Recent results from LHCb

or: where to search for New Physics in flavor

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On behalf of the LHCb Collaboration

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   limits on the rare decay $B_s \to \mu\text{-}\mu\text{+}$

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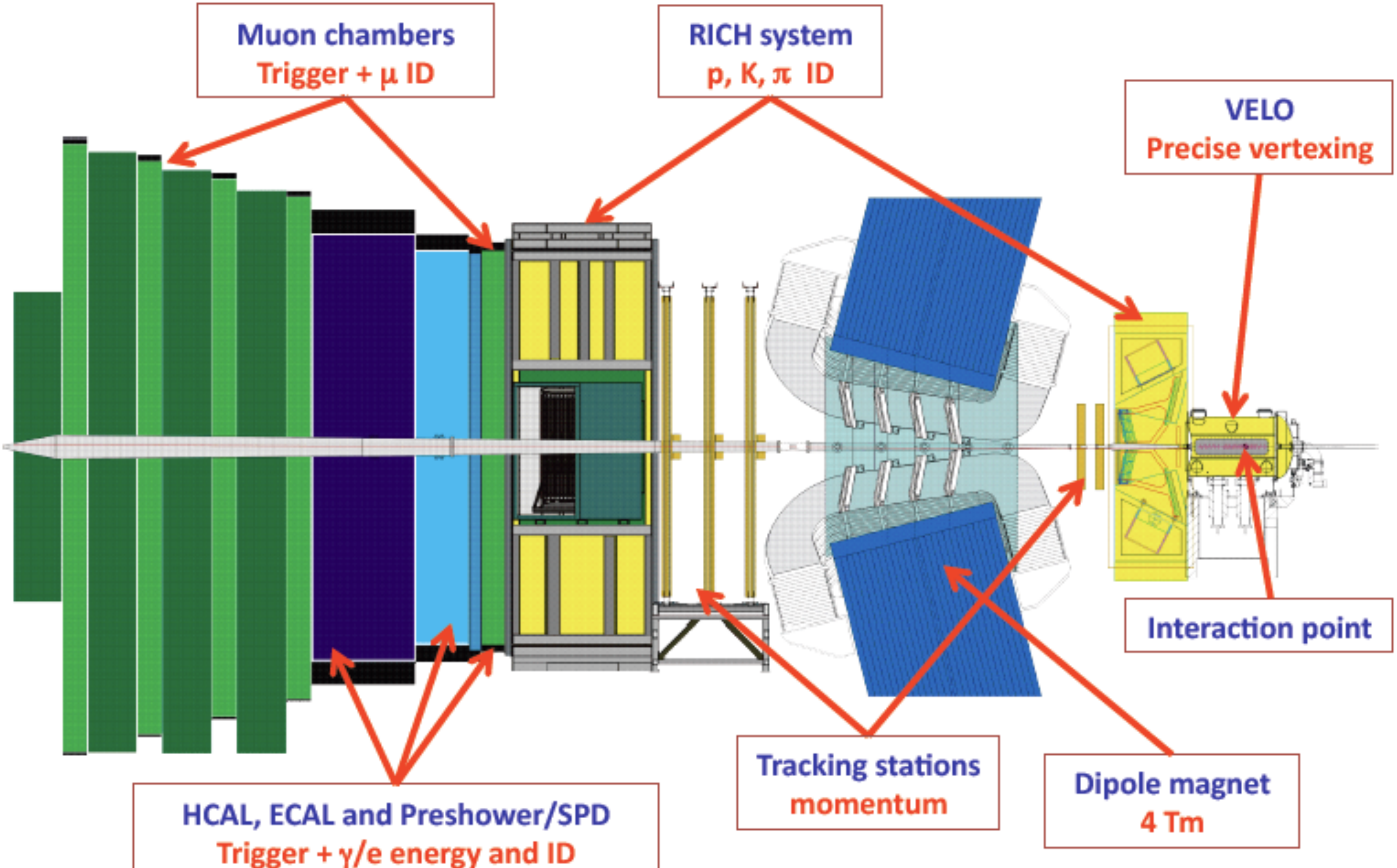
   the study of the decay $B \to K^*\ \mu\text{-}\mu\text{+}$

The LHCb detector

Single arm forward spectrometer optimized for b and c physics

covers $1.9 < \eta < 4.9$



The LHCb detector

The main important features:

Tracking

Good mass and impact parameter resolutions

Good vertex resolution for time dependent analysis

Excellent particle identification

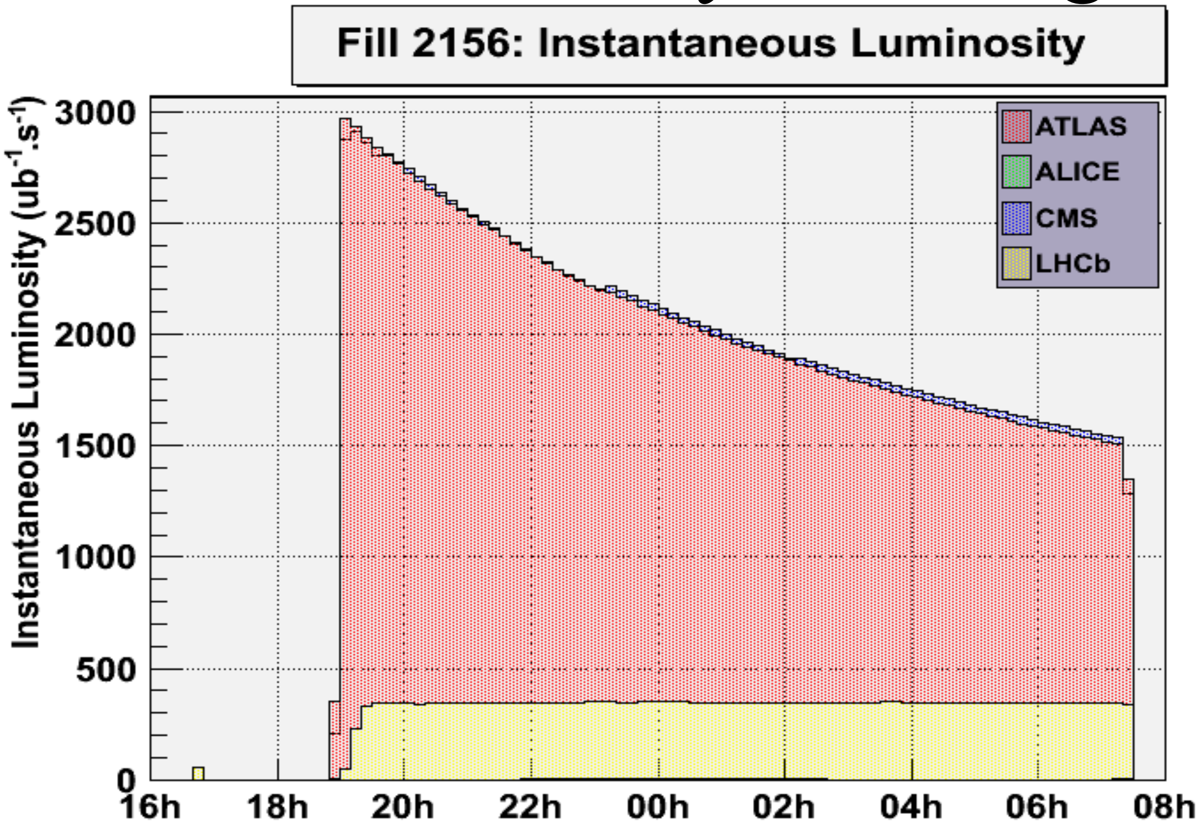
π/K/p separation over 2-100 GeV

Powerful muon identification

Can trigger on hadronic final states

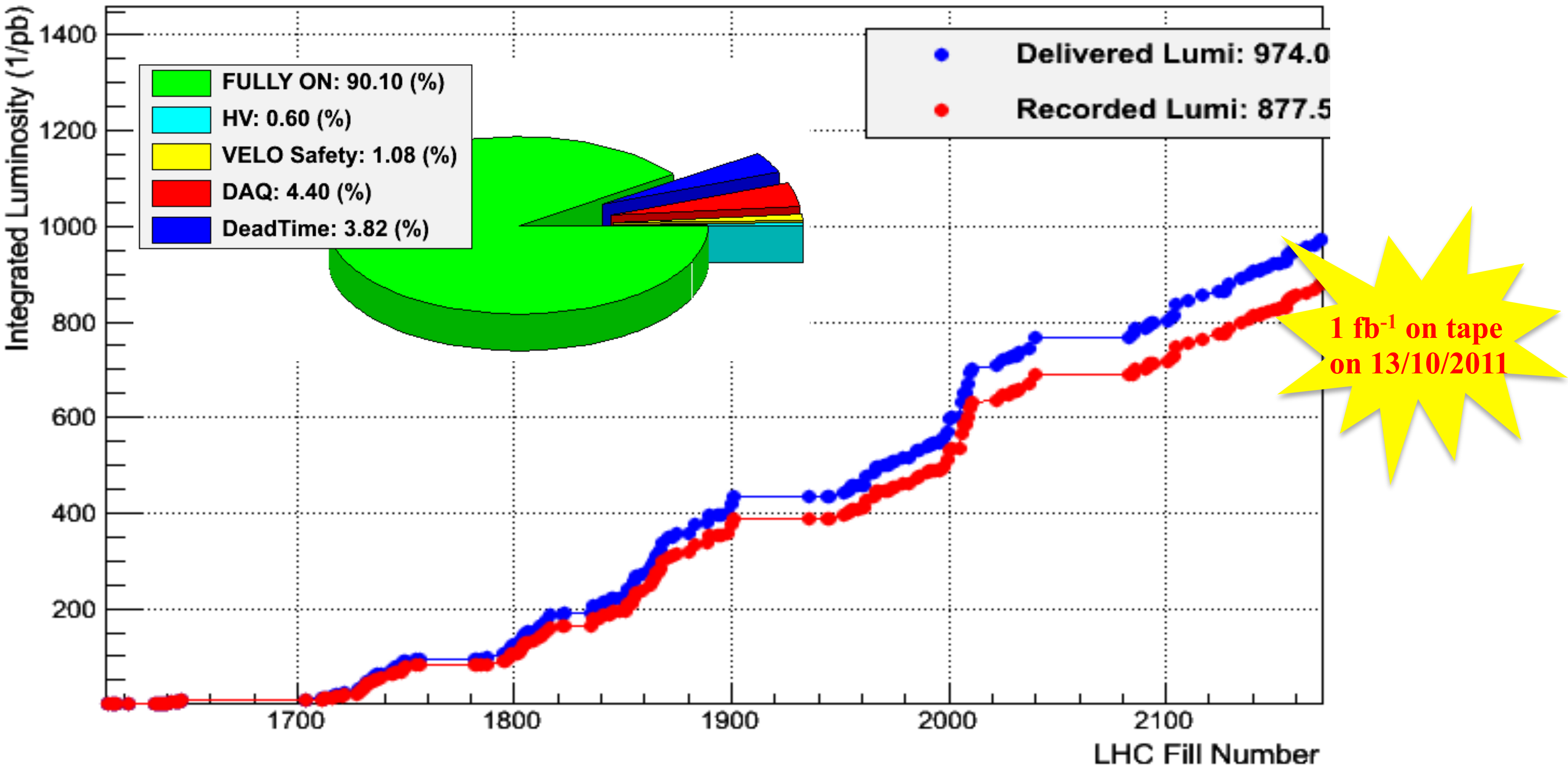
Operates at levelled Luminosity

Luminosity Leveling

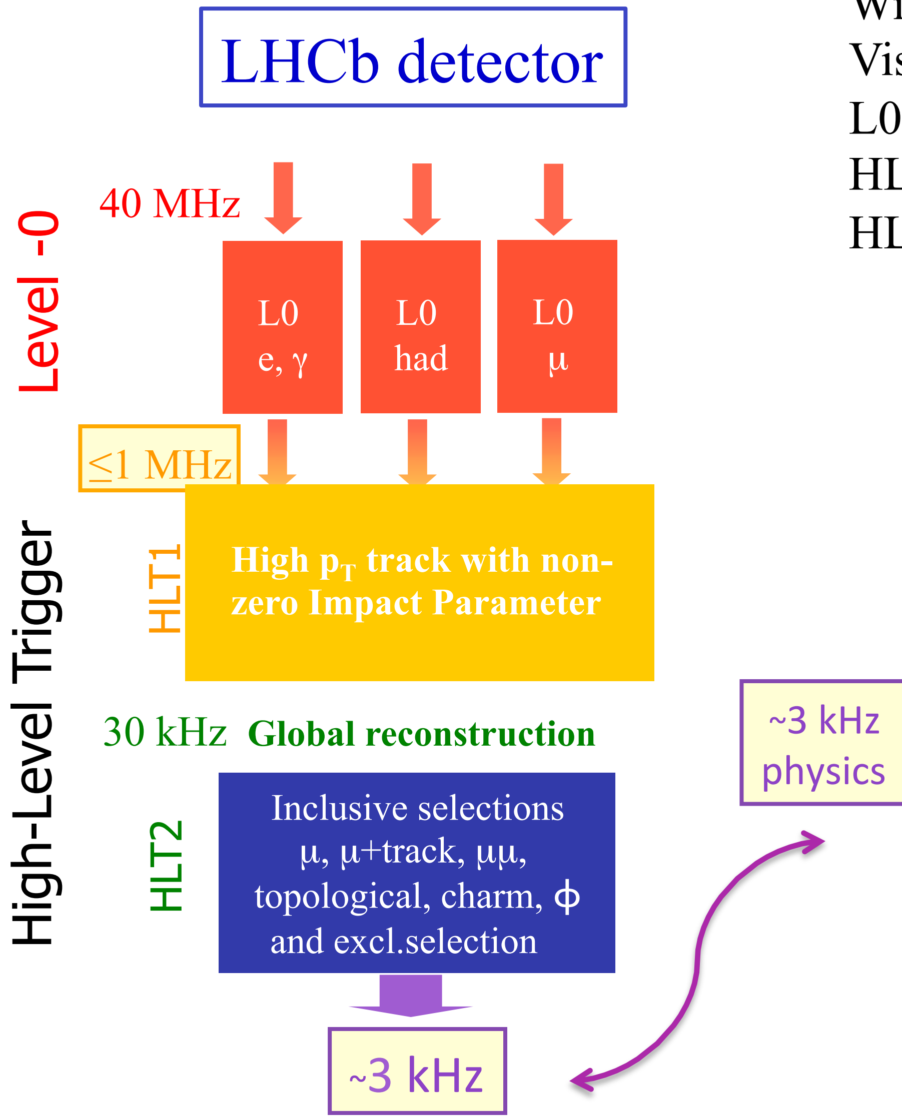


- Maintain luminosity close to the optimal (luminosity efficiency of ~98%)
- Control luminosity in order to have a stable detector
- Adjust automatically luminosity, moving the beams relative to each other

The LHCb detector operation

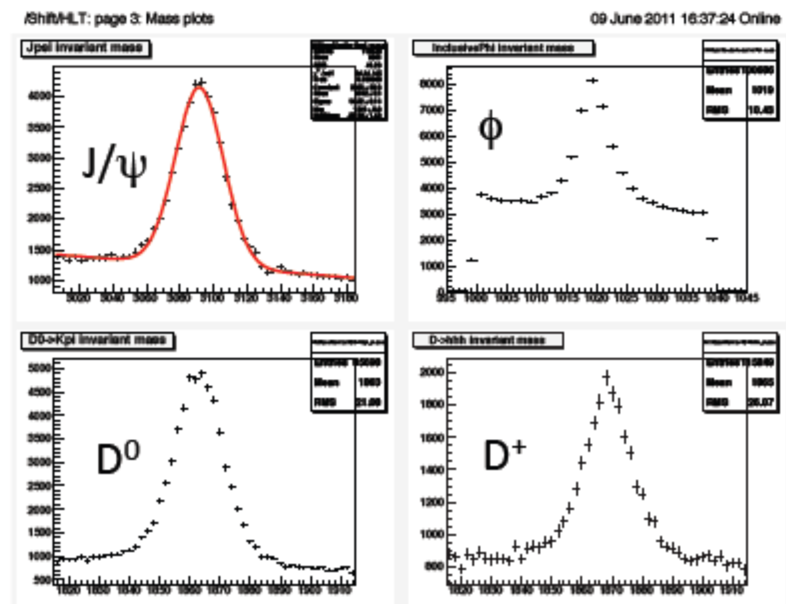


The LHCb trigger



With 1092 bunches , 3×10^{32} cm-2s^{-1}:
Visible crossing : 8.5 MHz
L0 output rate: 650 kHz
HLT output rate: 3.6 kHZ
HLT Farm CPU busy at 80%

Mass peaks seen online in the control room, at the output of the trigger.



The LHCb physics program

- Physics objective:

probing New Physics Beyond the Standard Model (BSM) through virtual effects in loops mediated processes

Through many aspects (not an exhaustive list!!!) :

1. Mass measurements
2. Lifetime measurements
3. Production and Spectroscopy (B_c,Y's, χ_{c2},χ_{c1},,…)
4. B_s decays

   rare and less rare, Cabibbo favored and Cabibbo suppressed,

   determination of fs/fd, $B_s^0 \to K^{*0} K^{*0}$, $B_s^0 \to D^0 K^{*0}$, $B^0 \to Dh(hh)$,…
5. CP violation time dependent measurements

   Δm_s, Δm_d, angular analysis of $B^0 \to J/\psi K^*$, $B^0 \to J/\psi\varphi$, $B^0 \to J/\psi K^0_s$,……..
6. Integrated CP violation measurements

… and much more

Strength of indirect approach

Can in principle access higher scales and therefore see effects earlier:

- Third quark family inferred by Kobayashi and Maskawa (1973) to explain small CP violation measured in kaon mixing (1964), but only directly observed in 1977 (b) and 1995 (t)
- c and t quarks were first "seen" via their effects produced in FCNC processes in K and B physics respectively
- Neutral currents (ν+N$\rightarrow$ ν+N) discovered in 1973, but real Z discovered in 1983

Can in principle also access the phases of the new couplings:

NP at TeV scale needs to have a "flavour structure" to provide the suppression mechanism for FCNC processes → once NP is discovered, it is important to measure this structure, including new phases

Complementary to the "direct" approach:

If NP found in direct searches at LHC, B (as well as D, K) physics measurements will help understanding its nature and flavour structure

The flavour stage

- All measurements related with electroweak quark transitions are coherent with the Cabibbo-Kobayashi-Maskawa picture of the Standard Model
- Overconstrained tests of the CKM matrix to the level of precision warrented by theoretical uncertainties *(will theory be able to calculate hadronic parameters with 1% precision in few years?)*
- The CKM phase is consistent with being the source for all CP-violating phenomena observed in the laboratory.

There must, however, be additional sources of CP violation

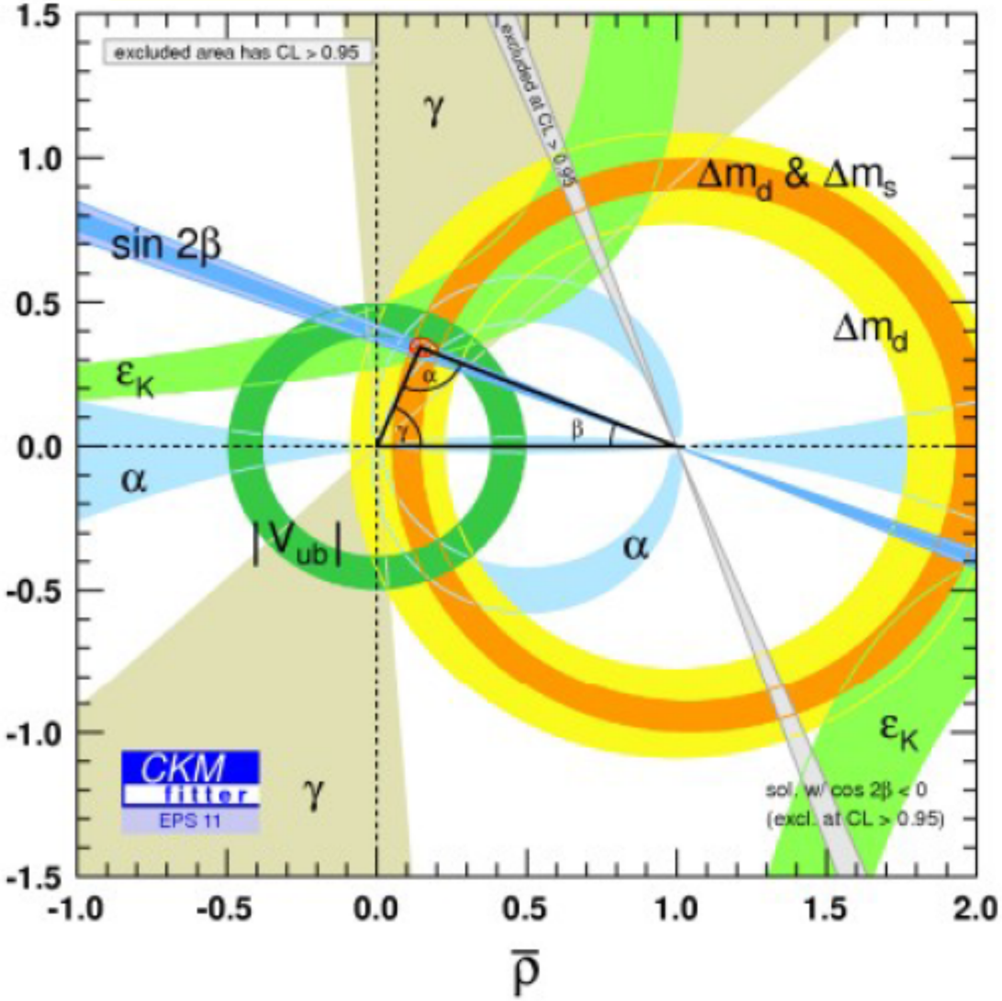
The SM fails to explain the cosmic matter-antimatter asymmetry

⇓

Need New Physics (NP) beyond the SM

Current status of CKM parameters

http://ckmfitter.in2p3.fr



(LP2011 update)

$$\bar{\rho} = 0.144\,^{+0.027}_{-0.018}$$

$$\bar{\eta} = 0.343 \pm 0.014$$

Accuracy of angles is limited by experiment:

Accuracy of sides is limited by theoretical uncertainty *(extraction of Vub , lattice calculation of ξ[2],..)*

Is there New Physics in B decays ?

Examples

1. $\phi_s \stackrel{SM}{=} -2\beta_s \equiv -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$ **phase of B_s mixing**
   - CKM fit prediction is very precise – 0.036 ± 0.002 rad
2. **Measurement of rare decay $Br(B_{s,d} \to \mu\mu)$**
   - Expect large contributions from NP models
3. **Angular distributions and other observables (*ex:* in $B_d \to K^*\mu\mu$)**
   - Sensitive to non-SM operators in interactions
4. $\gamma \cong -\arg(V_{ub})$
   - Comparison of tree processes with measurements from loop processes can reveal NP

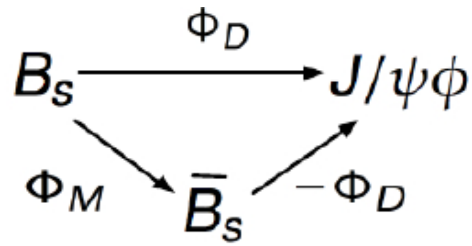
But also: $B_s \to \phi\gamma$, $B^o \to K^*\gamma$, $B_s \to \phi\phi$, ... D^0 mixing or decays, lepton flavor violation in charged leptons FCNC ($\tau \to \mu+\gamma$ and $\mu \to e+\gamma$), deviation from μ-e universality in $R_{K,\pi,B}$ ($R_K = \Gamma(K\to e\nu)/\Gamma(K\to\mu\nu)$, $R_B = (B\to K^*ee) / (B\to K^*\mu\mu)$)

the measurement of

Φ_s from $B_s \rightarrow J/\psi\ \phi\ (f_0)$ decays

New physics in B_s mixing

- Measure CP violation through interference of decays with and without mixing: $\phi_s = \phi_M - 2\phi_D$

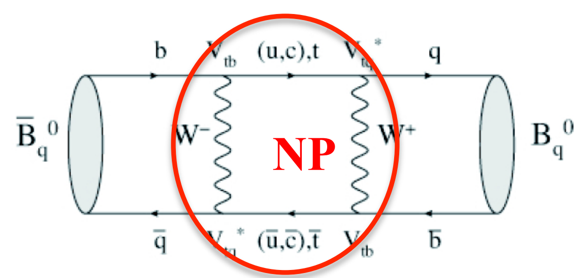


- In SM it is predicted to be small [A. Lenz, arXiv: 1102.4274]

$$\phi_s \stackrel{\text{SM}}{=} -2\beta_s \equiv -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) = -0.036 \pm 0.002 \text{ rad}$$

- New physics can affect mixing adding large terms to ϕ_s: SUSY, Little Higgs, extra dimension, 4th generation, extra Z', …

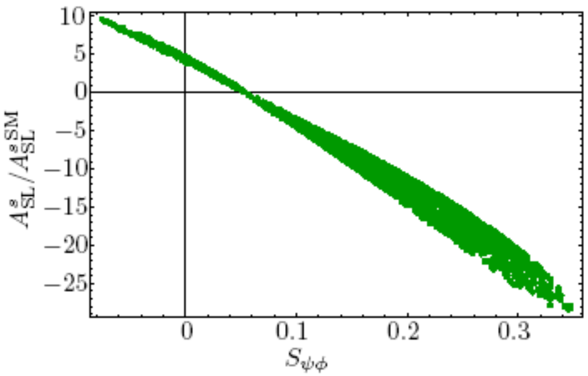
$$\Phi_s = \Phi_s^{SM} + \Phi_s^{NP}$$



Examples New Physics effects

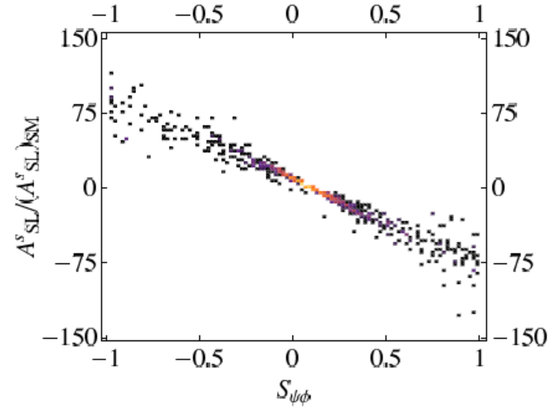
Little Higgs Model with T-Parity

[M. Blanke *et al.*, Acta Phys.Polon.B41:657, 2 010]

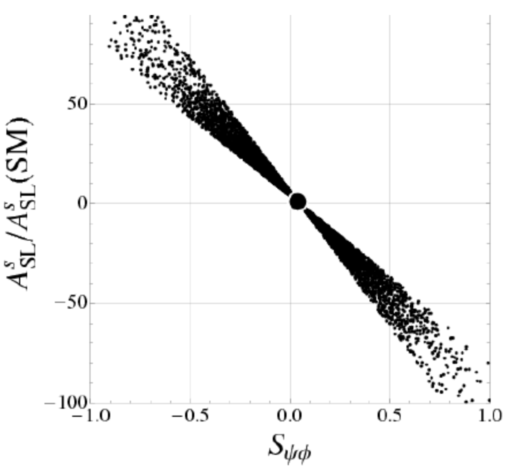


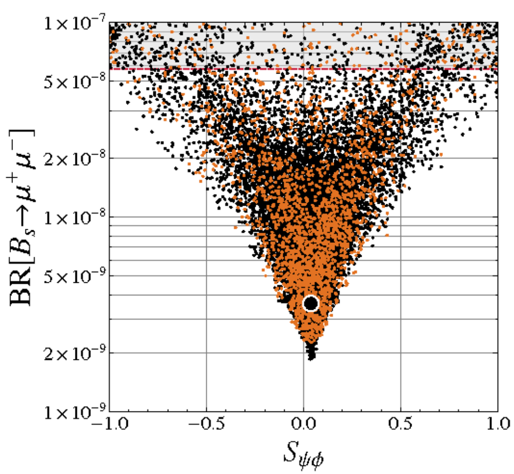
Warped Extra Dimension Model

[M. Blanke *et al.*, JHEP 0903:001,2009]

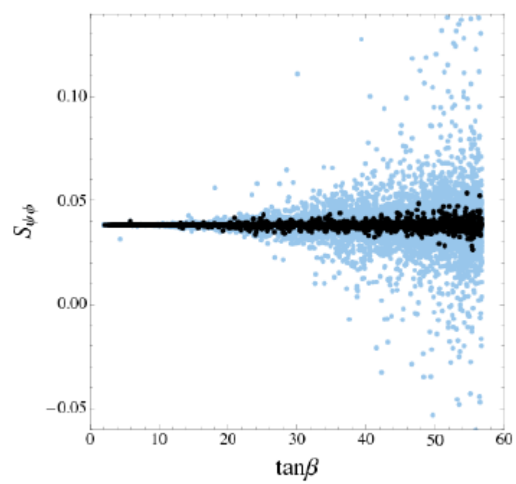


SUSY "AC" Model





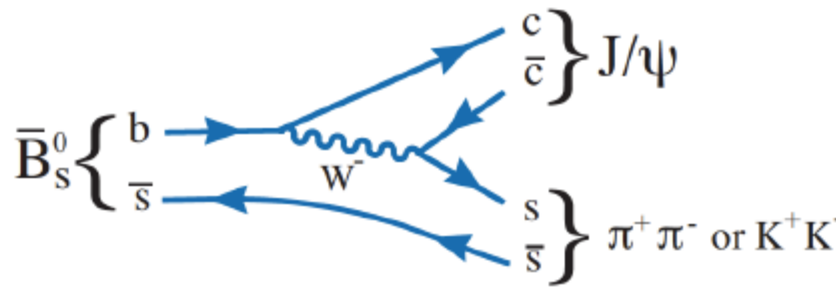
MFV SUSY Model



[W. Altmannshofer *et al.*, arXiv:0909.1333]

measuring Φ_s from $B_s \to J/\psi\,\phi$ in LHCb

- Very clean final states thanks to:
  - powerful muon trigger
  - excellent kaon/pion identification
  - require $t(B_s)>0.3$ ps to remove dominant background from prompt J/ψ



$B_s \to J/\psi\phi$

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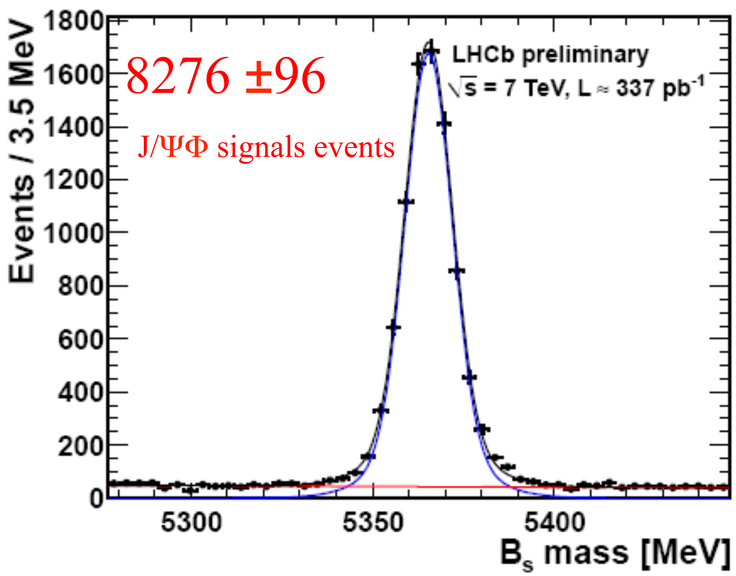
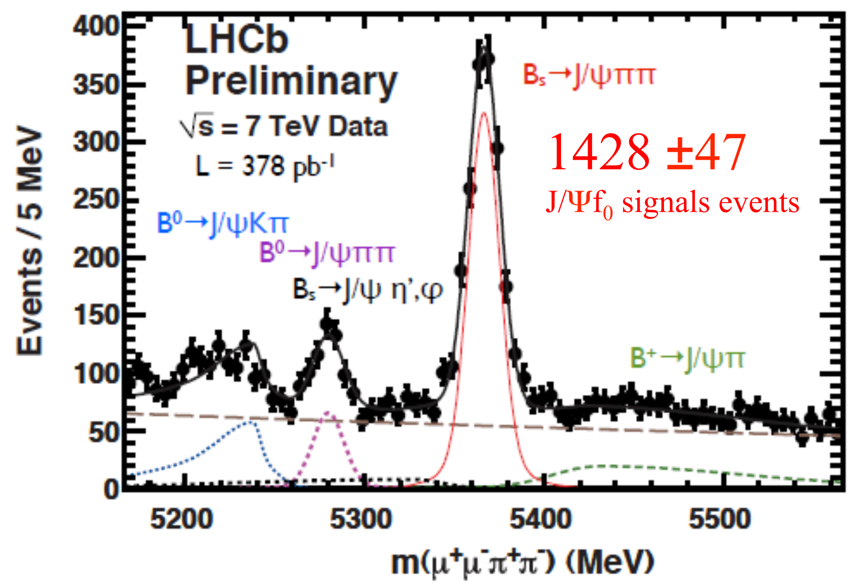


$B_s \to J/\psi f_0$



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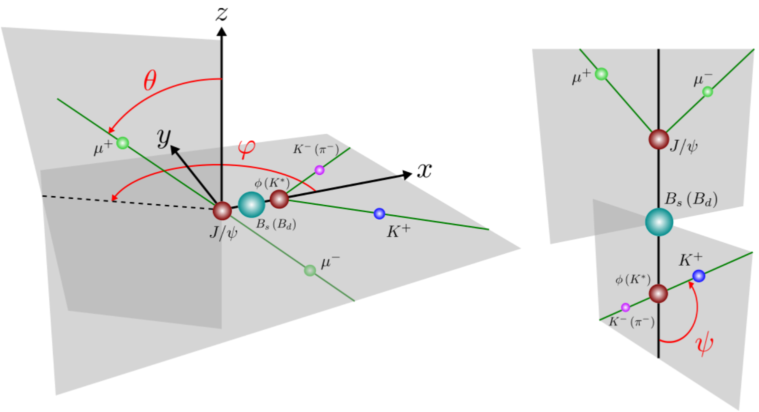
in $L=337\ pb^{-1}$

measuring Φ_s in $B_s \to J/\psi\, \phi$: the ingredients

Transition Pseudoscalar → Vector Vector
→ 3 polarization amplitudes

Need to separate CP-odd and CP-even final states

Description in trasversity basis:
l=1 : A_T (CP-odd)
l=0,2 : A_0, $A_\parallel$ (CP-even)



3 angles (θ,φ,ψ) and time t

The phase ϕ_s is extracted with an unbinned max L fit to m, t, initial B_s flavor, and the 4 body decay angles.
The physics parameters include $\Delta\Gamma_s$, Γ_s Δm_s , ϕ_s , the complex amplitudes.

$$S(\vec{\lambda},t,\vec{\Omega}) = \epsilon(t,\vec{\Omega}) \times \left(\frac{1+qD}{2} s(\vec{\lambda},t,\vec{\Omega}) + \frac{1-qD}{2} \overline{s}(\vec{\lambda},t,\vec{\Omega}) \right) \otimes R_t$$

Basic ingredients: acceptance, flavour tagging, proper time resolution

measuring Φ_s from $B_s \to J/\psi\ \phi$

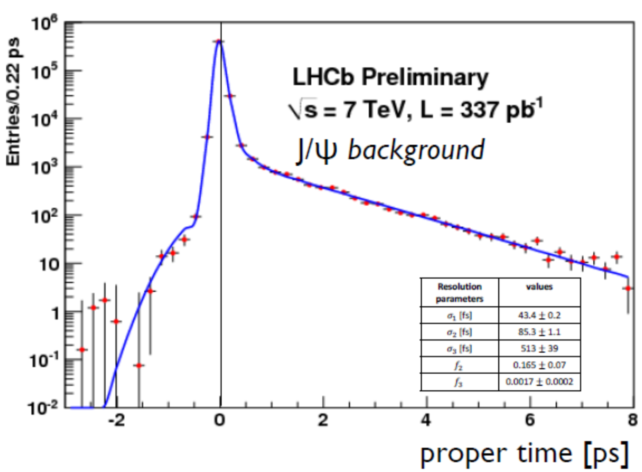
$$
\begin{aligned}
|A_0|^2(t) &= |A_0|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right) + \sin\phi_s \sin(\Delta m t)\right], \\
|A_{\|}(t)|^2 &= |A_{\|}|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right) + \sin\phi_s \sin(\Delta m t)\right], \\
|A_{\perp}(t)|^2 &= |A_{\perp}|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) + \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right) - \sin\phi_s \sin(\Delta m t)\right], \\
\Im(A_{\|}^*(t)\, A_{\perp}(t)) &= |A_{\|}||A_{\perp}| e^{-\Gamma_s t}\left[-\cos(\delta_{\perp} - \delta_{\|}) \sin\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right)\right. \\
&\quad \left. - \cos(\delta_{\perp} - \delta_{\|}) \cos\phi_s \sin(\Delta m t) + \sin(\delta_{\perp} - \delta_{\|}) \cos(\Delta m t)\right], \\
\Re(A_0^*(t)\, A_{\|}(t)) &= |A_0||A_{\|}| e^{-\Gamma_s t} \cos(\delta_{\|} - \delta_0)\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right)\right. \\
&\quad \left. + \sin\phi_s \sin(\Delta m t)\right], \\
\Im(A_0^*(t)\, A_{\perp}(t)) &= |A_0||A_{\perp}| e^{-\Gamma_s t}\left[-\cos(\delta_{\perp} - \delta_0) \sin\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right)\right. \\
&\quad \left. - \cos(\delta_{\perp} - \delta_0) \cos\phi_s \sin(\Delta m t) + \sin(\delta_{\perp} - \delta_0) \cos(\Delta m t)\right], \\
|A_s(t)|^2 &= |A_s|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) + \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right) - \sin\phi_s \sin(\Delta m t\right], \\
\Re(A_s^*(t) A_{\|}(t)) &= |A_s||A_{\|}| e^{-\Gamma_s t}\left[-\sin(\delta_{\|} - \delta_s) \sin\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right) - \sin(\delta_{\|} - \delta_s)\ \cos\phi_s \sin(\Delta m t)\right. \\
&\quad \left. + \cos(\delta_{\|} - \delta_s) \cos(\Delta m t)\right], \\
\Im(A_s^*(t) A_{\perp}(t)) &= |A_s||A_{\perp}| e^{-\Gamma_s t} \sin(\delta_{\perp} - \delta_s)\left[\cosh\left(\frac{\Delta\Gamma}{2}t\right) + \cos\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right)\right. \\
&\quad \left. - \sin\phi_s \sin(\Delta m t)\right], \\
\Re(A_s^*(t) A_0(t)) &= |A_s||A_0| e^{-\Gamma_s t}\left[-\sin(\delta_0 - \delta_s) \sin\phi_s \sinh\left(\frac{\Delta\Gamma}{2}t\right)\right. \\
&\quad \left. - \sin(\delta_0 - \delta_s) \cos\phi_s \sin(\Delta m t) + \cos(\delta_0 - \delta_s) \cos(\Delta m t)\right].
\end{aligned}
$$

Not to be read now . . . .

measuring Φ_s from $B_s \to J/\psi\ \phi$: time resolution and acceptance

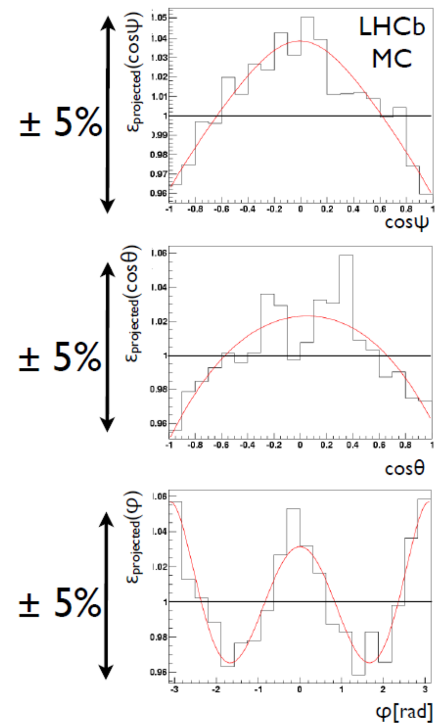
Proper time resolution

- Time resolution model obtained from prompt J/ψ events
- Effective proper time resolution 50 fs
- 2% systematic error

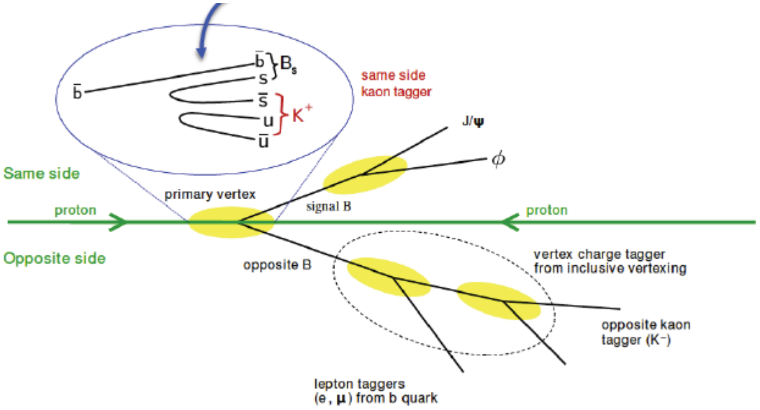


Acceptance

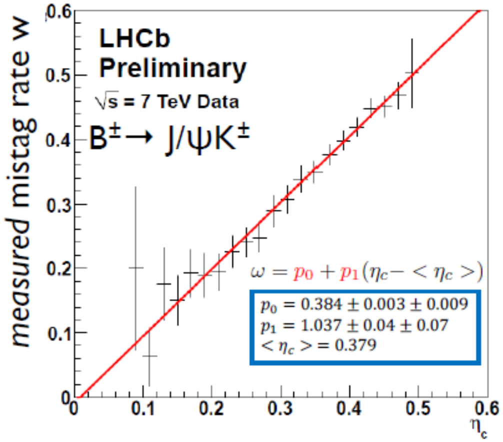
- detector covers $10<\theta<400$ mrad
- Determined from MC simulation
- Deviation from uniform within 5%



measuring Φ_s in LHCb : the flavor tagging



- ★ Use opposite side (for now) 4 taggers: high pt μ's, e's, K's and vertex charge



- ★ Wrong tagging probability calibrated with $B^+ \rightarrow J/\psi K^+$

- ★ ε_{tag} = (27 ± 0.4)%
  Average dilution factor D = (27.7 ± 0.28)%
  Effective tagging power ε_{tag} D^2 = (2.08 ± 0.41)%

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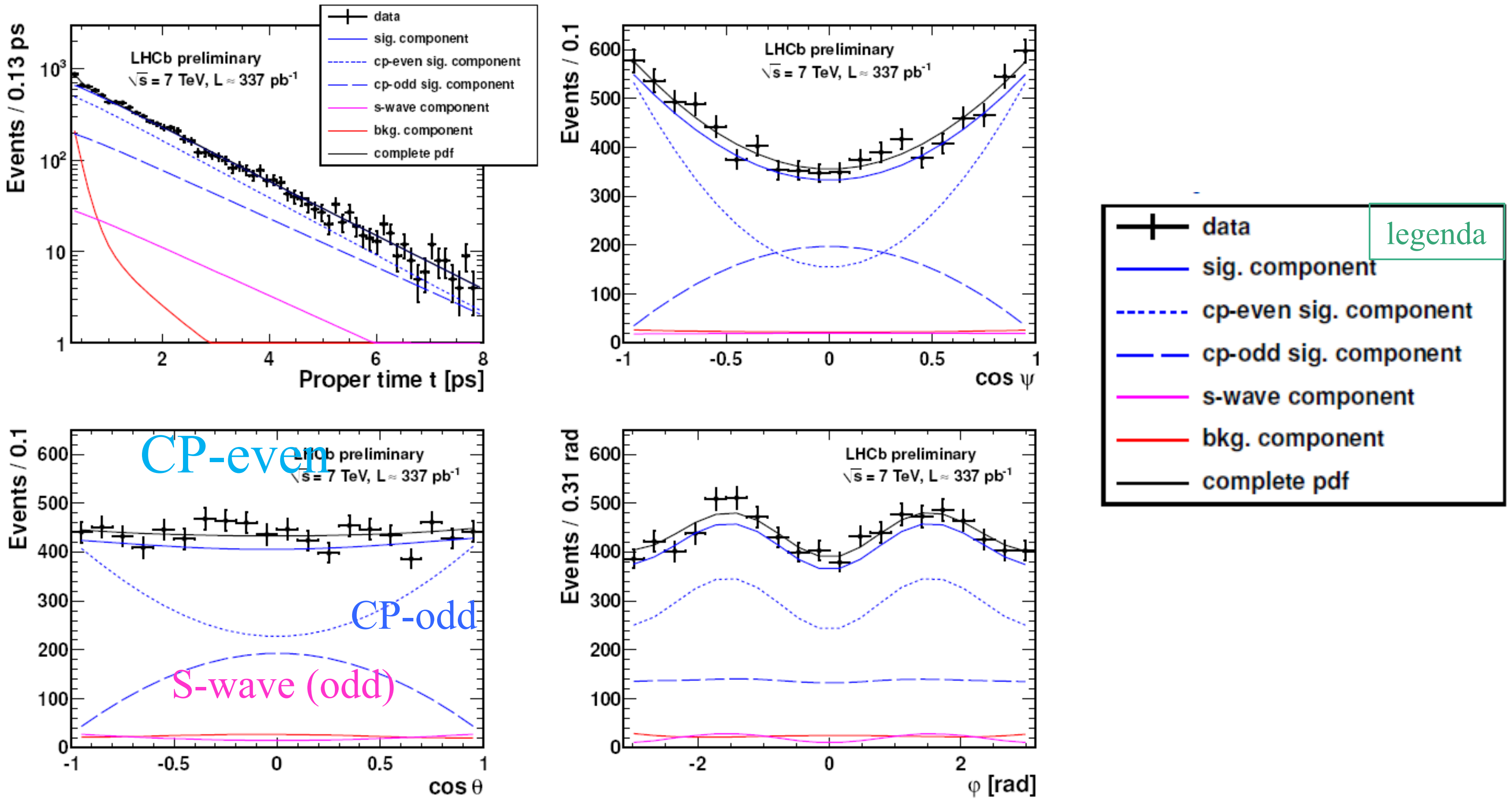
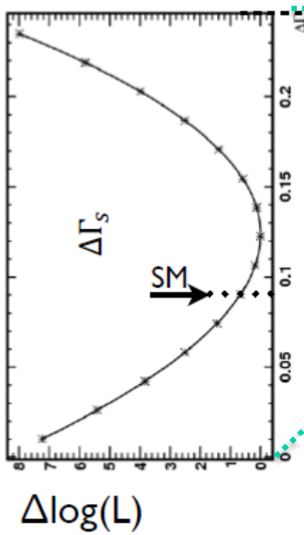
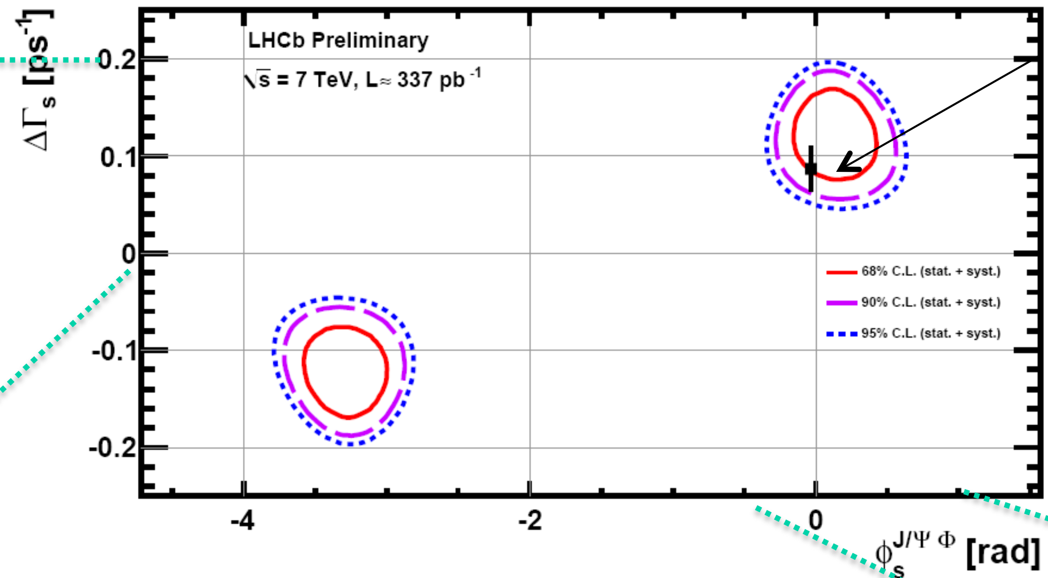
Time and angular distributions in data



Projections are very well described

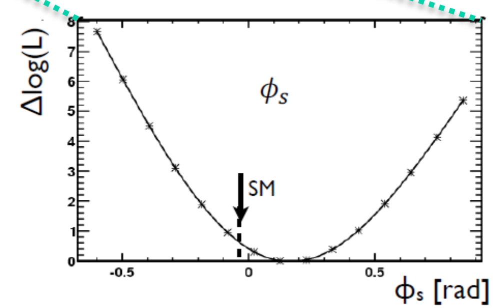
measuring Φ_s from $B_s \to J/\psi\,\phi$: **the results**





SM prediction

[Lenz,Nierste:arXiv:1102.4274]



- Two ambiguous solutions $\phi_s \leftrightarrow \pi\text{-}\phi_s$; $\Delta\Gamma_s \leftrightarrow -\Delta\Gamma_s$
- World's most precise measurement of ϕ_s

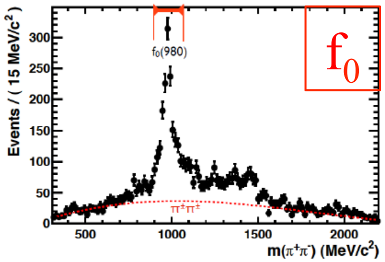
$$\phi_s = 0.13 \ \pm 0.18\ (\text{stat}) \pm 0.07\ (\text{sys})\ \text{rad}$$

consistent with SM prediction ϕ_s^{SM} =-0.036 ± 0.002 rad)

- 4σ evidence for $\Delta\Gamma_s \neq 0$

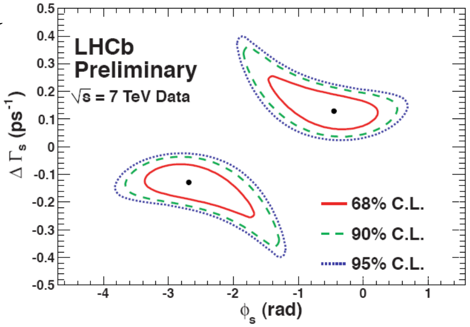
$$\Delta\Gamma_s = 0.123 \ \pm 0.029\ (\text{stat}) \pm 0.008\ (\text{sys})\ \text{ps}^{-1}$$

measuring Φ_s adding $B_s \rightarrow J/\psi\ f_0$



$B_s \rightarrow J/\psi f_0$

CP odd final state : no angular analysis required



Using $\Delta\Gamma_s$ and Γ_s from $B_s \rightarrow J/\psi\phi$

$\phi_s = -0.44 \pm 0.44 \pm 0.02$ rad

(+ ambiguous solution)

Simultaneous fit of $B_s \rightarrow J/\psi\phi$ and $B_s \rightarrow J/\psi f_0$ data

LHCb-CONF-2011-056

$$\phi_s = 0.03 \pm 0.16\ (\text{stat}) \pm 0.07\ (\text{sys})\ \text{rad}$$

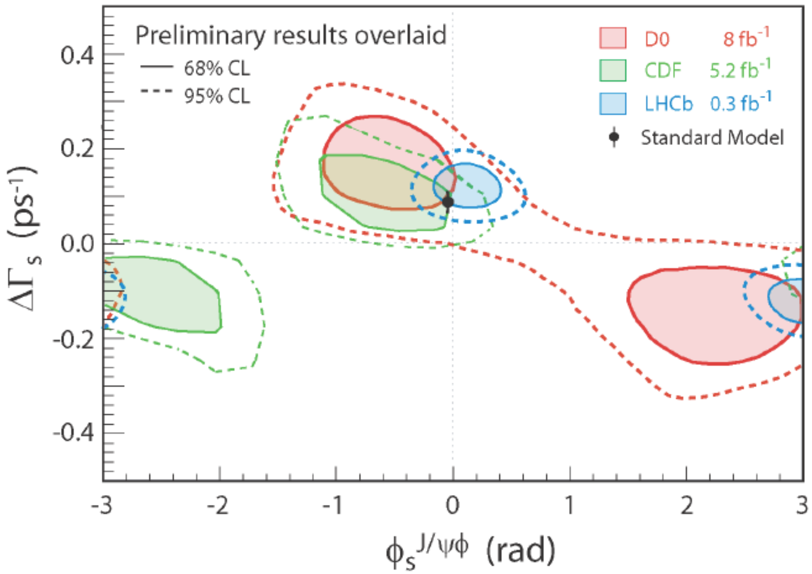
(+ ambiguous solution)

Caveat for the combination [R. Fleischer *et al*., arXiv:1109.1112)]

- Hadronic nature of f_0 not clear
- Different hadronic effects in $B_s \rightarrow J/\psi f_0$ and $B_s \rightarrow J/\psi\phi$

measuring Φ_s : next steps

Already significant improvement on existing data → but still more improvement to come



http://lhcb-public.web.cern.ch/lhcb-public/

This is just flipping and scaling the PDFs taken from talks to give impression

More luminosity being added (more statistics)

Improve tagging with same side kaons

Solve the ambiguity by looking at relative S-wave phase vs M(KK) in $J/\psi\Phi$

….for end of 2011:

Decrease the error from ~0.2 to ~0.1

Search for the rare decay $B_s \to \mu^+\mu^-$

Search for rare decay $B_s \to \mu^+\mu^-$

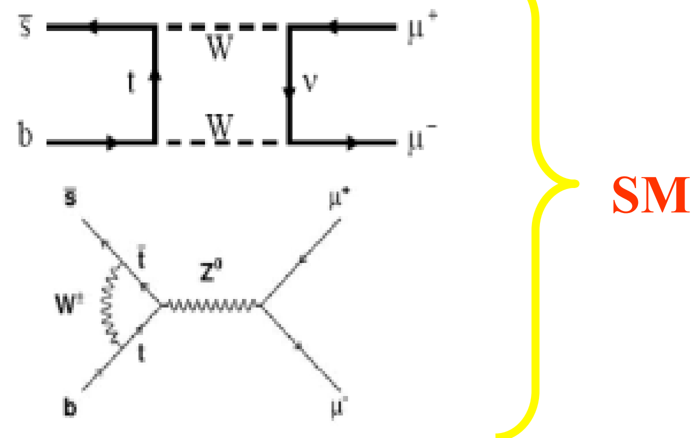
SM expectation:

$BR(B_s \to \mu^+\mu^-) = (3.2\pm0.2) \times 10^{-9}$

$BR(B_d \to \mu^+\mu^-) = (1.0\pm0.5) \times 10^{-10}$

(FCNC suppression and helicity suppressed)

[A.J.Buras, arXiv:1012.1447]

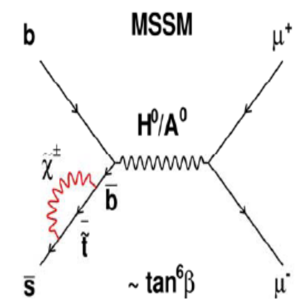


In Supersymmetry:

Large contributions in some SUSY models

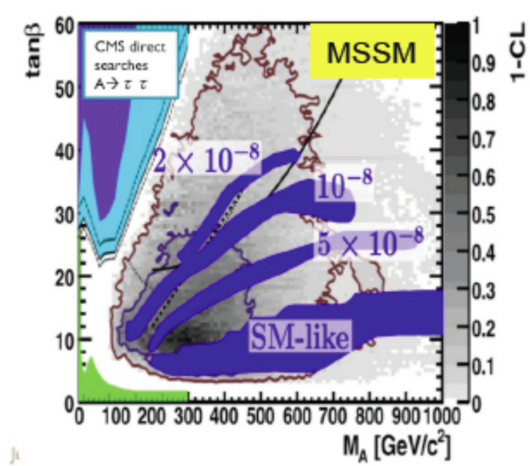
$BR(B_{d,s} \to \mu+\mu-)$ very sensitive if high values of tan β

$$Br_{MSSM}(B_q \to \ell^+\ell^-) \propto \frac{M_b^2 M_\ell^2 \tan^6\beta}{M_A^4}$$



Measurement or limit will become strong constraint on

NP on (tanβ, M_A) plane [O. Buchmuller *et al.*, arXiv0907.5568



Existing limits of rare decay $B_s \to \mu^+\mu^-$

$B_s \to \mu^+\mu^-$

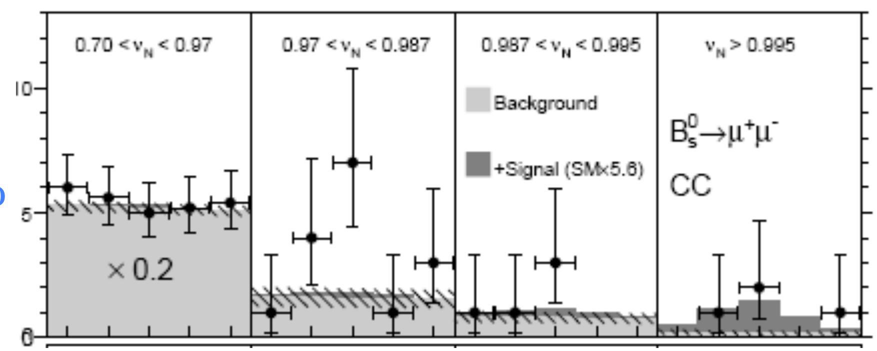
Spring 2011

Experiment	Data	Upper Limit (95% C.L.)
CDF	3.7 fb^{-1}	< 4.3×10^{-8}
D0	6.1 fb^{-1}	< 5.1×10^{-8}
LHCb	36 pb^{-1}	< 5.6×10^{-8}

- CDF recently (july 2011) reported a hint of signal with 7 fb^{-1}
  - p-value background only: 0.3%
  - p-value background + SM BR: 1.9%
  - p-value background + 5.6×SM BR: 50%

$$B\left(B_s \to \mu^+\mu^-\right) = 1.8^{+1.0}_{-0.9} \times 10^{-8}$$

CDF, arXiv:1107.2304



LHCb analysis of the decay $B_s \to \mu^+\mu^-$

2010 LHCb analysis published in [PLB 699 (2011) 330]

Update with $\approx 300\ pb^{-1}$ LHCb-CONF-2011-037

- Discriminating signal from background using 2 variables

  invariant mass of $\mu^+\mu^-$ and

  a Boosted Decision Tree (BDT) combining 9 kinematical and topological variables

  BDT calibrated on $B \to h^+h^-$ for the signal and sidebands for the background

- Mass resolution obtained $J/\psi \to \mu\mu$ and $Y(1S) \to \mu\mu$ (and $B^0 \to K\pi$, $B_s \to KK$)

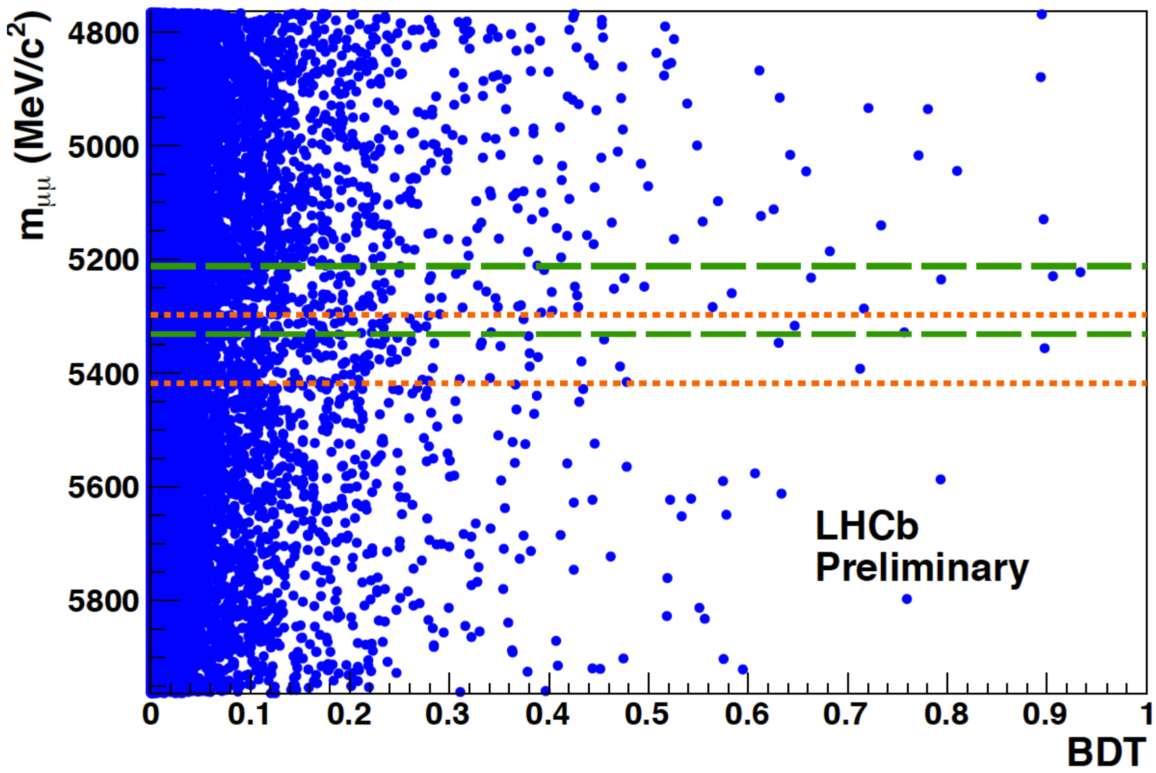
- To obtain relative BR, use normalization channels:

  $B^+ \to J/\psi K^+$, $B_s \to J/\psi\phi$ and $B_d \to K\pi$

  and use LHCb results $f_s/f_d = 0.267^{+0.021}_{-0.20}$ [LHCb arXiv: 1106.4435]

LHCb analysis of the decay $B_s \to \mu^+\mu^-$

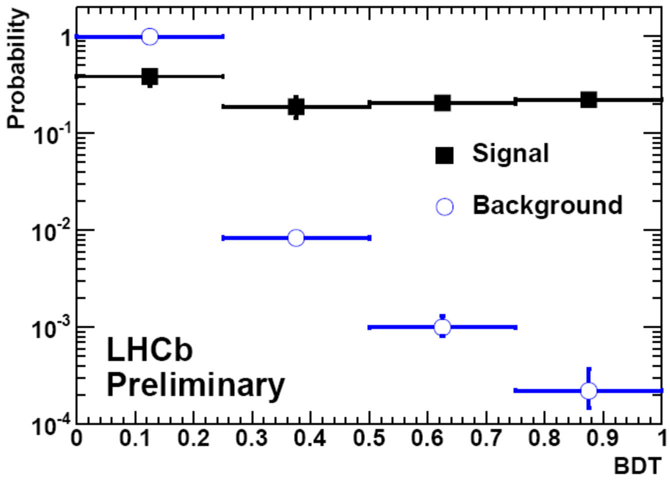
Look at 4 regions in BDT and 6 in μμ invariant mass

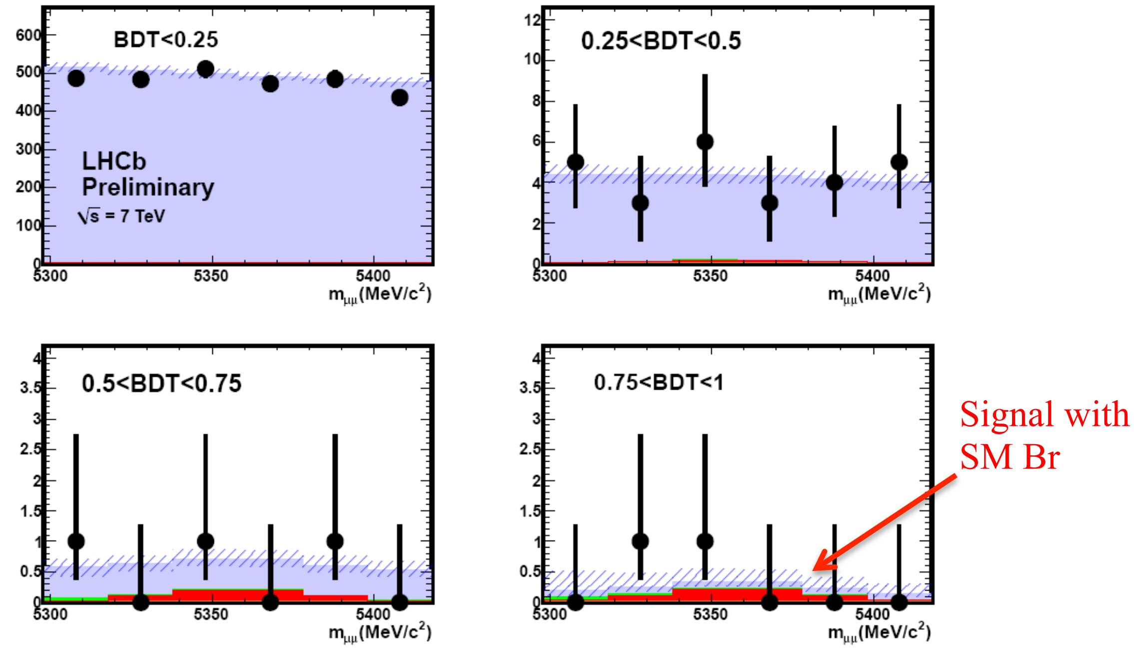


LHCb analysis of the decay $B_s \to \mu^+\mu^-$

4 bins in BDT output
120 MeV B mass search window divided into 6 bins

LHCb-CONF-2011-037

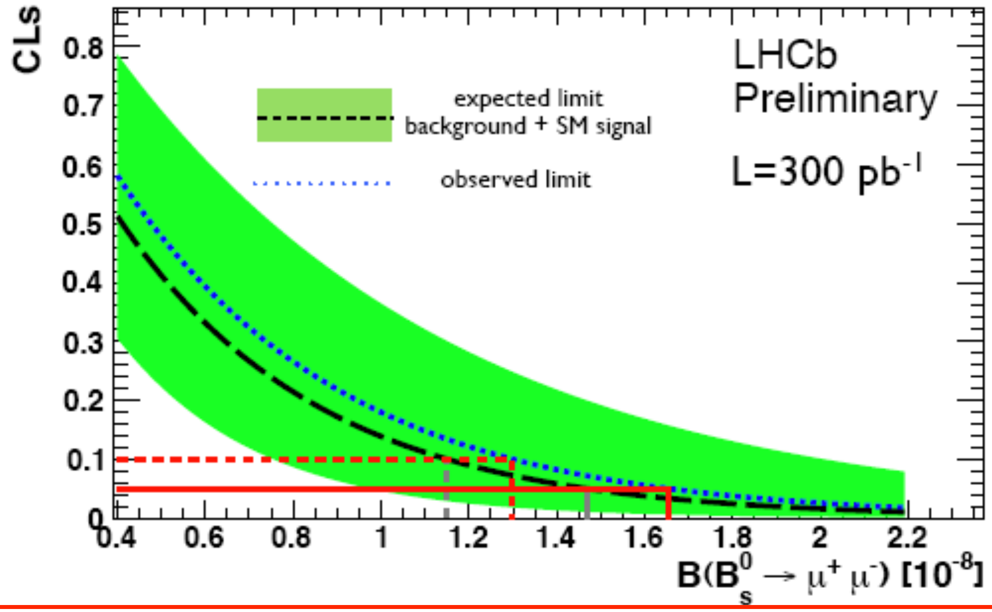




	BDT<0.25	0.25<BDT<0.5	0.5<BDT<0.75	0.75<BDT
Exp.combinatorial	2968 ± 69	25 ± 2.5	2.99 ± 0.89	0.66 ± 0.40
Exp. SM signal	1.26 ± 0.13	0.61 ± 0.06	0.67 ± 0.07	0.72 ± 0.07
Observed	2872	26	3	2

LHCb limit on Br ($B_s \to \mu^+\mu^-$)

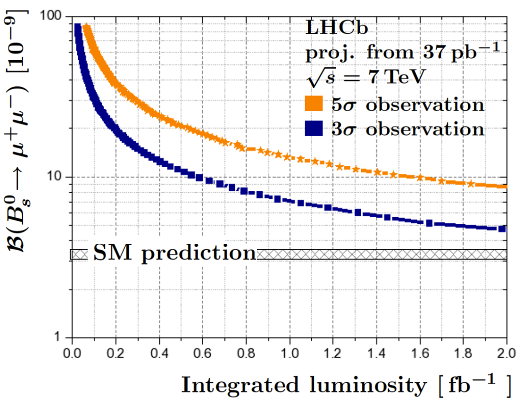
Determine limits using CLs method



LHCb-CONF-2011-037

Observed limit: BR($B_s \to \mu^+\mu^-$) < 1.6 (1.3) ×10^{-8} @ 95% (90%) C.L.

Combined with 2010 data: BR($B_s \to \mu^+\mu^-$) < 1.5 (1.2) ×10^{-8} @ 95% (90%) C.L.



Near future prospects (winter 2012 conferences):

3σ evidence for SM (but could be even better!!!)

LHCb +CMS combined limit on Br ($B_s \to \mu^+\mu^-$)

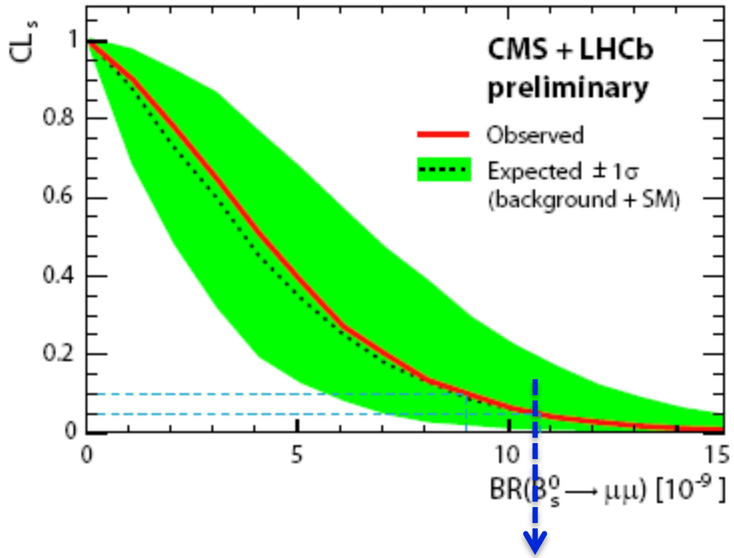
cf. CMS result using 1.14 fb^{-1} CMS -BPH-11-002

Expected limit < 1.8 ×10-8 @ 95% C.L.

Observed limit < 1.9 ×10-8 @ 95% C.L.

LHCb and CMS have performed a combined limit

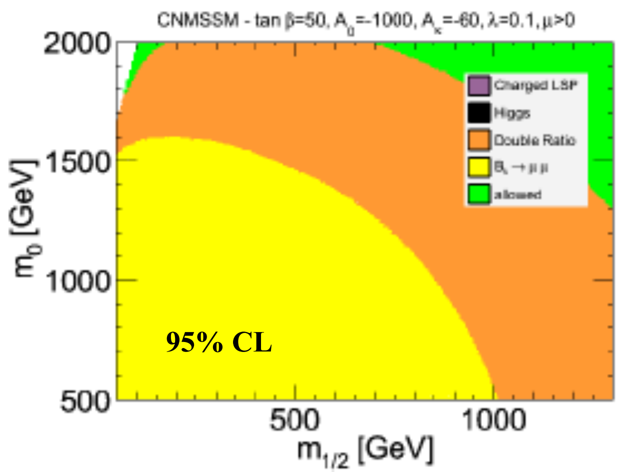
LHCb-CONF-2011-047,CMS-PAS-BPH-11-019



Combined LHCb+CMS: BR($B_s \to \mu^+\mu^-$) < 1.08 (0.9) ×10^{-8} @ 95% (90%) C.L.

Example of possible implication on SUSY models

From arXiv:1108.3018 (A.G Akeroyd et al.)

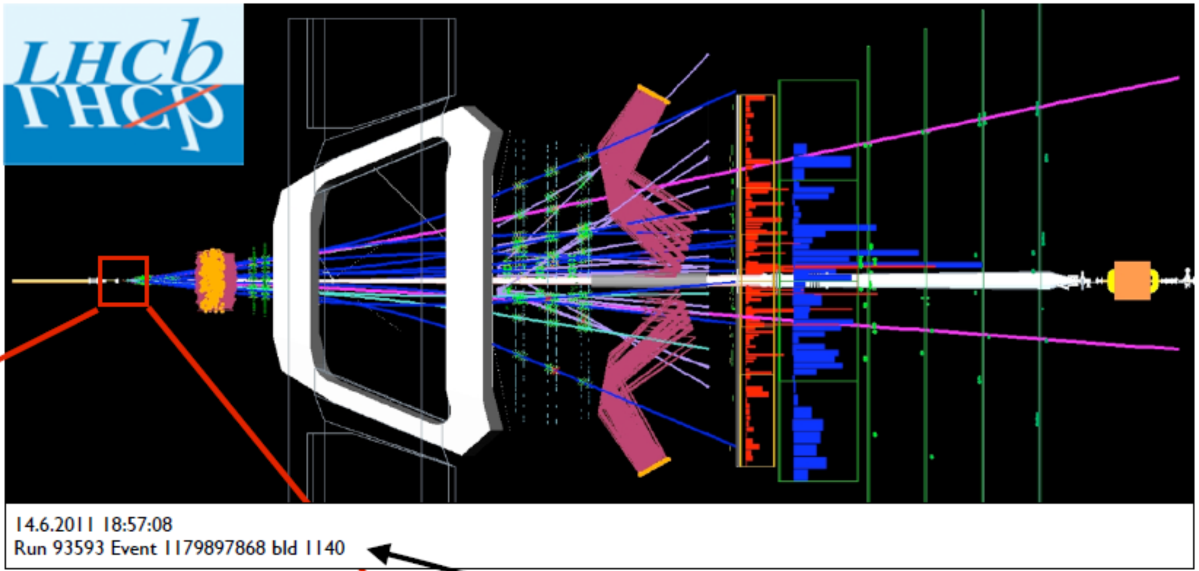


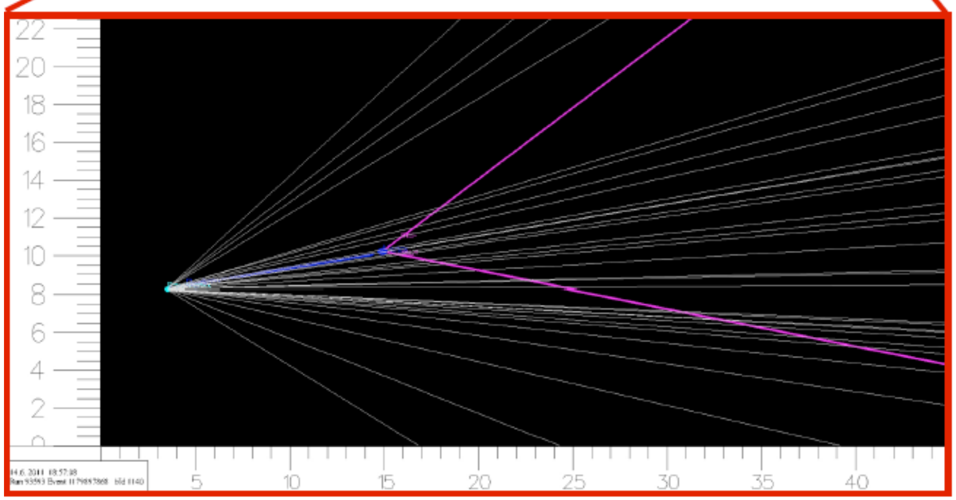
Allowed region

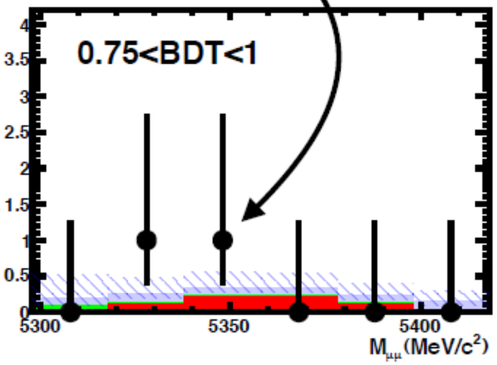
Figure 15: Constraints from BR($B_s \to \mu^+\mu^-$) and the double ratio R in the CNMSSM parameter plane $(m_{1/2}, m_0)$ for $A_0 = 1000$ GeV, $A_\kappa = -60$ GeV, $\tan\beta = 50$ and $\lambda = 0.1$.

LHCb: the decay $B_s \to \mu^+\mu^-$

$m_{\mu\mu}$ = 5.357 GeV
BDT = 0.90
Decay length = 11.5 mm
Tracks shown for p_T > 0.5 GeV







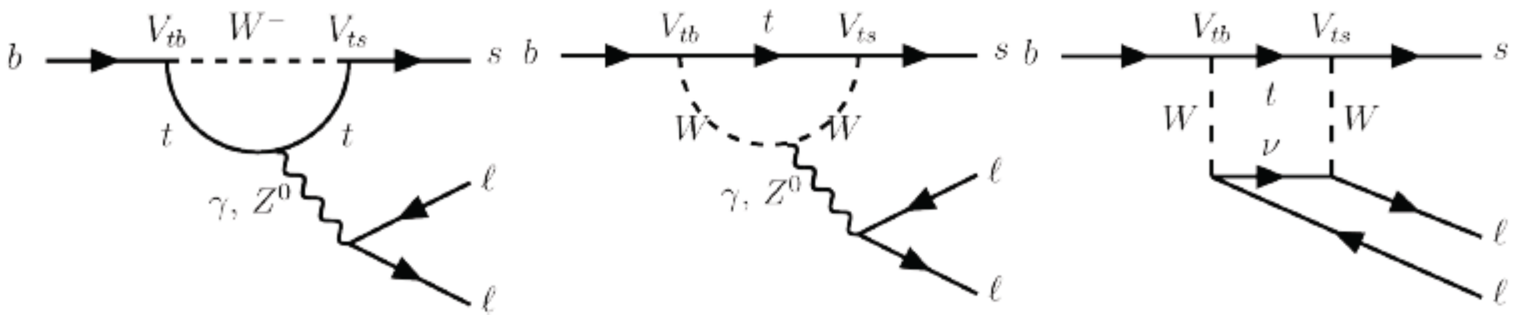
Clara Matteuzzi

Search for rare decay B $\rightarrow$ $K^*\mu^+\mu^-$

Search for $B^0 \to K^{*0}\mu^+\mu^-$ decay

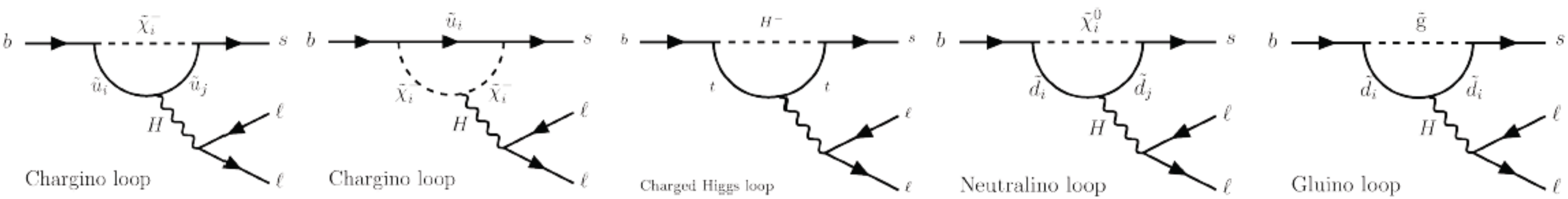
$b \to s$ transitions: FCNC process very sensitive to NP in loops

SM processes contributing to decay:

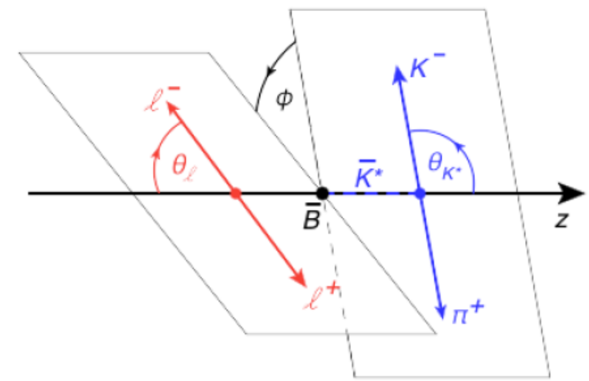


BR($B^0 \to$ lls) = 4.5×10^{-6}
BR($B^0 \to$ llK) = 0.5×10^{-6}
BR($B^0 \to$ llK*) = $3.3 \pm 1.0 \times 10^{-6}$

Analysis of angular distributions allow to extract information about New Physics (SUSY, graviton exchange,extra dimension)



Observables in $B^0 \to K^{*0}\mu^+\mu^-$ decay



Forward-backward asymmetry $A_{FB}(s)$ in the μμ rest-frame is sensitive probe of New Physics:

- Predicted zero of $A_{FB}(s)$ depends on Wilson coefficients C_7^{eff}/C_9^{eff}

$$A_{FB}(s) = \frac{\int_0^1 \frac{d^2\Gamma}{ds\,dcos\theta}dcos\theta - \int_{-1}^0 \frac{d^2\Gamma}{ds\,dcos\theta}dcos\theta}{\int_0^1 \frac{d^2\Gamma}{ds\,dcos\theta}dcos\theta + \int_{-1}^0 \frac{d^2\Gamma}{ds\,dcos\theta}dcos\theta}$$

Transverse Asymmetry:
(asymmetry in the spin amplitude of the K*

$$A_T^{(2)}(s) = \frac{|A_\perp|^2 - |A_\parallel|^2}{|A_\perp|^2 + |A_\parallel|^2}.$$

K^{*0} polarisation can be measured

q^2 Invariant mass squared of the dimuon system $q^2 = m^2_{\mu^+\mu^-}$.

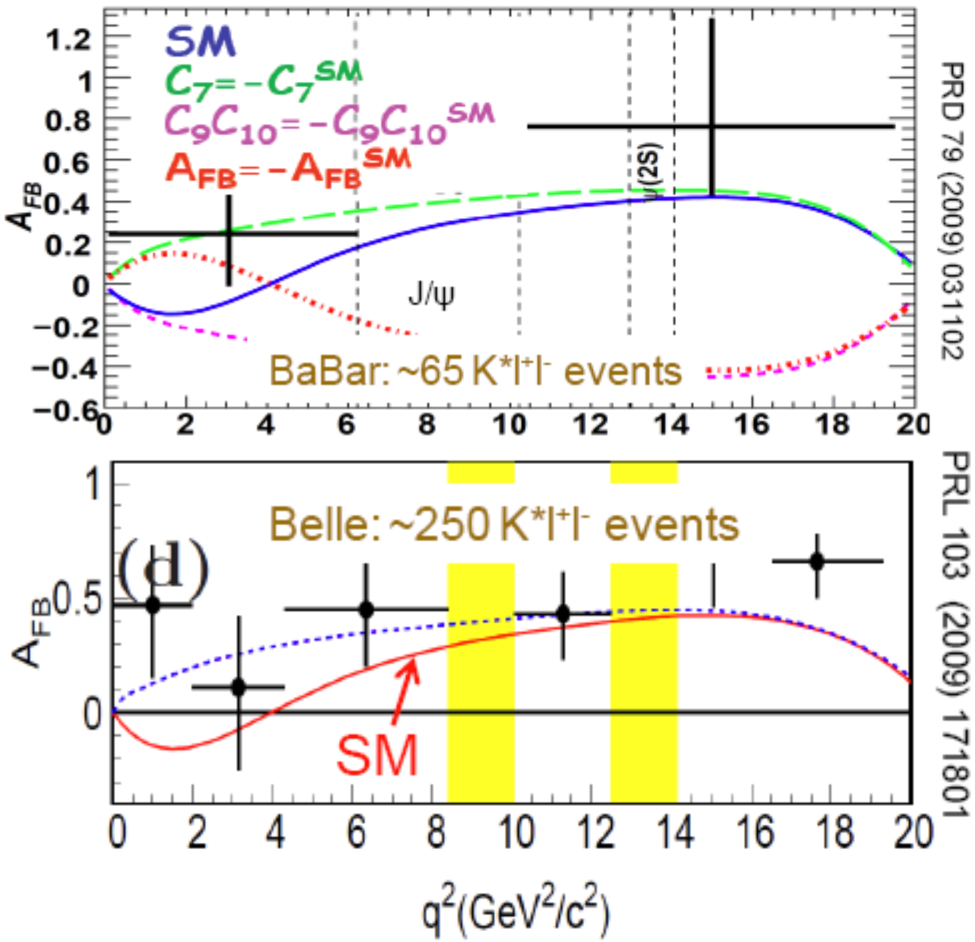
θ_ℓ Angle between the direction of the μ^- in the $\mu^+\mu^-$ rest frame and the direction of the $\mu^+\mu^-$ in the $\overline{B}_d$ rest frame.

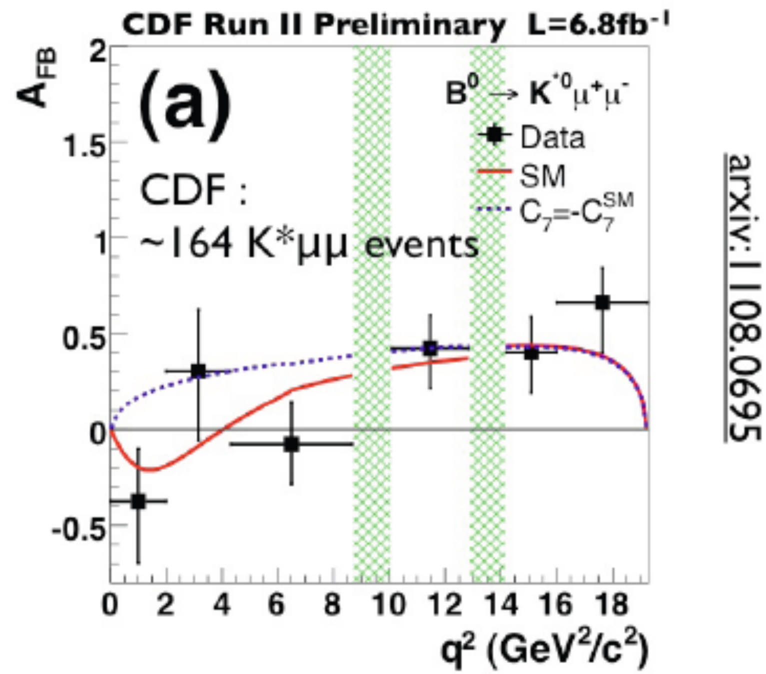
θ_K Angle between the kaon in the $\overline{K}^{*0}$ rest frame and the $\overline{K}^{*0}$ in the $\overline{B}_d$ rest frame.

ϕ Angle between planes defined by $\mu^-\ \mu^+$ and the $K\pi$ in the $\overline{B}_d$ frame.

A_{FB} in $B^0 \rightarrow K^{*0}\mu^+\mu^-$ decay

Present results from B-factories and CDF have poor precision



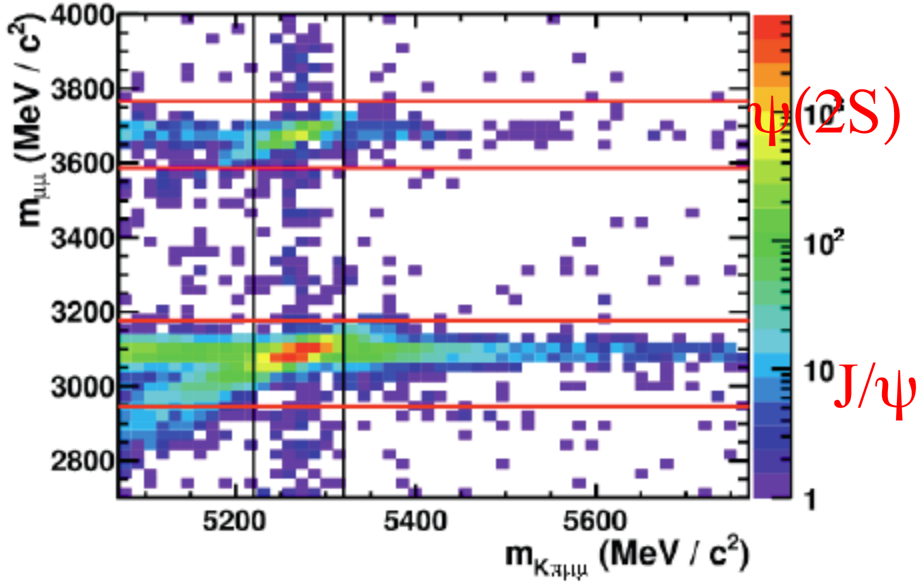


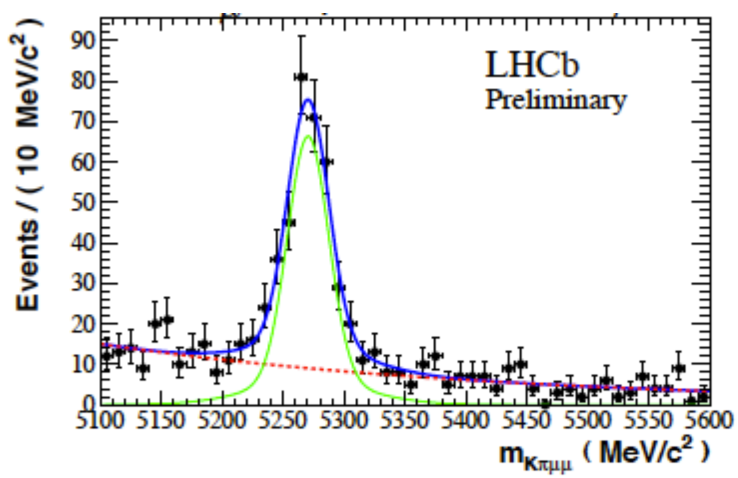
LHCb analysis of $B^0 \to K^{*0}\mu^+\mu^-$ decay

Select events using a Boosted Decision Tree

Veto J/ψ and $\psi(2S)$ regions

323 ± 21 signals in 309 pb^{-1}

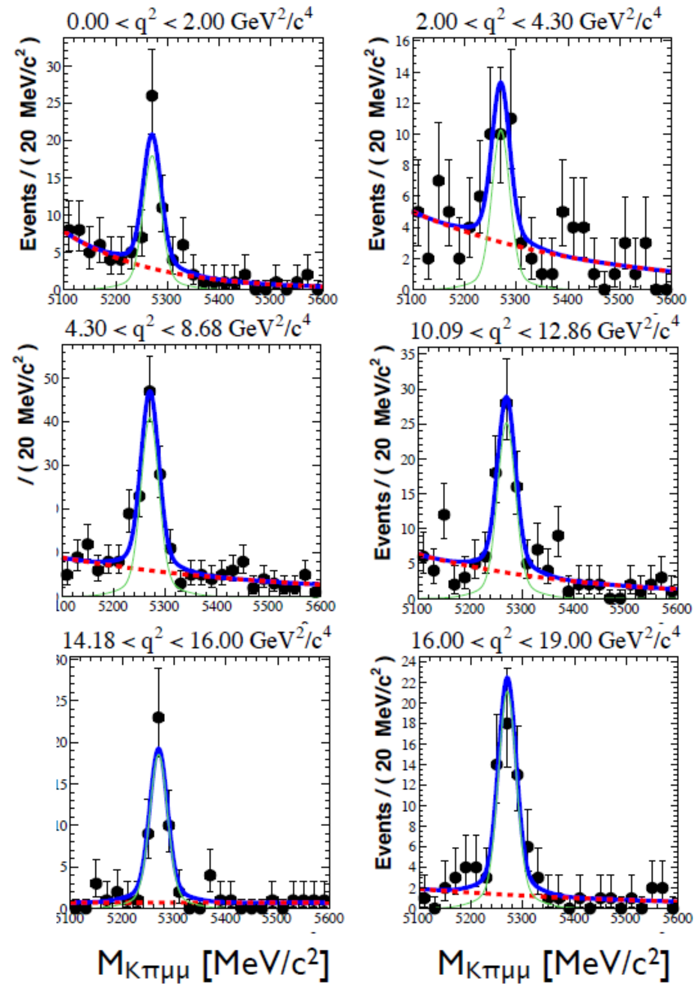




LHCb analysis of $B^0 \rightarrow K^{*0}\mu^+\mu^-$ decay

➡ Measure in 6 bins of q^2:

- Differential BR $d\Gamma/dq^2$ relative to BR ($B^0 \rightarrow J/\psi K^*$)
- A_{FB}
- Longitudinal polarization F_L



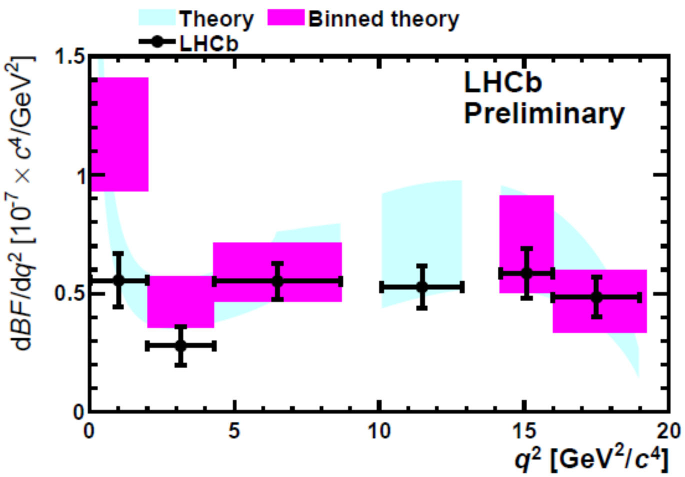
➡ Perform simultaneous fit of θ_l and θ_K

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_K\, dq^2} = \frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

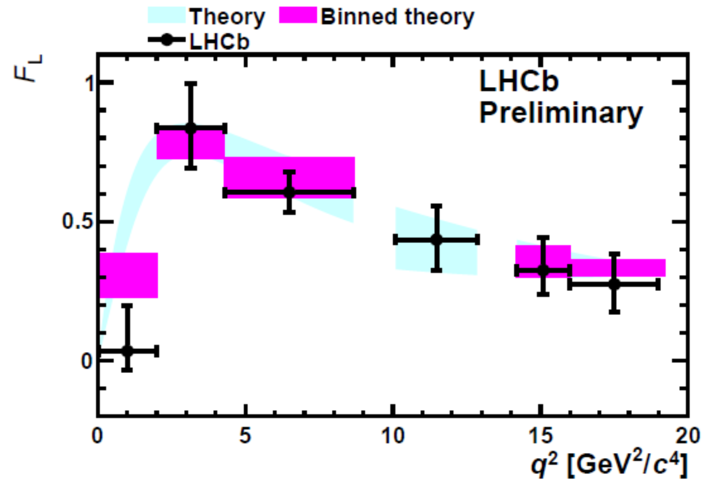
$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_\ell\, dq^2} = \frac{3}{4}F_L(1-\cos^2\theta_\ell) + \frac{3}{8}(1-F_L)(1+\cos^2\theta_\ell) + A_{FB}\cos\theta_\ell$$

➡ Fit procedure validated on $B^0 \rightarrow J/\psi K^*$ data and MonteCarlo

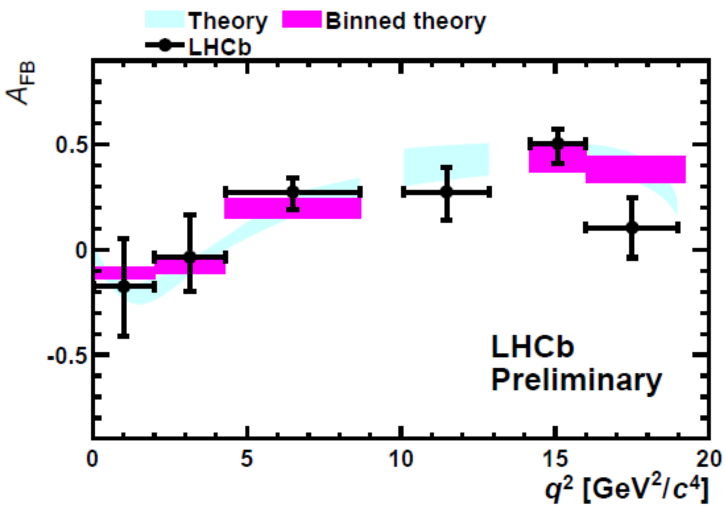
LHCb results of $B^0 \to K^{*0}\mu^+\mu^-$ decay



dBR/dq²



F_L



A_{FB}

Theory prediction from C. Bobeth et al. 1006.5013 hep-ph

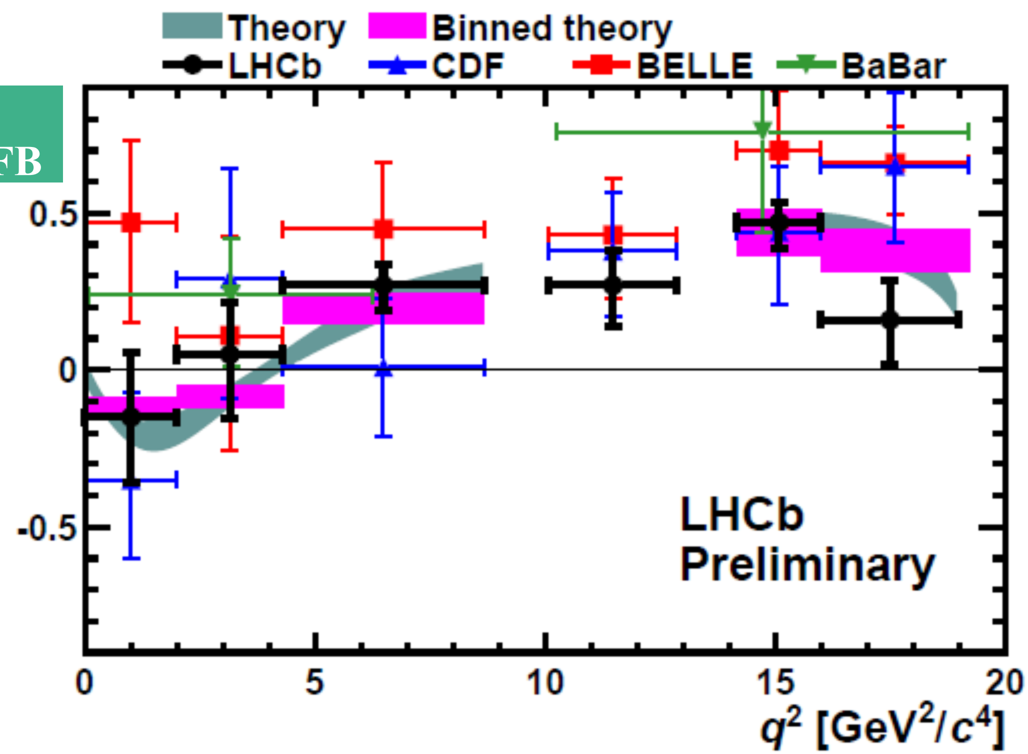
Small systematic uncertainty

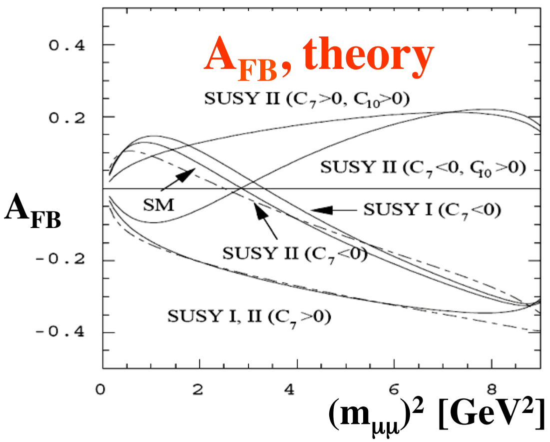
Data in agreement with SM and with previous experiments (BaBar, Belle, CDF)

Future: measure other observables ($A_T^{(2)}$, K* pol)

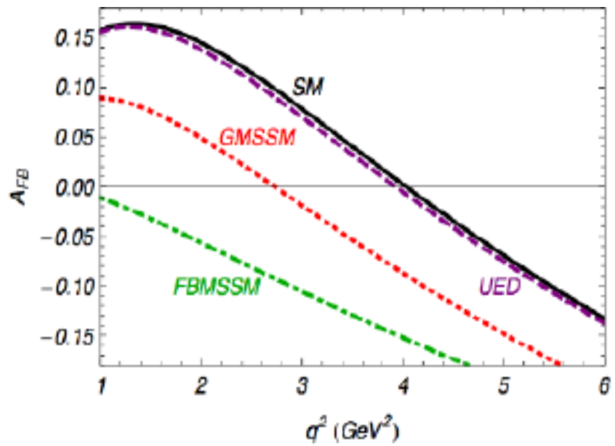
LHCb results for A_{FB} : comparison

Results (A_{FB} and F_L) are consistent with measurements from previous experiments





(from Phys.Rev.D61 (2000) 074024)



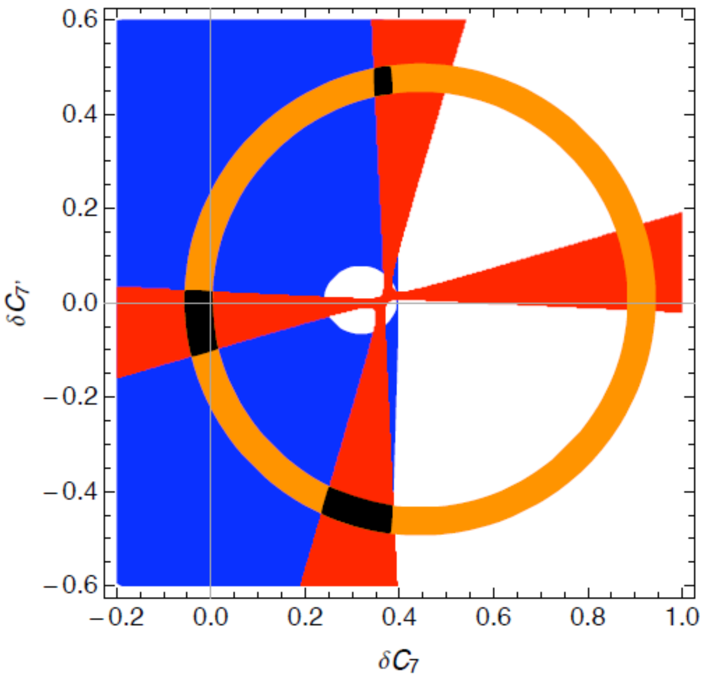
LHCb-CONF-2011-038

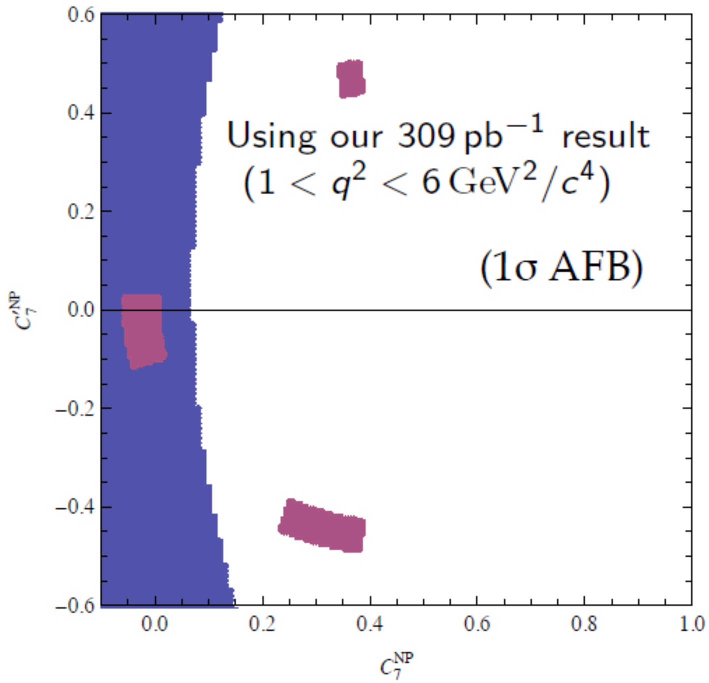
W.Altmannshofer et al. [JHEP 0901:019 (2009)]

BaBar [PRD **79** (2009)], Belle [PRL **103** (2009)], CDF [PRL **106** (2011)]

LHCb results as a constraint on $C_7^{(\prime)}$

From [arXiv:1104.334]





$A_I(K^{*0}\gamma)$, $S_{K^{*0}\gamma}$, $\mathcal{B}(b \to s\gamma)$

A_{FB} probes $\mathcal{C}_{10}(\mathcal{C}_9 + \beta(q^2)\mathcal{C}_7)$

A_{FB} does not strongly constrain $\mathcal{C}_7'$.
Large effects in A_T^2 can still be possible with SM-like A_{FB}.

Summary

Flavor Physics can give information on some major open problems of physics today

- The effects of New Physics in loops can be seen in rare decay branching fractions (B, τ) and kinematic distributions, and in *CP*-violating asymmetries in channels with small (10^{-5}- 10^{-6}) Branching Fractions
- New source of CP violation must exist : find out where it is will disclose New Physics

LHCb will (and already does) contribute crucially to this field now and for the years to come

Summary

other future projects will greatly contribute in improving the knowledge in the flavor sector :

- in the near future LHCb will improve with higher precision , better understanding of the detector, the study of a wide variety of processes where loops can contain New Physics

- Super *B*-Factories can, in the next decade, provide high precision measurements ($\rightarrow$ leptonic decays, searches for lepton flavor violation) complementary to those of hadronic experiments ($\rightarrow$ B_s, and B_d /B_s very rare decays at LHC)

- Rare K decay experiments ($K\rightarrow\pi\nu\nu$, $K\rightarrow\pi l^+l^-$ *Br* $\sim 10^{-10}$, 10^{-11})

Better theoretical understanding and predictions will be fundamental for the achievement of this program

Effects on flavor physics

Buras, arXiv:0910.1032v1

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ε_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	★★

Table 2: "DNA" of flavour physics effects [55] for the most interesting observables in a selection of SUSY and non-SUSY models. ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.