Feasibility of Observing Open Charm with Year-2 STAR Data

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1 Introduction

We make here a brief estimate of the feasibility of observing the D^0 meson through its decay $D \rightarrow K + \pi$ with the statistics available in year 2 data. The measurement we describe involves the standard mixed event method: reconstructing the invariant mass of the D from its daughter particles and using mixed-events to subtract the background, as demonstrated in figure 1 for the $K^* \rightarrow K + \pi$.

2 Production

Production estimates for the D vary drastically. The largest prediction we currently know of (statistical model of Gazdzicki et. al. [1]) gives $< D^0 + \bar{D}^0 >= 20$ in central (200A GeV) RHIC collisions. The smallest are almost two orders of magnitude lower.

This statistical model gives $(D + \bar{D})/h^-$ of .009 ; for comparison $(K^* + \bar{K}^*)/h^-$ is measured at .065 at 130 GeV $\sqrt{s}$. The recent PHENIX measurement [2] from electrons at $\sqrt{s} = 130GeV$ gives $dN_{c\bar{c}}/dy = 2.1$. Assuming that 50% of the charm quarks go into $D + \bar{D}$ (this is a 20% overestimate according to some references), this would give $(D + \bar{D})/h^-$ of $.007(\pm 50\%)$.

We assume this statistical model number in the following.

3 Expected Signal Counts per Event

Assuming an inverse slope 300 MeV and a Gaussian in rapidity of width 2.0 (chosen to match the HIJING kaon width), our geometrical acceptance with the cuts listed below is about 20%. Assuming an efficiency of 75% for each track and a branching ratio of 4% along with a 100% efficient mass cut (see below), we should then have

$$20 \times .20 \times (0.75)^2 \times (.04) = .09 \tag{1}$$

counts per event of signal (meaning D and $\bar{D}$). Of course, our signal will scale with efficiency squared so if this number is 85% rather than 75%, we gain a factor of 1.3 in signal.

4 Background Counts per Event

A simple monte carlo assuming a 2% momentum resolution for all tracks gives us a width of $25MeV$ for the invariant mass of the reconstructed D mesons (if the resolution is 3%, our width increases by about $7MeV$). For a $\pm 50MeV$ range around the D mass, we are then essentially 100% efficient for signal. By looking at 910 central events, we see 2.8×10^6 background counts in this mass range in the invariant mass plot for $K^+\pi^-$ and $K^-\pi^+$ pairs, or about 3100 background counts per event. The figure of merit is signal over sqrt(background); $.09/\sqrt{3170} = 1.6 \times 10^{-3}$ per event.

In 3M events then, we can hope for signal/sqrt(background) of $1.6 \times 10^{-3} \times \sqrt{3 \times 10^6} = 2.8\sigma$.

The track and pair cuts used here are:

1. dE/dx within 2σ for kaon candidates, 3σ for pions.
2. $p_T > 120MeV/c$,$p < 2GeV/c$, $|y| < 1.2$ for all tracks.
3. $DCA < 3cm$, at least 20 hits on track
4. 'parent' has $|y| < 0.8$, pair opening angle $> .1$ rad

No serious effort has been made to optimize the cuts for signal to background or to optimize the mass range over which signal is integrated, and likely some amount could be gained by this.

5 Consistency Check: Estimate from K^* measurement

We can check this for consistency with numbers from the measurement of $K^* \rightarrow K + \pi$ From year one data [3], the $K^* + \bar{K}^*$ has a 15σ signal in 440K central events. The K^* branching ratio is 2/3, the measured width is 55 MeV and the gain in data of year 2 compared to year 1 is a factor of 30/4.4 (assuming 3M central events). The background level around the D mass is lower than that around the K^* mass by a factor of 5.5 (see figure 1) . We can then estimate that if the D production is 1/7 of the K^* production, we would see

$$15\sigma \times \frac{1}{7} \times \frac{.04}{.66} \times \sqrt{\frac{55}{25}} \times \sqrt{\frac{30}{4.4}} \times \sqrt{5.5} = 1.2\sigma \tag{2}$$

compared to the 2.8σ we estimated above. Part of the difference is that more K^*s are lost due to a daughter having too low p_T. This gain is about 25% as estimated by our monte carlo. Also, a larger acceptance in rapidity by a factor of about 1.6 has been assumed above compared to that used in the K^* measurement, so this will likely add some extra signal significance, though exactly how much is not completely clear. We will estimate it here as $\sqrt{1.6}$, but this is a very loose number. Taking these two factors into account, we estimate a signal of $1.2\sigma \times 1.25 \times \sqrt{1.6} = 1.9\sigma$ by this method compared to the estimate above of 2.8σ

6 Year 2 Min-Bias: Estimate from K^* min-bias measurement

Using the same argument as above, we can estimate from the K^* measurement our expected D signal from minbias year 2 data. From year 2 data, in 500K events, a signal of 16σ is seen for $K^* + \bar{K}^*$. Using the same equation as above, we find the expected signal in 3M minimum bias events is

$$16\sigma \times \frac{1}{7} \times \frac{.04}{.66} \times \sqrt{\frac{55}{25}} \times \sqrt{\frac{30}{5.0}} \times \sqrt{5.5} = 1.2\sigma \tag{3}$$

or about the same as for the central case. After applying the various corrections discussed in the previous section, this again becomes about a 1.9σ signal.

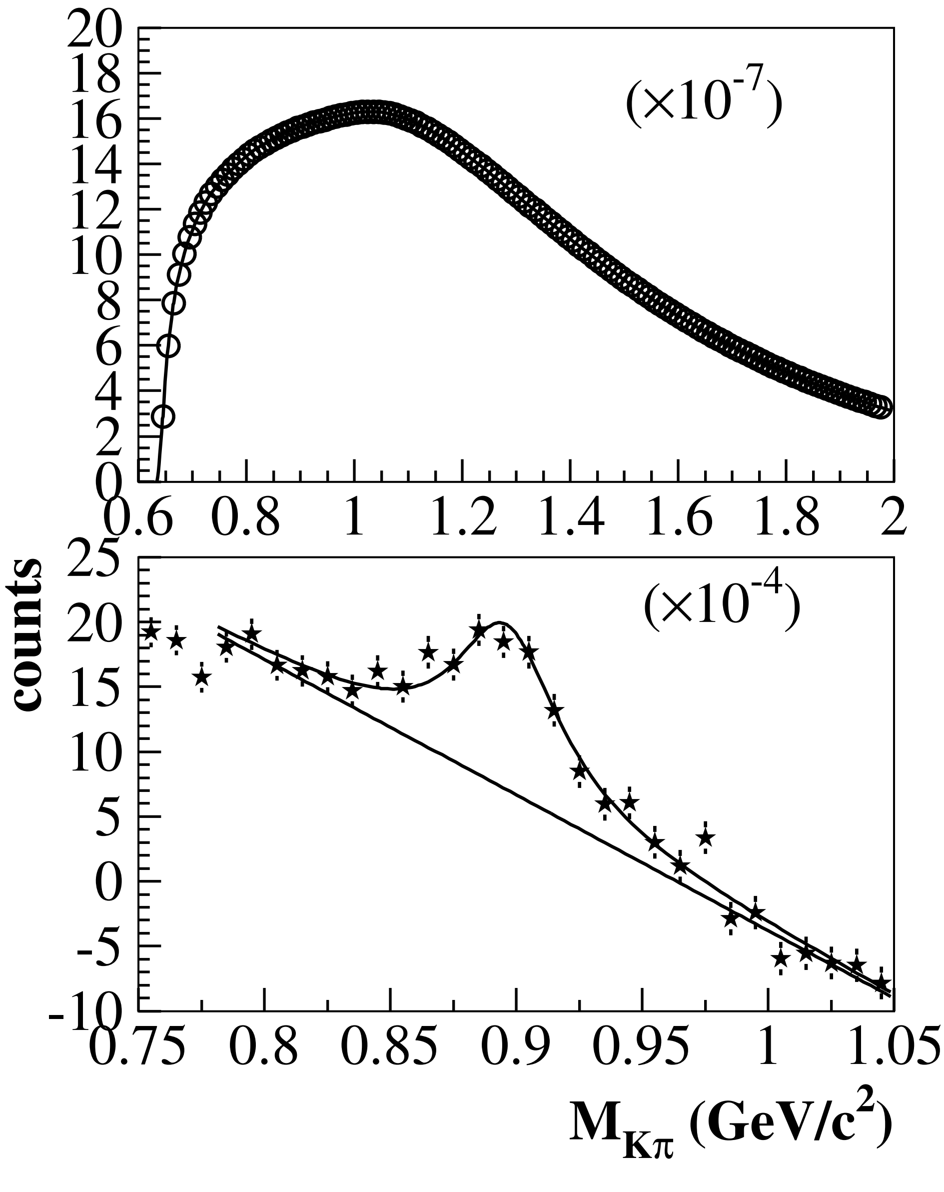

Figure 1: Invariant mass distribution of $K-\pi$ pairs in central year 1 events showing the size of background (scaled by 10^7) for the open charm signal. The lower panel has the background subtracted by mixed events and shows the K^* signal.

7 D measurement in $p-p$?

From Haibin's recent p-p studies of the K^*, we can make a similar estimate for D from $p-p$. He sees a 20σ signal in 600K events. The background level around the D mass is a factor of 12 less than that around the K^* mass. So if the productions scale by 1/7, we'd see (in 20M pp events) a signal of

$$20\sigma \times \frac{1}{7} \times \frac{.04}{.66} \times \sqrt{\frac{55}{25}} \times \sqrt{\frac{20}{0.6}} \times \sqrt{12} = 5.1\sigma \qquad (4)$$

But note that the statistical model predictions scaled by $< h^- >$ are much larger than measured D production in p-p at SPS energies [1]. Haibin is also looking into the measurement of $D^{\pm}$ decaying to three particle final states in $p-p$.

8 Conclusion

If production of D and $\bar{D}$ is as expected from the statistical model of Gazdzicki et. al. (which, under certain assumptions, is consistent with the PHENIX electron measurement within error bars), we would expect to see a marginal $2-3\sigma$ signal in 3M central or 3M min-bias year 2 Au-Au events. It is likely that the track and pair cuts can be optimized to increase this somewhat, but a drastic improvement from changing the cuts is not to be expected. As with all such analyses, the signal's significance scales as the square root of the number of events.

References

[1] M. Gazdzicki and M. Gorenstein, hep-ph/9803462, P. Levai et. al. nucl-th/0011023, M. Gazdzicki and C. Markert hep-ph/99004441.

[2] K. Adcox, et. al. nucl-ex/0202002

[3] STAR k-star paper draft