BELLE2-NOTE-PL-2019-XXX
DRAFT Version 0.1
August 4, 2019

Hadronic B decay reconstruction in 2.62 fb^{-1} of early Phase III data

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Abstract

We report the material, approved for the LP 2019 conference, from studies of hadronic $B^{+/0} \to D^{(*)}h^+$ ($h = \pi$ or ρ) decays based on 2.62 fb^{-1} of early phase III data. Details are in the internal note BELLE2-NOTE-PH-2019-039.

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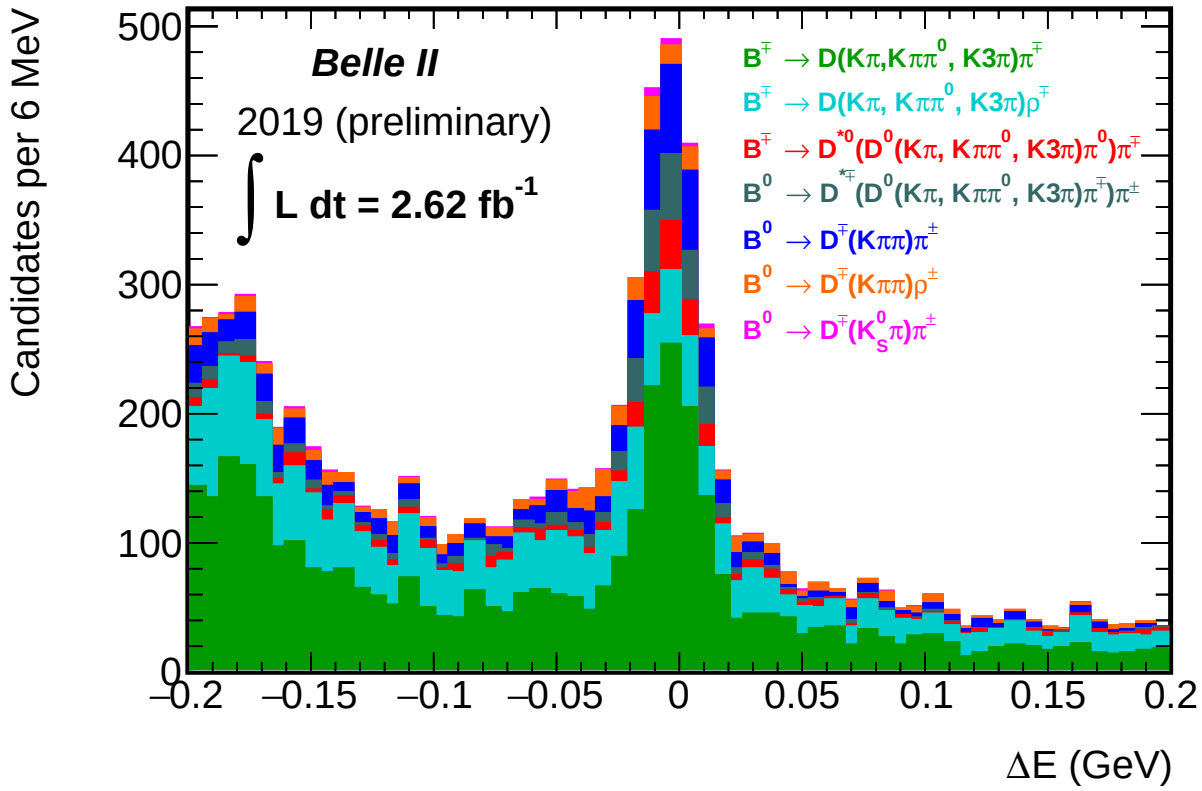

FIG. 1: Distribution of ΔE for all $B^{+/0} \to D^{(*)}h^+$ candidates reconstructed in 2.62 fb^{-1} of collision data. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha scattering, 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 $\mathrm{M_{bc}} > 5.27$ GeV/c^2.

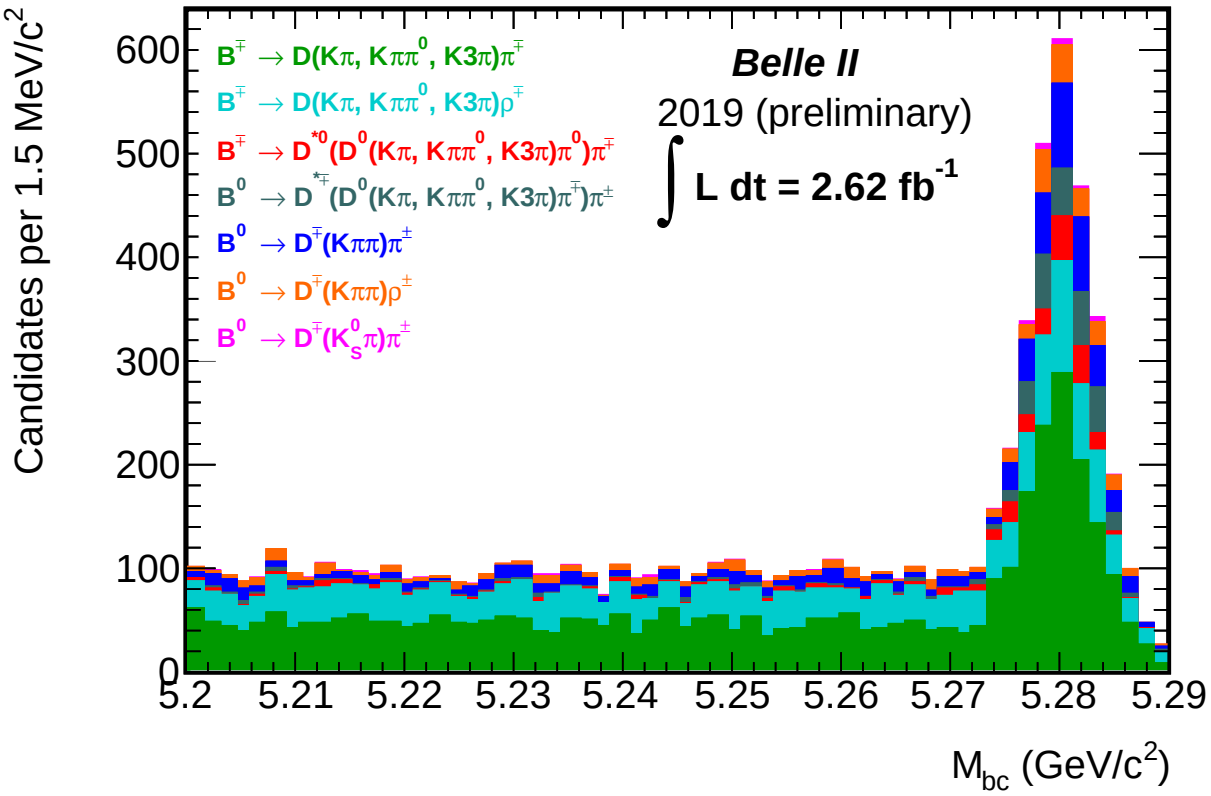

FIG. 2: Distribution of $\mathrm{M_{bc}}$ for all $B^{+/0} \to D^{(*)}h^+$ candidates reconstructed in 2.62 fb^{-1} of collision data. Events are required to contain at least three good-quality tracks to enrich the sample in $e^+e^- \to$ hadrons processes while suppressing beam-induced background, Bhabha 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.

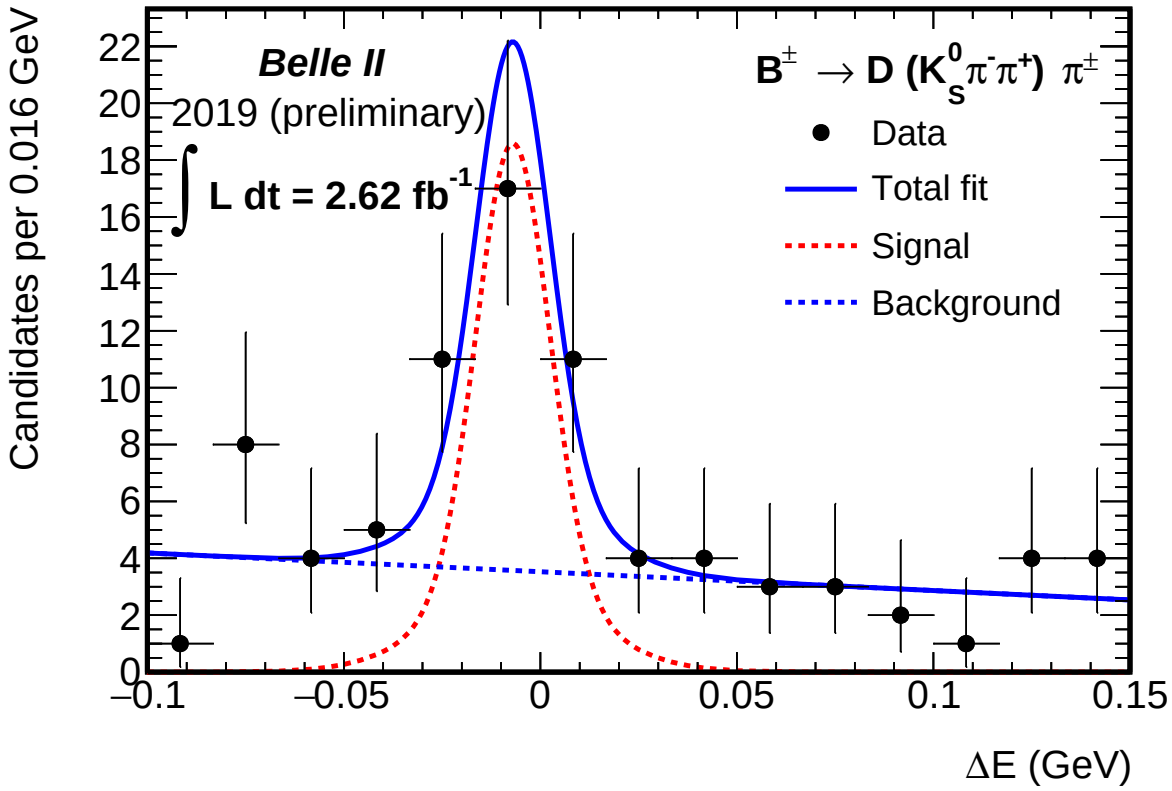

FIG. 3: Distribution of ΔE for $B^{\pm} \to D[\to K^0_S(\to \pi^+\pi^-)\pi^+\pi^-]\pi^{\pm}$ candidates reconstructed in 2.62 fb^{-1} of collision data, with projections of a two-dimensional fit of the unbinned ΔE and $\mathrm{M_{bc}}$ distributions overlaid. Events are required to contain at least three 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 30 ± 6 signal decays, corresponding to a statistical significance of 8σ as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable. Events shown are restricted to the signal region $\mathrm{M_{bc}} > 5.27$ GeV/c^2.

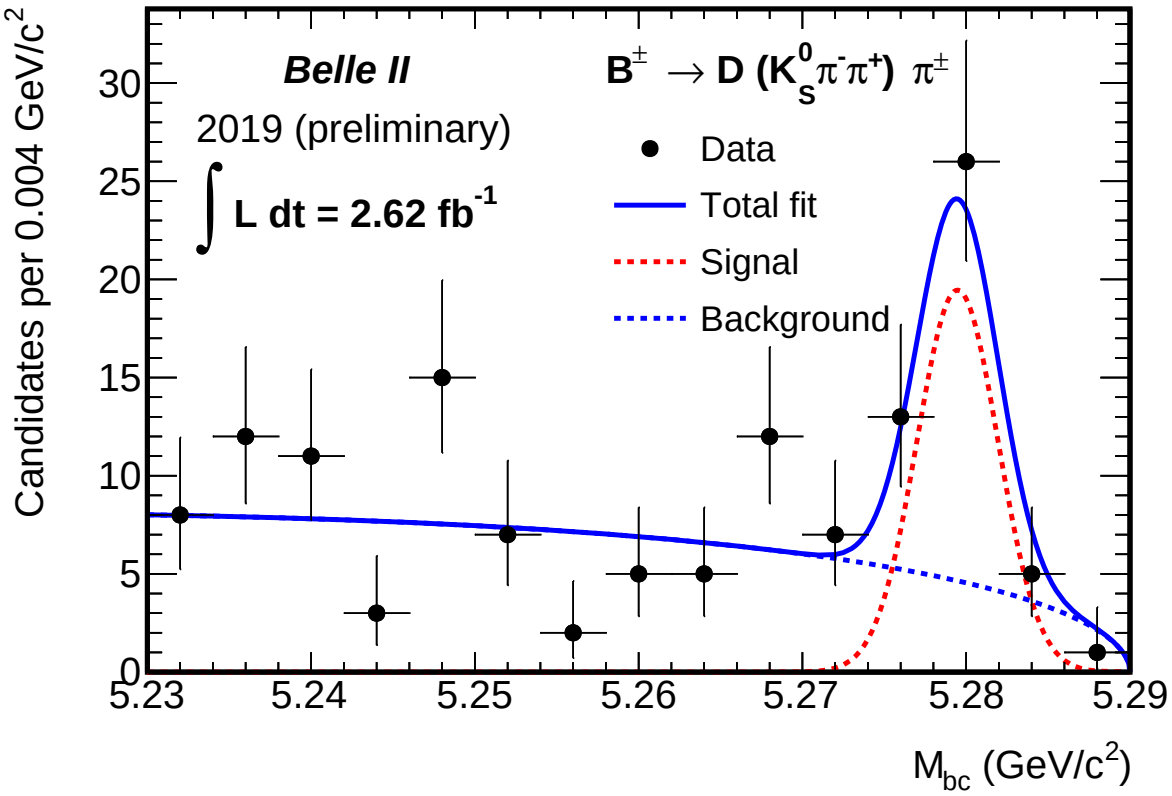

FIG. 4: Distribution of $\mathrm{M_{bc}}$ for $B^{\pm} \to D[\to K^0_S(\to \pi^+\pi^-)\pi^+\pi^-]\pi^{\pm}$ candidates reconstructed in 2.62 fb^{-1} of collision data, with projections of a two-dimensional fit of the unbinned ΔE and $\mathrm{M_{bc}}$ distributions overlaid. Events are required to contain 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 $\mathrm{M_{bc}}$ 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 30 ± 6 signal decays, corresponding to a statistical significance of 8σ as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable. Events shown are restricted to the signal region $|\Delta E| < 0.05$ GeV.

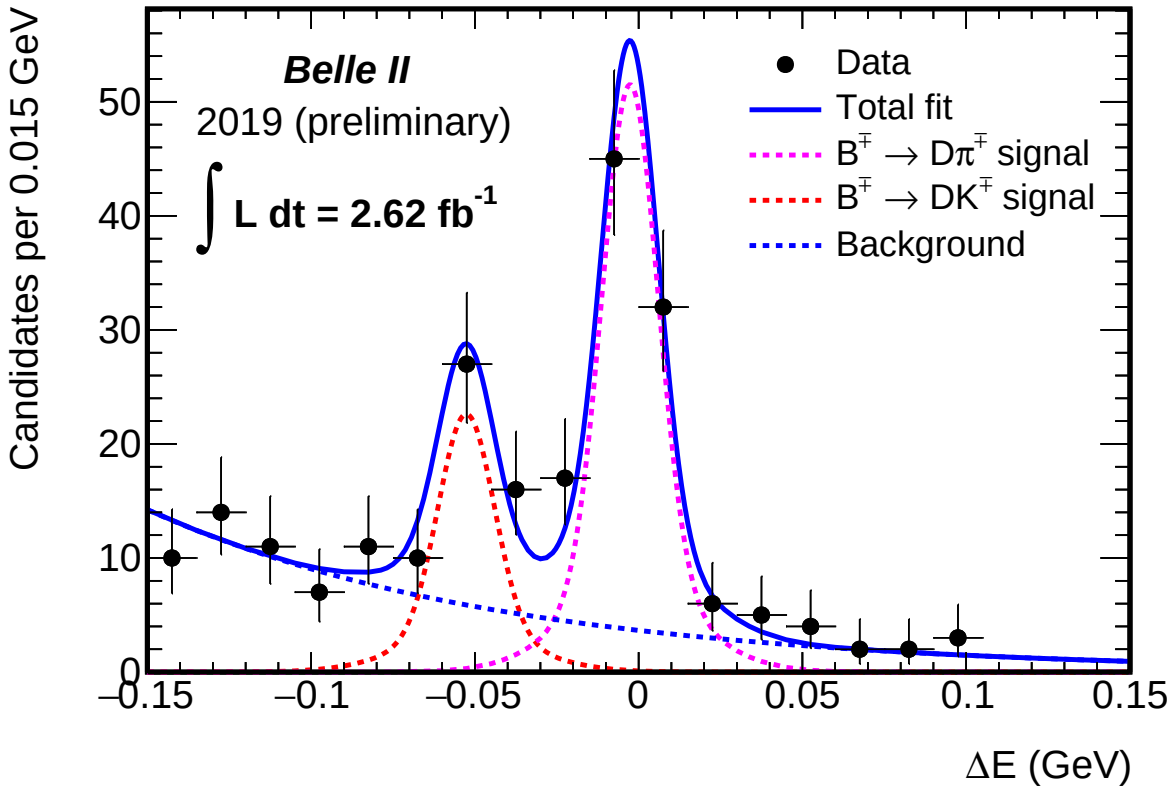

FIG. 5: Distribution of ΔE for $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)\pi^{\pm}$ and $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)K^{\pm}$ candidates reconstructed in 2.62 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 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 38 ± 8 decays, corresponding to a statistical significance of 6σ, as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable.

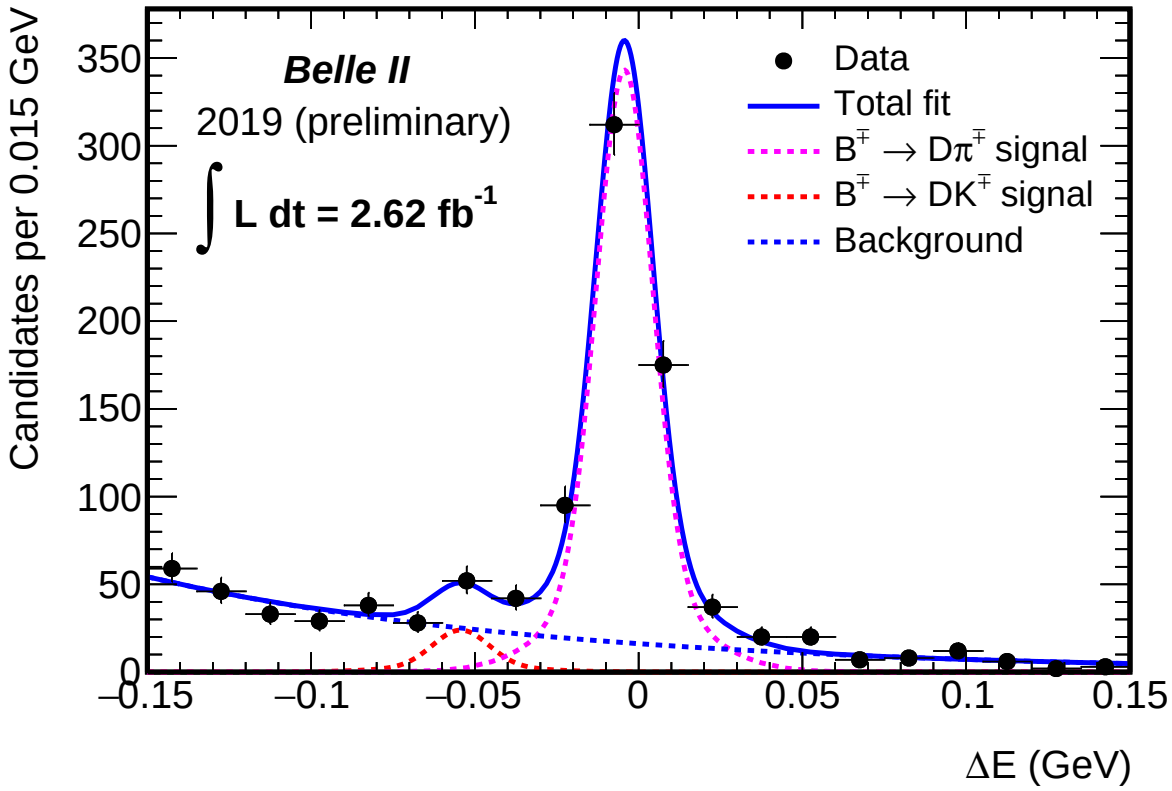

FIG. 6: Distribution of ΔE for $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)\pi^{\pm}$ and $B^{\pm} \to D(\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+)K^{\pm}$ candidates reconstructed in 2.62 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 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 40 ± 11 $B^{\pm} \to DK^{\pm}$ and 575 ± 26 $B^{\pm} \to D\pi^{\pm}$ decays. The $B^{\pm} \to DK^{\pm}$ signal corresponds to a statistical significance of 3.8σ, as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable.

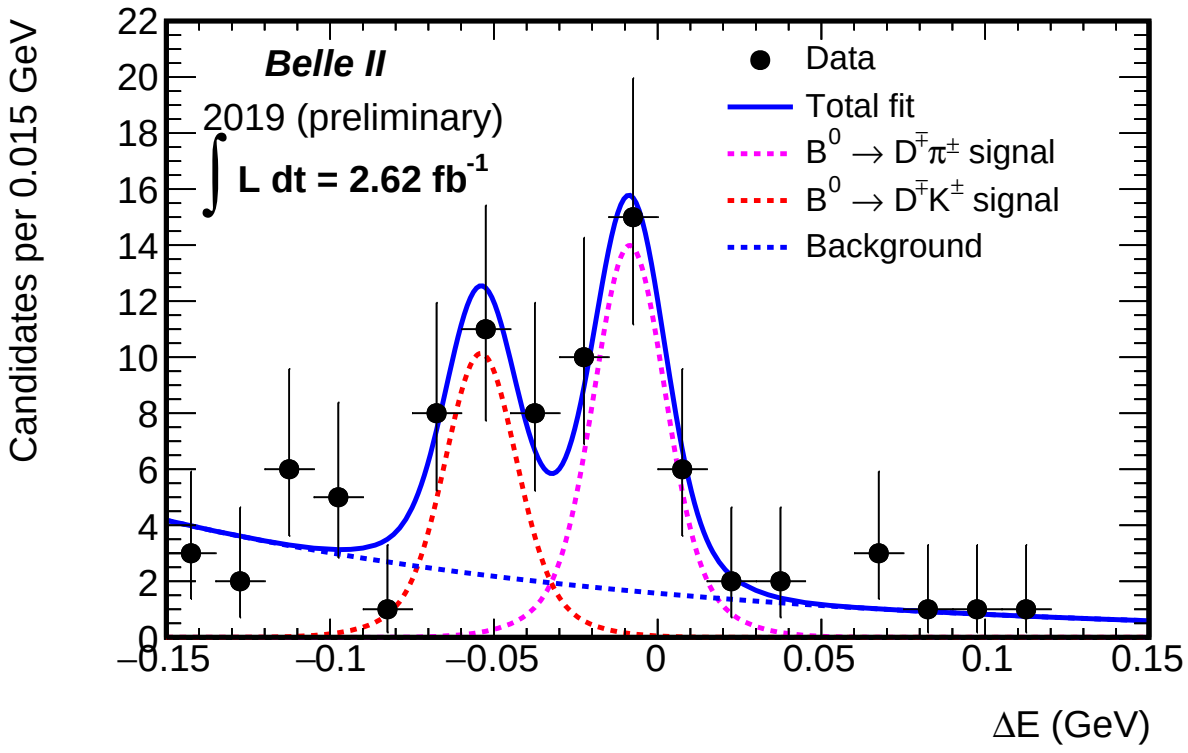

FIG. 7: Distribution of ΔE for $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]\pi^+$ and $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]K^+$ candidates reconstructed in 2.62 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections 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 $q\overline{q}$ 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 20 ± 6 decays, corresponding to a statistical significance of 3.3σ, as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable.

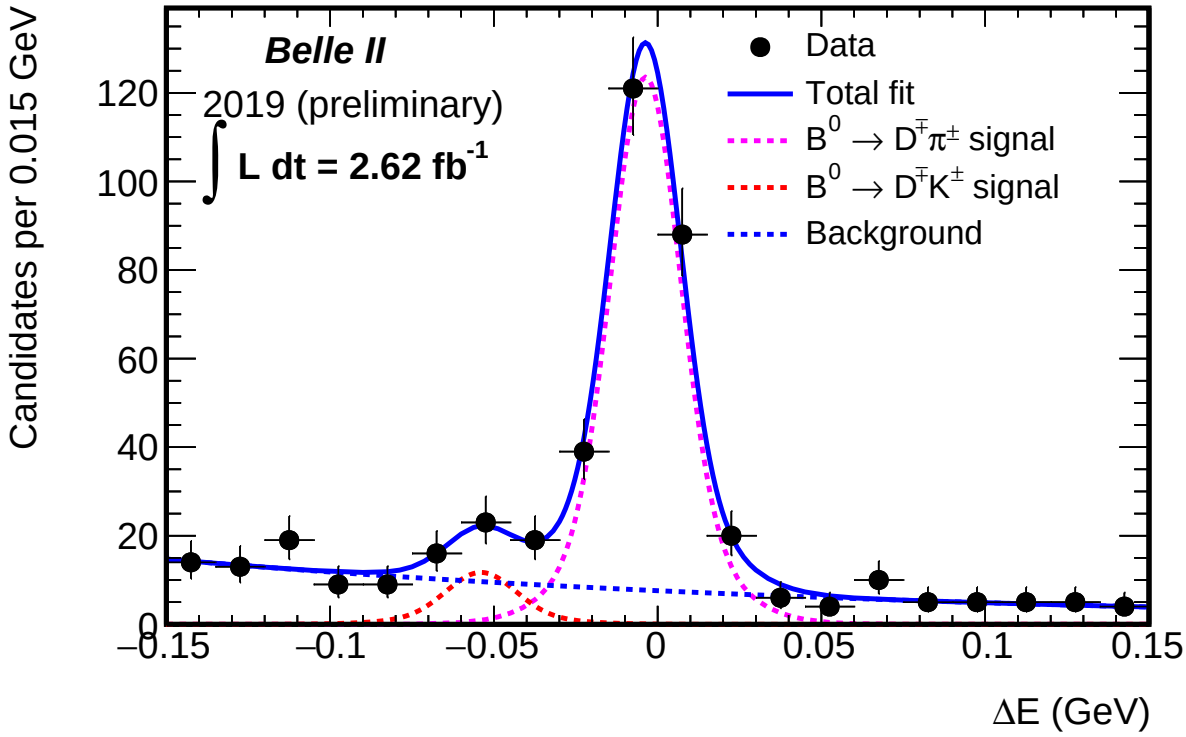

FIG. 8: Distribution of ΔE for $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]\pi^+$ and $B^0 \to D^-[\to K^+\pi^-\pi^-, K^0_S(\to \pi^+\pi^-)\pi^-]K^+$ candidates reconstructed in 2.62 fb^{-1} of collision data and restricted to the region $\mathrm{M_{bc}} > 5.27$ GeV/c^2 with projections 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 247 ± 17 $B^0 \to D^-\pi^+$ decays and 23 ± 8 $B^0 \to D^-K^+$ decays. The latter corresponds to a statistical significance of 2.2σ, as determined from the Wilks' theorem assuming the likelihood ratio distributed as a χ^2 variable.

Decay	Yield
$B^- \to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^-$	944 ± 35
$B^- \to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\rho^-$	369 ± 28
$B^- \to D^{*0}(\to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^0)\pi^-$	140 ± 13
$B^0 \to D^{*-}(\to D^0(\to K\pi, K\pi\pi^0, K\pi\pi\pi)\pi^-)\pi^+$	236 ± 16
$B^0 \to D^-(\to K\pi\pi)\pi^+$	351 ± 21
$B^0 \to D^-(\to K\pi\pi)\rho^+$	156 ± 17
$B^0 \to D^-(\to K^0_S\pi)\pi^+$	21 ± 5

TABLE I: Signal yields obtained obtained in 2.62 fb^{-1}. Observed yields are generally consistent, within 10-20%, with expectations from simulation.