

T-REX Instrument Project



75%

Christian Franz, Lead Scientist
Nicolò Violini, Lead Scientist

Marcel Serwe, Lead Engineer
Mario Koenen, Project Engineer
Teddy Kozielski, Project Engineer

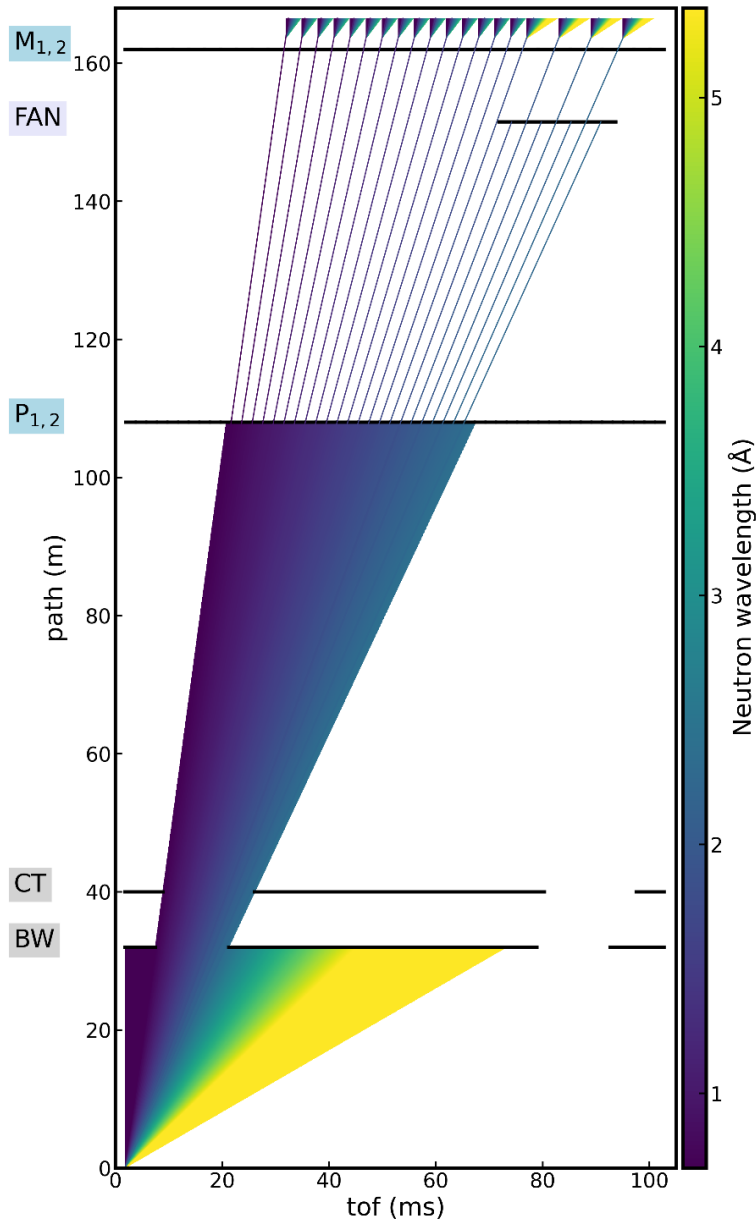
ESS: Mohamed Aouane (Jan. 2025)

25%

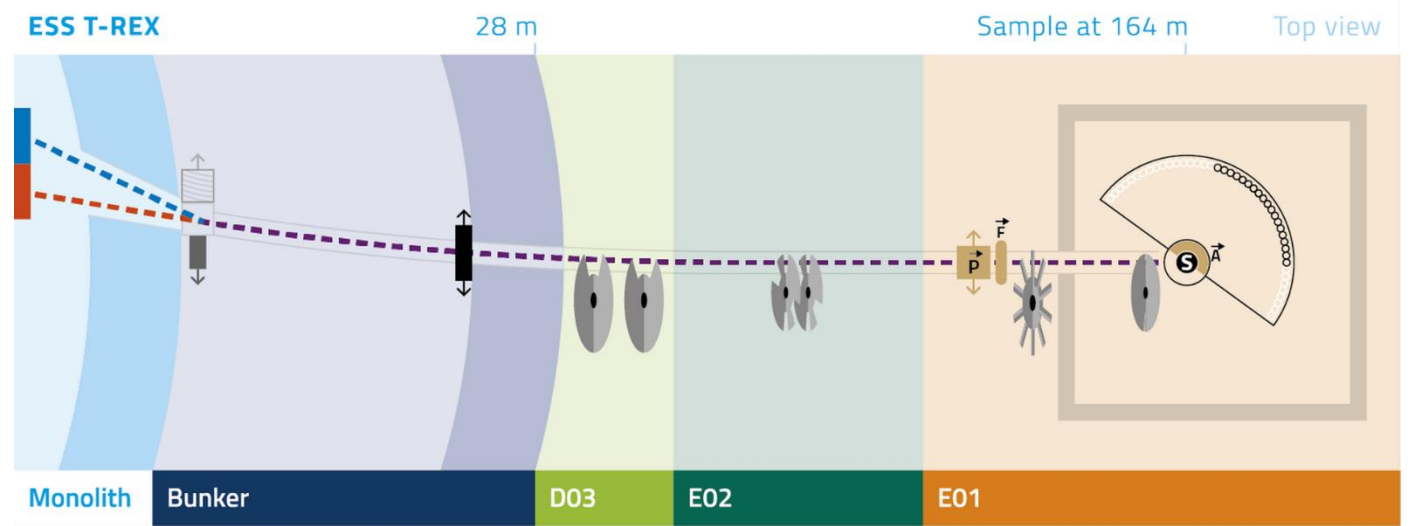
Andrea Orecchini,
CNR Work-package scientific
responsible

Enrico Zanieri, Project Engineer
Francesco Sacchetti, Senior advisor
Alessio Lalonì, Project Engineer

T-REX: bi-spectral polarized time-of-flight spectrometer



2 meV < E_i < 160 meV
 @ 2MW ESS:
 (3x 4-SEASONS, 6xIN5) x
 n.of useful RRM spectra



Bi-spectral:

Neutron guide optimised for thermal
 Cold extraction does not compromise
 thermal

Repetition rate multiplication (RRM):

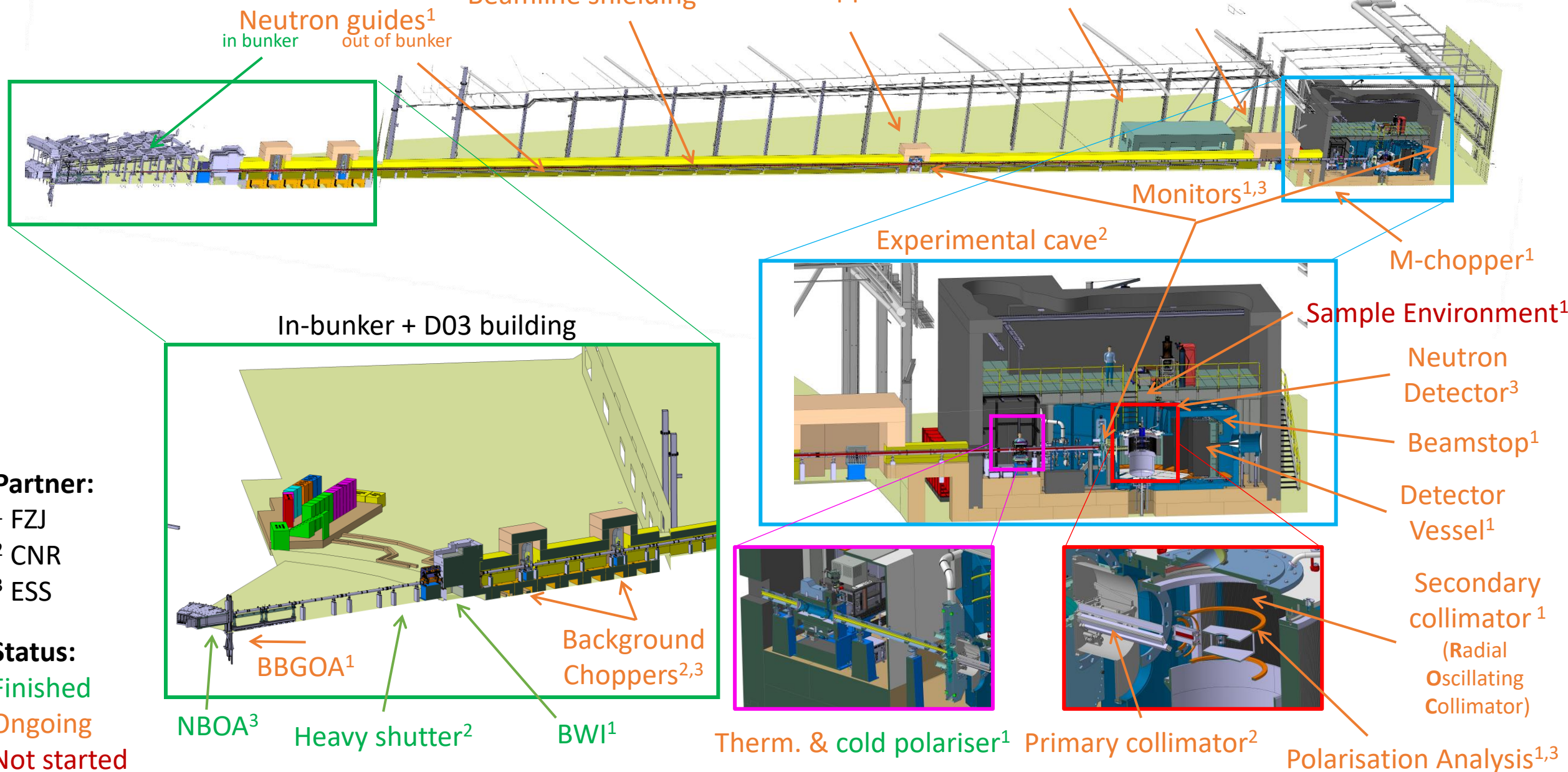
Flexible chopper configuration
 Resolution \rightarrow flux
 < 24 RRM pulses

XZY Polarisation Analysis:

Thermal and cold polariser
 Full polarisation analysis

T-REX layout*

* after work package exchange



Partner:

- ¹ FZJ
- ² CNR
- ³ ESS

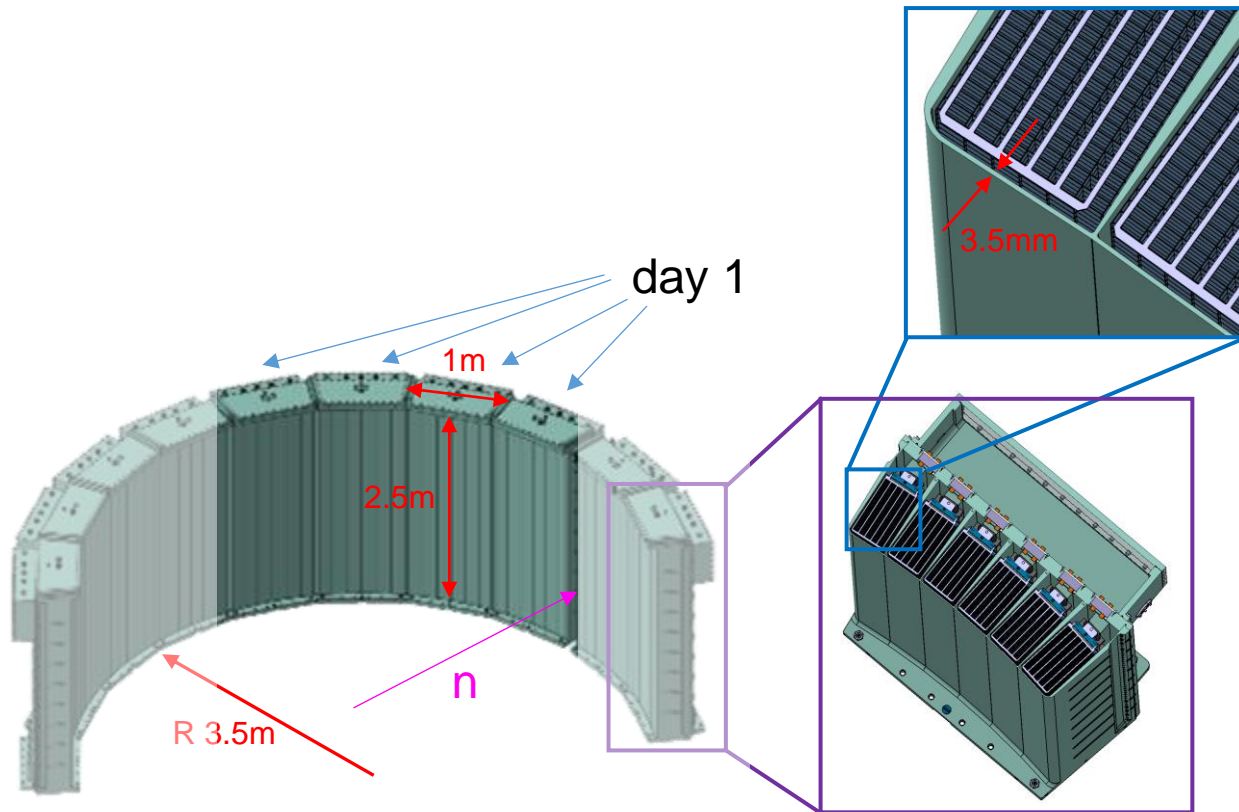
Status:

- Finished
- Ongoing
- Not started

Upgrade stages to full scope

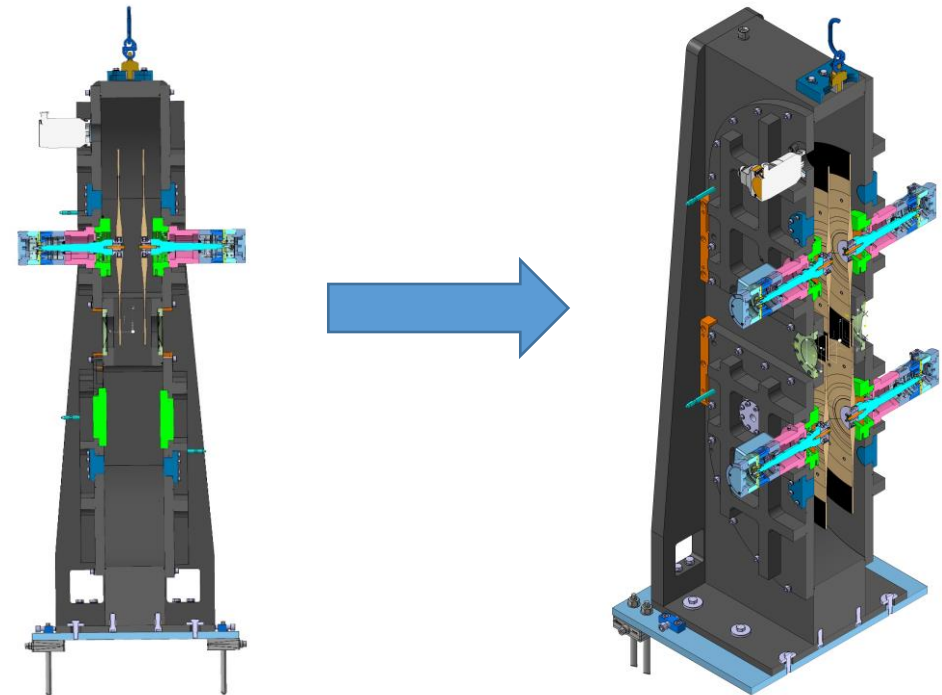
Multi-Grid detector

- upgrade from 40% (4 boxes) to 100% (10 boxes)
→ in total 2.2sr
- estimate from TG2 (2017):
2.3 M€

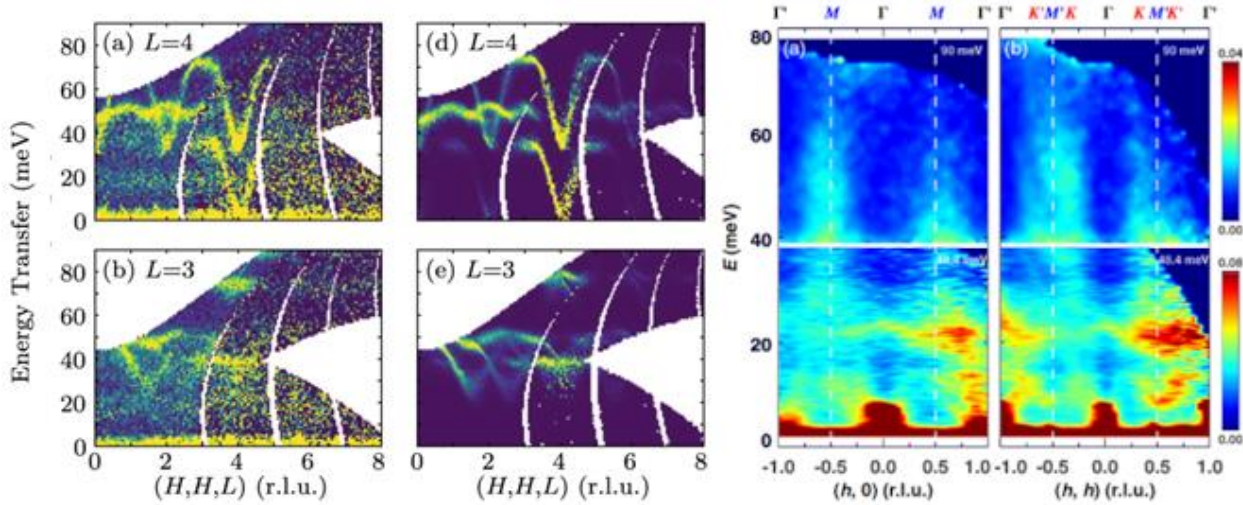
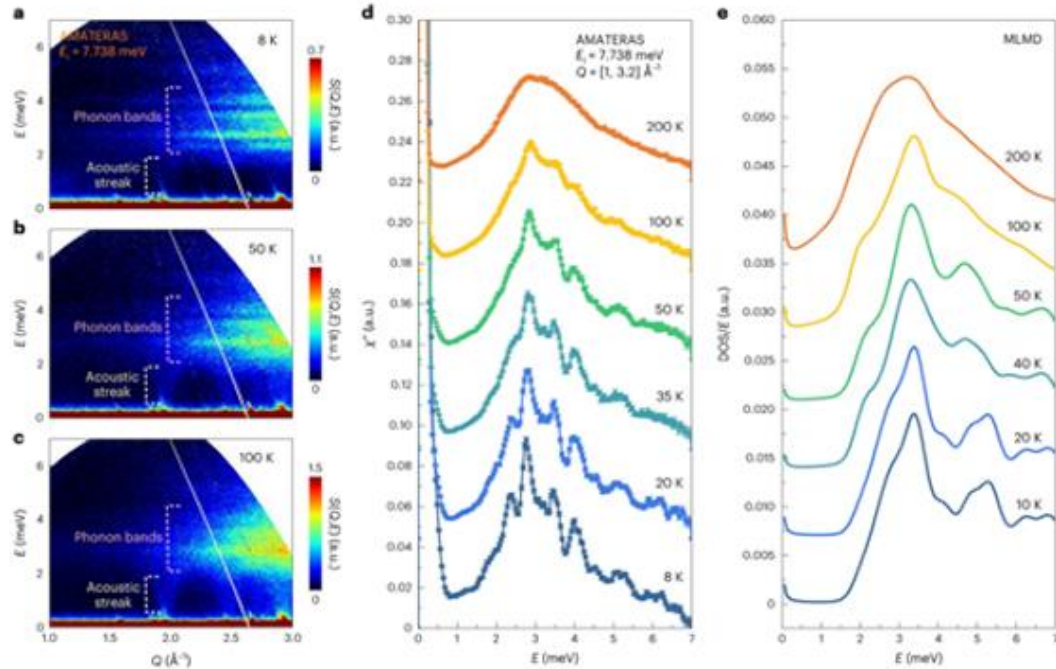


P-Chopper

- upgrade from 2 to 4 discs
- improved background
- better control over pulse shape
- flexible resolution setting
- price tag: $\sim 0.6M€$



Scientific impact



- **Thermoelectrics**

A good understanding of thermal conductivity requires knowledge about the phonon density of states

- **Magnons for applications in devices**

Understanding of magnon modes throughout the entire Brillouin zone is a prerequisite for applications, here in prototypical material YIG

- **Itinerant ferromagnetism**

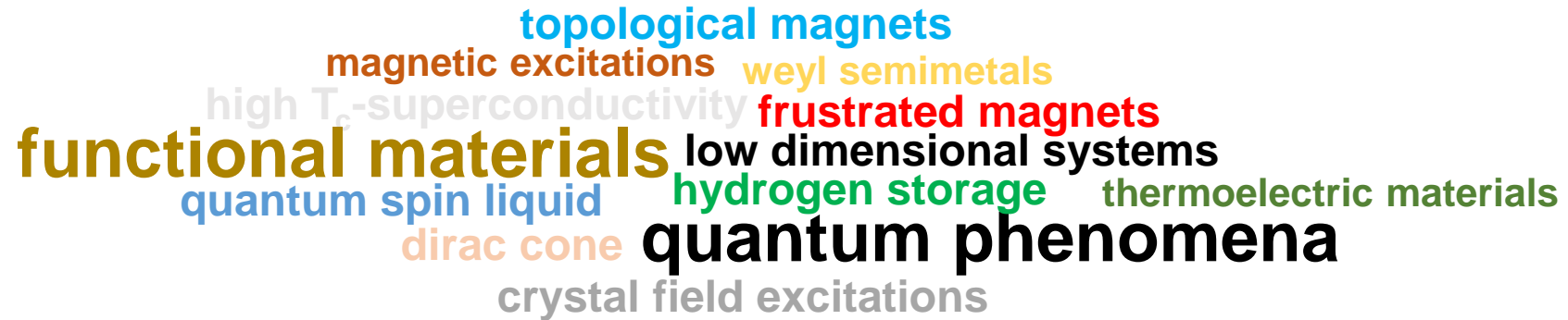
Spin-carrying electrons act as (almost) single particles, requiring large momentum transfers

Bao et al., *Phys. Rev. X* 12, 011022 (2022)

Ren et al., *Nature Materials* 22, (2023)

Princep et al., *npj Quantum Materials* 2, 63 (2017)

Science case

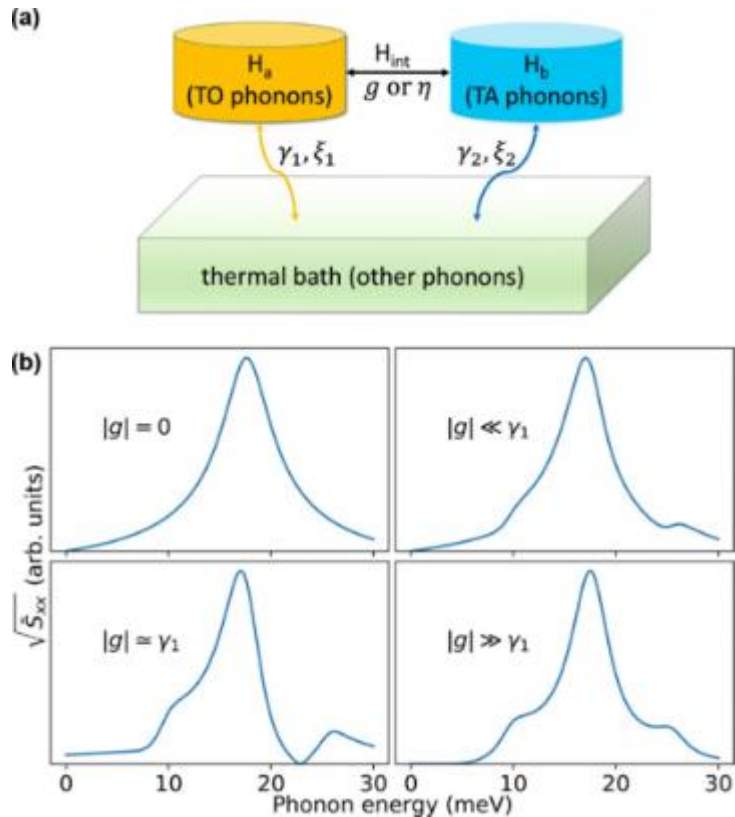


Unique features of the instrument:

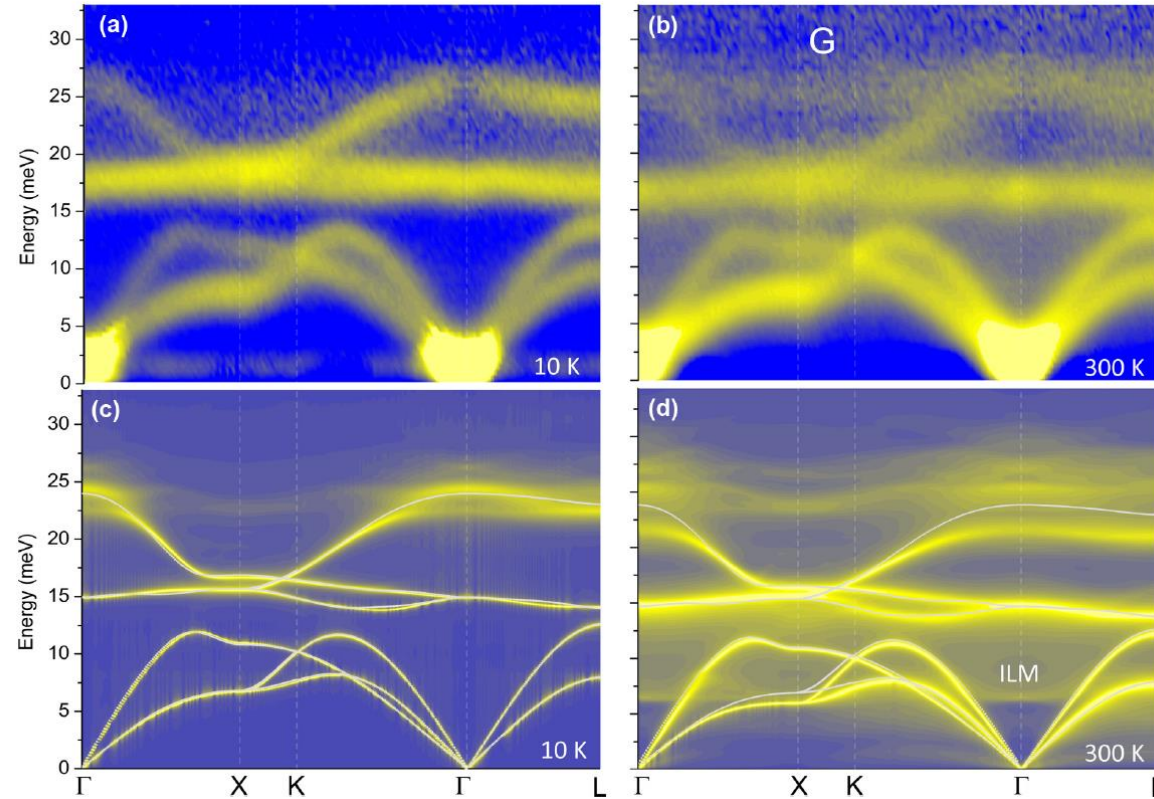
- **Heavy use of RRM** (<24 subpulses) over broad wavelength band of 1.7Å
Measure „everything everywhere all at once“ → Need support from DMSC
- **Bi-spectral extraction**
Do the work of different instruments in one
- **Full x-y-z polarisation analysis** integral part of the instrument
Separation of magnetic/nuclear scattering and coherent/incoherent

Thermoelectric materials

Anharmonic phonons in NaBr



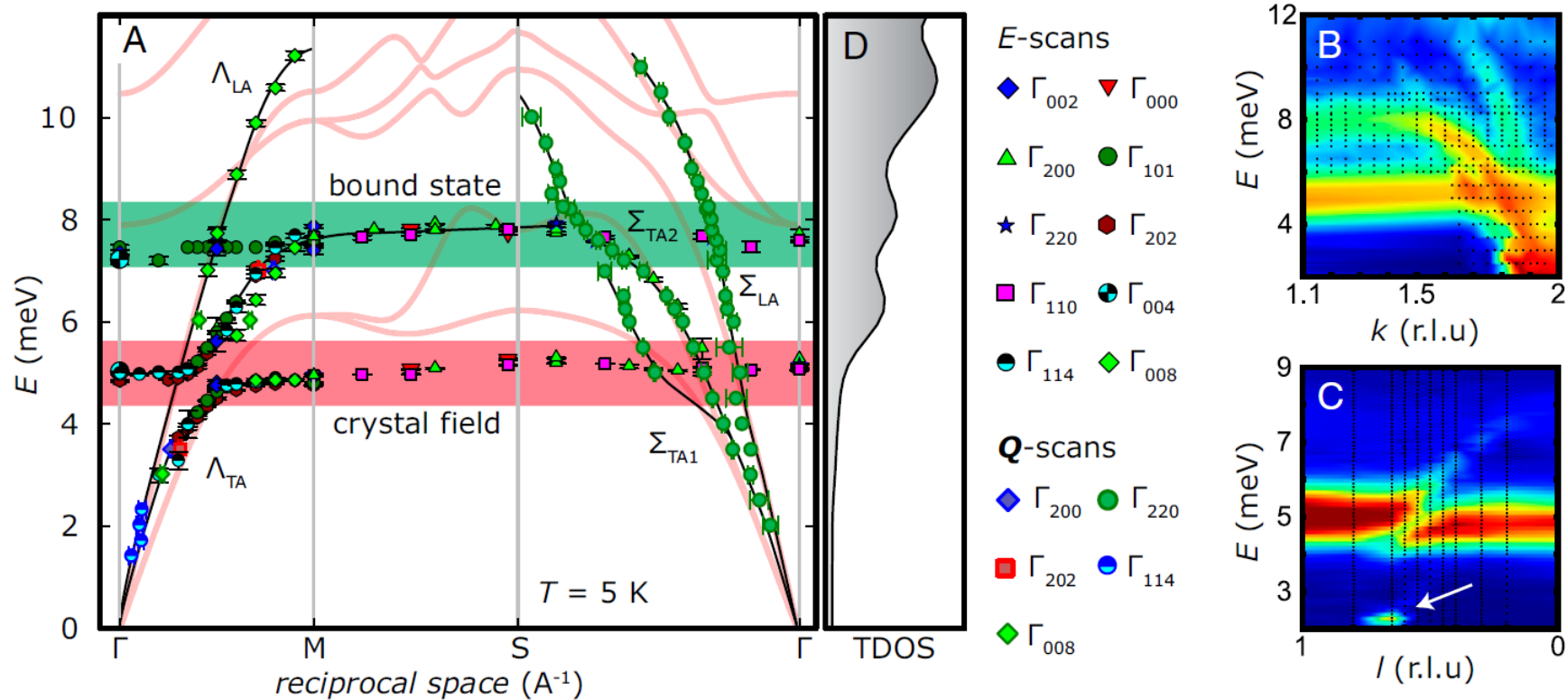
4D – data from ARCS
 $E_i = 50\text{meV}$



could benefit from multi – E_i mode!

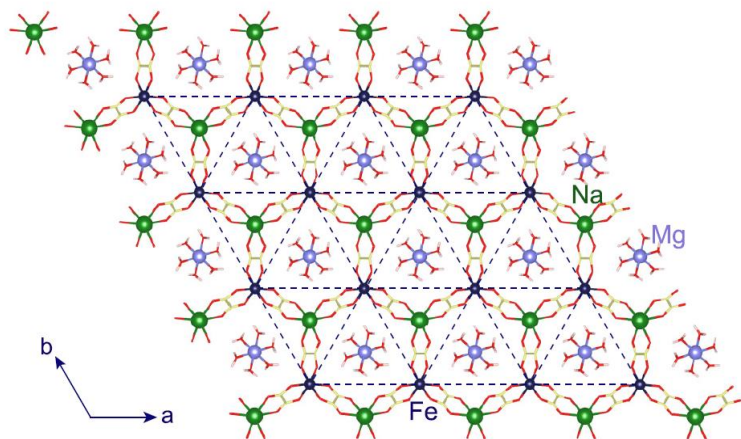
Hybrid modes

Magnetoelastic coupling in CeAuAl_3



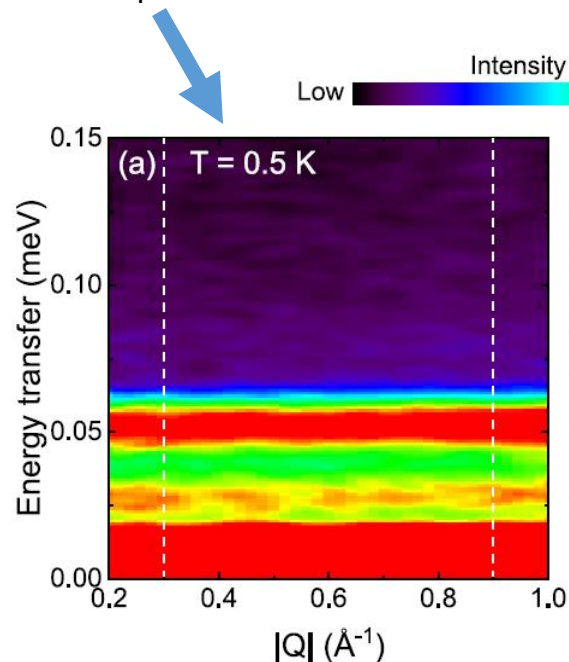
single crystal: 4D mapping, collect all information at once
polarisation analysis: dis-entangle crystal field (magnetic) and phonon (nuclear)

Metal Organic Frameworks (MOFs)



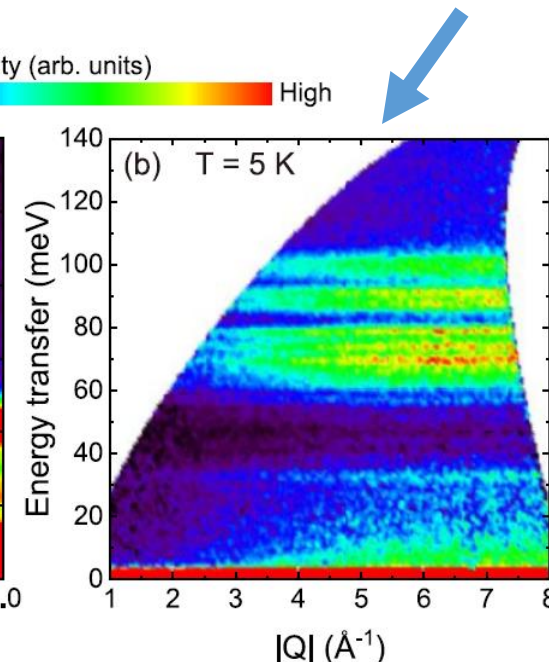
porous materials composed of metal ions or clusters connected by organic ligands

CNCS, $E_i = 1.5\text{meV}$



Low energy: magnetic transitions zero-field splitting (ZFS) of $S = 5/2$ ground state multiplets of Fe^{3+} ion.

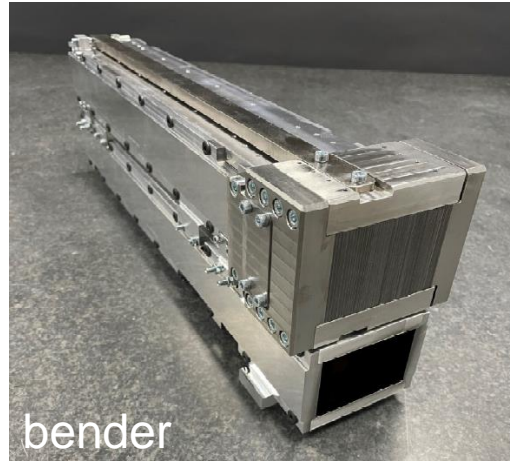
Sequoia, $E_i = 160\text{meV}$



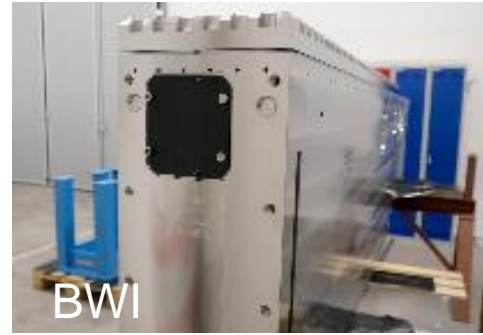
High energy: translational and librational vibrations of structural water molecules

bi-spectral extraction: do work of several instruments at once!

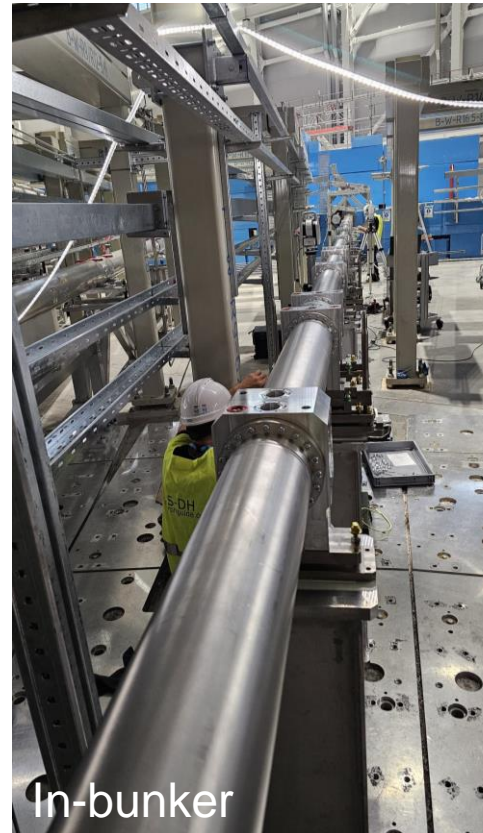
Neutron guide system & Heavy shutter



bender



BWI



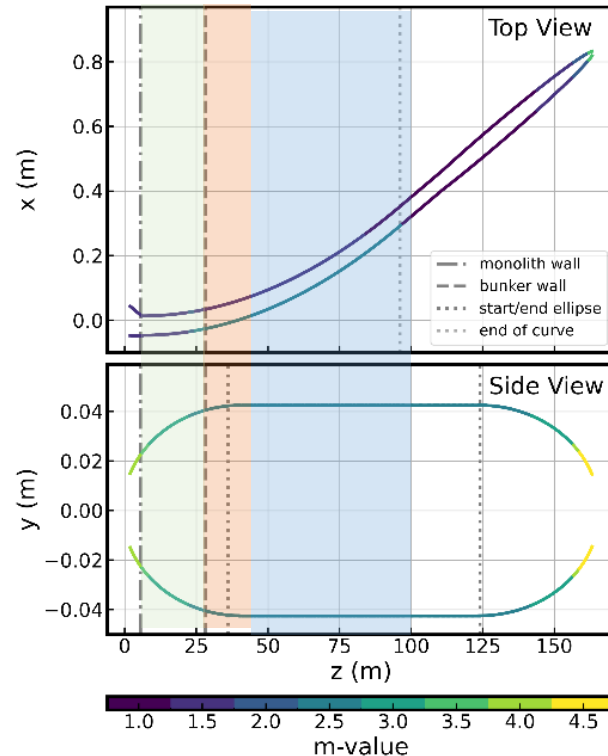
In-bunker

Heavy shutter:

- Installation complete



Heavy shutter



NBOA

- at ESS, installed ✓

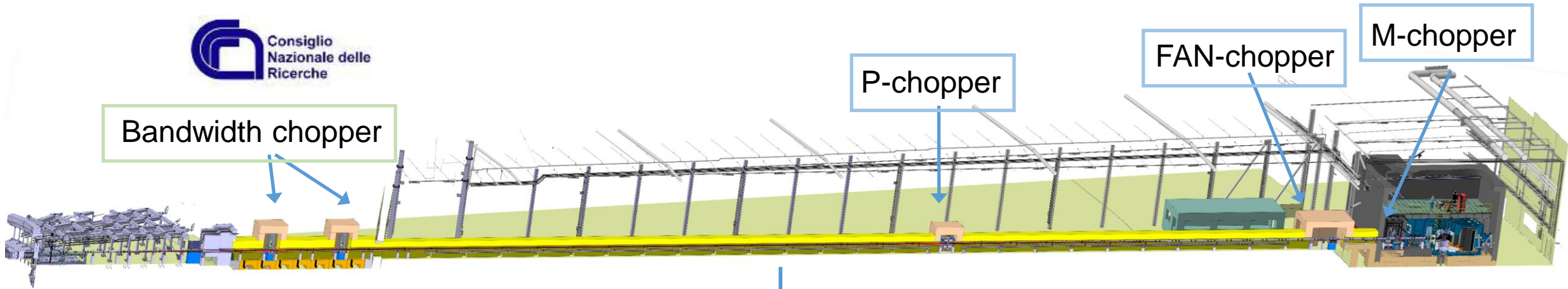
in-bunker & BWI

- Installed ✓

out of bunker guides & BBGOA

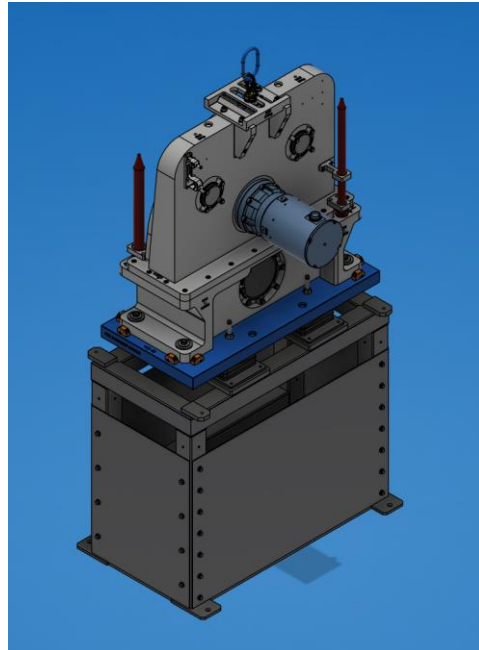
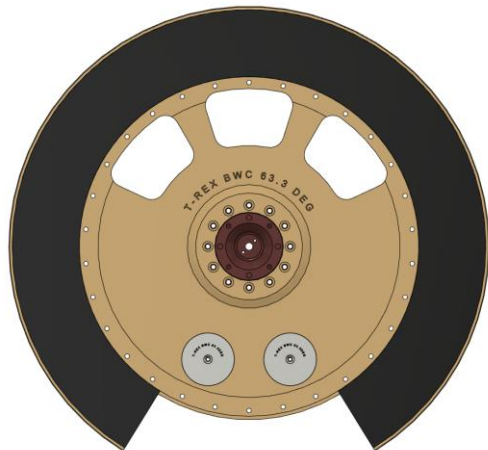
- Tranche 1 (40-96m) in manufacturing
- Tranche 2 (28-40) close to subTG3
- Bender waiting for neutrons to align

Neutron choppers



Band Width & Cross Talk Chopper (14Hz)

- Hybrid solution: hardware external company, electronics common project
- IDR in November '24



- contract awarded to ZEA-1
- subTG3 passed
- Installation mid 2026

ZEA-1

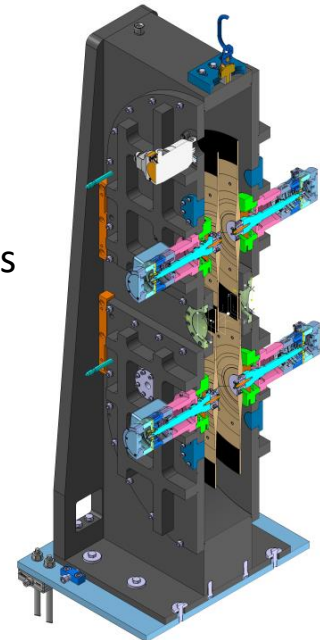
P-Chopper

- 252Hz, High-res and Low-res openings
- Scope: Two discs, upgradeable to 4 discs
- design is advancing, decided to use ZEA spindles
- Airbus discs

M-chopper

- 336Hz, High-res and low res openings
- Airbus discs

early procurement of chopper discs!

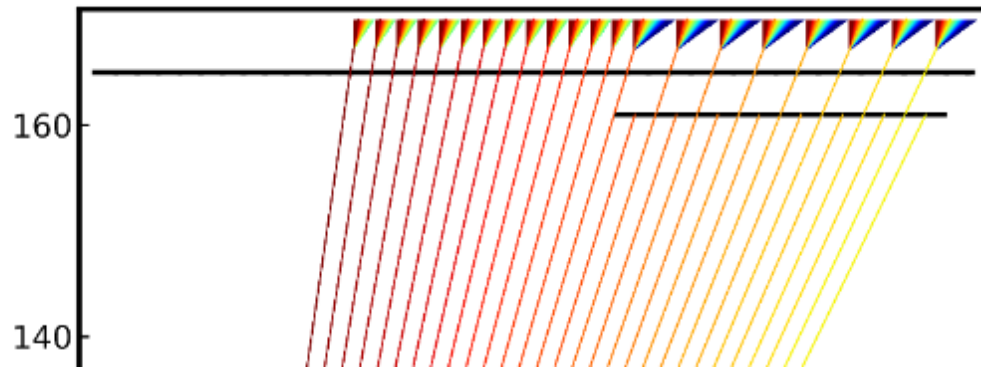
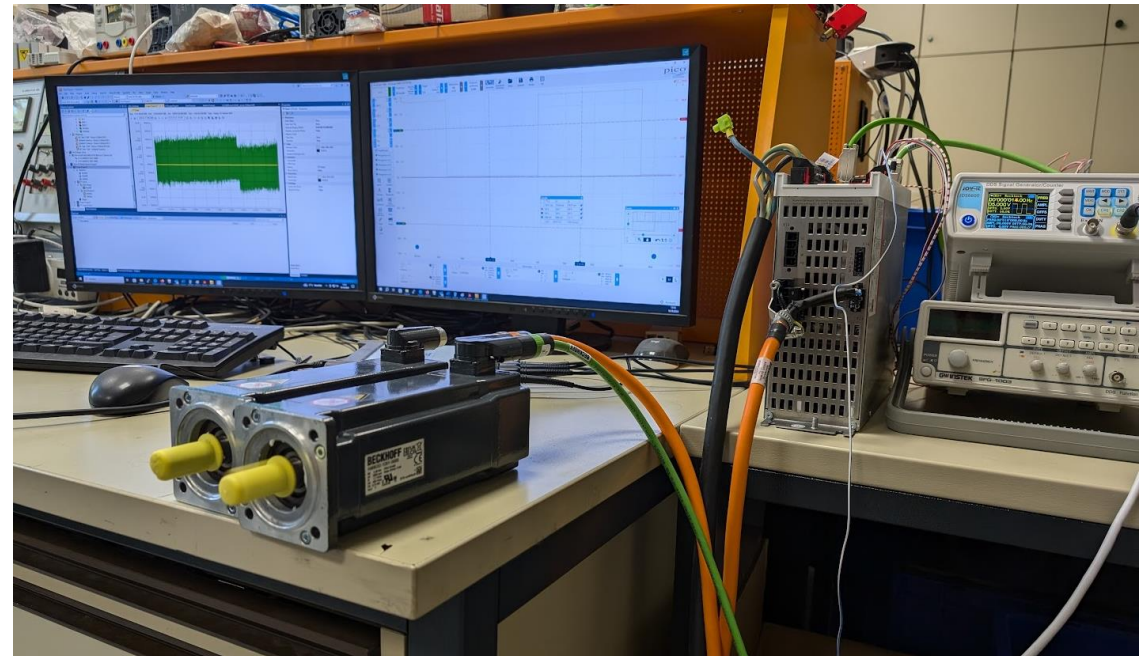
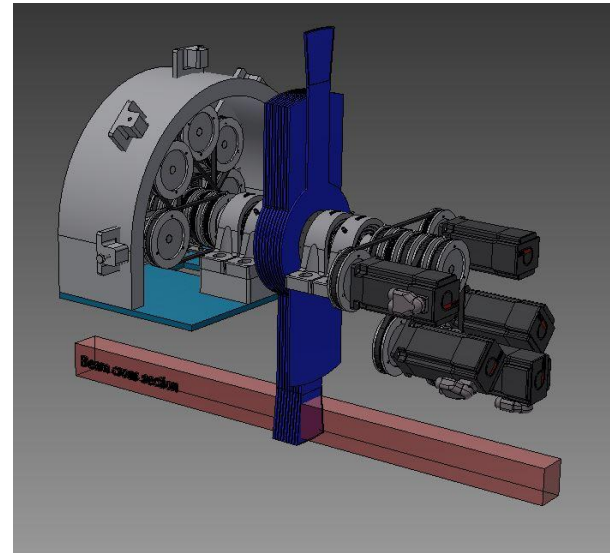


FAN chopper

- Test at ISIS – concept study based on master thesis
- First of its kind component – high engineering effort (but limited budget)
- Considered alternative designs
- Used a rating matrix to find the best solution
- Alternative design stays as a fallback option in case of unexpected difficulties

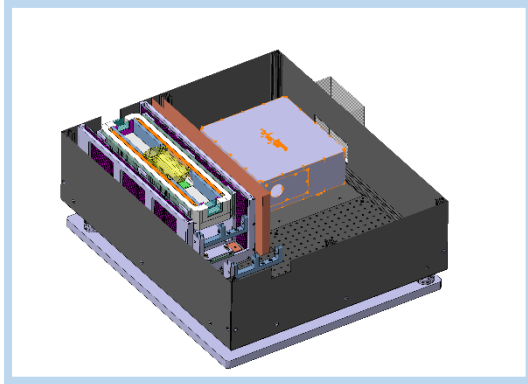
- Kick off meeting with ESS chopper group
- SubTG3.4 as soon as possible to create time contingency for extensive testing

- Competing with other projects for resources



Polarization equipment

1. Thermal polarizer



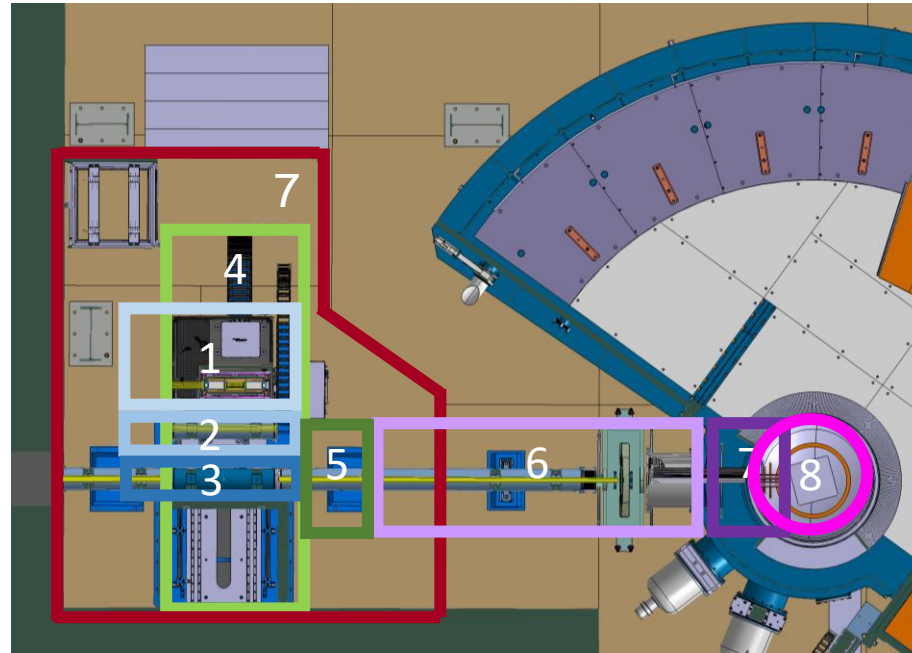
2. Cold polarizer



3. Neutron guide

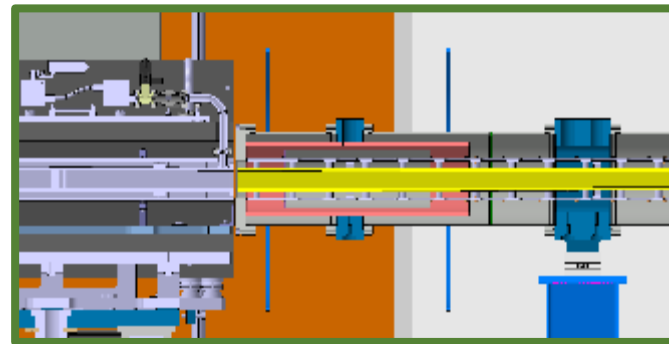
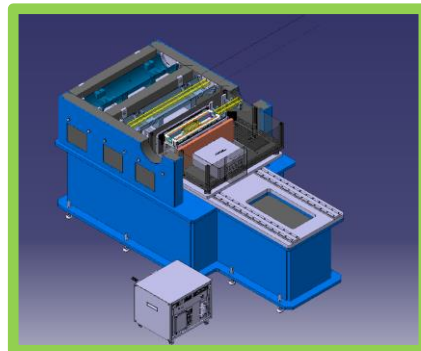


7. Laser lab

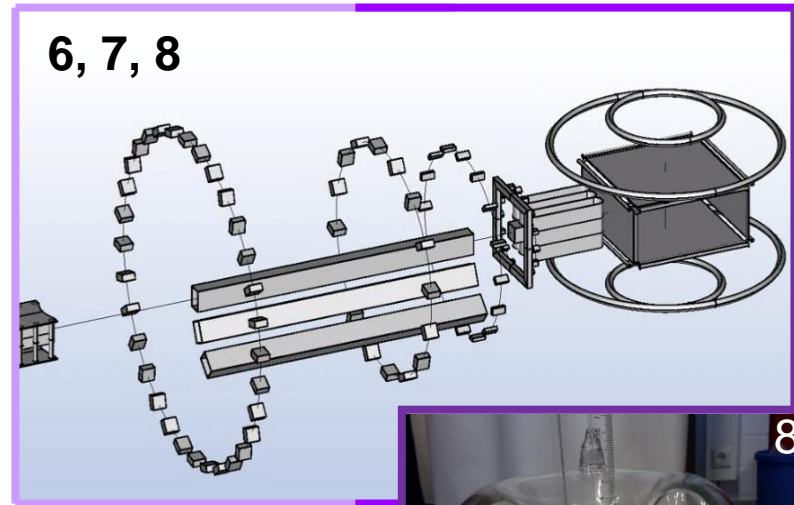


4 Guide exchange unit

5. Spin Flipper



- 6. Guide field (spin holding)
- 7. Adiabatic field (spin rotation)
- 8 .PASTIS setup

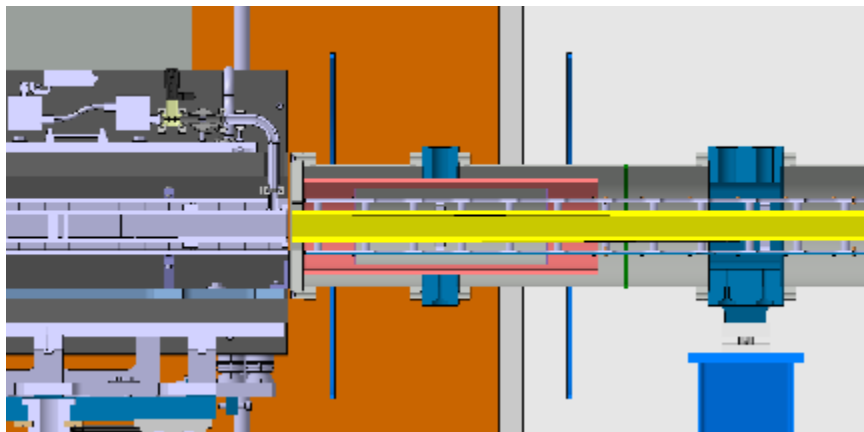


Polarization equipment

- Cold neutrons polarizer finished

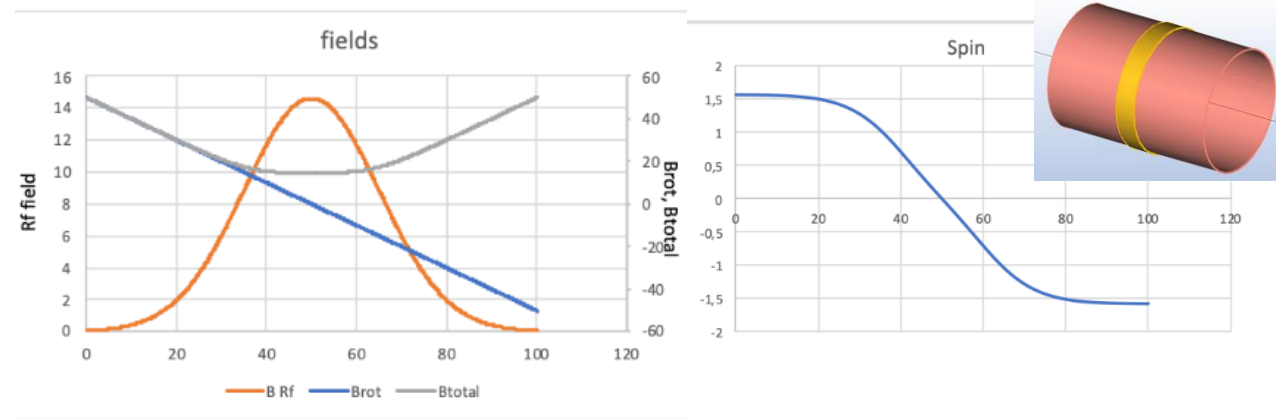
IDR readiness:

- Thermal neutrons polarizer design: ready
- Guide exchange unit design: ready
- Guide field design: only minor updates needed
- Race-track coils: ready
- PASTIS design: see next slide
- Spin flipper: currently in design (Earl Babcock & Helmut Soltner)
- Documentation and CE: not ready!



Option 1: Adiabatic fast passage flipper

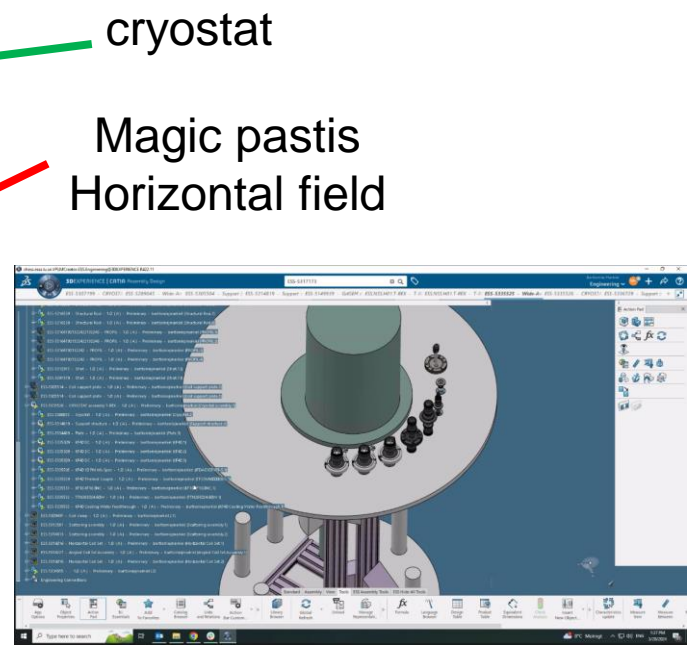
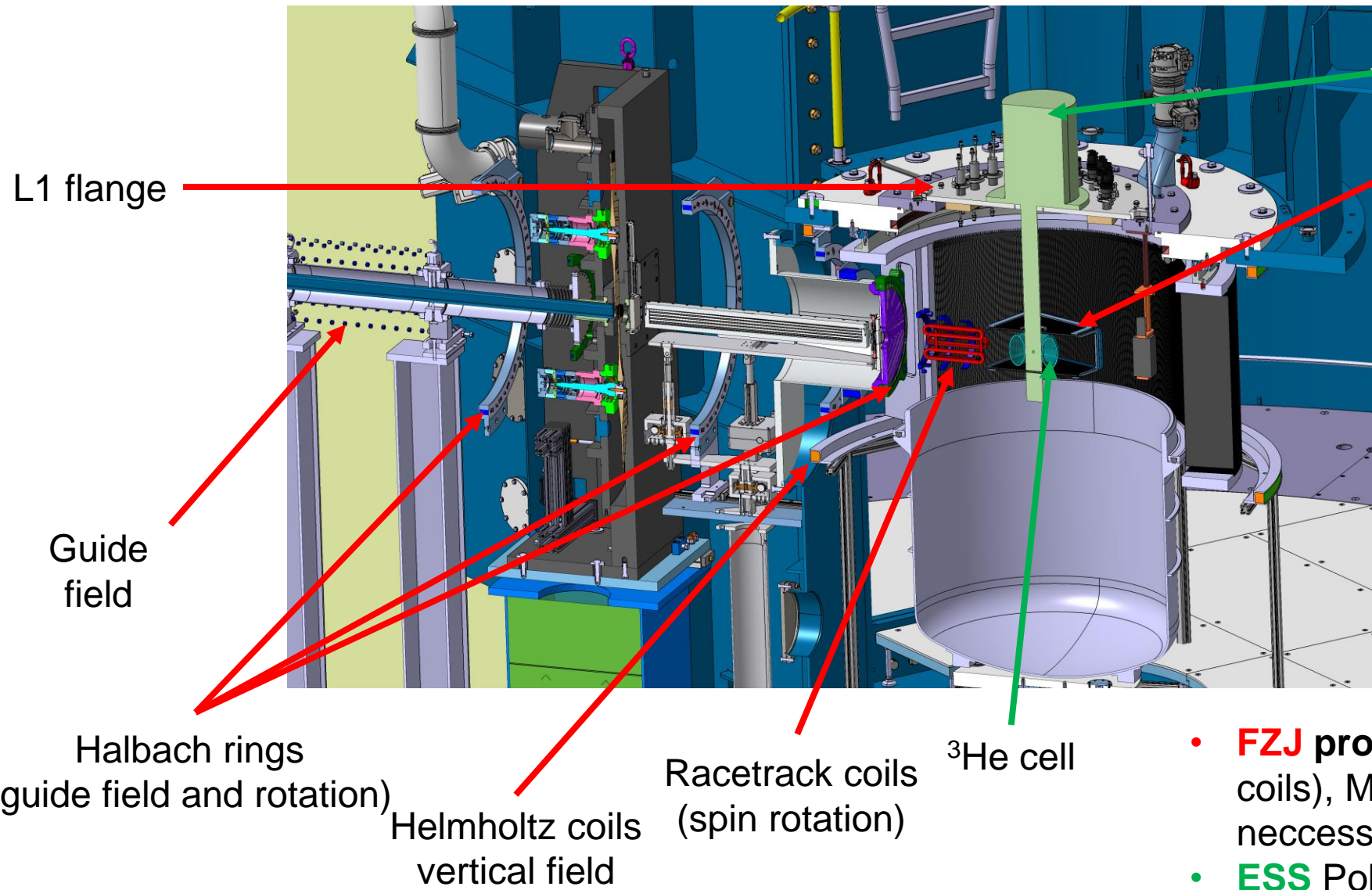
- $\lambda_{\min} = 0.6\text{\AA}$
- $k = 20$
- $f = 150\text{kHz}$
- $L = 400\text{mm}$



Option 2: ^3He + Mezei flipper

- Use ^3He als flipper for thermal neutrons
- Additional Mezei flipper after cold polariser (Similar to LET)
- More effort, have to change guide design, ramp with pulse
→ Fallback option

Polarization analysis



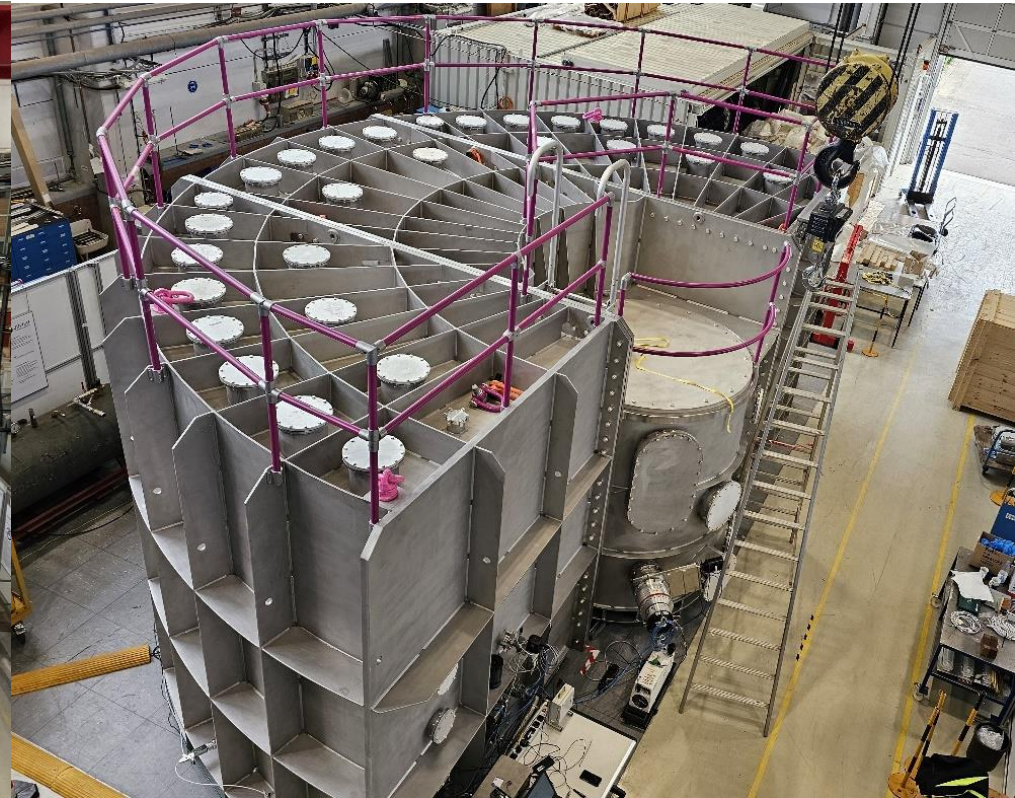
cryostat

Magic pastis
Horizontal field

Hal Lee (ESS): in-situ re-filling of the ^3He cell

Re-design to make Z^+ method possible

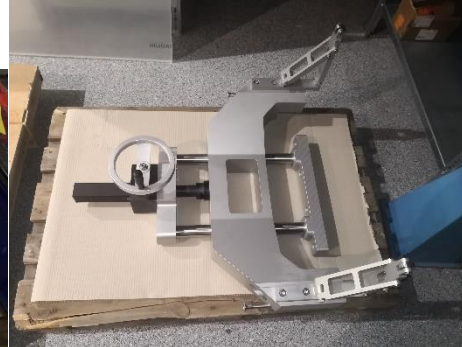
- **FZJ** provides Spin Rotation (Racetrack coils), Magic Pastis and Sample flange with necessary feedthroughs
- **ESS** Polarisation Group provides ^3He cell and cryostat with bespoke tail



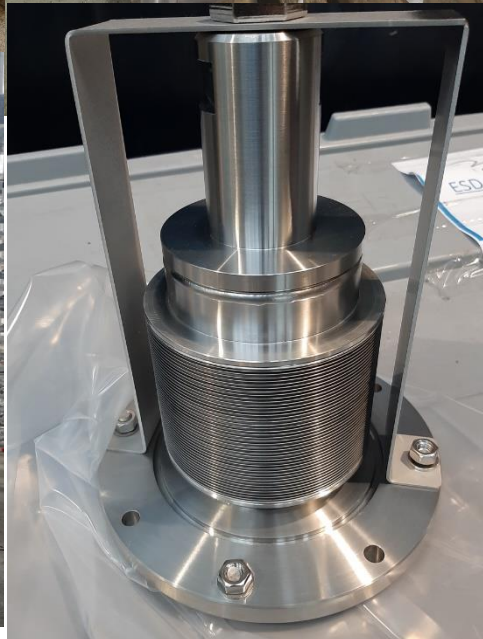
- Manufacturing finished
- Pre-installation in Jülich started
detector feet and false floor already in

- Vacuum test passed ($<10^{-5}$ mbar on empty vessel)
- Next step: integration of interior accessoires
detector box, shielding, ROC,...

Interior accessories



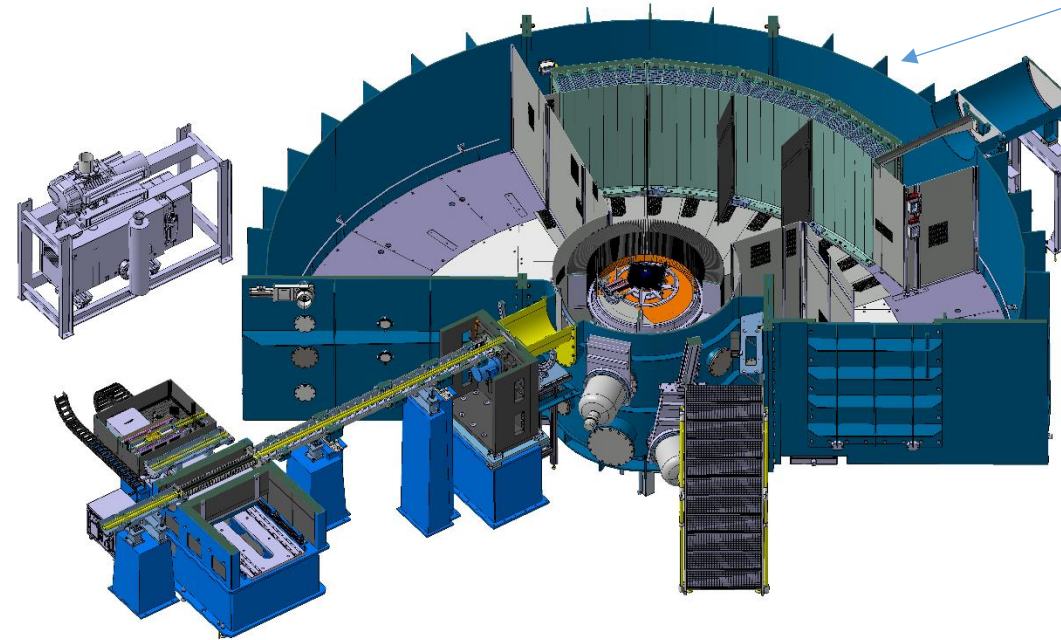
Gate Valve; Sample Environment flanges; Detector support; Vessel flooring; Entry pedestal, sample exchange container



Detector

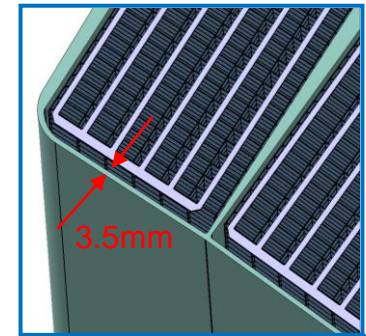
- Novel „MultiGrid“ (MG) detector based on ^{10}B (instead ^3He)
- Scope of ESS
- FZJ took over design of detector boxes and manufacturing of one box
- Box manufacturing is finished, box is at FZJ
- Mock-up column will be integrated in summer (at FZJ)
- Only one box for hot commissioning -> no science possible
- Need at least 40% coverage for early users and benchmark experiments
- **Ongoing development: Get rid of spurious signals!**

Reduced scope: 40% coverage (4/10 boxes)

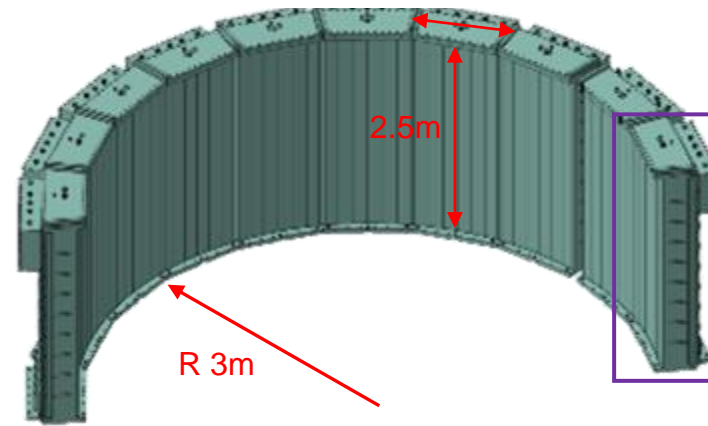


„Detector vessel“

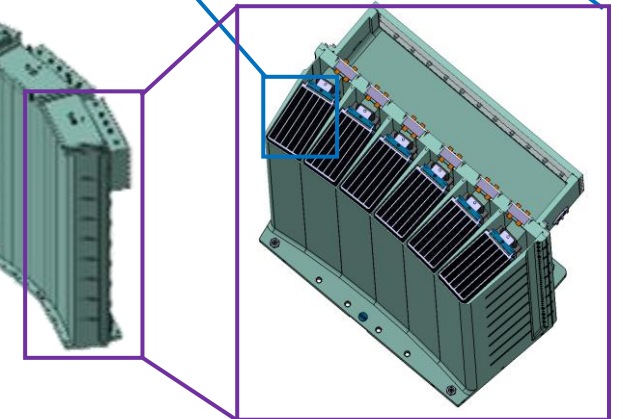
„Detector column“
> 200 grids



3.5mm



For reference: Full scope (10 boxes)

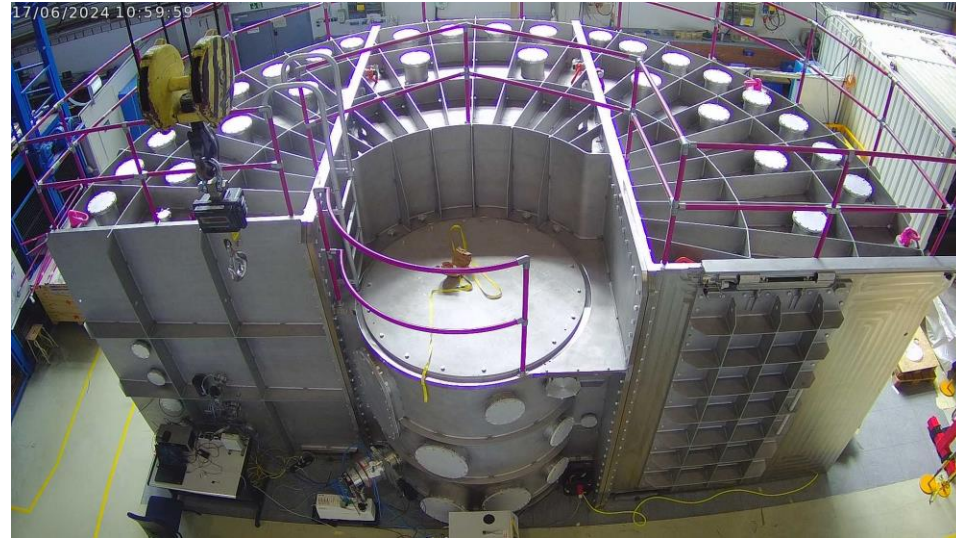


„Detector box“
6 columns per box

Detector

- Novel „MultiGrid“ (MG) detector based on ^{10}B (instead ^3He)
- Scope of ESS
- FZJ took over design of detector boxes and manufacturing of one box
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- Mock-up column will be integrated in summer (at FZJ)
- Only one box for hot commissioning -> no science possible
- Need at least 40% coverage for early users and benchmark experiments
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„Detector vessel“



„Detector box“
6 columns per box



„Detector column“

Neutron Detector (Multi GRID) &

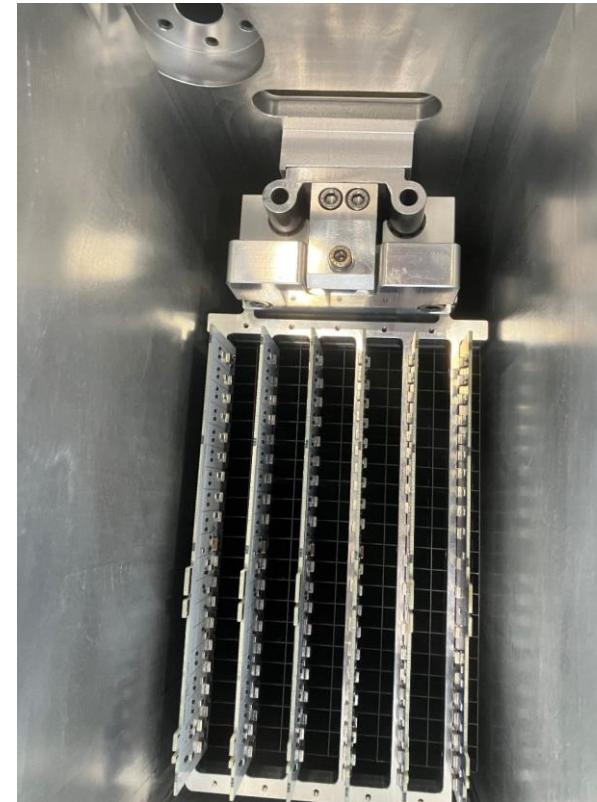
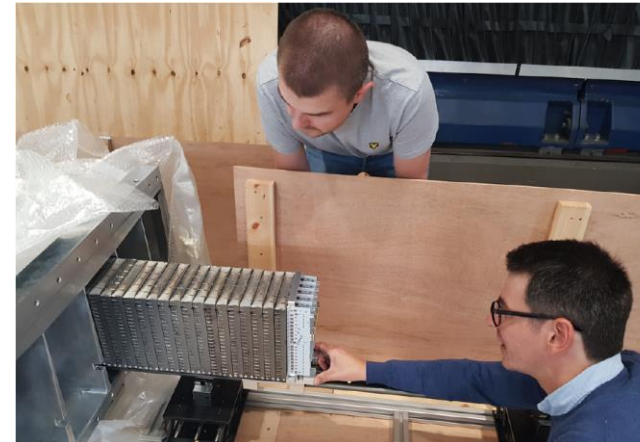
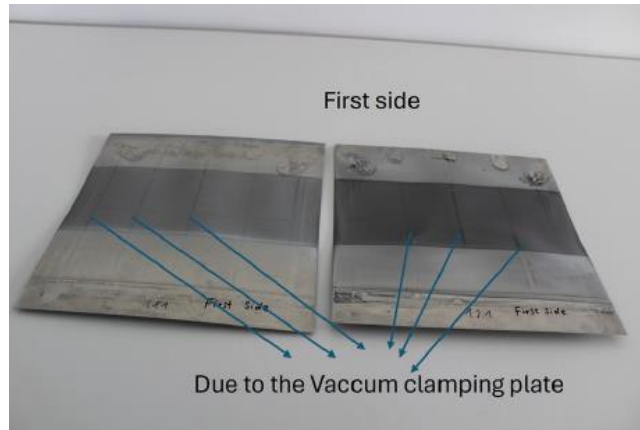
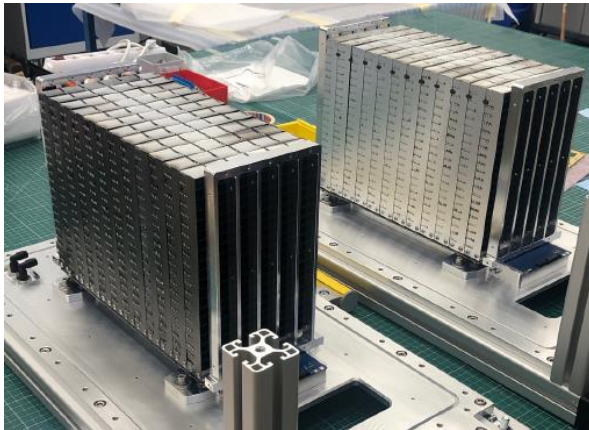
Detector box

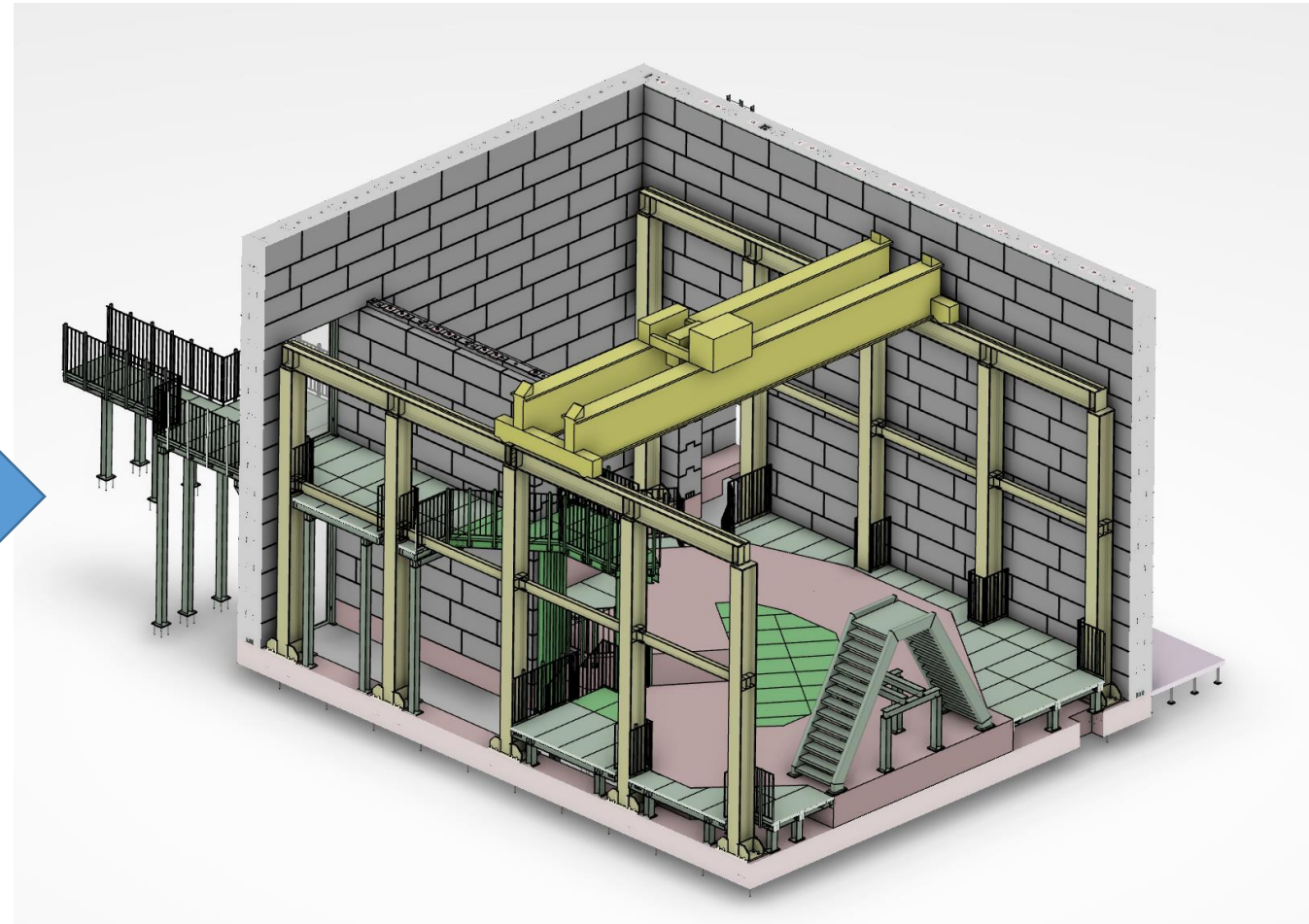
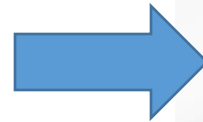
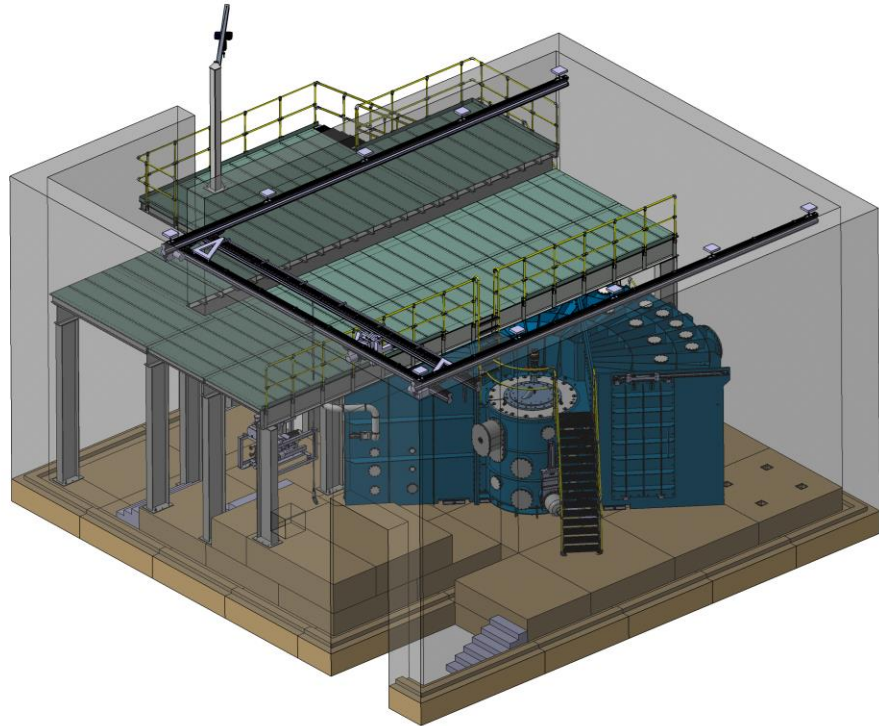
STAP report april '23

“Clearly, the development needs to be accelerated if a working TREX instrument is to operate in 2027. No functional prototype exists to-date. A 2027 start for TREX with MG detector is totally unrealistic at this point.”



- Protoype box in in Jülich
- Integration of demonstrator grid succesful
- Integration of box into vessel in next two weeks





- Redesign of the cave!
- IDR passed
- Detailed design complete
- **subTG3 on 8th November**

- Split detailed design and manufacturing to speed up
- **CNR/INFN process complex**, Enrico&Andrea working hard on administration part

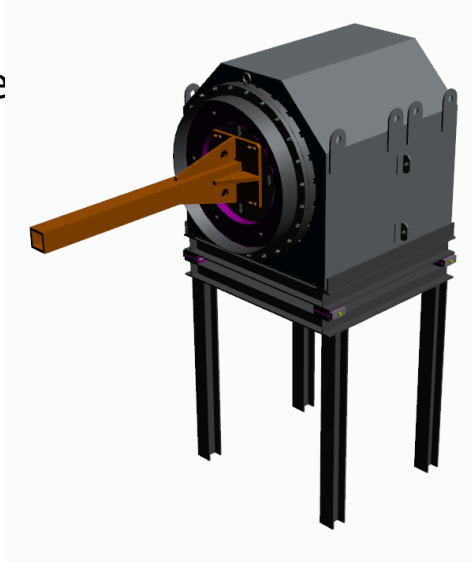
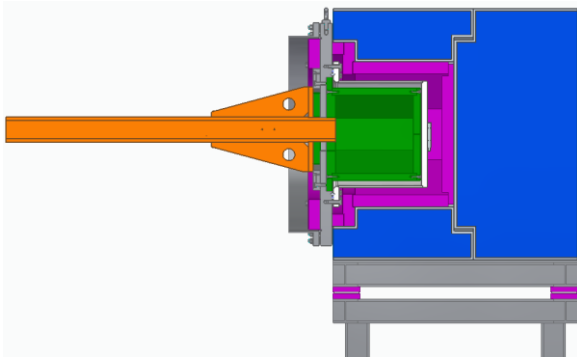
- Talks with possible manufacturers

Beamline shielding

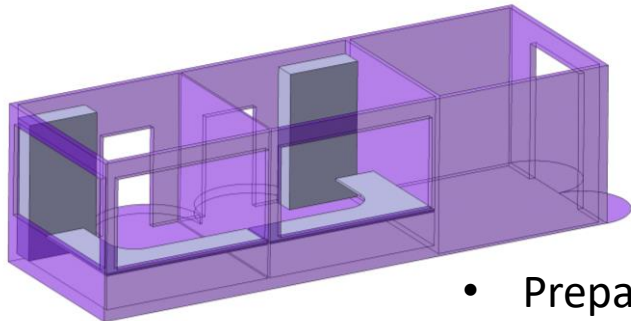
- joined common project

Beam stop

- Discussions with Matt Stone on transmission monitor



Hutch and sample prep.



- Preparing CTV documents

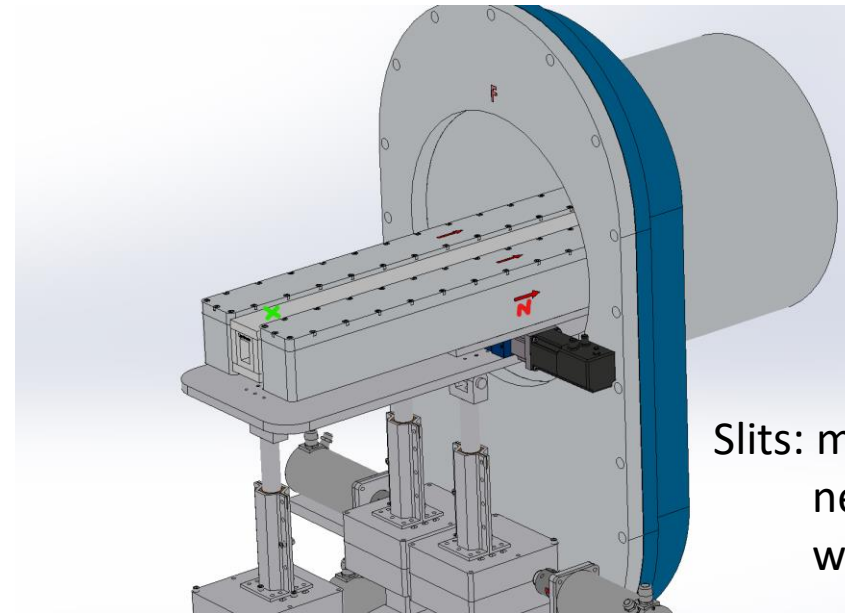
Primary collimator and slits

Technically challenging component!



Re-design of the component

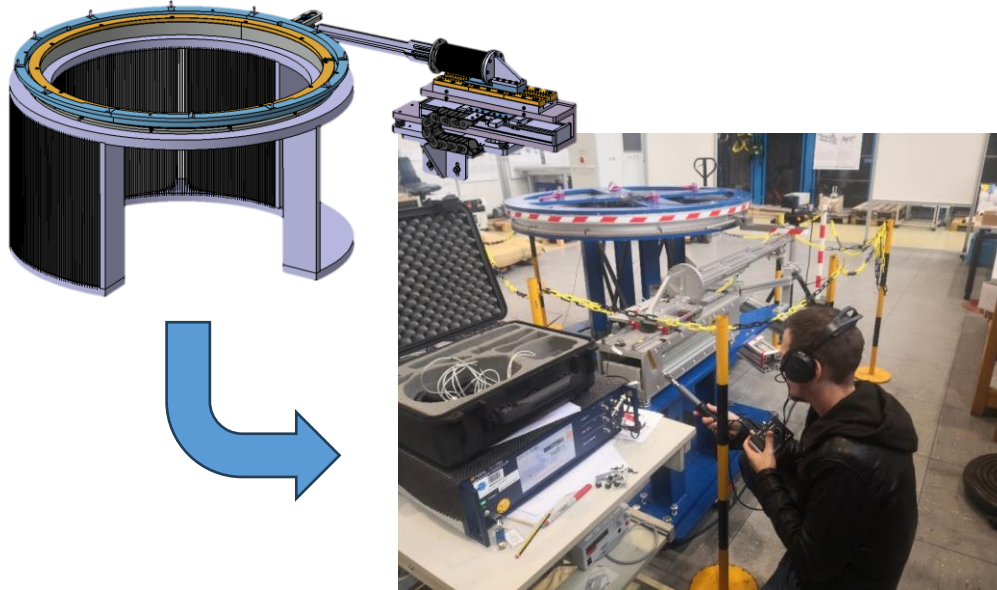
- Decoupled from detector vessel to avoid misalignment
- Translation table instead of revolver solution



Slits: motion control options need to be discussed with MCA and FZJ.

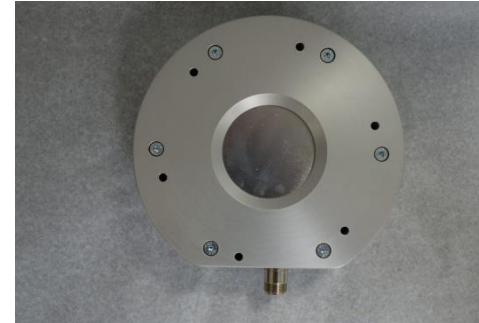
IDR 24th October

Secondary (ROC) collimator



- Two packages: drive and mount (FZJ), collimator (CNR)
- Exchange of workpackages planned between CNR and FZJ (Collimator)
- Test bench for drive in Jülich, integration in detector vessel
- Kick-off with JJ X-ray for collimator last Friday

Monitors



- Joined ESS common project
- 3 monitors in the scope: after P-chopper, after M-chopper, after sample
- Meanwhile: Discussion with CDT for P-Chopper and sample monitor design

Summary



Take-home message:

- More photos, less schematic drawings! We are building... ✓
- Major threat: Detector! ⚠
- Timeline: Cave