Pis'ma v ZhETF, vol. 119, iss. 1, pp. 7 – 8 January 10

On production of heavy charged particles in $\gamma\gamma$ fusion at planned pp colliders

S. I. Godunov[+1)], *E. K. Karkaryan*[+], *V. A. Novikov*[+], *A. N. Rozanov*[*], *M. I. Vysotsky*[+], *E. V. Zhemchugov*[+]

[+] *I. E. Tamm Department of Theoretical Physics, Lebedev Physical Institute, 119991 Moscow, Russia*

[*] *Centre de Physique de Particules de Marseille (CPPM), Aix-Marseille Universite, CNRS/IN2P3, 13288 Marseille, France*

Submitted 15 November 2023
Resubmitted 21 November 2023
Accepted 22 November 2023

DOI: 10.31857/S1234567824010026, EDN: sarbyy

In the course of the Standard Model expansion new heavy particles are usually introduced. If these particles are electrically charged they should be produced in the $\gamma\gamma$-fusion, $\gamma\gamma^{(*)} \to \chi^+\chi^-$, and the cross section of this reaction is determined by the values of the electric charge and the mass of χ. One popular example of $\chi^\pm$ is chargino – a mixture of superpartners of charged Higgs and $W^\pm$ bosons. In the recent paper [1], the CMS collaboration presented the results of a search for a long-lived chargino in the LHC 2016-2018 data. In [2], exclusion intervals of chargino masses in some particular models are presented by the ATLAS collaboration.

We consider two reactions: ultraperipheral collisions when both protons remain intact and can be used for event tagging with the help of forward spectrometers, and the semiexclusive process when only one proton survives while the second disintegrates. We calculate their cross sections for the planned colliders: HE-LHC (collision energy 27 TeV), SPPC (70 TeV) and FCC (100 TeV) and compare them with what is obtainable at the LHC (13 TeV).

One of the necessary ingredients of the calculation is the cross section of the $\gamma\gamma^{(*)} \to \chi^+\chi^-$ reaction. Formulas for the cross section of the massive fermions pair production in the collision of a real and a virtual photons are presented in [3, Appendix E, Eq. (E3)]. For the total cross section of $\gamma\gamma^{(*)} \to \chi^+\chi^-$ reaction we get:

$$\sigma\left(W^2, Q_2^2, m_\chi^2\right) = \frac{4\pi\alpha^2}{W^2}\frac{1}{\left(1+\frac{Q_2^2}{W^2}\right)^3} \times$$
$$\times \left(\left(1 + \frac{Q_2^4}{W^4} + \frac{4m_\chi^2}{W^2} - \frac{8m_\chi^4}{W^4} - \frac{8m_\chi^2 Q_2^2}{W^4}\right) \times \right.$$
$$\left. \times \ln\frac{1+\sqrt{1-\frac{4m_\chi^2}{W^2}}}{1-\sqrt{1-\frac{4m_\chi^2}{W^2}}} - \right.$$
$$\left. - \left(1 - \frac{6Q_2^2}{W^2} + \frac{Q_2^4}{W^4} + \frac{4m_\chi^2}{W^2}\right)\sqrt{1-\frac{4m_\chi^2}{W^2}}\right), \quad (1)$$

where α is the fine structure constant, m_χ is the mass of $\chi^\pm$, W is the invariant mass of the produced pair, Q_2^2 is the virtuality of the photon emitted by the disintegrating proton.

Formulas for the cross section of $\chi^+\chi^-$ pair production in the fusion of photons emitted by a disintegrating and an elastically scattered protons are presented in [4, Eqs. (18)–(21), see also Eq. (41)]. For the quasielastic process $pp \to p\chi^+\chi^- p$ the cross section is given by Eqs. (2.15) and (2.16) in [5].

Cross sections for pair production of heavy charged particles for the future pp colliders are presented in Table 1. Total numbers of events were estimated based on the expected luminosity of these experiments. The SPPC has the greatest potential and can find heavy charged fermions with masses up to about 800 GeV in one year of operation. Let us stress that there are many more semiexclusive events than quasielastic ones.

The main advantage of the considered processes is the possibility to detect survived proton(s) which provides effective means for background suppression. Nowadays, when the detectors for these colliders are intensively discussed, we would like to emphasize the importance of forward spectrometers that could provide unique model independent methods for Beyond Standard Model searches.

Numerical results were obtained with the help of `libepa` library [6].

Funding. This work is supported by Russian Science Foundation grant # 19-12-00123-П.

[1)] e-mail: sigodunov@lebedev.ru

Table 1. Total cross sections (in fb) for $\chi^+\chi^-$ pair production in ultraperipheral collisions $pp \to p\chi^+\chi^- p$ (UPC) and in the inelastic process $pp \to p\chi^+\chi^- X$ (SE). The column with $m_\chi = 0.106$ GeV corresponds to muon pair production with the threshold $W > 12\,\text{GeV}$

m_χ, GeV / $\sqrt{s}$, TeV	0.106		100		200		400		800	
	UPC	SE	UPC	SE	UPC	SE	UPC	SE	UPC	SE
13	69100	229000	3.45	20.9	0.341	2.11	0.0253	0.157	0.00117	0.00697
27	102000	367000	7.46	50.4	0.901	6.17	0.0903	0.617	0.00681	0.0458
70	158000	638000	16.6	134	2.36	19.2	0.301	2.4	0.0326	0.253
100	184000	772000	21.4	187	3.19	27.9	0.433	3.7	0.0514	0.424

Conflict of interest. Authors declare that there is no conflict of interest.

This is an excerpt of the article "On production of heavy charged particles in $\gamma\gamma$ fusion at planned pp colliders". Full text of the paper is published in JETP Letters journal. DOI: 10.1134/S0021364023603743

1. A. Hayrapetyan, A. Tumasyan, W. Adam, et al. (The CMS collaboration), arXiv: 2309.16823 [hep-ex].
2. G. Aad, B. Abbott, K. Abeling, et al. (The ATLAS collaboration), arXiv: 2310.08171 [hep-ex].
3. V. M. Budnev, I. F. Ginzburg, G. V. Meledin, and V. G. Serbo, Phys. Rept. **15**, 181 (1975); DOI: 10.1016/0370-1573(75)90009-5.
4. S. I. Godunov, E. K. Karkaryan, V. A. Novikov, A. N. Rozanov, M. I. Vysotsky, and E. V. Zhemchugov, Phys. Rev. D **108**(9), 093006 (2023); DOI: 10.1103/PhysRevD.108.093006; arXiv: 2308.01169 [hep-ph].
5. S. I. Godunov, V. A. Novikov, A. N. Rozanov, M. I. Vysotsky, and E. V. Zhemchugov, JHEP **10**, 234 (2021); doi: 10.1007/JHEP10(2021)234; arXiv: 2106.14842 [hep-ph].
6. E. V. Zhemchugov, S. I. Godunov, E. K. Karkaryan, V. A. Novikov, A. N. Rozanov, and M. I. Vysotsky, arXiv: 2311.01353 [hep-ph].