Di-Electron Resonances Search

Di-Electron resonances can be produce by Z' particles with masses in the TeV range which arise in a number of BSM theories such as Grand Unified Theories [21] (possibly embedded in string or quantum gravity models [6]), Left-Right Symmetric models, or TeV-scale extra-dimension theories [7],[8], as well as by Kaluza-Klein graviton excitations in Randall and Sundrum (RS) model [10] of extra-dimensions. The di-lepton decay channel is particularly promising because of its relatively large cross section and clear signature: two very high E_T charged leptons over a small SM background. The main irreducible background comes from the Drell-Yan continuum.

In 2008-9, V. Timciuc performed preliminary studies of prospects of Z' observation in electron decay mode at 14 TeV. This analysis was extended and updated for 7 TeV . Our analysis results (Figure 5.2.3) show that with the 1 fb^{-1} of data at 7 TeV we expect to accumulate this year, a Z' could be discovered up to a mass of 1.5 TeV, depending on the model [21][6][7][8][9], which exceeds the 1023 GeV exclusion limit on a Z'_{SSM} at 95 % CL set by D0 [20].

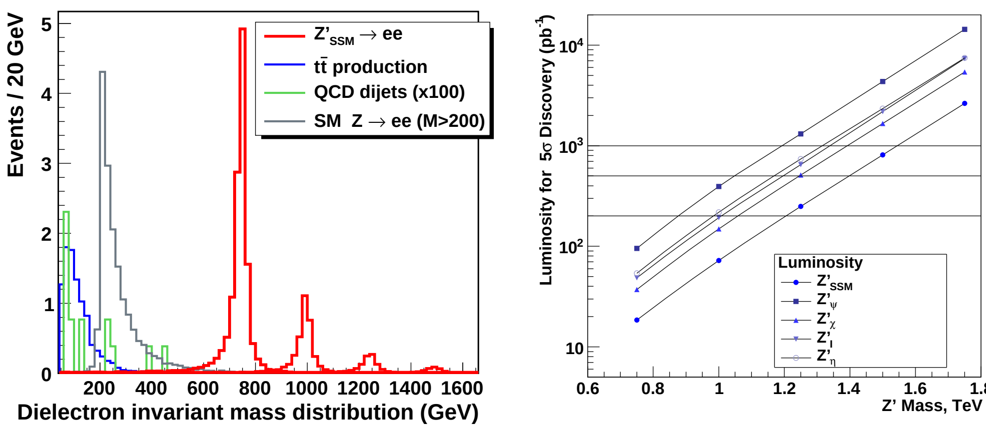

Figure 5.7: (Left) The di-electron invariant mass spectrum for four different masses of a Z'_{SSM} (750, 1000, 1250 and 1500 GeV) and the three main backgrounds: Drell-Yan, $t\bar{t}$ and QCD. The plot shows the results scaled to 100 pb^{-1}. (Right) The 5σ discovery reach for Z'_{SSM}, Z'_χ, Z'_I, Z'_η and Z'_ψ at 7 TeV.

With arrival of first 7 TeV data in spring 2010 we have concentrated on validation of electron object in data. Extensive comparisons of electron parameters have been performed, with particular interest to the values that enter final electron identification for Z' analysis (so called HEEP ID). That required continuous analysis of arriving data and frequent reports to CMS Exotica Electron group. It permitted us to be among the first to identify problem with Ecal Endcap misalignment, as well as first indications of ECAL energy scale shift were observed in this prompt data analysis.

In the first period of data taking, when luminosity was relatively low, $J/\Psi \rightarrow e^+e^-$

resonance, rediscovered among the first at CMS by our group, was used as a source of real electrons to study electron ID variables (Figure 5.2.3) as well as for first investigations of ECAL energy scale, which is summarized in CMS Note [11].

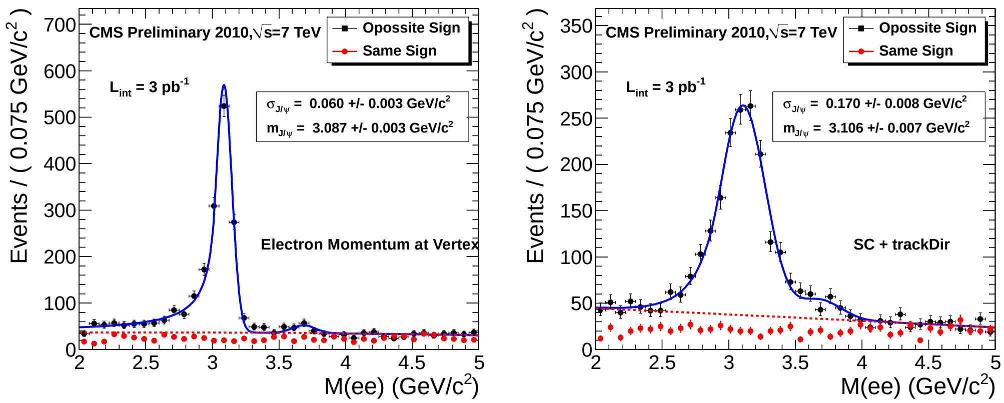

Figure 5.8: J/ψ signal in early data. Invariant mass is computed based on the electron track values at vertex (Left) and based on the energy deposition in ECAL combined with track direction (Right).

As luminosity increased and J/Ψ rates were significantly reduced by triggers, $Z \to e^+e^-$ channel was used to continue electron ID validation and ECAL energy scale monitoring. Detailed study of fit and $Z \to e^+e^-$ peak position and width extraction procedures have been performed. Unbinned likelihood fit to convolution of Crystal-Ball and Breit-Wigner distributions was used to extract energy scale from $Z \to e^+e^-$ signal and to study di-electron mass resolution this study is summarized in CMS Note [12]. Based on these studies the effect of energy scale offset in ECAL endcap region due to crystal transparency loss was accounted for by adding an average energy scale correction to super cluster energies associated with electrons at analysis level [13] (Figure 5.2.3).

Background contributions from Drell-Yan process, $t\bar{t}$ as well as other processes contributing prompt leptons have been estimated based on MC predictions, good agreement between data and MC in control region was established. $e\mu$ method didn't accumulate yet enough statistics to be used as an independent data driven method for estimating $t\bar{t}$ background, but it was used to further validated data and MC agreement for this process [13]. Contribution to di-electron mass spectrum from jets was estimated using data-driven method based on the rates at which jet can fake an electron [13]. Resulting di-electron invariant mass spectrum corresponding to the full 2010 data set can be seen in Figure 5.2.3.

Another major activity was development and validation of methods and applications for statistical analysis of accumulated data. We have provided all the signal and background parametrization for the limit extraction procedures as well as performed acceptance and efficiency studies [13] [14] Figure 5.2.3. In addition investigation of di-electron mass resolution parametrization for Z' signal Figure 5.2.3 and appropriate

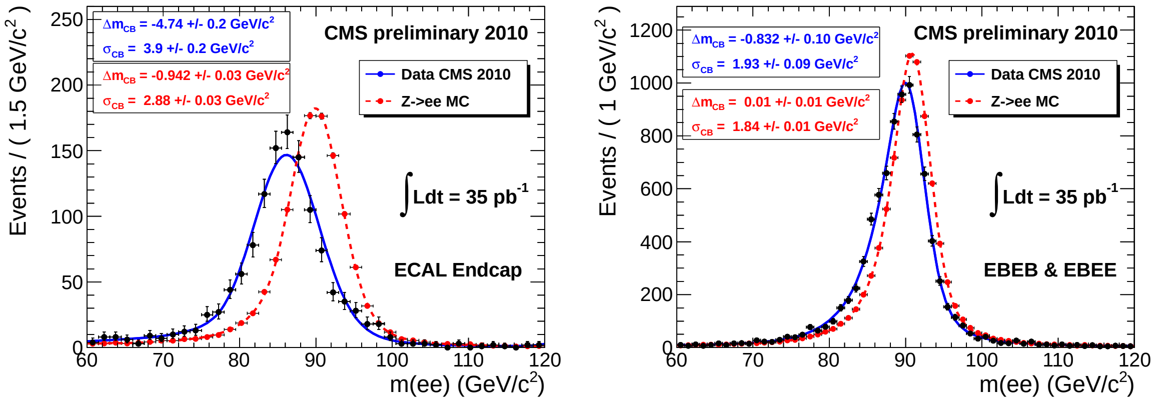

Figure 5.9: (Left) Energy scale shift in ECAL endcap due to loss of crystal transparency is accounted for by a 4% energy correction applied to the data. (Right) Di-electron mass resolution in MC has to be adjusted to match measurment in data by a multiplicative factor 1.03 ± 0.05.

Data/MC correction at Z peak was performed [13] Figure 5.2.3. We have studies a number of methods for setting an exclusion limit on the mass of Z' [13] [14], such as CLsb [16], Feldman-Cousins [17], MCMC [18] and counting experiment [19].

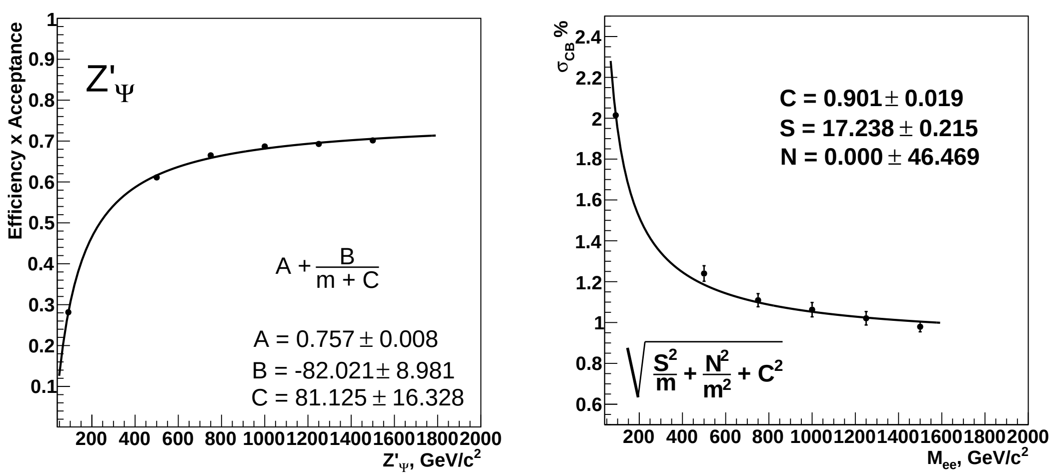

Figure 5.10: (Left) Efficiency $\times$ Acceptance as a function of di-electron invarinat mass. (Right) Di-electron invarinat mass resolution as a function of invariant mass.

Based on the full 2010 data set corresponding to 35 pb-1 of integrated luminosity we exclude at 95 % CL Z'_{SSM} and Z'_{ψ} with mass below 958 and 731 GeV respectively, and RS graviton below 729(931) GeV for couplings of 0.05(0.1) (Figure 5.2.3). Our final results have been summarized in CMS Note [13] and a CMS Paper was produced in combination with di-muon channel [15] and submitted for publication to JHEP.

Along side these studies, in recent months major activity was to investigate and

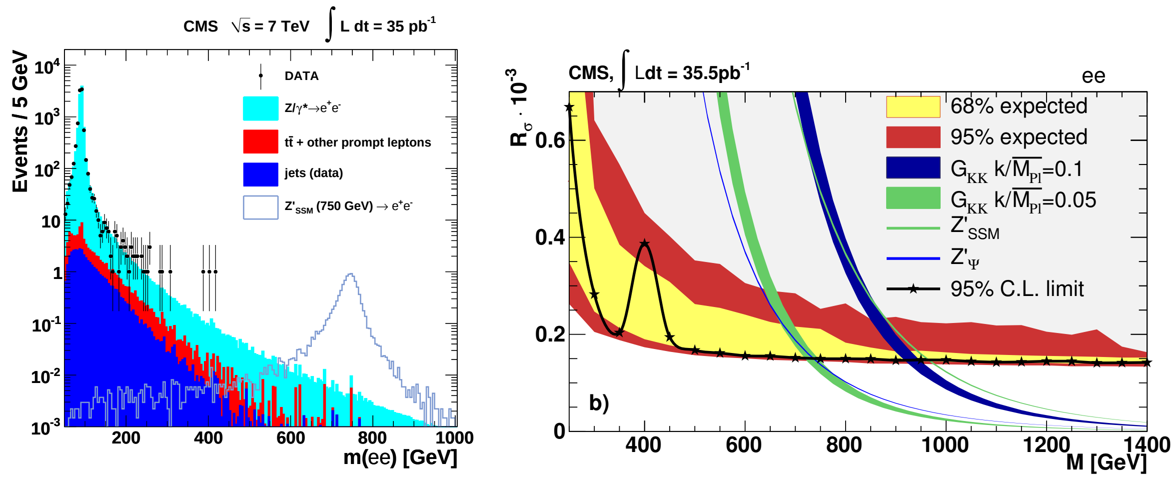

Figure 5.11: (Left) The di-electron invariant mass spectrum correcponding to 35 pb^{-1} accumulated during 2010 datataking by CMS at 7TeV. (Right) The 95 % C.L exclusion limit.

validate corrections applied to full 2010 data-set reprocessing, with updated laser and super cluster corrections. Based on the method studied in detail and mentioned above [12] the di-electron mass resolution was shown to approach MC predictions for categories of electrons that do not create showers when propagating through tracker material in front of the ECAL detector (Figure 5.2.3).

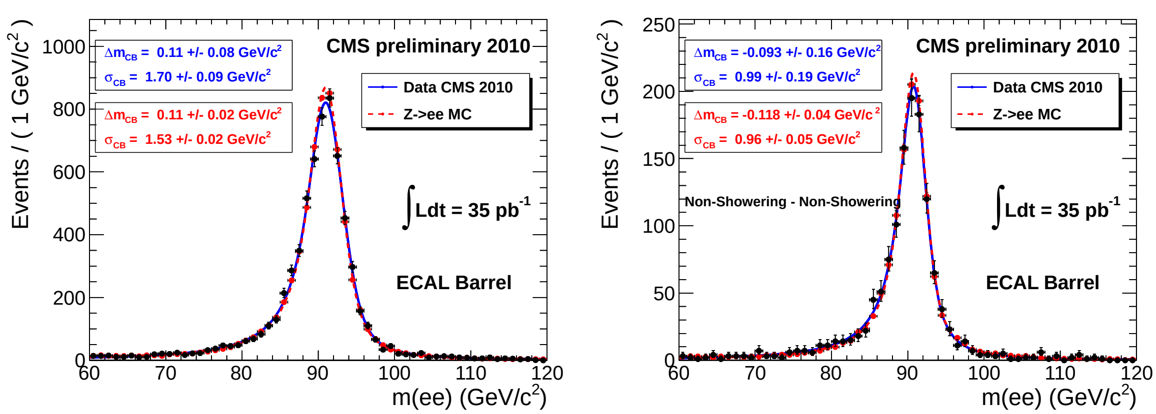

Figure 5.12: Di-electron mass spectrum corresponding to 35 pb^{-1} accumulated during 2010 data taking by CMS at 7TeV, ECAL Barrel for all electrons (Left) and for non showering electrons (Right).

The focus in coming months will be on investigation of pile-up effects on the electron ID varibales, investigation and monitoring of ECAL energy scale and resolution in new running conditions, and re-validation of statistical methods for discovery. With increased luminosity we will be able to make more stringent exclusion limits then Tevatron experiments have published [20].