The Common Calibration Protocol and Neutron Quality Label for Neutron Strain Scanning Instrumentation

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Motivation

Background

- Demand for access to Neutron Strain Scanners
  - Demand & complexity increase
  - Access limited & competitive
- Measurement quality & instrument interchangeability
- Harmonization of protocol and reporting → *NQL*

Neutron Quality Label (NQL)

Background

Quality standard for a **measurement/ specific setup** on neutron strain scanners

Obtained by following a series of **common calibration measurements and reporting**

NQL and other standard

Background

VAMAS TWA20 & RESTAND

Round robin activities → establish neutron diffraction as reliable method for residual stress measurement

ISO 21432:2019

General guidelines on how to perform neutron diffraction for residual stress measurement

Neutron Quality Label (NQL)

Practical guideline to characterized setup using common method i.e., samples & protocol (+ how to report)

→

NQL

Neutron Quality Label

Template includes:
Instrument setup info
& measurement result

To reproduce measurement on other time/ instrument

The project

Background

Project → Development of possible methods to characterise particular setup of instruments → **Positional accuracy**

Participants

brightness²

Work Package 2
D2.1 Preliminary report on engineering

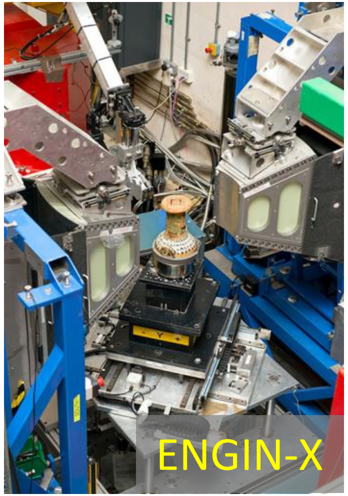
Background

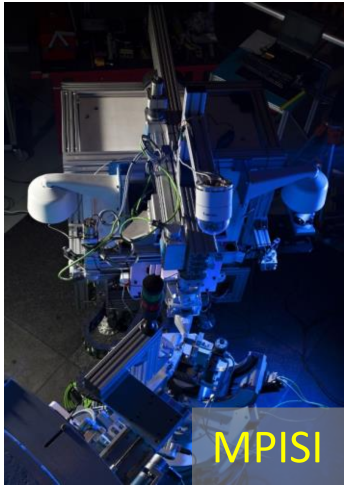
NEUTRONS FOR SOCIETY

Science & Technology Facilities Council ISIS

MLZ Heinz Maier-Leibnitz Zentrum

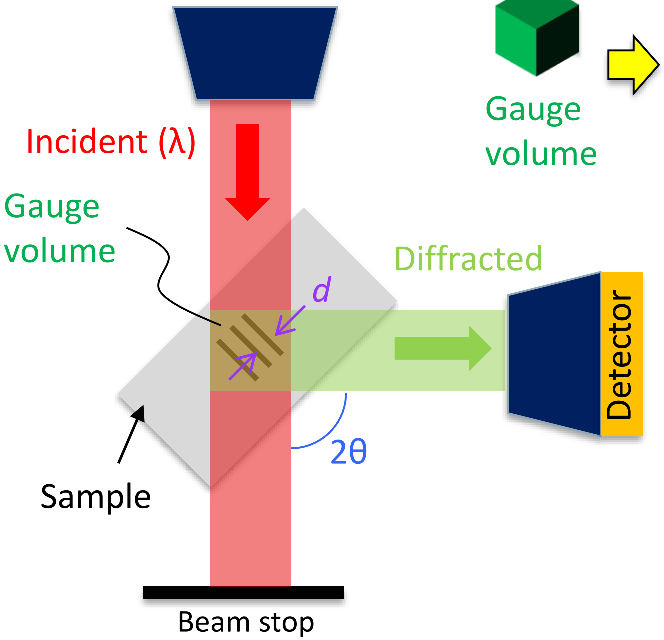
necsa We're in your world
South African Nuclear Energy Corporation SOC Limited





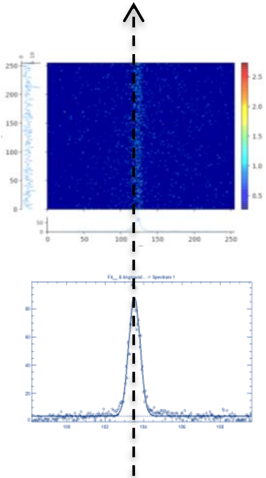
Neutron diffraction for stress determination

Technical overview



Gauge volume

Peak position
2θ or ToF



Lattice spacing
d

Bragg's Law
$\lambda = 2d \sin\theta$

$d \rightarrow$ stressed
$d_0 \rightarrow$ unstressed

Strain
ε

$$\varepsilon = \frac{d - d_0}{d_0}$$

Stress
σ

Hooke's Law in principal direction

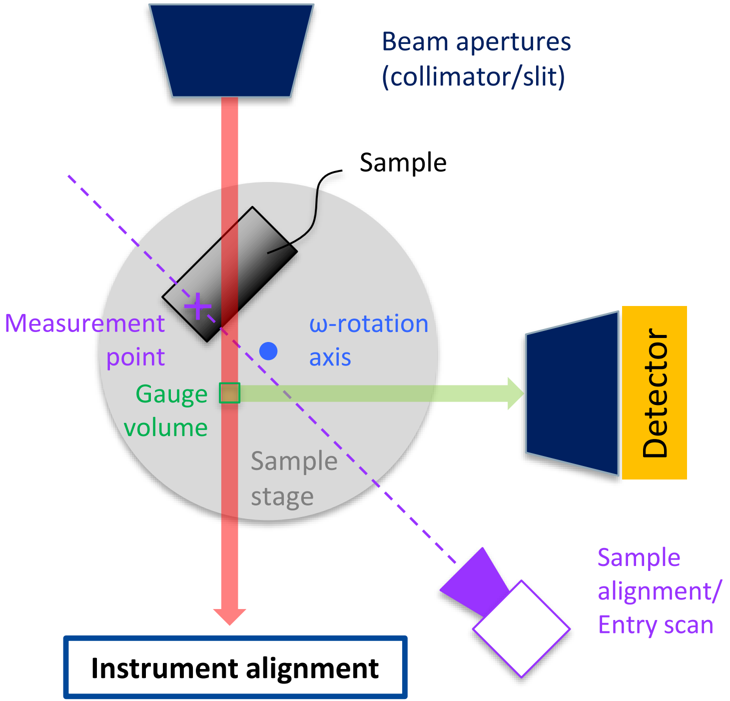
$$\sigma_{xx} = \frac{E_{hkl}}{(1+\nu_{hkl})(1-2\nu_{hkl})}[(1-\nu_{hkl})\varepsilon_{xx} + \nu_{hkl}(\varepsilon_{yy}+\varepsilon_{zz})]$$

$$\sigma_{yy} = \frac{E_{hkl}}{(1+\nu_{hkl})(1-2\nu_{hkl})}[(1-\nu_{hkl})\varepsilon_{yy} + \nu_{hkl}(\varepsilon_{xx}+\varepsilon_{zz})]$$

$$\sigma_{zz} = \frac{E_{hkl}}{(1+\nu_{hkl})(1-2\nu_{hkl})}[(1-\nu_{hkl})\varepsilon_{zz} + \nu_{hkl}(\varepsilon_{xx}+\varepsilon_{yy})]$$

Neutron strain scanner & stress mapping

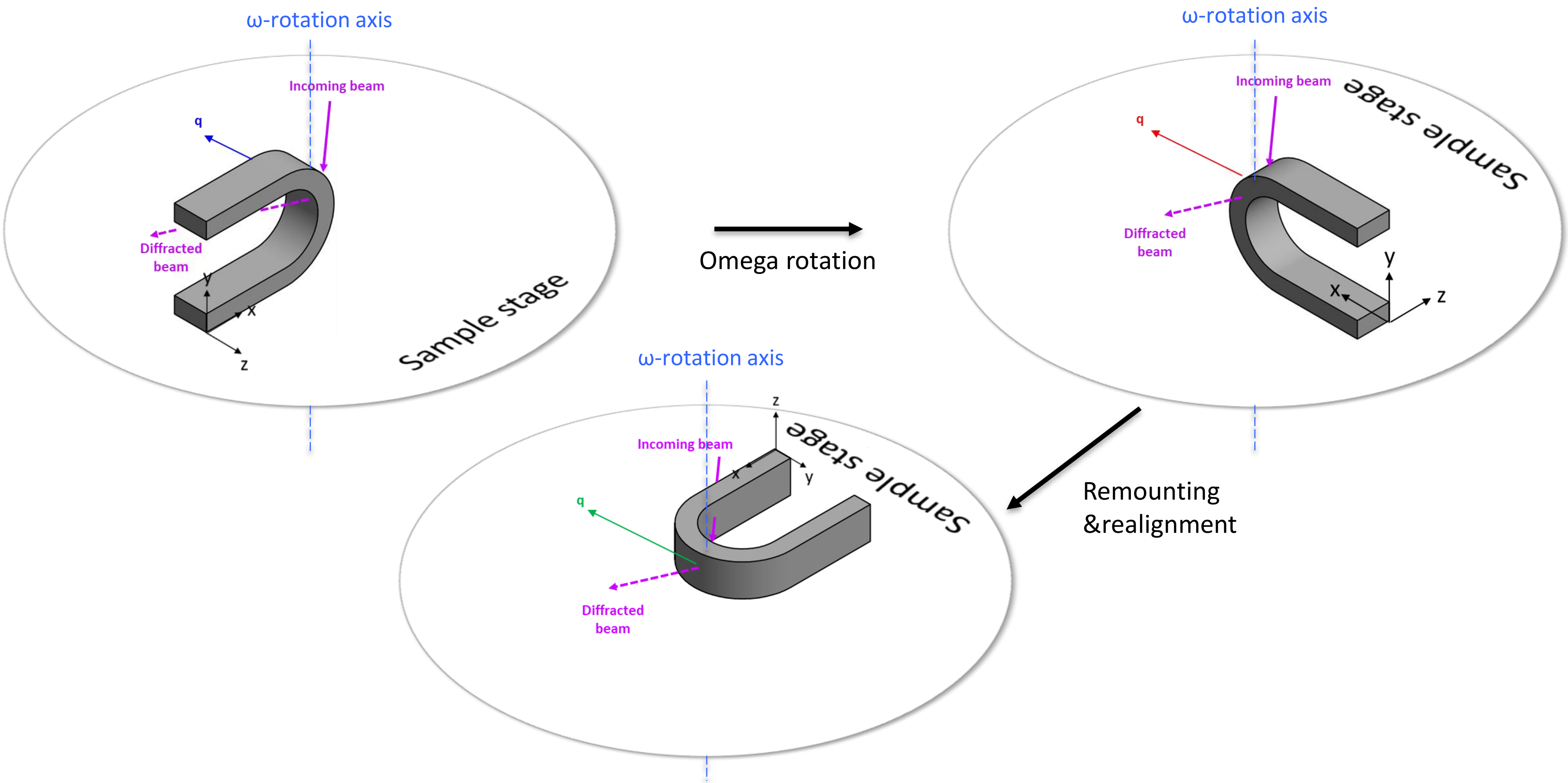
Technical overview



- ω-rotation axis
- Gauge volume (GV) reference point (center of IGV)
- Measurement point

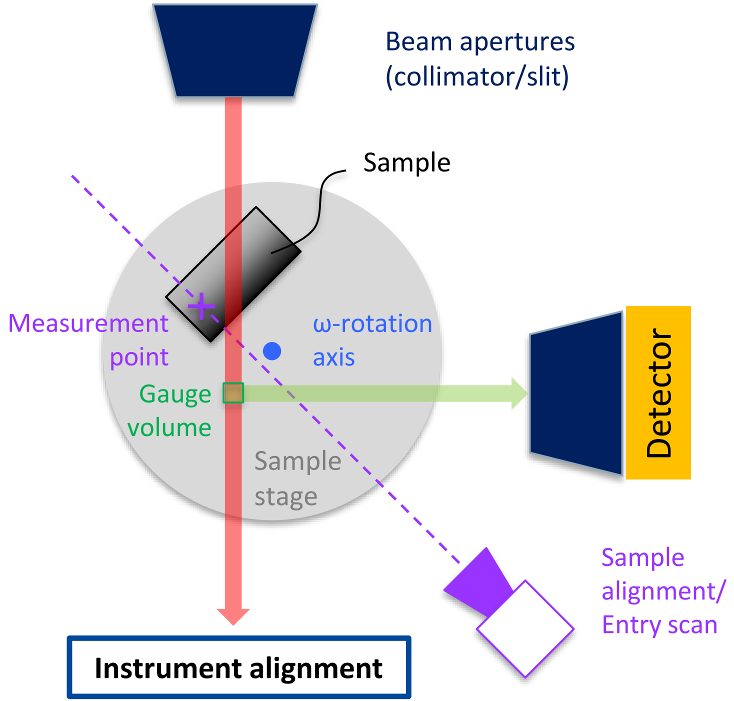
Accurate within 10% GV width (ISO)

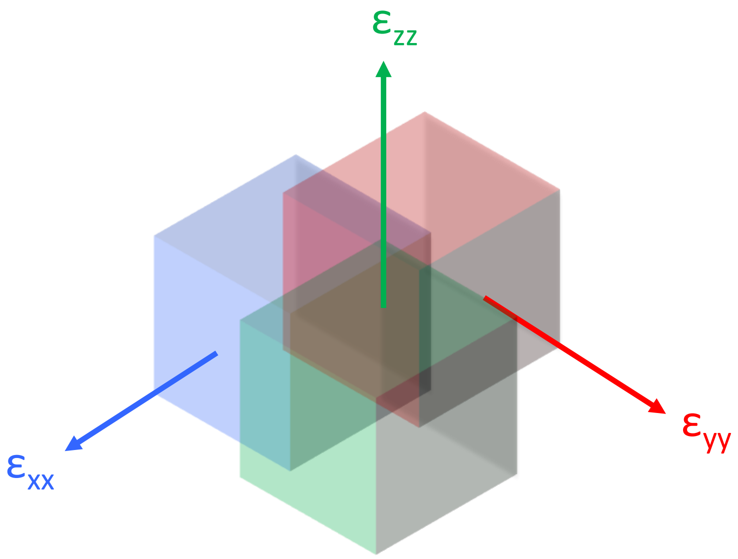
Neutron strain scanner & stress mapping



Neutron strain scanner & stress mapping

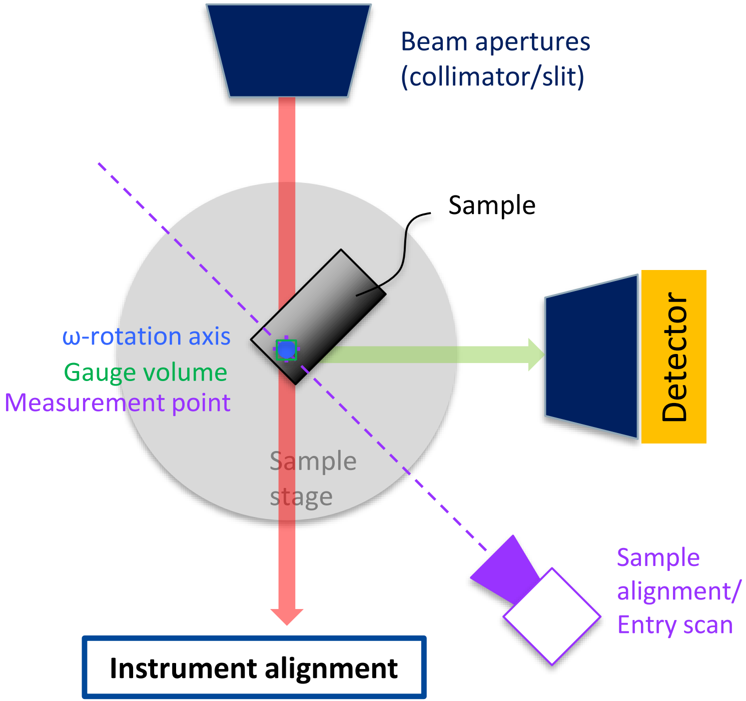
Technical overview

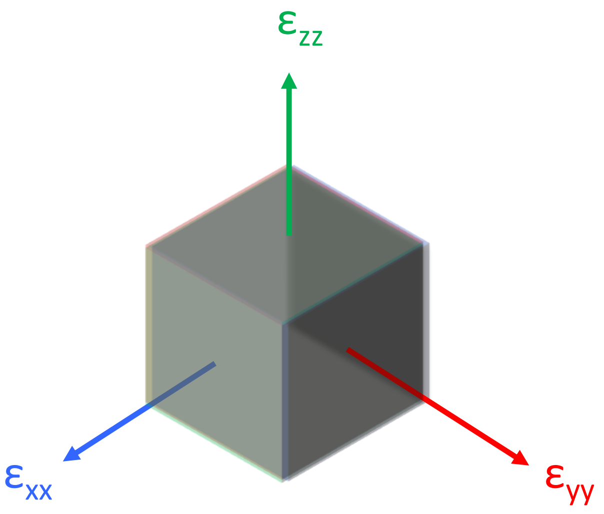




Neutron strain scanner & stress mapping

Technical overview

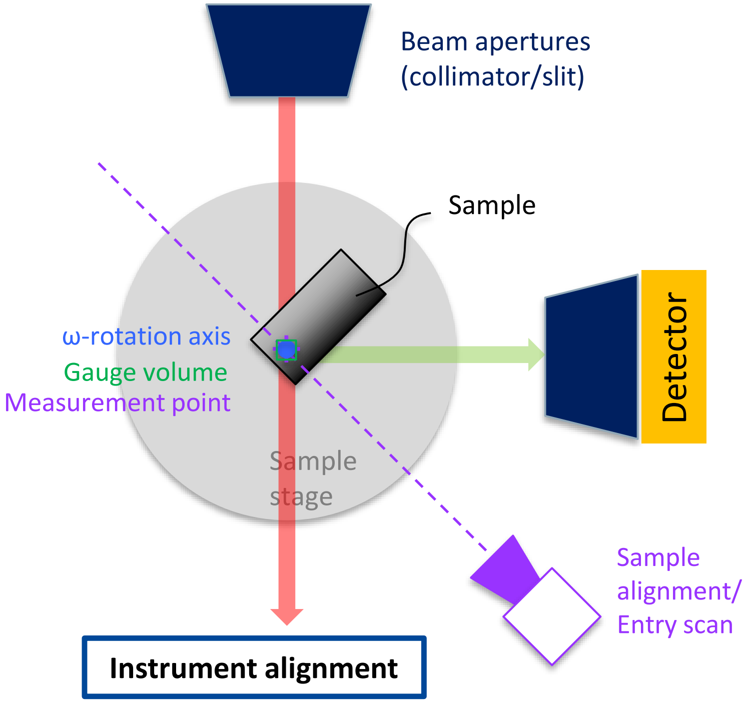




Positional accuracy is very important!

Neutron strain scanner & stress mapping

Technical overview



Development of possible methods to **characterise** particular setup of instruments →

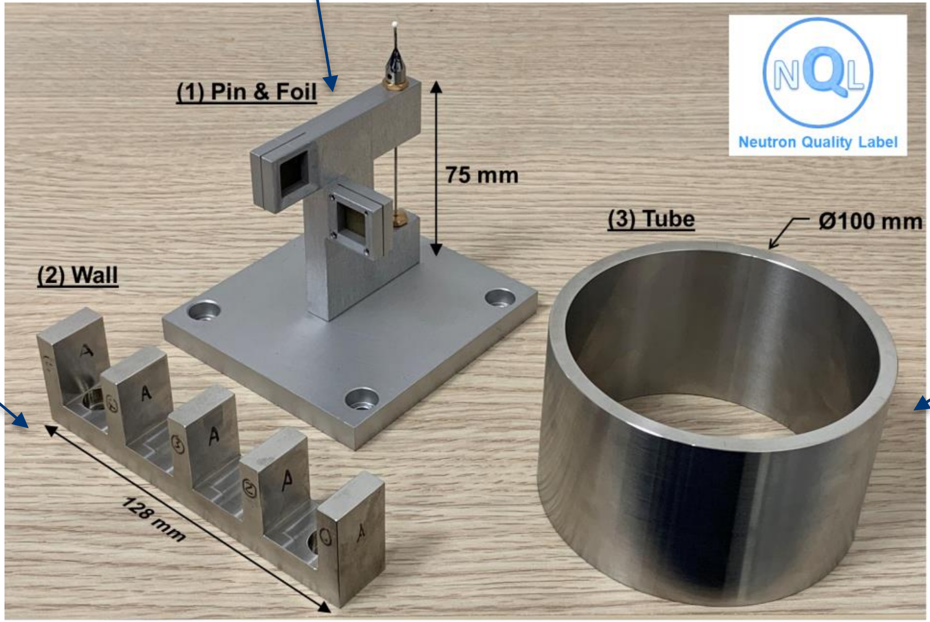
- **gauge volume centroid (reference point) vs *ω*-rotation axis**
- **precision of sample alignment using optical system**
- **accuracy of entry scan analysis software for sample alignment**

Calibration samples

Methods

Pin & foil calibration sample: orthogonal 0.3 mm foils, changeable + changeable pins → instrument alignment

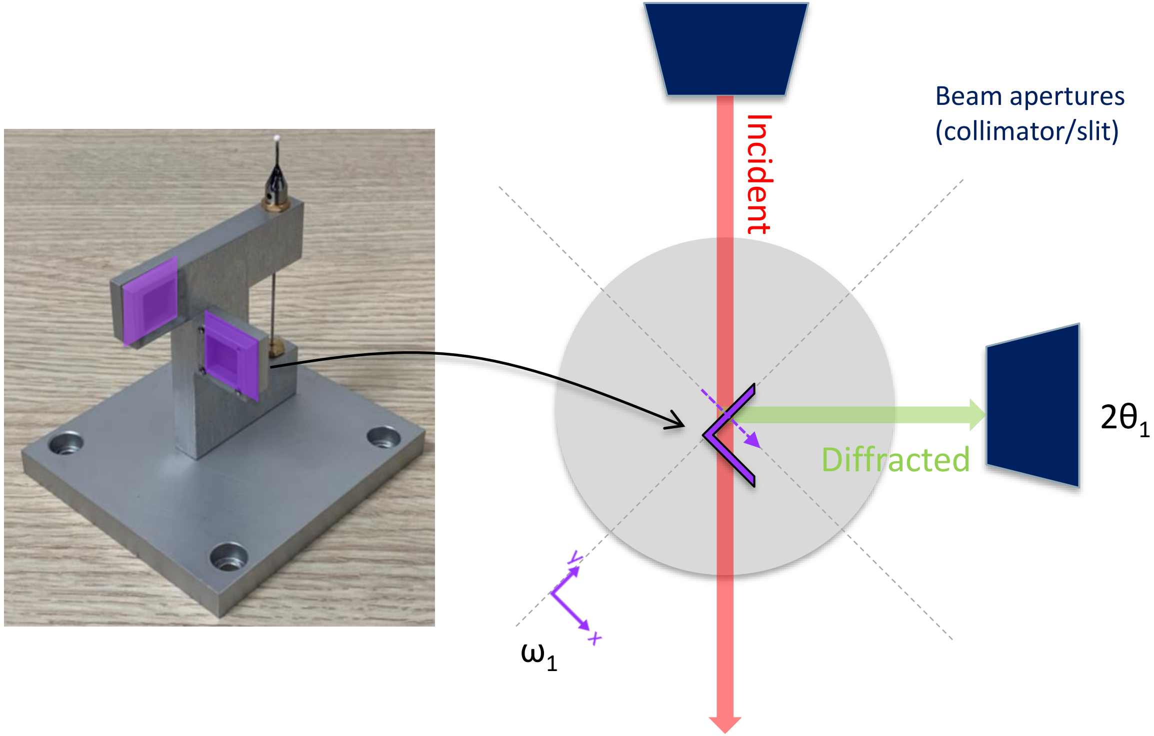
5-Wall sample: 5 equidistance walls→ reproducibility of sample alignment, i) optical & ii) entry scan analysis on flat surfaces



Tube sample → sample alignment, entry scan analysis on curved surfaces

Instrument alignment: Pin and foil scans

Methods



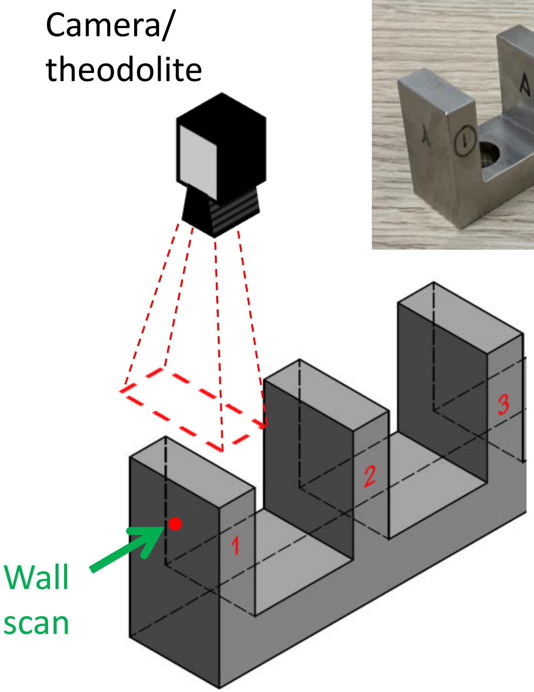
Foil scans at different ω-angle

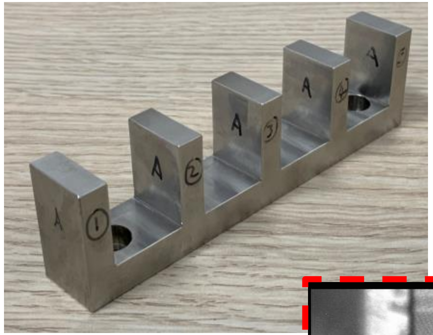
↓

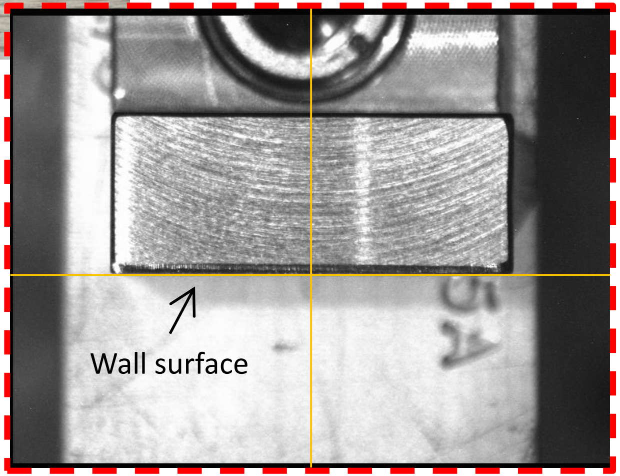
Characterise the rotation axis of ω relative to reference point (centre of IGV)

Sample alignments (optical): wall scans

Methods







Wall alignment position **vs** wall position determined with neutron

Characterise the precision of sample alignment using optical system

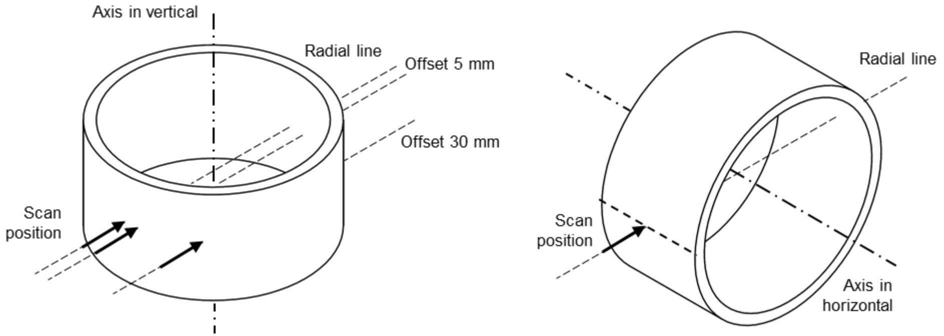
Sample alignments (entry scan): wall scans

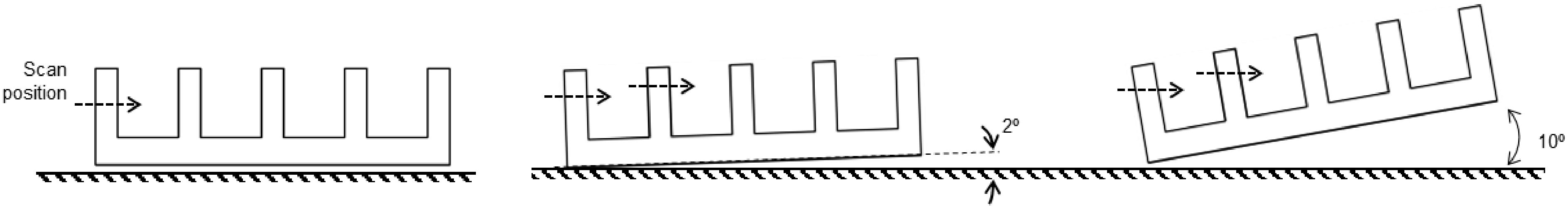
Methods

Wall thickness determined with neutron **vs** CMM measurement (accuracy <5 µm)

→

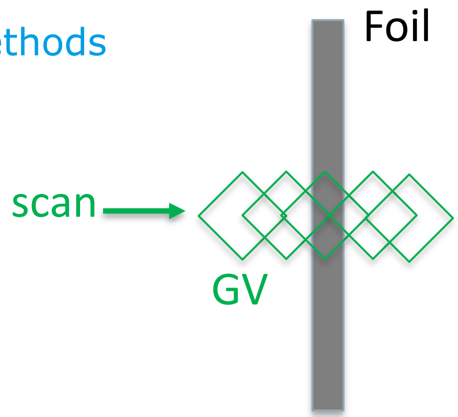
Characterise the accuracy of the entry scan analysis software for surface determination

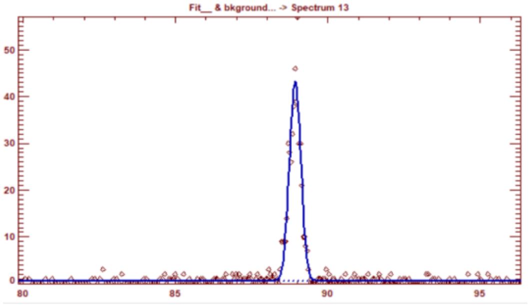


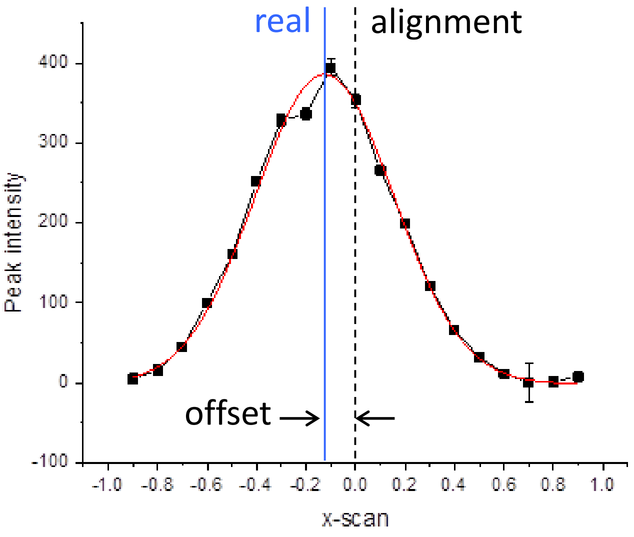


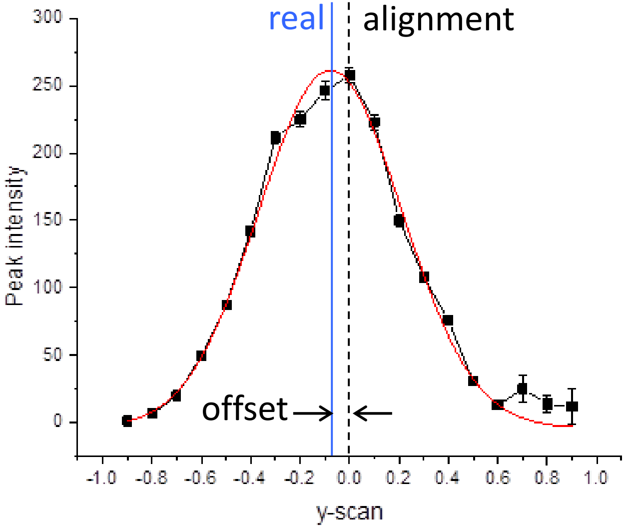
Data analysis: Foil scans

Methods





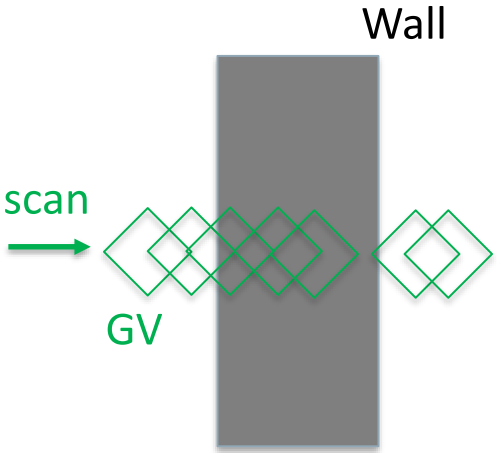


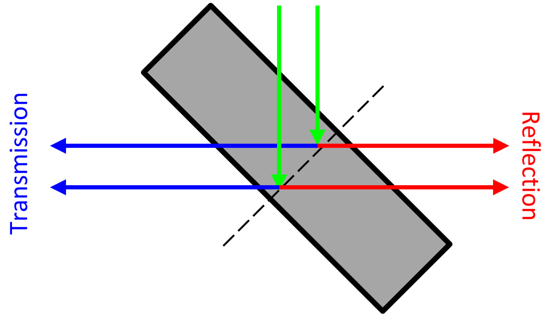


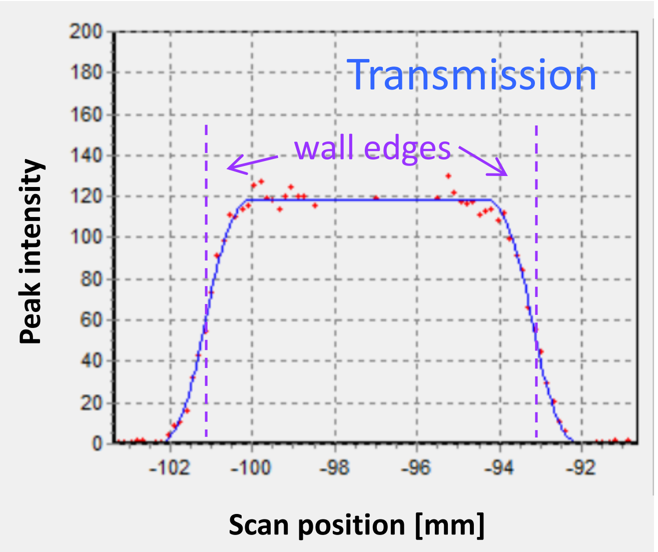
Peak intensity

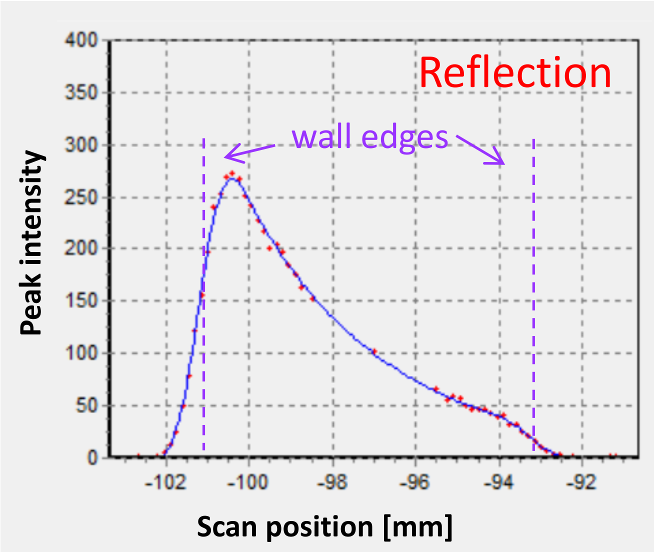
Data analysis: Wall scans

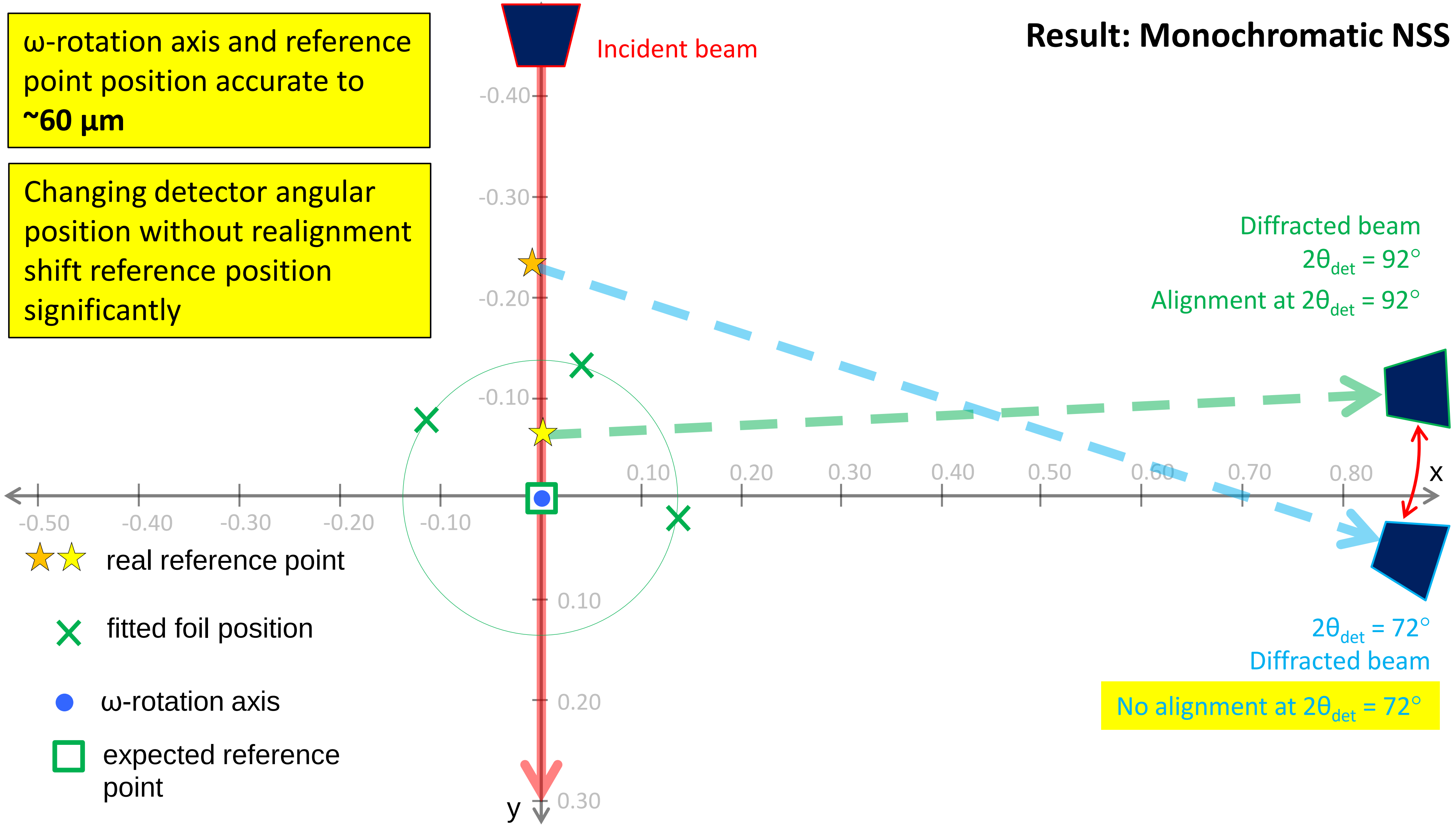
Methods







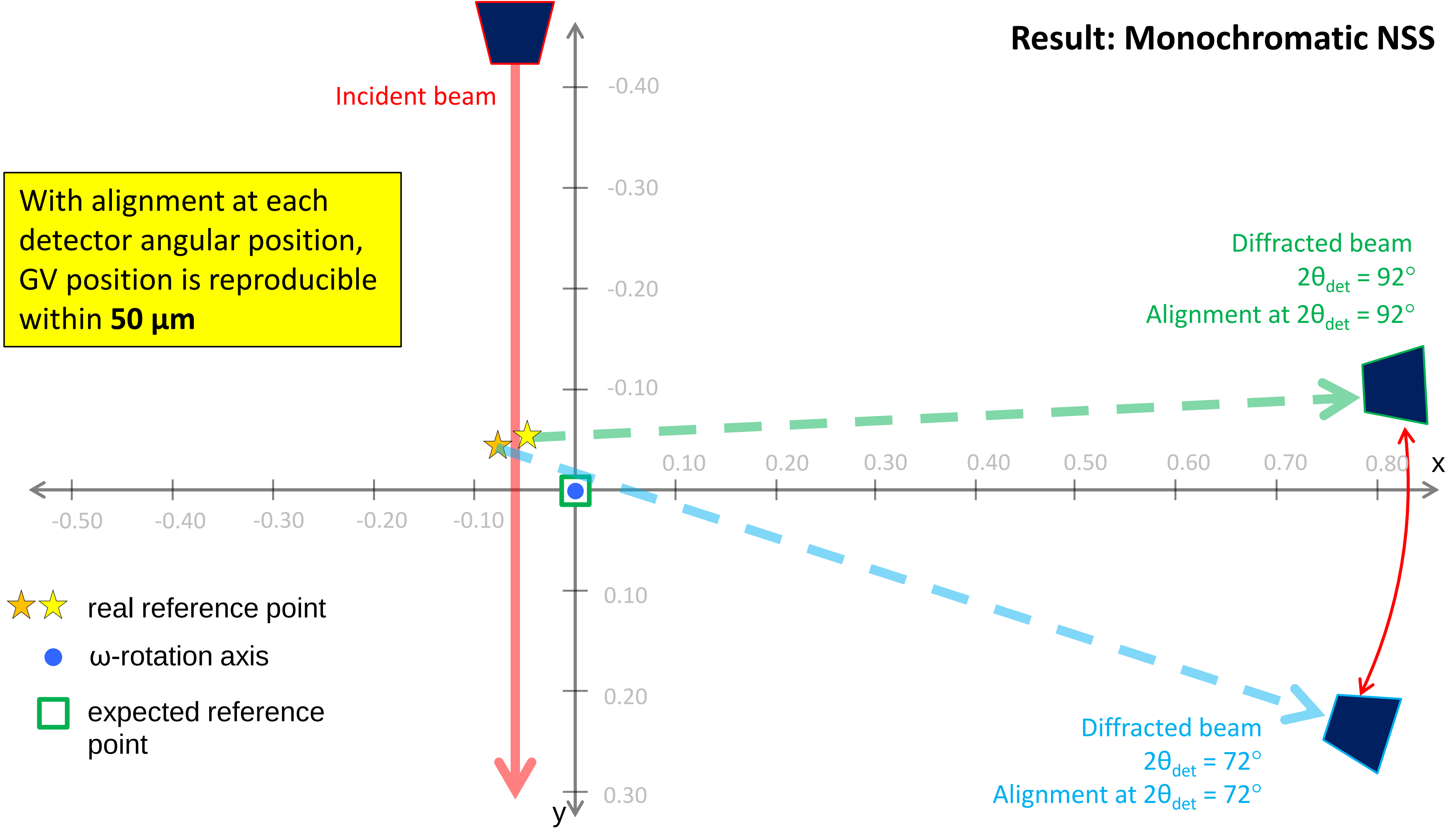




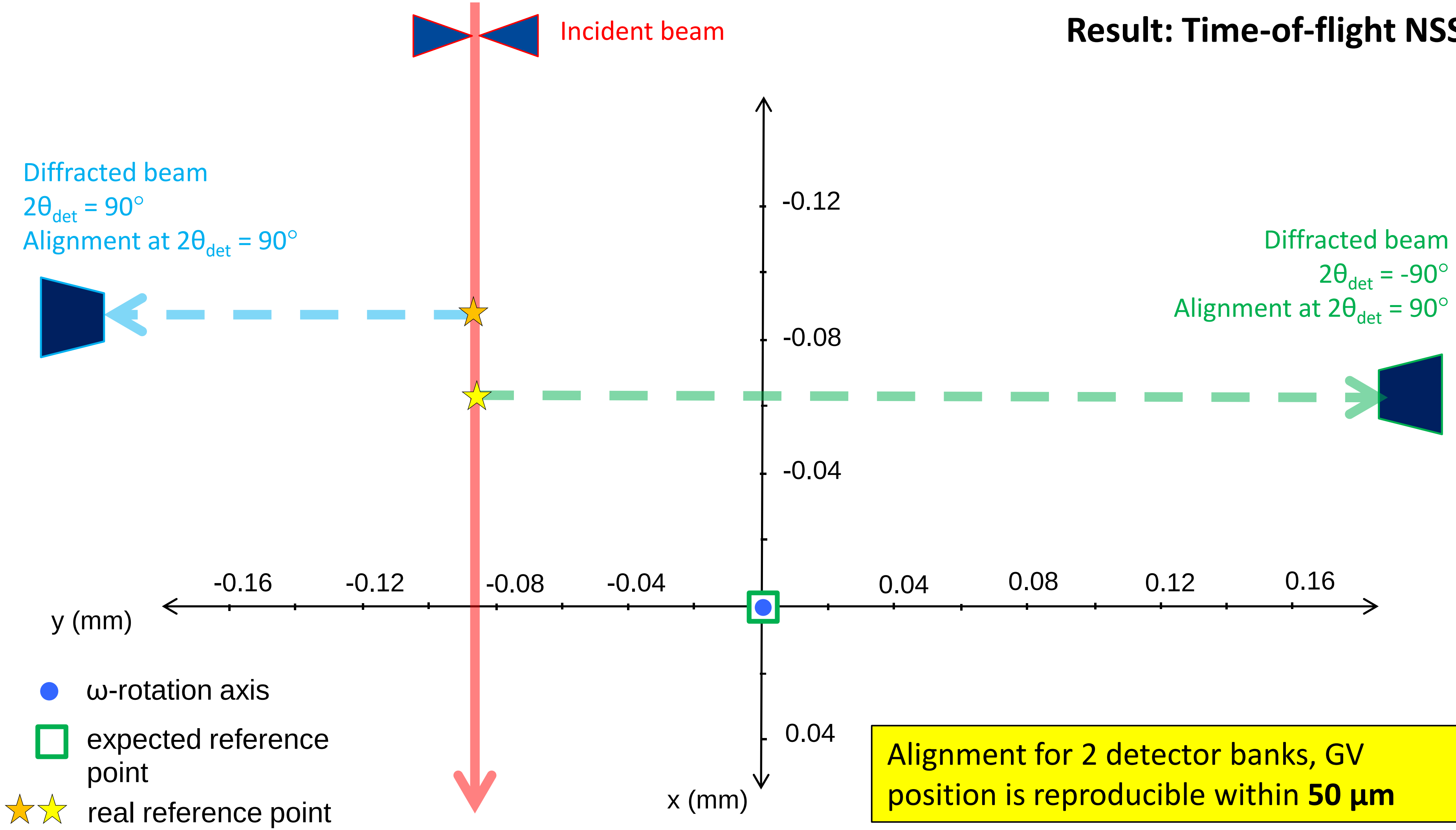
Result: Monochromatic NSS
ω-rotation axis and reference point position accurate to **~60 µm**
Changing detector angular position without realignment shift reference position significantly
Incident beam
Diffracted beam
2θdet = 92°
Alignment at 2θdet = 92°
2θdet = 72°
Diffracted beam
No alignment at 2θdet = 72°
x
y
-0.50
-0.40
-0.30
-0.20
-0.10
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
real reference point
fitted foil position
ω-rotation axis
expected reference point

Result: Monochromatic NSS

With alignment at each detector angular position, GV position is reproducible within **50 µm**



Result: Time-of-flight NSS



Alignment for 2 detector banks, GV position is reproducible within **50 µm**

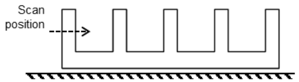
Sample alignment

Result

Reproducibility of sample alignment procedures (camera/ theodolite) → ~100 µm

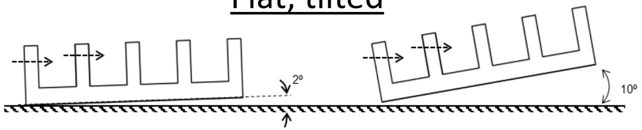
Accuracy of entry scan for alignment:

Flat



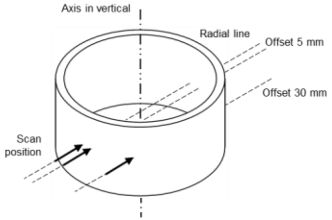
<100 µm
(Better than **10% of GV** width)

Flat, tilted



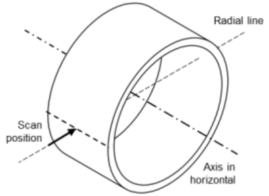
Can achieve **100 µm**
(**10% of GV** width) depend on GV height; taller GV worse accuracy

curved, axis vertical



Geometry model necessary, can achieve **100 µm**
(**10% of GV** width)

curved, axis horizontal

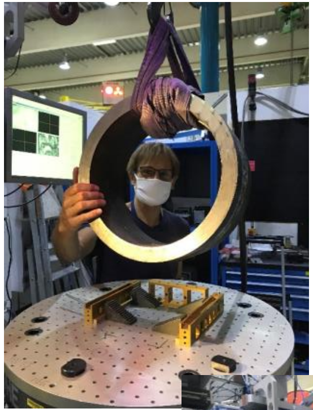


Simple model can achieve **100 µm**
(**10% of GV** width)
depend on GV height

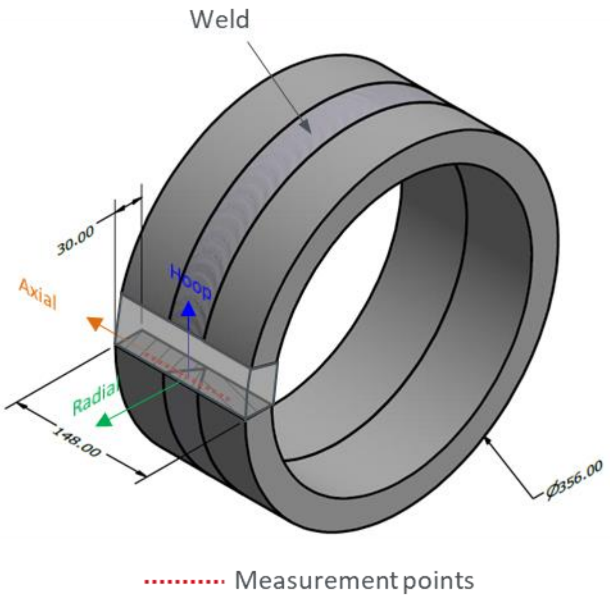
Conclusion

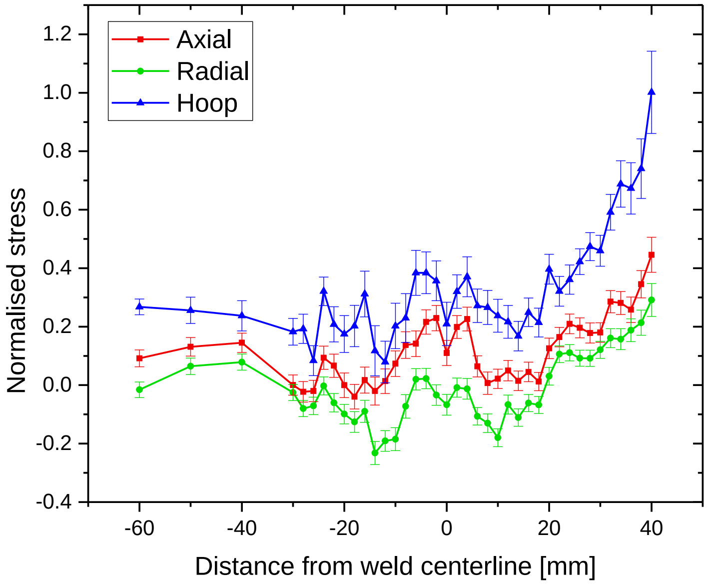
- A possible common method for evaluating positional accuracy of the NSS has been proposed
- Benchmarking results showed participating NSS setup has comparable numbers → agree with VAMAS TWA20 results and ISO guidelines → sufficient for many engineering application
- Other instruments are invited to join and attain the NQL

Next step…



Measurement of engineering samples with industrial partners





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