Impact of SPD J/ψ A_{LL} measurements

I. I. Denisenko[1], A. V. Karpishkov[1,2], M. A. Nefedov[3] and V. A. Saleev[1,2]

[1] Joint Institute for Nuclear Research
[2] Samara National Research University
[3] Universite Paris-Saclay, IJCLab

27.04.2023
SPD collaboration meeting

Outline

- NRQCD model
- Previous results for the A_{LL}: a short reminder
- A_{LL}: new results
- Summary

A sketch of NRQCD formalism

The NRQCD framework [G. T. Bodwin, E. Braaten, and G. P. Lepage, Phys. Rev. D **51**, 1125 (1995)] describes heavy quarkonia in terms of Fock state decompositions. In case of orthoquarkonium state the wave function can be written as power series expansion in the velocity parameter $v \sim 1/\ln M_Q$:

$$|\mathcal{H}\rangle = \mathcal{O}(v^0)|Q\bar{Q}[^3S_1^{(1)}]\rangle + \mathcal{O}(v)|Q\bar{Q}[^3P_J^{(8)}]g\rangle + \mathcal{O}(v^2)|Q\bar{Q}[^1S_0^{(8)}]g\rangle \quad (1)$$

$$+\mathcal{O}(v^2)|Q\bar{Q}[^3S_1^{(1,8)}]gg\rangle + \dots \quad (2)$$

In the NRQCD effects of short and long distances are separated, and then the cross-section of heavy-quarkonium production via a partonic subprocess $a + b \to \mathcal{H} + X$ can be presented in a factorized form:

$$d\hat{\sigma}(a + b \to \mathcal{H} + X) = \sum_n d\hat{\sigma}(a + b \to Q\bar{Q}[n] + X) \times \langle \mathcal{O}^{\mathcal{H}}[n] \rangle, \quad (3)$$

where n denotes the set of quantum numbers of the $Q\bar{Q}$ pair, and its nonperturbative transitions into $\mathcal{H}$ is described by the NMEs $\langle \mathcal{O}^{\mathcal{H}}[n] \rangle$.
In the general case, the partonic cross-section of quarkonium production from the $Q\bar{Q}$ Fock state $n = {}^{2S+1}L_J^{(1,8)}$ has the form:

$$d\hat{\sigma}(a + b \to Q\bar{Q}[^{2S+1}L_J^{(1,8)}] \to \mathcal{H}) = d\hat{\sigma}(a + b \to Q\bar{Q}[^{2S+1}L_J^{(1,8)}]) \times \frac{\langle \mathcal{O}^{\mathcal{H}}[^{2S+1}L_J^{(1,8)}] \rangle}{N_{col} N_{pol}},$$

where $N_{col} = 2N_c$ for color-singlet state, $N_{col} = N_c^2 - 1$ for color-octet state, and $N_{pol} = 2J + 1$.

Double-spin asymmetry

The double longitudinal-spin asymmetry is defined as

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{\Delta\sigma}{\sigma},$$

LO Collinear Parton Model + LO NRQCD-factorization:

$$\Delta\sigma = \sum_{n} \left\langle \mathcal{O}^X[n] \right\rangle \sum_{i,j} \Delta f_i \otimes \Delta f_j \otimes \Delta\hat{\sigma}_{ij}[n],$$

$$\sigma = \sum_{n} \left\langle \mathcal{O}^X[n] \right\rangle \sum_{i,j} f_i \otimes f_j \otimes \hat{\sigma}_{ij}[n].$$

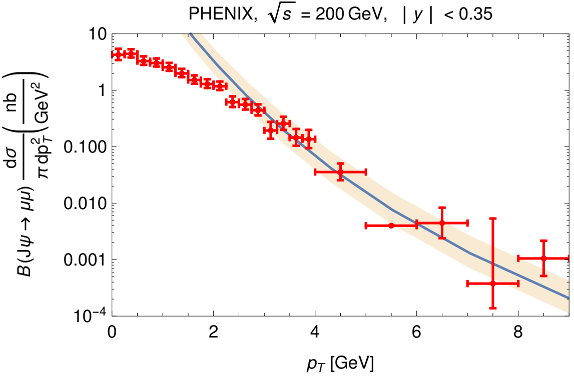
Un-polarized partonic cross-sections $\hat{\sigma}_{ij}[n]$ are well-known at LO (e.g. [P.L. Cho, A.K. Leibovich (1996)] and [R. Gastmans, W. Troost and T. T. Wu, Phys. Lett. B **184**, 257-260 (1987)]).
Details on LO calculations of $\Delta\hat{\sigma}_{ij}[n]$ can be found in [Klasen, Kniehl, Steinhauser, Phys.Rev.D **68** (2003) 034017, hep-ph/0306080]

A short reminder (Maxim's results)

LO LDMEs from [Braaten, Kniehl, Lee, Phys.Rev.D**62** (2000) 094005] together with `NNPDF30_nlo_as_0119_nf_6` PDF set and `NNPDFpol11_100` polarized PDF set. Within NRQCD LO fits determine only linear combination of octet LDMEs:

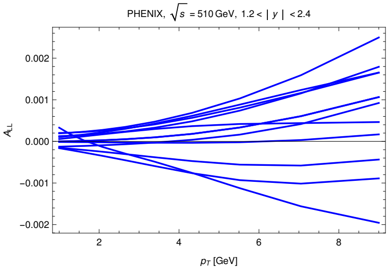
$$\mathcal{M}_8 = \left\langle \mathcal{O}^{J/\psi}\left[{}^1S_0^{(8)}\right]\right\rangle + \frac{r}{m_c^2}\left\langle \mathcal{O}^{J/\psi}\left[{}^3P_0^{(8)}\right]\right\rangle,\ r = 3.5,\ m_c = 1.5$$

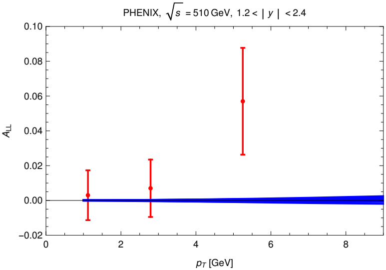
The J/ψ p_T-spectrum from RHIC (direct and feed-down contributions):



A short reminder (Maxim's results)

Results for different replicas of Δg vs. PHENIX data:





A short reminder: LO asymmetry at $\sqrt{s} = 24$ GeV (Maxim's results)

Maxim's results of A_{LL} for ten replicas of Δg:

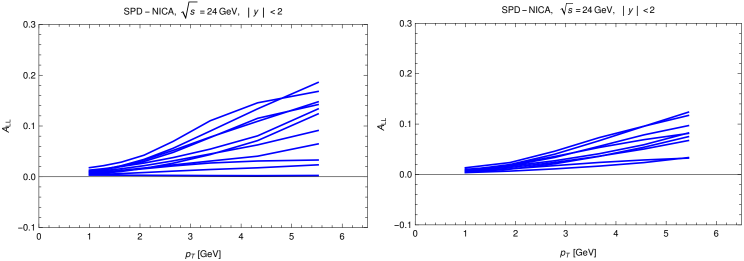
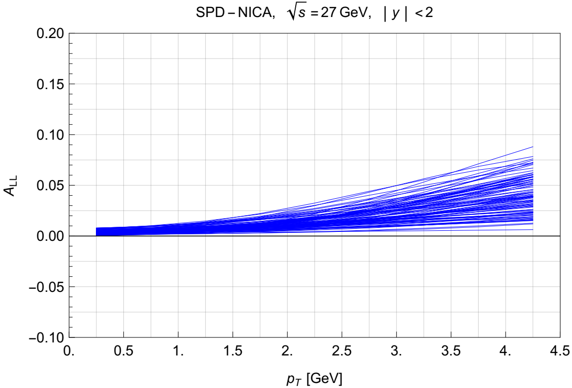


Figure 1: An impact of the qg-contributions on the A_{LL} for prompt J/ψ production at $\sqrt{s} = 24$ GeV, $|y| \leq 2$. Left panel: the A_{LL} with only gg contributions. Right panel: $gg + qg$ contributions.

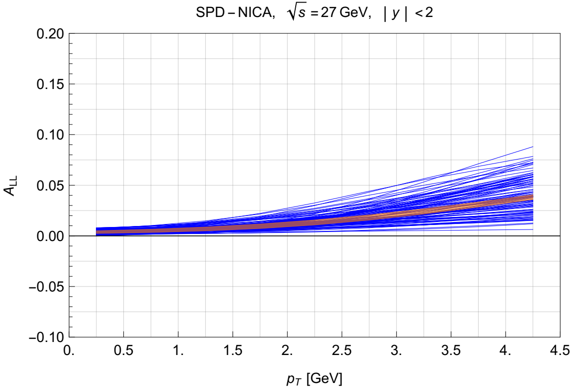
New calculations at $\sqrt{s} = 27$ GeV

A_{LL} for a hundred replicas of Δg:



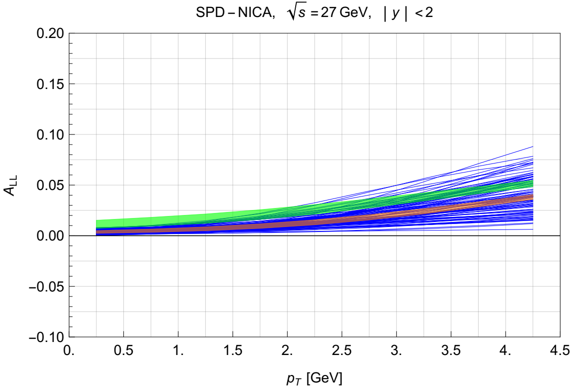
LO asymmetry at $\sqrt{s} = 27$ GeV

A_{LL} for a hundred replicas of Δg, band – scale variaton for the average on replicas:



LO asymmetry at $\sqrt{s} = 27$ GeV

A_{LL} for a hundred replicas of Δg, bands – scale and LDME-variation :



Summary

- New calculations at $\sqrt{s} = 27$ GeV are in agreement with the previous ones.
- We see, that inclusion of qg-processes makes range of the double longitudinal-spin asymmetry narrower.

Thank you for your attention!