The ALP search with NeuralRinger - ATLAS experiment

Yara do Amaral Coutinho[a], Luiz Balabram[a], Artur Cordeiro Oudot Choi[b],
Mateus Hufnagel[c], Mikola Khandoga[b], Bertrand Laforge[b], Jose Ocariz[b]
[a]COPPE, EE, IF, Universidade Federal do Rio de Janeiro (UFRJ),
[b]Paris LPNHE Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE),
Sorbonne Université, Université de Paris, CNRS/IN2P3,
[c]Universidade Federal de Juiz de Fora (UFJF)

The discovery of the Higgs boson in 2012 by ATLAS and CMS experiments, confirmed the mechanism related to the mass generation of elementary particles proposed in the Standard Model (SM). The observed boson has, up to the present experimental precision, characteristics as predict by the SM, but more properties must be confirmed, stimulating the high energy physics (HEP) comunity to map the full scalar sector of the SM, including the expected autocouplings of the Higgs boson. However, some connections and the search translates into a discovery potential at the Large Hadron Collider (LHC) experiments, ATLAS and CMS.

The standard axion brought solution for the strong (charge-parity) CP violation problem of quantum chromodymanics (QCD), and provides a possible candidate for dark matter (DM). The axion-like particle (ALP) suggested in some extensions of the SM, unrelated to the strong CP problem, is a possible candidate for DM, with softer theoretical constraints than the ones of the axion. In this way, the ALP mass can present a wide range (eV-GeV mass), which can be explored by astrophysical search and colliders experiments, mainly the LHC going to the Run 3 conditions. The ALP we are looking for is a long-lived particle (LLP).

This work focuses on the exotic decay of the SM Higgs into an ALP produced in association of a Z gauge boson (Z),

$$h \to Z(\ell\ell) + a(\gamma\gamma),$$

where $\ell = (e, \mu)$ are electron and muon and γ is the photon.
For the mass range to be searched, a large fraction of the ALP, decays inside the detector.

In order to increase the efficiency to separate the photons coming from a possible ALP decay from those possible fake coming from hadron decays, we consider using the NeuralRinger algorithm approach which was developped to trigger single electron. The calorimetry information around a photon candidate is formatted in concentric ring energy sums using artificial neural networks (ANN) for hypotheis testing, aiming separating signal and backgrounds.

For this study, a NeuralRinger for photons has been implemented. In order to improve the performance, the calorimeter information is corrected for cross talk (XT) effects that modifies the photon arrival time reconstruction and its energy measurements to a lower extent.

Moroever, we use quarter rings and strips to capture the asymmetric energy deposition in electromagnetic showers to help to identify/desintangle the two photons coming from the ALP decay.

For the LHC energies it is usual that particles like W, Z or t are produced with $p_t >> m$, generating collimated decays (boosted regime), decay products reconstructed into single jets, while on the other hand, some decay products will be reconstructed into multiple jets. The jet substructure studies determine the origin of the jet and also discriminate the signal used to search new physics. Based on the internal structure of the jets, the use of the Lund Jet Plane (LJP) technique infers different possible origins of the jets, QCD, QED, or decay of a heavy particle, exploring different kinematical regions. The QCD phase space of all emissions is described by two variables: transverse momentum and the angle of any given emission with respect to its emitter. The LJP has a possible potential to identify the two di-photons/ALP topologies: di-photon system as a single photon (merged regime) from di-photon system as two photon-showers (resolved regime) and QCD jets.

The study is based on frameworks employing jet tagging to disentangle boosted jets from background, and will allow us to build an original ALP search.