



The Canadian Light Source and the Biomedical Beamline Facility



Dean Chapman
Science Director, Canadian Light Source
University of Saskatchewan



Plan





- ✿ Brief Overview of the Canadian Light Source
- ✿ Design of the Biomedical Imaging and Therapy Beamlines

CLS Timeline

- 🌸 **September 27, 1999** – Groundbreaking ceremony
- 🌸 **February 26, 2001** – Building dedication ceremony
- 🌸 **September 18, 2002** – Booster ring commissioning complete
- 🌸 **December 9, 2003** – First synchrotron light detected
- 🌸 **October 22, 2004** – Official opening
- 🌸 **May 27, 2005** – First CLS user
- 🌸 **June 30, 2005** – Official completion of the CFI project

Capital Investment to Date

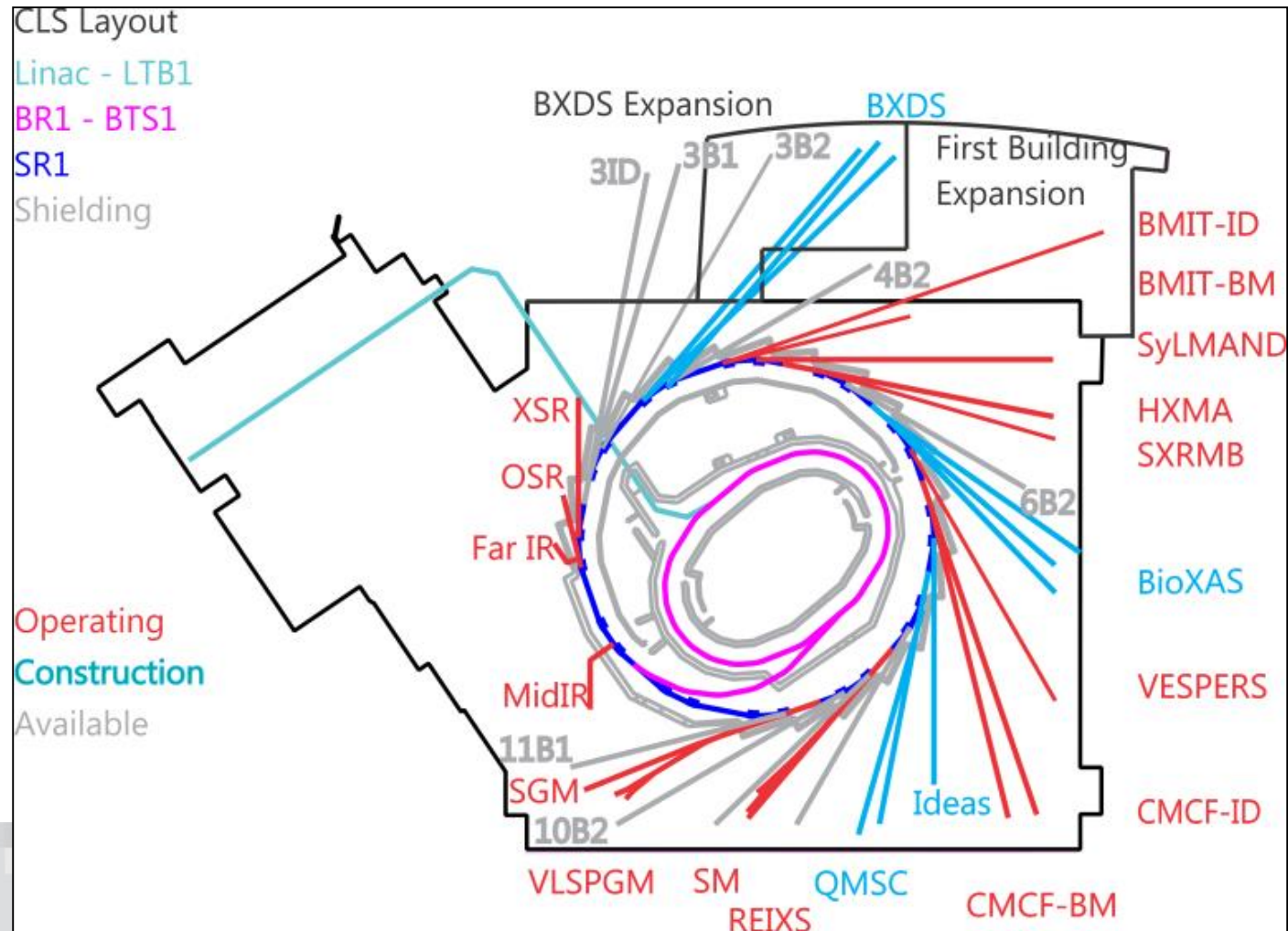


 Original Construction (7 beamlines)	\$141M
 Phase II (7 beamlines)	\$52M
 Phase III (7 beamlines & upgrade)	\$68M
 Isotopes Project	\$12M

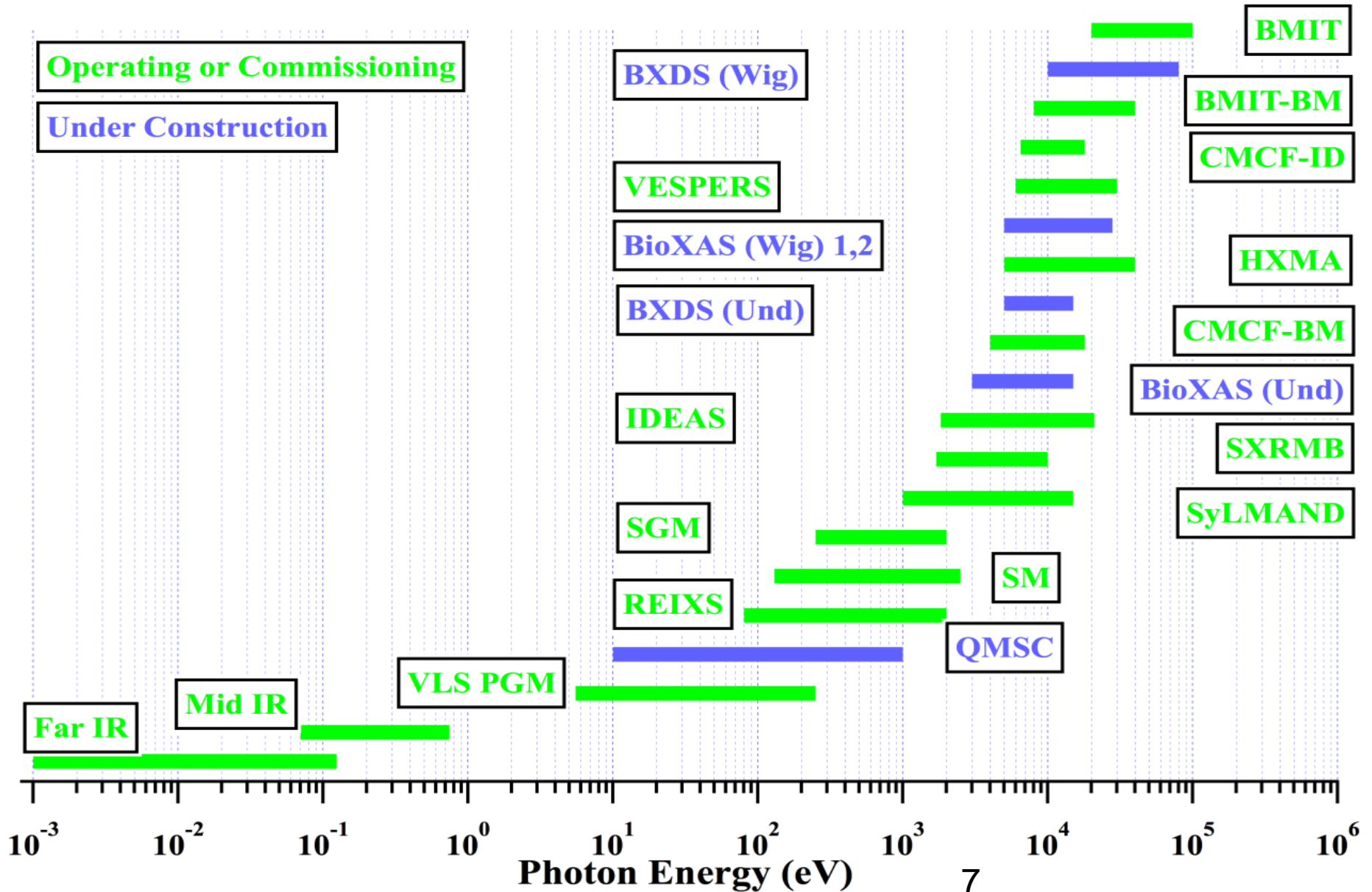
CLS Features

- ✿ Canada's national synchrotron facility
- ✿ One of the world's first ~ 3 GeV synchrotrons
 - ✿ Superconducting RF cavity
 - ✿ Canted insertion devices
 - ✿ Hard X-rays from superconducting wigglers
- ✿ Full spectrum of photon energies for spectroscopy (THz to hard X-rays)
- ✿ Other highlights: STXM, medical imaging, soft X-ray REIXS, soil science and mining applications

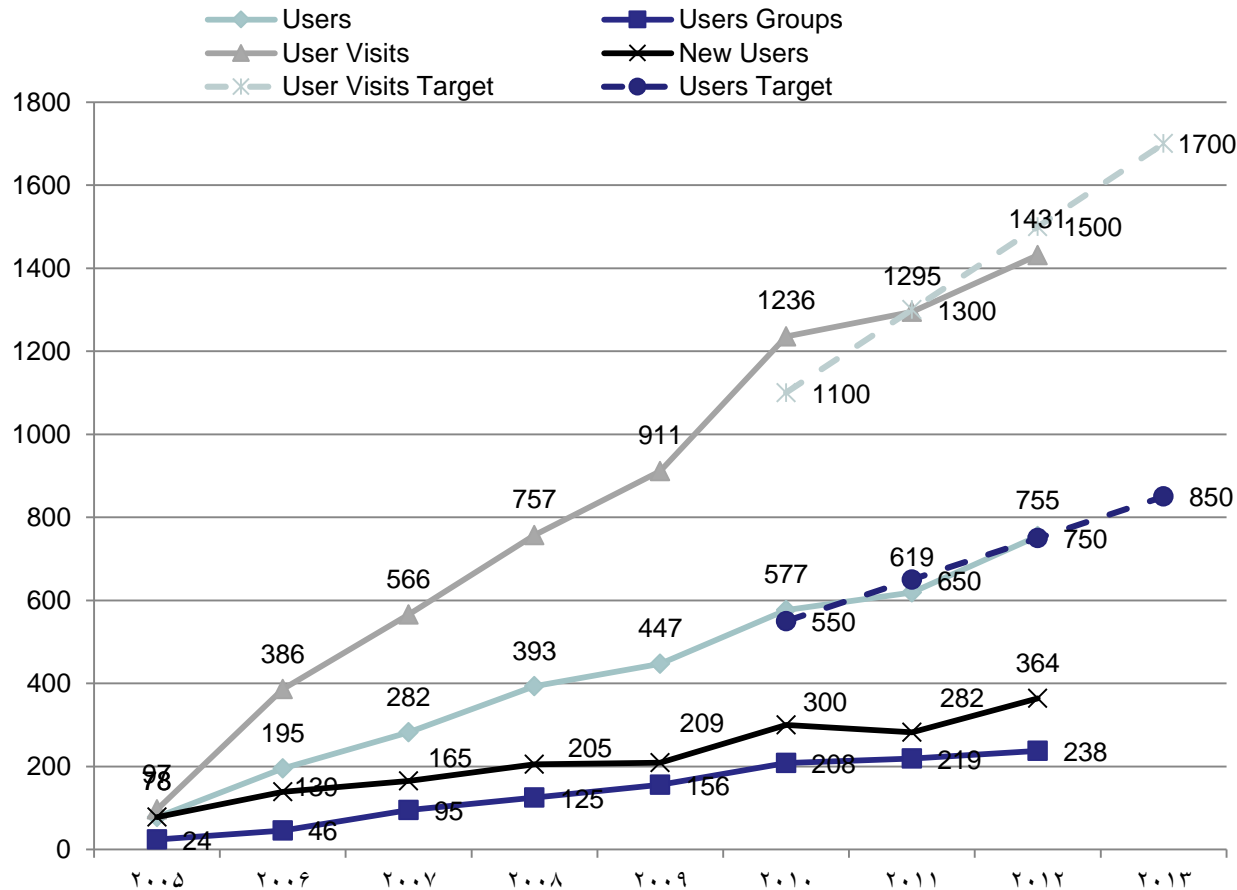
CLS Layout



Energy Range



Users and User Visits

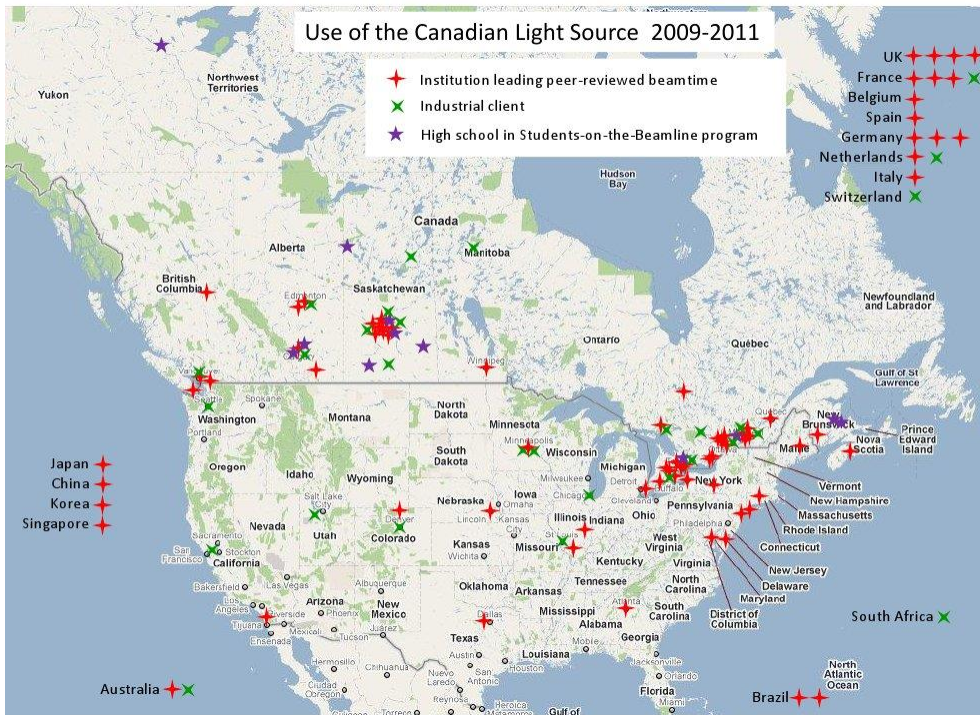


Peer Review Access

	2009	2010	2011	2012
Number of shifts requested	1768	2675	3456	4410
Number of shifts allocated	1252	1816	2203	3168
Oversubscription	41%	47%	57%	39%

1 shift = 8 hours of beamtime

User Base



Based on # of users (2012)

Canada – SK: 44%

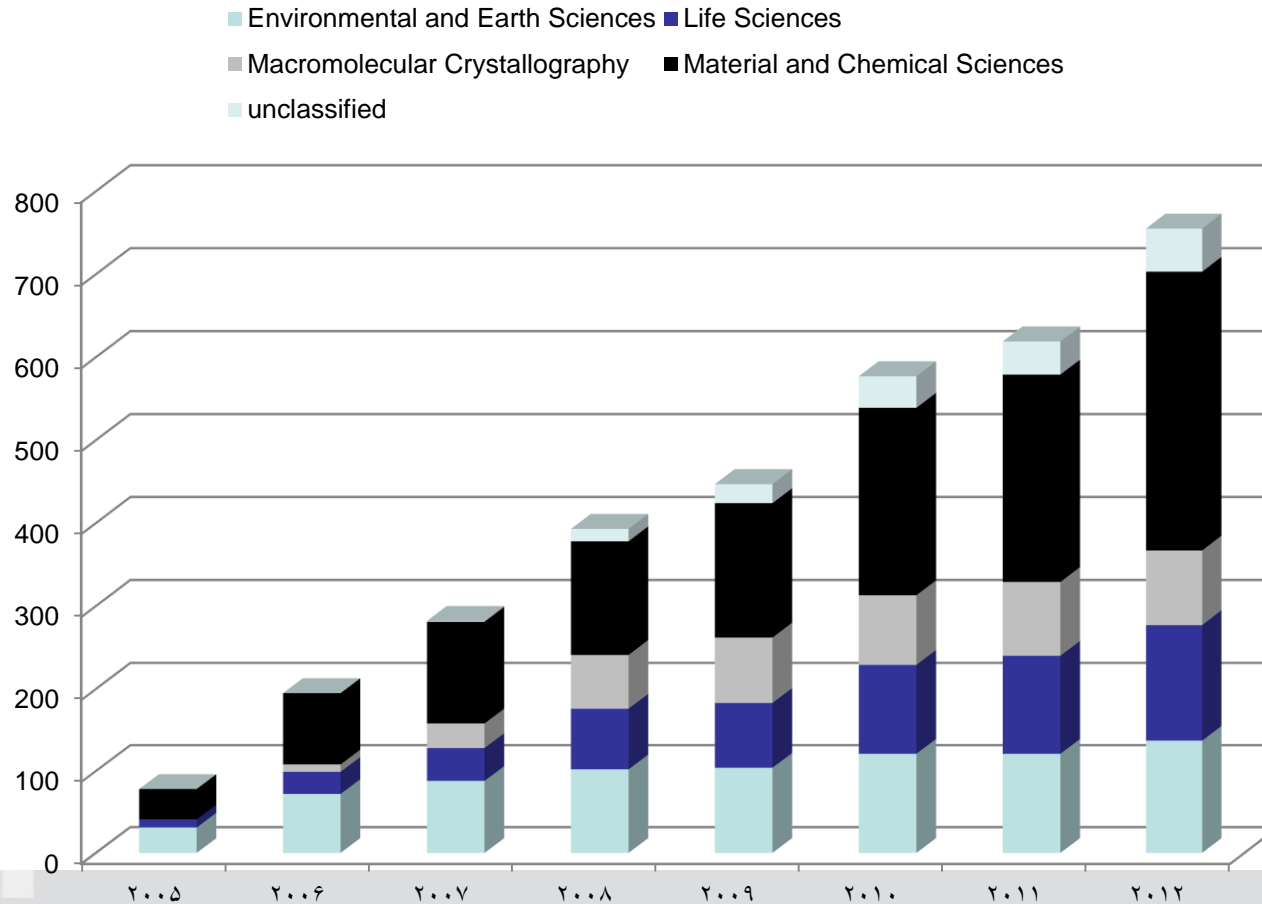
Canada – Other: 35%

International: 21%

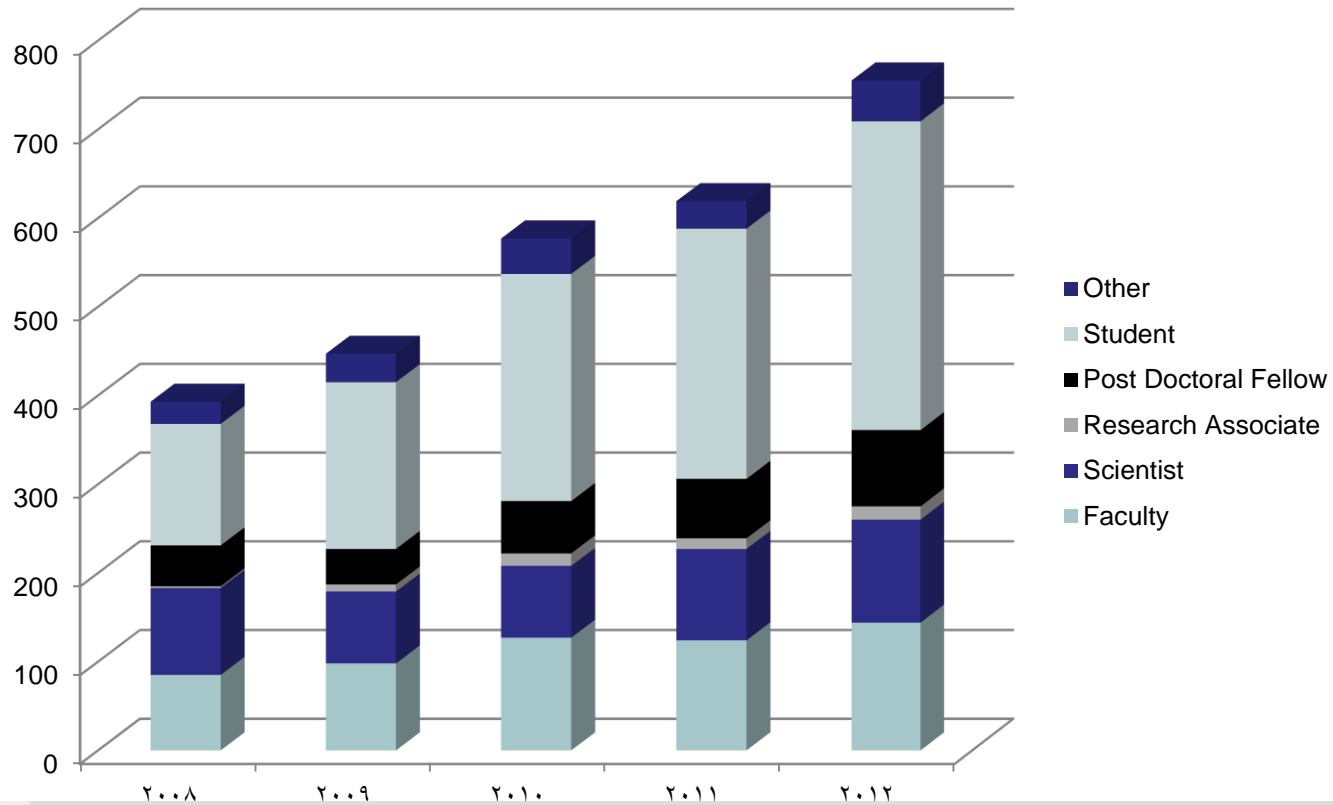
Based on shifts:

Geographic Distribution	2008	2009	2010	2011	2012
Canada - SK	560 (46%)	590 (35%)	716 (30%)	1106 (38%)	1184 (36%)
Canada - Other	554 (45%)	828 (49%)	1232 (52%)	1304 (44%)	1370 (42%)
International	114 (9%)	275 (16%)	406 (17%)	532 (18%)	728 (22%)

Broad Range of Disciplines



Students and Postdocs



Some CLS Stats

Beam energy	2.9 GeV
Circumference	171 m
Number of straight sections	12
Average current	~200 mA
Top-up	No
Horizontal emittance	18.2 nm rad
Facility employees	215
Phase I cost	\$173M (7 Phase I beamlines)
Operating costs (2013)	\$28M

Opened for peer-reviewed users	2006
Beamlines producing publications in 2013	13
Funded beamlines	22
Publications in 2013	242*
Shifts requested / allocated in 2013	4788 / 3077
Oversubscription factor 2013	1.56
Users/User visits 2013	883 / 1630
Publications/Beamline	19
Publications/100 shifts	5.5
Publications/User	0.28
Publications/User Visit	0.15
Publications/\$1M Operating Cost	8.9

Biomedical Imaging and Therapy (BMIT) Beamlines

- Some design considerations based on proposed user programs

Synchrotron Biomedical Imaging Methods

Projection and CT

in vivo
tissues

- ✿ Absorption Imaging
 - Uses tunability
- ✿ K-edge Subtraction
 - Uses tunability
- ✿ In-Line Phase Contrast Imaging
 - Uses high source brightness (small source size)
- ✿ Analyzer Based Imaging / Diffraction Enhanced Imaging / Multiple Image Radiography
 - Uses high source brightness (high intensity)
- Grating (Talbot) Interferometry Imaging (in progress)
 - Uses brightness
- ✿ High Resolution Imaging / Microtomography
 - Uses high source brightness (intensity & source size)
 - Can apply most of above imaging methods

LOCATION, LOCATION, LOCATION

**City Hospital /
Breast Health
Centre**

CLS

**VIDO /
InterVac**

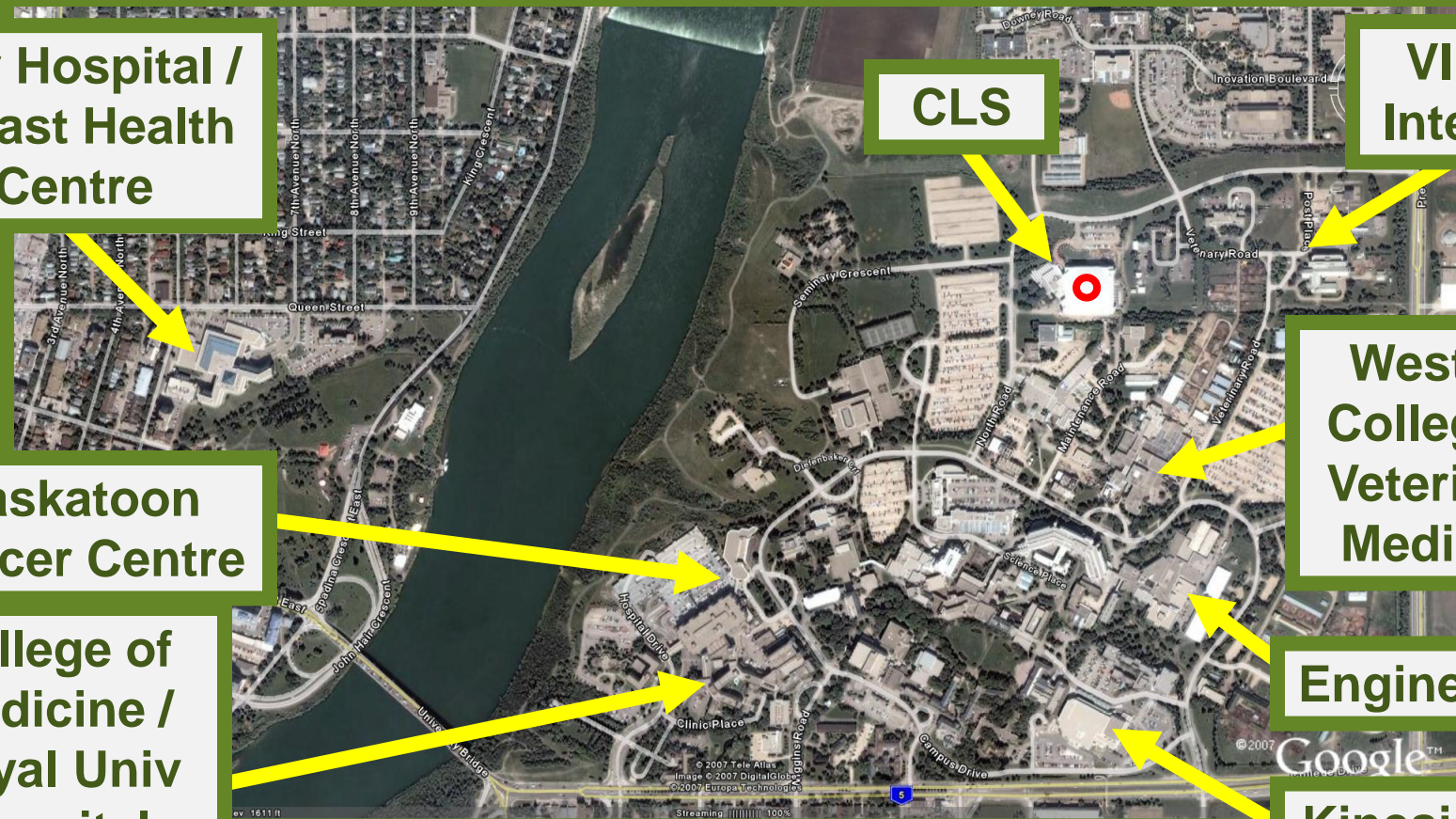
**Saskatoon
Cancer Centre**

**College of
Medicine /
Royal Univ
Hospital**

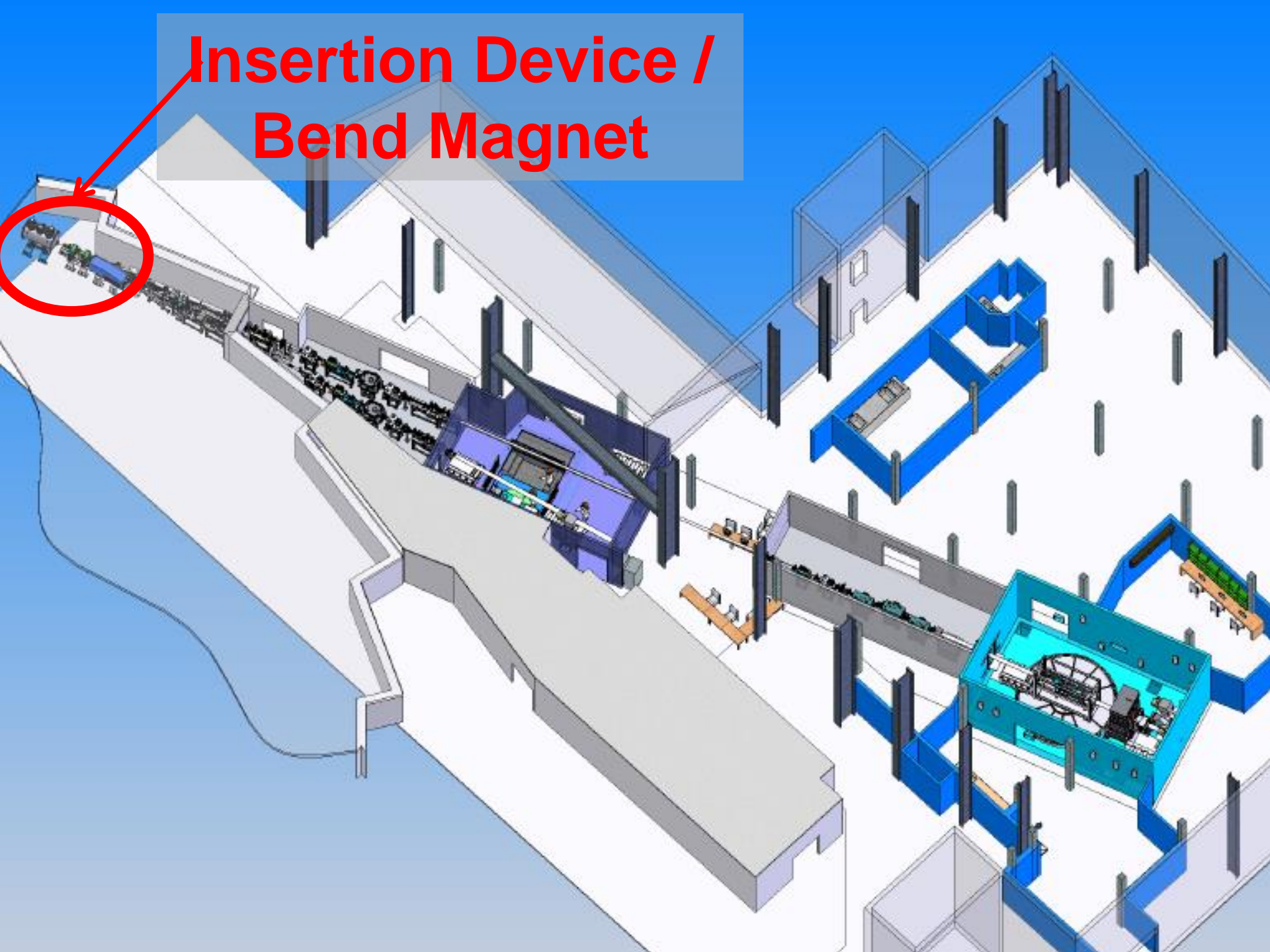
**Western
College of
Veterinary
Medicine**

Engineering

Kinesiology



**Insertion Device /
Bend Magnet**



05B1-1 Beamline Overview

Source:	Bending Magnet: White/Mono Beam
Monochromator:	Double Crystal Mono (Bragg)
Spectral range:	8 – 40 keV (temp limit 15-40 keV)
Resolving power (Mono):	1×10^{-4}
Beam size:	240 mm (H) x 7 mm (V) @ 25 m
White Beam Power:	~350 W (250 mA, 2.9 GeV)
Max. Power Density:	~2.3 W/mm² (250 mA, 2.9 GeV)
Max. dose rate using pink beam:	~4 Gy/min @ 250 mA @ 50 keV

BMIT Superconducting Wiggler

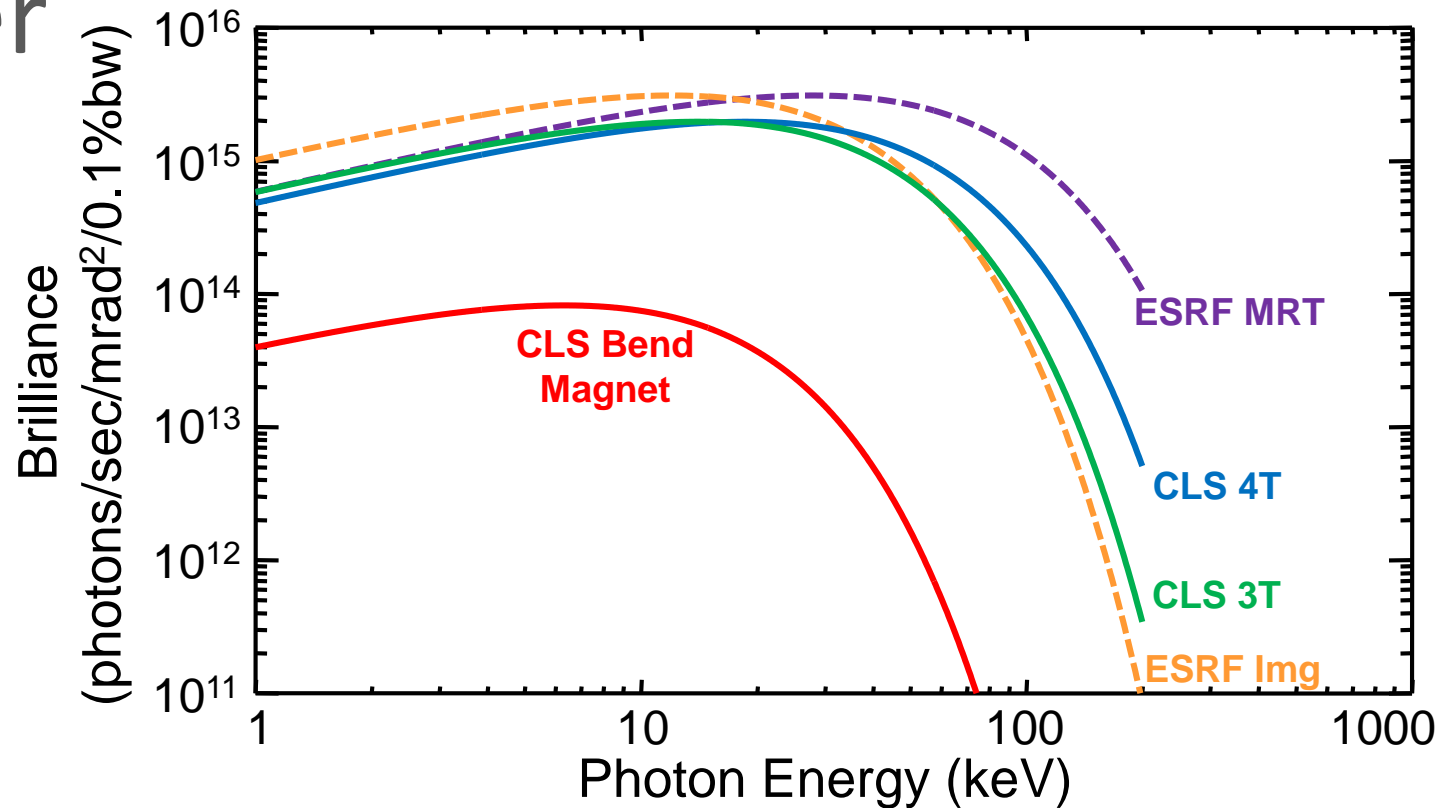
4.3T max field 4.8cm period

25 full field poles 2 half field poles

- 15kW @ 250mA ring current
- 30kW @ 500mA
- ***Highest field to period ratio in world***



BMIT Beamlines – one bend & one wiggler

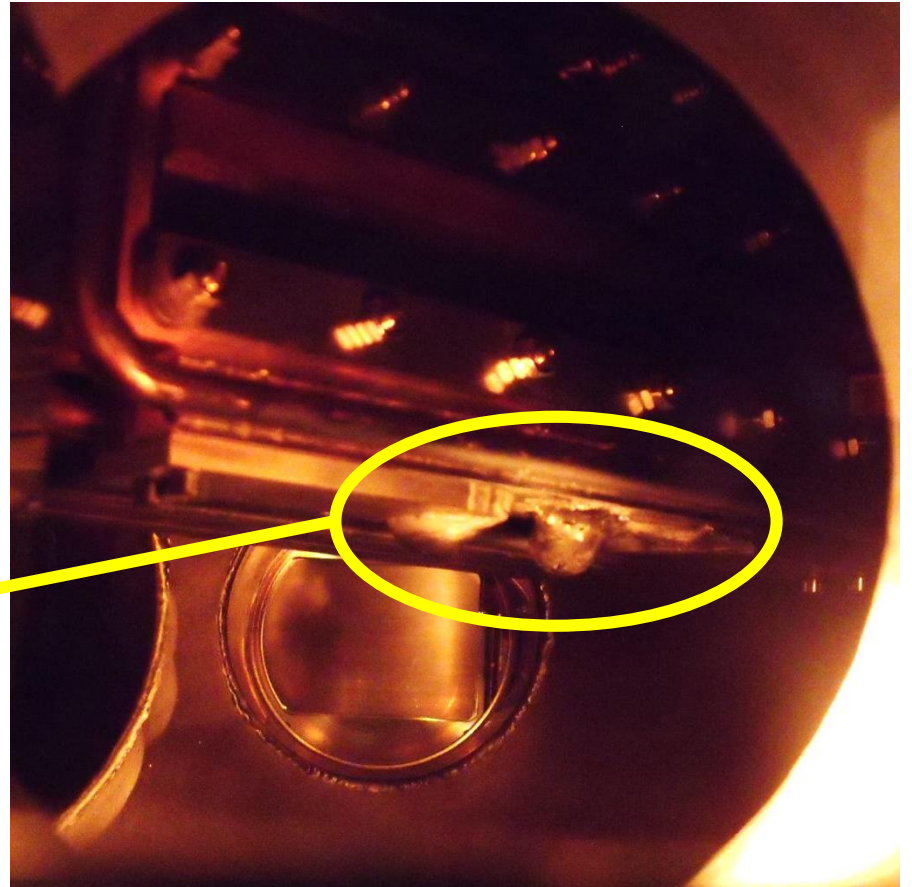


CLS Bend
 $B_0 = 1.354\text{T}$
 $E_c = 7.57\text{keV}$

BMIT Superconducting Wiggler (Bukder, Novosibirsk, Russia)
 $B_0 = 1.0$ to 4.3T $\lambda_u = 4.8$ 26 effective poles (25 full, 2 half)
 $K = 4.5$ to 19.3
 $E_c = 5.6$ to 24.0

Wiggler Beamline Filter Assembly

- ✿ Filter assembly had shipping plate and bolts on bottom
- ✿ Missed in final assembly
- ✿ Beam hit plate and bolt –



Choice of Wiggler Characteristics

Imaging

-  20 to 100keV

-  High flux


Microbeam Radiation Therapy (MRT)

-  High dose rate @ 100keV

Wiggler

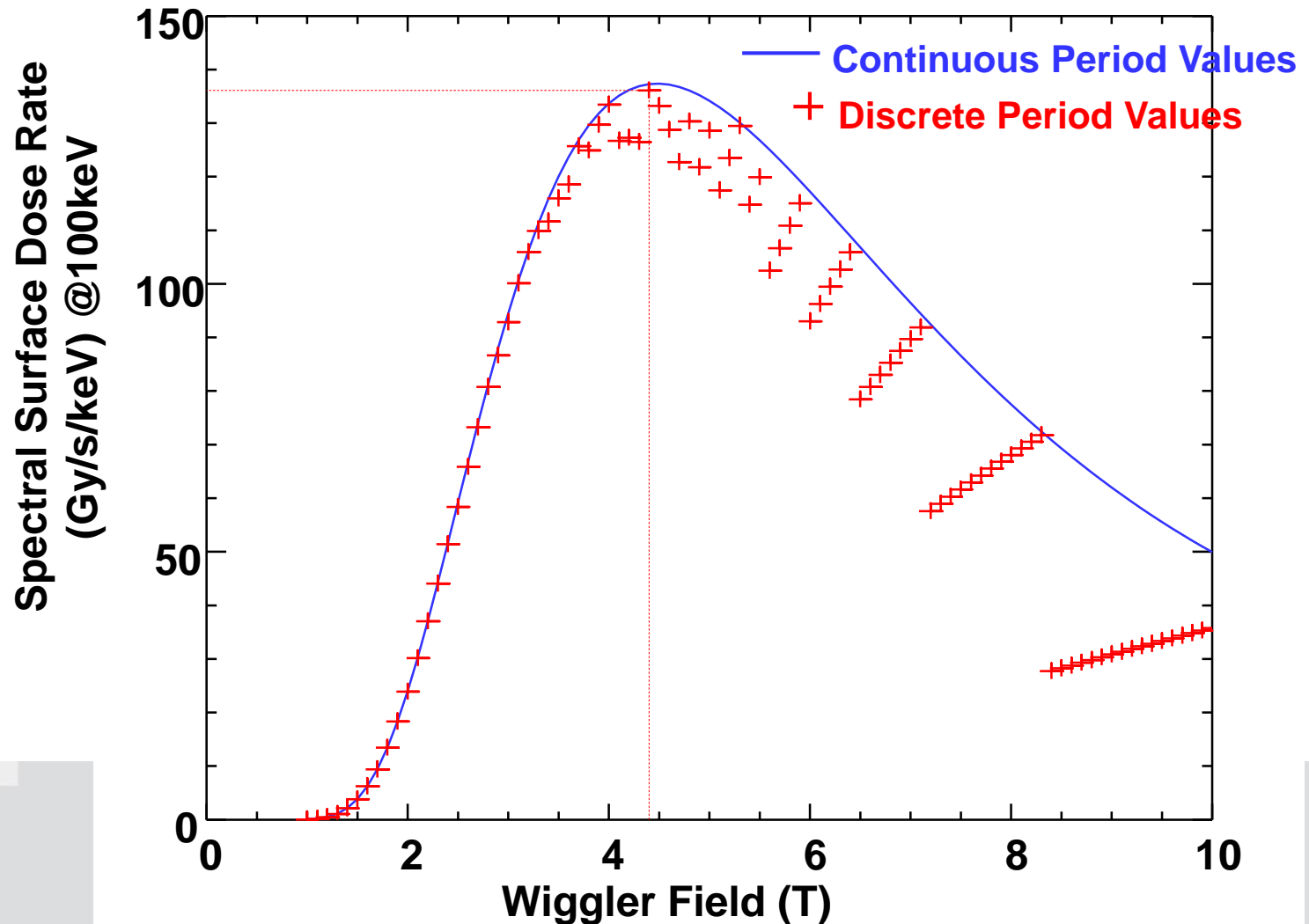
-  Need for high x-ray energies => high B

-  Need for high flux => large number of poles

-  Efficiency => small period




-  Front end power limitation of ~30kW @ 500mA

Insertion Device Optimization for Imaging and MRT



BMIT Instrumentation

Unique Large Positioning Systems

-  Large Animal Positioning System (LAPS)
-  Microbeam Radiation Therapy Lift (MRT Lift)
-  Detector Positioning Systems (POE2 and SOE)

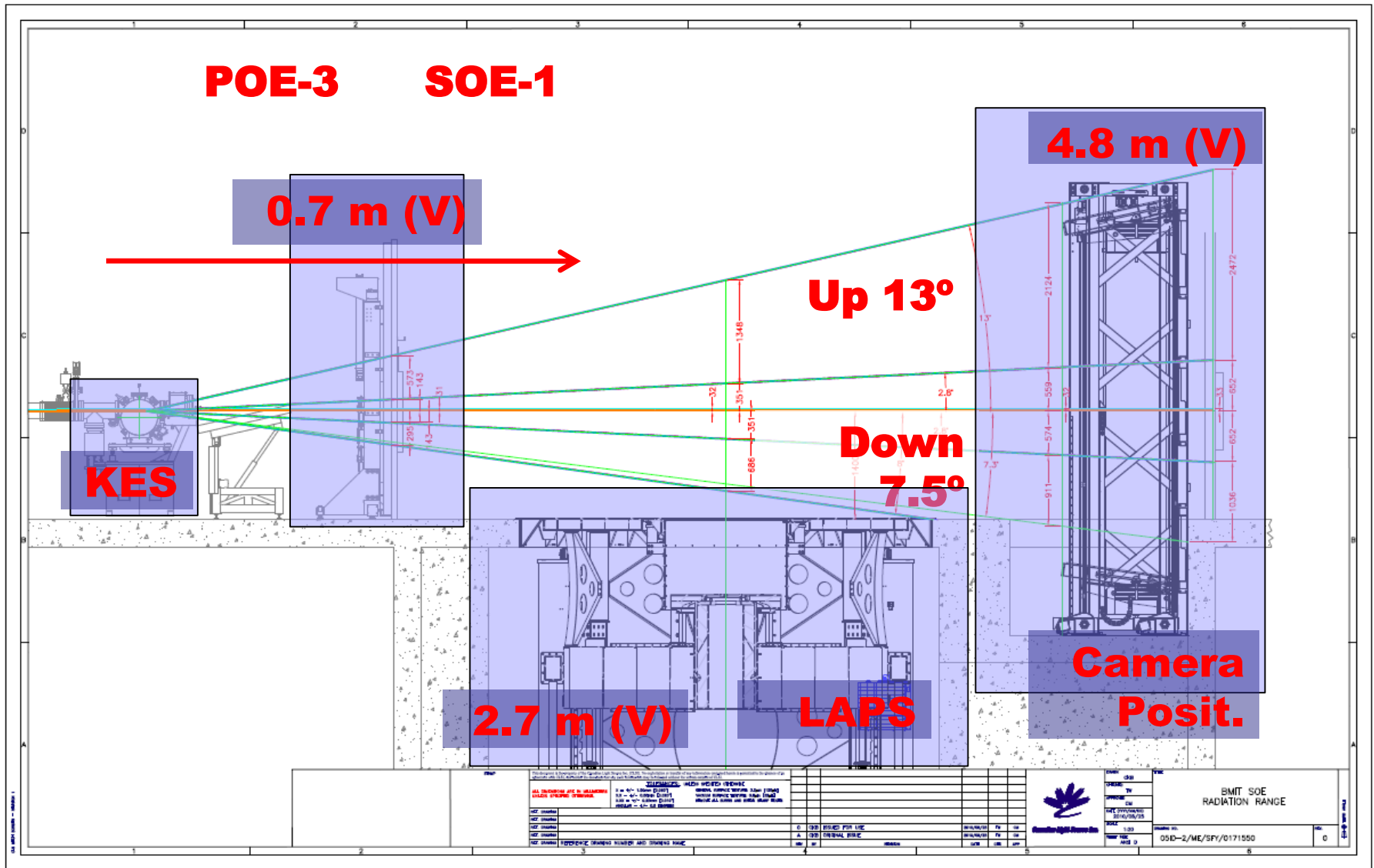
A 3D architectural rendering of a building interior, showing a large open space with a blue floor and white walls. The space is divided into several sections by low blue walls. In the center, there is a large blue structure, possibly a stage or a large piece of equipment. To the right, there is a red circle highlighting a specific area, which appears to be a small stage or a performance area. The text "Insertion Device SOE Hutch" is overlaid in red on the right side of the image.

**Insertion
Device SOE
Hutch**

Unique in the world: the large animal positioning system on the Biomedical Imaging and Therapy (BMIT) Beamline



Denise Miller, BMIT Systems Analyst
George Belev, BMIT Beamline Scientist



Large Animal Positioning System



Large Animal Positioning System



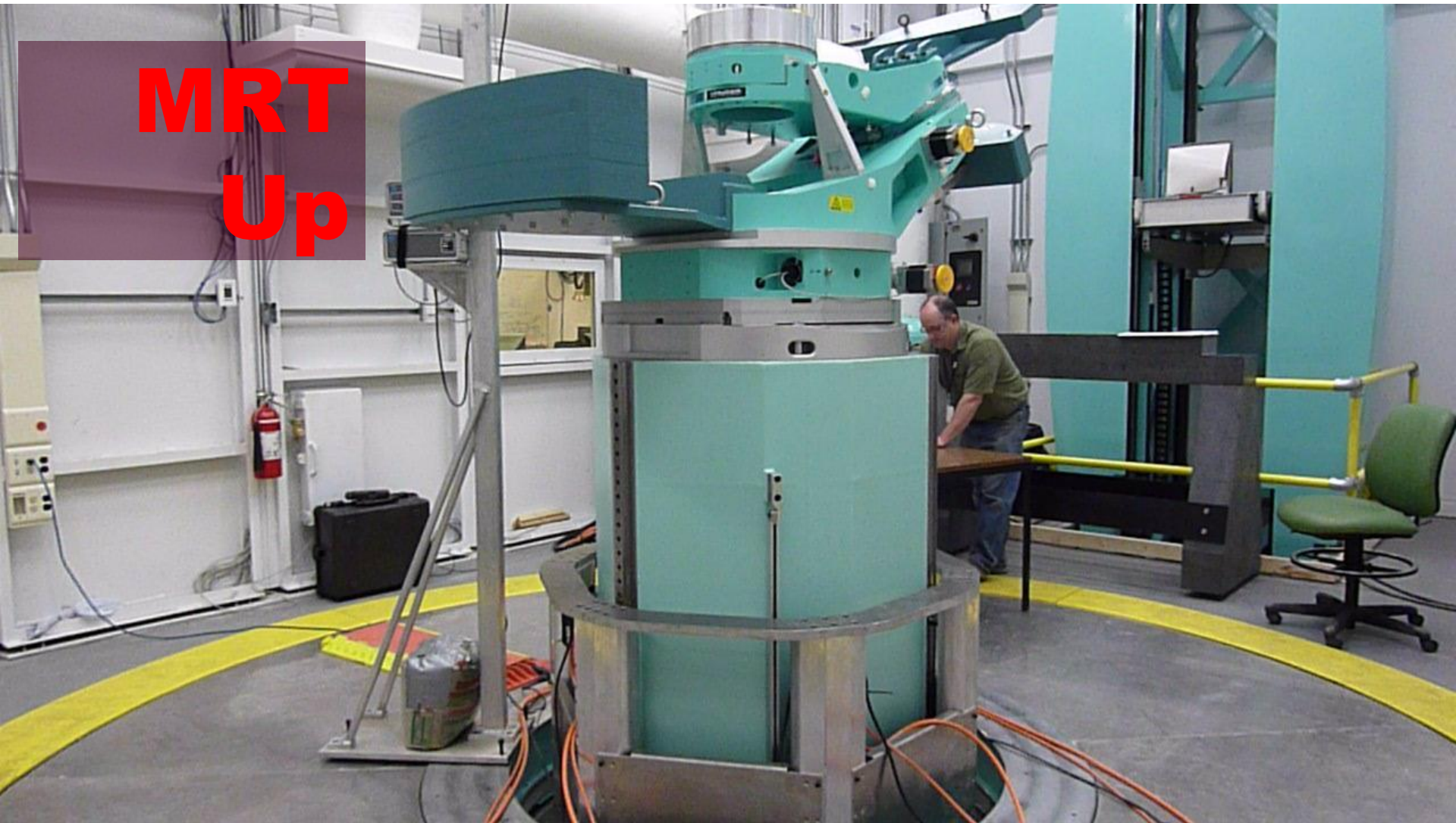
Large Animal Positioning System



**MRT
Down**



**MRT
Up**



MRT Lift in operation...



SOE Detector Holder

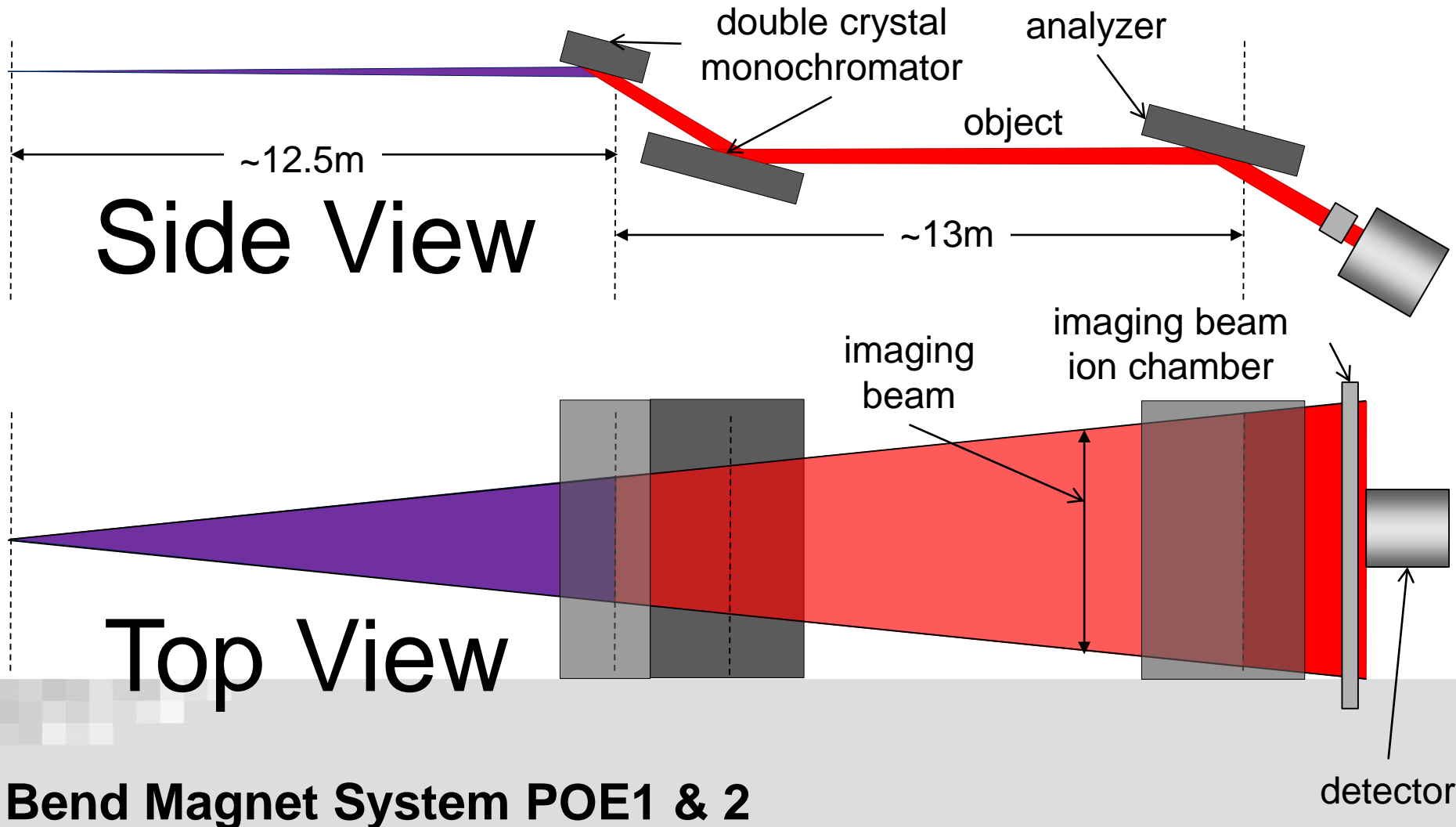
- Positions detector for all imaging modes
 - KES
 - DEI/MIR
 - In-Line Phase
 - ...
- Granite stand it front holds DEI Analyzer



**Bend Magnet
POE 2 Hutch**



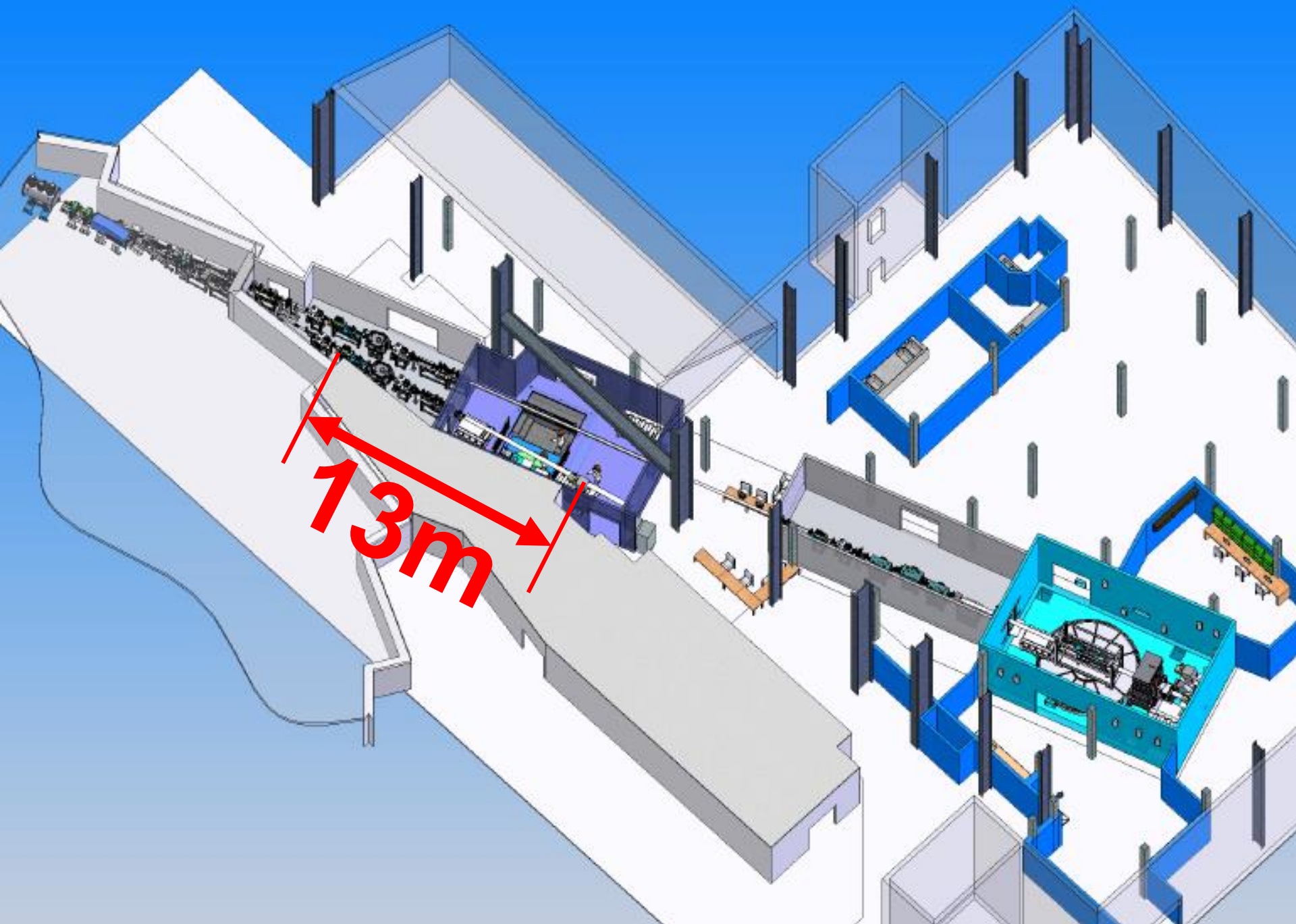
Analyzer Based Imaging / Diffraction Enhanced Imaging System



BMIT Lives!!

Mouse @ 41keV ~2mGy exposure 17 Dec 2008

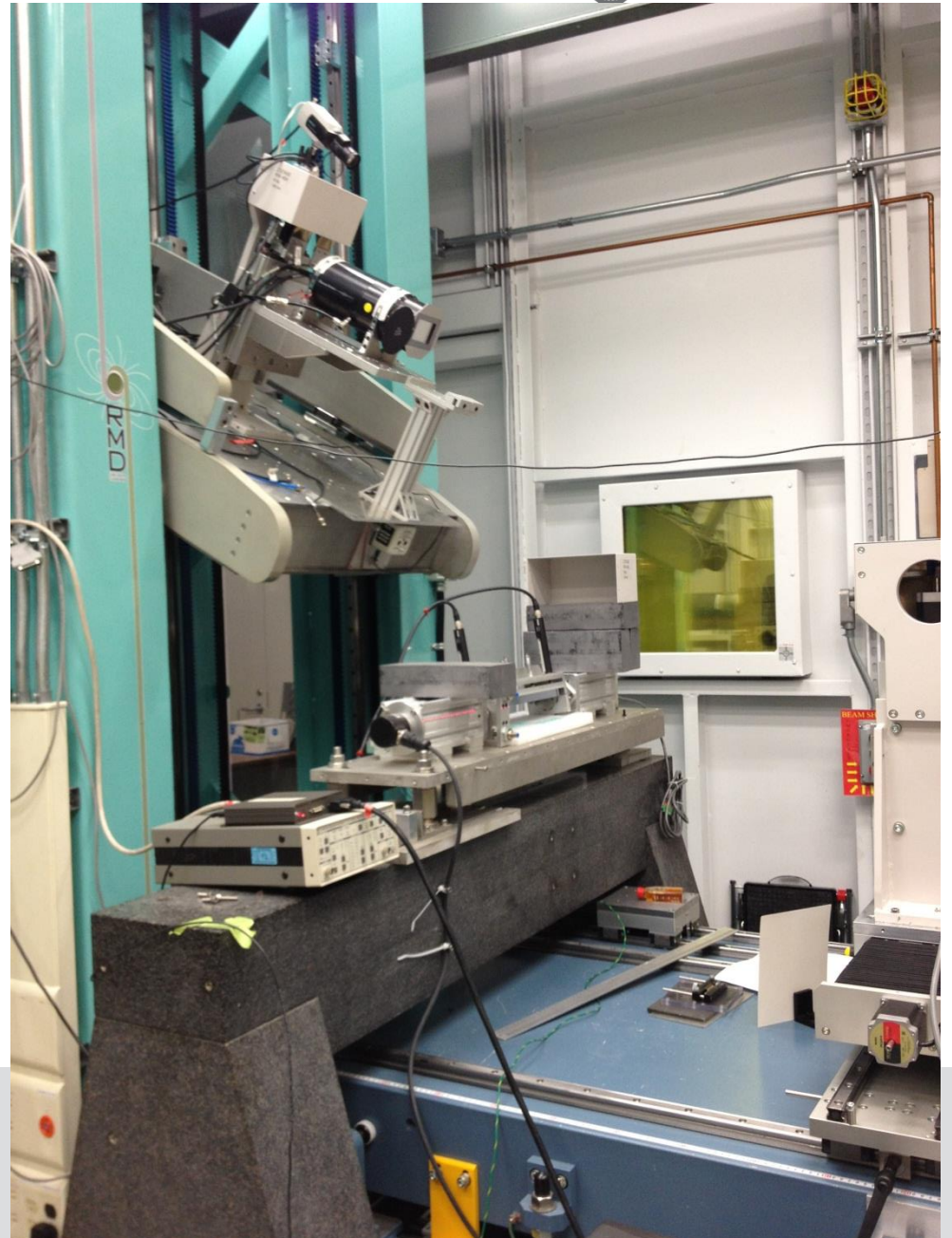




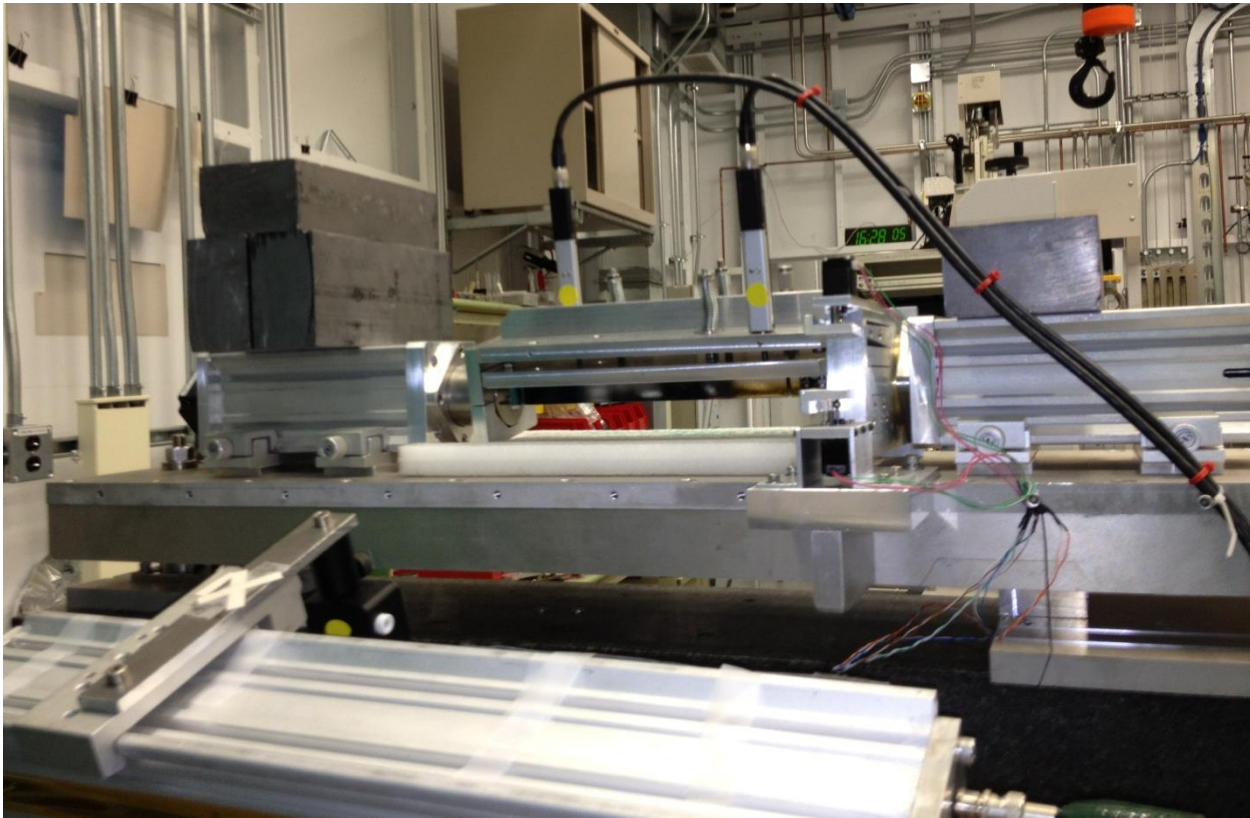
13m

POE 2 BM Analyzer and Detector Holder

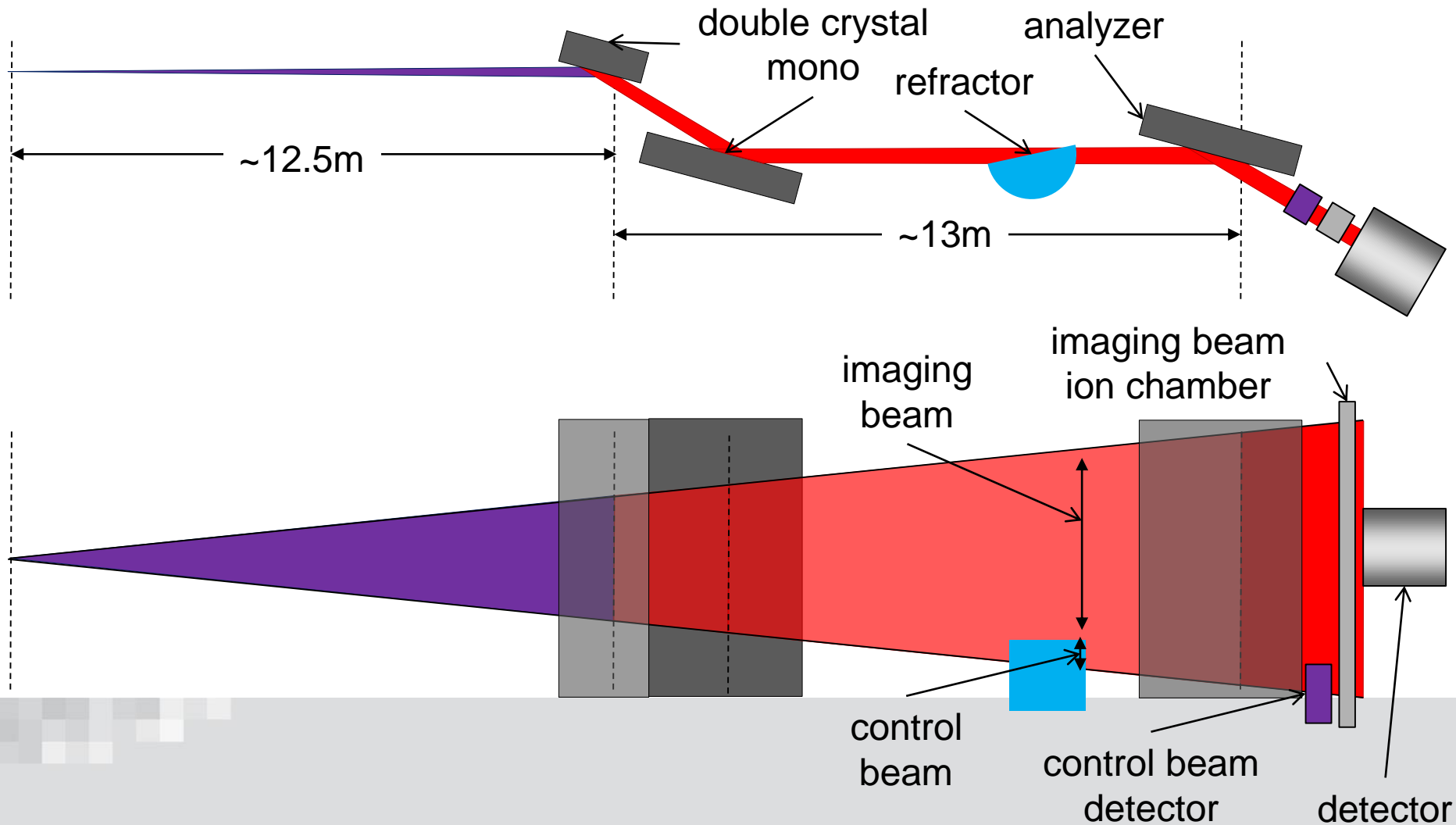
- ❁ Position detector for same modalities as in SOE
- ❁ DEI Analyzer in front of holder with analyzer in place



Analyzer Based Imaging System @ BMIT BM

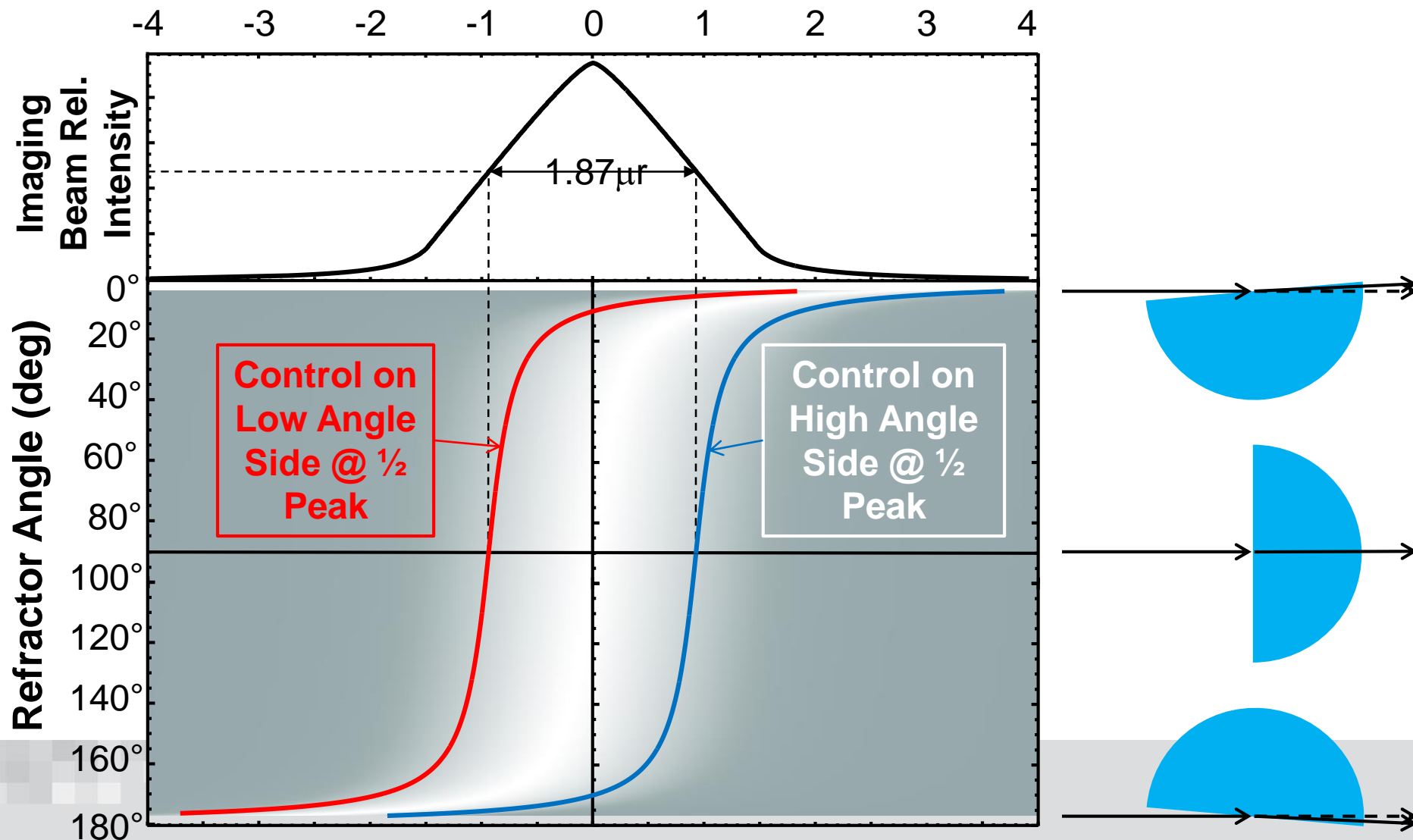


Analyzer Control System



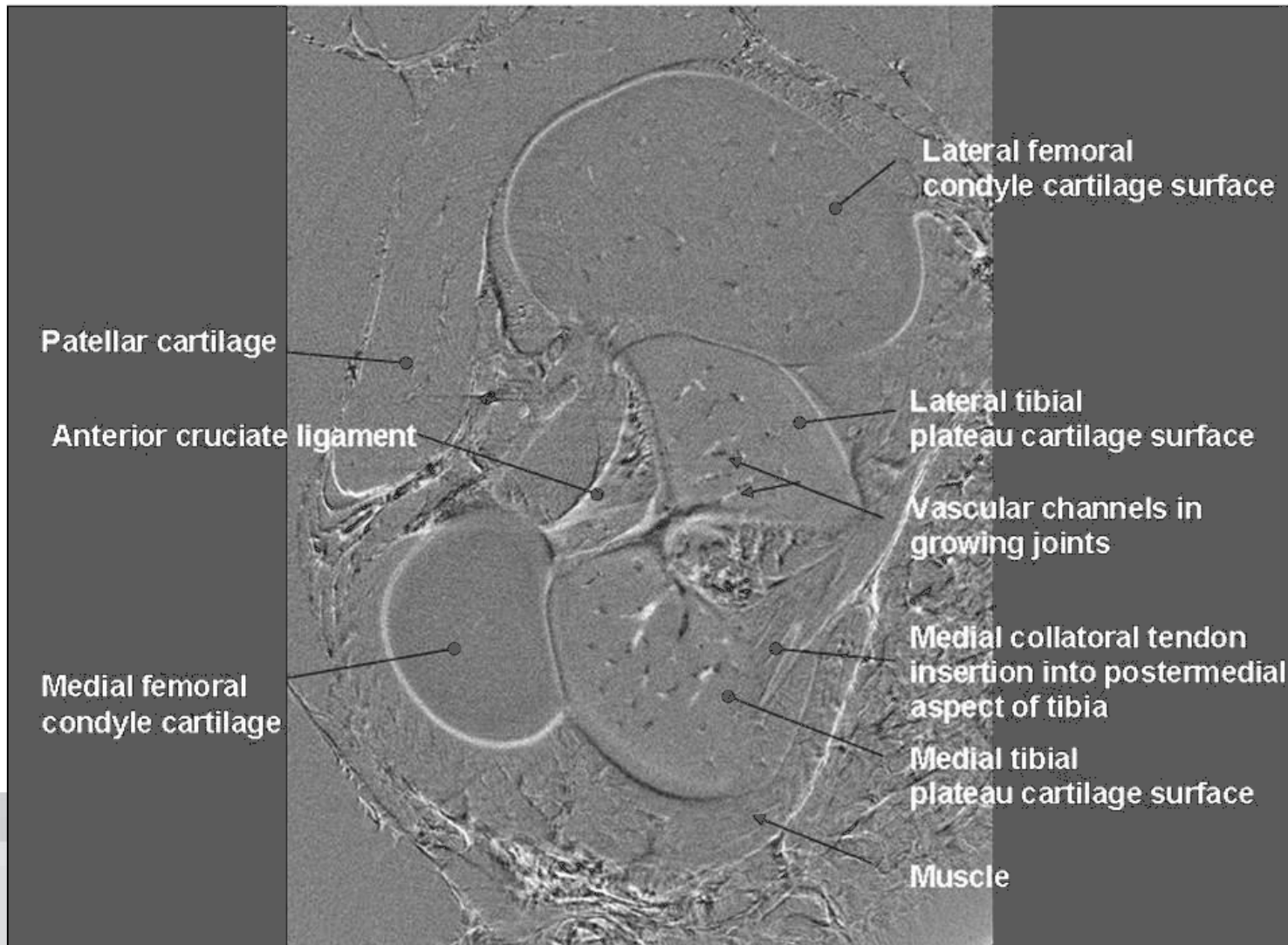
Si(4,4,0) @ 40keV

Location on Imaging Beam Rocking Curve (μr)



Earliest Signs of Osteoarthritis...

DEI CT of Piglet Joints

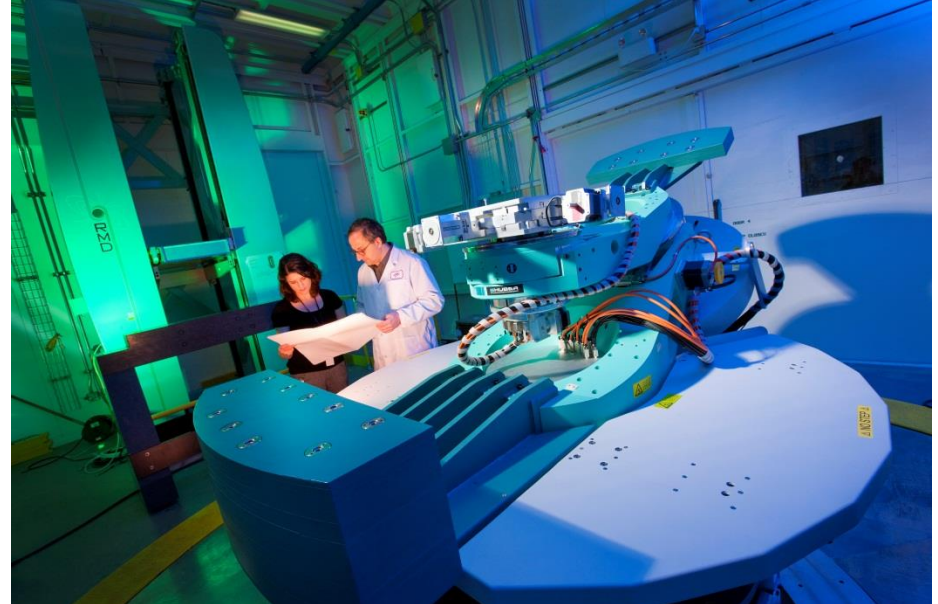


DEI CT
Refraction
Image
40keV
BMIT 05B1-1

Glendon
Rhoades,
Alan Rosenberg,
Sheldon Wiebe,
Chapman, et al

Conclusion

- Unique opportunity and environment for biomedical research
- Very flexible facility – “wind tunnel”
- Training a new generation of scientists in interdisciplinary research
- Insertion Device beamline recently on-line
- New concepts to expand utility of beamline
- We have just started...





*David
Cooper*

*Denise
Miller*

*Adam
Webb*

*Tomasz
Wysokinski*

*George
Belev*



Ning Zhu

$$\begin{bmatrix} H \\ \bar{H} \end{bmatrix} = \begin{bmatrix} 0.325 & 6.58 \\ 0.322 & 35.4 \end{bmatrix} \begin{bmatrix} \bar{H} \\ H \end{bmatrix}$$

You can contact us at

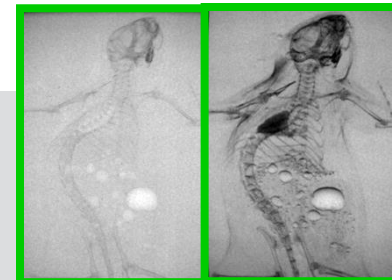
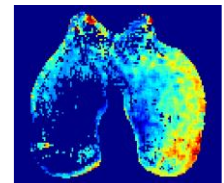
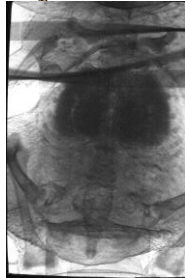
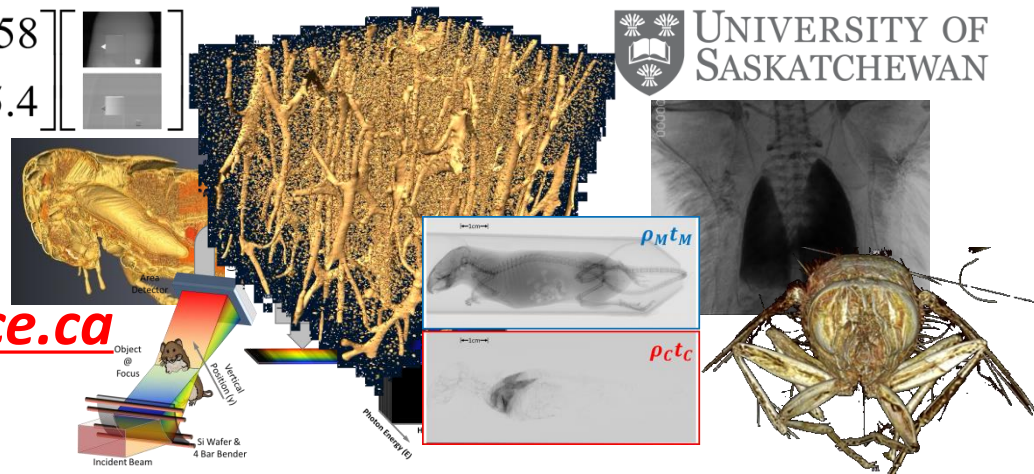
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*Canada Foundation for Innovation
Province of Saskatchewan
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Regina Qu'Apelle Health Region
Hospitals of Regina Foundation
Canadian Cancer Society - SK*

*Saskatchewan Cancer Agency
Alberta Cancer Board
Breast Cancer Society of Canada
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College of Medicine
Western College of Veterinary Medicine
College of Kinesiology
Department of Psychology
College of Nursing
College of Dentistry
College of Agriculture
Canadian Light Source*





Thank you!