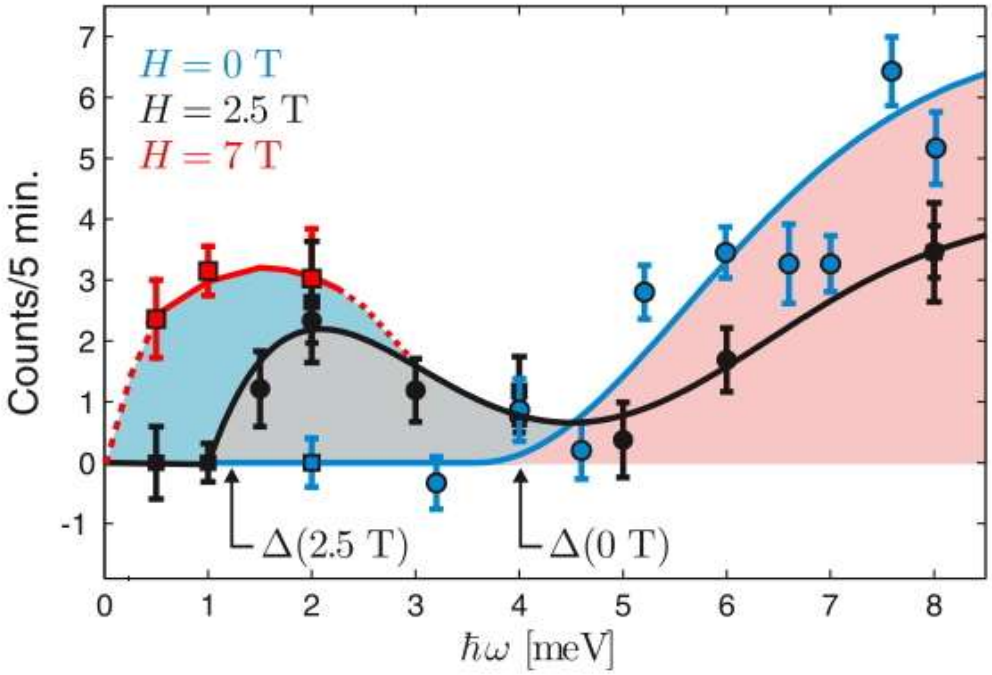
$$\frac{\hbar^2 k_i^2}{2m} - \frac{\hbar^2 k_f^2}{2m} = \Delta E$$



We can directly measure the excitation spectrum

And characterize the magnetic system

Magnetism in superconductors



J. Chang et al, Physical Review Letters **102** , 177006 (2009)

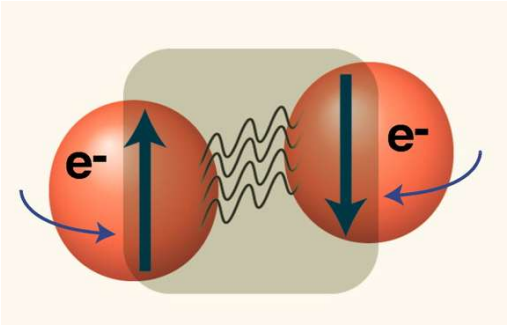
Applied magnetism:

Magnetic excitations, the electron-glue in the high-Tc superconductors?

This entire field is limited by lack of neutron flux

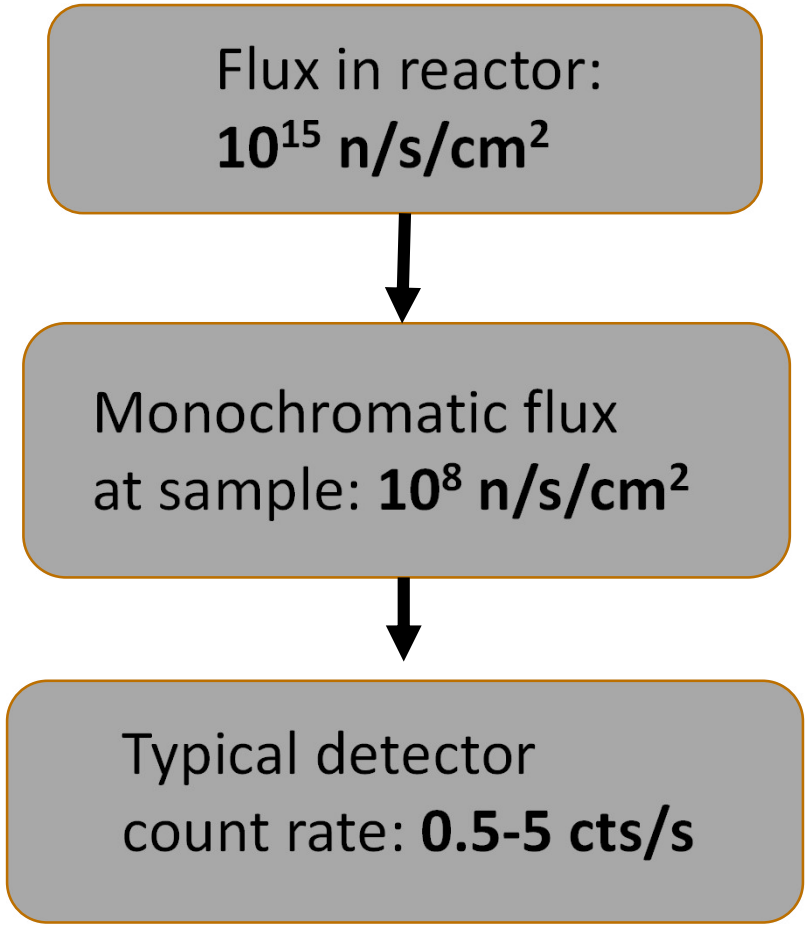
Gap

ΔE



State-of-the-art

Current state-of-the-art:



Triple-axis spectrometer

Mono Flux	10^7-10^8 n/s/cm^2
Spatial angle	0.015 steradians
Energy transfer	Single value

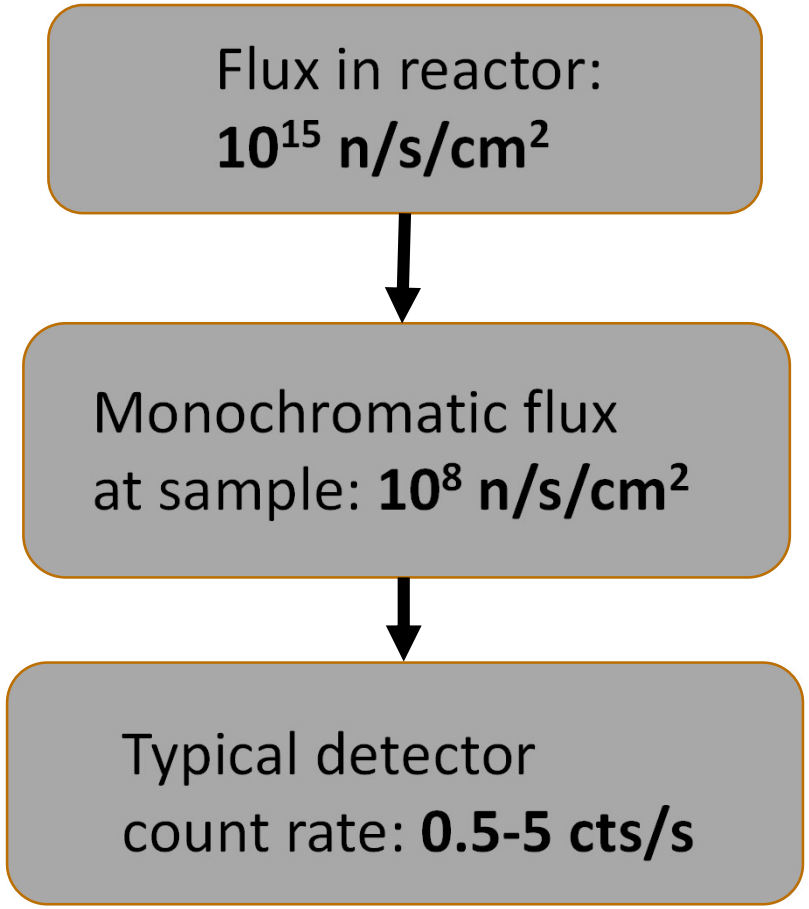
Time-of-flight spectrometer

Mono Flux	10^5-10^6 n/s/cm^2
Spatial angle	3 steradians
Energy transfer	Continuous

In both cases, getting the full picture takes about a week

State-of-the-art

Current state-of-the-art:



Triple-axis spectrometer

Mono Flux	10^7-10^8 n/s/cm^2
Spatial angle	0.015 steradians
Energy transfer	Single value

Time-of-flight spectrometer

Mono Flux	10^5-10^6 n/s/cm^2
Spatial angle	3 steradians
Energy transfer	Continuous

Bifrost

Polychromatic Flux	10^8-10^{10} n/s/cm^2
Spatial angle	0.5 steradians
Energy transfer	Continuous

State-of-the-art

Current state-of-the-art:

Flux in reactor:
10^{15} n/s/cm^2

↓

Monochromatic flux
at sample: **10^{8} n/s/cm^2**

↓

Typical detector
count rate: **0.5-5 cts/**

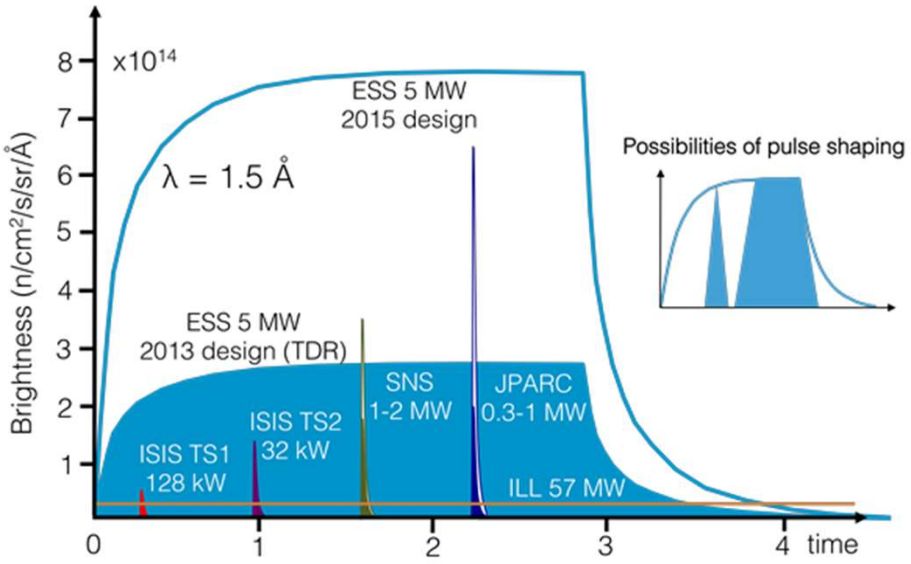
Triple-axis spectrometer

Mono Flux	10^{7}-10^{8} n/s/cm^2
Spatial angle	0.015 steradians
Energy transfer	Single value

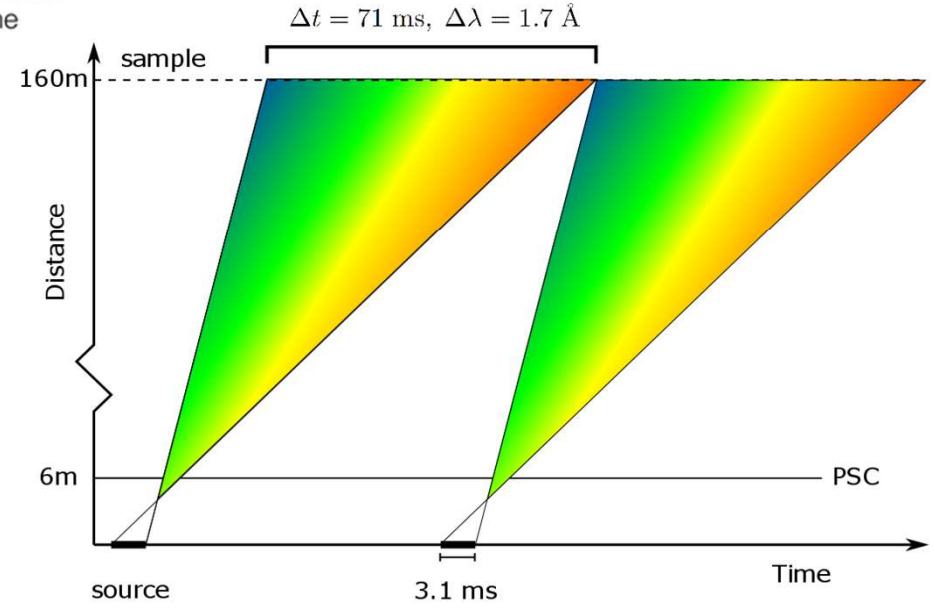
Time-of-flight spectrometer

Mono Flux	10^{5}-10^{6} n/s/cm^2
Spatial angle	3 steradians

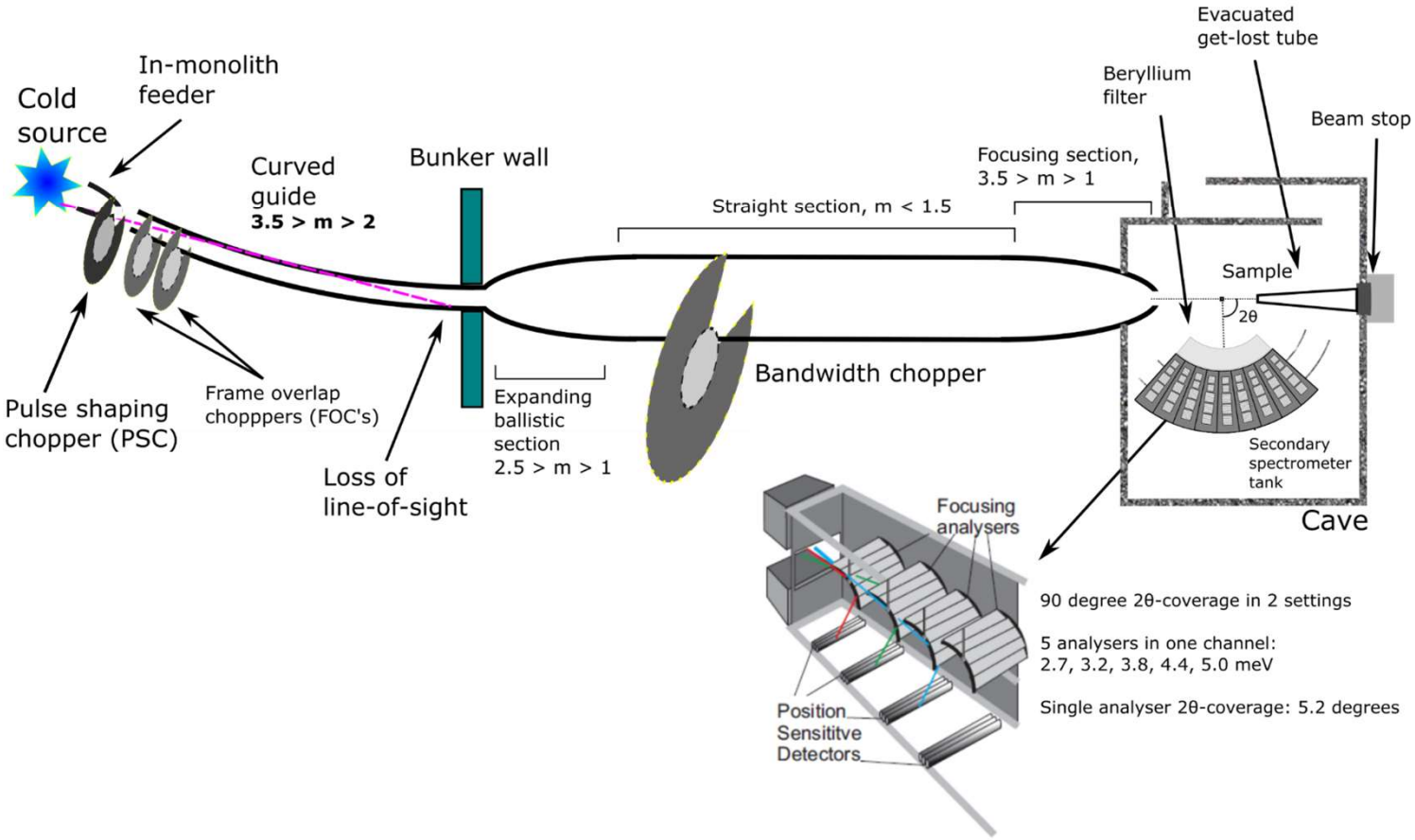
The power of Bifrost



Combine a long instrument with long-pulsed source.
Flight time: 100 ms



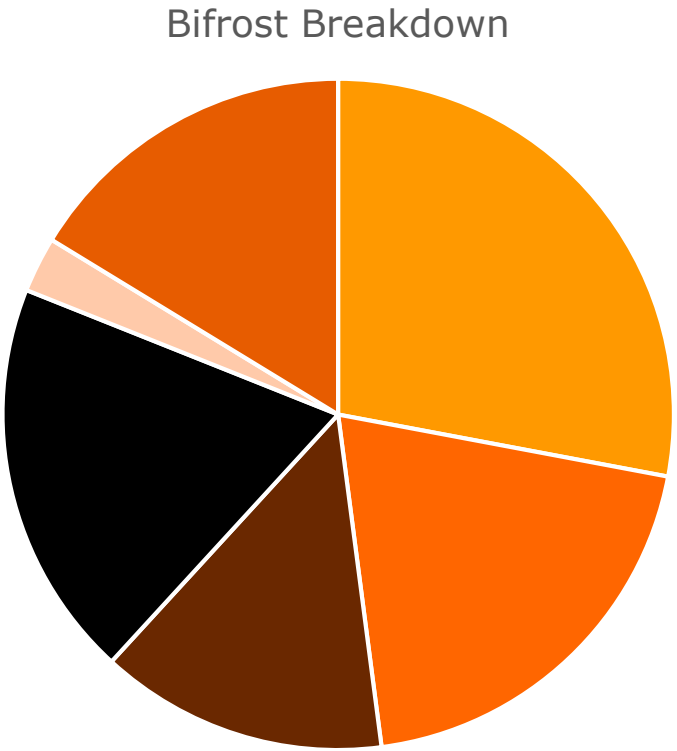
Bifrost: Outline



- Efficient use of pyrolytic graphite and a long primary flight path is a powerful cocktail (at least in one scattering plane)
- Scope is focused on extreme sample environment but there is plenty to do without a 20 T magnet

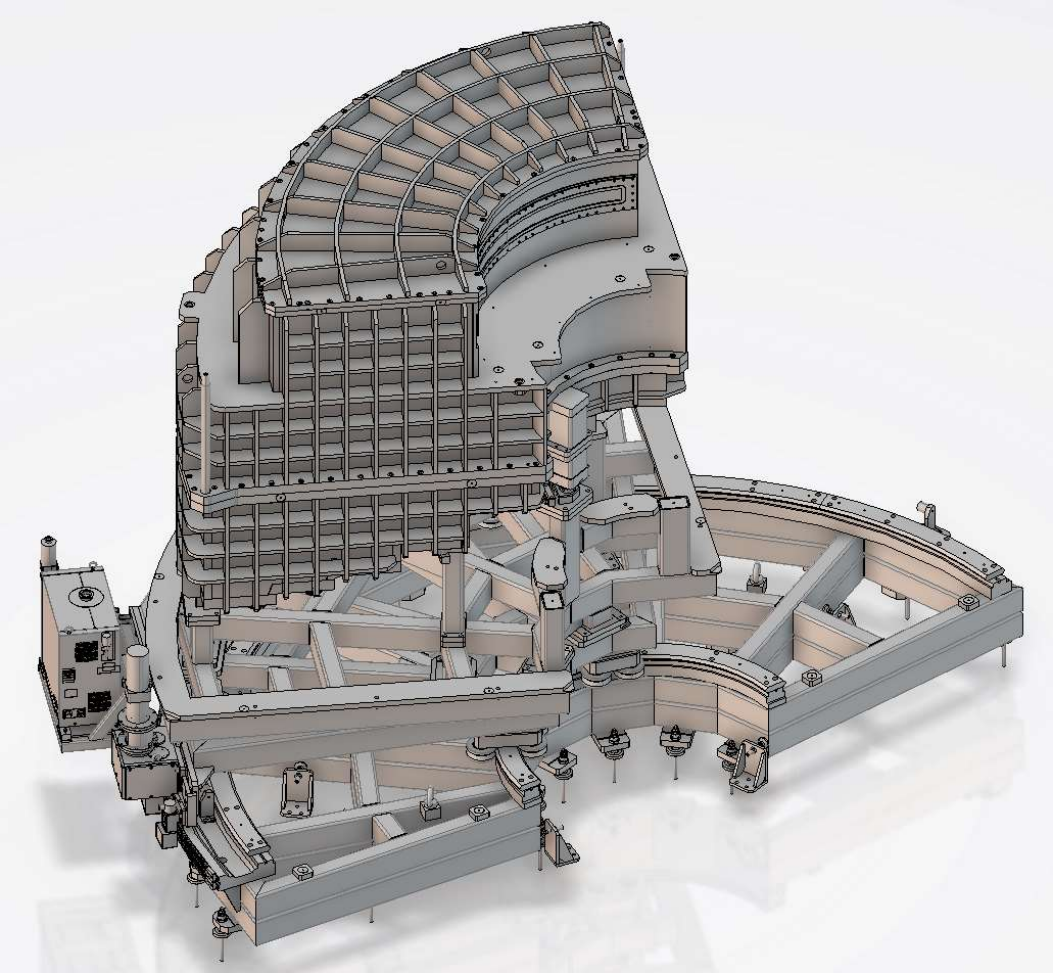
Bifrost – current situation and hardware budget

- Project started in earnest in 2016
- Project to finish by 2022
- Hardware budget: 12 M€
- Detailed design about to finish
- Two major contracts (> 500 k€) signed, 4-5 to go
- About to start installing!



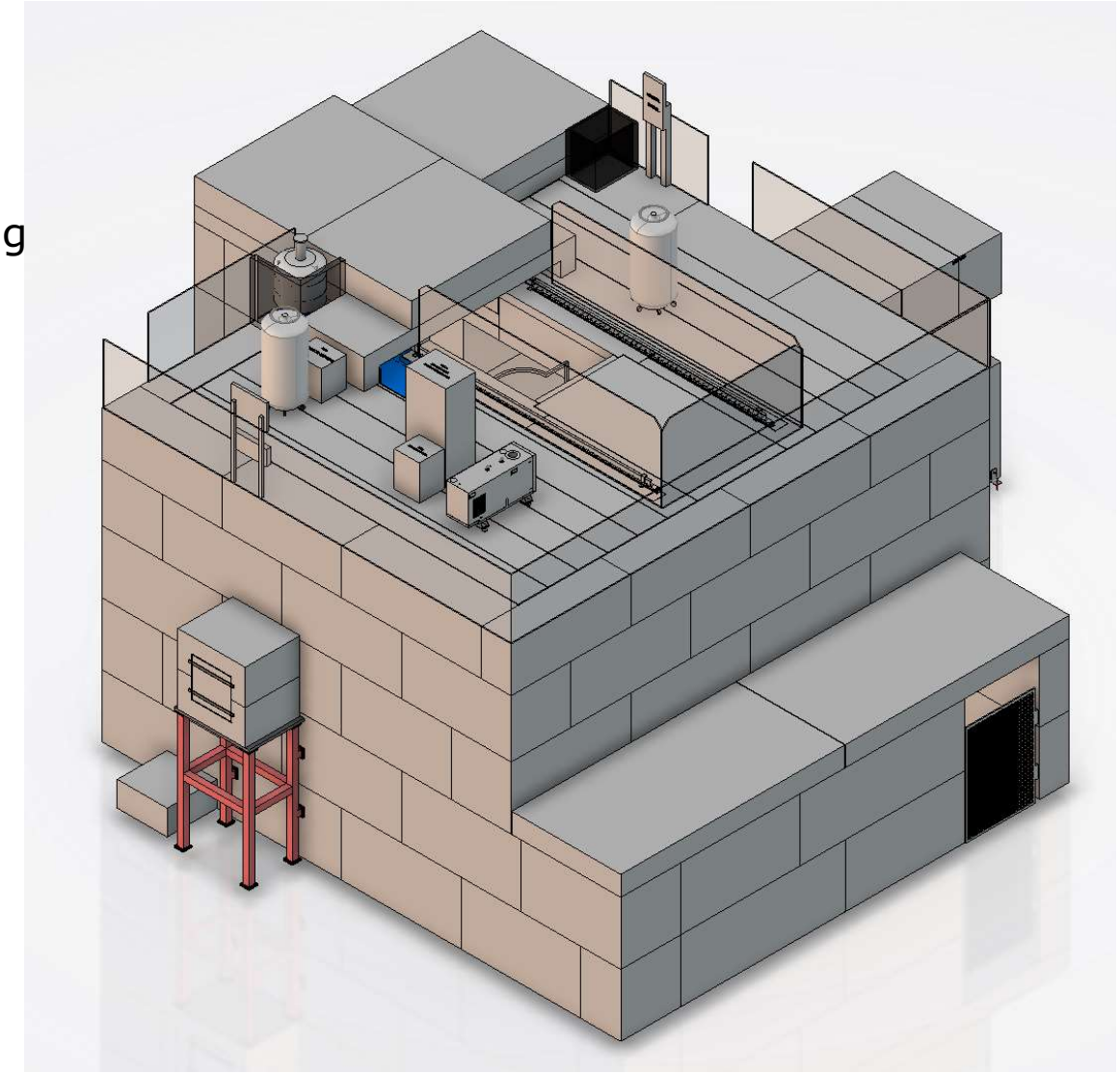
Spectrometer tank (DTU)

- Design-and-build tender
- Tank and motion system
- Won by spanish company
- As always: Many non-standard requirements (Deformations, magnetic components, etc)



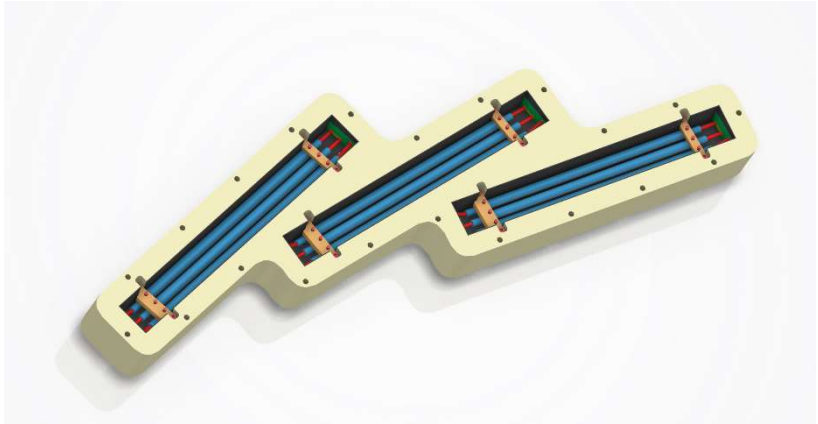
Cave (IFE, Norway)

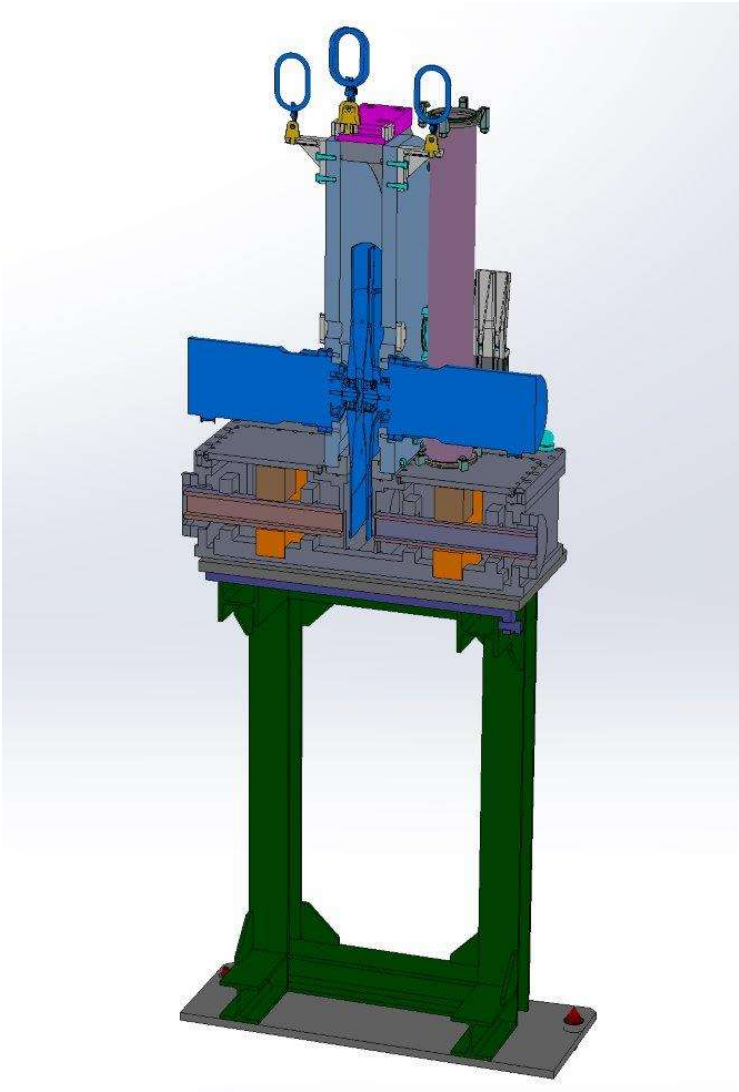
- Complex design,
- Requirements for load bearing
- Stainless steel rebar
- Hatch not included
- Won by czech company



Other procurements

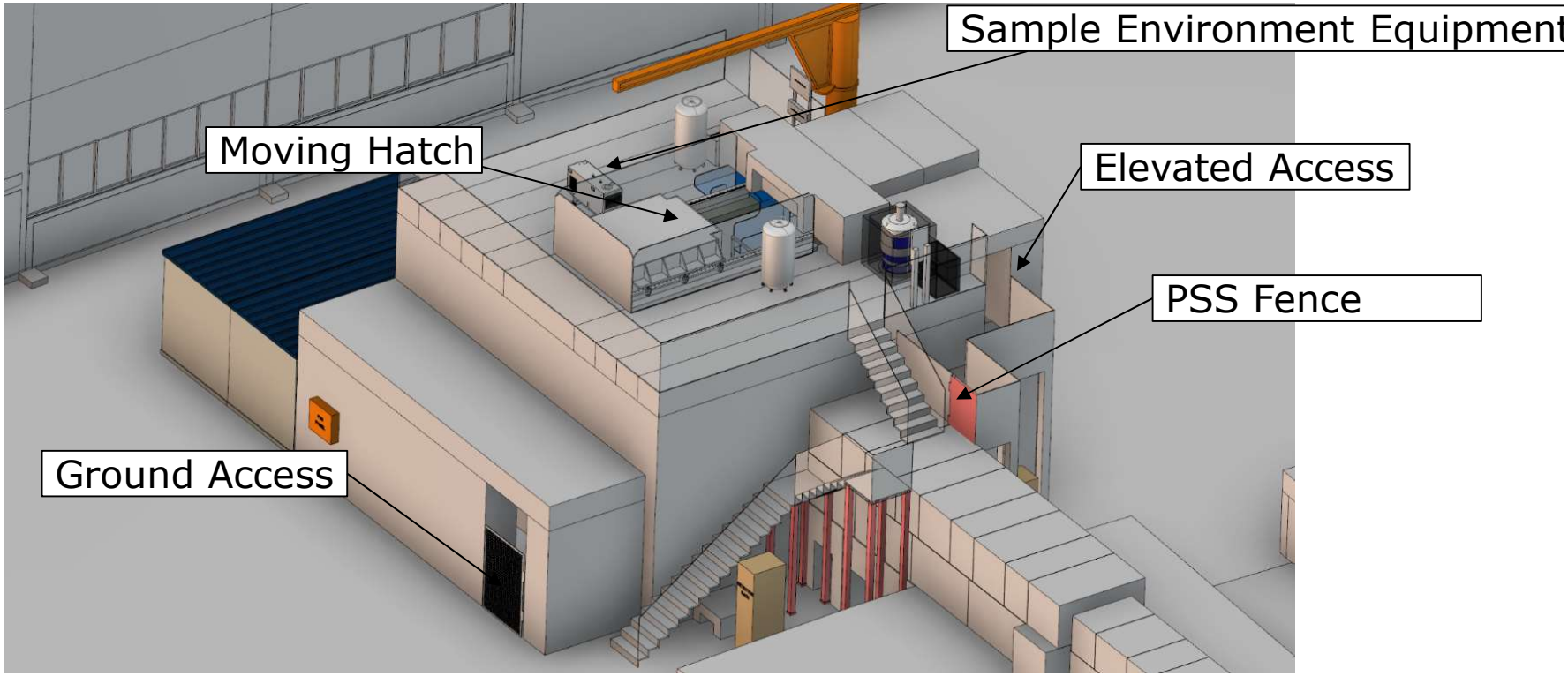
- Choppers
- He-3 detectors
- Detector electronics
- Neutron guide (incl vacuum)
- Possibly beryllium filter (incl oscillation)
- **All within the next few months!**





DTU's main contributions

DTU handles infrastructure: spectrometer tank, mounts, motors hutches, sample stack, etc



The key to Bifrost success: keeping the background low

Careful block design - modular

Machining of Cadmium, B4C, beryllium problematic

Can we 3D print components containing 20 % boron?

Otherwise: Coat non-absorbing components with Gd.

We already see the first start-ups printing neutron-absorbers

Sample handling

Fast experiments,
many sample changes.

Parametric studies requires sample changes in cryostat

Sample alignment in Dy-booster

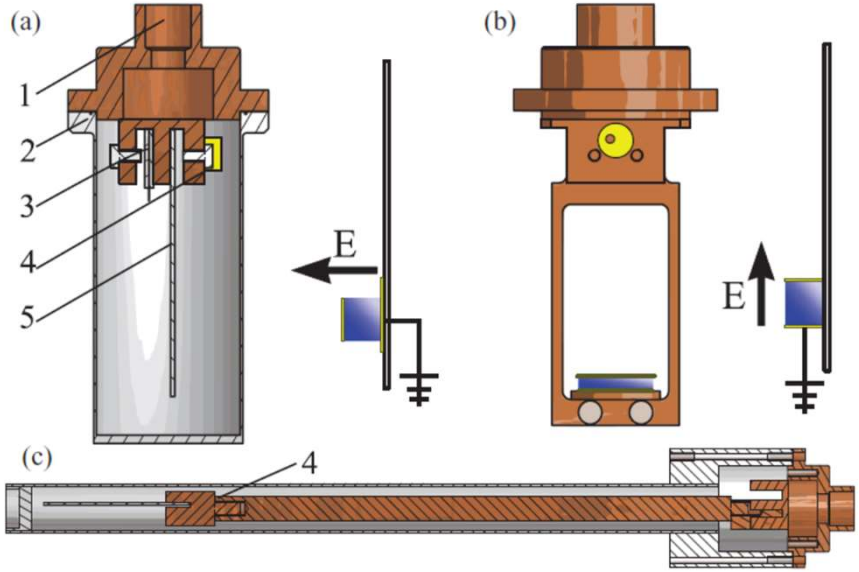
3D printed custom holders

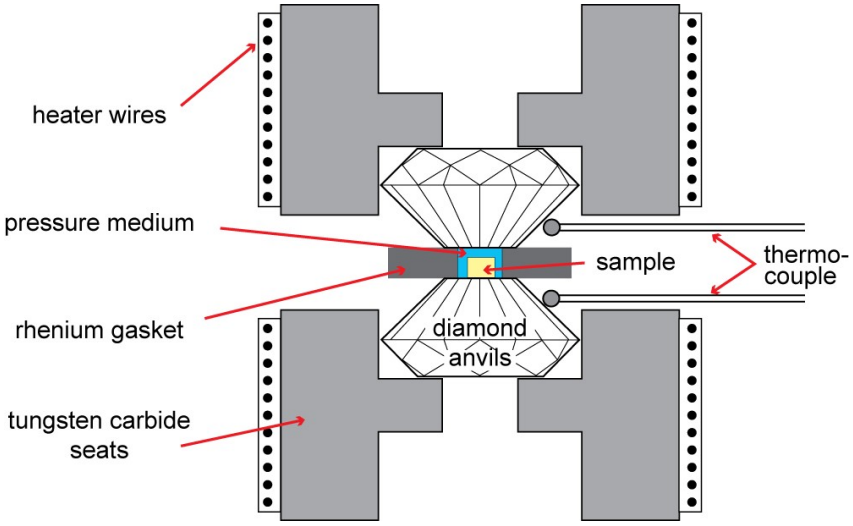
Electrical fields

Pressure and electrical fields

Once we go into operation, the ESS will open up the arena of using small samples – potential game changer in some fields (protein crystallography)

Some sample environments are inherently for small samples.





Thank you for your attention

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