Motion Control Commissioning on the V20 Beamline

- @ HZB -

DENIM 2018

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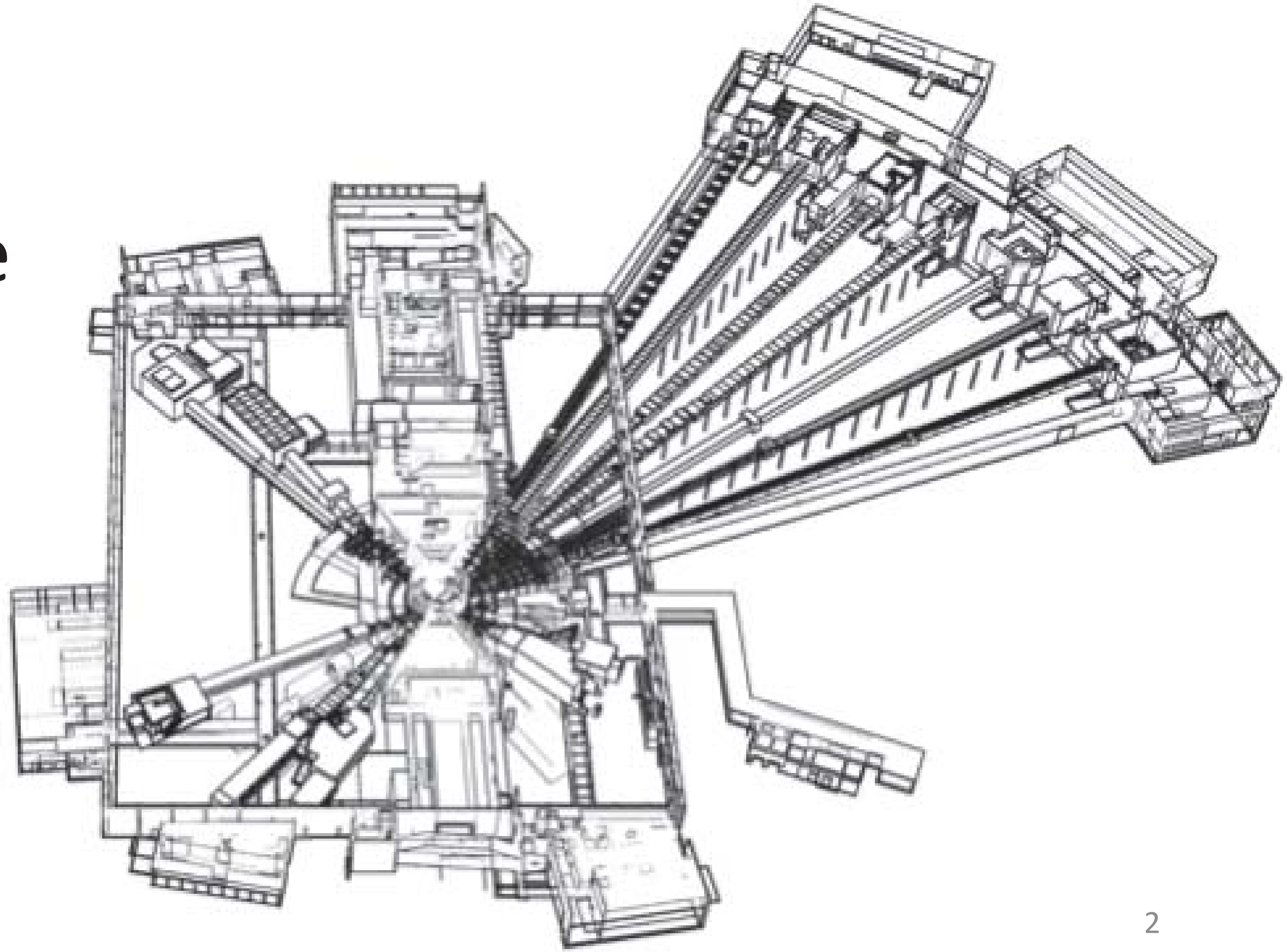
Introduction

- The European Spallation Source (ESS) is a spallation neutron source under construction in Lund, Sweden.
- 15 initial instruments delivered by in-kind partners across Europe with 22 anticipated and ~400 initial motion axes.



Introduction

- Presentation on the first motion control system commissioned on the ESS Test Beamline in **Germany**.

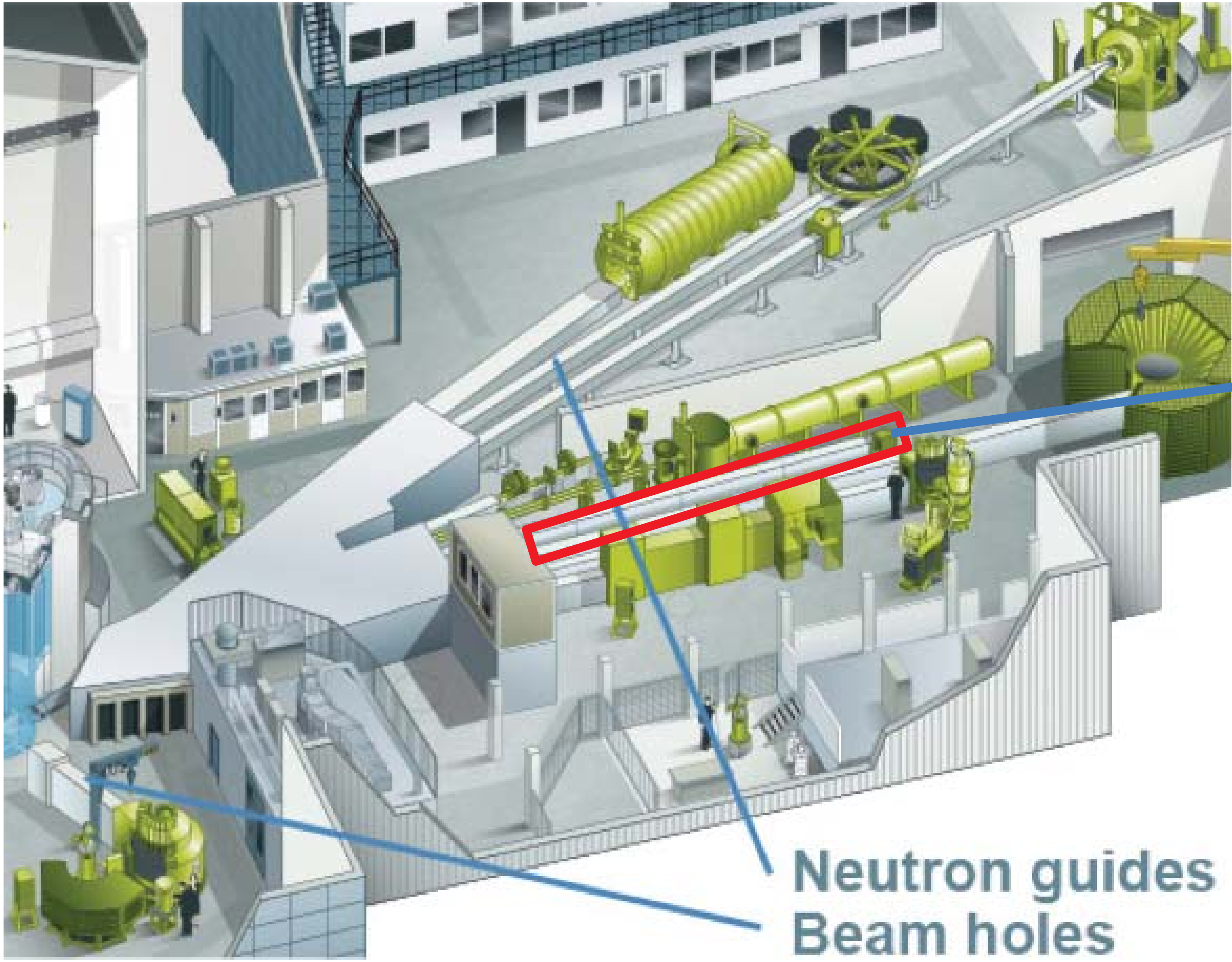
Overview

- BER-II reactor & ESS Test beamline
- Project scope
- Requirements
- Hardware design
- Standard software design
- Control architecture levels
- Implementation of slit system
- Commissioning outcomes
- Lessons Learnt

ESS Test Beamline @ BER-II Reactor

- ESS Test Beamline, V20, was originally part of a German In-Kind contribution.
- 10MW BER-II research reactor reactor located in Berlin and operated by Helmholtz-Zentrum Berlin (HZB).
- Commissioned 1973 but will shut down permanently end of 2019.
- Two guide halls and 23 instruments.

HZG Guide Halls

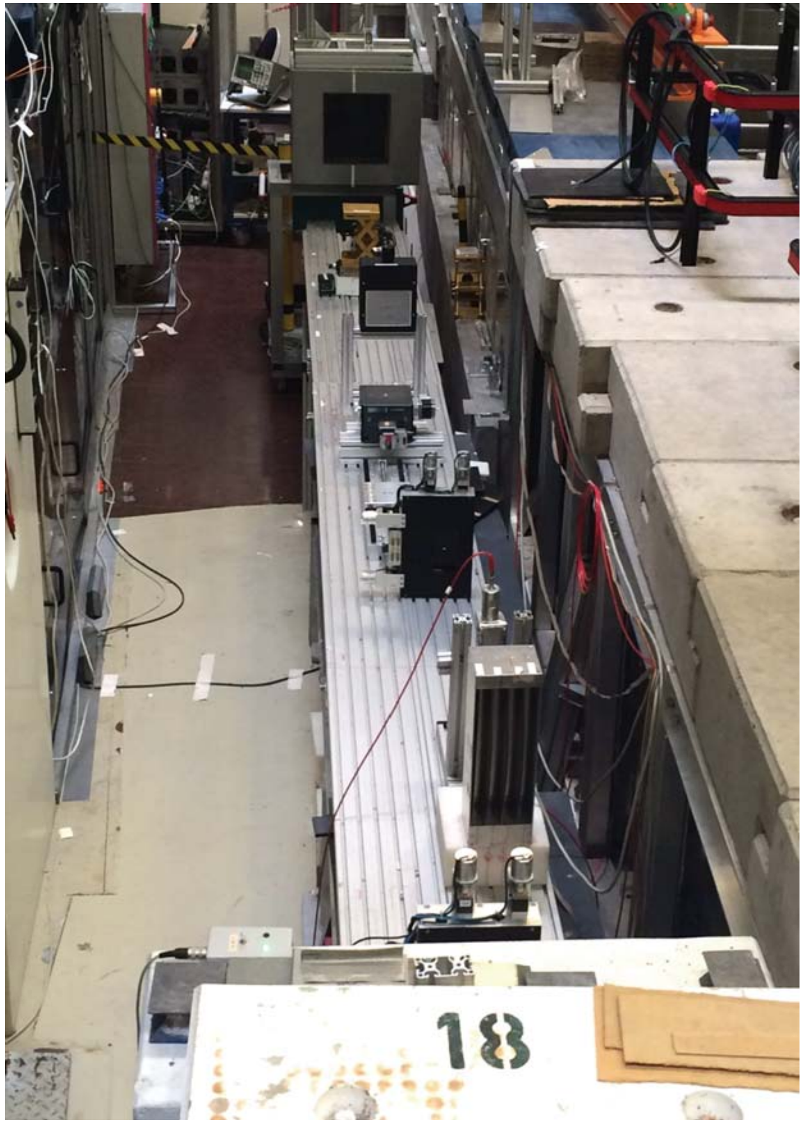


ESS Test
Beam Line
V20

Neutron guides
Beam holes

V20 Beamline

- Designed to mimick the ESS pulse structure (14Hz, 2.86ms).
- Thereby enabling the development of techniques and technology adapted to the long pulse source of ESS.
- V20 project includes integration and development of components and control systems.
- Flexible experimental setups and a wide selection of components (motion stages) in different configurations.



V20 Beamline Project

- 2011 to 2014: Design and installation in p[illegible]h the instruments upgrade program of HZ[illegible]
- Spring 2015: “hot” commi[illegible]ase.
- 2015/2016: First [illegible] mainly used by instrume[illegible] for method development.
- 20[illegible]ations of detectors and control system [illegible] (on top of HZB control system CARESS).
- 2017/2018: Control system integration (NICOS, EPICS).
- 2018: Motion control upgrade <- this presentation.
- 2019: Reactor shut down and some components shifted to ESS.

First real commissioning for ESS MCA Group

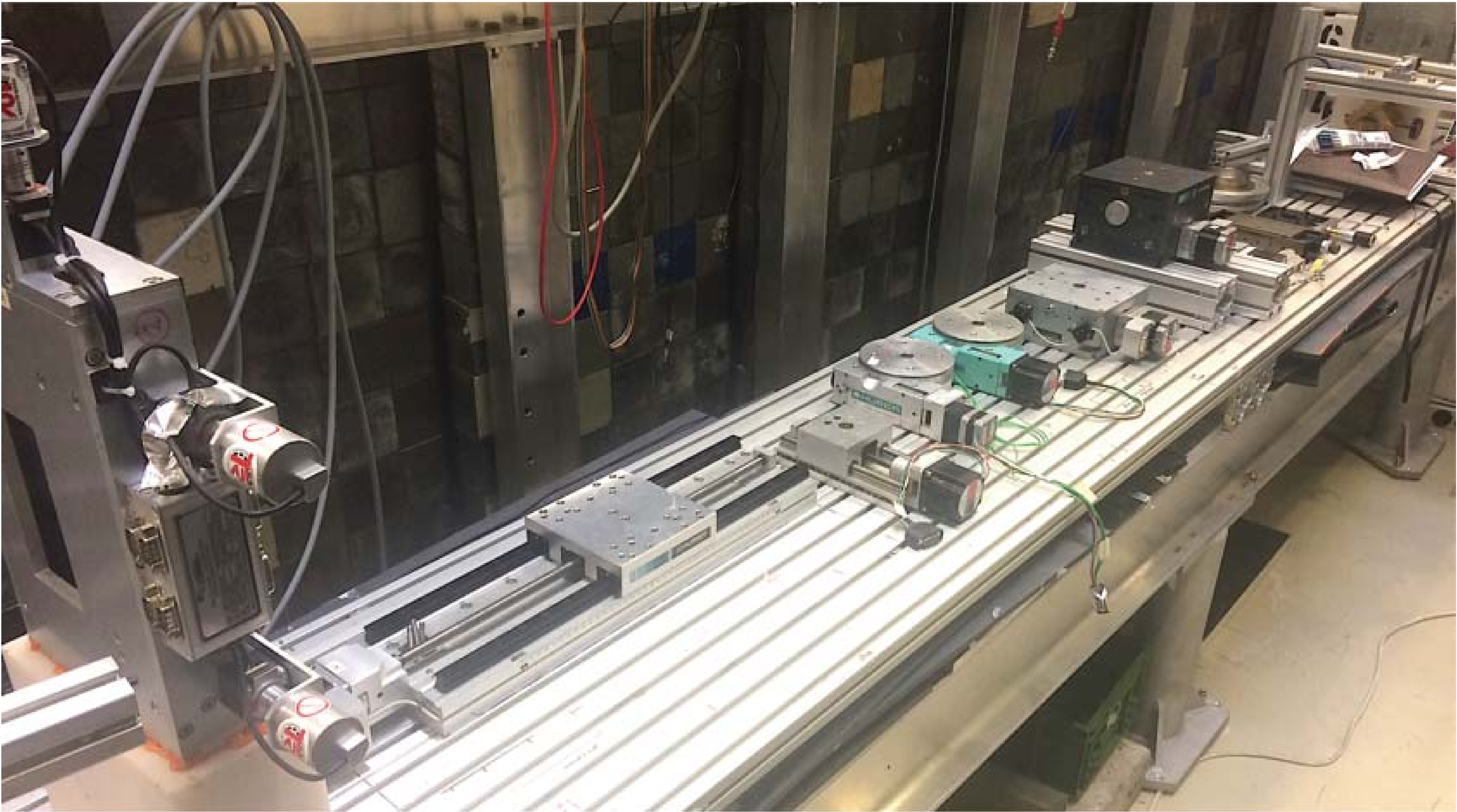
Table of Motion

Axis #	Axis Name	Device	Motion Type	Type	Brand	Part #	Driver Voltage [V]	Set Current [A]	Steps / Rotation (if stepper)
1	WFM Chopper 1	WFM Chopper distance	Linear						
2	WFM Chopper 2	WFM Chopper distance	Linear						
3	Slit1 horizontal top	Slit 1	Linear		VEXTA				
4	Slit1 horizontal bottom	Slit 1	Linear		VEXTA				
5	Slit1 vertical left	Slit 1	Linear		VEXTA				
6	Slit1 vertical right	Slit 1	Linear		VEXTA				
7	Polarizer_ROT	Polarizer Positioning Unit	Rotary		Phytron?				
8	Polarizer_Translation	Polarizer Positioning Unit	Rotary		Festo?				
9	Slit2 horizontal top	Slit 2	Linear		VEXTA				
10	Slit2 horizontal bottom	Slit 2	Linear		VEXTA				
11	Slit2 vertical left	Slit 2	Linear		VEXTA				
12	Slit2 vertical right	Slit 2	Linear		VEXTA				
13	Slit3 horizontal top	Slit 3	Linear		VEXTA				
14	Slit3 horizontal bottom	Slit 3	Linear		VEXTA				
15	Slit3 vertical left	Slit 3	Linear		VEXTA				
16	Slit3 vertical right	Slit 3	Linear		VEXTA				
17	LIN1	Linear stage I	Linear	2 Phase Stepper	VEXTA	PK266-02B		2A?	
18	LIN2	Linear stage II	Linear	2 Phase Stepper	VEXTA	PK266-03A		3A?	
19	LIN4X	Linear stage 4XY	Linear	2 Phase Stepper	VEXTA	PK266-03A		3A?	
20	LIN4Y	Linear stage 4XY	Linear						
21	LIN5Z	Linear stage 5	Linear	2 Phase Stepper	VEXTA	PK266-03A		3A?	
22	Omega1	Rotation table I	Rotary	2 Phase Stepper	VEXTA	PK243A1-SG36		0.35A?	
23	Omega2	Rotation table II	Rotary	2 Phase Stepper	VEXTA	PK266-03A		3A?	
24	ALPHA	Goniometer I	Rotary	2 Phase Stepper	VEXTA	PK223PB		0.95A?	
25	BETA	Goniometer II	Rotary	2 Phase Stepper	VEXTA	PK266-03A		3A?	
26	KAPPA	Goniometer II	Rotary	2 Phase Stepper	VEXTA	PK266-02B		2A?	
27	CHI	Sample Goniometer	Rotary	2 Phase Stepper	VEXTA	PK266-02B		2A?	
28	PHI	Sample Goniometer	Rotary	2 Phase Stepper					

fixed installed

portable installed

Motion stages



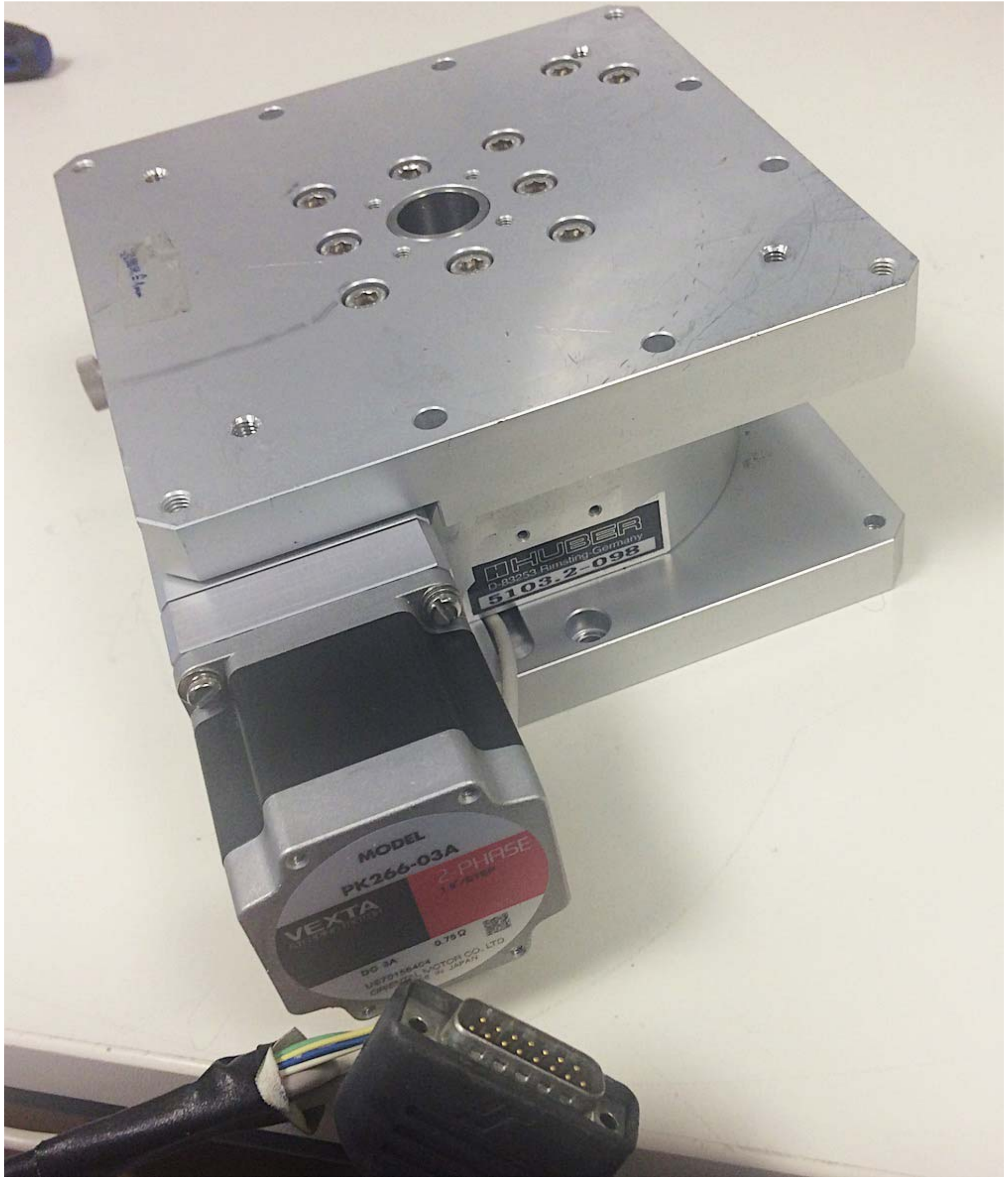
Aim & Scope of MCA Project

- Aim
  - Apply and test ESS MCA technologies and principles to a real beamline.
  - Upgrade existing motion control system for instrument scientist.
  - Work as a team with different groups with ESS.
- Scope
  - Construct motion control system to **control 8 axes**.
  - Axes 1-4: Slit system, axes 5-8: removable motion stages.
  - Control from EPICS and NICOS (vertical integration).
  - Investigation of virtual axes at MCU level and evaluate the benefits of logic at different control levels.
  - Commission the MCU in Berlin.

The Team

- Hardware, installation, ePLAN drawings: Markus Larsson (ESS MCA)
- Planning, motion controller programming, commissioning: Paul Barron (ESS MCA)
- EPICS: Torsten Bögershausen (ESS MCA)
- ICS (EPICS): John Sparger (ESS ICS), Krisztian Löki (ESS ICS based in Hungary)
- DMSC (NICOS): Matt Clarke, Michael Hart (ESS In-Kind team at ISIS)
- Instrument scientists: Robin Woracek (ESS), Peter Kadletz (ESS)

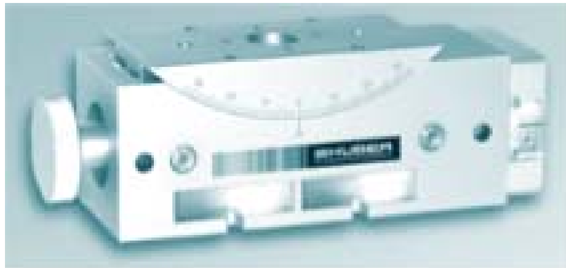
MCA components – Height stage



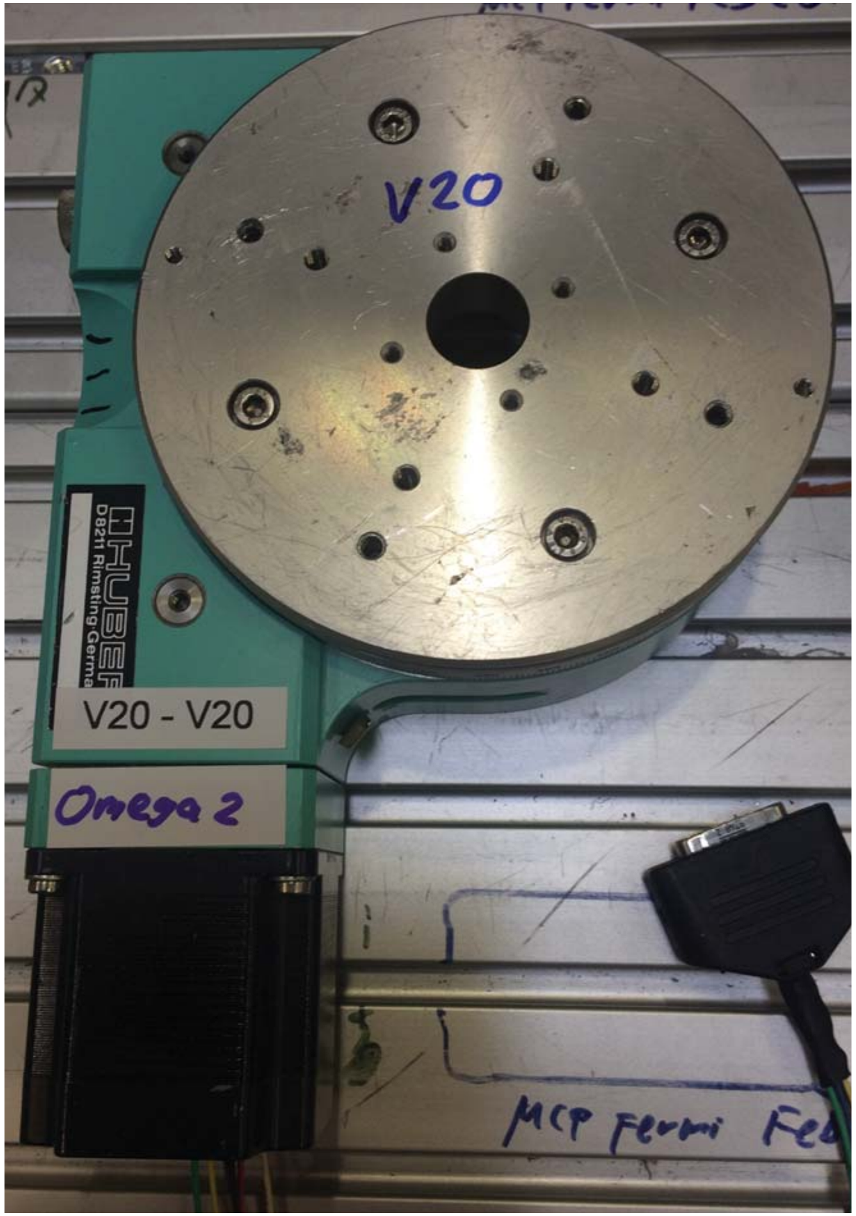
Z-Stage (Z-Sample)
Huber Model 5103.2 (≈5103.A20-40), travel 40mm

MCA components – Goniometer

Goniometer (BETA),
Huber Model 5202.4
(≈5202.40), range ± 30°
No limit switches

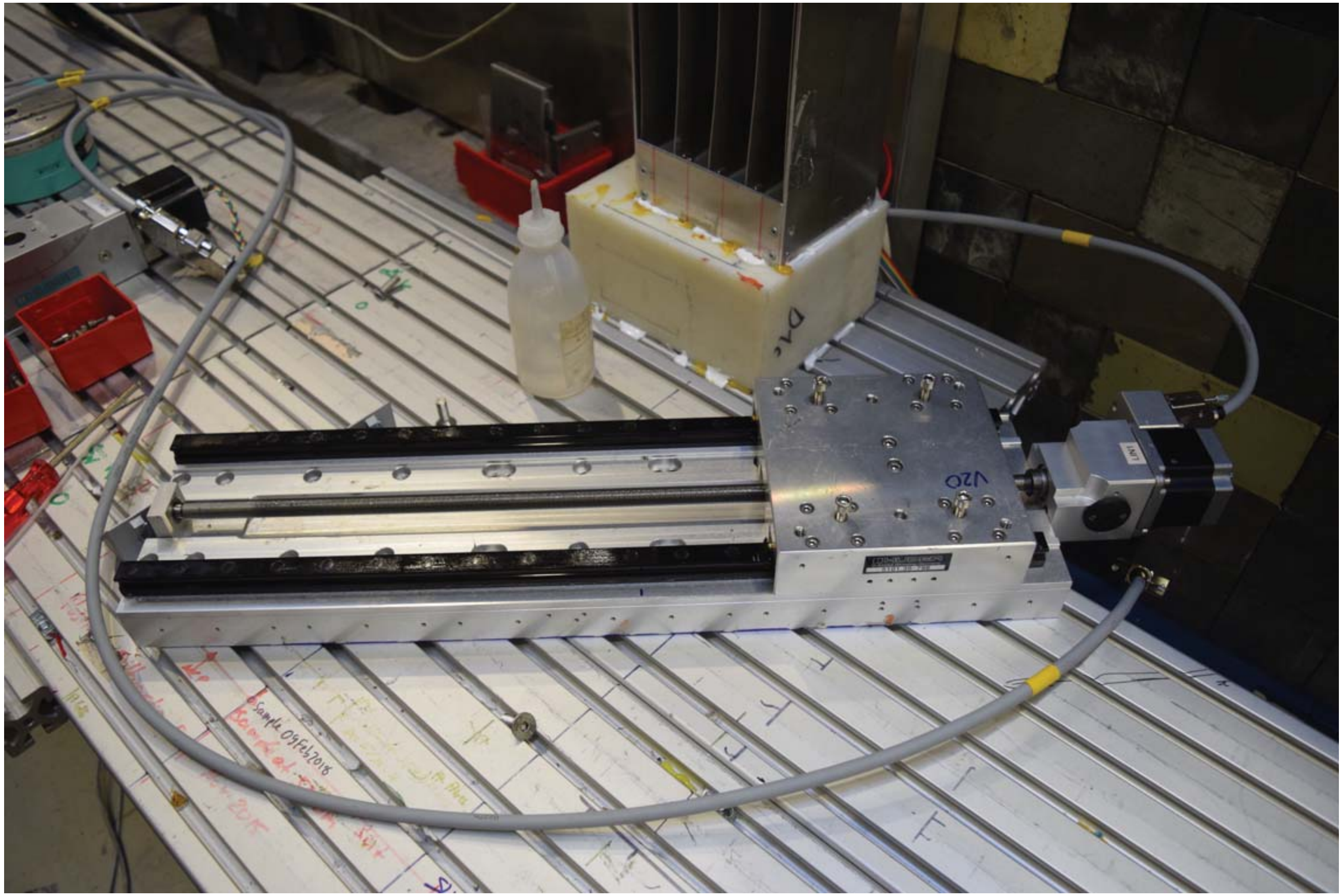


MCA components – Omega Stage



Rotation (OMEGA2)
Huber rotation stage Model 410
No limit switches

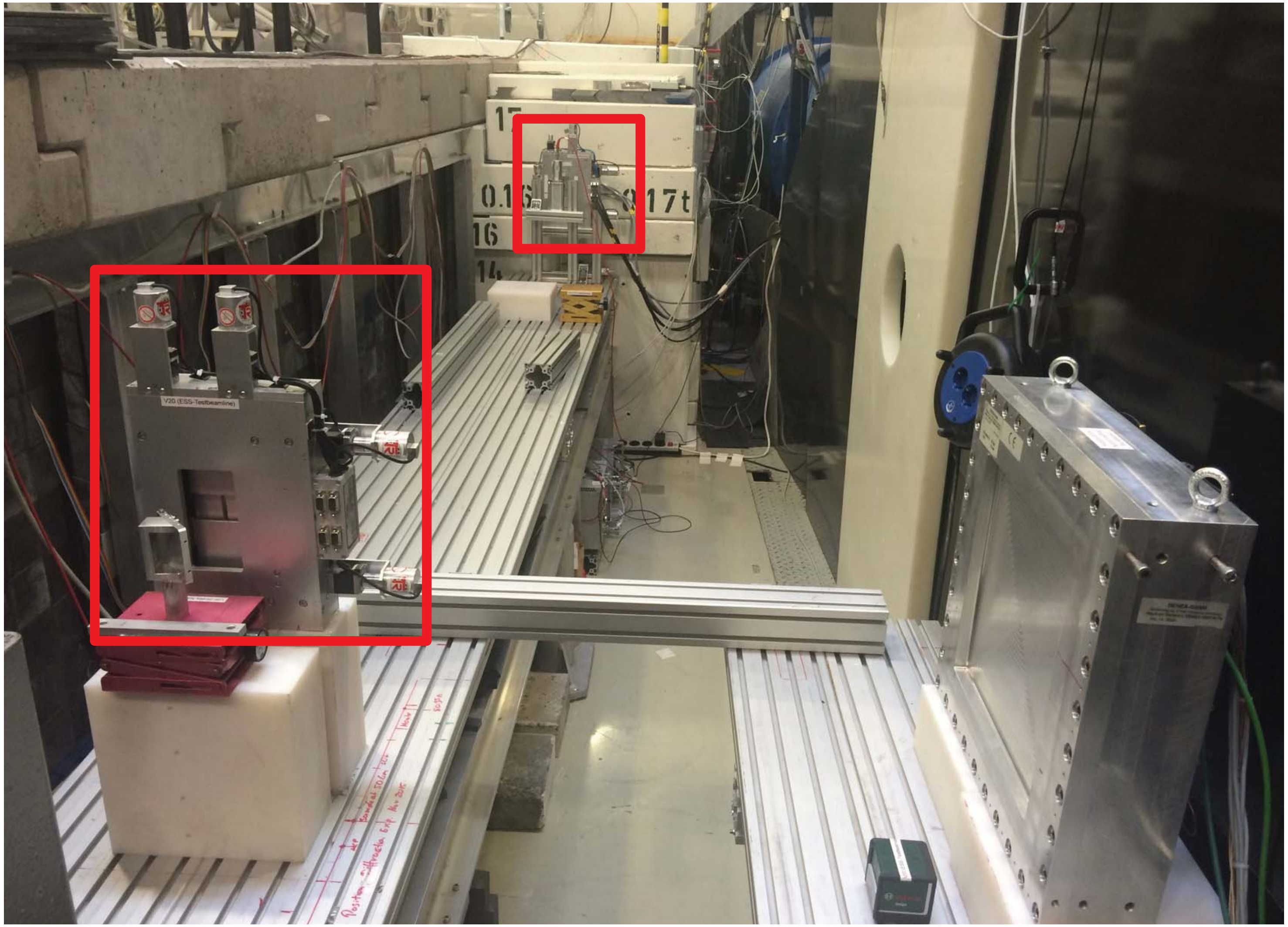
MCA components – Lin 1 stage



Translation (LIN1)
Huber linear table, Model 5101.30-400, travel 400mm

MCA components – Slit system III

EUROPEAN SPALLATION SOURCE

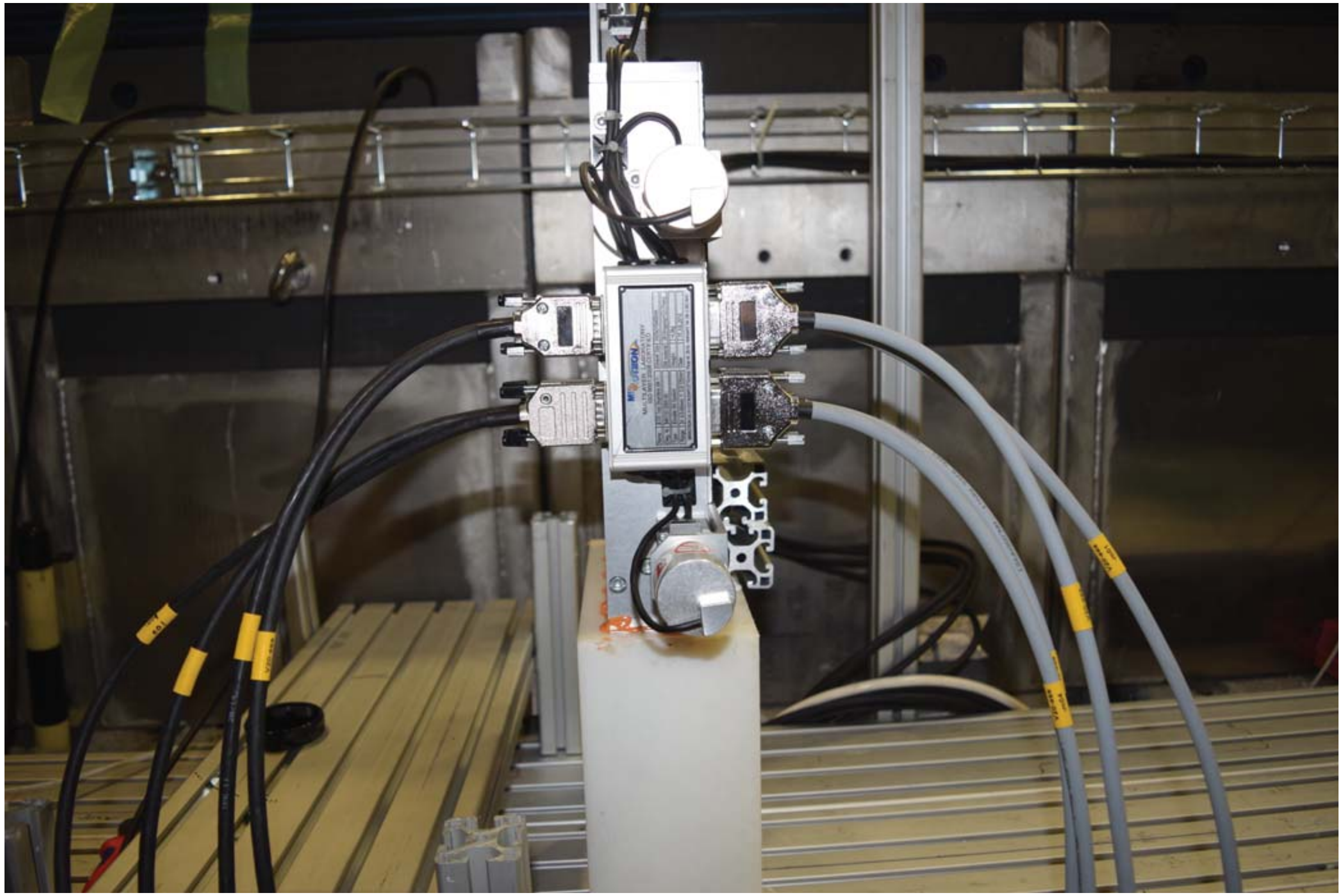


Mirrotron slit system

ESS Test BeamLine Slits
HZB

MIRROTRON LTD
Neutron Optics & Instruments

MCA components – Slit system III



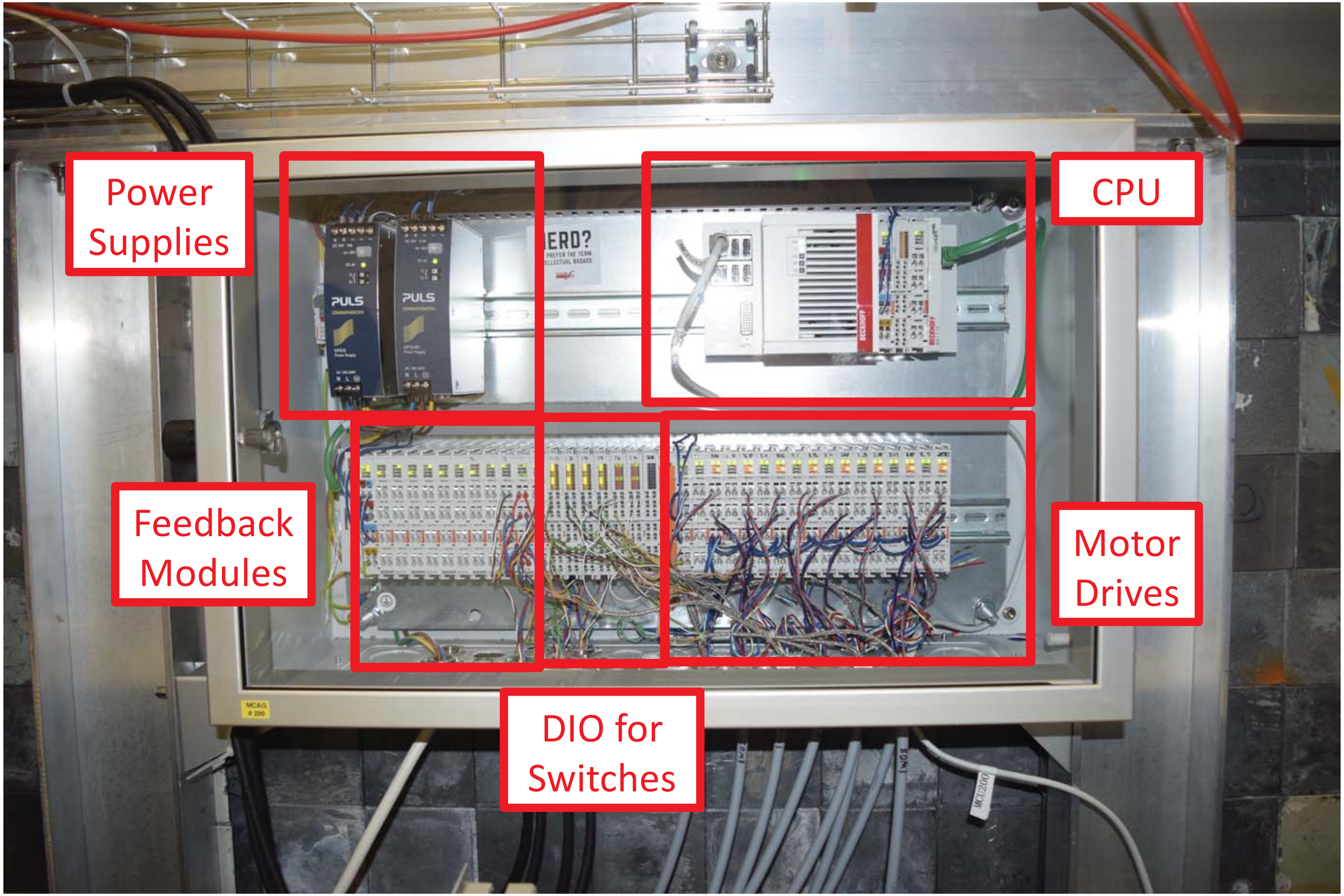
Axes

Axis #	Axis Name	Device	Motor	Encoder
1	Slit Y+ Left Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
2	Slit Y- Right Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
3	Slit Z+ Upper Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
4	Sit Z- Lower Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
5	Motion Stage Height (height1)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
6	Motion Stage Omega Rotation (omega2)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
7	Motion Stage Goniometer (beta)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
8	Motion Stage Linear stage (lin1)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop

Control Unit Hardware

- Beckhoff CPU CX-5130
- 8 x EL7047 Stepper motor modules
- 2 x EL5002 2 Channel Absolute SSI encoder modules
- 1 x EL2014 DO module for SSI Power
- 4 x EL1808 DI & 2 x EL2819 DO for limits
- 4 x EL5101 Incremental encoder modules (for future)

Control Unit Hardware - Cabinet Installed



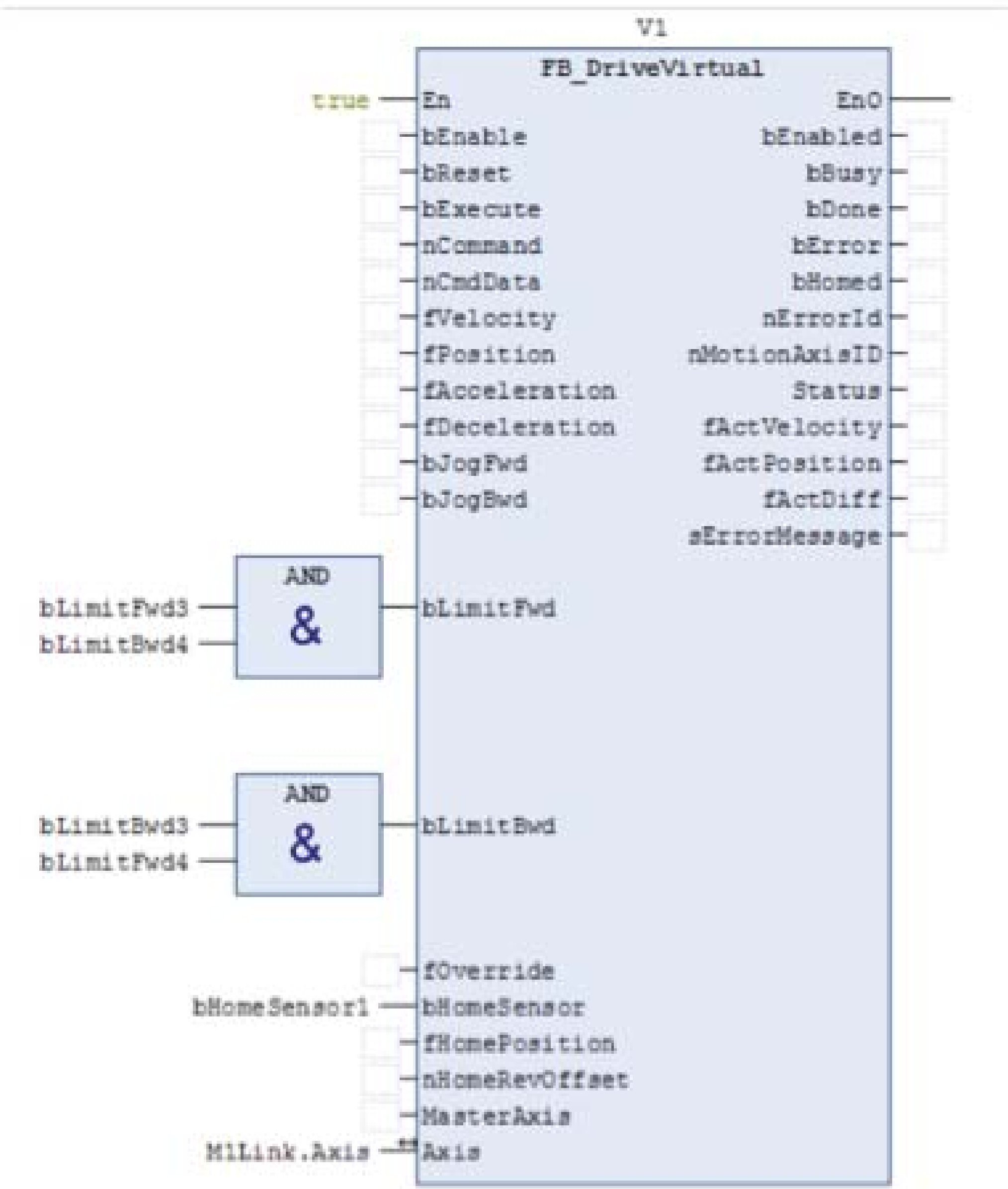
Installation

Cabinet Installation

ESS Standard Software

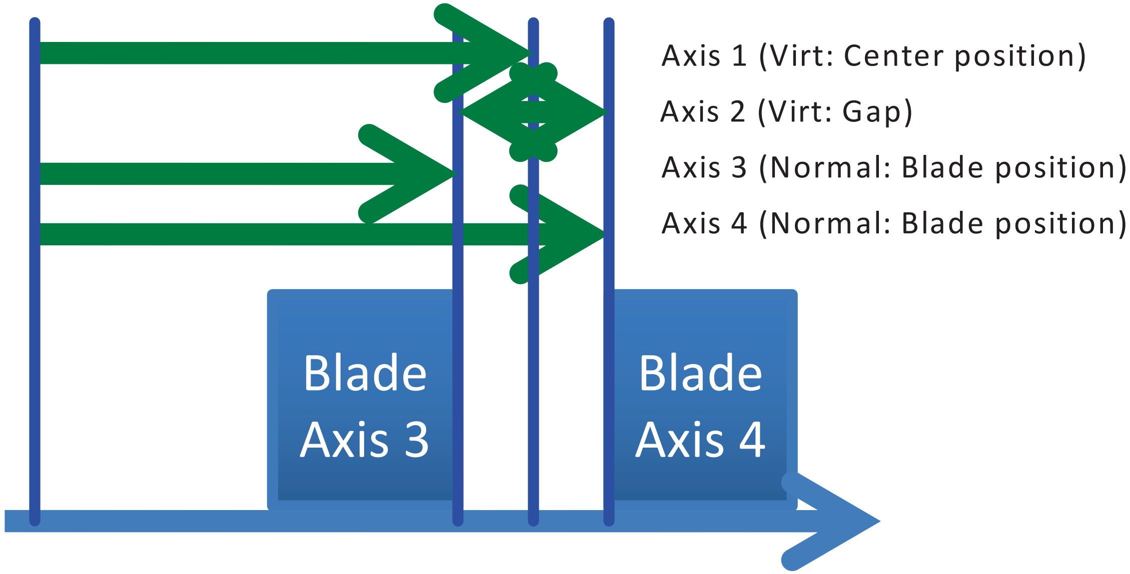
- Three layers
  - TwinCAT: Utilising function blocks from the ESS MCA standard library (tc_mca_std_lib). Standard way of controlling axes. EPICS communications module to talk to EPICS. https://bitbucket.org/europeanspallationsource/tc_mca_std_lib.git
  - EPICS TwinCAT driver developed over a 2-3 year period within MCA Group. New method with ADS driver talking directly to TwinCAT.
  - NICOS implemented during commissioning but not too much testing before commissioning.

Standard Axes (FB_DriveVirtual)



Non-standard Slit Axes

- Slit axes are are non standard since the blades can collide -> machine protection.
- Scientists prefer to specify gap and gap centre using virtual axes which feeds into our requirements. This is often done in higher levels.

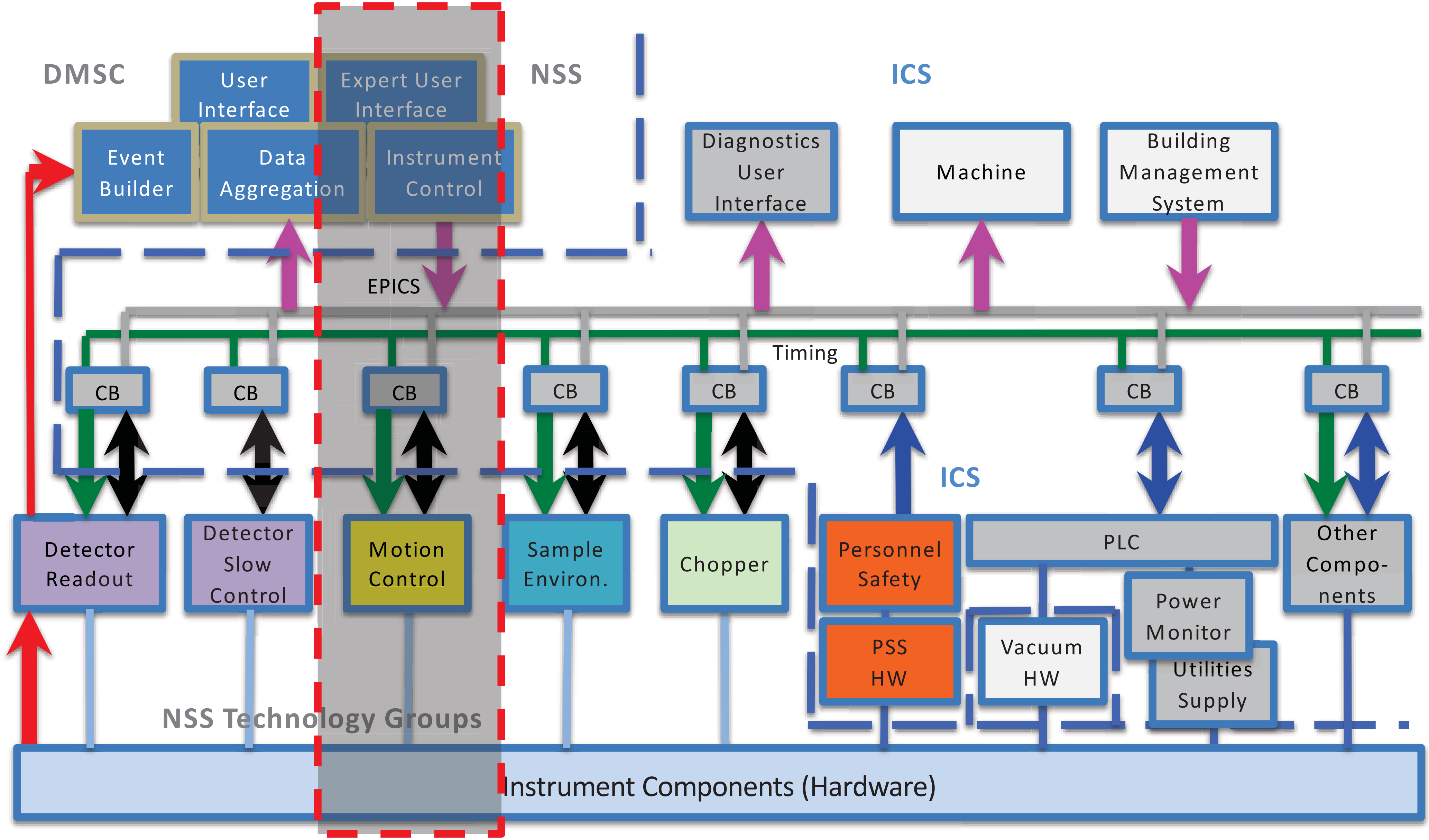


Slit Requirements

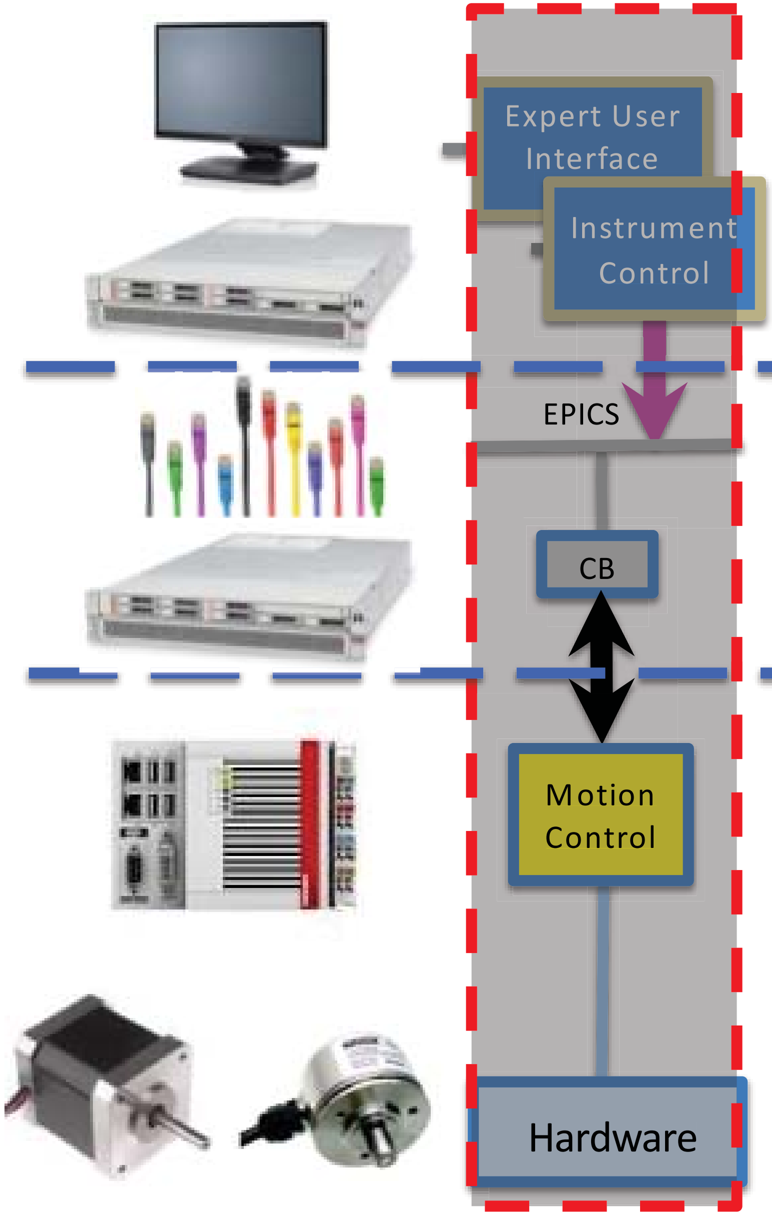
- The control software shall:
  - Be controlled by two virtual axes: one for gap and one for the centre of the gap.
  - **Prevent collision of the blades.**
  - Have proper soft limits set for virtual axes.
  - Show correct axis data in EPICS for gap/centre. This includes correct read back values for position and status bits.
  - Able to recover from an error without requiring specialist intervention.
- The control software should:
  - Able to drive physical axes independently from EPICS without requiring user intervention such as homing/toggling a bit.

- But where to implement the logic……..

The ESS modular control system architecture



Application for motion control



User Interface

Instrument Control

Instrument Representation Layer

EPICS network

EPICS IOC

Abstraction & Integration Layer

Local Controller

Hardware Controller

Hardware & Hardware Representation Layer

Strengths of Lower Level Logic

Motion Hardware layer

- Performance: Control is near to the hardware, low latencies.
- Safety aspects can be handled on hardware basis.
- Full control of machine protection.
- Control can be well adapted to the mechanics.

Strengths of Higher Level Logic

- The EPICS network is distributed over all ESS and is connecting all control devices.
- Flexibility: Changes can be implemented easier by the user with more people able to customise.
- Central services like archiving or alarm/warning handling are already implemented in the layer.

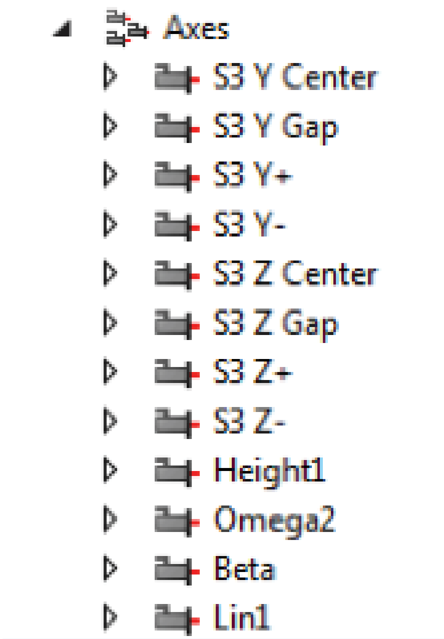
Trade offs

Balance between:

- The user **can** do everything vs. the technical personnel **needs** to do everything.
- The more is implemented in the lowest level, the more the technical personnel will be called in to fix things.
- Minimize the number of layers (= service groups involved) when distributing functionality over the layers.
- Use already existing functionality in the layers to facilitate software development.

Implementation of Slits (TwinCAT)

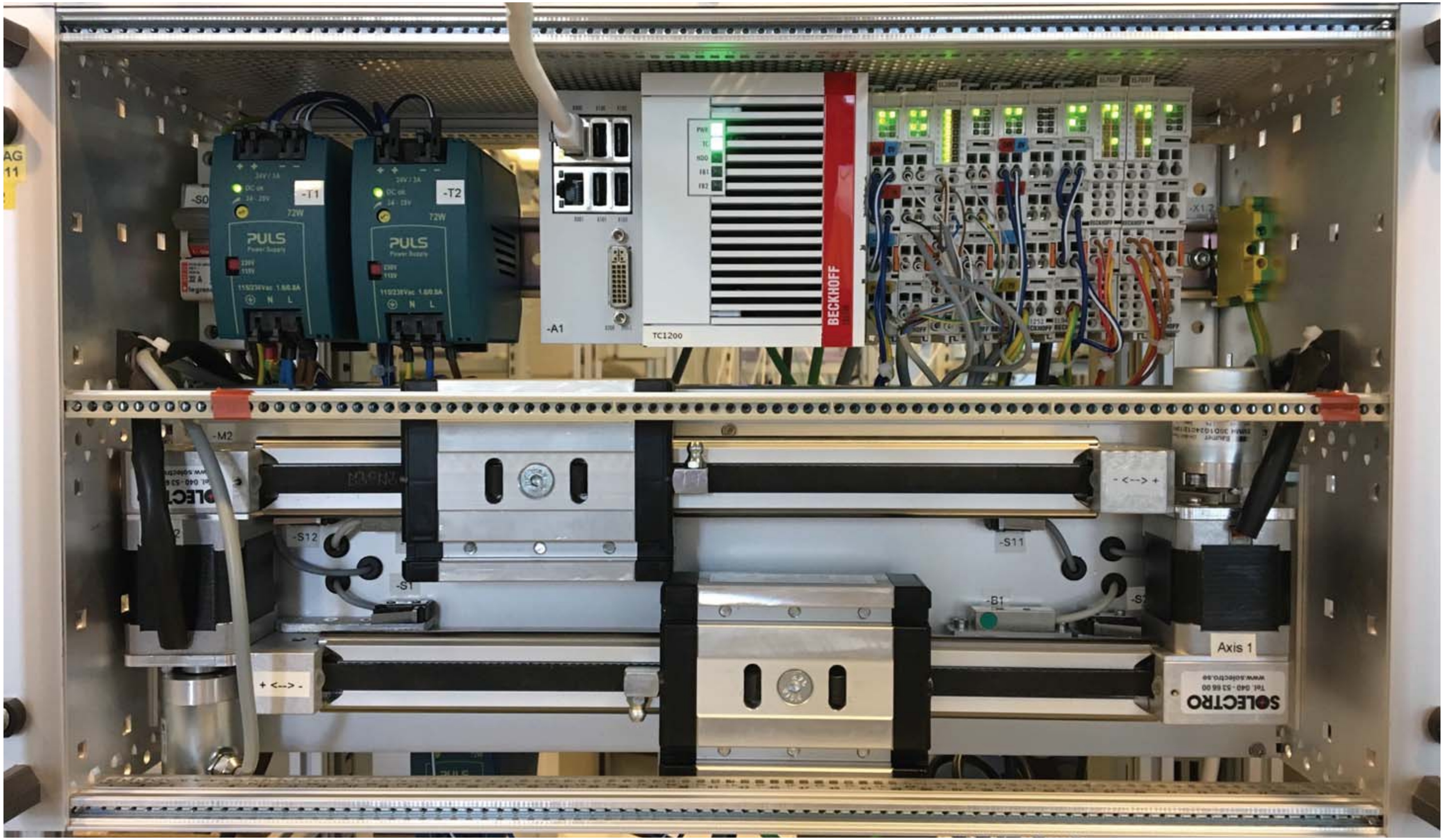
- Four TwinCAT axes per slit pair: two virtual and two physical. Convention as follows:
  - V1-Center (virtual)
  - V2-Gap (virtual)
  - M3-Positive Blade (physical)
  - M4-Negative Blade (physical)



Implementation of Slits (TwinCAT)

- Beckhoff function block (GearInMultiMaster): two master axes (virtual) driving the slave axes (physical).
- Master/slave relationship only enabled when a command is received on a virtual axes; otherwise physical axes free to move independently.
- Special slit function block to co-ordinate slit control. Checks to prevent the blades colliding with each other and reduce the speed as the blades approach each other.

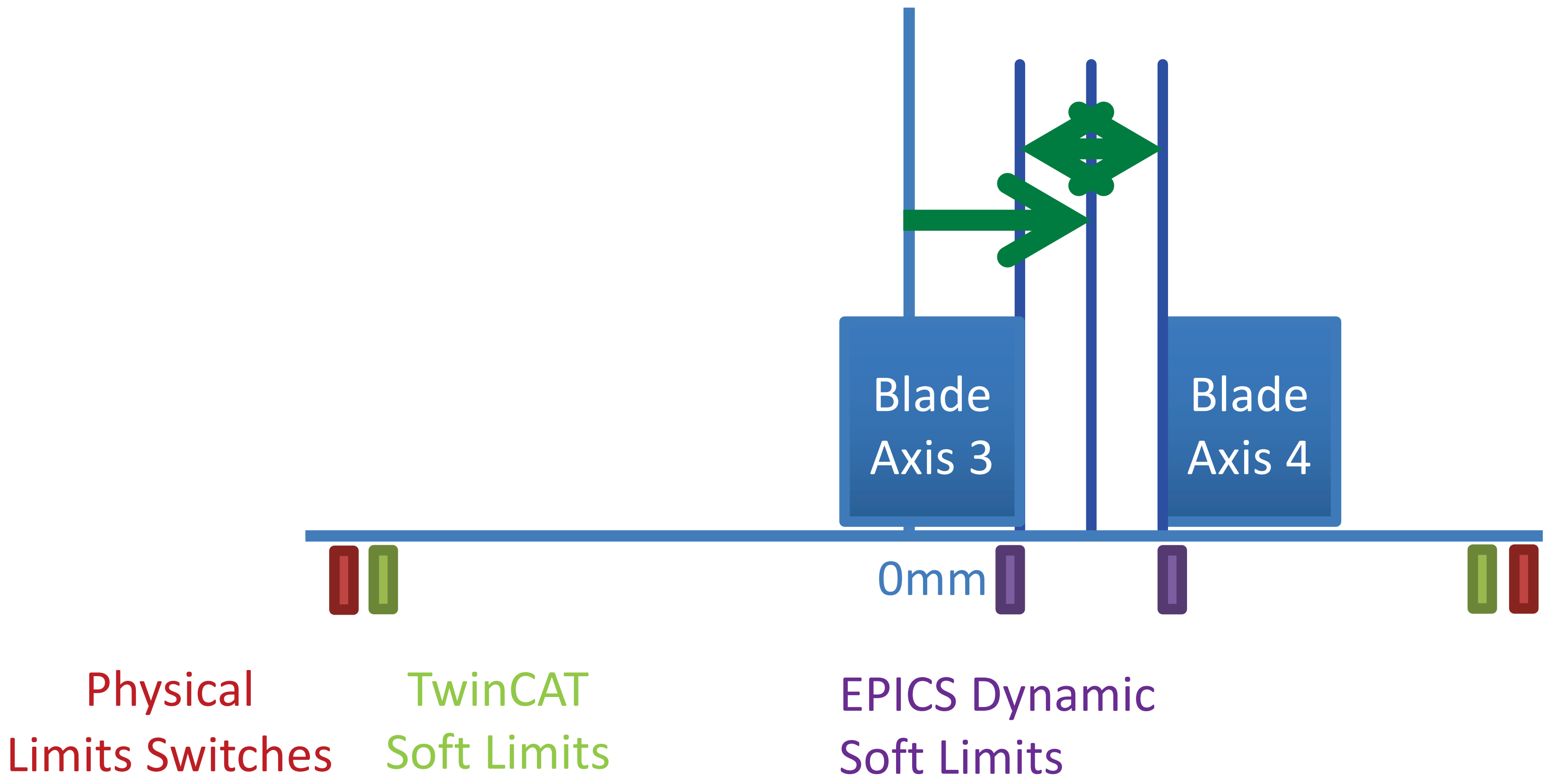
Implementation of Slits (Testing)



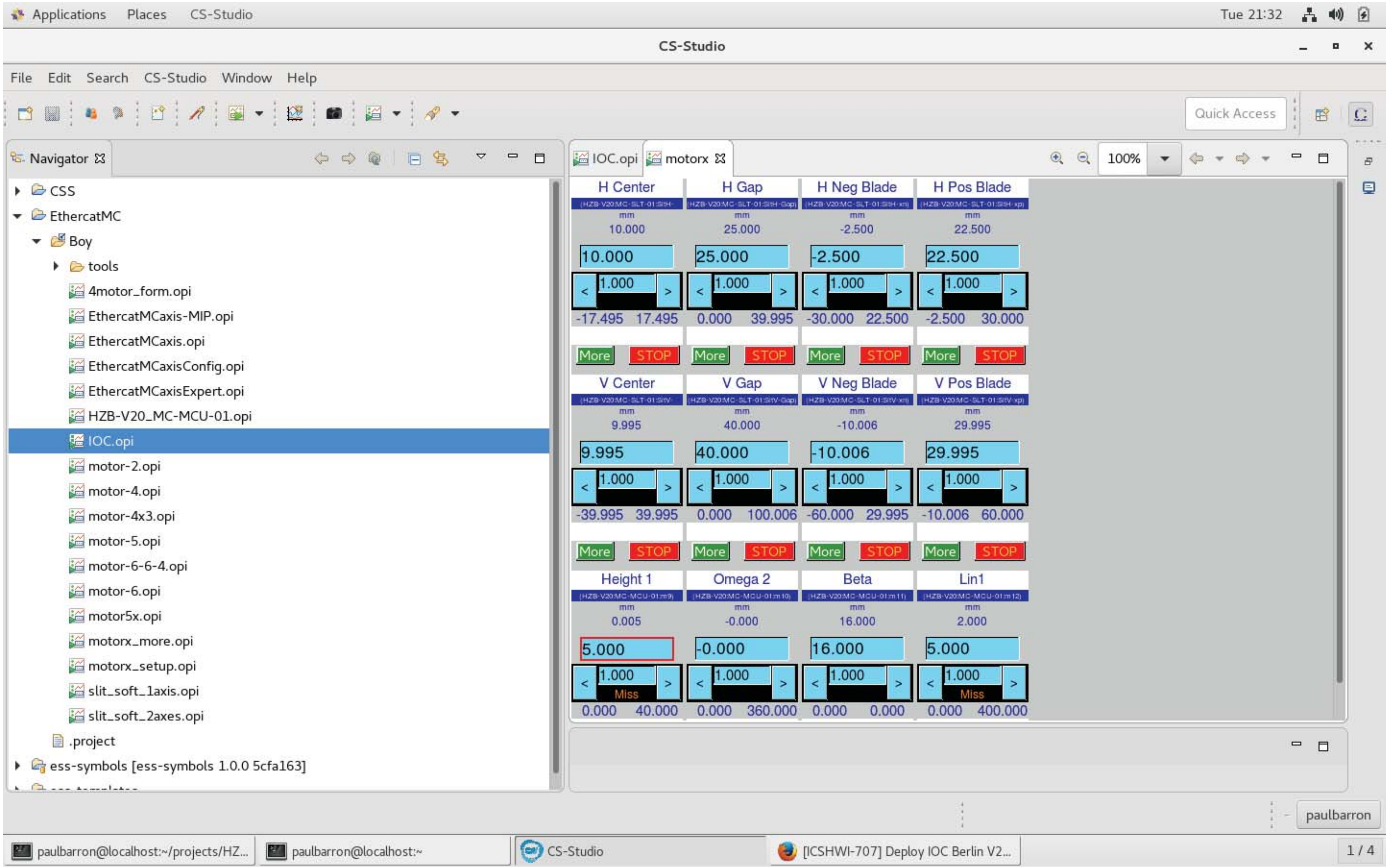
Implementation of Slits (EPICS & NICOS)

- A soft slit object was implemented in the EPICS layer with dynamic soft limits to further avoid collision of the slit blades.
- NICOS has existing functionality to convert virtual axes positions into physical axes positions.
- The slit system is able to be controlled using centre and gap virtual axes at all three software layers.

Implementation of Slits (Limits)



Implementation (EPICS)



Outcomes

- Motion stages commissioned without major problems in TwinCAT.
- Slit functionality currently at the TwinCAT level.
- EPICS worked well with a few small bugs to do with displaying virtual axis parameters.
- NICOS was used but lacking a few features for portable temporary axes.
- Experience gained on using virtual axes in TwinCAT for slit systems.

Lessons Learnt

- Test as much as possible in the lab beforehand.
- Cabling the device cables prior would have saved time during commissioning.
- Beckhoff TwinCAT licenses.

Future work

- Make additional functionalities available in NICOS software for instrument scientists.
- Synchronization bugs with some parameters not updating after a move on virtual axes.
- Create automated tests for commissioning.
- Install encoders on motion stages without feedback.
- Install limit switches on motion stages that are missing them.

Questions