Ξ^- and Ω Distributions in Hadron-Nucleus Interactions

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Leading particle effects, flavor correlations between the final-state hadron and the projectile valence quarks, have long been observed in strange particle production. With new data from the WA89 collaboration on Ξ^- production by π^-, n, and Σ^- projectiles on nuclear targets, in addition to Ξ^- production data from Ξ^- beams, doubly strange hadron production can be studied as a function of the number of strange projectile valence quarks. We compare our model calculations to both the x_F distributions and the integrated A dependence reported by WA89 as well as Ξ^- and Ω production by the Ξ^- beam [1].

We employ the intrinsic model as developed for strangeness production in Ref. [2]. In the intrinsic model, a hadron can fluctuate into Fock state configurations with a combination of light and strange quark pairs. The heavier quarks in the configuration are comoving with the other partons in the Fock state and thus can coalesce with these comoving partons to produce strange hadrons at large x_F. The model combines leading-twist production of $s\overline{s}$ pairs with intrinsic Fock states with up to nine particles.

We calculate leading-twist strangeness in perturbative QCD, assuming the strange quark is massive. When the projectile has nonzero strangeness, we also consider the possibility of flavor excitation. We choose proton parton distribution functions with the lowest possible initial scale μ_0^2 so that $m_s^2 > \mu_0^2$. The baryon parton distribution functions are based on the GRV 94 LO proton densities. We also use the recent GRS pion parton densities. We assume that the scale μ at which α_s and the parton densities are evaluated is $\mu = 2m_T$ where $m_T = \sqrt{p_T^2 + m_s^2}$ and $m_s = 500$ MeV.

Hyperon parton distributions can be inferred from the proton distributions [3] by simple counting rules. We can relate the valence s distribution of the Σ^-, $f_{s_v}^{\Sigma^-}$, to the proton valence d distribution, $f_{d_v}^p$, and the valence d distribution in the Σ^-, $f_{d_v}^{\Sigma^-}$, to the valence u in the proton, $f_{u_v}^p$, so that

$$\int_0^1 dx\, f_{s_v}^{\Sigma^-}(x,\mu^2) \;=\; \int_0^1 dx\, f_{d_v}^p(x,\mu^2) = 1\,, \tag{1}$$

$$\int_0^1 dx\, f_{d_v}^{\Sigma^-}(x,\mu^2) \;=\; \int_0^1 dx\, f_{u_v}^p(x,\mu^2) = 2\,. \tag{2}$$

We also identify the up quark in the sea of the Σ^- with the strange sea of the proton, $f_u^{\Sigma^-}(x,\mu^2) = f_s^p(x,\mu^2)$. Similar relations hold for the antiquark distributions. Likewise, for the Ξ^-, we relate the valence s, $f_{s_v}^{\Xi^-}$, to the valence u in the proton, $f_{u_v}^p$, and equate the valence d distributions so that,

$$\int_0^1 dx\, f_{s_v}^{\Xi^-}(x,\mu^2) \;=\; \int_0^1 dx\, f_{u_v}^p(x,\mu^2) = 2\,, \tag{3}$$

$$\int_0^1 dx\, f_{d_v}^{\Xi^-}(x,\mu^2) \;=\; \int_0^1 dx\, f_{d_v}^p(x,\mu^2) = 1\,. \tag{4}$$

Here also, $f_u^{\Xi^-}(x,\mu^2) = f_s^p(x,\mu^2)$. The gluon distributions are assumed to be identical for all baryons, $f_g^p = f_g^{\Sigma^-} = f_g^{\Xi^-}$.

The hadron wavefunction is a superposition of Fock state fluctuations in which the hadron contains one or more "intrinsic" $Q\overline{Q}$ pairs. These pairs can hadronize when the hadron interacts, breaking the coherence of the state. The model gives heavy quarks a larger fraction of the projectile momentum due to their greater mass. The intrinsic strangeness probability is not small, $P_{\rm is}^5 \sim 2\%$. We assume that the intrinsic probabilities are independent of the valence quark content of the projectile. Then $P_{\rm is}^5$ is identical for nucleons and hyperons. The Fock state probabilities for up to $3Q\overline{Q}$ pairs where at least one $Q\overline{Q}$ pair is strange are given in Ref. [2].

Once the coherence of the Fock state is broken, the partons in the state can hadronize in two ways. The first, uncorrelated fragmentation of the strange quark, is the same basic mechanism as at leading twist. The second occurs when the Fock state fluctuation includes all the valence quarks of the final-state hadron which then coalesce into that hadron. Thus, to calculate the full strange and antistrange hadron x_F distributions in the intrinsic model, we include uncorrelated fragmentation of the strange quark in every state considered and coalescence from those states where it is possible. In Ref. [2], a comparison to strange baryon asymmetries suggested that fragmentation may not be an effective mechanism because when the Fock state has minimal invariant mass, fragmentation may cost too much energy so that the final state hadrons must be produced by coalescence alone.

We compared our intrinsic calculations to Ξ^- production by π^-, n and Σ^- projectiles and to Ξ^- and Ω production by Ξ^- projectiles. We find good agreement with the WA89 data for leading-twist fusion and coalescence. Flavor excitation seems excluded as a significant mechanism of low p_T strange hadron production. The difficulties with uncorrelated fragmentation [2] are confirmed. Coalescence is then the most effective mechanism for strange hadron production in the intrinsic model.

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