Rare B meson decays

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Introduction and outline

Rare decays are a crucial probe of physics beyond the Standard Model

- High precision predictions of SM observables
- Tiny effects so NP can be at the same level of SM
- Higher energy scales than directly accessible for production of new particles
- Probing the flavour structure leads to clear signatures of the type of new physics to expect

B meson rare decays:

- FCNC - Suppressed by GIM mechanism
- Forbidden decays (e.g. Lepton or Baryon number violation)

Today:

- Searches for $B^0_{d,s} \to \mu^+\mu^-$ decays at LHC
- Search for $B^0_{d,s} \to \mu^+\mu^-\mu^+\mu^-$

The $B^0_{d,s} \to \mu^+\mu^-$ decays in theory

- Standard Model prediction for CP averaged branching fractions at $t = 0$:

$$\begin{aligned}\mathcal{B}^{t=0}(B^0_s \to \mu^+\mu^-) &= (3.25 \pm 0.17) \times 10^{-9} \\ \mathcal{B}^{t=0}(B^0 \to \mu^+\mu^-) &= (1.07 \pm 0.10) \times 10^{-10}\end{aligned}$$

[A. Buras et al. arXiv:1303.3820]

[Eur.Phys.J. C72 (2012) 2172]

To compare with experimental values, which are time integrated, a correction due to the finite $B^0_s - \bar{B}^0_s$ width difference has to be applied [De Bruyn et al. [PRL 109, 041801]] [Phys.Rev.Lett.108 (2012) 101803]

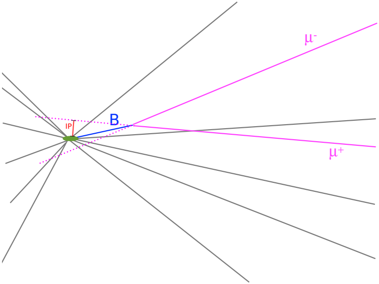
$$\mathcal{B}^{\langle t\rangle}(B^0_s \to \mu^+\mu^-) = \left(\frac{1 + \mathcal{A}_{\Delta\Gamma} y_s}{1 - y_s^2}\right)\mathcal{B}^{t=0}(B^0_s \to \mu^+\mu^-) \stackrel{SM}{=} (3.56 \pm 0.18) \times 10^{-9}$$

- New Physics models predict various and different enhancements or suppressions

Analysis strategy

The strategy is very similar for the three experiments.

1. Loose pre-selection:
   - ⋆ Pairs of opposite charged muons
   - ⋆ Vertex displaced with respect to interaction point
   - ⋆ p_{T}, IP and quality requirements
2. Blind analysis
3. Normalisation to $B^+ \to J/\psi K^+$ (and $B^0 \to K^-\pi^+$ for LHCb)
4. Final classification with tight selection
   - ⋆ Straight cuts for CMS
   - ⋆ Multivariate cut for ATLAS
   - ⋆ Multivariate and 2D classification for LHCb
5. CLs method for the limits

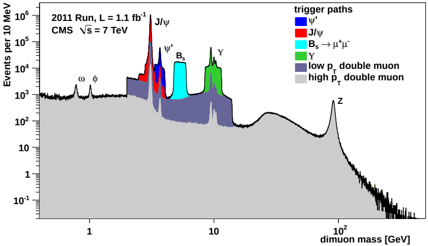


CMS analysis

2011 analysis based on 5 fb^{-1} at $\sqrt{s} = 7$ TeV

Trigger

- Dimuon triggers
- Tightening with increasing instantaneous luminosity
- Trigger selection based on
  - p_T and η of muons
  - invariant mass
  - secondary vertex probability
  - impact parameters
  - flight length
  - pointing angle
- Evaluated both with MC methods and on data with tag & probe

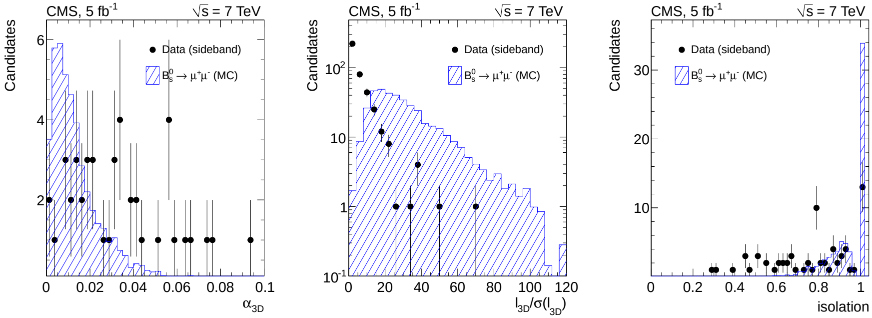


CMS analysis: selection

Selections optimized (random grid search) for best upper limit

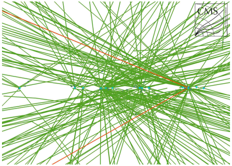
- Pointing angle α_{3D}
- Flight length significance $l_{3D}/\sigma(l_{3D})$
- Impact parameter significance
- Isolation cone around primary vertex: $I = p_{\mathrm{T}}(B)/(p_{\mathrm{T}}(B) + \sum_{\mathrm{trk}} |p_{\mathrm{T}}|)$
- Isolation of secondary vertex

Data sidebands vs Signal MC



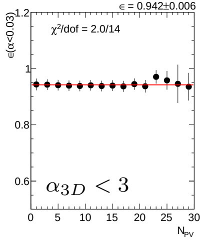
CMS analysis: Pile-up

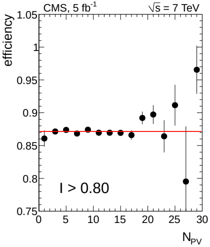
- In 2011: $\langle N_{PV} \rangle = 8$, RMS(z) = 5.6 cm
- Selections have been tuned to be pile-up independent (e.g. isolation searches only for tracks coming from the same primary vertex or not associated to any.)
- Efficiencies of all selection criteria have been evaluated versus N_{PV}
- All selections are compatible with a constant at least until 30 PV
- The same conclusion is also obtained from MC simulations, looking at samples with low (< 6) or high (10) PU events

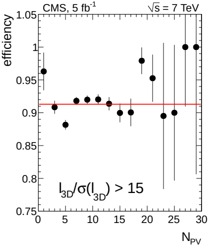


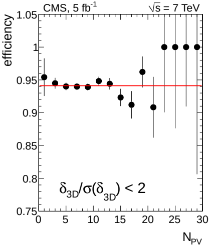
$B^+ \to J/\psi K^+$

$B_s^0 \to J/\psi \phi$









ATLAS analysis: trigger and selection

ATLAS 2011 analysis based on 2.4 fb^{-1} at $\sqrt{s} = 7$ TeV

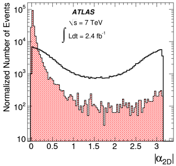
- Trigger L1 dimuon trigger $p_T > 4$GeV
- 2- (B0s) or 3- (B) prong vertex constraint
- Primary vertex selection:
  - ⋆ The closest in z to the B candidate
  - ⋆ Re-fit excluding B daughters
- Tracks:
  - ⋆ $|\eta| < 2.5$ and $p_T > 4$ (2.5) GeV for muons (kaons)
  - ⋆ At least 1 pixel, 6 SCT and 9 TRT hits
  - ⋆ ID tracks matching tracks in Muon Spectrometer for muons

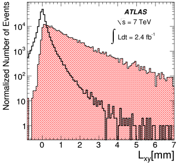
B candidates

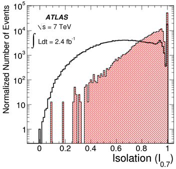
- ⋆ $p_T > 8$ GeV and $|\eta| < 2.5$

Signal/Bkg discrimination

- ⋆ Boost Decision Tree on 14 variables
- ⋆ Optimisation with $\mathcal{P} = \frac{\varepsilon_{sig}}{\frac{a}{2} + \sqrt{N_{bkg}}}$

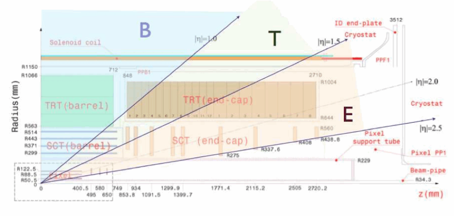






ATLAS analysis: mass resolution categories

- Mass resolution for dimuon candidates changes substantially between barrel and end-cap detectors
- Data sample divided in three mass resolution bin categories according to the largest pseudorapidity of the muons



$\lvert\eta_{max}\rvert$	1.0	1.5	2.5
σ_m [MeV]	60	80	110
Relative fraction [%]	51	24	25
Invariant mass window [MeV]	±116	±133	±171
BDT output threshold	0.234	0.245	0.270

LHCb analysis: trigger and preselection

LHCb analysis: 1fb^{-1} at $\sqrt{s} = 7$ TeV (2011) and 1.1fb^{-1} at $\sqrt{s} = 8$ TeV (2012)

- L0 Single and dimuon triggers
- Signal trigger efficiency about 90%

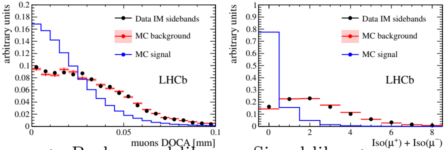
Soft preselection based on

- High quality dimuon displaced from PV
- Flight distance significance
- Impact parameters
- Transverse momenta

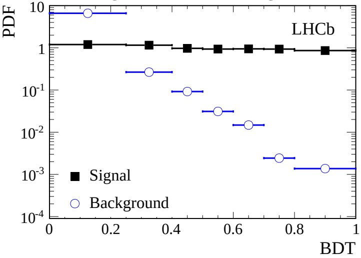
Final classification with multivariate analysis:

- Boosted Decision Tree with 9 variables:

  B IP, B isolation, B p_{T}, B τ, μ IP , $\min(\mu p_{\mathrm{T}})$, μ isolation, DOCA, μ to B angle
- Training with MC
- Calibration with data



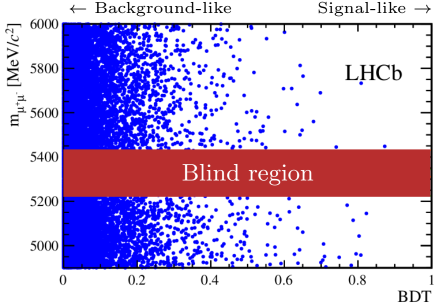
← Background-like Signal-like →



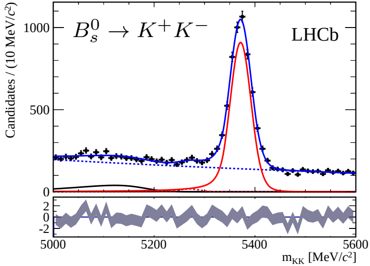
LHCb analysis: classification

Search performed in 8×6 bins of invariant mass ($m_{\mu\mu} \in [m_B \pm 60\mathrm{MeV/c}^2$]) and BDT

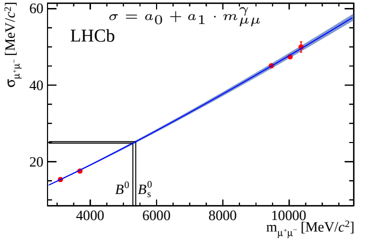
- Signal PDFs calibrated with $B \to h^+h^-$ and quarkonia
- Background with sidebands



Calibration of mass central value



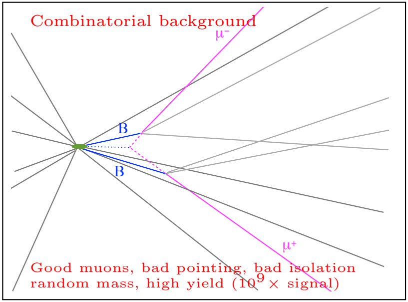
Calibration of mass central resolution

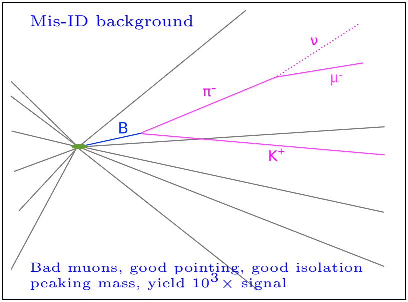


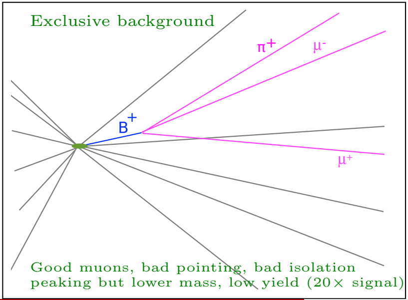
$\sigma_{B^0} = (24.6 \pm 0.4)\ \mathrm{MeV/c}^2$

$\sigma_{B_s^0} = (25.0 \pm 0.4)\ \mathrm{MeV/c}^2$

Backgrounds







Hadronic	$B \to h^+ h'^-$ with $h = \pi, K$
Semileptonic	$B^0 \to \pi^- \mu^+ \nu$ $B_s^0 \to K^- \mu^+ \nu$ $\Lambda_b^0 \to \bar{p} \mu^+ \nu$ $B_c^+ \to J/\psi \mu^+ \nu_\mu$ $B_s^0 \to D_s^-(\to \mu^- \nu)\mu^+ \nu$
Rare decays	$B^{+(0)} \to \pi^{+(0)} \mu^+ \mu^-$ $B_s^0 \to \mu^+ \mu^- \gamma$

Normalisation

The normalisation is very similar for the three experiments:

$$\mathcal{B} = \frac{\epsilon_{\rm cc}}{\epsilon_{\rm sig}} \cdot \frac{f_{\rm cc}}{f_q} \cdot \frac{N_{B_q^0 \to \mu^+\mu^-}}{N_{\rm cc}} \cdot \mathcal{B}_{cc} = \alpha_q \cdot N_{B_q^0 \to \mu^+\mu^-}$$

- Reconstruction and selection efficiencies from MC but cross-checked with data
- Trigger efficiency from data where possible
- Hadronisation fractions from updated LHCb measurement
  $f_s/f_d = 0.256 \pm 0.020$
  $\rightarrow$ ATLAS and CMS assume no kinematic dependence:
  verified within statistical accuracy by CMS with $B_s^0 \to J/\psi\phi / B^+ \to J/\psi K^+$
- LHCb exploits also $B^0 \to K^-\pi^+$

Single event sensitivities examples:

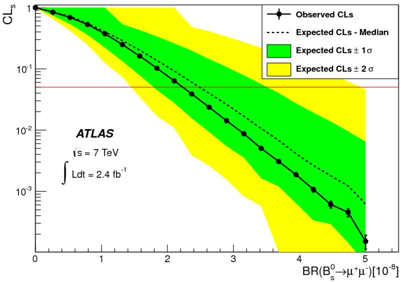
- ATLAS 2011 2.4 fb^{-1} $\alpha_{B_s^0 \to \mu^+\mu^-} = 3.6 \cdot 10^{-9}$
- CMS 2011 5fb^{-1} Barrel $\alpha_{B_s^0 \to \mu^+\mu^-} = 1.03 \cdot 10^{-9}$
- LHCb 2012 1fb^{-1} $\alpha_{B_s^0 \to \mu^+\mu^-} = 2.80 \cdot 10^{-10}$

ATLAS analysis: results

	Mass Resolution bins		
	$\vert\eta\vert < 1.0$	$1.0 < \vert\eta\vert < 1.5$	$1.5 < \vert\eta\vert < 2.5$
Events in sidebands	5	0	2
Exp. bkg in SR	3.86	0	2.28
Exp. resonant bkg	0.1	0.06	0.8
Observed events in SR	2	1	0

Limit extracted with modified frequentist method CLs.

$$\mathcal{L} = \text{Gauss}(\epsilon_{\text{obs}}|\epsilon, \sigma_\epsilon) \times \text{Gauss}(R^{\text{bkg}}_{\text{obs}}|R^{\text{bkg}}, \sigma_{R^{\text{bkg}}}) \times \prod_{i=1}^{N_{\text{bin}}} \text{Poisson}(N_i^{\text{obs}}|\epsilon\,\epsilon_i \text{BR} + N_i^{\text{bkg}} + N_i^{B\to hh}) \times \text{Poisson}(N^{\text{bkg}}_{\text{obs},i}|R^{\text{bkg}}\, R_i^{\text{bkg}} N_i^{\text{bkg}}) \times \text{Gauss}(\epsilon_{\text{obs},i}|\epsilon_i, \sigma_{\epsilon_i}) \, .$$

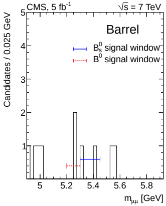


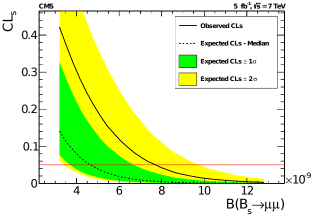
Expected limit at 95% CL (Extracted from unbiased sidebands): 2.3×10^{-8}

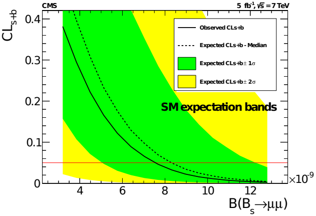
Observed limit at 95% CL: 2.2×10^{-8}

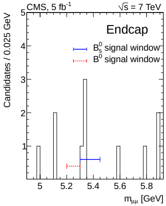
CMS results

Variable	$B^0 \to \mu^+\mu^-$ Barrel	$B_s^0 \to \mu^+\mu^-$ Barrel	$B^0 \to \mu^+\mu^-$ Endcap	$B_s^0 \to \mu^+\mu^-$ Endcap
$N^{\rm exp}_{\rm signal}$	0.24 ± 0.02	2.70 ± 0.41	0.10 ± 0.01	1.23 ± 0.18
$N^{\rm exp}_{\rm peak}$	0.33 ± 0.07	0.18 ± 0.06	0.15 ± 0.03	0.08 ± 0.02
$N^{\rm exp}_{\rm comb}$	0.40 ± 0.34	0.59 ± 0.50	0.76 ± 0.35	1.14 ± 0.53
$N^{\rm exp}_{\rm total}$	0.97 ± 0.35	3.47 ± 0.65	1.01 ± 0.35	2.45 ± 0.56
$N_{\rm obs}$	2	2	0	4







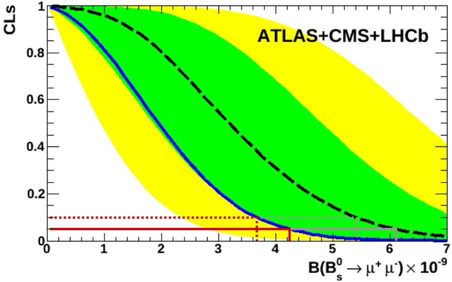


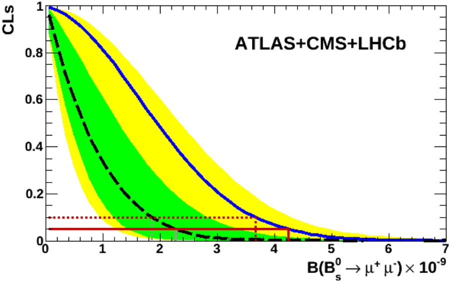
Limit with CLs method:

	Observed	Median expected
$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	$< 7.7 \cdot 10^{-9}$	$< 8.4 \cdot 10^{-9}$
$\mathcal{B}(B^0 \to \mu^+\mu^-)$	$< 1.8 \cdot 10^{-9}$	$< 1.6 \cdot 10^{-9}$

LHC Combination

Combination of analysis by the three experiments: ATLAS (2.4fb^{-1}), CMS (5fb^{-1}) LHCb (1fb^{-1} 2011 + 0.037fb^{-1} 2010)



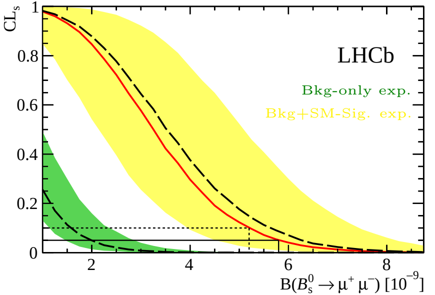


Mode	Limit	ATLAS	CMS	LHCb 2010	LHCb 2011	Combined
$B_s^0 \to \mu^+\mu^-$ (10^{-9})	Bkg Only	23	(3.6)	65	3.4	2.3
	Bkg+SM		8.4		7.2	6.1
	Obs	22	7.7 (7.2)	56	4.5	4.2

- Compatible with SM signal within 1 σ ($1 - CL_{s+b} = 84\%$)
- P-value bkg-only hypothesis: 5%

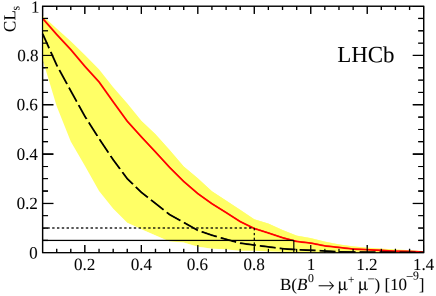
ATLAS-CONF-2012-061, CMS-PAS-BPH-12-009, LHCb-CONF-2012-017

LHCb updated results



Upper limit at 95 % CL	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$
Exp. bkg+SM	6.3×10^{-9}
Exp. bkg	2.0×10^{-9}
Observed	5.8×10^{-9}

Compatibility with background p-value (1-CL_b) is 5×10^{-4}
Excess of $B_s^0 \to \mu^+\mu^-$ events with a significance of 3.5σ.
First evidence of $B_s^0 \to \mu^+\mu^-$ decay

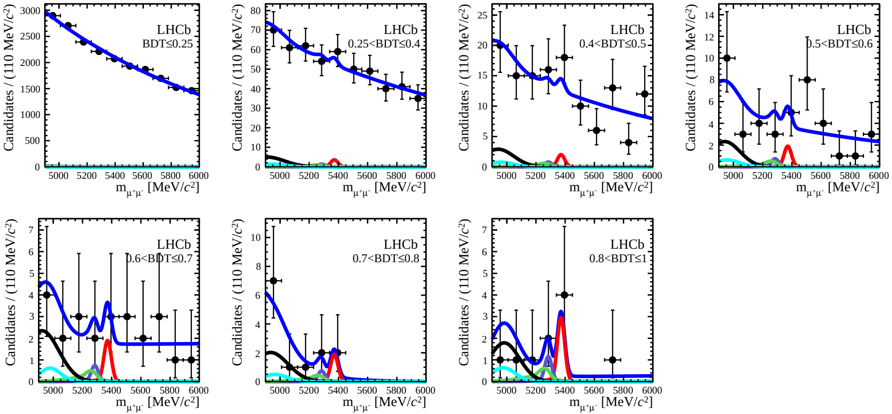


Upper limit at 95 % CL	$\mathcal{B}(B^0 \to \mu^+\mu^-)$
Exp. bkg+SM	7.1×10^{-10}
Exp. bkg	6.0×10^{-10}
Observed	9.4×10^{-10}

LHCb results: full fit to combined dataset

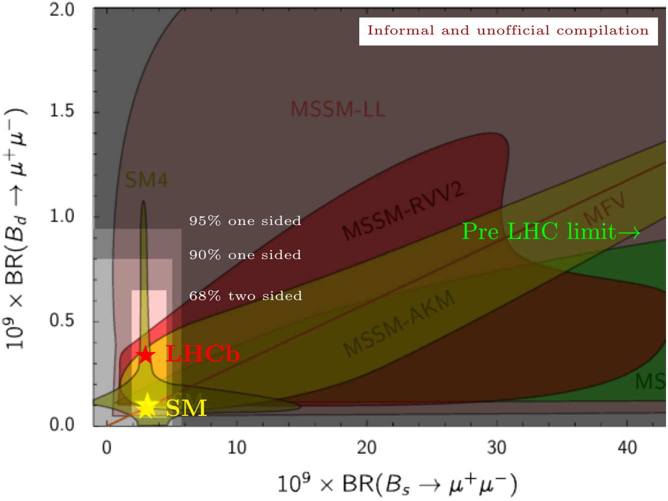
- Simultaneous fit to the two years dataset
- Shared branching ratio parameters

2012 dataset, 7 BDT bins



$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.2^{+1.4}_{-1.2}(\text{stat})^{+0.5}_{-0.3}(\text{syst})) \times 10^{-9}$$

The parameter space and outlook



Original figure from D. Straub - Nuovo Cim. C035N1 (2012) 249-256

Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

[arXiv:hep-ex/1303.1092]

Standard Model

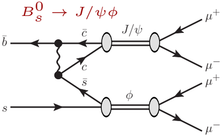
- Main resonant component: $B^0_s \to J/\psi\phi$, with J/ψ and ϕ decaying in two muons. $[\mathcal{B} = (2.3 \pm 0.9) \times 10^{-8}]$
- SM non-resonant: $B^0_{(s)} \to \mu\mu\gamma(\to \mu\mu)$
  $\mathcal{B} < 10^{-10}$ [Phys.Rev.D 70 (2004) 114028]

In NP models scalar and pseudoscalar particles can enhance the branching fraction via $B \to PS$ intermediate states.

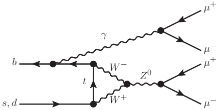
In particular it is sensitive to sgoldstino mediated decays decays in MSSM models.

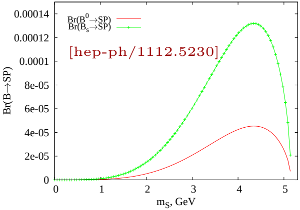
hypothesized pseudoscalar particle to explain HyperCP evidence in $\Sigma^+ \to p\mu\mu$ tested.

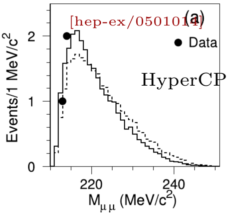
$B^0_s \to J/\psi\phi$



$B^0_{s,d} \to \mu^+\mu^-\mu^+\mu^-$







Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

[arXiv:hep-ex/1303.1092]

- Four muons with high IPχ^2 with good vertex ($\chi^2 < 30$)
- Tight muon PID criteria:
  $\varepsilon_\mu = 78.5\%$, $\varepsilon_{\pi\to\mu} = 1.4\%$
- Resonant component ($m_{\mu\mu} \in [950, 1090]$ and $[3000, 3200]$) excluded an used as control channel
- $N = 5.5 \pm 2.3$ expected $B^0_s \to J/\psi\phi$, 7 observed events
- Dominant background: combinatorial
- Peaking backgrounds negligible. Largest one $B \to \psi(2S)K^*$ with expected yield 0.44 events

Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

[arXiv:hep-ex/1303.1092]

Normalisation

- $B^0 \to J/\psi(\to \mu^+\mu^-)K^{*0}(\to K^+\pi^-)$ with S-wave excluded
- Same selection (apart from PID)

$$\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-) =$$

$$\mathcal{B}(B^0 \to J/\psi K^{*0}) \frac{f_s}{f_d} \frac{\varepsilon_{J/\psi K^*}}{\varepsilon_{4\mu}} \frac{N_{B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-}}{N_{B^0 \to J/\psi K^{*0}}} \kappa$$

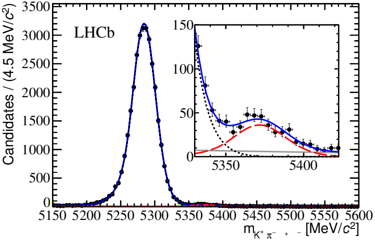
κ is a correction for the S-wave exclusion

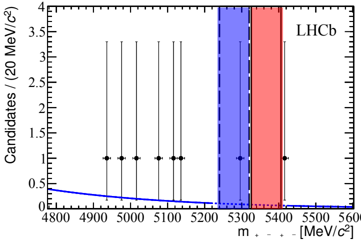
Upper limits at 90% (95%) CL for phase space decays:

- $\mathcal{B}(B^0_s \to \mu^+\mu^-\mu^+\mu^-) < 1.2(1.6) \times 10^{-8}$
- $\mathcal{B}(B^0 \to \mu^+\mu^-\mu^+\mu^-) < 5.3(6.6) \times 10^{-9}$

Upper limits at 90% (95%) CL for the MSSM models ($m_{P(S)} = 214.3\text{MeV/c}^2 (2.5\text{GeV/c}^2)$):

- $\mathcal{B}(B^0_s \to SP \to 4\mu) < 1.2(1.6) \times 10^{-8}$
- $\mathcal{B}(B^0 \to SP \to 4\mu) < 5.1(6.6) \times 10^{-9}$





Other rare decay results

- First observation of $B^+ \to \pi^+\mu^+\mu^-$

  LHCB-PAPER-2012-020 - JHEP 12 (2012) 125 [hep-ex/1210.2645]

- Searches for Majorana neutrinos in B^- decays

  LHCB-PAPER-2011-038 - Phys. Rev. D 85, 112004 (2012) [hep-ex/1201.5600]

- Search for the lepton number violating decays $B^+ \to \pi^-\mu^+\mu^+$ and $B^+ \to K^-\mu^+\mu^+$

  LHCB-PAPER-2011-009 - Phys.Rev.Lett. 108 (2012) 101601 [hep-ex/1110.0730]

- Measurement of the ratio of branching fractions $\mathcal{B}(B^0 \to K^{*0}\gamma)/\mathcal{B}(B_s^0 \to \phi\gamma)$ and the direct CP asymmetry in $B^0 \to K^{*0}\gamma$

  LHCb-PAPER-2012-019 - Nucl. Phys. B 867 (2013) 1-18 [hep-ex/1209.0313]

Plus all the $B \to K^*\mu\mu$ physics will be discussed in the next session.

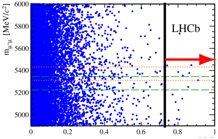
Conclusions and outlook

- B rare decays are fundamental tools to explore New Physics and to probe its flavour structure
- $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ decays have been searched for 30 years now tightening the space of new physics parameters
- First evidence of $B_s^0 \to \mu^+\mu^-$ seen
  - ⋆ To be confirmed soon by other experiments and by increased data samples
  - ⋆ The precision era is just at the beginning
- All the three experiments are in the process of finalizing their updated analysis
- The playground of rare decays is large and yet to be fully exploited

Additional material

Invariant mass distribution

[Phys. Rev. Lett. 110, 021801 (2013)]



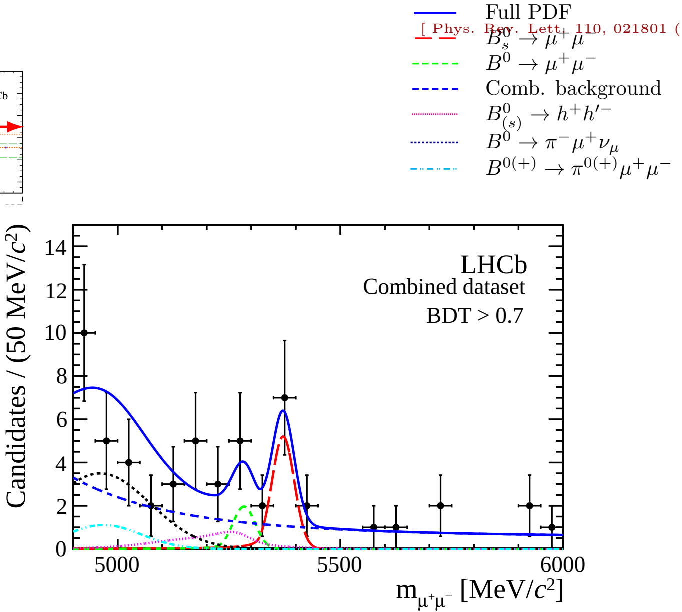


TABLE II. Expected combinatorial background, $B^0_{(s)} \to h^+h'^-$ peaking background, cross-feed, and signal events assuming SM prediction, together with the number of observed candidates in the $B^0_s \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ mass signal regions, in bins of BDT for the 2012 data sample. The quoted errors include statistical and systematic uncertainties.

Mode	BDT bin	0.0 – 0.25	0.25 – 0.4	0.4 – 0.5	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8 – 1.0
$B^0_s \to \mu^+\mu^-$	Exp. comb. bkg	2345^{+40}_{-40}	$56.7^{+3.0}_{-2.9}$	$13.1^{+1.5}_{-1.4}$	$4.42^{+0.91}_{-0.81}$	$2.10^{+0.67}_{-0.56}$	$0.35^{+0.42}_{-0.22}$	$0.39^{+0.33}_{-0.21}$
	Exp. peak. bkg	$0.250^{+0.083}_{-0.068}$	$0.145^{+0.049}_{-0.040}$	$0.081^{+0.027}_{-0.023}$	$0.075^{+0.024}_{-0.020}$	$0.071^{+0.023}_{-0.019}$	$0.062^{+0.021}_{-0.017}$	$0.104^{+0.034}_{-0.028}$
	Exp. signal	$3.69^{+0.59}_{-0.52}$	$2.14^{+0.37}_{-0.33}$	$1.20^{+0.21}_{-0.18}$	$1.16^{+0.18}_{-0.16}$	$1.17^{+0.18}_{-0.16}$	$1.15^{+0.19}_{-0.17}$	$2.13^{+0.33}_{-0.29}$
	Observed	2274	65	19	5	3	1	3
$B^0 \to \mu^+\mu^-$	Exp. comb. bkg	2491^{+42}_{-42}	$59.5^{+3.3}_{-3.2}$	$13.9^{+1.6}_{-1.5}$	$4.74^{+1.00}_{-0.89}$	$2.10^{+0.74}_{-0.61}$	$0.55^{+0.50}_{-0.31}$	$0.29^{+0.34}_{-0.19}$
	Exp. peak. bkg	$1.49^{+0.50}_{-0.36}$	$0.86^{+0.29}_{-0.22}$	$0.48^{+0.16}_{-0.12}$	$0.44^{+0.15}_{-0.11}$	$0.42^{+0.14}_{-0.10}$	$0.369^{+0.126}_{-0.093}$	$0.62^{+0.21}_{-0.15}$
	Exp. cross-feed	$0.627^{+0.104}_{-0.091}$	$0.363^{+0.066}_{-0.057}$	$0.204^{+0.036}_{-0.032}$	$0.197^{+0.032}_{-0.027}$	$0.199^{+0.032}_{-0.028}$	$0.196^{+0.034}_{-0.030}$	$0.362^{+0.058}_{-0.051}$
	Exp. signal	$0.442^{+0.062}_{-0.057}$	$0.256^{+0.040}_{-0.036}$	$0.144^{+0.022}_{-0.020}$	$0.139^{+0.019}_{-0.017}$	$0.140^{+0.019}_{-0.018}$	$0.138^{+0.021}_{-0.019}$	$0.255^{+0.035}_{-0.031}$
	Observed	2433	59	19	3	2	2	2

TABLE III. Expected combinatorial background, $B^0_{(s)} \to h^+h'^-$ peaking background, cross-feed, and signal events assuming SM prediction, together with the number of observed candidates in the $B^0_s \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ mass signal regions, in bins of BDT for the 2011 data sample. The quoted errors include statistical and systematic uncertainties.

Mode	BDT bin	0.0 – 0.25	0.25 – 0.4	0.4 – 0.5	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8 – 0.9	0.9 – 1.0
$B^0_s \to \mu^+\mu^-$	Exp. comb. bkg	1880^{+33}_{-33}	$55.5^{+3.0}_{-2.9}$	$12.1^{+1.4}_{-1.3}$	$4.16^{+0.88}_{-0.79}$	$1.81^{+0.62}_{-0.51}$	$0.77^{+0.52}_{-0.38}$	$0.47^{+0.48}_{-0.36}$	$0.24^{+0.44}_{-0.20}$
	Exp. peak. bkg	$0.129^{+0.066}_{-0.050}$	$0.066^{+0.024}_{-0.019}$	$0.052^{+0.018}_{-0.015}$	$0.047^{+0.015}_{-0.013}$	$0.053^{+0.017}_{-0.014}$	$0.050^{+0.016}_{-0.013}$	$0.052^{+0.017}_{-0.014}$	$0.049^{+0.018}_{-0.014}$
	Exp. signal	$2.70^{+0.81}_{-0.80}$	$1.30^{+0.27}_{-0.23}$	$1.03^{+0.20}_{-0.17}$	$0.92^{+0.15}_{-0.13}$	$1.06^{+0.17}_{-0.15}$	$1.10^{+0.17}_{-0.15}$	$1.26^{+0.20}_{-0.17}$	$1.31^{+0.28}_{-0.25}$
	Observed	1818	39	12	6	1	2	1	1
$B^0 \to \mu^+\mu^-$	Exp. comb. bkg	1995^{+34}_{-34}	$59.2^{+3.3}_{-3.2}$	$12.6^{+1.6}_{-1.5}$	$4.44^{+0.99}_{-0.86}$	$1.67^{+0.66}_{-0.54}$	$0.75^{+0.58}_{-0.40}$	$0.44^{+0.57}_{-0.38}$	$0.22^{+0.48}_{-0.20}$
	Exp. peak. bkg	$0.78^{+0.38}_{-0.29}$	$0.40^{+0.14}_{-0.10}$	$0.311^{+0.107}_{-0.079}$	$0.280^{+0.092}_{-0.068}$	$0.314^{+0.103}_{-0.076}$	$0.297^{+0.096}_{-0.071}$	$0.309^{+0.101}_{-0.075}$	$0.296^{+0.107}_{-0.079}$
	Exp. cross-feed	$0.43^{+0.13}_{-0.13}$	$0.205^{+0.044}_{-0.037}$	$0.163^{+0.032}_{-0.027}$	$0.145^{+0.025}_{-0.021}$	$0.168^{+0.029}_{-0.025}$	$0.174^{+0.029}_{-0.024}$	$0.199^{+0.033}_{-0.029}$	$0.206^{+0.046}_{-0.040}$
	Exp. signal	$0.328^{+0.096}_{-0.097}$	$0.158^{+0.030}_{-0.027}$	$0.125^{+0.022}_{-0.019}$	$0.112^{+0.016}_{-0.015}$	$0.129^{+0.019}_{-0.017}$	$0.134^{+0.018}_{-0.016}$	$0.153^{+0.022}_{-0.019}$	$0.159^{+0.032}_{-0.029}$
	Observed	1904	50	20	5	2	1	4	1