Hard X-Ray Monochromators at PETRA III

evolution and status

Horst Schulte-Schrepping, DESY FS-BT
DCM workshop, ESRF, 2014

Acknowledgments

More or less chronological…

Carsten Detlefs and the ID6 team, Philippe Marion, Anatoly Snigirev

Ulrich Hahn, Joachim Heuer, Mathias Hesse, Hans-Christian Wille

Jan Horbach, Hans-Bernhard Peters

Hartmut Lüdecke, Alexander Donath, Gerald Falkenberg

Karen Appel, Edmund Welter, Roman Chernikov

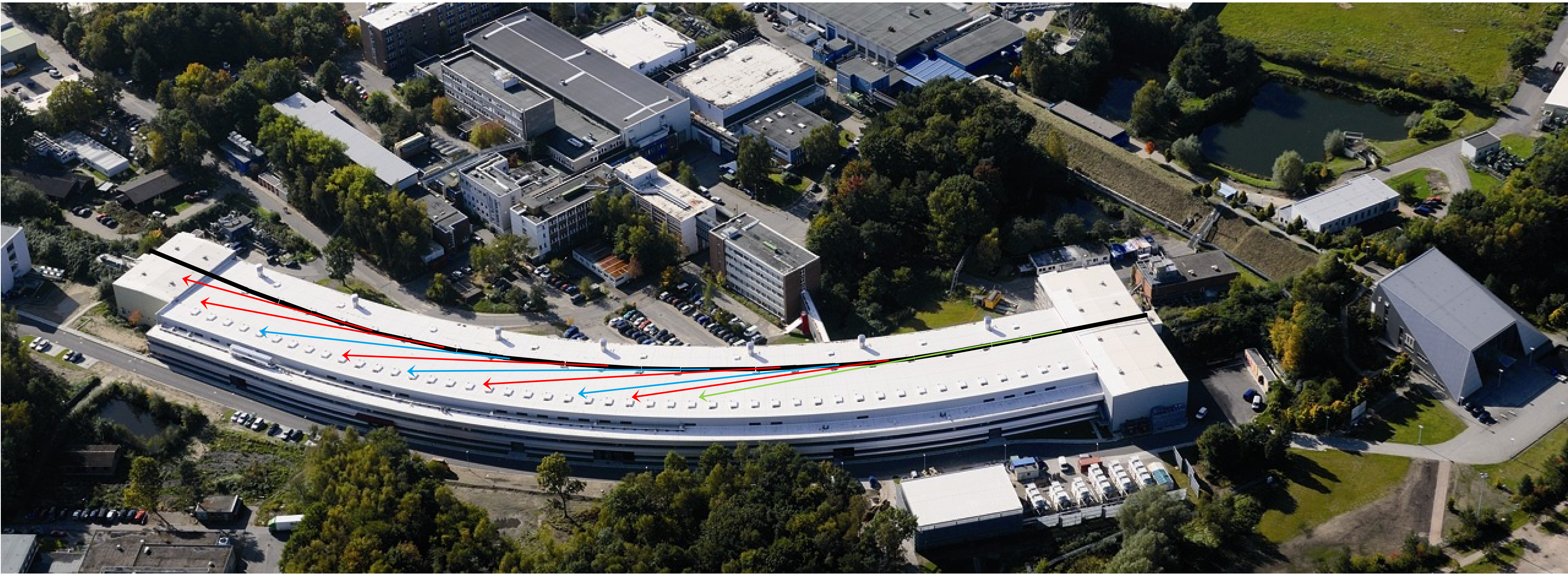
Ralph Döhrmann, Ilya Sergeev

and all

DESY FS-BT colleagues

PETRA III colleagues

PETRA III



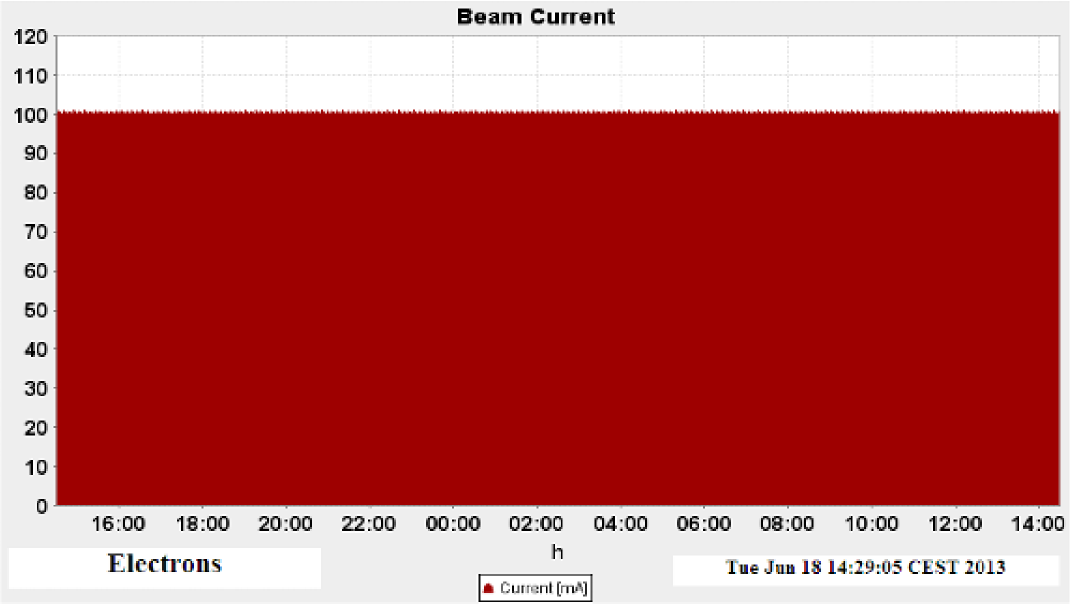
- particle energy: 6 GeV
- stored current: 100 mA (top-up)
- emittance: 1 nmrad
- circumference: 2304 m
- sectors: 9
- # of undulators: 14 (2*2m canted, 5m single, 10m single)
- beamline length: 70 - 100 m

- built in 1978
- rebuilt as a synchrotron radiation source in 2007/08
- commissioning since 2009
- user operation since 2010

PETRA III Extension Halls East and North

100 mA Top-Up Operation

PETRA Energy: **6.084** GeV Lifetime: **12.04** h Current: **100.87**mA



Und.	Gap	Status
PU01a	25.42	
PU01b	25.61	
PU02	10.00	
PU03	10.21	
PU04	22.19	
PU05	11.22	
PU06	11.46	
PU07	10.31	
PU08	11.82	
PU09	18.80	
PU10	10.96	
PU11	15.68	
PU12	20.05	
PU13	101.00	
PU14	11.01	

Number of Bunches: **960** Mean Vacuum Pressure: **1.529E-08** mbar

Orbit Control: **On** Top-Up Operation: **1.02 mA (Max-Min)**

User Operations->Experiments

User run, 960 bunches, 100 mA

Hard X-ray Monochromators at PETRAIII

Evolution of the High-Heatload DCM at PETRAIII
- **channel-cut integration**
- **undulator/monochromator scanning**

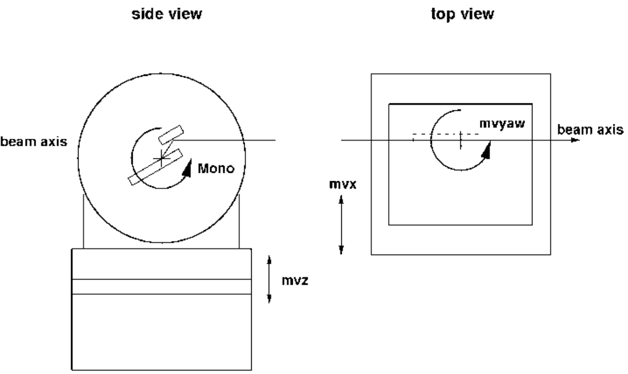
Systems for canted undulator sectors: solutions for a geometrical constraint

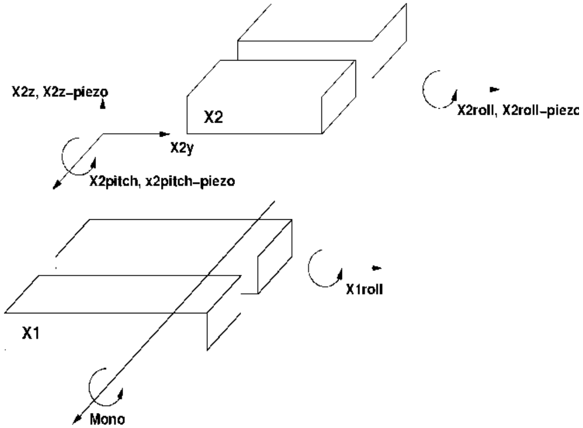
Special systems
- **diamond – silicon Laue monochromator at P02.1**
- **Multilayer monochromator at P06**

"(not so) Oldies but Goldies"
- **DORIS C-Type DCM for PETRA III Extension beamlines**

DCM Specifications, Prototypes 2005 and Series 2008

cryogenically cooled, 2 crystal systems, 20-24mm offset, Bragg direct drive

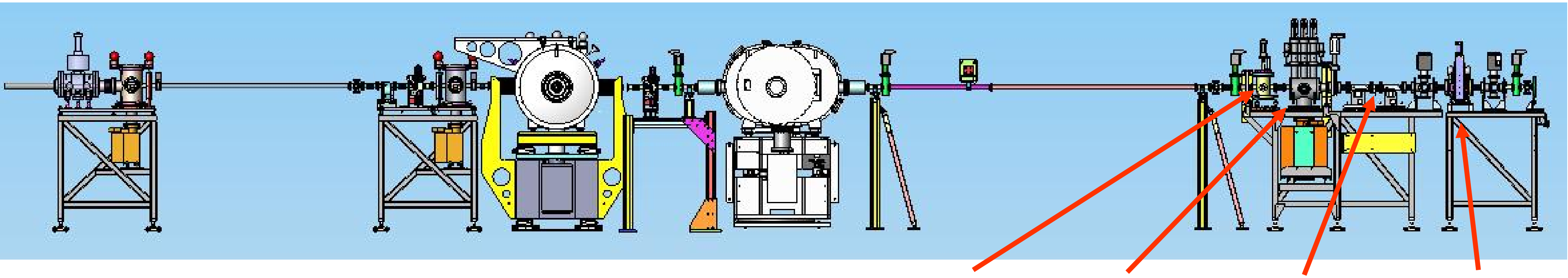


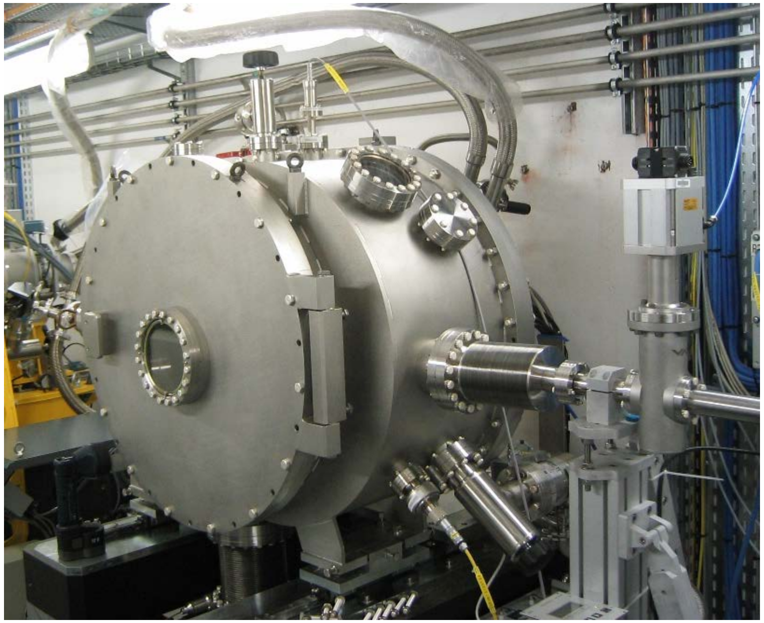


Motion	Range	Accuracy	Resolution
mvx	±40 mm	±0.010 mm	0.005 mm
mvz	±10 mm	±0.02 mm	0.002 mm
mvyaw	±1°	±0.01°	0.001°
Mono range	**2.1° - 55.5°**	**±0.1 arc sec**	
Mono step		**0.05 arc sec ~ 240nrad**	**±0.01 arc sec ~ 48nrad**
X1roll	±1.0°	±0.001°	0.0001°
X2pitch	**±1.0°**	**±0.0005°**	**0.0001°**
X2pitch-piezo	**±0.002°**	**±0.00001° ~170nrad**	**0.000001° ~ 17nrad**
X2roll	±1.0°	±0.001°	0.0001°
X2roll-piezo	±0.02°	±0.0005°, feedback	0.0001°
X2y	290 mm	±0.005 mm pitch < 0.0001°/ 1mm	0.001 mm
X2z	15 mm	±0.005 mm pitch < 0.0001°/ 1mm	0.001 mm
X2z-piezo	**±0.025 mm**	**±0.0001 mm,feedback**	**0.00005 mm**

ESRF/ID6 Test Installation

Setup of the optics hutch at ID06 of the ESRF; length 15m

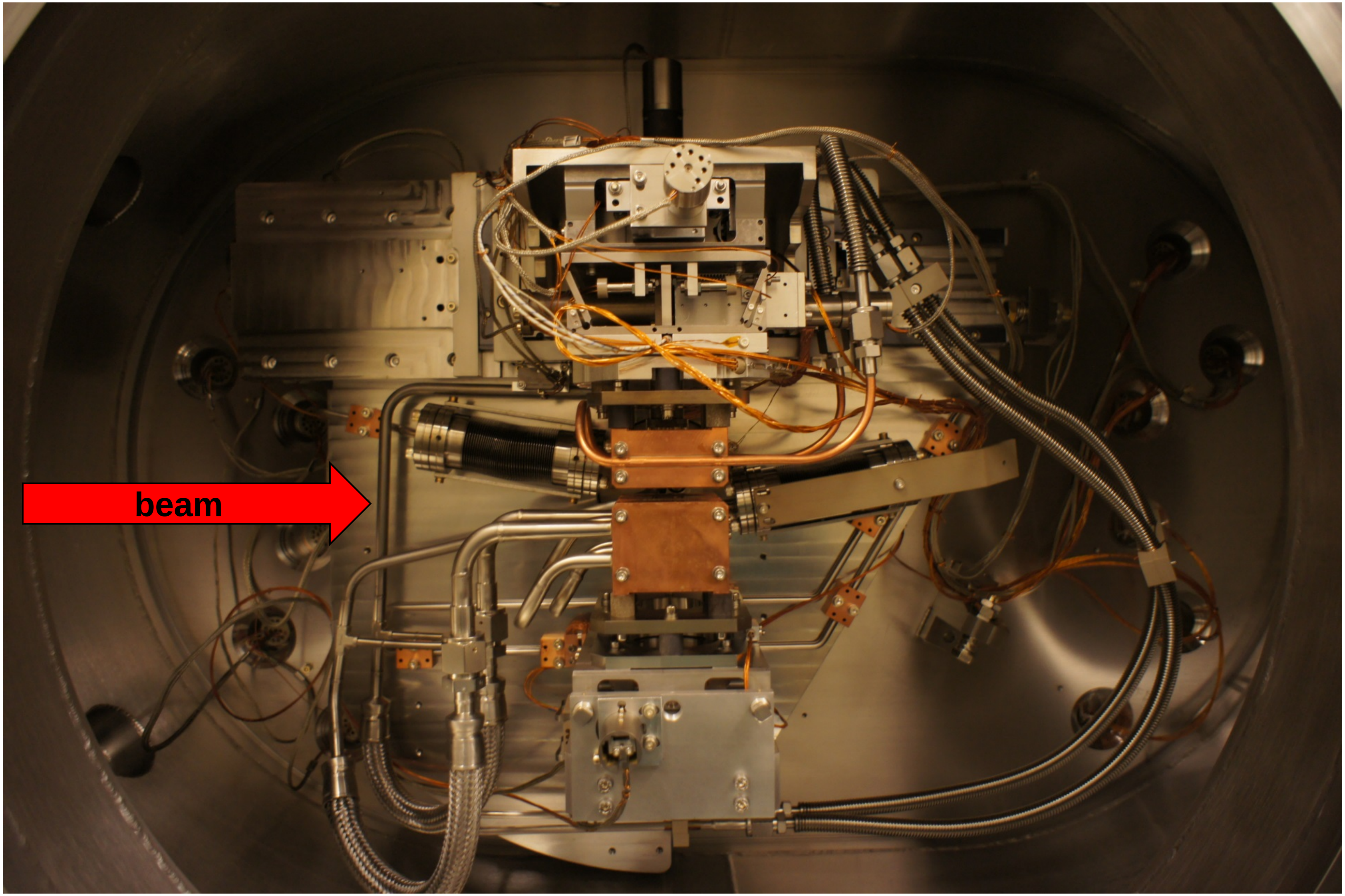




Targets:
- **Stable fixed exit**
- **Maximum reflectivity, theoretical resolution**
- **Coherence conservation**
- **Tunability in a wide energy range (2kev – 100keV)**
- **pink beam: HHLM to cope with heat load ~1kW.**

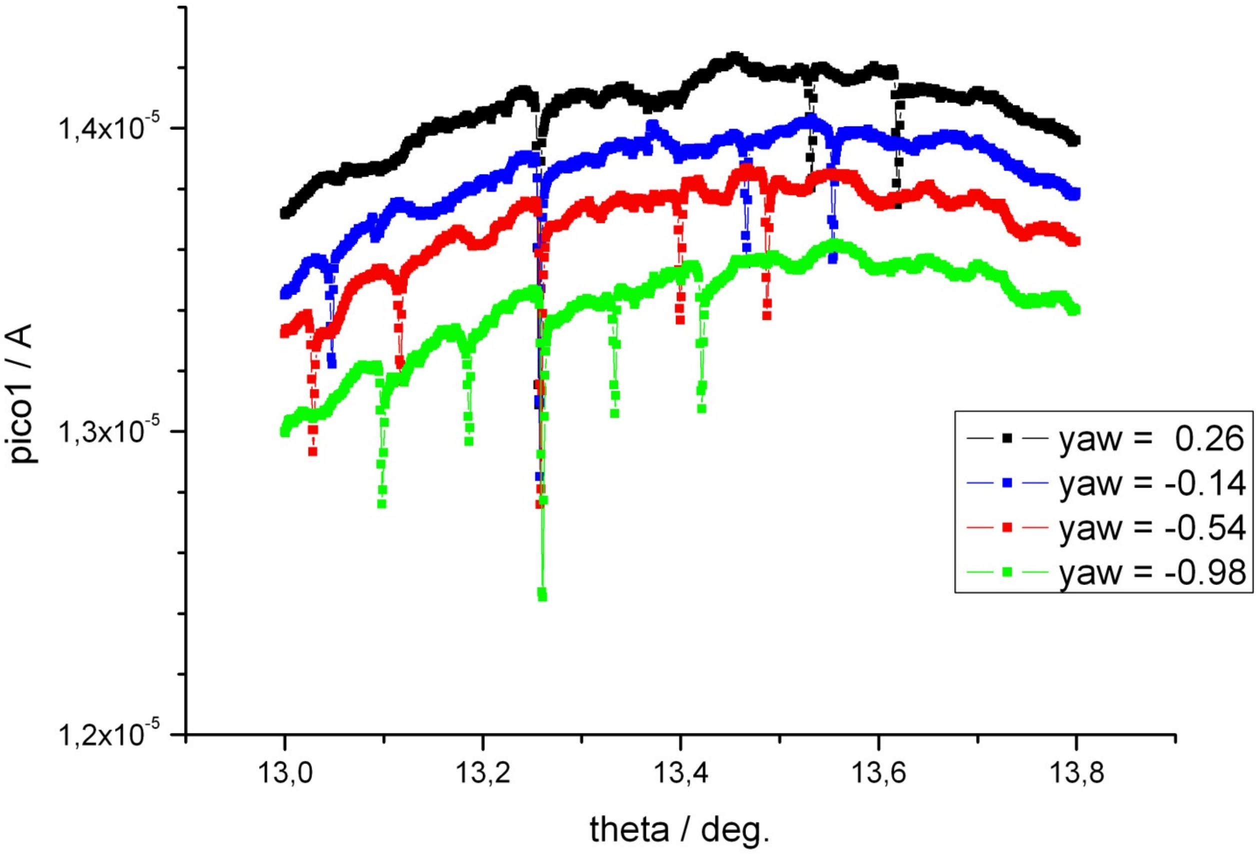
Since Feb 2008 beam from in-vacuum undulator (P=18mm, min. gap=6mm) + standard U34mm (12mm gap) . 500W / 200W in 2mm x 1mm resp.

DCM mechanics

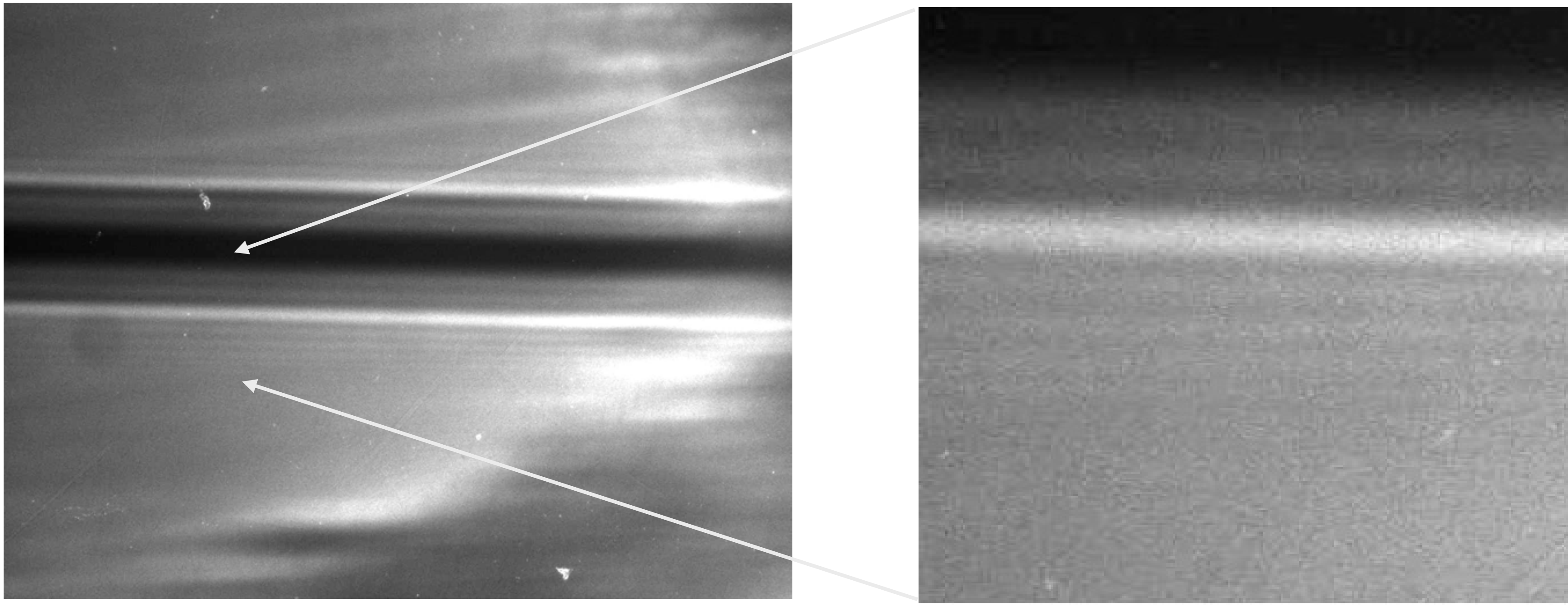


DCM mechanics at home position, 0 degree Bragg, 0 mm parallel axis

Special Feature: Yaw Axis Glitch Tuning



Apparent Source Size: Sensicam



@ 54Hz pump frequency

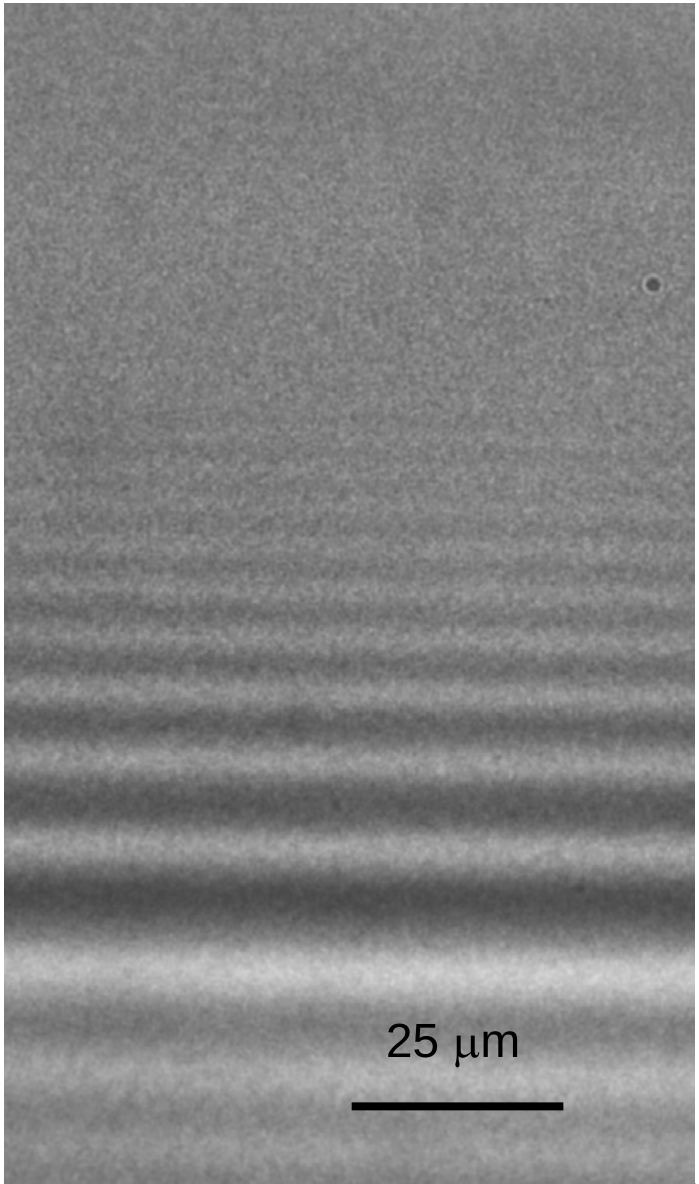
zoom

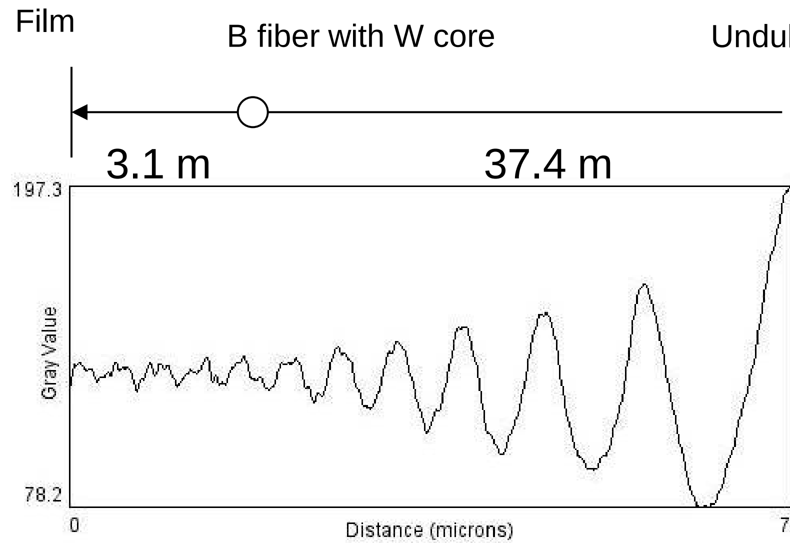
E = 13.5 keV

Source to fiber = 54 m, Fiber to camera = 5.3 m

eff. source size best about = 50 µm

Apparent Source Size: Film





Cryo-pump frequency 38 Hz
Up to 10-11 fringes are visible

E = 14 keV
Source-to-fiber = 37.4 m, Fiber-to-film = 3.1 m
Last visible inter-fringe distance = 3.6 µm

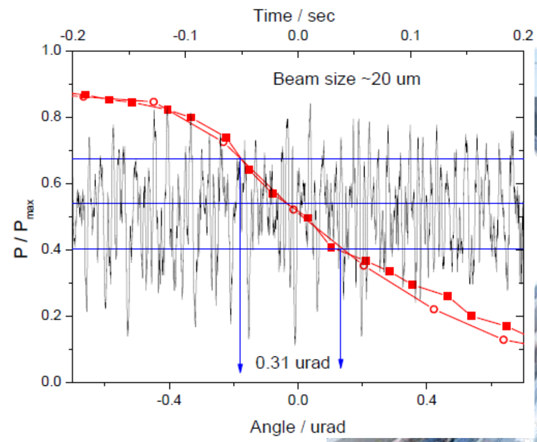
eff. source size 3.6µm*(37.4/3.1) = 44 µm
(theoretical high β value from machine group vert. FWHM = 23 µm)(year 2000 measurement high β ID22 FWHM = 35 µm)
Measurement by A.Snigirev/ESRF

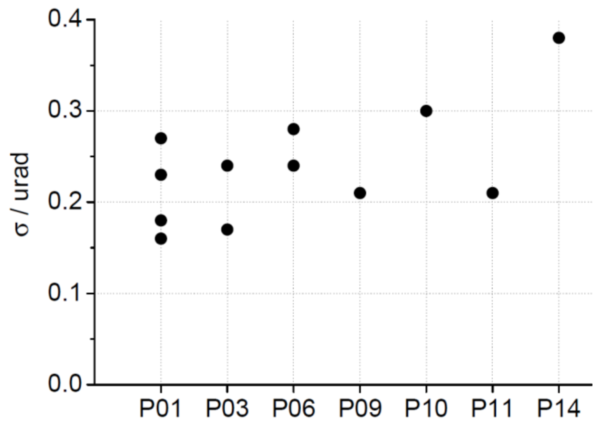
PETRA III and the present state of the DCM

> 14 Beamlines P01-P14
  - 8 standard Oxford-DCM
  - 2 LOM
  - 3 modified Oxford-DCM/EMBL
  - 5 other types (3*Laue, XUV, Multilayer)

> Beam vibrations from 0.15 µrad to 0.4 µrad

> Goal: 50nrad, down to ??

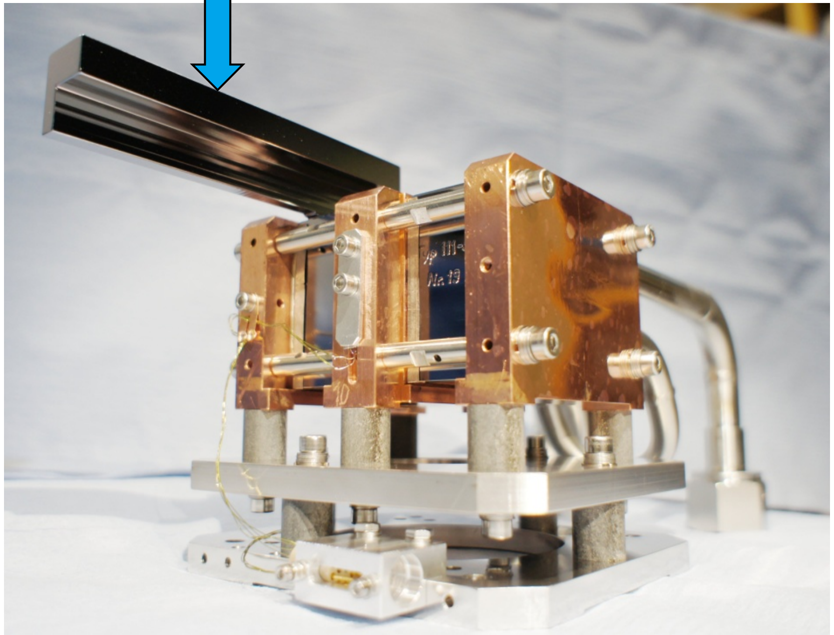




Ilya Sergeev

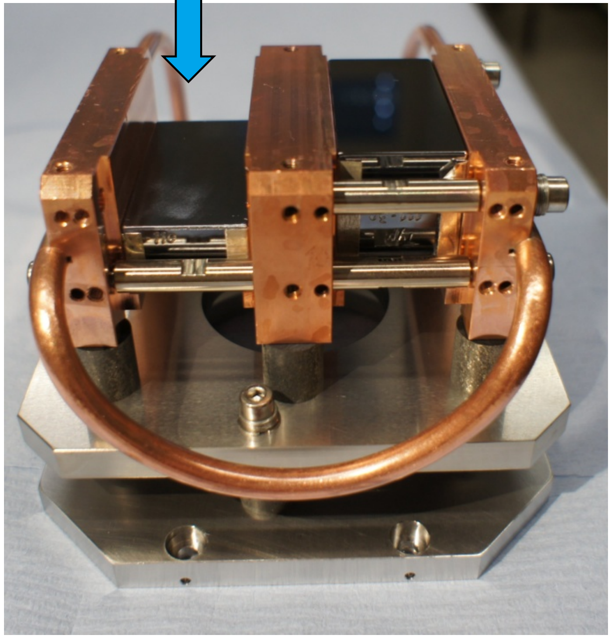
Integration of a Channel-Cut

channel-cut crystal without weak-link



first crystal set

cut-out for channel-cut

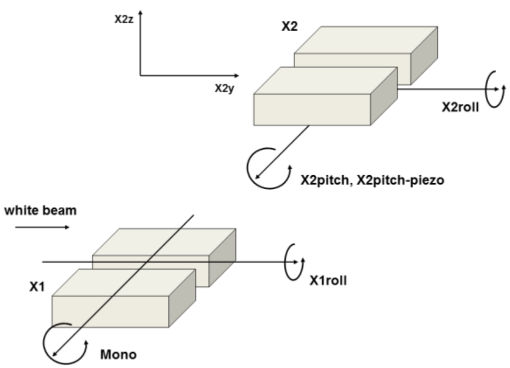


second crystal set

Channel-Cut crystal system integrated into the high heatload fixed exit design.

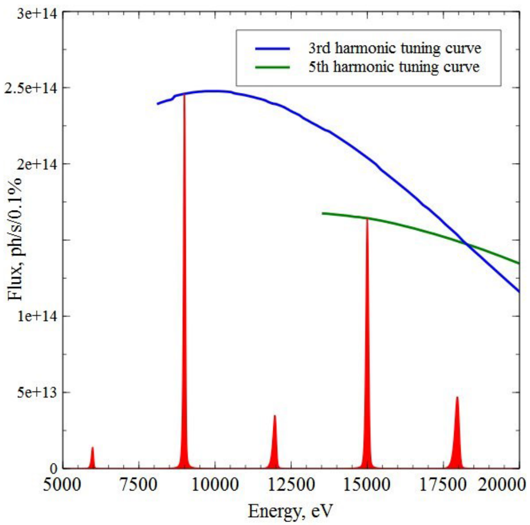
DCM Specifications 2012 for PETRAIII-Extension

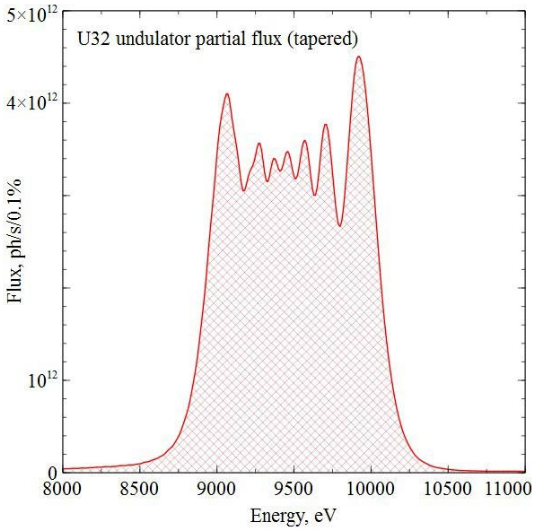
Red: parameters/definitions from 2008 DCM specification



Motion	Range	Repeatability (Accuracy)	Min. Step Resolution for setpoint position (Resolution)
mvx	±40 mm	±0.010 mm	0.005 mm
mvz	±10 mm	±0.02 mm	0.002 mm
mvyaw	±1°	±175µrad	17.5µrad
Mono range	2.1° - 55.5°	±240nrad	
Mono step			100nrad
X1roll	±0.5° (±1.0°)	±17.5µrad	1.75µrad
X2pitch	±0.5° (±1.0°)	±17.5µrad	1.75µrad
X2pitch-piezo	±35µrad	±175nrad	17nrad
X2roll	±0.5° (±1.0°)	±0.001°	0.0001°
~~X2roll-piezo~~	~~±0.02°~~	~~±0.0005°, feedback~~	~~0.0001°~~
X2y	290 mm	±0.005 mm pitch < 0.0001°/ 1mm < 17.5µrad accumulated 150µrad (300µrad)	0.001 mm
X2z	15 mm	±0.005 mm pitch < 17.5µrad/10mm	0.001 mm
~~X2z-piezo~~	~~±0.025 mm~~	~~±0.0001 mm,feedback~~	~~0.00005 mm~~

Scanning at PETRAIII





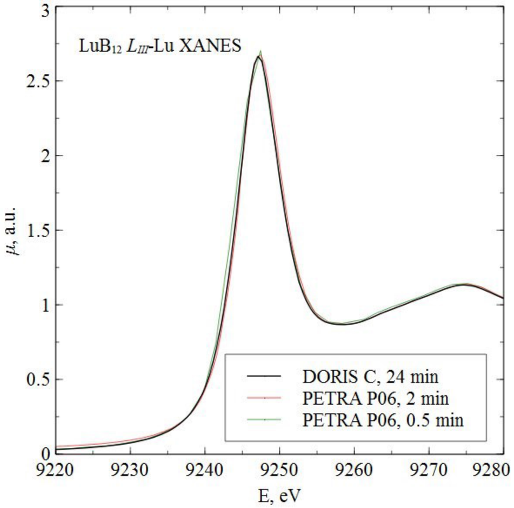
Fast EXAFS measurement in synchronous mode at P06
R. Chernikov, E. Welter, W. Caliebe, G. Falkenberg

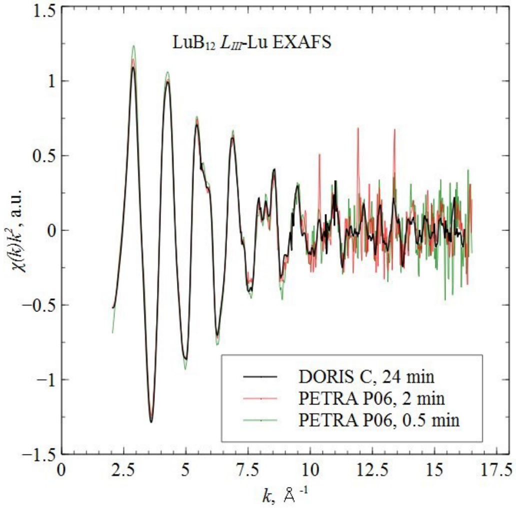
Undulator taper vs. Undulator scanning

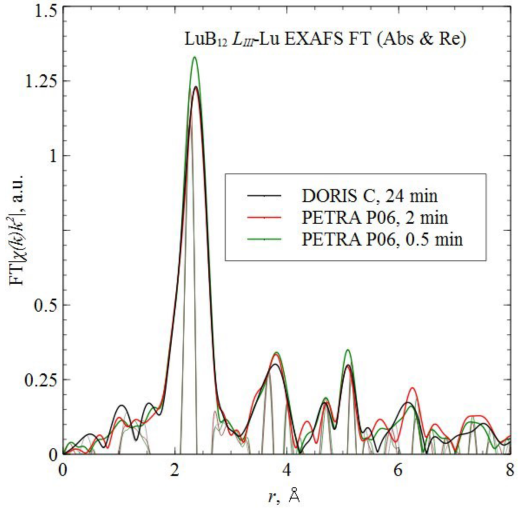
Pros Taper:
- No parts moving in the undulator during the scan
- High reliability
- The scan speed is not limited by the undulator performance

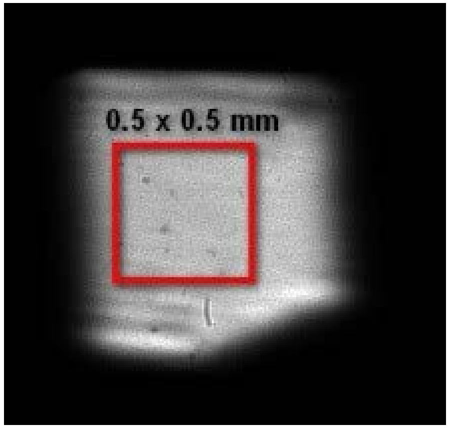
Cons Taper:
- Complicated spatial structure of the beam
- Intensity variation of up to one order within one scan
- Energy bandwidth is limited
- Lower flux comparing to the single peak harmonic scanning

Energy/Undulator Scanning at PETRAIII









boundary conditions:

homogeneous illumination of the sample

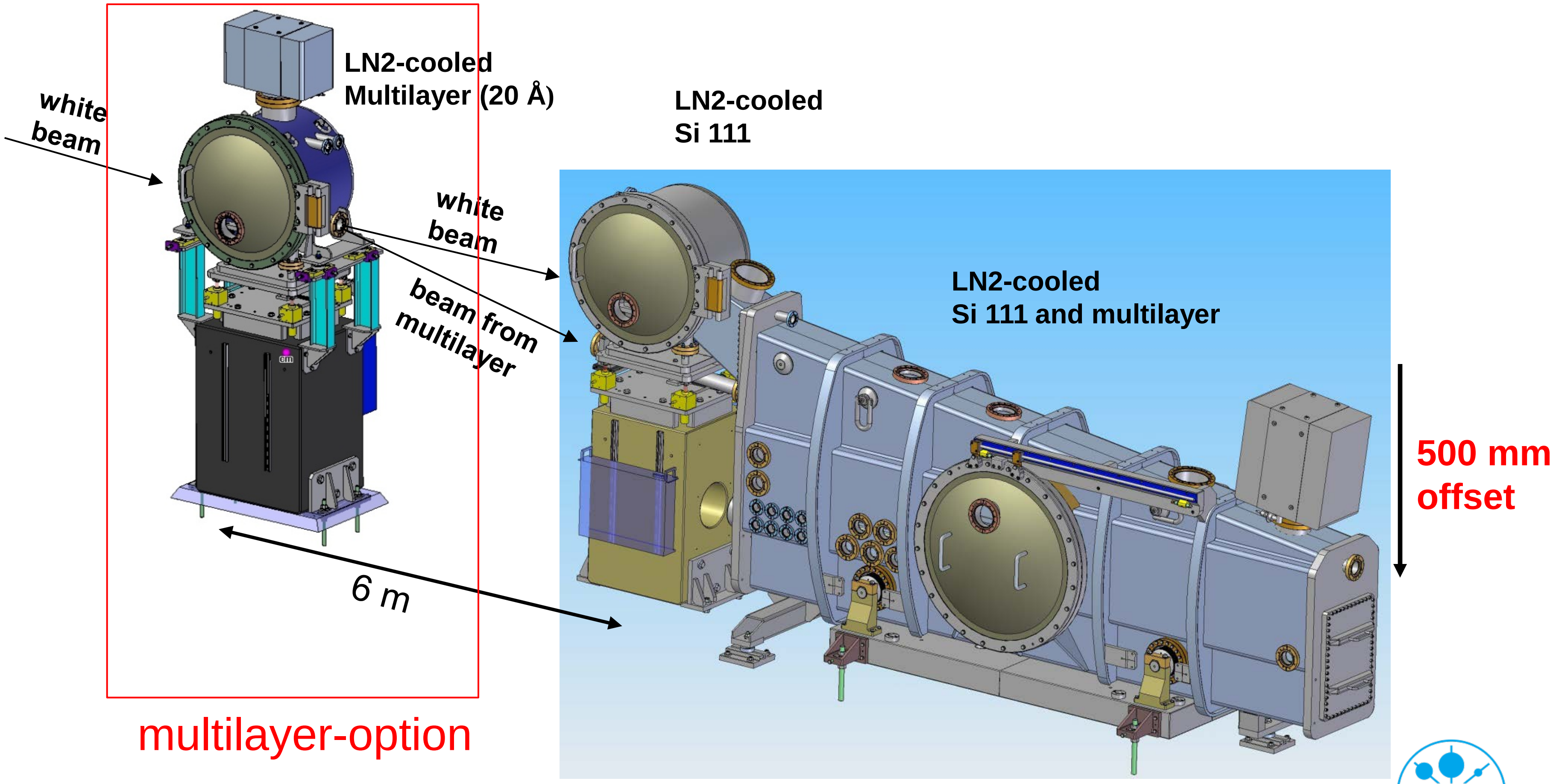
3rd harmonic/monochromator match within 2 eV over 1000 eV

LOM 500 - P03 (Micro and Nano Saxs/Waxs)

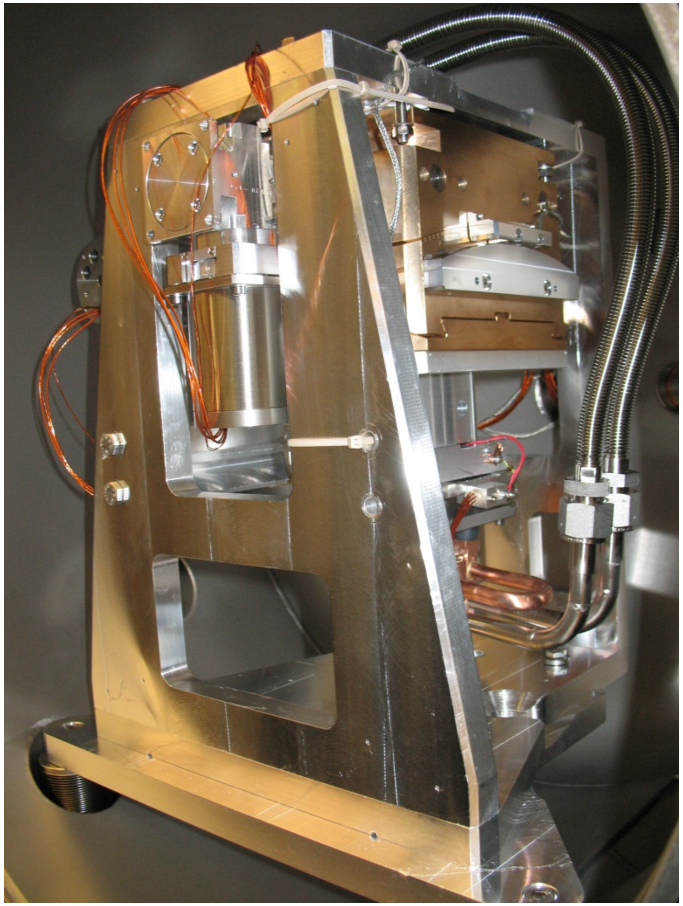
2 different beam paths:

- Si 111 crystal set (8 – 25 keV) and multilayer set (8.4 – 11.5 keV for 20 Å spacing)

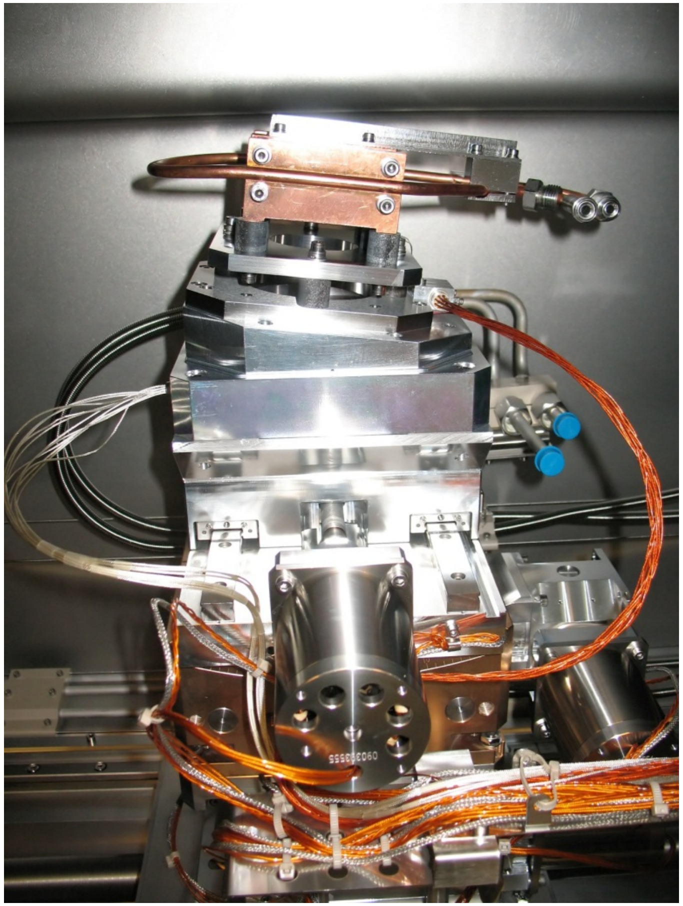
- All optical components are LN2 cryocooled



LOM 500 – crystal set (Si 111)



1st crystal

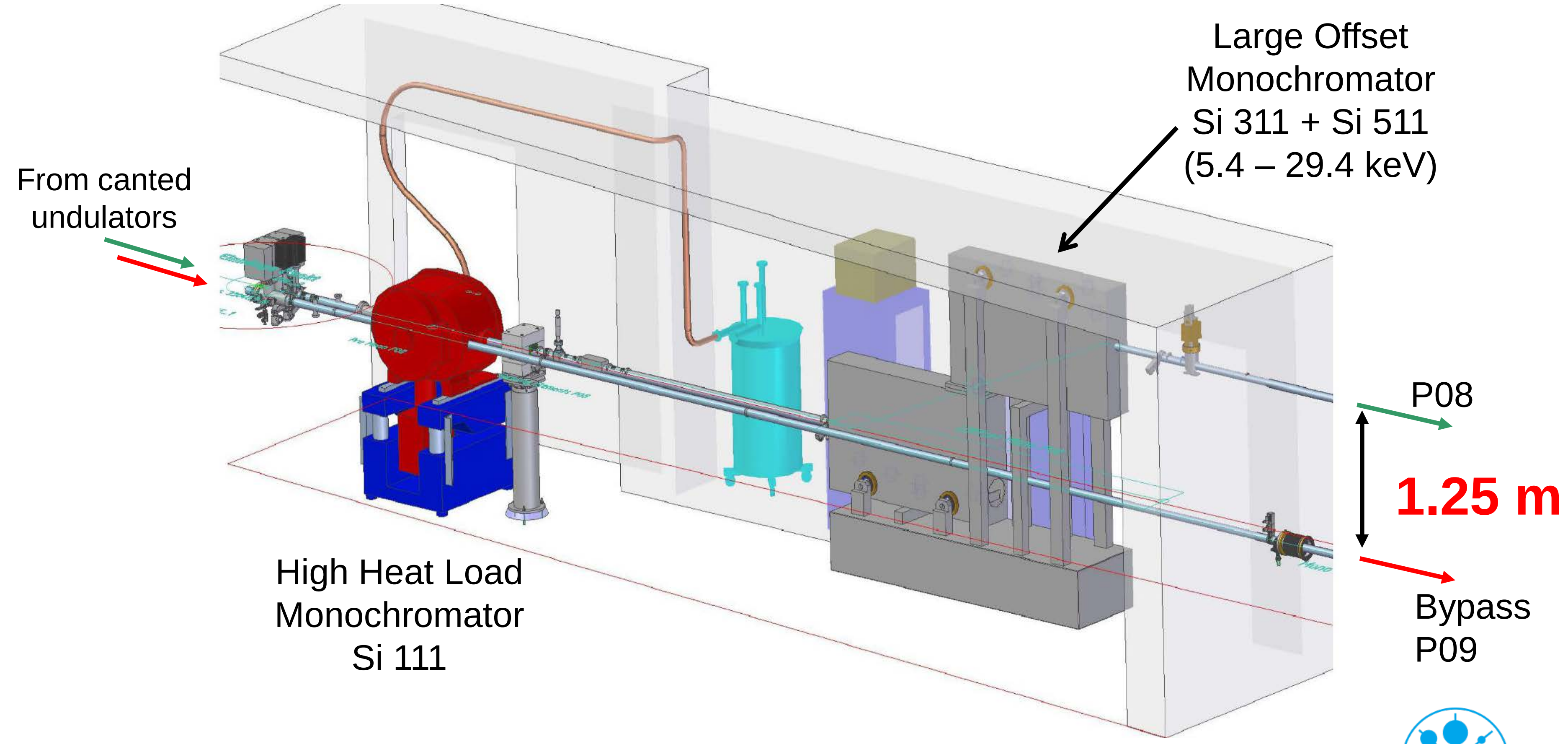


2nd crystal and multilayer option
on 2.5 m translation

LOM 1250 - P08 (High resolution diffraction)

- accepts monochromatic beam from high heat load monochromator

- higher harmonics suppression without additional mirrors



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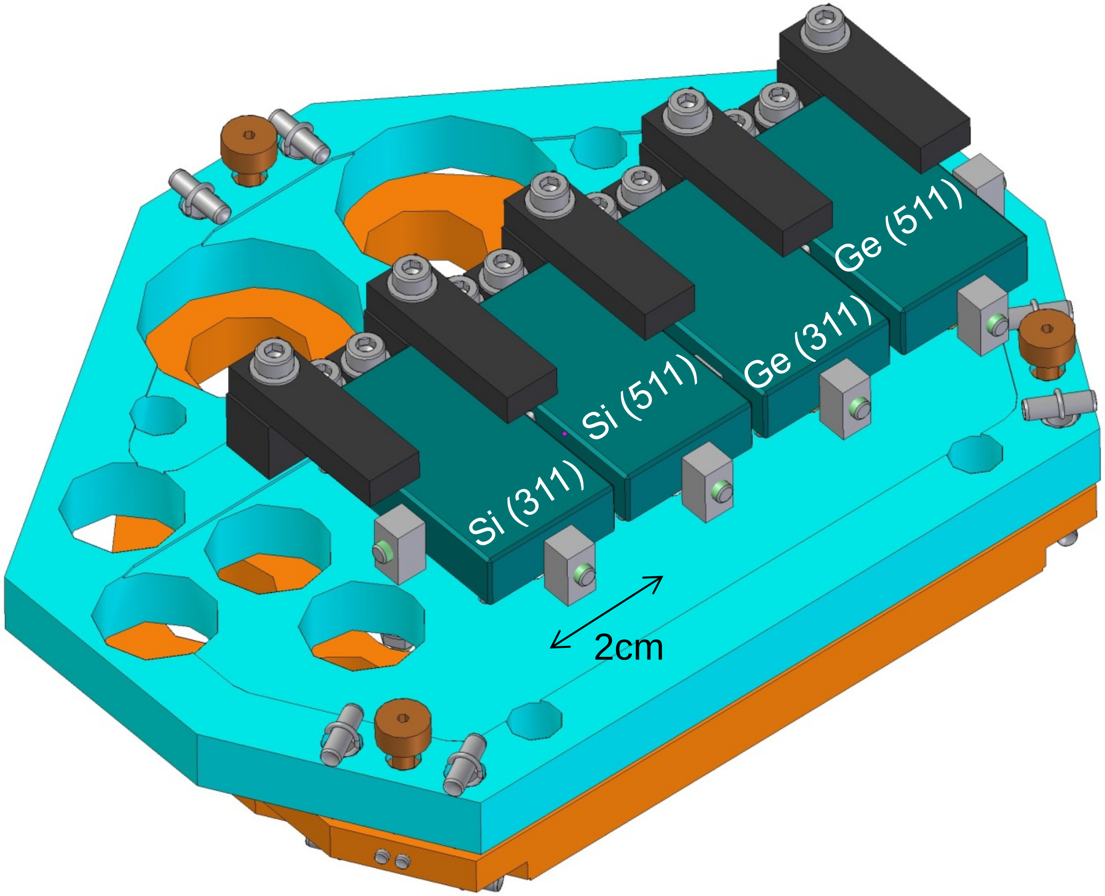
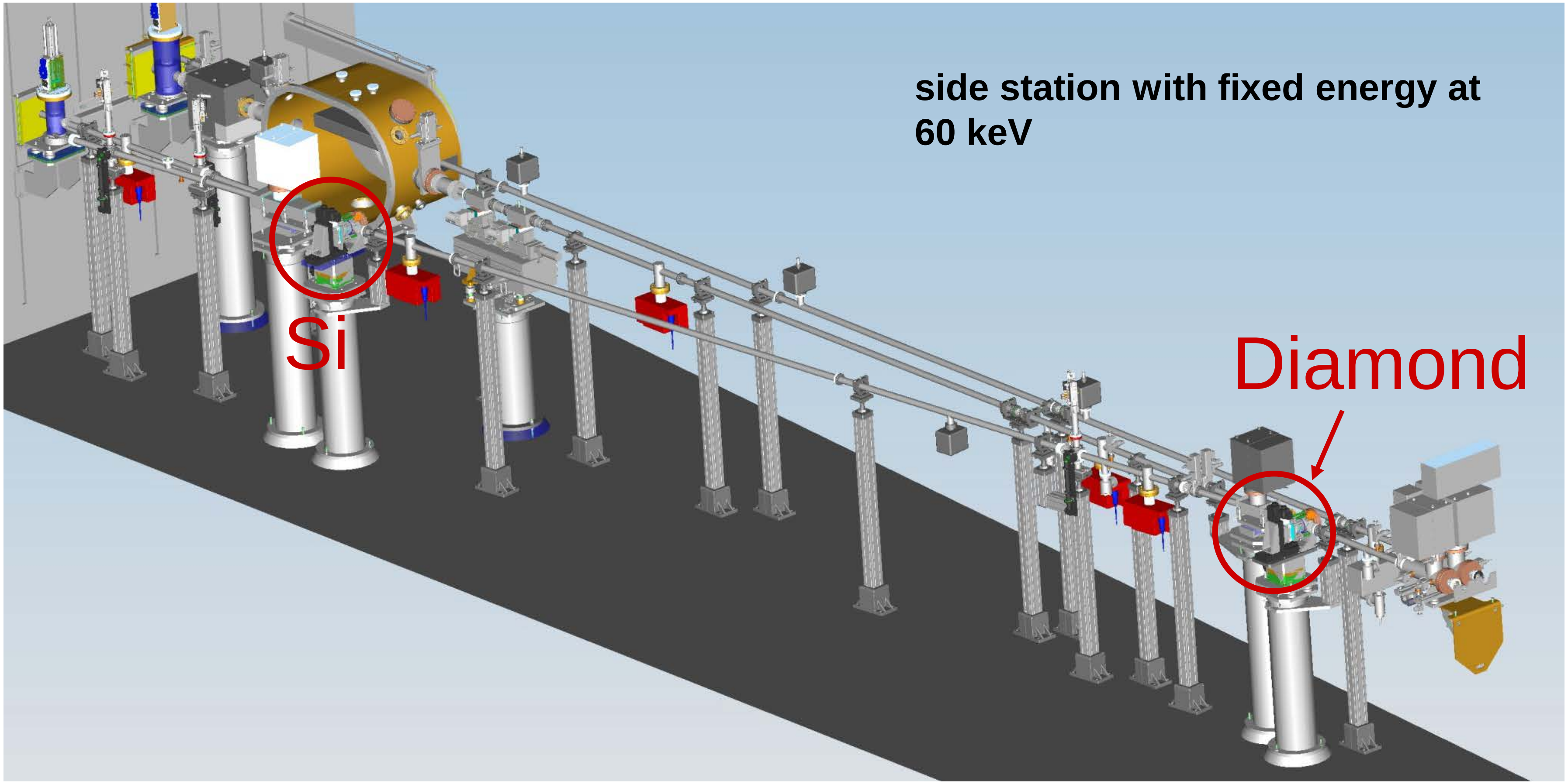
LOM 1250 – upgrade



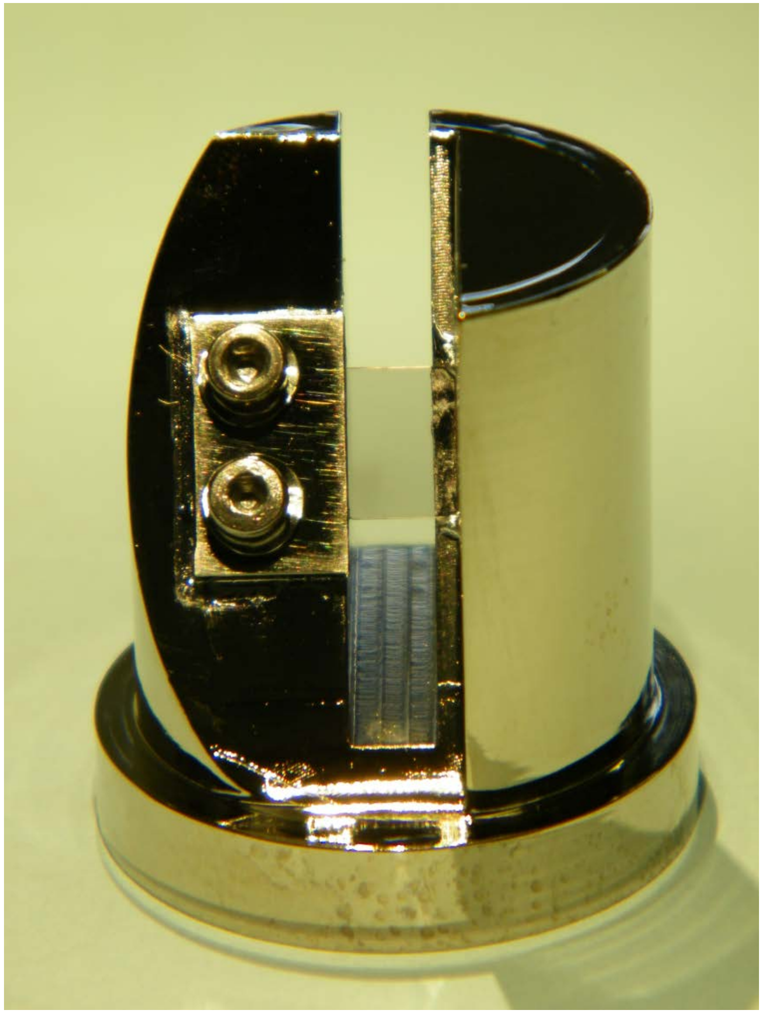
four crystal pairs
adding germanium crystals for higher intensity

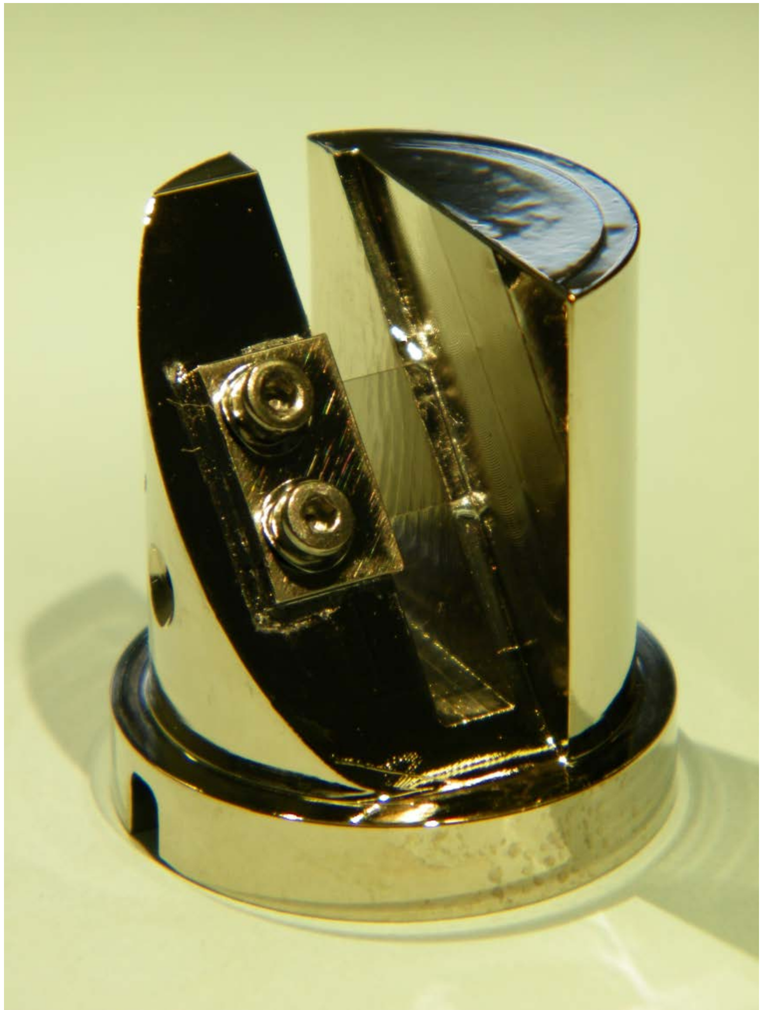
Diamond / Silicon Laue Monochromator at Beamline P02.1

side station with fixed energy at 60 keV



P02.1 Diamond





Mounted (100) E6-Diamond crystal (6.5mm x 6.5mm x 0.4mm)

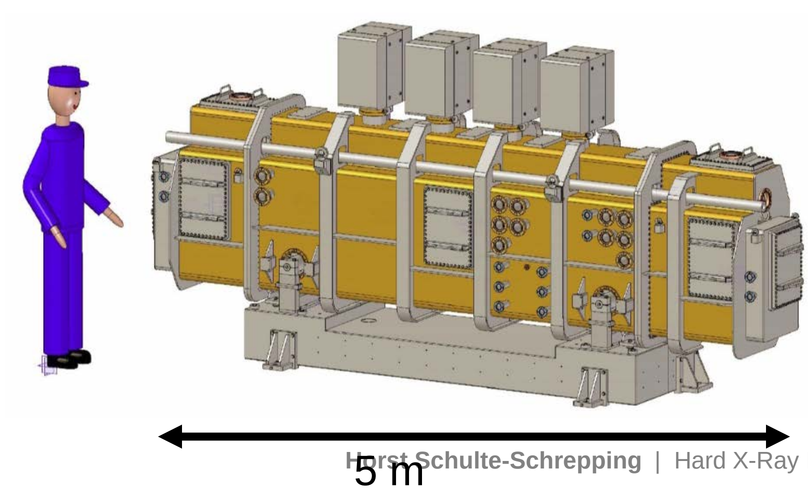
Laue case (111), liquid Gallium/Indium interface, indirect water cooling from the bottom

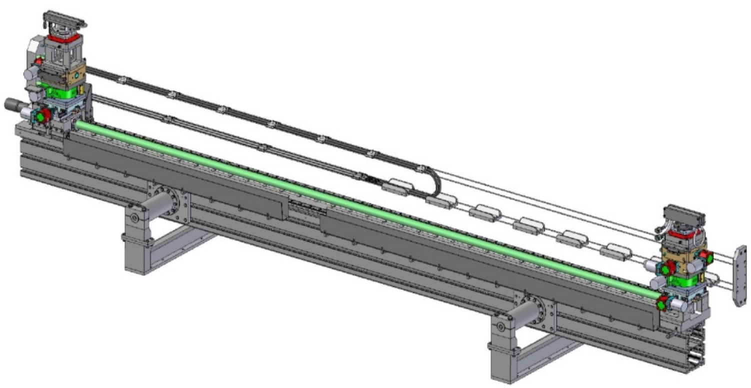
ML06 – LN2 cooled Multilayermonochromator at P06

Developed and build in collaboration with:
A. Donath and H. Lüdecke (DESY-Zeuthen), G. Falkenberg (DESY-Hamburg)

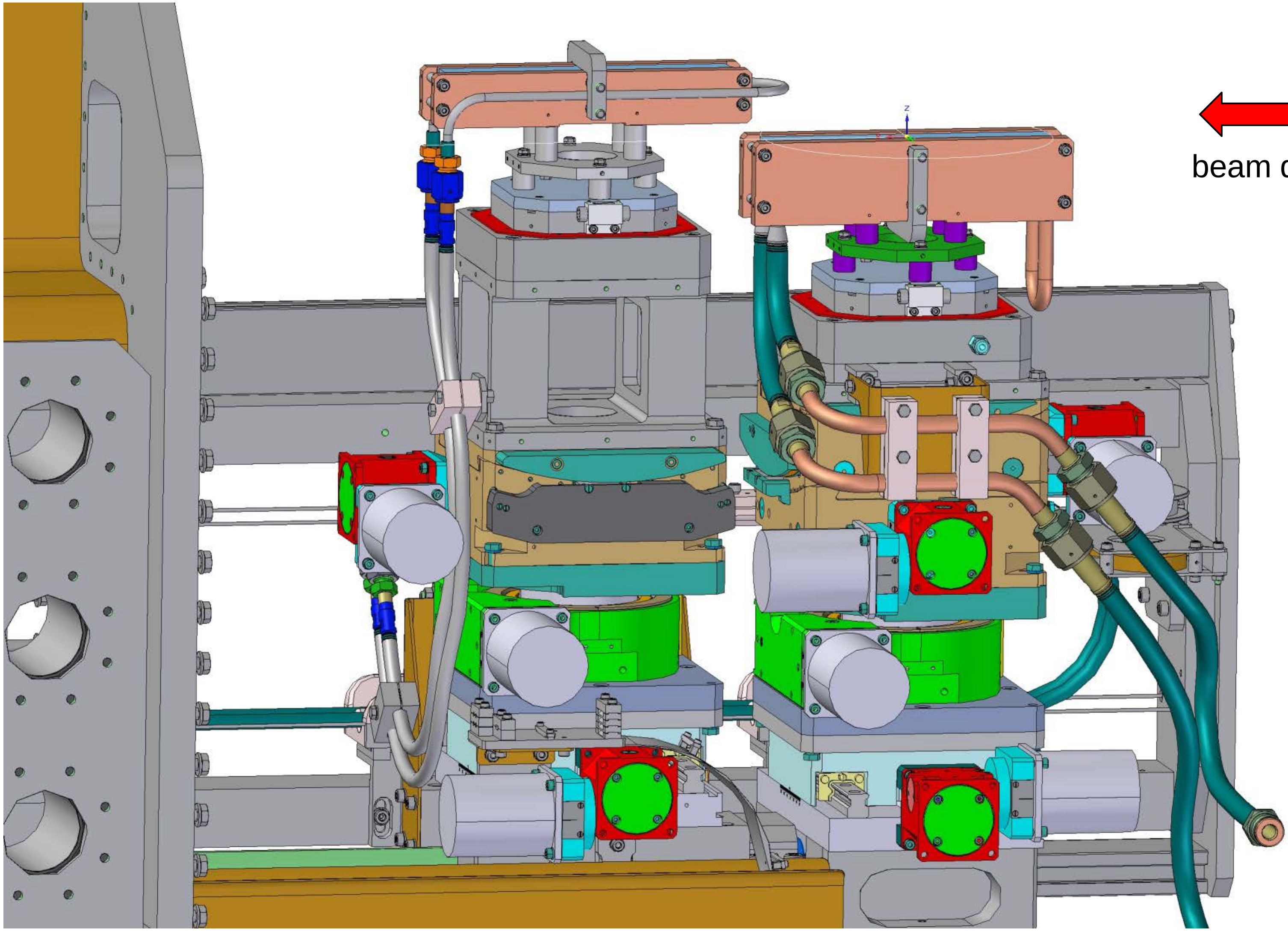
Increased Flux for XRD and Pink beam Laue diffraction

- **Pair of flat Si-mirror (Zeiss) substrates (200 x 25 mm^2)**
- **Coated (AXO) with 2 ML stripes of different d-spacing, 1 metal mirror stripe**
- **Energy range 10 – 100 keV**
- **distance of multilayers: 0.22 - 3.91 m**
- **both crystals cryogenically side cooled**
- **Installation of mechanics in 2011**



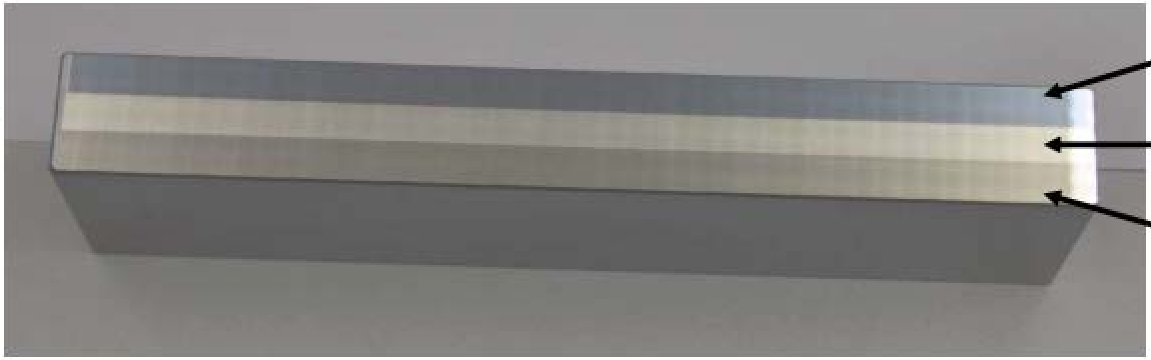


Cryo-cooled Multilayer Set



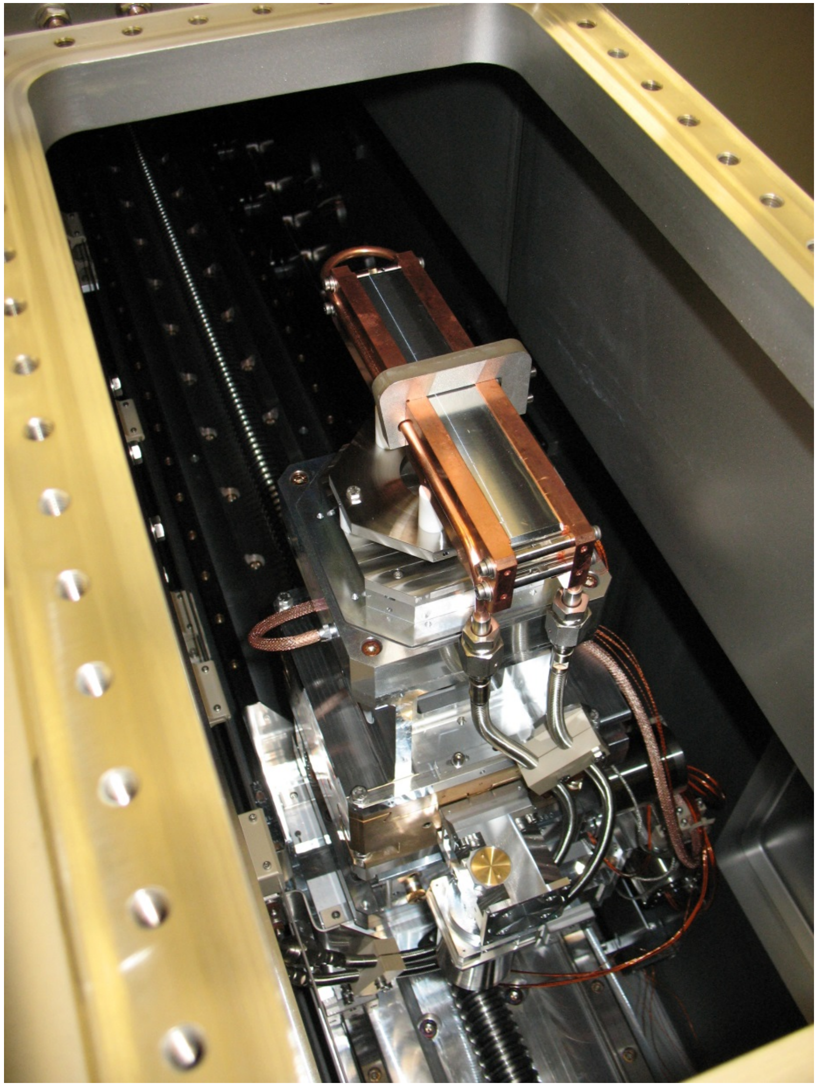
beam direction

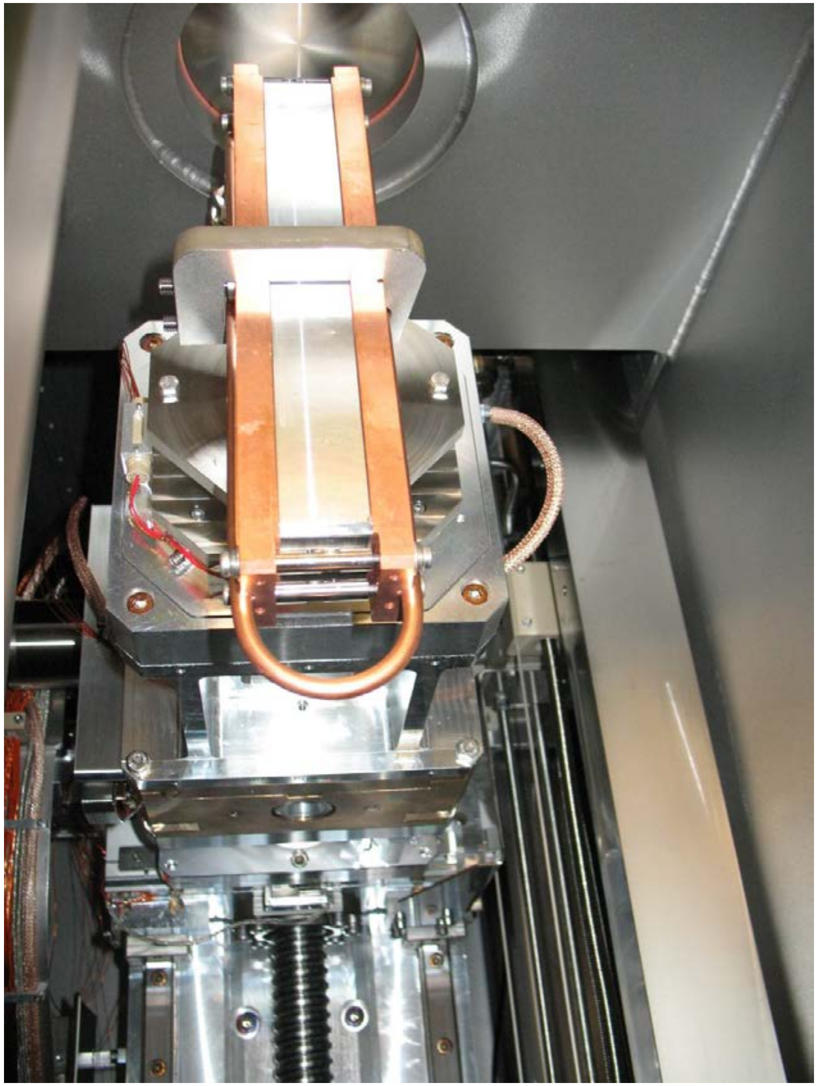
Multilayer Specifications (AXO Dresden)



Mirror	M1			M2		
Coating	Pd/B_4C	Ni/C	Ir	Pd/B_4C	Ni/C	Ir
Period thickness [nm]	2.519	3.224	34.7	2.522	3.211	34.7
Peak reflectance R @ Cu Kα [%]	44.7	69.7	-	42.1	65.3	-
Resolution $\Delta\theta/\tan\theta$ [%]	1.53	1.90	-	1.56	2.05	-
Meridional uniformity σ [%]	0.06	0.04	0.11	0.06	0.04	0.11
Sagittal width (FWHM) [mm]	5.6	6.7	7.4	5.9	6.8	7.4

ML06 – LN2 cooled Multilayermonochromator at P06

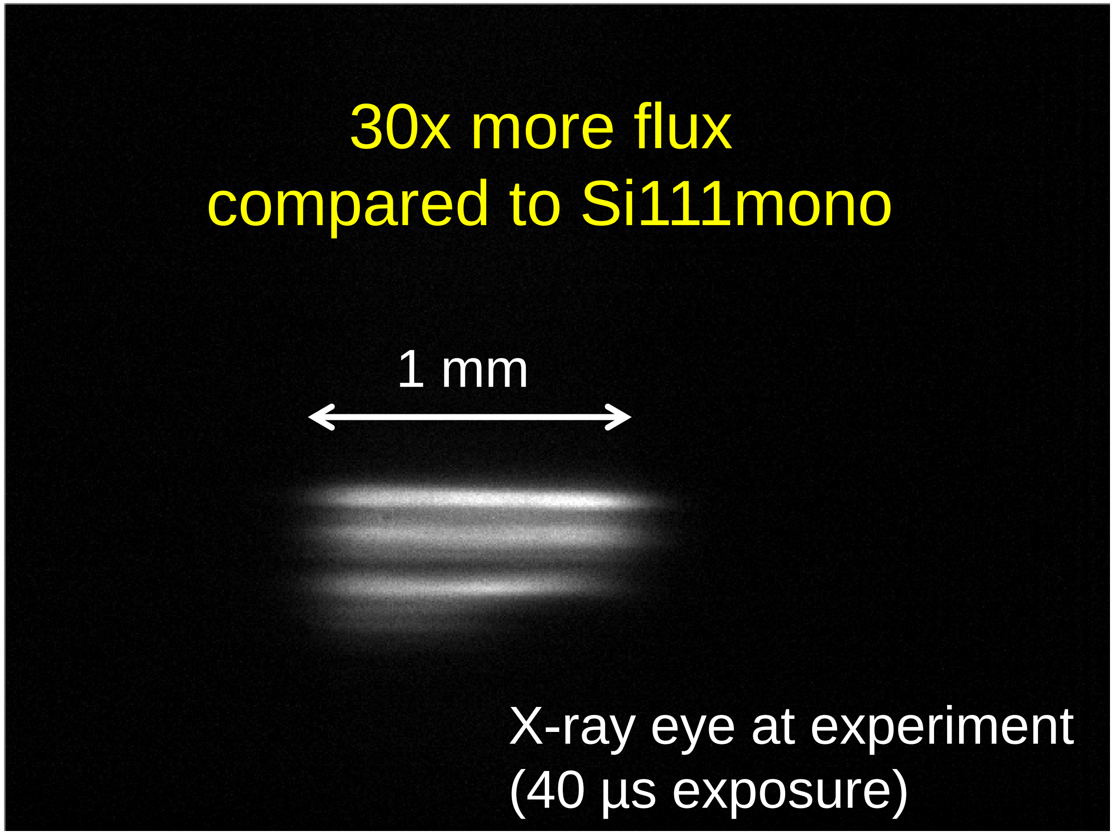




Second multilayer system on long translation

First Beam

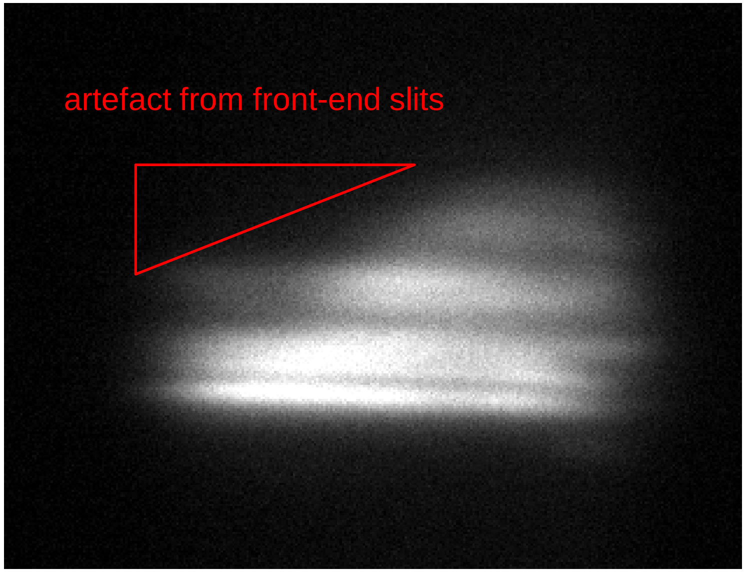
Installation of cryo-system and ML's in March 2013
First ML beam: Pd/B4C @ 11.8 keV (3rd harmonic)



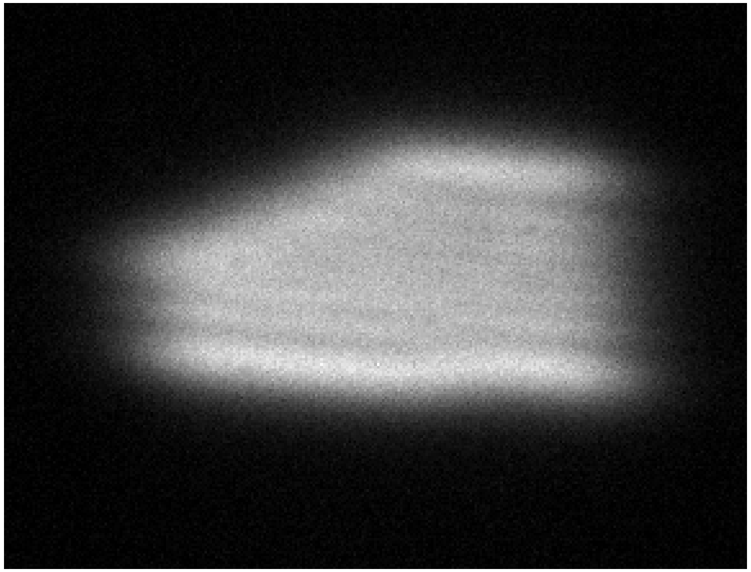
Courtesy G. Falkenberg

Comparison ML/Crystal Optics

ML Pd/B4C
(at 95m from source, 10ms)



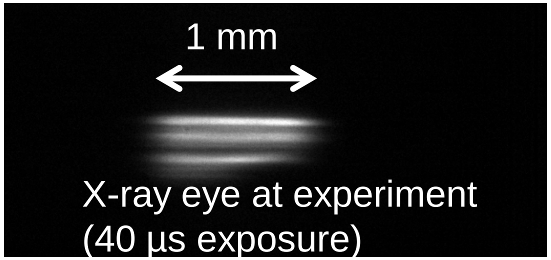
Si-111 High-Heatload Mono



Courtesy G. Falkenberg

Installation of cryo-system and ML's in March 2013
First ML beam: Pd/B4C @ 11.8 keV (3rd harmonic)

30x more flux compared to Si111mono



DESY

C-Type Compact Monochromator Concept

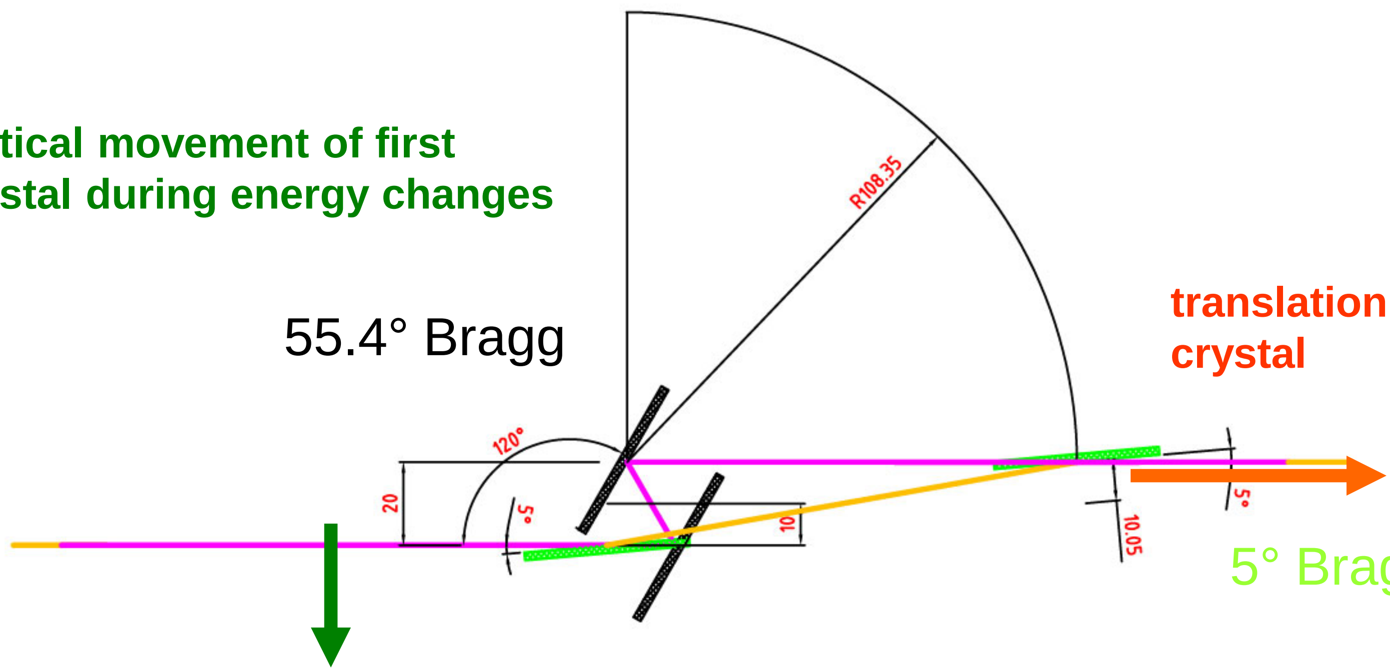
D. M. Mills and M. T. King, *Nucl. Instr. Methods* 85, 341 (1983).

Crystal	length (mm)	width (mm)	spacing (Å)	Theta	possible energy range (keV)
Si (111)	40	40	3.135532	5° - 55.6°	2.4 - 22-5
Si (311)	40	40	1.637478	5° - 55.6°	4.6 - 43.4

vertical movement of first crystal during energy changes

55.4° Bragg

translation of second crystal



5° Bragg

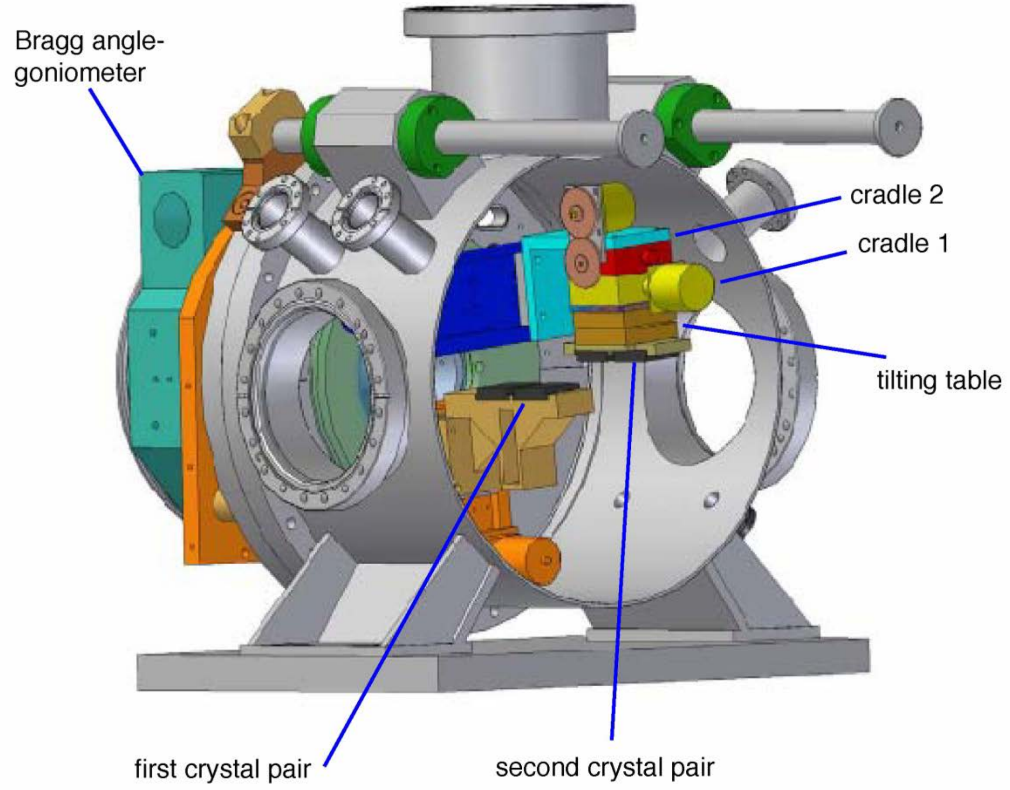
Basic Parameters

- Si-111 and Si-311 crystal sets,
- crystal set change by translation of vacuum chamber

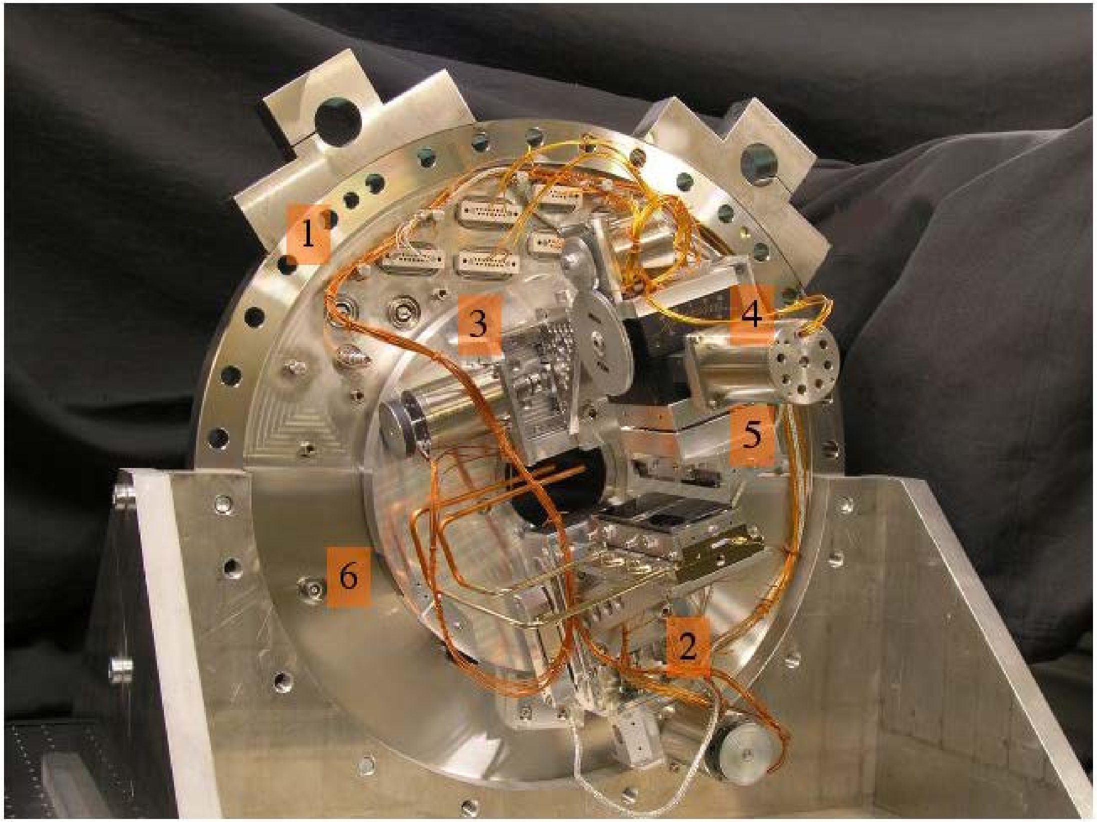
- common central rotation
- ex-vacuum goniometer (Huber 420), in-vacuum encoder (Renishaw®)

- first crystal translates vertically
- second crystal translates tangentially

- Bragg angle 5° to 55.5°
- energy range: 2.4 - 22.6 keV, $Si_{(111)}$
  4.6 - 43.4 keV, $Si_{(311)}$

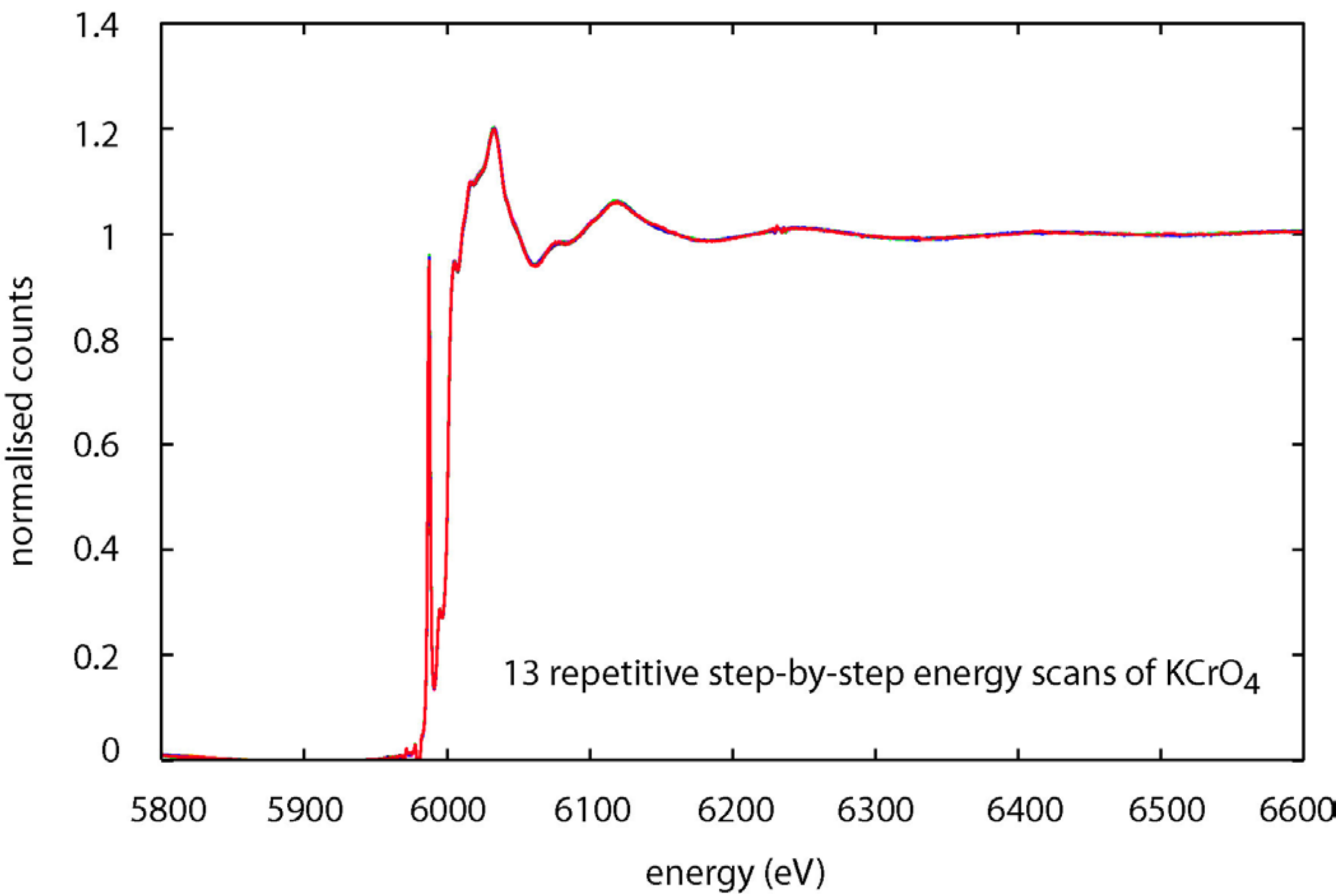


Completed Mechanics



O-ring sealed 400 mm flange (1). The goniometer is positioned outside the vacuum (not on the picture) and is coupled by a hollow-shaft ferrofluidic® sealed feedthrough to the common rotation. The first crystal pair (2) is indirectly water-cooled. The second crystal pair is mounted on a two-tilt cradle (4) and a piezo-driven micrometer (5). The unit may be translated along the beam (3). The Bragg angle position is determined with a Renishaw® optical encoder system (6).

Reproducibility



13 repetitive energy scans of a pressed powder pellet of $KCrO_4$.

Total shift of the pre-edge position is < 0.06 eV with an average of 0.032 eV.

Outlook

ongoing and upcoming DCM work

PETRA III Extension beamlines
- **3 new cryo-cooled DCMs**
- **3 C-type upgrade DCMs**

Review and enhance stability of critical optical components
- DCMs and Mirrors

further related talk:

Stability Issues at Monochromators and Mirrors, Ilya Sergeev

Thank you