Erratum: Light in the beam dump. Axion-Like Particle production from decay photons in proton beam-dumps

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Abstract: We correct a number of figures in [1], in which the PYTHIA MC result of secondary π^0 mesons was displayed wrongly due to a missing factor of 2. Scrutinizing the corrected data-MC comparsion, we review and model the trigger condition used in the LEBC-EHS experiment, and present an improved data-MC comparison. We review the sensitivity estimates for ALP searches in past and present experiments based on MC distributions scaled to data and find that the main conclusions of the paper remain unchanged.
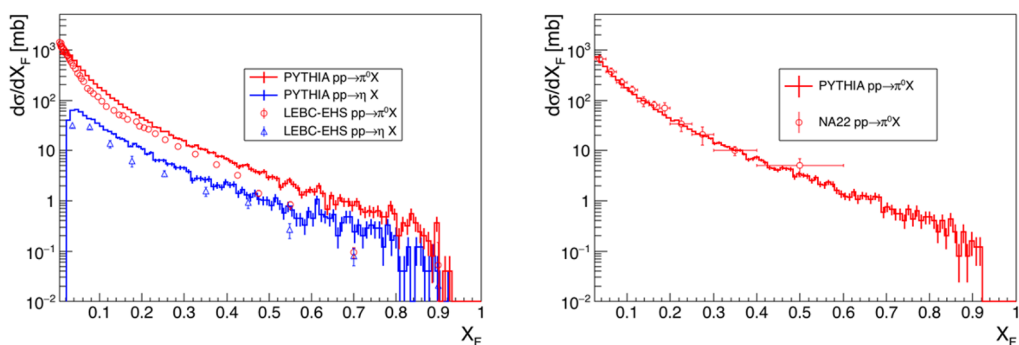
Figure 1. Data-MC comparison of the differential cross-section of neutral pions and eta mesons produced from 400 GeV (250 GeV) protons, to replace figure 3 (the right panel of figure 6) in JHEP 05 (2019) 213.
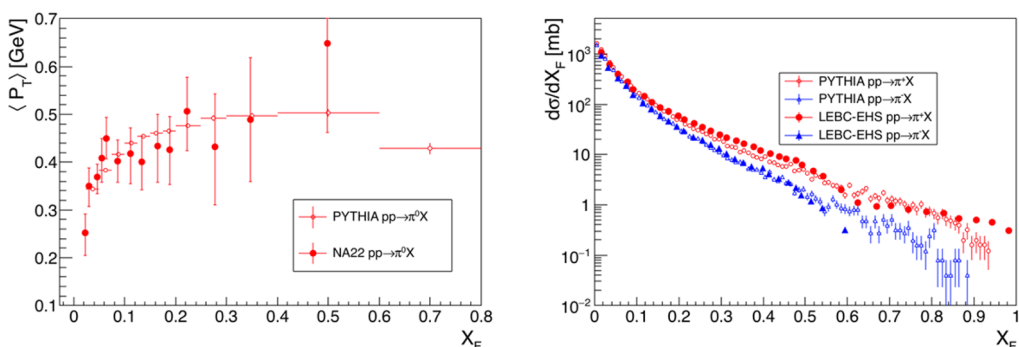

Figure 2. Left: data-MC comparison for the average transverse momentum as a function of the Feynan X_F for a beam momentum of 250 GeV, to replace figure 7 in JHEP 05 (2019) 213. Right: data-MC comparison of the differential cross-section of charged pions produced from 400 GeV protons.

In [1], the differential cross section for inclusive π^0 production in proton-proton interactions is shown as a function the Feynman variable $X_F = P_Z/P_Z(\max) \sim 2P_Z^*/\sqrt{s}$. The evaluation of X_F after PYTHIA MC simulation was lacking a factor 2, affecting the display of the results for 250 and 400 GeV beam energy, in the right panel of figure 6 and in figure 3 of [1], respectively. After correcting for this mistake, the new distributions are shown in figure 1. Contrary to the distribution shown in [1] the MC now populates X_F up to large values and a segmentation of the variable at high X_F to quantify the data-vs-MC agreement as done in table 1 of [1] seems inappropriate. The agreement with the data is better for 250 GeV protons from the NA22 experiment [2] than for 400 GeV protons from the LEBC-EHS experiment [3]. The correlation between average transverse momentum and X_F in the left panel of figure 2 shows a good agreement between data and MC at 250 GeV, too.
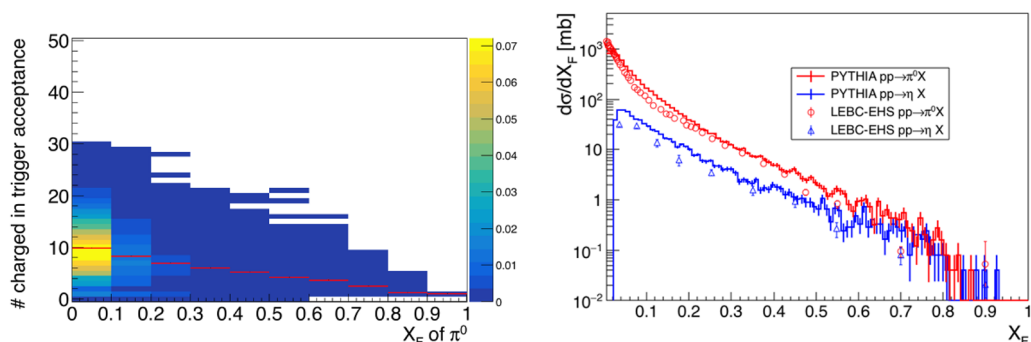
Figure 3. Left: number of charged particles in the acceptance of the trigger chambers in the LEBC-EHS experiment as a function of the Feynman X_F of a co-emitted π^0 meson, as evaluated using a PYTHIA simulation: the red line indicates the average values for each X_F bin. Right: data-MC comparison of the differential cross-section of neutral pions and η mesons produced from 400 GeV protons, after accounting for the trigger efficiency in the LEBC-EHS setup.

At 400 GeV beam energy, the PYTHIA predicted yield is higher than the data especially at large X_F. To further scrutinize this issue, we first present the same comparison for charged pions at 400 GeV beam energy: as shown in the right panel of figure 2, the data-MC comparison is significantly better than for π^0 mesons.

A careful review of [3] shows that a comprehensive data-MC comparison for neutral particles demands modelling and accounting for the trigger condition in the Monte Carlo output. In the LEBC-EHS data, the trigger requirement was to have 3 or more hits from charged particles in dedicated forward tracking stations right downstream of the hydrogen bubble-chamber target. As stated in [3], the trigger efficiency is as low as 2% when only two charged particles are emitted in acceptance and trigger inefficiencies may alter significantly the differential cross section at large X_F. We modelled this effect while analyzing the PYTHIA output[1] and found that the number of charged particles emitted in the acceptance of the trigger chambers strongly depends on the X_F of a co-emitted π^0, as shown in the left panel of figure 3. After correcting for the trigger efficiency, the differential cross section significantly changes, as shown in the right-hand side of figure 3. The data-MC ratio within large-X_F bins of sufficient statistics saturates at ~ 0.8, and one can safely use the entire X_F range for sensitivity studies. The data-MC ratio for charged pions and η mesons as a function of X_F is higher than 0.8 for any value of X_F.

Checking the results of figure 10 in [1] for a number of benchmark points we verify that the sensitivity of proposed and past searches does not change very visibly in the double-log presentation such that the conclusions of [1] remain largely unchanged.

Acknowledgments

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[1]The expected distribution of the interaction point has been considered as well.

References

[1] B. Döbrich, J. Jaeckel and T. Spadaro, *Light in the beam dump. Axion-Like Particle production from decay photons in proton beam-dumps*, *JHEP* **05** (2019) 213 [`arXiv:1904.02091`] [INSPIRE].

[2] NA22 collaboration, *Inclusive π^0 Production in $\pi^+ p$, $K^+ p$ and pp Interactions at 250-GeV/c*, *Z. Phys. C* **35** (1987) 7 [INSPIRE].

[3] M. Aguilar-Benitez et al., *Inclusive particle production in 400-GeV/c p p interactions*, *Z. Phys. C* **50** (1991) 405 [INSPIRE].