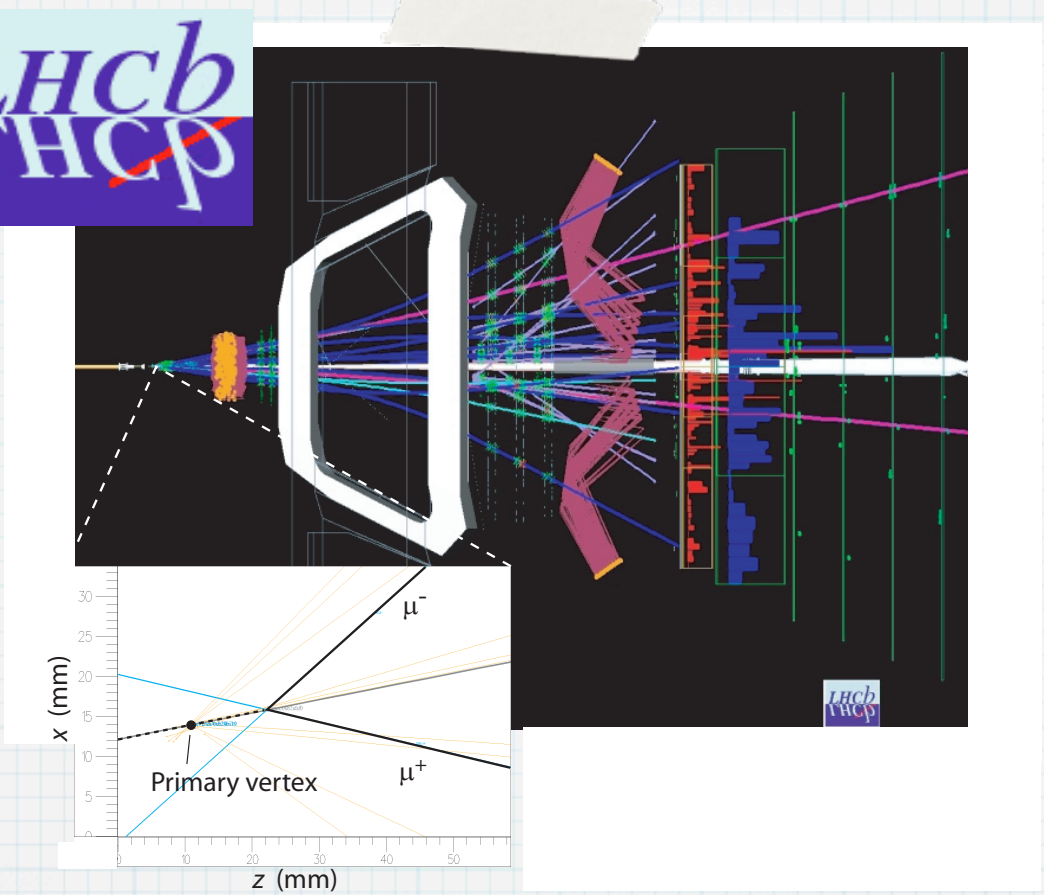
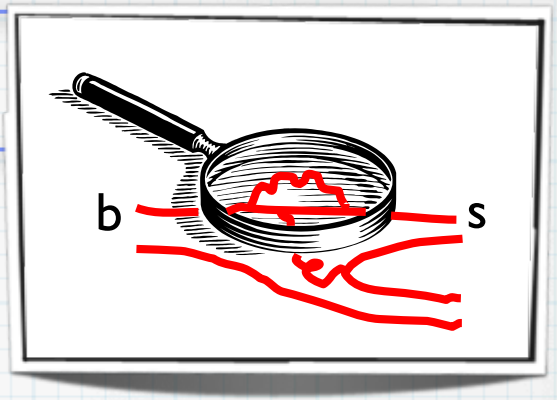


Rare decays in LHCb

47th Rencontres de Moriond 2012

José Ángel Hernando Morata
Universidade de Santiago de Compostela, Spain
(on behalf of the LHCb collaboration)
05/03/2012

Introduction



- LHCb searches for NP
  - in FCNC with B (and D) decays, where new particles can enter in the loops and modify the SM prediction on some observables
- LHCb Rare Decays (RD) analyses:
  - Search for $B_{(s)} \to \mu\mu$ rare decays — [37 pb^{-1} arXiv:1103.2465, PLB 699 (2011) 330-340, 0.37 fb^{-1} arXiv:1112.3515, PLB 707 (2012) 497-505]
    - Update with 1 fb^{-1} — [LHCb-PAPER-2012-007]
  - Angular analysis of the $B \to K^* \mu\mu$ decay — [0.37 fb^{-1} arXiv:1112.3515]
    - Measurement of $B(B_s \to \phi\mu\mu)/B(B_s \to J/\psi\phi)$ — [LHCb-CONF-2012-003]
  - Measurement of $B(B_s \to \phi\gamma)/B(B \to K^*\gamma)$ — [0.37 fb^{-1} arXiv:1202.6267]
    - Measurement of CP Asymmetry on $B \to K^*\gamma$ — [LHCb-CONF-2012-004]

presented a La Thuille!

LHCb-CONF-2012-004

Measurement of A_{CP} B→K*γ

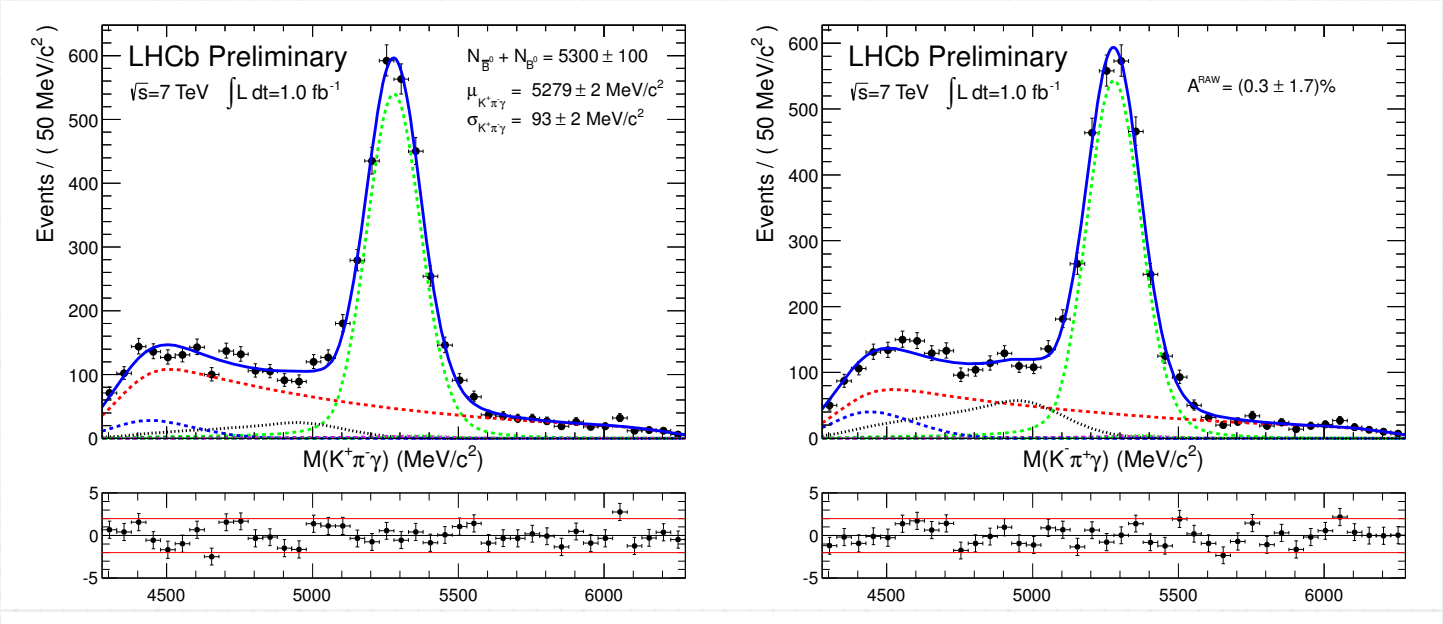
SM prediction:

A_{CP} = -0.0061±0.0043

[arXiv:0406055]

Experimental status:

	CLEOII	BABAR	Belle
$\mathcal{A}_{CP}$	$+0.08 \pm 0.13 \pm 0.03$	$-0.016 \pm 0.022 \pm 0.007$	$0.015 \pm 0.044 \pm 0.012$
	PRL 84 (2000)	PRL 103 (2009)	RD 68 (2004)



Correction by detector and production asymmetries:

$$\mathcal{A}_{CP}(B^0 \to K^{*0}\gamma) = \mathcal{A}^{\rm RAW}(B^0 \to K^{*0}\gamma) - \mathcal{A}_{\rm D}(K\pi) - \kappa\mathcal{A}_{\rm P}(B^0)$$

		correction	uncertainty
Background model	: $\Delta\mathcal{A}_{bkg}$	-0.002	±0.007
Detection	: $-\mathcal{A}_{\rm D}(K\pi)$	$+0.010$	±0.002
Magnet polarity	: $\Delta\mathcal{A}_{\mathcal{M}}$	$+0.001$	±0.002
B^0 production	: $-\kappa\mathcal{A}_{\rm P}(B^0)$	-0.004	±0.005
Total		$+0.005$	±0.009

$$\mathcal{A}_{CP}(B^0 \to K^{*0}\gamma) = 0.008 \pm 0.017(\text{stat}) \pm 0.009(\text{syst})$$

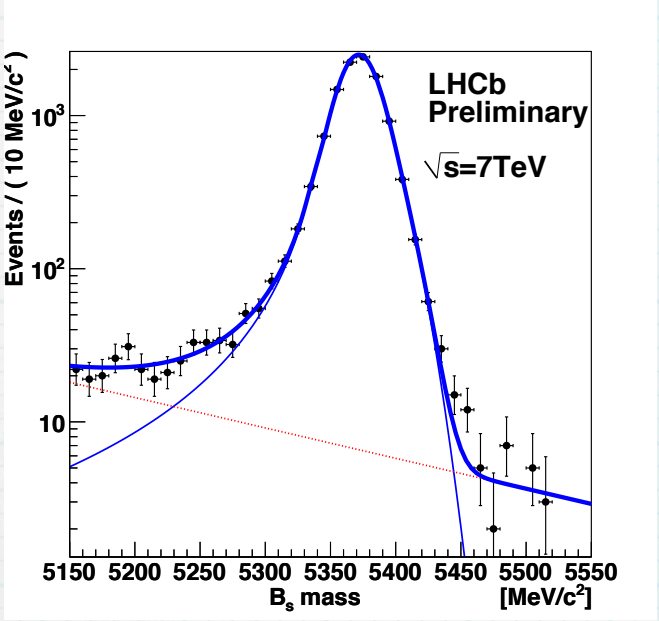
most precise measurement!

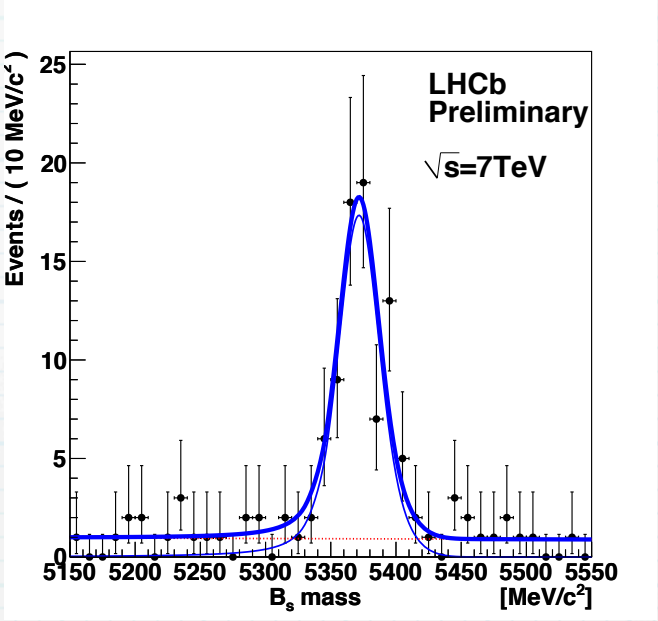
LHCb-CONF-2012-003

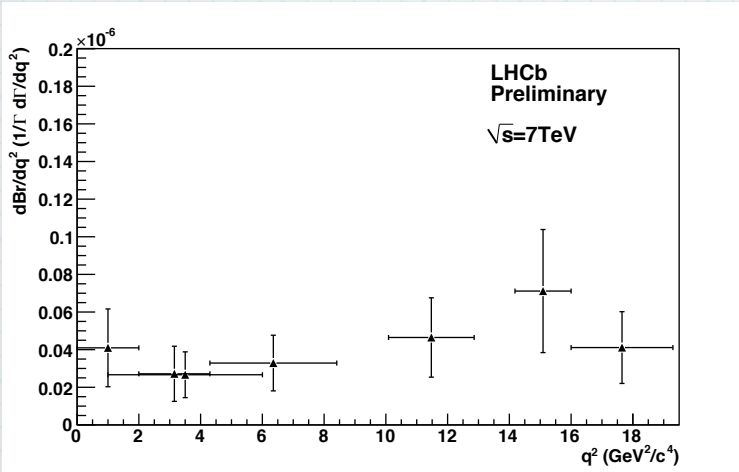
Measurement $B(B_s \to \phi\mu\mu)/B(Bs \to J/\psi\phi)$

Experimental status: $\frac{\mathcal{B}(B_s^0 \to \phi\mu\mu)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)} = (1.13 \pm 0.19(\text{stat}) \pm 0.07(\text{syst})) \times 10^{-3}$ (CDF)

arXiv:1107.3753.







dB/dq² vs q²

$$\frac{N_{\phi\mu\mu}}{N_{J/\psi\,\phi}} = \frac{76.5 \pm 9.5}{11073.5 \pm 113.0} = (6.905 \pm 0.863(\text{stat}) \pm 0.014(\text{syst})) \times 10^{-3}$$

$$\frac{\mathcal{B}(B_s^0 \to \phi\mu\mu)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)} = \frac{N_{\phi\mu\mu}}{N_{J/\psi\,\phi}}^{\text{data}} \times \frac{\mathcal{B}(J/\psi \to \mu^+\mu^-)}{1}^{\text{PDG}} \times \frac{\varepsilon_{J/\psi\,\phi}}{\varepsilon_{\phi\mu\mu}}^{\text{MC}}$$

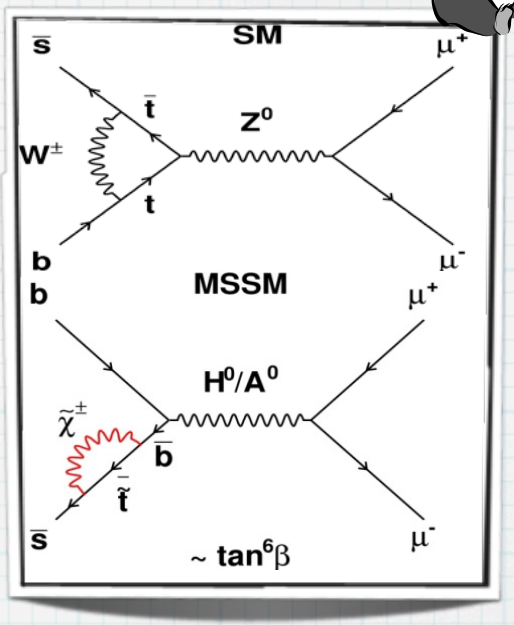
$$\frac{\mathcal{B}(B_s^0 \to \phi\mu\mu)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)} = (0.556 \pm 0.069(\text{stat}) \pm 0.043(\text{syst}) \pm 0.006(\mathcal{B})) \times 10^{-3}$$

most precise measurement!

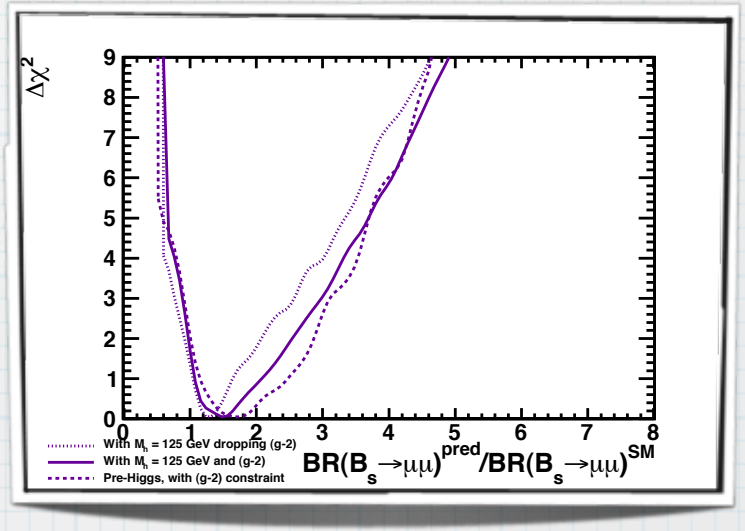
Search for the $B_{(s)} \to \mu\mu$ decay

LHCb-PAPER-2012-007

- SM prediction (FCNC, helicity suppressed)
  - SM $B(Bs \to \mu\mu) = (3.2 \pm 0.2)\ 10^{-9}$ arXiv:1005.5310 arXiv:1012.1447
  - SM $B(B \to \mu\mu) = (0.1 \pm 0.01)\ 10^{-9}$
- Branching ratio very sensitive to NP
- Current Status
  - LHCb limit: [0.37 fb^{-1} arXiv:1112.3515, PLB 707 (2012) 497-505]
    - $B(B_s \to \mu\mu) < 1.4\ 10^{-8}$ 95 % C.L (LHCb)
    - $B(B \to \mu\mu) < 3.2\ 10^{-9}$ 95 % C.L (LHCb)
  - CDF has an excess of events (10 fb^{-1}):
    - $B(Bs \to \mu\mu) = (1.0^{+0.8}_{-0.6})\ 10^{-8}$ (CDF)
  - Best limit 28/02/12 (5 fb^{-1})
    - $B(B_s \to \mu\mu) < 7.7\ 10^{-9}$ 95 % C.L (CMS)



NUHM arXiv:1112.3564



$B_{(s)} \to \mu\mu$

Similar selection for signal and normalization channels:

$B^+ \to J/\psi(\mu\mu)K^+$, $B_s \to J/\psi(\mu\mu)\phi$, $B \to K\pi$

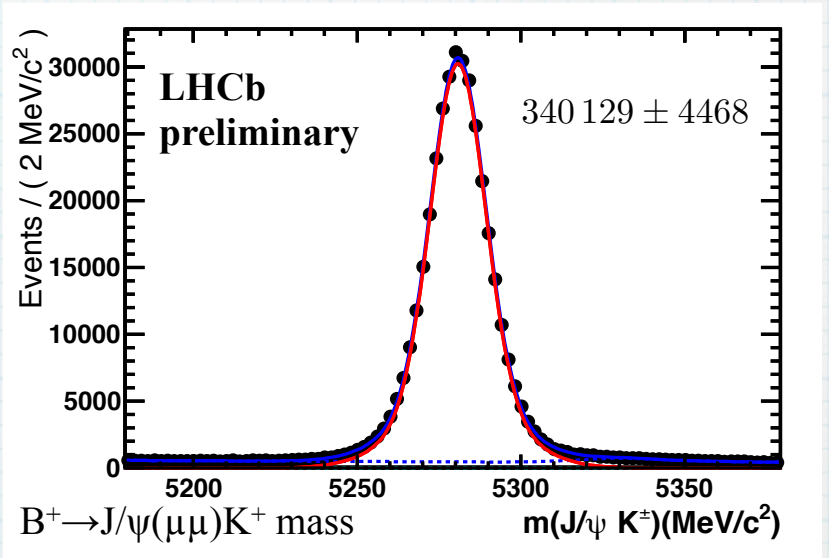
new! added a multi variate cut to the selection

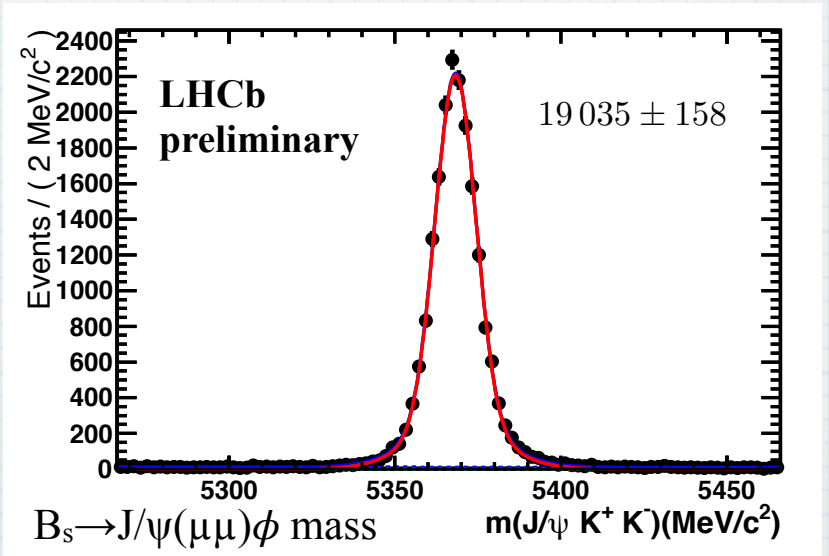
$$\mathcal{B} = \mathcal{B}_{\rm norm} \times \frac{\epsilon_{\rm norm}}{\epsilon_{\rm sig}} \times \frac{f_{\rm norm}}{f_{d(s)}} \times \frac{N_{B^0_{(s)}\to\mu^+\mu^-}}{N_{\rm norm}}$$
$$= \alpha^{\rm norm}_{B^0_{(s)}\to\mu^+\mu^-} \times N_{B^0_{(s)}\to\mu^+\mu^-},$$

$f_s/f_d = 0.267^{+0.021}_{-0.020}$ PRL 107 (2011) 211801, arXiv:1106.4435

$\epsilon^{\rm TRIG|SEL}_{B^0_s\to\mu^+\mu^-} = (91.4 \pm 0.4_{\rm stat} \pm 3.9_{\rm syst})\%,$

$\alpha_{B^0_s\to\mu^+\mu^-} = (3.19 \pm 0.28) \times 10^{-10},$
$\alpha_{B^0\to\mu^+\mu^-} = (8.38 \pm 0.39) \times 10^{-11},$





10 SM signal events in 17 k candidates [4.9, 6] GeV/c² mass window!

$B_{(s)} \to \mu\mu$

- Background:

  combinatorial background ($bb \to \mu\mu X$)

  $B \to hh'$ ($h \to \mu$ mis ID)

  new! tighter PID requirement (reduction ~1/6)

  $$\epsilon_{hh\to\mu\mu} = (1.52 \pm 0.07_{\text{stat}} \pm 0.07_{\text{syst}}) \times 10^{-5}.$$

  $\mu\mu$ from elastic diphoton production (PT(B)>500 MeV/c)

  Exclusive decays: (irrelevant!)

  $B_s \to \mu\mu\gamma$, $B^+ \to \pi^+\mu\mu$, $B_c^+ \to J/\psi\mu\nu$

- A multivariate discriminant BDT:

  kinematical and geometrical variables

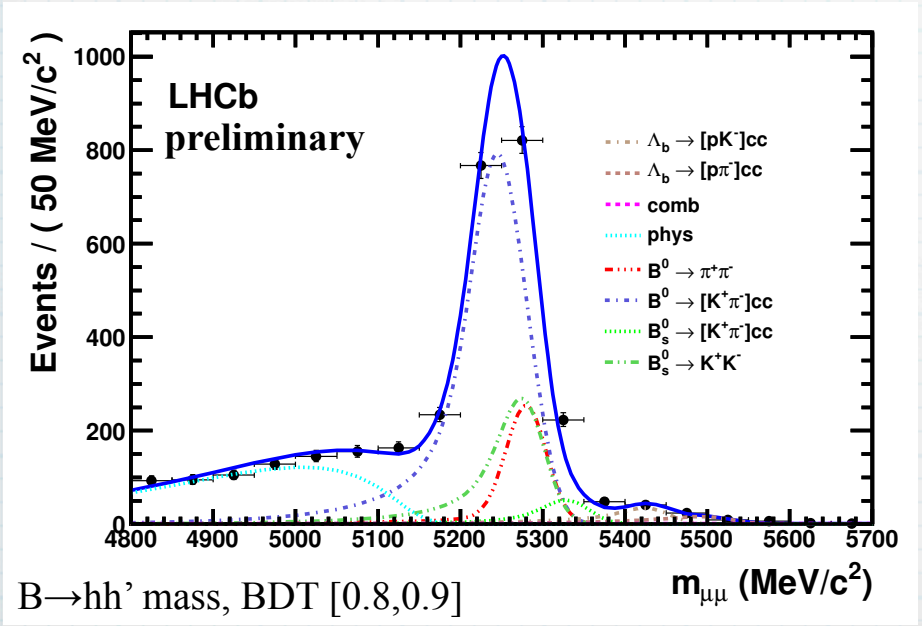
  signal uniformly distributed [0,1]

  trained with MC

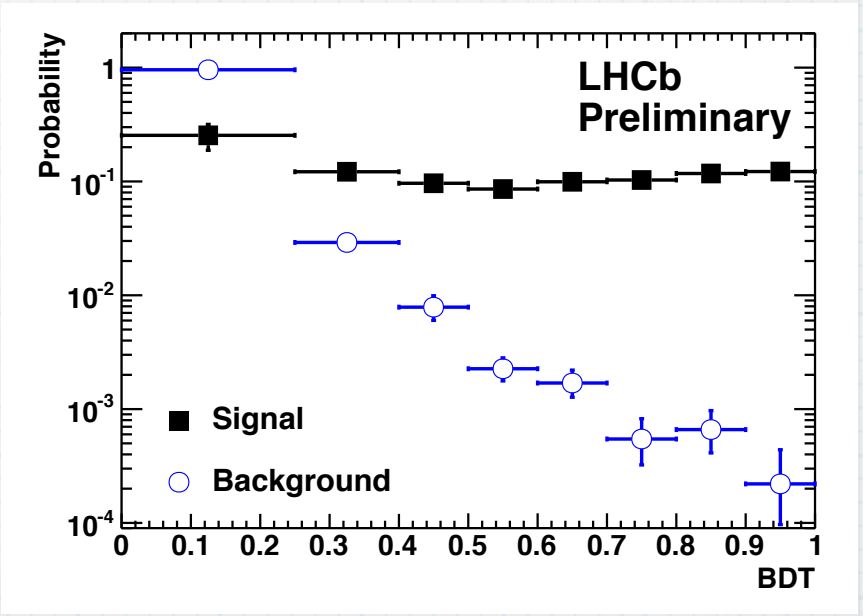
  estimated with data:

  signal $B \to hh$ trigger unbias

  background: $Bs \to \mu\mu$ sidebands



$B \to hh'$ mass, BDT [0.8,0.9]



$B_{(s)} \to \mu\mu$

Mass:

signal: CB shape

central values B→hh fit

resolution: interpolation between μμ resonances J/ψ, Ψ(2S), Υ(*1S,2S,3S*)

bkg: exponential fit in bins of BDT

$$\begin{aligned}\sigma(B_s^0) &= (24.8 \pm 0.3_{\text{stat}} \pm 0.7_{\text{syst}})\,\text{MeV}/c^2 \\ \sigma(B^0) &= (24.3 \pm 0.3_{\text{stat}} \pm 0.6_{\text{syst}})\,\text{MeV}/c^2\end{aligned}$$

BDT *vs* Mass:

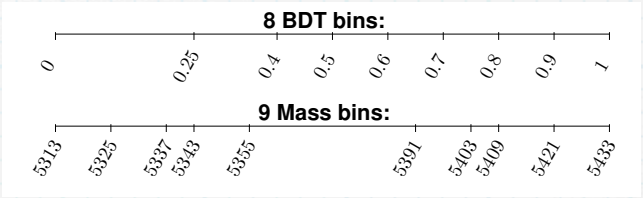
Divide BDT and mass plane in bins

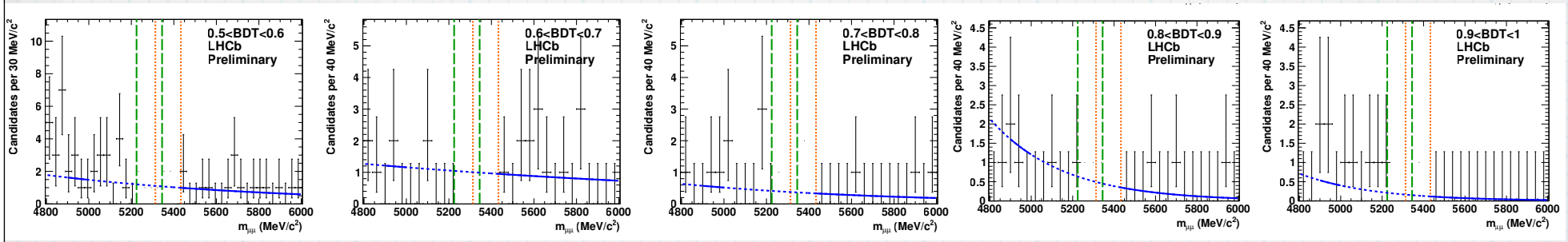
estimate number of background and signal (for each BR) events in each bin

Use CLs method!

$$Q = \frac{\mathcal{P}(d,s+b)}{\mathcal{P}(d,b)}$$

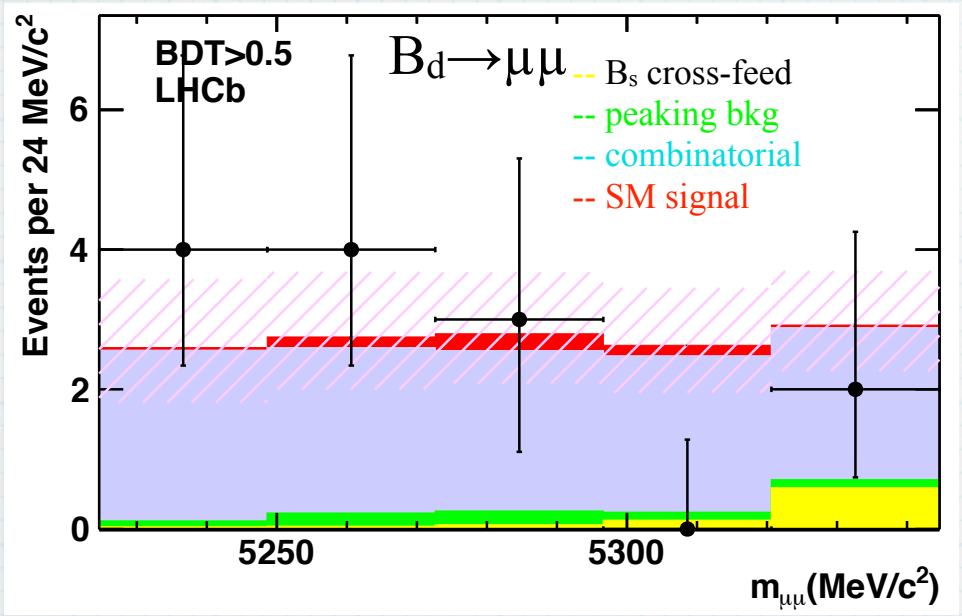
new! binning,optimized using MC toys!

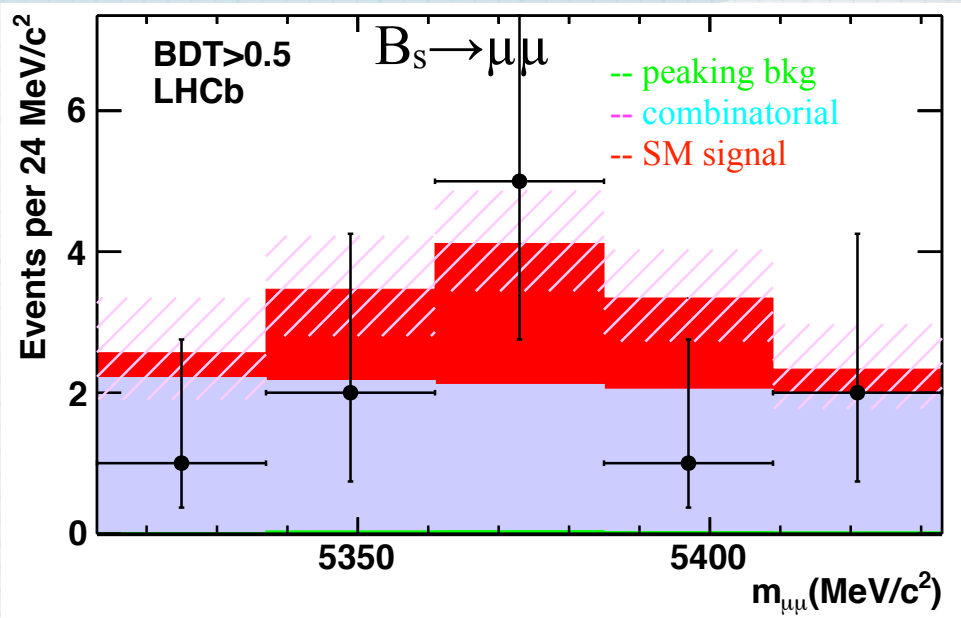




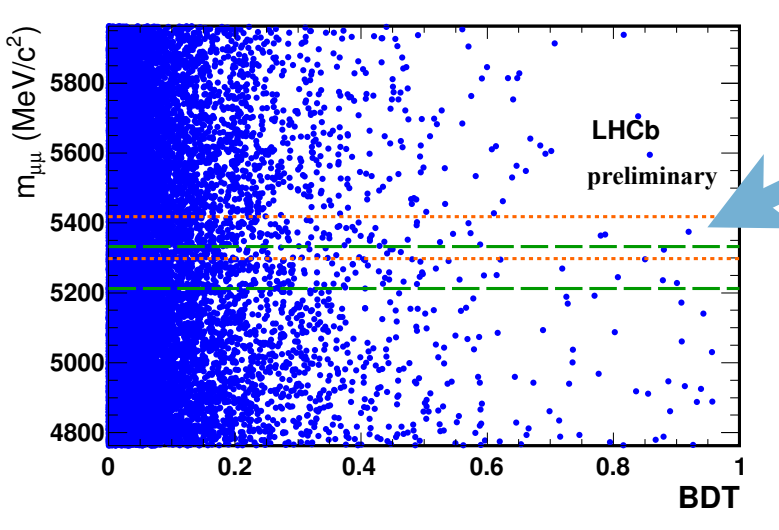
$B_{(s)} \to \mu\mu$

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
$B_s^0 \to \mu^+\mu^-$	Exp. comb. bkg	1889^{+38}_{-39}	57^{+11}_{-11}	$15.3^{+3.8}_{-3.8}$	$4.3^{+1.0}_{-1.0}$	$3.30^{+0.92}_{-0.85}$	$1.06^{+0.51}_{-0.46}$	$1.27^{+0.53}_{-0.52}$	$0.44^{+0.41}_{-0.24}$
	Exp. peak. bkg	$0.124^{+0.066}_{-0.049}$	$0.063^{+0.024}_{-0.018}$	$0.049^{+0.016}_{-0.012}$	$0.045^{+0.016}_{-0.012}$	$0.050^{+0.018}_{-0.013}$	$0.047^{+0.017}_{-0.013}$	$0.049^{+0.017}_{-0.013}$	$0.047^{+0.018}_{-0.014}$
	Exp. signal	$2.55^{+0.70}_{-0.74}$	$1.22^{+0.20}_{-0.19}$	$0.97^{+0.14}_{-0.13}$	$0.861^{+0.102}_{-0.088}$	$1.00^{+0.12}_{-0.10}$	$1.034^{+0.109}_{-0.095}$	$1.18^{+0.13}_{-0.11}$	$1.23^{+0.21}_{-0.21}$
	Observed	1818	39	12	6	1	2	1	1
$B^0 \to \mu^+\mu^-$	Exp. comb. bkg	2003^{+42}_{-43}	61^{+12}_{-11}	$16.6^{+4.3}_{-4.1}$	$4.7^{+1.3}_{-1.2}$	$3.52^{+1.13}_{-0.97}$	$1.11^{+0.71}_{-0.50}$	$1.62^{+0.76}_{-0.59}$	$0.54^{+0.53}_{-0.29}$
	Exp. peak. bkg	$0.71^{+0.36}_{-0.26}$	$0.355^{+0.146}_{-0.088}$	$0.279^{+0.110}_{-0.068}$	$0.249^{+0.099}_{-0.055}$	$0.280^{+0.109}_{-0.062}$	$0.264^{+0.103}_{-0.057}$	$0.275^{+0.108}_{-0.060}$	$0.267^{+0.106}_{-0.069}$
	Exp. cross-feed	$0.40^{+0.11}_{-0.12}$	$0.193^{+0.033}_{-0.030}$	$0.153^{+0.023}_{-0.021}$	$0.136^{+0.017}_{-0.015}$	$0.158^{+0.019}_{-0.017}$	$0.164^{+0.019}_{-0.017}$	$0.187^{+0.022}_{-0.020}$	$0.194^{+0.036}_{-0.033}$
	Exp. signal	$0.300^{+0.086}_{-0.090}$	$0.145^{+0.027}_{-0.024}$	$0.115^{+0.020}_{-0.017}$	$0.102^{+0.014}_{-0.013}$	$0.119^{+0.017}_{-0.015}$	$0.123^{+0.016}_{-0.015}$	$0.140^{+0.019}_{-0.017}$	$0.145^{+0.030}_{-0.026}$
	Observed	1904	50	20	5	2	1	4	1

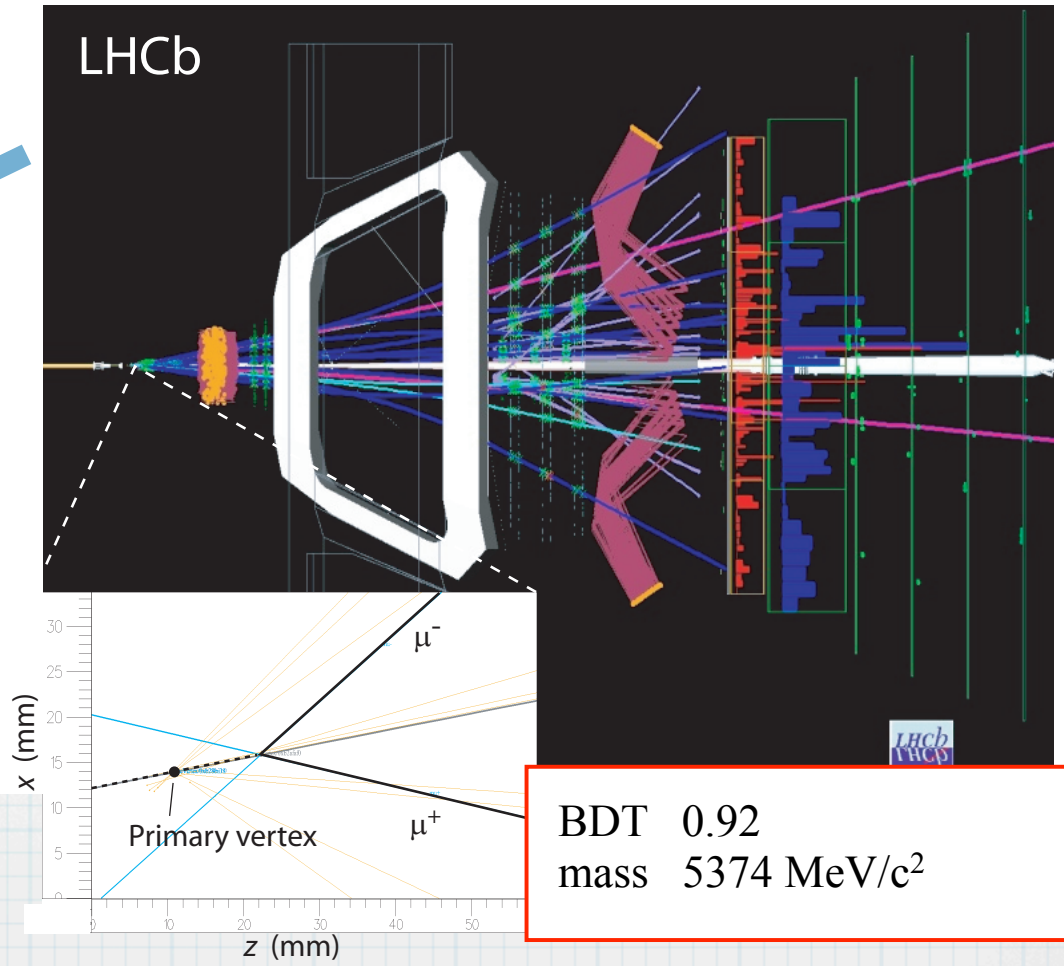




$B_{(s)} \rightarrow \mu\mu$

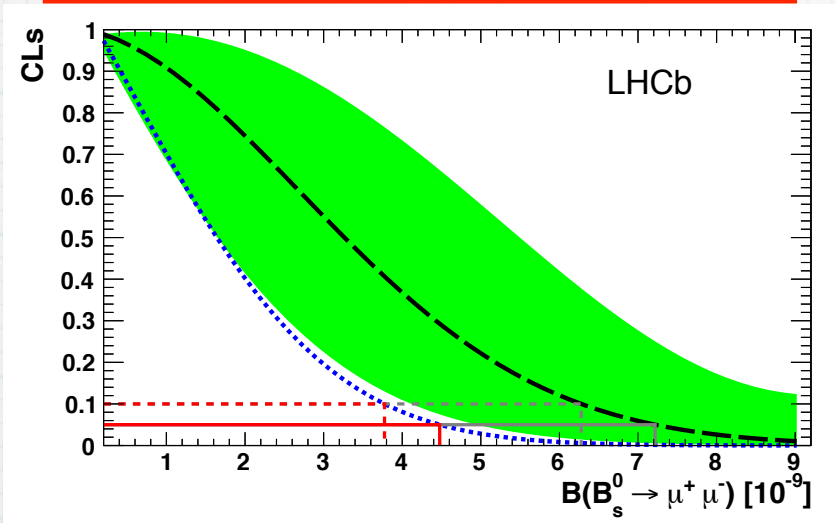


mass vs BDT data

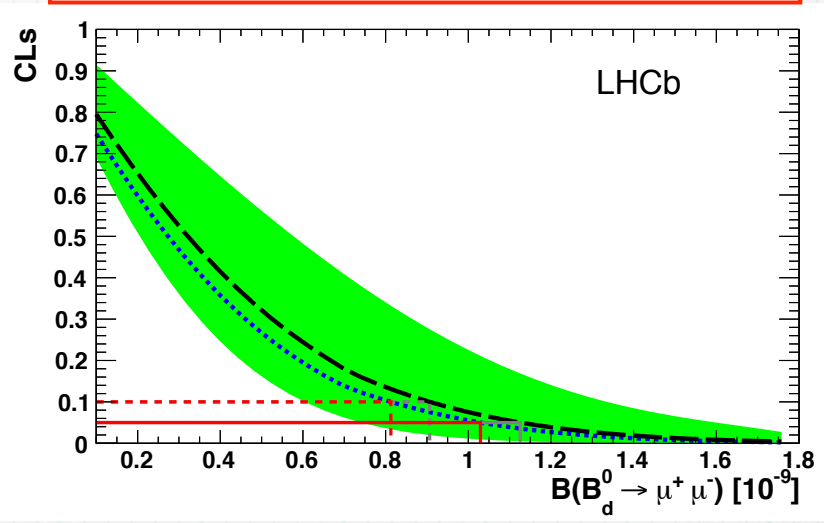


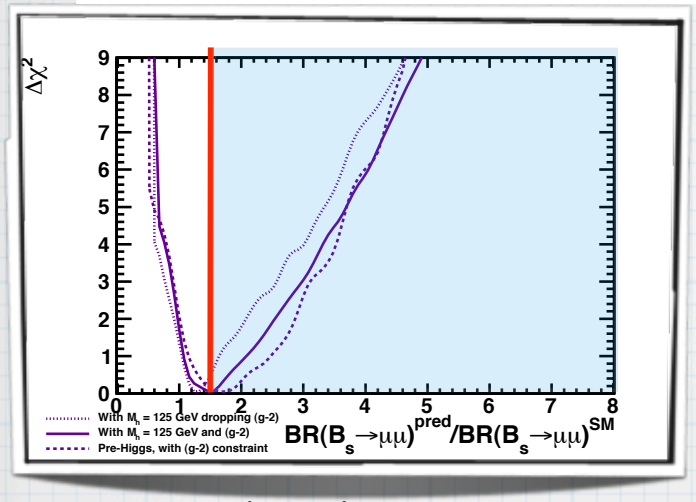
$B_{(s)} \to \mu\mu$

$B(Bs \to \mu\mu) < 4.5\ 10^{-9}$ at 95% CL



$B(B \to \mu\mu) < 10.3\ 10^{-10}$ at 95% CL





mode	limit	at 90 % C.L.	at 95 % C.L.
$B_s^0 \to \mu^+\mu^-$	expected bg+SM	6.3×10^{-9}	7.2×10^{-9}
	expected bg only	2.8×10^{-9}	3.4×10^{-9}
	observed	3.8×10^{-9}	4.5×10^{-9}
$B^0 \to \mu^+\mu^-$	expected	9.1×10^{-10}	11.3×10^{-10}
	observed	8.1×10^{-10}	10.3×10^{-10}

best limit!

1-CLb = 0.18

1-CLb =0.60

BR estimation:

$B(Bs \to \mu\mu) = (0.8^{+1.8}_{-1.3})\ 10^{-9}$

simultaneous unbinned LL fit to the mass to the 8 BDT bins

expected BR from minimum of the LL and error from ΔLL=0.5, coverage BR [0,SM] 82%

Conclusions

- LHCb has an intense program on RD searches:
  - Results with 0.37 fb^{-1}:
    - $B(B_{(s)} \to \mu\mu)$, Angular analysis $B \to K^* \mu\mu$, $B(B_s \to \phi\gamma)/B(B \to K^*\gamma)$
  - Results with 1 fb^{-1}
    - A_{CP} with $B \to K^*\gamma$
    - $B(B_s \to \phi\mu\mu)/B(B_s \to J/\psi\phi)$
    - Update $B_{(s)} \to \mu\mu$
  - Results in the pipeline
    - Update of the angular analysis $B \to K^* \mu\mu$
    - Isospin Asymmetry in $B \to K^{(*)}\mu\mu$, $B^{\pm} \to K^{(*)\pm}\mu\mu$
    - Search for $B^+ \to \pi^+\mu\mu$, $B_{(s)} \to \mu\mu\mu\mu$, ...

most precise!

$$\mathcal{A}_{CP}(B^0 \to K^{*0}\gamma) = 0.008 \pm 0.017(\text{stat}) \pm 0.009(\text{syst})$$

$$\frac{\mathcal{B}(B_s^0 \to \phi\mu\mu)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)} = (0.556 \pm 0.069(\text{stat}) \pm 0.043(\text{syst}) \pm 0.006(\mathcal{B})) \times 10^{-3}$$

$B(B_s \to \mu\mu) < 4.5\ 10^{-9}$ at 95% CL

$B(B \to \mu\mu) < 10.3\ 10^{-10}$ at 95% CL

best limit!

D rare decays cover in Jonas Rademacker's presentation!