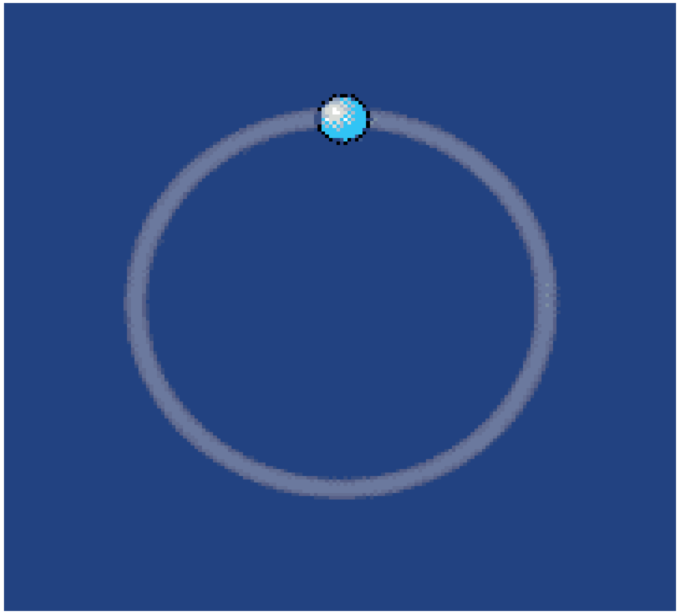
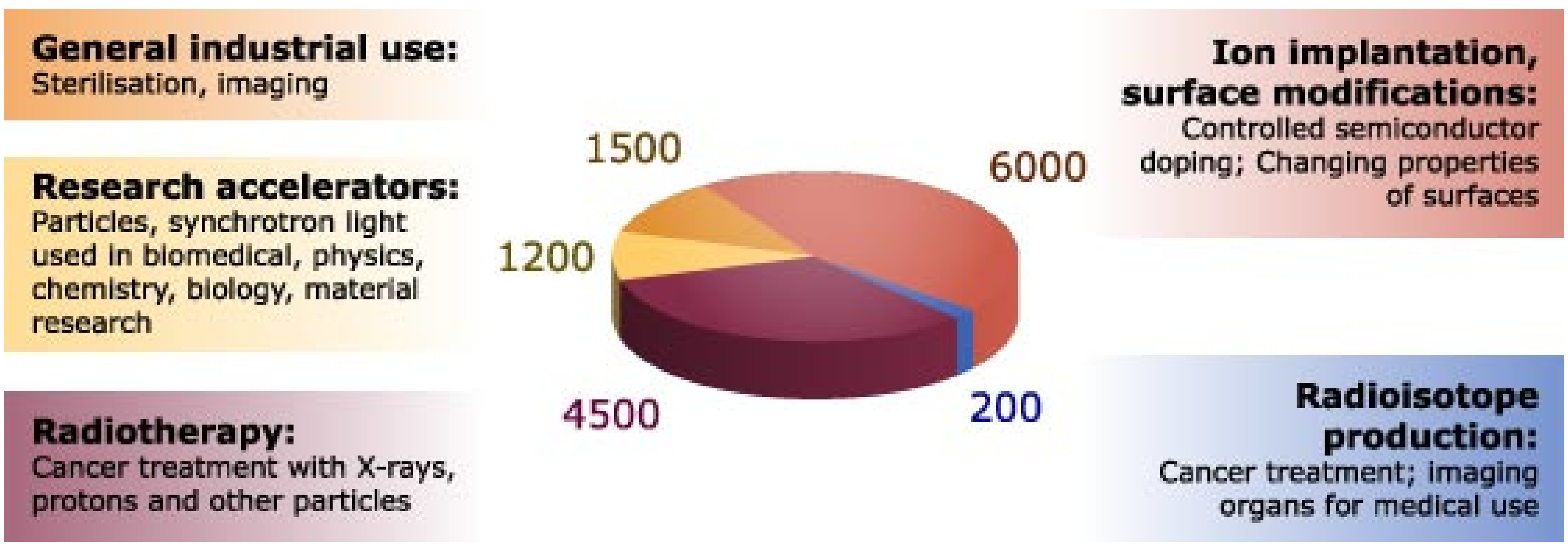
The emission of "parasitic" electromagnetic light by accelerated (bending) relativistic charged particles

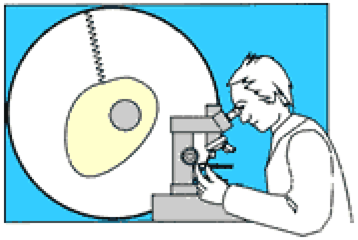


This "parasitic" light is the Synchrotron Radiation

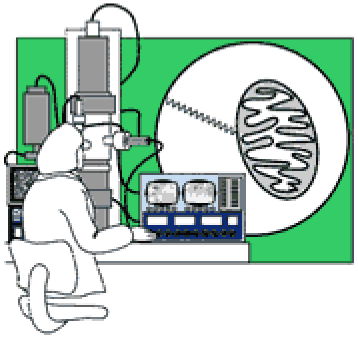
Accelerators and their applications



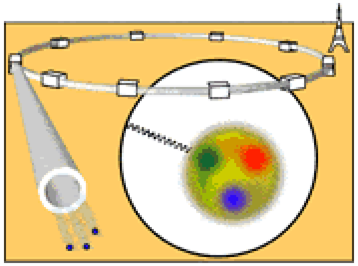
Microscopy of matter



The living cell is commonly studied by means of an optical **microscope** which receives scattered photons of visible light.



Sub-micron objects such as the constituents of a living cell are often investigated in **electron microscopes** where electrons, accelerated typically to a few hundred kilovolts, are used to hit the objects and scatter from them.



Quarks and leptons can be sensed down to distances of 10^{-18} meters by means of particles from **giant accelerators.**

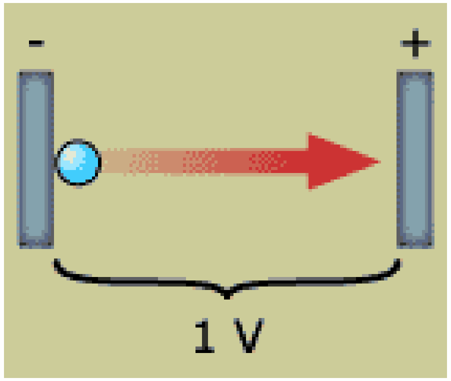
How to accelerate particles?

Electrostatic acceleration based on charges falling though dc potential

two typical examples

- Cockroft Walton (Particle energy <2 MeV)
- Van de Graaff   (,,   ,,   <20 MeV)

PINSTECH's 250 keV accelerator is also an electrostatic accelerator



The electron volt

1 MeV = 10^6 eV

1 GeV = 10^9 eV

1 TeV = 10^{12} eV

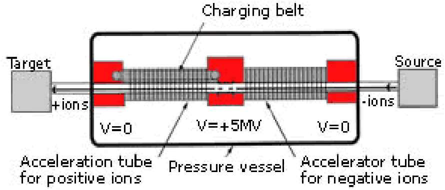
The energy of a particle is increased with 1 electronvolt (eV) when it is accelerated by 1 V.

The PINSTECH Accelerator

An experiment in accelerator design and fabrication with local resources

1. Project aim was to indigenize the ***accelerator technology***
2. Started with PC1 for Rs. 30 m in 1989
3. The main machine built 1989-1992
4. On the job training to 20 scientists and more than 30 technicians
5. Developed new ion and cluster sources and related diagnostics
6. 20 international publications in last 5 years with more than 50 presentations

Electrostatic Van de Graaf type accelerators



One of the biggest tandem accelerators was used for many years at Daresbury in the United Kingdom. Its acceleration tube, placed vertically, was 42 meters long and the centre terminal could hold a potential of up to 20 million volts.

Cockroft and Walton's 1951 Nobel Prize on the "Transmutation of atomic nuclei" by electrostatic

Cockroft and Walton's 1951 Nobel Prize on the "Transmutation of atomic nuclei" by electrostatic accelerator

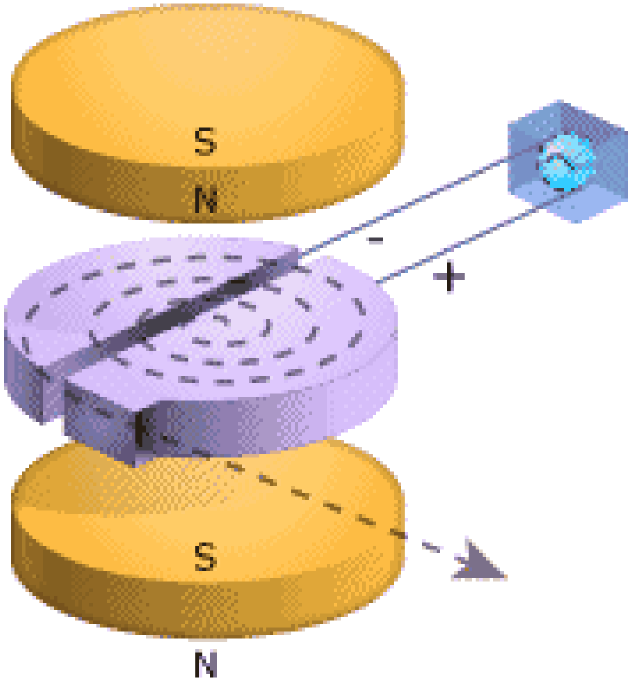

0 eV/c
1 MeV/c
1 GeV/c
1 TeV/c
NOTHING CAN
BE DETECTED...


0 eV/c
1 MeV/c
1 GeV/c
1 TeV/c
λ=10-12 m
ATOMS DETECTED!


0 eV/c
1 MeV/c
1 GeV/c
1 TeV/c
λ = 10-15 m
NUCLEUS DETECTED!


0 eV/c
1 MeV/c
1 GeV/c
1 TeV/c
λ=10-18 m
QUARKS DETECTED!

Cyclotron-the 1st cyclic accelerator invented by Livingston (Nobel prize in 1939)

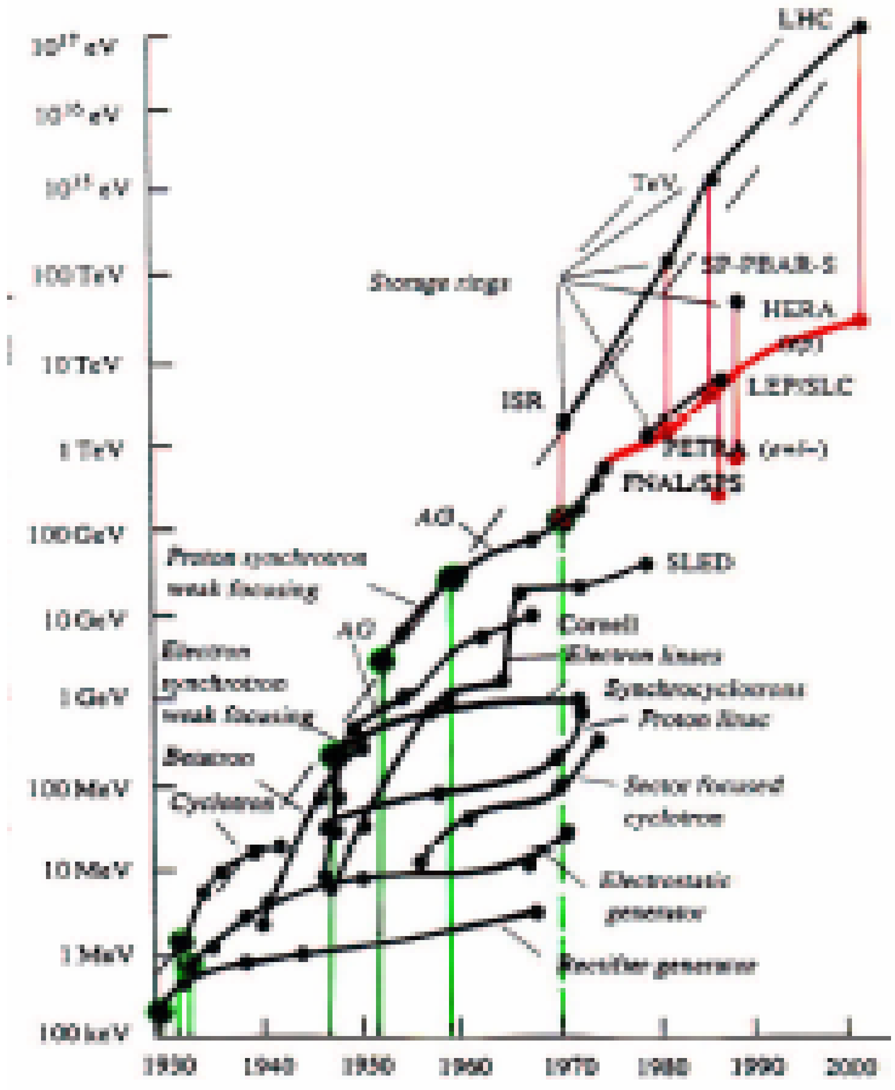


Principle of the cyclotron

1. The ionization of a gas confined in the centre results in ions which are accelerated by a voltage of fixed frequency equal to the ion frequency of rotation in the magnetic field.
2. The magnetic field lines are directed towards the lower magnet pole implying that positively charged ions circulate in the clockwise direction.
3. The ions are accelerated when they move in the gap between the electrodes inside which they move screened from the electric field.
4. When the beam of ions reaches the magnetic field boundary it is extracted from the cyclotron and formed into an external beam.

$$E = mc^2$$

The Livingston Chart of Accelerator developments

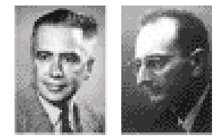


Inventions of new accelerators and high energy physics

1950

The Bevatron began to operate in **1954** and the **antiproton** was discovered in **1955**.

The Nobel Prize in Physics 1959



Segrè Chamberlain

1960

The inner structure of **nucleons** (protons and neutrons) was discovered at SLAC in **1969**.

The Nobel Prize in Physics 1990

Friedman Kendall Taylor

1970

Discovery of **J/Ψ particle** (composed of charm quarks) was discovered at Brook-haven and SLAC in **1974**.

The Nobel Prize in Physics 1976

Richter Ting

1980

The **tau lepton** was discovered at SLAC in **1976**.

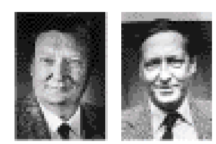
The Nobel Prize in Physics 1995

Perl

1990

The **W and Z particles** were discovered at the proton-antiproton collider at CERN in **1983**.

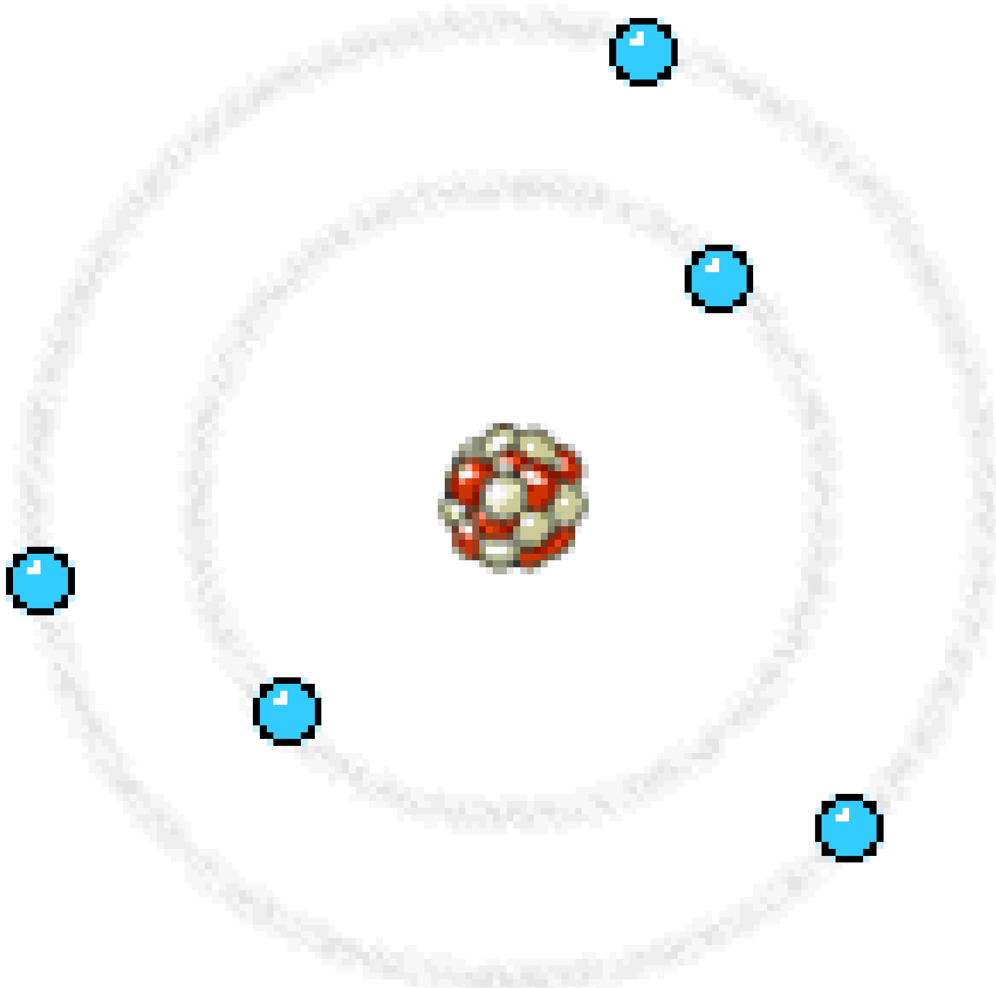
The Nobel Prize in Physics 1984

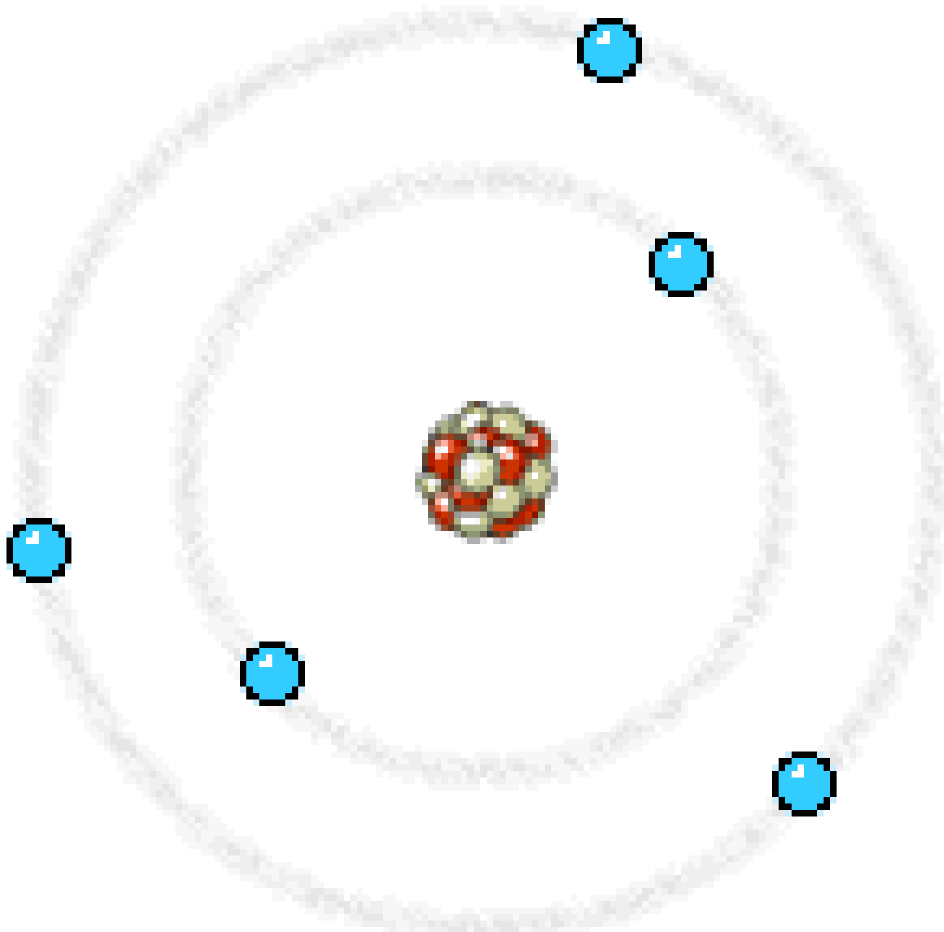


Rubbia van der Meer

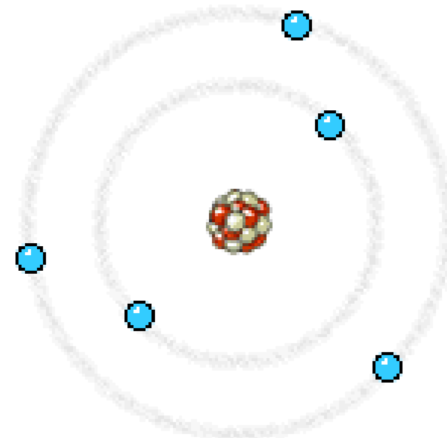
The first direct evidence for the **top quark** was announced at the Tevatron at Fermilab in **1995**.

2000

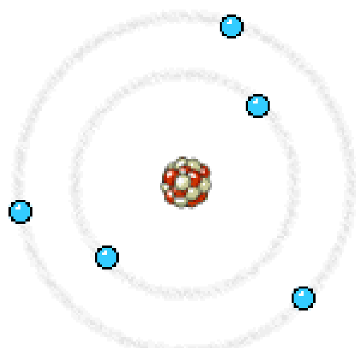




The two types of x rays



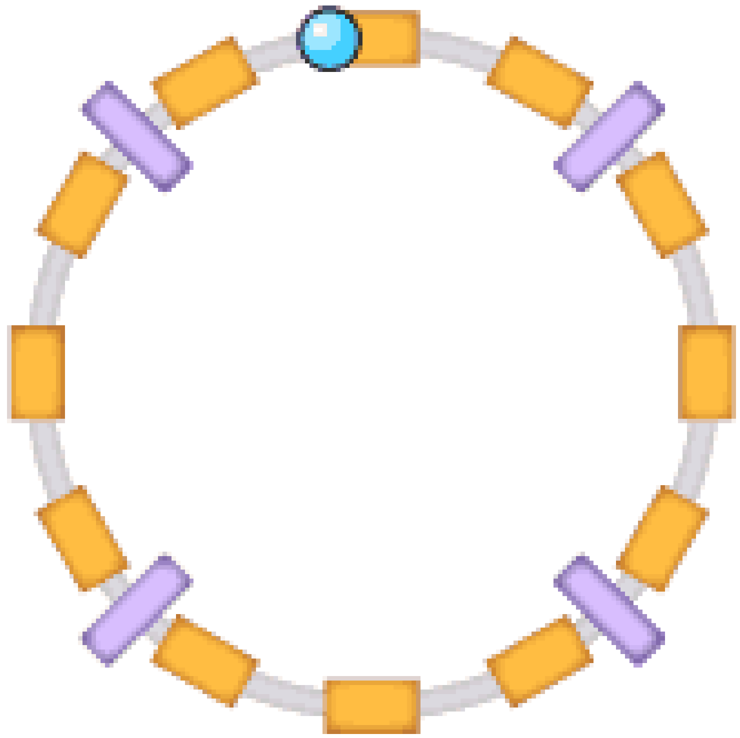
Characteristic x rays from
the core level of the atom



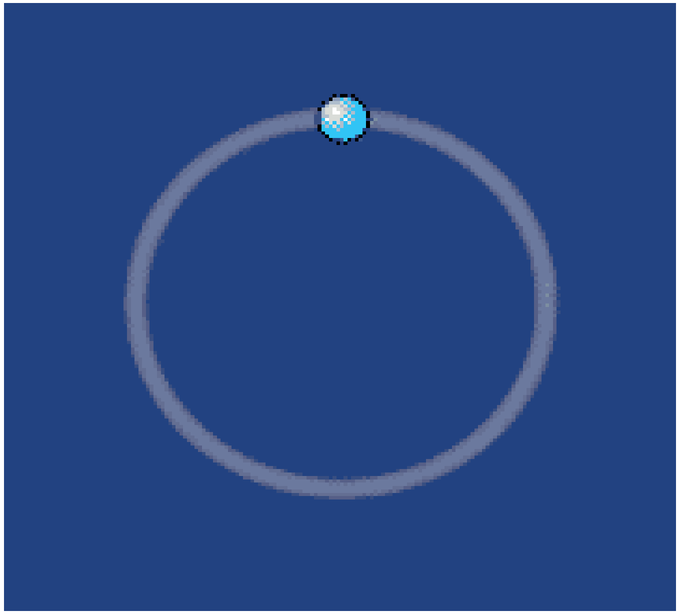
A continuum or the Bremsstrahlung
is emitted as the incoming electron
is accelerated in the field of the nucleus

A circular accelerator

with periodic momentum increase and bending with dipole magnets



The emission of "parasitic" electromagnetic light by accelerated (bending) relativistic charged particles



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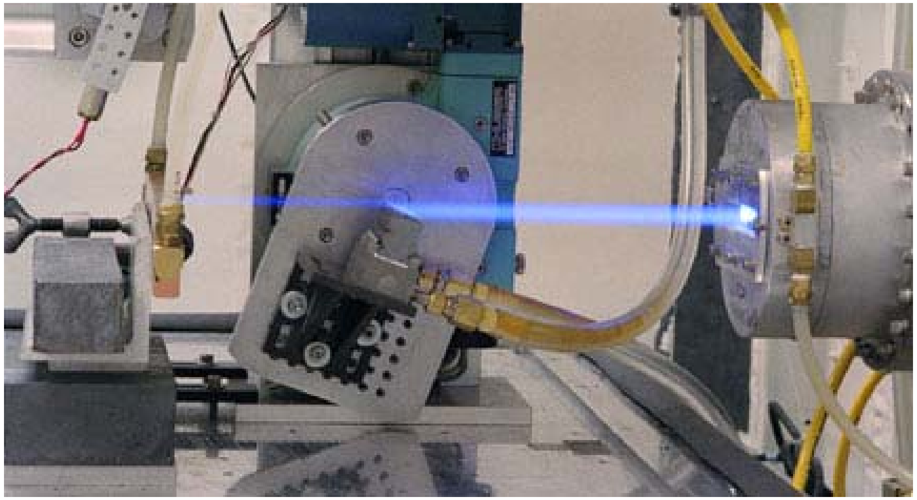
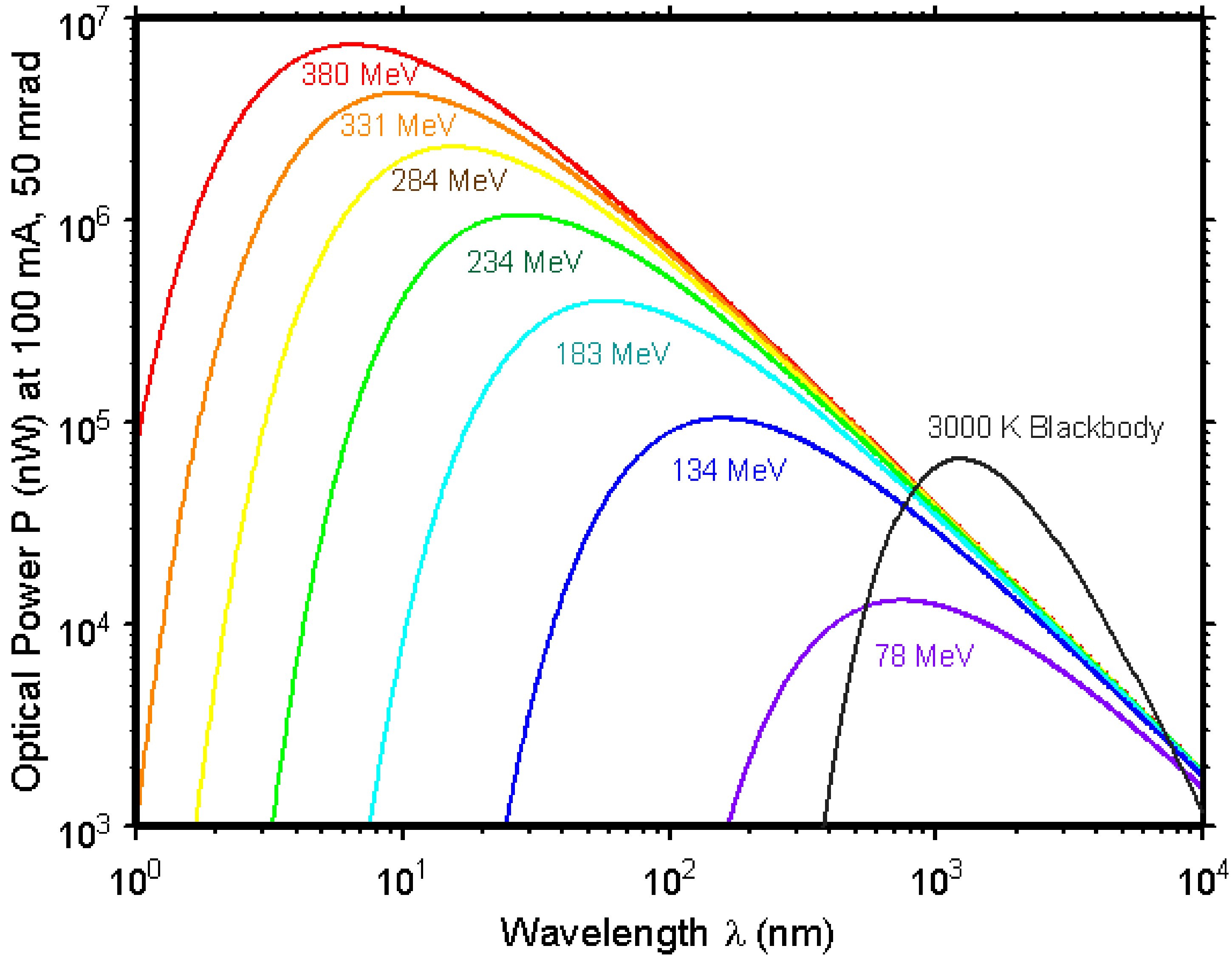
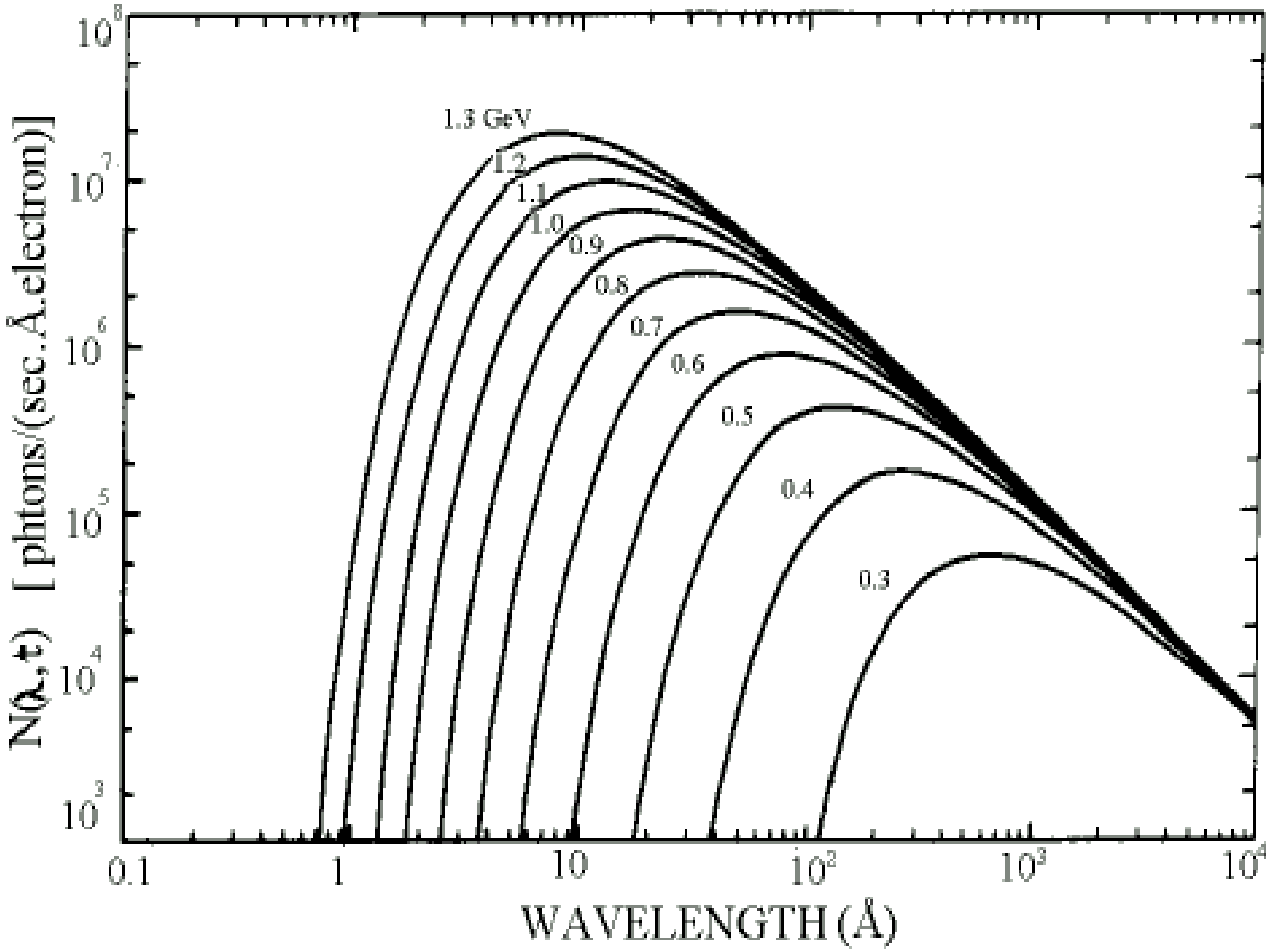


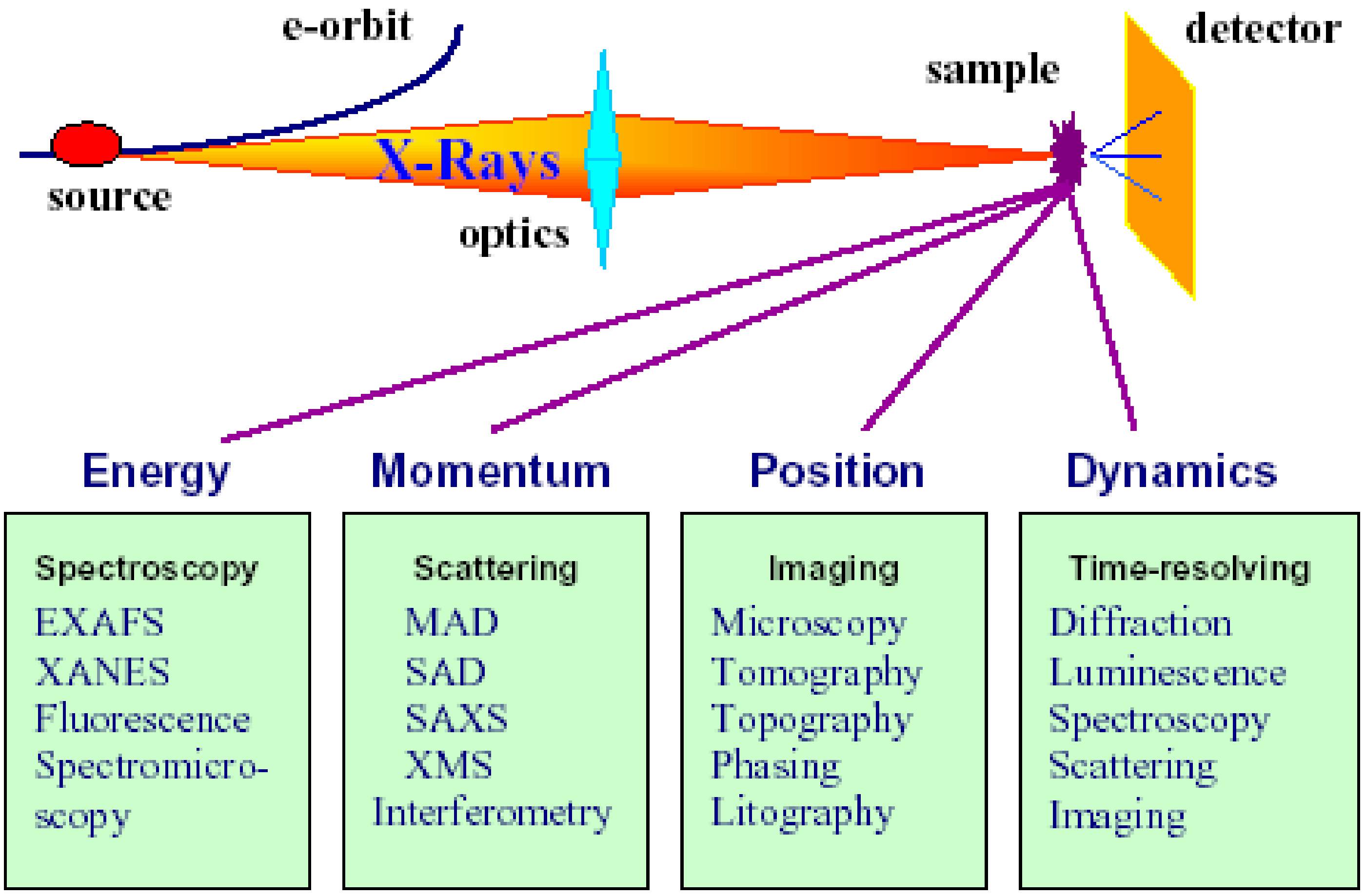


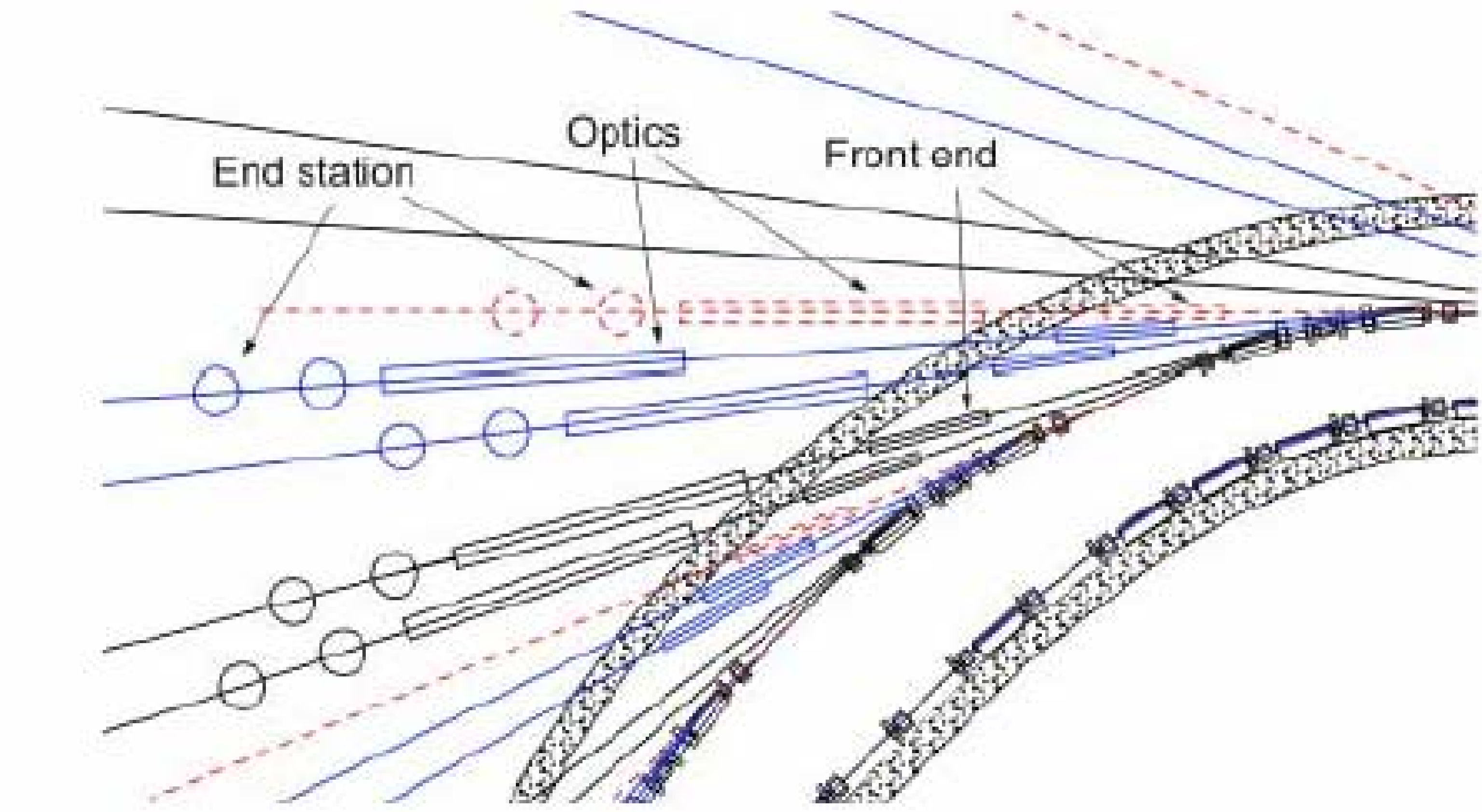
Optical Power P (nW) at 100 mA, 50 mrad
Wavelength λ (nm)
380 MeV
331 MeV
284 MeV
234 MeV
183 MeV
134 MeV
78 MeV
3000 K Blackbody



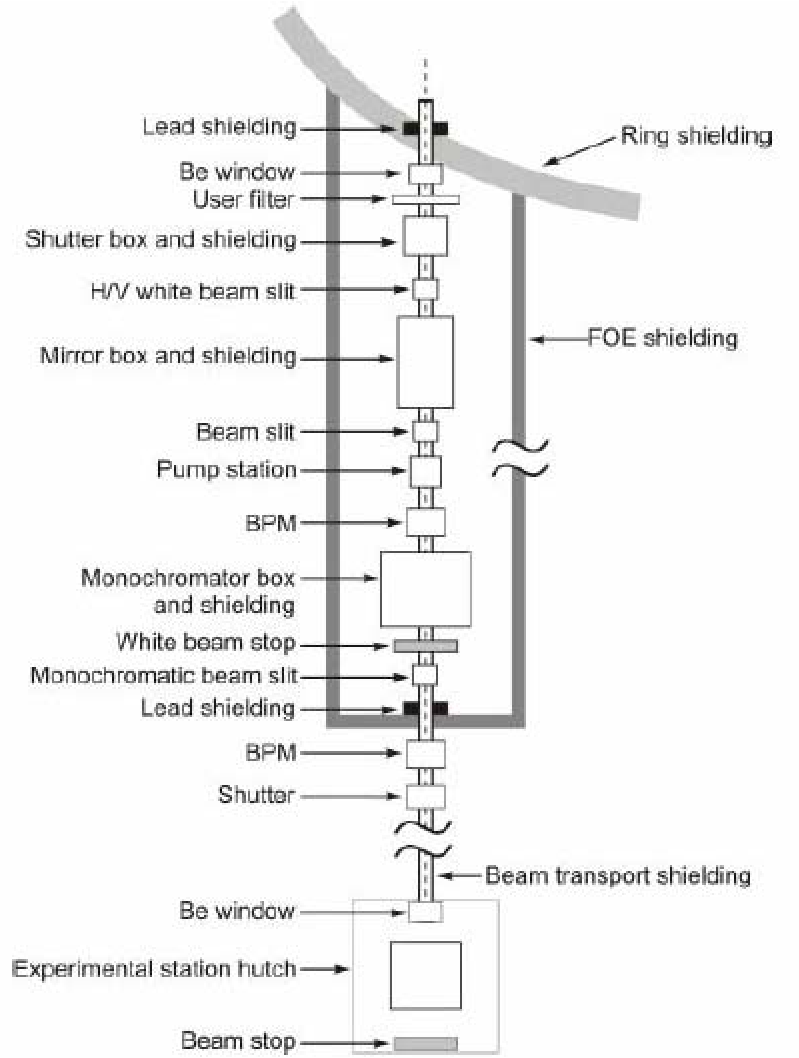
1.3 GeV
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
N(λ, t) [phtons/(sec.Å.electron)]
WAVELENGTH (Å)

Photon energy (eV)	Kind	Source	Size	Wavelength (Å)
1				10^4
	Visible light	Laser& Lamps	Cell	
10				10^3
			Virus	
10^2				10^2
	Ultraviolet		Protein	
10^3		Synchrotron Radiation		10
			Molecule	
10^4				1
	X-Rays	X-ray tube	Atoms	
10^5				10^{-1}
10^6		Radiact. sources		10^{-2}
	Gamma Rays			
10^7				10^{-3}
10^8			Nucleus	10^{-4}
10^9		Accelerators	Proton	10^{-5}


e-orbit
X-Rays
detector
sample
source
optics
Energy
Momentum
Position
Dynamics
Spectroscopy
EXAFS
XANES
Fluorescence
Spectromicro-
scopy
Scattering
MAD
SAD
SAXS
XMS
Interferometry
Imaging
Microscopy
Tomography
Topography
Phasing
Litography
Time-resolving
Diffraction
Luminescence
Spectroscopy
Scattering
Imaging

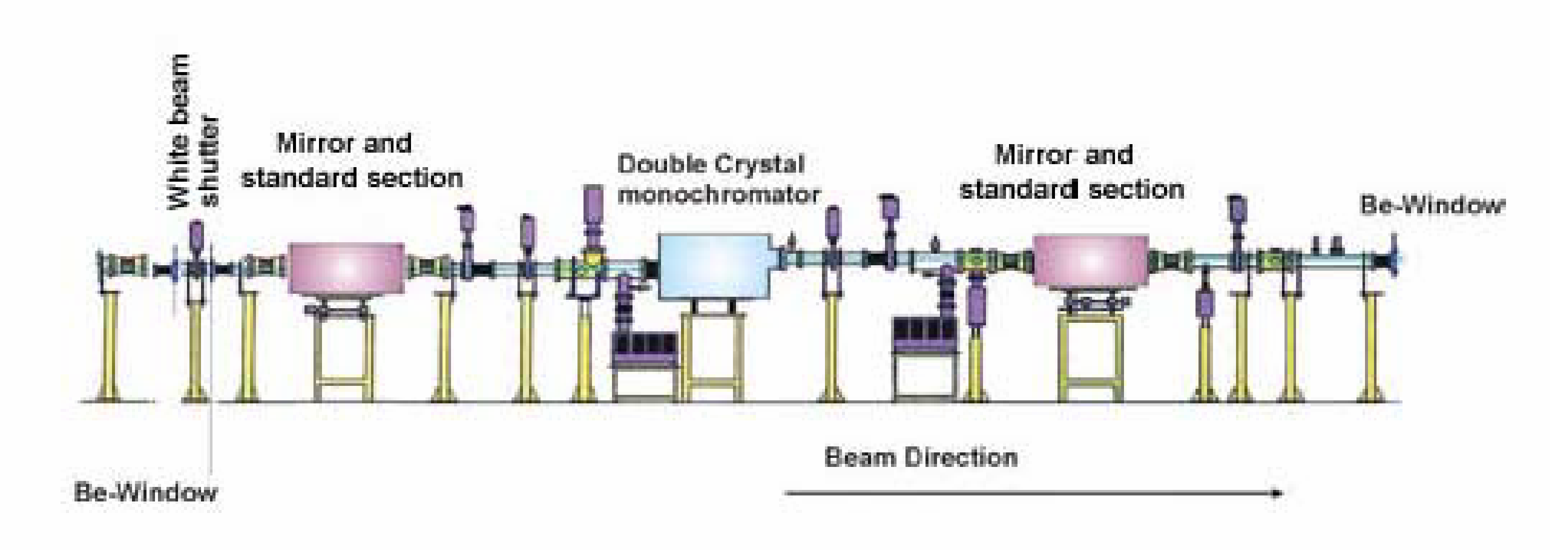


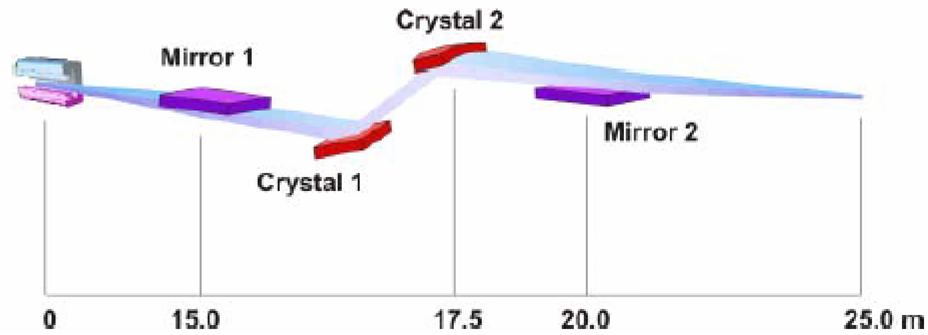
Dipole (solid) and ID (dash line) photon beams delivery system.



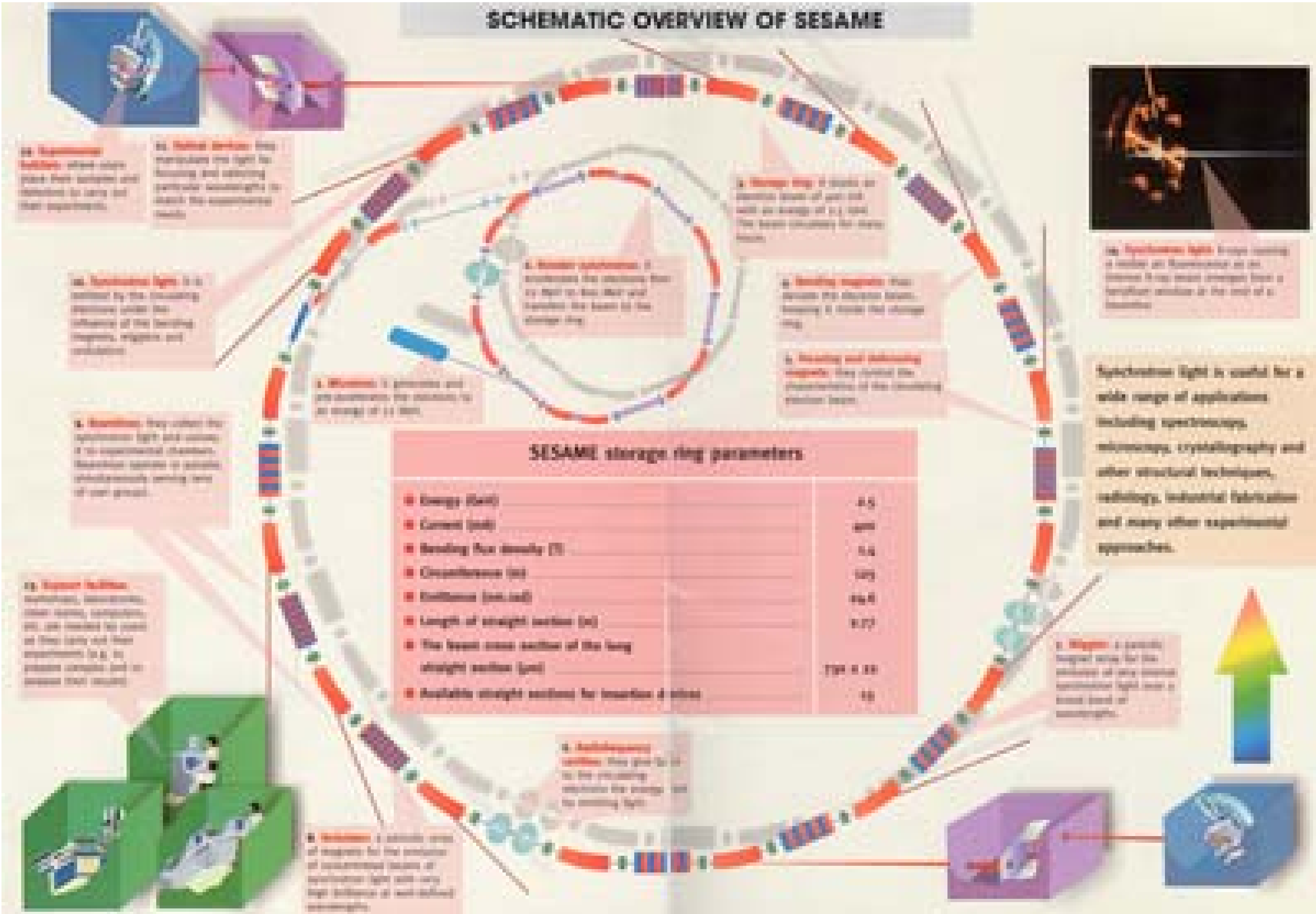
A typical scheme for a beamline

The general layout of the diffraction and scattering beamline





The X-ray optics of the beamline


SCHEMATIC OVERVIEW OF SESAME
SESAME storage ring parameters
Energy (GeV)
Current (mA)
Bending flux density (T)
Circumference (m)
Emittance (nm.rad)
Length of straight section (m)
The beam cross section of the long straight section (μm)
Available straight sections for insertion devices
Synchrotron light is useful for a wide range of applications including spectroscopy, microscopy, crystallography and other structural techniques, radiology, industrial fabrication and many other experimental approaches.

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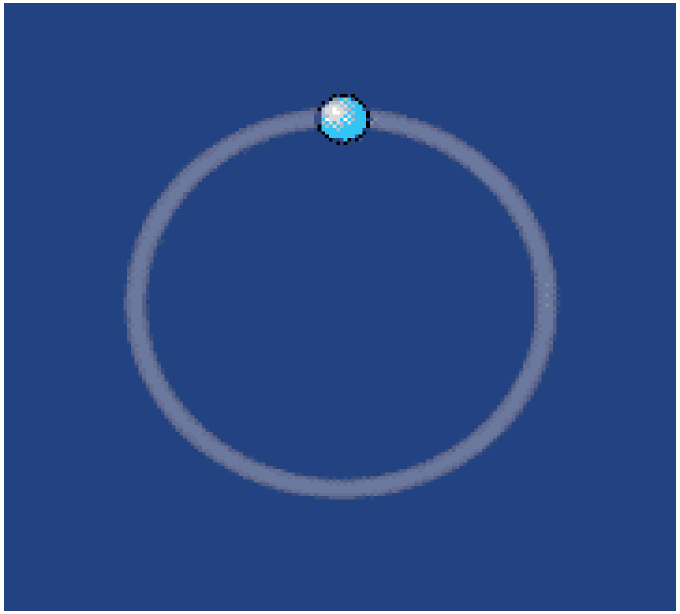

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