

THE RATIO Σ^0/Λ AT RHIC

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Abstract. While yields of Σ^0 have been measured in many different colliding systems, no measurements exist in high energy nuclear collisions [1]. It also remains unexplored whether the relative yields of Σ^0 and Λ change in collisions of heavy ions where a dense medium may permit alternate production mechanisms, such as quark coalescence [2]. The STAR detector at RHIC is able to reconstruct the electromagnetic Σ^0 decay into Λ plus γ via the weak decay of the Λ and γ conversions into e^+e^- pairs in the detector material. We report here on our measurement of the ratio Σ^0/Λ in minimum bias 200 GeV d+Au collisions. We also compare the measured ratio to expectations from various models.

Key words: RHIC, relativistic heavy ion, quark coalescence, Σ^0/Λ ratio.

1. THE Σ^0 IN NUCLEAR COLLISIONS

Physics experiments at colliders have mapped production of strange hadron species over a variety of systems and energies. Such measurements have commonly included production of the Λ but, due to the complexities of its observation, rarely the Σ^0 . These two hyperons share the same quark content, differing only in isospin and mass, separated by a mere $77 \text{ MeV}/c^2$ [3]. Reconstructing the Σ^0 requires reconstructing the Λ , so comparing the ratio of yields of the two species¹ provides a simple test of whether conditions are different for these two similarly-composed hyperons. Are they produced similarly? Are their final state interactions the same? Without measurements, these traits may only be assumed.

Above threshold energies for production of Σ^0 , the experimental data for the value of the ratio Σ^0/Λ cluster around $1/3$, matching the ratio of isospin degeneracy

* For the full author list and acknowledgements, see Appendix “Collaborations” in this volume.

¹ The yield used here for Λ will be exclusive of its feed-down from Σ^0 decays, but contributions from resonance decays into both species will be included.

factors ($1/g_i$) of the Σ and Λ ground states ($g_\Sigma = 3$, $g_\Lambda = 1$), as will be shown later in this paper. However there are absences in measurements for hadronic collisions at moderate to high energies, and for collisions of sizable nuclei. High energy nuclear collisions are of particular interest for the possibility of opening new channels of production via partonic degrees of freedom [2, 4, 5].

2. MODEL EXPECTATIONS

Models often start with the production of all particles, followed by the rapid decay of resonance states. Both the Λ and Σ^0 receive contributions from decays of strange resonances, but those feeding the Λ are much more numerous. Knowledge of these contributions is pertinent to understanding the full picture, and efforts to measure these are underway [6].

The predictions for Σ^0/Λ from a variety of particle production models are as follows: the event generator HIJING/B \bar{B} [7] gives 0.37 for $\sqrt{s_{NN}} = 200$ GeV d+Au collisions; the THERMUS [8] statistical thermal model gives 0.36 at $T = 160$ MeV, $\gamma_S = 1.0$; the ‘‘sudden hadronization’’ [9] thermal model gives ~ 0.33 at $T = 160$ MeV; and the ALCOR [10] quark coalescence model gives 0.20. Both thermal models feature little sensitivity to input parameters, as seen in Fig. 1 and elsewhere [9], with nearly no dependence upon chemical potentials.

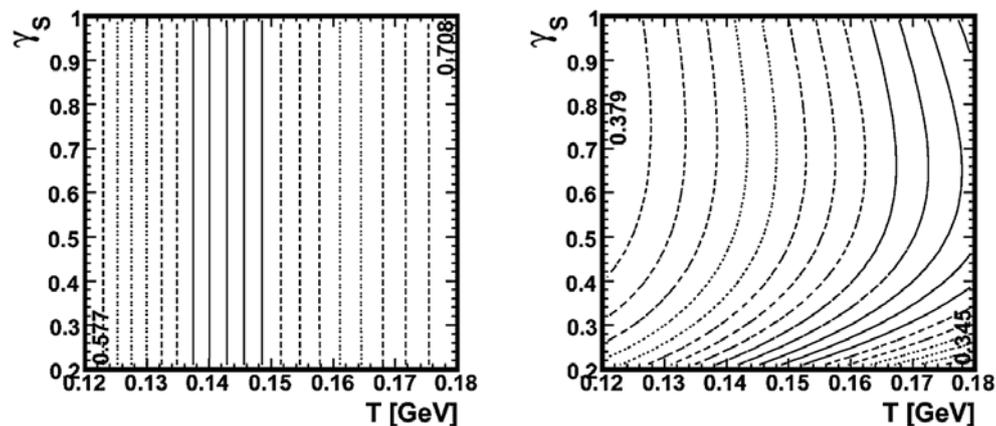


Fig. 1 – Σ^0/Λ contours for the primordial (left) and final (right) ratios as a function of γ_S and T in THERMUS. Minima and maxima of the plots are indicated.

Though there is some spread in the predicted values, it should be noted that the *primordial ratio* (taken from direct production before resonance contri-

butions) is much higher. So the final value of Σ^0/Λ may reflect even more upon resonance yields than the direct production of Λ and Σ^0 . For example, quark coalescence treats the Λ and Σ^0 equally: the entirety of their difference then results from the copious resonances [11]. Thermal models place a penalty on production of more massive states, so they begin with a primordial value below that of quark coalescence, but have less resonance contributions to drop the final ratio.

3. RECONSTRUCTION IN THE STAR DETECTOR

The STAR Detector is capable of reconstructing the decay $\Lambda \rightarrow p\pi^-$ with excellent signal-to-noise [12]. Reconstruction of photon conversions ($\gamma \rightarrow e^+e^-$) in detector material can be accomplished similarly [13], the validity of which is underscored by the ability to visualize the structure of detector material from identified conversion points as seen in Fig. 2 (left). Focusing on low transverse momentum (p_T) photons then provides sufficient resolution to identify Σ^0 through invariant mass of $\Lambda\gamma$ pairs when combinatoric backgrounds are adequately low, shown in Fig. 2 (right). To extract a yield, the shape of the background under the invariant mass peak is obtained by rotating candidate Λ and γ daughters from same events to avoid mixing event classes. Preliminary signals for Σ^0 have been observed via this technique in $\sqrt{s} = 200$ GeV p+p collisions, as well as $\sqrt{s_{NN}} = 62$ and 200 GeV Cu+Cu collisions at RHIC, but we concentrate here on minimum bias 200 GeV d+Au collisions.

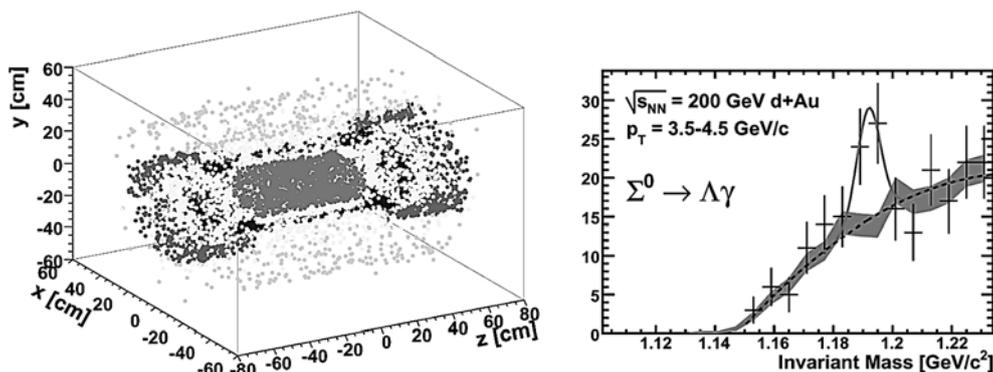


Fig. 2 – Reconstruction of γ conversion locations reveals inner structure of the STAR Detector (left, coordinates are in cm about the center of the detector, shadings represent locations of specific components). Σ^0 signal can be seen via invariant mass of $\Lambda\gamma$ pairs (right, signal is black crosses, shading is rotated background, lines are polynomial fit to background plus Gaussian signal).

4. CORRECTIONS

By using the same Λ candidates in both numerator and denominator of Σ^0/Λ , efficiencies for finding the Λ cancel out and we are left with three main corrections. The first is weak decay feed-downs from doubly or triply strange hadrons, which is essentially an issue for Λ only. Based on preliminary analyses of Λ , Ξ^- , and Ω^- in minimum bias 200 GeV d+Au data in STAR, approximately 20% of the Λ candidates at all p_T come from such feed-down [14].

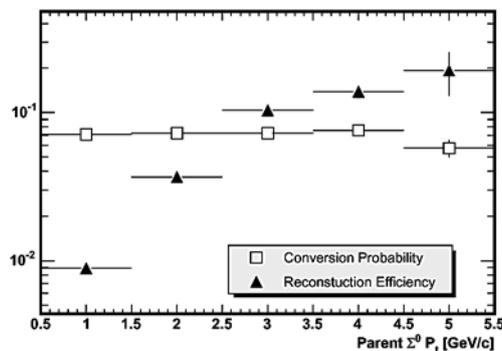


Fig. 3 – Correction factors for detecting Σ^0 photon daughters as a function of their parent $\Sigma^0 p_T$.

The second and third correction factors are the conversion probability of photons in detector material and the reconstruction efficiency of those conversions. These are obtained via embedding simulated Σ^0 decays into real data. The conversion probability is difficult to determine accurately as it involves simulating every possible conversion volume properly, but there seems to be rather little dependence on the p_T of the parent Σ^0 . In contrast, the reconstruction efficiency drops rapidly with decreasing parent p_T , due mostly to reduced acceptance for low p_T electrons (which are found only for conversions in the gas volume of the STAR TPC).

To improve statistics, we exploit the expectation that $\bar{\Sigma}^0/\Sigma^0 \approx \bar{\Lambda}/\Lambda$ and sum baryon+antibaryon counts under the assumption $\Sigma^0/\Lambda \approx (\Sigma^0 + \bar{\Sigma}^0)/(\Lambda + \bar{\Lambda})$. As the number of reconstructed counts are still small and bounded by zero yield, the errors are large and asymmetric. Determination of the measured ratio thus involves a Monte Carlo allowing values to vary appropriately within their combined statistical and systematic errors, and we report the most probable value with errors determined by the RMS of outcomes above and below it.

5. PRELIMINARY RESULTS AND CONCLUSIONS

We reconstruct sufficient numbers of Σ^0 to determine Σ^0/Λ with significance in two p_T bins from minimum bias 200 GeV d+Au ($|rapidity| < 1$). We find preliminary $\Sigma^0/\Lambda = 0.16^{+0.57}_{-0.08}$ for $\Sigma^0 p_T = 2.5\text{--}3.5$ GeV/c, and $0.17^{+0.78}_{-0.10}$ for $\Sigma^0 p_T = 3.5\text{--}4.5$ GeV/c. Combining the two bins leads to $\Sigma^0/\Lambda = 0.16^{+0.41}_{-0.09}$ and this is shown along with past experiment results in Fig. 4. We also find $\bar{\Sigma}^0/\Sigma^0 = 0.6 \pm 0.3$, which does not discount the summation of baryons+antibaryons for our ratio. The large error bars on Σ^0/Λ prevent definitive model differentiation, but the low value suggests that strong resonance contributions are prevalent even in d+Au collisions.

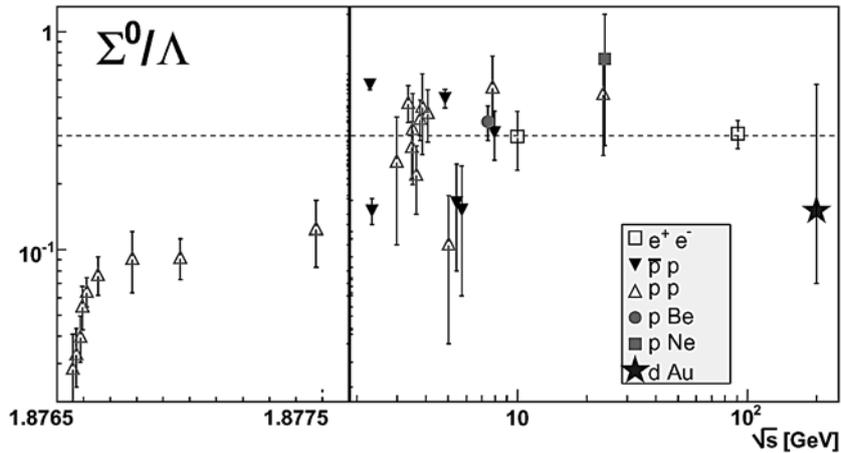


Fig. 4 – Σ^0/Λ results versus collision \sqrt{s} ($\sqrt{s_{NN}}$ for p/d+A) [1]. Meson-nucleon reaction results are excluded for clarity, but exist only at intermediate energies and lie in the same range. The dashed line is the ratio of isospin degeneracy factors (1/3).

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