

Experimental report on

$$B_{(s)}^0 \rightarrow \mu^+ \mu^-$$

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Why $B_{(s)}^0 \rightarrow \mu^+ \mu^-$?

➤ Rare Process in SM:

- Flavour Changing Neutral Current
- Helicity Suppressed

➤ Precise SM Prediction (improved by 37% due to F_{B_s} ¹ and τ_{B_s})

- Budget: $|V_{tb}^* V_{ts}| : 4\%$ $F_{B_s} : 2.7\%$ $M_t : 1.5\%$ $\tau_{B_s} : 0.7\%$

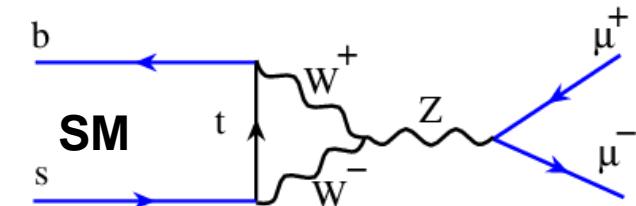
$$B^0 (B_s^0 \rightarrow \mu^+ \mu^-)_{SM} = (3.25 \pm 0.17) \times 10^{-9}$$

$$B (B^0 \rightarrow \mu^+ \mu^-)_{SM} = (1.07 \pm 0.10) \times 10^{-10}$$

Time integrated BR: PRD86, 014027

$$\langle B(B_s^0 \rightarrow \mu^+ \mu^-)_{SM} \rangle = B^0 / (1 - y_s)$$

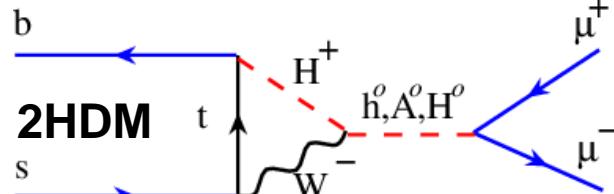
$$= (3.46 \pm 0.18) \times 10^{-9}$$



NEW! 03/13 arXiv 1303.3820
Eur.Phys.J. C72 (2012)

NEW y_s ! 04/13
LHCb.2012.002 → HFAG average
 $0.088 \pm 0.015 \rightarrow 0.061 \pm 0.006$

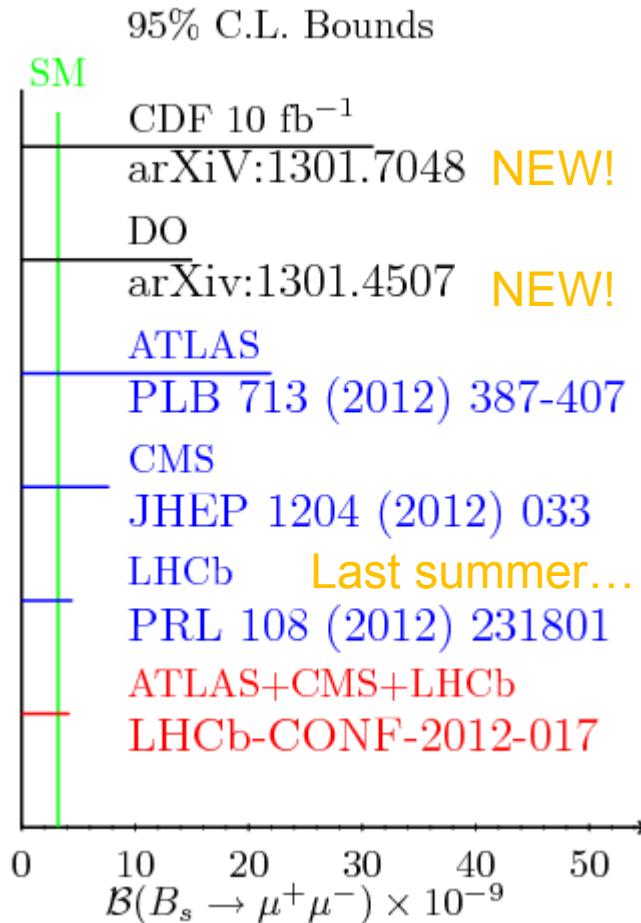
➤ New Physics measurable contributions could show up



1. arXiv 1302.2644
awaiting for confirmation

Experimental Status – Limit-wise

Drastic improvement of the upper limits during the past year:



- LHCb last summer 2012 Results:
 $B(B_s^0 \rightarrow \mu^+ \mu^-) < 4.5 \times 10^{-9}$
- Significant NP enhancements ruled out for $B(B_s^0 \rightarrow \mu^+ \mu^-)$
- Not the end of the story...

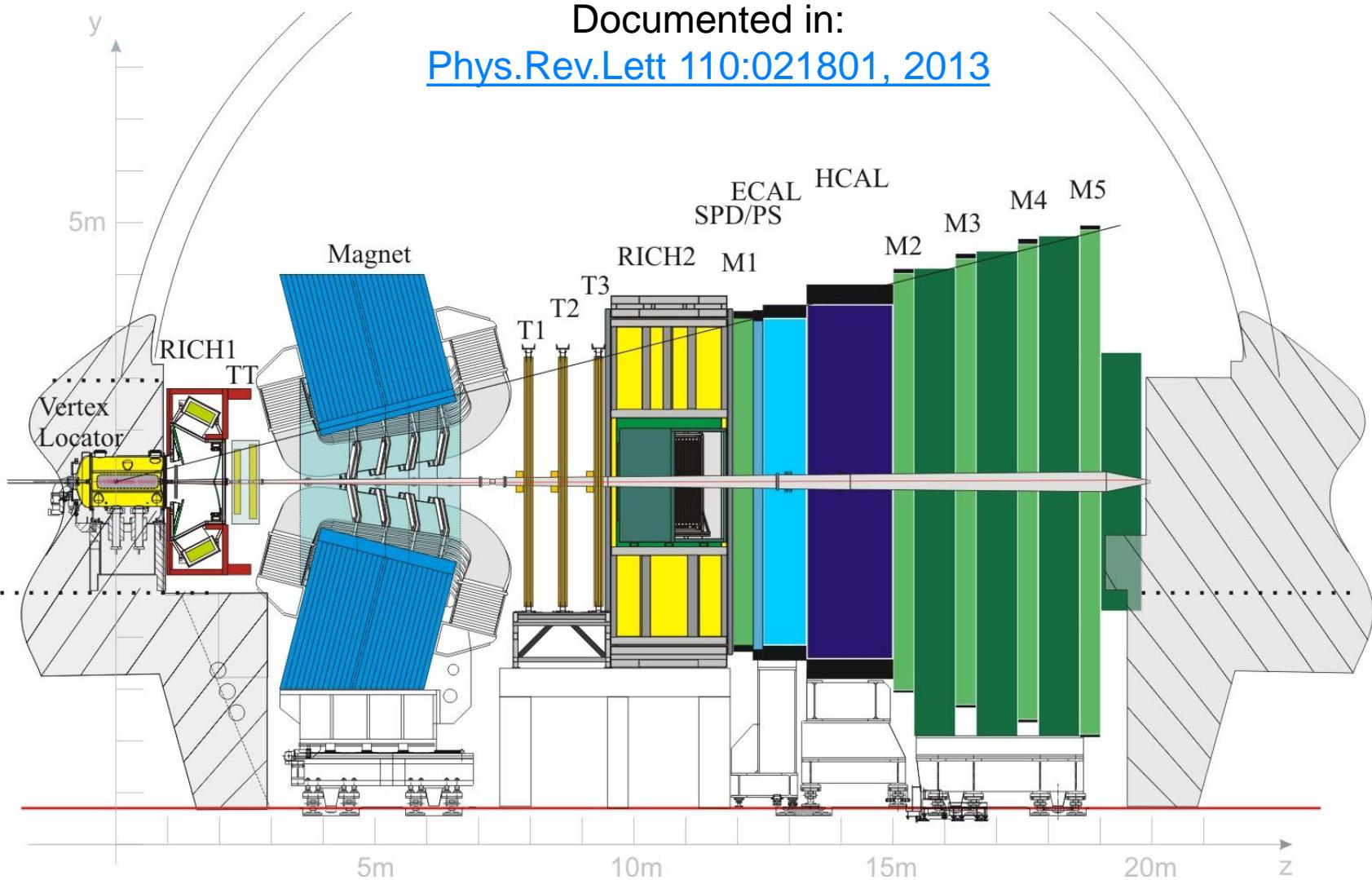
LHCb 2012 Analysis

~ First Evidence ~

Apologies for being so brief on other experiments analysis

$B_s^0 \rightarrow \mu^+ \mu^-$ at LHCb

Documented in:
[Phys.Rev.Lett 110:021801, 2013](https://doi.org/10.1103/PhysRevLett.110.021801)



Overview of the Analysis

Strategy:

1. Loose selection
2. Classify events in a 2D binned plane

➤ $m_{\mu\mu} \times \text{BDT}$ combining topological information

and derive expectations for sig and bkg

➤ need control channels

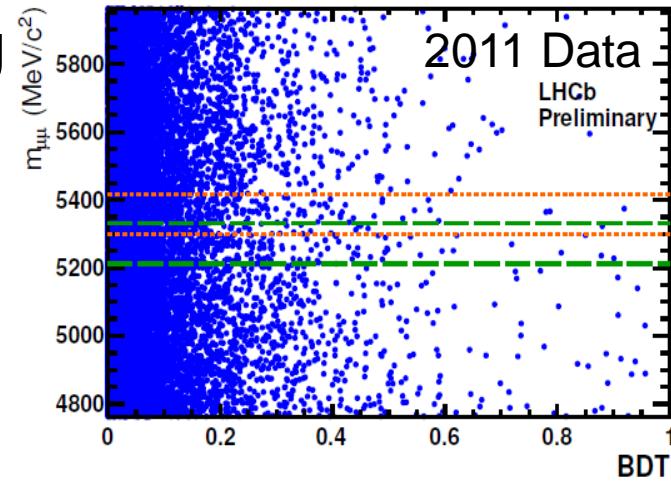
$B \rightarrow hh'$ and $B^+ \rightarrow J/\psi K^+$

3. Extract Limit and BR

Data Set:

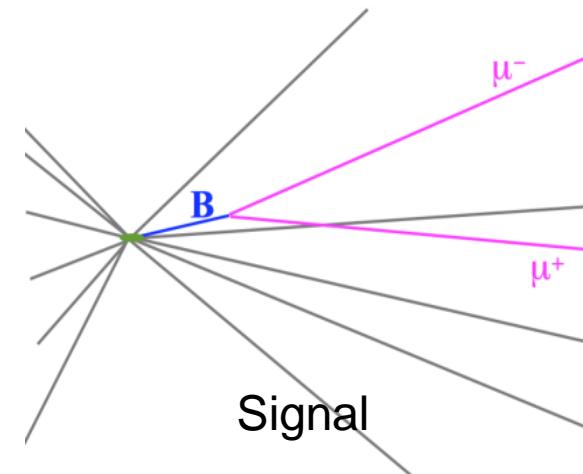
1.0 fb^{-1} + 1.1 fb^{-1} collected in 2011 and 2012 at 7 and 8 TeV

Blind analysis: all choices are made without looking at the signal region

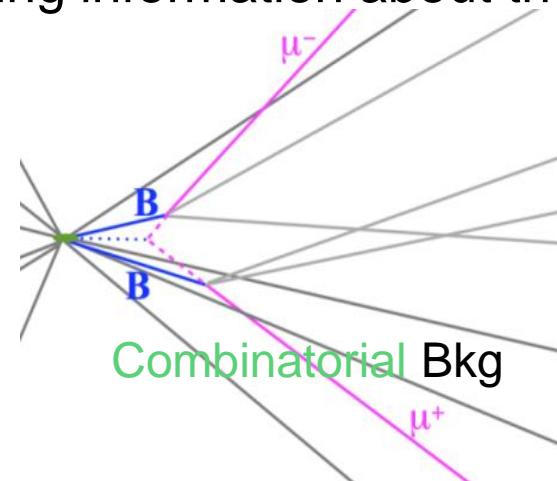


Selection

- Selection should be:
 - very efficient for the signal
 - similar for signal and control channels
- Initial Selection requires:
 - good tracks with a large impact parameter
 - good and displaced secondary vertex pointing to the primary vertex
 - good particle ID to remove $B \rightarrow h^+ h^- (\mu^+ \mu^-)$
- Tighten initial selection to reduce combinatorial bkg:
 - cut on the output of a MVA combining information about the candidate topology

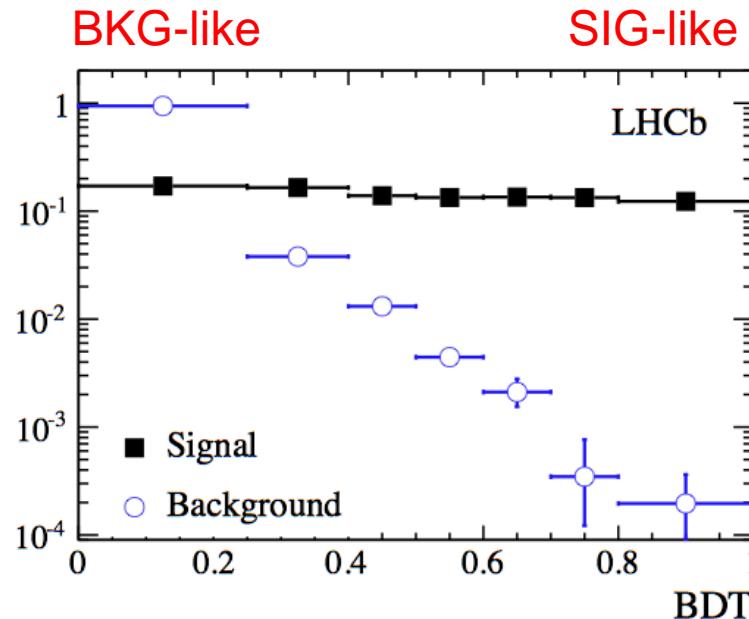


70% bkg rejection
95% sig efficiency



Classification

- Boosted Decision Tree
- Inputs : 9 variables uncorrelated with $m_{\mu\mu}$
- Flat for signal by design
- Signal line shape calibrated on data using an unbiased $B^0 \rightarrow hh'$ sample (same topology as signal)



Combinatorial Background

- 2011 strategy**

Exponential interpolation from the mass side-bands:
 $[4900 - 5000] \cup [5432 - 6000] \text{ MeV}/c^2$

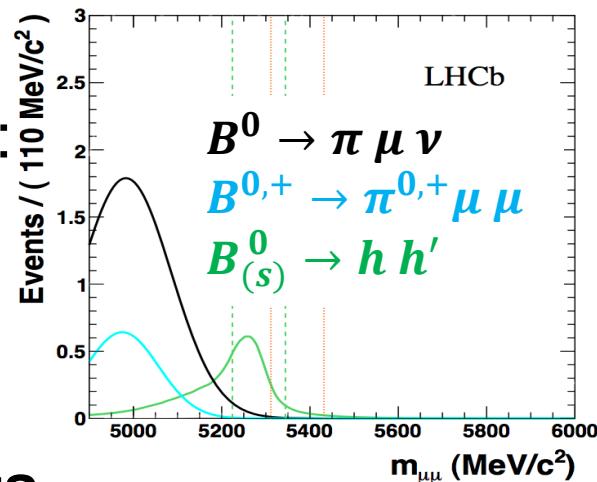
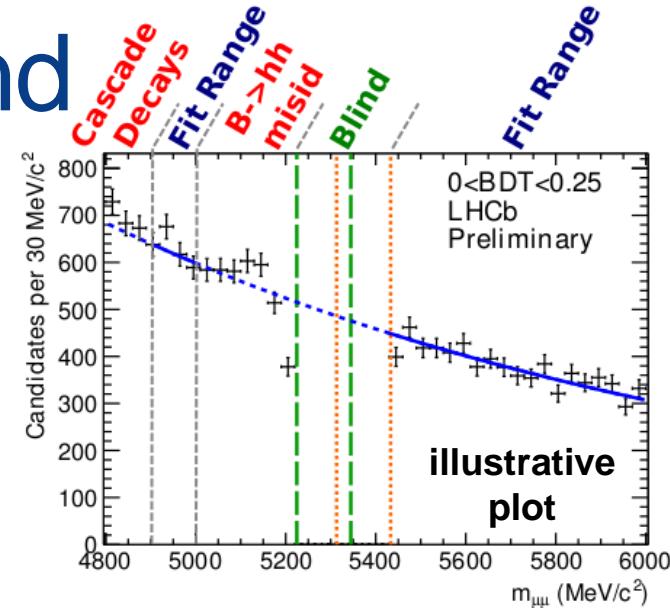
- 2012 refinement**

Study additional background sources:

$$B^0 \rightarrow \pi \mu \nu \quad \text{and} \quad B^{0,+} \rightarrow \pi^{0,+} \mu \mu$$

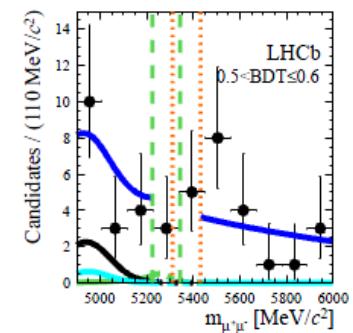
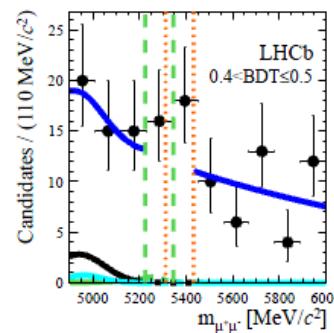
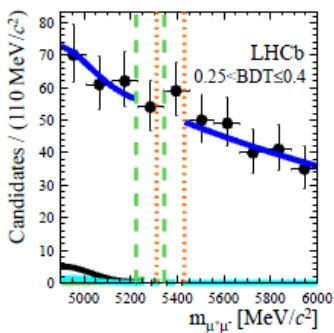
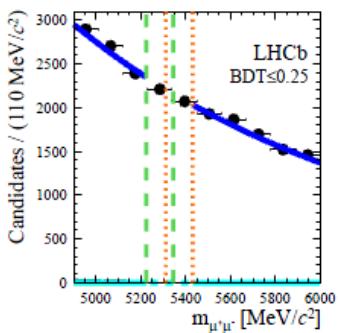
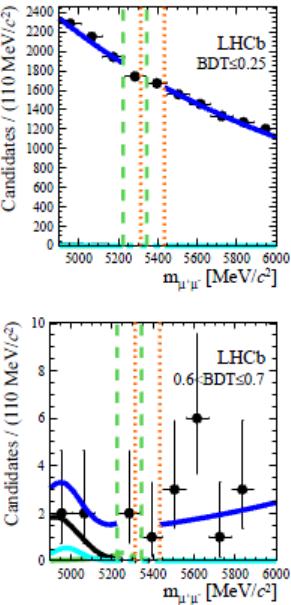
➤ Yields for $[4900 - 6000] \text{ MeV}/c^2, \text{BDT}>0.8$:

$B^0 \rightarrow \pi \mu \nu$	4.04 ± 0.28
$B^{0,+} \rightarrow \pi^{0,+} \mu \mu$	1.32 ± 0.39
$B_{(S)}^0 \rightarrow h h'$	1.37 ± 0.11

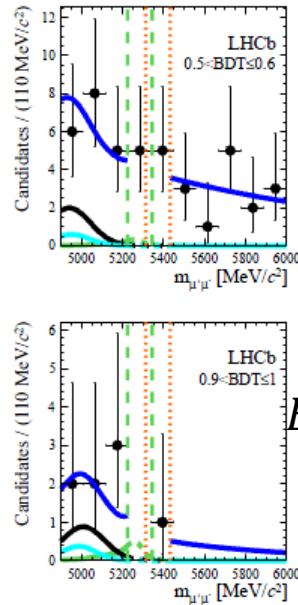
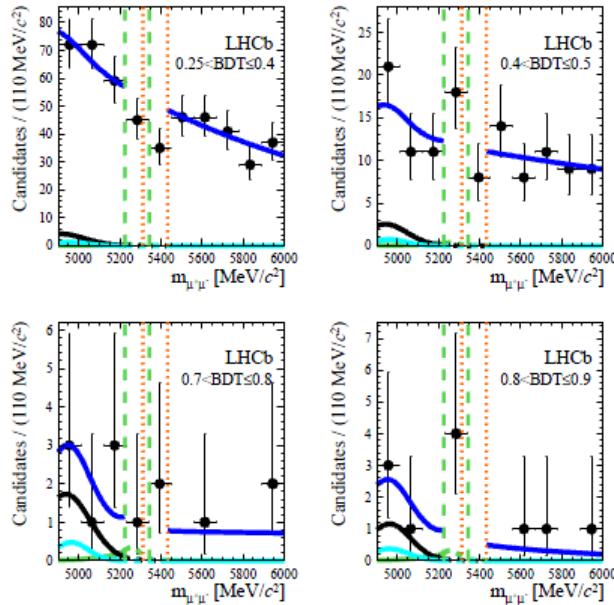


- Re-evaluate 2011 Bkg and update limits**
 interpolation: exponential + exclusive PDF

2012



— Full PDF
 - - $B_{(s)}^0 \rightarrow h^+ h^-$
 — $B^0 \rightarrow \pi^- \mu^+ \nu_\mu$
 — $B^{0(+)} \rightarrow \pi^0(+) \mu^+ \mu^-$



2011

Upper Limits: new (old)

$$B(B_s^0 \rightarrow \mu\mu) < 5.1 (4.5) \times 10^{-9}$$

$$B(B^0 \rightarrow \mu\mu) < 13 (10.3) \times 10^{-10}$$

at 95%CL

Normalisation

- Number of signal events corresponding to a B :

$$N_{B_{(s)}^0 \rightarrow \mu^+ \mu^-} \propto B(B_{(s)}^0 \rightarrow \mu^+ \mu^-) \times N_{B_s}$$

- N_{B_s} obtained with a channel of known BR:

$$N_{B_s} \propto \frac{N_{B^+ \rightarrow J/\psi K^+}}{B(B^+ \rightarrow J/\psi K^+)} \times \frac{f_s}{f_u}$$

$$N_{B_s} \propto \frac{N_{B^0 \rightarrow K\pi}}{B(B^0 \rightarrow K\pi)} \times \frac{f_s}{f_d}$$

- Correcting for efficiencies:

$$N(B_s^0 \rightarrow \mu^+ \mu^-) = B(B_{(s)}^0 \rightarrow \mu^+ \mu^-) \times \frac{N_{norm}}{B_{norm}} \frac{\epsilon_{sig}^{REC} \epsilon_{sig}^{SEL,REC}}{\epsilon_{norm}^{REC} \epsilon_{norm}^{SEL,REC}} \frac{\epsilon_{sig}^{TRIG,SEL}}{\epsilon_{norm}^{TRIG,SEL}} \frac{f_{B_{(s)}^0}}{f_{norm}}$$

Extracted
from Data

Evaluated from MC,
x-checked with data

Measured on
data

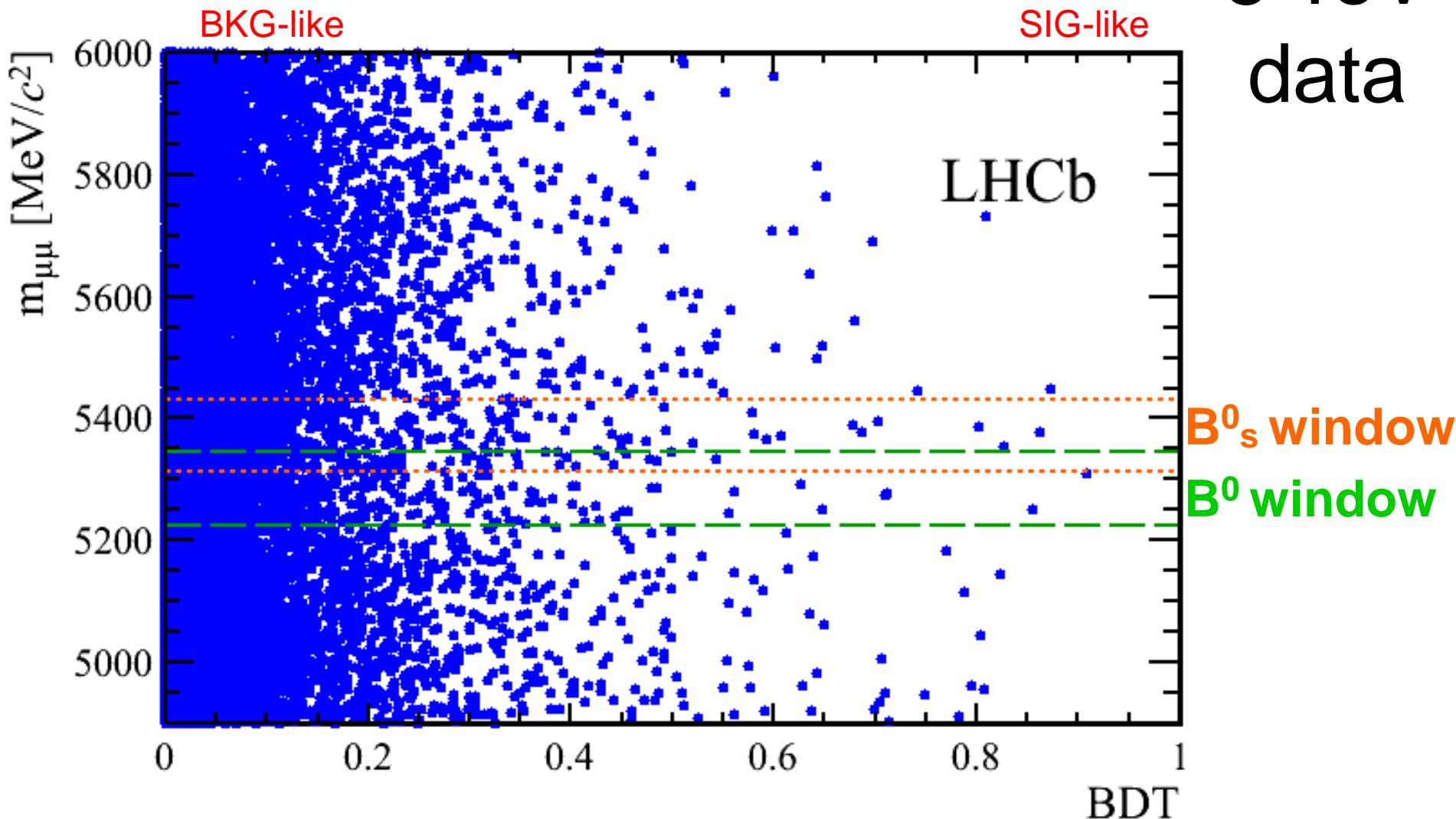
Ratio of prob for a b quark
to hadronise into a $B_{(s)}^0$ or
into the norm. init. state

SM expectations 2012+2011 in the mass windows:
13 + 11 $B_s^0 \rightarrow \mu^+ \mu^-$ and **1.5 + 1.3 $B^0 \rightarrow \mu^+ \mu^-$**

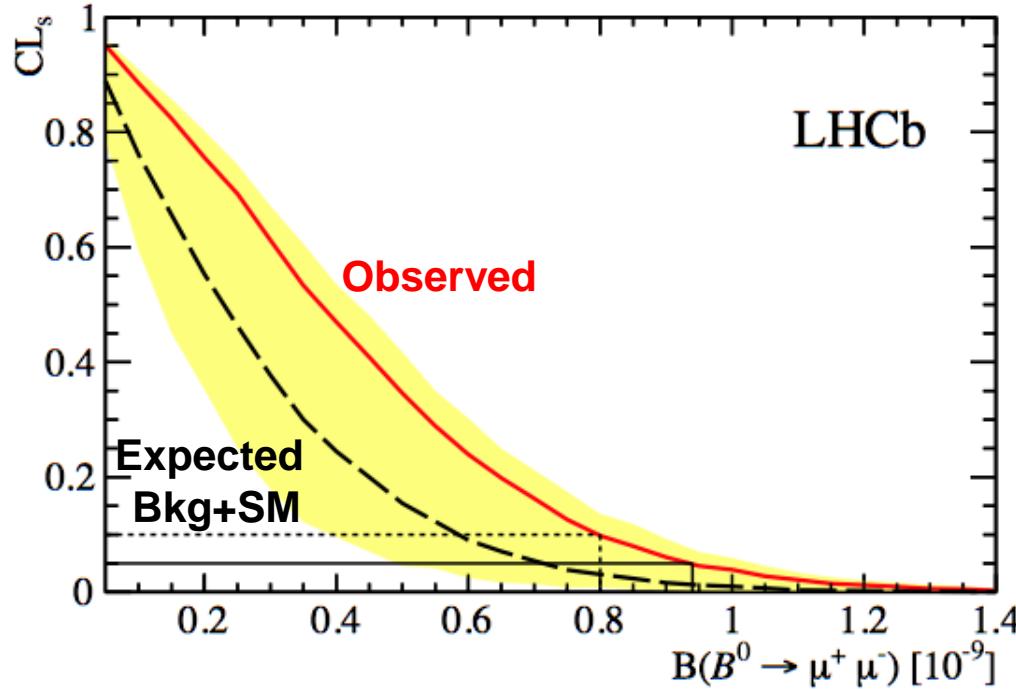
Results

2012
8 TeV
data

Mass-BDT plane



$B^0 \rightarrow \mu^+ \mu^-$ upper limits 2011-2012



Compatibility with
bkg only
hypothesis:

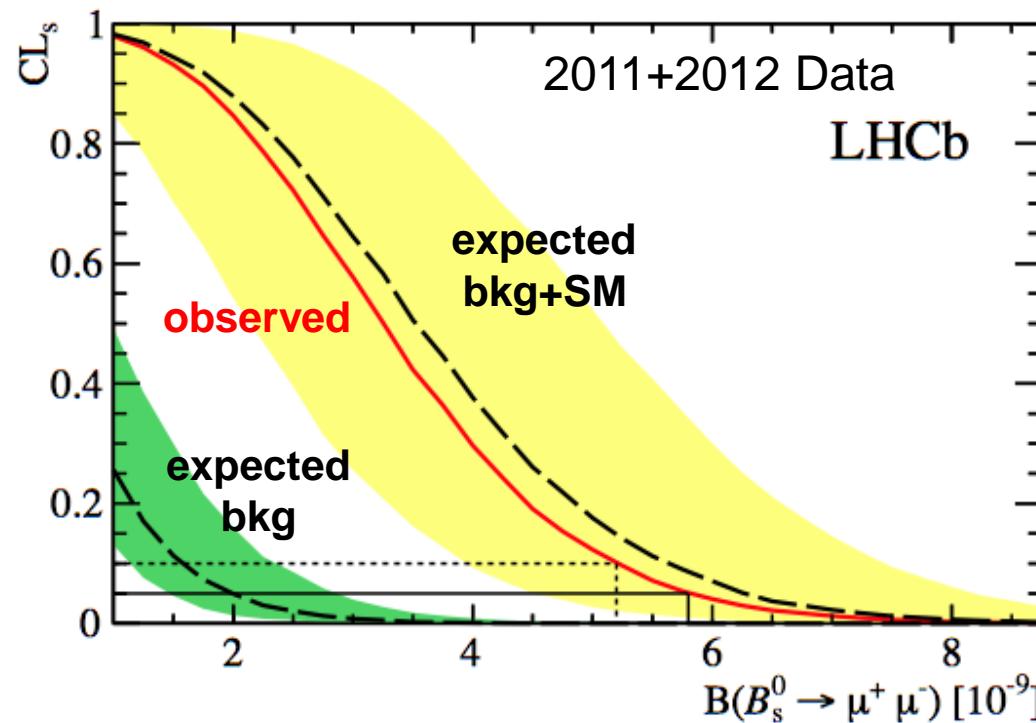
p-value = 11%

Obs. limit: $B(B^0 \rightarrow \mu^+ \mu^-) < 9.4 \times 10^{-10}$ at 95% CL

Exp. limit: $B(B^0 \rightarrow \mu^+ \mu^-) < 7.1 \times 10^{-10}$ at 95% CL

$B_s^0 \rightarrow \mu^+ \mu^-$ sensitivity 2011-2012

- Good separation Bkg Only / Bkg+SM expectations



- Double-sided limit at 95% CL:
 $1.1 < B(B_s^0 \rightarrow \mu^+ \mu^-) \times 10^9 < 6.4$

With lower and upper limits evaluated at:
 $CL_{s+b} = 0.975$ and $CL_{s+b} = 0.025$

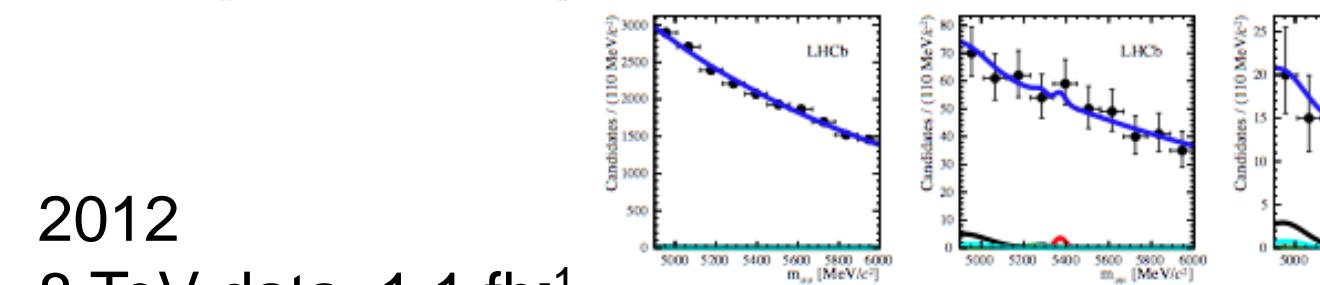
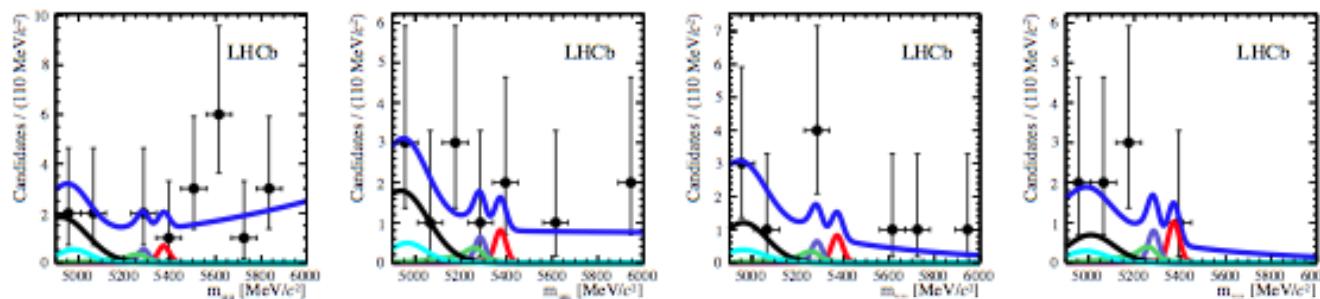
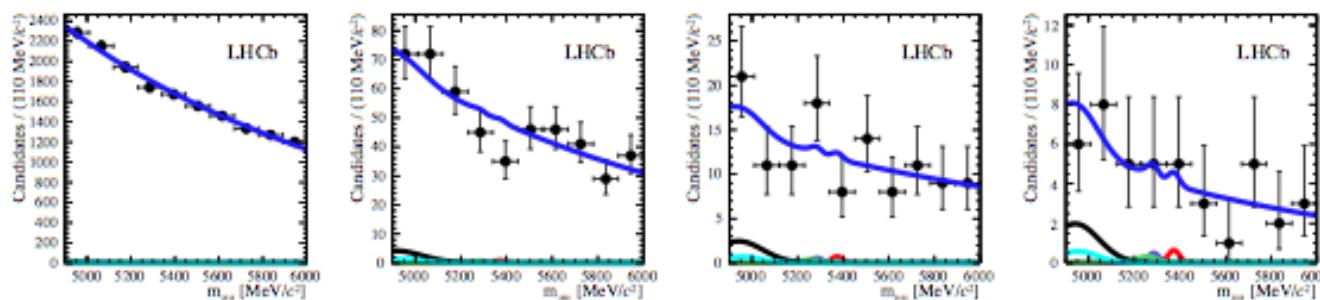
Bkg only p-value: 5.3×10^{-4}
3.5 σ excess
FIRST EVIDENCE

Unbinned maximum likelihood fit

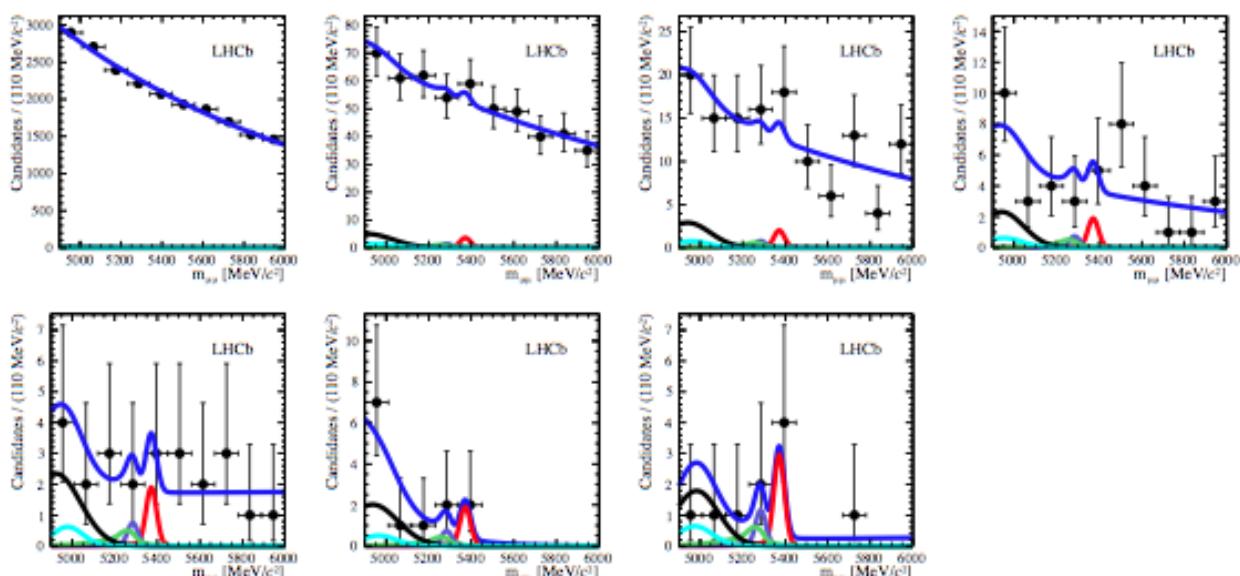
2011

7 TeV data, 1.0 fb⁻¹
8 BDT bins

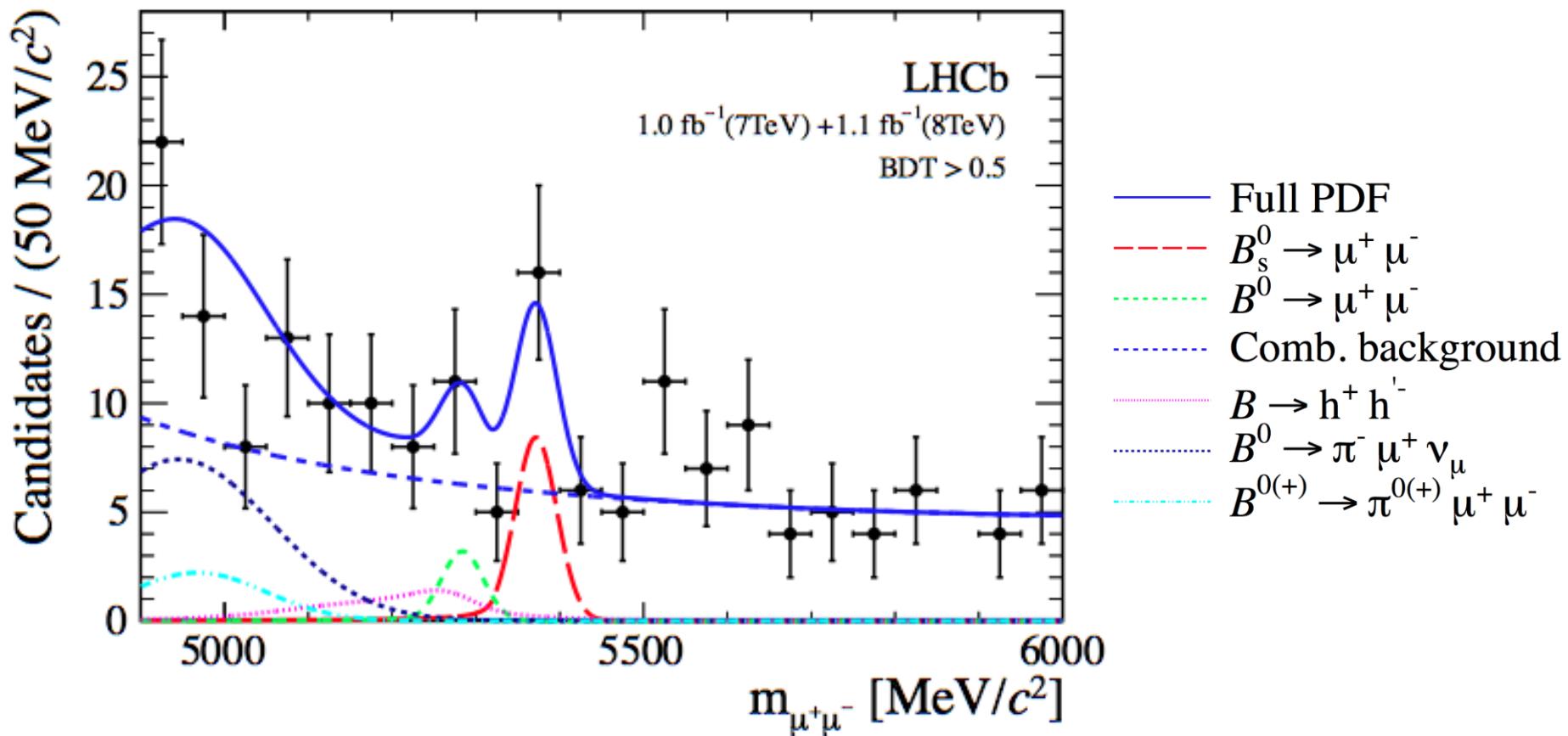
$$\begin{aligned}
 & B_s^0 \rightarrow \mu^+ \mu^- \\
 & B^0 \rightarrow \mu^+ \mu^- \\
 & B_s^0 \rightarrow h^+ h'^- \\
 & B^0 \rightarrow \pi^- \mu^+ \nu_\mu \\
 & B^{\pm,0} \rightarrow \pi^{\pm,0} \mu^+ \mu^- \\
 & \text{total}
 \end{aligned}$$



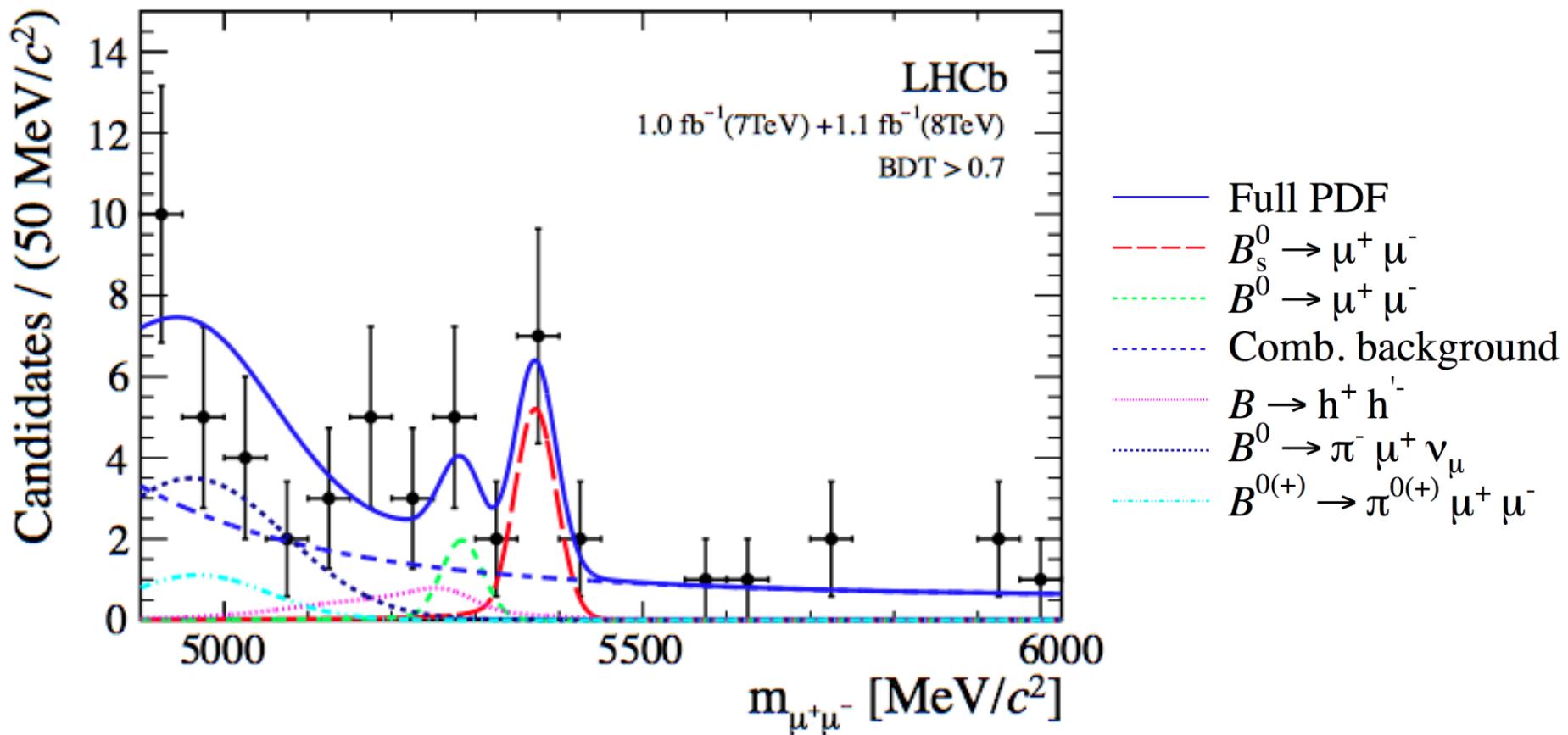
2012
8 TeV data, 1.1 fb⁻¹
7 BDT bins



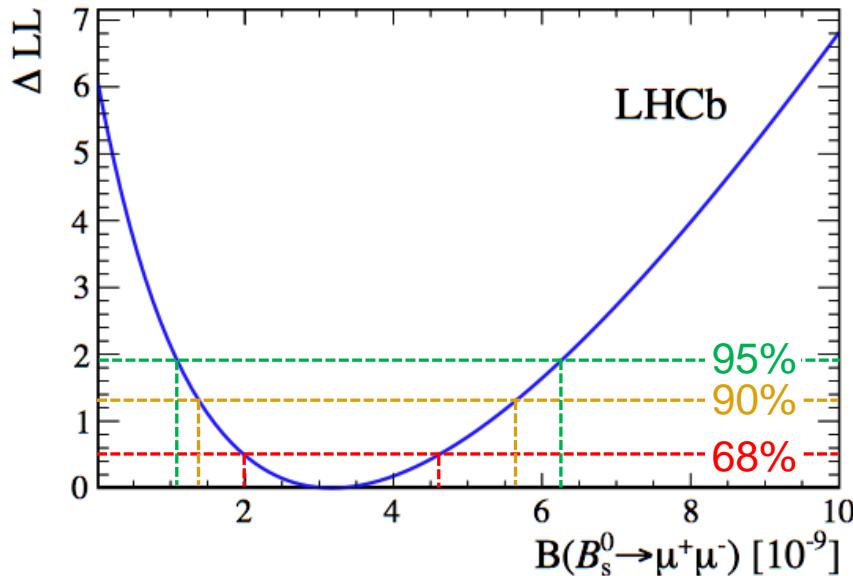
In the Signal Region BDT>0.5



In the Signal Region $BDT > 0.7$



Fit Results 2011+2012



- Profile Likelihood

all parameters except $B(B_s^0 \rightarrow \mu^+ \mu^-)$ are floated within their errors.

$$B(B_s^0 \rightarrow \mu^+ \mu^-) = (3.2^{+1.5}_{-1.2}) \times 10^{-9}$$

- Value in agreement with SM time integrated prediction :
 $B(B_s^0 \rightarrow \mu^+ \mu^-)_{SM} = (3.46 \pm 0.18) \times 10^{-9}$

Nota: 95% interval in perfect agreement with the one provided by the CL_s method

Measurements vs NP Predictions (I)

- Time-dependent decay rate in the mass eigenstates:

$$\langle \Gamma(B_s^0(t) \rightarrow \mu^+ \mu^-) \rangle \equiv R_H e^{-\Gamma_H^S t} + R_L e^{-\Gamma_L^S t}$$

- Γ is model dependent and parametrised by:

$$A_{\Delta\Gamma} = \frac{R_H - R_L}{R_H + R_L} \underset{SM}{\Rightarrow} 1.0 \quad \text{and} \quad y_s = \frac{\Gamma_L - \Gamma_H}{\Gamma_L + \Gamma_H}$$

- Initial CP average BR used for predictions:

$$B^0(B_s^0 \rightarrow f) \equiv \frac{\tau_{B_s^0}}{2} \langle \Gamma(B_s^0(t) \rightarrow f) \rangle \Big|_{t=0}$$

- Time integrated BR experimentally measured:

$$\begin{aligned} \langle B(B_s^0 \rightarrow f) \rangle &= \frac{1}{2} \int_0^\infty \langle \Gamma(B_s^0(t) \rightarrow f) \rangle dt \\ &= B^0(B_s^0 \rightarrow f) \frac{1 - y_s^2}{1 + A_{\Delta\Gamma} \times y_s} \end{aligned}$$

- Translating measurement to prediction is model dependent:

translation factor varies by 15% over $A_{\Delta\Gamma}$ range

Measurements vs NP Predictions (II)

- Time integrated efficiency:

$$\epsilon_{sig} = \frac{\int \Gamma(A_{\Delta\Gamma}, y_s, t) \times \epsilon_{sig}(t) dt}{\int \Gamma(A_{\Delta\Gamma}, y_s, t) dt}$$

- ϵ_{sig} is model dependent since $\Gamma = \Gamma(A_{\Delta\Gamma}, y_s)$
- ϵ_{sig} is used in normalisation and BDT PDF Calibration
- Preliminary studies:

Normalisation varies by ~6% over $A_{\Delta\Gamma}$ range

Bin 7 (most sensitive) varies by ~14% over $A_{\Delta\Gamma}$ range

- Conclusion:

➤ Analysis results are model dependent

➤ Provide results parametrised by $A_{\Delta\Gamma}$ or (far future) fit $A_{\Delta\Gamma}$

Conclusions

- $B_{(s)}^0 \rightarrow \mu^+ \mu^-$ are very powerful tests of the SM

- Constrains on $B^0 \rightarrow \mu^+ \mu^-$:

$$\mathbf{B}(B^0 \rightarrow \mu^+ \mu^-) < 9.4 \times 10^{-10}$$

- First evidence of $B_s^0 \rightarrow \mu^+ \mu^-$:

$$\begin{aligned} \mathbf{p\text{-}value: } & 5.3 \times 10^{-4} \\ & 3.5\sigma \end{aligned}$$

- BR measurement:

$$\mathbf{B}(B_s^0 \rightarrow \mu^+ \mu^-) = 3.2^{+1.5}_{-1.2} \times 10^{-9}$$

Analyses aiming for a precision measurement

- Analysis results are model dependent

Prospects: Precision Measurements

Short Scale:

- Major Update from CMS
- Update from LHCb
- More statistics
- MVA?

Longer Scale:

- LHCb Run 2: $B(B_s^0 \rightarrow \mu^+ \mu^-)$ at $\pm 0.5 \times 10^{-9}$
- LHCb Upgrade: $B(B_s^0 \rightarrow \mu^+ \mu^-)$ at $\pm 0.15 \times 10^{-9}$

LHCb-TDR-012

➤ New Observables:

- $\frac{B(B_s^0 \rightarrow \mu^+ \mu^-)}{B(B^0 \rightarrow \mu^+ \mu^-)}$
- $A_{\Delta\Gamma}$ via a time dependent analysis

arXiv 1303.3820/1204.1737

Spares

D0 – CDF – ATLAS – CMS – Analyses

	D0	CDF	ATLAS	CMS	LHCb
$\int \mathcal{L}$ [fb $^{-1}$]	10.4	10	3.4	5	1+1.1
\sqrt{s} [TeV]	1.96	1.96	7	7	7+8
$N(B^+ \rightarrow J\psi K^+)$	87.4K	30.2K	6.8K	106.5K	340.1K+424.2K
$\sigma_{B_s^0}$ [MeV/c 2]	125	24	60 – 110	37 – 77	25
$N(B_s^0 \rightarrow \mu^+ \mu^-)_{SM}$	1.23	2.4	0.88	2.7	11+13
$B(B_s^0 \rightarrow \mu^+ \mu^-) \times 10^9 <^{95\%}_{CL}$	15	31	22	7.7	4.2 + Evidence
Analysis Type	MVA	MVA	MVA	NO MVA	MVA

- No more updates expected by Tevatron experiments ☹
- New results by CMS, eagerly waited:
 - More statistics
 - MVA analysis?

Fit Statistical Error

Fix all the nuisance parameters to their expectations, subtract the error in quadrature with the errors obtained when all parameters are floating:

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

fully dominated by stat error

Comparison 2012-2011

- 2011, 7 TeV (1 fb^{-1})

$$B(B_s^0 \rightarrow \mu^+ \mu^-) = 1.4_{-1.3}^{+1.7} \times 10^{-9}$$

p-value 0.11

- 2012, 8 TeV (1.1 fb^{-1}):

$$B(B_s^0 \rightarrow \mu^+ \mu^-) = 5.1_{-1.9}^{+2.4} \times 10^{-9}$$

p-value 9×10^{-4}

results from 7 TeV and 8 TeV are compatible at $\sim 1.5\sigma$

Exclusive Background Effect on 2011

New Analysis:

- $B_s^0 \rightarrow \mu^+ \mu^-$
 - bkg only p-value: 0.11
 - $\text{UL} = 5.1 \times 10^{-9}$, 95% CL
- $B^0 \rightarrow \mu^+ \mu^-$
 - bkg only p-value: 0.19
 - $\text{UL} = 13 \times 10^{-10}$, 95% CL

Published Analysis

- $B_s^0 \rightarrow \mu^+ \mu^-$
 - bkg only p-value: 0.18
 - $\text{UL} = 4.5 \times 10^{-9}$, 95% CL
- $B^0 \rightarrow \mu^+ \mu^-$
 - bkg only p-value: 0.60
 - $\text{UL} = 10.3 \times 10^{-10}$, 95% CL

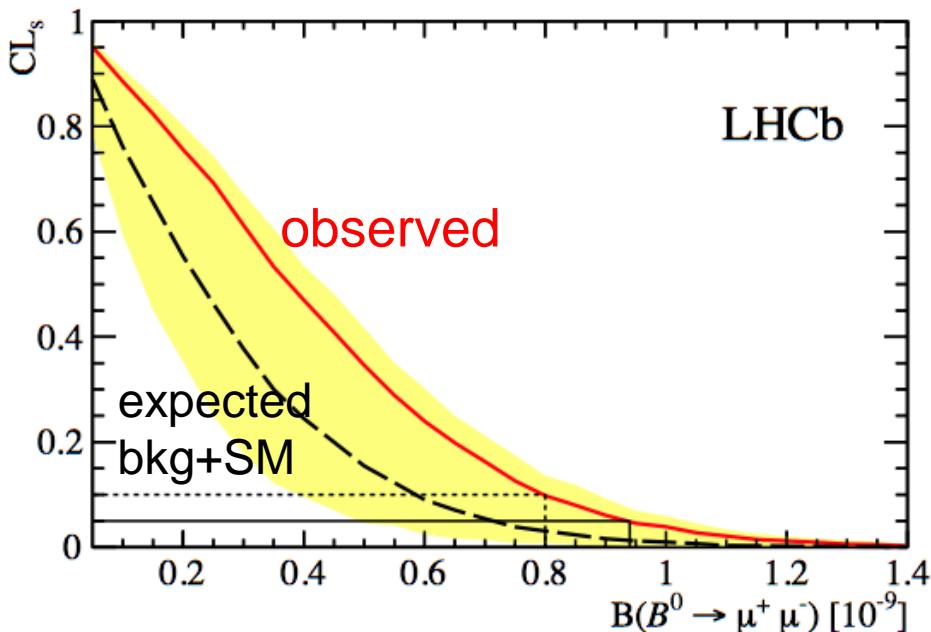
$B^0 \rightarrow \mu^+ \mu^-$: limits and sensitivity

7 TeV (1 fb^{-1}) + 8 TeV (1.1 fb^{-1}):

$$B(B^0 \rightarrow \mu^+ \mu^-) < 9.4 \times 10^{-10}$$

bkg only p-value (1-CL_b): 0.11
 (corresponds to $\sim 1.5\sigma$ excess)

UL are quoted at 95%CL



	Expected UL (SM+bkg)	Observed UL	Observed 1-CL _b
7 TeV	6.0×10^{-10}	$13.0 \times 10^{-10} *$	0,19 *
8 TeV	10.5×10^{-10}	12.5×10^{-10}	0,16
7TeV + 8TeV	7.1×10^{-10}	9.4×10^{-10}	0,11

*published results:
 UL = 10.3×10^{-10}
 1-CL_b = 0.60

Some projections

- From LHCb-TDR-012:

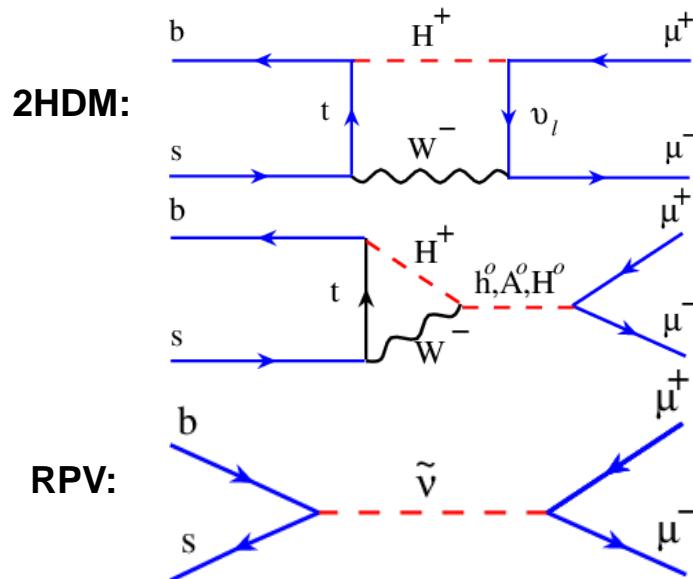
Obs.	End 2018	LHCb upgrade $50fb^{-1}$
$B(B_s^0 \rightarrow \mu^+ \mu^-)$	0.5×10^{-9}	0.15×10^{-9}
$\frac{B(B_s^0 \rightarrow \mu^+ \mu^-)}{B(B^0 \rightarrow \mu^+ \mu^-)}$	100%	35%

$B_{(s)}^0 \rightarrow \mu^+ \mu^-$ phenomenology

Model independent expression of the Branching Ratio:

$$B(B_s^0 \rightarrow \mu^+ \mu^-) \propto \left(1 - \frac{4m_\mu^2}{m_{B_s}^2}\right) |C_s - C'_s|^2 + \left| (C_P - C'_P) + 2 \frac{m_\mu}{m_{B_s}} (C_{10} - C'_{10}) \right|^2$$

In MSSM: $c_{S,P}^{MSSM} \propto \frac{m_b^2 m_\mu^2 \tan^6 \beta}{M_A^4}$



SM Higgs contribution < 1%

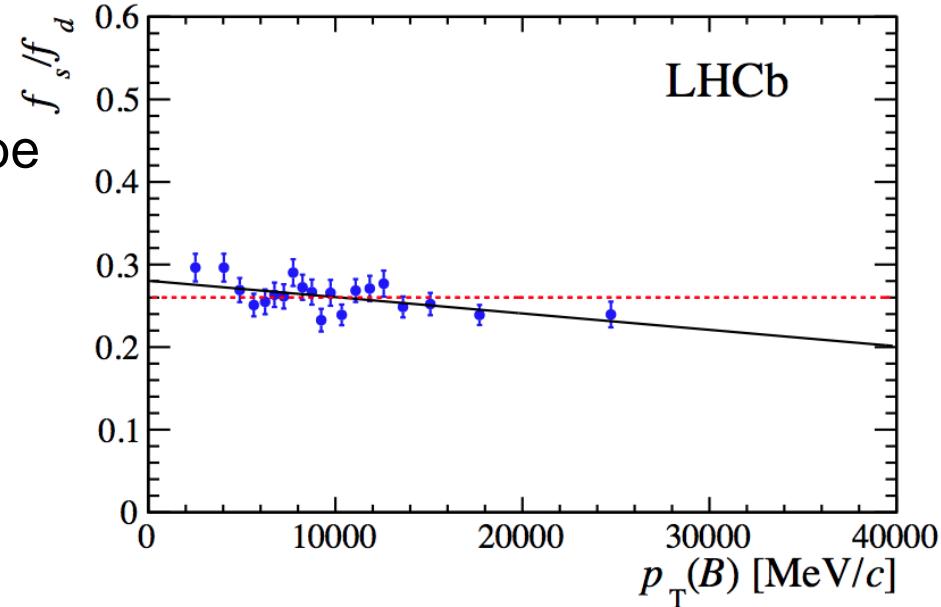
MVA Selection Variables

- B Candidate
 - impact parameter*
 - impact parameter χ^2
 - χ^2 of the vertex
 - pointing angle
 - distance of closest approach
- Muons
 - minimum impact parameter*
- Nota for the following:
 - *Selection biases the life time distribution

Hadronisation Probability f_s/f_d

- f_s/f_d is measured at LHCb by comparing abundances of:
 - $B_s^0 \rightarrow D_s^- \pi^+$, $B^0 \rightarrow D^- K^+$ and $B^0 \rightarrow D^- \pi^+$ arXiv:111.2357 aka PRD85 032008 (2012)
 - $B_s^0 \rightarrow D_s^- \mu^+ X$ and $B^0 \rightarrow D^- \mu^+ X$ LHCb-paper-2012-037 in preparation
- at 7 TeV: $f_s/f_d = 0.256 \pm 0.020$

- p_T dependency small enough to be negligible
- \sqrt{s} dependency checked with $B^+ \rightarrow J/\psi K^+$ and $B_s^0 \rightarrow J/\psi \phi$: stable within 1σ



Mass PDF - Mean

- **Bkg**: see previous slide
- **Signal** Crystal Ball Shape
- **Mean** form $B^0 \rightarrow \pi\pi, K\pi$ and $B_s \rightarrow KK$

$$m_{B^0} = 5284.36 \pm 0.29 \text{ MeV}/c^2$$

$$m_{B_s^0} = 5371.55 \pm 0.44 \text{ MeV}/c^2$$

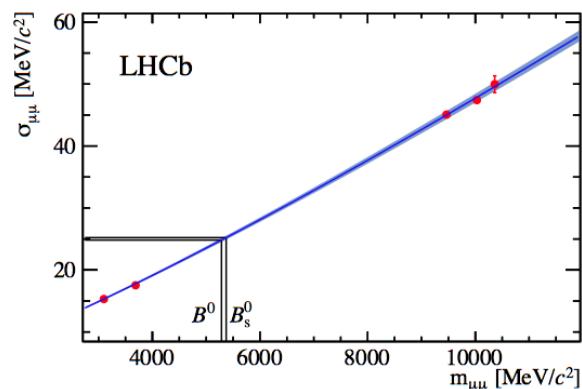
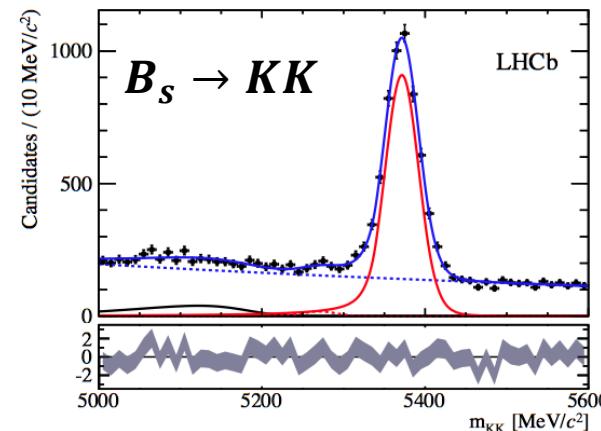
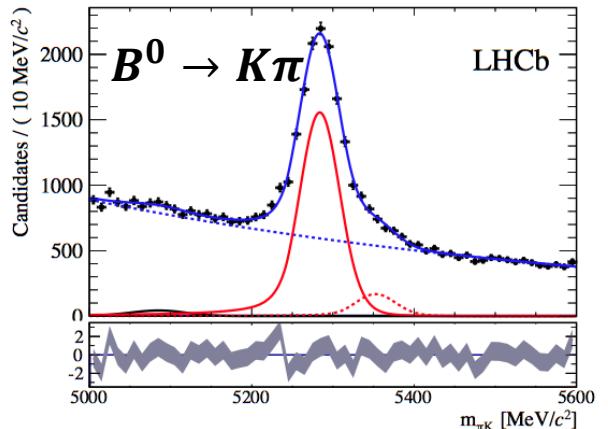
- **Resolution** form $B^0 \rightarrow \pi\pi, K\pi$ and $B_s \rightarrow KK$ averaged with $J/\psi, \psi(2S), \Upsilon(1S, 2S, 3S)$

$$\sigma_{B^0} = 24.63 \pm 0.38 \text{ MeV}/c^2$$

$$\sigma_{B_s^0} = 25.05 \pm 0.40 \text{ MeV}/c^2$$

- Two modes are **resolved** :

$$m_{B_s^0} - m_{B^0} \simeq 3.5\sigma_B$$



Exclusive Backgrounds :

$B_s^0 \rightarrow K^+ \mu^- \bar{\nu}_\mu$ and $B^0 \rightarrow \pi^+ \mu^- \bar{\nu}_\mu$

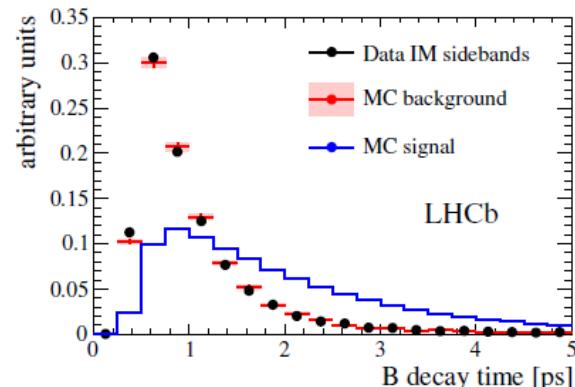
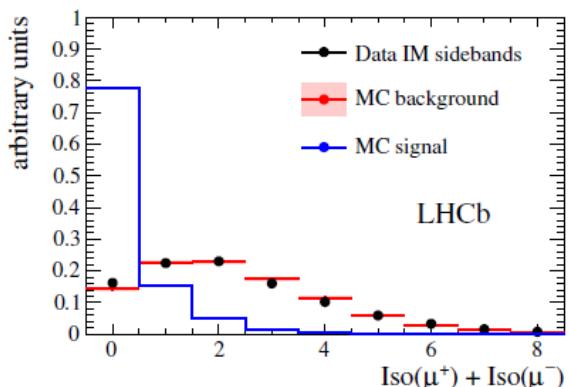
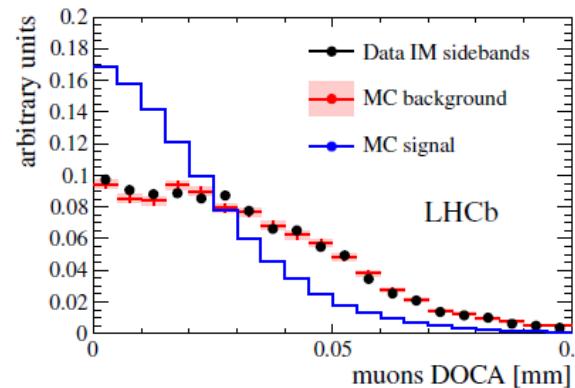
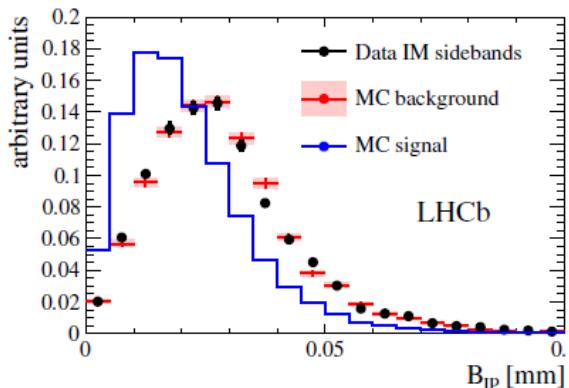
- $B_s^0 \rightarrow K^+ \mu^- \bar{\nu}_\mu$ contribution is found **negligible**
- Accounted in the fit as a **systematics**
- Lower contribution from $B_s^0 \rightarrow K^+ \mu^- \bar{\nu}_\mu$ explained by:
 - $f_s/f_d = 0.26$
 - $B(B_s^0 \rightarrow K^+ \mu^- \bar{\nu}_\mu)/B(B^0 \rightarrow \pi^+ \mu^- \bar{\nu}_\mu) = 0.88$
 - $\epsilon_{K \rightarrow \mu}/\epsilon_{\pi \rightarrow \mu} = 0.28$ (RICH efficiency and $B(K^- \rightarrow \mu^- \bar{\nu}_\mu)/B(\pi^- \rightarrow \mu^- \bar{\nu}_\mu)$)

	2011	2012
$B^0 \rightarrow \pi^- \mu^+ \nu_\mu$	3.51 ± 0.25	4.04 ± 0.28
$B_{(s)}^0 \rightarrow h^+ h'^- \text{ misID}$	0.91 ± 0.12	1.37 ± 0.11
$B^{+(0)} \rightarrow \pi^{+(0)} \mu^+ \mu^-$	1.12 ± 0.35	1.32 ± 0.39
$\Lambda_b^0 \rightarrow p \mu^- \nu$	0.29 ± 0.17	0.50 ± 0.29
$B_s^0 \rightarrow K^- \mu^+ \nu_\mu$	0.33 ± 0.13	0.46 ± 0.19
$B_c^+ \rightarrow J/\psi \mu^+ \nu$	0.29 ± 0.33	0.34 ± 0.39

Yields for
 $[4900 - 6000] \text{MeV}/c^2$, $\text{BDT} > 0.8$

Classification – BDT Definition

- Boosted Decision Tree
- Inputs : 9 inputs variables uncorrelated with $m_{\mu\mu}$
- Trained and tested on MC signal and $b\bar{b} \rightarrow \mu\mu X$



B candidate:

- **proper time**
- impact parameter
- transverse momentum
- B isolation

muons:

- min p_T
- **min IP significance**
- dist. of closest approach
- muon isolation,
- polarisation angle

BDT Variables

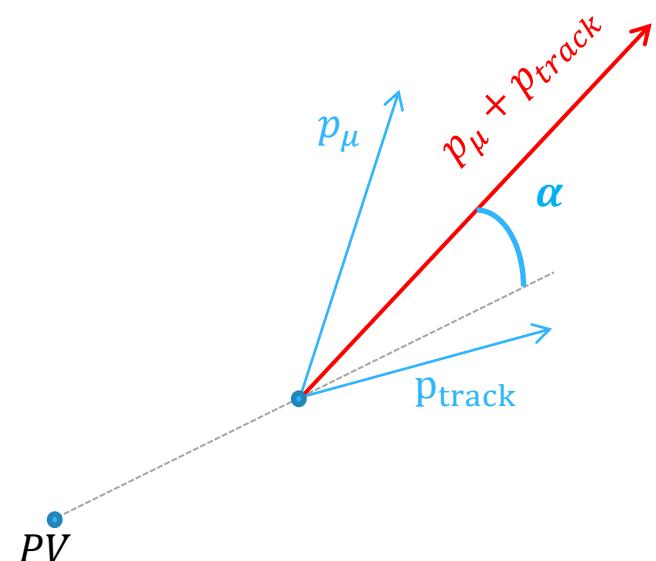
Muon isolation: number of other tracks with which the muon can make a good vertex

Other tracks requirement:

- Long track
- Impact Param Significance with PV > 3

Vertex requirement:

- Angle track-muon<0.27rad
- Distance of Closest Approach < 130 μm
- Distance to PV: 0.5cm< d < 4cm
- Distance to SV: -0.15cm < d < 30cm
- $$\frac{|\vec{p}_\mu + \vec{p}_{\text{track}}| \sin \alpha}{|\vec{p}_\mu + \vec{p}_{\text{track}}| \sin \alpha + p_{T,\mu} + p_{T,\text{track}}} < 0.6$$



BDT Variables

Polarisation Angle:

angle between the muon momentum in the B rest frame and the vector perpendicular to the B momentum and the beam axis

B Isolation:

$$I = \frac{p_{T,B}}{p_{T,B} + \sum_{\text{tracks}} p_{T,\text{track}}}$$

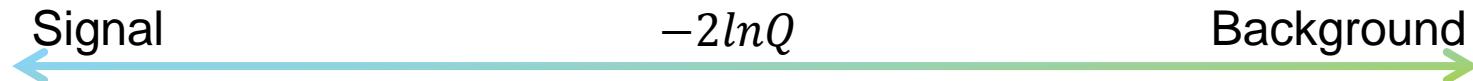
sum running on the tracks such that $\delta\eta^2 + \delta\phi^2 < 1.0$

Combinatorial Background Interpolation

- Fit the mass side-bands with an exponential and separate PDFs for $B_{(s)}^0 \rightarrow h h'$, $B^0 \rightarrow \pi \mu \nu$ and $B^{0,+} \rightarrow \pi^{0,+} \mu \mu$
- PDF determination of Exclusive Bkg:
 - Derive misId probability $\pi, K \rightarrow \mu$ on data in p and p_T bins
 - Apply these probabilities to large MC samples
 - Mass and BDT PDF extracted from the weighted MC sample
 - Normalisation to $B^+ \rightarrow J/\psi K^+$
- Other backgrounds studied; all negligible:
$$B_s^0 \rightarrow K \mu \nu, \quad \Lambda_b \rightarrow p \mu \nu, \quad B_c \rightarrow J\psi(\mu\mu) \mu \nu$$

CLs method

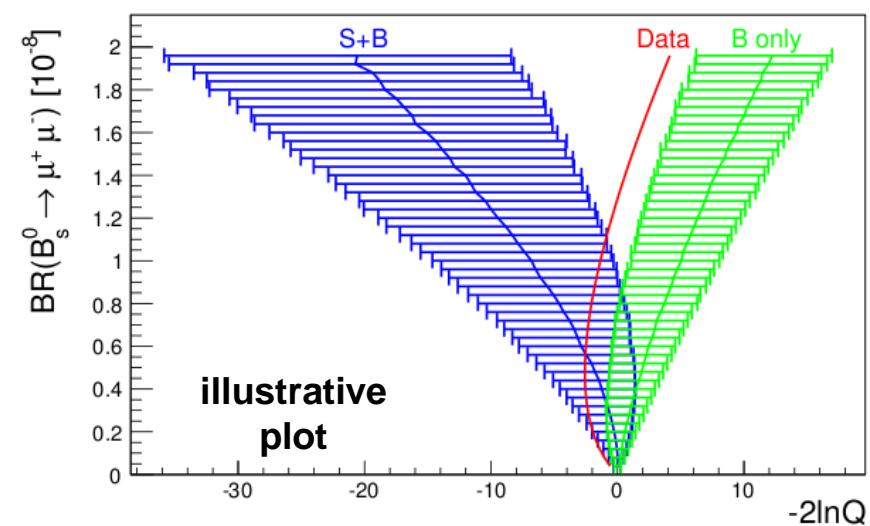
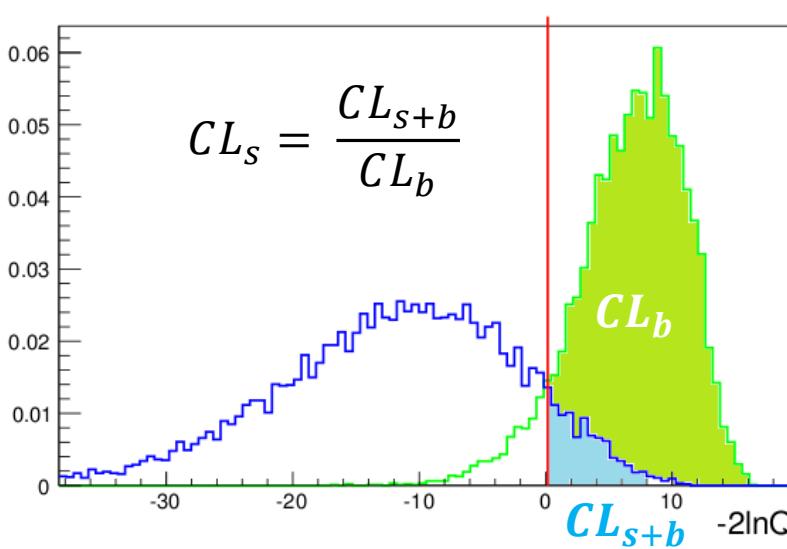
- Idea: compare observed data with expectations
- Define a test statistic for this comparison:

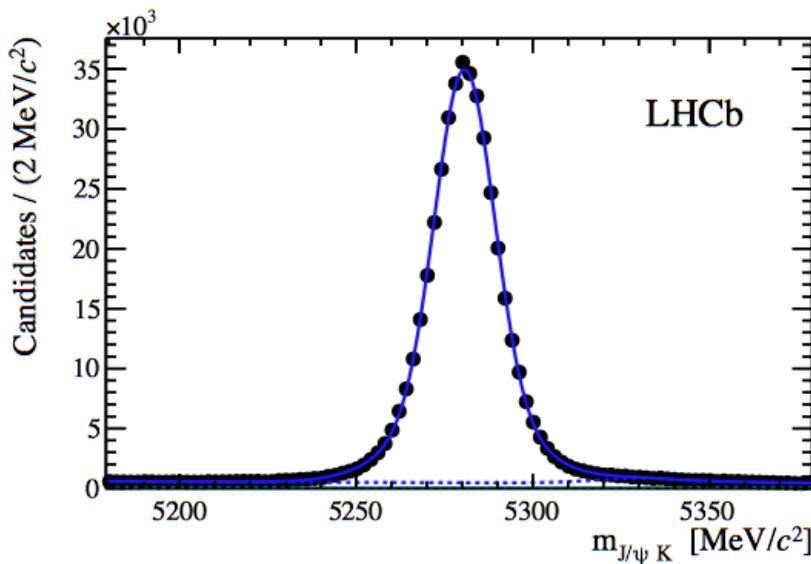
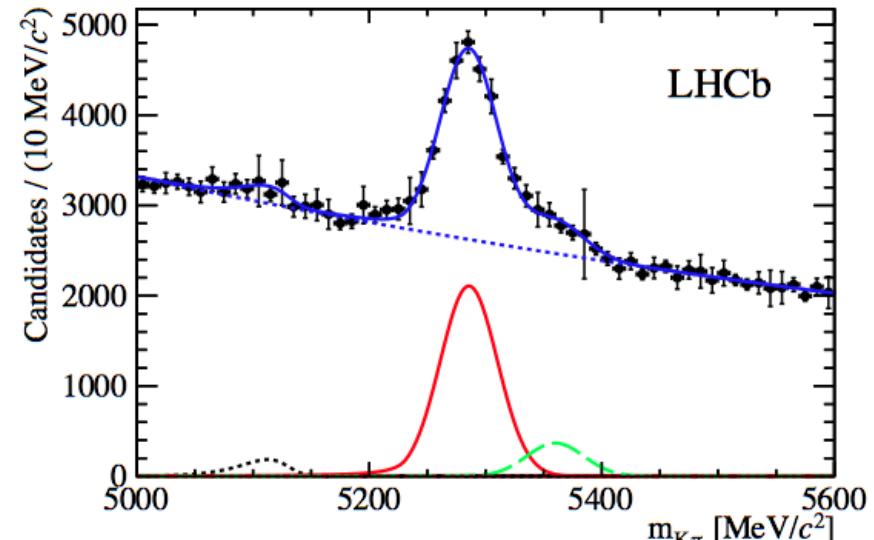


- Calibrate this test statistic with pseudo-experiments

if Br was such then $Bkg\ Only$ would give $-2\ln Q$ of $such$
 $Sig + Bkg$ such

- Compute the $-2\ln Q$ of the observed data



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

 $B^0 \rightarrow K\pi$


- Use f_s/f_d measured at LHCb PRD85 (2012) 032008 and LHCb-PAPER-2012-037
- Weighted average of the 2 channels:

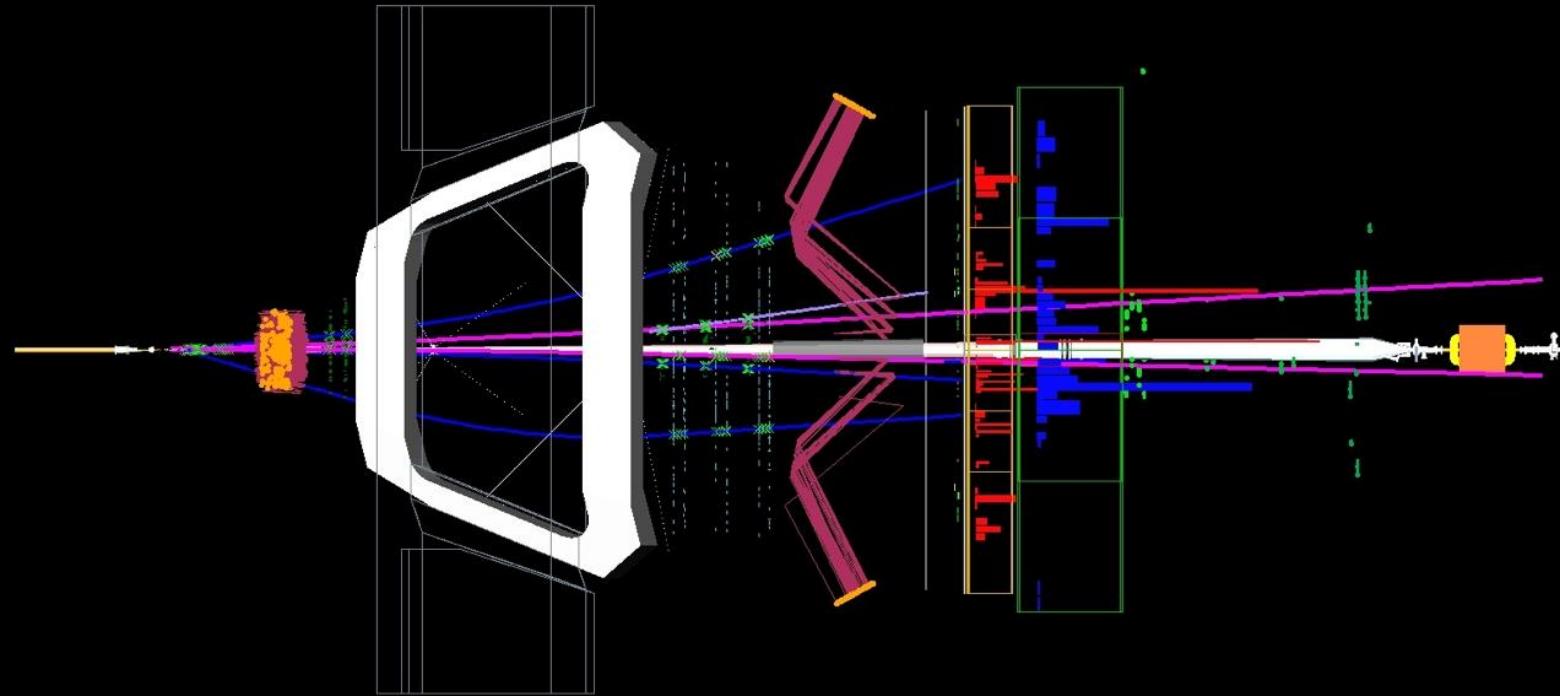
$$\alpha_{B_s^0 \rightarrow \mu^+ \mu^-} = (2.80 \pm 0.25) \times 10^{-10}$$

$$\alpha_{B^0 \rightarrow \mu^+ \mu^-} = (7.16 \pm 0.34) \times 10^{-11}$$

SM expectations 2012+2011 in the mass windows:

13 + 11 $B_s^0 \rightarrow \mu^+ \mu^-$ and **1.5 + 1.3 $B^0 \rightarrow \mu^+ \mu^-$**

$B_s^0 \rightarrow \mu^+ \mu^-$ Candidate



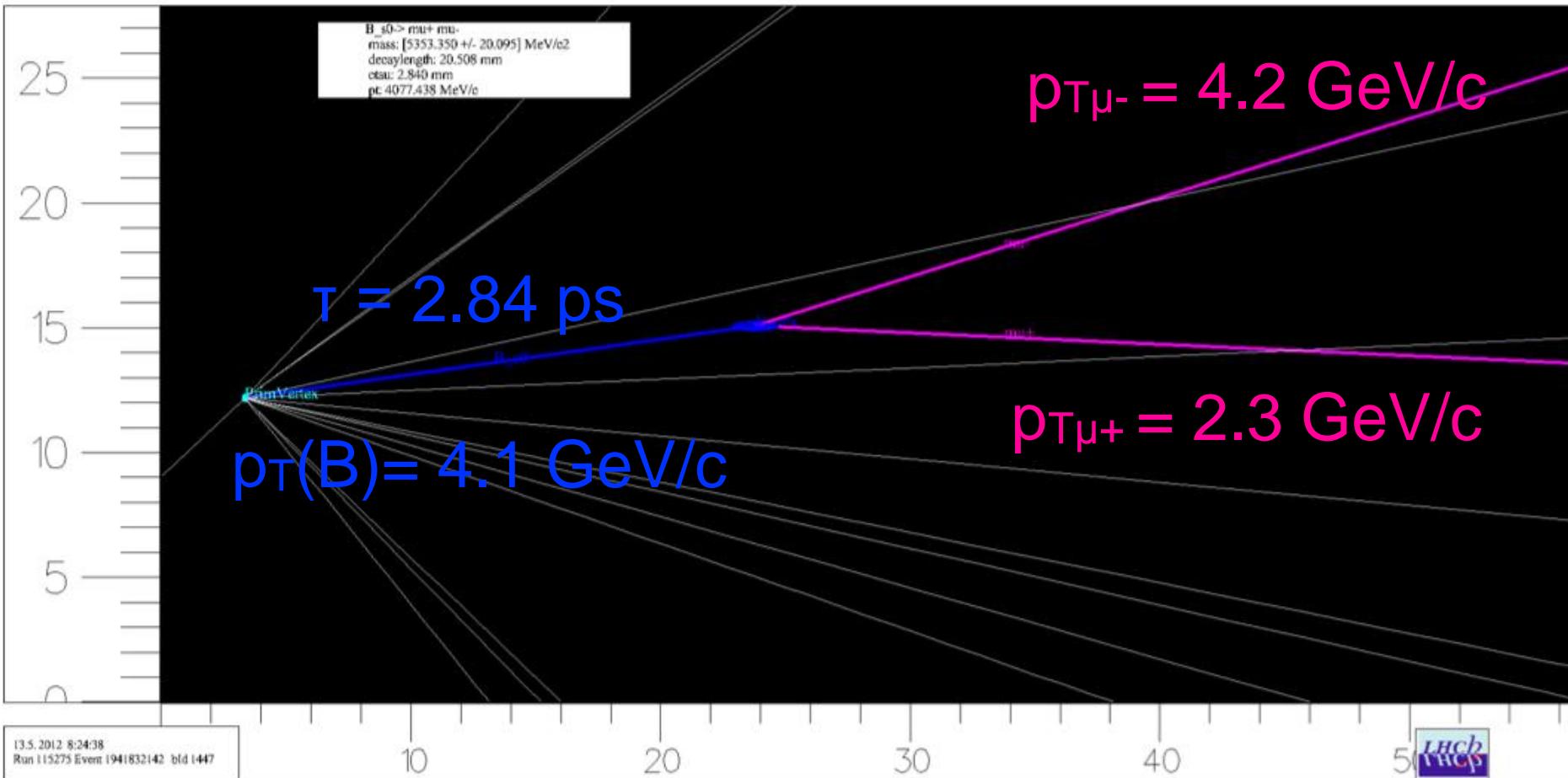
13.5.2012 8:24:38
Run 115275 Event 1941832142 bId 1447



B candidate: $m_{\mu\mu} = 5353.4 \text{ MeV}/c^2$ BDT = 0.826

$p_T = 4077.4 \text{ MeV}/c$ $\tau = 2.84 \text{ ps}$

muons: $p_{T\mu +} = 2329.5 \text{ MeV}/c$ $p_{T\mu -} = 4179.4 \text{ MeV}/c$

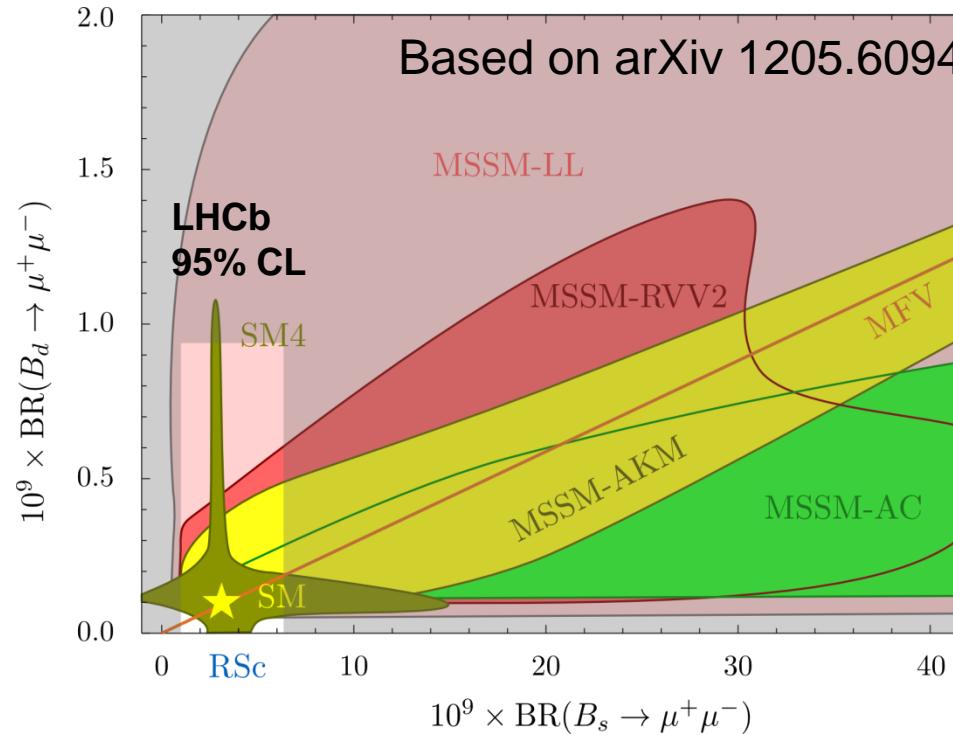


Branching Ratio Fit

- Unbinned maximum likelihood fit of the $m_{\mu\mu}$ distribution in the 2012 and 2011 BDT bins.
- $B(B_s^0 \rightarrow \mu^+ \mu^-)$ and $B(B^0 \rightarrow \mu^+ \mu^-)$ are free and fit simultaneously
- Combinatorial bkg is free
- All other parameters (e.g. m_{B_s} , σ_{B_s} , exclusive bkg...) are gaussian constrained to their expectations
- An additional systematics is added to account for the hypotheses made on the combinatorial bkg shape (exponential vs double-exponential)

Impact of the results

- Hard time for SuperSymmetry...



- But SUSY never dies ;-)

The observation is "quite consistent with supersymmetry. In fact, it was actually expected in (some) supersymmetric models. I certainly won't lose any sleep over the result."

J. Ellis interviewed by BBC

