MEASUREMENT OF RATIO OF BRANCHING RATIOS

$BR(B^+ \to J/\psi K^+)/BR(B^0 \to J/\psi K^0)$

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1. INTRODUCTION

This paper reports a preliminary measurement of the ratio of branching ratios $BR(B^+ \to J/\psi K^+)/BR(B^0 \to J/\psi K^0)$. The reconstruction of J/ψ's is done via the decay $J/\psi \to \mu^+\mu^-$ while the K^0_S's are identified through the decay $K^0_S \to \pi^+\pi^-$. The data used was obtained at the Collider Detector at Fermilab from $p\bar{p}$ collisions at $\sqrt{s}$ =1.8 TeV. There are several reasons why this measurement is important. It embodies the first observation of the decay mode $B^0 \to J/\psi K^0_S$ at a hadronic machine and it permits us to measure the ratio of charged to neutral lifetimes and the $BR(B^0 \to J/\psi K^0)$.

1.1 Ratio of Lifetimes

There are recent predictions [1] that the ratio of lifetimes should be in the range

$$1.02 \leq \tau(B^+)/\tau(B^0) \leq 1.08 \tag{1}$$

By assuming that

$$\Gamma(B^+ \to J/\psi K^+) = \Gamma(B^0 \to J/\psi K^0) \tag{2}$$

with Γ the decay rate, we have the following relation

$$\begin{aligned} \frac{BR(B^+ \to J/\psi K^+)}{BR(B^0 \to J/\psi K^0)} &= \frac{\Gamma(B^+ \to J/\psi K^+)/\Gamma(B^+ \to X)}{\Gamma(B^0 \to J/\psi K^0)/\Gamma(B^0 \to X)} \\ &= \frac{1/\Gamma(B^+ \to X)}{1/\Gamma(B^0 \to X)} \\ &= \tau(B^+)/\tau(B^0) \end{aligned} \tag{3}$$

1.2 Branching Ratio

By using the $BR(B^+ \to J/\psi K^+)$ from CLEO we can obtain the $BR(B^0 \to J/\psi K^0)$ with higher precision than the present PDG value which has 50% error.

2. METHOD

The basic necessary relationships are

$$\begin{aligned}\mathcal{L} \times \sigma(p\bar{p} \to B^+) & \\ \times BR(B^+ \to J/\psi K^+) \times \epsilon_{B^+} &= N(J/\psi K^+)\end{aligned}$$

$$\begin{aligned}\mathcal{L} \times \sigma(p\bar{p} \to B^0) & \\ \times BR(B^0 \to J/\psi K^0) \times \epsilon_{B^0} &= N(J/\psi K^0)\end{aligned} \tag{4}$$

Here $\mathcal{L}$ is the integrated luminosity, σ is a cross section, ϵ represents the reconstruction efficiency and N is the number of reconstructed events for the specific decay mode.

Assuming that

$$\sigma(p\bar{p} \to B^+) = \sigma(p\bar{p} \to B^0) \tag{5}$$

(this is a good assumption because of the smallness of the u and d quark masses compared to the b quark mass) we then have

$$\frac{BR(B^+ \to J/\psi K^+)}{BR(B^0 \to J/\psi K^0)} = \frac{N(J/\psi K^+)}{N(J/\psi K^0)} \times \frac{\epsilon_{B^0}}{\epsilon_{B^+}} \tag{6}$$

3. PARTICLE SELECTION

3.1 J/ψ Selection

We require a good match between the stubs from the muon chambers and the corresponding track from the Central Tracking Chamber (CTC). The softer muon is required to have a transverse momentum > 1.7 GeV while the harder muon must be > 2.7 GeV. This requirement is needed only because these are the minimum momentums above which the level 1 and level 2 muon triggers are understood. The track parameters are then constrained to a common vertex and the J/ψ candidates are selected as di-muons with mass within $\pm 2.5\sigma$ of the world average.

3.2 K± Selection

All tracks with $P_t > 1.5$ GeV are considered $K^\pm$ candidates.

3.3 K^0_S Selection

We require both π tracks to have an impact parameter (with respect to the beam position) over its error greater than 1.0. We then constrain the parameters to a common vertex and require the decay distance to be > 1.0 cm and the K^0_S impact parameter to be < 0.3 cm if both tracks only have CTC information or 0.03 cm if both tracks have information from the Silicon Vertex Detector. The K^0_S candidates are selected as di-pions with mass within $\pm 2.5\sigma$ of the world average.

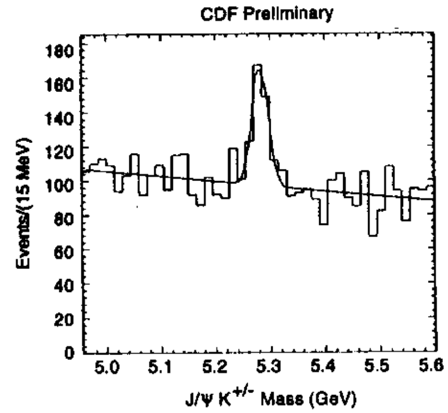

Figure 1: $J/\psi\ K^\pm$ mass distribution. The smooth line is a log likelihood fit of a gaussian plus a straight line. There are 167 ± 38 (stat) fitted events in the peak.

3.4 B± Reconstruction

Mass constrain all J/ψ candidates and simultaneously vertex constrain the di-muons plus the $K^\pm$ candidates to a common vertex. The $B^\pm$ candidate must have $P_t > 6$ GeV and a positive displacement with respect to the primary vertex. Figure 1 shows the resulting mass distribution. The smooth line is a log likelihood fit of a gaussian plus a straight line. There are 167 ± 38(stat) fitted events in the peak.

3.5 B^0 Reconstruction

Mass and vertex constrain all J/ψ candidates. Then mass, point and vertex constrain all K^0_S candidates. Require that the K^0_S transverse momentum be greater than 1.5 GeV. The B^0 candidate must have $P_t > 6$ GeV and a positive displacement with respect to the primary vertex. Figure 2 shows the resulting mass distribution. The smooth line is a log likelihood fit of a gaussian plus a straight line. There are 31 ± 5(stat) fitted events in the peak.

4. RECONSTRUCTION EFFICIENCY

For this measurement we assume all efficiencies common to both modes cancel in the ratio. Now we present a list of the efficiencies that are particular to each mode. The cuts are studied in succession in order to properly consider the correlation among them. Some efficiencies are determined by using a simple B-decay Monte Carlo (no underlying event or fragmentation) and a full simulation of the detector.

4.1 B± Mode

Use the M.C. simulation to determine the following two efficiencies

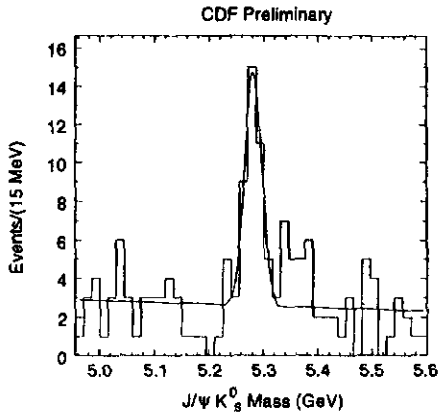

Figure 2: $J/\psi K^0_S$ mass distribution. The smooth line is a log likelihood fit of a gaussian plus a straight line. There are 31 ± 5 (stat) fitted events in the peak.

$\epsilon_{K^\pm}$ detection

Count number of found J/ψ within a $\pm 2.5\sigma$ mass window of the PDG value. Then count the number of B candidates. No cuts applied to the K. The ratio of these two numbers is $\epsilon_{K^\pm \text{ detection}}$.

$$\epsilon_{K^\pm \text{ detection}} = 0.878 \pm 0.028 \tag{7}$$

$\epsilon_{P_t(K^\pm)}$

Ratio of number $K^\pm$ after requiring $P_t(K^\pm) > 1.5$ GeV to the number before.

$$\epsilon_{P_t(K^\pm)} = 0.627 \pm 0.023 \tag{8}$$

4.2 B^0 Mode

Use the M.C. simulation to determine the following three efficiencies

$\epsilon_{K^0_S}$ detection

Count number of found J/ψ within a $\pm 2.5\sigma$ mass window of the PDG value. Count the number of K^0_S within a $\pm 2.5\sigma$ mass window. The ratio of these two numbers is $\epsilon_{K^0_S \text{ detection}}$.

$$\epsilon_{K^0_S \text{ detection}} = 0.611 \pm 0.017 \tag{9}$$

$\epsilon_{P_t(K^0_S)}$

Ratio of number K^0_S after requiring $P_t(K^0_S) > 1.5$ GeV to the number before.

$$\epsilon_{P_t(K^0_S)} = 0.748 \pm 0.024 \tag{10}$$

$\epsilon_{dist(K^0_S)}$

Ratio of number K^0_S after requiring $dist(K^0_S) > 1$ cm to the number before.

$$\epsilon_{dist(K^0_S)} = 0.926 \pm 0.031 \tag{11}$$

Use inclusive K^0_S sample to determine

$$\epsilon_{\text{other cuts}} = 0.789 \pm 0.040 \tag{12}$$

4.3 Ratio of Efficiencies

It comes to

$$\frac{\epsilon_{J/\psi K^0_S}}{\epsilon_{J/\psi K^\pm}} = 0.57 \pm 0.05 \tag{13}$$

An efficiency correction of 0.94 has been applied to account for the extra track in the $J/\psi K^0_S$ mode. This is needed as the M-C does not have a simulation of fragmentation or of the underlying event and the presence of extra tracks lowers the tracking efficiency.

5. RATIO OF BRANCHING RATIOS

$$\begin{aligned} \frac{BR(B^+ \to J/\psi K^+)}{BR(B^0 \to J/\psi K^0)} &= \frac{N_{J/\psi K^\pm}}{N_{J/\psi K^0_S}} \times \\ &\quad \frac{\epsilon_{J/\psi K^0_S}}{\epsilon_{J/\psi K^\pm}} \times 0.686 \times 0.5 \\ &= 1.05 \pm 0.3 \pm 0.2 \end{aligned} \tag{14}$$

where 0.686 is the $K^0_S \to \pi^+\pi^-$ branching ratio and 0.5 is the $K^0 \to K^0_S$ ratio. The 20% systematic uncertainty reflects our best guess for a conservative upper limit.

6. REFERENCES

1. I.I. Bigi, B. Blok, M. Shifman, N.G. Uratselv and A. Vainshtein, *A QCD "Manifesto" on Inclusive Decays of Beauty and Charm*, (DPF meeting of APS, November 1992).