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Comment on “ η_c production in photon-induced interactions at the LHC”

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In “ η_c production in photon-induced interactions at the LHC,” [Phys. Rev. D **97**, 094009 (2018)] Goncalves and Moreira discuss inclusive and exclusive η_c production at pp and pA collisions at LHC energies. The exclusive channels are via two-photon and photon-Odderon interactions. This comment points out that there is a large additional source of almost-exclusive η_c in ultraperipheral collisions: from the radiative decay of J/ψ that are produced in photon-nucleon interactions. Although the $J/\psi \rightarrow \gamma\eta_c$ branching ratio is small, the J/ψ production cross-section is large enough that it dominates over the exclusive channels considered in [1], and is comparable to the nonexclusive production. In $J/\psi \rightarrow \gamma\eta_c$, the photon is very soft and therefore easy to miss, and the η_c will have very similar kinematics to the J/ψ .

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Two-photon production of the η_c has long been a target for ultraperipheral collisions at heavy ion colliders [2–4], and early RHIC [5] and ALICE [6] studies considered its production in the two-photon channel. Production via double-Pomeron (also called central exclusive production) has also been considered [7]. These calculations found rather small cross-sections, leading to a decline in interest.

Goncalves and Moreira [1] consider pp and pA collisions, via both two-photon and photonuclear channels, finding that inclusive γp interactions dominate, with cross sections of 3.492 nb in pp collisions at $\sqrt{s} = 13$ TeV, and 3.194 μb in pPb collisions at $\sqrt{s} = 8.1$ TeV. The total inclusive rates (two-photon + photon-Odderon [8]) are much smaller, 0.059 nb and 0.501 nb respectively for pp collisions, and 0.182 μb and 0.351 μb for pPb collisions. The existence of the Odderon is rather speculative, so it is important to consider whether there are any exclusive production channels with cross-sections larger than the $\gamma\gamma$ channel, to avoid possible false claims for the existence of the Odderon.

As Sec. 4.4 of Ref. [9] pointed out, the rate for coherent J/ψ photoproduction, followed by the decay $J/\psi \rightarrow \gamma\eta_c$ is larger than that for two-photon production of the η_c . Because the emitted photon is so soft (energy of

111 MeV in the J/ψ rest frame), it is likely to be missed in any LHC detector, and the η_c will have a similar rapidity and transverse momentum as the J/ψ parent, so the final state will look like exclusive photoproduction.

Here, I use STARlight [10] to make a similar calculation for the pp and pA collisions discussed in Ref. [1]. STARlight uses a fairly standard model for photoproduction [11], using the Weizsacker-Williams photon flux and requiring that the two nuclei do not interact hadronically. For pp collisions, STARlight uses a photon flux [12] similar to that used by Goncalves and Moreira. STARlight does not include nuclear shadowing, but, since the bulk of the production in pA collisions comes when the proton is a target, shadowing should not be important here, and STARlight has been shown to accurately predict J/ψ photoproduction at the LHC, in both pPb [13] and pp collisions [14].

Table I gives the coherent photoproduction cross-sections for J/ψ and η_c production cross sections for these pp and pPb collisions, based on the branching ratio $\text{Br}(\eta_c \rightarrow \gamma\eta_c) = 0.17$ [15].

TABLE I. The cross-sections for J/ψ photoproduction in pp and pPb collisions at the LHC (with separate lines for photon emission by the proton and the lead nucleus), along with the production cross section for the η_c in all three modes.

	$\sigma(J/\psi)$	$\sigma(J/\psi \rightarrow \eta_c\gamma)$
pp	79 nb	1.34 nb
pPb (proton-shine)	3.21 μb	54 nb
pPb (lead-shine)	57.5 μb	1.0 μb

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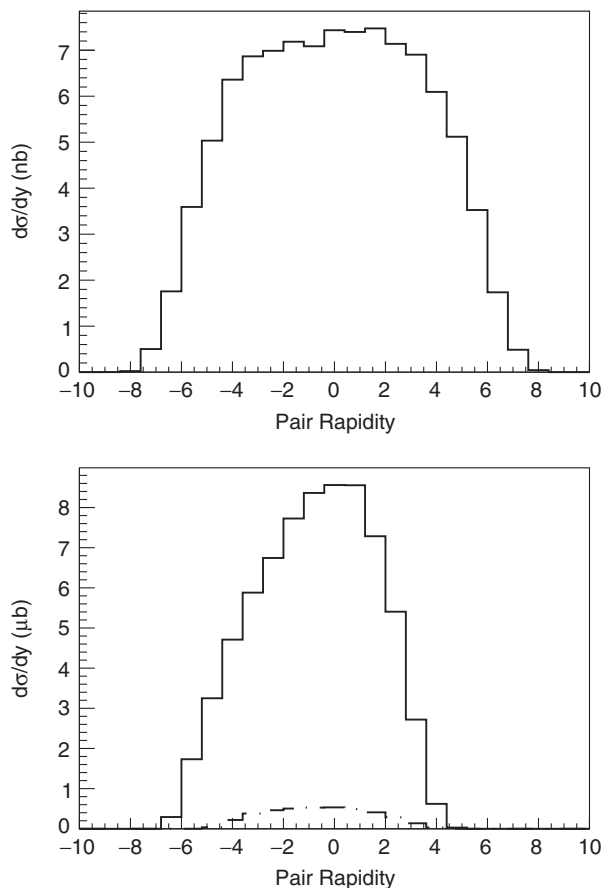


FIG. 1. The rapidity distribution $d\sigma/dy$ for J/ψ photoproduction at the LHC for (top) pp collisions at $\sqrt{s} = 13$ TeV and (bottom) pPb collisions at $\sqrt{s_{NN}} = 8.1$ TeV. In the bottom plot, the solid black curve is “lead-shine,” and the dashed dark blue curve is “proton-shine”.

For both pp and pPb collisions, the η_c rate is higher than the exclusive channels considered in Goncalves and Moreira. The cross sections are also higher than the nonexclusive diffractive production channel (which also leaves both beam particles intact).

Figure 1 shows the rapidity distribution for J/ψ produced in pp and pA collisions; the latter is separated out by photon emitter. The bulk of the pPb production occurs when photons are emitted by the lead nucleus. Both overall distributions are quite similar to the $d\sigma/dy$ for diffractive photoproduction in Fig. 4 of Ref. [1].

One way to differentiate between $\gamma\gamma$ and photon-Pomeron (or photon-Odderon) production is by examining the transverse momentum distribution, p_T , of the η_c . Two-photon production has a considerably smaller p_T than the photoproduction channels [16], particularly when a proton is the photoproduction target. Photon-Pomeron and photon-Odderon processes should have a similar p_T spectra, so be indistinguishable.

These cross sections are considerably larger than any of the exclusive η_c cross-sections discussed in Ref. [1], and are the most likely source for apparent exclusive η_c . Similar conclusions will apply for collisions of other beam particles [8]. It is important that J/ψ photoproduction be considered; otherwise, any observation of exclusive η_c beyond that expected from two-photon physics might be mistaken for a more exotic process.

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- [1] V. P. Goncalves and B. D. Moreira, *Phys. Rev. D* **97**, 094009 (2018).
- [2] N. Baron and G. Baur, *Phys. Rev. C* **49**, 1127 (1994); The results here are consistent with other results if one wrongly takes $\hbar c = 1$, in units of GeV-fm; Gerhard Baur (private communication).
- [3] M. Vidovic, M. Greiner, and G. Soff, *J. Phys. G* **21**, 545 (1995).
- [4] A. J. Schramm and D. H. Reeves, *Phys. Rev. D* **53**, 4092 (1996).
- [5] J. Nystrand *et al.*, [arXiv:nucl-ex/9811007](https://arxiv.org/abs/nucl-ex/9811007).
- [6] S. Sadkovsky, Report No. ALICE/93-07, 1993.
- [7] A. J. Schramm and D. H. Reeves, *Phys. Rev. D* **55**, 7312 (1997).
- [8] V. P. Goncalves, *Nucl. Phys.* **A902**, 32 (2013).
- [9] C. A. Bertulani, S. R. Klein, and J. Nystrand, *Annu. Rev. Nucl. Part. Sci.* **55**, 271 (2005).
- [10] S. R. Klein, J. Nystrand, J. Seger, Y. Gorbunov, and J. Butterworth, *Comput. Phys. Commun.* **212**, 258 (2017).
- [11] S. Klein and J. Nystrand, *Phys. Rev. C* **60**, 014903 (1999).
- [12] S. R. Klein and J. Nystrand, *Phys. Rev. Lett.* **92**, 142003 (2004).
- [13] J. Adam (ALICE Collaboration), Proc. Sci., DIS2016 (2016) 187.
- [14] LHCb Collaboration, Report No. LHCb-CONF-2016-007, <http://inspirehep.net/record/1482815?ln=en>.
- [15] C. Patrignani *et al.* (Particle Data Group), *Chin. Phys. C* **40**, 100001 (2016).
- [16] A. J. Baltz, Y. Gorbunov, S. R. Klein, and J. Nystrand, *Phys. Rev. C* **80**, 044902 (2009).