We present measurements of the transverse momentum spectra for $K_0^S$, $\Lambda$, $\Xi^-$ and their antiparticles in p+p collisions at $\sqrt{s} = 200$ GeV. The extracted mid-rapidity yields and $\langle p_T \rangle$ are in agreement with previous p+$\bar{p}$ experiments while they have smaller statistical errors. We compare the measured particle spectra and $\langle p_T \rangle$ values to predictions from the PYTHIA leading order pQCD model (v6.221) and see significant disagreements with the default settings. Finally we compare the spectra to the latest calculations from NLO pQCD and see a good agreement for the $K_0^S$, but large discrepancies $\Lambda$.

1 Introduction

We report results from the 2002 $p + p$ running with the STAR experiment at RHIC. We present the high statistics measurement of $K_0^S$, $\Lambda$ and $\Xi$ particles and obtain the yield and $\langle p_T \rangle$ for each species. We compare our measurement to the PYTHIA model incorporating leading-order (LO) pQCD processes and note large discrepancies between our data and the model in it’s default setting. Attempts to tune the LO K-Factor and the intrinsic parton momentum distribution $k_T$ produce better agreements. We also compare to next-to-leading order (NLO) calculations which exhibit a better agreement with our $K_0^S$ data, but still fail to describe the $\Lambda$. Furthermore, we study the dependency of $\langle p_T \rangle$ as a function of charged particle event multiplicity ($N_{ch}$) for different particle species. It has been shown that the high transverse momentum final state particle is mostly governed by hard partonic processes and subsequent string fragmentation. We observe a strong dependence of this part of the spectra with respect to event multiplicity.
2 Analysis Description

The present data were reconstructed using the STAR experiment which is described in more detail elsewhere. The main detector used in this analysis is the Time Projection Chamber (TPC) covering the full acceptance in azimuth together with a large pseudo-rapidity coverage ($|\eta| < 1.5$). A total of 14 million non-singly diffractive (NSD) events were triggered with the STAR beam-beam counters (BBC) requiring two coincident charged tracks at forward rapidity. Due to the particularly low track multiplicity environment in p+p collisions only 76% of primary vertices are found correctly; from the remainder, 14% are lost and 10% are incorrectly reconstructed as demonstrated by a MC-study. Of all triggered events, 11 million events passed the selection criteria requiring a valid primary vertex within 100cm along the beam-line from the center of the TPC detector. The strange particles were identified from their weak decay to charged daughter particles. The following decay channels and the corresponding anti-particles were analyzed: $K^0_S \rightarrow \pi^+ + \pi^-$ (b.r. 68.6%), $\Lambda \rightarrow p + \pi^-$ (b.r. 63.9%), $\Xi^- \rightarrow \Lambda + \pi^-$ (b.r. 99.9%). Particle identification of daughters was achieved by requiring the dE/dx to fall within the $3\sigma$-bands of theoretical Bethe-Bloch parameterizations. Further background in the invariant mass was removed by applying topological cuts to the decay geometry. Corrections for acceptance and particle reconstruction efficiency were obtained by a Monte-Carlo based method of embedding simulated particle decays into real events and comparing the number of simulated and reconstructed particles in each $p_T$-bin.

3 Results for mid-rapidity yield and $\langle p_T \rangle$

| Particle | $dN/dy$ | $|y| < 0.5$ | $\langle p_T \rangle$ [GeV/c] |
|----------|--------|------------|-----------------|
| $K^0_S$  | 0.128 ± 0.002(stat) ± 0.010(syst) | 0.60 ± 0.01(stat) ± 0.02(syst) |
| $\Lambda + \bar{\Lambda}$ | 0.070 ± 0.002(stat) ± 0.006(syst) | 0.76 ± 0.02(stat) ± 0.04(syst) |
| $\Xi + \bar{\Xi}$ | 0.0036 ± 0.0002(stat) ± 0.0010(syst) | 0.96 ± 0.05(stat) ± 0.09(syst) |

Table 1: Results of mid-rapidity yields and $\langle p_T \rangle$ for $K^0_S$, $\Lambda$ (feed-down corrected) and $\Xi$ measured in $p + p$ collisions at $\sqrt{s} = 200$ GeV

In table 1 results for yield and $\langle p_T \rangle$ of corrected inclusive spectra are shown for $K^0_S$, $\Lambda$, $\Xi$ and their respective antiparticles. The particle acceptance at mid-rapidity ($|y| \leq 0.5$) in the TPC starts at a transverse momentum of 0.2 GeV/c for $K^0_S$, 0.3 GeV/c for the $\Lambda$ and 0.5 GeV/c for the $\Xi$. In order to extract the $\langle p_T \rangle$ and yield at mid-rapidity, a parametrization to the spectra has to be applied to extrapolate the measurement to cover the full $p_T$-range. In contrast to previous $p + \bar{p}$ experiments, which used either a single exponential function in transverse mass or power-law functions, we found that a combination of these functions is more effective in fitting the singly-strange particles. Composite fits, using an exponential function in $m_T$ at low $p_T$ and power-law functions at high $p_T$ yielded the lowest $\chi^2$ and were used to extract the values for yield and $\langle p_T \rangle$ of $K^0_S$ and $\Lambda$. For the $\Xi$ spectrum the limited coverage at low $p_T$ makes it insensitive to the different functions and thus only an exponential function in $m_T$ was used. The values as shown in table 1 are in agreement with the measurements by UA5 when scaled using a rapidity distribution obtained from simulation.

The systematical errors are mainly due to the different fit parameterizations as well as the normalization uncertainty due to ‘pile-up’. The $\Lambda/\Lambda$ ratio is 0.92±0.09 and $\Xi/\Xi$ ratio is 0.90±0.09 and both are independent of $p_T$. The data sample was split into event classes with increasing mean charged particle multiplicity per unit $\eta$. For $K^0_S$ and $\Lambda$ six event classes with sufficient statistics were possible. The goal is to study the large momentum transfer region of
the parton-parton collisions by measuring the spectra in high multiplicity events, where this type of interaction is expected to be more probable.

4 Comparison to PYTHIA 6.221 (LO pQCD)

In figure 1 the $p_T$-spectra are compared to predictions from PYTHIA LO model. The default settings of version 6.221 clearly underestimate the data. However by introducing a LO K-Factor in agreement with studies by Eskola et al. the simulation describes the data much better. Figure 2 presents the $\langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$ for $K_0^0$ and $\Lambda$. A rise in $\langle p_T \rangle$ with increasing $N_{ch}$ is observed and the increase is stronger for the $\Lambda$ than for the $K_0^0$. Several authors have attributed this phenomenon to the increased number of large momentum transfer parton-parton collisions that produce mini-jets in the high multiplicity events. In order to reproduce the strength of the correlation between $\langle p_T \rangle$ and $N_{ch}$ the intrinsic $k_T$ value was tuned to 4 GeV, although considered very high, from a default value of 1 GeV.

5 Comparison to NLO pQCD calculations

It has been shown previously that the charged particle and neutral pion spectra at RHIC are well described by NLO pQCD calculations. Therefore it is interesting to test the NLO calculations for the strange particles as shown in figure 3. These calculations use KKP fragmentation functions for $K_0^0$ and fragmentation functions by Vogelsang et al. for $\Lambda$. The disagreement...
Figure 3: $K_0^0$ (left) and $\Lambda$ (right) $p_T$-spectra compared to NLO calculations using fragmentation functions by KKP for $K_0^0$ and Jager et al. for $\Lambda$. Errors shown are statistical only.

between the calculations and the data are small for $K_0^0$ but considerably larger for the $\Lambda$. This may be due to the higher mass of the $\Lambda$, where the massless quark formalism breaks down and the $(m/p_T)$-scale approximations become non-negligible. Bourrely and Soffer have calculated alternative fragmentation functions for octet baryons which need to be tested\textsuperscript{13}.

6 Summary

The STAR experiment has made the first high statistics measurement of mid-rapidity $K_0^0$, $\Lambda$ and $\Lambda$, $\Xi$ and $\Xi$ in $p+p$ collisions at $\sqrt{s} = 200$ GeV. The results agree with those made by the UA5 collaboration for $p+\bar{p}$ collisions at the same energy. The ratio of $\bar{\Lambda}/\Lambda$ and $\bar{\Xi}/\Xi$ suggests a small net baryon number at mid-rapidity. Furthermore, we show that PYTHIA 6.221 needs to be tuned significantly to describe the strange particle spectra in STAR. Also, NLO calculations agree reasonably well with $K_0^0$ data above 1.5 GeV/c but fail to reproduce the shape of the $\Lambda$ spectra. Finally, we have undertaken studies to understand the change in $\langle p_T \rangle$ of different strange particle species with increasing event multiplicity in an attempt to understand the flavor dependance of fragmenting mini-jets in high multiplicity event samples.

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