BELLE2-NOTE-PL-2019-009
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# Plots for approval: Full Event Interpretation Reconstruction Performance with 5.15 fb$^{-1}$ of Phase III data in proc 9 and bucket 7.

The Belle II Collaboration

## Abstract

This note presents hadronic FEI performance plots associated with the analysis work presented in BELLE2-NOTE-PH-2019-031 for approval made using proc 9 and bucket 7 (5.15 fb$^{-1}$) of early phase III data. Plots include a comparison of the classifier output for the tag-side B mesons in data to the shape expected from simulation, fits to the beam constrained mass distributions in data in different purity regions, the beam constrained mass distributions of neutral and charged tag-side $B$ mesons in data with different categories of tag-side $B$ meson decay modes stacked and, finally, comparisons of the distributions of the missing mass squared and the centre of mass momentum of leptons associated with a signal side reconstruction of $B \to Xe\nu$ decays with hadronic tagging in data and simulation.

## 1. PLOTS FOR APPROVAL

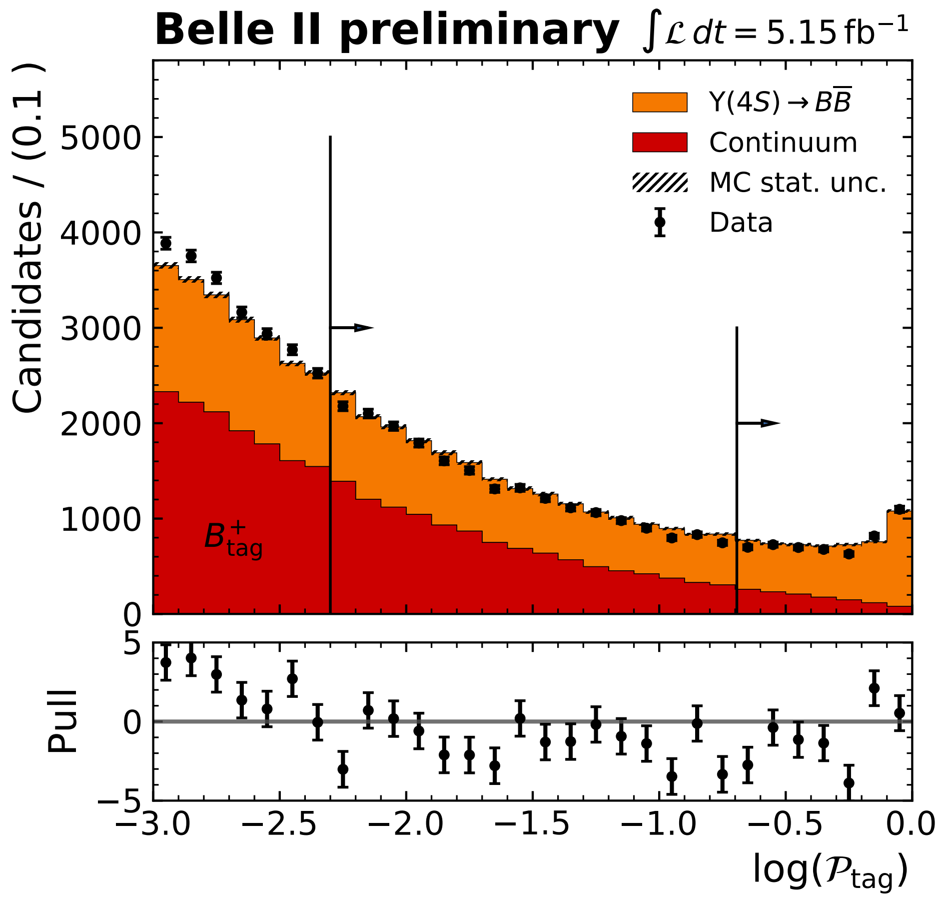


FIG. 1: Comparison of the distribution of $\log \mathcal{P}$ in early phase III data to the shape expectation from simulation. Here $\log \mathcal{P}$ is the logarithm of the tag-side $B^+$ meson classifier output, $\mathcal{P}$. Simulated Monte Carlo data here is scaled to the normalisation of the data making this purely a shape comparison. Two cuts choices are illustrated, which correspond to cuts of $\mathcal{P} > 0.1$ and $\mathcal{P} > 0.5$. Selections on $\mathcal{P}$ can be used to remove background from incorrectly reconstructed tag-side $B$ mesons. Additional selections include an asymmetric selection on the beam energy difference to lie in the region $-0.15 < \Delta E < 0.1$ GeV and a loose selection on the cosine of the thrust axis between particles in the $B$ system and those in its rest of event to be less than 0.95 to suppress continuum. In addition, a best candidate candidate selection is made selecting the reconstructed $B$ meson tag-side candidate in each event with the highest $\mathcal{P}$. At lower values of $\log \mathcal{P}$ there appears to be a discrepancy between the shape of the distribution from simulation to that in data. This is likely due to the fact that at a lower signal probability one has an abundance of decay modes with lower purity, which gives more room for mismodelling the $\mathcal{P}$ for a given mode. In addition, it is expected that the shape of this variable for continuum is not perfectly modelled.

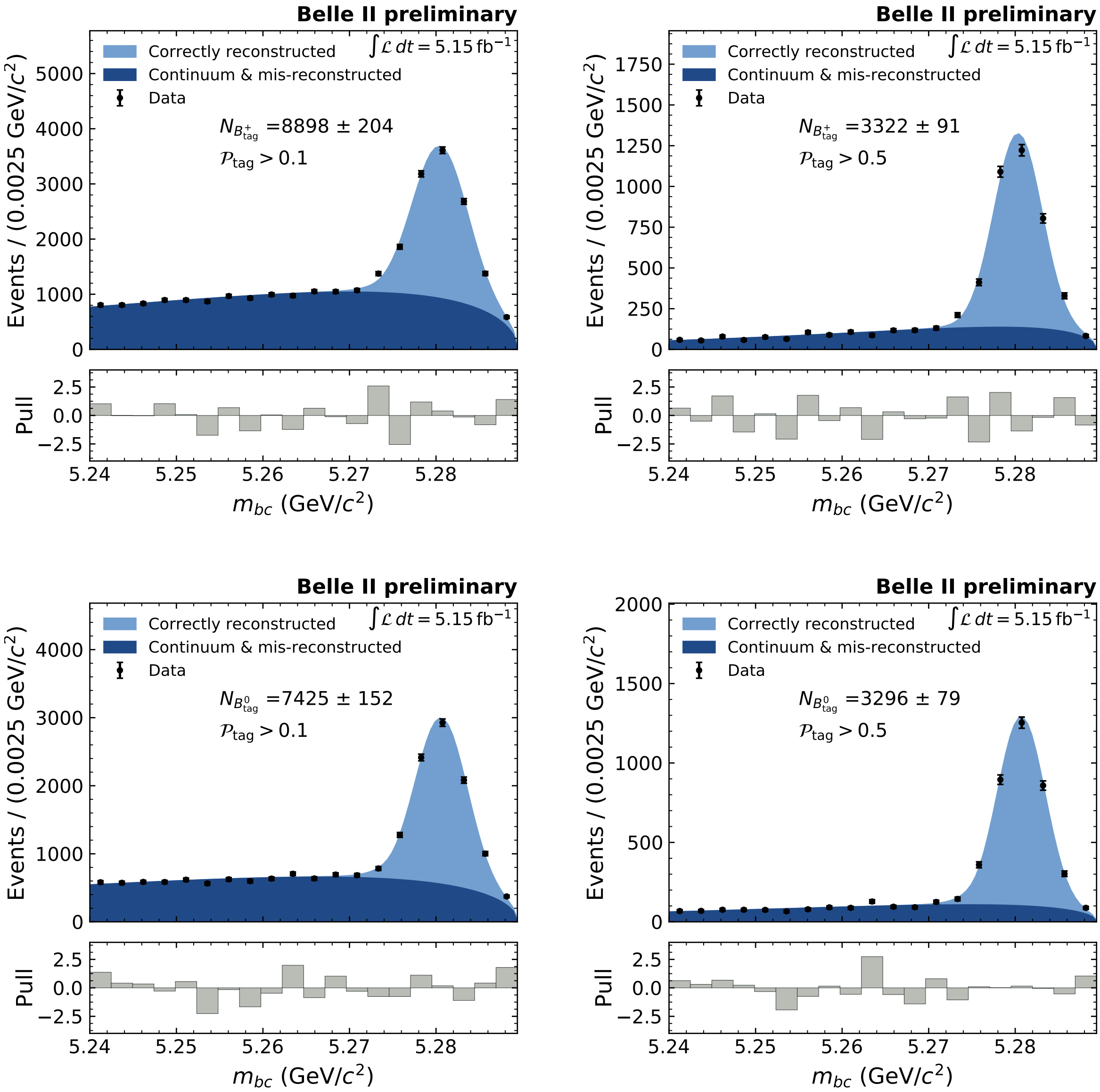


FIG. 2: Fits to the beam constrained mass, $m_{bc}$, distribution of reconstructed $B^+$ (top) and $B^0$ (bottom) tag-side $B$ mesons in data. Here correctly reconstructed signal is modelled with a Cystal Ball and mis-reconstructed $B$ mesons and continuum are modelled with an argus shape. While the mean and sigma paramters of the Crystal Ball are free to float, the tail parameters are fixed based on fits to correctly reconstructed tag-side candidates in simulation. Two choices of selection are employed on the $B$ meson classifier output, $\mathcal{P}$, a looser selection of $\mathcal{P} > 0.1$ (left) and a tighter selection of $\mathcal{P} > 0.5$ (right). The corresponding yields of correctly reconstructed $B^+$ or $B^0$ mesons are displayed on each plot. Additional selections include an asymmetric selection on the beam energy difference to lie in the region $-0.15 < \Delta E < 0.1$ GeV and a loose selection on the cosine of the thrust axis between particles in the $B$ system and those in its rest of event to be less than 0.95 to suppress continuum. In addition, a best candidate candidate selection is made selecting the reconstructed $B$ meson tag-side candidate in each event with the highest $\mathcal{P}$.

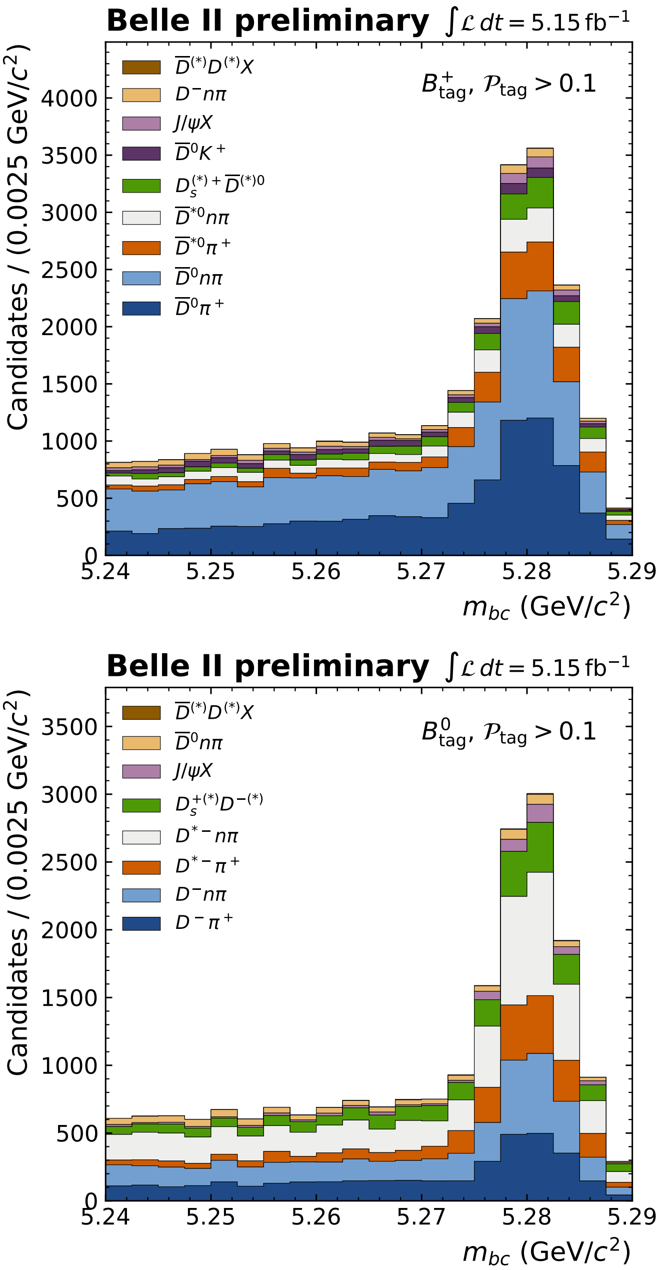


FIG. 3: The $m_{bc}$ distribution of tag-side $B^+$ (top) and $B^0$ (bottom) mesons is shown in data with a selection of the tag-side $B$ meson classifer $\mathcal{P}$ to be greater than 0.1. The Full Event Interpretation reconstructs 29 and 26 hadronic $B^+$ and $B^0$ modes, respectively. Contributions from 9 different categories of modes are stacked. Additional selections include an asymmetric selection on the beam energy difference to lie in the region $-0.15 < \Delta E < 0.1$ GeV and a loose selection on the cosine of the thrust axis between particles in the $B$ system and those in its rest of event to be less than 0.95. In addition, a best candidate candidate selection is made selecting the reconstructed $B$ meson tag-side candidate in each event with the highest $\mathcal{P}$. The dominance of $B^0 \to D^{*-}n\pi$ relative to $B^0 \to D^- n\pi$ compared with $B^+ \to D^{*0}n\pi$ relative to $B^+ \to \bar{D}^0 n\pi$ is due to the fact that the efficiency (including branching fraction coverage) is substantially greater for $D^0$ compared with $D^+$, meanwhile, the efficiency for $D^{*+}$ is also greater than that for $D^{*0}$.

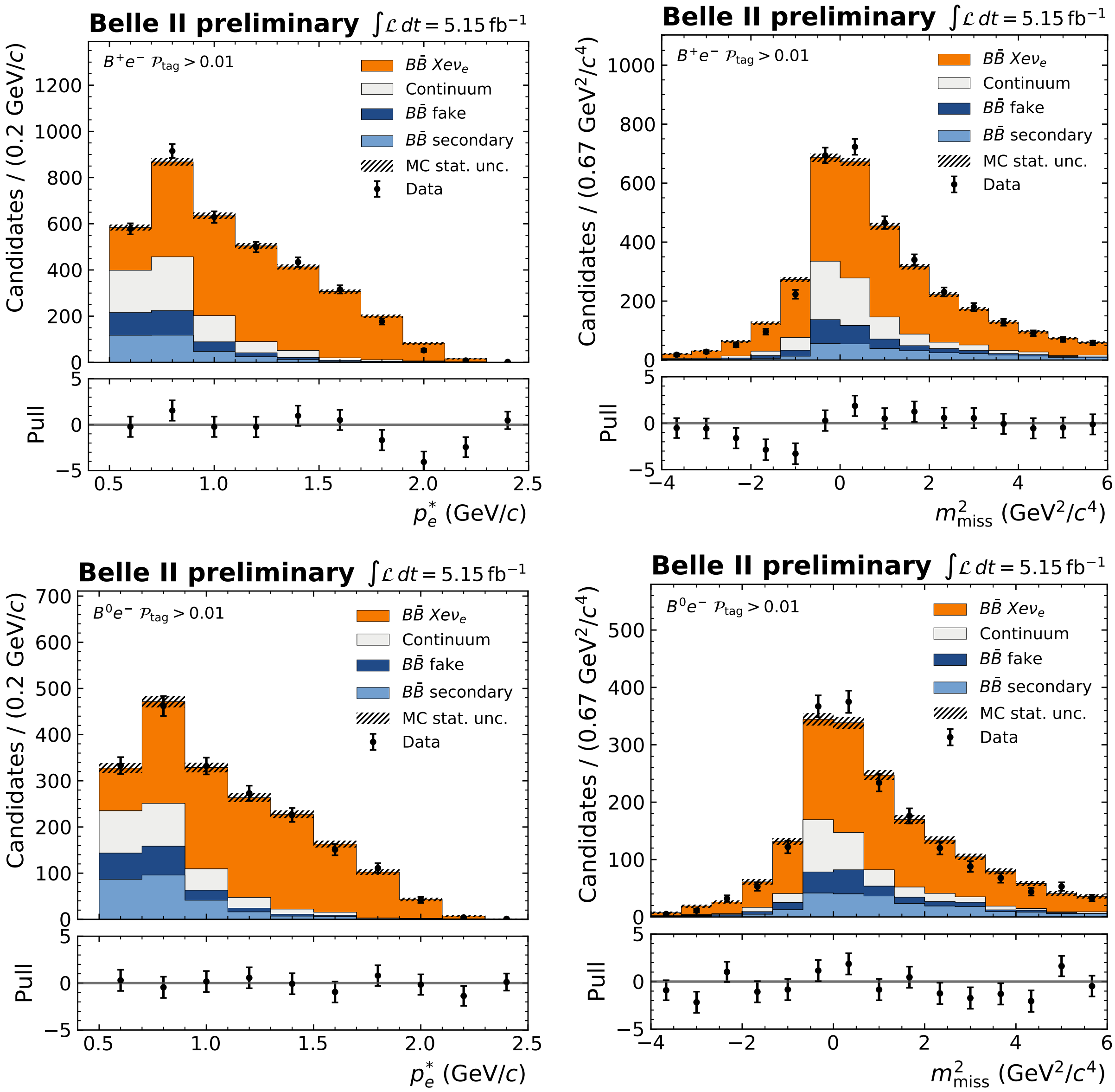


FIG. 4: Comparison of the missing mass squared, $m^2_{\mathrm{miss}}$, and centre of mass (CoM) momentum, $p_e^*$, distributions in data to the shape expected from Monte Carlo simulation for $B^+_{\mathrm{tag}}e^-$ (top) and $B^0_{\mathrm{tag}}e^-$ (bottom) combinations. Here a signal-side electron has been selected after reconstructing a tag-side $B$ meson hadronically with the Full Event Interpretation. Selections on the electron include $p_e^* > 0.6$ GeV/$c$ and electronID $> 0.85$. Selections on the tag-side $B$ meson include an asymmetric selection on the beam energy difference to lie in the region $-0.15 < \Delta E < 0.1$ GeV, a selection of $m_{bc} > 5.27$ GeV/$c^2$, $\mathcal{P} > 0.01$ and a loose selection on the cosine of the thrust axis between particles in the $B$ system and those in its rest of event to be less than 0.95 to suppress continuum. Finally best candidate selections are made on both the tag-side $B$ meson classifier $\mathcal{P}$ and $p_e^*$, which select the highest value candidates in these variables. The missing mass squared is computed in the CoM frame using the rest of event of the $Be$ combination according to the following expression: $m^2_{\mathrm{miss}} = (p^*_{ee+} - p^*_{B_{\mathrm{tag}}} - p^*_e - p^*_{\mathrm{RoE}})^2$. Tracks and clusters in the rest of the event were subject to basic clean up selection on cluster energies and track momenta and impact parameters. The normalisation of Monte Carlo is scaled to data making this purely a shape comparison.