

# How does a synchrotron radiation source work?

---



Rolf Landua  
CERN

- ★ What is SESAME?
- ★ Production of synchrotron light
- ★ SESAME components
- ★ Synchrotron light spectrum for experiments

***Later today:***

SESAME - Status/Prospects (Chris Llewellyn-Smith)

CERN-SESAME parallels and differences (Herwig Schopper)

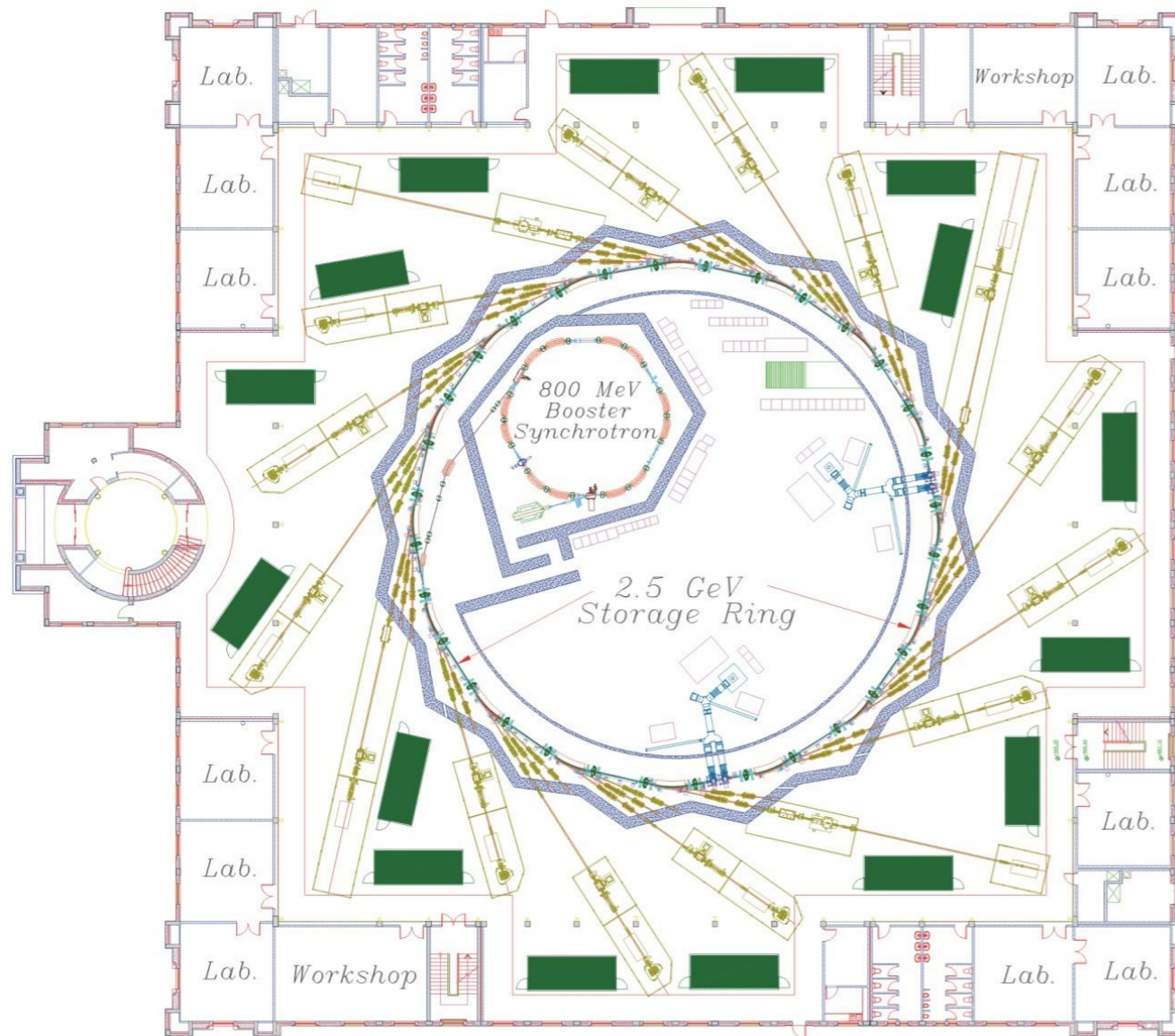
## ★ **What is SESAME?**

★ Production of synchrotron light

★ SESAME components

★ Synchrotron light spectrum for experiments

# SESAME is an 'electron synchrotron'

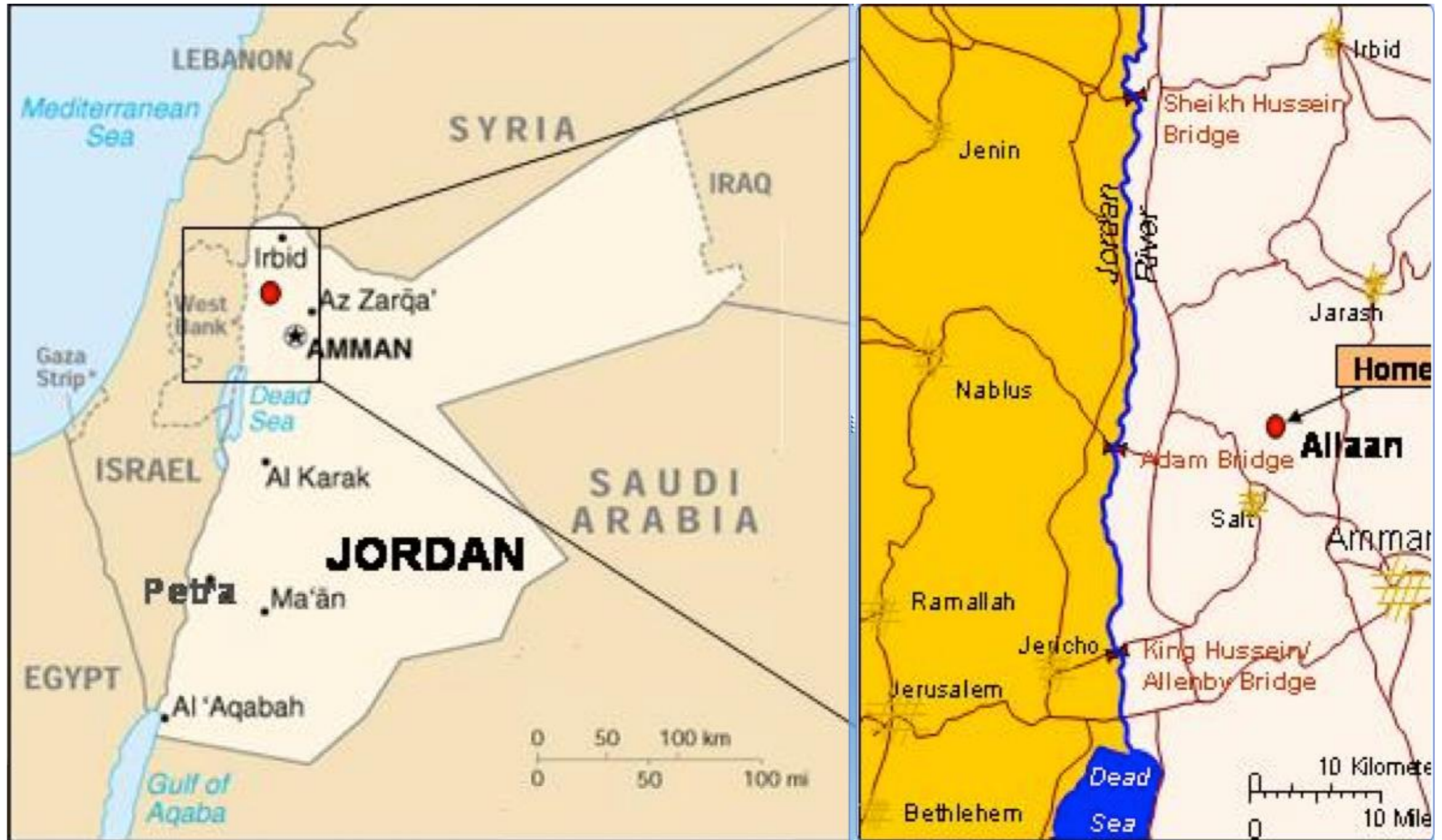


Energy = 2.5 GeV  
Circumference = 133.2 m  
Magnet strength = 1.455 T  
Max. current = 400 mA ( $3 \cdot 10^{12}$  e)

**Very intense beams of X-rays\*, infrared and UV light (billion times brighter than Sun)**

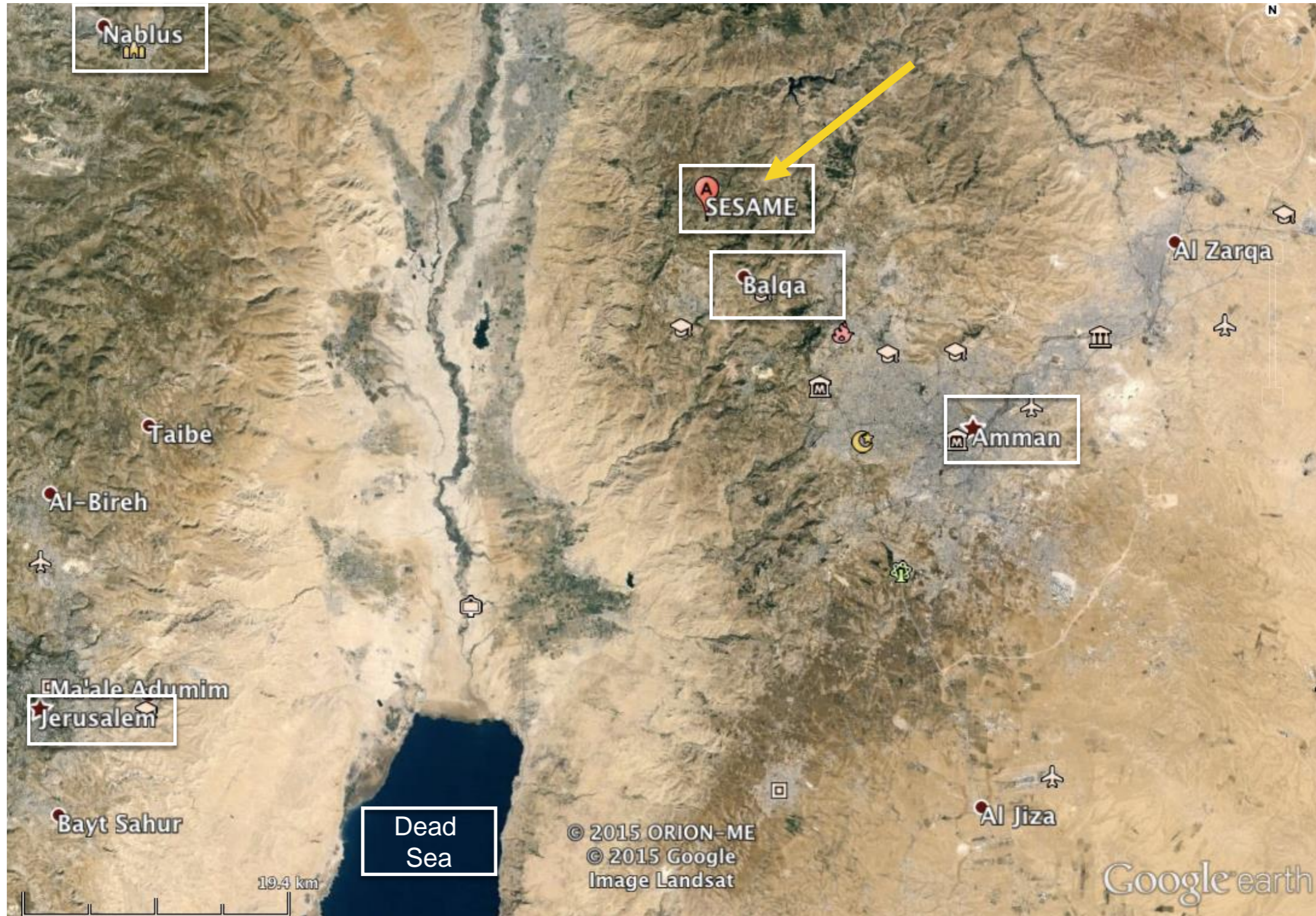
**Allows to study objects that are much smaller than 1  $\mu\text{m}$  (~ cell size)**

## *A "CERN" in the Middle East*



<http://www.sesame.org.jo/sesame/>

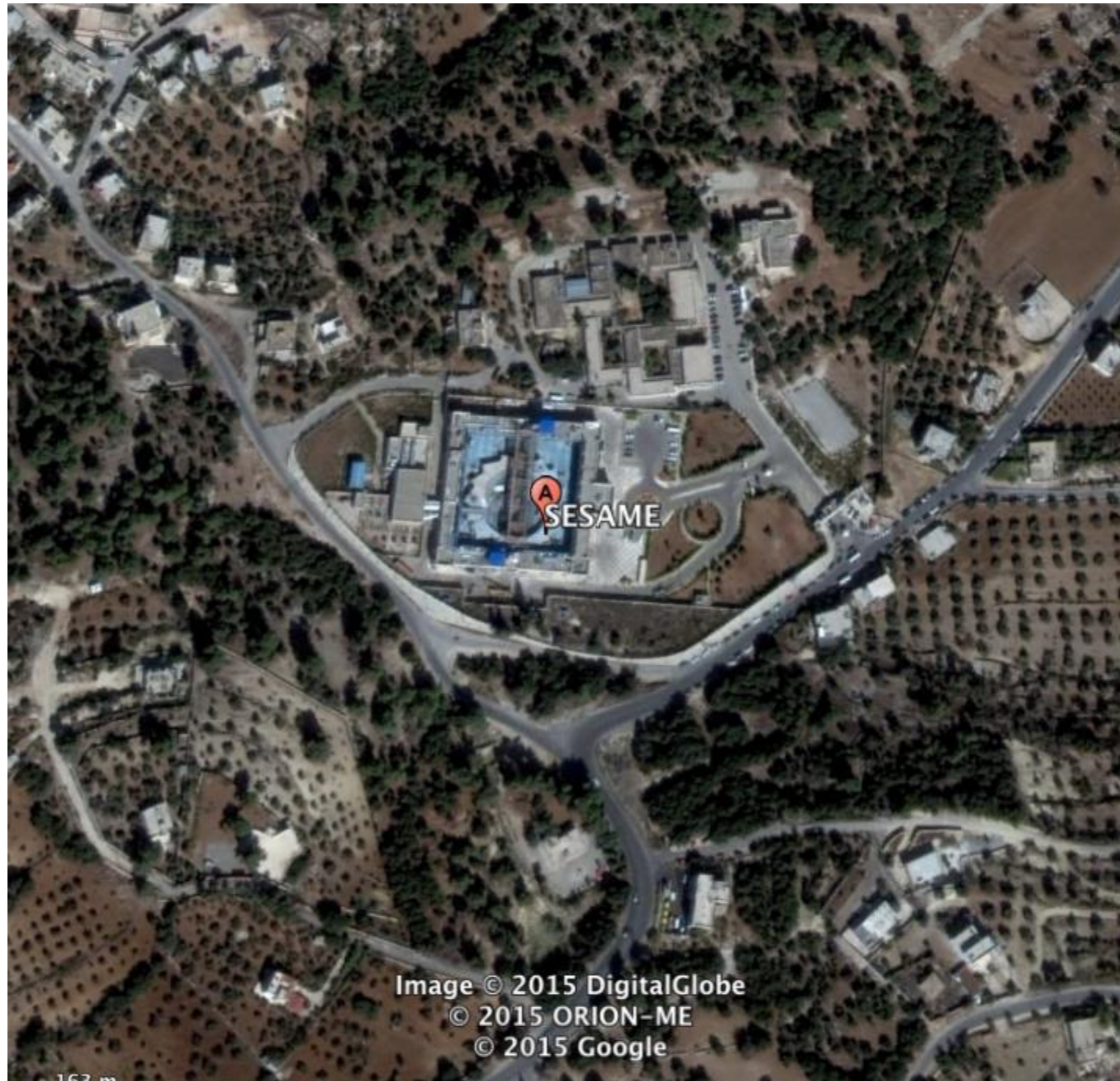
# SESAME on 'Google Earth'



# SESAME on 'Google Earth'

## SESAME

King Al-Hussein Bin Talal, Allan, Al  
Salt 19252, Jordan  
+962 5 351 1348 · [sesame.org.jo](http://sesame.org.jo)



# SESAME building





# PRESIDENTS/VICE-PRESIDENTS OF COUNCIL

[Presidents](#)

[Vice-Presidents](#)

## Presidents

*Current President*

November 2008-

Chris LLEWELLYN SMITH (U.K, Director of Energy Research [University of Oxford](#) and former Director-General of European Organization for Nuclear Research ([CERN](#)) and Chairman of the International Thermonuclear Experimental Reactor ([ITER](#)) Council)

*Past Presidents*

July 2004-November 2008

Herwig SCHOPPER (Germany, former Director-General of European Organization for Nuclear Research ([CERN](#)))

## Vice-Presidents

*Current Vice-Presidents*

December 2011-

Seyed Mahmoud Reza AGHAMIRI (Islamic Republic of Iran, [Shahid Beheshti University](#))

June 2010-

Mohamed Tarek HUSSEIN (Egypt, former President of Academy of Scientific Research and Technology ([ASRT](#)))

*Past Vice-Presidents*

July 2004-June 2010

Dincer ÜLKÜ (Turkey, [Hacettepe University](#))

July 2004-June 2005

Khaled TOUKAN (Jordan, Minister of Education)

**Chris Llewellyn-Smith**

President SESAME council  
Former CERN DG

**Herwig Schopper**

Former president SESAME council  
Former CERN DG



**Left to Right:**

**Dincer Ulku**, Past Vice President of SESAME Council until June 2011

**Chris Llewellyn-Smith**, President of SESAME Council (Nov.2008 -)

**Yasser Khalil**, Administrative Director of SESAME

**Khaled Toukan**, Director of SESAME

**Herwig Schopper**, Past President SESAME Council until Nov. 2008

**Hafeez Hoorani**, Scientific Director of SESAME

**Amor Nadji**, Technical Director of SESAME

**Albin Wrulich**, Chair of SESAME Technical Advisory Committee

<http://mag.digitalpc.co.uk/fvx/iop/esrf/sesamepeople/>

**SESAME** Synchrotron-light for Experimental Science and Applications in the Middle East

SESAME is an international centre for research and advanced technology established under the auspices of UNESCO. The synchrotron facility, which is under construction some 35km northwest of Amman, Jordan, is due to begin operations in 2014/2015.

This brochure offers an insight into some of the people behind the SESAME project. It has been produced by the ESRF, in collaboration with UNESCO, and with support from the ESRF and the Canon Foundation. IOP Publishing provided this digital edition.

UNESCO International Basic Sciences Programme  
CANON FOUNDATION  
ESRF IOP Publishing

View Quick User Guide ▶

**Sesame People**

SESAME

## Sesame People

**Mohammad Yousef**  
Mohammad Yousef, shown here inspecting a monochromator at the Japanese Photon Factory, is a biophysicist and structural biologist from Cairo University who works on anchoring proteins, protein-DNA and protein-ligand complexes. The use of X-ray crystallography to determine the three-dimensional structures of biological macromolecules at atomic resolution is central to his work. The results of such studies provide the basis for understanding biological functions and guide the rational design of new therapeutics.

Mohammad, who has attended and spoken at many SESAME meetings, says "My research requires X-ray synchrotron beamlines, which are currently unavailable in the Middle East. Therefore, I do most of my research abroad. SESAME, when operational, will bring me home!"

**Mohammad**  
Sumera Javeed, who attended the 8th SESAME Users' Meeting in 2009, is interested in studying the growth of carbon nanoparticles and their disintegration using different techniques, says "For most of the experiments of interest to us, the diagnostics can be most effectively carried out using the soft X-ray beamlines of SESAME. The broad spectrum of research programmes of SESAME will cater for the synchrotron radiation needs of the region, including specifically those of Pakistan. There are definitely cultural benefits involved in having scientists from different countries working close together."

Sumera, specialized working on a hollow cathode DC magnetron sputtering setup for carbon film deposition, is based at the Accelerator and Carbon-based Nanotechnology Laboratory, Pakistan Institute of Nuclear Science and Technology, Islamabad. Her basic field of research is carbon-based nanotechnology and ion physics. She is currently working on the formation of carbon thin films on metal substrates using a wide range of techniques.

**Mohammad Attai**  
Mohammad Attai attended the first SESAME workshop in Jordan (at Al-Balqa University) in 2000, was subsequently a SESAME trainee at the French synchrotron LURE, and has attended all the SESAME technical meetings and several of the Users' Meetings. He says that "As the first synchrotron light source in the Middle East, SESAME is a valuable and challenging experience through which I learned a completely new scientific field and obtained my PhD in accelerator physics. I think it will be a vital scientific research center which will activate, and make it much easier to carry out, scientific research in the region."

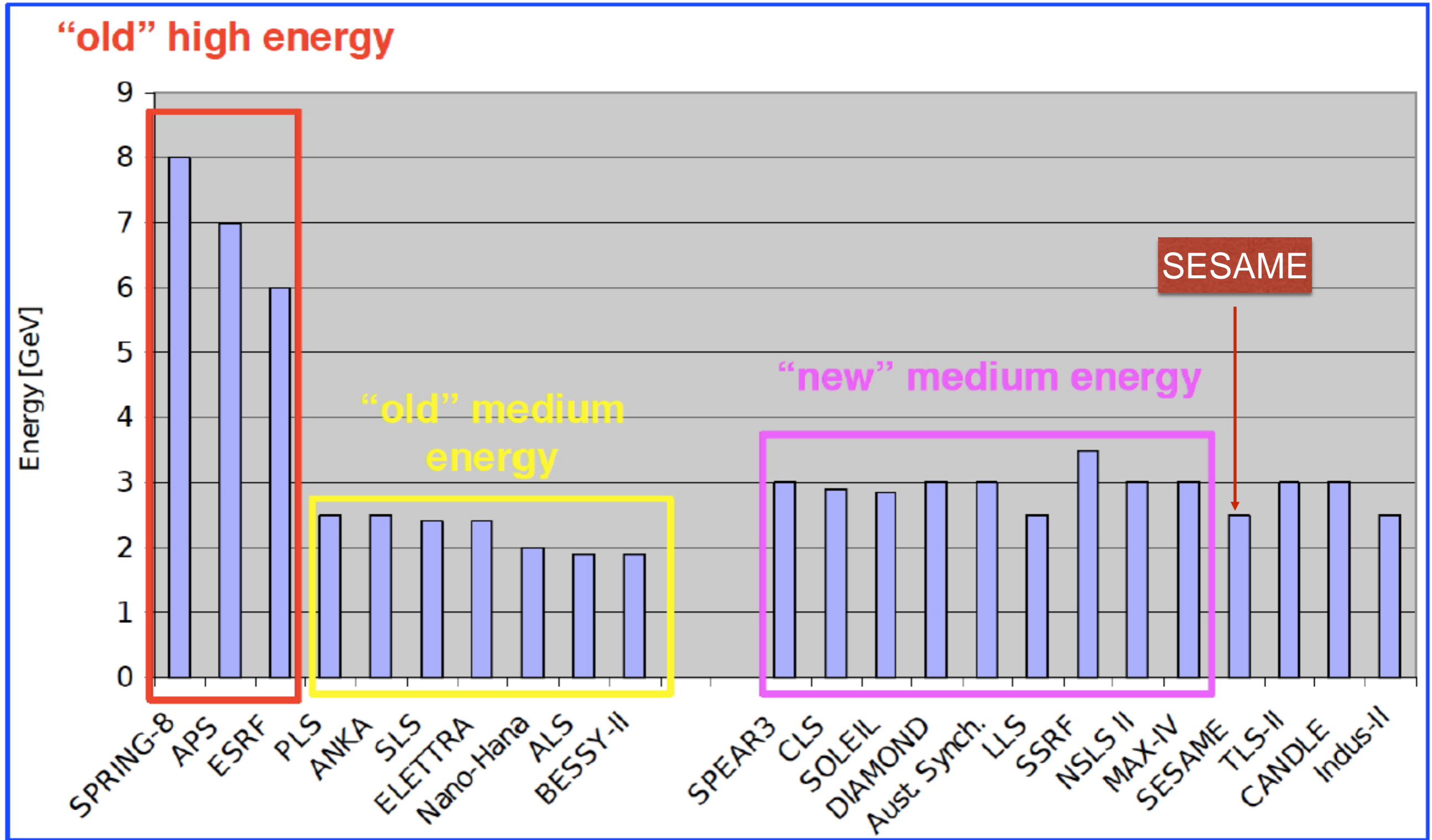
Mohammad, seen here with the SESAME Electron Injector, is a Palestinian accelerator physicist who works at SESAME on accelerator physics related issues.

**Irit Sagi**  
Irit Sagi is a professor of biophysics at the Weizmann Institute of Science in Rehovot. She is applying a unique, multidisciplinary approach to investigating enzymes, the complex molecular machines that regulate the chemistry of cells and organisms. Using synchrotron radiation in the X-ray regime, she advanced a method for precisely tracking, in real time, changes taking place in active enzymes at the level of single atoms. This method is currently employed by her research team to decipher the enzymes' mechanisms of action and to develop a new generation of safe and effective drugs.

Irit, who has been a member of the SESAME Scientific Advisory Group since 2008, says "I have strongly supported SESAME for many years. Having a synchrotron in our area will create a unique opportunity to merge scientific expertise without regard to borders or nationalities. SESAME is designed to promote regional scientific projects and advance young scientists by extending their horizons with modern technology. I am looking forward to that day."

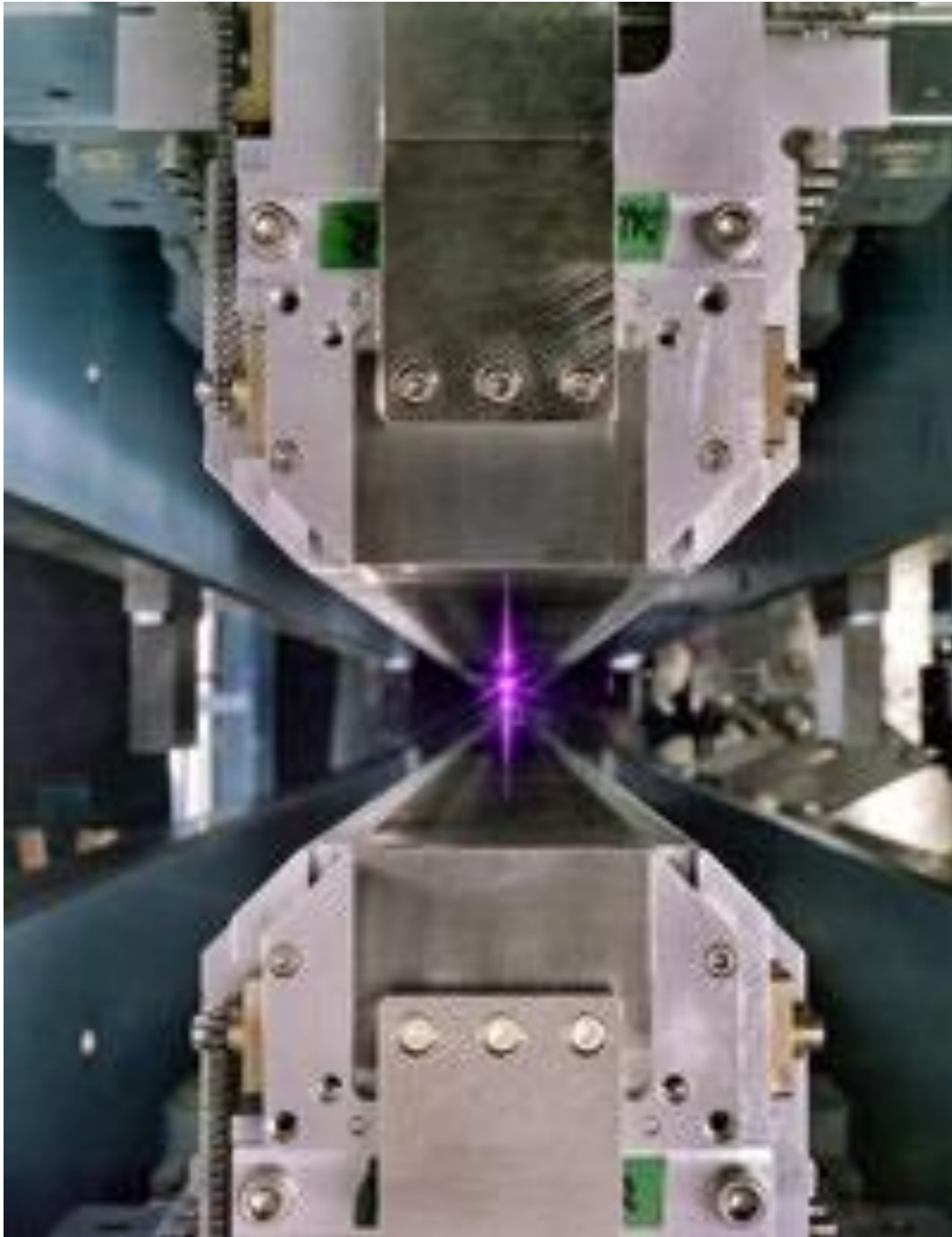
SESAME

# Comparison of synchrotron light sources world-wide



- ★ What is SESAME?
- ★ **Production of synchrotron light**
- ★ SESAME components
- ★ Synchrotron light spectrum for experiments

# Synchrotron light: artificial and natural sources

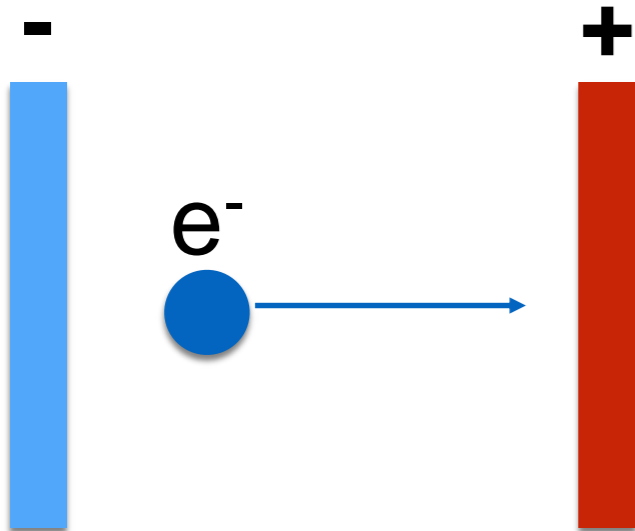


Synchrotron



Crab nebula (neutron star)

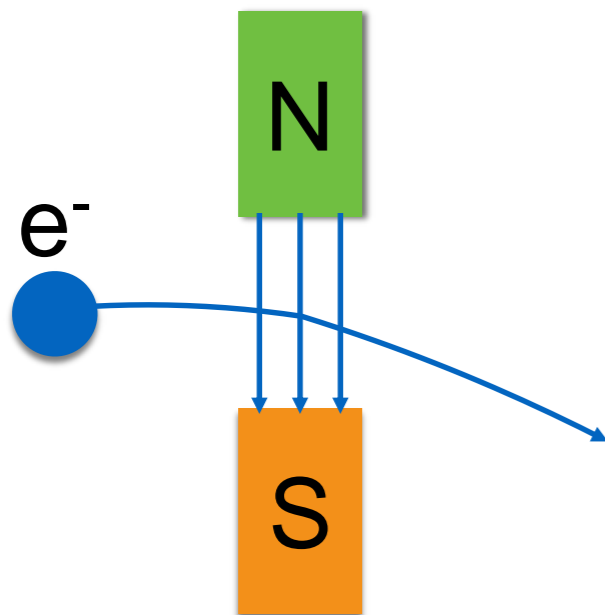
# Two important concepts about electromagnetism



Electric force on electron (with charge  $q$ ) in the direction of the electric field  $E$

$$F = q \cdot E \quad (\text{Coulomb force})$$

Electric fields increase kinetic energy



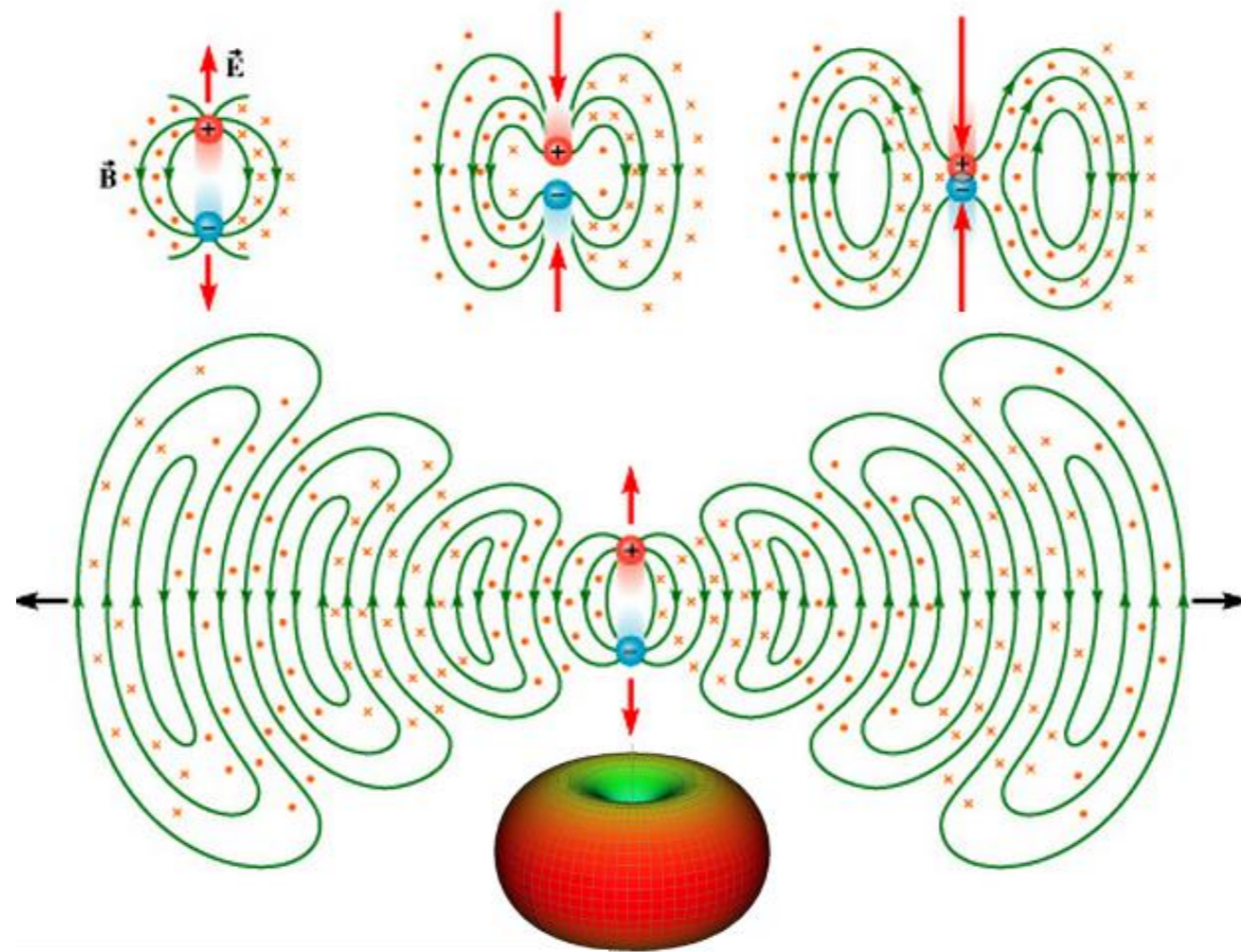
Magnetic force on electron (with charge  $q$ ) is perpendicular to the direction of the magnetic field  $B$

$$F = q \cdot v \cdot B \quad (\text{Lorentz force})$$

Magnetic field change the direction

# And what about accelerated charges ?

Whenever a charged particle accelerates it emits electromagnetic waves



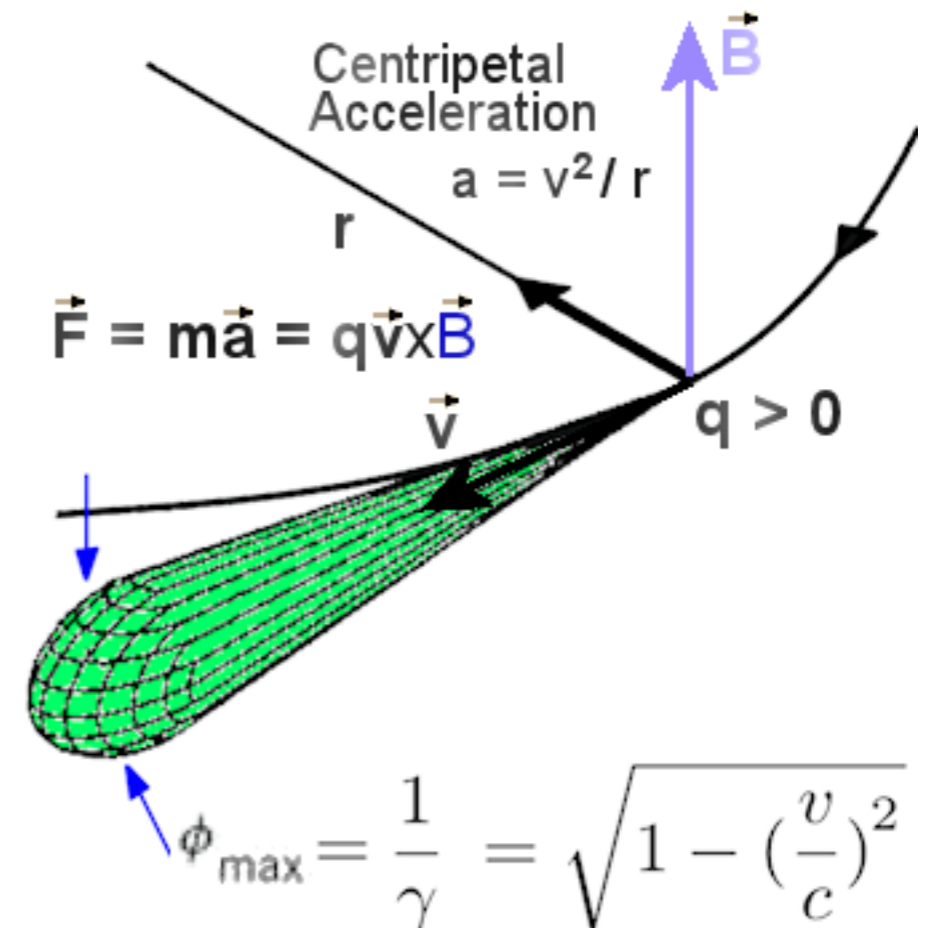
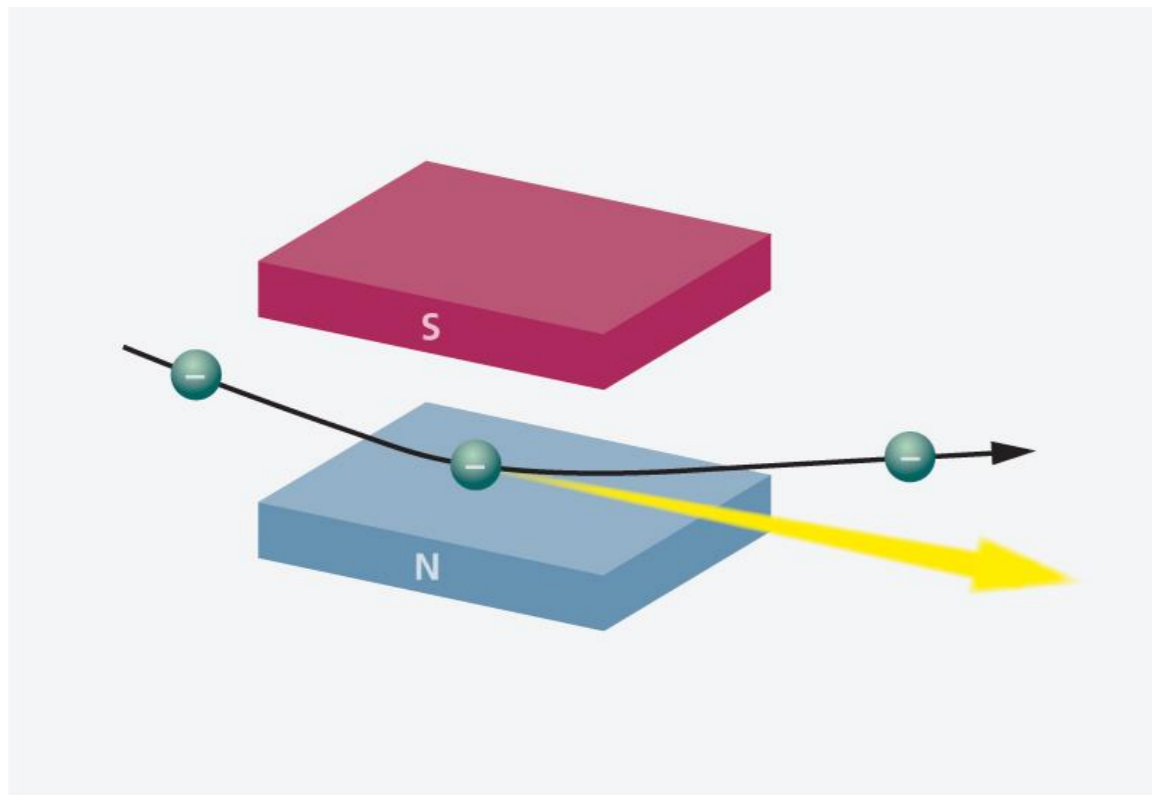
**Electromagnetic Radiation from Oscillating Dipole**

Principle of radio station / antenna



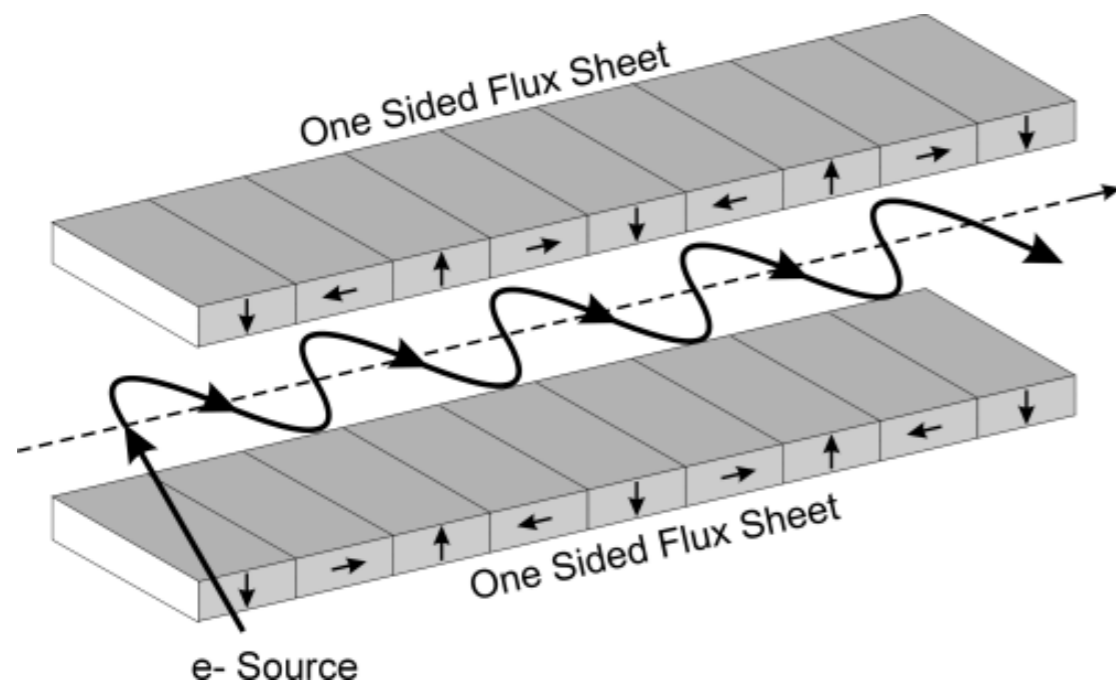
# Electrons in a synchrotron emit radiation

## Acceleration by magnetic dipole field



SESAME:  $\gamma \sim 5000$

## Wiggler



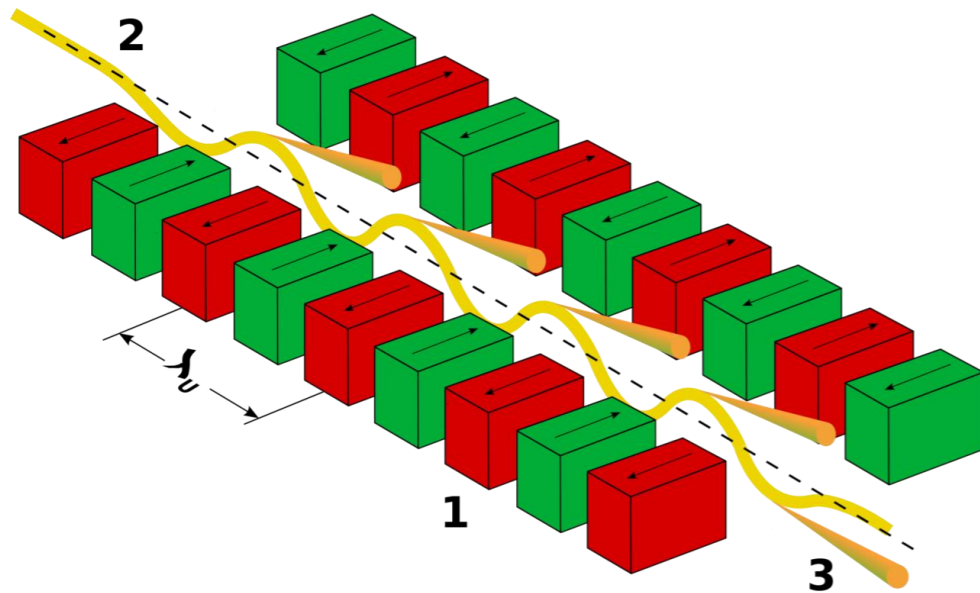
Array of magnets

Lateral deflection of electrons

**Broad and incoherent** emission spectrum

Higher intensity and energy than inside a bending magnet

# Undulator



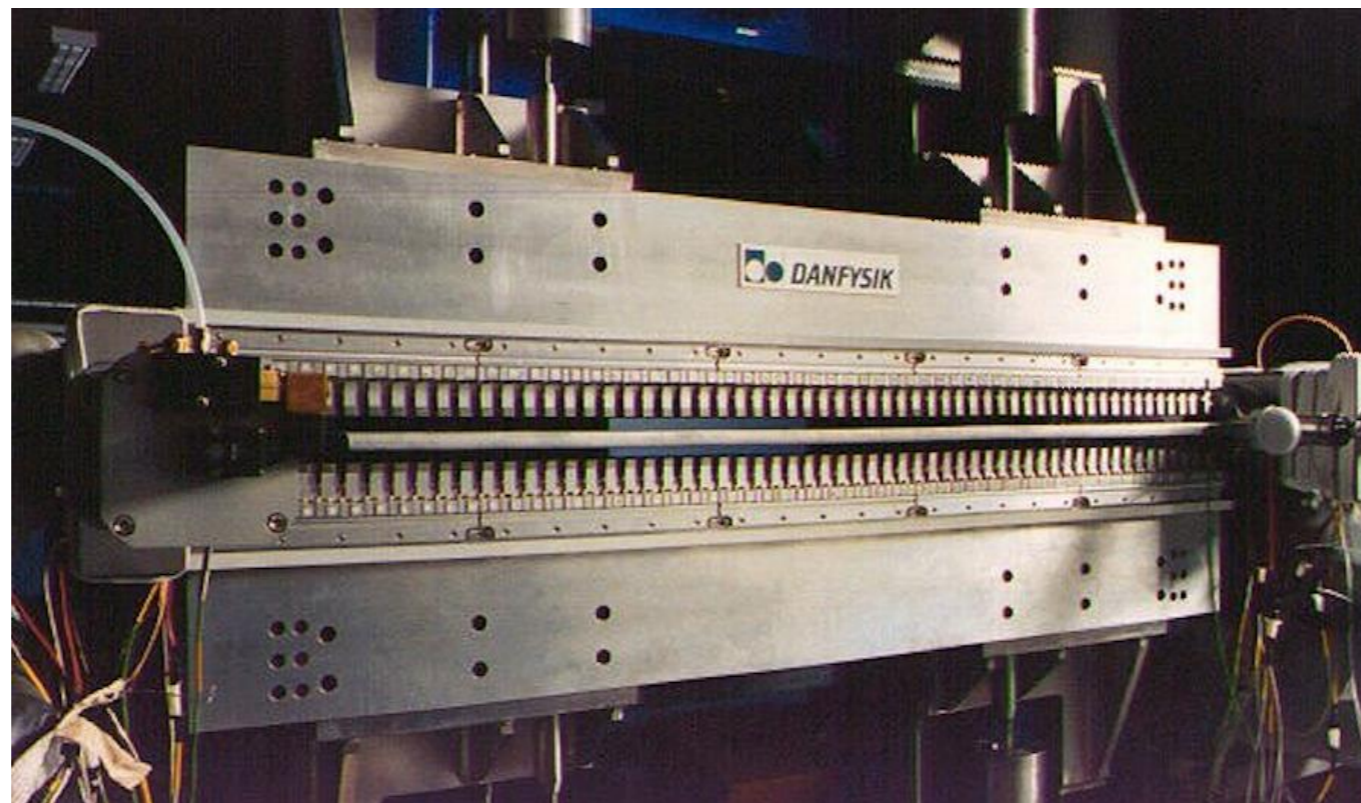
Less powerful magnets —> gentler undulations

Match transverse motion to transit speed:

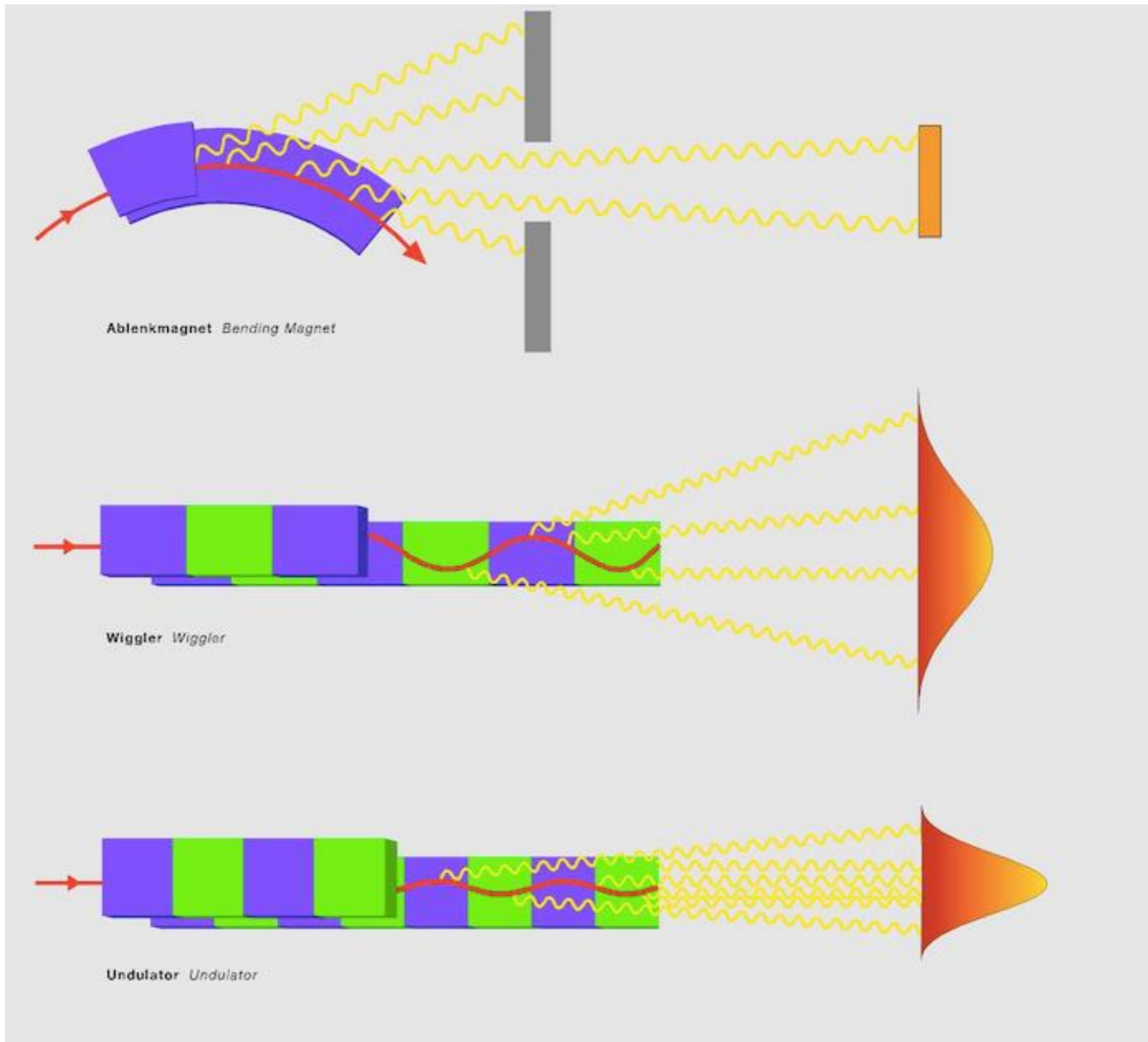
constructive interference !

Frequency tuneable (alter gap between magnets)

**Narrow and coherent** emission spectrum

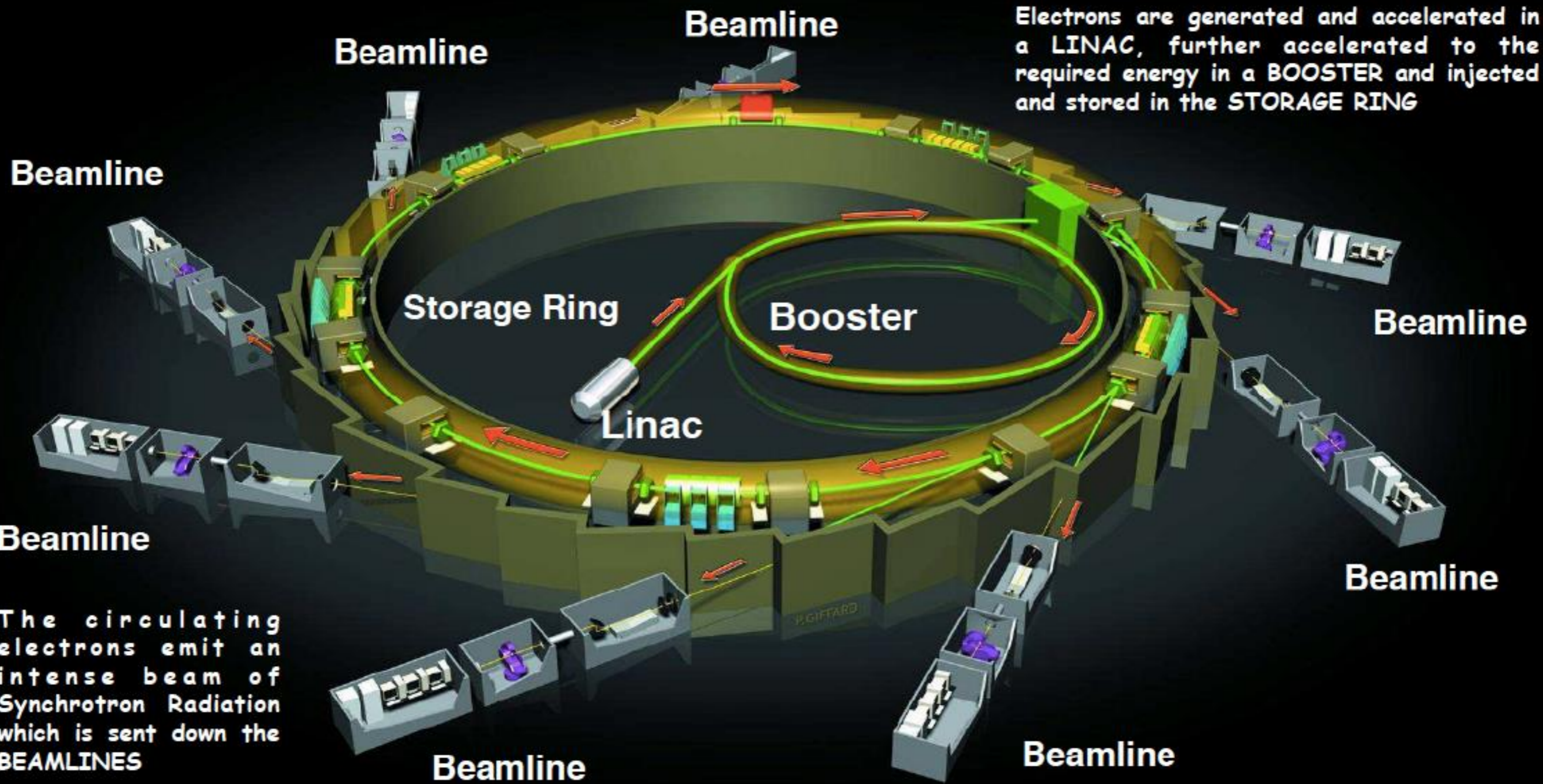


# Overview: Dipole magnet, Wiggler, Undulator

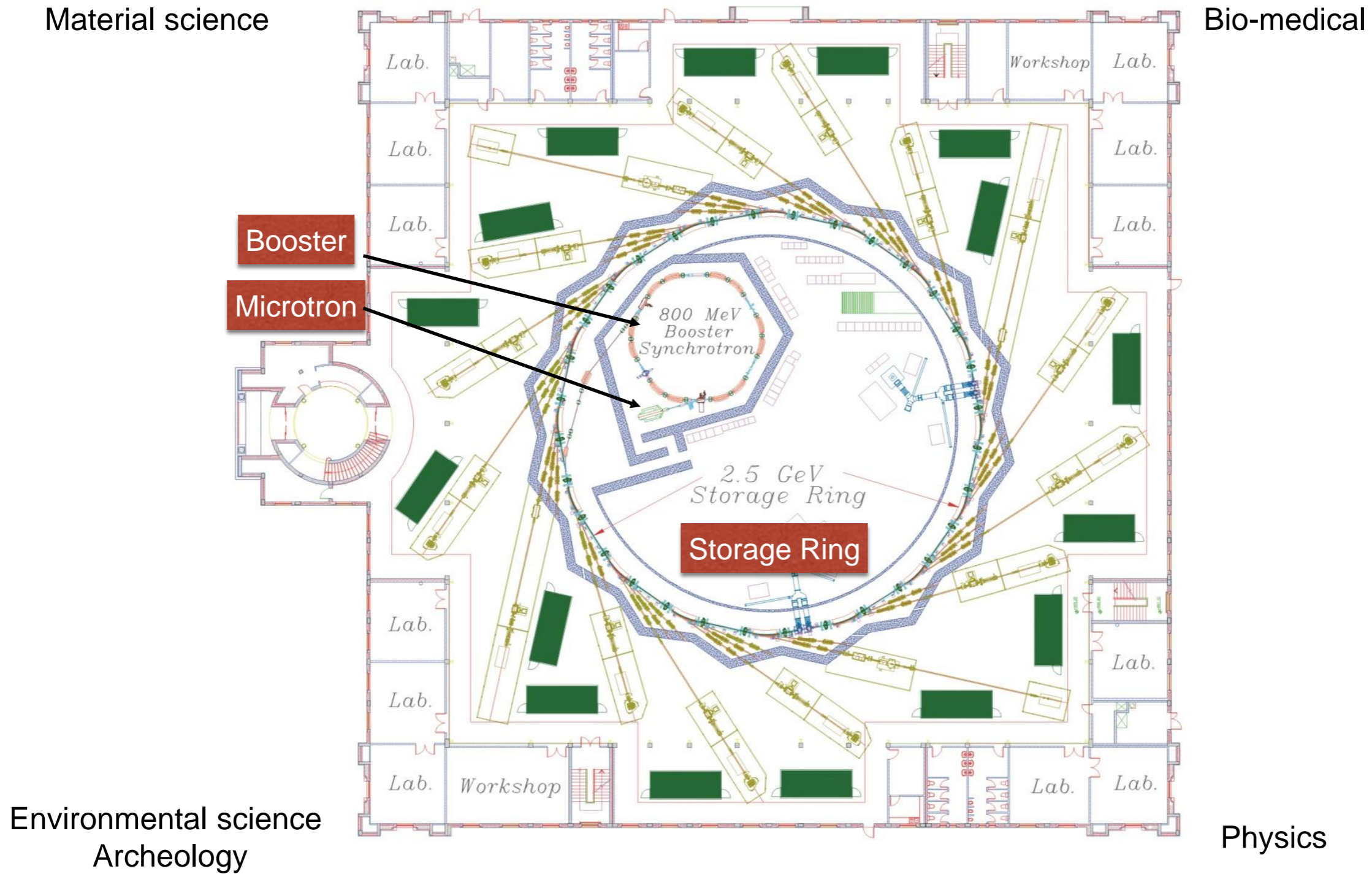


- ★ What is SESAME?
- ★ Production of synchrotron light
- ★ **SESAME components**
- ★ Synchrotron light spectrum for experiments

# Schematic overview of a Synchrotron Radiation Source



# Layout of the SESAME complex

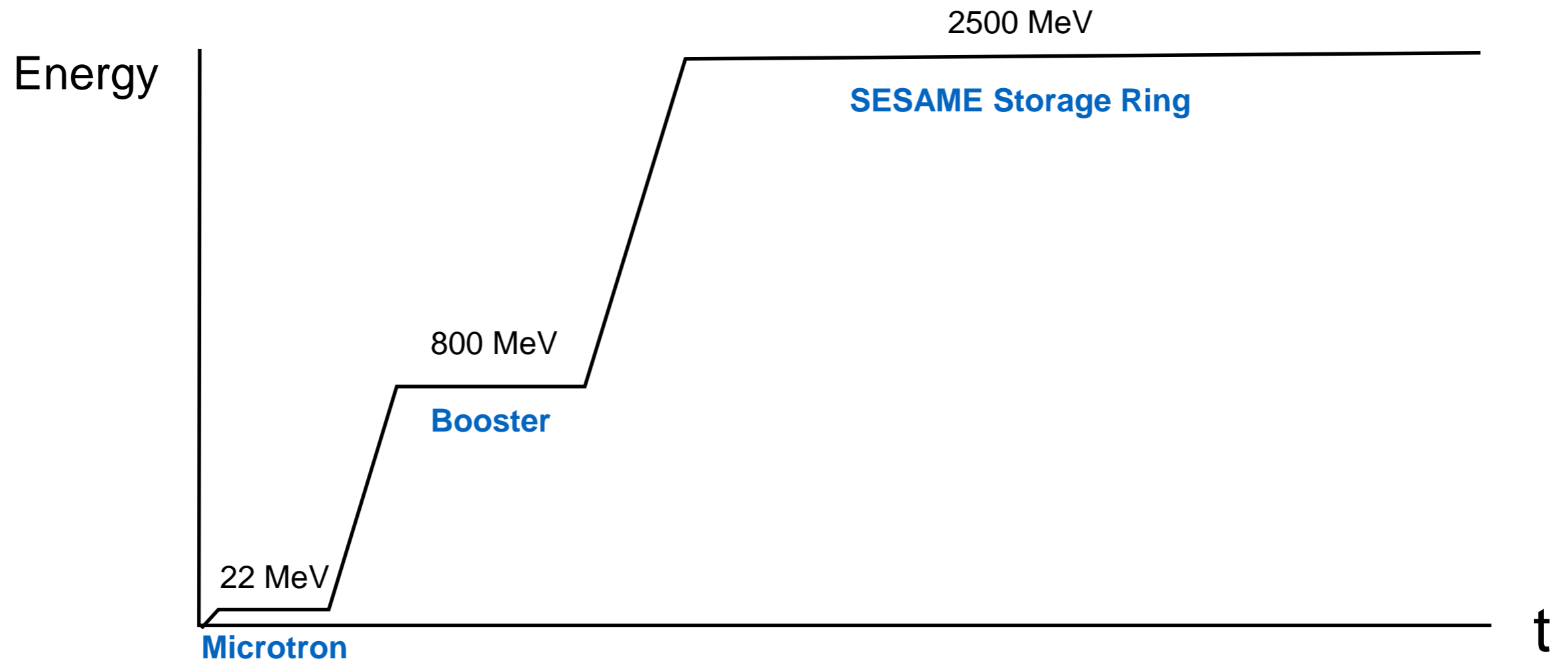


# Main steps of SESAME

Electrons are generated in an electron gun (like cathode ray tubes in old TVs)

## Acceleration in three steps:

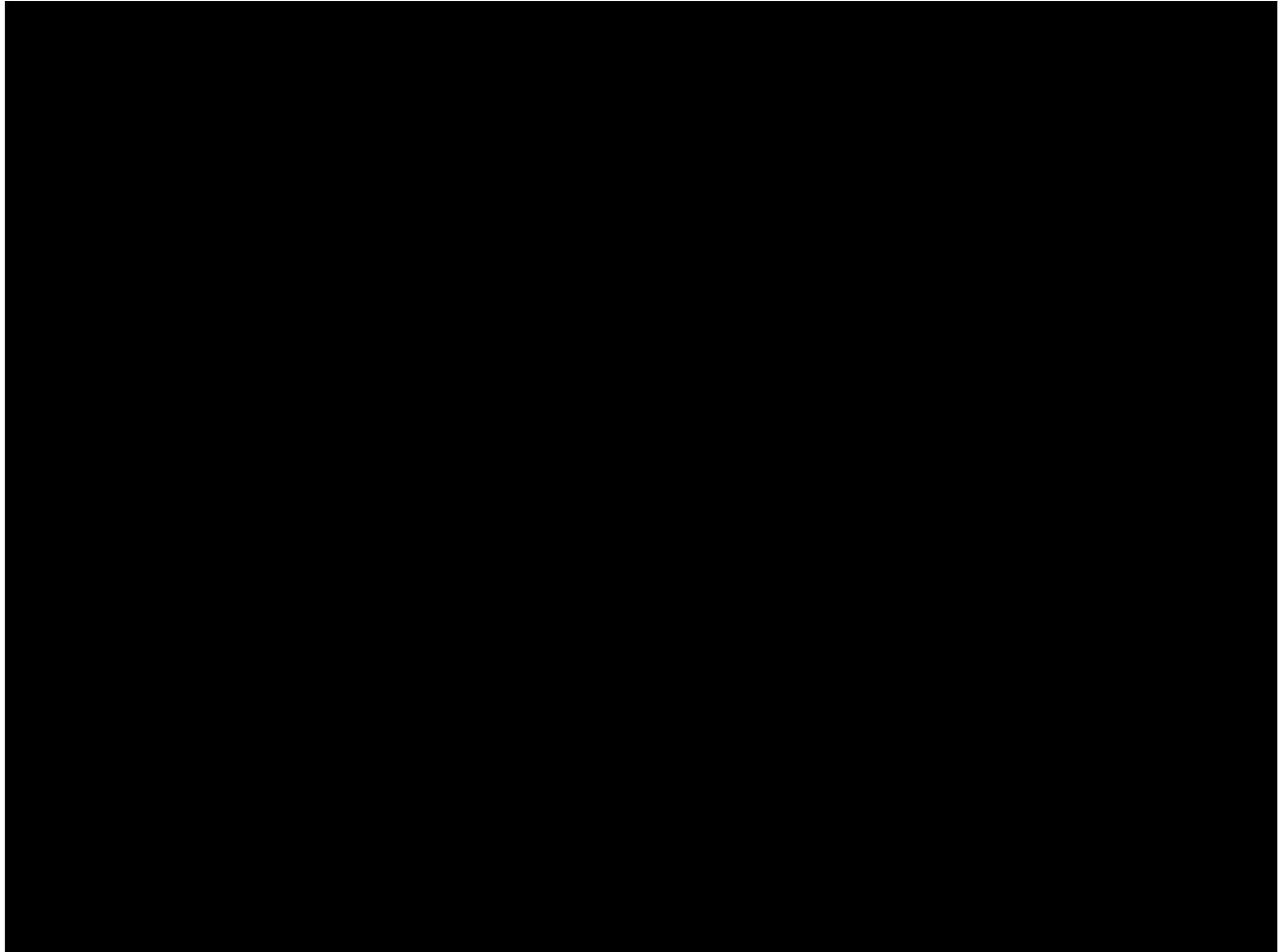
- 1) Microtron (= linear accelerator, up to 22 MeV)
- 2) Booster synchrotron (22 - 800 MeV)
- 3) Storage ring (800 - 2500 MeV)





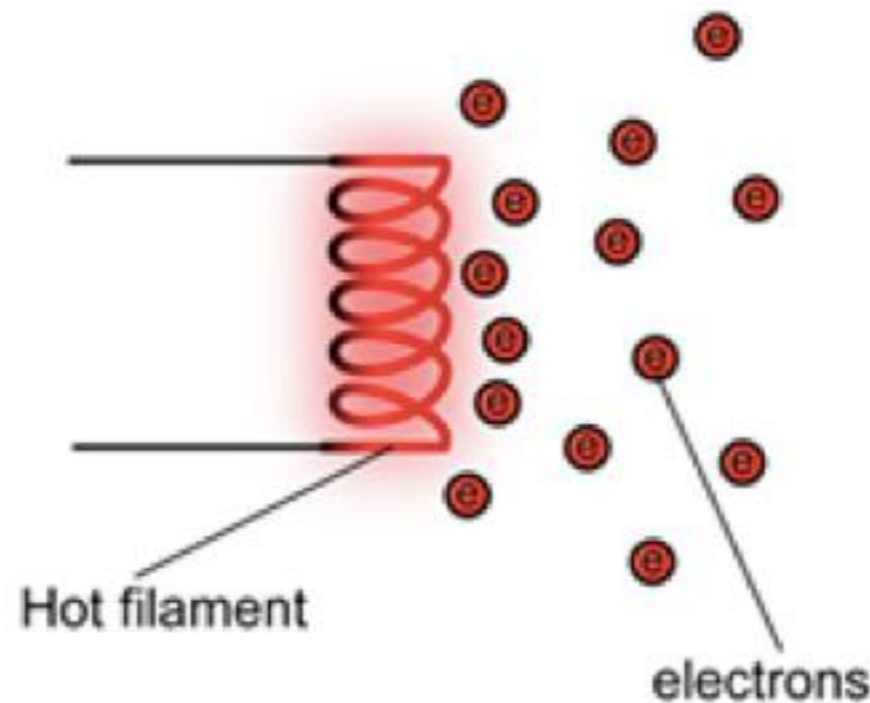
# Overview: Synchrotron light source animation

---



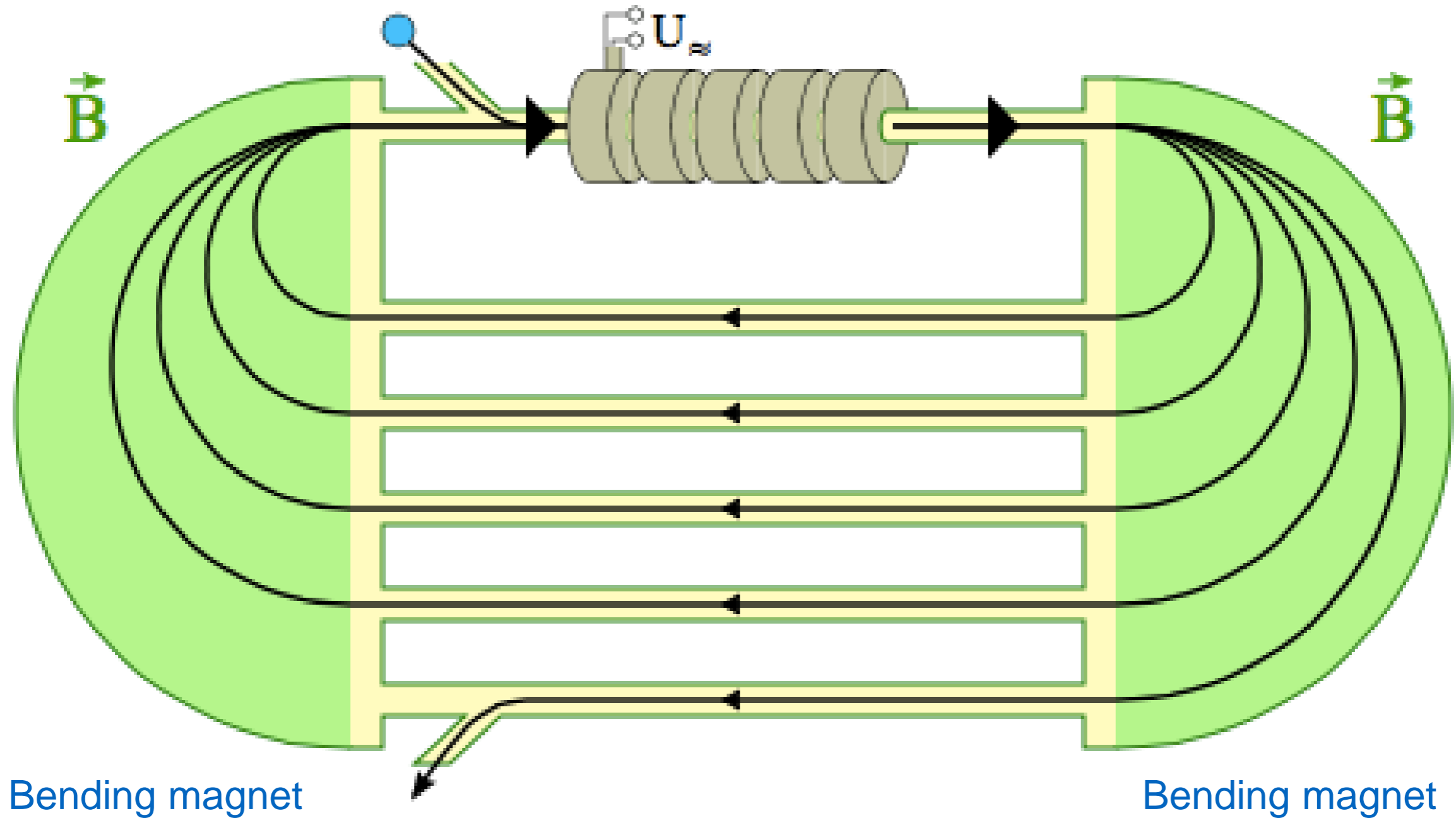
## Thermionic Emission

Thermionic emission is a process of emission of charge particle (known as thermion) from the surface of a heated metal. The charge particles normally are electrons.



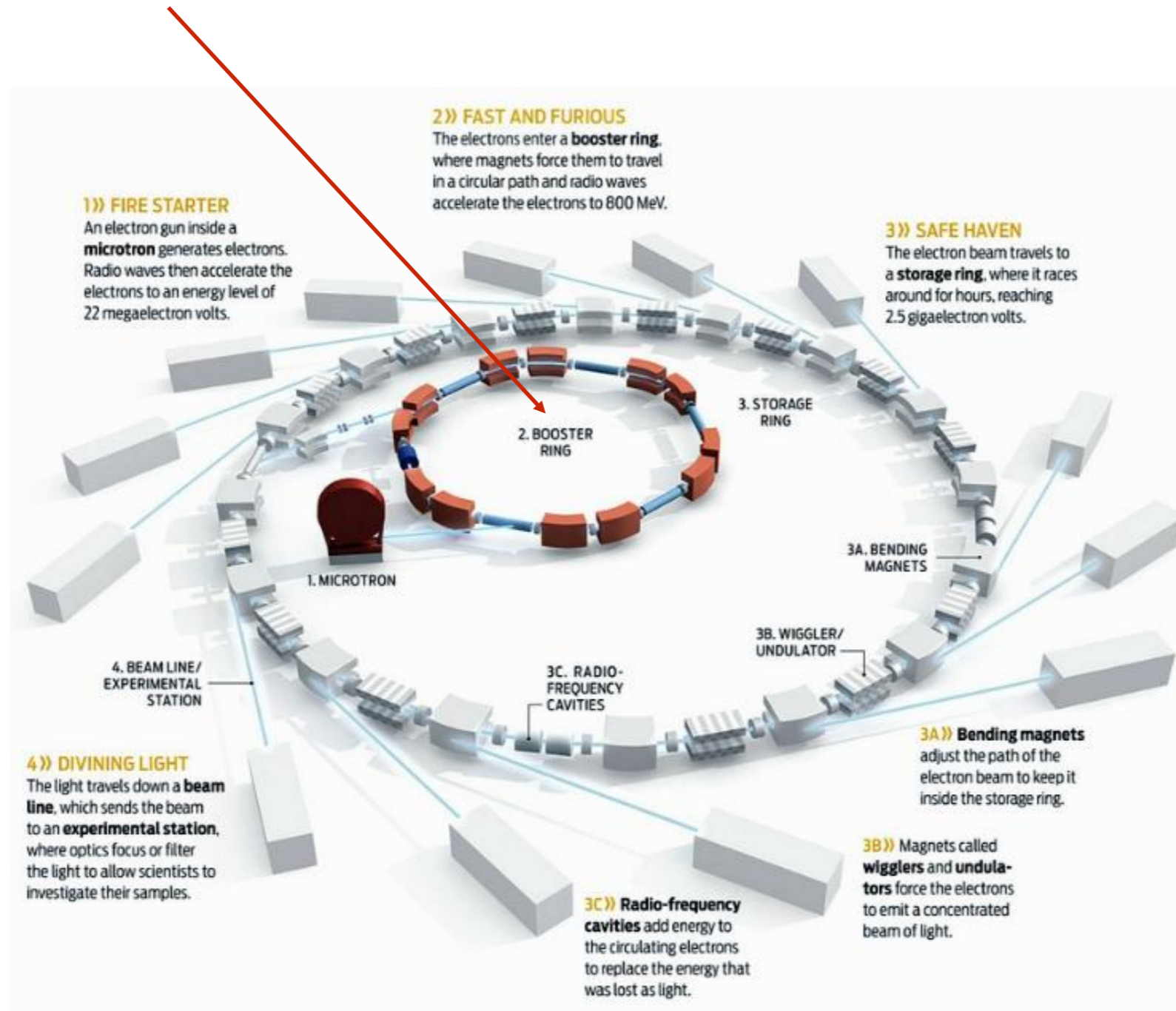
# Step 1b : the Microtron (up to 22 MeV)

linear accelerator



# Step 2 : the Booster (up to 800 MeV)

Booster = BESSY I 0.8 GeV synchrotron  
 decommissioned at BESSY, Berlin, Germany in 1999  
 donated to the SESAME project



## Step 2 : the Booster (up to 800 MeV)



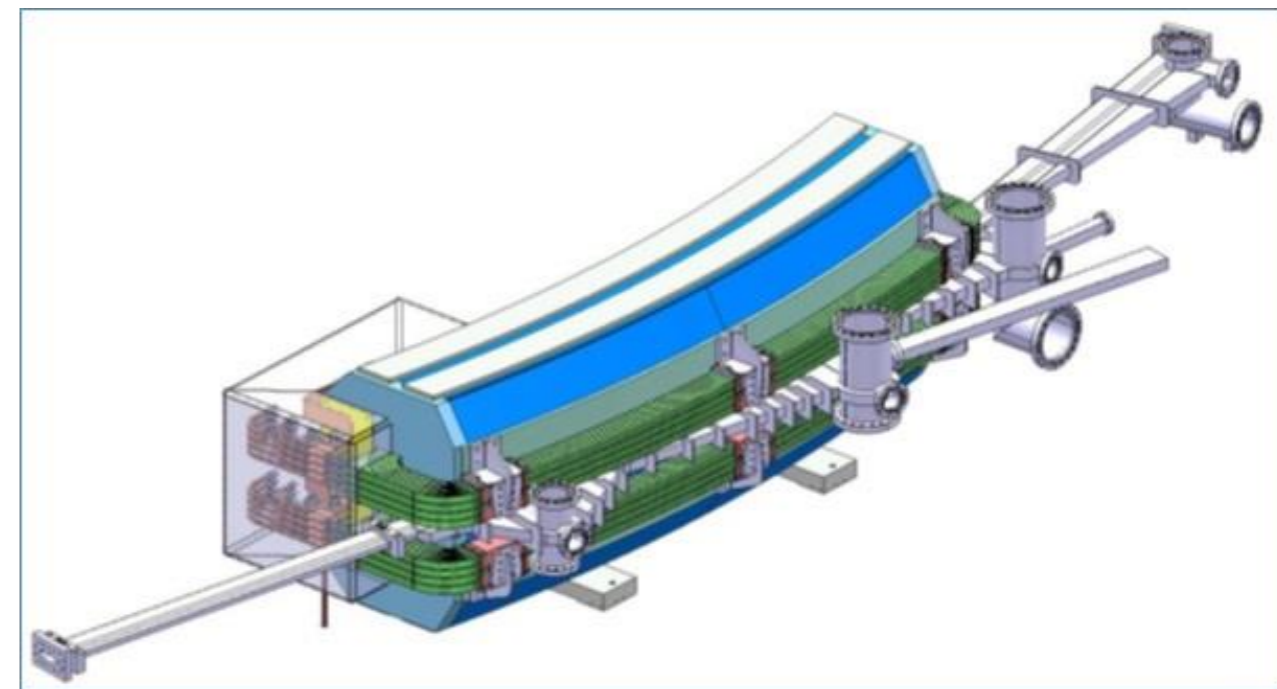
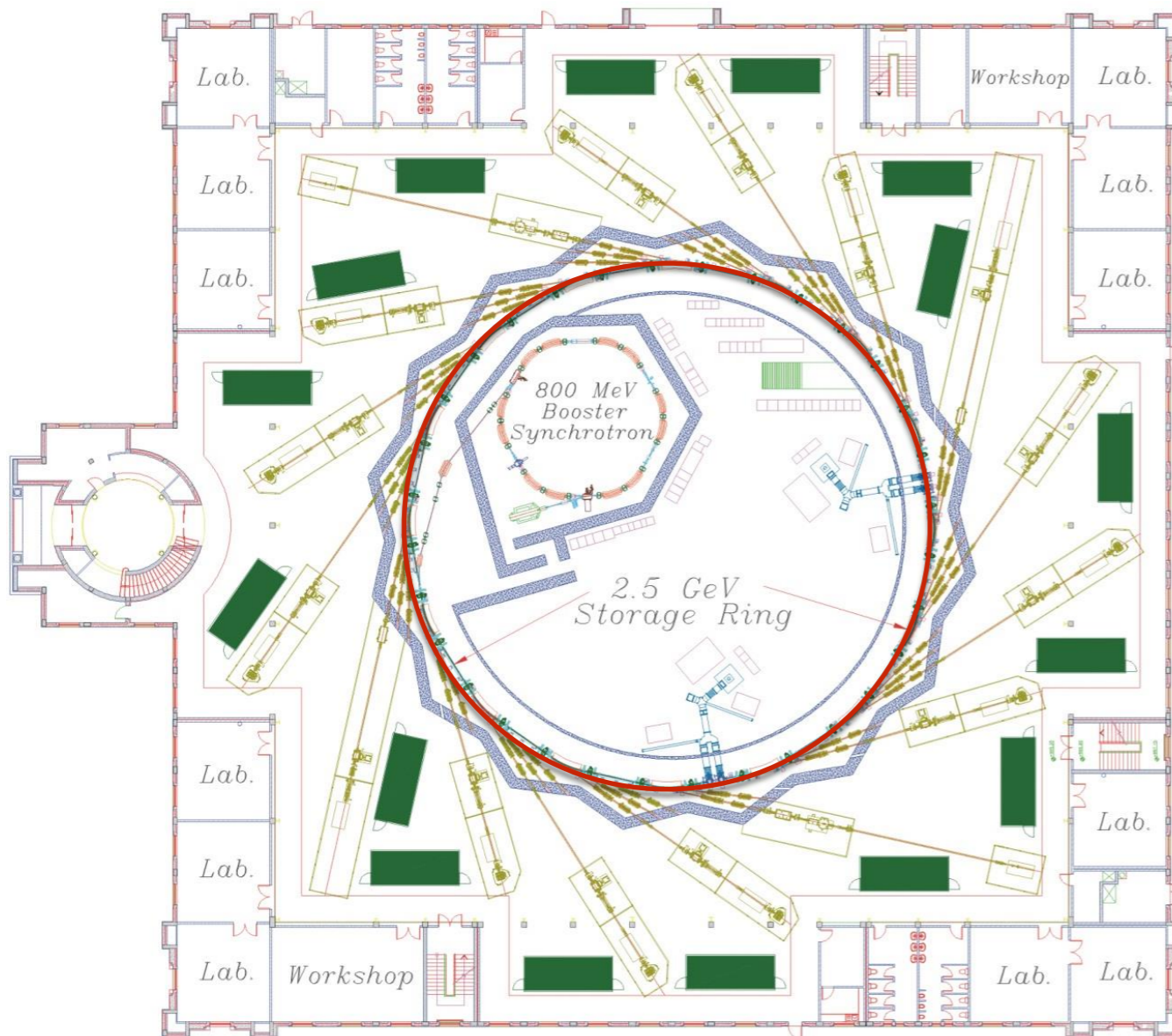
Mr. Salameh, Mayor of Salt City, Jordan, and Herman Winick (SLAC)

# Step 3 : the Storage Ring (up to 2500 MeV)

CESSAMAG project: European Union grant €5 million

CERN supplies magnetic system allowing for the completion of the main ring

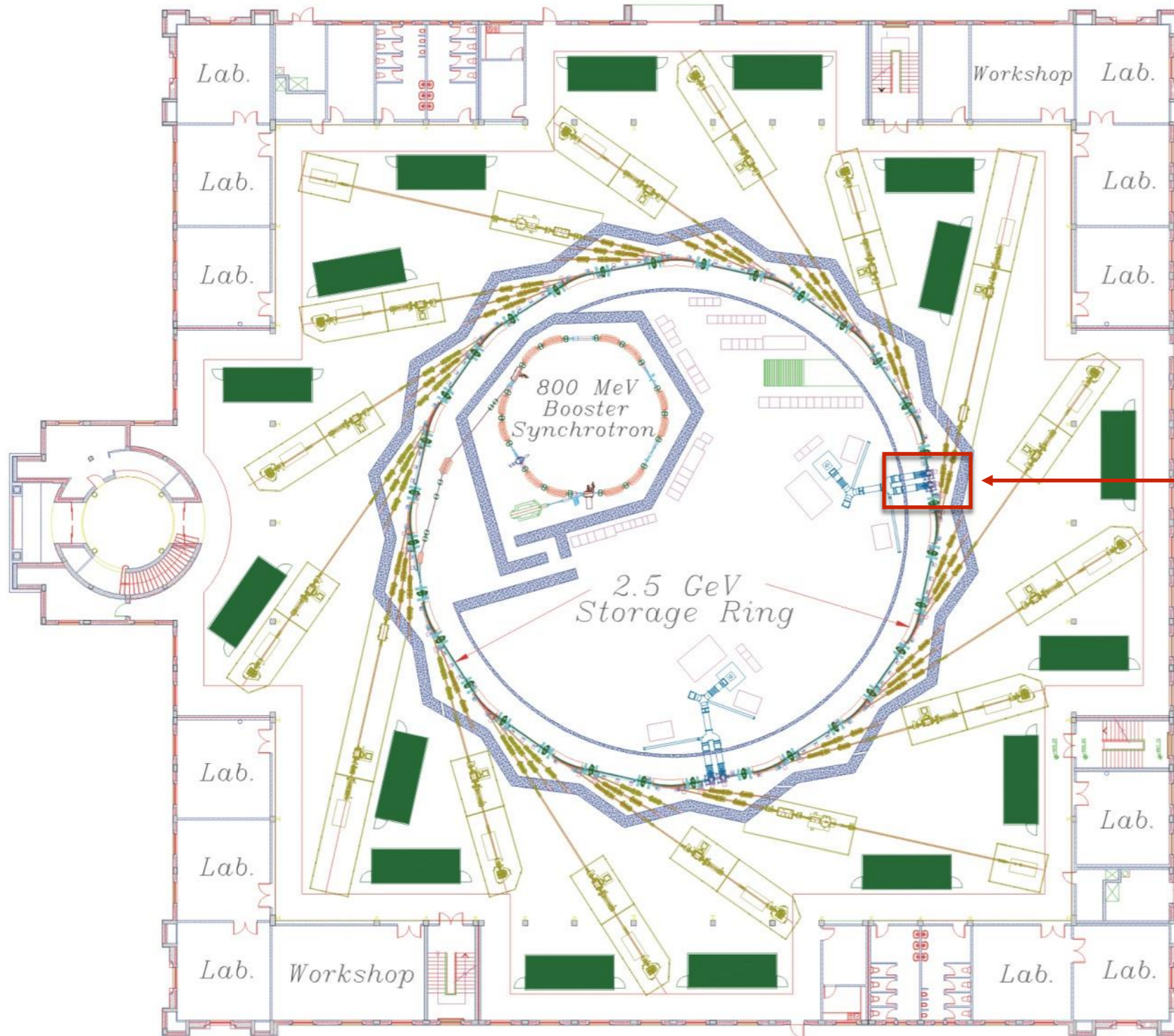
CERN is the main contractor, coordinates the delivery of the magnet system.



16 Dipole magnets (CERN)

+ 64 quadrupole magnets  
+ 64 sextupole magnets

# Other important components



RF cavities  
(compensate for lost energy)

Vacuum pumps  
(no scattering)

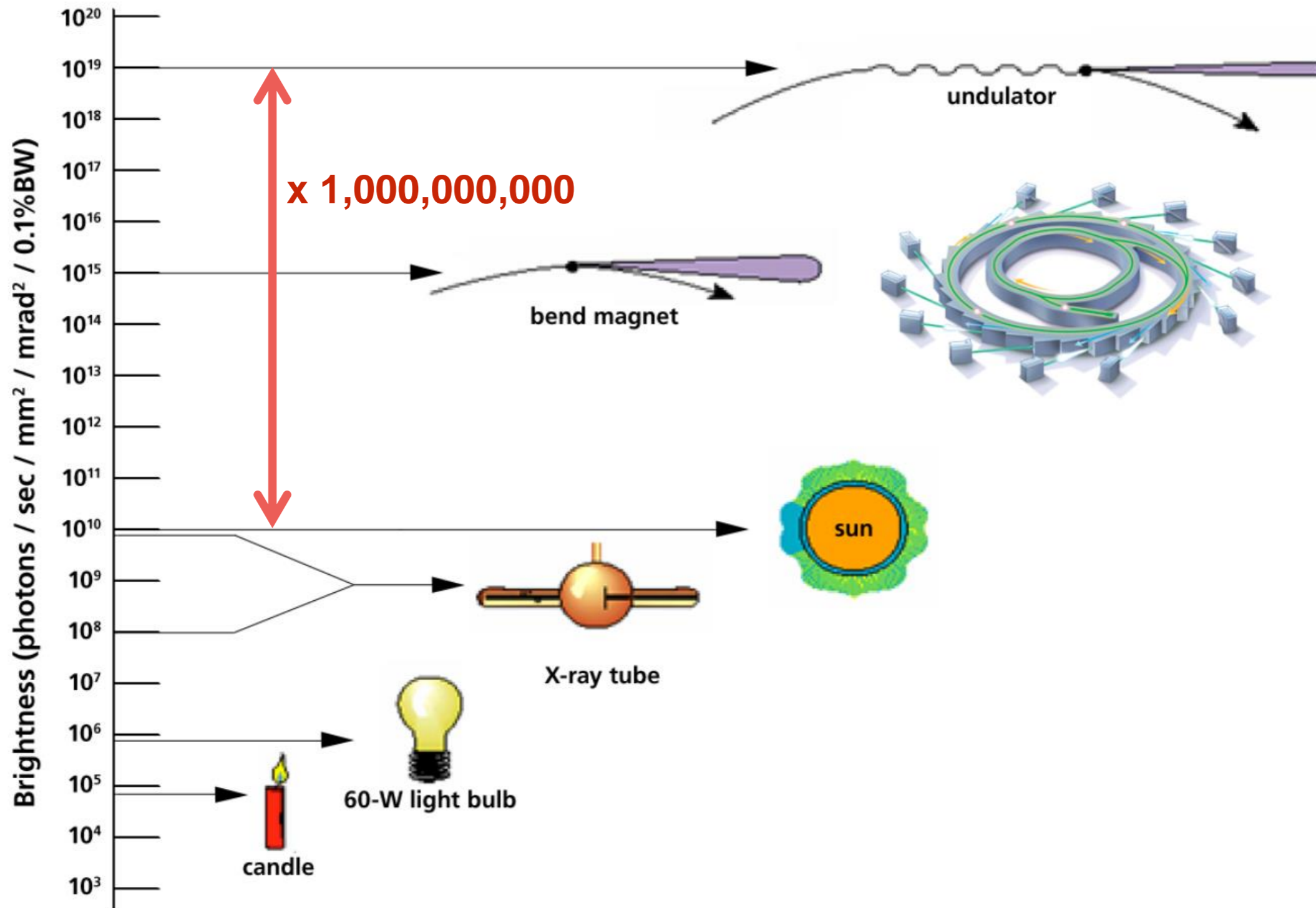
- ★ What is SESAME?
- ★ Production of synchrotron light
- ★ SESAME components
- ★ **Synchrotron light spectrum for experiments**



# Animation: emission of synchrotron radiation

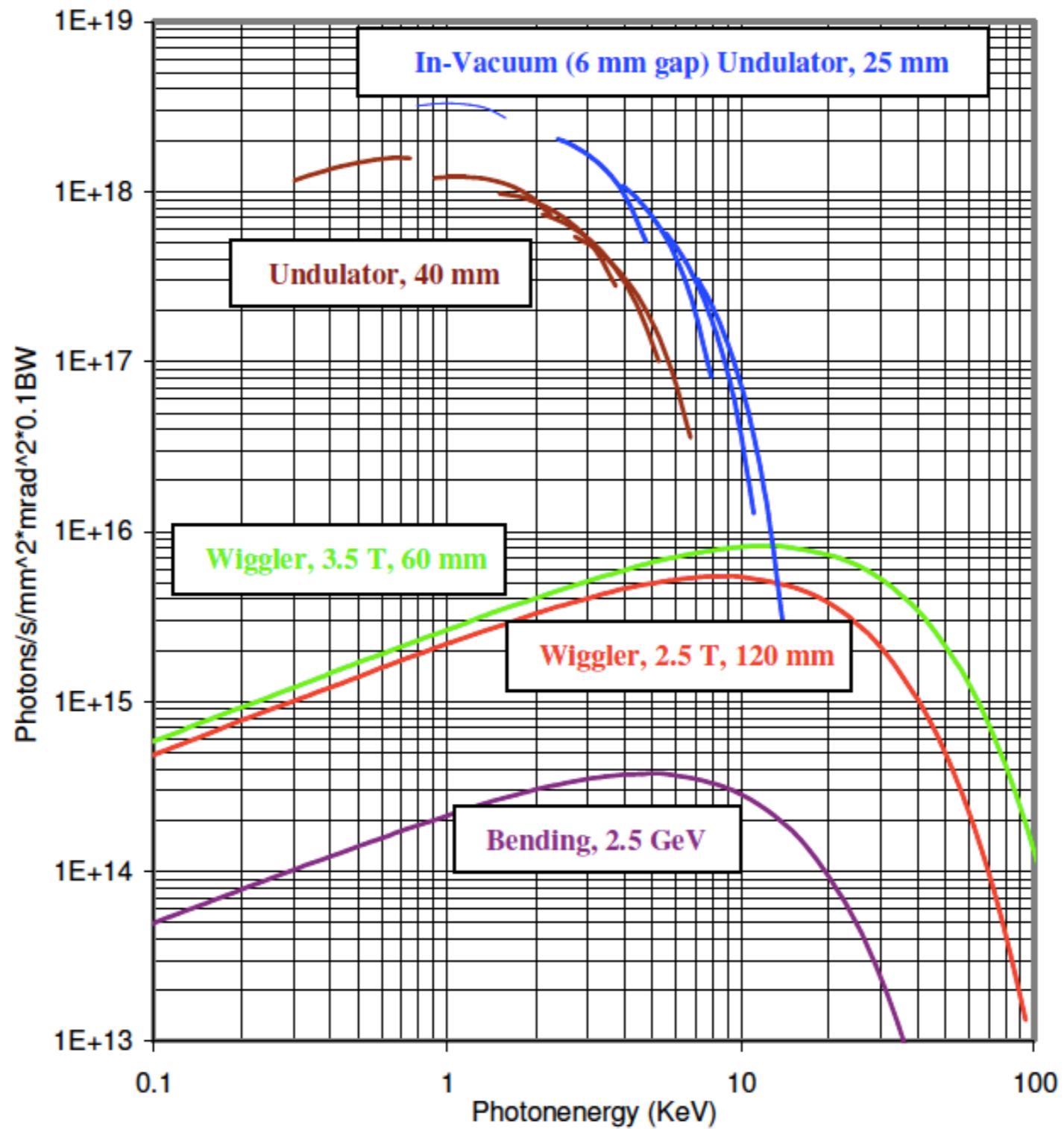


# Synchrotron light is very, very bright

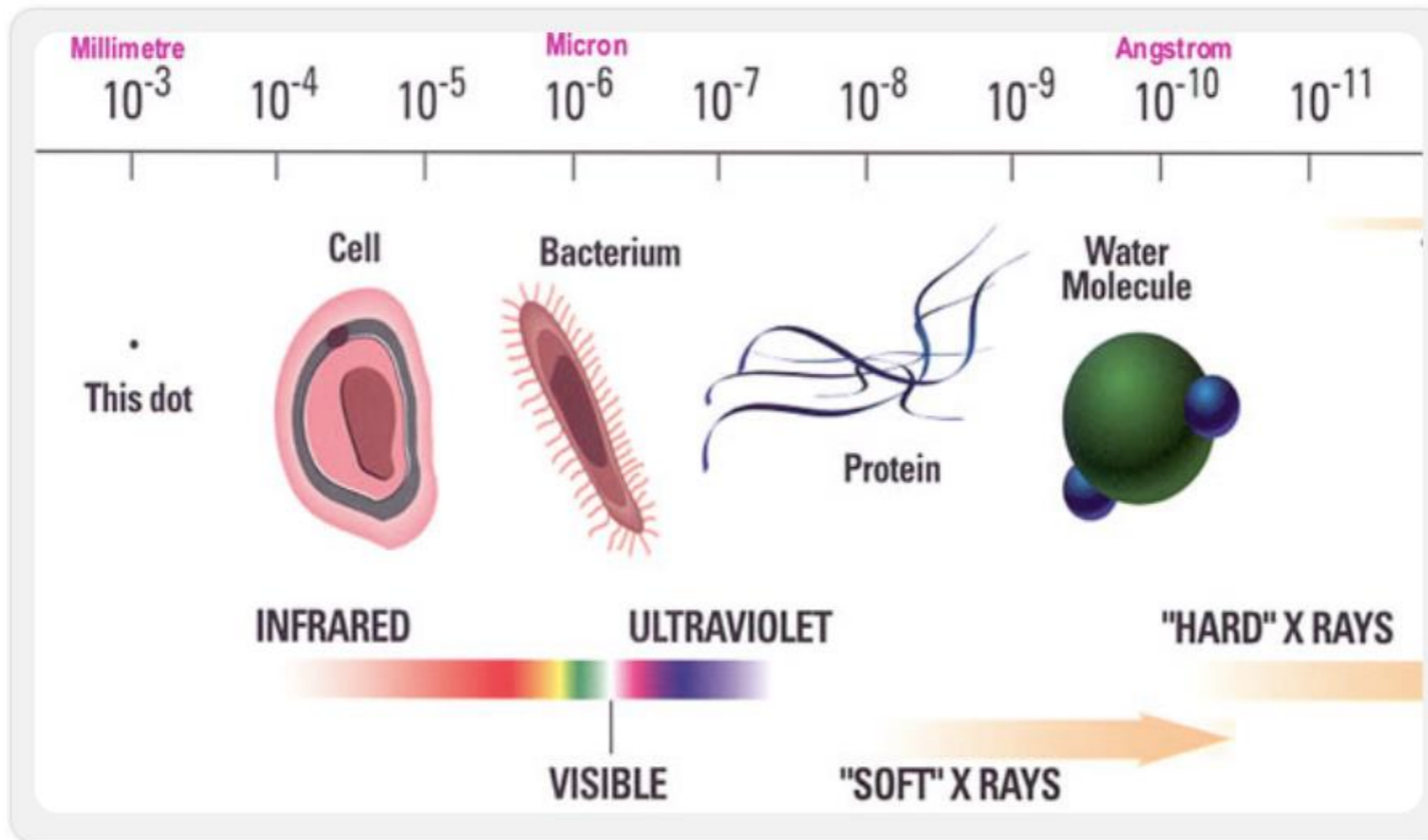


**Brightness of the light produced by the Australia Synchrotron**  
*Image courtesy: Australian Synchrotron, State of Victoria*

# Brilliance (“concentration”) of SESAME light



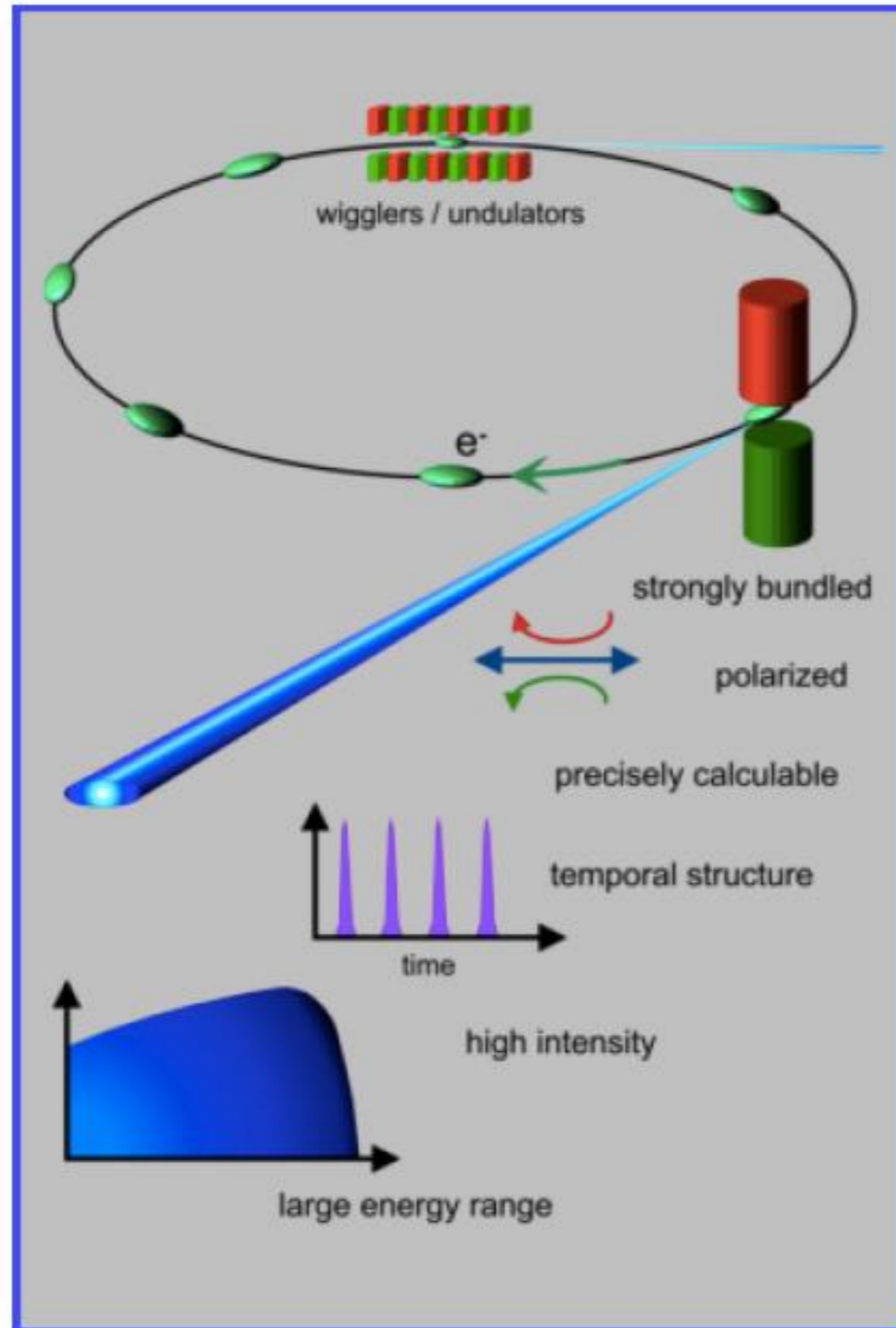
# Synchrotron "light" covers a wide range of wavelengths



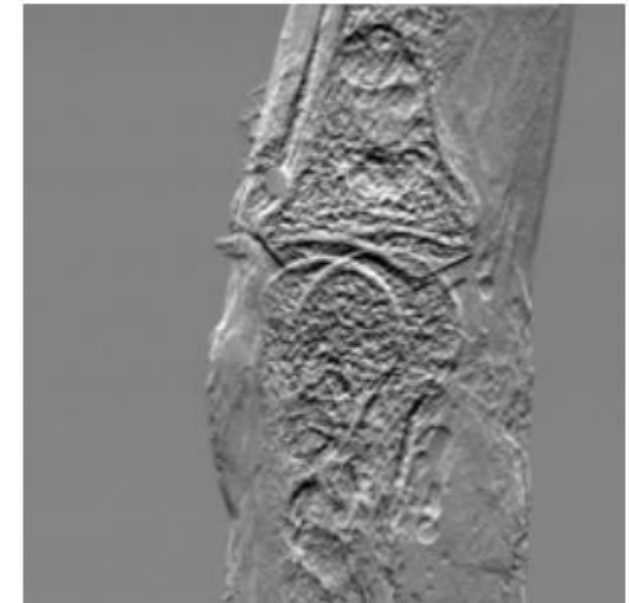
## WIDE RANGE OF EXPERIMENTS:

- Material science
- Molecular biology
- Archeology
- Medicine
- Environmental studies
- AND MANY OTHERS

# Advantages of synchrotron light sources



# ... incredibly detailed pictures



A conventional X-ray image of a human finger joint

A synchrotron X-ray image of a human finger joint

A synchrotron phase contrast X-ray image of a human finger joint

*Image courtesy: Australian Synchrotron, State of Victoria*

# World-class tool for many fields of science

(Talk by H. Abualrob)

