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CARBON-STEEL/POLIETHYLENE RADIATION ENCLOSURES FOR THE SIRIUS BEAMLINES*

L. Sanfelici†, F. H. Cardoso, H. F. Canova, R. Madacki, M. A. Pereira, M. L. R. Santo, J. E. Santos, M. Saveri Silva, L. G. Silva, LNLS, Campinas, Brazil
M. H. A. Costa#, L. Bucianti, E. Palombarini, C. Prudente, Biotec Solução Ambiental, São José dos Campos, Brazil

Abstract

Lead enclosures have been used over the past decades for radiation protection at mid and high-energy synchrotron light-sources, requiring nearly 10% of the investment needed to set up a new beamline. Due to the increasing concern about neutron levels, in part due to the reduction of the photon radiation levels with the increased thickness of the hutch walls, the existing constructive models were revisited and a new constructive approach based on Carbon-Steel (CS) and High-Density Polyethylene (HDPE) is proposed for the SIRIUS beamlines, leading to increased overall radiation protection and potentially lower cost. This work is going to show preliminary simulation results, cost-comparison, as well as a few mechanical design details and prototyping initiatives.

INTRODUCTION

With the progress of the beamlines design for Sirius [1], and driven by the strong bias to foment the national industry motivated by the project sponsors, in 2015 a review of existing constructive options for optical hutches began. In that way the LNLS partnered to Biotec [2], a local company specialized in the design and construction of animal holding houses and clean rooms, not only to develop a solution for optical hutches that meet the radiological requirements but also to explore other companies in the region capable of manufacturing beamline hutches.

As part of an initial survey and assessment of existing solutions, a cost projection was carried out for the main constructive options identified, such as the traditional Pb hutches [3], Barite concrete [4] and CS/HDPE versions. Table 1 presents a simple functional comparison. The price is normalized by reference values obtained from traditional suppliers in the field.

Table 1- Constructive Options for Optical Hutches: Comparing Basic Features and Projected Costs

	Lead	CS/HDPE	Barite Concrete
Wall Thickness	30 mm	50 mm/50 mm	300 mm
Bremsstrahlung	Best	Best	Best
Neutrons	Bad	Best	Best
Synchrotron	Best	Best	Best
Thermal Insul.	Bad	Best	Good
N. Price [0..1]	~1	~0.7	~0.6

The projected costs showed the potential advantage of working with Barite concrete or CS/HDPE combined in comparison to conventional Pb hutches, not to mention the occupational benefits brought by avoiding handling a toxic material such as Lead. The selected option to mechanical-design was the double-walled CS/HDPE due to their dust-free and easy-machining characteristics.

It is not the aim of this work to present deep details regarding radiation protection of the Sirius beamlines or the mechanical design attained but offer a panorama and perspectives of the whole study and development process.

FIRST SIMULATION RESULTS

Table 2: Main Simulation Parameters for Sirius

Simulation Parameters	Value	
Straight section (SS) length	10.34	m
Pressure in the SS	5.10^{-8}	mbar
Distance to hatchet wall	24	m
Electrons energy	3	GeV
Fill current	500	mA
Max. dose rate ($\gamma + n^0$)	0.5	µSv/h

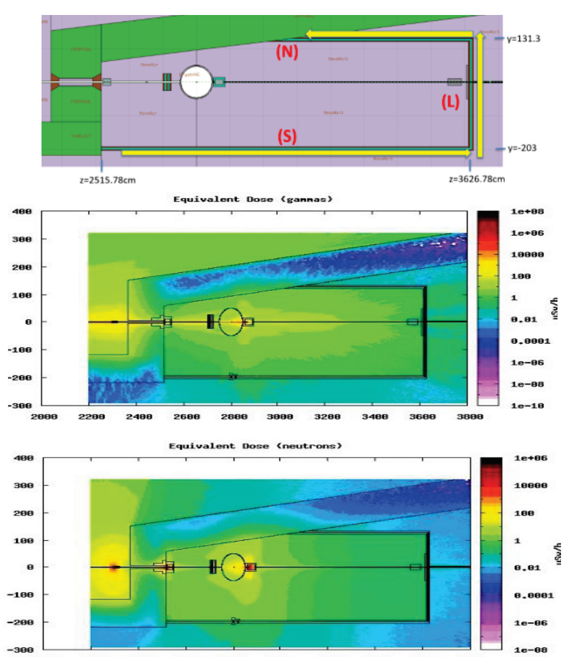

Figure 1: Results for a double-wall hutch composed of 50mm CS followed by 50mm HDPE at Sirius. Top: geometric model. Middle: effective dose distribution for photons. Bottom: effective dose distribution for neutrons.

* Work supported by the Brazilian Ministry of Science, Technology, Innovation and Communication
† lucas.sanfelici@lnls.br
# mhc064@gmail.com

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Table 3: Comparison of Effective Doses for Different Constructive Scenarios at Sirius and The Shielding Thicknesses

Shielding Material	Photons/Neutrons Doses (µSv/h) and Thickness (mm)			
	South	East	North	Roof
Barite Concrete	0.10/0.26	0.28/0.02	0.01/0.02	0.16/0.35
	200	300	200	150
Fe/Pb/Fe	0.24/1.11	0.37/0.09	0.02/0.17	0.43/0.99
	3+30+3	3+60+3	3+30+3	3+10+3
Fe/HDPE	0.20/0.23	0.38/0.04	0.08/0.05	0.14/0.15
	50+50	70+50	50+50	48+50

Table 2 shows the main parameters adopted for the simulation runs with FLUKA [5]. Figure 1 presents the resulting dose distribution for a hutch employing CS/HDPE as shielding materials in the dimensions of Sirius, whereas Table 3 summarizes the results for all cases under investigation. The masks at the front end were not considered in this scenario. Because of the forward peaking nature of the high energy bremsstrahlung scattering the CS shielding thickness required at small angles along the beam direction is large. Considering a uniform downstream wall (East wall) thickness of ~7 cm, additional shielding of 5 cm of Pb will be required for scattering angles < 6 degrees. It was also considered 6 mm of Pb shielding against ground shine effect.

PROTOTYPE AT THE UVX RING

Table 4: Specification of The Optical Hutch Prototype

Enclosure Description		Prototype White Beam Enclosure
Shielding Material		CS/HDPE
Outer Dimensions	Height max	2.5 m
	Width max	5.3 m
	Length max	6.5 m
Shielding Panels	Side	50 mm/50 mm
	Roof	40 mm/50 mm
	Downstream	50 mm/50 mm
	Guillotine	Not required
	Alignment Window	Not required
Roof Static Load		500 kg/m^2
Internal Crane		Not required
Door	Position	Outboard side
	Size (m)	2.2 H x 2.45 W
	Type	Sliding double
	Floor groove	No
	Window	Not required
Labyrinths	Fluids labyrinth	1
	Gases labyrinth	1
	Electrical labyrinth	3
	Air inlet labyrinth	1 (on roof)
	Air outlet labyrinth	1 (on roof)
	Users' labyrinth	2
	LN_2 labyrinth	1 (on roof)
Air Conditioning	Temperature	24±0.1°C
	Thermal Load	3 kW

The table below summarizes the main features of the optical hutch prototype currently entering the manufacturing tests phase.

Figure 2 depicts the prototype hutch developed in the past months implanted in the UVX ring [6]. It is going to be installed at the exit of a free straight section to allow the highest gas-bremsstrahlung levels that the LNLS can provide at the moment for radiological tests. The hutch follows similar specifications planned for the Sirius' optical hutches, except for the height, 1m lower due to conflicts with the pipe rack.

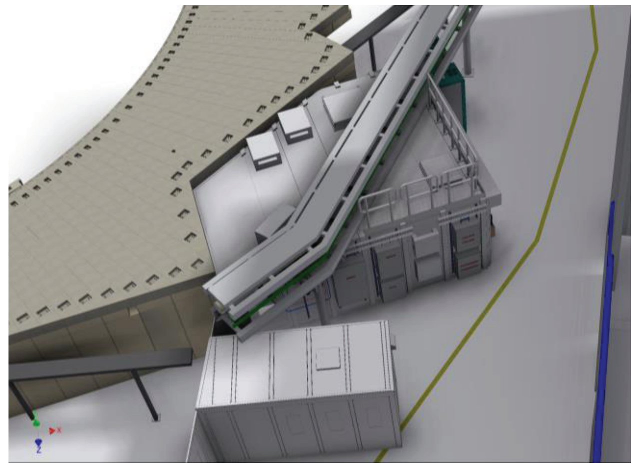

Figure 2: Optical hutch prototype – implantation to be installed in the UVX storage ring.

MECHANICAL DESIGN

The mechanical design encompassed all main hutches components: wall and roof modules, chicanes, doors, joints and supports to general infrastructure. The development took place based on a set of premises:

1. The prototype follows strictly the specifications of an optical hutch for Sirius;
2. Any ray leaving the hutch must cross at least the specified radiation protection thickness;
3. The radiation tightness of joints must not rely on strict fabrication or assembly tolerances, overlaps and chicanes must be pursued throughout the design;
4. The design must allow the use of both CS/HDPE modules as CS alone;
5. Modular design seeking standardization of dimensions and easy assembly;
6. The structural design must allow the eventual removal of roof and wall modules for survey and equipment transportation;
7. The assembly process shall be possible without cranes, and at height-restricted places;
8. The roof must be capable of supporting human traffic, instrumentation cabinets and air handling units;
9. The final price shall be comparable to the offered by Chinese suppliers of Fe/Pb hutches.

Figure 3 shows the main cuts of the hutch. They exhibit the closing design employing a double shielding layer composed of thick Carbon-Steel and HDPE plates.

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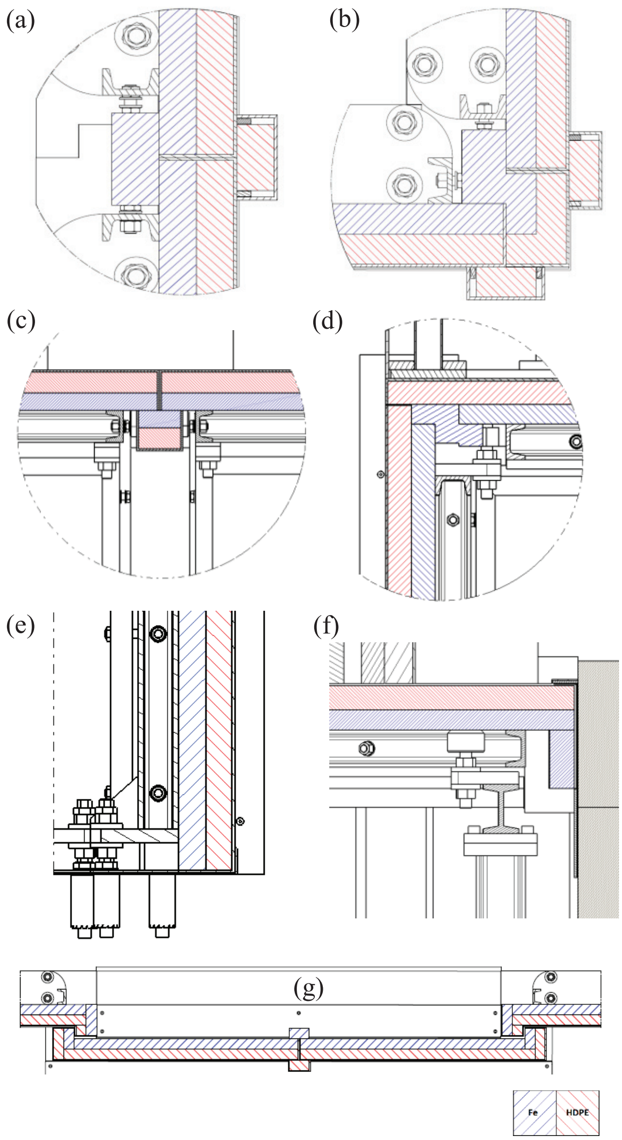

Figure 3: (a) Joint of 2 wall modules, (b) Corner of 2 wall modules, (c) Joint of roof modules, (d) Joint of wall and roof modules, (e) Floor fixation of wall module, (f) Roof interface to hatchet wall, (g) Double-sliding door.

UTILITIES, SAFETY SYSTEMS AND HVAC

The underway prototyping effort at the LNLS spams from utilities to sophisticated optical components responsible for delivering ultra-stable beams to the new Beamlines [7, 8]. This sort of initiative is of uppermost importance to the engineering teams in charge of the design and construction of the beamlines to validate and improve the design patterns being created, before widely replicate them to the Sirius' phase-1 beamlines.

The teams have as a premise to design highly monitored facilities, integrated to the beamline and building management system, which supports the maintenance teams work by employing alarms and historical data, enabling real-time monitoring of the whole facility, not to mention the advantages this integration brings during the commissioning phase.

The prototype hutch is equipped with a typical set of mechanical and electrical utilities, equipment and personal protection systems, as well as a precise air conditioning system.

STATUS AND PERSPECTIVES

Given the innovative nature of the project, a small set of wall, roof, and chicanes modules are about to be prototyped and heavily inspected in order to validate the production process before the complete manufacturing of the hutch. The full installation (hutch, utilities, HVAC and protection systems) in the UVX ring is planned to take place until February/2017 when extensive radiological and functional tests begin.

In parallel, the production process is going to be reviewed and optimized in costs, risks and overall quality.

The hutches of the first set of Sirius beamlines shall be installed in the new building by July/2018. The completion of the bid process is expected for Q2/2017.

We look forward that the current prototyping stage assists to improve the design of this new type of hutch, ending up with a safer optical hutch in the radiation protection perspective, especially during the early operational stage of the new accelerator. Also that this partnership model proves successful in fostering the local industry.

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