Search for Baryogenesis and Dark Matter in B-meson Decays at $BABAR$

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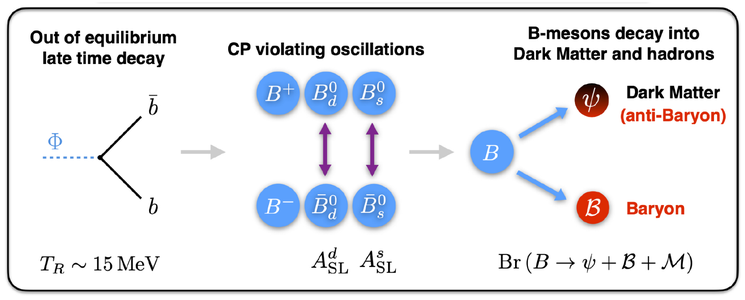
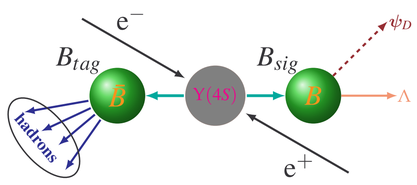
Introduction and Motivation

- Cosmological observations reveal that visible matter only accounts for $\sim$15% of the matter in the universe, and dark matter (DM) constitutes the remaining 85%.
- Baryogenesis mechanism is required for producing the baryon asymmetry observed in the universe.
- A B-mesogenesis mechanism has been proposed to explain the DM abundance and the baryon asymmetry simultaneously, as shown in the right figure [1, 2].
- The decays $B \to \psi_D \mathcal{B}\mathcal{M}$, together with CP violation in neutral $B - \bar{B}$ mixing give rise to an excess of baryons and anti-baryons, where ψ_D, $\mathcal{B}$ and $\mathcal{M}$ refer to dark sector antibaryon, SM baryon and light meson, respectively.
- We probe this mechanism by searching for the decay $B \to \psi_D \Lambda$ in $BABAR$ data.



Hadronic Recoil Method

- Data collected by $BABAR$ with $e^+e^- \to \Upsilon(4S)$, and $\Upsilon(4S) \to B\bar{B}$.
- Recoil B_{tag} is fully reconstructed through hadronic B meson decays $B \to SX$:
  - A "seed" meson S: $D^{(*)0}$, $D^{(*)\pm}$, $D_s^{*\pm}$ or J/ψ,
  - Hadronic system X: up to five kaons or/and pions with total charge 0 or ± 1.
- Recoil B_{tag} candidate is selected based on two variables in center-of mass frame: $\Delta E = E_{beam} - E_{tag}$ and $m_{ES} = \sqrt{E_{beam}^2 - p_{B_{tag}}^2}$.

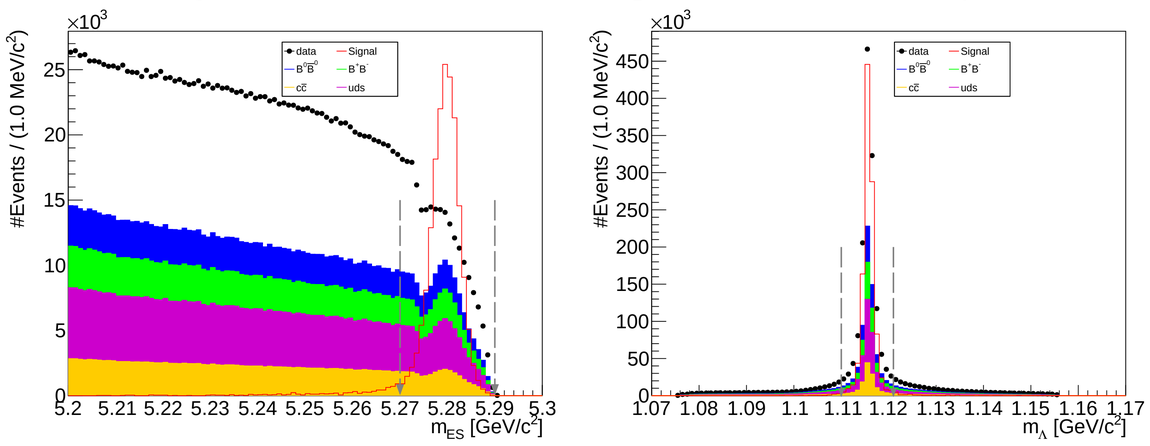


Event Selection

- We select events with a B_{tag} candidate and a $\Lambda \to p\pi$ decay with no additional charged particles.
- Kinematic fit applying to reconstruct the Λ, and the ratio between the Lambda flight length over its uncertainty must be larger than 1.0.
- Requirements on the mass of the B_{tag} and Λ candidates are set to suppress background.
- To further increase the signal purity, we cut on the output of a boosted decision tree (BDT) that combines 16 of B_{tag}-, B_{sig}- and Λ-related variables.
- The ψ_D mass (missing mass) is calculated with $m_{\psi_D} = \sqrt{(E_{B_{sig}} - E_\Lambda)^2 - ||\mathbf{p}_{B_{sig}} - \mathbf{p}_\Lambda||^2}$, where ($\mathbf{p}_{B_{sig}}$, $E_{B_{sig}}$) and ($\mathbf{p}_\Lambda$, E_Λ) are four momenta of the B_{sig} and Λ, respectively.

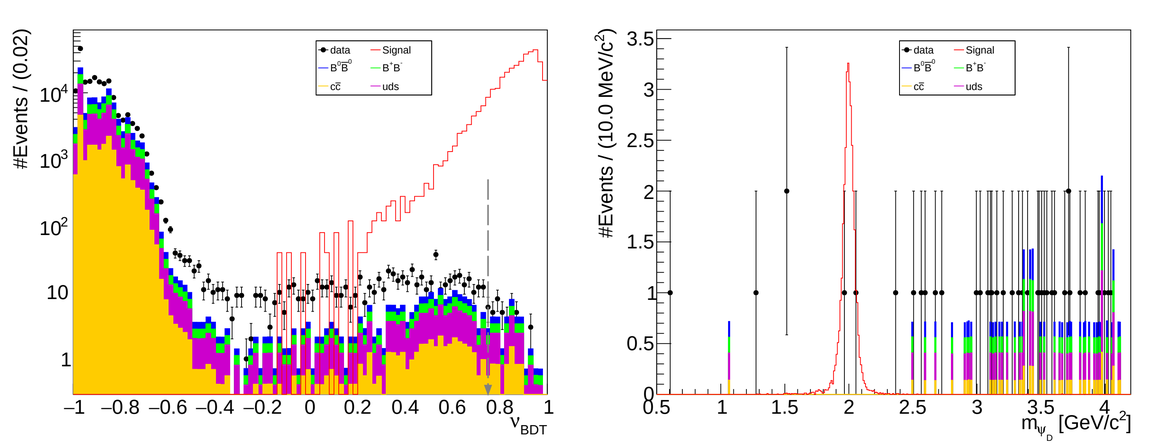
Mass Distributions of B_{tag} and Λ Candidates

Signal ($\psi_D = 2.0$ GeV/c^2 as an example) is normalized arbitrary.



BDT Score (ν_{BDT}) and Missing Mass Distributions

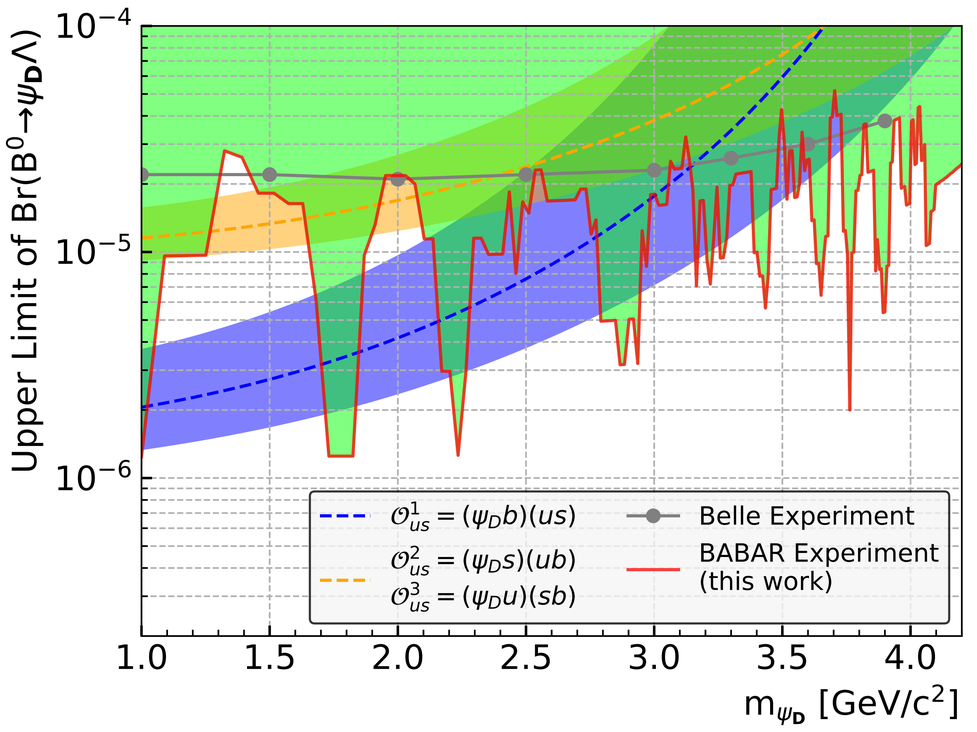
Selected events after applying the BDT score requirement ($\nu_{BDT} > 0.75$).



Preliminary Results

- We correct simulations for differences in B_{tag} and signal reconstruction efficiencies, by comparing the inclusive MC samples and data in a ν_{BDT} sideband region.
- Signal MC efficiency varies from 5.9×10^{-4} at $m_{\psi_D} = 1.0$ GeV/c^2 to 2.1×10^{-4} around $m_{\psi_D} = 4.2$ GeV/c^2.

- Signal yield is extracted by scanning the ψ_D mass spectrum in steps of the mass resolution, a total of 193 mass hypotheses.
- Largest local significance of the signal is $\sim 2.3\sigma$ near $m_{\psi_D} = 3.7$ GeV/c^2, while the global significance is $\sim 0.4\sigma$ after trial factor included, consistent with the null hypothesis.
- Upper limits on the branching fraction $B^0 \to \Lambda\psi_D$ at 90% confident level (CL) are derived with a profile likelihood method.
- We probe branching fractions in the range of 0.13–5.2×10^{-5}, improving previous constraints by up to one order of magnitude [3].
- The results exclude most of the parameter space allowed by B-mesogenesis involving Λ baryon.



References

[1] G. Elor, M. Escudero and A. E. Nelson, Phys. Rev. D **99**, 035031 (2019).
[2] G. Alonso-Álvarez, G. Elor and M. Escudero, Phys. Rev. D **104**, 035028 (2021).
[3] C. Hadjivasiliou *et al.* [Belle], Phys. Rev. D **105**, L051101 (2022).