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THE b-QUARK FLAVOR TAGGING VIA Λ-HYPERON FOR CP-VIOLATION STUDIES

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Abstract

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A method of the b-flavor tagging via Λ is proposed for the CP-violation parameter $sin(2\beta)$ measurement at a collider detector. The statistical error is expected to be about the same as in the case of b-tagging via muons.

Аннотация

Ройнишвили Н.Н. Определение аромата b-кварка посредством Λ-гиперонов для изучения CP-нарушений: Препринт ИФВЭ 93-148. – Протвино, 1993. – 4 с., библиогр.: 6.

Предлагается новый метод определения аромата b-кварковой струи по Λ-гиперонам для измерения параметра нарушения CP-четности $sin(2\beta)$ в экспериментах на коллайдерах. Статистическая точность в измерении этого параметра такого же порядка, как и в случае применения традиционного метода определения аромата b-струи по знаку мюонов.

There are several problems in the field of HEP where it is necessary to know the flavor of the b-quark produced in hadron-hadron or e^+e^- interactions. Ordinary and simplest way of b tagging is the measurement of the charge of muons from the semileptonic decay of beauty hadrons. In this case, a wrong tagging due to the cascade decay $b \to c \to \mu$, π-, K-decays, punchthrough in detectors and possible false muons arises.

We propose another method – to tag $b(\bar{b})$ via inclusive decays of beauty hadrons into $\Lambda(\bar{\Lambda})$, i.e. $b \to c \to s(\bar{b} \to \bar{c} \to \bar{s})$ chain, which is free from the above mentioned misstagging sources. The $\Lambda(\bar{\Lambda})$ can be identified by its decay into $p\pi^-(\bar{p}\pi^+)$ in a detector with a good tracking system in magnetic field. The ambiguities between Λ and $\bar{\Lambda}$, will be, as it is known, very small even without particle identifications, since the $p(\bar{p})$ momentum is in average much larger than the pion one. The expected branching ratio: $b \to \Lambda + X$ (the same for $\bar{b} \to \bar{\Lambda} + X$) can be roughly estimated as:

$$Br[b \to \Lambda X] = f(b \to \bar{B}X) \times Br[\bar{B} \to \Lambda X] + f(b \to \Lambda_b X) \times$$

$$\times Br[\Lambda_b \to \Lambda X] = 0.074,$$

where $\bar{B} = (B^-,\ \bar{B}^o_d,\ \bar{B}^o_s)$, using:

i) the measured values of $Br[\bar{B} \to \Lambda X] = 0.042$/1/ and $Br[\Lambda_c \to \Lambda X] =$ $= 0.45$/2/,

ii) the assumption that $Br[\Lambda_b \to \Lambda_c X]$ is equal to the $Br[B \to DX]$, which is the sum of the measured values/1/:

$$Br[B \to D^{\pm}X] + Br[B \to D^o/\bar{D}^o X] + Br[B \to D_s^{\pm}X] =$$

$$= 0.227 + 0.46 + 0.115 = 0.80,$$

iii) the assumption that the values of the production fraction of beauty mesons and baryons (mainly Λ_b) are equal to:

$$f(b \to B^- X) = f(b \to \bar{B}^o X) = 0.38, \quad f(b \to \bar{B}^o_s X) = 0.14$$

and $f(b \to \Lambda_b X) = 0.1$.

One can expect an additional source of $\Lambda(\bar{\Lambda})$ which is not directly connected with the $b(\bar{b})$ decay, but giving the right tagging. In the case of the $b(\bar{b})$ fragmentation into $\bar{B}^o_d(B^o_s)$ an extra $s(\bar{s})$-quark from the sea, strongly correlated with the $\bar{B}^o_s(B^o_s)$ momentum, will arise. This quark with the probability of about 10% can hadronizate into $\Lambda(\bar{\Lambda})$ and will give additional right tagging in about 1.4%.

Thus we expect that the probability of the good b-tagging via Λ can be equal to $0.074 + 0.014 = 0.088$, or 0.055 including $Br[\Lambda \to p\pi]$. This value is only twice less than $Br[b \to \mu X]$.

However, there will be quite a lot of Λ's produced in pp interactions and not related to the b production in the energy range of LHC/SSC. Though most of them will have low transvers momentum and can be removed by the proper p_t cut, there still exists a probability of wrong tagging and one must take it into account when studing certain physics problems.

We apply here the method of b-tagging of via Λ for investigation of the possibility to measure the CP-violation parameter $sin(2\beta)$ (β – one angle of the unitarity triangle of the CKM mixing matrix) in B^o_d and $\bar{B}^o_d$ decay. There are several suggestions, how to measure this parameter at LHC colluder/3,4,5/. All of them are based on the detection of $B^o_d/\bar{B}^o_d$ by their decay into $J/\Psi K_s$, followed by $J/\Psi \to \mu^+\mu^-(e^+e^-)$ and on tagging of associated beauty hadrons by the charge of the muon in their semileptonic decay.

The angle β is related to the time-integrated asymmetry:

$$A = \frac{\Gamma(B^o_d \to J/\Psi K_s) - \Gamma(\bar{B}^o_d \to J/\Psi K_s)}{\Gamma(B^o_d \to J/\Psi K_s) + \Gamma(\bar{B}^o_d \to J/\Psi K_s)}$$

and mixing parameter x_d:

$$sin(2\beta) = A \times \frac{(1 + x_d^2)}{x_a}.$$

The measured asymmetry $A_m = (N^+ - N^-)/(N^+ + N^-)$, where $N^+(N^-)$ are the numbers of the detected events with B^o_d or $\bar{B}^o_d$ decaying into $J/\Psi K_s \to \mu^+\mu^-\pi^+\pi^-$ associated with $\mu^+(\mu^-)$ in the case b-tagging via μ or with $\Lambda(\bar{\Lambda})$ in the case of b-tagging via Λ, is affected by dilution effects due to the mixing of the tagged $B's(D_m)$ and due to the wrong tagging (D_w) arising from the $b \to c \to \mu$ chain, π-, K-decay, etc. in the case of b-tagging via μ or from the soft Λ yield in the case of b-tagging via Λ. Note, that in the last case D_m is more close to unity than in the case of b-tagging via μ, since about half of Λ's are decay product of beauty-baryons, which can not mix.

Thus, the CP-violation parameter can be measured as:

$$sin(2\beta) = \frac{A_m}{D} \times \frac{(1+x_d^2)}{x_d}$$

with the statistical error for $sin(2\beta)$:

$$\delta[sin(2\beta)] \simeq \frac{1}{D\sqrt{N}} \times \frac{(1+x_d^2)}{x_d},$$

where N is the number of tagged events and $D = D_m \times D_w = 1 - 2 \times W$. W is the probability of wrong tagging including mistagging because of mixing and wrong muons or soft Λ's.

For the estimation of the efficiency of the b-tagging via Λ for CP-violation studies we used PYTHIA 5.6 and JETSET 7.3 to generate B_d^o in the reaction $pp \to b\bar{b}+$ ... at $\sqrt{s}$=14 TeV. To reduce the computing time we forced: $Br[J/\Psi \to \mu^+\mu^-] \equiv Br[K_s \to \pi^+\pi^-) \equiv Br[\Lambda(\bar{\Lambda}) \to p(\bar{p}) + \pi] = 1$. We also forced $Br[B \to \Lambda\bar{p} + 3\pi] = 0.042$ (instead of $B \to \Lambda X$) and kept the probabilities of beauty baryons production and decay corresponding to the PYTHIA version used. Note, we use only events with $B_d^o \to J/\Psi K_s$. The events with $\bar{B}_d^o \to J/\Psi K_s$ have the same efficiencies and we take them into account when estimating the total number of the expected events.

The 1.2×10^6 generated events with $B_d^o \to J/\Psi K_s \to \mu\mu\pi\pi$ passed through a collider detector with properties similar to the CMS[3,5] applying the following cuts:

i) for muons from J/Ψ - $|\eta| < 2.4$, $p_{t\mu}$ >3.5 GeV/c;

ii) for π's from K_s - $|\eta| < 2.4$, $p_t > 0.5$ GeV/c, K_s decay length in the transverse plane is between 2 and 40 cm and $|Z_{vertex}| < 1.5$ m.

In the remaining events we looked for Λ's and $\bar{\Lambda}$'s with $p_\perp$ >2 GeV/c which for their decay products fulfil the requirement ii) and move in the direction oposite to the B_d^o in the transverse plane - $\Delta\varphi > 90^o$.

After all cuts we are left with 677 events with $B_d^o \to J/\Psi K_s \to \mu\mu\pi\pi$ and Λ or $\bar{\Lambda}$. The events are distributed: N_r=505 and N_w=172, where N_r and N_w are the numbers of right and wrong tagged events corrected for $B^o - \bar{B}^o$ mixing. (We call here right/wrong tagged event if B_d^o is associated with $\Lambda/\bar{\Lambda}$). These numbers give the dilution factor D=0.49.

The total number of events for:

- $L_{int} = 10^4$ pb^{-1},

- $\sigma(b\bar{b})$=500 μb,

– probability of B_d^o or $\bar{B}_d^o$ production equal 0.8,
– $Br[B_d \to J/\Psi K_s] \times Br[J/\Psi \to \mu\mu] \times Br[K_s \to \pi^+\pi^-]$=1.35×10^{-5},
– $Br[\Lambda \to p\pi]$=0.64,
– losses of Λ due to the Λ/K^o ambiguity 0.9,
– trigger and tracking efficiency of muon $(0.8)^2$,
– tracking efficiency for K^o and Λ decay products 0.95,

expected to be N=9100. With such statistics $sin(2\beta)$ can be measured with the precision $\delta[sin(2\beta)] = 0.045$. We use $x_d = 0.7$/6/. The obtained error is about the same as those in the case of b-tagging via μ /3-5/.

In conclusion – the b-flavor tagging via Λ can be used as a method to measure the CP-violation parameter $sin(2\beta)$ at a collider detector, as well as the b-flavor tagging via μ.

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References

[1] Particle Data Group, Phys. Rev. D45, Part 2 (1992).

[2] G.Grawford et al., Phys. Rev. D45, 752 (1992).

[3] CMS Letter of Intent, CERN/LHCC 92-3.

[4] ATLAS Letter of Intent, CERN/LHCC 92-4.

[5] N.Neumeister, B Physics Workshop, CERN, May (1993).

[6] H.Alberclit et al., W. Phys. C55, 357 (1992).

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