BELLE2-NOTE-PL-2019-XXX
DRAFT Version 0.1
September 27, 2019

Hadronic B decay reconstruction in 5.15 fb^{-1} of early Phase III data

E. Ganiev*

University and INFN, Trieste, Italy

J. Libby, N. Rout†

Indian Institute of Technology, Madras, India

D. Tonelli

INFN Trieste, Italy

K. Trabelsi

LAL Orsay, France

Abstract

We report the material, approved for the Beauty 2019 conference, from studies of hadronic $B^{+/0} \to D^{(*)}h^+$ ($h = \pi$ or ρ) decays based on 5.15 fb^{-1} of early phase III data. Details are in the internal note BELLE2-NOTE-PH-2019-039.

*Electronic address: eldar.ganiev@ts.infn.it
†Electronic address: niharikarout@physics.iitm.ac.in

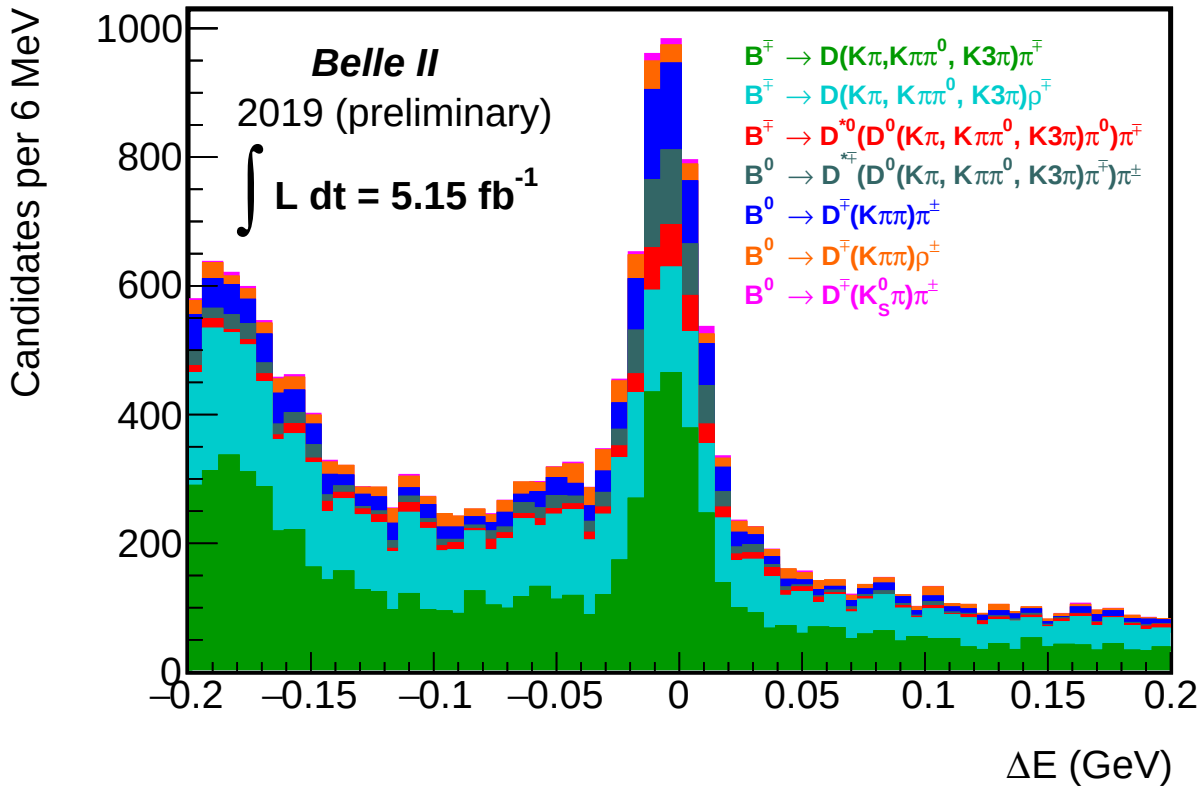

FIG. 1: Distribution of ΔE for all $B^{+/0} \to D^{(*)}h^+$ candidates reconstructed in 5.15 fb^{-1} of collision data. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle- identification likelihood ratio of > 0.6 is applied to K candidates. Candidate ρ and K^0_S decays are restricted to $|M(\pi^+\pi^0) - m_\rho| < 100$ MeV/c^2 and $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2, respectively. A $\cos\theta_\rho >$ -0.8 requirements is applied for $B \to D\rho$ candidates to further suppress combinatorial backgrounds. The invariant masses of D^0 and D^+ candidates are restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2 and $1.844 < M(K^-\pi^+\pi^+) < 1.894$ GeV/c^2, respectively. Candidate D^{*+} decays are required to meet $0.143 < M(D^0\pi^+) - M_{D^0} < 0.147$ GeV/c^2 and D^{*0} candidates are required to have $0.14 < M(D^0\pi^0) - M_{D^0} < 0.144$ GeV/c^2, where M_{D^0} is the known D^0 mass. Contributions from continuum $q\bar{q}$ background are suppressed with the following requirements on the second (normalized) Fox-Wolfram moment, R2 < 0.3 and 0.25 for $B \to D^{(*)}\pi$ and $B \to D\rho$ modes, respectively. Events shown are restricted to the signal region $M_{bc} > 5.27$ GeV/c^2. The signal yields from individual channel using a signal enhanced 2D fit of ΔE and M_{bc} are shown in table I.

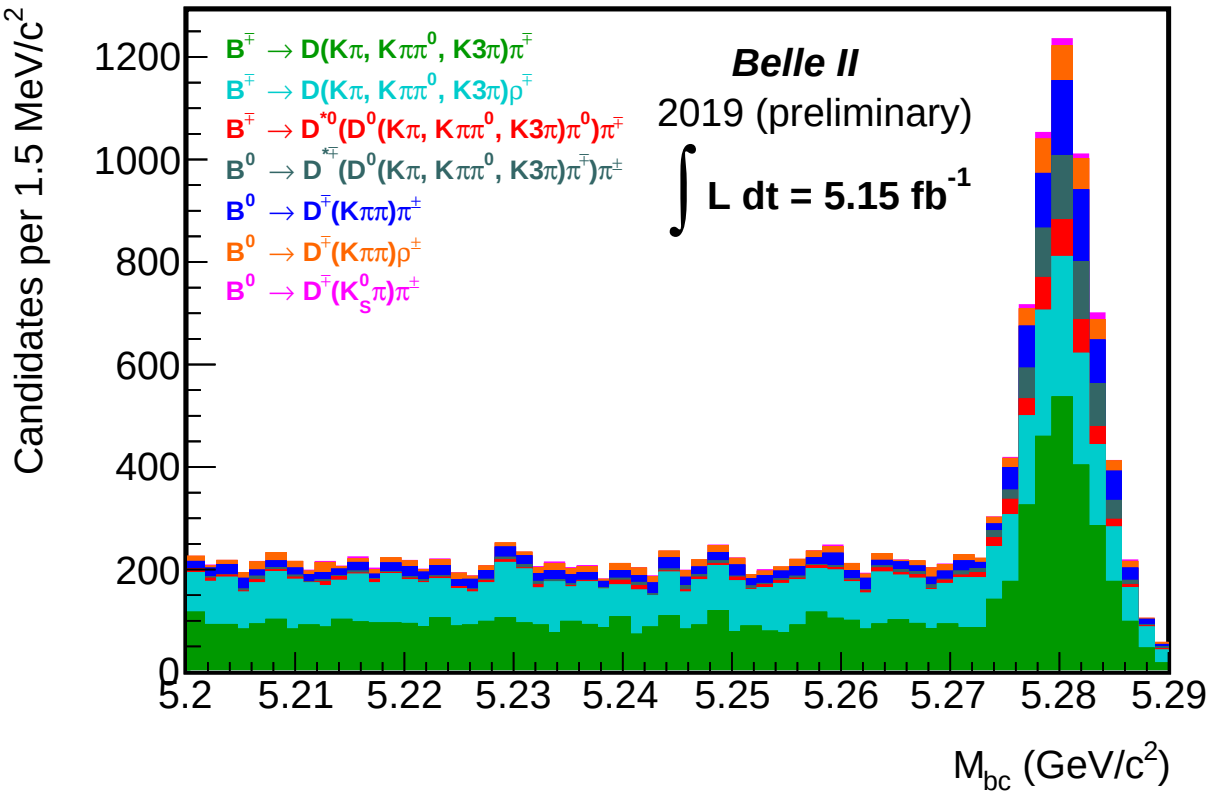

FIG. 2: Distribution of $\mathrm{M_{bc}}$ for all $B^{+/0} \to D^{(*)}h^+$ candidates reconstructed in 5.15 fb^{-1} of collision data. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle- identification likelihood ratio of > 0.6 is applied to K candidates. Candidate ρ and K^0_S decays are restricted to $|M(\pi^+\pi^0) - m_\rho| < 100$ MeV/c^2 and $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2, respectively. A $\cos\theta_\rho >$ -0.8 requirements is applied for $B \to D\rho$ candidates to further suppress combinatorial backgrounds. The invariant masses of D^0 and D^+ candidates are restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2 and $1.844 < M(K^-\pi^+\pi^+) < 1.894$ GeV/c^2, respectively. Candidate D^{*+} decays are required to meet $0.143 < M(D^0\pi^+) - M_{D^0} < 0.147$ GeV/c^2 and D^{*0} candidates are required to have $0.14 < M(D^0\pi^0) - M_{D^0} < 0.144$ GeV/c^2, where M_{D^0} is the known D^0 mass. Contributions from continuum $q\bar{q}$ background are suppressed with the following requirements on the second (normalized) Fox-Wolfram moment, R2 < 0.3 and 0.25 for $B \to D^{(*)}\pi$ and $B \to D\rho$ modes, respectively. Events shown are restricted to the signal region $|\Delta E| < 0.05$ GeV. The signal yields from individual channel using a signal enhanced 2D fit of ΔE and $\mathrm{M_{bc}}$ are shown in table I.

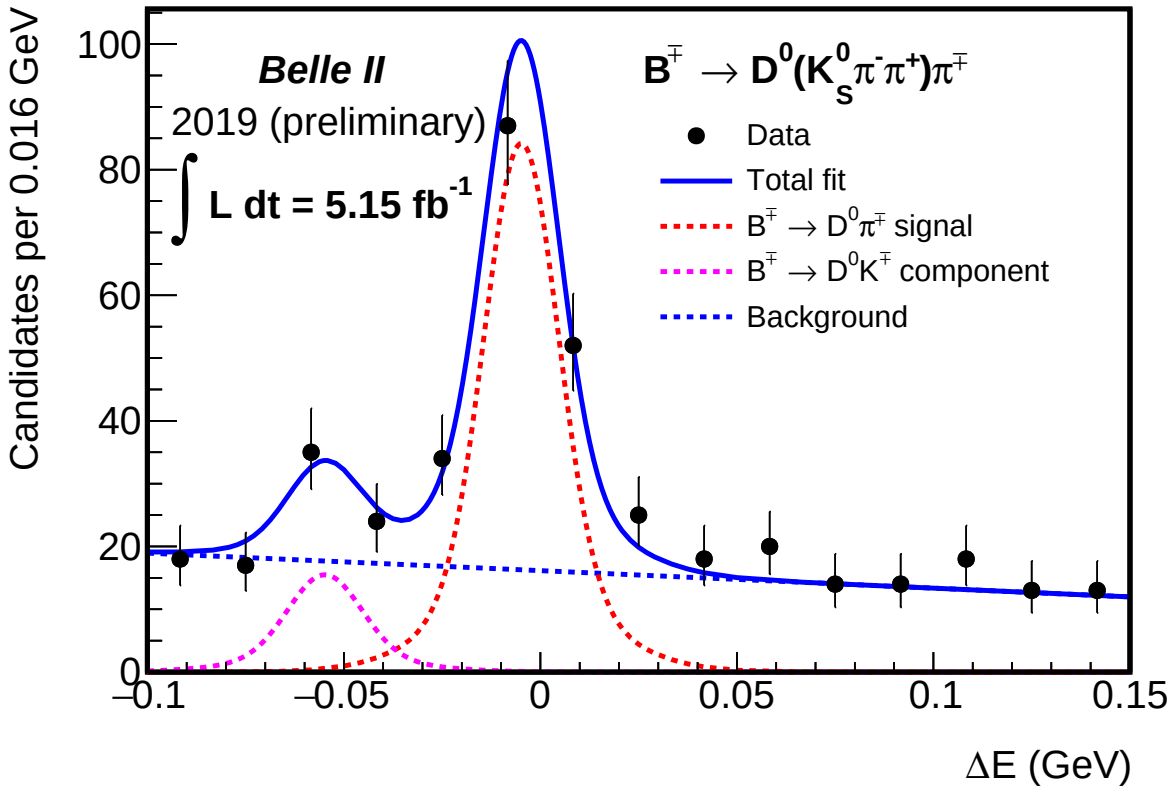

FIG. 3: Distribution of ΔE for $B^{\pm} \to D[\to K^0_S(\to \pi^+\pi^-)\pi^+\pi^-]\pi^{\pm}$ candidates reconstructed in 5.15 fb^{-1} of collision data, with projections of a two-dimensional fit of the unbinned ΔE and $\mathrm{M_{bc}}$ distributions overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). Candidate K^0_S decays are restricted to $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2. The invariant mass of D^0 candidates is restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a R2 < 0.3 requirement on the second (normalized) Fox-Wolfram moment. The ΔE fit model consists of a double Gaussian function for signal and a straight line for background, with signal means, narrow width, and yield; and background slope and yield as floating parameters. The fit determines a yield of 137 ± 13 signal decays. Events shown are restricted to the signal region $\mathrm{M_{bc}} > 5.27$ GeV/c^2.

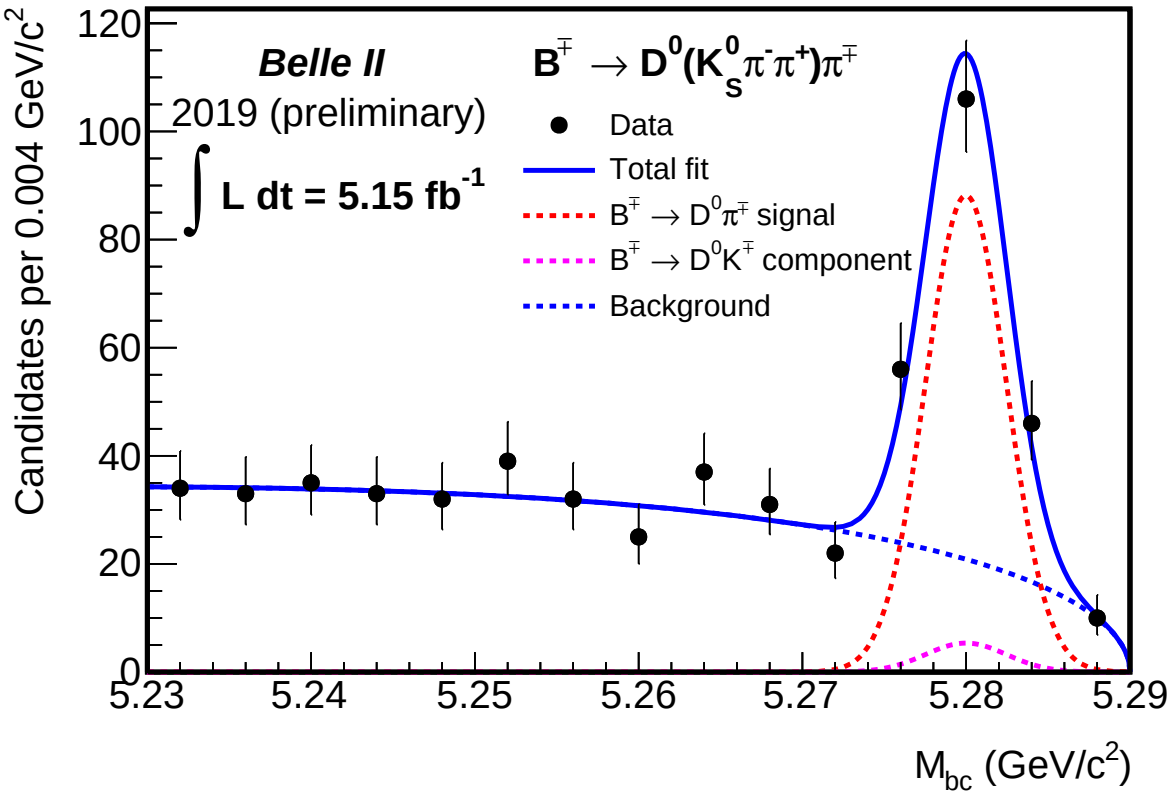

FIG. 4: Distribution of $\mathrm{M_{bc}}$ for $B^{\pm} \to D[\to K^0_S(\to \pi^+\pi^-)\pi^+\pi^-]\pi^{\pm}$ candidates reconstructed in 5.15 fb^{-1} of collision data, with projections of a two-dimensional fit of the unbinned ΔE and $\mathrm{M_{bc}}$ distributions overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). Candidate K^0_S decays are restricted to $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2. The invariant mass of D^0 candidates is restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a $\mathrm{R2} < 0.3$ requirement on the second (normalized) Fox-Wolfram moment. The $\mathrm{M_{bc}}$ fit model consists of a Gaussian function for signal and an Argus function for background, with signal mean, yield, and width; background yield; and Argus shape parameters floating. The fit determines a yield of 137 ± 13 signal decays. Events shown are restricted to the signal region $|\Delta E| < 0.05$ GeV.

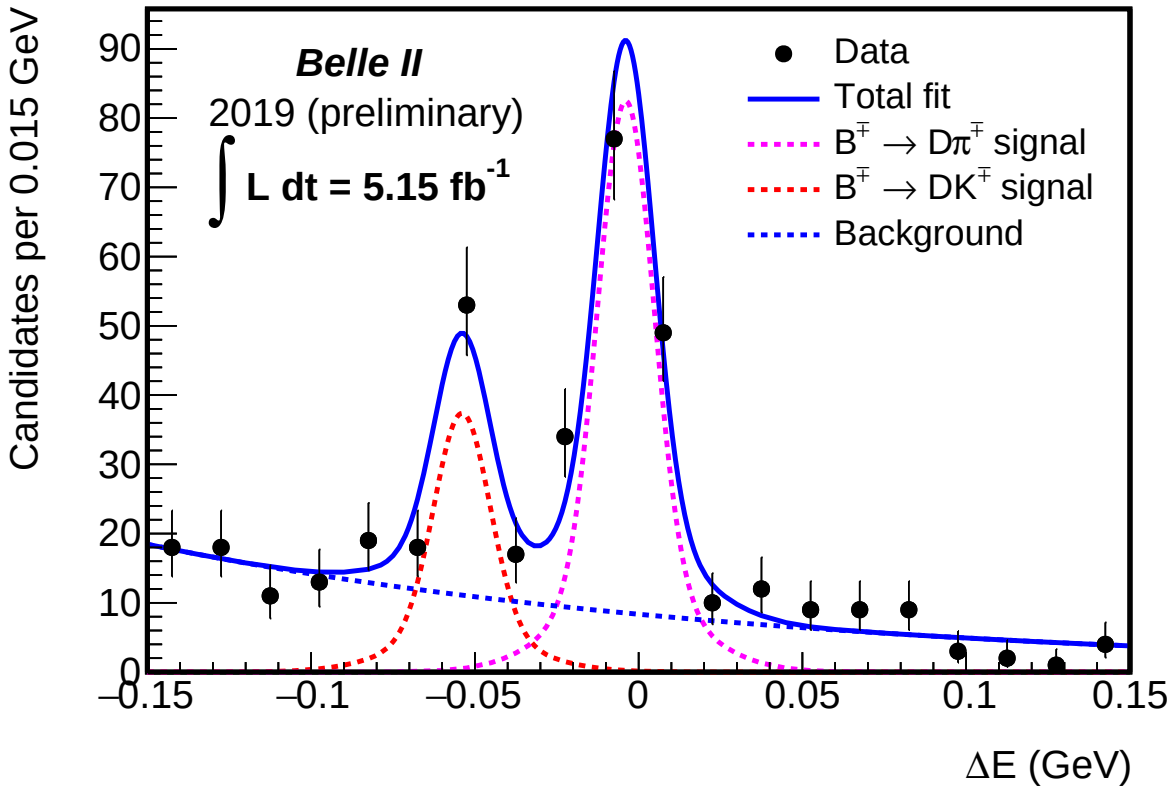

FIG. 5: Distribution of ΔE for $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)\pi^{\pm}$ and $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)K^{\pm}$ candidates reconstructed in 5.15 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections of an unbinned fit overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle-identification likelihood ratio of > 0.6 is applied to all charged K candidates and an additional requirement < 0.4 is applied to the candidate charged pion from the B meson decay. The invariant mass of D^0 candidates is restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a (> 0.94) requirement on the output of a fast-boosted-decision-tree classifier, trained in simulation to distinguish signal from background using about 20 topological discriminating variables, and shown to retain 50% of signal while rejecting 95.5% of background in an independent sample. The ΔE fit model consists of a double Gaussian function for each of the signals and an exponential function for background, with $D\pi$ signal mean, signal yields, and background slope and yield as floating parameters. The fit determines a $B^{\pm} \to DK^{\pm}$ yield of 53 ± 9 signal decays.

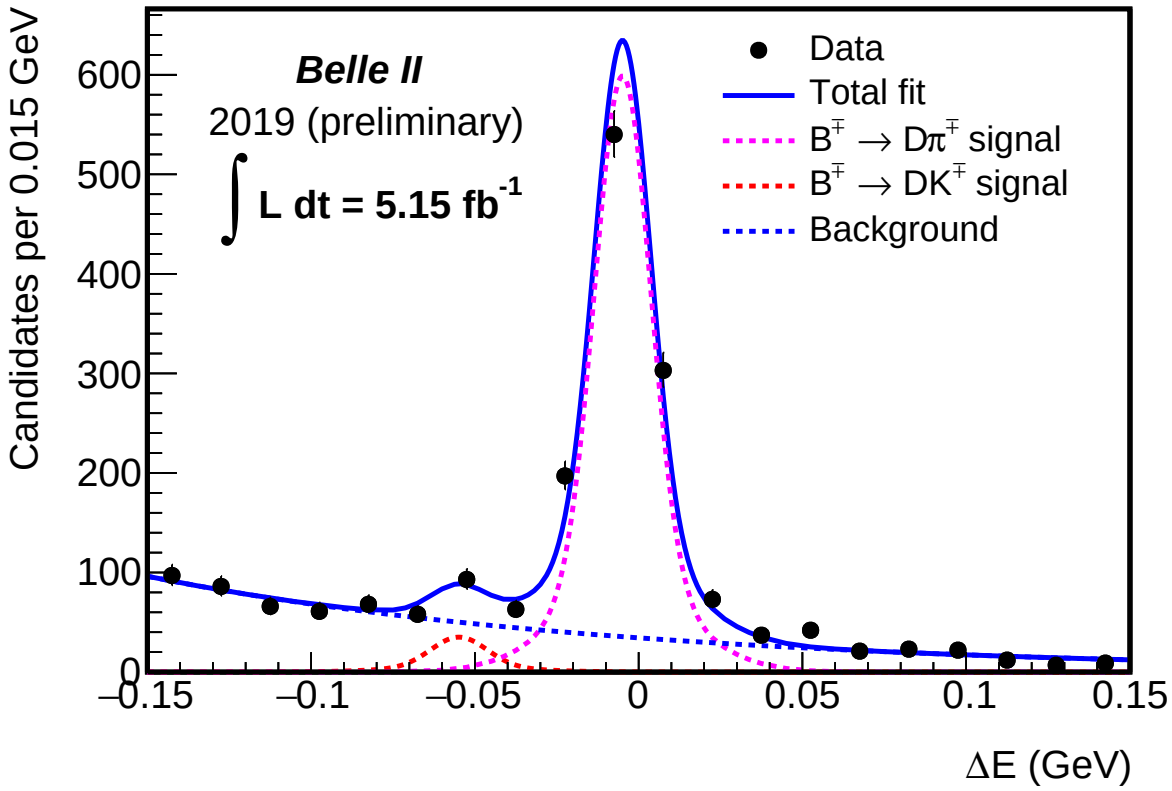

FIG. 6: Distribution of ΔE for $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)\pi^{\pm}$ and $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)K^{\pm}$ candidates reconstructed in 5.15 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections of an unbinned fit overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle-identification likelihood ratio of > 0.6 is applied to all charged K candidates. The invariant mass of D^0 candidates is restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a (> 0.94) requirement on the output of a fast-boosted-decision-tree classifier, trained in simulation to distinguish signal from background using about 20 topological discriminating variables, and shown to retain 50% of signal while rejecting 95.5% of background in an independent sample. The ΔE fit model consists of a double Gaussian function for each of the signals and an exponential function for background, with $D\pi$ mean, signal yields, and background slope and yield as floating parameters. The fit determines yields of of 58 ± 15 $B^{\pm} \to DK^{\pm}$ and 1004 ± 34 $B^{\pm} \to D\pi^{\pm}$ decays.

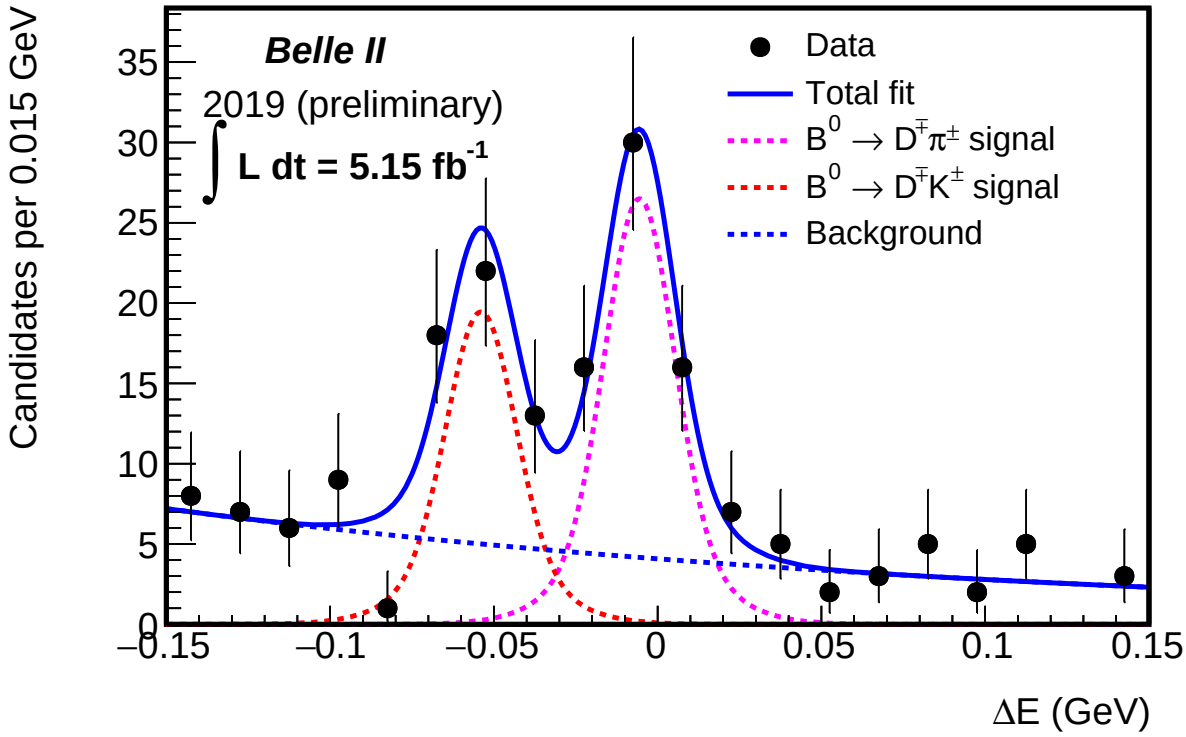

FIG. 7: Distribution of ΔE for $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]\pi^+$ and $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]K^+$ candidates reconstructed in 5.15 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections of an unbinned fit overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle-identification likelihood ratio of > 0.6 is applied to all charged K candidates and an additional requirement < 0.4 is applied to the candidate charged pion from the B meson decay. Candidate K^0_S decays are restricted to $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2. The invariant mass of D^- candidates is restricted to $1.844 < M(K^+\pi^-\pi^-, K^0_S\pi^-) < 1.894$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a (> 0.92) requirement on the output of a fast-boosted-decision-tree classifier, trained in simulation to distinguish signal from background using about 20 topological discriminating variables, and shown to retain 65% of signal while rejecting 96% of background in an independent sample. The ΔE fit model consists of a double Gaussian function for each of the signals and an exponential function for background, with $D\pi$ mean, signal yields, and background slope and yields as floating parameters. The fit determines a $B^0 \to D^-K^+$ yield of 39 ± 8 decays.

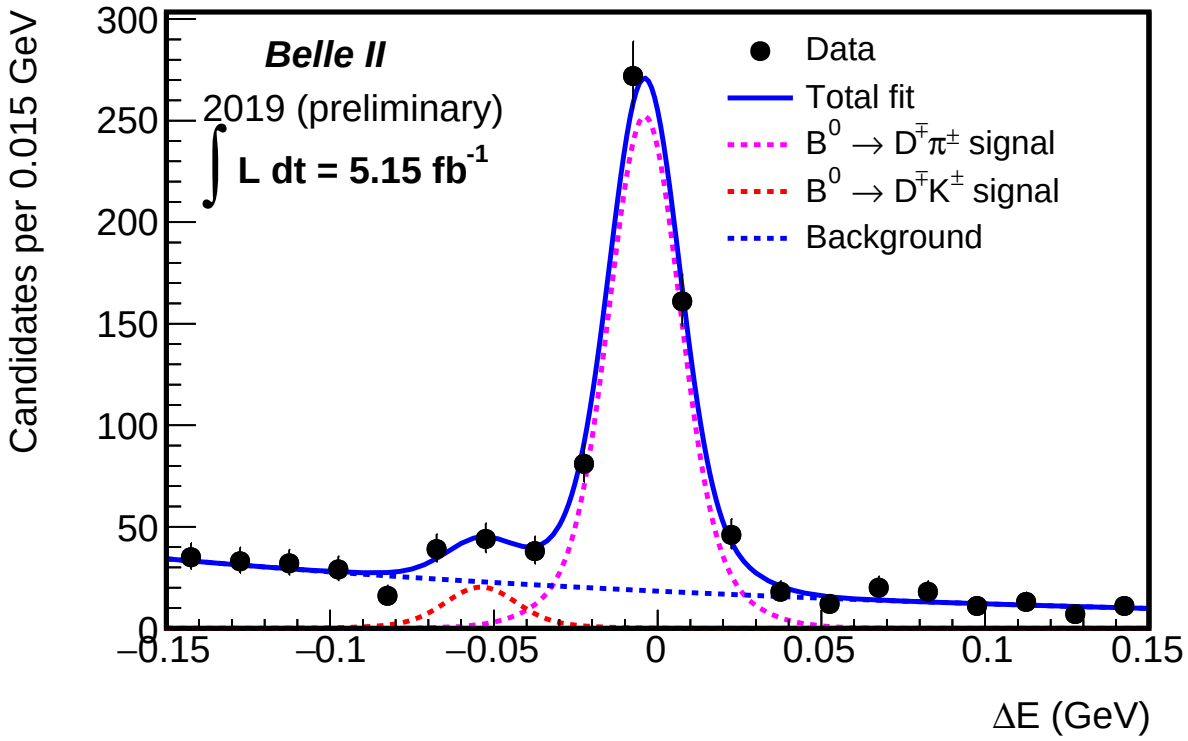

FIG. 8: Distribution of ΔE for $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]\pi^+$ and $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]K^+$ candidates reconstructed in 5.15 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections of an unbinned fit overlaid. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle-identification likelihood ratio of > 0.6 is applied to all charged K candidates. Candidate K^0_S decays are restricted to $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2. The invariant mass of D^- candidates is restricted to $1.844 < M(K^+\pi^-\pi^-, K^0_S\pi^-) < 1.894$ GeV/c^2. Contributions from continuum $q\bar{q}$ background are suppressed with a (> 0.92) requirement on the output of a fast-boosted-decision-tree classifier, trained in simulation to distinguish signal from background using about 20 topological discriminating variables, and shown to retain 65% of signal while rejecting 96% of background in an independent sample. The ΔE fit model consists of a double Gaussian function for each of the signals and an exponential function for background, with $D\pi$ mean, signal yields, and background slope and yield as floating parameters. The fit determines yields of 505 ± 25 $B^0 \to D^-\pi^+$ decays and 41 ± 12 $B^0 \to D^-K^+$ decays.

Decay	Yield
$B^- \to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^-$	1764 ± 48
$B^- \to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\rho^-$	997 ± 45
$B^- \to D^{*0}(\to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^0)\pi^-$	263 ± 17
$B^0 \to D^{*-}(\to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^-)\pi^+$	484 ± 23
$B^0 \to D^-(\to K\pi\pi)\pi^+$	598 ± 27
$B^0 \to D^-(\to K\pi\pi)\rho^+$	311 ± 23
$B^0 \to D^-(\to K^0_S\pi)\pi^+$	54 ± 8

TABLE I: Signal yields obtained obtained in 5.15 fb^{-1}. Observed yields are generally consistent, within 10-20%, with expectations from simulation.

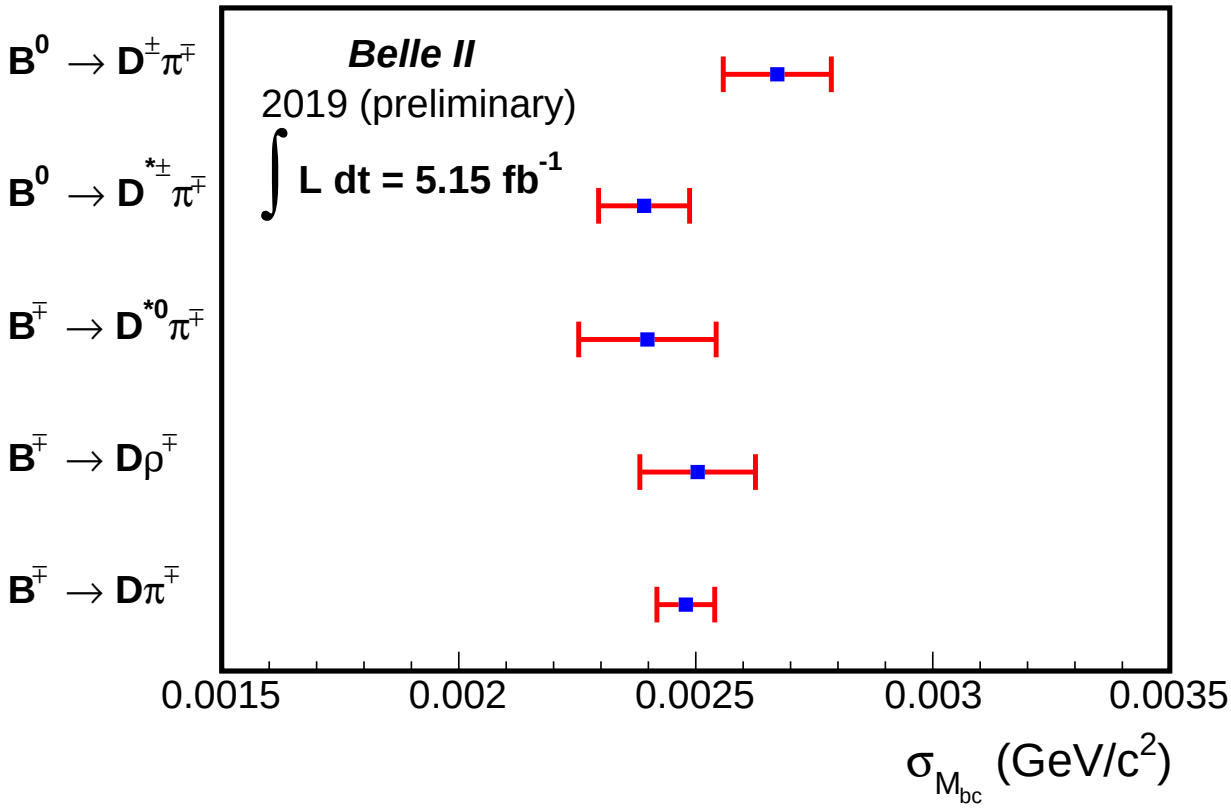

FIG. 9: Distribution of spread in beam-energy determined using independent hadronic channels $B^{+/0} \to D^{(*)}h^+$ candidates. The value of the spread is obtained from the 2D fit ΔE and M_{bc} of individual channels, where the spread in the M_{bc} has been taken into account as the uncertainty on the B momentum is negligible. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, and other low-multiplicity processes. The charged-kaon and -pion candidate tracks are required to have transverse (longitudinal) displacement from the interaction point $|d_0| < 0.5$ cm ($|z_0| < 3.0$ cm). A requirement on the (binary) particle- identification likelihood ratio of > 0.6 is applied to K candidates. Candidate ρ and K^0_S decays are restricted to $|M(\pi^+\pi^0) - m_\rho| < 100$ MeV/c^2 and $0.45 < M(\pi^+\pi^+) < 0.55$ GeV/c^2, respectively. A $\cos\theta_\rho >$ -0.8 requirements is applied for $B \to D\rho$ candidates to further suppress combinatorial backgrounds. The invariant masses of D^0 and D^+ candidates are restricted to $1.84 < M(K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+) < 1.89$ GeV/c^2 and $1.844 < M(K^-\pi^+\pi^+) < 1.894$ GeV/c^2, respectively. Candidate D^{*+} decays are required to meet $0.143 < M(D^0\pi^+) - M_{D^0} < 0.147$ GeV/c^2 and D^{*0} candidates are required to have $0.14 < M(D^0\pi^0) - M_{D^0} < 0.144$ GeV/c^2, where M_{D^0} is the known D^0 mass. Contributions from continuum $q\bar{q}$ background are suppressed with the following requirements on the second (normalized) Fox-Wolfram moment, R2 < 0.3 and 0.25 for $B \to D^{(*)}\pi$ and $B \to D\rho$ modes, respectively. Events shown are restricted to the signal region $|\Delta E| < 0.05$ GeV.