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b-QUARKS FLAVOR TAGGING USING B_J^{*+-}-DECAY FOR $sin2\beta$ MEASUREMENT

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Abstract

Roinishvili V.N. b-Quarks Flavor Tagging Using B_J^{*+-}-Decay for $sin2\beta$ Measurement: IHEP Preprint 96-107. – Protvino, 1996. – p. 4, figs. 1, refs.: 6.

It is shown that the b-flavor tagging via B_J^*-decay is more sensitive than the conventional method of tagging via muons for $sin2\beta$ measurement at LHC with the principal advantage that the dilution factor is very close to 1.

Аннотация

Ройнишвили В.Н. Определение аромата b-кварков по распаду B_J^{*+-} для измерения $sin2\beta$: Препринт ИФВЭ 96-107. – Протвино, 1996. – 4 с., 1 рис., библиогр.: 6.

Показано, что для измерения $sin2\beta$ на LHC метод определения аромата b-кварков с использованием распада B_J^* более чувствителен, чем традиционный метод с использованием мюонов.

It has been shown in [1] that b-tagging methods based on the measurements of charge of both b-jets — containing B_d meson (self-tagging ST) and associated with it (associated-tagging AT) are efficient methods for $sin2\beta$ measurement. For a detector similar to CMS [2] the sensitivity of the AT method could be about 1.3 times higher than the sensitivity of the conventional method of tagging with high p_T muons (MT), while the ST method is about 30% worse than MT.

But when [1] was under preparation the yield of excited $B's$, which would be able to decay into B_d and pion, was not known and in the event simulation program used this source of B_d was not included. Now LEP experiments [3,4,5] observe orbitally excited B mesons (B_J^* — notation of PDG [6]) decaying finally into B and pion in b-jets with rather high rate. In those papers it has been also noted that the ST method would be very efficient for CP studies.

The results of this work are related to the b-flavor determination via $B_J^{*+(-)} \to B_d\pi^{+(-)}$ chain for $sin2\beta$ measurement at LHC with a collider detector similar to CMS assuming that:

$$\frac{BR(\bar{b} \to B_J^{*-} \to B^{*0}\pi^-)}{BR(\bar{b} \to B_d)} = 0.18, \tag{1}$$

which corresponds to the experimentally observed relation [4]:

$$\frac{BR(Z \to \bar{b} \to B_J^{*0} \to B^{*+}\pi^-)}{BR(Z \to \bar{b} \to B^+)} = 0.18 \pm 0.04.$$

For the $sin2\beta$ measurement the most suitable is the study of B_d decay into the state $F \equiv J/\Psi + K_s \to \mu^+\mu^- + \pi^+\pi^-$. The angle β is related to the time - integrated asymmetry $A = \frac{\Gamma(\bar{B}_d \to F) - \Gamma(B_d \to F)]}{\Gamma(\bar{B}_d \to F) + \Gamma(B_d \to F)}$ and to the mixing parameter x_d: $sin2\beta = A \times \frac{1+x_d{}^2}{x_d}$.

The measured asymmetry $A_m = \frac{N^+ - N^-}{N^+ + N^-}$, where $N^+(N^-)$ are the numbers of experimentally defined events like $\bar{B}_d(B_d)$ decay into F, is affected by the dilution effects due to the mixing (MT and AT) of tagging $B's - D_m$ and wrong tagging — D_w.

Thus, $sin2\beta$ can be measured as

$$sin2\beta = \frac{A_m}{D} \times \frac{1+{x_d}^2}{x_d}, \; with\, the\, statistical\, error \;\; \Delta sin2\beta = \frac{1}{S} \times \frac{1+{x_d}^2}{x_d},$$

where the sensitivity S of an experimental sample, with the total number of events N and overall dilution $D = D_m \times D_w$, is

$$S = \frac{D}{\sigma_{A_m}} = D \times \sqrt{\frac{N}{1-A_m^2}}. \tag{2}$$

The factor $\frac{1+{x_d}^2}{x_d}$ is common for all three methods and is not included in S.

PYTHIA 5.7 and JETSET 7.3, adjusted for the production and decay of B_J^* according to (1) and with no CP-violation, were used to generate $B's$ in the reaction $pp \to b\bar{b} + ...$ at $\sqrt{s} = 14.0$ TeV. The values of the mass and width of the B_J^* were taken from PDG — 5.73 GeV and 0.13 GeV, respectively. Only the channel of $B_J^* \to B^*\pi$ decay was used.

About 800.000 events were generated with $B_d \to J/\Psi K_s \to \mu\mu\pi\pi$. The following cuts were applied to satisfy the CMS acceptance and its trigger capability :

(i) for muons:

$p_T > 4.5 GeV/c$ if $\mid \eta_\mu \mid < 1.5$,
$p_T > 3.6 GeV/c$ if $1.5 < \mid \eta \mid < 2.0$ and
$p_T > 2.6 GeV/c$ if $2.0 < \mid \eta \mid < 2.4$;

(ii) for all other charged particles $p_T > 0.7 GeV/c$ and $\mid \eta \mid < 2.4$.

At least one pair of $\mu^+\mu^-$ with the effective mass corresponding to the mass of J/Ψ had to be observed.

The generated sample contains 1517 3μ events with p_T of the muons, not coming from J/Ψ, larger than $4\,GeV/c$. 1185 events give the right b-flavor tagging, while 332 — the wrong one (including B^0 mixing). These figures give $D = 0.56$ and the sensitivity of the sample for b-flavor tagging via $\mu\, S_\mu = 22. \pm 0.8$. Note that only cascade decays and mixing were included for the estimation of S_μ.

If we assume all efficiencies and acceptances (trigger, muons, K^0) and $b\bar{b}$ production cross-section to be like in CMS TP [2], then the generated sample will correspond to the integrated luminosity:

$$L_{int} = 0.2 \times 10^4 pb^{-1}. \tag{3}$$

In Fig.1a the distribution of the effective mass of B_d and charged pions (all hadrons are supposed to be pions) is presented. The distribution was fitted by a Gaussian function with 3 free parameters (number of events, mass and width) plus a background (dashed histogram). The shape of the background was defined using the effective mass distribution of B_d and pions from different events. The normalization of the background was made for $M(B_d\pi) > 6\,GeV$. The fitted values of the parameters $M_f = 5.68\,GeV$ and $\sigma_f = 0.079\,GeV$ do not coincide with the mass and width of B_J^* since missing $\gamma's$ from B^* decay. The values of M_f and σ_f were used to fit the effective mass spectra for $B_d\pi^+$ and $B_d\pi^-$ separately which are presented in Fig.1b,c. The only parameter corresponding to the number of $B_J^{*+(-)}$ events - $N^+(N^-)$ was free. The backgrounds were defined as for Fig.1a.

The "measured" values $N^+ = 1440 \pm 59$ and $N^- = 1428 \pm 58$ give the "measured" asymmetry A_m and the sensitivity of the sample S_{ST}:

$$A_m = 0.004 \pm 0.028(\sigma_{A_m}) \; and \; S_{ST} = \frac{1}{\sigma_{A_m}} = 35. \pm 1. \tag{4}$$

In this case $\sigma_{A_m} = \frac{\sqrt{[\delta N^+]^2 + [\delta N^-]^2}}{N^+ + N^-}$. There is no D factor in (4). A possible dilution could arise from neutral B_J^* decay into $B_d(or B_d^*)$ and $\pi^+ + \pi^-$, but the influence on the mass spectra of this decay is negligible because of two reasons: i) the probability of this decay is about few percent, since the mass difference between B_J^* and B_d is small and ii) pions from this decay are more soft than in the case of a single pion emission. Therefore the peaks in Fig.1b,c are related to the charge B_J^* decay and thus determine the b-flavor unambiguously.

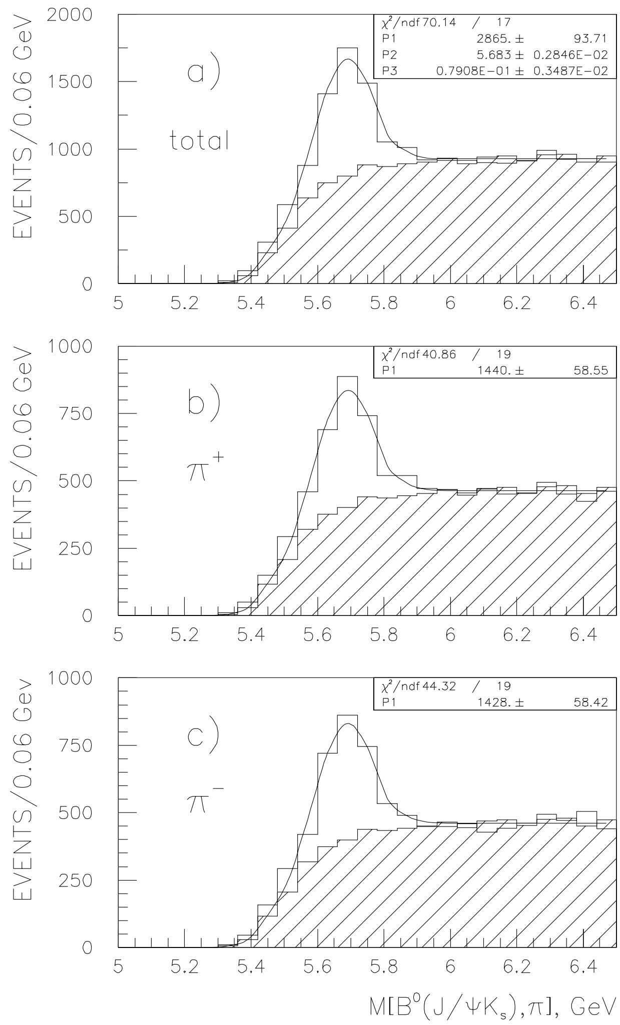

Fig. 1. $B_d(J/\Psi, K_s)$ and π effective mass distributions. Dashed histograms — background, solid lines — results of fits (see text): a) — total; b) — $B_d(J/\Psi, K_s)$ and π^+; c) — $B_d(J/\Psi, K_s)$ and π^-.

In conclusion: the self-tagging method via B_J^* decay is about 1.5 times more sensitive that the μ-tagging method for $sin2\beta$ measurement with a collider detector similar to the CMS. Note that direct $B_J^* \to B_d\pi$ decay (which was not included) will increase the sensitivity of ST.

From (3) and (4) one can expect that during 1 year of the CMS running ($L_{int} = 10^4 pb^{-1}$) an asymmetry could be measured with the precision of about 0.012 by the ST method alone and thus $sin2\beta$ could be measured with the statistical error of about ($x_d = 0.7$):

$$0.012 \times \frac{1 + x_d^2}{x_d} = 0.026.$$

Using all 3 methods (ST, AT and MT) the overall error for $sin2\beta$ could be about 0.018.

The principal advantage of ST via B_J^*: for MT and AT it is necessary to measure the dilutions with a good precision while for ST via B_J^*, D is very close to 1, since the electrical sign of the charged B_j^* determines the b-flavor unambiguously.

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