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Search for the B-meson decay to four baryons $B \to pp\bar{p}\bar{p}$ at BABAR

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B mesons are the lightest mesons which can decay to various final states containing baryons. The measurement and comparison of exclusive branching fractions of baryonic B decays, as well as studies on the dynamic of the decay, may allow better understanding of baryon production in B decays and, more generally, hadron fragmentation into baryons. We present here a search for the decay of a B meson in four baryons, $B^0 \to pp\bar{p}\bar{p}$. From the observation of (10.4 ± 4.3) signal events, we provide the upper limit $\mathscr{B}(B^0 \to pp\bar{p}\bar{p}) < 2 \times 10^{-7}$ at 90% CL. The data set consists of about 470 million $B\bar{B}$ pairs collected with the BABAR detector at the SLAC National Accelerator Laboratory.

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1. Introduction

Due to its large mass, the B meson decays also into final states containing baryons and therefore it is an optimal tool to study the mechanism of baryonic fragmentation of hadrons, only poorly understood. The inclusive branching fraction (BF) of B mesons decaying into baryonic final states is approximately 7% [1] and it is not covered by the sum of the measured exclusive baryonic channels of the B meson. Indeed, this puzzle motivates the search for unmeasured B meson decays to baryons. Main open issues in baryonic B decays are related to the hierarchy of the branching fractions, due to resonant subchannels, and the threshold enhancement effect. So far, the only four-baryon final state studied by the BABAR collaboration is the decay mode $\bar{B}^0 \to \Lambda_c^+ p\bar{p}\bar{p}$ [2], for which no event was observed and the upper limit on the branching fraction at 90% CL was set to 2.8×10^{-6}. From this measurement, for the search of $B^0 \to pp\bar{p}\bar{p}$[1] we assume as working hypothesis $BF = 10^{-7}$, which is used for optimizing the selection.

2. The *BABAR* experiment

The data sample analysed corresponds to an integrated luminosity of 424 fb^{-1} electron-positron collisions at the centre-of-mass (CM) energy of the $\Upsilon(4S)$ resonance, $\sqrt{s} = 10.58$ GeV/c^2 (on-peak data), collected with the BABAR detector [3] at the asymmetric-energy collider PEP-II. Charged-particle momenta are precisely measured by means of a five-layer double-sided silicon vertex tracker and a 40-layer multiwire drift chamber, both operating in the 1.5 T magnetic field of a superconducting solenoid. The particle identification (PID) for protons, kaons and pions uses the specific energy loss measured in the tracking devices and the Cherenkov radiation measurement provided by the internally reflecting, ring-imaging Cherenkov detector.

3. Method

This study is performed as a *blind* analysis, which means that all cuts are optimized without looking at the data in the region where the signal is expected. The event is reconstructed combining 4 oppositely charged tracks identified as protons and antiprotons and kinematically fitted to a common vertex, with a fit probability larger than 0.1%. Cuts are also applied to the kinematic variables $m_{ES}= \sqrt{(E^*_{beam})^2 - (\vec{p}_B{}^*)^2}$ and $\Delta E= E^*_B - E^*_{beam}$ [4], related to the momentum, $\vec{p}_B{}^*$, and the reconstructed energy, E^*_B, of the B-candidate and to the beam energy, E^*_{beam}, in the CM reference frame. The PID efficiency for protons is excellent for this analysis ($> 99\%$) and mis-identification rates for wrongly assigning the proton identity to kaons and pions are lower than 1%. Real protons coming from continuum hadronization processes ($e^+e^- \to q\bar{q}$) are expected to be the main source of combinatoric background. Further background is rejected by cutting on the output of a multivariate analysis method, the Boosted Decision Tree (BDT), whose response is evaluated on the input variable distributions ΔE, $cos\theta^*_B$, θ^*_B being the flight polar angle of the B meson in the centre-of-mass frame, and two event-shape variables which discriminate between the spherical shape of a signal event ($e^+e^- \to B\bar{B}$) and a jet-like $q\bar{q}$ event. The signal efficiency, computed on the signal MC sample as the ratio of the number of selected to generated events, is assessed to

[1] The charge conjugate is always implied throughout the article.

be $\varepsilon = 0.207 \pm 0.005$. The associated uncertainty is systematic and takes into account the contributions from the PID and tracking efficiency, and from the BDT selection. The signal yield is extracted from an extended unbinned maximum likelihood fit to the selected events in the range $5.2 < m_{ES} < 5.3$ GeV/c^2. The shape of the signal and of the background components is fixed in the fit to the results of the modeling studies performed on both MC samples and on the sideband region data.

4. Results

The result from the fit to the on-peak data is reported in Figure 1. It provides a signal yield of

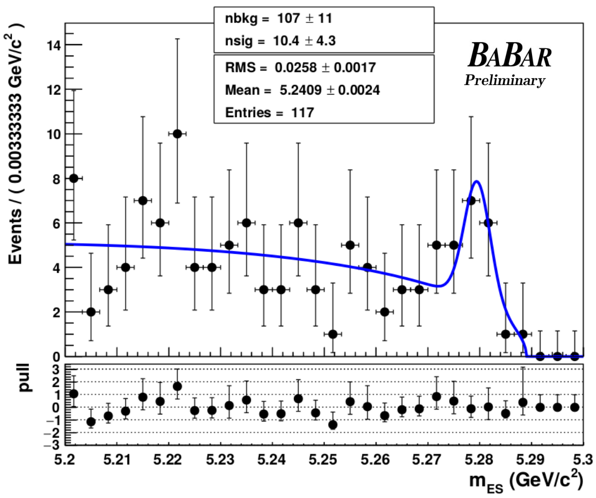

Figure 1: Preliminary result from the fit (blue line) to unblinded data. The signal yield $N_{sig} = 10.4 \pm 4.3$ is extracted by fitting the on-peak data (black dots) in the whole reconstruction range $5.2 < m_{ES} < 5.3$ GeV/c^2, after the final selection is applied.

$N_{sig} = 10.4 \pm 4.3$ and the corresponding branching fraction is calculated with the formula:

$$\mathscr{B}(B^0 \to pp\bar{p}\bar{p}) = \frac{N_{sig}}{\varepsilon \cdot 2N_{B^0\bar{B}^0}} = \frac{N_{sig}}{\varepsilon \cdot N_{B\bar{B}}} = (1.1 \pm 0.5_{stat} \pm 0.2_{sys}) \times 10^{-7}, \quad (4.1)$$

where the experimental inputs are N_{sig}, ε and the number of B meson pairs $N_{B\bar{B}}$. The number of neutral B mesons, $N_{B^0\bar{B}^0}$, is taken as half of the total number of B-meson pairs $N_{B\bar{B}}$, assuming exactly the same branching fractions for $\Upsilon(4S) \to B^0\bar{B}^0$ and for $\Upsilon(4S) \to B^+B^-$. The 0.5 factor then eliminates due to the charge conjugation, leading to the final formula in Equation 4.1.

5. Upper limit calculation

This measurement is statistically limited by the low number of fitted signal events. To obtain the statistical significance we repeat the fit with the background hypothesis only, and we calculate the difference between the likelihood logarithm from the two fits, $-2(\Delta \log L) = 9.97$, which corresponds to a significance of 3.16σ. Since available data are not sufficient to claim a 5σ discovery, the upper limit at 90% CL on the branching fraction is computed by integrating the likelihood function projection on N_{sig}, up to the value of N_{sig}^{UL} such that the equality $\int_0^{N_{sig}^{UL}} L(n_{sig})dn_{sig} = 0.90\int_0^{+\infty} L(n_{sig})dn_{sig}$ is verified. This calculation is based on the Bayesian approach, assuming a flat prior for $N_{sig} > 0$ and 0 otherwise, and it results in an upper limit on the signal yield of $N_{sig}^{UL} = 18$. We therefore obtain the upper limit for the searched branching fraction to be $\mathscr{B}(B^0 \to pp\bar{p}\bar{p}) < 2\times 10^{-7}$ at 90% CL.

References

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