# Trigger for Radiative B Decays at the HERA-B experiment.


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**Abstract:** We have studied the possibility to extend the HERA-B trigger to accept events of type $B \longrightarrow X\gamma$. An interesting aspect of the measurement of the radiative $B$ decays branching fractions is the extraction of the ratio $|V_{td}|/|V_{ts}|$ which gives a constraint on one side of the unitarity triangle. This trigger will also allow to search for $B_s$ and $\Lambda_b$ radiative decays.


## 1 Introduction

The evidence for Penguin decays (Figure. 1) has been seen by the CLEO collaboration [1]. They have observed the decays $B^0 \rightarrow K^*(892)\gamma$ and $B^- \rightarrow K^*(892)^-\gamma$ in a data sample of $1.39 \cdot 10^6$ $B\bar{B}$ events with an average branching ratio of $(4.5 \pm 1.5 \pm 0.9) \cdot 10^{-5}$. With the additional measurement of the decay $B^0 \rightarrow \rho^0\gamma$ one can extract the ratio $|V_{td}|/|V_{ts}|$ [2] providing a constraint on the unitarity triangle [3] and allowing precision tests of the Standard Model. This ratio is also given by the measurement of the mixing parameters $x_d$ and $x_s$. But if $x_s$ is too high its measurement within HERA-B will be technically limited by the vertex detector resolution.

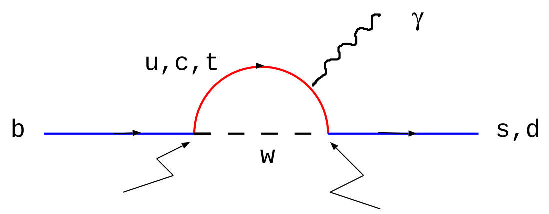


Figure 1: *Penguin diagram*

In HERA-B we expect a production of more than $10^8$ $b\bar{b}$ pairs/year and hence thousands of radiative $B$ decays. Some of the predicted radiative $B$ decay modes which can be reconstructed in HERA-B are summarized in Table 1 where we show the theoretical predictions for the corresponding branching ratios [4] and the number of produced events per year. The decays $B_s \rightarrow \phi\gamma$ (which can be reconstructed in the decay mode $\phi \rightarrow K^+K^-$) and $\Lambda_b \rightarrow \Lambda\gamma$ are

| Decay modes | BR | Decays/year |
|---|---|---|
| $B_d \to K^*\gamma$ | $(4.5 \pm 1.75) \cdot 10^{-5}$ | 14500 |
| $B_d \to X_s\gamma$ | $(3.2 \pm 0.58) \cdot 10^{-4}$ | 103000 |
| $B_d \to \rho^0\gamma$ | $(0.85 \pm 0.6) \cdot 10^{-6}$ | 270 |
| $B_d \to X_d\gamma$ | $(1.0 \pm 0.8) \cdot 10^{-5}$ | 3220 |
| $B_s \to \phi\gamma$ | $(4.8 \pm 1.5) \cdot 10^{-5}$ | 2850 |
| $\Lambda_b \to \Lambda\gamma$ | $(3.8 \pm 1.5) \cdot 10^{-5}$ | 1040 |

Table 1: *Theoretical branching ratios [4] and expected produced radiative $B$ decays assuming* $3.7 \cdot 10^8$ *produced $b\bar{b}$ pairs/year and the production probabilities* $\overset{(-)}{B}_d : \overset{(-)}{B}_s : \overset{(-)}{\Lambda}_b$ *= 0.87:0.16:0.074 (the probabilities include a factor 2 due to pair production). Note that for $B^0 \to K^*(892)\gamma$ the experimentally measured branching ratio is used.*

very interesting to measure in HERA-B since they can not be measured by $e^+e^-$ B factories at $\Upsilon(4S)$.

The originally proposed HERA-B first level trigger system based on charged track finding is very selective and does not accept this kind of events. In this paper we will present an extension of the first level trigger with a reasonable signal efficiency and a low background rate. This study is based on the channel $B^0 \to K^*(892)\gamma$ where $K^{*0} \to K^+\pi^-$.

## 2 Signatures of the decay $B^0 \to K^*(892)\gamma$

Due to the high background interaction rate in the HERA-B environment ($\sigma_{b\bar{b}}/\sigma_{inel} \approx 10^{-6}$) the first level trigger system has to reject background events by a factor better than 200 while keeping the signal efficiency high. To achieve such high background rejection one need a very good signature for the signal.

In this section we will look for such a signature for the decay chain $B^0 \to \gamma K^{*0}(892) \to K^+\pi^-$ using Monte Carlo events without detector simulation. HERA-B Monte Carlo event generation is based on PYTHIA for heavy flavor production and FRITIOF for nuclear interactions. The $pN$ interaction center of mass energy is 40 $GeV$. One event is a mixture of several single $pN$ interactions. The number of interactions $n_i$ per event is generated according to a Poisson distribution with $n_i = 5$ as mean value.

Fig. 2 shows momentum and transverse momentum distributions of photons from radiative $B$ decays and photons from background events. The transverse momentum $P_\perp$ [1] of photons from $B$'s is in average large and this fact represents a good signature. Also the decay products of $K^*$ carry a valuable information in their transverse momentum.

## 3 Hard photon trigger

We will briefly describe the general concept of the First Level Trigger FLT of the HERA-B experiment (for details see [5] [6]). The basic task of the HERA-B first level trigger is to

[1] In this note $P_\perp$ is defined with respect to the beam axis.

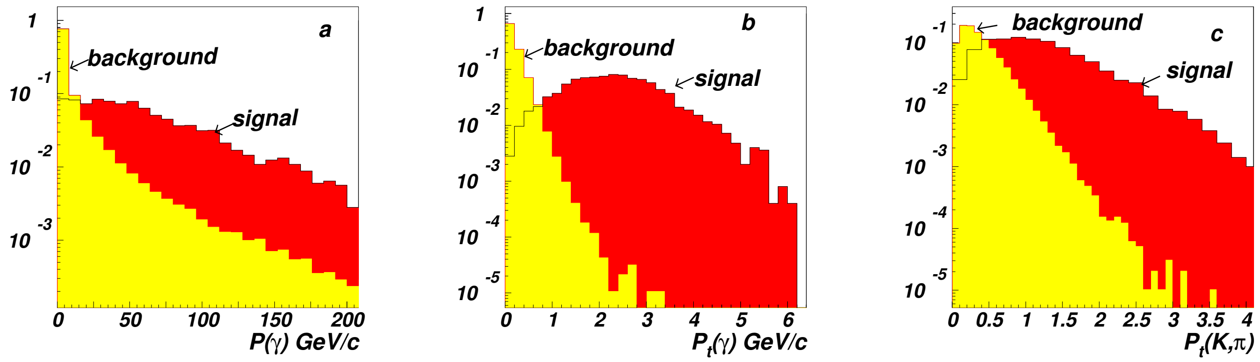


Figure 2: *a)Momentum and b) transverse momentum distributions for photons from* $B^0 \to K^*(892)\gamma$ *and from background. c)Transverse momentum of decay products of the* $K^*$ *and charged tracks from background. The plots are drawn at arbitrary scale.*

accept events with lepton pairs ($e^+e^-$, $\mu^+\mu^-$) that originate from the decay of a $J/\psi$ meson and events with charged hadrons pairs that originate from a $B$ meson decay. In addition it should allow triggers based on any combination of leptons and charged hardrons with given type, charge, momentum, transverse momentum and mass. Thus the original FLT design does not accept photons. To trigger on photons we will use the electromagnetic calorimeter (ECAL) pretrigger. The photon clusters fortunately satisfy the electron pretrigger thresholds. The new high $P_\perp$threshold and a flag for photon triggers are implemented in the ECAL pretrigger processors. The second step is to allow the photon candidates to pass all the track finding steps without requiring found hits. This condition is implemented in the redesigned FLT processors. The hard photon trigger is combined with the high $P_\perp$hadron trigger (see [5]) used to trigger on the $K^*$ decay products.

# 4 FLT simulation and results

Using a full Geant simulation of the HERA-B detector and the FLT simulation software L1SIMU, we generated 10000 background events and 3000 signal events. Each signal event involves one decay $B^0 \to K^*\gamma$. Figure 3 presents the efficiencies and the rejection factor as a function of the $P_\perp$ cut.

The rejection factor using only the photon information i.e. requiring an ECAL cluster with $E_\perp > 3.0\,GeV/c$ is better than 300 but it is not a sufficient requirement which can be used by the higher level triggers to reject further background. Hence we have used the High $P_\perp$trigger as additional requirement. The high $P_\perp$trigger efficiency is shown in Figure 3.

Requiring a photon with $P_\perp > 3.GeV/c$ and a high $P_\perp$track with $P_\perp > 1.5\,GeV/c$, the FLT efficiency for $B^0 \to K^*(892)\gamma$ is 10% and the background rejection factor is better than 500. It is possible to increase the rejection factor requiring neutral clusters (i.e. no track is matched to the ECAL photon pretrigger). But to keep the FLT efficiency as high as possible, this requirement can be used together with a refit of the high $P_\perp$tracks and cuts on their impact parameters in the higher level triggers.

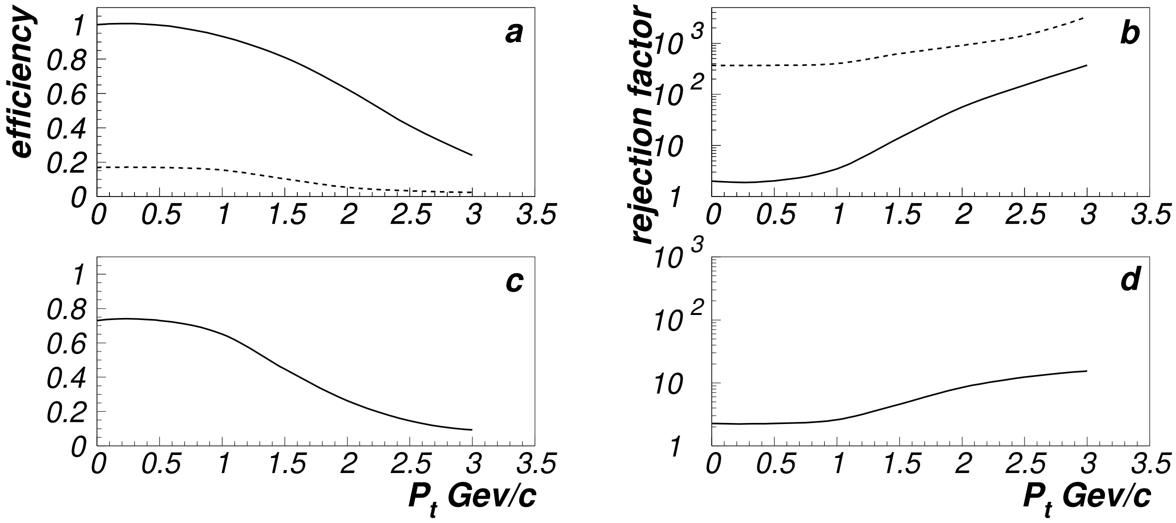


Figure 3: *FLT signal efficiency and background rejection factor as functions of transverse momentum cut: a-b) solid line: cut on $P_\perp$ of photon, dashed line: cut on $P_\perp$ of the photon and at least one high $P_\perp$ track, c-d) cut on high $P_\perp$ trigger tracks only.*

# 5 Semileptonic FCNC B-decays $B \to Xl^+l^-$

The semileptonic FCNC B-decays $B \to Xl^+l^-$ are of great interest for precision tests of the SM and may probe physics beyond the SM as discussed in [4] [7]. The forward backward asymmetry of the dileptons in their center of mass system as calculated in [4] is proportional only to the $Z$ and $W^+W^-$ exchange diagrams. Thus this observable is sensitive to any enhancement due to non standard effect. Experimentally the measurement of the short distance contribution is interesting if we are in a regime where the dilepton invariant mass is far below the $J/\psi$ and $\psi$' resonances. For the HERA-B experiment the most critical step is to accept this kind of events at the first level trigger. The actual lower cut on the dilepton invariant mass is 2.75 $GeV/c^2$. Hence the mass window for the measurement of the decays $B \to Xl^+l^-$ below the $J/\psi$ mass is quite tight and the expected reconstruction efficiency of these channels is lower than 2%. With the expected branching fractions $Br(B \to X_s e^+e^-) = (8.4 \pm 2.2) \cdot 10^{-6}$ and $Br(B \to X_s\mu^+\mu^-) = (5.7 \pm 1.3) \cdot 10^{-6}$ [4] and after collecting a few $10^9$ $B$ mesons the detection of the discussed channels could be possible with few tens of events. Since the HERA-B trigger is flexible one will investigate the possibility to increase the trigger efficiency of these channels based on high $P_\perp$mixed tracks trigger.

# 6 Conclusion

We have extended the HERA-B First Level Trigger scheme to accept radiative B decay events. The achieved FLT efficiency is better than 10% for the studied channel $B^0 \to K^*(892)\gamma$ and behaves accordingly for similar radiative $B$ decays. Assuming $3.7 \cdot 10^8$ produced $b\bar{b}$ pairs/year, we expect about 1000 events/year of the studied channel passing the FLT trigger and about 100 events after full reconstruction. This redesigned trigger enriches the HERA-B physics program by opening the possibility to extract the ratio $|V_{td}|/|V_{ts}|$ via the measurement of Br($B \to K^*\gamma$) and Br($B \to \rho\gamma$) which provides a constraint on the unitarity triangle. It will also allow to search for observation of $B_s$ and $\Lambda_b$ radiative decays.

# References


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