University of Glasgow | Experimental Particle Physics

Two-Body Charmless Hadronic *B* Decays at LHCb

Laurence Carson
University of Glasgow

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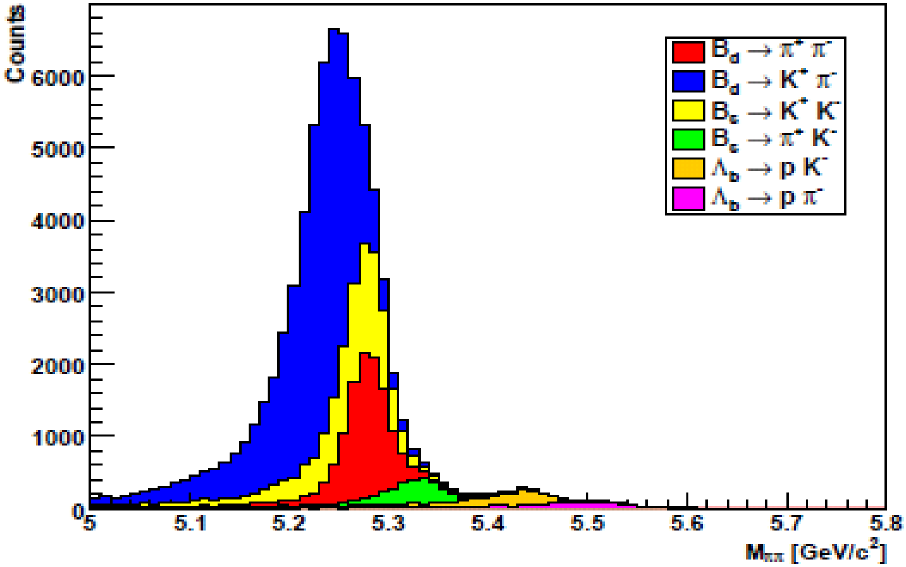
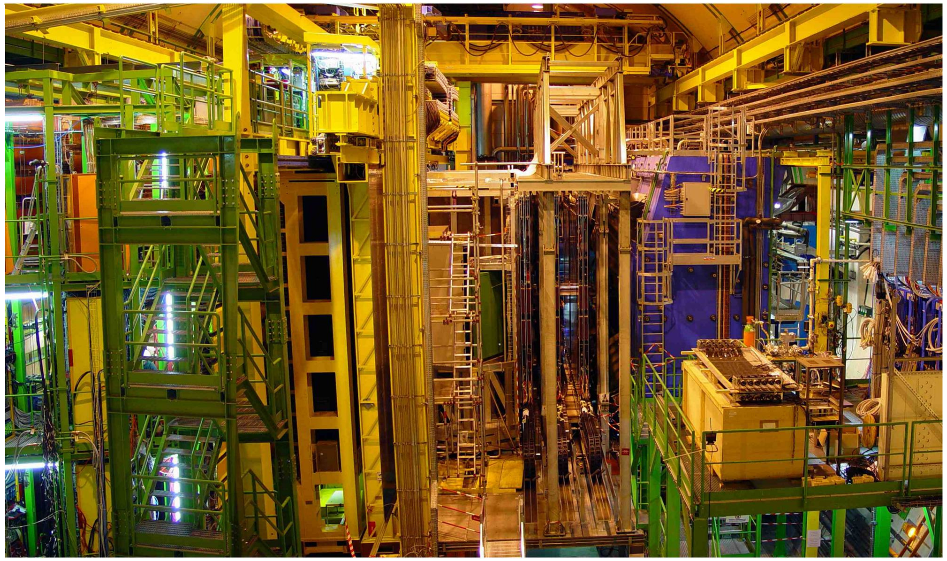
l.carson@physics.gla.ac.uk

Overview

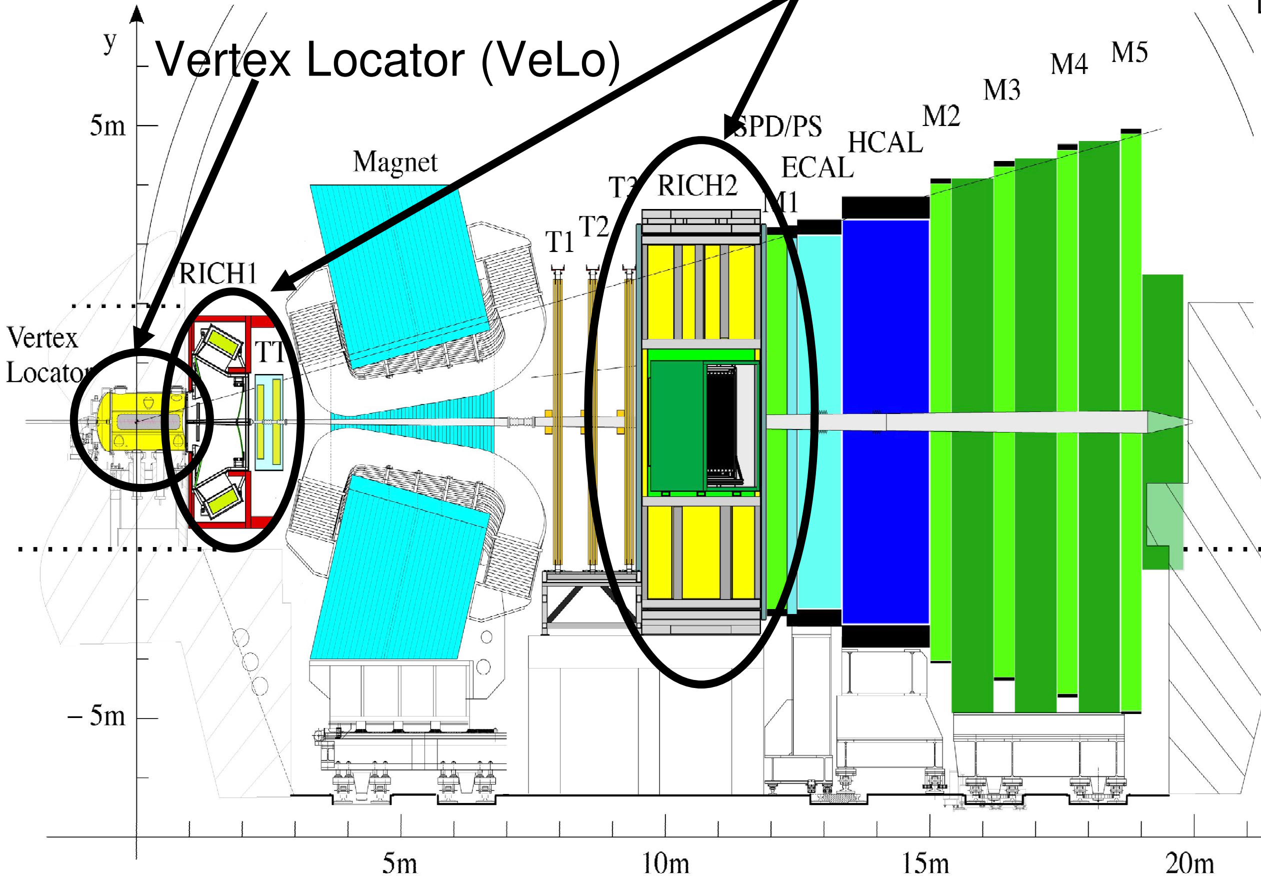
- What are two-body hadronic *B* decays good for?
  - Measurement of CKM angle γ
  - Discovery of rare baryonic modes
- What LHCb needs to study such decays
  - Proper time resolution calibration for γ measurement
  - Selection for rare decay $B_d \rightarrow p\bar{p}$





The LHCb Experiment

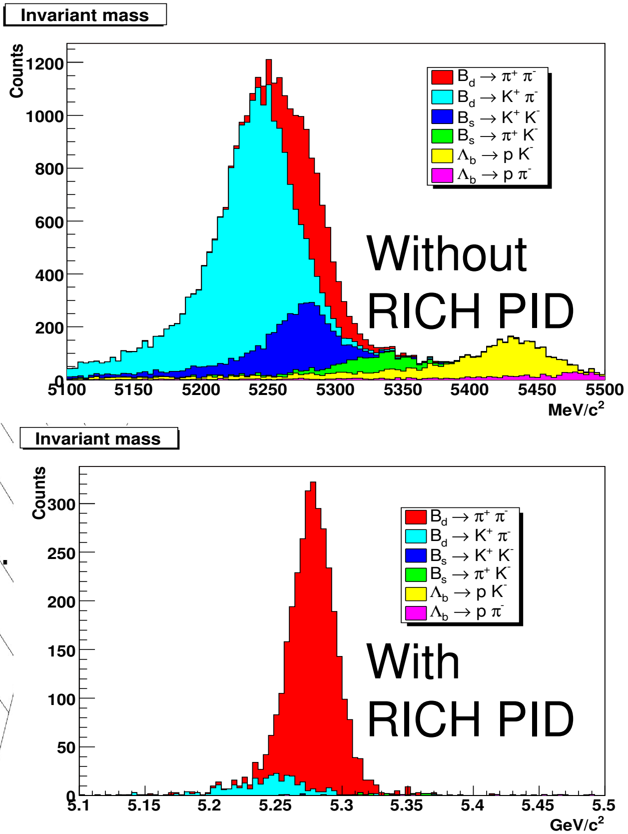
- Dedicated *B* physics experiment at the LHC
- Well suited to study two-body hadronic (a.k.a. $B \to h^+ h'^-$) decays



2 Ring Imaging Cherenkov (RICH) detectors

Vertex Locator (VeLo)

Example: $B_d \to \pi^+ \pi^-$



Without RICH PID

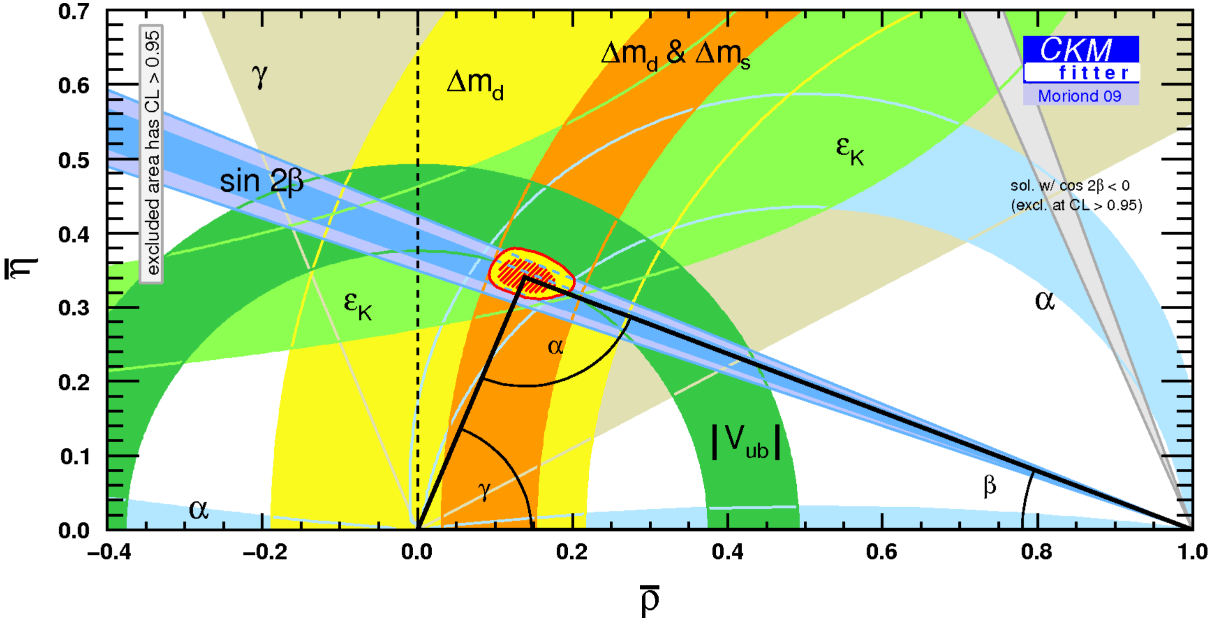
With RICH PID

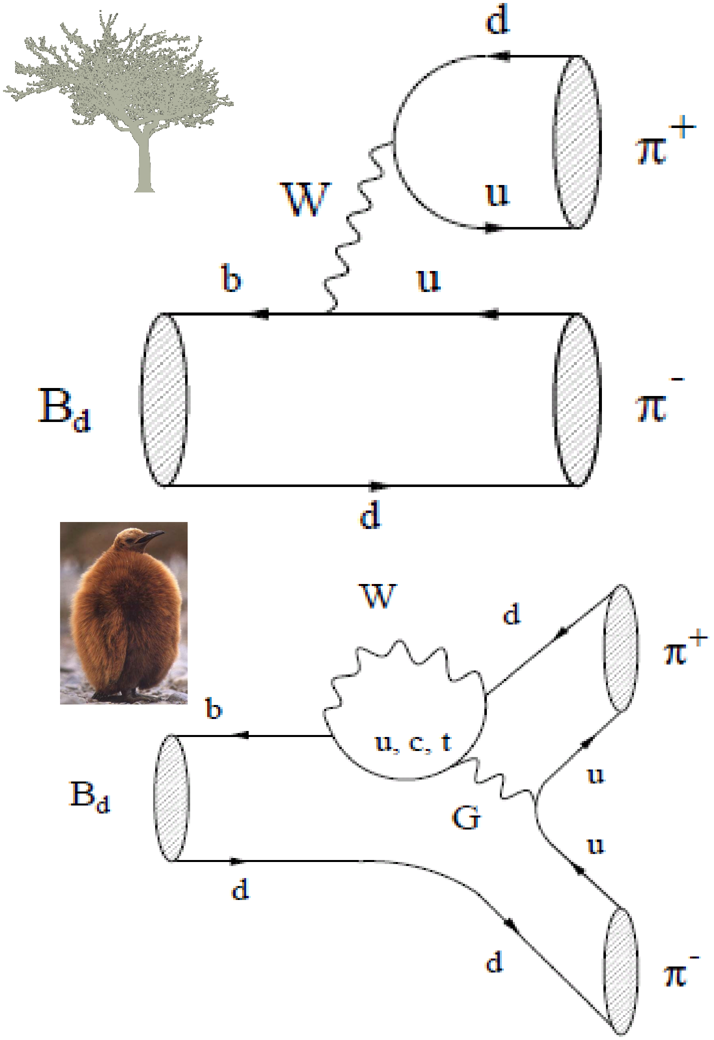
Full details in public LHCb note 2008-060

Proper Time Resolution Calibration

Measuring γ

- γ easily the least well-constrained CKM parameter:
  - Direct measurements give $\gamma = (70^{+27}_{-30})\ ^\circ$



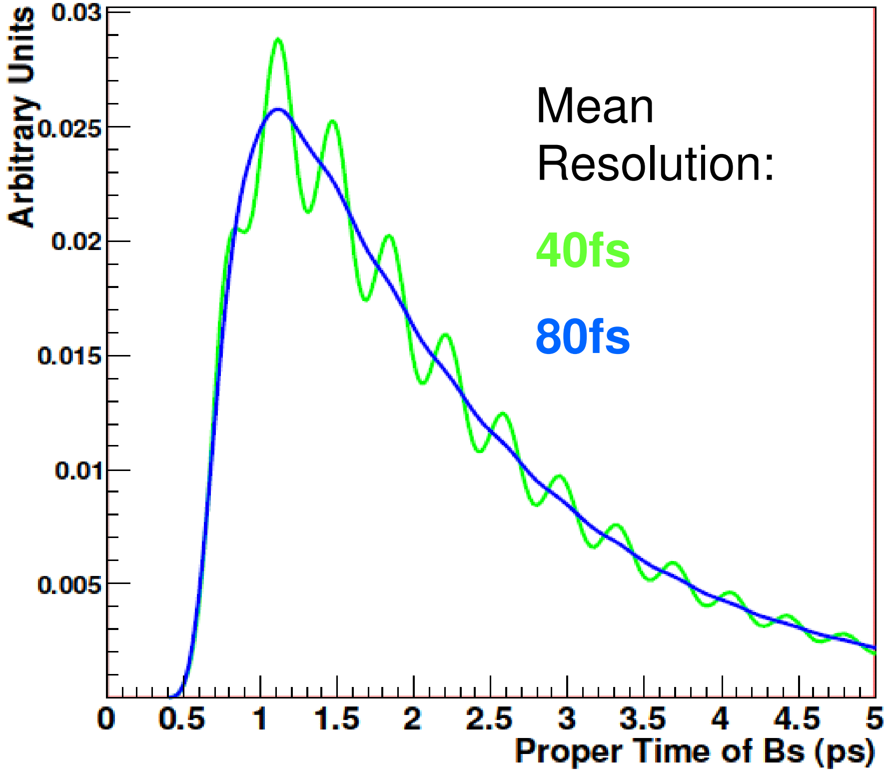


- One method(*) of measuring γ uses the time-dependent CP asymmetries (direct and indirect) from $B_d \rightarrow \pi^+\pi^-$ and $B_s \rightarrow K^-K^+$
  - Compare with tree-only decays (e.g. $B \rightarrow DK$)

(*) First proposed by R. Fleischer, Phys. Lett. B459, 306 (1999)

Proper Time Resolution Model

- Fast B_s oscillations mean that the reconstructed proper time (τ_{rec}) distribution for B_s channels is dependent on detector proper time resolution.
- τ_{rec} distribution for flavour-specific final state (e.g. $B_s \rightarrow K^- \pi^+$) will not depend on the CP asymmetry. But for a *CP* eigenstate (e.g. $B_s \rightarrow K^- K^+$) it will depend on CP asymmetries (direct and indirect).



- Hence incorrect proper time resolution model can bias extraction of γ.
- Resolution model used has the form (where $\Delta\tau \equiv \tau_{rec} - \tau_{true}$):

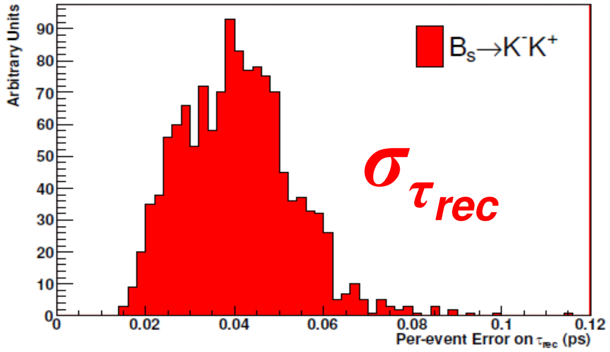
$$R(\Delta\tau) = (1-F)\cdot e^{-\frac{1}{2}\left(\frac{\Delta\tau - M}{S}\right)^2} + F \cdot e^{-\frac{1}{2}\left(\frac{\Delta\tau}{S_{fixed}}\right)^2}$$

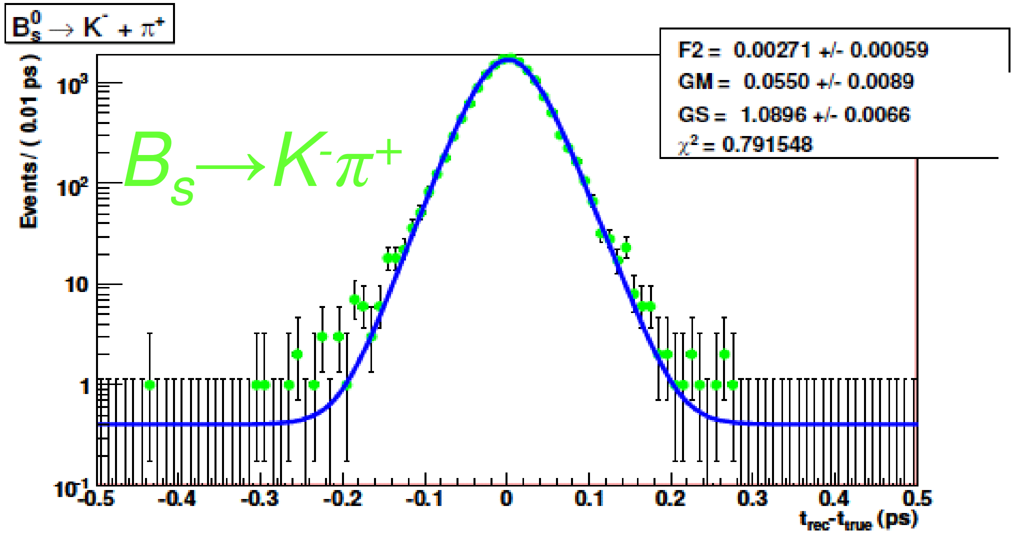
Main Gaussian

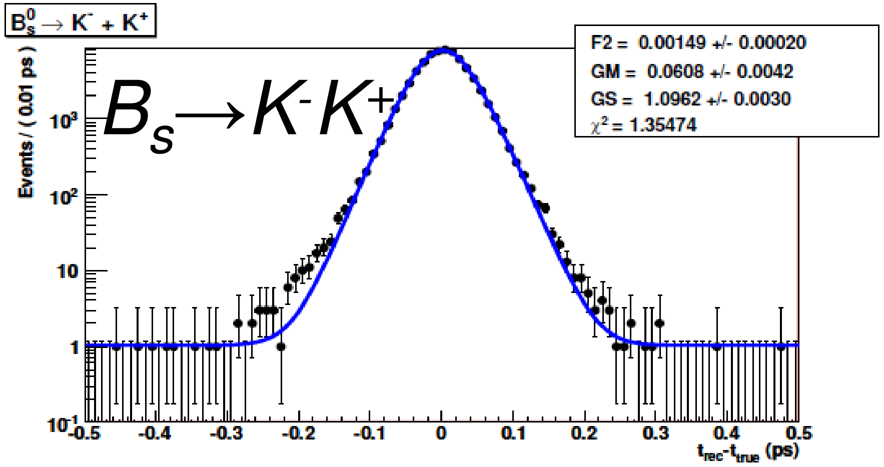
Secondary Gaussian

Validation of Resolution Model

- Model validated by fitting to $\Delta\tau$ distribution for simulated $B \rightarrow h^{+}h'^{-}$ events.
- Parameters M and S are calculated event-by-event, using $M \equiv GM \cdot \sigma_{\tau rec}$ and $S \equiv GS \cdot \sigma_{\tau rec}$ ($\sigma_{\tau rec}$ is per-event error).
  - *GM* (*GS*) is effectively the pull mean (width) of the τ_{rec} calculation.
- Values of *GS*, *GM* and *F2* are found that allow $R(\Delta\tau)$ to accurately describe the $\Delta\tau$ distribution in each channel. Values across channels are consistent.

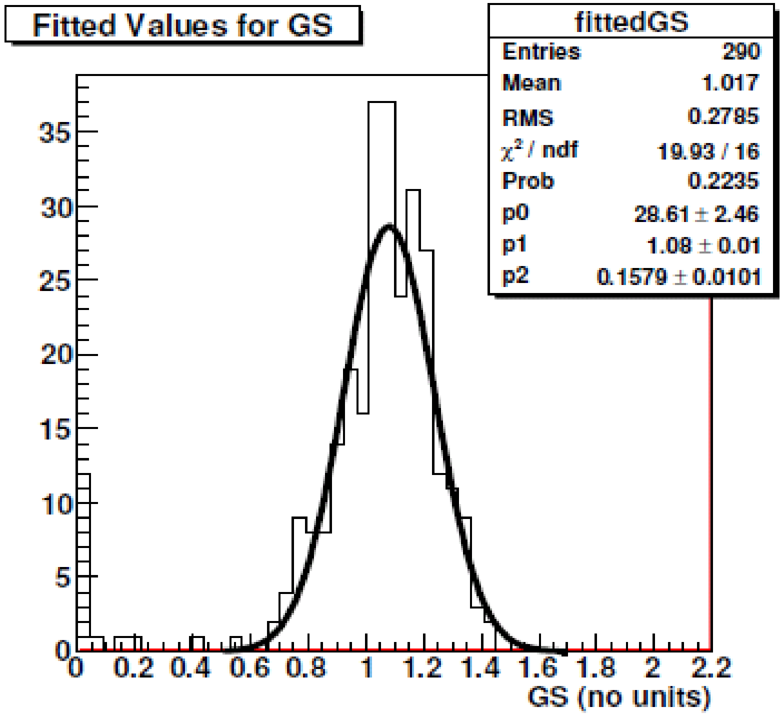






Fit for Parameters from Data

- Extract parameters from fit to τ_{rec} of $B_s \to K^-\pi^+$, then apply to $B_s \to K^-K^+$.
- Build toy τ_{rec} distribution for $B_s \to K^-\pi^+$
  - Use resolution model found from fit to (full MC) $\Delta\tau$ distribution.
  - Physics parameters (like τ_{Bs}) and mistag rate are assumed to have been measured from other channels.
  - Add background: combinatoric bkg (dominant), and specific bkg from $B_d \to K^+\pi^-$.
- Each toy job contains 20k events (6k signal)
  - Corresponds to 2fb^{-1} of data



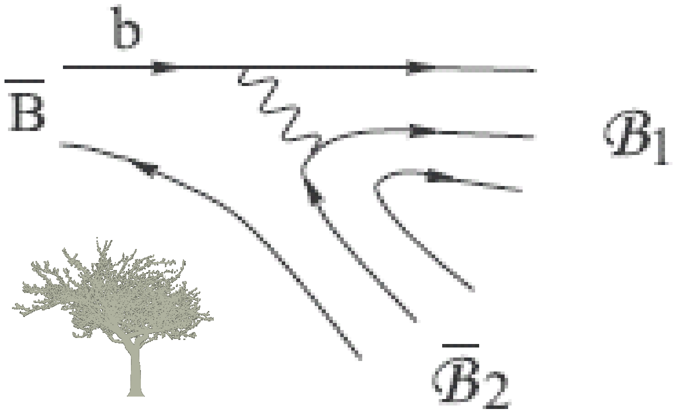
- Input values recovered without significant biases, and pull widths all compatible with 1.
- The sensitivities are such that from 2fb^{-1} onwards the fit can start to give non-trivial input into the analysis of $B_s \to K^-K^+$, and hence the γ measurement.

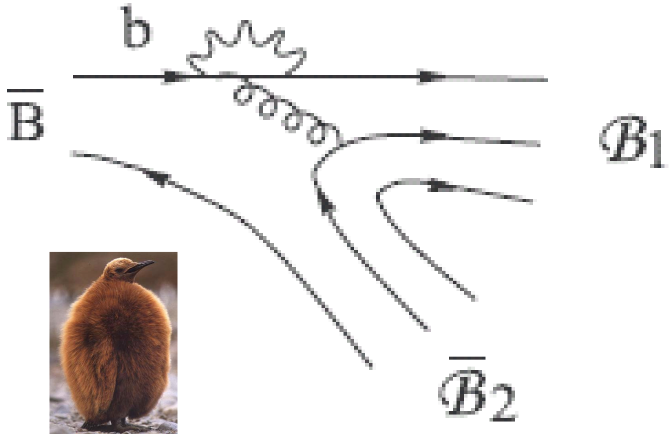
Full details in public LHCb note 2009-006

Search for $B_d \rightarrow p\bar{p}$

Two-Body Baryonic *B* Decays

- No decay of a *B* to two charmless baryons has yet been observed.
  - Several possibilities exist (p, n, Λ, Σ…)
- Theoretical predictions for SM branching ratios (B.R.s) vary widely
  - No agreement between different methods, even in order of magnitude

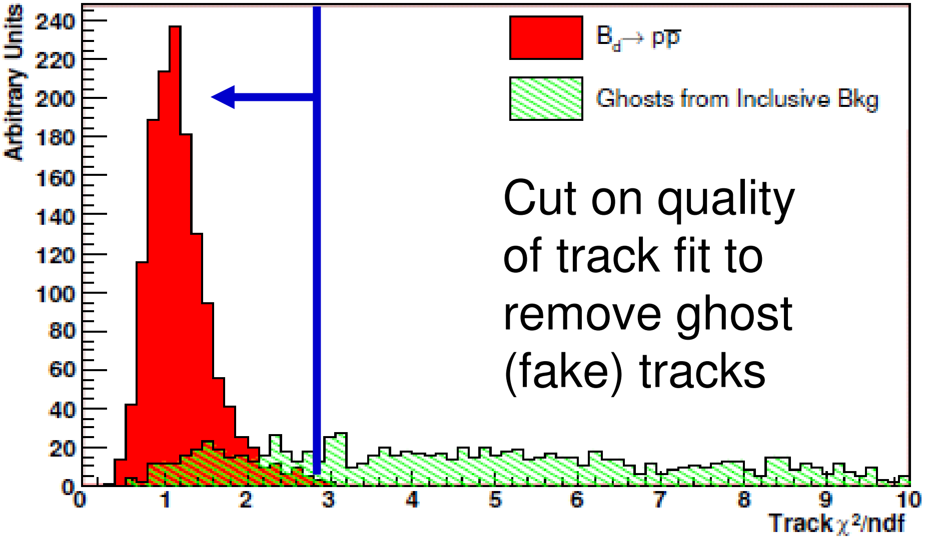




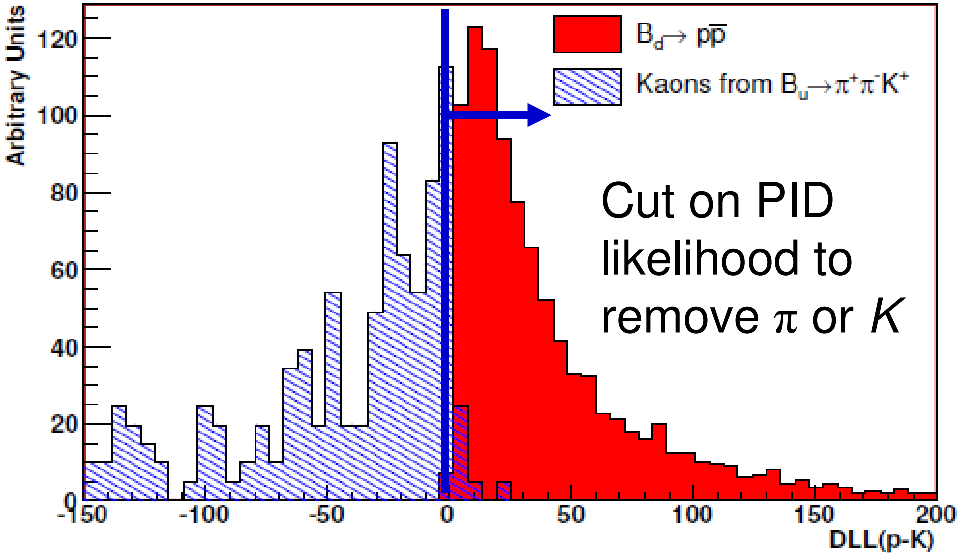
- Most promising channel for LHCb is $B_d \to p\overline{p}$
  - Commonality with benchmark $B \to h^+h'^-$ ($h = \pi$, K) modes
  - PID can reduce combinatorial and specific backgrounds
  - Experiment: B.R. < **$1.1*10^{-7}$** (dominated by Belle)
  - Other possibilities for LHCb include $B_s \to p\overline{p}$ and $B_u \to p\overline{\Lambda}$.

$B_d \to p\bar{p}$ Selection

- Starting point for selection is that used for standard $B \to h^+ h'^-$ modes
  - Geometrical cuts (impact parameter significance, flight distance)
  - Kinematic cuts (transverse momentum, invariant mass)
- Extra cuts added to further reduce background



Cut on quality of track fit to remove ghost (fake) tracks

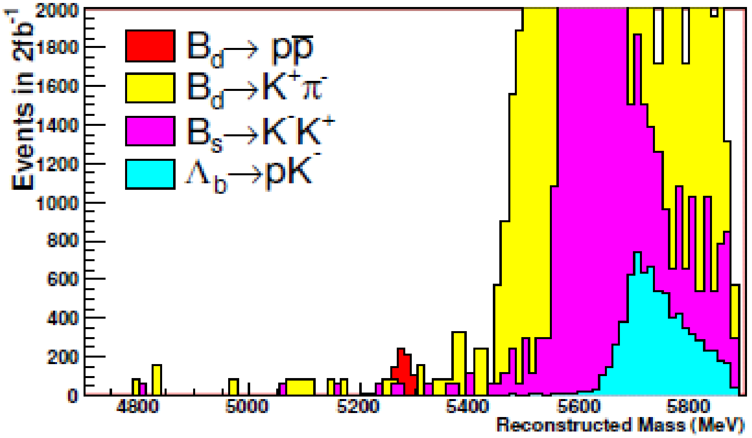


Cut on PID likelihood to remove π or *K*

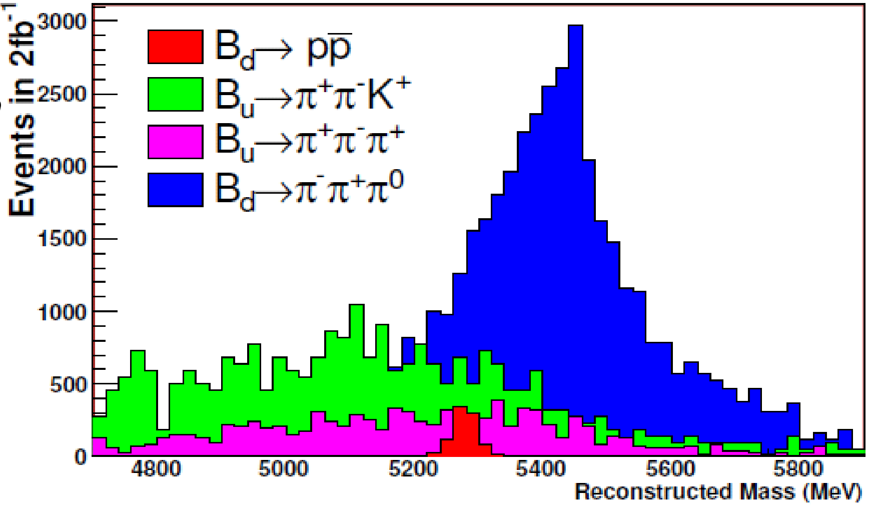
- Overall efficiency of selection on signal = ***9.8%***

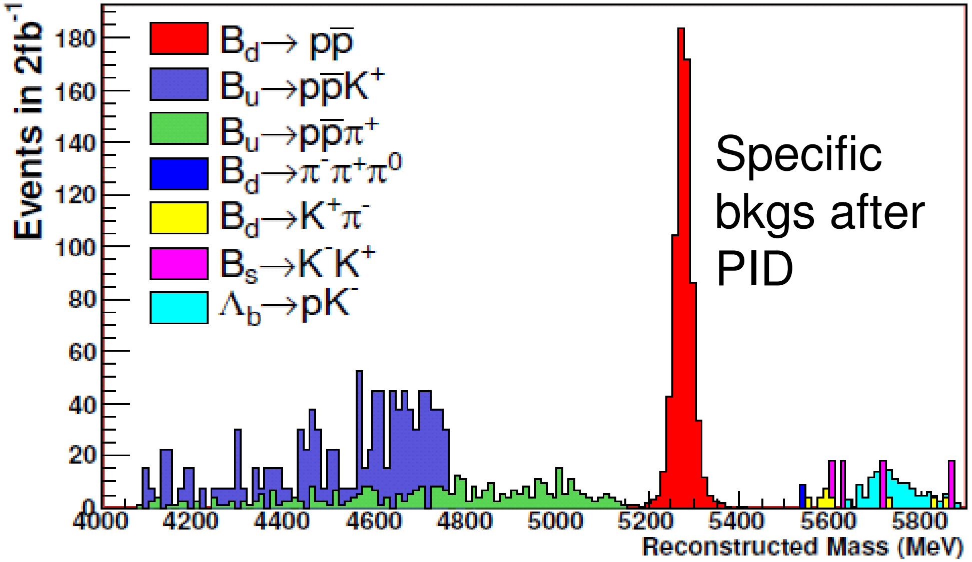
Backgrounds to $B_d \to p\bar{p}$

- Combinatorial background killed by geometrical and kinematic cuts
- Specific background killed by mass and PID cuts



B→*hh* (left) and *B*→*hhh* (right) bkgs before PID





Specific bkgs after PID

In signal mass region (m_{Bd}±50MeV), no background events (combinatorial or specific) survive selection.

- Allows upper limit on selection "efficiency" for backgrounds to be set using Feldman-Cousins method.

Yields & Sensitivity

- Signal and background yields given by:

$$Yield = \varepsilon_{sel} * \varepsilon_{geo} * \varepsilon_{trig/sel} * 2 * f_B * BR * \sigma_{b\bar{b}} * \int L$$

Selection eff.

LHCb acceptance
(~20% for $B \to hh$)

Trigger eff.
(~36%)

b and $\overline{\text{b}}$
produced

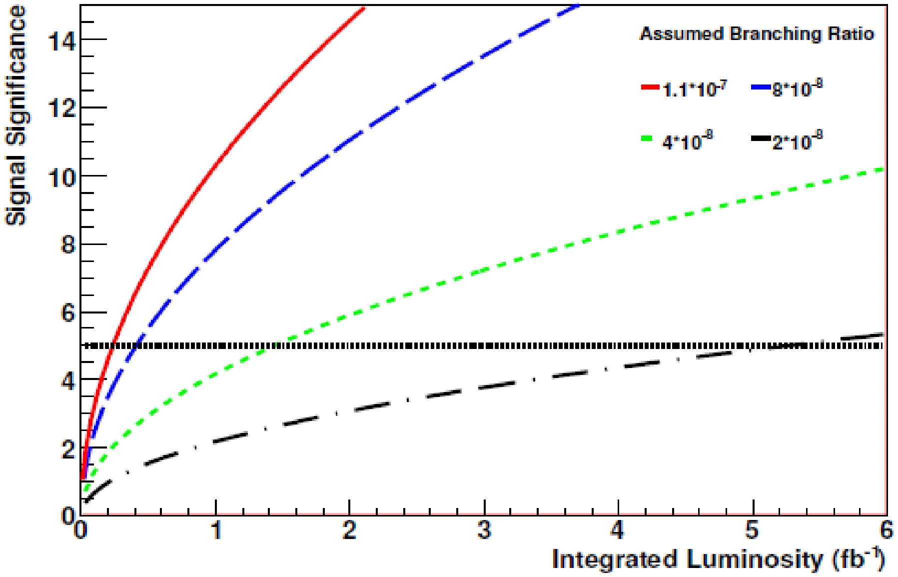
Hadronisation
probability

Branching
ratio

~500μb

Integrated
luminosity

(assuming BR=1.1*10^{-7})	2fb^{-1} Yield	B/S
$B_d \to p\bar{p}$	678	
$B \to hh$ bkg	<33	<0.05
$B \to hhh$ bkg	<272	<0.40
Inclusive $b\bar{b}$ bkg	<1 188	<1.75
Total bkg	<1 493	<2.20



- If BR($B_d \to p\bar{p}$) ≈ current expt limit, discovery with 0.24fb^{-1} (in 2009/10 run).
- BR measured by normalising to BR($B_d \to K^+\pi^-$), which is already well known.

Conclusions

Two-body hadronic *B* decays offer exciting opportunities for LHCb:

- γ measurement with $B_d \rightarrow \pi^+\pi^-$ and $B_s \rightarrow K^-K^+$
  - Need calibration of $B_s \rightarrow K^-K^+$ proper time resolution model to avoid bias on γ.
  - Calibration method developed using $B_s \rightarrow K^-\pi^+$ as control channel.
- Discovery of new baryonic modes
  - Selection developed for $B_d \rightarrow p\bar{p}$.
  - Can be observed in 2009/10 run if branching ratio is near current experimental limit.
  - Observation of $B_s \rightarrow p\bar{p}$ and $B_u \rightarrow p\bar{\Lambda}$ may be possible with more data.