X-ray photoemission capabilities at the Canadian Light Source

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Canada's National Synchrotron Science Facility

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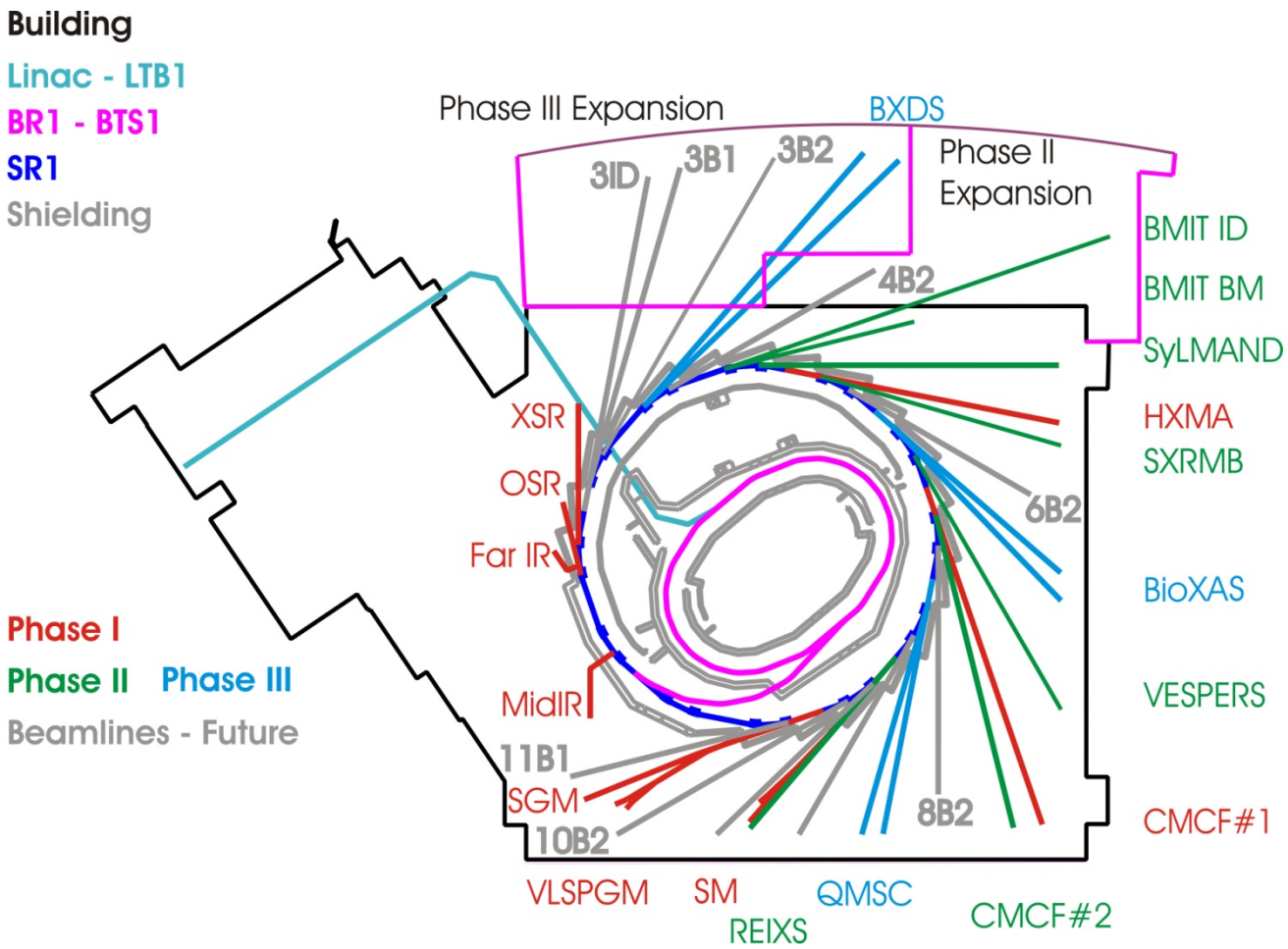
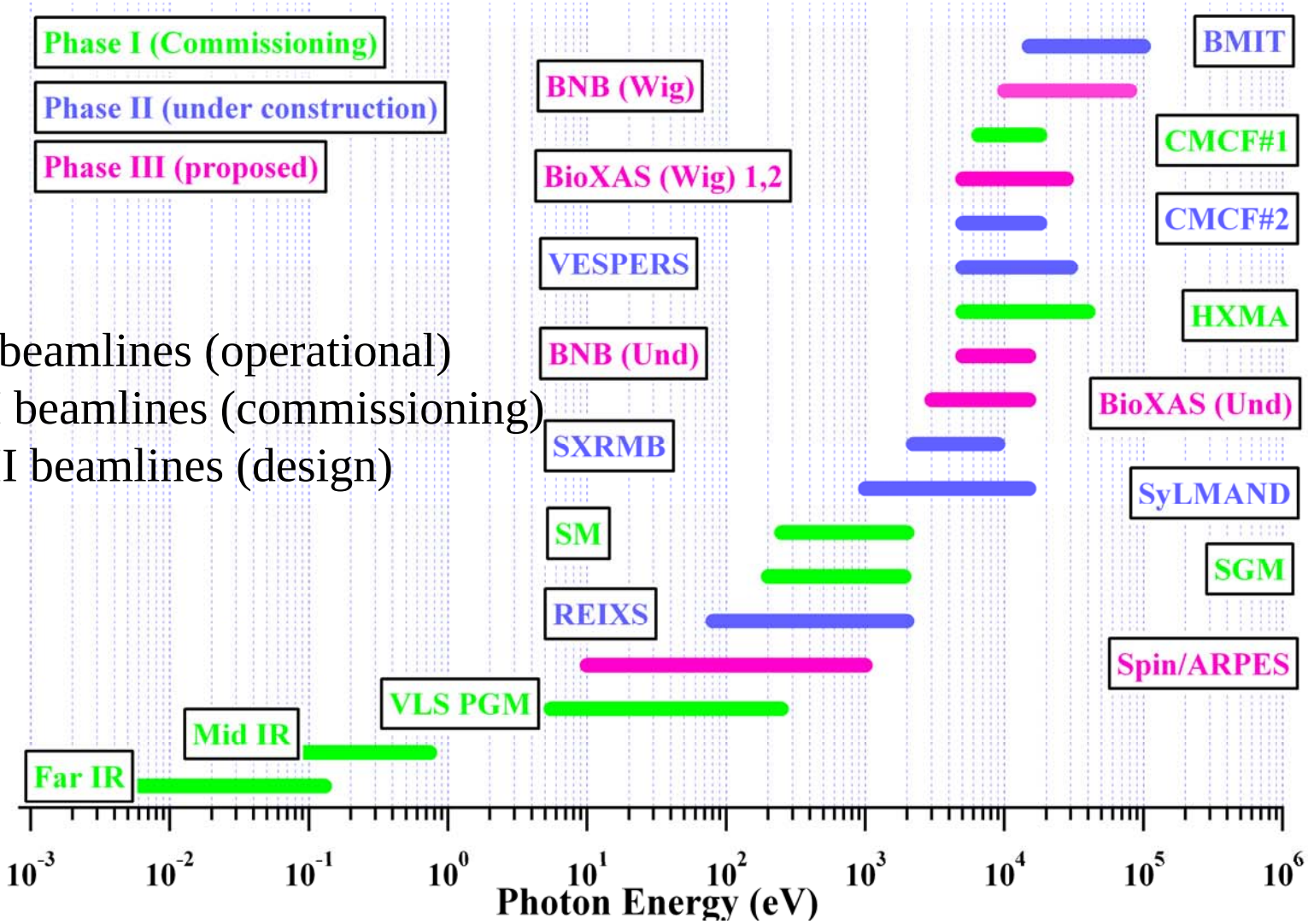
Phases I, II and III



Beamlines at CLS

- 7 Phase I beamlines (operational)
- 6 Phase II beamlines (commissioning)
- 3 Phase III beamlines (design)



Phase III Beamlines

- The Brockhouse X-Ray Diffraction and Scattering Sector
- The Quantum Materials Spectroscopy Centre (S-ARPES)
- Bio-XAS Life Sciences Beamline

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Phase II - Commissioning

Beamline	Energy (eV) / Wavelength (Å) (cm^{-1} for IR)		Resolution $\Delta E / E$ @ E	Flux (γ/s/0.1%BW) @ 500 mA / Spot size Hor x Vert	Techniques
Resonant Elastic and Inelastic X-ray Scattering (REIXS)	80	2000	1×10^{-4} @100 eV 2×10^{-4} @1000 eV	2×10^{13} @ 100 eV 5×10^{12} @ 1000eV 250 µm x 15 µm 60 µm x 10 µm	X-ray Absorption Spectroscopy X-ray Emission Spectroscopy Resonant Inelastic X-ray Scattering Resonant Elastic X-ray Scattering Coherent X-ray Scattering (Specle Magnetic X-ray Dichroism Molecular Beam Epitaxy sample preparation
	155	6.2			
Soft X-ray Microcharacterization Beamline (SXRMB)	1700	10000	3.3×10^{-4} Insb (III) 1×10^{-4} Insb (III)	> 1×10^{11} 1×10^{9} 0.3 mm x 0.3 mm ~ 0.01 mm x 0.01 mm	X-ray Absorption Spectroscopy Microprobe X-ray Excited Optical Luminescence (XEOL) Resonant spectroscopies X-ray Magnetic Linear Dichroism (XMLD) Photo Emission Electron Microscopy (PEEM) X-ray Magnetic Circular Dichroism (XMCD) Photo and Auger Electron Spectroscopy
	7.3	1.3			
Synchrotron Laboratory for Micro And Nano Devices (SyLMAND)	1000	15000	NA	NA 150 mm x 15 mm	Deep X-ray lithography LIGA process lithography steps
	12.4	0.82			
Very Sensitive Elemental and Structural Probe Employing Radiation from a Synchrotron (VESPERS)	6000	30000	Si(111) – 10^{-4} MLM1 – 10^{-2} MLM2 – 10^{-1} Pink Beam	Si-111 ~ 2×10^{9} @ 15 keV MLM1 ~ 1×10^{11} @ 15 keV MLM2 ~ 4×10^{11} @ 15 keV (2 – 4) µm x (2 – 4) µm	X-ray Laue Diffraction X-ray Fluorescence Spectroscopy X-ray Absorption Near Edge Structure Differential Aperture X-ray Microscopy Multi-bandpass and pink beam capability
	2	0.4			
Canadian Macromolecular Crystallography Facility (CMCF 2)	5000	20000	10^{-4}	10^{12} @ 12 keV 230 µm x 160 µm	X-ray diffraction Multiwavelength Anomalous Dispersion (MAD)
	2.5	0.6			
Biomedical Imaging and Therapy (BMIT - BM)	8000	40000	MI: 10^{-3}	1.5×10^{13} @ 10 keV NA	Conventional absorption imaging Diffraction Enhanced Imaging (DEI) / Multiple Image Radiography (MIR) Phase contrast or in-line holography Ultra-small, small, wide angle scattering imaging Computer Tomography (CT)
	1.6	0.3			
Biomedical Imaging and Therapy (BMIT - ID)	20000	100000	M1:10^{-3} M2:10^{-3} M3:10^{-2} DEI:10^{-5}	4×10^{14} @ 40 keV 200 mm x 10 mm	Imaging – conventional absorption imaging, DEI / MIR, CT, K-edge Subtraction (KES) Therapy – Microbeam Radiation Therapy, CT Therapy
	0.6	0.1			

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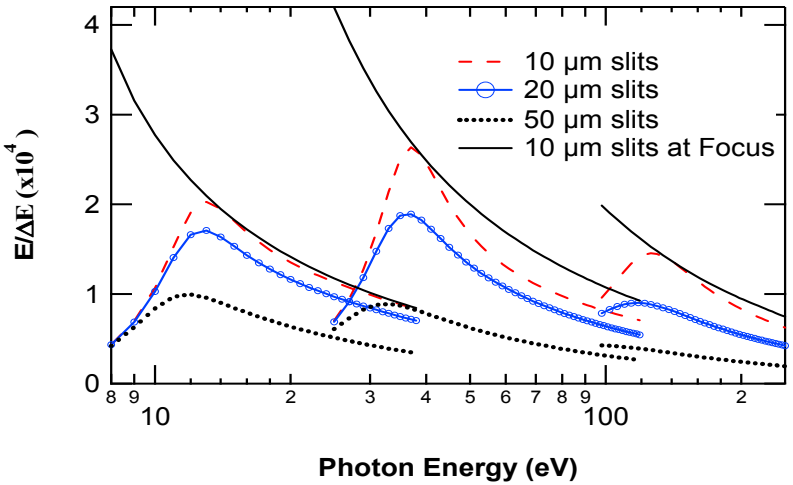
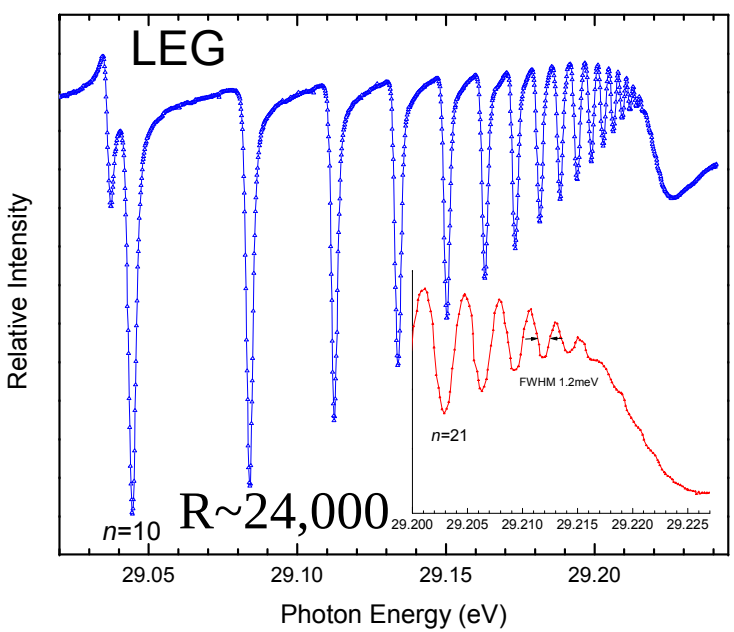
Phase I Beamlines - Built

Beamline	Energy (eV) / Wavelength (Å) (cm^{-1} for IR)		Resolution ΔE / E @ E	Flux (γ/s/0.1%BW) @ 500 mA / Spot size Hor x Vert	Techniques
Far Infrared Spectroscopy (Far-IR)	50	1000	≥ 0.001 cm^{-1}	1×10^{13} @ 100 μm	• Stable gas phase molecules of atmospheric interest at cryogenic temperatures in a 2m-multipass absorption cell • Short-lived gas-phase molecules of astrophysical interest generated in a 1.5m hollow-cathode cell and 1.2m discharge/furnace cell • Complexes generated in a supersonic expansion chamber • Surface-adsorbate interactions at grazing angle of incidence • High-pressure samples in a Diamond Anvil Cell • Powdered samples in a Photoacoustic Cell
	NA			Diffraction limited	
Mid Infrared Spectromicroscopy (Mid- IR)	0.09	0.74	16.0 – 0.125 cm^{-1}	1×10^{14} @ 10 μm	• Spectromicroscopic imaging at diffraction-limited spatial resolution • Spectromicroscopy at grazing angle of incidence • Spectromicroscopy with Attenuated Total Internal Reflection (ATR) • Photoacoustic Emission Spectroscopy
	6000	750		λ / 2	
Variable Line Spacing Plane Grating Monochromator (VLS PGM)	5.5	250	> 1×10^4	1×10^{11} @ 60 eV	• X-ray Absorption Spectroscopy (XAS) • X-ray Excited Optical Luminescence (XEOL) • Photoemission Electron Microscopy (PEEM)
	2254	49.6		0.05 mm x 0.5 mm	
High Resolution Spherical Grating Monochromator (SGM)	250	2000	> 5000	4×10^{12} @ 250 eV 1×10^{11} @ 1900 eV	• X-ray Absorption Spectroscopy (XAS) • X-ray Photoelectron Spectroscopy (XPS) • Auger Electron Spectroscopy (AES) • X-ray Excited Optical Luminescence (XEOL) • Photoemission Electron Microscope (PEEM) • Gas phase photoionization and TOF measurements
	62	6.5		50 μm x 100 μm	
Soft X-ray Spectromicroscopy (SM)	100	2000	3000 – 7000	~ 10^8 ph/s in 50 μm spot ~ 10^{12} ph/s in 50 μm spot	• Scanning transmission X-ray Microscopy (STXM) • Photoemission Electron microscopy (PEEM)
	125	6.2		10^8 in 50 μm	
Canadian Macromolecular Crystallography Facility (CMCF 1)	6500	18000	10^{-4}	2×10^{12}	• Single crystal X-ray diffraction • Multiwavelength Anomalous Dispersion (MAD) • XANES on crystals
	1.9	0.7		150 μm x 50 μm	
Hard X-ray MicroAnalysis (HXMA)	5000	40000	10^{-4}	~ 6×10^{11} photons/s Si(111) b.w ~ 7×10^{10} photons/s Si(111) b.w	• X-ray Absorption Fine Structure (XAFS) • Microprobe • Diffraction
	NA			0.1 x 0.5 mm^2 2 x 4 μm^2	

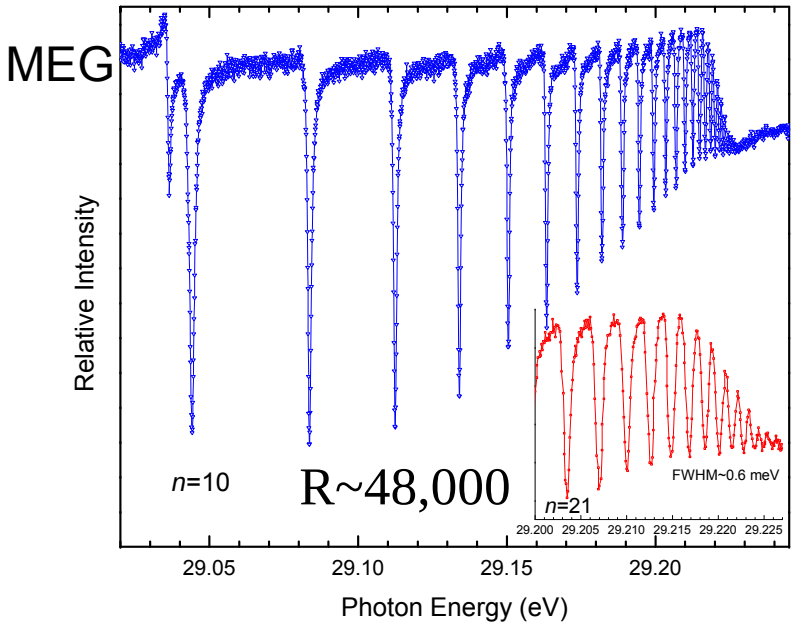
VLS-PGM at CLS

- **Resolution: a resolving power of 10,000 is expected**





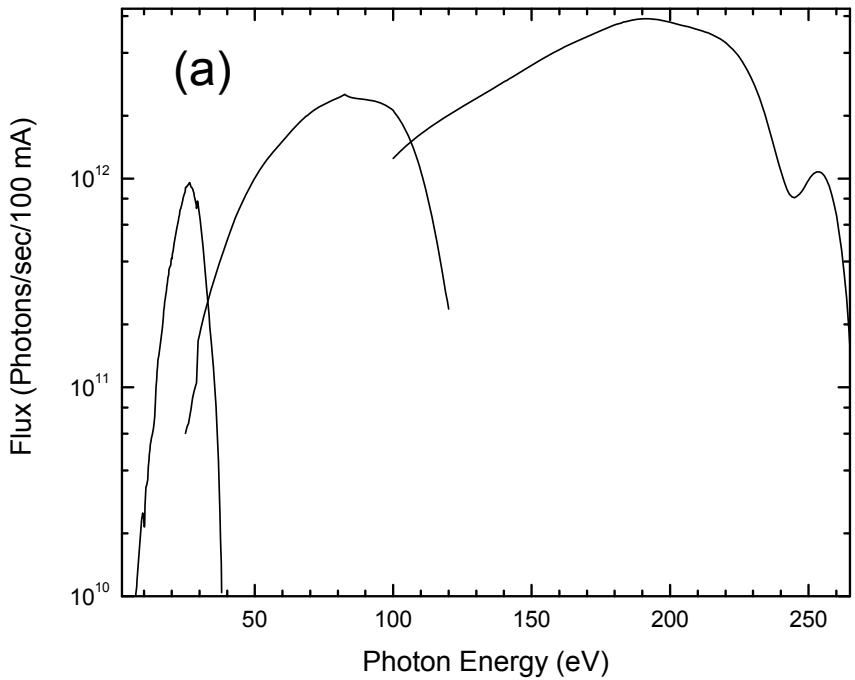
Ar 3s3p^6 *n*p series 10μmx10μm slits

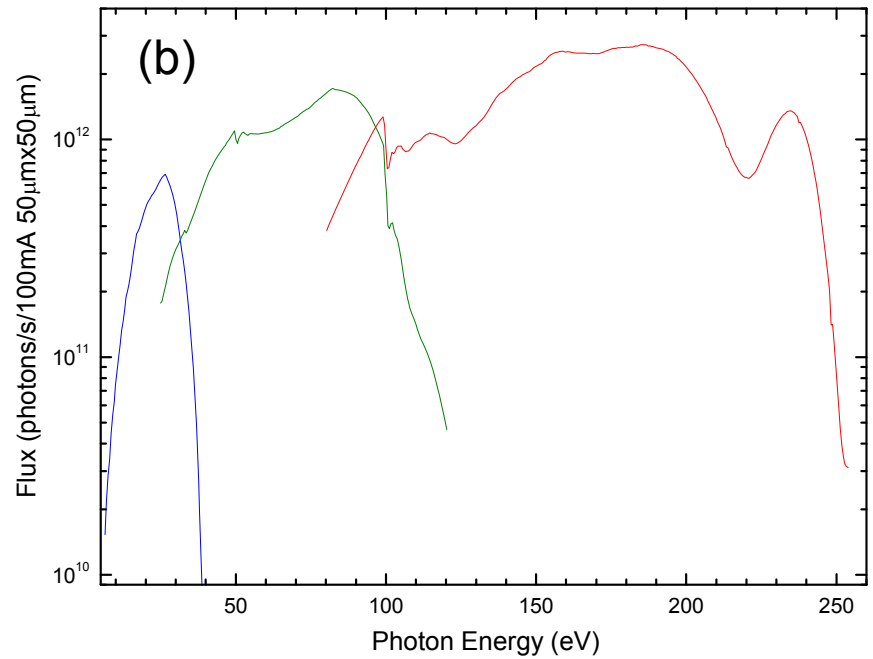


Excellent resolving power has been achieved using different gratings. At ~29 eV, medium energy grating has a resolving power of ~50,000.

VLS-PGM at CLS

- **Calculated vs Measured Flux**



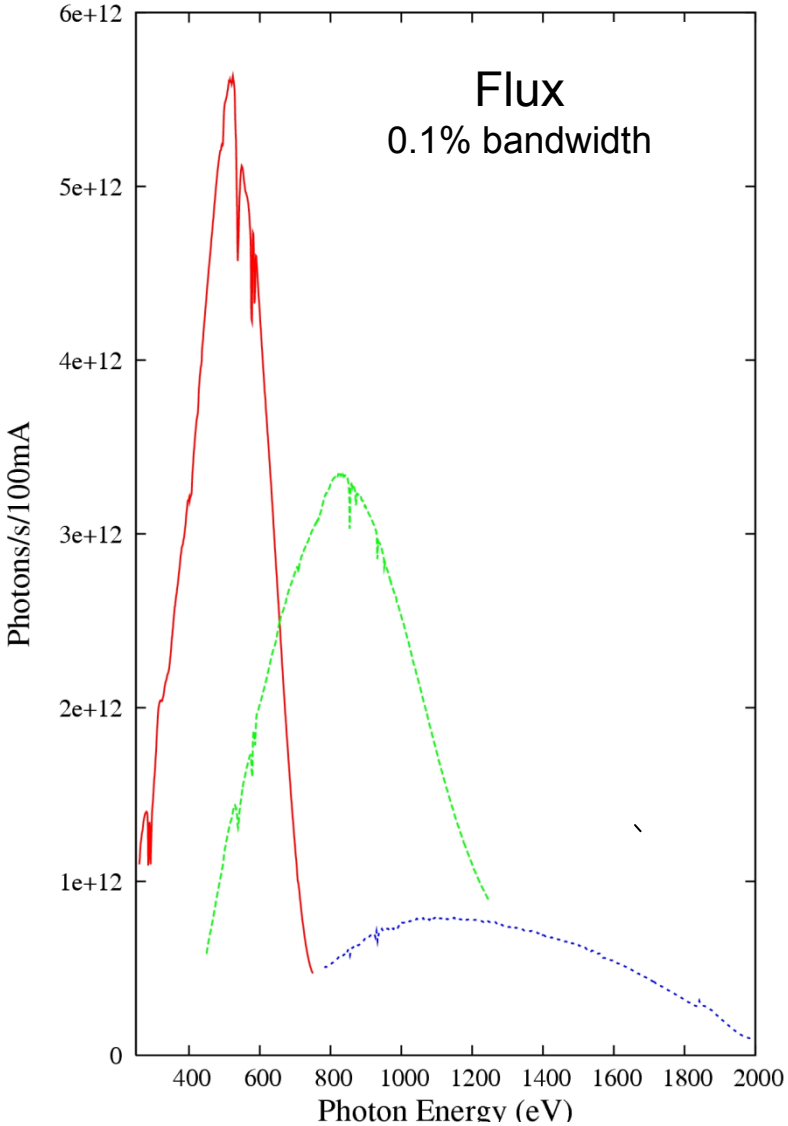


Photon flux of 10^{12} is expected and achieved using three gratings with slits setting of 50x50 μm, normalized to 100 mA ring current;

(a) calculated flux

(b) experimental flux measured with an AXUV-100 Si photodiode

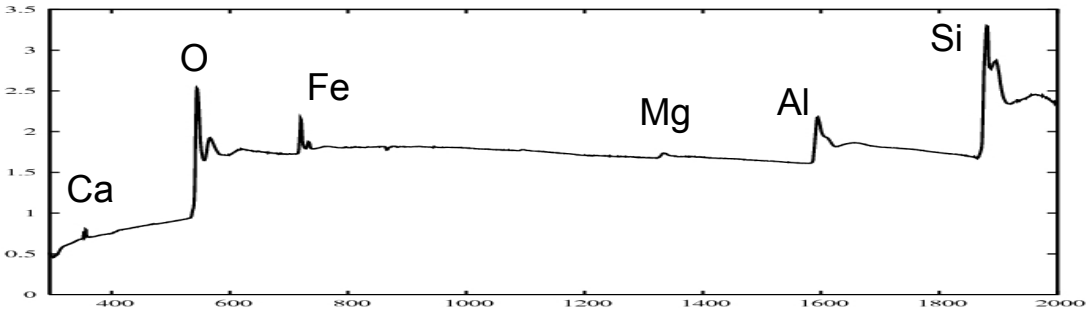
SGM Performance: Flux



Comparable to BL25SU (Spring-8)

Factor of 10 better than Gas Phase (ELETTRA)

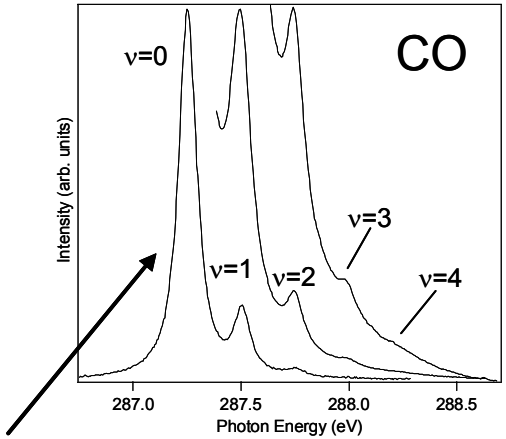
Still very good in the difficult 1keV to 2 keV range



X-ray absorption, Saskatchewan Soil
Data from St. Joseph High School, Saskatoon

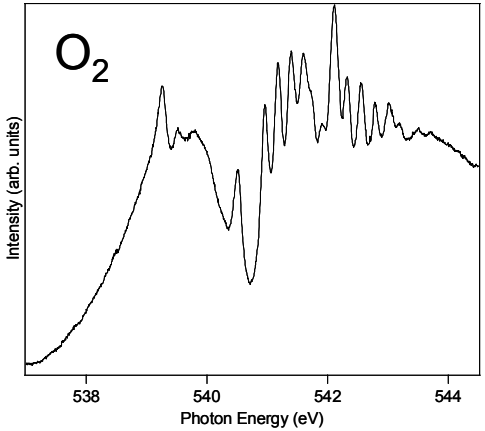
SGM Performance: Resolution

LEG



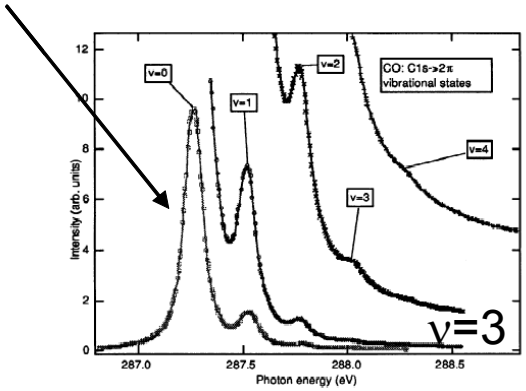
SGM

MEG

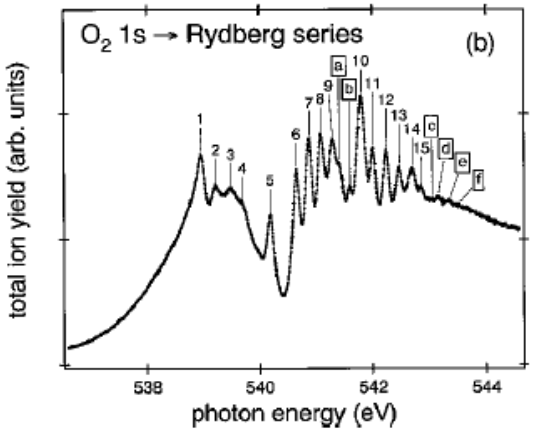


SGM

Note statistics



Gas Phase Beamline
Elettra
E/ΔE = 12000

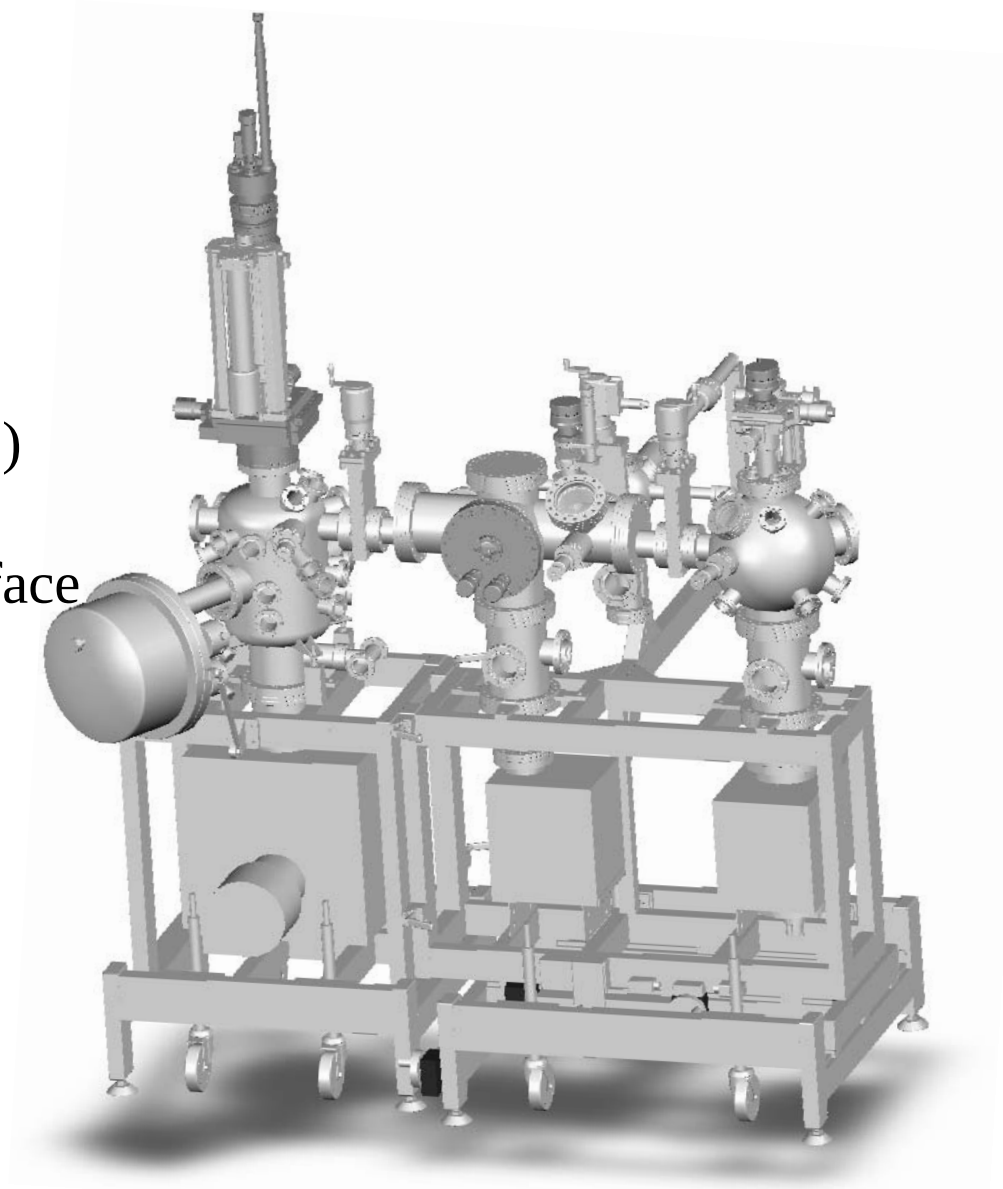


BL25SU Beamline
Spring 8
E/ΔE = 17000

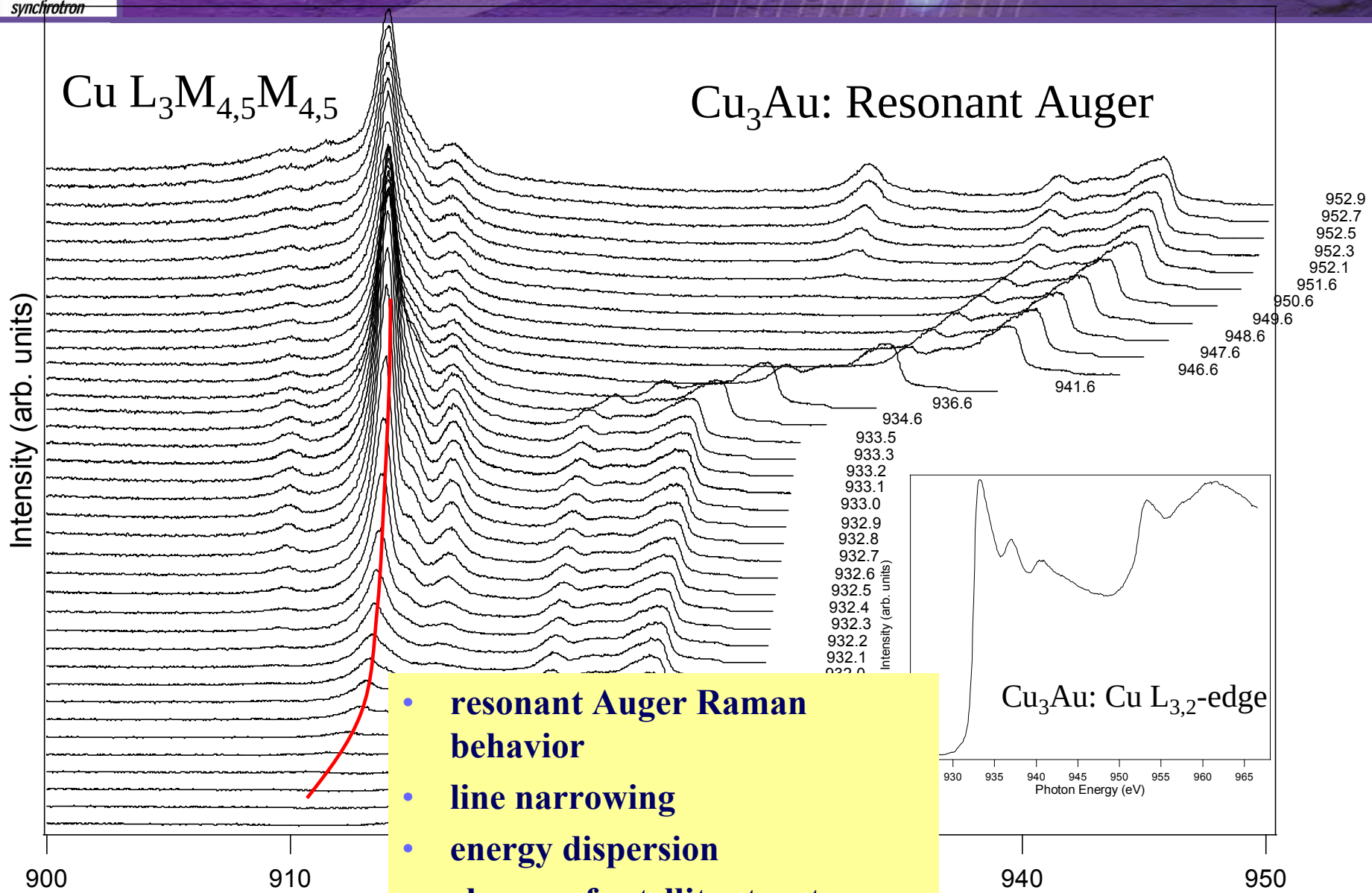
Photoemission Capabilities at CLS

- Soft X-ray beamlines
  - PGM (5.5-250 eV)
  - SGM (250-2000 eV)
  - Shared a straight, 10^{12} flux, RP>10,000
  - Photoemission systems (SES-100)

- Material research, particularly in surface and interface studies of minerals



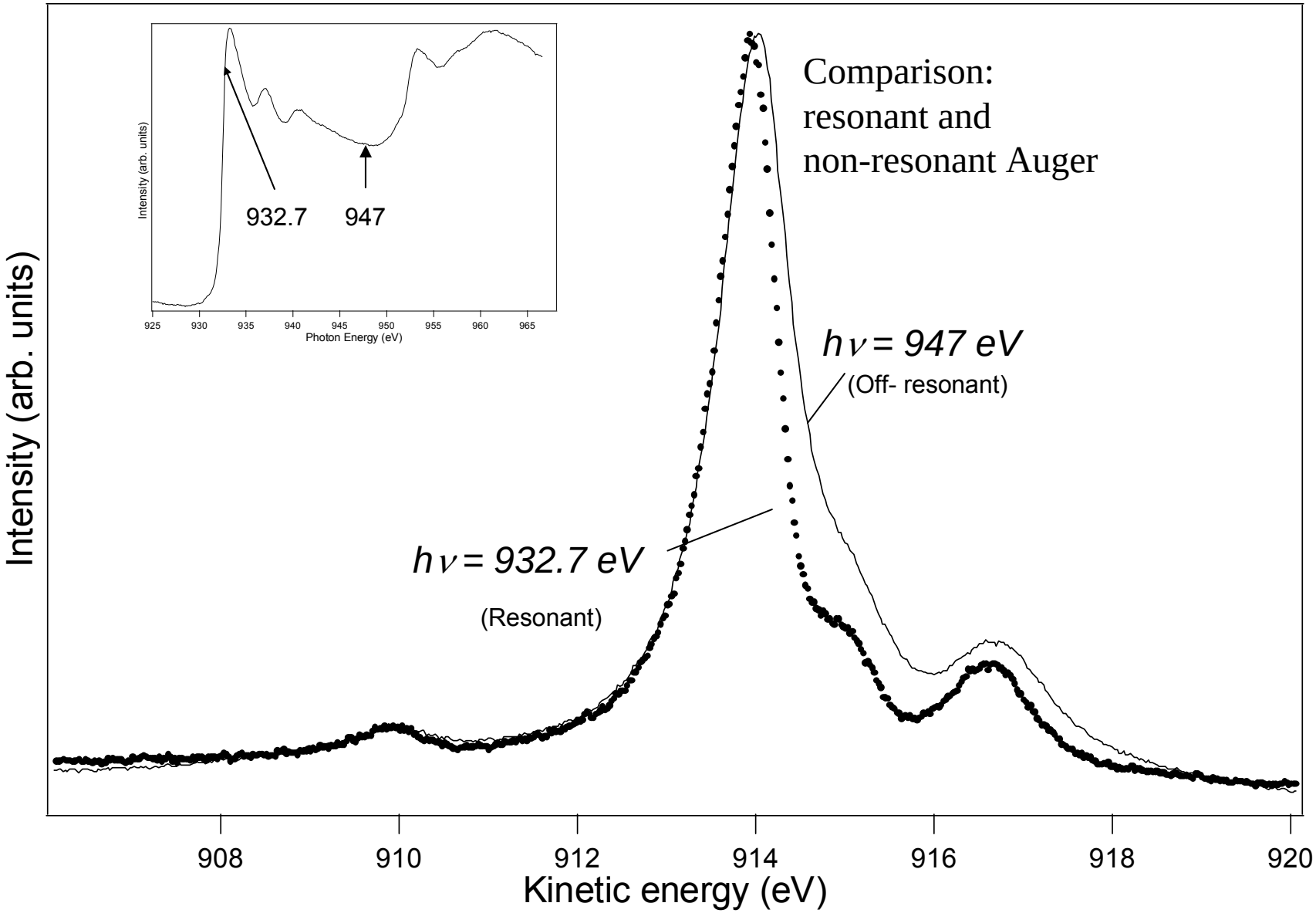
Photoemission Capabilities at CLS



- **resonant Auger Raman behavior**
- **line narrowing**
- **energy dispersion**
- **change of satellite structure**

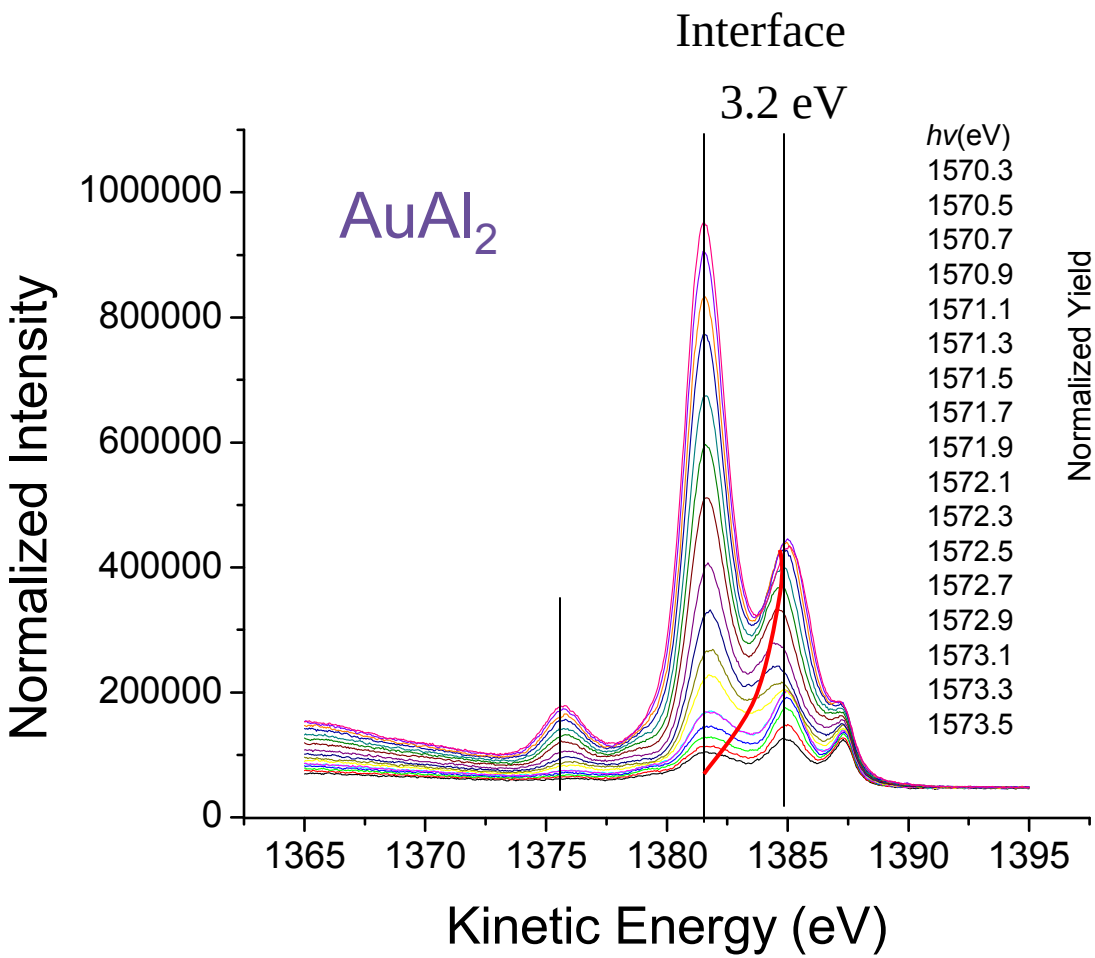
Blyth, Regier & Sham, SGM data

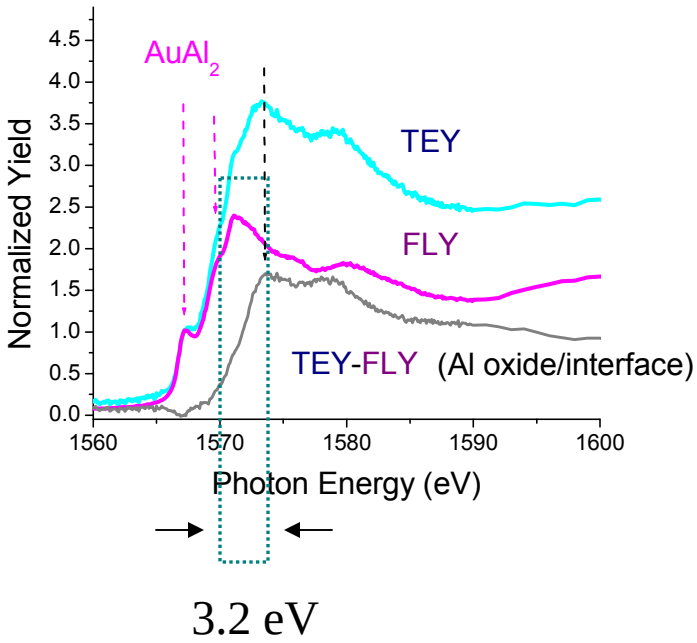
Photoemission Capabilities at CLS



Blyth, Regier & Sham, SGM data

Resonance Auger and Interface Analysis

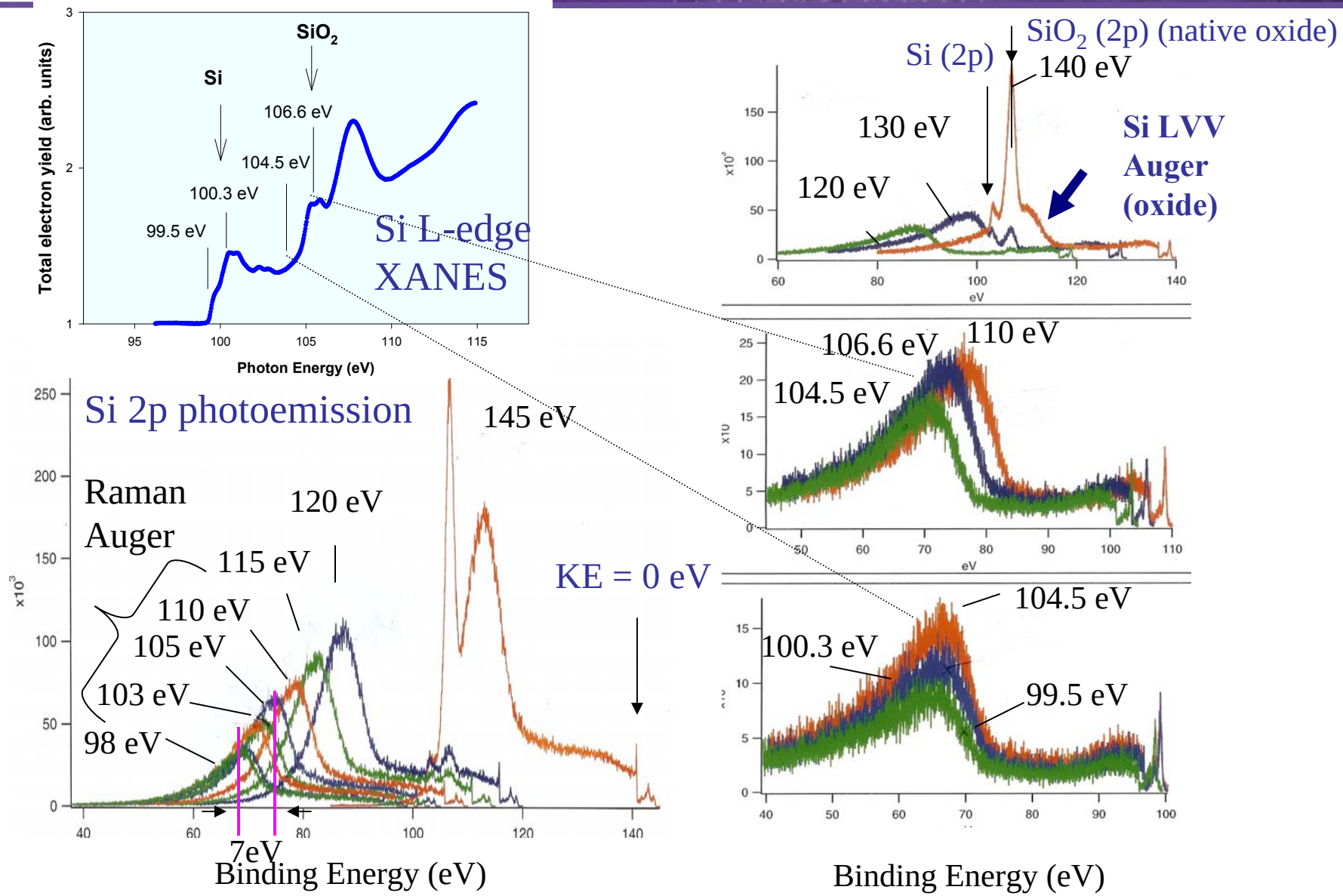




Non-dispersive: $AuAl_2$
Dispersive: Raman interface

Sham, Blyth & Regier CLS SGM data

Si $L_{3,2}$-edge Resonant Auger @ PGM



Heigl, Hu & Sham, SRC data (unpublished)

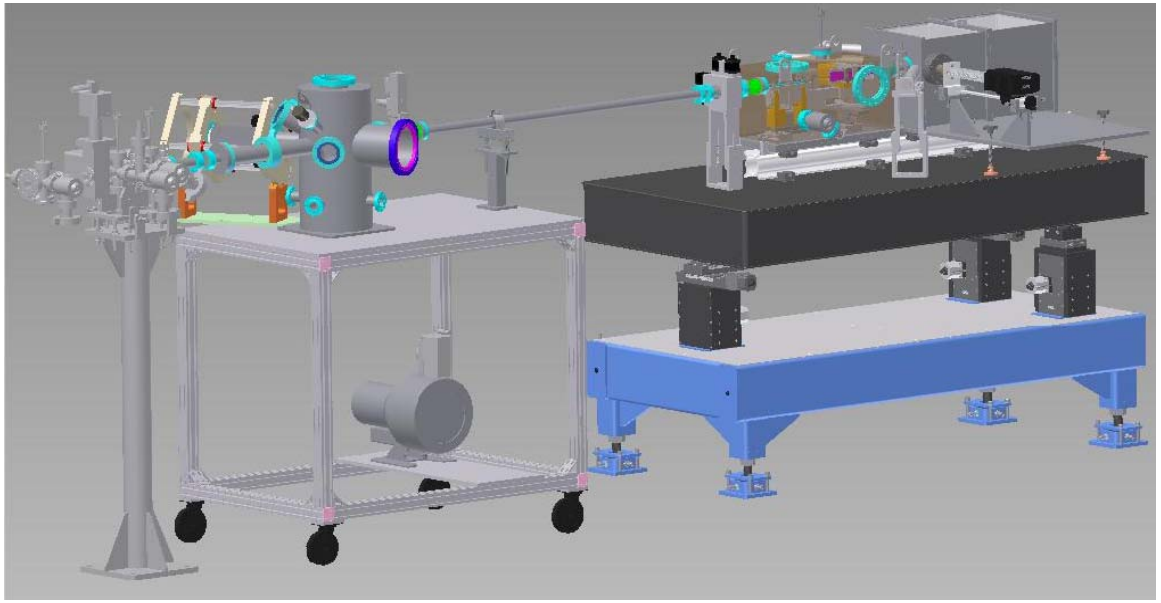
Hard X-ray Photoemission at SXRMB

Scientific Objectives:

•Facility beamline (1.7-10 KeV, up to 10^{12} flux)

•CSRF/CLS users will be able to do what they have been doing at CSRF with at least 10 to 10^2 fold increase in performance (e.g. flux, brightness)

•Users will be able to new experiments in Spectroscopy, Material Science, Life and Environmental Science



Endstations:

•XAS (in vacuum and noble gas filled)
•Gas phase (TOF)
•PEEM
•Microprobe station
•Hard X-ray Photoemission

Hard X-ray photoemission system at SXRMB (R4000 based)

•Beamline is open to users by Letter of Intent (XAS)

•End station to be designed and built