Trigger development studies on tau events at the *BelleII* experiment

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Abstract

In this report the development of a new Level 1 trigger for the *BelleII* experiment is studied using τ-pair events. The process $ee \rightarrow \tau[\rightarrow 1prong]\tau[\rightarrow 1prong]$ (1x1 topology) is considered while bhabha MC events are used as main background source. All the combinations of decays with the 1prong track being π, μ or e are taken into consideration. The development of a new trigger bit is based on calorimetric (ECL) information Finally we propose trigger requirements that would decrease the trigger rate and have high efficiency for most of the tau decays.

Contents

1 Introduction

The *BelleII* experiment at the SuperKEKB asymmetric e^+e^- collider is being made to search new physics beyond the standard model using large statistical sample (expected to collect 50 ab^{-1} of integrated luminosity). It is designed to collide electrons and positrons at the centre-of-mass energy of the Υ resonances. Most of the data will be collected at the Υ(4S) resonance, which is just above threshold for B-meson pair production where no fragmentation particles are produced. The accelerator is designed with asymmetric beam energies to provide a boost to the centre-of mass system. *BelleII* accelerator will produce a total of 5 x 10^{10} b, c and τ pairs over a period of 8 years. Due to the large number of events, the acquisition rate exceeds the capacity of data collection and data storage systems thus triggers are used to reduce the event rate.
During the data taking the trigger system of *BelleII* is used to identify interesting events. The trigger system is composed of two levels: hardware based, low level trigger (L1), and software based, high level trigger (HLT).The L1 is expected to reduce the event rate to a maximum of 30 kHz at the design luminosity of 6×10^{35} $cm^{-2}s^{-1}$, while the HLT would reduce it to a few kHz. L1 trigger is comprised of two primary components: a CDC track trigger and an ECL trigger. The ECL can generate fast trigger signals that can provide a highly efficient trigger for detector signatures containing both neutral and charged particles. Two complementary trigger schemes are present: a total energy trigger and an isolated cluster counting trigger. The ECL trigger system can also identify Bhabha events. Trigger is a delicate topic because we need to use it to cut a lot of background and still select our signal with very few information available. The first step of this work is to understand what are the dominant background sources. Since tau pair processes with 1x1 topology have a back-to-back kinematics, bhabha events are the major source of background. The cross section of bhabha events is very high (295.8 nb) with respect to the one of taupair (0.919 nb). This is the main difficulty in developing a trigger for tau decays with 1x1 topology.

2 Data samples description and tools

For our studies we only used MC samples to develop new trigger bits. Our $\tau\tau$ data-set is $10fb^{-1}$ integrated luminosity large while the bhabha one is $10pb^{-1}$ large.
The following τ decays topologies are investigated separately: $\tau[\rightarrow \pi\nu_\tau]$ $\tau[\rightarrow \pi\nu_\tau]$, $\tau \rightarrow [\mu\nu_\tau\nu_\mu]$ $\tau \rightarrow [\pi\nu_\tau]$, $\tau \rightarrow [e\nu_\tau\nu_e]$ $\tau[\rightarrow \pi\nu_\tau]$, $\tau \rightarrow [\mu\nu_\tau\nu_\mu]$ $\tau \rightarrow [\mu\nu_\tau\nu_\mu]$, $\tau \rightarrow [\pi\nu_\tau]$ $\tau \rightarrow [\mu\nu_\tau\nu_\mu]$ in order to understand if a specific channel needs a dedicated treatment with respect to the others. For our studies we used calorimetric variables, coming from the Electromagnetic CaLorimeter (ECL) of *BelleII*.

The list of the available variables that we investigated is in the following:

- $\Delta\Phi$: defined as the difference between $\Phi_{truck1\ cluster}$ and $\Phi_{truck2\ cluster}$, where $\Phi_{truck1\ cluster}$ ($\Phi_{truck2\ cluster}$) is the Φ coordinate of the clusters of track1 (track2) detected by the ECL[1];
- $\sum\theta$: defined as sum of $\theta_{truck1\ cluster}$ and $\theta_{truck2\ cluster}$, where $\theta_{truck1\ cluster}$ ($\theta_{truck2\ cluster}$) is the θ coordinate of the clusters of track1 (track2) detected by the ECL[1];

[1] As we don't have any angular information for tracks, we are estimating the angles using the ECL cluster positions.

- Cluster energy of tracks;
- Total cluster energy of the event.

For each topology we produced the distributions of the variables mentioned above.

3 Results

Our main purpose is to reduce the background contribution therefore we needed to study the distribution of the variables that can well separate the signal from the background. Some of the variables we considered can not be used to discriminate the signal from the bhabha background but can be of help to select the signal events and reject different background contaminations.
For every topologies mentioned in Sec.2 we produced the plots in Figures 1, 2, 3, 4, 5.
As we mentioned previously, the integrated luminosity for bhabha events is 10pb^{-1} and the signal has 10fb^{-1}, so we scaled bhabha 0.001 times. In this way we can compare them properly.

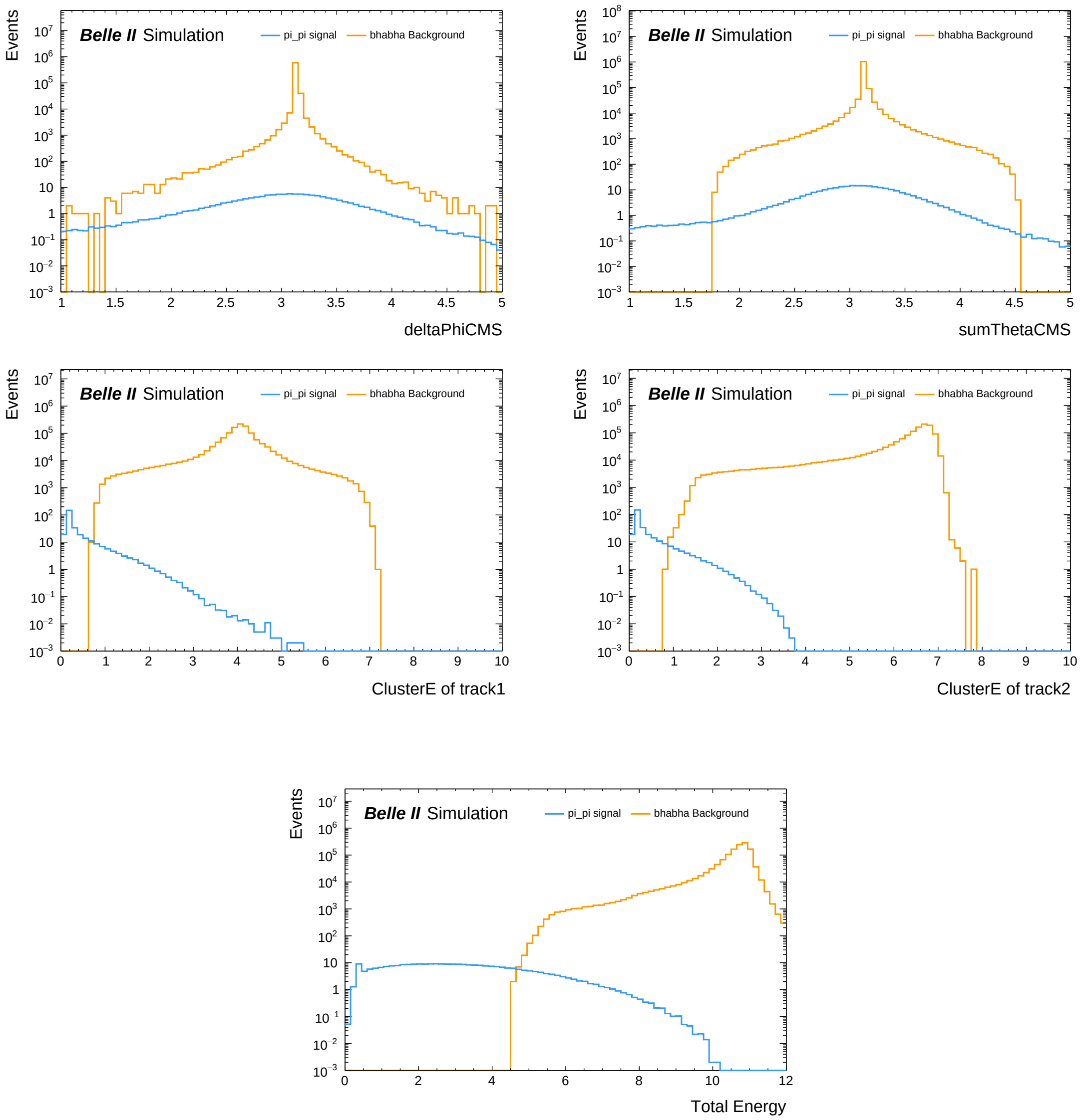

Figure 1: On the top the deltaPhi (left) and sumTheta (right) distributions are shown. In the center the clusterE of track1 (left) and track2 (right) are reported. On the bottom the total energy distribution is shown. All the plots refer to the $\pi\pi$ topology. We can see good discrimination using total energy and the clusterE of both tracks.

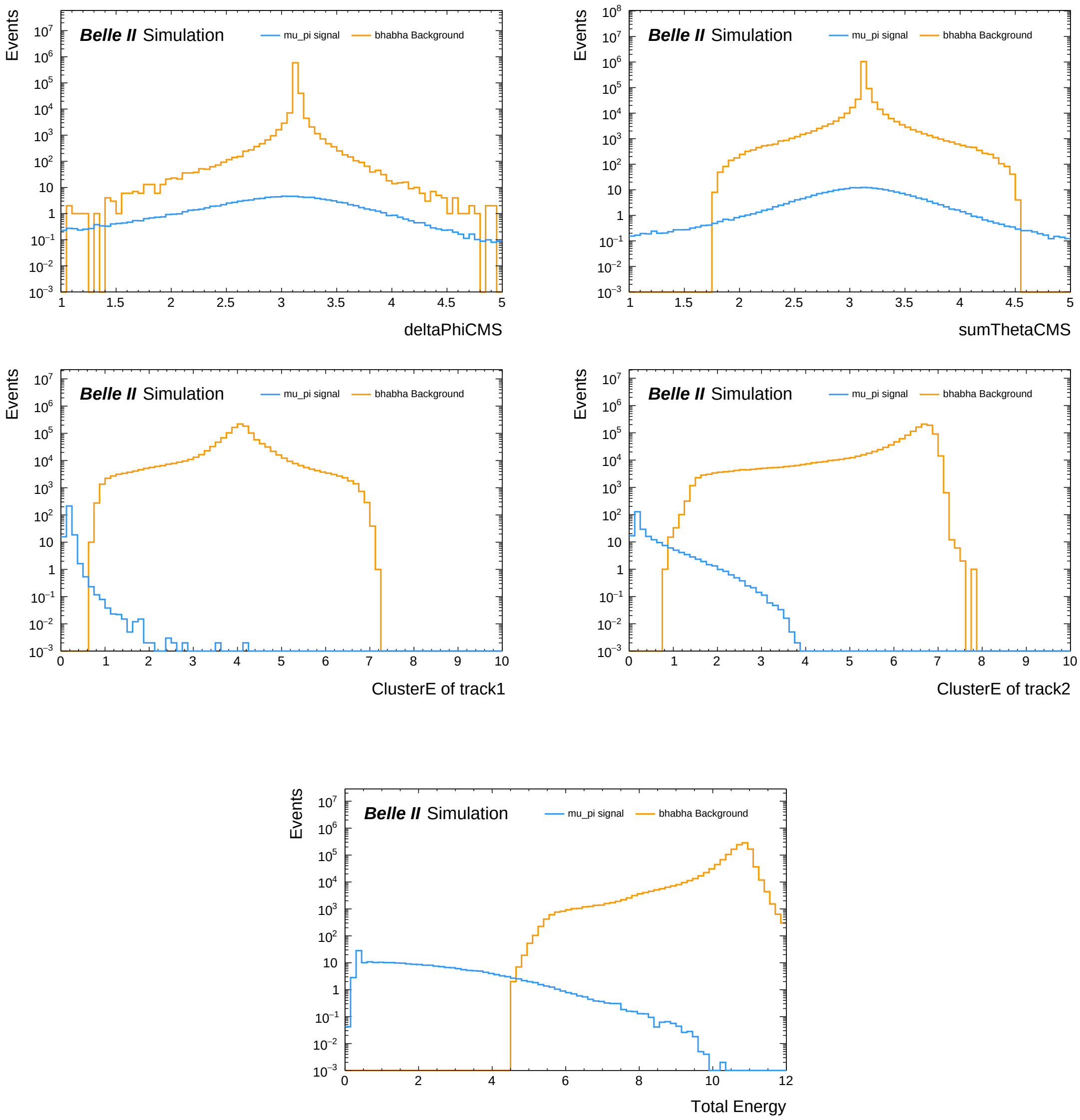

Figure 2: On the top the deltaPhi (left) and sumTheta (right) distributions are shown. In the center the clusterE of track1 (left) and track2 (right) are reported. On the bottom the total energy distribution is shown. All the plots refer to the $\mu\pi$ topology. We can see good discrimination using total energy and the clusterE of both tracks

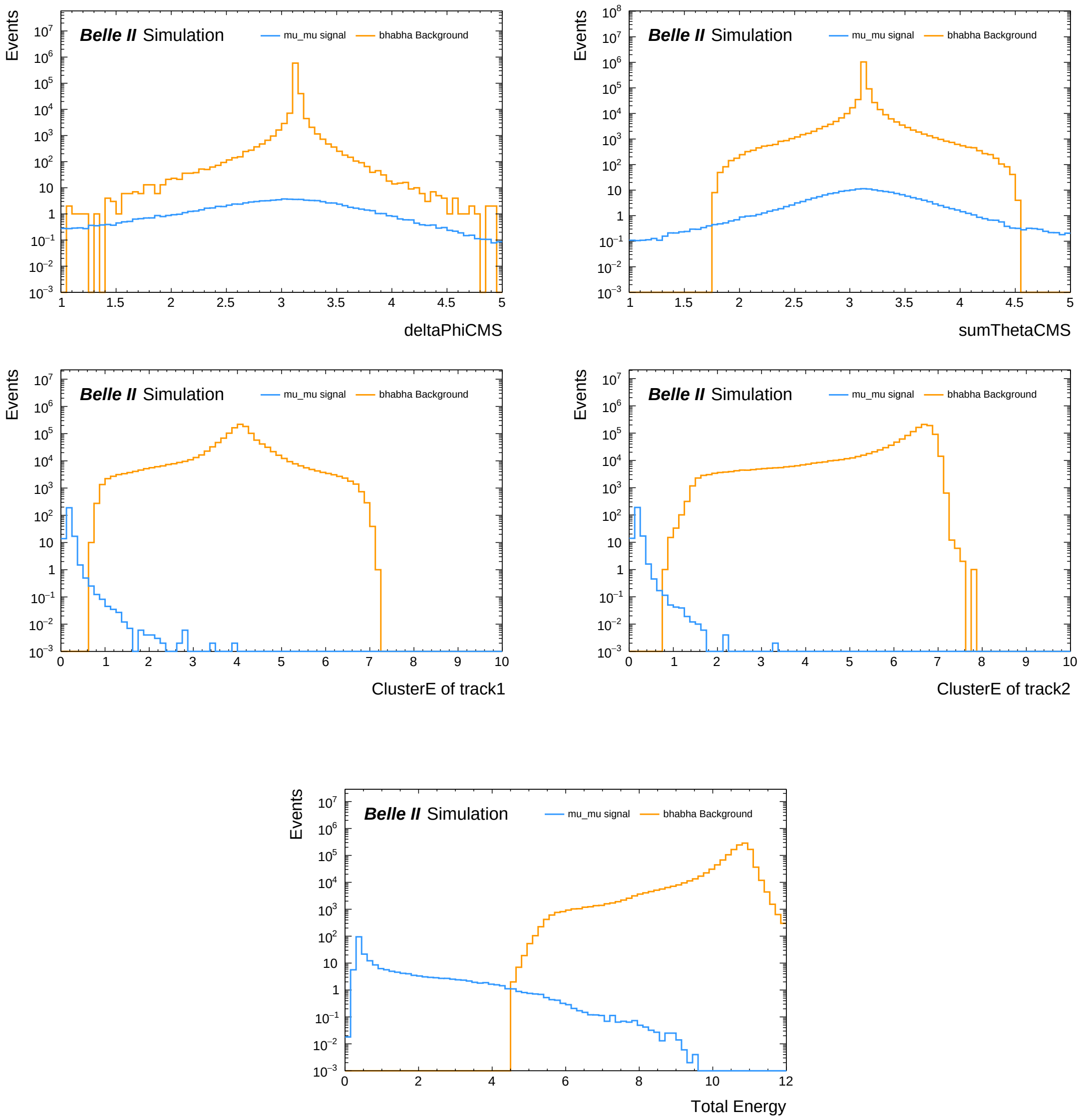

Figure 3: On the top the deltaPhi (left) and sumTheta (right) distributions are shown. In the center the clusterE of track1 (left) and track2 (right) are reported. On the bottom the total energy distribution is shown. All the plots refer to the $\mu\mu$ topology. We can see good discrimination using total energy and the clusterE of both tracks

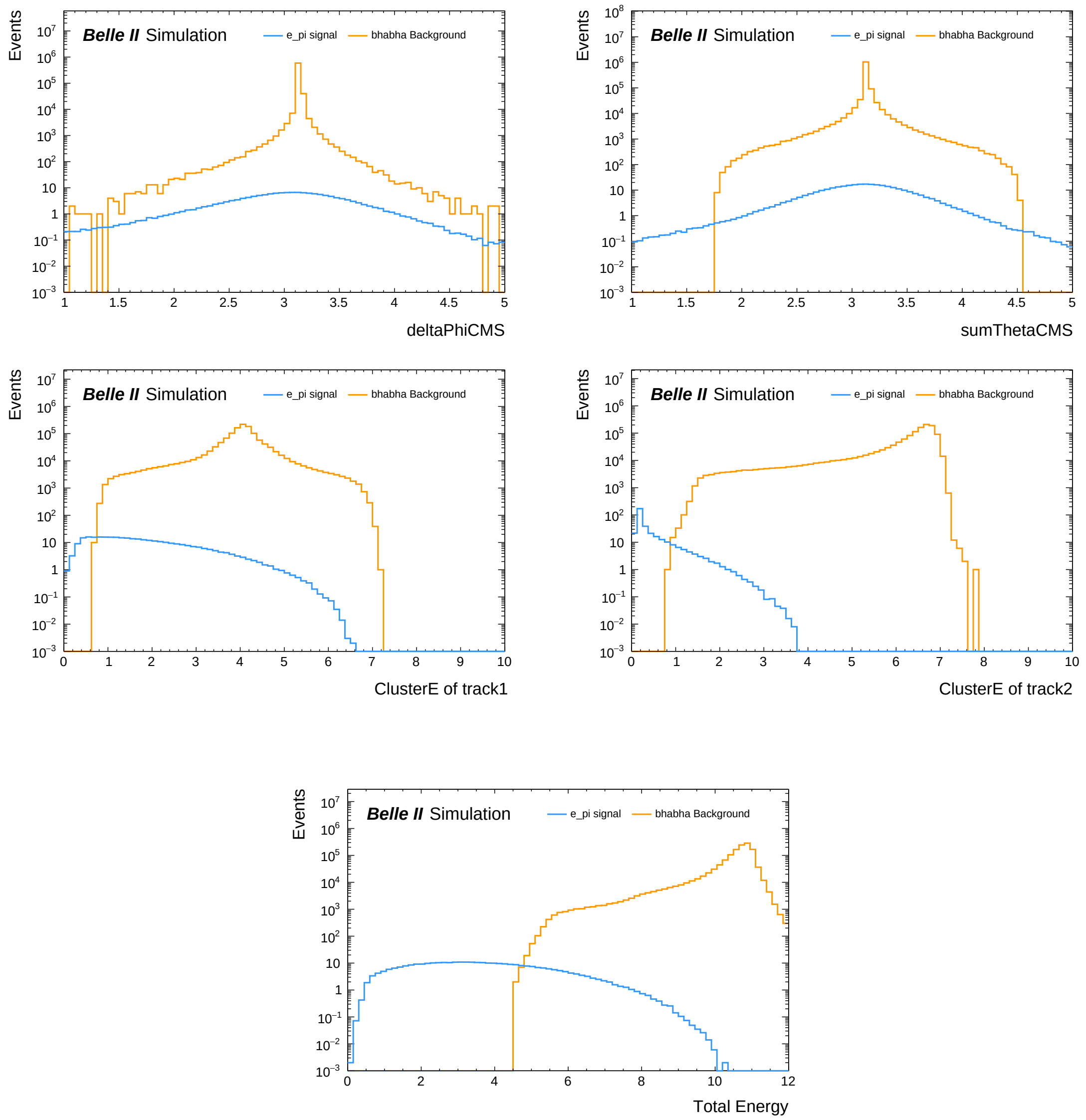

Figure 4: On the top the deltaPhi (left) and sumTheta (right) distributions are shown. In the center the clusterE of track1 (left) and track2 (right) are reported. On the bottom the total energy distribution is shown. All the plots refer to the $e\pi$ topology. We can see good discrimination using total energy and the clusterE of 1 track only.

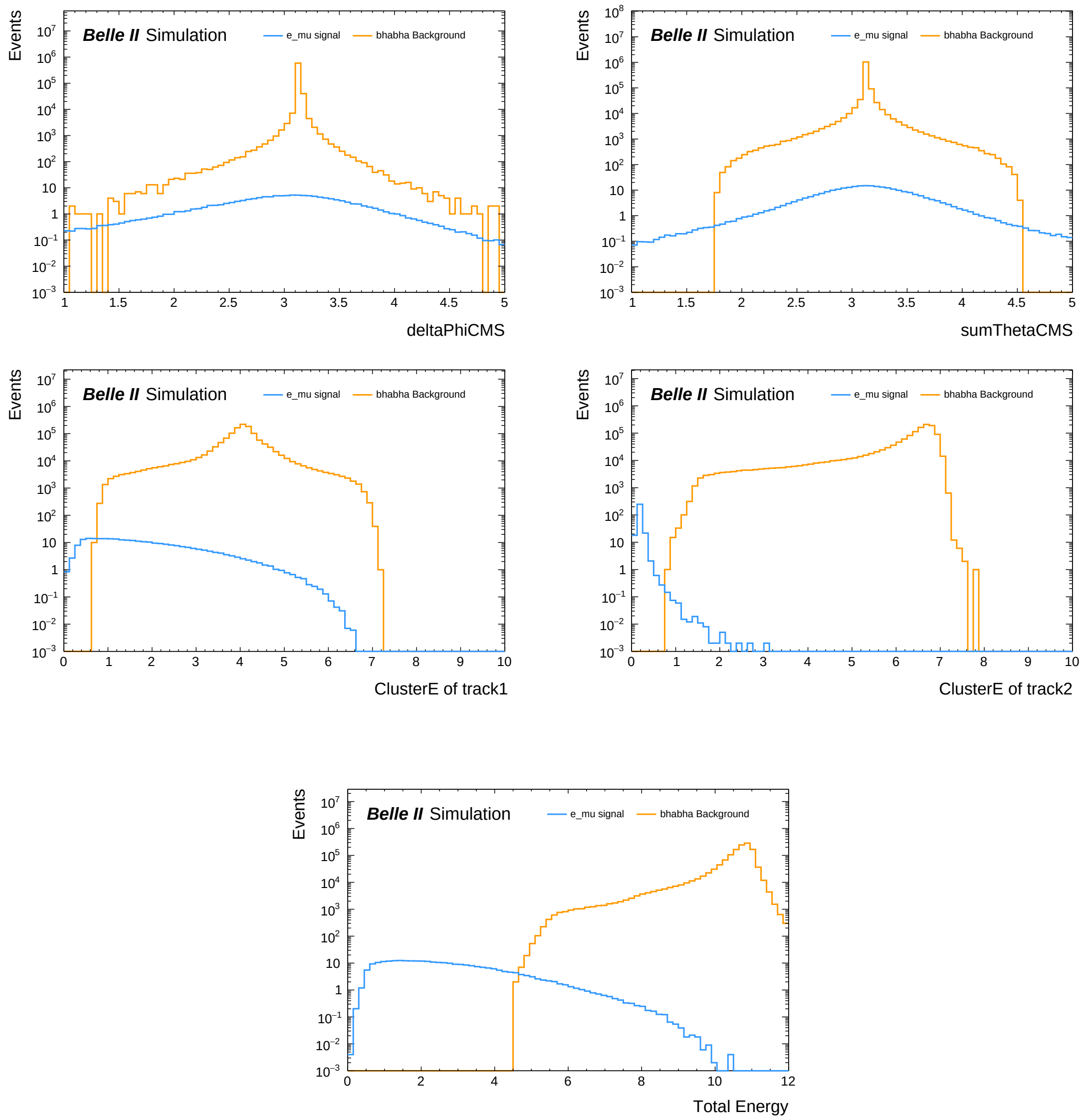

Figure 5: On the top the deltaPhi (left) and sumTheta (right) distributions are shown. In the center the clusterE of track1 (left) and track2 (right) are reported. On the bottom the total energy distribution is shown. All the plots refer to the $e\mu$ topology. We can see good discrimination using total energy and the clusterE of 1 track only.

For the angular variables we have selected the area around the signal peak, between 134° and 223 °, in order to pick back to back events (feature of the tau 1x1 topology). We choose a quite wide window on purpose because, along with the charged particles, in the tau events also neutral particles are produced; this means that the kinematics of the event is not perfectly back to back. For example in the case that the 2 tracks in the event are both pions, π^0s can originates from the τ decays and each of them then decay into 2 photons. Therefore, sometimes we could also have 2π and $2\pi^0$ (4γ). When we have an electron in the topology, we can not rely too much on the clusterE of the tracks because we would kill a lot of signal events. That's why in such cases we would like to ask for only one cluster with tight cuts. The total energy distribution can discriminate very well and we estimated a cut by simply looking at the distributions.

Following these results we can propose cuts that we can use to remove the bhabha contamination, therefore to reduce the trigger rate: see Tab.1. In conclusion we can say that the sum of theta and the delta phi variables are good to select back to back events while cluster energy of tracks and total energy can be used to distinguish between signal and background. Different cuts are proposed for each of the channel we investigated, since the distributions seem to be too different between each other.

	ΔΦ [rad]	*∑θ [rad]*	N Clusters	Total energy [Gev]	*Cluster E [Gev]*
$\tau_1 \to \pi - \tau_2 \to \pi$	2.3<ΔΦ <3.9	2.3<∑θ <3.9	N < 6	E < 8	0.18 < E 1CL < 1 0.18 < E 2CL < 1.9 0CL w/ E > 3.5
$\tau_1 \to e - \tau_2 \to \pi$	2.3<ΔΦ <3.9	2.3<∑θ <3.9	N < 5	E < 8	0.18 < E 1CL < 1.9
$\tau_1 \to \mu - \tau_2 \to \pi$	2.3<ΔΦ <3.9	2.3<∑θ <3.9	N < 5	E < 6	0.18 < E 1CL < 0.6 0.18 < E 2CL < 1.9 0CL w/ E > 3.5
$\tau_1 \to \mu - \tau_2 \to \mu$	2.3<ΔΦ <3.9	2.3<∑θ <3.9	N < 3	E < 5	0.18 < E 1CL < 0.6 0.18 < E 2CL < 0.6 0CL w/ E > 3.5
$\tau_1 \to e - \tau_2 \to \mu$	2.3<ΔΦ <3.9	2.3<∑θ <3.9	N < 3	E < 8	0.18 < E 1CL < 0.6

Table 1: Cuts for each topology and corresponding variable. N cluster is used as an additional upper limit cut (can be avoided). The lower value of 0.18 for ClusterE is chosen in order to include the muons, that typically leave 0.2GeV in the calorimeter.

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