Search for the rare $B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu}$ decay at the BABAR experiment

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Outline

• The BaBar experiment
• $B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu}$ - theory and motivation
• Analysis method - hadronic tag reconstruction
• Analysis method - signal selection
• Preliminary results
• Conclusion and next steps
The BABAR experiment - PEP-II collider

PEP-II: Located at the SLAC National Accelerator Laboratory, California. Provides electrons and positrons for collision inside BABAR detector.

- High energy ring - 9.0 GeV electrons
- Low energy ring - 3.1 GeV positrons

- Collide at CoM energy 10.58 GeV - mass of the $\Upsilon(4S)$ resonance ($b\bar{b}$ quark-antiquark pair)

- $\Upsilon(4S)$ decays 96% to $B\bar{B}(B^+B^- or B^0\bar{B}^0)$ - “B factory”.

- BABAR collected data from 1999 to 2008
- Produced 471 million $B\bar{B}$ pairs
- 429 fb$^{-1}$ integrated luminosity at $\Upsilon(4S)$ resonance
The BABAR experiment - detector

Canadian groups: U. Victoria, UBC, U. de Montréal, McGill U.
**B**\(^-\) → **Λ**\(\bar{p}\)ν\(\bar{ν}\) - details and motivation

C.Q. Geng, Y.K. Hsiao.  

Predict \(\mathcal{B}(B^- \rightarrow \Lambda \bar{p}\nu\bar{ν}) = (7.9 \pm 1.9) \times 10^{-7}\)

**B**\(^-\) → **K**\(^-\)ν\(\bar{ν}\)  
Measured: <3.7 \times 10^{-5}  
Predicted: (4.5 \pm 0.7) \times 10^{-6}  

**B**\(^-\) → **Λ**\(\bar{p}\)ν\(\bar{ν}\)  
\(\rightarrow \rho\pi^-(63.9 \pm 0.5)\%\)

- Rare decay (suppressed by the standard model)  
- New physics potentially hiding in loops - will affect branching fraction  
- Amenable to further study: angular asymmetries, T-odd observables etc.
**Analysis method - hadronic $B_{\text{tag}}$ reconstruction**

$B_{\text{tag}}$
- Exclusively reconstruct from known hadronic decays.
- Require:
  - one $B_{\text{tag}}$
  - mass consistent with $B$ meson
  - charge is opposite that of $B_{\text{sig}}$ daughters

$B_{\text{sig}}$
- Everything else in the event, including missing energy, that isn’t assigned to $B_{\text{tag}}$ is assumed to come from the $B_{\text{sig}}$

**Advantages:**
- Completely separates $B_{\text{tag}}$ from $B_{\text{sig}}$
- Fully determines kinematics of $B_{\text{sig}}$
- Missing energy and all other particles assigned to $B_{\text{sig}}$
- Eliminates background

**Disadvantages:**
- Low efficiency
Analysis method - Monte Carlo simulation

- Use Monte Carlo data and detector simulation to perform analysis.
- Signal Monte Carlo weighted to match theoretically-predicted phase space constraints.
Use a multivariate likelihood to measure the shape of the event:

Continuum event

Jet-like events

Too much continuum background, cut

Continuum likelihood

Number of events

spherical events

Signal
Analysis method - extra energy

Extra energy - in theory represents energy deposits from neutral particles, in reality can be:

- showers from decay products
- misassignment of B-meson daughters
- real neutral particles

![Graph showing analysis method - extra energy]

- Too much background, cut
Analysis method - PID, lambda reconstruction

\[ B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu} \]

Useful constraints in this decay:
- Require three charged tracks
- Identify (anti)protons, remaining charged track must be the pion
- Require good lambda mass from proton and pion

\( m_\Lambda = 1.116 \text{GeV} \)

**Figure 1.** Contributions to the effective Hamiltonian for the inclusive mode of

\[ \nu \bar{\nu} \]

\( (m_{\nu} = 4.5 \pm 0.7) \times 10^{-1} \)

**Number of events**

**Mass of reconstructed lambda (GeV/c^2)**
Analysis method - distance of closest approach

DOCA = extrapolated distance of closest approach to interaction point.

$$B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu} \rightarrow p \pi^-$$

Expect:
- Lowest DOCA - proton from B
- Middle DOCA - proton from lambda
- Highest DOCA - pion

With DOCA cut - 81% real lambdas

Without DOCA cut - 67% real lambdas
Signal selection - preliminary results

**B\text{tag} side cuts:**
- One B\text{tag}
- Correct charge
- Reconstructed B mass
- Continuum likelihood

**B\text{sig} side cuts:**
- Extra energy
- Three charged tracks
- Particle ID
- Reconstructed lambda mass
- Distance of closest approach
- etc...

~7 background events
~0.04% signal efficiency

Expect branching fraction upper limit on the order of <10^{-5}.

Number of events vs. Mass of reconstructed lambda (GeV/c^2)

- B^+ B^-
- B^0 \bar{B}^0
- \tau \bar{\tau}
- q\bar{q} (q = u, d, s)
- c\bar{c}
- \bar{c}\bar{c}
- signal

~7 background events
~0.04% signal efficiency
Conclusion

• Searching for new physics in form of $B^- \rightarrow \Lambda\bar{\nu}\bar{\nu}$ decay - never been experimentally measured before
• Rare decay - good probe to test for new physics

Next steps

• Finalise optimisation of signal selection cuts
• Quantify systematic errors
• Unblind data
• Measure branching fraction limit
• Publish