$B_d^0\ H_b\ \to J/\psi\ K^0\ \mu\ X$ reaction: rates, dilution factor and the error on $\sin(2\phi)$ as a function of trigger p_t threshold.

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Abstract

For statistics 24000 reactions $B_d^0\ H_b\ \to J/\psi\ K^0\ \mu\ X$ the rates dN/dt of reconstructed events were calculated for several options of the detector setup (air-core toroid vs. iron-core toroid, electron vs. muon tracking, full vs. staged detector) as a function of the tagging muon p_t . The dilution factor D due to mistagging of the muon dependence on p_t was derived. From dN/dt and D the p_t -dependence of the error on CP-violation parameter $\sin(2\phi)$ was obtained.

Event generation

$pp \to b\ \bar{b}\ X$ events were generated by PYTHIA with only lowest-order graphs. The cross section given by PYTHIA for this process is $150\mu b$. This value is about 5-times less than the one with higher-order processes involved. In order to enrich statistics at higher p_t four samples of $pp \to b\ \bar{b}\ X$ events were generated with p_t cuts on hard-process choosen at ($p_t\ < 6GeV$), ($6GeV\ < p_t\ < 12GeV$), ($12GeV\ < p_t\ < 20GeV$), ($p_t\ > 20GeV$). To obtain the correct spectrum the sum of four p_t - distributions of b-hadrons each weighted by a coefficient was fitted to the spectrum of b-hadrons obtained by the generation without p_t cuts.

$B_d^0\ H_b\ X$ events were taken and forced to decay the following way

(1) $$B_d^0\ \to J/\psi\ K^0$$

and for b quark in beauty hadron H_b only two semileptonic decay channels were opened:

(2) $$b\ \to \mu^-\ c\ \overline{\nu}_\mu \quad or\ b\ \to \tau^{\ -}\ \overline{c}\ \overline{\nu}_T \quad ;\ b\ \to \tau^{\ -}\ \overline{c}\ \overline{\nu}_T$$

Four other analogical samples of events were generated with decay channels:

(3) $$b\ \to c\ X\ ;\ c\ \to \mu^+\ X'$$

instead of (2); here X doesn't contain muon. The two sets of events are called *good-tag* (with decays (1) and (2)) and *bad-tag* (with decays (1) and (3)) respectively. Mixing of the neutral B mesons was omitted.

Acceptance calculations

The probability ϵ_{rec} of the

$$(4) \qquad B_d^0\ H_b\ \rightarrow J/\psi\ K^0\ \mu\ X\ ;\ J/\psi\ \rightarrow l^+l^-\ ;\ K^0\ \rightarrow \pi^+\pi^-$$

events (that have already satisfied trigger conditions -first two lines in Table 1) to fulfil the sets of cuts presented in Table 1 was calculated. The rapidity cuts 1.2 (0.7) for the tagging muon and 1.4 for l^+l^- and $\pi^+\pi^-$ are values taken for the staging the detector. The cuts were taken from ([1]). The lepton identification efficiency (80%) and the track-finding efficiency (95%) were taken into account.

$p_t\ (\mu\ tag) > 6GeV; 12GeV$ $\lvert\eta\rvert(\mu\ tag) < 2.0; 1.2; 0.7$	air-core; iron-core full detector; staged air-core; staged iron-core
$p_t\ (\pi^\pm\ ) > 1GeV$ $\lvert\eta\rvert(l^+l^-\ \pi^+\pi^-\ ) < 2.0; 1.4$ $r_\perp(K^0\ ) \in < 1; 30 > cm$ $\angle(J/\psi\ ; K^0\ ) < 45^o$ $p_t\ (l^+l^-\ ) > 1GeV; 5GeV$	 full detector; staged detector electrons; muons

Table 1: Cuts used for the ϵ_{rec} calculation

Number of reconstructed events (4) per year at luminosity $10^{33}\ cm^{-2}s^{-1}\ dN/dt$ for different p_t triggers (Table 2 and also Figure 2b with the cut $1GeV$ for l^+,l^-) was obtained from ϵ_{rec} and N_{trig}. N_{trig} is a number of events (4) per year collected with a single muon trigger with $|\eta| < 2$ of tagging muon and different values of p_t trigger. N_{trig} was derived from $d\sigma/dp_t$ (Figure 1a) - the differential cross section of the process (4) which was obtained from generated events as explained in next section.

Muon spectrum and dilution

The differential cross section $d\sigma/dp_t$ (Figure 1a) where p_t is transversal momentum of μ from H_b decays was obtained as a sum of *good-tag* and *bad-tag* $d\sigma/dp_t$ (Figure 1b) with relative normalization correspondingly to branching ratios of decays (2) and (3).

The absolute normalization of $d\sigma/dp_t$ was made in accordance to the cross section $\sigma = 0.150mb$ given by PYTHIA for $pp \rightarrow b\ \bar{b}\ X$.

Asymmetry defined as:

$$(5) \qquad A = \frac{\sigma(B_d^0\ H_b\ \rightarrow J/\psi\ K^0\ \mu\ ^+X\ \ ) - \sigma(B_d^0\ H_b\ \rightarrow J/\psi\ K^0\ \mu\ ^-X\ \ )}{\sigma(B_d^0\ H_b\ \rightarrow J/\psi\ K^0\ \mu\ ^+X\ \ ) + \sigma(B_d^0\ H_b\ \rightarrow J/\psi\ K^0\ \mu\ ^-X\ \ )}$$

measured in a pp process would differ from $\sin(2\phi)*x/(1+x^2)$, where $\sin(2\phi)$ is a CP-violation parameter and x is mixing of B_d^0 meson, for several reasons. This is usualy expressed by dilution factors. We have calculated the dilution due to misstagging t.e. when tagging muon comes from *bad-tag* event. The ambigous events $b \rightarrow \mu^- \, c \, \overline{\nu}_\mu$; $c \rightarrow \mu^+ \, X'$ with two muons (4.8% of events) were treated sepparately: for the certain value of trigger threshold p_t the event was considered as a *good-tag* if $p_t \, (\mu^-) \geq p_t > p_t \, (\mu^+)$ and as a *bad-tag* if $p_t \, (\mu^+) \geq p_t > p_t \, (\mu^-)$. We exclude also the ambigous events with both muons above the trigger threshold which will be admitted by the trigger but will have to be excluded in off-line analyses. This way for $p_t = 6 GeV$ we choose 5% of the ambiguity events as *good-tag* and 0.5% as *bad-tag* events. The rest of 94.5% are not triggered or have ambigous tag. Two other processes leading to two tagging muon final states: $H_b \rightarrow J/\psi \, X; J/\psi \rightarrow \mu^+ \mu^-$ and the double $pp \rightarrow b \, \overline{b} \, X$ production are not considered here. From *good-tag* and *bad-tag* muon spectra (Figure 1b) the dilution factor D defined as

$$(6) \qquad D(p_t) = \frac{\int_{p_t}^{\infty} \frac{d\sigma(good-tag)}{dp_t{}'} dp_t{}' - \int_{p_t}^{\infty} \frac{d\sigma(bad-tag)'}{dp_t} dp_t{}'}{\int_{p_t}^{\infty} \frac{d\sigma(good-tag)}{dp_t{}'} dp_t{}' + \int_{p_t}^{\infty} \frac{d\sigma(bad-tag)'}{dp_t} dp_t{}'}$$

was calculated as a function of p_t (Figure 2a).

From $D(p_t)$ and dN/dt (Figure 2b) the statistical error on CP-violation parameter $\sin(2\phi)$ which is equal to

$$(7) \qquad (x/(1+x^2) * d * D(p_t) * \sqrt{dN/dt})^{-1}$$

can be derived as a function of p_t (Figure 2c). The factor d is a correction to dilution due to mixing, when all H_b hadrons - not only charged mesons are used for tagging. Factor d was calculated using the formula

$$(8) \qquad d = p_- + p_\Lambda + (x + x_s)/(1 + x_s^2)/x * p_s + 1/(1 + x^2) * p_d$$

taken from [3], where x_s is a mixing parameter of B_s^0 meson, p_-, p_d, p_s and p_Λ are the production rates of the B^- ,$\overline{B}_d^0$, $\overline{B}_s^0$ and the beauty baryon respectively. For our generated events we obtained the relative values of

$$(9) \quad p_- : p_d : p_s : p_\Lambda = (0.400 \pm 0.005) : (0.398 \pm 0.005) : (0.117 \pm 0.003) : (0.085 \pm 0.002)$$

The differences in $B/\overline{B}$ production rates in pp interactions are omitted. Using the value $x = 0.67$ [2] and $x_s = 8$ [3] the factor $d = 0.79$ is derived.

Conclusion

For trigger threshold $p_t = 6 GeV$ and more the dilution due to tagging is independent on p_t and is equal to

$$(10) \qquad D = 0.82 \pm 0.04$$

the error on D is statistical (here the error on number of generated events is undertood) and here we take it for $6 GeV$. As a consequence the error (7) on $\sin(2\phi)$ depends on p_t only through rates dN/dp_t . Staging would degrade this error 1.3 times for the air-core toroid or 1.6 times for the iron-core toroid.

References

[1] P.Eerola, "Measurement of CP-violation in B-decays with the ATLAS", ATLAS Internal Note, PHYS-NO-009,1992.

[2] M.V.Danilov, "Heavy flavour physics", Proceedings of the Lepton-Photon Symposium & and Europhysics Conference on High Energy Physics, Geneva, 1991,vol.2,p.333.

[3] M.Bolto et al.,"Further comments about B-physics in pp interactions",SSCL-538/A,SLAC-PUB-5795,1992.

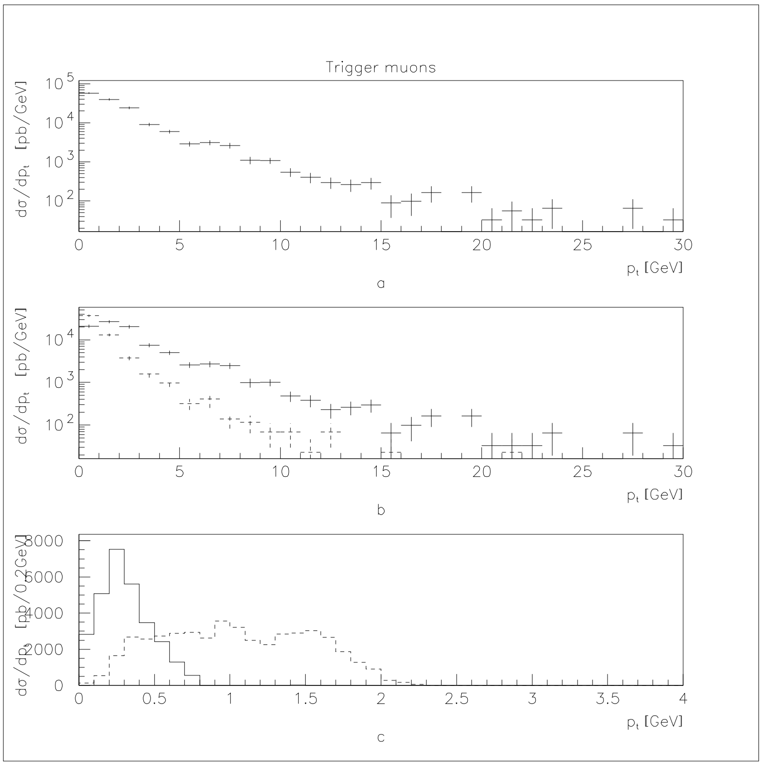

Figure 1: Fig.1a) p_t -distribution of muons from semileptonic H_b decays Fig.1b) p_t -spectra of *good-tag* (upper points) and *bad-tag* (lower points) muons from semileptonic H_b decays (The errors are statistical.) Fig.1c) p_t -spectra of *good-tag* (dashed line) and *bad-tag* tagging (full line) muons with respect to H_b direction.

$p_t^{\ min}(\mu - tag)$ $[GeV]$	$p_t^{\ min}(l^+l^-)$ $[GeV]$	N_{trig}	ϵ_{rec} [%]	dN/dt	D	$\delta(\sin(2\phi))$
6 (air-core)	1	37200	11.3 ± 0.8	2430	0.82 ± 0.04	0.07
	5		2.2 ± 0.3	491		0.15
12 (iron-core)	1	3900	17.6 ± 2.4	398	0.86 ± 0.06	0.16
	5		6.7 ± 1.4	151		0.26
6 (staged air-core)	1	23700	9.7 ± 0.8	1340	0.82 ± 0.04	0.09
			1.9 ± 0.3	261		0.21
12 (staged iron-core)	1	1930	14.0 ± 3.3	153	0.86 ± 0.06	0.26
			3.3 ± 1.2	37		0.53

Table 2: Results obtained for various detector setup(the air-core, the iron-core), different lepton identification limits (1 or 5 GeV) and full and staged detector. The number of triggers N_{trig} and dN/dt are calculated for the PYTHIA lowest-order $b\,\overline{b}$ production. These values are about 5-times less than those with higher-order graphs involved.

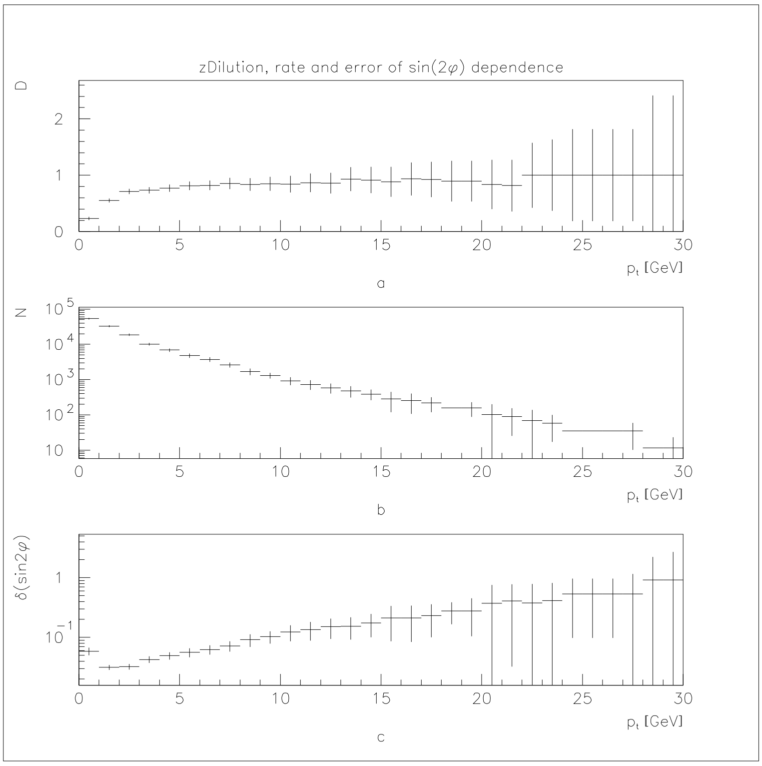

Figure 2: Fig.2a) Dilution factor due to muon tagging as a function of muon p_t . Fig.2b) Rates of reconstructed events $J/\psi\ K^0\ \mu\ X$; $J/\psi\ \rightarrow l^+l^-$; $K^0\ \rightarrow \pi^+\pi^-$ per year at luminosity $10^{33}\ cm^{-2}s^{-1}$ as a function of p_t -trigger threshold. Fig.2c) The error on CP-violance factor $sin(2\phi)$ after one year at luminosity $10^{33}\ cm^{-2}s^{-1}$ as a function of p_t -trigger threshold. (The errors are statistical.)