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Extending the search potential for axion-like particles decaying into two photons with the ATLAS detector at the LHC

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Title : Extending the search potential for axion-like particles decaying into two photons with the ATLAS detector at the LHC

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Team : Masses and fondamental interactions ; ATLAS experiment

Description :

Light and weakly-interacting particles are predicted in a variety of theoretical models, and gather interest as possible Dark Matter (DM) mediators. Such axion-like particles (ALP) would couple predominantly to gluons and photons, and would therefore be produced in proton-proton collisions, leading to a clear experimental signature as narrow resonances decaying into pairs of photons, a final state that benefits from the excellent performances of the ATLAS liquid-argon (LAr) electromagnetic calorimeter.

Both ATLAS and CMS experiments have searched for diphoton resonances at masses both above and below the Higgs boson mass, with no observed evidence for New Physics. An ongoing ATLAS effort led by the LPNHE team, and based on signatures from boosted diphoton pairs, extends the mass search down to 10 GeV. Yet, lower masses are likely to remain out of reach with data collected during the LHC Run-2 data-taking period, due to limitations driven both by energy thresholds in the online diphoton trigger chains applied during Run-2, and to decreasing selection performances to reconstruct and identify low-energy photons.

Based on an innovative usage of Machine Learning (ML) techniques, this proposal intends to yield a significant improvement of the future search potential for ALPs in the diphoton channel in Run-3, by overcoming the two limitations mentioned above. The two key proposed breakthroughs are :

- The design of a new trigger chain using neural networks fed from calorimeter ring sums, to be implemented in the HLT stage of the ATLAS trigger system. A trigger chain devoted to boosted low-mass diphotons is an excellent candidate to take full advantage of Machine Learning algorithms, as these can exploit the specific signatures of closely-collimated photon pairs in the ATLAS LAr calorimeter, and outperform the limitations of the diphoton triggers used during Run-2.

- An innovative redesign of the offline ATLAS diphoton reconstruction and selection criteria, based on ML techniques, and specifically intended for boosted diphotons. Photons are currently identified in ATLAS using information from the calorimetric and tracking systems, with criteria that have been trained on single, isolated photon candidates, and are therefore not optimized for closely collimated photon pairs. A previous study led by the LPNHE team has driven evidence that a ML-based implementation of such multivariate information allows for an optimal improvement of photon and diphoton identification at various steps in the ATLAS reconstruction chain, and translates into a large improvement of the sensitivity in the search for narrow diphoton resonances, including an extension of the search domain to yet uncovered very-low-mass ranges.

The ATLAS LPNHE team has a long-standing expertise on electromagnetic calorimetry, dating back to the R&D and construction of the ATLAS LAr calorimeter. Over the years since the LHC startup, the team activities have covered nearly all aspects related to the triggering/reconstruction/identification of electrons and photons. Members of the team participated in the Higgs boson discovery in 2012, and have coordinated several ATLAS physics results using photons and diphotons, including searches for Dark Matter produced with a Higgs boson decaying to photons, and searches for new diphoton resonances at masses both above and below the Higgs boson mass.

The LPNHE team has an active, fruitful collaboration with the Brazilian ATLAS cluster, devoted to the improvement of electron/photon triggers using ML techniques. The team is also member of DMwithLLPatLHC , a recently approved ANR project involving three French laboratories, devoted to the search for Dark Matter with long-lived particles (LLP) at the LHC, that relies heavily on ML developments to exploit the specific characteristics of jets and photons produced in the decay of LLPs.

Possible trips :

- Missions régulières au CERN, Genève
- Un séjour de courte/moyenne durée au CERN peut être envisagé

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Documentations :

- ATLAS
- ATLAS at LPNHE