CSPEC: An update on the development of the cold chopper spectrometer of the ESS

PASCALE DEEN
CSPEC LEAD SCIENTIST (DARIA NOFERINI)
SENIOR SCIENTIST FOR SPECTROSCOPY

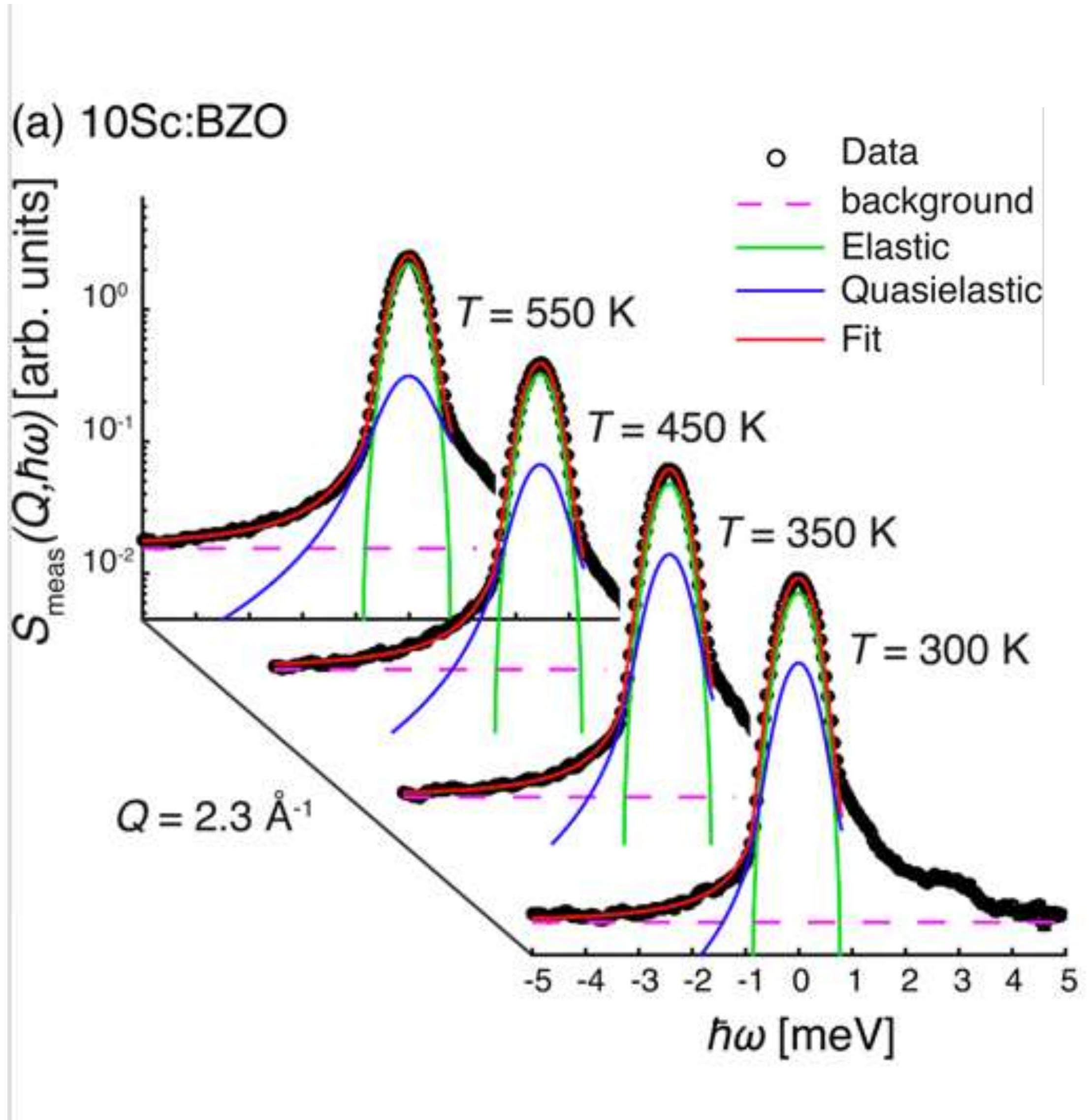
CSPEC: Scientific aims

Quasielastic scattering:

Translational dynamics

Diffusive dynamics

Rotational dynamics



J. Phys. Chem. C 121, 7088 (2017)

Materials: Glass forming, liquid dynamics, crystal growth, hydrogen storage, fuel cells.

Soft matter: Polymer nanocomposites, organic photovoltaics, polymer electrolytes

Biology: hydration water, protein structure-dynamics-function, cell membrane-protein, drug delivery

Chemistry: ionic liquids, clays, complex fluids

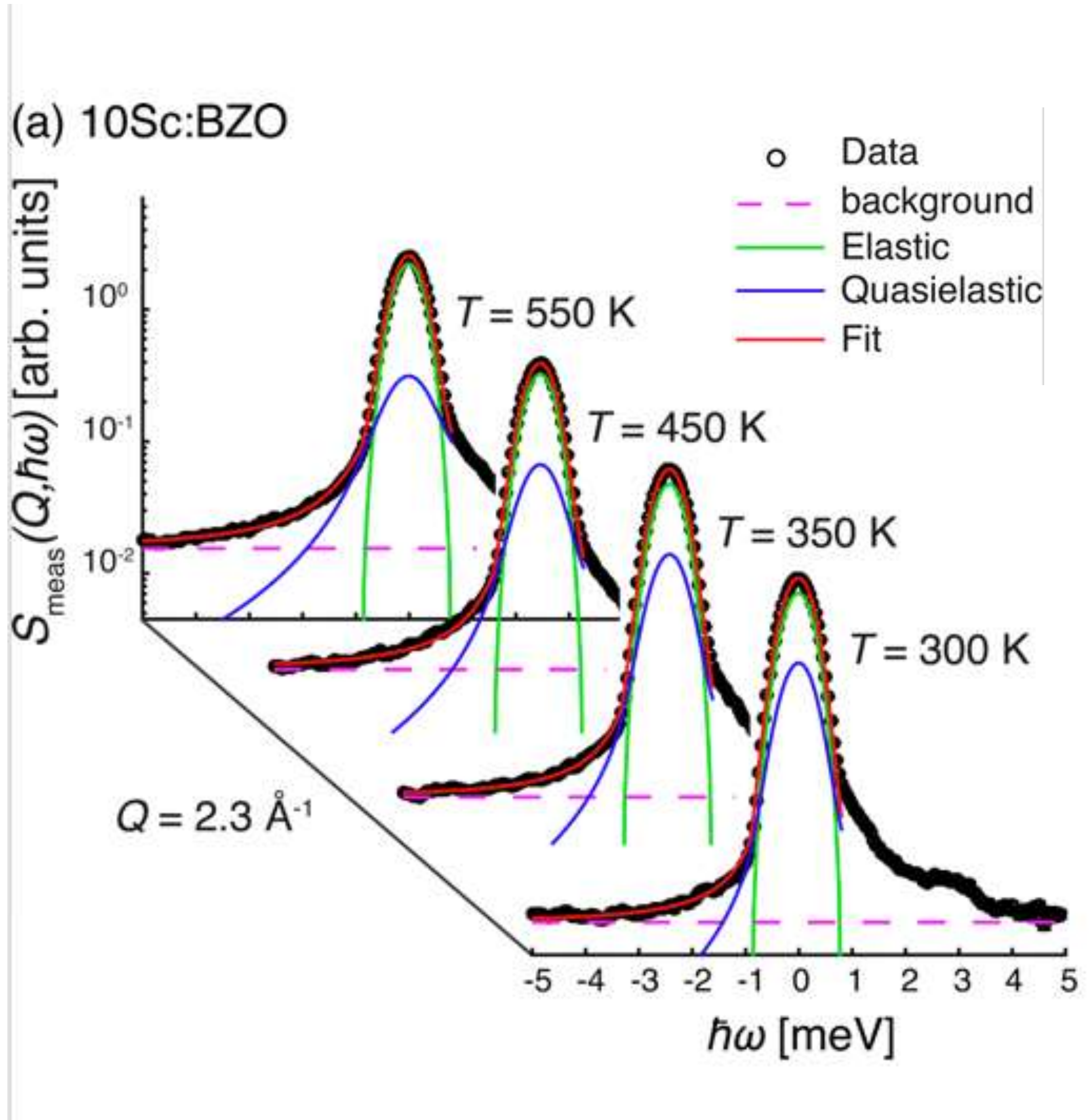
CSPEC: Scientific aims

Quasielastic scattering:

Translational dynamics

Diffusive dynamics

Rotational dynamics



J. Phys. Chem. C 121, 7088 (2017)

Materials: Glass forming, liquid dynamics, crystal growth, hydrogen storage, fuel cells.

Soft matter: Polymer nanocomposites, organic photovoltaics, polymer electrolytes

Biology: hydration water, protein structure-dynamics-function, cell membrane-protein, drug delivery

Chemistry: ionic liquids, clays, complex fluids

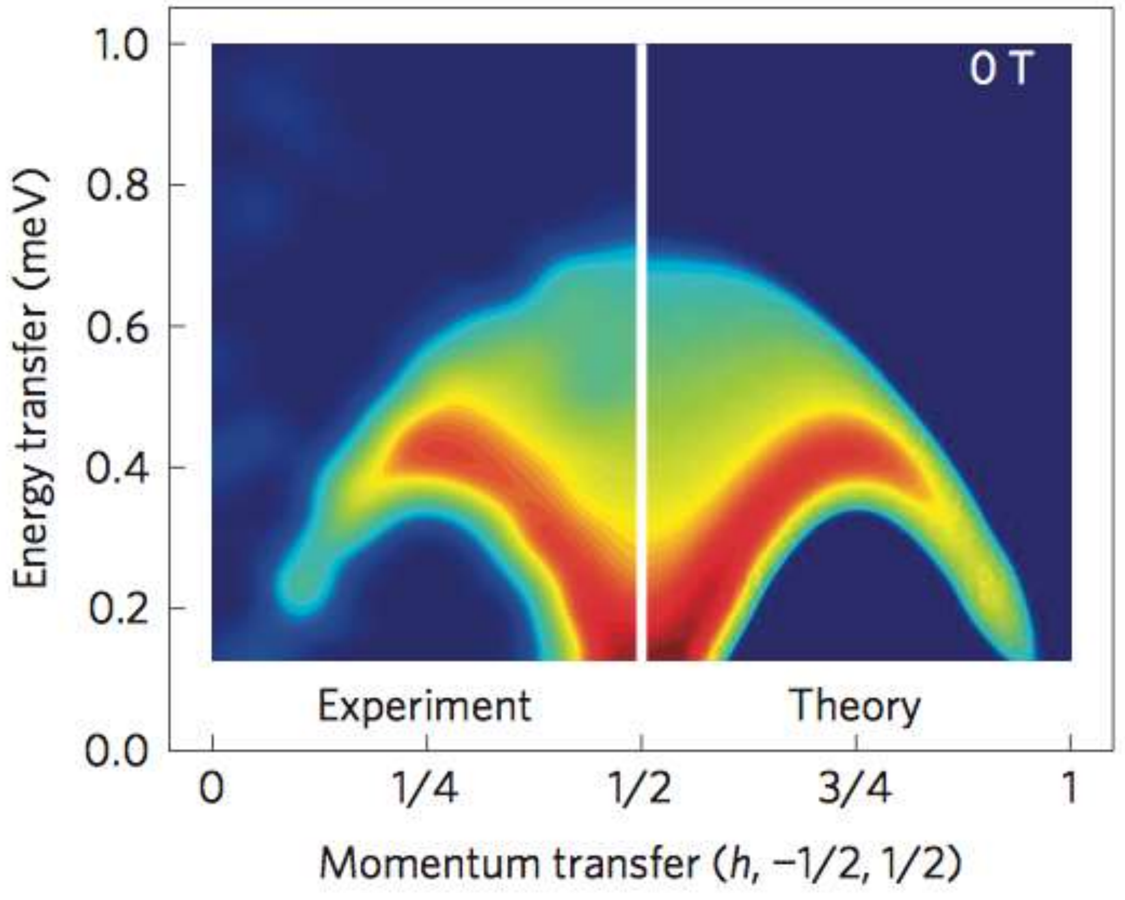
Low lying energy modes:

Spin dynamics

Critical scattering

Collective excitations

Quasiparticles



Nature Physics **9**, 435–441 (2013)

Magnons, phonons, polarons

Topological states of matter: Majorana fermions.

RVB states, Quantum spin liquids, emergent behaviour.

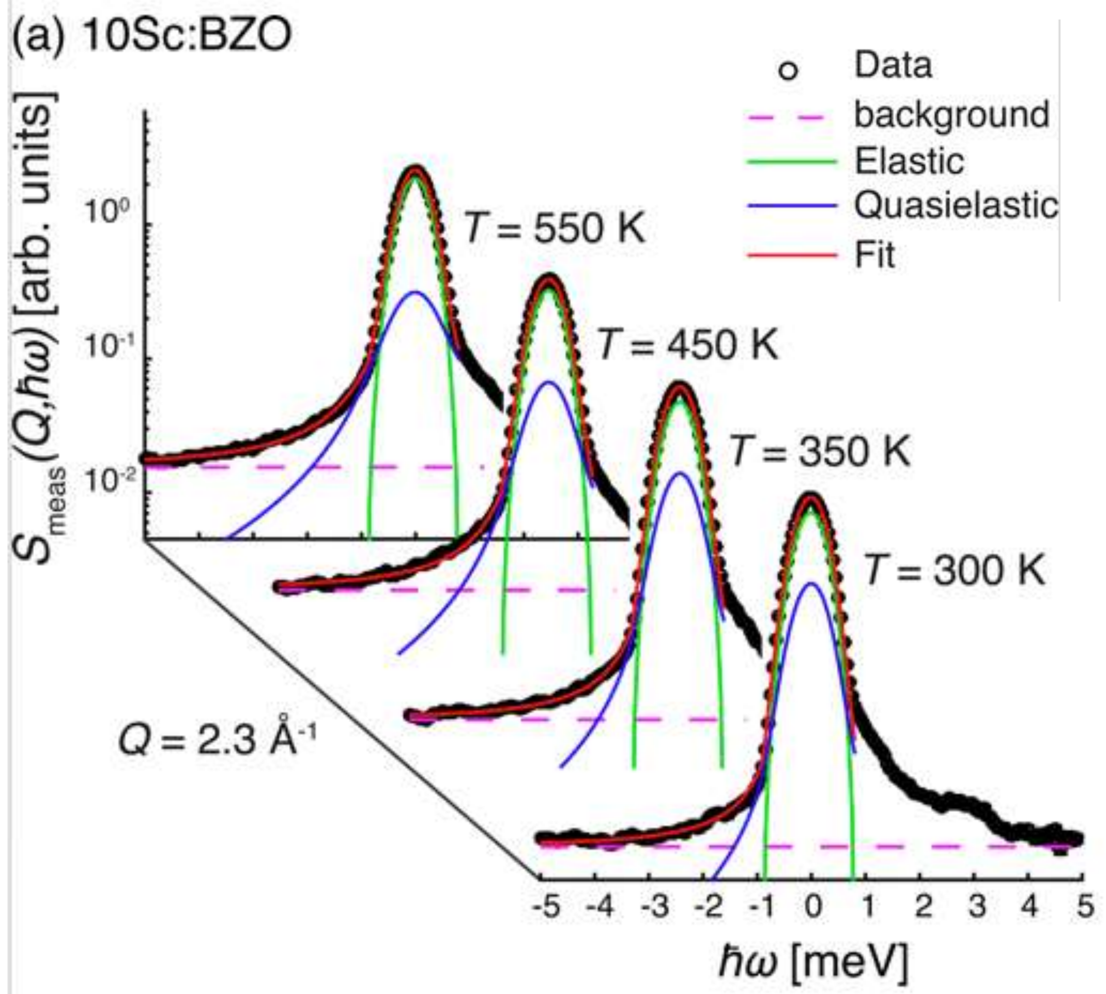
CSPEC: Scientific aims

Quasielastic scattering:

Translational dynamics

Diffusive dynamics

Rotational dynamics



J. Phys. Chem. C 121, 7088 (2017)

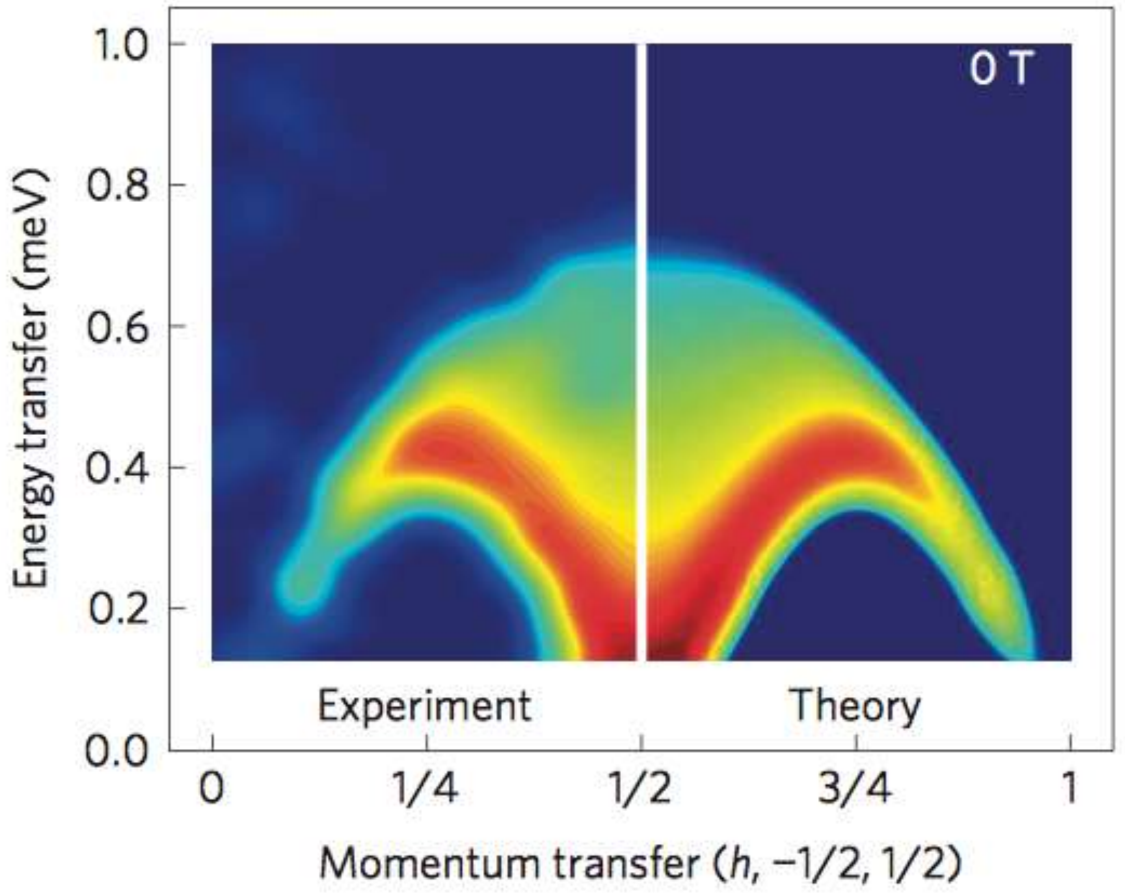
Low lying energy modes:

Spin dynamics

Critical scattering

Collective excitations

Quasiparticles



Nature Physics **9**, 435–441 (2013)

Materials: Glass forming, liquid dynamics, crystal growth, hydrogen storage, fuel cells.

Soft matter: Polymer nanocomposites, organic photovoltaics, polymer electrolytes

Biology: hydration water, protein structure-dynamics-function, cell membrane-protein, drug delivery

Chemistry: ionic liquids, clays, complex fluids

Magnons, phonons, polarons

Topological states of matter: Majorana fermions.

RVB states, Quantum spin liquids, emergent behaviour.

Study of low lying excitations of materials with a focus on small samples, in-operando/kinetic behaviour
Need 10-50 x current day signal/noise to perform adequately

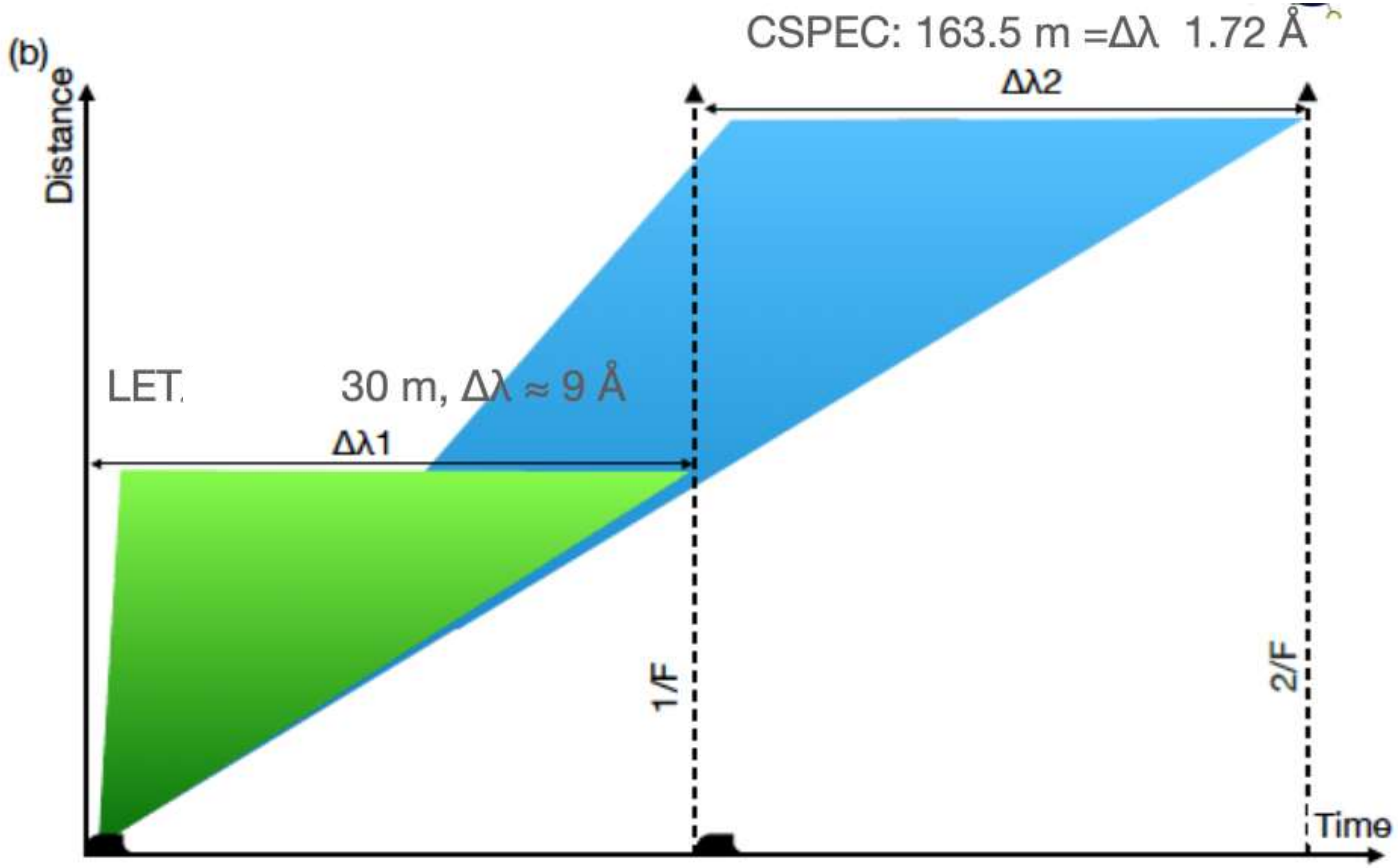
CSPEC Specifications

Study of low lying excitations of materials with a focus on small samples, in-operando/kinetic behaviour
Need 10-50 x current day signal/noise to perform adequately

- The cold chopper spectrometer of the ESS (2 - 20 Å).
- Cold neutrons (2-20 Ang) with $\Delta E/E = 1.5$ % @ 4 Å (Ei, $\Delta E = \infty < E_i < 0.2E_i$).
- Focus flux on range of sample areas 4 x 2 $cm^2 \rightarrow$ 1 x 1 cm^2.
- **Signal to noise = 10^5 (@5 Å, Vanadium).**
- Detector will provide angular range of $-30 < 2\theta < 140^o$ in the horizontal plane and +/- 26.5^o in the vertical plane with a planar sample to detector distance = 3.5 m = **2.49 Str**
- **Enhanced sample environment : in-situ/kinetic phenomena. < 1 min resolution.**
- **Polarisation analysis.**
- **Much improved coupling of neutron scattering with theory.**

CSPEC Instrument length

$\Delta tof = 252.78 L \Delta\lambda$



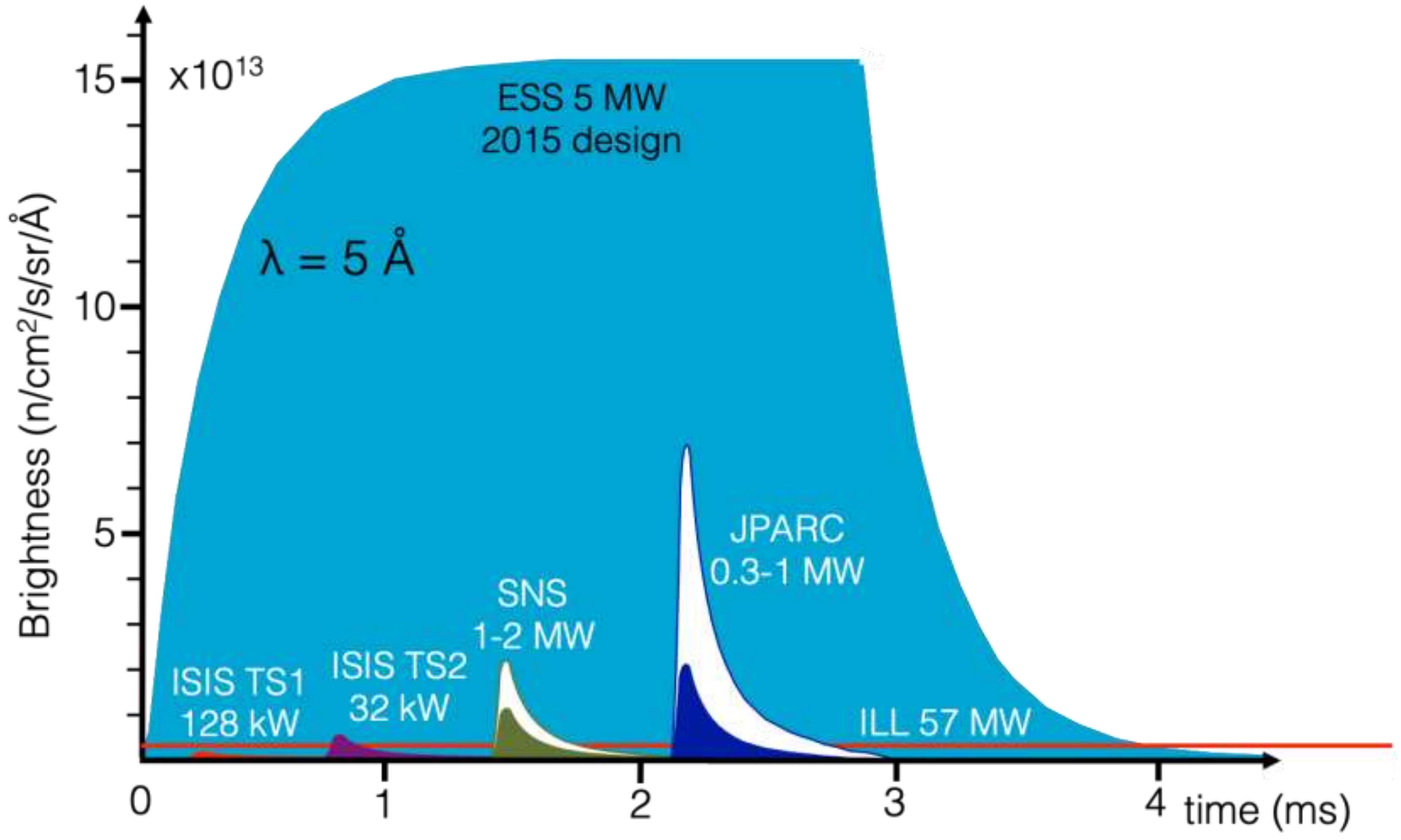
14 Hz 14 Hz

30 - 160 m instruments

Question of science case, do I want to see many length scales, timescales or do I want to focus?

Question of bandwidth

Long pulse versus short pulse spallation versus reactor

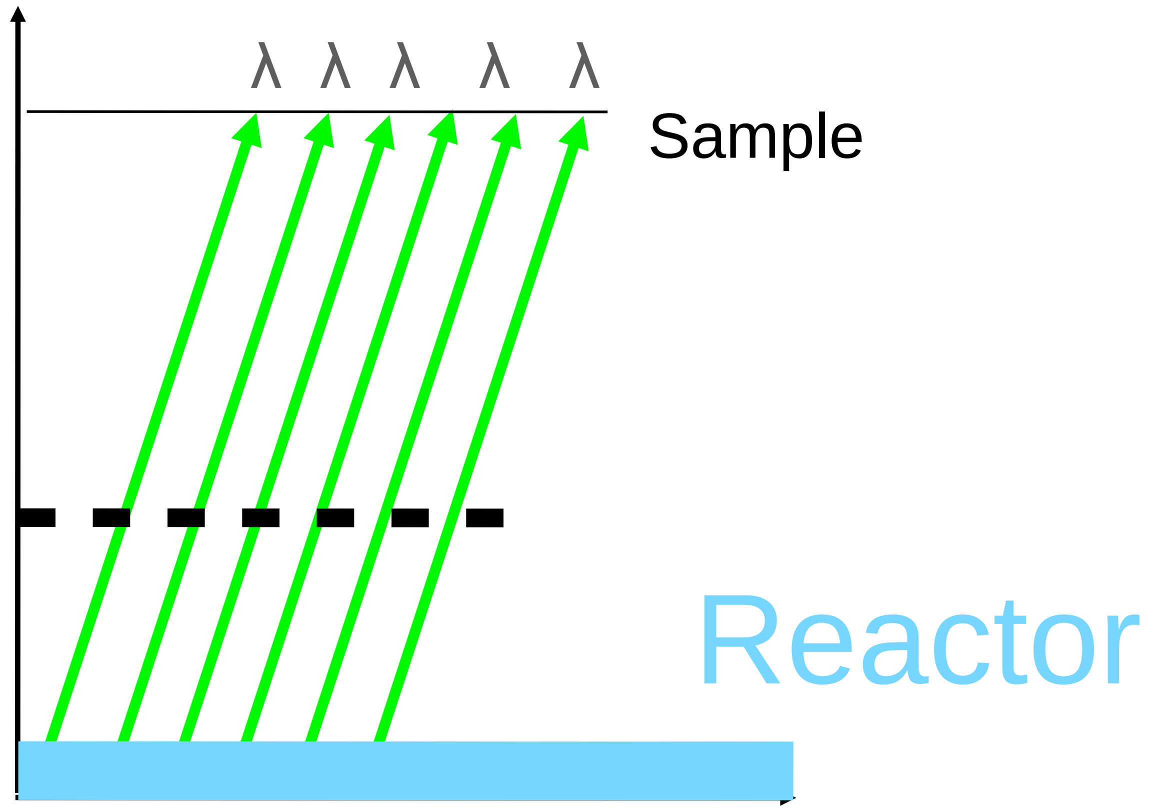


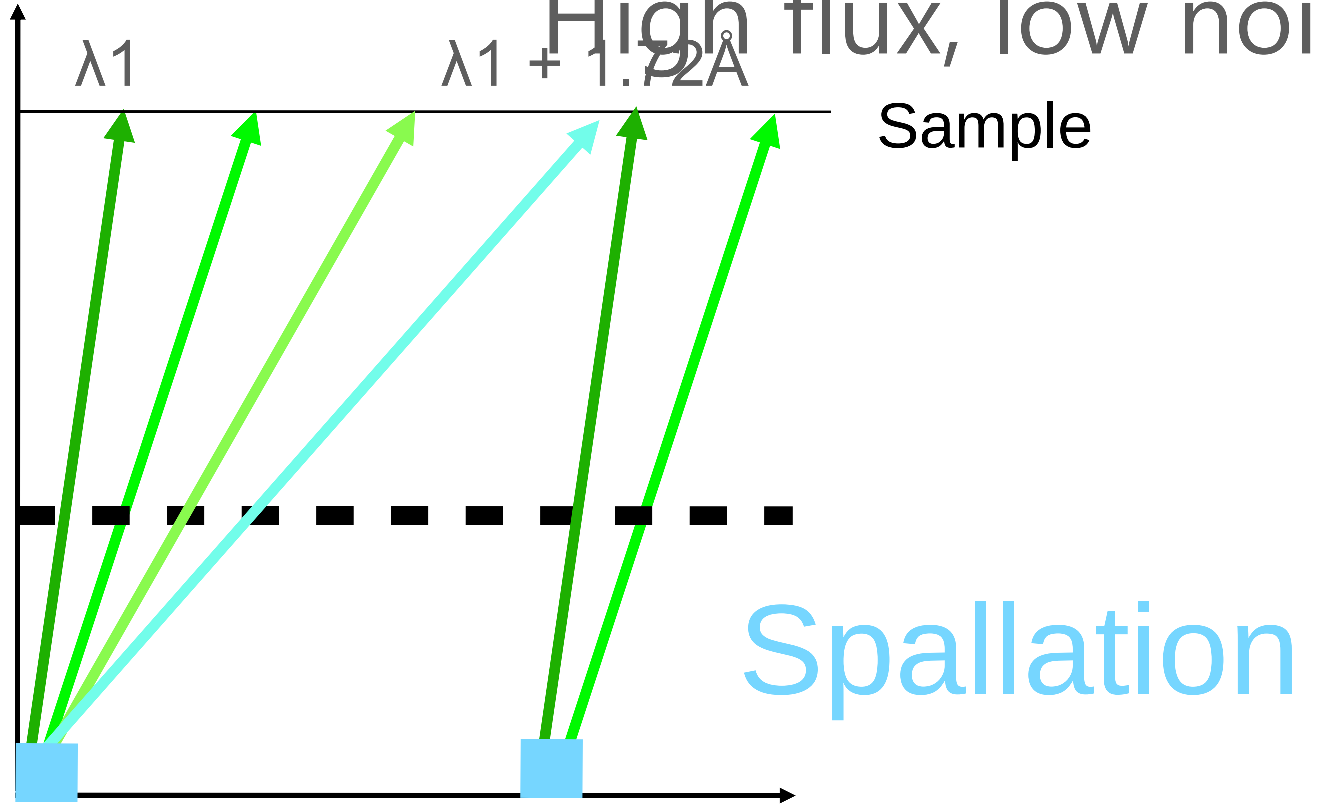
Brightness
Reactor: Continuous
Spallation: high but sparse (RRM)

Background
Reactor: continuous
Spallation: pulsed, clean in between …

Lineshapes
Reactor: Symmetric line shapes derived from chopper openings.
Spallation: Short pulse instruments - Carpenter function
Long pulse: choppers.

Chopper spectroscopy at ESS:
High flux, low noise, symmetric lineshapes.

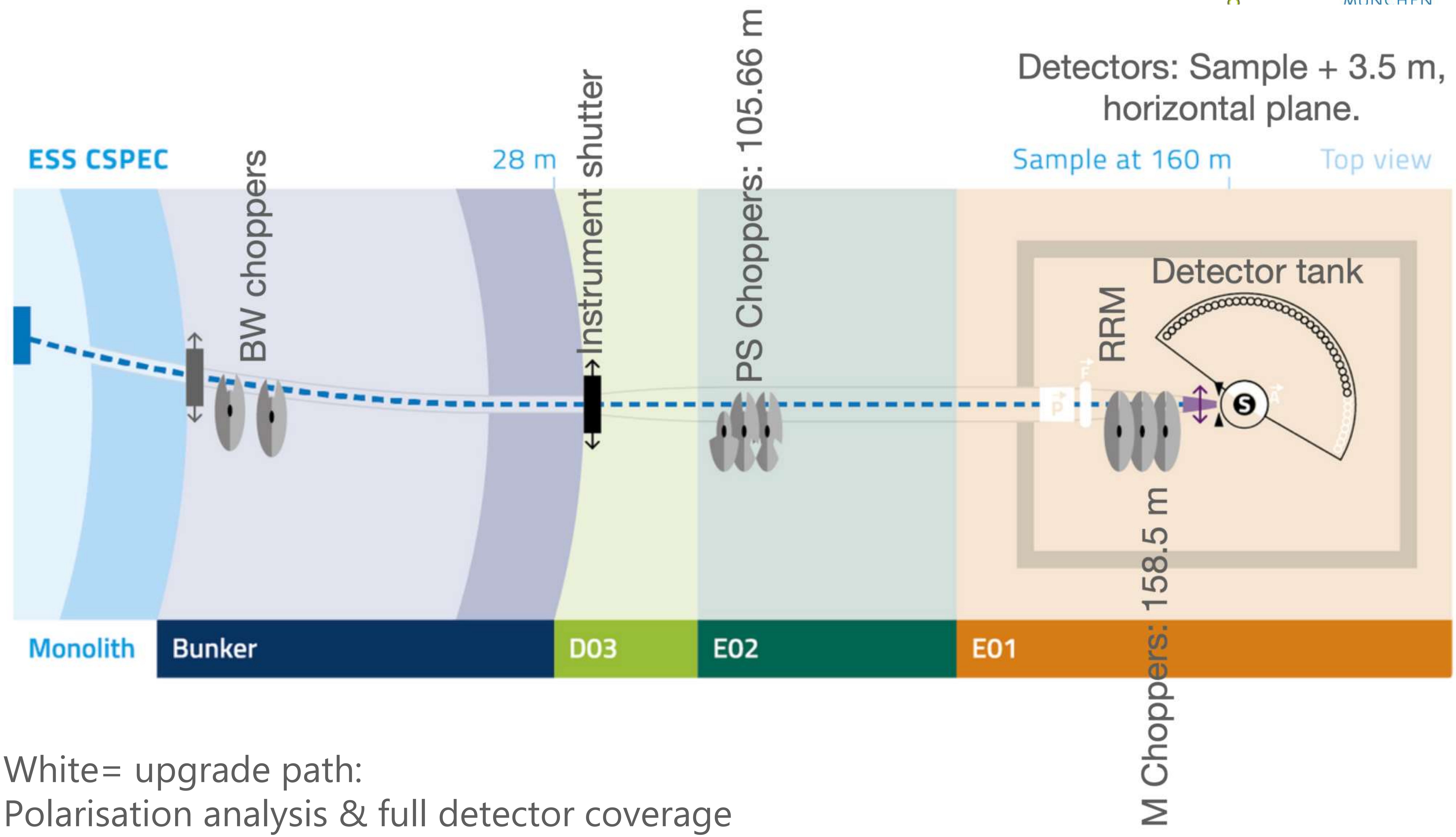




CSPEC broad parameters

Instrument Class	Spectroscopy
Moderator	Cold
Primary flightpath (Moderator to M chopper)	158.5 m
Secondary flightpath (M Chopper to detector)	5 m
Wavelength range	1.72 Å
Flux at sample (4 x 2 cm^2), 5 MW (λ = 5 Å, $\Delta E/E$ =3%)	3e6n/s/cm^2 (single pulse) x 5 - 10 with RRM cumulative
Flux at sample (1 x 1 cm^2), 5 MW (λ = 5 Å, $\Delta E/E$ =3%)	7.8e6n/s/cm^2 (focussed beam, single pulse)
Detector coverage	Complete: (H) $-30^{o} < 2\theta < 140^{o}$, (V) $\pm 26.5^{o}$ day 1 : (H) $5^{o} < 2\theta < 90^{o}$, (V) $\pm 26.5^{o}$ · September 2023.
Energy resolution	1.5% @ 4 Å

CSPEC Overview



White= upgrade path:
Polarisation analysis & full detector coverage

CSPEC within the ESS

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

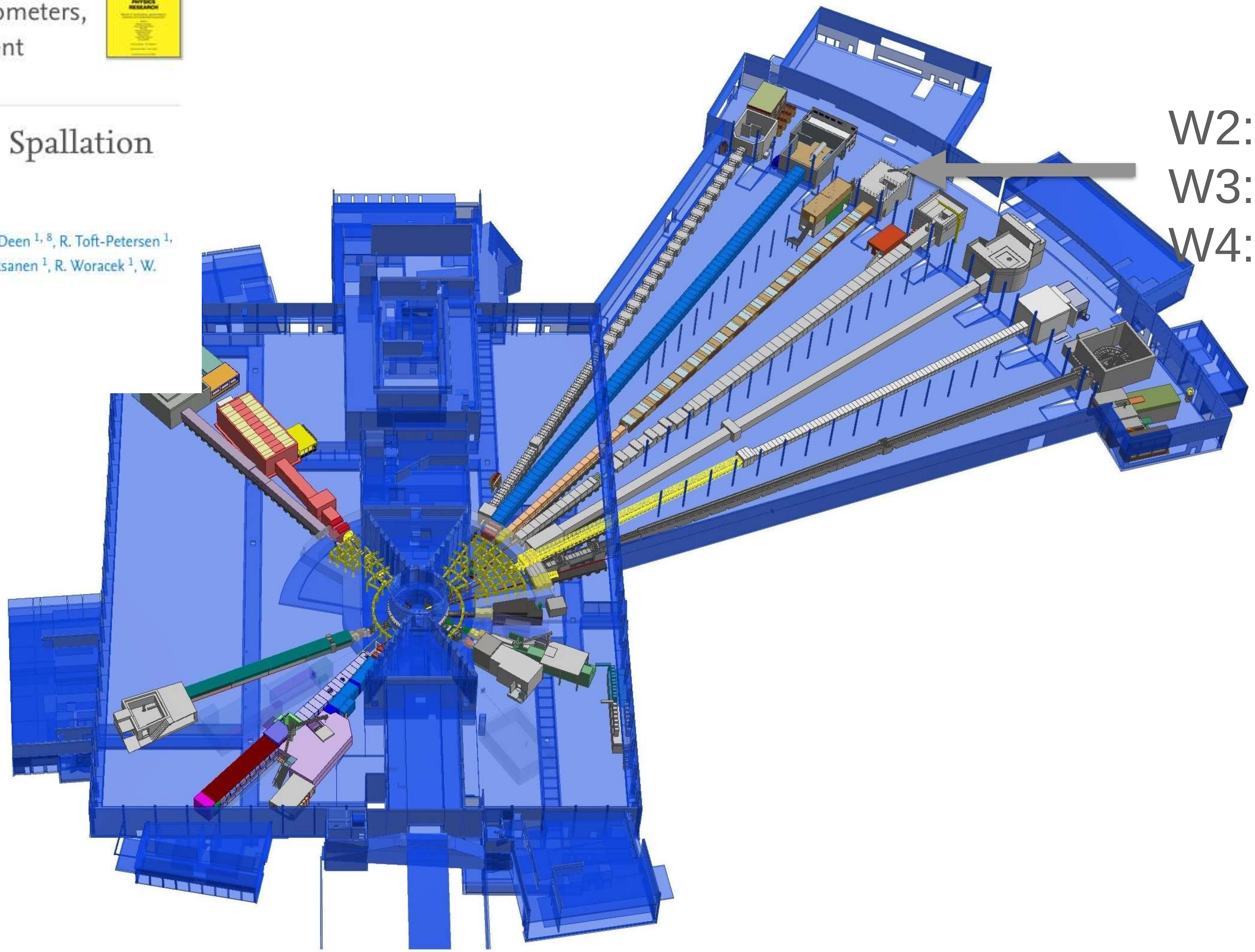
Volume 957, 21 March 2020, 163402

The instrument suite of the European Spallation Source

K.H. Andersen [1], D.N Argyriou [1], A.J. Jackson [1], J. Houston [1], P.F. Henry [1, 3, b], P.P. Deen [1, 8], R. Toft-Petersen [1, 13], P. Beran [1, 23], M. Strobl [1, 9], T. Arnold [1, 3], H. Wacklin-Knecht [1], N. Tsapatsaris [1], E. Oksanen [1], R. Woracek [1], W. Schweika [1, 4], D. Mannix [1, 12, 35], A. Hiess [1], S. Kennedy [1] ... A. Schreyer [1]

Show more

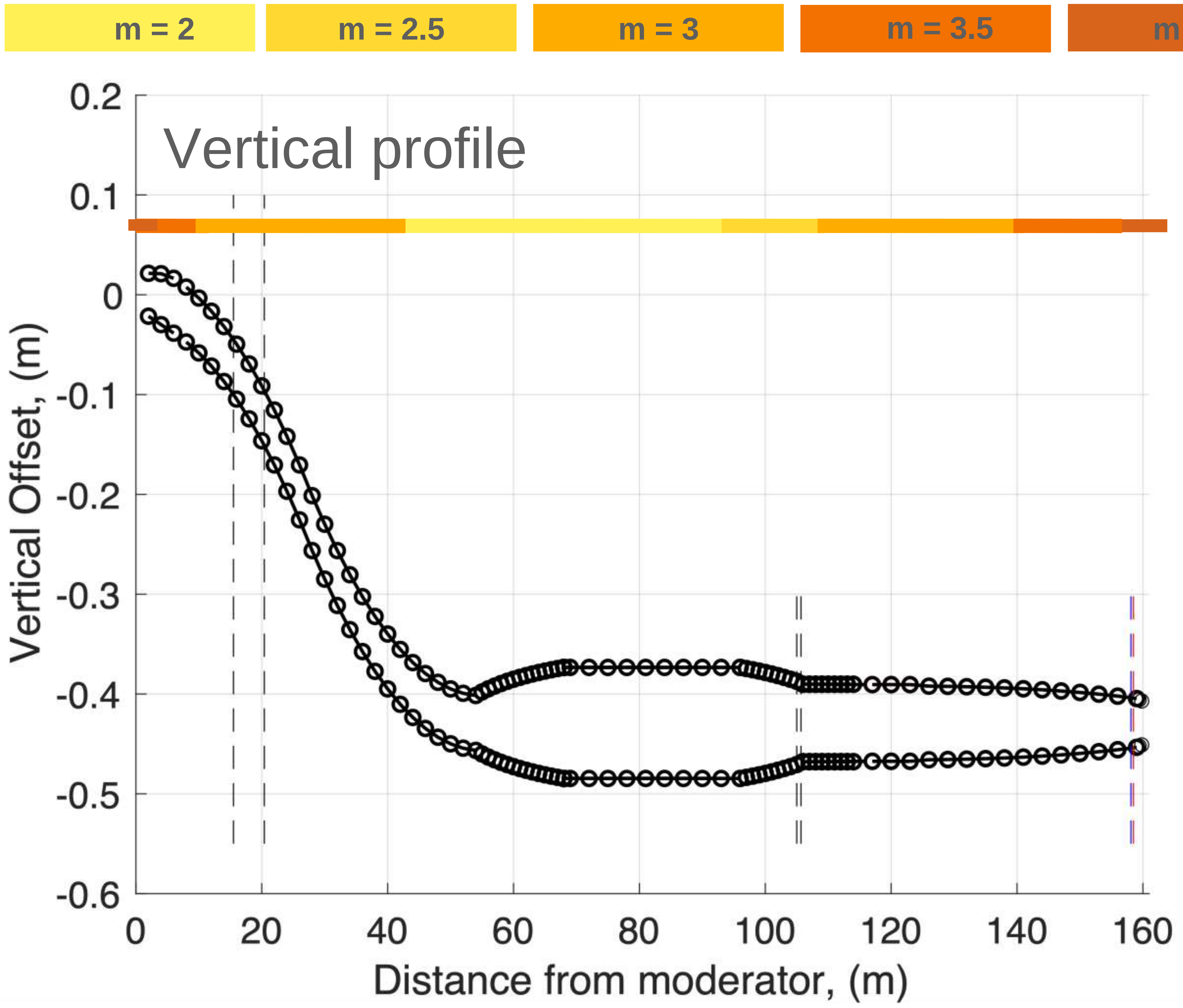
+ Add to Mendeley   Share   Cite

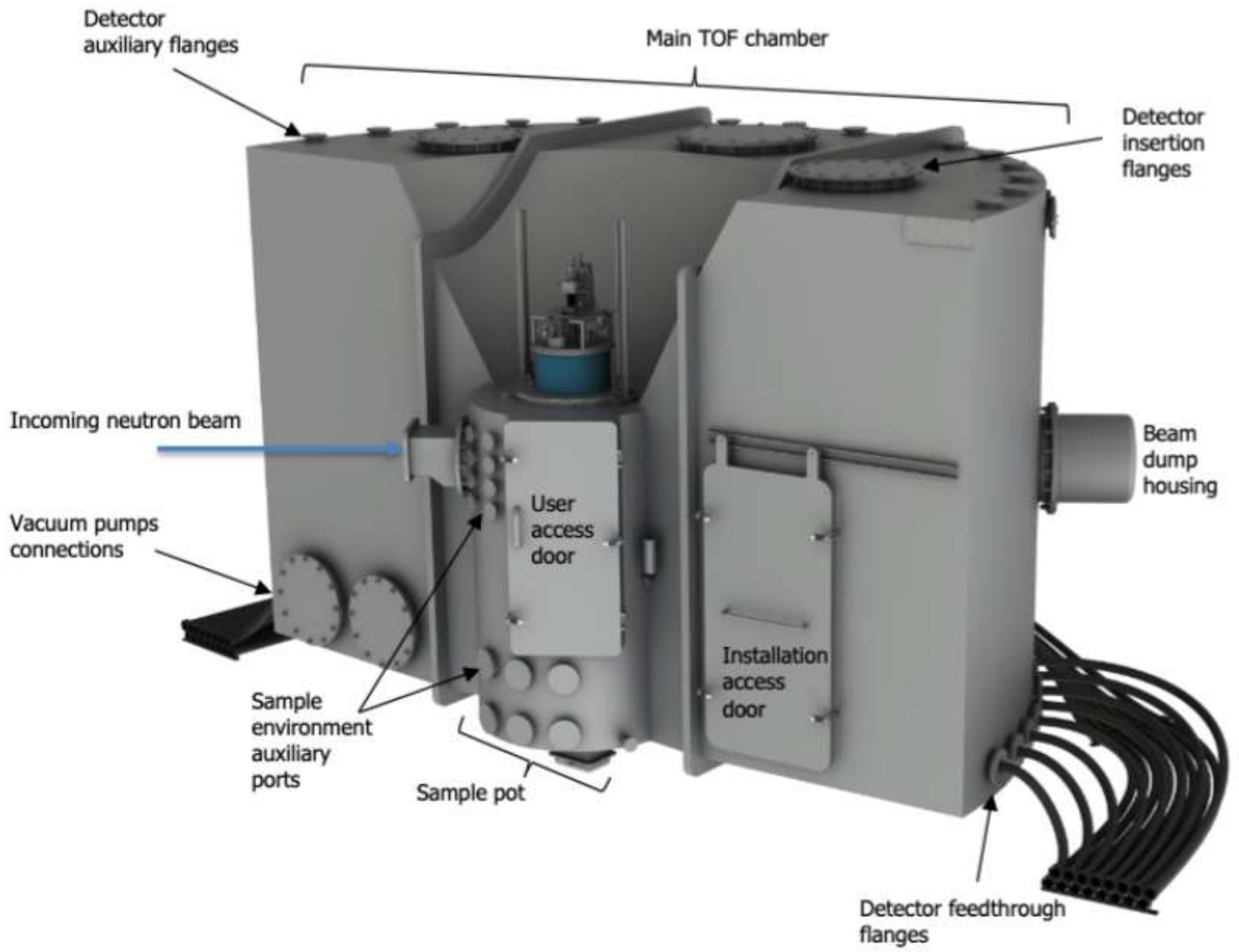


W2: BEER
W3: CSPEC
W4: BIFROST

CSPEC Guide

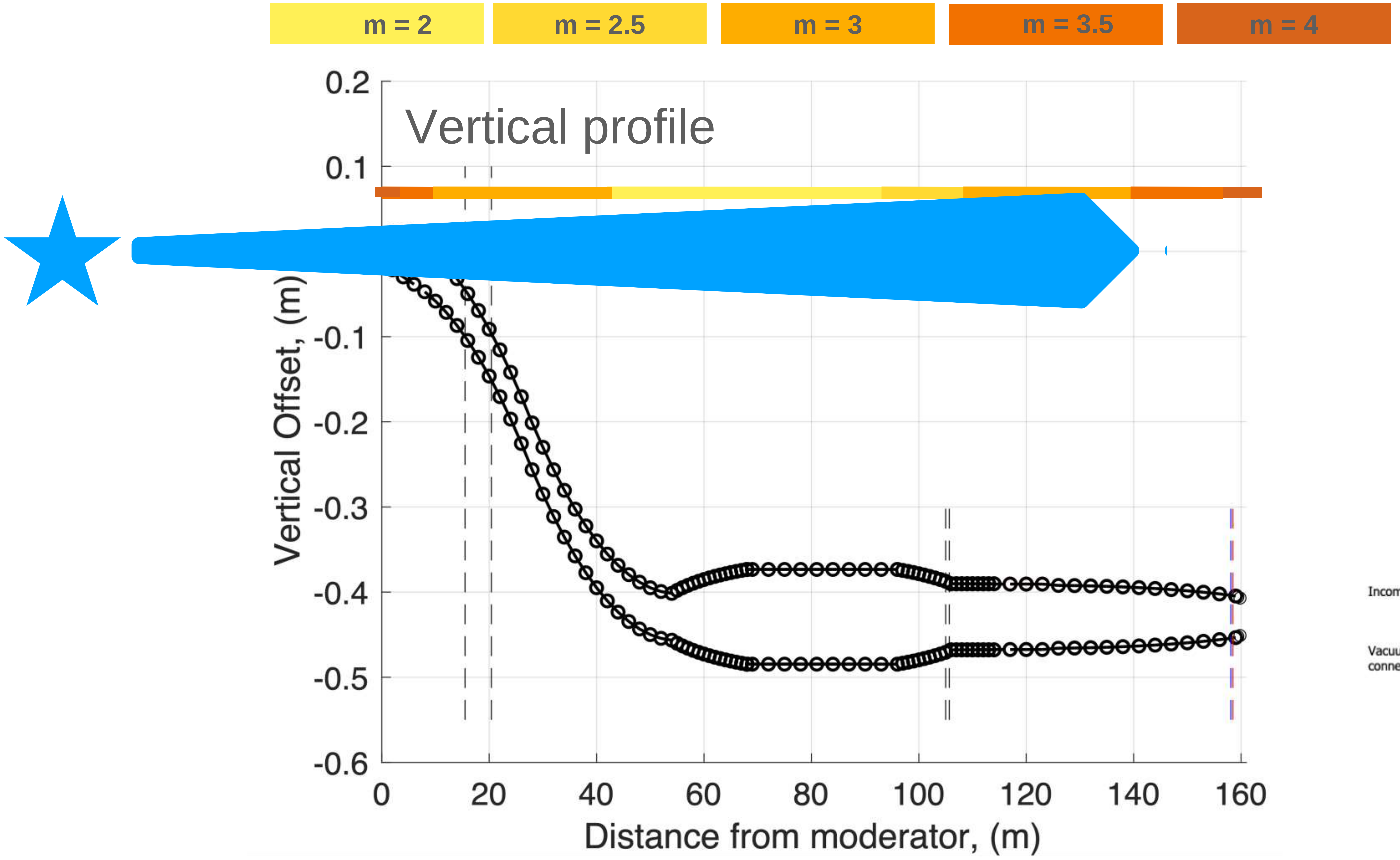
- Signal to noise = 10^5 (@5 Å, Vanadium).
- Optimise to cold moderator.
- 2 x LOS (Prompt pulse)

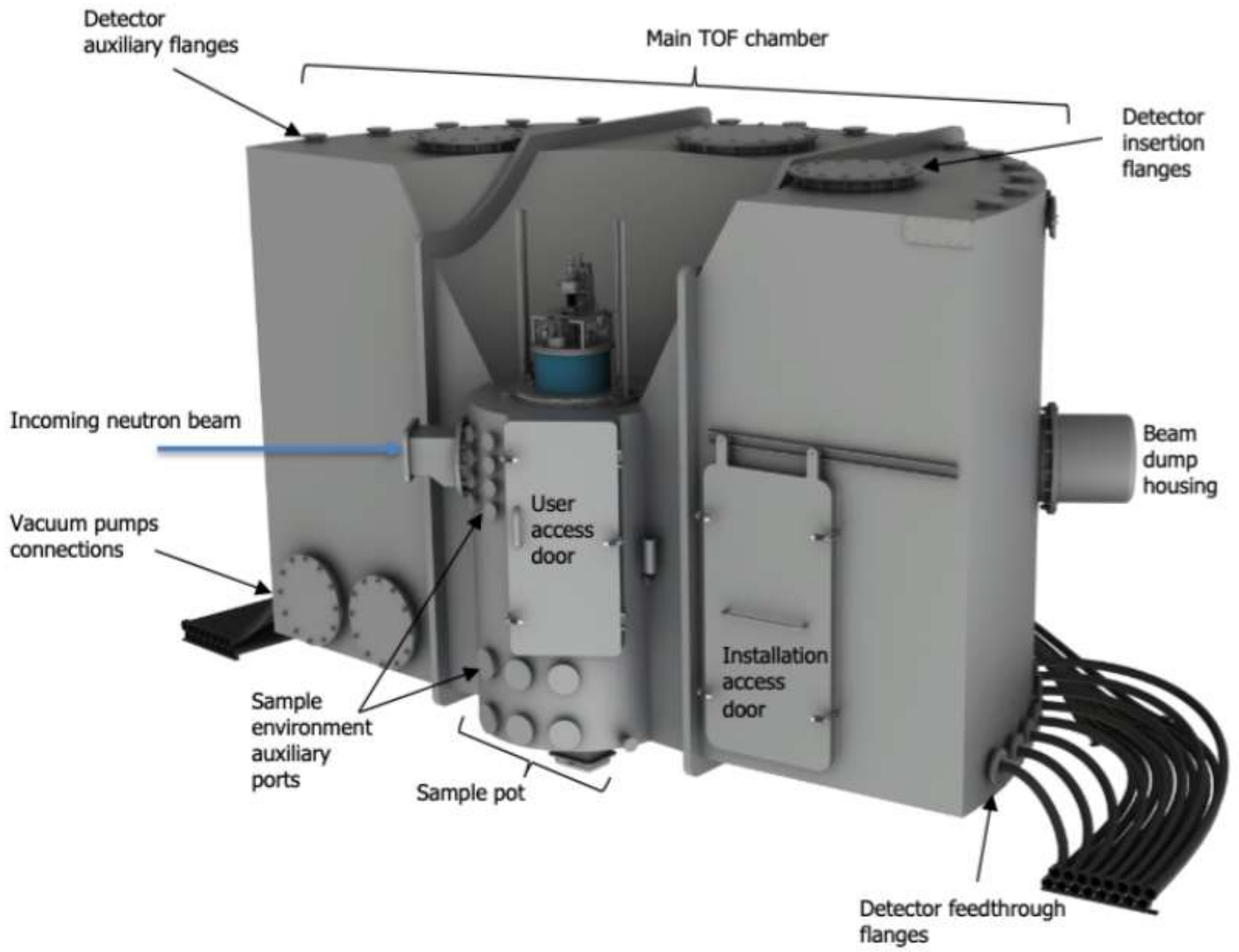




CSPEC Guide

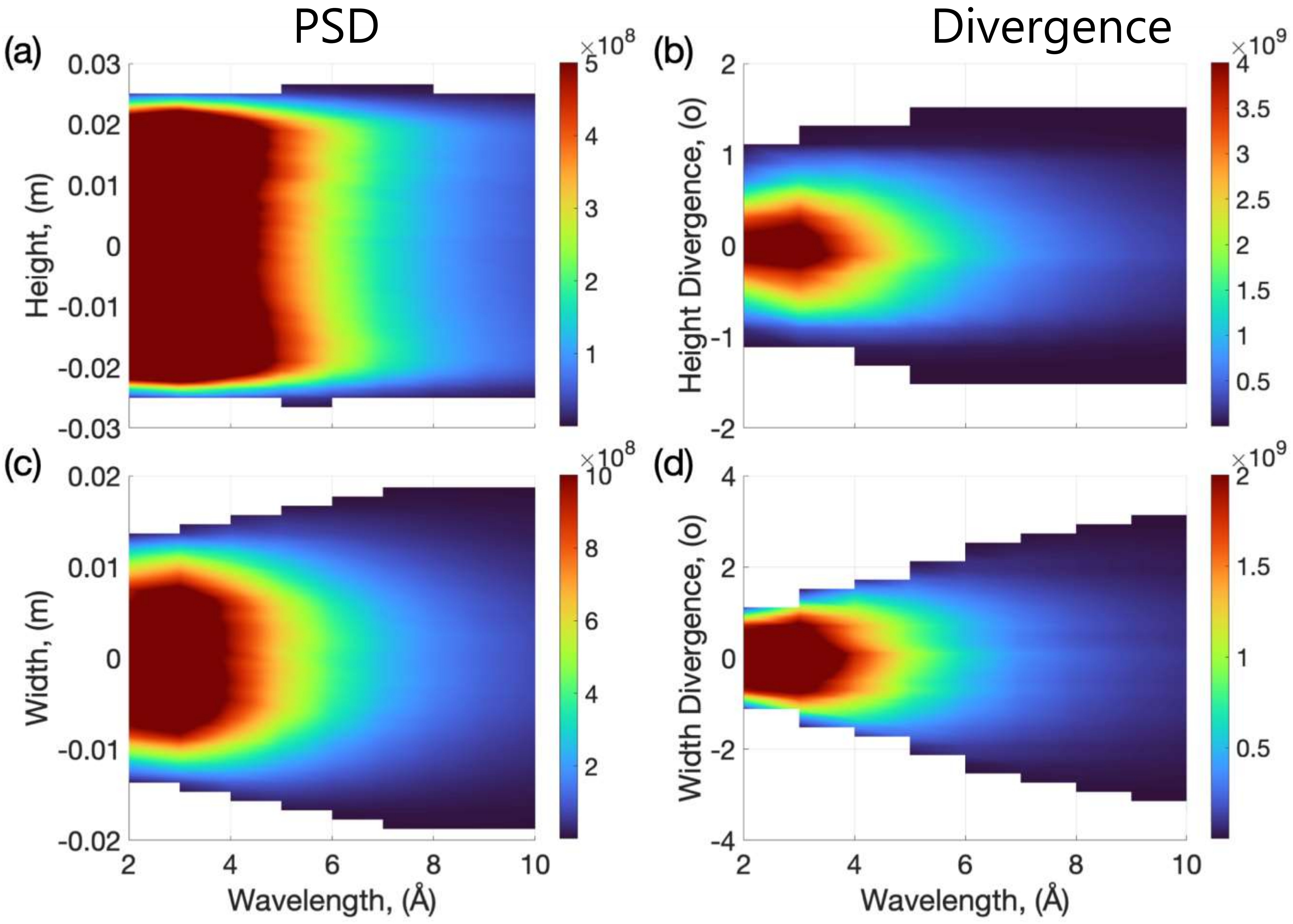
- **Signal to noise = 10^5 (@5 Å, Vanadium).**
- **Optimise to cold moderator.**
- **2 x LOS (Prompt pulse)**





CSPEC Guide (McStas)

Positional & divergence coverage (**4 x 2 cm²**). Tapered guide
Clean divergence profiles

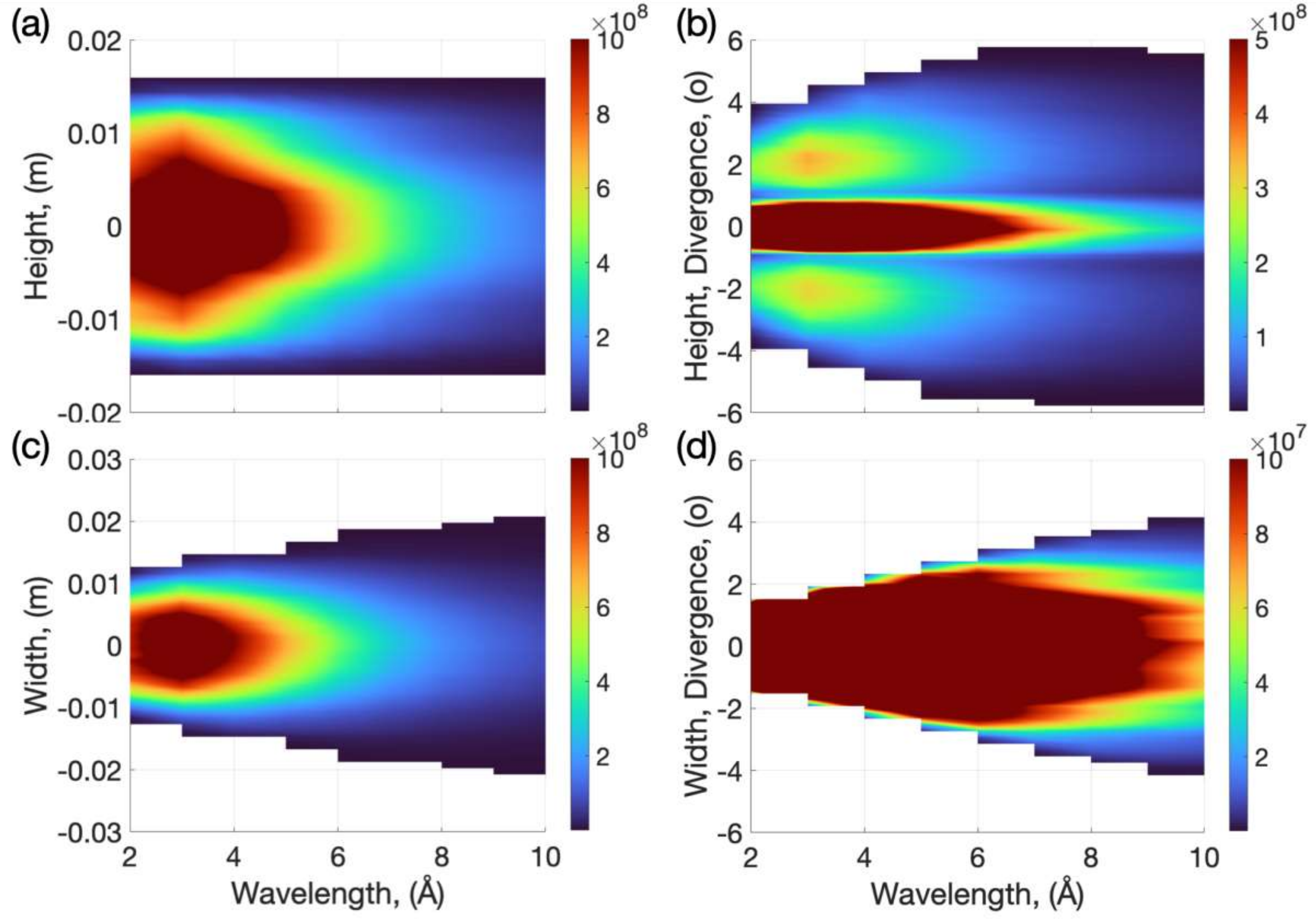


PSD < 10 % variation across 4 x 2 cm^2

Horizontally, the beam divergence extends to 1^o for λi < 4 Å, 1.5^o for λi > 4 Å.

CSPEC Guide (McStas)

Positional & divergence coverage (**1 x 1 cm^2**): elliptical guides x 2.5 in flux for 2 Å< λ < 10Å.

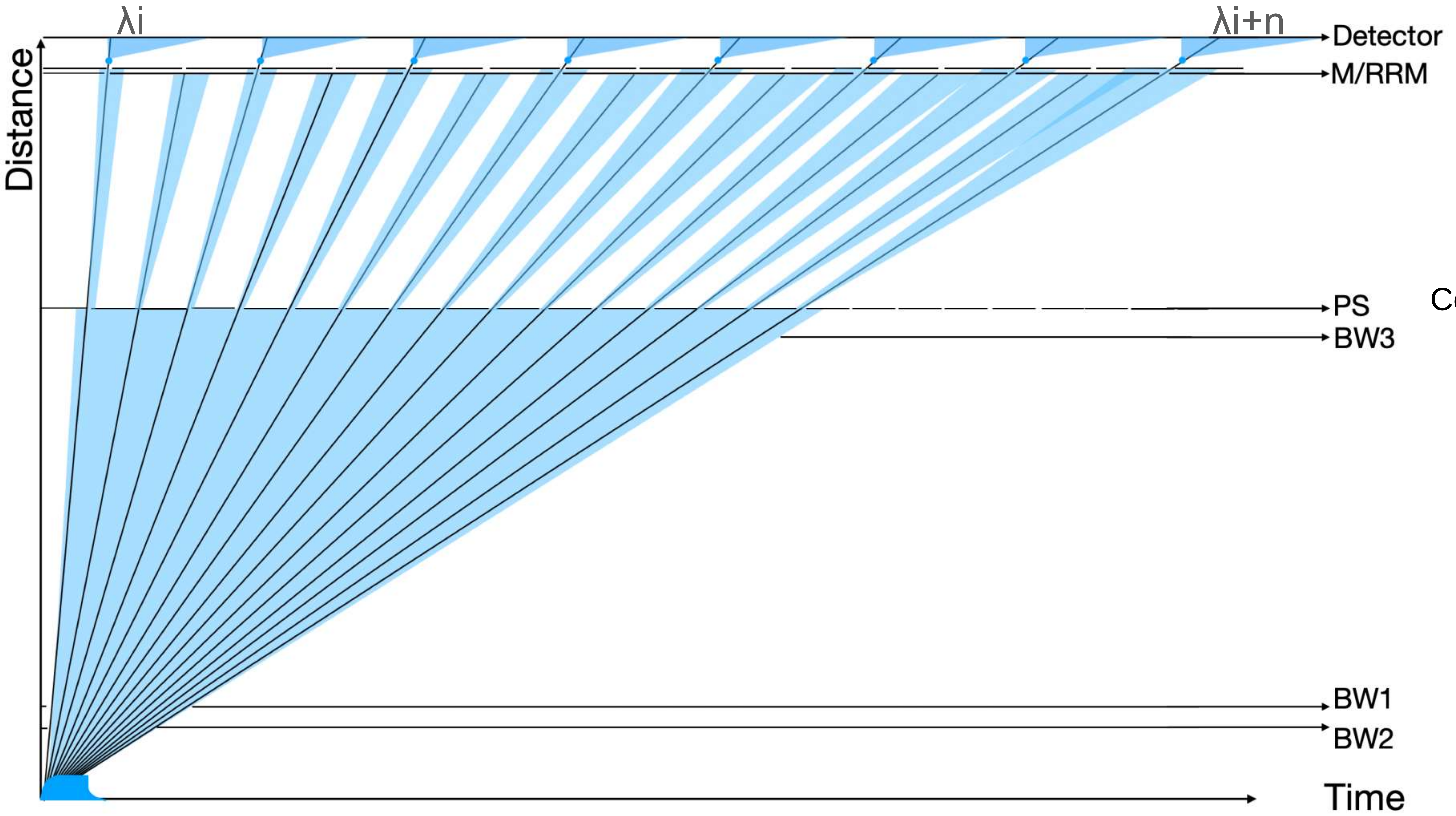


PSD < 10 % variation across 1 x 0.7 cm^2.

Divergence increases linearly from 1^o for lambda = 3 Å and 3^o for λ =10 A (width)
Structure in divergence in vertical direction / consider experimental conditions.

Chopper cascade

- Cold neutrons (2-20 Ang) with ∆E/E = 1.5 % @ 4 Å (Ei, ∆E = ∞ < E_i < 0.2E_i).
- Long pulse source: spallation with reactor source incident pulse

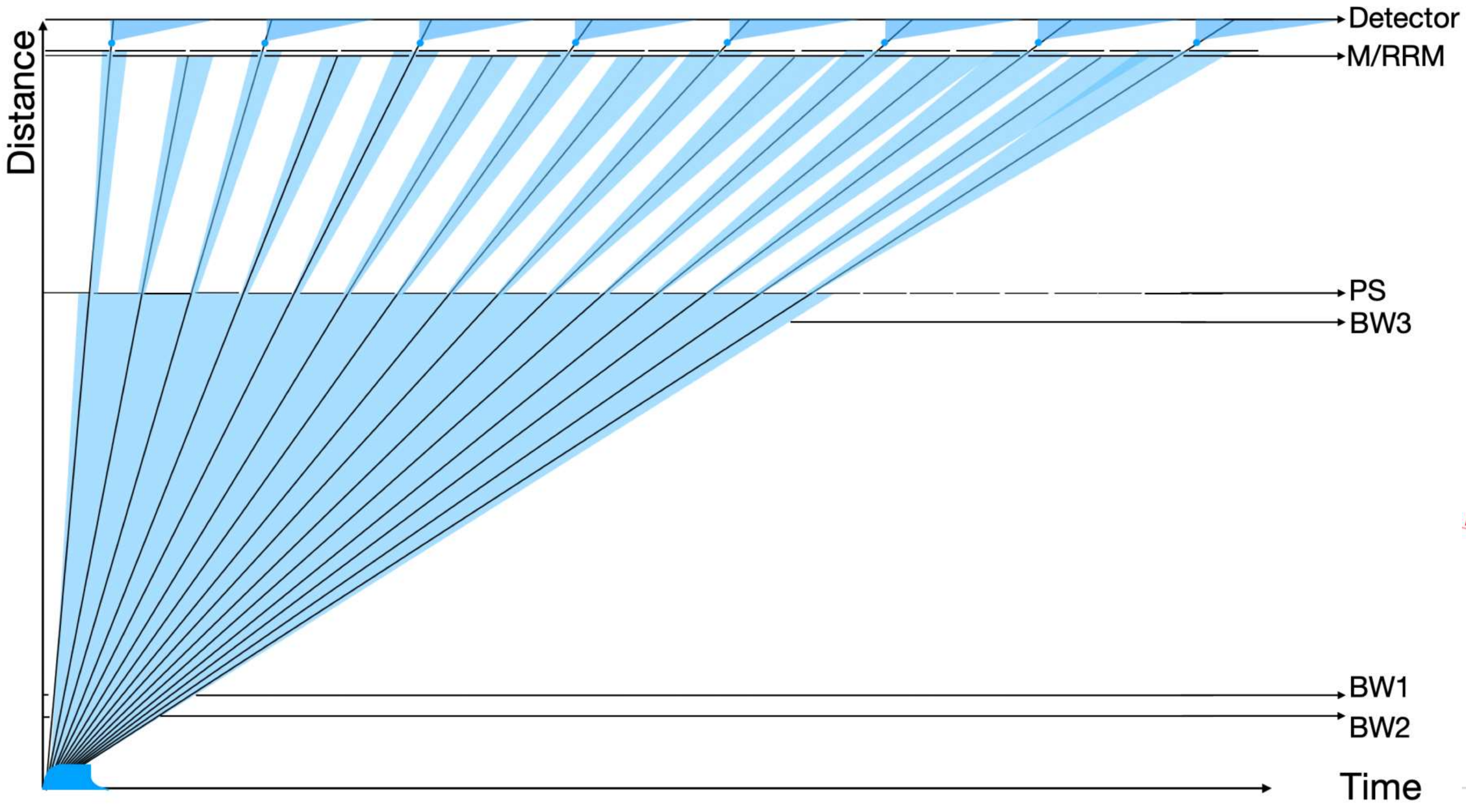


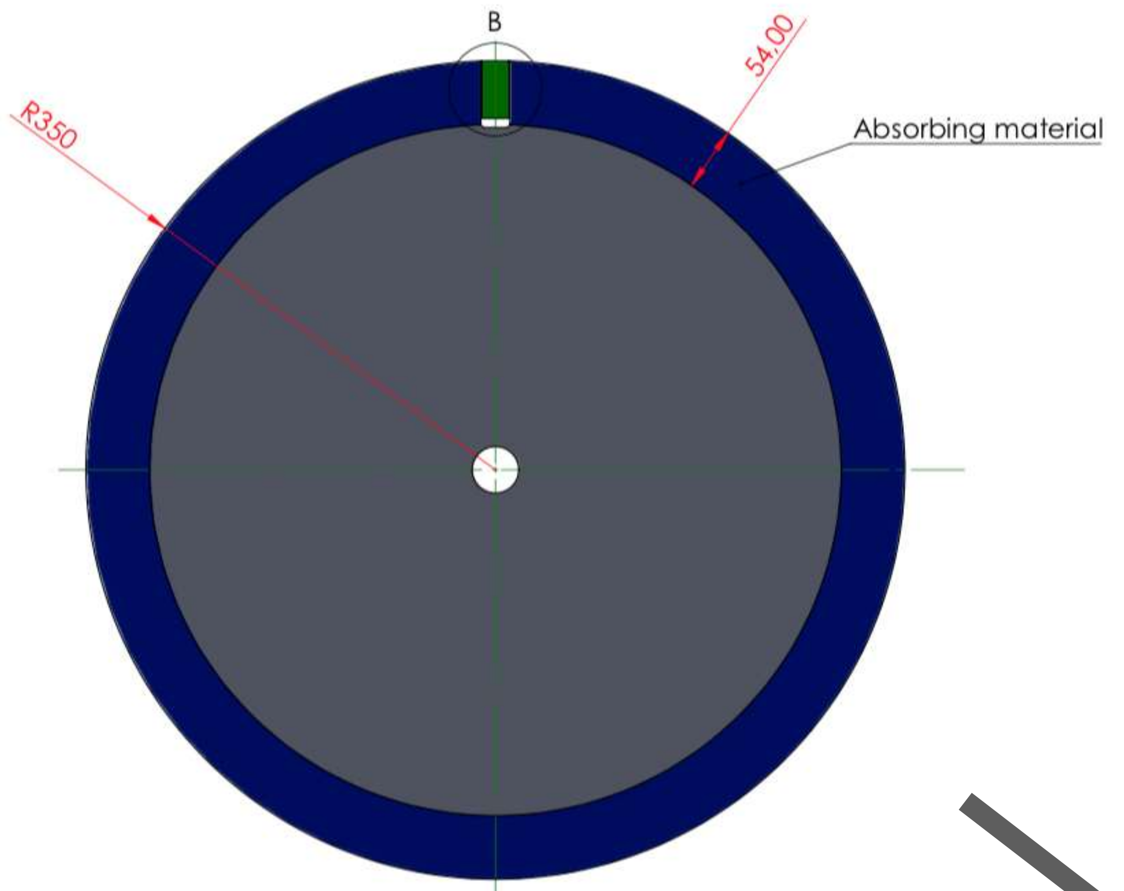
Counter Rotating (14*24 Hz)

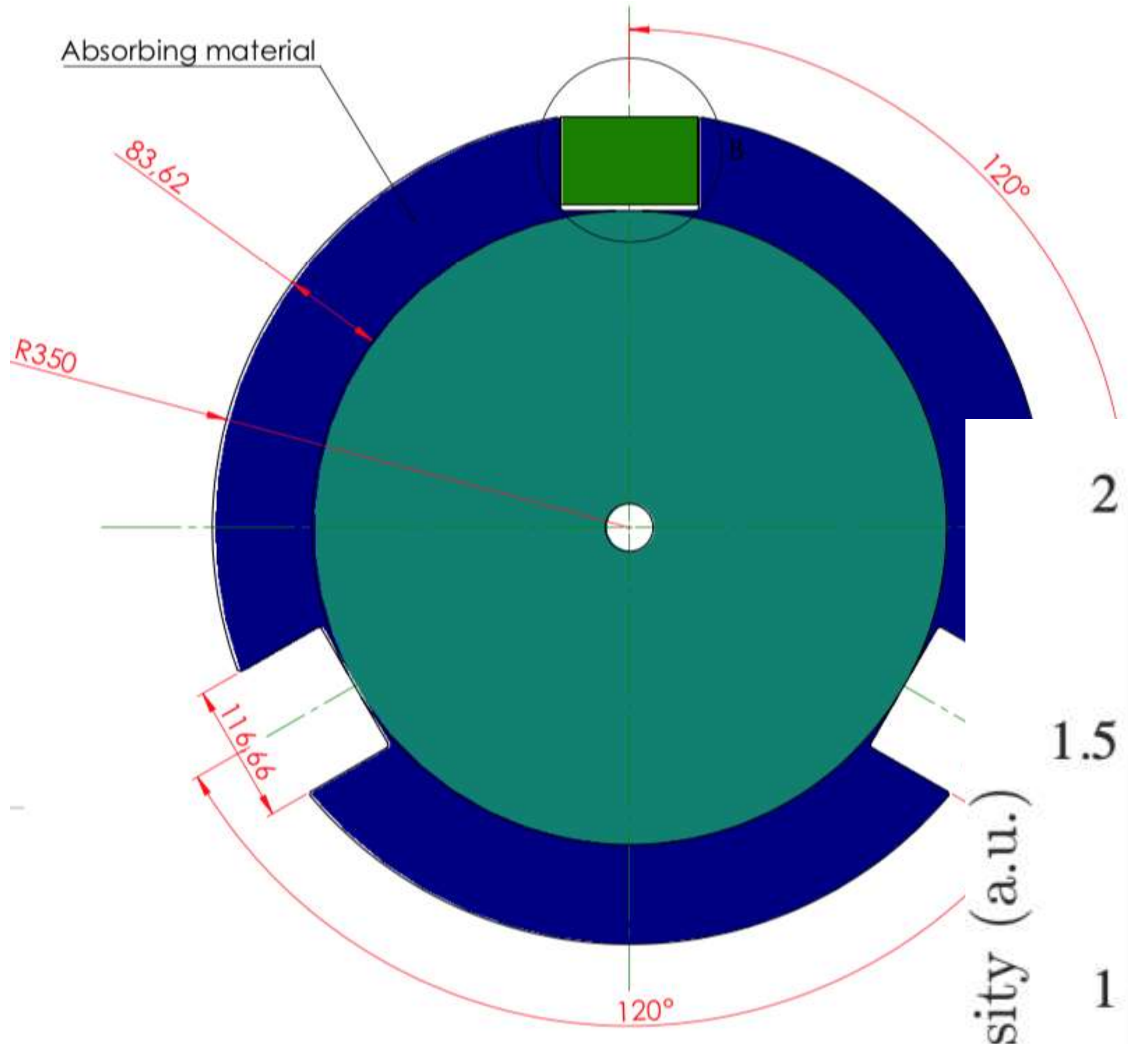
Counter Rotating (14*24/2 Hz)

Chopper cascade: high speed choppers

Fmax: 336 Hz, 20160 RPM.



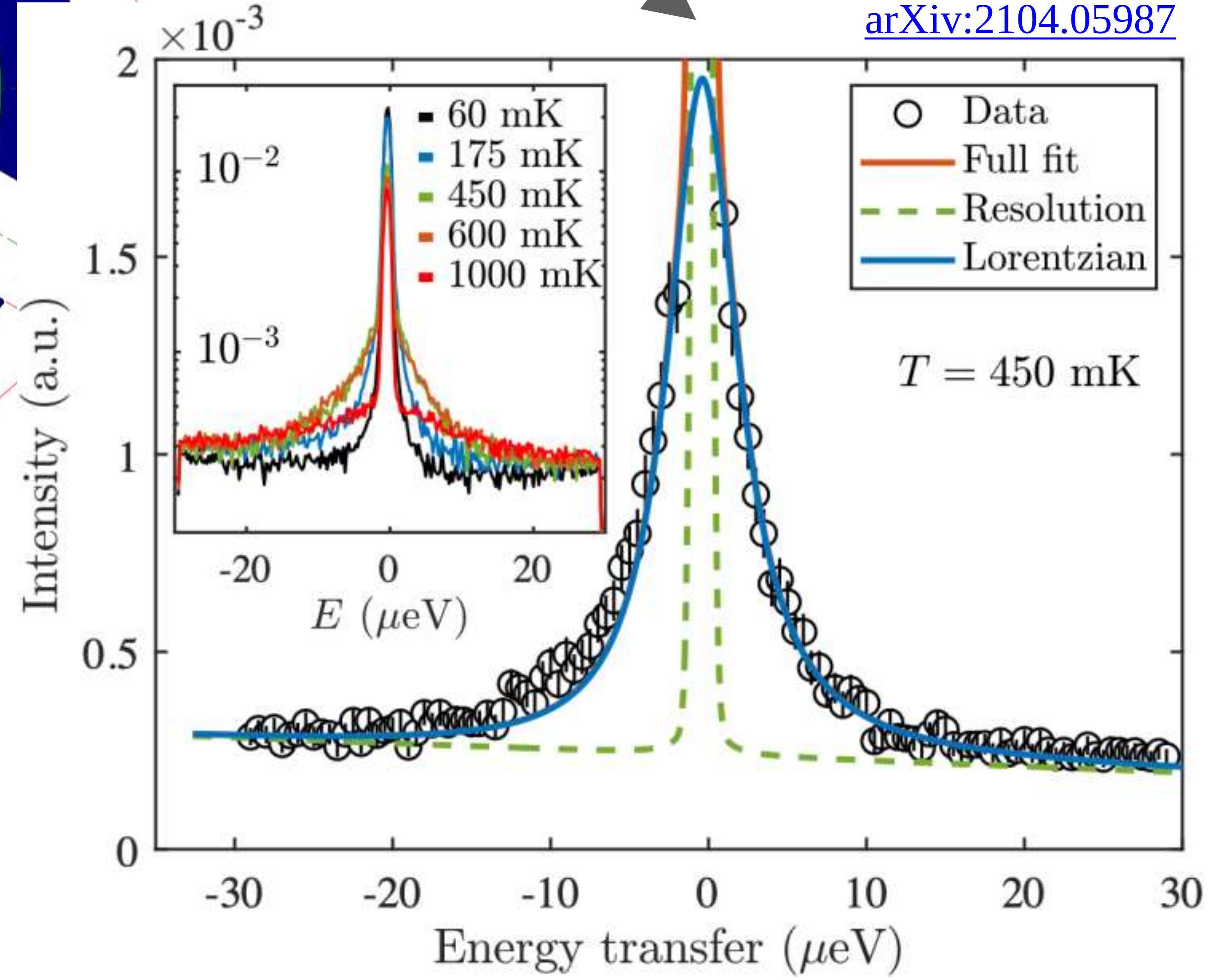




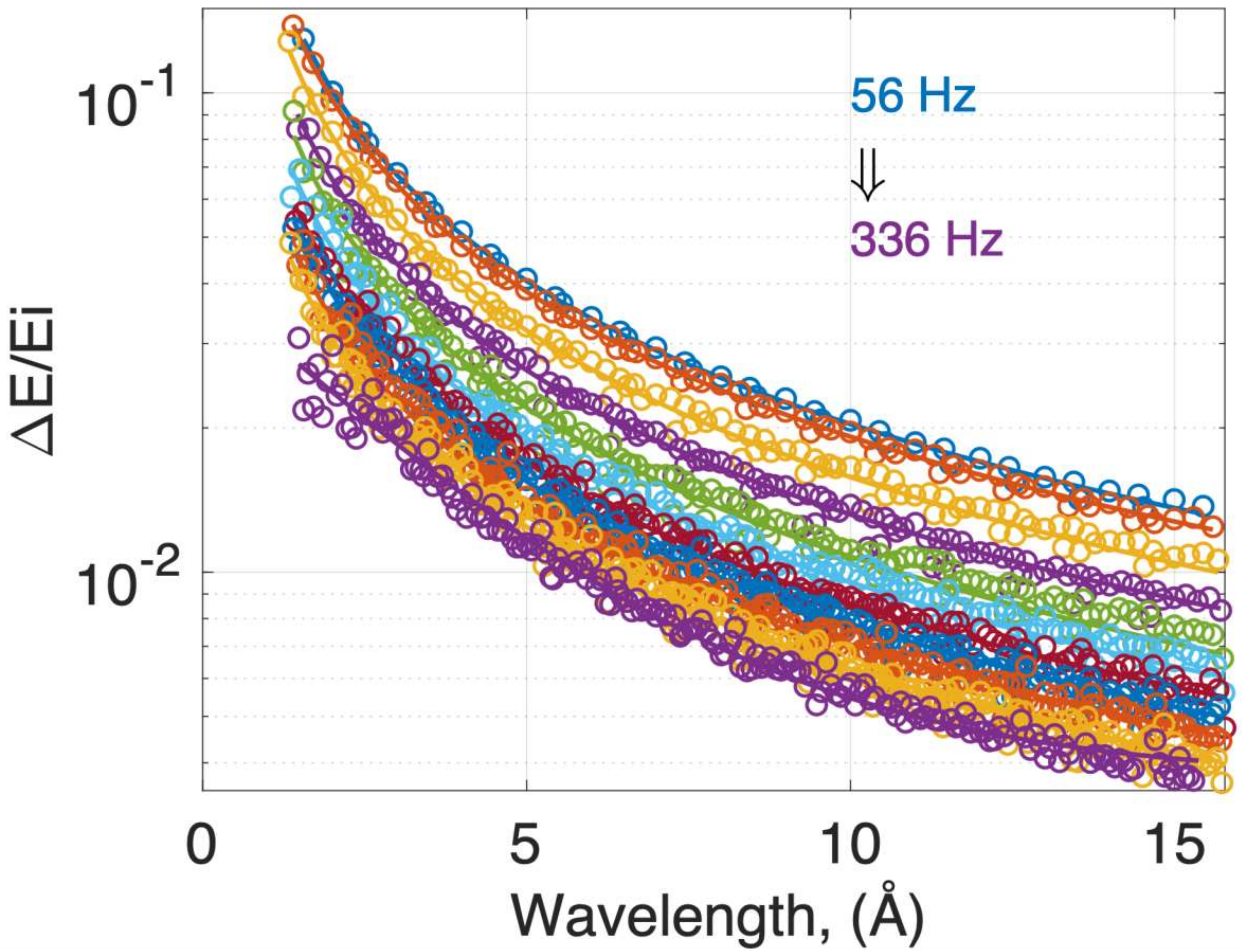
FWHM = 80 µeV @ 4 Å

FWHM = 6 µeV @ 10 Å

arXiv:2104.05987



Elastic energy resolution across Δλ = 1.7 Å.



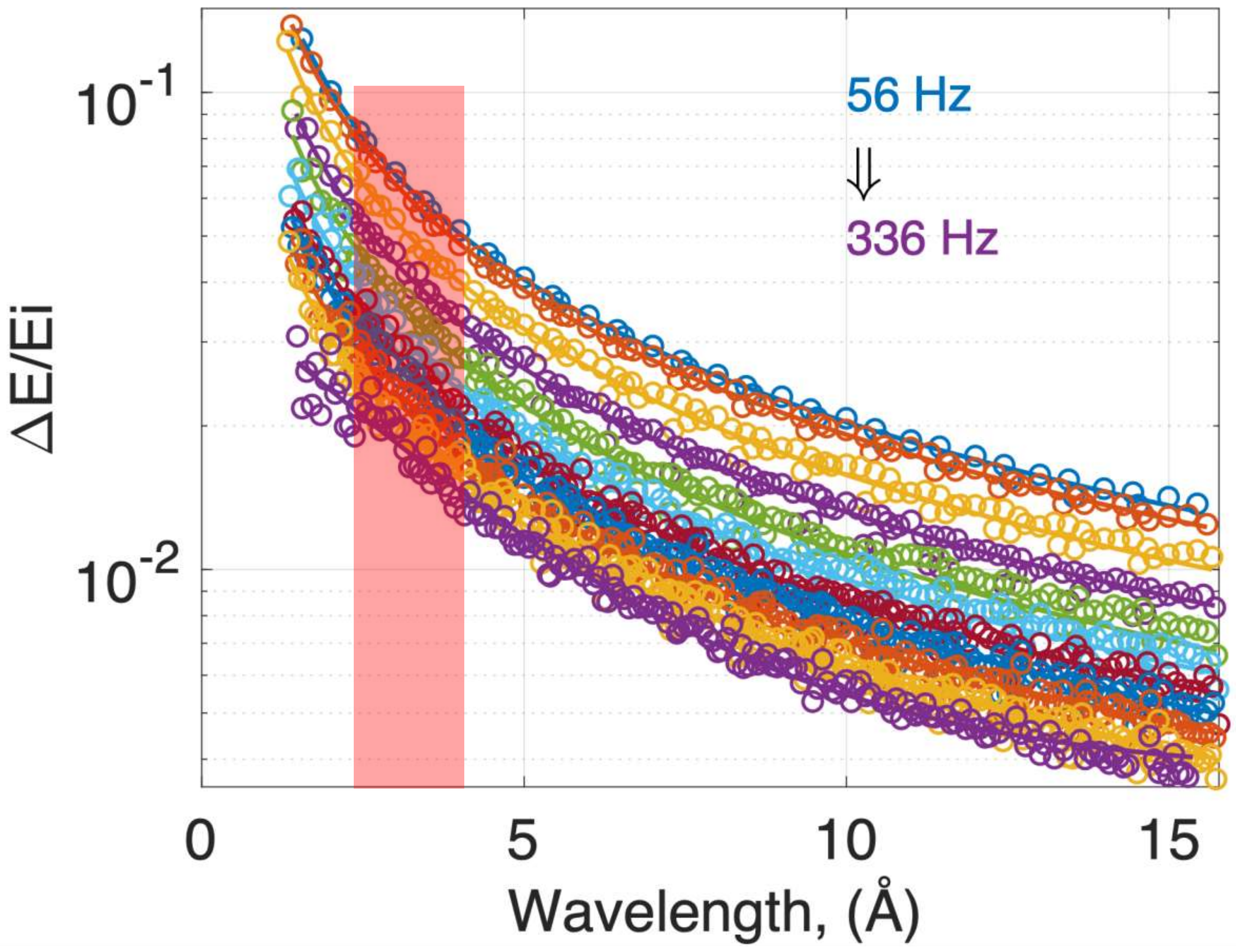
Across accessible bandwidth (1.72 Å)

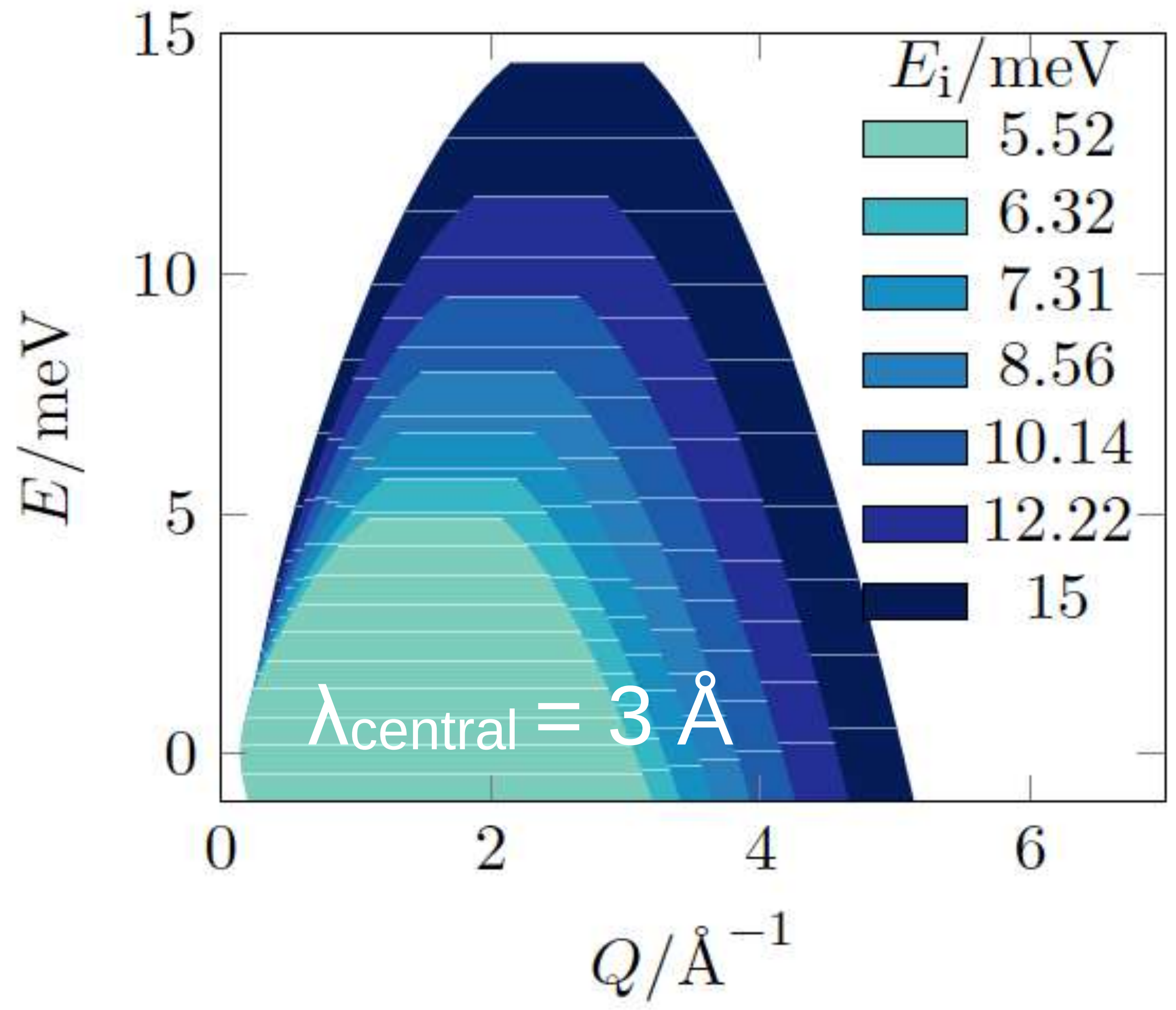
3Å = 0.023 < ΔE/E < 0.039

8Å = 0.01 < ΔE/E < 0.012

Add pulses, gain flux, if possible.

Elastic energy resolution across Δλ = 1.7 Å.





(b) $5.52 \leq E_i \leq 15$ meV

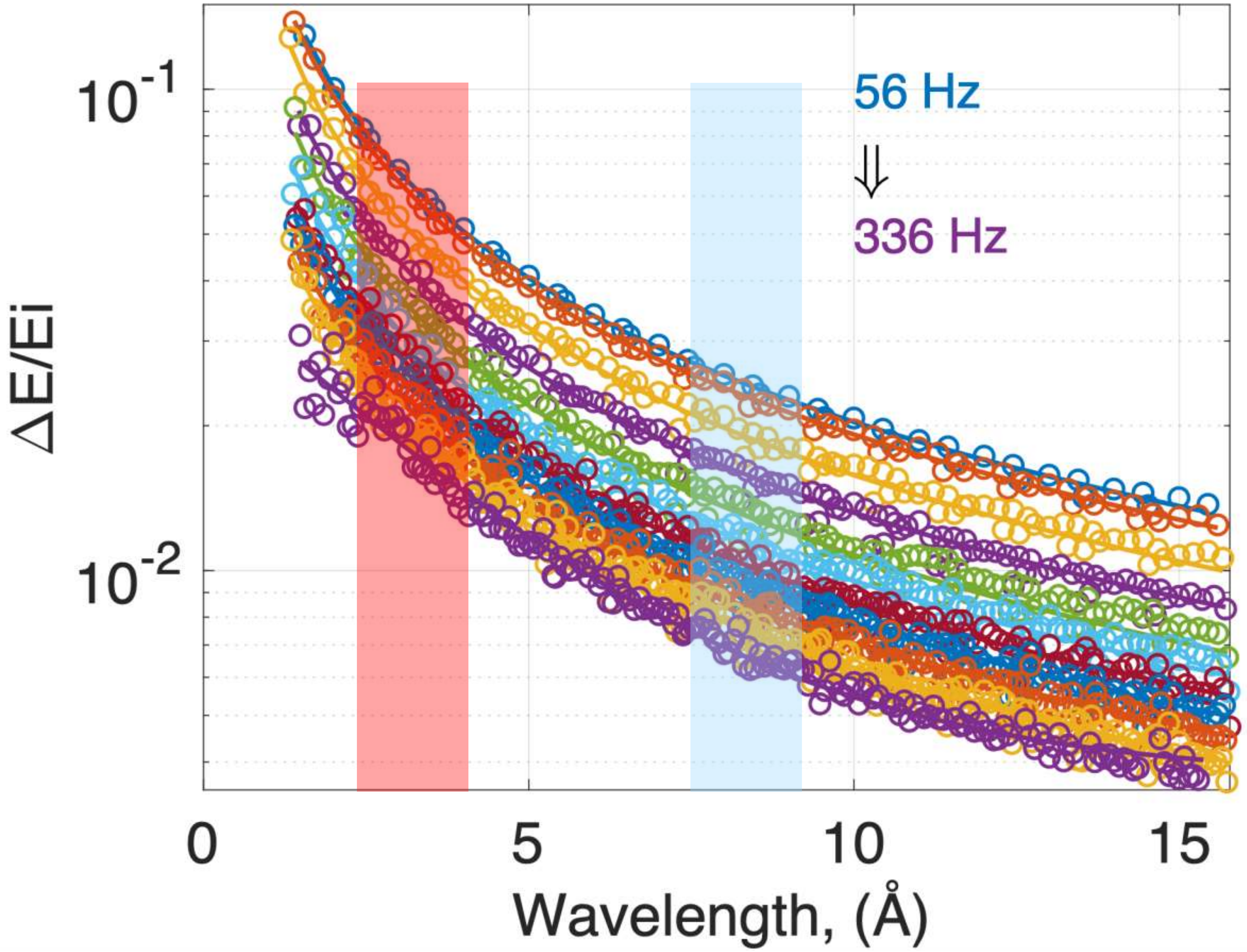
Across accessible bandwidth (1.72 Å)

3Å = 0.023 < ΔE/E < 0.039

8Å = 0.01 < ΔE/E < 0.012

Add pulses, gain flux, if possible.

Elastic energy resolution across Δλ = 1.7 Å.

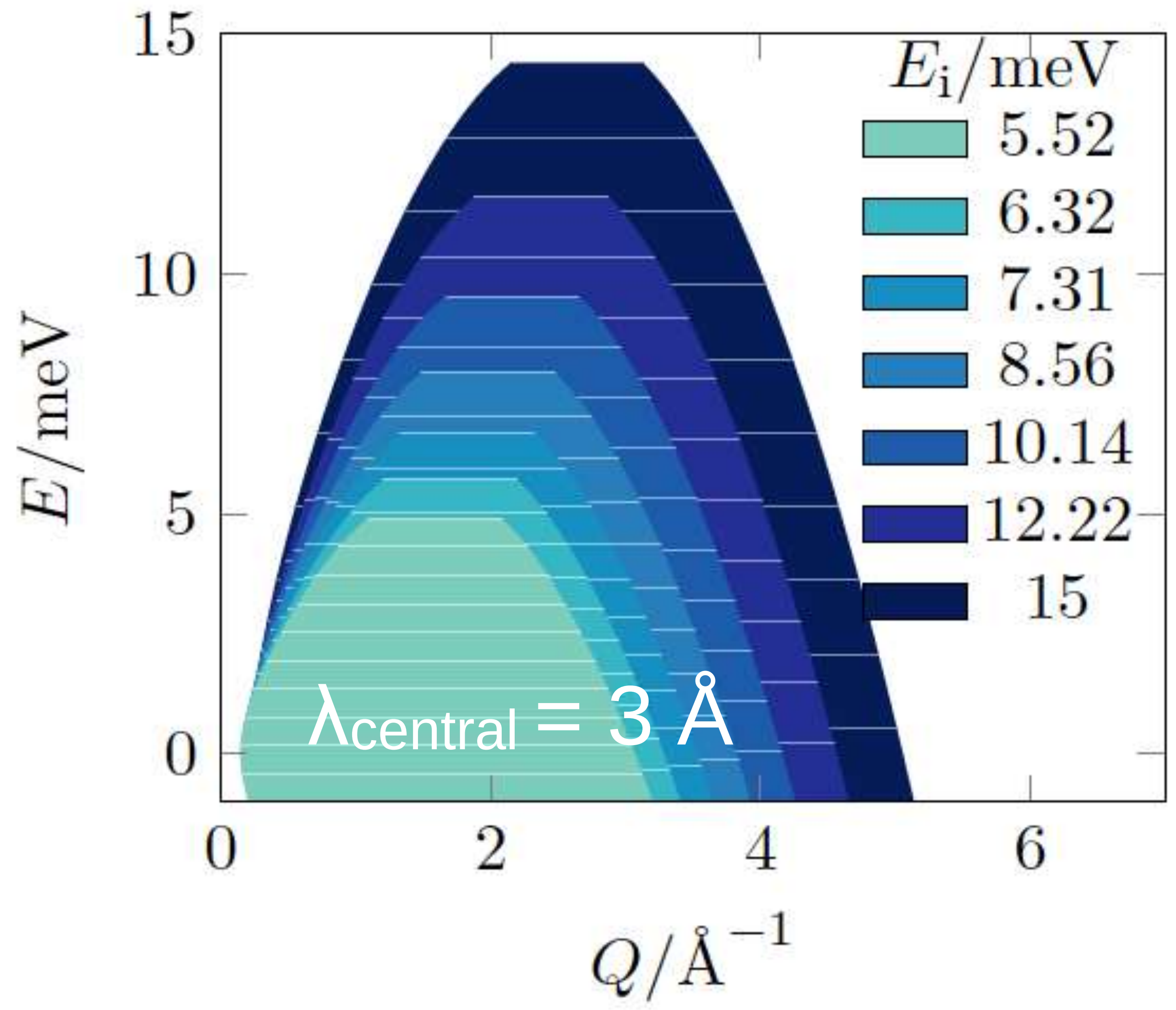


Across accessible bandwidth (1.72 Å)

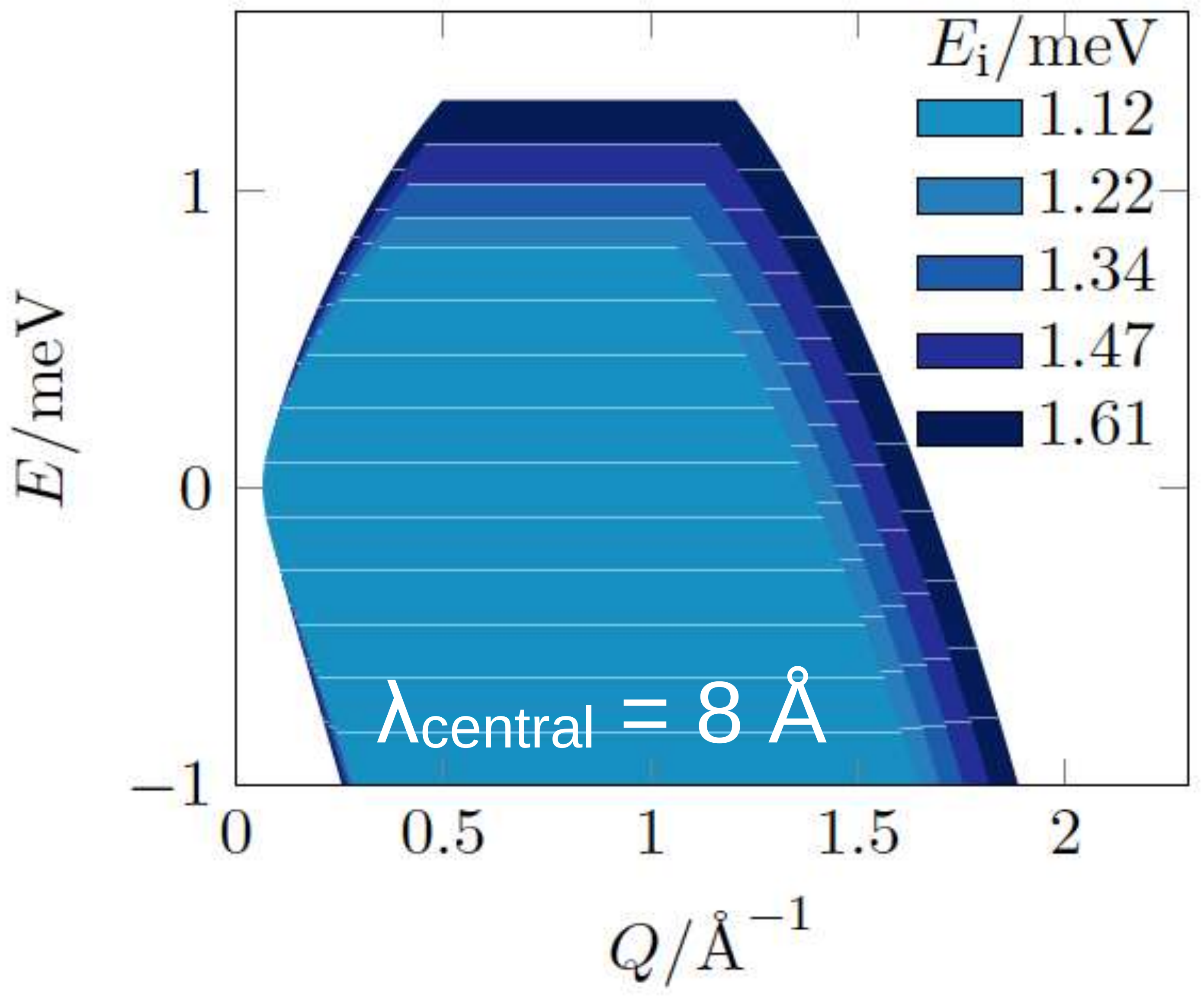
3Å = 0.023 < ΔE/E < 0.039

8Å = 0.01 < ΔE/E < 0.012

Add pulses, gain flux, if possible.



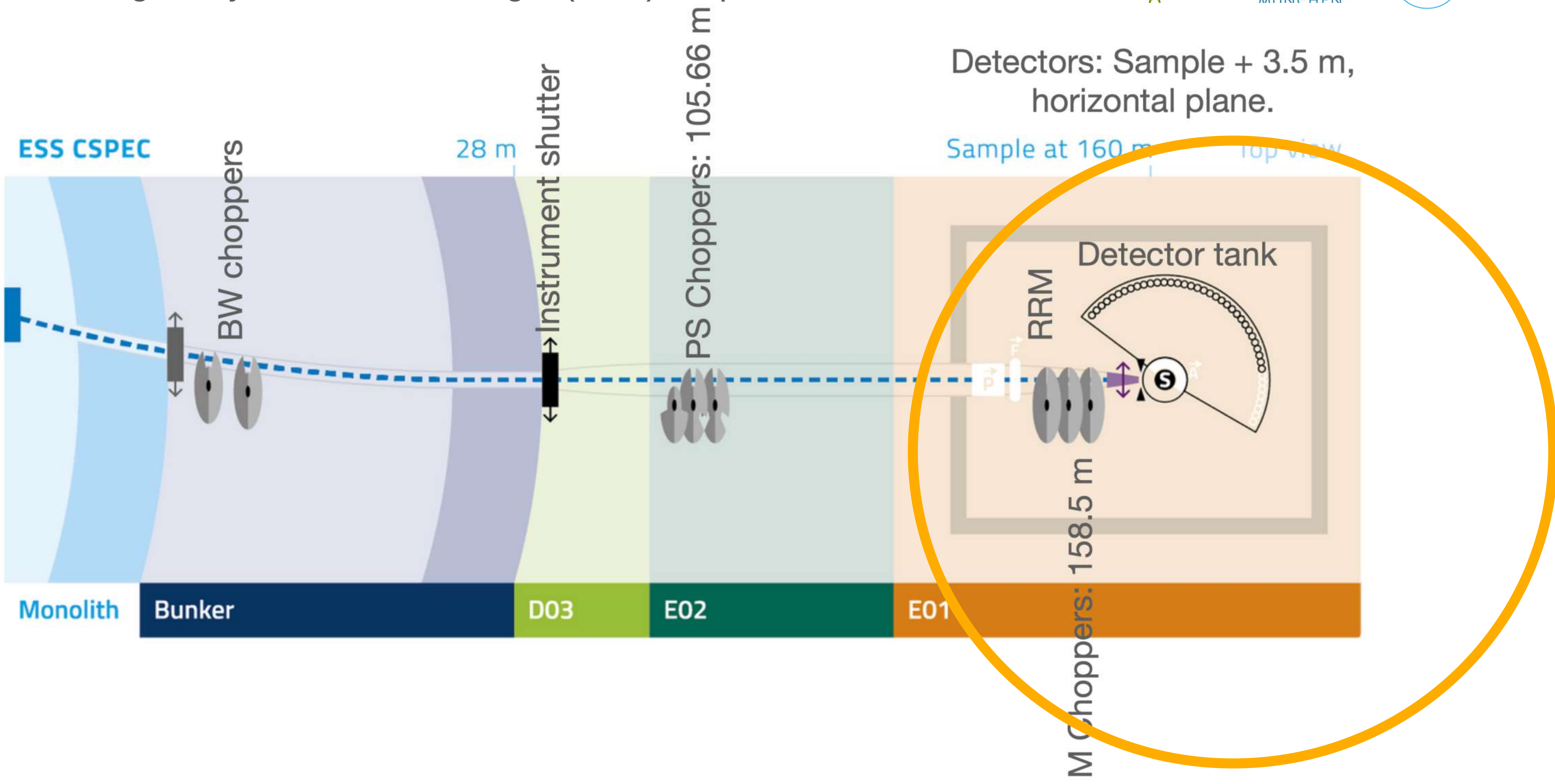
(b) $5.52 \leq E_i \leq 15$ meV



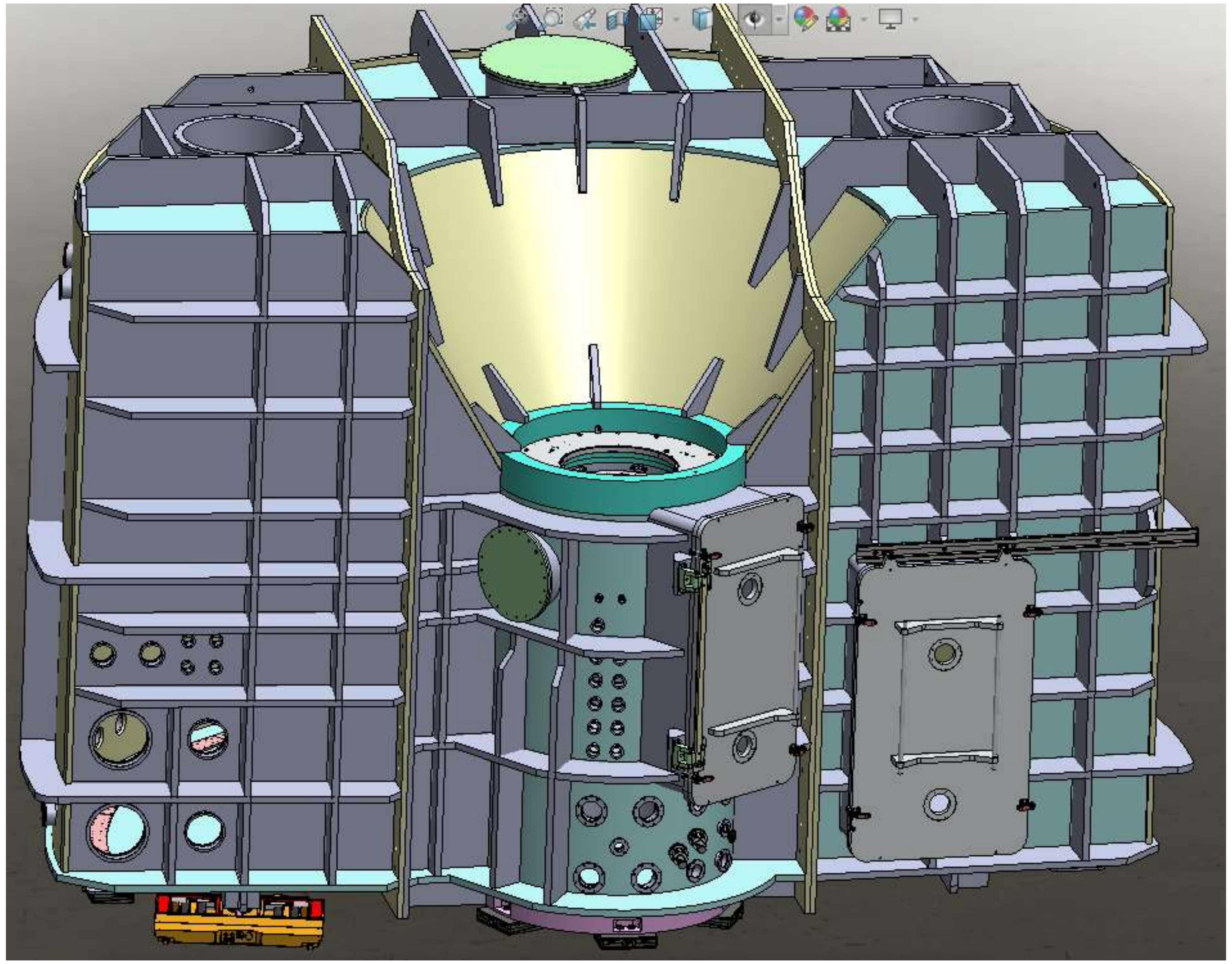
(a) $1.12 \leq E_i \leq 1.61$ meV

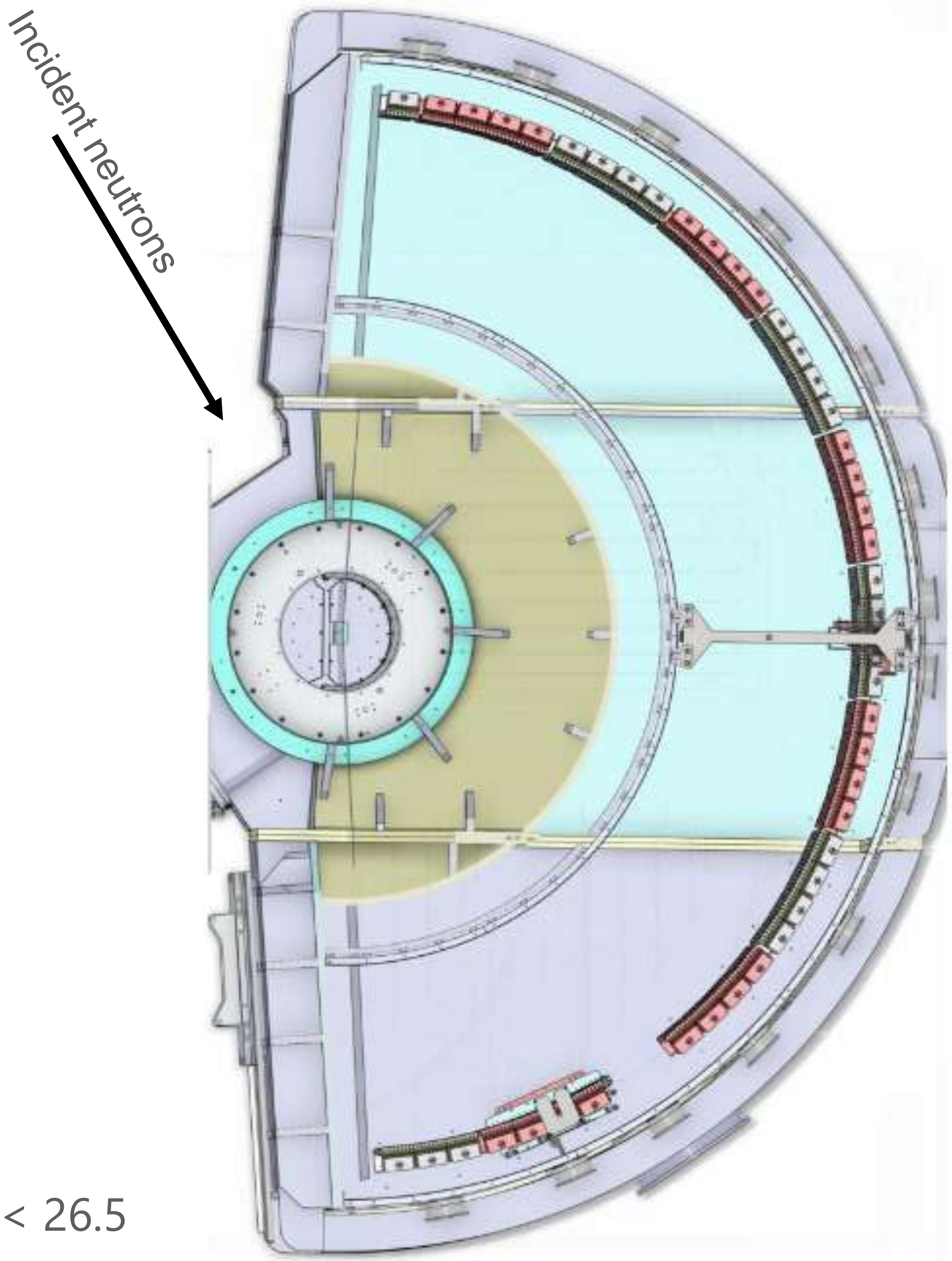
CSPEC Overview

Hot commissioning ready for Beam on Target (BOT), September 2023.



Secondary spectrometer
Detector tank





Incorporate:

(a)Guide exchanger (4x2 - 1x1 cm^2)

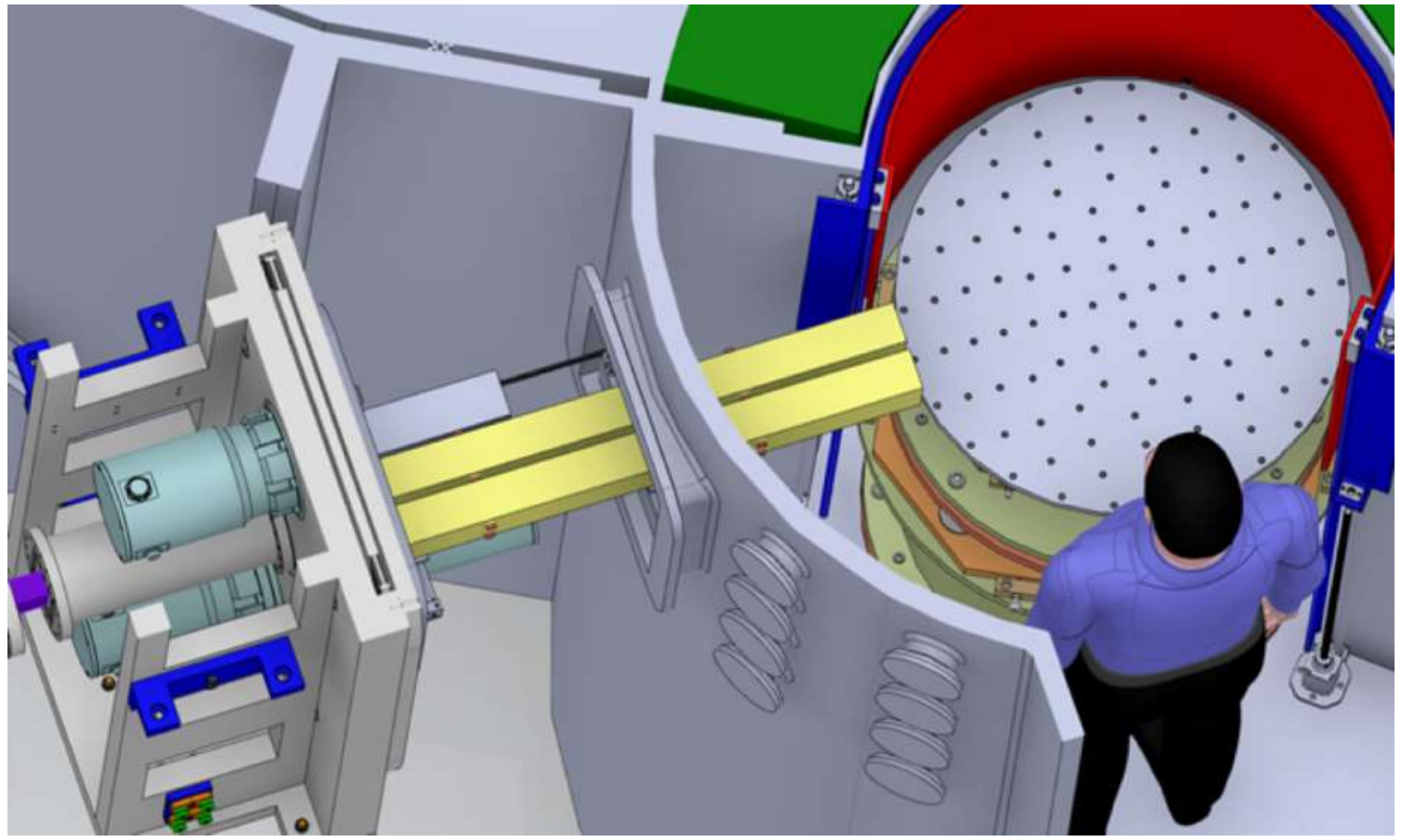
(b)Gate valve

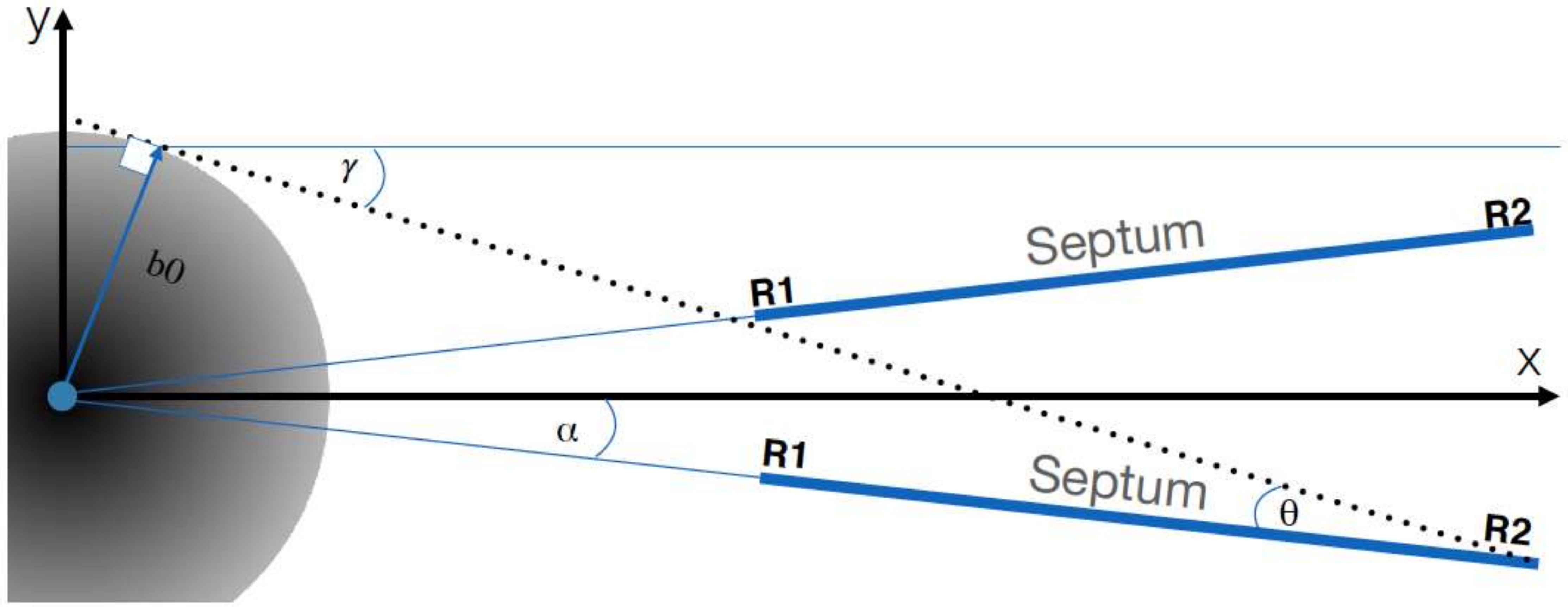
(c)Radial Oscillating collimator

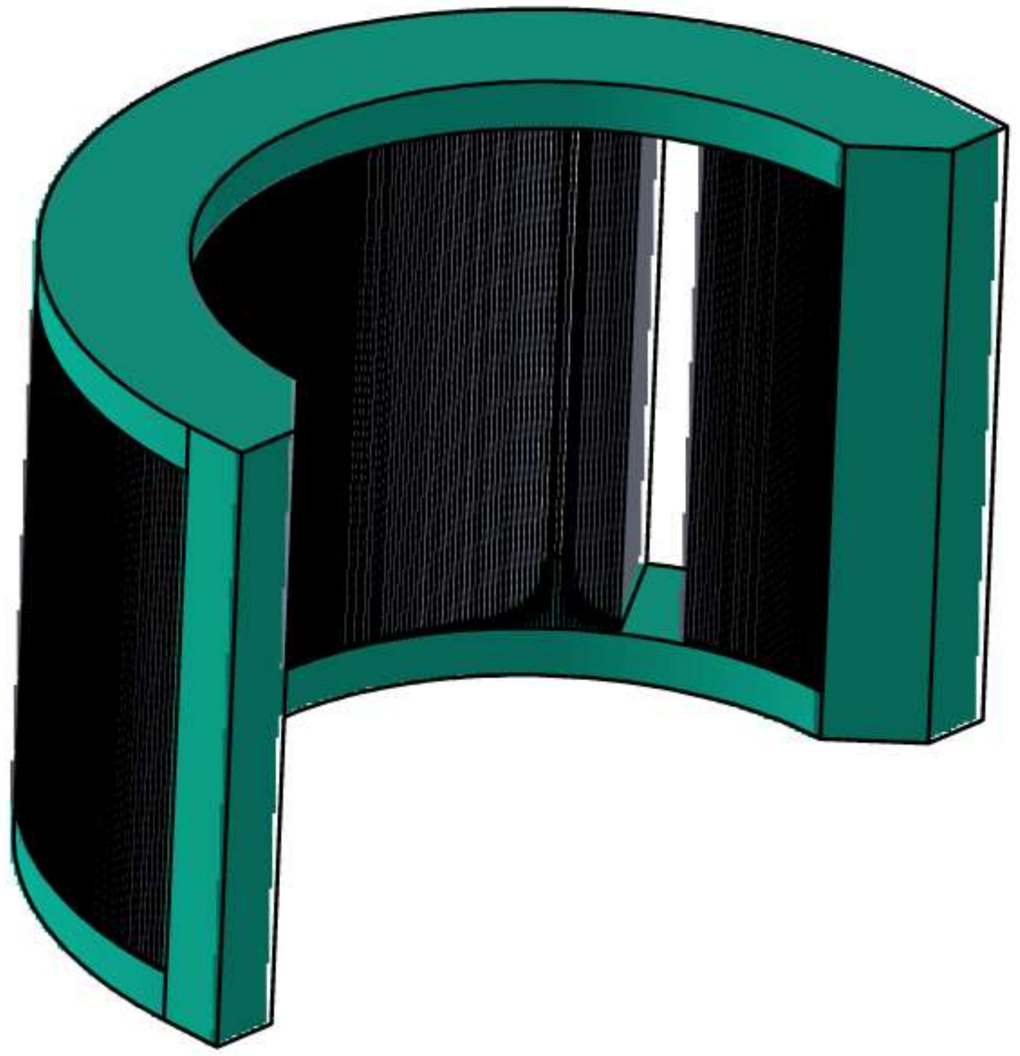
(d)Detector collimation vanes

(e)3He detectors $-30 < 2\theta < 140$ (H), $-26.5 < 2\theta < 26.5$

Secondary spectrometer
Radial collimator



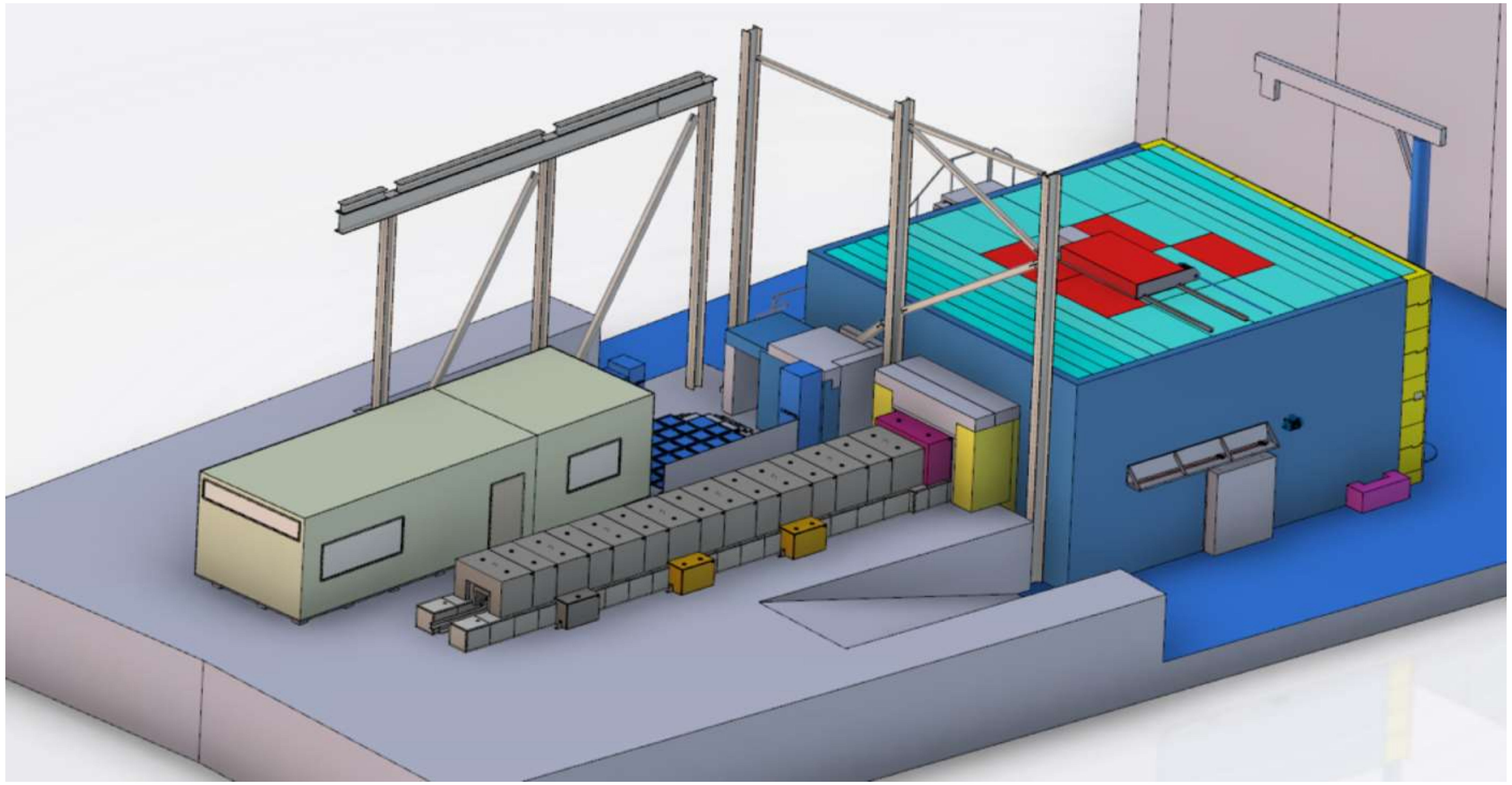




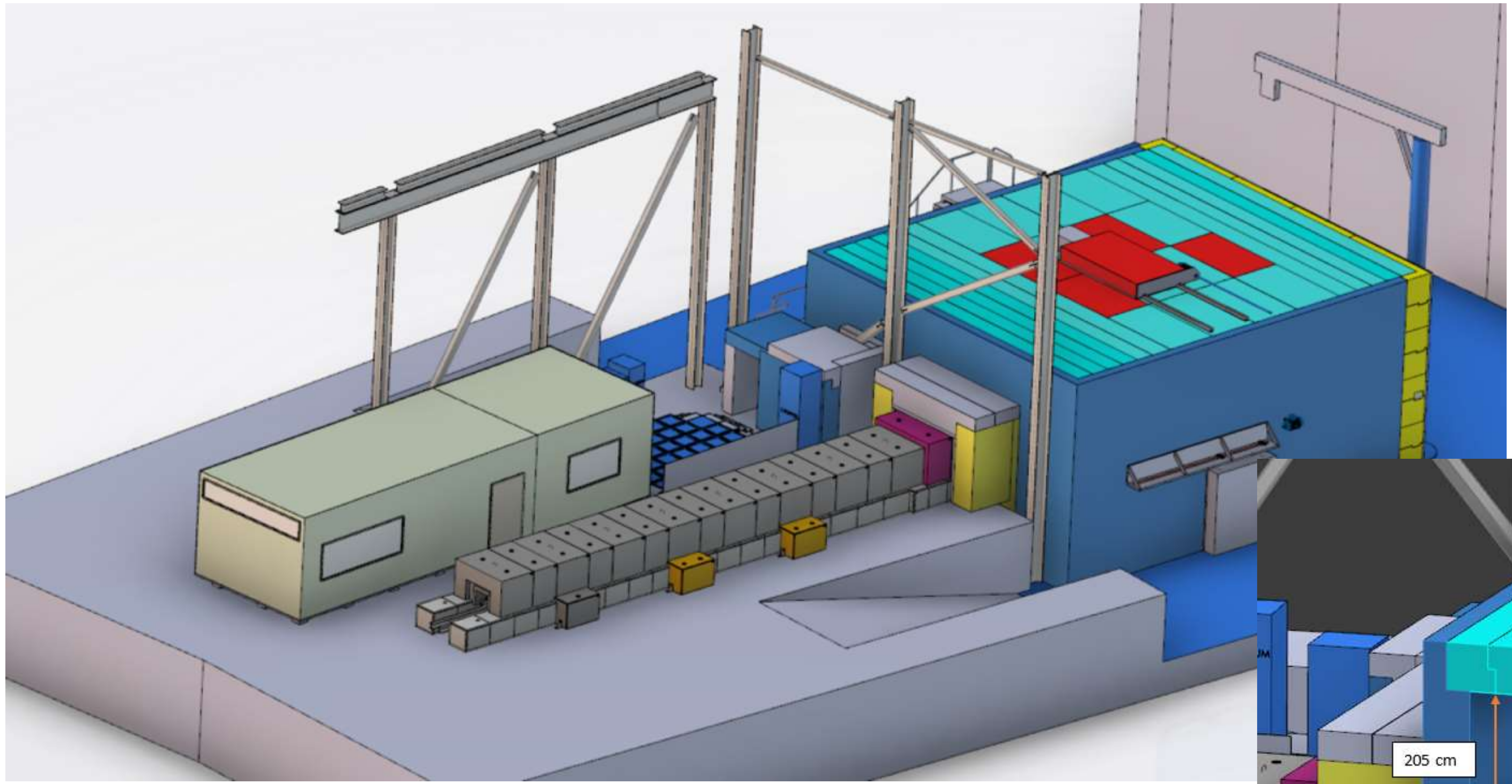
$R1$	$R2$	2α	$2b_0$	γ ^{o}
504 mm	708 mm	0.8 ^{o}	48.85 mm	2.38 ^{o}

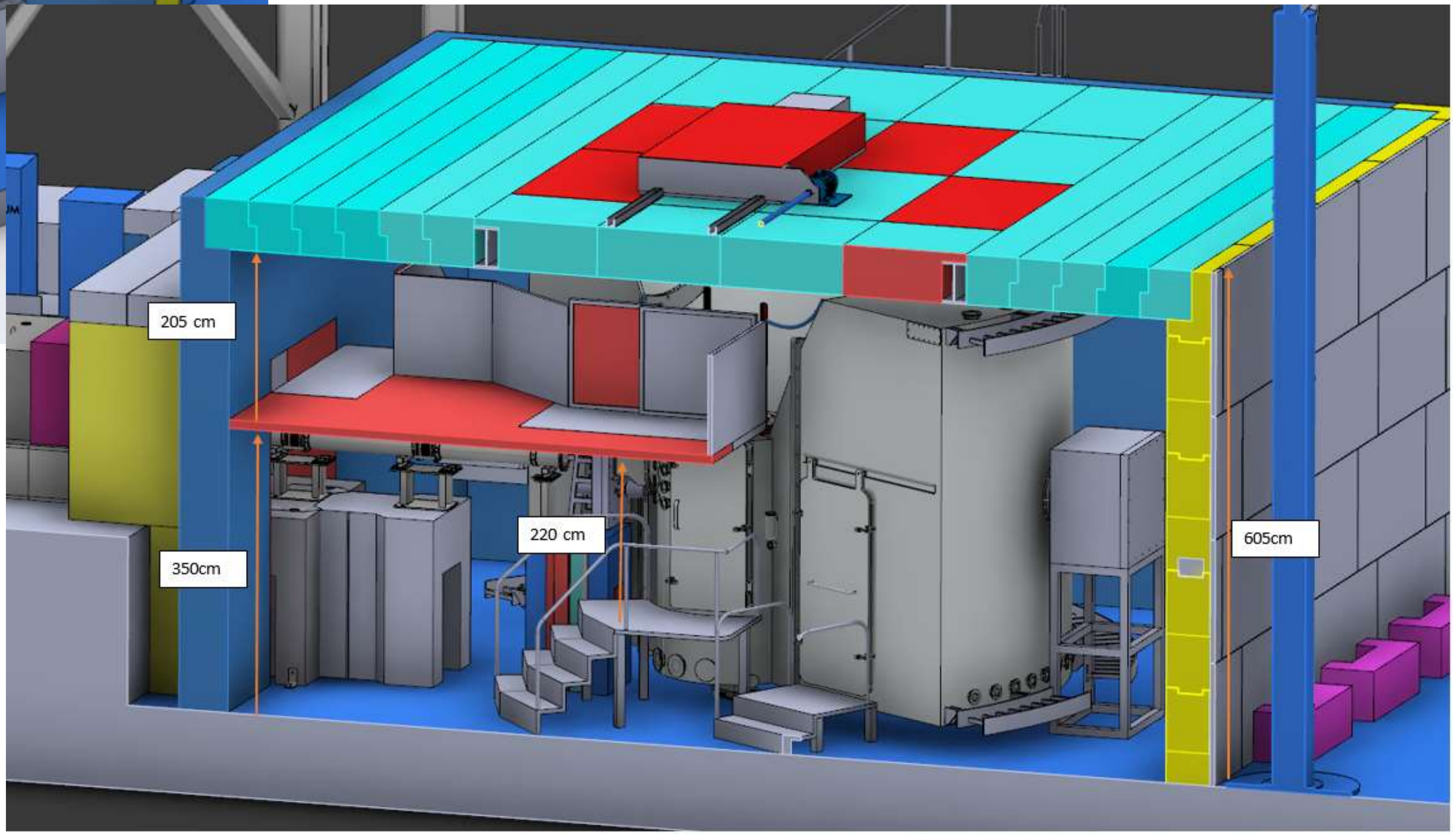
TABLE III. CSPEC radial collimator parameters.

Cave and control cabin



Cave and control cabin



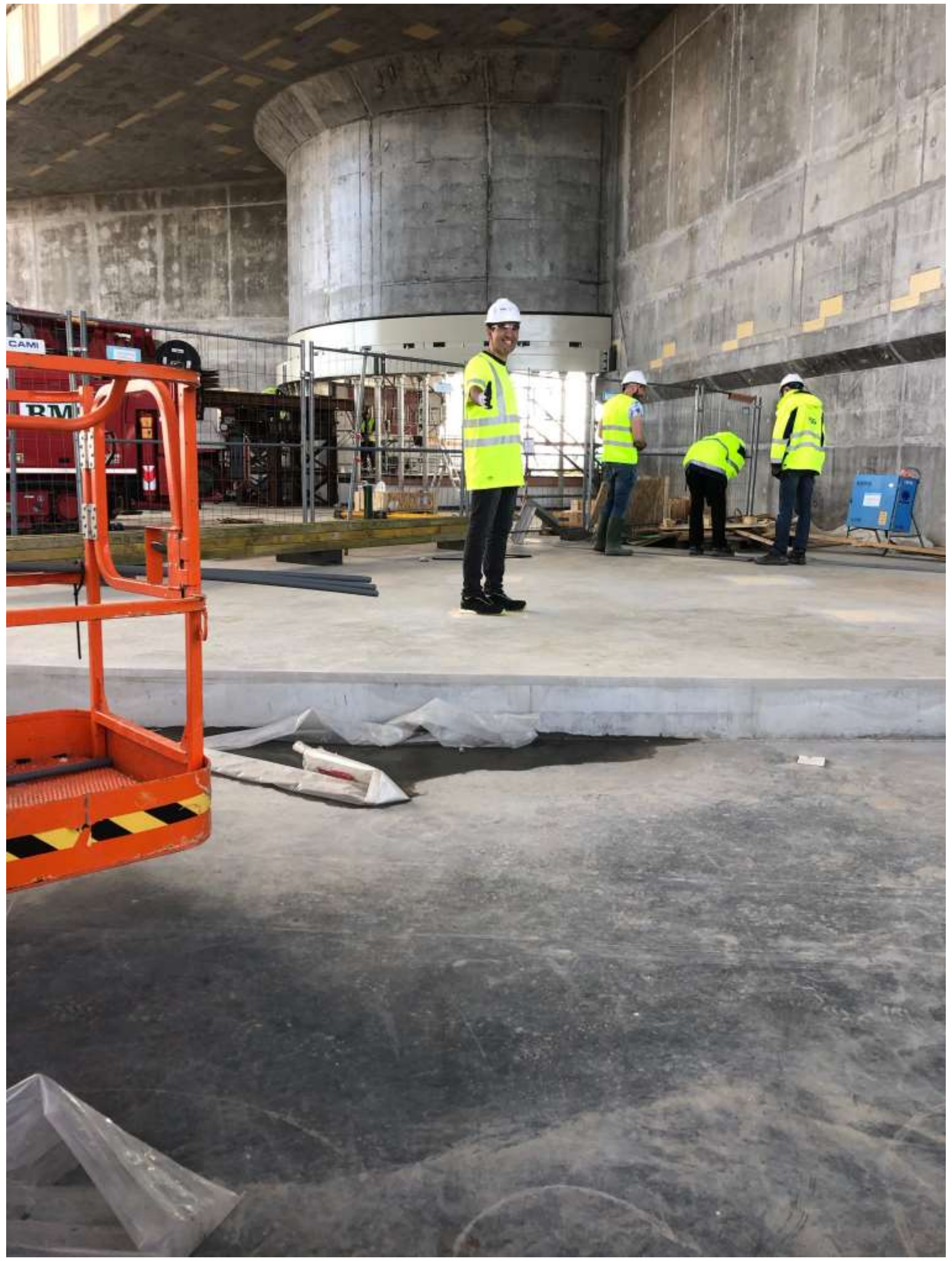


Some reality

CSPEC – HAll E01 – 160 m from moderator

Target and bunker area

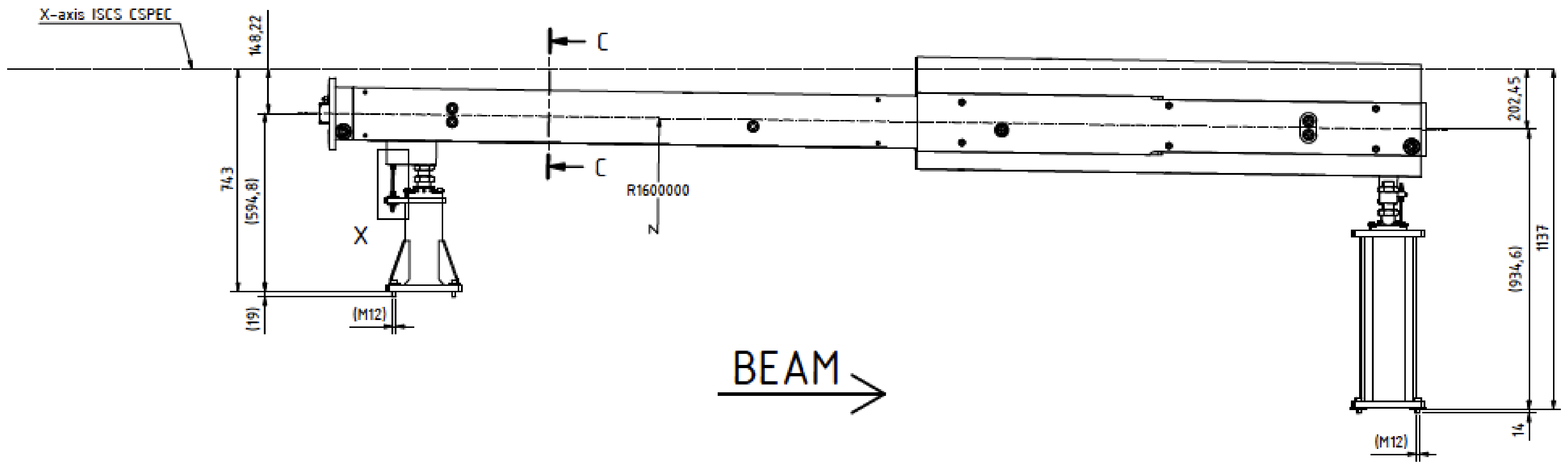
April 2020

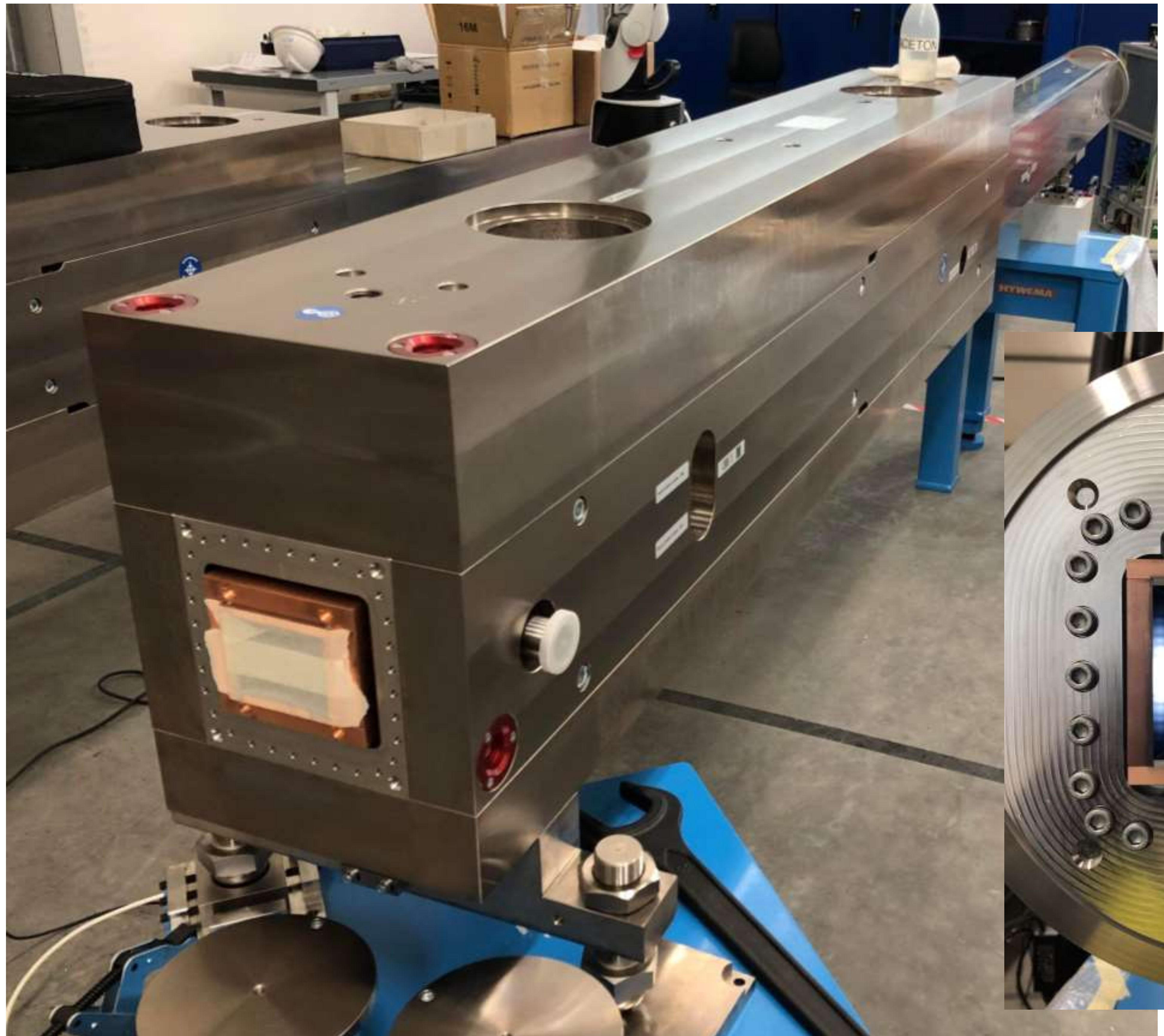


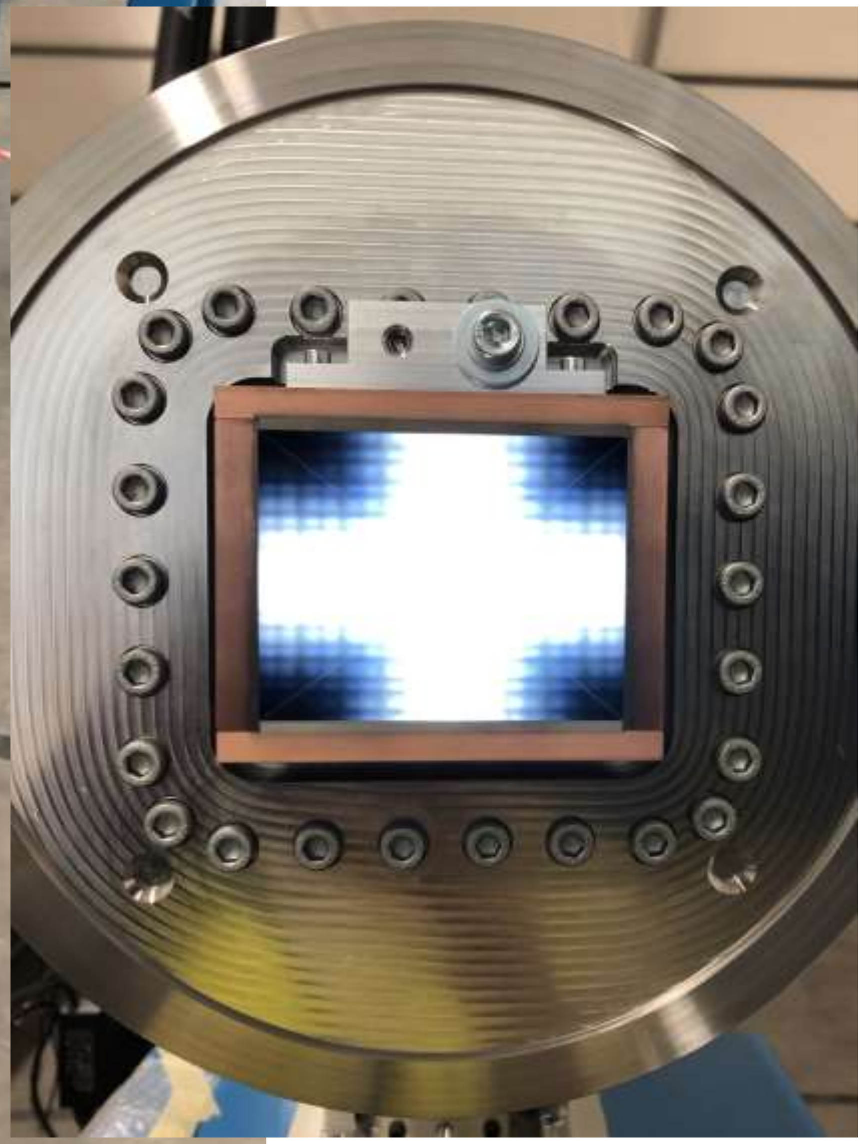
Bunker wall

April 2021

Bunker wall feedthrough

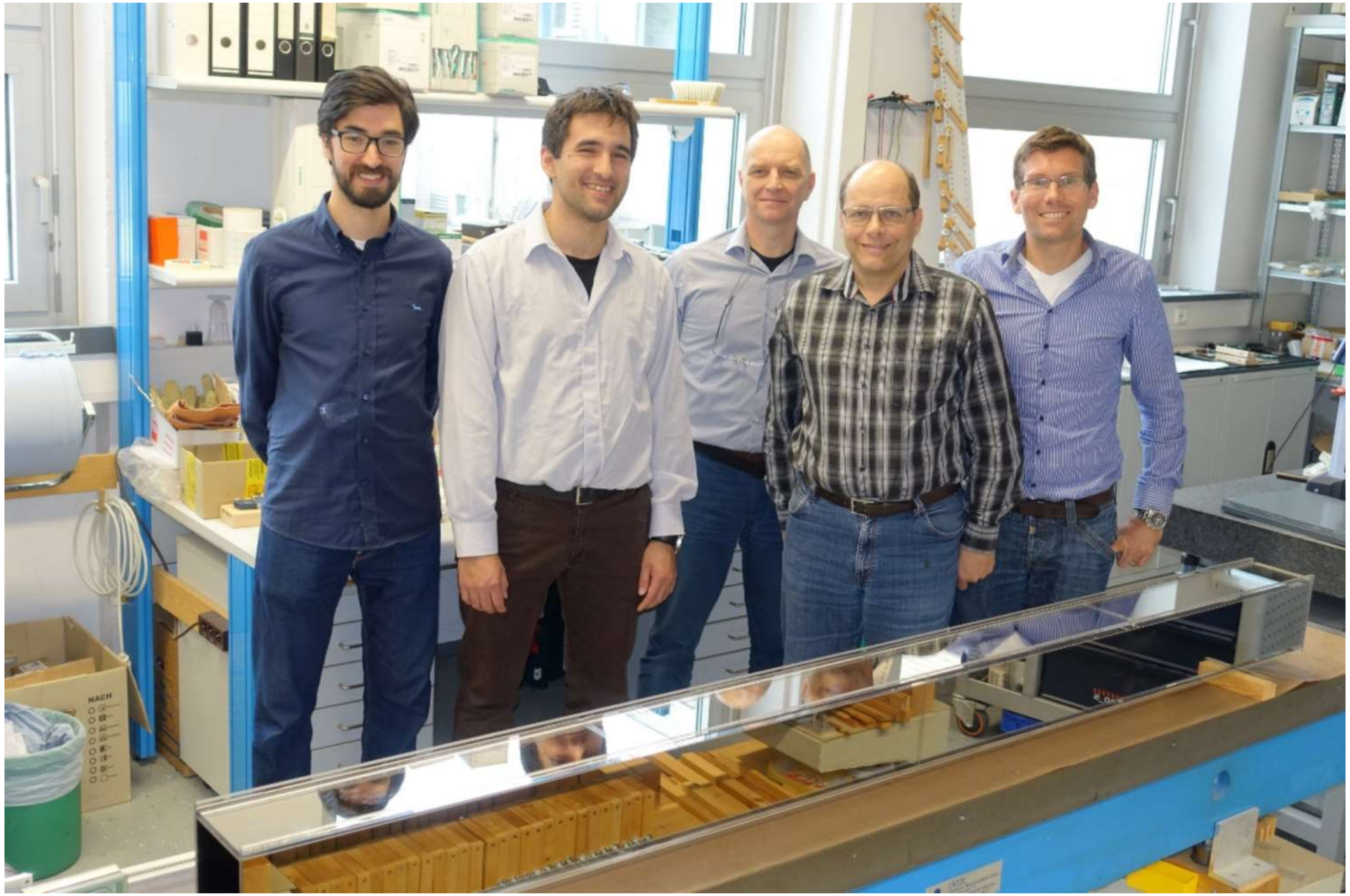




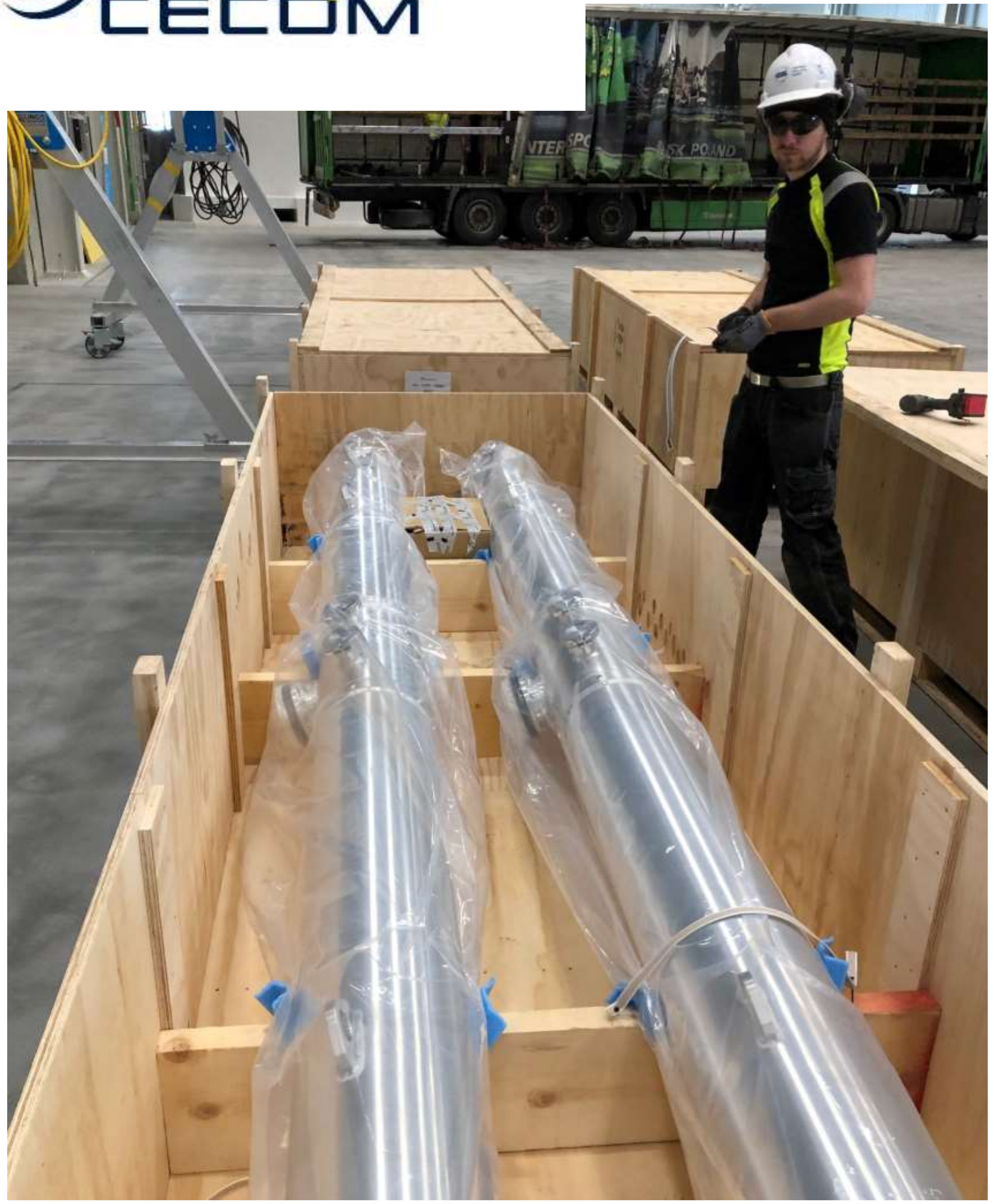


Guide

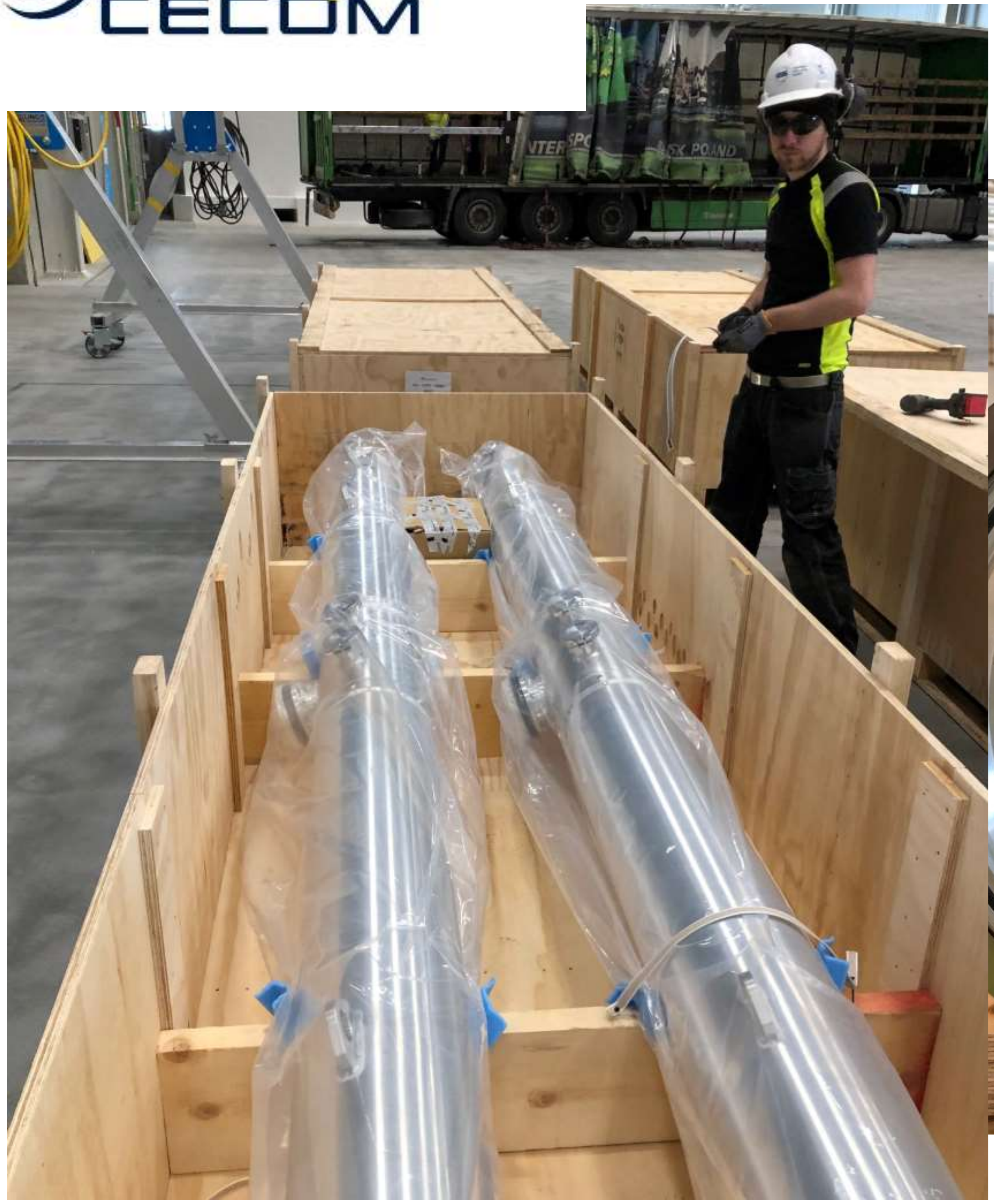
Production of neutron guides by the TUM optics group



Guide vacuum housing



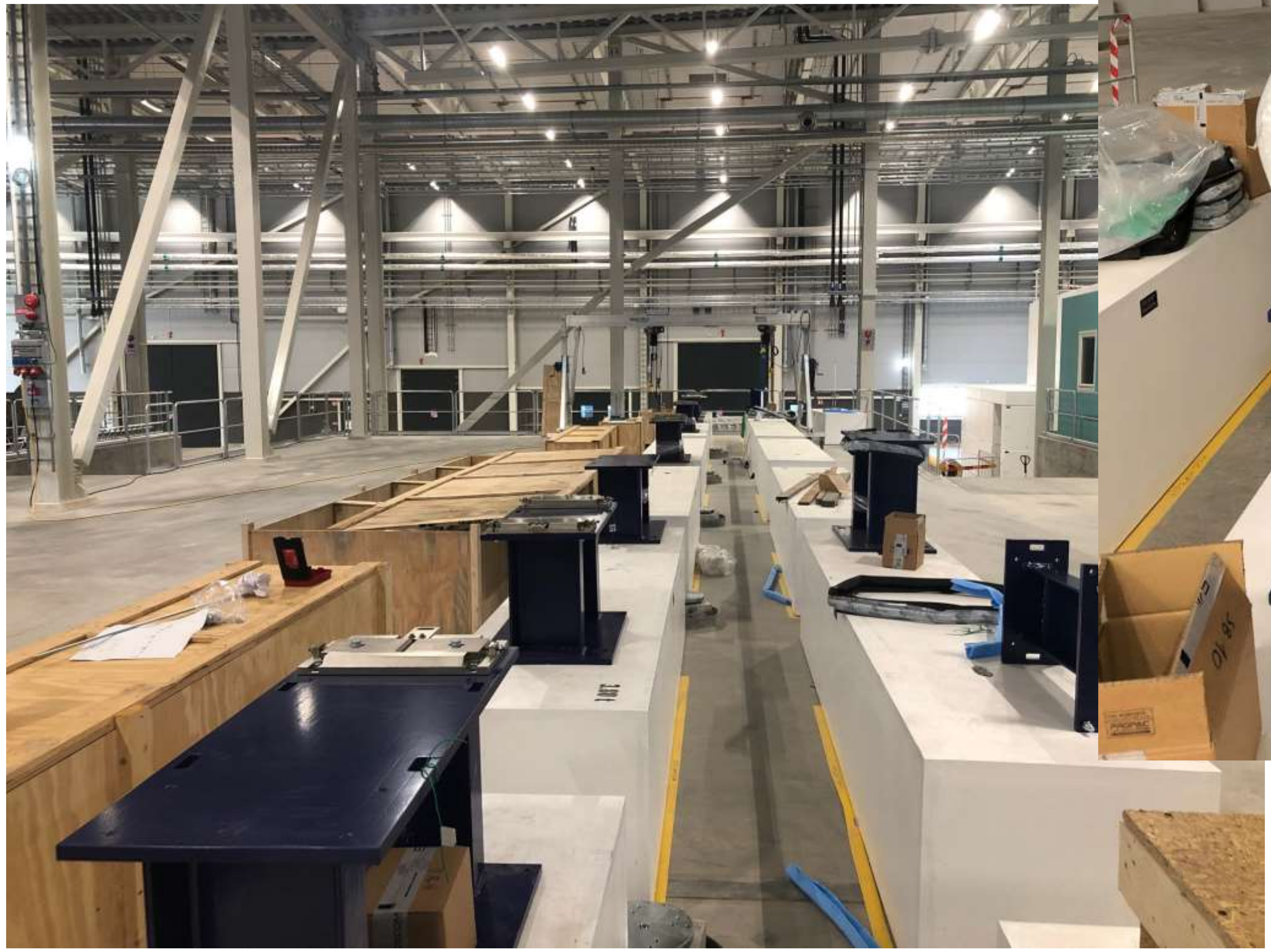
Guide vacuum housing



Verification of all components
Alignment < 50 µm
Vacuum tests/ check seals
Acceptance of components

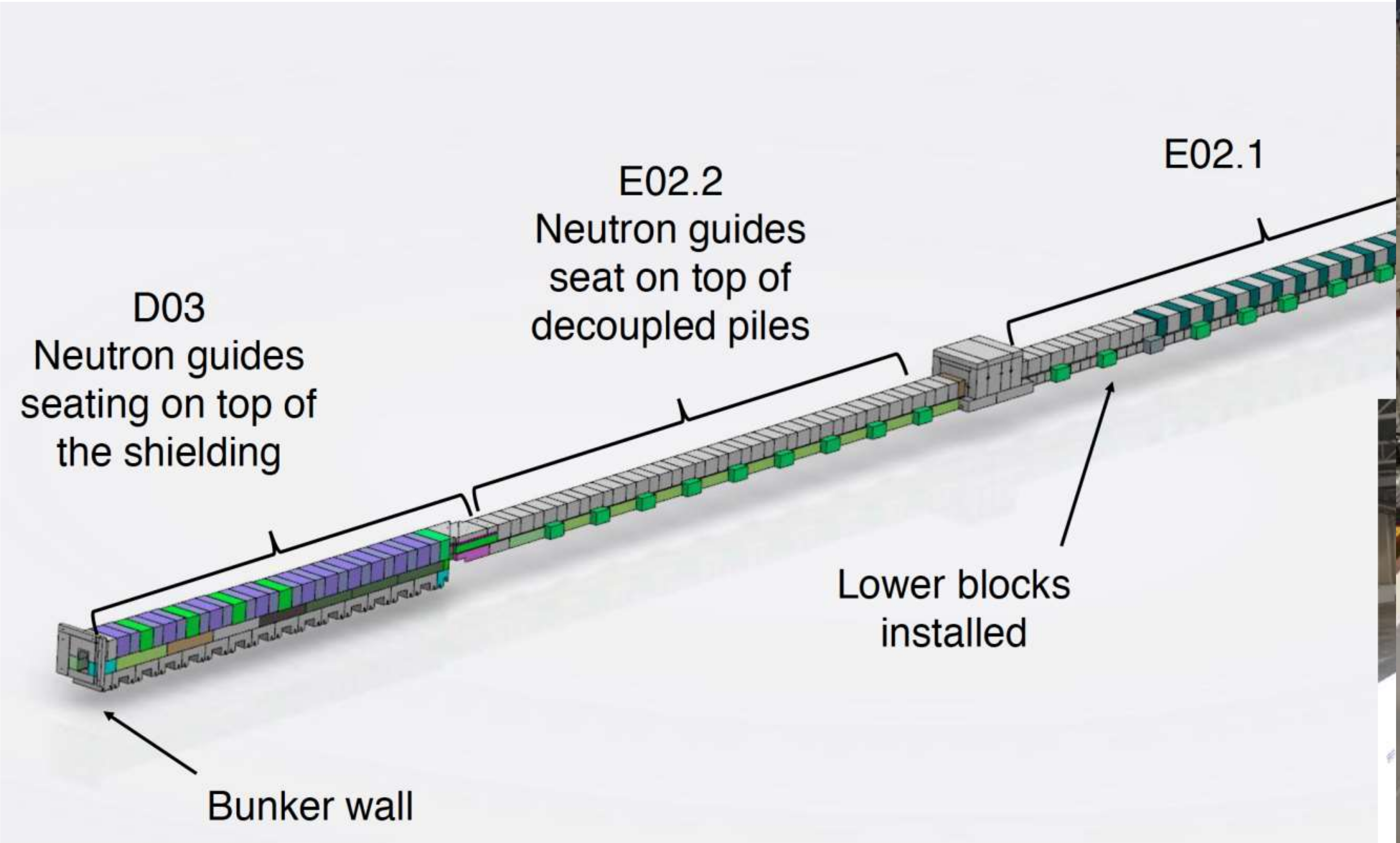
Guide vacuum housing

CECOM



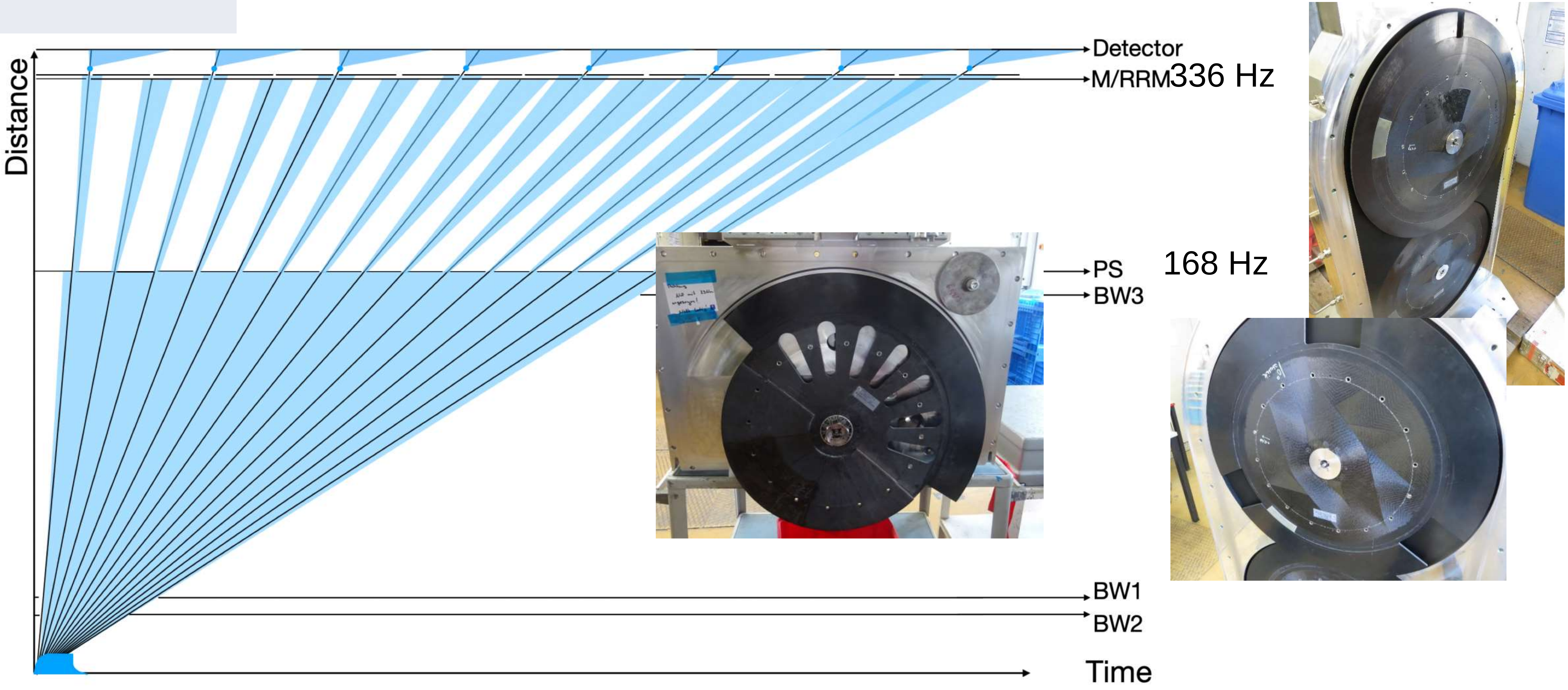
Primary spectrometer shielding

PACADAR GROUP

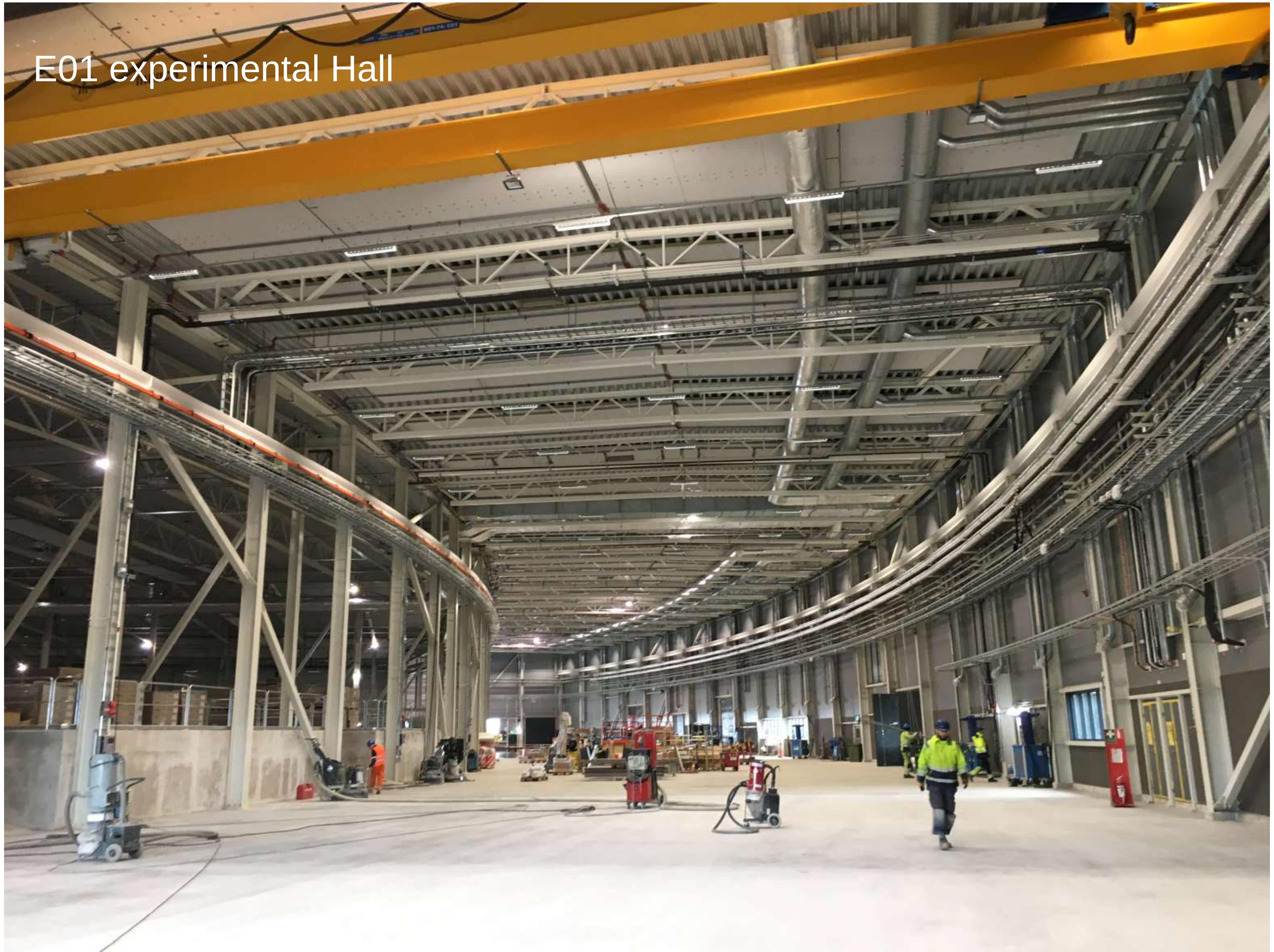


Chopper cascade

AIRBUS

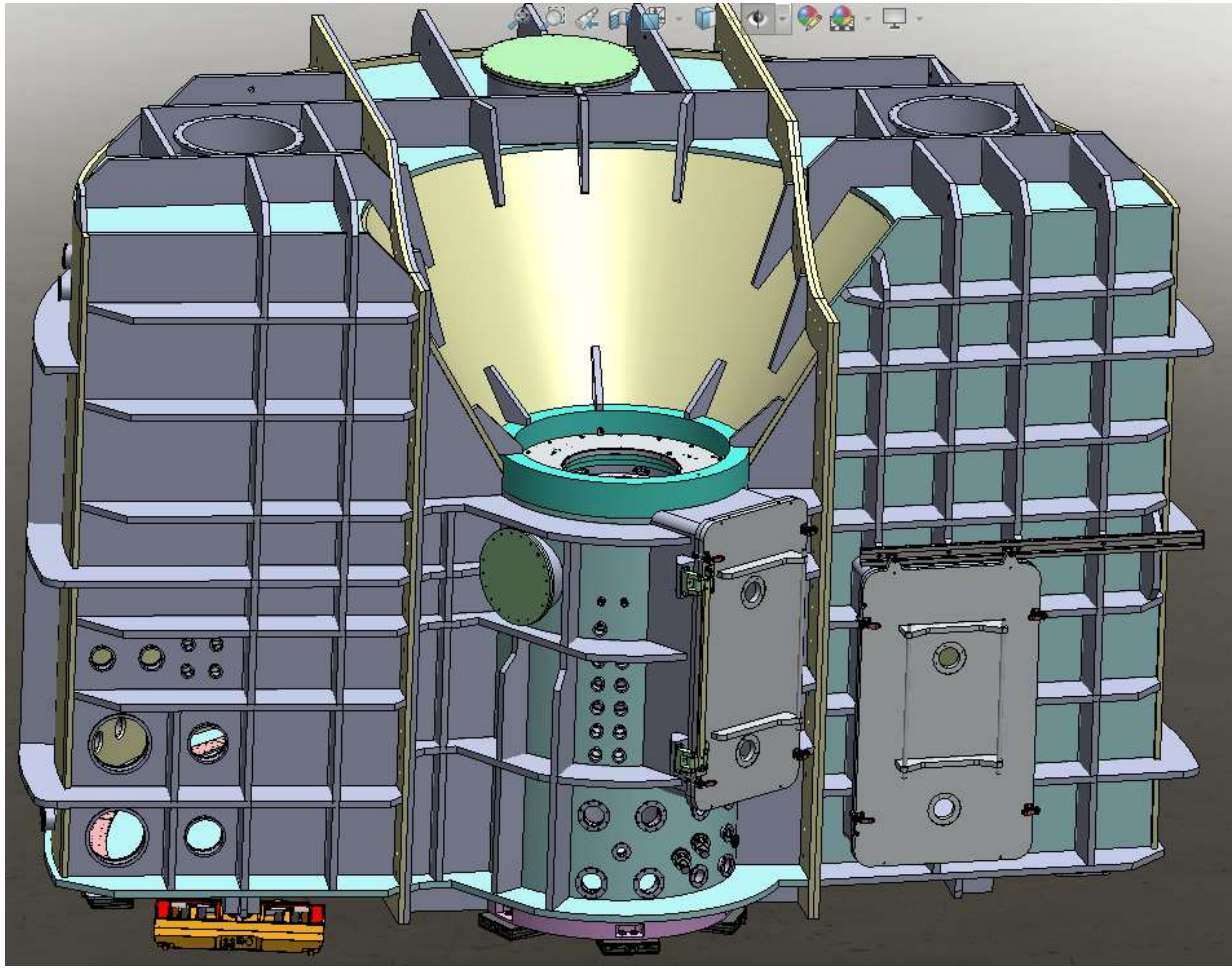


Secondary spectrometer in hall E01



Detector tank

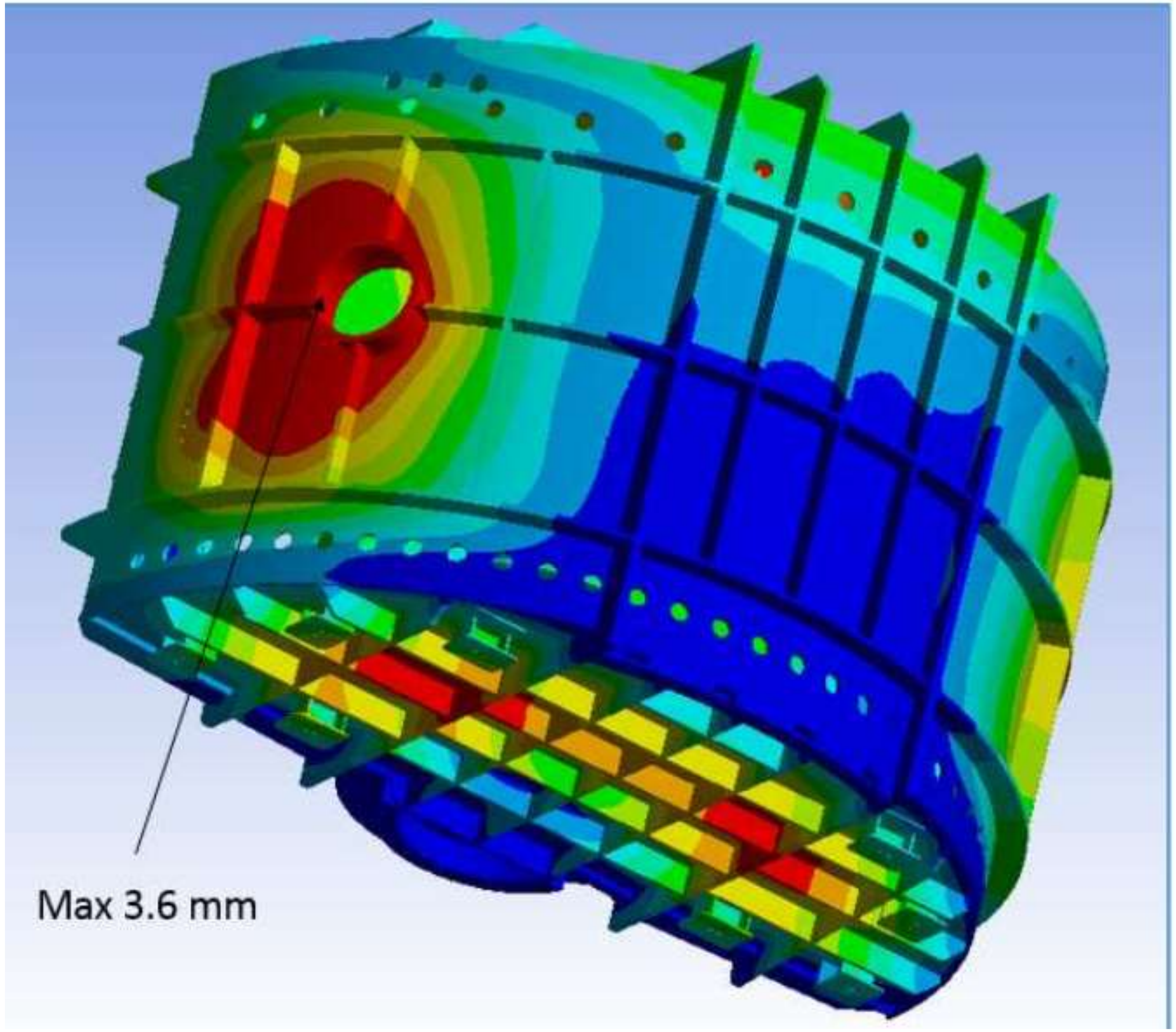
Particular points:
- 100 m^3
- Evacuation to 1e-04 mbar (huge stresses).
- Aluminium (PA).
- Collimation.
- Internal Cd coating.
- Particular sample environment access.
- Access from side and top.
- Careful consideration for enhanced SE.
- Extraction of detector vessels.
- 35 T, 1 mm positional resolution
- Walls are 40 mm thick - reinforcement 350 mm tall
- 2 mm Al. gate valve



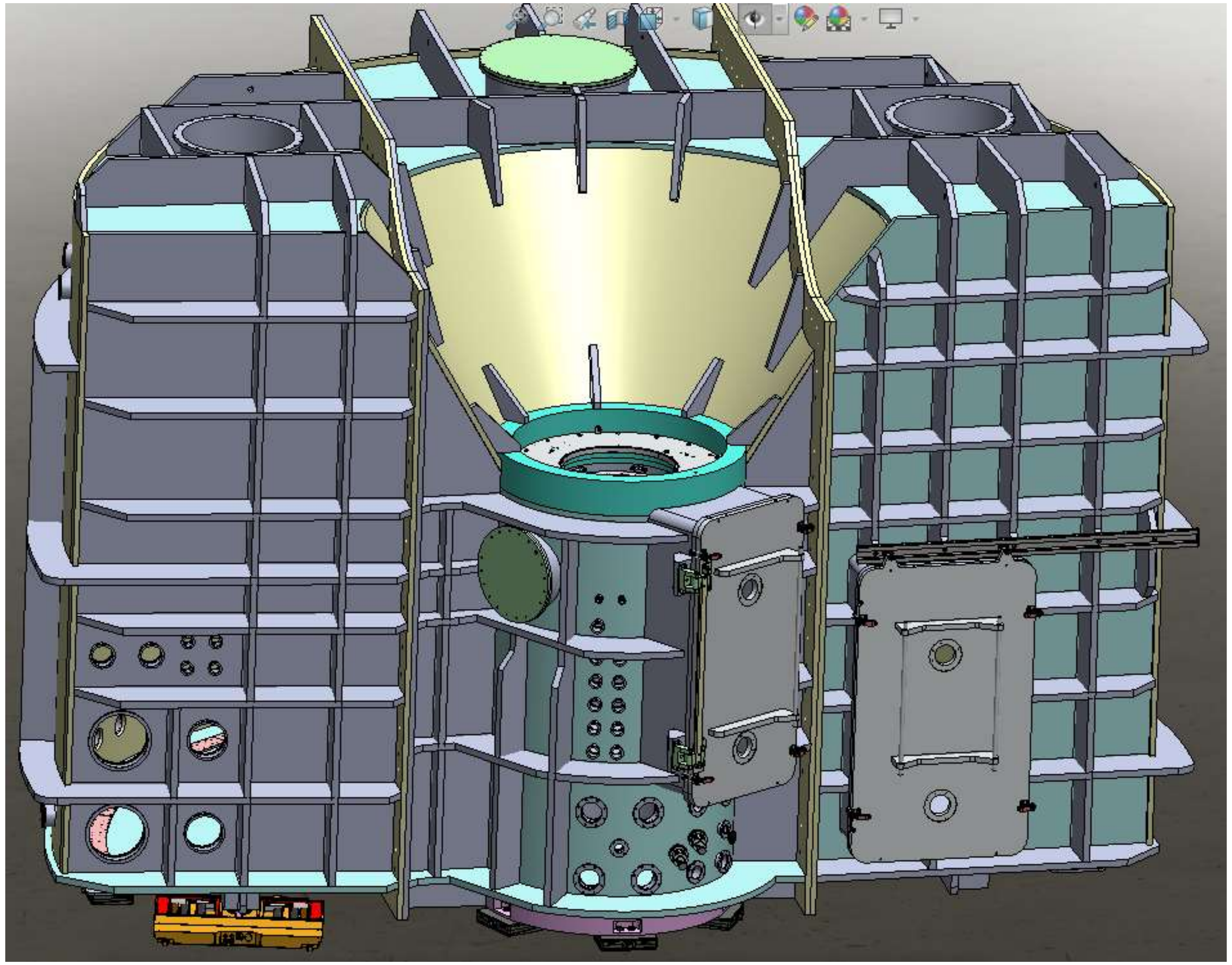
Detector tank

Particular points:

- $100\ m^3$
- Evacuation to 1e-04 mbar (huge stresses).
- Aluminium (PA).
- Collimation.
- Internal Cd coating.
- Particular sample environment access.
- Access from side and top.
- Careful consideration for enhanced SE.
- Extraction of detector vessels.
- 35 T, 1 mm positional resolution
- Walls are 40 mm thick - reinforcement 350 mm tall
- 2 mm Al. gate valve



Detector tank



Radial oscillating collimator

Improve signal to noise 10^5

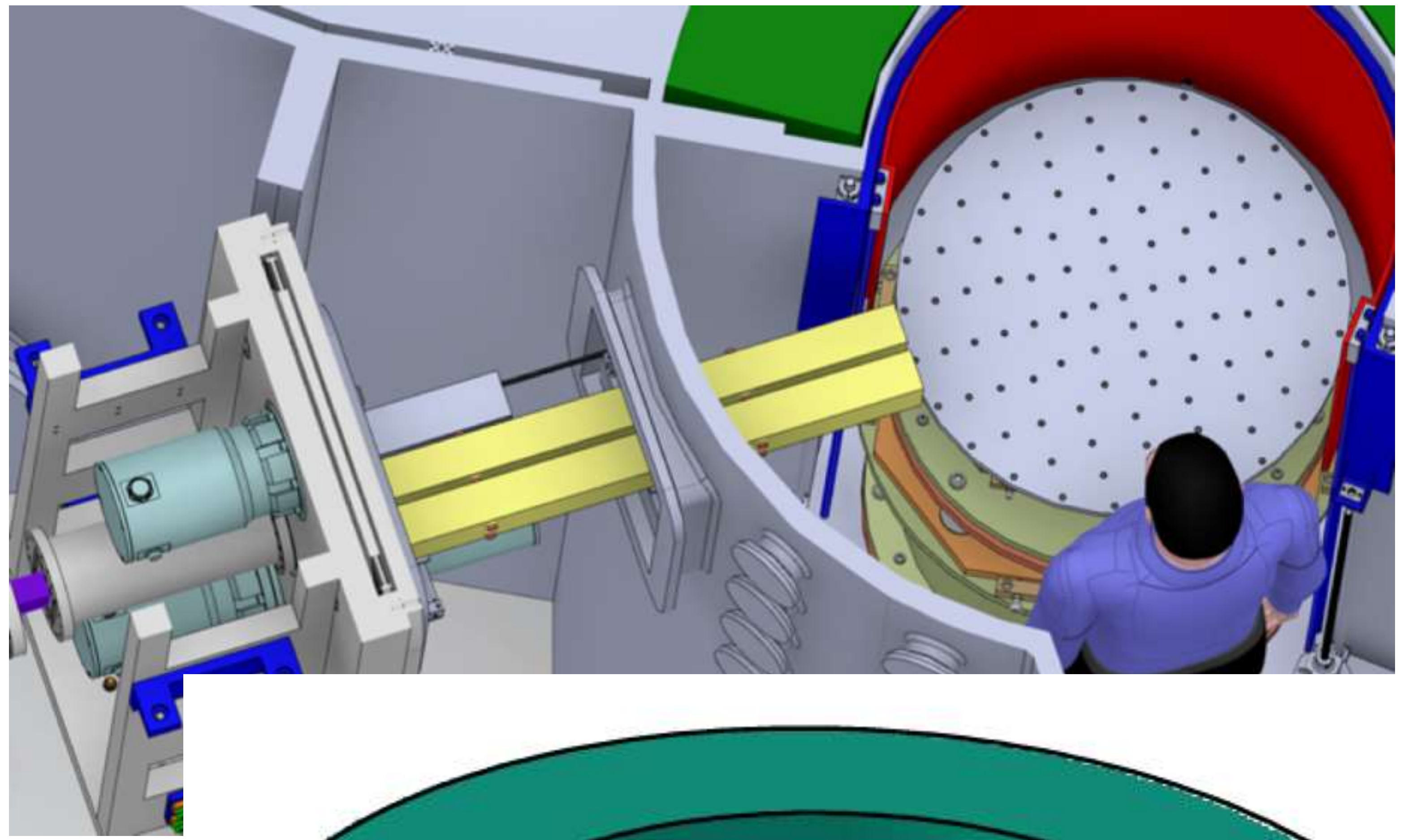
Oscillates with ~ 1 Hz

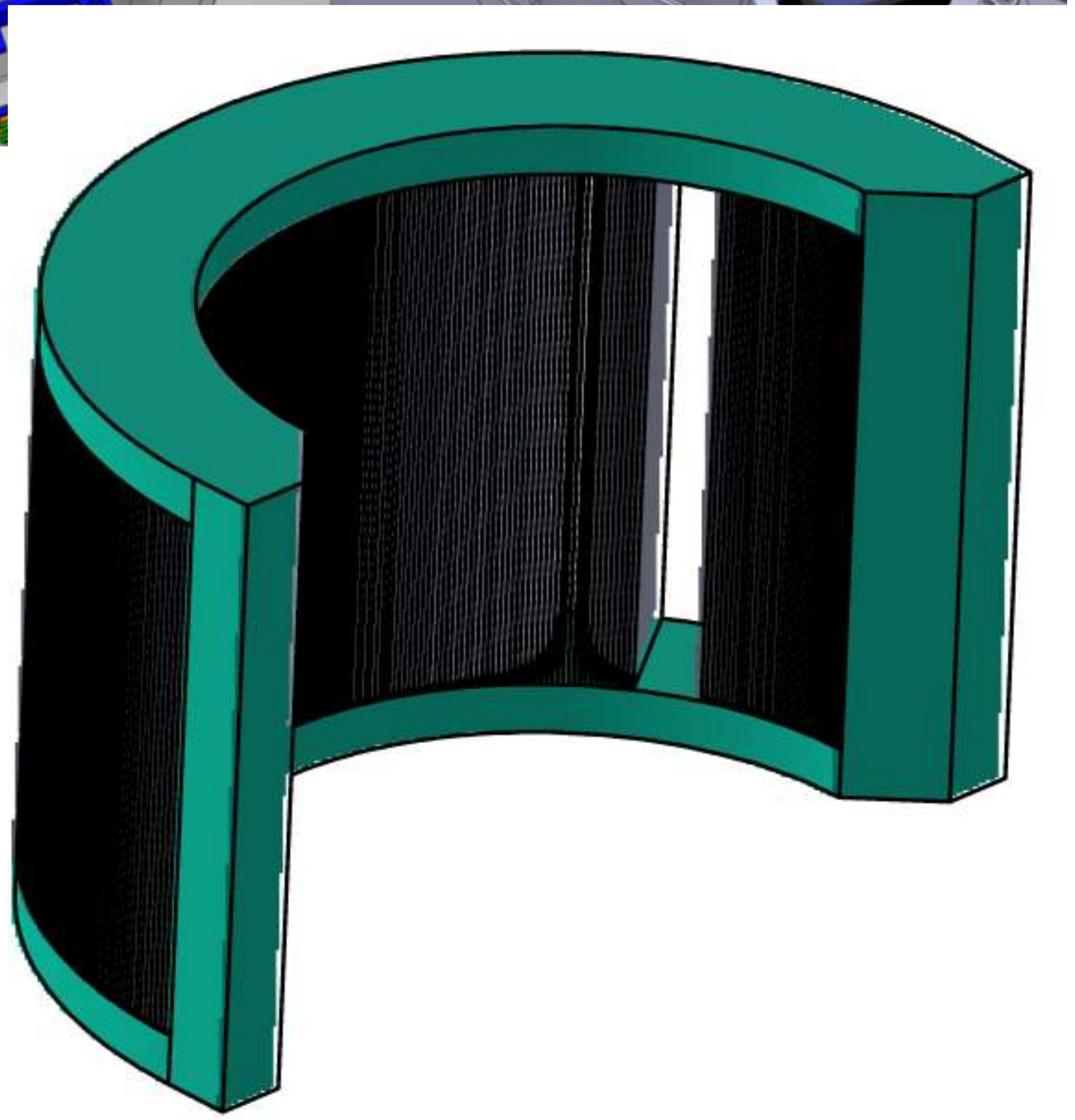
JJ X-RAY
Danish Science Design

Orphée Laboratoire Léon Brillouin

TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

ess





Secondary spectrometer

Detectors
He3

$^3He + n = ^3H + p + 764$ keV

3.5 m long,
position sensitive pixels = 2.5 cm
= 48000 pixels

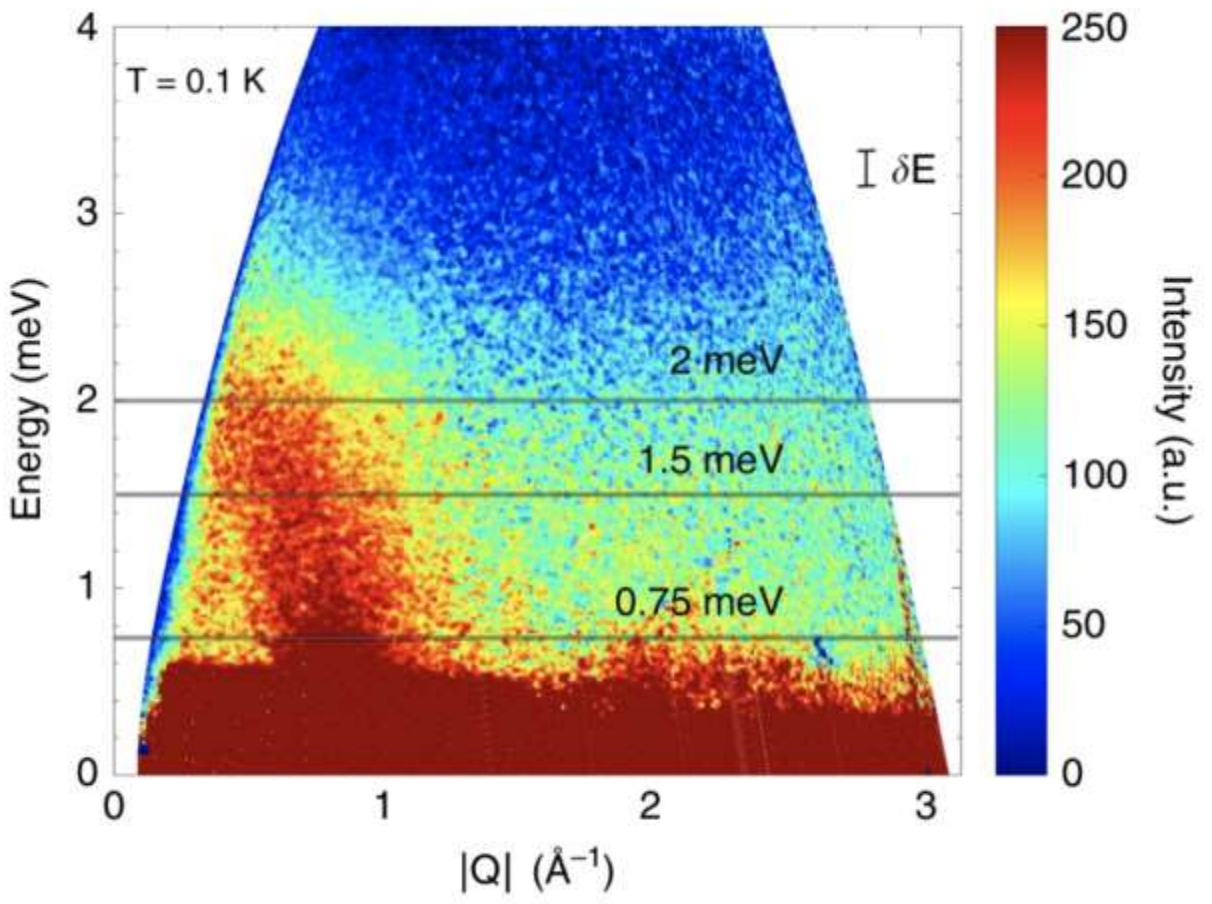
LET (ISIS)
4 m long position sensitive detectors

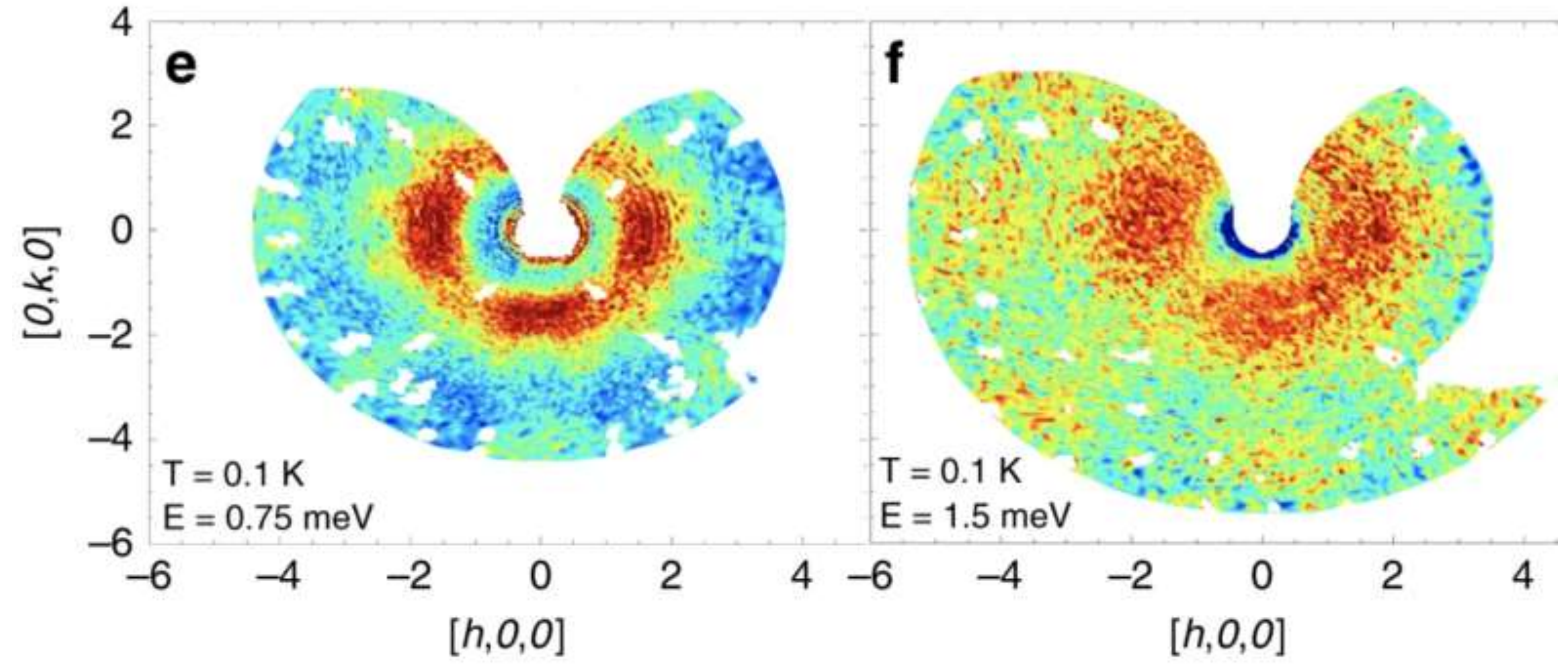
Secondary spectrometer

Laboratoire Léon Brillouin
TECHNISCHE UNIVERSITÄT MÜNCHEN
ess

Evidence for a three-dimensional quantum spin liquid in $PbCuTe_2O_6$

Shravani Chillal, Yasir Iqbal, Harald O. Jeschke, Jose A. Rodriguez-Rivera, Robert Bewley, Pascal Manuel, Dmitry Khalyavin, Paul Steffens, Ronny Thomale, A. T. M. Nazmul Islam, Johannes Reuther & Bella Lake

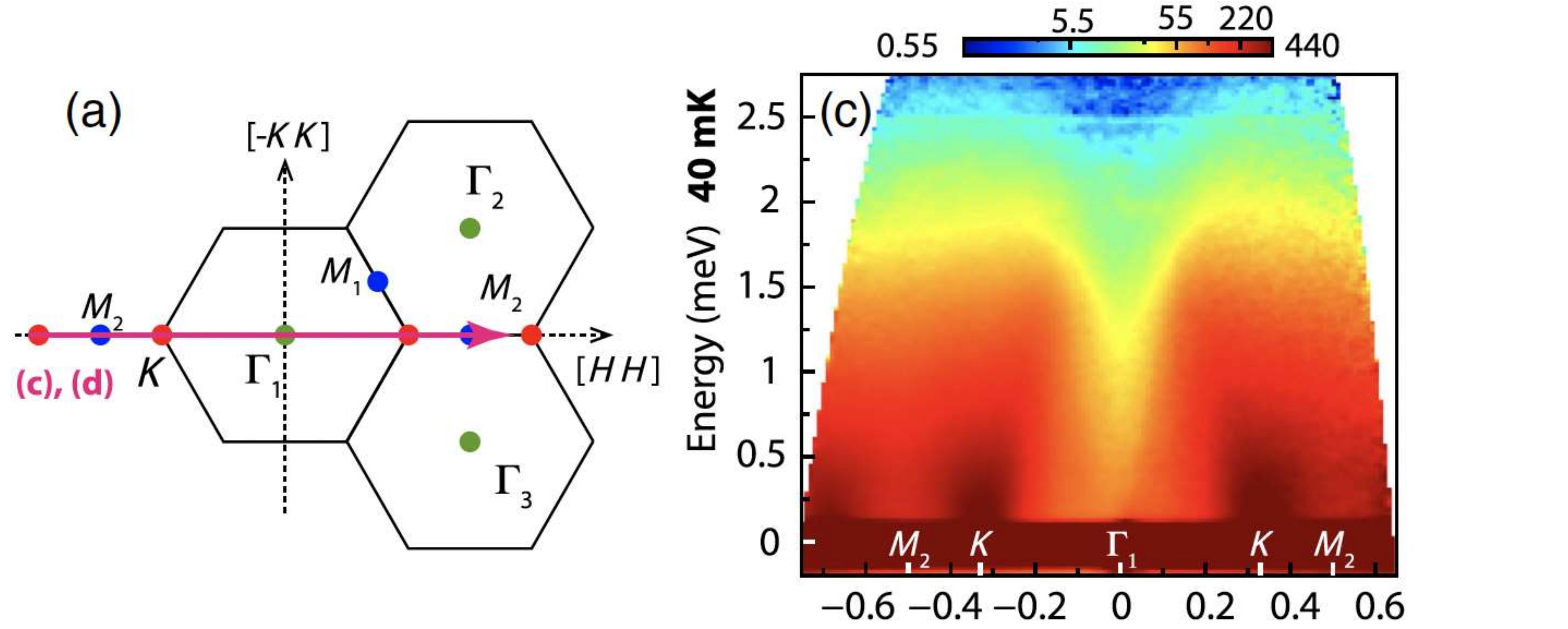


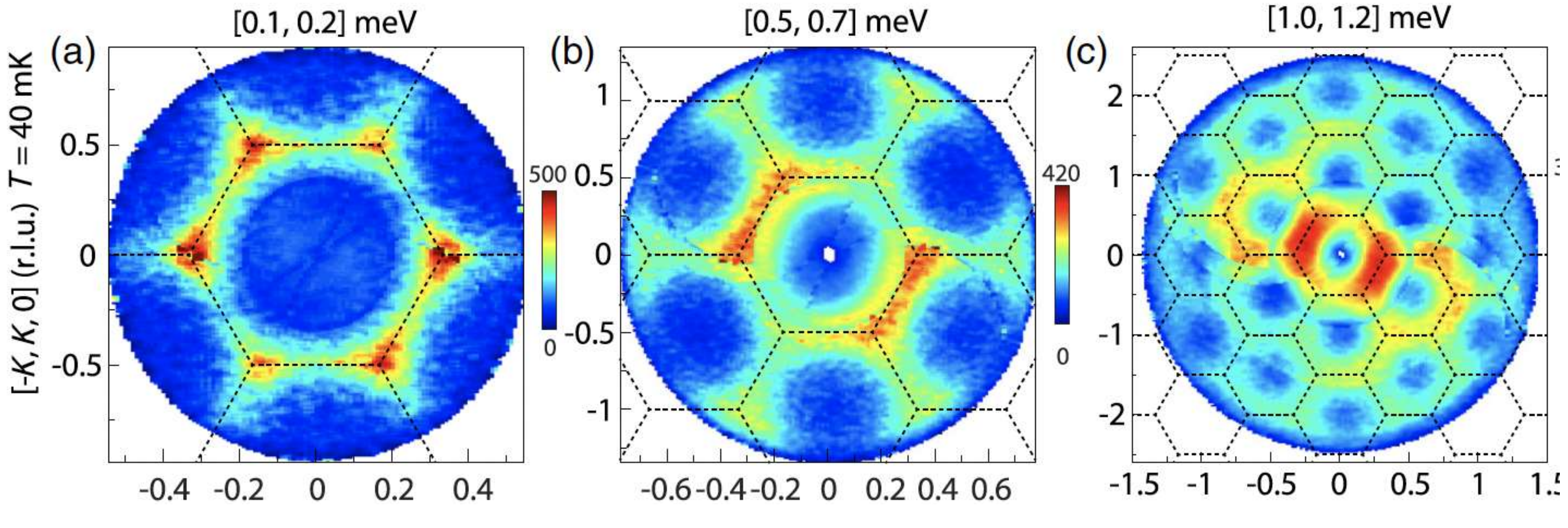


PHYSICAL REVIEW X 11, 021044 (2021)

Spinon Fermi Surface Spin Liquid in a Triangular Lattice Antiferromagnet $NaYbSe_2$

Peng-Ling Dai,[1,‖] Gaoning Zhang,[2,‖] Yaofeng Xie,[3] Chunruo Duan,[3] Yonghao Gao,[4] Zihao Zhu,[4] Erxi Feng,[5] Zhen Tao,[1] Chien-Lung Huang,[3] Huibo Cao,[5] Andrey Podlesnyak,[5] Garrett E. Granroth,[5] Michelle S. Everett,[5] Joerg C. Neuefeind,[5] David Voneshen,[6,7] Shun Wang,[8] Guotai Tan,[1] Emilia Morosan,[3] Xia Wang,[2] Hai-Qing Lin,[9] Lei Shu,[4] Gang Chen,[10,4,*] Yanfeng Guo,[2,†] Xingye Lu,[1,‡] and Pengcheng Dai[3,§]

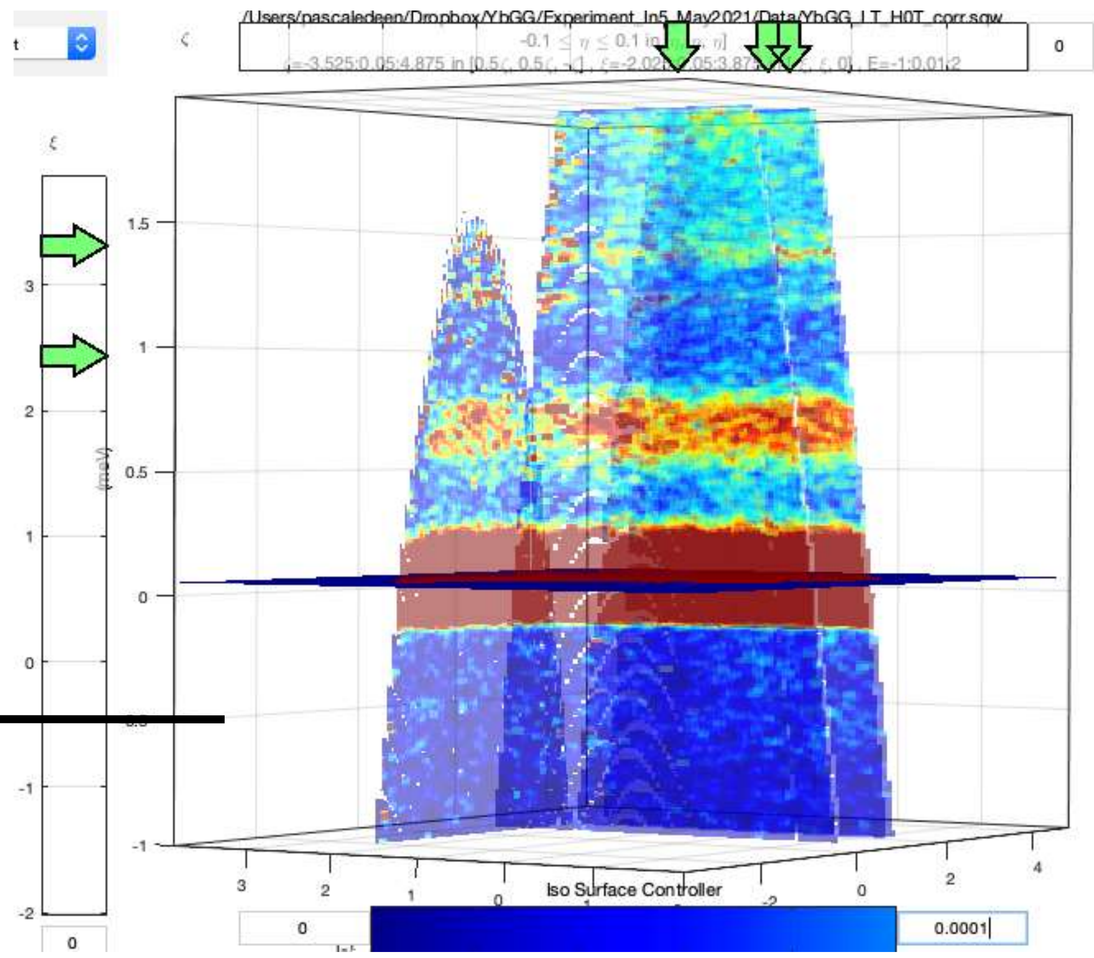


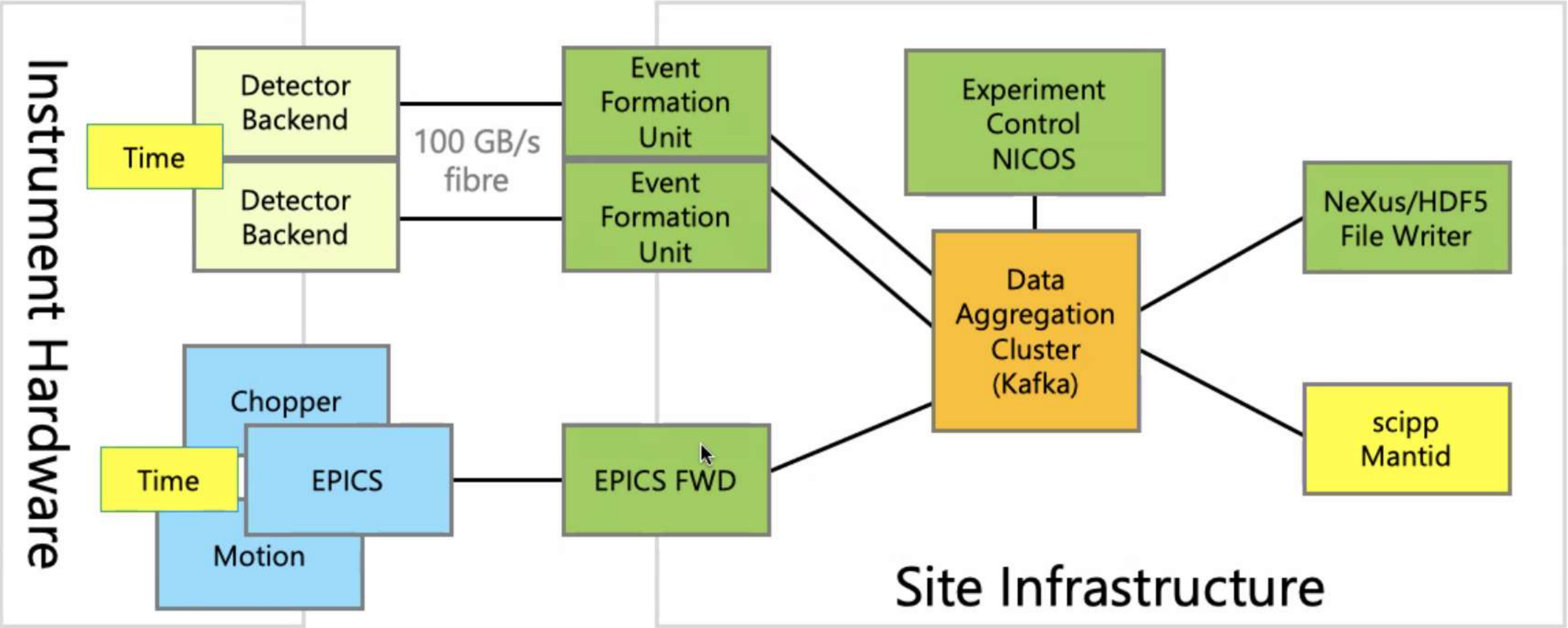


Instrument readout streaming architecture

- 38 TiB in event information per experiment.

MSlice/Horace/PACE





BrightnESS is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 676548

CSPEC Sample environment (BOT = Beam on target)

* In scope

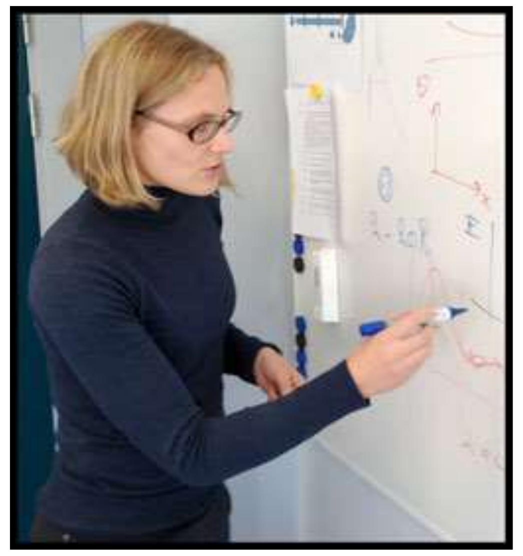
BOT	HC= BOT + 3 months	FS= BOT + 6 months	SOUP=BOT + 12 months
Cryofurnace*	14 T magnet (access to)	High pressure (large samples)	Pump and probe setup*
He3 insert*	Automatic sample changer*	Humidity chamber	High pressure (small samples)
Sample stick rotation stage*		High temperature furnace (access to)	
6 T magnet*			

Dilution insert (From Pool)
Uniaxial pressure cell (2 GPa)
Further collaboration with university teams
(Roskilde University, Malmö University, Copenhagen University, Lund University)

CSPEC core team

Engineer: Fernando Moreira (Lead, LLB), Matts Olson (TUM), Miguel Campos Ferro(LLB)
Scientists: D. Noferini, P.P. Deen, G. Tucker (DMSC)



TUM: W. Lohstroh
LLB: S. Longeville


A difficult project but a very collaborative/committed team

& ESS & TUM & LLB technical groups

AIP Review of Scientific Instruments

SUBMIT YOUR ARTICLE

HOME BROWSE INFO FOR AUTHORS COLLECTIONS SIGN UP FOR ALERTS

Home > Review of Scientific Instruments > Volume 92, Issue 10 > 10.1063/5.0059907

‹ PREV NEXT ›

No Access • Submitted: 14 June 2021 • Accepted: 13 September 2021 • Published Online: 07 October 2021

CSPEC: The cold chopper spectrometer of the ESS, a detailed overview prior to commissioning

Review of Scientific Instruments **92**, 105104 (2021); https://doi.org/10.1063/5.0059907

P. P. Deen[1,2,a)], S. Longeville[3], W. Lohstroh[4], F. Moreira[1], G. Fabrèges[3], L. Loaiza[4], *and* D. Noferini[1]

pascale.deen@ess.eu

https://europeanspallationsource.se/instruments/cspec

We welcome you all soon(ish).

pascale.deen@ess.eu

Radial Oscillating Collimator

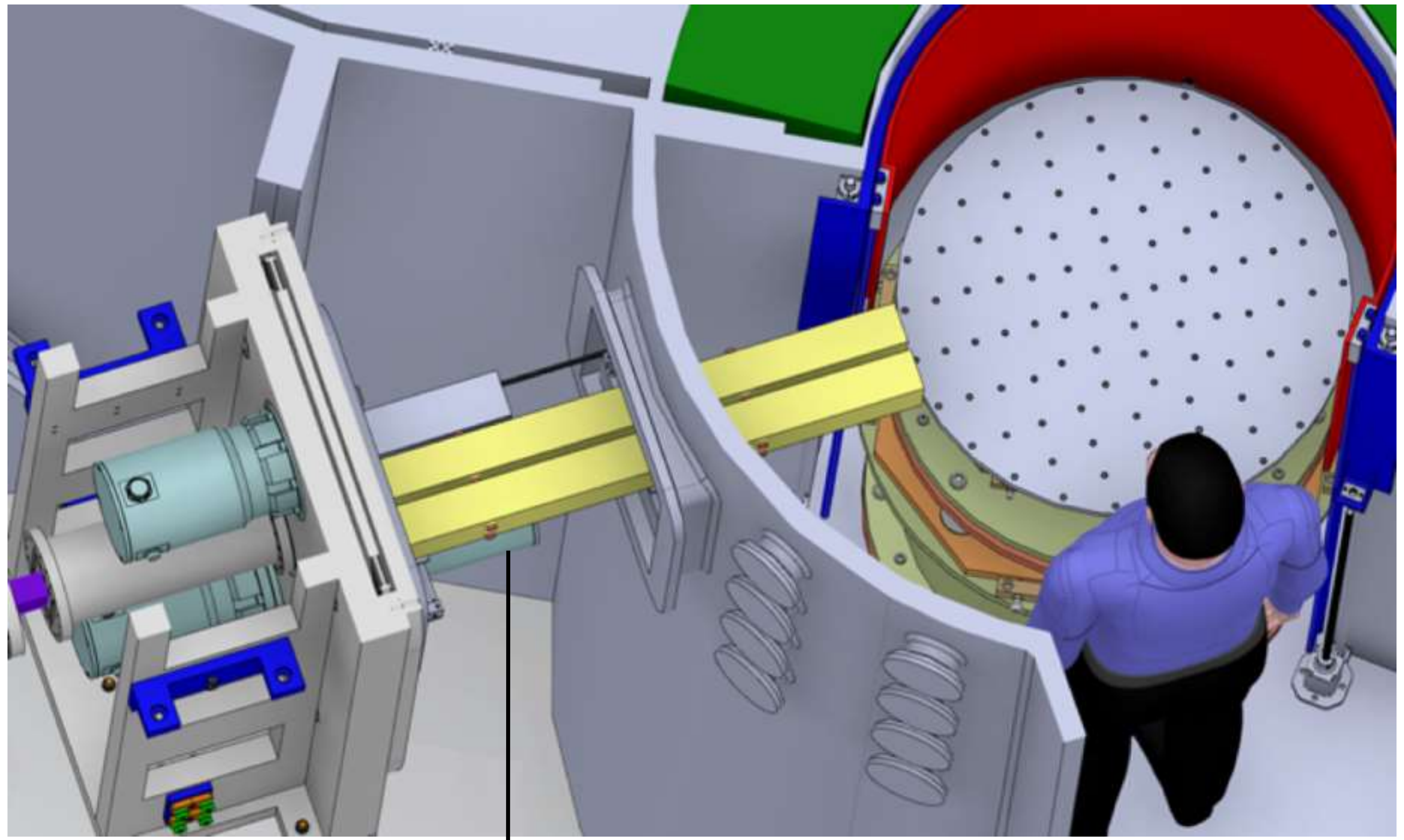
JJ X-RAY Danish Science Design

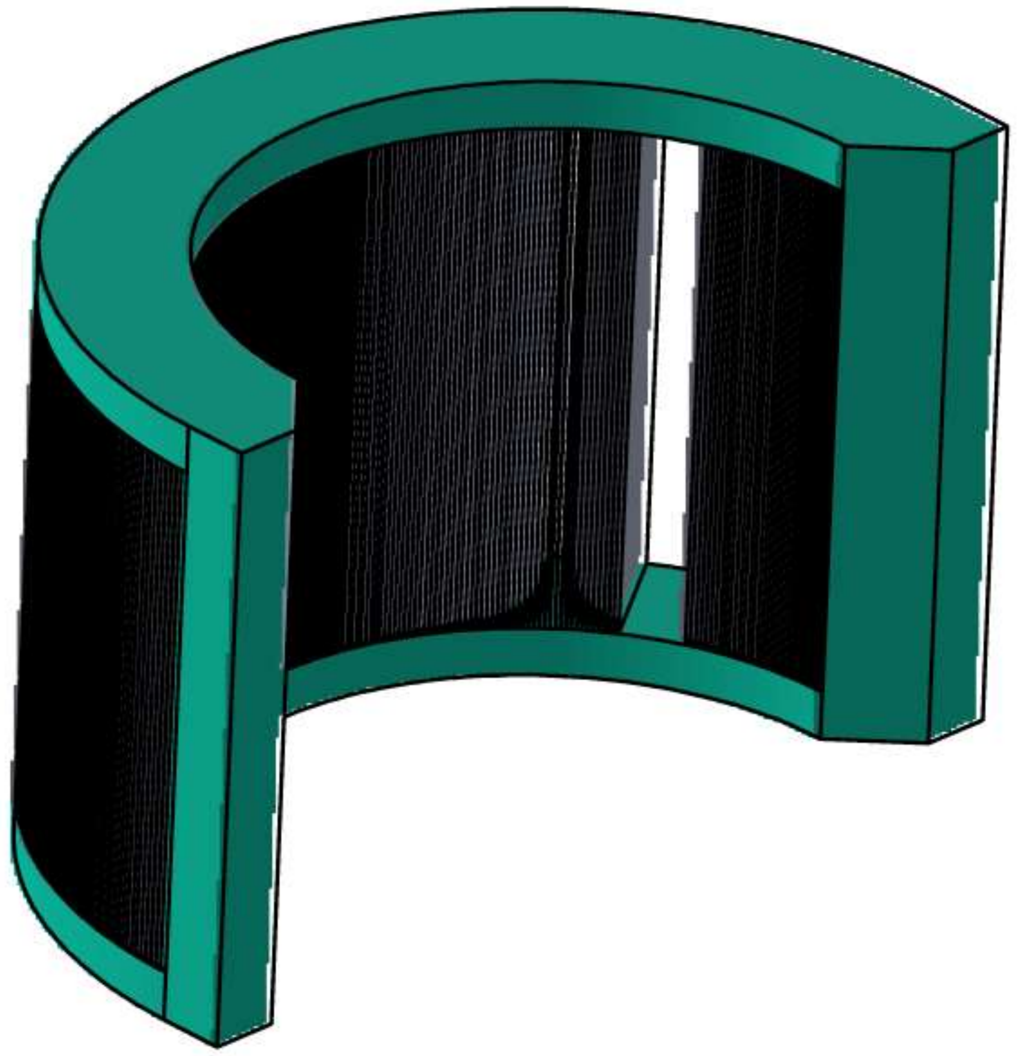
In manufacture

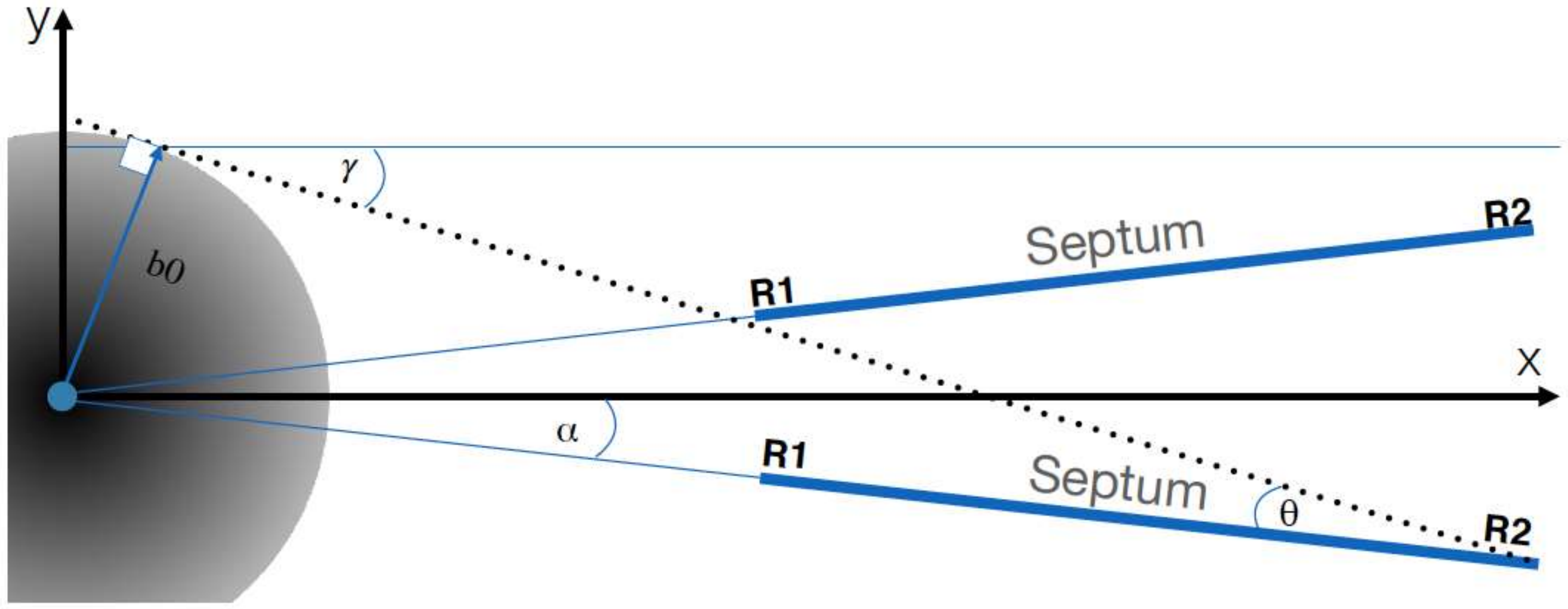
Orphée Laboratoire Léon Brillouin

TECHNISCHE UNIVERSITÄT MÜNCHEN

ess







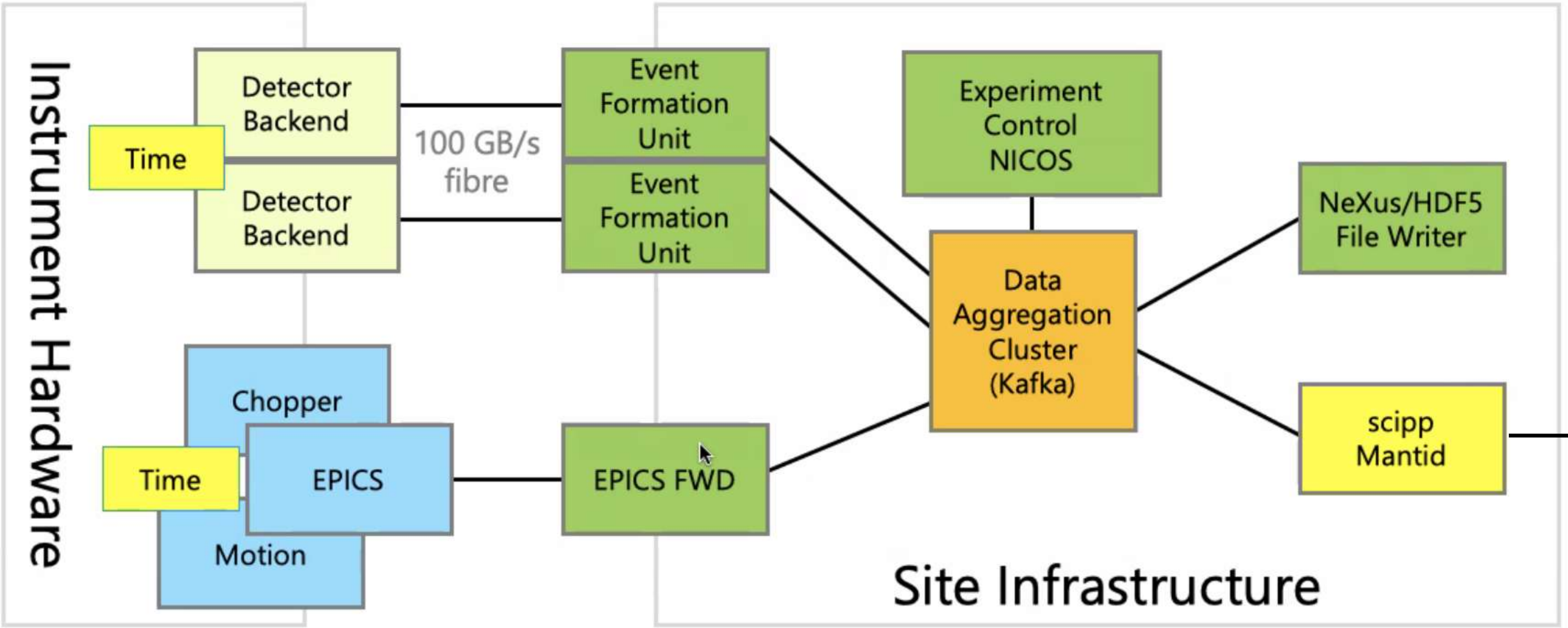
$R1$	$R2$	2α	$2b_0$	$\gamma\ ^o$
504 mm	708 mm	0.8 ^{o}	48.85 mm	2.38 ^{o}

TABLE III. CSPEC radial collimator parameters.

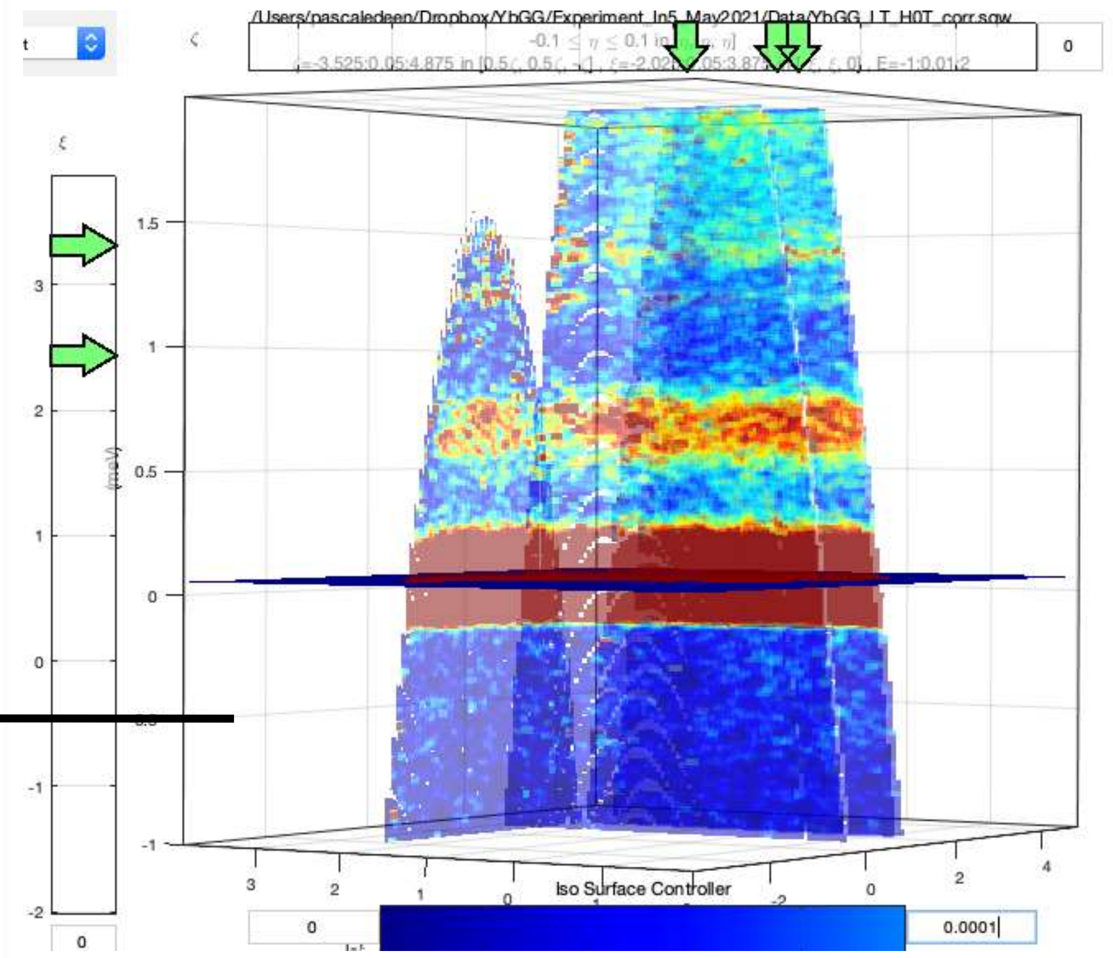
Instrument readout streaming architecture

- 26880 voxels per detector vessel and 860 160 detector voxels
- 38 TiB in event information per experiment.

Result of an extensive test and evaluation phase involving many partners



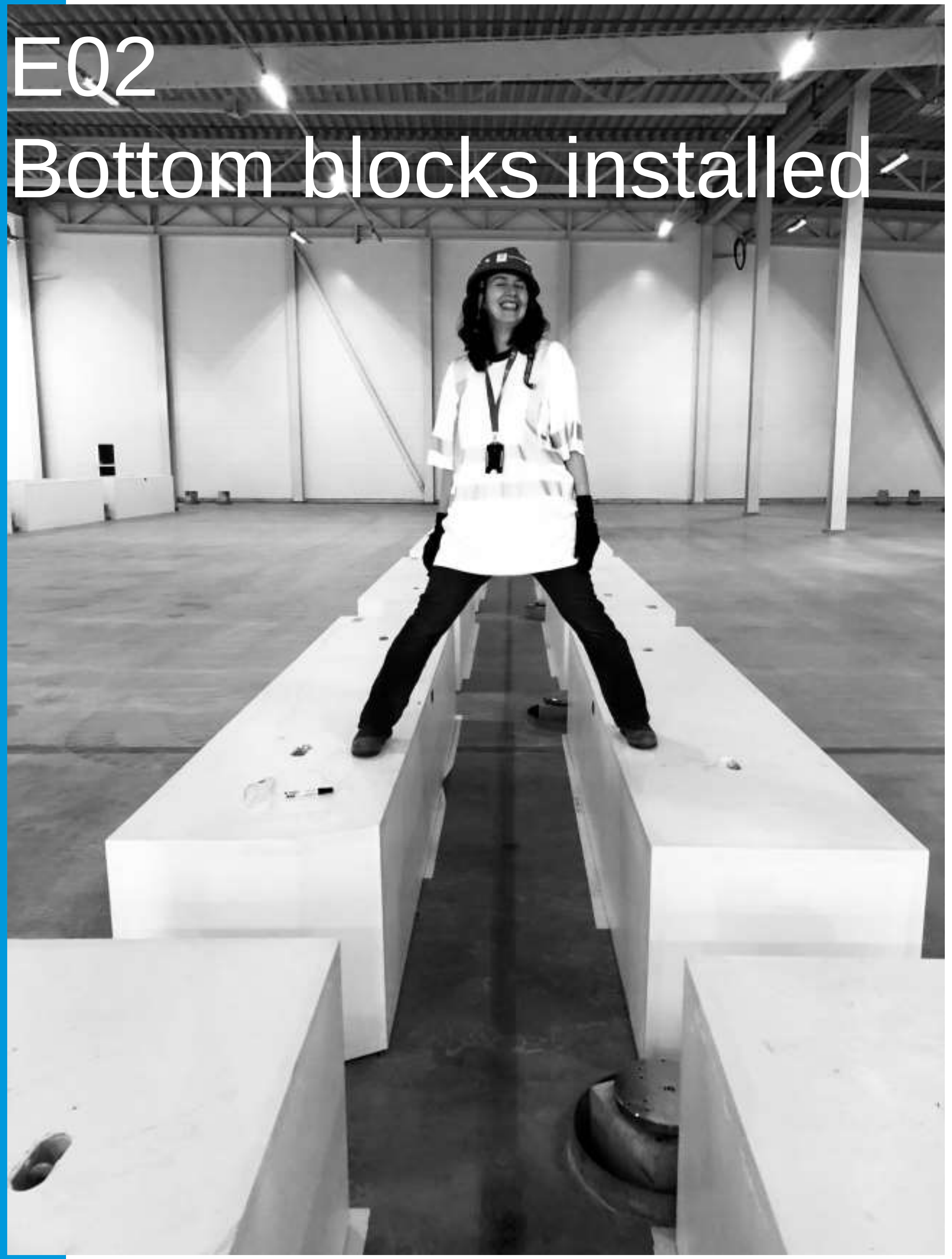
MSlice/Horace/PACE

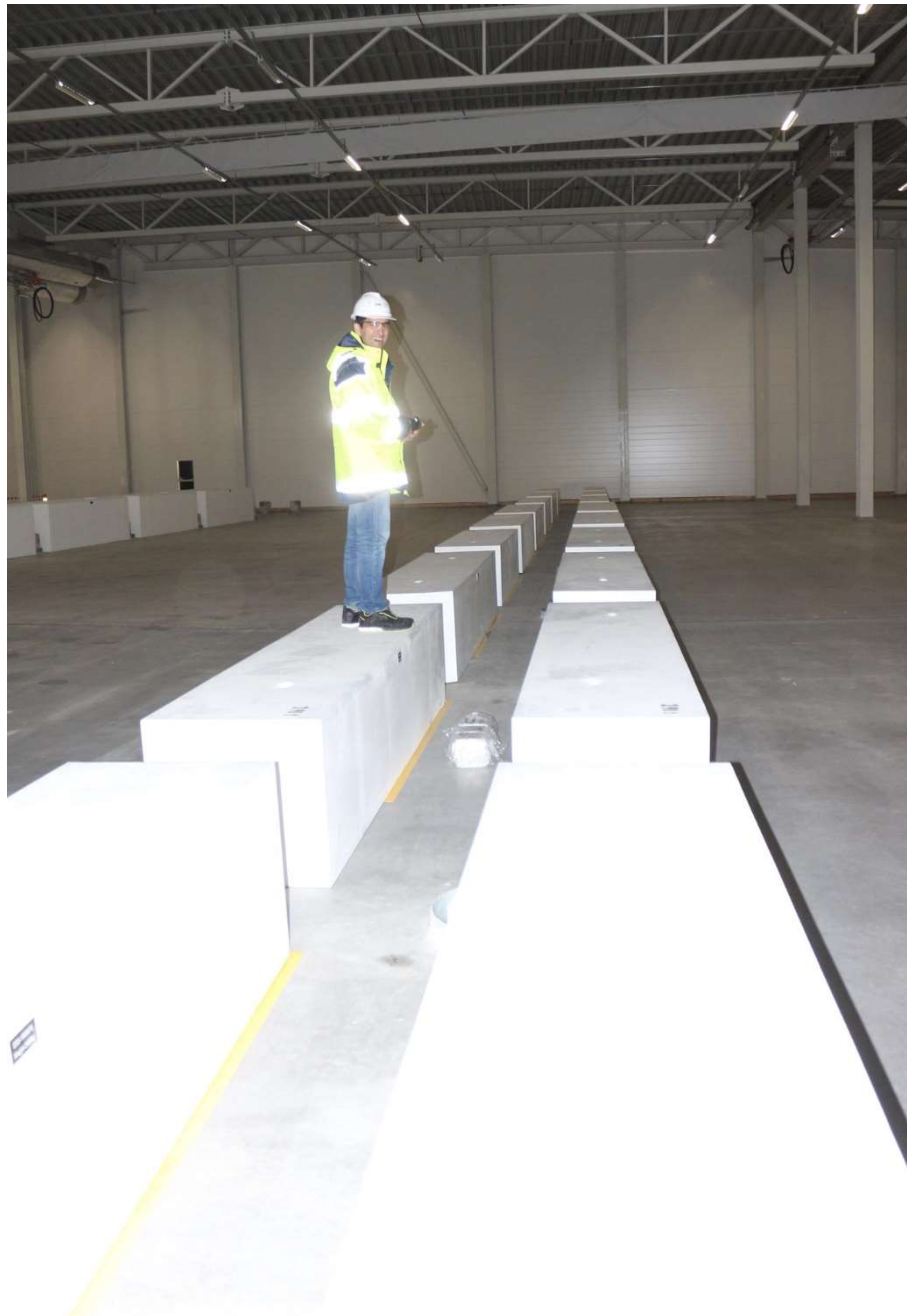


BrightnESS is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 676548

EQ2

Bottom blocks installed





Top blocks casted

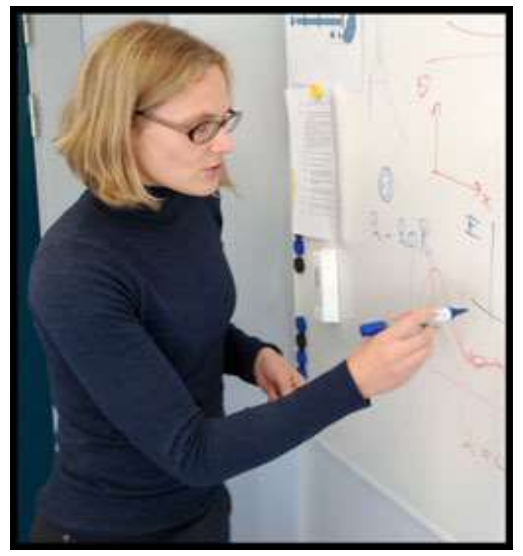
Detector tank

33 T
Walls are 40 mm thick - reinforcement 350 mm tall
3 mm gate valve
Aligned with air pads - achieve 1 mm positional resolution

CSPEC core team

Engineer: Fernando Moreira (Lead, LLB), Luis Loaiza (TUM), Gregoire Fabrèges (LLB)
Scientists: P.P. Deen, D. Noferini, G. Tucker (DMSC)



TUM: W. Lohstroh
LLB: S. Longeville


& ESS technical groups

CSPEC Specifications

Instrument Class	Spectroscopy
Moderator	Cold
Primary flightpath (Moderator to M chopper)	158.5 m
Secondary flightpath (M Chopper to detector)	5 m
Wavelength range	1.72 Å
Flux at sample (4 x 2 cm^2), 5 MW (λ = 5 Å, ΔE/E =3%)	3e6n/s/cm^2 (single pulse) x 5 - 10 with RRM cumulative
Flux at sample (1 x 1 cm^2), 5 MW (λ = 5 Å, ΔE/E =3%)	7.8e6n/s/cm^2 (focussed beam, single pulse)
Detector coverage	Complete: (H) -30º < 2θ < 140º, (V) ±26.5º day 1 : (H) 5º < 2θ < 90º , (V) ±26.5º · September 2023.
Energy resolution	1.5% @ 4 Å

CSPEC

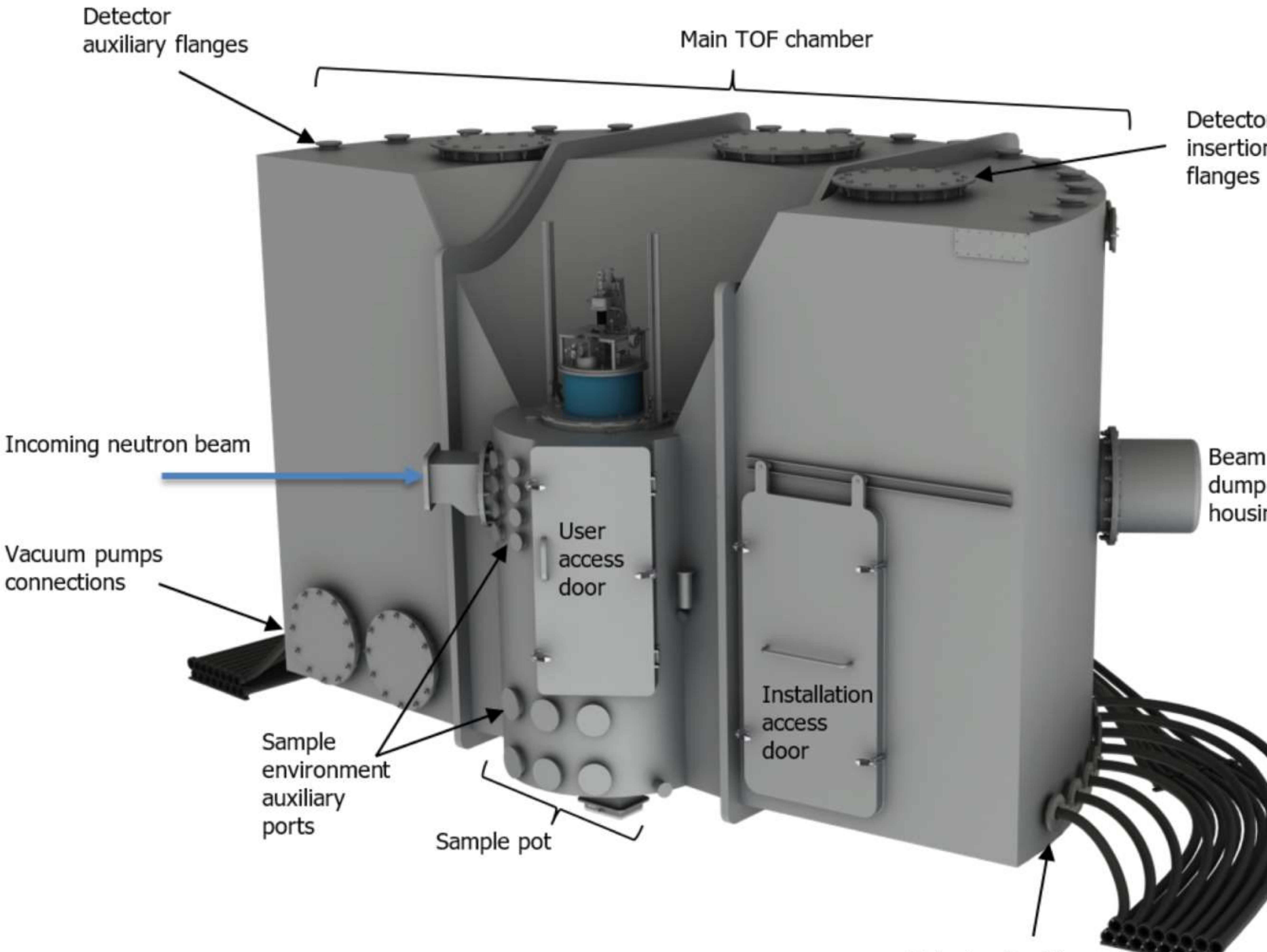
The Cold Chopper spectrometer of the ESS

Detector tank (sample to detector = 3.5 m, height = 3.5 m)

Out to tender: reply 5th March (slight covid delay), 8 interested.

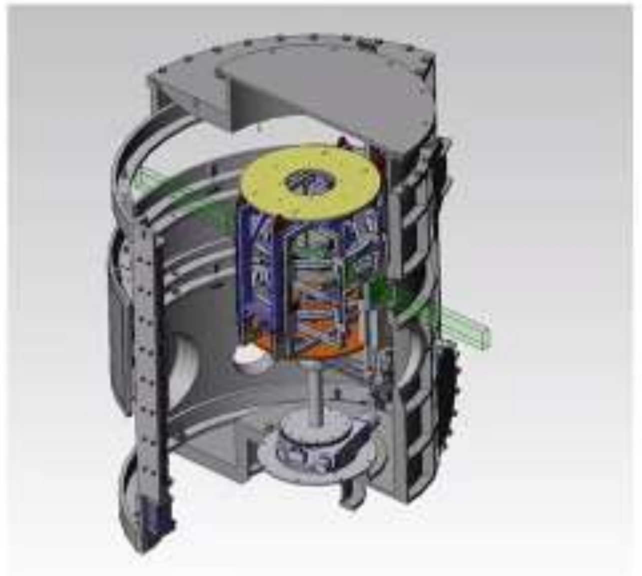
Particular points:

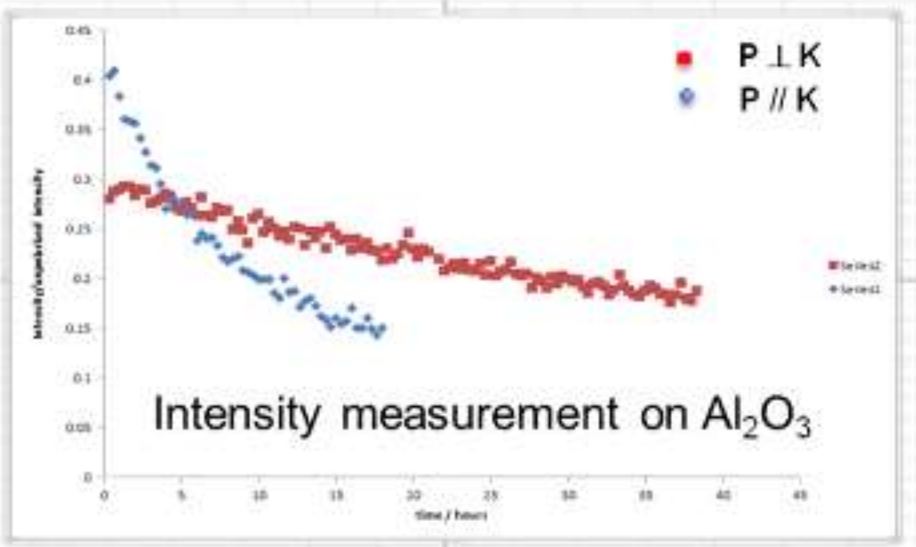
- Evacuation to 1e-04 mbar (huge stresses)
- Aluminium / Stainless steel with muR < 1.01
- Particular sample environment access
- Careful consideration for enhanced SE
- Extraction of detector vessels.



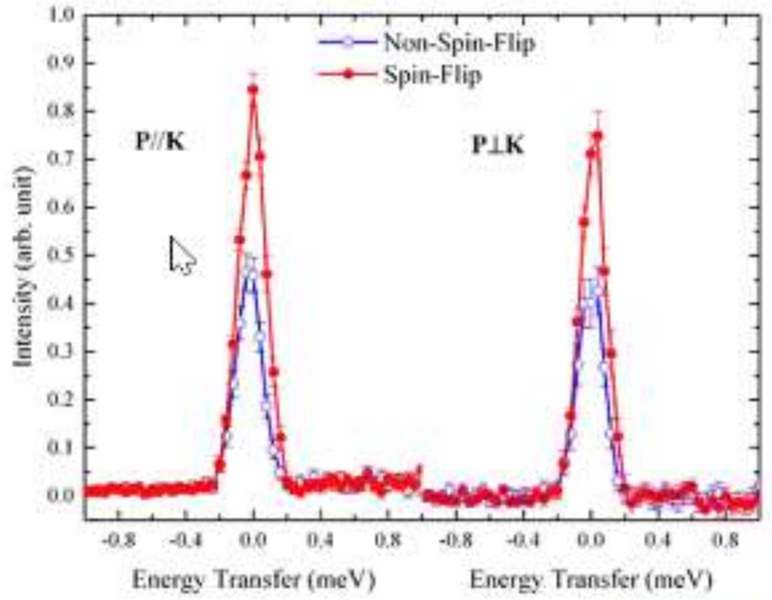
Pelican

Polarisation Analysis System





Overall polarisation efficiency: 90%
Spin flipper efficiency: 97%
Polariser efficience: 99%
^{3}He analyser efficience: 93%
^{3}He analyser lifetime: 100 hours



Pelican Dehong Yu.

- Single crystal measurements and data processing.
- One touch λ/2
- Transition from LAMP to Mantid
- New sample environment:

7 T Superconductor Magnet

- Achieved up to 7 T magnetic field with variable sample temperature from 300 K down to 50 mK.
- Very low stray field: 5 gauss at 1 m diameter.
- Easy operate: one command
- Open up new scientific opportunities for spin dynamics under high magnetic field.

High Pressure – up to 2 GPa

- Achieved up to 2 GPa pressure with sample temperature from 300 K down to 100 K.
- Several user experiments performed successfully.
- Open up new scientific opportunities for material dynamics under high pressure, for example, pressure induced order to disorder phase transition, responsible for caloric effect in plastic crystals; Protein dynamics for deep sea life under hundreds of MPa pressure, …

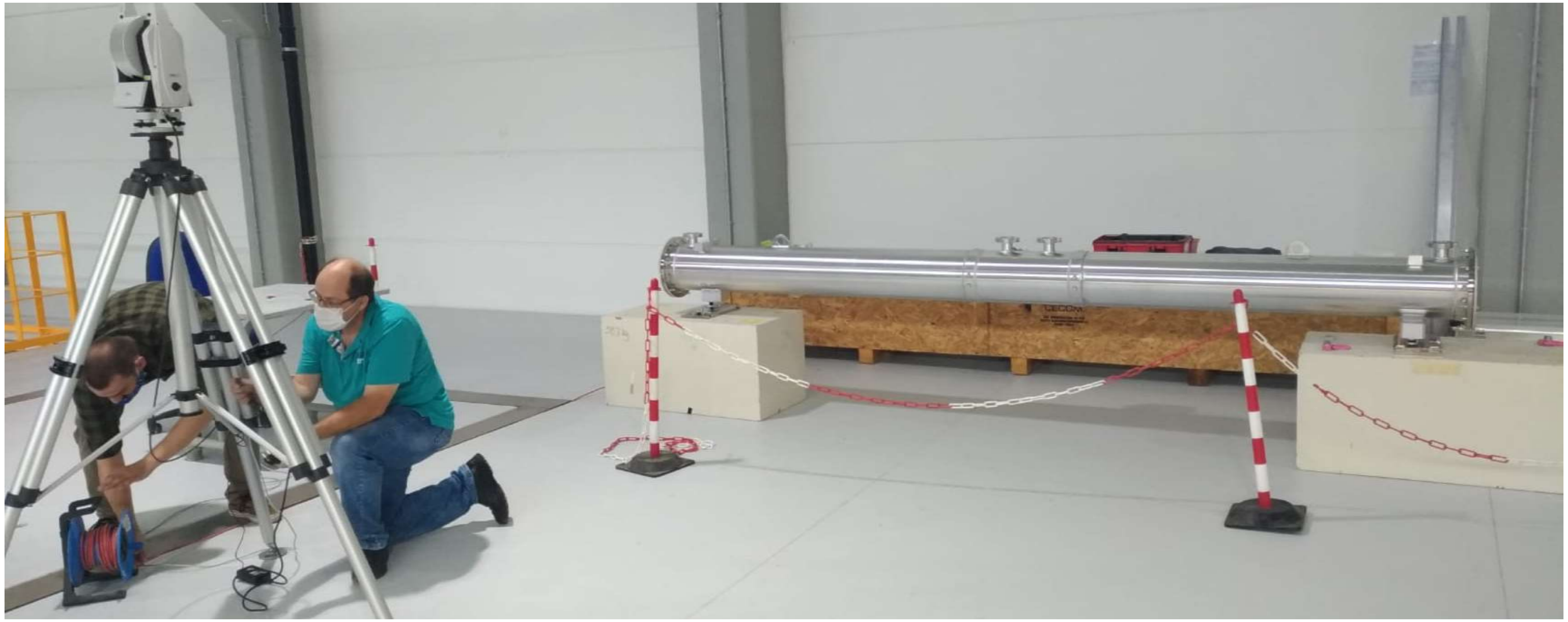
CuBe-

Installation campaign of guides/ housing.
September 2022

Installation: 3 to 4 campaigns, 10 days each.

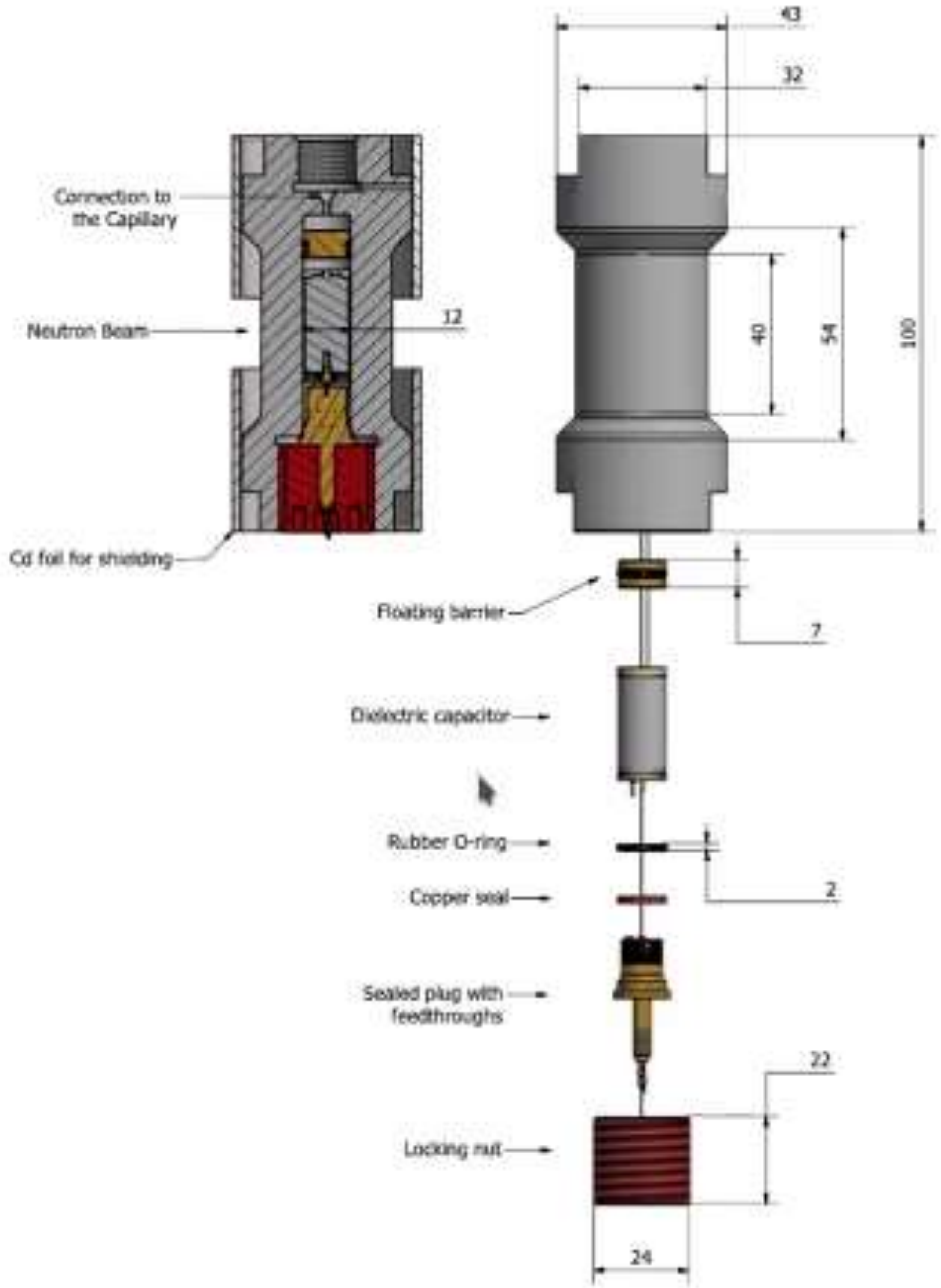
Outside bunker: 2 campaigns.

In-bunker + choppers: 1 or 2 campaigns.



Sample Environment

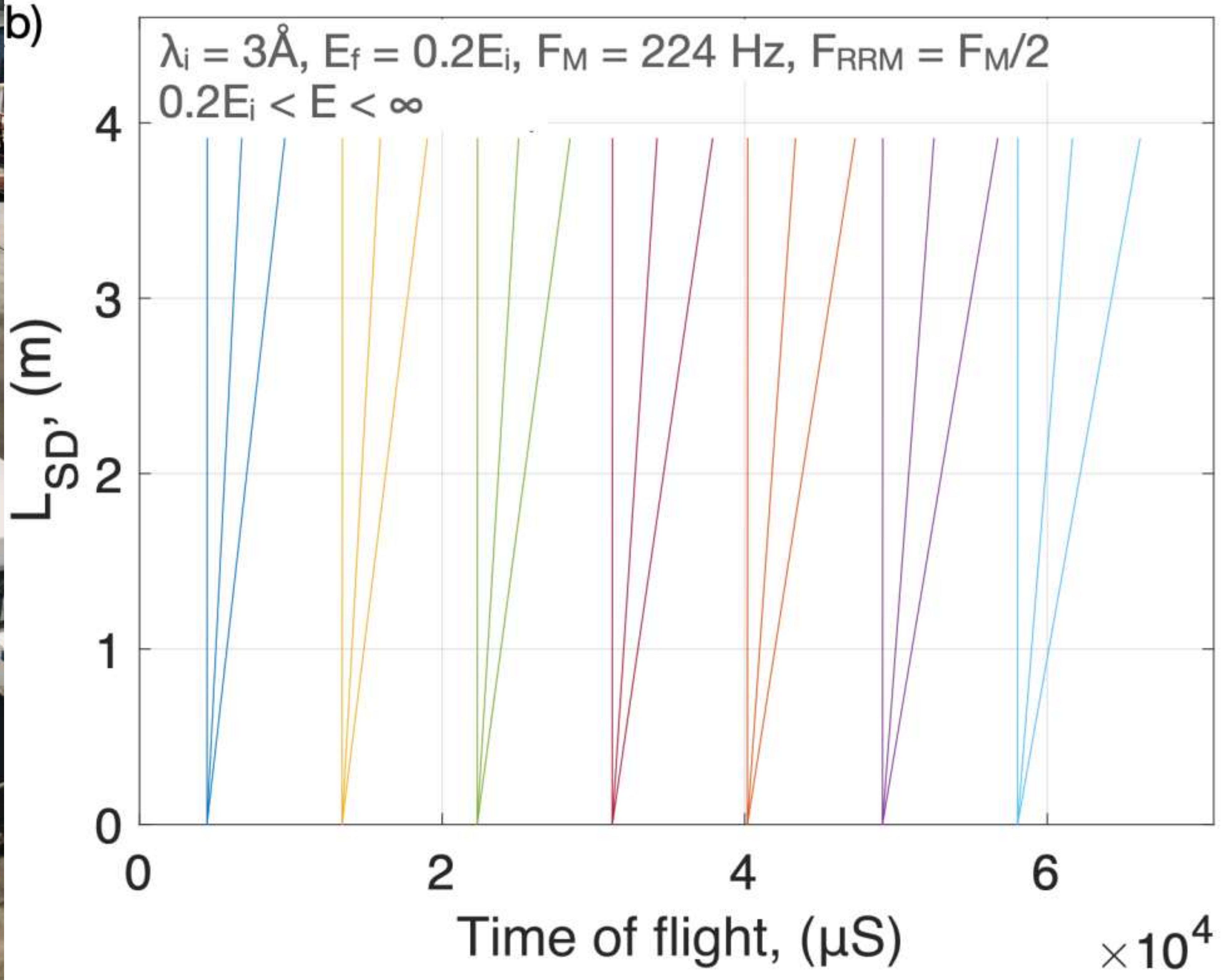
- ▶ Standard orange cryostat and -furnace 1.5 . . . 550 K
- ▶ Dilution inserts 40 mK
- ▶ Dedicated furnace 1000 °C
- ▶ Liquid and clamp pressure cells
- + Simultaneous dielectric spectroscopy (under pressure)
- ▶ User provided equipment . . .

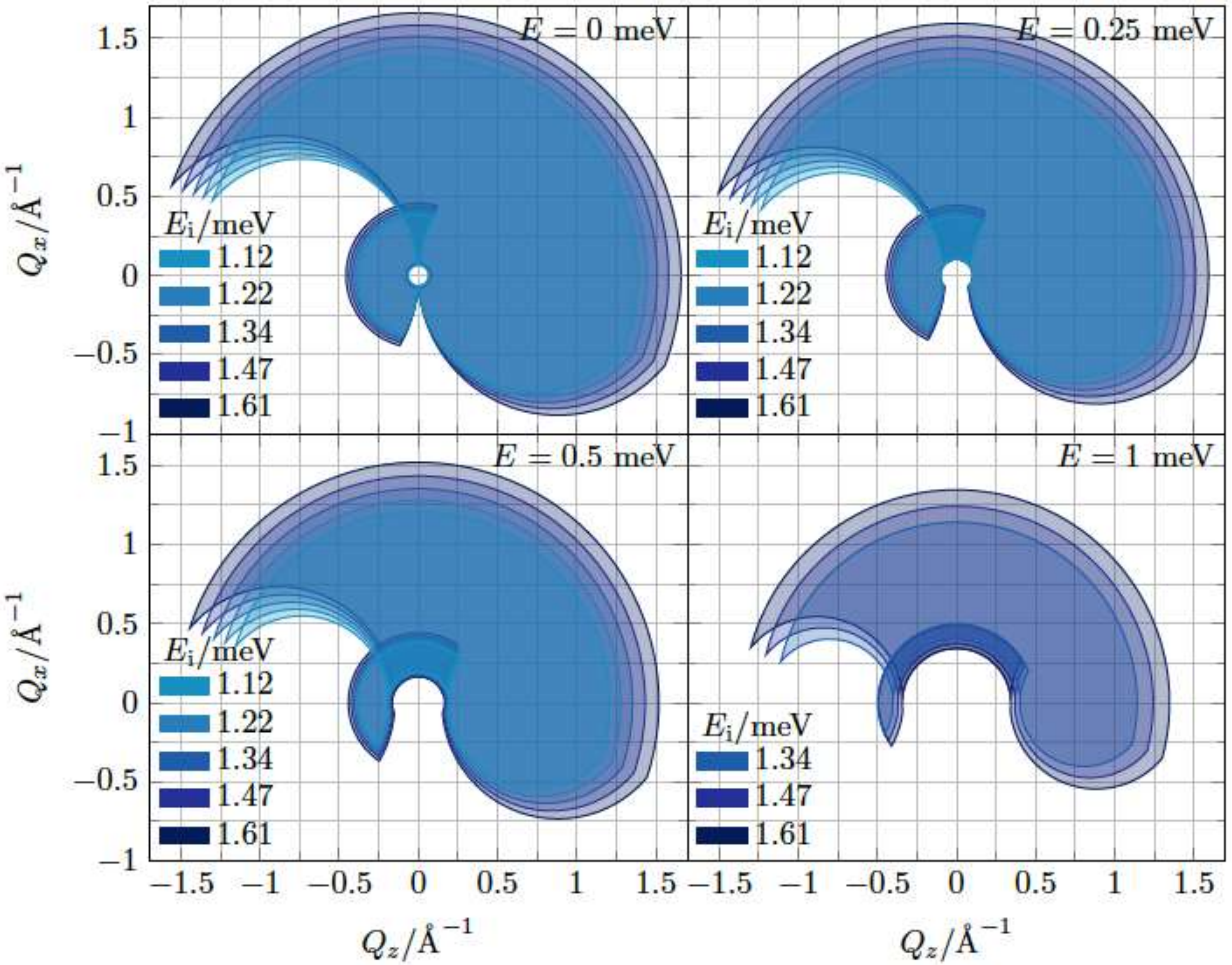


LTP-6-7, K. Niss et al., U Roskilde
Sanz et al., Rev. Sci. Instr. **89**, 023904 (2018)

(a)

b)

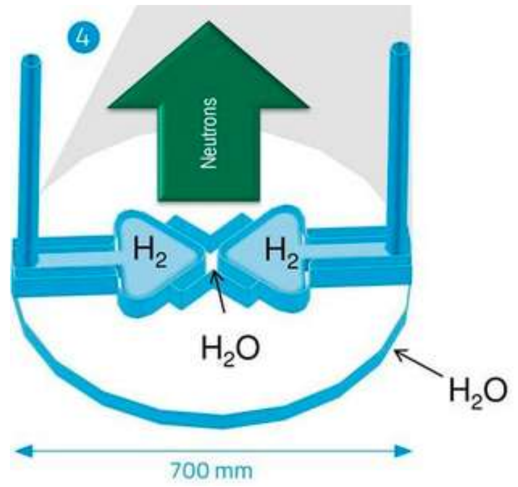

λi = 3Å, Ef = 0.2Ei, FM = 224 Hz, FRRM = FM/2
0.2Ei < E < ∞
LSD', (m)
0
1
2
3
4
0
2
4
6
Time of flight, (μS)
×10^4

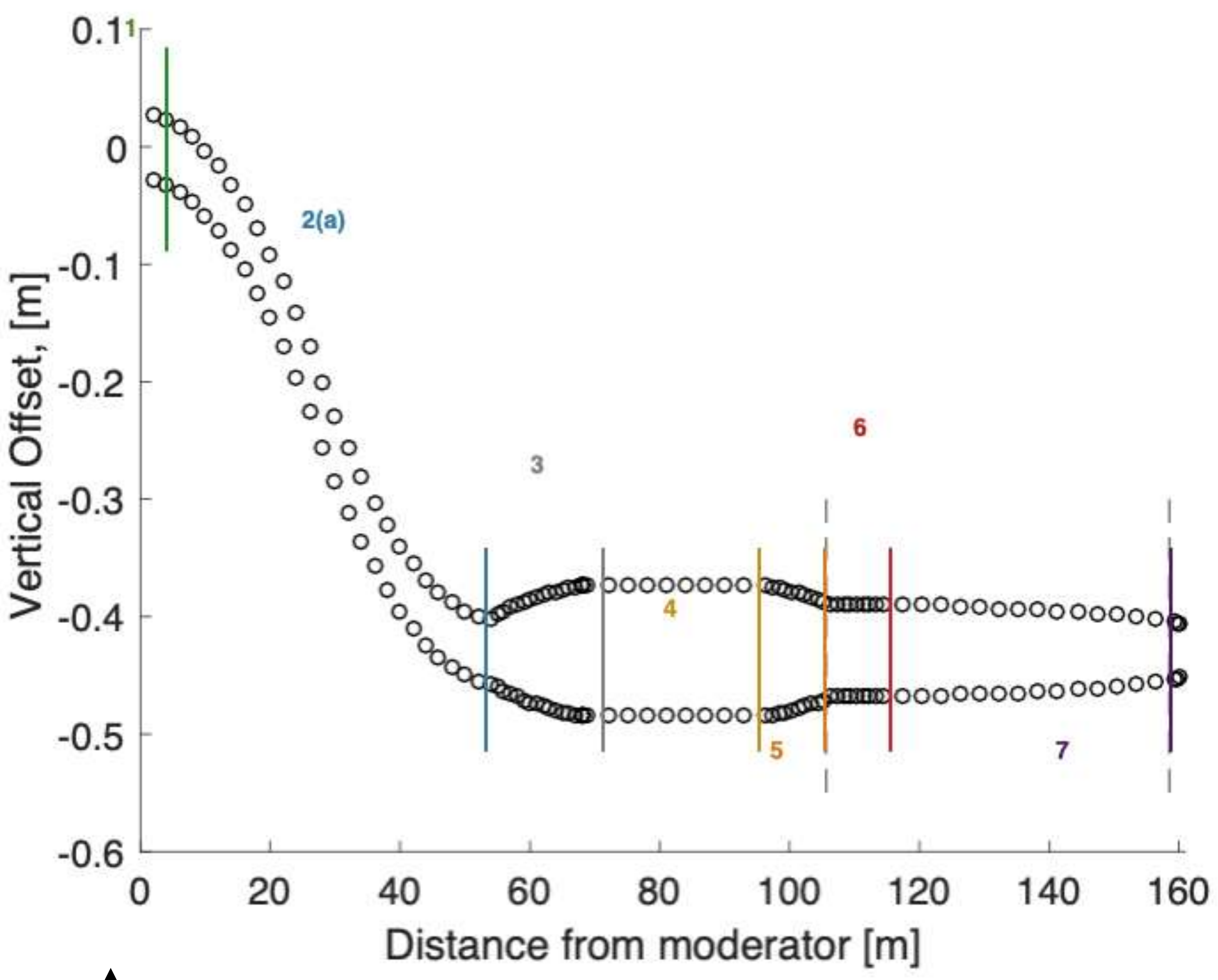

E = 0 meV
E = 0.25 meV
E = 0.5 meV
E = 1 meV
E_i/meV
1.12
1.22
1.34
1.47
1.61
$Q_x/\text{Å}^{-1}$
$Q_z/\text{Å}^{-1}$
1.5
1
0.5
0
−0.5
−1
−1.5

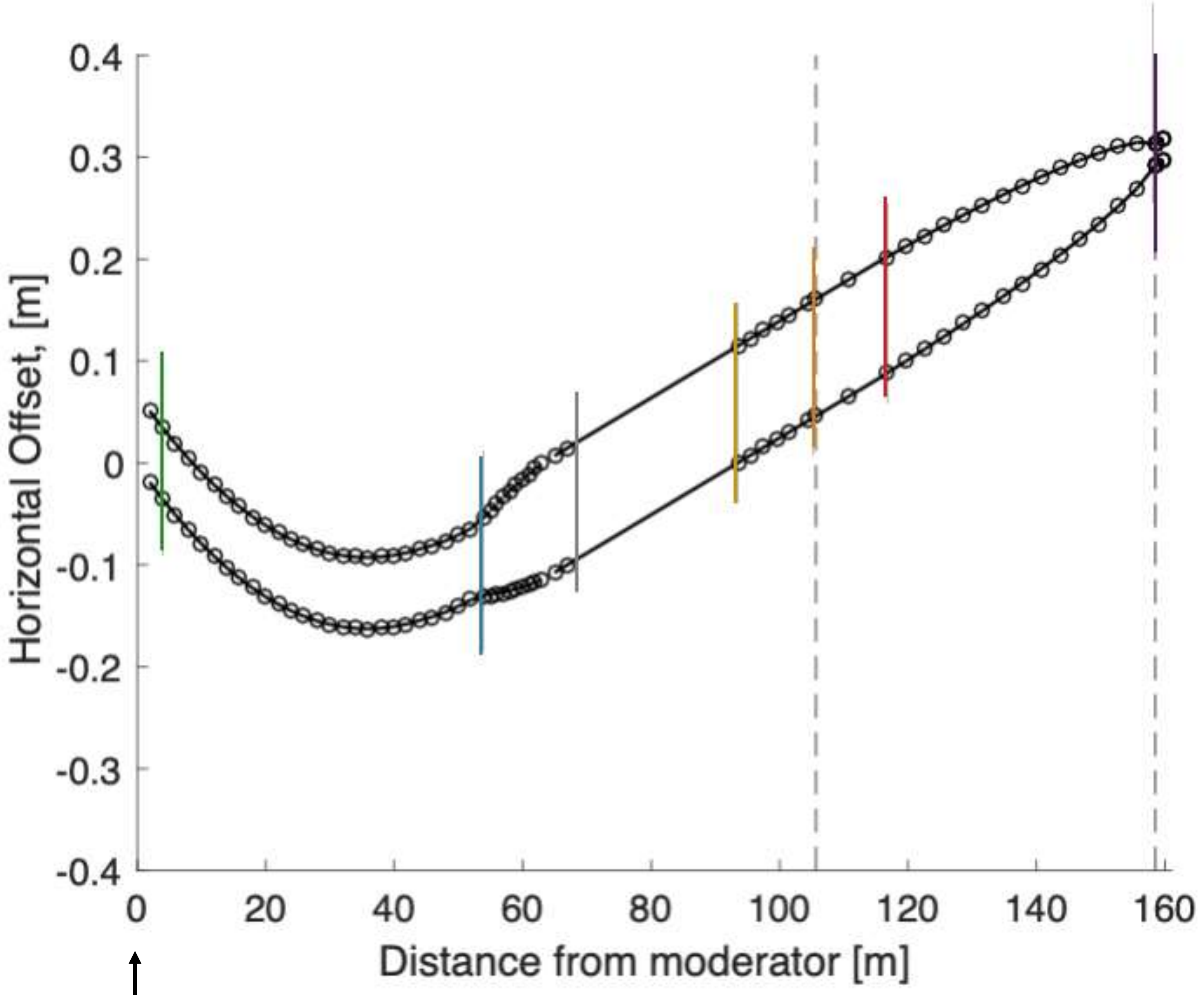
CSPEC
The Cold Chopper spectrometer of the ESS

TECHNISCHE UNIVERSITÄT MÜNCHEN · Orphée Laboratoire Léon Brillouin · EUROPEAN SPALLATION SOURCE

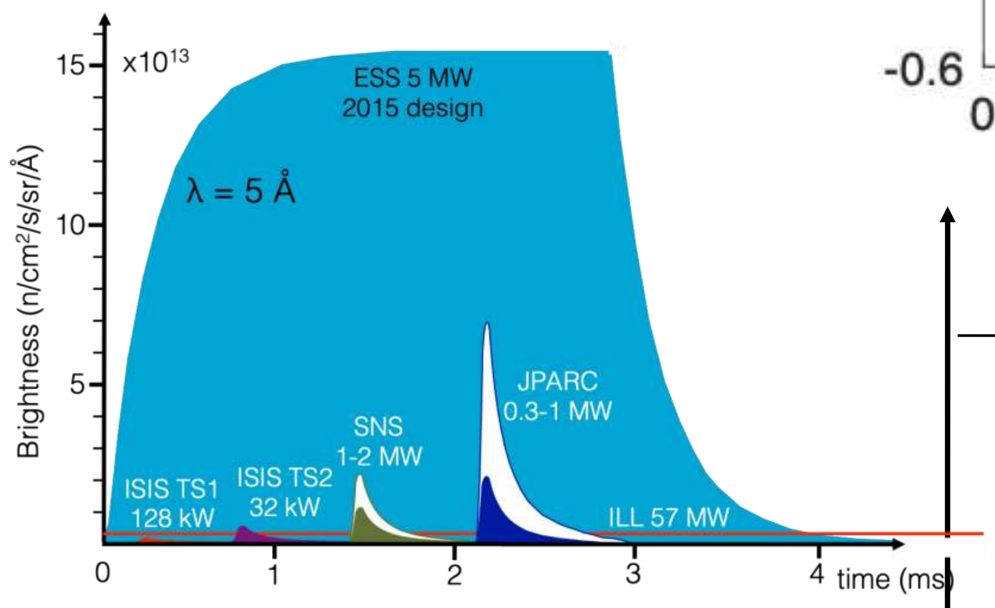
(2) 160 m & cold neutrons & spallation source = less noise. S/N 10^5.

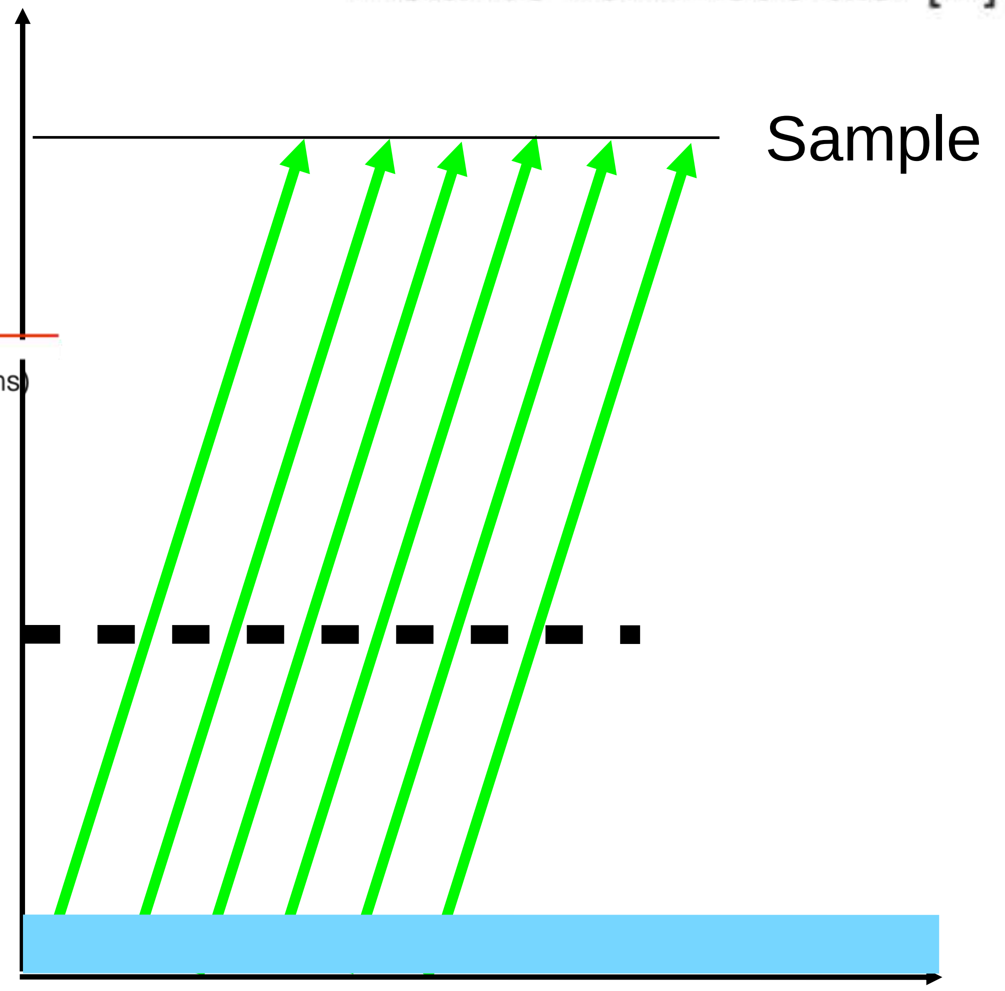




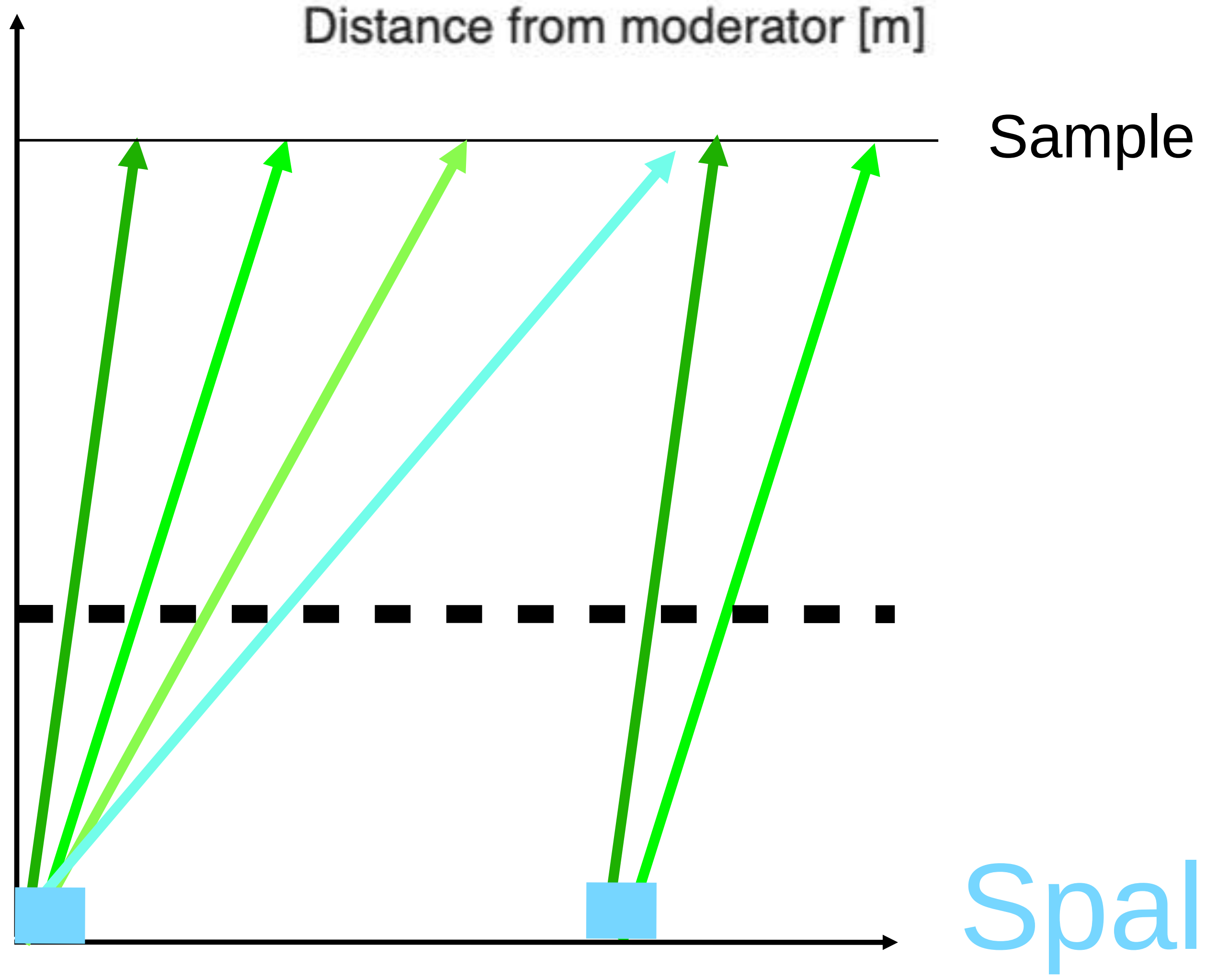


Cold neutrons: S-Bender





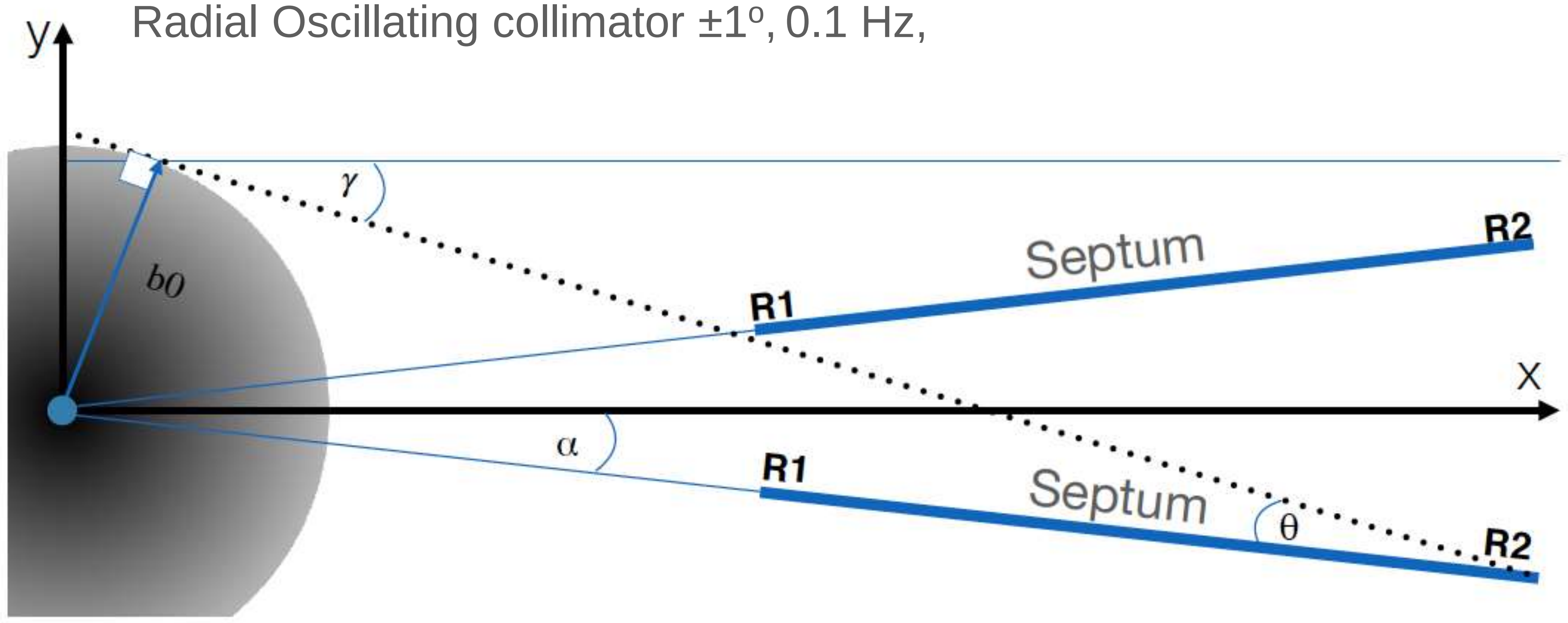
Reactor

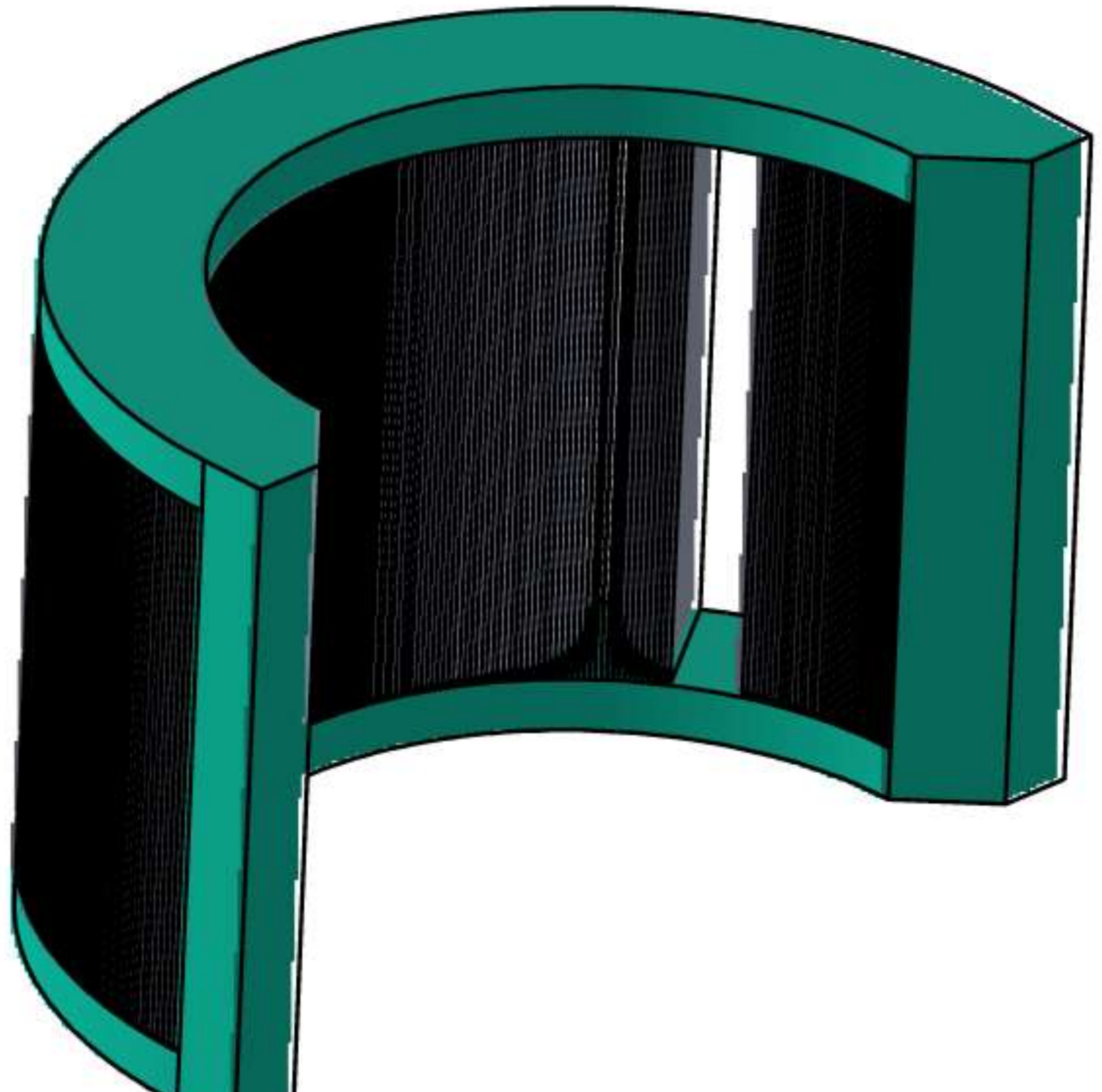


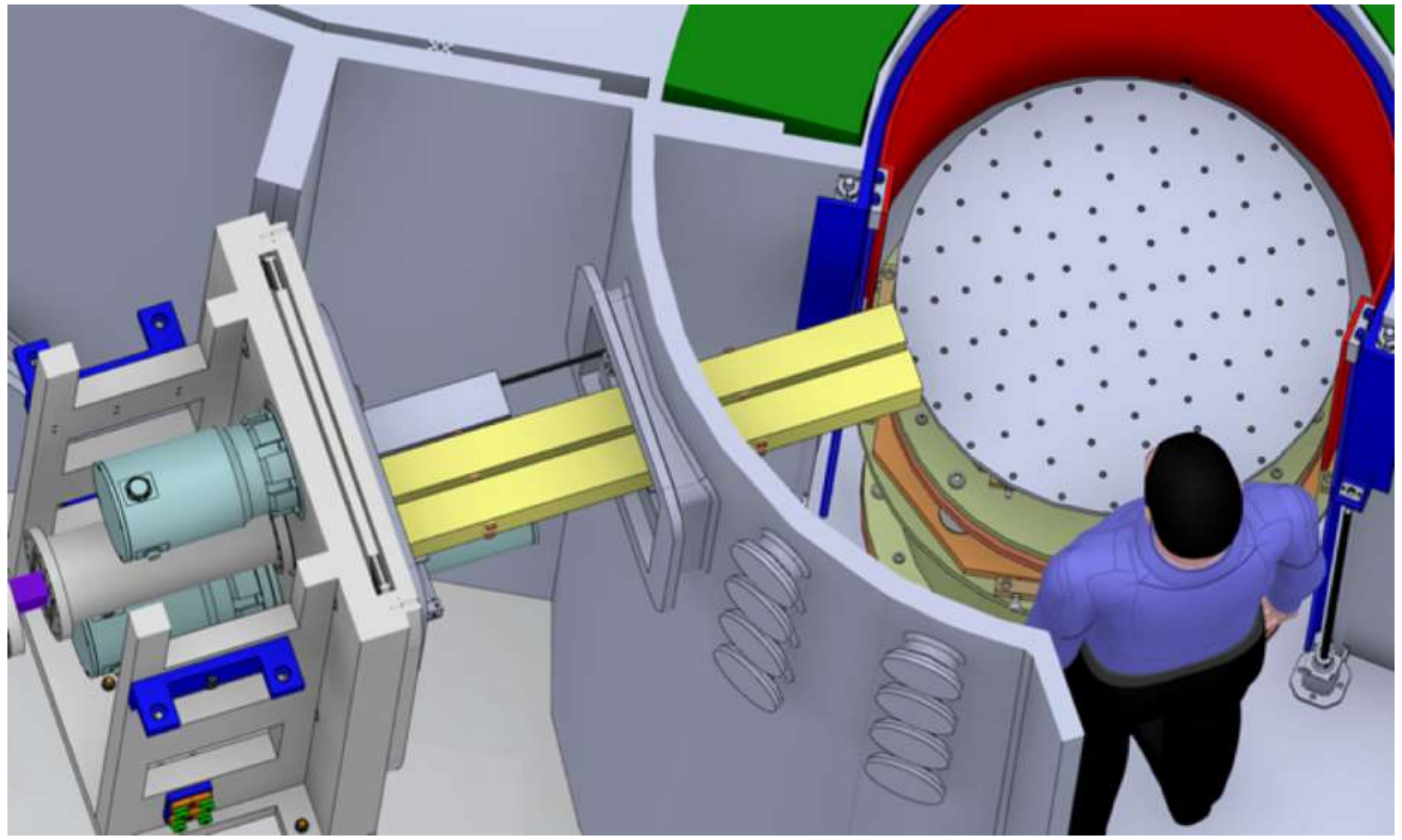
Spallation

No ambient background

Radial Oscillating collimator ±1°, 0.1 Hz,

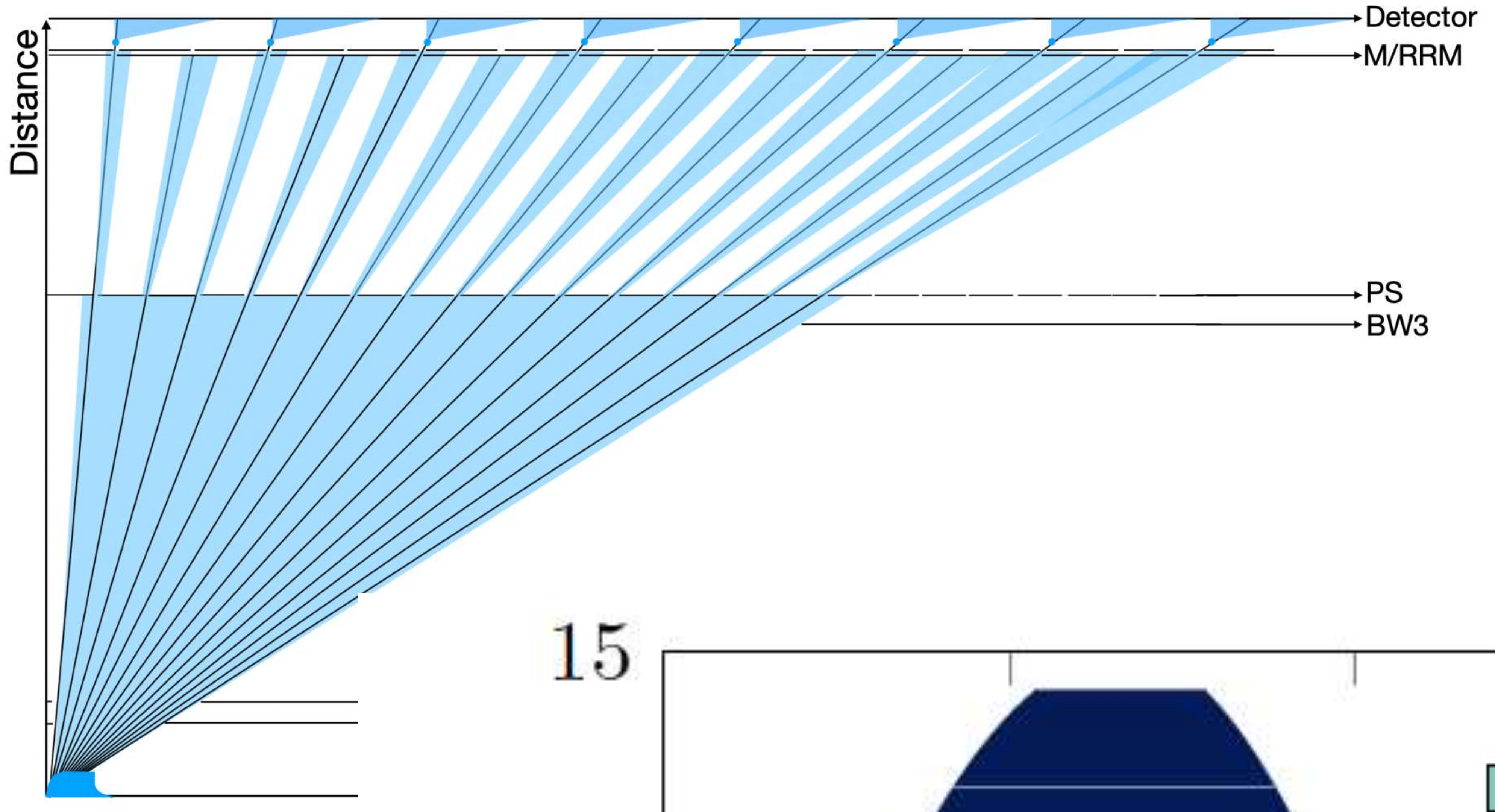




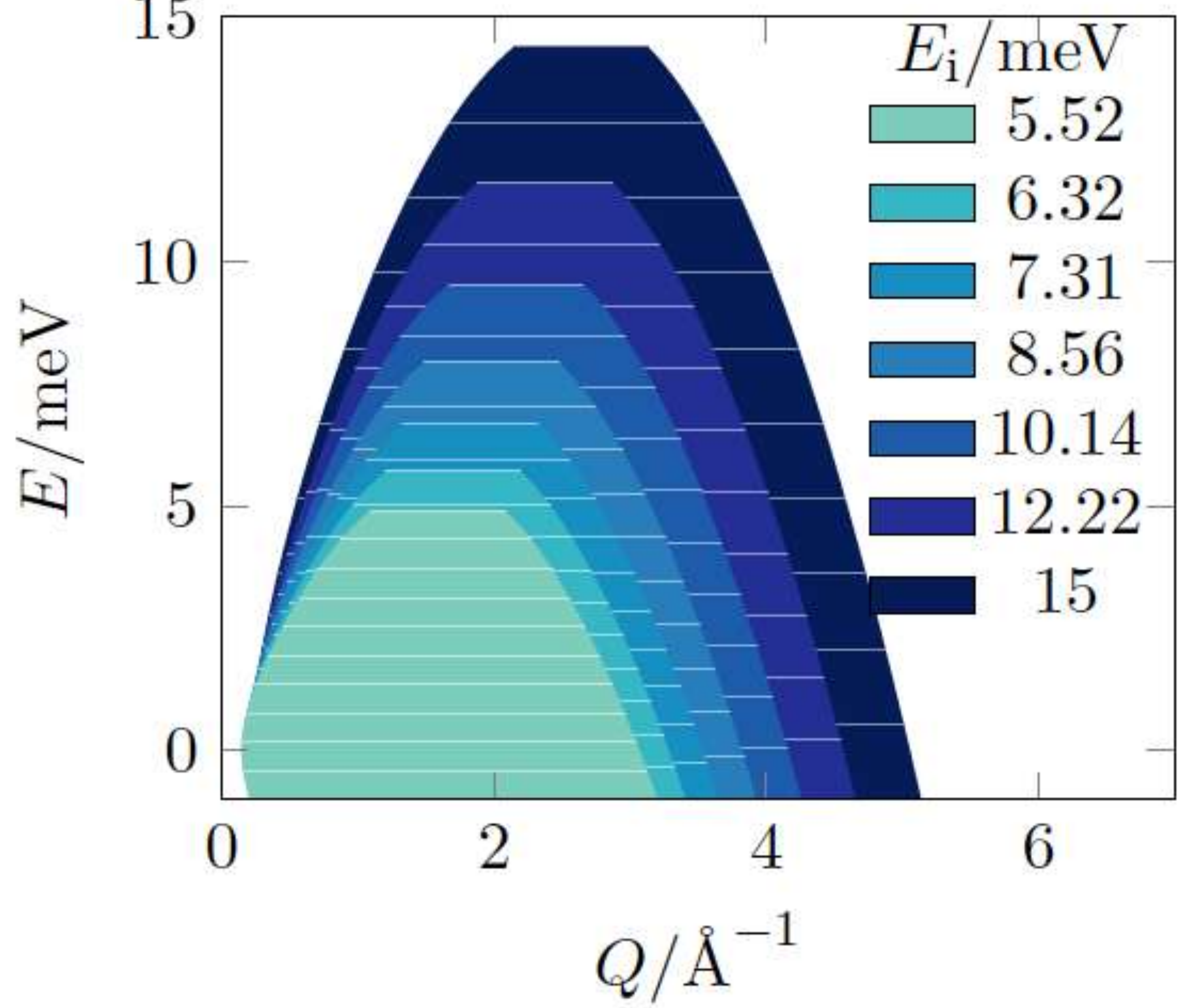


$R1$	$R2$	2α	$2b_0$	γ ^{o}
504 mm	708 mm	0.8 ^{o}	48.85 mm	2.38 ^{o}

TABLE III. CSPEC radial collimator parameters.

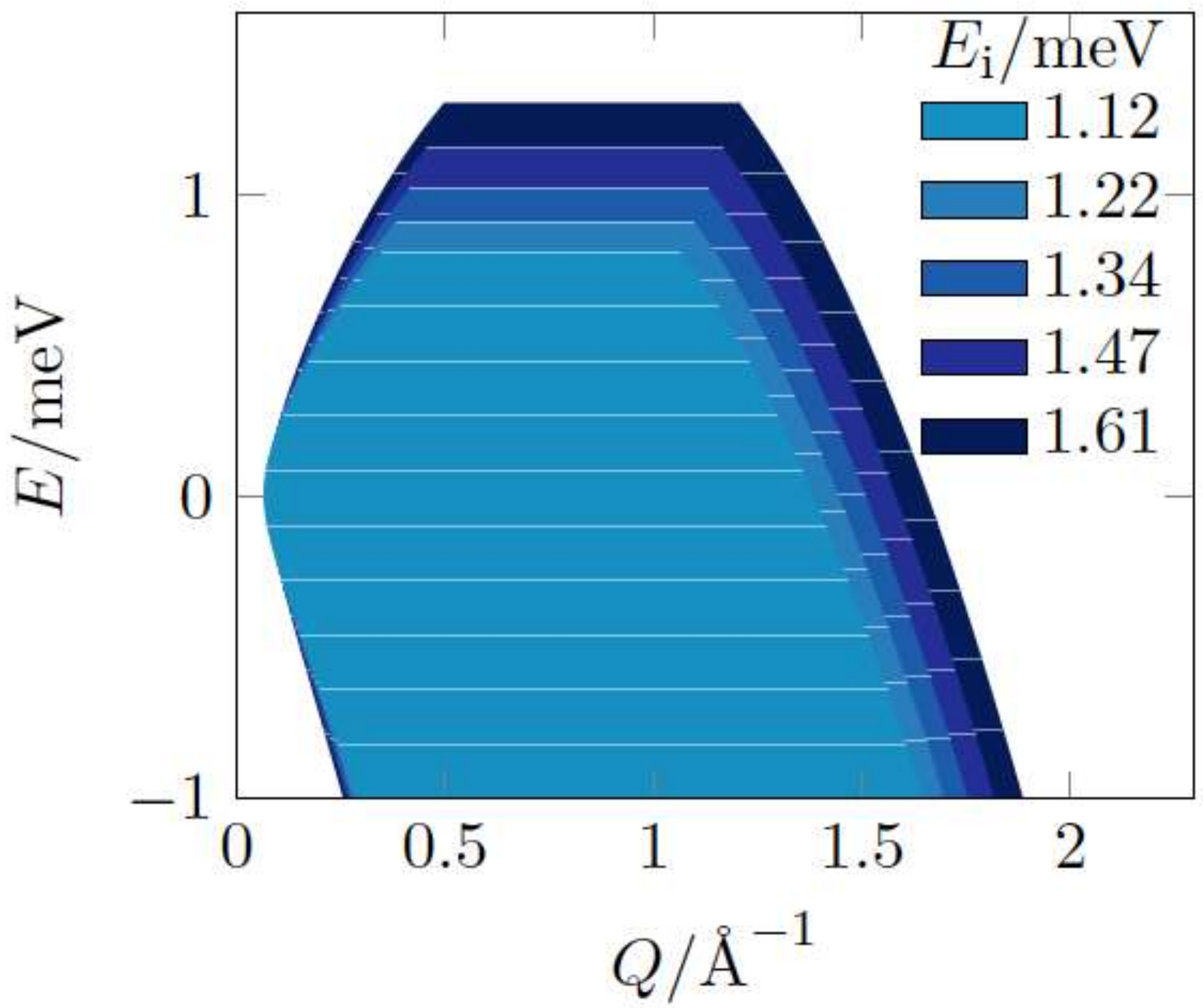


$\lambda_{central}$ = 3 Å



(b) $5.52 \leq E_i \leq 15\,\mathrm{meV}$

$\lambda_{central}$ = 8 Å



(a) $1.12 \leq E_i \leq 1.61\,\mathrm{meV}$