Rare B → hh decays

Chris Parkes, Eduardo Rodrigues
University of Glasgow

LHCb CP Measurements WG, CERN, 31 Jan 2008

---

h is not always π, K:

how to make a discovery

“by changing one line in a selection code ;-)”

Charmless B $\to$ h h decays

- Glasgow interested in looking for this family of rare decays
- First studies done with DC04 data by Charlotte Newby
  - CERN-THESIS 2007-018
  - Expect ~ 2000 $B_d \to KK$ and $B_s \to \pi\pi$ events per nominal year
    assuming branching ratios 10x smaller than $B_d \to \pi\pi$, etc.
- We will look at these decays but will focus on baryonic decays …
  … see next slides

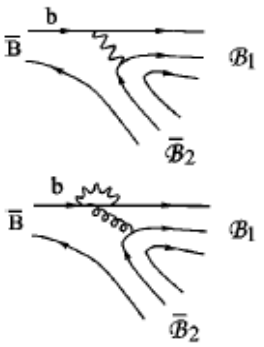
Charmless baryonic B decays: theoretical predictions

	Ref. [3]	Ref. [7]	Ref. [10]	Ref. [11] nonlocal	Ref. [11] local	This work
$\bar{B}^0 \to p\bar{p}$	4.2×10^{-6}	1.2×10^{-6}	7.0×10^{-6}	2.9×10^{-6}	2.7×10^{-5}	$1.1\times10^{-7\dagger}$
$\bar{B}^0 \to n\bar{n}$		3.5×10^{-7}	7.0×10^{-6}	2.9×10^{-6}	2.7×10^{-5}	$1.2\times10^{-7\dagger}$
$B^- \to n\bar{p}$		6.9×10^{-7}	1.7×10^{-5}	0	0	5.0×10^{-7}
$\bar{B}^0 \to \Lambda\bar{\Lambda}$			2×10^{-7}			$0^{\dagger}$
$B^- \to p\bar{\Delta}^{--}$	1.5×10^{-4}	2.9×10^{-7}	3.2×10^{-4}	2.4×10^{-6}	8.7×10^{-6}	1.4×10^{-6}
$\bar{B}^0 \to p\bar{\Delta}^{-}$		7×10^{-8}	1.0×10^{-4}	1.0×10^{-6}	4.0×10^{-6}	4.3×10^{-7}
$B^- \to n\bar{\Delta}^{-}$			1.1×10^{-4}	2.7×10^{-7}	1×10^{-7}	4.6×10^{-7}
$\bar{B}^0 \to n\bar{\Delta}^{0}$			1.0×10^{-4}	1.0×10^{-6}	4.0×10^{-6}	4.3×10^{-7}
$B^- \to \Lambda\bar{p}$		$\lesssim 3\times10^{-6}$				$2.2\times10^{-7\dagger}$
$\bar{B}^0 \to \Lambda\bar{n}$						$2.1\times10^{-7\dagger}$
$\bar{B}^0 \to \Sigma^{+}\bar{p}$		6×10^{-6}				$1.8\times10^{-8\dagger}$
$B^- \to \Sigma^{0}\bar{p}$		3×10^{-6}				$5.8\times10^{-8\dagger}$
$B^- \to \Sigma^{+}\bar{\Delta}^{--}$		6×10^{-6}				2.0×10^{-7}
$\bar{B}^0 \to \Sigma^{+}\bar{\Delta}^{-}$		6×10^{-6}				6.3×10^{-8}
$B^- \to \Sigma^{-}\bar{\Delta}^{0}$		2×10^{-6}				6.7×10^{-8}

tree

penguin

Bag model & harmonic oscillator model disagree



Theoretical predictions do not really agree

Cheng & Yang, Phys Rev D 66 014020 (2002)

Charmless baryonic B decays: measurements (1/3)

No 2-body decay discovered

Heavy Flavor Averaging Group
Aug. 2007

Compilation of B^+ Baryonic Branching Fractions
All branching fractions are in units of 10^{-6}; limits are 90% CL

In PDG2006 | New since PDG2006 (preliminary) | New since PDG2006 (published)

RPP#	Mode	PDG2006 Avg.	BABAR	Belle	CLEO	New Avg.
286	$p\bar{p}\pi^+$	$3.1^{+0.8}_{-0.7}$	$1.69 \pm 0.29 \pm 0.26$ †	$1.68^{+0.26}_{-0.22} \pm 0.12$ ‡	< 160	$1.69^{+0.24}_{-0.22}$
289	$p\bar{p}K^+$	5.6 ± 1.0	$6.7 \pm 0.5 \pm 0.4$ †	$5.98^{+0.29}_{-0.27} \pm 0.39$ ‡		$6.24^{+0.39}_{-0.38}$
290	$\Theta^{++}\bar{p}$ *	< 0.091	< 0.09	< 0.091		< 0.09
291	$f_J(2221)K^+$ *	< 0.41		< 0.41		< 0.41
292	$p\bar{\Lambda}(1520)$	< 1.5	< 1.5			< 1.5
294	$p\bar{p}K^{*+}$	$10.3^{+3.6+1.3}_{-2.8-1.7}$	$5.3 \pm 1.5 \pm 1.3$ †	$10.3^{+3.6+1.3}_{-2.8-1.7}$ ‡		6.6 ± 1.7
–	$f_J(2221)K^{*+}$ *	New	< 0.77			< 0.77
295	$p\bar{\Lambda}$	< 0.49		< 0.32	< 1.5	< 0.32
–	$p\bar{\Lambda}\pi^0$	New		$3.00^{+0.61}_{-0.53} \pm 0.33$		$3.00^{+0.69}_{-0.62}$
–	$p\bar{\Sigma}(1385)^0$	New		< 0.47		< 0.47
–	$\Delta^+\bar{\Lambda}$	New		< 0.82		< 0.82
299	$\Lambda\bar{\Lambda}\pi^+$	< 2.8		< 2.8 ‡		< 2.8 ‡
300	$\Lambda\bar{\Lambda}K^+$	$2.9^{+0.9}_{-0.7} \pm 0.4$		$2.9^{+0.9}_{-0.7} \pm 0.4$ ‡		$2.9^{+1.0}_{-0.8}$
301	$\bar{\Delta}^0 p$	< 380		< 1.42	< 380	< 1.42
302	$\Delta^{++}\bar{p}$	< 150		< 0.14	< 150	< 0.14

§Di-baryon mass is less than 2.85 GeV/c^2; † Charmonium decays to $p\bar{p}$ have been statistically subtracted.

‡ The charmonium mass region has been vetoed. * Product BF - daughter BF taken to be 100%: $\Theta(1540)^{++} \to K^+p$ (pentaquark candidate);

Charmless baryonic B decays: measurements (2/3)

No 2-body decay discovered

Heavy Flavor Averaging Group
Aug. 2007

Compilation of B^0 Baryonic Branching Fractions
All branching fractions are in units of 10^{-6}; limits are 90% CL

In PDG2006 New since PDG2006 (preliminary) New since PDG2006 (published)

RPP#	Mode	PDG2006 Avg.	BABAR	Belle	CLEO	New Avg.
266	$p\overline{p}$	< 0.27	< 0.27	< 0.11	< 1.4	< 0.11
268	$p\overline{p}K^0$	$2.1^{+0.6}_{-0.4}$	$3.0 \pm 0.5 \pm 0.3$ †	$2.40^{+0.64}_{-0.44} \pm 0.28$ ‡		$2.73^{+0.47}_{-0.42}$
269	$\Theta^+\overline{p}$ *	< 0.23	< 0.05	< 0.23		< 0.05
–	$f_J(2221)K^0$ *	New	< 0.45			< 0.45
270	$p\overline{p}K^{*0}$	< 7.6	$1.47 \pm 0.45 \pm 0.40$ †	< 7.6 ‡		1.5 ± 0.6
–	$f_J(2221)K^{*0}$ *	New	< 0.15			< 0.15
271	$p\overline{\Lambda}\pi^-$	2.6 ± 0.5	$3.30 \pm 0.53 \pm 0.31$	$3.23^{+0.33}_{-0.29} \pm 0.29$	< 13	$3.25^{+0.36}_{-0.34}$
–	$p\overline{\Sigma}(1385)^-$	New		< 0.26		< 0.26
–	$\Delta^0\overline{\Lambda}$	New		< 0.93		< 0.93
272	$p\overline{\Lambda}K^-$	< 0.82		< 0.82		< 0.82
273	$p\overline{\Sigma}^0\pi^-$	< 3.8		< 3.8		< 3.8
274	$\Lambda\overline{\Lambda}$	< 0.69		< 0.32	< 1.2	< 0.32

§Di-baryon mass is less than 2.85 GeV/c^2; † Charmonium decays to $p\bar{p}$ have been statistically subtracted. ‡ The charmonium mass region has been vetoed. * Product BF - daughter BF taken to be 100%; $\Theta(1540)^+ \to pK^0$ (pentaquark candidate).

Charmless baryonic B decays: measurements (3/3)

- **Several 3-body decays observed by BaBar and/or Belle; e.g. :**

$$B^- \to p\bar{\Lambda}\pi^- \quad , \quad B^+ \to p\bar{p}\pi^+ \quad , \quad B^0 \to p\bar{p}K^0$$
$$B^+ \to p\bar{p}K^{*+} \quad , \quad B^+ \to \Lambda\bar{\Lambda}K^+ \quad , \quad B^+ \to p\bar{\Lambda}\gamma$$

  - Branching fractions ~10^{-6}

- **No 2-body decays yet discovered! At least at the level of 10^{-7}-ish …**

- **Note: calculations tricky and not all “schools” in agreement …**

Conclusions

- No 2-body baryonic charmless decays observed so far

- Theoretical calculations/predictions do not always agree
  - some limits already exclude certain models

- Particular interest in $p\bar{p}$ mode: is easiest for LHCb
  - we could expect of order 1000-3000 events per nominal year
  - selection should be simpler than for $B_d \to KK$ and $B_s \to \pi\pi$:
    do not expect many p and $\bar{p}$ per event forming a good vertex
- Observation should be easy with early data

  $\Rightarrow$ Possible observation by LHCb of first 2-body baryonic B decay

- We could also look e.g. at Λ's …