First results from the H_0 di-baryon search and hyperon production measurements by the AGS Experiment 896.

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The AGS Experiment 896 was designed to study strangeness production in Au–Au collisions at 11.6A GeV/c, in particular the formation of a six-quark di-baryon the H_0. Heavy ion collisions provide favorable conditions for the H_0 formation either via coalescence of two Λ particles (owing to the large Λ production cross section) or direct production from the possible formation of a quark-gluon plasma. E896 also measured strange meson and baryon distributions from mid-rapidity. Preliminary results from this experiment are presented as well as details of the expected sensitivity for the H_0 search.

1. INTRODUCTION

The H_0 di-baryon (a six-quark state of uuddss) was first predicted by R.Jaffe [1] over twenty years ago. Many experiments have since searched for this elusive meta-stable strangelet state e.g. E810 [2], E888 [3], E836 [4] but no conclusive proof has yet been discovered. (See [5] for an overview summary of the search for the H_0.)

The large production of Λ's in Heavy ion collisions means that there should be a correspondingly high production of di-Λ's from simple coalescence arguments [6]. If the H_0 is more deeply bound than a coalescing $\Lambda\Lambda$ pair they may spontaneously decay into an H_0. This process allows for the creation of the strangelet without the need for a QGP formation.

Di-Λ events are of interest in the case that the $M_{H0} > 2M_\Lambda$ where the H_0 will manifest itself as a broad resonance in the invariant mass plot. The di-Λ events will also be used to determine an upper limit for the production rate of the H_0 di-baryon via coalescence per produced di-Λ.

E896 was optimized to search for the H_0 using two complementary tracking detectors, a Distributed Drift Chamber (DDC) and a Silicon Drift Detector Array (SDDA). The DDC had a large sensitivity to detect the H_0 decay modes $H_0 \rightarrow \Sigma^- p \rightarrow pn\pi^-$ and $H_0 \rightarrow \Lambda p\pi^-$ over a wide range of lifetimes, while the SDDA was ideally positioned for detecting the H_0, with a $c\tau \sim 4cm$, at the low end of the DDC's sensitivity range.

The SDDA also had a good acceptance for measuring neutral and charged strange particle production, the Λ, $\bar{\Lambda}$ and Ξ^-, around mid-rapidity via their decay products. These results will complement the hyperon measurements already reported by previous SPS and AGS experiments [7]. It is also intended to use the good dE/dx resolution obtainable from the SDDA to measure $\bar{p}$ production and investigate the $\bar{\Lambda}/\bar{p}$ ratio. Recent results both at the AGS [8] and SPS [9] have shown unusual behavior in this ratio and E896 will be able to supply an alternative statistically significant direct measurement.

The Distributed Drift Chamber (DDC) identifies Λ's, $\bar{\Lambda}$'s and K_s^0's at high rapidity and low p_T. The differing acceptances of the SDDA and DDC combined with the symmetry of the collision means that E896 will measure the production of Λ's over virtually the whole rapidity region.

2. THE EXPERIMENT 896

The design of E896 can be seen schematically in Fig. 1. The DDC consists of 144 planes with $\sim$ 8000 channels and an active volume of $120cm$ x $67.5cm$ x $20cm$. It was located $1.3m$ downstream of the target in a 1.7T analyzing magnet. The SDDA, positioned in the 6.2T sweeper magnet approximately $10cm$ downstream of the target, consisted of 15 planes of silicon drift detectors [10]. Each plane of the SDDA was formed by a $6.3cm$ x $6.3cm$ x $300\mu m$ n-type silicon wafer. The SDDA was a proto-type of the technology to be used by the STAR experiment [11] in the Silicon Vertex Tracker (SVT).

Although the H_0 can be identified unambiguously using a constrained fit to the unique topology characteristics of the $H_0 \rightarrow \Sigma^- p$ decay, redundant particle identification will be provided by using the MUlti-Functional Neutron Spectrometer (MUFFINS)[12] to detect the neutron from the subsequent Σ^- decay and the Time-Of-Flight (TOF) walls to aid the definition of the charged tracks reconstructed in the DDC.

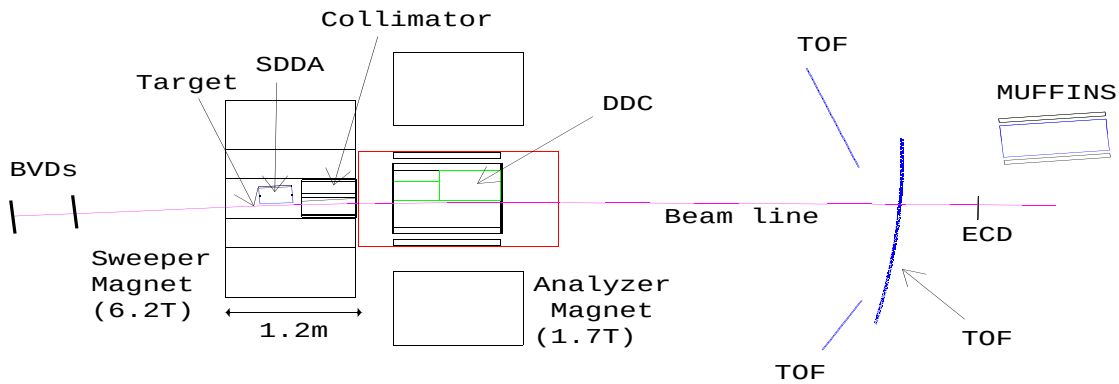

Figure 1. The experimental setup.

Two beam vertexing detectors (BVDs) were used for locating the primary vertex position and a forward multiplicity array determined the centrality of the collision for triggering.

3. THE RESULTS

During the April 1998 run 100 million central events were recorded by the DDC and 680,000 central events by the SDDA. Since silicon drift detectors are slow detectors the SDDA was operated using a 1 Hz data acquisition system, much slower than that of the DDC.

From these data it is predicted, from the DDC acceptance and reconstruction efficiency, that it will be possible to reconstruct $\sim$ 450,000 Λ's, 45,000 K_s^0's and 200 H_0's. A similar calculation shows that the SDDA data should yield $\sim$ 200,000 Λ's, 400 $\bar{\Lambda}$'s and 500 Ξ's from their data set. The acceptance for the Λ's in the SDDA and DDC is shown in Fig. 2.

The clean environment created by the sweeper field and collimator, on average there are less than 10 tracks in the DDC per event, means that the track reconstruction efficiency in the DDC is very high. Neutral decays occuring within the DDC can be cleanly reconstructed with very little background (Fig. 7). This is to be compared to the higher track density observed in the SDDA of $\sim$ 60 particles per event [13].

3.1. The SDDA results

Presented here are preliminary results for primary proton and Λ reconstruction in the SDDA; for more details on the current progress of SDDA analysis see [13].

The position, and hence momentum, resolution is influenced by external factors, such as the high magnetic field, ambient temperature and sampling frequency. The accuracy of the calibrations, in particular the velocity profile of each detector also have an effect. Bench tests have proven that these detectors are capable of a position resolution of the order of 20μm [14]. Currently the SDDA calibrations show a slightly larger resolution but progress is still being made in this area.

The energy deposited per unit length (dE/dx) vs momentum plot for positively charged

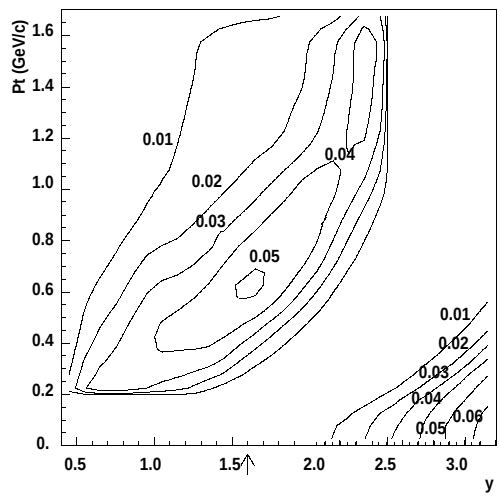

Figure 2. Λ acceptance in the SDDA and DDC as a function of p_T and rapidity. The contours are labelled with the fractional acceptance and the arrow indicates mid-rapidity.

particles reconstructed in the SDDA for 1000 events can be seen in Fig. 3. A clear proton band can be seen emerging below a momentum of $\sim 0.7GeV$. Improving the statistics will allow the clean identification of deuterons which can also be observed in this plot. When the whole data set has been reconstructed it is expected that a positive identification of $\bar{p}$'s will be possible from a similar plot for negatively charged particles. Fig. 4 compares the p_T distribution for identified protons to that expected from Monte-Carlo simulations. It can be seen that $\sim 70\%$ of the expected protons, those with total momentum $< 0.7GeV$, are recovered. We currently calculate an overall reconstruction efficiency for primary tracks of $> 85\%$. Work is in progress to try to improve the dE/dx calibration and thus increase the separation of the bands allowing the identification of protons to higher total momentum.

Fig. 5 shows the invariant mass distribution for Λ's in the SDDA. 10,000 central events have been reconstructed to produce this distribution. A clear peak can be seen around the nominal Λ mass. The solid histogram represents the signal reconstructed from mixed events and undergoing identical cuts. Due to the imperfect calibration of some parts of the SDDA at this time only a portion of the detector is used in the Λ reconstruction. This results in a reduced acceptance and reconstruction efficiency to that shown in Fig. 2 and assumed when calculating the yield of Λ's from the total data sample. It is expected that the whole detector will ultimately be used and hence the Λ yield per event will be enhanced.

3.2. The DDC Λ and K_s^0 results

Fig. 6 shows the invariant mass distributions for the Λ and K_s^0. 15 million events have been reconstructed in these plots with the requirement that the reconstructed v0 occur

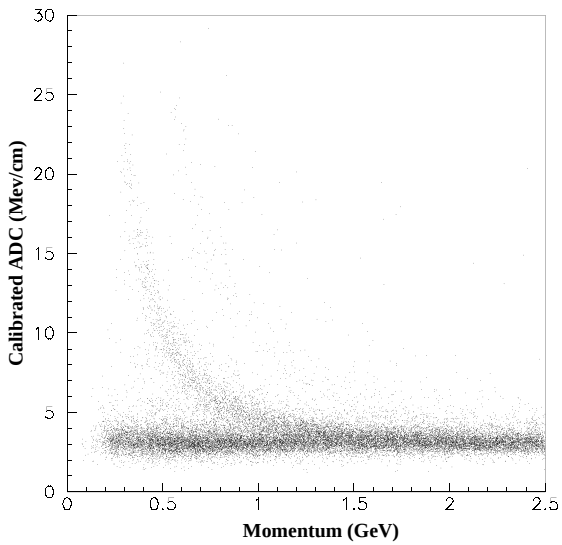

Figure 3. dE/dx for positively charged tracks in the SDDA for ~ 1000 events.

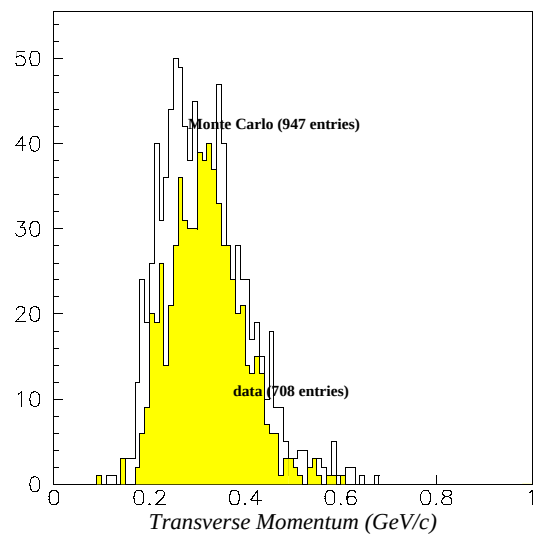

Figure 4. The p_T distribution for identified protons from the SDDA (solid plot) compared to Monte-Carlo simulation for an identical number of events. Approximately 70% of the expected protons are identified.

within the fiducial volume of the DDC. The mass resolution for Λ's is $4MeV$ and $11MeV$ for the K_s^0's. We expect to further increase the acceptance by identifying neutral decays occuring outside of the DDC.

3.3. The DDC double Λ results and H_0 predictions

Double Λ events are identified if two Λ's are reconstructed in the same event within 3σ of the calculated invariant Λ mass. From 15 million events we have identified 67 double Λ events, this is consistent with the number of events expected from acceptance and efficiency calculations assuming 15 Λ's produced per central collision. The increase in statistics from reconstructing the whole data set and extrapolating the neutral particle decay search to outside of the DDC should allow a significant sample to be obtained.

The H_0 reconstruction process is demonstrated in Fig.7 where a decaying H_0 has been embedded into a real DDC event. First the algorithm identifies a stiff positive particle, next a negative track is located with which the stiff positive track appears to form a secondary vertex within the active volume of the DDC. If successful, a search is then performed for a kink in the negative track. If all three steps are successful the event is flagged as containing a possible H_0 candidate and thus requiring further investigation. The H_0 embedded in Fig. 7 was correctly identified by this technique.

From calculations of the acceptance and efficiency for H_0 reconstruction using embedding of simulated H_0's into real data we can estimate our sensitivity for identifying H_0's. The sensitivity is strongly dependent on the lifetime of the H_0 and defined by

$$sensitivity = \frac{\#H_0}{\#events \cdot acc \cdot eff \cdot BR} \tag{1}$$

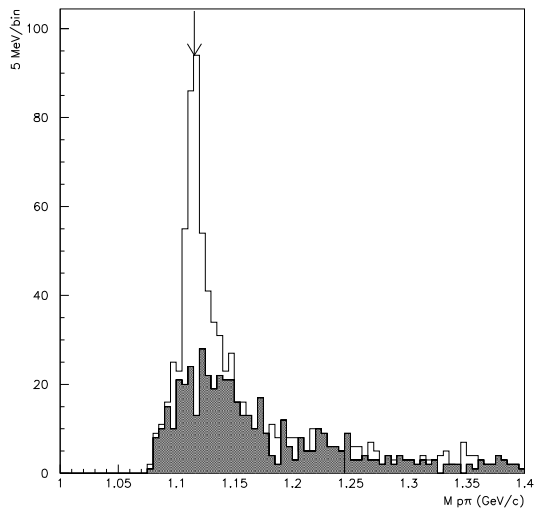

Figure 5. Invariant mass distribution for Λ's in the SDDA. 10,000 events have been reconstructed. See main text for details.

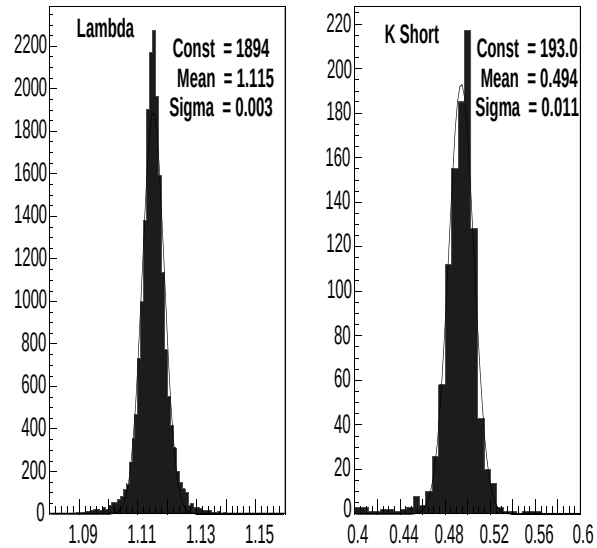

Figure 6. Invariant mass distributions of the Λ and K_s^0 for the DDC. 15 million events have been reconstructed.

where the acceptance (acc) and efficiency (eff) were calculated from simulations, 10^8 events were assumed and 2 H_0's, with a branching ratio (BR) of 1/3, were required to be identified to constitute a "discovery". The calculated sensitivity as a function of the H_0 lifetime is shown in Fig. 8.

4. CONCLUSIONS

The DDC recorded 100 million central events and the SDDA 680,000 central events. Based on the coalescence model, and assuming 0.1 H_0 /central collision and a $c\tau = 4cm$, the DDC may reconstruct as many as 200 H_0's. The statistics taken by both detectors should allow a definite statement to be made about the H_0 di-baryon existence.

The SDDA has been shown to be a mature technology able to track efficiently in a high multiplicity regime and high magnetic field. We are able to positively identify particles based on momentum and dE/dx. Given the number of events recorded by the SDDA during the run we expect to be able to identify a significant number of $\bar{p}s$. A preliminary Λ invariant mass peak has aslo been reconstructed. With the expected improvement in reconstruction efficiency resulting from further calibration of the SDDA we expect to be able to measure the production of Λ's, $\bar{\Lambda}$'s and Ξ's.

The DDC has identified Λ's and K_s^0's with a mass resolution of $4MeV$ and $11MeV$ respectively. The DDC has a good sensitivity for the H_0 and has currently identified 67 double Λ events, when the whole data sample has been examined it is expected that a good statistical sample will have been identified.

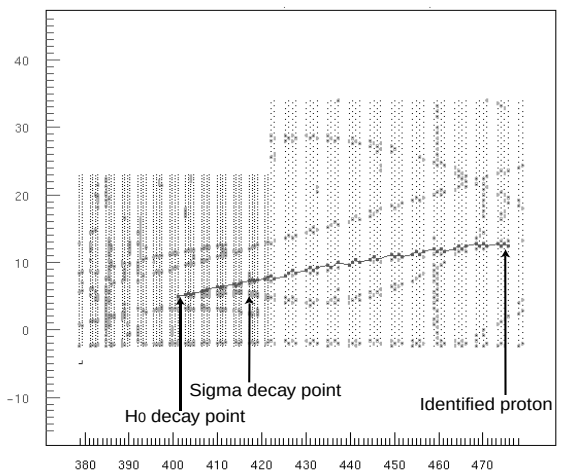

Figure 7. An embedded H_0 in a real DDC event and correctly reconstructed via the current software.

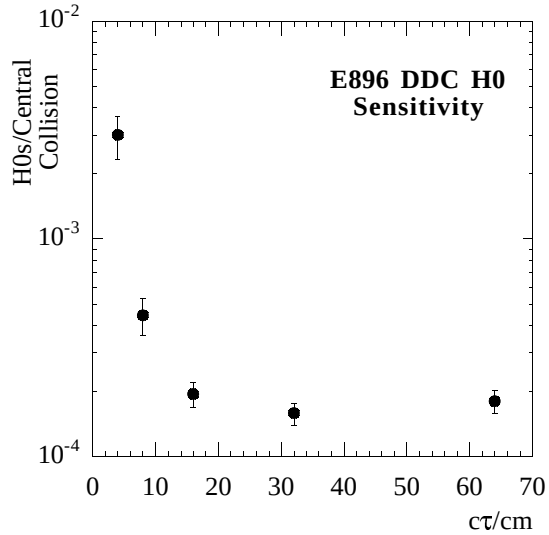

Figure 8. The DDC sensitivity to the H_0 as a function of lifetime.

5. ACKNOWLEDGEMENTS

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