Low p_t lepton tag at the HERA-B experiment

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Abstract: The low p_t lepton tag is proposed for the HERA-B experiment. The tagging efficiency, dilution and the statistical power are expected to be 14%,0̇.21 and 0.08 correspondingly.

To measure mixing-induced $\mathcal{CP}$ asymmetries in B mesons, the initial flavor of the neutral B meson under study has to be determined. Several tagging techniques are expected to be used in the HERA-B experiment: high p_t lepton tag, charged kaon tag, secondary vertex charge tag [1, 2, 3] and tag with B** decays [4]. The idea of the soft "wrong-sign" (with respect to the sign of primary leptons from B-decays) lepton tag of the B meson flavor belongs to BaBar Collaboration [5] and can also be effectively used in the HERA-B experiment. The transverse momentum spectrum of the "wrong-sign" leptons (mainly cascade leptons from $\bar{b} \to \bar{c} \to \ell^- \nu X$ decay chain) and the "right-sign" leptons (mainly from $\bar{b} \to \ell^+ \nu X$) taking into account the mixing of the b-hadrons which accompany the neutral B meson to be tagged are shown in Figure 1(a). The significant excess of the "wrong-sign" leptons over the "right-sign" leptons in the low transverse momentum region can be effectively used as a tool for B flavour tagging.

The estimation of the characteristics of the low p_t lepton tag was performed at the level of Monte Carlo event generators. The `PYTHIA 5.6` [6] and `FRITIOF 7.0` [7] generators were combined [1] to generate events with $b\bar{b}$ pairs. The momentum of the tagging candidate was required to exceed 5 GeV/c, which is close to the minimal momentum where the reliable lepton identification at HERA-B is possible. The transverse momentum of the candidates was deemed to be less than 0.5 GeV/c.

The numbers of lepton and hadron tag candidates satisfying these requirements per event are listed in Table 1. The corresponding momentum spectra are shown in Figure 1(b).

For the estimation of the total misidentification probability for hadrons to be detected as leptons the information from Muon system [8], Electromagnetic Calorimeter (ECAL) and Ring Imaging Čerenkov Counter (RICH) can be used (see Figure 2). The μ-π, e-π, e-K and μ-K separation capabilities with the aid of the RICH Detector were recalculated from the π-K separation studied in detail in [2]. The results of the Neural Network Analysis of ECAL information were used. The misidentification probabilities were convoluted with the hadron momentum spectra to obtain the numbers of fake leptons (see Table 2).

Particles from the main vertex will be additionally suppressed by the vertex cut. Three values of the suppression factor α have been considered in this work: 1.0, 0.5 and 0.1. The statistical powers for low p_t μ-tag and low p_t e-tag are correspondingly $P_\mu = \{0.060,\ 0.064,\ 0.067\}$

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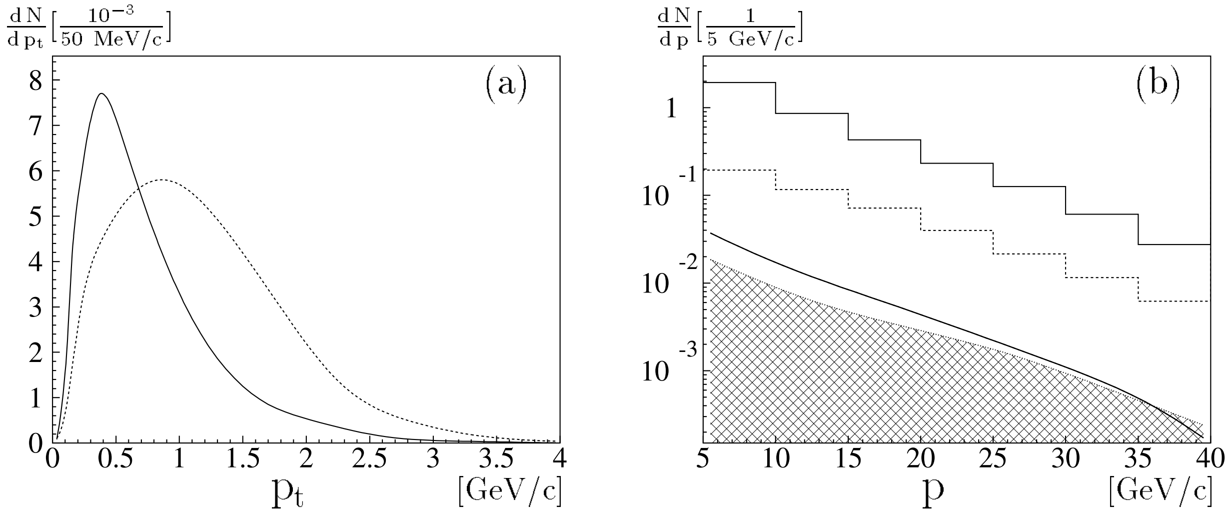

Figure 1: (a) *The transverse momentum spectra of "wrong-sign" (solid line) and "right-sign" (dashed line) leptons* ($p >$ 5 GeV/c). (b) *The momentum spectra of pions (solid histogram), kaons (dashed histogram), "wrong-sign" (solid line) and "right-sign" (hatched area) leptons* ($p_t <$ 0.5 GeV/c). *The normalization corresponds to one* $B^0 \to J/\psi K^0_S$ *decay to be tagged. Regarded are tracks in the geometrical acceptance only.*

Table 1: *The numbers of lepton and hadron tag candidates per event. "–" stands for the "wrong-sign" and "+" stands for the "right-sign" leptons. Main vertex* (MVx) *is a* B *production vertex and tracks from secondary vertices* (SVx) *are the tracks which can not be assigned to the main vertex, placed on the target wire.*

	μ			e			π		K	
	SVx		MVx	SVx		MVx	SVx	MVx	SVx	MVx
	–	+		–	+					
production	0.11	0.13	-	0.16	0.18	0.17	5.0	12.0	0.73	1.1
acceptance	0.10	0.12	-	0.14	0.15	0.10	4.1	7.0	0.62	0.75
$p > 5$ GeV/c	0.074	0.10	-	0.083	0.11	0.016	2.6	3.8	0.58	0.51
$p_t < 0.5$ GeV/c	0.028	0.013	-	0.032	0.018	0.013	1.4	2.3	0.21	0.25

and $P_e = \{0.047,\ 0.051,\ 0.056\}$. Since the e and μ tagging efficiencies are small, the combined statistical power can be estimated as $P_{\mu+e} = \{0.075,\ 0.080,\ 0.087\}$. The characteristics of the low p_t and high p_t lepton tags are compared in Table 3. Also, neglecting the probability to have in the event both the high p_t and low p_t lepton tags, the combined statistical power can be roughly estimated to be 0.19. This is equivalent (taking into account the difference in the dilution factors) to the effective enhancement of the high p_t lepton tag statistics by about 22%.

In summary, the low p_t lepton tag was proposed for the HERA-*B* experiment and its characteristics were estimated. The statistical power was found to be 0.08.

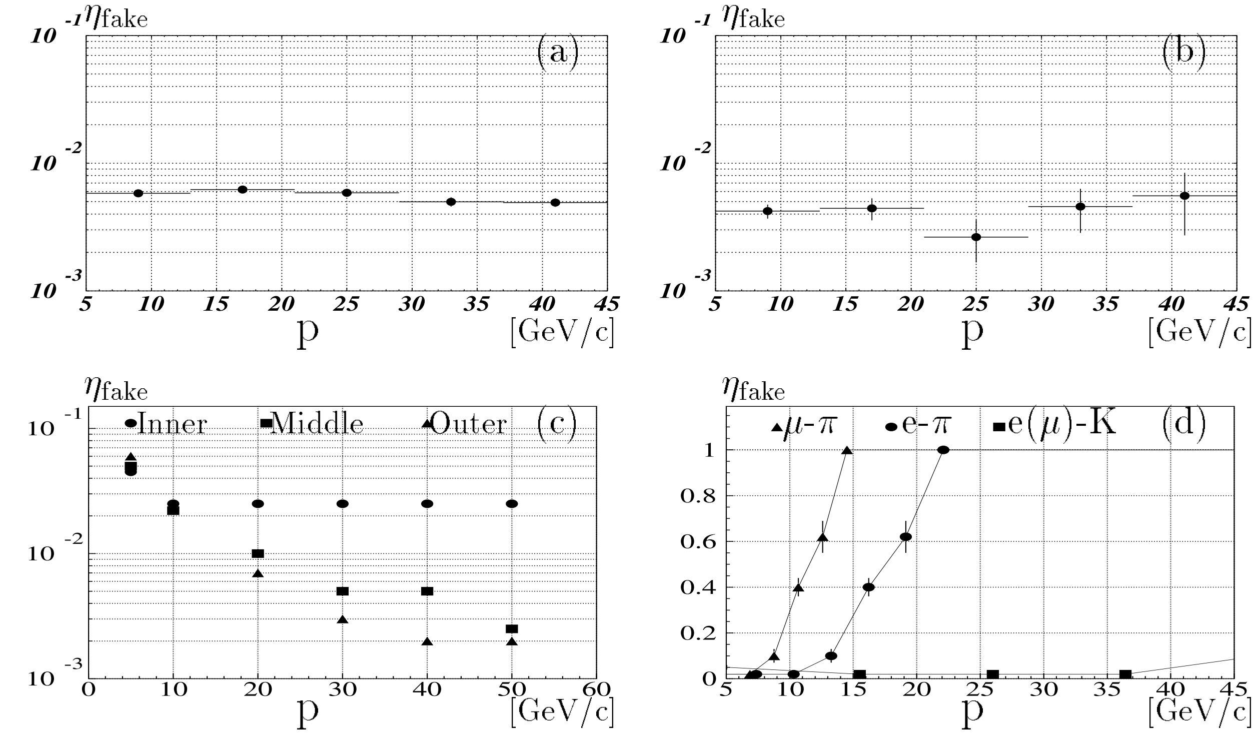

Figure 2: *The total (sum of the punch-through and decays-in-flight) fake rate of* μ-π (a) *and* μ-K (b) *separation with Muon System and Tracker.* (c) *The fake rates for* e*-hadron separation with ECAL: Inner, Middle and Outer parts.* (d) *The fake rates for* μ-π, e-π, e-K *and* μ-K *separation with RICH. The lepton identification efficiency is as high as 95%.*

Table 2: *The numbers of tagging fake leptons per event.*

	SVx	MVx
μ-π	$7.7 \cdot 10^{-3}$	$12.7 \cdot 10^{-3}$
μ-K	$1.5 \cdot 10^{-4}$	$1.8 \cdot 10^{-4}$
e-π	$9.9 \cdot 10^{-3}$	$16.3 \cdot 10^{-3}$

Table 3: *Tagging efficiency, dilution factor and statistical power for low* p_t *lepton tag* ($\alpha = 0.5$) *and for high* p_t *lepton tag.*

	ε [%]	D	P
Low p_t leptons ($\alpha = 0.5$)	14	0.21	0.08
High p_t leptons	16	0.43	0.17

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