“The ALBA Synchrotron Light Source”

XXXVII International Meeting on Fundamental Physics

Benasque

- Thank the organizers for participating again in a Winter Meeting
  - Baqueira
- Memory of Paco Yndurain
  - Actor in the return of Spain to CERN
- ALBA is neither a HEP experiment, nor a Cosmological or Astrophysical Observatory, but a medium size accelerator devoted to production of SR

Outline

- Research Infraestructures in Science
- Synchrotron Light Sources
  - Description
  - Applications of Synchrotron Light
- The ALBA project
  - Characteristics
  - Organization
  - Economical aspects
  - Present situation

European Research Infraestructures: EIROforum

- CERN, European Laboratory for Particle Physics
- EFDA, European Fusion Development Agreement
- EMBL, European Molecular Biology Laboratory
- ESRF, European Synchrotron Radiation Facility
- ESA, European Space Agency
- ESO, European Southern Observatory
- ILL, Institut Laue-Langevin

Role of the Large Facilities

Janez Potocnik,
European Comissaire of Science and Research

"European Research Infrastructures are a key asset in implementing our vision of a Knowledge Europe. Our new proposal for a research programme looks to increase EU support to research infrastructures. In this competition for excellence, we must adopt a common European approach, and define clear priorities to fund the most important projects over the next 10 to 20 years"

What are the Research Infraestructures?

The Research Infraestructures are tools to provide essential services to the scientific community for pure or applied research

They can be related to all the scientific and technological fields, from the social sciences to the astronomy, through genomics and nanotechnologies.

Examples include libraries, databases, biological archives, clean rooms, communication networks, research vessels, satellites and navigation centers, coastal observatories, telescopes, synchrotrons and accelerators.

They can have a unique location or can be distributed or can be virtual.

(European Strategy Forum for Research Infrastructures, ESFRI)

Scientific / Strategic Criteria

- *The Infrastructure projects should:*

- *correspond to a real need to develop the field in Europe*
- *have the support of the appropriate scientific community at European level*
- *be of pan-European interest*
- *be a multi-user facilities that offer open access (physical or virtual) to scientists from across Europe*
- *be relevant at the international level*

Technical and financial criteria

The Infrastructure projects should:

- ***be actual and mature***
- ***be technologically feasible***
- ***open new possibilities or offer better technological benefits***
- ***have evaluated the costs of construction and operation***
- ***provide opportunities for European collaboration and commitment of key stakeholders***

ESFRI Roadmap (updated 2008)

- Social Sciences and Humanities
- Environmental Sciences
- Energy
- Biological and Medical Sciences
- Materials and Analytical Facilities
- Physical Sciences and Engineering
- e-Infrastructures

European Strategy Forum on Research Infrastructures

ESFRI Roadmap

- **Materials and Analytical Facilities**

- EMFL, European Magnetic Field Laboratory
- ESRF, Upgrade of the European Synchrotron Radiation Facility
- Complementary Free Electron Lasers in the Infrared to soft X-ray range
- European Spallation Source for neutron spectroscopy
- EX-FEL, Hard X-ray Free Electron Laser in Hamburg
- ILL, Upgrade of the European Neutron Spectroscopy Facility

ESFRI Roadmap

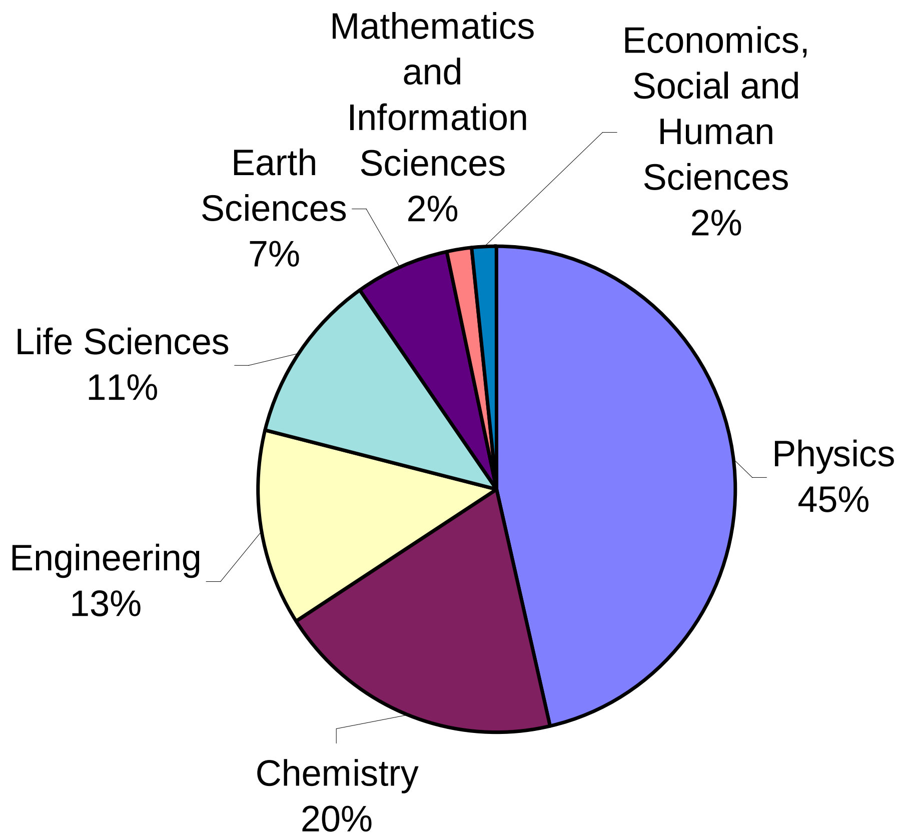
- **Physical Sciences and Engineering**

- **CTA, Cherenkov Telescope Array for Gamma-ray astronomy**
- European Extremely Large Telescope for optical astronomy
- Extreme Light Intensity short pulse laser
- FAIR, Facility for Antiproton and Ion Research
- **KM3Net, Kilometre Cube Neutrino Telescope**
- Pan-European Research Infrastructure for Nano-structures
- SKA, Square Kilometre Array for radio-astronomy
- SPIRAL 2, Facility for the production and study of rare isotope radioactive beams

- **e-Infrastructures**

- Partnership for Advanced Computing in Europe

Distribution of Research Infraestructures



New projects in Spain

- Grantecan
  - Commissioning
- Fuente de Luz de Sincrotrón ALBA
  - To be finished in 2010
- Buque Oceanográfico SARMIENTO DE GAMBOA (a acabar el 2007)
- Centro Nacional de Investigación sobre la Evolución Humana (CENIEH, Burgos)
- Fuente de Neutrones por Espalación Europea (Bilbao)
- And the new “Instalaciones Científicas Singulares” decided in January 2007

Accelerators running in the world

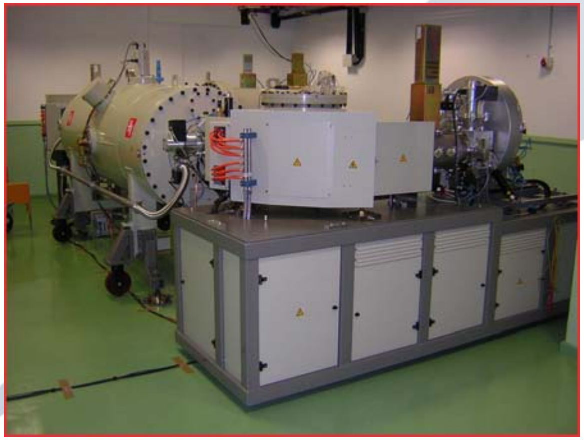
CATEGORY OF ACCELERATORS	NUMBER IN USE (*)	
High Energy acc. (E >1GeV)	~120	
Synchrotron radiation sources	>100	
Medical radioisotope production	~200	
Radiotherapy accelerators	> 7500	9000
Research acc. included biomedical research	~1000	
Acc. for industrial processing and research	~1500	
Ion implanters, surface modification	>7000	
TOTAL	> 17500	

(*) W. Maciszewski and W. Scharf: Int. J. of Radiation Oncology, 2004

Centro Nacional de Aceleradores de Sevilla

ACELERADOR TANDEM VAN DE GRAAFF

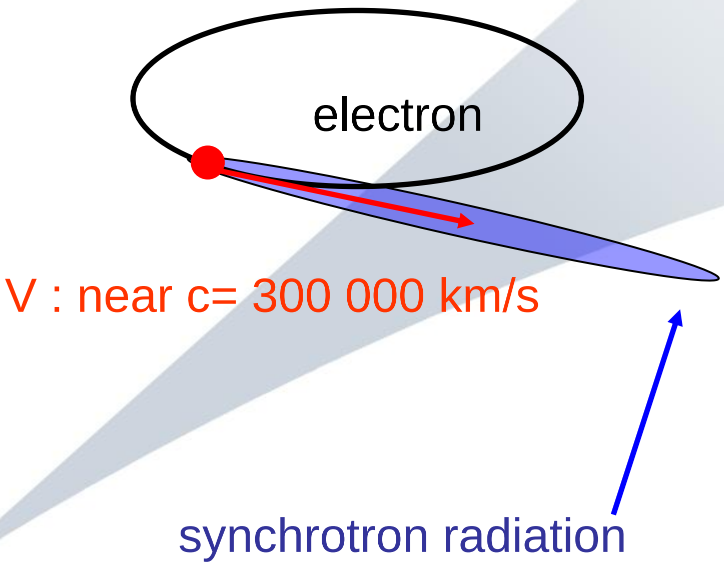
CICLOTRÓN

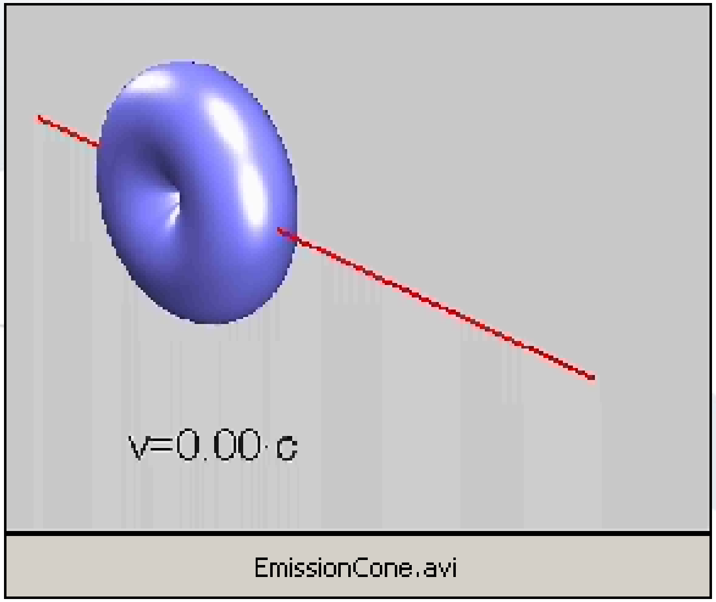


ACELERADOR TANDETRÓN AMS

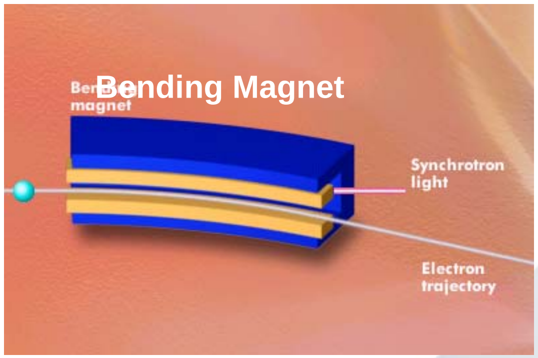
Centro de Microanálisis de Materiales (UAM)

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.





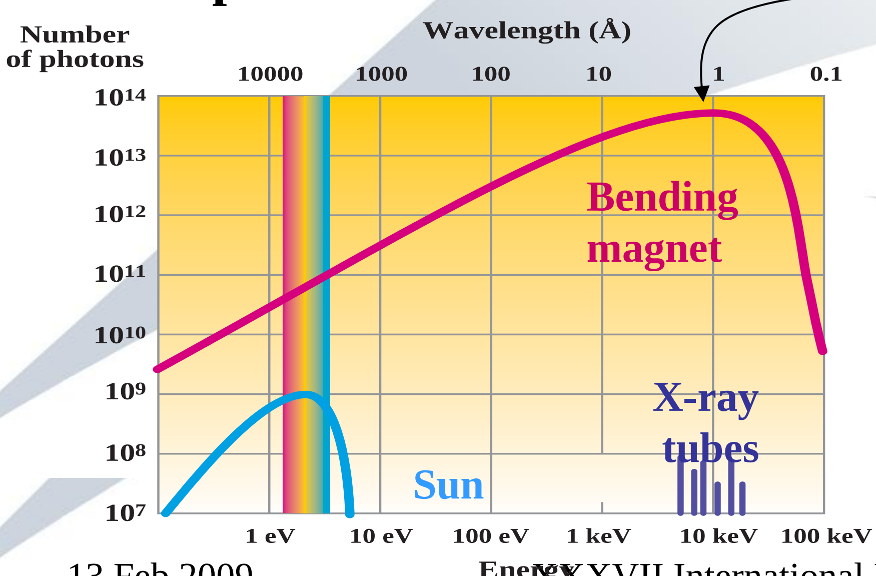
Synchrotron radiation is produced when relativistic electrons are curved by means the Lorentz force generated by an applied magnetic field



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 , E_c = 5.94 keV

λ_c = 2.0 Å

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

λ_c = 0.52 Å

Main parameters of the SL
(as predicted by Maxwell Equations)

$$dE/dt = -2/3 \cdot e^2 a^2 / c^3$$

$$W(\mathrm{keV/turn}) = 8.85\, E^4\,(\mathrm{GeV}) / r\,(\mathrm{m})$$
$$= 26.5\, E^3\,(\mathrm{GeV}) \cdot B(\mathrm{T})$$
$$= 87.45\, E^2\,(\mathrm{GeV}) \cdot B^2\,(\mathrm{T}) / r\,(\mathrm{m})$$

Main characteristics of SL

Continuous Spectrum, from infrared to X-rays, with

E_{crit} (keV) = 0.665 E^2 (GeV) B(T)

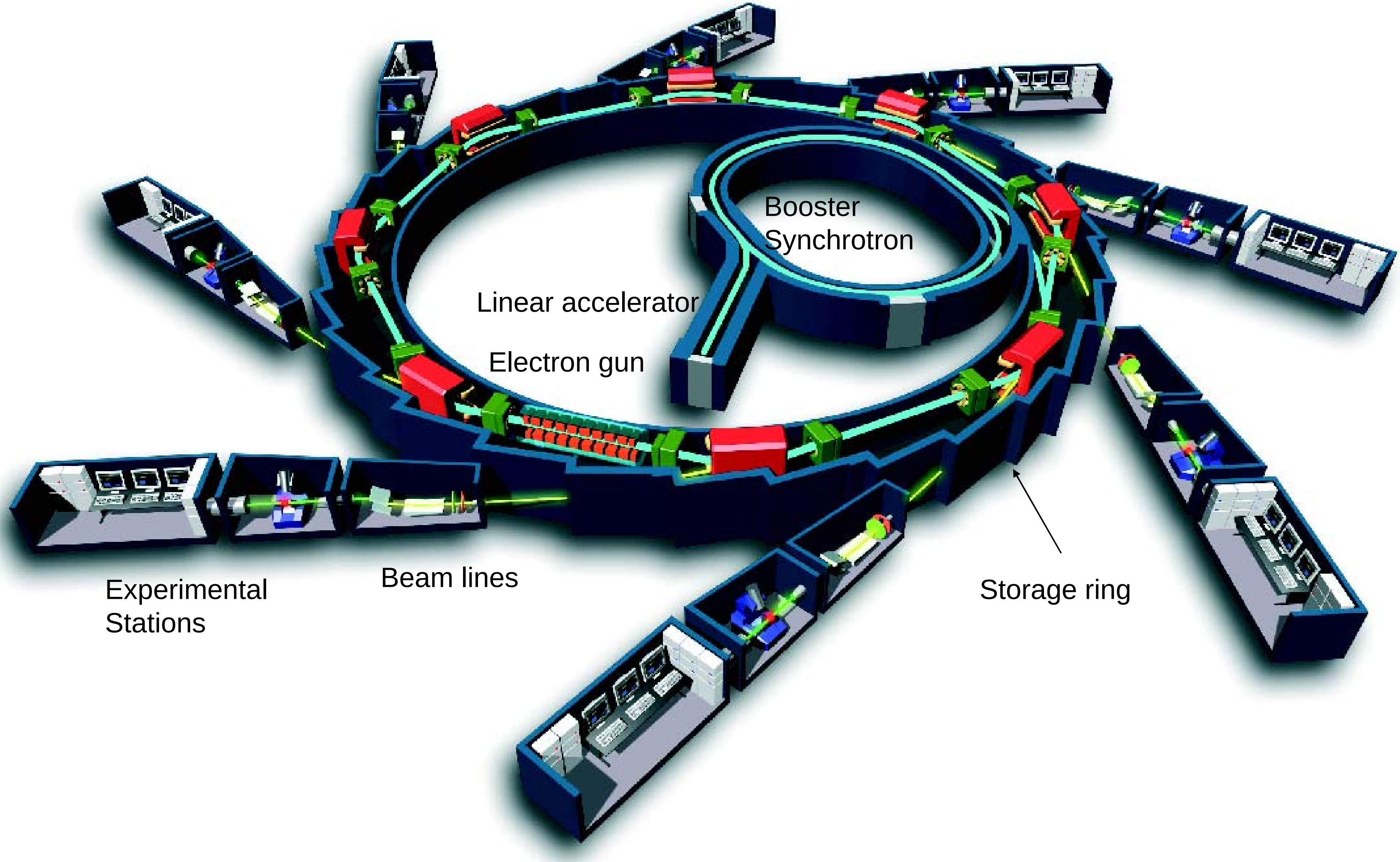
Intense, as a narrow beam

ϑ(rad) = 0.51/E (MeV)

Polarized in the orbital plane

With **temporal structure**

Accelerator complex to produce SR



1947

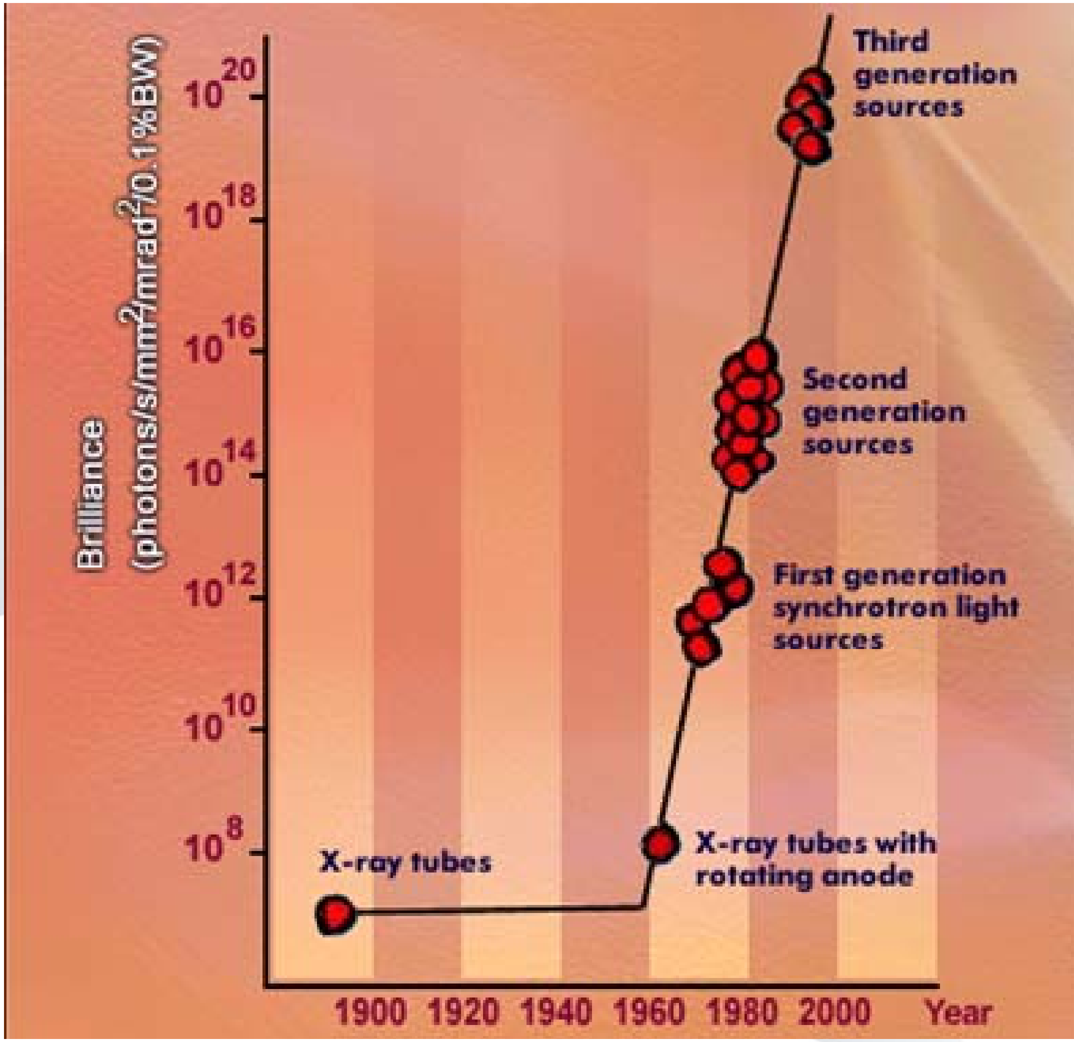
Fig. 1. General Electric Scientists inspecting the vacuum chamber of the 70-MeV synchrotron in which synchrotron radiation was first observed. Left to right: Robert Langmuir, Frank Elder, Toly Gurewitsch, Ernest Charlton, and Herb Pollock.

History of X-Ray Sources

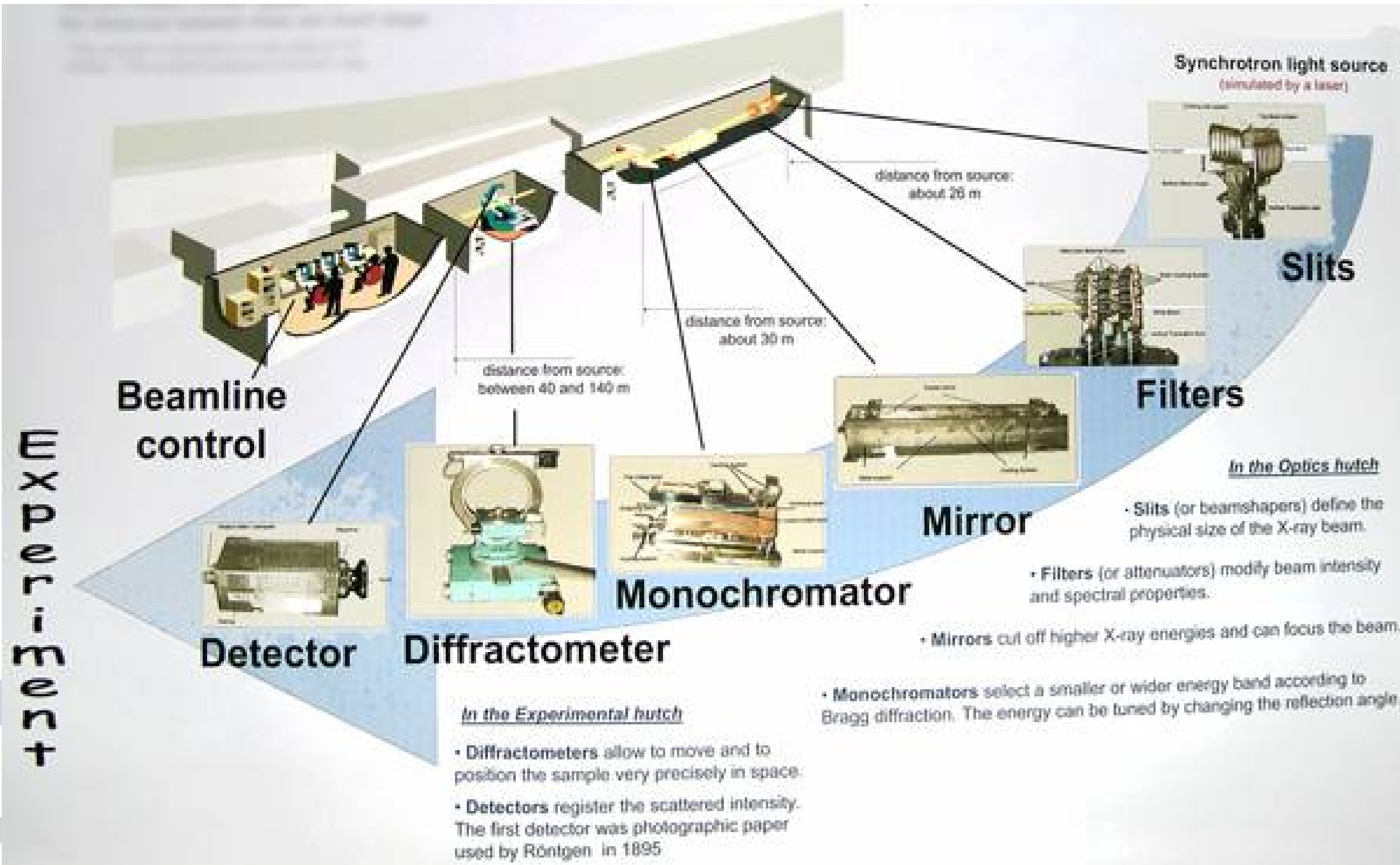
1960's: First uses of SL

1977: First dedicated SL source
Tantalus, U. Wisconsin

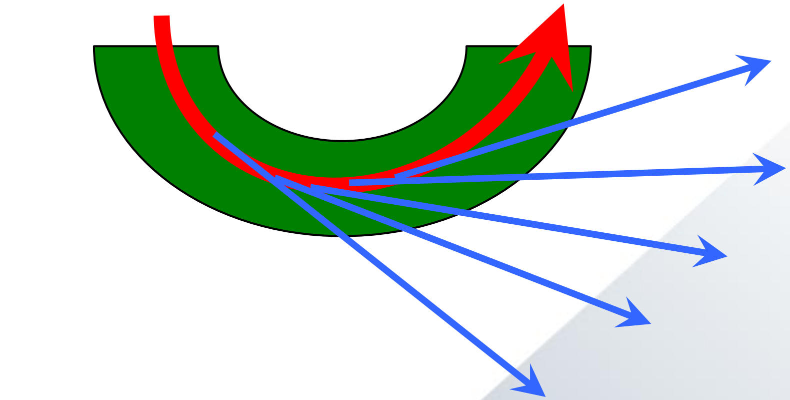
1978: Daresbury



Beam Lines

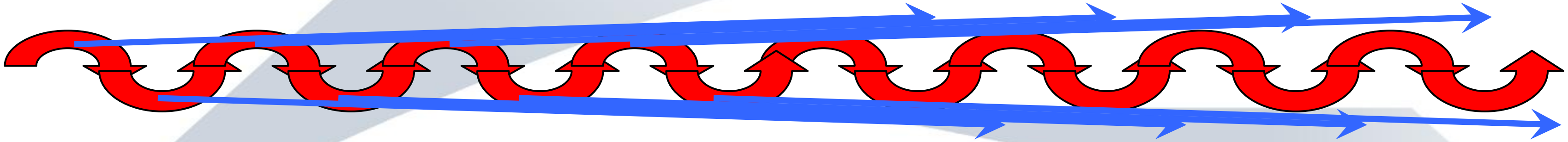

Synchrotron light source
(simulated by a laser)
distance from source: about 26 m
distance from source: about 30 m
distance from source: between 40 and 140 m
Slits
Filters
Mirror
Monochromator
Diffractometer
Detector
Beamline control
Experiment
In the Optics hutch
• Slits (or beamshapers) define the physical size of the X-ray beam.
• Filters (or attenuators) modify beam intensity and spectral properties.
• Mirrors cut off higher X-ray energies and can focus the beam.
• Monochromators select a smaller or wider energy band according to Bragg diffraction. The energy can be tuned by changing the reflection angle.
In the Experimental hutch
• Diffractometers allow to move and to position the sample very precisely in space.
• Detectors register the scattered intensity. The first detector was photographic paper used by Röntgen in 1895

Third generation SLS



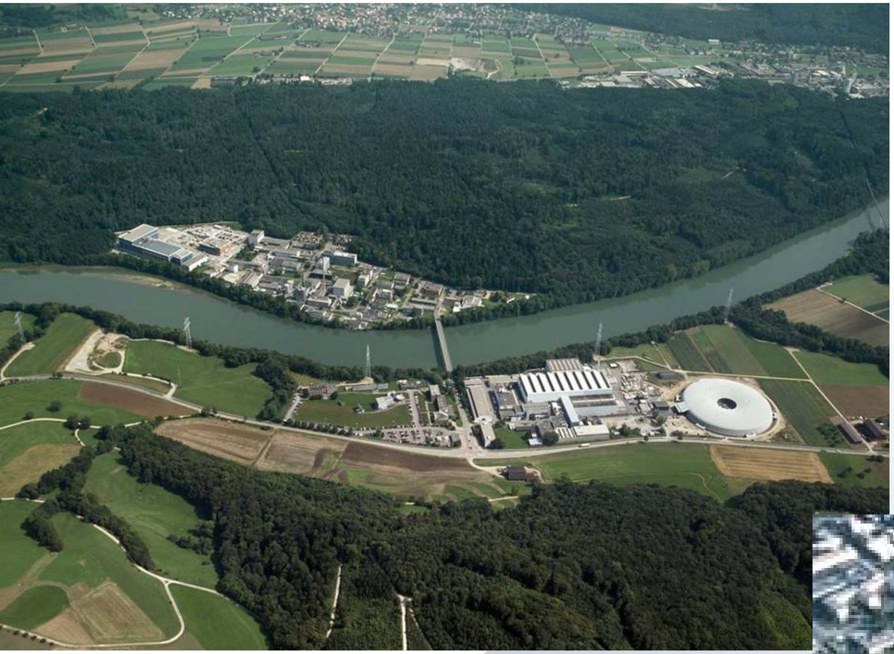
Dipol Magnets:
First and Second Generation

Undulators and multipole wigglers:
Third Generation



Electrons

Synchrotron Light



SLS, PSI, near Zurich

ESRF, Grenoble

Fields of application

- **Basic Science**

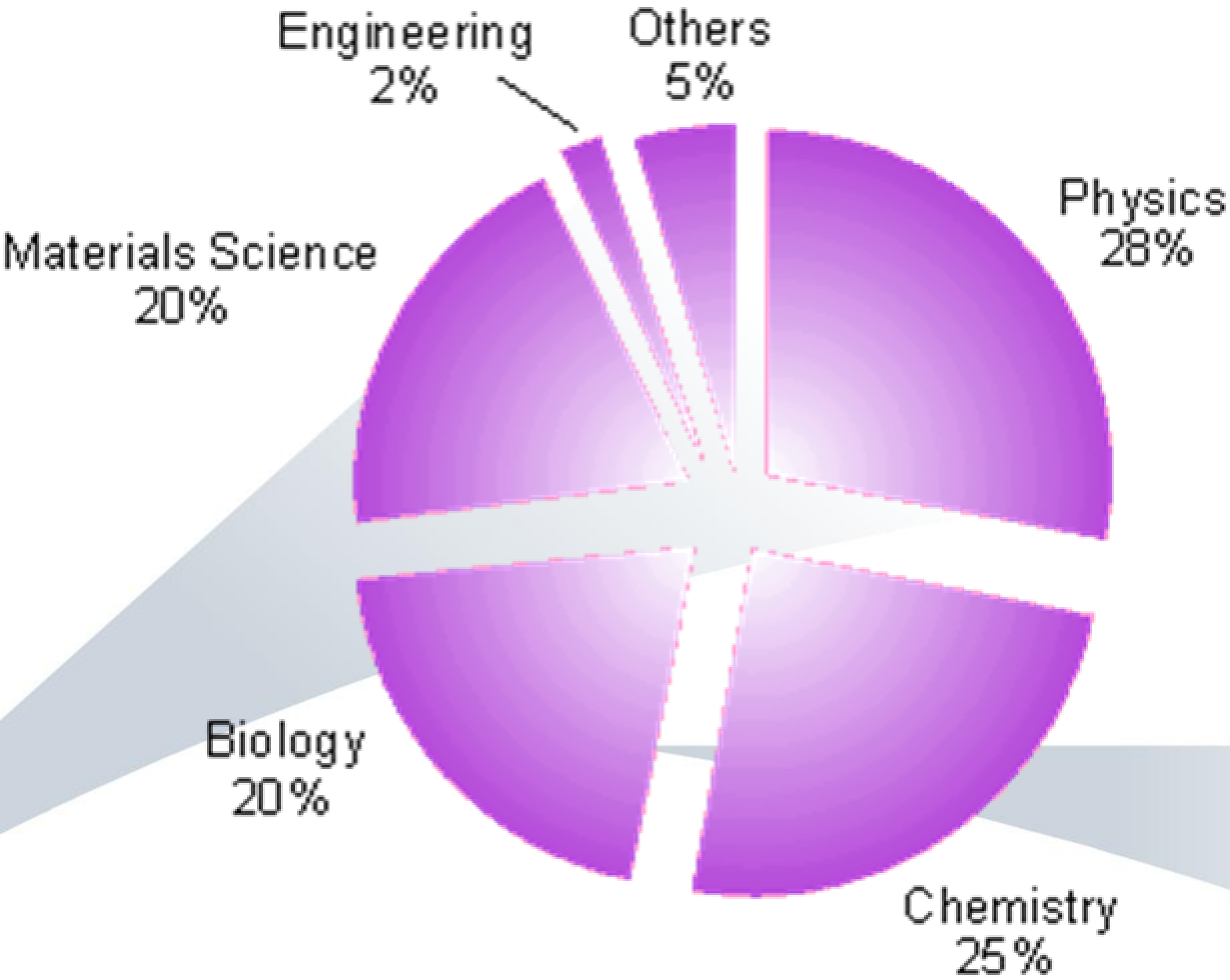
- Physics
- Chemistry
- Material sciences
- Surfaces
- Life sciences
- Medicine
- Lithography and Microfabrication
- Metrology

- **Applied Science**

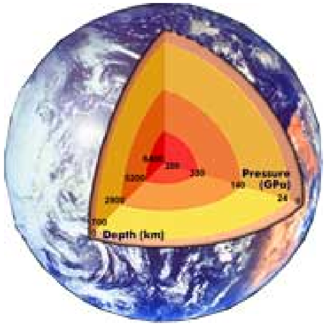
- Pharmacy and Health
- Alimentation
- Plastics
- Microelectronic
- Environment
- Metallurgy
- Cosmetics
- Textile and paper
- Construction

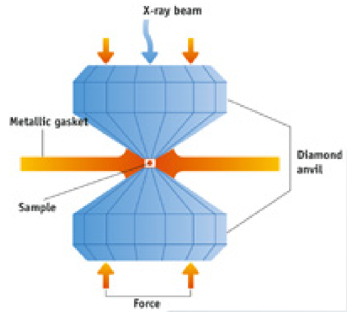
Major Fields of Application

- Structural Biology
  - Structures of proteins and viruses; new drugs design
- Environmental Sciences
  - Chemical structure of contaminants
- Material Science
  - Structure of catalysts, polymers and semiconductors
- Medical Diagnostic and Therapy
  - Use of collimated X-Rays
- Cultural heritage


Engineering
2%
Others
5%
Physics
28%
Materials Science
20%
Biology
20%
Chemistry
25%

Study of conditions in the Earth center

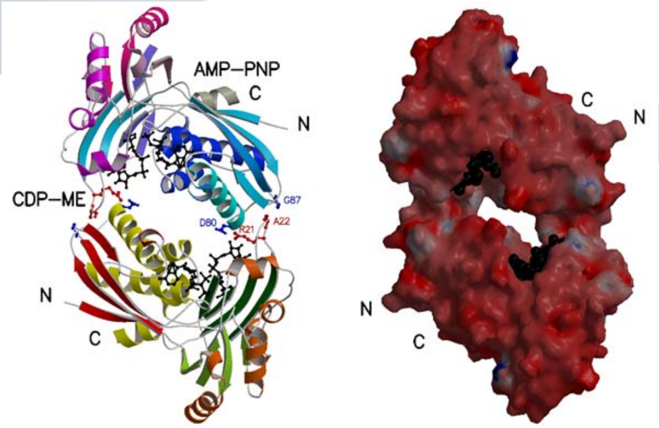




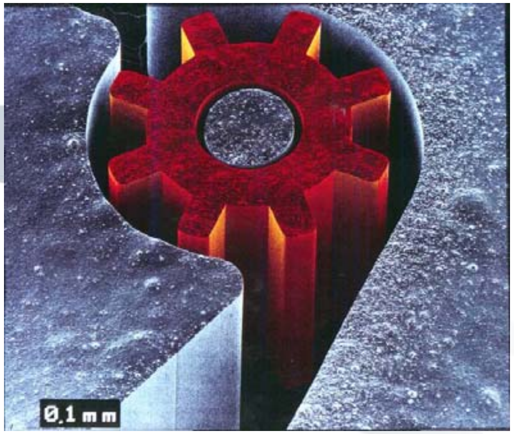
Study of new fibers

Cultural Heritage

Designing new drugs

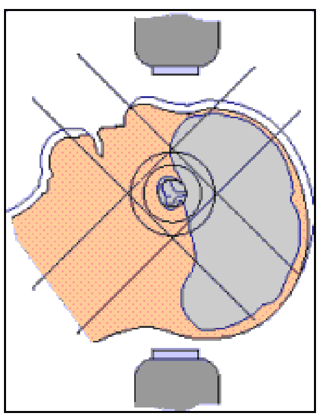


Microfabrication

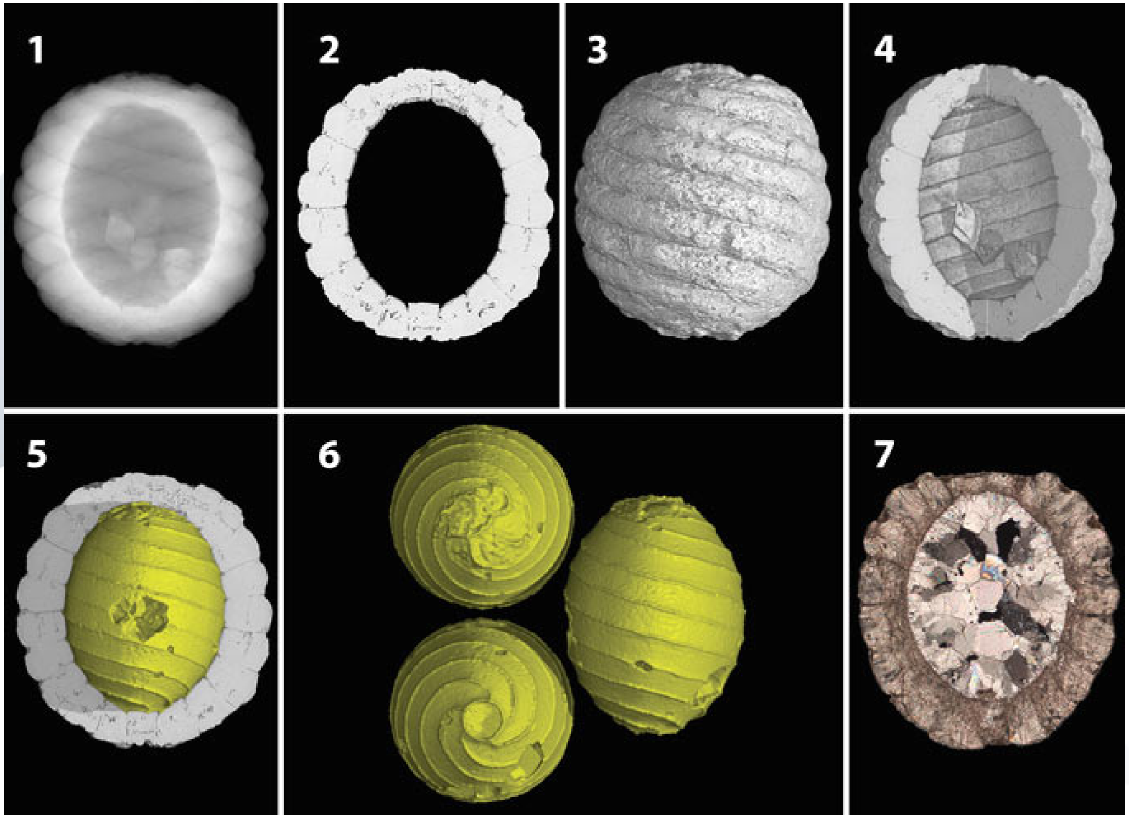


Medical Image

Radiotherapy



Undestructive study of fossils




ISA
MAX LAB
DIAMOND
SRS
DESY
BESSY
FELIX
DELTA
ANKA
SOLEIL
SLS
ESRF
ELETTRA
ALBA

Main steps of ALBA

- ✓ 1992: A Committee of the Generalitat (regional administration) order a viability study
- ✓ 1993: Nomination of a Steering Committee and establishment of a training programme
- ✓ 1995: Agreement between Spanish and Catalan governments to make a detailed study (first **within the IFAE,** later in an independent consortium)
- ✓ March 2002: Formal agreement between governments
- ✓ March 2003: Creation of the CELLS consortium
- ✓ June 2003: First meeting of the CELLS Rector Council
- ✓ October 2003: Starting of the activity

Objectives

- To get experience in the field of accelerator technologies
- To have an important tool to meet the demand of pure and applied research (public and private) in many different fields
- To have a large scientific installation of international level
  - Around such facilities often take place the crossed fertilization from research to developement and to innovation
- To increase the know-how of companies
  - It is necessary to get non standard instrumentation, both at the installation and running phases (more than 30 years)

Implied Technologies

Civil Engineering and security systems
Electromagnets

- Power supplies
- Refrigeration
- Electrical Materials
- Precision Mechanics

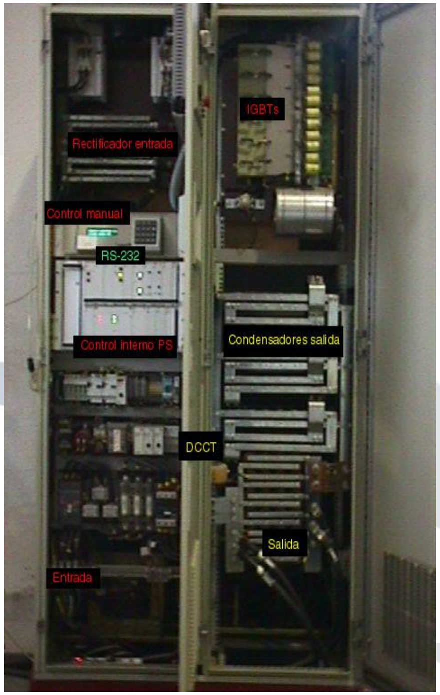
Electronics and Radiofrequency
Ultra-High Vacuum Techniques
Instrumentation

- Accelerator
- Beam Lines
- Insertion Devices (Wigglers and Undulators)

Computation and control

- Software
- Hardware

Diagnostic Systems
Optical Systems
Services
Cryogenics



The ALBA Consortium

Spanish and Catalan Administrations (50-50)

Consejo Rector

Chairpersons: Minister of Science and Innovation
Minister of Innovation, Universities and Enterprises

4 representatives of each administration

Chairperson of the Executive Committee (without vote)

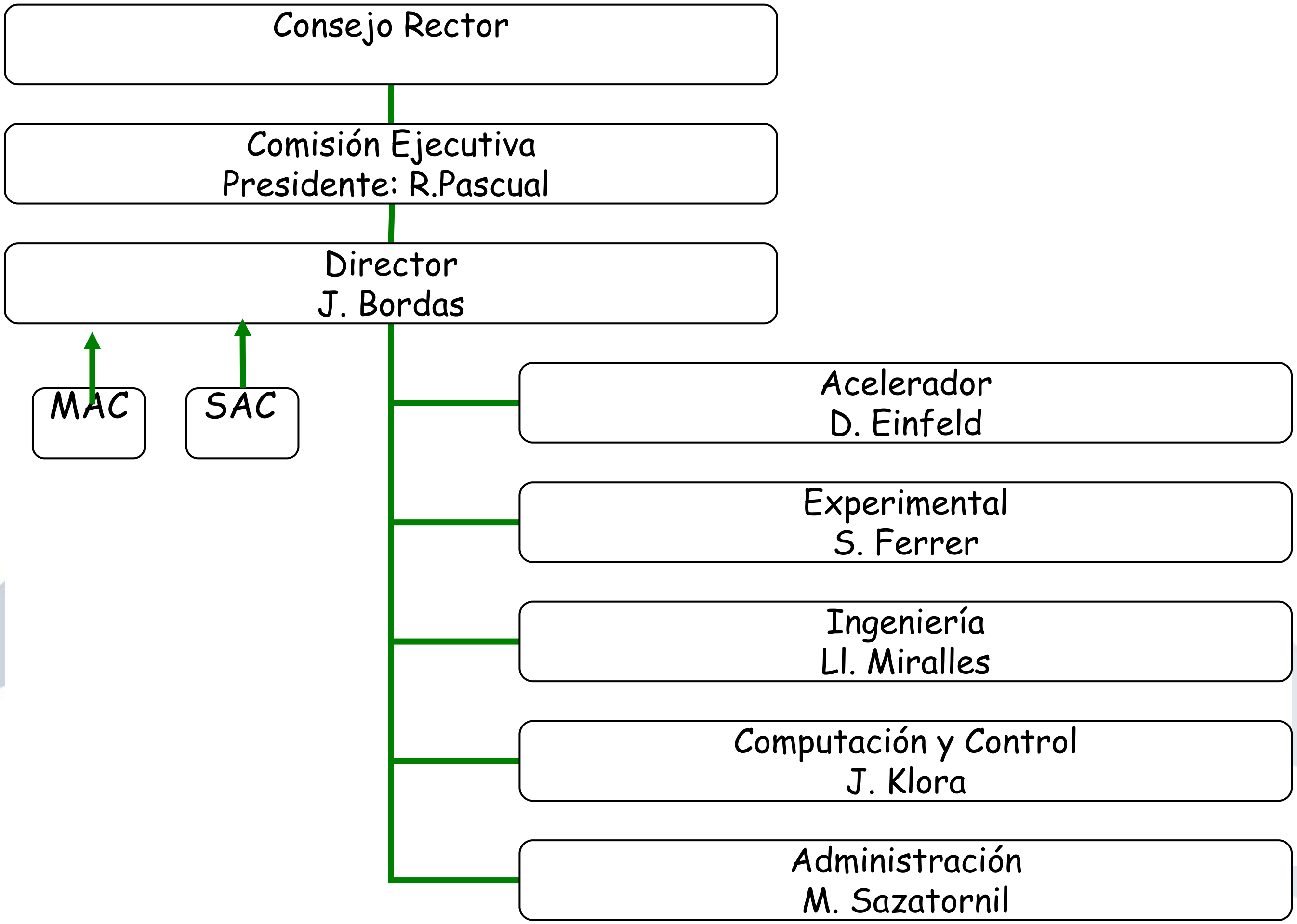
Comision Ejecutiva

Chairperson: Appointed by agreement of both administrations

2 of the members of the Consejo Rector of each administration

Director of the Consortium

Internal Organization of the ALBA Consortium

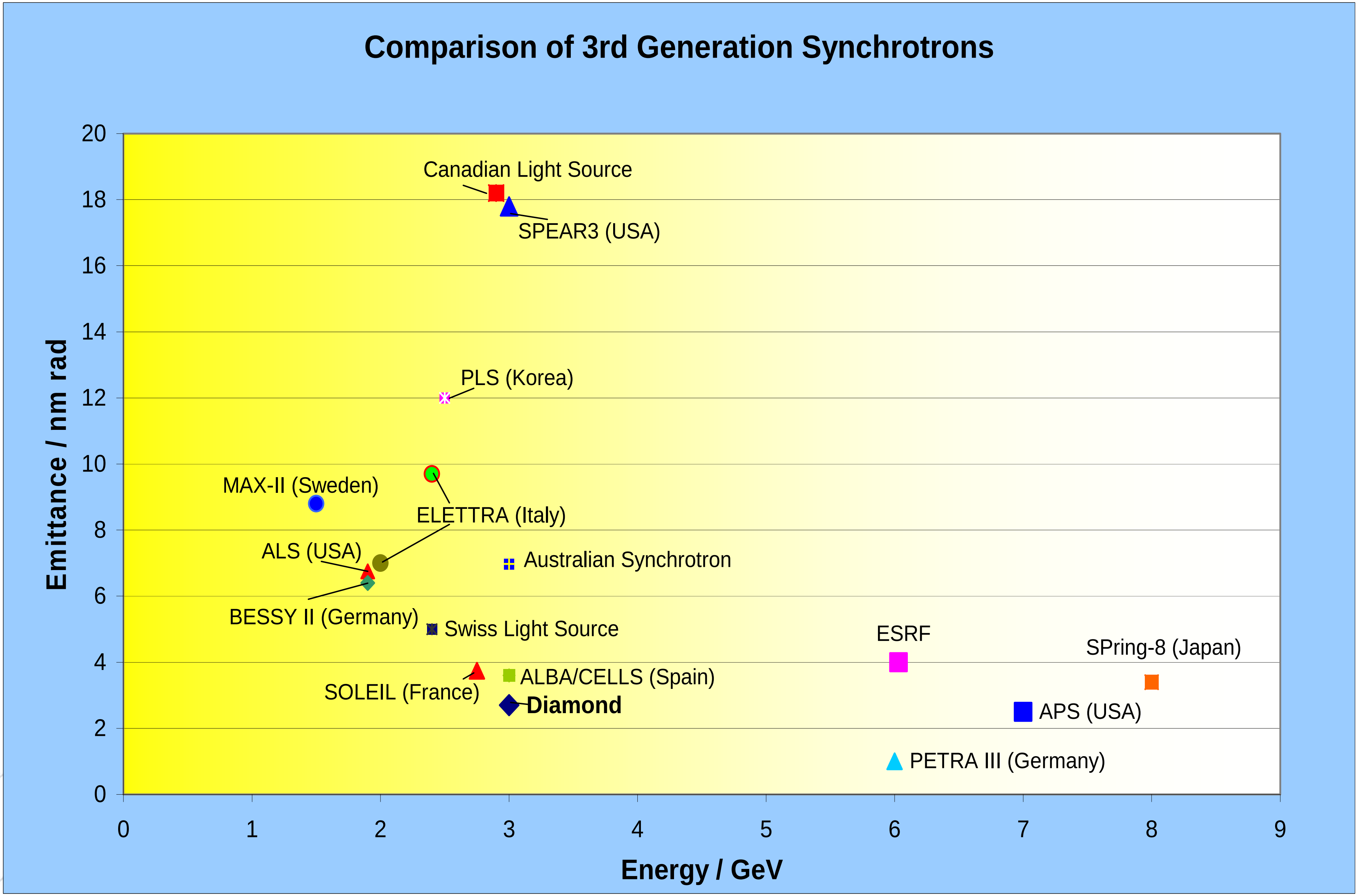


Storage Ring: Main Parameters

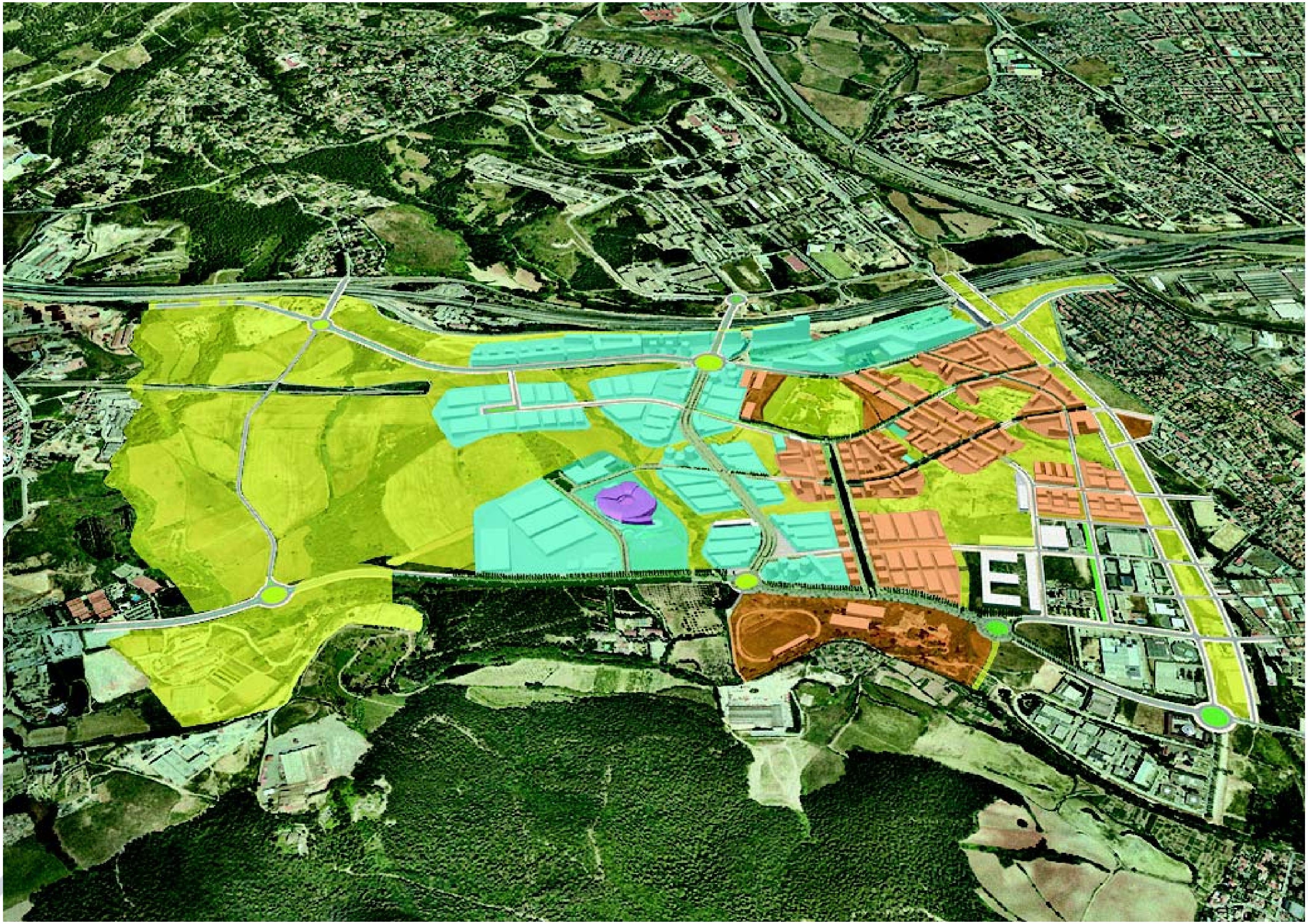
Electron beam energy	3.0 GeV
Storage Ring Circumference	268.8 m
Number of cells	16
Symmetry	4
Straight section lengths	4 x 8.0 m (3 ID's)
	12 x 4.4 m (10 ID's)
	8 x 2.6 m (5 (ID's)
Beam current	400 mA
Horizontal Emittance	4.3 nm.rad
Lifetime	> 10 h

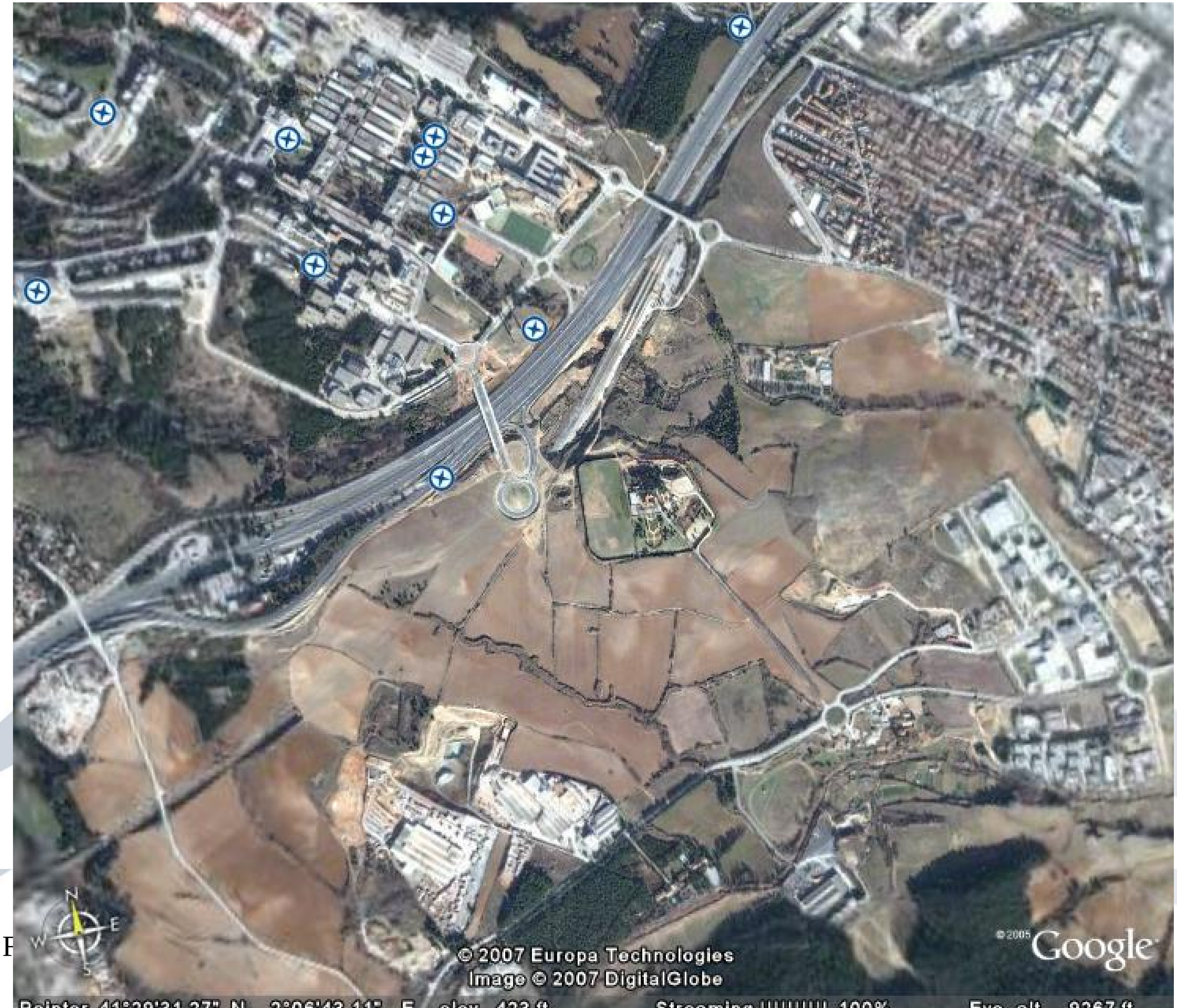
Parameters of the recent or European sources

Name and place	E GeV	Cells	Circumf.	Emit. H. nmrad
ANKA (Karlsruhe, GeV	2.5	8	110.4 m	80
SLS (Villengen, CH)	2.4	12	288.0 m	5
DIAMOND (Chilton, UK)	3.0	24	561.6 m	2.7
SOLEIL (Saint-Aubain, F)	2.5	24	354.0 m	3
ALBA (Cerdanyola)	3.0	16	268.8 m	<4



Comparison of 3rd Generation Synchrotrons
Emittance / nm rad
Energy / GeV
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
Canadian Light Source
SPEAR3 (USA)
PLS (Korea)
MAX-II (Sweden)
ELETTRA (Italy)
ALS (USA)
Australian Synchrotron
BESSY II (Germany)
Swiss Light Source
ESRF
SPring-8 (Japan)
SOLEIL (France)
ALBA/CELLS (Spain)
Diamond
APS (USA)
PETRA III (Germany)




N
E
W
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© 2007 Europa Technologies
Image © 2007 DigitalGlobe
© 2005
Google
Pointer 41°29'31.27" N 2°06'43.11" E elev 423 ft
Streaming |||||||||| 100%
Eye alt 9267 ft


UAB
AP-7/B-30
Castell Sant Marçal
Cerdanyola
Carretera Sant Cugat-Bellaterra
Entrada ALBA
Carretera BP 1413
Sant Cugat
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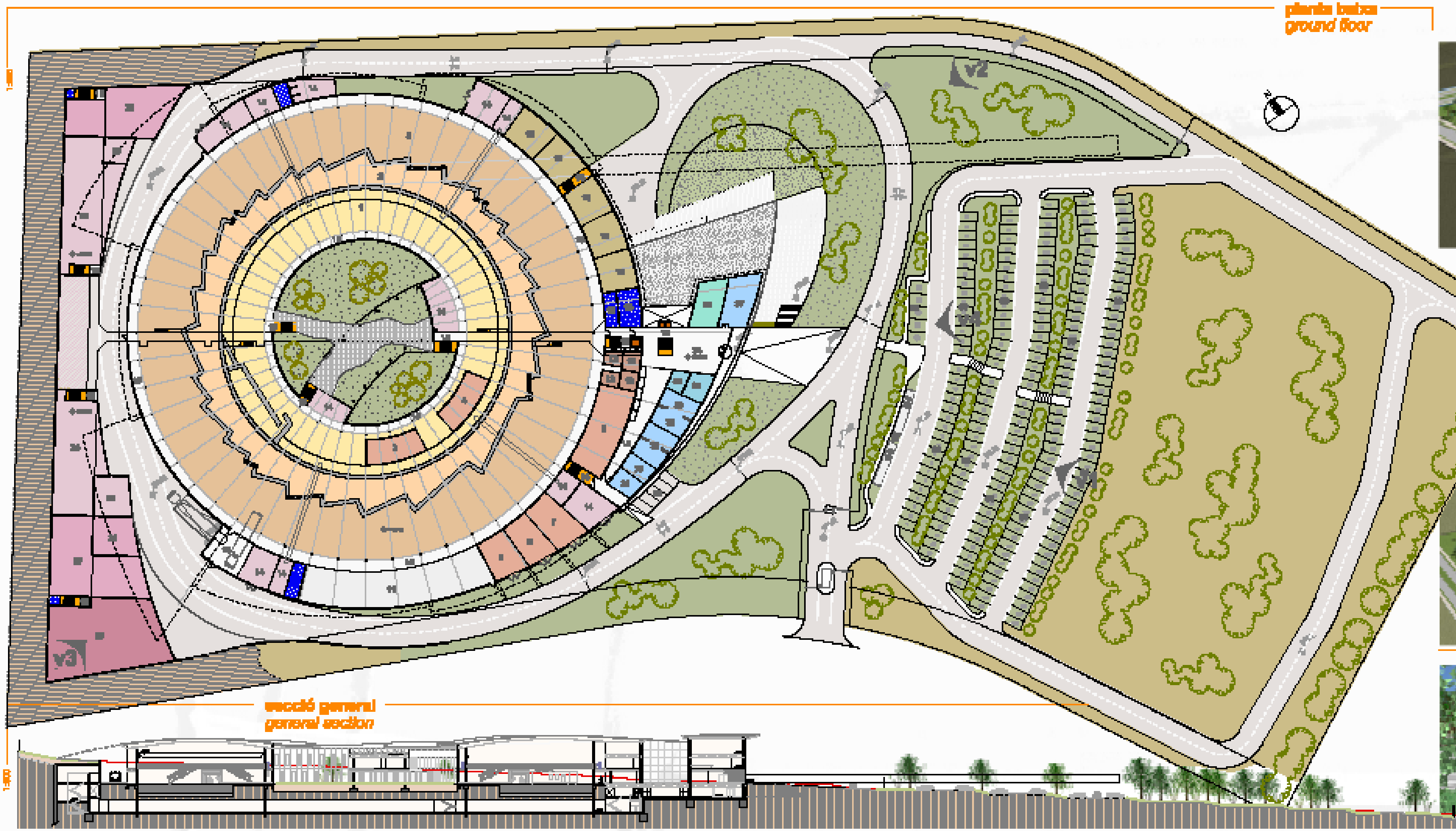
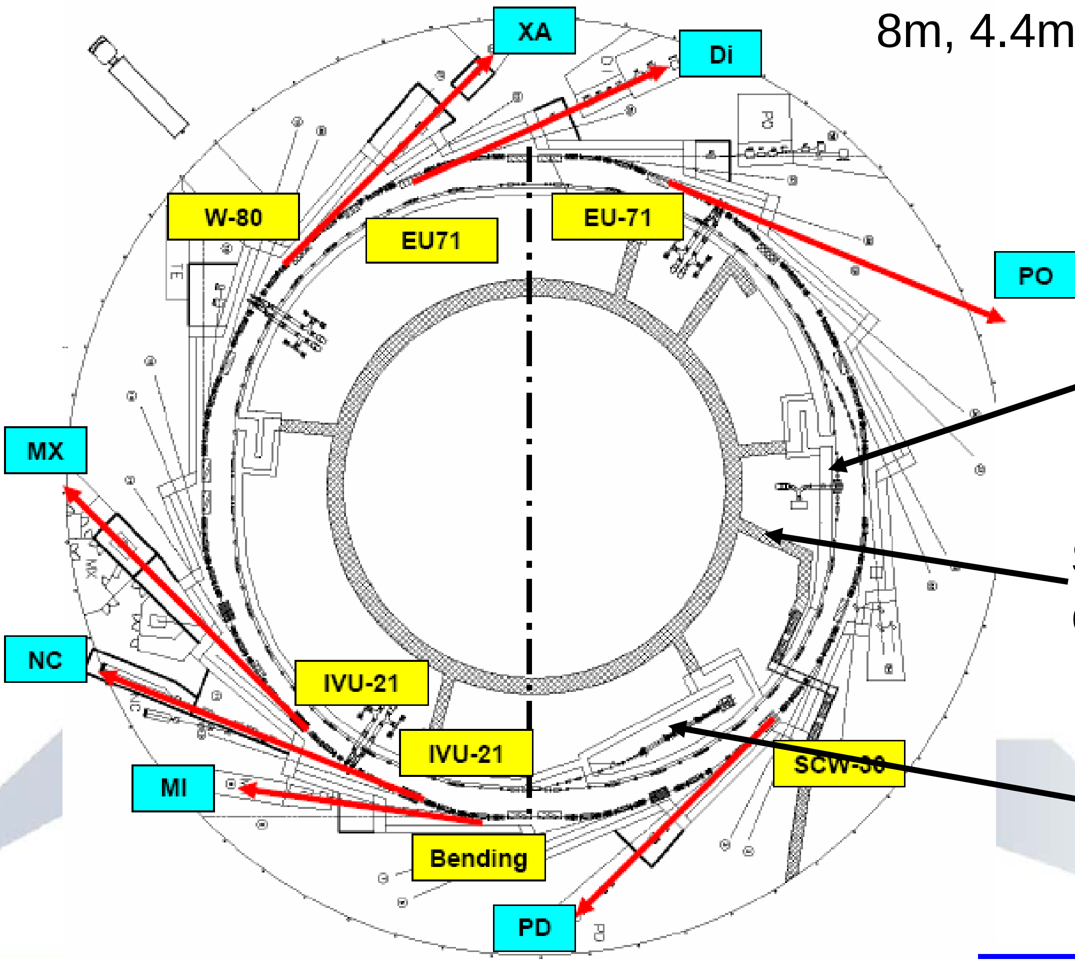
Pointer 41°29'15.73" N 2°06'33.04" E elev 369 ft
Streaming 100%
Eye alt 6044 ft



65,000 squared meters



16 straight sections of
8m, 4.4m and 2.6 m long

Booster: 3 GeV, 250 m
4 fold symmetry
emittance smaller **20 nm·rad**

Storage ring: 268 m
double bend achromat lattice
16 cells with 4 fold symmetry

Linac: 100 MeV
At 3 GHz
Repetition rate of 3Hz

Civil Engineering

- Main Building for accelerators and experimental stations:
  - Donought of 18,500 m^2
  - Critical zone: a slab of 1 m thick floating over 2 m of graduated gravels, disconected from the building
- Administrative Buildings:
  - 4,000 m^2
- Technical Buildings
  - 7,600 m^2, including and auxiliary building for storage and future projects

Critical Floor Area: dimensions and stability

Inner diameter of critical floor area:	ca. 60m
Outer diameter of critical floor area:	ca. 120m
Slow relative displacements:	<0.25 mm/10m/year <0.05 mm/10m/month <0.01 mm/10m/day <0.001mm/10m/hour
Perimeter differential displacement:	<2.5 mm/year
Vertical vibrations amplitude:	<0.004 mm from 0.05-1 Hz <0.001 mm from 1-100 Hz
Horizontal vibrations amplitude:	<0.002 mm

Vibrations		
Vertical amplitudes	< 4 µm	From 0.05 – 1 Hz
	< 0.4 µm	From 1 – 100 Hz
Horizontal amplitudes	2 µm	

Thermal Stability	
Within the Ring Tunnel	23 ± 0.1°
In the Experimental Hall	23 ± 1°

Electrical Stability	
Long power cuts (t > 0.6s)	< 1 per year
Medium duration power cuts (0.4s < t < 0.6s) and ΔV > 12% in 2 phases	< 3 per year
Short duration power cuts (t < 0.4s) and ΔV > 8% in 3 phases	< 3 per year

Other Electrical data	
Voltage Supply	25 kV
Expected power Consumption	9 MW

Power suply

Redundant electrical power suply

Dedicated transformer connected to a 220 kV line

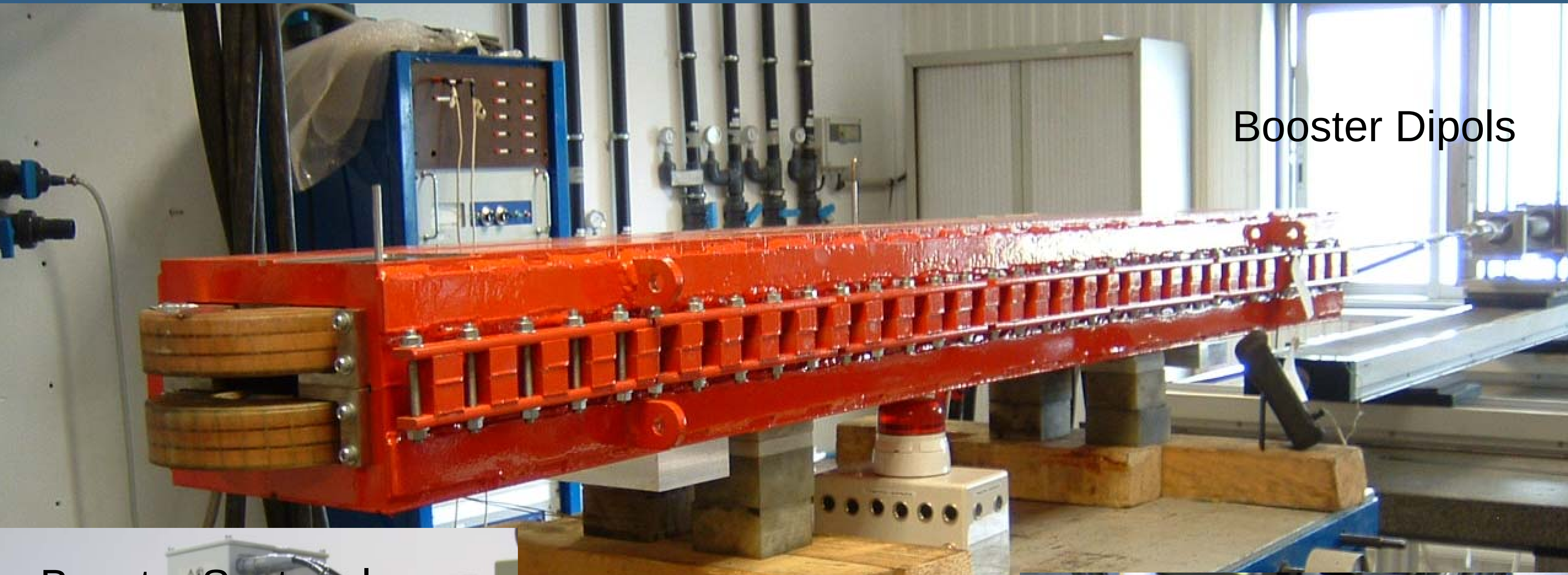
Natural gas cogeneration plant, also for thermal energy supply

Static and dynamic UPS will guaranty the supply to the most critical parts of the facility

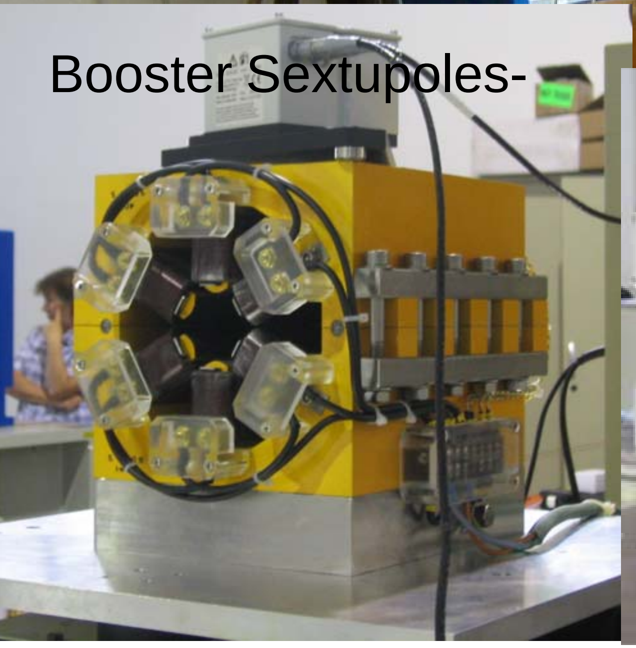
Control by the Consejo de Seguridad Nuclear


Sincrotró ALBA
Generalitat
de Catalunya


ALBA

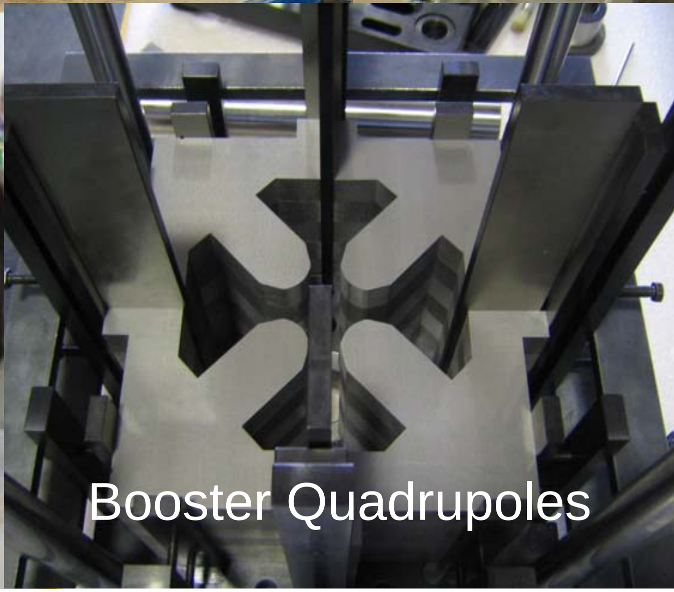


Booster Dipols



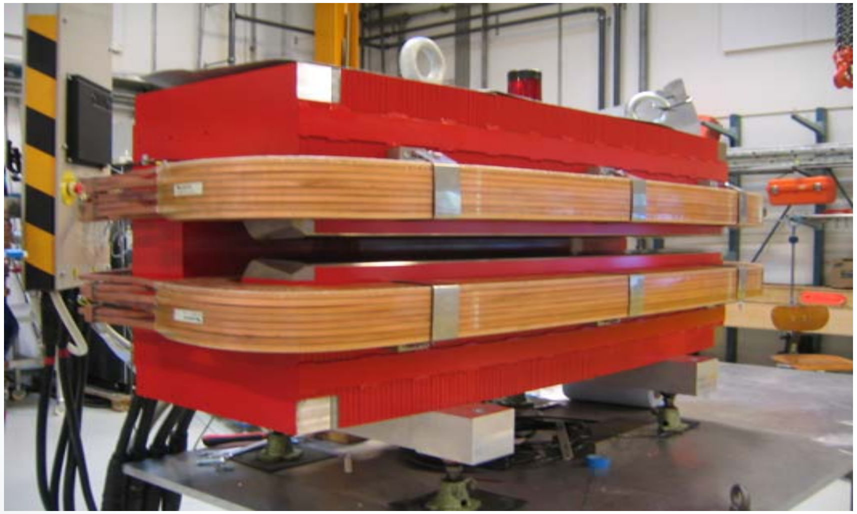
Booster Sextupoles-

Booster Correctors-

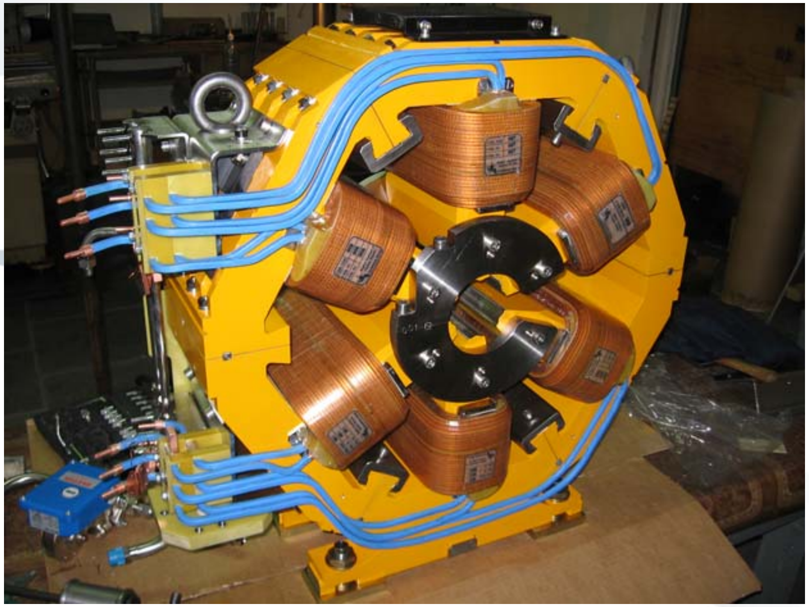


Booster Quadrupoles

32 DIPOLS (1.42 T)
with GRADENT(5.9T/m)



128 quadrupols 500 mm long

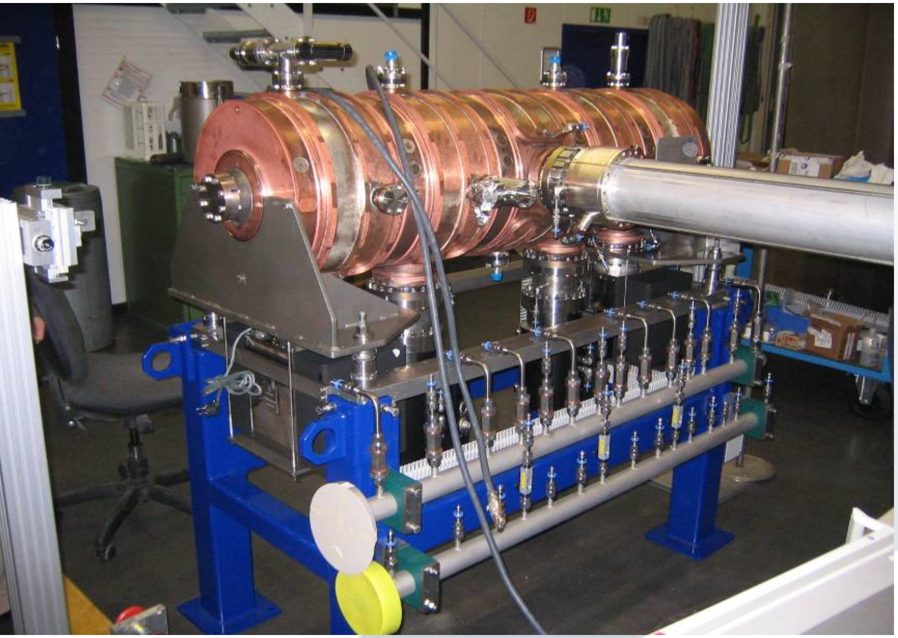


120 sextupols
150 mm long,
With more
than 100
correctors

Preinstallation of one of the 32 sectors of
the storage ring in the UAB workshop:

1 dipole, 2 quadrupoles, 2 sextupoles, beam tube and vacuum pumps on a girder

RF cavity for the booster



6 RF stations for the SR: 2 IOT amplifiers (80 kW and 67% efficiency) combined in a new Cavity Combiner

Storehouse and electronic laboratory for rack's preinstallation


TAIM-TFC
TAIM-TFC

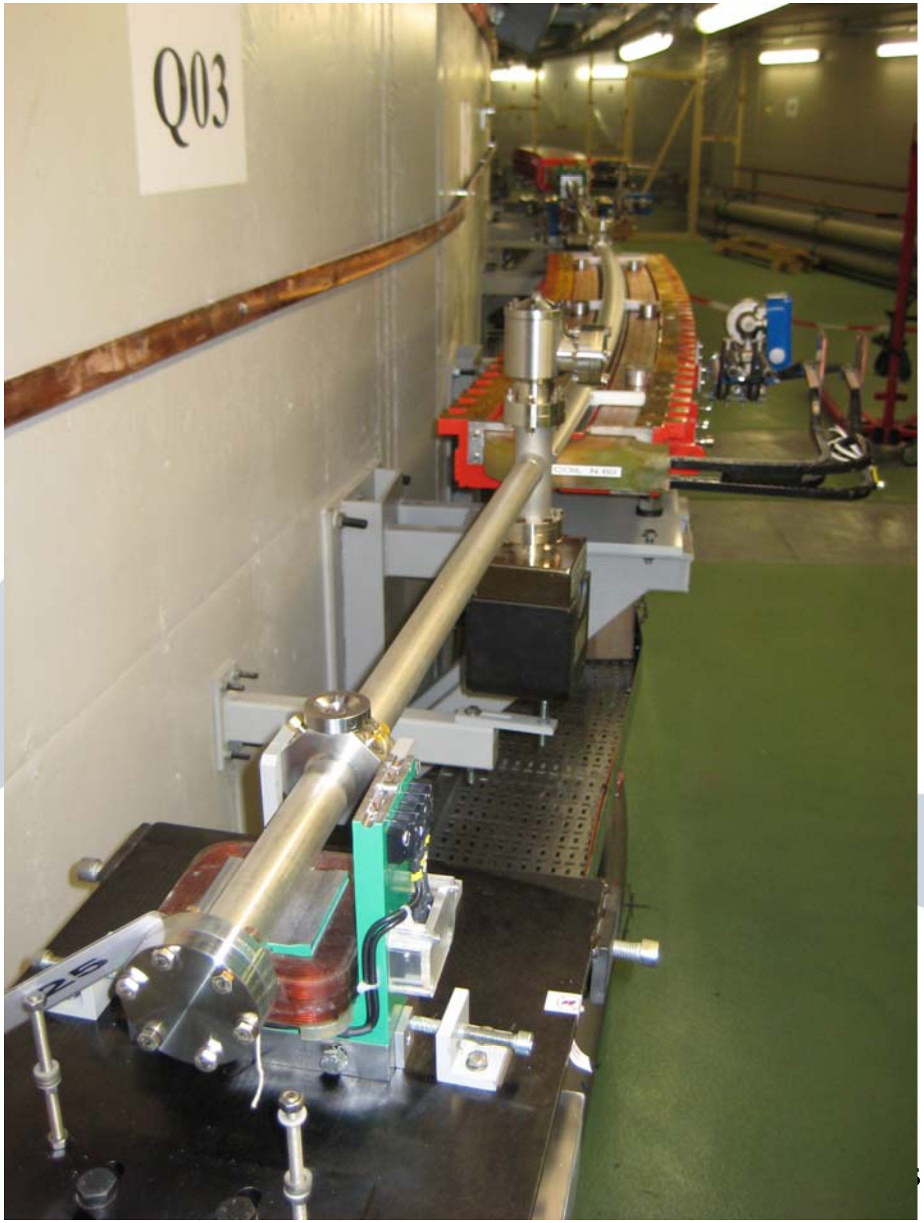

Linde


TAIM-TFC
TAIM-TFC
FRAGILE


THALES

Figure 6: Beam image at SM3 (Linac Exit)


Q03


Q03
25

Vacuum lab in the new building


31

Booster and Storage Ring, SLS, PSI

Port	Beam-line	Experimental techniques	Scientific applications
4	MSPD (SCW-30)	- High resolution powder diffraction. - High pressure diffraction	Structure of Materials, Time resolved diffraction
9	MISTRAL (BM)	Soft X-ray full field transmission X-ray microscope. Optimized on the water window	Cryogenic tomography of biological objects. Spatially resolved spectroscopy
11	NCD (IVU-21)	High Resolution Small and High Angle X-ray Scattering/Diffraction	Structure and phase transformations of biological fibers, polymers, solu-tions. Time resolved X-ray studies
13	XALOC (IVU-21)	X-ray diffraction from crystals of biological macromolecules	Protein crystallography, with particular emphasis on large unit cell crystals
22	XAS (MPW-80)	- EXAFS, XANES, Quick-EXAFS - In situ catalytic cell	Material Science, Chemistry, Time resolved studies
24	CIRCE (EU-62)	- Photoemission microscopy (PEEM) - Near atmospheric pressure photoemission (NAPP)	Nano-science and magnetic domain imaging (PEEM). Surface chemistry (NAPP)
29	XMCD (EU-71)	- Circular Magnetic Dichroism - Resonant Magnetic Diffraction	Magnetism, surface magnetism and magnetic structure

With the collaboration of AUSE. The second phase BL are in preparation

Budget and Characteristics

- Total budget: 201 M€ (including personnel and running costs from 2003 to 2009)
- Annual starting budget since 2010: 16 M€
- Personnel: 138
- Around 1000 users per year (for the first phase beam lines)
- Atraction of companies and new investments: (XFEL, Centro de Biología Estructural,…)

Indicators of the Financial Analysis in the baseline scenario *

Indicators	
VAN** (5%)	30,7 Mil. €
VAN (4%)	**58,5 Mil. €**
VAN (2,5%)	114,8 Mil. €
B/C***	1,14
TIR****	6,5%

*The basic scenario considers an inflation rate of 2.5%, a discount rate of 4%, 230 days of annual operation of the facility and 5 years until saturation

** Valor Actualizado Neto (Net Actualized Value)

***Benefit/Cost

***Tasa Interna de Rentabilidad (Internal Rate of Return)

Main Steps in ALBA (since 2003)

- Geological studies of a possible site
- Socio-economic study
- Decision on the site and design of the executive project
- Establishment of the Advisory Boards (MAC and SAC)
- Selection of personnel and establishment of provisional headquarters (UAB)
- Final Detailed Design and contacts with technological companies
- Starting of civil works (May 2006, fast track method)
- Installation and commissioning of the linac (summer 2008)
- Final of civil works (end 2008)
- Starting of booster and SR installation (December 2008)
- First light production: end 2009
- Routine activities: end 2010

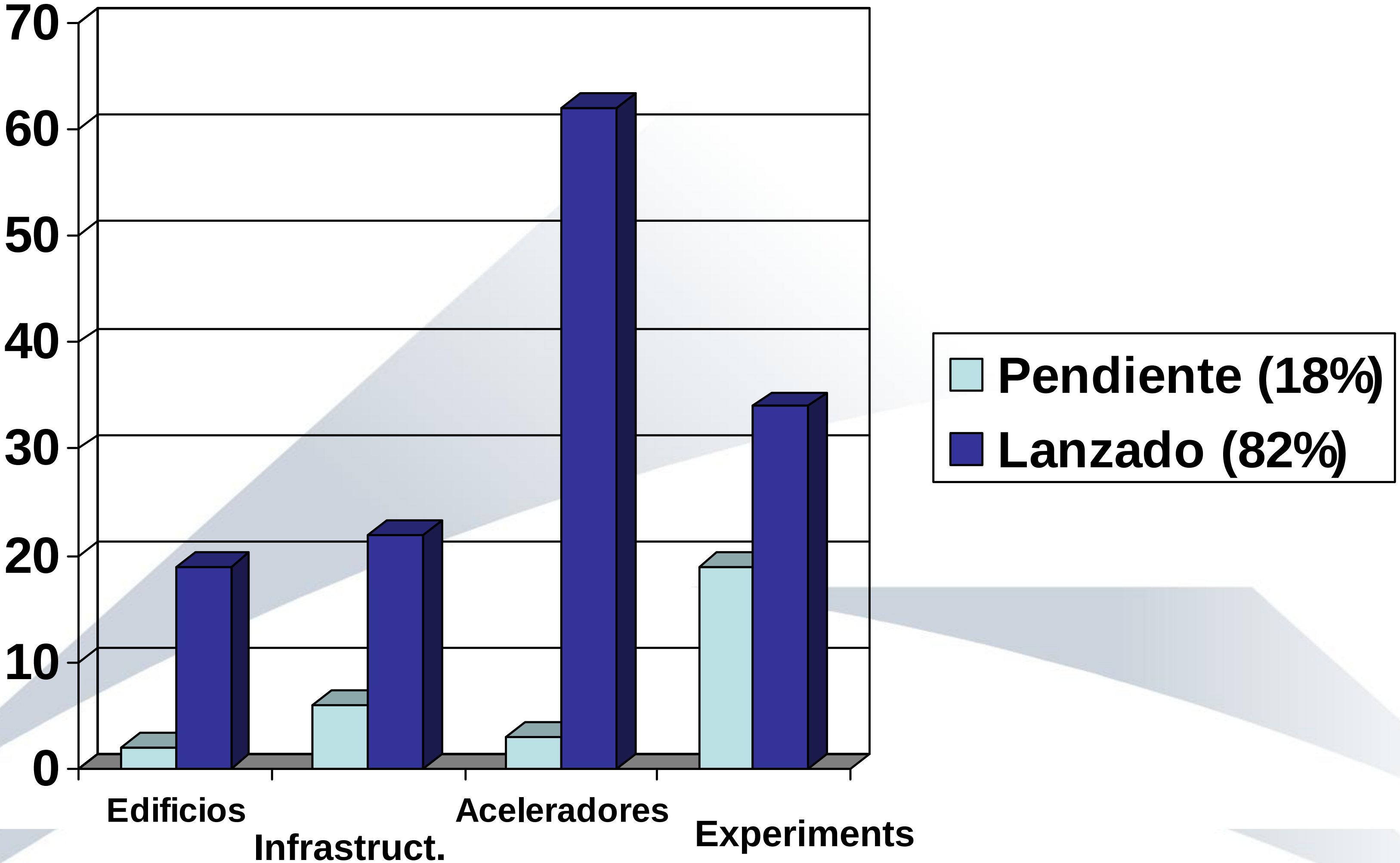
- (1+ 1 years latter than initially expected, with some 5% more than the expected budget)

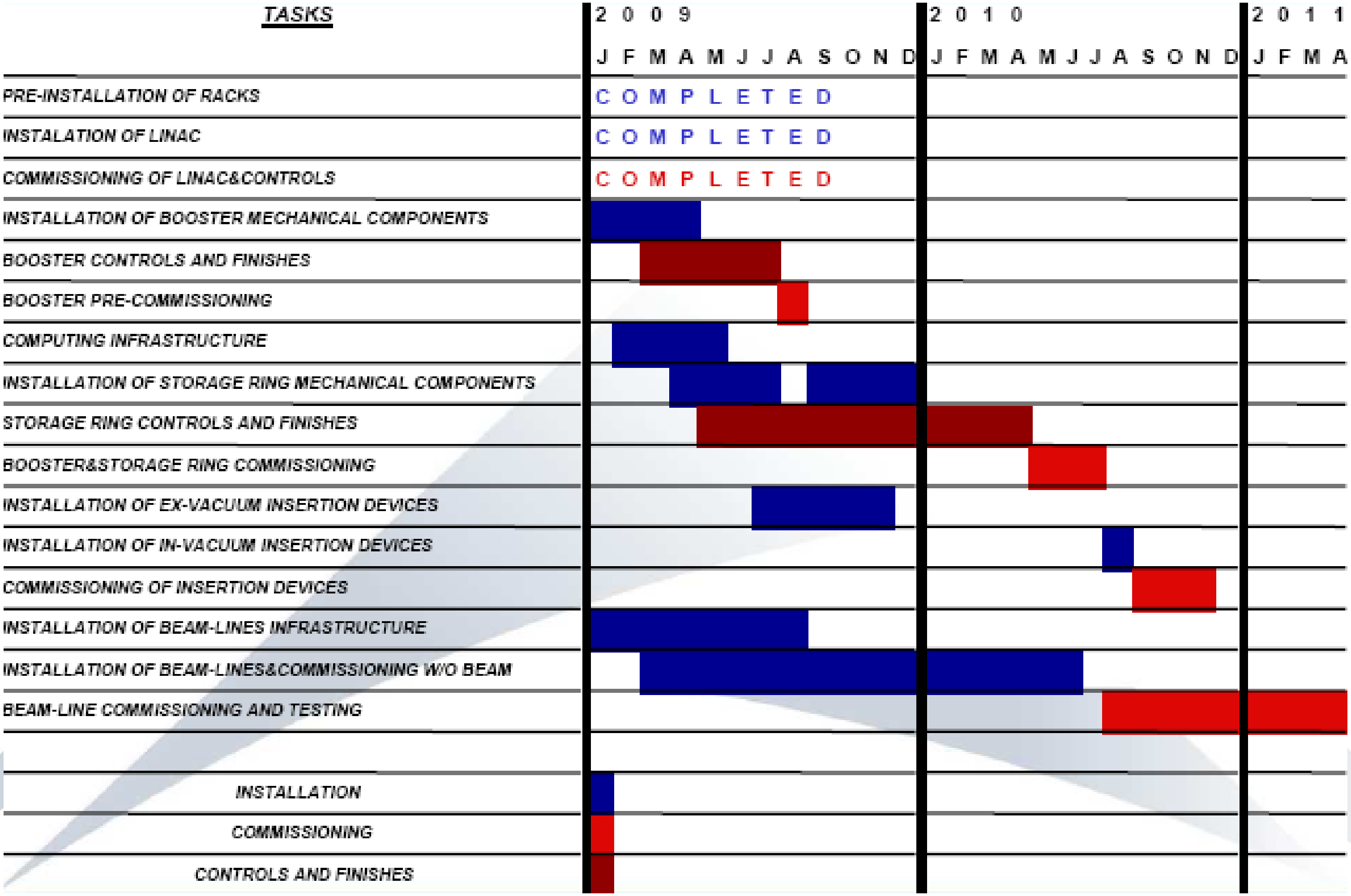
Personnel (31/08/08)

Presidente Comisión Ejecutiva	*1*
Director	*1*
Gestión Proyecto	*2*
Protección radiológica	*2*
Aceleradores	*15*
Experimentos	*18*
Ingeniería	*41 (+3)*
Computación, controles y datos	*36 (+8)*
Administración	*13*
Asesores	*1*
TOTAL	*130 (+11)*

In brackets: temporal personnel for the instalation phase.
Plus 10 visitors from the Check Republique training in the instalation.

CONTRACTS


70
60
50
40
30
20
10
0
Pendiente (18%)
Lanzado (82%)
Edificios
Infrastruct.
Aceleradores
Experiments


TASKS
2 0 0 9
2 0 1 0
2 0 1 1
J F M A M J J A S O N D J F M A M J J A S O N D J F M A
PRE-INSTALLATION OF RACKS
C O M P L E T E D
INSTALATION OF LINAC
C O M P L E T E D
COMMISSIONING OF LINAC&CONTROLS
C O M P L E T E D
INSTALLATION OF BOOSTER MECHANICAL COMPONENTS
BOOSTER CONTROLS AND FINISHES
BOOSTER PRE-COMMISSIONING
COMPUTING INFRASTRUCTURE
INSTALLATION OF STORAGE RING MECHANICAL COMPONENTS
STORAGE RING CONTROLS AND FINISHES
BOOSTER&STORAGE RING COMMISSIONING
INSTALLATION OF EX-VACUUM INSERTION DEVICES
INSTALLATION OF IN-VACUUM INSERTION DEVICES
COMMISSIONING OF INSERTION DEVICES
INSTALLATION OF BEAM-LINES INFRASTRUCTURE
INSTALLATION OF BEAM-LINES&COMMISSIONING W/O BEAM
BEAM-LINE COMMISSIONING AND TESTING
INSTALLATION
COMMISSIONING
CONTROLS AND FINISHES

CELLS contribution to XFEL

- CELLS has proposed to produce, measure and install one of the SASE undulators (known as SASE3), made of 21 segments of undulators of 5 meters each.
- This proposal has already been accepted by the “in-kind” Review Committee of the EXFEL and by the EXFEL management and CELLS is receiving from the Spanish Ministry of Science and Innovation the resources needed for that.
- There is a preliminary phase (already started) in which a prototype will be designed, constructed and tested by DESY staff.

- CELLS will manage the contracts and follow up production of 21 undulators.
- Undulator parts will be delivered at the EXFEL facility in Hamburg where CELLS staff will carry out their assembly and alignment as well as the subsequent magnetic measurements and undulator tuning.
- EXFEL personnel will install the undulators in the EXFEL tunnel.

Meeting of the Council
15 December in the new building