Report of Referee A – CR10456D/Kumar

The present manuscript analyzes charmonium production in hadronic collisions within the framework of Non-Relativistic QCD (NRQCD). The authors use a leading-order (LO) NRQCD analysis throughout the paper. I fail to see how such an analysis brings anything new at this point, since the current state of the art is to use next-to-leading-order (NLO) full NRQCD analyses. The NLO NRQCD computation has already been performed by three different groups, and all of them have extensively analyzed the available data (including LHC data) and performed several phenomenological studies. In fact, there has been much discussion lately about finally being able to prove, or disprove, the validity of the NRQCD factorization formalism. All these discussions consider NLO analyses and the LHC data. I do not see any reason why a LO analysis, such as the present one, brings any new significant piece of information. In summary, I do not think this manuscript contains any piece of new and significant information that could justify its publication.

Ans: We thanks the referee for his comments. Our response is as follows:

An LO NRQCD analyis is useful as it is straightforward and once the parameters are obtained by fitting over large datasets it has excellent predictability power for unknown cross sections. They provide a reference for comparison with NLO calculations which vary since the NLO techniques are not unique. Most of the NLO analysis do not include the feed down contribution from the higher charmonia states because the short distance cross-sections for excited charmonia states are not very well known at NLO. We compare here the work of two groups [1, 2] who calculate the J/ψ cross-section at NLO. Ref [1] fit all three color-octet ($[^3S_1]_8$, $[^1S_0]_8$ and $[^3P_0]_8$) LDMEs independently while Ref [2] define two quantities $\mathrm{M}_{1,r_1}^{J/\psi}$ and $\mathrm{M}_{0,r_0}^{J/\psi}$ as a linear combination of $[^3S_1]_8$, $[^1S_0]_8$ and $[^3P_0]_8$.

$$M_{0,r_0}^{J/\psi} = [^1S_0]_8 + \frac{r_0}{m_c^2}[^3P_0]_8$$

and

$$M_{1,r_0}^{J/\psi} = [^3S_1]_8 + \frac{r_1}{m_c^2}[^3P_0]_8$$

It uses values of r_0=3.9 and r_1=-0.56. We compare the values of Ref [1] and Ref [2] here.

It can be clearly seen from the Table V that LDMEs does not match with each other. Our work includes most uptodate datasets for the fitting of LDMEs. We believe that an updated

TABLE I. Comparison of J/ψ LDMEs at NLO

	$[^3S_1]_1$(GeV^3)	$M^{J/\psi}_{1,r_1}$(10^{-2}GeV^3)	$M^{J/\psi}_{0,r_0}$(10^{-2}GeV^3)
[2]	1.16	0.05$\pm$0.02$\pm$0.02	7.4 $\pm$ 1.9 $\pm$ 0.4
[1]	1.32	0.594	2.47

QCD LO study on the charmonium hadroproduction is necessary for the convenience of researchers who have not been equipped with the tools to do QCD NLO computation.

Report of Referee B – CR10456D/Kumar

This manuscript calculated the hadroproduction cross sections of the J/ψ , ψ(2s) and χ_c mesons at QCD LO. These calculations have been performed 20 years ago in e.g. [3–6] and also in a recent paper [7]. Neither the inclusion of the LHC data in the fitting nor the prediction of $\sigma(\psi(2s))/(J/\psi)$ is new. Actually, they have been studied at QCD NLO level [8, 9]. Nevertheless, I believe that an updated QCD LO study on the charmonium hadroproduction is necessary for the convenience of some researchers who have not been equipped with the tools to do QCD NLO computation. But just these materials do not justify the publication in Physical Review D. I suggest that the authors could publish their paper in some lower-level journal. However, if they can make some major extensions, I can also recommend publication of their paper in Physical Review D. In addition, I provide some comments regarding more specific issues of this paper as follows.

Ans: We thank the referee for his thorough and useful comments. We sincerly attempt to address all his comments.

1. The authors should provide the complete definitions of the variables used in their manuscript, for example, the definition of M, σ, p_T , m_T , and m_H. The symbol $\times$ in Eq.(1) is confusing. According to my calculation, it should be simply times.
   Ans: We have defined all the variables in the equation (1) and replace the $\times$ symbol.

2. The statement below Eq.(1), ... depends ... on the renormalization scale μ_R is wrong. The PDF depends on μ_F , however, does not depend on μ_R.
   Ans: We agree with the refree and modify the equation accordingly.

3. The authors used $M_L(QQ(n) \to H)$ to denote the LDMEs. Although optional, I believe that using the generally used notations would improve the readability of their paper.

   Ans: There is no fixed notation for LDMEs. Different autors use different notations according to their tastes. We will prefer our notations but if refree feels very strongly about it We will change them.

4. The relations between the LDMEs for ${}^3S_1^{[8]}$ and ${}^3P_J^{[8]}$ to J/ψ and $\psi(2s)$ in Eq.(10) and Eq.(11) are strange. Actually, there is neither theoretical nor phenomenological evidence for these relations. More confusingly, even their own results in Eq.(14) and Eq.(15) do not support their relations.

   Ans: We are now fitting the linear combination of the LDMEs according to your suggestion 7.

5. Another optional suggestion is that the authors could include the RHIC data, which is also suitable for perturbative calculations.

   Ans: The RHIC data are very low p_T and hence are not included in the fit.

6. I dont know why the authors ignored the copius χ_c data at the Tevatron and the LHC, namely [11–14]. The authors should at least address this, and compare there results with [15]. They should also notice that [16] only measured four points, namly the ratio $\sigma(\chi_c)/(J/\psi)$. The differential cross section for χ_c production was obtained by extrapolation.

   Ans: This dataset is used in the present work and the results are compared in table IV.

7. The presentation of the LDMEs, $M_L({}^1S_0^{[8]}...) = M_L({}^3P_0^{[8]}...)/m^2_{charm}$ in Eq.(14) and Eq.(15) seems strange to me. This equation has no foundation. So, I suggest they present their results following the form in Ref. [4] or Ref. [3]. Actually, they can use the η_c hadroproduction data to fix these LDMEs, as Ref. [17] did. It would be interesting to see whether this approach also applies at QCD LO.

   Ans: We are following the method described in ref. [3, 4] and presenting the results accordingly.

8. The authors should compare their results with Ref. [3, 6, 7]. Once the authors can address all the issues raised above and make major extensions, I can recommend publication of this paper in Physical Review D.

   Ans: We give a table for LDMES with results from LO, Ref. [3, 6, 7] and NLO from our paper Ref [1, 2]. The LDMEs for $\psi(2S)$ are given in table II and the LDMEs for J/ψ(2S) are given in table III. The LDMEs for χ_{c0} are given in table IV.

TABLE II. Comparison of ψ(2S) LDMEs

	$[^3S_1]_1$(GeV^3)	$[^3S_1]_8$(GeV^3)	$[^1S_0]_8$(GeV^3)	$\frac{[^1S_0]_8}{3}+\frac{[^3P_0]_8}{m_c^2}$(GeV^3)
Present	0.76	0.00362±0.00006	−−	0.02280±0.00028
[3]	−−	0.0046±0.0010	−−	0.0059±0.0019
[4](CTEQ4L)	−−	0.0044±0.0008	−−	0.0180±0.0056
[6](MRST98LO)	0.65	0.0042±0.0010	−−	0.0130±0.050
[6](CTEQ5L)	0.67	0.0037±0.0090	−−	0.0078±0.0036
[7]	0.76	0.0033±0.00021	0.0080±0.00067	−−

TABLE III. Comparison of J/ψ LDMEs

	$[^3S_1]_1$(GeV^3)	$[^3S_1]_8$(GeV^3)	$[^1S_0]_8$(GeV^3)	$\frac{[^1S_0]_8}{3}+\frac{[^3P_0]_8}{m_c^2}$(GeV^3)	$[^3P_0]_8$(GeV^5)
Present	1.2	0.00206±0.00014	−−	0.06384±0.00106	−−
[3]	−−	0.0066±0.0021	−−	0.0220±0.050	−−
[4](CTEQ4L)	−−	0.0106±0.0014	−−	0.0438±0.0115	−−
[6](MRST98LO)	1.3	0.0044±0.0007	−−	0.087±0.0090	−−
[6](CTEQ5L)	1.4	0.0039±0.0007	−−	0.067±0.0070	−−
[7]	1.2	0.0013±0.0013	0.018±0.0087	−−	$m_c^2.[^1S_0]_8$
[1]	1.32	0.00312±0.00093	0.0450±0.0072	−−	-0.0121±0.0035

Ref [2] define two quantities $M_{1,r_1}^{J/\psi}$ and $M_{0,r_0}^{J/\psi}$ as a linear combination of combination of $[^3S_1]_8$, $[^1S_0]_8$ and $[^3P_0]_8$ color octet LDMEs.

$$M_{0,r_0}^{J/\psi} = [^1S_0]_8 + \frac{r_0}{m_c^2}[^3P_0]_8$$

TABLE IV. Comparison of χ_{c0} LDMEs

	$[^3P_0]_1(\mathrm{GeV}^3)$	$[^3S_1]_8(\mathrm{GeV}^3)$
Present	$0.054\mathrm{m}_{c^2}$	0.01112±0.00068
[3]	$--$	0.0098±0.0013
[6](MRST98LO)	0.089±0.013(GeV^5)	0.0023±0.0003
[6](CTEQ5L)	0.091±0.013(GeV^5)	0.0019±0.0002
[7]	$0.054\mathrm{m}_{c^2}$	0.00187±0.00025
[15](LO)	$--$	0.00031±0.00009
[15](NLO)	$--$	0.0021±0.00004

and

$$M_{1,r_0}^{J/\psi} = [^3S_1]_8 + \frac{r_1}{m_c^2}[^3P_0]_8$$

It uses values of r_0=3.9 and r_1=-0.56. We compare the values of Ref [1] and Ref [2] here.

TABLE V. Comparison of J/ψ LDMEs

	$[^3S_1]_1(\mathrm{GeV}^3)$	$M_{1,r_1}^{J/\psi}(10^{-2}\mathrm{GeV}^3)$	$M_{0,r_0}^{J/\psi}(10^{-2}\mathrm{GeV}^3)$
[2]	1.16	0.05±0.02±0.02	7.4 ± 1.9 ± 0.4
[1]	1.32	0.594	2.47

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