Lecture on LNLS + Sirius (3GeV)

Monday 22 Nov 2010 at 16:20 (00h55')

Primary authors : Prof. PETROFF, Yves (LNLS)

Co-authors :

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LNLS AND SIRIUS

Y. Petroff

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LNLS AND SIRIUS

1. PRESENTATION OF LNLS

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LNLS AND SIRIUS

1. PRESENTATION OF LNLS
2. NEW DEVELOPMENTS
3. INDUSTRIAL RESEARCH

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LNLS AND SIRIUS

1. PRESENTATION OF LNLS
2. NEW DEVELOPMENTS
3. INDUSTRIAL RESEARCH
4. THE NEW PROJECT: SIRIUS (3 GeV)

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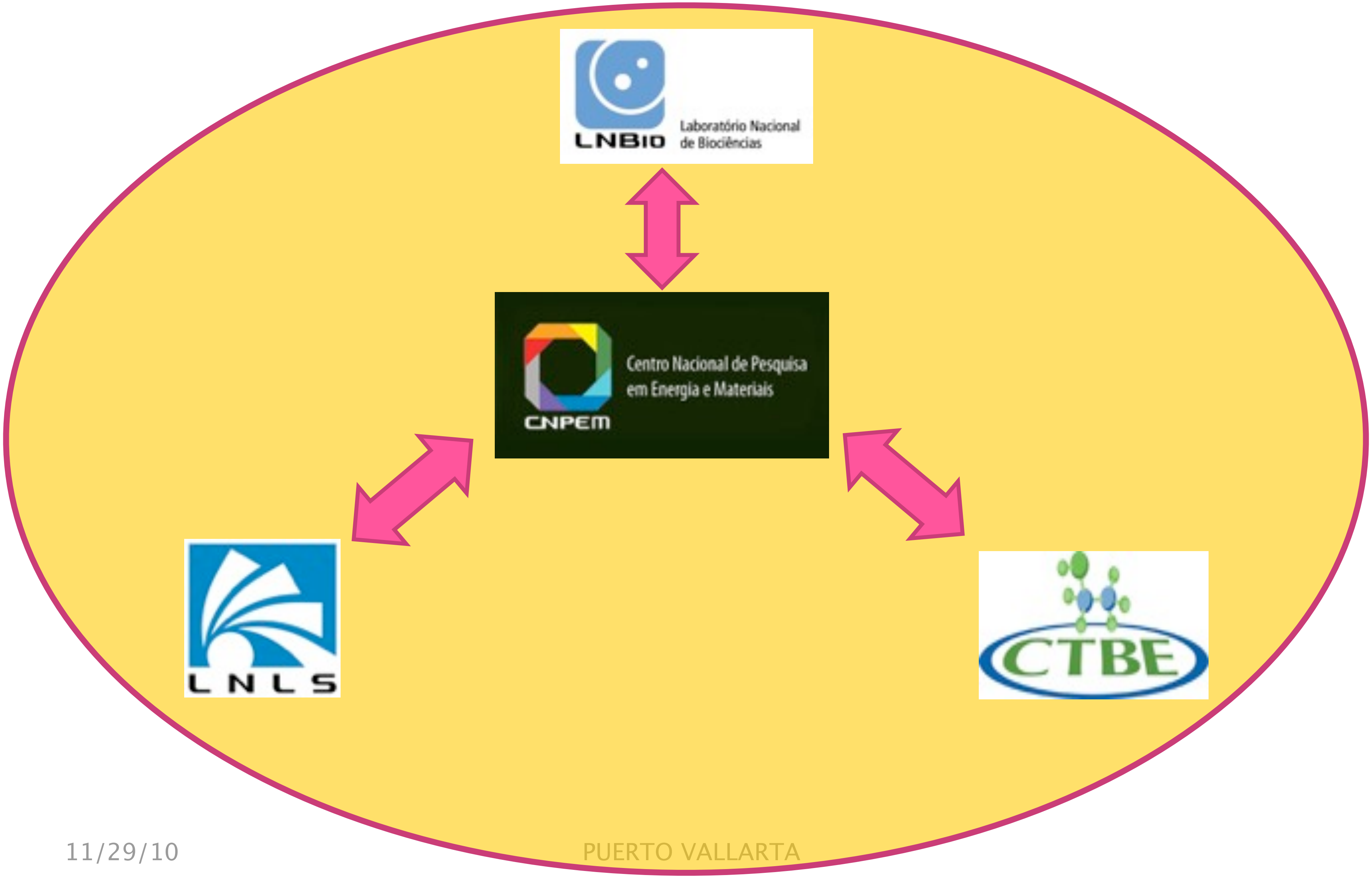
LNLS AND SIRIUS

1. PRESENTATION OF LNLS
2. NEW DEVELOPMENTS
3. INDUSTRIAL RESEARCH
4. THE NEW PROJECT: SIRIUS (3 GeV)
5. CONCLUSIONS

Y. Petroff

LNLS – Laboratório Nacional de Luz Síncrotron, CP 6192, 13084-971, Campinas, SP, Brazil

Operated by ABTLuS via a Contract with MCT

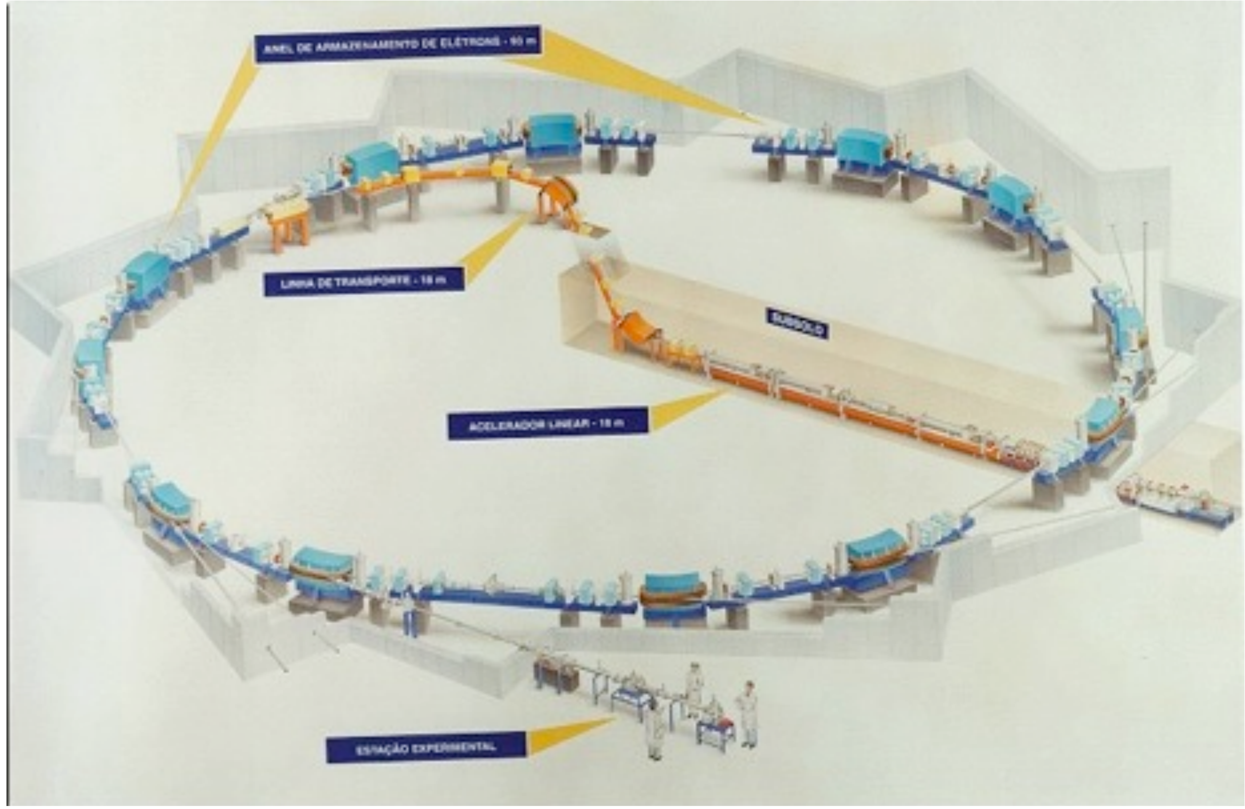


LNLS - Laboratório Nacional de Luz Síncrotron

- 1.37 GeV / 250 mA
- 100 nm.rad emittance
- 14 beamlines in operation (16 in 2011)

- Design and construction: 1987 to 1997
- Designed and built in Brazil in very difficult conditions and with a very low budget
- First synchrotron light source of the southern hemisphere

LNLS 1.37 GeV Storage Ring

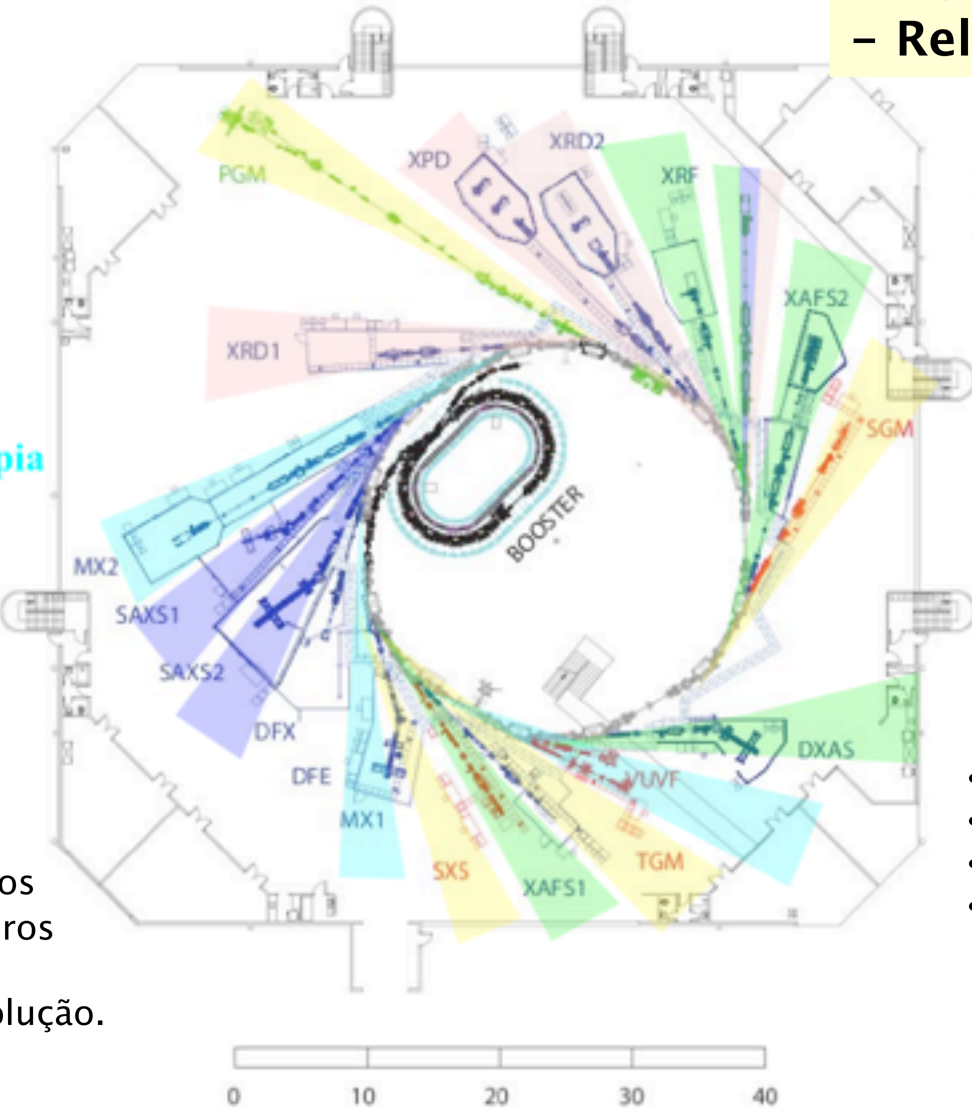


Operation	1.3	Ge
Maximum	25	m
Circunference	93.	m
Average	29.	m

Dipoles	1.6	T
Critical energy	2.0	ke
Number of	12	
Number of	4	
Available	2.9	m

14 beamlines – 13 dipoles, 1 wiggler (structural biology)
2011 – 2 more beamlines
- **1 undulator (100eV-1KeV)**
- **1 wiggler (20-30 KeV)**

- **2nd generation machi**
- **Large emittance:100 r**
- **Low energy**
- **Very few insertion de**
- **Reliability:97-98%**



Difração de raios-X

- Estrutura de monocristais
- Estrutura de policristais
- Filmes
- Difração Magnética

Cristalograia e Espectroscopia de macromoléculas

- Estruturas de macromoléculas biológicas
- Estrutura de polímeros

Espalhamento de raios-X

- Materiais nanoestruturados
- Microestruturra de Polímeros
- Estruturas fractais
- Forma de proteínas em solução.

Espectroscopia de absorção de raios-X

- Estrutura de materiais ordenados e desordenado
- Medidas in-situ de eletroquímica,
- Catálise
- Transições de fase
- Análise química de traços

Espectroscopia de UV e raios-X moles

- Física de Superfícies
- Espectroscopia molecular
- Estrutura eletrônica
- Propriedades magnéticas.

● DURING THE LAST FEW YEARS, LNLS HAS BEEN SUFFERING FROM EXTREMELY LOW BUDGETS: 10/12 M$/YEAR TO RUN THE SYNCHROTRON LAB+ BIOLOGY LAB + C2NANO (e microscopy, STM, AFM, MICROFABRICATION LABS)

● NOW, THE BIOLOGY LAB HAS A SEPARATED BUDGET AND FOR THE FIRST TIME IN 2010, WE HAVE OBTAINED A REASONABLE BUDGET: 19 M$ WHICH SHOULD ALLOW A SERIOUS REFURBISHEMENT OF THE LAB

● STARTING 2011, WE WILL HAVE A 6 YEARS CONTRACT WITH A BUDGET FROM A SINGLE ORIGIN (MINISTRY).

New Developments

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1. Soft X-Ray PGM beamline: 90/1500 eV (under commissioning)
   - liquids, at.+mol. physics
   - nanociences, surfaces, magnetism

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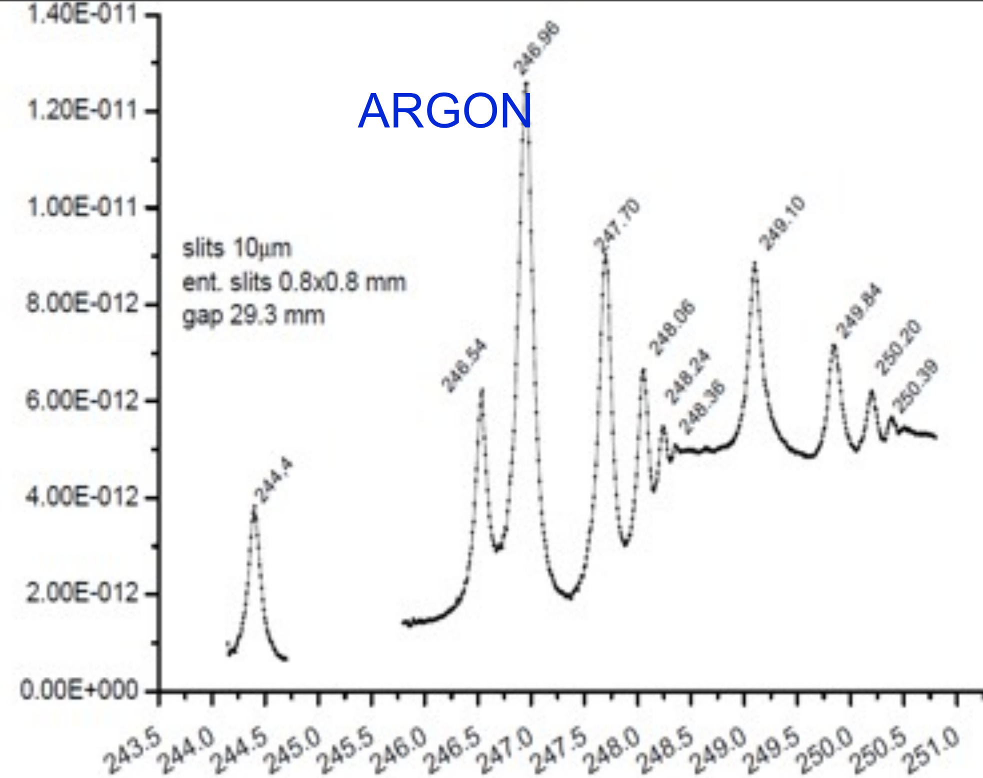
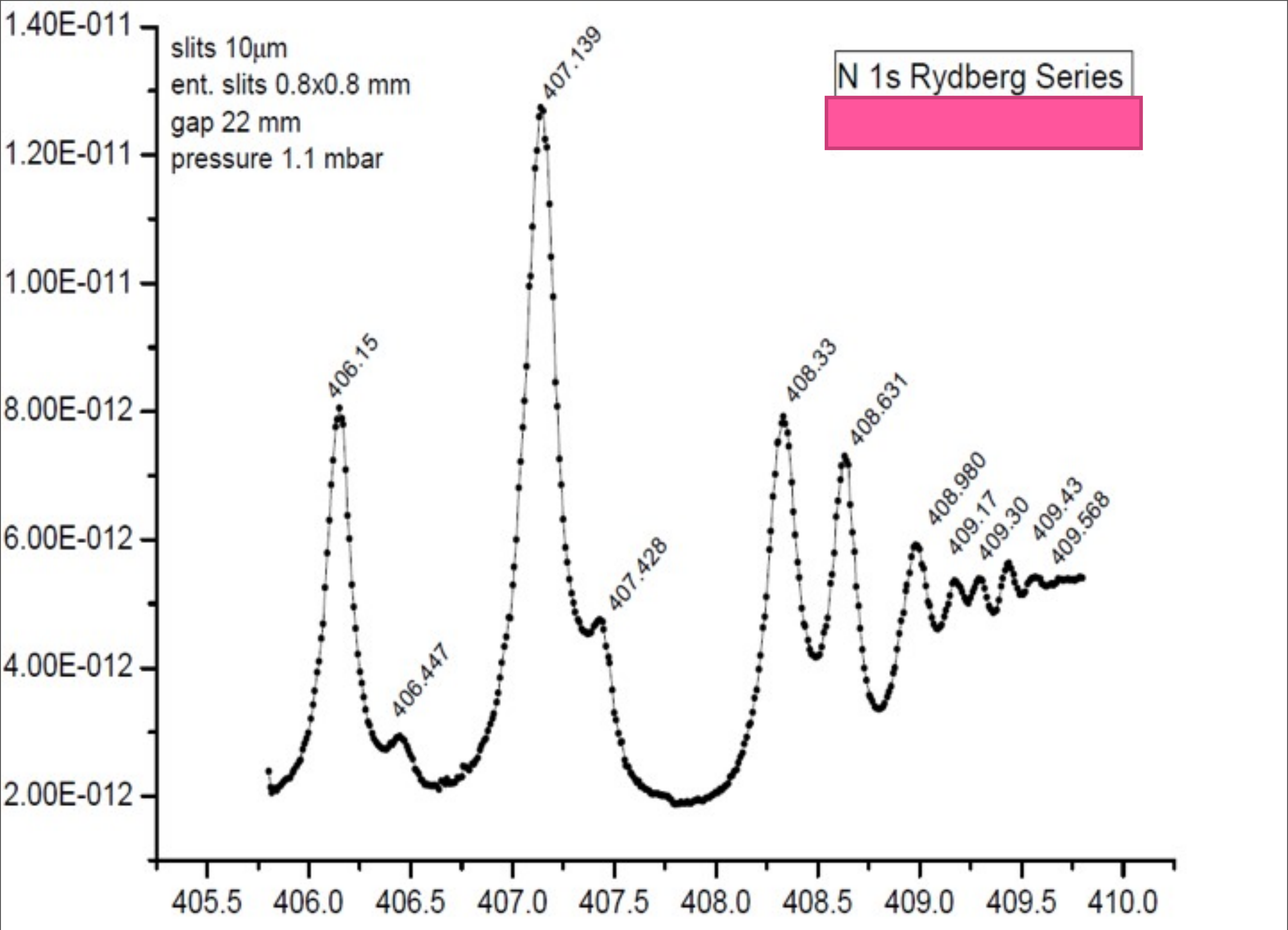
PGM beamline

Under comissioning

Open to users in 2011



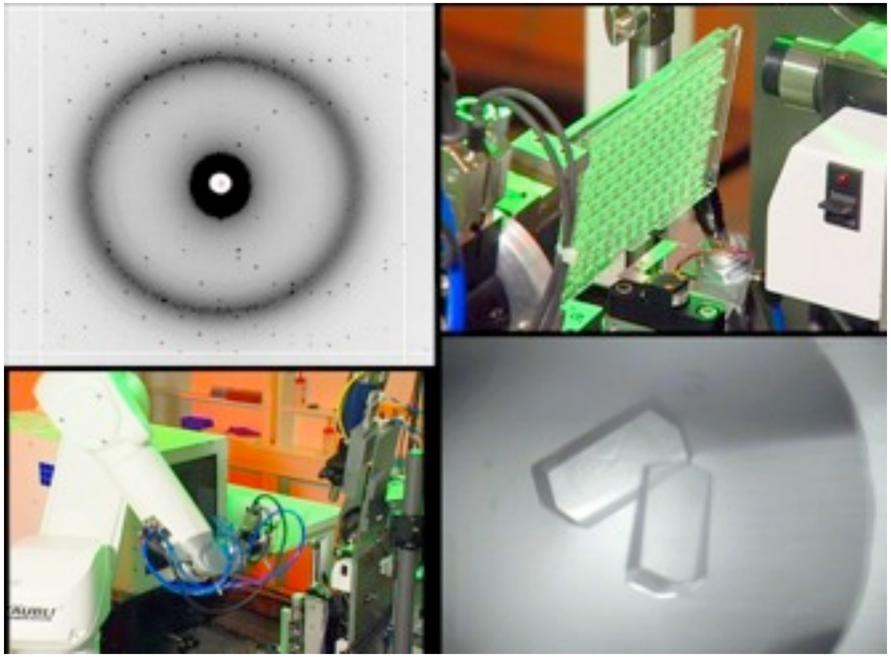

N 1s Rydberg Series
slits 10µm
ent. slits 0.8x0.8 mm
gap 22 mm
pressure 1.1 mbar
406.15
406.447
407.139
407.428
408.33
408.631
408.980
409.17
409.30
409.43
409.568
1.40E-011
1.20E-011
1.00E-011
8.00E-012
6.00E-012
4.00E-012
2.00E-012
405.5
406.0
406.5
407.0
407.5
408.0
408.5
409.0
409.5
410.0

Remote usage

1.Labweb Project

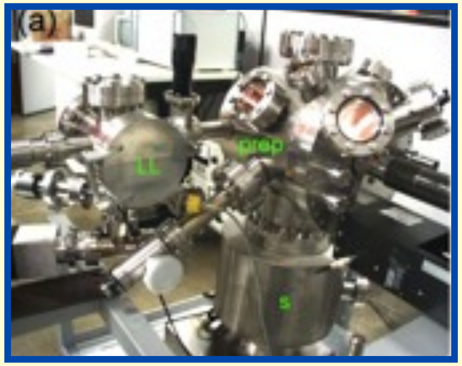
Goal: allow researchers to perform their experiments via the internet

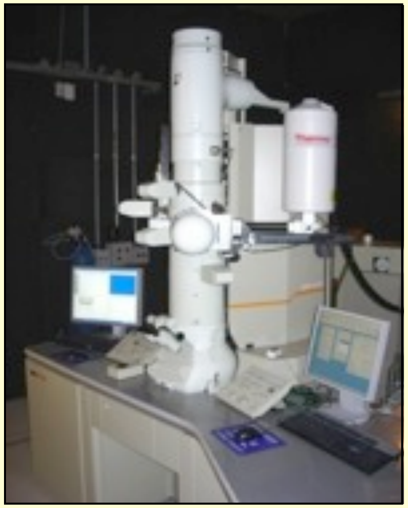
2. Automation of the biology beamline



Integrated solutions due to the presence of various complementary techniques in the same campus

Nanoscience and Nanotechnology Center Cesar Lattes (LNNano)

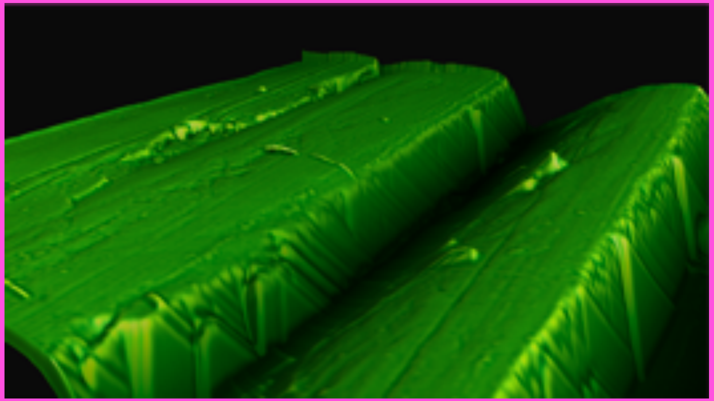




Electron, STM, AFM Microscopies

Strong interaction among the Labs

- Automation of the protein crystallography beamline
- Cryo-microscopy
- Nano-cosmetics
- Cellulose microscopy



LNBio Laboratório Nacional de Biociências

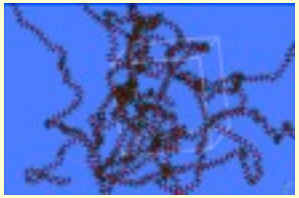
CTBE

Interaction with industry

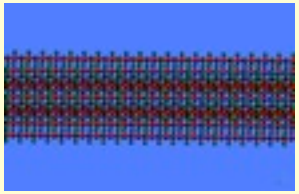
- Examples:
  - OXITENO – catalysis
  - PETROBRAS – catalysis, thermo-mechanical properties, geophysics, etc.

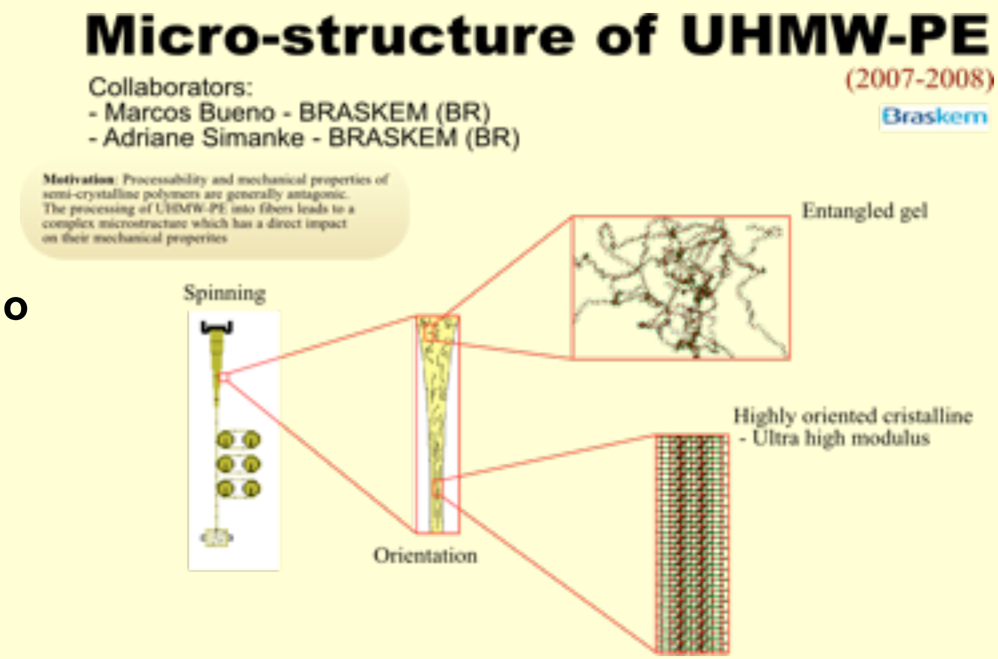
Ultra-high molecular weight polyethylene (UHMWPE)

Gel



Cristal Orientado





Cables for oil platform

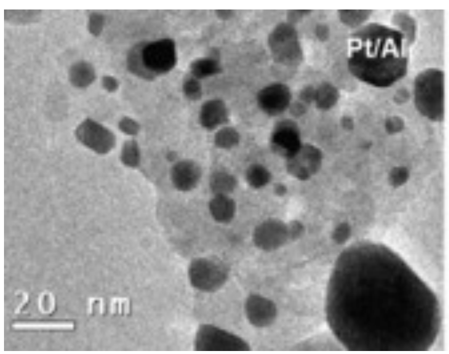
Contents lists available at ScienceDirect
Journal of Catalysis
Journal of Catalysis 263 (2009) 335–344

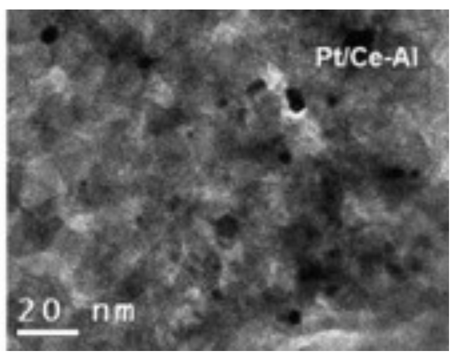
A.P. Ferreira [a], D. Zanchet [b], J.C.S. Araújo [a], J.W.C. Liberatori [a], E.F. Souza-Aguiar [d], F.B. Noronha [c], J.M.C. Bueno [a,*]

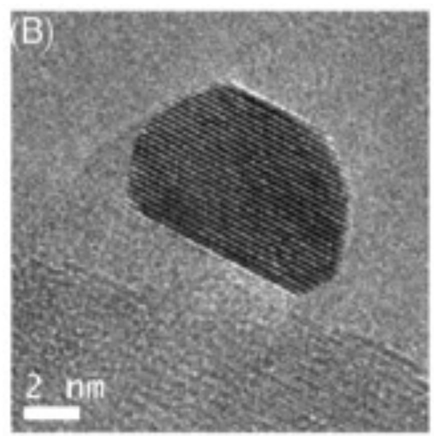
[a] Universidade Federal de São Carlos-UFSCar, Cx. P. 676, São Carlos, SP, Brazil
[b] Laboratório Nacional de Luz Síncrotron-LNLS, Cx. P. 6192, 13083-970, Campinas, SP, Brazil
[c] Laboratório de Catálise, Instituto Nacional de Tecnologia, Av. Venezuela, 82/518, Centro, 21081-312, Rio de Janeiro, RJ, Brazil
[d] Universidade Federal do Rio de Janeiro, CENPES/PETROBRAS, Rio de Janeiro, RJ, Brazil

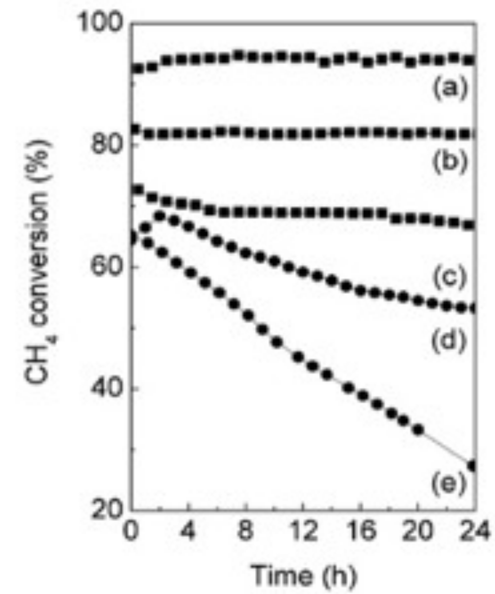
- The effects of CeO_2 on the activity and stability of Pt supported catalysts for methane reforming were addressed by **in situ studies using synchrotron and electron microscopy**

- Addition of Ce to Pt/Al_2O_3 catalysts increases their performance:
  - improved thermal stabilty of the support
  - interaction of reduced Pt nanoparticles with Ce, which prevents their migration.









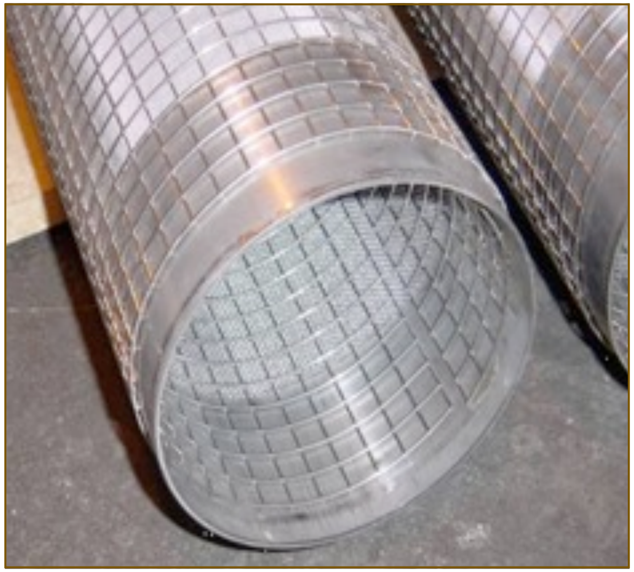
PETROBRAS

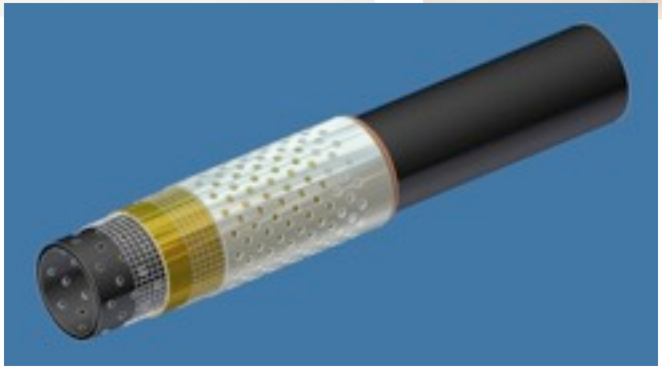
Development of sieves for sand retention

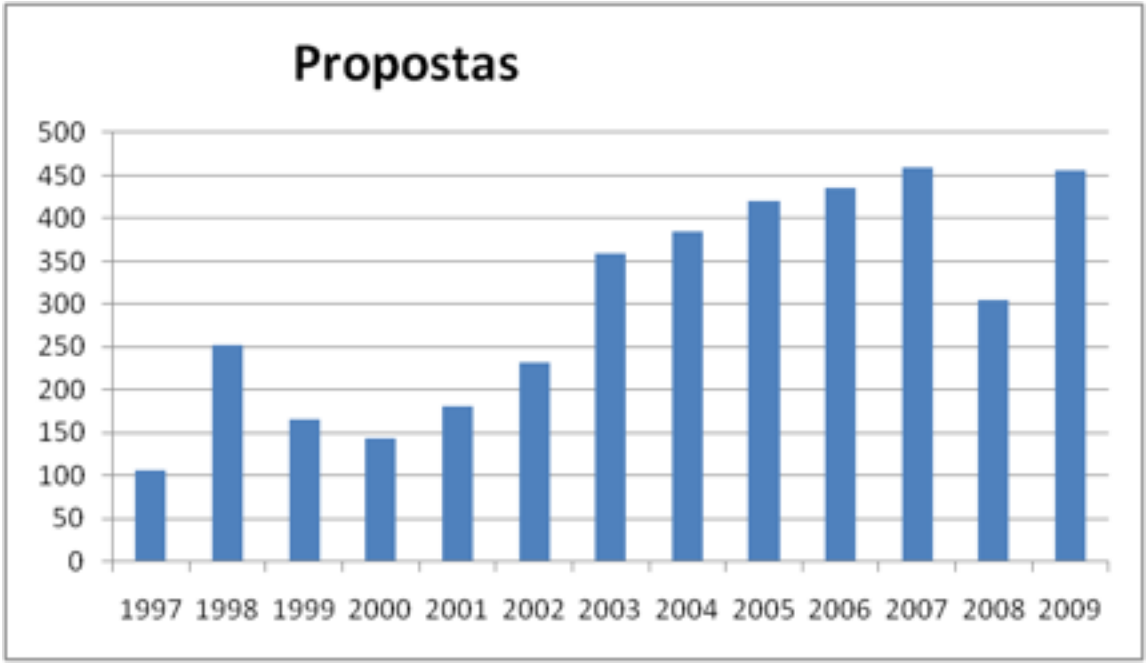
Laboratório Nacional de Luz Síncrotron – LNLS e

Filtering Element

Diffusion Bonding to weld 3 or 4 metallic layers

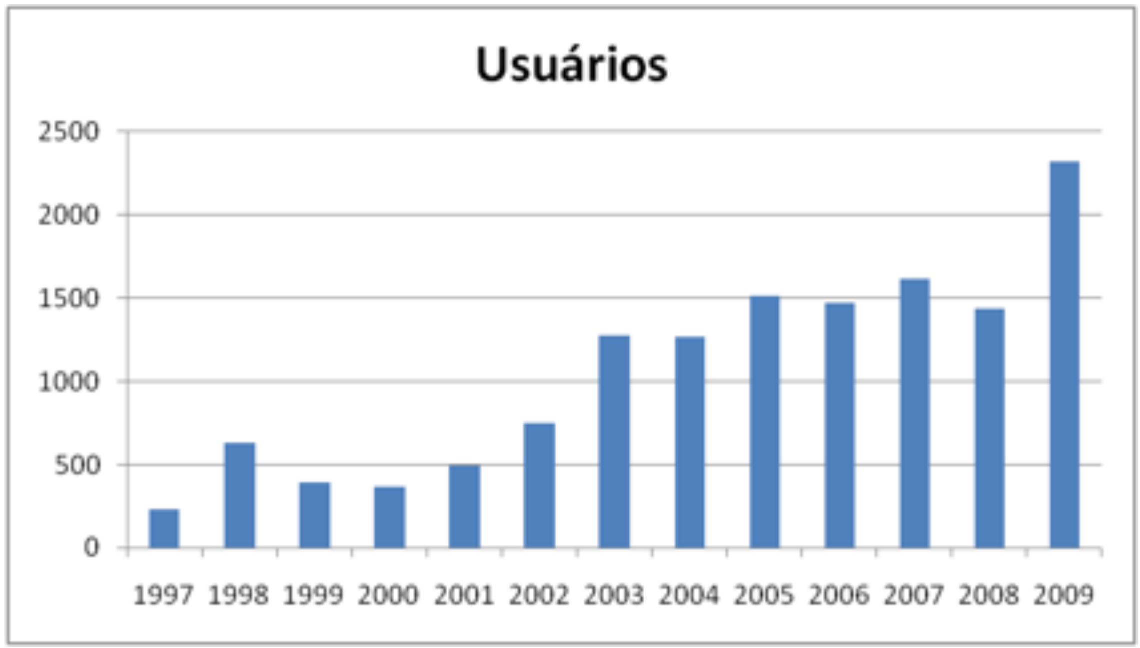






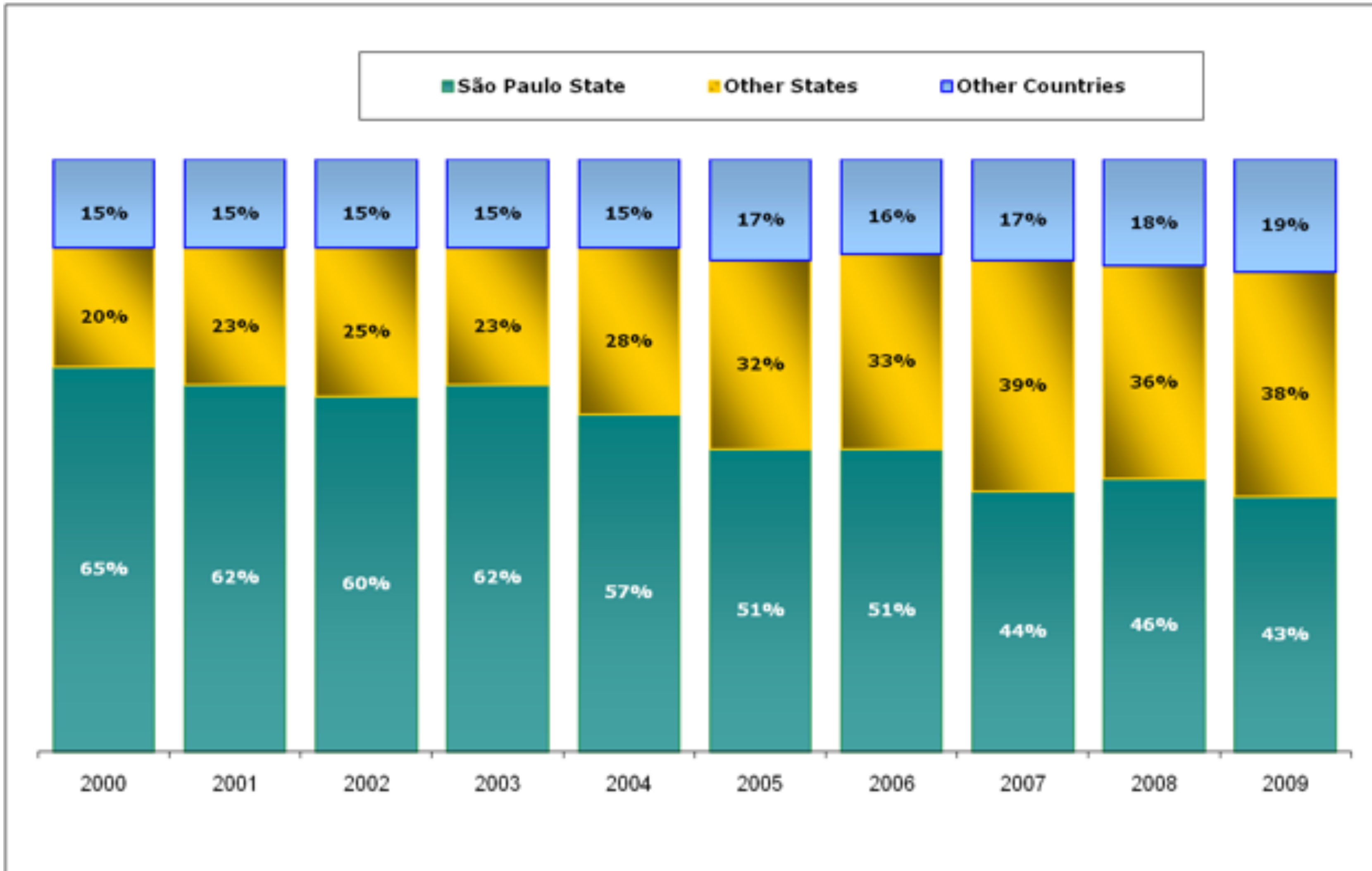
Propostas
500
450
400
350
300
250
200
150
100
50
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

Encontro
Técnicas e Aplicaçoes da Radiação Sincrotron
PRS/CBPF, Rio de Janeiro, agosto de 1983
PROJETO RADIAÇÃO SINCROTRON
PRS
TÉCNICAS E APLICAÇÕES DA RADIAÇÃO SINCROTRON
220 participantes



Usuários
2500
2000
1500
1000
500
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

Geographical distribution of academic users of beamlines



Proposals realized at the beamlines

Linha (2009)	Total
Total realizado nas Linhas	455
Por país:	
Alemanha	3
Argentina	64
Colombia	2
Chile	2
Cuba	6
Estados Unidos da América	4
Índia	1
México	2
Noruega	2
Portugal	1
Total	87

14%

19%

SIRIUS

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● In order to satisfy the future demand for synchrotron radiation in Brazil, a proposal for a new ring is being developed to replace the existing 1.37 GeV UVX light source, a facility that is being operated for users since July 1997 in Campinas, São Paulo. The proposed new source, SIRIUS, is a 3rd generation 3.0 GeV low emittance synchrotron light source facility to be built at the same LNLS site.

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- to build a SR source able to compete with the best in the world
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● Many alternative lattices have been analysed in the last year, including the 2.5 GeV, 16 cell TBA lattice presented at PAC09 [J.A. Brum *et al, "LNLS-2: A New High Performance* SR Source for Brazil", PAC'09, Vancouver, Canada (2009); http://www.JACoW.org]**. *That design was based on the use of low field (0.45 T) permanent magnets for the storage ring dipoles*.**

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- The use of permanent magnets can reduce both the investment and operation costs of the project with the elimination (or significant decrease) of power supplies and cooling systems.
-***The low dipole field also favors emittance reduction by wigglers.***

● There is however the considerable drawback of excluding hard x-ray bending magnet sources, which can have substantial demand from users since the beam size is naturally very small at dipole sources and some experiments do not need the high brightness of the insertion devices.

SIRIUS

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● The idea is to combine:
- the low bending field (0.5 T) for the main beam deflection
- with a high magnetic field (2 T) which extends over only a very short longitudinal length (a slice magnet, for 1° deflection) so that the hard x-ray radiation is produced only at the beamline exit. In addition, this high field slice could be used to create a longitudinal bending field profile designed to help reducing the emittance.

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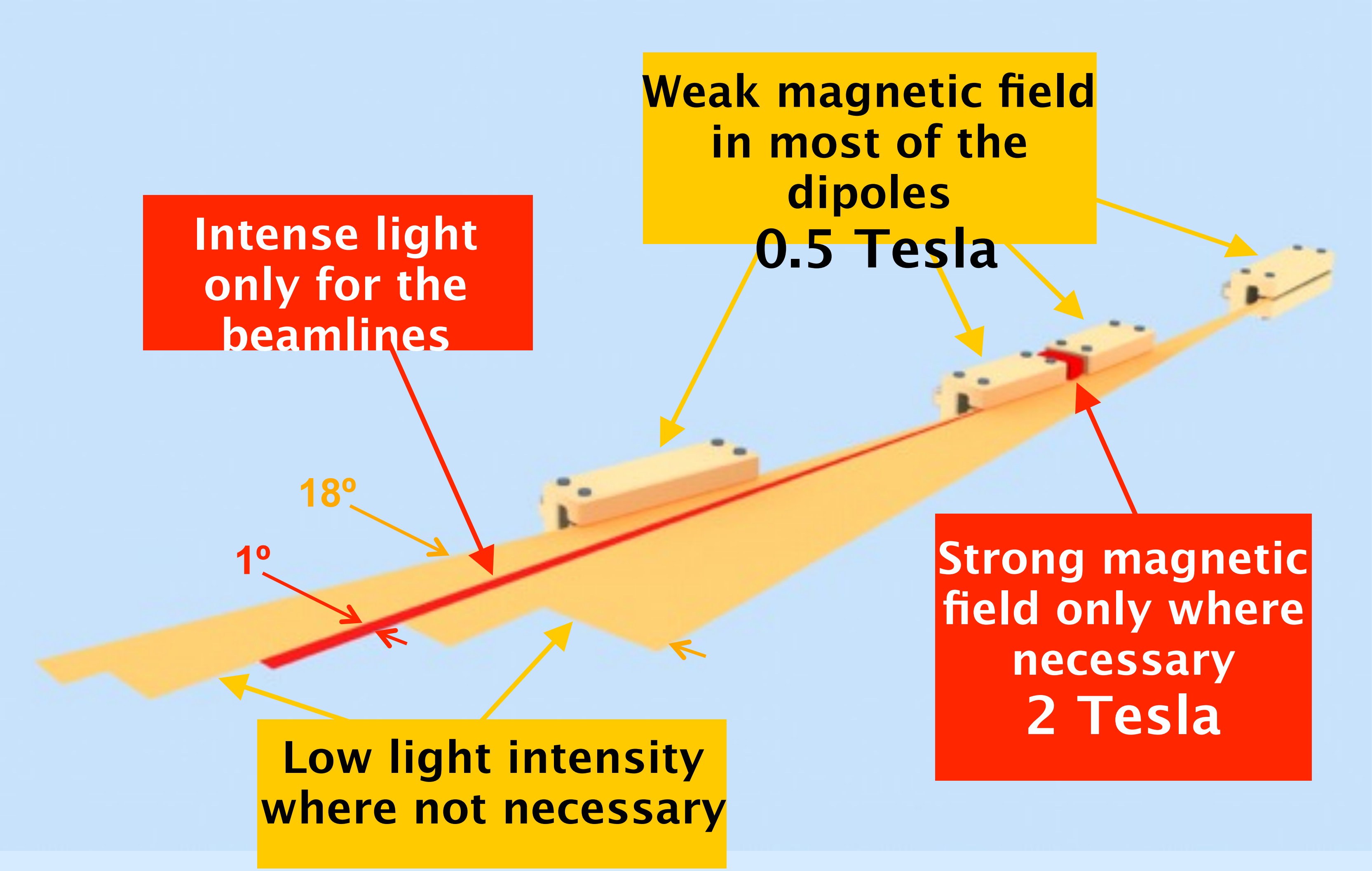
● The idea was implemented in the new lattice design and, together with further considerations on the need to produce high brightness radiation up to about 100 keV, led to a modification of the project to a 3.0 GeV electron storage ring with 20 TBA cells. The permanent magnet dipoles now combine a low bending field of 0.5 T for the main beam deflection with a 2.0 T (in fact 2. 5 today→3.0) slice to produce hard x-ray bending magnet photons of 12 keV critical energy.

Design approach – optics

- 20 triple-bend achromat with low field dipoles to achieve low emittance.
- Split central dipole to accommodate a high field slice in order to preserve hard x-rays from dipoles.



SIRIUS

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► The lattice has distributed dispersion function and provides a beam with 1.7 nm.rad natural emittance. The slightly positive dispersion function at the ID straights increases the effective emittance to 1.9 nm.rad.

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► Care has been taken to limit the dispersion function value so that the inclusion of IDs in the lattice still reduces the emittance. This should allow a brightness of 10^{21} (ph/s/mm^2 /mr^2/0.1%bw) at 10 keV.

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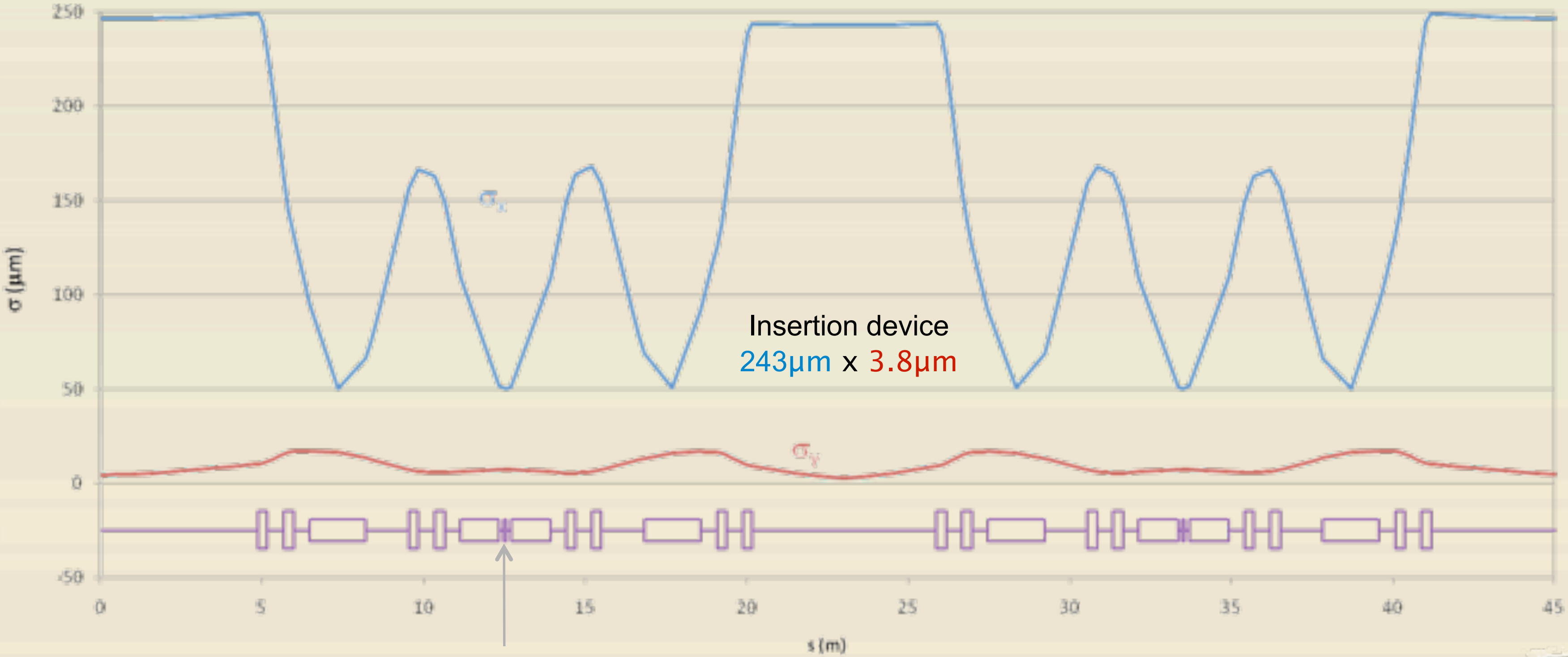
► The circumference of 460.5 m contains 20 ID straights with alternating lengths of 5 m and 9.4 m.

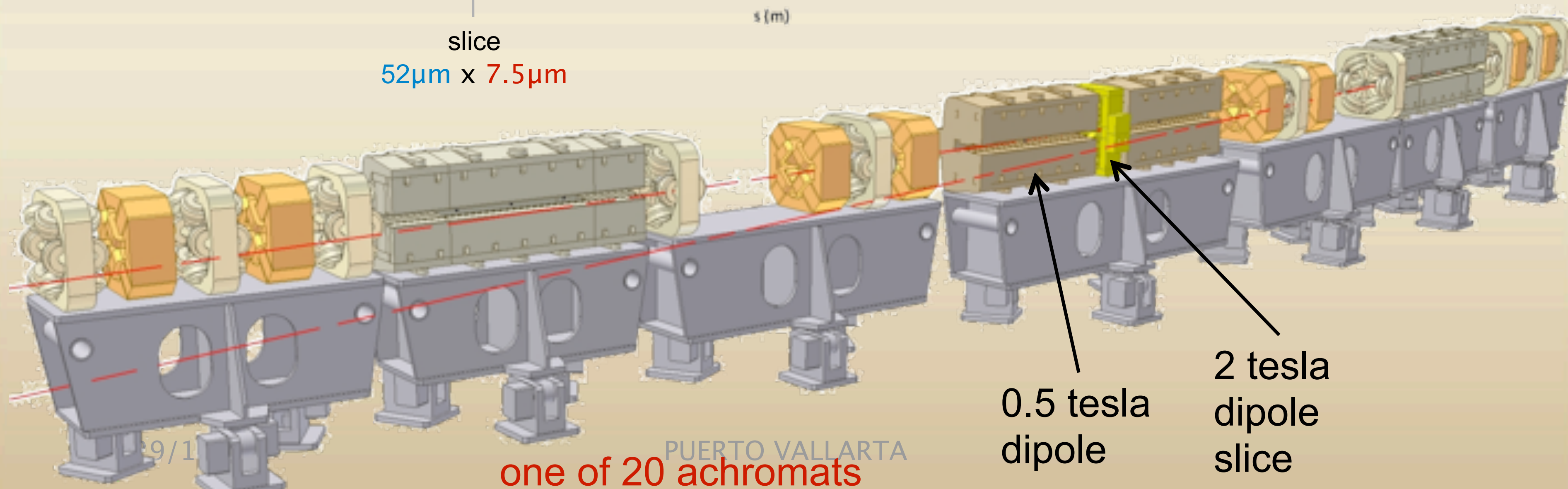
► The lattice has distributed dispersion function and provides a beam with 1.7 nm.rad natural emittance. The slightly positive dispersion function at the ID straights increases the effective emittance to 1.9 nm.rad.

► Care has been taken to limit the dispersion function value so that the inclusion of IDs in the lattice still reduces the emittance. This should allow a brightness of 10^{21} (ph/s/ mm^2 /mr^2/0.1%bw) at 10 keV.

► The installation of 2 superconducting wigglers (1m long, 4T), and 2 wigglers (2.7m long, 2T) could reduce the effective emittance to less than 1.2 nm.rad.

Electron-beam size





one of 20 achromats

Technology

▶Use of permanent magnet dipoles

Lower investments

In power supplies

In cooling system

PROTOT

5 T)

Savings in operational costs *

2.5 GWh/year in Power supplies

0.5 GW.h/year in cooling system

▶Strong magnetic field only where necessary

Lower investments

In high power RF amplifiers (less power for unused sy

light)

In vacuum equipment (less heating and photo-desorp

unused synchrotron light)

Savings in operational costs *

4.0 GW.h/year in RF power generation

0.8 GW.h/year in cooling system

▶Use of solid state RF power amplifiers

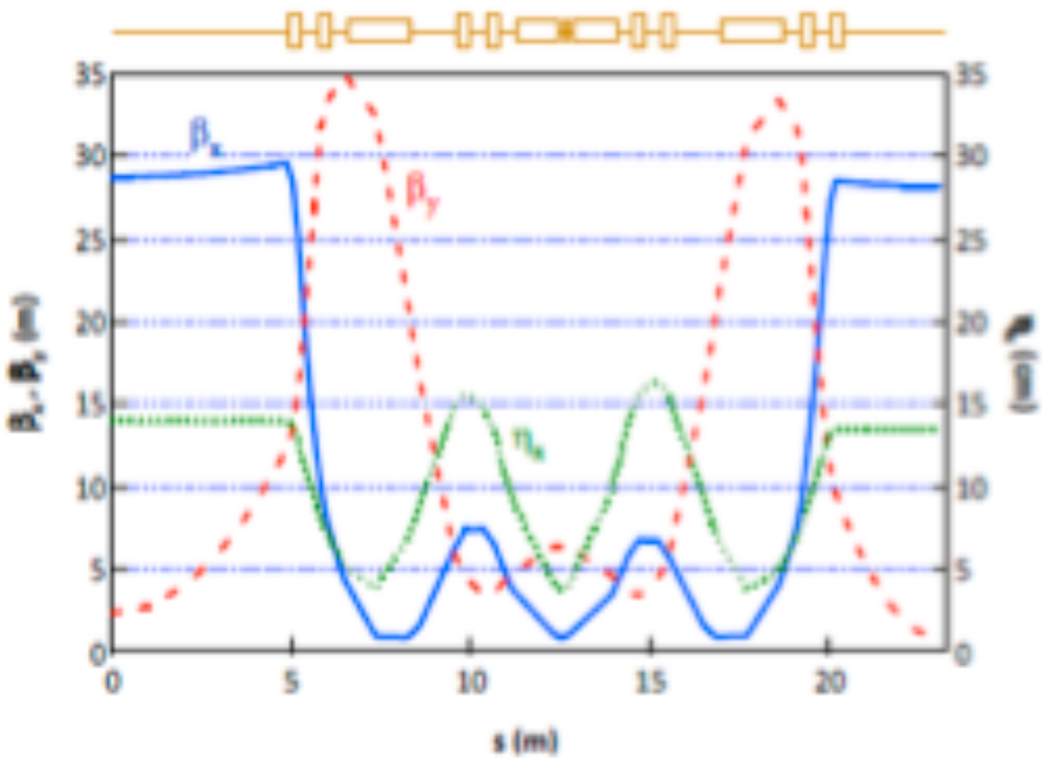
Sirius general parameters

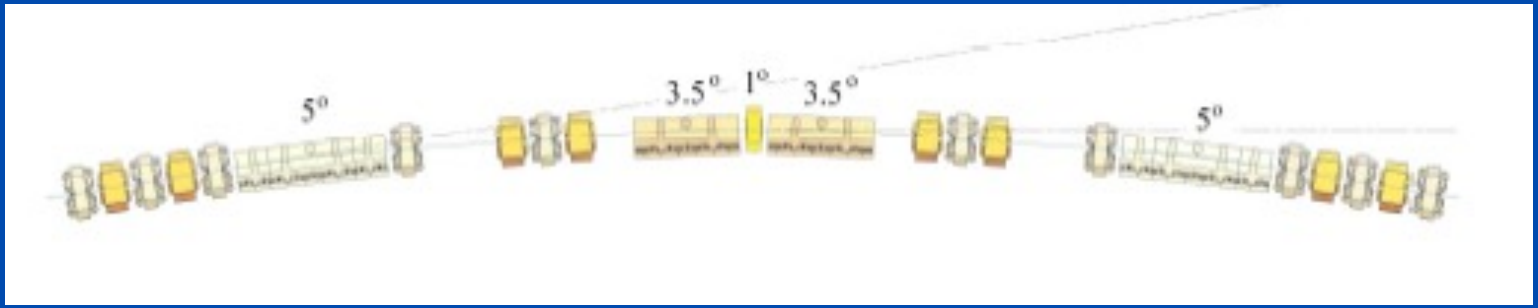
Parameter	Value	unit
Operation energy	**3.0**	**GeV**
Injection energy (top-off ready)	3.0	GeV
Maximum beam current	500	mA
Revolution period	1.54	µs
Beam emittance without Insertion devices (@ 0.5% coupling)		
horizontal	**1.7**	**nm.rad**
vertical	**8.5**	**pm.rad**
Main bending field (ferrite)	0.5	T
Slice (1°) bending field (NdFeB)	2.0	T
Number of achromats	20	
Number of dipoles per achromat	3	
Critical energy from dipoles (2 Tesla slice)	**12**	**keV**
Critical wavelength from dipoles (2 Tesla slice)	**1.0**	**Å**
Energy loss per turn from dipoles	418	keV
Synchrotron radiation power from dipoles	209	kW

Table 1: Main parameters of SIRIUS.

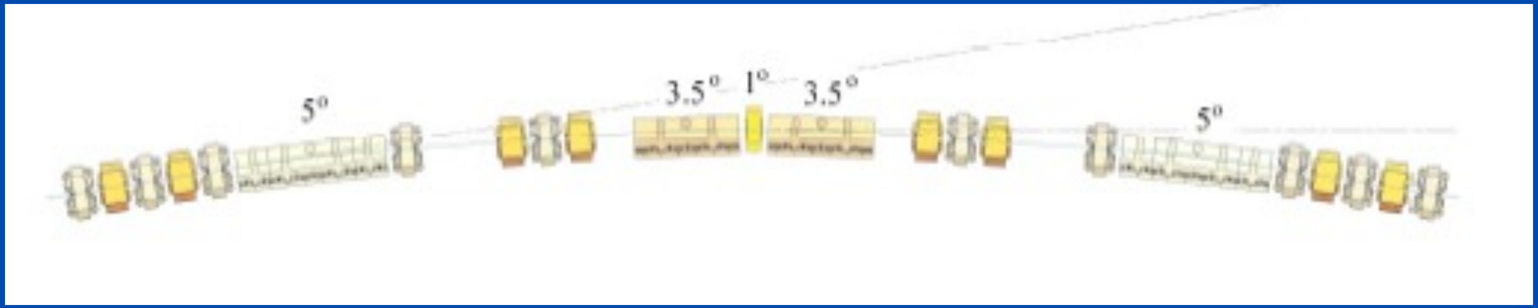
Energy (GeV)	3.0
Beam current (mA)	500
Circumference (m)	460.5
Nat. emittance (nm.rad)	1.7
Effective emittance (nm.rad)	1.9
Cell / symmetry / structure	20 / 10 / TBA
Main dipole field (T)	0.5
Slice dipole field (T)	2.0
Total deflection by main dipoles	340°
Total deflection by slice dipoles	20°
Critical energy, main dip. (keV)	3.0
Critical energy, slice dip. (keV)	12.0
SR loss/turn, all dipoles (keV)	417.7
SR power, all dipoles (kW)	208.8
Betatron tune (h/v)	24.2 / 13.2
Synchrotron tune	9.3×10^{-3}
Nat. chromaticity (h/v)	-53.4 / -48.0
Nat. energy spread (%)	0.079
Momentum compaction	6.9×10^{-4}
Harmonic number	768
RF frequency (MHz)	500
RF voltage (MV)	3.2
Bunch length (mm)	4.3
Damping time (ms) (h/v/s)	16.3 / 22.1 / 13.4
Straight sections	10*9.4m +10*5.0m
Beam size (k=0.5%) @ slice (μm^2)	50 x 7
Beam size (k=0.5%) @ SS (μm^2)	246 x 4

Optical functions for one SIRIUS TBA superperiod



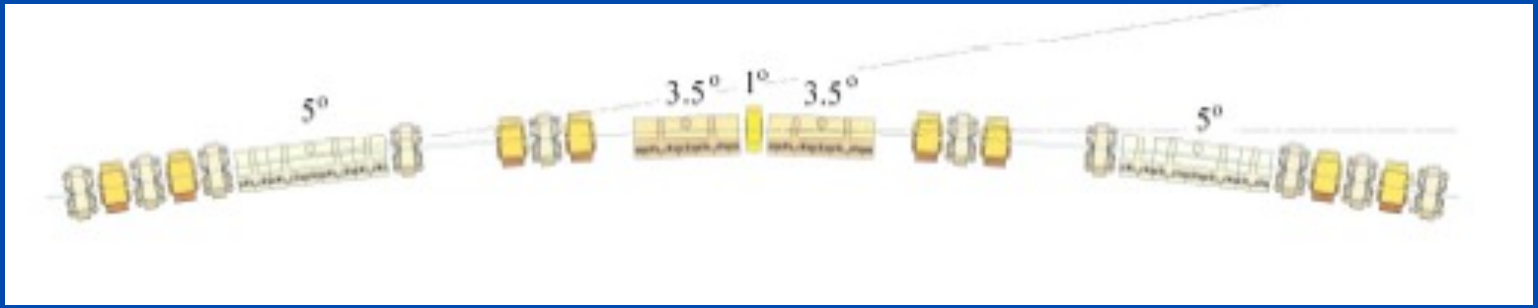

5°
3.5°
1°
3.5°
5°

DYNAMIC APERTURE OPTIMIZATION



DYNAMIC APERTURE OPTIMIZATION

► Five families of sextupoles are used to correct the chromaticity and optimize the nonlinear beam dynamics. In order to lower the strength of the chromaticity correction sextupoles, a space in the center of the arc quadrupole is created by splitting it into a pair of quadrupoles.



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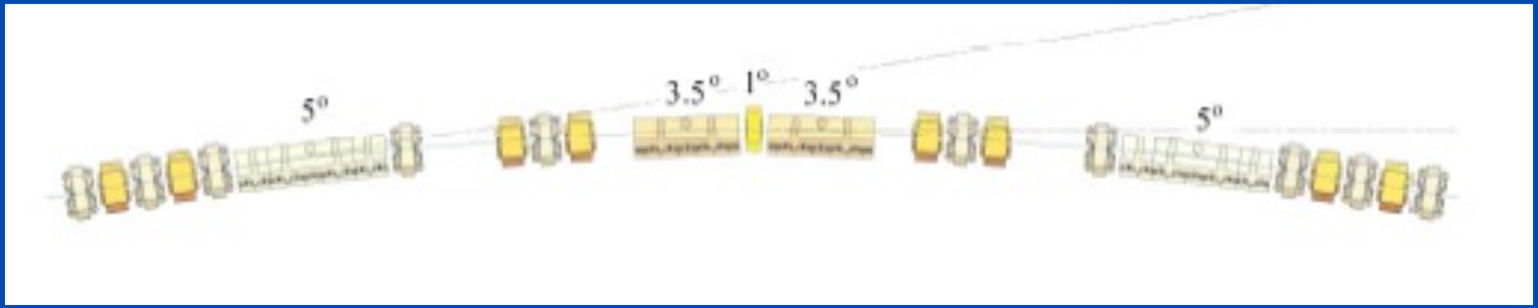
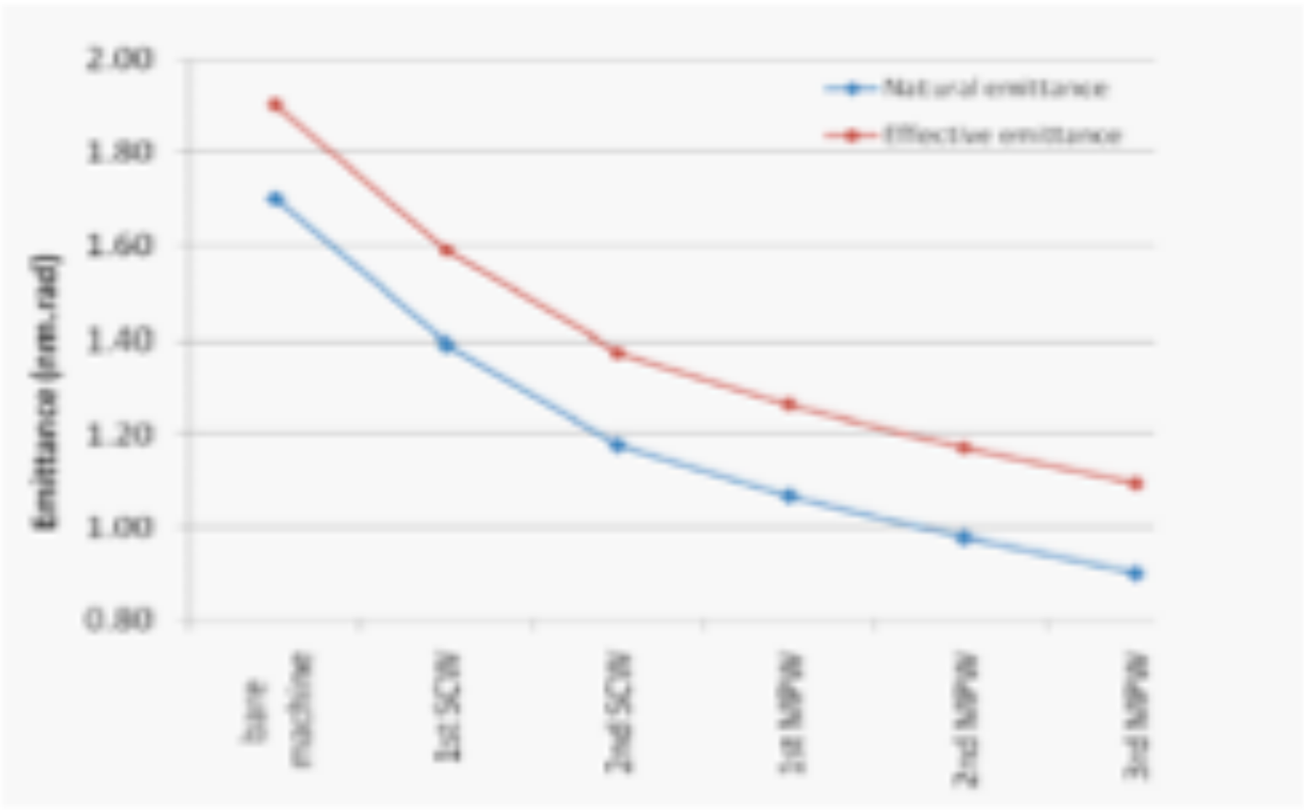
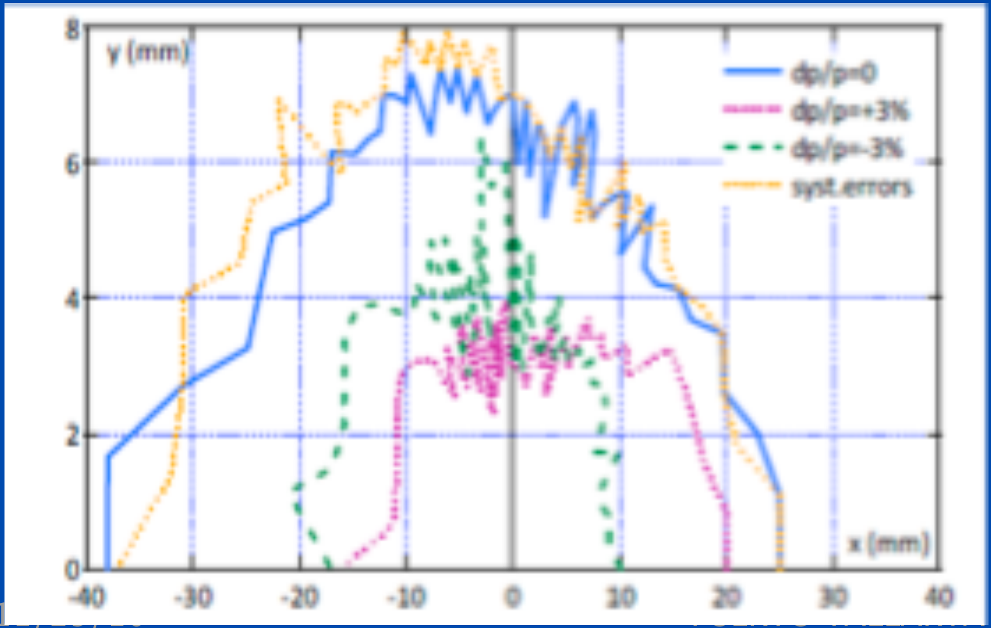
► *The space created is ideal to place a sextupole since this is where the betatron functions are more separated. In this way we succeeded in finding a relatively robust lattice configuration with fairly large dynamic aperture*. The sextupole families were optimized using the program OPA and the dynamic aperture is calculated by tracking particles with the code MAD.

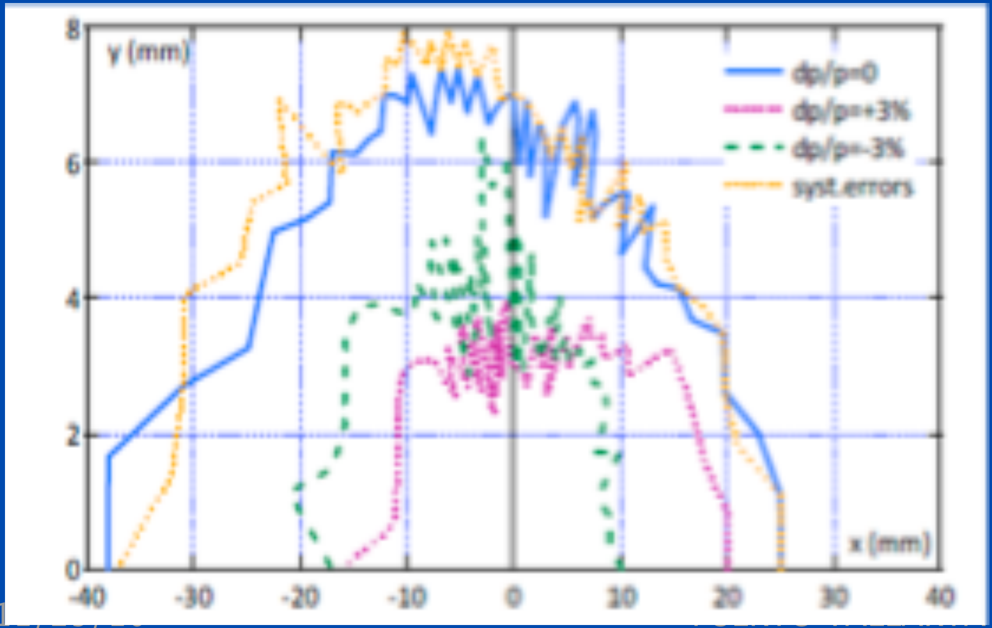


Evolution of natural and effective emittance as user IDs are installed in the ring. SCW is a 1 m, 4 T wiggler and MPW a 2.7 m, 2 T wiggler.



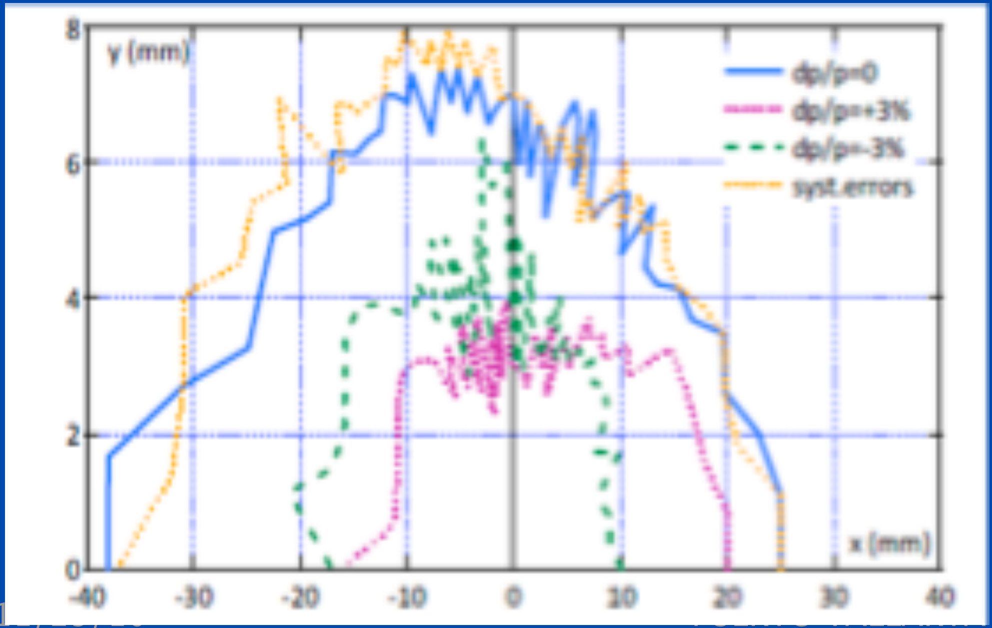

y (mm)
x (mm)
dp/p=0
dp/p=+3%
dp/p=-3%
syst.errors
0
2
4
6
8
-40
-30
-20
-10
0
10
20
30
40

DYNAMIC APERTURE OPTIMIZATION



DYNAMIC APERTURE OPTIMIZATION

► The figure shows the dynamic aperture for on-energy and off-energy particles, with and without systematic multipole errors, at the center of the long straight section. The systematic multipole errors considered do not affect the dynamic aperture.The five sextupole families used in this preliminary optimization can be further subdivided into a total of 8 families.



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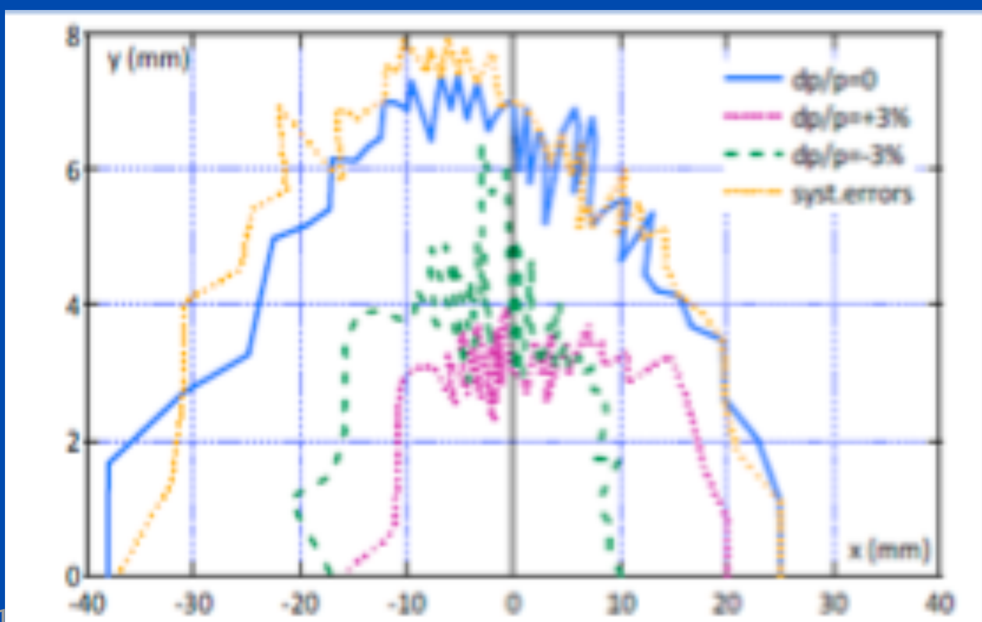
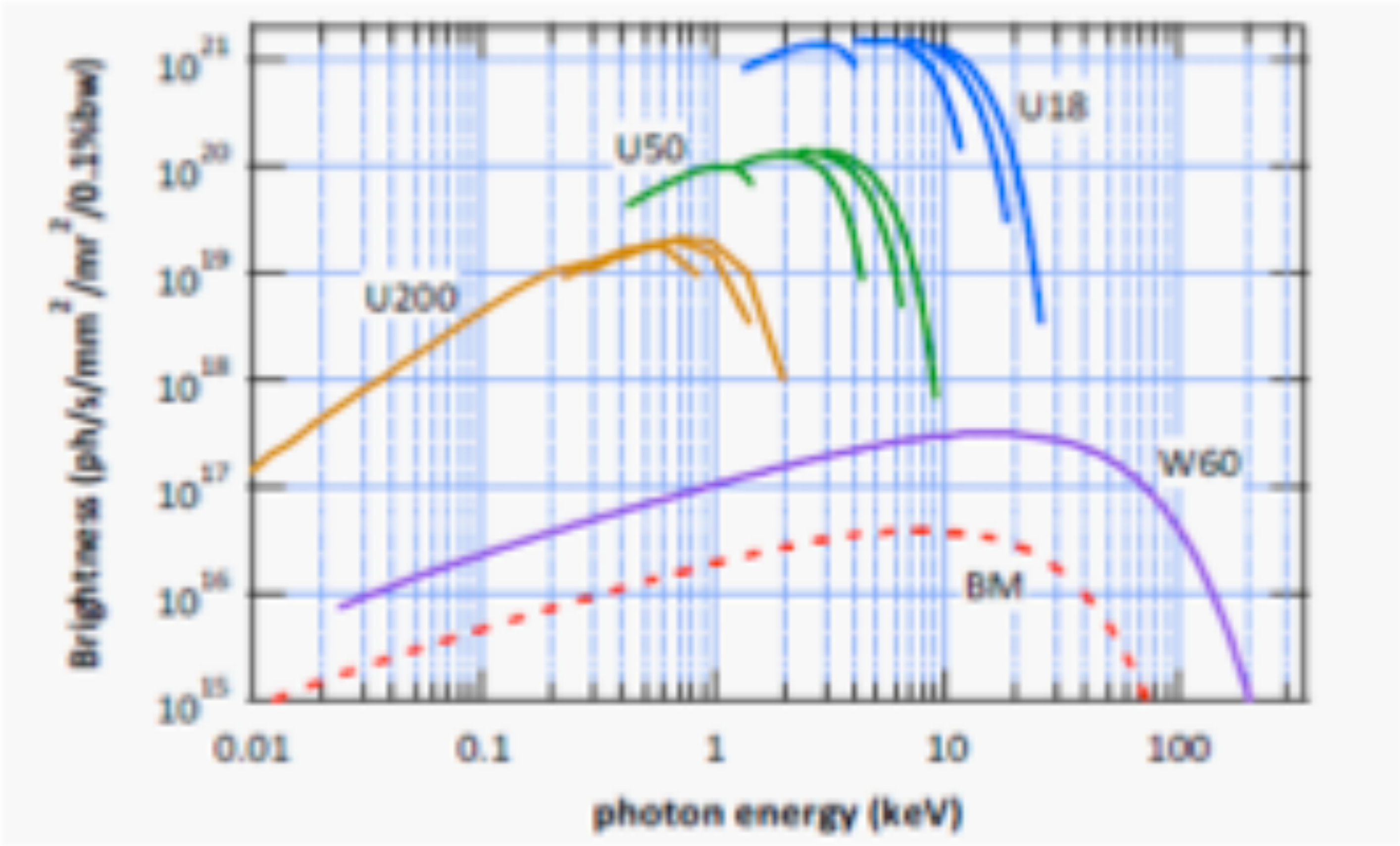


Dynamic aperture tracking for 4096 turns in the middle of the long SS (β_x=28.7m, β_y=2.4m) with MAD.

Sirius brightness



Brightness for SIRIUS for 0.5% coupling, 500 mA and some selected IDs. $ID_{\lambda}=(N_{\lambda},K)$: U18=(194,2.2), U50=(54,2.5), U200=(30,10.3), W60=(17,22.4).

Comparison of Sirius with today's LNLS source and most recent facilities in construction or operation

	UVX[1]	Sirius[2]	Soleil[1]	Diamond[1]	Shanghai[1]	NSLS II[3]
Energy (GeV)	1,37	3,0	2,75	3,0	3,5	3,0
Average diameter (m)	30	147	113	179	137	252
Brightness from dipoles @ 10 keV *	1	5600	1560	3600	2200	370[4]
Brightness from dipoles @ 50 keV *	1	$25 \cdot 10^9$	$1{,}9 \cdot 10^9$	$4{,}4 \cdot 10^9$	$5{,}8 \cdot 10^9$	2700[4]
Number of dipole beamlines	24	20	32	48	40	0 [4]
Number of insertion device beamlines	4	18	22	22	18	28
Emittance (nm.rad)	100	1,7	3,7	2,7	3,9	2,1

Notes: * normalized to that of LNLS existing source; [1] in operation; [2] in design; [3] in construction; [4] the design does not envisage dipole beamlines.

TOP-UP

- With the spread of “top-up” injection for synchrotron radiation (SR) sources, it has become very important to suppress stored beam oscillation during beam injection. In top-up injection, a stored beam current in an electron storage ring is kept at a constant value by continuous beam injection to conduct high-flux SR experiments with constant SR heat load on beam line optics and to eliminate current dependent systematic errors in the SR experiments.

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● In conventional beam injection for electron storage rings, a pulsed local bump produced by several kicker magnets is employed to reduce the amplitude of coherent dipole oscillation in the injected beam. This method has been adopted in most electron storage rings. However, it is difficult to provide the complete closed bump because of the magnetic field errors, timing jitters, and nonlinear effects such as from sextupole magnets inside the bump. <u>The unclosed bump generates the coherent dipole oscillation of the stored beam, which degrades the quality of the photon beam for the SR experiments in top-up injection.</u>

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● To solve this problem, H. Takaki et al, have developed a new beam injection method using a pulsed sextupole magnet (PSM) without the pulsed bump and examined the performance at the Photon Factory storage ring (PF ring). *In this method, the injected beam is captured into the ring acceptance by a kick of the PSM while the stored beam passes through the center of the PSM where the magnetic field is almost zero.* Thus, the method allows us to realize a high quality photon beam for SR users without large coherent oscillation of the stored beam even in top-up injection. In this paper, we describe the first demonstration of beam injection using a PSM carried out in an electron storage ring.

Beam injection with a pulsed sextupole magnet in an electron storage ring

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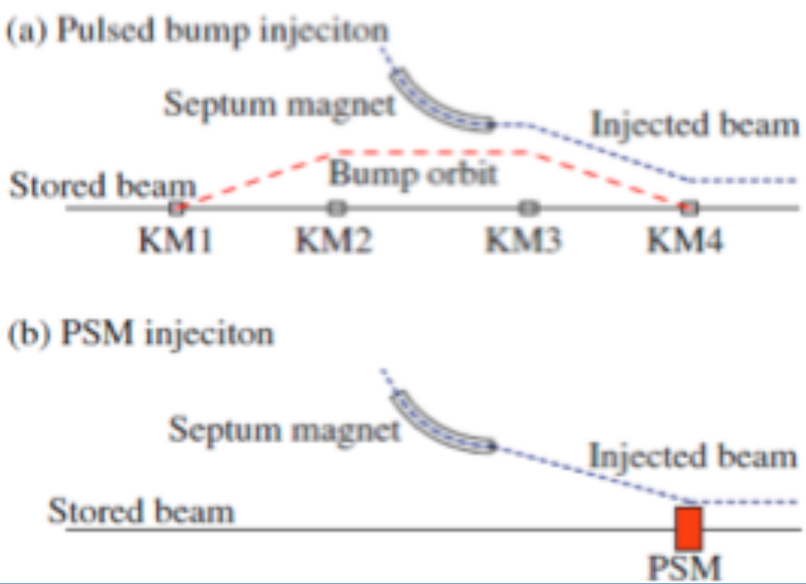
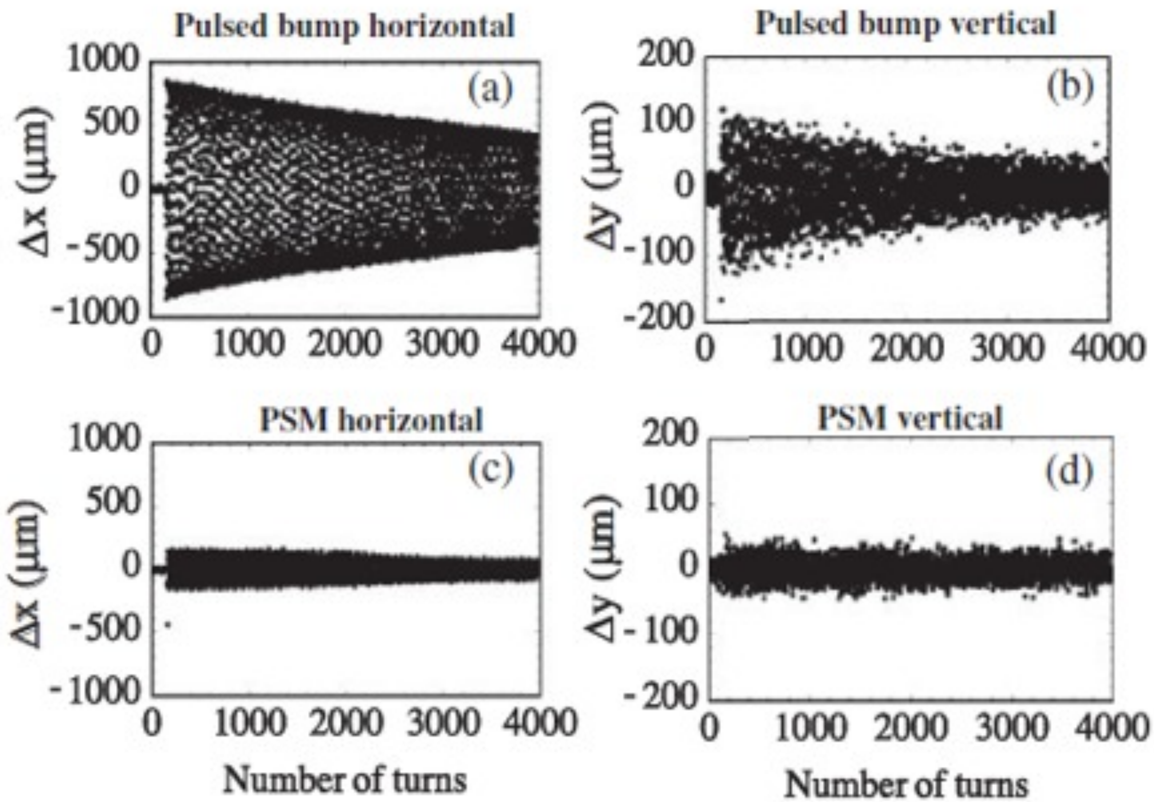
Yukinori Kobayashi, Kentaro Harada, Tsukasa Miyajima, Akira Ueda, Shinya Nagahashi, Miho Shimada, Takashi Obina, and Tohru Honda
Photon Factory, High Energy Accelerator Research Organization,
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 020705 (2010)



A schematic view of beam injection.
(a) Conventional pulsed bump injection. The bump orbit (red) is employed by four pulsed dipole kicker magnets (KM1-KM4). Trajectories of the injected beam (blue) and the stored beam(black) are shown.
(b) PSM injection.

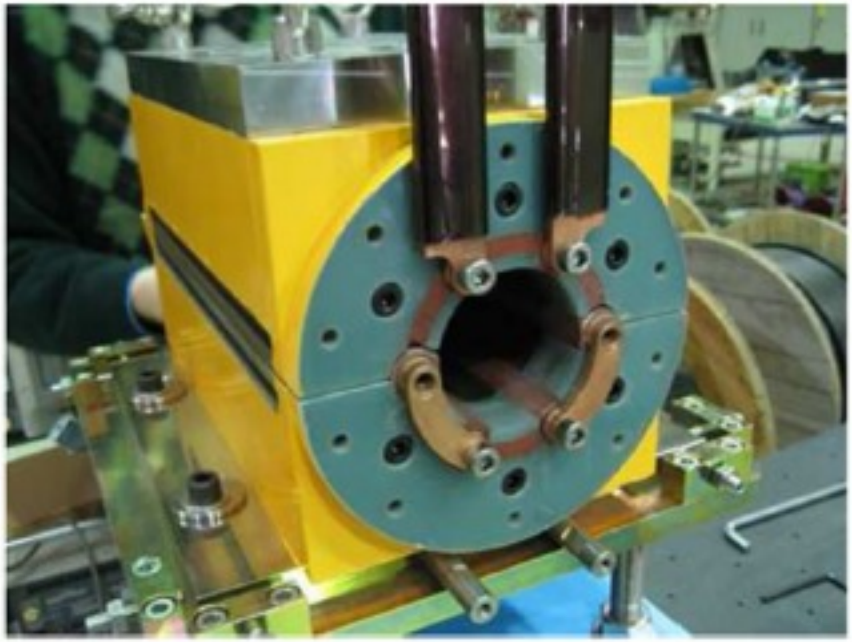


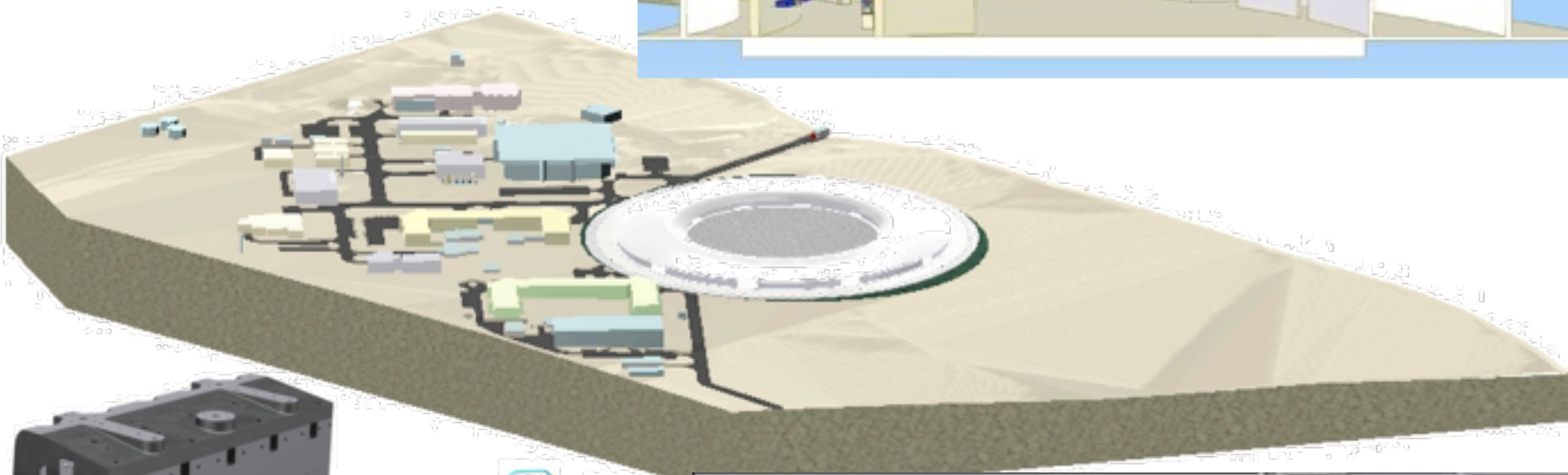
Horizontal and vertical beam oscillations (x and y) of the stored beam immediately after injection. The oscillations produced by the pulsed bump are shown in the upper two figures, (a) and (b), and those by the PSM are in the lower two figures, (c) and (d).

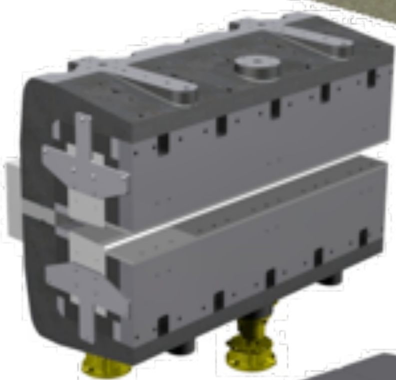
TABLE III. Main parameters of the PSM system.

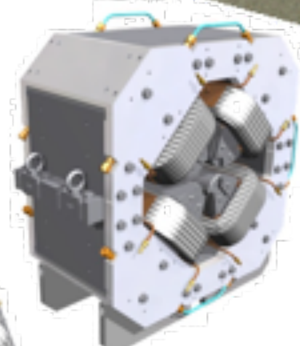
Parameter	Value
Core length	300 mm
Bore diameter	66 mm
Number of coil turns	1
Integrated magnetic field at $x = 15$ mm	120 Gauss m
Peak current	3000 A
Inductance	4.3 μH
Pulse width	1.2 (2.4)[a] μs

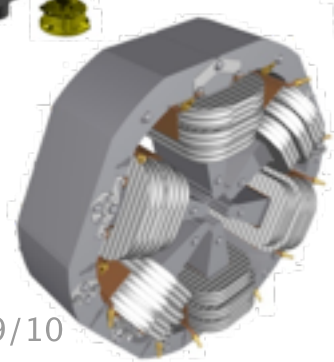
[a]The design value is 1.2 μs, but prepared power supply had 2.4 μs.



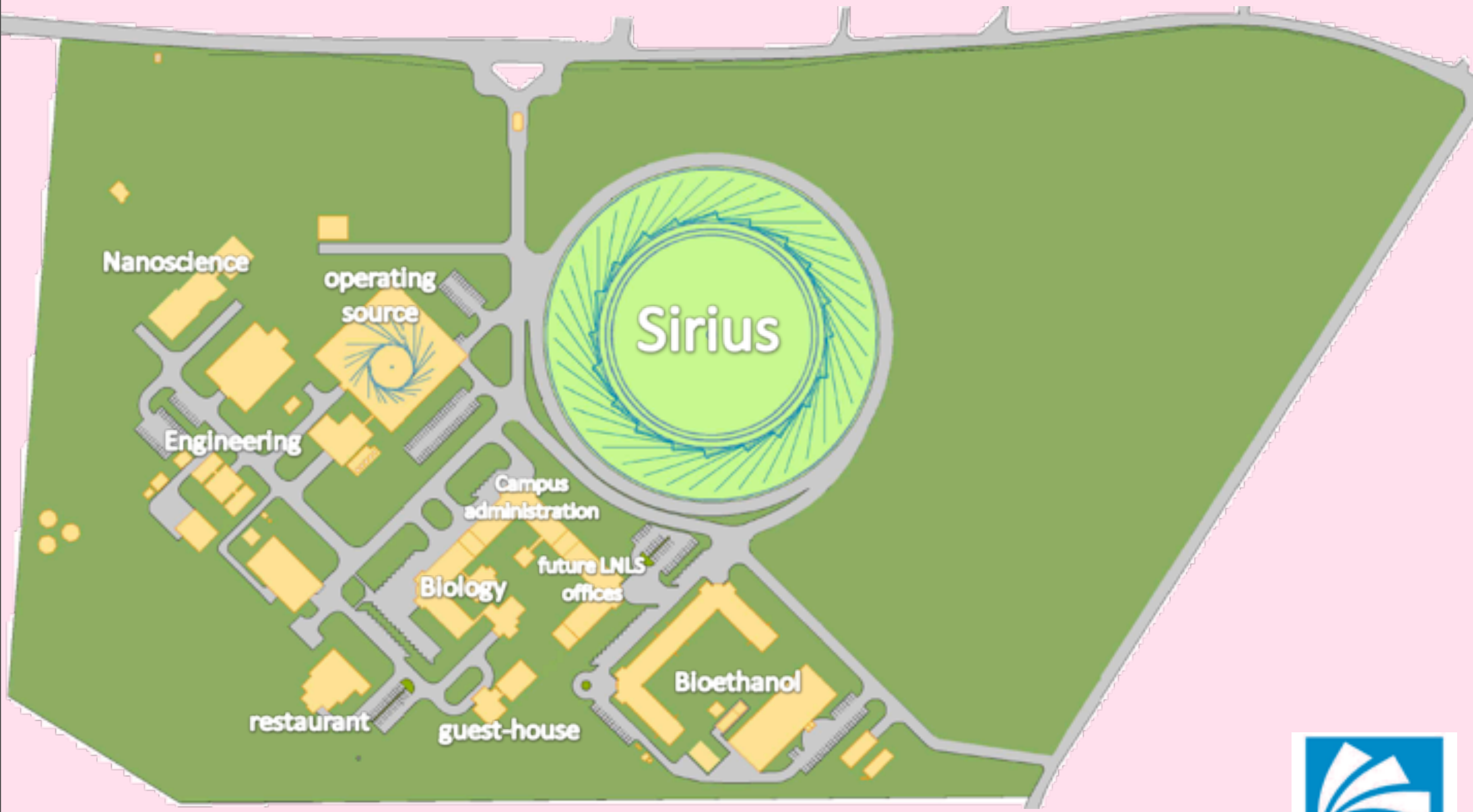




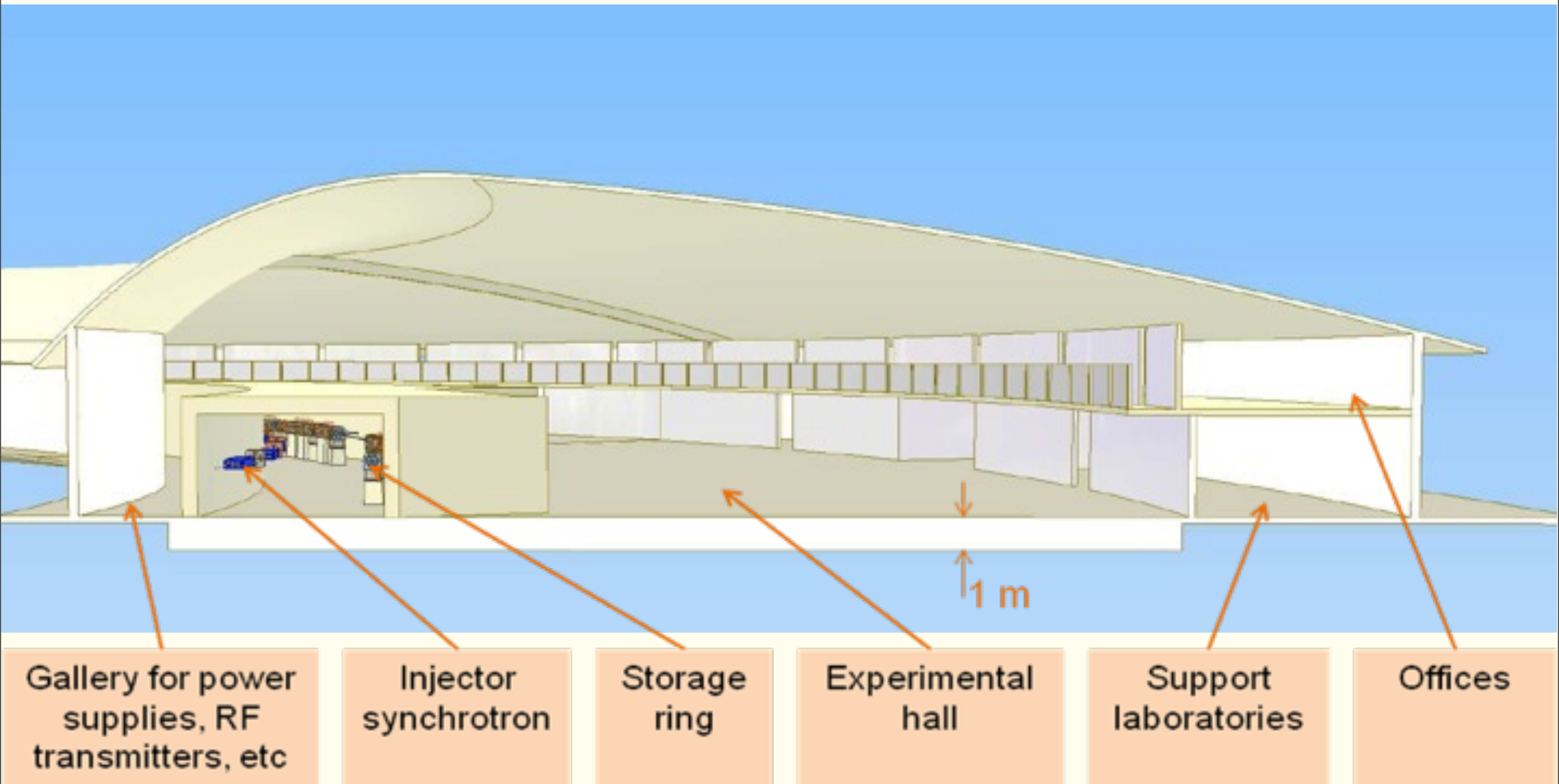




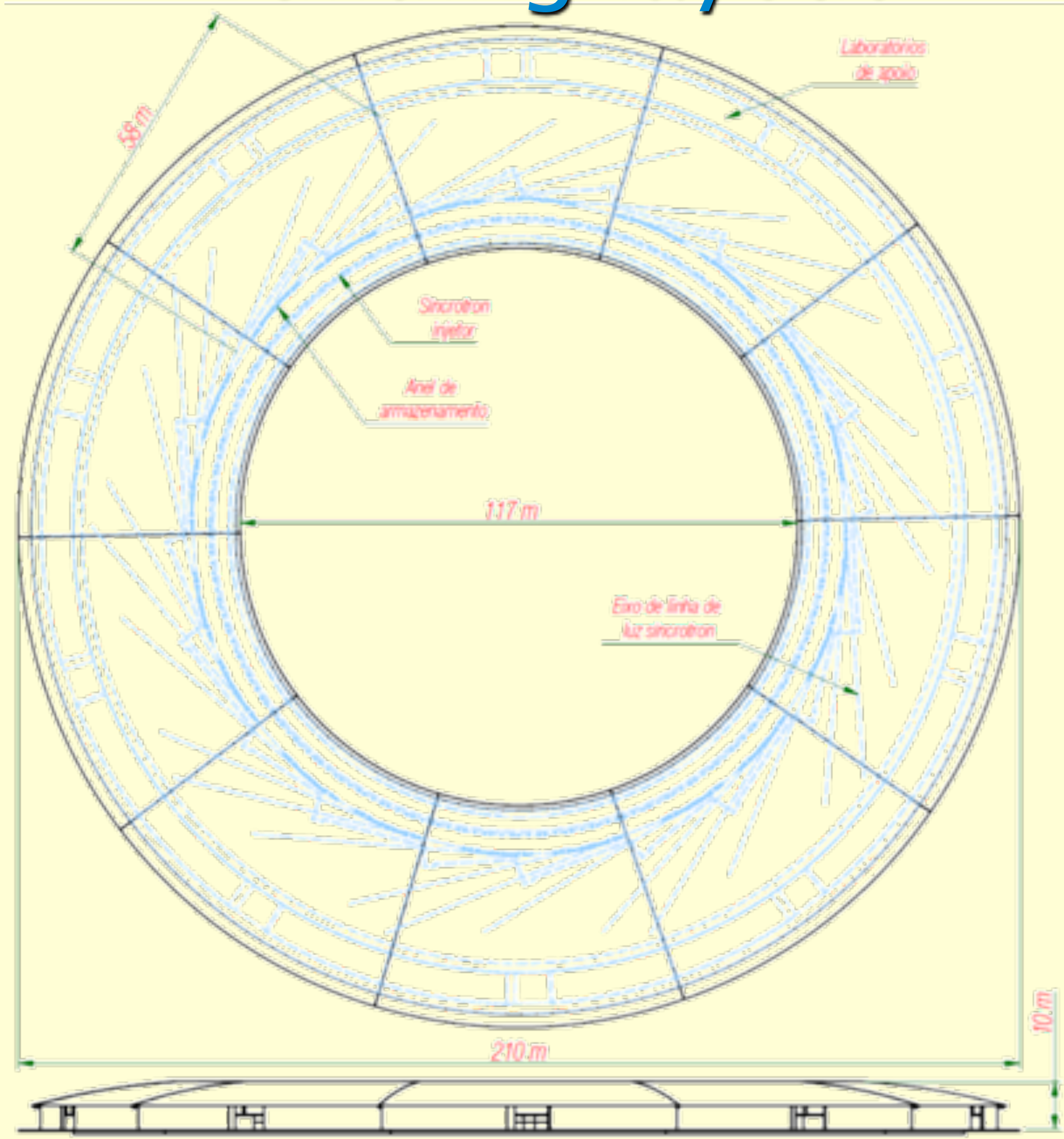
Proposed location on the Campus



Building cross-section



Building layout



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► THE ESTIMATED COST IS 225 M$, INCLUDING 6 BEAMLINES (5 SOFT AND HARD X-RAY, ONE IR): the PGM and the superconducting wiggler beamlines will be moved on SIRIUS. There are discussions with Argentina for the construction of 1 or 2 beamlines. In parallel, we will be looking for financing 5 more beamlines (FAPESP).

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► FOR MORE INFORMATIONS, YOU CAN CONTACT:
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- L.Liu: liu@lnls.br
- Y. Petroff: yves.petroff@gmail.com, yves.petroff@lnls.br

► THANK YOU VERY MUCH FOR YOUR ATTENTION