Double-crystal CINEL mono at the GALAXIES inelastic/photoemission (undulator) beamline

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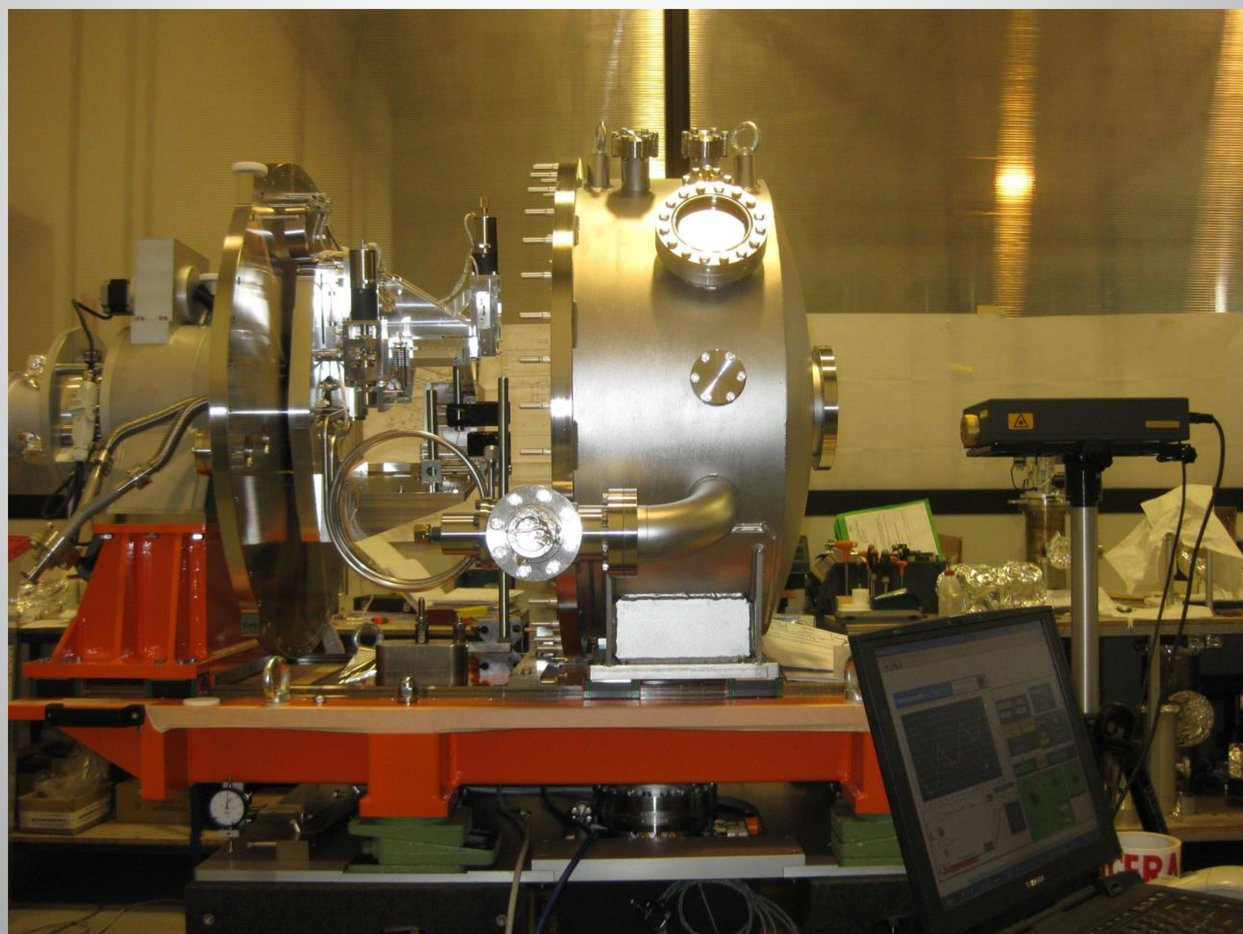
Beamline Staff: J.-P. Rueff (Beamline Responsible), D. Céolin (Scientist), D. Prieur (Technician), T. Moreno (Optician)



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Outline

- **Brief Introduction to the GALAXIES Beamline**
- **Technical Specifications and Design of the GALAXIES DCM**
- **Performance Tests and Experimental Data**
- **Conclusion**

Timeline for the GALAXIES DCM

- **Design started: September 2008**
  (2 DCMs in parallel: GALAXIES and SIXS)
- **Finished: November 2009 ✔ (on time)**
- **Delivered: February 2010**
- **Cost: 210,000 € (on ordering 2 DCMs)**
  - Si 111 crystals included (Crystal Scientific)
  - not including crycooler

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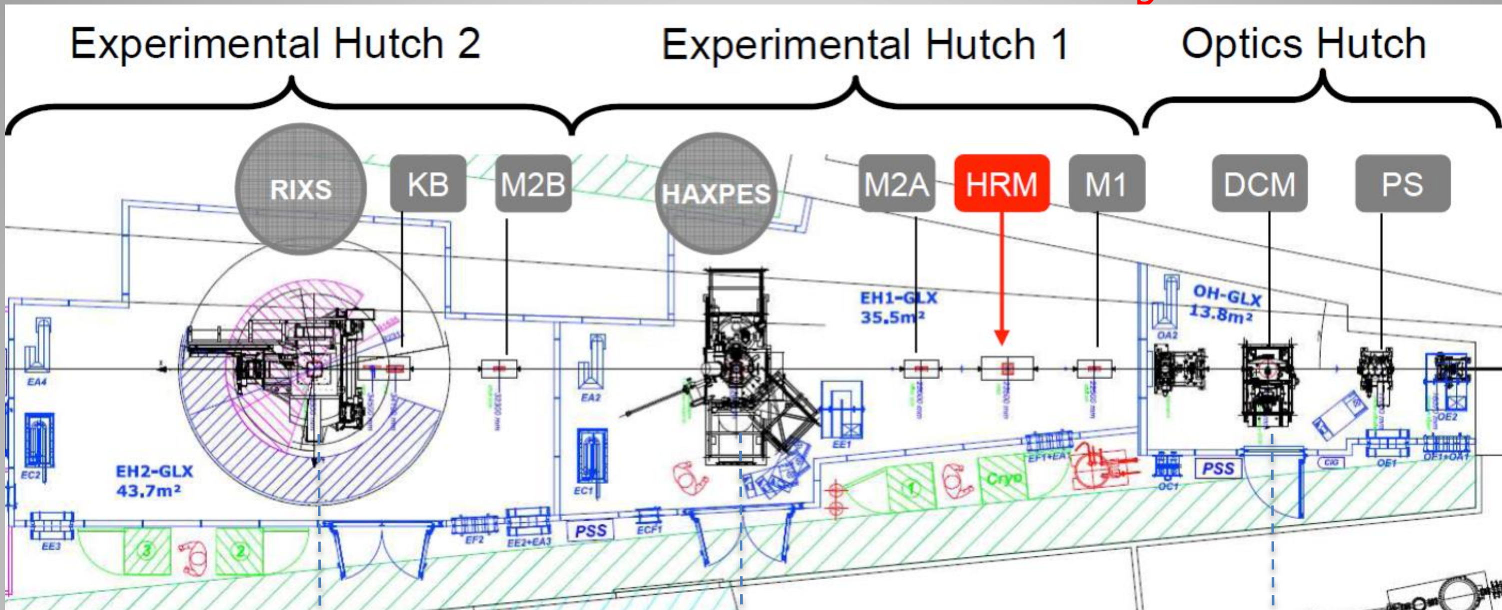
GALAXIES Beamline Layout



Distance from undulator source

35.5m 28.2m 19m

Resonant Inelastic Scattering Endstation

Techniques: **Resonant and non-resonant IXS, X-ray emission spectroscopy, HERFD XANES**

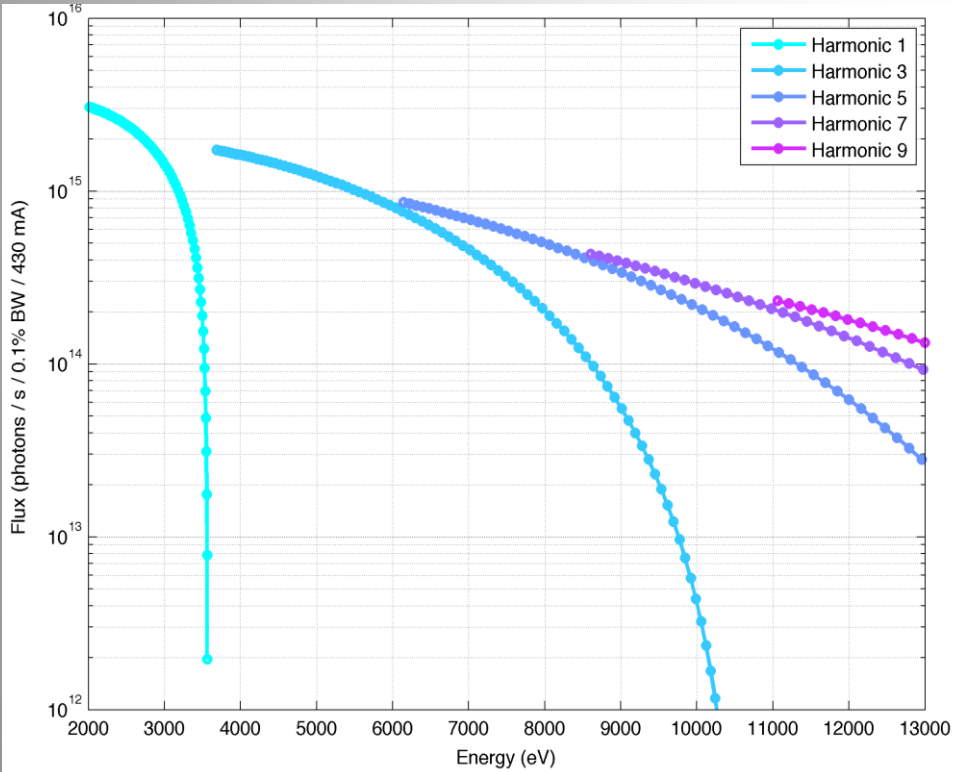
Topics: **Strongly Correlated Materials, Magnetism, Superconductivity High-Pressure Physics.**

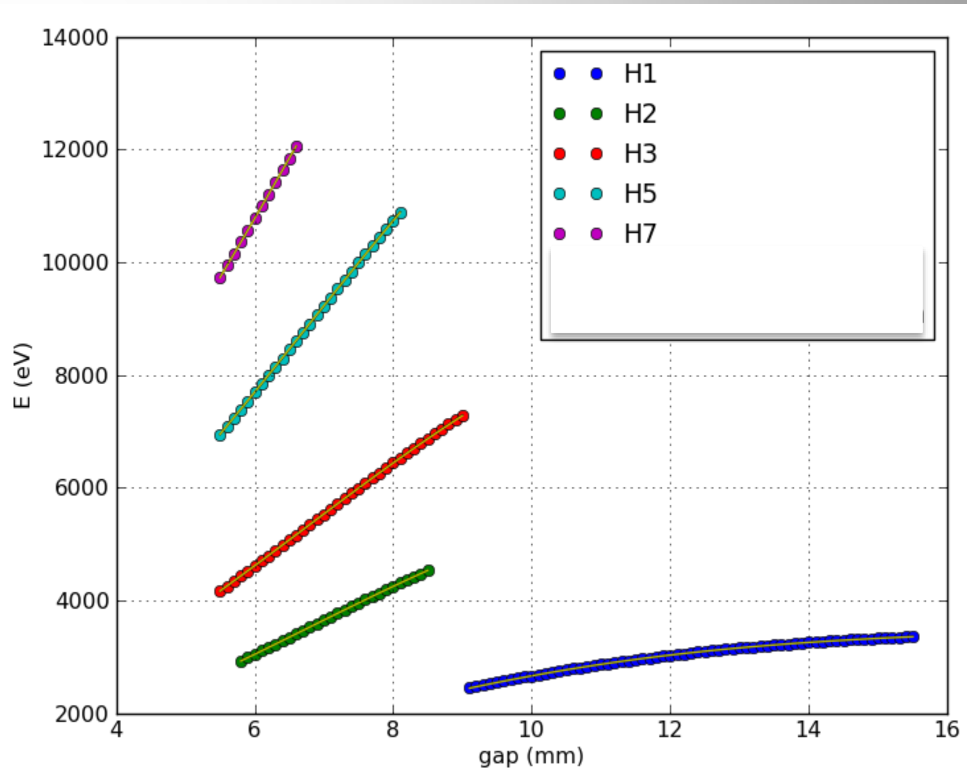
Hard X-ray Photelectron Spectroscopy Endstation

Topics: Burried Interfaces, semi-conductors, thin-films, angle-resolved HAXPES, Gas-Phase

GALAXIES U20 Power and Spectral Characteristics

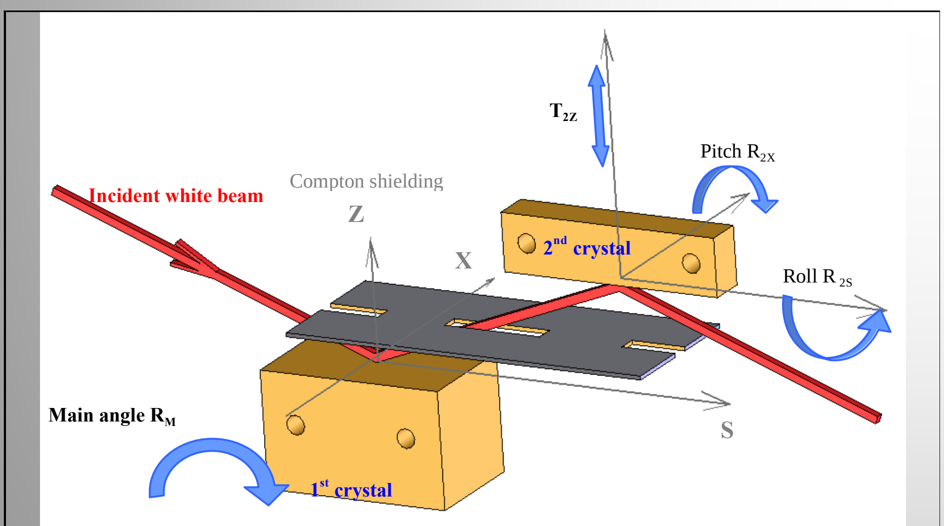
- **Source (SOLEIL:2.75 GeV, 430mA (to increase to 500mA this year):**
  U20 in-vacuum undulator ($Nd_2Fe_{14}B$, 20mm period, 98 periods, min gap 5.5mm)
- **Energy Range: 2.3 -> 12keV (θ_{bragg}: 59.3 ->9.5° Si(111)**
- **DCM 19 m from source, beam height 1.4m, beam-off set 20mm**
- **Max. Beam size: ≈ 3mm (hor.) x 2mm(ver.)**
- **1st xtal: Max. Power load: 200 Watts , Max power density: 33 W/mm²**



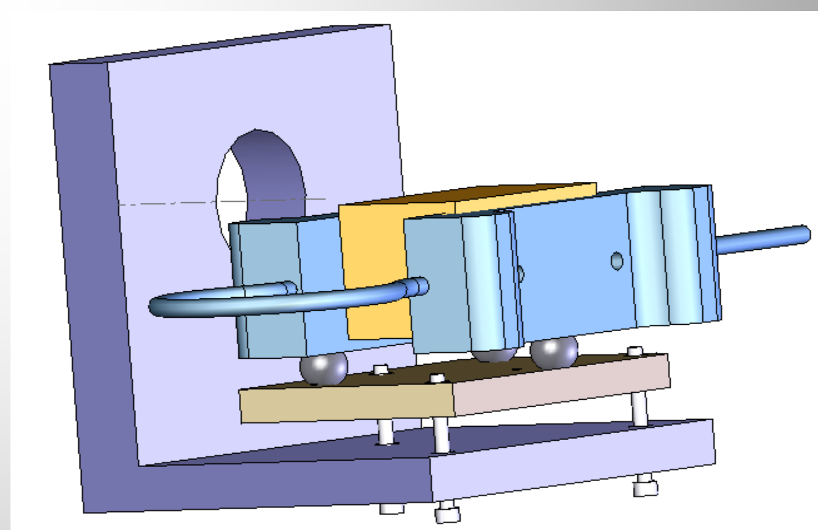


Technical Specifications

- Energy Range: 2.3 -> 12keV , θ_{bragg}: 59.3 ->9.5° Si(111) .
- Fixed Exit (independent crystals).
- Flat crystals : no focusing.
- Pressure in chamber <$5x10^{-8}$ bar.
- Centre of rotation on 1st crystal (incident beam).
- 1st crystal clamped between heat absorbers.
- 2^{nd} crystal cooled via copper braids linked to 1st xtal mechanism.
- Hard limits on all motions.



Galaxies initial proposed design. Added in later piezo.



Galaxies proposed ,first xtal mounting and cooling arrangement.

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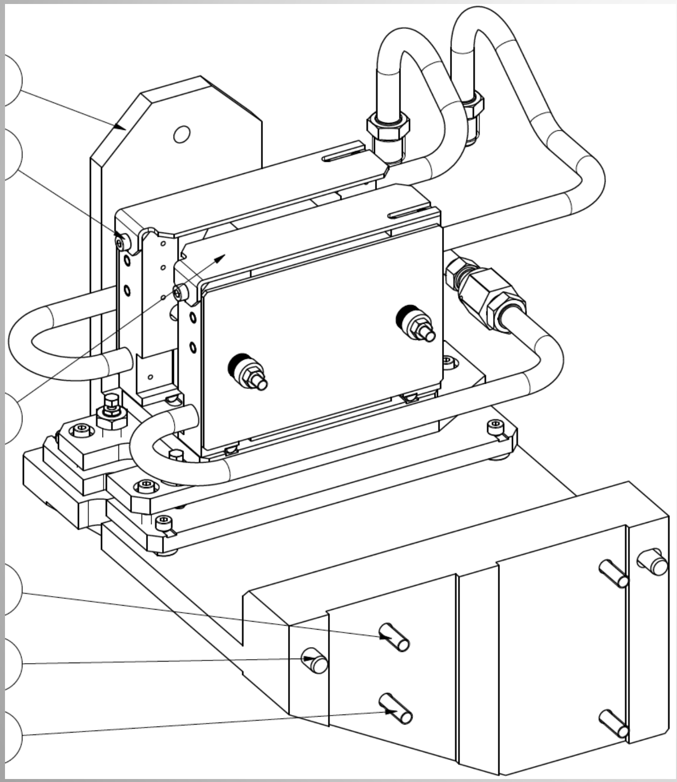
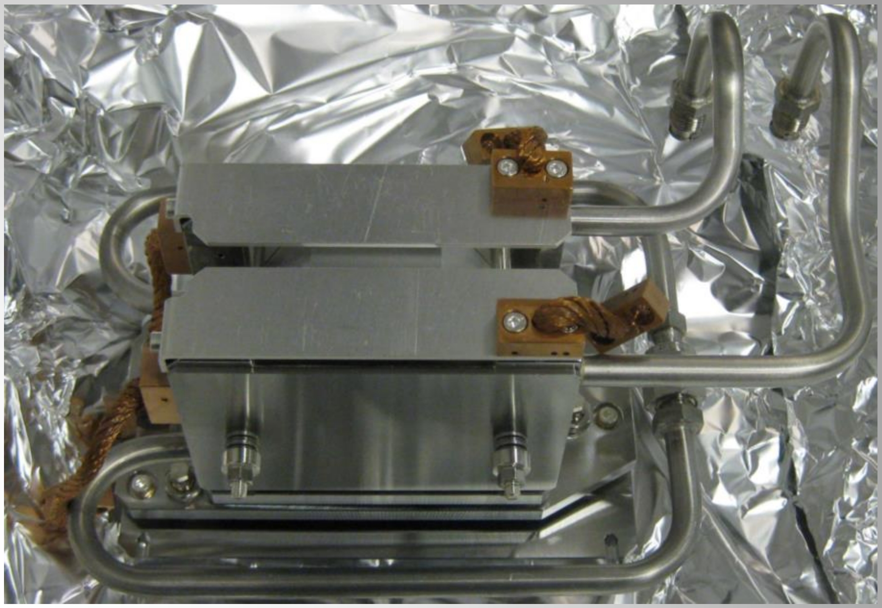
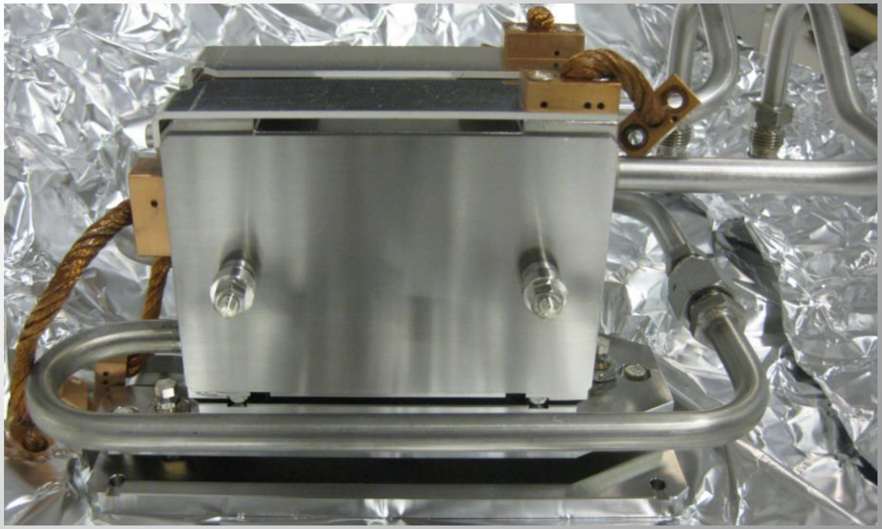
GALAXIES 1st Crystal Mount Design

- Nickel plated heat absorbers
- 0.5mm thick Indium foil between absorbers and xtal
- In-Ga eutectic paste
- Copper braids: Cooling of 2nd xtal and Anti-Compton Shield







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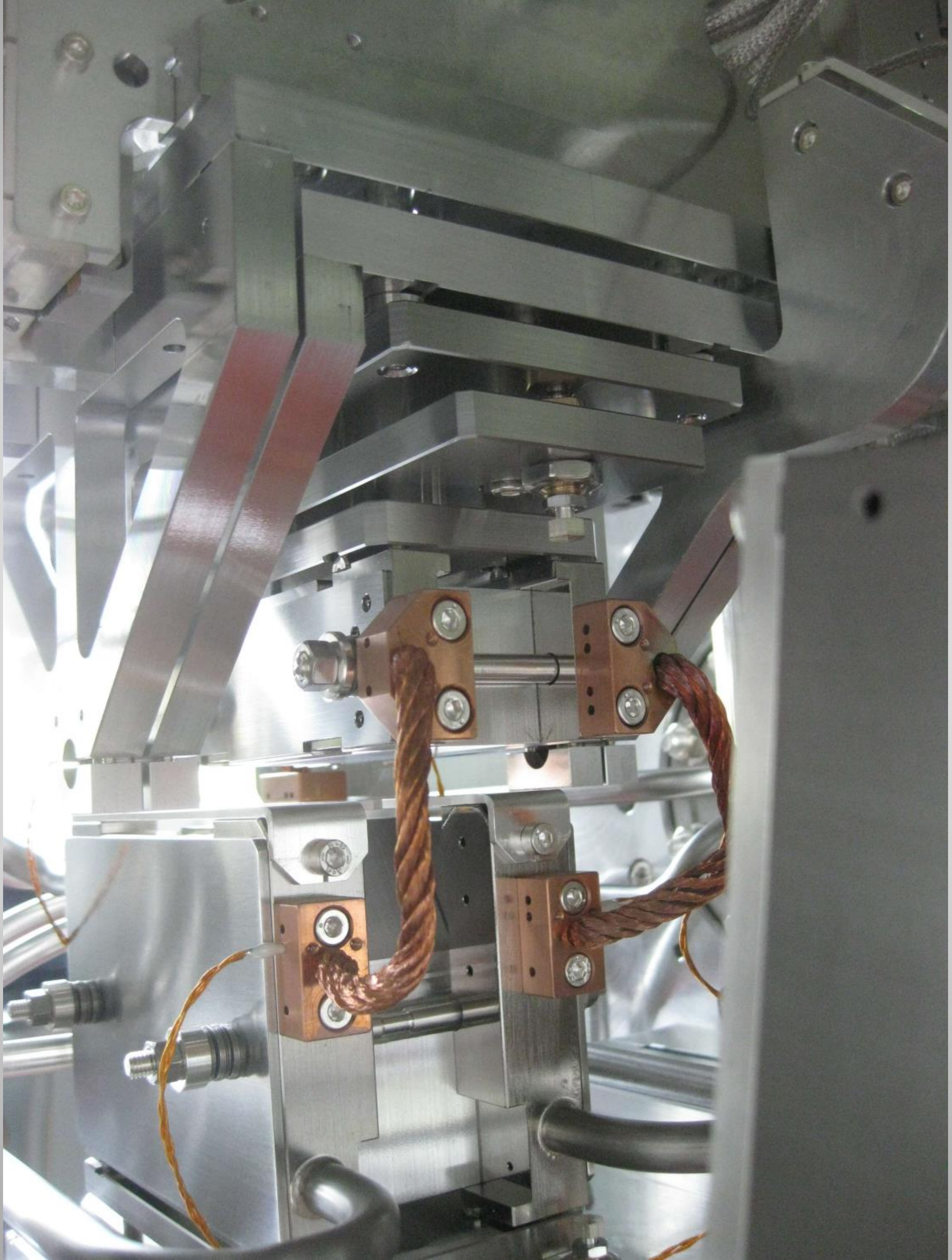

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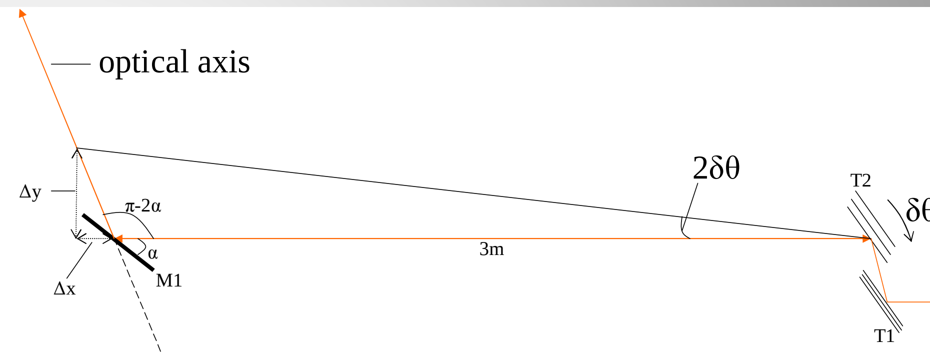
GALAXIES U20 Power and Spectral Characteristics

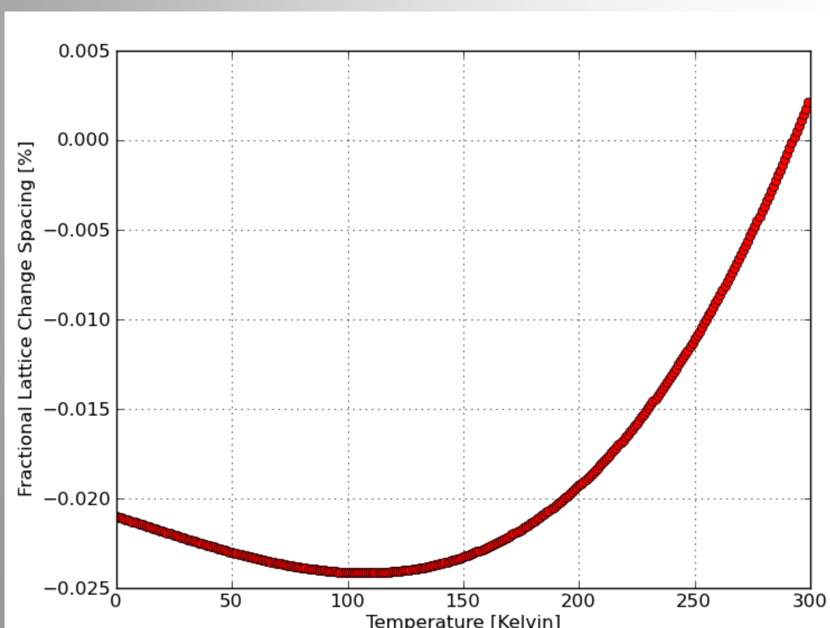
Total Power Emitted by U20 Undulator =4.2 kW ($P[kW]=0.633E^2[GeV]*B^2[T]*L[cm]*I[A]$)

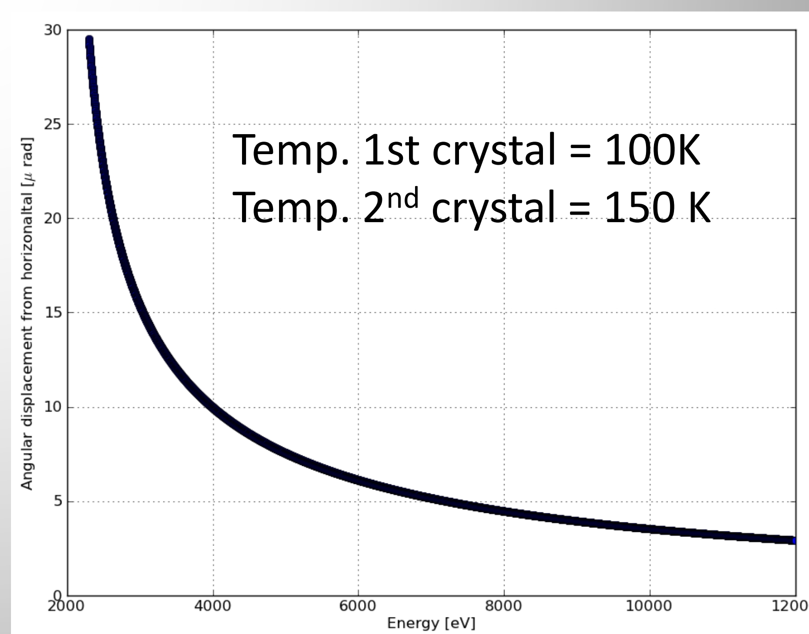
Power absorbed by DCM 1st crystal = 83.4 sin θ_{bragg} W/mm^2

Element	Power Transmitted (W)	Power absorbed (W)	Power Density W/mm2 ---check
Absorber (2.5x2.5mm^2) @ 10m	1325	2915	290 (centre)
Diaphragm (1.8x0.6mm^2) @ 11.7m	222	1103	206 (centre)
Primary Slits (2.0 x 0.7mm^2) @ 17m	139	83	100 (centre)
Si 111 First Crystal (23.3^o, 5keV) @ 19m	8x10^{-3}	**139**	33 (at surface)

$$\frac{\Delta d}{d_{293K}} = 0.01\left(-0.021 - 4.149x10^{-5}T - 4.61x10^{-8}T^2 + 1.4826x10^{-9}T^3\right)$$







Bragg Angle Technical Specifications

Item	Required (GALAXIES)	Obtainable (CINEL)	Note
Resolution	0.9 µrad	0.25µrad	
Repeatability	1.8 µrad over 2^{O}	3 µrad/< 1 µrad	Open/closed loop
Accuracy	1.8 µrad over 2^{O}	±2 µrad	Encoder limited
Wobble	<9 µrad	<7.5 µrad	
Encoder Resolution	<0.9 µrad	0.11 µrad	36000 lines, 400 fold interpolator, readout in ¼ of wave
Maximum Speed	≥0.5°/s	0.5°/s	Speeds up to 1°/sec have been obtained with DC motors. The optimum speed with stepper motor is 0.35°/sec

2 harmonic Drives

3 Dynamic Seals

Backlash free

Galaxies DCM installed on the beamline

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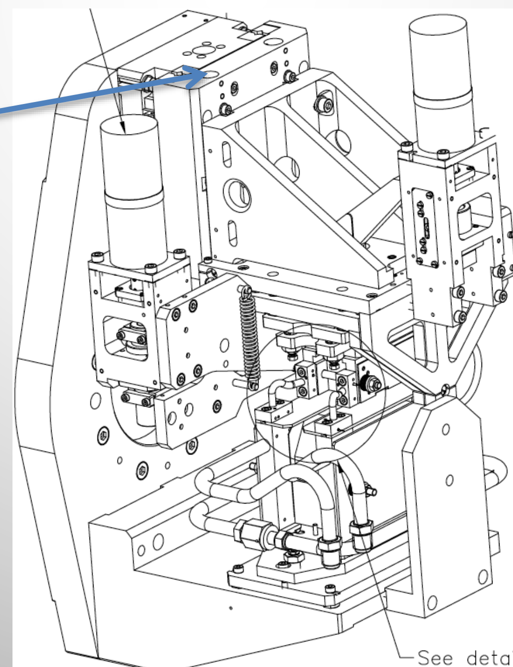
2nd Crystal Gap Technical Specifications

Item	Required (GALAXIES)	Obtainable (CINEL)	Note
Resolution	1 µm	0.05 µm	
Repeatability	2 µm	1 / 0.1 µm	Open/closed loop
Wobble	0.9 µrad	1 µrad/mm	

« The translation of the 2nd xtal must not induce perturabations to the pitch and roll larger than their specified repeatability »

Gap Slide



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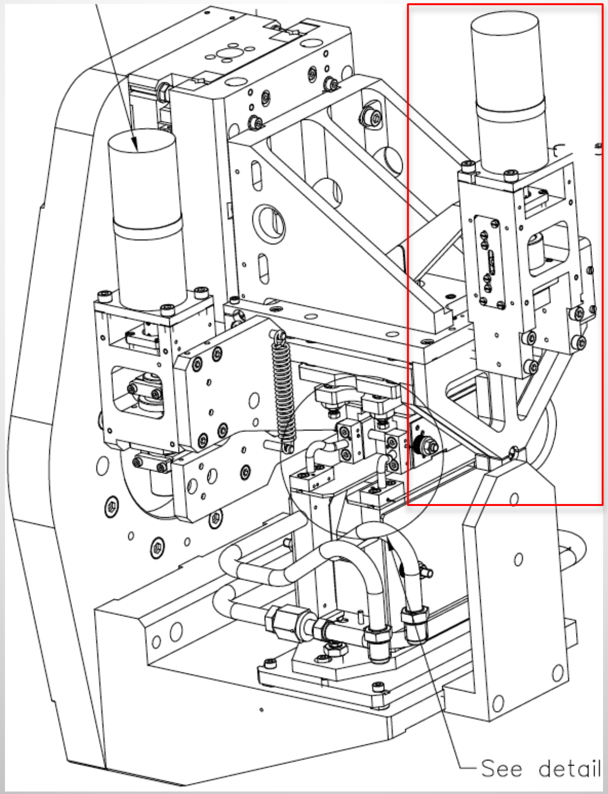
2nd Crystal Pitch Technical Specifications

Item	Required (GALAXIES)	Obtainable (CINEL)	Note
Resolution	0.45 µrad	0.25 µrad	
Repeatability	0.9 µrad	3 / 0.9 µrad	Open/closed loop



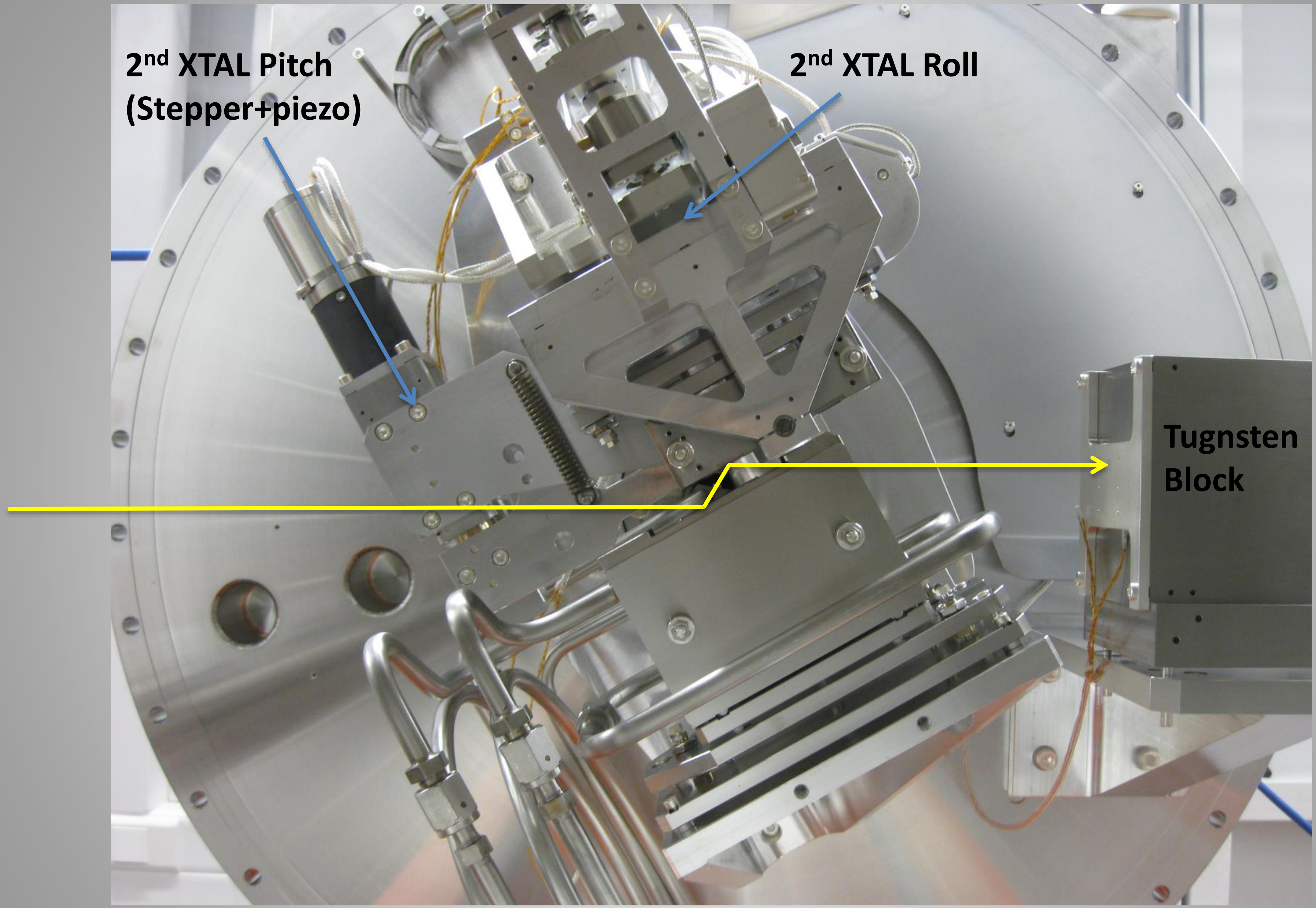
160mm lever arm. 200 steps per rev. 20x gear reduction

✗ corrected during FAT

2 day Factory Acceptance Test Results
10/02/2010 – 11/02/2010

Measurement: Interferometer (Renishaw ML 10)

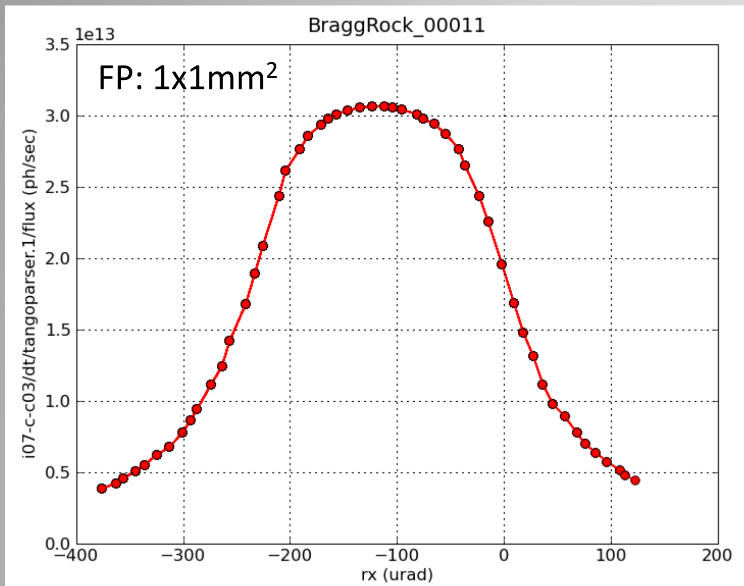
	Bragg Rotation motor: Oriental PK 266 DB 200 full steps/rev Encoder: HEIDENHAIN RON 886 Interpolator: HEIDENHAIN IBV660B	**2nd crystal pitch** motor: Phytron VSS42.200.2,5-E-VGPL42.2-HV Encoder: RENISHAW RGH25F 15 M 01 C Interopolator: RENISHAW REF0200 E 01 A	**2nd crystal roll** motor: Phytron VSS42.200.2,5-E-VGPL42.2-HV Encoder: RENISHAW RGH25F 15 M 01 C Interopolator: RENISHAW REF0200 E 01 A	**2nd crystal gap** motor: Phytron VSS42.200.2,5-E-VGPL42.2-HV Encoder: RENISHAW RGH25F 15 M 01 C Interopolator: RENISHAW REF0200 E 01 A
Resolution (specs/measured)	**0.9µrad** / **0.1 µrad** ✓ Bragg Angle @ 35º,58º Tz @ 0mm, Rx @ 0º Range : ±2 mrad 35 scans. 8 points per scan.	**0.5µrad** / **<1.6 µrad** ✗ Bragg Angle @ 10º Around Rx @0º 30 scans. 10 measures/step.	**4µrad** / **<1 µrad** ✓ Bragg Angle @ 10º Rz @0º Backlash 2.5 µrad 30 scans. 8 measures/step.	**2µm** /**2 µm** ✓ Bragg Angle @ 10º Range: ±1mm 15 scans. 8 measures/step.
Repeatability (specs/measured)	**1.8µrad** / **3 µrad** ✗ Bragg Angle @ 10º Tz @ 0mm, Rx @ 0º Range : ±2 mrad 16 scans. 8 points per scan.	**0.9µrad** / **3 µrad** ✗ Bragg Angle @ 10º Tz @ 0mm, Rx @ 0º Range : ±2 mrad 16 scans. 8 points per scan.	**8µrad** / **2.1 µrad** ✓ Bragg Angle @ 10º Range : ±2 mrad 15 scans. 8 points per scan.	**1µm** /**1 µm** ✓ Bragg Angle @ 10º 30 scans. 8 measures/step.
Parasitic Motion (specs/measured)		Parasisitic motion in moving Tz **1µrad/mm** / **<1 µrad/mm** ✓ Bragg Angle @ 10º Tz range 9.6mm 7 scans. 47 steps per scan	Parasisitic motion in moving Tz **1µrad/mm** / **<1 µrad/mm** ✓ Bragg Angle @ 10º Tz range 9.6mm 7 scans. 47 steps per scan	


2nd XTAL Pitch
(Stepper+piezo)
2nd XTAL Roll
Tugnsten
Block

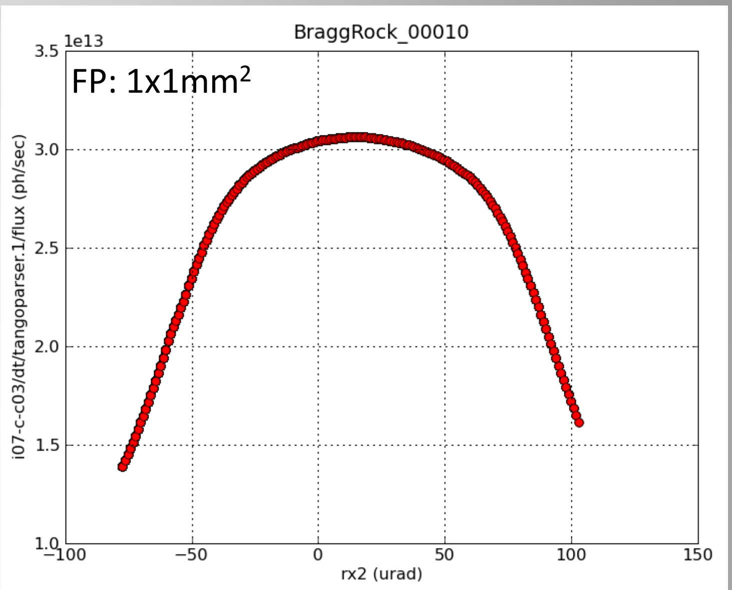
2nd XTAL Stepper and Piezo Capabilities

Stepper

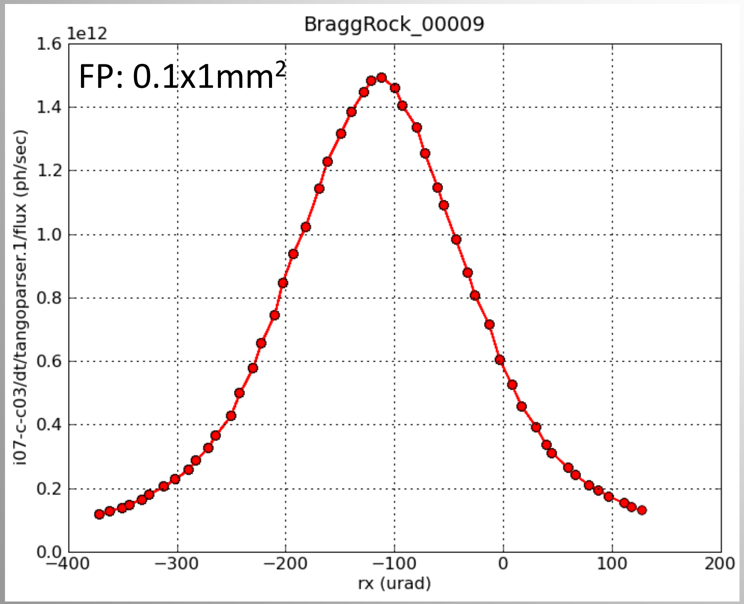
Piezo

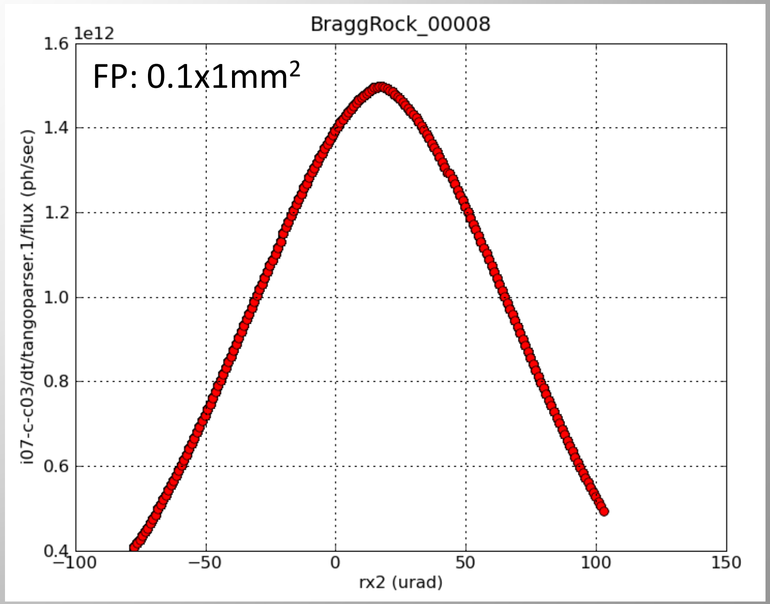


Date 05/08/2011
Energy 3 keV
(Si 111)

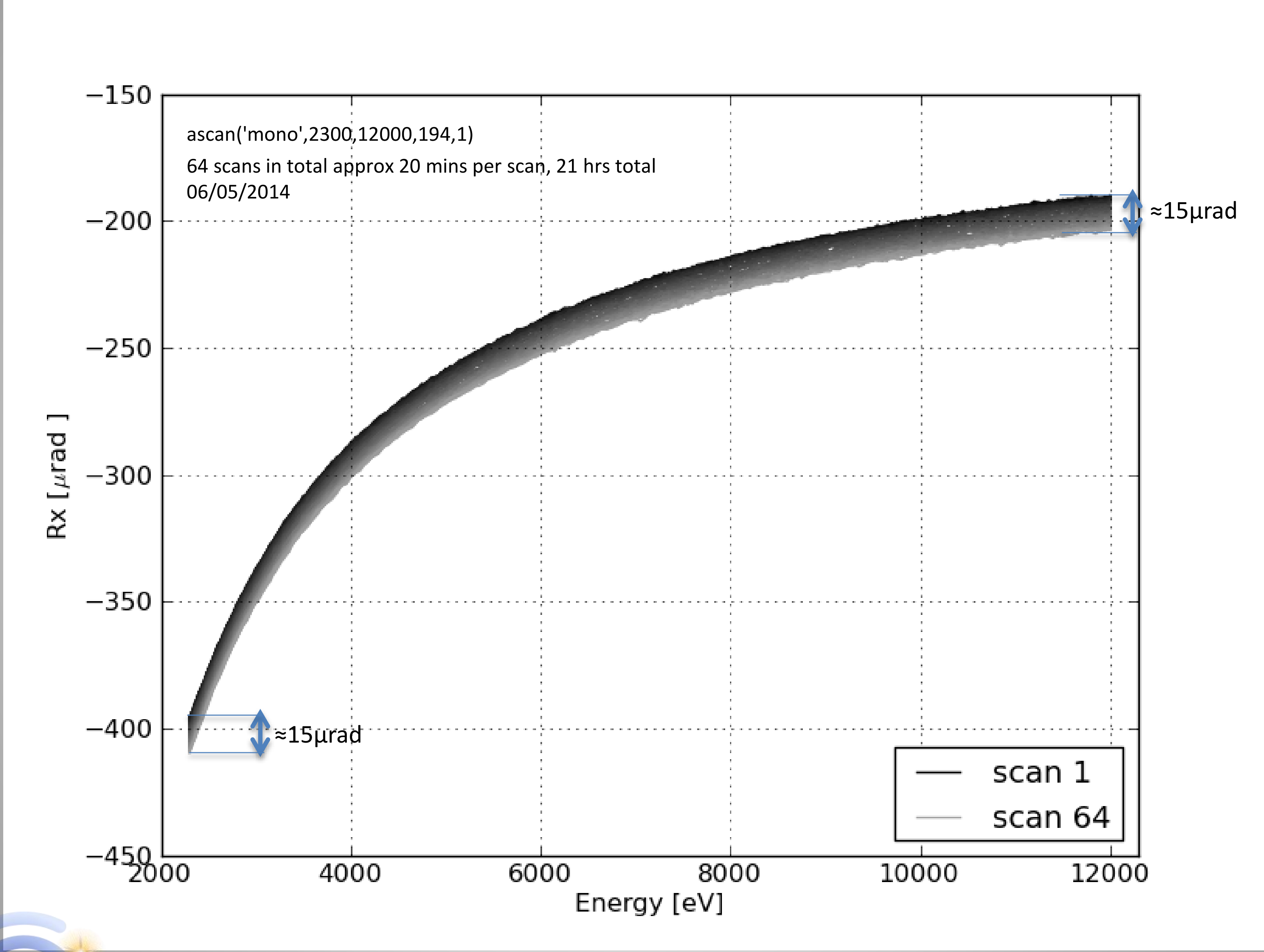


0.1x1mm2

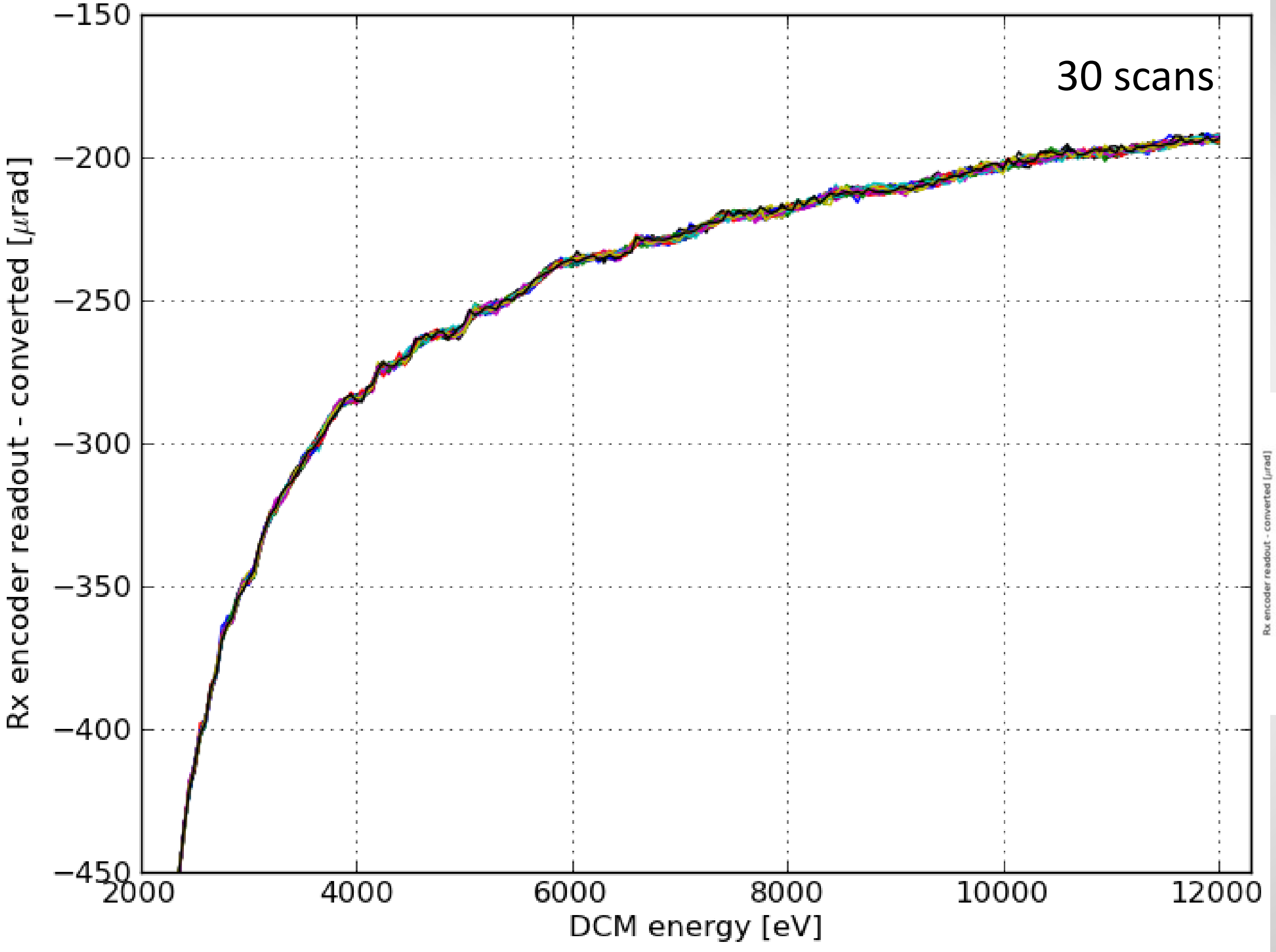


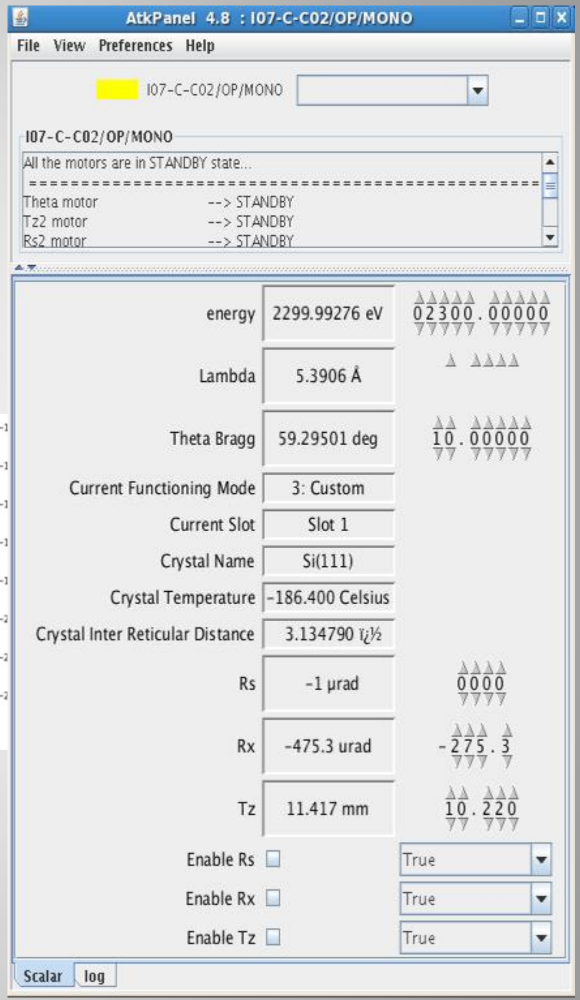


2nd Xtal Pitch Encoder Readout as function of bragg angle (No Beam)

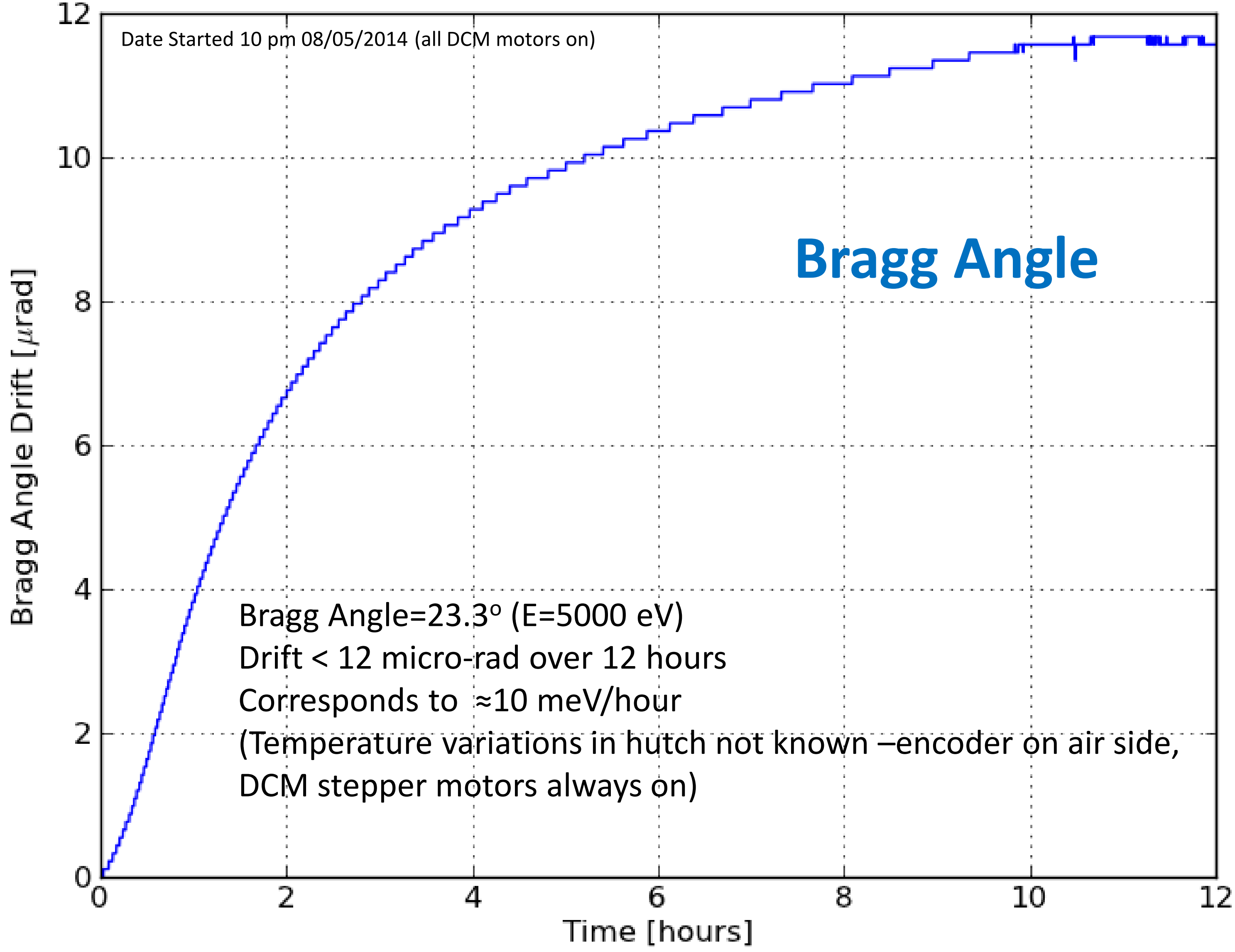


2nd Xtal Pitch Encoder Readout as function of bragg angle (No Beam): Rx Enabled

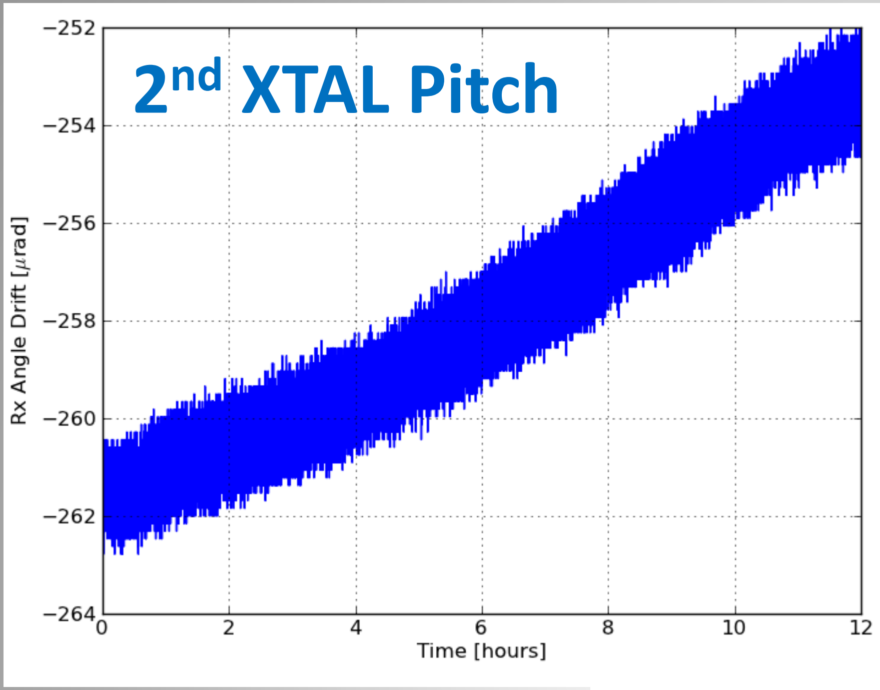


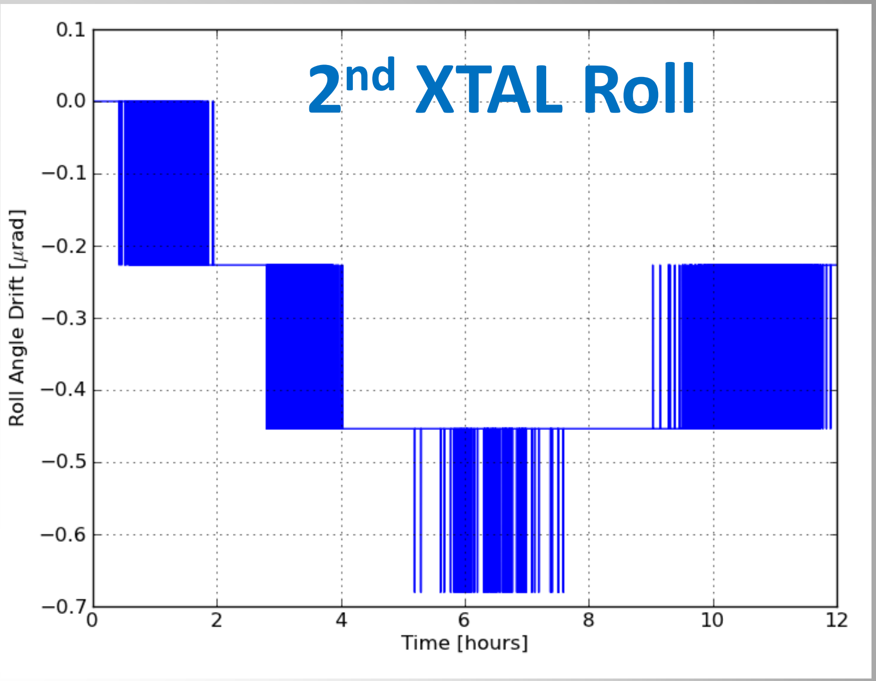


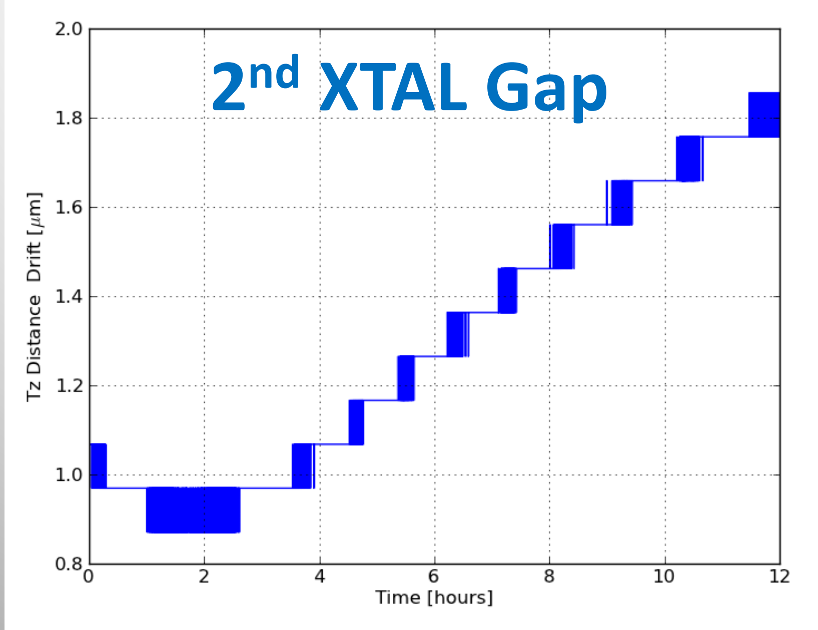
DCM Stability Tests (No Beam)



DCM Stability Tests (No Beam)

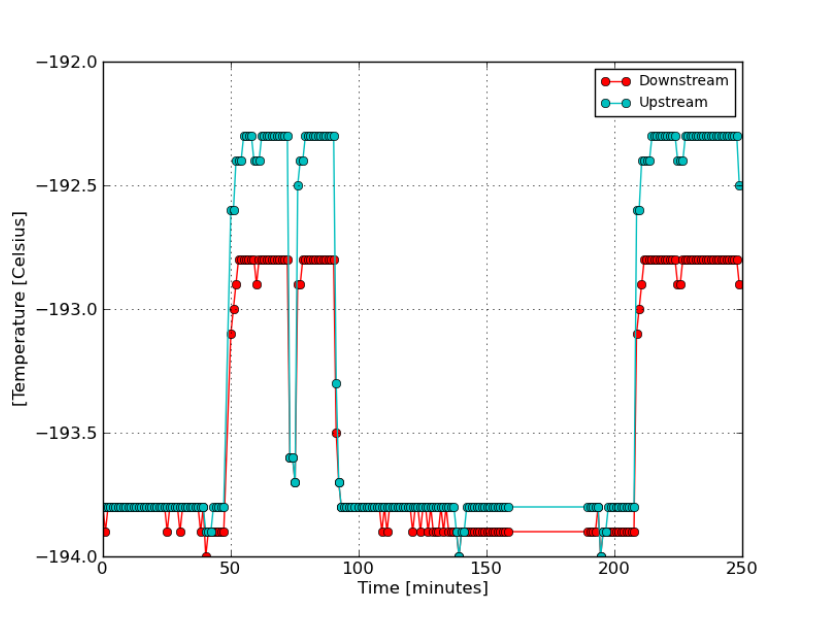


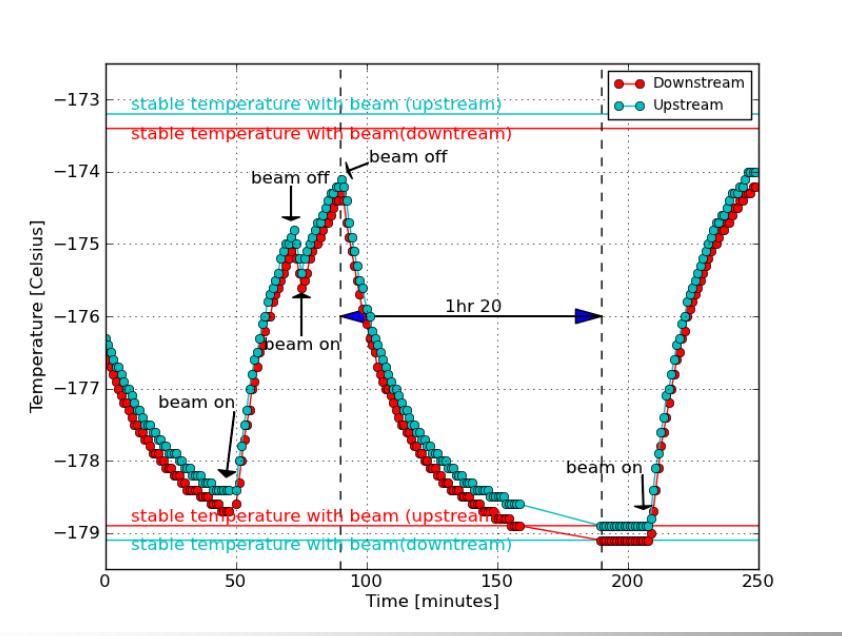


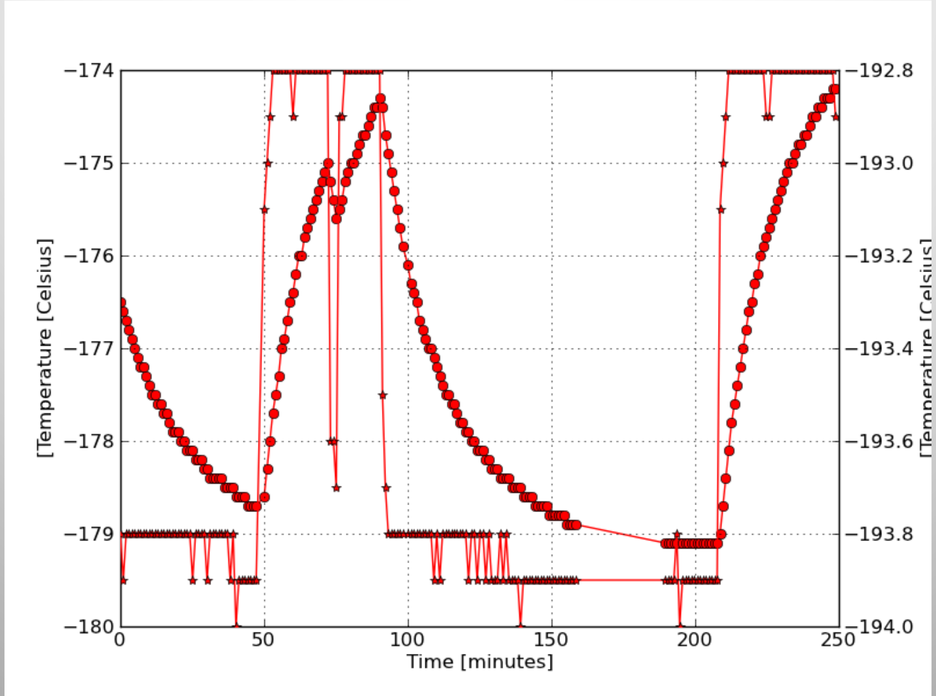


Date Started 10 pm 08/05/2014

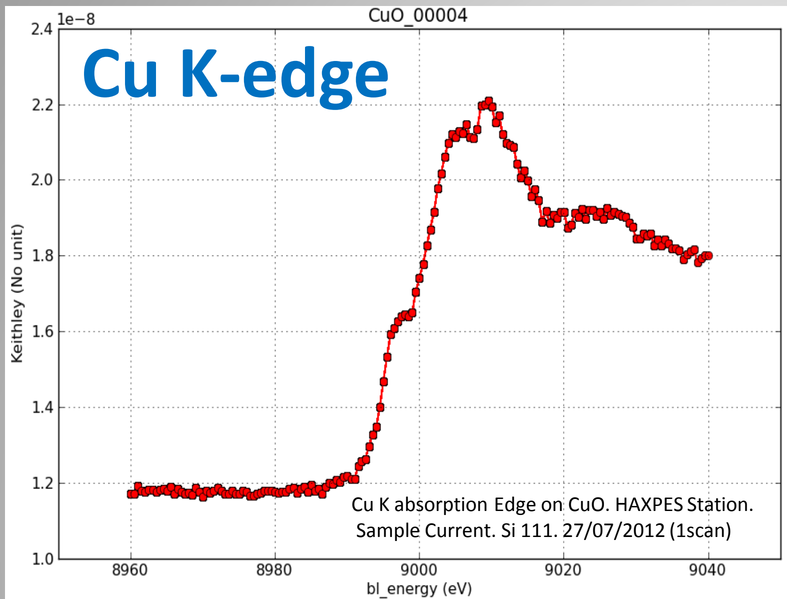
DCM warm up / cool down. Bragg angle =11.7º)

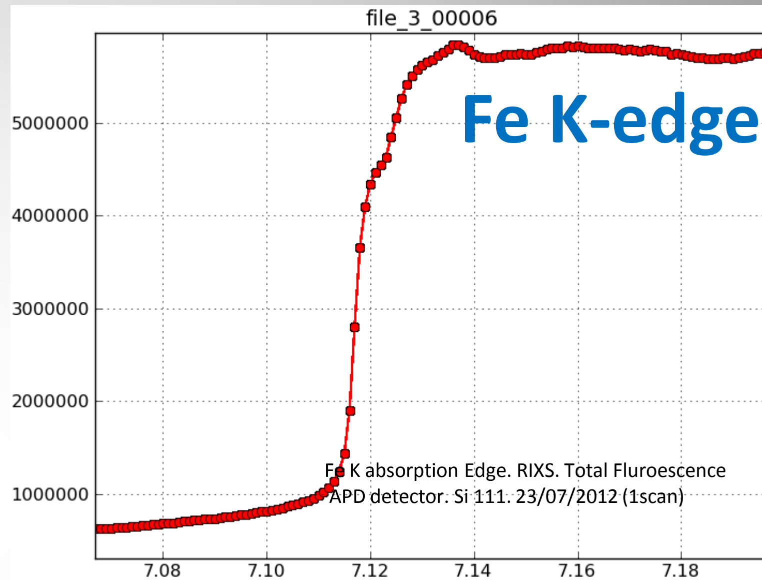


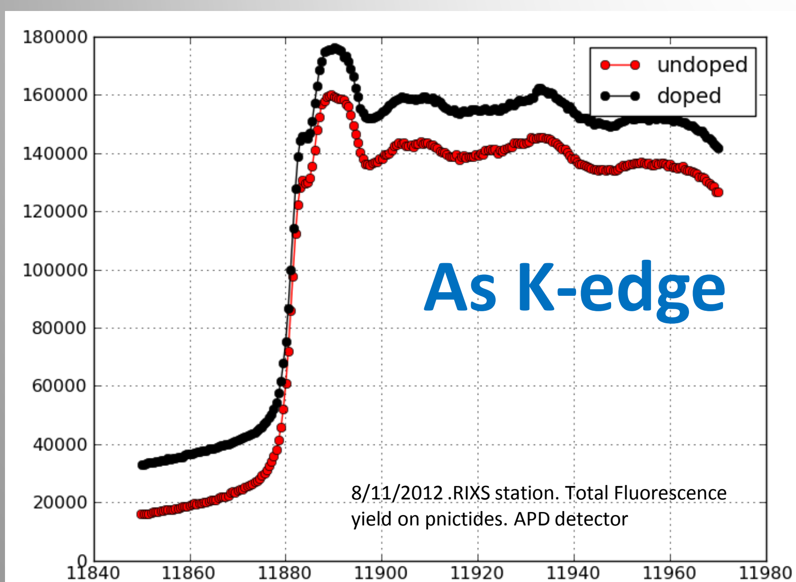


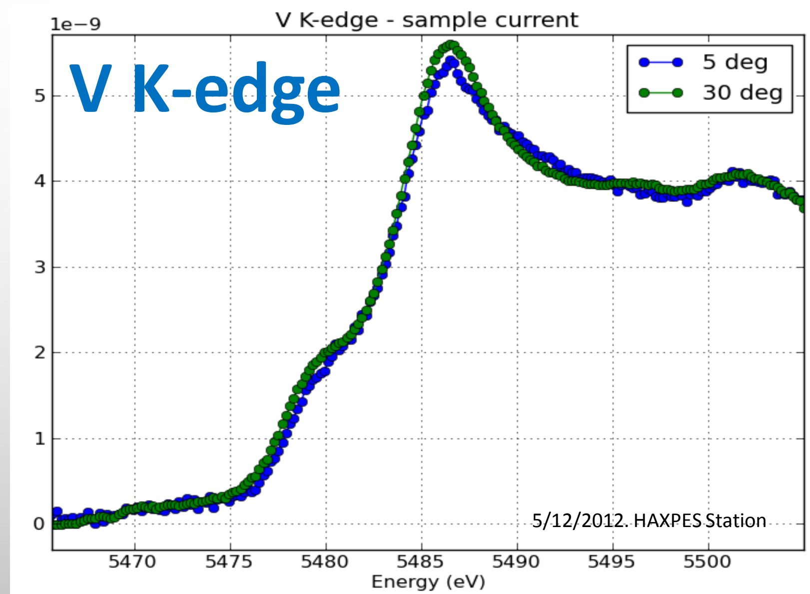


Example Energy Scans

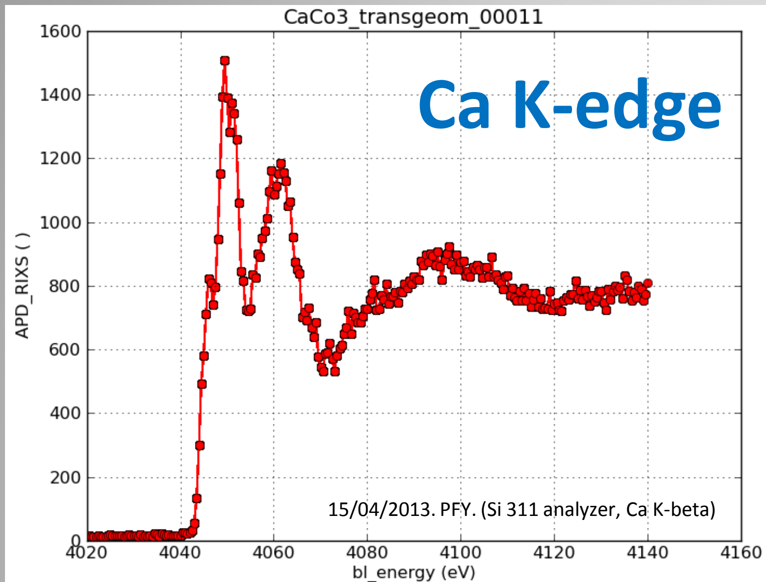


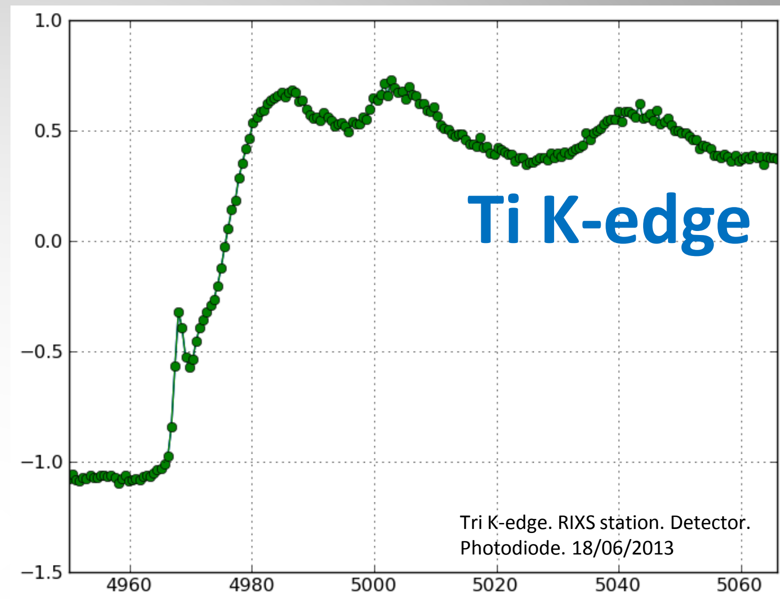


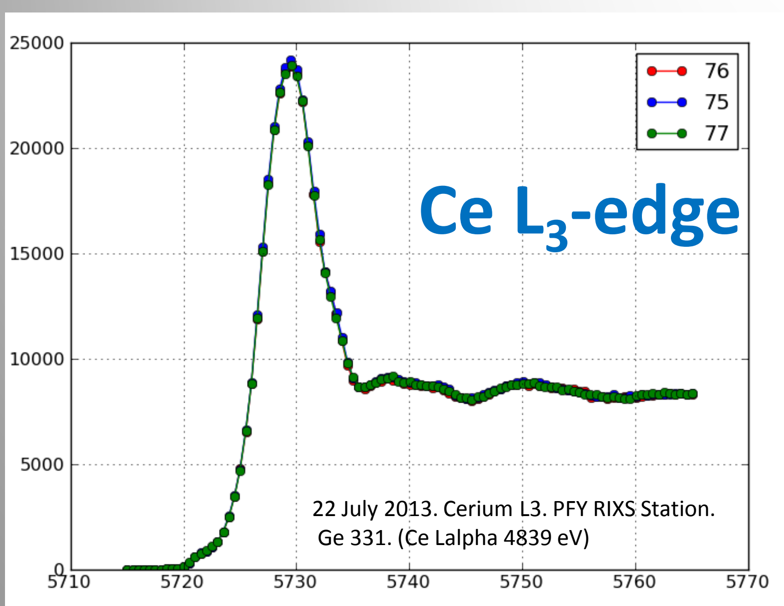


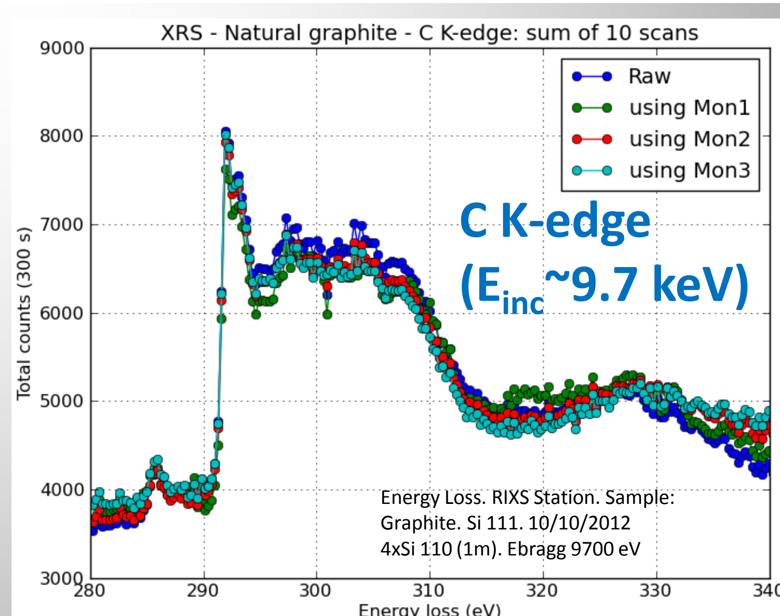


Example Energy Scans









Gold L_3-edge and Argon K-edge measurements (HAXPES station)

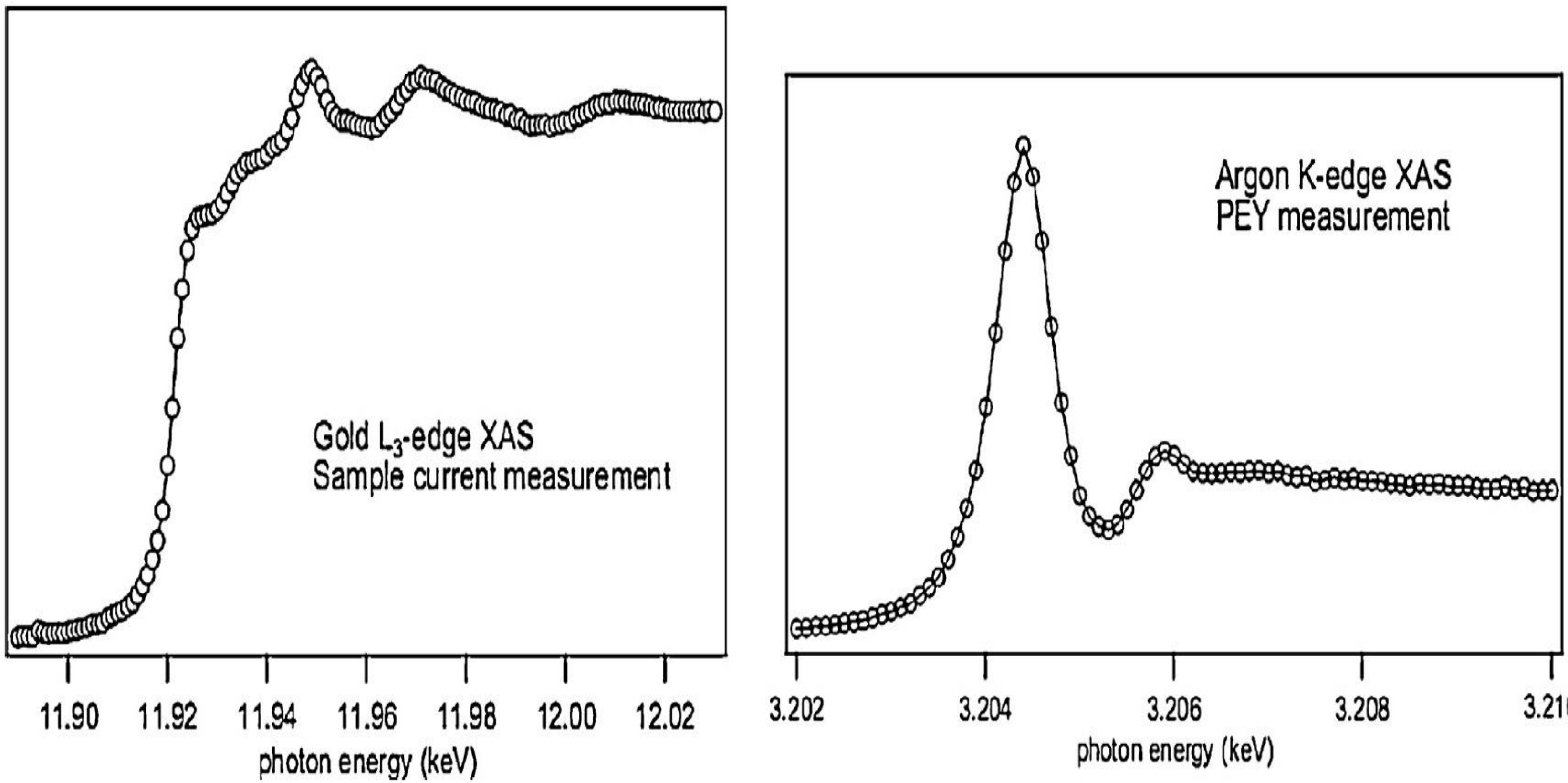


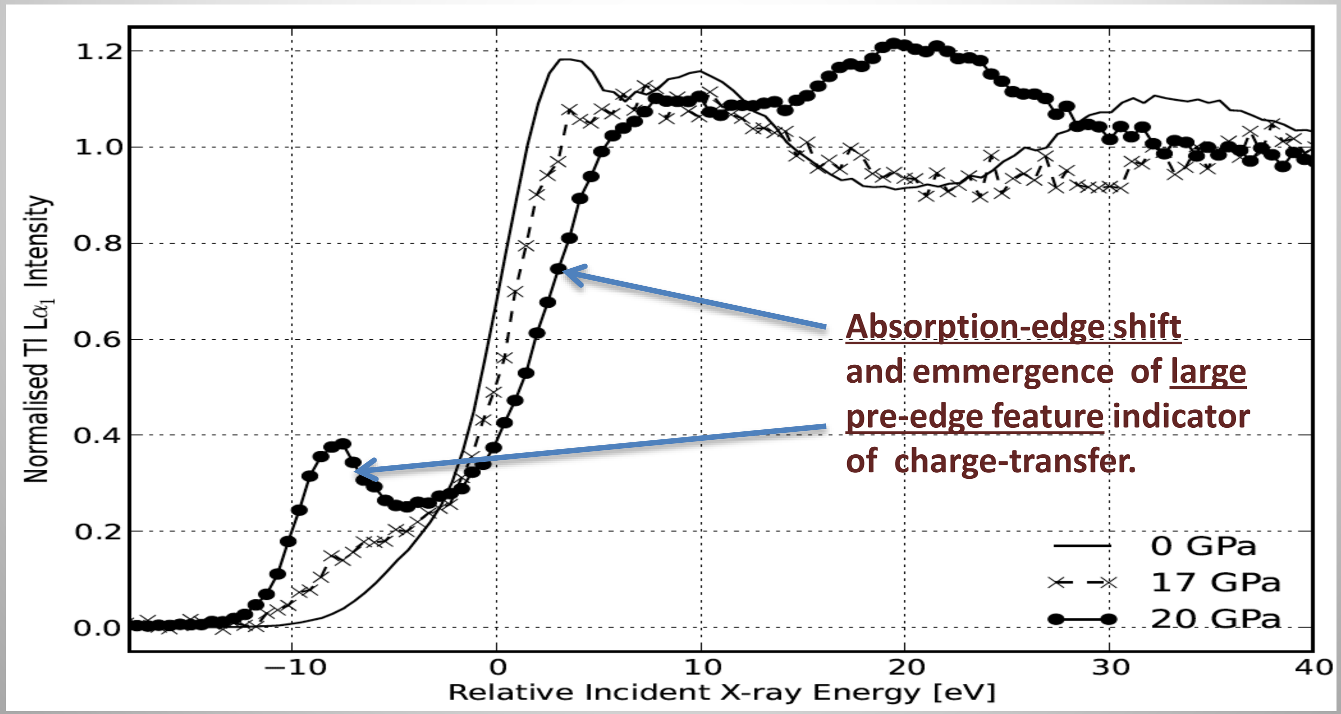
Fig. 5. Au L_3-edge XAS measured using the sample current and Ar K-edge XAS measured using the partial electron yield.

Experimental Study: High-Pressure XANES study of $TlReO_4$

"High-Pressure Induced Charge Transfer in Thallium-Rhenium Oxide at Room Temperature", J. M. Ablett et al., in preparation

- ❑ ***Technique: High Energy Resolved Fluorescece Detected XANES (HERFD XANES) using DAC***
- ❑ ***2 Analysers (Si 555). 1m radius. Bragg Angle 74.2^o (10269 eV, Tl L□$_{1:}$ 3d$_{5/2}$□2p$_{3/2}$)***
- ❑ ***X-ray Energy Scans around the Tl L_3-edge (12658 eV).***

Proposed high-pressure charge transfer: $Tl^{1+}(Re^{7+}O^{4-})^{-1} \rightarrow Tl^{3+}(Re^{5+}O^{4-})^{-3}$
(Jayaraman et al., PRB 36(16) 8547, 1987.)



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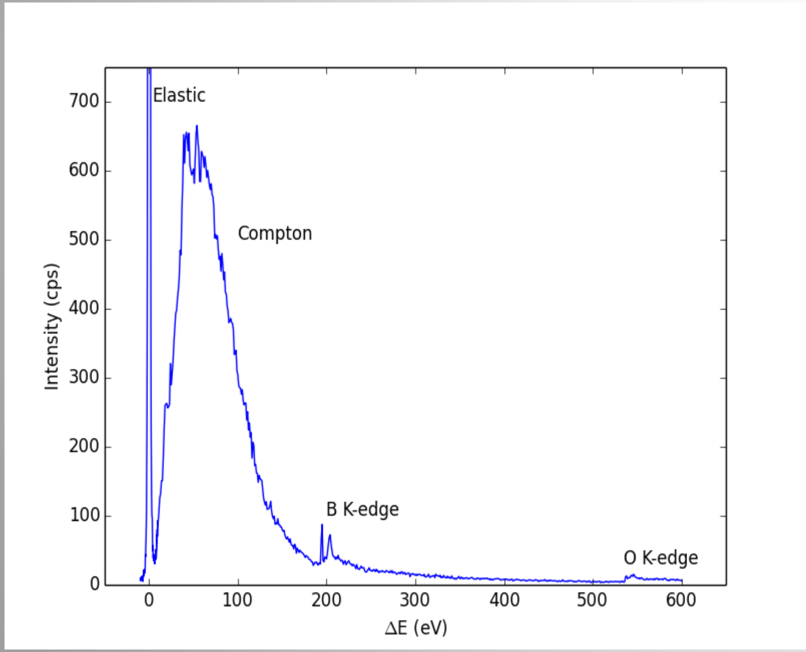
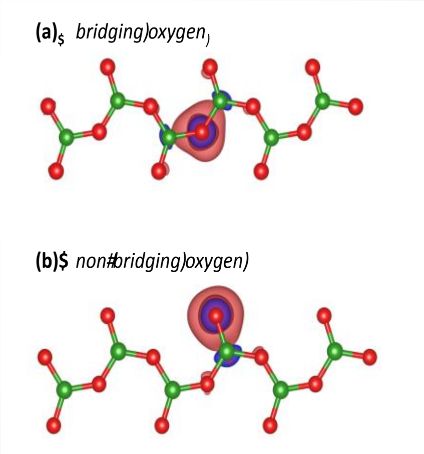
Experimental Study: Non-resonant IXS on Lithium Borate Systems

"Spectroscopic signature of non-bridging oxygen in the O K-edge of lithium borate crystals using inelastic X-ray scattering: an experimental and theoretical study", G. Lelong et al., submitted to Inorganic Chemistry.

- *Technique: Non-resonant IXS (Energy Loss)*
- *4 Analysers (Si 660). 1m radius. Bragg Angle 86^o (9720 eV)*
- *X-ray Energy Scans around the Oxygen K-edge (10255 eV)*

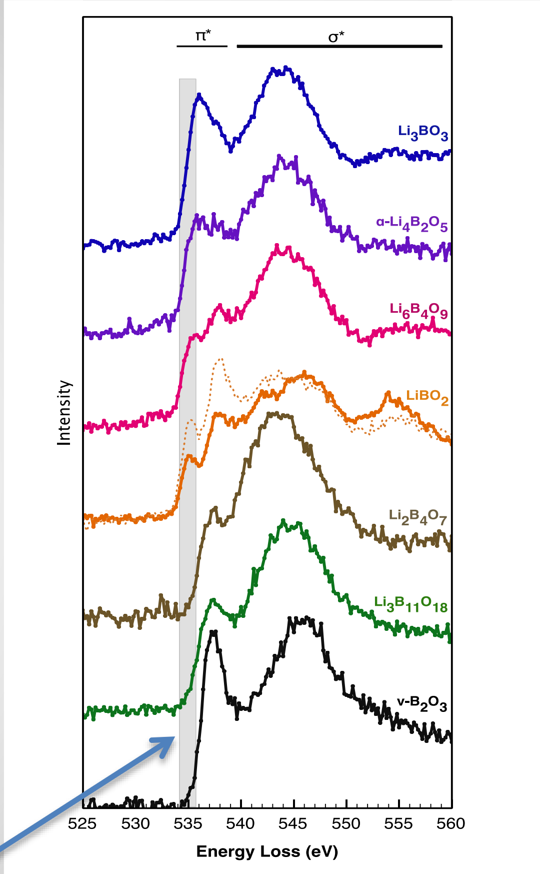


Wide-range energy-loss spectra on lithium borate crystal, clearly showing the B K-edge, OK-edge, the elastic peak, the Compton profile, as well as other features.



Calculated core-hole screening maps for a bridging oxygen (a) and a non-bridging oxygen (b) in the case of $LiBO_2$.

Grey-area : spectral signature of non-bridging oxygen atoms



O K-edge IXS spectra for the six crystalline compounds of the Li_2O-B_2O_3 system.

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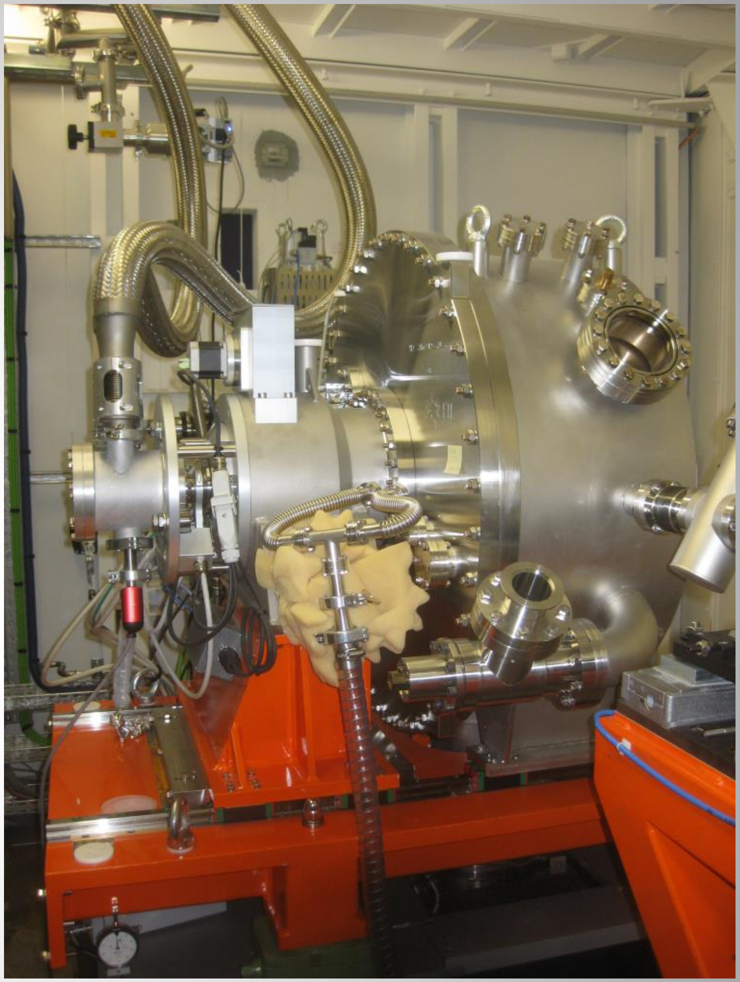
Conclusions

- CINEL DCM successfully designed and then installed on GALAXIES in February 2010.
- No major problems encountered with system to date.
- CINEL extremely cooperative throughout design phase (piezo mount redesigned), installation, and with small problems encountered afterwards (thermocouple breakage, position of limit switch on Tz).
- We also use Si 333 and Si 444 reflections for higher resolution measurements.
- Feedback to be implemented in future using 2nd xtal piezo.



"The GALAXIES Beamline at the SOLEIL Synchrotron: Inelastic X-ray Scattering and Photoelectron Spectroscopy in the Hard X-ray Range", J.P. Rueff et al., submitted to Journal of Synchrotron Radiation.

"Hard X-ray Photoelectron Spectroscopy on the GALAXIES beamline at the SOLEIL synchrotron.", D. Céolin et al., *Journal of Electron Spectroscopy and Related Phenomena, 2013, 190 part B: 188–192*

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http://www.synchrotron-soleil.fr/Recherche/LignesLumiere/GALAXIES

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