# The Scientific Program of SESAME

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**Scientific Director, SESAME**

# OVERVIEW

- **This talk gives:**
  - Introduction
  - Machine Status
  - Beamline Planning
  - Donation of Equipment
  - Summary

# Five Grand Challenges for Science

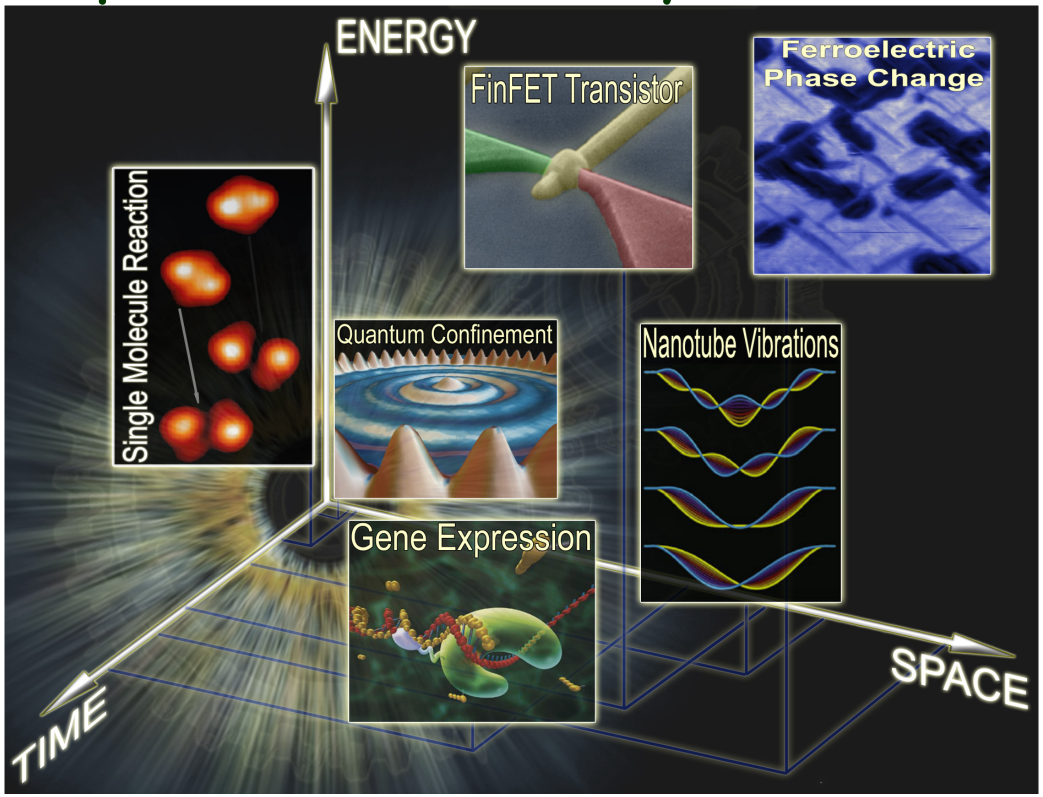

- *How do we control materials and processes at the level of electrons?*
- *How do we design and perfect atom-and energy-efficient synthesis of new forms of matter with tailored properties?*
- *How do remarkable properties of matter emerge from complex correlations of atomic and electronic constituents and how can we control these properties?*
- *Can we master energy and information on the nanoscale to create new technologies with capabilities rivaling those of living systems?*
- *How do we characterize and control matter away—especially very far away—from equilibrium?*

# Overall Challenge: *Making the Leap from Observation Science to Control Science*

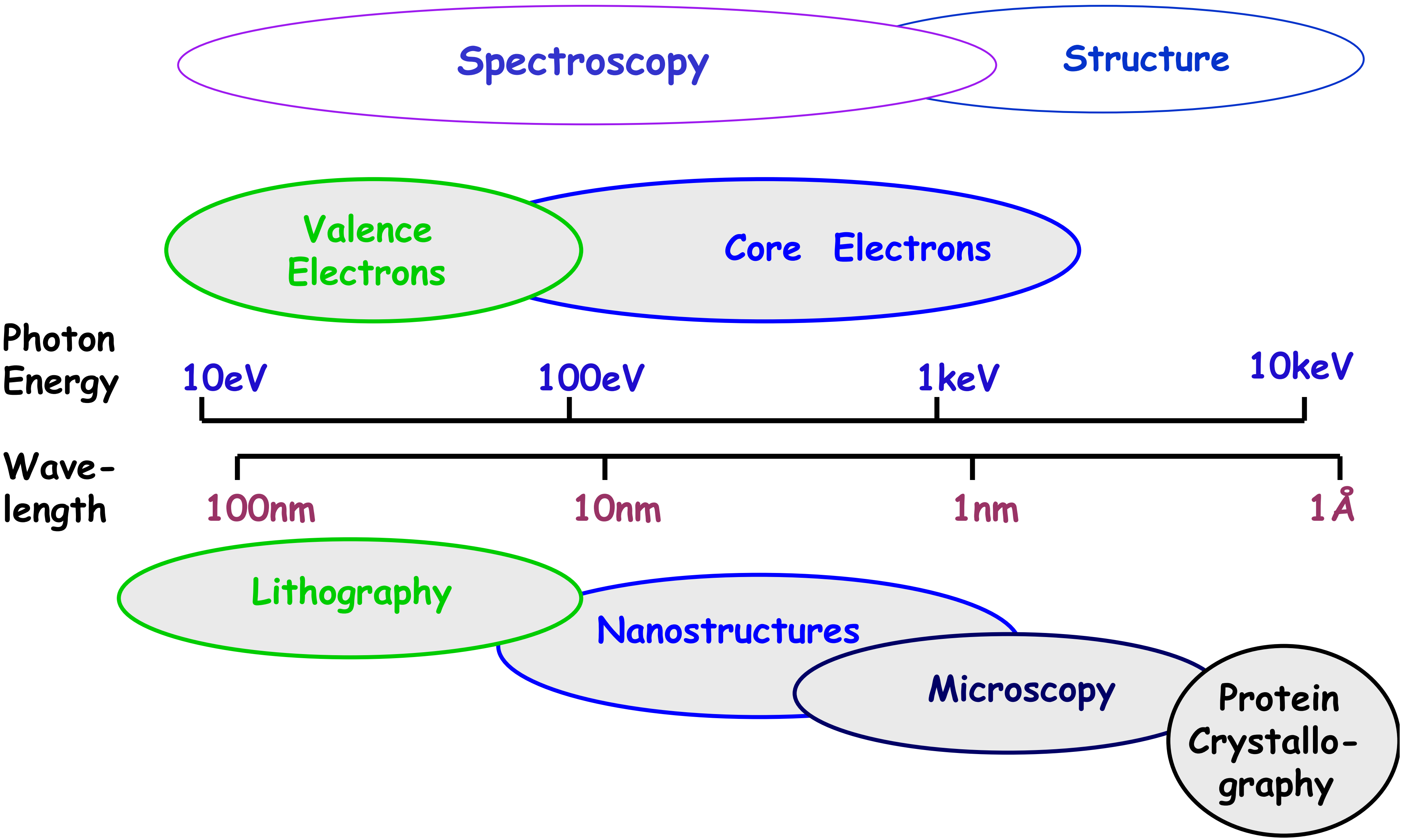
The things we want to do (i.e. designing materials to have the properties we want & directing synthesis to achieve them) require the ability to see functionality at the relevant *time, length & energy scales.*

We will need *to develop & disseminate new tools* capable of viewing the inner workings of matter—transport, fields, reactivity, excitations & motion

*This new generation of instruments will naturally lead to devices capable of directing matter at the level of electrons, atoms, or molecules.*



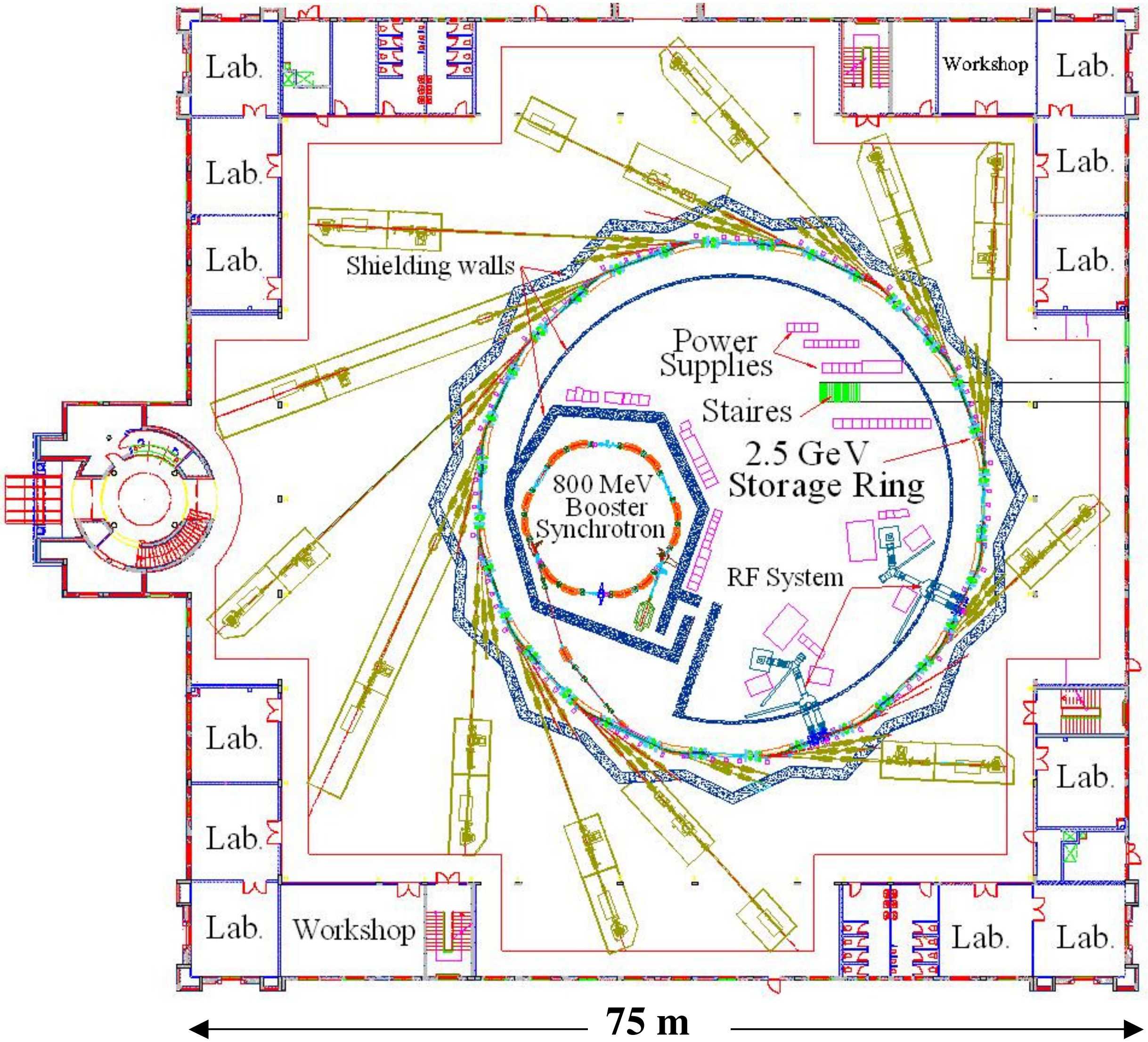
# Science with Light Sources



# Machine Status

# *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 |




| | |
|---|---|
| Energy | 2.5 GeV |
| Current | 400 mA |
| Circumference | 128.4m |
| Emittance (horiz) | 26.4 nm-rad |
| Possible IDs | 12 |
| ID Length | 2.75 m |

**$e^-$ Beam Size in Straight Sections**

| | |
|---|---|
| $\sigma_x/\sigma_y$ | 700μm/35μm |
| Critical Energy | 5.9 KeV |
| $e^-$ Energy Spread | 0.1% |
| Bending Mag. Field | 1.425 T |

# Outlay of SESAME

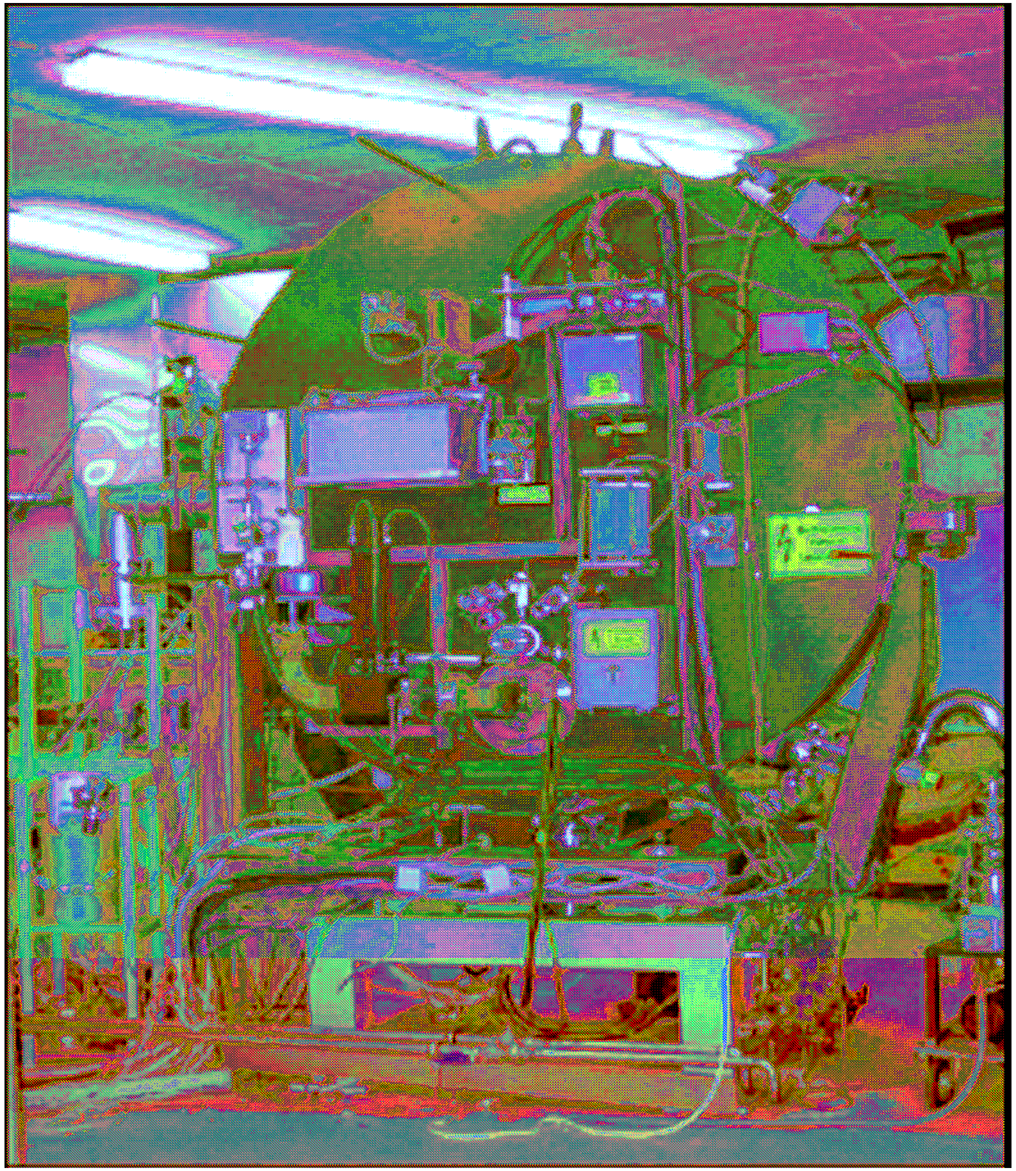
**Parameters: 2.5 GeV ring with 12 possible insertion device beam lines. Beam lines can also come from the 16 bend magnets.**

# MICROTRON Parameters

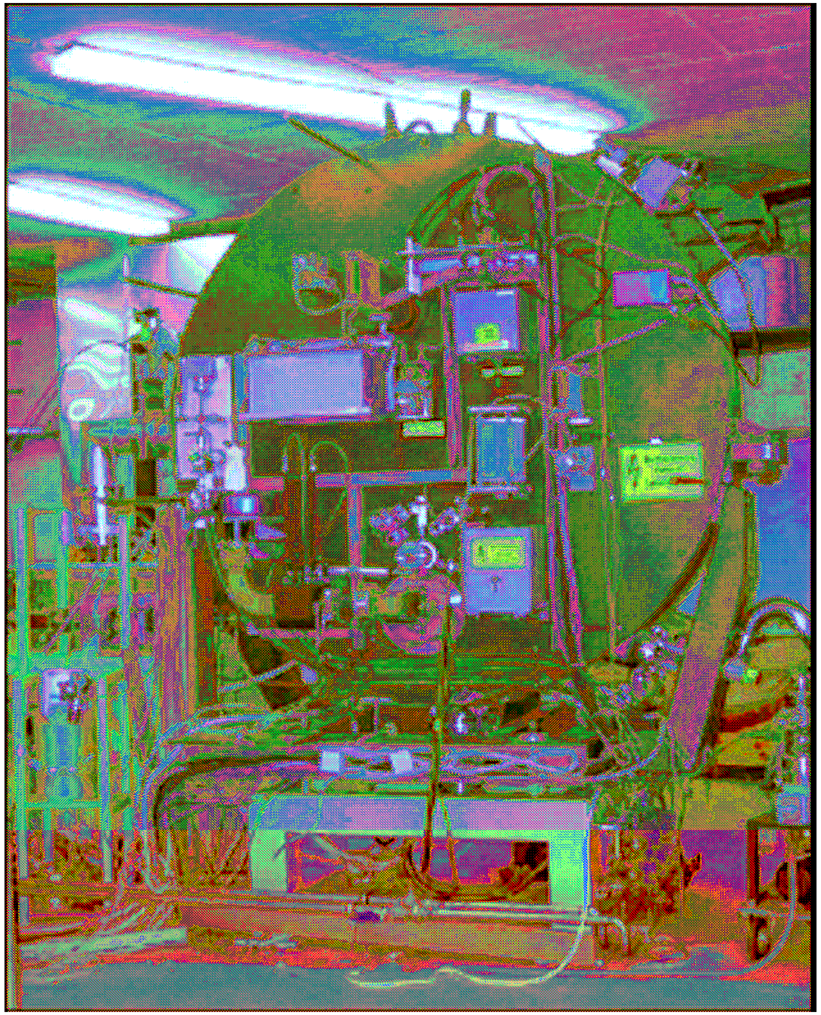
| | |
|---|---|
| Extractable energy | 5.3 - 22.5MeV |
| Magnetic field | 0.112T |
| Magnet diameter | 2.22m |
| Pole diameter | 1.8m |
| Gap | 0.11m |
| Magnet Weight | 11Tons |
| Microwave frequency | 3GHz |
| Microwave peak power | 2MW |
| Pulse duration | 2μs |

Emittance for 100% of the beam
At 21MeV:

| | |
|---|---|
| Horizontal | 3.8π mm.mrad |
| Vertical | 12.8π mm.mrad |



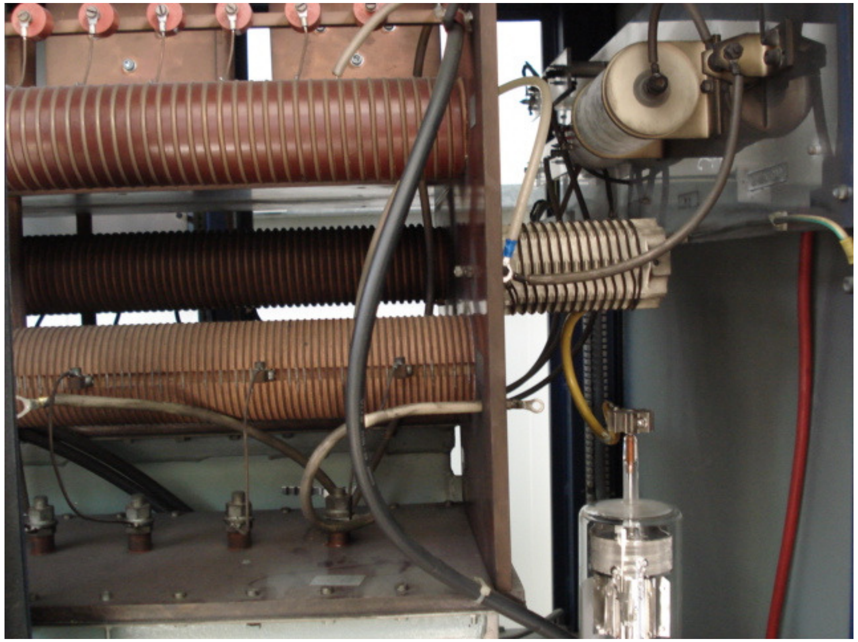
# The Installed MICROTRON System

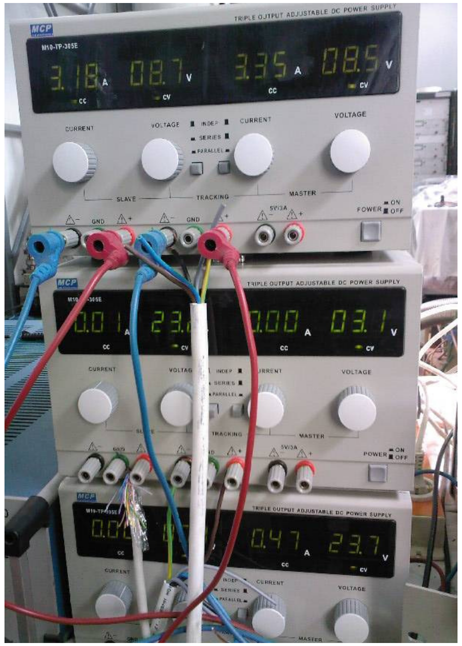


at BESSY (1998)


at SESAME (2008)

# Test of the Modulator

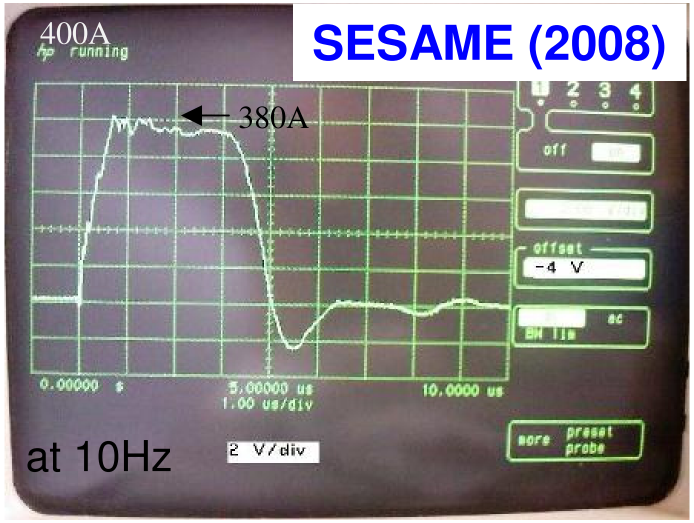


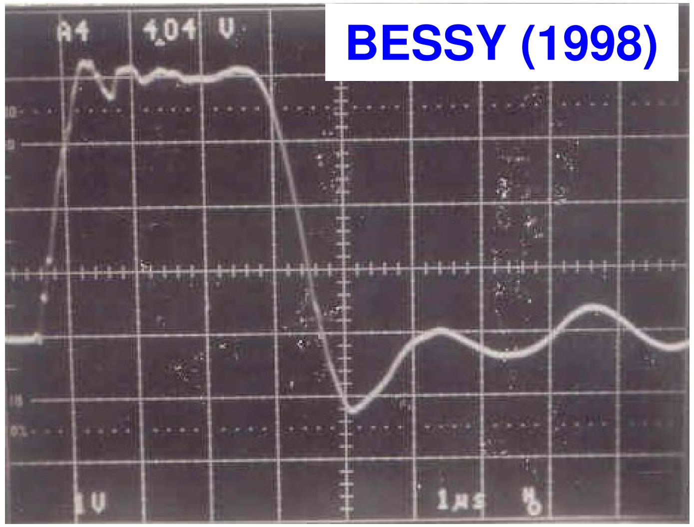



Magnetron filament (8.5 v, 6.53 A)

HVPS control voltage

Modulator control signals



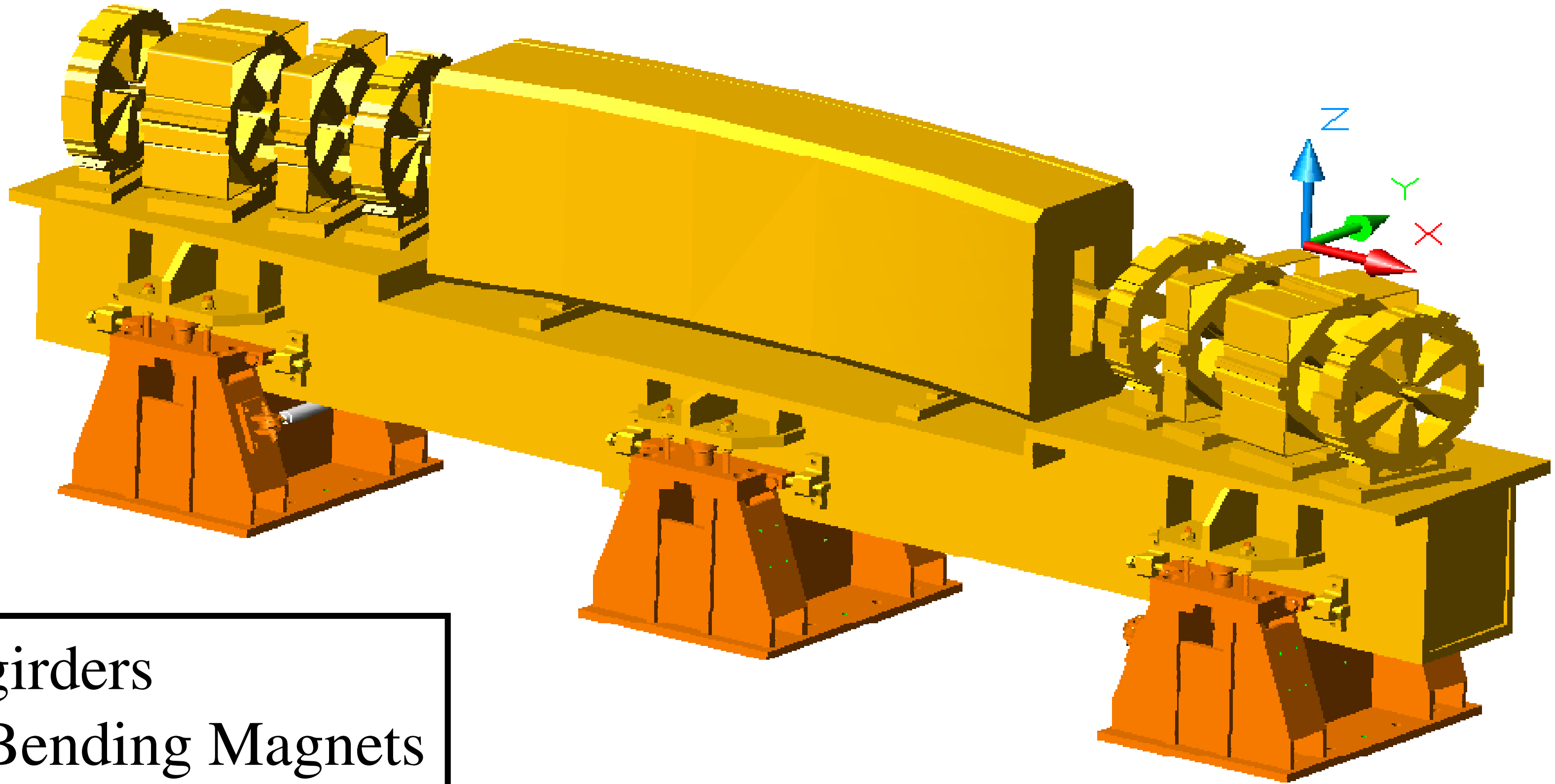
# Booster Parameters

| | |
|---|---|
| Maximum energy , *MeV* | 800 |
| Injection energy , *MeV* | 20 |
| Circumference , *m* | 38.4 |
| Super periodicity | 6 |
| Number of bending magnets | 12 |
| No. of focusing quadrupoles | 12 |
| No. of defocusing quadrupoles | 6 |
| Repetition rate , *Hz* | 1 |
| Horizontal tune , $Q_x$ | 2.22 |
| Vertical tune , $Q_y$ | 1.30 |
| Momentum compaction factor $\alpha$ | 0.18 |
| Harmonic number | 64 |
| RF-frequency , *MHz* | 500 |
| RF-output power , *kW* | 2 |
| Cavity shunt impedance , $M\Omega$ | 3 |
| Current @maximum energy , *mA* | 7 |
| Vertical emittance , mm-mrad | 0.016 |
| Horizontal emittance , mm-mrad | 0.155 |

# Booster Girders and Magnets Pre-assembly November - 2008

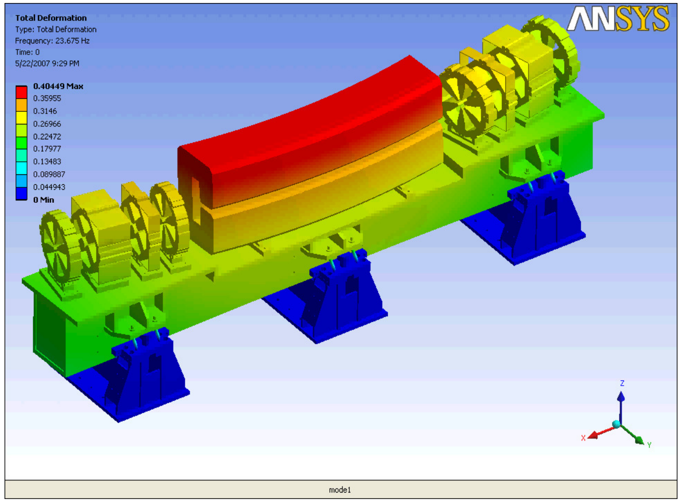
SESAME

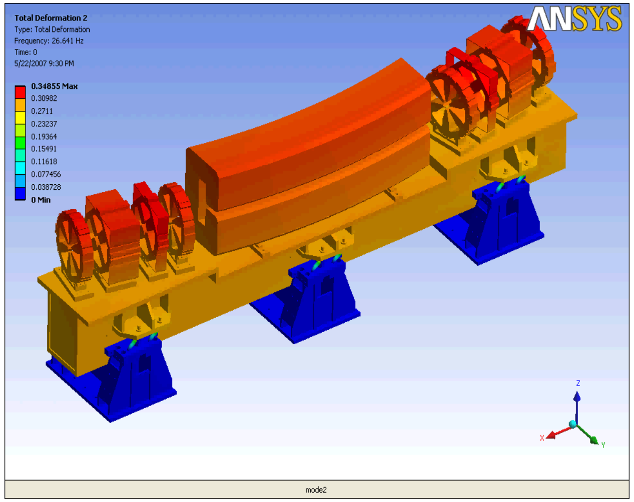
# Storage Ring Girder- Magnets Design

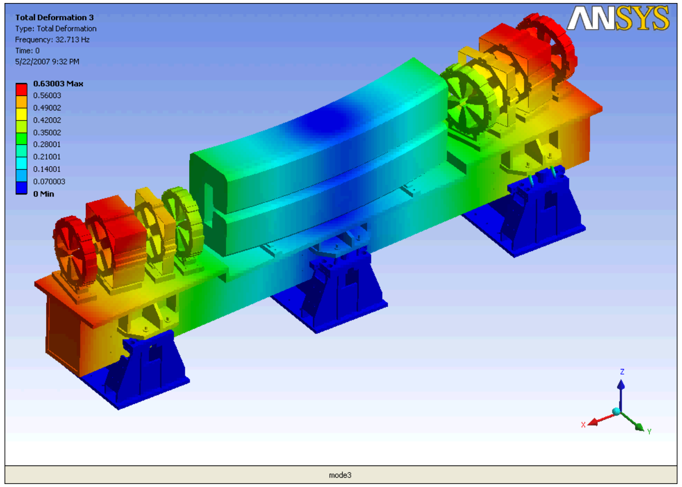


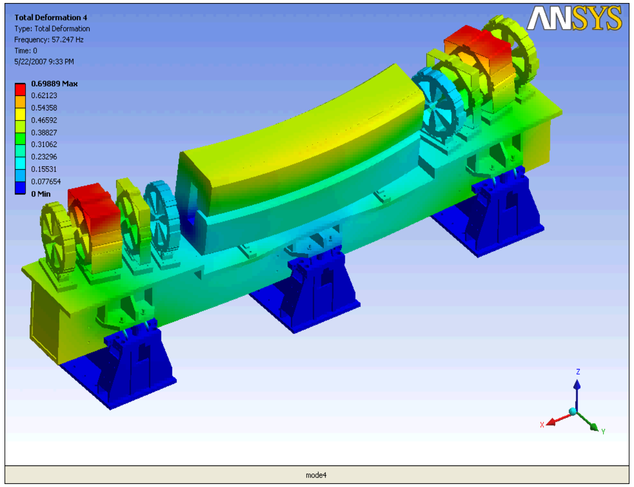

16 girders
16 Bending Magnets
64 Quadrupoles
64 Sextupoles

# Storage Ring Girder- Magnets Design:
## Modal Analysis




| Mode | 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| Frequency (Hz) | 23.7 | 26.6 | 32.7 | 57.3 |

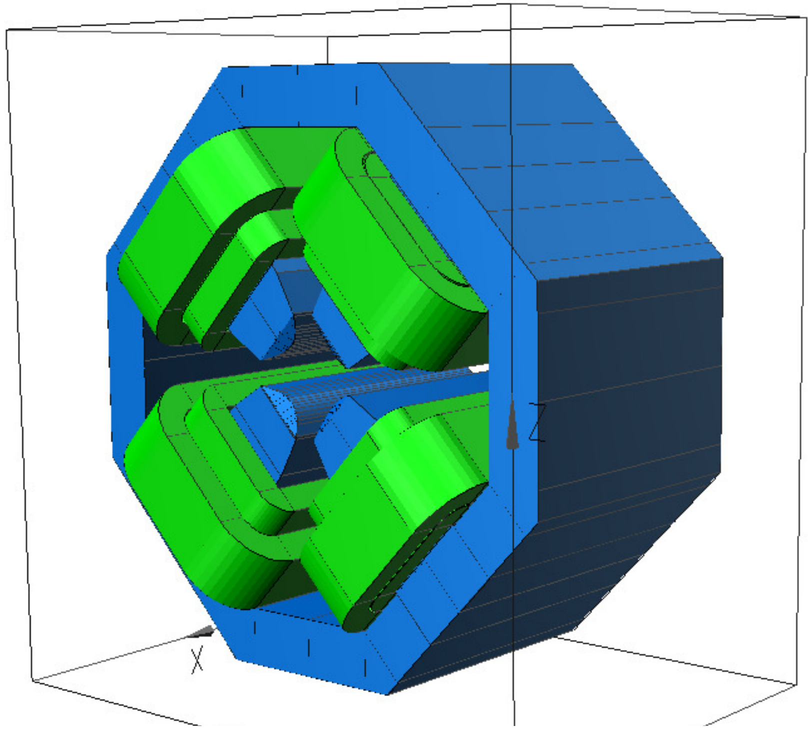
# Magnetic Design of the Quadrupole

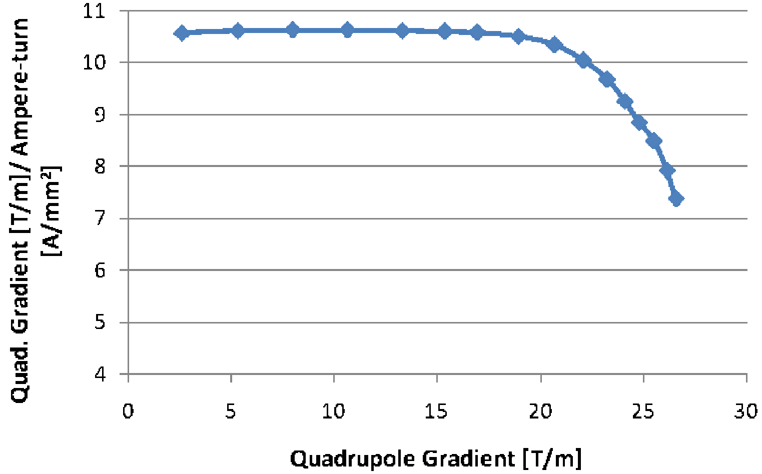
Two Quadruples families with the same pole profile

QF: Gradient =16.9 T/m
Iron Length = 280 mm
Magnetic length = 300mm
Bore diameter = 70 mm

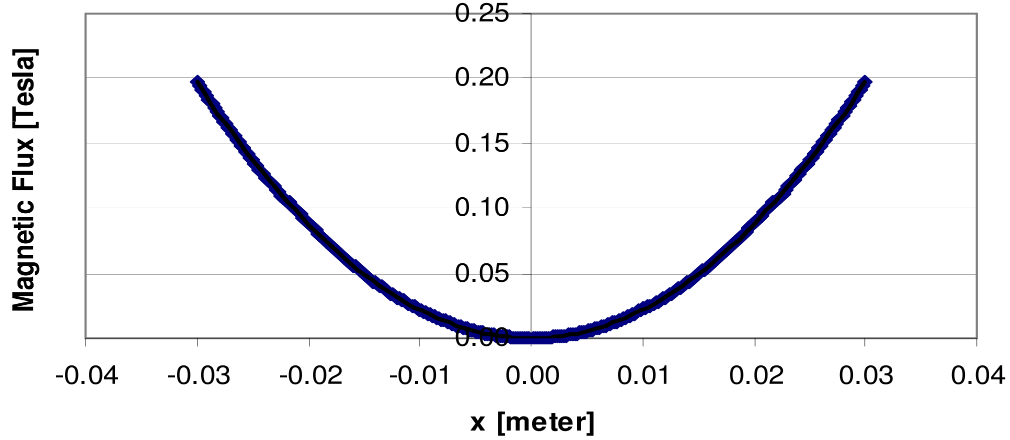
QD: Gradient = -10.2 T/m,
Iron Length = 100 mm
Bore diameter = 70 mm

LAYOUT: No cut in the yoke for the passage of beamlines.



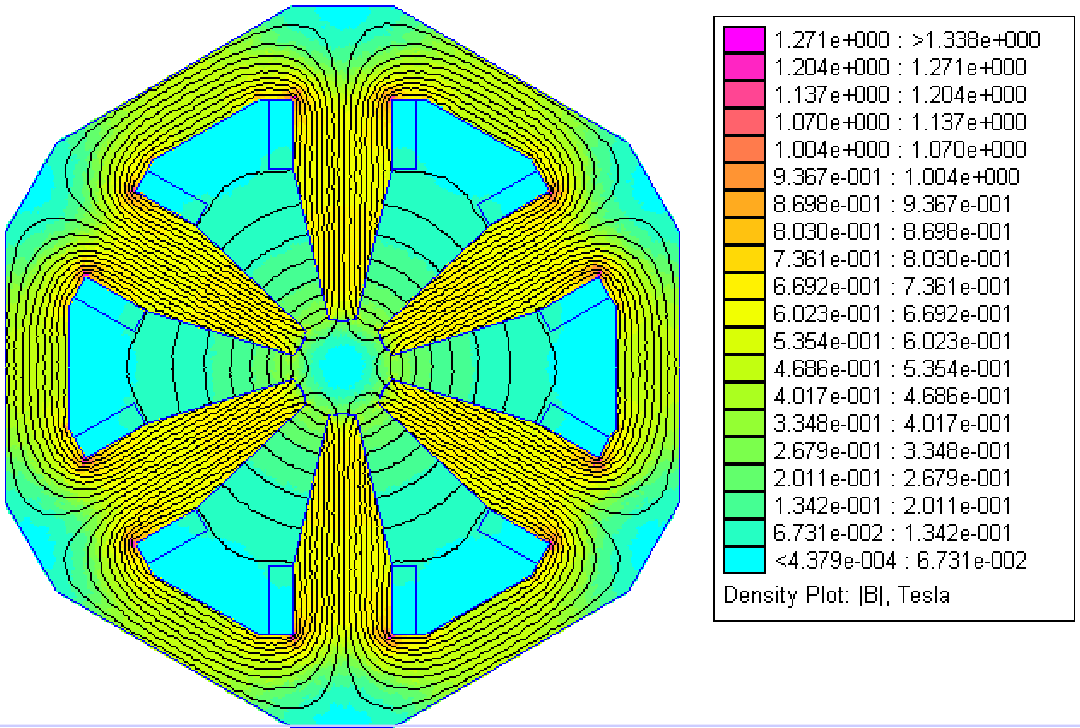



# Magnetic Design of the Sextupole




Two sextupole families

+1 chromaticity in both planes.

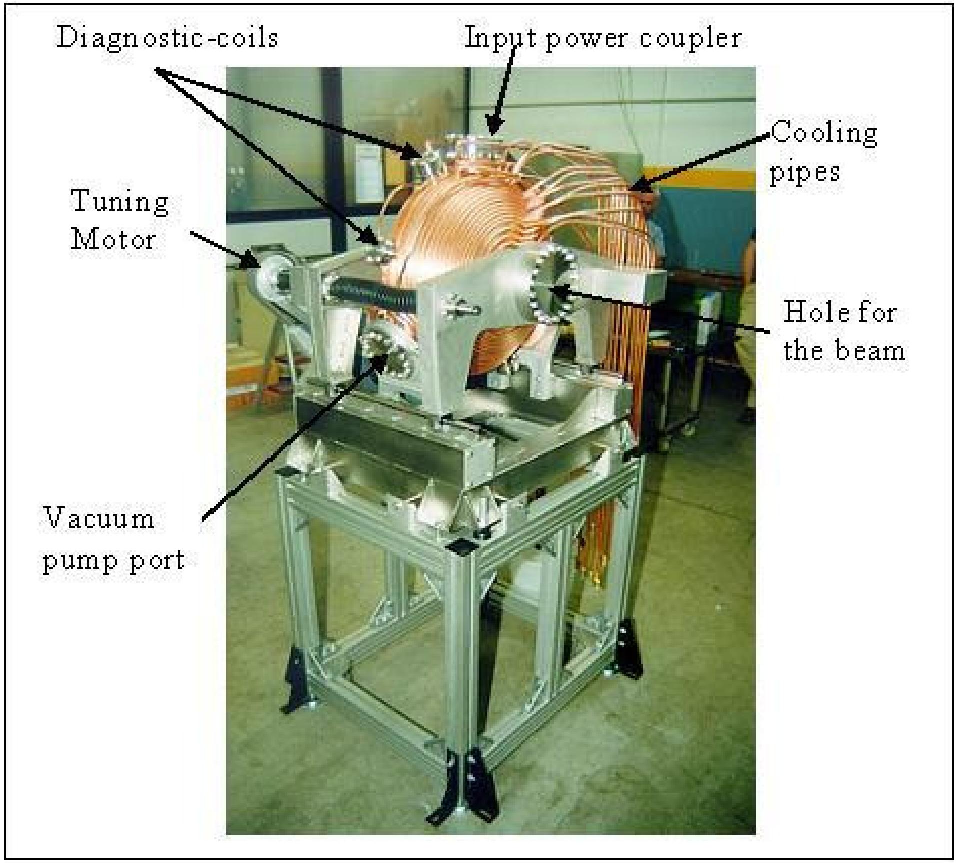



**SF: L=10cm, g=219.5 $T/m^2$, R=37.5mm**

**SD: L=10cm, g=141.7 $T/m^2$, R=37.5mm**

# STORAGE RING RF

- So far it is based on ELETTRA type cavity
- Donation of 2 RF cavities by ELETTRA (we need 4 for nominal performances)
- Getting rid of HOMs in this cavity is done by means of temperature control and plunger



# Scientific Programme

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

# Radiation Sources

## Bending magnets

- Radiation emitted tangentially to the orbit

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

- Dipole magnet is used as bend magnet

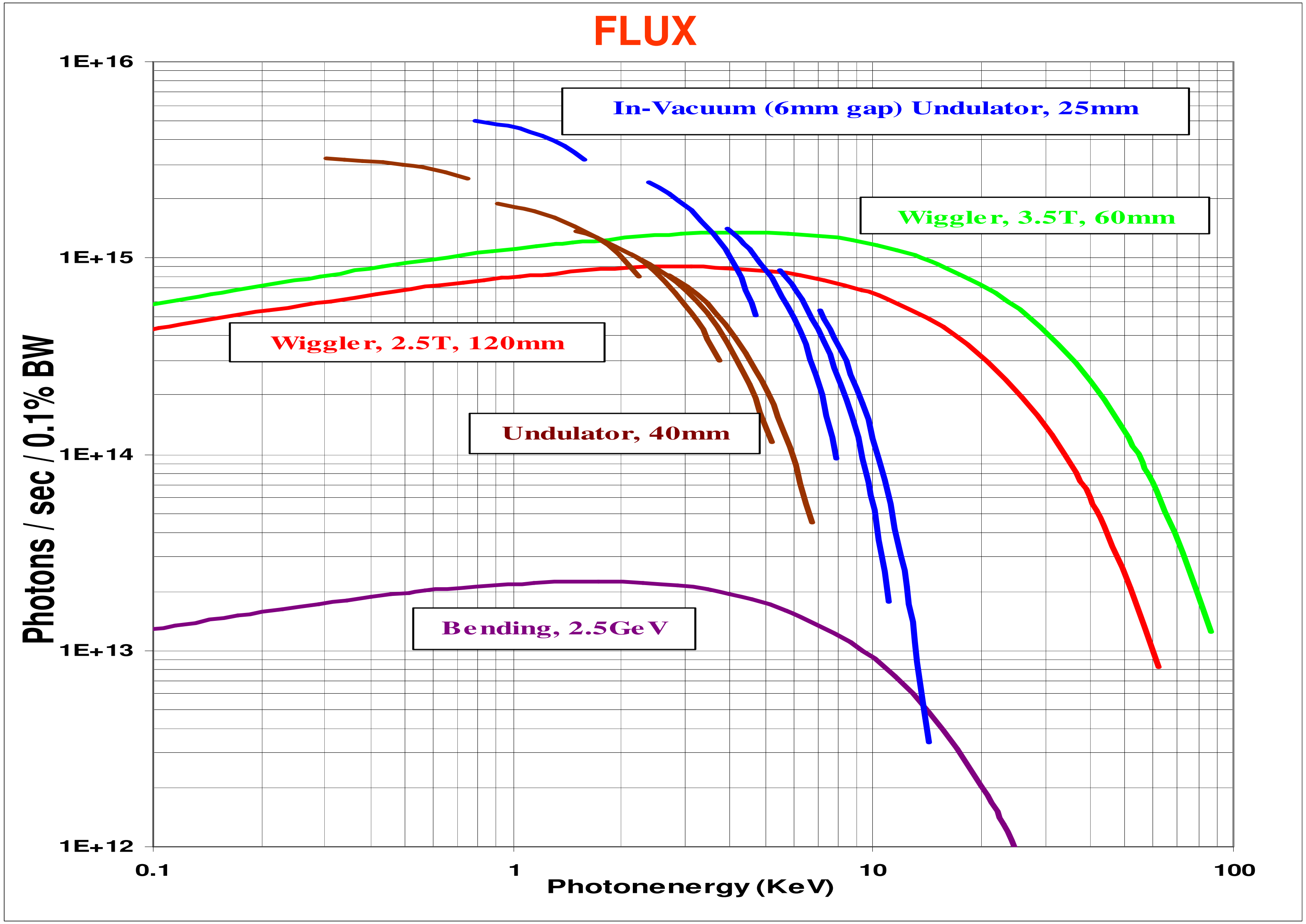
$$\varepsilon_c[\text{keV}] = 0.665 E^2[\text{GeV}^2] B[\text{T}]$$

- For SESAME **$\varepsilon_c$ = 5.73 keV**

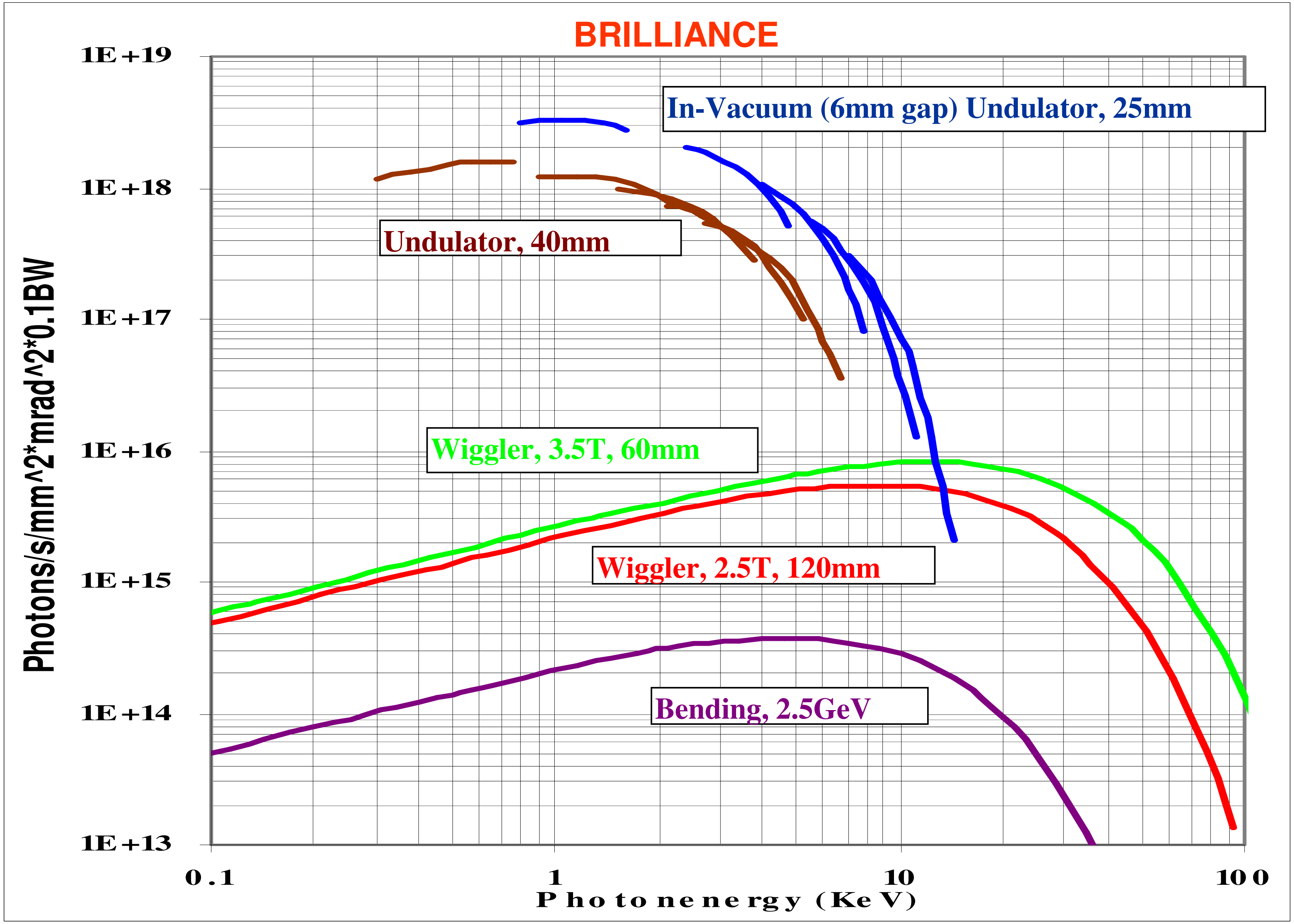
## Insertion devices

- Multipole Wigglers
- Undulators

# Radiation from BM & IDs



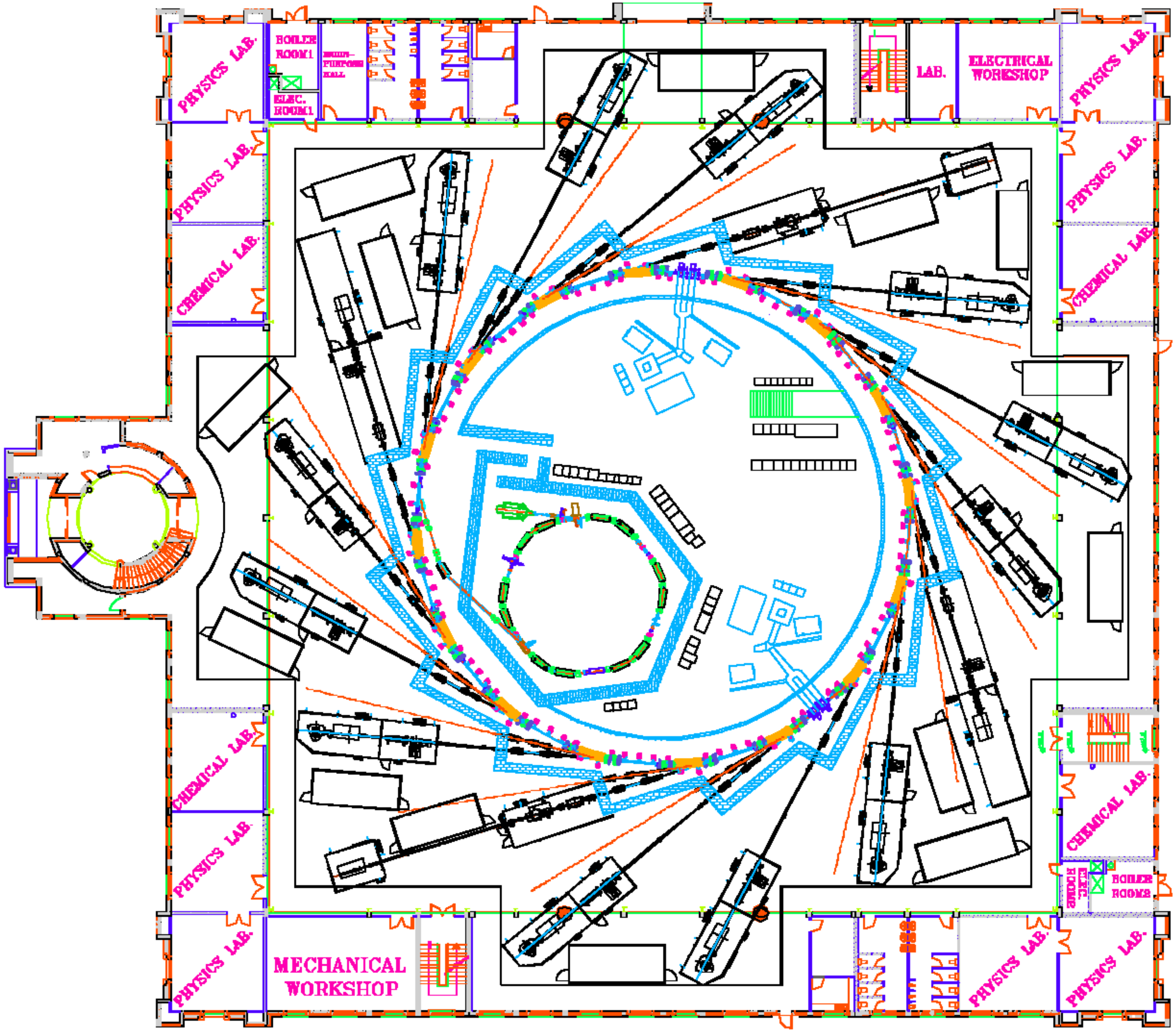
# Radiation from BM & IDs



# Scientific Programme

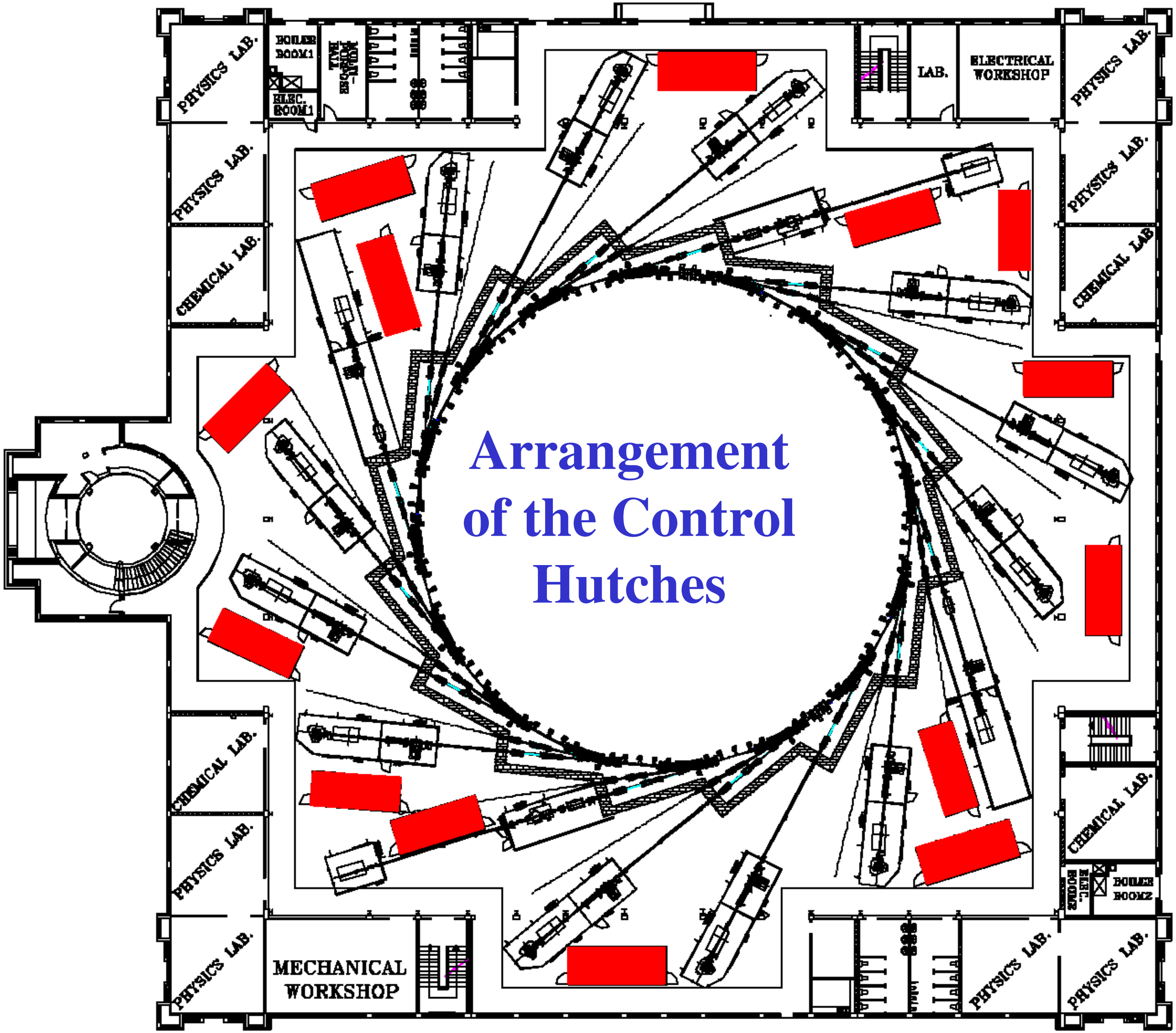
- SESAME has the capacity for ~ 28 beamlines
  - Straight Sections = 16 ( 8 long 4.44 m, 8 short 2.38 m): Beamline Length 21 - 36.7 m
- Storage ring energy = 2.5 GeV
  - Photon energies from IR to soft x-rays to hard x-rays
- Mission for beamline development is to ensure appropriate capabilities are 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

| Name | Max Length (m) | Name | Max Length (m) | Section Type |
|---|---|---|---|---|
| D1 - IR | … | NA | … | … |
| D2 - IR | … | NA | … | … |
| **D3 - DP** | **26.9** | NA | … | … |
| **D4 - DP** | **21.2** | **I4 - ID** | **23.6** | **SHORT** |
| **D5 - DP** | **24.7** | **I5 - ID** | **28.2** | **LONG** |
| **D6 - DP** | **28.0** | **I6 - ID** | **32.9** | **SHORT** |
| **D7 - DP** | **31.9** | **I7 - ID** | **36.5** | **LONG** |
| **D8 - DP** | **34.7** | **I8 - ID** | **36.6** | **SHORT** |
| **D9 - DP** | **34.3** | **I9 - ID** | **35.3** | **LONG** |
| **D10 - DP** | **29.6** | **I10 - ID** | **33.0** | **SHORT** |
| **D11 - DP** | **26.9** | **I11 - ID** | **31.3** | **LONG** |
| **D12 - DP** | **29.2** | **I12 - ID** | **31.3** | **SHORT** |
| **D13 - DP** | **27.2** | **I13 - ID** | **28.8** | **LONG** |
| **D14 - DP** | **20.7** | **I14 - ID** | **21.2** | **SHORT** |
| **D15 - DP** | **21.9** | **I15 - ID** | **26.3** | **LONG** |
| D16 - IR | … | NA | … | … |




**A possible arrangement of the beam lines within the experimental hall**

# Arrangement of the Control Hutches



# Beamline Development: Strategy

**SESAME is committed for developing facility-wide plan that is:**

- **Responsive to the needs of the various communities with input from users**

- **Coherent and in line with competing facilities,**

- **User access policy will ensure that the facility is as scientifically productive as possible**

- **Reviewed by beamline and science committees to maintain state-of-the-art performance**

# SESAME PHASE - I BEAMLINES

| No. | Beamline | Energy Range | Source Type | Research Area | Champions |
|---|---|---|---|---|---|
| 1. | **Mad Protein Crystallography** | 4 - 14 keV | In-vacuum undulator | Biology | S. Hasnain, **M. Yousef** |
| 2. | **Soft X-ray - VUV** | 0.05 - 2 keV | Elliptically Polarizing | Atomic Molecular | **B. Suleman**, Aslam Baig |
| 3. | **SAXS/WAXS** | 8 - 12 keV | Undulator | Material Science | **M. Al-Hussein**, Zehra Seyers |
| 4. | **XAFS/XRF** | 3 - 30 keV | 2.0 Tesla MPW | Material, Arch. | **Awni Hallak**, Abu Samak |
| 5. | **Powder Diffraction** | 3 - 25 keV | 2.1 Tesla MPW | Material, Arch.,Env. | **E. Ozdas** |
| 6. | **IR Spectro-microscopy** | 0.01 - 1 eV | Bending Magnet* | Material, Arch.,Env. | **Z. El Bayyari**, I. Sagi |
| 7. | **AMO - Zero BL** | 5 - 250 eV | Bending Magenet | Atomic Molecular | **M. Gharaibeh**, Rami Ali |

# Phase I Beamlines at SESAME & Other Facilities

SESAME: Phase I
1) PX (und)
2) Soft X-ray
3) SAXS/WAXS
4) EXAFS/XRF
5) Powder Diffraction
6) IR
7) AMO

NSLS-II
1) Inelastic
2) Nanoprobe
3) Soft Coherent
4) Hard Coherent
5) EXAFS
6) Powder

A(ustralian)SP
1) IR
2) PX (BM)
3) Soft X-ray
4) EXAFS
5) Powder

C(anadian)LS
1) IR
2) XAS
3) STXM
4) MAD
5) XAFS

# Donation of Equipment

# Equipment from LURE

– **SU6 undulator** (beam axis 1240 mm, spectral range 30 – 110 eV, peak field 0.25 T, min. gap 39 mm)

– **Hutches** (100 walls 80 x 320 cm, 90 walls 115 x 235 cm, 35 walls 100 x 235 cm)

– **SA31 beamline** (Refocusing mirror, monochromator)

# Equipment from SLAC and ALS

## ❖ Equipment from SLAC:

- **PEP Undulator** (period length 77 mm, overall length 223 cm, Max. K value: 1.58)
- **Hower-Brown** double-crystal monochromator (size 26 in. dia. 36 in., weight ~ 500 lbs)

## ❖ Equipment from ALS:

- **Wiggler W16** (Peak Field 2.0 T, Period length 16 cm, No. of periods 19)

# Equipment from Daresbury

## ❑ 5 Beamlines:

- ❖ DL 14.1: Protein Crystallography, non-crystalline diffraction.
- ❖ DL 14.2: High throughput protein crystallography
- ❖ DL 4.1: XUV Spectroscopy
- ❖ DL 4.2: Near edge X-ray Absorption Fine Structure
- ❖ DL 16.1:Small and Wide Angle X-ray Diffraction (SAXS/WAXS)

SESAME

# Equipment from Daresbury

## ❖ Beamline 14.1

- ❖ **Protein Crystallography, non-crystalline diffraction.**

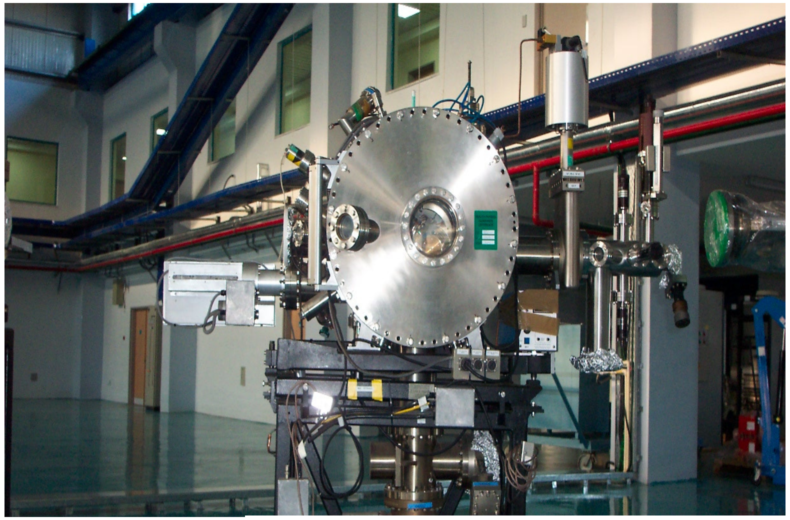
- ❖ This station provides a focused X-ray beam at either 1.488 Å or 0.977 Å . The station is designed for protein crystallography data collection from crystals as small as 50 microns.

- ❖ The station can be used for Multi-wavelength Anomalous Diffraction (MAD) data collection near the two wavelengths listed.

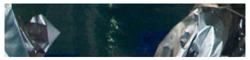
- ❖ The station is also used for non-crystalline diffraction experiments on samples as diverse as corneal tissue and archaeological samples.

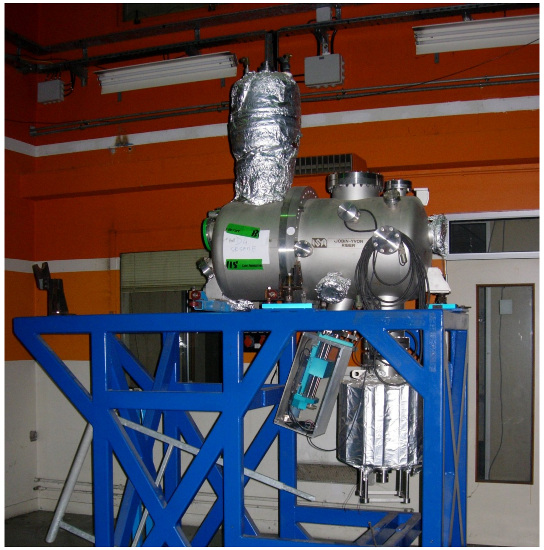
# BLs 4.1 and 4.2 from Daresbury

# Photos of some donated components



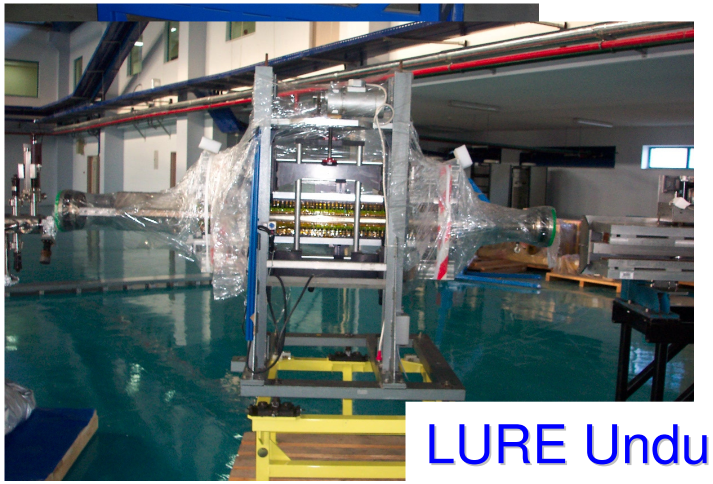
Daresbury Double Crystal Monochromator BL 4.2





LURE Grasshopper Monochromator


SLAC Undulator



LURE Undulator

# Phase I Beamlines

| No | Beamline | Coordinator | Expert | Donation |
|---|---|---|---|---|
| 1. | Mad Protein Crystallography | M. Yousef, S. Hasnain, | Samar Hasnain | Daresbury DL – 14.1 & 14.2 |
| 2. | Soft X-ray – VUV | B. Suleman, Aslam Baig | Zahid Hussain | Daresbury DL – 4.1 & 4.2 |
| 3. | SAXS/WAXS | M. Al-Hussein, Zehra Seyers | Wim Bras | Daresbury DL – 16.1 |
| 4. | XAFS/XRF, | Awni Hallak, Abu Samak | A. Simionovici | --- |
| 5. | Powder Diffraction, | E. Ozdas | Fabia Gozzo | SLS |
| 6. | IR Spectro-microscopy | Z. El Bayyari, I. Sagi | Paul Dumas | --- |
| 7. | Zero beamline, | M. Gharaibeh, Rami Ali | --- | LURE |

# Proposals Submitted to SESAME

| Originating from | Research Area/ Beamline | Number |
|---|---|---|
| Egypt | A/b and e | 4 |
| Iran | A/a and e | 3 |
| Israel | B/b, e,c,f | 11 |
| Jordan | A,B,C/a,b,c,d,e,f | 16 |
| Oman | A/a, d, c | 4 |
| Palestinian Authority | A,B/b,d,e | 3 |
| Saudi Arabia | A/d,e | 2 |
| Turkey | A,B,D/a,b,c,d,e | 5 |
| United Arab Emirates | A/d,e | 4 |
| Canada | A/e | 2 |
| Greece | B/b.c | 6 |
| Japan | B/b | 1 |
| **Total** | **61** | |

A: Material Science,
B: Structural Molecular Biology
C: Environmental Science,
D: Archaeological Sciences.
a: Photoabsorption/ photoemission spectroscopy,
b: MAD protein crystallography,
c: Small/wide angle solution X-ray scattering,
d: Powder diffraction,
e: X-ray absorption fine structure and X-ray fluorescence spectroscopy,
f: infrared spectromicroscopy

# Our task: Design, Build and Run the Facility