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

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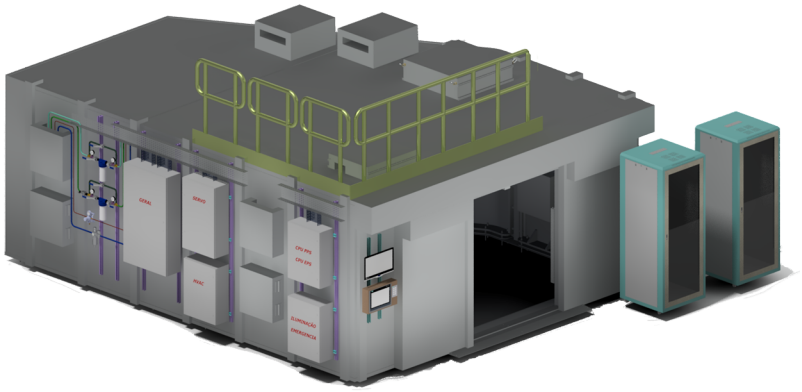


*Abstract*

Lead enclosures have been used over the past decades for radiation protection at mid and high-energy light-sources, requiring nearly 10% of the investment needed to set up a new beamline. Due to the increasing concern about neutron levels, 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 potential 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

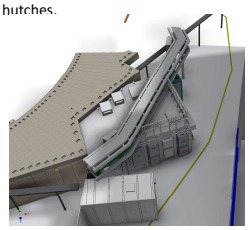
With the progress of the beamlines design for Sirius [1], and driven by the strong bias to foment the national industry motivated by the project sponsors, in 2015 a review of existing constructive options for optical hutches began. In that way the LNLS partnered to Biotec [2], a local company specialized in animal holding houses and clean rooms. 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, Barite concrete and CS/HDPE. The table below presents a simple functional comparison. The price is normalized by reference values obtained from traditional suppliers in the field.

Constructive options for optical hutches: comparing basic features and projected costs.

| | Carbon Steel/Lead | Carbon Steel/HDPE | Barite Concrete |
|---|---|---|---|
| **Side Wall Tickness** | 30mm Pb | 50mm Fe<br>50mm HDPE | 30cm |
| Bremmstrahlung | Best | Best | Best |
| Neutrons | Bad | Best | Best |
| Synchrotron | Best | Best | Best |
| Thermal Insul. | Bad | Best | Good |
| Normalized Price [0..1] | ~1 | ~0.7 | ~0.6 |

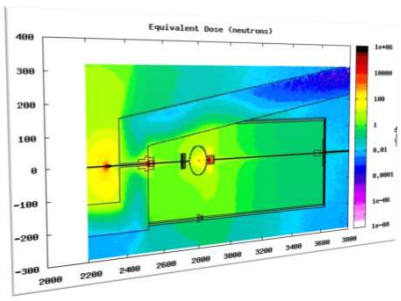
## Prototype at the UVX ring

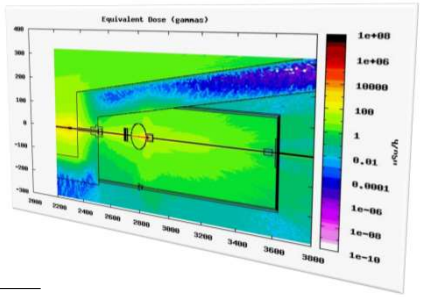
Prototype hutch developed in the past months implanted in the UVX ring. It is going to be installed at the exit of a free straight section to allow the highest gas-bremsstrahlung levels that the LNLS can provide at the moment for radiological tests. The hutch follows similar specifications planned for the Sirius' optical hutches.



| | | |
|---|---|---|
| **Enclosure Type** | | **IVU FOE** |
| **Enclosure Description** | | Prototype White Beam Enclosure |
| **Shielding Material** | | Carbon Steel (CS) and Polyethylene (PE) |
| **Outer Dimensions (m)** | Height max | 2.5 m |
| | Width max | 5.3 m |
| | Length max | 6.5 m |
| **Shielding** | Side panels | 50 mm CS/ 50 mm PE |
| | Roof panels | 40 mm CS/ 50 mm PE |
| | Downstream wall panels | 50 mm CS/ 50 mm PE |
| | Guillotine | Not required |
| | Alignment Window | Not required |
| **Roof Static Load** | | 500 kg/m² |
| **Internal Crane** | | Not required |
| **Door** | Position | Outboard side |
| | Size (m) | 2.2 H x 2.45 W (estimated) |
| | Type | Sliding double |
| | Floor groove | No |
| | PPS Interfaces | Mounting plates for magnetic lock and dual position switches. |
| | Window | Not required |
| | Strip Curtain (Internal) | Yes |
| **Labyrinths** | Fluids labyrinth | 1 |
| | Gases labyrinth | 1 |
| | Electrical labyrinth | 3 |
| | Air inlet labyrinth | 1 (on roof) |
| | Air outlet labyrinth | 1 (on roof) |
| | Exhaust outlet | Not required |
| | User access labyrinth | 2 |
| | Liquid nitrogen labyrinth | 1 (on roof) |
| **Air Conditioning** | Temperature | 24±0.1°C |
| | Thermal Load | 3 kW |

## Simulation Results



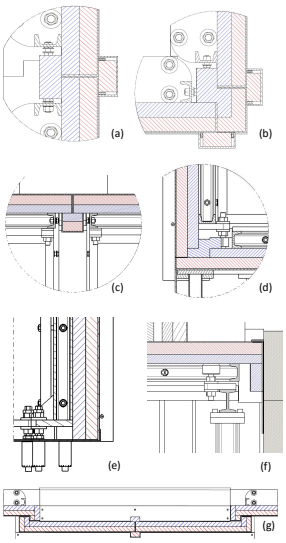

| Simulation Parameters | Value | |
|---|---|---|
| Straight section (SS) length | 10.34 | m |
| Pressure in the SS | $5.10^{-8}$ | mbar |
| Distance to hatchet wall | 24 | m |
| Electrons energy | 3 | GeV |
| Fill current | 500 | mA |
| Max. dose rate ($\gamma + n^0$) | 0.5 | µSv/h |

| Shielding Material | Thickness (mm) | | | |
|---|---|---|---|---|
| | South | East | North | Roof |
| Barite Concrete | 200 | 300 | 200 | 150 |
| Fe/Pb/Fe | 3+30+3 | 3+60+3 | 3+30+3 | 3+10+3 |
| Fe/HDPE | 50+50 | 70+50 | 50+50 | 48+20 |

## Mechanical Design

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

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




Different cuts of the hutch: (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

| Shielding Material | Photons Dose (µSv/h) | | | | Neutrons Dose (µSv/h) | | | | Total Dose (µSv/h) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | South | East | North | Roof | South | East | North | Roof | South | East | North | Roof |
| Barite Concrete | 0.100 | 0.275 | 0.007 | 0.159 | 0.262 | 0.021 | 0.021 | 0.354 | 0.362 | 0.296 | 0.028 | 0.514 |
| Fe/Pb/Fe | 0.241 | 0.366 | 0.016 | 0.427 | 1.105 | 0.093 | 0.172 | 0.988 | 1.346 | 0.459 | 0.188 | 1.415 |
| Fe/HDPE | 0.203 | 0.380 | 0.081 | 0.141 | 0.228 | 0.043 | 0.046 | 0.153 | 0.431 | 0.423 | 0.127 | 0.294 |

The figures above present 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 front end were not considered in this scenario. Due to 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.

## Utilities, HVAC and Safety Systems

The underway prototyping effort at the LNLS spams from utilities to sophisticated optical components. This sort of initiative is of uppermost importance to validate and improve the design patterns being created, before they are widely replicated to the Sirius' phase-1 beamlines.

There is a premise to design highly monitored facilities, integrated 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.

The prototype hutch is equipped with a typical set of mechanical and electrical utilities, equipment protection 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 and protection systems) in the UVX ring is planned to take place until February/2017, when extensive radiological tests begin. In parallel, the production process is going to be reviewed and optimized in order to reduce costs, risks and improve 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.

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Sirius (August 2016)

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MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION