The Scientific Program of SESAME

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Layout

- Introduction and Overview
- SESAME Beamlines
- Training Opportunities

Radiation Sources

Bending magnets

- Radiation emitted tangentially to the orbit

$$\frac{1}{\gamma} = \frac{mc^2}{E}$$

- Dipole magnet is used as bend magnet

$$\varepsilon_c[\mathrm{keV}] = 0.665\,E^2[\mathrm{GeV}^2]B[\mathrm{T}]$$

- For SESAME ***E = 2.5 GeV, B = 1.455 T***

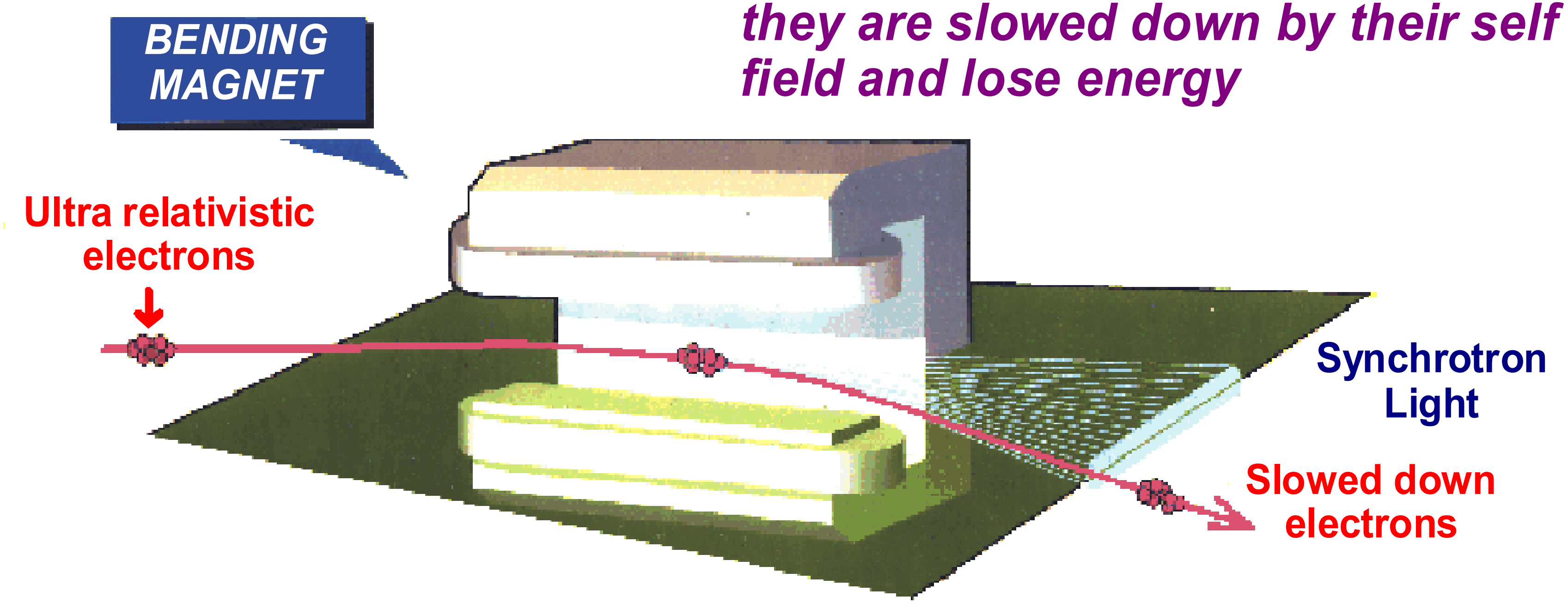
$$\boldsymbol{\varepsilon_c = 5.73\ \mathrm{keV}}$$

Insertion devices

- Multipole Wigglers
- Undulators

Ultra relativistic electrons can be deviated by the constant magnetic field of bending magnets in which their trajectory is an arc of circle

Due to the bending of their trajectory, they are slowed down by their self field and lose energy



They emit photons in a direction tangent to their trajectory

This is synchrotron radiation

Such conditions are met in electron storage rings

Radiation Sources

A parameter of prime importance in experiments with **synchrotron radiation** sources is the spectral **brilliance** (brightness) defined as

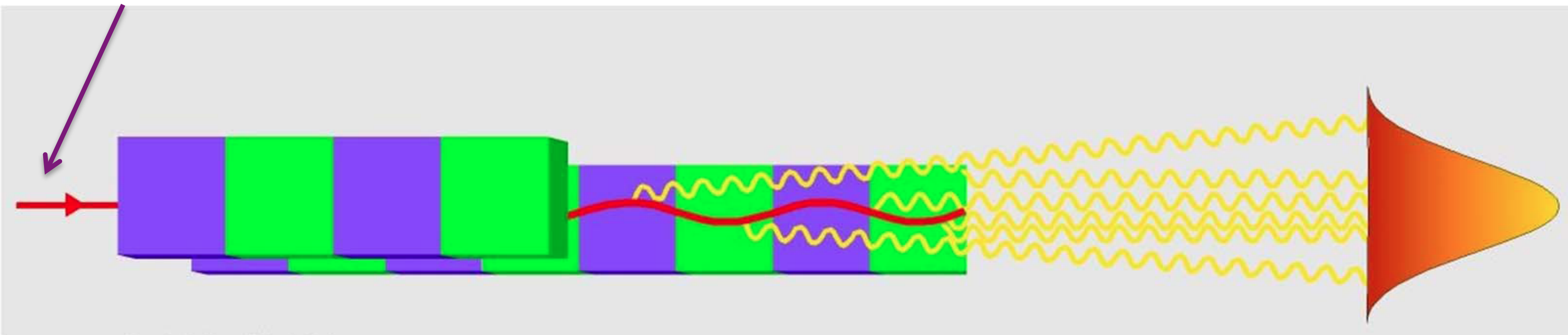
$$\boxed{B = \frac{dN_{ph}}{dA\, d\Omega\, dt\, d\lambda / \lambda}} \qquad \frac{photons\ \ per\ \sec ond}{mm^2\, mrad^2\, 0.1\% b.w}$$

Apart from *diffraction effects*, we have :

$$\boxed{dA\, d\Omega \approx \varepsilon_x \varepsilon_z}$$

High brilliance of PHOTON BEAM ⇨ Low emittance of ELECTRON BEAM

Insertion Devices



- Insertion devices are inserted in the straight section
- Oscillating magnetic field causes wiggling trajectory
- Period Length λ_u = 15 – 400 mm, Magnetic gap = 5 – 40 mm
- Flux from a wiggler = 2N x $\text{Flux}_{\text{dipole}}$ – Continuous spectrum
- Flux from an undulator = N^2 x $\text{Flux}_{\text{dipole}}$ – Discrete spectrum

Insertion Devices

- Generally K-factor is used to distinguished between wiggler and undulator:

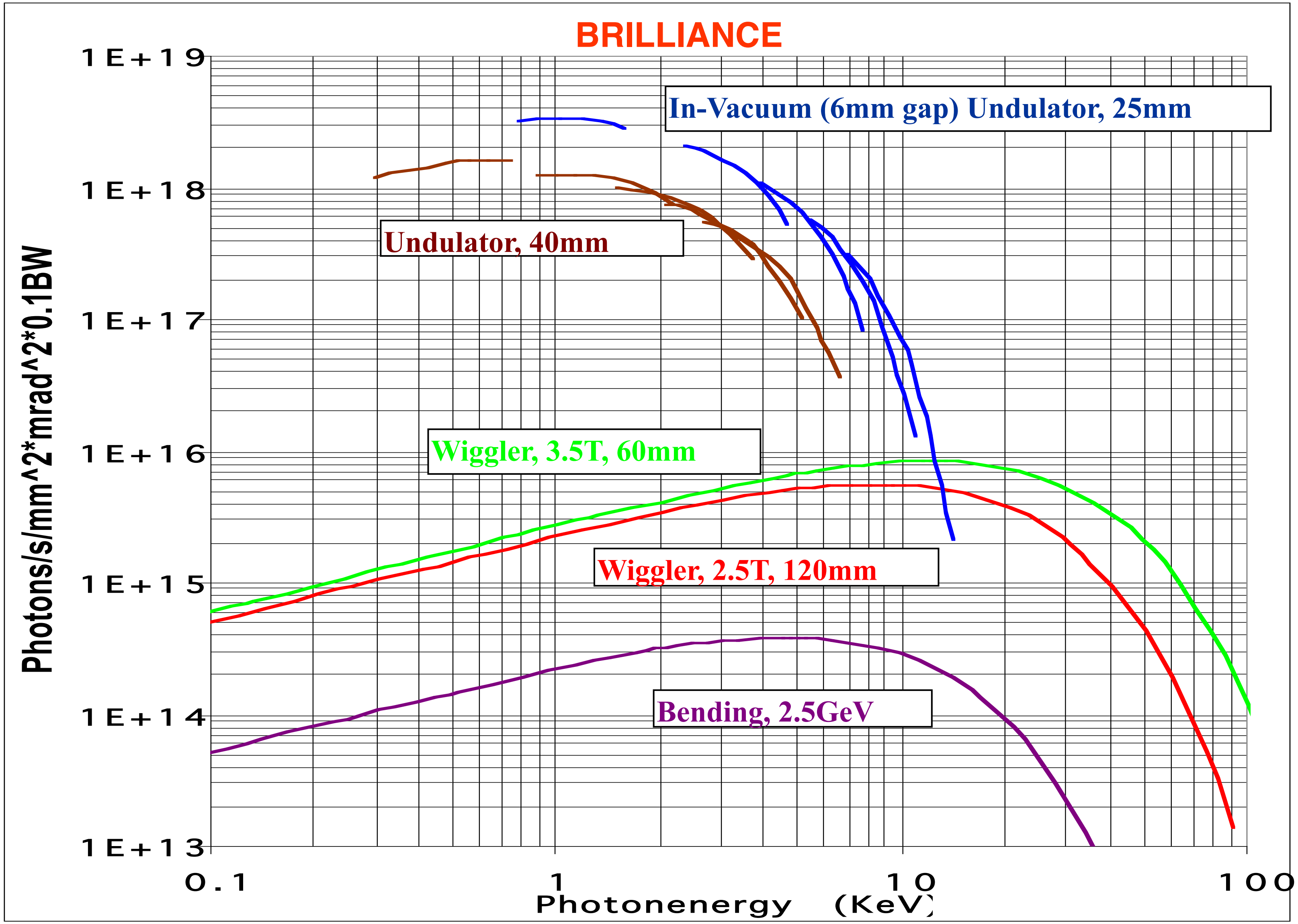
$$K = \frac{q\lambda B}{2\pi\beta mc}$$

- Wigglers (K >> 1)
  - Radiation spectrum is broad
- Undulators (K < 1)
  - Radiation spectrum is narrow
  - Intensity of radiation varies as N^2 where N is number of poles

SESAME - STORAGE RING Main Parameters

Parameter	Unit	Value
Energy	GeV	2.5
Circumference	m	133.2
Maximum Current	mA	400
Bending Dipole field; gradient	T; T/m	1.45545 ; -2.794
Emittance x / z	nm.rad	26 / 0.26
RF frequency ; peak voltage	MHz ; kV	499.564 ; 2.4
Natural bunch length	cm	1.16
Expected Beam Lifetime	h	18

Radiation from BM & IDs



IDs @ SESAME

SU6 Undulator from LURE

- spectral range 30 – 110 eV, peak field 0.25 T, min. gap 39 mm, Max. K value 1.7

PEP Undulator

- period length 77 mm, overall length 223 cm, Max. K value: 1.58

ALS Wiggler

- Period length 16 cm, 33 full poles, effective max. K value 27.

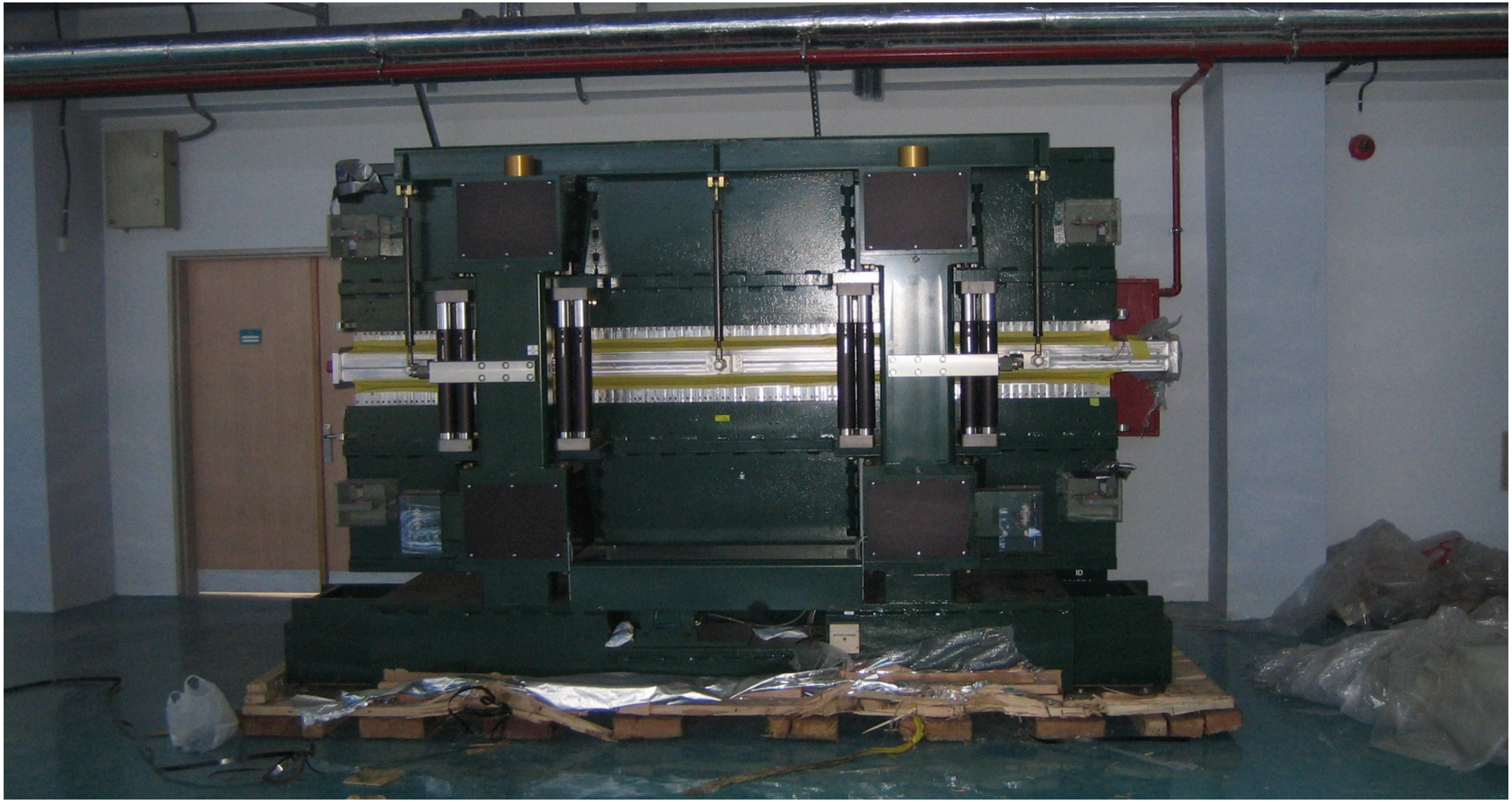
SLS - Wiggler W61

- Peak Field 2.0 T, Period length 16 cm, No. of periods 19

SLAC Undulator

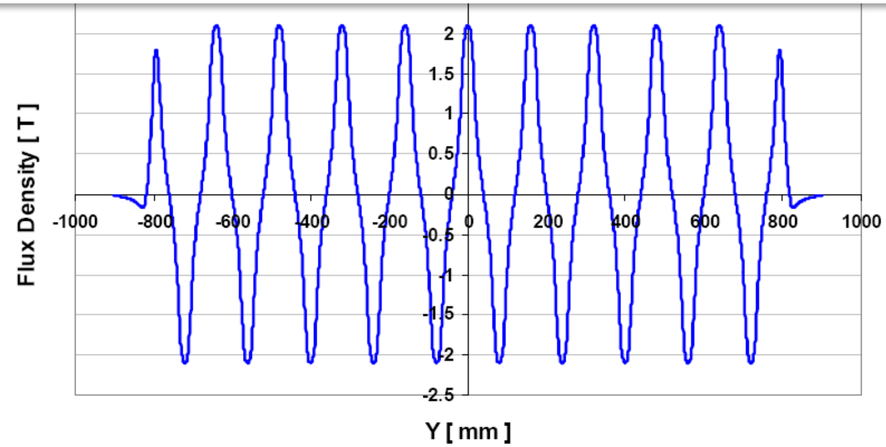
02/11/2008

ALS Wiggler



ALS WIGGLER WITH SESAME MACHINE

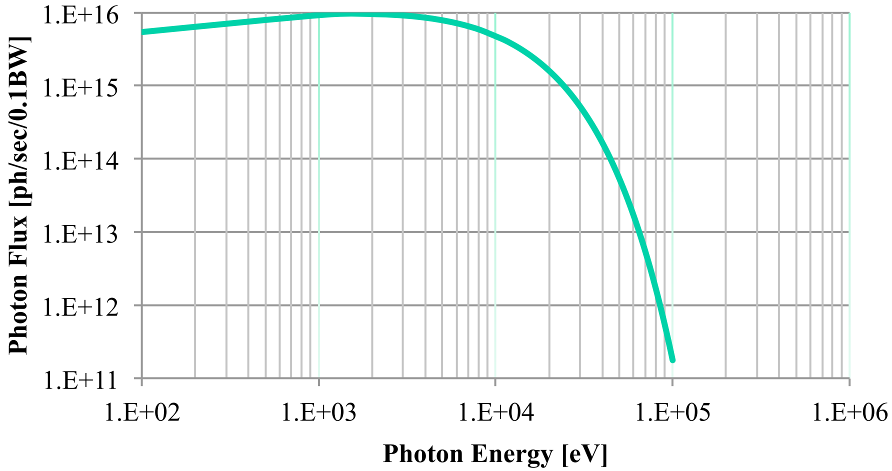
Measured Magnetic Flux



ALS wiggler:

Period length 16cm
33 full field poles
Mag. Gap 14 mm
Max. field 2.1Tesla
Effective K of 27.

Estimated Photon Flux



The implication of the radiation opening angle of ±6.5 mrad on the vacuum chamber in the horizontal plane to be studied.

W61 MINIGAP WIGGLER

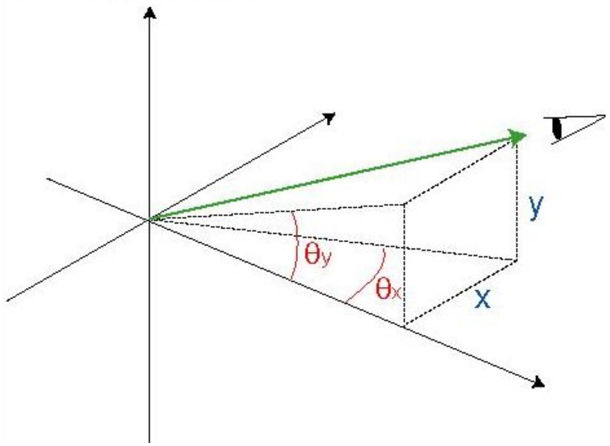
Overall length (L_w)	2 m
Minimum magnetic gap (w)	8 mm
Period length (l_w)	60.5 mm
Number of poles (N_p)	63
Magnet material	NdFe:B
Pole material	CoFe
Maximum field (B_{max})	1.84 T
Effective field (B_{eff})	1.63 T
Fourier amplitude ratio (B1/B0)	- 0.163
Deviation parameter (K)	8.6
Critical energy (E_c)	7.0 keV

SLS WIGGLER WITH SESAME MACHINE

- SLS wiggler will be housed in long straight section.

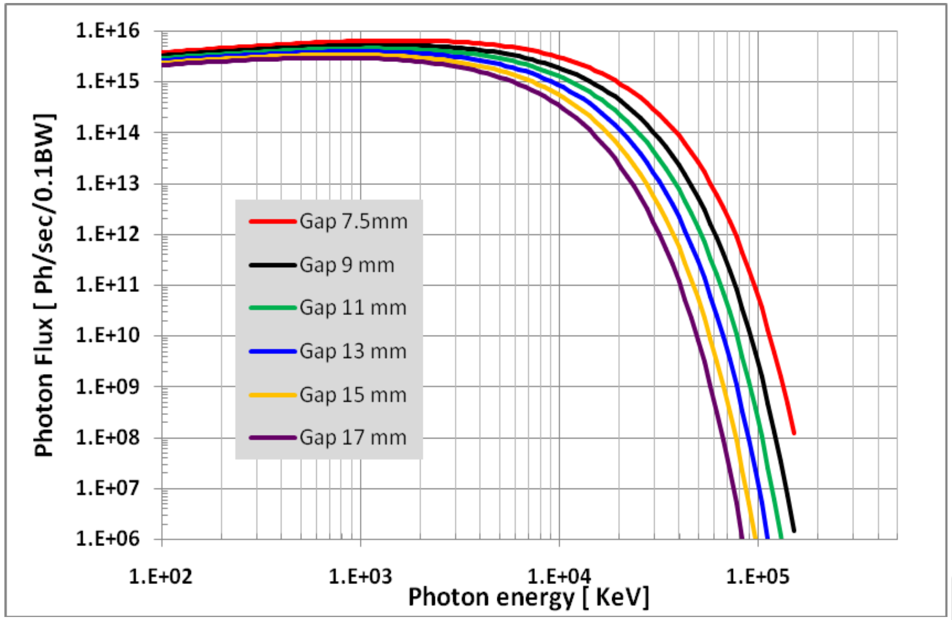
- Wiggler parameters:
  L=2m, Min. gap=7.5mm (B=1.86 T)
  Period length =61mm.

- Observation point :
  Fixed aperture of 2.2mm(V) × 24.2mm(H)
  at 9.67m from source point.



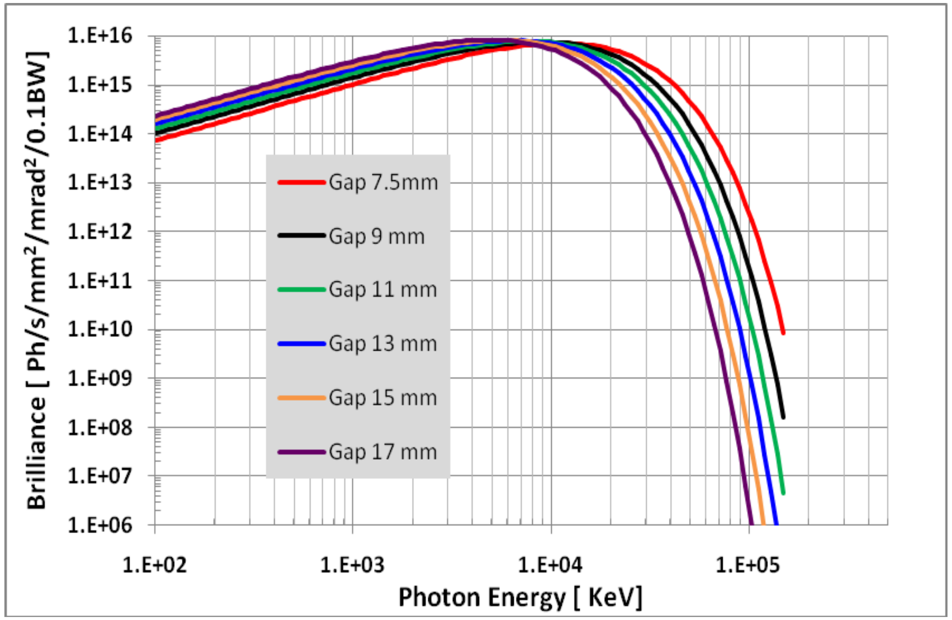
Magnetic Gap [mm]	Vacuum Cham. Inner wall [mm]	Max. Field [Tesla]	Maximum Photon Flux [Photons/sec/0.1BW]	Critical Photon Energy [KeV]	Total Power [KW]	Photon Energy Range [KeV] (1% of Maximum Photon Flux)
7.5	3.5	1.800	6.44×10^{15}	8.19	11.98	0.1 - 42.7
9	5	1.598	5.23×10^{15}	6.64	7.88	0.1 – 34.2
11	**7**	**1.375**	**4.50×10^{15}**	**5.72**	**5.84**	**0.1 – 29.5**
13	**9**	**1.188**	**3.89×10^{15}**	**4.93**	**4.35**	**0.1 – 25.5**
15	11	1.029	3.37×10^{15}	4.28	3.27	0.1 – 23.7
17	13	0.895	2.93×10^{15}	3.72	2.47	0.1 – 20.4

SLS WIGGLER WITH SESAME MACHINE



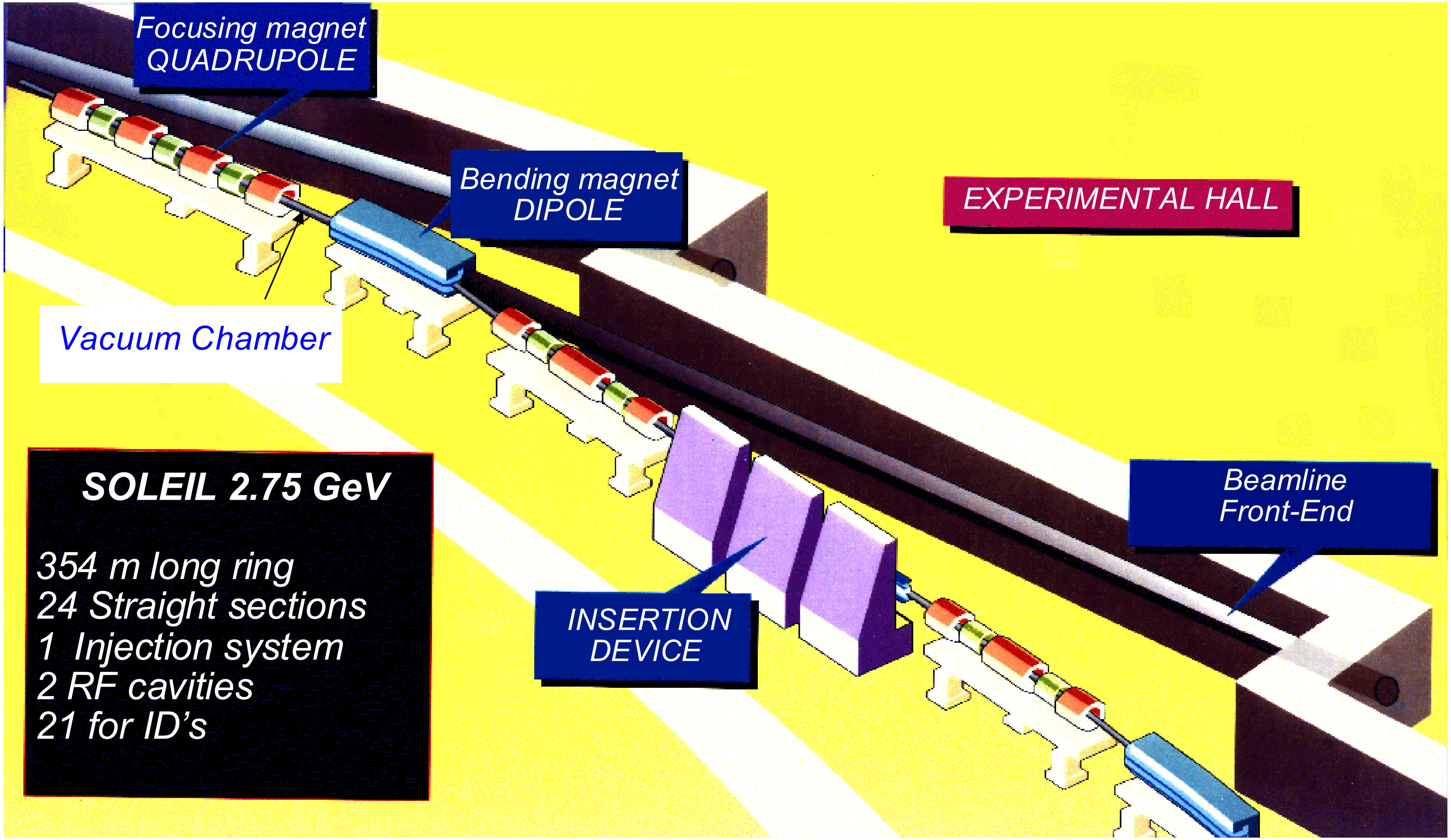
FLUX

Brilliance

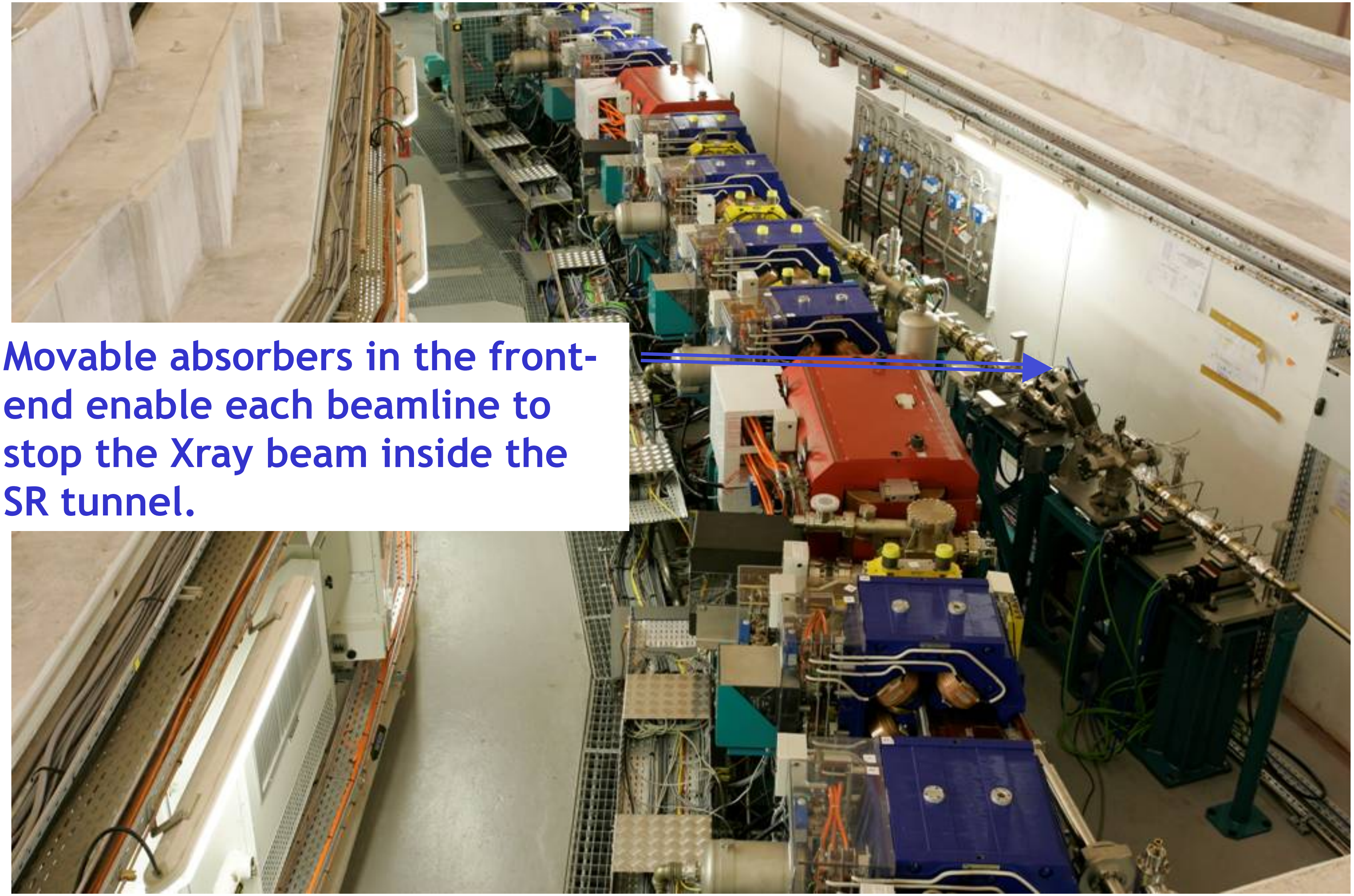


What is a Storage Ring?

Arrangement of components that enables electrons to circulate on a **closed orbit** for periods of several hours.

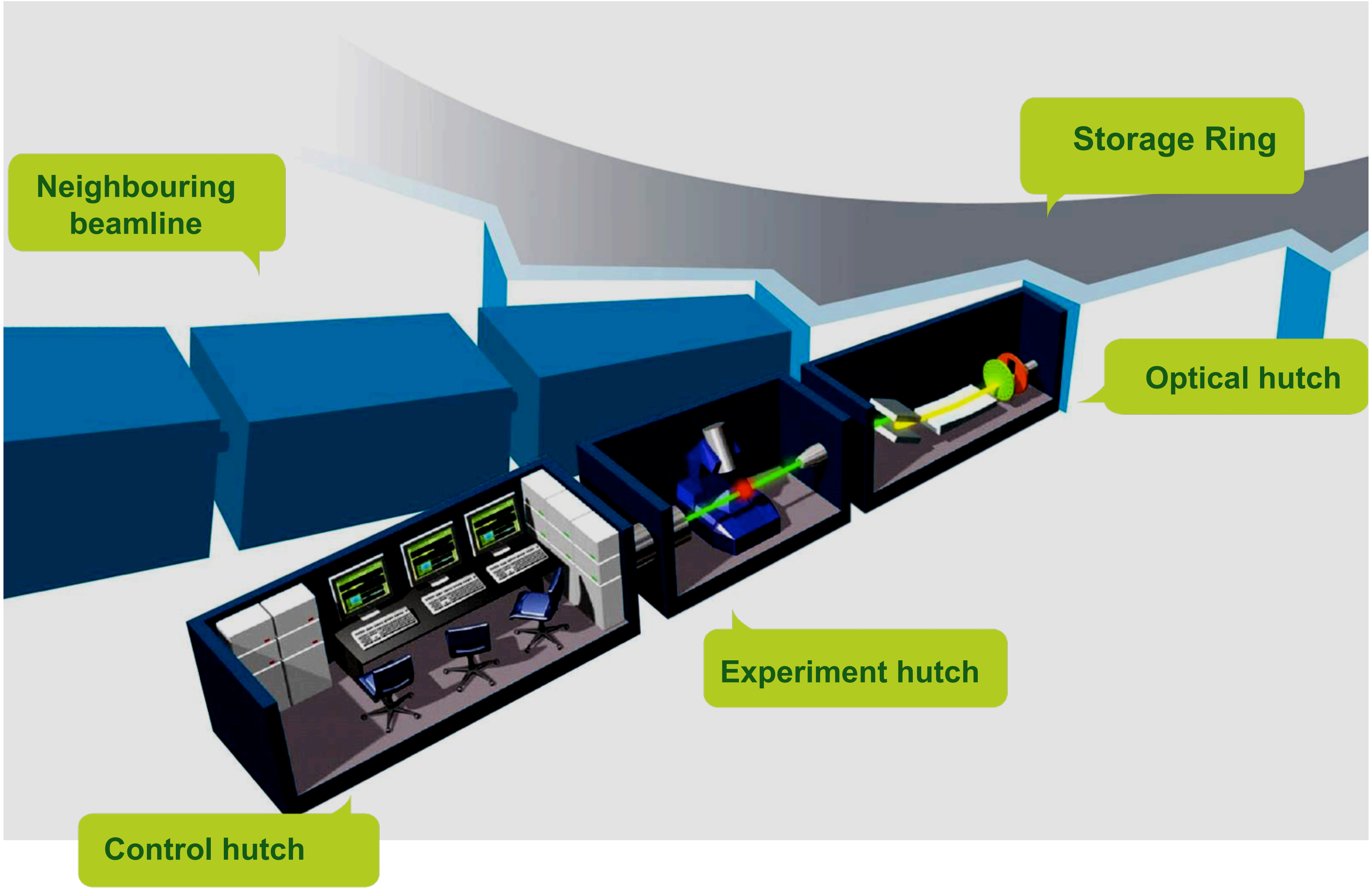


Synchrotron Radiation Facility



Movable absorbers in the front-end enable each beamline to stop the Xray beam inside the SR tunnel.

A Beamline = several hutches



Scientific Programme

- **Research in the domains :**
  - **Atomic and Molecular Physics**
  - **Material science**
  - **Nanotechnology**
  - **Molecular biology**
  - **Archaeology**
  - **Environmental studies**
  - **Medical research**

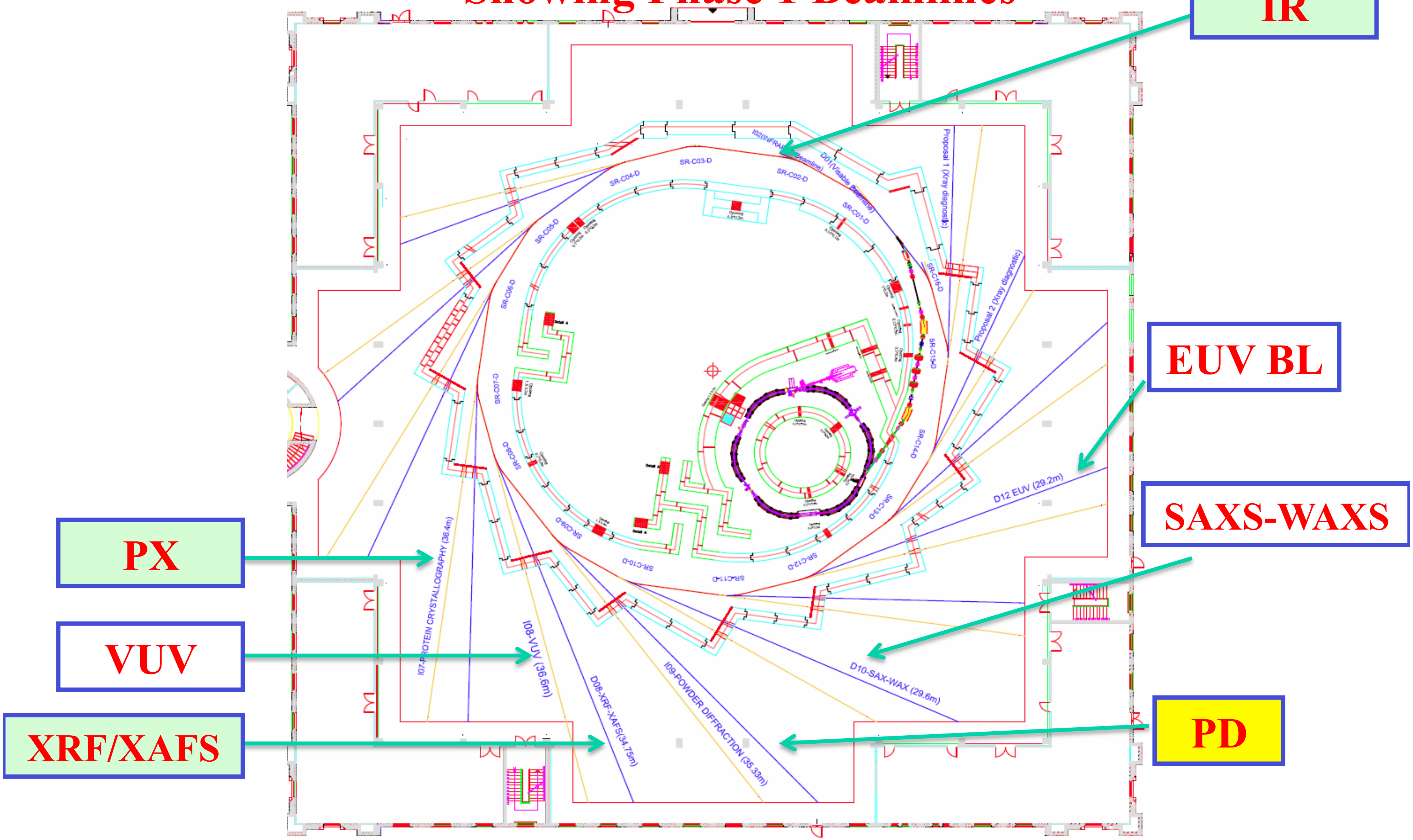
Scientific Programme

- **SESAME has the capacity for ~ 28 beamlines**
  - **Straight Sections = 16 (8 long 4.44 m, 8 short 2.38 m): Beamline Length 21 - 36.7 m**
- **Storage ring energy = 2.5 GeV**
  - **Photon energies from IR to soft x-rays to hard x-rays**
- **Mission for beamline development is to ensure appropriate capabilities are present that:**
  - **Meet needs of very diverse user community (novice to experienced in many different areas of science)**
  - **Develop state-of-the-art user-friendly capabilities**
  - **Provide user support for carrying out outstanding science,**
  - **Clear and transparent policy that provide equal opportunities for access of beamtimes, and**
  - **Reward facility partners for their contributions**

SESAME PHASE – I BEAMLINES

Beamline	Energy Range	Source
Protein Crystallography *(PX)*	4 – 14 keV	Bending Magnet
X-ray Absorption Fine Structure & X-ray Fluorescence *(XAFS/XRF)*	3 – 30 keV	Bending Magnet
Infra-red Spectro-microscopy *(IR)*	0.01 – 1 eV	Bending Magnet
Powder Diffraction *(PD)*	3 – 25 keV	MPW
Soft X-ray	0.05 – 2 keV	EPU
Small and Wide Angle X-ray Scattering *(SAXS/WAXS)*	8 – 12 keV	Bending Magnet
Extreme Ultraviolet *(EUV)*	10 – 200 eV	Bending Magnet

Layout of SESAME Experimental Hall
Showing Phase 1 Beamlines



SESAME DAY-ONE BEAMLINES

- **PX Beamline – IMCAN**
  - **International Macromolecular CrystAllography Nexus**

- **XRF Beamline – BASEMA**
  - **Beamline for Absorption Spectroscopy for Environment and Material Applications**

- **IR Beamline – EMIRA**
  - **ElectroMagnetic Infrared Radiation**

- **PD Beamline – SUSAM**
  - **SESAME USers Application for Material Science**

PROTEIN CRYSTALLOGRAPHY - PX

PROTEIN CRYSTALLOGRAPHY - PX

Technical Specification:

- Source is bending magnet
- Energy range 4 – 14 keV
- Energy resolution ΔE/E 1.0×10^{-3}
- Divergence (at sample) < 0.3 mrad
- Beam size (at sample) $100 \times 100\ \mu m^2$
- Beam intensity (at sample): > 10^{10} ph/s into the 10^{-3} band pass at 1 Å

✓ Study of Structural Molecular Biology
✓ Understanding proteins at the atomic level
✓ PX provides guidelines for developing new drugs

STRATEGY FOR PX

- Mohammad Yousef mentor for the PX
- Spend summer(s) on SESAME site
- PX Beamline Scientist (hired soon) will work closely with him
- PX Groups: Egypt, Israel, Jordan, Pakistan, Turkey
- Plan to setup a dedicated laboratory on SESAME site

✓ Using components from Daresbury beamlines 14.1 & 14.2

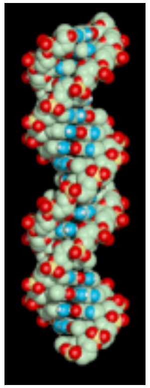
✓ Use bending magnet as the source

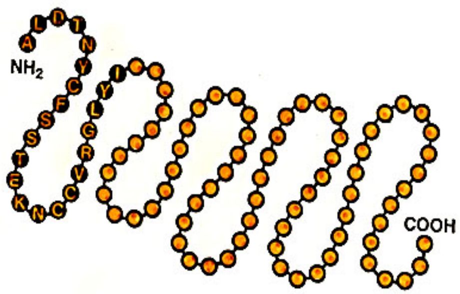
✓ For future PX upgrade donation of in-vacuum undulator from NSLS1 or may be a complete beamline

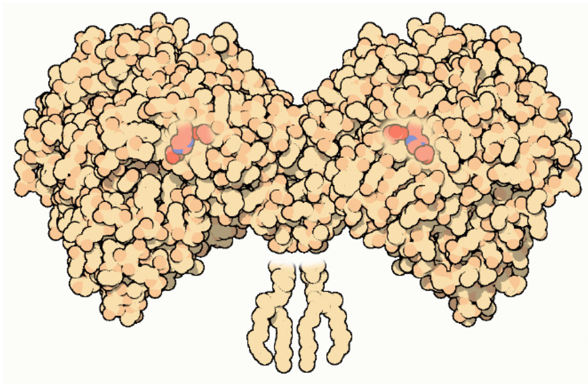
New drug discovery

- Time from conception to approval of a new drug is typically 10-15 years
- The vast majority of molecules fail along the way
- Cost to bring to market a successful drug ~ $800 million!!
- Anything to speed this up & reduce cost - most welcome

Proteins Fold in Defined 3D Structures → Function







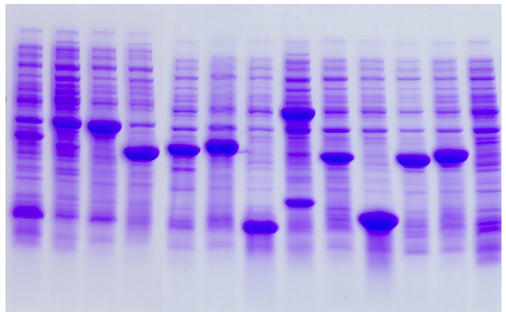
DNA

Chain of Amino Acids

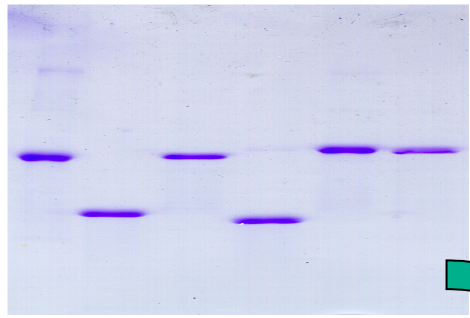
Protein 3D Structure

Function

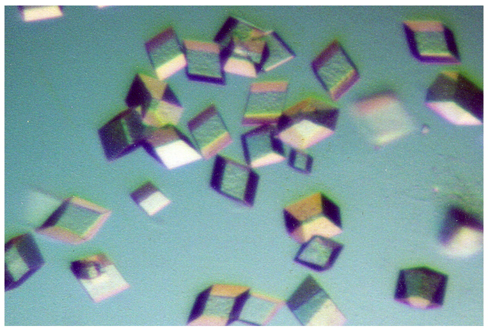
Determining 3D Structure: a Very Complex Task



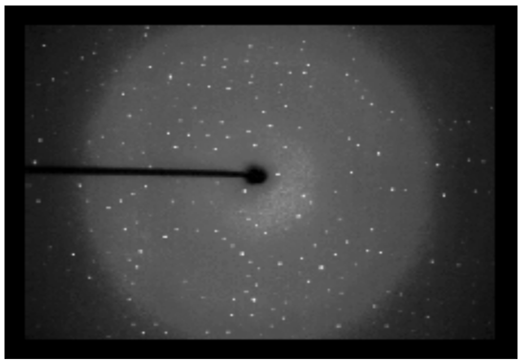
Produce the Proteins



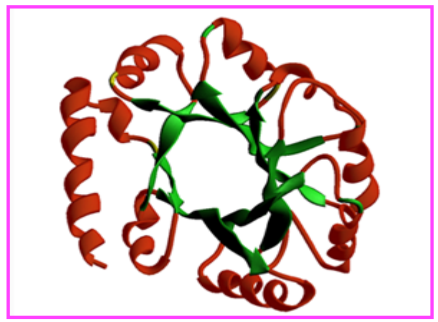
Purify the Proteins



Crystallize

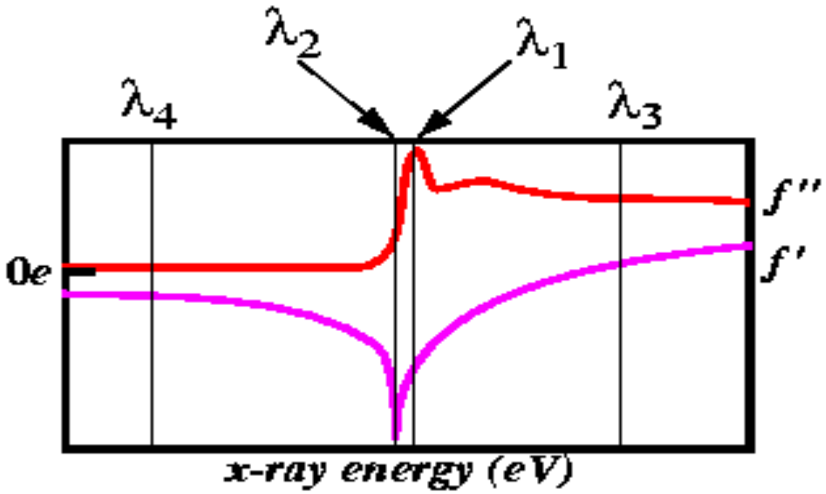


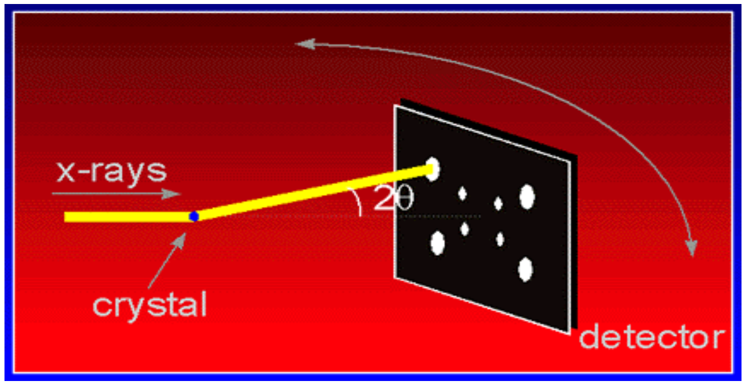
X-ray Data



Determine/analyze structure

Solving Proteins using MAD





- MAD (Multi-wavelength Anomalous Dispersion
- Requires:
  - **Synchrotron beam lines**
  - protein with multiple scattering centres
- Allows rapid phasing
- **Proteins can now be "solved" in just 1-2 days**

X-RAY ABSORPTION FINE STRUCTURE AND FLUORESCENCE BEAMLINE – XAFS/ XRF

X-Ray Absorption Fine Structure & Fluorescence

Technical Specifications:

- **Fixed exit monochromatic beam**
- **The energy range is 4 - 30 keV**
- **Energy Resolution $\Delta E/E \approx 1 \times 10^{-4}$**
- **Focused beam (KB): 8x10 μm^2 for ~ $5x10^9$ ph/S at 8 keV**
- **Flux on a sample $2x10^{12}$ ph/s at 8 keV (non focused beam)**

Techniques

✓ **XAS, XRF, XRD combine with other techniques such as RAMAN, XES**

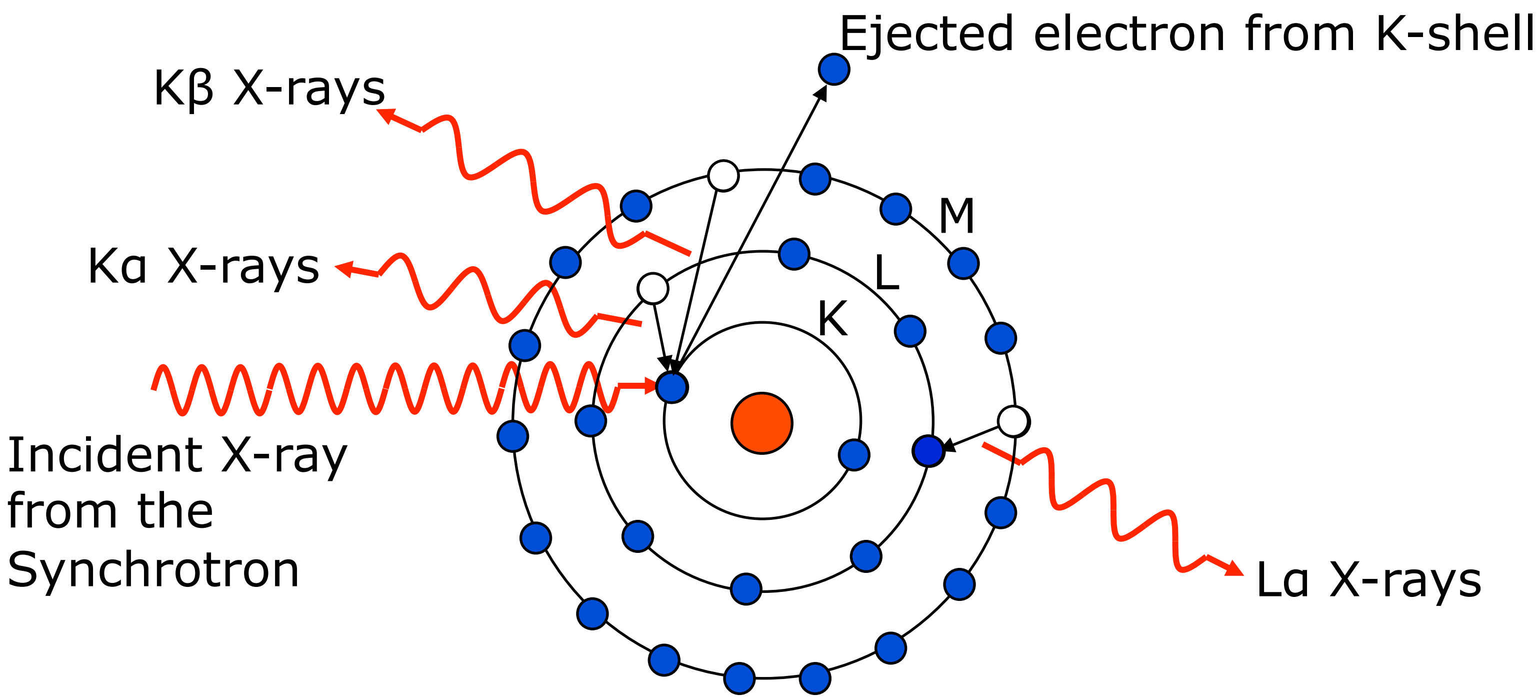
✓ **Redox imaging for small beam size**

STRATEGY FOR XRF/XAFS

Messaoud Harfouche is the beamline scientist

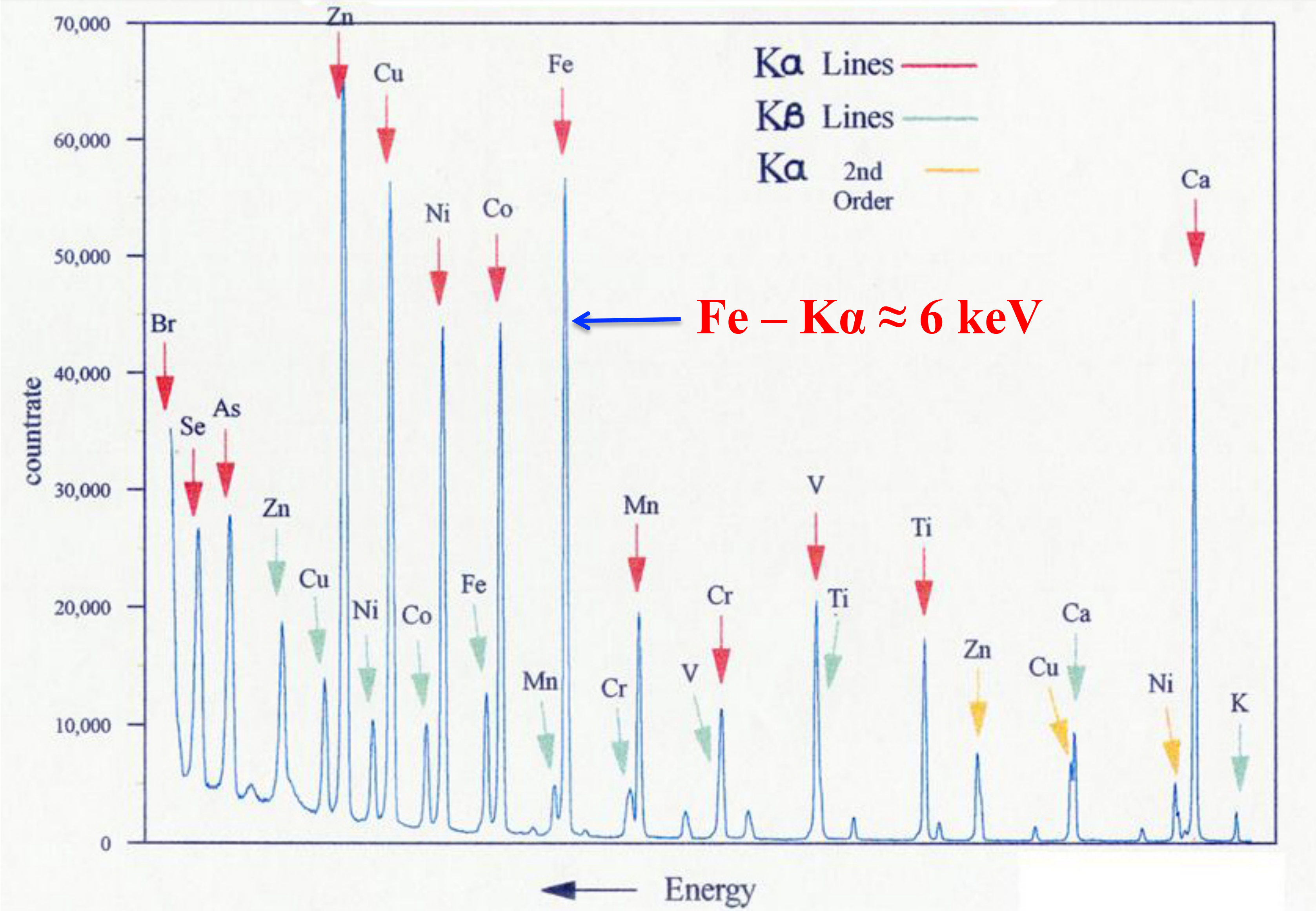
- **XRF/XAFS beamline of SESAME is a donation from FZD – Germany**
- **Known as ROBL beamline was operated by FZD at ERSF**
- ROBL was dismantled last year.
- SESAME BL scientist was involved – July 2011
- ROBL beamline arrived at SESAME in April 2012
- BL boxes were open in last three months
- To discuss various aspects of the BL, expert from ESRF A. Siminovici visited SESAME in October.

Principle of X-Ray Fluorescence

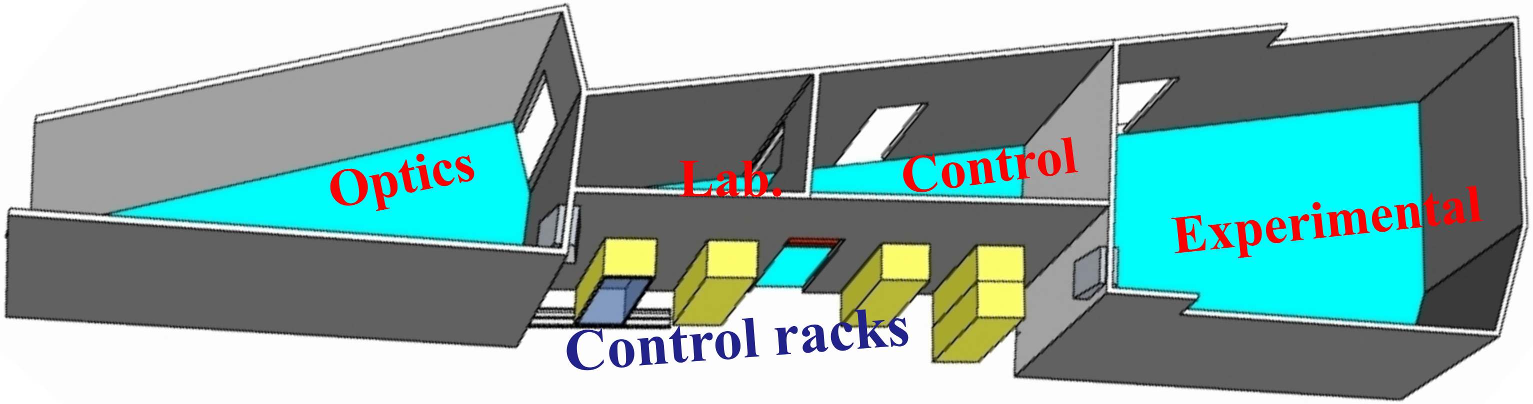


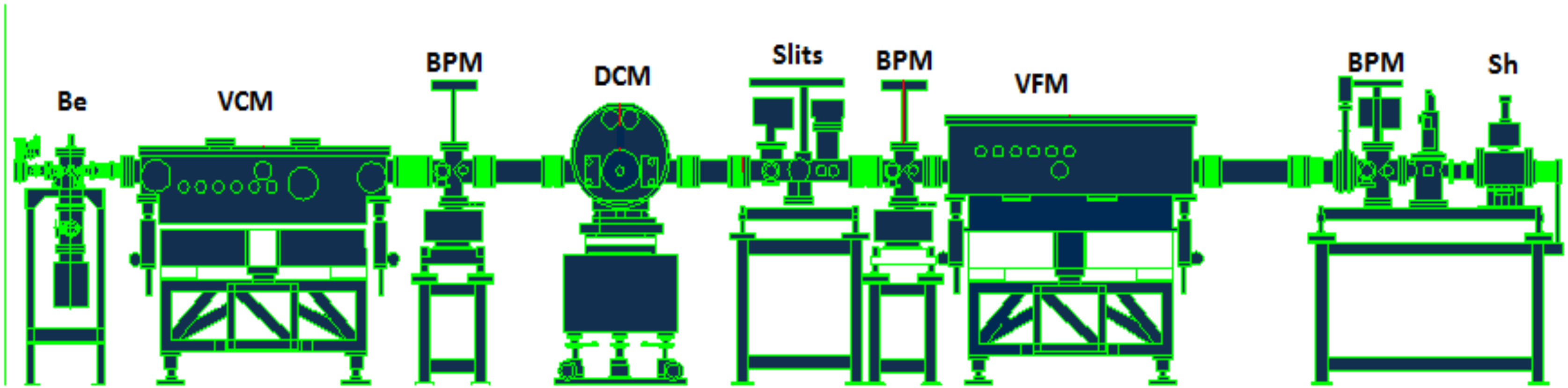
Atom in the sample material

Example of X-Ray Fluorescence



Status of BASEMA






OXFORD
OXFORD
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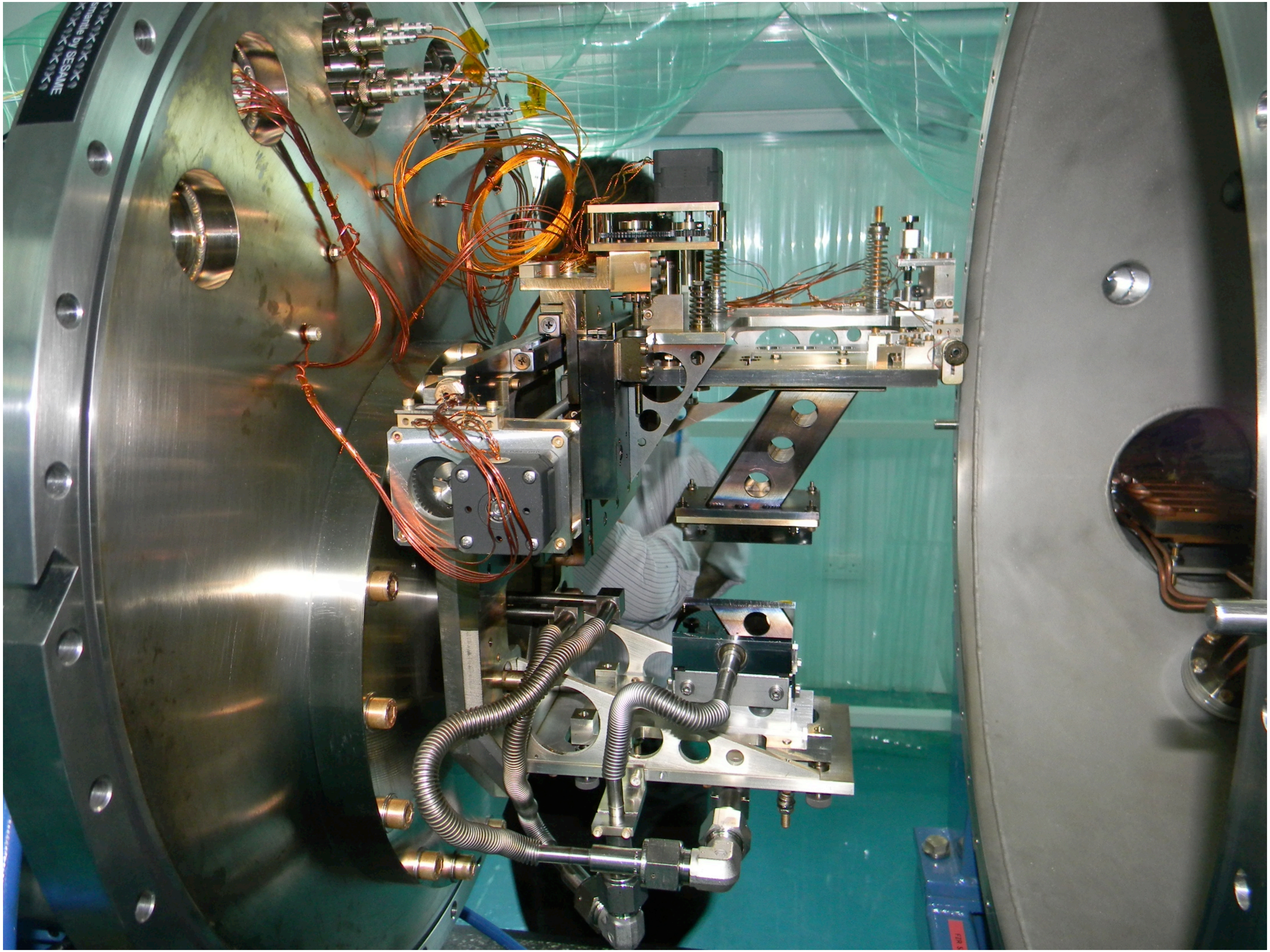
OXFORD



INFRARED BEAMLINE - IR

Infrared Spectro-Microscopy

Infrared beamlines around the world are built using two types of emission:

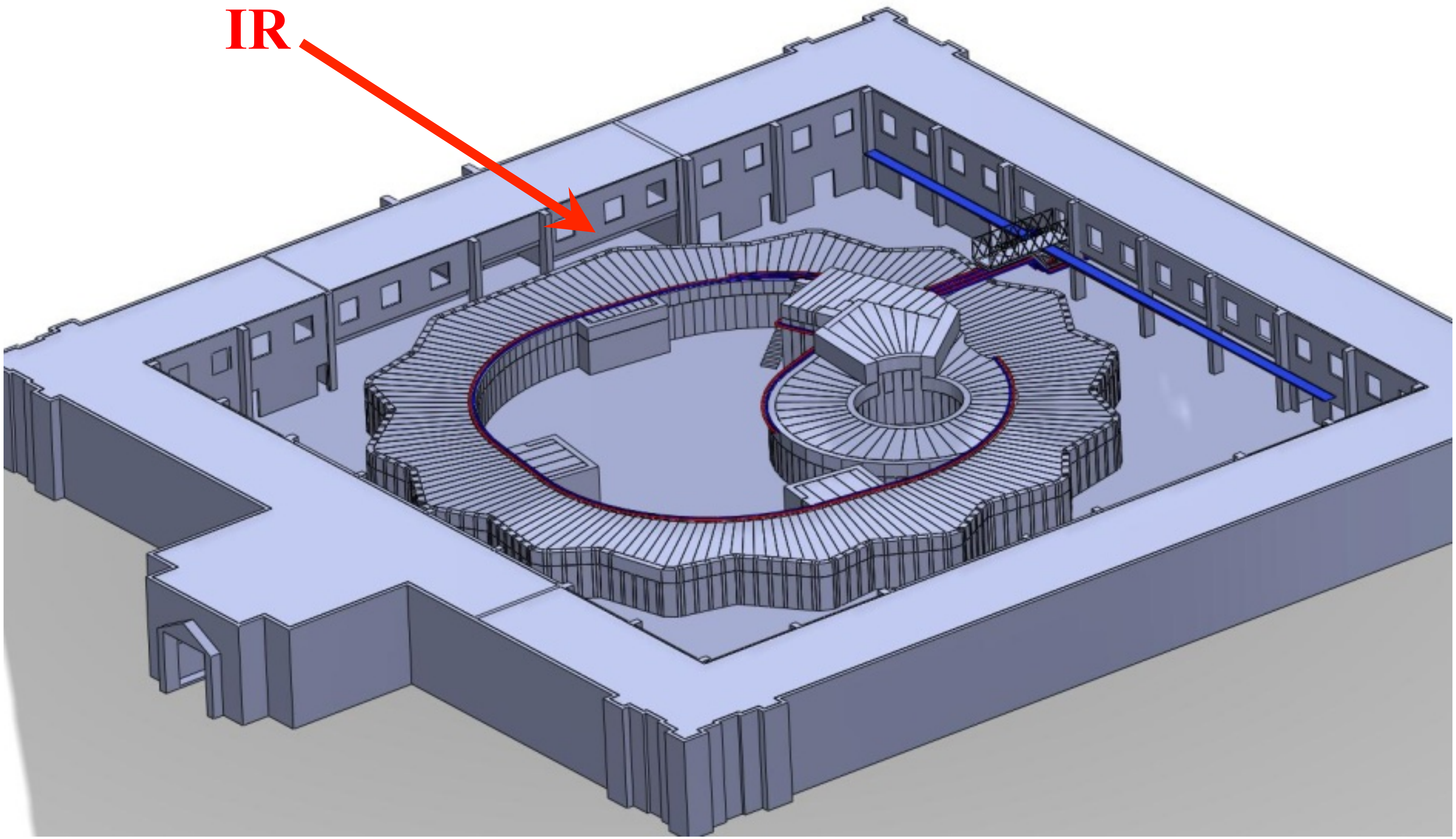
- **Bending magnet (constant field) emission** : Most of IR beamlines in the world uses this type of emission

- **Edge radiation** : more recently exploited, and few beamlines uses this type of emission.

- **At SESAME:** IR radiation (BM + ER) will be collected at the end of 4.4 m long straight section
- With 15 mrad Vertcial and 39 mrad Horizontal opening

TECHNICAL SPECS IR BEAMLINE

SOURCE	BM + ER
OPENING ANGLES	39 X 15 $mrad^2$ (HXV)
NUMBER OF BRANCHES	1 (with possibility of 2)
OPTICS	Toroidal, plane, cylindrical metallic (Al) mirrors
MICROSCOPES + SPECTROMETER COUPLED WITH SYNCHROTRON	1
DETECTORS	Mid IR 675-4000 cm^{-1} (MCT broadband) Far IR 50-700 cm^{-1}
ACCESSORIES	32X,15X, ATR, Grazing Incidence objectives Si, KBr,, QUARTZ BEAMSPLITTERS SINGLE & DOUBLE APERTURING MODE


IR

STRATEGY FOR IR

Paul Dumas from SOLEIL is the mentor: **Ibraheem Yousef is the beamline scientist**

- **Start generating science from SESAME even before the storage ring is operational**
- **IR microscopy at SESAME:**
  - Globar source
  - FTIR Spectrometer
  - Microscope
- For SESAME IR beamline same equipment will be used – for the completion of beamline only needs to add the optics
- Using SESAME capital funding for purchasing IR microscope, 3 – 4 months needed for the delivery
- IR lab will be operational by March 2013.

IR Microscope & FTIR

POWDER DIFFRACTION BEAMLINE - PD

POWDER DIFFRACTION - PD

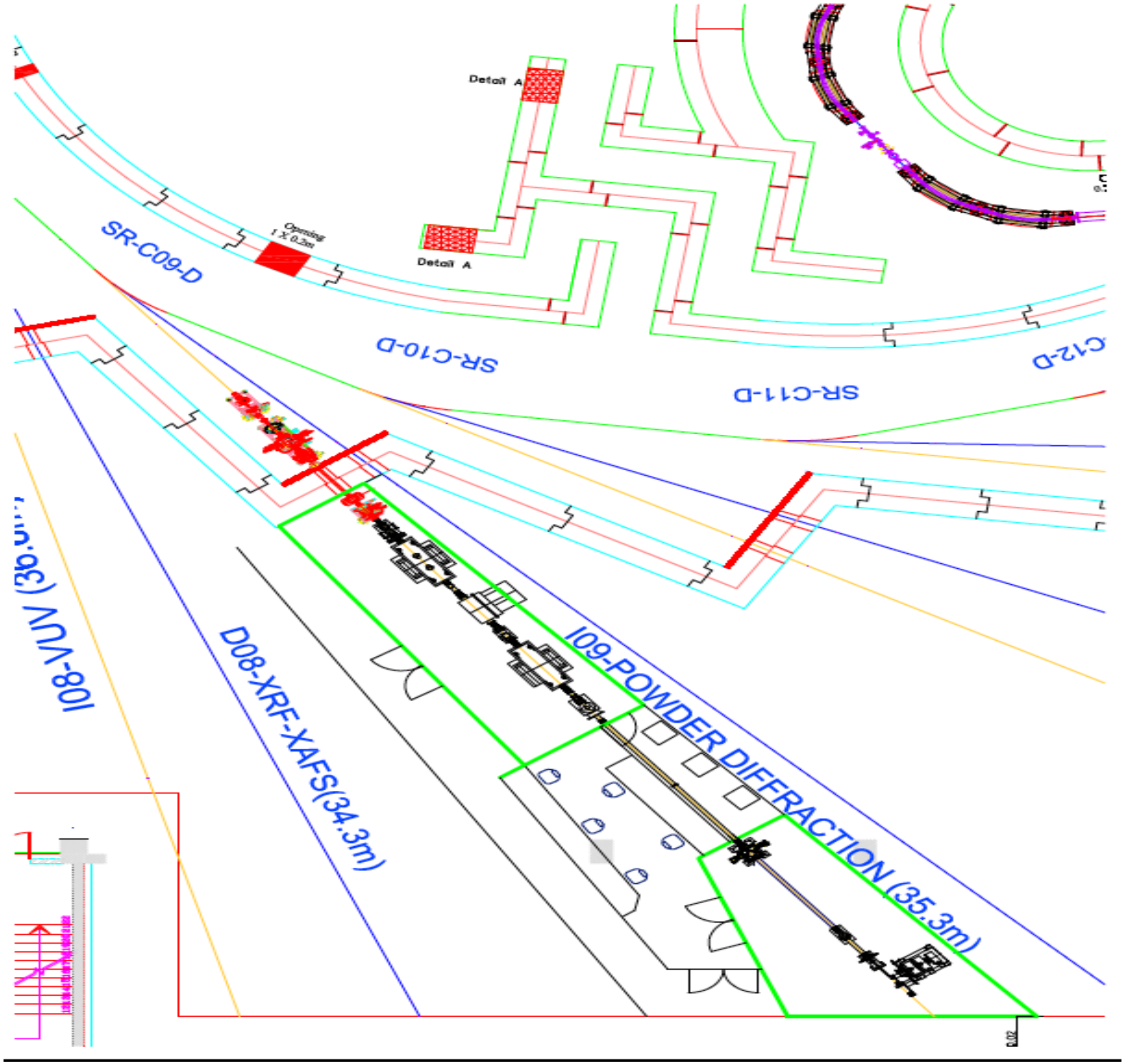
Technical Specifications:

- **Energy range** 3 - 25 keV
- **Flux (10 keV)** 1×10^{13} ph/s/0.1%BW/0.4 A
- **Focused spot size** 160 (v) µm x 450 (h) µm
- **Energy resolution $\Delta E/E$** 0.0139% (Si(111))
- **Accepted divergence** 0.23 (v) x 2.5 (h) $mrad^2$

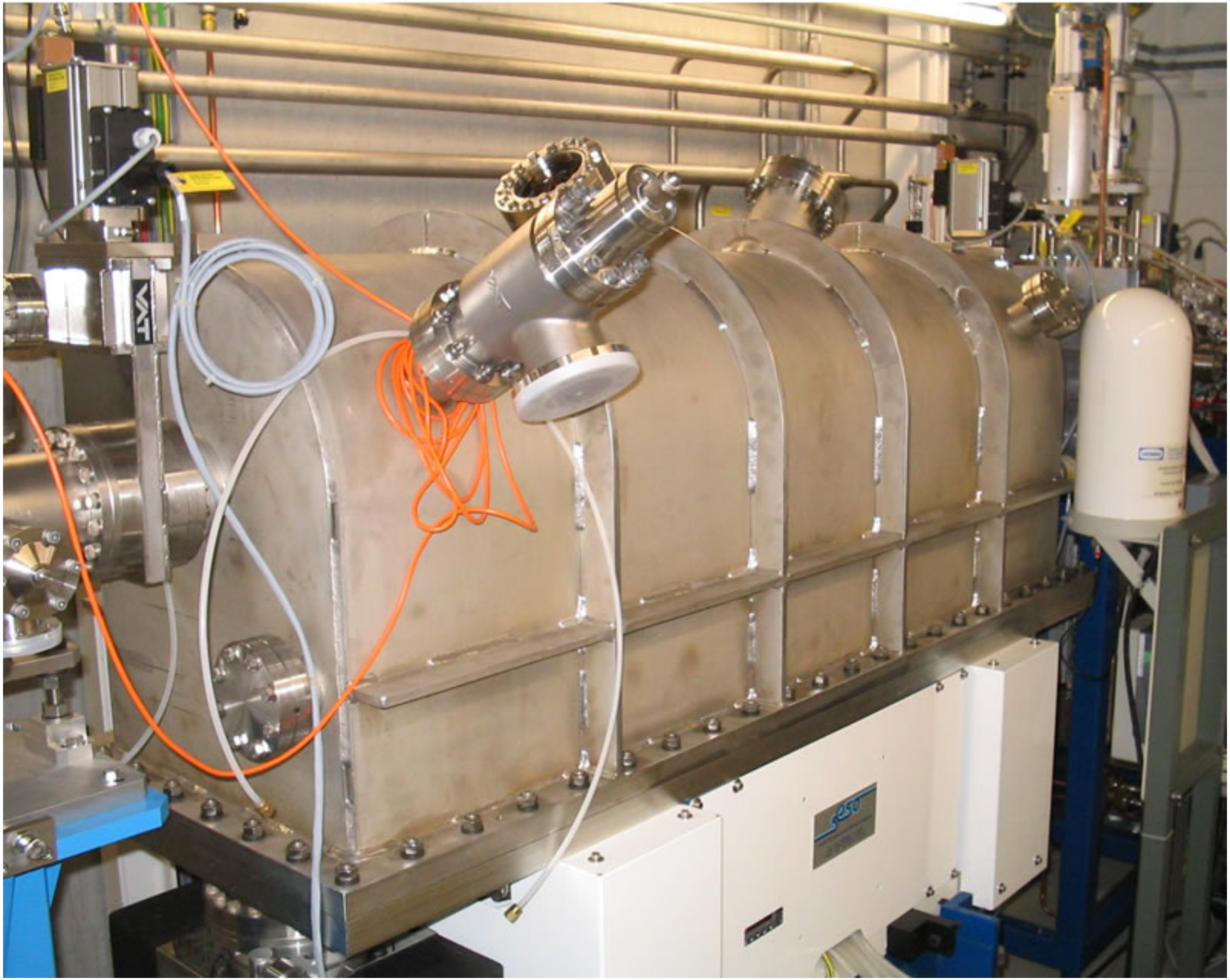
✓ **Use X04SA beamline donated by the Swiss Light Source (SLS)**

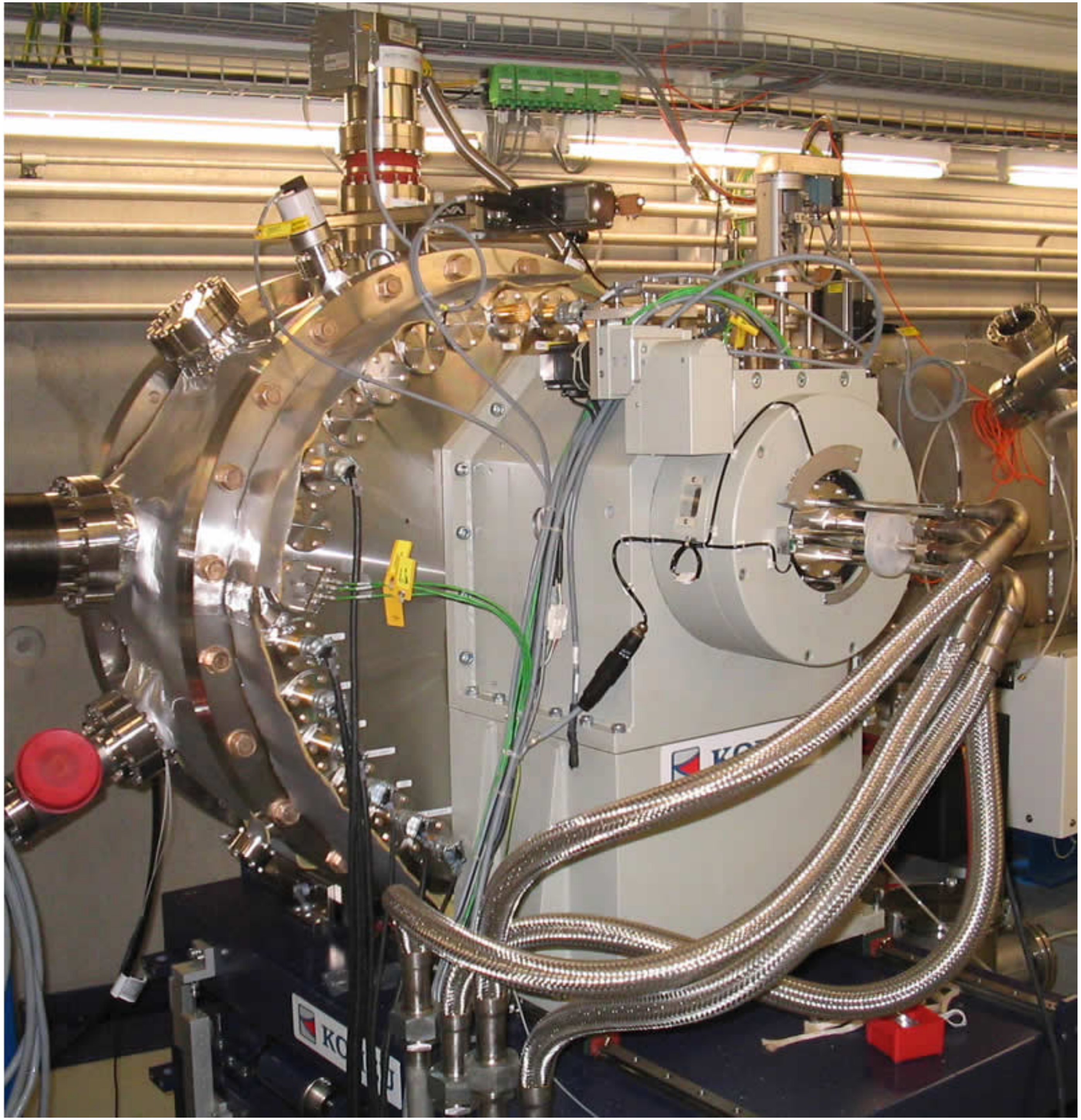
✓ **Adaptation for SESAME is needed**

✓ **Use of mini-gap wiggler W61 with 11 mm magnetic gap**

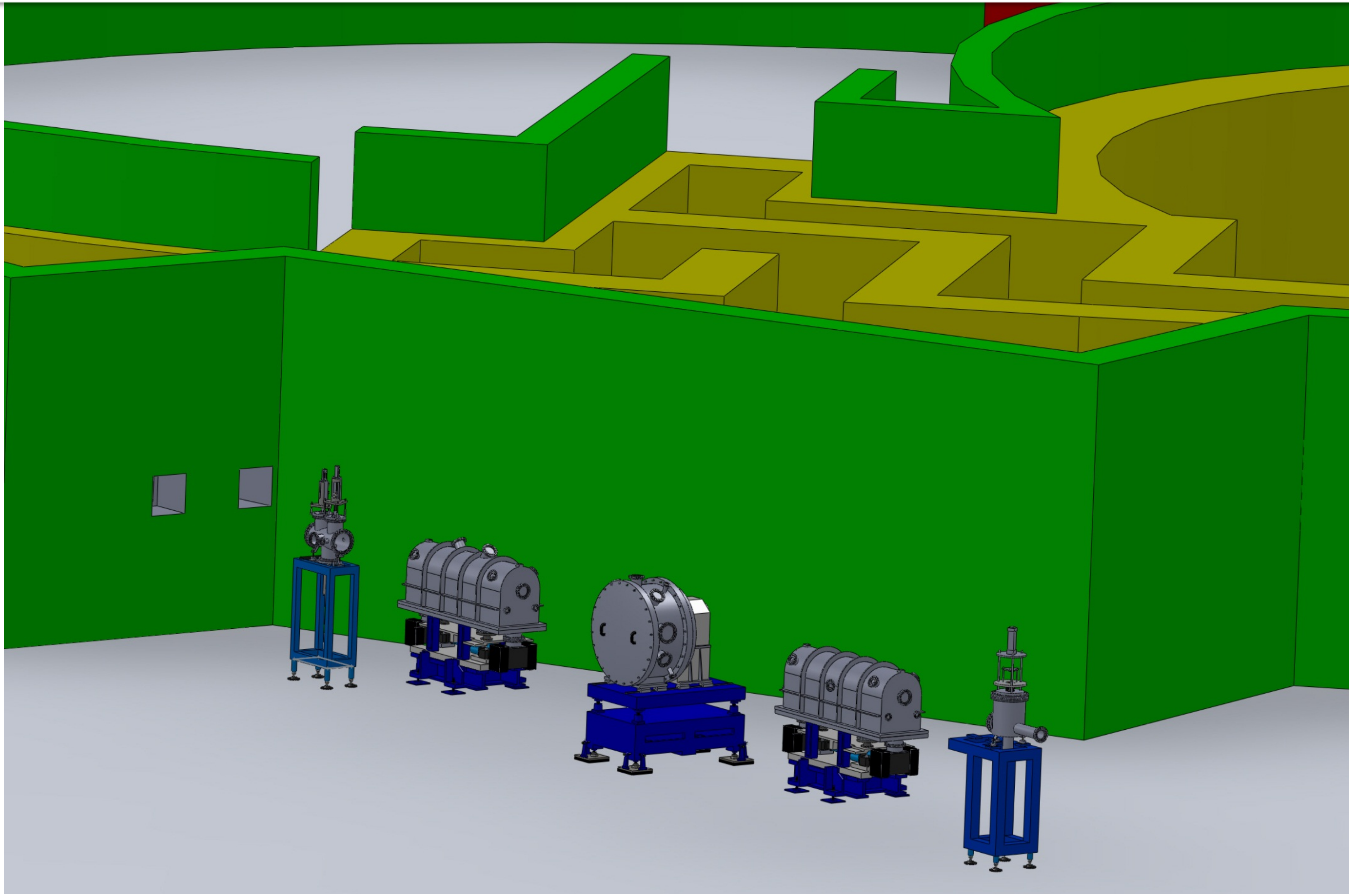


Detail A
Detail A
Opening 1 X 0.2m
SR-C09-D
SR-C10-D
SR-C11-D
C12-D
I08-VUV (36.0
D08-XRF-XAFS(34.3m)
I09-POWDER DIFFRACTION (35.3m)


VAT



Layout for Powder Diffraction Beamline



STRATEGY FOR PD

- Ideas are discussed such as the concept of BL manager (not necessarily SESAME staff rather a senior person from an institute)
- **BL Manager:**
  - Expertise, Resources (manpower and financial)
  - Act like a spoke-person for a given beamline
- **SESAME provides:**
  - Limited budget for travel (USD 5 – 10k per year)
  - Technical support in the form of staff
- MoU needs to be signed at the institutional level for each such case
- **SESAME will hire a dedicated BL scientist**

COLLABORATION & TRAINING

COLLABORATION & TRAINING

1. **SOLEIL:**
   - **IR beamline – Lot of work and efforts by Paul Dumas**
   - **RF & Alignment**
2. **Canadian Light Source:**
   - **Control Software and Hardware, Beamline Instrumentation**
   - **Using beamlines for various applications**
   - **MoU already signed between CLS and SESAME**
3. **ALBA – Spanish Light Source**
   - **Beamline Construction and Commissioning**
   - **Design of Storage Ring components**
   - **Radiation Protection**
   - **Fellowships are offered**
4. **Swiss Light Source**
   - **Frontends for BLs closely followed by Amor and Albin**
   - **Material Science BL as donation**

COLLABORATION & TRAINING

5. NSRRC – Taiwan Light Source
    - Electronics and Instrumentation
    - Beamline Science and Techniques
    - Fellowships are offered
6. Portugal - SESAME
    - Fellowship Program
    - Both PhD and Postdoc Level
7. LNLS - Brazilian Light Source
    - Beamline Construction and Commissioning
    - Beamline Optics and Control
    - Fellowships are offered
8. Elettra
    - RF Cavities
    - Support for Training

COLLABORATION & TRAINING

- **IAEA Support**
  - TC Project INT-1-055 ended in 2011
  - New TC Project INT-0086 covering period 2012 – 15
- **UNESCO Support**
  - SESAME Council Secretariat
  - Financial Assistance
- **CERN**
  - Procurement of magnets for the storage ring
  - Cost for magnets covered by EU (~ 5 M Euro)
- **JSPS**
  - Organization of SESAME – JSPS School for training
- **ICTP**
  - Training & Dissemination

COLLABORATION & TRAINING

- **Cyprus Institute**
  - **LinkSCEEM Project – Phase II on going**
  - **Focused on HPC and its applications**
- **APS/IoP/EPS/DPS/ACS/IUPAP**
  - **Various scientific societies contributing**
  - **Travel grants are given under the program**
- **Canon Foundation**
  - **Financial Assistance**
  - **In-kind contribution – in terms of manpower (Steve Jones)**
- **Lounsbery Foundation**
  - **Support for young scientists visiting EU and US SR Facilities**
  - **SESAME Technical Team is also supported**
  - **Two year, one time, fixed funding**

SESAME – ESRF

- MoU signed in May 2012 at CERN, Geneva
- Many activities already taking place:
  - Optics, Computing, Training, Outreach
  - Donation of Equipment
- Future Avenues:
  - SESAME staff visits
  - Expert Visits
  - SESAME Summer School
  - Beamline Optics
  - Computing
  - LinkSCEEM Project

Available Opportunities

http://www.sesame.org.jo/sesame/training-and-scholarships.html

- Lounsbery Foundation
  - One month fellowship for USA or Europe
- Portugal – SESAME Fellowships
  - PhD student – 3 years
  - Postdoc Fellowship – 1 year
- Postgraduate studies in UK
  - PhD students
- SESAME – SOLEIL Fellowships
  - PhD students to work at SOLEIL
  - September 2013
  - For PX & PDB beamlines