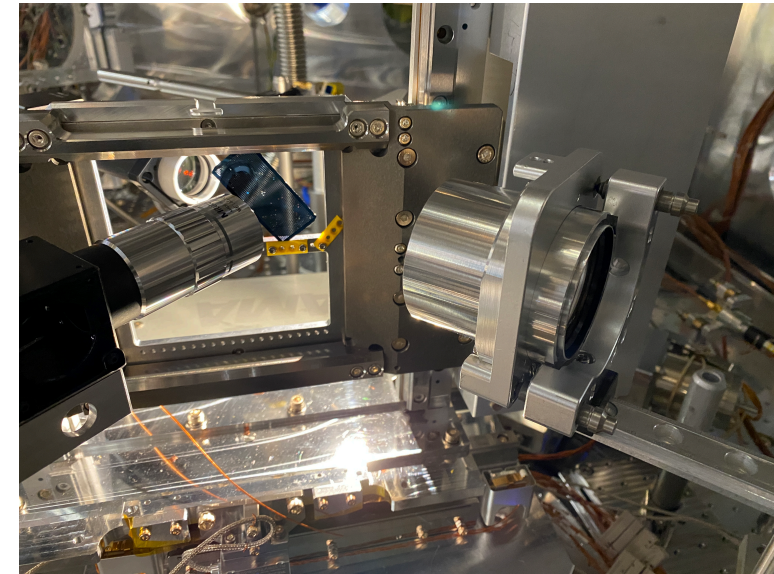


The solid sample scanning workflow at the European XFEL

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I. Karpics, J. Schulz, F. Sohn
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[*ana.garcia-tabares@xfel.eu](mailto:ana.garcia-tabares@xfel.eu)

19TH INTERNATIONAL CONFERENCE ON
ACCELERATOR AND LARGE EXPERIMENTAL
PHYSICS CONTROL SYSTEMS (ICALEPCS 2023)



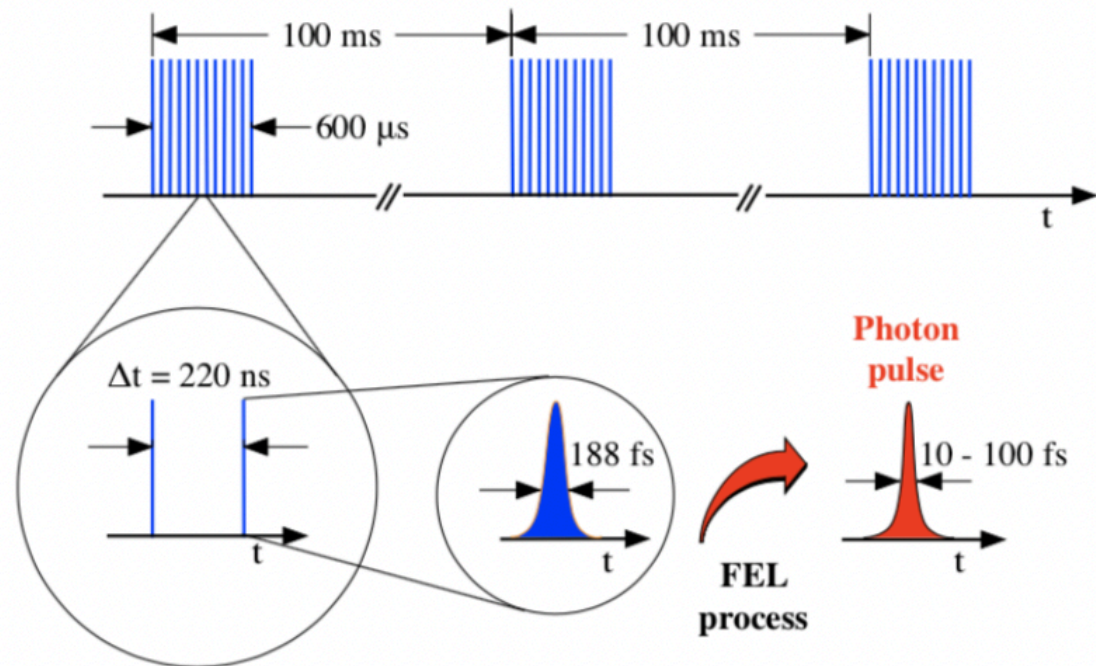
Outlook

- European X-ray Free Electron Laser
- Karabo: The European XFEL Control system
- The Fast Solid Sample Scanner @ European XFEL
 - Overview
 - Automation Opportunities
 - Workflow after automation
- Database and Karabo Integration
- Commissioning results
- Conclusions

European X-ray Free Electron Laser: Pulse structure and Peak Brilliance

EuXFEL has a unique feature in the time structure of its X-ray pulses, generating a pulse train of up to 2700 X-ray pulses, 10 times per second. The pulses arrive with a maximum frequency of 4.5 MHz, with 220 ns between each pulse.

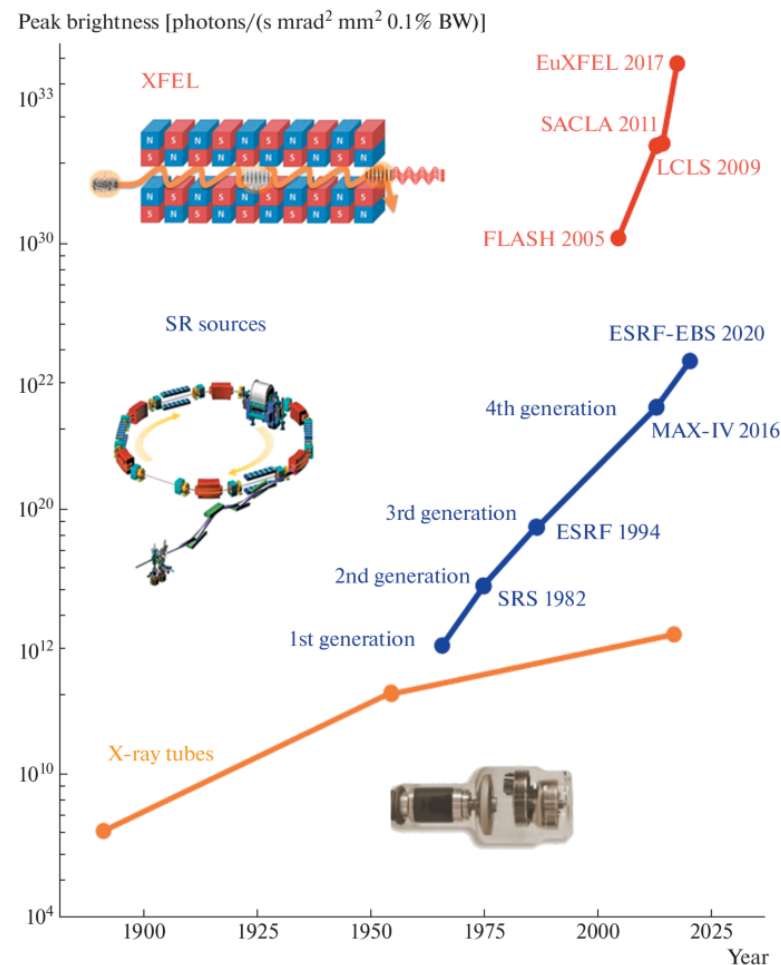
Brilliance Peak $5 \cdot 10^{33}$ (photons / s / mm² / mrad² / 0.1% bandwidth).



European X-ray Free Electron Laser: Peak Brilliance

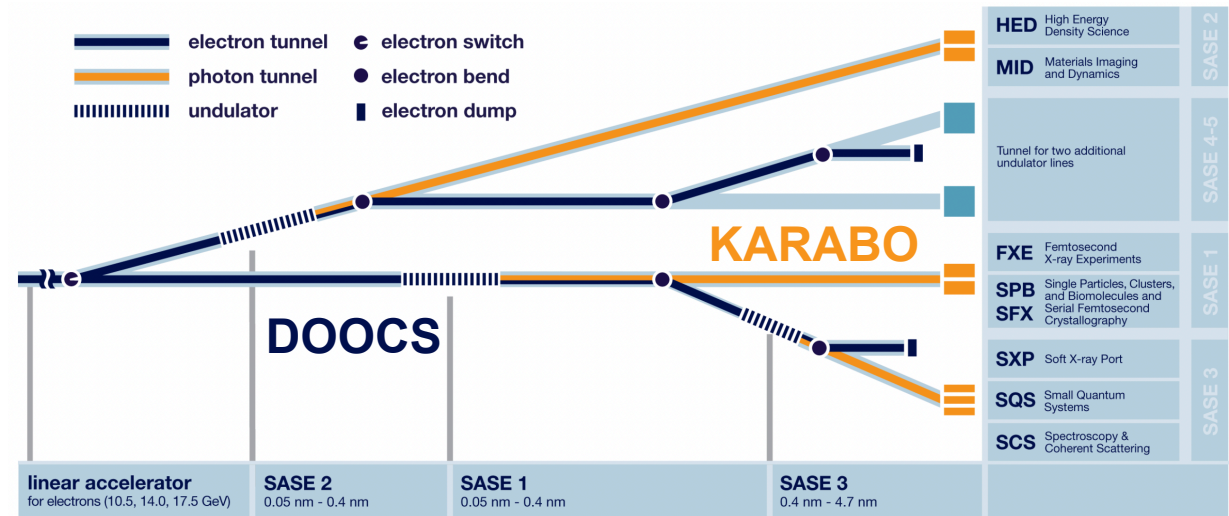
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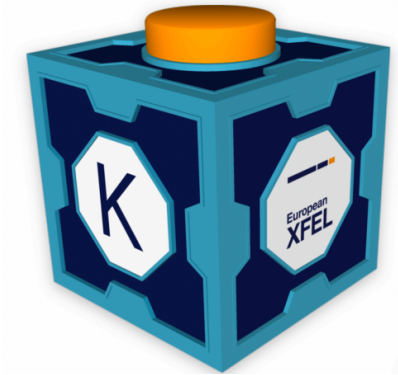


Karabo: The European XFEL Control system

- Linear electron accelerator is run by DESY and it's controlled via DOOCS
- Undulators creating X-ray laser photons are also controlled via DOOC
- Photon beam steered through 3 tunnel to 7 instruments controlled via Karabo
- Karabo is a distributed control system designed and developed for:
 - control of hardware,
 - monitoring,
 - data acquisition
 - data analysis



Karabo: The European XFEL Control system



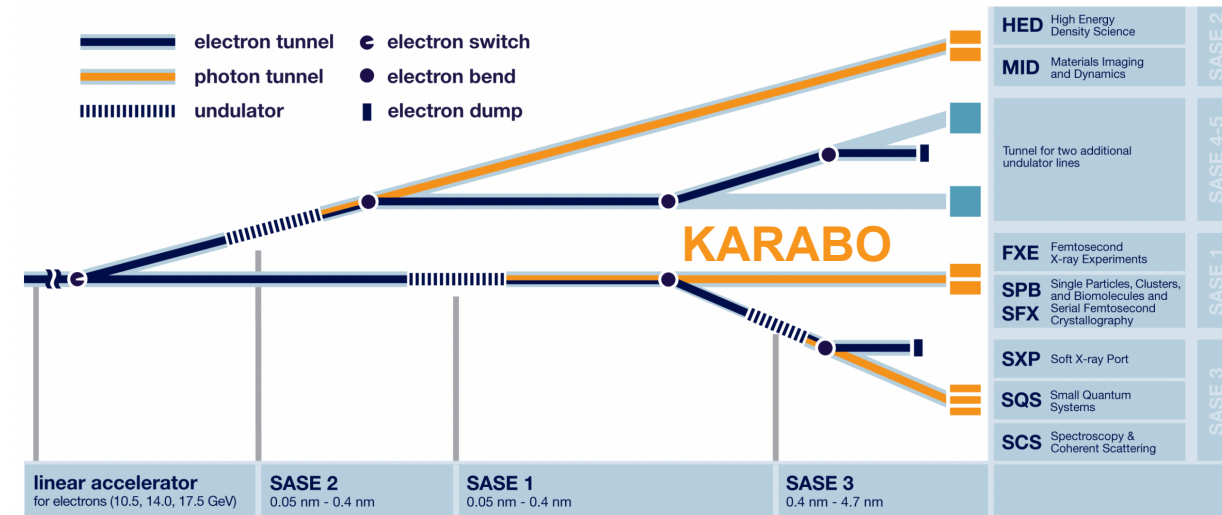
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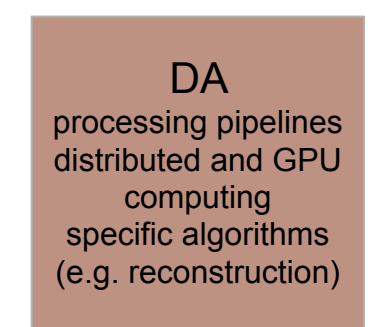
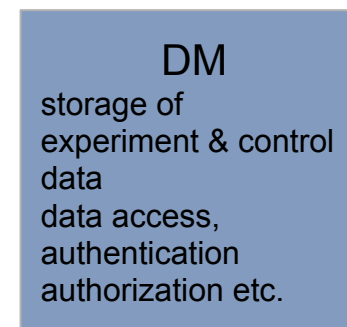
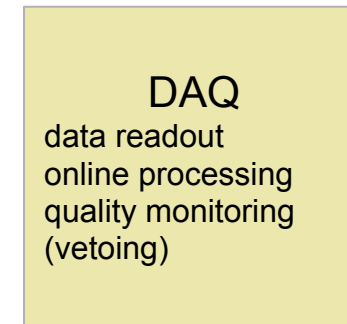
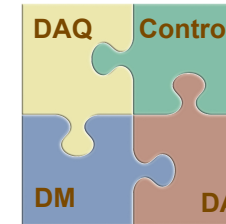
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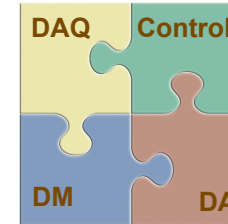


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MORE INFORMATION:
TH1BCO06: The Karabo Control System
Speaker: Steffen Hauf

DAQ
data processing
monitoring

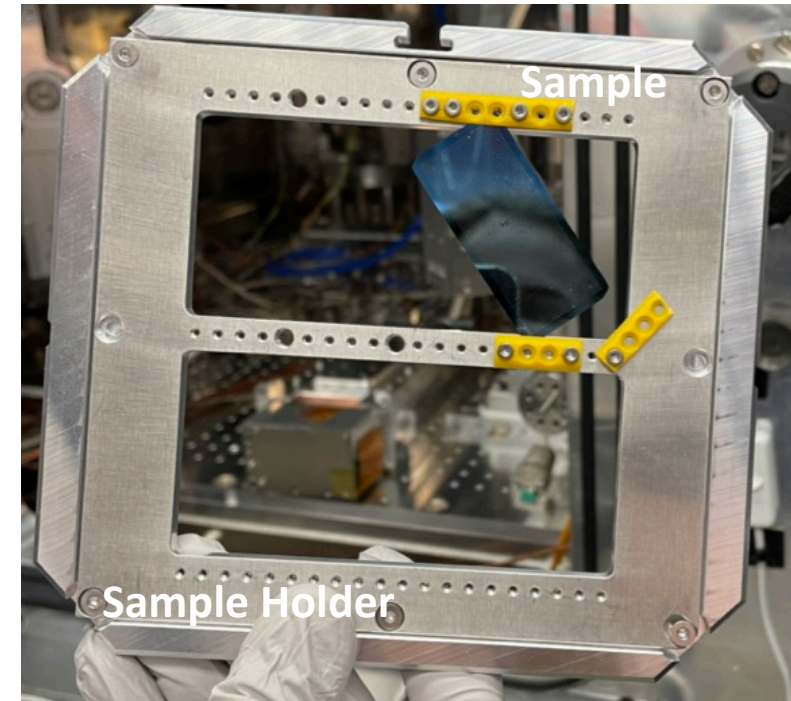
Control
drive hardware and complex experiments
monitor variables & trigger alarms

DM
storage of experiment & control data
data access, authentication authorization etc.

DA
processing pipelines distributed and GPU computing
specific algorithms (e.g. reconstruction)

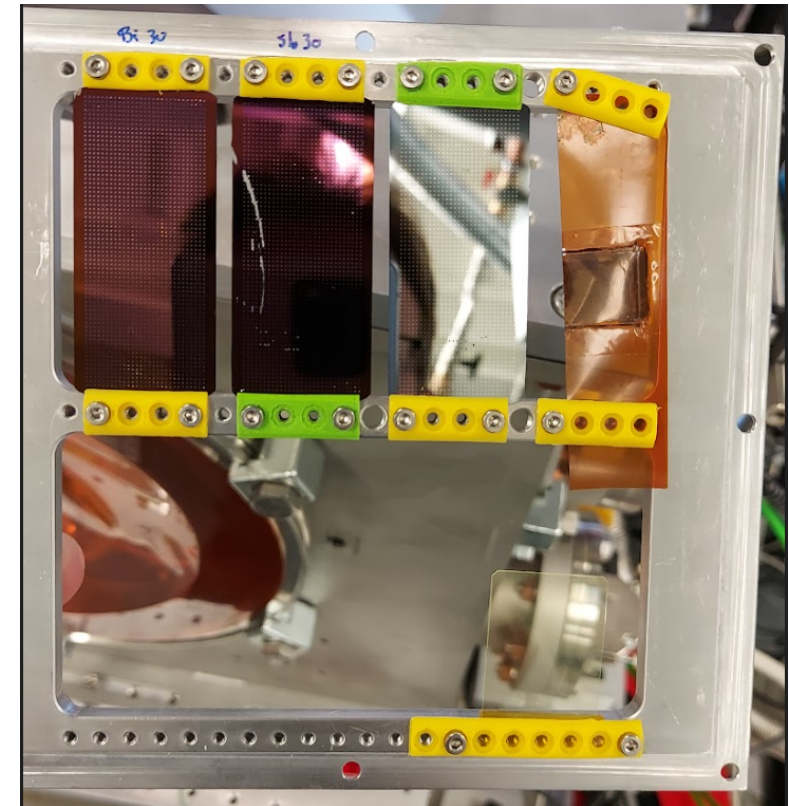
The Fast Solid Sample Scanner @ European XFEL: Overview

- Fixed targets are widely used among the instruments at the European XFEL, including foil targets, wires, structured samples, among others.
- To scan such solid samples, the Fast Solid Sample Scanner (FSSS), is used at 5 out of the 7 instruments.
- The FSSS has two perpendicular stepper motors, enabling precise scanning along both the X and Y axes, where the Z-axis represents the beam direction.



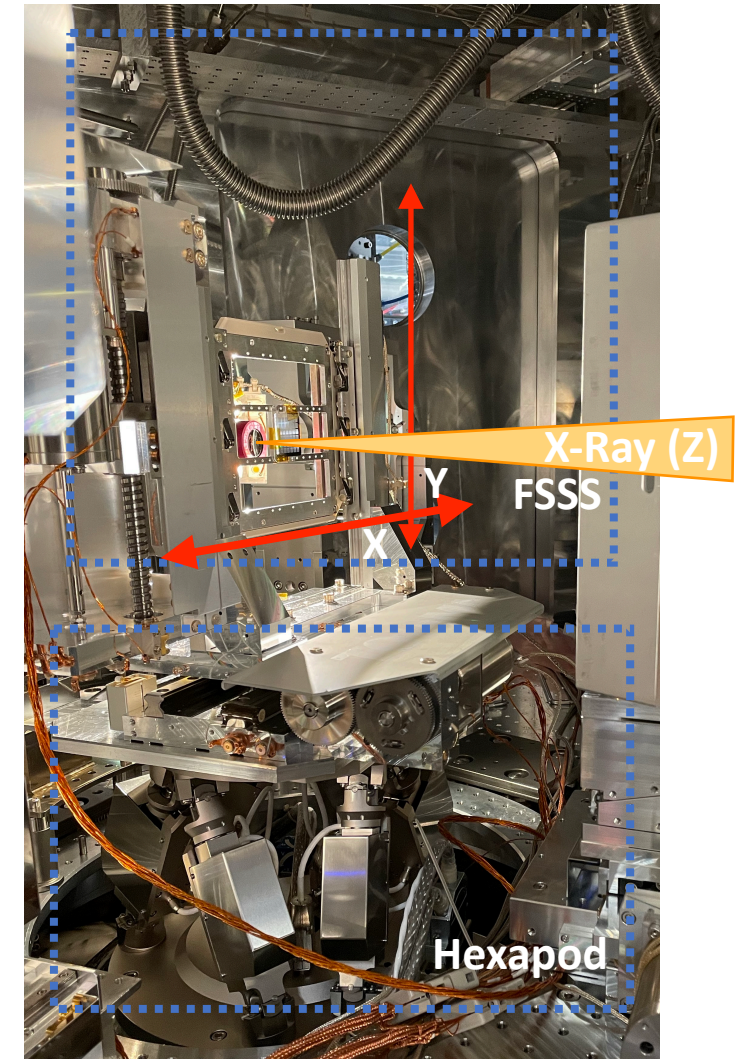
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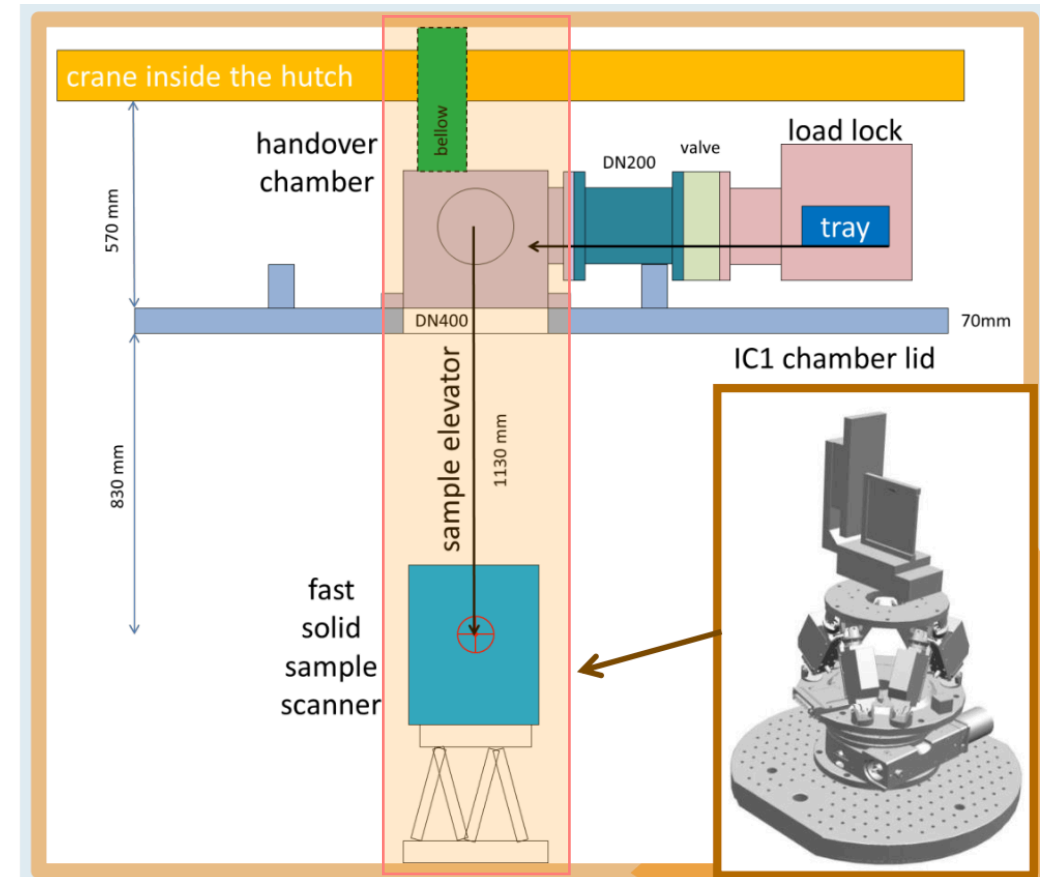
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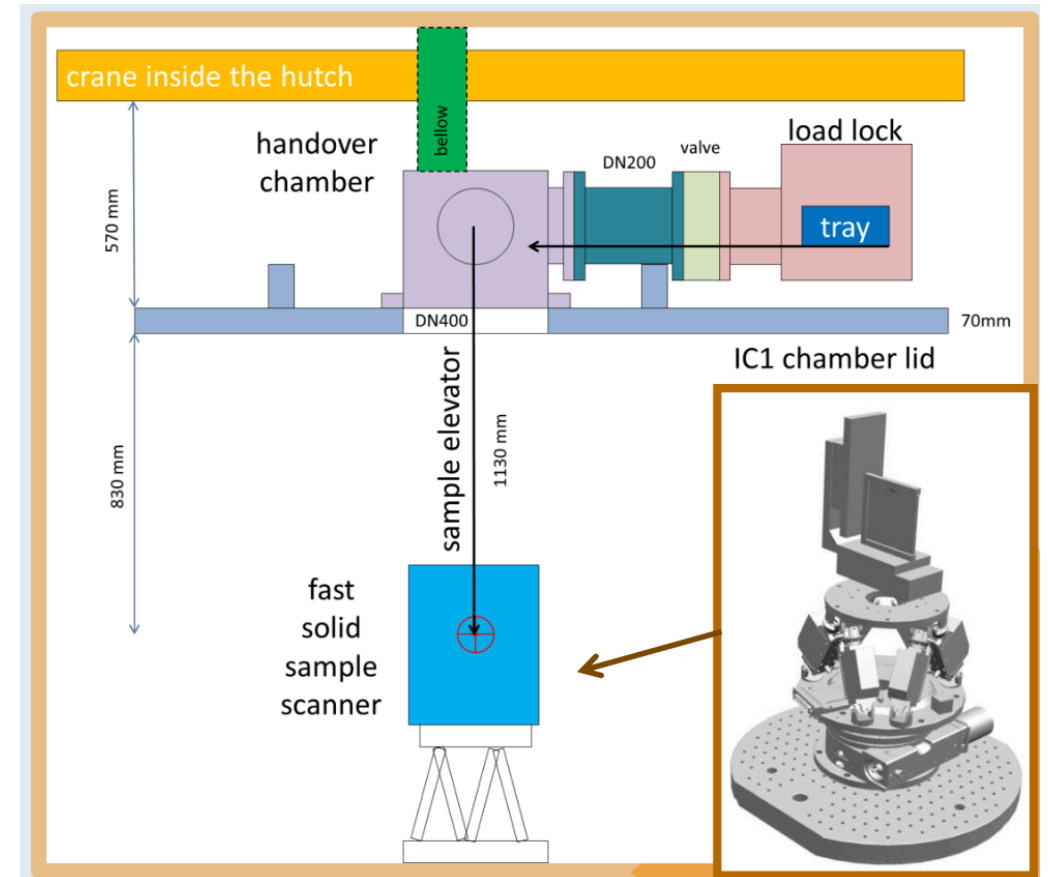
The Fast Solid Sample Scanner @ European XFEL: Automation opportunities

- Samples are loaded into a holder outside the vacuum chamber and then placed into the chamber without breaking the vacuum.
- Preparing the sample scanner for measurements can be a time-consuming process.
- HED workflow improved by implementing pre-characterization of samples and creating a database for storing sample information.



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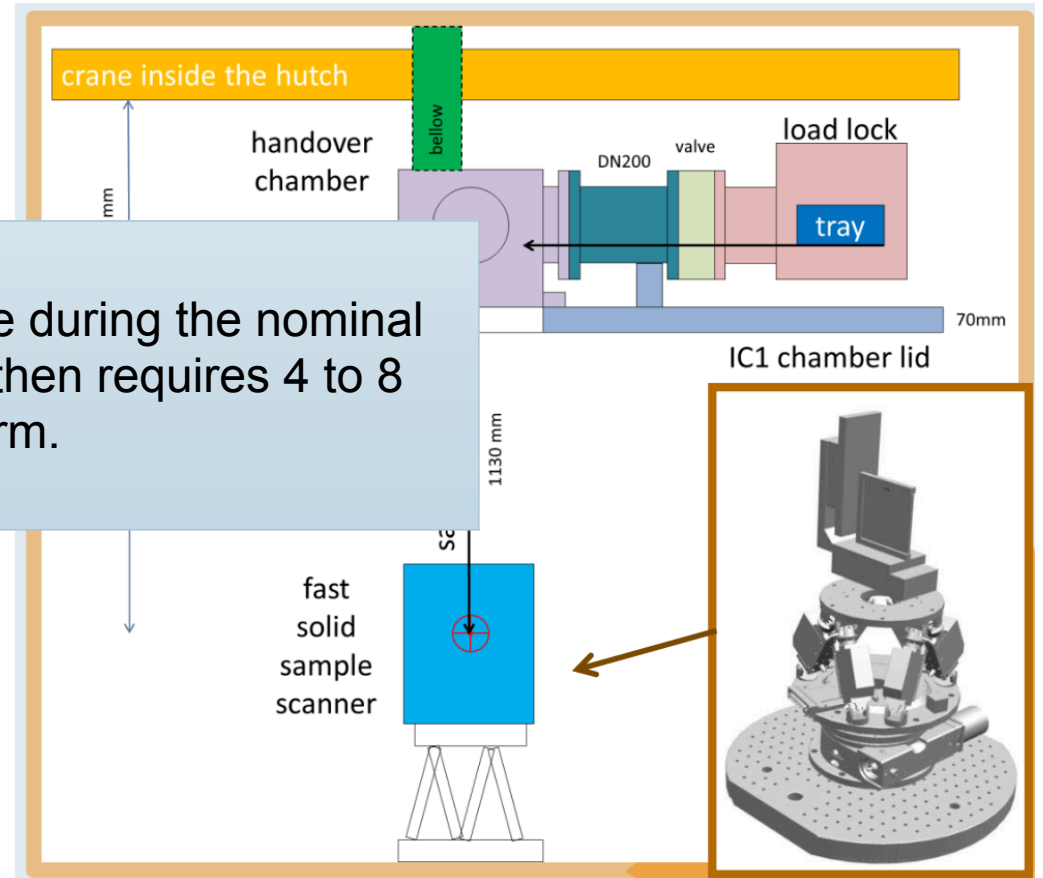
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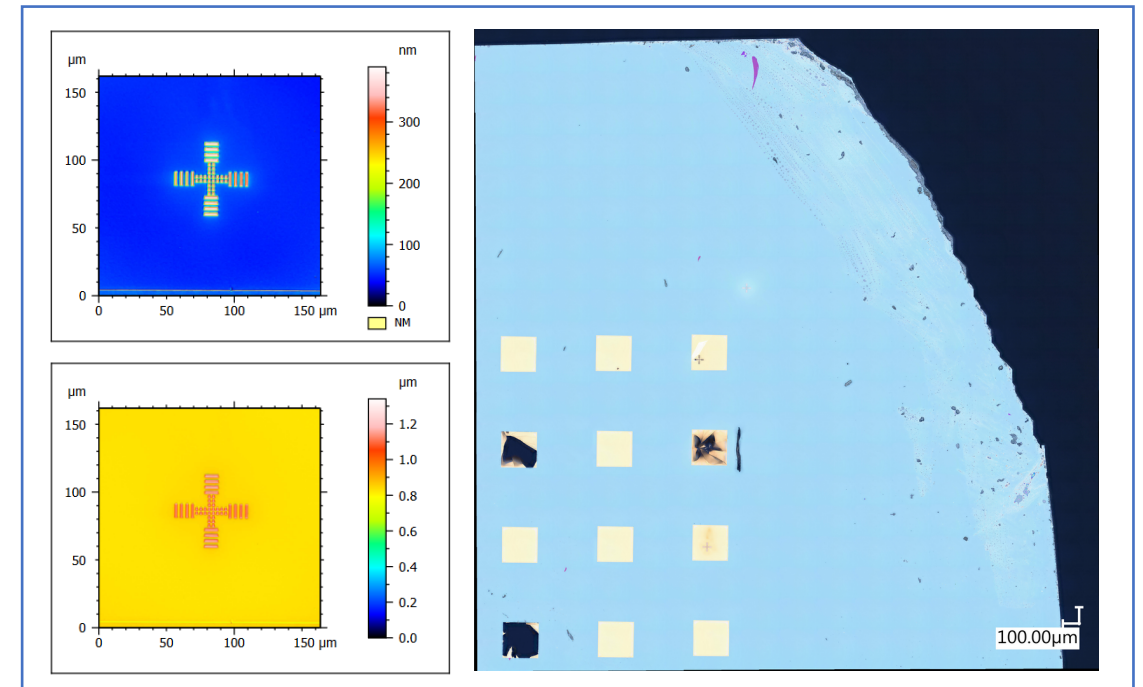
- Samples are loaded into a holder outside the vacuum chamber and then placed into the chamber without breaking the vacuum.
- Preparing the sample to be a time-consuming process.
- HED workflow improvement: characterization of samples and creating a database for storing sample information.

Sample characterization is done during the nominal beam time, usually at night. It then requires 4 to 8 hours to perform.



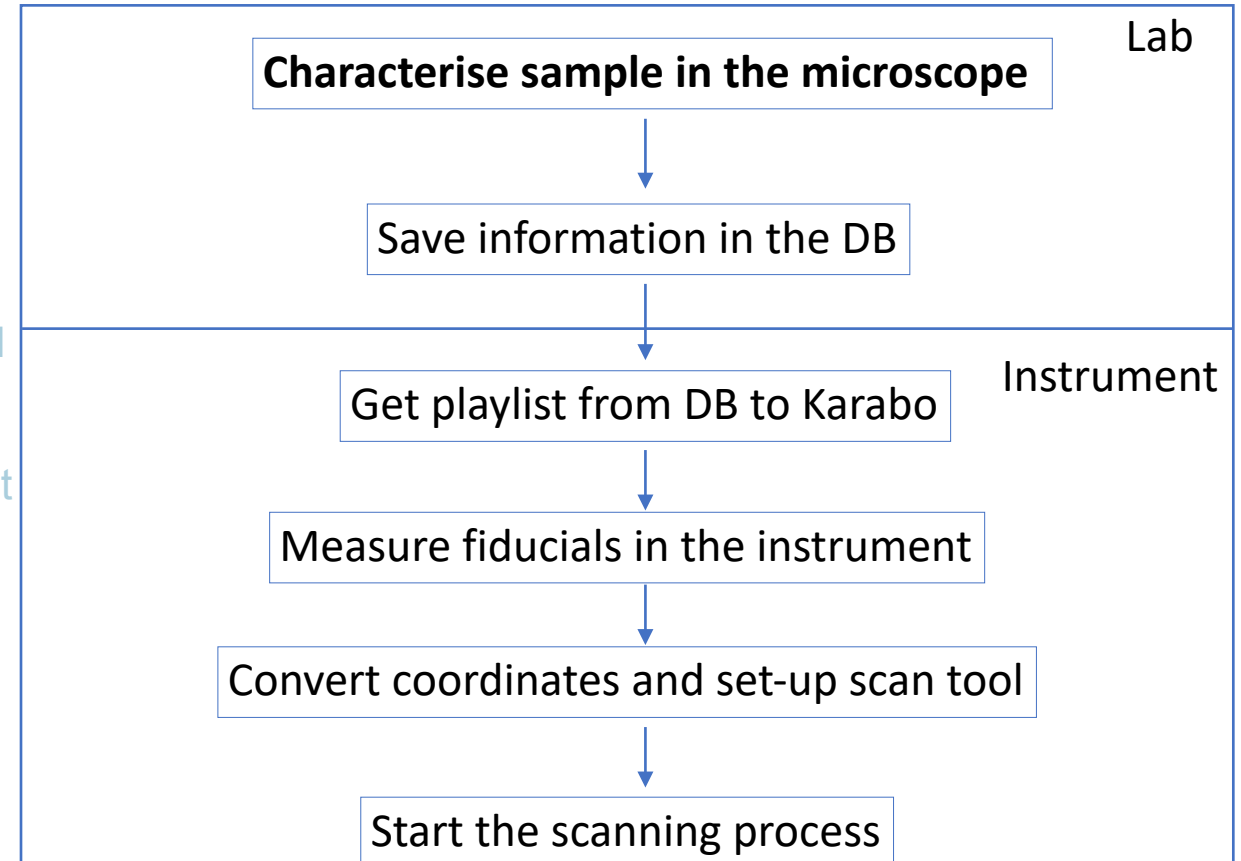
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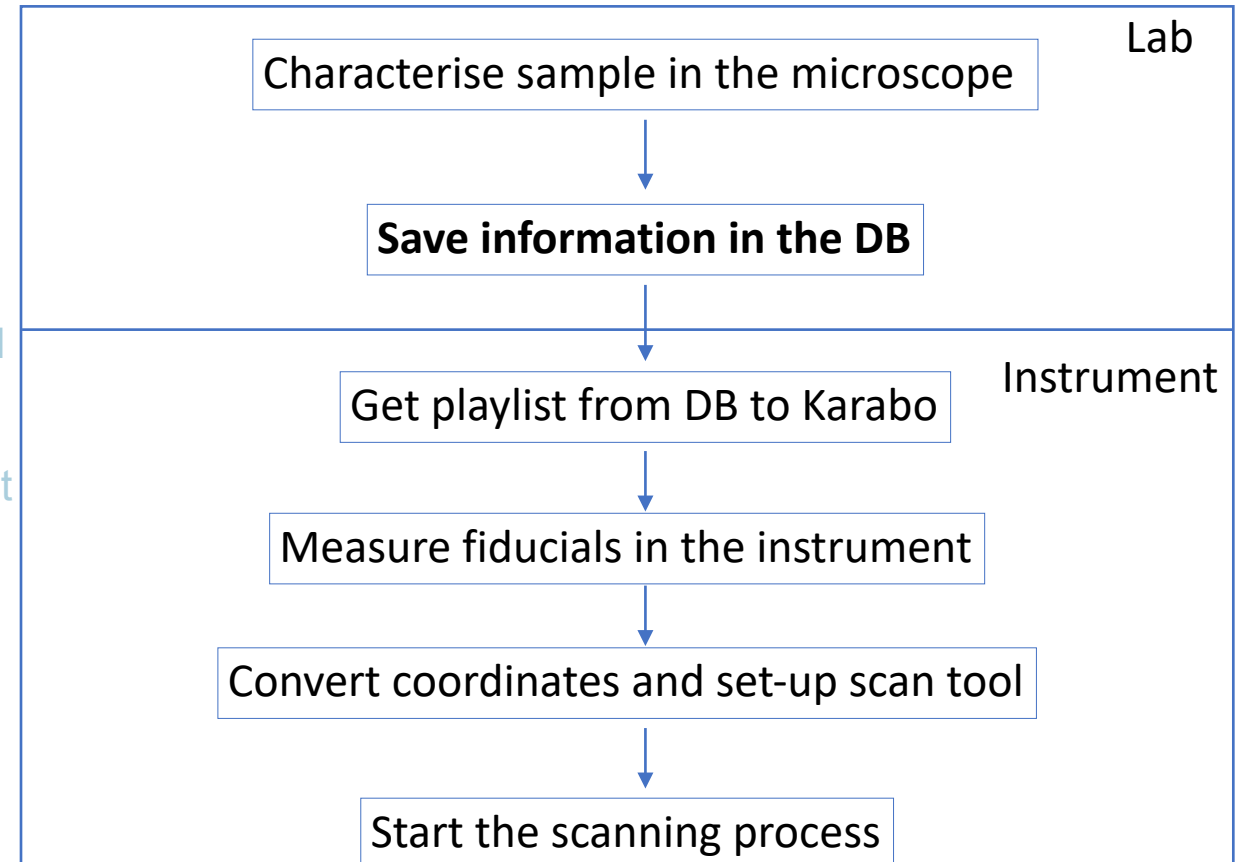
The Fast Solid Sample Scanner @ European XFEL: Workflow Automation

- The target coordinates are located along with the fiducials in the laboratory prior to the experiment.
- Relational database stores target and fiducial coordinates for easy management.
- Information is directly accessible via the Karabo control system.
- Fiducial measurements are performed in the instrument
- Target coordinates are transformed from the lab base system to the instrument base.
- The transformed coordinates are then sent to the Karabo scanning tool.



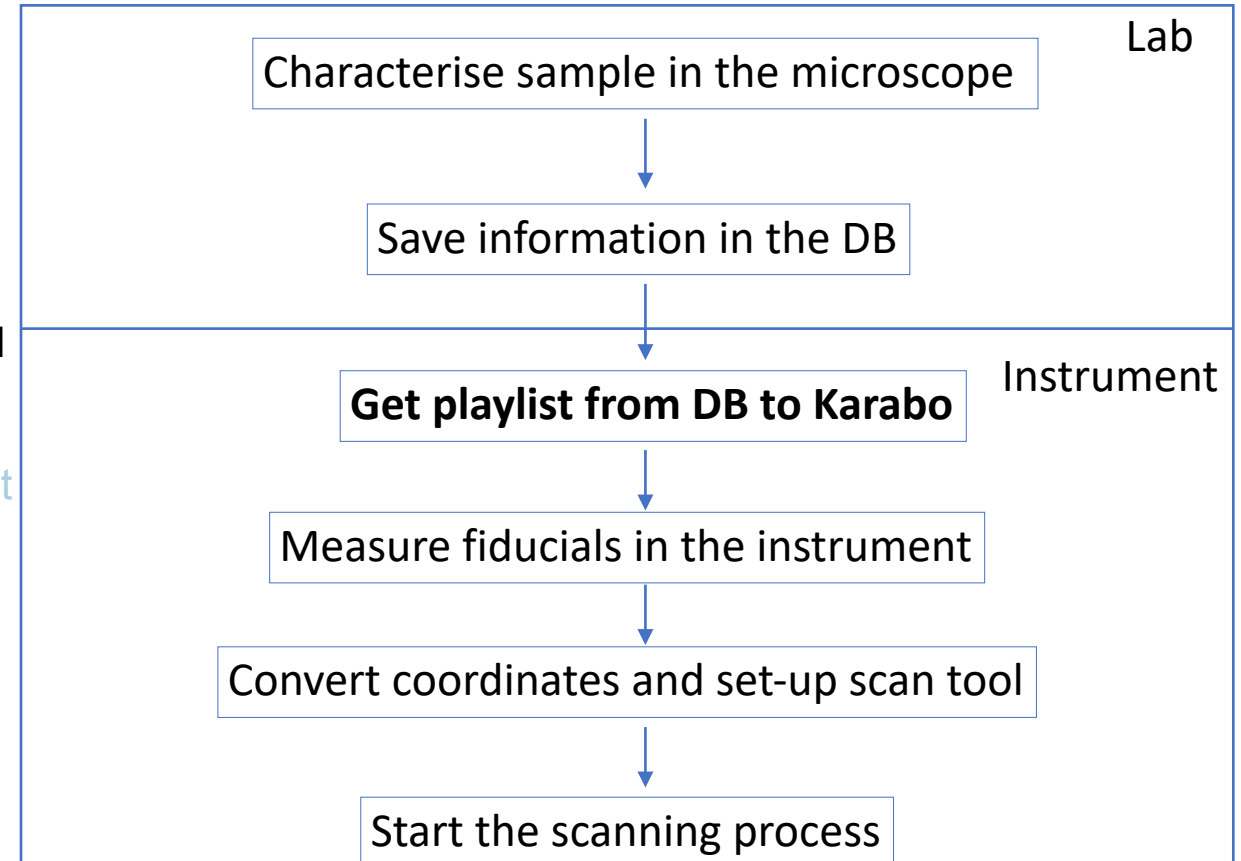
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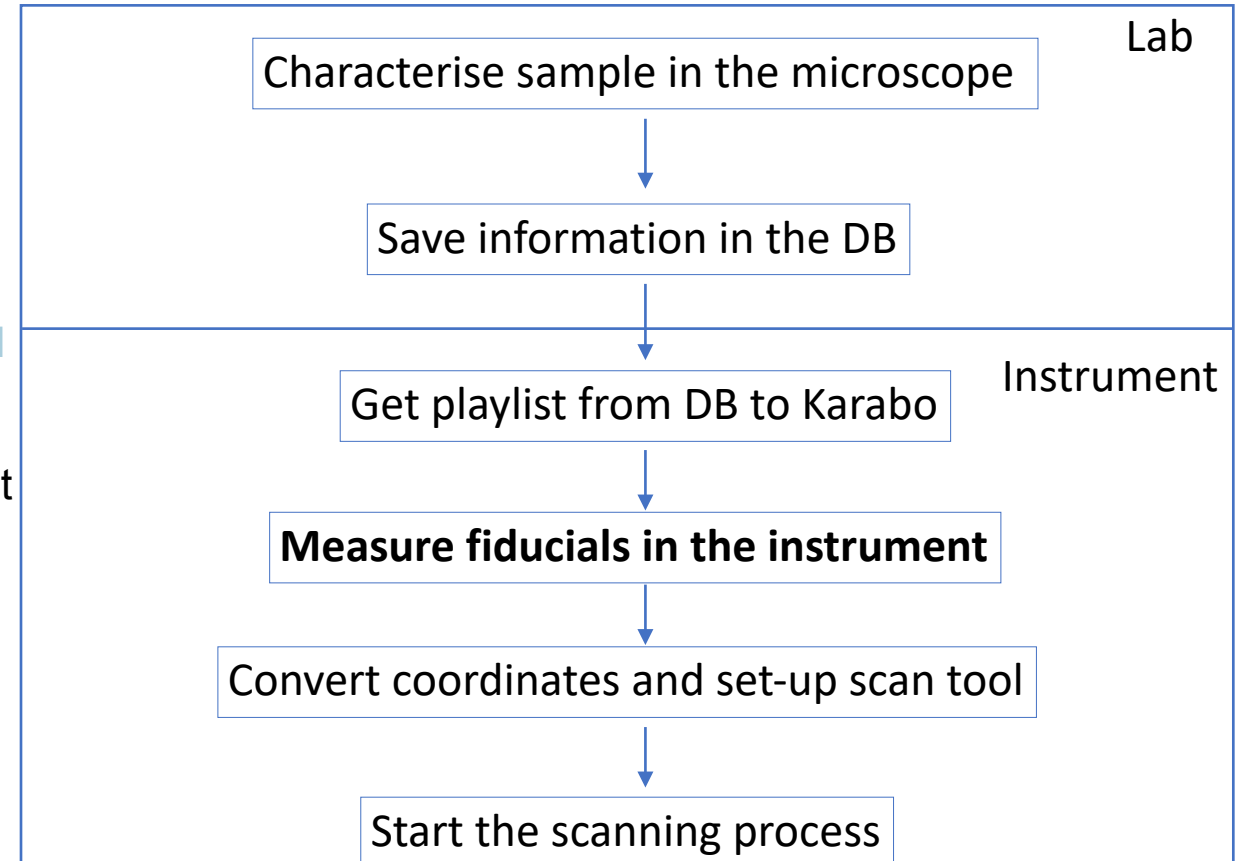
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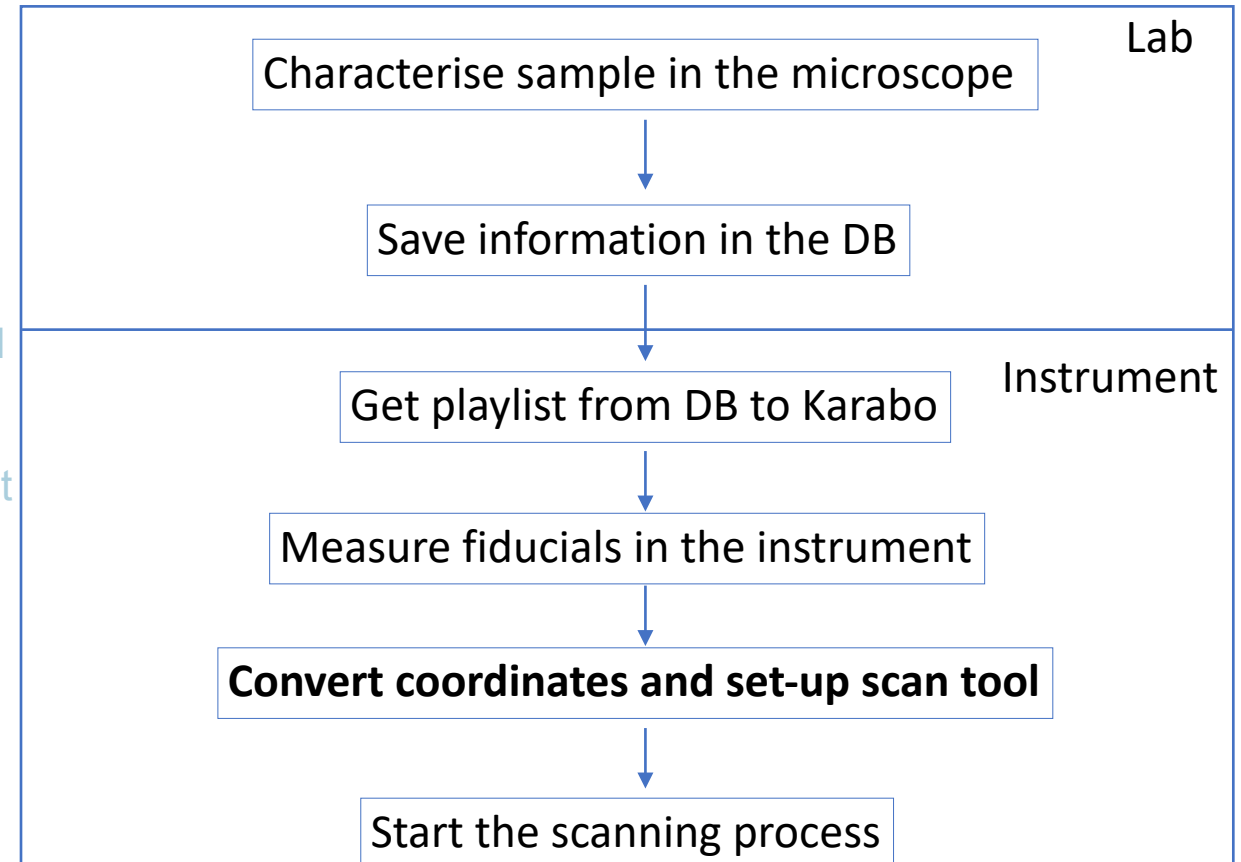
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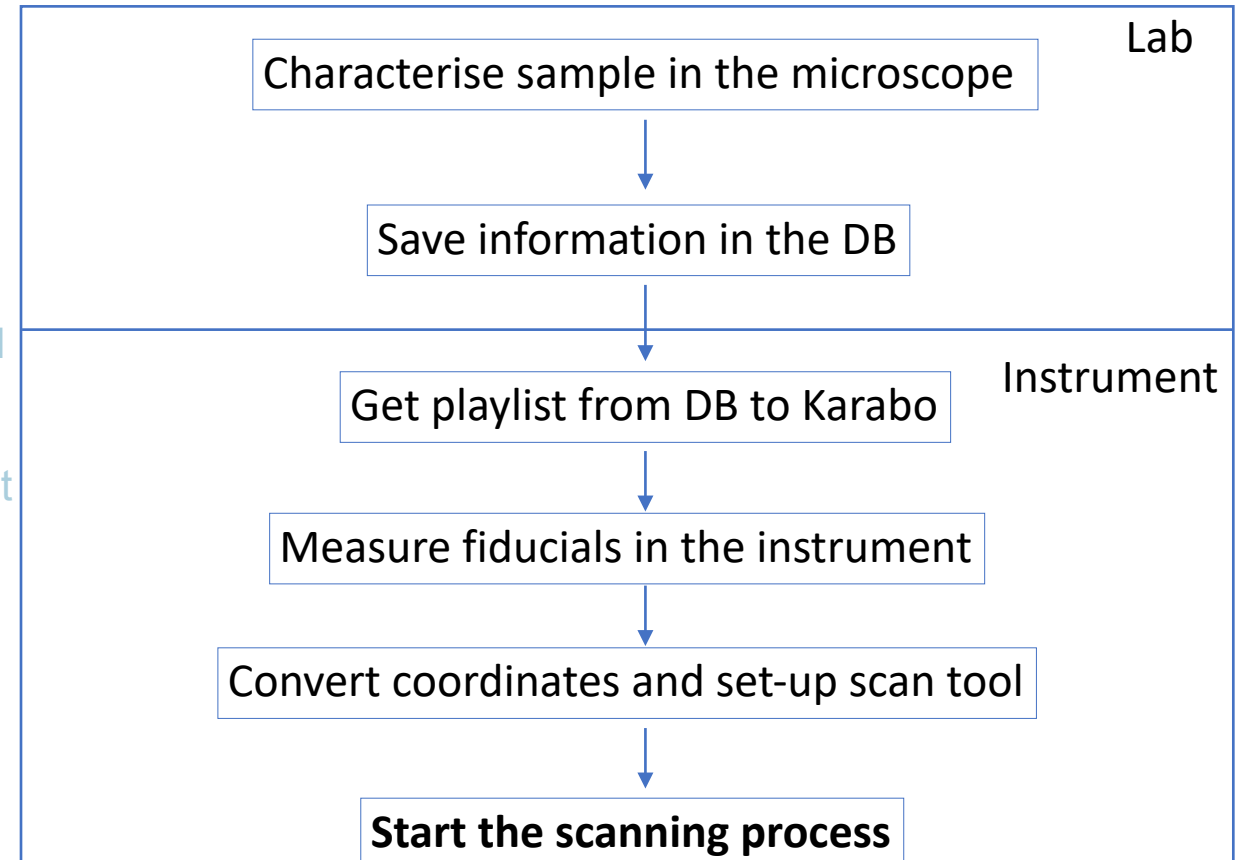
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Karabo Integration

■ Karabo integration guides users through an automated workflow:

■ Configure motors

■ Retrieve playlist

■ Save Fiducials

■ Transform data

■ Send to Scan Tool

The screenshot displays the 'SOLID_SAMPLE_SCANNER_TEST|scene' interface. It is divided into several sections:

- State:** A green indicator and a status box showing 'All motors connected'.
- Motors to scan:** A table with columns for Motor ID (Horizontal, Vertical, Longitudinal) and their respective values: XHQ_EG_A/MOTOR1, XHQ_EG_A/MOTOR1, and HEXAPOD_TEST.
- 1. Get Sample Information from DB:** A section with input fields for Subframe ID (EXFELFOI000001), Available Playlists (3), and Selected Playlist (3, 3). It includes a 'Get Sample Information from DB' button.
- Fiducial Coordinates (Lab):** A table with columns for Fiducial ID, Fiducial Coordinates (Lab), and Axis.

Fiducial ID	Fiducial Coordinates (Lab)	Axis	
0	bottom-right	0.0,0.0,0.0	referenceFiducial
1	bottom-left	-45.204,0.082,-0.0071	X
2	top-right	0.028,19.138,0.0224	Y
- 2. Add new fiducial:** A section with dropdowns for 'Relative position of fiducial to save' (bottom-left) and 'Coordinate Origin' (bottom-right), and a 'Save Selected Fiducial' button.
- Fiducial Coordinates (Instrument):** A table with columns for Fiducial ID (Instrument) and Fiducial Coordinates (Instrument).

Fiducial ID (Instrument)	Fiducial Coordinates (Instrument)	
0	top-right	41.321,59.07475,0.2
1	bottom-right	26.0022,47.61495,0.1
2	bottom-left	-1.0327964,83.8108,0.17000663
- 3. Send Coordinates to Scan Tool:** A section with a 'Scan Tool Scene' dropdown, a 'Scan Tool ID' field (SCANTOOL_TEST), and buttons for 'Transform Coordinates' and 'Send Coordinates to Scan Tool'.
- Target Coordinates (Instrument):** A table with columns for Target Coordinates (Instrument).

Target Coordinates (Instrument)	
0	5.836,57.061996,-8.950604e-09
1	-36.509,12.238999,-0.0009000022
2	-29.544,16.289999,0.0026999973
- Scan Tool Scene:** A large image showing a scan of a sample with fiducial markers. The X-axis is labeled 'X-axis (pixels)' and the Y-axis is labeled 'Y-axis (pixels)'. The image shows a circular scan area with several fiducial markers.

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Karabo integration guides users through an automated workflow:

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The screenshot shows the 'SOLID_SAMPLE_SCANNER_TEST|scene' interface. At the top, the state is 'All motors connected'. Below this, there are sections for 'Motors to scan' and 'Fiducial Coordinates (Lab)'. A red box highlights the '1. Get Sample Information from DB' section, which includes a table of fiducial coordinates. Below this is the '2. Add new fiducial' section with dropdown menus for 'Relative position of fiducial to save' and 'Coordinate Origin', and a 'Save Selected Fiducial' button. To the right, there is a '3. Send Coordinates to Scan Tool' section with a 'Scan Tool Scene' dropdown and buttons for 'Transform Coordinates' and 'Send Coordinates to Scan Tool'. At the bottom right, there is a table for 'Target Coordinates (Instrument)'. On the right side of the interface, there is a large image showing a scan tool scene with a circular field of view and various fiducial markers.

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The screenshot displays the 'SOLID_SAMPLE_SCANNER_TEST|scene' interface. At the top, the state is 'All motors connected'. Below this, the 'Motors to scan' section lists motor IDs for horizontal, vertical, and longitudinal axes. The main workflow is divided into three steps:

- 1. Get Sample Information from DB**: This section includes a subframe ID, available and selected playlists, and a button to get sample information from the database. A table below shows fiducial coordinates in the lab frame.
- 2. Add new fiducial**: This section allows adding a new fiducial by selecting its relative position and coordinate origin. A table below shows the resulting instrument coordinates.
- 3. Send Coordinates to Scan Tool**: This section includes a 'Scan Tool Scene' dropdown and buttons to transform coordinates and send them to the scan tool. A table below shows the target coordinates in the instrument frame.

On the right side of the interface, there is a large image showing the scan tool scene with a circular field of view and various fiducial markers. The axes are labeled 'X-axis (pixels)' and 'Y-axis (pixels)'.

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- State and Status:** A green state indicator and a status box showing 'All motors connected'.
- Motors to scan:** A table with columns for Motor ID (Horizontal, Vertical, Longitudinal) and a 'Reset Connection' button. The motor IDs are XHQ_EG_A/MOTOR1, XHQ_EG_A/MOTOR1, and HEXAPOD_TEST.
- 1. Get Sample Information from DB:** Fields for Subframe ID (EXFELFOI000001), Available Playlists (3), and Selected Playlist (3, 3). A button 'Get Sample Information from DB' is present.
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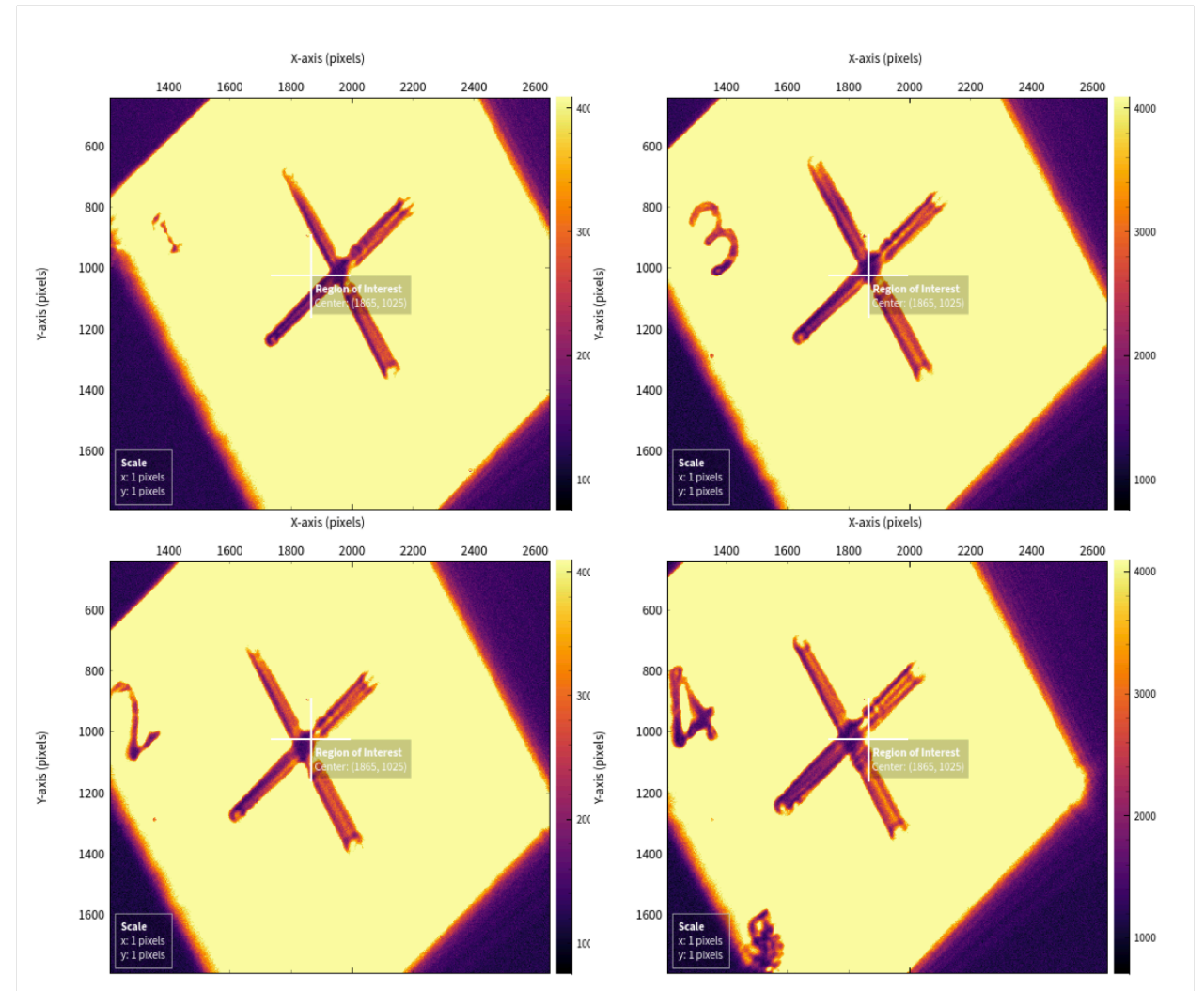
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On the right side, there is a large image showing a scan of a sample with fiducial markers. The image has X and Y axes in pixels, ranging from 0 to 50 on the X-axis and 0 to 240 on the Y-axis. A circular region is highlighted on the image.

Commissioning Results (I): Accuracy

- After transforming coordinates, motors were driven to expected positions and the difference between expected and actual positions was measured to verify target positions.

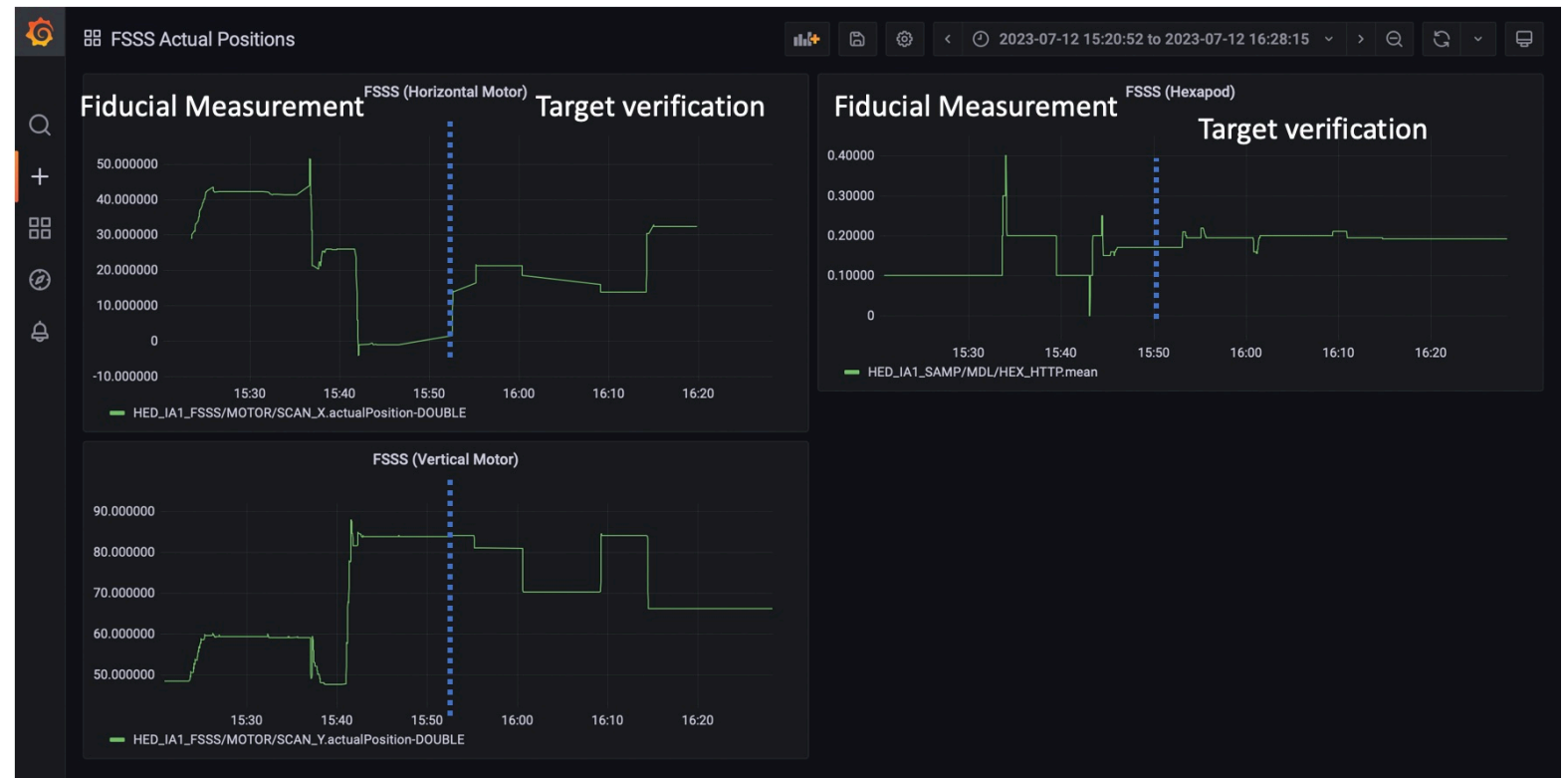
	Horizontal [um]	Horizontal [%]	Vertical [um]	Vertical [%]
Average	8 +- 3	$(4+-2)10^{-3}$	5+-1	$(7+-2)10^{-3}$



Commissioning Results (II): Time

Positions and acquiring target coordinate positions typically takes about 30 minutes.

Approximately 25 extra minutes were dedicated to the thorough verification of the target positions.



Conclusions

- Pre-characterizing samples saves 4-8 hrs of beam time, reducing costs and increasing efficiency. Beam times are 5-6 days, with 4-5 reserved for measurements, so the impact is significant.

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- The integration of the scanner into the facility's control system, Karabo, has been successfully tested.

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- The results of the calculation of the positions of the four targets within the sample were found to be accurate.
- The integration of the scanner into the facility's control system, Karabo, has been successfully tested.
- Data accessibility has been improved, the system now enables access to historical data values.

Thank you for your attention