Overview of the Status and Strangeness Capabilities of STAR

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Abstract. STAR is a large acceptance spectrometer capable of precision measurements of a wide variety of strange particles. We discuss the STAR detector, its configuration during the first two years of RHIC operation, and its initial performance for Au+Au collisions. The expected performance for strangeness physics and initial data on strange particle reconstruction in Au+Au collisions are presented.

1. The Status of the STAR Experiment

The STAR detector at RHIC [1] is a large acceptance spectrometer with a very broad physics program, including precision measurements of a wide variety of strange particles. The STAR experimental configuration during the early years of RHIC operation is shown in Figure 1. For the first year of RHIC running, the active detectors are the Time Projection Chamber (TPC), the Zero Degree Calorimeters (ZDC) [2], the Central Trigger Barrel (CTB), and the Ring Imaging Cerenkov Counter (RICH). The solenoidal magnet has a maximum field strength of 0.5 Tesla but for the first year is run at 0.25 Tesla. For operation in the second year, STAR will install the Silicon Vertex Tracker (SVT), two forward TPCs (FTPC), a time-of-flight (TOF) patch, and 26 modules of the Barrel Electromagnetic Calorimeter (EMC), comprising 22% of the full barrel EMC which will be completed by 2003. Details on the acceptance of the various detector components relevant for strange particle reconstruction are given in the following section.

RHIC began operations for physics in the summer of 2000. Together with the other RHIC experiments, STAR observed collisions immediately. The quality of track reconstruction in the TPC is high and efforts to understand and quantify the tracking efficiency are underway. The performance of the STAR TPC is illustrated in Figure 2. The left panel shows the specific ionization (truncated mean dE/dx) in the TPC for Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV, as a function of track momentum. The curves are the Bethe-Bloch parameterization of dE/dx. The bands for pions, kaons, protons, deuterons and electrons are visible. The relative dE/dx resolution is approaching the design goal of 8%. The left panel shows the momentum resolution of the TPC as a function of momentum for charged tracks from cosmic rays that have been independently reconstructed in the upper and lower halves of the TPC in a 0.5 Tesla magnetic field. The solid curve labelled "CDR" is the design goal, with the difference from measurement due in large part to known instrumental effects that have since been rectified.

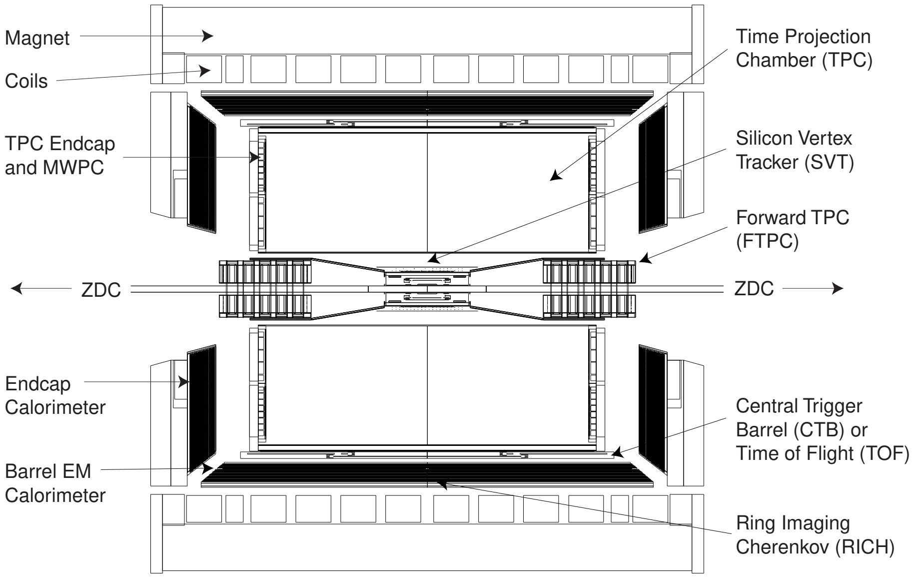

Figure 1. Side view of the STAR detector configuration in the first two years of RHIC operation.

The response of the STAR trigger detectors (ZDC and CTB) to Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV is shown in Figure 3, under the condition that both ZDC signals are above a threshold.‡ The vertical axis is the summed pulse height of all CTB slats and horizontal axis is the summed pulse height of the two ZDCs. The ZDC measures forward-going neutrons ($\theta < 2$ mrad) and its response contains contributions from both nuclear collisions and mutual Coulomb dissociation [3] (the latter process does not generate tracks at mid-rapidity and is not visible in the figure). For nuclear collisions, low ZDC response corresponds to a low number of spectator neutrons, which can occur for both very peripheral and very central collisions, whereas the CTB signal increases monotonically with increasing multiplicity at mid-rapidity. Thus, the most central nuclear collisions correspond to low ZDC and high CTB response (corresponding to high multiplicity at mid-rapidity). The trigger inefficiency for central collisions due to the coincidence condition applied to the ZDCs was measured to be much less than 1%.

The RICH is a proximity-focusing ring imaging Cerenkov counter for identifying charged hadrons at high momentum within an acceptance of 10 msr at y_{CM}=0, and was developed as a joint project with the ALICE collaboration. Rings with the expected photon yields have been observed in the RICH for Au+Au collisions.

In summary, the STAR detector for the first year of RHIC operation is performing extremely well, and we expect many physics results from this first round of data taking.

‡ The threshold is set to eliminate coincidences due to electronic noise but not those due to single neutrons at beam energy.

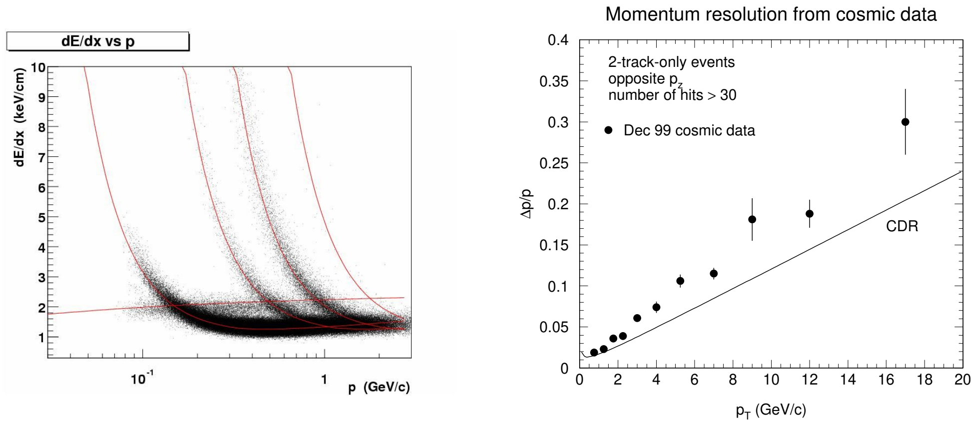

Figure 2. Preliminary data on TPC performance. Left panel: specific ionization (dE/dx) versus track momentum for Au+Au collisions. Right panel: momentum resolution in percent vs. momentum for cosmic rays reconstructed independently in the upper and lower halves of the TPC. See text for further details.

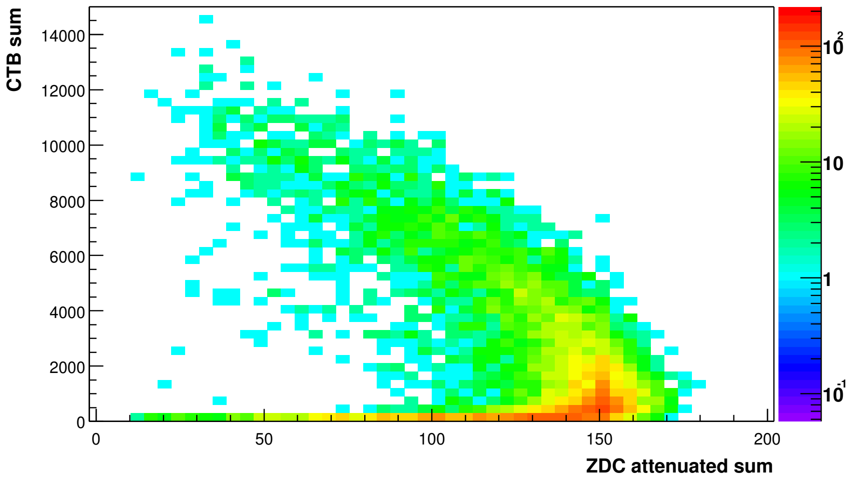

Figure 3. Preliminary data from STAR Trigger detectors, showing total pulse height in the CTB vs. summed pulse height in the two ZDCs.

2. Strange particle measurements accessible to STAR

By virtue of its large tracking acceptance and the ability to perform particle identification over a wide kinematic range, STAR is well suited to measuring a variety of strange particles. Table 1 lists the strange particles and resonances that are accessible to STAR and which have been studied in Monte-Carlo simulations. Based on the result of these simulations we discuss the expected reconstruction performance of the STAR detector for various strange particle measurements.

Particle	Decay Mode	Branching (%)	Lifetime (cm/c)
$K^{\pm}$	$\mu^{\pm}\nu_{\mu}$	64	371
K_s^0	$\pi^+\pi-$	68	2.67
Λ	$p\pi-$	64	7.89
Ξ^-	$\Lambda\pi^-$	100	4.91
Ω^-	ΛK^-	68	2.46
ϕ	K^+K^-	64	Resonance
K^{0*}	$K^{\mp}\pi^{\pm}$	67	Resonance

Table 1. List of some of the strange particles and their decay modes accessible to STAR.

2.1. Charged kaon reconstruction

About 70% of the strange quarks produced in a heavy-ion collision at RHIC are carried by the kaons. Charged kaons can be identified in STAR using a number of different techniques. The measurement of the specific ionization of tracks in the TPC (dE/dx) gives an excellent separation of kaons from protons and pions up to a momentum of around 800 MeV/c (Figure 2). Charge kaons can also be identified in the TPC via their decay (see Table 1). In principle, using this method it is possible to extend the measurement of kaons out to a transverse momentum of around 5 GeV/c.

The identification of charged kaons at mid-rapidity in the range $1.1 < p_T < 3.0$ GeV/c is performed by the RICH. In year two, the charged kaon measurement will be augmented by the addition of a time-of-flight patch, which will replace part of the central trigger barrel and provide acceptance in the range $0.3 < p_T < 1.5$ GeV/c.

2.2. Hyperon reconstruction

Hyperons can be reconstructed in the central TPC from their charged decay products. Λ and $\overline{\Lambda}$ are found by considering all pairs of oppositely charged tracks in the TPC which are compatible with having originated from a vertex separated from the primary interaction. Neutral kaon decays, K_s^0, are also reconstructed in this way. Geometrical cuts are used to eliminate the majority of the combinatorial background. The most effective cuts are on the separation of the decay from the primary vertex and on the impact parameter of the parent and daughters to the primary vertex. An important cut for Λ ($\overline{\Lambda}$) is on the specific ionization information (dE/dx), which selects tracks compatible with being protons (anti-protons).

Figure 4 shows the invariant mass and Podolanski-Armenteros plots [4] for 3000 HIJING central Au+Au events and approximately 16000 minimum bias events from the current run. In both cases, no dE/dx information has been used. The analysis of the HIJING simulations found a reconstructed yield of approximately 2 K_s^0 and 0.3 Λ ($\overline{\Lambda}$) per event. The same cuts, which were tuned to optimise the signal to noise ratio in the Monte-Carlo, were applied to the real data. A clear signal is observed. The background in the real data is larger than expected from the simulation and this has since been understood as due in part to an instrumental effect and an error in the way one of the cuts was defined, both of which have been corrected.

Ξ reconstruction has also been studied in STAR. Signal extraction in the year one configuration has been studied using events in which an enhanced Ξ signal had been

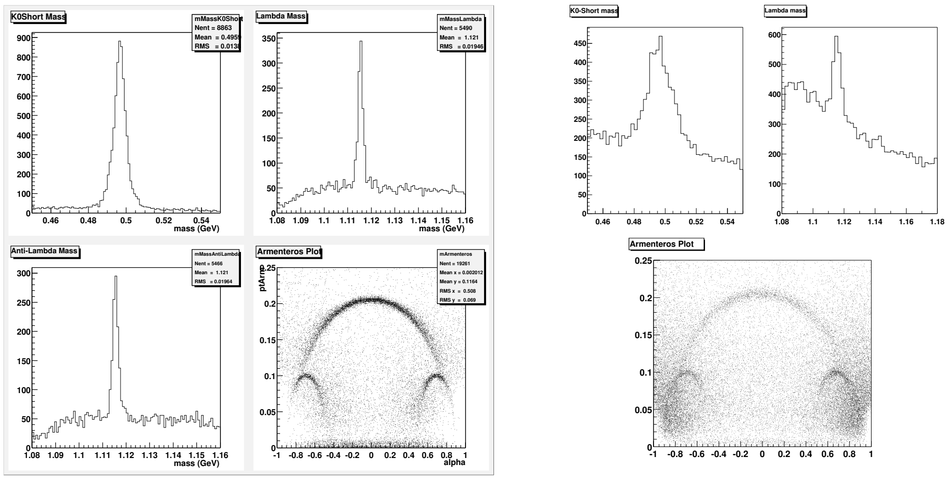

Figure 4. The invariant mass distribution of K_s^0, Λ, and $\overline{\Lambda}$ from 3000 HIJING events (left panel) and the preliminary K_s^0 and Λ mass distributions from approximately 16000 minimum bias events of the current run (right panel).

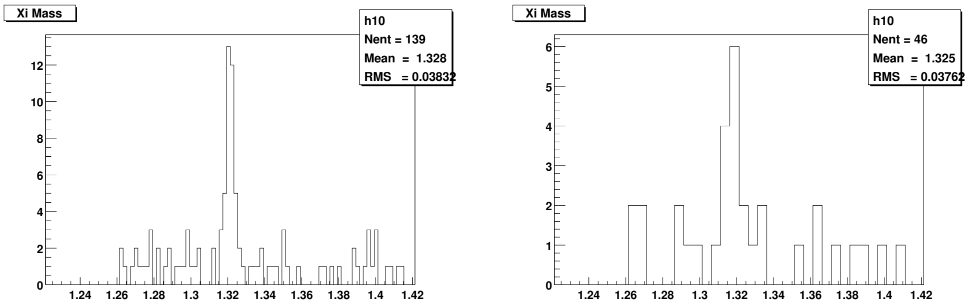

Figure 5. The invariant mass distribution of Ξ^- and $\overline{\Xi}^+$ from 7000 HIJING central Au+Au events (left panel) and the preliminary distribution from approximately 16000 minimum bias events of the current run (right panel).

added. By limiting the acceptance to Ξ with transverse momentum $p_T > 0.8$ GeV/c, it was found that nearly all the combinatorial background could be eliminated. The cuts used were similar to those found useful for extracting Λ and K_s^0. Figure 5 shows the result of applying these cuts to 7000 reconstructed HIJING events. Also shown is a hint of a peak in the experimental data obtained from 16000 minimum bias events from the current experimental run. In both cases, the sum of Ξ^- and $\overline{\Xi}^+$ is shown.

In the second year of RHIC operation, the efficiency of hyperon reconstruction will be significantly enhanced by the addition of the Silicon Vertex Tracker. This detector comprises three layers of Silicon Drift Detectors at approximately 5, 10 and 15 cm radius from the nominal beam axis. (An additional layer of Silicon Strip Detectors at a radius 25 cm will be added in year three). Due to the superior two-track resolution of the SVT, it should be possible to extend the measurement of hyperons to lower transverse momentum, where the combinatorial background for tracks reconstructed in the TPC alone becomes prohibitive. It will also make possible the measurement of the rare Ω baryon.

Particle	HIJING (4π)	>9 TPC hits	Reconstructed	
			TPC	TPC+SVT+SSD
K_s^0	250	30	2.0	6.5
Λ	80	5	0.3	1.5
Ξ^-	5	0.3	0.05	0.01-0.02
Ω^-	0.05	0.03		

Table 2. The expected reconstructed yield of various strange particles per central Au+Au collision, obtained from the HIJING model.

The two Forward Time Projection Chambers (FTPC) will also be installed for the second year of RHIC operation. These are novel radial drift devices operating in the challenging tracking environment close to the beam, inside the inner field cage of the main TPC. A feasibility study has shown momentum resolution to be sufficient for Λ reconstruction. This will add new acceptance in the range $2.75 < y_\Lambda < 3.5$.

2.3. Resonance reconstruction

The reconstruction of strange particle resonances is also possible in STAR. Resonance production presents an important test of thermal production models and can be sensitive to the properties of the state of matter in which they are produced. The ϕ meson is of particular interest as a probe of chiral symmetry restoration. STAR measures the ϕ via the charged kaon channel, $\phi \rightarrow K^+K^-$. This measurement uses the TPC dE/dx information to select kaons and the background is determined by mixing positive and negative tracks from different events having approximately the same total multiplicity. Other resonances have also been studied. A simulation of 5000 HIJING events, for example, has shown that it is should be possible to reconstruct the $K^{0*}(892)$ from year one data.

3. Summary and Outlook

The STAR experiment has begun taking data for physics and is performing very well. STAR will measure integrated yields and particle ratios of strange particles in collisions ranging from p+p to Au+Au. Table 2 shows the expected reconstruction performance based upon the HIJING model's prediction for the strange particle yields in central Au+Au collisions. Based upon these results, a measurement of all but the rarest multiply strange baryons should be possible in the first year of RHIC operation. Taking advantage of the complete azimuthal coverage of the STAR TPC, it might even be possible to perform $K_s^0K_s^0$ interferometry. With the addition of the SVT in year two, we will be able to measure the production of the Ω baryon and with increased efficiency at lower transverse momentum, it may also be possible to study $\Lambda\Lambda$ correlations.

References

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