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Summary of the Rare Decays Session, HQL12

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We present a short summary of the rare decay session at the XIth International Conference of Heavy Quark and Lepton, 2012. The majority of this session was devoted to dimuon decays of B mesons. In HQL 12 the Large Hadron Collider experiments, in particular LHCb began to make significant contributions to this area, previously dominated by the Babar and Belle e^+e^- experiments.

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1. Introduction

As the LHC has increased in luminosity, the sensitivity of the LHC experiments, CMS, ATLAS, and especially LHCb, for rare decays has increased dramatically. In addition, the Babar and Belle analyses continue to be refined and more data was added to previous results. The Tevatron experiments represented by CDF continue to make contributions. We summarize in the following table the results presented at this conference:

Table I
Presentations in the Rare Decay Session HQL12

Presenters→ Mode↓	ATLAS Ibragimov	CMS Ronchese	LHCb Archilli	BaBar Wilson	Belle Wilson	CDF Maestro	Theory Bobeth
$B_{(s)} \to \mu^+\mu^-$	x	x	x		x	x	x
$B_{(s)} \to \mu^+\mu^-\mu^+\mu^-$			x				
$D^0 \to \mu^+\mu^-$			x				
$b \to s\mu^+\mu^-$			x	x	x	x	x
$B^+ \to \pi^+\mu^+\mu^-$			x				
$B^0 \to \nu\nu(\gamma)$				x	x		
LFV $B^+ \to h^+\tau l$				(x)			
CLNV $B^+ \to X^- l^+ l^-$				(x)	(x)		

I.1 $B^0_s \to \mu^+\mu^-$

In this conference new upper limits on $B^0_s \to \mu^+\mu^-$ were presented by the ATLAS and CMS experiments. Table 2 gives the new 95% CL observed upper limits compared to previously published limits. The integrated luminosities of the data sets used in the ATLAS, CDF, CMS, and LHCb analyses are 2.4, 7, 4.9, and 1 fb^{-1} respectively.

Table II
95% CL Upper Limits for $B \to \mu\mu$ presented at this conference

Experiment	$B_s \to \mu^+\mu^-$	$B_d \to \mu^+\mu^-$	$B^0 \to \mu^+\mu^-$	Reference
ATLAS	2.2×10^{-8}			[1]
CMS	7.7×10^{-9}	1.8×10^{-9}		[3]
ATLAS+CMS+LHCB	4.2×10^{-9}	8.1×10^{-10}		[5]
LHCb	4.5×10^{-9}		1.0×10^{-9}	[4], [6]
CDF	4.0×10^{-8}			[2]

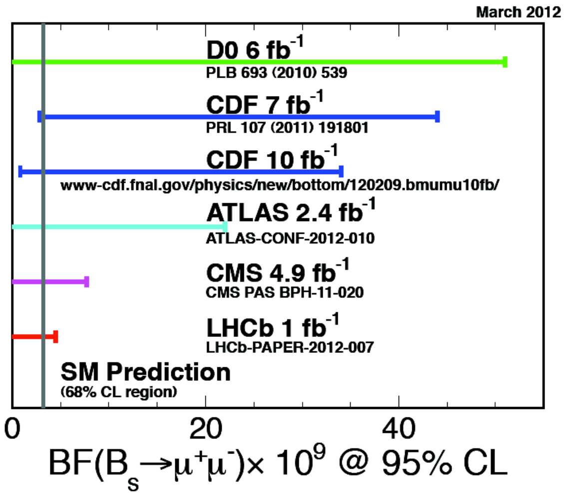


Fig. 1
Experimental Status of BR measurements of $B_s \rightarrow \mu\mu$.
(P. Maestro presentation these proceedings)

The collection of the 95% CL upper limits from the various experiments is shown in Fig. 1. The SM expectation for $B_s \rightarrow \mu\mu$ by Buras et al. [7] is (3.4±0.2) x10^{-9}. We see that the LHCB experiment is challenging this upper limit but at this point there is no conflict with the SM at present or any sign yet of new physics.

As pointed out by C. Bobeth in his talk in the rare decay session

$$BR(B_s \rightarrow \mu\mu) = \frac{1 + y_s A_{\Delta\Gamma}}{1 - y_s^2} BR[B_s(t=0) \rightarrow \mu\mu]$$

where $y_s = \frac{\Delta\Gamma_s}{2\Gamma_s} = 0.088 \pm 0.014$. In the SM $A_{\Delta\Gamma} = 1$ but if new physics is present, $A_{\Delta\Gamma}$ can range from +1 to -1. Therefore, one sign of new physics would be a lower BR for $B_s \rightarrow \mu\mu$ than predicted by the SM.

I.2 $b \rightarrow s\mu^+\mu^-$

The $b \rightarrow s\mu^+\mu^-$ decays are rare flavor changing neutral current decays forbidden at tree level in the SM with SM BR predictions of order 10^{-6}. Measurements of the branching ratios for decays of this kind are good tests of the SM. In addition, measurements of the forward backward symmetries of the leptons also are a probe for new physics.

An impressive list of BR measurements of B^0 and $B^+ \rightarrow Kll$ and K^*ll have been reported at this conference by Belle and CDF II. Table III summarizes the BRs measurements.

Table III

Branching Ratios for B→Kll and B→K*ll modes [7]

Exp.	B→Kll	B→K*ll
Belle [8]	$BR(B\to K\, l^+l^-)=4.7\pm0.06\pm0.2)x10^{-7}$	$BR(B\to K^*\, l^+l^-)=10.2+1.4-1.3\pm0.5)x10^{-7}$
CDF II [9]	$BR(B^+\to K^+\mu^+\mu^-)=0.46\pm0.04\pm0.02)x10^{-6}$ $BR(B^0\to K^0\mu^+\mu^-)=0.32\pm0.10\pm0.02)x10^{-6}$	$BR(B^0\to K^{*0}\mu^+\mu^-)=1.02\pm0.10\pm0.06)x10^{-6}$ $BR(B^+\to K^{*+}\mu^+\mu^-)=0.95\pm0.32\pm0.08)x10^{-6}$

In addition, CDF II reported a measurement of $BR(B_s^+\to\phi^+\mu^+\mu^-)=1.47\pm0.24\pm0.46)x10^{-6}$. There is no conflict with any of these measurements and the SM expectations at this point.

I.2.1 Forward-Backward Lepton Asymmetry in $B\to K^*ll$ Decays

Fig. 2 compares the forward backward asymmetry as a function of q^2 expected in $B\to K^*ll$ decays in the SM with BSM expectations. Previous measurements have been made by several experiments (CDF, Belle, and BaBar). In this conference, LHCb has presented a new measurement using1 fb^{-1} of data.

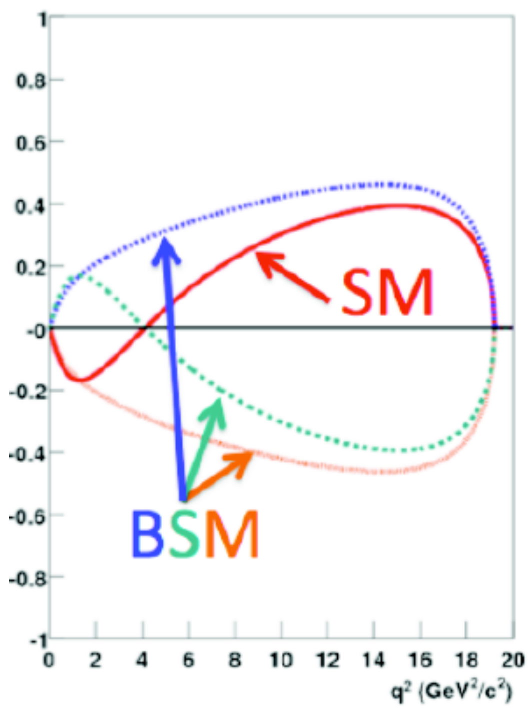


Fig.2

Expected forward backward asymmetry of leptons in $B\to K^{*0}\mu^+\mu^-$ for SM and BSM

(P. Maestro presentation these proceedings)

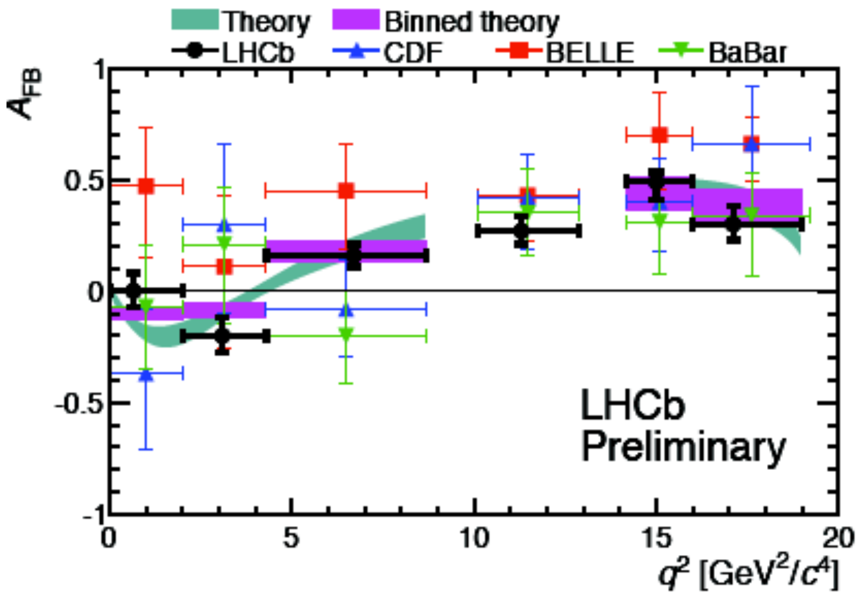


Fig. 3
Variation of the forward-backward asymmetry of the leptons in $B \rightarrow K^{*0}\mu^+\mu^-$ decays [10]

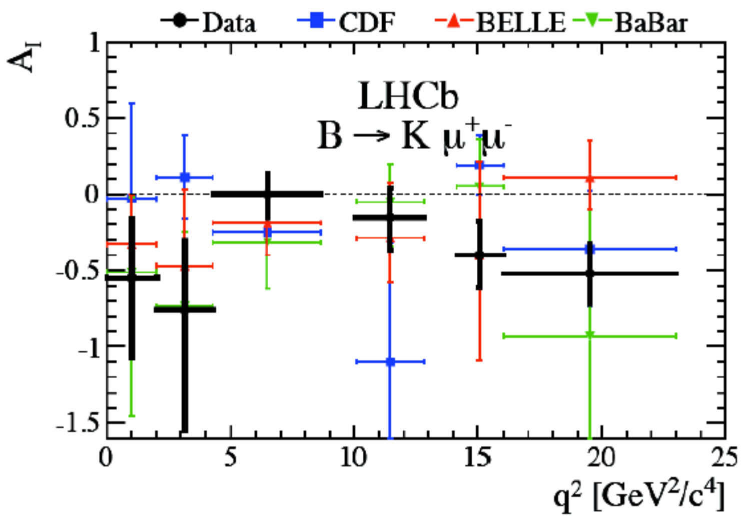
The LHCb data has allowed a first measurement of the A_{FB} zero crossing at $q^2 = 4.9^{+1.1}_{-1.3}$ GeV^2/c^4. As can be seen in Fig, 3, these measurements are consistent with the SM expectation but there is still room for new physics [11].

I.2.2 Isospin asymmetry in $B \rightarrow K^*\mu^+\mu^-$ and $B \rightarrow K\mu^+\mu^-$

The isospin asymmetry of $B \rightarrow K^*\mu^+\mu^-$ and $B \rightarrow K\mu^+\mu^-$ defined as

$$A_I = \frac{BR\left(B^0 \rightarrow K^{(*)0}\mu^+\mu^-\right) - \frac{\tau_0}{\tau_+}BR\left(B^\pm \rightarrow K^{(*)\pm}\mu^+\mu^-\right)}{BR\left(B^0 \rightarrow K^{(*)0}\mu^+\mu^-\right) + \frac{\tau_0}{\tau_+}BR\left(B^\pm \rightarrow K^{(*)\pm}\mu^+\mu^-\right)}$$

is supposed to be zero according to the SM for $B \rightarrow K^*\mu^+\mu^-$. This is confirmed by the data from LHCb. However, the LHCb data from 1 fb^{-1} of data for $B \rightarrow K\mu^+\mu^-$ seems to be non-zero and low as shown in Fig. 4 when integrated over q^2 at the 4.4σ level. However the BaBar and Belle data, also shown in Fig. 4, is consistent with the SM prediction at the 2.1 and 1.2 σ level respectively. So, once again, no conclusive evidence for new physics is found.



Fig, 4

Isospin asymmetry as a function of q^2 in $B \rightarrow K\mu^+\mu^-$ decays [12].

I.3 First Observations

There were a few first observations announced at this conference in the rare decay session. The LHCb experiment reported on the first observation of the decay $B^+ \rightarrow \pi^+\mu^+\mu^-$ as shown in Fig. 5 using 1 fb^{-1} of data.

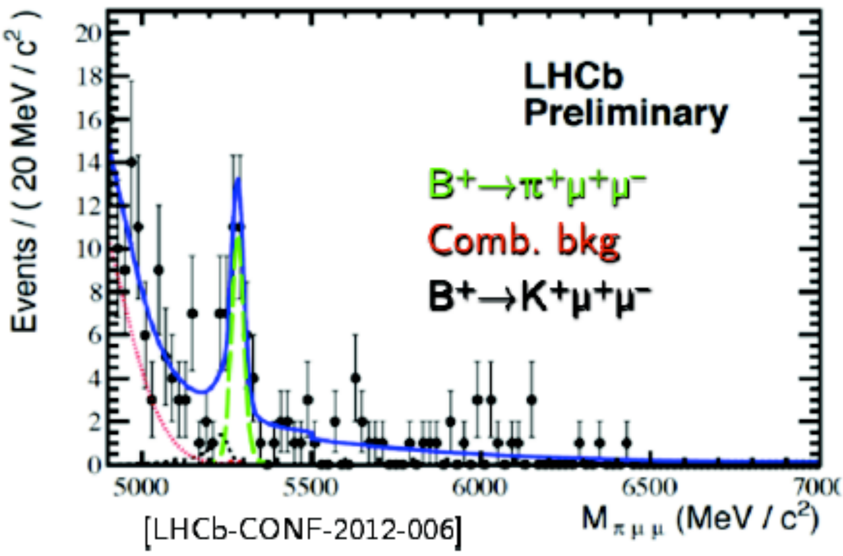


Fig. 5

Observation of the $B^+ \rightarrow \pi^+\mu^+\mu^-$ decay [13].

They have observed $25.3^{+6.7}_{-6.4}$ events over background (a 5.6σ excess). Using the $J/\Psi K^+$ decay as the normalization channel, a $BR(B^+ \to \pi^+\mu^+\mu^-) = (2.4\pm0.6\pm0.2)\times10^{-8}$ is obtained [13]. This is the rarest B decay ever measured. It matches the SM prediction of $BR(B^+ \to \pi^+\mu^+\mu^-) = (1.96\pm0.21)\times10^{-8}$ [14].

Finally, CDF II has observed a new decay mode $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ and measured a branching ratio $BR(\Lambda_b^0 \to \Lambda\mu^+\mu^-)=(1.73\pm0.42\pm0.55)\times10^{-6}$.

I.4 $B^0 \to \nu\nu$bar (γ)

Other B decay modes sensitive to new physics is the decay $B^0 \to \nu\nu$bar or $B^0 \to \nu\nu$bar γ. The SM prediction for the ννbar BR is of order 10^{-9}. New physics is expected to enhance this branching ratio to between 10^{-6} and 10^{-7}. Both BaBar and Belle have reported at this conference 90% CL upper limits for $B^0 \to \nu\nu$bar of 2.4×10^{-3} and 1.3×10^{-4} respectively. The BaBar collaboration has also reported a branching ratio upper limit at the 90% CL of 1.7×10^{-3} for $B^0 \to \nu\nu$bar γ. So the SM is not yet challenged by these results.

I.5 Conclusion

With the advent of the LHC experiments into the arena of B muonic decays, based on the very nice early data, we can anticipate that the upper limits for various to date unseen decays to be pushed down significantly and, provide that the SM predictions are correct, observation of decay modes such as $B_s \to \mu\mu$ by the time of the next Heavy Quark and Lepton Conference. However, to date, there is no evidence yet for new physics.

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