STAR NOTE 233: Measurements of Strangeness Production in the STAR Experiment at RHIC (Presented at the Workshop on Physics with the Collider Detectors at RHIC and LHC, Quark Matter 95)

W.K. Wilson[a] for the STAR Collaboration

[a]Physics Department, Wayne State University,
Detroit, MI USA 48201

Simulations of the ability of the STAR (Solenoidal Tracker at RHIC) detector to measure strangeness production in central Au+Au collisions at RHIC are presented. Emphasis is placed on the reconstruction of short lived particles using a high resolution inner tracker. The prospects for performing neutral kaon interferometry are discussed. Simulation results for measurements of strange and multi-strange baryons are presented.

1. Strangeness at RHIC

Strangeness production may help to distinguish between quark-gluon plasma (QGP) scenarios and simple hot hadron gas (HG) scenarios at RHIC.[1] Since the temperatures reached will be higher than the strange quark mass, strangeness will be copiously produced in both scenarios. However, the high cross section for strangeness production due to gluon fusion in a QGP causes the strangeness sector to reach its maximum value very rapidly, perhaps a few fm/c. This is an order of magnitude faster than in a HG phase, so the strangeness production is more likely to reach its chemical equilibrium limiting value in the QGP than in the HG scenario. Production of particles with two or more strange quarks should be particularly sensitive to the high strangeness density expected in a QGP. Strange particle yield ratios have already proven to be a use tools for measuring the degree of strangeness saturation and other thermodynamic properties of systems formed in heavy-ion collisions.[2]

One caveat should be mentioned, however. Even if a QGP is formed, the system must finally evolve through a hadron gas phase. A clear picture of the impact of hadronization on proposed strangeness QGP signals has not yet emerged in the modeling of these collisions. However, it is expected that the background from multi-strange baryons formed in the final HG phase should be small since their formation requires a chain of several collisions. In any case, it is certain that whatever impact hadronization has upon the strangeness content of the system, it will be necessary to measure strangeness production in order to obtain a clear picture of the hadronic sector in these collisions. Our simulations establish that the addition of the SVT (Silicon Vertex Tracker) inner tracker will provide STAR with measurements of particles with single and multi-strange quark content.

2. Simulations of STAR Performance

The baseline STAR detector[3] system will consist of a cylindrical TPC (Time Projection Chamber) within a 0.5 T magnetic field parallel to the beam axis. The TPC will have acceptance for charged particles with pseudo-rapidity $|\eta| \leq 2$. The strange mesons which are of interest to the STAR experiment include the charged kaons, the neutral kaon, and the ϕ meson. The strange baryons of interest are the Λ, the Ξ, and the Ω. The charged kaons are directly identifiable by their dE/dx in the SVT and the TPC up to transverse momenta of 600-700 MeV/c. The proposed addition of time-of-flight (TOF) elements to the STAR detector[4] would extend the kinematical region in which charged kaons can be identified up to transverse momenta of more than 1 GeV/c. The ϕ meson can be reconstructed from its decay charged kaons. Since this decay occurs essentially in the interaction region, all possible kaon pairs must be considered. Fortunately, the mass and width of the ϕ are such that it easily stands above the combinatoric background[5], even with the TPC momentum resolution taken into account. The proposed TOF system also extends the transverse momentum acceptance of STAR for the ϕ. The remainder of this report will be concerned with the reconstruction of strange particles whose lifetimes give them path lengths on the order of centimeters.

The high multiplicity of particles produced in these collisions places severe demands on the performance of the tracking system if secondary decays are to be distinguished from combinatoric background. Using TPC information alone, the position resolution near the main vertex is insufficient for eliminating the combinatoric background. Secondary reconstruction requires an inner tracker which provides the tracks with a few high precision points near the secondary vertices. The SVT upgrade to the STAR detector, shown in fig. 1, fulfills this requirement with three layers of silicon drift detectors arranged in cylindrical barrels at radii of 6, 10, and 15 cm. The detector covers $|\eta| \leq 1.0$ with 95% active area per layer. Combining the precision vectoring capability of the SVT with the good momentum resolution of the TPC (a few percent) allows one to place tight geometrical cuts on the decay which removes most of the combinatoric background.

Simulations of the SVT capacity for reconstructing strange particles which decay centimeters away from the main vertex have been performed previously.[5]. These preliminary studies employed assumptions such as perfect tracking in the SVT and perfect matching to TPC tracks. In the past year we have developed an integrated SVT-TPC tracking package which makes no such assumptions. This development has allowed us to update the strange particle reconstruction simulations and make a much more realistic appraisal of the SVT's performance. We have found that we are able to reconstruct the unstable particles which we studied previously. As expected, the efficiencies are lower than in our previous studies, but not to such a degree that it impacts our ability to perform the physics program.

The simulations presented in the following sections consist of $\sqrt{s} = 200$ GeV central Au+Au FRITIOF events passed through a full GEANT representation of the STAR detector followed by tracking and secondary vertex reconstruction software. Tracking is performed independently in the SVT and TPC, then the SVT and TPC tracks are extrapolated to a cylinder midway between the two detectors and matched. At present, a simple prescription for combining the SVT and TPC tracking information is in use. Only

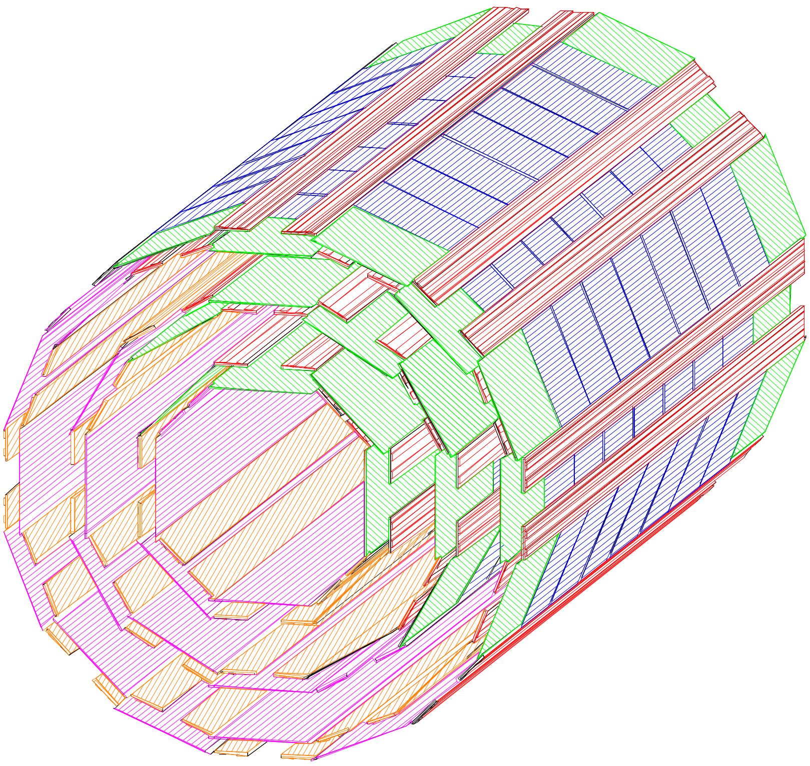

Figure 1. The three barrel structure of the SVT

the magnitude of the track's transverse momentum is taken from the TPC; all other helix parameters are better constrained by the SVT tracking. A full refit of the SVT and TPC space points taking into account the material between them will be implemented in the future.

After the tracking for an event is completed, the software searches for tracks which intersect away from the main vertex. In the case of reconstruction of the Λ, which decays into a proton and a negative pion, the code searches for tracks which come within 2 mm of each other at least 8 mm from the main vertex. The trajectory of the parent particle is then checked to see whether or not it came from the main vertex. Additional kinematical cuts were also used to reduce the combinatoric background. There is a trade off between efficiency on the one hand (open cuts) vs. purity on the other (tight cuts). Some effort has been made in the following results to maximize the efficiency even at the expense of allowing some combinatoric background to pass through the cuts.

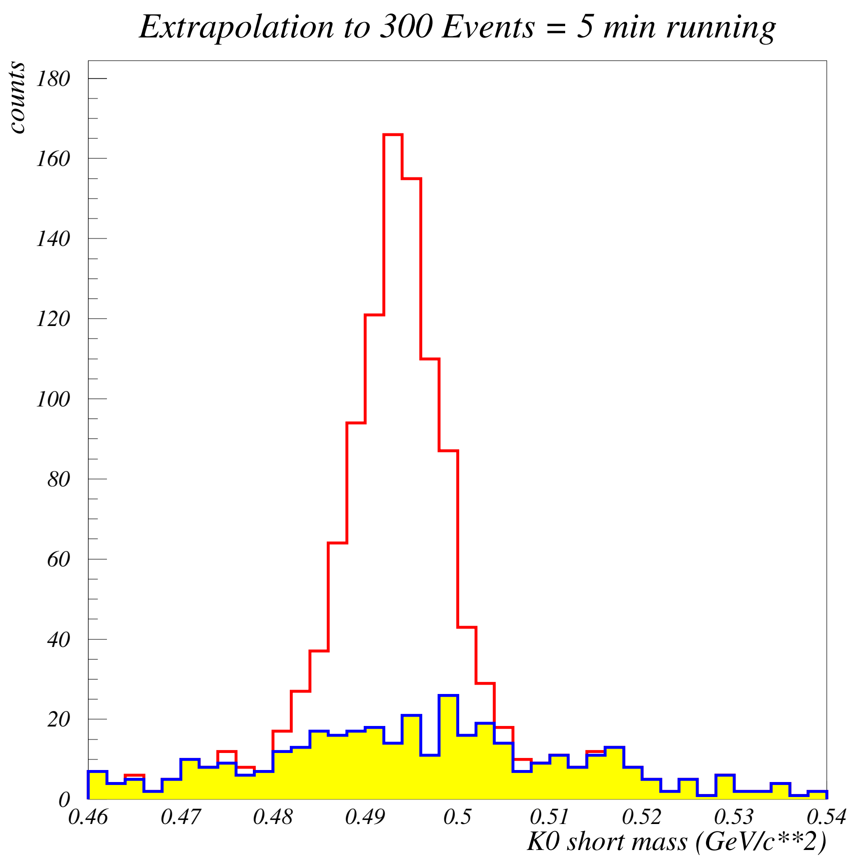

Figure 2. Reconstructed K_s° mass spectrum

3. Results

The FRITIOF event generator produces about 60 K_s° mesons per event within $|\eta| \leq 1.0$ under the collisions described above. We performed a full analysis of 20 events and found that about 2.55 are reconstructed per event. In fig. 2 we show the invariant mass spectrum we expect for 300 events. This and the following spectra were produced by analyzing K_s° events and background events separately, and combining the results according to the signal and background yields from the 20 event full analysis. The 2.55 K_s° per event yields ≈ 3 K_s° pairs per event on average, opening the possibility of K_s° interferometry. Interferometry using K_s° has two distinct advantages over charged pion and charged kaon interferometry. First, the correlation function for neutral kaons is not affected by the coulomb repulsion term which complicates the interpretation of charged particle correlation functions. Second, there is no degradation of two track resolution at low relative momentum since, even if two K_s° have identical momentum vectors,, the tracks of their daughters are usually well separated. Preliminary estimates of the number of events needed to begin to place limits on the size of a 10 fm source with K_s° interferometry are on the order of 100 thousand events which corresponds to 28 hrs. running time at an event rate of 1.0 Hz. See Ref. [6] for more details.

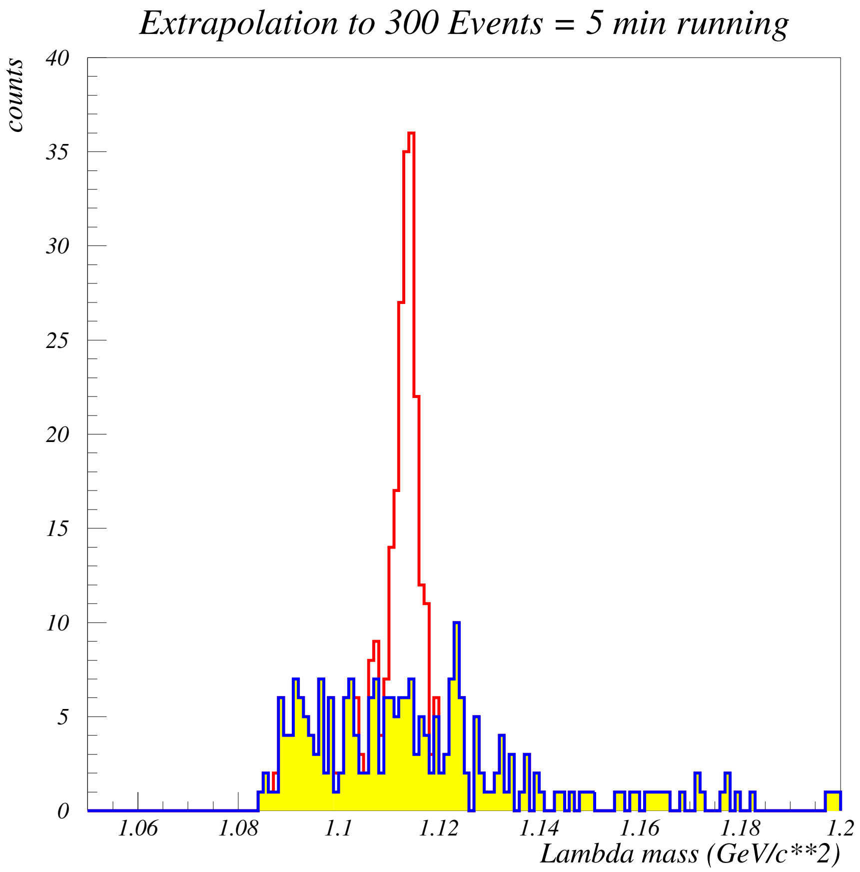

Figure 3. Reconstructed Λ mass spectrum

About 6.5 Λ particles are produced by FRITIOF in the SVT acceptance. These S=1 baryons decay into a proton and a pion. The proton may be easily identified by dE/dx measurements in either the SVT or the TPC since they are found at relatively low transverse momenta. Under the assumption of perfect PID information, we reconstruct 0.5 of the Λ particles per event. The signal/background relationship for these cuts can be seen in fig. 3 which shows the mass spectrum extrapolated to 300 events.

As mentioned in the introduction, multi-strange particles are predicted to be a sensitive probe of the strangeness density produced in the collisions.[1] The Ξ has strangeness S=2 and decays into a pion and a Λ which proceeds on to decay as described earlier. Both of these decays must occur before the first layer of the SVT to be reconstructed in the current version of our software. The top panel of fig. 4 shows our reconstructed mass spectrum extrapolated to 100 thousand events, or about 28 hours of running time. In the

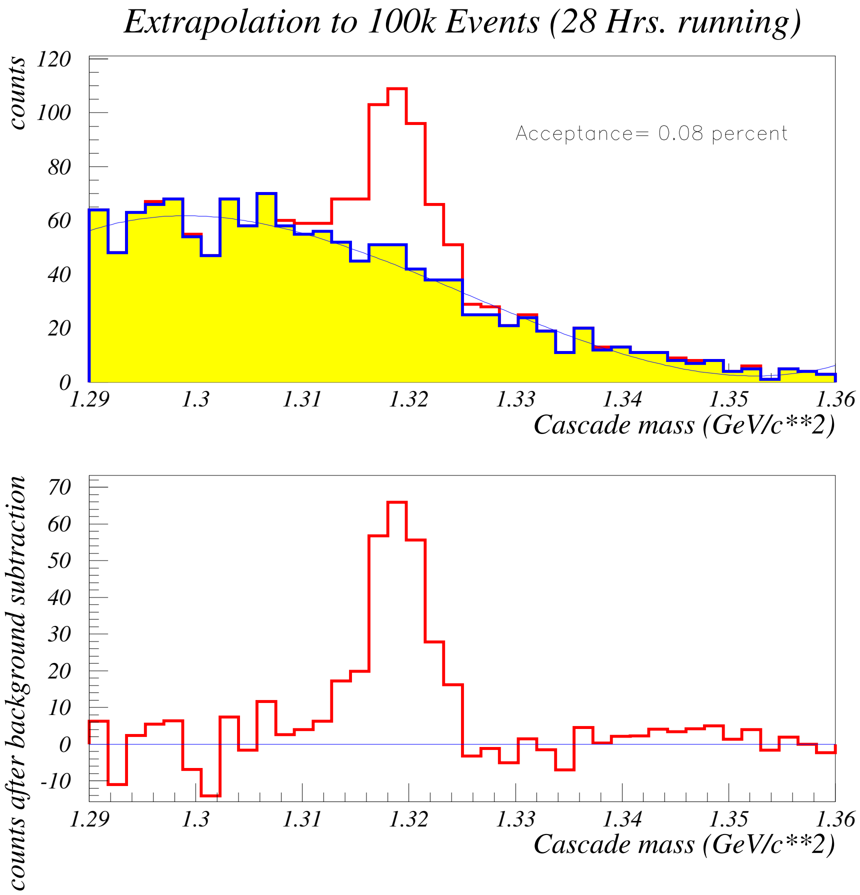

Figure 4. Reconstructed Xi mass spectrum

bottom panel the background has been parameterized by a polynomial and subtracted.

4. Conclusions

Simulations of the ability of the STAR experiment plus the SVT upgrade to reconstruct secondary vertices near the main vertex have been presented. These simulation show that the current SVT design should be able to fulfill its physics mission with regard to strange particle physics. In the future, we plan further studies of the ability to perform K_s° interferometry and to study the ability of the SVT to reconstruct the S=3 Ω meson.

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