Rare decays searches

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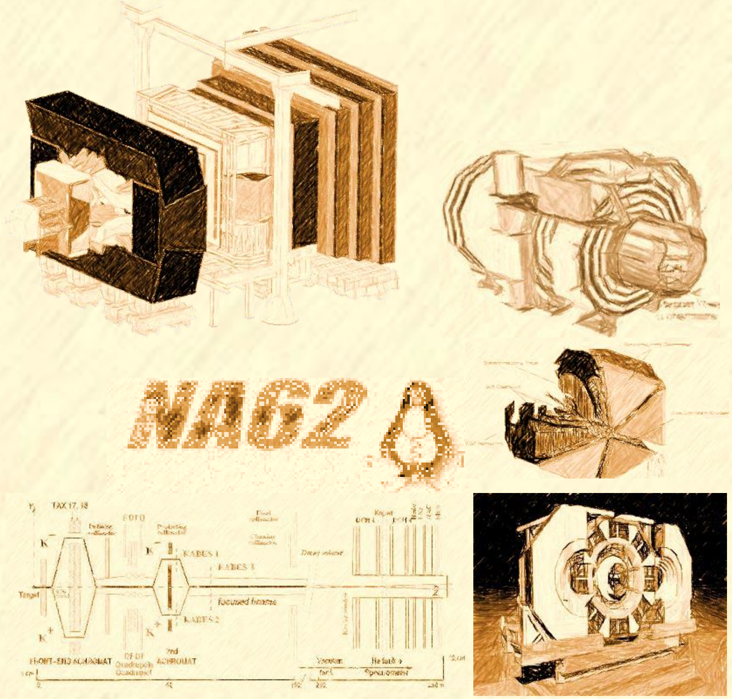
On behalf of LHCb
Including also results from BES-III, CLAS, CMS, NA48/2, and NA62

Rare Decays

- Very rare decays
  - $B_s \to \mu\mu$, $B_d \to \mu\mu$
  - Rare charm decays
  - Rare strange decays
- Lepton universality tests
  - Tests on $B \to D^{(*)}\, l\, \upsilon$
  - Tests on $b \to s\, ll$ transitions
- Other results from $b \to s(d)\, ll$ transitions
  - Branching ratios
  - Angular analyses
- Not covered here: radiative decays



See also:

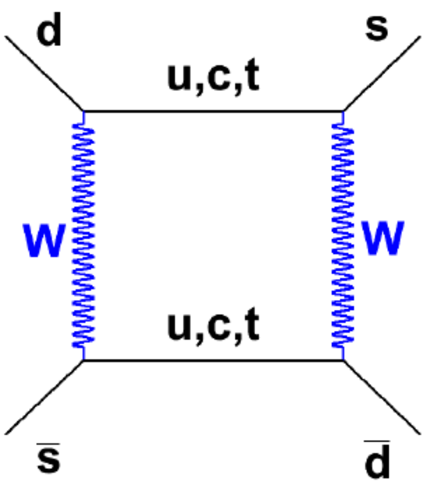
Federico Redi, Exotics session
31/8/2015 14:30 - 14:55
Giovanni Veneziano, HF Physics session
2/9/2015 11:36 - 11:54

Rare Decays

- Rare decays correspond to **indirect searches for BSM Dynamics** (i.e, new particles)

- Indirect approach has been very successful in the past

  - Neutral Currents
    (Z^0 inferred ten years before direct observation)
  - Kaon mixing
    (top-quark inferred 30 years before direct observation)



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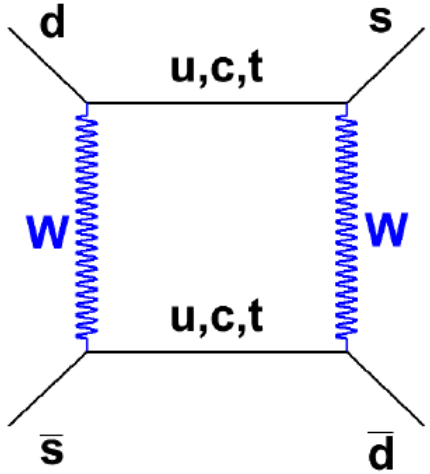
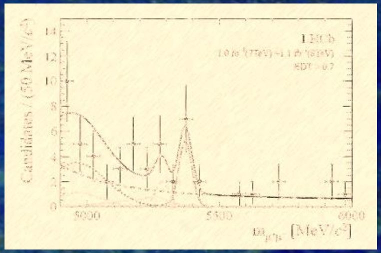
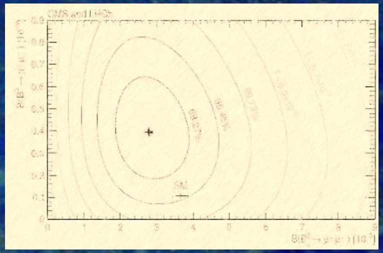


(you may also notice Earth' radius was inferred indirectly 2.3k years before direct observation…)

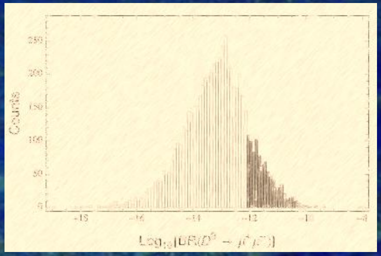
Eratosthenes

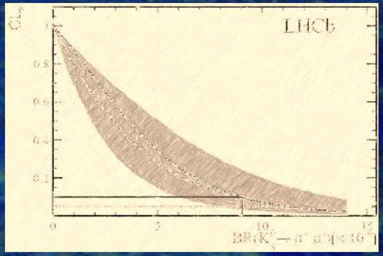
~2.3 K years till the direct observation…





VERY RARE DECAYS



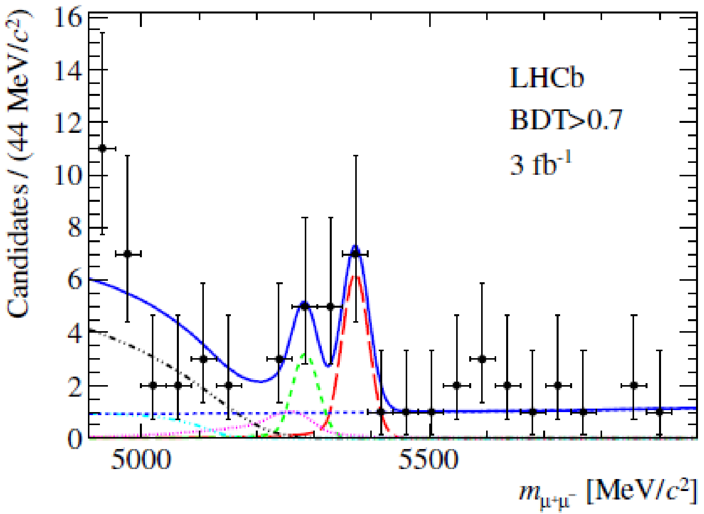


$B_{s(d)} \to \mu\mu$ (results)

Phys. Rev. Lett. 111 (2013) 101804

Full Run-I dataset analysed, giving:

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (2.9\,^{+1.1}_{-1.0}(\text{stat})\,^{+0.3}_{-0.1}(\text{syst})) \times 10^{-9}\,,$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.7\,^{+2.4}_{-2.1}(\text{stat})\,^{+0.6}_{-0.4}(\text{syst})) \times 10^{-10}$$



Consistent with SM predictions:

$BR(B_s \to \mu\mu) = (3.66 \pm 0.23) \times 10^{-9}$ $BR(B_d \to \mu\mu) = (1.06 \pm 0.09) \times 10^{-10}$

PRL 112, 101801

(time averaged)

$B_{s(d)} \to \mu\mu$ *(results)*

Phys. Rev. Lett. 111 (2013) 101804

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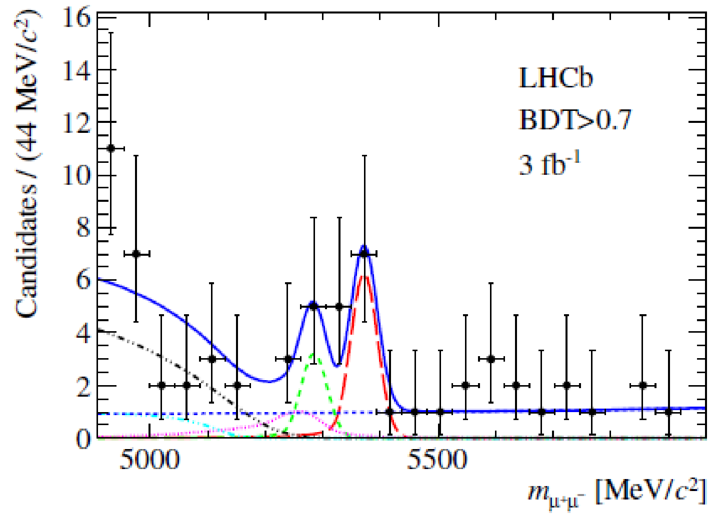


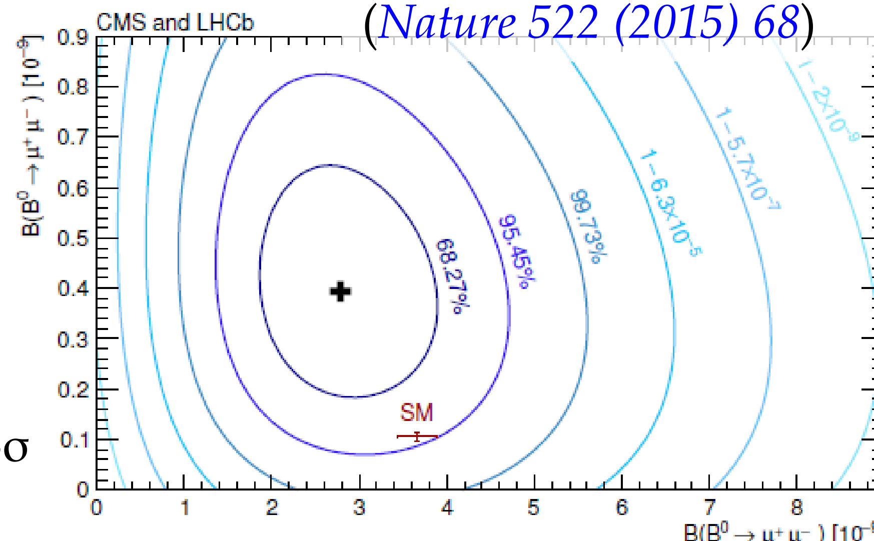
Combined with CMS (joint likelihood fit)

CMS: Phys. Rev. Lett. 111, 101805

6.2σ observation of $B_s \to \mu\mu$
3.0σ evidence for $B_d \to \mu\mu$

$$\mathcal{BR}(B_s \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \times 10^{-9}$$
$$\mathcal{BR}(B_d \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \times 10^{-10}$$

(*Nature 522 (2015) 68*)

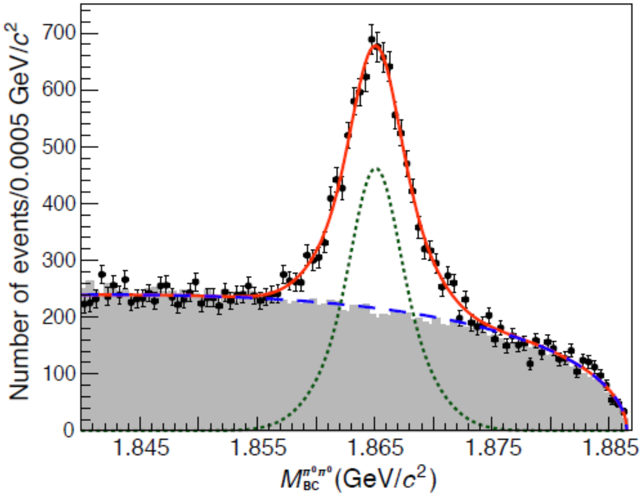


Ratio B_s/B_d BF's agreement with SM at 2.3σ

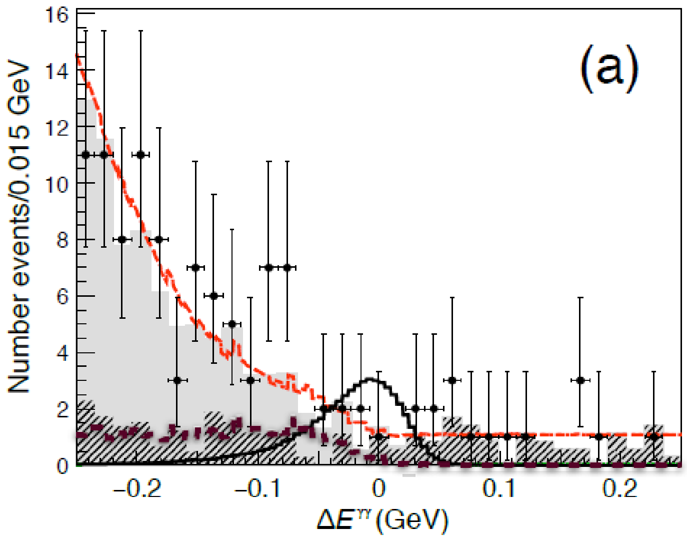
Rare charm decays: $D^0 \rightarrow \gamma\gamma$ BES III

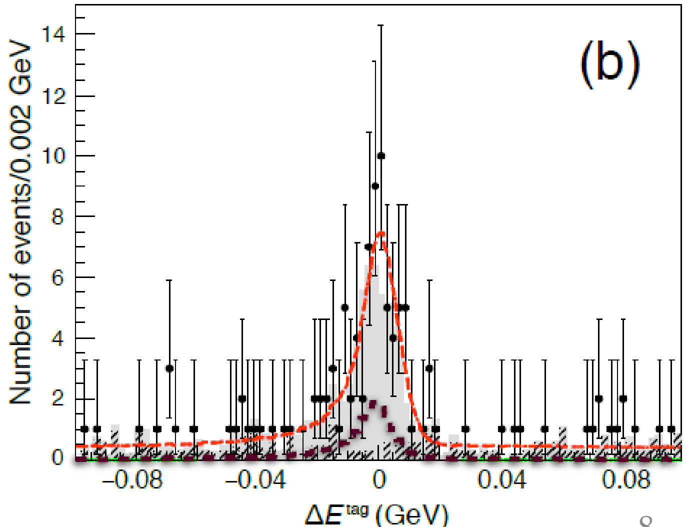
Phys.Rev. D91 (2015) 11, 112015

- Analyzed 2.9 fb-1
- BR normalized to $D^0 \rightarrow \pi^0\pi^0$, which is also a background source



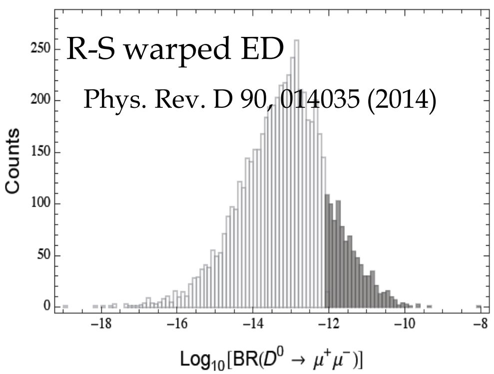
$$\mathcal{B}(D^0 \rightarrow \gamma\gamma) < 3.8 \times 10^{-6}$$ (@ 90% CL)





Rare charm decays: $D^0 \to \mu\mu$

Phys.Lett. B725 (2013) 15-24



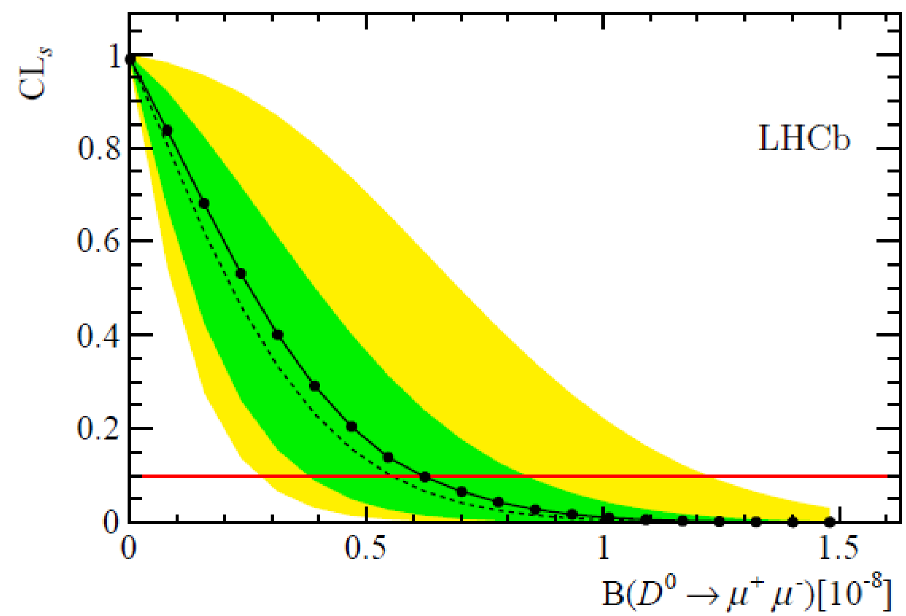
SM prediction: $BR(D^0 \to \mu\mu) < 1.6 \times 10^{-11}$

(Precision depends on knowledge of $BR(D^0 \to \gamma\gamma)$)

BSM physics (RPV, ED's) can enhance it up to the 10^{-10} level

LHCb performed a search using 1 fb^{-1}

$BR(D^0 \to \mu\mu) < 6.2(7.6) \times 10^{-9}$ @ 90(95) $\%CL_s$



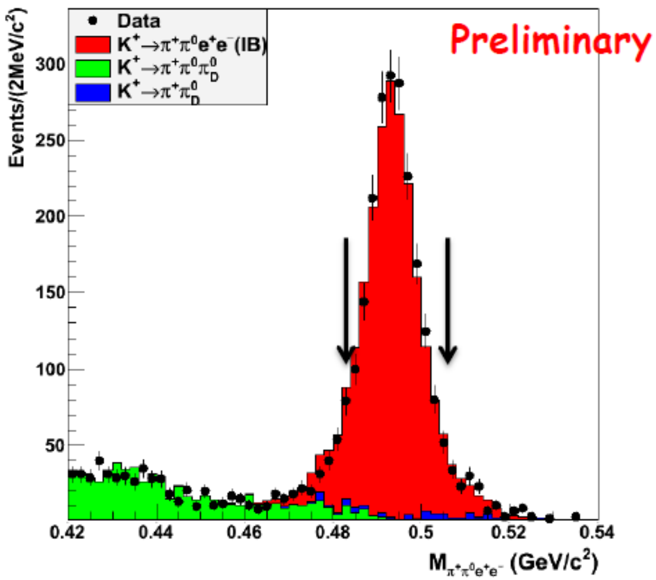
Potential to reach more interesting region with LHCb upgrade

Other rare charm decays@LHCb

	Run –I	Run- II	Upgrade	Status
$D^+_{(s)} \to \pi^+\mu^+\mu^-$	Few 10^{-8}	Fewer 10^{-8}	Few 10^{-9}	1/3 Run-I arXiv:1304.6365, Phys. Lett. B 724 (2013) 203-212
$D^+_{(s)} \to \pi^-\mu^+\mu^+$	Few 10^{-8}	Fewer 10^{-8}	Few 10^{-9}	1/3 Run-I arXiv:1304.6365, Phys. Lett. B 724 (2013) 203-212
$D^+_s \to K^+\mu^+\mu^-$	Few 10^{-7}	Fewer 10^{-7}	Few 10^{-8}	Work ongoing
$D^0 \to h^+h'^-\mu^+\mu^-$	Few 10^{-7}	Fewer 10^{-7}	Few 10^{-8}	Work ongoing
$\Lambda^+_c \to p\mu^+\mu^-$	Few 10^{-7}	Fewer 10^{-7}	Few 10^{-8}	Work ongoing
$D^0 \to \mu^+ e^-$	Few 10^{-8}	Fewer 10^{-8}	Few 10^{-9}	Work ongoing
$\sigma(A_{CP} D^0 \to \phi\gamma)$	~10%	5%	?	Work ongoing

Rare strange decays: Recent results

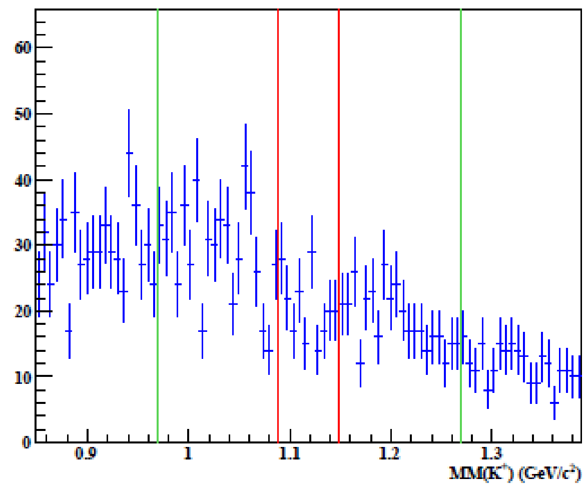
NA48/2: Discovery of $K^{\pm}\to\pi^{\pm}\pi^{0}e^{+}e^{-}$



BR($K^{\pm}\to\pi^{\pm}\pi^{0}e^{+}e^{-}$) = (4.06±0.17) x$10^{-6}$

(Preliminary)
arXiv:1508.01307 [hep-ex]

CLAS collaboration (Jefferson Lab): Limits on B and L violation

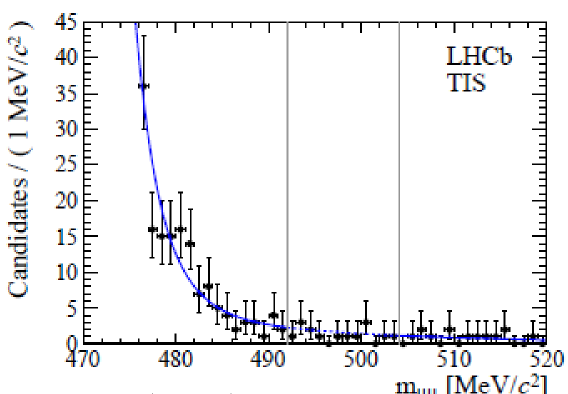


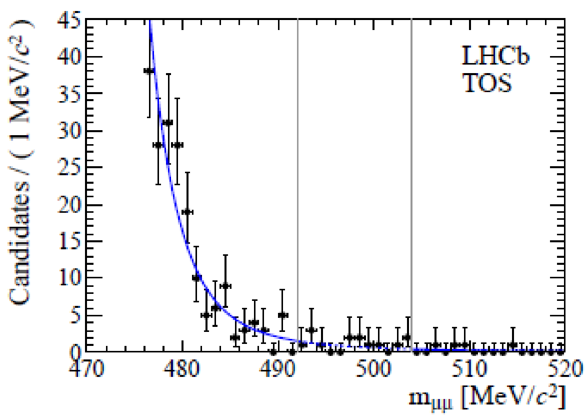
Reaction	$\mathcal{B}_{\mathrm{UL}}$
$\Lambda\to K^{+}e^{-}$	2×10^{-6}
$\Lambda\to K^{+}\mu^{-}$	3×10^{-6}
$\Lambda\to K^{-}e^{+}$	2×10^{-6}
$\Lambda\to K^{-}\mu^{+}$	3×10^{-6}
$\Lambda\to\pi^{+}e^{-}$	6×10^{-7}
$\Lambda\to\pi^{+}\mu^{-}$	6×10^{-7}
$\Lambda\to\pi^{-}e^{+}$	4×10^{-7}
$\Lambda\to\pi^{-}\mu^{+}$	6×10^{-7}
$\Lambda\to\bar{p}\pi^{+}$	9×10^{-7}
$\Lambda\to K^{0}_{S}\nu$	2×10^{-5}

arXiv:1507.03859 [hep-ex]

Rare strange decays: $K_S \to \mu\mu$

- SM prediction: $BR(K_S \to \mu\mu) = (5.1\pm1.5)\times10^{-12}$
  JHEP 0401 (2004) 009
- $K_S \to \mu\mu$ sensitive to different physics than $K_L \to \mu\mu$
  (see JHEP 0401 (2004) 009)
- LHCb performed a search using $1fb^{-1}$:

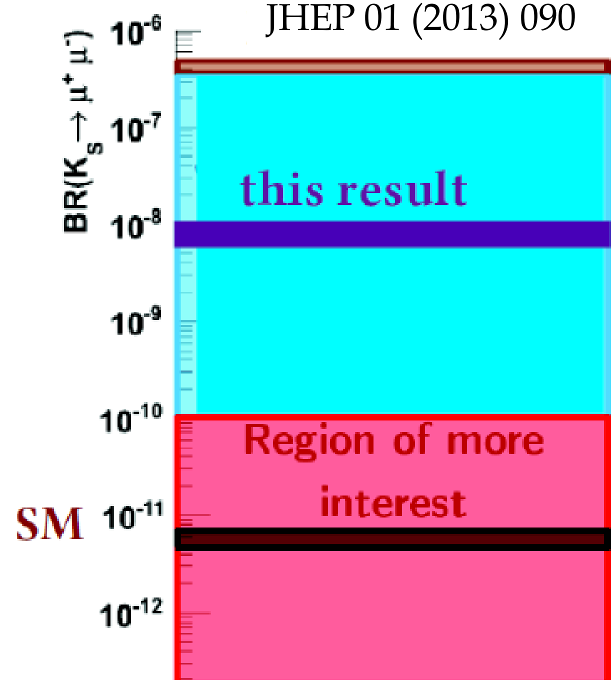


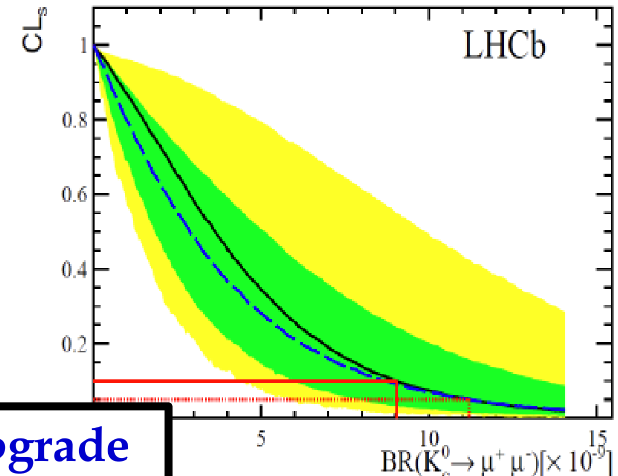


JHEP 01 (2013) 090

$BR(K_S \to \mu\mu) < 9(11)\times10^{-9}$ @90(95)% CL_s

JHEP 01 (2013) 090



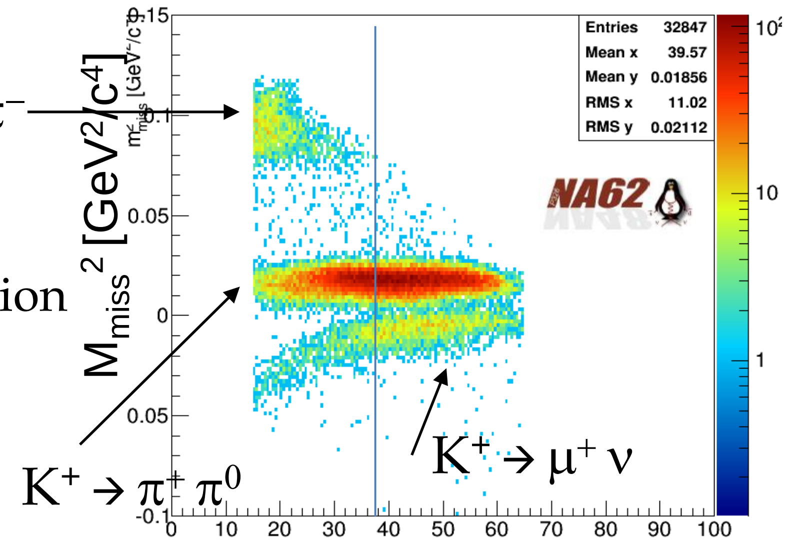


Potential to reach more interesting region with LHCb upgrade

Rare strange decays: prospects

NA62

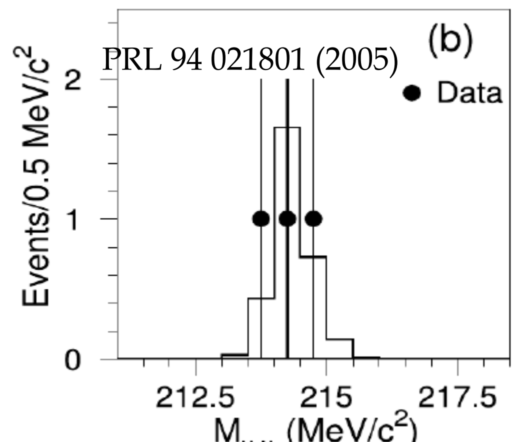
- Started data taking end of June
- Measured detector performances within expectation
- Aims for 10% precision in BR($K^{\pm} \to \pi^{\pm} \nu\nu$)

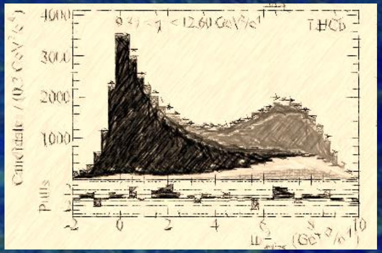


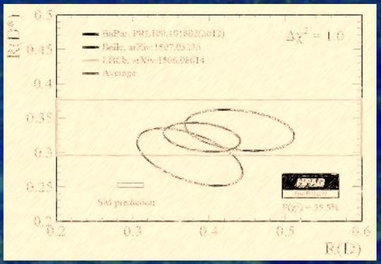
KOTO BR($K_L \to \pi^0 \nu\nu$) also starting data taking

LHCb

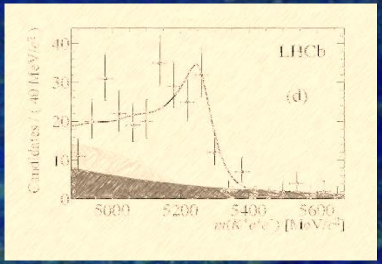
- **$\Sigma \to p\mu\mu$**: aim to confirm / reject Hyper CP anomaly
- Work ongoing in **$K_S \to \mu\mu$** update
- Several other kaon/hyperon decays being explored ($K_S \to \pi^0\mu\mu$, $K_S \to \pi\pi\mu\mu$, $K_S \to \mu\mu\mu\mu$, electron modes…)

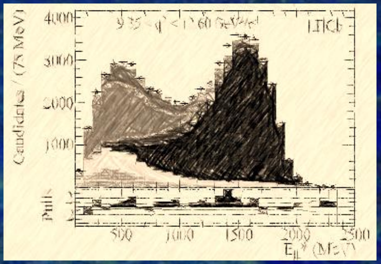






LEPTON UNIVERSALITY



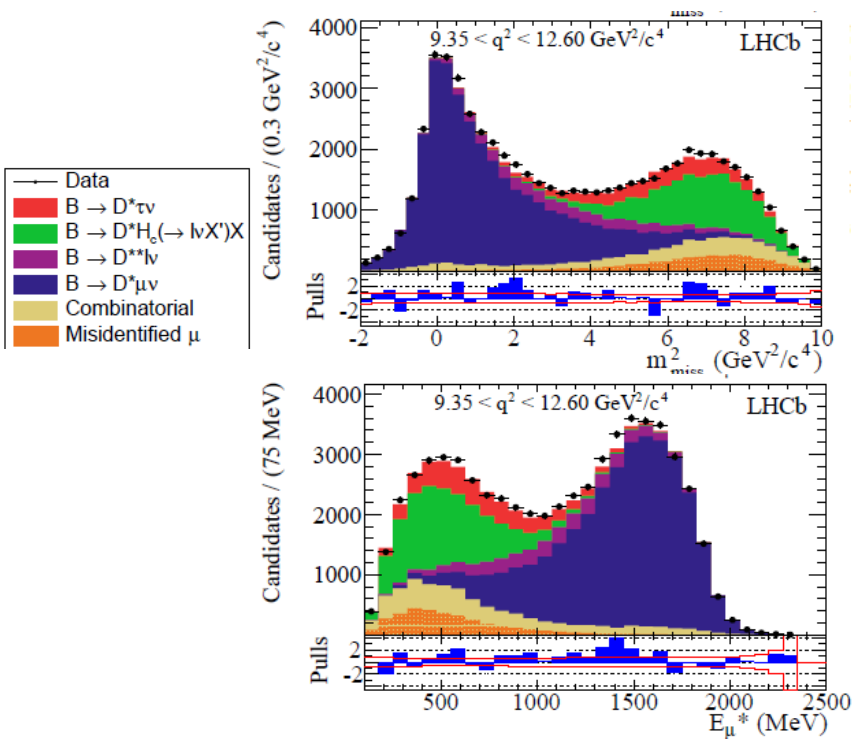


Lepton Universality in $B \to D^{(*)} l \upsilon$

arXiv:1506.08614

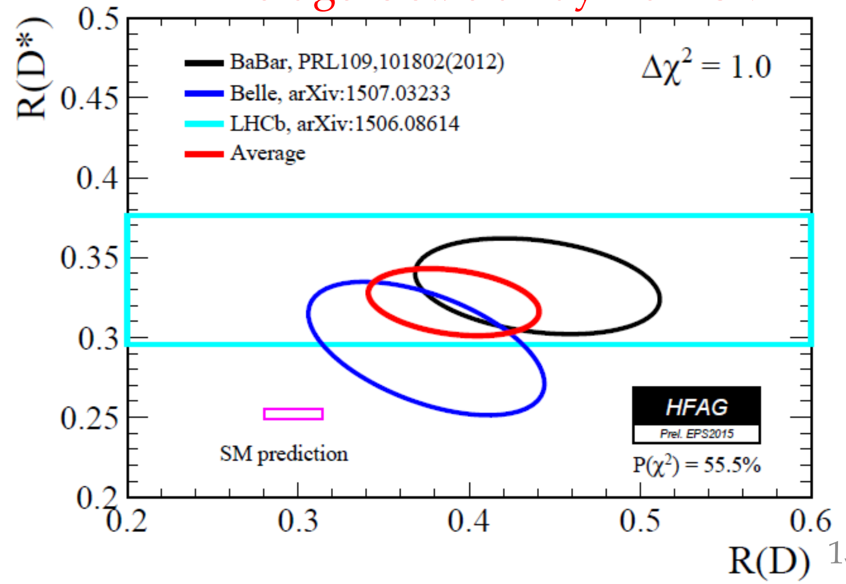
$$R(D) = \frac{B(B^0 \to D^+ \tau^- \upsilon)}{B(B^0 \to D^+ \mu^- \upsilon)} \qquad R(D^*) = \frac{B(B^0 \to D^{*+} \tau^- \upsilon)}{B(B^0 \to D^{*+} \mu^- \upsilon)}$$

- Some tension found in the past by Babar and Belle
- LHCb analyzed the full Run-I dataset, using $\tau \to \mu\nu\nu$
- Separate signal from background fitting M_{miss}^2, q^2, and E_μ



R(D*) measured value in LHCb is 2.1 σ higher than SM prediction, strengthening the tension.

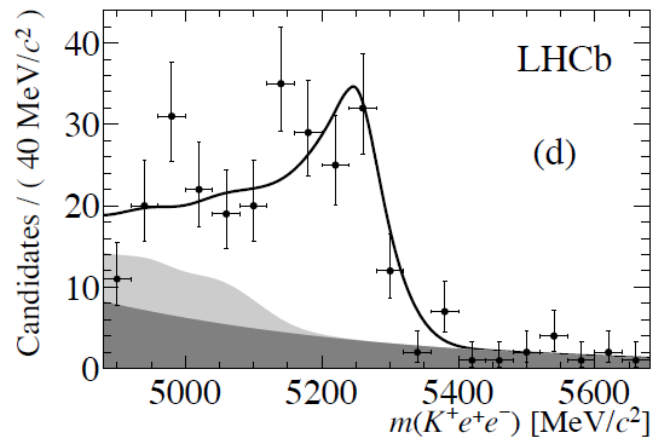
Average is 3.9σ away from SM



Lepton Universality in b → sll transitions

Phys. Rev. Lett. 113, 151601

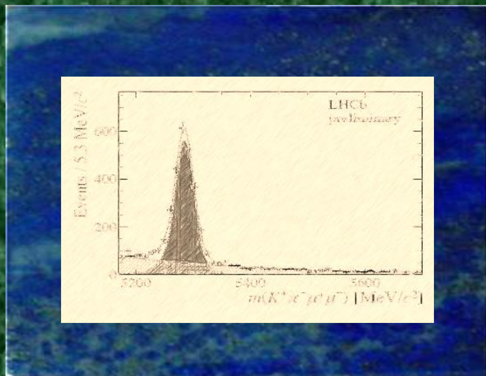
LHCb performed a lepton universality test in $B^+ \to K^+\ell^+\ell^-$ with full Run-I dataset

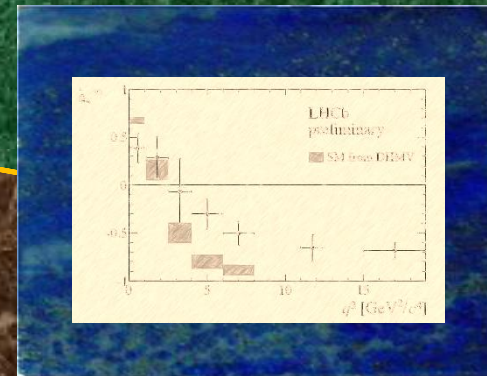


$$R_K = \frac{BF(B^+ \to K^+\mu^+\mu^-)}{BF(B^+ \to K^+e^+e^-)}$$
$$= 0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{syst})$$

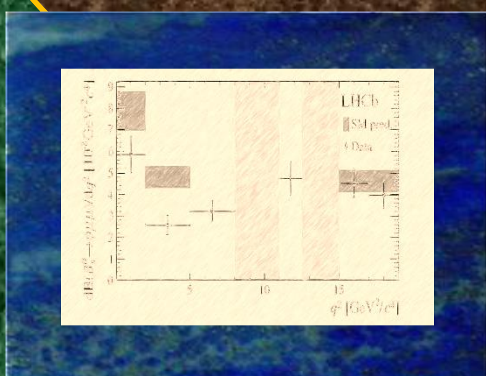
Result in agreement within **2.6σ** from SM prediction of $R_K = 1$
Result with m_{ll} at the J/ψ resonance consistent with 1

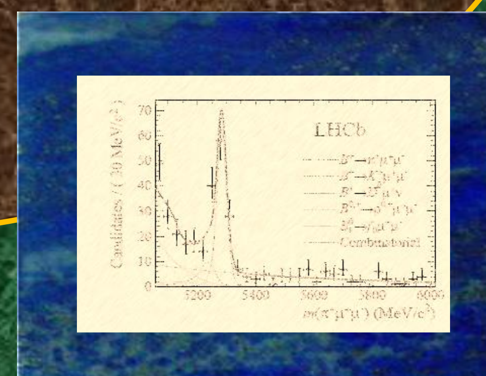
Work ongoing to test lepton universality in $K^*\ell^+\ell^-$ and $\Phi\ell^+\ell^-$ models





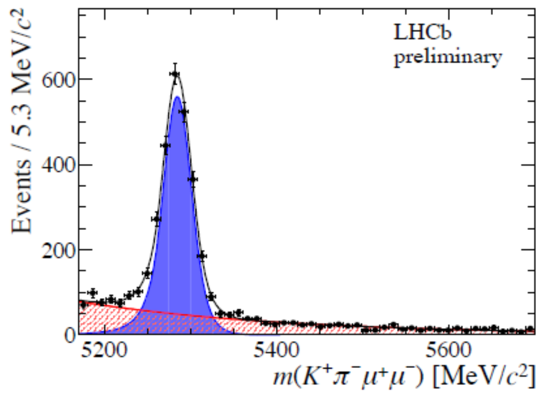
Other b →s(d) l^+l^- transitions



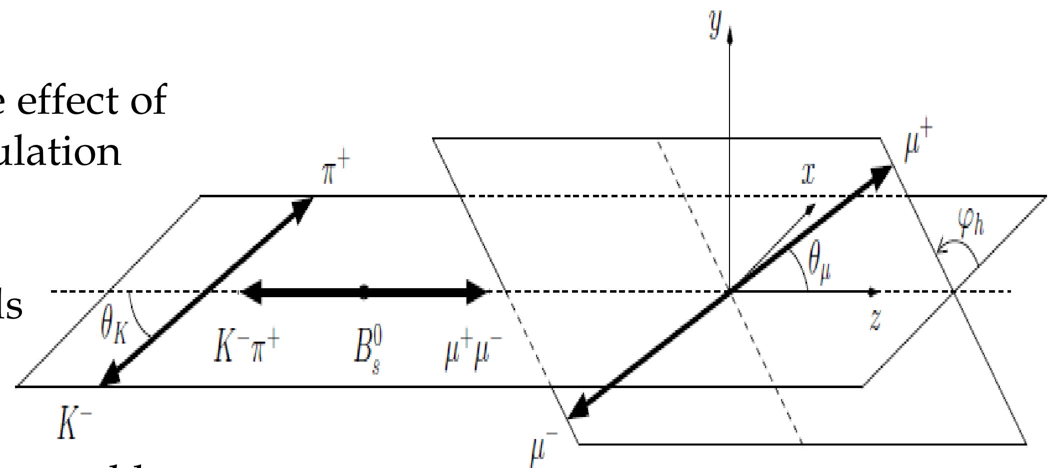


$B_d \to K^*(\to K\pi)\, \mu\mu$

LHCb-CONF-2015-002

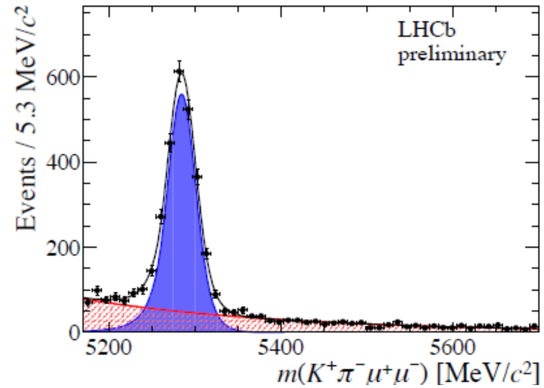


- Full Run-I dataset analyzed.
- We select events using a BDT and special vetoes for specific backgrounds
- Correct (in an event-by event basis) for the effect of reconstruction/selection/trigger using simulation
    - Validated on data via control channels (mainly $B_d \to J/\psi(\mu\mu)\, K^*(K\pi)$)
- Fit yields and angular distributions for observables in bins of q^2 (dimuon invariant mass squared)

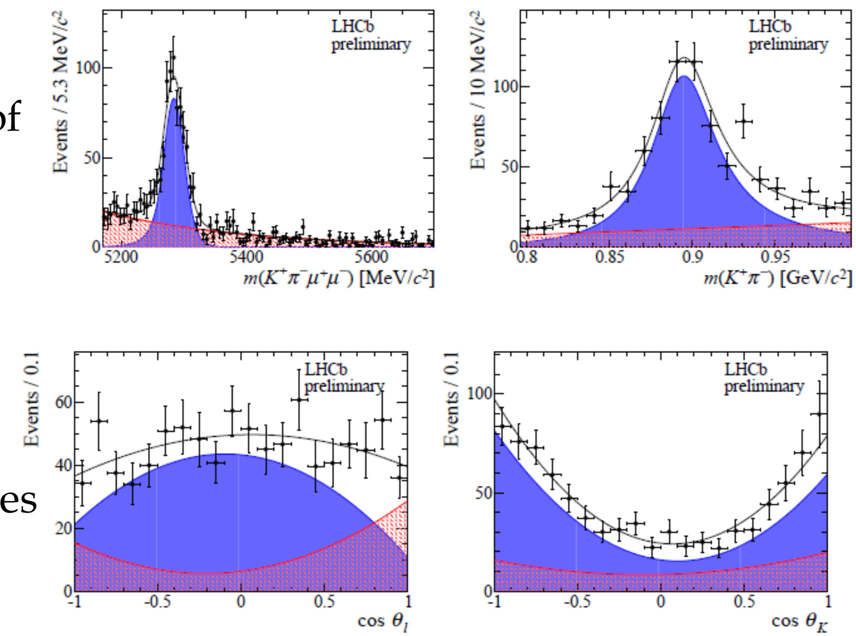


$B_d \rightarrow K^*(\rightarrow K\pi)\ \mu\mu$

LHCb-CONF-2015-002



$1 < q^2 < 6$



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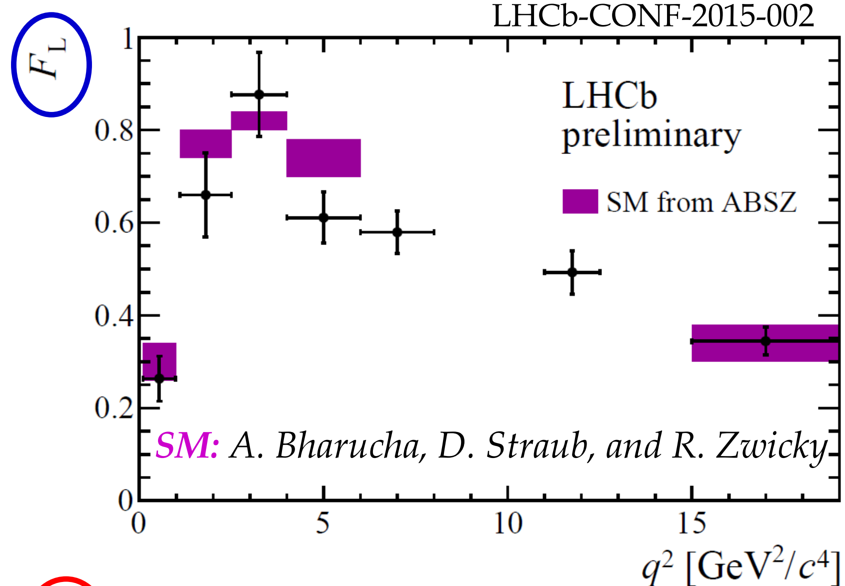
$B_d \to K^*(\to K\pi)\,\mu\mu$

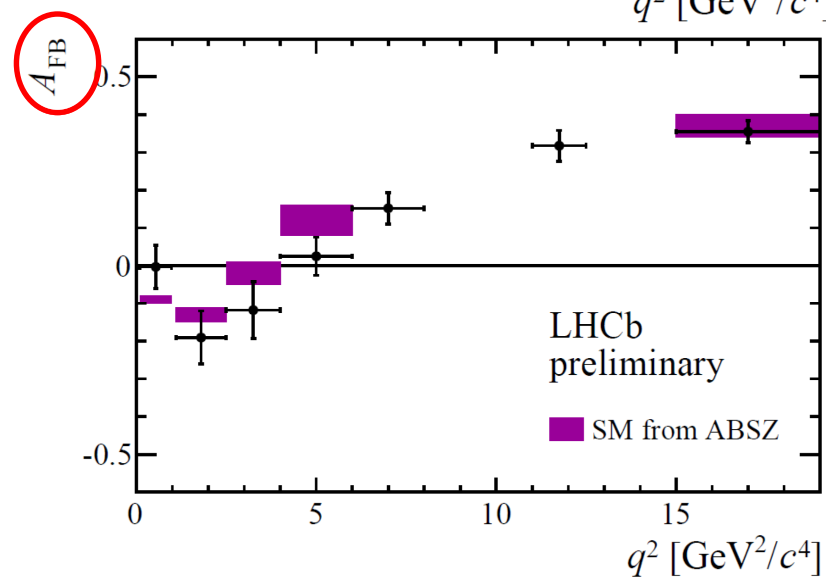
LHCb-CONF-2015-002

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{dq^2\,d\cos\theta_\ell\,d\cos\theta_K\,d\hat{\phi}} = \frac{9}{16\pi}\Big[F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K) - F_L\cos^2\theta_K(2\cos^2\theta_\ell-1) + \frac{1}{4}(1-F_L)(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + S_3(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}A_{FB}(1-\cos^2\theta_K)\cos\theta_\ell + A_9(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$



Zero crossing point of A_{FB}

$q_{ZCP}^2 = 3.7^{+0.8}_{-1.1}\,\text{GeV}^2$ (Preliminary)



Consistent with SM:

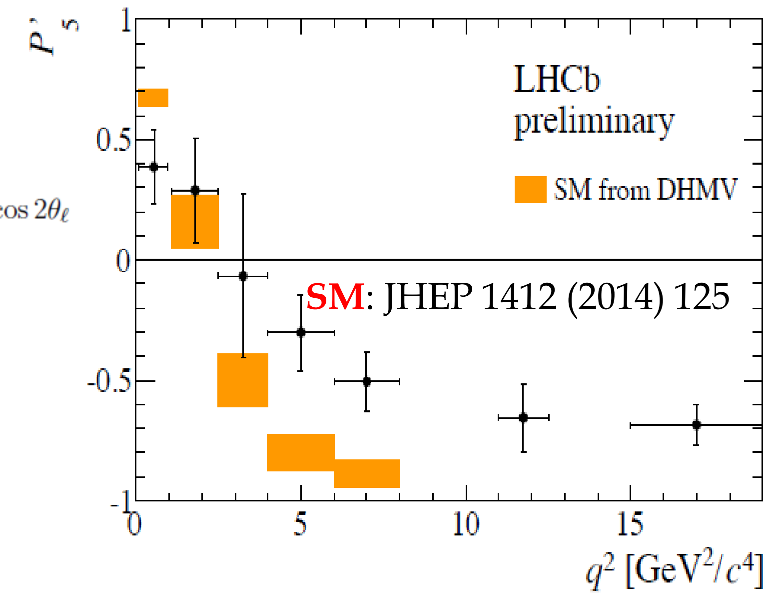
JHEP 01 (2012) 107
Eur. Phys. J. C41 (2005) 173

$B_d \rightarrow K^*(\rightarrow K\pi)\ \mu\mu$

PDF can also be parameterized to minimize form factors uncertainties

$$\frac{1}{\mathrm{d}\Gamma/dq^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi\,\mathrm{d}q^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K + \frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_\ell - F_\mathrm{L}\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_\mathrm{L}(1-F_\mathrm{L})}}$$

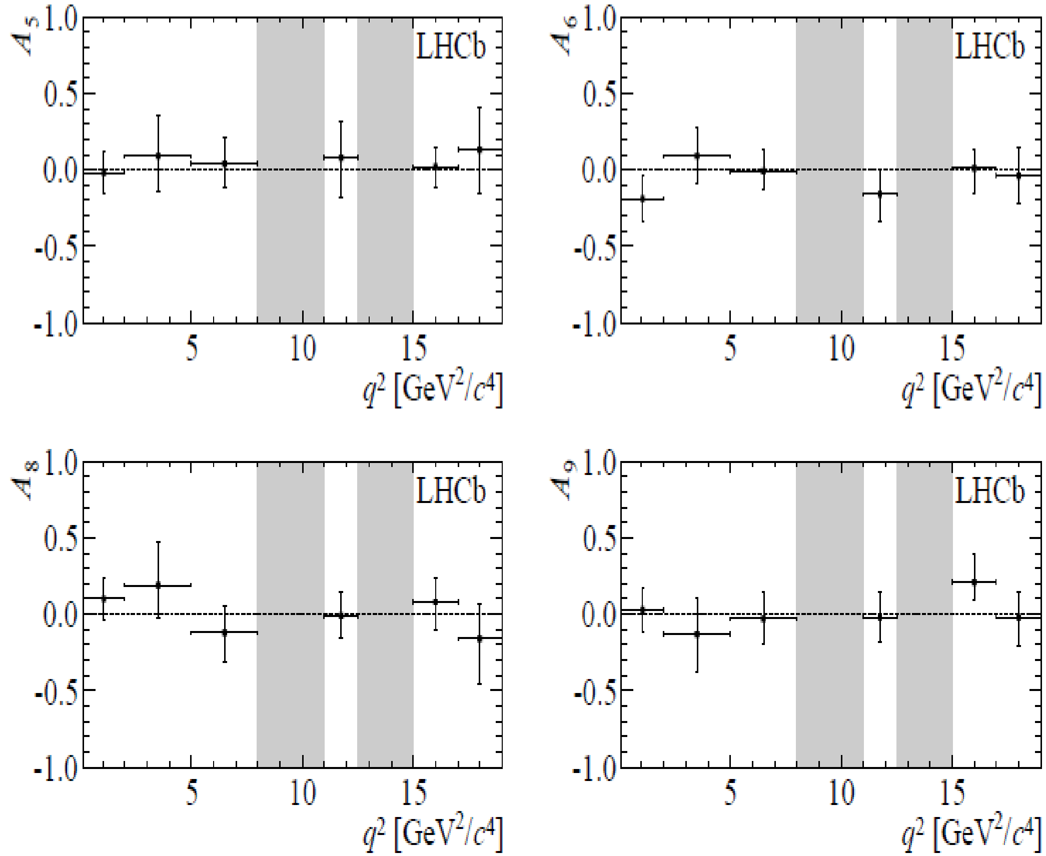


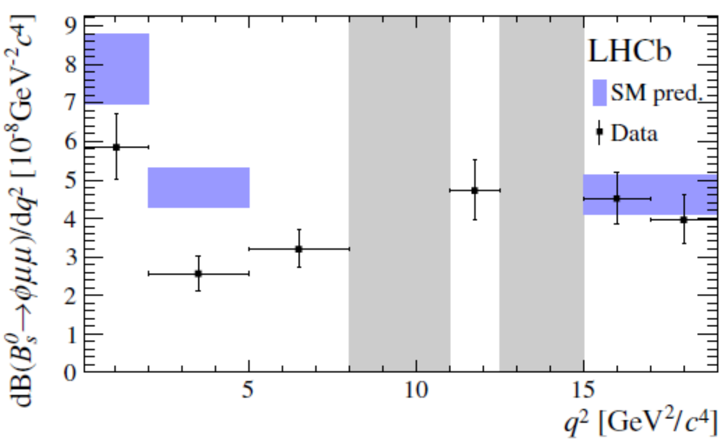
Experimental precision will keep improving
Work ongoing in the theory community (SM/NP) to better understand the pattern

arXiv:1506.08777

$B_s \rightarrow \Phi(\rightarrow KK)\ \mu\mu$

- Similar to $B_d \rightarrow K^*(\rightarrow K\pi)\ \mu\mu$ but changing spectator quark (s → d)
- Full Run-I dataset analysed

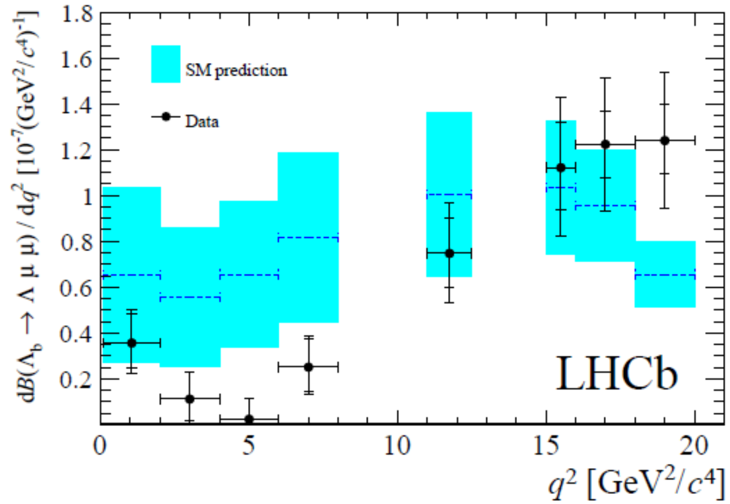


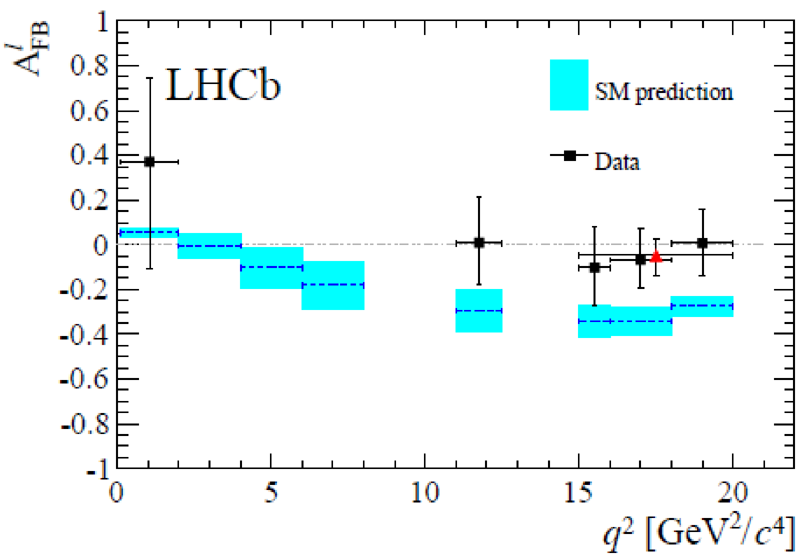


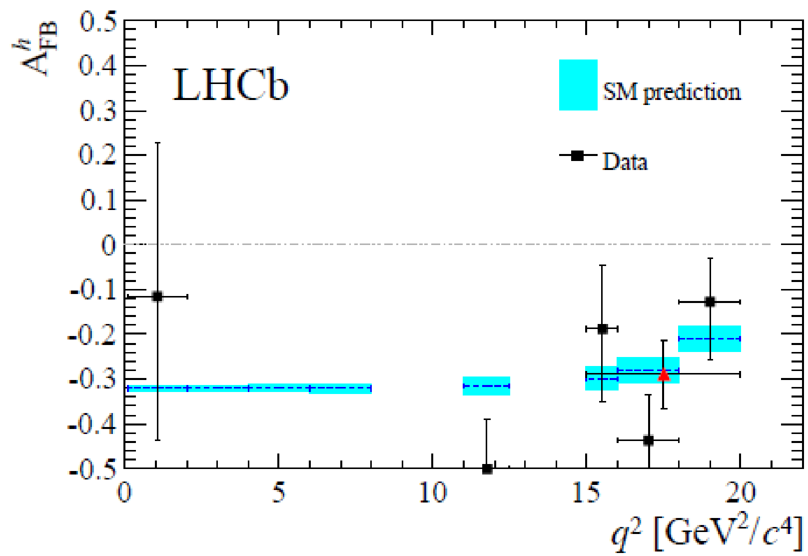
$\Lambda_b \rightarrow \Lambda(\rightarrow p\pi)\ \mu\mu$

JHEP 06 (2015) 115

- Similar to $B_d \rightarrow K^*(\rightarrow K\pi)\ \mu\mu$ but in the baryonic mode
- There is also an additional observable: $A_{FB}{}^h$
- Full Run-I dataset analysed



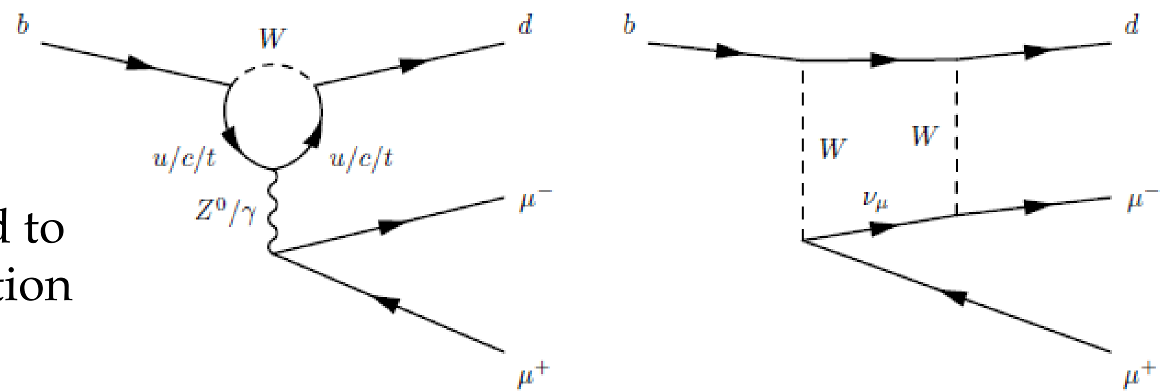




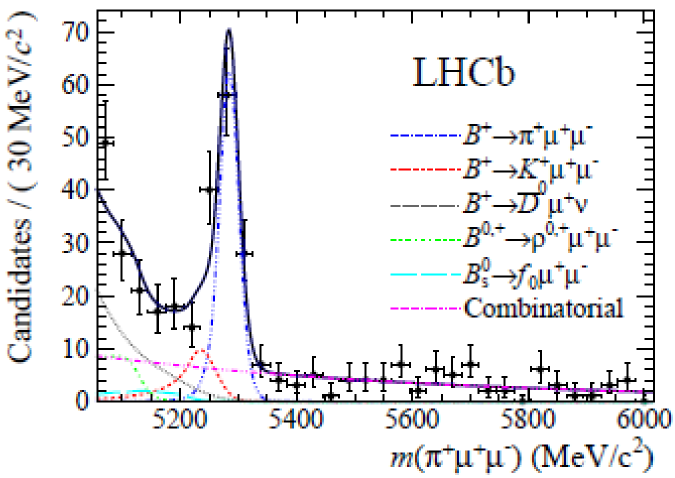
$B^+ \to \pi^+\mu\mu$

LHCb-PAPER-2015-035

- $b \to d\mu\mu$ transition
- Full Run-I data analysed to measure branching fraction an CP asymmetry



Preliminary



$$\mathcal{A}_{CP} \equiv \frac{\Gamma(B^- \to \pi^-\mu^+\mu^-) - \Gamma(B^+ \to \pi^+\mu^+\mu^-)}{\Gamma(B^- \to \pi^-\mu^+\mu^-) + \Gamma(B^+ \to \pi^+\mu^+\mu^-)}$$

$$\mathcal{B}(B^\pm \to \pi^\pm\mu^+\mu^-) = (1.83 \pm 0.24 \pm 0.05) \times 10^{-8}$$
$$\mathcal{A}_{CP}(B^\pm \to \pi^\pm\mu^+\mu^-) = -0.11 \pm 0.12 \pm 0.01\,,$$

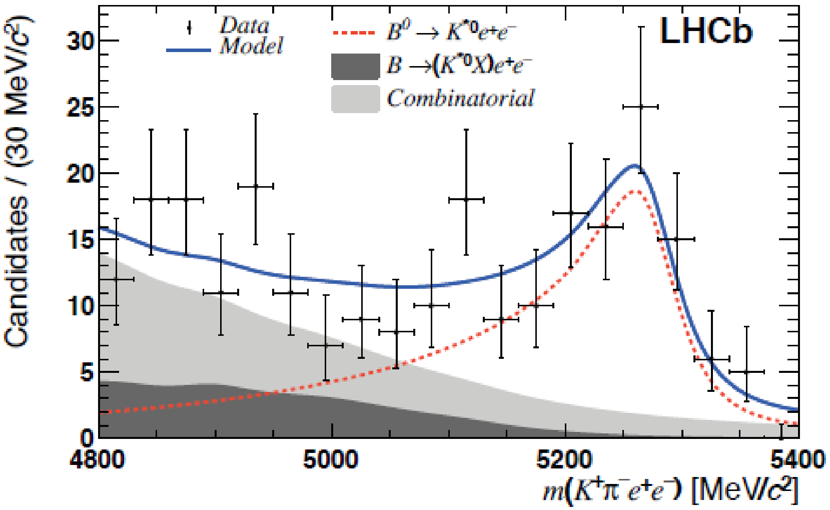
Preliminary

$B_d \to K^*(\to K\pi)\, ee$

JHEP 1504 (2015) 064

Angular analysis of $B_d \to K^{*0}e^+e^-$ at small q^2 values is sensitive to photon polarization, which is predominantly left-handed in the SM

Measurement of F_L , $A_T^{(2)}$ $A_T^{(Im)}$ $A_T^{(Re)}$ in the q^2 region [0.004,1.0] GeV^2, using 124 signal candidates using full Run-I dataset



$$A_T^{(2)}(q^2 \to 0) = \frac{2\mathcal{R}e(\mathcal{C}_7\mathcal{C}_7'^*)}{|\mathcal{C}_7|^2 + |\mathcal{C}_7'|^2} \qquad A_T^{\rm Im}(q^2 \to 0) = \frac{2\mathcal{I}m(\mathcal{C}_7\mathcal{C}_7'^*)}{|\mathcal{C}_7|^2 + |\mathcal{C}_7'|^2}$$

Result:

obs.	result
$F_{\rm L}$	$+0.16 \pm 0.06 \pm 0.03$
$A_{\rm T}^{(2)}$	$-0.23 \pm 0.23 \pm 0.05$
$A_{\rm T}^{\rm Re}$	$+0.10 \pm 0.18 \pm 0.05$
$A_{\rm T}^{\rm Im}$	$+0.14 \pm 0.22 \pm 0.05$

Jaeger et al. JHEP 05 (2013) 043

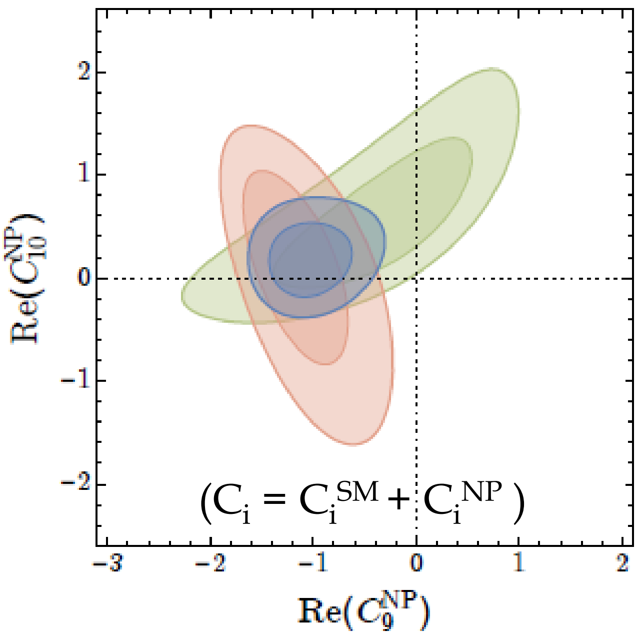
obs.	SM prediction
$F_{\rm L}$	$+0.10^{+0.11}_{-0.05}$
$A_{\rm T}^{(2)}$	$+0.03^{+0.05}_{-0.04}$
$A_{\rm T}^{\rm Re}$	$-0.15^{+0.04}_{-0.03}$
$A_{\rm T}^{\rm Im}$	$(-0.2^{+1.2}_{-1.2}) \times 10^{-4}$

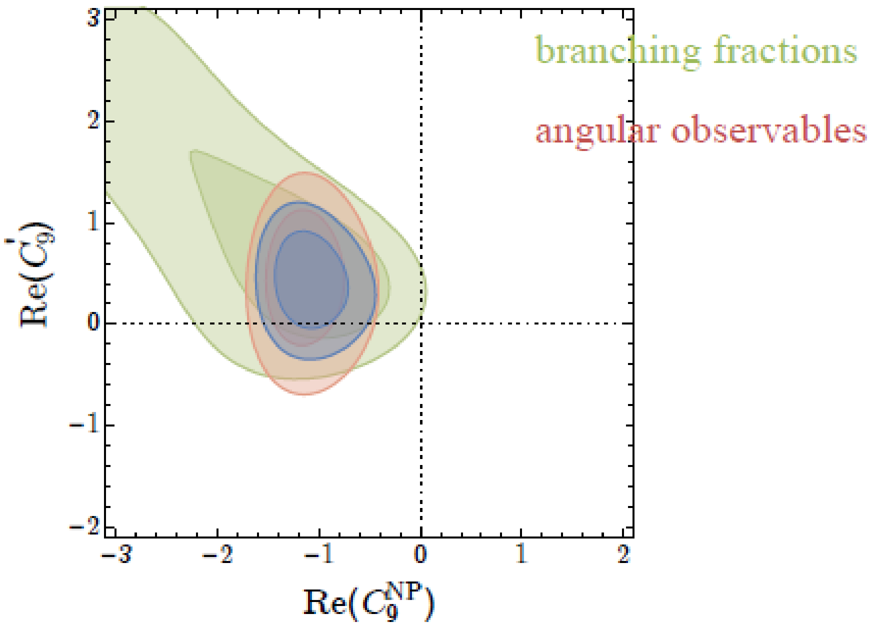
Results consistent with SM, sensitivity to C'_7 comparable to time-dependent analysis of $B \to K_s \pi^0 \gamma$ by B factories (PRD 78 071102, PRD 74 111104)

b → sll transitions: Global analysis

arXiv:1503.06199

Global model-independent fit of the Wilson coefficients using measurements from ATLAS, CMS, LHCb (Altmannshofer, Straub)



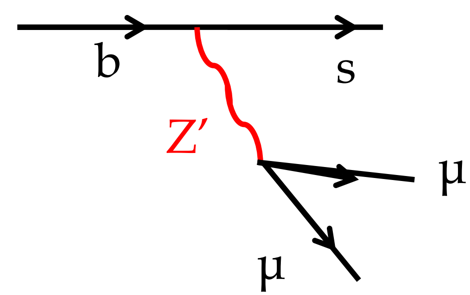


The fit prefers C_9^{NP}~-1.1

Could be due to a Z′ (Gauld et al., JHEP 1401 (2014) 069, Buras et al., JHEP 1402 (2014) 112, Altmannshofer et al. PRD 89 (2014) 095033,...)

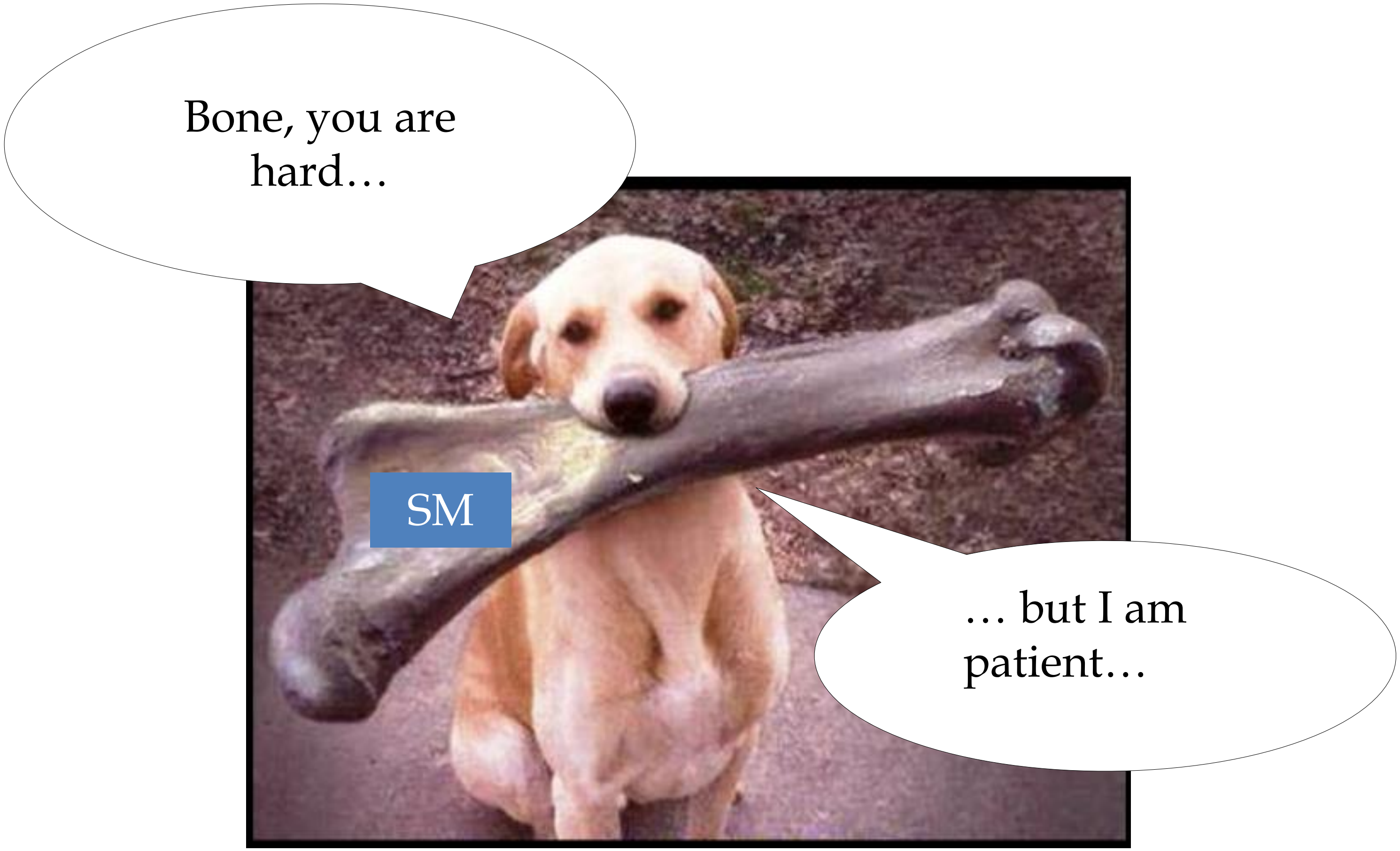
or not well understood hadronic effect.

For details see C. Bobeth's talk yesterday



Conclusions

- $B_{s(d)} \to \mu\mu$ full Run-I dataset analysed, also combined with CMS Run-I data
  - $B_s \to \mu\mu$ significance is 6.2σ.
  - First evidence for $B_d \to \mu\mu$ (3.2σ) . Ratio B_d/B_s within SM at **2.3σ** Level
- Results and prospects for rare charm and strange and decays presented
- $b \to s(d)ll$ transitions: several analyses using full Run-I data.
  - The overall picture shows some tension with SM in the Wilson coefficient C_9 (If not a fluctuation, then its either missing SM contributions or, if interpreted as NP then the likeliest is a Z′).
- Lepton universality tests on $B^+ \to K^+\ell^+\ell^-$ show **2.6σ** agreement with SM.

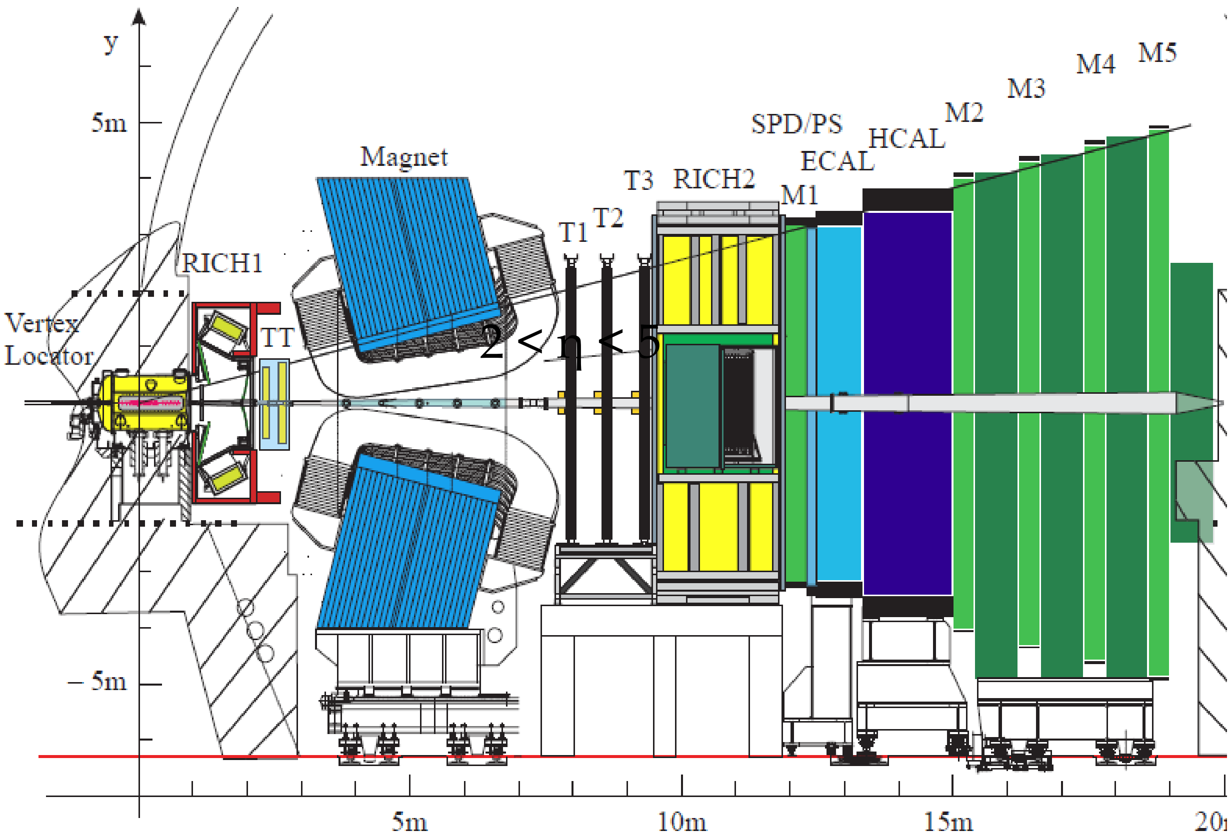


source: google osso duro

The LHCb experiment

Forward spectrometer with very precise tracking and PID

- Decay time resolution
  40 fs ($B \rightarrow J/\psi KK$)
- Invariant mass resolution
  ~23 MeV ($B \rightarrow \mu\mu$)
- 95% (K-π) ID efficiency
  for 5% fake rate



Efficient and flexible trigger
ε ~90% $B \rightarrow \mu\mu$ decays

Recorded luminosity: 3 fb^{-1}

1 fb^{-1} at 7 TeV (2011)
2 fb^{-1} at 8 TeV (2012)

Also, took 13nb^{-1} of pA data

Rare strange decays: prospects

- LHCb will keep being world leading on $K_S \to \mu\mu$
- **Most interesting region** ($BR(K_S \to \mu\mu) < 10^{-10}$) might be achievable with LHCb upgrade (**requires trigger developments**)
- Sensitivity to other decays under investigation:

- **$\Sigma \to p\mu\mu$**: aim to confirm / reject Hyper CP anomaly
- **$K_S \to \pi^0\mu\mu$**: $K_L \to \pi^0\mu\mu$ (sensitive to eg, ED) NP reach is limited by experimental uncertainty on $K_S \to \pi^0\mu\mu$. We might have a chance to improve that (**requires trigger developments**)
- Other possibilities under investigation: $K_S \to \pi\pi\mu\mu$, $K_S \to \mu\mu\mu\mu$, electron modes…

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

These decays are very supressed in SM

$BR(B_s \to \mu\mu) = (3.66 \pm 0.23)\times 10^{-9}$ $BR(B_d \to \mu\mu) = (1.06 \pm 0.09)\times 10^{-10}$

PRL 112, 101801 *(time averaged)*

… but can be modified by NP.

Scenario	Would point to →
$BR(B_s \to \mu\mu) >> SM$	Big enhancement from NP in the scalar sector, SUSY at high $\tan\beta$
$BR(B_s \to \mu\mu) \neq SM$	SUSY, ED's, LHT, TC2
$BR(B_s \to \mu\mu) \approx SM$	Anything (→ rule out regions of parameters space that predict sizable departures w.r.t SM)
$BR(B_s \to \mu\mu) << SM$	NP in the scalar sector, but full MSSM ruled out. NMSSM (Higgs singlet) good candidate
$BR(B_s \to \mu\mu) / BR(B_d \to \mu\mu) \neq SM$	CMFV ruled out. New FCNC independent of CKM matrix (RPV-SUSY, ED's ,etc …)

$B_{s(d)} \to \mu\mu$ (what does it imply?)

Scenario	Would point to
$BR(B_s \to \mu\mu) >> SM$	Big enhancement from NP in the scalar sector, SUSY at high tanβ
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$BR(B_s \to \mu\mu) / BR(B_d \to \mu\mu) \neq SM$	CMFV ruled out. New FCNC fully independent of CKM matrix (RPV-SUSY, ED's ,etc …)

… You expect some constraints at least in SUSY at high tanβ

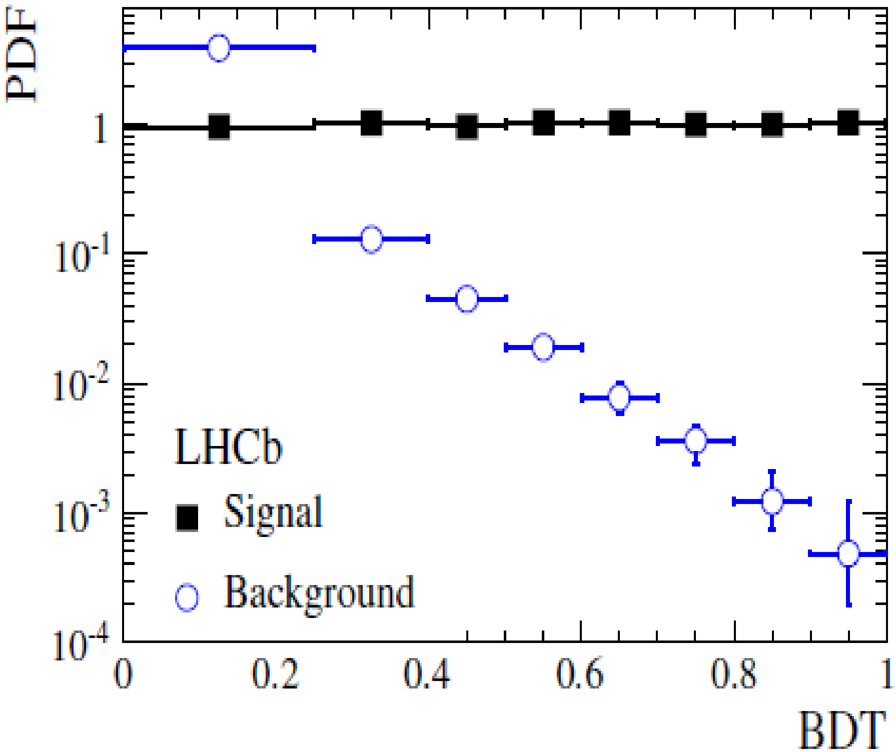
$B_{s(d)} \rightarrow \mu\mu$ (LHCb analysis strategy)

Phys. Rev. Lett. 111 (2013) 101804

I) Selection cuts in order to reduce the amount of data to analyse.

II) Classification of $B_{s,d} \rightarrow \mu\mu$ events in a 2D space

- Invariant mass of the μμ pair
- Boosted Decision Tree (BDT) combining geometrical and kinematical information about the event.



III) Control channels ($B \rightarrow hh$, $B \rightarrow J/\psi K$, mass sideb.) to get signal and background expectations w/o relying on simulation

IV) Fit for signal strength : simultaneous fit of the mas spectrum in the different BDT regions

Rare strange decays: introduction

- Minimal Flavour Violation motivated by search of NP ~ TeV
- But if NP > few TeV, non-MFV scenarios become very interesting
- In such contest rare decays of strange particles are very important : s→d transitions have the strongest CKM suppression (i.e, strongest suppression of SM "background")

$$A = A_0 \left[c_{SM} \frac{1}{M_W^2} + c_{NP} \frac{1}{\Lambda^2} \right]$$

↑ $\sim V_{ts} V_{td} \sim 10^{-4}$

From G. Isidori @ Rare'n'Strange

Other very rare decays @ LHCb

(update)

Decay	Main BSM test	95% upper limit
$B_s \to \mu\mu\mu\mu$	Some SUSY scenarios	$<1.6 \times 10^{-8}$ (PRL. 110, 211801)
$B_d \to \mu\mu\mu\mu$	Some SUSY scenarios	$<6.6 \times 10^{-9}$ (PRL. 110, 211801)
$\tau \to \mu\mu\mu$	LFV (ex: LHT)	$<5.6 \times 10^{-8}$ (arXiv:1409.8548) (still below B-factories sensitivity)
$B_s \to e\mu$	RPV, Pati-Salam LQ…	$<1.4 \times 10^{-8}$ (PRL 111 141801)
$B_d \to e\mu$	RPV, Pati-Salam LQ…	$<3.7 \times 10^{-9}$ (PRL 111 141801)
$B \to X\mu^+\mu^+$	4^{th} gen. Majoranas	See Phys. Rev. D 85, 112004

$M_{\rm LQ}(B_s^0 \to e^\pm \mu^\mp) > 106 \ {\rm TeV}/c^2$

$M_{\rm LQ}(B^0 \to e^\pm \mu^\mp) > 127 \ {\rm TeV}/c^2$

A good example of flavour physics accessing high energy scales

(arXiV references in backup)

ABSZ and DHMV =

simult. scan of groups of parameters (ABSZ incl. corr. of FF parameters)

⇒ error = linear or quadratic sum of spreads in observable

JMC (68%)=

gaussian priors for parameters

⇒ error = 68% of posterior predictive

JMC (max spread) =

simult. scan of all parameters

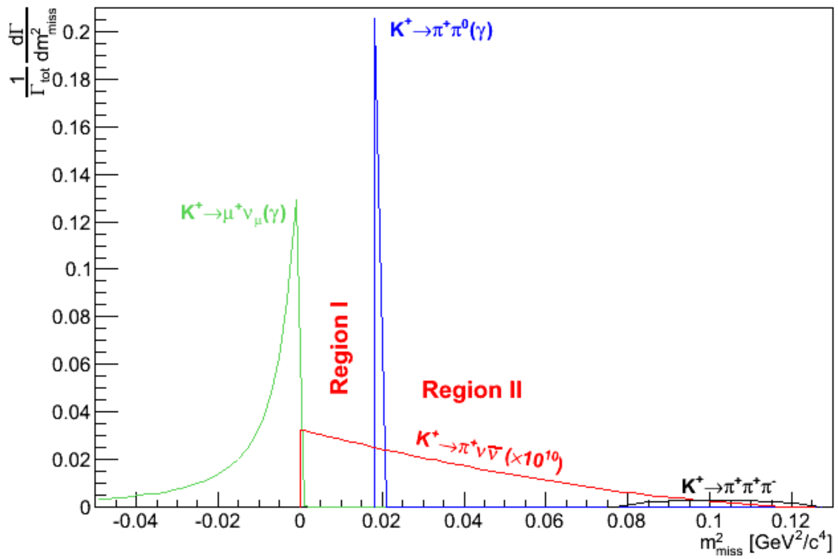
⇒ error = max spread in observable

Ref.	$q^2 \in [2.5, 4]$ GeV^2	$q^2 \in [4, 6]$ GeV^2
LHCb (3/fb)	$-0.07^{+0.34}_{-0.36}$	-0.30 ± 0.16
ABSZ (qua)	-0.50 ± 0.10	-0.77 ± 0.07
ABSZ (lin)	-0.50 ± 0.16	-0.77 ± 0.11
DHMV (qua)	$-0.49^{+0.14}_{-0.16}$	$-0.79^{+0.10}_{-0.12}$
DHMV (lin)	$-0.49^{+0.26}_{-0.30}$	$-0.79^{+0.16}_{-0.21}$
JMC (68%)	$-0.28^{+0.14}_{-0.13}$	$-0.71^{+0.11}_{-0.10}$
JMC (max spread)	$-0.28^{+0.54}_{-0.42}$	$-0.70^{+0.49}_{-0.31}$

LHCb = LHCb-CONF-2015-002

ABSZ = 1411.3161 + 1503.05534, DHMV = 1407.8526 + 1503.03328, JMC = 1412.3183 + talk S. Jäger Portoroz '15

C. Bobeth, yesterday



$\frac{1}{\Gamma_{tot}} \frac{d\Gamma}{dm^2_{miss}}$
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
m^2_{miss} [GeV^2/c^4]
$K^+ \to \pi^+ \pi^0 (\gamma)$
$K^+ \to \mu^+ \nu_\mu (\gamma)$
Region I
Region II
$K^+ \to \pi^+ \nu \bar{\nu}$ ($\times 10^{10}$)
$K^+ \to \pi^+ \pi^+ \pi^-$

Results on b→sll

(update)

Measurement	Luminosity	Reference
$BR(B^+ \to \pi^+\mu^+\mu^-)$	1 fb^{-1}	JHEP 12 (2012) 125
$BR(B_d \to K^* e^+e^-)$	1 fb^{-1}	JHEP 05(2013) 159
$B_d \to K^*\mu^+\mu^-$, angular analysis (I) (A_{FB}, F_L, S_3…)	1 fb^{-1}	JHEP 1308 (2013) 131
$B_s \to \Phi\mu^+\mu^-$, angular analysis	1 fb^{-1}	JHEP 1307 (2013) 084
$BR(\Lambda_b \to \Lambda\mu^+\mu^-)$	3 fb^{-1}	PLB 725 (2013) 25
Resonance searches in $B^+ \to K^+\mu^+\mu^-$	3 fb^{-1}	PRL 111, 112003 (2013)
$B_d \to K^*\mu^+\mu^-$, angular analysis (II) (P'_i)	1 fb^{-1}	PRL 111, 191801 (2013)
$B \to K^{(*)} \mu^+\mu^-$, BR and Isospin Asymmetry	3 fb^{-1}	JHEP 06 (2014) 133
$B \to K\mu^+\mu^-$, A_{FB}, F_H	3 fb^{-1}	JHEP 05 (2014) 082
$B \to Kl^+l^-$ Lepton universality	3 fb^{-1}	PRL 113, 151601 (2014)
$B \to K^{(*)} \mu^+\mu^-$ CP asymmetries	3 fb^{-1}	JHEP 09 (2014) 177
$BR(B^+ \to hhh\mu^+\mu^-)$	3 fb^{-1}	JHEP 1410 (2014) 064

(arXiV references in backup)

LHCb-PAPER-2015-035 (B->pimumu)
LHCb-PAPER-2015-023 (phimumu)
LHCb-PAPER-2015-025 (D*taunu)