Conversion Veto Analysis

Vassu Doomra, Roli Esha, Axel Drees

1 Introduction

The low invariant mass region ($0 < m_{ee} < 1$ GeV) in the dielectron mass spectrum is dominated by photon conversion background from the Silicon Vertex Detector (VTX) detector (due to the small opening angle of the e^+e^- pair). In the intermediate and the high mass region, random combinations of e^+ and e^- tracks from different photon conversions contaminate the spectrum. Given the limited acceptance of the PHENIX central arms, the probability of both the conversion tracks being reconstructed by the DC is rather low. Thus it becomes very important to develop a conversion rejection technique that can remove conversions on a track by track basis. In this analysis note, we present such a technique utilizing the VTX detector itself.

2 Basic Outline of the Idea

If we run single photon simulations through the PISA framework and require that both the conversion tracks are reconstructed by the Drift Chamber, we can extract information on the average opening angle between the electron and the positron track at the various VTX layers as a function of the parent photon p_T. Figure 1 shows the variation of opening angle with the p_T of the photon and the corresponding average values are shown in Table 1 for conversions happening at the beam pipe and the innermost VTX layer.

p_T (GeV/c)	B1 [mrad]	B2 [mrad]	B3 [mrad]
1.00	4.09	30.97	51.53
5.00	2.36	8.68	13.19

Table 1: Average opening angle as a function of the parent photon p_T at the B1, B2 and B3 VTX layers.

The sensor size in the ϕ direction at B1 VTX layer is 50 μm. The B1 layer is a radial distance of 5.13 cm from the origin (0, 0). And that translates to a sensor ϕ extent of ≈ 1 mrad. By a similar argument the sensor size in the ϕ direction for the outer two VTX layers is of the order of 0.7 mrad. Thus ideally if the VTX detector works perfectly and there are no dead regions, we will always find a neighbouring hit in the vicinity of a conversion track even if

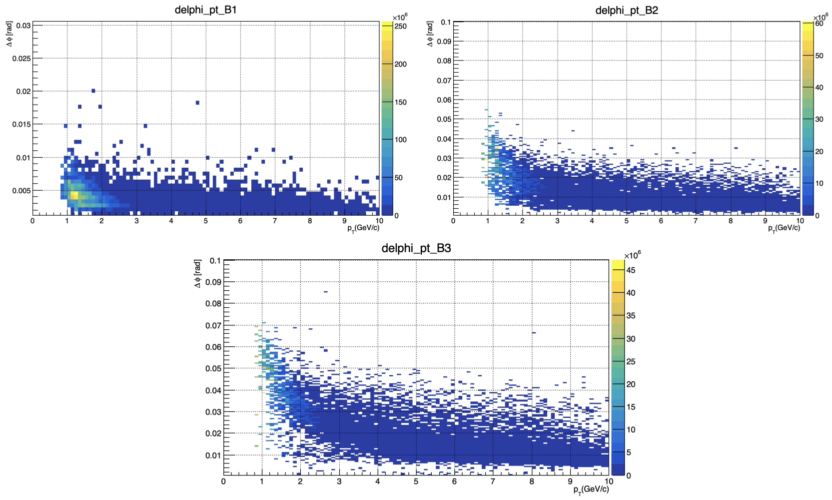

Figure 1: Opening angle as a function of the parent photon p_T at the B1, B2 and B3 VTX layers.

it's partner track was not reconstructed by the DC (the VTX detector has a much larger ϕ acceptance that the DC). For the high p_T photons ($p_T > 5$ GeV or so) however, we will have to rely more on the B2 and the B3 layers to find a neighbouring hit since the $\Delta\phi$ between the the two conversion tracks is of the same order as the sensor size at the B1 layer.

Also shown are the dz distributions (Figure 2) at the B1, B2 and B3 VTX layers, where dz is the difference between the z hit location of the electron and positron tracks. In the PHENIX convention, the magnetic field points in the +z direction and thus the conversion tracks should ideally only bend in the ϕ direction and not in the z direction. However the multiple scattering can lead to a non-zero dz between the two conversion tracks.

3 Wrong Associations of VTX Hits and DC Tracks

The DC tracking algorithm assumes that all the tracks originate from the interaction vertex determined by the BBC. However most of the photon conversions happen at the VTX and thus there is a significant probability that a given conversion track will be wrongly associated with the VTX hits produced by it's partner track. Figure 3 illustrates one such scenario. In this figure a photon gets converted at the innermost VTX layer. The electron-positron tracks represented by red are the true conversions and the ones represented by blue are the reconstructed DC tracks. Geometrically, the radial location of the crossing point can be anywhere beyond R_{B0}, the radius of the innermost B0 layer, for a conversion happening at the innermost layer and that depends upon the

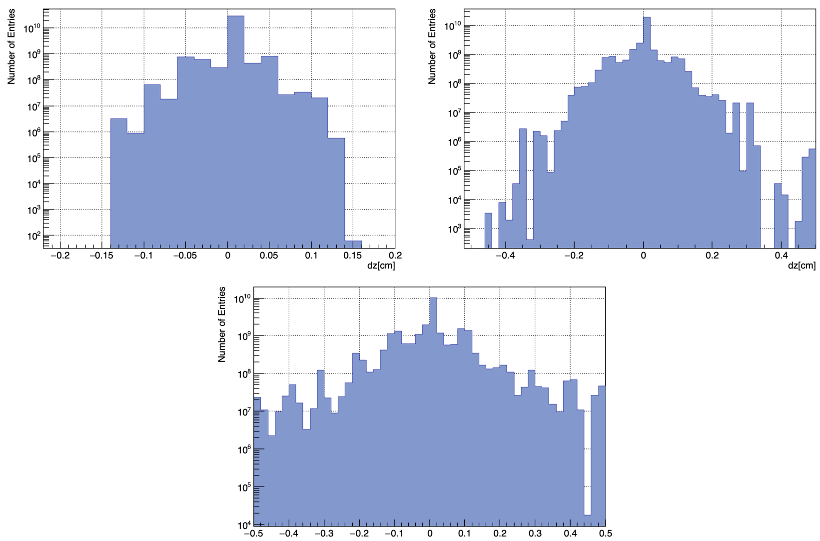

Figure 2: dz distribution at the B1, B2 and B3 VTX layers.

reconstructed p_T of the tracks.

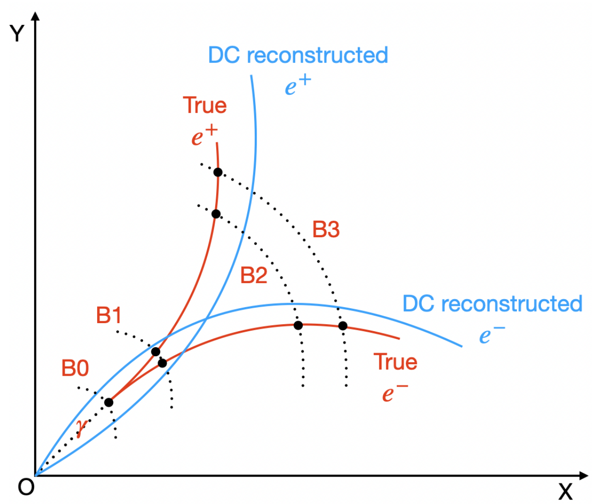

Figure 3: A cartoon illustrating the possibility of wrong VTX hits assigned to a conversion track

However these wrong associations will not limit our ability to reject conversions on a track by track basis as we will see in the following sections.

4 Veto Windows: Single Photon Simulations

The following plots show $\Delta\phi = \phi^{hit}_{asso}$ - $\phi^{hit}_{neighbour}$ as a function of the p_T of the reconstructed track, where ϕ^{hit}_{asso} and $\phi^{hit}_{neighbour}$ represents the ϕ of the VTX hit associated with the track and that of the neighbouring hit respectively. In this convention, for the electron (positron) tracks $\Delta\phi$ must be positive (negative) with the B field pointing in the +z direction and thus any negative (positive) $\Delta\phi$ component will represent mis-associations as discussed in the previous section. In producing these plots, we have put a dz cut of 0.1 cm on the neighbouring hits for the B1 layer and 0.2 cm for the outer two VTX layers.

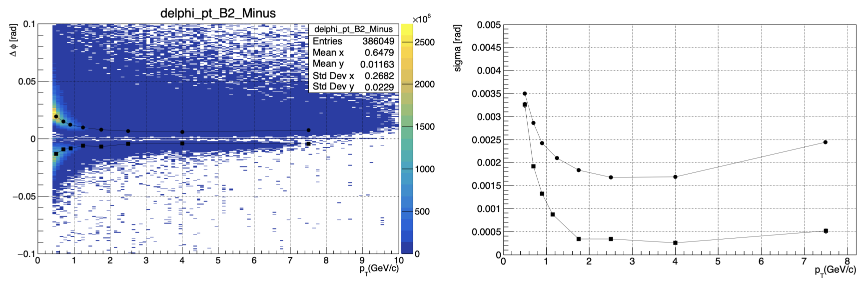

Figure 4: $\Delta\phi$ as a function of p_T at the B2 layer on the left and the corresponding sigma vs p_T on the right for the electron tracks.

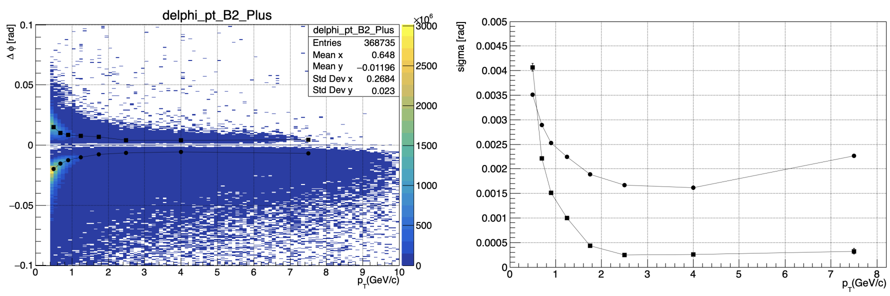

Figure 5: $\Delta\phi$ as a function of p_T at the B2 layer on the left and the corresponding sigma vs p_T on the right for the positron tracks.

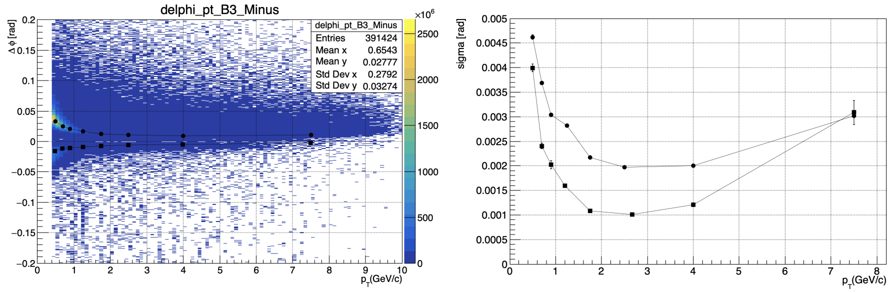

Figure 6: $\Delta\phi$ as a function of p_T at the B3 layer on the left and the corresponding sigma vs p_T on the right for the electron tracks.

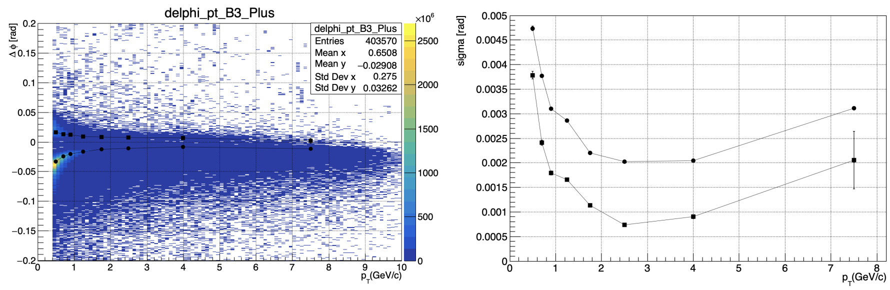

Figure 7: $\Delta\phi$ as a function of p_T at the B3 layer on the left and the corresponding sigma vs p_T on the right for the positron tracks.

4.1 Understanding sigma from these results

In order to have a rough estimate of what sigma means, let's have a look at one particular case. In Figure 8 the $\Delta\phi$ distribution is fitted with a landau function in the p_T range from 1.0-1.5 GeV/c for electron tracks at the outermost VTX layer. 10 sigma covers around 89% and 15 sigma covers around 93% of the total area under the curve.

5 Confirmation of the Veto Windows

In order to confirm the validity of the our veto windows we perform various tests which are listed below:

- Applying the veto windows back to the single photon simulations.
- Applying the veto windows to the hadron tracks in real data.
- Applying the veto windows to conversion tracks in real data identified using Wenqing's Algorithm.

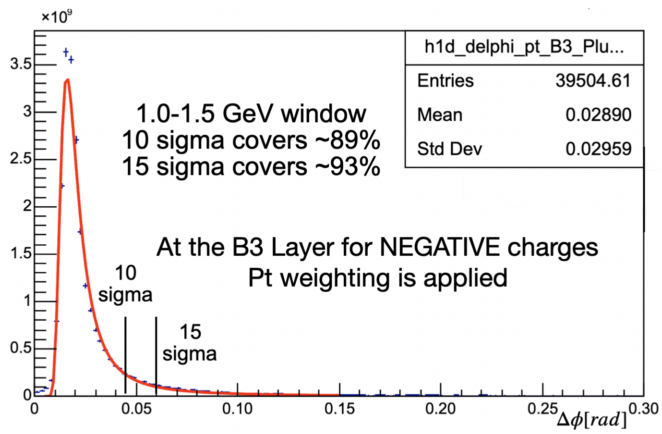

Figure 8: $\Delta\phi$ in the p_T window (1.0, 1.5) GeV/c for electron tracks at the B3 layer fitted with a landau distribution.

5.1 Veto Confirmation: Single Photon Simulations

Figure 9 shows the result of applying our veto windows in both single photon simulations and in data for the hadron tracks (Run15 p+p data at 200 GeV). As can be seen with the 15 sigma windows we are rejecting around 86% conversion tracks whereas loosing only around 4% hadron/primary tracks in data. This loss of hadron tracks can have two contributions: hadronic interactions with the VTX material resulting in delta rays or random neighbouring hits in the vicinity of a hadron track. We can rely on single π^+/π^- simulations to extract the effect of hadronic interactions. The results from single π^+/π^- simulations suggests that we loose around 0.2% of our tracks due to our veto windows which implies that the major contribution is coming from the presence of random neighbouring hits in the vicinity of a hadron track.

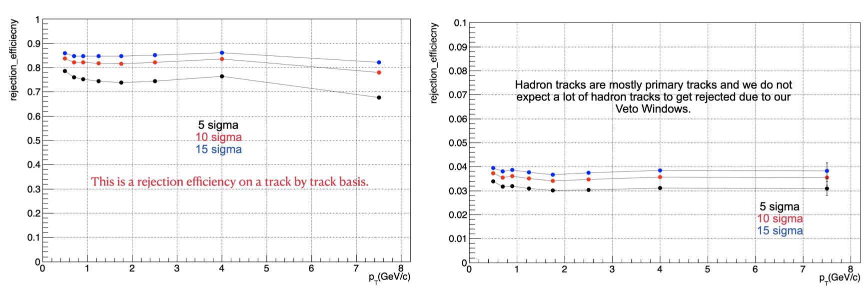

Figure 9: Rejection efficiency as a function of the p_T of the tracks for single photon simulations (on the left) and for the hadron tracks in data (Run 15 p+p) (on the right).

5.2 Veto Confirmation: Conversions found using Wenqing's Algorithm in Data

Wenqing's algorithm for finding conversions relies on both the conversion tracks being reconstructed by the DC. We apply this algorithm with the dzed cut to Minimum Bias Run 15 p+p data set and obtain the set of events with possible conversions as well as their pair p_T. Figure 10 shows the distribution of the number of possible conversion pairs found using Wenqing's algorithm and their corresponding pair p_T distribution in the Run15 data set.

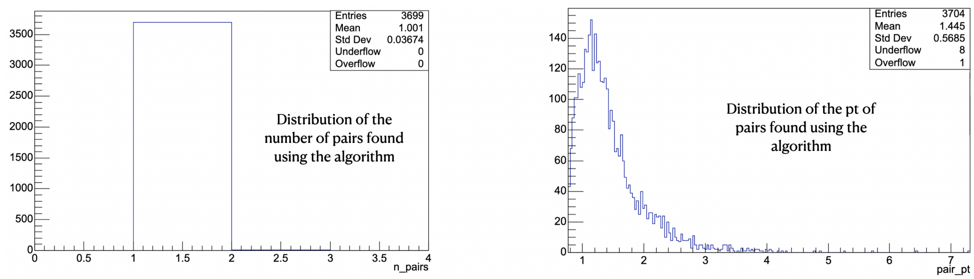

Figure 10: Shown are the N_{pair} distribution (on the left) and the pair p_T distribution on the right obtained by applying Wenqing's algorithm to Minimum Bias Run15 p+p data set.

As can be seen most of the events have only one such pair. Next we apply our Veto Windows to these tracks that we have found and see how it performs.

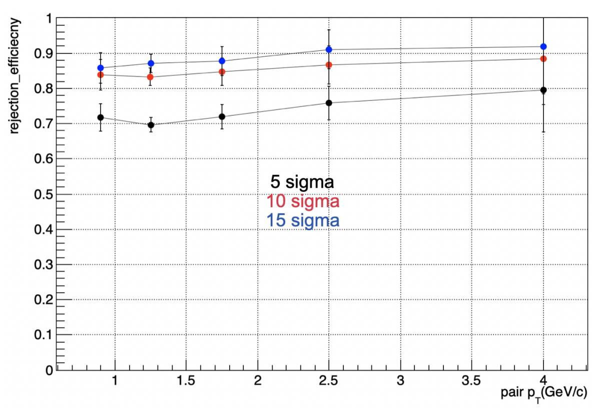

Figure 11: Result of applying our Veto Windows on tracks that passed Wenqing's algorithm and thus can be tagged as possible conversions. The rejection efficiency is plotted a s function of pair p_T.

As can be seen from Figure 11 that with the 15 sigma window we are able to reject around 90% of those tracks which is close to what we would have expected.