MEDSI 2016
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION
BARCELONA

Engineering Challenges on the I14 Nanoprobe Beamline

Andy Peach
Diamond Light Source

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Structure of talk

I14 Overview

- Outline of the beamline layout
- Key goals & challenges
- Highlight a few key points
  - Building
  - Primary optics

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I14 Endstation in more detail

- Nano KB/sample station
- Detector table

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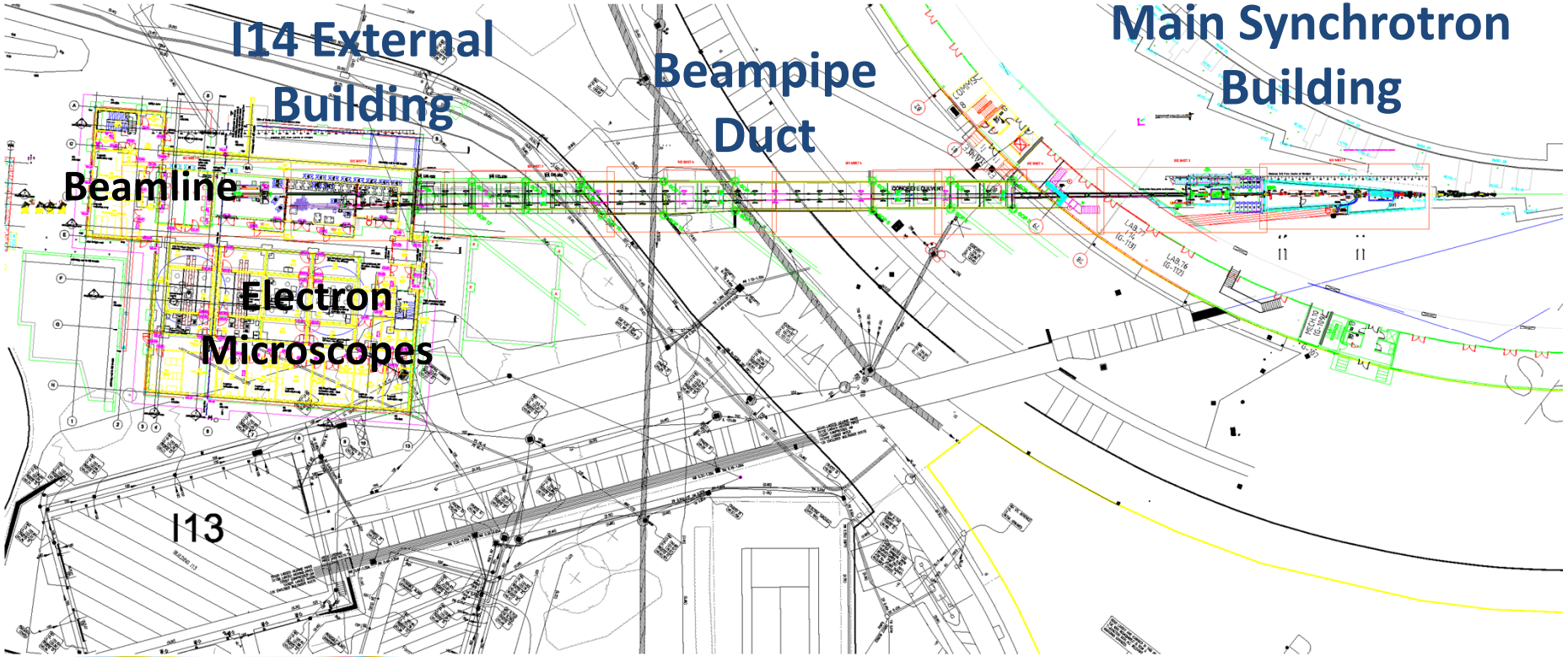
I14 Site Layout

- 186m long for demagnification & coherence
- 2 Branches – Nanoprobe & Mesoprobe



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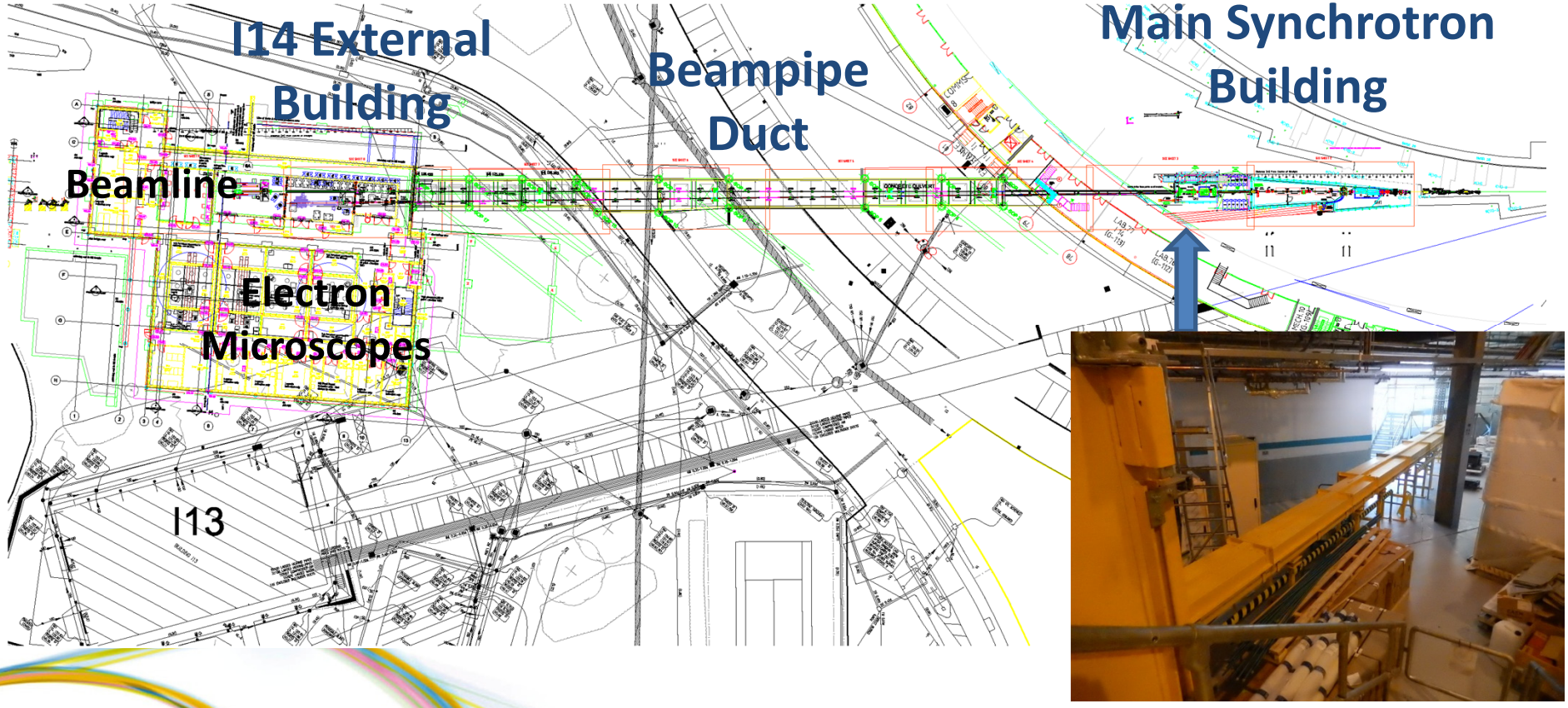

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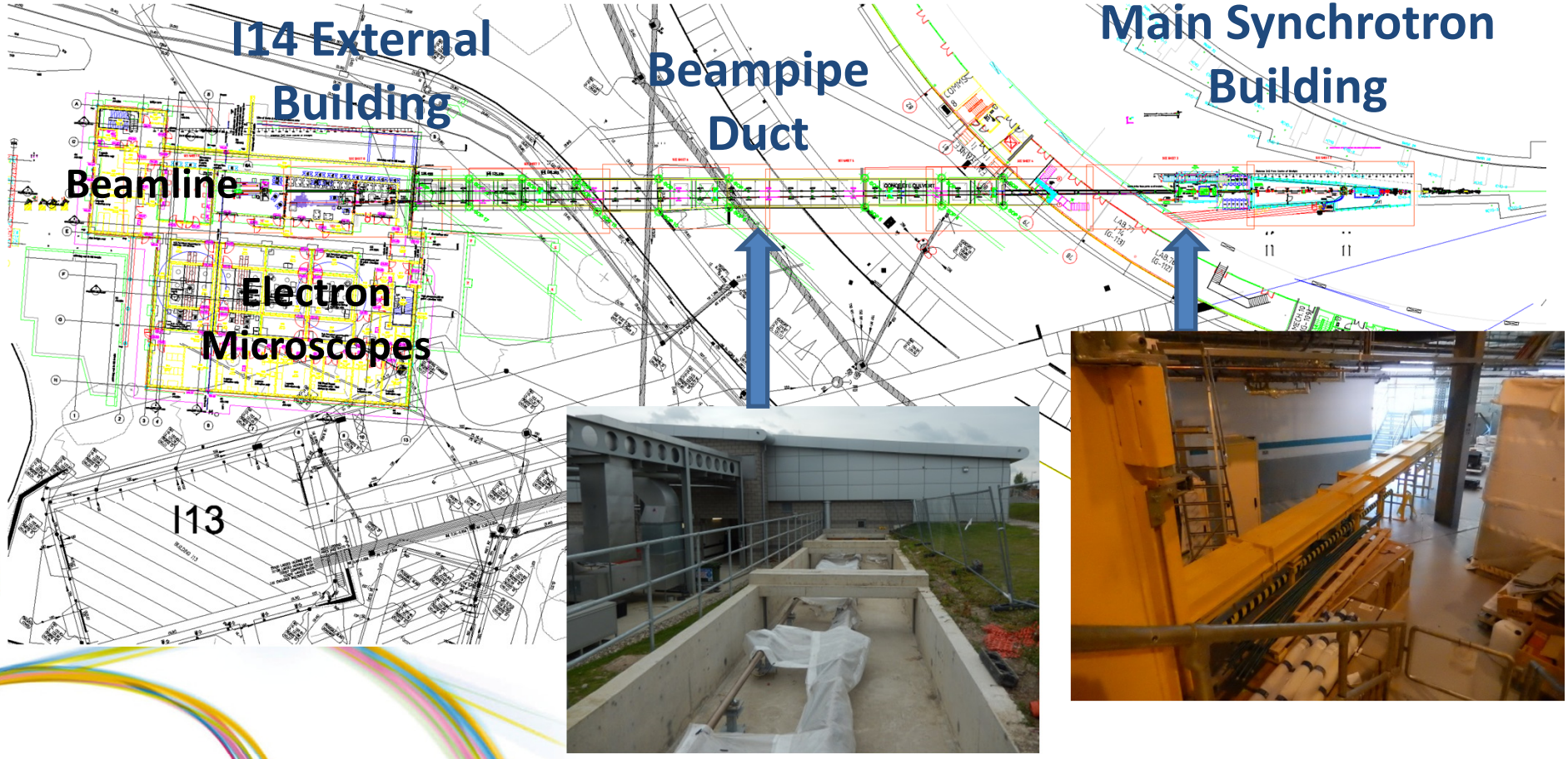

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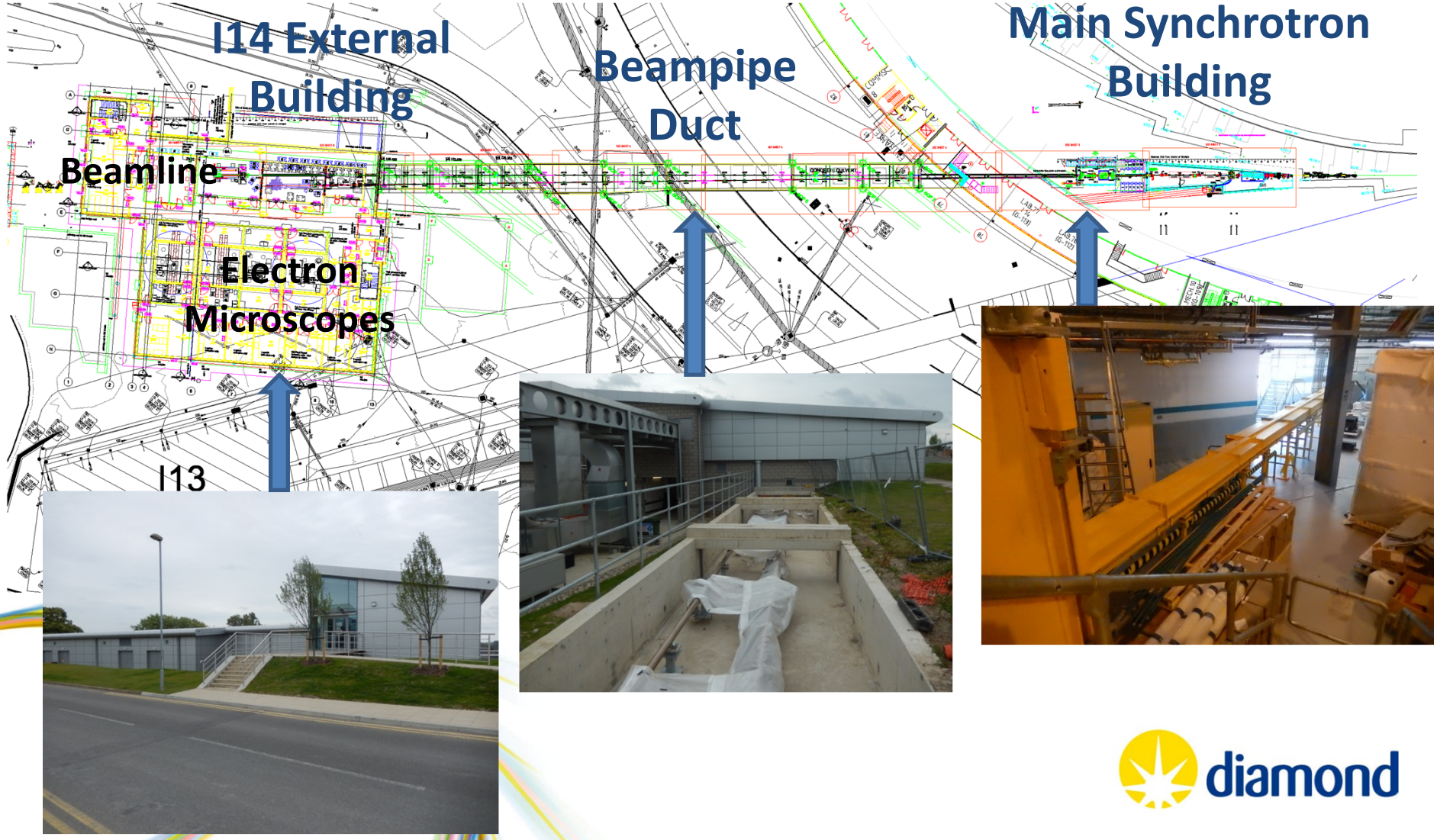
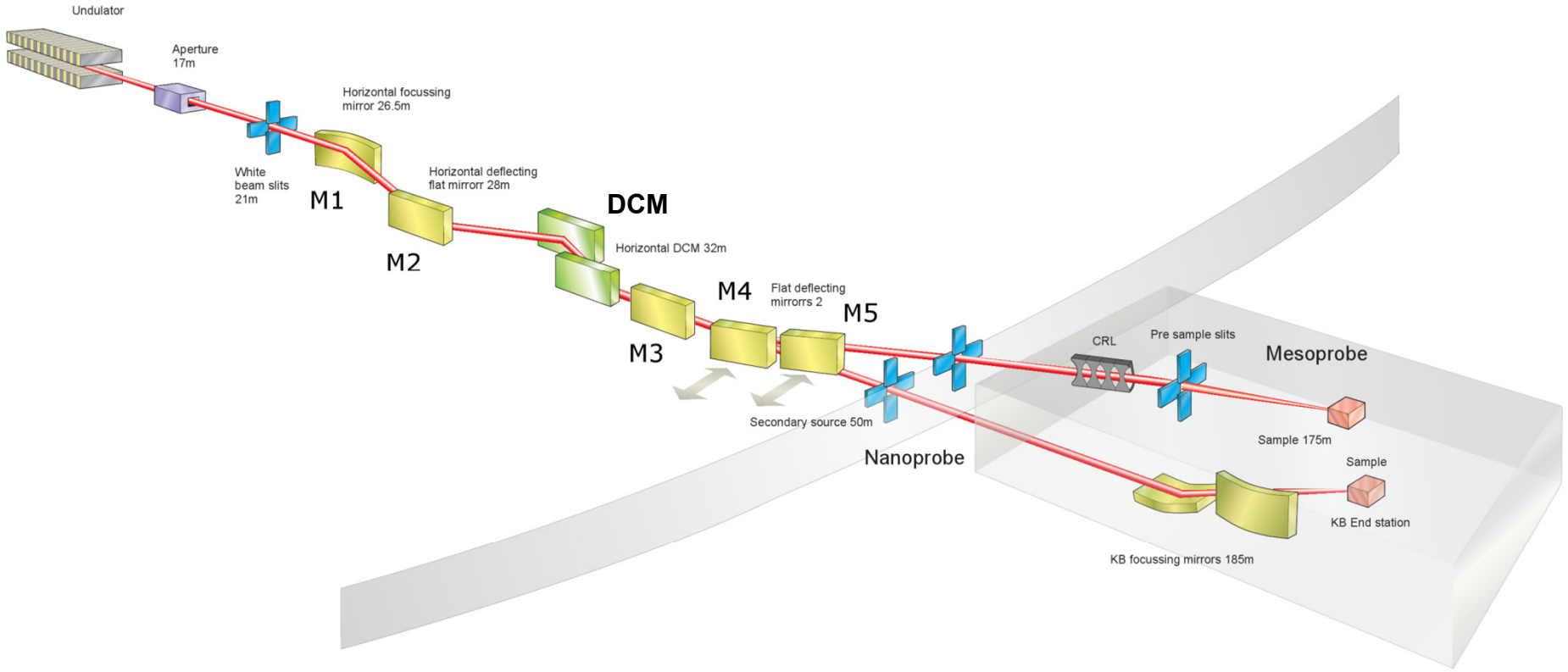


I14 Beamline Layout

- All primary optics side bounce for best vertical beam stability



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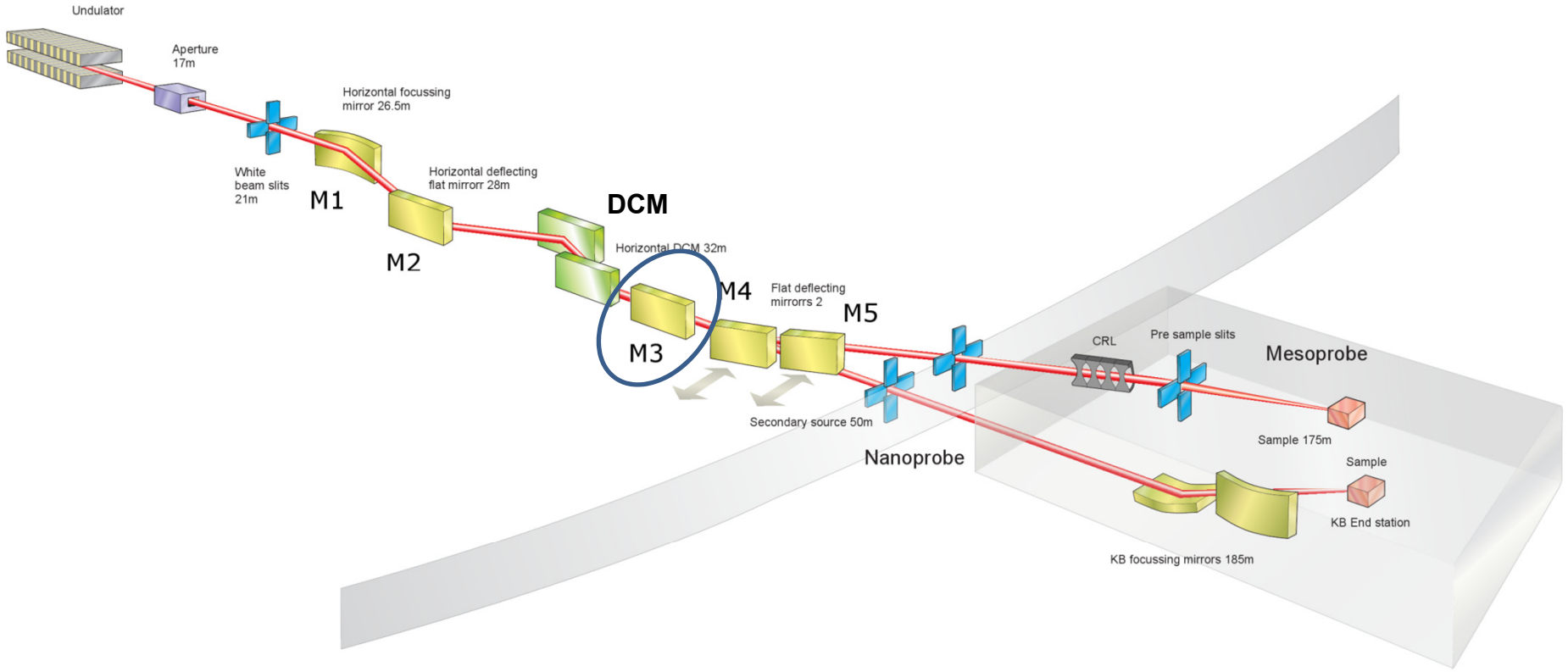
- Pink beam option - M3 (future)



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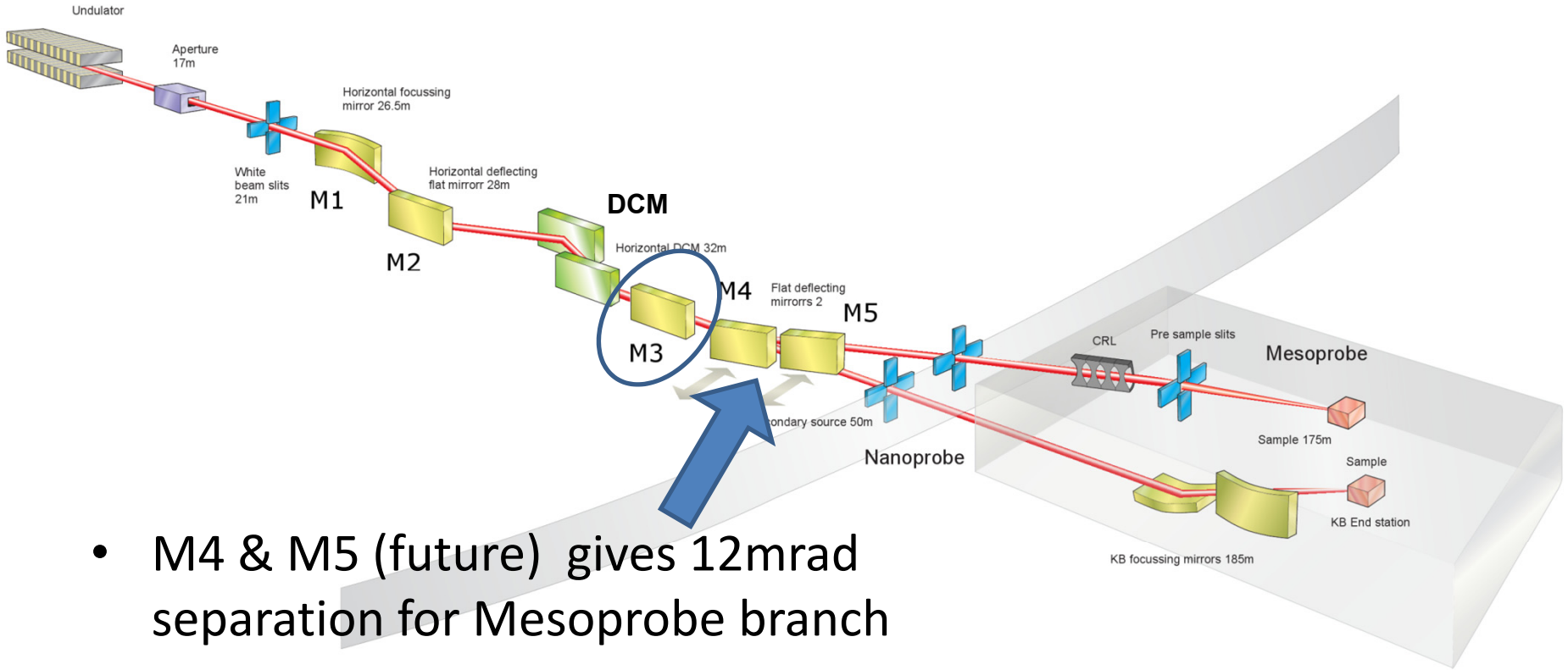
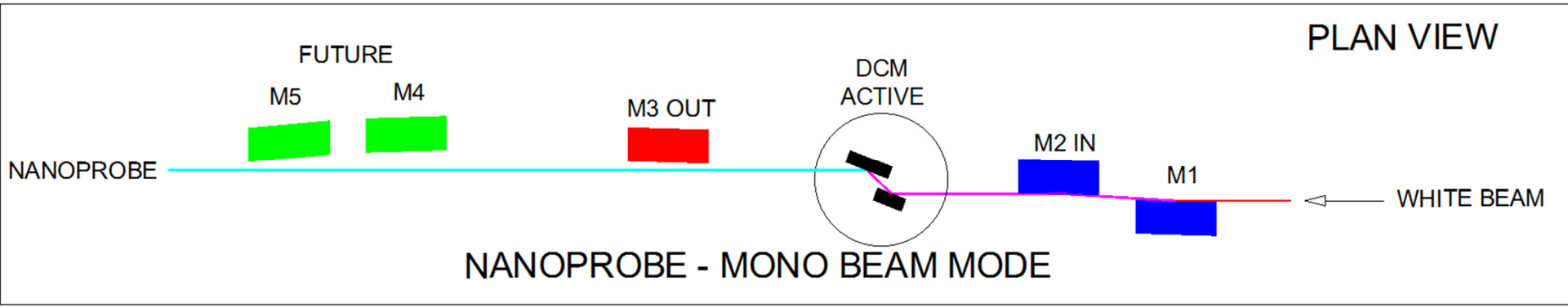


- M4 & M5 (future) gives 12mrad separation for Mesoprobe branch

Mono & Pink Beams to Both Branches



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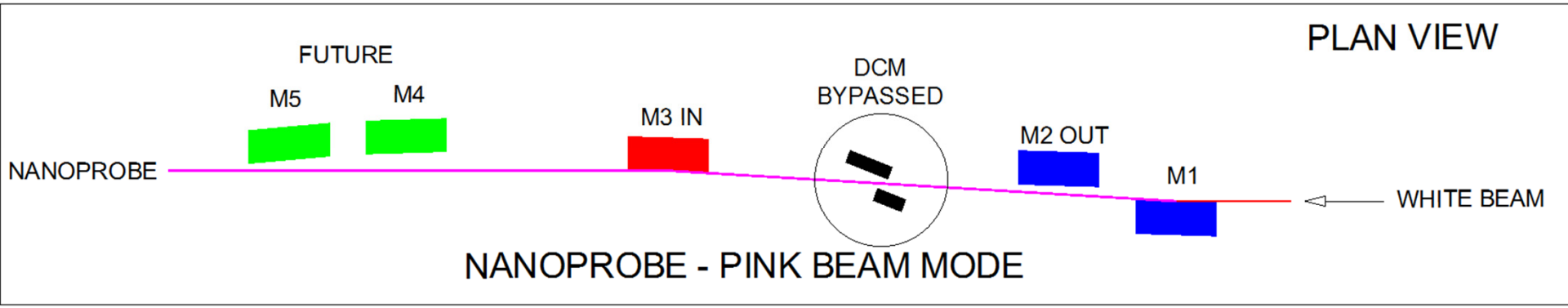

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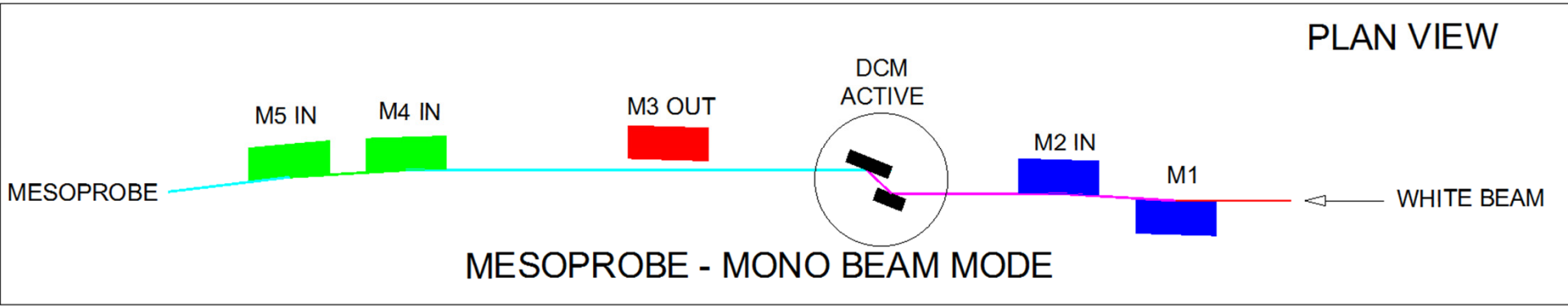

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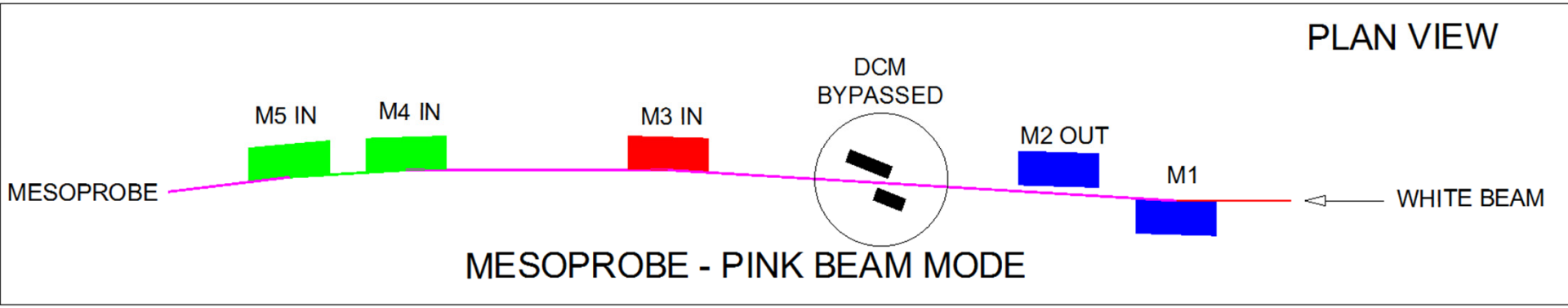
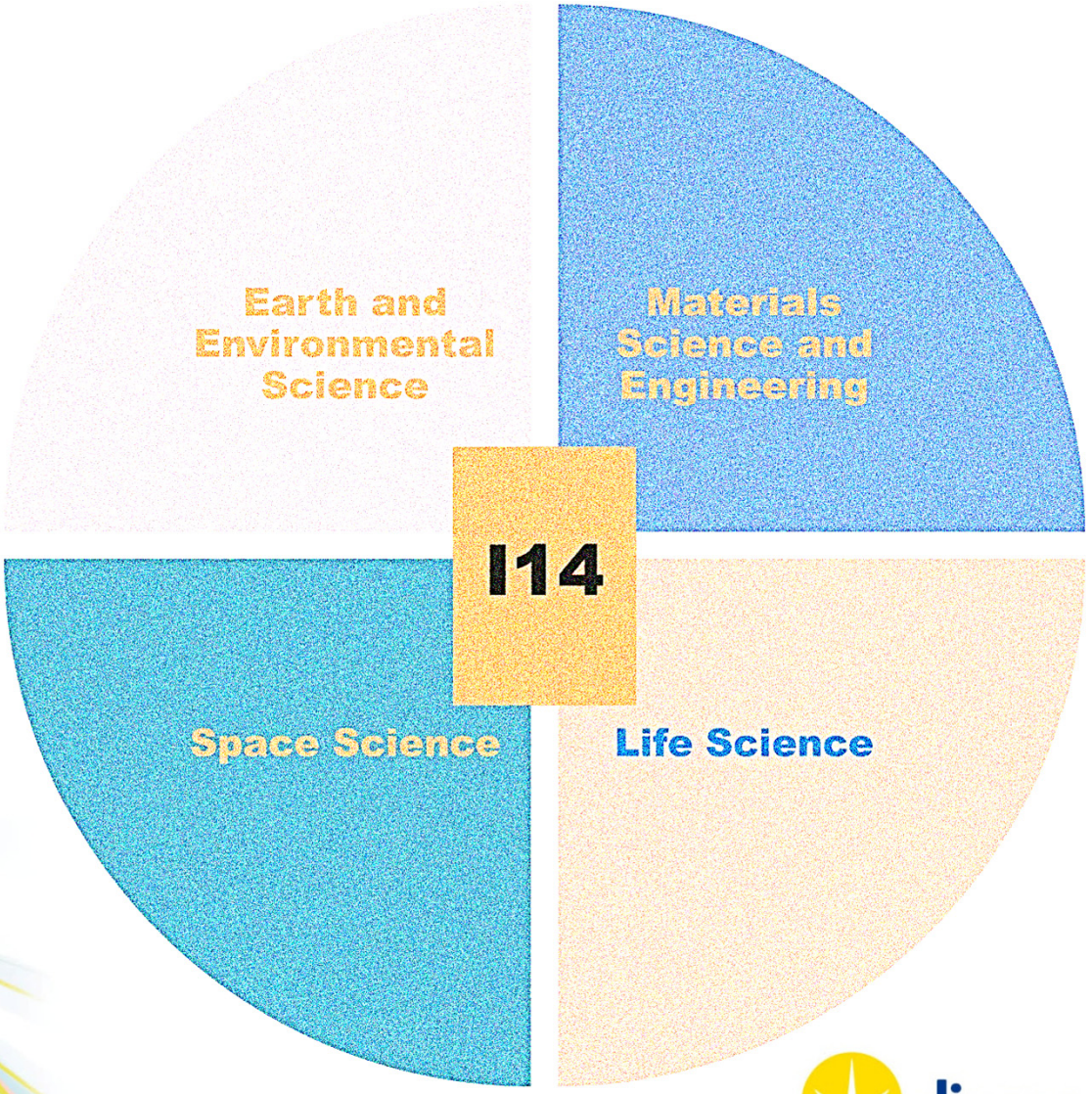


Key Goals of the I14 Nanoprobe



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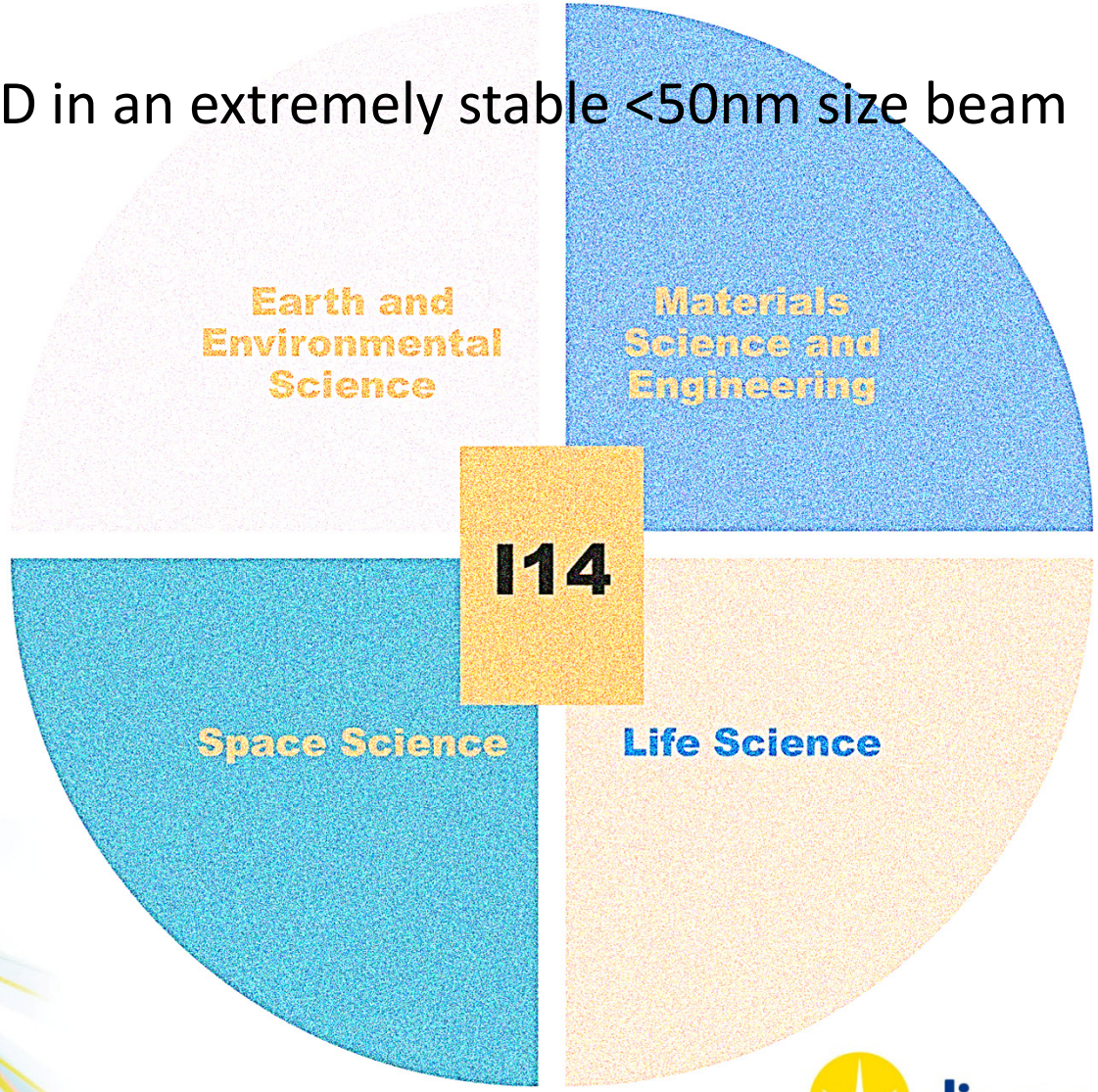
Scan samples in 2D/3D in an extremely stable <50nm size beam



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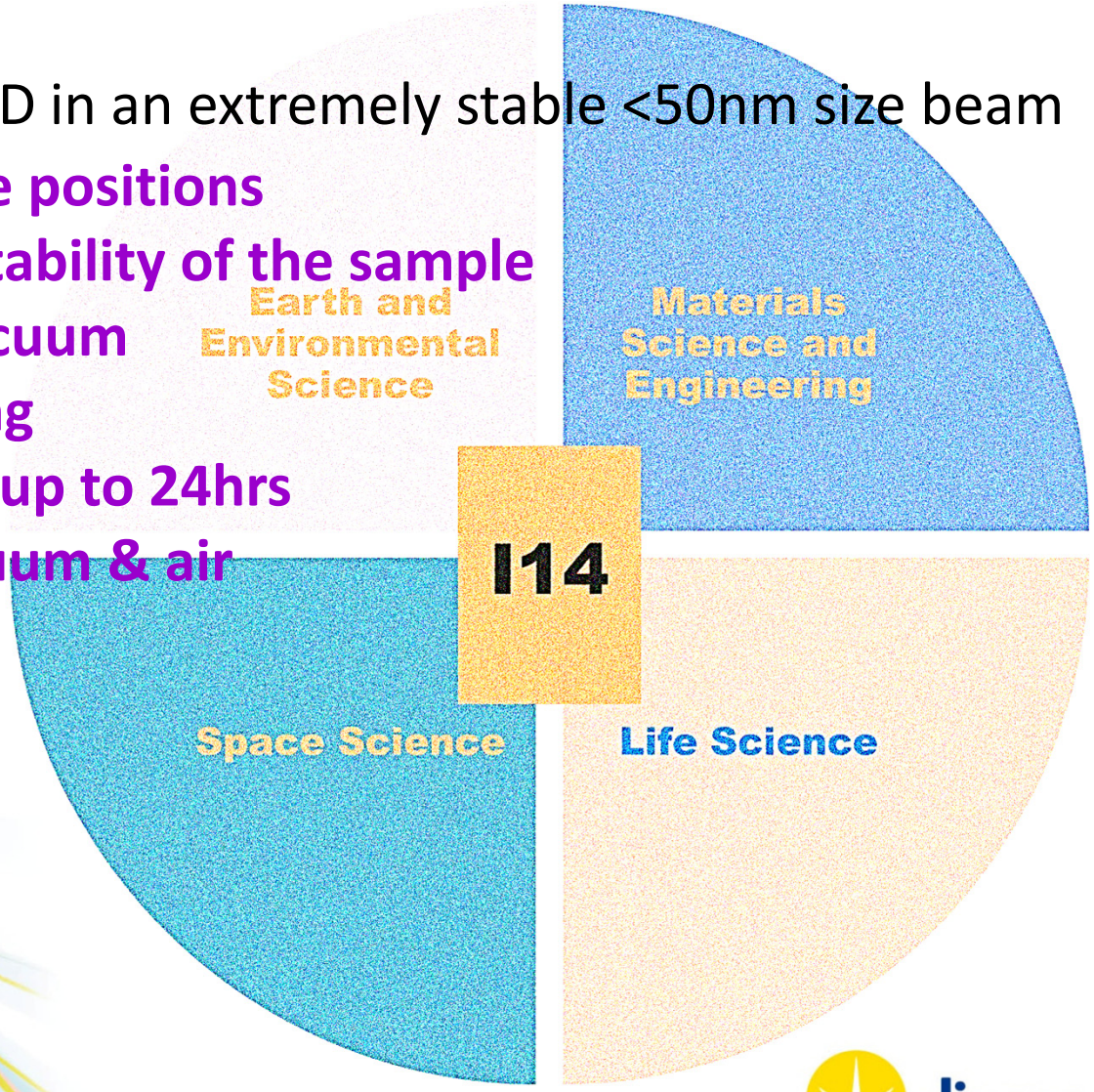
Scan samples in 2D/3D in an extremely stable <50nm size beam

- ✓ **Different sample positions**
- ✓ **Maintain 3nm stability of the sample**
- ✓ **Atmosphere/vacuum**
- ✓ **Cryogenic cooling**
- ✓ **Long duration – up to 24hrs**
- ✓ **Detectors – vacuum & air**



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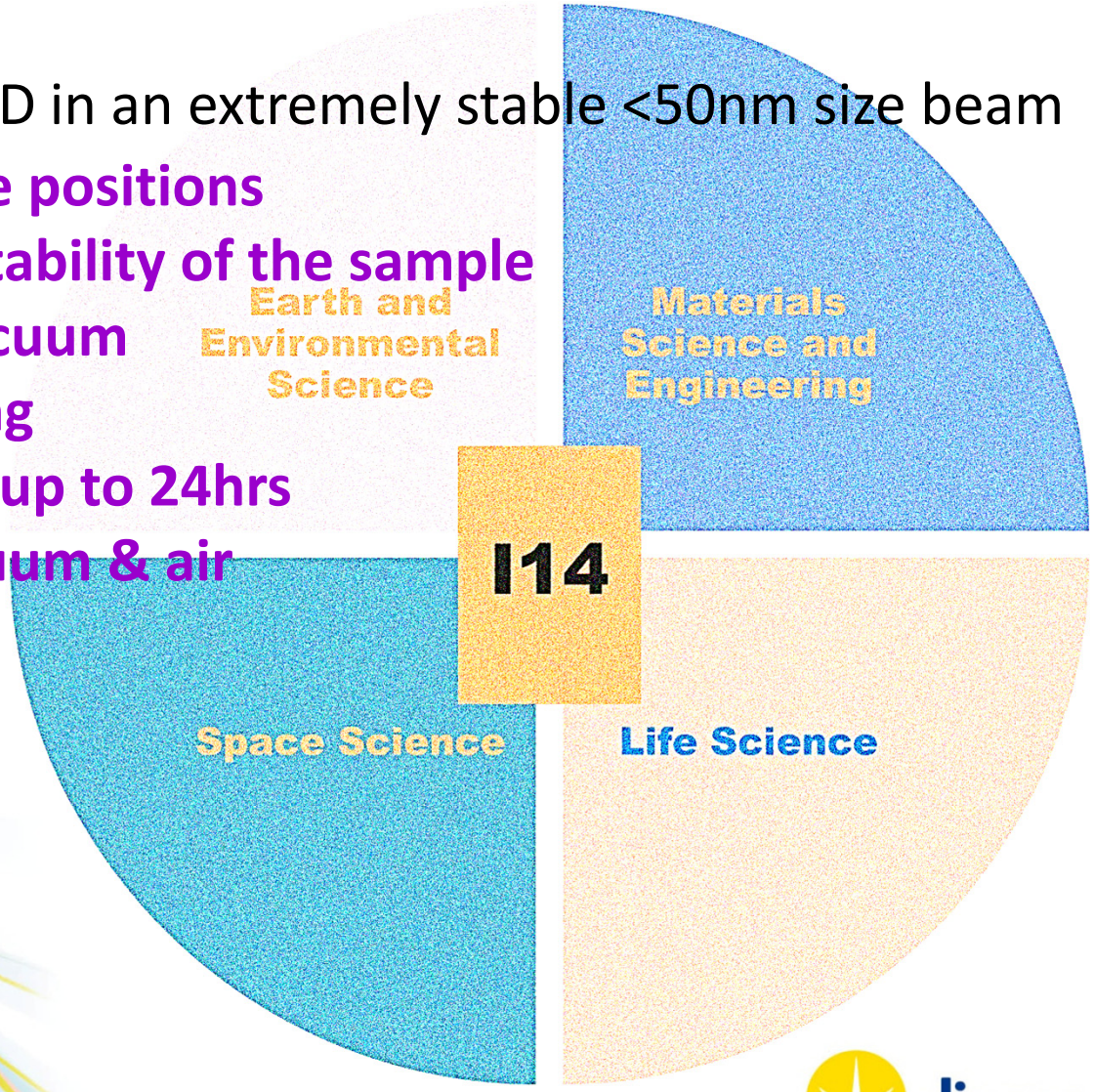

Primary Challenges

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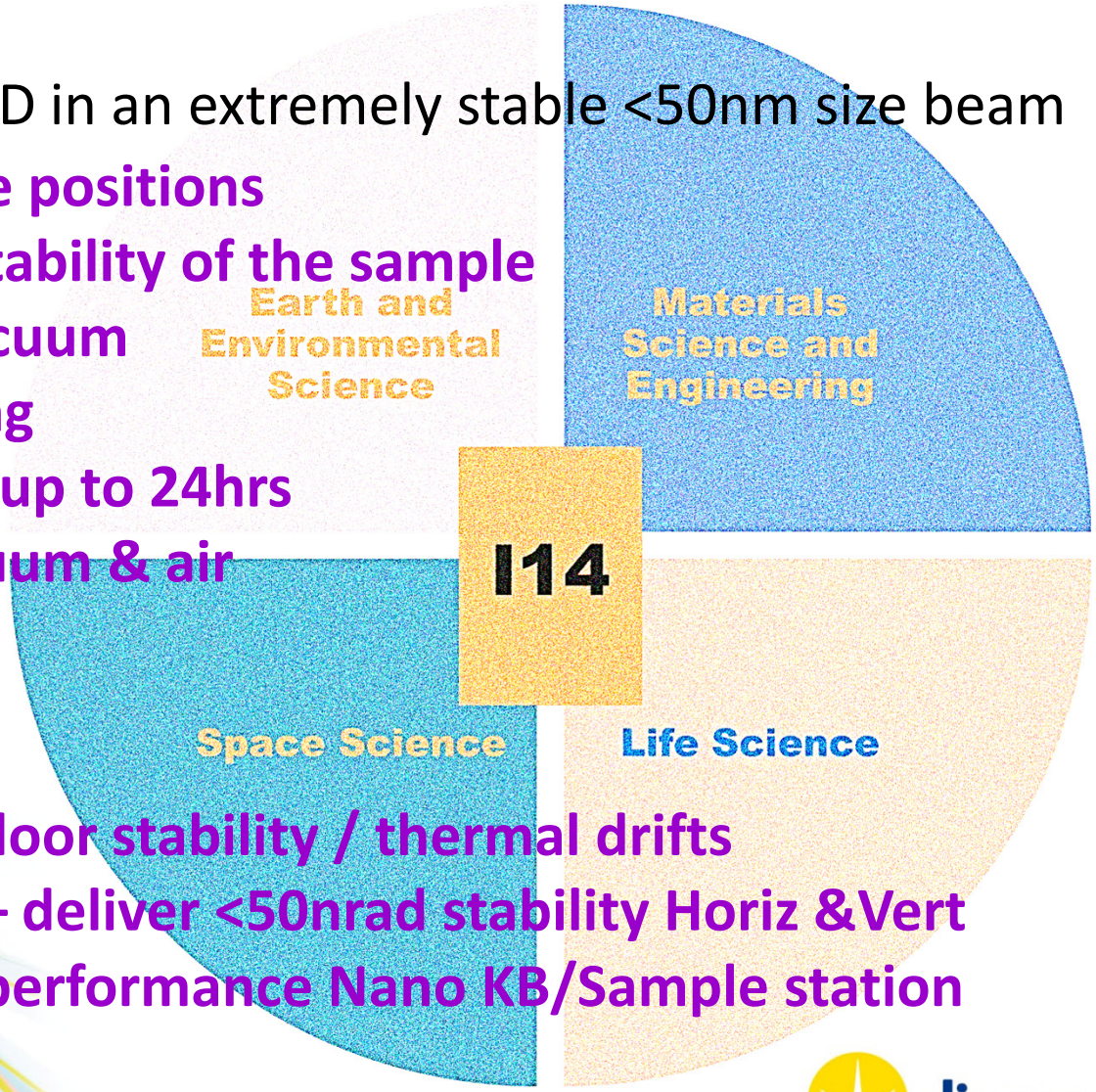

Primary Challenges

- ✓ Environment – floor stability / thermal drifts
- ✓ Primary Optics – deliver <50nrad stability Horiz &Vert
- ✓ Develop a high performance Nano KB/Sample station

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Environment – External Building

- Concrete hutches – high thermal mass
- Floors – 0.8m thick concrete on 14m piles
- Floors isolated from walls (separate foundation)
- Radiant panels not forced air conditioning

Concrete hutches under construction - Jan 2015

Environment – Radiant Panels

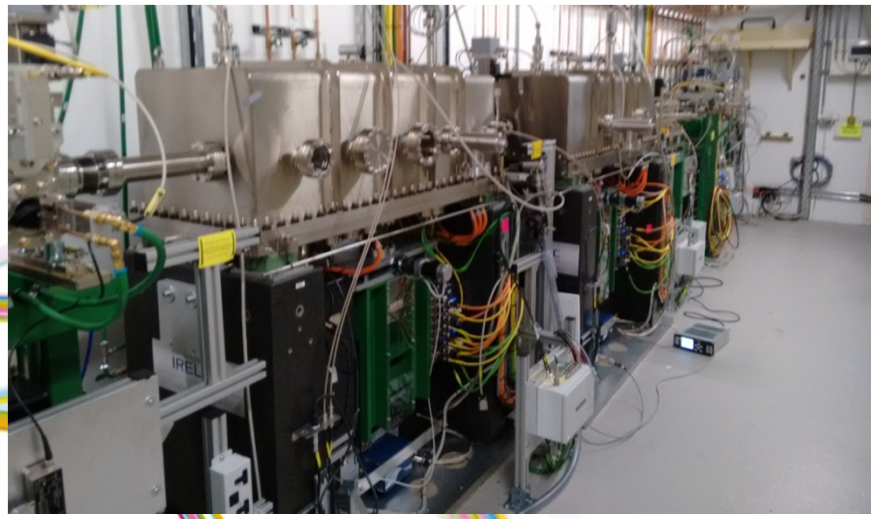
- Passive cooling (idea from EM labs)
- Low air pressure fluctuations
- Removes short term thermal oscillations
- Fitted to walls and ceilings
- Vestibule entrance to hutch

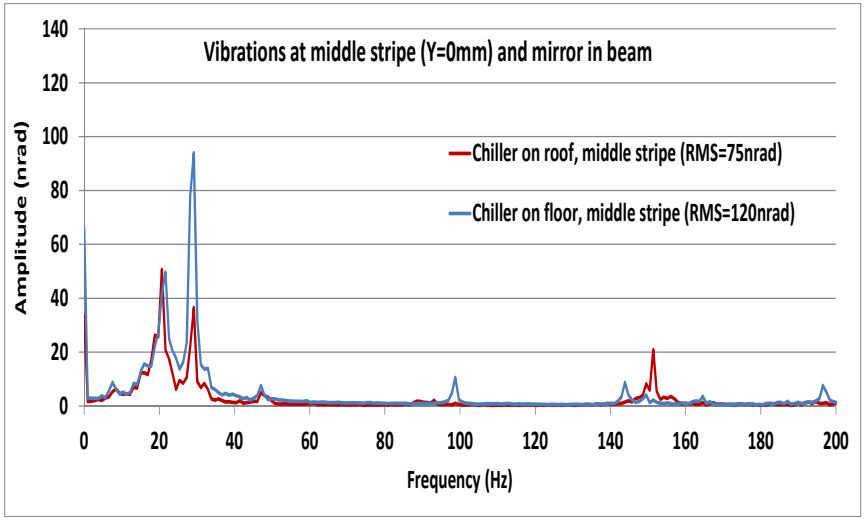
Cooling Capacity:
3-4KW per room.

Primary Optics

Mirrors

- Metrology - autocollimator & cap sensor tests
- Some issues with vibration & repeatability – cooling related
- Modified cooling + gravity feed cooling
- Stability now 75 nrad RMS (horiz) with cap sensors





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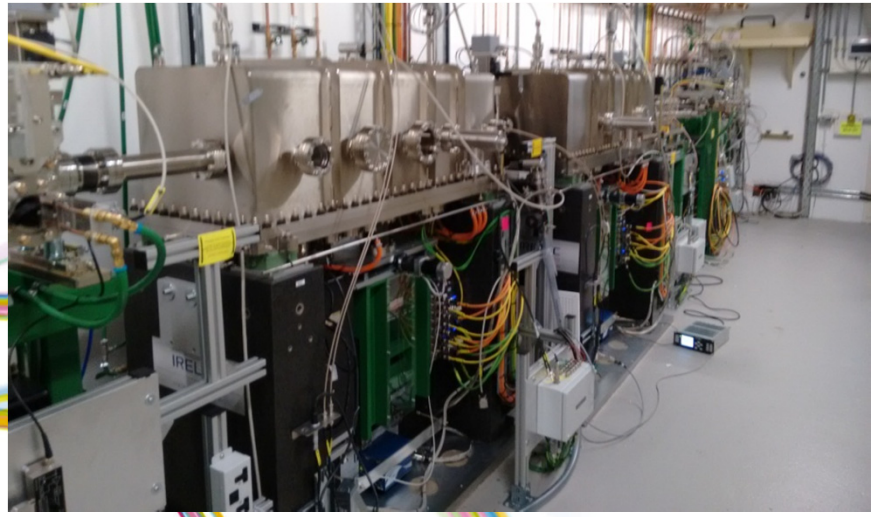
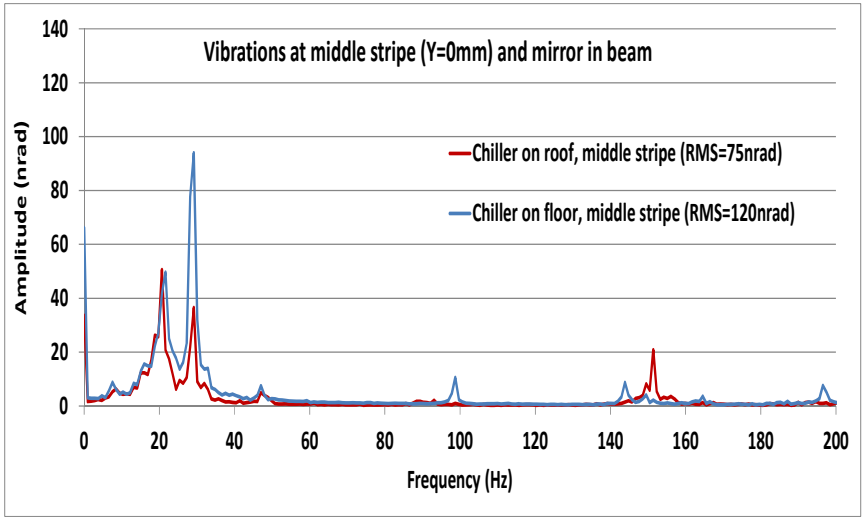
- 20HZ resonance – stiffness improvements possible (future)





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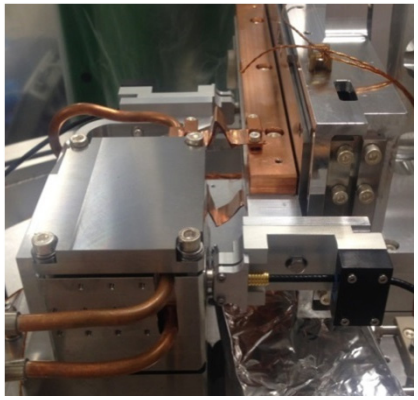
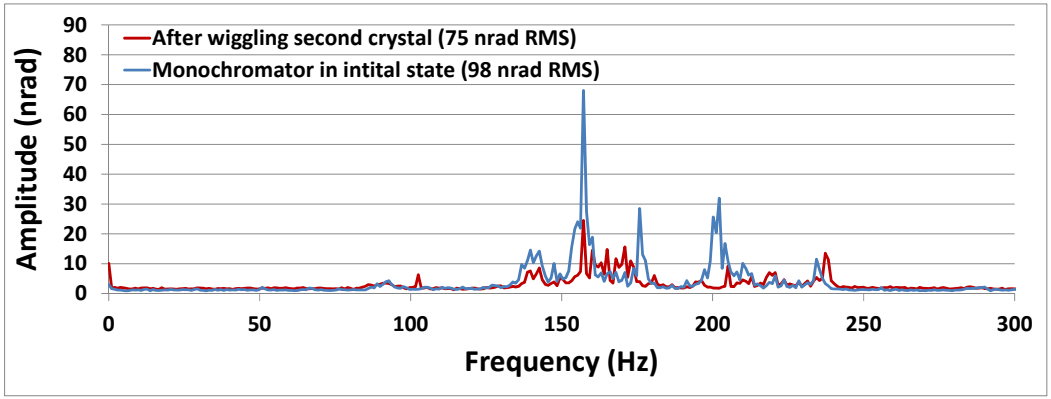
Primary Optics

DCM

- No vibration peaks <150Hz, 75nrad RMS (cap sensors)





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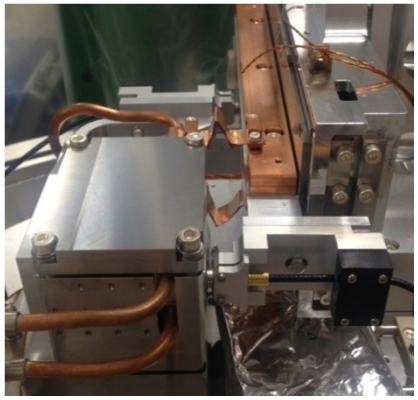
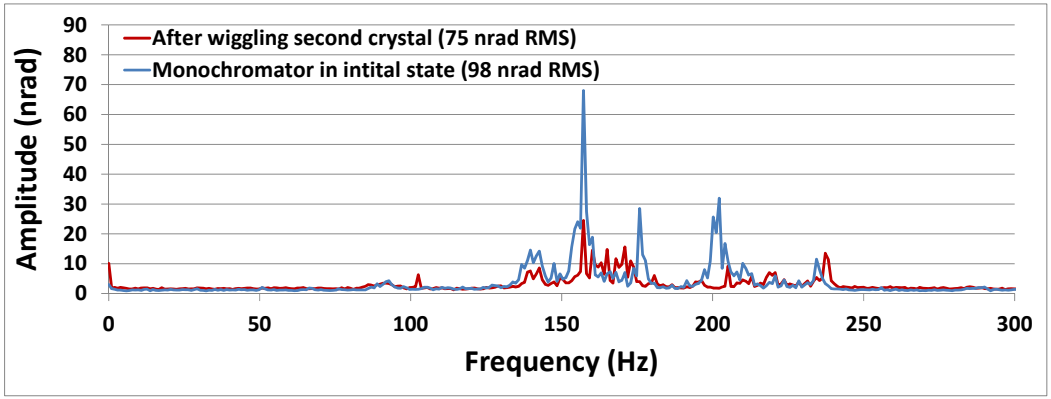
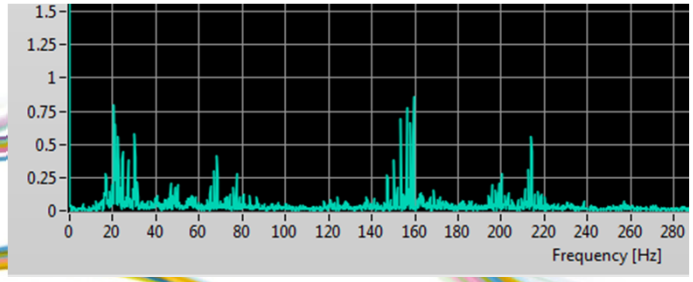
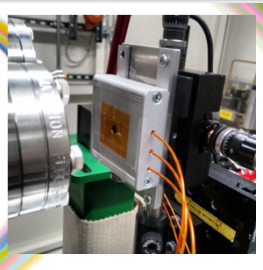




Initial beam measurements in OH2 with Cividec diamond BPM





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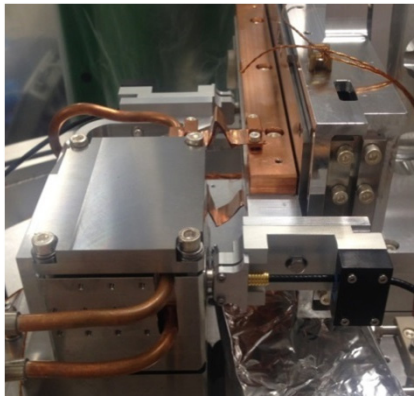

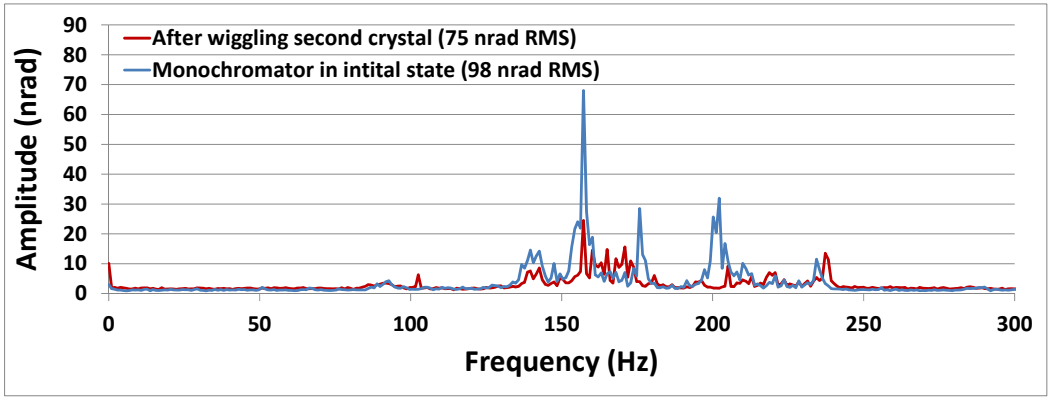

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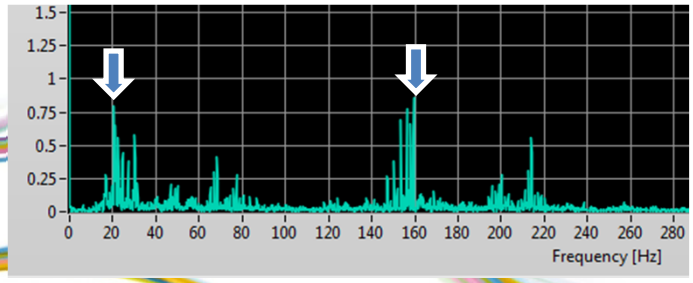

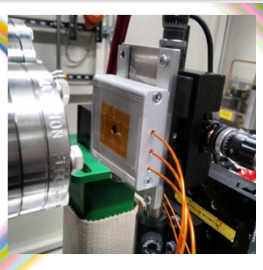

- Mirrors/DCM frequencies clearly seen
- Cap sensors good for frequency
- Cap sensors conservative on amplitude (set up)
- Reality with beam both systems total instability more like 40-50nrad (horiz), negligible vertical vibration

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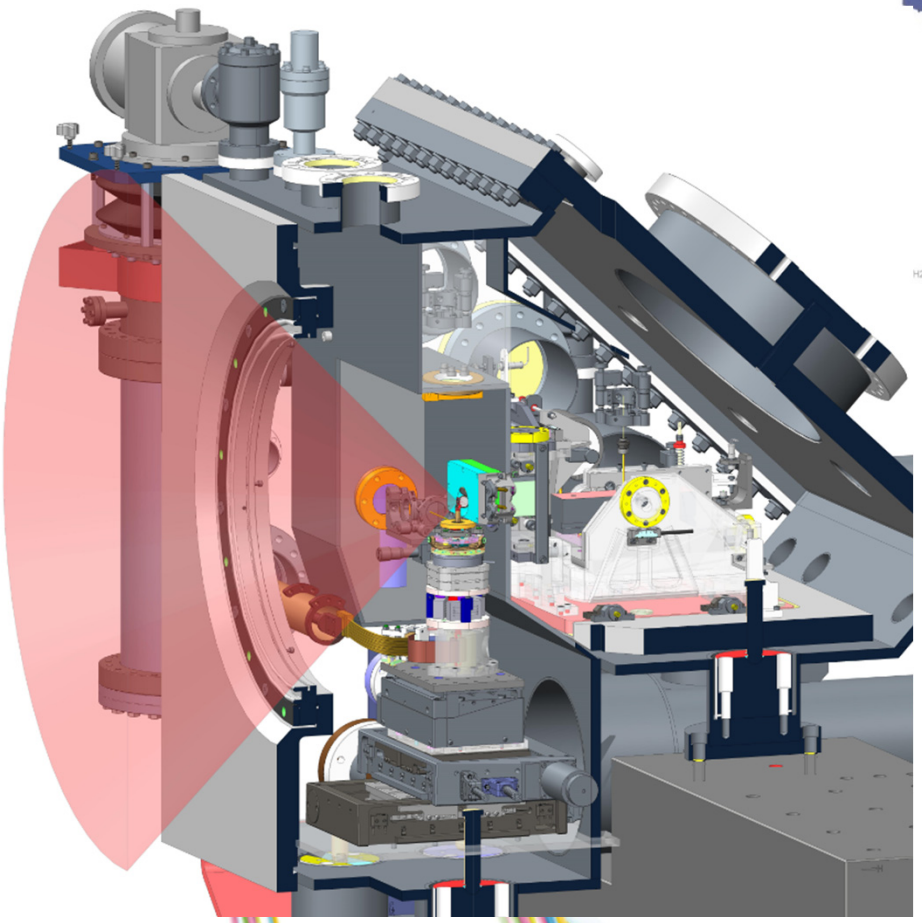
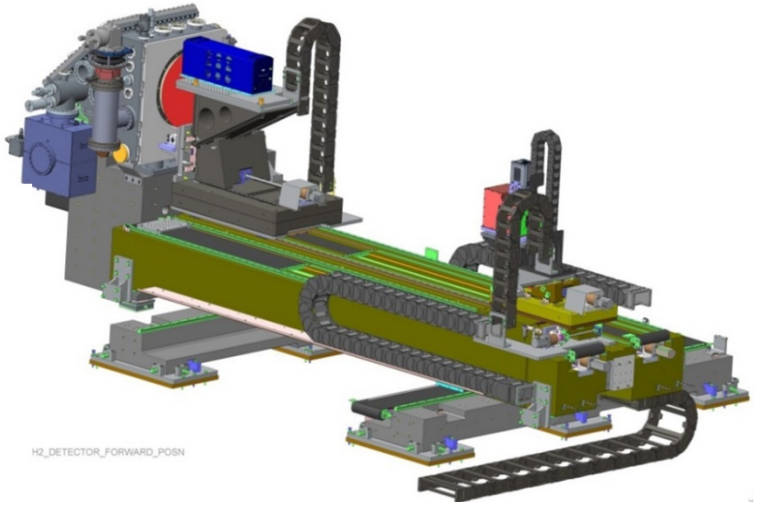
KB/Sample Station - Major Design Areas





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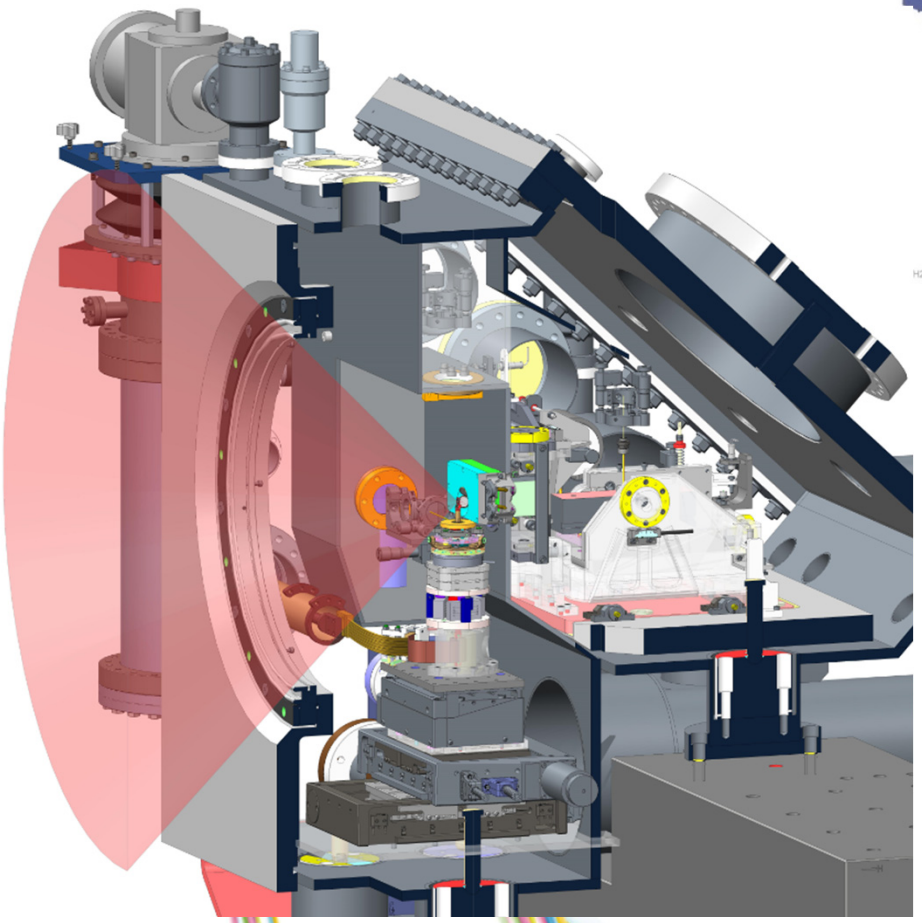

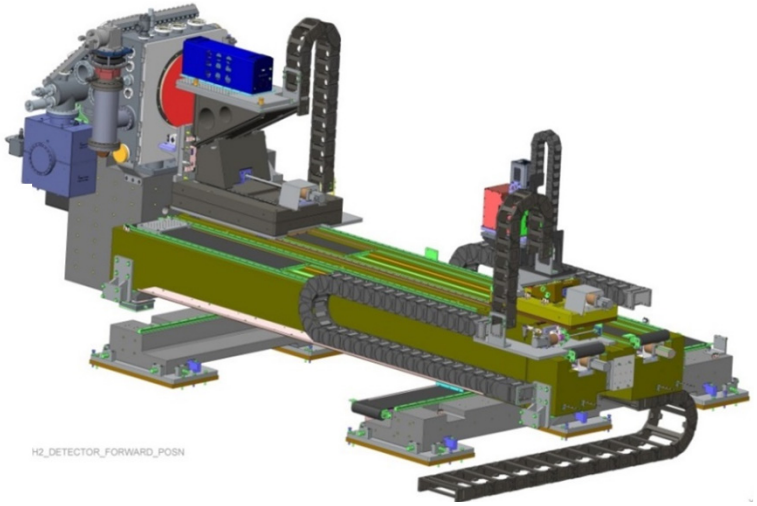

- KB mirror mechanism
- Sample environment
- Cooling
- Sample mounts & transfer
- Interferometry
- Vessel / support
- Sample viewing camera
- Detectors

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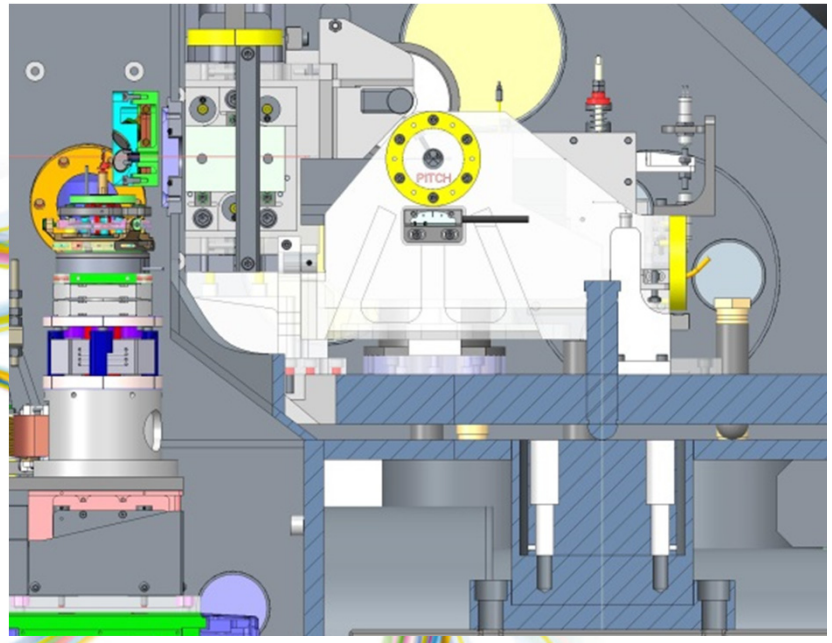
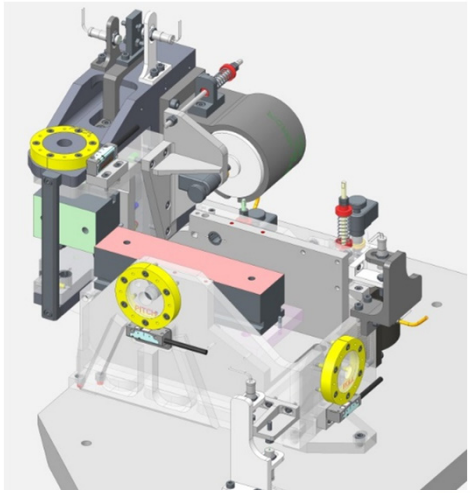
KB Mirror Mechanism

- Coarse/piezo fine pitch & roll <50nrad resolution
- Axes directly encoded, 35nrad resolution – may improve on
- Optics slope errors <50nrad, 0.2nm figure error verified by DLS

Challenges

- Space constraints dominated support
- Maintain KB's at UHV – complex vessel
- Mechanism built & tested – unable to establish any issues…





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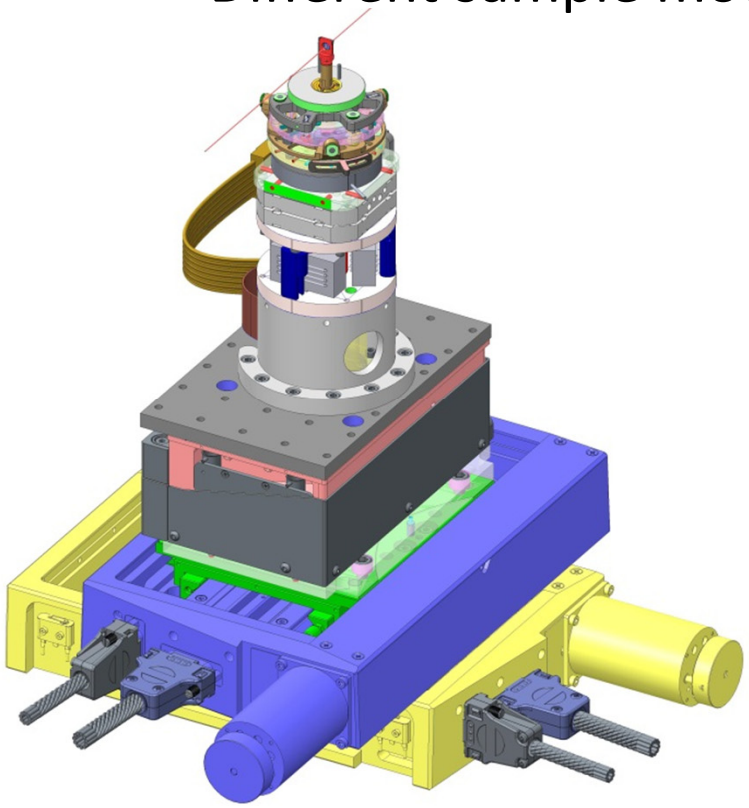
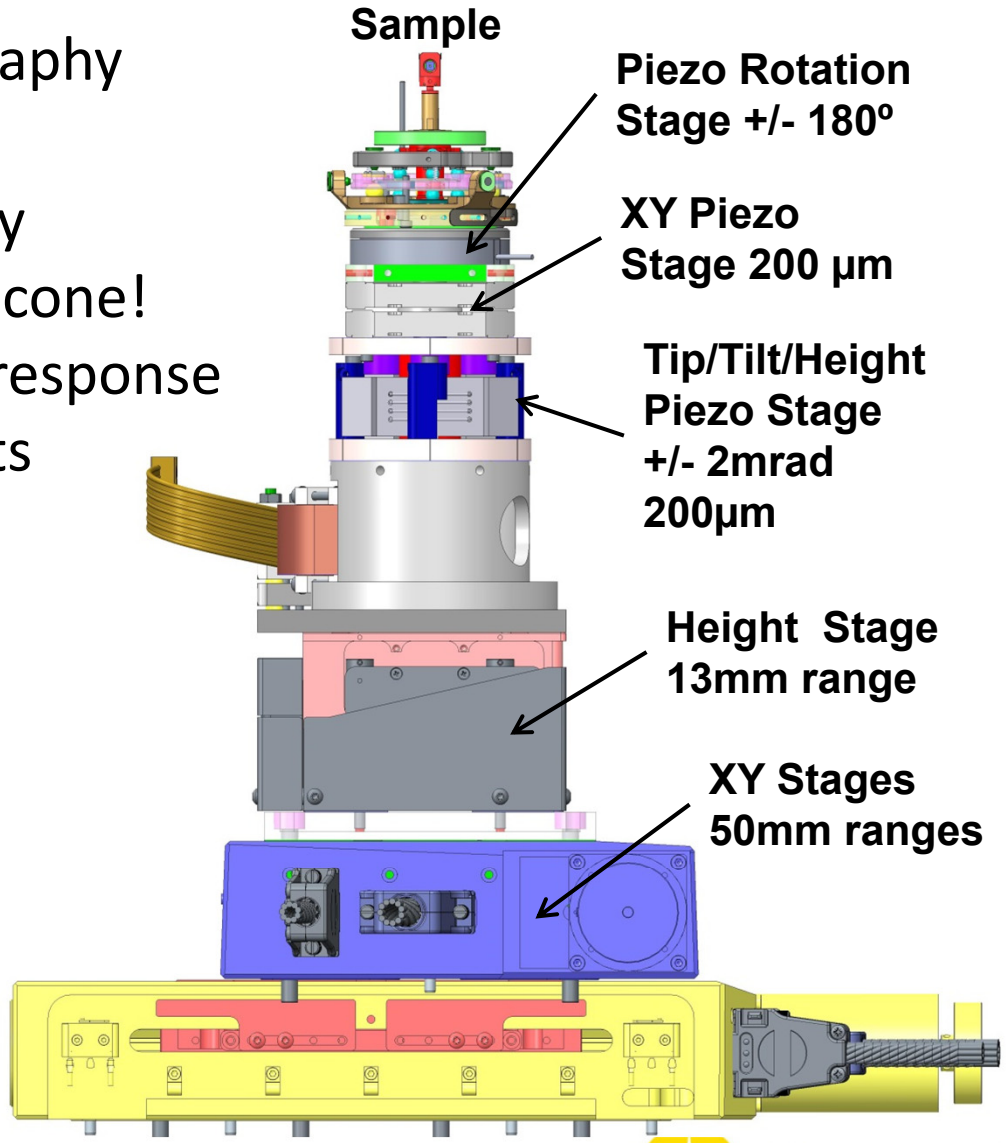
Sample Stages

- 2D Scanning, 3D tomography

Challenges

- Flexibility & 3nm stabilty
- Space constraints – the cone!
- Minimise mass – piezo response
- Different sample mounts





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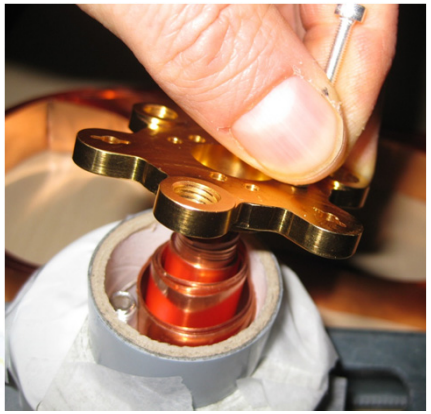
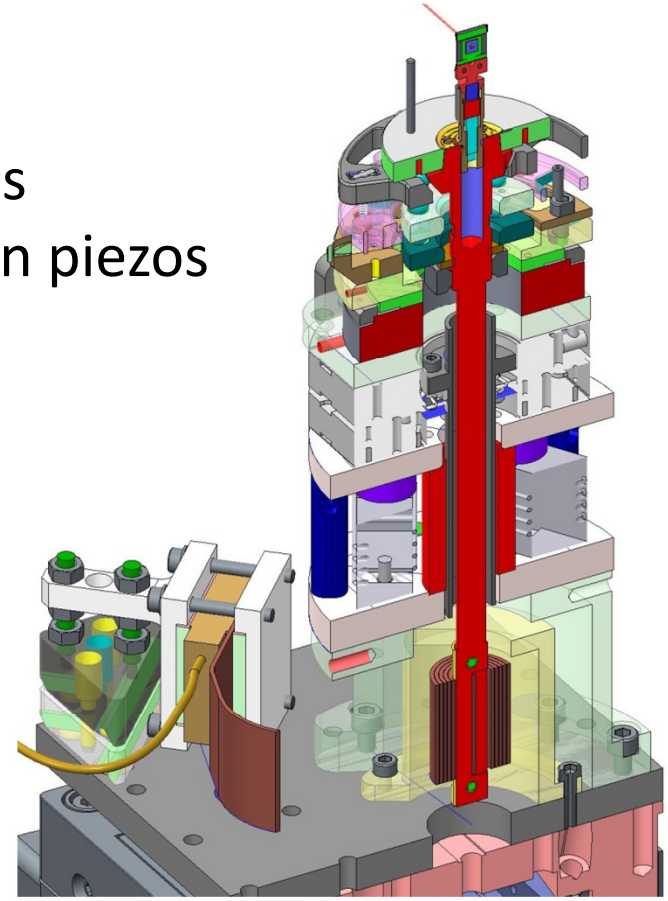
Cooling the Sample

- Max sample temp ~ 100K with beam
- 0.01mW over a 0.1µm x 0.1µm – high power density
- FEA showed LN2 not enough – He pulse tube cooler

Challenges

- Getting cooling through centre of stages
- Soft needed link for rotation – strains on piezos
- Minimise cold leakage





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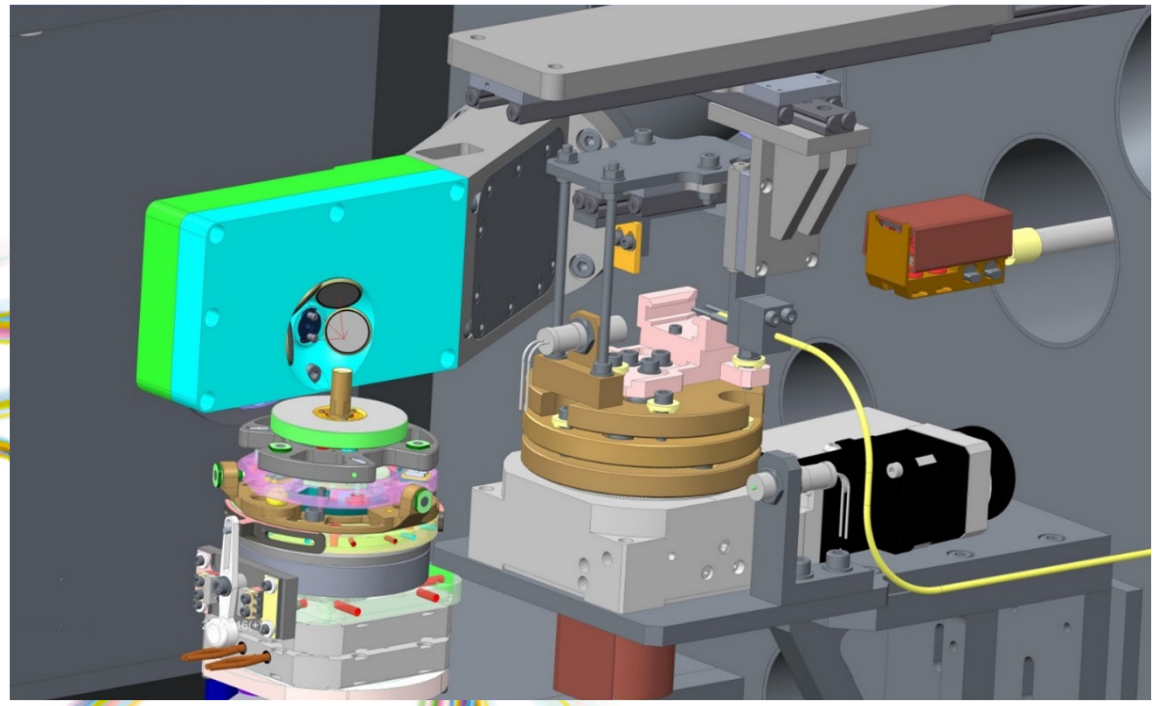
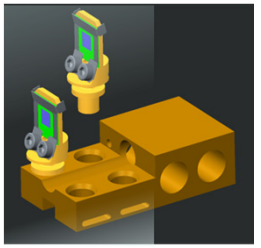
Sample Mounts & Transfer

- Adaption of Leica transfer arm system

Challenges

- 4 samples loaded at once
- Minimise thermal gain during transfer
- In vacuum remote handling
- Reliability – endoscope for image recognition?





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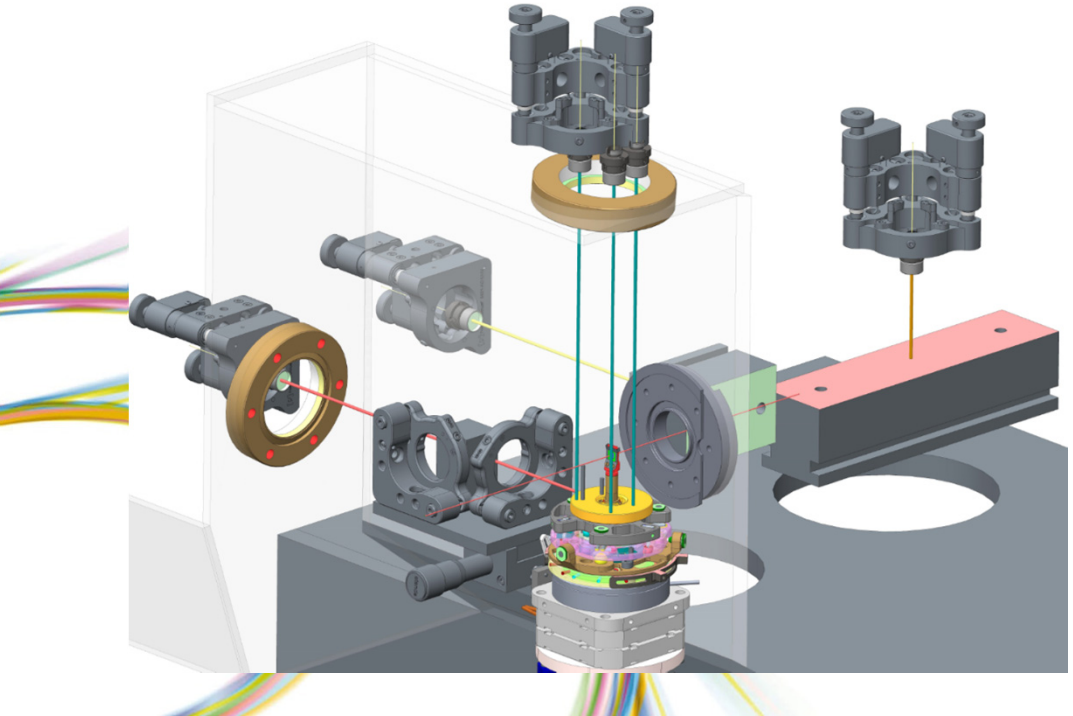
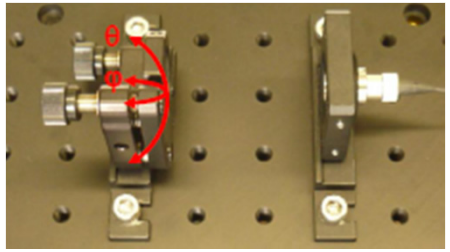
Interferometry

- Intereferometry on sample posn & KB's for active feedback
- Highly polished mirror disk near sample (cryo temp)

Challenge

- Stablity of interferometer support – common reference (KB side)
- Getting view thro' vessel to sample side
- Tracking stage – and remote adjustments – motorised mounts





Attocubes
& mirrors

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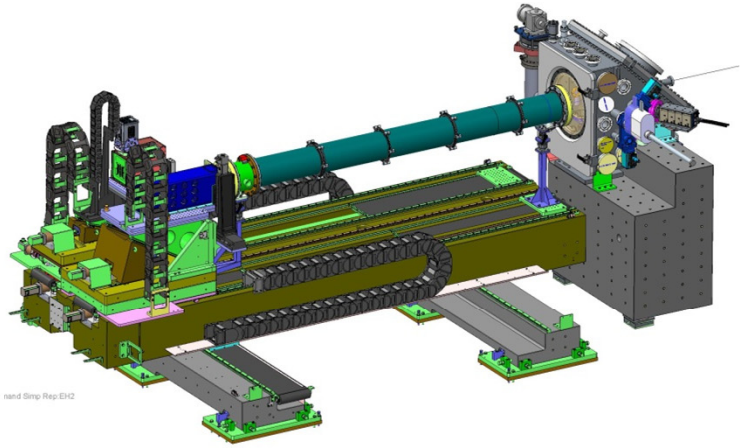
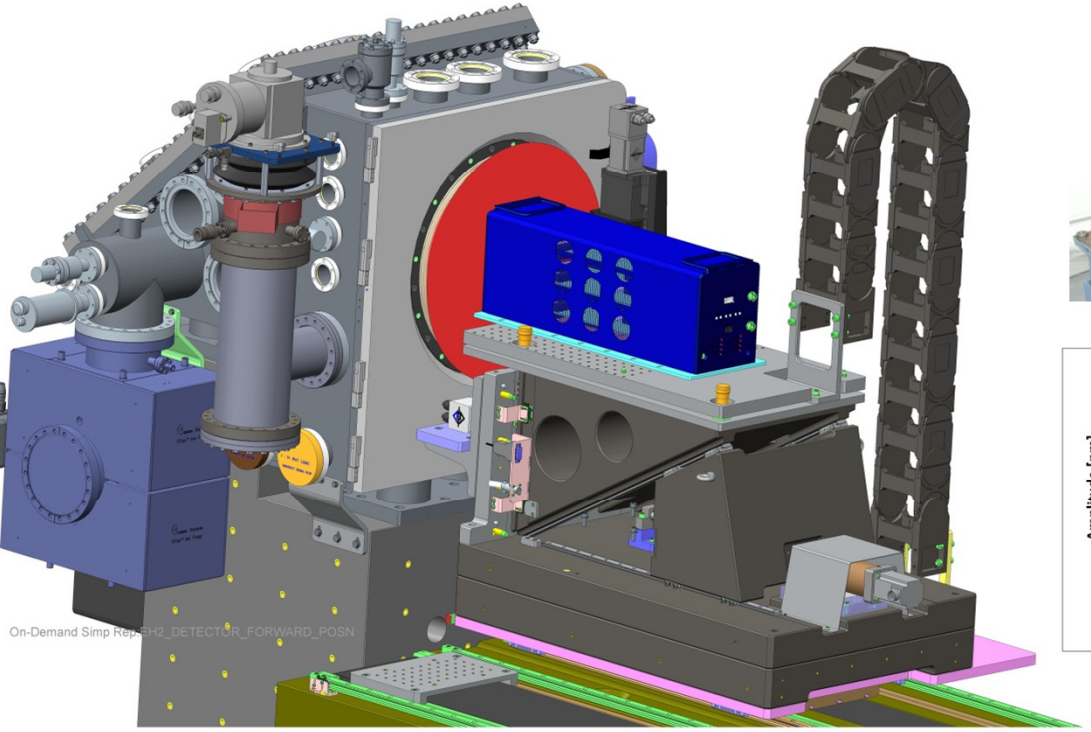
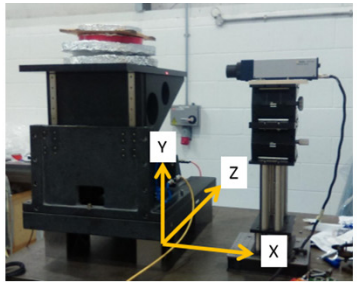
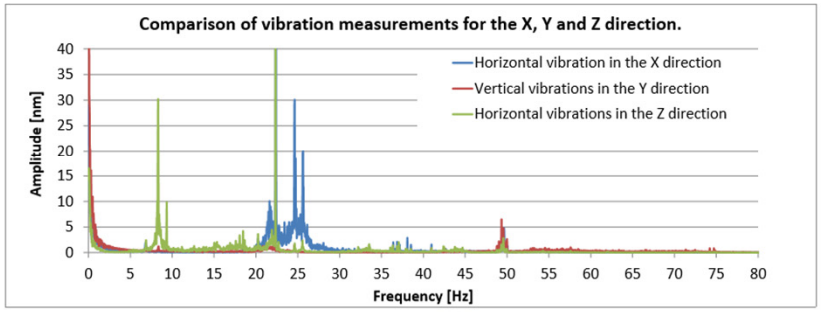
External Detectors Table



- Detector 0.25-3m from sample
- High as poss table height requested
- Originally designed for Pilatus 2M
- “Aggressive” super wedge - 200mm lift
- 45 sec swap time between detectors



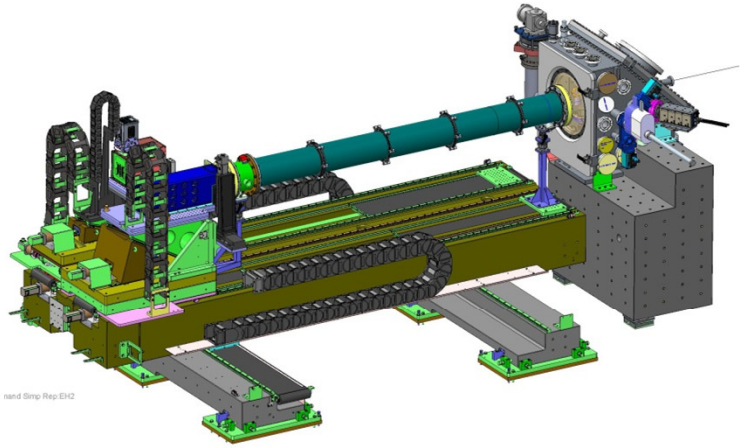




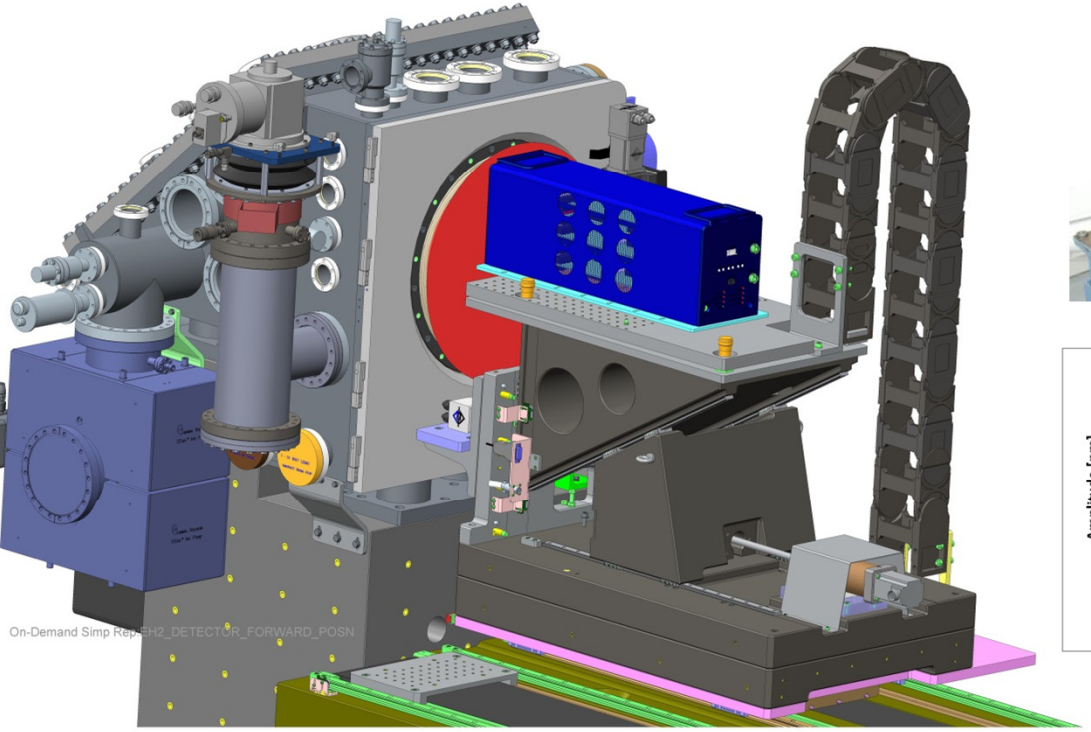
X.X+-0.1
X.XX+-0.01
X.XXX+-0.001
ANG.+-0.5

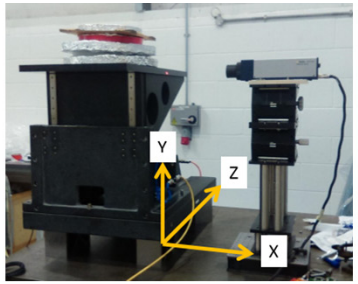
diamond

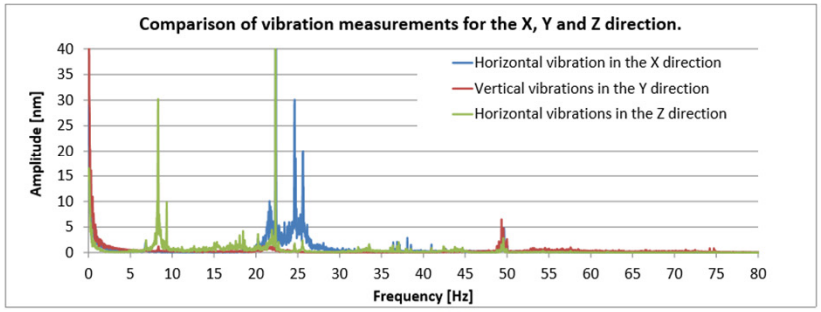
External Detectors Table



- Detector 0.25-3m from sample
- High as poss table height requested
- Originally designed for Pilatus 2M
- “Aggressive” super wedge - 200mm lift
- 45 sec swap time between detectors



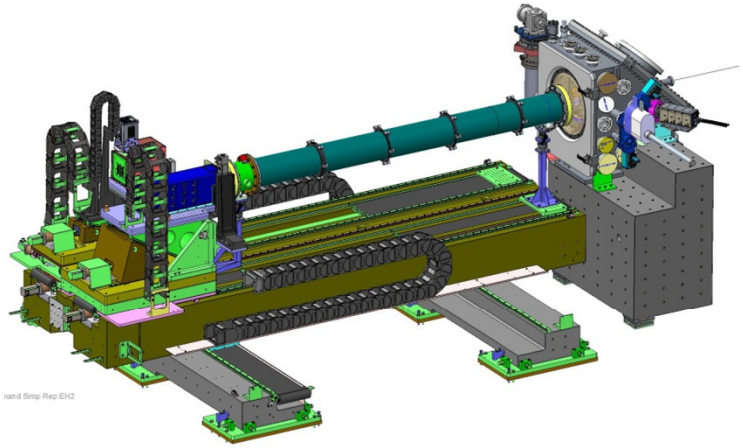




X.X+-0.1
X.XX+-0.01
X.XXX+-0.001
ANG.+-0.5

diamond

External Detectors Table



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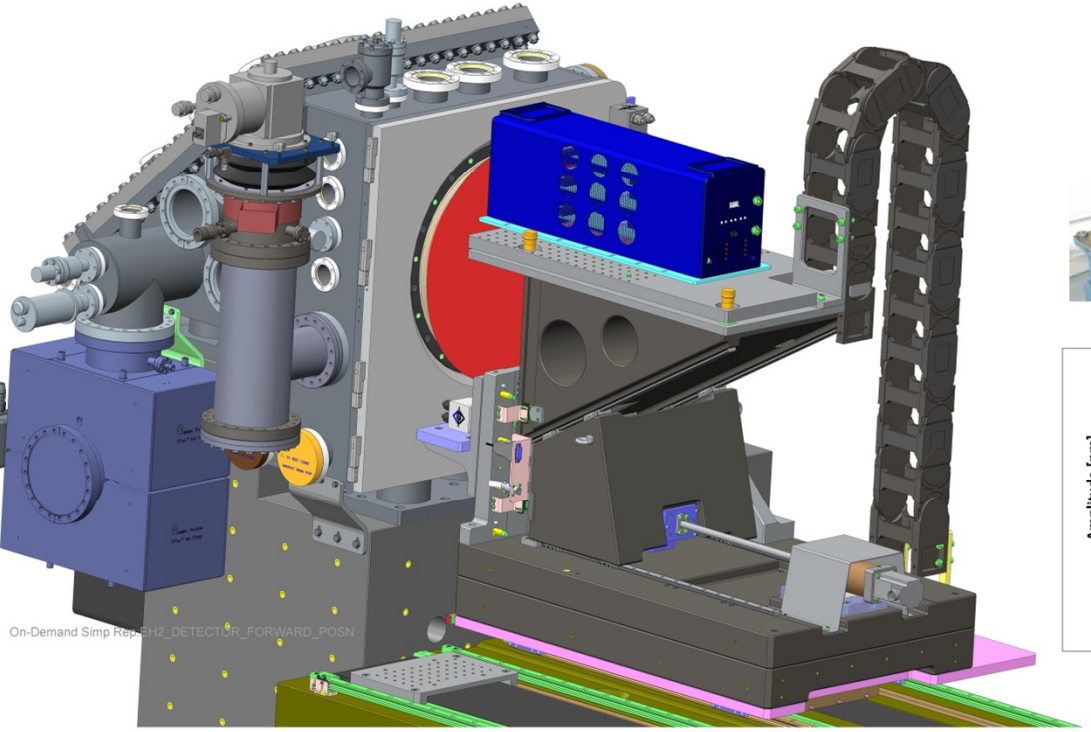
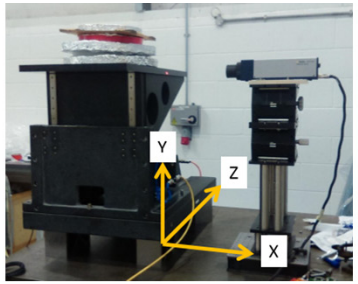
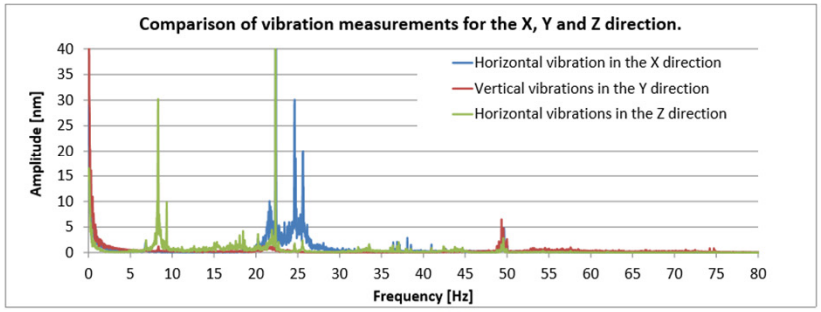




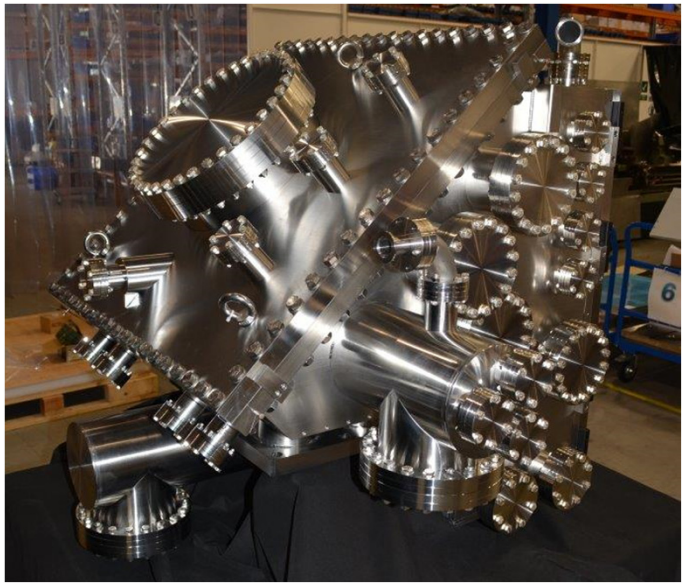


X.X+-0.1
X.XX+-0.01
X.XXX+-0.001
ANG.+-0.5

diamond

Summary

- Beam achieved at external building last week
- Beam stability looks within spec
- Much work to do to refine, build & test KB/Sample system
- Critical that sample station reliability is proved
- Air bearing slide base to swap setups - future upgrade
- First users Spring 2017



Thank You For Your Attention !

Thanks to:
Paul Quinn, Julia Parker, Fernando Cacho-Nerrin, Kevin Collins, Ljubo Zaja, Mark Hooper, Dave Mahoney, Rob Pocock, Guy Wilkin, Adrian Marsh, Lee Hudson