DLS Development of an Improved Stability DCM Crystal Cage

Andy Peach

DLS Improved Stability Crystal Cage

- Summary of DLS Monos 2007
- I16, I18, I22 DCM outline specification
- Investigation of the I18 stability problems
- Interim fixes
- New crystal cage design
- Improvement gains
- Some key considerations for good Crystal Cage mechanics

Phase 1 DLS Monos

	Energy Range (KeV)	Crystal	Coolant
I06	0.08 – 1.5	Grating	Water
I15	20 - 80	Si (1,1,1)	LN2
I02,3,4 (MX)	5 - 24	Si (1,1,1)	LN2
I16	3.4 – 20	3 crystal sets	LN2
I18	2 – 20	3 crystal sets	LN2
I22	3.7 - 20	3 crystal sets	LN2

8 Monos operational during 2007 !

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I16, I18, I22 Outline Specification

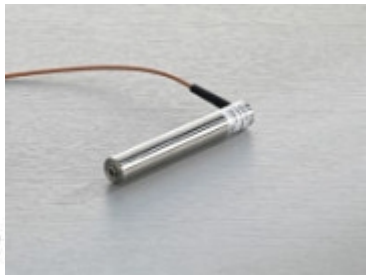
- 3 Identical LN2 DCM's
- Large energy range 2-20 keV *(Cover-all)*
  5-82º Bragg rotation Si(111)
- 25mm fixed offset *(bounce up)*
- 2mm(h) x 1mm(v) typical beam size
- 50W (typ) -100W (max) power load
- Bottom cooled 1st & 2nd Crystals
- 2nd Crystal "*direct – indirect*"

I16, I18, I22 Outline Specification

- Designed for 3 Crystal sets (2 sets fitted)
- Lateral translation of whole mono to select crystal set

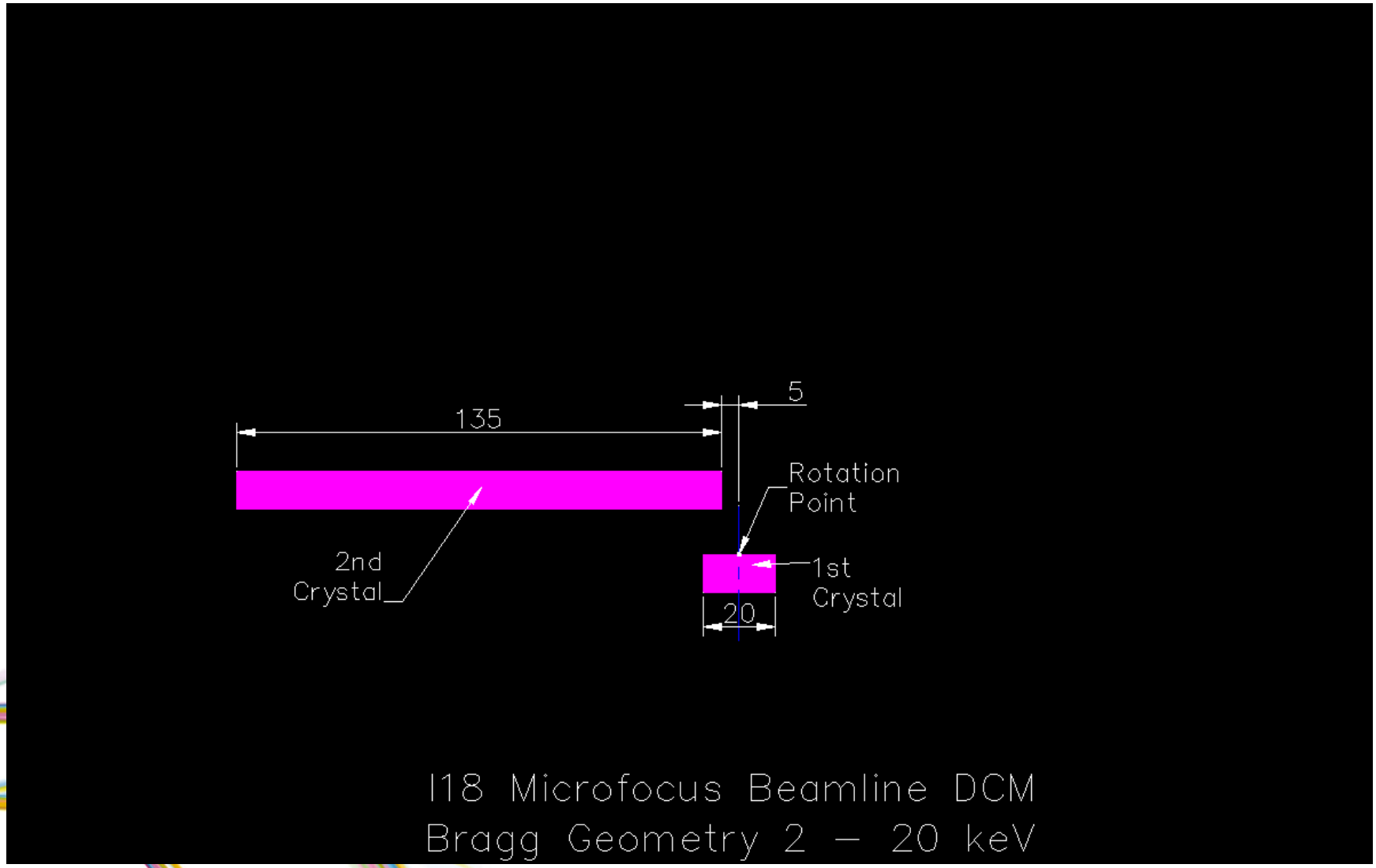
2nd Crystal

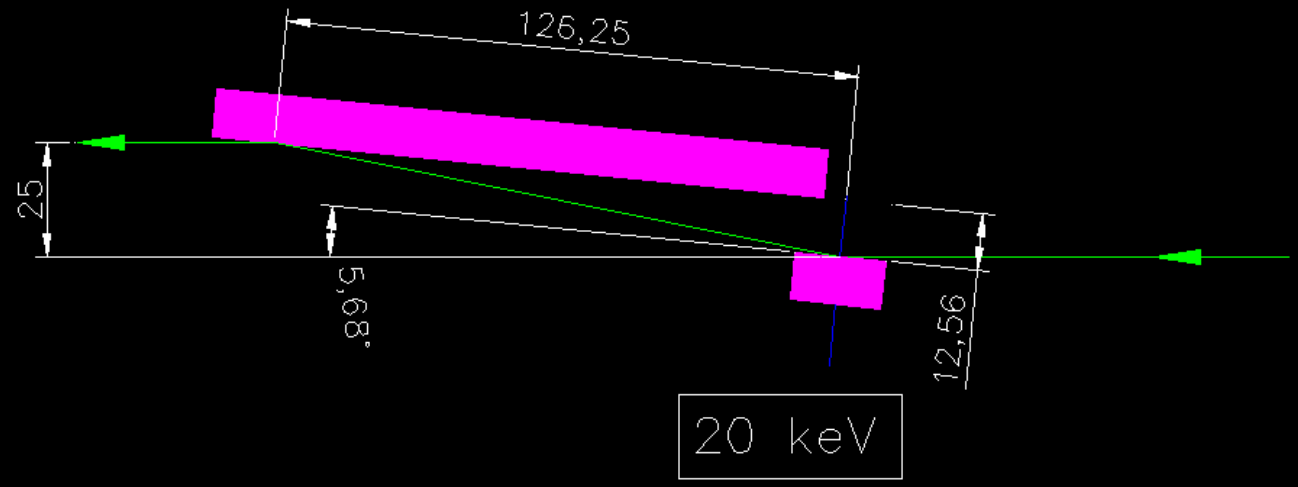
- Long (135mm) crystal (no parallel translation)
- Perpendicular translation 85mm
- Motorised Pitch/Roll
  Coarse adjust - PicoMotors
  Fine adjust - Queensgate Piezos



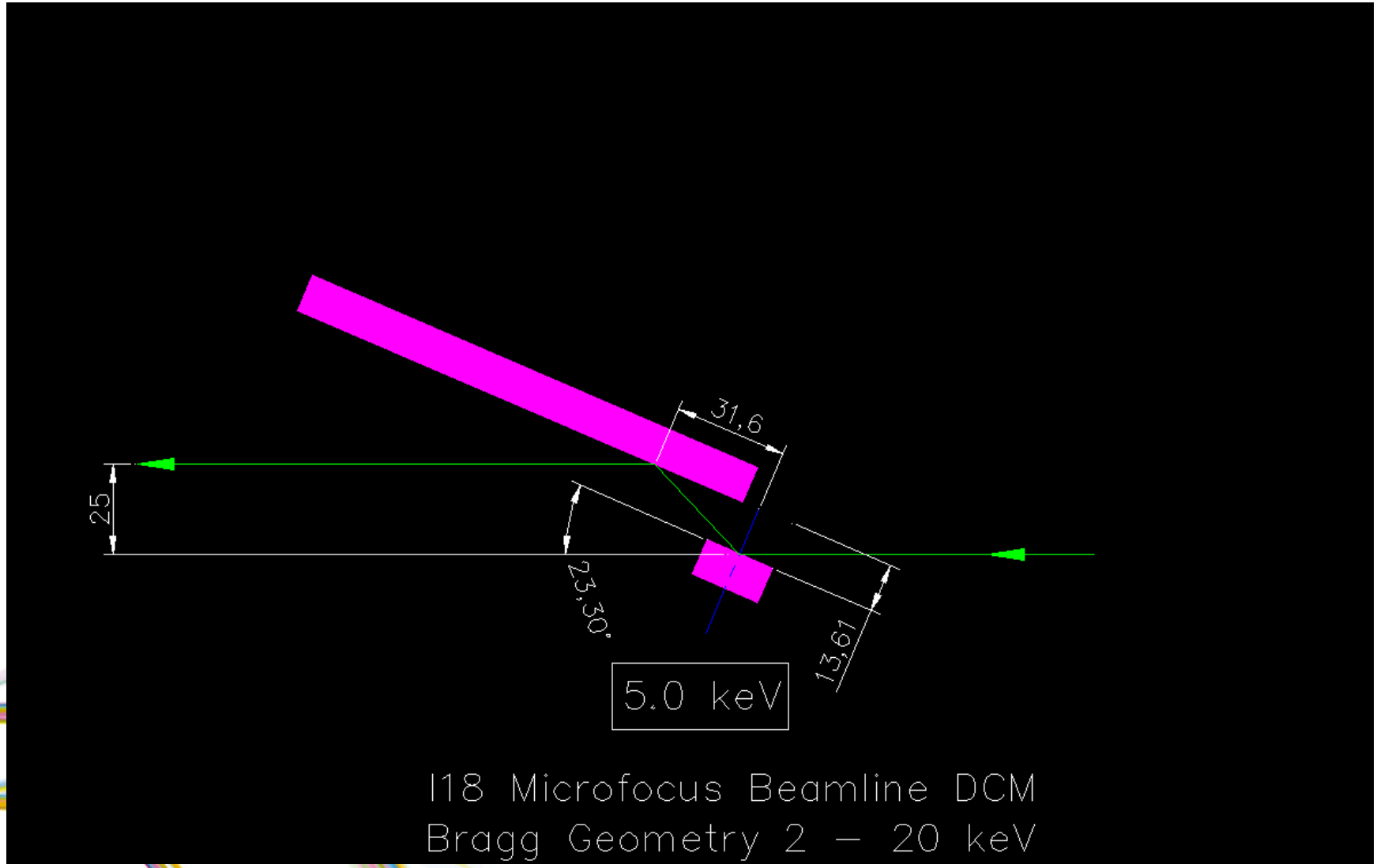
- Motorised roll on 1st Crystal

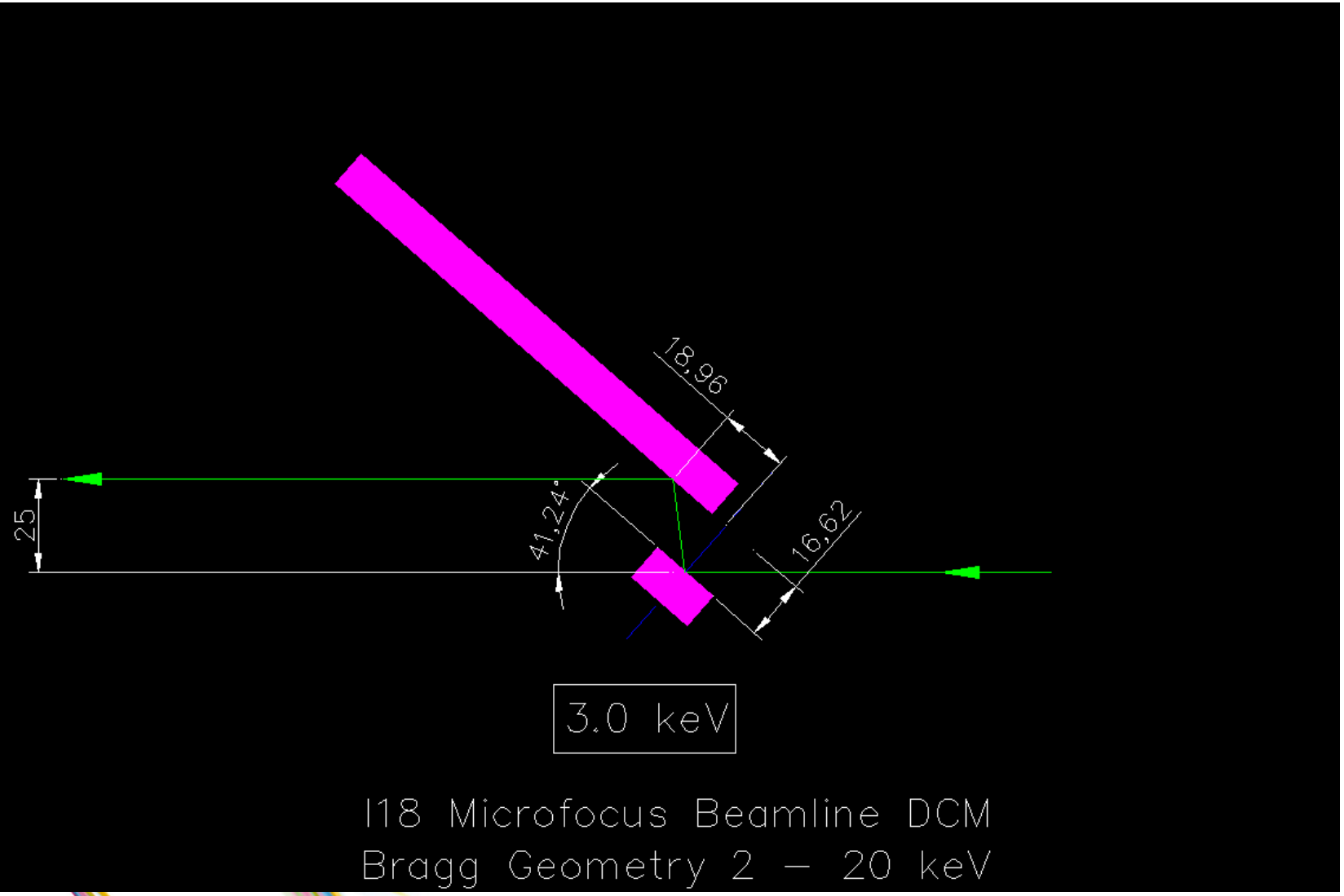
Rotate about 1st Crystal, long 2nd Crystal

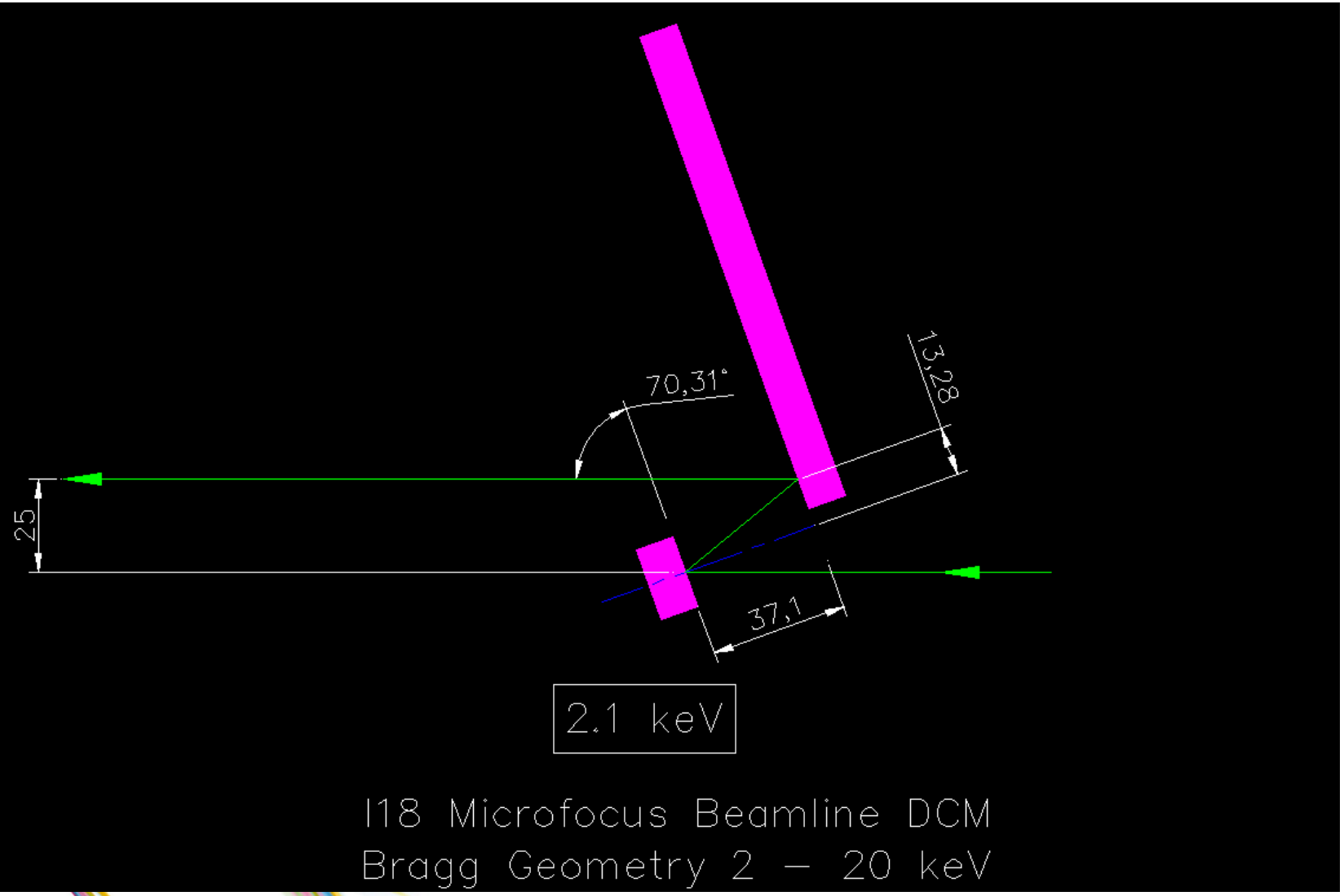


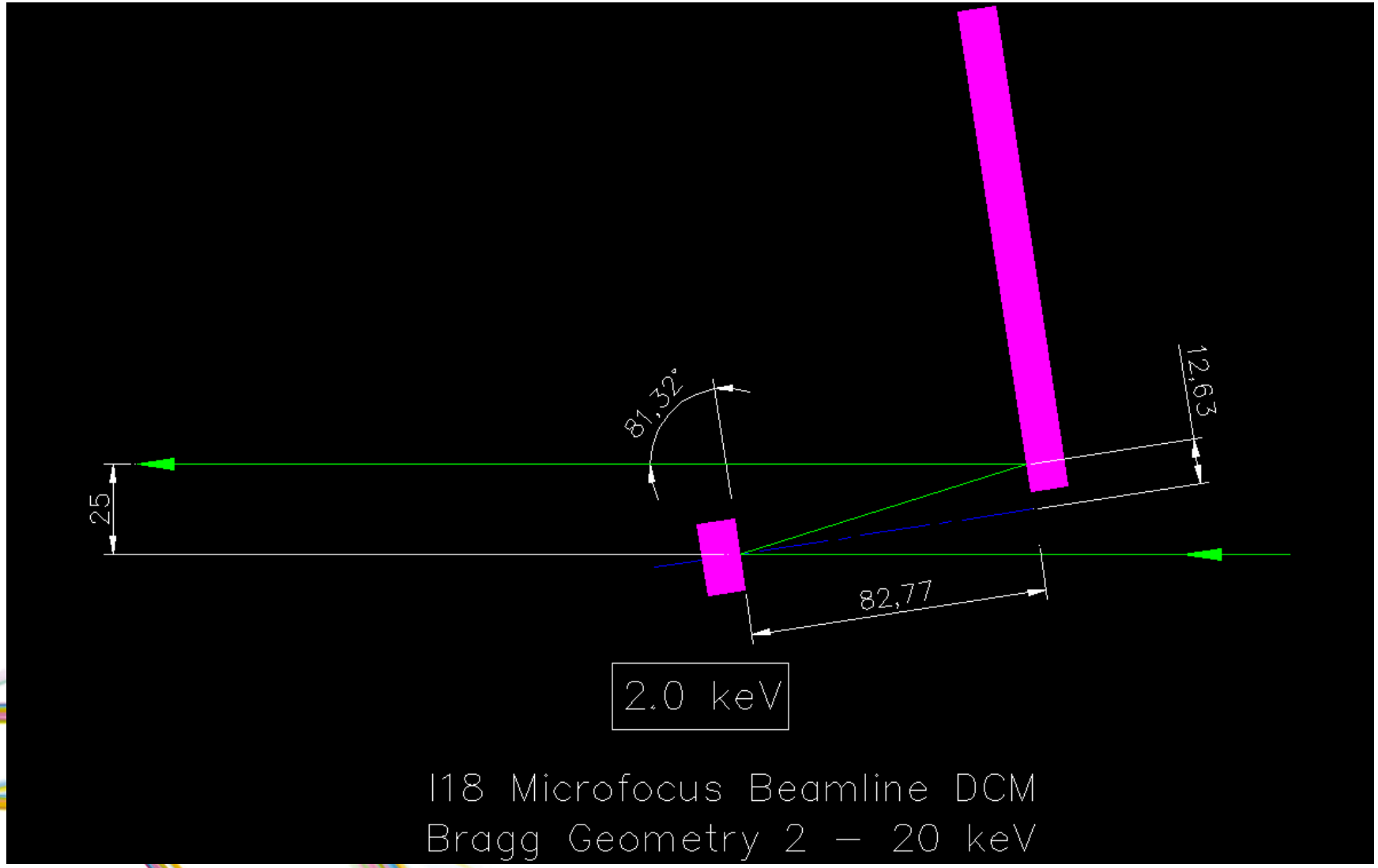


I18 Microfocus Beamline DCM
Bragg Geometry 2 – 20 keV


31,6
25
23,30°
13,61
5.0 keV
I18 Microfocus Beamline DCM
Bragg Geometry 2 – 20 keV


18,96
25
41,24°
16,62
3.0 keV
I18 Microfocus Beamline DCM
Bragg Geometry 2 – 20 keV


70,31°
13,28
25
37,1
2.1 keV
I18 Microfocus Beamline DCM
Bragg Geometry 2 – 20 keV


81,32°
12,63
25
82,77
2.0 keV
I18 Microfocus Beamline DCM
Bragg Geometry 2 – 20 keV

Stability Issues

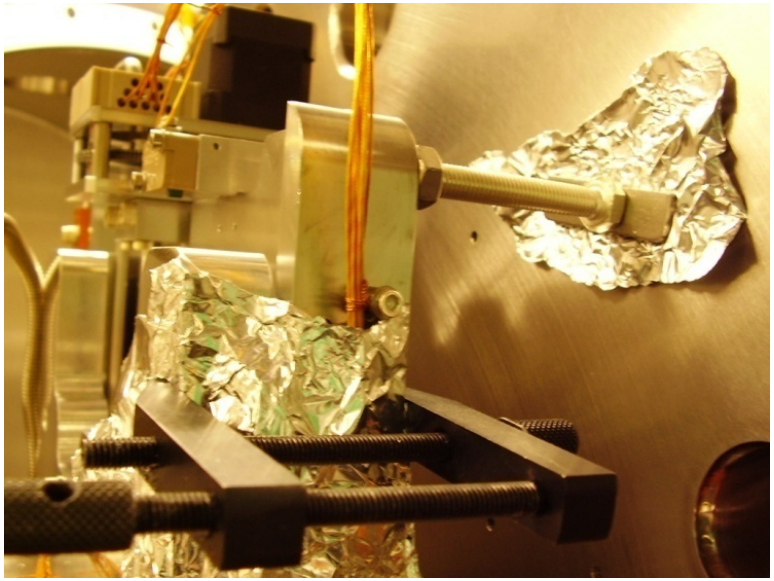
- I16 & I18 reported problems early 2007
- >25µm (V) beam movement at I18 sample position
- >700nrad RMS with (DCM 14m upstream)

- I16 elected to fit Channel Cut Crystal
- I22 beamline was not yet operational
- I18 – Channel Cut not an option – fix needed

March Shutdown 2008

- Offered chance to open up and investigate I18

- 3 Main Sensitive Areas Confirmed
  - 2nd Crystal Cooling Pipes
  - Compton Shield
  - Crystal Cage Back Plate



Accelerometers very useful for “real time” tests

Quick Fixes (over 2 shutdowns)

- Restraints / supports for 2nd Crystal LN2 pipes
- Removed 2nd crystal Compton shield
- Fitted bolt - on stiffeners for back plate

Quick Fixes (over 2 shutdowns)

- Restraints / supports for 2nd Crystal LN2 pipes
- Removed 2nd crystal Compton shield
- Fitted bolt - on stiffeners for back plate
- By July 2008 - stability now around 450nrad rms (but energy range now slightly limited by pipe restraint)

A useful improvement but still way short.....

Radical Rethink Needed

- Modified/new crystal cage? New DCM?
- FEA confirmed the weak areas and highlighted others
- Our Spec was very ambitious – compromise needed

Key "gain areas"

- Reduce crystal sets
- 2nd Crystal cooling
- Back plate
- Pitch/Roll flexures

*September 2008 "**FOCUS**" crystal cage project approved*
*(**F**ixed **O**ffset **C**rystal cage **U**ltra **S**table)*

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FOCUS Design Objectives

Key Performance Aims

- Target <50nrad rms stability
- Improve reliability of pitch / roll coarse motors
- Improve pitch/roll angular feedback
- Improve temperature monitoring (PT100's)

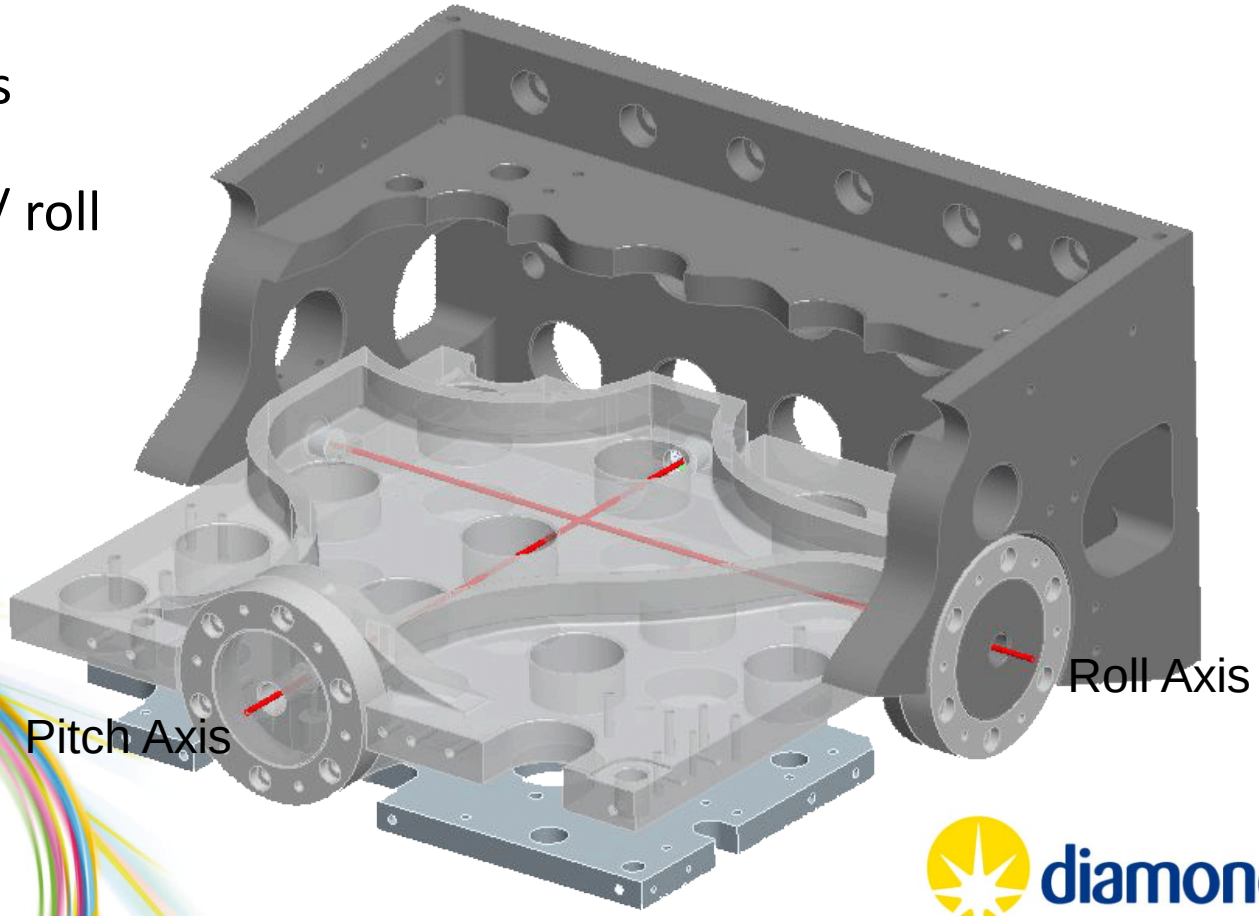
Project Constraints

- Use existing crystals (1 pair but provision space for 2)
- Fit to existing Bragg axis & vessel
- Use Queensgate Piezos/ Picomotors
- Fit in April 2009 Shutdown (6 month time frame)

Key Design Concepts

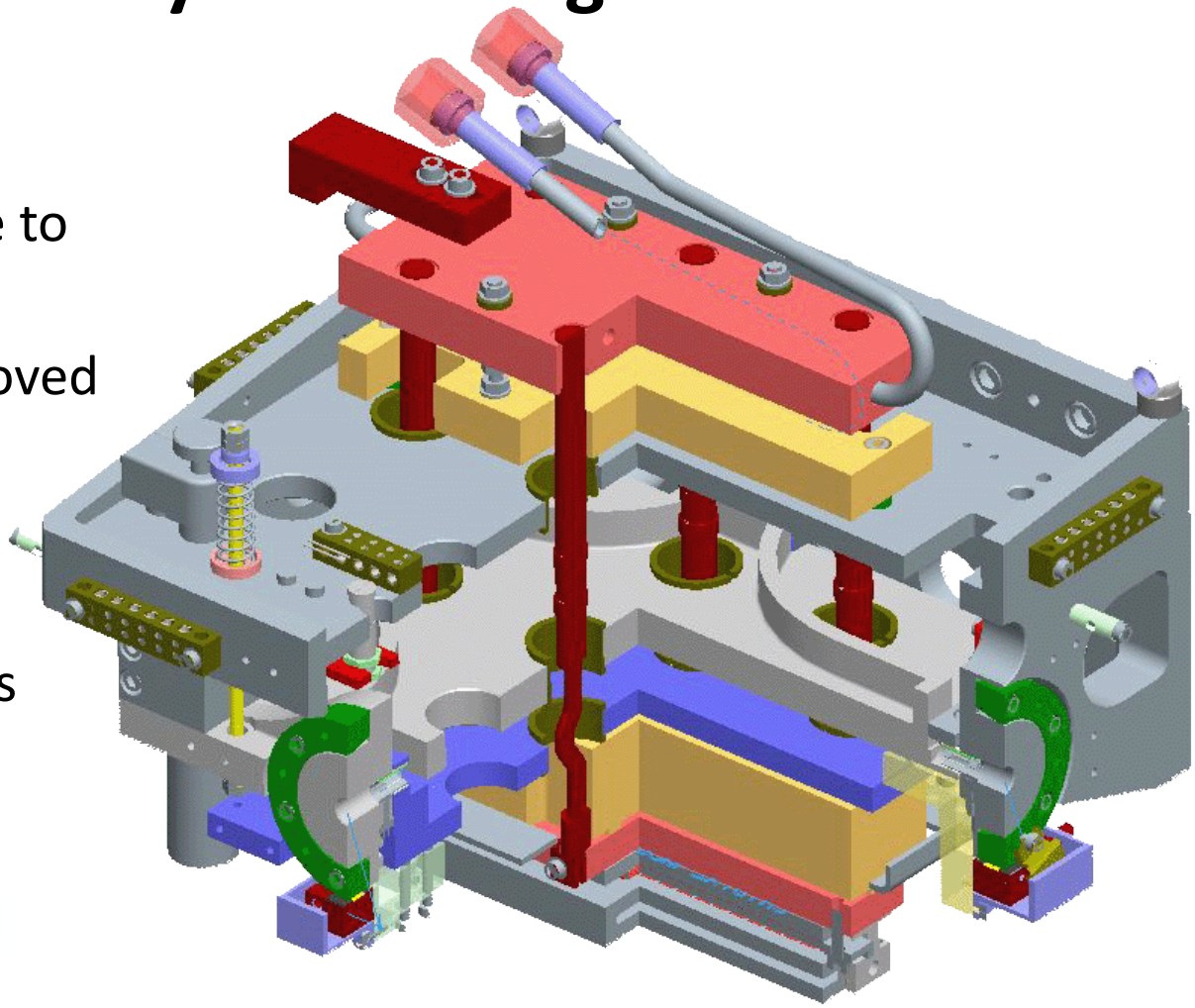
2nd Crystal Pitch / Roll

- Use proprietary Cross Flexures
- Minimise pivot distance to Crystal face
- Make pitch / roll pivots co-planar
- Rotary encoders on axis
- Tuneable pitch / roll preload



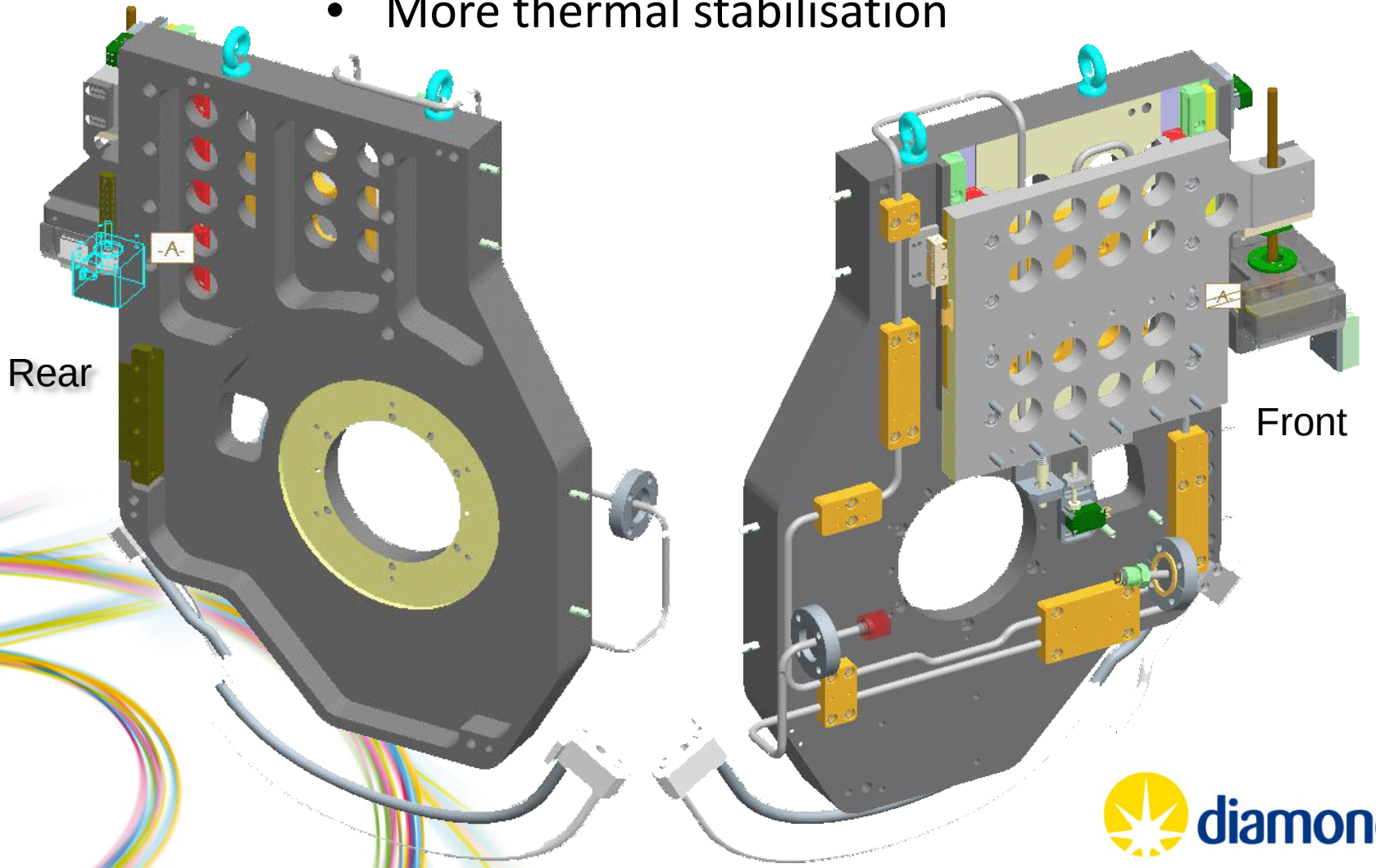
2nd Crystal Cooling

- Energy range too large to braid to 1st Crystal
- Active cooled plate moved above the cage
- Cold fingers / braid to crystal mounting plate
- Peek insulation sleeves



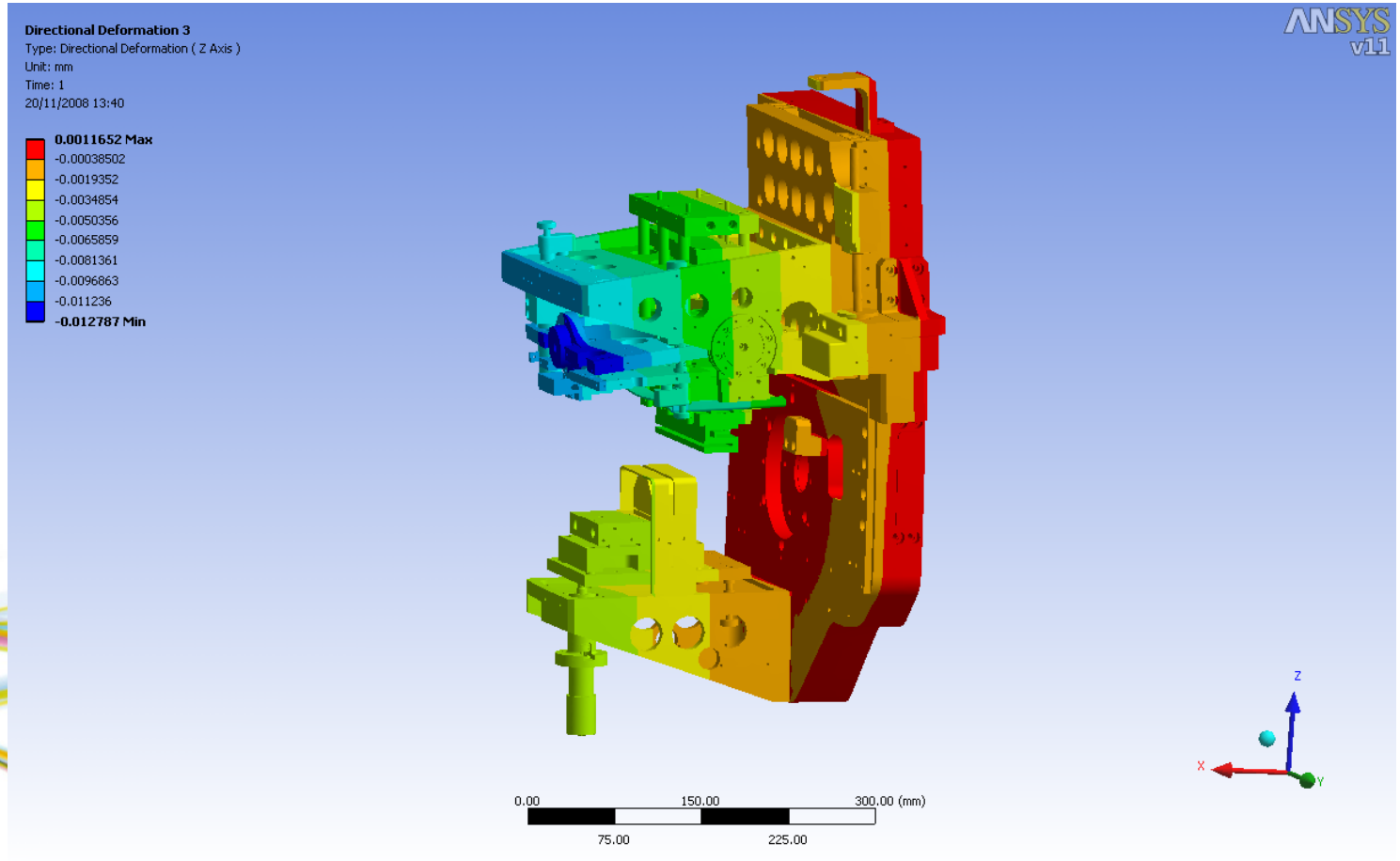
Back Plate

- Increased sectional stiffness
- “Over Long” linear bearings
- More thermal stabilisation

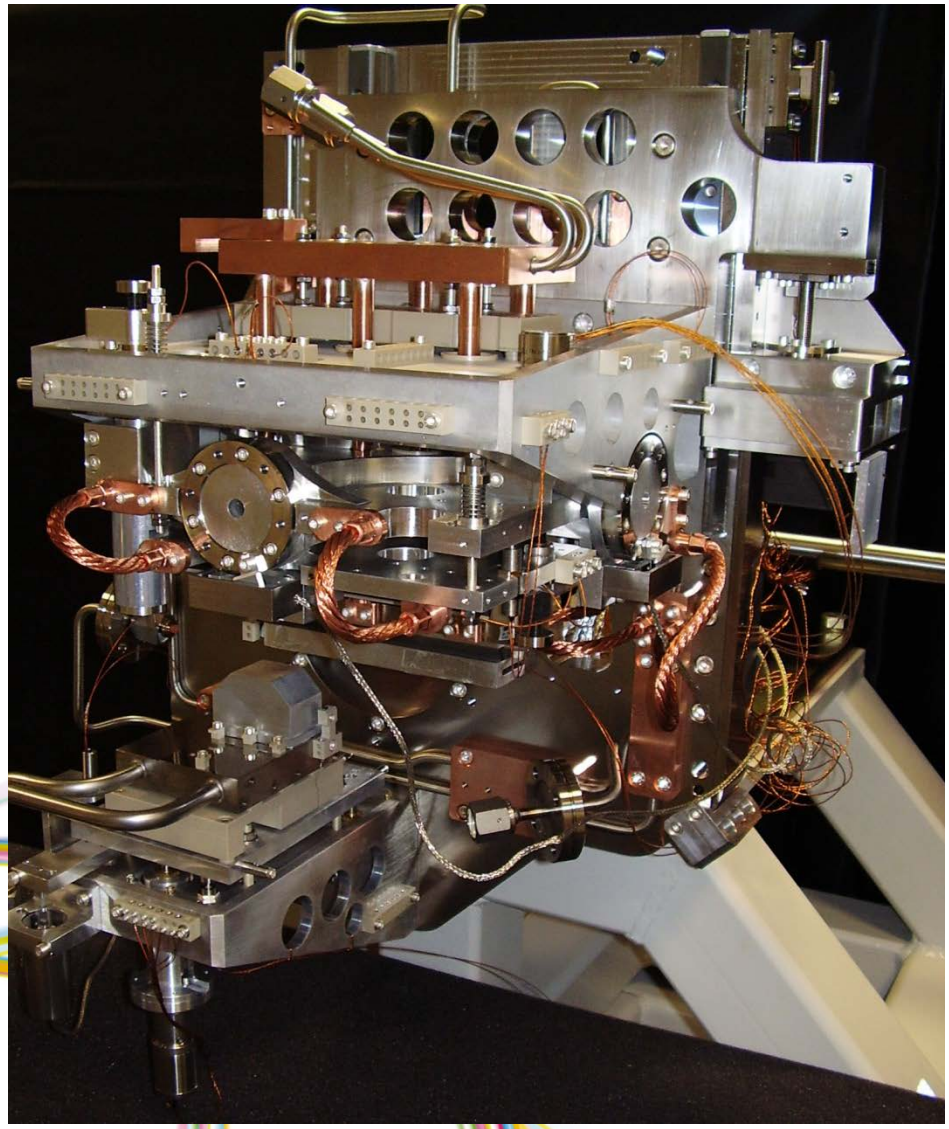


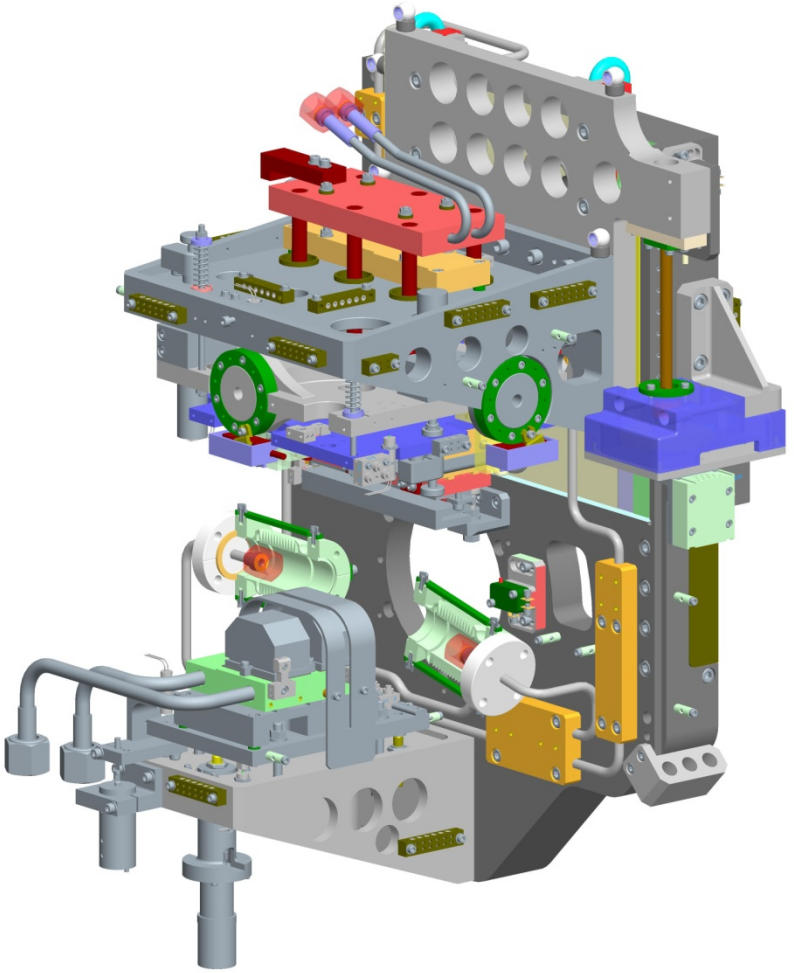
FEA

- Used to optimise stiffness / vibration modes in key areas
- Showed big stiffness improvement over the original



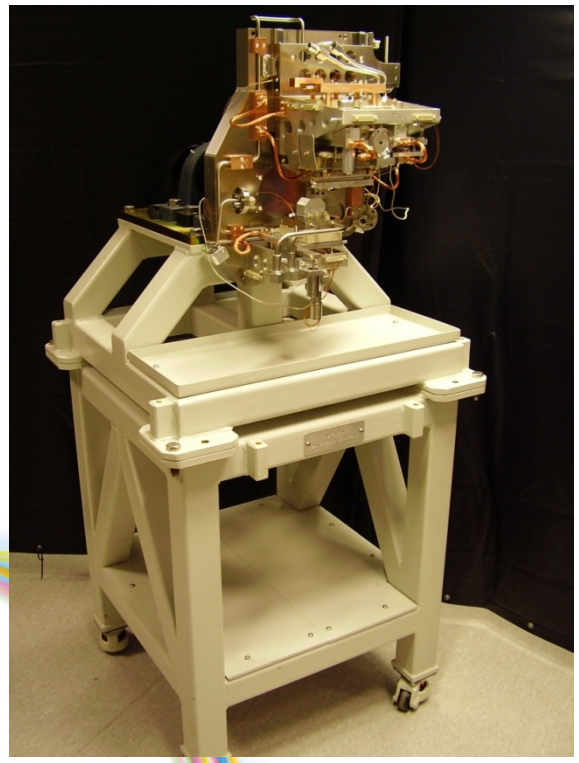
Feb 2009 - New Crystal Cage Built

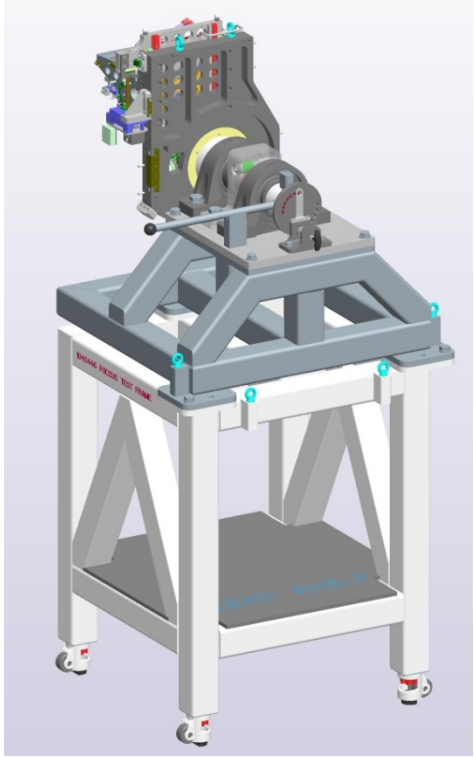




Assembly / Test Jig

- Built a jig to build and move the assembly around
- Sand filled split frame to allow testing on granite table
- Evaluate angular stiffness, parasitic pitch/roll errors etc.
- Potentially 1 use only but since used to build 3 other cages





Metrology Tests

Autocollimator

- Translation /Pitch/Roll repeatability, parasitic errors etc.

All at different Bragg angles

Vibrometer

- Checked for any signs of vibration

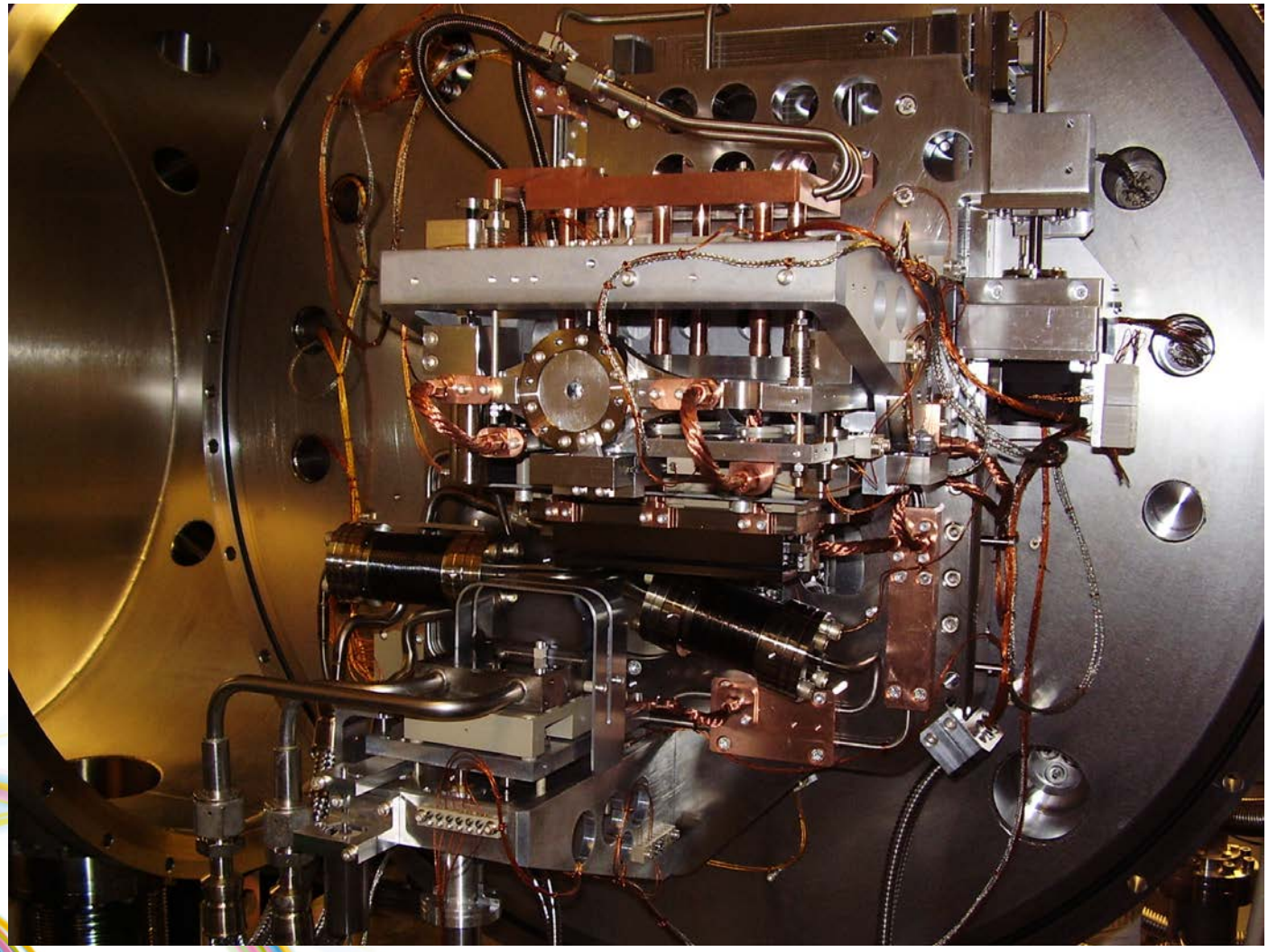
Cooling Tests

- Used water to get idea how the 2nd crystal cooling was working

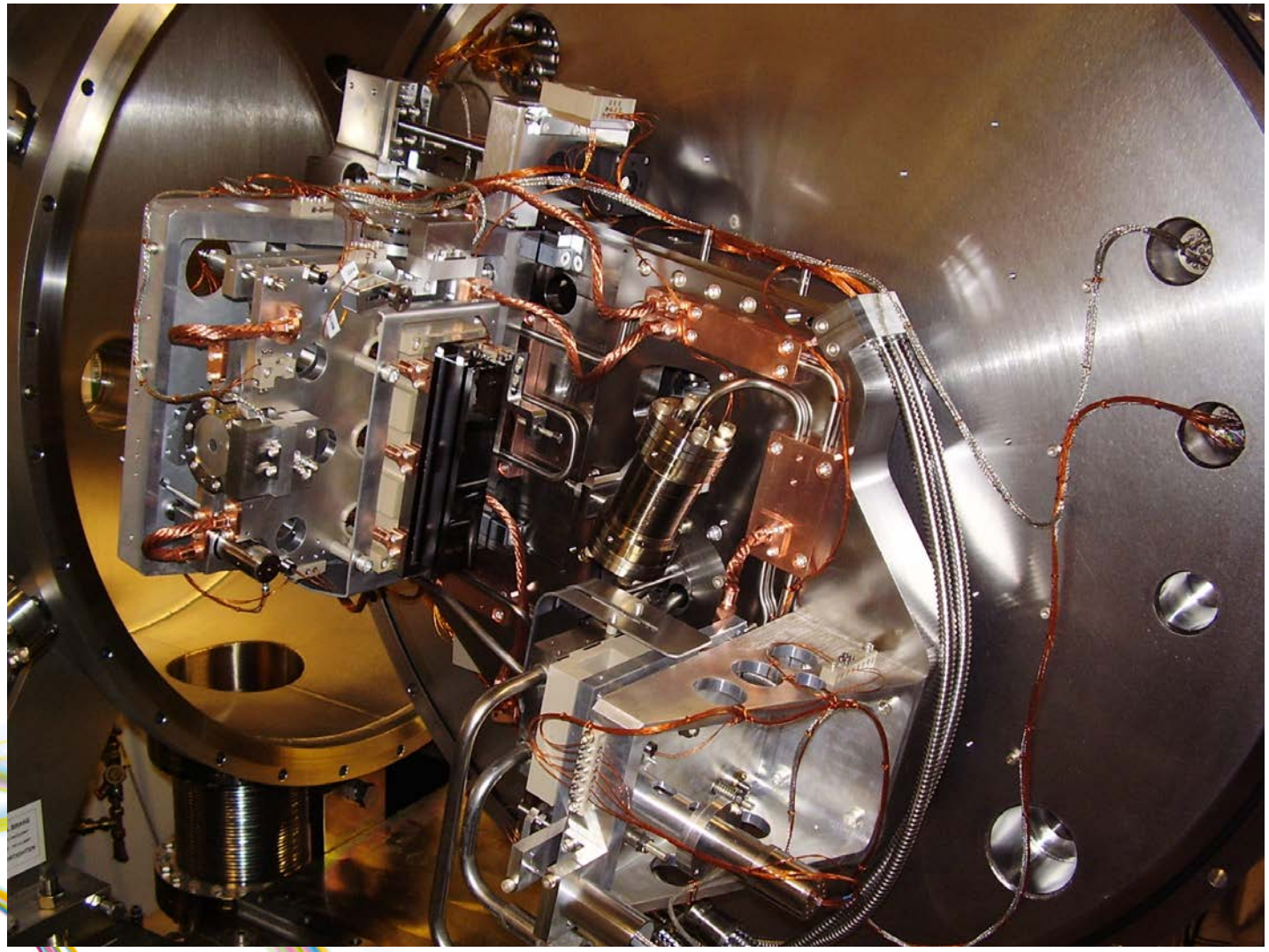
Found nothing alarming!

Decision made to carry on and install in the shutdown

April 2009 New Crystal Cage In Vessel



Crystal Cage 82º Bragg



So How Does It Perform?

Stability

- As built Crystal Cage
  Stability 170nrad rms

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- As built Crystal Cage
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- Grouted granite block to Floor (was on m/c wedge feet)
  Stability 120nrad rms

So How Does It Perform?

Stability

- As built Crystal Cage
  Stability 170nrad rms
- Grouted granite block to Floor (was on m/c wedge feet)
  Stability 120nrad rms
- Optimised CryoCooler tuning, better water chiller
  Stability 80nrad rms
- Didn't quite achieve the <50nrad target
- Nearly 10X stability improvement over the original cage

- **Identical cage fitted to I22 in 2010**

Could I18's Stability be Further Improved?

Fixed Limitations

- Large energy range (fixed constraint)

Removable Limitations?

- Still a 2 crystal set design (compromise with one set?)
- Crystals some way out from back plate.
  Could be optimised with small cage - would need new vessel
- Lateral translation D.O.F. a source of weakness
  Revisit Bragg stage support and interface

May never happen for I18 but <50nrad rms stability should be readily achievable with careful design

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Some Other Performance Indicators

1st Crystal thermal performance

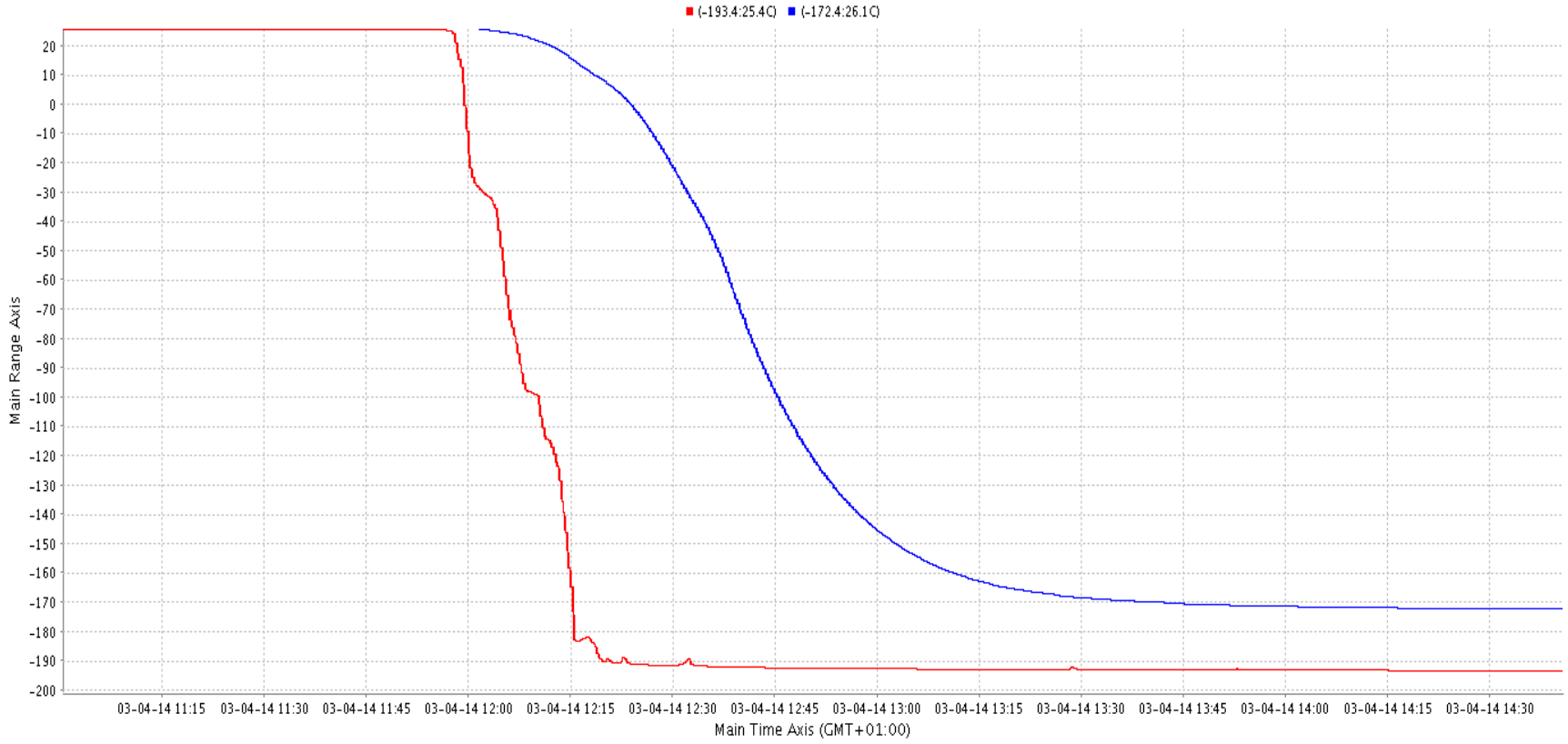
- Change to side cooled crystal 2012/2013
- Improved temp control during scans
  - change now <0.07°K (was 0.2°K) over 700eV scan
- Varies by around 2.5°K over whole energy range

2nd Crystal

- 2nd Crystal temp varies by 0.8°K over whole range.
- All 2nd Crystal pitch/roll adjustments now within range of piezos over the whole energy range
  Pitch *– 150 µrad change*
  Roll *– 320 µrad change*

Cool Down Times

- 1st Crystal stabilises around 80K in around 1 hr
- 2nd Crystal stabilises around 100K in around 2.5 hrs



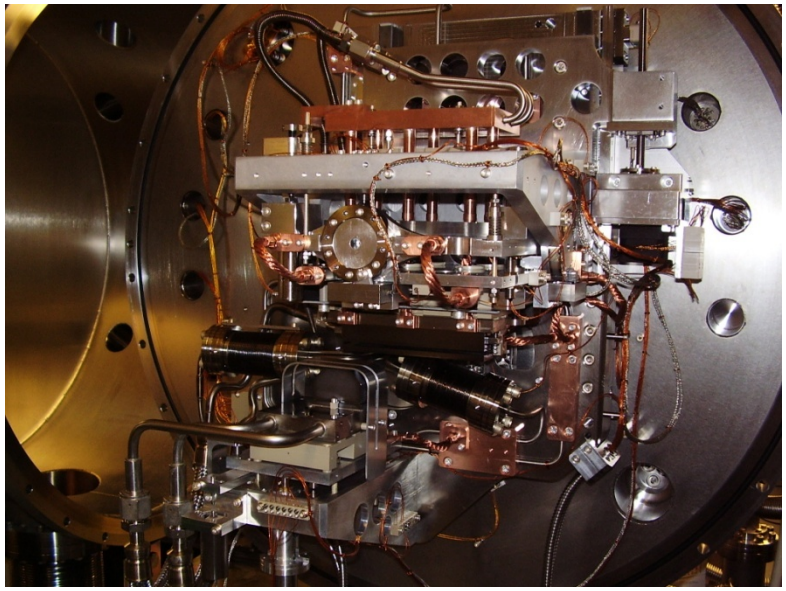
Summary of Key Considerations For Good Crystal Cage Mechanics

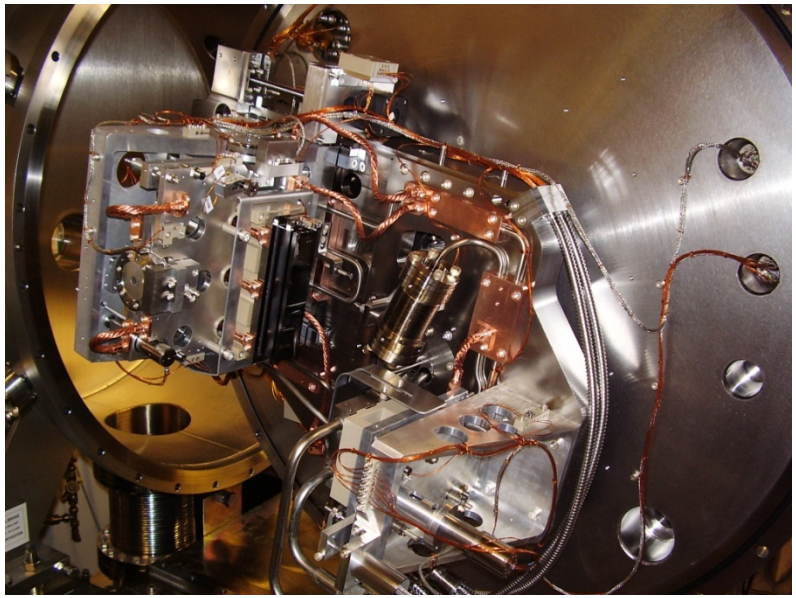
- A “Cover All” spec – inevitably carries a compromise
- Minimise cage size – 1 crystal set
  More sets? More mono(s) may be a better option if stability is ultra critical.
- Back plate the foundation of the cage – needs to be very stiff
- Make linear bearings oversized and good machining critical to optimise parallelism performance

Summary of Key Considerations For Good Crystal Cage Mechanics

- Minimise / eliminate stacks of flexures
- Improve mechanism balance where possible to minimise gravity effects
- Tuneable preloads (esp over large Bragg ranges)
- Coarse / fine motors make installation and commissioning easy.
  Shouldn't compromise stiffness if engineered correctly
- Firmly fix / grout mono to floor

DCM's are never straightforward...





Thank You For Your Attention

Any Questions?

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