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Nuclear modification factor of D^0 mesons in PbPb collisions at $\sqrt{s_{_{NN}}} = 5.02\,\text{TeV}$

The CMS Collaboration*

Abstract

The transverse momentum (p_T) spectrum of prompt D^0 mesons and their antiparticles has been measured via the hadronic decay channels $D^0 \rightarrow K^-\pi^+$ and $\overline{D}^0 \rightarrow K^+\pi^-$ in pp and PbPb collisions at a centre-of-mass energy of 5.02 TeV per nucleon pair with the CMS detector at the LHC. The measurement is performed in the D^0 meson p_T range of 2–100 GeV/c and in the rapidity range of $|y| < 1$. The pp (PbPb) dataset used for this analysis corresponds to an integrated luminosity of 27.4 pb^{-1} (530 μb^{-1}). The measured D^0 meson p_T spectrum in pp collisions is well described by perturbative QCD calculations. The nuclear modification factor, comparing D^0 meson yields in PbPb and pp collisions, was extracted for both minimum-bias and the 10% most central PbPb interactions. For central events, the D^0 meson yield in the PbPb collisions is suppressed by a factor of 5–6 compared to the pp reference in the p_T range of 6–10 GeV/c. For D^0 mesons in the high-p_T range of 60–100 GeV/c, a significantly smaller suppression is observed. The results are also compared to theoretical calculations.

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*See Appendix A for the list of collaboration members

1 Introduction

Relativistic heavy ion collisions allow the study of quantum chromodynamics (QCD) at high energy density and temperature. Lattice QCD calculations predict that under such extreme conditions a transition to a strongly interacting and deconfined medium, called the quark-gluon plasma (QGP), occurs [1–3]. Heavy quarks are effective probes to study the properties of the deconfined medium created in heavy ion collisions. These quarks are mostly produced in primary hard QCD scatterings with a production timescale that is shorter than the formation time of the QGP [4]. During their propagation through the medium, heavy quarks lose energy via radiative and collisional interactions with the medium constituents. Quarks are expected to lose less energy than gluons as a consequence of their smaller colour factor. In addition, the so-called "dead-cone effect" is expected to reduce small-angle gluon radiation of heavy quarks when compared to both gluons and light quarks [5–7]. Energy loss can be studied using the nuclear modification factor (R_{AA}), defined as the ratio of the PbPb yield to the pp cross-section scaled by the nuclear overlap function [8]. Precise measurements of the R_{AA} of particles containing both light and heavy quarks can thus provide important tests of QCD predictions at extreme densities and temperatures and in particular allow one to test the expected flavour dependence of the energy loss processes. The comparison to theoretical calculations is fundamental in order to claim any evidence of flavour dependence of the energy loss mechanisms since sizeable discrepancies in the R_{AA} of light and heavy particles can arise as a consequence of the different transverse momentum spectra and fragmentation functions of beauty, charm, and light quarks and gluons.

Evidence of open charm suppression at the CERN LHC was observed by the ALICE Collaboration using the R_{AA} of promptly produced D mesons (D^0, D^+, D^{*+} mesons and their conjugates) at mid-rapidity ($|y| < 0.5$) at a nucleon-nucleon centre-of-mass energy $\sqrt{s_{NN}} = 2.76\,\text{TeV}$. The measurement was performed as a function of centrality (i.e. the degree of overlap of the two colliding nuclei) and transverse momentum ($1 < p_T < 36\,\text{GeV}/c$) [9, 10]. A maximum suppression by a factor of 5–6 with respect to the pp reference was observed for the 10% most central collisions at p_T of about $10\,\text{GeV}/c$. A suppression by a factor of about 3 was measured at the highest p_T range studied, from 25 to $35\,\text{GeV}/c$. The D meson R_{AA} was found to be consistent with that for all charged particles for p_T from 6 to $36\,\text{GeV}/c$. For lower p_T, the D meson R_{AA} was observed to be slightly higher than the charged-particle R_{AA}, although still compatible within the uncertainties [11, 12]. At RHIC, the R_{AA} of D^0 mesons for the 10% most central AuAu collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$ was measured by the STAR Collaboration in the rapidity range of $|y| < 1$ [13]. A suppression by a factor of 2–3 for p_T larger than $3\,\text{GeV}/c$ was seen. This suggests that a significant energy loss of charm quarks in the hot medium also occurs at RHIC energies. A first indication of a sizeable difference in the R_{AA} of B and D mesons was observed when comparing the ALICE D meson R_{AA} with the nonprompt J/ψ meson (i.e. from b-hadron decays) R_{AA} measurement performed by the CMS Collaboration in PbPb collisions at the same energy and collision centrality [14]. The R_{AA} of nonprompt J/ψ mesons in the p_T range 6.5–30 GeV/c was indeed found to be significantly larger than the R_{AA} of D mesons in the 8–16 GeV/c p_T region for central events. The D^0 p_T range was chosen to give a similar median p_T value to that of the parent b hadrons decaying to J/ψ particles [9]. Several measurements were also performed to address the relevance of cold nuclear matter effects for the suppression observed for heavy-flavour particles. Indeed, these phenomena can affect the yield of such particles, independently of the presence of a deconfined partonic medium. For instance, modifications of the parton distribution functions (PDFs) in the nucleus with respect to nucleon PDFs [15–17] could change the production rate of heavy-flavour particles. To evaluate the relevance of these effects, the production of prompt D mesons was measured in pPb collisions at mid-rapidity at 5.02 TeV by the ALICE Collaboration [18]. The nuclear modification factor in pPb collisions (R_{pA}) was found to be consistent within the 15–20% uncertainties with unity for p_{T} from 2 to 24 GeV/c. This suggests that the suppression of D mesons observed in PbPb collisions cannot be explained in terms of initial-state effects but is mostly due to strong final-state effects induced by the QGP. A similar conclusion was obtained from the study of the R_{pA} of B mesons in pPb collisions at 5.02 TeV, where values consistent with unity within the uncertainties were found for p_{T} from 10 to 60 GeV/c [19].

In this Letter, the production of prompt D^0 mesons in PbPb collisions at 5.02 TeV is measured for the first time up to a p_{T} of 100 GeV/c, allowing one to study the properties of the in-medium energy loss in a new kinematic regime. The D^0 meson and its antiparticle are reconstructed in the central rapidity region ($|y| < 1$) of the CMS detector via the hadronic decay channels $\mathrm{D}^0 \rightarrow \mathrm{K}^-\pi^+$ and $\overline{\mathrm{D}}^0 \rightarrow \mathrm{K}^+\pi^-$. The production cross section and yields in pp and PbPb collisions, respectively, and the R_{AA} of prompt D^0 mesons are presented as a function of their p_{T}. The R_{AA} is reported for two centrality intervals: in the inclusive sample (0–100%), and in one corresponding to the most overlapping 10% of the collisions.

2 The CMS detector

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the solenoid volume are a silicon tracker which measures charged particles within the pseudorapidity range $|\eta| < 2.5$, a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass and scintillator hadron calorimeter (HCAL). The ECAL consists of more than 75 000 lead tungstate crystals, and is partitioned into a barrel region ($|\eta| < 1.48$) and two endcaps extending out to $|\eta| = 3.0$. The HCAL consists of sampling calorimeters composed of brass and scintillator plates, covering $|\eta| < 3.0$. Iron hadron forward (HF) calorimeters, with quartz fibers read out by photomultipliers, extend the calorimeter coverage out to $|\eta| = 5.2$. A detailed description of the CMS experiment can be found in Ref. [20].

3 Event selection and Monte Carlo samples

The pp (PbPb) dataset used for this analysis corresponds to an integrated luminosity of 27.4 pb^{-1} (530 $\mu\mathrm{b}^{-1}$). The D^0 meson production is measured from p_{T} of 2 up to 20 GeV/c using large samples of minimum-bias (MB) events (≈2.5 billion pp events and ≈300 million PbPb events). Minimum-bias events were selected online using the information from the HF calorimeters and the beam pickup monitors. For measuring the D^0 meson production above 20 GeV/c, dedicated high-level trigger (HLT) algorithms were designed to identify online events with a D^0 candidate. Since events with a high-p_{T} D^0 meson are expected to leave large energy deposits in HCAL, HLT algorithms were run on events preselected by jet triggers in the level-1 (L1) calorimeter trigger system. In PbPb collisions, the D^0 triggers with p_{T} threshold below 40 GeV/c were run on events passing the L1 MB trigger selection. While the MB and lower-threshold triggers had to be prescaled because of the high instantaneous luminosity of the LHC, the highest threshold trigger used in the analysis ($p_{\mathrm{T}} > 60$ (50) GeV/c for PbPb (pp) data taken) was always unprescaled. The efficiency of the HLT algorithms was evaluated in data, and modeled by a linear function of D^0 p_{T}. The efficiency was found to be about 100 (90)% in pp (PbPb) collisions for events passing the corresponding L1 selection.

For the offline analysis, events have to pass a set of selection criteria designed to reject events from background processes (beam-gas collisions and beam scraping events) as described in Ref. [21]. In order to select hadronic collisions, both pp and PbPb events are required to have at least one reconstructed primary interaction vertex with a distance from the centre of the nominal interaction region of less than 15 cm along the beam axis. In addition, in PbPb collisions the shapes of the clusters in the pixel detector have to be compatible with those expected from particles produced by a PbPb collision [22]. The PbPb collision events are also required to have at least three towers in each of the HF detectors with energy deposits of more than 3 GeV per tower. The combined efficiency for this event selection, and the remaining non-hadronic contamination, is $(99 \pm 2)\%$. Selection efficiencies higher than 100% are possible, reflecting the possible presence of ultra-peripheral (nonhadronic) collisions in the selected event sample. The collision centrality is determined from the total transverse energy deposition in both the HF calorimeters. Collision centrality bins are given in percentage ranges of the total inelastic hadronic cross section, with the 0–10% bin corresponding to the 10% of collisions having the largest overlap of the two nuclei.

Several Monte Carlo (MC) simulated event samples are used to evaluate background components, signal efficiencies, and detector acceptance corrections. The events produced include both prompt and nonprompt (from b hadron decays) D^0 meson events. Proton-proton collisions are generated with PYTHIA 8 v212 [23] tune CUETP8M1 [24] and propagated through the CMS detector using the GEANT4 package [25]. The D^0 mesons are decayed with EVTGEN 1.3.0 [26], and final-state photon radiation in the D^0 decays is simulated with PHOTOS 2.0 [27]. For the PbPb MC samples, each PYTHIA 8 event is embedded into a PbPb collision event generated with HYDJET 1.8 [28], which is tuned to reproduce global event properties such as the charged-hadron p_T spectrum and particle multiplicity.

4 Signal extraction

The D^0 candidates are reconstructed by combining pairs of oppositely charged particle tracks with an invariant mass within $0.2\,\text{GeV}/c^2$ of the world-average D^0 mass [29]. Each track is required to have $p_T > 1\,\text{GeV}/c$ in order to reduce the combinatorial background. For high-p_T D^0 mesons (above $20\,\text{GeV}/c$) in PbPb data, the single track cut is raised to $p_T > 8.5\,\text{GeV}/c$ to account for the selection ($p_T > 8\,\text{GeV}/c$) performed at the HLT. All tracks are also required to be within $|\eta| < 1.5$. For each pair of selected tracks, two D^0 candidates are created by assuming that one of the particles has the mass of the pion while the other has the mass of the kaon, and vice-versa. The D^0 mesons are required to be within $|y| < 1$, optimised in conjunction to the track pseudorapidity selection to give the best signal to background ratio over the whole range of D^0 p_T studied. In order to further reduce the combinatorial background, the D^0 candidates are selected based on three topological criteria: on the three-dimensional (3D) decay length L_{xyz} normalised to its uncertainty (required to be larger than 4–6), on the pointing angle θ_p (defined as the angle between the total momentum vector of the tracks and the vector connecting the primary and the secondary vertices and required to be smaller than 0.12), and on the χ^2 probability, divided by the number of degrees of freedom, of the D^0 vertex fit (required to be larger than 0.025–0.05). The selection is optimised in each p_T bin using a multivariate technique [30] in order to maximise the statistical significance of the D^0 meson signals.

The D^0 meson yields in each p_T interval are extracted with a binned maximum-likelihood fit to the invariant mass distributions in the range $1.7 < m_{\pi K} < 2.0\,\text{GeV}/c^2$. Several examples of D^0 candidate invariant mass distributions are shown in Fig. 1 for pp (top) and PbPb (bottom) collisions. The combinatorial background, originating from random pairs of tracks not produced by a D^0 meson decay, is modeled by a third-order polynomial. The signal shape was found to be best modeled over the entire p_{T} range measured by two Gaussian functions with the same mean but different widths. An additional Gaussian function is used to describe the invariant mass shape of D^0 candidates with incorrect mass assignment from the exchange of the pion and kaon designations. The widths of the Gaussian functions that describe the D^0 signal shape and the shape of the D^0 candidates with swapped mass assignment are free parameters in the fit. Also, the ratio between the yields of the signal and of the D^0 candidates with swapped mass assignments is fixed to the value extracted from simulation.

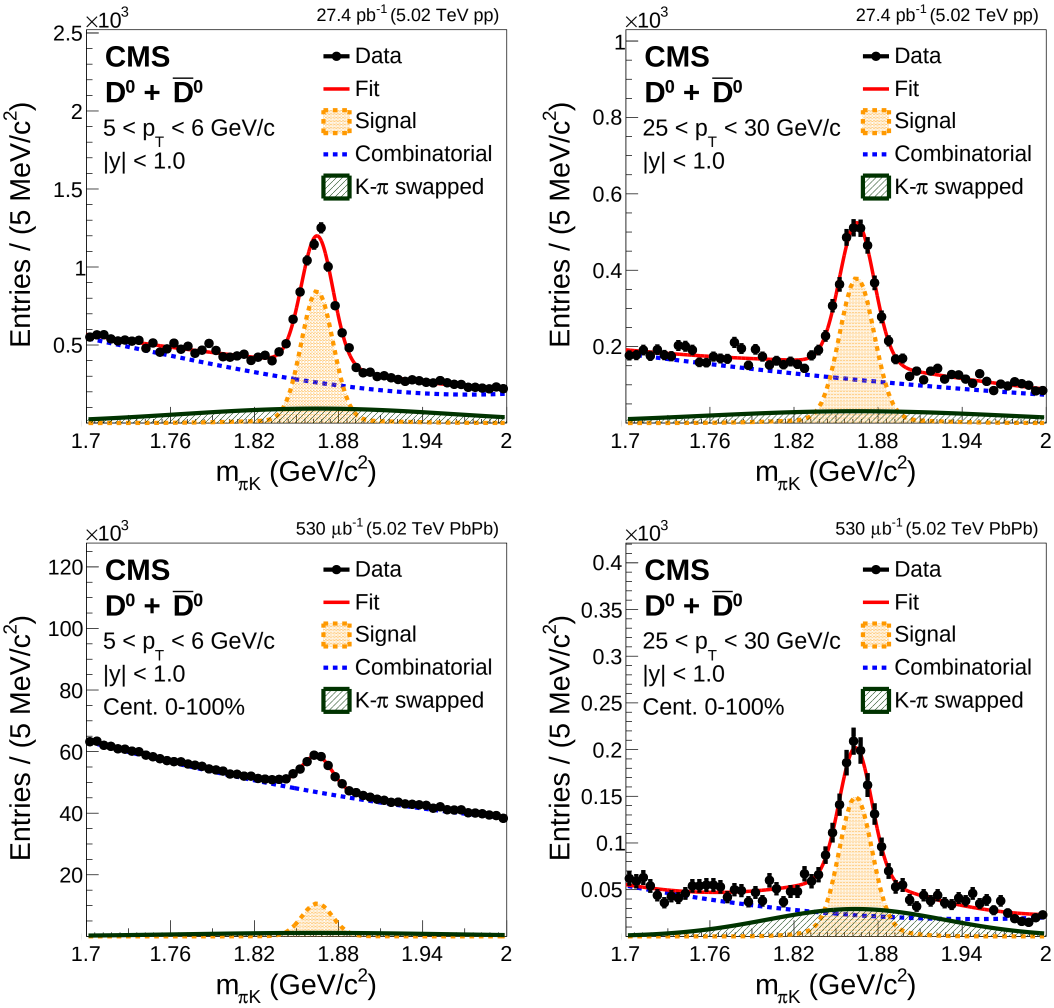

Figure 1: Examples of D^0 candidate invariant mass distributions in pp (top) and PbPb (bottom) collisions at 5.02 TeV.

The D^0 p_{T}-differential cross section in each p_{T} interval in pp collisions is defined as:

$$\left.\frac{\mathrm{d}\sigma_{\mathrm{pp}}}{\mathrm{d}p_{\mathrm{T}}}\right|_{|y|<1} = \frac{1}{2}\frac{1}{\Delta p_{\mathrm{T}}}\frac{1}{\mathcal{B}\,\mathcal{L}} \left.\frac{f_{\mathrm{prompt}}\,N_{\mathrm{pp}}}{(\alpha\,\epsilon)_{\mathrm{prompt}}\,\beta_{\mathrm{prescale}}\,\epsilon_{\mathrm{trigger}}}\right|_{|y|<1}, \quad (1)$$

where Δp_{T} is the width of the p_{T} interval, $\mathcal{B}$ is the branching fraction of the decay chain, $\mathcal{L}$ is the integrated luminosity, $(\alpha\,\epsilon)_{\mathrm{prompt}}$ represents the correction for acceptance and efficiency and N_{pp} is the yield of D^0 and $\overline{\mathrm{D}}^0$ mesons extracted in each p_{T} interval. In both pp and PbPb cases, the value of α_{prompt} ranges from about 0.3 at 2–3 GeV/c to about 100% at 60–100 GeV/c. The value of $\epsilon_{\mathrm{prompt}}$ ranges for PbPb (pp) from about 0.02 (0.03) at 2–3 GeV/c to about 0.4 (0.6) at 60–100 GeV/c. The factor 1/2 accounts for the fact that the cross section is given for the average of particles and antiparticles. The raw yields N_{pp} are corrected in order to account for the average prescale factor $\beta_{\mathrm{prescale}}$ and the efficiency $\epsilon_{\mathrm{trigger}}$ of the trigger that was used to select events in that specific p_{T} interval. The factor f_{prompt} is the fraction of D^0 mesons that comes directly from c quark fragmentation and is measured using control samples in data by exploiting the difference in the distributions of a quantity found by multiplying the 3D D^0 decay length L_{xyz} by the sine of the pointing angle $\sin(\theta_{\mathrm{p}})$ of prompt and nonprompt D^0 mesons. In particular, the value of f_{prompt} (typically in the range 0.8–0.9) is measured in each p_{T} interval by fitting the distribution of $L_{\mathrm{xyz}}\sin(\theta_{\mathrm{p}})$ using the prompt and nonprompt shapes obtained from MC simulation.

The D^0 p_{T}-differential production yield in each p_{T} interval in PbPb collisions is defined as:

$$\frac{1}{T_{\mathrm{AA}}}\left.\frac{\mathrm{d}N_{\mathrm{PbPb}}}{\mathrm{d}p_{\mathrm{T}}}\right|_{|y|<1} = \frac{1}{T_{\mathrm{AA}}}\frac{1}{2}\frac{1}{\Delta p_{\mathrm{T}}}\frac{1}{\mathcal{B}\,N_{\mathrm{MB}}}\left.\frac{f_{\mathrm{prompt}}\,N_{\mathrm{PbPb}}}{(\alpha\,\epsilon)_{\mathrm{prompt}}\,\beta_{\mathrm{prescale}}\;\epsilon_{\mathrm{trigger}}}\right|_{|y|<1}, \tag{2}$$

where N_{MB} is the number of MB events used for the analysis and T_{AA} is the nuclear overlap function [8], which is equal to the number of nucleon-nucleon (NN) binary collisions divided by the NN cross section and can be interpreted as the NN-equivalent integrated luminosity per heavy ion collision. The values of T_{AA} are $5.61\,\mathrm{mb}^{-1}$ for inclusive PbPb collisions and $23.2\,\mathrm{mb}^{-1}$ for central events [21]. The other terms were defined analogously to Eq. (1).

5 Systematic uncertainties

The yields are affected by several sources of systematic uncertainties arising from the signal extraction, acceptance and efficiency corrections, branching fraction, and integrated luminosity determination. The uncertainty in the raw yield extraction (1.6–8.2% for pp and 1.3–17.5% for PbPb data, with the highest value at low-p_{T}, which is the region with the smallest signal to background ratio) is evaluated by repeating the fit procedure using different background fit functions and by forcing the widths of the Gaussian functions that describe the signal to be equal to the values extracted in simulations to account for possible differences in the signal resolution in data and in MC. In the background variation study, an exponential plus a second-order polynomial function was considered instead of the first order polynomial one, which is used as default. The final uncertainty in the raw yield extraction is defined as the sum in quadrature of the relative differences of the signal variation and the maximum of all the background variations.

The systematic uncertainty due to the selection of the D^0 meson candidates (0.5–3.6% for pp and 2.7–8.1% for PbPb data, with the highest value at low-p_{T}) is estimated by considering the differences between MC and data in the reduction of the D^0 yields obtained by applying each of the D^0 selection variables described in Sec. 4. The study was performed by varying one selection at a time, in a range that allowed a robust signal extraction procedure and by considering the maximum relative discrepancy in the yield reduction between data and MC. The total uncertainty was the quadratic sum of the maximum relative discrepancy obtained by varying each of the three selection variables separately.

The uncertainty due to the D^0 trigger efficiency (1% for pp and 2% for PbPb data) is evaluated as the statistical uncertainty in the zeroth-order coefficient of the linear function used to describe the plateau of the efficiency distribution. The systematic uncertainty in the hadron tracking efficiency (4.0% for pp and 6.0–6.5% for PbPb data) is estimated from a comparison of two- and four-body D^0 meson decays in data and simulated samples [31].

To evaluate the systematic uncertainty in the prompt D^0 meson fraction, the width of the $L_{xyz}\sin(\theta_p)$ MC prompt and nonprompt templates are varied in a range that covers the observed differences between the data and MC values. The systematic uncertainty (10% for both pp and PbPb data) was obtained in each p_T bin as the difference between the f_{prompt} value extracted from the variation that gives the best χ^2 fit to data and the nominal f_{prompt} value. To evaluate this uncertainty for the R_{AA} measurement, the widths of the template distributions are varied simultaneously in pp and PbPb. The systematic uncertainty on the f_{prompt} correction was evaluated as the spread of the ratios of f_{prompt} in PbPb and pp to account for partial cancellations of the systematic effects in the two analyses.

The uncertainty related to the simulated p_T shape (smaller than 0.5% for both pp and PbPb data) is evaluated by reweighting the simulated D^0 meson p_T distribution according to the p_T shape obtained from a fixed-order plus next-to-leading logarithmic (FONLL) prediction [32].

The systematic uncertainty in the cross section measurement is computed as the sum in quadrature of the different contributions mentioned above. The global uncertainty in the pp measurement (2.5%) is the sum in quadrature of the systematic uncertainty in the integrated luminosity (2.3% [33]) and in the branching fraction $\mathcal{B}$ (1.0% [29]). The global uncertainty in the PbPb measurement (+3.6%, −4.1% for the centrality range 0–100% and +2.9%, −3.7% for 0–10%) is the sum in quadrature of the uncertainties in the MB selection efficiency (2%), in the branching fraction (1.0%) and in the T_{AA} (+2.8%, −3.4% for the centrality range 0–100% and +1.9%, −3.0% for 0–10%). For the R_{AA} results, no cancelation of uncertainties is assumed between the pp and PbPb results.

6 Results

The p_T-differential production cross section in pp collisions measured in the interval $|y| < 1$ is presented in the left panel of Fig. 2. The result is compared to the prediction of FONLL and a general-mass variable flavour number scheme (GM-VFNS) [34–36] calculation. The CMS measurement lies close to the upper bound of the FONLL prediction and the lower bound of the GM-VFNS calculation. The D^0 p_T-differential production yields divided by the nuclear overlap functions T_{AA} in PbPb collisions in the 0–100% and 0–10% centrality ranges are presented in the right panel of Fig. 2 and compared to the same pp cross section shown in the left panel.

The nuclear modification factor, R_{AA} is computed as:

$$R_{AA} = \frac{1}{T_{AA}} \frac{dN_{PbPb}}{dp_T} \bigg/ \frac{d\sigma_{pp}}{dp_T} . \tag{3}$$

The R_{AA} in the centrality range 0–100% is shown in the left panel of Fig. 3 as a function of p_T. The R_{AA} shows a suppression of a factor 3 to 4 at p_T of 6–8 GeV/c. At higher p_T, the suppression factor decreases to a value of about 1.3 in the p_T range 60–100 GeV/c. The R_{AA} for the centrality range 0–10% is presented in the right panel of Fig. 3. The D^0 R_{AA} in central events shows a hint of stronger suppression if compared to the inclusive R_{AA} result for $p_T > 5$ GeV/c. In this comparison, the large overlap between the two results has to be considered. Indeed, roughly 40% of the D^0 candidates used in the measurement in the centrality range 0–100% are also included in the 0–10% result.

The results are also compared to calculations of four types of models: (a) two perturbative QCD-based models that include both collisional and radiative energy loss, (M. Djordjevic [37] and CUJET 3.0 [38–40]) and one that includes radiative energy loss only (I. Vitev [41, 42]), (b) a

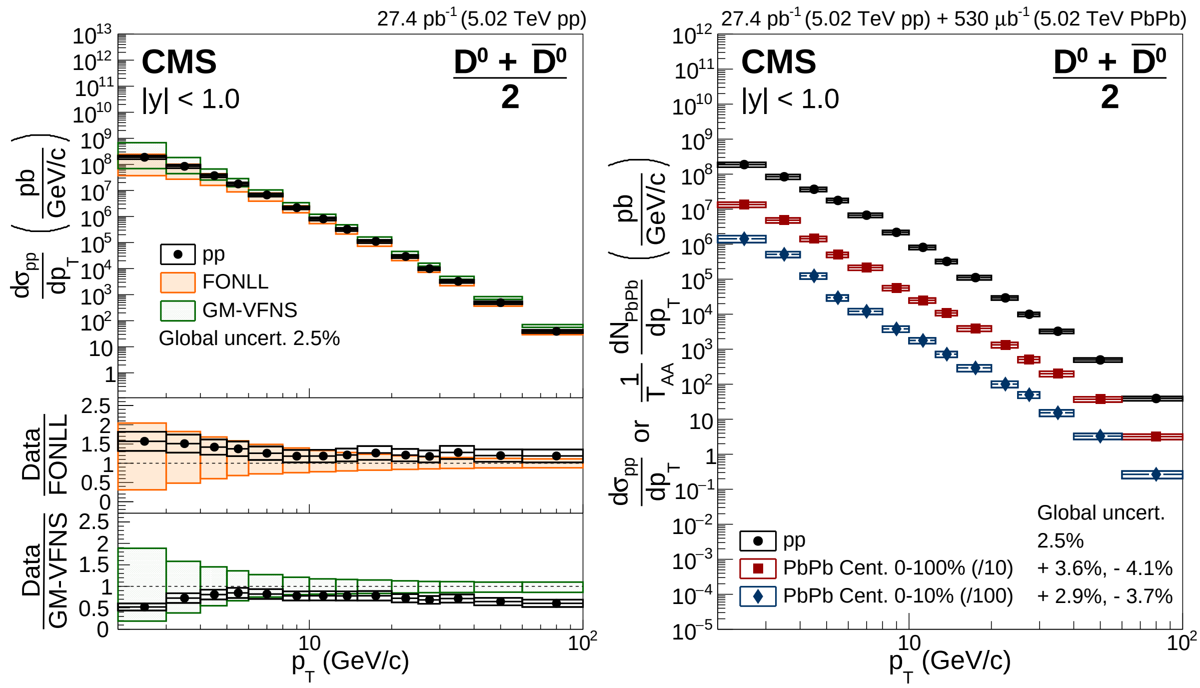

Figure 2: (left) The p_T-differential production cross section of D^0 mesons in pp collisions at $\sqrt{s} = 5.02$ TeV. The vertical bars (boxes) correspond to statistical (systematic) uncertainties. The global systematic uncertainty, listed in the legend and not included in the point-to-point uncertainties, comprises the uncertainties in the integrated luminosity measurement and the D^0 meson $\mathcal{B}$. Results are compared to FONLL [32] and GM-VFNS [34–36] calculations. (right) The p_T-differential production yields of D^0 mesons divided by the nuclear overlap functions T_{AA} for PbPb collisions in the 0–100% (red) and 0–10% (blue) centrality ranges compared to the same pp cross sections shown in the left panel (black).

transport model based on a Langevin equation that includes collisional energy loss and heavy-quark diffusion in the medium (S. Cao et al. [43, 44]), (c) a microscopic off-shell transport model based on a Boltzmann approach that includes collisional energy loss only (PHSD [45, 46]), and (d) a model based on the anti-de Sitter/conformal field theory (AdS/CFT) correspondence, that includes thermal fluctuations in the energy loss for heavy quarks in a strongly coupled plasma [47]. The AdS/CFT calculation is provided for two settings of the diffusion coefficient D of the heavy quark propagation through the medium: dependent on, and independent of the quark momentum. For D^0 meson $p_T > 40\,\text{GeV}/c$, the perturbative QCD-based models describe the suppression in both centrality ranges within the uncertainties, although the trend suggested by these predictions is typically lower than that in the experimental data. The model based on a Langevin approach describes the measurement well in the centrality range 0–100%, while it predicts slightly too much suppression for central events. The AdS/CFT calculations describe well both the 0–100% and the 0–10% measurements. In the intermediate p_T region ($10 < p_T < 40\,\text{GeV}/c$), all the theoretical calculations describe well the R_{AA} results in both centrality intervals. For $p_T < 10\,\text{GeV}/c$, the PHSD prediction that includes shadowing can reproduce the measurement in the 0–100% centrality region accurately, while the Langevin calculation predicts significantly more suppression than seen in data for both centrality ranges. In the same low-p_T region, the AdS/CFT calculation lies at the lower limit of the experimental uncertainties for both 0–10% and 0–100% measurements.

The D^0 R_{AA} measured in the centrality range 0–100% is compared in the top panel of Fig. 4 to

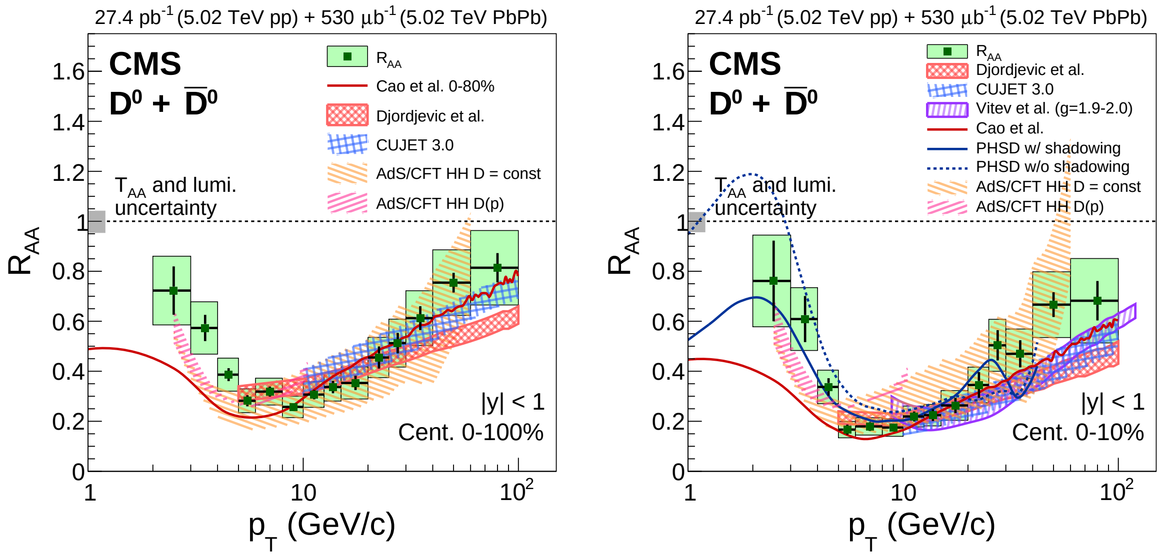

Figure 3: R_{AA} as a function of p_T in the centrality range 0–100% (left) and 0–10% (right). The vertical bars (boxes) correspond to statistical (systematic) uncertainties. The global systematic uncertainty, represented as a grey box at $R_{AA} = 1$, comprises the uncertainties in the integrated luminosity measurement and T_{AA} value. The D^0 R_{AA} values are also compared to calculations from various theoretical models [37–47].

the CMS measurements of the R_{AA} of charged particles [21], $B^{\pm}$ mesons [48] and nonprompt J/ψ meson [49] performed at the same energy and in the same centrality range. The systematic uncertainties between the R_{AA} measurement of the D^0 mesons, and of the light and beauty particles, are almost completely uncorrelated. The only common contribution comes from the systematic uncertainty of one track (4%), which is however negligible when compared to the total uncertainties. The D^0 meson R_{AA} values are consistent with those of charged particles for $p_T > 4\,\text{GeV}/c$. For lower p_T, a somewhat smaller suppression for D^0 mesons is observed. The R_{AA} of the $B^{\pm}$ mesons, measured in the p_T range 7–50 GeV/c and the rapidity range of $|y| < 2.4$, is also consistent with the D^0 meson measurement within the experimental uncertainties. The R_{AA} of nonprompt J/ψ, which was found to have almost no rapidity dependence [49], is shown here measured in the p_T ranges 6.5–50 GeV/c in $|y| < 2.4$, and 3–6.5 GeV/c in $1.8 < |y| < 2.4$. Its R_{AA} is found to be higher than the D^0 meson R_{AA} in almost the entire p_T range. The D^0 meson R_{AA} in the centrality range 0–10% is compared in Fig. 4 to the charged-particle R_{AA}. As observed for 0–100% PbPb events, the two results are consistent within uncertainties for $p_T > 4\,\text{GeV}/c$ and a somewhat smaller suppression for charmed mesons is observed at lower p_T.

7 Summary

In this Letter, the transverse momentum (p_T) spectra of prompt D^0 mesons in pp and PbPb collisions and the D^0 meson nuclear modification factor (R_{AA}) in the central rapidity region ($|y| < 1$) at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ from CMS are presented. The R_{AA} of prompt D^0 mesons is measured as a function of their p_T from 2 to 100 GeV/c in two centrality ranges, inclusive and 10% most central. The D^0 meson yield is found to be strongly suppressed in PbPb collisions when compared to the measured pp reference data scaled by the number of binary nucleon-nucleon collisions. These measurements are consistent with the R_{AA} of charged hadrons in both centrality intervals for $p_T > 4\,\text{GeV}/c$. A hint of a smaller suppression of D^0 R_{AA} with

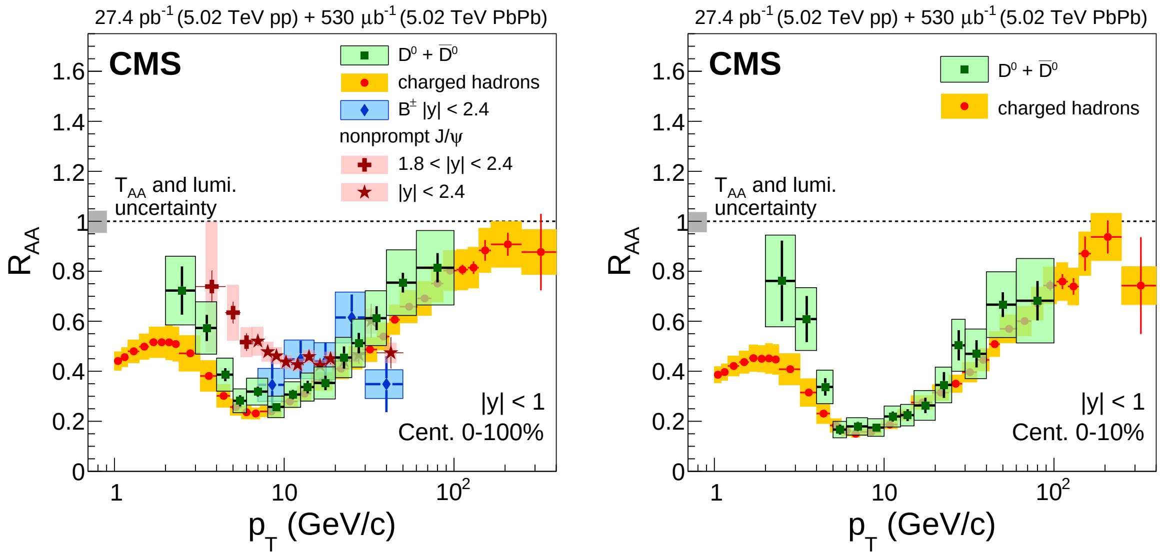

Figure 4: (left) Nuclear modification factor R_{AA} as a function of p_T in the centrality range 0–100% (green squares) compared to the R_{AA} of charged particles (red circles) [21], $B^{\pm}$ mesons (blue triangles) [48] and nonprompt J/ψ meson (purple crosses and stars) [49] in the same centrality range at 5.02 TeV. (right) Nuclear modification factor R_{AA} as a function of p_T in the centrality range 0–10% (green squares) compared to the R_{AA} of charged particles (red circles) [21] in the same centrality range.

respect to charged particle R_{AA} is observed for $p_T < 4\,\mathrm{GeV}/c$. The D^0 R_{AA} was found to be compatible with the $B^{\pm}$ R_{AA} in the intermediate p_T region and significantly lower than the nonprompt J/ψ meson R_{AA} for $p_T < 10\,\mathrm{GeV}/c$. Comparisons to different theoretical models show that the general trend of the R_{AA} is qualitatively reproduced at high p_T. Comparisons to different theoretical models show that the general trend of the R_{AA} is qualitatively reproduced at high p_T, while quantitative agreement for all centrality and p_T selections is yet to be attained.

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A The CMS Collaboration

Yerevan Physics Institute, Yerevan, Armenia
A.M. Sirunyan, A. Tumasyan

Institut für Hochenergiephysik, Wien, Austria
W. Adam, F. Ambrogi, E. Asilar, T. Bergauer, J. Brandstetter, E. Brondolin, M. Dragicevic, J. Erö, M. Flechl, M. Friedl, R. Frühwirth[1], V.M. Ghete, J. Grossmann, J. Hrubec, M. Jeitler[1], A. König, N. Krammer, I. Krätschmer, D. Liko, T. Madlener, I. Mikulec, E. Pree, D. Rabady, N. Rad, H. Rohringer, J. Schieck[1], R. Schöfbeck, M. Spanring, D. Spitzbart, W. Waltenberger, J. Wittmann, C.-E. Wulz[1], M. Zarucki

Institute for Nuclear Problems, Minsk, Belarus
V. Chekhovsky, V. Mossolov, J. Suarez Gonzalez

Universiteit Antwerpen, Antwerpen, Belgium
E.A. De Wolf, D. Di Croce, X. Janssen, J. Lauwers, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel

Vrije Universiteit Brussel, Brussel, Belgium
S. Abu Zeid, F. Blekman, J. D'Hondt, I. De Bruyn, J. De Clercq, K. Deroover, G. Flouris, D. Lontkovskyi, S. Lowette, S. Moortgat, L. Moreels, Q. Python, K. Skovpen, S. Tavernier, W. Van Doninck, P. Van Mulders, I. Van Parijs

Université Libre de Bruxelles, Bruxelles, Belgium
H. Brun, B. Clerbaux, G. De Lentdecker, H. Delannoy, G. Fasanella, L. Favart, R. Goldouzian, A. Grebenyuk, G. Karapostoli, T. Lenzi, J. Luetic, T. Maerschalk, A. Marinov, A. Randle-conde, T. Seva, C. Vander Velde, P. Vanlaer, D. Vannerom, R. Yonamine, F. Zenoni, F. Zhang[2]

Ghent University, Ghent, Belgium
A. Cimmino, T. Cornelis, D. Dobur, A. Fagot, M. Gul, I. Khvastunov, D. Poyraz, C. Roskas, S. Salva, M. Tytgat, W. Verbeke, N. Zaganidis

Université Catholique de Louvain, Louvain-la-Neuve, Belgium
H. Bakhshiansohi, O. Bondu, S. Brochet, G. Bruno, C. Caputo, A. Caudron, S. De Visscher, C. Delaere, M. Delcourt, B. Francois, A. Giammanco, A. Jafari, M. Komm, G. Krintiras, V. Lemaitre, A. Magitteri, A. Mertens, M. Musich, K. Piotrzkowski, L. Quertenmont, M. Vidal Marono, S. Wertz

Université de Mons, Mons, Belgium
N. Beliy

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
W.L. Aldá Júnior, F.L. Alves, G.A. Alves, L. Brito, M. Correa Martins Junior, C. Hensel, A. Moraes, M.E. Pol, P. Rebello Teles

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
E. Belchior Batista Das Chagas, W. Carvalho, J. Chinellato[3], A. Custódio, E.M. Da Costa, G.G. Da Silveira[4], D. De Jesus Damiao, S. Fonseca De Souza, L.M. Huertas Guativa, H. Malbouisson, M. Melo De Almeida, C. Mora Herrera, L. Mundim, H. Nogima, A. Santoro, A. Sznajder, E.J. Tonelli Manganote[3], F. Torres Da Silva De Araujo, A. Vilela Pereira

Universidade Estadual Paulista [a], Universidade Federal do ABC [b], São Paulo, Brazil
S. Ahuja[a], C.A. Bernardes[a], T.R. Fernandez Perez Tomei[a], E.M. Gregores[b], P.G. Mercadante[b], S.F. Novaes[a], Sandra S. Padula[a], D. Romero Abad[b], J.C. Ruiz Vargas[a]

Institute for Nuclear Research and Nuclear Energy of Bulgaria Academy of Sciences
A. Aleksandrov, R. Hadjiiska, P. Iaydjiev, M. Misheva, M. Rodozov, M. Shopova, S. Stoykova, G. Sultanov

University of Sofia, Sofia, Bulgaria
A. Dimitrov, I. Glushkov, L. Litov, B. Pavlov, P. Petkov

Beihang University, Beijing, China
W. Fang[5], X. Gao[5]

Institute of High Energy Physics, Beijing, China
M. Ahmad, J.G. Bian, G.M. Chen, H.S. Chen, M. Chen, Y. Chen, C.H. Jiang, D. Leggat, H. Liao, Z. Liu, F. Romeo, S.M. Shaheen, A. Spiezia, J. Tao, C. Wang, Z. Wang, E. Yazgan, H. Zhang, S. Zhang, J. Zhao

State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China
Y. Ban, G. Chen, Q. Li, S. Liu, Y. Mao, S.J. Qian, D. Wang, Z. Xu

Universidad de Los Andes, Bogota, Colombia
C. Avila, A. Cabrera, L.F. Chaparro Sierra, C. Florez, C.F. González Hernández, J.D. Ruiz Alvarez

University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia
B. Courbon, N. Godinovic, D. Lelas, I. Puljak, P.M. Ribeiro Cipriano, T. Sculac

University of Split, Faculty of Science, Split, Croatia
Z. Antunovic, M. Kovac

Institute Rudjer Boskovic, Zagreb, Croatia
V. Brigljevic, D. Ferencek, K. Kadija, B. Mesic, A. Starodumov[6], T. Susa

University of Cyprus, Nicosia, Cyprus
M.W. Ather, A. Attikis, G. Mavromanolakis, J. Mousa, C. Nicolaou, F. Ptochos, P.A. Razis, H. Rykaczewski

Charles University, Prague, Czech Republic
M. Finger[7], M. Finger Jr.[7]

Universidad San Francisco de Quito, Quito, Ecuador
E. Carrera Jarrin

Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt
Y. Assran[8,9], M.A. Mahmoud[10,9], A. Mahrous[11]

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
R.K. Dewanjee, M. Kadastik, L. Perrini, M. Raidal, A. Tiko, C. Veelken

Department of Physics, University of Helsinki, Helsinki, Finland
P. Eerola, J. Pekkanen, M. Voutilainen

Helsinki Institute of Physics, Helsinki, Finland
J. Härkönen, T. Järvinen, V. Karimäki, R. Kinnunen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, P. Luukka, E. Tuominen, J. Tuominiemi, E. Tuovinen

Lappeenranta University of Technology, Lappeenranta, Finland
J. Talvitie, T. Tuuva

IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France
M. Besancon, F. Couderc, M. Dejardin, D. Denegri, J.L. Faure, F. Ferri, S. Ganjour, S. Ghosh, A. Givernaud, P. Gras, G. Hamel de Monchenault, P. Jarry, I. Kucher, E. Locci, M. Machet, J. Malcles, G. Negro, J. Rander, A. Rosowsky, M.Ö. Sahin, M. Titov

Laboratoire Leprince-Ringuet, Ecole polytechnique, CNRS/IN2P3, Université Paris-Saclay, Palaiseau, France
A. Abdulsalam, I. Antropov, S. Baffioni, F. Beaudette, P. Busson, L. Cadamuro, C. Charlot, R. Granier de Cassagnac, M. Jo, S. Lisniak, A. Lobanov, J. Martin Blanco, M. Nguyen, C. Ochando, G. Ortona, P. Paganini, P. Pigard, S. Regnard, R. Salerno, J.B. Sauvan, Y. Sirois, A.G. Stahl Leiton, T. Strebler, Y. Yilmaz, A. Zabi, A. Zghiche

Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France
J.-L. Agram[12], J. Andrea, D. Bloch, J.-M. Brom, M. Buttignol, E.C. Chabert, N. Chanon, C. Collard, E. Conte[12], X. Coubez, J.-C. Fontaine[12], D. Gelé, U. Goerlach, M. Jansová, A.-C. Le Bihan, N. Tonon, P. Van Hove

Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules, CNRS/IN2P3, Villeurbanne, France
S. Gadrat

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France
S. Beauceron, C. Bernet, G. Boudoul, R. Chierici, D. Contardo, P. Depasse, H. El Mamouni, J. Fay, L. Finco, S. Gascon, M. Gouzevitch, G. Grenier, B. Ille, F. Lagarde, I.B. Laktineh, M. Lethuillier, L. Mirabito, A.L. Pequegnot, S. Perries, A. Popov[13], V. Sordini, M. Vander Donckt, S. Viret

Georgian Technical University, Tbilisi, Georgia
T. Toriashvili[14]

Tbilisi State University, Tbilisi, Georgia
Z. Tsamalaidze[7]

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany
C. Autermann, S. Beranek, L. Feld, M.K. Kiesel, K. Klein, M. Lipinski, M. Preuten, C. Schomakers, J. Schulz, T. Verlage, V. Zhukov[13]

RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany
A. Albert, E. Dietz-Laursonn, D. Duchardt, M. Endres, M. Erdmann, S. Erdweg, T. Esch, R. Fischer, A. Güth, M. Hamer, T. Hebbeker, C. Heidemann, K. Hoepfner, S. Knutzen, M. Merschmeyer, A. Meyer, P. Millet, S. Mukherjee, M. Olschewski, K. Padeken, T. Pook, M. Radziej, H. Reithler, M. Rieger, F. Scheuch, D. Teyssier, S. Thüer

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany
G. Flügge, B. Kargoll, T. Kress, A. Künsken, J. Lingemann, T. Müller, A. Nehrkorn, A. Nowack, C. Pistone, O. Pooth, A. Stahl[15]

Deutsches Elektronen-Synchrotron, Hamburg, Germany
M. Aldaya Martin, T. Arndt, C. Asawatangtrakuldee, K. Beernaert, O. Behnke, U. Behrens, A. Bermúdez Martínez, A.A. Bin Anuar, K. Borras[16], V. Botta, A. Campbell, P. Connor, C. Contreras-Campana, F. Costanza, C. Diez Pardos, G. Eckerlin, D. Eckstein, T. Eichhorn,

E. Eren, E. Gallo[17], J. Garay Garcia, A. Geiser, A. Gizhko, J.M. Grados Luyando, A. Grohsjean, P. Gunnellini, M. Guthoff, A. Harb, J. Hauk, M. Hempel[18], H. Jung, A. Kalogeropoulos, M. Kasemann, J. Keaveney, C. Kleinwort, I. Korol, D. Krücker, W. Lange, A. Lelek, T. Lenz, J. Leonard, K. Lipka, W. Lohmann[18], R. Mankel, I.-A. Melzer-Pellmann, A.B. Meyer, G. Mittag, J. Mnich, A. Mussgiller, E. Ntomari, D. Pitzl, A. Raspereza, B. Roland, M. Savitskyi, P. Saxena, R. Shevchenko, S. Spannagel, N. Stefaniuk, G.P. Van Onsem, R. Walsh, Y. Wen, K. Wichmann, C. Wissing, O. Zenaiev

University of Hamburg, Hamburg, Germany
S. Bein, V. Blobel, M. Centis Vignali, T. Dreyer, E. Garutti, D. Gonzalez, J. Haller, A. Hinzmann, M. Hoffmann, A. Karavdina, R. Klanner, R. Kogler, N. Kovalchuk, S. Kurz, T. Lapsien, I. Marchesini, D. Marconi, M. Meyer, M. Niedziela, D. Nowatschin, F. Pantaleo[15], T. Peiffer, A. Perieanu, C. Scharf, P. Schleper, A. Schmidt, S. Schumann, J. Schwandt, J. Sonneveld, H. Stadie, G. Steinbrück, F.M. Stober, M. Stöver, H. Tholen, D. Troendle, E. Usai, L. Vanelderen, A. Vanhoefer, B. Vormwald

Institut für Experimentelle Kernphysik, Karlsruhe, Germany
M. Akbiyik, C. Barth, S. Baur, E. Butz, R. Caspart, T. Chwalek, F. Colombo, W. De Boer, A. Dierlamm, B. Freund, R. Friese, M. Giffels, A. Gilbert, D. Haitz, F. Hartmann[15], S.M. Heindl, U. Husemann, F. Kassel[15], S. Kudella, H. Mildner, M.U. Mozer, Th. Müller, M. Plagge, G. Quast, K. Rabbertz, M. Schröder, I. Shvetsov, G. Sieber, H.J. Simonis, R. Ulrich, S. Wayand, M. Weber, T. Weiler, S. Williamson, C. Wöhrmann, R. Wolf

Institute of Nuclear and Particle Physics (INPP), NCSR Demokritos, Aghia Paraskevi, Greece
G. Anagnostou, G. Daskalakis, T. Geralis, V.A. Giakoumopoulou, A. Kyriakis, D. Loukas, I. Topsis-Giotis

National and Kapodistrian University of Athens, Athens, Greece
G. Karathanasis, S. Kesisoglou, A. Panagiotou, N. Saoulidou

National Technical University of Athens, Athens, Greece
K. Kousouris

University of Ioánnina, Ioánnina, Greece
I. Evangelou, C. Foudas, P. Kokkas, S. Mallios, N. Manthos, I. Papadopoulos, E. Paradas, J. Strologas, F.A. Triantis

MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary
M. Csanad, N. Filipovic, G. Pasztor, G.I. Veres[19]

Wigner Research Centre for Physics, Budapest, Hungary
G. Bencze, C. Hajdu, D. Horvath[20], Á. Hunyadi, F. Sikler, V. Veszpremi, A.J. Zsigmond

Institute of Nuclear Research ATOMKI, Debrecen, Hungary
N. Beni, S. Czellar, J. Karancsi[21], A. Makovec, J. Molnar, Z. Szillasi

Institute of Physics, University of Debrecen, Debrecen, Hungary
M. Bartók[19], P. Raics, Z.L. Trocsanyi, B. Ujvari

Indian Institute of Science (IISc), Bangalore, India
S. Choudhury, J.R. Komaragiri

National Institute of Science Education and Research, Bhubaneswar, India
S. Bahinipati[22], S. Bhowmik, P. Mal, K. Mandal, A. Nayak[23], D.K. Sahoo[22], N. Sahoo, S.K. Swain

Panjab University, Chandigarh, India
S. Bansal, S.B. Beri, V. Bhatnagar, R. Chawla, N. Dhingra, A.K. Kalsi, A. Kaur, M. Kaur, R. Kumar, P. Kumari, A. Mehta, J.B. Singh, G. Walia

University of Delhi, Delhi, India
A. Bhardwaj, S. Chauhan, B.C. Choudhary, R.B. Garg, S. Keshri, A. Kumar, Ashok Kumar, S. Malhotra, M. Naimuddin, K. Ranjan, Aashaq Shah, R. Sharma

Saha Institute of Nuclear Physics, HBNI, Kolkata, India
R. Bhardwaj, R. Bhattacharya, S. Bhattacharya, U. Bhawandeep, S. Dey, S. Dutt, S. Dutta, S. Ghosh, N. Majumdar, A. Modak, K. Mondal, S. Mukhopadhyay, S. Nandan, A. Purohit, A. Roy, D. Roy, S. Roy Chowdhury, S. Sarkar, M. Sharan, S. Thakur

Indian Institute of Technology Madras, Madras, India
P.K. Behera

Bhabha Atomic Research Centre, Mumbai, India
R. Chudasama, D. Dutta, V. Jha, V. Kumar, A.K. Mohanty[15], P.K. Netrakanti, L.M. Pant, P. Shukla, A. Topkar

Tata Institute of Fundamental Research-A, Mumbai, India
T. Aziz, S. Dugad, B. Mahakud, S. Mitra, G.B. Mohanty, N. Sur, B. Sutar

Tata Institute of Fundamental Research-B, Mumbai, India
S. Banerjee, S. Bhattacharya, S. Chatterjee, P. Das, M. Guchait, Sa. Jain, S. Kumar, M. Maity[24], G. Majumder, K. Mazumdar, T. Sarkar[24], N. Wickramage[25]

Indian Institute of Science Education and Research (IISER), Pune, India
S. Chauhan, S. Dube, V. Hegde, A. Kapoor, K. Kothekar, S. Pandey, A. Rane, S. Sharma

Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
S. Chenarani[26], E. Eskandari Tadavani, S.M. Etesami[26], M. Khakzad, M. Mohammadi Najafabadi, M. Naseri, S. Paktinat Mehdiabadi[27], F. Rezaei Hosseinabadi, B. Safarzadeh[28], M. Zeinali

University College Dublin, Dublin, Ireland
M. Felcini, M. Grunewald

INFN Sezione di Bari [a], Università di Bari [b], Politecnico di Bari [c], Bari, Italy
M. Abbrescia[a,b], C. Calabria[a,b], A. Colaleo[a], D. Creanza[a,c], L. Cristella[a,b], N. De Filippis[a,c], M. De Palma[a,b], F. Errico[a,b], L. Fiore[a], G. Iaselli[a,c], S. Lezki[a,b], G. Maggi[a,c], M. Maggi[a], G. Miniello[a,b], S. My[a,b], S. Nuzzo[a,b], A. Pompili[a,b], G. Pugliese[a,c], R. Radogna[a,b], A. Ranieri[a], G. Selvaggi[a,b], A. Sharma[a], L. Silvestris[a,15], R. Venditti[a], P. Verwilligen[a]

INFN Sezione di Bologna [a], Università di Bologna [b], Bologna, Italy
G. Abbiendi[a], C. Battilana[a,b], D. Bonacorsi[a,b], S. Braibant-Giacomelli[a,b], R. Campanini[a,b], P. Capiluppi[a,b], A. Castro[a,b], F.R. Cavallo[a], S.S. Chhibra[a], G. Codispoti[a,b], M. Cuffiani[a,b], G.M. Dallavalle[a], F. Fabbri[a], A. Fanfani[a,b], D. Fasanella[a,b], P. Giacomelli[a], C. Grandi[a], L. Guiducci[a,b], S. Marcellini[a], G. Masetti[a], A. Montanari[a], F.L. Navarria[a,b], A. Perrotta[a], A.M. Rossi[a,b], T. Rovelli[a,b], G.P. Siroli[a,b], N. Tosi[a]

INFN Sezione di Catania [a], Università di Catania [b], Catania, Italy
S. Albergo[a,b], S. Costa[a,b], A. Di Mattia[a], F. Giordano[a,b], R. Potenza[a,b], A. Tricomi[a,b], C. Tuve[a,b]

INFN Sezione di Firenze [a], Università di Firenze [b], Firenze, Italy
G. Barbagli[a], K. Chatterjee[a,b], V. Ciulli[a,b], C. Civinini[a], R. D'Alessandro[a,b], E. Focardi[a,b], P. Lenzi[a,b], M. Meschini[a], S. Paoletti[a], L. Russo[a,29], G. Sguazzoni[a], D. Strom[a], L. Viliani[a,b,15]

INFN Laboratori Nazionali di Frascati, Frascati, Italy
L. Benussi, S. Bianco, F. Fabbri, D. Piccolo, F. Primavera[15]

INFN Sezione di Genova [a], Università di Genova [b], Genova, Italy
V. Calvelli[a,b], F. Ferro[a], E. Robutti[a], S. Tosi[a,b]

INFN Sezione di Milano-Bicocca [a], Università di Milano-Bicocca [b], Milano, Italy
A. Benaglia[a], L. Brianza[a,b], F. Brivio[a,b], V. Ciriolo[a,b], M.E. Dinardo[a,b], S. Fiorendi[a,b], S. Gennai[a], A. Ghezzi[a,b], P. Govoni[a,b], M. Malberti[a,b], S. Malvezzi[a], R.A. Manzoni[a,b], D. Menasce[a], L. Moroni[a], M. Paganoni[a,b], K. Pauwels[a,b], D. Pedrini[a], S. Pigazzini[a,b,30], S. Ragazzi[a,b], T. Tabarelli de Fatis[a,b]

INFN Sezione di Napoli [a], Università di Napoli 'Federico II' [b], Napoli, Italy, Università della Basilicata [c], Potenza, Italy, Università G. Marconi [d], Roma, Italy
S. Buontempo[a], N. Cavallo[a,c], S. Di Guida[a,d,15], F. Fabozzi[a,c], F. Fienga[a,b], A.O.M. Iorio[a,b], W.A. Khan[a], L. Lista[a], S. Meola[a,d,15], P. Paolucci[a,15], C. Sciacca[a,b], F. Thyssen[a]

INFN Sezione di Padova [a], Università di Padova [b], Padova, Italy, Università di Trento [c], Trento, Italy
P. Azzi[a,15], L. Benato[a,b], D. Bisello[a,b], A. Boletti[a,b], R. Carlin[a,b], A. Carvalho Antunes De Oliveira[a,b], P. Checchia[a], P. De Castro Manzano[a], T. Dorigo[a], U. Dosselli[a], F. Gasparini[a,b], U. Gasparini[a,b], A. Gozzelino[a], S. Lacaprara[a], P. Lujan, M. Margoni[a,b], A.T. Meneguzzo[a,b], N. Pozzobon[a,b], P. Ronchese[a,b], R. Rossin[a,b], F. Simonetto[a,b], S. Ventura[a], M. Zanetti[a,b], P. Zotto[a,b], G. Zumerle[a,b]

INFN Sezione di Pavia [a], Università di Pavia [b], Pavia, Italy
A. Braghieri[a], A. Magnani[a,b], P. Montagna[a,b], S.P. Ratti[a,b], V. Re[a], M. Ressegotti, C. Riccardi[a,b], P. Salvini[a], I. Vai[a,b], P. Vitulo[a,b]

INFN Sezione di Perugia [a], Università di Perugia [b], Perugia, Italy
L. Alunni Solestizi[a,b], M. Biasini[a,b], G.M. Bilei[a], C. Cecchi[a,b], D. Ciangottini[a,b], L. Fanò[a,b], P. Lariccia[a,b], R. Leonardi[a,b], E. Manoni[a], G. Mantovani[a,b], V. Mariani[a,b], M. Menichelli[a], A. Rossi[a,b], A. Santocchia[a,b], D. Spiga[a]

INFN Sezione di Pisa [a], Università di Pisa [b], Scuola Normale Superiore di Pisa [c], Pisa, Italy
K. Androsov[a], P. Azzurri[a,15], G. Bagliesi[a], J. Bernardini[a], T. Boccali[a], L. Borrello, R. Castaldi[a], M.A. Ciocci[a,b], R. Dell'Orso[a], G. Fedi[a], L. Giannini[a,c], A. Giassi[a], M.T. Grippo[a,29], F. Ligabue[a,c], T. Lomtadze[a], E. Manca[a,c], G. Mandorli[a,c], L. Martini[a,b], A. Messineo[a,b], F. Palla[a], A. Rizzi[a,b], A. Savoy-Navarro[a,31], P. Spagnolo[a], R. Tenchini[a], G. Tonelli[a,b], A. Venturi[a], P.G. Verdini[a]

INFN Sezione di Roma [a], Sapienza Università di Roma [b], Rome, Italy
L. Barone[a,b], F. Cavallari[a], M. Cipriani[a,b], N. Daci[a], D. Del Re[a,b,15], E. Di Marco[a,b], M. Diemoz[a], S. Gelli[a,b], E. Longo[a,b], F. Margaroli[a,b], B. Marzocchi[a,b], P. Meridiani[a], G. Organtini[a,b], R. Paramatti[a,b], F. Preiato[a,b], S. Rahatlou[a,b], C. Rovelli[a], F. Santanastasio[a,b]

INFN Sezione di Torino [a], Università di Torino [b], Torino, Italy, Università del Piemonte Orientale [c], Novara, Italy
N. Amapane[a,b], R. Arcidiacono[a,c], S. Argiro[a,b], M. Arneodo[a,c], N. Bartosik[a], R. Bellan[a,b], C. Biino[a], N. Cartiglia[a], F. Cenna[a,b], M. Costa[a,b], R. Covarelli[a,b], A. Degano[a,b], N. Demaria[a], B. Kiani[a,b], C. Mariotti[a], S. Maselli[a], E. Migliore[a,b], V. Monaco[a,b], E. Monteil[a,b], M. Monteno[a],

M.M. Obertino[a,b], L. Pacher[a,b], N. Pastrone[a], M. Pelliccioni[a], G.L. Pinna Angioni[a,b], F. Ravera[a,b], A. Romero[a,b], M. Ruspa[a,c], R. Sacchi[a,b], K. Shchelina[a,b], V. Sola[a], A. Solano[a,b], A. Staiano[a], P. Traczyk[a,b]

INFN Sezione di Trieste [a], Università di Trieste [b], Trieste, Italy
S. Belforte[a], M. Casarsa[a], F. Cossutti[a], G. Della Ricca[a,b], A. Zanetti[a]

Kyungpook National University, Daegu, Korea
D.H. Kim, G.N. Kim, M.S. Kim, J. Lee, S. Lee, S.W. Lee, C.S. Moon, Y.D. Oh, S. Sekmen, D.C. Son, Y.C. Yang

Chonbuk National University, Jeonju, Korea
A. Lee

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
H. Kim, D.H. Moon, G. Oh

Hanyang University, Seoul, Korea
J.A. Brochero Cifuentes, J. Goh, T.J. Kim

Korea University, Seoul, Korea
S. Cho, S. Choi, Y. Go, D. Gyun, S. Ha, B. Hong, Y. Jo, Y. Kim, K. Lee, K.S. Lee, S. Lee, J. Lim, S.K. Park, Y. Roh

Seoul National University, Seoul, Korea
J. Almond, J. Kim, J.S. Kim, H. Lee, K. Lee, K. Nam, S.B. Oh, B.C. Radburn-Smith, S.h. Seo, U.K. Yang, H.D. Yoo, G.B. Yu

University of Seoul, Seoul, Korea
M. Choi, H. Kim, J.H. Kim, J.S.H. Lee, I.C. Park

Sungkyunkwan University, Suwon, Korea
Y. Choi, C. Hwang, J. Lee, I. Yu

Vilnius University, Vilnius, Lithuania
V. Dudenas, A. Juodagalvis, J. Vaitkus

National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia
I. Ahmed, Z.A. Ibrahim, M.A.B. Md Ali[32], F. Mohamad Idris[33], W.A.T. Wan Abdullah, M.N. Yusli, Z. Zolkapli

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
Duran-Osuna, M. C., H. Castilla-Valdez, E. De La Cruz-Burelo, Ramirez-Sanchez, G., I. Heredia-De La Cruz[34], Rabadan-Trejo, R. I., R. Lopez-Fernandez, J. Mejia Guisao, Reyes-Almanza, R, A. Sanchez-Hernandez

Universidad Iberoamericana, Mexico City, Mexico
S. Carrillo Moreno, C. Oropeza Barrera, F. Vazquez Valencia

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
I. Pedraza, H.A. Salazar Ibarguen, C. Uribe Estrada

Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
A. Morelos Pineda

University of Auckland, Auckland, New Zealand
D. Krofcheck

University of Canterbury, Christchurch, New Zealand
P.H. Butler

National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
A. Ahmad, M. Ahmad, Q. Hassan, H.R. Hoorani, A. Saddique, M.A. Shah, M. Shoaib, M. Waqas

National Centre for Nuclear Research, Swierk, Poland
H. Bialkowska, M. Bluj, B. Boimska, T. Frueboes, M. Górski, M. Kazana, K. Nawrocki, M. Szleper, P. Zalewski

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
K. Bunkowski, A. Byszuk[35], K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski, M. Misiura, M. Olszewski, A. Pyskir, M. Walczak

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
P. Bargassa, C. Beirão Da Cruz E Silva, A. Di Francesco, P. Faccioli, B. Galinhas, M. Gallinaro, J. Hollar, N. Leonardo, L. Lloret Iglesias, M.V. Nemallapudi, J. Seixas, G. Strong, O. Toldaiev, D. Vadruccio, J. Varela

Joint Institute for Nuclear Research, Dubna, Russia
S. Afanasiev, P. Bunin, M. Gavrilenko, I. Golutvin, I. Gorbunov, A. Kamenev, V. Karjavin, A. Lanev, A. Malakhov, V. Matveev[36,37], V. Palichik, V. Perelygin, S. Shmatov, S. Shulha, N. Skatchkov, V. Smirnov, N. Voytishin, A. Zarubin

Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
Y. Ivanov, V. Kim[38], E. Kuznetsova[39], P. Levchenko, V. Murzin, V. Oreshkin, I. Smirnov, V. Sulimov, L. Uvarov, S. Vavilov, A. Vorobyev

Institute for Nuclear Research, Moscow, Russia
Yu. Andreev, A. Dermenev, S. Gninenko, N. Golubev, A. Karneyeu, M. Kirsanov, N. Krasnikov, A. Pashenkov, D. Tlisov, A. Toropin

Institute for Theoretical and Experimental Physics, Moscow, Russia
V. Epshteyn, V. Gavrilov, N. Lychkovskaya, V. Popov, I. Pozdnyakov, G. Safronov, A. Spiridonov, A. Stepennov, M. Toms, E. Vlasov, A. Zhokin

Moscow Institute of Physics and Technology, Moscow, Russia
T. Aushev, A. Bylinkin[37]

National Research Nuclear University 'Moscow Engineering Physics Institute' (MEPhI), Moscow, Russia
R. Chistov[40], M. Danilov[40], P. Parygin, D. Philippov, S. Polikarpov, E. Tarkovskii

P.N. Lebedev Physical Institute, Moscow, Russia
V. Andreev, M. Azarkin[37], I. Dremin[37], M. Kirakosyan[37], A. Terkulov

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
A. Baskakov, A. Belyaev, E. Boos, A. Ershov, A. Gribushin, A. Kaminskiy[41], O. Kodolova, V. Korotkikh, I. Lokhtin, I. Miagkov, S. Obraztsov, S. Petrushanko, V. Savrin, A. Snigirev, I. Vardanyan

Novosibirsk State University (NSU), Novosibirsk, Russia
V. Blinov[42], D. Shtol[42], Y.Skovpen[42]

State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
I. Azhgirey, I. Bayshev, S. Bitioukov, D. Elumakhov, V. Kachanov, A. Kalinin, D. Konstantinov, V. Krychkine, V. Petrov, R. Ryutin, A. Sobol, S. Troshin, N. Tyurin, A. Uzunian, A. Volkov

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
P. Adzic[43], P. Cirkovic, D. Devetak, M. Dordevic, J. Milosevic, V. Rekovic

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
J. Alcaraz Maestre, A. Álvarez Fernández, M. Barrio Luna, M. Cerrada, N. Colino, B. De La Cruz, A. Delgado Peris, A. Escalante Del Valle, C. Fernandez Bedoya, J.P. Fernández Ramos, J. Flix, M.C. Fouz, P. Garcia-Abia, O. Gonzalez Lopez, S. Goy Lopez, J.M. Hernandez, M.I. Josa, A. Pérez-Calero Yzquierdo, J. Puerta Pelayo, A. Quintario Olmeda, I. Redondo, L. Romero, M.S. Soares

Universidad Autónoma de Madrid, Madrid, Spain
J.F. de Trocóniz, M. Missiroli, D. Moran

Universidad de Oviedo, Oviedo, Spain
J. Cuevas, C. Erice, J. Fernandez Menendez, I. Gonzalez Caballero, J.R. González Fernández, E. Palencia Cortezon, S. Sanchez Cruz, I. Suárez Andrés, P. Vischia, J.M. Vizan Garcia

Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
I.J. Cabrillo, A. Calderon, B. Chazin Quero, E. Curras, J. Duarte Campderros, M. Fernandez, J. Garcia-Ferrero, G. Gomez, A. Lopez Virto, J. Marco, C. Martinez Rivero, P. Martinez Ruiz del Arbol, F. Matorras, J. Piedra Gomez, T. Rodrigo, A. Ruiz-Jimeno, L. Scodellaro, N. Trevisani, I. Vila, R. Vilar Cortabitarte

CERN, European Organization for Nuclear Research, Geneva, Switzerland
D. Abbaneo, E. Auffray, P. Baillon, A.H. Ball, D. Barney, M. Bianco, P. Bloch, A. Bocci, C. Botta, T. Camporesi, R. Castello, M. Cepeda, G. Cerminara, E. Chapon, Y. Chen, D. d'Enterria, A. Dabrowski, V. Daponte, A. David, M. De Gruttola, A. De Roeck, M. Dobson, B. Dorney, T. du Pree, M. Dünser, N. Dupont, A. Elliott-Peisert, P. Everaerts, F. Fallavollita, G. Franzoni, J. Fulcher, W. Funk, D. Gigi, K. Gill, F. Glege, D. Gulhan, P. Harris, J. Hegeman, V. Innocente, P. Janot, O. Karacheban[18], J. Kieseler, H. Kirschenmann, V. Knünz, A. Kornmayer[15], M.J. Kortelainen, M. Krammer[1], C. Lange, P. Lecoq, C. Lourenço, M.T. Lucchini, L. Malgeri, M. Mannelli, A. Martelli, F. Meijers, J.A. Merlin, S. Mersi, E. Meschi, P. Milenovic[44], F. Moortgat, M. Mulders, H. Neugebauer, S. Orfanelli, L. Orsini, L. Pape, E. Perez, M. Peruzzi, A. Petrilli, G. Petrucciani, A. Pfeiffer, M. Pierini, A. Racz, T. Reis, G. Rolandi[45], M. Rovere, H. Sakulin, C. Schäfer, C. Schwick, M. Seidel, M. Selvaggi, A. Sharma, P. Silva, P. Sphicas[46], A. Stakia, J. Steggemann, M. Stoye, M. Tosi, D. Treille, A. Triossi, A. Tsirou, V. Veckalns[47], M. Verweij, W.D. Zeuner

Paul Scherrer Institut, Villigen, Switzerland
W. Bertl[†], L. Caminada[48], K. Deiters, W. Erdmann, R. Horisberger, Q. Ingram, H.C. Kaestli, D. Kotlinski, U. Langenegger, T. Rohe, S.A. Wiederkehr

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
F. Bachmair, L. Bäni, P. Berger, L. Bianchini, B. Casal, G. Dissertori, M. Dittmar, M. Donegà,

C. Grab, C. Heidegger, D. Hits, J. Hoss, G. Kasieczka, T. Klijnsma, W. Lustermann, B. Mangano, M. Marionneau, M.T. Meinhard, D. Meister, F. Micheli, P. Musella, F. Nessi-Tedaldi, F. Pandolfi, J. Pata, F. Pauss, G. Perrin, L. Perrozzi, M. Quittnat, M. Reichmann, M. Schönenberger, L. Shchutska, V.R. Tavolaro, K. Theofilatos, M.L. Vesterbacka Olsson, R. Wallny, D.H. Zhu

Universität Zürich, Zurich, Switzerland
T.K. Aarrestad, C. Amsler[49], M.F. Canelli, A. De Cosa, R. Del Burgo, S. Donato, C. Galloni, T. Hreus, B. Kilminster, J. Ngadiuba, D. Pinna, G. Rauco, P. Robmann, D. Salerno, C. Seitz, Y. Takahashi, A. Zucchetta

National Central University, Chung-Li, Taiwan
V. Candelise, T.H. Doan, Sh. Jain, R. Khurana, C.M. Kuo, W. Lin, A. Pozdnyakov, S.S. Yu

National Taiwan University (NTU), Taipei, Taiwan
P. Chang, Y. Chao, K.F. Chen, P.H. Chen, F. Fiori, W.-S. Hou, Y. Hsiung, Arun Kumar, Y.F. Liu, R.-S. Lu, E. Paganis, A. Psallidas, A. Steen, J.f. Tsai

Chulalongkorn University, Faculty of Science, Department of Physics, Bangkok, Thailand
B. Asavapibhop, K. Kovitanggoon, G. Singh, N. Srimanobhas

Çukurova University, Physics Department, Science and Art Faculty, Adana, Turkey
F. Boran, S. Cerci[50], S. Damarseckin, Z.S. Demiroglu, C. Dozen, I. Dumanoglu, S. Girgis, G. Gokbulut, Y. Guler, I. Hos[51], E.E. Kangal[52], O. Kara, A. Kayis Topaksu, U. Kiminsu, M. Oglakci, G. Onengut[53], K. Ozdemir[54], D. Sunar Cerci[50], B. Tali[50], S. Turkcapar, I.S. Zorbakir, C. Zorbilmez

Middle East Technical University, Physics Department, Ankara, Turkey
B. Bilin, G. Karapinar[55], K. Ocalan[56], M. Yalvac, M. Zeyrek

Bogazici University, Istanbul, Turkey
E. Gülmez, M. Kaya[57], O. Kaya[58], S. Tekten, E.A. Yetkin[59]

Istanbul Technical University, Istanbul, Turkey
M.N. Agaras, S. Atay, A. Cakir, K. Cankocak

Institute for Scintillation Materials of National Academy of Science of Ukraine, Kharkov, Ukraine
B. Grynyov

National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
L. Levchuk, P. Sorokin

University of Bristol, Bristol, United Kingdom
R. Aggleton, F. Ball, L. Beck, J.J. Brooke, D. Burns, E. Clement, D. Cussans, O. Davignon, H. Flacher, J. Goldstein, M. Grimes, G.P. Heath, H.F. Heath, J. Jacob, L. Kreczko, C. Lucas, D.M. Newbold[60], S. Paramesvaran, A. Poll, T. Sakuma, S. Seif El Nasr-storey, D. Smith, V.J. Smith

Rutherford Appleton Laboratory, Didcot, United Kingdom
A. Belyaev[61], C. Brew, R.M. Brown, L. Calligaris, D. Cieri, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, E. Olaiya, D. Petyt, C.H. Shepherd-Themistocleous, A. Thea, I.R. Tomalin, T. Williams

Imperial College, London, United Kingdom
G. Auzinger, R. Bainbridge, S. Breeze, O. Buchmuller, A. Bundock, S. Casasso, M. Citron, D. Colling, L. Corpe, P. Dauncey, G. Davies, A. De Wit, M. Della Negra, R. Di Maria,

A. Elwood, Y. Haddad, G. Hall, G. Iles, T. James, R. Lane, C. Laner, L. Lyons, A.-M. Magnan, S. Malik, L. Mastrolorenzo, T. Matsushita, J. Nash, A. Nikitenko[6], V. Palladino, M. Pesaresi, D.M. Raymond, A. Richards, A. Rose, E. Scott, C. Seez, A. Shtipliyski, S. Summers, A. Tapper, K. Uchida, M. Vazquez Acosta[62], T. Virdee[15], N. Wardle, D. Winterbottom, J. Wright, S.C. Zenz

Brunel University, Uxbridge, United Kingdom
J.E. Cole, P.R. Hobson, A. Khan, P. Kyberd, I.D. Reid, P. Symonds, L. Teodorescu, M. Turner

Baylor University, Waco, USA
A. Borzou, K. Call, J. Dittmann, K. Hatakeyama, H. Liu, N. Pastika, C. Smith

Catholic University of America, Washington DC, USA
R. Bartek, A. Dominguez

The University of Alabama, Tuscaloosa, USA
A. Buccilli, S.I. Cooper, C. Henderson, P. Rumerio, C. West

Boston University, Boston, USA
D. Arcaro, A. Avetisyan, T. Bose, D. Gastler, D. Rankin, C. Richardson, J. Rohlf, L. Sulak, D. Zou

Brown University, Providence, USA
G. Benelli, D. Cutts, A. Garabedian, J. Hakala, U. Heintz, J.M. Hogan, K.H.M. Kwok, E. Laird, G. Landsberg, Z. Mao, M. Narain, J. Pazzini, S. Piperov, S. Sagir, R. Syarif, D. Yu

University of California, Davis, Davis, USA
R. Band, C. Brainerd, D. Burns, M. Calderon De La Barca Sanchez, M. Chertok, J. Conway, R. Conway, P.T. Cox, R. Erbacher, C. Flores, G. Funk, M. Gardner, W. Ko, R. Lander, C. Mclean, M. Mulhearn, D. Pellett, J. Pilot, S. Shalhout, M. Shi, J. Smith, M. Squires, D. Stolp, K. Tos, M. Tripathi, Z. Wang

University of California, Los Angeles, USA
M. Bachtis, C. Bravo, R. Cousins, A. Dasgupta, A. Florent, J. Hauser, M. Ignatenko, N. Mccoll, D. Saltzberg, C. Schnaible, V. Valuev

University of California, Riverside, Riverside, USA
E. Bouvier, K. Burt, R. Clare, J. Ellison, J.W. Gary, S.M.A. Ghiasi Shirazi, G. Hanson, J. Heilman, P. Jandir, E. Kennedy, F. Lacroix, O.R. Long, M. Olmedo Negrete, M.I. Paneva, A. Shrinivas, W. Si, L. Wang, H. Wei, S. Wimpenny, B. R. Yates

University of California, San Diego, La Jolla, USA
J.G. Branson, S. Cittolin, M. Derdzinski, R. Gerosa, B. Hashemi, A. Holzner, D. Klein, G. Kole, V. Krutelyov, J. Letts, I. Macneill, M. Masciovecchio, D. Olivito, S. Padhi, M. Pieri, M. Sani, V. Sharma, S. Simon, M. Tadel, A. Vartak, S. Wasserbaech[63], J. Wood, F. Würthwein, A. Yagil, G. Zevi Della Porta

University of California, Santa Barbara - Department of Physics, Santa Barbara, USA
N. Amin, R. Bhandari, J. Bradmiller-Feld, C. Campagnari, A. Dishaw, V. Dutta, M. Franco Sevilla, C. George, F. Golf, L. Gouskos, J. Gran, R. Heller, J. Incandela, S.D. Mullin, A. Ovcharova, H. Qu, J. Richman, D. Stuart, I. Suarez, J. Yoo

California Institute of Technology, Pasadena, USA
D. Anderson, J. Bendavid, A. Bornheim, J.M. Lawhorn, H.B. Newman, T. Nguyen, C. Pena, M. Spiropulu, J.R. Vlimant, S. Xie, Z. Zhang, R.Y. Zhu

Carnegie Mellon University, Pittsburgh, USA
M.B. Andrews, T. Ferguson, T. Mudholkar, M. Paulini, J. Russ, M. Sun, H. Vogel, I. Vorobiev, M. Weinberg

University of Colorado Boulder, Boulder, USA
J.P. Cumalat, W.T. Ford, F. Jensen, A. Johnson, M. Krohn, S. Leontsinis, T. Mulholland, K. Stenson, S.R. Wagner

Cornell University, Ithaca, USA
J. Alexander, J. Chaves, J. Chu, S. Dittmer, K. Mcdermott, N. Mirman, J.R. Patterson, A. Rinkevicius, A. Ryd, L. Skinnari, L. Soffi, S.M. Tan, Z. Tao, J. Thom, J. Tucker, P. Wittich, M. Zientek

Fermi National Accelerator Laboratory, Batavia, USA
S. Abdullin, M. Albrow, G. Apollinari, A. Apresyan, A. Apyan, S. Banerjee, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, G. Bolla[†], K. Burkett, J.N. Butler, A. Canepa, G.B. Cerati, H.W.K. Cheung, F. Chlebana, M. Cremonesi, J. Duarte, V.D. Elvira, J. Freeman, Z. Gecse, E. Gottschalk, L. Gray, D. Green, S. Grünendahl, O. Gutsche, R.M. Harris, S. Hasegawa, J. Hirschauer, Z. Hu, B. Jayatilaka, S. Jindariani, M. Johnson, U. Joshi, B. Klima, B. Kreis, S. Lammel, D. Lincoln, R. Lipton, M. Liu, T. Liu, R. Lopes De Sá, J. Lykken, K. Maeshima, N. Magini, J.M. Marraffino, S. Maruyama, D. Mason, P. McBride, P. Merkel, S. Mrenna, S. Nahn, V. O'Dell, K. Pedro, O. Prokofyev, G. Rakness, L. Ristori, B. Schneider, E. Sexton-Kennedy, A. Soha, W.J. Spalding, L. Spiegel, S. Stoynev, J. Strait, N. Strobbe, L. Taylor, S. Tkaczyk, N.V. Tran, L. Uplegger, E.W. Vaandering, C. Vernieri, M. Verzocchi, R. Vidal, M. Wang, H.A. Weber, A. Whitbeck

University of Florida, Gainesville, USA
D. Acosta, P. Avery, P. Bortignon, D. Bourilkov, A. Brinkerhoff, A. Carnes, M. Carver, D. Curry, R.D. Field, I.K. Furic, J. Konigsberg, A. Korytov, K. Kotov, P. Ma, K. Matchev, H. Mei, G. Mitselmakher, D. Rank, D. Sperka, N. Terentyev, L. Thomas, J. Wang, S. Wang, J. Yelton

Florida International University, Miami, USA
Y.R. Joshi, S. Linn, P. Markowitz, J.L. Rodriguez

Florida State University, Tallahassee, USA
A. Ackert, T. Adams, A. Askew, S. Hagopian, V. Hagopian, K.F. Johnson, T. Kolberg, G. Martinez, T. Perry, H. Prosper, A. Saha, A. Santra, V. Sharma, R. Yohay

Florida Institute of Technology, Melbourne, USA
M.M. Baarmand, V. Bhopatkar, S. Colafranceschi, M. Hohlmann, D. Noonan, T. Roy, F. Yumiceva

University of Illinois at Chicago (UIC), Chicago, USA
M.R. Adams, L. Apanasevich, D. Berry, R.R. Betts, R. Cavanaugh, X. Chen, O. Evdokimov, C.E. Gerber, D.A. Hangal, D.J. Hofman, K. Jung, J. Kamin, I.D. Sandoval Gonzalez, M.B. Tonjes, H. Trauger, N. Varelas, H. Wang, Z. Wu, J. Zhang

The University of Iowa, Iowa City, USA
B. Bilki[64], W. Clarida, K. Dilsiz[65], S. Durgut, R.P. Gandrajula, M. Haytmyradov, V. Khristenko, J.-P. Merlo, H. Mermerkaya[66], A. Mestvirishvili, A. Moeller, J. Nachtman, H. Ogul[67], Y. Onel, F. Ozok[68], A. Penzo, C. Snyder, E. Tiras, J. Wetzel, K. Yi

Johns Hopkins University, Baltimore, USA

B. Blumenfeld, A. Cocoros, N. Eminizer, D. Fehling, L. Feng, A.V. Gritsan, P. Maksimovic, J. Roskes, U. Sarica, M. Swartz, M. Xiao, C. You

The University of Kansas, Lawrence, USA
A. Al-bataineh, P. Baringer, A. Bean, S. Boren, J. Bowen, J. Castle, S. Khalil, A. Kropivnitskaya, D. Majumder, W. Mcbrayer, M. Murray, C. Royon, S. Sanders, E. Schmitz, R. Stringer, J.D. Tapia Takaki, Q. Wang

Kansas State University, Manhattan, USA
A. Ivanov, K. Kaadze, Y. Maravin, A. Mohammadi, L.K. Saini, N. Skhirtladze, S. Toda

Lawrence Livermore National Laboratory, Livermore, USA
F. Rebassoo, D. Wright

University of Maryland, College Park, USA
C. Anelli, A. Baden, O. Baron, A. Belloni, B. Calvert, S.C. Eno, C. Ferraioli, N.J. Hadley, S. Jabeen, G.Y. Jeng, R.G. Kellogg, J. Kunkle, A.C. Mignerey, F. Ricci-Tam, Y.H. Shin, A. Skuja, S.C. Tonwar

Massachusetts Institute of Technology, Cambridge, USA
D. Abercrombie, B. Allen, V. Azzolini, R. Barbieri, A. Baty, R. Bi, S. Brandt, W. Busza, I.A. Cali, M. D'Alfonso, Z. Demiragli, G. Gomez Ceballos, M. Goncharov, D. Hsu, Y. Iiyama, G.M. Innocenti, M. Klute, D. Kovalskyi, Y.S. Lai, Y.-J. Lee, A. Levin, P.D. Luckey, B. Maier, A.C. Marini, C. Mcginn, C. Mironov, S. Narayanan, X. Niu, C. Paus, C. Roland, G. Roland, J. Salfeld-Nebgen, G.S.F. Stephans, K. Tatar, D. Velicanu, J. Wang, T.W. Wang, B. Wyslouch

University of Minnesota, Minneapolis, USA
A.C. Benvenuti, R.M. Chatterjee, A. Evans, P. Hansen, S. Kalafut, Y. Kubota, Z. Lesko, J. Mans, S. Nourbakhsh, N. Ruckstuhl, R. Rusack, J. Turkewitz

University of Mississippi, Oxford, USA
J.G. Acosta, S. Oliveros

University of Nebraska-Lincoln, Lincoln, USA
E. Avdeeva, K. Bloom, D.R. Claes, C. Fangmeier, R. Gonzalez Suarez, R. Kamalieddin, I. Kravchenko, J. Monroy, J.E. Siado, G.R. Snow, B. Stieger

State University of New York at Buffalo, Buffalo, USA
M. Alyari, J. Dolen, A. Godshalk, C. Harrington, I. Iashvili, D. Nguyen, A. Parker, S. Rappoccio, B. Roozbahani

Northeastern University, Boston, USA
G. Alverson, E. Barberis, A. Hortiangtham, A. Massironi, D.M. Morse, D. Nash, T. Orimoto, R. Teixeira De Lima, D. Trocino, D. Wood

Northwestern University, Evanston, USA
S. Bhattacharya, O. Charaf, K.A. Hahn, N. Mucia, N. Odell, B. Pollack, M.H. Schmitt, K. Sung, M. Trovato, M. Velasco

University of Notre Dame, Notre Dame, USA
N. Dev, M. Hildreth, K. Hurtado Anampa, C. Jessop, D.J. Karmgard, N. Kellams, K. Lannon, N. Loukas, N. Marinelli, F. Meng, C. Mueller, Y. Musienko[36], M. Planer, A. Reinsvold, R. Ruchti, G. Smith, S. Taroni, M. Wayne, M. Wolf, A. Woodard

The Ohio State University, Columbus, USA
J. Alimena, L. Antonelli, B. Bylsma, L.S. Durkin, S. Flowers, B. Francis, A. Hart, C. Hill, W. Ji, B. Liu, W. Luo, D. Puigh, B.L. Winer, H.W. Wulsin

Princeton University, Princeton, USA
S. Cooperstein, O. Driga, P. Elmer, J. Hardenbrook, P. Hebda, S. Higginbotham, D. Lange, J. Luo, D. Marlow, K. Mei, I. Ojalvo, J. Olsen, C. Palmer, P. Piroué, D. Stickland, C. Tully

University of Puerto Rico, Mayaguez, USA
S. Malik, S. Norberg

Purdue University, West Lafayette, USA
A. Barker, V.E. Barnes, S. Das, S. Folgueras, L. Gutay, M.K. Jha, M. Jones, A.W. Jung, A. Khatiwada, D.H. Miller, N. Neumeister, C.C. Peng, H. Qiu, J.F. Schulte, J. Sun, F. Wang, W. Xie

Purdue University Northwest, Hammond, USA
T. Cheng, N. Parashar, J. Stupak

Rice University, Houston, USA
A. Adair, B. Akgun, Z. Chen, K.M. Ecklund, F.J.M. Geurts, M. Guilbaud, W. Li, B. Michlin, M. Northup, B.P. Padley, J. Roberts, J. Rorie, Z. Tu, J. Zabel

University of Rochester, Rochester, USA
A. Bodek, P. de Barbaro, R. Demina, Y.t. Duh, T. Ferbel, M. Galanti, A. Garcia-Bellido, J. Han, O. Hindrichs, A. Khukhunaishvili, K.H. Lo, P. Tan, M. Verzetti

The Rockefeller University, New York, USA
R. Ciesielski, K. Goulianos, C. Mesropian

Rutgers, The State University of New Jersey, Piscataway, USA
A. Agapitos, J.P. Chou, Y. Gershtein, T.A. Gómez Espinosa, E. Halkiadakis, M. Heindl, E. Hughes, S. Kaplan, R. Kunnawalkam Elayavalli, S. Kyriacou, A. Lath, R. Montalvo, K. Nash, M. Osherson, H. Saka, S. Salur, S. Schnetzer, D. Sheffield, S. Somalwar, R. Stone, S. Thomas, P. Thomassen, M. Walker

University of Tennessee, Knoxville, USA
A.G. Delannoy, M. Foerster, J. Heideman, G. Riley, K. Rose, S. Spanier, K. Thapa

Texas A&M University, College Station, USA
O. Bouhali[69], A. Castaneda Hernandez[69], A. Celik, M. Dalchenko, M. De Mattia, A. Delgado, S. Dildick, R. Eusebi, J. Gilmore, T. Huang, T. Kamon[70], R. Mueller, Y. Pakhotin, R. Patel, A. Perloff, L. Perniè, D. Rathjens, A. Safonov, A. Tatarinov, K.A. Ulmer

Texas Tech University, Lubbock, USA
N. Akchurin, J. Damgov, F. De Guio, P.R. Dudero, J. Faulkner, E. Gurpinar, S. Kunori, K. Lamichhane, S.W. Lee, T. Libeiro, T. Peltola, S. Undleeb, I. Volobouev, Z. Wang

Vanderbilt University, Nashville, USA
S. Greene, A. Gurrola, R. Janjam, W. Johns, C. Maguire, A. Melo, H. Ni, P. Sheldon, S. Tuo, J. Velkovska, Q. Xu

University of Virginia, Charlottesville, USA
M.W. Arenton, P. Barria, B. Cox, R. Hirosky, A. Ledovskoy, H. Li, C. Neu, T. Sinthuprasith, Y. Wang, E. Wolfe, F. Xia

Wayne State University, Detroit, USA
R. Harr, P.E. Karchin, J. Sturdy, S. Zaleski

University of Wisconsin - Madison, Madison, WI, USA
M. Brodski, J. Buchanan, C. Caillol, S. Dasu, L. Dodd, S. Duric, B. Gomber, M. Grothe, M. Herndon, A. Hervé, U. Hussain, P. Klabbers, A. Lanaro, A. Levine, K. Long, R. Loveless, G.A. Pierro, G. Polese, T. Ruggles, A. Savin, N. Smith, W.H. Smith, D. Taylor, N. Woods

†: Deceased
d: Also at Vienna University of Technology, Vienna, Austria
d: Also at State Key Laboratory of Nuclear Physics and Technology; Peking University, Beijing, China
d: Also at Universidade Estadual de Campinas, Campinas, Brazil
d: Also at Universidade Federal de Pelotas, Pelotas, Brazil
d: Also at Université Libre de Bruxelles, Bruxelles, Belgium
d: Also at Institute for Theoretical and Experimental Physics, Moscow, Russia
d: Also at Joint Institute for Nuclear Research, Dubna, Russia
d: Also at Suez University, Suez, Egypt
d: Now at British University in Egypt, Cairo, Egypt
d: Also at Fayoum University, El-Fayoum, Egypt
d: Now at Helwan University, Cairo, Egypt
d: Also at Université de Haute Alsace, Mulhouse, France
d: Also at Skobeltsyn Institute of Nuclear Physics; Lomonosov Moscow State University, Moscow, Russia
d: Also at Tbilisi State University, Tbilisi, Georgia
d: Also at CERN; European Organization for Nuclear Research, Geneva, Switzerland
d: Also at RWTH Aachen University; III. Physikalisches Institut A, Aachen, Germany
d: Also at University of Hamburg, Hamburg, Germany
d: Also at Brandenburg University of Technology, Cottbus, Germany
d: Also at MTA-ELTE Lendület CMS Particle and Nuclear Physics Group; Eötvös Loránd University, Budapest, Hungary
d: Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary
d: Also at Institute of Physics; University of Debrecen, Debrecen, Hungary
d: Also at Indian Institute of Technology Bhubaneswar, Bhubaneswar, India
d: Also at Institute of Physics, Bhubaneswar, India
d: Also at University of Visva-Bharati, Santiniketan, India
d: Also at University of Ruhuna, Matara, Sri Lanka
d: Also at Isfahan University of Technology, Isfahan, Iran
d: Also at Yazd University, Yazd, Iran
d: Also at Plasma Physics Research Center; Science and Research Branch; Islamic Azad University, Tehran, Iran
d: Also at Università degli Studi di Siena, Siena, Italy
d: Also at INFN Sezione di Milano-Bicocca; Università di Milano-Bicocca, Milano, Italy
d: Also at Purdue University, West Lafayette, USA
d: Also at International Islamic University of Malaysia, Kuala Lumpur, Malaysia
d: Also at Malaysian Nuclear Agency; MOSTI, Kajang, Malaysia
d: Also at Consejo Nacional de Ciencia y Tecnología, Mexico city, Mexico
d: Also at Warsaw University of Technology; Institute of Electronic Systems, Warsaw, Poland
d: Also at Institute for Nuclear Research, Moscow, Russia
d: Now at National Research Nuclear University 'Moscow Engineering Physics

Institute' (MEPhI), Moscow, Russia
d: Also at St. Petersburg State Polytechnical University, St. Petersburg, Russia
d: Also at University of Florida, Gainesville, USA
d: Also at P.N. Lebedev Physical Institute, Moscow, Russia
d: Also at INFN Sezione di Padova; Università di Padova; Università di Trento (Trento), Padova, Italy
d: Also at Budker Institute of Nuclear Physics, Novosibirsk, Russia
d: Also at Faculty of Physics; University of Belgrade, Belgrade, Serbia
d: Also at University of Belgrade; Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
d: Also at Scuola Normale e Sezione dell'INFN, Pisa, Italy
d: Also at National and Kapodistrian University of Athens, Athens, Greece
d: Also at Riga Technical University, Riga, Latvia
d: Also at Universität Zürich, Zurich, Switzerland
d: Also at Stefan Meyer Institute for Subatomic Physics (SMI), Vienna, Austria
d: Also at Adiyaman University, Adiyaman, Turkey
d: Also at Istanbul Aydin University, Istanbul, Turkey
d: Also at Mersin University, Mersin, Turkey
d: Also at Cag University, Mersin, Turkey
d: Also at Piri Reis University, Istanbul, Turkey
d: Also at Izmir Institute of Technology, Izmir, Turkey
d: Also at Necmettin Erbakan University, Konya, Turkey
d: Also at Marmara University, Istanbul, Turkey
d: Also at Kafkas University, Kars, Turkey
d: Also at Istanbul Bilgi University, Istanbul, Turkey
d: Also at Rutherford Appleton Laboratory, Didcot, United Kingdom
d: Also at School of Physics and Astronomy; University of Southampton, Southampton, United Kingdom
d: Also at Instituto de Astrofísica de Canarias, La Laguna, Spain
d: Also at Utah Valley University, Orem, USA
d: Also at Beykent University, Istanbul, Turkey
d: Also at Bingol University, Bingol, Turkey
d: Also at Erzincan University, Erzincan, Turkey
d: Also at Sinop University, Sinop, Turkey
d: Also at Mimar Sinan University; Istanbul, Istanbul, Turkey
d: Also at Texas A&M University at Qatar, Doha, Qatar
d: Also at Kyungpook National University, Daegu, Korea