Argonne NATIONAL LABORATORY

Beamline Optics Performance at 150mA:
Lessons Learned from the April High Current Studies

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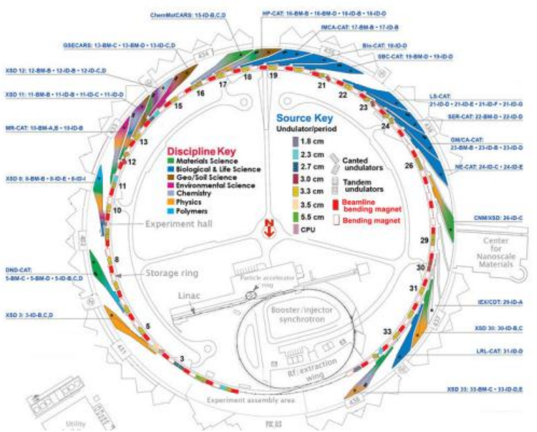
APS/Users Monthly Operations Meeting

26 June 2013

APS-U General Beamline Upgrades

- **KPP Driver:** 150mA Operations
- **Management Goals**
  - ‘Do no harm’ during upgrade
  - Maintain user operations during upgrade



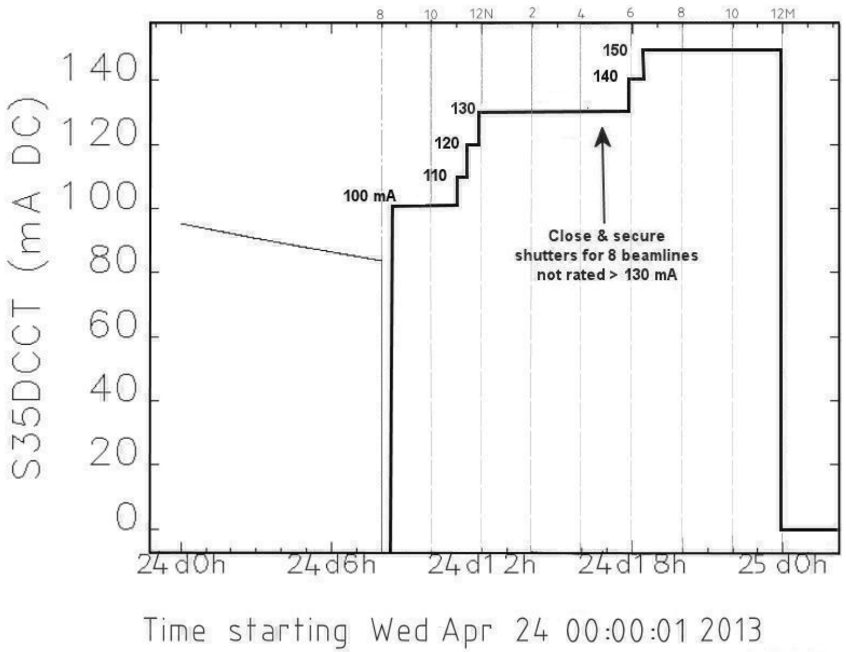
U1.04.04 General Beamline Upgrade Sectors (21)

- **Technical Goals**
  - **Identify marginal components for 150mA**
  - Assist individual beamline technical personnel with development of a mitigation plan – *including both* APS and CAT beamlines

Current Profile

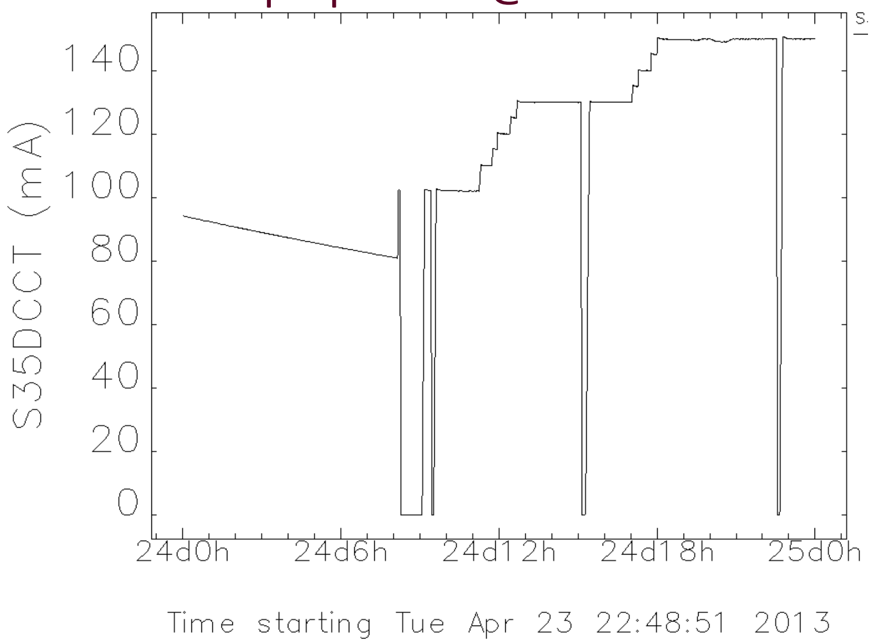
- 130/150 mA High Current Run – 24 April 2013
- A 'stress test' for beamline thermal control & optical systems.
- For most it was a 'first look' at high current performance

Request (simulated)

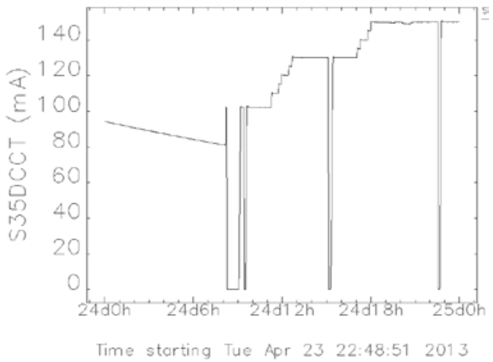


Delivered

Top-up mode @ 150 mA!



Participation



130/150 mA High Current Run - 24 April 2013

Charge:

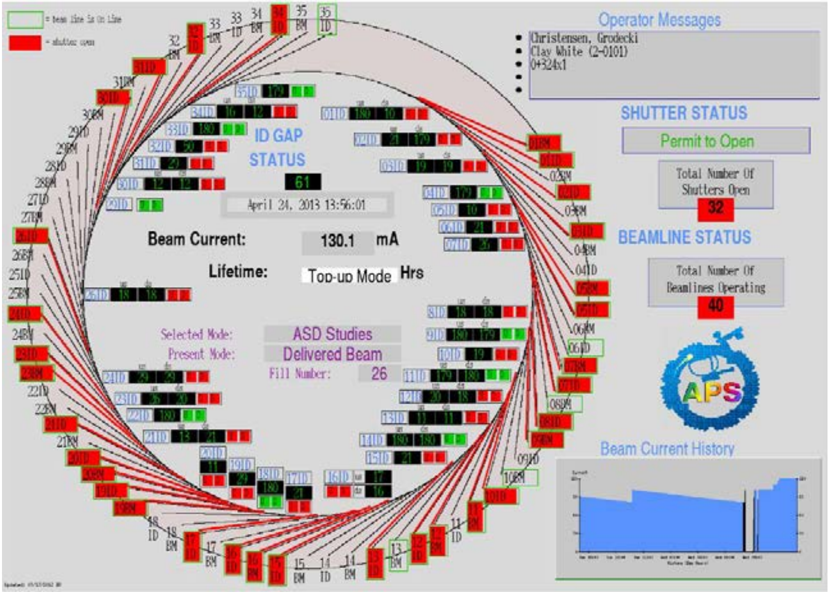
- Most importantly, protect your beamline components.
- Evaluate your beamline performance in its optimal or most-used configuration.
- Move to high-power conditions, smaller or minimum allowed gap, as time permits.

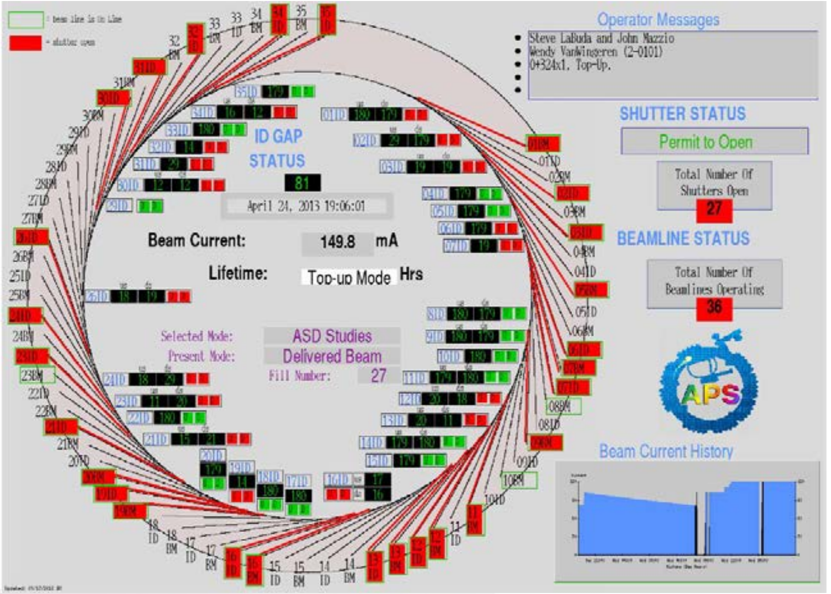
Participants:

- **BMs**
  - Thirteen (13) Bending Magnet Beamlines (1, 5, 7, 8, 9, 10, 11, 12, 13, 16, 19, 20, 23)
- **IDs @130 & 150mA:**
  - Twenty Four (24) Insertion Device Beamlines
  - (No restrictions: 13, 16, 21, 23, 24, 26, 30, 31, 32, 34)
  - (Restricted gaps: 1, 2, 3, 5, 6, 7, 8, 10, 12, 15, 17, 19, 20, 35)

Participation

- Usually we have
  ~58 shutters open during operation
- 130mA – 2:00 PM
  32 shutters open
- 150mA – 7:00 PM
  27 shutters open





Talk Outline:

Intercomparable metrics

- **#1** – Flux vs I_{APS}
- **#2** – Rocking curve width – Fundamental [i.e. Si(111)]
  – Third Harmonic [i.e. Si(333)]

Broad Results

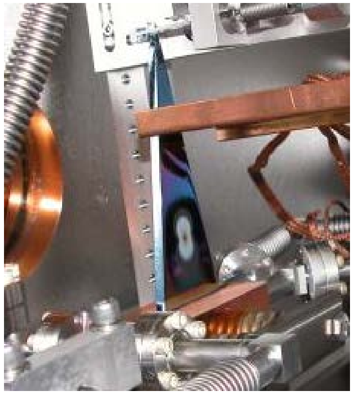
- LN_2 cooled silicon ID optics
- Water cooled diamond ID optics
- Water cooled mirrors
- Water cooled silicon BM & ID optics

High Current Studies Report

- Detailed report being written
- Will be widely disseminated mid-July

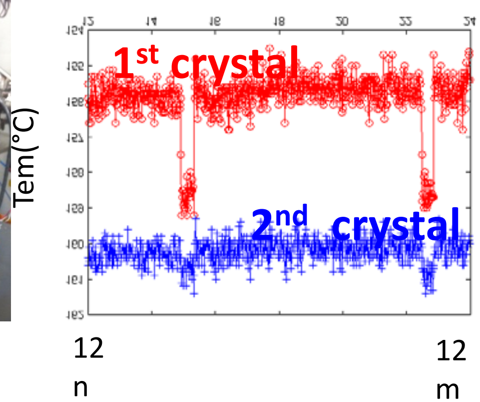
LN_2 Cooled Si Mono Results

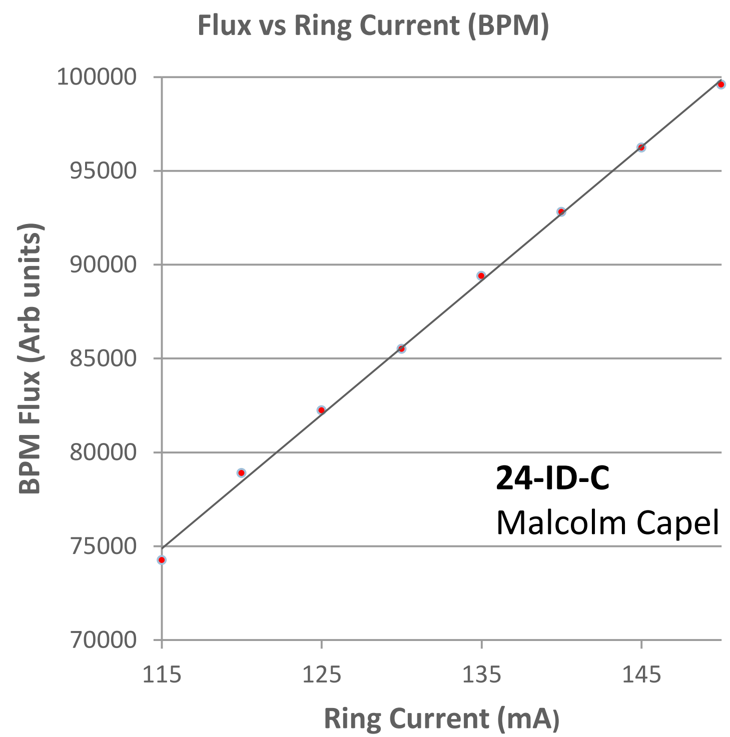
#1: Beam I_0 increases linearly with I_{APS}

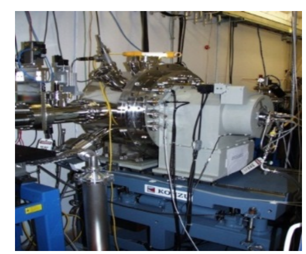


1-ID
Sarvjit Shastri

12-ID-B
Xiaobing Zuo

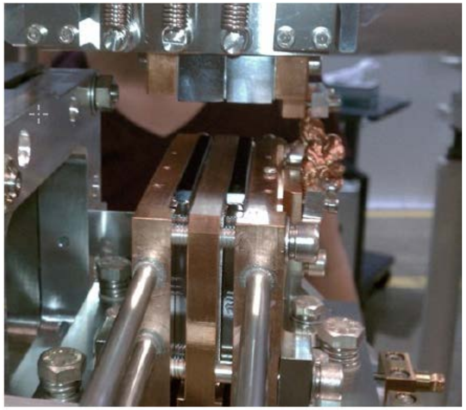




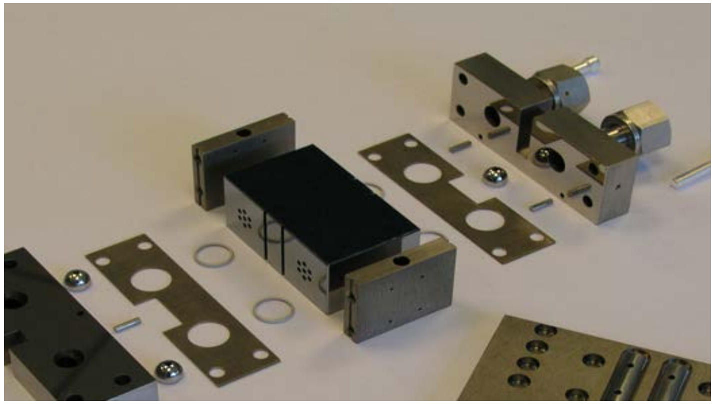


Also 1-ID, 12-ID-C

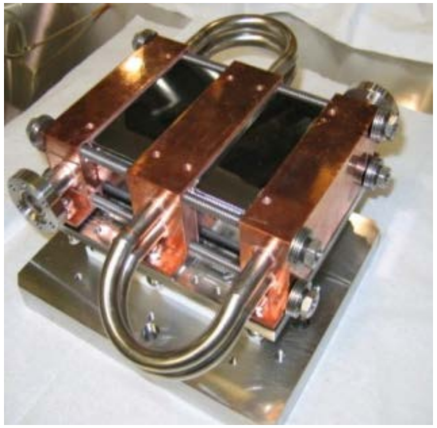
#2: Rocking Curve Widths vs. I_{APS}



GSE-CARS Sector 13-ID



NE-CAT Sector 24-ID

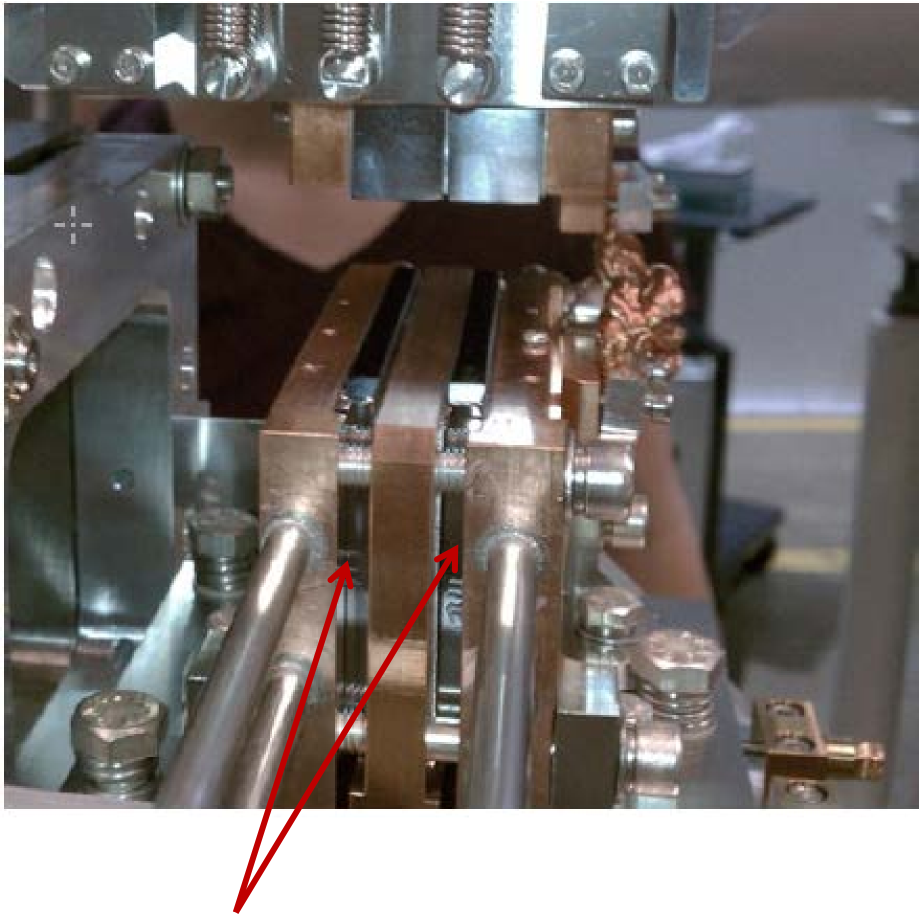


(PNC-CAT) Sector 20-ID

SBC-CAT Sector 19-ID

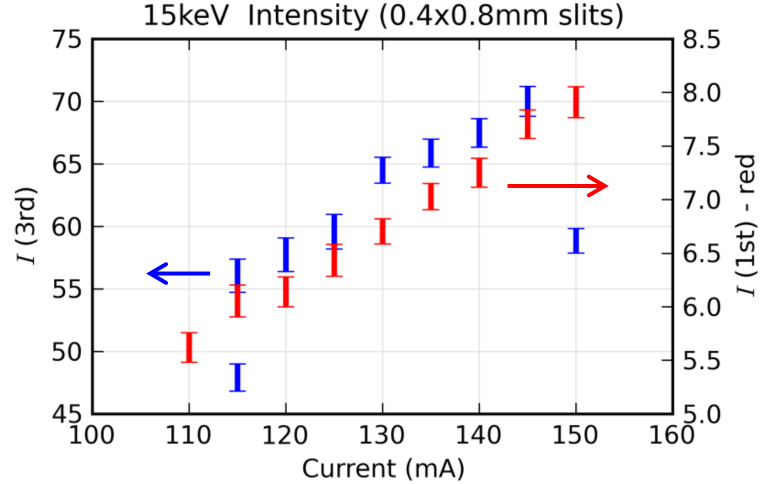
Also 1-ID, 12-ID-C

13-ID (Matt Newville, Peter Eng, Mark Rivers, et al.)

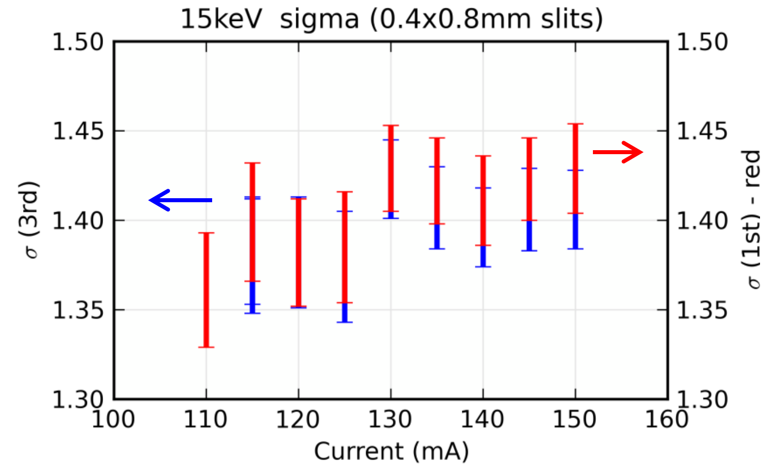


Si 1st Crystals 5 mmW x 200 mmL

I vs. I_{APS}



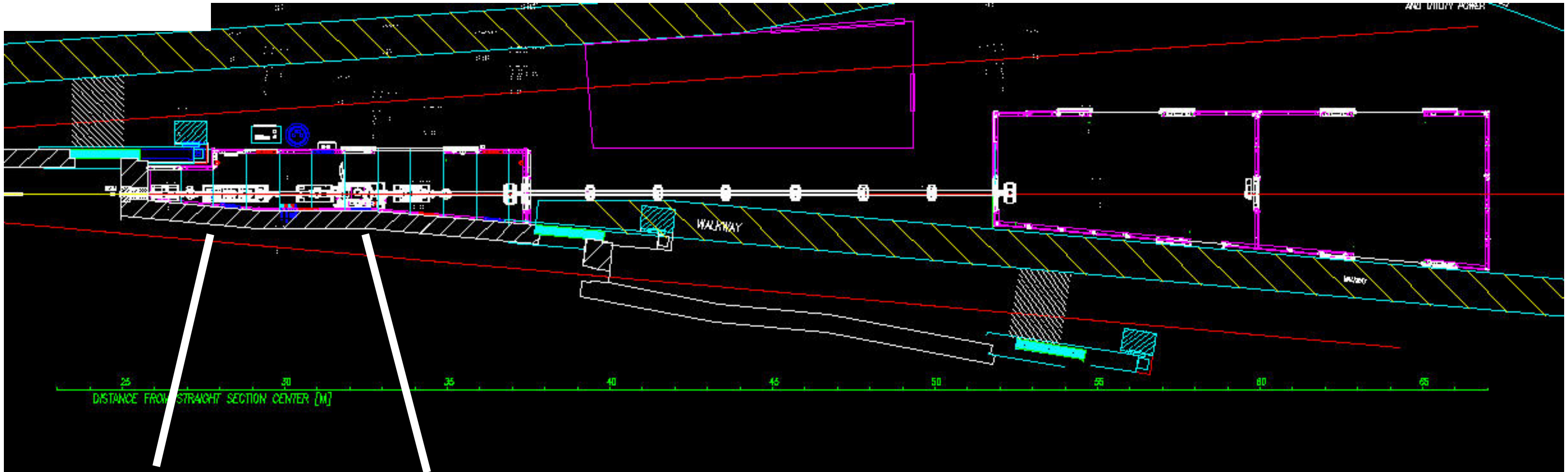
RC width vs. I_{APS}



20-ID (Steve. M. Heald, Chengjun Sun, et al.)

Side cooled LN2 Si(111) mono

Source UA33



White Slits
2.4mmH x 1.2mmV @ 31m

Si(111) LN_2 Side Cool
BESSRC mono @ 33m

Ion Chambers
~50-55m 20-ID-B

Results next page:

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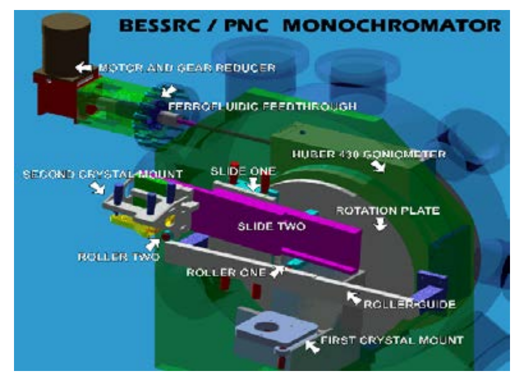
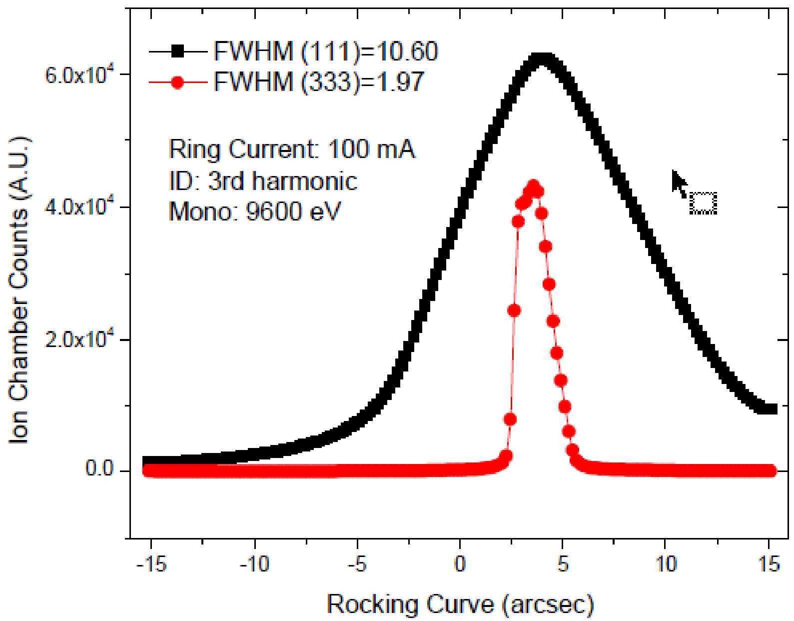


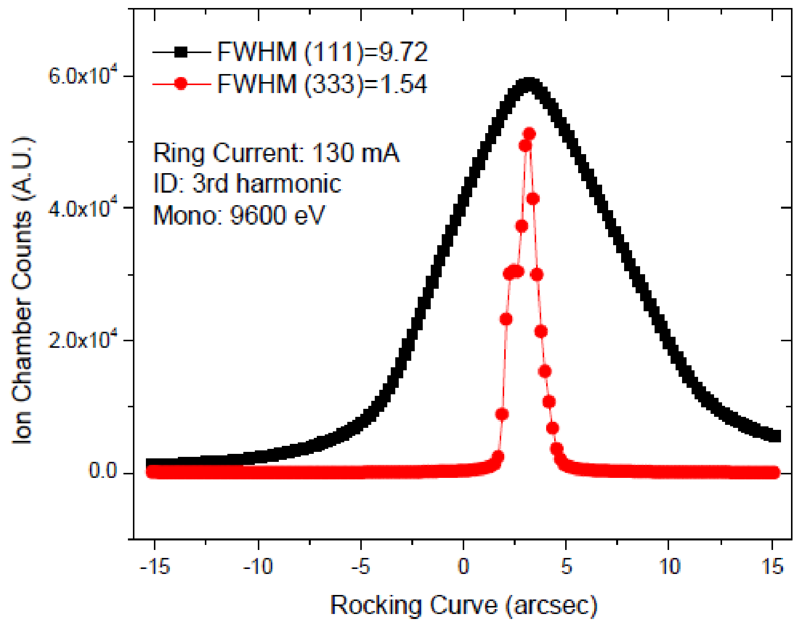
BESSRC Design

20-ID (Steve. M. Heald, Chengjun Sun, et al.)

Side cooled LN2 Si(111) mono

Source UA33 3rd Harmonic **9.6 keV Results** **Same E, Higher power** 11mm gap



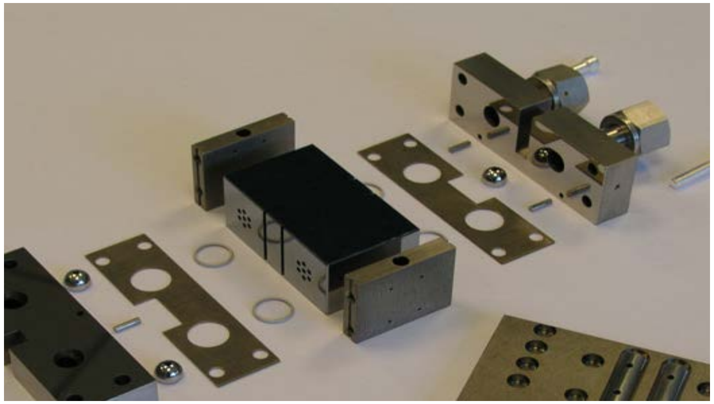


I_{APS}	100	110	115	120	125	130
(111)	10.60	8.54	9.60	9.73	9.33	9.72
(333)	1.97	1.61	1.76	1.71	1.56	1.54

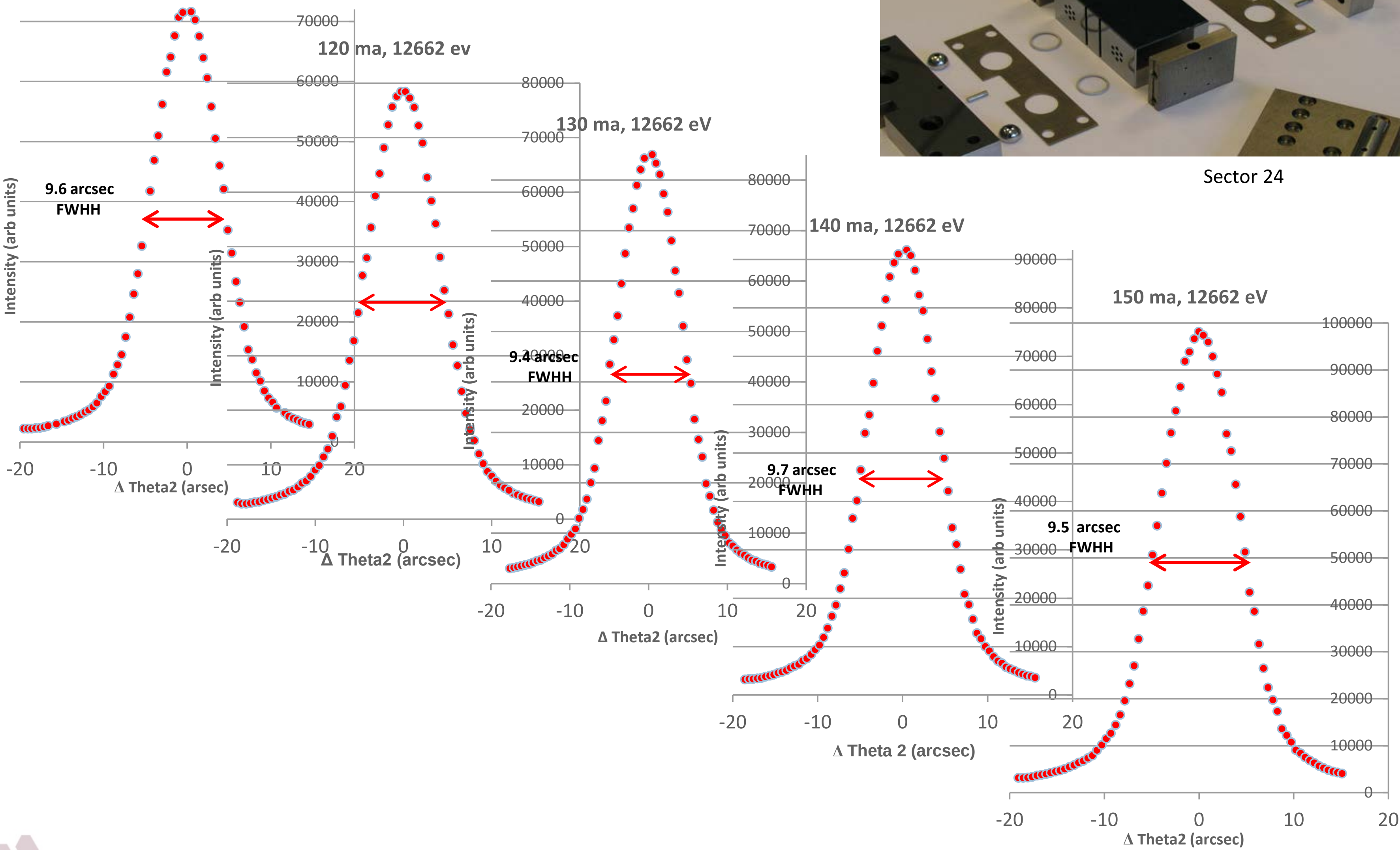
Also looked at 5, 12 & 25 keV

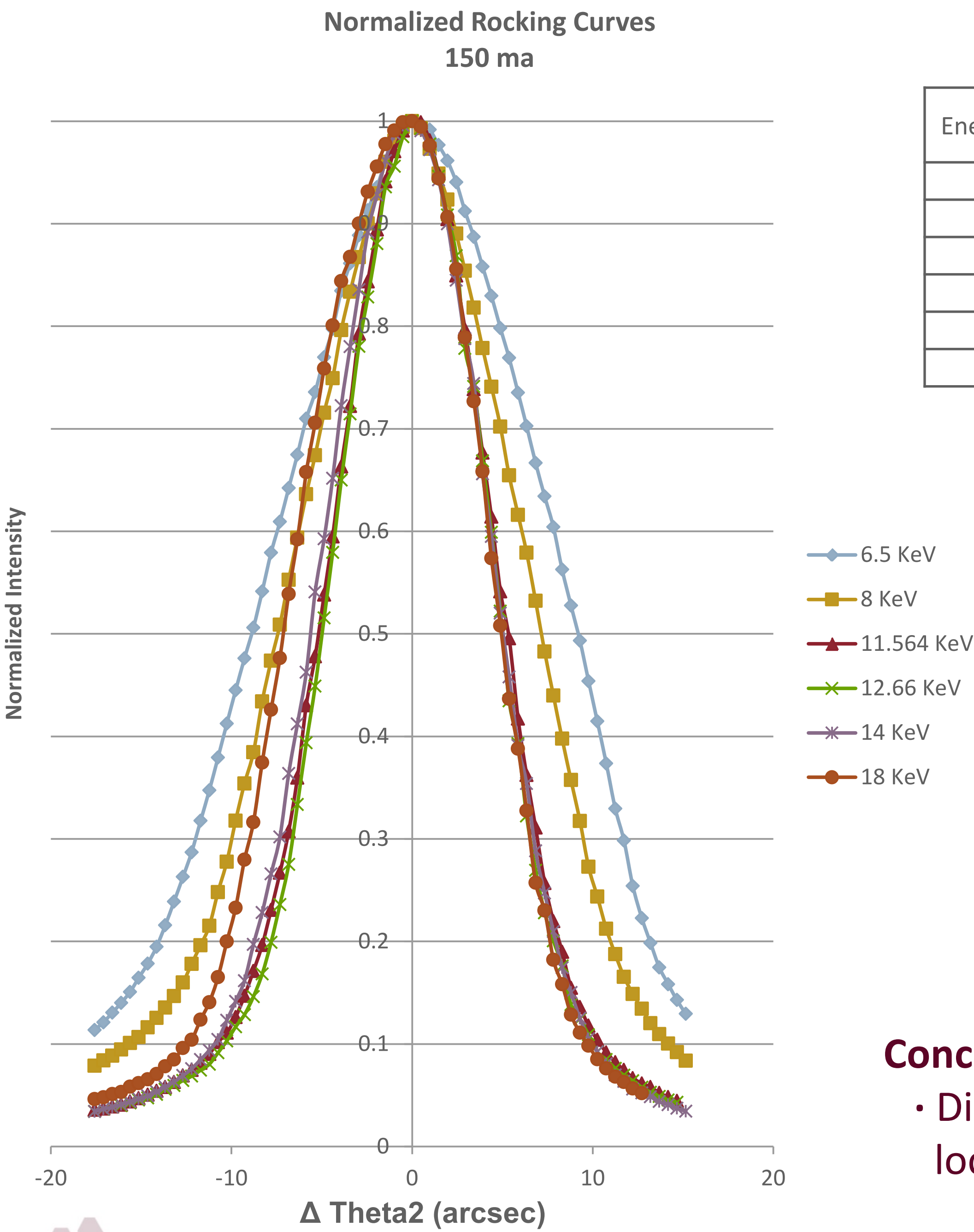
Conclusions: Expected broadening & shoulders, still OK for 150mA

24-ID-C (Malcolm Capel)



Sector 24





Energy (keV)	RC FWHH (arcsec)	Undulator Harmonic	~Gap (mm)
6.5	17.6	1st	**16.4**
8	14.7	1st	**18.6**
11.565	10.7	1st	**25.0**
12.622	9.5	1st	**28.3**
14	10.4	3rd	**11.5**
18	11.6	3rd	**12.3**

Conclusions:

- Distortion of 18 KeV rocking curve due to local crystal strain of second crystal.

19-ID (Gerd Rosenbaum)

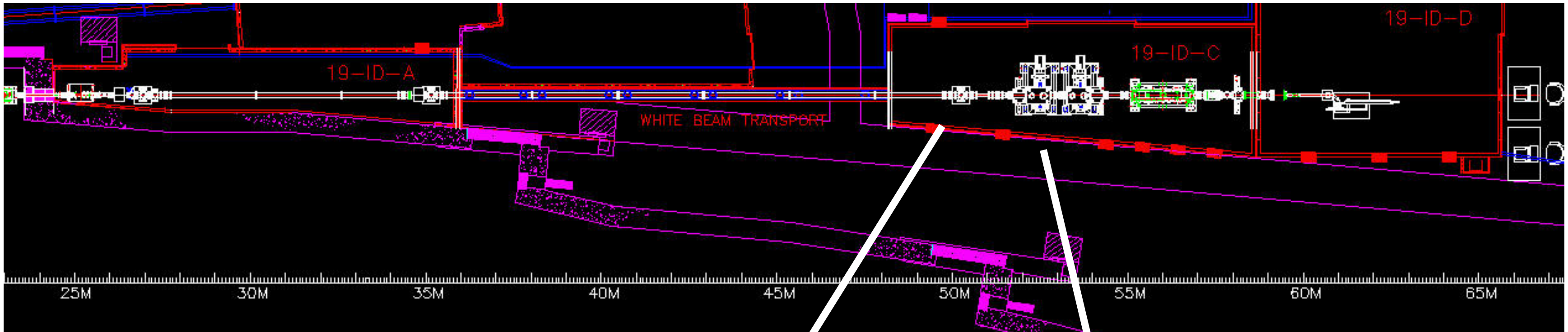
LN_2 cooled Si(111) hockey-puck mono

Source UA33

Gap Limited to 14.5mm min.

Ion Chambers

~65m

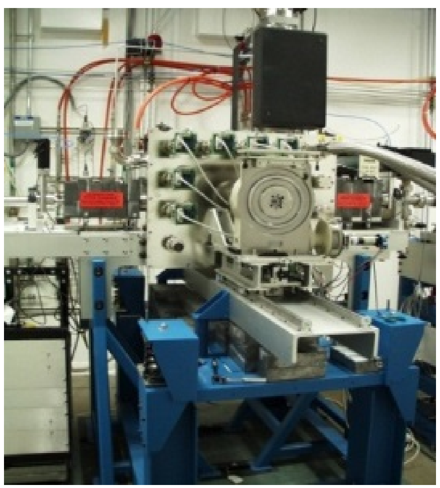


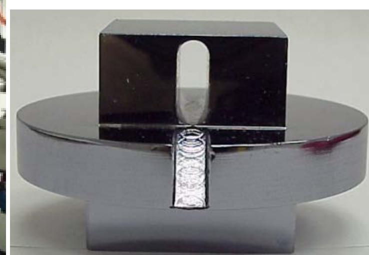
BLA

50m

Si(111) LN_2 'hockey puck'

53 m

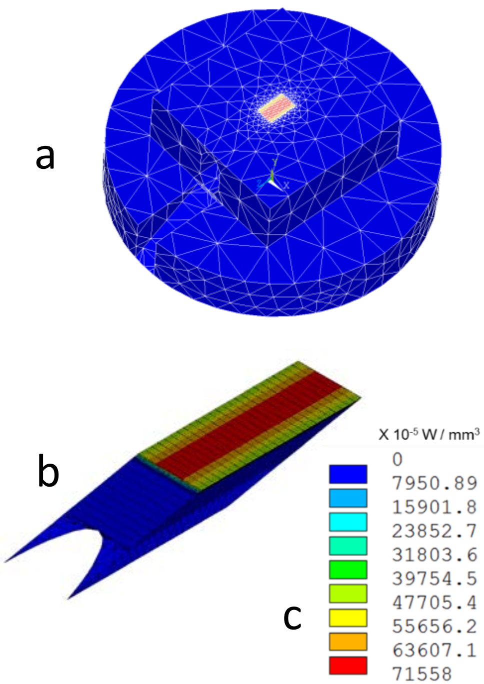




Conclusions: Performance OK @ 150mA & 14.5mm Gap

"..I can say nothing major happened going up to 150 mA at the limited gap.
The Si-111 rocking curve got a bit wider, not much. So did the Si-333 rocking curve. "

19-ID (Z. Liu FEA calcs)



d

Energy (keV)	Current (mA)	Peak power density* (W/mm²)	Power (W)	MLPD (W/mm)	Peak temperature (K)	Lowest temperature (K)	Slope error (arcsec)	Darwin width (arcsec)	Rocking curve, FWHM (arcsec)
6.5 (1st)	100	152.22	216	35.84	114.11	80.364	2.55	8.52	8.89
	150	228.33	324	53.76	144.14	81.68	1.65		8.67
	200	304.45	432	71.68	195.54	82.985	8.23		11.84
12.66 (1st)	100	24.02	48	4.99	82.21	78.299	0.19	4.22	4.22
	150	36.04	72	7.48	84.992	78.595	0.32		4.23
	200	48.05	96	9.97	87.656	78.893	0.42		4.24
13.474 (3rd)	100	99.22	304	30.15	113.69	81.456	1.74	3.96	4.32
	150	148.83	456	45.23	141.58	83.278	1.29		4.16
	200	198.44	613	60.75	192.21	85.119	5.25		6.57
19.5 (3rd)	100	87.28	253	18.99	99.967	80.813	0.83	2.72	2.84
	150	130.93	380	28.49	115.05	82.348	1.14		2.95
	200	174.57	507	37.99	134.12	83.865	1.02		2.90
30 (3rd)	100	71.56	132	16.24	93.542	79.334	0.75	0.37	0.84
	150	107.34	198	24.36	104.2	80.145	1.14		1.20
	200	143.12	264	32.48	116.13	80.952	1.39		1.43
30 (5th)	100	129.56	250	30.80	111.55	80.78	1.29	0.37	1.34
	150	194.33	376	46.21	138.2	82.299	0.89		0.96
	200	259.11	501	61.61	182.13	83.801	3.86		3.88

Z.Liu, et al., SRI2013

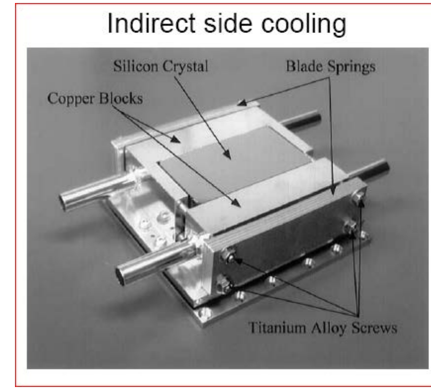
FEA model of the "hockey-puck" Si crystal with a heat load. a) Fine mesh in the footprint region and coarse mesh elsewhere. b) Magnified view of the heat loading for the volume absorption, the first ten layers are 0.01 mm thick each and next nine layers are about 0.1 mm thick each. c) The scale of power density corresponding to total absorbed power of 132 W for the 3rd harmonic 30 keV at 100 mA. d) cooling fin temperatures are less than 85 K, the boiling point of LN2 at 27 Psi,

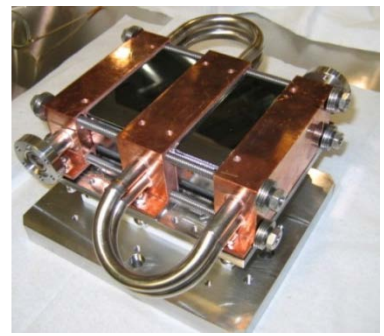
- The "hockey-puck" crystal works well at 150 mA in terms of temperature and thermal slope error.

Results: LN_2 Cooled Insertion Device Optics

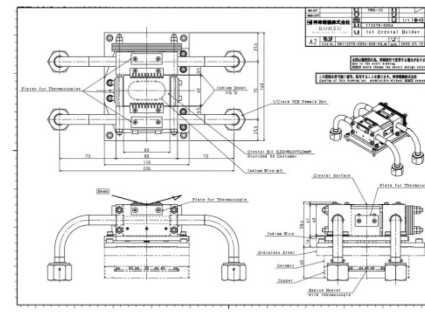
- **All LN_2 cryo-cooled Si monochromators performed extremely well.**
- Slight & expected broadening of rocking curves
- Most effects due to second crystal Compton heating

Sector 19

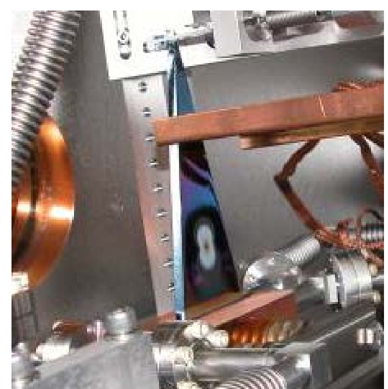




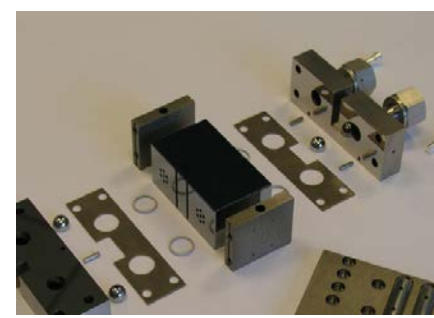
Sector 20



Kohzu (commercial)



Sector 1



Sector 24

Recommendations :LN_2 Cooled Optics

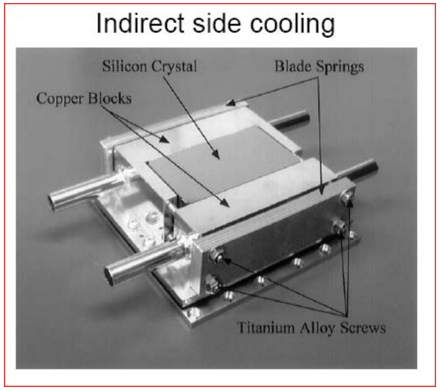
Take Home Message:

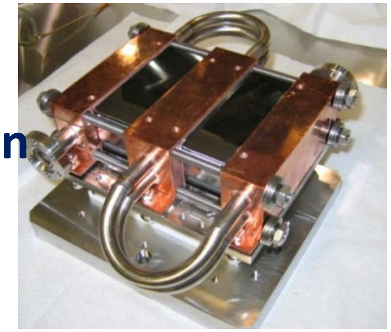
- SO FAR – All work well at high current
- Need to push designs further

Suggested Incremental Improvements:

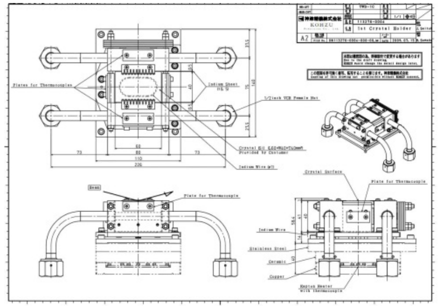
- Invest in improved Compton shielding
- Invest in 2nd crystal cooling stabilization

Sector 19

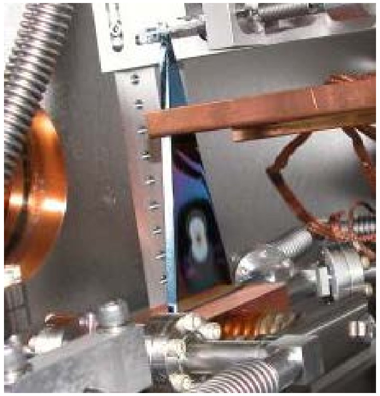




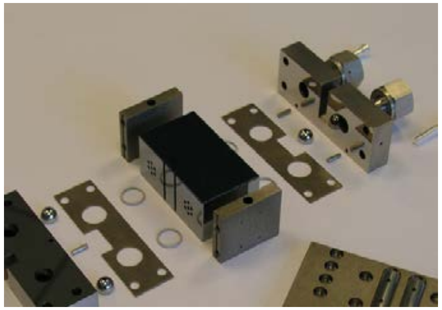
Sector 20



Kohzu (commercial)



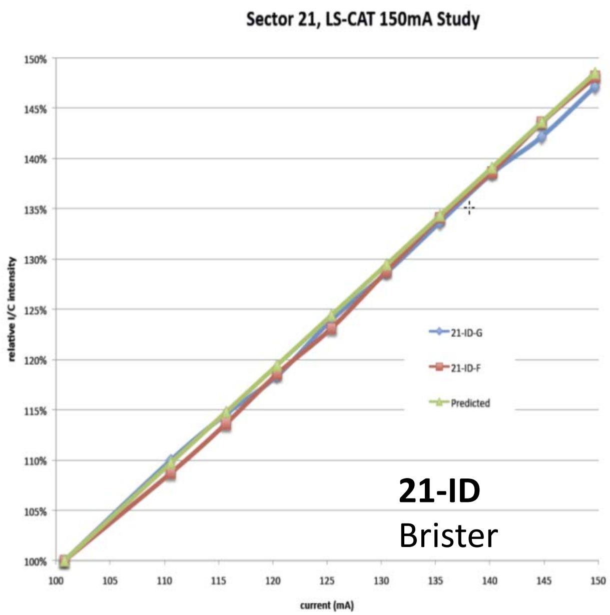
Sector 1

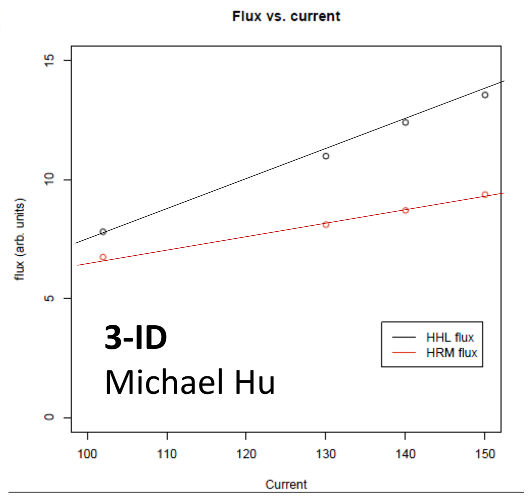


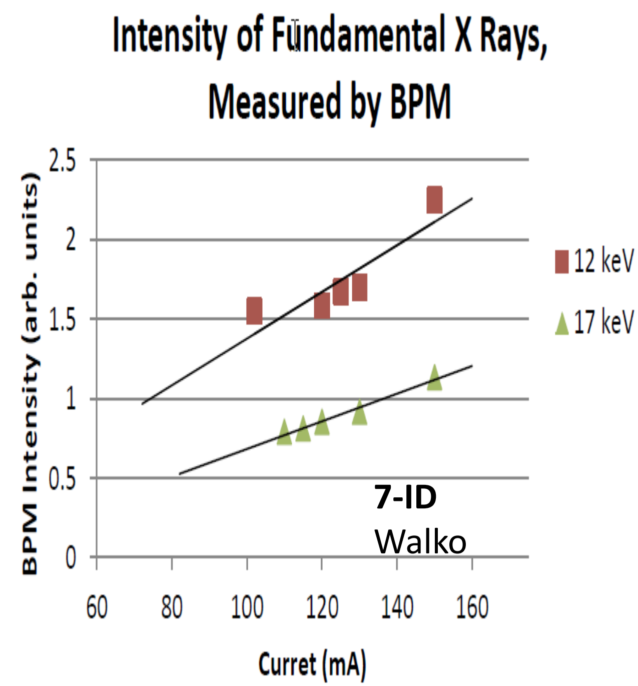
Sector 24

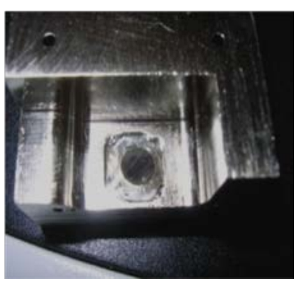
Diamond (111) Mono Results

#1: Beam I_0 increases linearly with I_{APS}

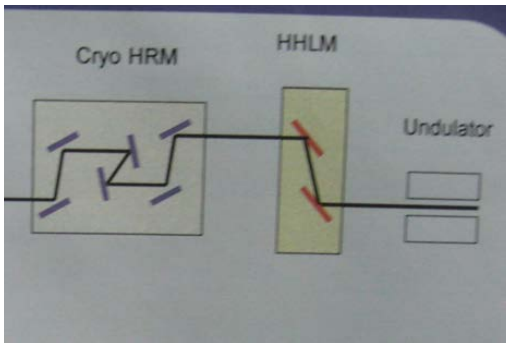


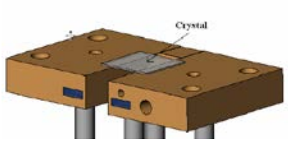






Sector 21

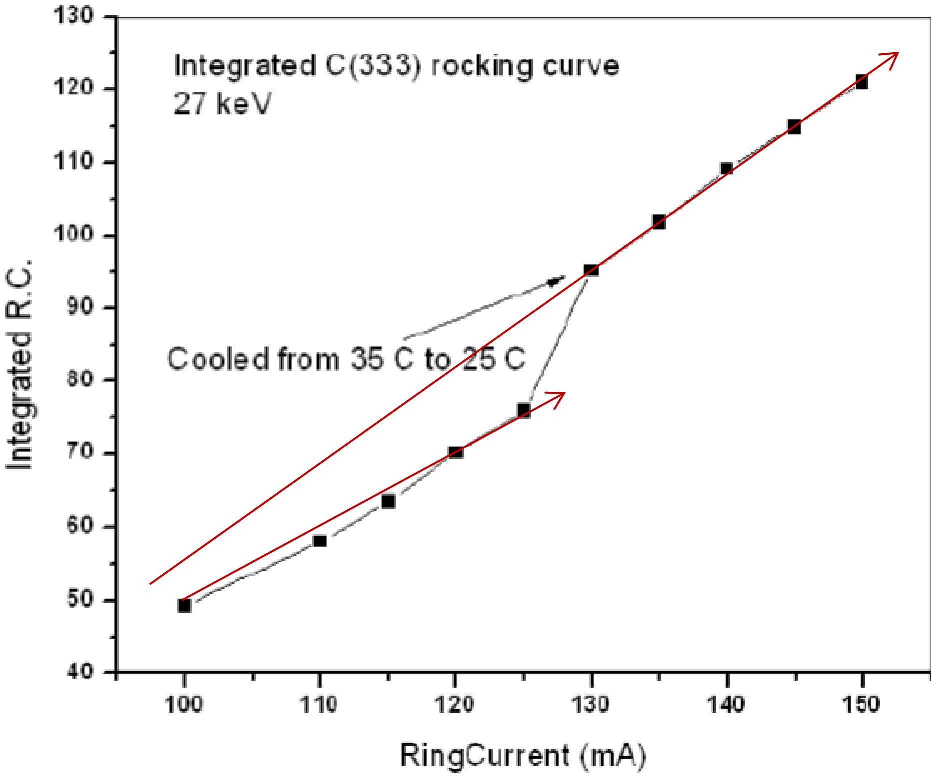




Beam I_0 increases linearly with I_{APS}

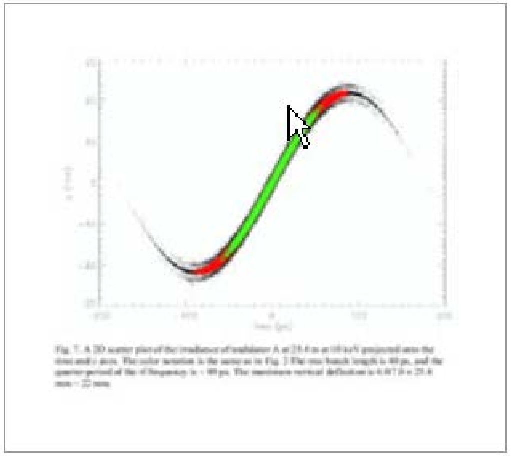
- MERIX/HERIX
- Source Dual in-line U30s
- Kohzu Monochromator
  - C(111) & C(333)
- 1mm x 1mm slits
- 9 keV (~15.8mm gap)

Sector 30, Integrated Intensity of 3rd harmonic

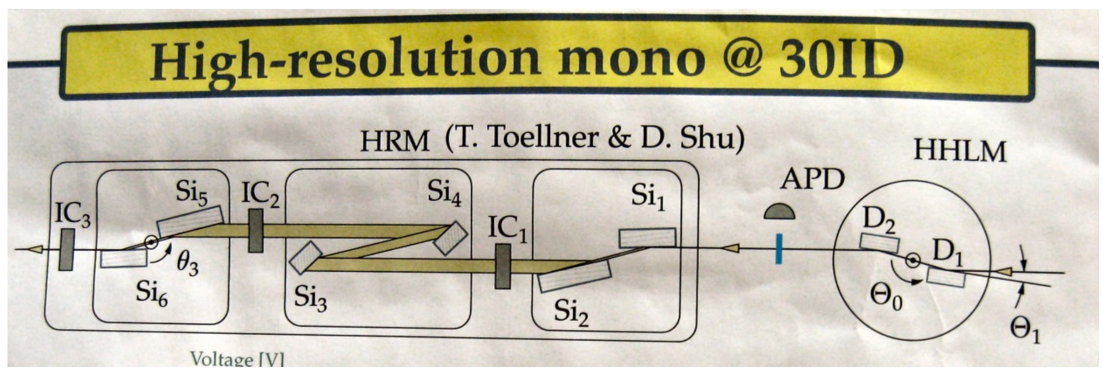


1-ID, 12-ID-C

#2: Rocking Curve Widths vs. I_{APS}



7-ID Time Resolved Research Group



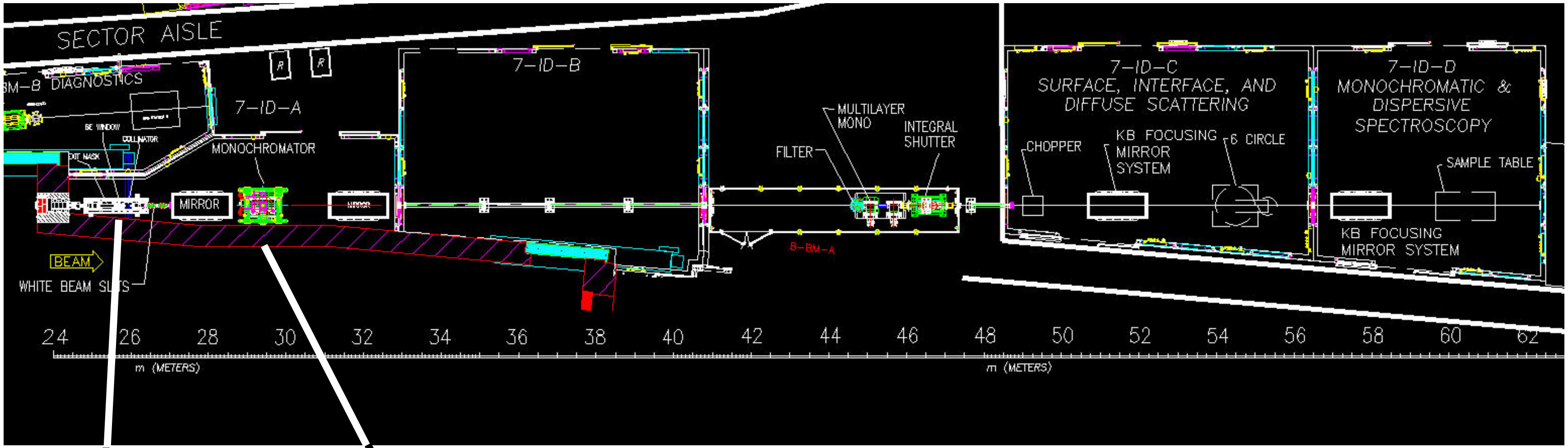
30-ID **HERIX & MERIX**

Also 1-ID, 12-ID-C

7-ID (Donald Walko)

Water cooled diamond(111) mono

Source UA33



White Slits
0.5mmH x 0.5mmV

Ion Chambers
50m

Diamond(111)
Kohzu @ 29m H_2O

7-ID (Donald Walko)

Water cooled diamond(111) mono

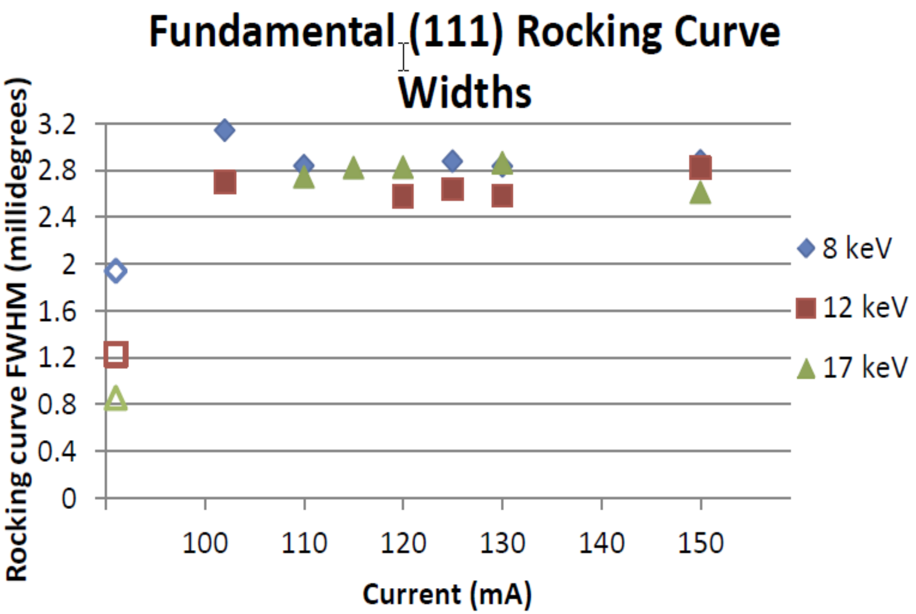
Source UA33

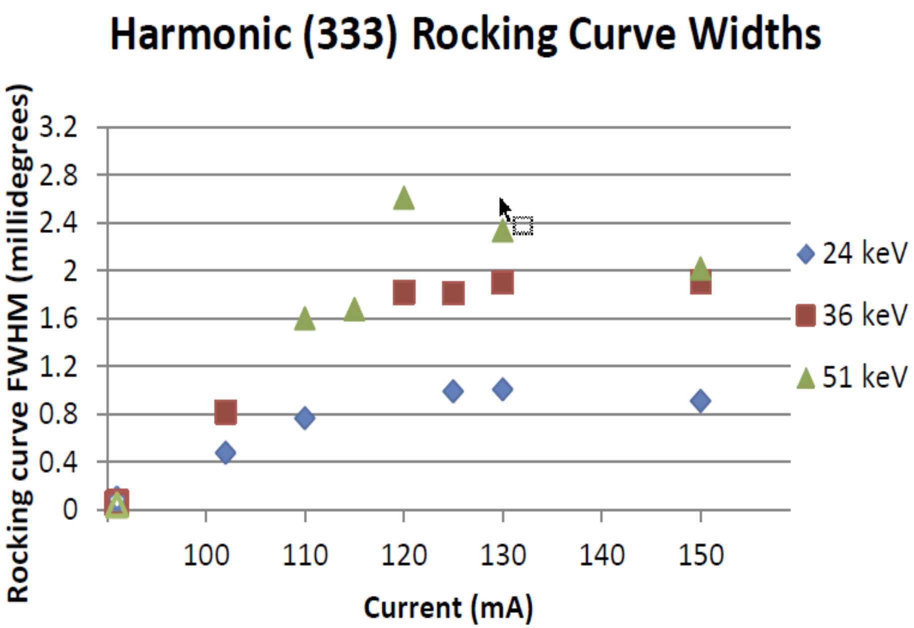
Sorted by E:

8.15keV, 1100W total @ 100mA 1st Harm.
12.15keV, 270W total @ 100mA 1st Harm.
17.19keV, 2300W total @ 100mA 3rd Harm.

Sorted by gap:

15.1mm gap @ 100mA 3rd Harm. = 17.19keV,
18.6mm gap @ 100mA 1st Harm. = 8.15keV,
26.6mm gap @ 100mA 1st Harm. = 12.15keV,

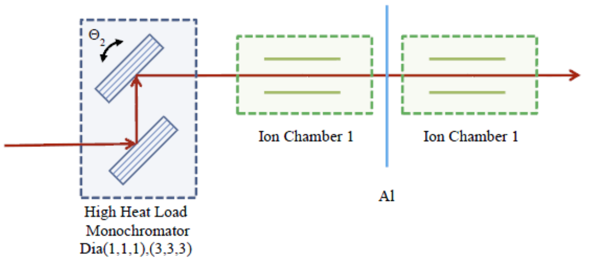




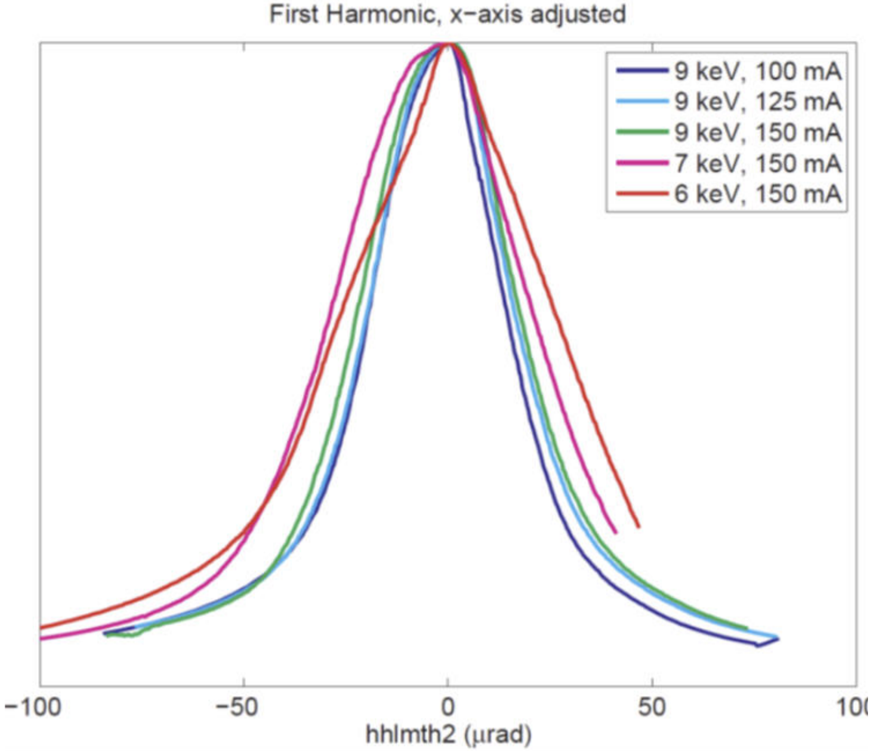
Conclusions: Only modest broadening at high power loads, seen in 3rd harmonic

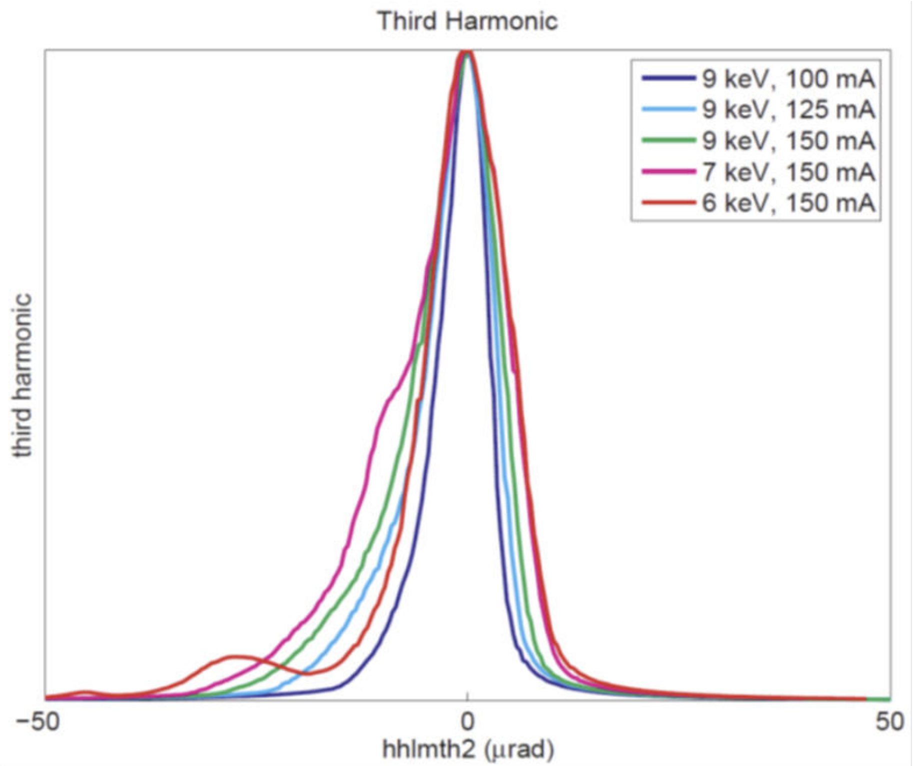
30-ID (Thomas Gog, Mary Upton)

Sources Dual in-line U30s



Incident beam characteristics:
Ky = 1.2 => Es = 9.0 keV @ 150mA
Total Power Pt = 2 x 136.8 W = 273.6 W
Power Density (Center) Pd = 2 x 146.9 W/mm2 = 293.8 W/mm2

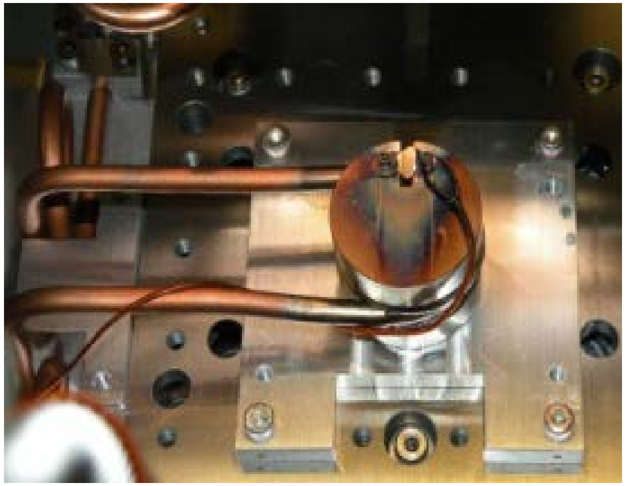




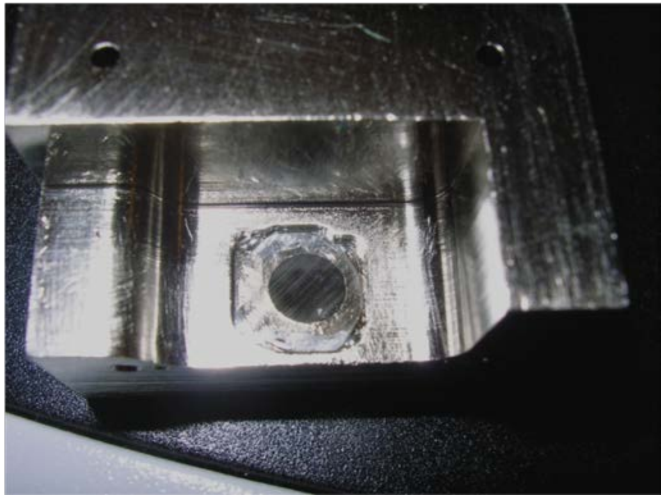
Conclusions: Only modest broadening at highest power loads

Results: Water Cooled Insertion Device Optics

- **All water cooled diamond ID monochromators performed extremely well. Expected broadening at high power loads**
- Known weakness – InGa eutectic coupling
- NO 'SHOW STOPPERS'.



Sector 33

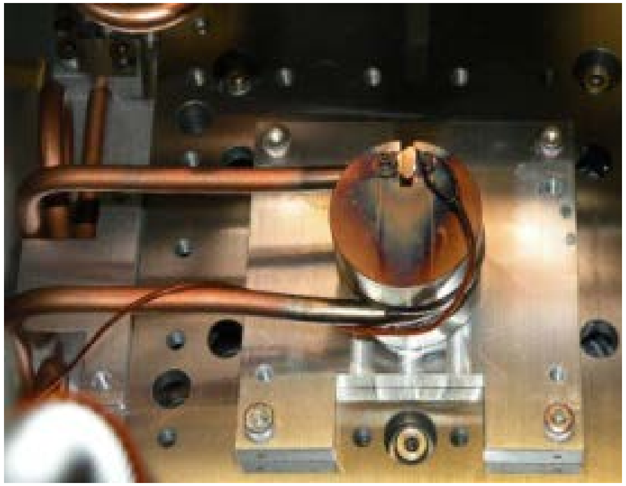


Sector 21

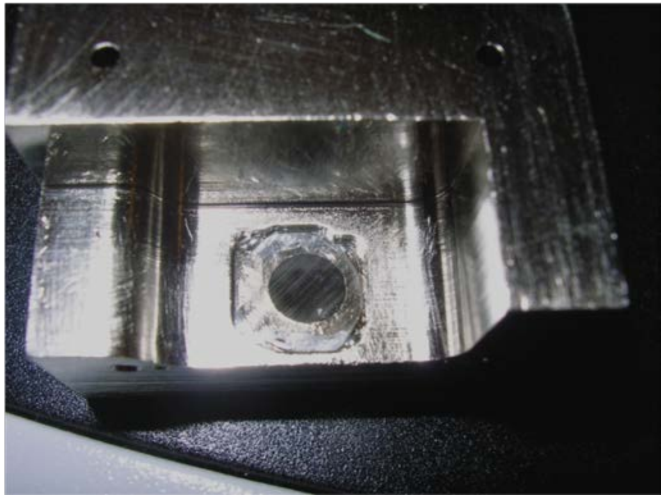
Results: Water Cooled Insertion Device Optics

Take Home Message:
- Work well at high current

Suggested Incremental Improvements:
- Invest in improved Compton shielding
- Invest in 2nd crystal cooling stabilization
  - increased contact area, two-side cooling
- Invest in routine maintenance
  - clean, re-polish, re-wet your diamonds



Sector 33



Sector 21

HHL Mirror Results

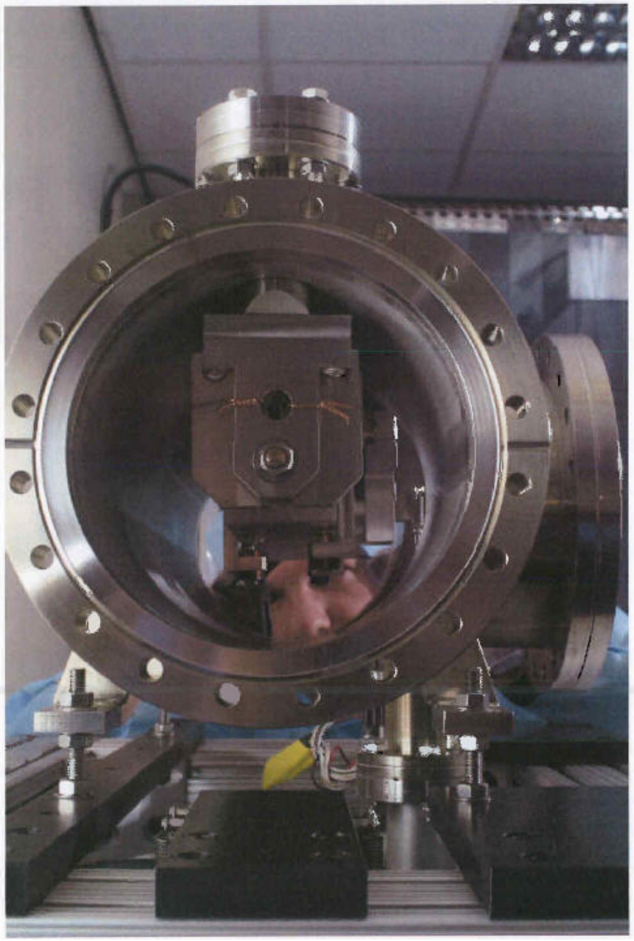
Results: Water Cooled Mirrors

- Two water cooled white beam mirror reports: 11-BM & 12-ID

All OK

- Temperatures stable,
- Beam size stable,
- Flux follows I_{APS}

Harmonic rejection mirror system for DND CAT at APS



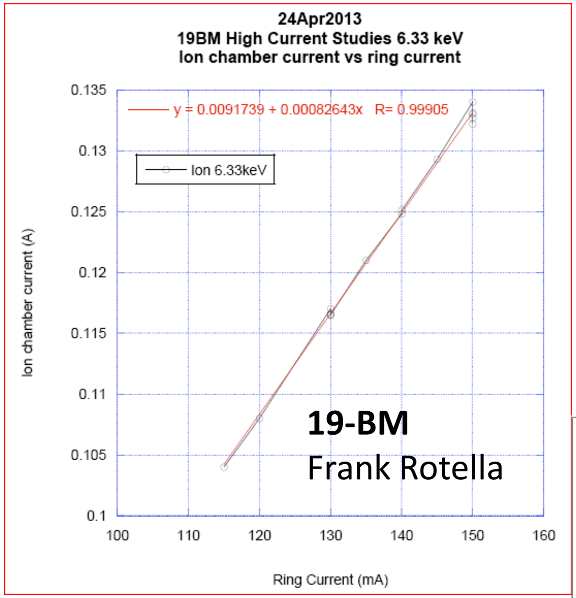
Results: Water Cooled Mirrors

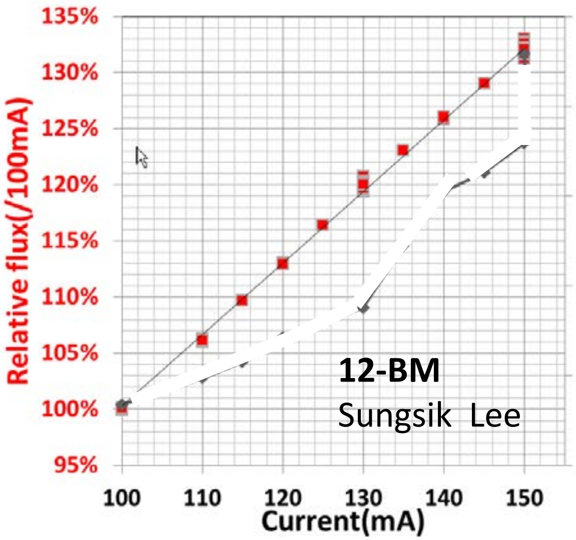
Take Home Message:

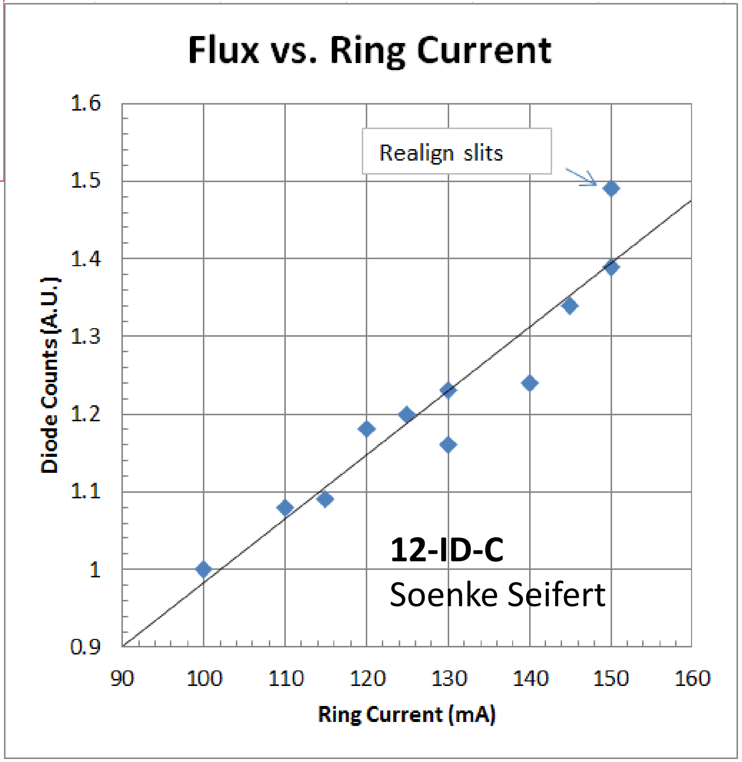
- **Cautiously optimistic**
- **Needs more participation / careful study**

Water Cooled Mono Results

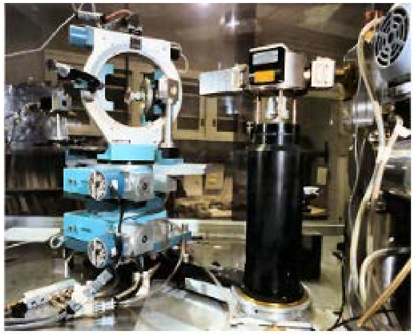
#1: Beam I_0 increases linearly with I_{APS}



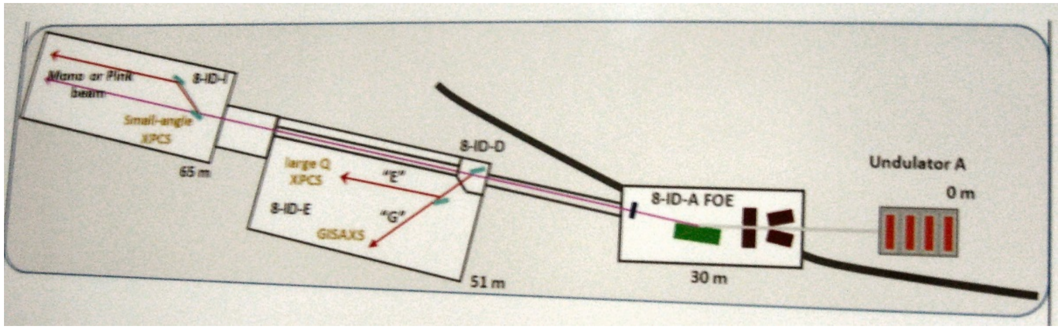




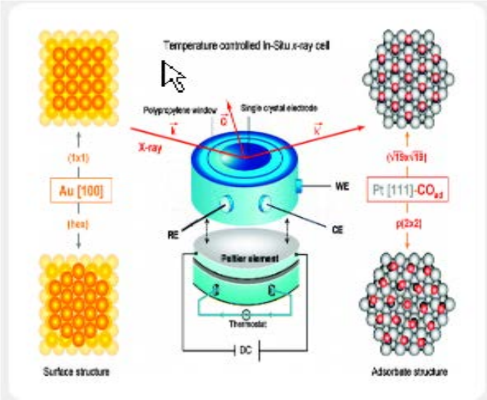
#2: Rocking Curve Widths vs. I_{APS}



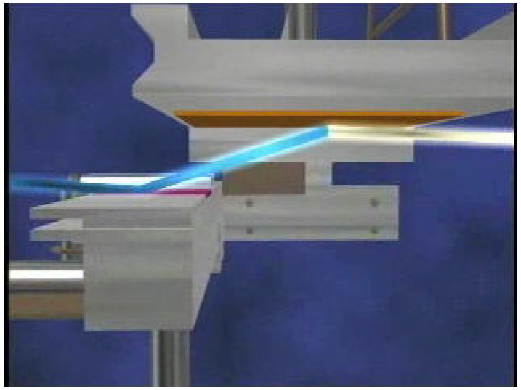
01-BM Optics and Detectors Testing Beamline



08-ID Time-Resolved Research



12-BM Chemical and Materials Science



SBC-CAT 19-BM

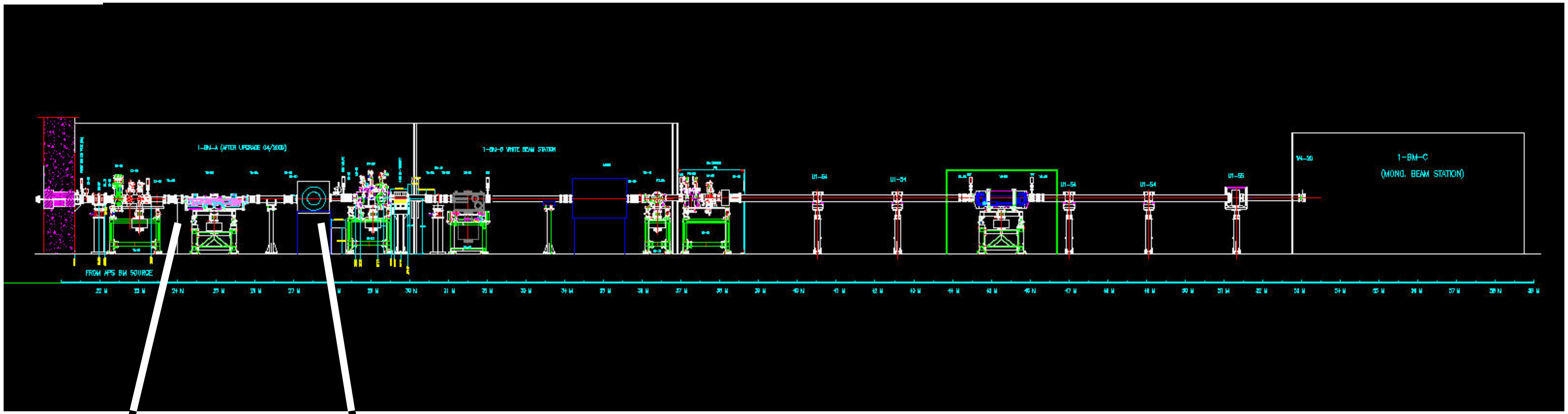
(PNC-CAT) 20-BM

Also 1-ID, 12-ID-C

1-BM (Al Macrander, Naresh Kujala)

Water cooled Si(111) mono

Source

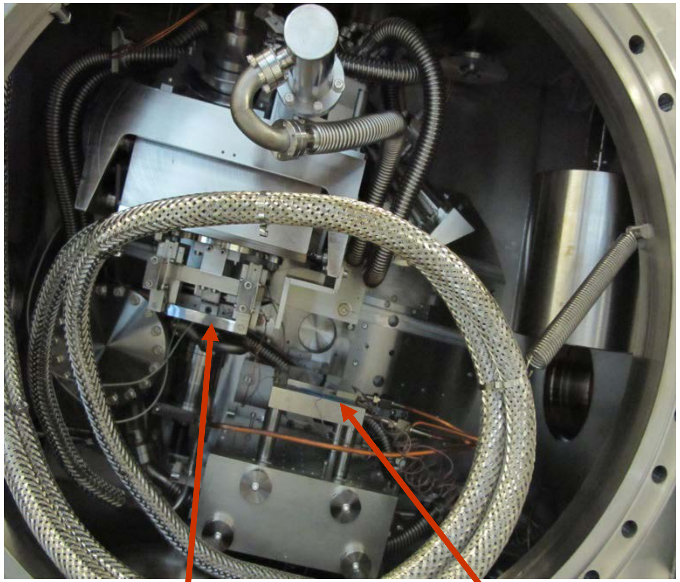


White Mirror
removed

PSL Mono
Water cooled

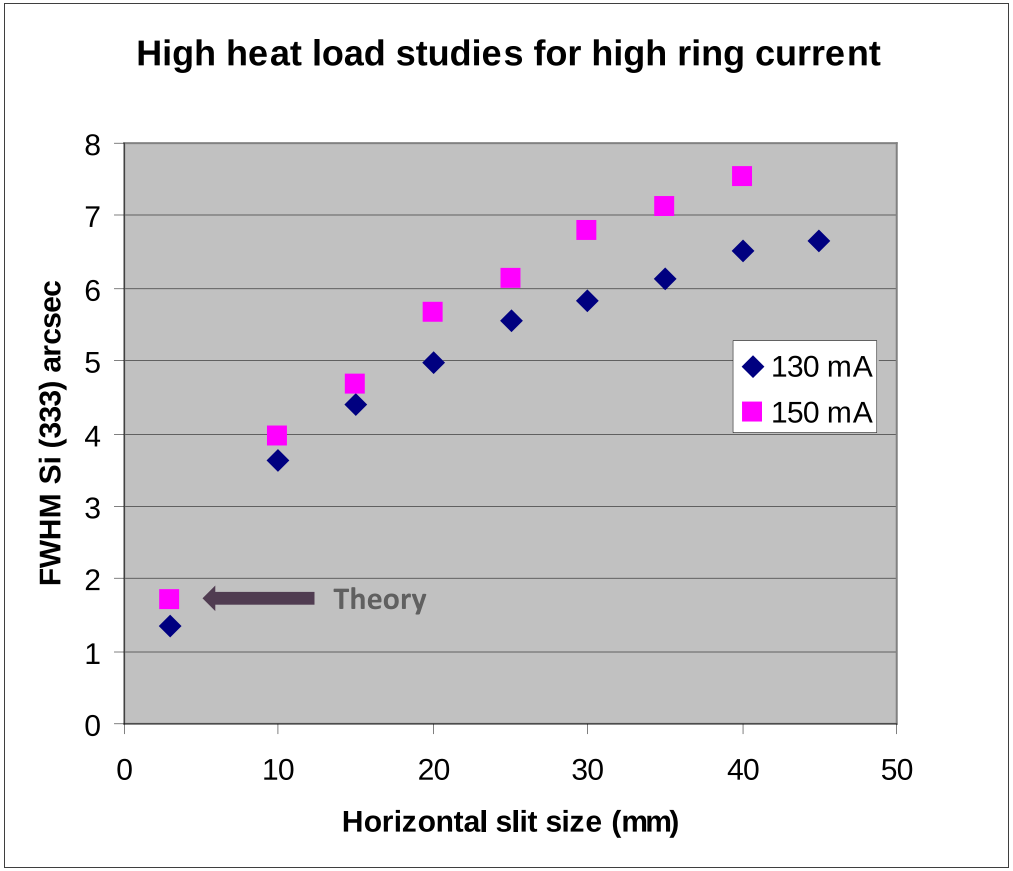
High heat load studies for ring currents 130 mA and 150 mA

Double Crystal Monochromator (DCM)



1st Si (111) crystal

2nd Si (111) crystal



- 1-BM monochromator (made by Physical Science Laboratory, Madison WI) is water cooled from bottom.
- Monochromator energy was set to 8 keV.
- Two ion chambers were used to measure rocking curve with Al filter between two ion chambers for measuring both Si (111) and Si (333) reflections.
- Rocking curve was measured by rocking 2nd crystal for Si(333) reflection.
- Vertical slits were open 4 mm.
- Rocking curve measurements was done with 130 mA and 150 mA ring current.

8-ID (Alec Sandy)

Mirror + Water cooled Ge(111) channel-cut mono

Source 1X or 2X UA33

7.39keV, 615w @ 100mA

BLA Pinhole
Ø280µm @ 26.24m

Mirror
H. Defl. (inbd.) @ 29m

Ge channel-cut
H_2O cooled @ 64.8m

Be CRL
10 lens, r=0.2mm

Gap (mm)	E_1 (keV)	k_{eff}	# of UA's	I_{ring} (mA)	P_{tot} (W)	$\varnothing_0$ (W/mm²)	i_{meas} (mm)	Effective Object Distance o_{eff} (m)
17.6	7.39	1.34	1	100	1.0*	1.5	1768	17.056
17.6	7.39	1.34	2	100	1.9*	2.9	2005	7.963
18.8	8.1	1.21	1	130	2.6	2.0	3032	5.237
18.8	8.1	1.21	2	130	5.2	4.0	4442	3.383

Conclusions:

- power load significantly affects the performance of the 8-ID-I monochromator
- focus position is power-load dependent

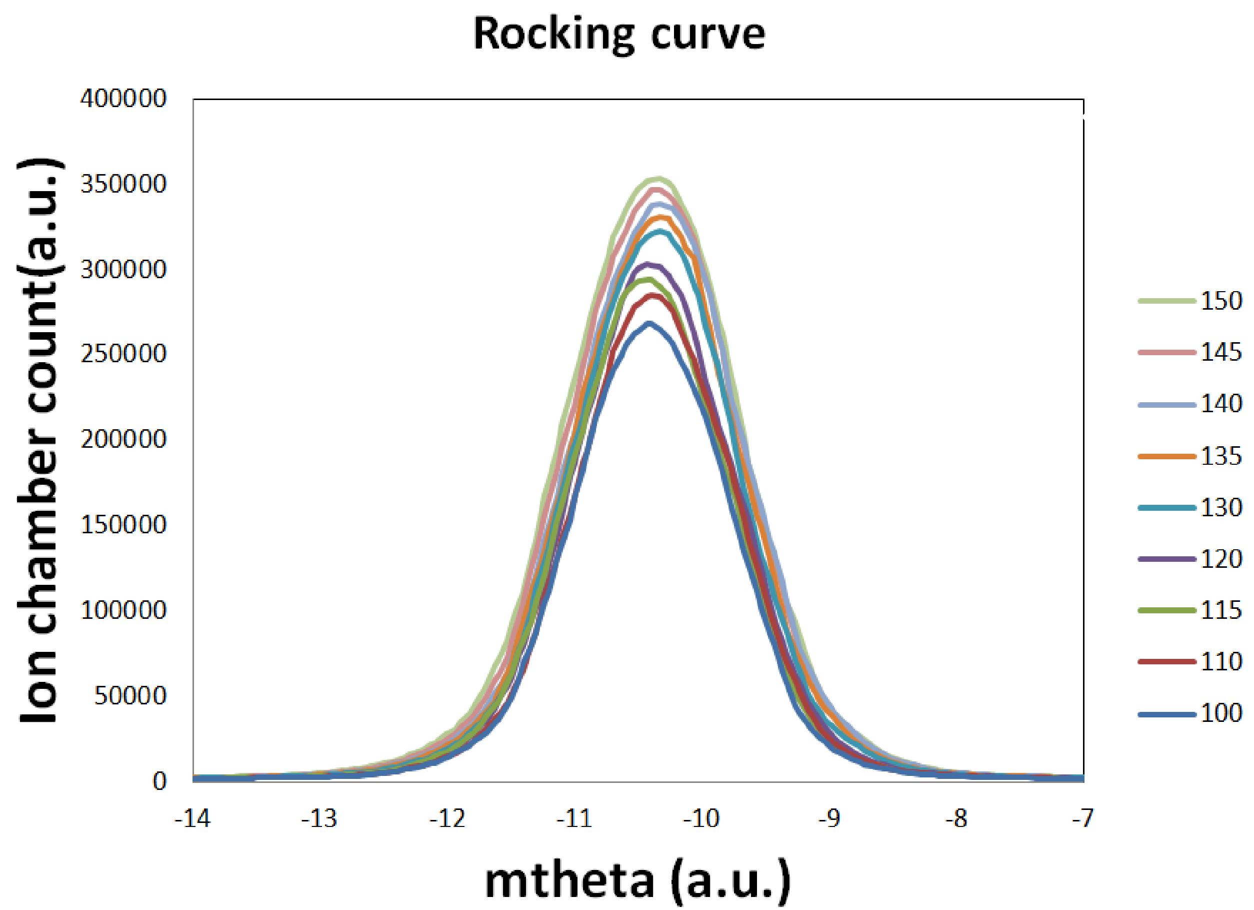
12-BM (Sungsik Lee)

Water Cooled Si(111) mono

Source BM E = 12.0keV

- RCs broaden with I_{APS}

Si(111) BESSRC Style Mono – Water Cooled

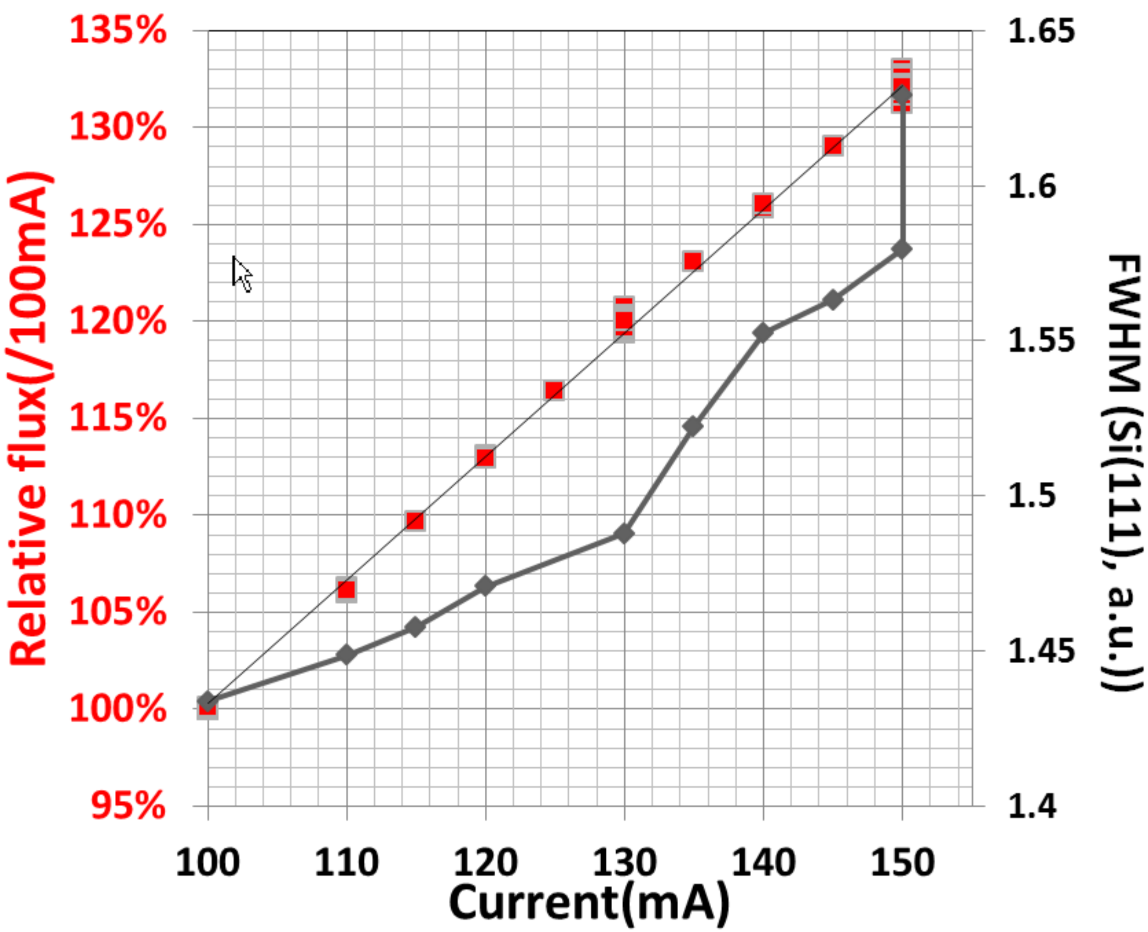


12-BM (Sungsik Lee)

Water Cooled Si(111) mono

Source BM E = 12.0keV

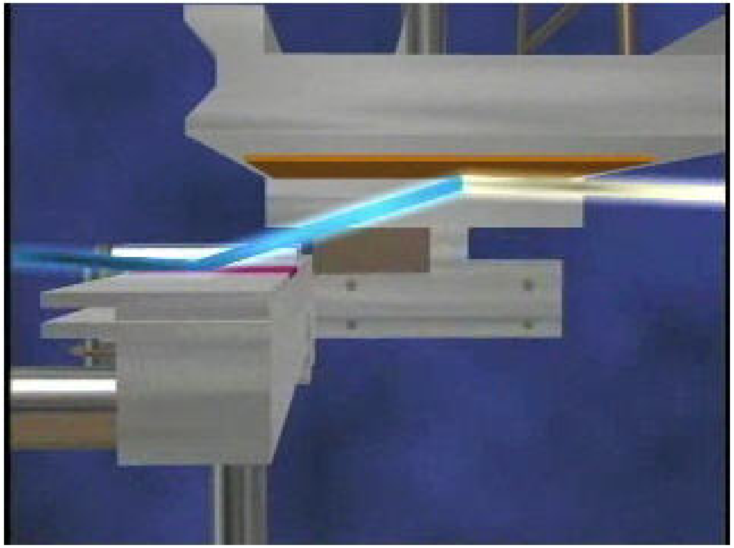
- Flux IS linear with I_{APS}
- Rocking Curve FWHM not linear with Power,

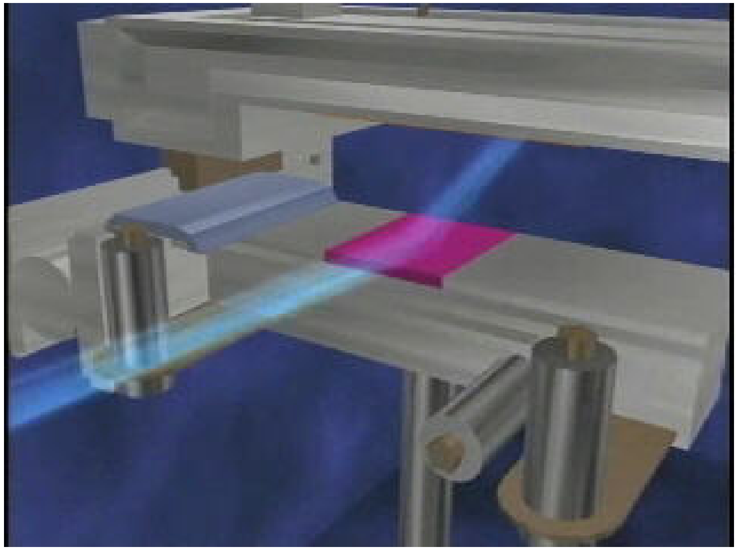


19-BM (Frank Rotella)

Water Cooled Si(111) mono

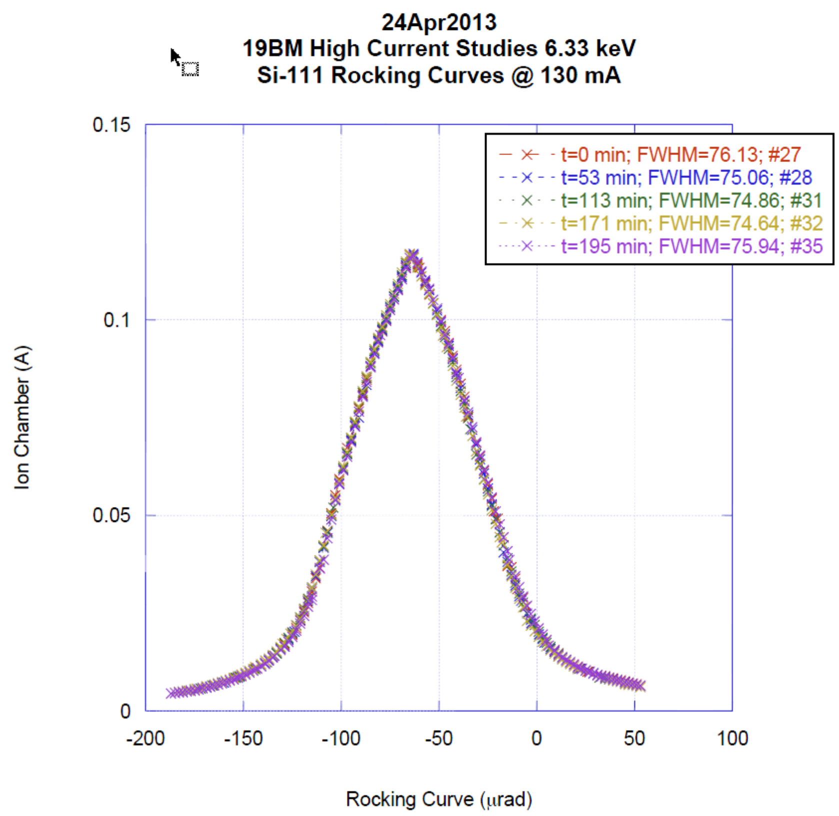
Source BM E = 6.3 & 19 keV tests up to 150mA

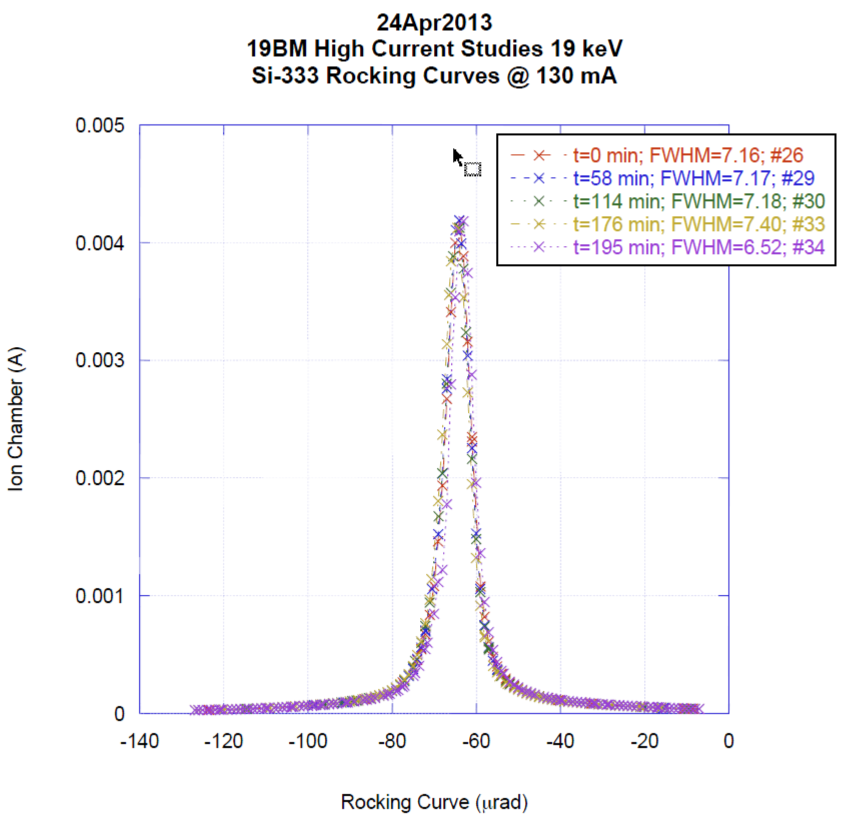




19-BM (Frank Rotella)

Water cooled Si(111) mono

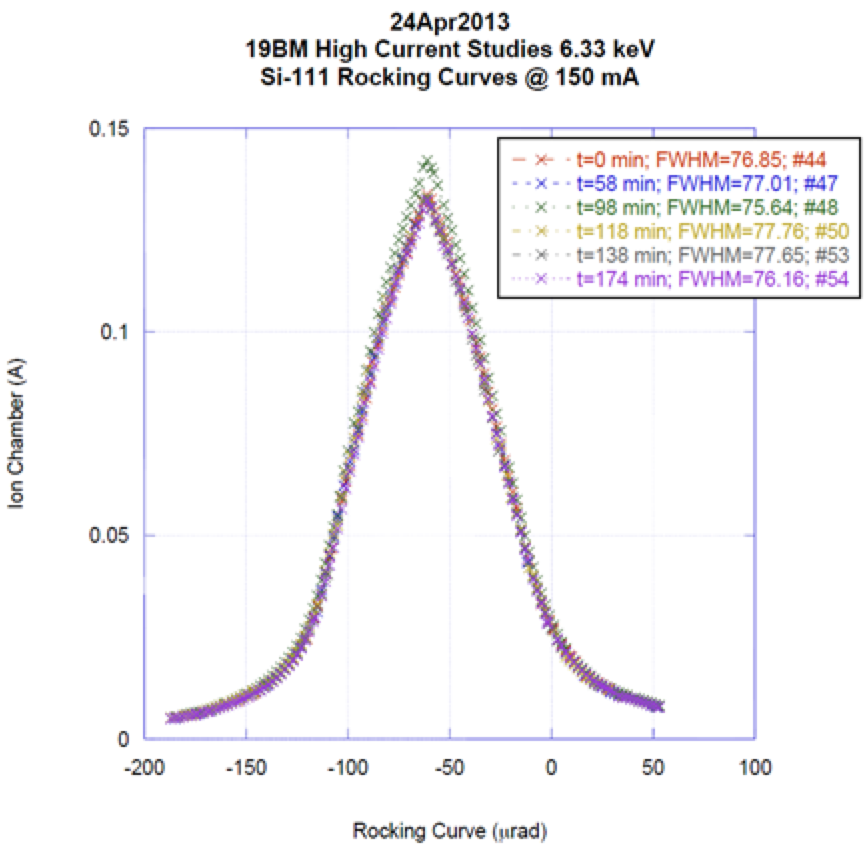


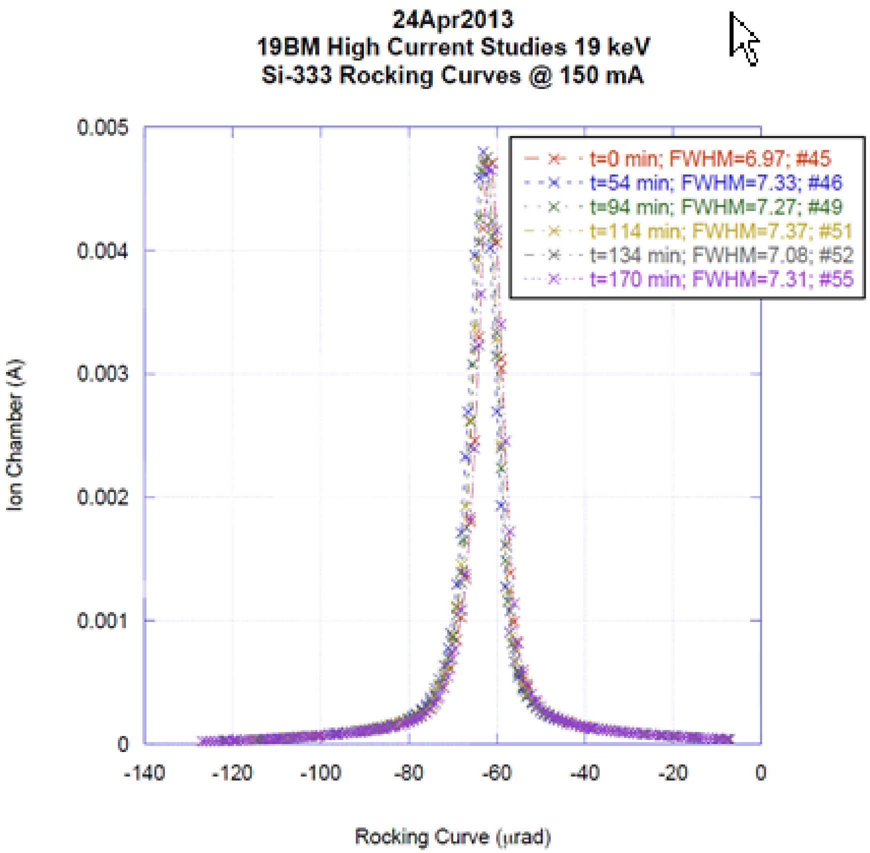


Conclusions: Performance GOOD

19-BM (Frank Rotella)

Water cooled Si(111) mono

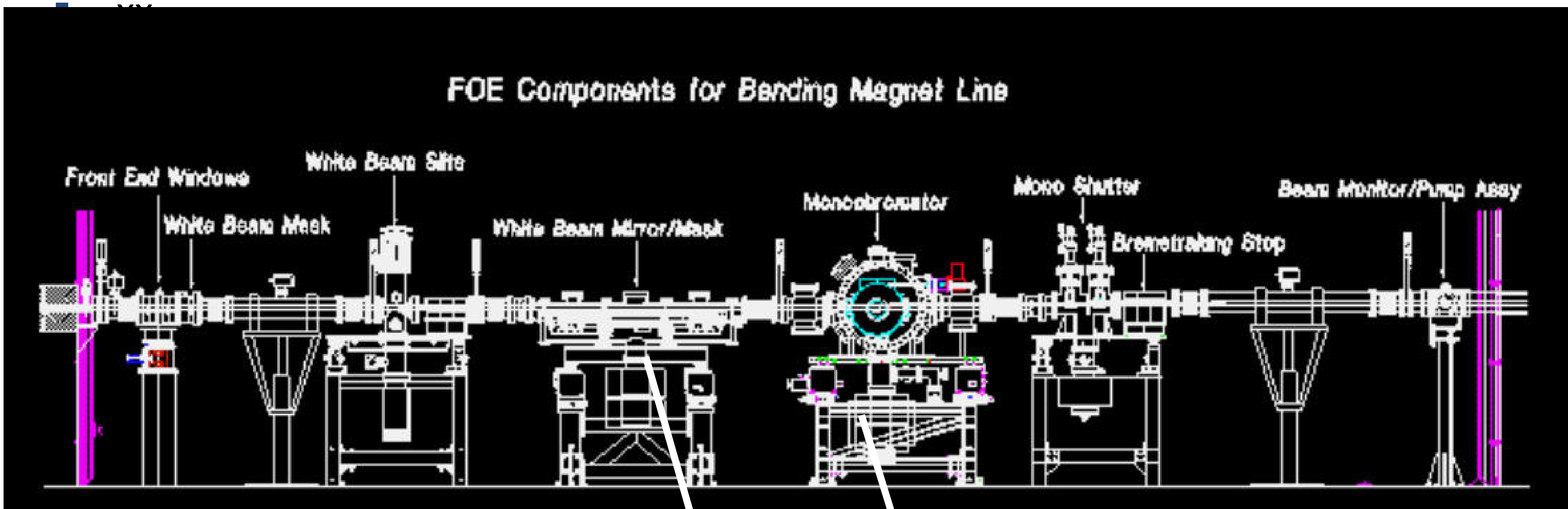




Conclusions: Performance GOOD

Sector 20-BM (Heald)

Xxxx mono



White Mirror

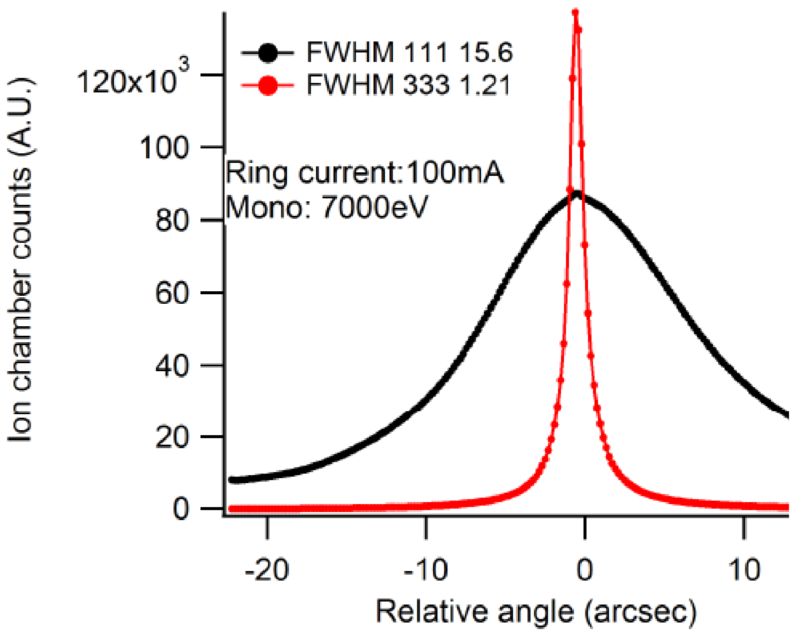
Mono

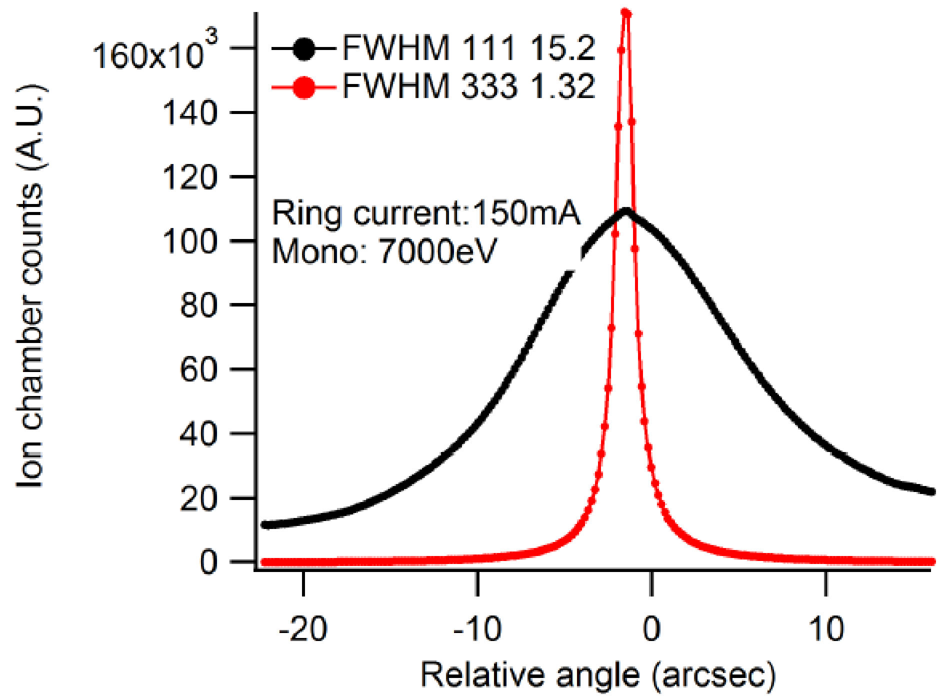
Water Cooled BESSRC mono

20-BM (Dale Brewe, Steve. M. Heald, et al.)

Water cooled Si(111) mono

BESSRC Si(111) Water Cooled 7.0 keV Results





I_{APS}	100	110	115	120	125	130	150
(111)	15.6	15.4	15.4	15.3	15.3	15.3	15.2
(333)	1.21	1.22	1.24	1.26	1.27	1.28	1.32

Conclusions: (Also did 20keV) mono OK

Results: Water Cooled Monochromators

- Already indications of monochromator distortions with some designs
- Good news: We can learn from 19-BM & 20-BM designs
- Optimistic: NO 'SHOW STOPPERS'. Simple know incremental improvements will help. Working examples exist.

Results: Water Cooled Monochromators

Take Home Message:

- **Cautiously optimistic**
- **Time to dust-off old water-cooling tricks**
- **Cooling plate & coupling methods should be reviewed**

Conclusions

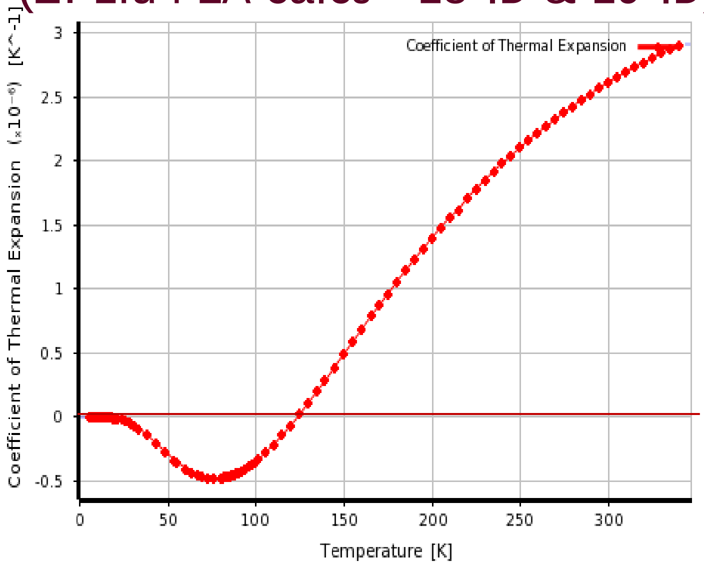
- **We didn't destroy any equipment !**
- Diamonds & LN2 Cooled Monos – Looking Good
  - If you look hard enough, most see broadening of RCs at high power
  - no 'show stoppers', fixes available
  - Some have but many have not pushed to highest powers
- Water Cooled devices are showing early signs of problems
  - We can learn from the nicely performing water cooled designs to repair/retrofit the poorly performing systems

Recommendations

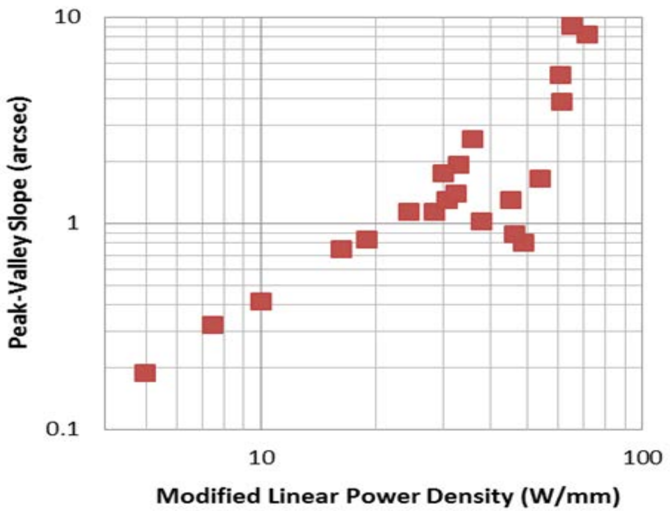
- **Second 2013-3 high current studies day, December 17, 2013**

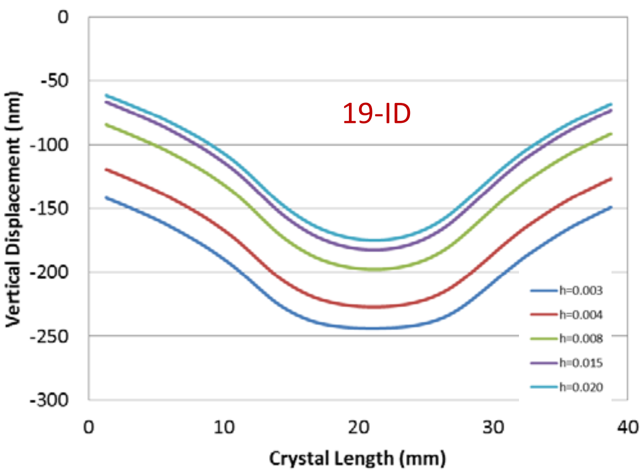
Better than linear ?!

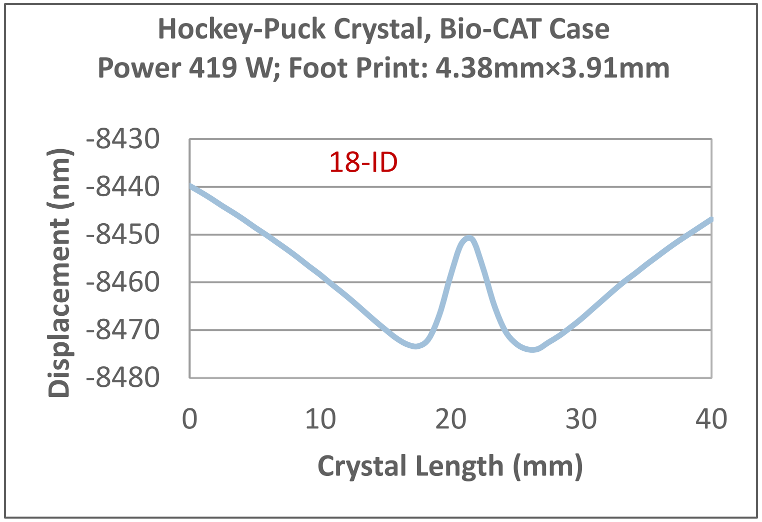
(Z. Liu FEA calcs – 18-ID & 19-ID)



Z.Liu, et al., SRI2013 – Sector 19-ID Case
MLPD concept: Huang, Bilderback, *Proc. Of SPIE*, **8502** (2012)



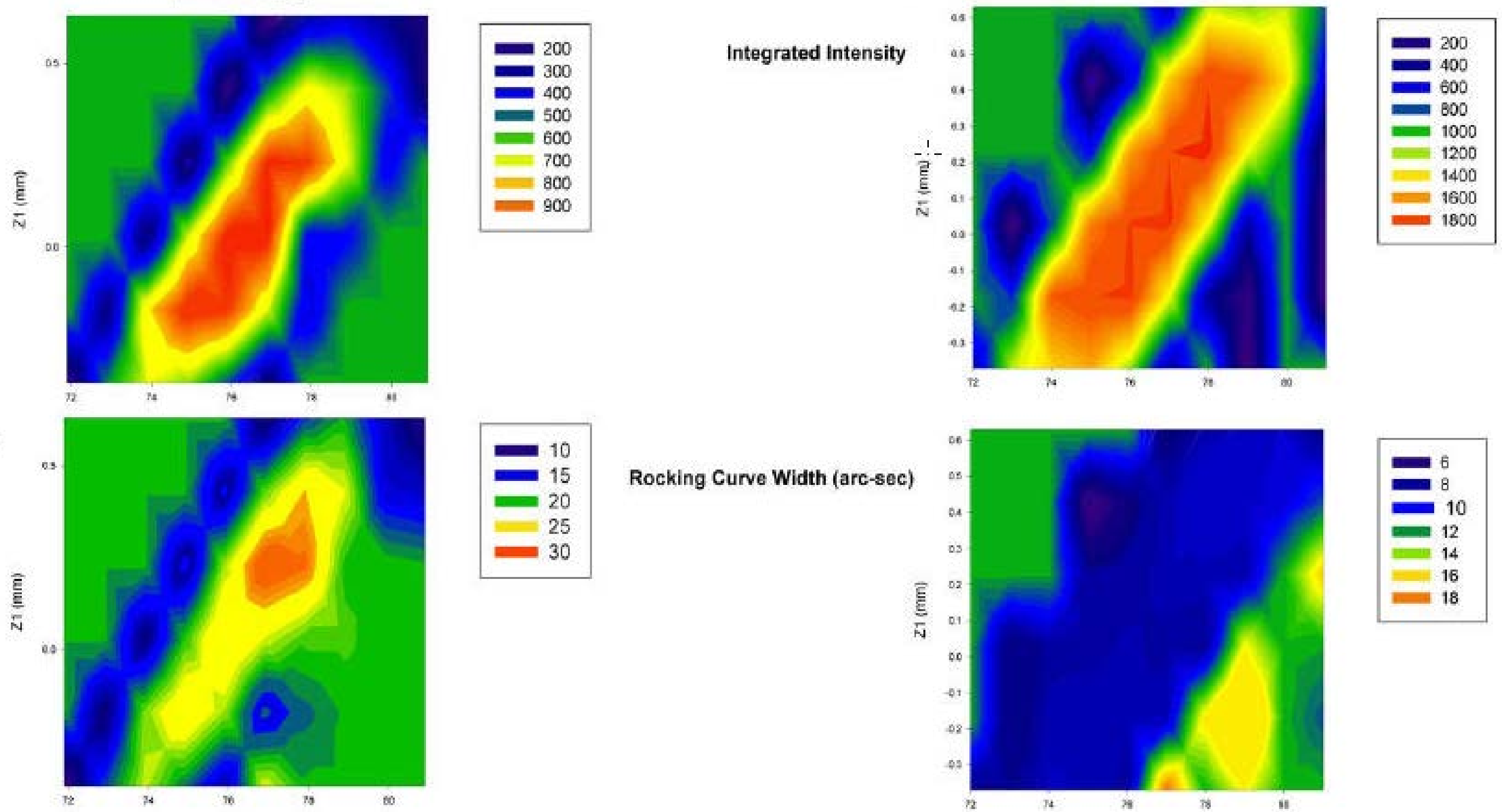




Diamond(111) Monochromator Strain Distribution

Strained Diamond

Un-Strained Diamond



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