Overview
X-ray Interface Science Beamlines

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X-ray Science Division

XIS Workshop
Jan 10-11, 2012

Outline

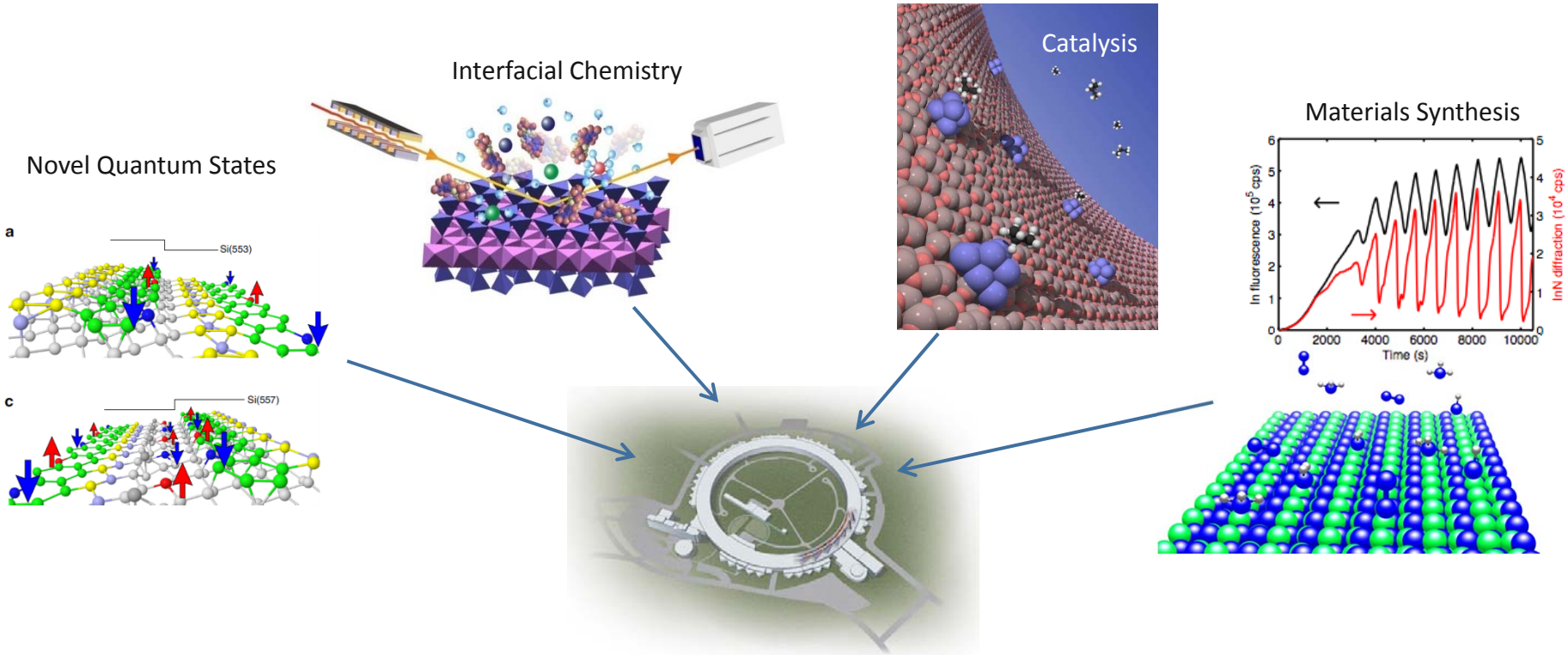
- Goal
- X-ray Interface Science (XIS)
- New Sector for X-ray Interface Science
- Presentation of beamline optics design
- Summary & Next Step

Goals

- Feedback to the sector design
  - CD-1 (conceptual design) to CD-2 (preliminary design)
  - From stake holders (dedicated users, potential users)
  - From other experts
  - Tell this will serve your future plan of research (sanity check)
- Forming groups to build dedicated instruments for XIS end stations

X-ray Interfaces Science

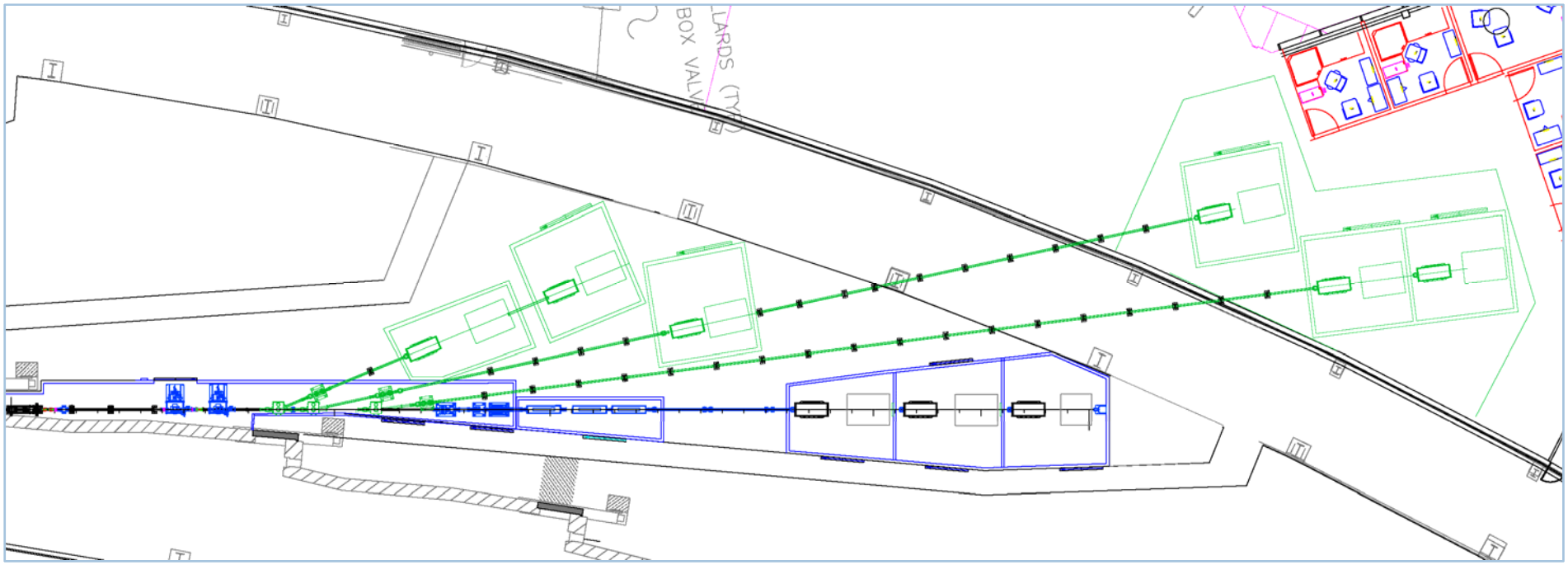
- *In-situ*, real-time studies are essential for our understanding and control of interfacial structure and properties
- Hard x-rays at the APS are ideally suited for interface science studies



- APS-Upgrade will provide dedicated facilities for transformational x-ray studies of interfaces in diverse systems

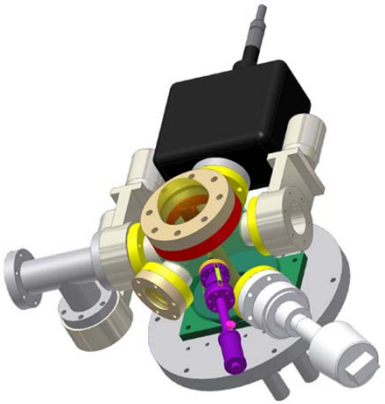
Interface Science Village

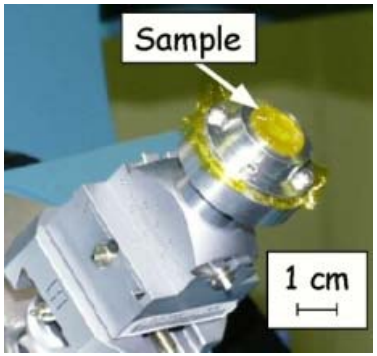
- Dedicated sector for In-Situ X-Ray Interface Science (XIS)
- Dual-canted undulator ID beamline
  - One fully tunable branch beamline: 4-40 KeV (Blue)
  - Fixed-energy branch lines: 10 keV, 30 keV, 30 keV (Green)
- 9 experimental stations with 4 simultaneous x-ray experiments
- Lab facilities & Infrastructure supporting interface science
- Partner groups required for end-station development

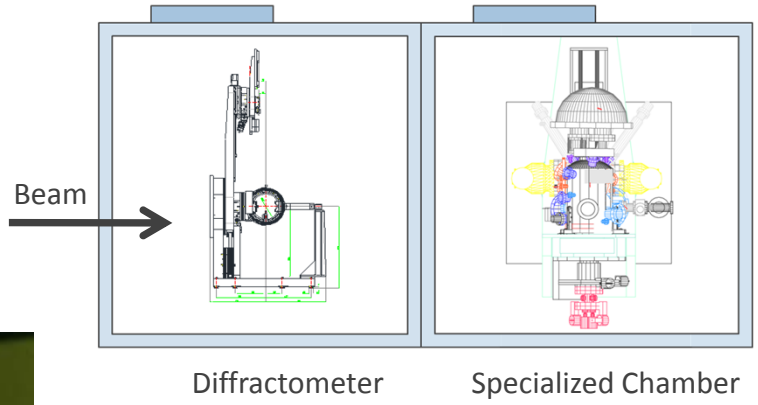


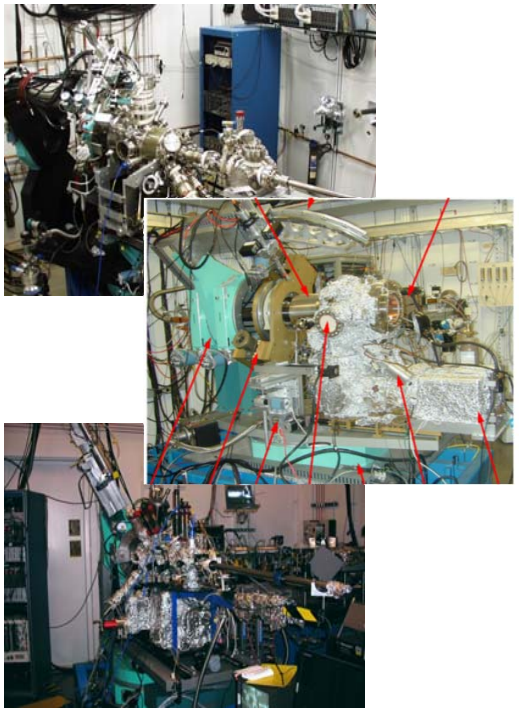
Tandem stations

- Specialized end-stations available off-line
- Environmental Cells on General Diffractometers







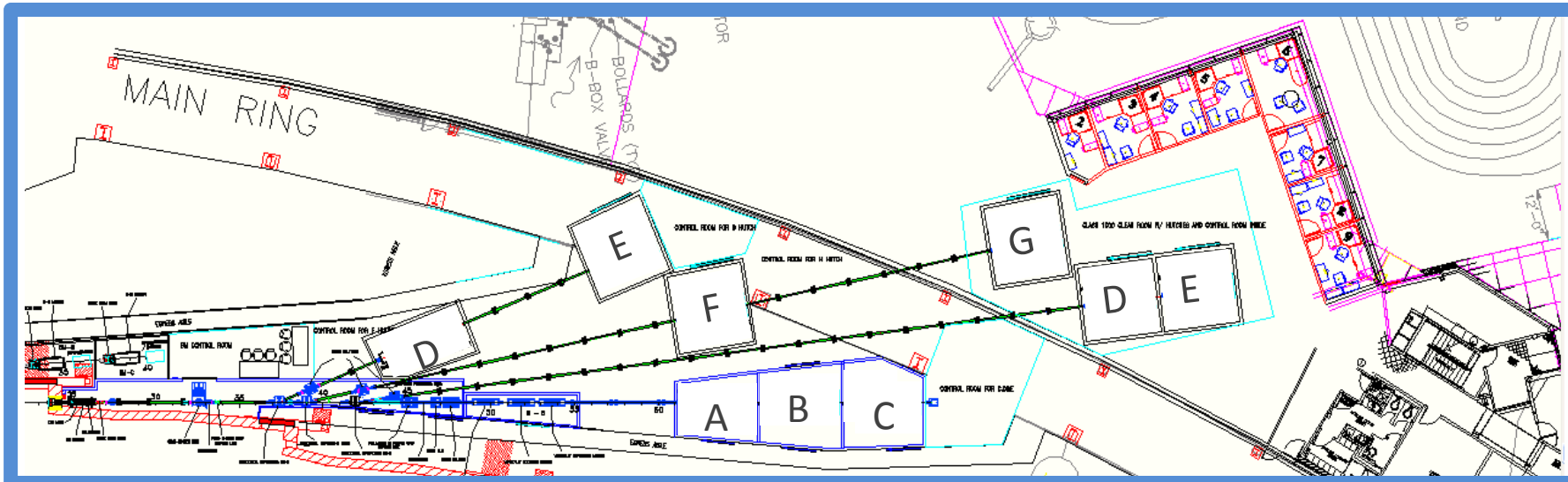


Which Instruments will fill the empty hutches?

I. Complex Gas-Phase Environments
II. X-Ray Reflection Interface Microscopy
III. Oxide MBE
IV. General-purpose interface diffraction
V. Growth chambers (MOCVD, ALD, PLD)
VI. Liquid Phase environments
VII. Ultra-high Vacuum Science
VIII. Resonant Scattering – A, B, C

Approach

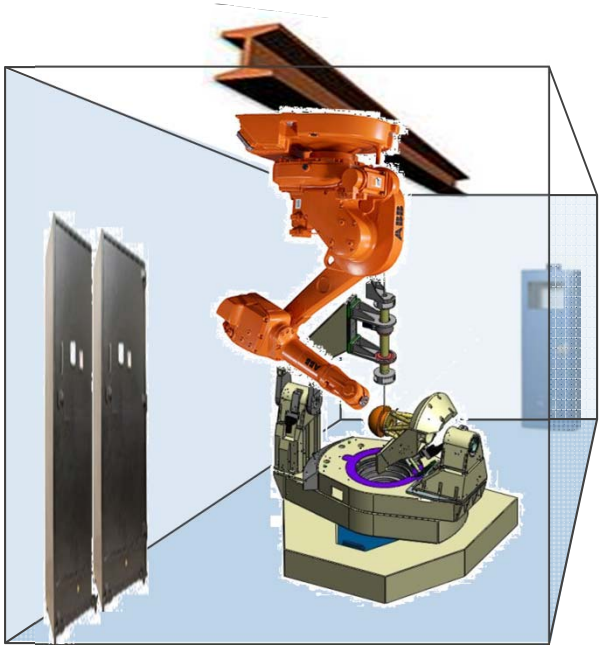
1. Single Purpose/Novel Instruments
   (e.g. X-UHV, LT < 4k, High Magnetic Field..)
2. Team of major players in the field
3. For large communities (PLD, SPM users)

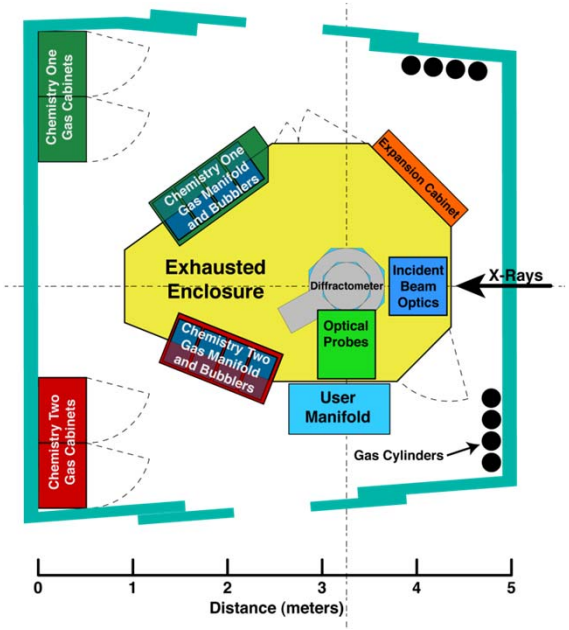


Schematic layout of the XIS Sector at 28-ID

APS-Upgrade funds one: Interfaces in Complex Environments (ICE)

- General large-scale heavy-duty diffractometer
- Small sample cells or larger, customized processing or environmental chambers that can be easily attached to the diffractometer through a standardized mounting interface.
- Flexible gas-handling, flow control & exhaust





Overall layout of hutch. Note that the bubblers extend into the exhausted enclosure below the beam height. Not shown are pumping stations that will be located next to the expansion cabinet.

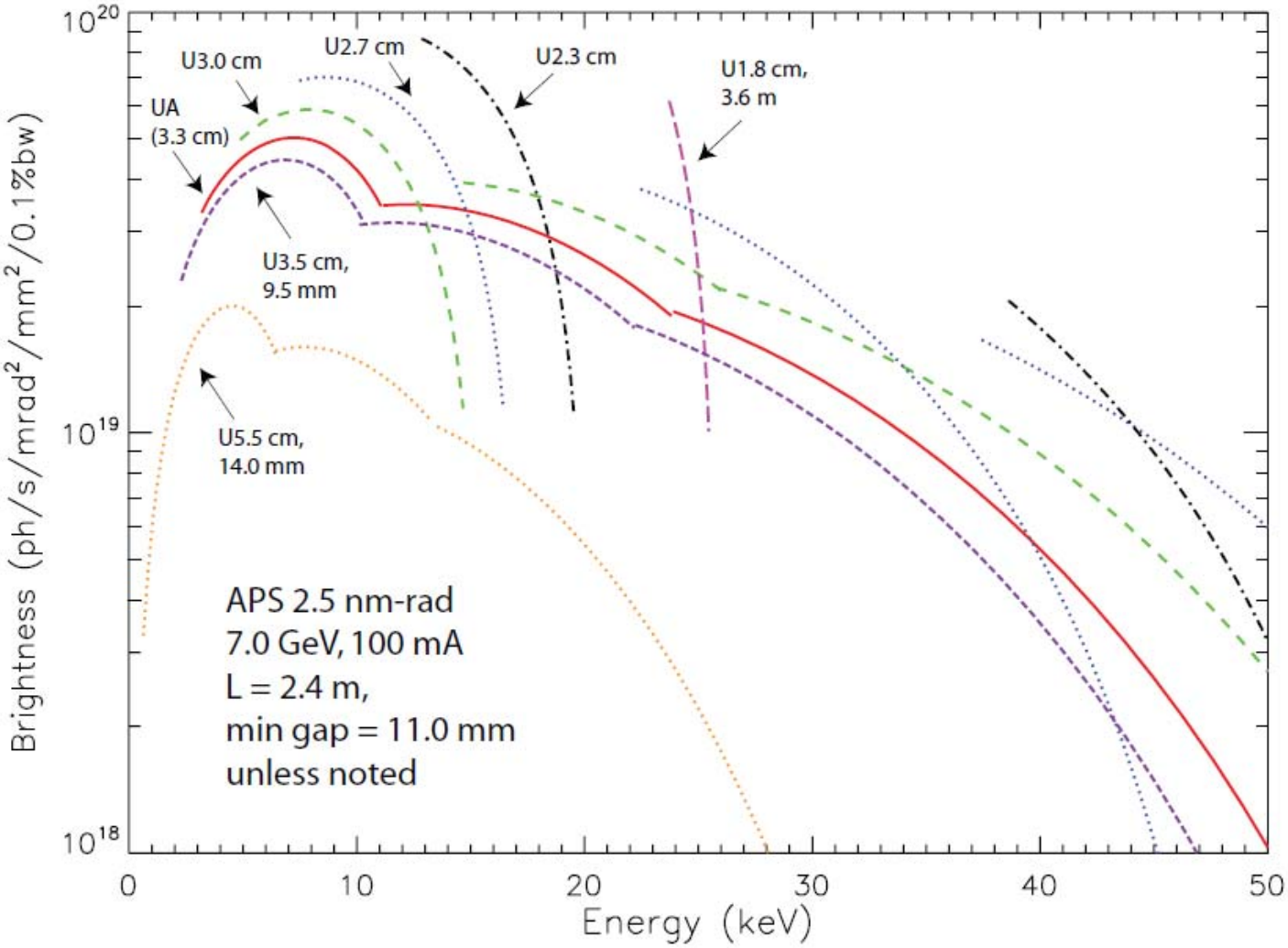
Presentation of Beamline Design

Sector-28 as of today

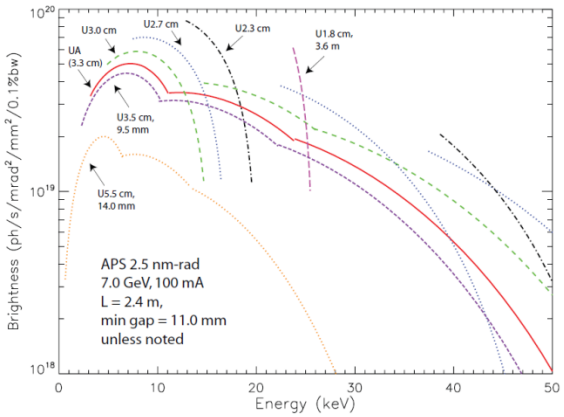
Contribution from

Paul Zschack (to be a NSLS-II Division Associate Director)
Gary Navrotski (Engineer assigned)

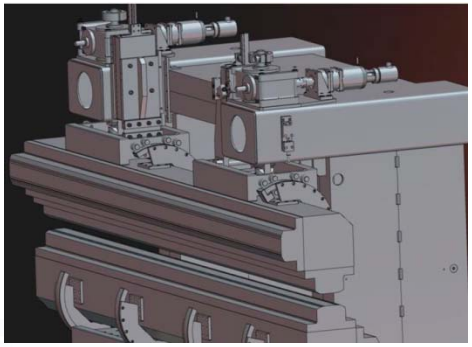
On-Axis Brilliance: Undulator with various periods



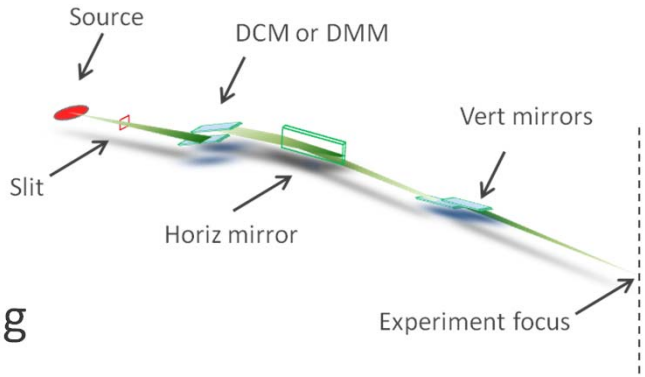
Source Choice



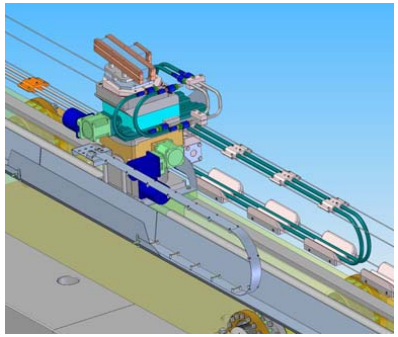
- Beamline configuration
  - Tunable line: fully tunable (4-40 keV)
  - Fixed Angle lines: three side-bouncing branch lines
- Two canted undulators
  - Tunable : 3.0-cm period
  - Fixed-A : Revolver mounted with 2.7 (for 10 and 30 KeV) and 3.1 cm periods.

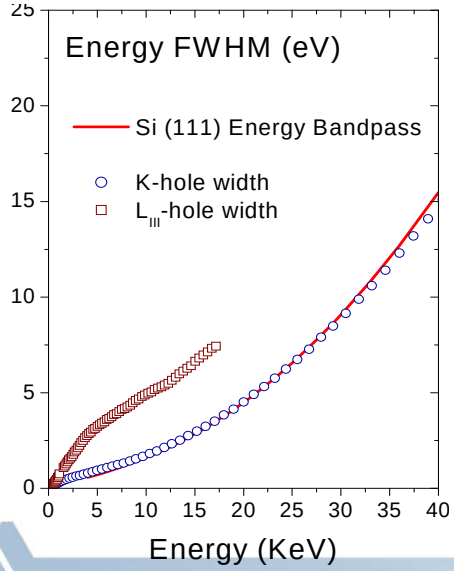


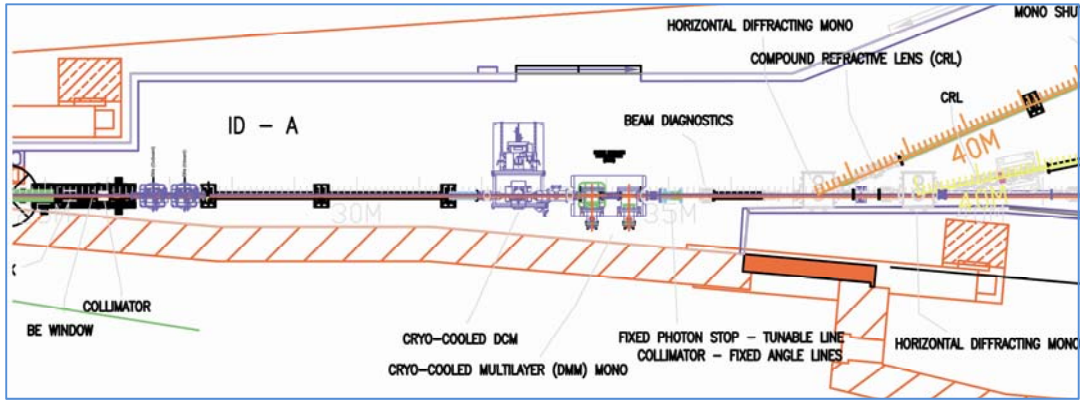
Tunable Beamline



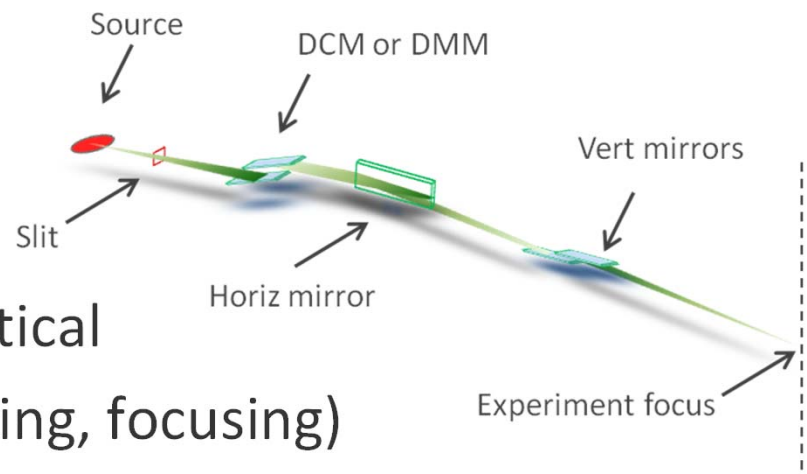
- **Double Crystal Monochromator**
  - Si(111) double x-tal, cryo –cooled
  - Scanning capability for resonant scattering
- **Multilayer Monochromator**
  - d = 20 Å (Petra-III cryo-cooled MLM)
  - 1 % band pass (over 50 x flux enhancement)
  - 10 to 40 KeV



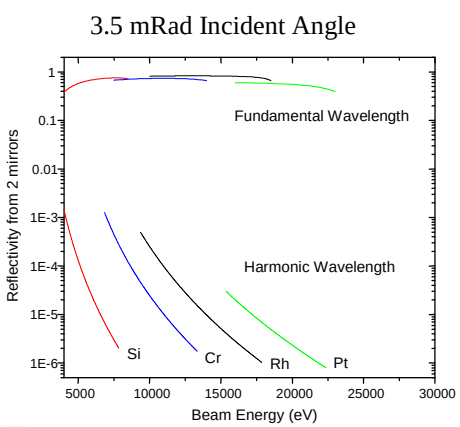


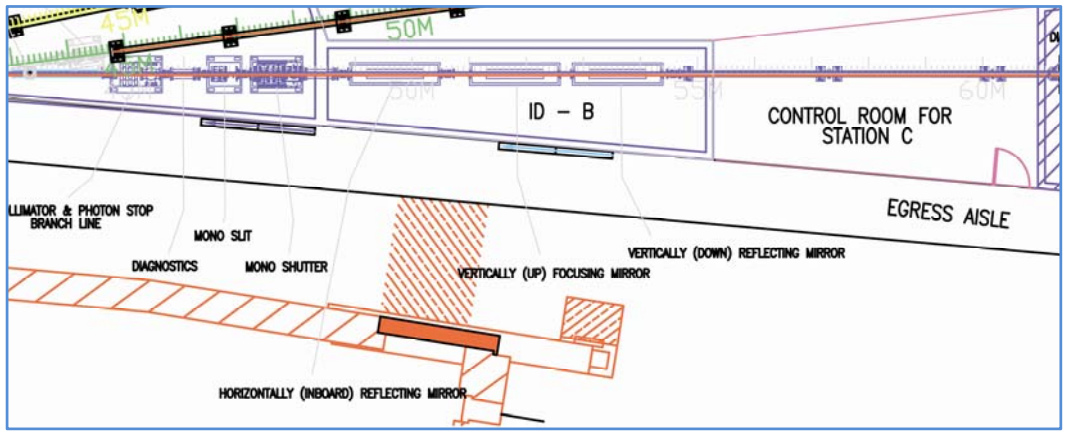


Tunable Beamline

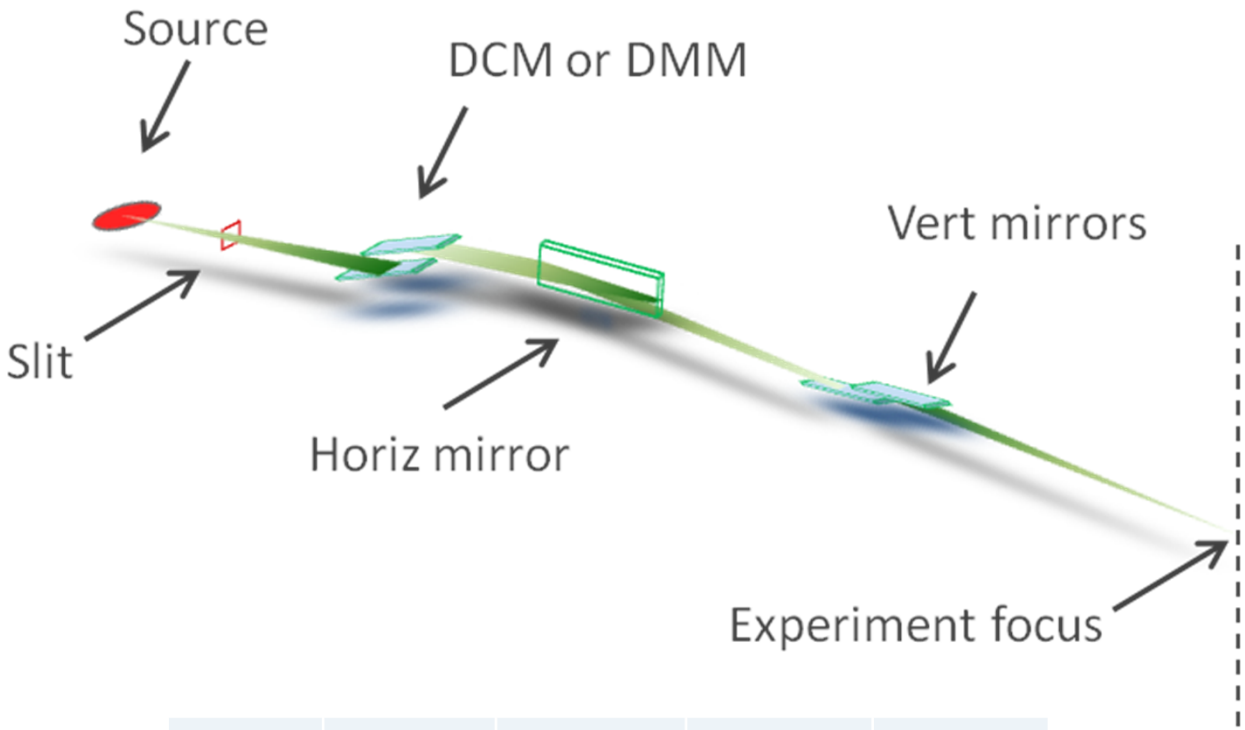


- Mirrors @ ~50 m
  - 1 horzontal (>1.2 m), 2 vertical
  - Dynamically bent (collimating, focusing)
  - Stripes
    - Hor: Rh/Pt @ 2 mrad
    - Vert: Si/Cr/Rh/Pt @3.5 (<22 KeV) or 2 mrad (> 22 KeV)





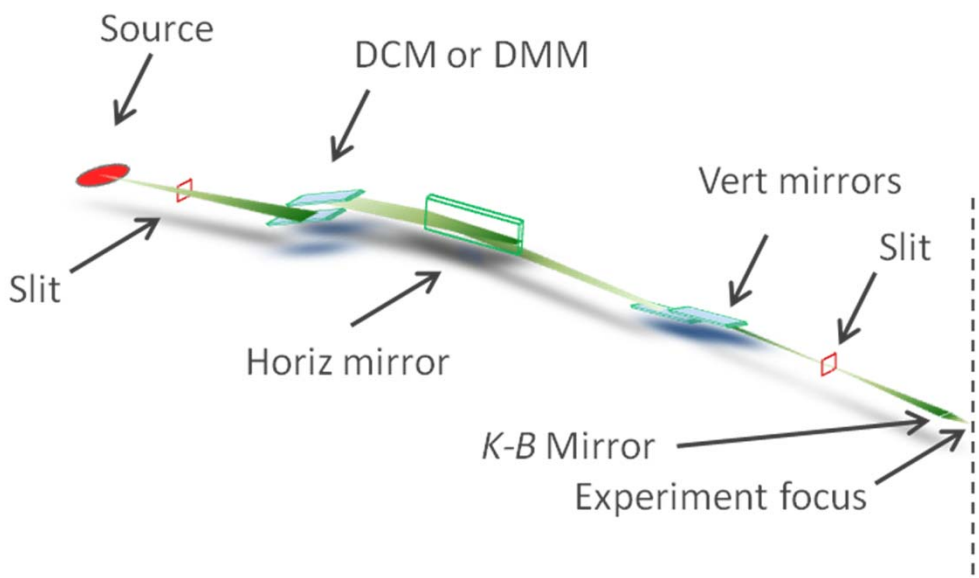
Tunable Beamline/Optical Performance



	Horiz Demag	Vert Demag	H Beam Size (μm)	V Beam Size (μm)
ID-C	4.4	5.5	164	63
ID-D	3.0	3.6	235	97
ID-E	2.3	2.7	306	130

Source	Slit	DCM	DMM	Horiz Mirror	Vert Mirror 1	Vert Mirror 2	ID-C	ID-D	ID-E
-1.25	27	32.5	34.5	50	52	54	64.5	69.5	74.5

Tunable Beamline/Secondary Source optics

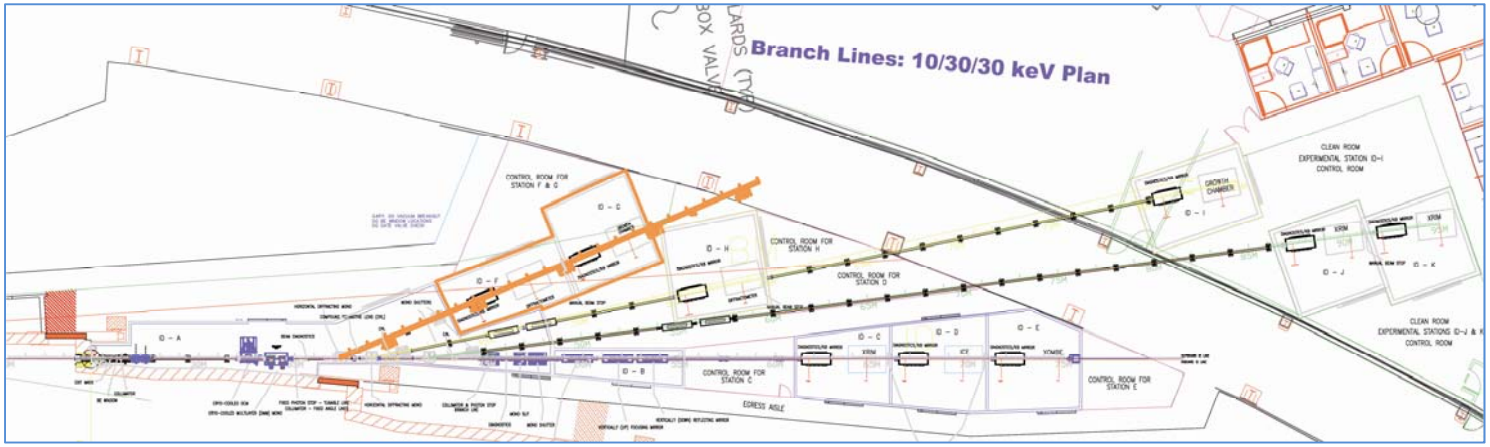


Focusing performance
(10:1 additional demag)

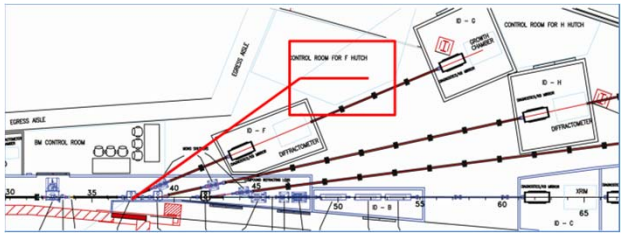
	H Beam Size (μm)	V Beam Size (μm)
ID-C	18	7
ID-D	26	11
ID-E	34	15

Fixed-Angle Beamline/Branch #1
10-KeV fixed energy

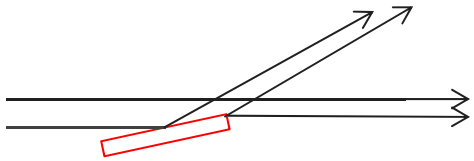
- **Monochromator**
  - Side bouncing Si(111), $2\vartheta = 22.8^{o}$
  - Cryo-Cooling
  - 85% transmission for 30 KeV
    - thickness < 100 μm
    - *A R&D project*

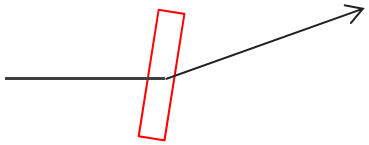


Fixed-A Beamline/Branch #1
10-KeV

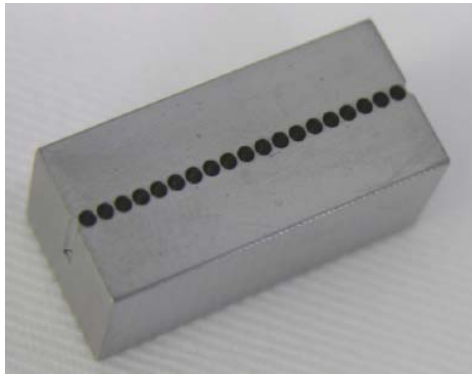


- **Monochromator alternatives**
  - Diamond (111): 22.8^{o} -> 35.0^{o}
    - Hutches will penetrate into Sector-27
    - Or Single Hutch with 2nd diffracting back crystal
  - Thick Si (111) and cut the beam half
    - Reduction of flux at branch #2 & #3
  - Asymmetric Laue Si(100)
    - incidence angle 82.2°, b = 2.1
    - 86% transmission with 0.5 mm thick Si
    - 50% reduction of flux at branch #1
    - change in focusing, polarization, coherence

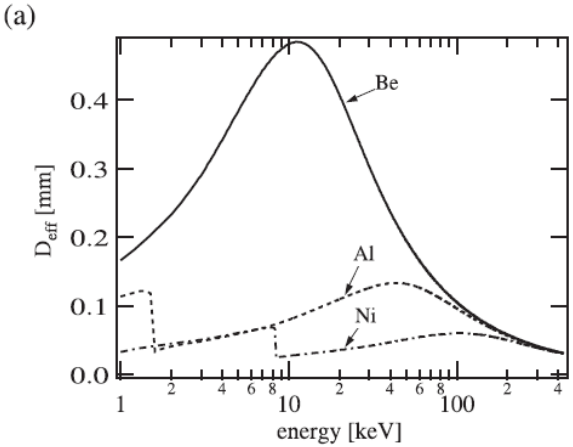




Fixed-A Beamline/Branch #1
10-KeV



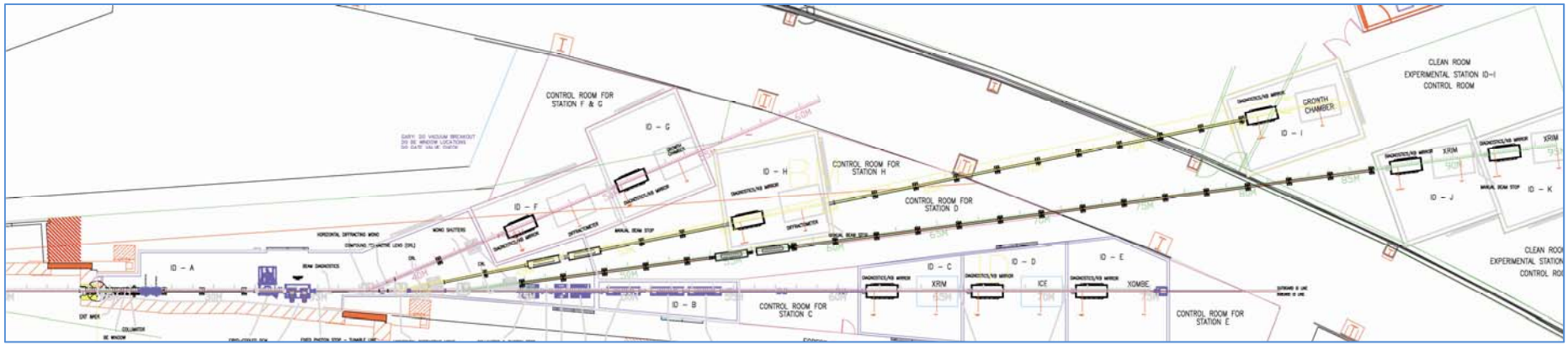
- Be compound refracting lenses (CRLs)
  - R=0.6 mm, N=10/6 (transmission:62%, 77%)
  - Harmonic rejection
    - $f \propto 1/\delta$, $\delta \propto 1/E^2$
    - Focal length difference and slits
    - Not sufficient suppression (50/30)
    - Harmonic rejection mirror at experimental stations



(a) Effective aperture of a parabolic compound refractive lens with focal distance f = 500mm for different lens materials (lens thickness d = 5µm). Christian G. Schroer et al,

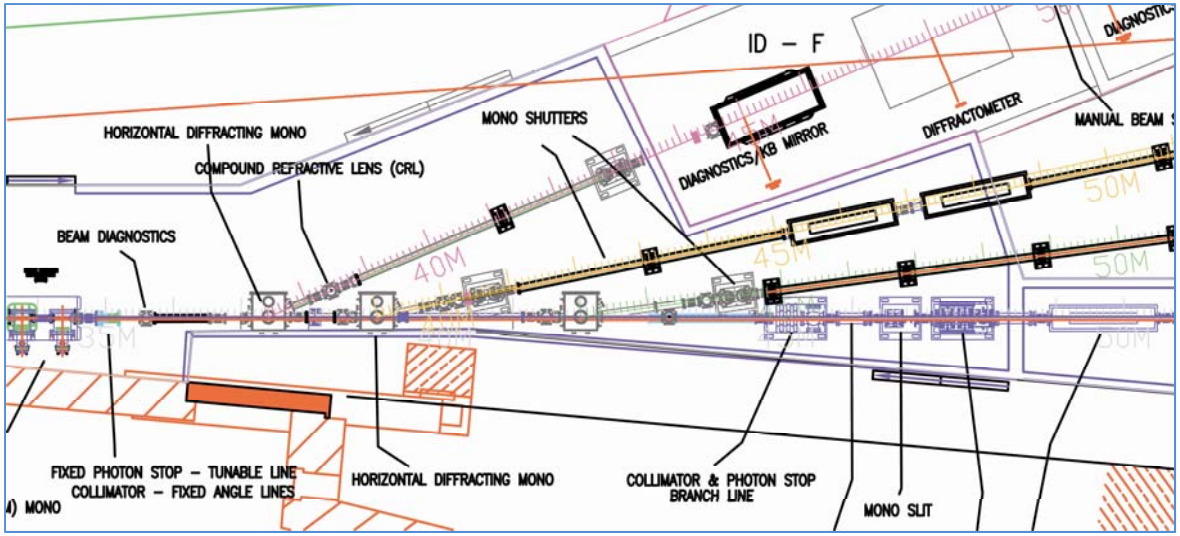
Fixed-A Beamline/Branch #2
30-KeV

- **Monochromator**
  - Side bouncing diamond (111), $2\vartheta = 11.51^{o}$
  - Cut out narrow band from broad 3-rd harmonic
  - Water cooled



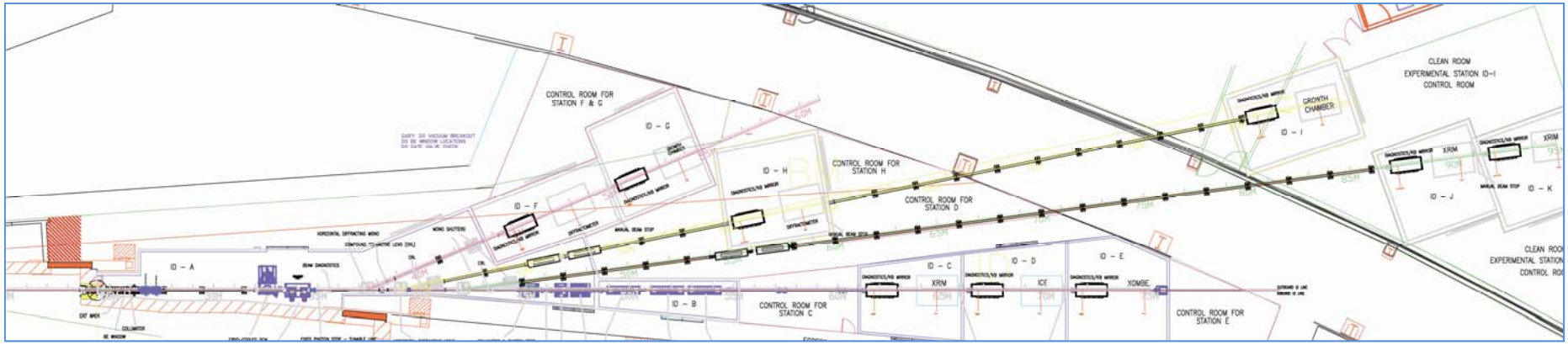
Fixed-E Beamline/Branch #2
30-KeV Fixed Angle

- **Mirror**
  - Pt-coated KB mirrors
  - Dynamically bent
  - Vertical reflecting-back mirror at exp. station



Fixed-A Beamline/Branch #3
30.01-KeV

- Si(111), $2\vartheta = 7.55^{o}$ monochromator
- Dynamically bent Pt-coated KB mirrors
  - Vertical leveling mirror at exp. Station
- Multilayer monochromator
  - 9.4 KeV (d = 10 Å)



Fixed-A Beamline
Available Photon Energies (keV) with different Xtals
(fixed beam angles in parenthesis)

	Si(111)	C(111)	Si(220)	MLM(d=1nm)
Branch #1 (22.8)	10.0	15.2	16.3	(3.1)
Branch #2 (11.5)	19.7	30.0	32.2	(6.2)
Branch #3 (7.55)	30.01	45.8	49.0	9.4

Fixed-A Beamline
Anticipated Performance

Demagnification and Beam Size (FWHM)

Including 1 μrad figure error

Branch	Fixed-A/#1		Fixed-A/#2		Fixed-A/#3	
Station	ID-F	ID-G	ID-H	ID-I	ID-J	ID-K
Hor. Demag.	3.2	2.3	3.9	1.1	1.3	1.1
Size (H, *μm*)	210	290	170	600	540	600
Ver. Demag.	3.2	2.3	4.9	1.2	1.4	1.2
Size (V, *μm*)	56	78	46	190	190	220

Additional demagnificantion (5 to 10:1) is possible by secondary source optics

Source Size and divergence (sigma)

H. size	H. div	V. size	V. div
270 μm	11.3 μrad	15 μm	3.9 μrad

Expected Photon Flux (photons/sec)

Energy (KeV)	33-ID (U-3.3 cm)	Tunable (U-3.0 cm)	Fixe-A/#1 (U-2.7 cm)	Fixed-A/#2 (U-2.7 cm)	Fixed-A/#3 (U-2.7 cm)
10 KeV	2E13	4E13	2 to 5E13		
20 KeV	2E13	3E13			
30 KeV	8E12	1E13		7E12	1.6E13

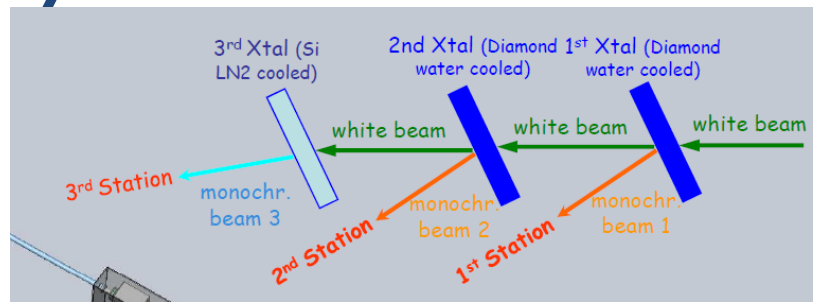
- Rough estimates based on the band width of monochromator and undulator performance
- 150 mA operation will enhance the flux by factor of 1.5

Spectral widths (FWHM, eV)

- Darwin width of the mono xtal
- Beam divergence

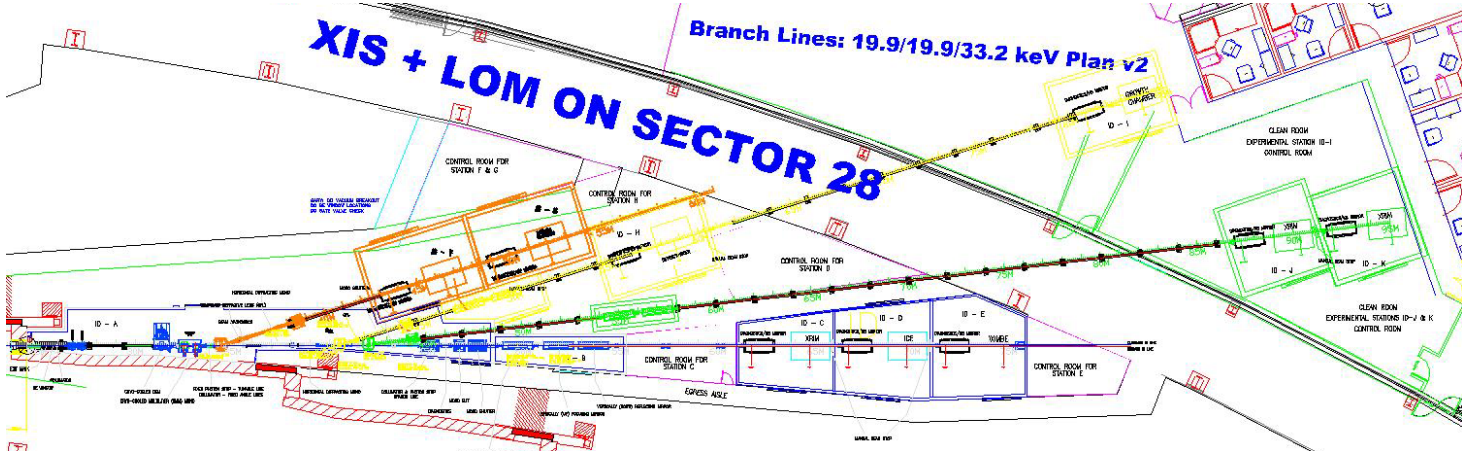
	Tunable line	Fixed-A/#1	Fixed-A/#2	Fixed-A/#3
10 KeV	1.4	1.8		
20 KeV	3.2			
30 KeV	5.7		8.1	12.7

Fixed energy scheme (Plan-B) (19.9/19.9/33.2 KeV)



ESRF ID30 (Laue/Laue/Laue)

- Why alternate?
  - Low detector efficiency at high energy
  - More mature Diamond beam splitter than Si
- 3rd /3rd/5th harmonic, Bragg/Bragg/Bragg



Fixed energy scheme (plan-B) (19.9/19.9/33.2 KeV)

- Available Energies with different Crystals

	Si(111)	C(111)	Si(220)	MLM(d=1nm)
Branch #1 (17.4)	13.1	19.9	21.4	(4.1)
Branch #2 (17.4)	13.1	19.9	21.4	(4.1)
Branch #3 (6.83)	33.2	50.5	54.2	10.4

- Reduction of flux can be from 30% to 60% (perfect C(111) and 33 ID C(111))

Summary and Next step

- Grand plan of XIS sector : 4 ID stations taking x-ray at the same time
  - With enhanced performance (beam size, photon flux)
- Issues to be dealt with
  - Risk management
    - Low energy branch line mono (Fixed-A line #1)
    - Diamond mono
  - Choice between 10/30/30 KeV or 19.9/19.9/33.2 KeV
  - Quick Staffing Increase
  - Engineering such as Stability and repeatability (in position and energy)
  - Ancillary facilities
  - Analysis/Prep lab