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Analysis Note

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HEEP selection with impact parameter (dxy) and photon conversion rejection

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Abstract

Two methods have been proposed by the EGAMMA POG to improve electron identification in the analysis of 2012 data: impact parameter (IP) dxy and photon conversion rejection tool. The main aim of these two methods is to select electrons coming only from hard electromagnetic interaction. In this analysis note we study the efficiency of these two methods in the framework of HEEP selection V.4.

1 Introduction

The work presented in this analysis note is to study new cuts, based on the methods of impact parameters and photon conversion rejection tool which are proposed by EGAMMA POG [1], in the framework of HEEP (High Energy Electron Pairs) selection. The main target of this analysis is to reduce the contamination of high energetic electrons originating from decays of particles in QCD events and from converted photons from γ + jets background. The HEEP selection was originally introduced for the search of heavy resonances decaying into electron pairs by new physics beyond Standard Model [2]. It is also used for search of W′ [3] and heavy neutrino [4].

The Monte Carlo (MC) and data samples used in this analysis are described in section 1, together with the event selection.

The definitions of the impact parameter (dxy) [5] are introduced in section 2, respectively. The efficiency measurements of these variables with respect to Drell Yan MC and background are presented in the same section.

In section 3, we give the definition of the photon conversion rejection tool [6], and investigate how this cut can affect on the efficiency measurements.

The study based on the efficiency measurements of the cut based on the number of missing hits in the inner most track layer is presented in section 4

The comparison between data and Drell Yan MC is exposed in section 5.

The conclusion of this study is presented in section 6.

1.1 Monte Carlo (MC) data samples

The Summer12 (reconstructed with CMSSW software, version 5.2.x) Monte Carlo simulated samples are used:
(1) for Drell Yan (DY) samples;
/DYToEE-M-20-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-120-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-200-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-500-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-800-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-1000-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,

(2) for QCD background EM Enriched samples are used;
/QCD-Pt-80-170-EMEnriched-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/QCD-Pt-170-250-EMEnriched-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/QCD-Pt-250-350-EMEnriched-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/QCD-Pt-350-EMEnriched-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,

(3) for γ+jets background EM Enriched samples are used;
/G-Pt-120to170-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/G-Pt-170to300-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/G-Pt-300to470-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/G-Pt-470to800-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM.
The cross sections of listed Monte Carlo samples are given in [2].

For data, the following datasets have been used:
/Photon/Run2012A-13Jul2012-v1/AOD,
/DoublePhoton/Run2012B-13Jul2012-v1/AOD,
/SinglePhoton/Run2012C-PromptReco-v1/AOD,
/SinglePhoton/Run2012C-PromptReco-v2/AOD.
The good certified runs were selected via the following JSON file "Cert-190456-202016-8TeV-PromptReco-Collisions12-JSON.txt", corresponding to an integrated luminosity of about 10.4 fb^{-1} at 8 TeVcenter of mass energy.

1.2 Event selection and N-1 efficiency

Monte Carlo and data samples are required to pass HEEP selection v.4 defined in [2]. The main cut is that the electrons p_t should be higher than $35~\mathrm{GeV}/c$ in both ECAL barrel (EB) and ECAL endcaps (EE).

N-1 efficiency is computed according to the following definition

$$\text{Efficiency(N-1)} = \frac{\text{Nb. of electrons passing HEEP and the studied cut}}{\text{Nb. of electrons passing HEEP only}} \quad (1)$$

2 Impact parameter (dxy)

The following definitions is used for the impact parameter (dxy) [5]:

$$\text{dxy} = [(\text{ele.vy()} - \text{vtx.y()}) \times \text{ele.px()} - (\text{ele.vx()} - \text{vtx.x()}) \times \text{ele.py()}]\,/\text{ele.pt()}, \quad (2)$$

where ele.vx() and ele.vy() are respectively the x and y coordinates of the electron position calculated by the Gsf algorithm [7], while vtx.x() and vtx.y() are the x and y coordinates of the primary vertex. The variables ele.px() and ele.py() are electron momentum components in x and y coordinates, and ele.pt() is the transverse momentum of the electron.

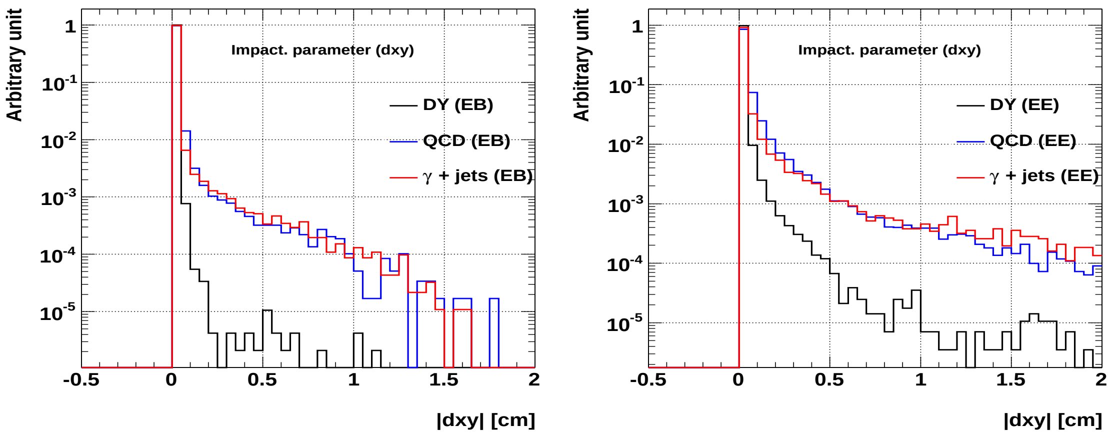

Figure 1: Distributions of the absolute value of impact parameter (dxy) in ECAL barrel (left plots) and ECAL endcaps in (right plots), for the electron candidates passing HEEP selection v.4.

Figure 1 presents the distribution of the absolute value of impact parameter (dxy) in ECAL barrel ”EB” (left plots) and ECAL endcaps ”EE” in (right plots), for the electron candidates passing HEEP selection v.4. In Figure 2 the same distributions are plotted, but with removing a cut on missing hits in the inner most layers of the tracker from HEEP selection v.4. This cut, proposed in a former study [8], affects very slightly the efficiency.

In Figs. 1 and 2 the distributions of both QCD and γ+jets backgrounds are characterized by bigger and longer tails than that of the Drell Yan distribution. This discrepancy between the Drell Yan distribution and backgrounds distributions, shows that the impact parameter (dxy) could be good cut to reduce the contamination of QCD and γ+jets backgrounds.

2.1 N-1 efficiency measurement of dxy variable versus E_T

Fig. 3 shows the distributions of N-1 efficiency for the impact parameter (dxy) versus the transverse energy E_T in ECAL barrel, for the electron candidates passing HEEP selection v.4; for $|\text{dxy}| < 0.01$ (left plots), and for $|\text{dxy}| < 0.02$ (right plots). Drell Yan MC sample is shown as black circles, QCD background is shown as blue boxes, while γ+jets background is presented as red circles.

In Fig. 4, we present the same distributions as those seen in Fig. 3, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

In Table 1, N-1 efficiency is illustrated for the impact parameter (dxy) for electrons passing full HEEP selection v.4, for different MC samples (first column), for two different cut values of the parameter (dxy) in EB. While in

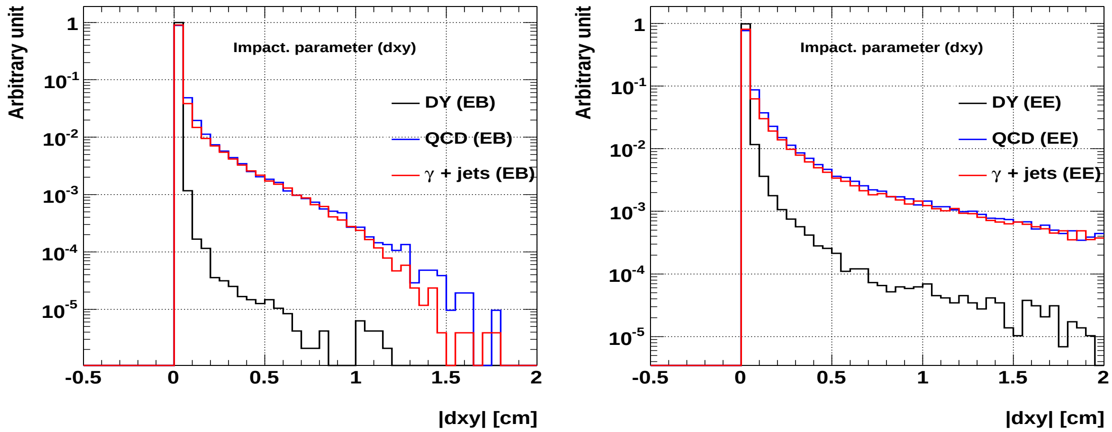

Figure 2: Same distributions as those seen in Fig. 1, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

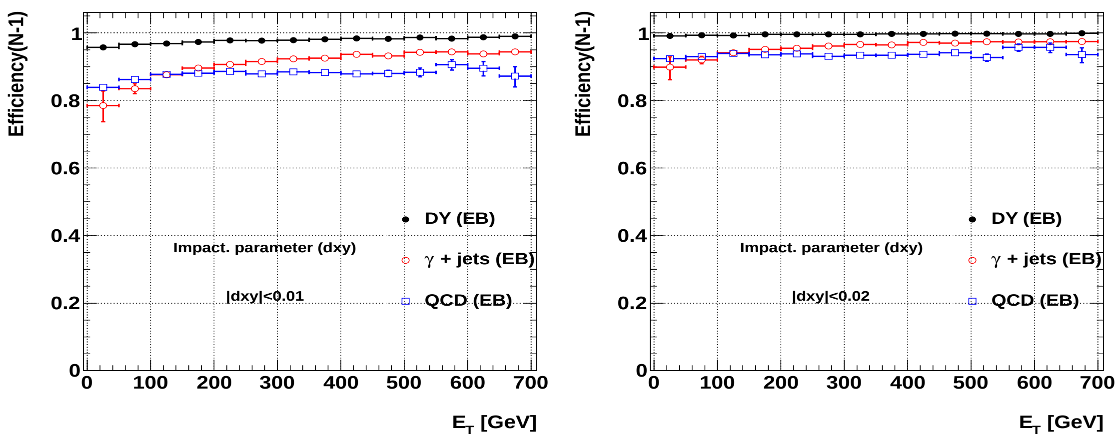

Figure 3: Distributions of N-1 efficiency for the impact parameter (dxy) versus the transverse energy E_T in the ECAL barrel, for the electron candidates passing HEEP selection v.4; with two different cut values on |dxy|; $|\text{dxy}| < 0.01$ (left plots), and for $|\text{dxy}| < 0.02$ (right plots).

$\lvert\text{dxy}\rvert <$	0.01	0.02
	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL barrel)
Drell Yan	96.43 ± 0.03	99.25 ± 0.01
QCD	87.04 ± 0.15	93.27 ± 0.11
γ+jets	91.44 ± 0.10	96.09 ± 0.07

Table 1: N-1 efficiency is presented for the impact parameter (dxy) for electrons passing full HEEP selection v.4, for different MC samples (first column), for $|\text{dxy}| < 0.01$ in EB (second column), $|\text{dxy}| < 0.02$ in EB (third column). Errors are statistical only.

Table 2 we repeat the same measurements, in EB, but with removing the cut on missing hits in the inner most layers of the tracker from HEEP selection v.4. The values mentioned in Tables 1 and 2 are summarised in Fig. 5.

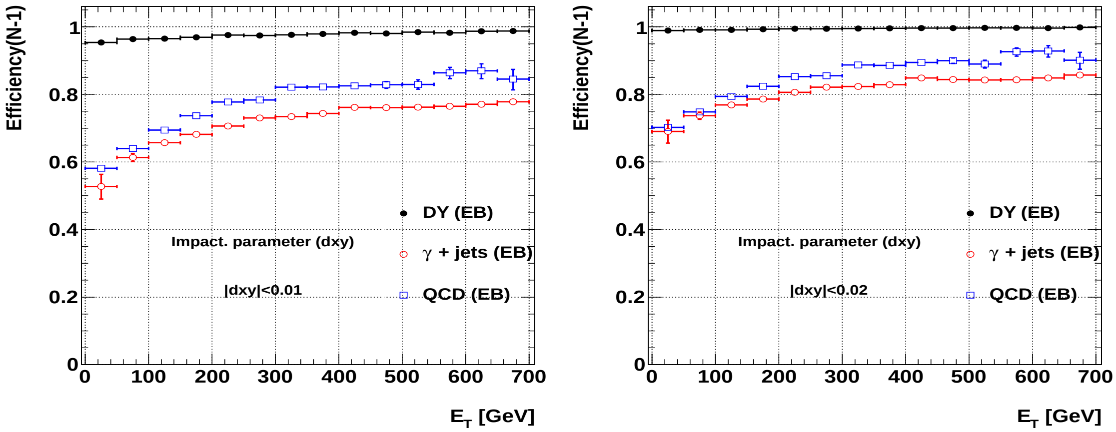

Figure 4: Same distributions as those seen in Fig. 3, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

$\lvert dxy \rvert <$	0.01	0.02
	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL barrel)
Drell Yan	96.41 ± 0.03	99.07 ± 0.01
QCD	69.70 ± 0.17	79.33 ± 0.14
γ+jets	72.10 ± 0.10	81.60 ± 0.08

Table 2: Same as in Table 1, except that the cut on missing hits in the inner most layers of the tracker was removed from the HEEP selection v.4.

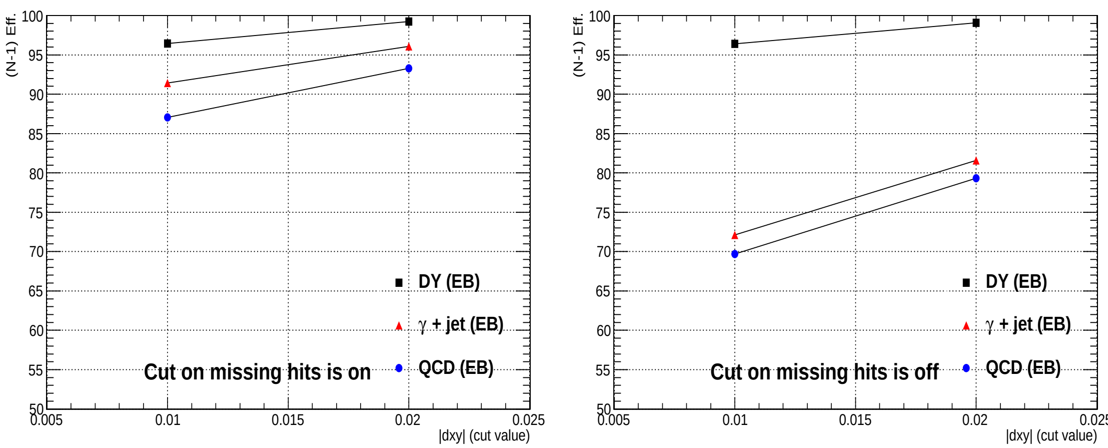

Figure 5: N-1 efficiency is presented for the impact parameter (dxy) for two different cut values of the parameter (dxy) in EB; for electrons passing full HEEP selection v.4 (left plot), and when the cut on missing hits in the inner most layers of the tracker is removed from the from HEEP ID (right plot).

The comparison between Tables 1 and 2 shows that the efficiency of this impact parameter (dxy) cut on the Drell Yan samples is not sensitive to adding or removing the cut on missing hits. While the rejection power of this cut, on both QCD and γ+jets background, is sensitive to the cut on missing hits, since for the QCD the rejection power increased by 17% in EB for $\lvert dxy \rvert < 0.01$ and 14% in EB for $\lvert dxy \rvert < 0.02$. While it increases by 19% in EB for

$|dxy| < 0.01$ and 15% in EB for $|dxy| < 0.02$ for γ+jets samples.

It is also shows that the efficiency of this impact parameter (dxy) cut on the Drell Yan samples is higher with the use of standard EGAMMA cut value (i.e. $|dxy| < 0.02$) by 3% in EB.

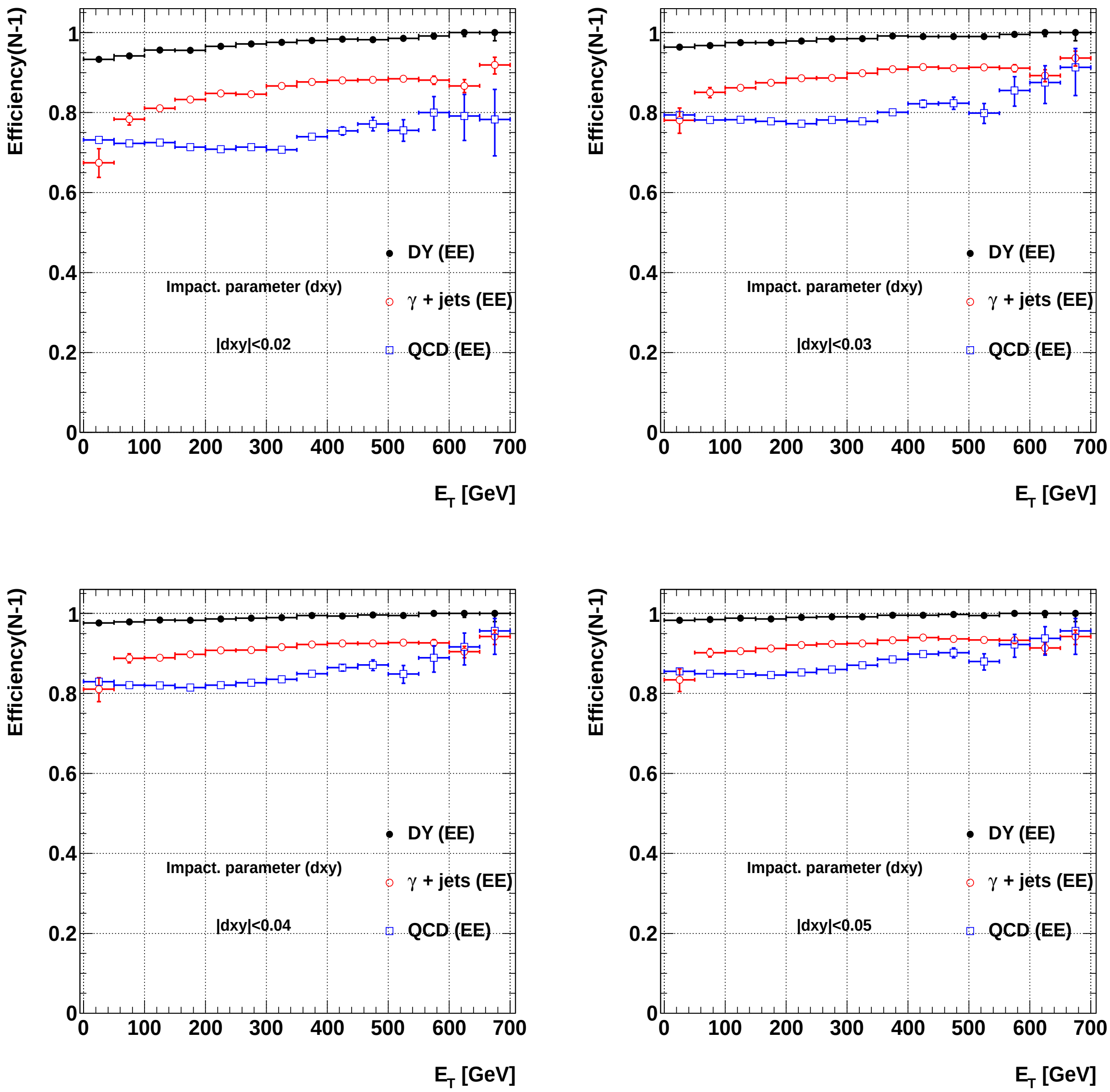

Figure 6: Distributions of N-1 efficiency for the impact parameter (dxy) versus the transverse energy E_T in the ECAL endcaps, for the electron candidates passing HEEP selection v.4; with different cut values on $|dxy|$; $|dxy| < 0.02$ (top left plots), $|dxy| < 0.03$ (top right plots), $|dxy| < 0.04$ (bottom left plots) and $|dxy| < 0.05$ (bottom right plots).

In Fig. 6, the distributions of N-1 efficiency for the impact parameter (dxy) are illustrated versus the transverse energy E_T in ECAL endcaps, for the electron candidates passing HEEP selection v.4; for $|dxy| < 0.02$ (top left plots), $|dxy| < 0.03$ (top right plots), $|dxy| < 0.04$ (bottom left plots) and $|dxy| < 0.05$ (bottom right plots).

In Fig. 7, we present the same distributions as those seen in Fig. 6, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

In Table 3, N-1 efficiency is presented for the impact parameter (dxy) for electrons passing full HEEP selection v.4, for different MC samples (first column), for several cut values of the parameter (dxy) in EE. While in Table 4 we repeat the same measurements, in EE, but with removing the cut on missing hits in the inner most layers of the

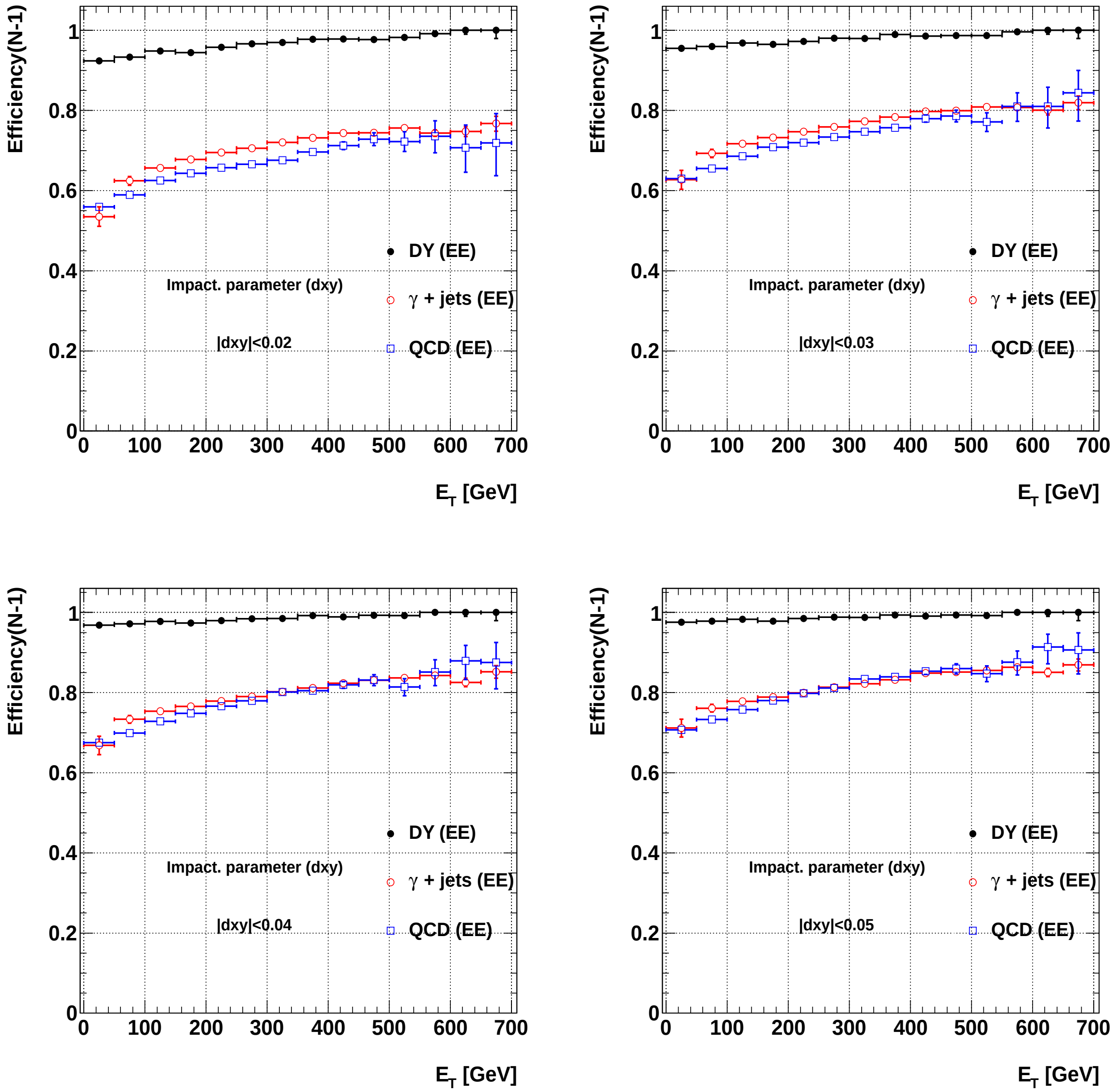

Figure 7: Same distributions as those seen in Fig. 6, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

$\lvert dxy \rvert <$	0.02	0.03	0.04	0.05
	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	94.01 ± 0.05	96.71 ± 0.03	97.86 ± 0.03	98.46 ± 0.02
QCD	72.15 ± 0.16	78.36 ± 0.14	82.47 ± 0.13	85.48 ± 0.12
γ+jets	83.97 ± 0.12	88.11 ± 0.12	90.32 ± 0.11	91.70 ± 0.10

Table 3: N-1 efficiency is presented for the impact parameter (dxy) for electrons passing full HEEP selection v.4, for different MC samples (first column), for different choices of the impact parameter $\lvert dxy \rvert$ cut in EE. Errors are statistical only.

from HEEP selection v.4. The outputs of these tables are summarised in Fig. 8

The comparison between Tables 3 and 4 shows the use of standard EGAMMA cut value in EE (i.e. $\lvert dxy \rvert < 0.02$ in EE) is less efficient for the Drell Yan samples. Also as in the EB case, the efficiency of this impact parameter

$\|dxy\| <$	0.02	0.03	0.04	0.05
	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	93.08 ± 0.05	95.87 ± 0.04	97.11 ± 0.03	97.79 ± 0.03
QCD	61.40 ± 0.14	67.98 ± 0.13	72.42 ± 0.12	75.65 ± 0.11
γ+jets	69.04 ± 0.12	74.60 ± 0.11	77.86 ± 0.10	80.12 ± 0.10

Table 4: Same as in Table 3, except that the cut on missing hits in the inner most layers of the tracker was removed from the from HEEP selection v.4.

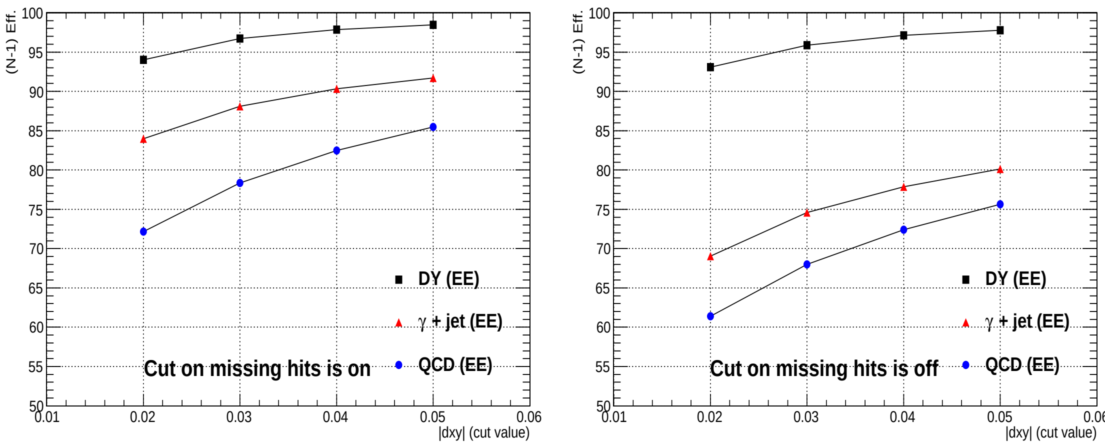

Figure 8: N-1 efficiency is presented for the impact parameter (dxy), for several cut values of the parameter (dxy) in EE; for electrons passing full HEEP selection v.4 (left plot), and when the cut on missing hits in the inner most layers of the tracker is removed from the from HEEP ID (right plot).

(dxy) cut on the Drell Yan samples is not sensitive to adding or removing the cut on missing hits.

Although the actual cuts recommended by EgammaPOG are 0.02 for EB and EE, we found that the optimal cut values on the impact parameter (dxy) are:

$$|\text{dxy}| < 0.02 \text{ cm } (EB), \qquad |\text{dxy}| < 0.05 \text{ cm } (EE). \tag{3}$$

Another variable, the impact parameter (dz) is defined in [5]. Cut based on this variable was tested with a method similar to the (dxy) one. The impact parameter (dz) exhibits a high efficiency for the Drell-Yan sample. On the other side it has very poor rejection power on both QCD and γ + jets background of 1% in EB and 10% in EE.

2.2 N-1 efficiency measurement of dxy variable versus number of vertexes

In Fig. 9, the N-1 efficiency of Drell Yan events for the impact parameter (dxy) versus the number of vertexes, for $|\text{dxy}| < 0.02$ in EB and $|\text{dxy}| < 0.05$ in EE. This plot shows that the impact parameter (dxy) is a robust cut, since the efficiency is independent from the number of vertices.

2.3 N-1 efficiency measurement of dxy variable versus η_{sc}

The distributions of N-1 efficiency for the impact parameter (dxy) versus pseudo-rapidity of the super cluster η_{sc} is presented in Fig. 10, for electrons passing full HEEP selection v.4 (left plots), and for electron candidates passing HEEP selection v.4 after removing cut on missing hits in the inner most layers of the tracker (right plots). In these plots the cut value of dxy variable has been chosen to be $|\text{dxy}| < 0.02$ in EB and $|\text{dxy}| < 0.05$ in EE. The efficiency measurements of dxy cut, for Drell Yan, QCD and γ+jets samples, have strong dependence on eta of the super cluster.

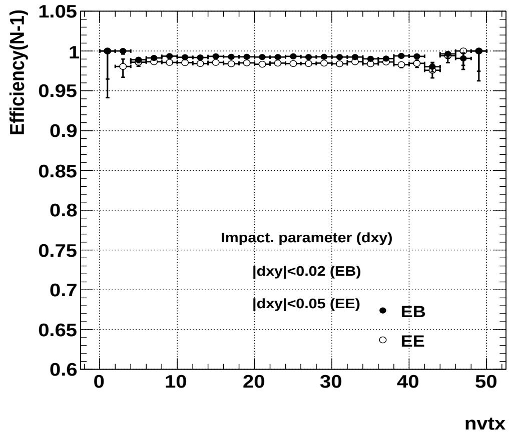

Figure 9: Distribution of N-1 efficiency of Drell Yan events for the impact parameter (dxy) versus the number of vertexes, for $|\mathrm{dxy}| < 0.02$ in EB and $|\mathrm{dxy}| < 0.05$ in EE.

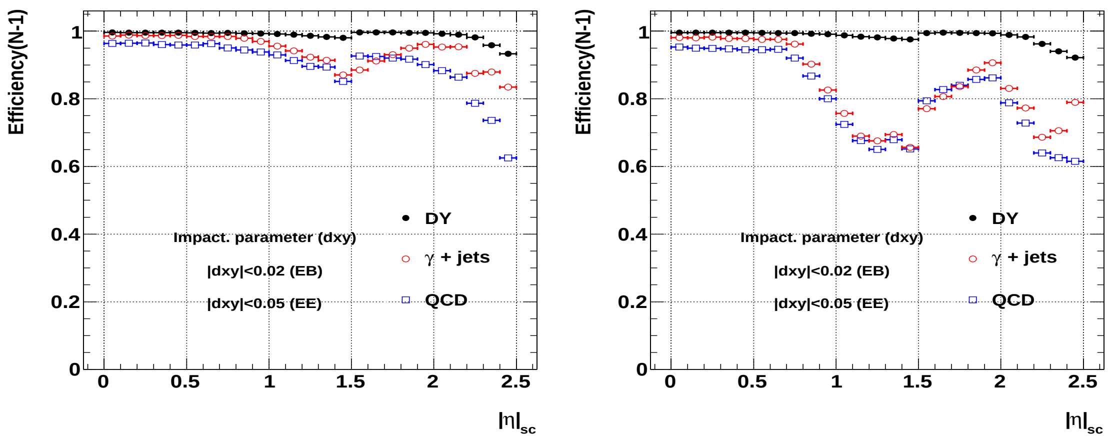

Figure 10: Distributions of N-1 efficiency for the impact parameter (dxy) versus pseudo-rapidity of the super cluster η_{sc}; for electrons passing full HEEP selection v.4 (left plots), and for electron candidates passing HEEP selection v.4 after removing cut on missing hits in the inner most layers of the tracker (right plots).

3 Photon conversion rejection tool

The new EGAMMA photon conversion rejection tool is a boolean function which depends on three variables [6]. The first one is the probability "prob" of fitting the track of any electron originated from photon conversion, the second variable is the number of hits before vertex "max(hitsbeforevtx)" at which the photon starts to convert, the third one called l_{xy}, is given by the following definition,

$$lxy = (\text{mom.x()*dbsx + mom.y()*dbsy})/\text{mom.rho()} \tag{4}$$

where,

$$\text{dbsx} = \text{vtx.x()} - \text{beamspot.x()},$$

$$\text{dbsy} = \text{vtx.y()} - \text{beamspot.y()}, \tag{5}$$

and vtx.x() and vtx.x() are the x and y coordinates of the primary vertex respectively, while beamspot.x() and beamspot.y() are the x and y coordinates of the beam spot position respectively.

The photon conversion rejection tool defaults values are:

$$\text{prob} > 10^{-6}, \qquad \max(\text{hitsbeforevtx}) == 0, \qquad l_{xy} > 2.0\text{cm}. \tag{6}$$

3.1 N-1 efficiency measurement of photon conversion rejection tool versus number of vertexes

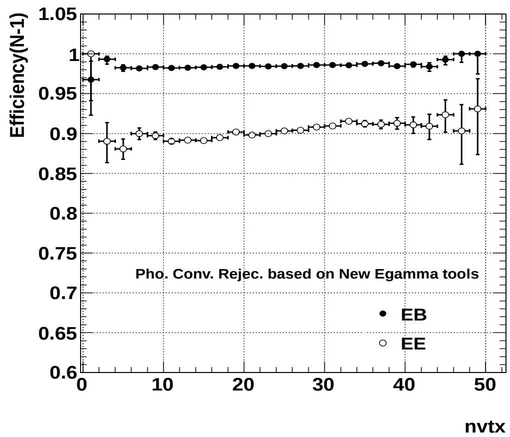

Figure 11: Distribution of N-1 efficiency for the photon conversion rejection tool versus the number of vertexes.

Fig. 11 shows the distribution of N-1 efficiency for the photon conversion rejection tool versus the number of vertexes for EB black circles and open circles in EE, which is flat distribution. This distribution implies that the photon conversion rejection tool is a robust cut, since the efficiency is independent of the number of vertexes.

3.2 N-1 efficiency measurement of photon conversion rejection tool versus η_{sc}

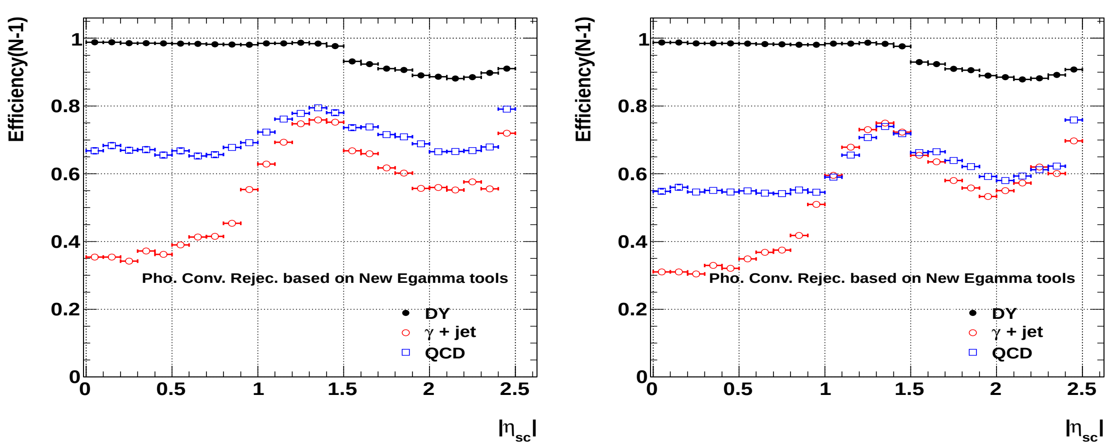

Figure 12: Distributions of N-1 efficiency for the photon conversion rejection tool versus pseudo-rapidity of the super cluster η_{sc}; for electrons passing full HEEP selection v.4 (left plots), and for electron candidates passing HEEP selection v.4 after removing cut on missing hits in the inner most layers of the tracker (right plots).

The distributions of N-1 efficiency for the photon conversion rejection tool versus pseudo-rapidity of the super cluster η_{sc} is presented in Fig. 12 for electrons passing full HEEP selection v.4 (left plots), and for electron candidates passing HEEP selection v.4 after removing cut on missing hits in the inner most layers of the tracker (right plots). The efficiency measurements of photon conversion rejection tool, for Drell Yan, QCD and γ+jets samples, have a strong dependence on eta of the super cluster.

3.3 N-1 efficiency measurement of photon conversion rejection tool versus E_T

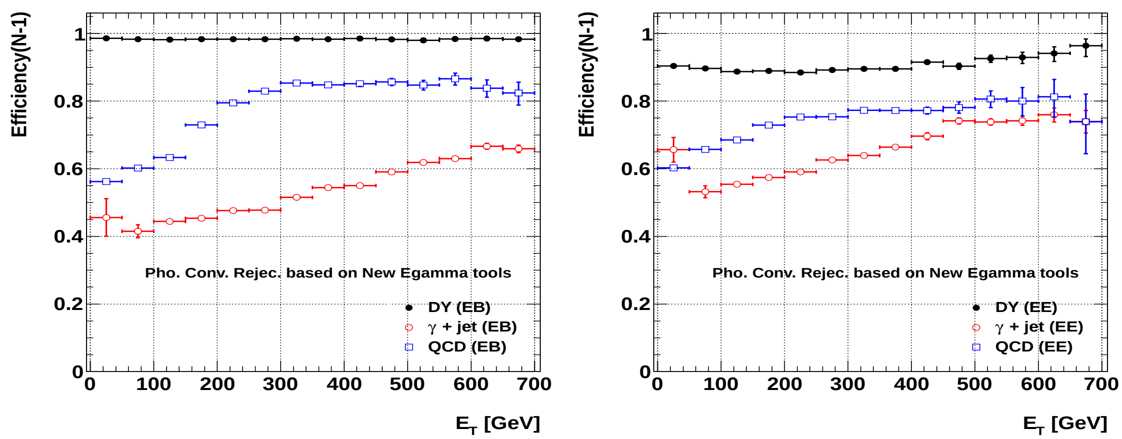

Figure 13: Distributions of N-1 efficiency for the photon conversion rejection tool versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP selection v.4.

Fig. 13 shows the distributions of N-1 efficiency for the photon conversion rejection tool versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP selection v.4.

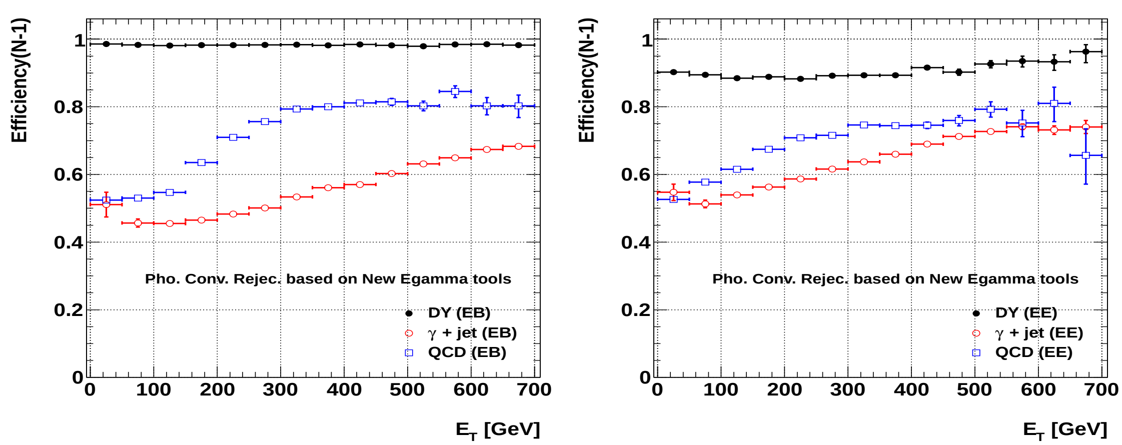

Figure 14: Same distributions as those seen in Fig. 13, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

In Fig. 14, we present the same distributions as those seen in Fig. 13, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

In Table 5 N-1 efficiency is shown for the photon conversion rejection tool for electrons passing full HEEP selection v.4, for different MC samples (first column), separately in EB (second column) and EE (third column). While in Table 6 we repeat the same measurements but with removing the cut on missing hits in the inner most layers of the tracker from HEEP selection v.4.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	98.45 ± 0.02	90.05 ± 0.06
QCD	71.07 ± 0.13	69.42 ± 0.17
γ+jets	52.81 ± 0.23	60.13 ± 0.22

Table 5: N-1 efficiency for the photon conversion rejection tool for electrons passing full HEEP selection v.4, for different MC samples (first column), separately in EB (second column) and EE (third column).

The comparison between Tables 5 and 6 shows that the efficiency of this photon conversion rejection tool cut

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	98.40 ± 0.02	89.86 ± 0.06
QCD	61.66 ± 0.20	61.83 ± 0.14
γ+jets	54.00 ± 0.13	59.20 ± 0.13

Table 6: Same as in Table 5, except that the cut on missing hits in the inner most layers of the tracker is removed from HEEP selection v.4.

on the Drell Yan samples is not sensitive to keep or remove the cut on missing hits in the inner most layer of the tracker from HEEP selection v.4. The rejection power of this cut on both QCD background is sensitive to the cut on missing hits in the inner most layer of the tracker, since the rejection power increased by 9% in EB and 8% in EE for QCD samples, but the rejection power for γ+jets samples almost remains the same (with and without cut on inner most layer in tracker) in EB and EE.

4 Missing hits in the inner most track layers

A cut based on the number of missing hits in the inner most layers of the tracker has been proposed in a former study [8]. This cut has been used as an official cut in HEEP ID since v.3. In this section we study the N-1 efficiency of this cut on the Drell Yan MC samples, and its effect on the rejection of QCD and γ+jets backgrounds.

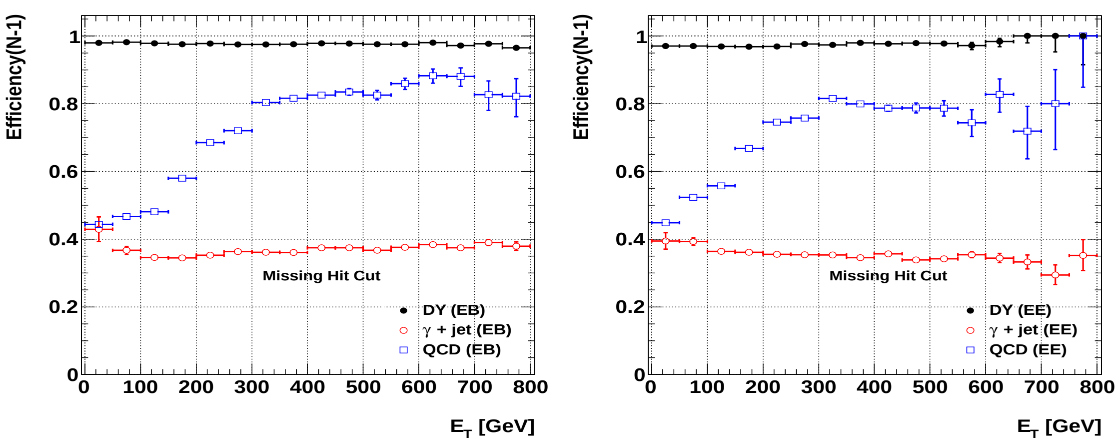

Figure 15: Distributions of N-1 efficiency for the missing hits in the inner most track layer versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP ID.

Fig. 15 illustrates the distributions of N-1 efficiency for the missing hits in the inner most track layer versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP ID. Drell Yan MC samples is shown as black circles, QCD background is shown as blue boxes, while γ+jets background is

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	97.94 ± 0.02	97.04 ± 0.03
QCD	56.90 ± 0.20	58.84 ± 0.15
γ+jets	36.04 ± 0.16	35.77 ± 0.17

Table 7: N-1 efficiency is presented for the missing hits in the inner most track layer for electrons passing full HEEP selection v.4, for different MC samples (first column), separately in EB (second column) and EE (third column). Errors are statistical only.

presented as red circles.

In Table 7, N-1 efficiency is shown for the missing hits in the inner most track layer for electrons passing full HEEP selection v.4, for different MC samples (first column), separately in EB (second column) and EE (third column). The rejection power, of this cut on QCD and γ+jets, is strong.

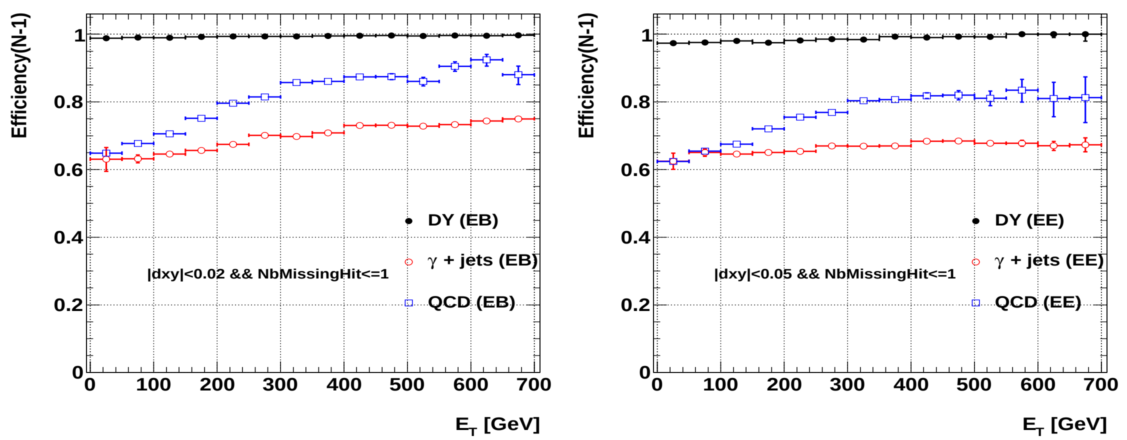

Figure 16: Distributions of N-1 efficiency for the convolution of IP dxy and the Missing hits in the inner most track layer versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP ID.

In Fig. 16, distributions of N-1 efficiency for the convolution of the missing hits in the inner most track layer (after relaxing this cut to be $<= 1$) and IP dxy ($|\text{dxy}| < 0.02$ in EB and $|\text{dxy}| < 0.05$ in EE) versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP ID.

The outputs of these plots, given in Fig. 16, are summarised in Table 8; at which the efficiency for DY sample is 99% in EB and 98% in EE, with rejection power of 27% in EB and 31% in EE for QCD background, while for γ+jets the rejection power is 31% in EB and 34% in EE.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	99.00 ± 0.01	97.52 ± 0.03
QCD	73.34 ± 0.16	68.80 ± 0.13
γ+jets	69.52 ± 0.11	65.71 ± 0.12

Table 8: N-1 efficiency is presented for the convolution of the missing hits in the inner most track layer (after relaxing this cut to be $<= 1$) and IP dxy ($|\text{dxy}| < 0.02$ in EB and $|\text{dxy}| < 0.05$ in EE); for electrons passing full HEEP selection v.4, for different MC samples (first column), separately in EB (second column) and EE (third column). Errors are statistical only.

5 Data and Monte Carlo comparison

In order to reduce the contamination of QCD and γ + jets backgrounds in the data, we select events with two electron candidates passing HEEP selection v.4. The same selection is applied on the Drell Yan (MC) samples. Data and Drell Yan (MC) events with two electrons in EE are eliminated for the same reason.

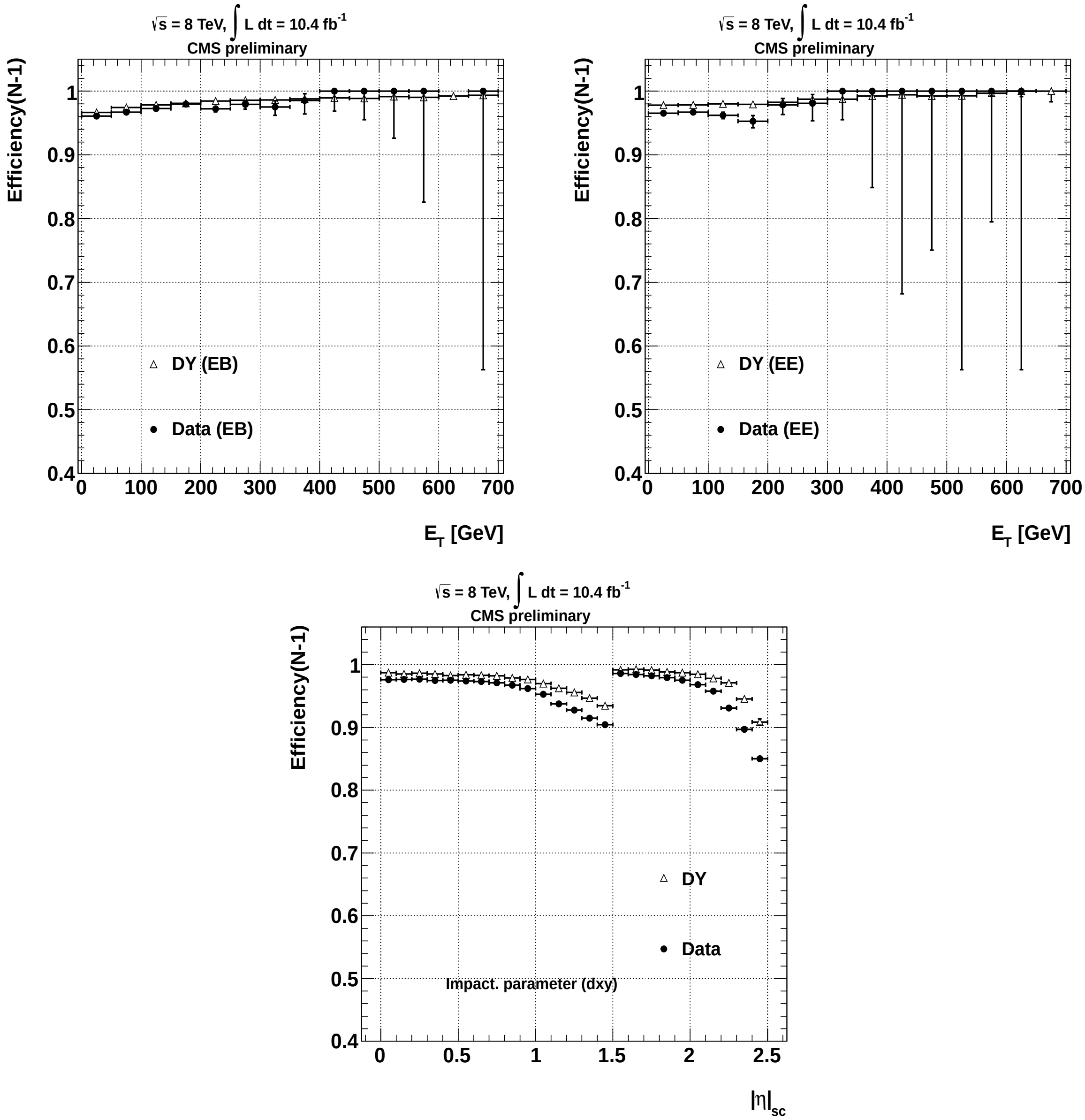

Figure 17: Distributions of N-1 efficiency for the impact parameter (dxy), for electron candidates from HEEP events, versus E_T in EB (top left), EE (top right), and $0.0 < |\eta_{sc}| < 2.50$ (bottom), for data and MC.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	97.61 ± 0.03	98.12 ± 0.05
Data	96.18 ± 0.02	96.54 ± 0.04

Table 9: N-1 efficiency of (dxy) cut for electron candidates from HEEP events, for Drell Yan MC and data (first column), separately in EB (second column) and EE (third column).

Data and Monte Carlo comparisons are displayed for impact parameter (dxy) in Fig. 17, for the photon conversion

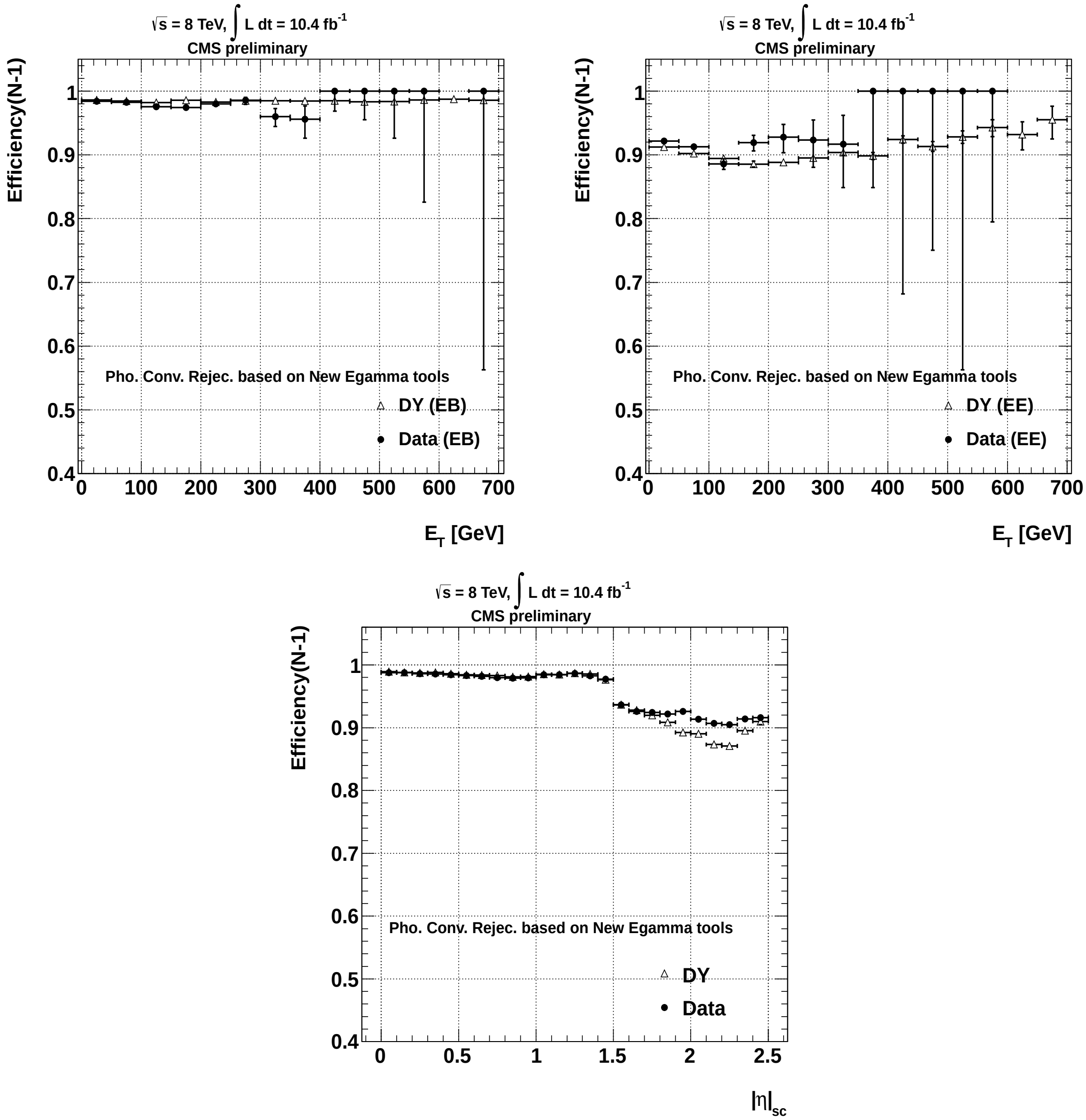

Figure 18: Distributions of N-1 efficiency for the photon conversion rejection tool, for electron candidates from HEEP events, versus E_T in EB (top left), EE (top right), and $0.0 < |\eta_{sc}| < 2.50$ (bottom), for data and MC.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	98.51 ± 0.02	90.47 ± 0.11
Data	98.35 ± 0.01	92.03 ± 0.07

Table 10: Same as in Table 9, but for the photon conversion rejection cut.

rejection tool in Fig. 18 and for the cut based on number of missing hits in the inner most layer of the tracker in Fig. 19.

The efficiency measurements extracted from these plots are summarised in Tables 9, 10 and 11.

Good agreement is observed between data and MC within less than a percent difference for the photon conversion rejection tool in both EB and EE.

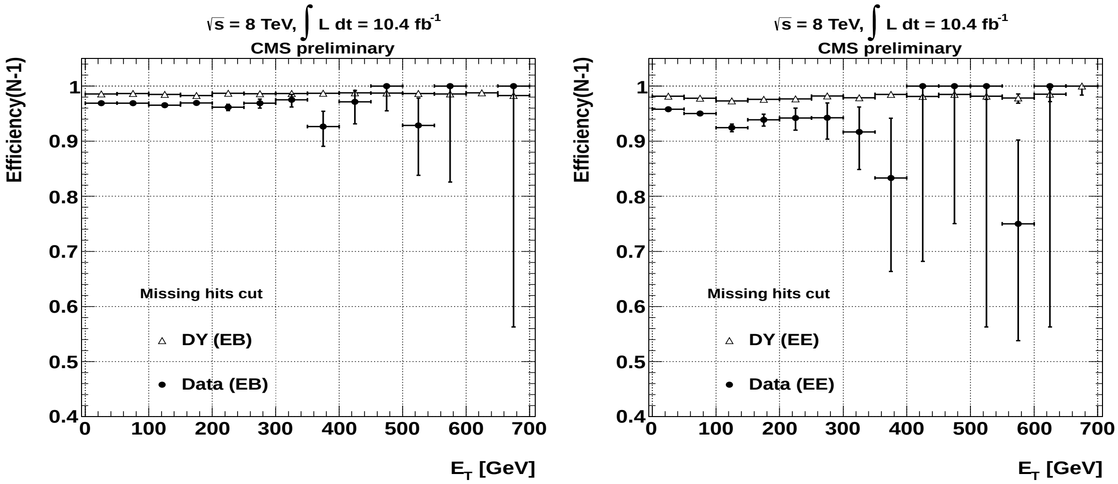

Figure 19: Distributions of N-1 efficiency for the cut based on number of missing hits in the inner most layer of the tracker, for electron candidates from HEEP events, versus E_T in EB (left), EE (right), for data and MC.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	98.58 ± 0.02	97.98 ± 0.05
Data	96.90 ± 0.02	95.68 ± 0.05

Table 11: Same as in Table 9, but for the cut based on number of missing hits in the inner most layer of the tracker.

Less agreement is seen between data and MC for the stand alone impact parameter (dxy), and for the cut based on number of missing hits in the inner most layer of the tracker of about 2% in both EB and EE. The disagreement between data and MC for the cut base on number of missing hits in the inner most layer of the tracker leads to a loss of about 4% of the data.

In order to avoid this loss, the cut based on the number of missing hits in the inner most layer of the tracker was relaxed to be $<= 1$ instead of $== 0$, it was also convoluted with the cut based on IP dxy. The result of this convolution is seen in Fig. 20.

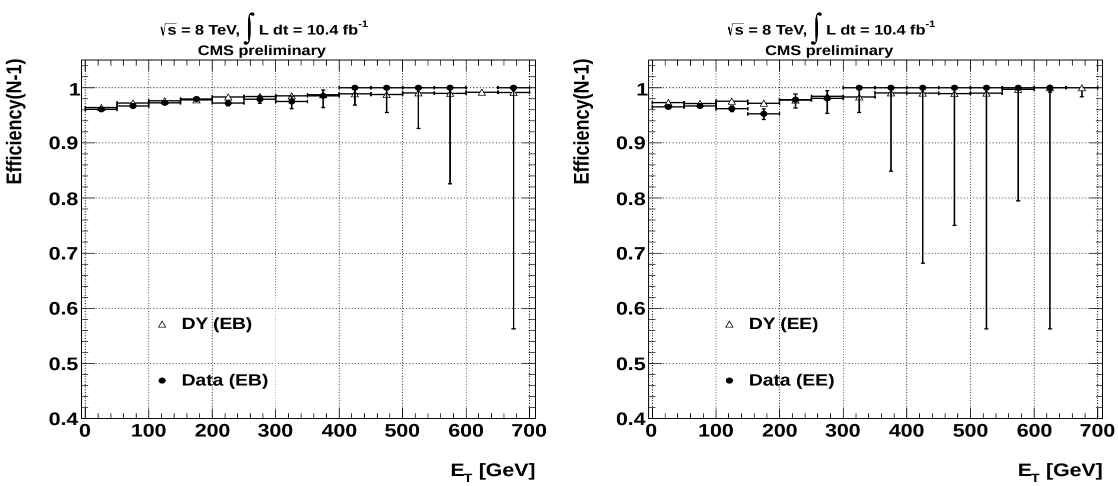

Figure 20: Distributions of N-1 efficiency for the convolution of IP dxy and the Missing hits in the inner most track layer versus the transverse energy E_T in EB (left plots) and EE in (right plots), for the electron candidates passing HEEP ID in data and MC.

The outputs of these plots, given in Fig. 20, are summarised in Table 12, with good agreement is observed between data and MC within 1%.

	N-1 efficiency (%) (ECAL barrel)	N-1 efficiency (%) (ECAL endcaps)
Drell Yan	97.43 ± 0.03	97.63 ± 0.05
Data	96.20 ± 0.02	96.54 ± 0.04

Table 12: N-1 efficiency is shown for the convolution of the missing hits in the inner most track layer (after relaxing this cut to be $<= 1$) and IP dxy ($|\text{dxy}| < 0.02$ in EB and $|\text{dxy}| < 0.05$ in EE); for electrons passing full HEEP selection v.4, for Drell Yan MC and data (first column), separately in EB (second column) and EE (third column).

6 Conclusion

The EGAMMA POG proposed two methods to be part of electron ID in the analysis of 2012 data. The first method is called impact parameter dxy, while the second one is called photon conversion rejection tool. In this analysis note, these two methods have been studied in the framework of HEEP selection using MC samples of Drell Yan, QCD, γ + jets and 2012 data (integrated luminosity of 10.4 fb-1).

The efficiency measurements for impact parameter (dxy) (using Drell Yan samples , QCD, γ + jets) have been studied for several cut values of the dxy variable in both ECAL barrel and endcaps. Although the actual cut values of dxy recommended by EgammaPOG are 0.02 for EB and EE, we found that the optimal cut values on the impact parameter (dxy), for electrons with high E_T, are 0.02 in EB (of about 99% efficiency) and 0.05 in EE (of about 98% efficiency).

The efficiency measurements for the photon conversion rejection tool is also studied using Drell Yan samples, at which the efficiency of this cut is $98.45\% \pm 0.02\%$ in EB, but it is strongly dropping in EE to be $90.05\% \pm 0.06\%$. For QCD the rejection power measurements are 29% in EB and 31% in EE, while after removing the cut on missing hits in the inner most layer of the tracker from HEEP selection the rejection power increases to be 38% in EB and 39% in EE. Finally for γ + jets background, the rejection power measurements are 47% in EB and 40% in EE, while after removing the cut on missing hits in the inner most layer of the tracker from HEEP selection the rejection power does not change much, to be 46% in EB and 41% in EE.

A comparison of these cuts applied to the MC Drell Yan and to a data sample of electrons is performed. Data and Drell Yan (MC) electron candidates are selected by the HEEP cuts to eliminate backgrounds. The E_T and η_{sc} distributions are consistent, except by a few percents for the photon conversion rejection tool in the endcaps.

To conclude this study, due to the old cut value for the number of missing hits in the inner most layer of the tracker (i.e. missing hits $== 0$) about 4% of the data is lost. For this reason we recommend relaxing the cut based on the number of missing hits in the inner most layer of the tracker in HEEP selection, in both EB and EE, to be $<= 1$.

In addition to this, we also recommend adding a cut based on impact parameter (dxy), in both in EB (i.e. $|\text{dxy}| < 0.02$) and in EE (i.e. $|\text{dxy}| < 0.05$), to the new version of HEEP selection v.4.1 (see Table 13).

Concerning the cut based on the new EGAMMA tool of photon conversion rejection tool, it will not be added to HEEP ID, since its efficiency measurement on Drell Yan samples drops by 10% in the ECAL endcaps.

Acknowledgements

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References

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[2] B. Clerbaux et al., *"Search for High Mass Resonances Decaying to Electron Pairs at 8 TeV"*, **CMS AN-NOTE** 12-171 (2012).

variable	barrel	endcap
E_T	> 35 GeV	> 35 GeV
$\|\eta_{SC}\|$	< 1.442	$1.56 < \|\eta\| < 2.5$
seed	ECAL seeded	ECAL seeded
missing hits	$<= 1$	$<= 1$
|dxy|	< 0.02	< 0.05
$\Delta\eta_{in}$	< 0.005	< 0.007
$\Delta\phi_{in}$	< 0.06	<0.06
H/E	< 0.05	< 0.05
E^{2x5}/E^{5x5}	> 0.94 OR $E^{1x5}/E^{5x5} > 0.83$	
$\sigma_{i\eta i\eta}$	-	< 0.03
isol Em + Had Depth 1	$< 2 + 0.03 \times E_T + \rho \times 0.28$ GeV	< 2.5 GeV $+\rho \times 0.28$ for $E_T < 50$ GeV $< 2.5 + 0.03 \times (E_T - 50) + \rho \times 0.28$ GeV
isol Pt Tracks	< 5 GeV/c	< 5 GeV/c

Table 13: The HEEP selection criteria v.4.1, the first set are the kinematic, geometric and seeding cuts, the second set are the ID cuts and the third set are the isolation cuts. The differences from the v.4 selection are the cut based on the missing hits in the inner most track layer is relaxed to be $<= 1$, and cut based on the IP dxy has been added.

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