Search for heavy resonances in the W/Z-tagged dijet mass spectrum in pp collisions at 7 TeV

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A B S T R A C T

A search has been made for massive resonances decaying into a quark and a vector boson, qW or qZ, or a pair of vector bosons, WW, WZ, or ZZ, where each vector boson decays to hadronic final states. This search is based on a data sample corresponding to an integrated luminosity of 5.0 fb

1. Introduction

New resonances that decay preferentially into hadronic final states are of particular interest in a variety of scenarios for physics beyond the standard model (SM) [1–9]. Searches for events having a pair of hadronic jets with large invariant mass have been performed by the Compact Muon Solenoid (CMS) and ATLAS experiments at the Large Hadron Collider (LHC) [10,11]. In principle, these searches are also sensitive to final states that include one or two massive vector bosons W/Z because the vector bosons have large hadronic branching fractions and because their masses are much smaller than those of the hypothetical parent states, i.e. they are highly “boosted”. This implies that the pairs of quark jets produced by the vector boson decays merge into single W/Z-jets in a real detector. Due to the large hadronic branching fractions of the vector bosons, at the highest accessible resonance masses, a search in the fully hadronic final state can be more sensitive than searches in leptonic channels. The sensitivity of the present large mass dijet searches is limited by the presence of background from ordinary strong interaction processes that produce pairs of quark and gluon jets.

The analysis presented here exploits the enhancement of the sensitivity of a standard dijet analysis for processes that produce W/Z-jets in the final state by the application of techniques that can identify W/Z-jets and suppress quark and gluon jets (“W/Z-tagging”). This CMS study is performed on pp collision data at a center-of-mass energy of 7 TeV, corresponding to an integrated luminosity of 5.0 fb

1. We consider events with two high-transverse-momentum jets in the final state. We identify “subjets” inside jets using recent developments in the area of jet substructure [12]. Pairs of subjets are used to explicitly reconstruct W or Z bosons, therefore substantially suppressing backgrounds from quantum chromodynamics (QCD) interactions. This search follows closely the procedures of the corresponding dijet search [10], performed in the same dataset, but with strongly reduced QCD background because of the W/Z-tagging.

We consider three benchmark scenarios that would produce singly or doubly tagged events: an excited quark q* [4] decaying into a quark and a W or Z boson; a Randall–Sundrum (RS) graviton G_{RS} [13] decaying to WW or ZZ; and a heavy partner of the SM W boson W' which decays to WZ [8]. The most stringent limits on the q* model have been set in dijet resonance searches at the LHC by considering the qq final state [10] or inclusively all-hadronic final states [11]. The most stringent lower limit (at 95% CL) on the q* mass to date is 3.3 TeV [10]. Specific searches for the qW and qZ final states have previously been reported at the Tevatron [14,15], which exclude resonances decaying to qW or qZ with masses up to 540 GeV, and at the LHC [16], which extends the mass exclusion of qZ resonances up to 1.94 TeV. For the G_{RS}, there are phenomenological models favoring the decay of the G_{RS} into vector bosons rather than photons or fermions [17–19]. In particular, the ZZ final state has been explored experimentally [20–22],
setting lower limits on the $G_{5}$ mass as a function of the coupling parameter $k/M_{Pl}$, where $k$ is the curvature of the warped space and $M_{Pl}$ the reduced Planck mass ($M_{Pl} \equiv M_{P} / \sqrt{8 \pi}$). For the $W'$, the most stringent limits are reported in searches with leptonic final states [23,24], and the current lower limit on the $W'$ mass is 2.5 TeV. The limit varies by 0.1 TeV, depending on the chirality of the $W'$ couplings. Specific searches in the WZ final state have also been reported [25,26] setting a lower limit of 1.1 TeV.

This Letter is organized as follows. First, the CMS detector, and the simulated and collision data samples on which the analysis is based are briefly described. Then the event reconstruction, and selection are detailed, and the W/Z-tagging technique is described. The following section describes the modeling of detector acceptances and signal efficiencies as well as the validation of the W/Z-tagging techniques with data. After this follows the description of the modeling of the background, the systematic uncertainties and the limit setting procedure. Finally the results and conclusions are presented.

2. CMS detector

The CMS detector [27] is well suited to the reconstruction of hadronic jets because it incorporates finely segmented electromagnetic and hadronic calorimeters, and a charged-particle tracking system. Charged particles are reconstructed in the inner tracker, which is immersed in a 3.8 T axial magnetic field. The inner tracker consists of three cylindrical layers and two endcap disks at each end of silicon pixel detectors, and ten barrel layers and twelve endcap disks at each end of silicon strip detectors. This arrangement results in full azimuthal coverage ($0 \leq \phi \leq 2 \pi$) within $|\eta| < 2.5$, where $\eta$ is the pseudorapidity defined as $\eta = -\ln\tan(\theta/2)$. CMS uses a polar coordinate system, with the $z$ axis coinciding with the beam axis; $\theta$ is the polar angle defined with respect to the positive $z$ axis. Muons are measured in gas-ionizing detectors embedded in the steel return yoke. A lead-tungstate crystal electromagnetic calorimeter (ECAL) up to $|\eta| = 3$ and a brass/scintillator hadronic calorimeter (HCAL) up to $|\eta| = 5$ surround the tracking volume and allow photon, electron, and jet reconstruction. The ECAL and HCAL cells are grouped into towers projecting radially outward from the interaction region. In the central region ($|\eta| < 1.74$) the towers have dimensions $\Delta \eta \times \Delta \phi = 0.087$; at higher $|\eta|$, the $\Delta \eta$ and $\Delta \phi$ widths increase. For optimum jet reconstruction, the tracking and calorimeter information is combined in an algorithm called particle flow [28], which is described below.

3. Simulated and collision data samples

The sample of proton–proton collision data at $\sqrt{s} = 7$ TeV, corresponding to an integrated luminosity of 5.0 fb$^{-1}$, was collected in 2011. The events were collected using the logical “or” of a set of triggers based on requirements on $H_{T} = \sum_{jets} p_{T}$ ($p_{T}$ is the transverse momentum of a jet) and the invariant mass of the two highest $p_{T}$ jets in an event, whose thresholds were raised progressively to cope with an increase in the peak luminosity during 2011. Data are compared to Monte Carlo (MC) simulations of the QCD background generated using both PYTHIA 6.424 [29] and HERWIG++ 2.4.2 [30]. PYTHIA 6 is used with CTEQ6L1 [31] and HERWIG++ with MRST2001 [32] parton distribution functions. Tune ZZ (identical to tune Z1 [33]) except that Z2 uses the CTEQ6L PDF while Z1 uses CTEQ5L is used with PYTHIA 6, while the tune version 23 [30] is used with HERWIG++. In this analysis, the background shape is modelled from the data themselves. Therefore, the analysis depends on QCD simulation only to provide guidance and cross checks.

The sensitivity of the event selection to the benchmark processes is evaluated using simulated samples of events from excited quarks, RS gravitons, and $W'$ production and decay models. The process $gg \rightarrow q^{*} \rightarrow W/Z + \text{jet}$ is generated using PYTHIA 6 assuming the couplings to the SU(2), U(1) and SU(3) groups are $f = f' = f_{z} = 1$ for the production and decay of the $q^{*}$. The process $G_{5} \rightarrow WW/ZZ$ is generated using HERWIG++ and its cross section is taken from PYTHIA 6. While HERWIG++ contains a more detailed description of the angular distributions than PYTHIA 6 for this process [34], the cross section is taken from PYTHIA 6 which has been used as a reference model in related analyses [20]. RS graviton production is studied with $k/M_{Pl} = 0.1$, which determines a resonance width of about 1% of the resonance mass which is about a factor 5 smaller than the experimental resolution for dijets. This width is much smaller than suggested by the model in Ref. [17], which predicts resonance widths of the order of the experimental resolution, allowing for interpretation in this model only approximately. The process $W' \rightarrow WZ$ is generated using PYTHIA 6 with Standard Model $V-A$ couplings and without applying k-factors. All Monte Carlo events are passed through the CMS detector simulation based on GEANT4 [35].

4. Event reconstruction and selection

Events are reconstructed using the particle flow algorithm, which attempts to identify and measure all the stable particles in a collision by combining information from all the subdetectors. This algorithm categorizes all particles into five types: muons, electrons, photons, charged and neutral hadrons. The resulting particle flow candidates are passed to the anti-kt [36] and Cambridge–Aachen (CA) [37,38] jet clustering algorithms, as implemented in FASTJET [39,40] to create jets. A distance parameter of size $R = \sqrt{(\Delta \eta)^{2} + (\Delta \phi)^{2}} = 0.8$ is used for the CA algorithm, while $R = 0.5$ is used for the anti-kt algorithm. While the anti-kt jets are used to select events and reconstruct the dijet invariant mass $m_{jj}$, the CA jets are used to identify events containing hadronically decaying W or Z bosons. This choice has been made because the CA algorithm was found to be more efficient (for the same mistag rate) at finding hard subjets within the jets in simulation-based studies [12], while the anti-kt jets have the best energy calibration.

Events must have at least one reconstructed vertex within $|z| < 15$ cm, to suppress backgrounds solely triggered by calorimeter noise. The primary vertex is defined as the vertex with highest sum of squared track transverse momenta ($p_{T}^{2}$). Charged particles not originating from it are removed from the inputs to the jet clustering algorithms. This requirement removes particles which arise from additional pp interactions in the same pp bunch crossing (pileup interactions). An event-by-event jet-area-based correction [41–43] is applied to remove the remaining pileup energy which is due to neutral particles originating from the other vertices. The pileup-subtracted jet four momenta are finally corrected to account for the difference between the measured and true responses to hadrons [43]. When jets are decomposed into subjets, as described later, the energy estimate relies on the calibrated reconstructed input particles without further corrections.

Events are initially selected by requiring that they have at least two anti-kt jets with $p_{T} > 30$ GeV and $|\eta| < 2.5$. The two highest-$p_{T}$ jets are required to have a pseudorapidity separation $|\Delta \eta| < 1.3$ to reduce the QCD dijet background [44]. Finally, the dijet invariant mass is required to be larger than 890 GeV. This threshold is defined by the triggers, which were found to be 99% efficient for dijet events with masses above this threshold.

In events passing this selection, “boosted” (high $p_{T}$) hadronically decaying W or Z bosons are identified with a W/Z-tagging algorithm using jet pruning [45], a technique which removes the softest components of the jets. In the jet pruning technique [46,47], a jet is reclustered using all the particles used to build
a CA jet, ignoring in each recombination step the softer “protojet” if the recombination is softer than a given threshold $z_{\text{cut}} = 0.1$ or forms an angle $\Delta R$ wider than $D_{\text{cut}} = 0.5m^{\text{orig}}_{\text{jet}}/p_T^{\text{jet}}$ with respect to the previous recombination step, where $m^{\text{orig}}$ and $p_T^{\text{orig}}$ are the mass and transverse momentum of the original CA jet. The hardness of a recombination $z$ is defined as $z = \min(p_T^{1}/p_T^{2}, p_T^{2}/p_T^{1})$, where $p_T^{1}$ and $p_T^{2}$ are the $p_T$ of the two protojets to be combined and $p_T^{0}$ is the $p_T$ of the combined jet. The following selection is then applied to the pruned jets to identify jets from hadronic W/Z decays by exploiting the variables used in Ref. [48].

The total pruned jet mass $m_{\text{jet}}$ must satisfy $70 \text{ GeV} < m_{\text{jet}} < 100 \text{ GeV}$. Two subjets are obtained by undoing the last clustering iteration of the pruned jet clustering. The ratio of masses of the highest mass subjet ($m_1$) and the total pruned jet mass is defined as the mass drop $m^{\text{drop}} = \frac{m_1}{m_{\text{jet}}}$. To discriminate against QCD jets, the mass drop is required to satisfy $m^{\text{drop}} < 0.25$. These criteria are designed to select W and Z candidates in which the subjets are similar in energy and mass.

Comparisons of the dijet invariant mass distributions for untagged, single-tagged, and double-tagged event samples are shown in Fig. 1. The data are shown as solid points and the PYTHIA 6 and HERWIG++ simulations are shown as solid red and dashed blue curves, respectively. The simulations are normalized to the number of data events in each category.

5. Signal characterization

A search for dijet resonances corresponding to several benchmark physics models is performed. Using the W/Z-tagging algorithm, both single W/Z-tag and double W/Z-tag events are examined. The signals that would be produced by the benchmark physics models have different characteristics that are described below.

The pruned jet mass and mass drop distributions in data, signal, and background simulations are shown in Fig. 2. The discriminative power of the pruned jet mass and mass drop for the different signals is evident. In both the pruned jet mass and the mass drop distributions, small differences may be seen between the results obtained with HERWIG++ (WW, ZZ) and PYTHIA 6 (WZ, qW, qZ), which arise from differences in the showering and hadronization models used by these generators. This effect is taken into account in the estimate of the systematic uncertainties on the tagging efficiency, as described below.

The acceptance, defined as the product of signal branching fraction into dijet final states $B(W/Z \rightarrow jets)$ times angular acceptance $|\eta| < 2.5, |\Delta\eta| < 1.3$, is shown in Fig. 3. Each model relevant for the singly (doubly) tagged data analysis is shown in the dijet invariant mass range up to 2 TeV (3 TeV). The fraction of events that produce dijet events, which have survived the kinematic selection, is between 26% and 47%. This fraction includes also the branching fraction of W/Z decaying into objects which are reconstructed from QCD interactions as jets. The different behavior of the acceptance for W and G_{RS} at low dijet masses is due to different angular distributions generated by PYTHIA 6 and HERWIG++.

The W/Z-tagging efficiency, which is not part of the acceptance, is shown for signal and background events in Fig. 4. The signal efficiency, determined from the simulation, is found to be between 20% and 45% (8% and 22%) for single (double) W/Z-tagged signals. The W-tagging efficiency is larger than the Z-tagging efficiency due to the choice of the jet mass window cut, which rejects a larger
The branching fraction into dijet final states $B(W/Z \rightarrow \text{jets})$ times angular acceptance ($|\eta| < 2.5, |\Delta\eta| < 1.3$). The W/Z-tagging efficiencies are excluded from the acceptance.

**Fig. 4.** Efficiency of requiring 1 $W/Z$-tag (top) and 2 $W/Z$-tags (bottom) in signal and background simulations, and in data for events passing the angular acceptance requirement ($|\eta| < 2.5, |\Delta\eta| < 1.3$).

**Fig. 3.** The branching fraction into dijet final states $B(W/Z \rightarrow \text{jets})$ times angular acceptance ($|\eta| < 2.5, |\Delta\eta| < 1.3$). The W/Z-tagging efficiencies are excluded from the acceptance.

The effect of pileup on the W/Z-tagging efficiency was also checked. Because of the rejection of charged particles not originating from the primary vertex and the application of pruning, the pileup dependence is weak and the uncertainty of the modeling of the pileup distribution is less than 2%.

The dijet mass dependence of the W/Z-tagging efficiency for background events shown in Fig. 4 is adequately described by the simulation. Therefore, no additional systematic uncertainty is assigned on the dijet mass dependence of the modeling of the W/Z-tagging in simulation.

Fig. 5 shows the signal shapes for $G_{RS} \rightarrow ZZ, WW$, $W' \rightarrow WZ$, and $q^* \rightarrow qW/qZ$, all of which correspond to a resonance mass of 1.5 TeV. The differences for the different models are to a large extent due to the different tagging efficiencies for $W$ and $Z$ and to a smaller extent to differences in the models in PYTHIA 6 and HERWIG++. The lower cut of 70 GeV on the jet mass in the W/Z-tag bias the resonance peak for WW, WZ and qW towards higher masses, especially when two tags are applied on the WW sample.
density function, and $P_1$, $P_2$, $P_3$ describe its shape. For the single $W/Z$-tagged analysis, all parameters are free to float in the fit. For the double $W/Z$-tagged analysis, $P_3$ is not needed as suggested by a Fisher F-test and is deleted, all parameters are free to float in the fit. For the double $W/Z$-tagged analysis, $P_3$ is not needed as suggested by a Fisher F-test and a simpler parametrization with $P_3$ fixed to 0 is used.

Fig. 6 shows the dijet mass spectra from single and double $W/Z$-tagged data fitted to Eq. (1) and the corresponding pull distributions, demonstrating the agreement between the background-only probability density function and the data.

Since no sizable deviation from the background-only hypothesis is seen, exclusion limits are set on the product of cross section, acceptance, and branching fraction for the five considered final states: $qW$, $qZ$, $WW$, $WZ$, and $ZZ$.

7. Systematic uncertainties

The sources of systematic uncertainties are summarized as follows. The only background-related systematic uncertainty is the choice of background parametrization which is discussed in Section 8. The leading signal-related systematic uncertainties are the $W/Z$-tagging efficiency (Section 5), jet energy scale (JES), jet energy resolution (JER), and luminosity measurement. Because the trigger and reconstruction efficiencies are larger than 99% in the relevant dijet mass range, the uncertainties associated with these efficiencies are negligible.

In the jet $p_T$- and $\eta$-regions considered in this analysis, the JES has an uncertainty of 2–3% [43]. The $p_T$- and $\eta$-dependent uncertainty is propagated to an uncertainty on the reconstructed dijet invariant mass of 2.2%, which is approximately mass independent. The effect of the JES uncertainty on the calculation of the limits is estimated by varying the reconstructed dijet mass in the statistical analysis. The JER is known to a precision of 10% and its tails are in agreement between data and simulation [43]. The effect of the JER uncertainty on the calculation of the limits is estimated by varying the reconstructed dijet resolution at the edges of the statistically limited analysis. The luminosity has an uncertainty of 2.2% [53], which is also taken into account in the statistical analysis.

8. Limit setting procedure

For setting upper limits on the resonance production cross section a Bayesian formalism with uniform prior for the cross section is used, following the procedure used in Ref. [51]. The binned likelihood, $L$, can be written as:

$$L = \prod_i \frac{\nu_i^m e^{-\nu_i}}{n_i!},$$  

where

$$\nu_i = \alpha N_i(S) + N_i(B),$$

$n_i$ is the observed number of events in the $i$th dijet mass bin, $N_i(S)$ is the expected number of events from the signal in the $i$th dijet mass bin, $N_i(B)$ is the expected number of events from background in the $i$th dijet mass bin. The background $N_i(B)$ is estimated as the background component of the best 5(4)-parameter fit of Eq. (3) to the singly (doubly) tagged data points. The signal is not restricted to be positive for the background estimate fit although it is restricted in the Bayesian prior for the signal. A flat prior in $\alpha$, which is the same as a flat prior in the resonance production cross section, is assumed.

The dominant sources of systematic uncertainty (the jet energy scale, the jet energy resolution, the integrated luminosity, and the $W/Z$-tagging efficiency) are considered as nuisance parameters associated to log-normal priors. The uncertainty on the background...
Fig. 7. Expected and observed limits for qW (top-left), qZ (top-right), WW (center-left), ZZ (center-right) and WZ (bottom) resonances. Here, $B \times A$ in the vertical axis label contains the branching fraction of $G_{RS} \rightarrow WW/ZZ \rightarrow 2j$ or $q^* \rightarrow qW/qZ \rightarrow 2$ jets, as well as the acceptance for reconstructing the jets in $|\eta| < 2.5$, $|\Delta\eta| < 1.3$. The predicted cross sections as a function of resonance mass for the considered benchmark models are overlaid.
shape is taken into account with nuisance parameters associated to Gaussian priors representing variations of the fit parameters along the eigenvectors of their correlation matrix. The systematic uncertainties are accounted for using a fully Bayesian treatment and integrating the likelihood over nuisance parameters.

The 95% confidence level (CL) upper limit $\sigma_5$ is calculated from the normalized posterior probability density $P_{\text{post}}$ as follows:

$$\int_0^{P_{\text{post}}(\sigma)} d\sigma = 0.95. \quad (4)$$

This method of using the data first to constrain the background fit and second to extract the limit induces a bias in the coverage of the limits. The actual coverage is reduced to 93.6% (94.3%) at a WW ($qW$) signal mass of 1200 GeV (1800 GeV).

9. Results

Fig. 7 shows the 95% CL cross section upper limits derived from the single and double W/Z-tagged event samples. The predicted cross sections as a function of resonance mass for the considered benchmark models are overlaid. A 95% CL lower limit is set on the mass of excited quark resonances decaying into qW (qZ) at 2.38 TeV (2.15 TeV), whereas a limit of 2.43 TeV (2.07 TeV) is expected. These are the most stringent limits in the qW and qZ final states to date. The sensitivity of our measurement with the present datasets is not sufficient to extract substantive mass limits on the states to date. The predicted cross section limits are the most stringent in the fully hadronic WW (qW) signal mass of 1200 GeV (1800 GeV).

Per limits on the cross section for resonances decaying to qW, qZ, WW, WZ, or ZZ final states. These are the most stringent limits in the qW and qZ final states to date. Comparing to the cross section limits on the qW and qZ final states to date. Finally, we acknowledge the enduring support for the construction and operation of the LHC and the CMS detector provided by the following funding agencies: BMWF and FWF (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MEYS (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES (Croatia); RPF (Cyprus); MoER, SF0690030S09 and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Republic of Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); MSI (New Zealand); NSC (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MON, RosAtom, RAS and RFBR (Russia); MSTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); The HPCCenter, IPST and NSTDA (Thailand); TUBITAK and TAEK (Turkey); NASU (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

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19 Also at Eötvös Loránd University, Budapest, Hungary.
20 Also at Tata Institute of Fundamental Research - HECR, Mumbai, India.
21 Also at University of Vycova-Bharati, Sarniketan, India.
22 Also at Sharif University of Technology, Tehran, Iran.
23 Also at Isfahan University of Technology, Isfahan, Iran.
24 Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran.
25 Also at Facoltà Ingegneria, Università di Roma, Roma, Italy.
26 Also at Università della Basilicata, Potenza, Italy.
27 Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
28 Also at Università degli Studi di Siena, Siena, Italy.
29 Also at University of Bucharest, Faculty of Physics, Bucuresti-Magurele, Romania.
30 Also at Faculty of Physics of University of Belgrade, Belgrade, Serbia.
31 Also at University of California, Los Angeles, Los Angeles, USA.
32 Also at Scuola Normale e Sezione dell’INFN, Pisa, Italy.
33 Also at INFN Sezione di Roma; Università di Roma, Roma, Italy.
34 Also at University of Athens, Athens, Greece.
35 Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
36 Also at Paul Scherrer Institut, Villigen, Switzerland.
37 Also at Institute for Theoretical and Experimental Physics, Moscow, Russia.
38 Also at Albert Einstein Center for Fundamental Physics, Bern, Switzerland.
39 Also at Gaziosmanpasa University, Tokat, Turkey.
40 Also at Adiyaman University, Adiyaman, Turkey.
41 Also at Izmir Institute of Technology, Izmir, Turkey.
42 Also at The University of Iowa, Iowa City, USA.
43 Also at Mersin University, Mersin, Turkey.
44 Also at Ozyegin University, Istanbul, Turkey.
45 Also at Kafkas University, Kars, Turkey.
46 Also at Suleyman Demirel University, Isparta, Turkey.
47 Also at Ege University, Izmir, Turkey.
48 Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
49 Also at INFN Sezione di Perugia; Università di Perugia, Perugia, Italy.
50 Also at University of Sydney, Sydney, Australia.
51 Also at Utah Valley University, Orem, USA.
52 Also at Institute for Nuclear Research, Moscow, Russia.
53 Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia.
54 Also at Argonne National Laboratory, Argonne, USA.
55 Also at Ertzincan University, Erzincan, Turkey.
56 Also at Mimar Sinan University, Istanbul, Istanbul, Turkey.
57 Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
58 Also at Kyungpook National University, Daegu, Korea.