Contribution ID: **11** Type: **Oral talk**

# Searches for axions in proton-proton and ion-ion collisions at energies of 5.02 TEV and 13 TEV

*Wednesday, 17 January 2024 15:00 (20 minutes)*

As a part of the ATLAS Collaboration experimental measurements of light-by-light scattering in Pb+Pb collisions during 2015 and 2018 at an integrated luminosity of 2.2 nb-1 and energy of 5.02 TeV, taking into account the obtained experimental constraints [1], we have modeled the production cross sections of axion production, which is candidate for dark matter with subsequent decay into γγ. Candidates for light-by-light scattering are selected in events with
two photons, pseudorapidity, $|\eta\gamma| < 2.37$, diphoton invariant mass $m\gamma\gamma$ = 5-30 GeV, and an interaction constant of the order of 10-3 GeV-1 [2]. The obtained calculations showed the dependence of the cross section on the number of axion events (Fig. 1), on the energy in the center of mass system (Fig. 2), and on the mass distribution of axions.
Proton-proton and ion-ion collisions were processed for QCD-axion formation using the SuperChic v.4.2 Monte Carlo event generator [3]. Corresponding production cross sections were obtained and compared with recent measurements of light-by-light scattering by ATLAS and CMS collaborations at the LHC during lead-to-lead collisions [4,5]. It is shown that the axion production cross section in proton-proton collisions is seven orders of magnitude larger than that in Pb+Pb collisions at an energy in the center-of-mass system of 5.02 TeV. An order of magnitude difference in the axion production cross section in proton-proton collisions for single dissociation in relation to double dissociation at an energy of 5.02 TeV and a mass range of 5-30 GeV was revealed (approximately 20-21 pb to 9-10 pb, depending on the model). In the same mass range, the axion production cross sections were calculated at 13 TeV and a difference of about 2.5 times
in the axion production cross sections for single dissociation versus double dissociation was found. The advantage of the 2nd model at 5.02 TeV and the 1st model at 13 TeV was found. The results of calculations for the four models are presented in Table 1.
The analysis of experimental data with 441 candidates for axions obtained during proton-proton collisions at an energy of 13 TeV [6] led to the need for us to search for a narrow resonance in the distribution of diphoton masses in the mass range of 5–1400 GeV with the number of events of 100,000. The obtained data do not exceed the experimental value of the upper limit of the production cross-section of a narrow resonance and are about 0.024 fb.

1. The ATLAS collaboration. Measurement of light-by-light scattering and search for axion-like particles with 2.2 nb−1 of Pb+Pb data with the ATLAS detector. JHEP 03 (2021) 243.
2. Klaudia Maj. On behalf of the ATLAS Collaboration. BSM physics using photon-photon fusion processes in UPC in Pb+Pb collisions with the ATLAS detector. ATL-PHYS-PROC-2023-037, arXiv:2307.07481v1 [hep-ex].
3. Lucian Harland-Lang. SuperChic v4.2 A Monte Carlo for Central Exclusive Production. URL: https://superchic.hepforge.org/superc
4. ATLAS collaboration. Evidence for light-by-light scattering in heavy-ion collisions with the ATLAS detector at the LHC, Nature Phys. 13 (2017) 852 [arXiv:1702.01625] [INSPIRE].
5. CMS collaboration. Evidence for light-by-light scattering and searches for axion-like particles in ultraperipheral PbPb collisions at √sNN = 5.02 TeV, Phys. Lett. B 797 (2019) 134826, [arXiv:1810.04602] [INSPIRE].
6. The ATLAS collaboration. Search for an axion-like particle with forward proton scattering in association with photon pairs at ATLAS. CERN-EP-2023-049, arXiv:2304.10953 [hep-ex].

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**Session Classification:** Afternoon Session 2

**Track Classification:** Physics of Nuclei and Elementary Particles