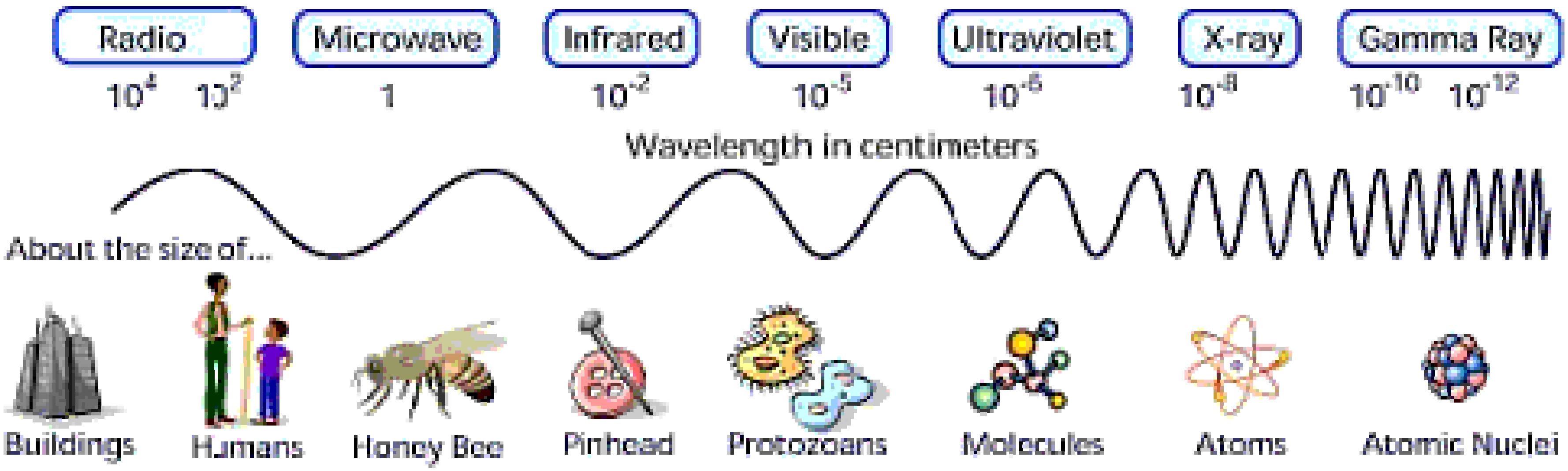
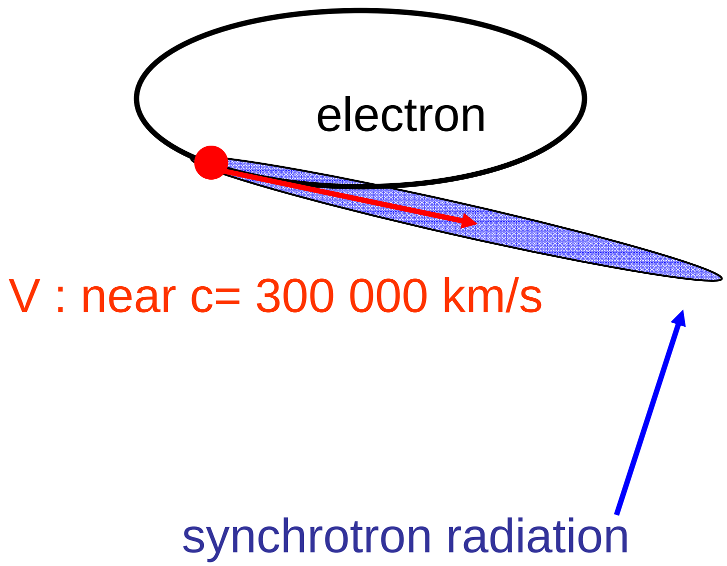
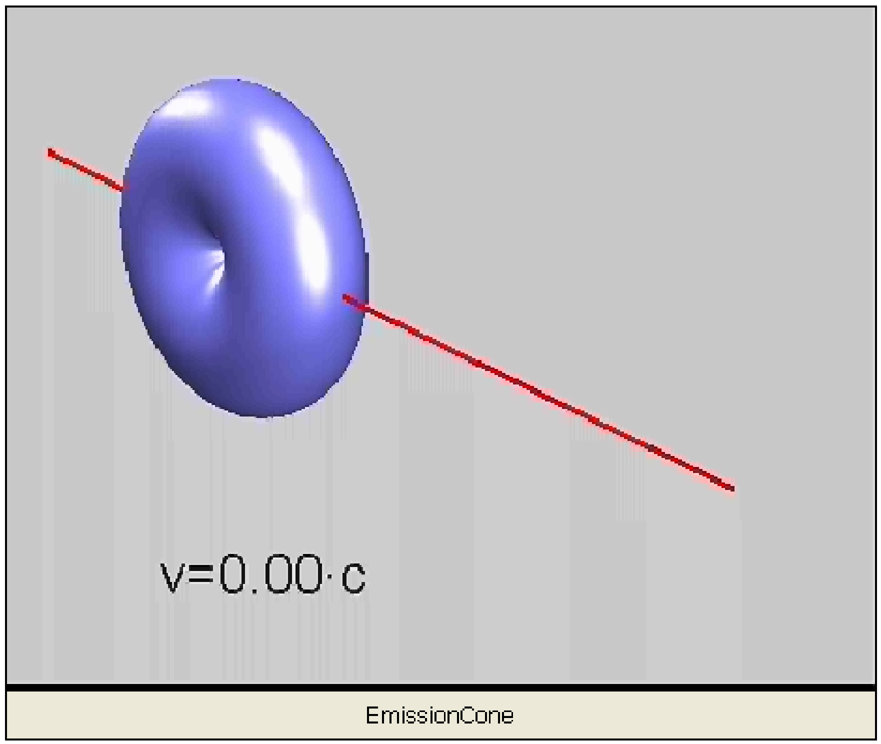
The electromagnetic spectrum

The electromagnetic spectrum: range of wavelengths

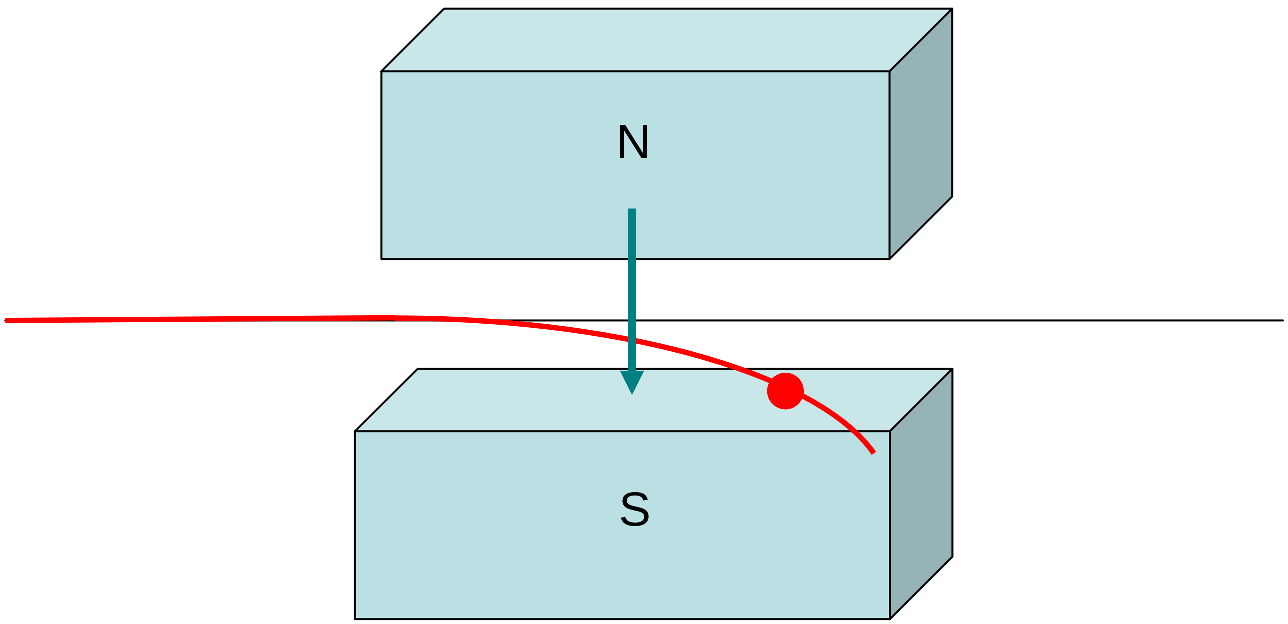


Synchrotron radiation are the electromagnetic waves emitted by a charged particle that moves in a curved trajectory at a speed close to the speed of light.





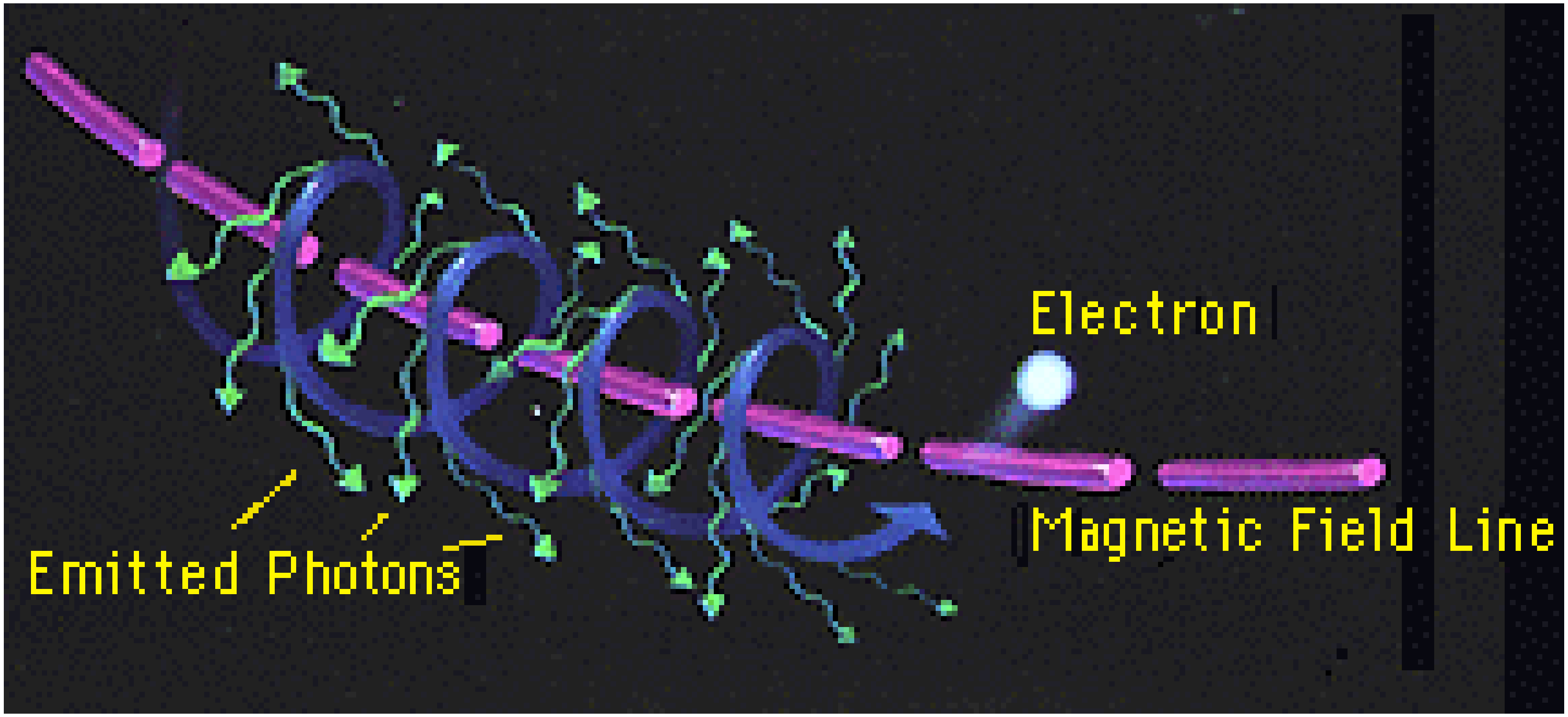
A magnetic field curves the trajectory of a charged particle



Electrons rotate around magnetic field lines

Synchrotron: “magnetic spin radiation”

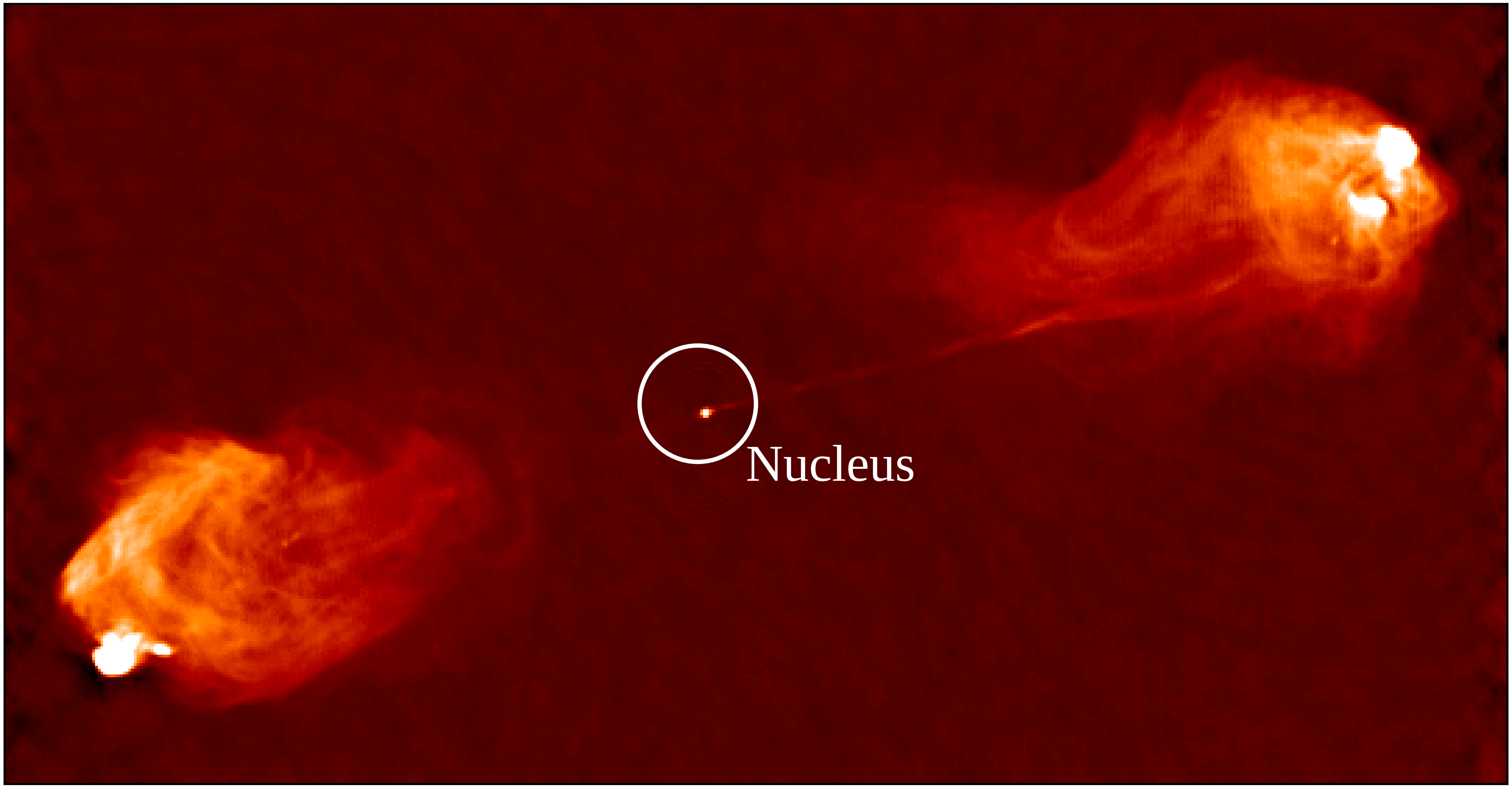
• Caused by a relativistic electron as it spirals around a magnetic field line



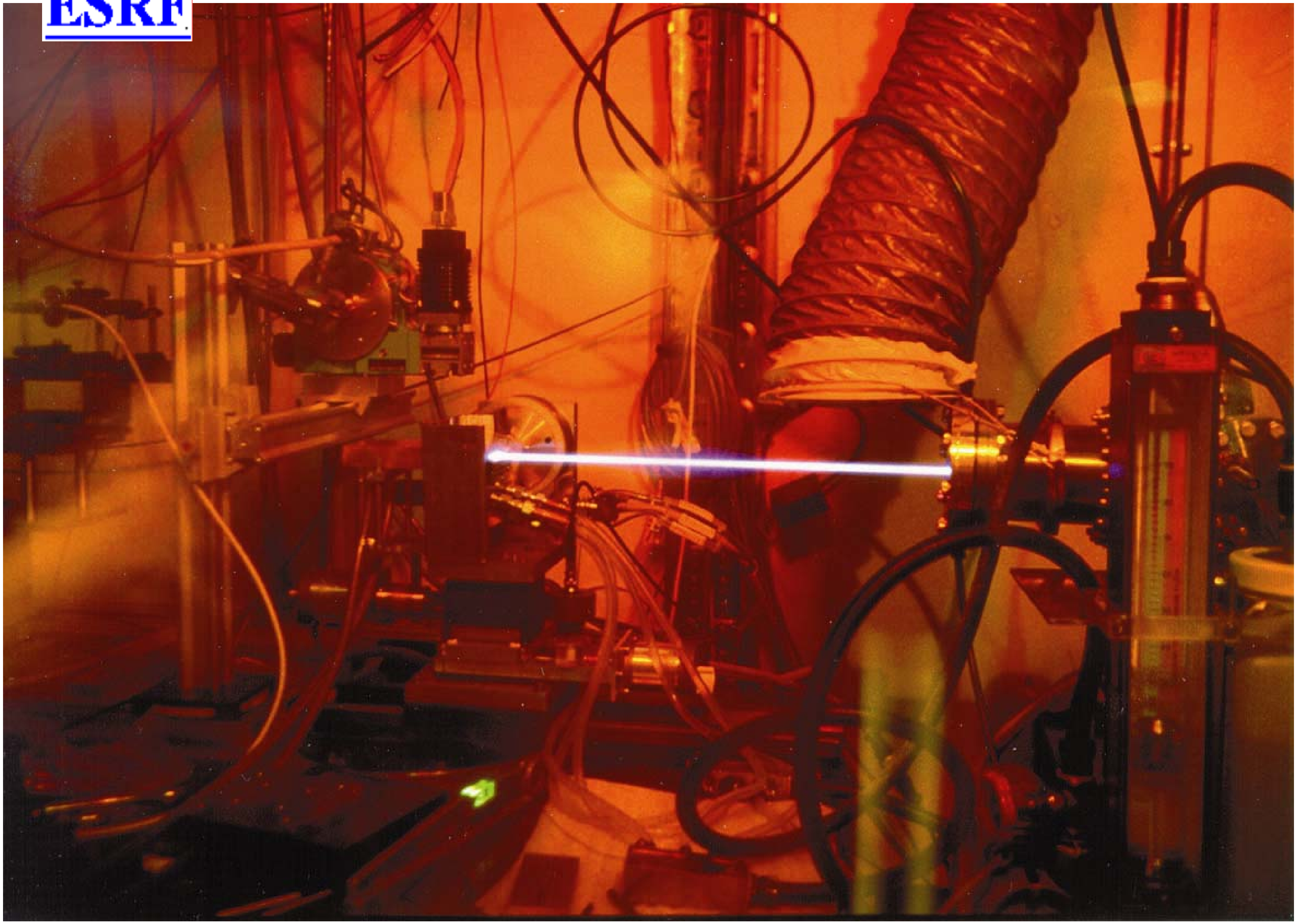
Nearby Radio Galaxy:Cygnus A

- Distance of 2000 Mpc = 6600 light years
- v = 16811 km/sec
- Observed in radio (many frequencies), optical, and x-ray
- Theory for origin of synchrotron emission comes from high velocity flow from AGN:
  - Flow “shocks and terminates”
  - Kinetic energy goes to relativistic electrons and **B** fields (Blandford and Rees 1974, Scheuer 1974)

A tour of Cygnus A

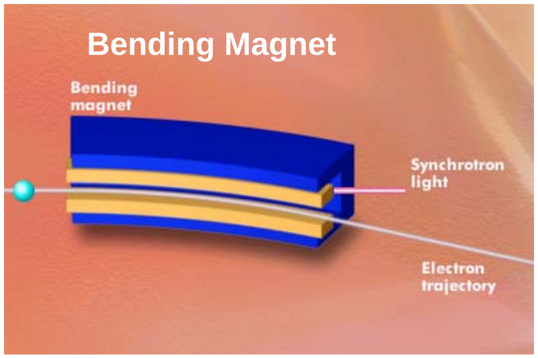


Aqui a la Terra, la radiacio sincrotro es “fabrica” a laboratoris especialitzats amb acceleradors circulars. Aixo es fa perque es molt util per fer experiments de reserca cientifica .



Synchrotron Radiation

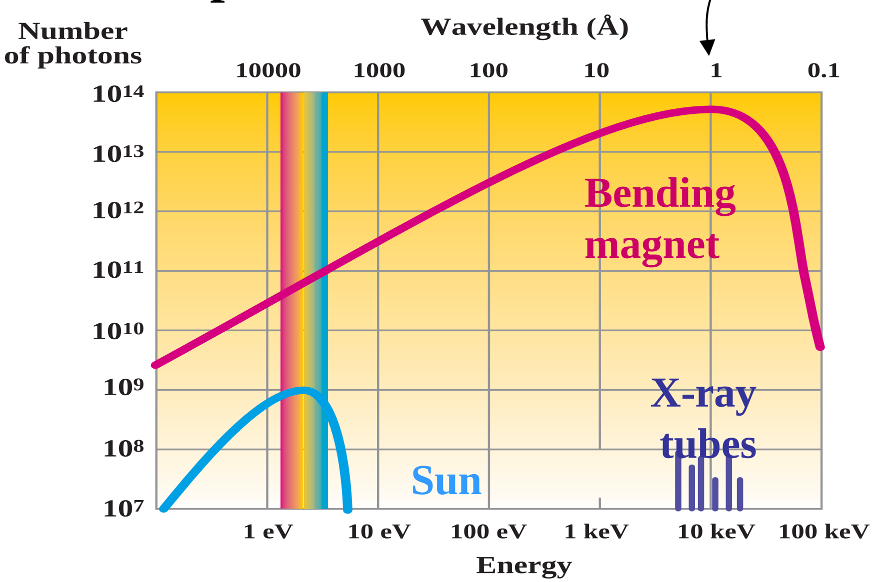
Synchrotron radiation is produced when relativistic electrons are curved by means the Lorentz force generated by an applied magnetic field



The angle of aperture of the radiation is very small : $1/\gamma$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

Emission spectrum



Characteristic energy ½ total power:

$$E_c(\text{keV}) = 0.66\, B(\text{T})\, E^2 (\text{GeV})$$

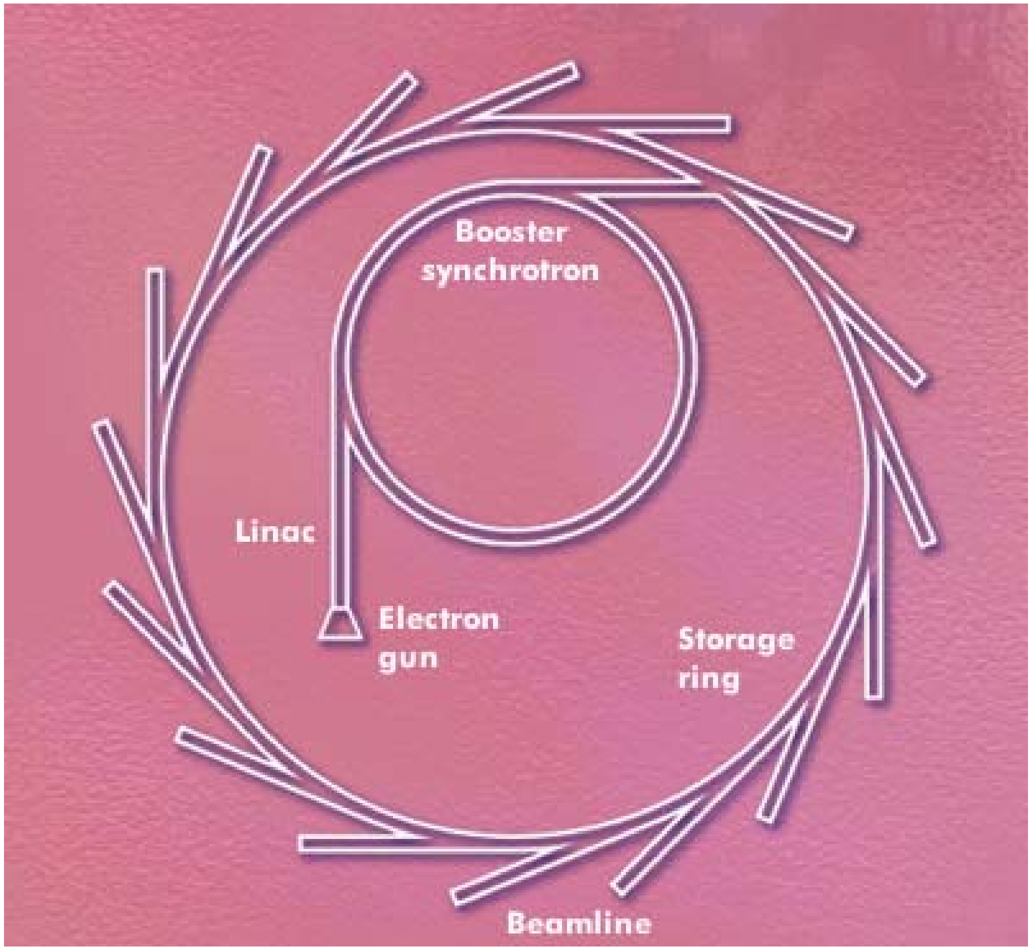
B=1, E=3 , Ec = 5.94 keV

λ_c= 2.0 Å

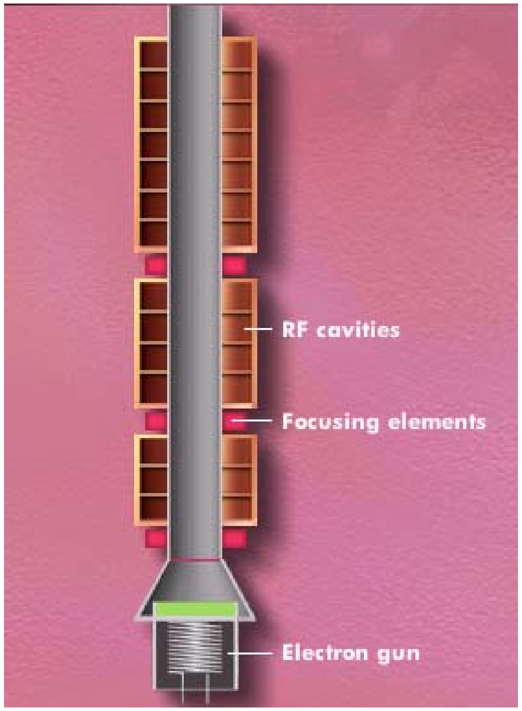
B=1 , E= 6 , Ec = 23.8 keV

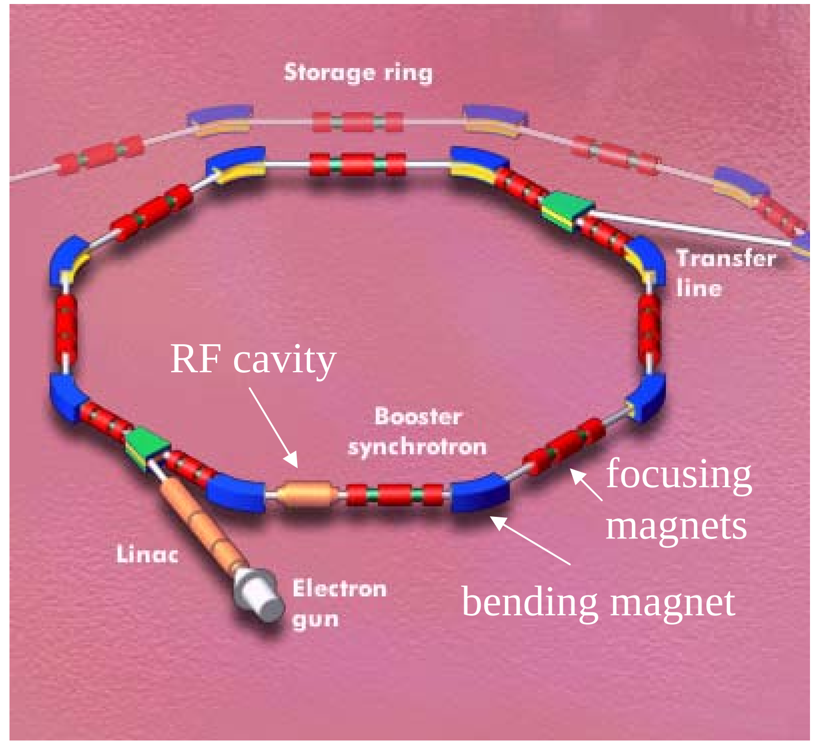
λ_c= 0.52 Å

Accelerator complex to produce SR



electron accelerators : Linac and Booster





Energy : 0 – 2 MeV

bunches of electrons

Energy : 2 MeV - 3 GeV

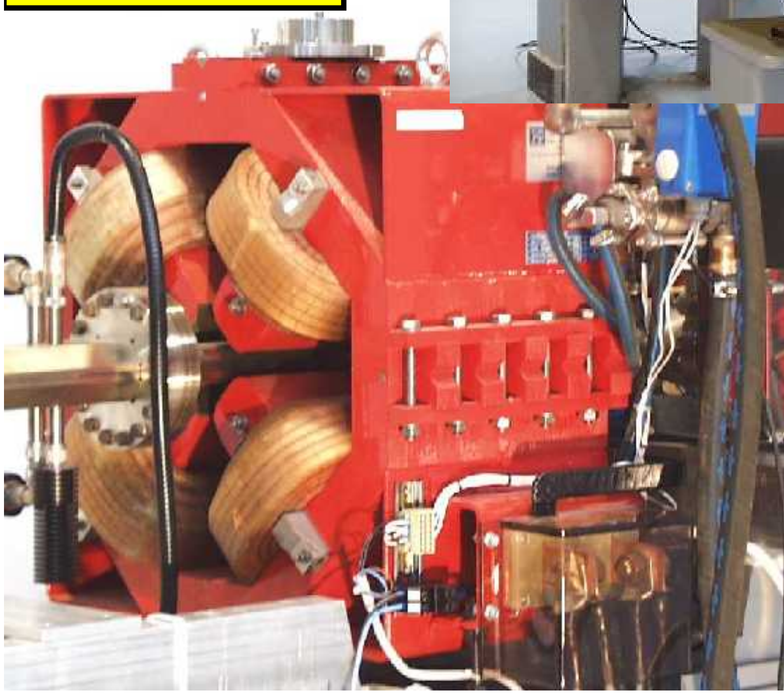
100 MeV LINAC at SLS

TUNNEL
WITH BOOSTER AND STORAGE RING

ALBA

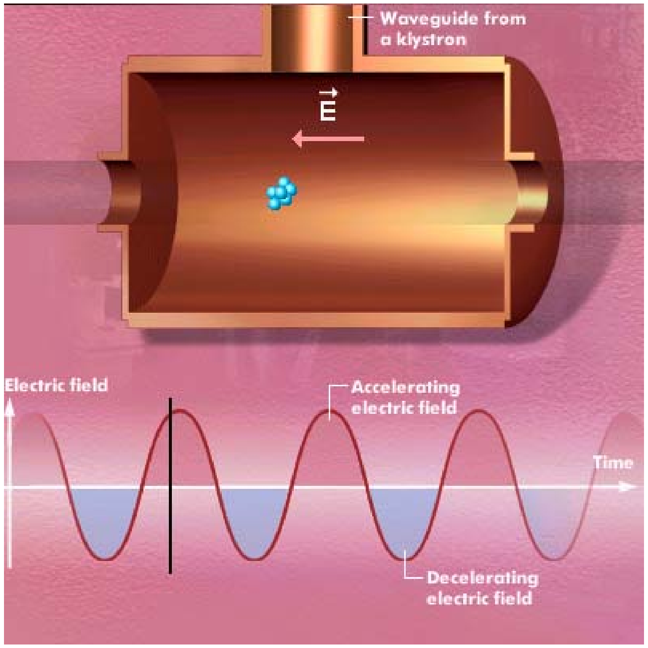
Bending magnet

Quadrupole

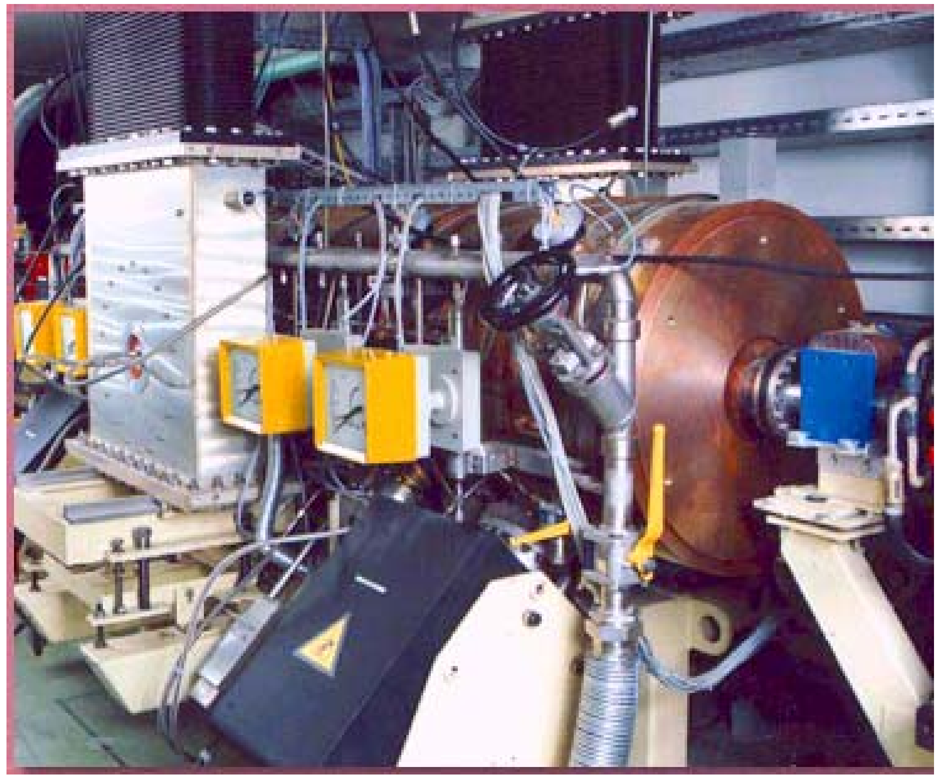


Sextupole

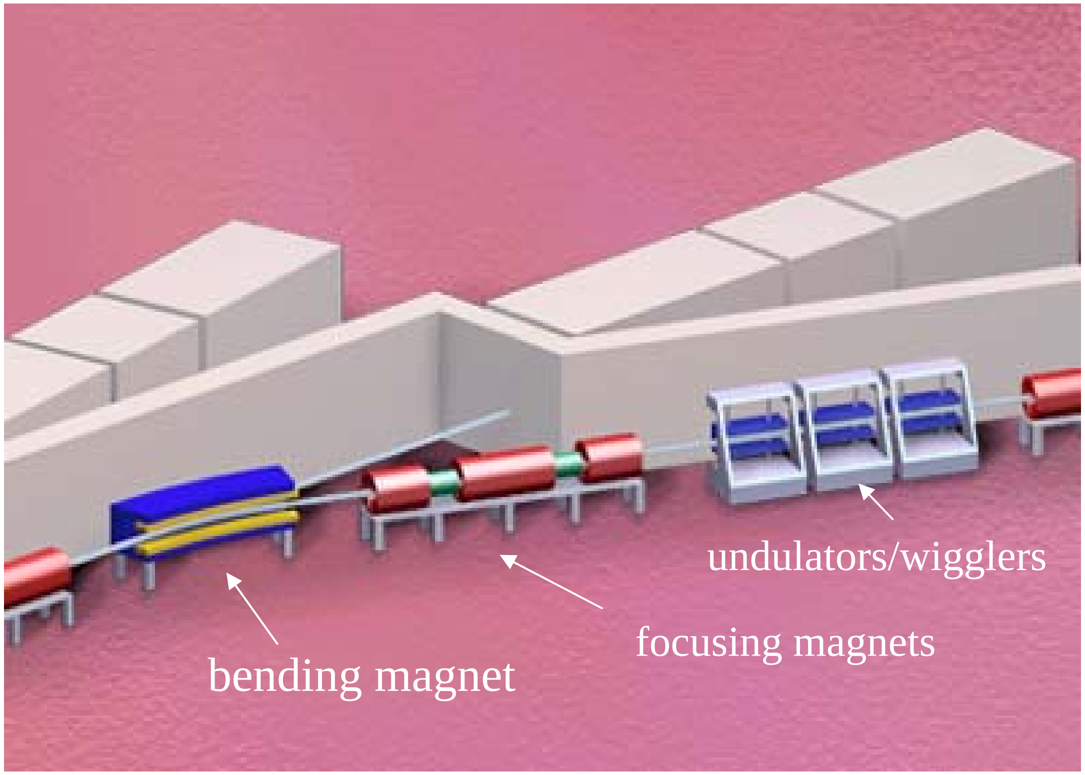
RF cavities

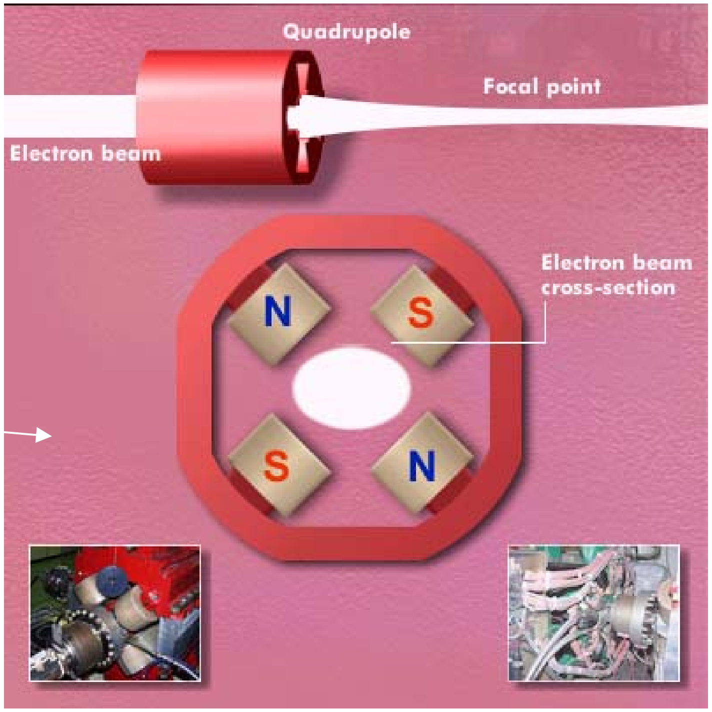


Waveguide from a klystron
E
Electric field
Accelerating electric field
Time
Decelerating electric field



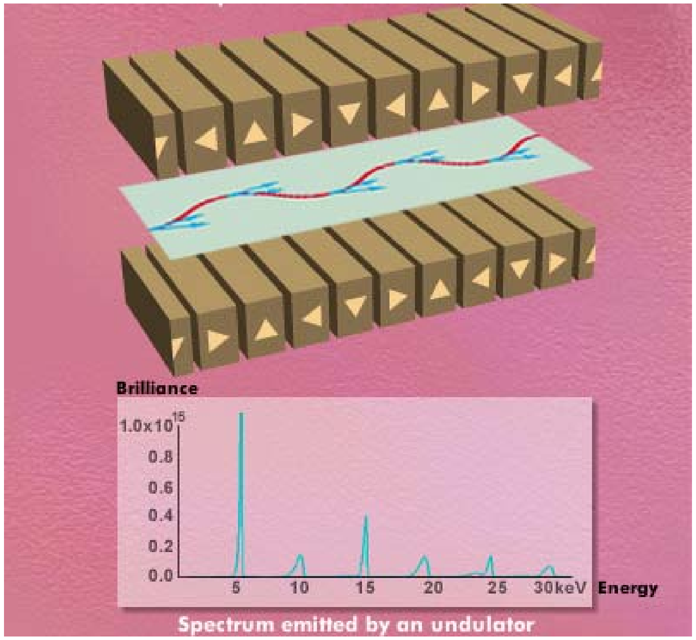
Storage Ring

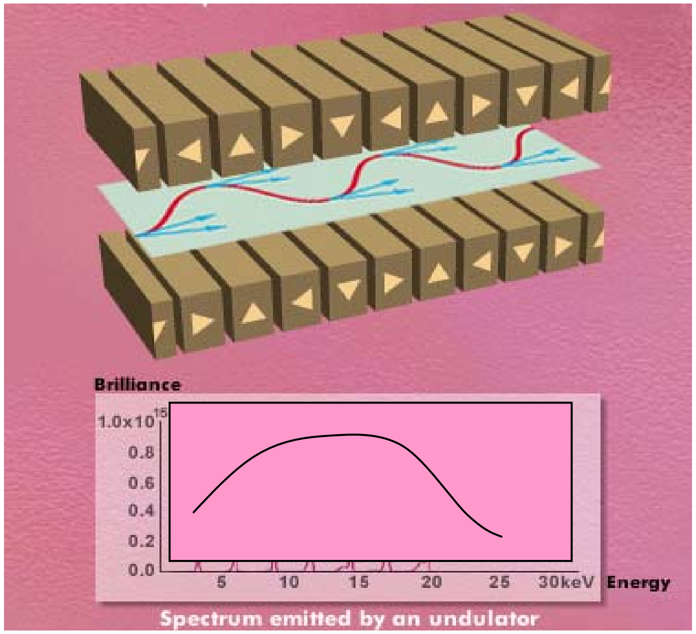




Insertion devices : undulators and wigglers

Third generation SR sources are characterized by sources of radiation more brilliant and intense than bending magnet sources

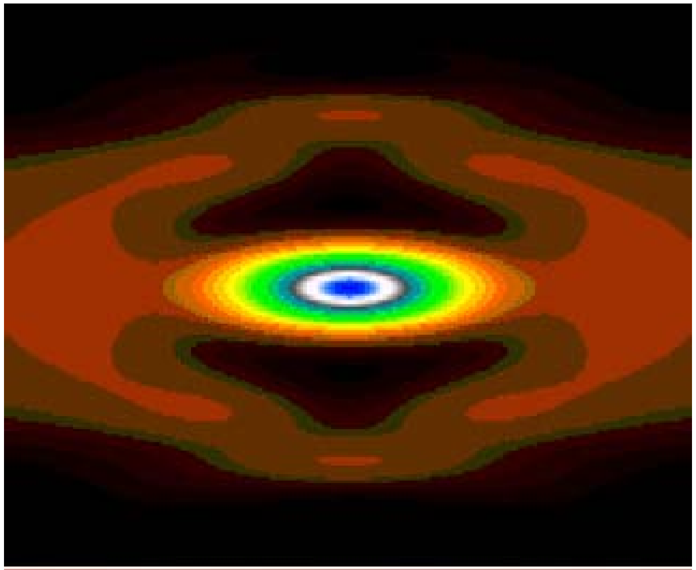




Undulators allow to tune the photon energy and provide high flux and brilliance

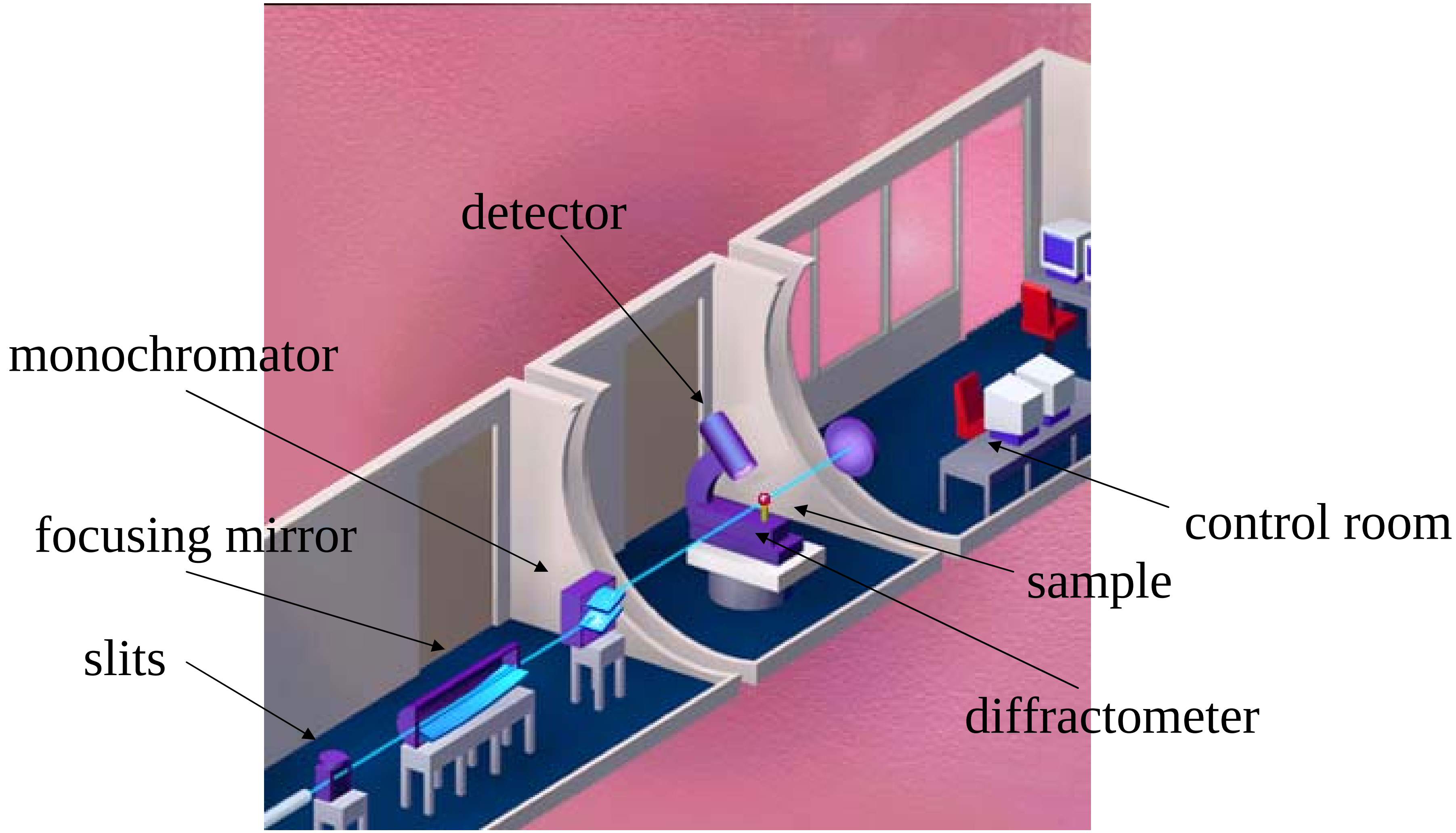
undulators

7 th harmonic, hν = 27 keV



beam dimensions:
1 mm H x 0.5 mm V
at 27 meters from the center of the undulator

Beamlines

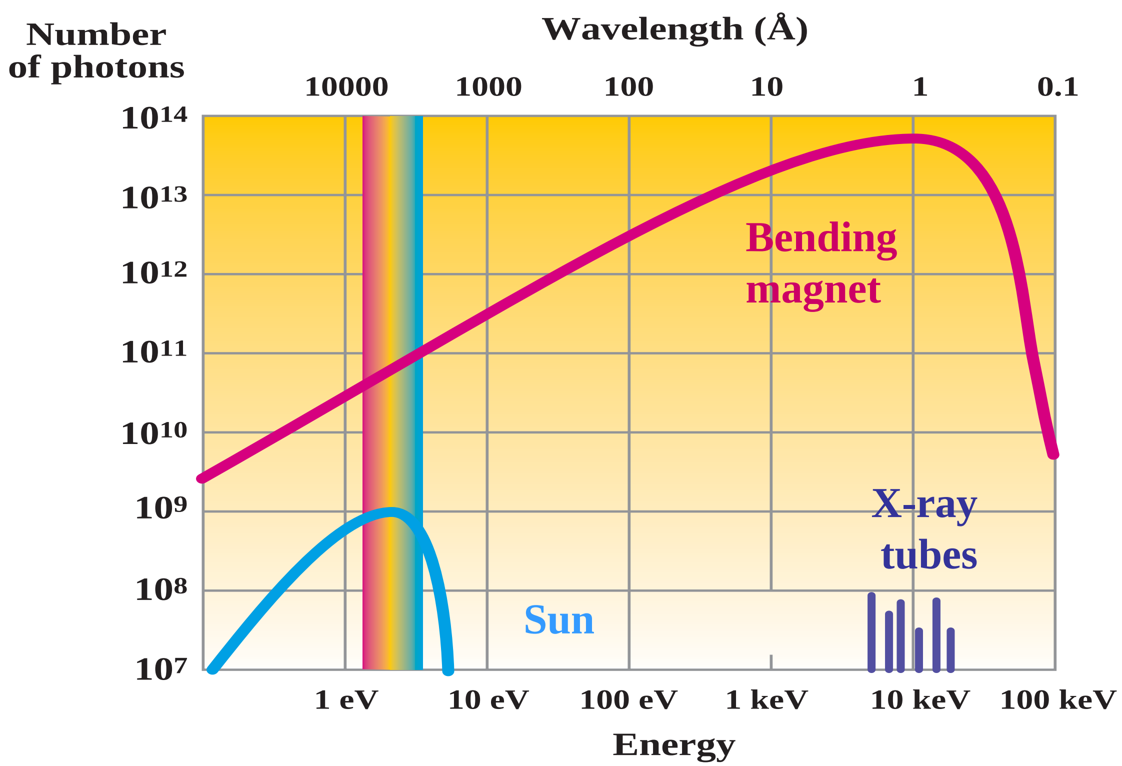

detector
monochromator
focusing mirror
slits
control room
sample
diffractometer

Main characteristics of SR radiation

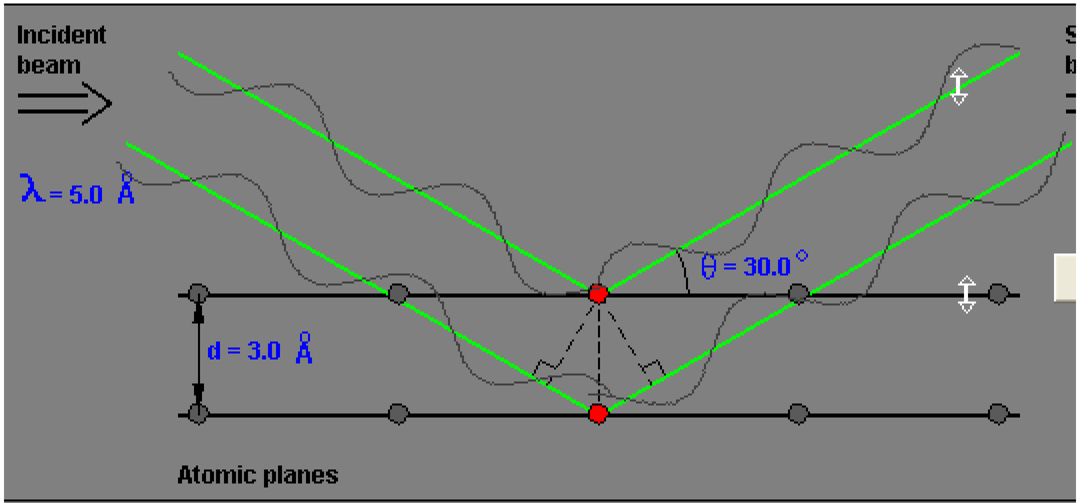
1)High flux (photons/s ·0.1%BW) and
High brilliance (ph/s·mm2·mrad2·0.1% BW)

2) Wavelength tunability

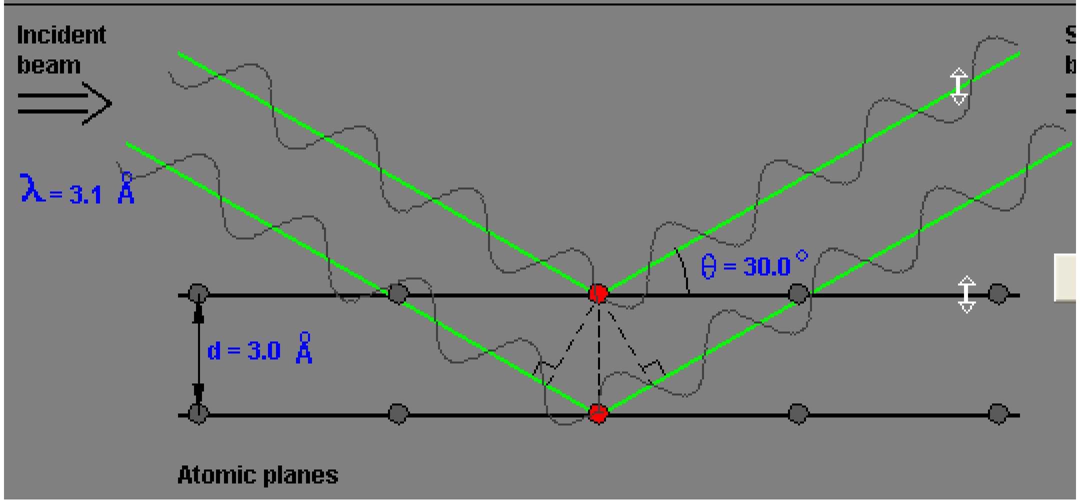
Emission spectrum



Bragg law: if $2d \sin\theta = \lambda$, constructive interference

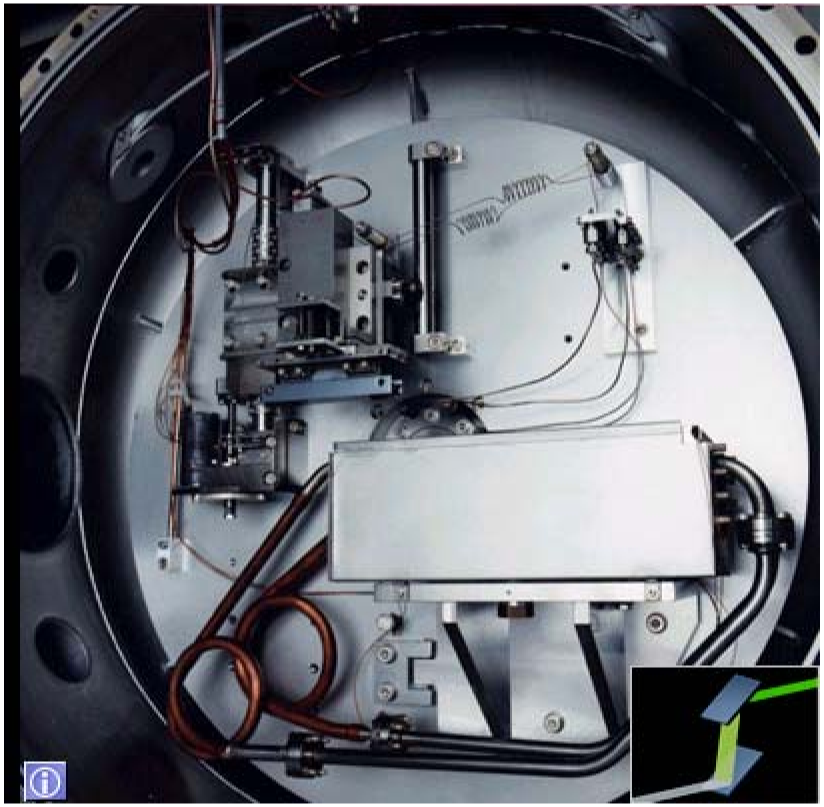


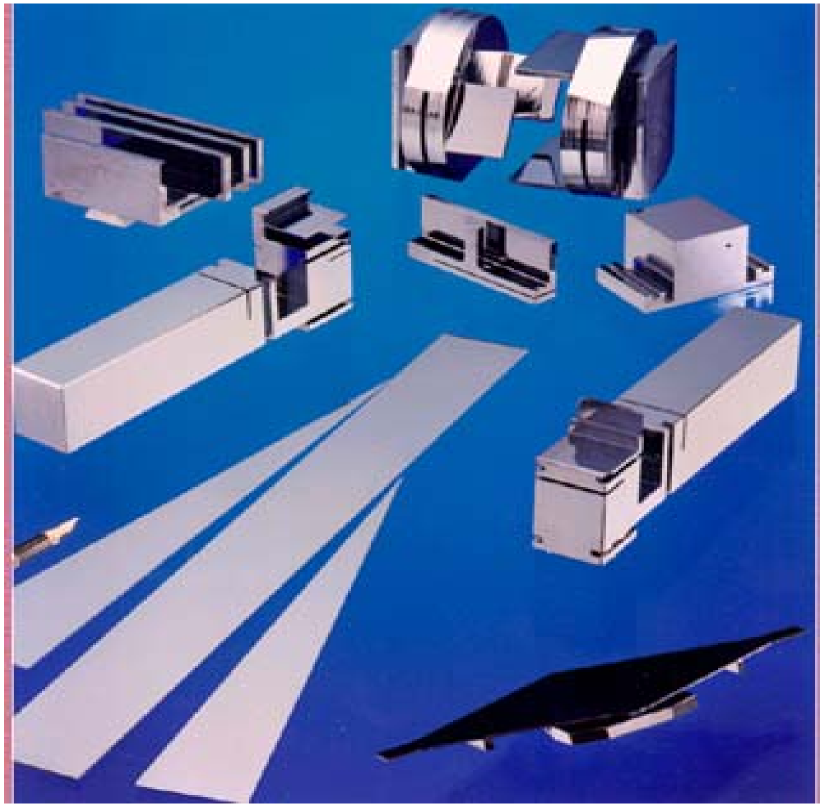
Destructive interference



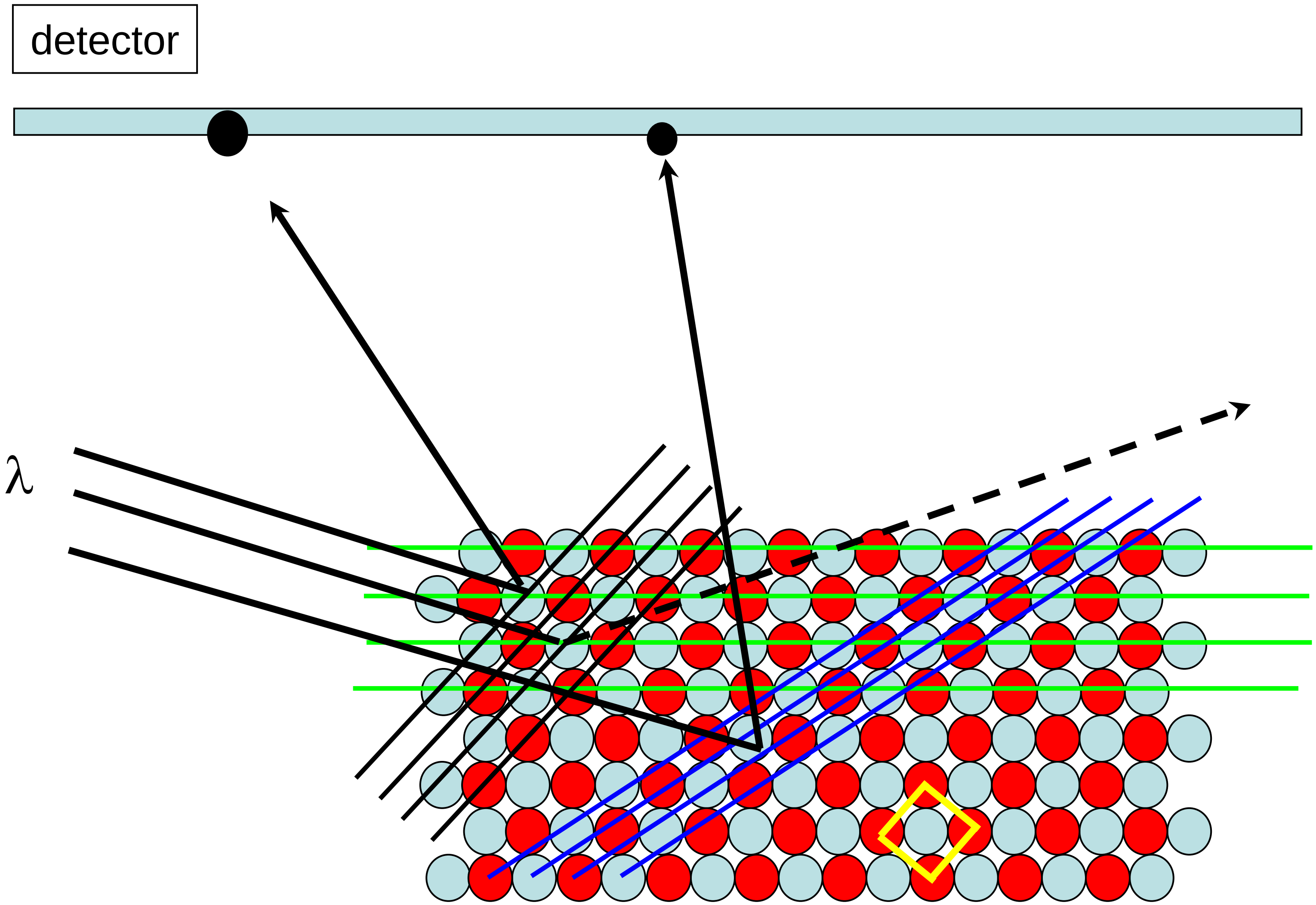
Constructive interference

Crystal monochromators

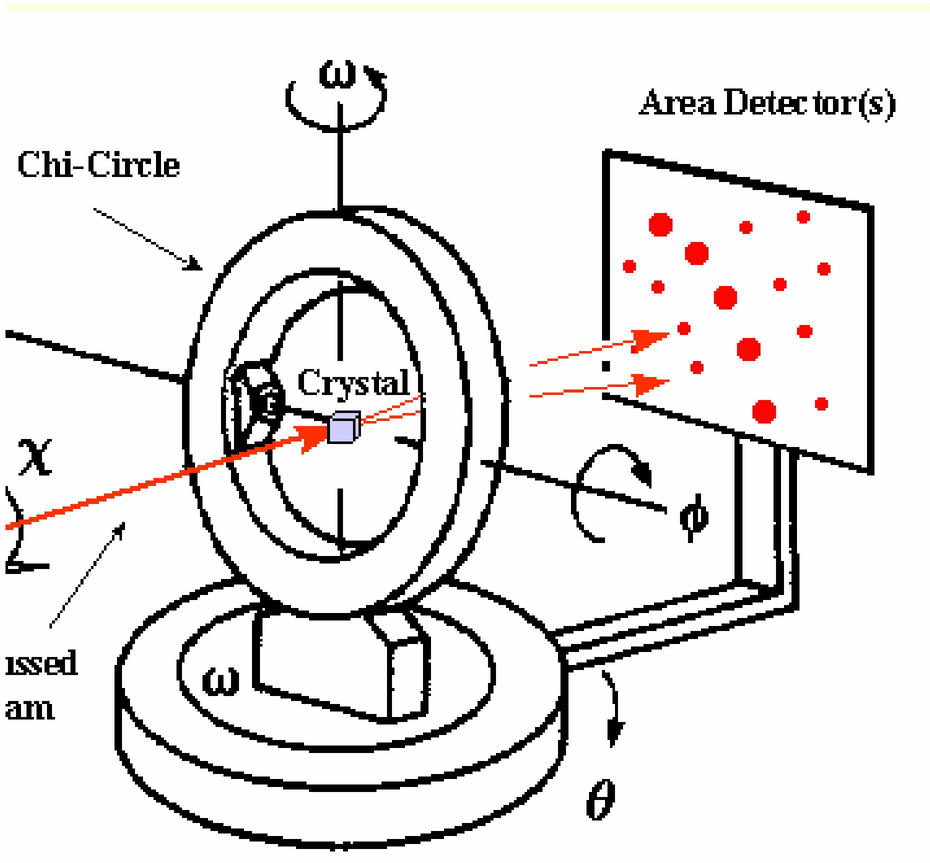




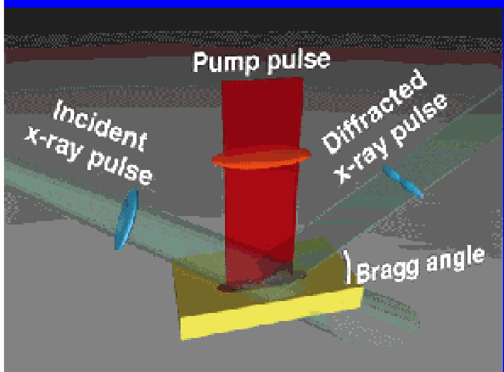
X-ray crystallography

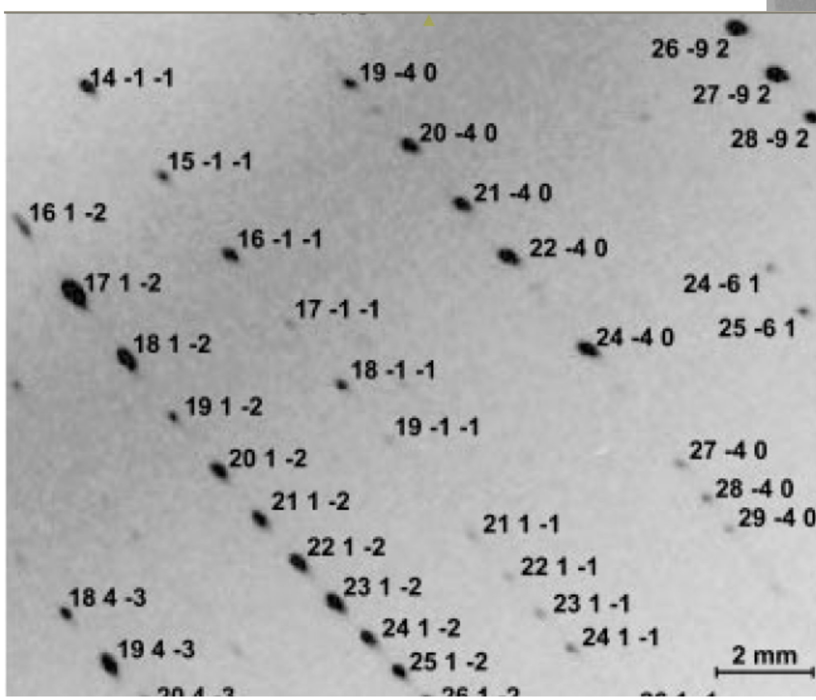


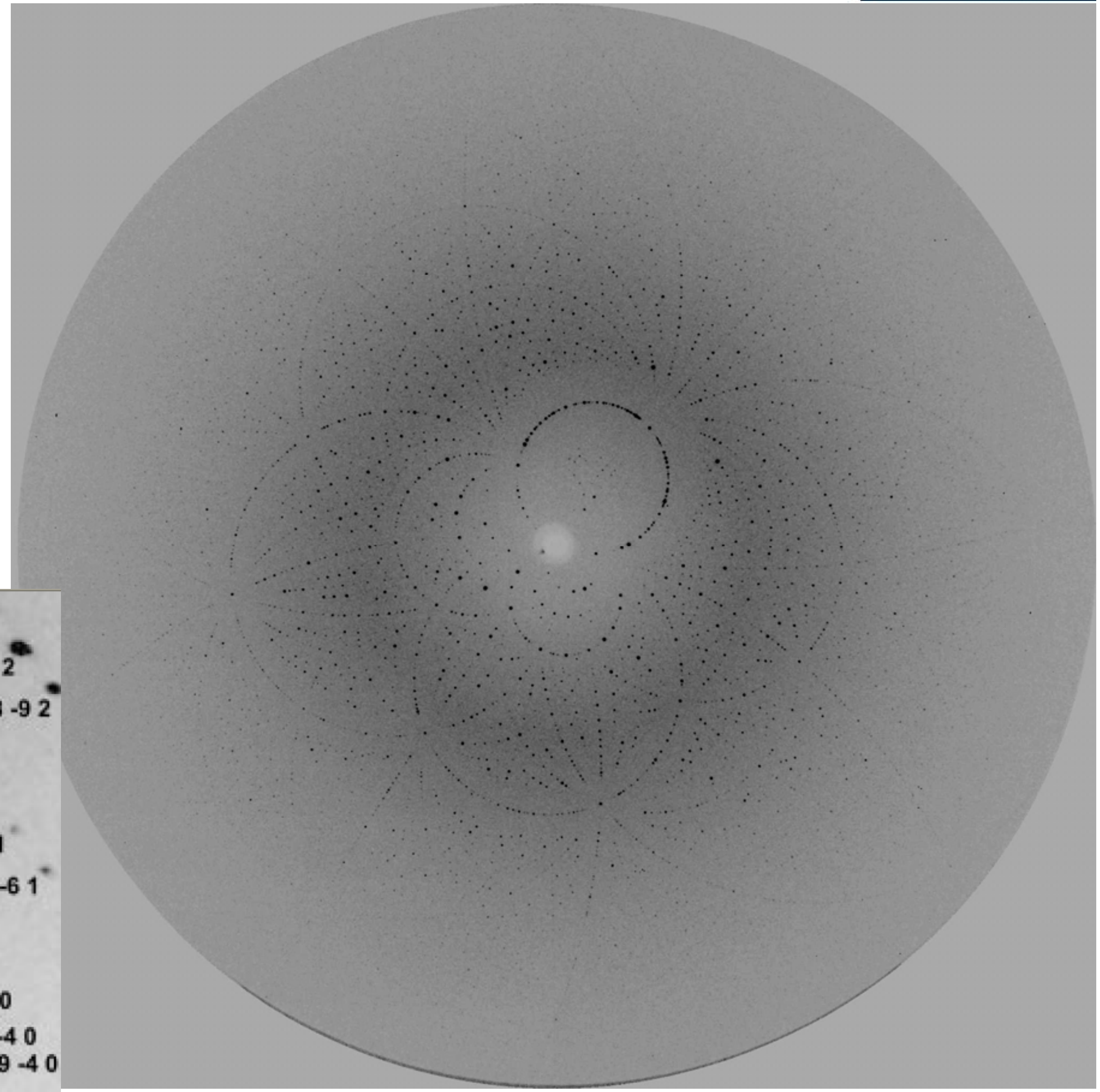
X-ray diffractometer



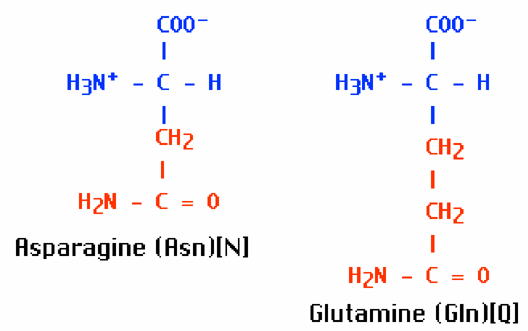
Protein diffraction

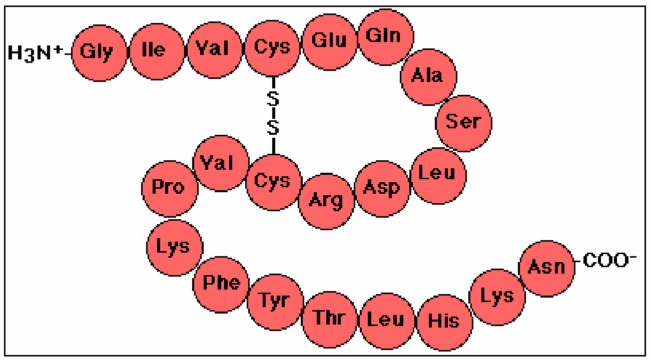


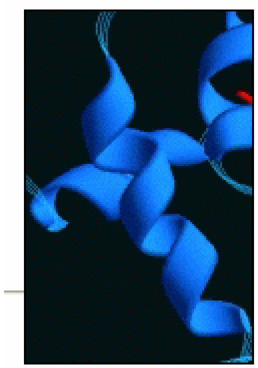


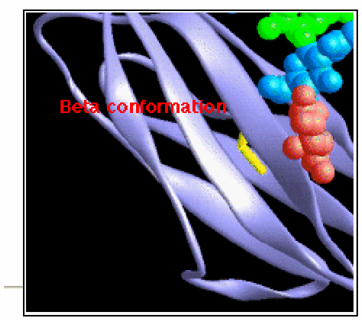


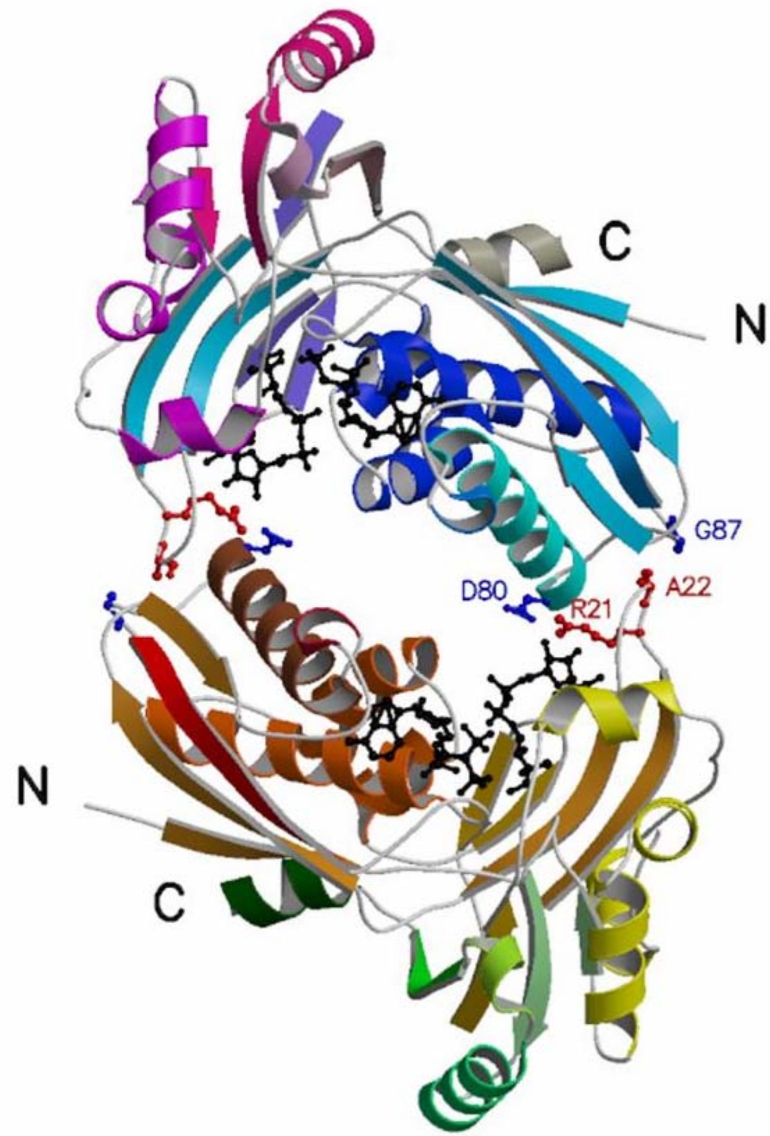
Structure of proteins











α helix

β conformation

ALBA

History:

1990: 1st attempts (bottom up) to get an accelerator and SL source in Spain

1994: Generalitat (Commissió Promotora in 1992) appoints staff for the preparation of a conceptual design report for a SL source

1996: LLS (as an IFAE subgroup and funded by Generalitat and OCYT) started to detail the Conceptual Design Report and Scientific Case.

1998: Conceptual design report handed to relevant authorities

2000: Creation of the LLS Consortium between DURSI and UAB to promote SR Lab.

2002: Approval of the project by the Spanish and the Catalan Government.

2003: Creation of a Consortium for the Construction, Equipping and Exploitation of the SL Laboratory as well as the governing Commissions: "Rectora" and" Ejecutiva".

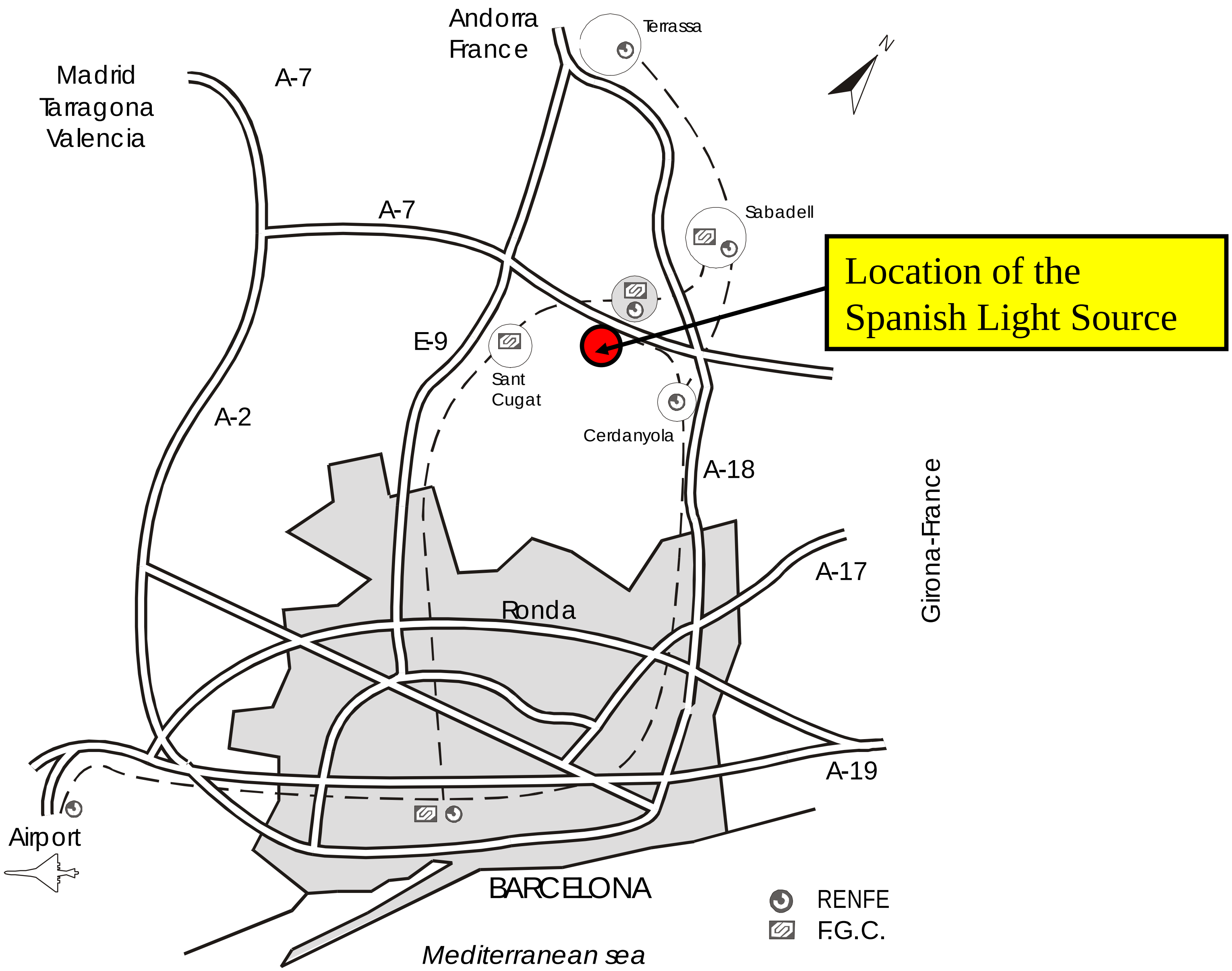
2003: Appointment of the Chairman of the Executive Commission and the Director

2003: Announcement of the positions for the Heads of the 5 Divisions

October 2003: Meeting in Mahon to present the project

February 2004: Meeting in Malaga to start defining scientific cases for future beamlines

February 2005: presentation of the BL projects to SAC



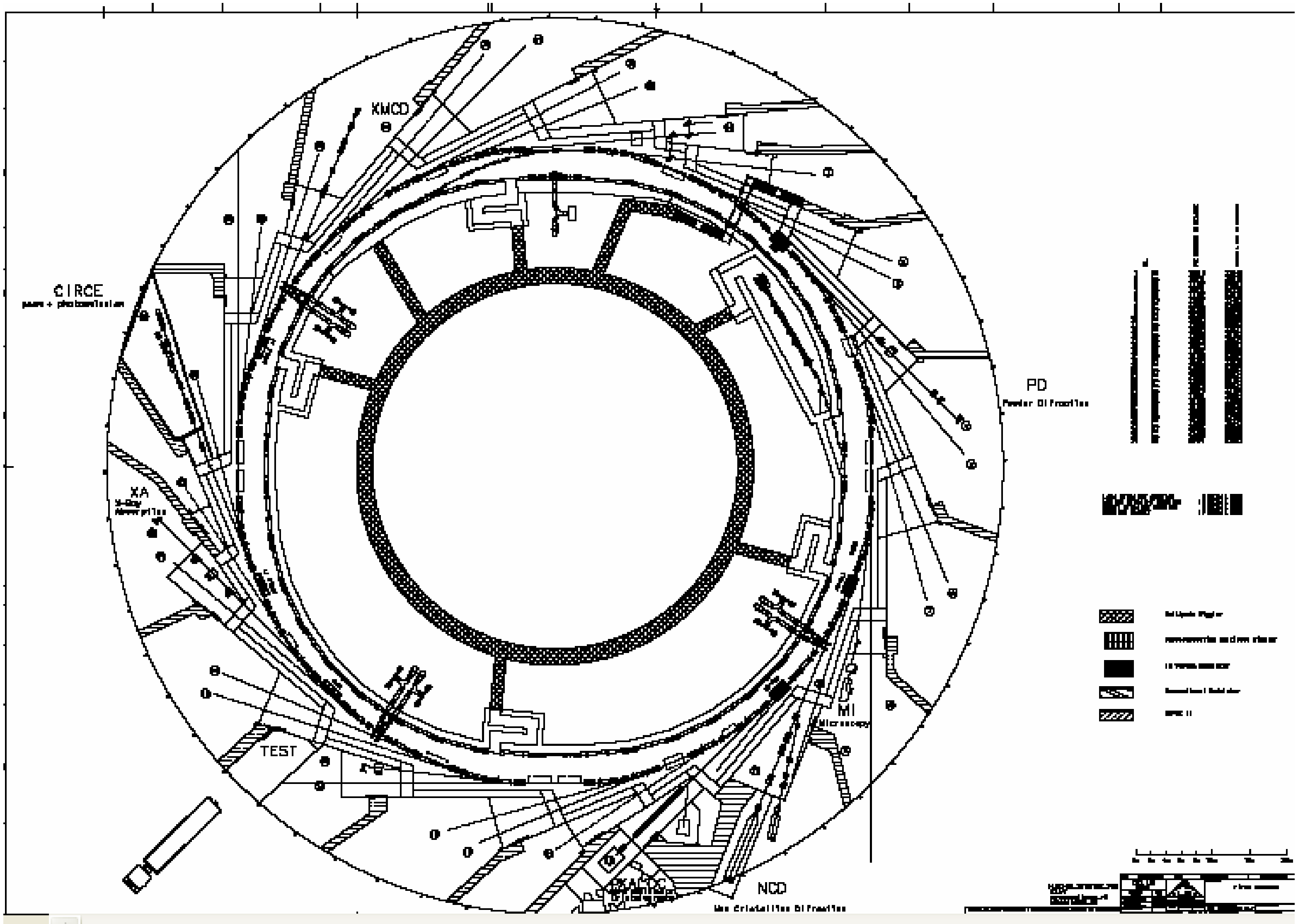
Andorra
France
Terrassa
Madrid
Tarragona
Valencia
A-7
A-7
Sabadell
Location of the Spanish Light Source
E-9
Sant Cugat
Cerdanyola
A-2
A-18
Girona-France
A-17
Ronda
A-19
Airport
BARCELONA
RENFE
F.G.C.
Mediterranean sea


19 th February 2007
ALBA
picture1.jpg

1 June 08

Planning: (starting dates)

- Reception of LINAC : Nov 07
- Start of installation in the tunnel : April 08
- Building ready: June 08
- Beamlines infrastructure: June 08
- Beamlines installation: Oct 08
- Commissioning Booster: Nov 08
- Commissioning of storage ring : March 09
- Installation of IDs : June 09


XMCD
CIRCE
PD
XA
MI
TEST
NCD

RELEVANT PARAMETERS OF ALBA:

E = 3.0 GeV

C = 268.8 m

4 fold DBA lattice

ε = 3.76 nm.rad

3 different straight sections:

1)	4 times 8 m:	3 useful for Beam-lines
2)	12 times 4.3 m:	12 useful for Beam-lines
3)	8 times 2.6 m:	2 useful for Beam-lines

32 BM

Phase I beamlines

1.- Non Crystalline Diffraction

2.- Macromolecular crystallography (XALOC)

3.- Photoemission Spectroscopy and Microscopy (CIRCE)

4.- High Resolution Powder diffraction and high pressure

5.- X-ray Absorption Spectroscopy

6.- Circular Dichroism and Resonant Scattering

7.- X- ray microscopy

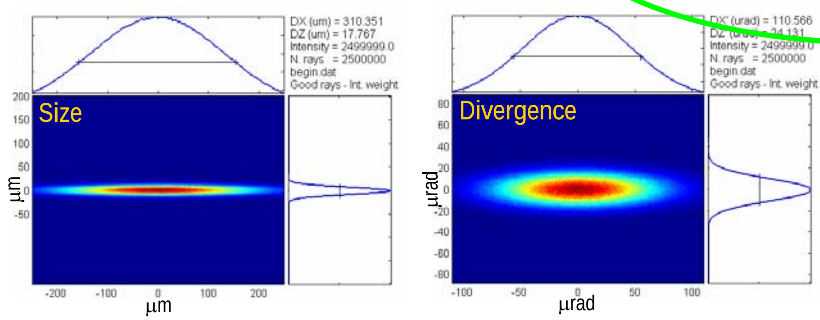
Non Crystalline Diffraction and Macromolecular crystallography (XALOC)

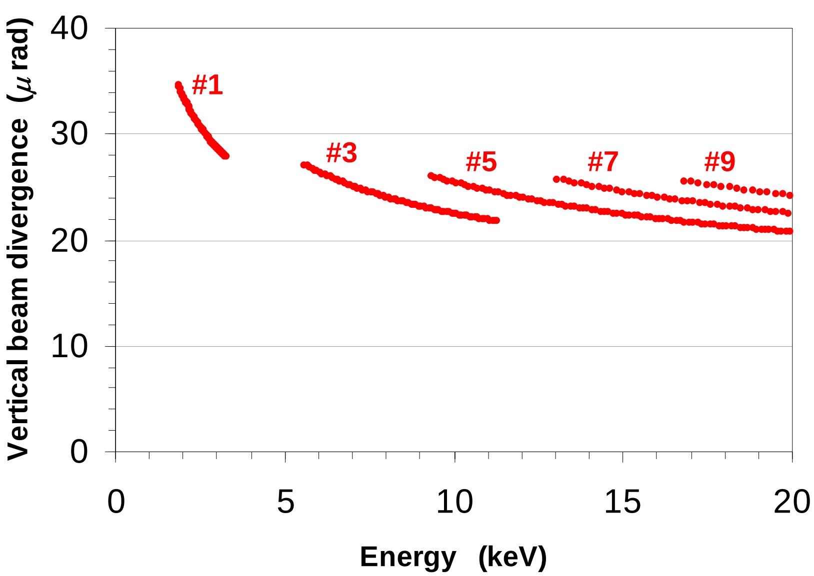
Source: dimensions (FWHM) and flux

Photon source size (H×V)	$\Sigma_{x,y}$	309 × 18	μm^2
Photon source divergence (H×V)	$\Sigma'_{x,y}$	0.11 × 0.03–0.02	$mrad^2$

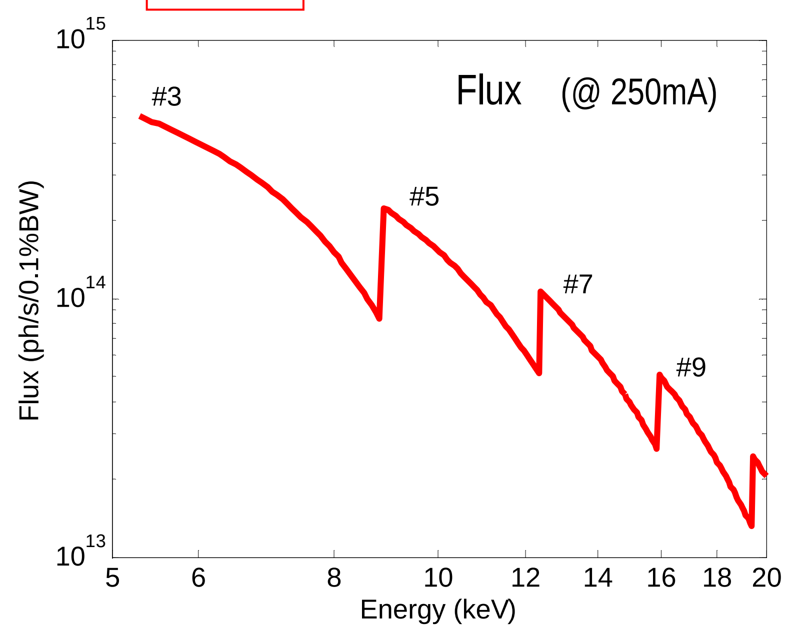
Source dimensions are basically constant in 5-15 keV range.

Only the vertical divergence changes due to the electron energy spread



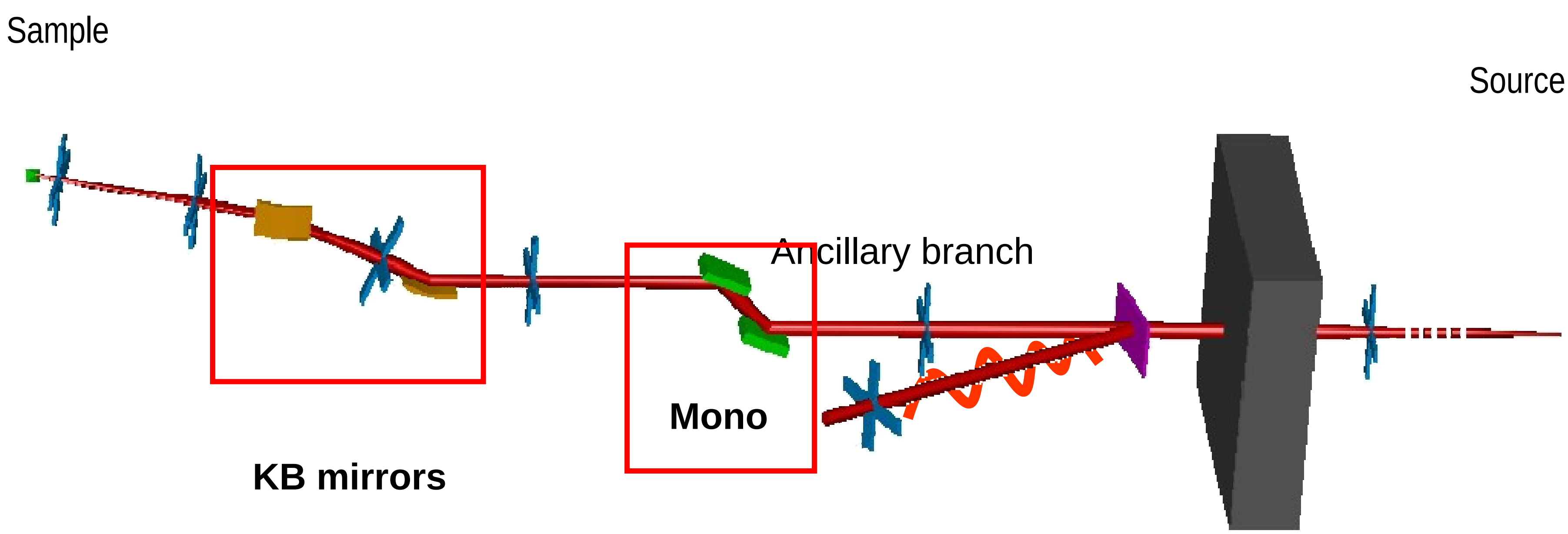


Flux



Macromolecular crystallography (XALOC)

Optics



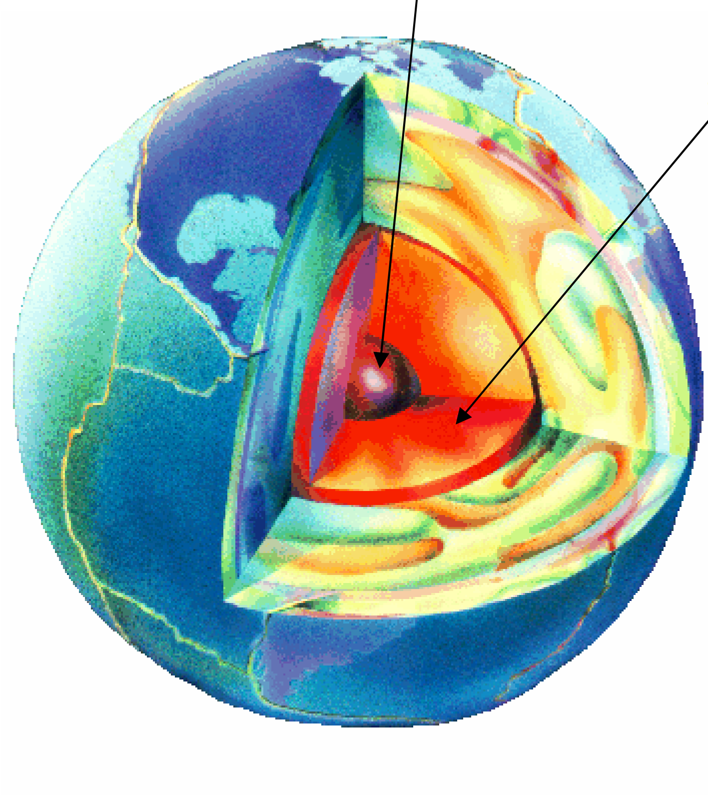
High resolution powder diffraction and high pressure diffraction beamline

Superconducting wiggler

Silicon monochromator and focusing mirror optics

Interior de la Tierra

Solid mostly Fe
4×10^6 atmospheres = 400 GPa , T~ 6000 C



liquid

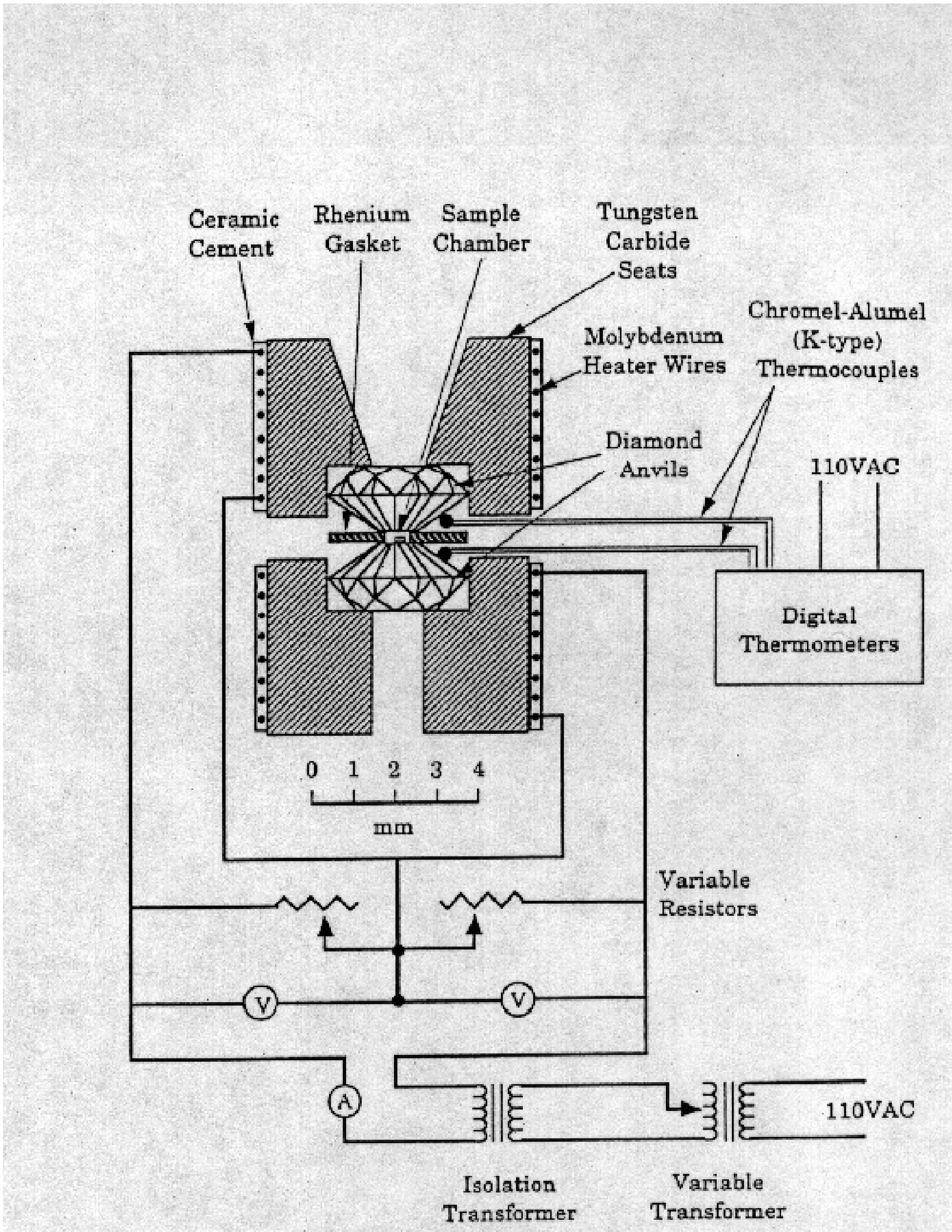
El Fe tiene la estructura cubica (bcc) en la superficie de la tierra

Estudios teoricos muestran que esta estructura no es estable en el interior del planeta.

Se ha observado una transicion de fase:

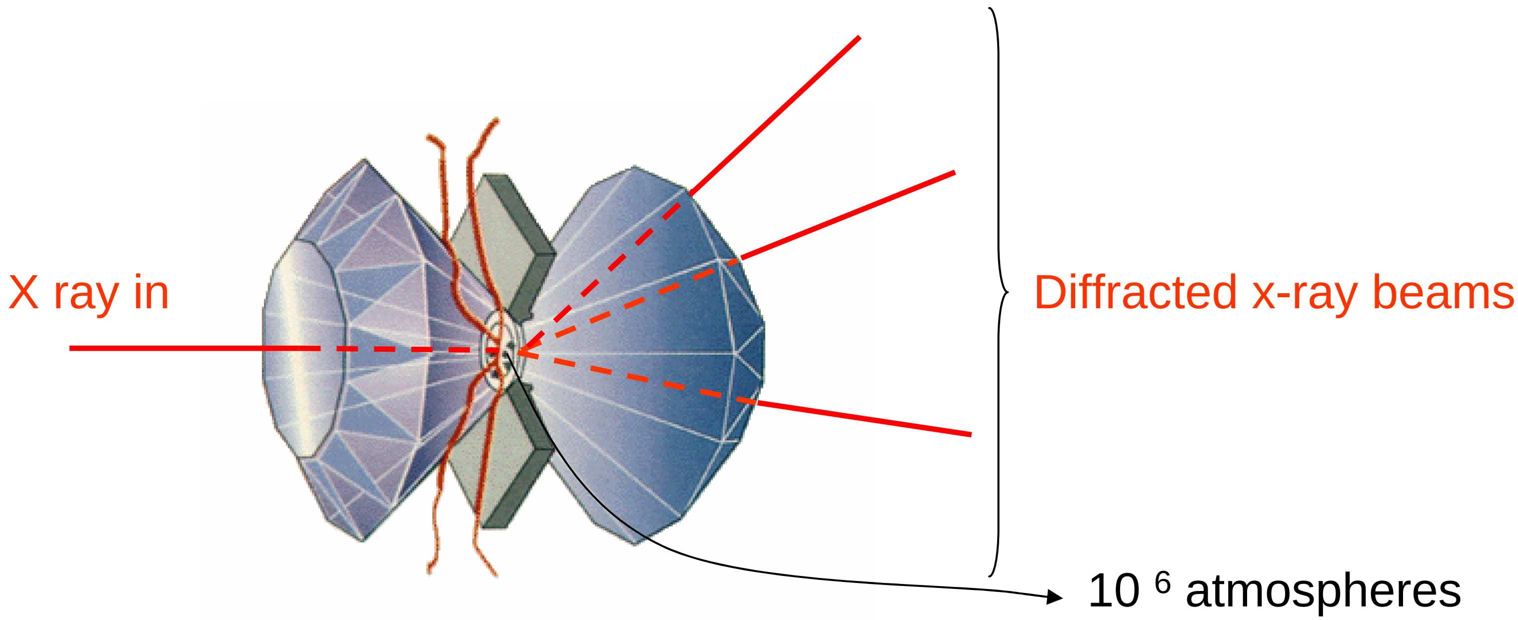
$$\text{Fe hexagonal } (\varepsilon) \xrightarrow[\text{T> 1000 C}]{\text{p = 1.3 – 3 millones de atmosferas}} \text{Fe doble hexagonal } (\beta)$$

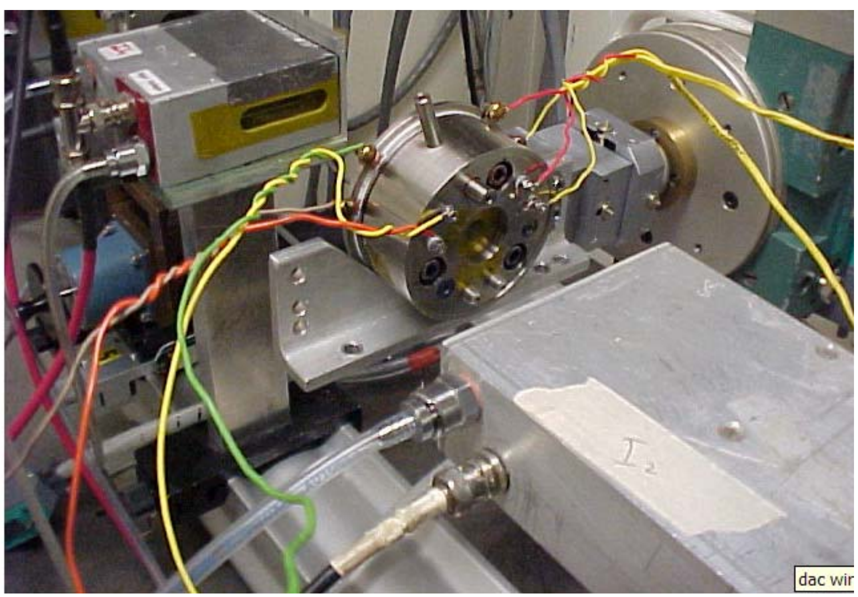
Esta observacion se ha realizado en el ESRF estudiando la difraccion de rayos x de cristales de Fe en el interior de celdas de diamante calentados con un haz laser. (Phys. Rev. Lett. **84**, 1920 (2000))



Ceramic Cement
Rhenium Gasket
Sample Chamber
Tungsten Carbide Seats
Molybdenum Heater Wires
Chromel-Alumel (K-type) Thermocouples
Diamond Anvils
110VAC
Digital Thermometers
0 1 2 3 4
mm
Variable Resistors
V
V
A
110VAC
Isolation Transformer
Variable Transformer

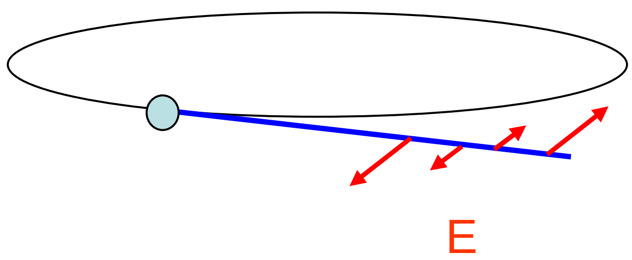
Diamond Anvil Cells to investigate the structure of the crystals at elevated pressures:

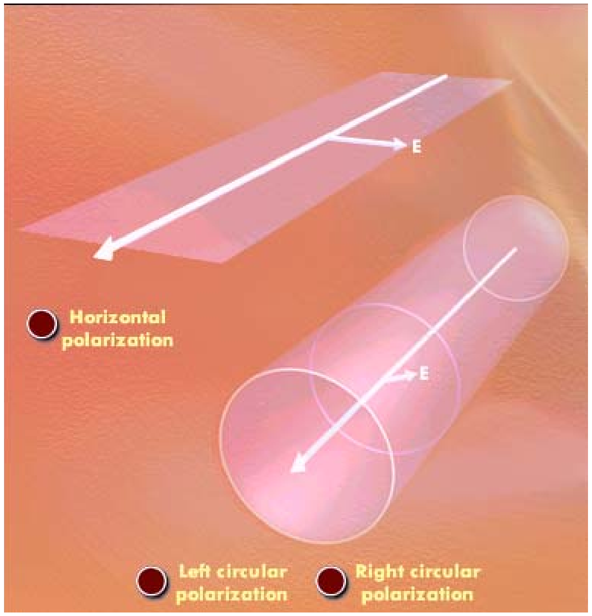




Variable polarization

Natural synchrotron radiation is plane polarized since the e$^-$ orbit is horizontal but the polarization may be manipulated with suitable insertion devices:



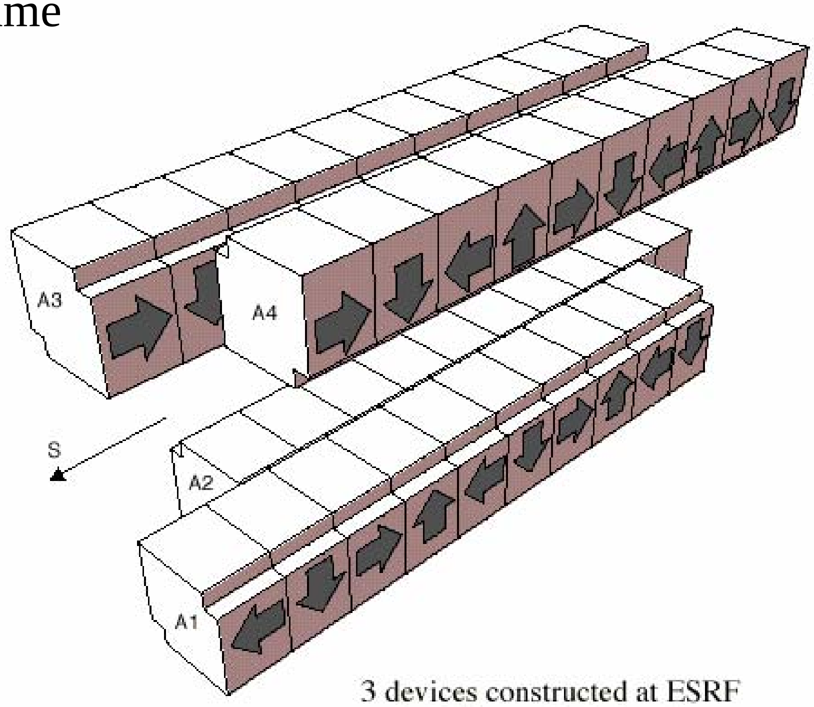


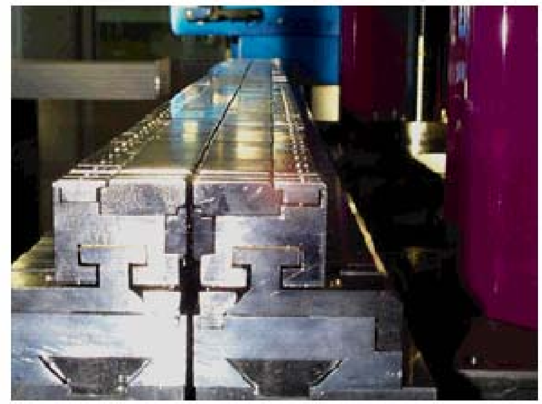
3) Variable polarization (cont.)

Undulator to produce elliptical polarization (H, V, CR, CL)

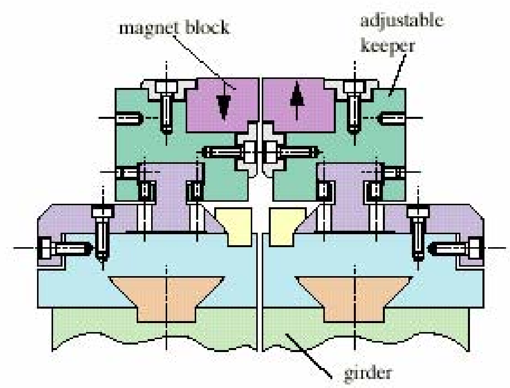
J. Chavanne
P. Elleaume
ESRF

APPLE II STRUCTURE



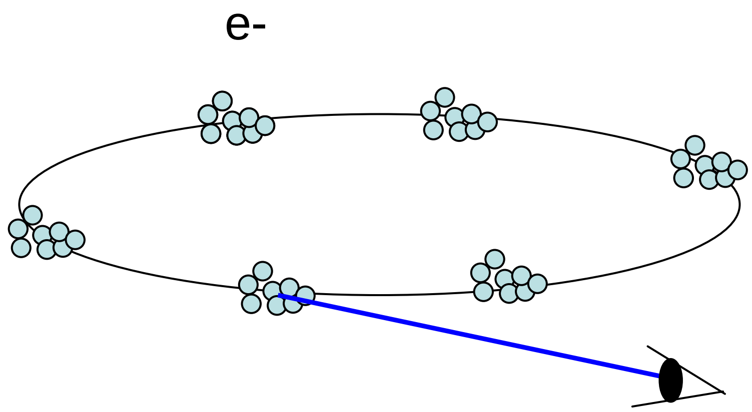


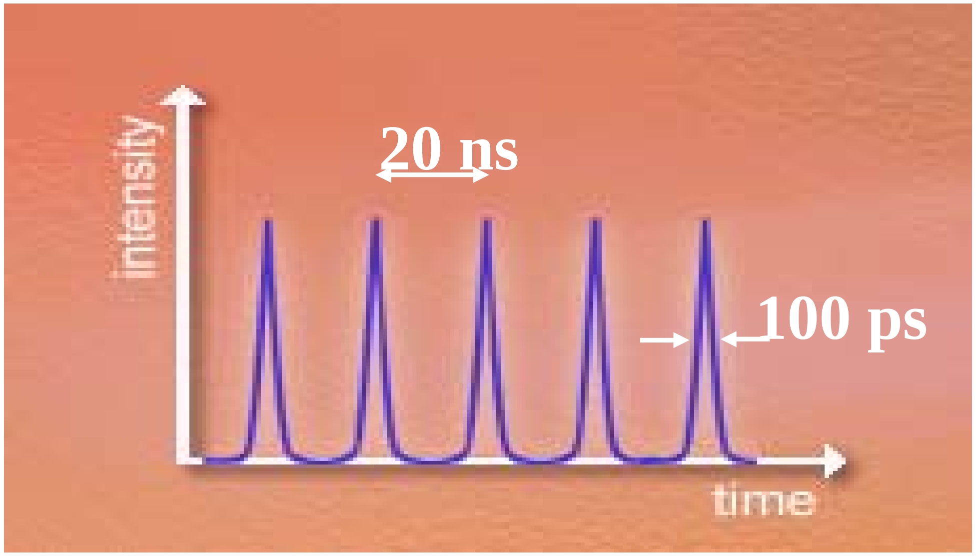
3 devices constructed at ESRF
period 88 mm (2 devices)
period 38 mm



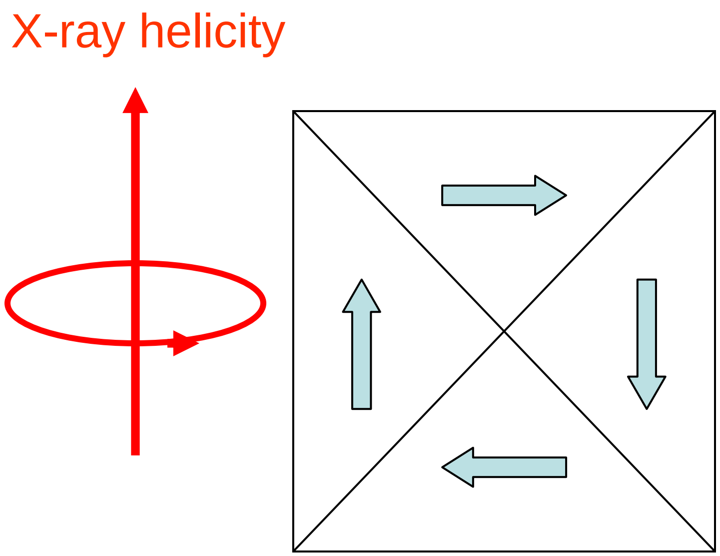
Temporal structure

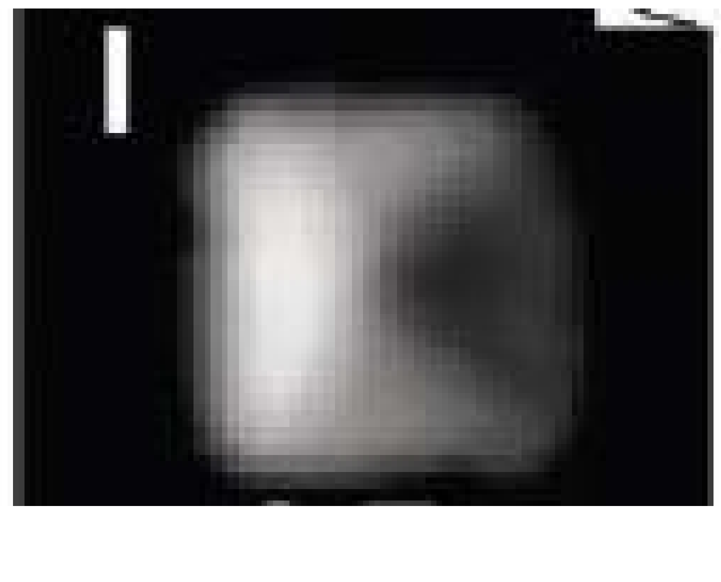
The electrons are grouped in packets and generate pulsed SR radiation:





Imaging magnetic domains





The absorption cross section
depends on the relative orientation
of the helicity of the x-rays
and the magnetization of the sample

PEEM image
Photoemission microscope

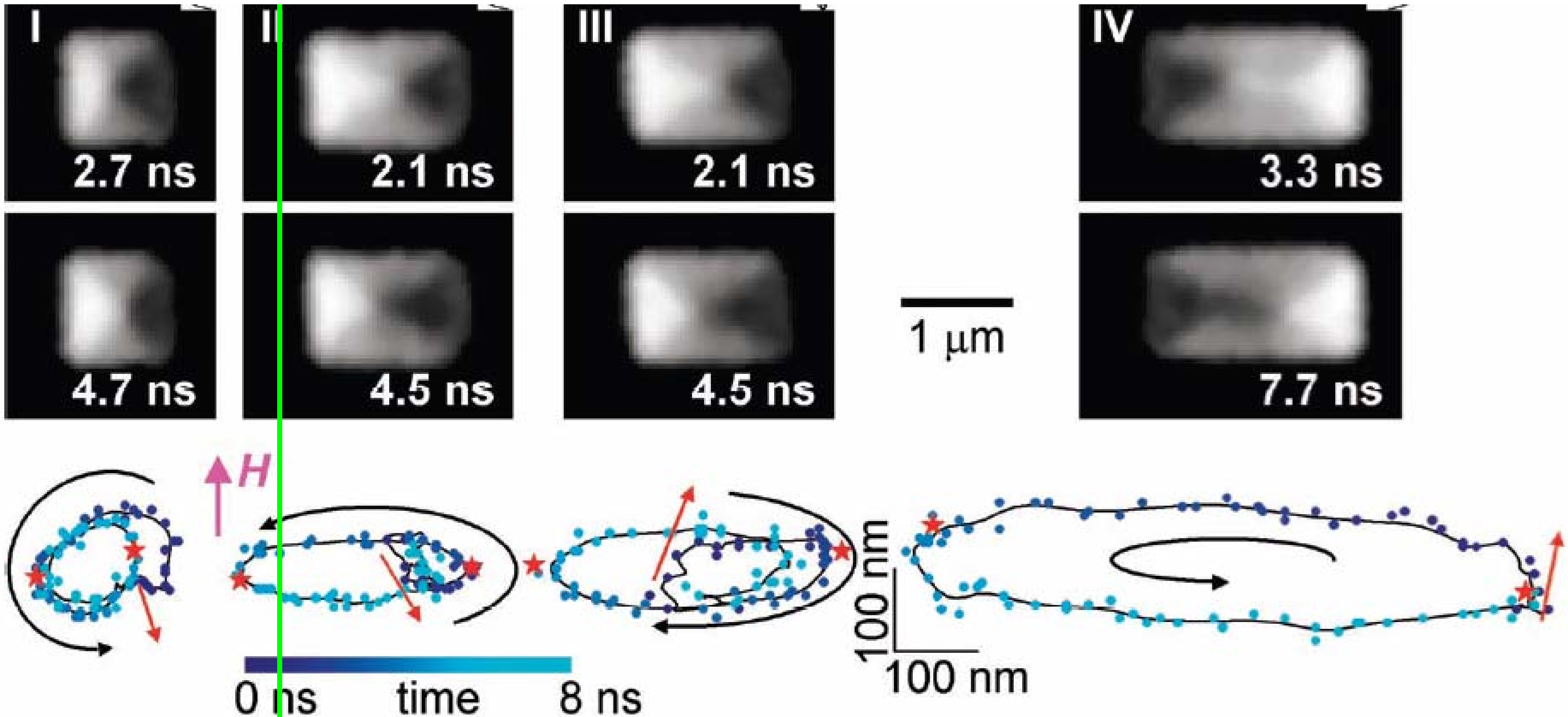


Fig. 1. (**Top**) Domain images of the in-plane magnetization of Pattern I ($1 \times 1\ \mu m^2$), Patterns II and III ($1.5 \times 1\ \mu m^2$), and Pattern IV ($2 \times 1\ \mu m^2$), taken at the specified delay times after the field pulse. The images are part of a time series that extends over 8 ns and were chosen so that the horizontal displacement of the vortex has maximum amplitude. Hands illustrate the vortex handedness and the out-of-plane core magnetization as determined from the vortex dynamics. (**Bottom**) Trajectories of the vortex core. The dots represent sequential vortex positions (in 100-ps steps). Lines represent time-averaged positions with a Gaussian weight function of 100 ps (FWHM) for 0 to 1 ns and 400 ps (FWHM) for 1 to 8 ns. The progression in time is symbolized by the dot color. Red arrows show the trajectory during the field pulse; black arrows show the direction of gyrotropic rotation after the pulse; and red stars show the vortex position for the shown domain images.

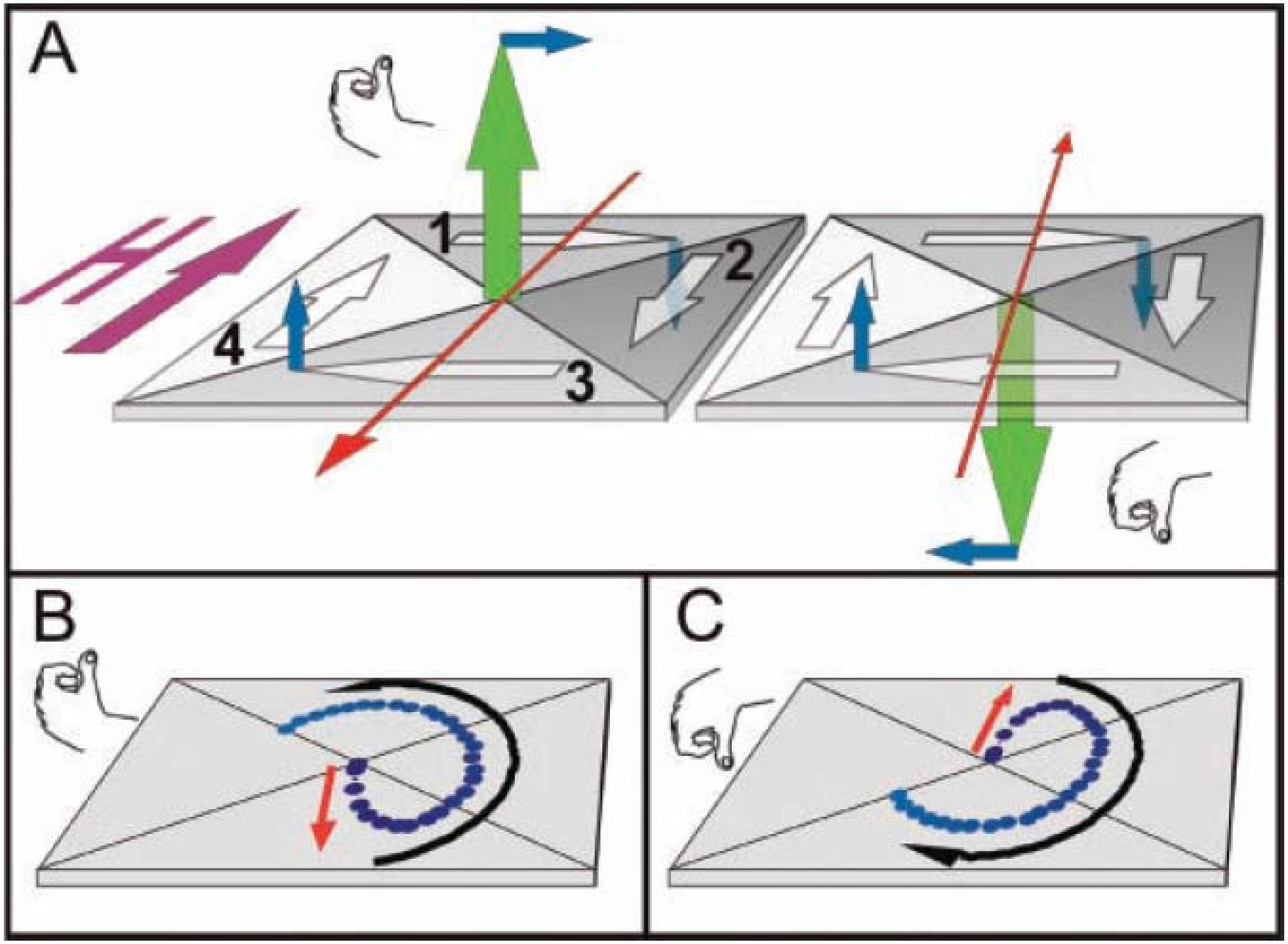
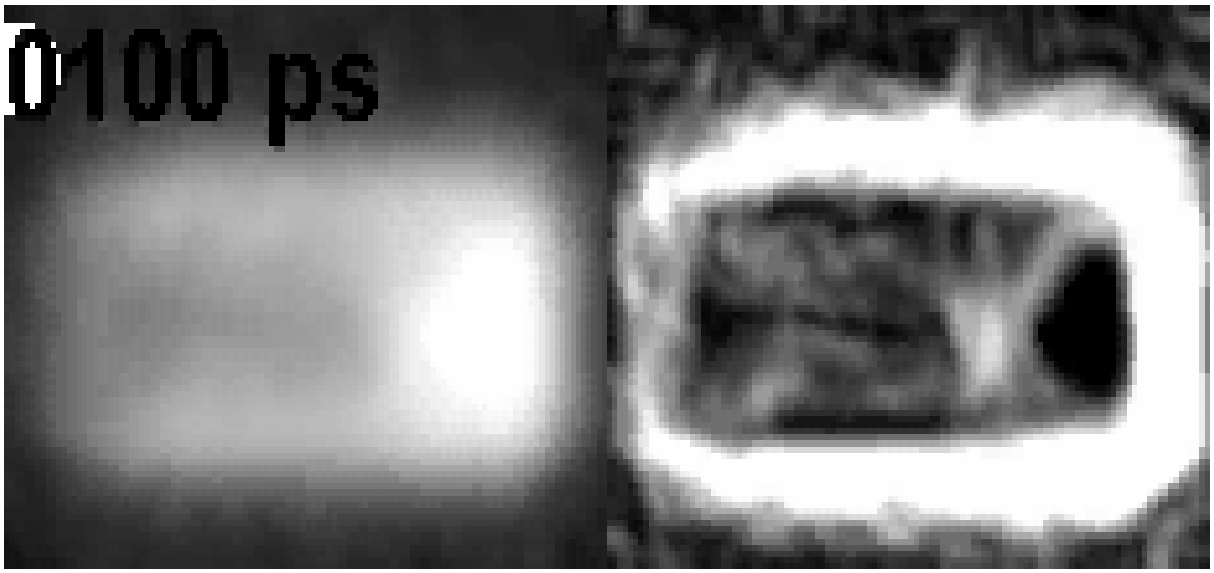


Fig. 2. (**A**) Spin structure (white arrows) of a left-handed (left side) and a right-handed (right side) square vortex. Blue arrows represent the precessional torque generated by the external magnetic field (purple arrow). Hands illustrate the vortex handedness, and a green arrow indicates the out-of-plane core magnetization. Red arrows indicate the acceleration direction in response to the field. (**B** and **C**) Simulated trajectory of the core of (B) a left-handed and (C) a right-handed vortex during and after a field pulse.


0100 ps

X ray microscopy

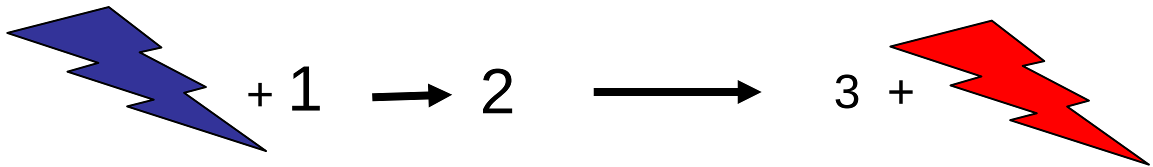
It is possible with microelectronic technology to make lenses

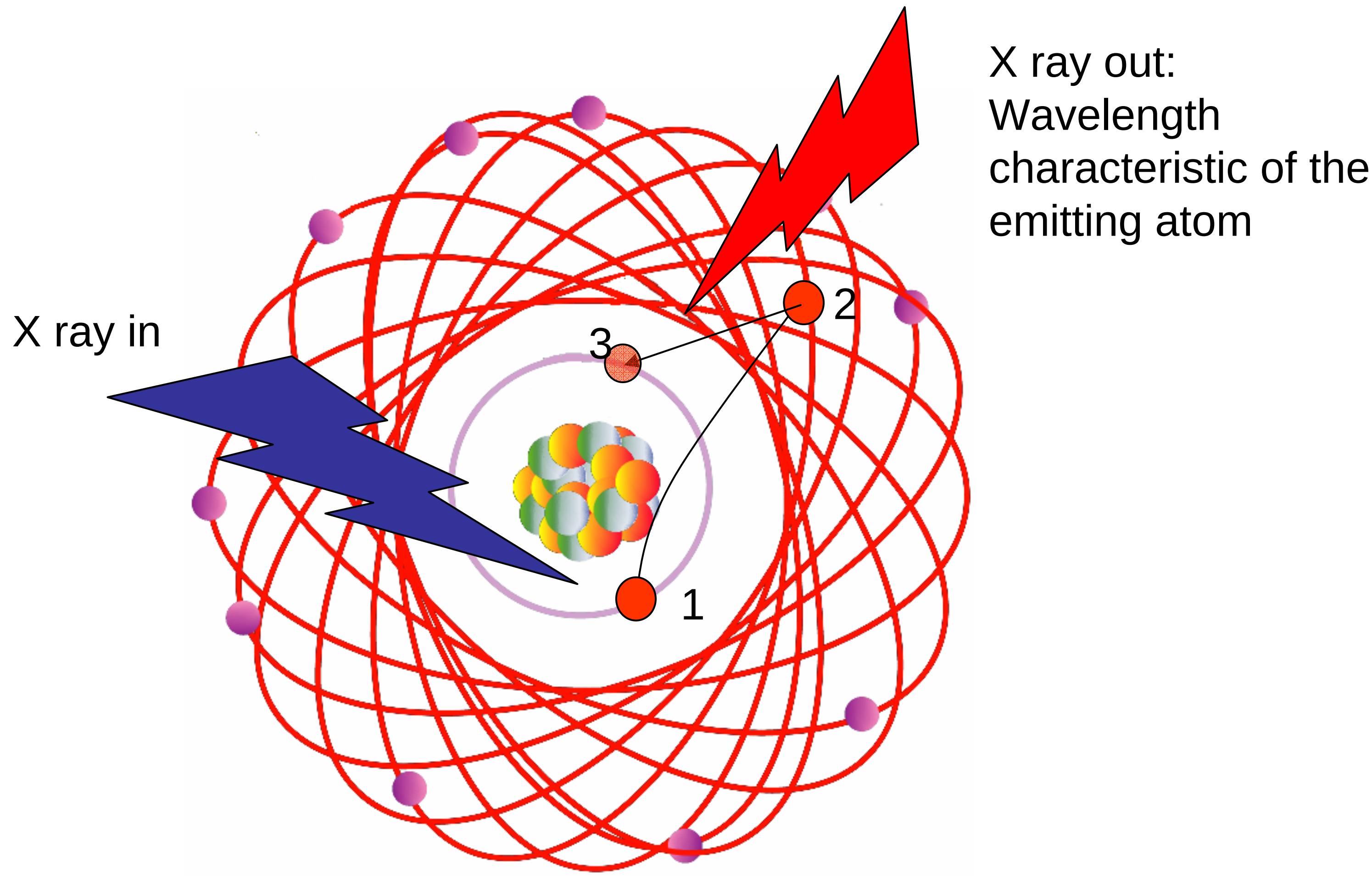
to construct an X ray microscope with better resolution that the

visible light microscope thanks to the small wavelength of the X rays

Compared to that of visible light.

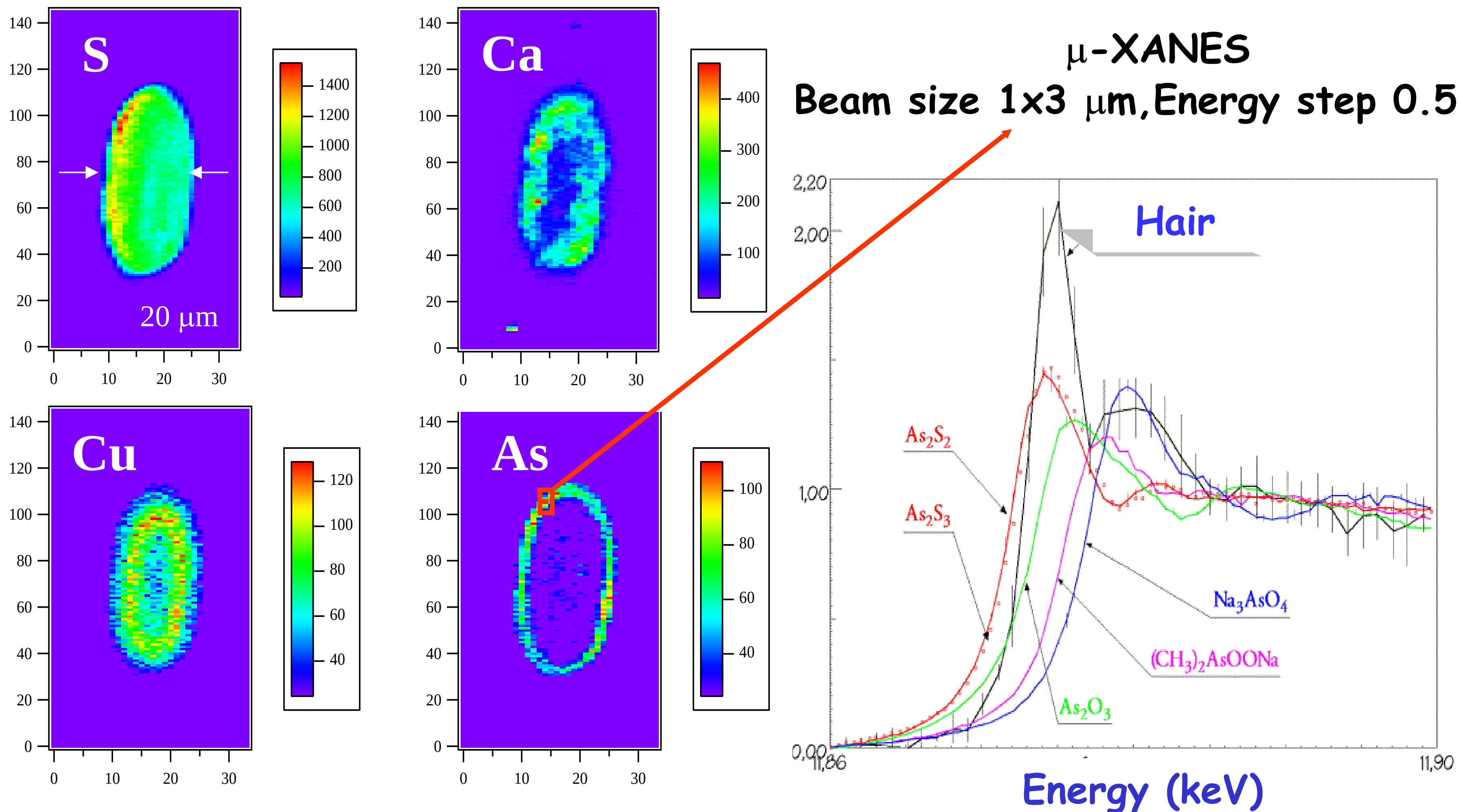
Absorcion y Emision de rayos x por atomos





Metabolism of an As-based drug against acute leukaemia
μ-XRF imaging and spectroscopy on patient's hair

μ-SXRF mapping of hair from patient treated As_2O_3 <1 μmol/l, section 15 μm thick *I.Nicolis, E.Curis, S.Bénazeth Lab. de Biomathématique, Université Paris V*

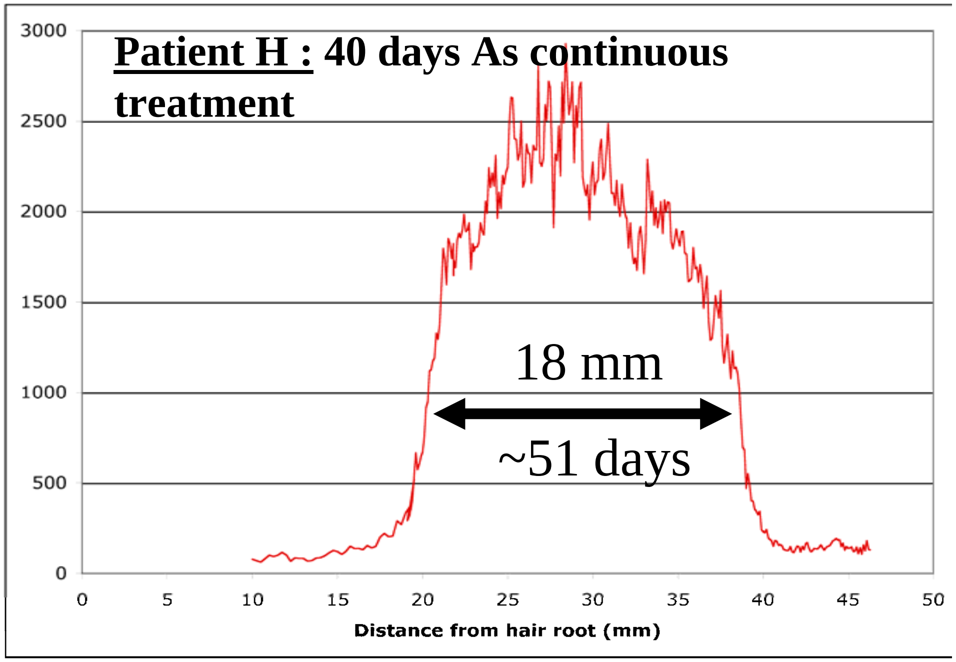


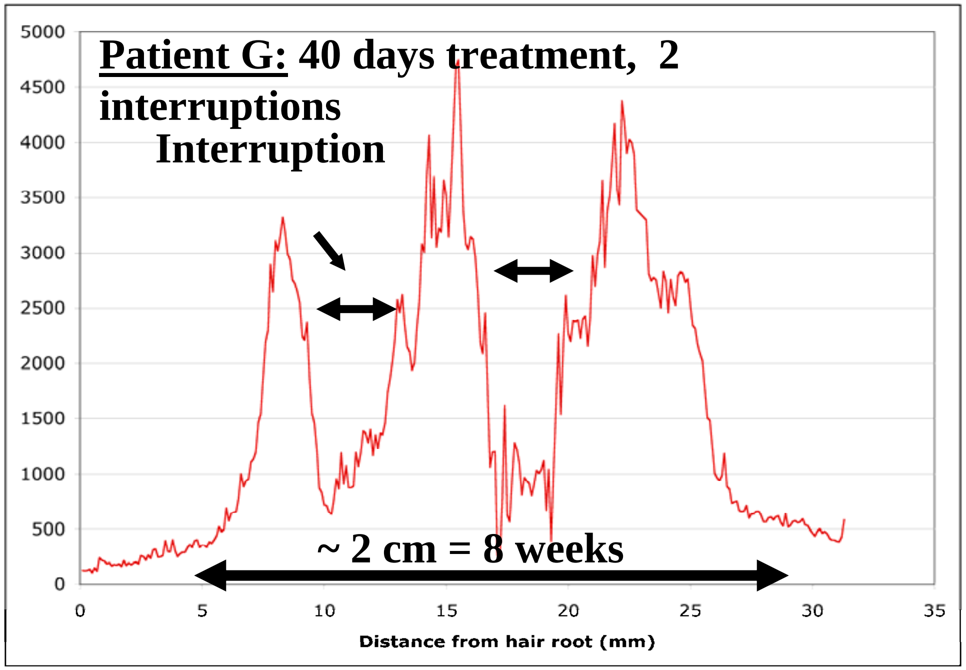
S. Bohic ESRF

As drug for acute leukemia treatment

hair growth ~ 350 μm/day

linescans: root → point , step 100 μm (~ 7h.growth)





- **Mapping:** located between cuticle et cortex
- **Speciation:** As(III), environment N and/or O, not S - not linked to the keratin cysteine
- **kinetic hair:** variation match patient treatment history

La radiacion sincrotron es util en muchos campos de la ciencia.

Ademas de los tradicionales (Fisica, Biologia, Quimica), se ha aplicado en:

- medicina
- geologia
- medio ambiente
- arqueologia
- ingenieria

……


Gracies per la seva atencio

ALBA

ALBA