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B-meson tagging improvement using HCAL information

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The hadronic calorimeter longitudinal segmentation (in three segments) and granularity (0.1×0.1 cell size in the η, ϕ plane) could help the low p_T muon identification.

The idea to investigate the possibility to use the hadron calorimeter information for muon identification has arisen from the need to improve the B-meson tagging in the context of CP violation measurement in B decays. One of the most suitable decay channels for such studies is $B_d^0 \rightarrow J/\psi K_s$. The J/ψ can be recognised by its decay into a muon pair. B_d^0 mesons can be tagged by an inclusive single muon trigger with $p_T \geq 5$ GeV, assuming that the muon is identified in the muon detector. Muons with $p_T \leq 5$ GeV are with a high probability absorbed in the calorimeter. The background in this case is very large. It can be reduced by requiring for example the second muon to be also identified in the muon detector (i.e. $p_T \geq 5$ GeV), but this reduces strongly the signal. A better solution would be to lower the p_T threshold for the second muon identification. It is expected that $p_T \geq 3$ GeV muons are able to penetrate until the hadron calorimeter last depth. This last depth of hadron calorimeter presents a particular interest, because in this place the presence of a muon can be easily detected. The hadrons, with a high probability are already absorbed in front of it. Using the ATLAS simulation programs it was generated the calorimeter response to muons and pions at $\eta = 0.3$ for various p_T values: 2, 4 and 10 GeV. The distributions of the deposited energy in the last depth of the hadronic calorimeter, in fig.1, shows that one can separate the muons from the pions by taking into account only the information obtained from the last depth of the hadron calorimeter. One obtains rejection factors about 50 for the pions, while the survival probability for the muons is greater than 95% for $p_T = 4$ and 10 GeV and only 84% for $p_T = 2$ GeV.

From a $B_d^0 \rightarrow J/\psi K_s$, $J/\psi \rightarrow \mu^+\mu^-$ sample of Monte Carlo generated events, about 13% of them were found to have $E \geq 5$ GeV for both muons. When this condition is relaxed to $E \geq 3$ GeV for one of the muons, the fraction increases to 34%. So, if the calorimeter information will allow the B-meson tagging in the latter conditions, this could increase the signal by more than 2.5 times with a background considerably reduced in respect with single muon trigger case.

B-mesons are not seen as isolated particles in the calorimeter, because they are produced together with other particles in low p_T (in the range of $10 - 20$ GeV) b-quark jets. Therefore our problem can be formulated in the following way:

Is it possible to distinguish b-jets with two muons: one with $p_T \geq 5$ GeV and the other with $3 \leq p_T \leq 5$ GeV, from only one muon with $p_T \geq 5$ GeV b-jets?

Firstly, we tried to see if the use of calorimetric information can help to answer to a more simple question: to distinguish between no muon b-jets and one muon b-jets with $3 \leq p_T \leq 5$ GeV.

In the frame of ATLAS simulation programs $p_T = 20$ GeV single b-jets were generated at $\eta = 0.3$ using JETSET/PYTHIA generator. Jets with $0, 1, 2$ muons were generated using this generator facilities to force different decay modes. An additional file containing the muon information was created, which helped to operate selection of events with muons in different kinematical ranges. To answer to the question of b-jets separation when in the muon detector there is no signal (no muon, or muon absorbed in the calorimeter), the same criterium as in the case isolated particles was applied. The results are shown in the fig.2. In this case, a rejection factor of 23 for b-jets containing no muons was obtained, with a 90% survival probability for the b-jets containing a muon with $3 \leq p_T \leq 5$ GeV.

The same method cannot be applied to separate b-jets in the case of a signal in the muon detector (i.e. b-jets with one energetic muon, or b-jets with one energetic muon and one muon absorbed in the calorimeter). This is illustrated in fig.3, where one can observe that despite of a shift of the maxima of the two deposited energy distributions, there is a large overlap of them. A simple cut on deposited energy doesn't allow an effective separation as for the no signal in the muon detector case.

The situation can be improved if the individual cell information is used. In fig.4 is shown the number of active cells distribution in the last depth of the hadronic calorimeter when the total deposited energy in this depth is more than 0.2 GeV. By requiring to have more than two such cells, 65% of one muon b-jets are rejected at the cost of loosing only 10% b-jet events with two muons.

Finally, one can conclude that the obtained results point out on the calorimeter information potential utility to improve the B-meson tagging. Work is in progress to refine this analysis and to investigate how this separation depends on b-jet pseudorapidity η and what is the effect of some real life phenomena like photostatistics, electronics noise, or pile-up.

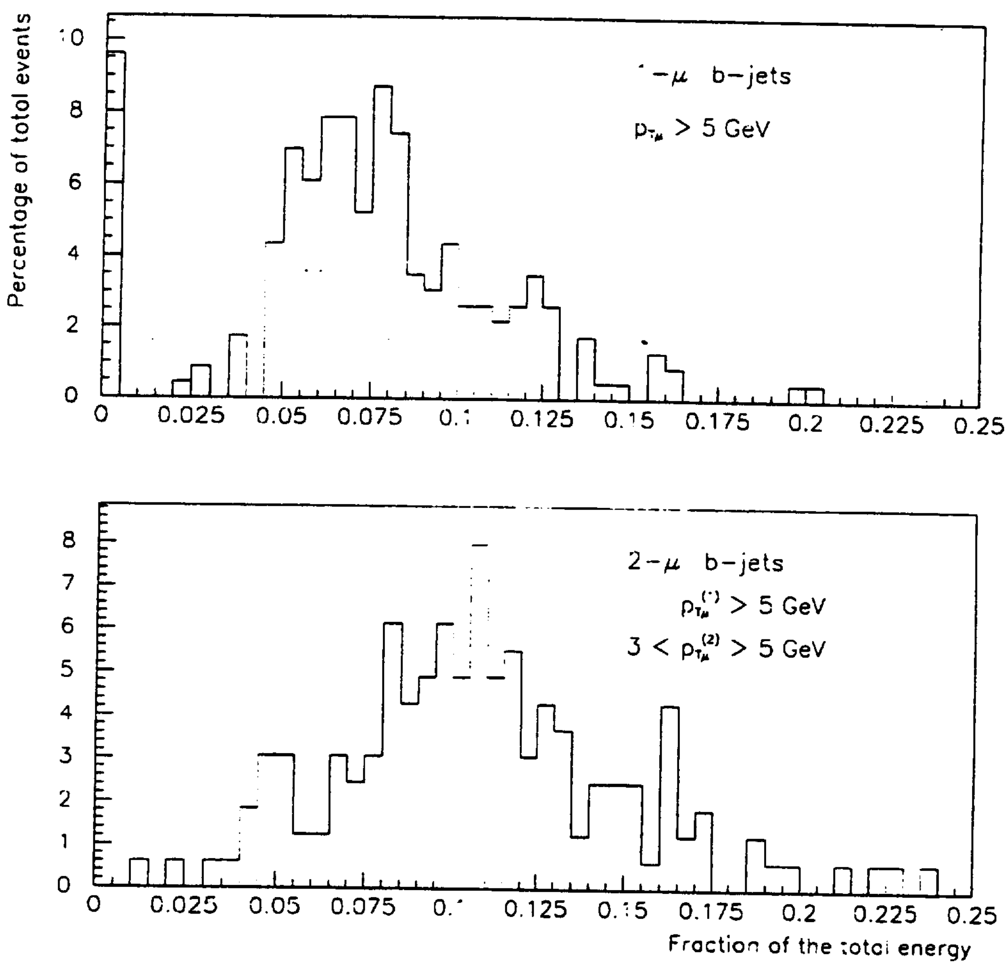

Figure 3: *Deposited energy in HCAL last depth by* $p_T = 20$ *GeV b-jets with a single muon signal in the muon detector*

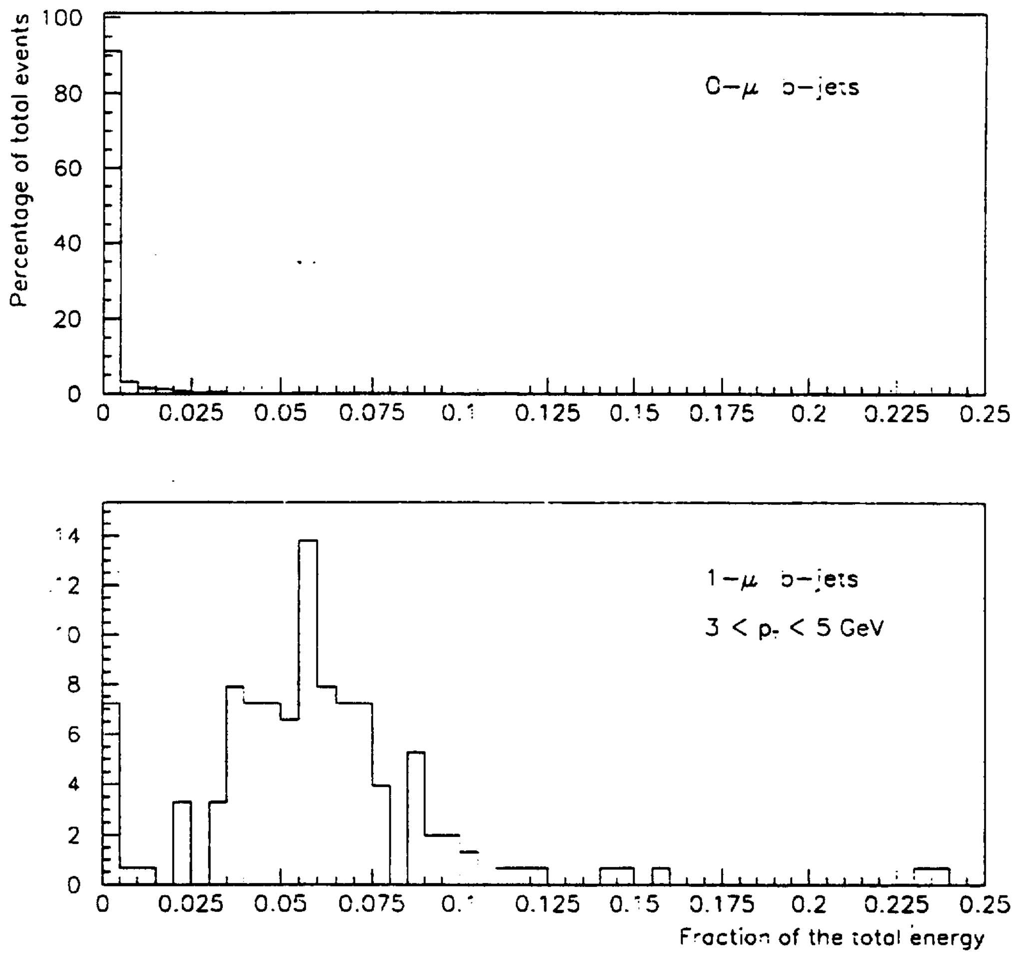

Figure 2: *Deposited energy in HCAL last depth by p_T = 20 GeV b-jets with no signal in the muon detector*