Z^0 Boson Measurement with the ALICE Central Barrel in pp collisions at 14 TeV

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The possibility to detect the Z^0 in the ALICE central barrel is studied via the electronic decay channel $Z^0 \to e^+e^-$. The signal and the background are simulated with the leading order event generator PYTHIA 6. The total cross-sections are taken from NLO calculations. Based on test beam data, the electron identification performance of the Transition Radiation Detector is extrapolated to high momenta. The expected yields for minimum-bias pp collisions at 14 TeV are presented. An isolation cut on the single electron, together with a minimum transverse momentum cut, allows to obtain a clear signal. The expected background is of the order of 1% with the main contribution coming from misidentified pions from jets.

The measurements of the $W^\pm$ and Z^0 bosons in $p\bar{p}$ and e^+e^- collisions have allowed precise test of the Standard Model (SM) of particle physics. In pp collisions at the LHC, the convergence of the NLO and NNLO calculations offers the possibility to use the total Z^0 cross section for a better understanding of the collider luminosity and the acceptance and efficiency of the detectors [1]. The high p_T electrons emitted in the electronic Z^0 decays can be a controlled observable for checks of the p_T calibration and resolution between 30 GeV/c and 50 GeV/c. In heavy ion collisions Z^0 is a good candidate for an alternative reference for quarkonium study, despite the large mass differences, $m_Z \gg m_{J/\psi}$, and the difference in production mechanisms, mainly $q\bar{q}$ for Z^0 and gg for quarkonium. It should be weakly affected by nuclear shadowing [2] and the presence of the Quark Gluon Plasma [3]. In this work, a feasibility study is presented to detect Z^0 through $Z^0 \to e^+e^-$ in the central barrel of ALICE. The detection of the $W^\pm$ and Z^0 bosons through their muon decays in the ALICE muon spectrometer has been previously extensively studied [4].

The leading order event generator PYTHIA 6.326 [5] is used to simulate the production of Z^0 bosons. Only the lowest order Born processes, $q\bar{q} \to \gamma^*/Z^0$, have been generated. The parton shower algorithm of PYTHIA produces additional jets, that mimic the contributions of higher processes, $q\bar{q} \to \gamma^*/Z\,g$ and $q(\bar{q})g \to \gamma^*/Z\,q(\bar{q})$. The CTEQ5L PDFs are used. It was shown that the p_T and y Z^0 distributions measured at Tevatron energies are well reproduced [6]. Pure Z^0 production, without the complete γ^*/Z^0 interference, has been simulated in this work. Due to the large vector boson masses, the contributions of higher order QCD processes can be approximated by a k factor, found to be about 1.5 from comparison with measurements in $p\bar{p}$ collisions. The extrapolated cross sections for the LHC are summarized in Tab. I. The yields were calculated taking an inelastic pp cross section of 70 mb at 14 TeV. Calculations have been carried out up to NNLO. In the following we normalise all the cross section to the NNLO calculations [1].

pp at 14 TeV	σ_{PYTHIA} [nb]	σ_{NNLO} [nb]	N^X_{pp}
$Z^0 \to e^+e^-$	2.4	1.84	3×10^{-8}
$W^\pm \to e\nu$	23.8	19.8	3×10^{-7}

TABLE I: Inclusive cross sections times branching ratio obtained with PYTHIA and extrapolated after comparison to SppS and Tevatron data, leading to a k factor of 1.5. Results are for pp collisions at 14 TeV and are compared with NNLO calculations [1].

The Inner Tracking System (ITS), Time Projection Chamber (TPC) and Transition Radiator Detector (TRD) provide good tracking capability within their geometrical acceptance, $|\eta| < 0.9$,

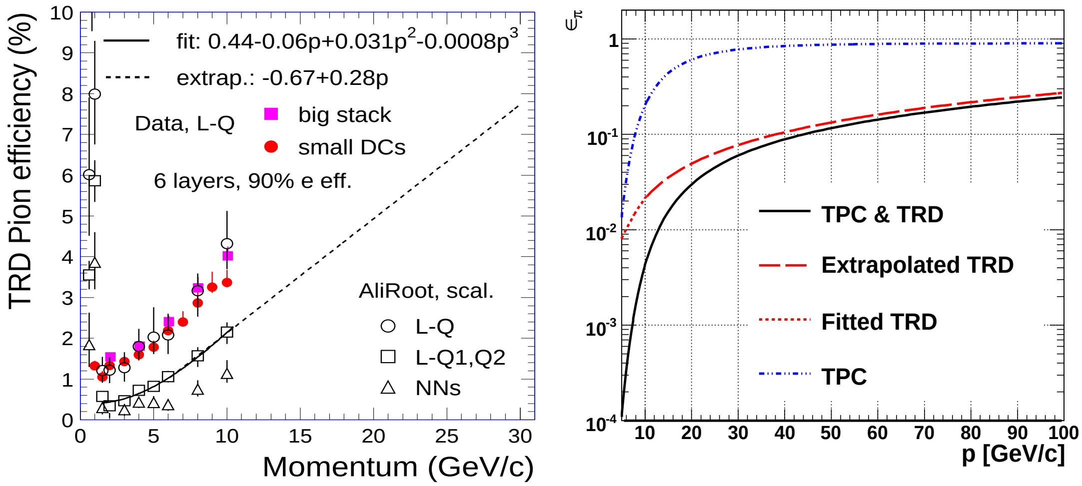

FIG. 1: ^{TRD} as function of momentum extracted from testbeam data compared with simulations within the AliRoot framework and extrapolated to high p (left panel). Calculated ^{TPC}, extrapolated ^{TRD} and combined as function of momentum (right panel).

0< < 2 . The Particle Identification (PID) algorithm used requires that the particles are reconstructed in at least five planes of the TRD, which leads to an overall mean reconstruction efficiency of 80% . The p_T resolution is about 3.5% at 100 GeV=c in the nominal 0.5 T magnetic field. To identify the electrons, the dE=dx of the TPC and the TRD are used. At such high p_T, the main difficulty comes from the much more numerous that can be misidentified as electrons. The percentage of misidentified , the efficiency , is determined for a given e efficiency, $_e$. The left panel of Fig.1 shows ^{TRD}, as it has been obtained from test beam data analysis of small and big chambers [7] and from simulations done within the AliRoot framework [8]. The results of a one dimensional likelihood method, L-Q, can be improved by using a two dimensional method, L-Q1,Q2 or a neural network, NNs [7]. A fit of the L-Q1,Q2 performances allows to extrapolate ^{TRD} to the p range of interest for the Z^0. On the right panel of Fig.1, ^{TPC} has been estimated with simulations for $^{TPC}_e$ = 90% . The final combined for $_e$ = 81% (= $^{TPC}_e$ $^{TRD}_e$ = 0.9 0.9) is also plotted in Fig.1. The response of the ALICE central barrel is simulated with a fast simulation program.

$\lvert_{e^+e^-}\rvert < 0.9$	8.6%
A_e $^{tr}_e$ $^{pid}_e$	3.5%
A_e $^{tr}_e$ $^{pid}_e$ p_{Te} > 25 GeV=c	3.2%
A_e $^{tr}_e$ $^{pid}_e$ p_{Te} > 25 GeV=c iso cut	3.2%

TABLE II: Acceptance and reconstruction efficiency for Z^0 in the mass range 60 GeV=c^2 < M_{e^+e} < 116 GeV=c^2 for different single track cuts.

The geometrical acceptance of the central barrel implies that both of the electrons have $\lvert_e\rvert < 0.9$. This reduces the Z^0 yield to 8.6% of the full phase space yield (see Tab.II). The statistical errors

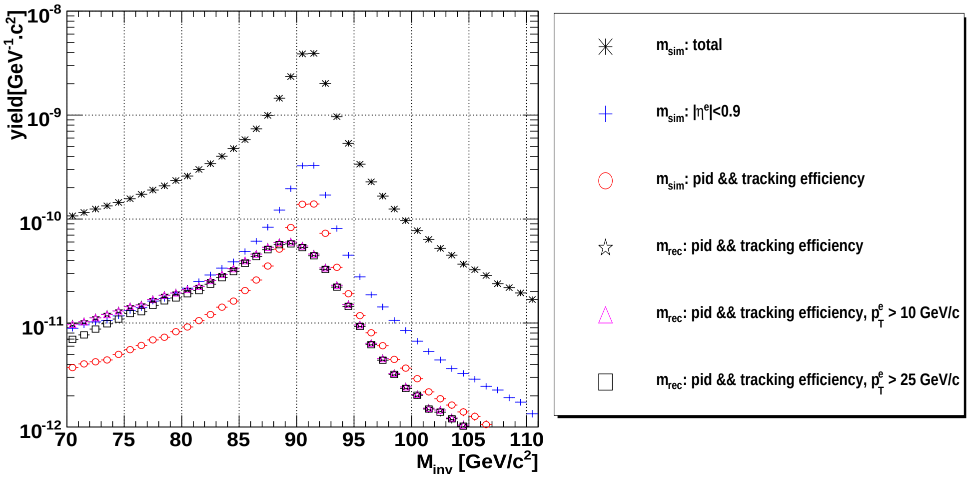

FIG. 2: e^+e generated (m_{sim}) and reconstructed (m_{rec}) invariant mass yield from Z^0 in the total phase space and within the central barrel acceptance for di erent $p_{T e}$ cut.

are below 1%. A clear signature of Z^0 decays is two high p_T isolated electrons. A p_T cut at 25 GeV/c is considered together with an isolation cut. It will reject a track i, if a track j is found to have: $p_T^j > 2$ GeV, $j_i \quad {}_j j$ 0.1 and $j_i \quad {}_j j$ 0.1 rad. 99% of the signal survives this cut. Fig 2 shows the generated $m_{sim}^{e^+e}$ in the total phase space and in the geometrical acceptance with and without tracking and PID e ciencies. The reconstructed $m_{rec}^{e^+e}$ is also plotted for di erent $p_{T e}$ cuts. Bremsstrahlung leads to a tail towards lower values of the mass.

The di erent sources of background that are investigated in pp collisions at $\sqrt{s} = 14$ TeV are: reconstructed dielectrons from jets, that can be real electrons or pions misidenti ed as electrons; W ! e events with an associated hadronic jet that results in a second reconstructed electron ($Br_{W\,!\,e} = 10.75\%$); Z^0! events, in which electrons or misidenti ed pions from decays ($Br_{!\,e=+X} = 44.0850\%$) are combined; electrons and misidenti ed pions from $t\bar{t}$ events ($Br_{t!\,bW}$ 100%); simultaneous semielectronic decays of D and D mesons ($Br_{c!\,eX}$ 9.6%); and simultaneous semielectronic decays of B and B mesons ($Br_{b!\,eX}$ 10.86%). The jets have been simulated with the PYTHIA using Tune A CDF, that gives a total cross section of 54.7 mb [9]. Due to the high masses of the W boson and the top quark, only the lowest order processes for W production (qq^0! W) and $t\bar{t}$ production (gg! $t\bar{t}$ and qq! $t\bar{t}$) have been generated with PYTHIA and normalised to the NLO cross sections. For the lighter c and b quarks production, contributions from higher order corrections, like avour excitations (qQ ! qQ) and gluon splitting (g! QQ) have also been taken into account. The tuned PYTHIA [10] p_T spectra of c and b have been compared to NLO predictions (HVQMNR program [11]) and found to be softer by an order 10 at very high p_T. This would result in a contribution of $c\bar{c}$ and $b\bar{b}$ about 100 higher in the invariant mass yield.

The left panel of Fig.3 shows the reconstructed electron spectra. Misidenti ed from jets constitute the main source of reconstructed electrons above 10 GeV/c. Nevertheless they are not isolated. The rejection factor of the isolation cut is of the order of 10^4. The di erent contributions to the dielectron reconstructed invariant mass yield per minimum-bias pp collisions are presented in the right panel of Fig.3. A p_T cut at 25 GeV/c and the isolation cut are applied. The isolation cut suppresses also the correlated background from simultaneous semi-electronic decays of D and D, or B and B, mesons, below one percent, even with a factor 100, due to higher order corrections.

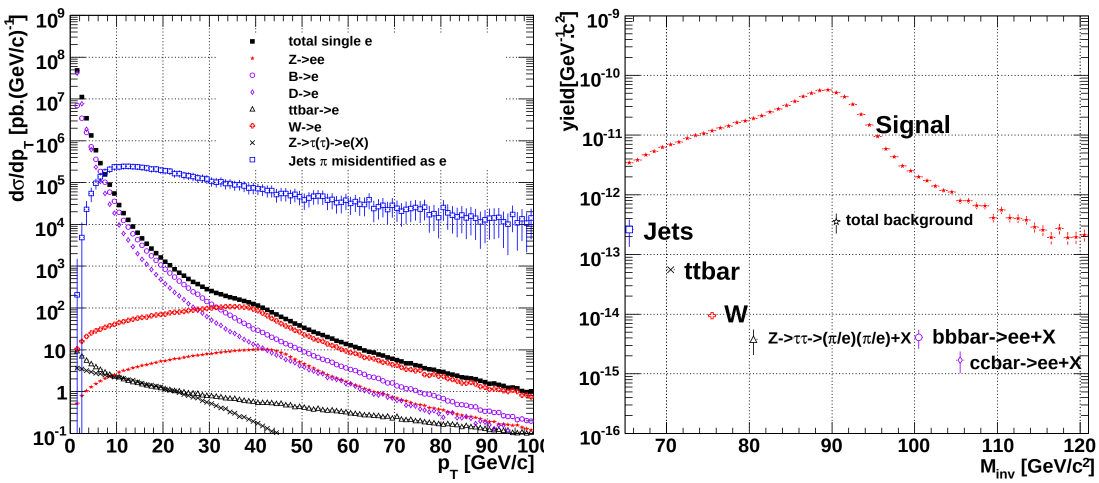

FIG. 3: Left panel: reconstructed single electron spectra in the central barrel. Right panel: comparison with Z^0 signal of different contributions to the background for a p_T cut at 25 GeV/c and the isolation cut. The contributions have been averaged over the invariant mass range 66 GeV/c^2 < $M_{e^+e^-}$ < 116 GeV/c^2.

The final total background amounts to about (0.7 ± 5.3)% of the signal, with a main contribution from misidentified pions from jets. The errors given are statistical.

We have presented a study of Z^0 reconstruction in pp collisions at 14 TeV with the central barrel of the ALICE detector. The $Z^0 \rightarrow e^+e^-$ yields are of the order of 3×10^{-8} per minimum-bias pp collisions. A Level1 TRD trigger (p_T > 10 GeV/c) for 10% of data taking time would lead to a Z^0 sample of about 100 per year. Further enhancement is possible using the High-Level Trigger. The decay electrons are identified with the TRD and the TPC detectors within the central barrel ($|\eta| < 0.9$). The probability to misidentify a π has been extrapolated to the high momentum region of interest and is of the order of 0.1 at 45 GeV/c. The two main characteristics of the electrons emitted in Z^0 decays, i.e. high p_T and isolation, have been used to reject the background. Two high p_T isolated reconstructed electrons constitute a very clear signature of the Z^0 in the central barrel. The background is expected to be of the order of 1% in pp collisions, dominated by misidentified pions from jets.

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