B physics at LHCb, $B \to \mu\mu$ and $K^*\mu\mu$

- **Almost No Introduction**
- **b $\to$ q transitions:**
  - **b $\to$ q$\mu\mu$ family**
  - **b $\to$ sγ family**
  - **$B_s \to \mu\mu$**
- **$\tau \to \mu\mu\mu$**
- **LHCb Upgrade plans**

31 May 2012
SuperB workshop, Elba

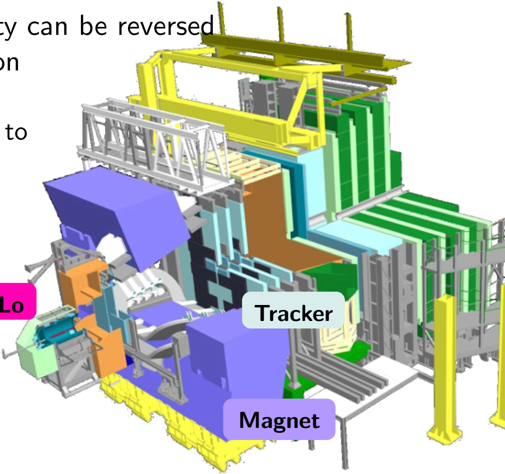
Patrick Koppenburg
on behalf of the LHCb Collaboration

www.koppenburg.org

LHCb DETECTOR

Forward detector (b-hadrons produced forward at LHC, $(75 \pm 5 \pm 13)\,\mu\mathrm{b}$ in acceptance [Physics Letters B 698 (2011) 14])

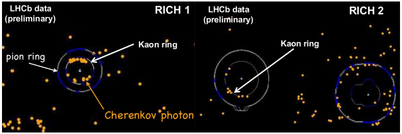
- Warm dipole magnet. Polarity can be reversed
- ✔ Good momentum and position resolution
  - Vertex detector gets 8mm to the beam

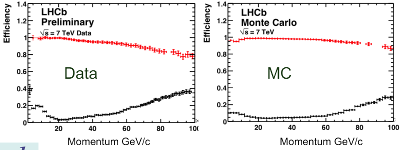


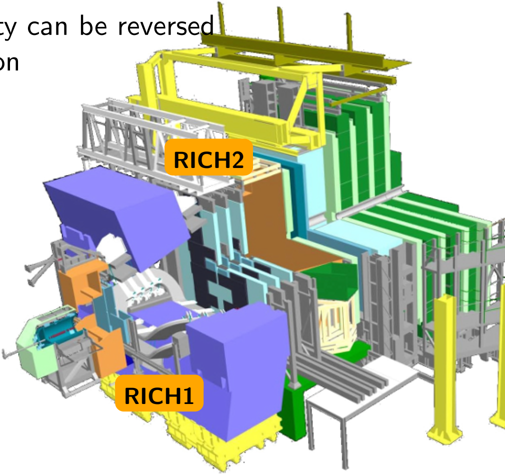
LHCb Detector & performance

Forward detector (b-hadrons produced forward at LHC, $(75 \pm 5 \pm 13)\,\mu\text{b}$ in acceptance [Physics Letters B 698 (2011) 14])

- Warm dipole magnet. Polarity can be reversed
- ✔ Good momentum and position resolution
- ✔ Excellent Particle ID



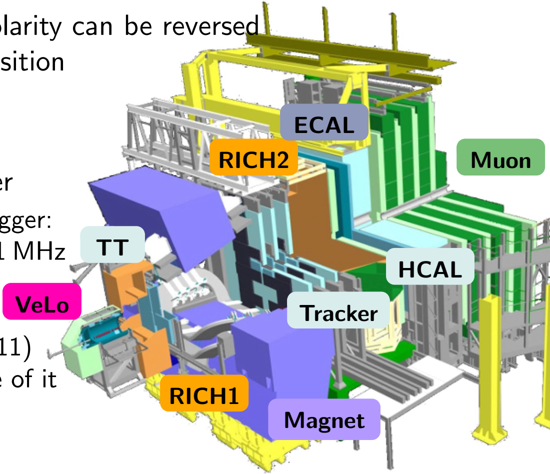




LHCb Trigger

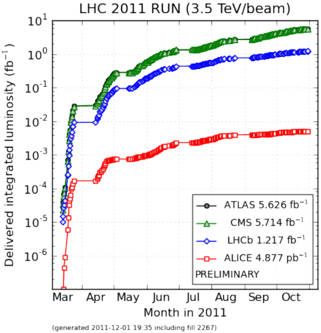
Forward detector (b-hadrons produced forward at LHC, $(75 \pm 5 \pm 13)\,\mu\text{b}$ in acceptance [Physics Letters B 698 (2011) 14])

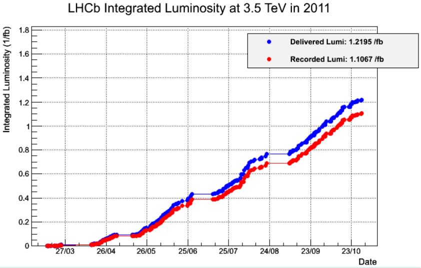
- Warm dipole magnet. Polarity can be reversed
- ✔ Good momentum and position resolution
- ✔ Excellent Particle ID
- ✔ Versatile two stage trigger
  - Hardware-based L0 trigger: moderate p_T cuts ➜ 1 MHz
  - Whole data sent to trigger farm
  - 3 kHz output rate (2011)
  - 4.5 kHz in 2012 (some of it deferred)

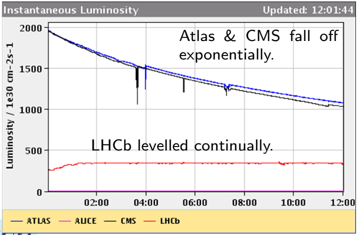


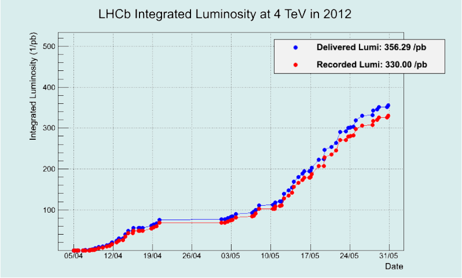
[Lumi Plots]

Luminosity in 2011 and 2012





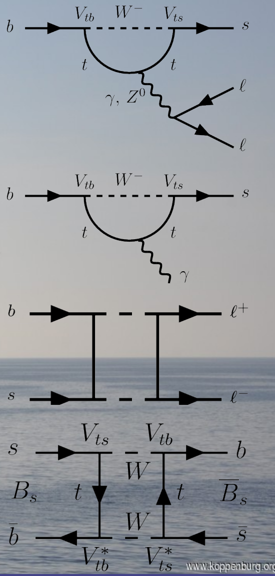




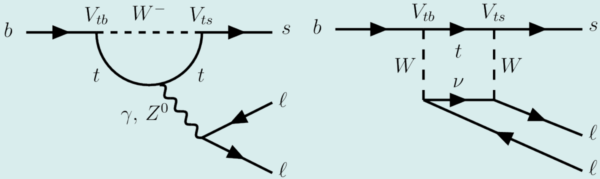
$b \to s$ Transitions

$b \to s$ transitions are loop-induced and thus suppressed in the SM. New Physics diagrams could compete.

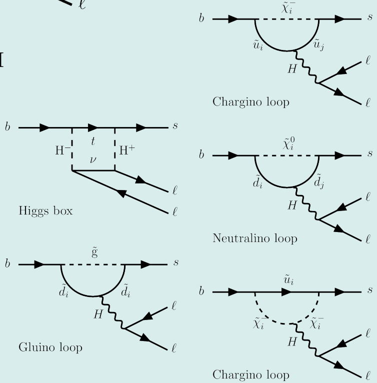
1. $b \to \ell\ell s$
2. $b \to s\gamma$
3. $B_s \to \mu\mu$
4. Not covered: B_s mixing



$b \to \ell\ell s$



- Start with $b \to s\gamma$, pay a factor $\alpha_{\rm EM}$
  - ➜ Decay the γ into 2 leptons
  - Add an interfering box diagram
  - ➜ $b \to \ell\ell s$, very rare in the SM
    $\mathcal{B}(B \to \ell\ell K^*) = (1.9 \pm 0.6) \cdot 10^{-6}$
    [Ali, et al.]



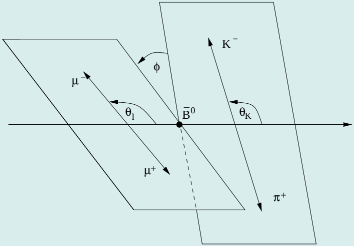
- Sensitive to Supersymmetry, Any 2HDM, Fourth generation, Extra dimensions, Axions . . .

✔ Ideal place to look for new physics

$B_d \to K^*\mu\mu$ Angular Distributions

A lot of information in the full θ_ℓ, θ_K and ϕ distributions

$$\frac{1}{\Gamma}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}\,\mathrm{d}q^2} = \frac{9}{16\pi}\Big[F_\mathrm{L}\cos^2\theta_K + \frac{3}{4}(1-F_\mathrm{L})(1-\cos^2\theta_K) \; + $$
$$F_\mathrm{L}\cos^2\theta_K(2\cos^2\theta_\ell - 1) \; +$$
$$\frac{1}{4}(1-F_\mathrm{L})(1-\cos^2\theta_K)(2\cos^2\theta_\ell - 1) \; +$$
$$S_3(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} \; +$$
$$\frac{4}{3}A_\mathrm{FB}(1-\cos^2\theta_K)\cos\theta_\ell \; +$$
$$A_\mathrm{Im}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi} \Big]$$



➜ Many observables depending on $q^2 = m^2_{\mu\mu}c^4$

[Altmannshofer, et al.]
[Krüger & Matias]
[Egede, et al.]
[Ali, et al.]

$B_d \to K^*\mu\mu$ Angular Distributions

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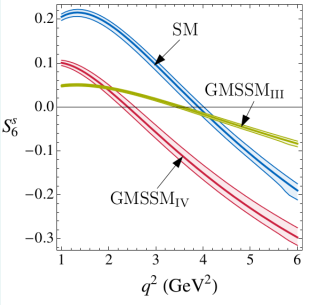

➜ **Forward-backward asymmetry $S_6 = \frac{4}{3}A_{\mathrm{FB}}$**

[Altmannshofer, et al.]
[Krüger & Matias]
[Egede, et al.]
[Ali, et al.]

$B_d \to K^*\mu\mu$ Angular Distributions

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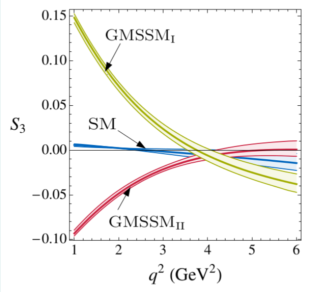
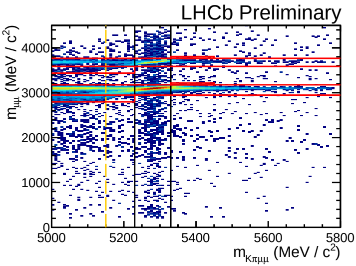
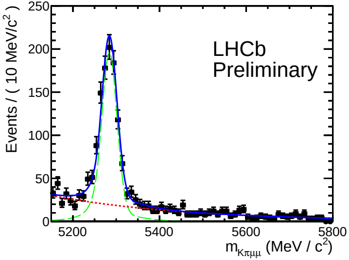


➜ **Transverse asymmetry $S_3 = (1-F_\mathrm{L})A_T^{(2)}$ (RH)**

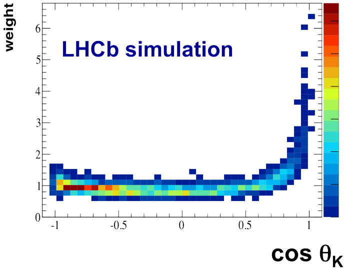
[Altmannshofer, et al.]
[Krüger & Matias]
[Egede, et al.]
[Ali, et al.]

$B \to \mu\mu K^*$ at LHCb ($1\ \text{fb}^{-1}$)

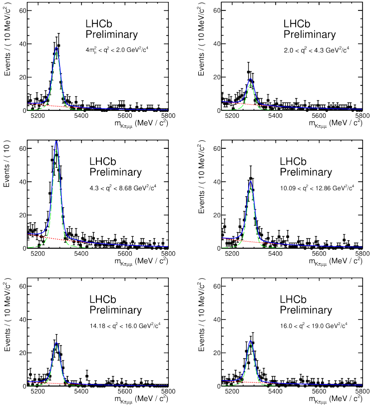




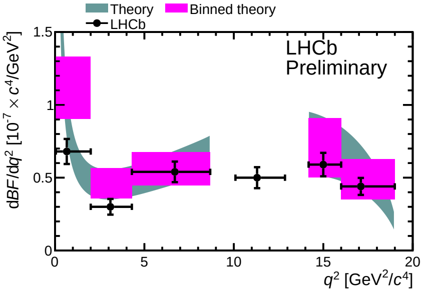
- We select $B^0 \to K^* \mu^+ \mu^-$ using boosted decision tree
  - Cut out J/ψ and $\psi(2S)$
  - Observe 900 ± 34 events in 1 fb^{-1}
  - Weight events according to $(\text{eff})^{-1}(\theta_\ell, \phi, \theta_K, q^2)$ using MC calibrated on $B_d \to J/\psi K^*$



$B \to \mu\mu K^*$ at LHCb ($1\ \text{fb}^{-1}$)

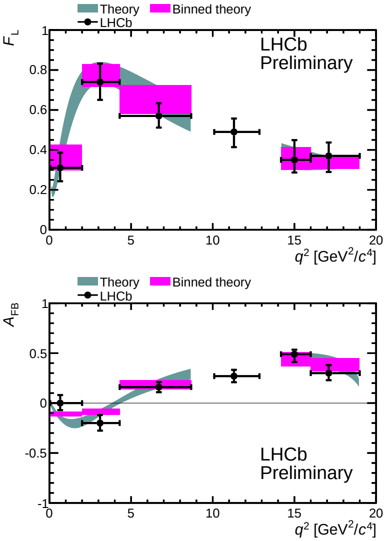


- We select $B^0 \to K^* \mu^+ \mu^-$ using boosted decision tree
- Bin in q^2 and extract $\mathrm{d}\Gamma/\mathrm{d}q^2$



SM: Bobeth et al., [arXiv:1105.0376]

$B \to \mu\mu K^*$ AT LHCb ($1\ \text{fb}^{-1}$)

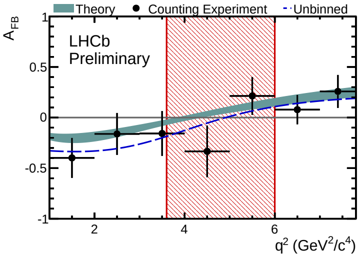


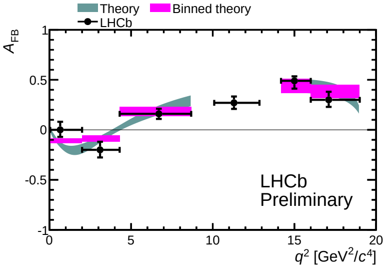
- We select $B^0 \to K^*\mu^+\mu^-$ using boosted decision tree
- Bin in q^2 and extract $d\Gamma/dq^2$
- Fit for θ_K and θ_ℓ
  - ➜ F_L and A_{FB}

SM: Bobeth et al., [arXiv:1105.0376]

[LHCb-CONF-2012-008]

$B \to \mu\mu K^*$ at LHCb ($1\ \mathrm{fb}^{-1}$)



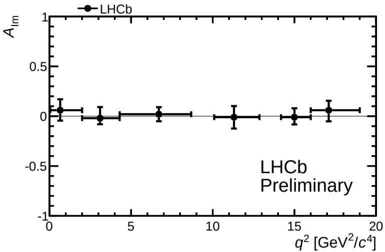


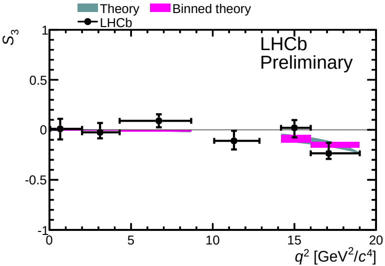
- We select $B^0 \to K^* \mu^+ \mu^-$ using boosted decision tree
- Bin in q^2 and extract $\mathrm{d}\Gamma/\mathrm{d}q^2$
- Fit for θ_K and θ_ℓ
  - → F_L and A_FB
  - → Extract zero crossing point $\left(4.9\,^{+\,1.1}_{-\,1.3}\right)$ GeV^2 (prelim.)

SM: Bobeth et al., [arXiv:1105.0376]

[LHCb-CONF-2012-008]

$B \to \mu\mu K^*$ at LHCb (1 fb^{-1})

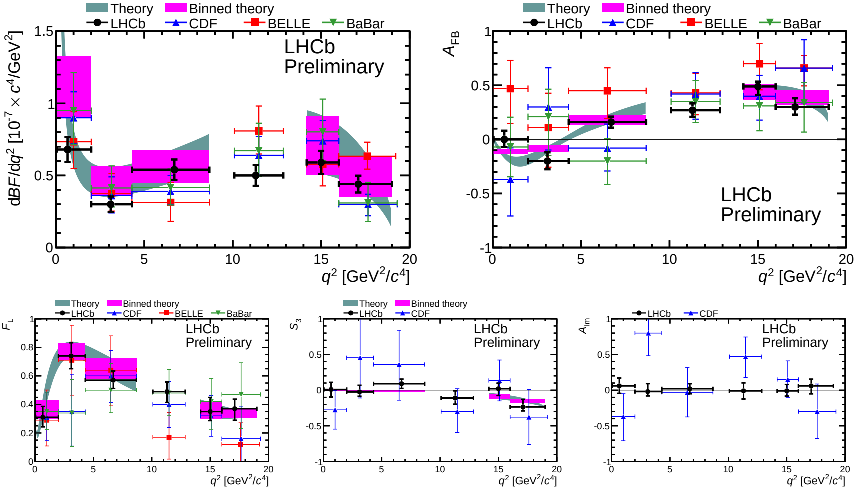




- We select $B^0 \to K^* \mu^+ \mu^-$ using boosted decision tree
- Bin in q^2 and extract $\mathrm{d}\Gamma/\mathrm{d}q^2$
- Fit for θ_K and θ_ℓ
  - ➜ $F_{\rm L}$ and $A_{\rm FB}$
  - ➜ Extract zero crossing point $\left(4.9\,^{+\,1.1}_{-\,1.3}\right)$ GeV^2 (prelim.)
  - ➜ Extract T-odd $A_{\rm Im}$
  - ➜ and S_3, sensitive to right handed currents
- All compatible with SM

SM: Bobeth et al., [arXiv:1105.0376]

Comparison with Other Experiments



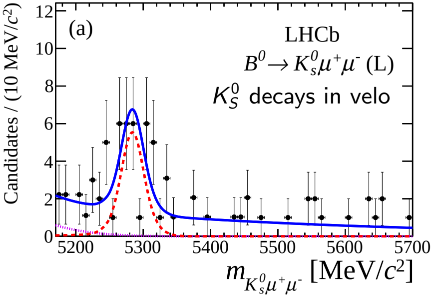
Isospin Asymmetry in $B \to \mu\mu K^{(*)}$

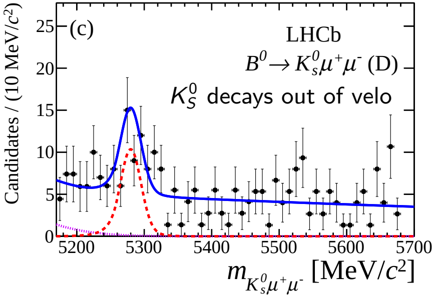
We reconstruct $B_d \to K^{(*)0}\mu^+\mu^-$ with $K^0 \to K^0_S \to \pi^+\pi^-$:

$$\mathcal{B}(B_d \to K^0\mu^+\mu^-) = (0.31^{+0.07}_{-0.06}) \times 10^{-6} \quad \text{and}$$
$$\mathcal{B}(B_u \to K^{*+}\mu^+\mu^-) = (1.16 \pm 0.19) \times 10^{-6},$$

(errors are stat+syst)

It's the first observation of the $B_d \to K^0\mu^+\mu^-$ mode (5.7σ)





[arXiv:1205.3422]

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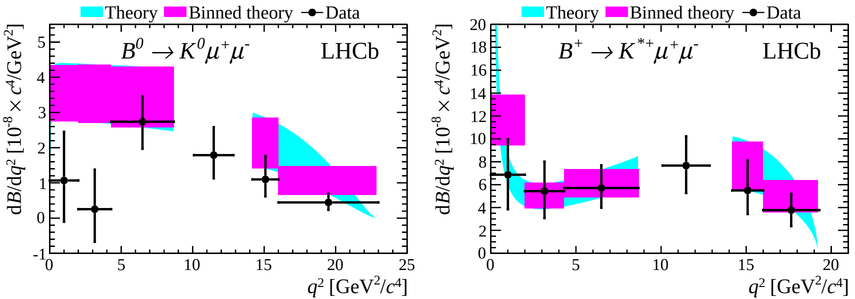
We extract $d\mathcal{B}/dq^2$



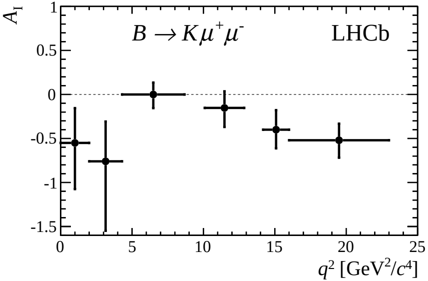
[arXiv:1205.3422]

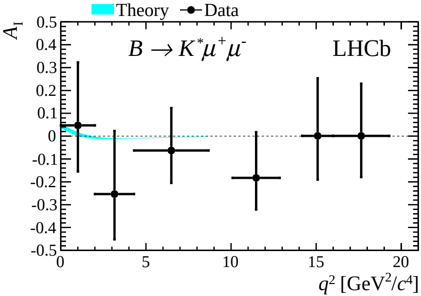
Isospin Asymmetry in $B \to \mu\mu K^{(*)}$

We compare with the charged modes $B_u \to K^{(*)+}\mu^+\mu^-$:

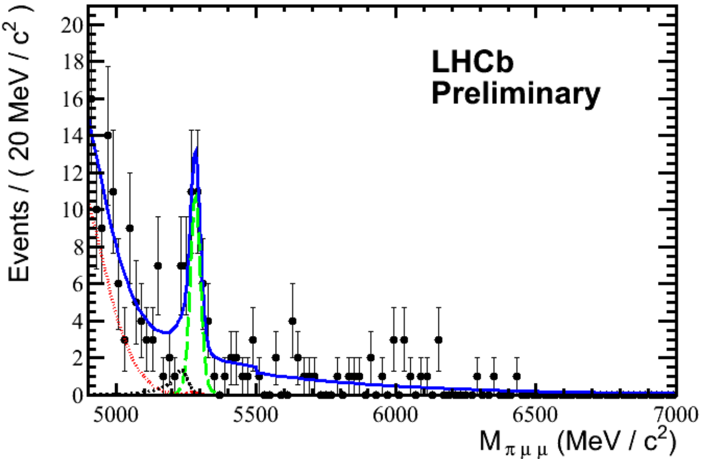
$$A_{\mathrm{I}} = \frac{\Gamma(B_d \to K^{(*)0}\mu^+\mu^-) - \Gamma(B_u \to K^{(*)+}\mu^+\mu^-)}{\Gamma(B_d \to K^{(*)0}\mu^+\mu^-) + \Gamma(B_u \to K^{(*)+}\mu^+\mu^-)}$$
$$= -0.35^{+0.23}_{-0.27} \quad (B \to K\mu\mu)$$
$$= -0.15 \pm 0.16 \quad (B \to K^*\mu\mu)$$

Both negative, as seen by Belle and Babar





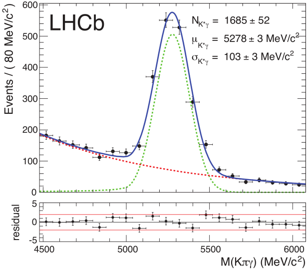
The rarest B decay ever seen

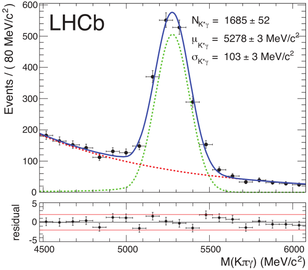


We measure $(2.4 \pm 0.6 \pm 0.2) \cdot 10^{-8}$ (5.2σ, prelim.) [LHCb-CONF-2012-006]

The SM predicts $(1.96 \pm 0.21) \cdot 10^{-8}$ [Song, Lu, Lu]

$b \to s\gamma$





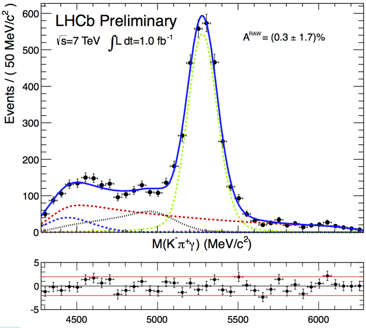
Ratio of $B \to K^*\gamma$ and $B_s \to \phi\gamma$

- ✗ Photons ➜ Broader signal peak than typical B decay

$$\frac{\mathcal{B}(B\to K^*\gamma)}{\mathcal{B}(B_s\to\phi\gamma)} = 1.12 \pm 0.08 \; {}^{+0.06}_{-0.04} \; {}^{+0.09}_{-0.08} \; (f_s/f_d)$$

- ✔ Largest $B_s \to \phi\gamma$ signal using $0.37\ \text{fb}^{-1}$ [arXiv:1202.6267]

$b \to s\gamma$



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- ✔ Largest $B_s \to \phi\gamma$ signal using $0.37\ \text{fb}^{-1}$ [arXiv:1202.6267]

Direct CP asymmetry in $B \to K^*\gamma$ ($1\ \text{fb}^{-1}$): [LHCb-CONF-2012-004]

$$0.008 \pm 0.017 \pm 0.009 \quad \text{(prelim.)}$$

$B_s \to \mu\mu$

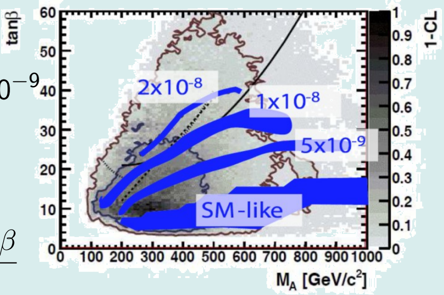
- Very rare decay, well described in the SM

  $\mathcal{B}(B_s\to\mu\mu)_{\text{SM}} = (3.5 \pm 0.2) \cdot 10^{-9}$

  [Buras], [De Bruyn, Fleischer, Knegjens, PK...]

- Very sensitive to NP, e.g. MSSM:

  $$\mathcal{B}(B_s\to\mu\mu)_{\text{MSSM}} \propto \frac{m_b^2 m_\ell^2 \tan^6\beta}{m_A^4}$$



Many previous measurements

D0 (6.1 fb^{-1}): $\mathcal{B} < 5.1 \cdot 10^{-8}$ (95%) [Phys. Lett. B 693, 539 (2010)]

LHCb (37 pb^{-1}): $\mathcal{B} < 5.6 \cdot 10^{-8}$ (95%) [Phys. Lett. B 699, 330 (2011)]

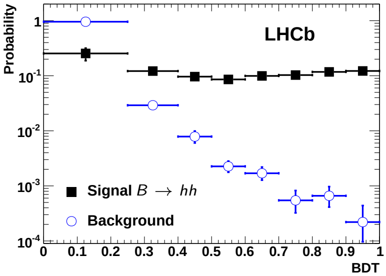
CDF (7 fb^{-1}): $\mathcal{B} = (1.8\,^{+1.1}_{-0.9}) \cdot 10^{-8}$ Hint! [Phys.Rev.Lett 107, 191801 (2011)]

CMS (1.1 fb^{-1}): $\mathcal{B} < 1.9 \cdot 10^{-8}$ (95%) [Phys. Rev. Lett. 107, 191802 (2011)]

CMS (5 fb^{-1}): $\mathcal{B} < 7.7 \cdot 10^{-9}$ (95%) [arXiv:1203.3976]

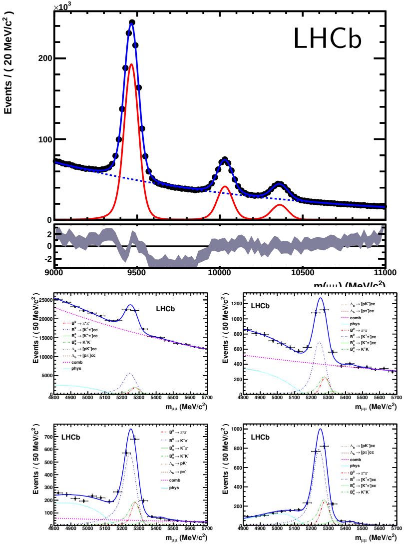
$B_s \to \mu\mu$ Strategy

1. Select $B \to \mu\mu$ using a boosted decision tree (BDT) tuned on MC but calibrated on real data $B \to hh$ signal and background from sidebands



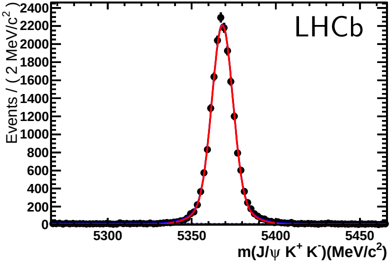
$B_s \to \mu\mu$ Strategy

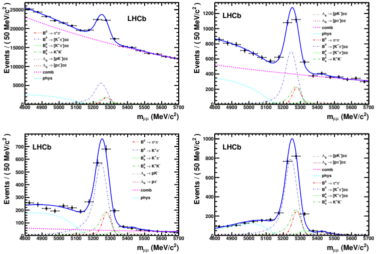
1. Select $B \to \mu\mu$ using a boosted decision tree (BDT) tuned on MC but calibrated on real data $B \to hh$ signal and background from sidebands
2. Mass resolution calibrated on $B \to hh$ and dimuon resonances: (24.8 ± 0.8) MeV$/c^2$
3. Look in 8$\times$6 bins of BDT$\times$Mass



$B_s \to \mu\mu$ Strategy

1. Select $B \to \mu\mu$ using a boosted decision tree (BDT) tuned on MC but calibrated on real data $B \to hh$ signal and background from sidebands
2. Mass resolution calibrated on $B \to hh$ and dimuon resonances: (24.8 ± 0.8) MeV$/c^2$
3. Look in 8×6 bins of BDT×Mass
4. Normalise to $B_s \to J/\psi\phi$, $B_d \to J/\psi K^*$, $B_d \to K\pi$





b FRAGMENTATION f_s/f_d

Fraction of $b \to B_s X$ is an essential ingredient for $B_s \to \mu\mu$ and other rare decays

- LHCb has measured it in 2 ways
  - Ratio of $B \to D_s \mu X$ to $B \to D^+ \mu X$ modes
    [Phys. Rev. D 85, 032008 (2012)]
  - Ratio of $B_d \to DK$ and $B_s \to D_s \pi$ modes
    [Phys. Rev. Lett. 107 21 (2011)]

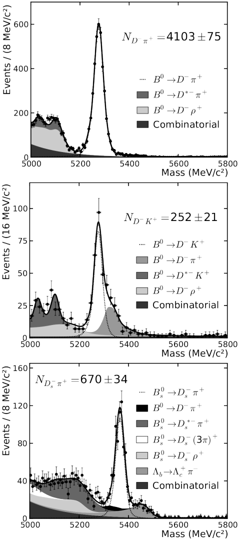
➜ Combination [Phys. Rev. Lett. 107 21 (2011)]

$$\left(\frac{f_s}{f_d}\right)_{\text{LHCb}} = 0.267 \begin{array}{l} +0.021 \\ -0.020 \end{array}$$

- Similar to LEP and Tevatron result

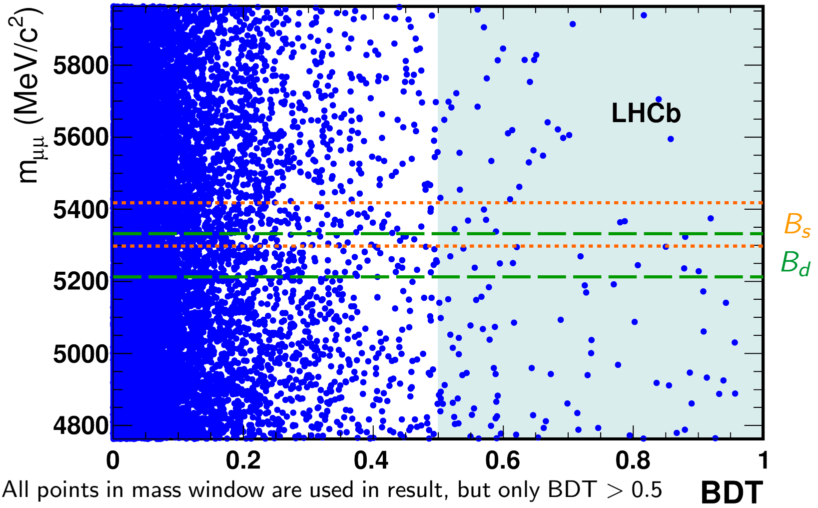
$$\left(\frac{f_s}{f_d}\right)_{\text{LEP, Tevatron}} = 0.271 \pm 0.027$$

Although there's no reason they should be the same



[arXiv:1203.4493]

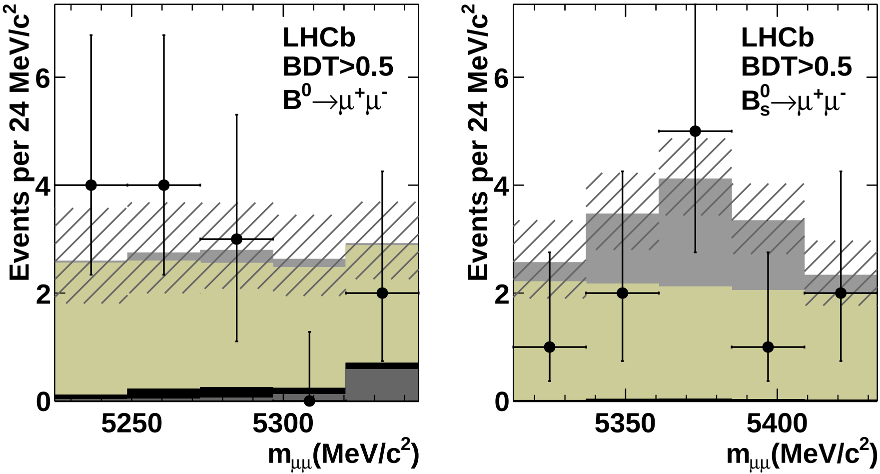
$B_s \to \mu\mu$ Signal window



All points in mass window are used in result, but only BDT > 0.5 shown in next slide

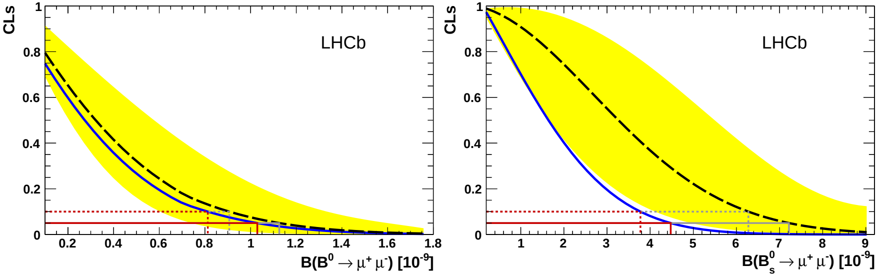
[arXiv:1203.4493]

B_d and $B_s \to \mu\mu$ Signal window



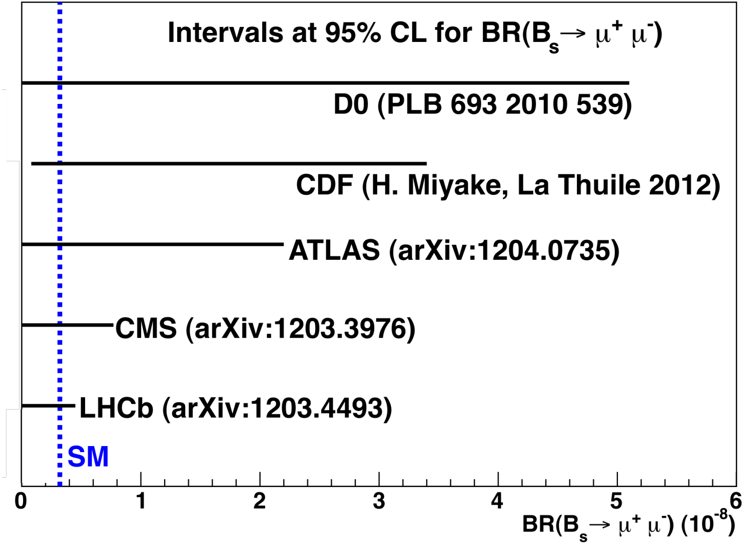
- Data, SM signal expectation, $B \to \pi\pi$ expectation, Combinatorial interpolation, B_s–B_d Cross-feed. Hatched: uncertainty

$B \to \mu\mu$ LHCb LIMITS



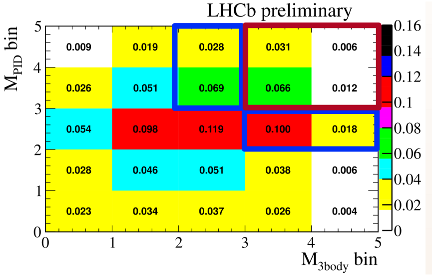
	$B_d \to \mu\mu$	$B_s \to \mu\mu$
Expected limit assuming bkg only (95%)	$1.1 \cdot 10^{-9}$	$3.4 \cdot 10^{-9}$
Expected limit assuming bkg+SM (95%)		$7.2 \cdot 10^{-8}$
Observed limit (95%)	$\mathbf{1.0 \cdot 10^{-9}}$	$\mathbf{4.5 \cdot 10^{-9}}$
p-value of background only hypothesis	60%	18%

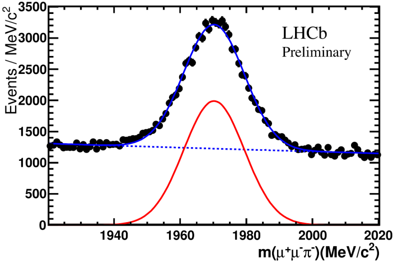
$B_s \to \mu\mu$ Status



Lepton Flavour Violation: $\tau^+ \to \mu^+\mu^-\mu^+$

- Difficulty at the LHC: τ do not come from the PV.
  - Mostly come from $D_s \to \tau\nu$
- Perform search in bins of two BDT of geometry and PID
  - Calibrate to $D_s \to \phi(\mu\mu)\pi$





Lepton Flavour Violation: $\tau^+ \to \mu^+\mu^-\mu^+$

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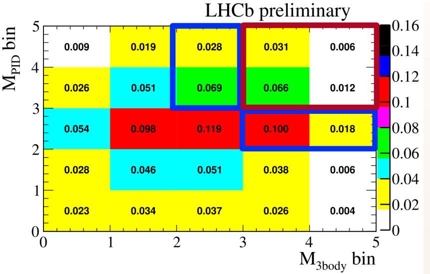
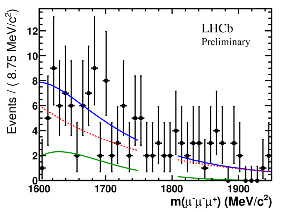
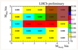
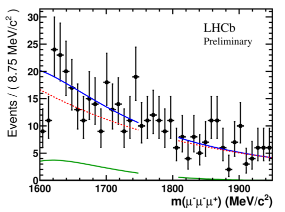
  - Mostly come from $D_s \to \tau\nu$
- Perform search in bins of two BDT of geometry and PID
  - Calibrate to $D_s \to \phi(\mu\mu)\pi$
- τ mass window: no signal



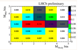


11 % of the signal
0.03 % of the background



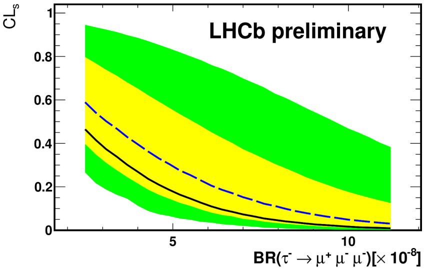


21 % of the signal
0.14 % of the background



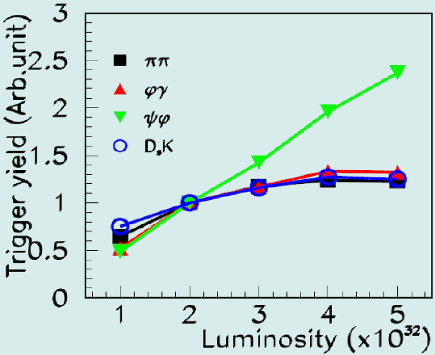
LEPTON FLAVOUR VIOLATION: $\tau^+ \to \mu^+\mu^-\mu^+$

- Difficulty at the LHC: τ do not come from the PV.
  - Mostly come from $D_s \to \tau\nu$
- Perform search in bins of two BDT of geometry and PID
  - Calibrate to $D_s \to \phi(\mu\mu)\pi$
- τ mass window: no signal
- Observed limit (1 fb^{-1}):
  - $\mathcal{B}(\tau\to\mu\mu\mu) < 6.3 \cdot 10^{-8}$ at 90% CL (prelim.) [LHCb-CONF-2012-015]
  - Current best: Belle $2.1 \cdot 10^{-8}$ at 90% CL [PLB 687, 139 (2010)]



LHCb Upgrade plans

- Expect that integrated luminosity increases linearly with time. After 6 fb^{-1}, would take $\sim$3 years to double statistics
  - Need an order of magnitude increase in luminosity ➜ $\mathcal{O}(10^{33})$
  - ✔ Most of the detector can cope, efficiencies don't degrade
- ✗ L0 saturates for hadronic channels
  - p_T is not a discriminating variable anymore
  - ➜ Cut on impact parameter
- ➜ Read all out at 40 MHz
  - Most of the electronics to be replaced



[CERN-LHCC-2011-001] [CERN-LHCC-2012-007]

Some Upgraded Physics

Type	Observable	Current precision	LHCb 2018	**Upgrade** (50fb^{-1})	Theory uncertainty
B_s mixing	$2\beta_s$ ($B_s \to J/\psi\,\phi$)	0.10	0.025	0.008	~ 0.003
	$2\beta_s$ ($B_s \to J/\psi\, f_0(980)$)	0.17	0.045	0.014	~ 0.01
	$A_{\rm fs}(B_s)$	6.4×10^{-3}	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\rm eff}(B_s \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\rm eff}(B_s \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\rm eff}(B_d \to \phi K_S^0)$	0.17	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\rm eff}(B_s \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\rm eff}(B_s \to \phi\gamma)/\tau_{B_s}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B_d \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\text{GeV}^2/c^4)$	0.08	0.025	0.008	0.02
	$s_0\, A_{\rm FB}(B_d \to K^{*0}\mu^+\mu^-)$	25 %	6 %	2 %	7 %
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\text{GeV}^2/c^4)$	0.25	0.08	0.025	~ 0.02
	$\mathcal{B}(B_u \to \pi^+\mu^+\mu^-)/\mathcal{B}(B_u \to K^+\mu^+\mu^-)$	25 %	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	1.5×10^{-9}	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B_d \to \mu^+\mu^-)/\mathcal{B}(B_s \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	γ ($B \to D^{(*)}K^{(*)}$)	$\sim$ 10–12°	4°	0.9°	negligible
	γ ($B_s \to D_s K$)	–	11°	2.0°	negligible
	β ($B_d \to J/\psi\, K_S^0$)	0.8°	0.6°	0.2°	negligible
Charm $\mathcal{CP}$ violation	A_Γ	2.3×10^{-3}	0.40×10^{-3}	0.07×10^{-3}	–
	$\Delta A_{\mathcal{CP}}$	2.1×10^{-3}	0.65×10^{-3}	0.12×10^{-3}	–

[CERN-LHCC-2012-007]

Conclusion

- The LHC is the new b factory
- Exploring b $\to$ s transitions
  - $B_s \to \mu\mu$ eating into the SM prediction
  - Many more measurements in b $\to \ell\ell$s and CP violation:
  - The LHC does not confirm the hints seen by the Tevatron or B factories
  - But all measurements are statistically limited
- More to come in the next years
- And beyond with the LHCb upgrade

Backup

$B_s \to \mu\mu$ EFFECTIVE LIFETIME

The effective lifetime allows the extraction of

$$\mathcal{A}_{\Delta\Gamma}\, y_s = \frac{(1-y_s^2)\tau_{\mu^+\mu^-} - (1+y_s^2)\tau_{B_s}}{2\tau_{B_s} - (1-y_s^2)\tau_{\mu^+\mu^-}}$$

$$\text{with } y_s = \frac{1}{2}\tau_{B_s}\Delta\Gamma_s = 0.075 \pm 0.010 \quad \text{[HFAG]}$$

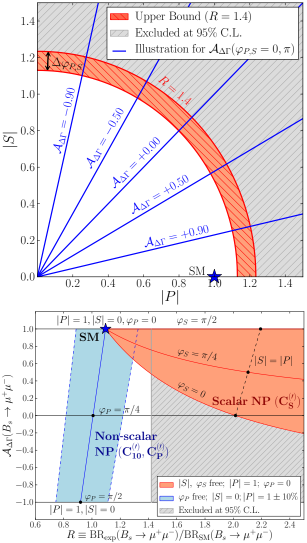
This gives sensitivity to the (pseudo-) scalar operators $\mathcal{O}_{P,S}$ with Wilson coefficients P and S ($=1,0$ in SM):

$$R \equiv \frac{\text{BR}(B_s \to \mu^+\mu^-)_{\text{exp}}}{\text{BR}(B_s \to \mu^+\mu^-)_{\text{SM}}} = \left[\frac{1+\mathcal{A}_{\Delta\Gamma} y_s}{1-y_s^2}\right]\left(|P|^2+|S|^2\right)$$

$$= \left[\frac{1+y_s\cos 2\varphi_P}{1-y_s^2}\right]|P|^2 + \left[\frac{1-y_s\cos 2\varphi_S}{1-y_s^2}\right]|S|^2,$$

LHCb expects $\mathcal{O}(500)$ events with 50 fb^{-1}, as many as for $\tau_{\text{eff}}(B_s \to KK)$ [Phys.Lett. B707 (2012) 349-356]

[De Bruyn, Fleischer, Knegjens, PK, Merk, Pellegrino, Tuning...]

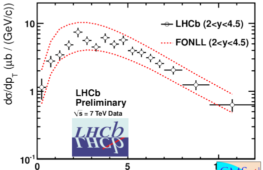


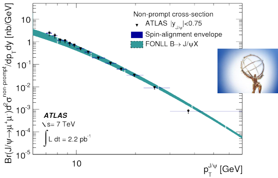
b PRODUCTION AT LHC

DETACHED J/ψ

CMS: [Eur.Phys.J. C71 (2011) 1575],
Atlas: [Nucl.Phys. B850 (2011) 387-444]
LHCb: [Eur. Phys. J. C 71 (2011) 1645]

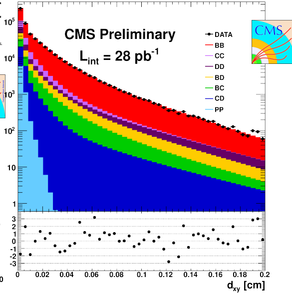
$$\sigma^{4\pi}_{b\bar{b}} = (288 \pm 4 \pm 48)\ \mu\mathrm{b}$$





DILEPTON TAGS

CMS: [CMS-PAS-BPH-10-015]

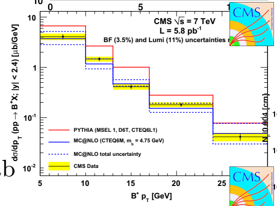


$D\mu$ TAGS

LHCb: [Physics Letters B 698 (2011) 14]

$$\sigma^{(2<\eta<6)}_{b\bar{b}} = (75 \pm 5 \pm 13)\ \mu\mathrm{b}$$

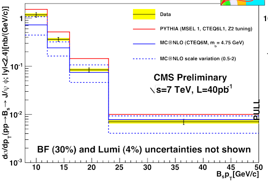
$$\sigma^{4\pi}_{b\bar{b}} = (284 \pm 20 \pm 49)\ \mu\mathrm{b}$$



FULLY RECONSTRUCTED

$B \to J/\psi X$

LHCb [CONF-2011-033]
CMS: [Phys.Rev.Lett.106:112001,2011]
[Phys. Rev. Lett. 106, 252001 (2011)]
[arXiv:1106.4048]



Flavour Factories and LHCb

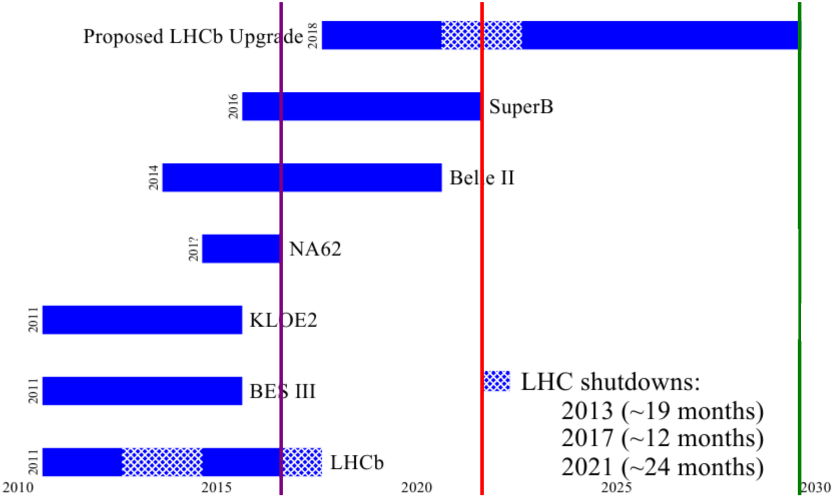
Decay	LHCb		Belle		Ratio
$B_u \to J/\psi K$	10049	34 pb^{-1}	41315	711 fb^{-1}	5.1
$B_u \to D^0{}_{\text{CP}}\pi$	1270	34 pb^{-1}	2163	250 fb^{-1}	4.3
$B_d \to K\pi$	838	35 pb^{-1}	4000	480 fb^{-1}	2.9
$B_u \to K\ell\ell$	35	35 pb^{-1}	161	605 fb^{-1}	2.6
$B_d \to K^*\ell\ell$	144	165 pb^{-1}	230	605 fb^{-1}	2.3
$B_d \to J/\psi K^0_S$	1100	33 pb^{-1}	12681	711 fb^{-1}	1.9
$B_d \to K^*\gamma$	485	88 pb^{-1}	450	78 fb^{-1}	1.0
$B_s \to J/\psi\phi$	1414	95 pb^{-1}	45	24 fb^{-1}	7.9
$B_s \to J/\psi f_0$	111	33 pb^{-1}	63	121 fb^{-1}	6.5
$B_s \to \phi\gamma$	60	88 pb^{-1}	18	24 fb^{-1}	0.9
$D^+ \to \phi\pi$	$90k$	35 pb^{-1}	$237k$	955 fb^{-1}	10

1 fb^{-1} at LHCb (7 TeV) is 1 to 5 ab^{-1} (8 for B_s) at a B factory

Cross sections: $e^+e^- \to B\overline{B}$: 1.1 nb ($\Upsilon(4S)$, 5 at Z) vs $pp \to b\bar{b}X$: 270 μb

[arXiv:hep-ex/0402042] [Nature] [arXiv:0904.0770] [arXiv:hep-ex/0601032] [arXiv:1008.2567] [arXiv:0905.4345]

Timeline



[Ciuchini]