LNLS radiological safety improvements

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Abstract

It will be presented some radiological safety improvements that were done in the LNLS machine since 1997, when the synchrotron source was opened to the users.
At that time the synchrotron source didn't have a Booster, nor shielding roof over the ring, nor totally metallic hutches. Personnel were not allowed to stay in the ring building during injections (except in the rooms of the 1st and 2nd floors of the south side, including the control room). That was our first type of machine operation. One of the most important upgrade on the machine performance was achieved by the construction of a 500 MeV Booster synchrotron, which brought a significant improvement for safety, on the dose distribution profile around the ring. After the installation of concrete roof and inner wall, additional localized lead inside the ring, and new gamma shutters, personnel now are allowed to stay at the experimental hall during injections. We also improved the safety at beamlines.

1. The LNLS machine parameters

The Brazilian Synchrotron Light Laboratory is operated by the Brazilian Association for Synchrotron Light Technology (ABTLuS) under a contract with the National Research Council of the Ministry of Science and Technology (CNPq) and the Brazilian Ministry of Science and Technology (MCT). The equipment was designed, built and is completely operated by Brazilians.

1.1. Initial parameters of the LNLS equipment

The first synchrotron light source in the Southern Hemisphere and the only one of this kind in Latin America has been in operation at LNLS since July 1997. The LNLS synchrotron light source was opened to external users with the following composition [1]:

- 1.37 GeV storage ring, 93 m perimeter (initially, with no roof) (Fig.1)
- Transport line
- 120 MeV electron LINAC injector
- 7 Beamlines

The LINAC is underground. The ring building has 3 floors:

- 1st floor, where are the experimental hall with the beamlines and several rooms for users support
- 2nd floor, where are the control room on the south side and several office rooms
- 3rd floor, for air conditioning machinery and maintenance

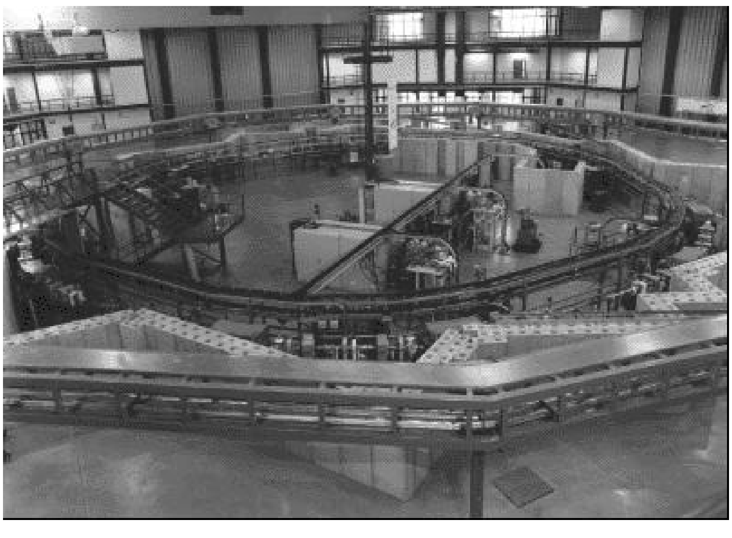

Fig.1 - General view of the LNLS ring in December, 1996.

Originally the storage ring was designed for 1.15 GeV/100 mA but the good performance of the magnets permitted to increase the energy to 1.37 GeV for routine operation (Table 1).

Operation energy	1.37	GeV
Injector:	linear accelerator	
Injection energy	120	MeV
Nominal electron current	100	mA
Circumference	93.21	m
Mean diameter	30	m
Magnetic structure	double bend achromat	
Lattice symmetry	6-fold.	
Revolution frequency.	3.2	MHz
Harmonic number.	148	
RF frequency.	476	Mhz
Natural emittance	100	nm.rad.
Horizontal betatron tune	5.27	
Vertical betatron tune	2.17	
Synchrotron tune (at 500 kV rf gap voltage)	9.19×10^{-3}	
Natural horizontal chromaticity	-7.8	
Natural vertical chromaticity	-9.5	
Momentum compaction factor	8.3 x 10-3	
Natural energy spread	6.0 x 10-4	
Horizontal betatron damping time	13	ms
Vertical betatron damping time	13	ms
Synchrotron damping time	6	ms
Dipole bending radius	2.735	m
Bending field	1.67	T
Number of dipoles	12	
Number of straight sections for insertion devices	4	
Length available for insertion devices	2.95	m
Energy loss per turn from bending magnets	114	keV
Total radiated power from bending magnets	11.4	kW
Critical photon energy from bending magnets	2.08	keV
Electron lifetime	10	hours

Table 1 - Main parameters of the LNLS electron storage ring

Initially, the LNLS injection system consisted of a 120 MeV LINAC, without a Booster (Fig.2), basically due to financial and time constraints during the construction period, although the addition of a Booster synchrotron was kept as a possible future upgrade of the facility. In order to minimize any dose possibility, the injection region was set diametrically opposite to the south side, where is located the control room, shaded by the concrete and lead shielding covering the transport line.

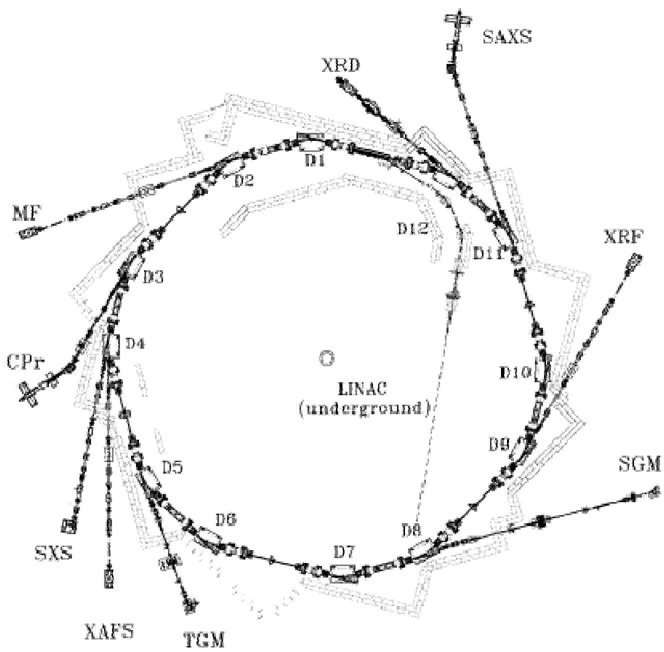

Fig.2 - Plan view of the LNLS storage ring in 1998.

Low injection energy like that can make injection difficult, with relatively high electron losses, and consequently, considering the fact that the ring had no roof, the dose profile around machine was at a higher level than that one aimed for unrestricted access to experimental hall. Because of this, personnel were not allowed to stay at the experimental hall (nor in other places of the ring building, except the 1st and 2nd floors of the south side) during injections. However, the individual doses, if the occupancy of the experimental hall was free all the time with normal injections, would be within the national and international limits for radiation workers, according to our estimates based on calculations and area dosimetry.

1.2. The LNLS machine parameters at the present days

Aiming to improve the injection efficiency and the performance of the stored beam (smaller stored beam transverse dimensions, a higher lifetime, greater total stored beam current, etc.), in particular for the small-gap insertion devices[1], it was constructed a Booster synchrotron, operating at 500 MeV [2]. The new basic composition of the light source consists of:

- 1.37 GeV storage ring, (Fig.3)
- Transport line
- 120 MeV electron LINAC pre-injector (underground)
- 500 MeV Booster synchrotron injector, 34 m perimeter
- 14 beamlines in full time operation for users, 1 under commissioning, 1 under design, 2 beamlines dedicated to beam diagnostics for the exclusive use of the LNLS staff.

The storage ring, transport line and Booster are encased at a 30 cm thick concrete roof with an additional 30 cm thick inner concrete wall. The new beam intensity is more than twice as large as the typical stored beam current before the installation of the Booster synchrotron. The more notable radiological consequence of the new injection system was the decreasing of values in mSv/month in the dose profile around machine, such as in the experimental hall, and in the second and third floor.

2. The improved LNLS shielding

The 1st operation of the 500 MeV Booster was in May of 2001, with no roof. On June 2003 was installed the last concrete block over the Booster. At the end of 2004 the Booster and storage ring were housed into a concrete tunnel (Fig.3), with additional lead shielding. This new machine configuration settled the present type of operation, resulting in the occupancy permit of the experimental hall during injections.

Fig.3 - Current operation type of the LNLS light source: it was constructed a Booster and installed concrete roof and inner wall. After that and other improvements people were allowed to stay at experimental hall during injections.

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[1] We have already installed 1 undulator, and 1 normal wiggler. We are going to install 1 sc wiggler at the end of 2009.

3. The old and new dose profile around machine

More than one hundred TLD gamma dosimeters are placed in the ring building, in walls, columns, glass windows, suspended in the air, etc., covering all the neighboring of the machine, after the concrete shielding, including the experimental hall. They are read monthly. The dose profiles are followed with LiF dosimeters and CaSO4 dosimeters, from two different companies, as a comparative procedure. We also have albedo monitors for neutrons mounted on belts which are placed around containers of water, as human body simulators (our "phantoms"), and active monitoring stations for gammas and neutrons.

The Fig.4 shows the light source in the ring building, with the north (N), south (S), east (E) and west (W) orientation. The X marks on the drawing of the Fig.4 give an idea of the positioning of the dosimeters considered in this document (one for each floor, at the N, S, E and W sides, 15-30 m distant from the ring, depending on the location.

The Fig.5, Fig.6 and Fig.7 show the gamma dose distribution, in mSv/month, on the N, S, E and W sides of the 1st, 2nd and 3rd floor, respectively. Some dosimeters in the 3rd floor were placed only after January 1998. The readings from a dosimeter placed inside machine (from January 1999 until March 2007), before any shielding, in the second (horizontal) deflecting dipole at the transport line, is also shown as a reference for the machine operation intensity. Note that the dose profile follows the machine operation profile. It can be noted that the doses related to the 1st floor occurred at lower levels compared to the doses from the 2nd and 3rd floor. The dosimeter on the 2nd floor of the south side is more exposed to the machine than the control room itself.

In the new injection system, the transfer of electrons from the LINAC to Booster and from the Booster to the Ring occur on the N and W side of the ring building, respectively.

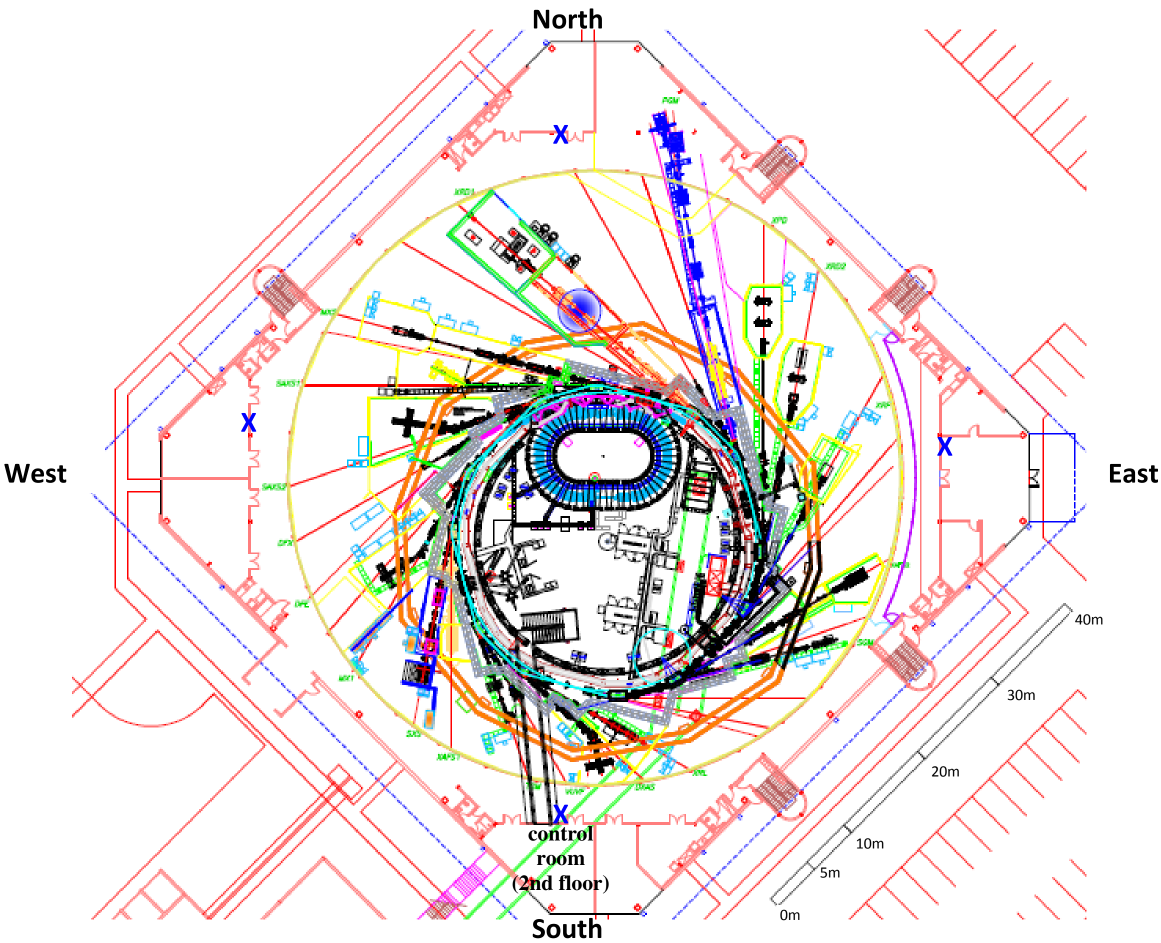

Fig.4 - The light source layout and the ring building. The considered dosimeters are placed in the positions marked X.

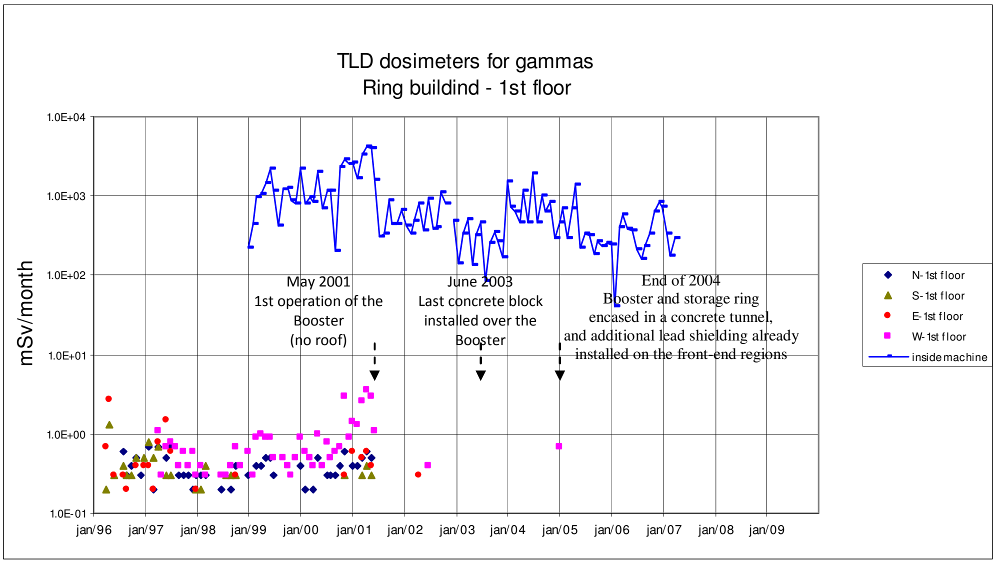

Fig.5 - Monthly doses from TLD dosimeters placed at N, S, E and W sides, in the 1st floor of the ring building.

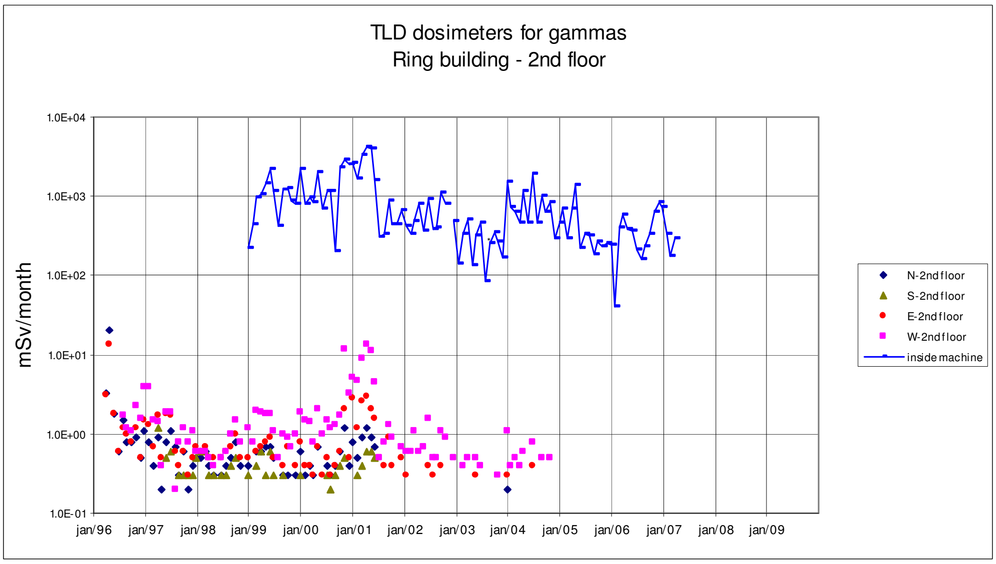

Fig.6 - Monthly doses from TLD dosimeters placed at N, S, E and W sides, in the 2nd floor of the ring building.

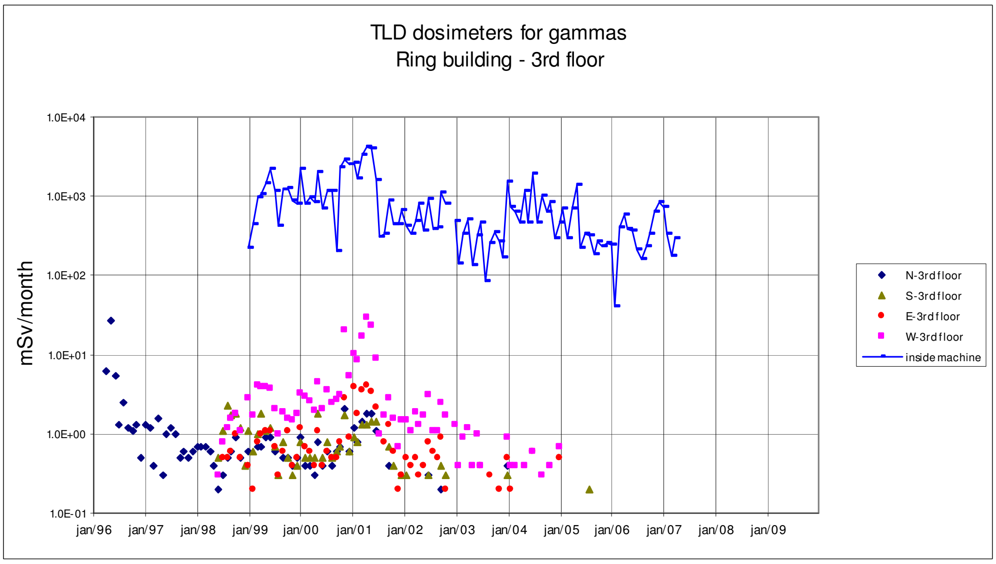

Fig.7 - Monthly doses from TLD dosimeters placed at N, S, E and W sides, in the 3rd floor of the ring building.

The neutron doses, not shown here, were always not greater than the gamma doses. As said above, several dosimeters, not shown, are placed at other positions around machine, covering different distances to the ring.

After the implementation of the current type of machine operation, all readings from all these dosimeters do not have presented values above the natural background levels. If the dose value is smaller than 0.2 mSv in a month, it is considered equivalent to the natural background radiation level (BG), and is plotted numerically zero for the purposes of this text. Note that after December 2004, after completion of the concrete shielding, no dose value was greater than 0.2 mSv in a month.
On the other hand, from the opening to users until now, the individual doses of monitored people at LNLS, given by TLD dosimeters for gammas, are BG. The same is always registered by the albedo monitors for neutrons, “worn” by the phantoms parked at strategic places in the ring building.

4. Beamline safety improvements

The beamlines received all-metal (steel) hutches. Before that, specific metal shielding was installed according to specific radiation monitoring. Now, the lead for gas-Bremsstrahlung in beamlines is designed according to ray-tracing method. Conservatively, we changed the experimental station shutters by ones with the same dimensions and material (Pb) of the gamma shutters.
We also improved our beamlines interlock system, which is now based on AS-i (actuator sensor interface) and programmable logic controllers. It is fail safe, comply redundancy, and has emergency buttons and safety keys.

References

[1] Aldo F. Craievich and A. Ricardo Rodrigues, "LNLS Synchrotron Source and Beamlines: Status, First Experiments and User Access”, Brazilian Journal of Physics, vol. 27, Nº 4, December 1997.
[2] P. R. Tavares and Liu Lin, “The 500 MeV Booster Synchrotron for the LNLS Light Source”, LNLS News Letter, Nº 2, page 3 (2000).
[3] http://www.lightsources.org/
[4] http://www.lnls.br