Novel Bragg-Laue high energy monochromator for bending magnet beamlines

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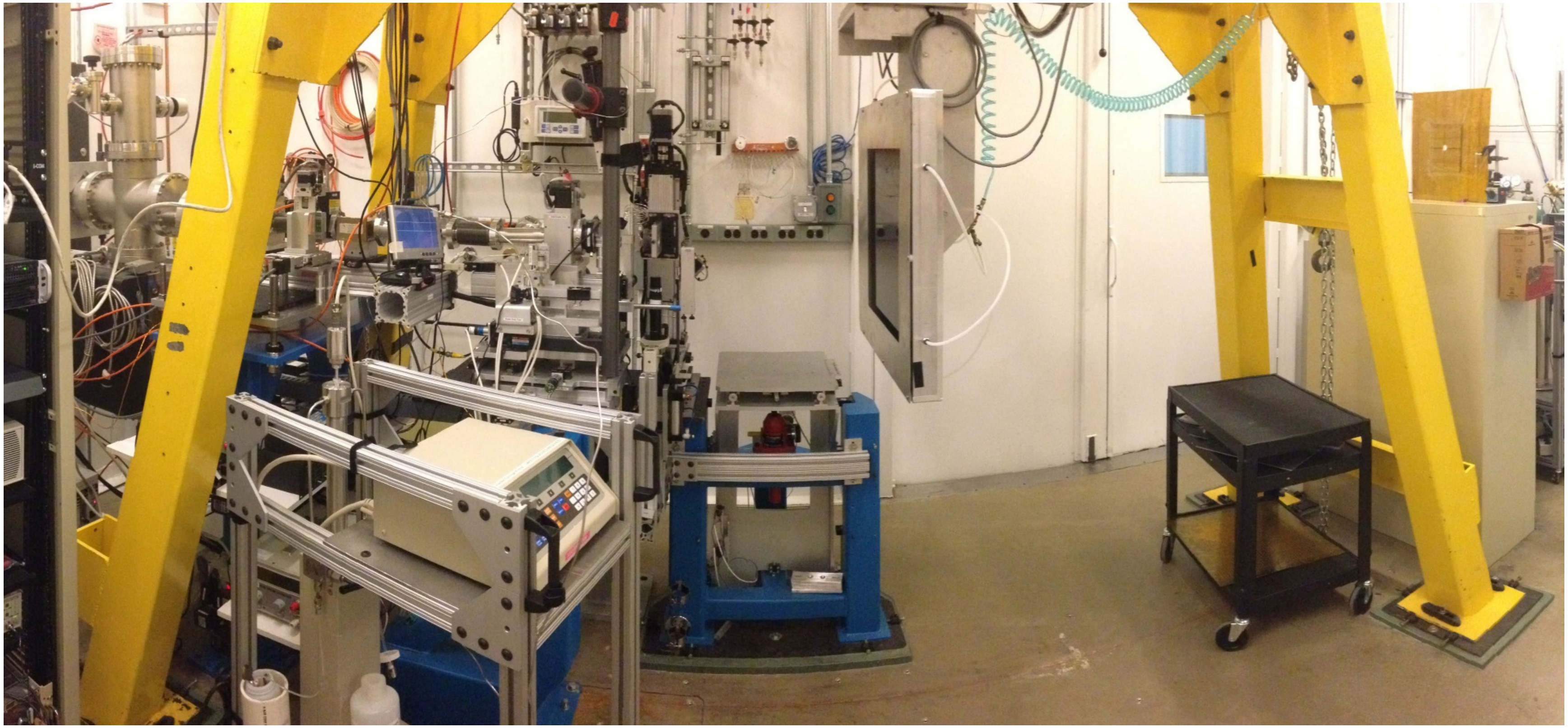
17-BM: Rapid Acquisition Powder Diffraction

- 17-BM-B station configuration
  - Debye geometry, area detector
  - Sample detector distance: 200 to 1300 mm
  - Energy was at 17 kev, now at 27 kev – 51 kev with the new mono

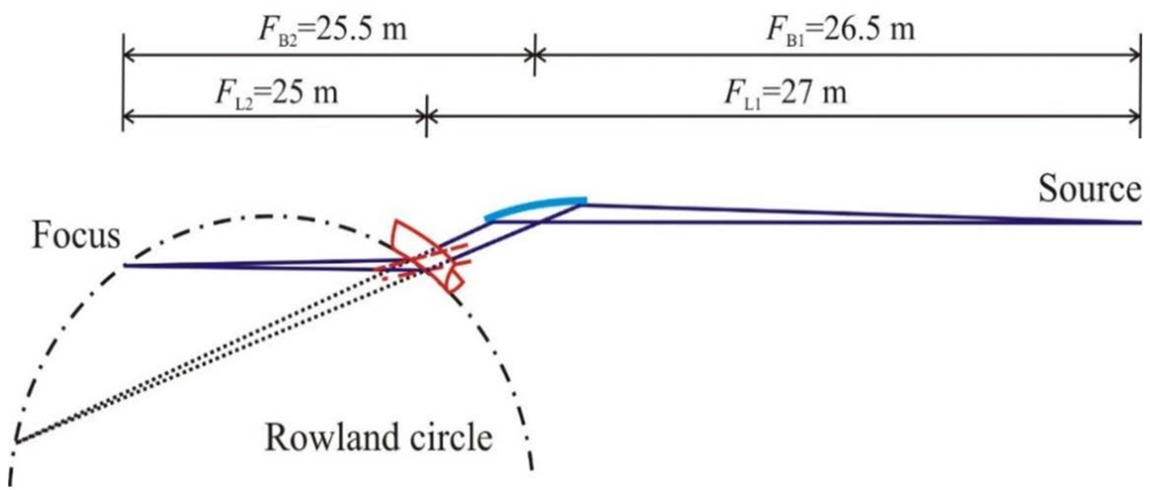


Novel high-energy monochromator for BM

- Motivation
  - Materials research, in situ or operando measurements
    - Sample and chamber attenuation
      - Prefer high energy
    - Area detector
      - Prefer high energy
    - Need for peak resolution at low Q
      - Prefer low
    - Bending magnet flux
      - Not much beyond 60 keV
    - **Target energies: 30 to 55 kev**
  - Simple and robust optics
    - Without mirrors. Mono does both H and V focusing
    - Easy energy tuning

Novel high-energy monochromator for BM

- Bent Bragg-Laue Theory
  - meridionally bent Bragg
    - Increase acceptance
    - Vertical focusing
  - sagittally bent Laue
    - Horizontal focusing

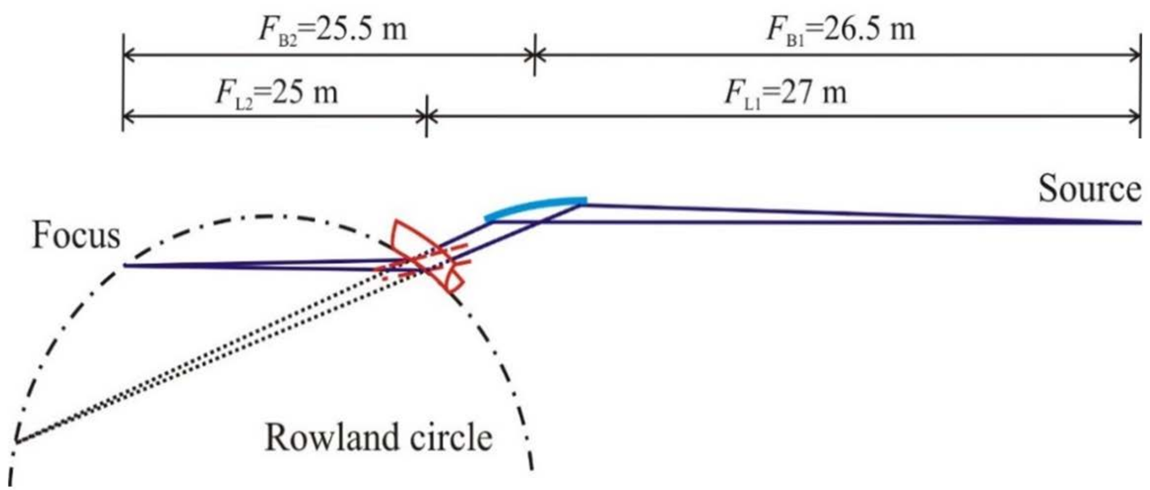


Novel high-energy monochromator for BM

- Bent Bragg-Laue Theory
  - Focusing, H

$$\frac{1}{F_{L1}} + \frac{1}{F_{L2}} = \frac{2\sin\theta_L \sin\chi_L}{R_{sL}}$$

R_{sL} Laue Sagittal bending radius
θ_L Bragg angle of Laue
χ_L Asymmetric angle



Novel high-energy monochromator for BM

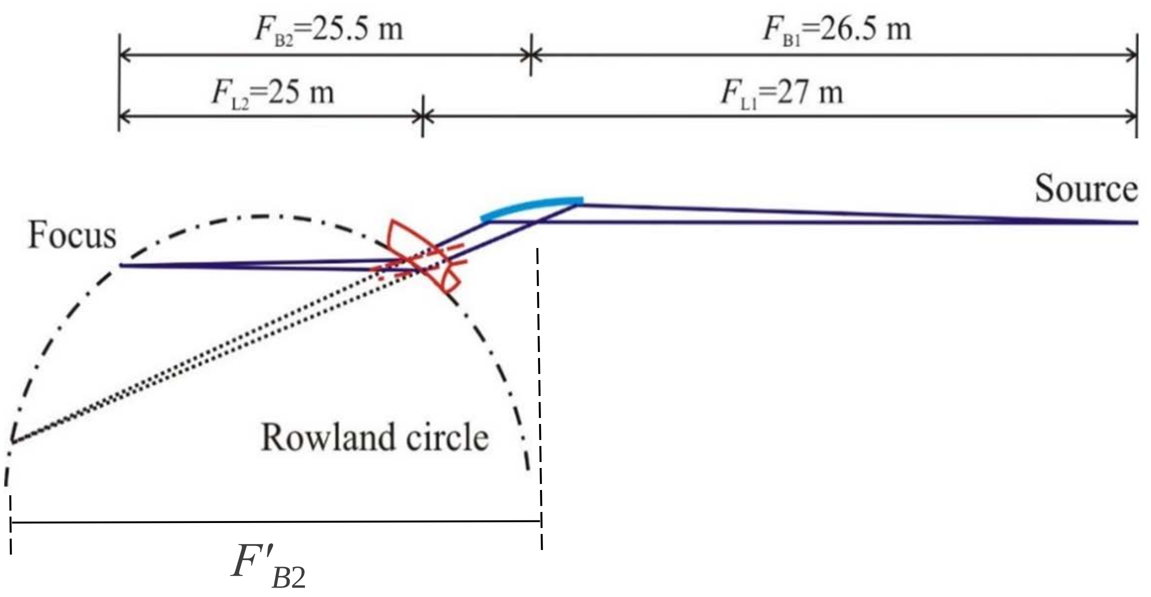
- Bent Bragg-Laue Theory
  - Focusing, V

$$\frac{\cos(\chi_L - \theta_L)}{F'_{B2} - (F_{B2} - F_{L2})} + \frac{\cos(\chi_L + \theta_L)}{F_{L2}} = \frac{2}{R_{mL}}$$

R_{mL} Laue anticlastic radius,
$R_{mL} = C_L \nu_L R_{sL}$

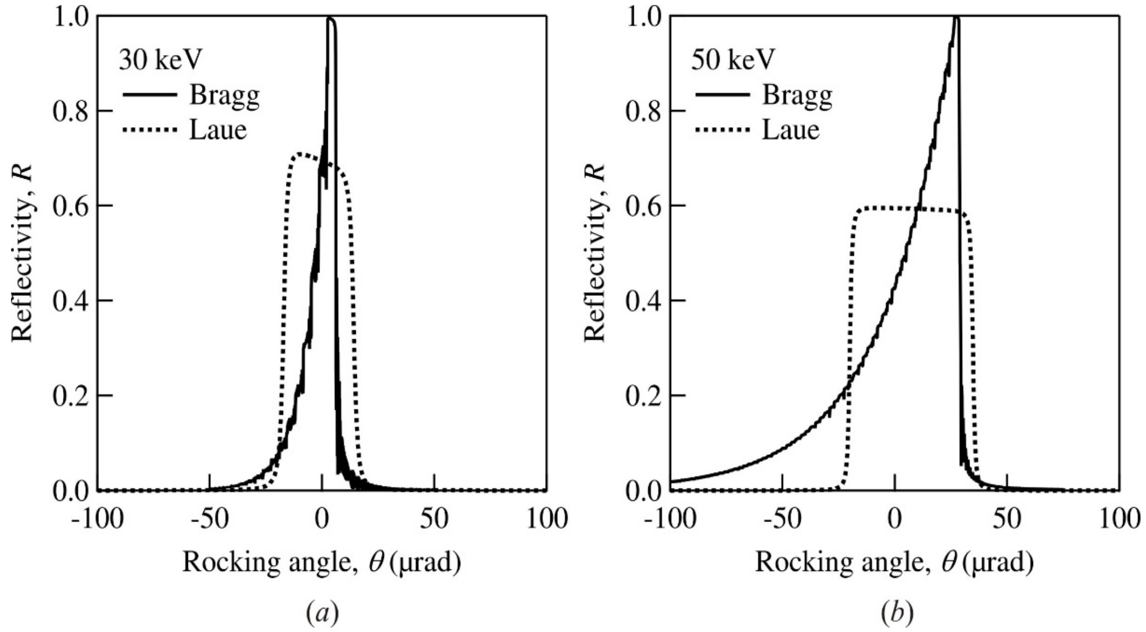
$$\frac{\cos(\chi_B - \theta_B)}{F_{B1}} + \frac{\cos(\chi_B + \theta_B)}{F'_{B2}} = \frac{2}{R_{mB}}$$

R_{mB} Bragg bending radius
$\theta_B = \theta_L$
χ_B asymm angle of Bragg



Novel high-energy monochromator for BM

- Bent Bragg-Laue Theory
  - Energy resolution



Calculated Si (311) diffraction profiles of meridionally bent Bragg crystals (solid lines) and sagittally bent Laue crystals (dotted lines) at (*a*) 30 keV and (*b*) 50 keV. The crystal parameters are T_L = 0.6 mm, χ_L = 49°, C_L = 0.7 (*a*) R_{sL} = 2.47m, R_{mB} = 216 m (*b*) R_{sL} = 1.48 m, R_{mB} = 227m.

Novel high-energy monochromator for BM

- Bent Bragg-Laue Theory
  - Energy resolution
    - Bragg off-Rowland bandwidth broadening

$$(\Delta E/E)_B = \frac{\sigma_v'}{\tan\theta_B}\left[\frac{F_{B1}}{R_{mB}\cos(\chi_B \mp \theta_B)} - 1\right]$$

σ_v' source vertical divergence

    - Laue …

$$(\Delta E/E)_L = \frac{\sigma_v'}{\tan\theta_L}\frac{F_{B1}}{F_{B2}'}\left[1 - \frac{F_{L2}}{R_{mL}\cos(\chi_L \pm \theta_L)}\right]$$

Novel high-energy monochromator for BM

- Bent Bragg-Laue Theory
  - To satisfy both focusing and Rowland conditions

Optimized parameters at each energy with Si(311)

Energy, E (keV)	30	40	50	60
θ_B, θ_L (°)	7.25	5.43	4.34	3.62
χ_B (°)	89.80	88.89	88.47	88.37
R_{mB} (m)	180	238	239	253
χ_L (°)	41.8	50.5	71.6	76.5
R_{sL} (m)	2.19	1.90	1.87	1.59
R_{mL} (m)	28.5	33.0	39.0	29.8

Novel high-energy monochromator for BM

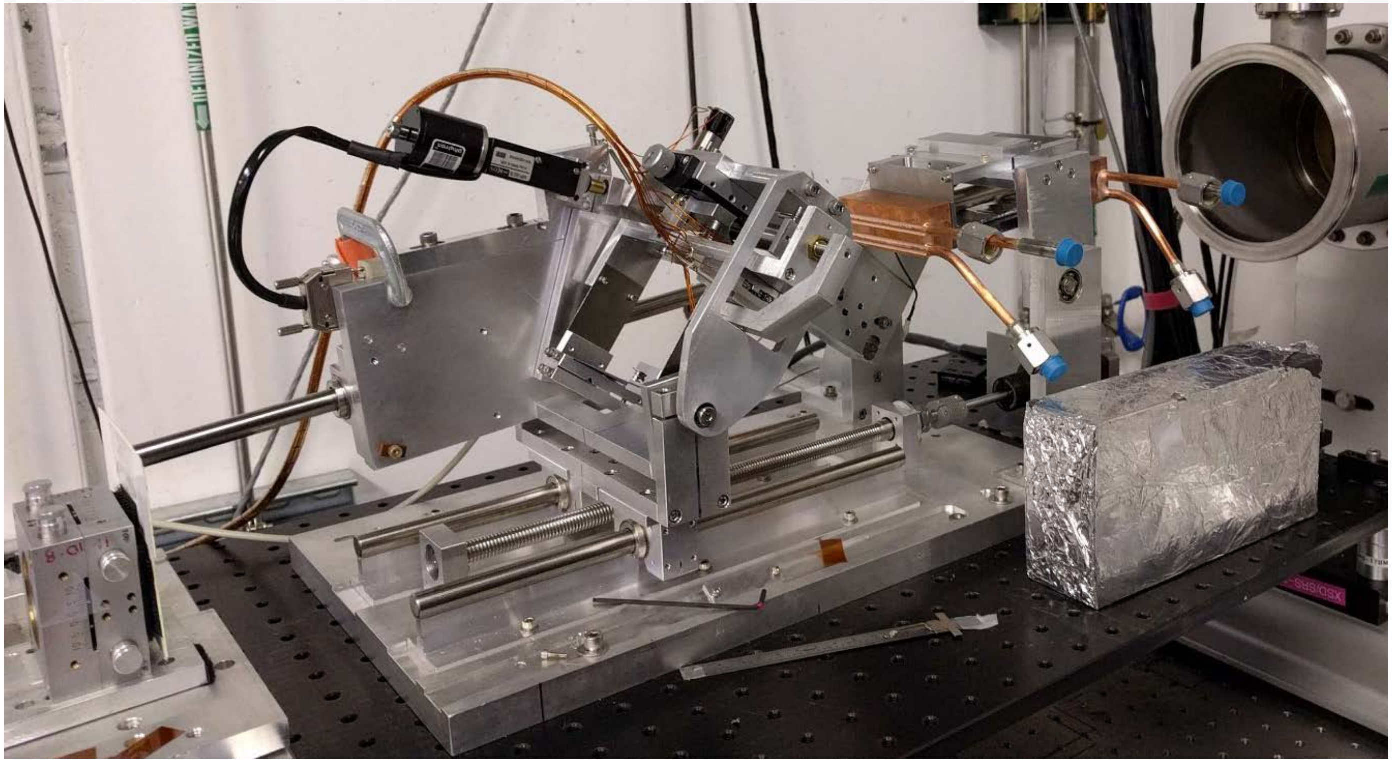
- Bent Bragg-Laue Mono at 17-BM
  - Si (311)
    - Bragg: symmetric, $\chi_B = 90°$
    - Laue: $(5\overline{11})$ surface, $\chi_L = 49°$

Optimized parameters at each energy with Si(311) at 17-BM

Energy, E (keV)	30	40	50	60
θ_B, θ_L (°)	7.25	5.43	4.34	3.62
χ_B (°)	90	90	90	90
R_{mB} (m)	216	223	227	231
χ_L (°)	49	49	49	49
R_{sL} (m)	2.47	1.86	1.48	1.24
R_{mL} (m)	41.0	30.7	24.6	20.5

Novel high-energy monochromator for BM

- Bent Bragg-Laue mono at 17-BM
  - Si (311)
    - Bragg: symmetric, 150 × 60 × 8 mm
    - Laue: $(5\overline{11})$ surface, $\chi_L = 49°$, 31 × 84 × 0.6 mm



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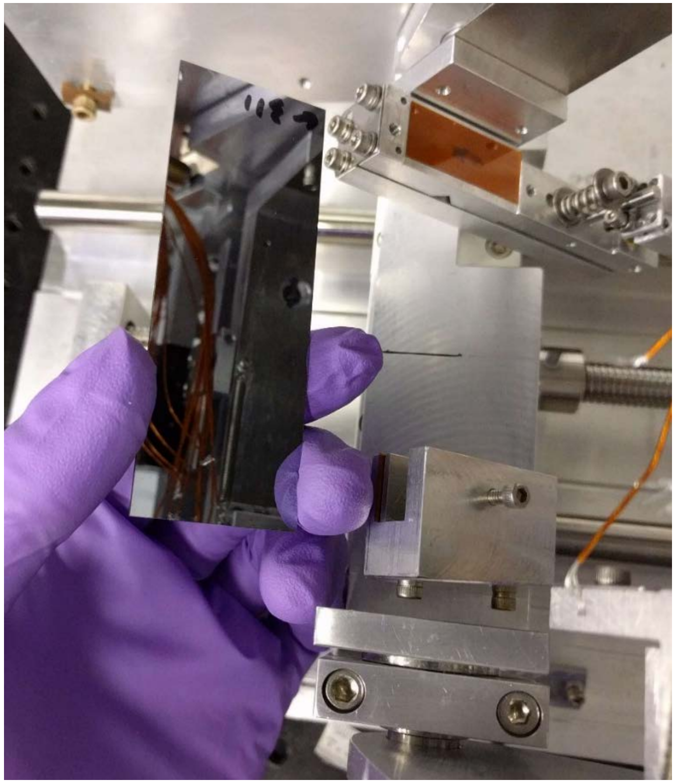
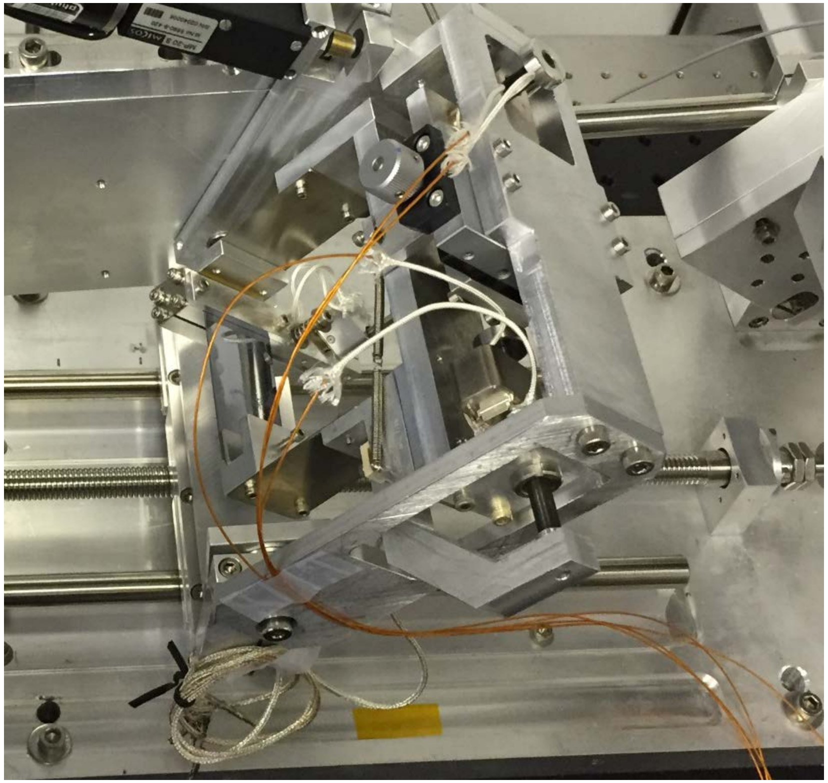
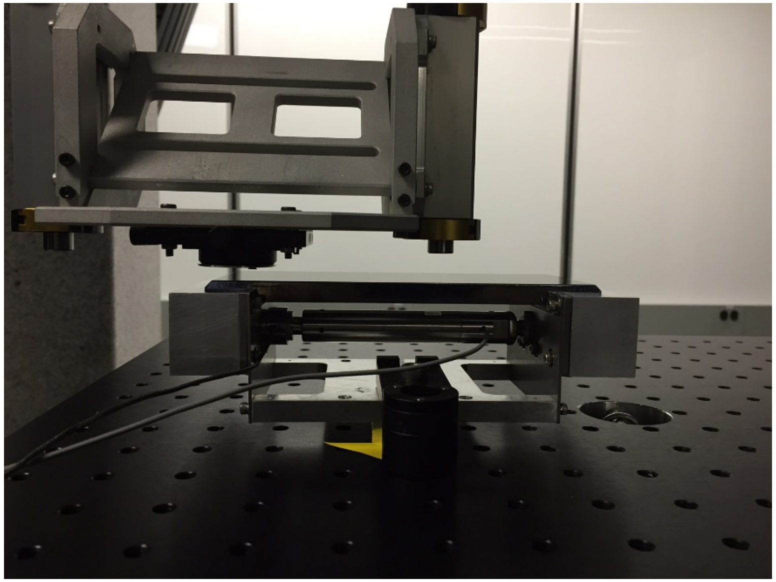
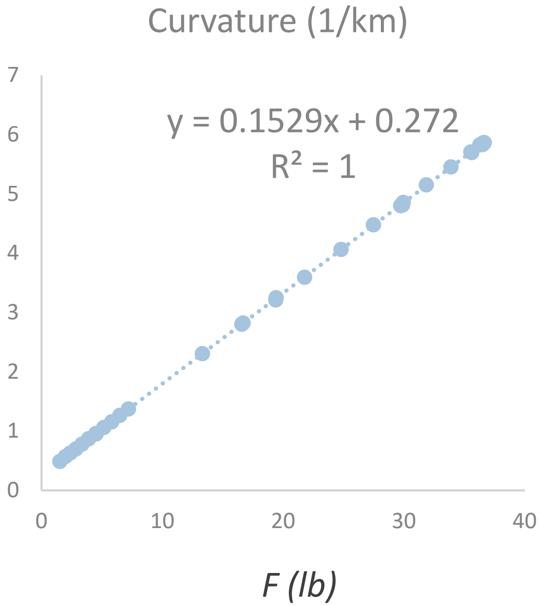




Novel high-energy monochromator for BM

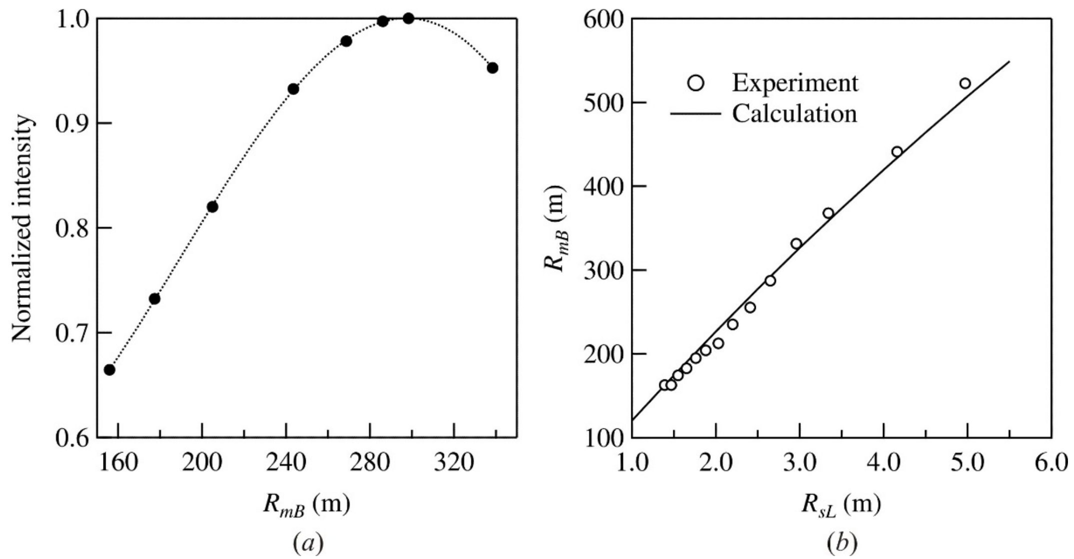
- Bent Bragg-Laue mono at 17-BM
  - Si (311)
    - Bragg: symmetric, 150 × 60 × 8 mm
    - $\frac{1}{R_{mB}} = 0.153\,F + 0.272$





Novel high-energy monochromator for BM

- Bent Bragg-Laue mono at 17-BM
  - Testing at 1-BM,



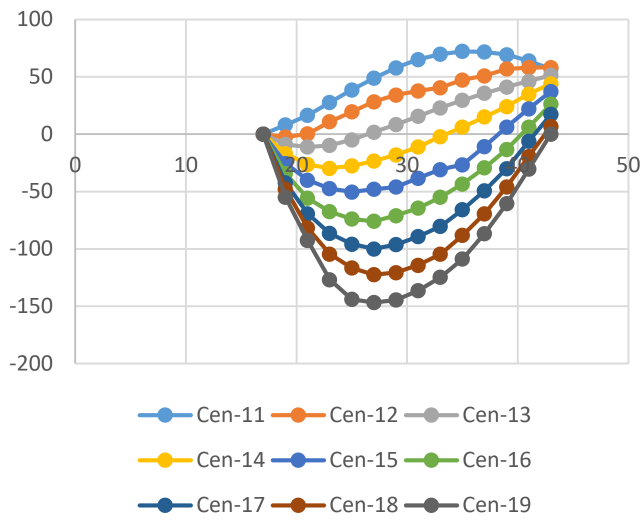
(*a*) Measured beam intensity vs. R_{mB} at 38 keV with a fixed R_{sL} = 2.7 m of the Laue crystal. (*b*) R_{mB} values to give the maximum flux at different R_{sL}

the white beam slit at 27 m from source was limited to 1 mm horizontally. The vertical beam aperture was 0.15 mrad, taking most of the vertical source divergence.

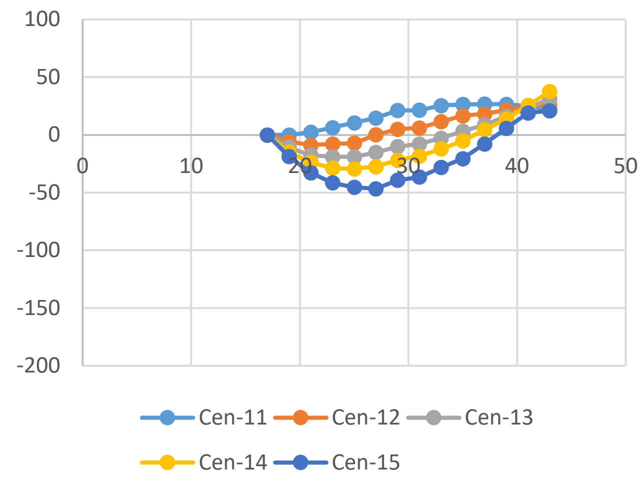
Novel high-energy monochromator for BM

- Bent Bragg-Laue mono at 17-BM
  - Testing at 1-BM, horizontal acceptance

Rocking curve centers at different Laue slide positions



E = 55 kev



E = 30 kev

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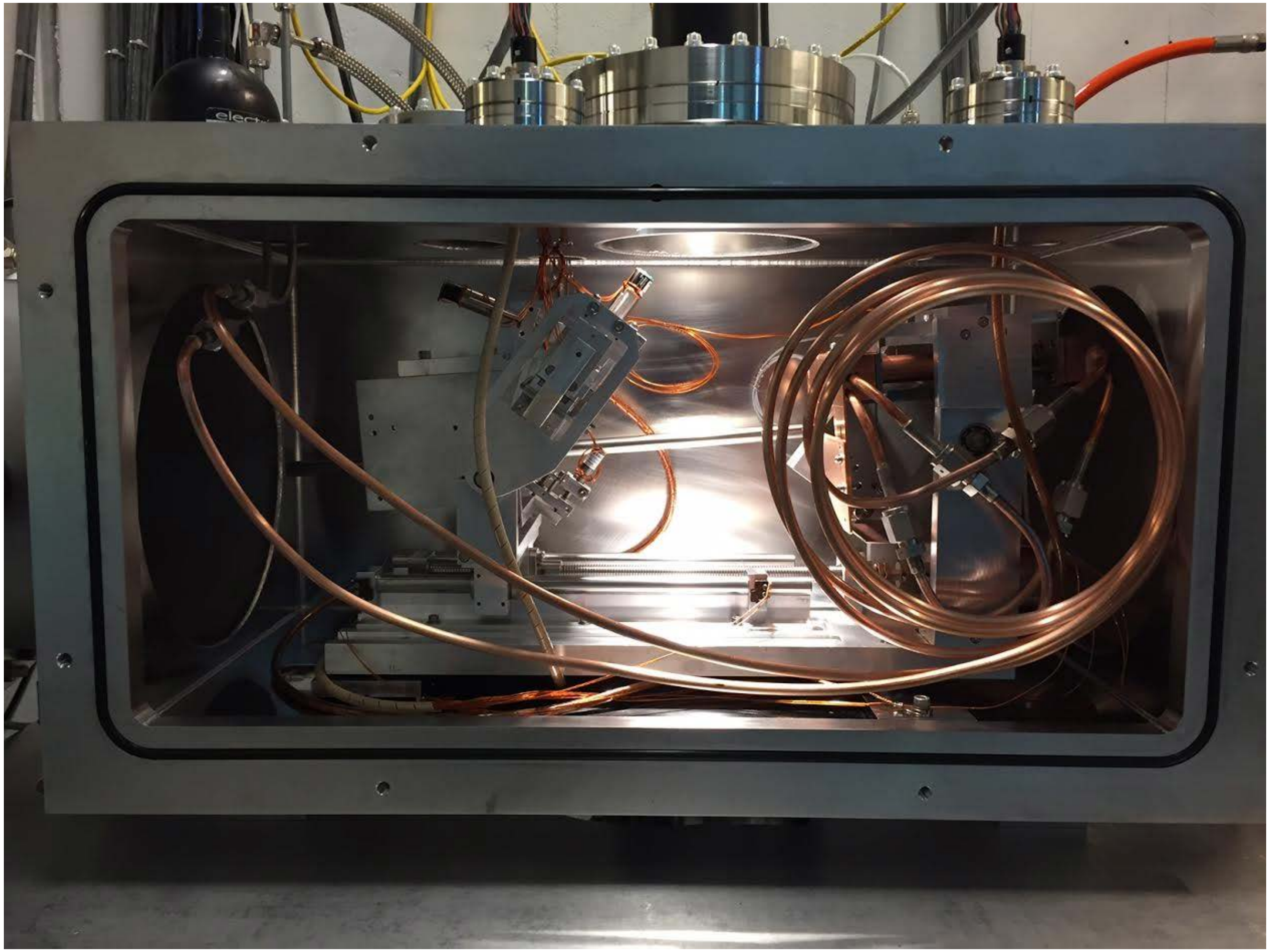

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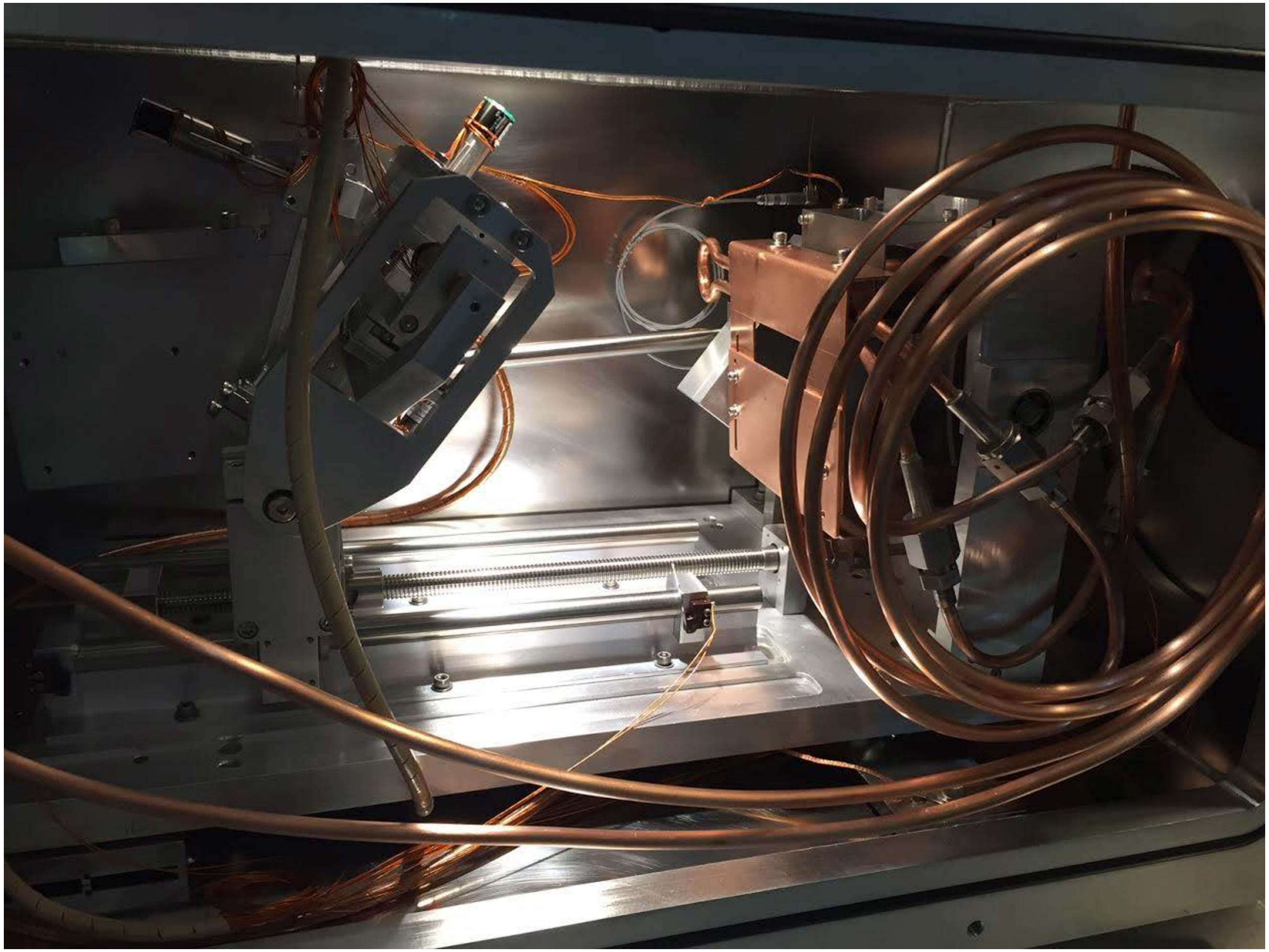

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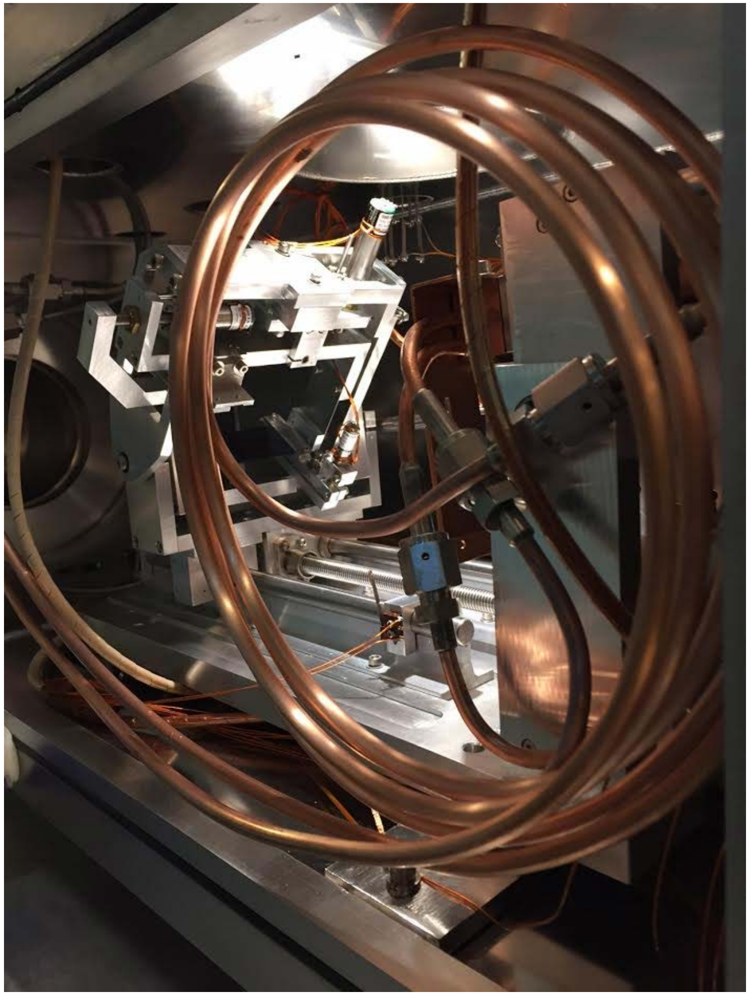

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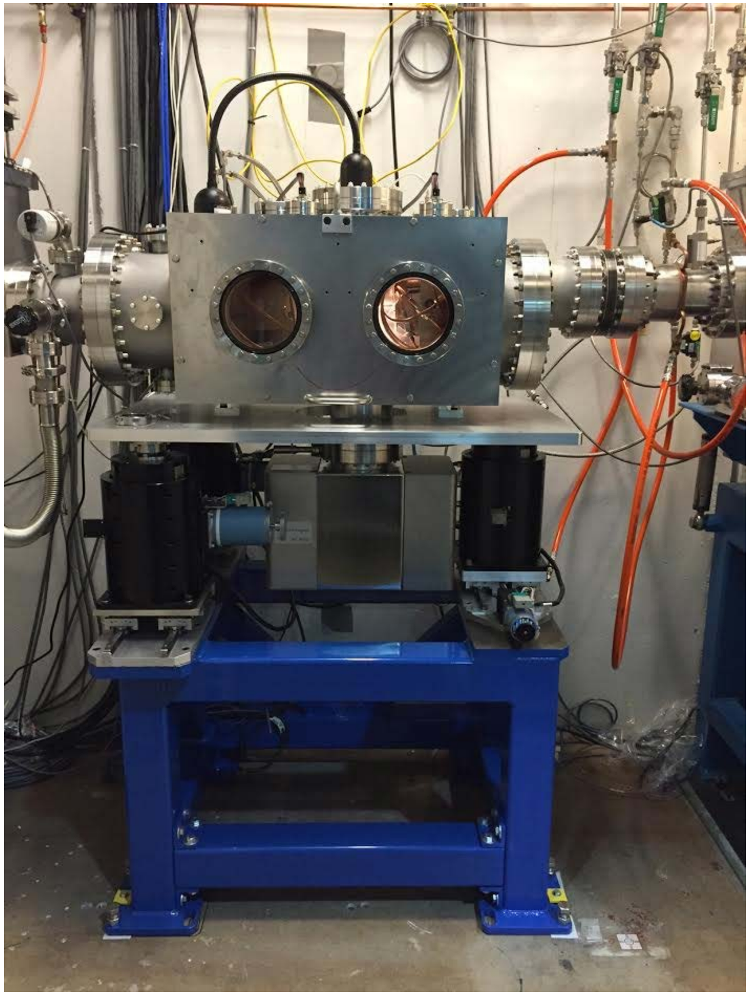


Novel high-energy monochromator for BM

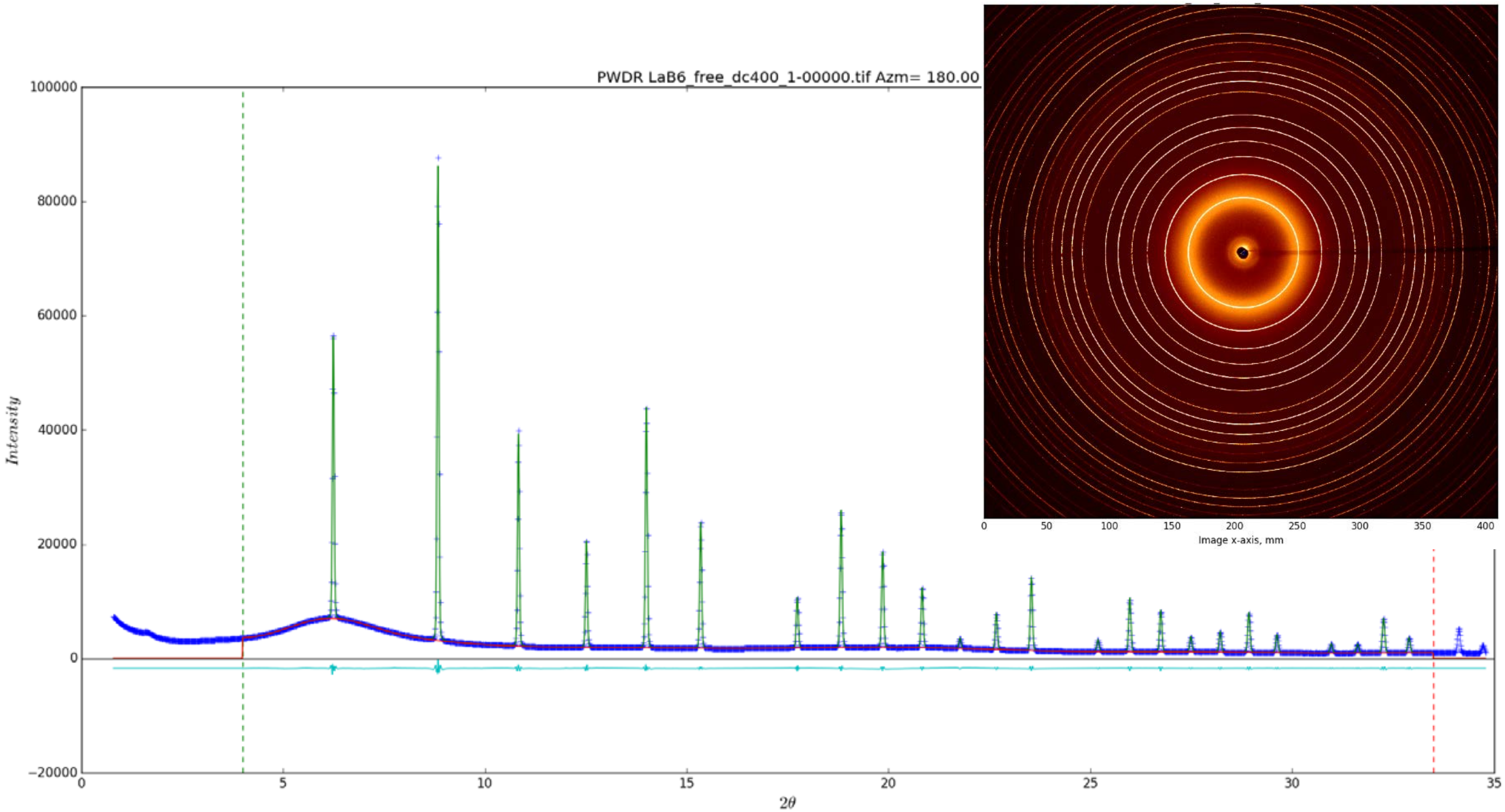
- Bent Bragg-Laue mono at 17-BM
  - filter

X-ray Transmission

	Thickness	Energy (keV)					
Material	mm	10	15	20	25	30	55
SiC	1.5	0.0%	3.2%	23.9%	48.7%	66.5%	94.2%
C	0.5	82.2%	94.9%	98.0%	99.0%	99.5%	99.9%
total	2	0.0%	3.1%	23.4%	48.2%	66.2%	94.1%
SiC	0.5	2.1%	31.8%	62.1%	78.7%	87.3%	98.0%
C	1.5	55.6%	85.4%	94.0%	97.0%	98.4%	99.8%
total	2	1.2%	27.2%	58.4%	76.3%	85.9%	97.8%

Novel high-energy monochromator for BM

- Bent Bragg-Laue mono at 17-BM
  - Instrument profile at 27 kev with 1 mm ID capillary



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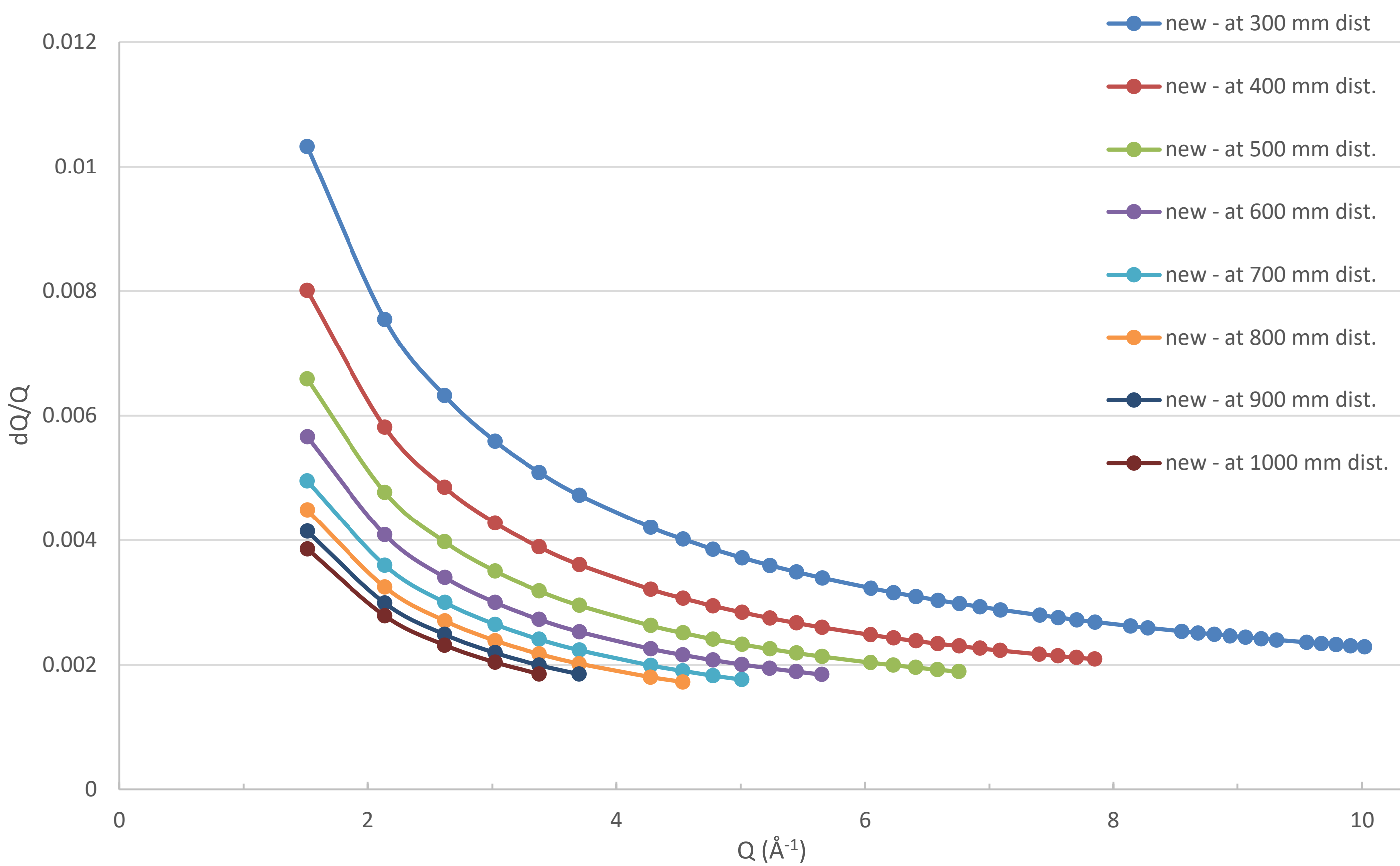

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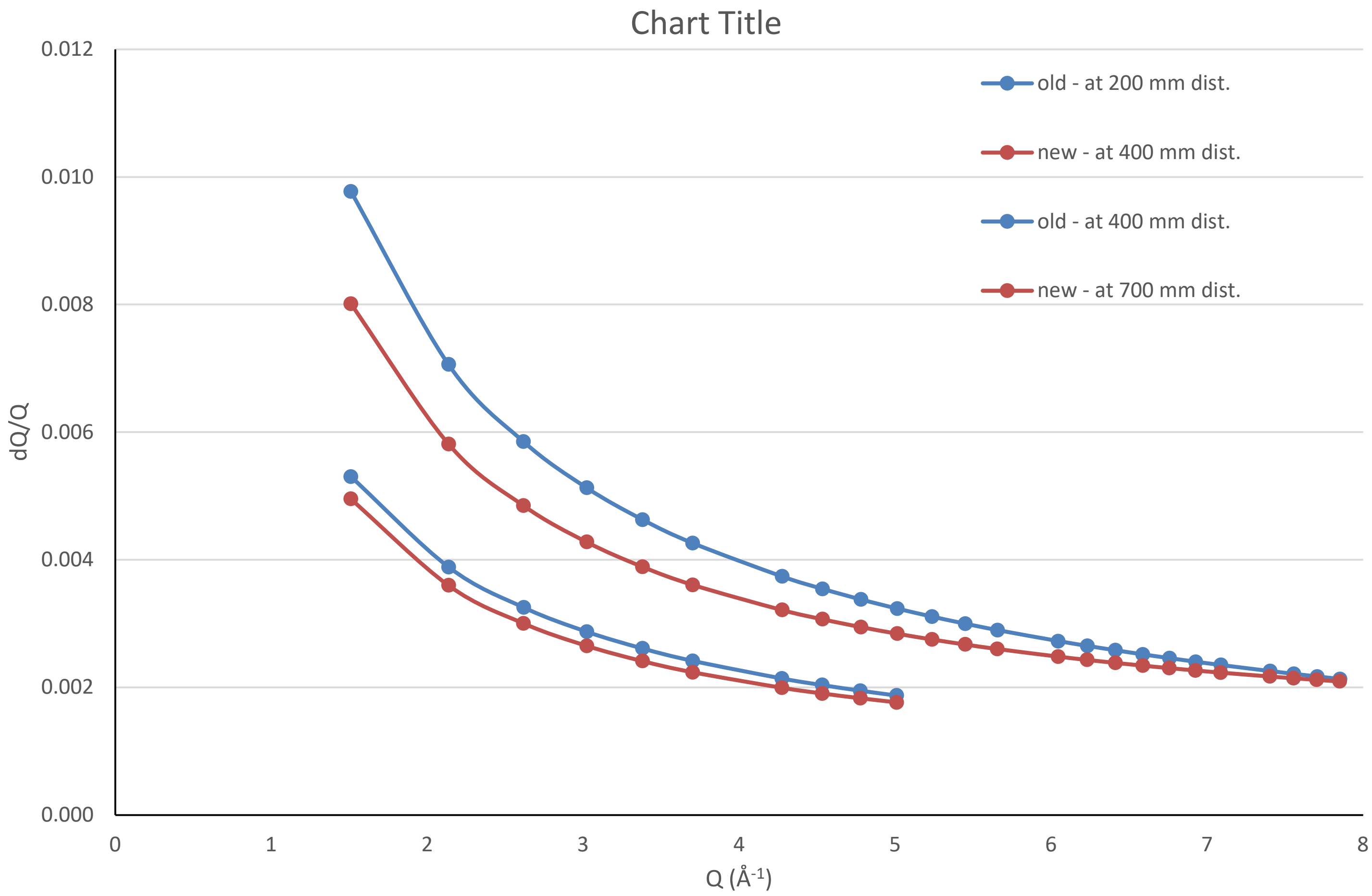

Novel high-energy monochromator for BM

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