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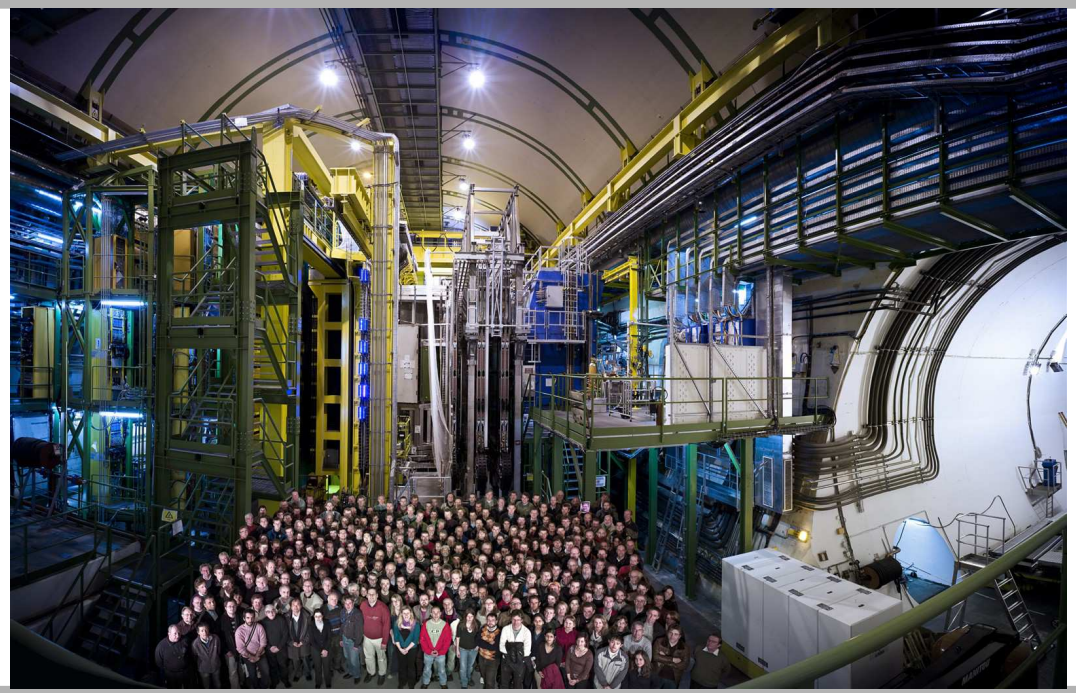
LHCb results now and tomorrow

M. Kreps on behalf of the LHCb Collaboration

Physics Department



Introduction

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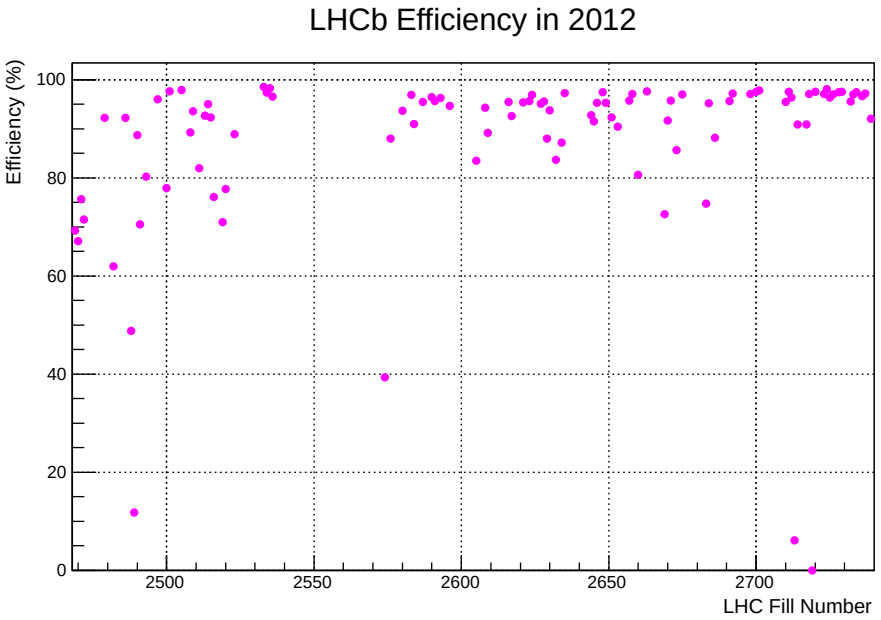
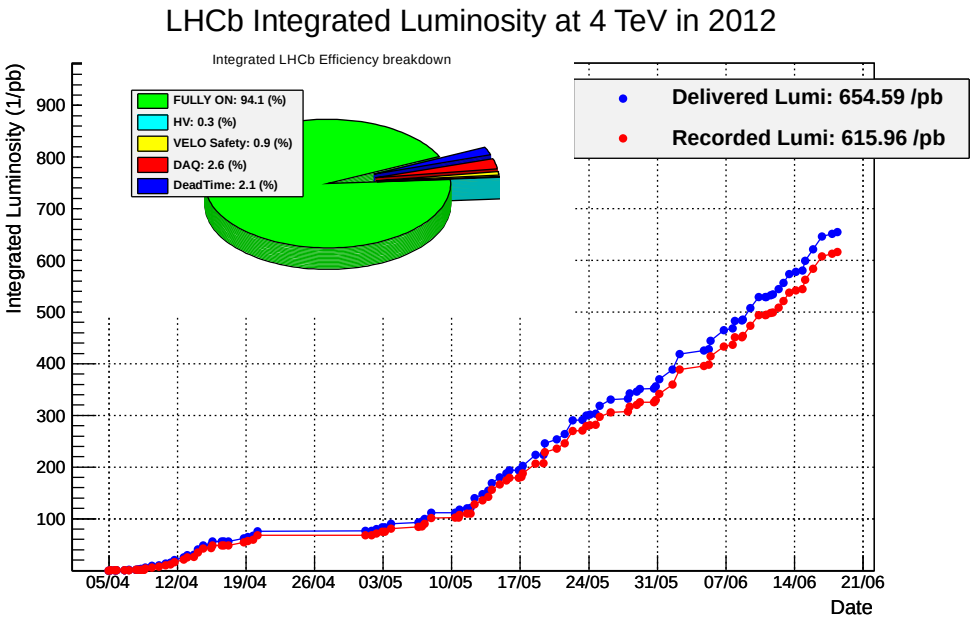
- LHCb running very well
- In 2011 collected $\approx 1\ \mathrm{fb}^{-1}$
- On track to collect 1.5 fb^{-1} this year
- Very high efficiency
- Practically all data we collect are good data
- Today all results still use 2011 data
- 300 pb^{-1} we had month ago do not add so much to statistics from last year
- Less explanations of physics and analysis details, more on results and where we could get in future





Towards angle γ

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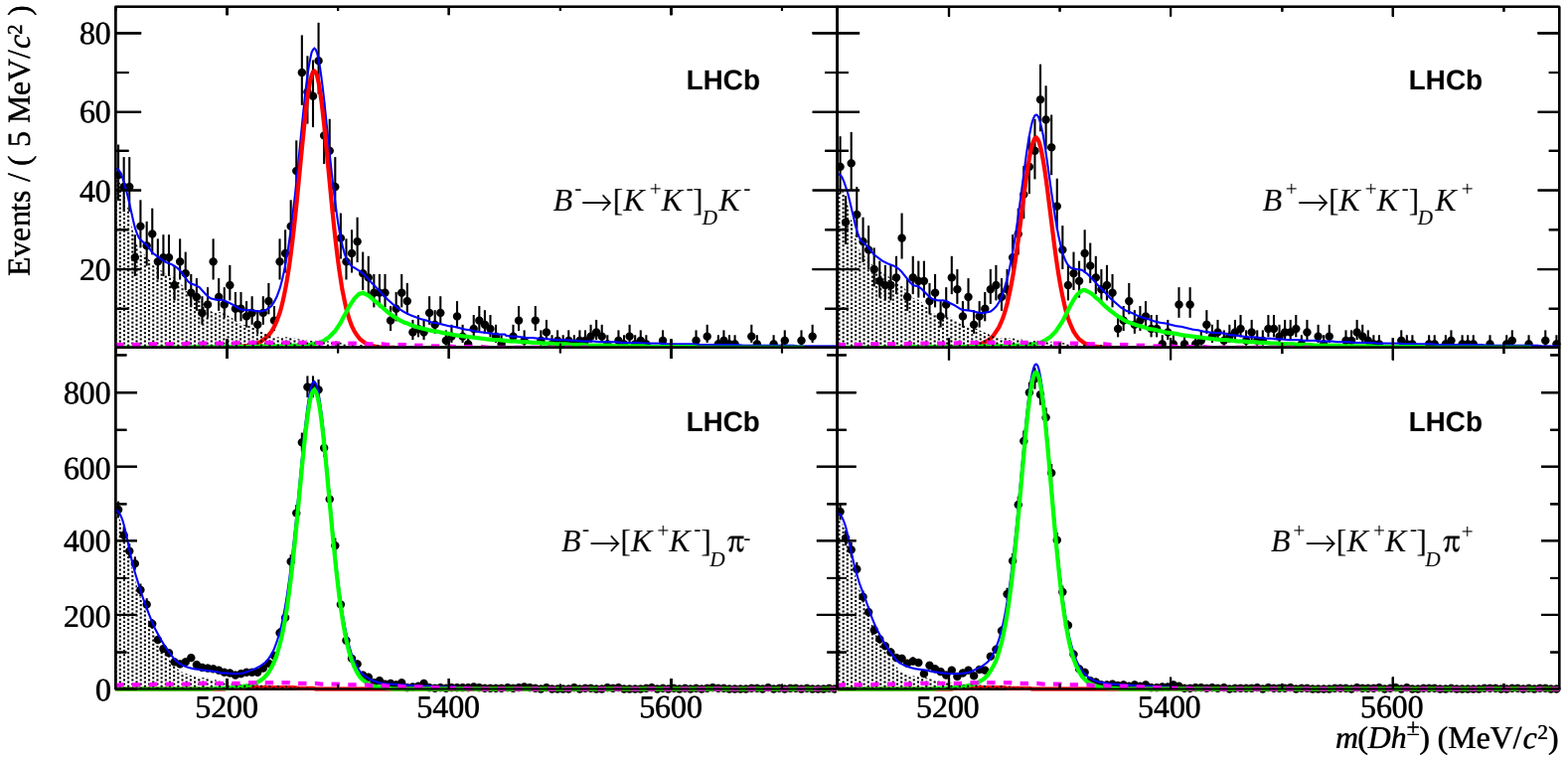
- Angle γ important to define standard model
- Least precision up to now
- Measure $A_{CP+} = 0.145 \pm 0.032 \pm 0.010$ (average of K^+K^- and $\pi^+\pi^-$)
- Significance of the CP violation is 5.8σ
- One of the main systematic uncertainty from detector asymmetry will decrease with statistics



PL B712, 203 (2012)

Towards angle γ

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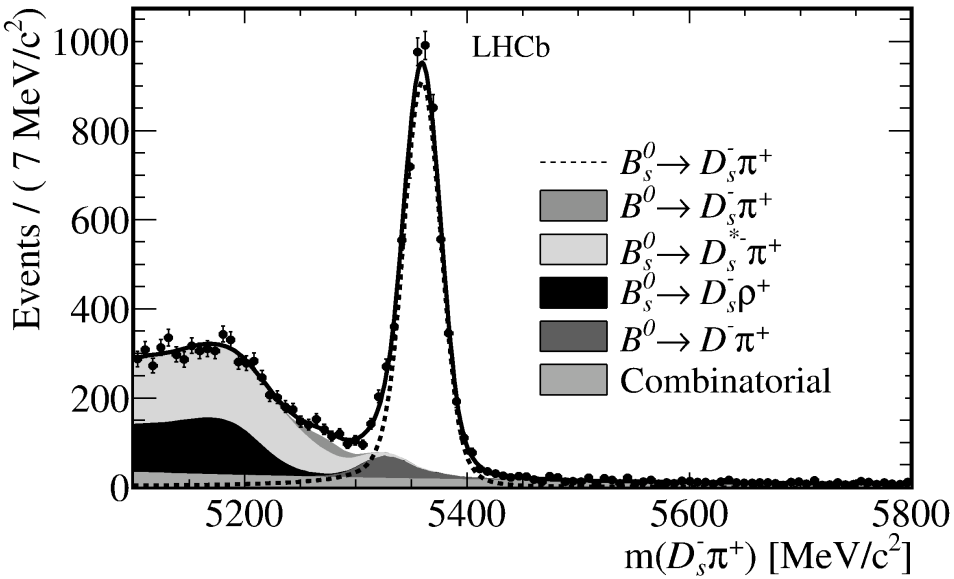
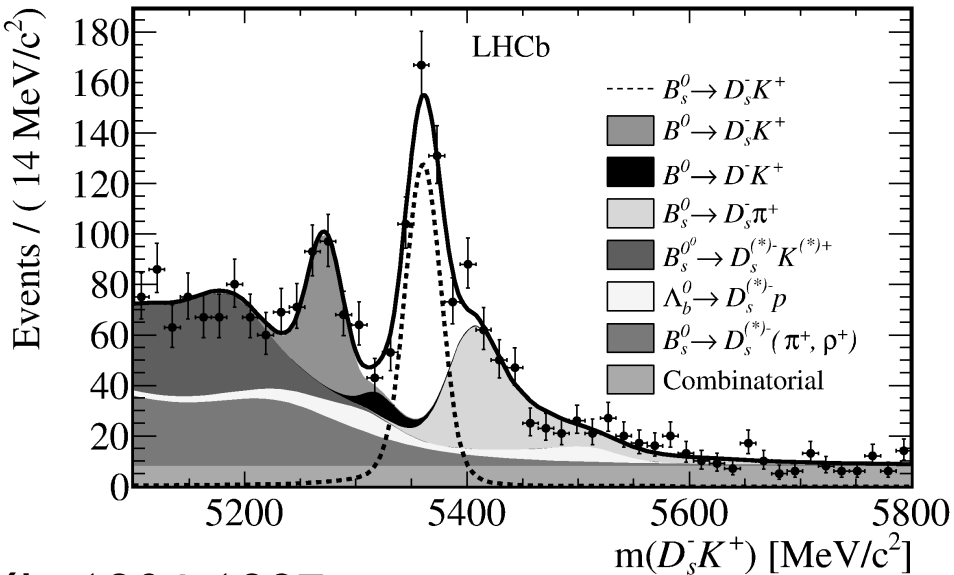
- Decay $B_s \rightarrow D_s K$ is one of the theoretically cleanest decay to extract angle γ
- Seen before by CDF and Belle, but not enough statistics to move towards γ
- In 370 pb^{-1} we observe ≈ 400 signal events
- Measure branching fraction of $(1.90 \pm 0.12 \pm 0.13^{+0.12}_{-0.14}) \times 10^{-4}$
- With full 2011 dataset about 1200 events
- Working on time dependent analysis relevant for γ extraction





arXiv:1204.1237

Measurement of ϕ_S

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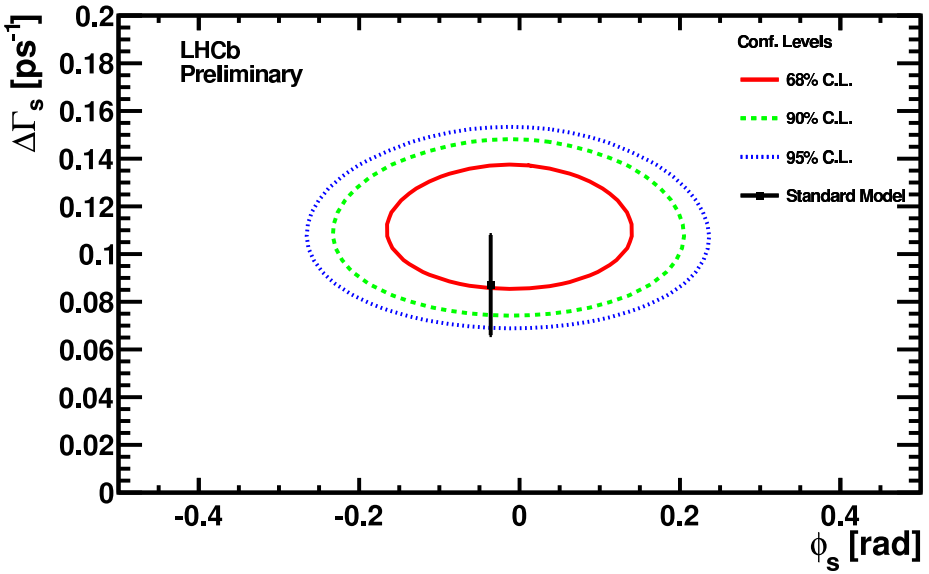
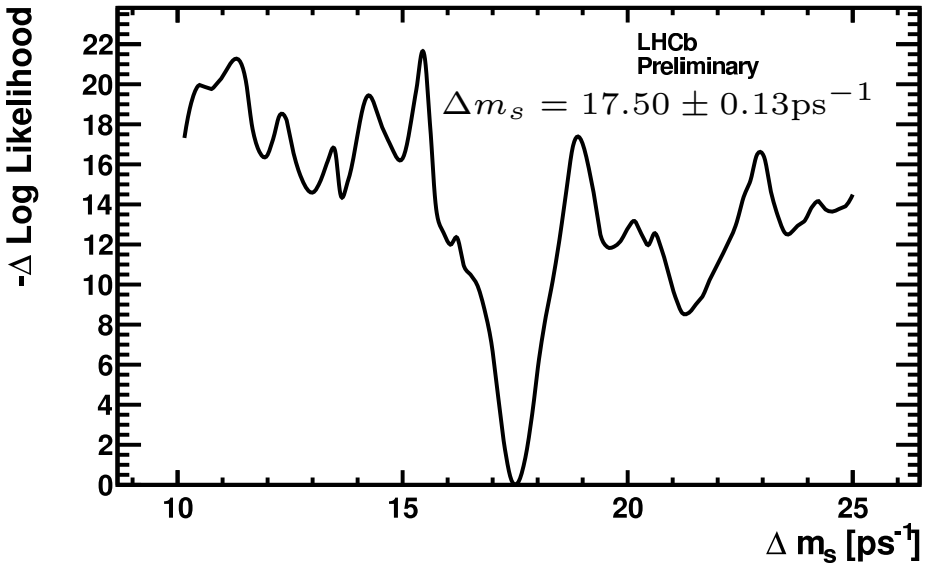
- Test new physics contribution in B_s mixing box diagrams
- Lot of excitement few years back from Tevatron results
- About 21k $B_s \to J/\psi\phi$ events
- $\phi_S = -0.001 \pm 0.101 \pm 0.027$
  $\Delta\Gamma_s = 0.116 \pm 0.018 \pm 0.006 \mathrm{ps}^{-1}$
- Most precise measurements
- Dominated by statistics
- Largest systematic uncertainty on ϕ_S from assuming no CPV in mixing or decay

$\to$ Can be tested directly by data





LHCb-CONF-2012-002

Measurement of ϕ_S

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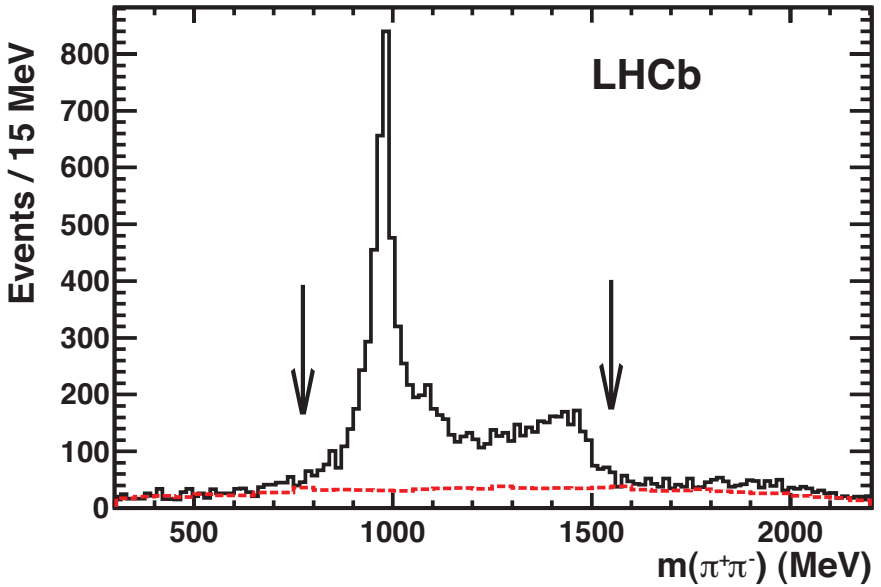
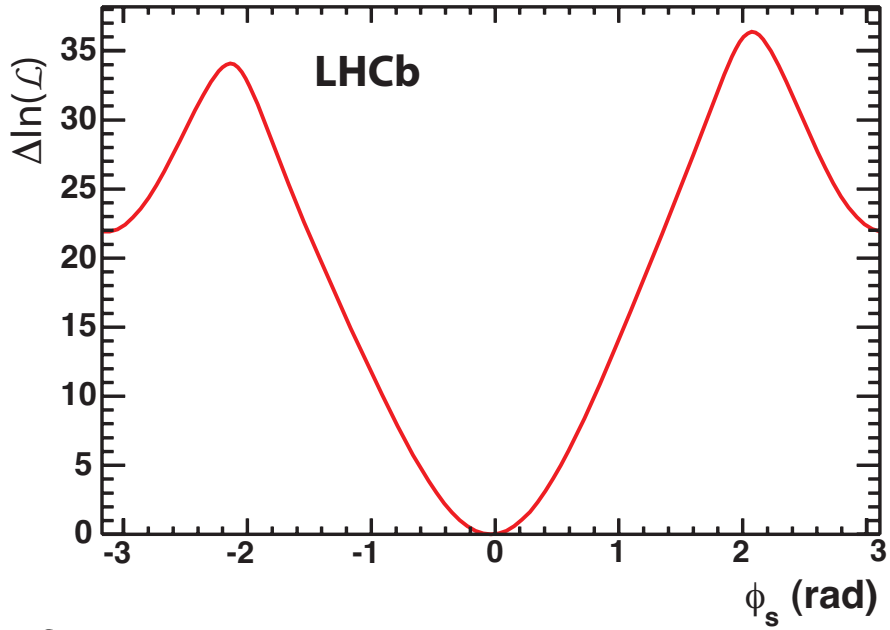
- $B_s \to J/\psi\pi^+\pi^-$ decays provide alternative sample
- About 7.4k signal decays
- From angular study final state is basically pure CP-odd ($> 97.7\%$)

→ Simplifies analysis (no angular fit needed)

- Use $\Delta\Gamma_s$ and Γ_s as found in $B_s \to J/\psi\phi$
- $\phi_S = -0.019^{+0.173\ +0.004}_{-0.174\ -0.003}$
- Again statistically limited
- Many systematic uncertainties likely to decrease with increased statistics
- Combined with $B_s \to J/\psi\phi$

  $\phi_S = -0.002 \pm 0.083 \pm 0.027$





arXiv:1204.5675

B_s^0 decay width difference

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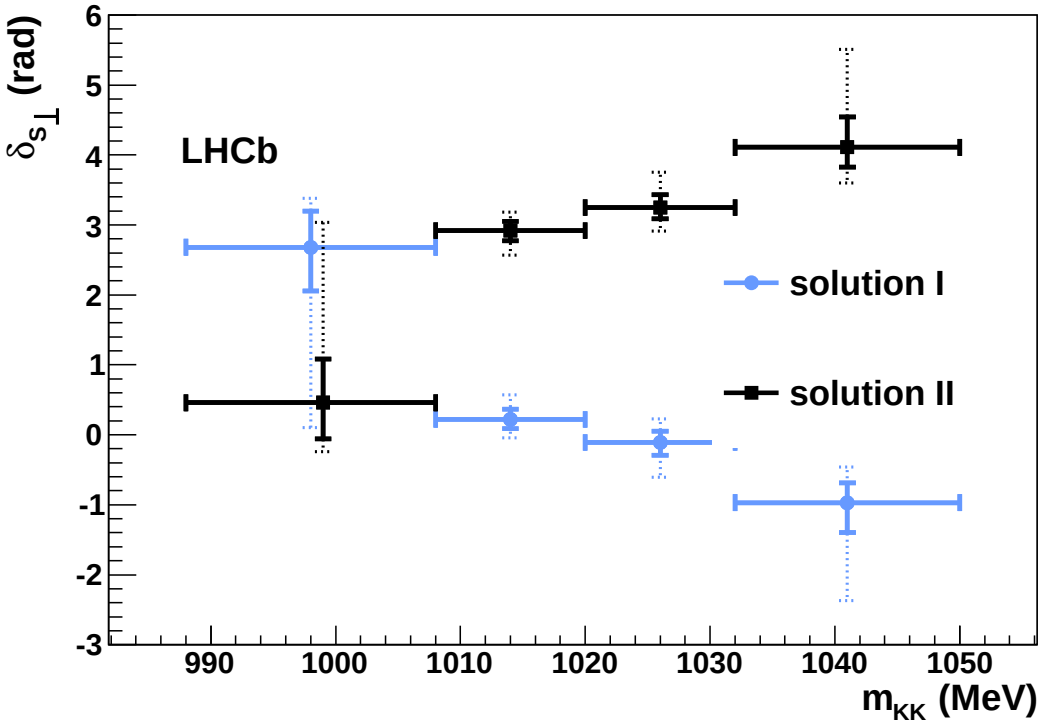
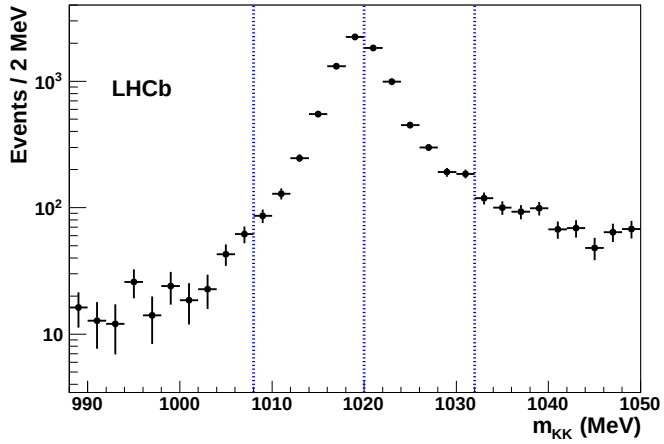
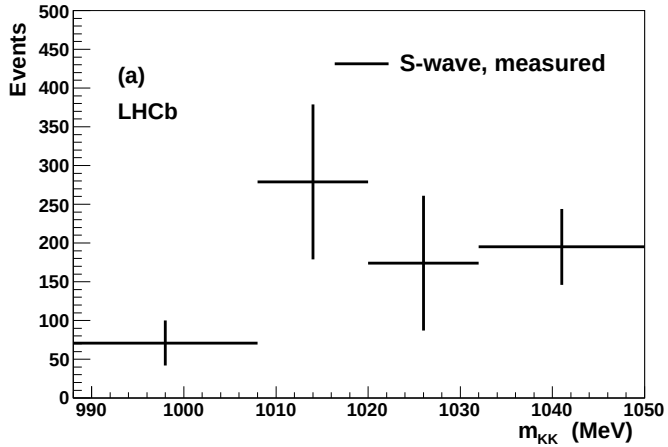
- Showed only one solution, but there is another $-\Delta\Gamma_s$, $\pi - \phi_S$
- Resolve them using $B_s \to J/\psi K^+ K^-$
- Interference between p- and s-wave key
- Physical solution should have decreasing phase between s- ad p-wave
- Solution with positive $\Delta\Gamma_s$ is physical
- ϕ_S close to standard model







PRL 108, 241801 (2012)

Direct CPV in $B \to hh$

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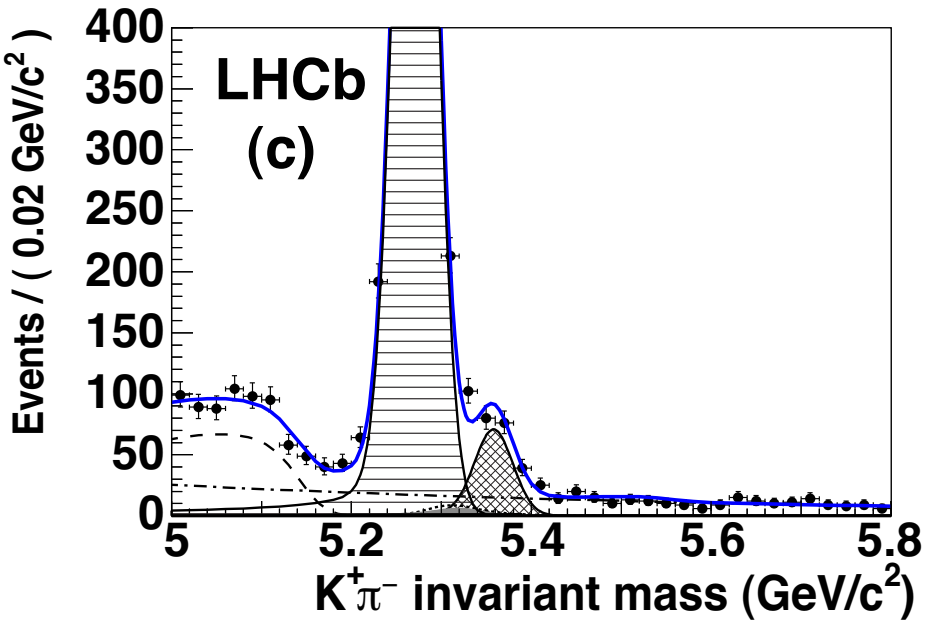
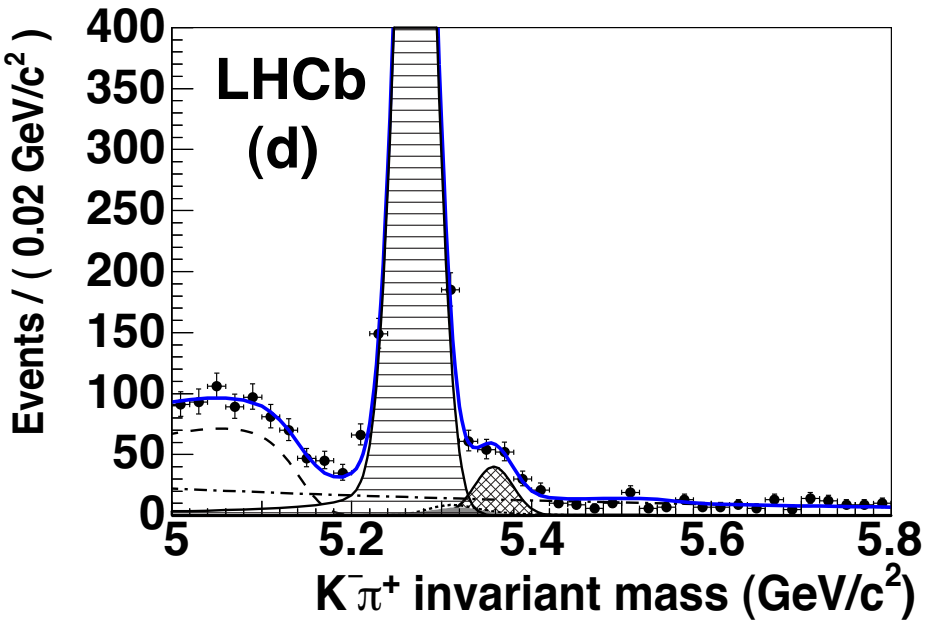
- Charmless two body decays proceed through gluonic penguins and $b \to u$ trees
- Sensitivity to new physics (but screened by hadronic physics)
- Comparing CPV in $B_s \to K^-\pi^+$ to $B^0 \to K^+\pi^-$ can serve as model independent test
- LHCb measures $A_{CP}(B^0 \to K^+\pi^-) = -0.088 \pm 0.011 \pm 0.008$
- For B_s, $A_{CP}(B_s \to K^-\pi^+) = 0.27 \pm 0.08 \pm 0.02$
- At 3.3σ this is first evidence of CPV in B_s system





PRL 108, 201601 (2012)

Effective lifetime in $B_s \to KK$

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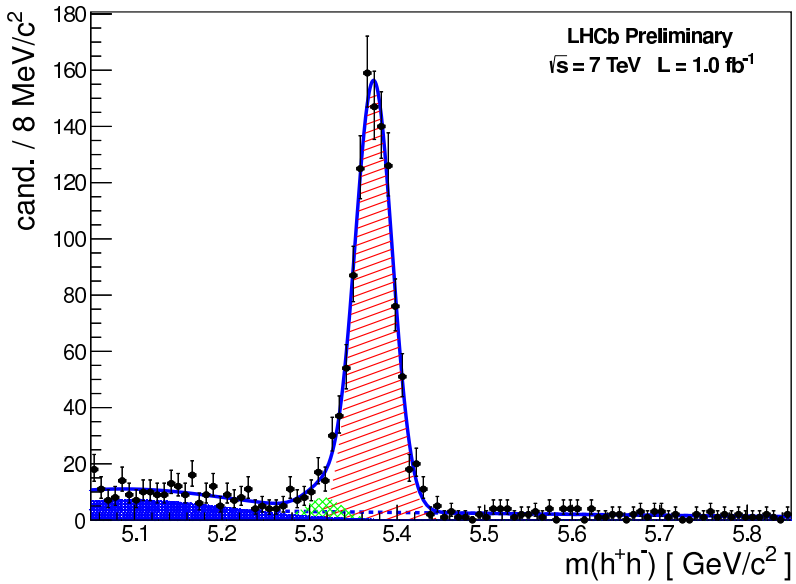
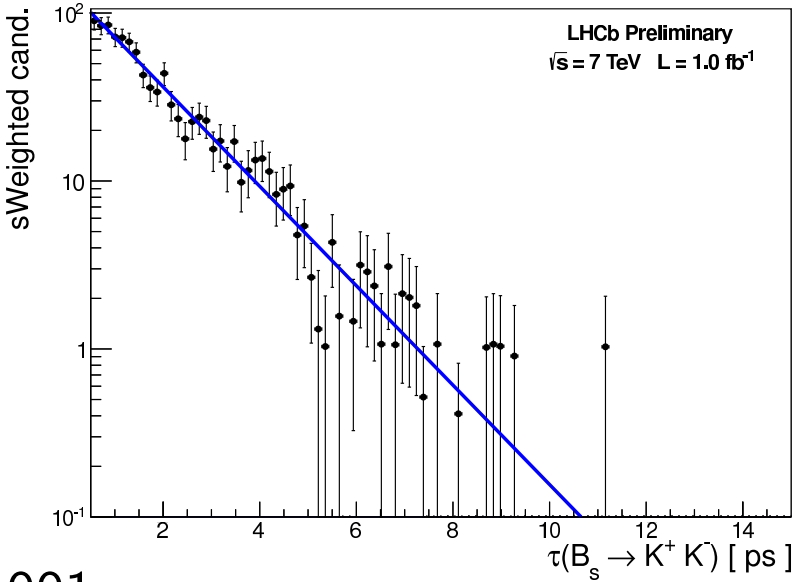
- K^+K^- is CP-even final state
- In the absence of CP violation (SM) it coincides with B_{sL} eigenstate
- Measurements with two exponentials difficult
- Measure effective lifetime in fit with single exponential
- Effective lifetime can be used with other measurements to constrain Γ_s, $\Delta\Gamma_s$ and CP violation
- Dedicated trigger to collect decay time unbiased sample
- $\tau_{eff} = 1.468 \pm 0.046 \pm 0.006$ ps
- Consistent with standard model





LHCb-CONF-2012-001

Time dependent $B \to hh$

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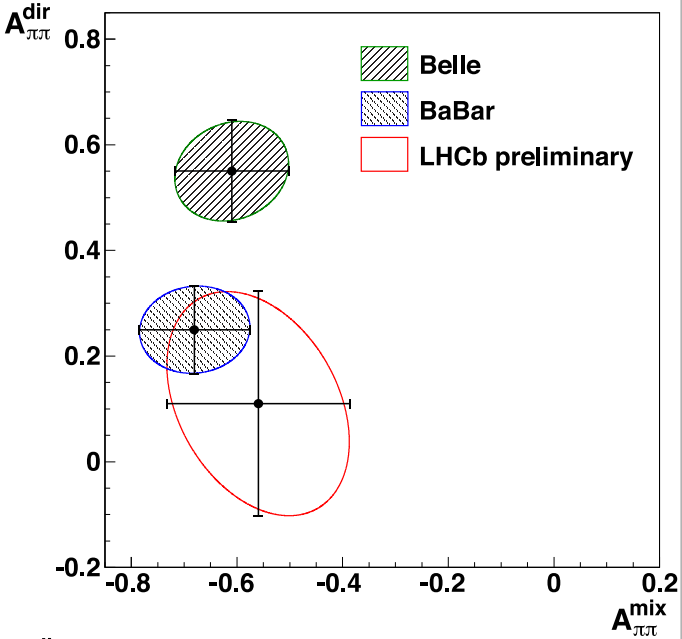
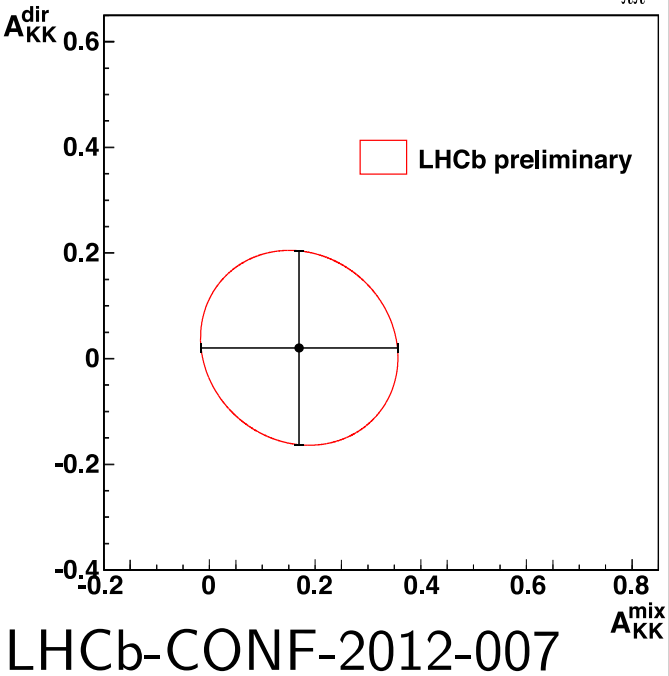
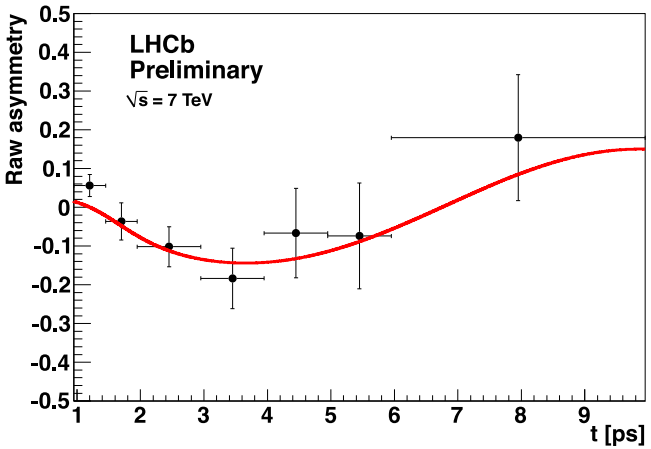
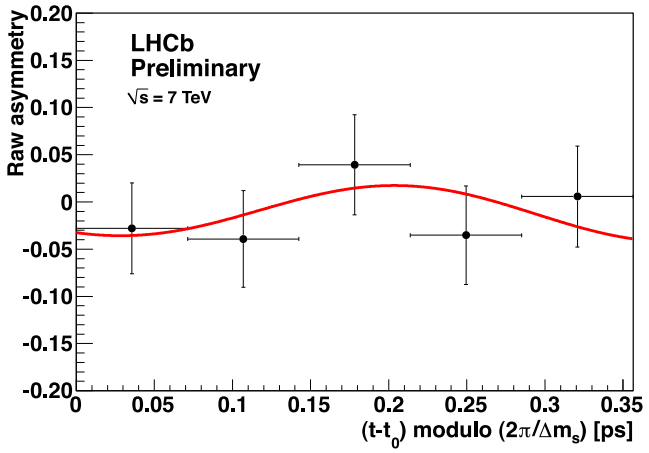
- Next obvious step is to add flavour tagging
- In same framework do $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$
- $A_{\pi\pi}^{dir} = 0.11 \pm 0.21 \pm 0.03$
  $A_{\pi\pi}^{mix} = -0.56 \pm 0.17 \pm 0.03$
- $A_{KK}^{dir} = 0.02 \pm 0.18 \pm 0.04$
  $A_{KK}^{mix} = 0.17 \pm 0.18 \pm 0.05$
- Not yet competitive with B-factories on B^0
- First time dependent CPV measurement on hadronic B_s decays









LHCb-CONF-2012-007

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

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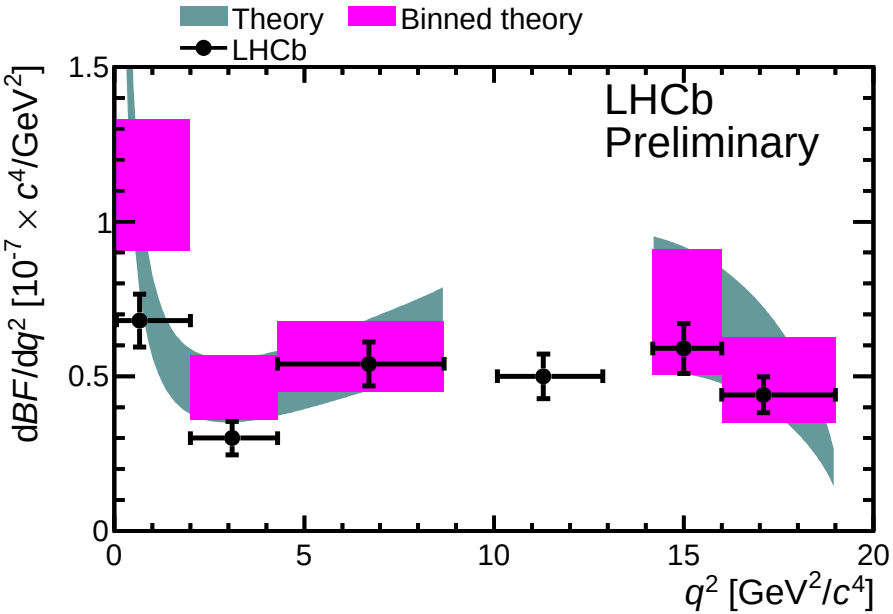
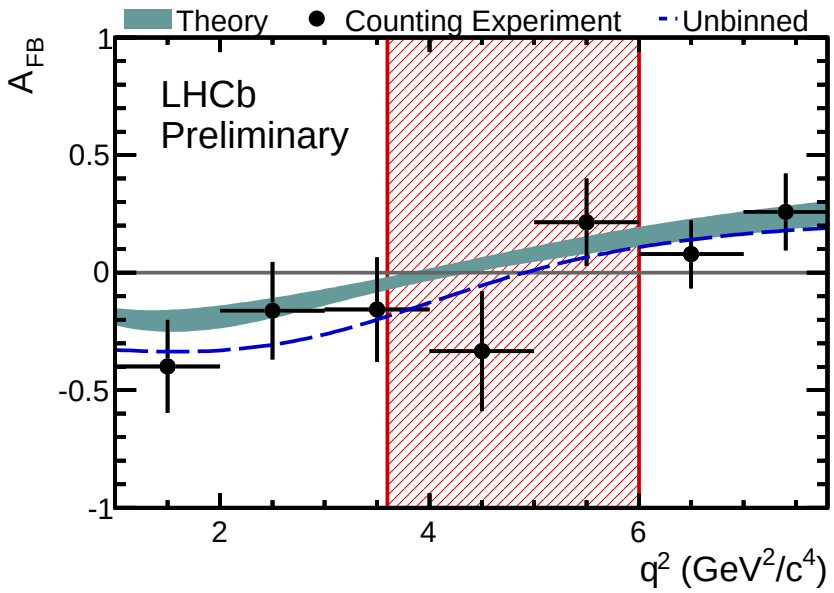
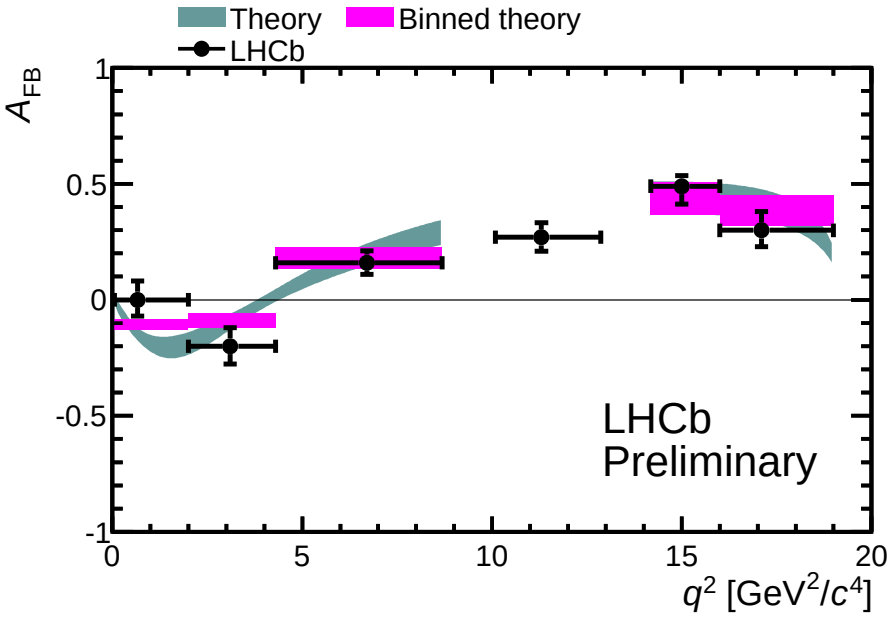
- EW $b \to s\mu^+\mu^-$ transition
- In 2011 about 900 signal events
- Statistics larger than sum of all other experiments
- Rich set of observables from angular analysis (q^2 dependent)
- First result on zero-crossing point $q_0^2 = (4.9^{+1.1}_{-1.3})\mathrm{GeV}^2/c^4$







LHCb-CONF-2012-008

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

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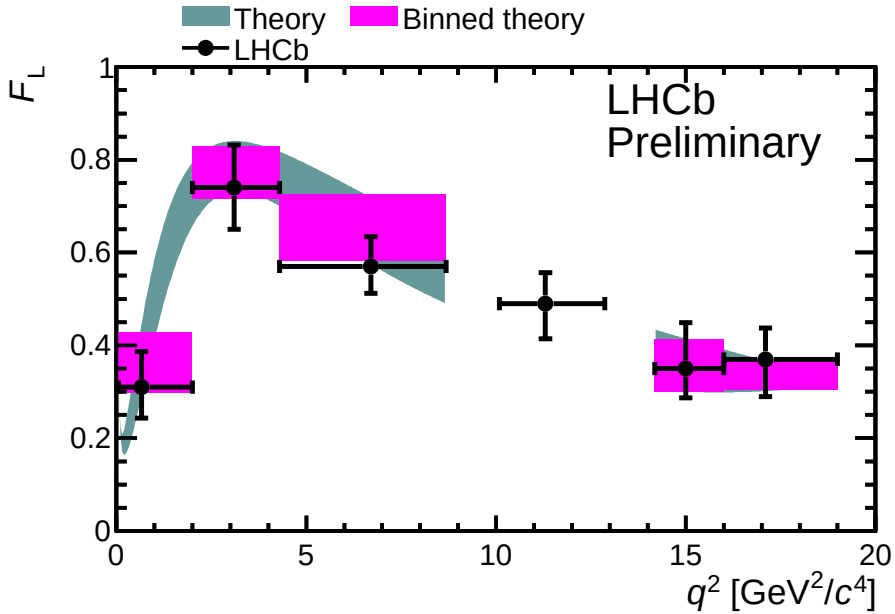
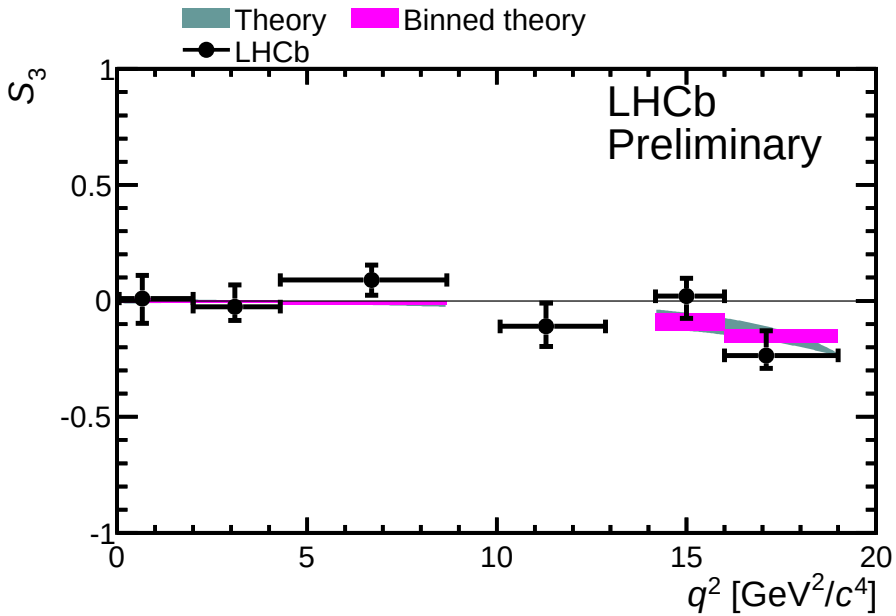
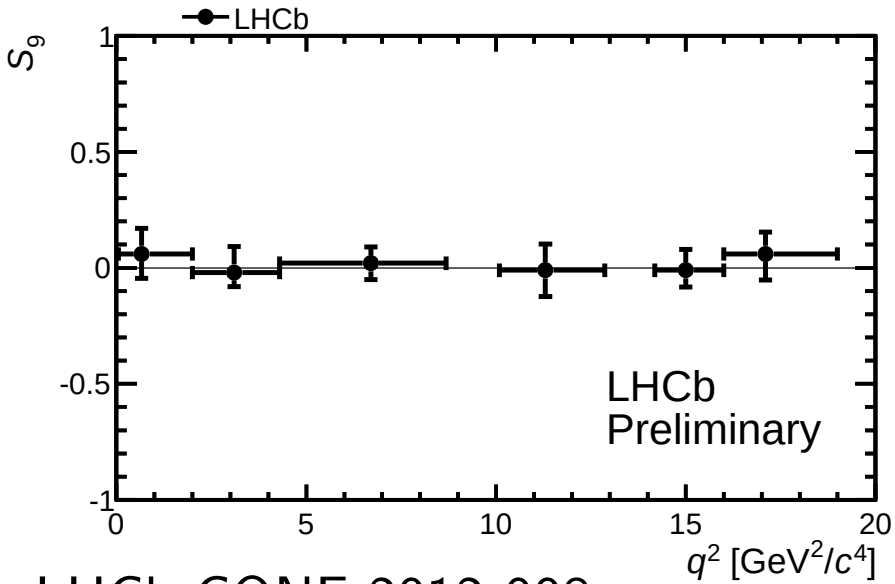
- With increased statistics include more observables
- Careful how angles are defined and treated, can make difference in meaning of observables
- Except of branching fraction pretty much statistically limited







LHCb-CONF-2012-008

$B \to K^{(*)}\mu^+\mu^-$ A_I

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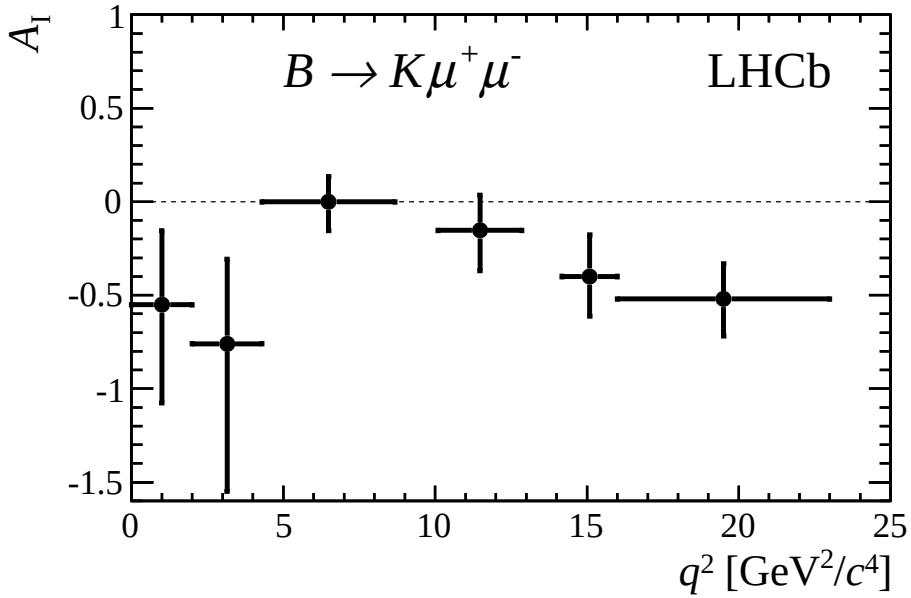
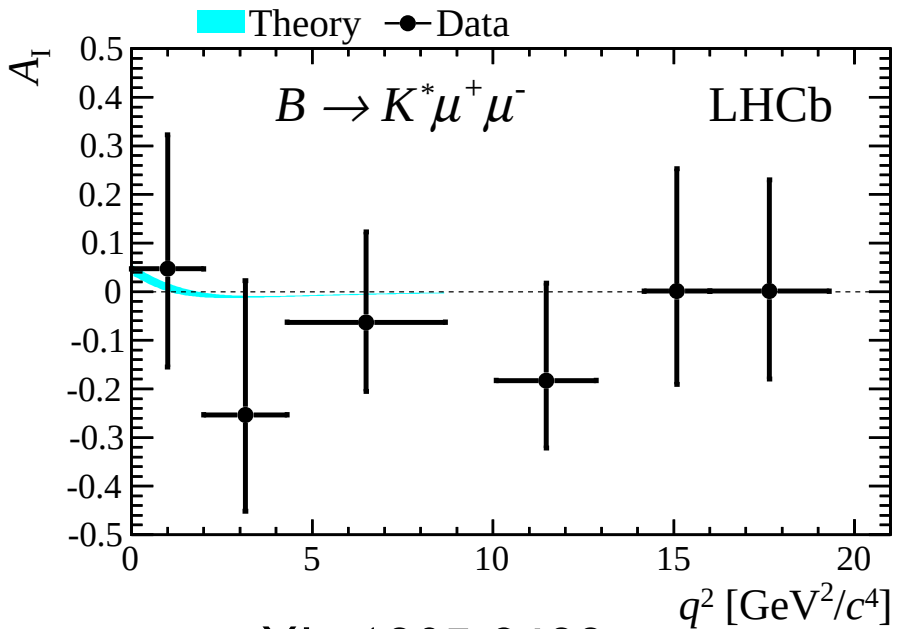
- Measurement of asymmetry between B^+ and B^0
- Challenging due to need to reconstruct long lived K_s
- Measurement limited by the statistics on decays with K_s
- Possibly larger systematic uncertainty from tracking as final states have different number of tracks
- All measurements in this class of transitions consistent with SM
- Possible hint of departure from zero for A_I in $B \to K\mu^+\mu^-$





arXiv:1205.3422

Other $b \to s(d)\mu^+\mu^-$

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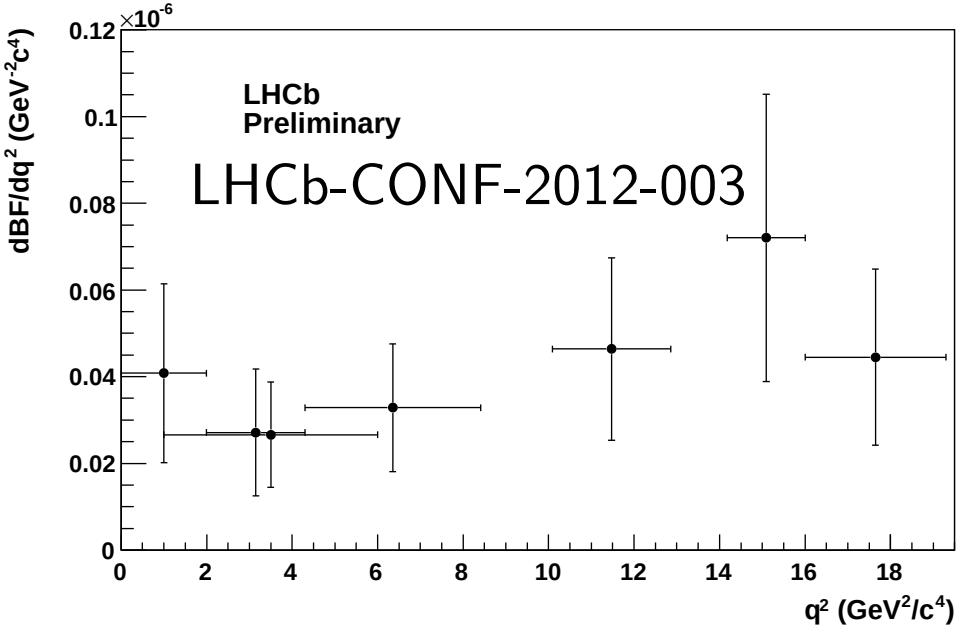
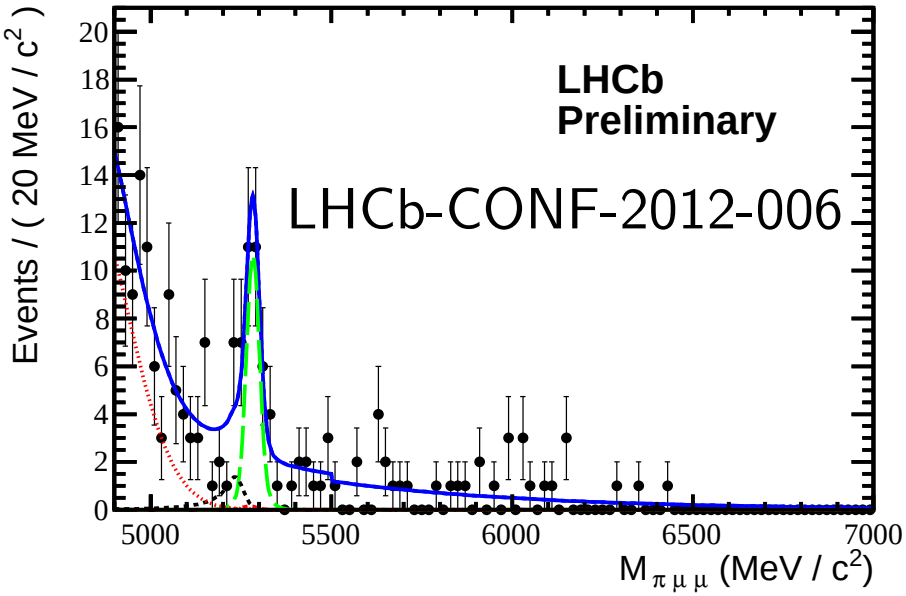
- $B_s \to \phi\mu^+\mu^-$ governed by $b \to s\mu^+\mu^-$ transition
- With 1 fb^{-1} we measure total and differential branching fraction
- See $\approx$ 77 signal events in full q^2 range
- Branching fraction measured to be $(0.78 \pm 0.10 \pm 0.06 \pm 0.28) \times 10^{-6}$



- For the first time see $b \to d\mu^+\mu^-$ transition
- Observe $B^+ \to \pi^+\mu^+\mu^-$ with significance of 5.2σ
- $\mathcal{B}(\pi^+\mu^+\mu^-) = (2.4 \pm 0.6 \pm 0.2) \times 10^{-8}$



Radiative decays

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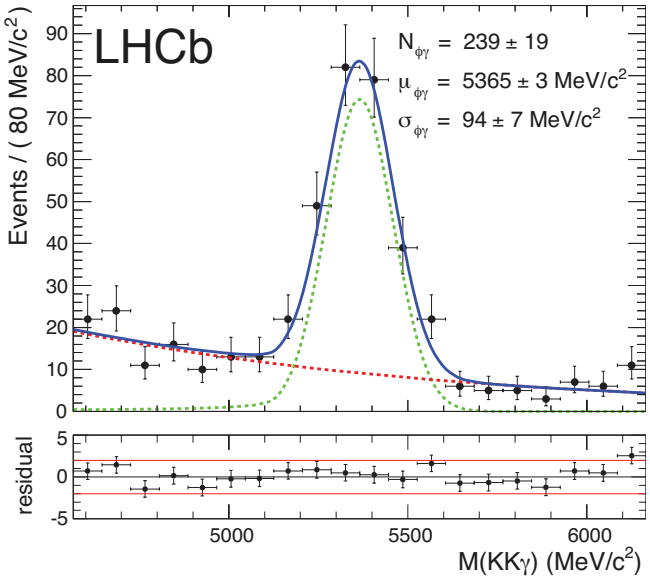
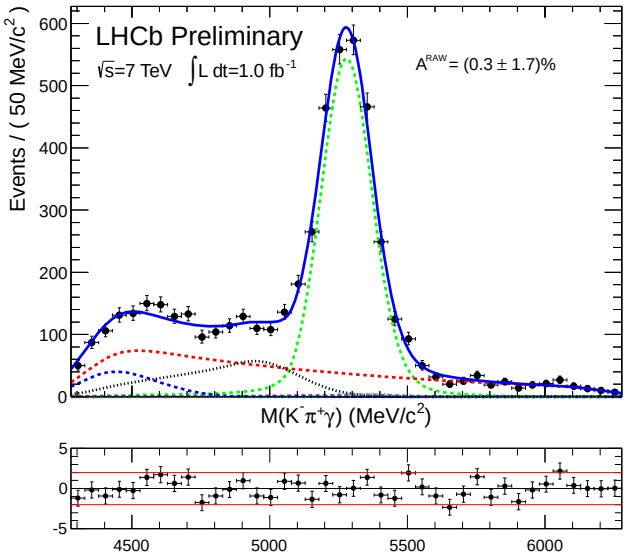
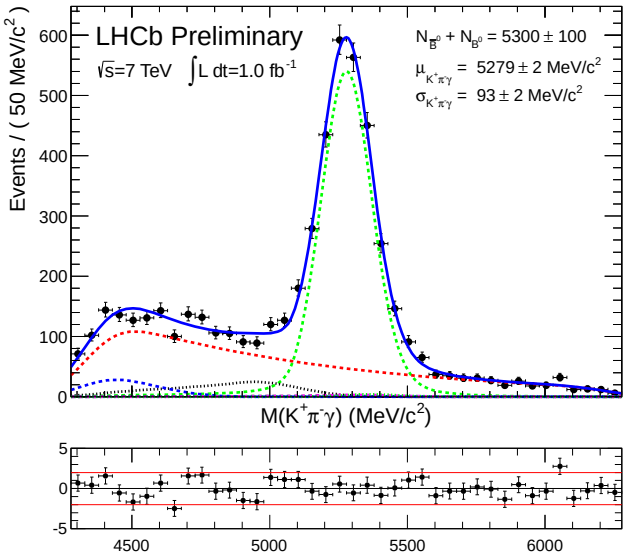
arXiv:1202.6267
LHCb-CONF-2012-004

- FCNC EM penguin transitions sensitive to V_{ts}
- Could be significantly enhanced by new physics
- While $B^0 \to K^*\gamma$ relatively well know, corresponding $B_s \to \phi\gamma$ only purely measured
- Measuring relative branching fractions between B^0 and B_s
  $R = 1.12 \pm 0.08^{+0.06\ +0.09}_{-0.04\ -0.08}(f_s/f_d)$
- For $B^0 \to K^*\gamma$ measure CP asymmetry of $A_{CP} = 0.008 \pm 0.017 \pm 0.009$
- Most precise measurements
- For A_{CP} systematic uncertainties should scale with increased statistics







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

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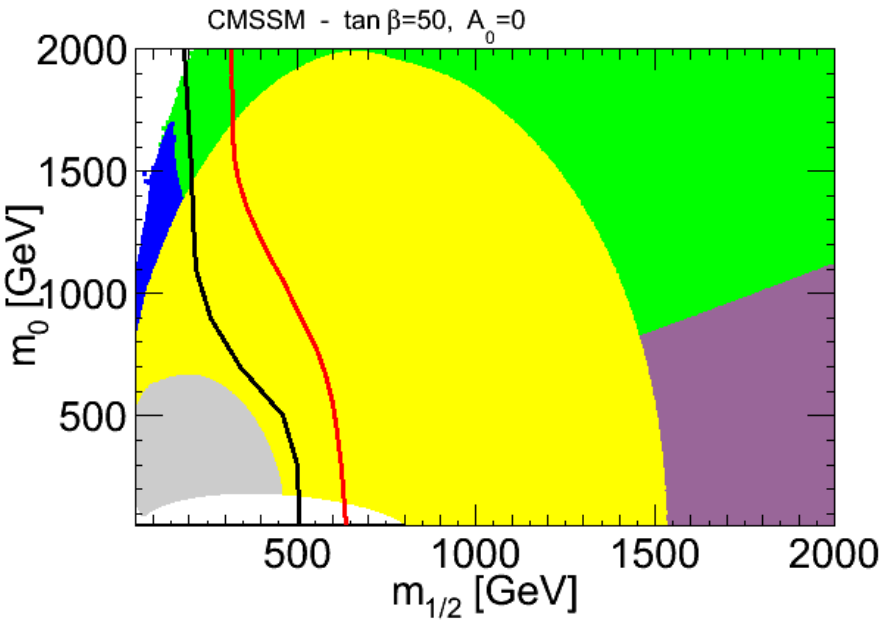
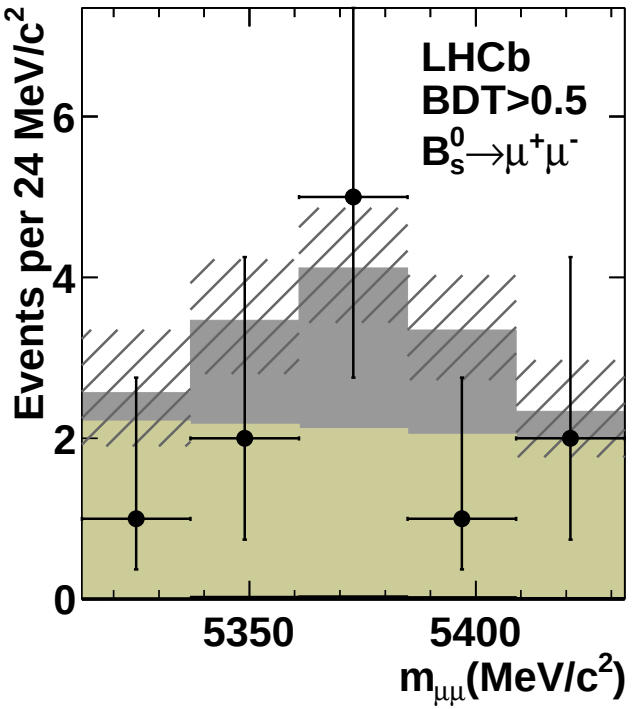
PRL 108, 231801 (2012)
LHCb-CONF-2012-017

- Theoretically well controlled decay
- Effective hammer to new physics models
- LHCb limit $< 4.5 \times 10^{-9}$ at 95% C.L. (expected $3.4/7.2 \times 10^{-9}$)
- LHC wide limit $< 4.2 \times 10^{-9}$ at 95% C.L.
- Getting close to SM prediction
- Feasible to get down to SM with this years data
- Once we see signal, normalization uncertainty becomes issue
- Input to measurement of f_s/f_d crucial



arXiv:1205.3099



$D^0 \to \mu^+\mu^-$

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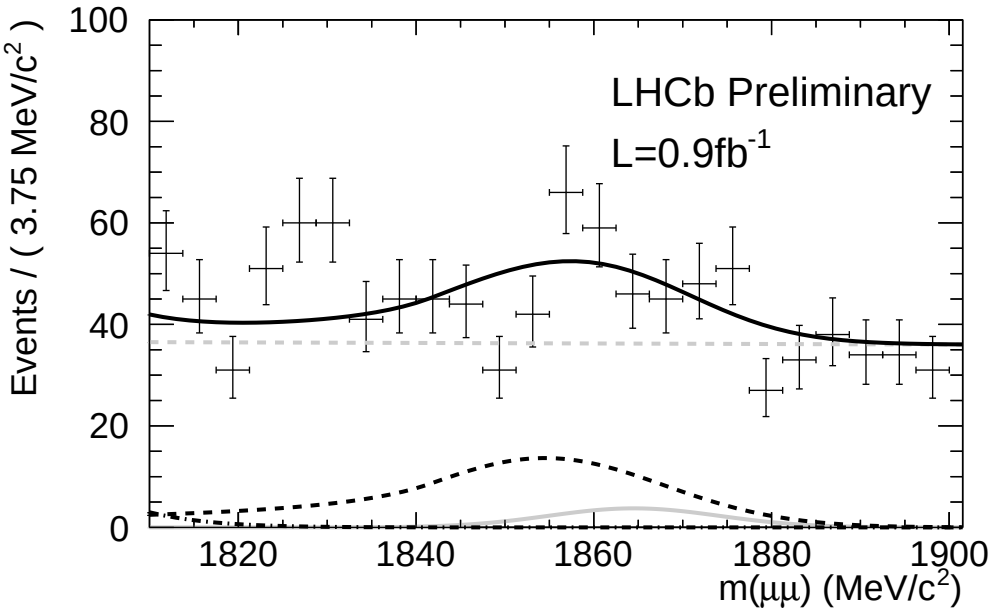
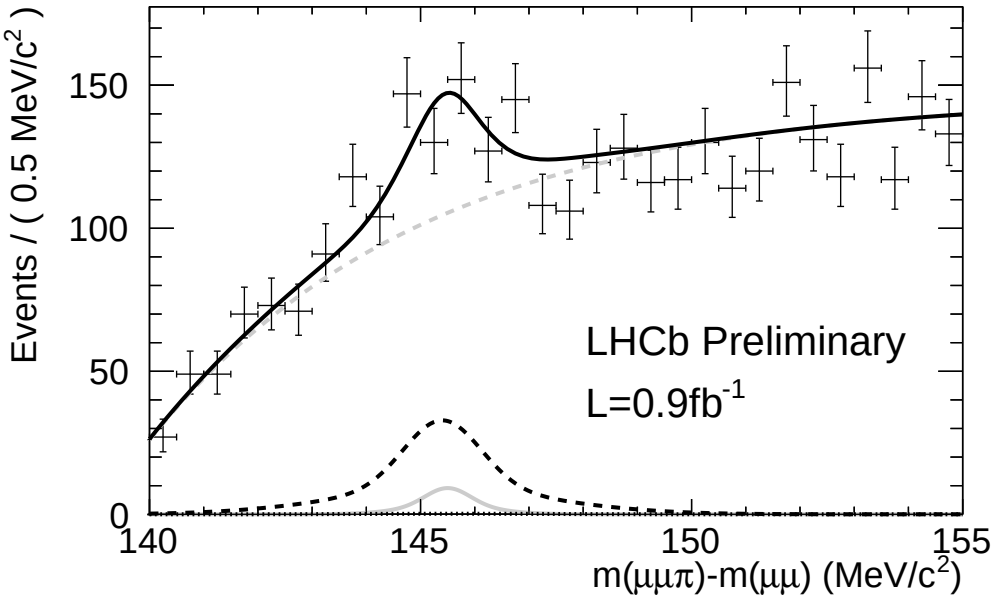
- Complement to B decays
- Testing down type quarks in loop

- GIM and CKM suppression gives strong suppression in SM
- Large enhancement possible in NP models
- Significant correlation to D^0 mixing in NP models
- Using D^{*+} tagged sample
- Upper limit 1.3×10^{-8} at 95% C.L.
- About order of magnitude better then Belle limit





LHCb-CONF-2012-005

Upgrade

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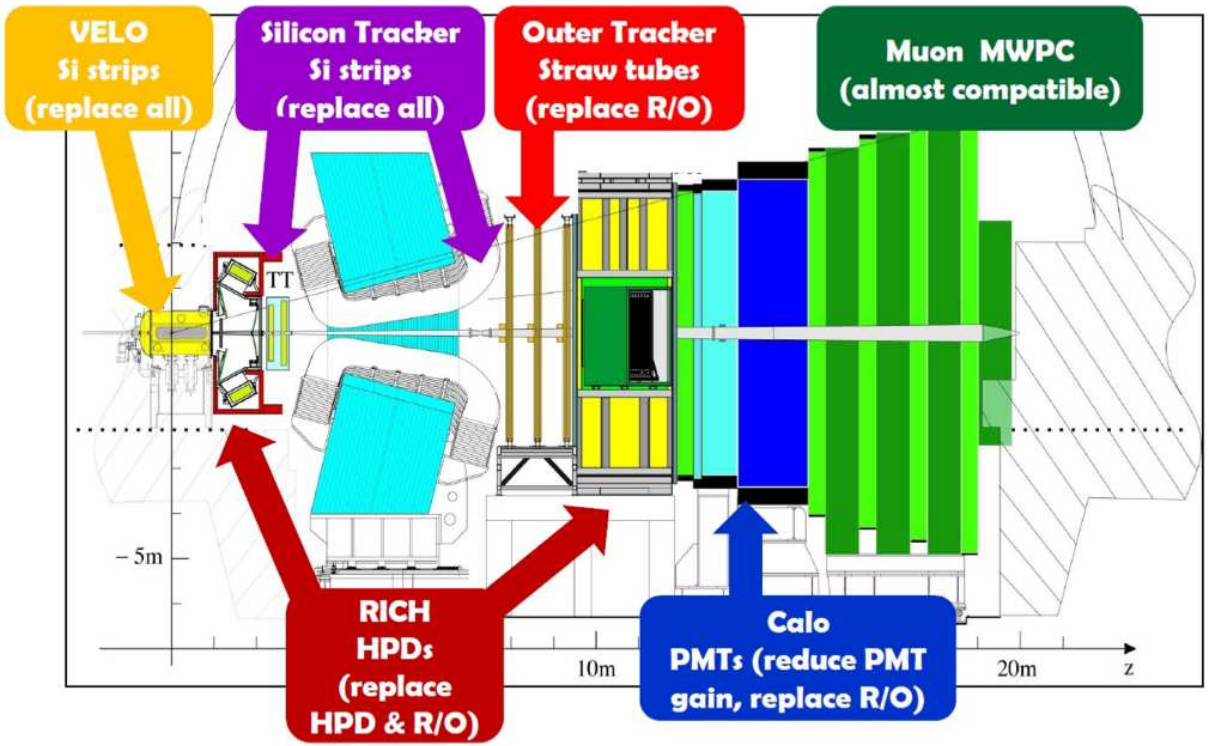
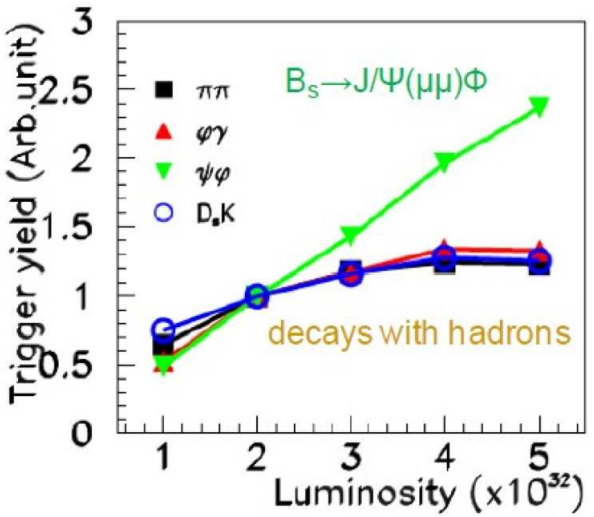
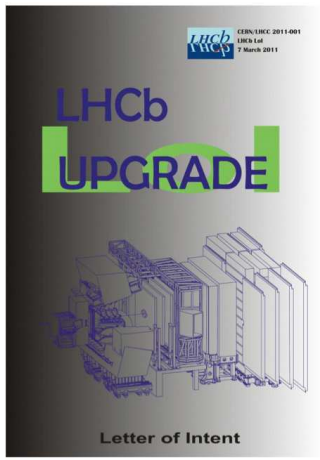
- Currently running at constant luminosity of 4×10^{32} cm^{2}s^1
- By 2018 we expect to have 5 fb^{-1}
- Current trigger limited by need to decrease rate to 1 MHz based on calorimeter and muon system
- Simple increase of luminosity does not help
- Upgrade for more flexible first stage trigger

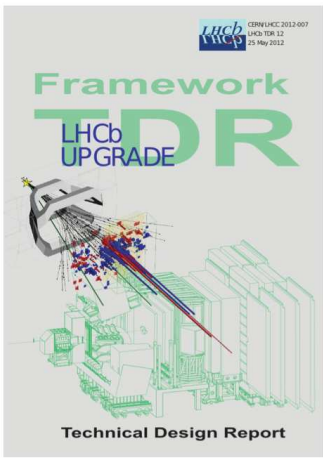


+ New front-end electronics and read-out network





CERN-LHCC-2011-001



CERN-LHCC-2012-007

Upgrade

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- Aim to collect 50 fb^{-1} at rate of 5 fb^{-1} per year
- Projections based on results on 2011 data
- Showing only statistical uncertainties in table (from Framework TDR)
- Expect to get close to the theoretical uncertainties

Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,\mathrm{fb}^{-1}$)	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\,\phi)$	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\,f_0(980))$	0.17 [10]	0.045	0.014	~ 0.01
	$A_{\mathrm{fs}}(B_s^0)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\mathrm{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\mathrm{eff}}(B^0 \to \phi K_S^0)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\mathrm{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\,A_{\mathrm{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_{\mathrm{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–12° [19, 20]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\,K_S^0)$	0.8° [18]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

Conclusions

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- LHCb is running very well
- Results shown today mostly use 1 fb^{-1}
- On track to increase statistics to 2.5 fb^{-1} by end of this year
- Already now putting significant constraints on new physics
- No major limitation from systematic effects foreseen in this decade
- 20 talks at ICHEP, many of them with brand new results