Erratum and addendum to 'A Search for the LHCb Charmed "Pentaquark" using Photoproduction of J/Ψ at Threshold in Hall C at Jefferson Lab'

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(A new experiment proposal to JLab-PAC44)

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Abstract

We identified an issue in the Monte-Carlo generator used for the experimental projects, that resulted in the P_c cross sections being *under*estimated by a factor of $1/2W \approx 1/9$. Correcting this error leads to a projected number of P_c events that is approximately 9 times *higher* than what was previously shown. The t-channel cross sections and projections are not affected by this factor.

Furthermore, we quantified the statistical precision with which we can identify the P_c resonances. We found that, for the most likely ($P_c(4450)$ 5/2+, $P_c(4380)$ 3/2-), a 5σ confidence level is achieved starting from a coupling of 1.3% to the $J/\Psi p$ channel.

Contents

1 Erratum: Fixing the P_c cross section in the Monte-Carlo generator

The Monte-Carlo generator uses the following relation for the cross section to simulate the resonant $\gamma p \to P_c \to J/\Psi p$ process,

$$\frac{d\sigma}{ds d\cos\theta_{J/\Psi}} = \frac{dn^\gamma}{ds} \frac{d\sigma^{\gamma p \to P_c \to J/\Psi p}}{d\cos\theta_{J/\Psi}}, \tag{1}$$

using the bremsstrahlung spectrum $\frac{dn^\gamma}{ds}$ for a 10% RL radiator from Tsai [1], and the P_c resonant production cross section $\frac{d\sigma^{\gamma p \to P_c \to J/\Psi p}}{d\cos\theta_{J/\Psi}}$ from Wang [2].

Unfortunately, a leftover $\frac{dW}{ds} = \frac{1}{2W}$ jacobian factor from a previous study was incorrectly multiplied with $\frac{d\sigma^{\gamma p \to P_c \to J/\Psi p}}{d\cos\theta_{J/\Psi}}$. This erroneous factor incorrectly lowers the total P_c cross section by approximately a factor of 9 (for the $P_c(4450)$, the average $W = 4.450\,\text{GeV}$).

After correcting this error, we updated the figures from the proposal. The updated figures are shown in Figs. 1, 2, 3, 4, with a reference to the corresponding figure in the original proposal given in the caption.

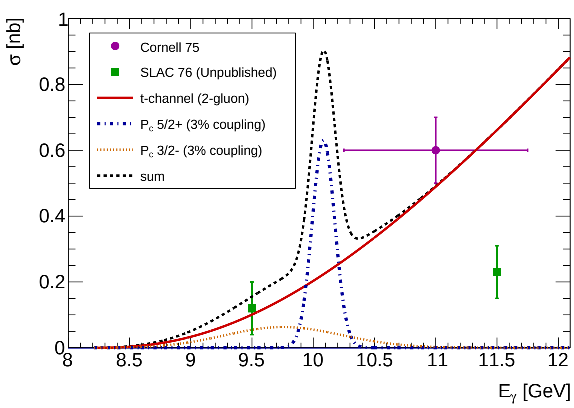

Figure 1: **This figure supersedes Fig. 11 of the proposal proposal.** J/Ψ production cross section as a function of the photon energy. The P_c resonant production is shown for the (5/2+, 3/2-) case assuming 3% coupling, compared with the available measurements in this region [3, 4].

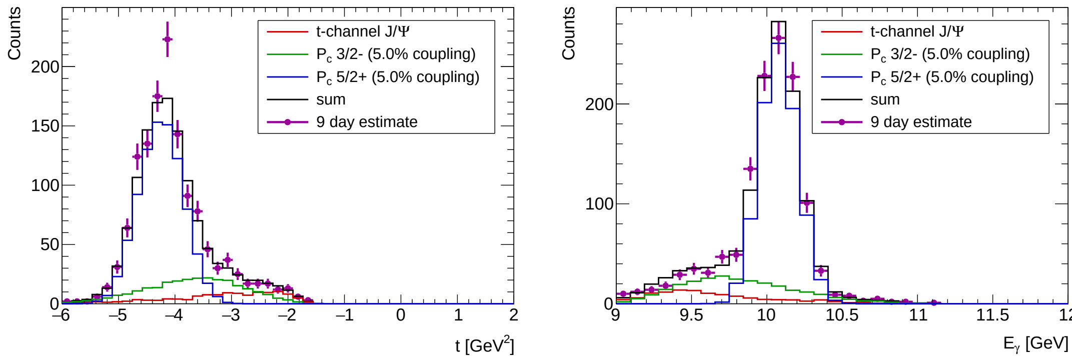

Figure 2: **This figure supersedes Fig. 13 of the original proposal.** Expected results for the reconstructed t and E_γ spectrum for 9 days of beam on target, assuming the most probable (5/2+, 3/2-) P_c from [2] with 5% coupling. There is clear separation in both spectra between the P_c (5/2+) resonant channel, and the t-channel.

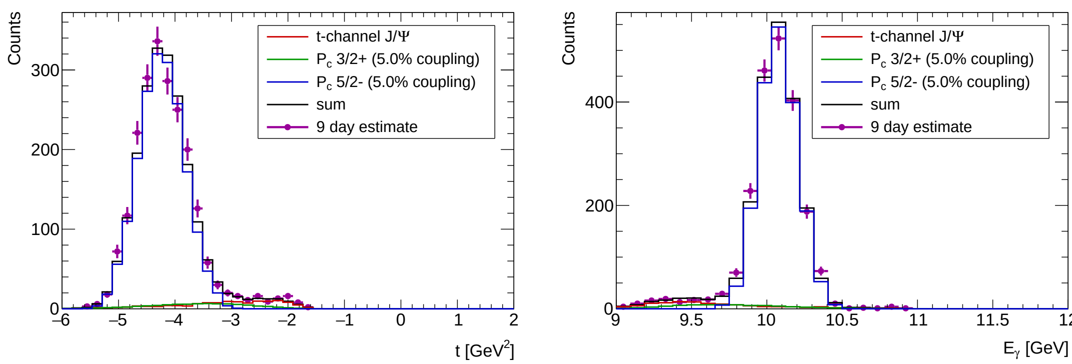

Figure 3: **This figure supersedes Fig. 14 of the original proposal.** Expected results for the reconstructed t and E_γ spectrum for 9 days of beam on target, assuming the less probable (5/2-, 3/2+) P_c from [2] with 5% coupling. Due to the larger cross section for the 5/2-, the separation in both spectra is even better than for the 5/2+ assumption shown in Fig. 2.

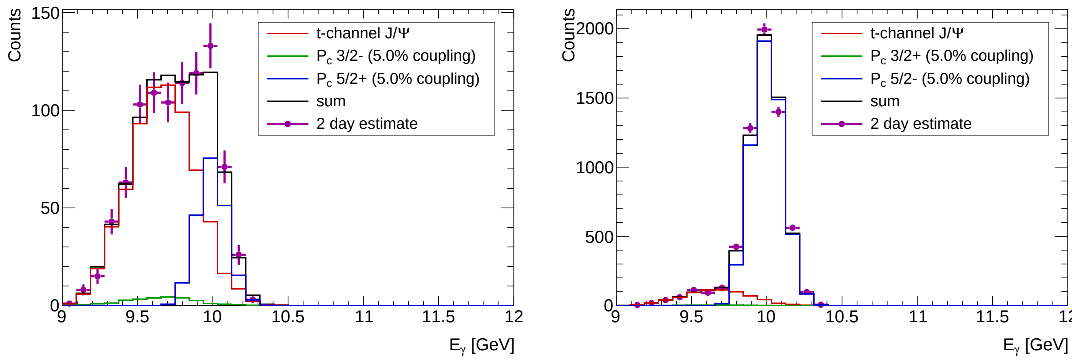

Figure 4: **This figure supersedes Fig. 15 of the original proposal.** Expected results for the reconstructed E_γ spectrum for the calibration measurement with 2 days of beam on target. The left panel shows the (5/2+, 3/2-) case , and the right panel shows the (5/2-, 3/2+) case, both with 5% coupling.

2 Addendum: Sensitivity to the P_c resonant production

To obtain an estimate of the sensitivity to the P_c resonant process as a function of the coupling to the $J/\Psi p$ channel, we calculated the log-likelihood difference $\Delta \log \mathcal{L}$ between the hypothesis that the simulated spectra can be described by just a t-channel process, and the hypothesis that the P_c resonances are present on top of the t-channel production. We assumed 9 days of beam at $50\,\mu A$ for setting #1. We then used Wilk's theorem [5] to relate the value of $2\Delta \log \mathcal{L}$ to a value of χ^2 with 5 degrees of freedom (one for the coupling, and 4 for the mass and width of each of the P_c). Note that a binned likelihood approach was used, which yields a conservative estimate compared to the results of a full unbinned extended maximum likelihood procedure.

The results of this sensitivity study can be found in Fig. 5. We found that, for values of the coupling of 1.3% and higher, we have a sensitivity of more than the 5σ necessary for discovery. Fig. 5 also shows the projected results in case of a 1.3% coupling.

In the proposal, we assumed a realistic coupling of 5% from Wang [2], which they found to be compatible with the currently existing J/Ψ photo-production data. A more recent statistical analysis by Blin [6] found an upper limit of the coupling values to be between $8 - 17\%$ at the 95% confidence level for the $P_c(4450)$ (5/2+). Furthermore, Karliner [7] argues that the coupling cannot be too small, as the $P_c(4450) \to J/\Psi p$ signal is 4.1% of the $J/\Psi p$ final state in $\Lambda_b \to K^- J/\Psi p$. If the coupling would be too small, the value of $\Lambda_b \to K^- P_c$ with the P_c decaying to final states other than $J/\Psi p$, becomes unreasonably large in comparison with the measured branching fraction of $\Lambda_b \to K^- J/\Psi p$. This means that, due to the sensitivity of the proposed experiment down to very low values of the coupling, we will have the ability to provide a very strong exclusion of the charmed-pentaquark assumption in case it is not found.

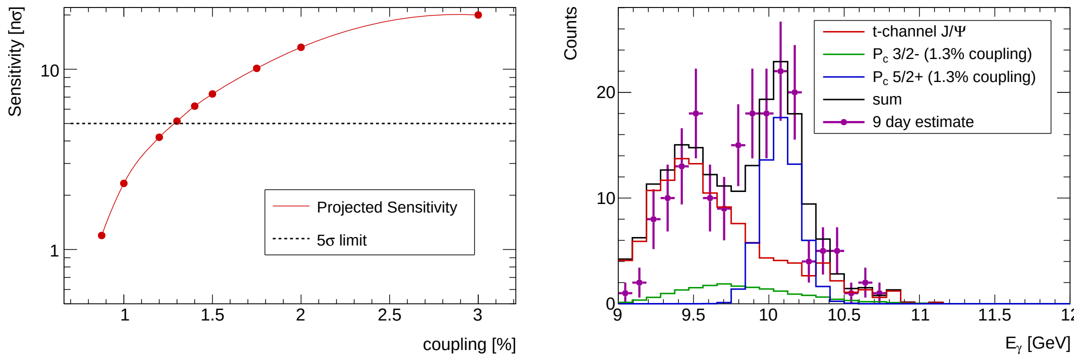

Figure 5: The left figure shows the sensitivity to the P_c as a function of the coupling to the $J/\Psi p$ channel, obtained from a log-likelihood analysis. The dashed line shows the 5σ level of sensitivity necessary for discovery. This level is reached starting from a coupling of 1.3%. The right panel shows the expected results for the reconstructed E_γ spectrum for this 1.3% coupling for the $P_c(4450)$ $(5/2+)$.

References

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