The LHCb Experiment: First Results and Prospects

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The University of Birmingham, 4th May 2011

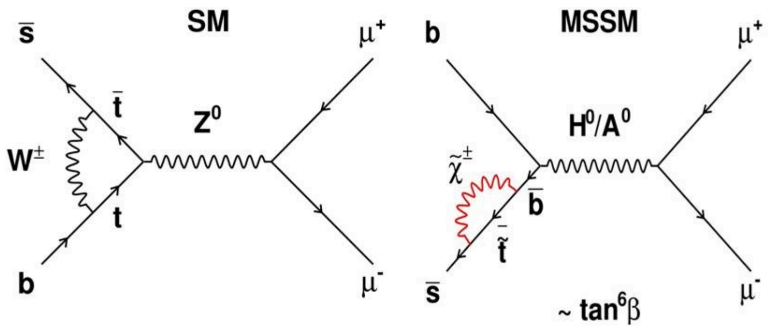
Outline

- An extended Higgs sector? ($B_d \rightarrow \mu^+\mu^-$ and $B_s \rightarrow \mu^+\mu^-$)
- New CP violating phases in B_s mixing? (ϕ_s from $B_s \rightarrow J/\psi\phi$)
- New particles, couplings? (angular observables in $B_d \rightarrow K^*\mu\mu$)
- A whistlestop tour…
- Will try and give you a feel for the prospects in each of these areas
  - Results from 2010 data ~36 pb^{-1}
  - As of yesterday, ~80 pb^{-1} on tape, expectation is ~200 pb^{-1} for summer conferences, ~1 fb^{-1} by the end of the year

The decays
$B_d \rightarrow \mu^+\mu^-$ and $B_s \rightarrow \mu^+\mu^-$

Introduction

- The branching ratios of the decays $B_d \to \mu^+\mu^-$ and $B_s \to \mu^+\mu^-$ allow the parameters of an extended Higgs sector to be probed



- The decays are doubly suppressed in the SM
  - FCNC
  - Helicity suppression

  However, rates well calculable – in the SM,

  $B(B_s \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$ **$B(B_d \to \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$**

  [*Buras et al., arXiv:1007.5291*]

- Sensitive to NP contributions in the scalar/pseudo-scalar sector:

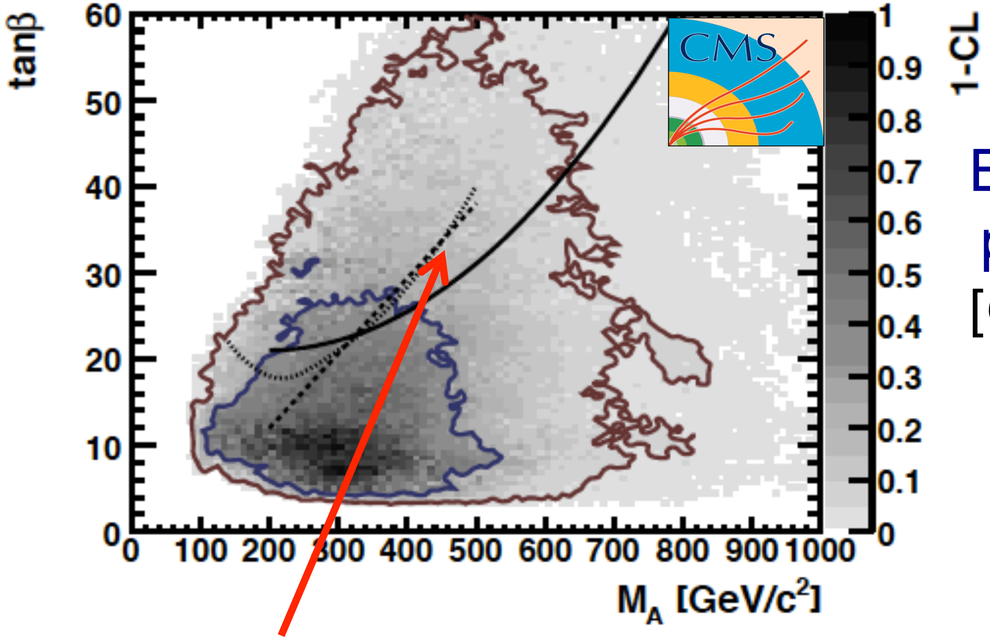
$$\left(c_{S,P}^{MSSM} \right)^2 \propto \left(\frac{m_b m_\mu \tan^3\beta}{M_A^2} \right)^2$$

MSSM, large tanβ approximation

Motivation

- “fully complementary to direct searches at ATLAS/CMS”

tanβ vs M_A plane



Best fit contours in tanβ vs M_A plane in the NUHM1 model
[*O. Buchmuller et al., arxiv:0907.5568*]

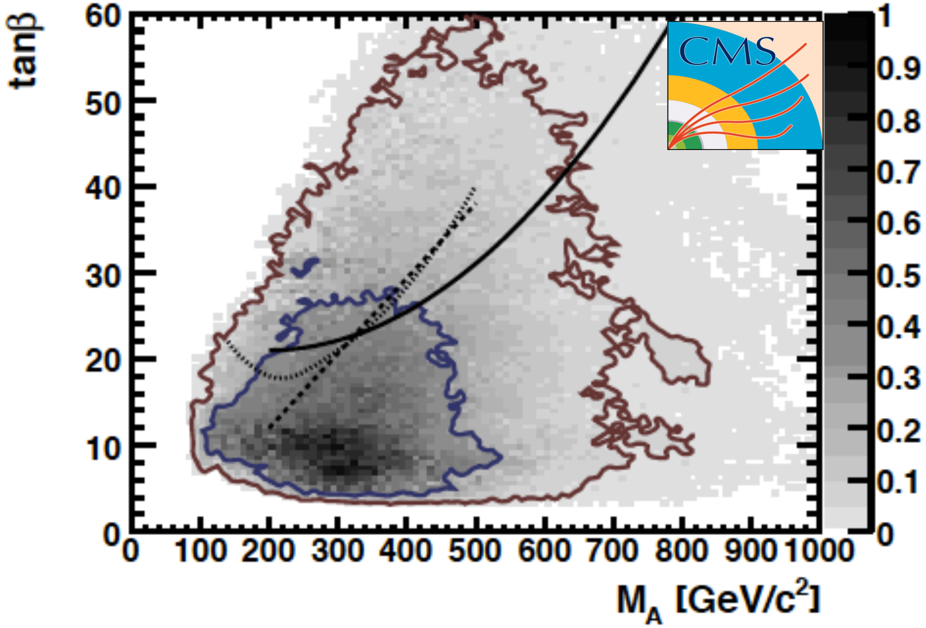
5σ discovery contours for observing the **heavy MSSM Higgs bosons H, A** in the three decay channels **H,A→$\tau^+\tau^-$ → jets (solid line), jet+μ (dashed line)**, **jet+e (dotted line) assuming 30-60 fb^{-1} collected by CMS**

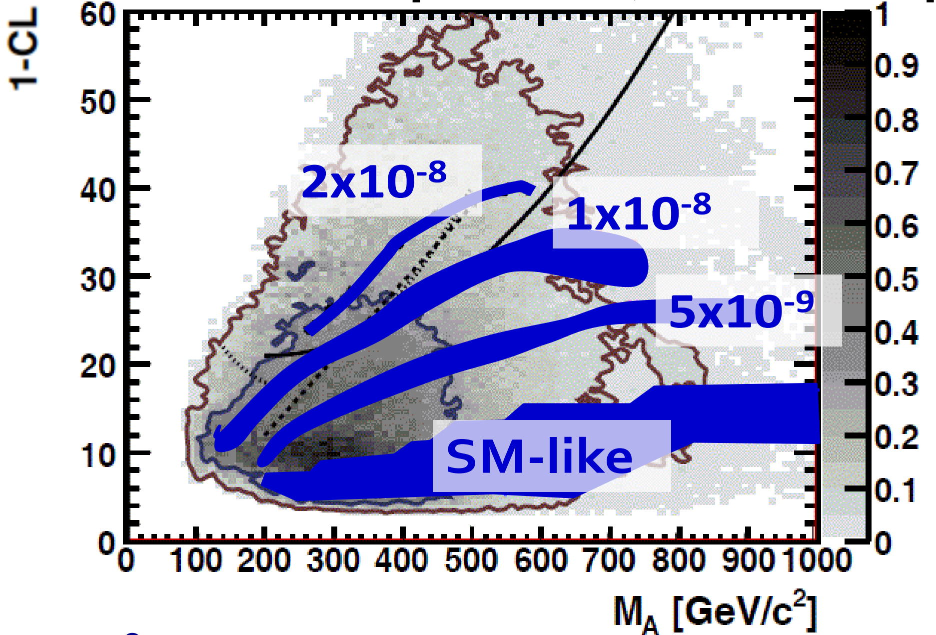
Motivation

- “fully complementary to direct searches at ATLAS/CMS”

tanβ vs M_A plane

[*F. Mahmoudi, arXiv: 08083144*]

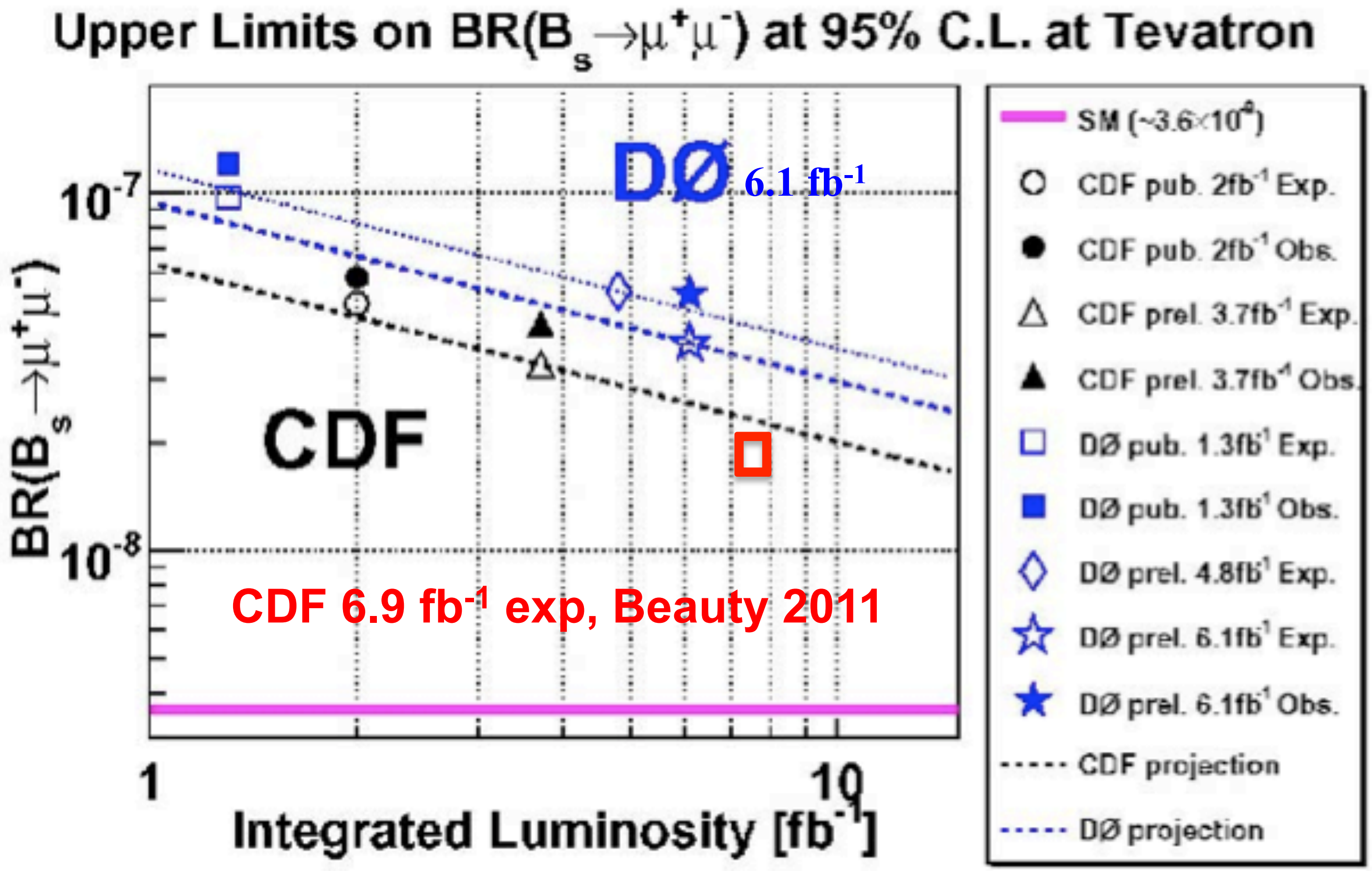




→ Measuring BR**($B_s \to \mu^+\mu^-$)** at the **1×10^{-8}** level would be like probing similar region to that of **H,A→$\tau^+\tau^-$** search with **30-60 fb^{-1}**

- Believe this is possible with 2011 data, O(1fb^{-1})

Current Experimental Results

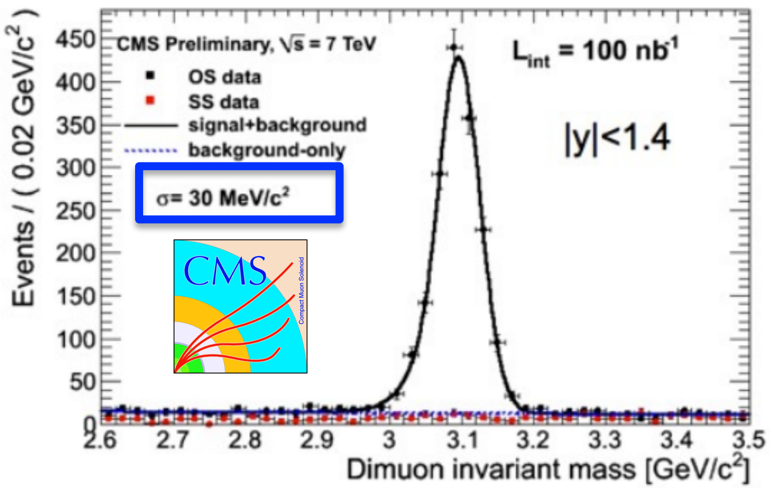


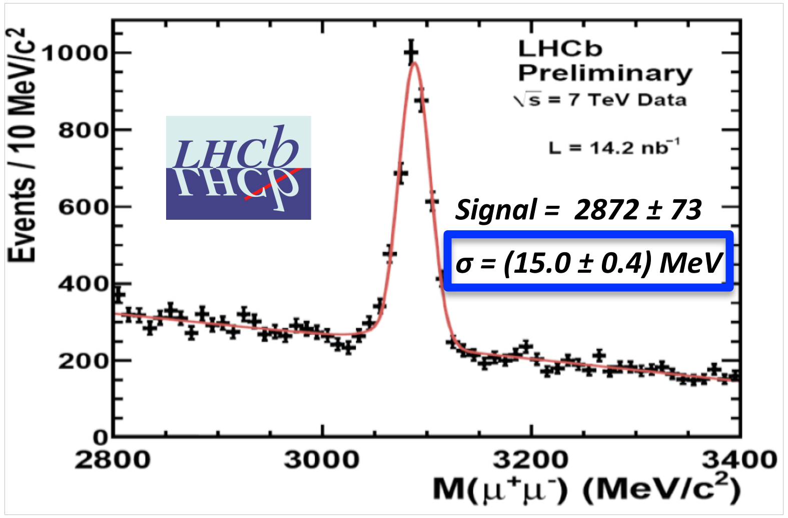
- Limits from Tevatron @ 95% CL:
  - CDF (~3.7 fb^{-1}): **$B_s(B_d) \to \mu^+\mu^-$ < 43 (7.6) ×10^{-9}**
  - D0 (~6.1 fb^{-1}): **$B_s \to \mu^+\mu^-$ < 51×10^{-9}**

Key ingredients for $B_{s,d} \to \mu^+\mu^-$

- Efficient trigger:
  - to identify leptonic final states

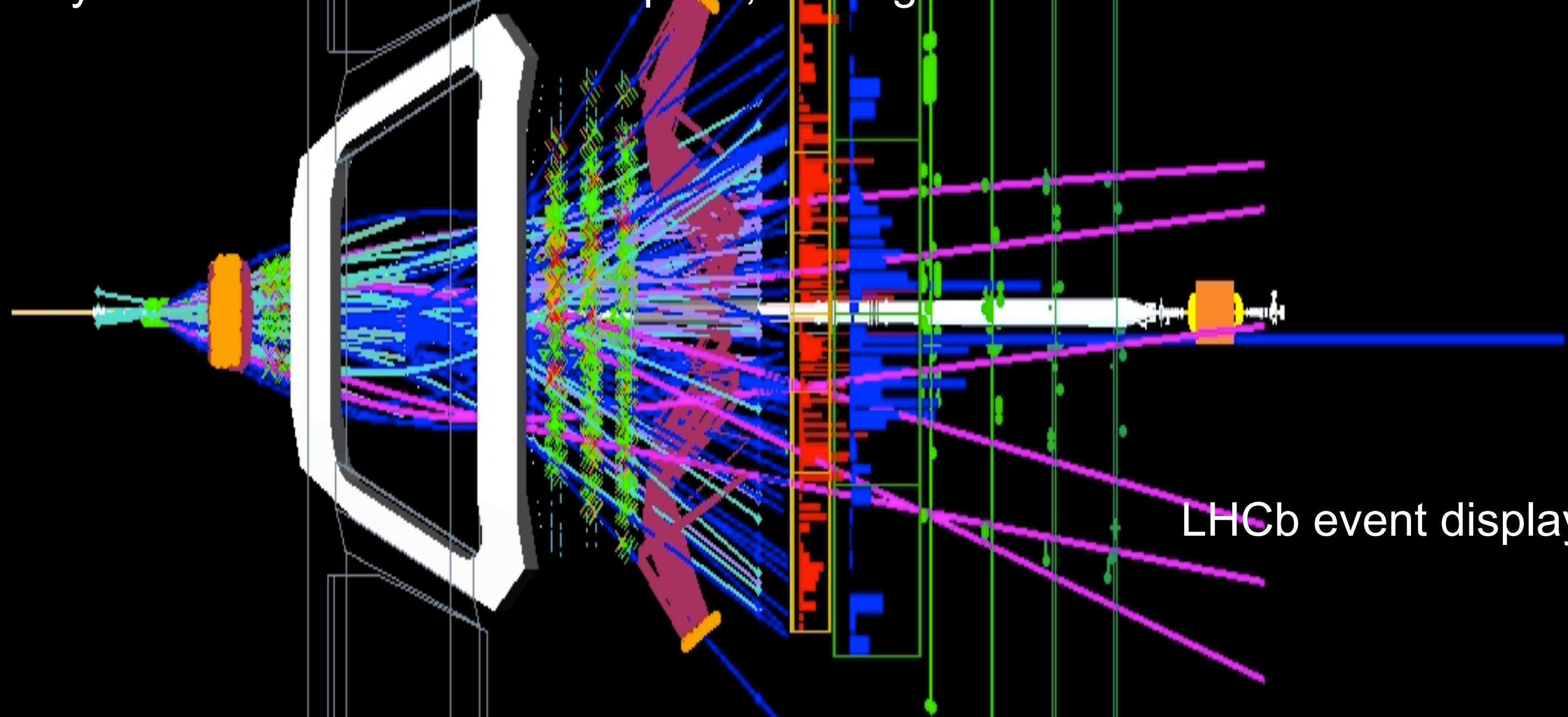
- Background reduction:
  - Excellent vertex & IP resolution: σ(IP) ~25 μm @ p_T=2 GeV/c
  - Particle identification: ε(μ→μ) ~97% for ε(h→μ)<1% for p>10 GeV/c
  - Very good mass resolution: δp/p~ 0.35%→0.55% for p=(5-100) GeV/c





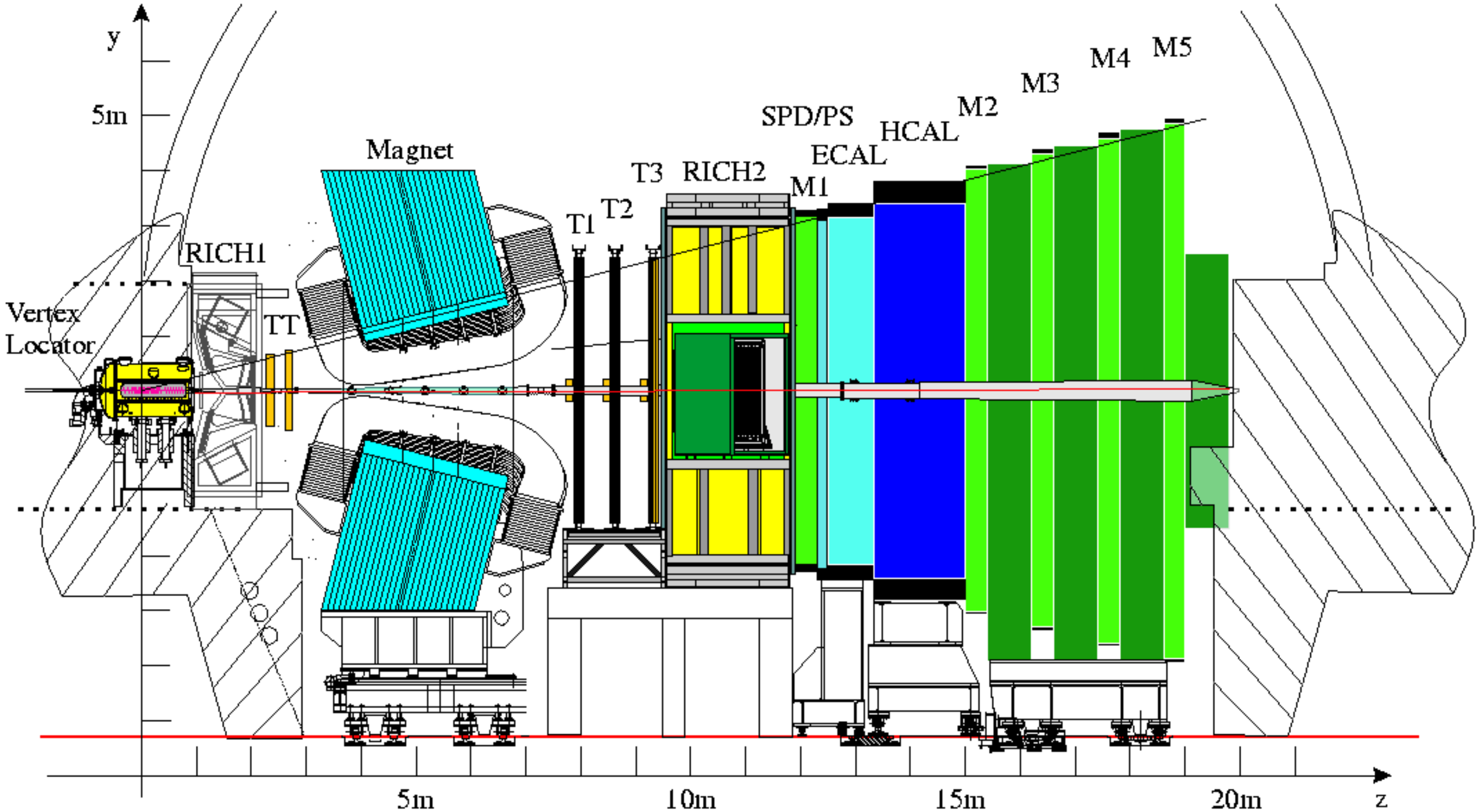
In a harsh environment

- $\sigma(pp, \text{inelastic})$ @ $\sqrt{s}$=7 TeV ~ 60 mb
  - 80 tracks per event in 'high'-pile-up conditions (~2.5 pp interactions crossing)
  - only 1/200 event contains a b quark, looking for BR ~ 10^{-9}

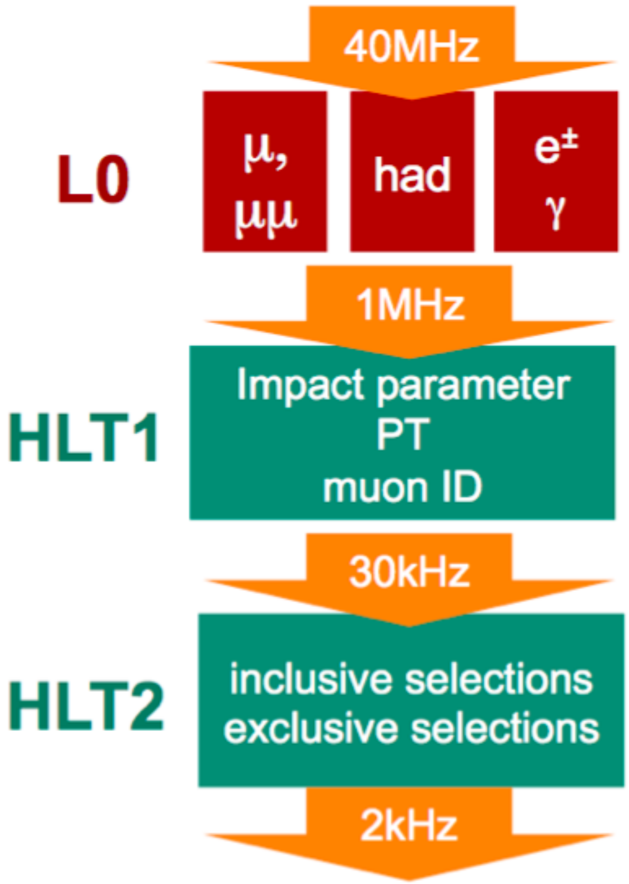


Expect 0.7 (0.08) $B_s(B_d) \rightarrow \mu^+\mu^-$ events triggered and reconstructed in 37 pb^{-1} if BR = BR(SM) – is all about the background

The LHCb Detector



Trigger for $B_{s,d} \to \mu^+\mu^-$



	Muon Lines
L0	Single-μ: **p_T> 1.4 GeV/c** μμ: **p_{T1}>0.48 GeV/c** **p_{T2}>0.56 GeV/c**
HLT1	single-μ: p_T>0.8 GeV/c IP>0.11 mm IPS> 5
HLT2	Several di-muon lines with $M_{\mu\mu}$ cuts and/or displaced vertex

+ Global Event Cuts for events with high multiplicity

- Half of the available 2 kHz bandwidth is given to the muon lines
- p_T cuts on muons kept low → ε(trigger $B_{s,d} \to \mu^+\mu^-$) ~ 90%

Analysis Strategy

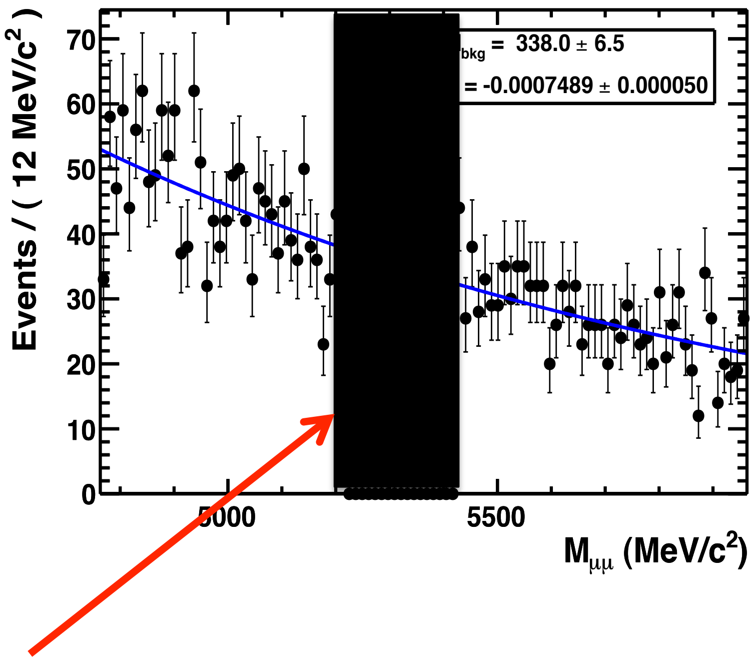
- Soft selection:
  - Reduces the dataset to a manageable level
- Discrimination between S and B via MultiVariate Discriminant variable (GL) and Invariant Mass (IM)
  - Events in the sensitive region are classified in bins of the 2D plane Invariant Mass-GL
- Normalisation:
  - Convert the signal PDFs into a number of expected signal events by normalising to (several) channels of known BR
- Extraction of the limit:
  - Assign to each observed event a probability to be S+B or B-only as a function of the BR($B_{s,d} \to \mu^+\mu^-$) value; exclude (observe) the assumed BR value at a given confidence level using the **CLs binned method**

Soft Selection

- Isolate pairs of opposite charged muons with high quality tracks, which make a common vertex, displaced with respect to the primary proton-proton vertex (PV), with $M_{\mu\mu}$ in the range 4769-5969 MeV/c^2

- Keeps high efficiency for signal events

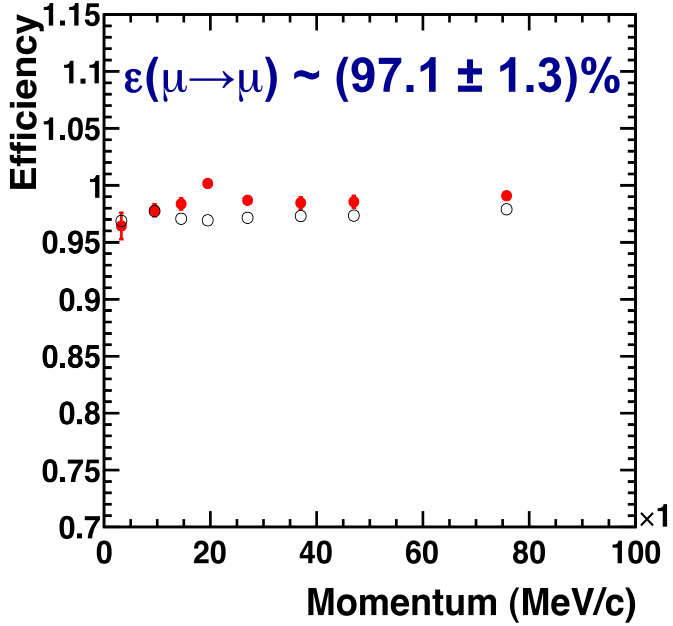
- Rejects the majority of bkgrd events
  - ~ 3000 background events in the large mass range 4769-5969 MeV/c^2
  - ~ 300 background events in the signal windows $m(B_{s,d})$ ± 60 MeV/c^2

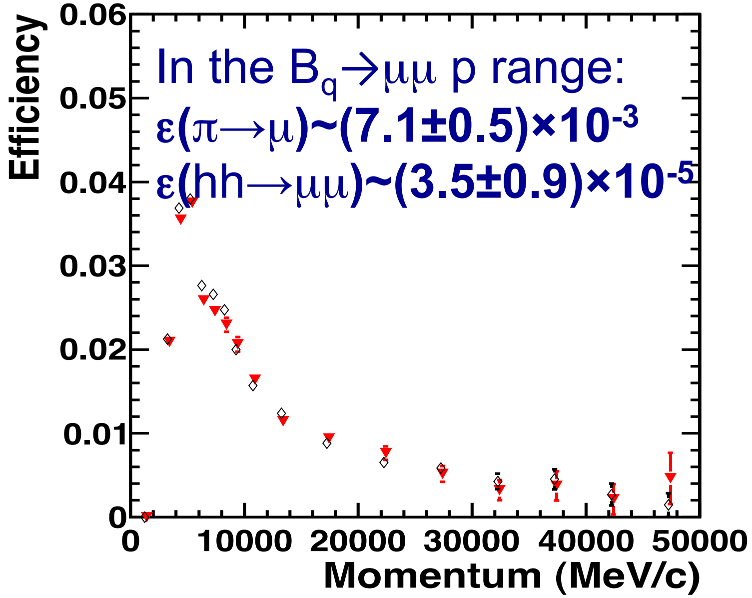


Signal regions blinded until analysis frozen

μ–ID performance & bkgrd composition

- μ–ID performance measured with samples of $J/\psi \rightarrow \mu\mu$, $K_s \rightarrow \pi\pi$, $\phi \rightarrow KK$, $\Lambda \rightarrow p\pi$



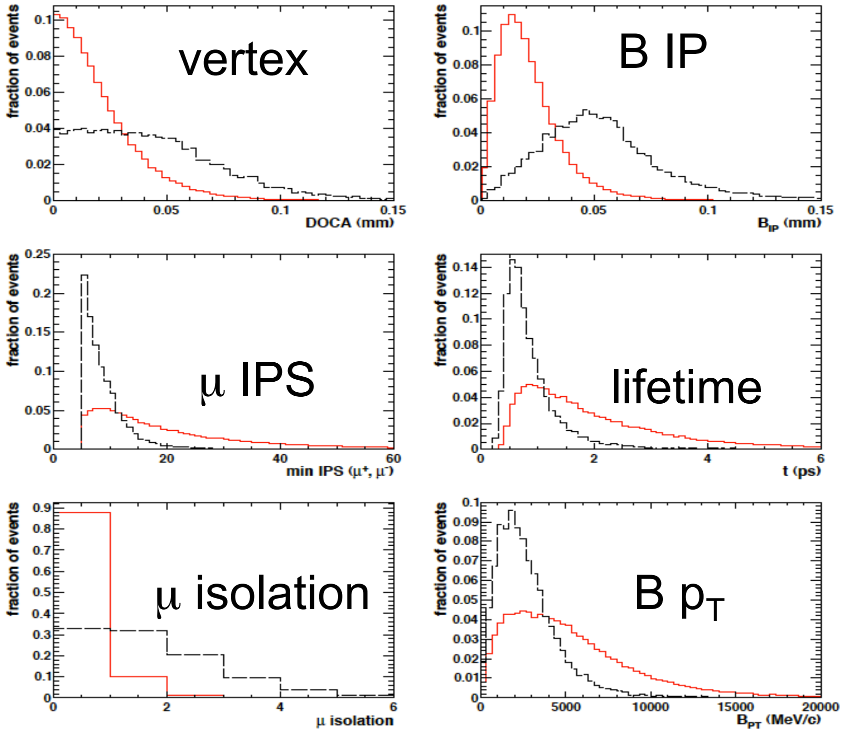


- Background is dominated by $bb \rightarrow \mu\mu X$ component i.e. double semi-leptonic decays and cascade processes
  - Mis-id μ + genuine μ ~10% and double mis-id μ ~0.3%
  - Peaking bkgrd from $B \rightarrow hh'$ negligible, expect <0.1 evts in signal region

MVA: Geometrical Likelihood

- Main bkgrd is combinatorial, with two genuine muons
- Reduce by using variables related to the event geometry
  - vertex, pointing, μ IPS, lifetime, mu-isolation, B p_T
- Variables are decorrelated and and the geometric likelihood (GL) built :
  - → flat for signal
  - → peaked at zero for bkgrd

Input Variables to the GL



- **MC $B_{d,s} \to \mu\mu$**
- **MC $bb \to \mu\mu X$**

MVA: Geometrical Likelihood

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  - vertex, pointing, μ IPS, lifetime, mu-isolation, B p_T
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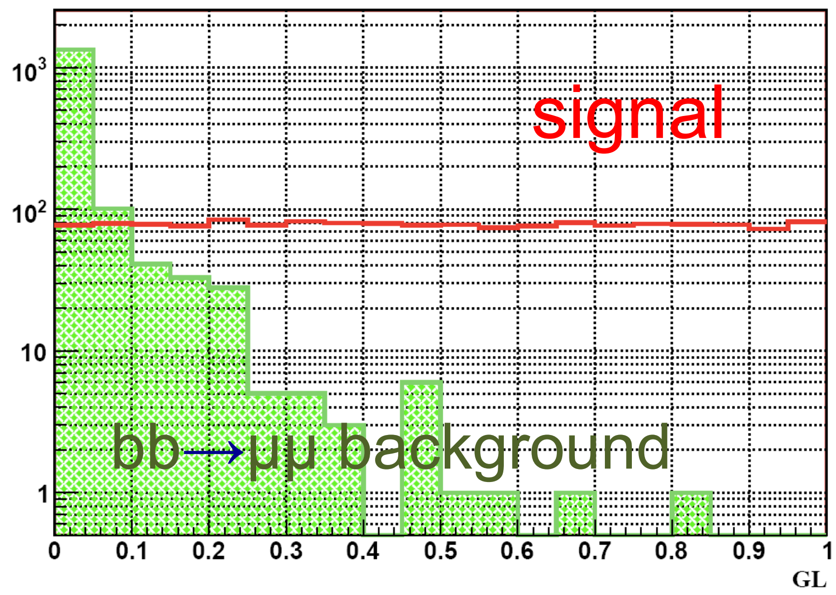
  → flat for signal

  → peaked at zero for bkgrd

Geometrical Likelihood (MC)

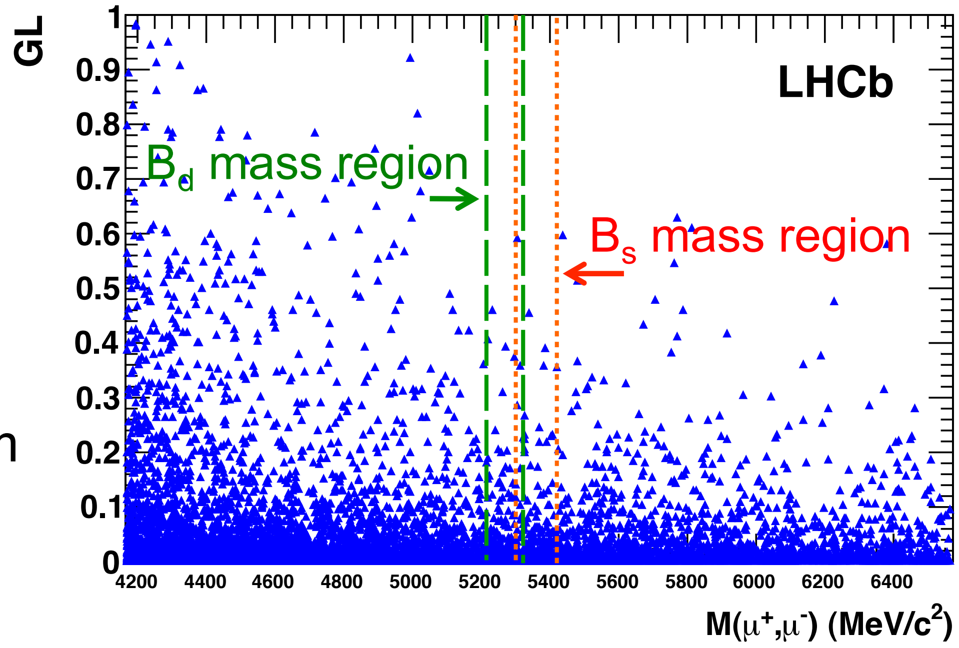


Measuring the BR

- Use the CL_s binned method
  - For each bin in the GL vs mass plane, the compatibility of the observed number of events with,
    - S+B [CL_{S+B}]
    - B only [CL_B]

    hypotheses is computed
- Get expected background from mass sidebands (in bins GL)
- For expected signal need mass and GL PDFs and an absolute normalisation

Geometrical Likelihood vs Mass



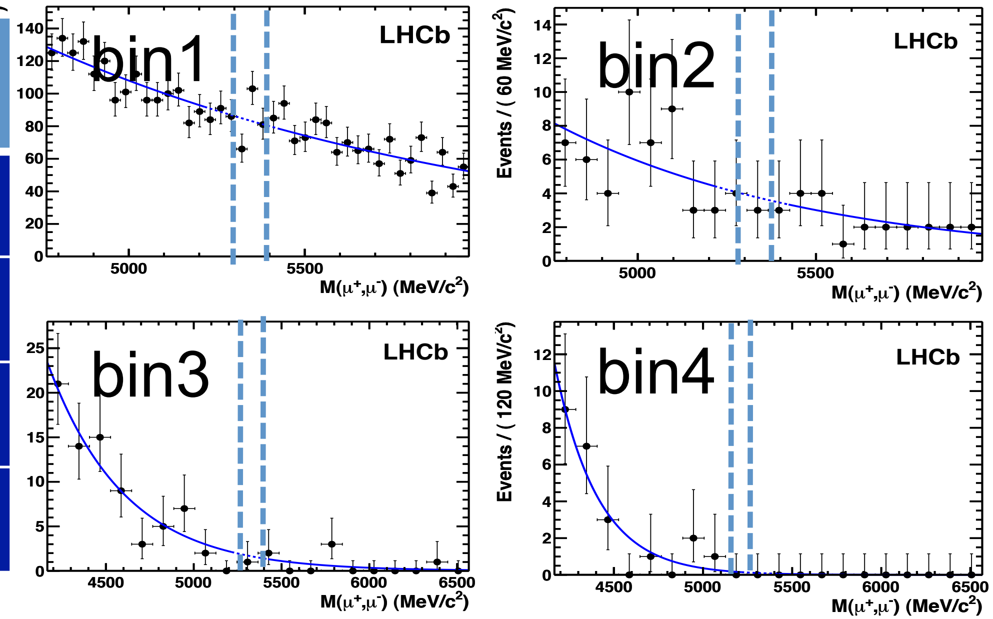
Expected Bkgrd in Signal Regions

- The expected background events in the signal plane is extracted from a fit of the mass sidebands divided into the appropriate GL bins

Expected (observed) background events in $B_{s,d}$ mass regions

GL bin	$B_s \to \mu\mu$	$B_d \to \mu\mu$
bin1	329.1±6.4 (335)	351.6±6.6 (333)
bin2	7.4 ± 1 (7)	$8.3^{+1.1}_{-1.0}$ (8)
bin3	$1.51^{+0.41}_{-0.35}$ (1)	$1.85^{+0.45}_{-0.39}$ (1)
bin4	$0.08^{+0.10}_{-0.05}$ (0)	$0.13^{+0.13}_{-0.07}$ (0)

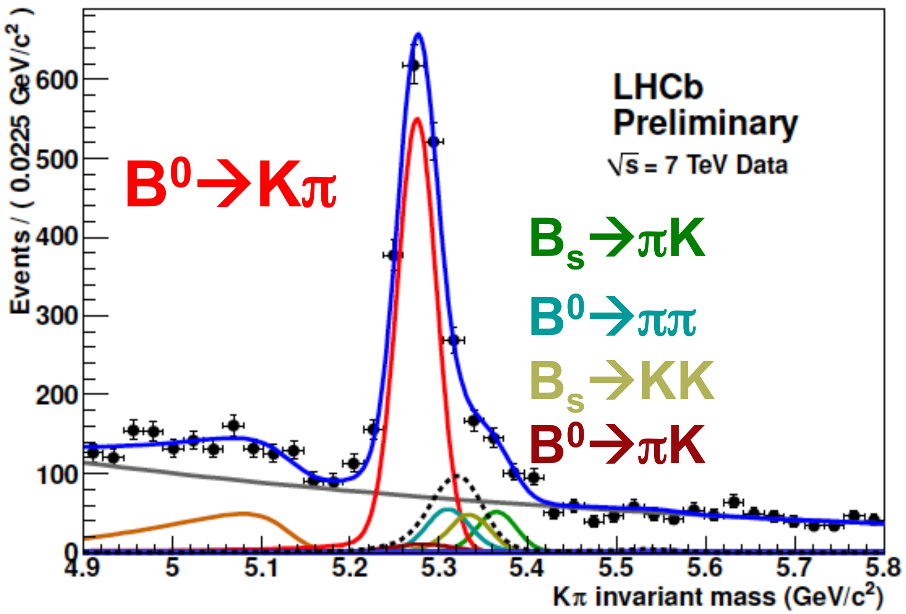
Invariant mass in GL bins

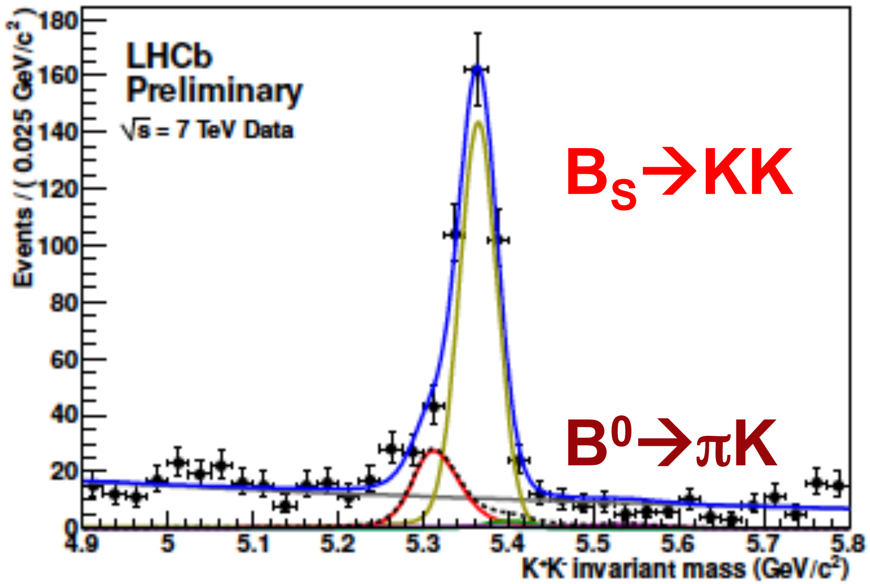


Signal Invariant Mass Calibration

- The $B_{s,d}$ mass line shapes are described by Crystal Ball function
- Parameters (μ,σ) calibrated with B→hh' and di-muon resonances
  - B→hh' has similar kinematics/topology, select w/o PID→ same seln
  - Interpolate from ϒ(1S), ϒ(2S), ϒ(3S) to B mass

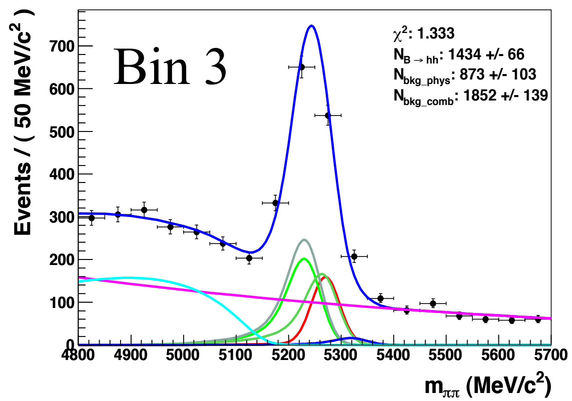
→ $\sigma(M) = 26.7 \pm 0.9$ MeV/c^2

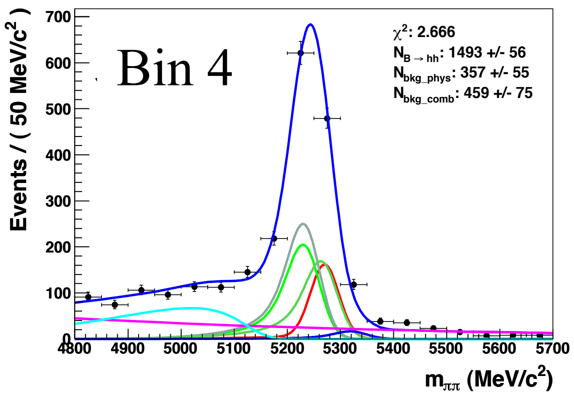




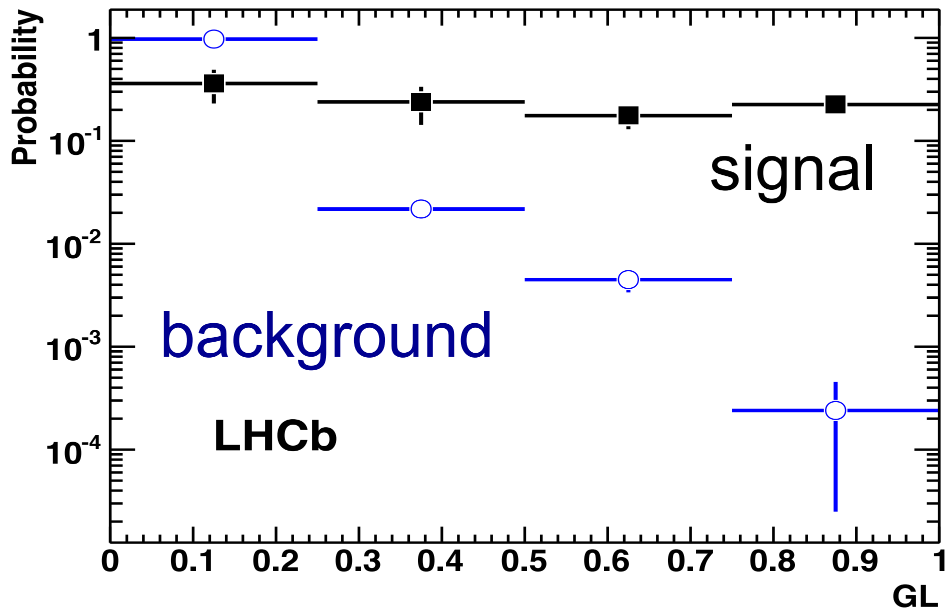
Geometrical Likelihood calibration

- B→hh' sample is also used to calibrate the GL





The GL signal shape is given by the fractional yield of B→hh' in each GL bin



- GL shape for signal extracted from B→hh' is flat as expected
- Systematic error dominated by the fit model

Normalisation

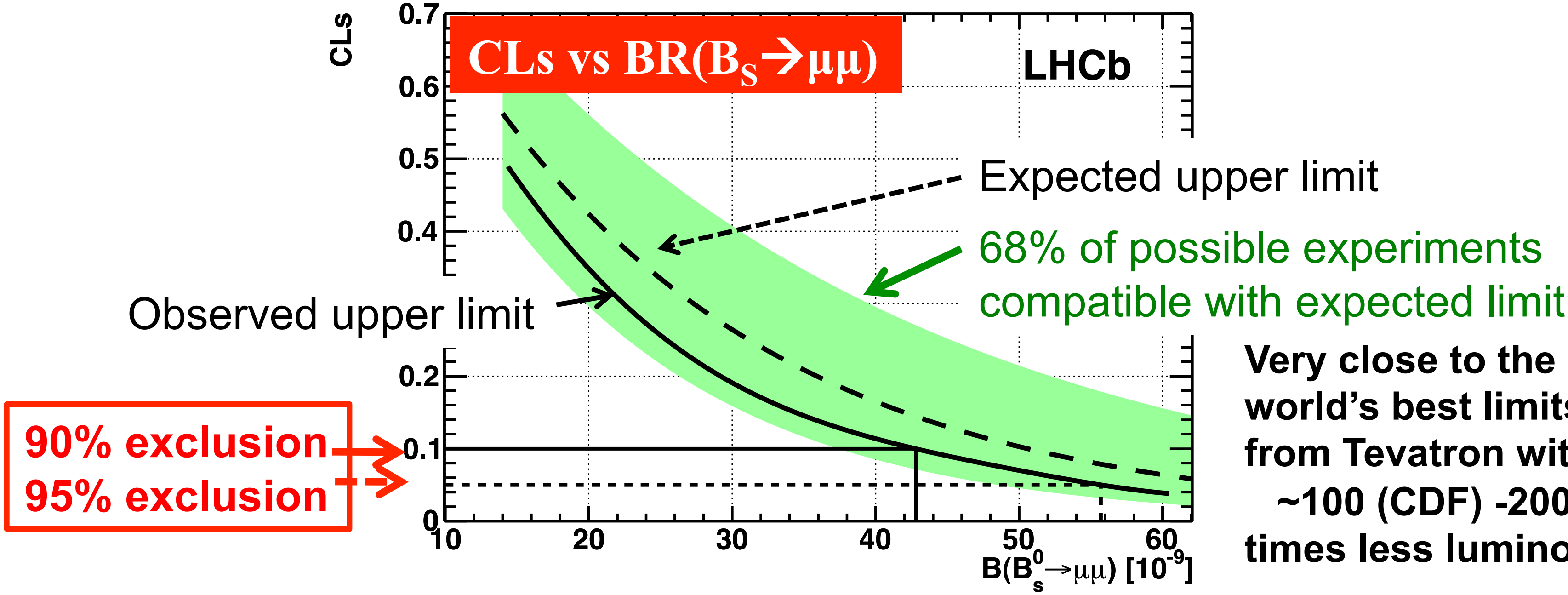
- The signal PDFs can be translated into a number of expected signal events by normalising to a channel with known BR

- Three different channels used:
  - **1) BR($B^+ \to J/\psi(\mu^+\mu^-) K^+$) = $(5.98 \pm 0.22)\times 10^{-5}$ 3.7% uncertainty**
    - Similar trigger and PID. Tracking efficiency (+1 track) dominates the systematic in the ratio of efficiencies. Needs f_d/f_s as input (13% uncertainty)
  - **2) BR($B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$) = $(3.35 \pm 0.9)\times 10^{-5}$ 26% uncertainty**
    - Similar trigger and PID. Tracking efficiency (+2 tracks) dominates the syst.
  - **3) BR($B^0 \to K^+\pi^-$) = $(1.94 \pm 0.06)\times 10^{-5}$ 3.1% uncertainty**
    - Same topology as the signal. Different trigger dominates the syst. Needs f_d/f_s

- All three normalisation channels give compatible results:

→ Weighted avge accounting for correlated systematic uncertainties

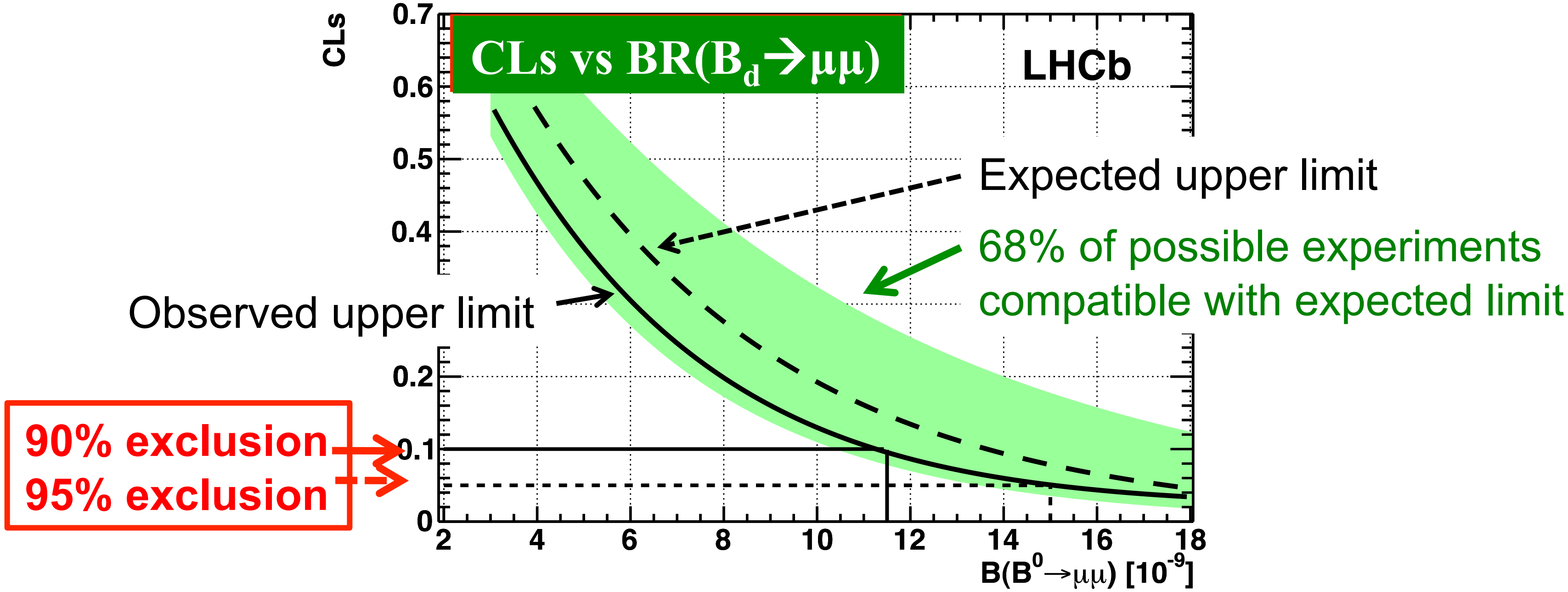
Results : $B_s \rightarrow \mu^+\mu^-$



Very close to the best world's best limits from Tevatron with ~100 (CDF) -200 (D0) times less luminosity

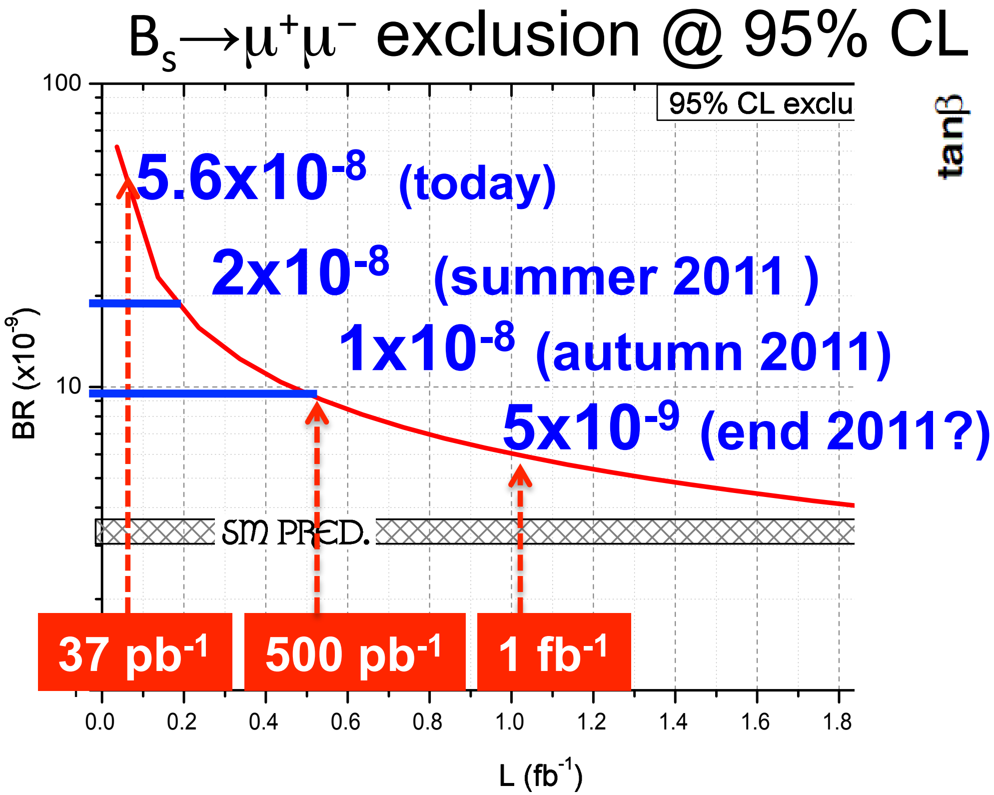
		@ 90% CL	@ 95% CL
LHCb	Observed (expected), **37 pb^{-1}**	**< 43 (51) $\times 10^{-9}$**	**< 56 (65) $\times 10^{-9}$**
D0	World best published, **6.1 fb^{-1}** PLB 693 539 (2010)	**< 42 $\times 10^{-9}$**	**< 51 $\times 10^{-9}$**
CDF	Preliminary, **3.7 fb^{-1}** Note 9892	**< 36 $\times 10^{-9}$**	**< 43 $\times 10^{-9}$**

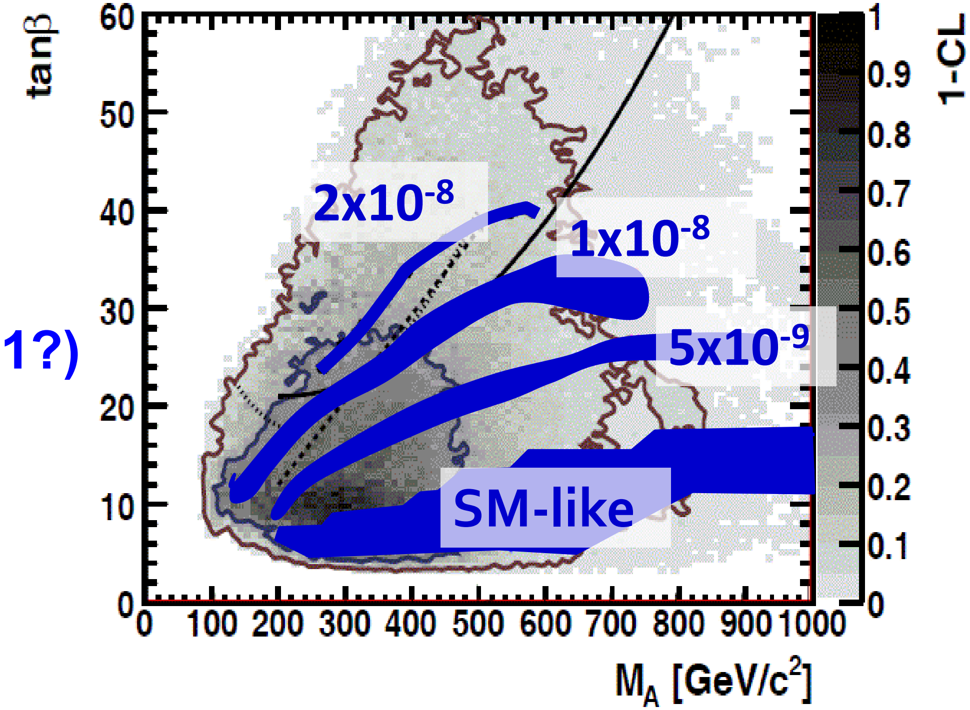
Results : $B_d \rightarrow \mu^+\mu^-$



		@ 90% CL	@ 95% CL
LHCb	Observed (expected), **37 pb^{-1}**	**< 12 (14) x10^{-9}**	**< 15 (18) x10^{-9}**
CDF	World best, **2 fb^{-1}** PRL 100 101802 (2008)	**< 15 x10^{-9}**	**< 18 x10^{-9}**
CDF	Preliminary, **3.7 fb^{-1}** Note 9892	**< 7.6 x10^{-9}**	**< 9.1 x 10^{-9}**

$B_s \to \mu^+\mu^-$: reach in 2011



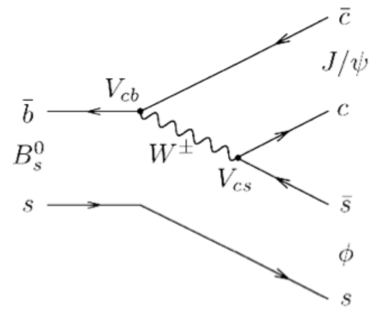


- With the data collected in 2011 we should be able to explore BR~ 10^{-8} and below

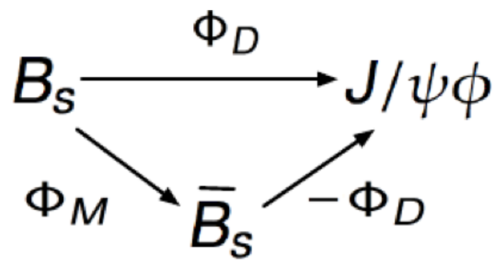
The CPV Phase ϕ_s

$B_s \to J/\psi\phi$ – Introduction

- $B_s \to J/\psi\phi$ decay dominated by $b \to c\bar{c}s$ transition
  - small penguin contribution, δP

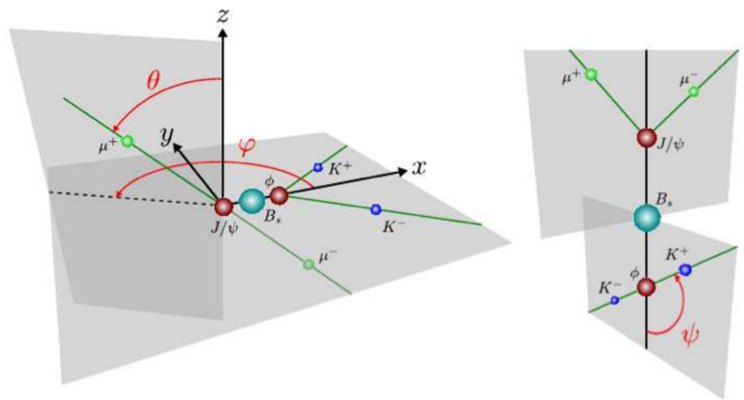


- Interference between *decay* or *mixing and then decay* results in CP violating phase:
  - $\phi_S = \phi_M - 2\phi_D$



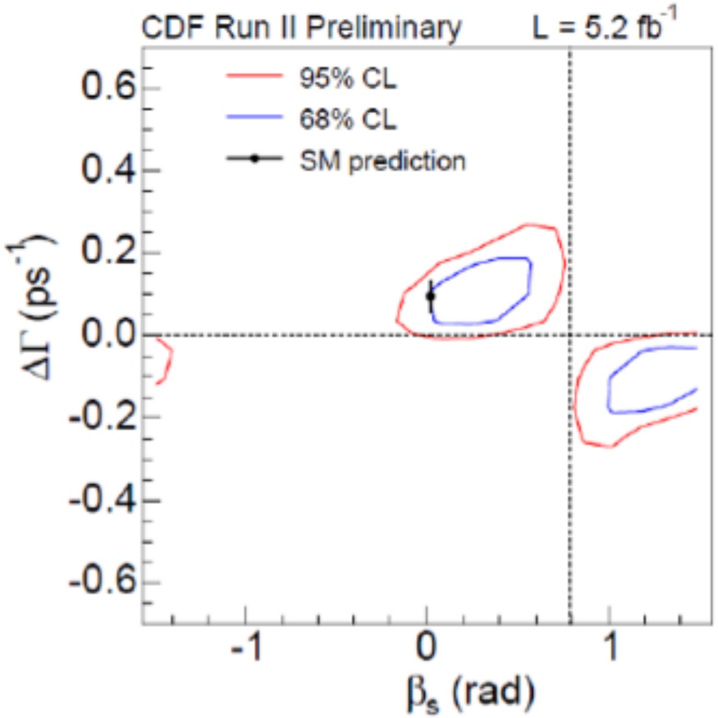
- SM prediction:
  - $\phi_S = -2\beta_s + \delta P \sim -2\beta_s \quad = 0.04$

- $J/\psi\phi$ is not a CP eigenstate
  → required angular analysis (in transversity base) to statistically separate CP-even/odd

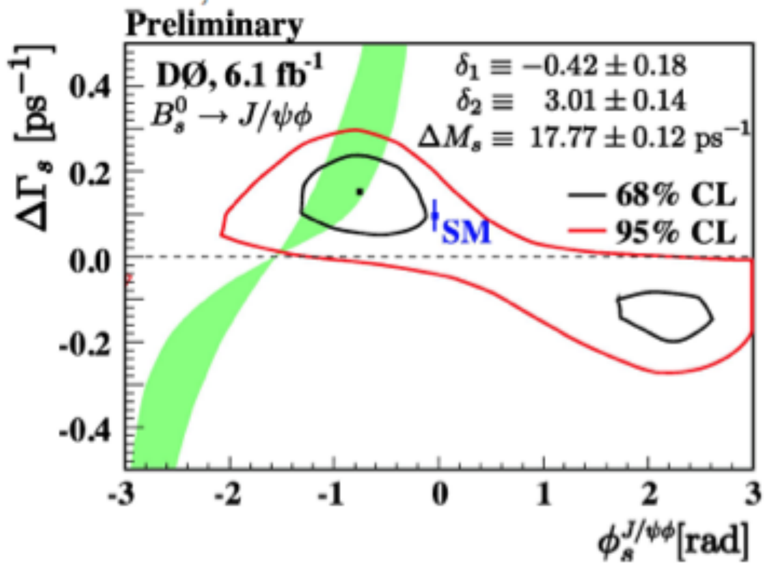


Experimental Status

CDF, FPCP'2010



DØ, ICHEP'2010



	Signal yield (lumi)	$\phi_s^{J/\psi\phi}$ (rad)	Ref.
CDF	6 500 (5.2 pb^{-1})	$-0.54 \pm 0.50^{(*)}$	CDF Note 10206
DØ	3 400 (6.1 fb^{-1})	$-0.76^{+0.38}_{-0.36}$(stat) $\pm$ 0.02(syst)	DØ 6098-CONF

(*) CDF quotes $\beta_s \in [0.02, 0.52] \cup [1.08, 1.55]$ rad at 68%CL. "-0.54 ± 0.50" is my estimate.

Principle of the measurement

- P→VV, ang. mom. → in the B rest frame J/ψ and φ have l=0,1,2
- CP|J/ψφ > = $(-1)^l$ |J/ψφ > → mixture CP-even (l=0,2), CP-odd (l=1)
- Decay ampl. in terms of linear polarization when J/ψ and φ are:
  - $A_\perp$ transversely polarised and ⊥ to each other (CP-odd)
  - $A_{//}$ transversely polarised and // to each other (CP-even)
  - A_0 longitudinally polarised (CP-even)
  - Three angles Ω=(θ, φ, ψ) describe directions of the J/ψ and φ

Signal event distribution:

Flavor tagging

time resolution

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

acceptance $\quad$ B_s $\quad$ $\overline{B}_s$

Physics parameters: $\lambda = (\Gamma_s, \Delta\Gamma_s, |A_0|^2, |A_\perp|^2, \delta_\parallel, \delta_\perp, \phi_s, \Delta m_s)$

$\Delta m_s = 17.77 \pm 0.12\,\mathrm{ps}^{-1}$ (constraint)

Road towards ϕ_S at LHCb

- Select signal and control channels
  - Determine lifetimes for: $B_s \to J/\psi\phi$, $B_d \to J/\psi K^*$, $B_d \to J/\psi K_S$, $\Lambda_b \to J/\psi\Lambda$

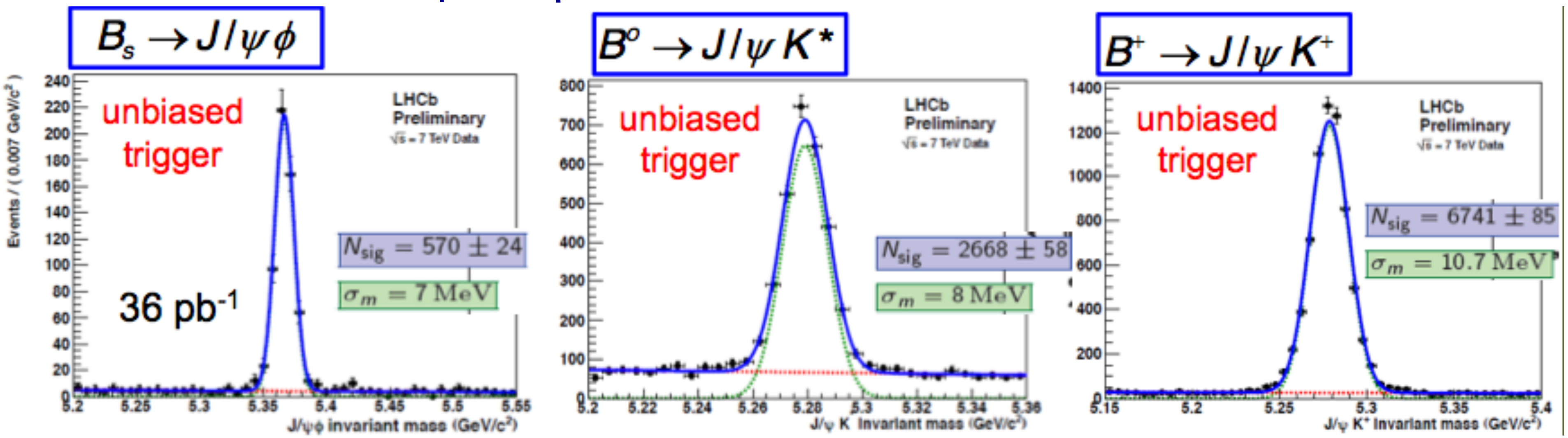
- Angular analysis and determination of $\Delta\Gamma_s$
  - Angular analysis of $B_d \to J/\psi K^*$
  - Untagged angular analysis of $B_s \to J/\psi\phi$

- Determination of B production flavour
  - Determination of B_s mixing frequency Δm_s

- Determination of ϕ_S
  - Tagged analysis of $B_s \to J/\psi\phi$ decays

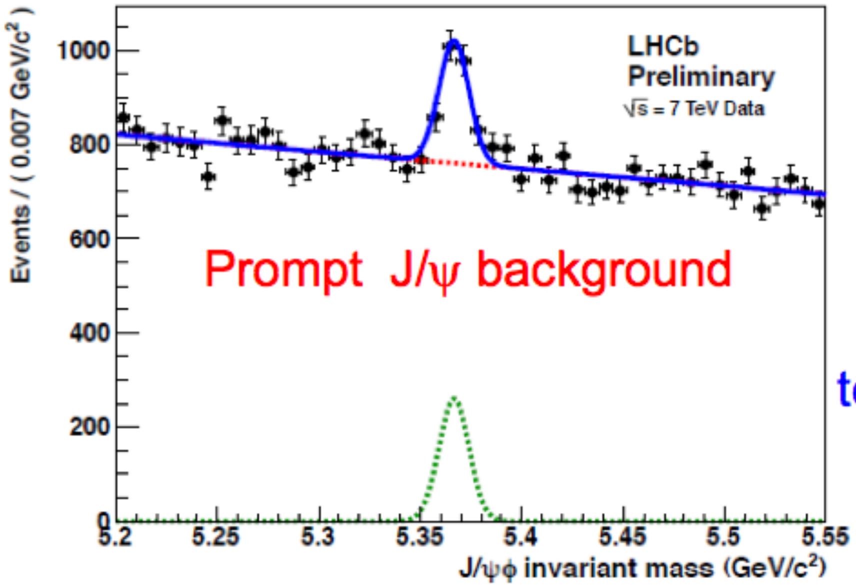
Selecting signal & control channels

- Similar selection for all channels : $B_s \to J/\psi\phi$, $B^+ \to J/\psi K^+$, $B_d \to J/\psi K^*$, $B_d \to J/\psi K_S$, $\Lambda_b \to J/\psi\Lambda$ → Cross-check and systematics
- No lifetime biasing cuts (IP, decay length…) → significant prompt background at small proper time
- Plots with t>0.3ps, J/ψ mass constrained:



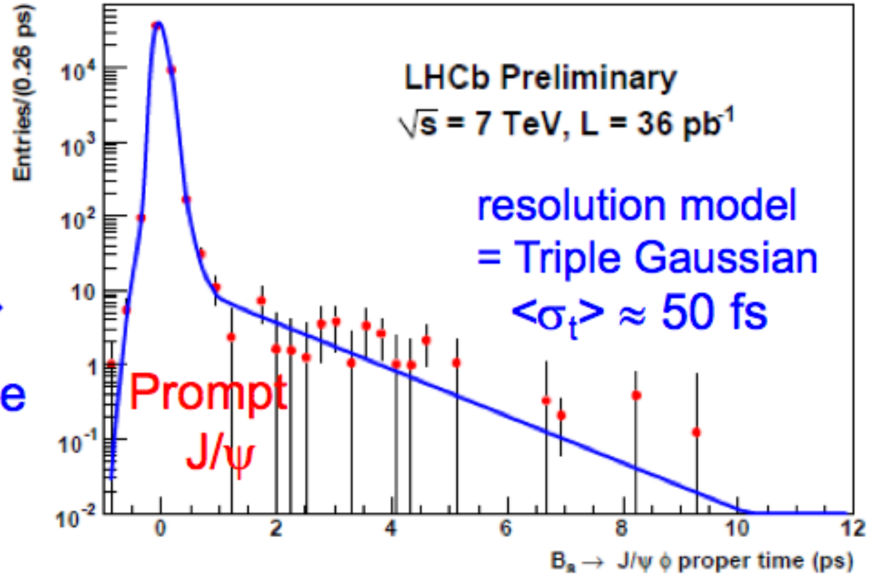
→ Excellent mass resolution and low background

t resolution and t acceptance



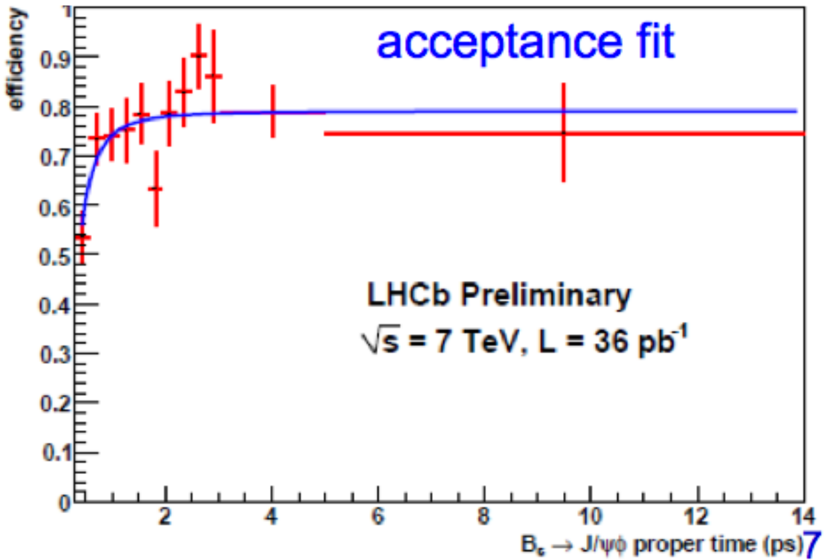
sPlot

technique

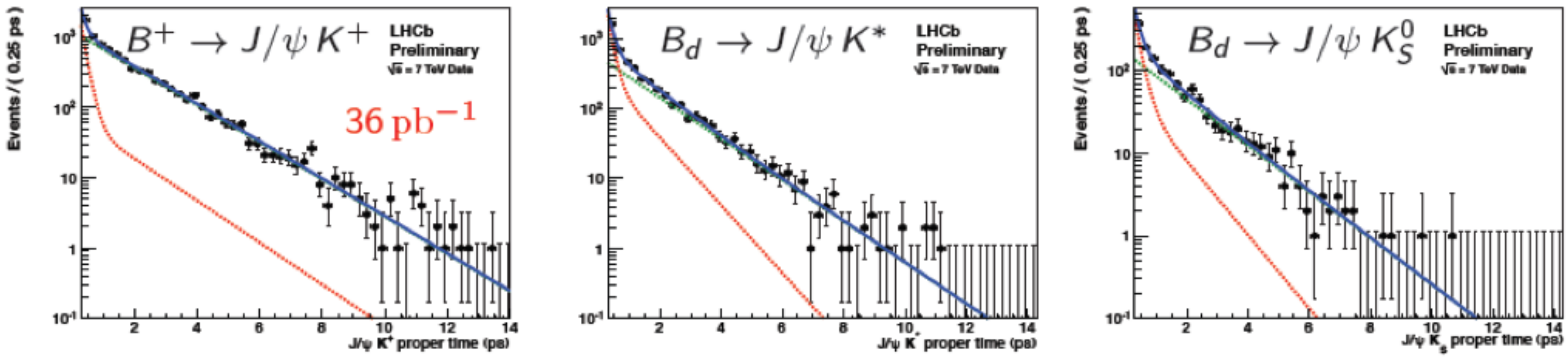


- Prompt J/ψ separated from background using s-plot technique, use to extract proper time resolution

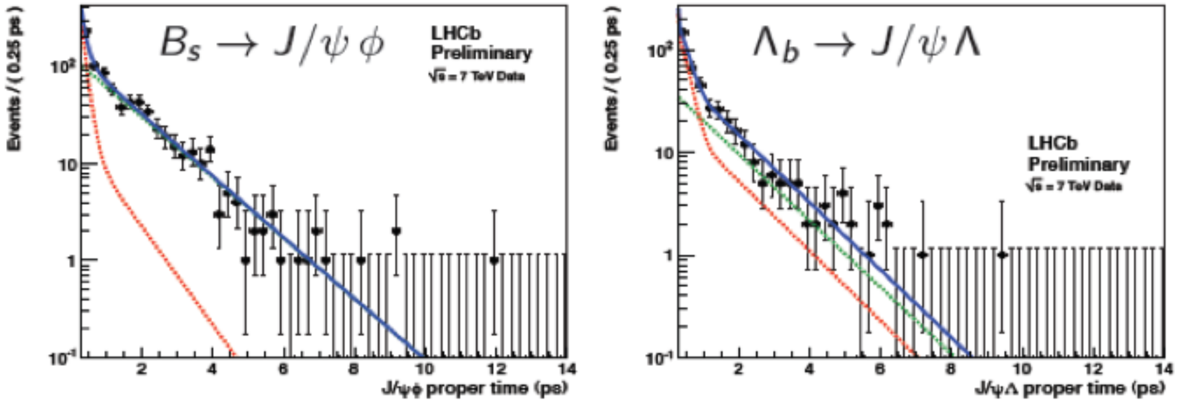
- Proper time acceptance also computed from data by using ratio between events selected with and without proper time bias



Lifetime measurements



fit with single exponential



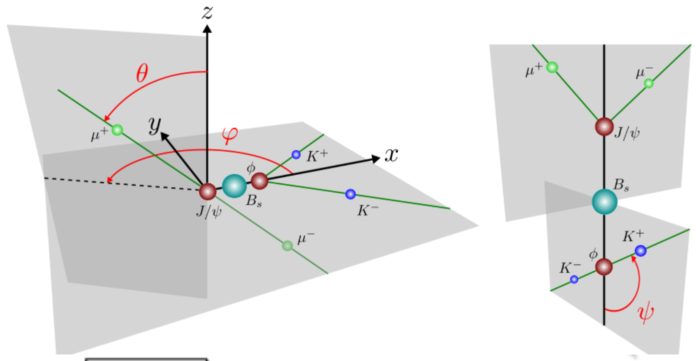
Unbiased trigger only

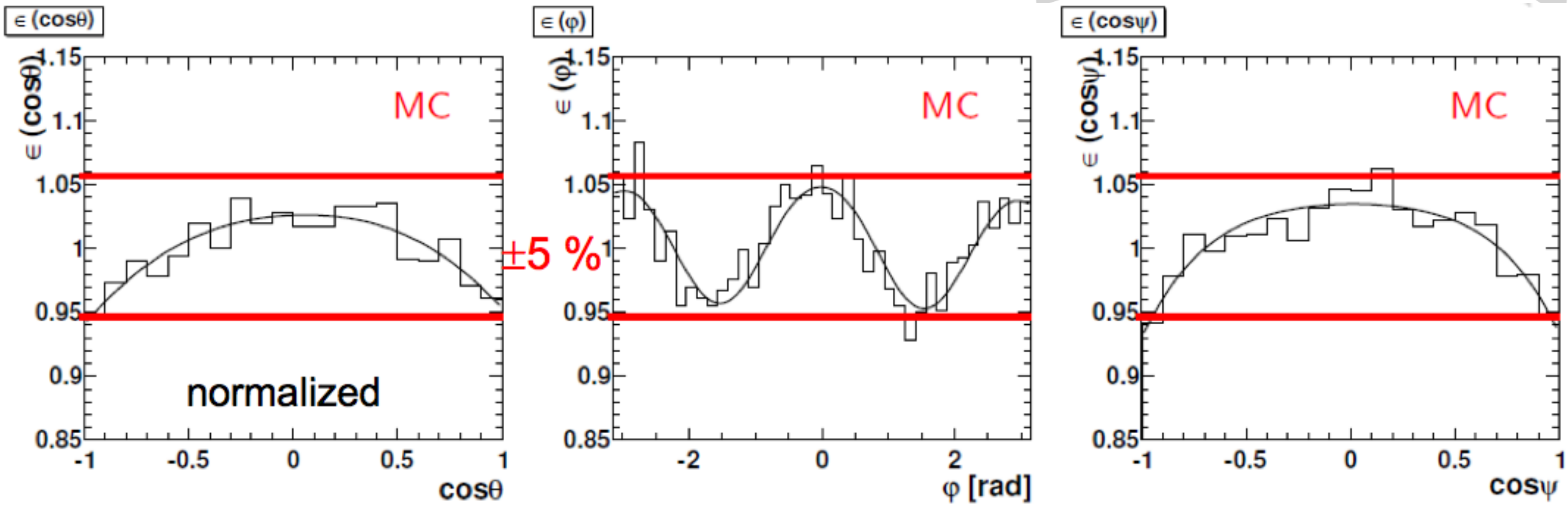
Decay channel	Yield	LHCb result τ[ps]*	PDG τ[ps]
$B^+ \to J/\psi K^+$	6741 ± 85	$1.689 \pm 0.022_{stat.} \pm 0.047_{syst.}$	1.638 ± 0.011
$B^0 \to J/\psi K^{*0}$	2668 ± 58	$1.512 \pm 0.032_{stat.} \pm 0.042_{syst.}$	1.5252 ± 0.009
$B^0 \to J/\psi K^0_S$	838 ± 31	$1.558 \pm 0.056_{stat.} \pm 0.022_{syst.}$	1.525 ± 0.009
$B^0_s \to J/\psi \phi$	570 ± 24	$1.447 \pm 0.064_{stat.} \pm 0.056_{syst.}$	1.477 ± 0.046
$\Lambda_b \to J/\psi \Lambda$	187 ± 16	$1.353 \pm 0.108_{stat.} \pm 0.035_{syst.}$	$1.391^{+0.038}_{-0.037}$

Systematics currently dominated by proper time acceptance uncertainty.

Angular Analysis & Acceptance Corrections

- Angular analysis in transversity basis:
  - Acceptance correction for reconstruction and selection
  - 3-dim. correction obtained from full simulation

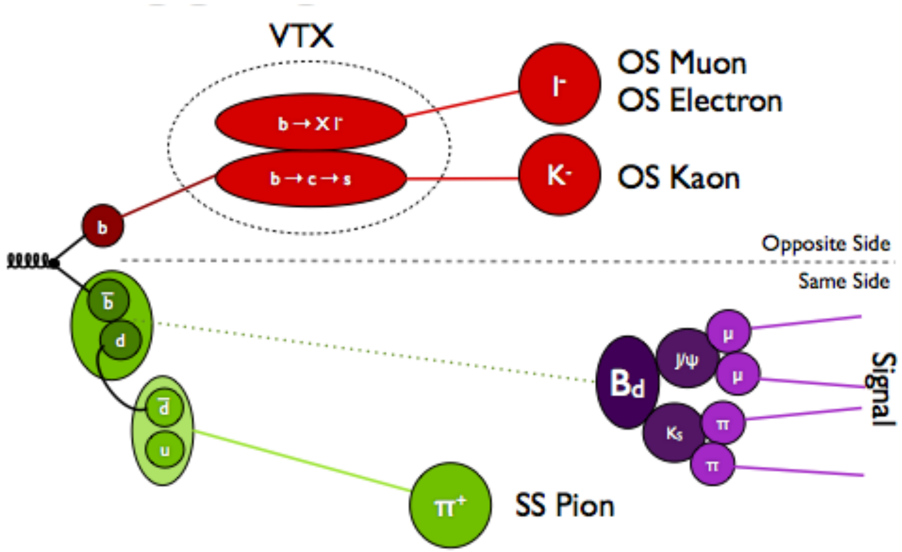




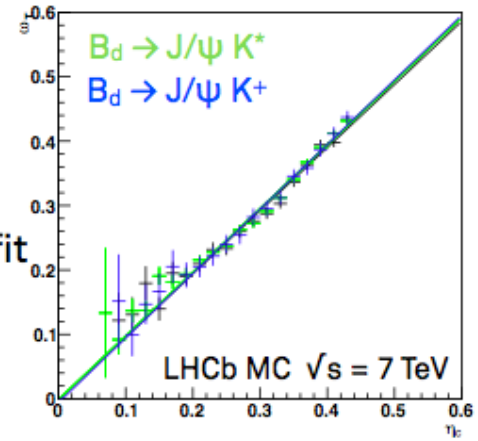
- Cross-check of complete procedure using another P→VV decay $B^0 \to J/\psi K^*(K\pi)$

Flavour Tagging

- Use neural nets, trained on MC, to extract tagging decision and mis-tag probability, η
- Calibrate on self-tagging decay modes such at $B^+ \rightarrow J/\psi K^+$
- Using only OS taggers, tagging power $\varepsilon D^2 = 2.2 \pm 0.5\%$



difference between predicted η and measured ω mistag probability on MC and fit of linear calibration function



B_s mixing frequency Δm_s

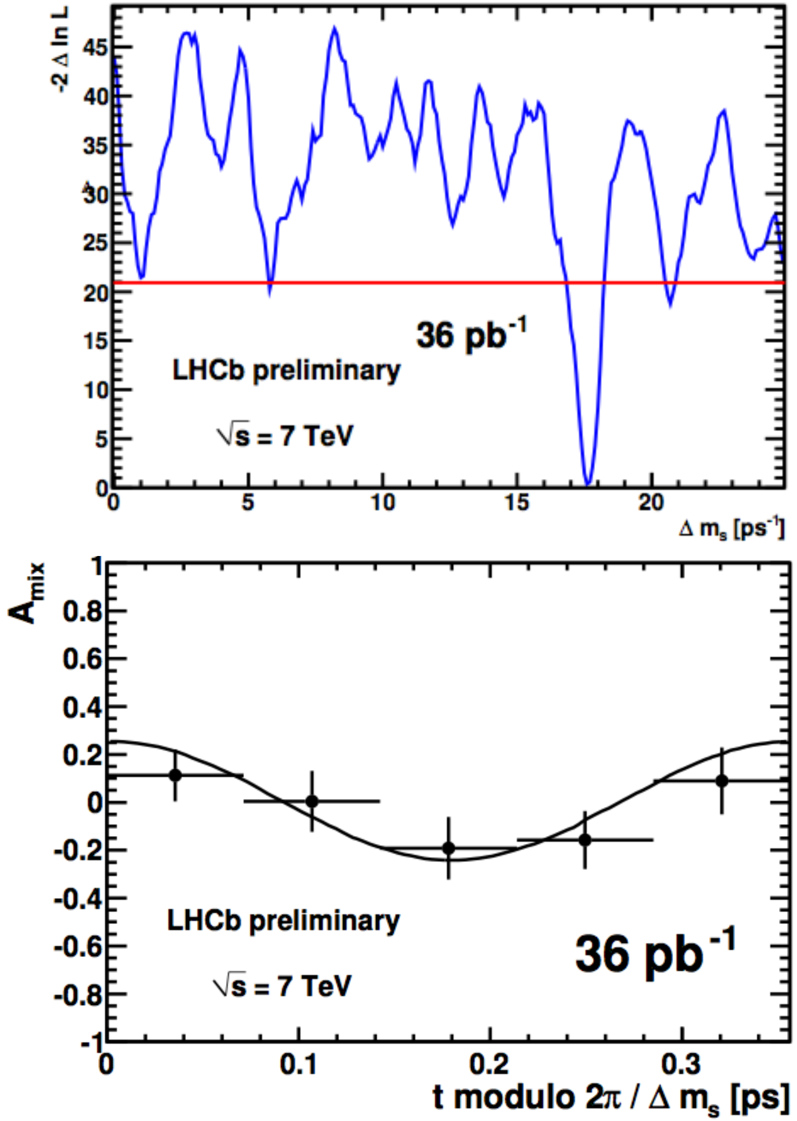
- Once tagging established can measure the B_s mixing frequency Δm_s

- See a clear dip in mixing frequency at 17.6 ps^{-1} , 4.6σ significance

- Comparable precision to CDF measurement with 36 pb^{-1}

$$\Delta m_s = {}^a\ 17.63 \pm 0.11(\text{stat}) \pm 0.04(\text{sys})\ ps^{-1}$$

($\Delta m_s = 17.77 \pm 0.10(\text{stat}) \pm 0.07(\text{sys})\ ps^{-1}$ CDF, 2006 [2])



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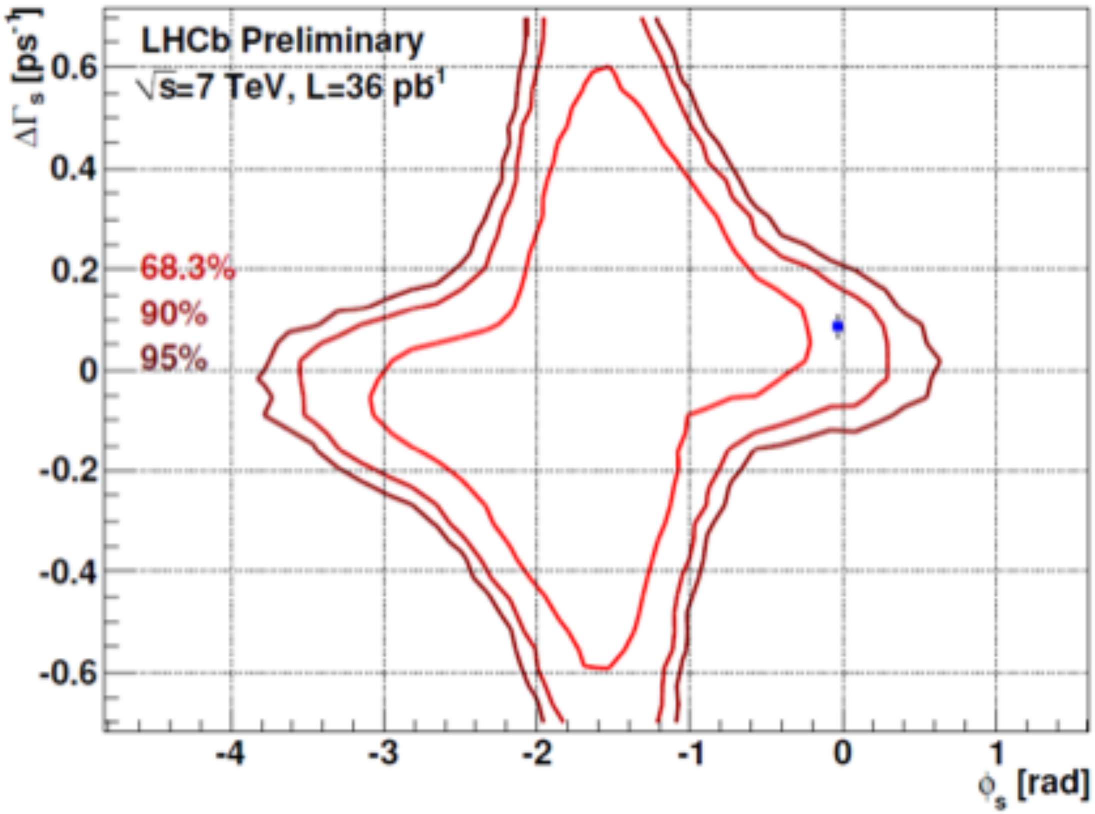
[a]Assumption: $\Delta\Gamma_s = 0.1 \times \Gamma_s$

Constraints on phase ϕ_s



- No meaningful point-estimate
  ⇒ Confidence contours using **Feldman-Cousins method**.
- **Statistical error only**: Accounts for syst. uncertainty of tagging (small).
- Compared to statistical error all systematic effects are negligible

← SM *P*-value: 22% ("1.2σ")

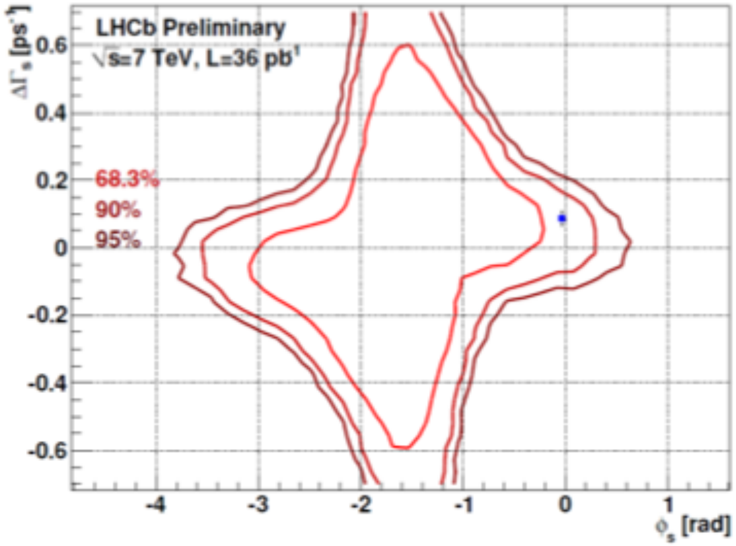
$\phi_s \in$ [-2.7, -0.5] rad at 68% CL
$\phi_s \in$ [-3.5, 0.2] rad at 95% CL

Standard Model:
$\Delta\Gamma_s = 0.087 \pm 0.021$ ps-1
(A.Lenz, U.Nierste. arXiv:1102.4274)
$\phi_s = -0.0363 \pm 0.0017$ rad (CKMfitter)

Prospects for 2011

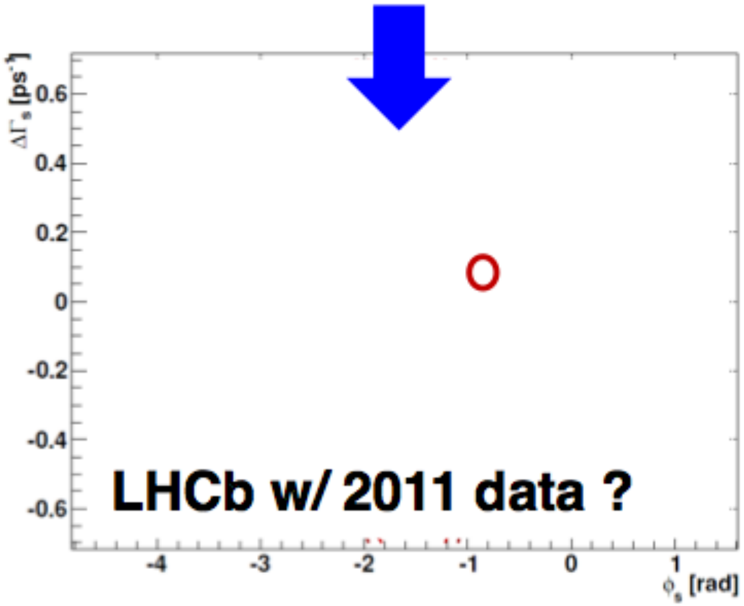
- Current performance:

	LHCb 36 pb^{-1}	CDF 5.2 fb^{-1}
$B_s \to J/\psi\,\phi$	836	6500
Proper time resolution	50 fs	100 fs
OS tagging power	$2.2 \pm 0.5\%$	$1.2 \pm 0.2\%$
SS tagging power	work ongoing	$3.5 \pm 1.4\%$



- With current performance and only OS tagger expected ϕ_s sensitivity for $1fb^{-1}$ is 0.13 rad

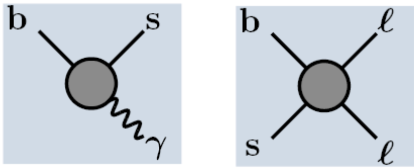
- SS tagger will improve sensitivity significantly, expect to have world's best measurement with the 2011 data



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

$B_d \to K^*\mu\mu$ – Introduction

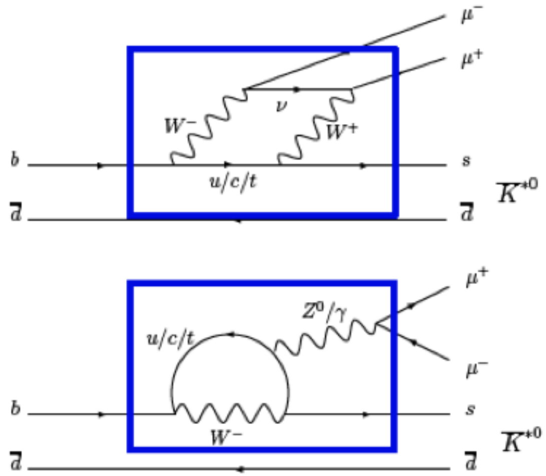
- Flavour changing neutral current → loop
- Sensitive to interference between

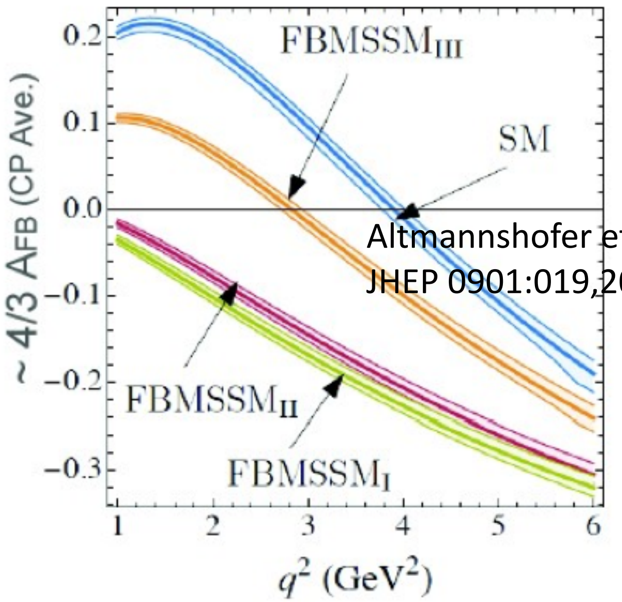


$O_{7\gamma}$ $O_{9,10}$

and their primed counterparts

- Exclusive decay → theory uncertainty from form factors
- Multitude of observables in which uncert. cancel to some extent e.g. A_{FB}, $A_T^{(i)}$
  - zero-crossing point of A_{FB}





Altmannshofer et al, JHEP 0901:019,2009

Experimental Status

- Babar, Belle and CDF have all measured angular asymmetry A_{FB} :

BABAR: $(0.1 < q^2 < 6.25\ GeV^2/c^2)$

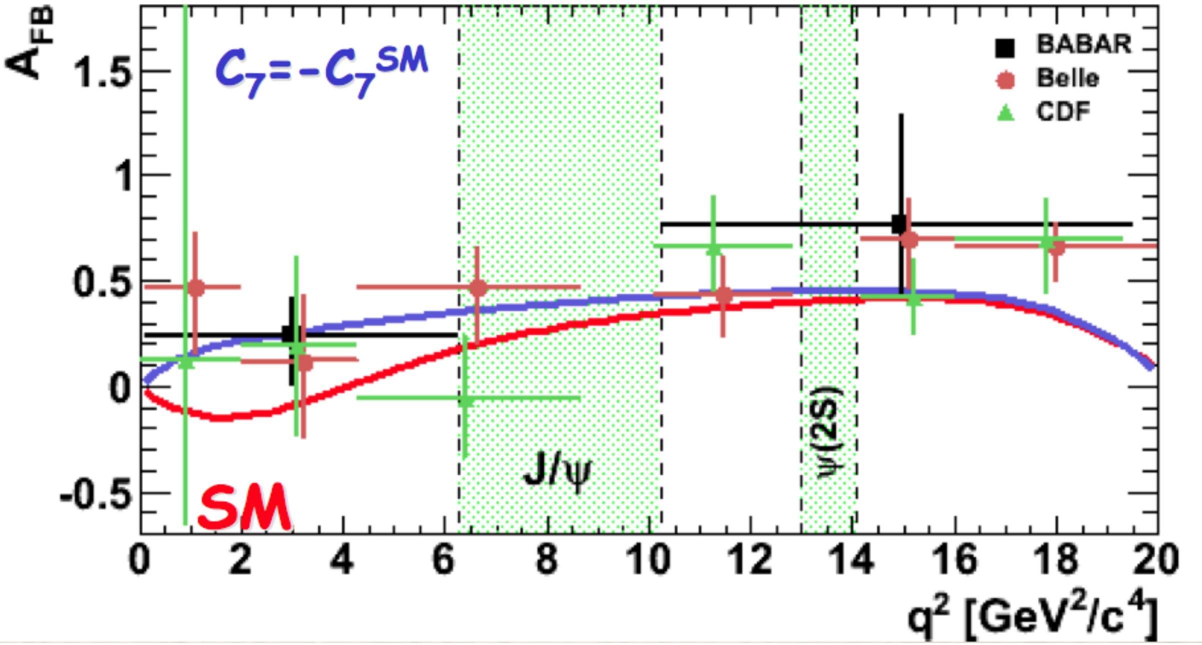
$\mathcal{A}_{FB} = 0.24^{+0.18}_{-0.23} \pm 0.05$

BELLE: $(1 < q^2 < 6\ GeV^2/c^2)$

$\mathcal{A}_{FB} = 0.26^{+0.27}_{-0.30} \pm 0.07$

CDF: $(1 < q^2 < 6\ GeV^2/c^2)$

$\mathcal{A}_{FB} = 0.43^{+0.36}_{-0.37} \pm 0.06$



- Measurements look consistent with each other but errors too large to give real discrimination between SM and NP models

BABAR: PRL 102, 091803 (2009); CDF: Note 10047 (2010); Belle: PRL 103, 171801 (2009)

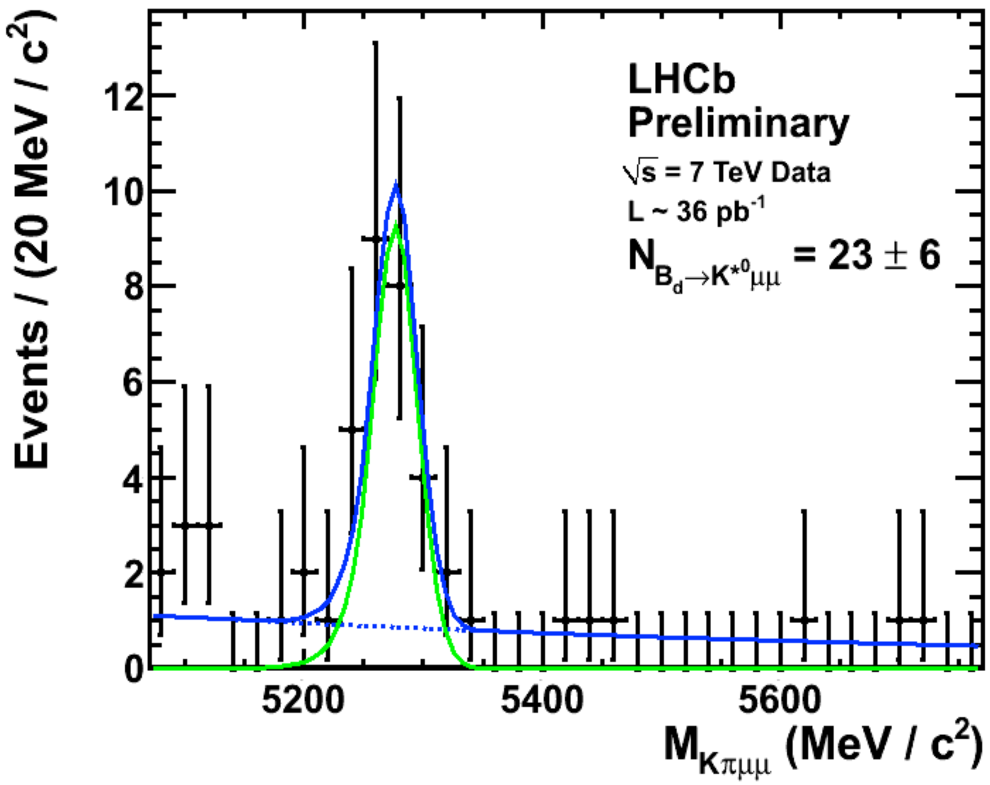
LHCb data

- Selection tuned on $B_d \rightarrow K^* J/\psi$ without use of signal decay

- $36pb^{-1}$ 2010 data yielded 23±6 signal events with B/S=0.2
  - → $200pb^{-1}$: 127±31 events
  - → $1fb^{-1}$: 635±154 events

  (cleanest bin of multivariate discriminant, further ~50% of statistics with B/S=1)

- cf.
  - Babar 60 events with B/S=0.3
  - Belle 230 0.25
  - CDF 100 0.4

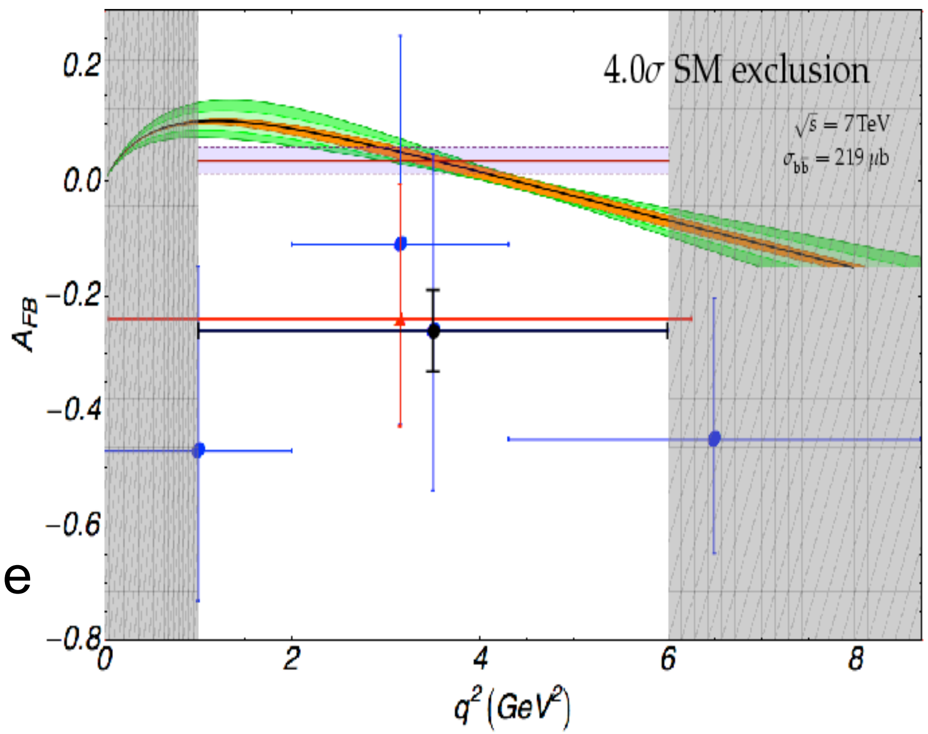


Prospects for 2011

- Measurement requires :
  - Signal selection
  - Acceptance correction
  - Angular fit

- Former items being validated on $B_d \to K^* J/\psi$ decay

- Assuming that with $1 fb^{-1}$ of data LHCb sees the same central value as Belle in the low q^2 region, would exclude the SM at 4σ



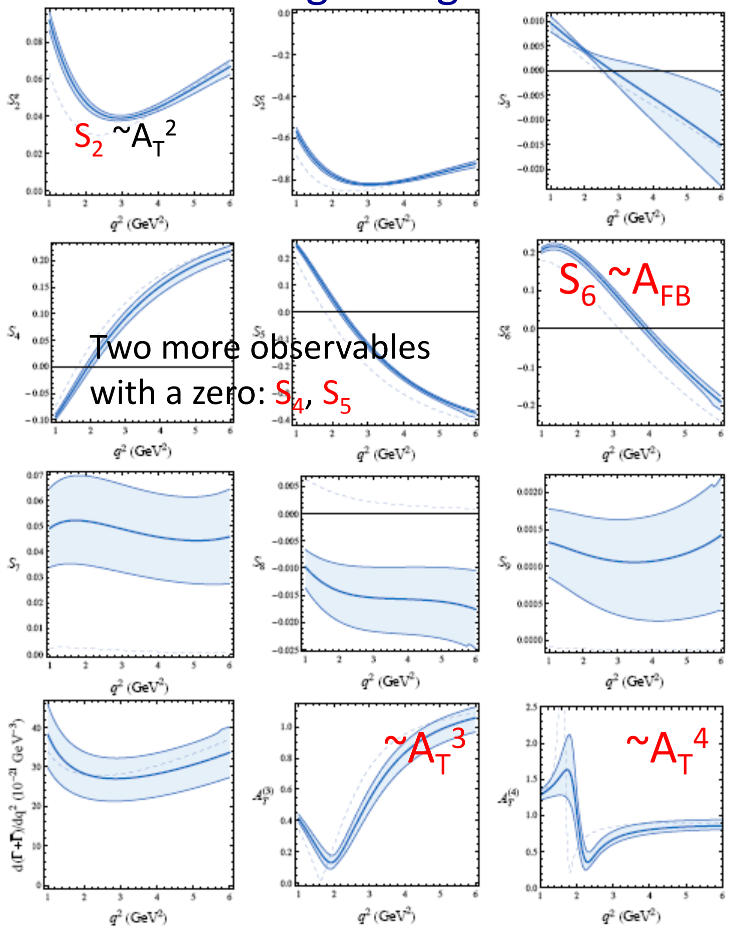
$B_d \rightarrow K^*\mu\mu$ – Outlook

- More data will enable a full angular fit to extract complete information from $B_d \rightarrow K^*\mu\mu$ decays

  → host of theoretically well calculable observables

- Correlation between measurements also of interest…

CP-averaged angular coeff.



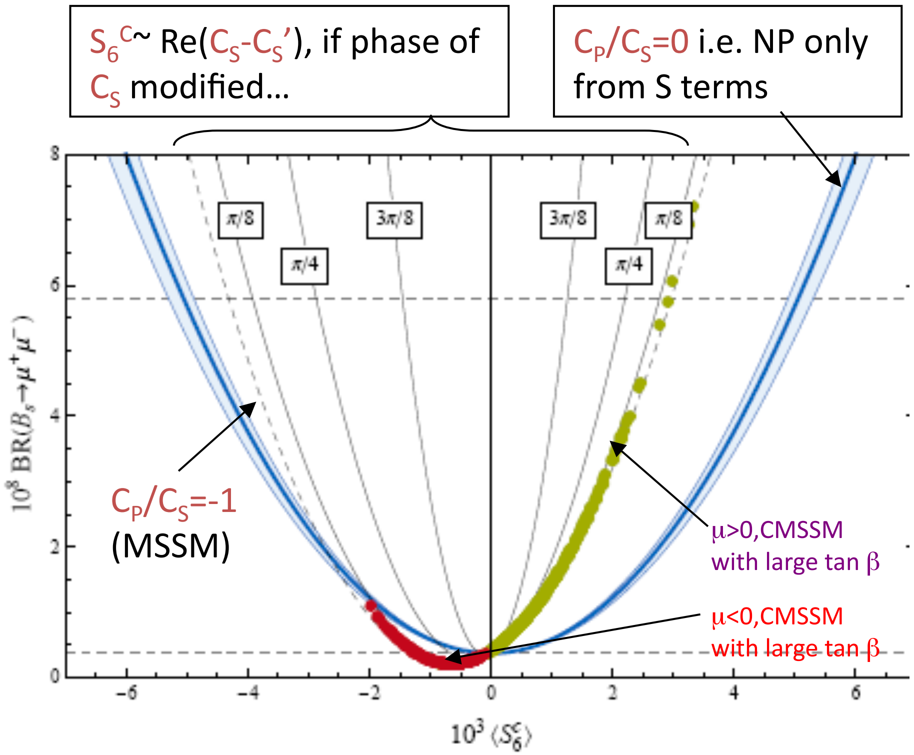
Ball *et al*. arXiv:0811.1214v2

$B_d \rightarrow K^*\mu\mu$ – Outlook

- More data will enable a full angular fit to extract complete information from $B_d \rightarrow K^*\mu\mu$ decays

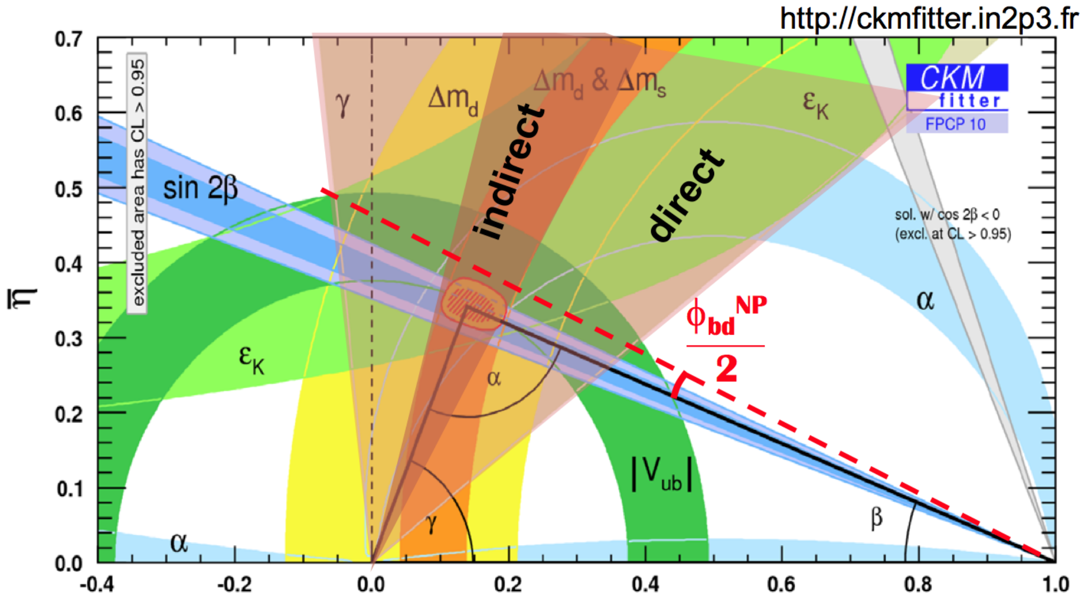
  → host of theoretically well calculable observables

- Correlation between measurements also of interest…



A whistlestop tour…

CKM Measurements



- $B_s \rightarrow J/\psi\phi$ measurement about looking for NP in B_s mixing
- Still scope for NP in B_d mixing?
  - CKM angle γ determined indirectly $(68 \pm 4)^o$
  - Loop processes → sin $(2\beta + \varphi_{bd}^{NP})$
  - cf. direct measurement of γ from tree processes (currently $(70\ ^{+14}\ _{-21})^o$)

CKM Measurements

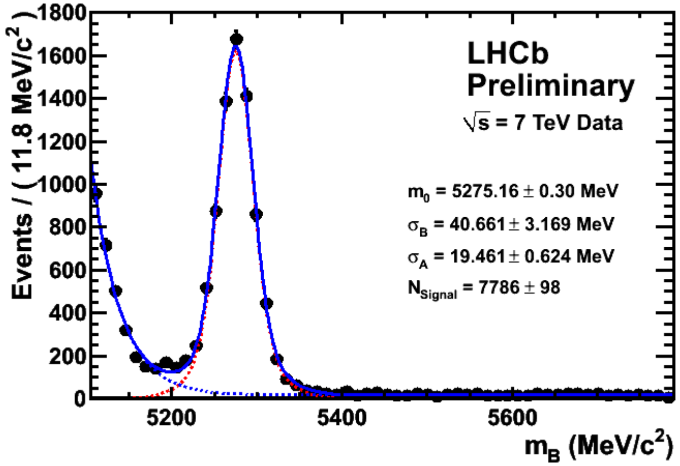
- Time independent strategies:
  - $B^+ \rightarrow D(hh)K^+$
  - $B^0 \rightarrow D(hh)K\pi^+$
  - $B^+ \rightarrow D(K_S\pi\pi)K^+$
  - $B^+ \rightarrow D(K\pi\pi\pi)K^+$
  - $B_s \rightarrow D_s\phi$

  } $\sigma_\gamma \sim 10^o$ with $1 fb^{-1}$

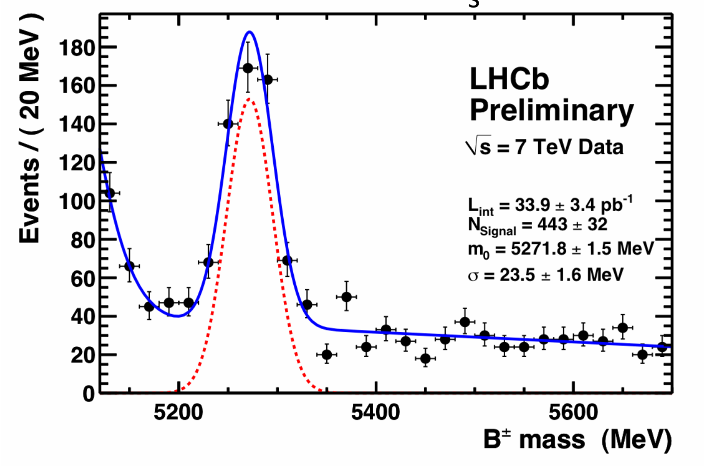
- Time dependent strategies:
  - $B_s \rightarrow D_s^- K^+$ $B \rightarrow hh$ [loops]

$B^- \rightarrow D^0\pi^-$

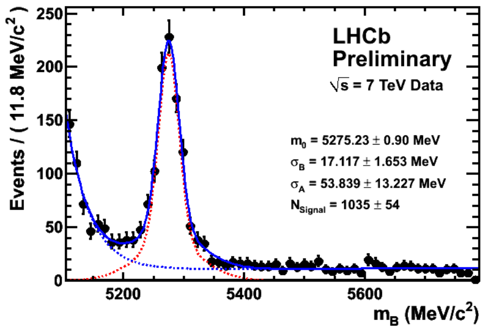
With $D^0 \rightarrow K\pi$



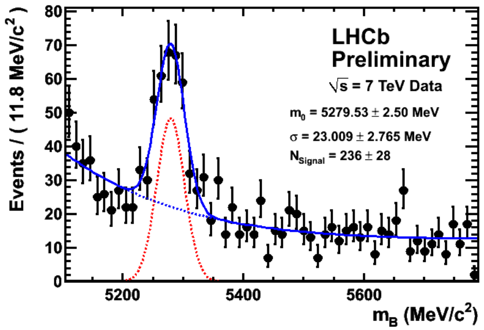
With $D^0 \rightarrow K_s\pi\pi$



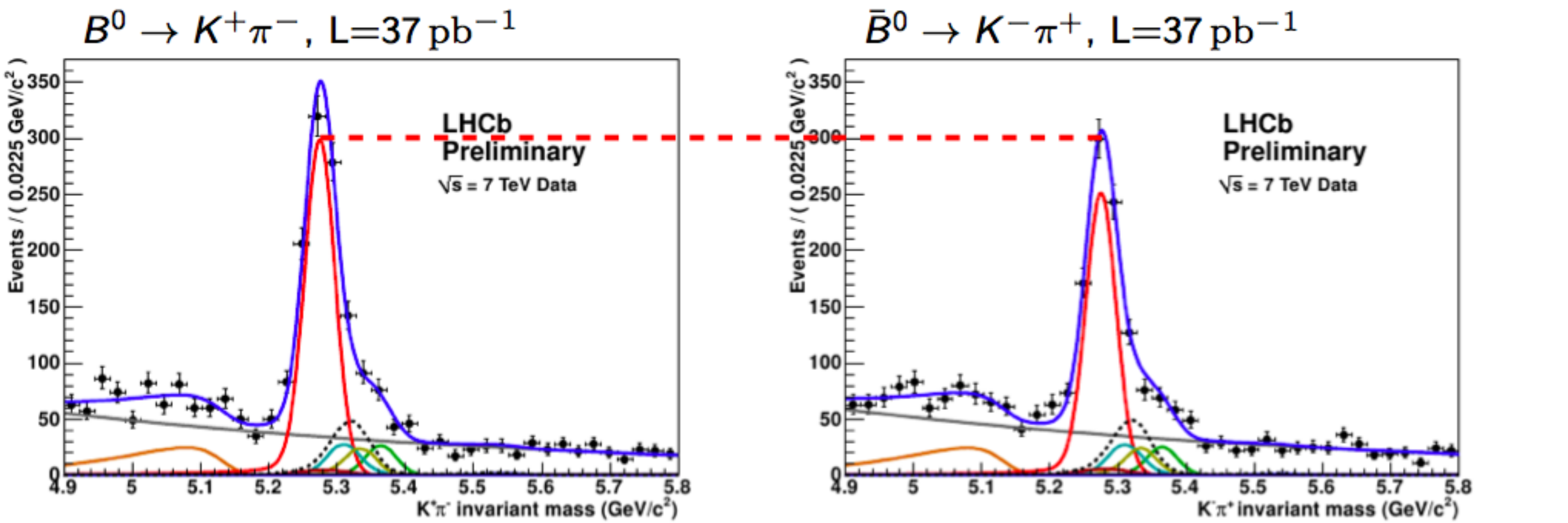
With $D^0 \rightarrow KK$



With $D^0 \rightarrow \pi\pi$



First sign of CPV at LHCb



	LHCb	world average
$A_{CP}(B^0 \to K^+\pi^-)$	$-0.077 \pm 0.033_{stat.} \pm 0.007_{syst.}$	-0.098±0.012
$A_{CP}(B_s \to \pi^+K^-)$	$0.15 \pm 0.19_{stat.} \pm 0.02_{syst.}$	0.39±0.17

- Interference of penguin and tree diagms … no measurement of γ yet

f_d/f_s

$B^0 \to D^- K^+$

$$\frac{f_d}{f_s} = 12.88 \times \frac{\tau_{B_s}}{\tau_{B_d}} \times \left[\mathcal{N}_a \mathcal{N}_F \frac{\epsilon_{D_s\pi}}{\epsilon_{D_d K}} \frac{N_{D_d K}}{N_{D_s\pi}}\right]$$

$$\frac{f_s}{f_d} = 0.242 \pm 0.024^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.016^{\text{theor}}$$

$B^0 \to D^- \pi^+$

$$\frac{f_d}{f_s} = 1.018 \times \frac{\tau_{B_s}}{\tau_{B_d}} \times \left[\tilde{\mathcal{N}}_a \mathcal{N}_F \mathcal{N}_E \frac{\epsilon_{D_s\pi}}{\epsilon_{D_d\pi}} \frac{N_{D_d\pi}}{N_{D_s\pi}}\right]$$

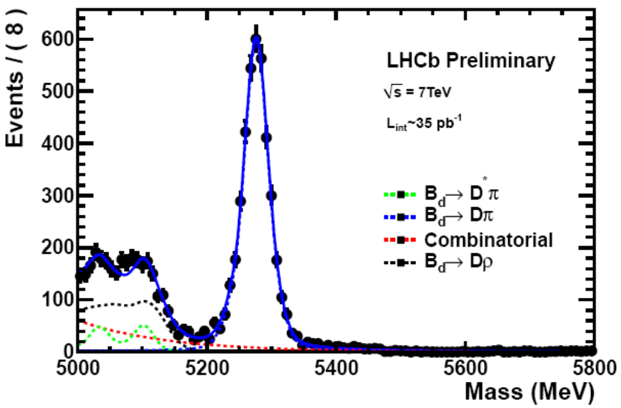
$$\frac{f_s}{f_d} = 0.249 \pm 0.013^{\text{stat}} \pm 0.020^{\text{syst}} \pm 0.025^{\text{theor}}$$

Combined:

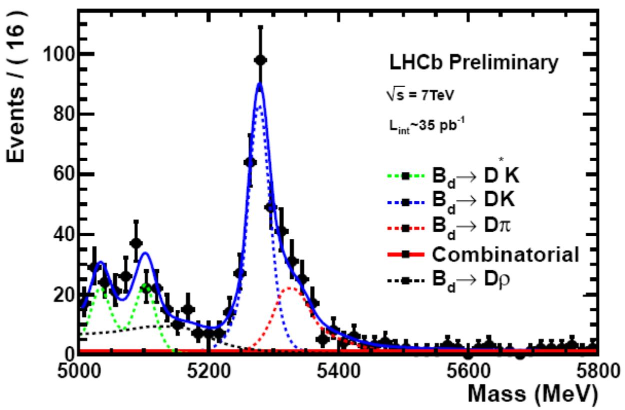
$$\frac{f_s}{f_d} = 0.245 \pm 0.017^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.018^{\text{theor}}$$

(LHCb preliminary)

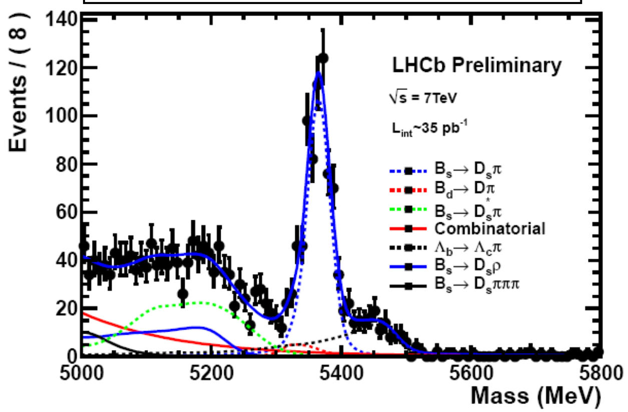
$N(B^0 \to D^- \pi^+) = 4109 \pm 75$



$N(B^0 \to D^- K^+) = 253 \pm 21$



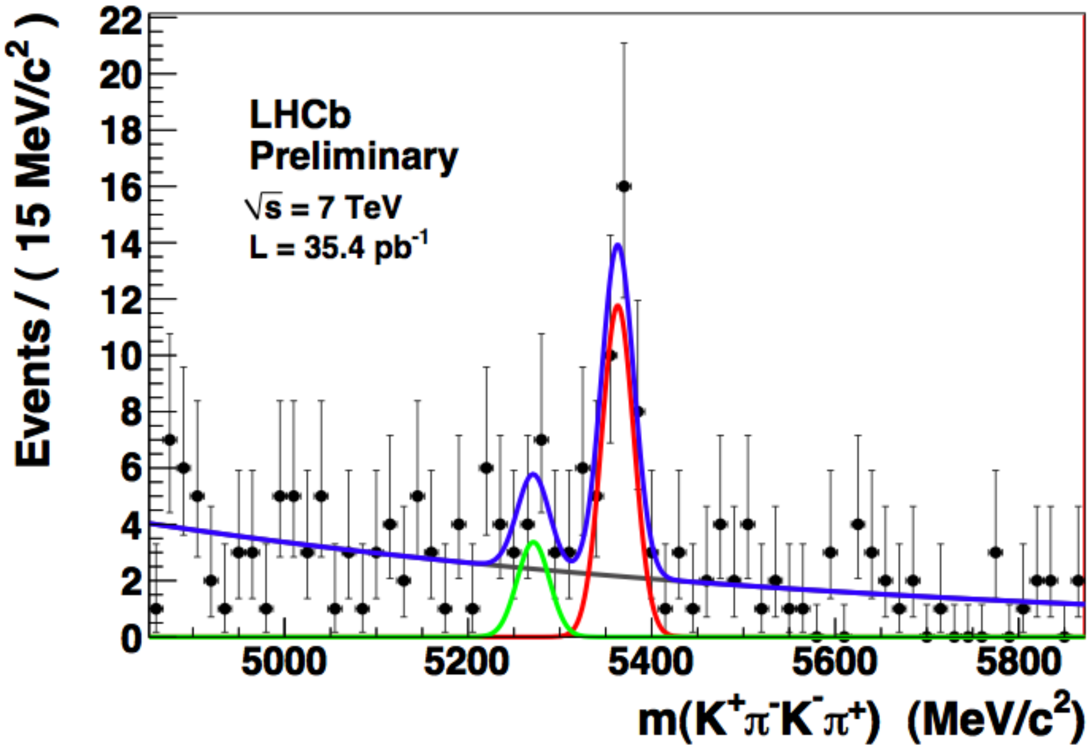
$N(B_s^0 \to D_s^- \pi^+) = 670 \pm 34$



First observation of $B_s \rightarrow K^*K^*$

- Observed with 7.4σ significance
- Sensitivity to NP in mixing box and penguin diagram
- no measurement of CPV, yet

$$\mathcal{B}(B_s \rightarrow K^* \bar{K}^*) = (1.95 \pm 0.47_{\text{stat.}} \pm 0.66_{\text{syst.}} \pm 0.29_{f_d/f_s}) \cdot 10^{-5}$$

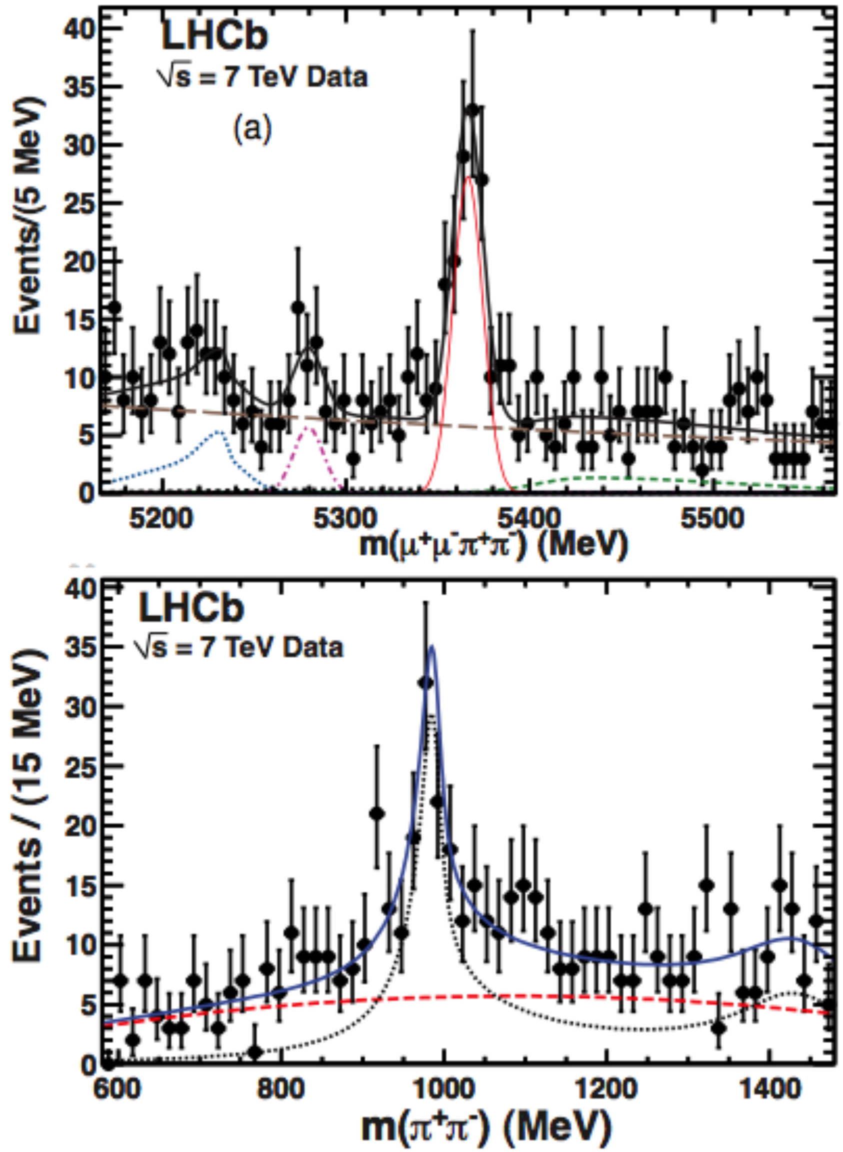


First Observation of $B_s \to J/\psi f_0(980)$

- Measurement of the BR of the two interfering resonances f_0 (980) and $f_0(1370)$
- CP-odd final state, therefore possible measurement of ϕ_s w/o angular analysis
- Ratio to J/ψ production determined,

$$R_{f_0/\phi} = \frac{\Gamma(B_s \to J/\psi\, f_0,\ f_0 \to \pi^+\pi^-)}{\Gamma(B_s \to J/\psi\, \phi,\ \phi \to K^+K^-)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$$

- R.Aaij *etal.*, Phys. Lett. B. 698 (2011) 115-122



Conclusions

- $B_d \to \mu^+\mu^-$ and $B_s \to \mu^+\mu^-$
  - Very close to the world's best limits with ~100× less luminosity than CDF
  - With the data collected in 2011 we should be able to explore BR < $\sim 10^{-8}$

- ϕ_s from $B_s \to J/\psi\phi$
  - Full measurement chain established – currently OS-tagger only
  - Expect to have world's best measurement with the 2011 data

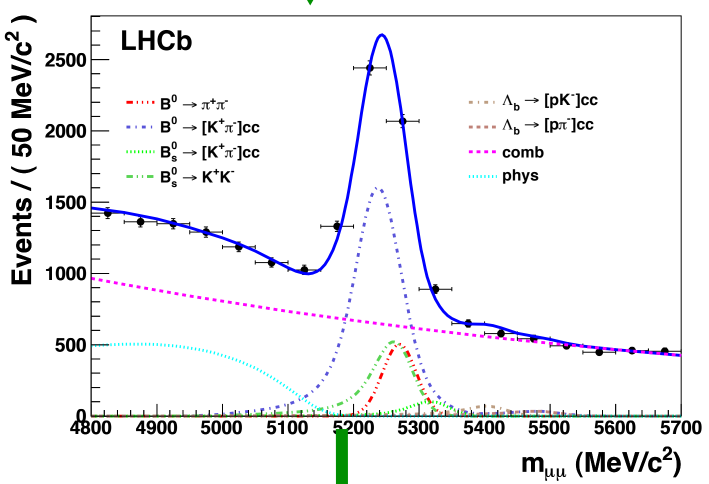
- $B_d \to K^*\mu\mu$
  - First signal isolated, very clean
  - A_{FB} measurement competitive with B-factories, CDF with ~200 pb^{-1}

- Large number of other analyses in progress
  - CKM angle γ, charm physics, exotics … should be a range of results for summer conferences

Signal Invariant Mass calibration

Mass resolutions $\sigma(M(B_{d,s}))$ from :

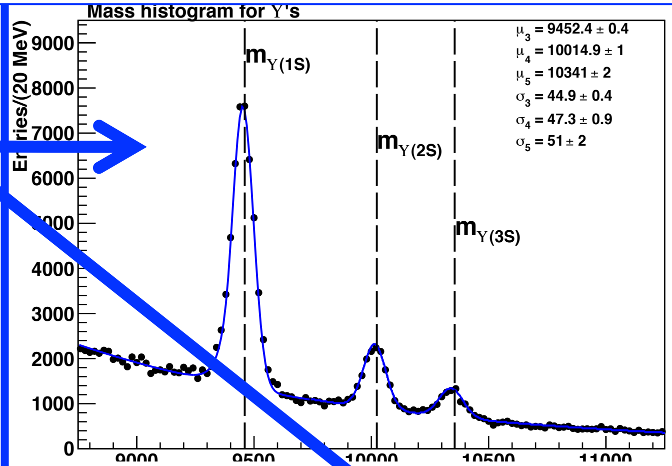
1) B→hh' inclusive sample:
2) Interpolation from dimuon resonances

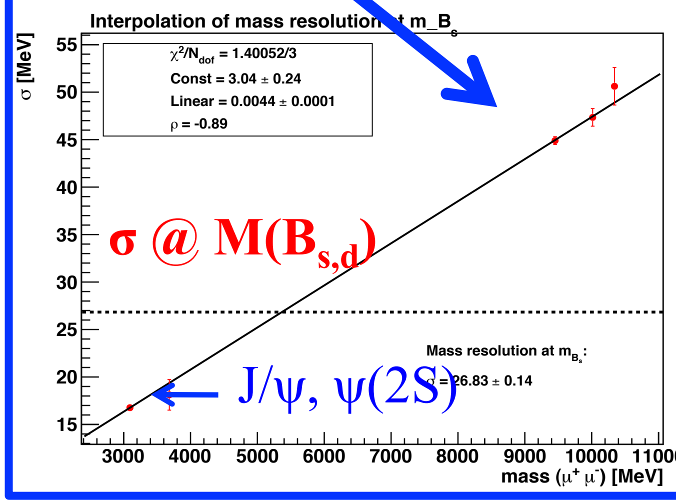


- similar kinematics/topology
- Selection identical to the signal one:

→Avoid to using PID and use only events triggered by the other b to avoid bias in the phase space [eg resolution]

The ϒ family: ϒ(1S), ϒ(2S), ϒ(3S)





$B_s \rightarrow \mu\mu$ search window

Invariant Mass bins (MeV/c^2)

Invariant Mass bins (MeV/c^2)		Geometrical Likelihood Bins [0, 0.25]	[0.25, 0.5]	[0.5, 0.75]	[0.75, 1]
[−60, −40]	Exp. bkg.	$56.9^{+1.1}_{-1.1}$	$1.31^{+0.19}_{-0.17}$	$0.282^{+0.076}_{-0.065}$	$0.016^{+0.021}_{-0.010}$
	Exp. sig.	$0.0076^{+0.0034}_{-0.0030}$	$0.0050^{+0.0027}_{-0.0020}$	$0.0037^{+0.0015}_{-0.0011}$	$0.0047^{+0.0015}_{-0.0010}$
	Observed	39	2	1	0
[−40, −20]	Exp. bkg.	$56.1^{+1.1}_{-1.1}$	$1.28^{+0.18}_{-0.17}$	$0.269^{+0.072}_{-0.062}$	$0.015^{+0.020}_{-0.009}$
	Exp. sig.	$0.0220^{+0.0084}_{-0.0079}$	$0.0146^{+0.0066}_{-0.0053}$	$0.0107^{+0.0036}_{-0.0026}$	$0.0138^{+0.0034}_{-0.0024}$
	Observed	55	2	0	0
[−20, 0]	Exp. bkg.	$55.3^{+1.1}_{-1.1}$	$1.24^{+0.17}_{-0.16}$	$0.257^{+0.069}_{-0.059}$	$0.014^{+0.018}_{-0.009}$
	Exp. sig.	$0.038^{+0.015}_{-0.014}$	$0.025^{+0.012}_{-0.010}$	$0.0183^{+0.0063}_{-0.0047}$	$0.0235^{+0.0059}_{-0.0042}$
	Observed	73	0	0	0
[0, 20]	Exp. bkg.	$54.4^{+1.1}_{-1.1}$	$1.21^{+0.17}_{-0.16}$	$0.246^{+0.066}_{-0.057}$	$0.013^{+0.017}_{-0.008}$
	Exp. sig.	$0.03761^{+0.015}_{-0.015}$	$0.025^{+0.012}_{-0.010}$	$0.0183^{+0.0063}_{-0.0047}$	$0.0235^{+0.0060}_{-0.0044}$
	Observed	60	0	0	0
[20, 40]	Exp. bkg.	$53.6^{+1.1}_{-1.0}$	$1.18^{+0.17}_{-0.15}$	$0.235^{+0.063}_{-0.054}$	$0.012^{+0.015}_{-0.007}$
	Exp. sig.	$0.0220^{+0.0084}_{-0.0081}$	$0.0146^{+0.0067}_{-0.0054}$	$0.0107^{+0.0036}_{-0.0027}$	$0.0138^{+0.0035}_{-0.0025}$
	Observed	53	2	0	0
[40, 60]	Exp. bkg.	$52.8^{+1.0}_{-1.0}$	$1.15^{+0.16}_{-0.15}$	$0.224^{+0.060}_{-0.052}$	$0.011^{+0.014}_{-0.007}$
	Exp. sig.	$0.0076^{+0.0031}_{-0.0027}$	$0.0050^{+0.0025}_{-0.0019}$	$0.0037^{+0.0013}_{-0.0010}$	$0.0047^{+0.0013}_{-0.0010}$
	Observed	55	1	0	0

$B_d \to \mu\mu$ search window

Invariant Mass bins (MeV/c^2)		Geometrical Likelihood Bins [0, 0.25]	[0.25, 0.5]	[0.5, 0.75]	[0.75, 1]
[−60, −40]	Exp. bkg.	$60.8^{+1.2}_{-1.1}$	$1.48^{+0.19}_{-0.18}$	$0.345^{+0.084}_{-0.073}$	$0.024^{+0.027}_{-0.014}$
	Exp. sig.	$0.0009^{+0.0004}_{-0.0003}$	$0.0006^{+0.0003}_{-0.0002}$	$0.0004^{+0.0002}_{-0.0001}$	$0.0006^{+0.0002}_{-0.0001}$
	Observed	59	2	0	0
[−40, −20]	Exp. bkg.	$59.9^{+1.1}_{-1.1}$	$1.44^{+0.19}_{-0.17}$	$0.329^{+0.080}_{-0.070}$	$0.022^{+0.024}_{-0.013}$
	Exp. sig.	$0.0026^{+0.009}_{-0.009}$	$0.0017^{+0.0008}_{-0.0006}$	$0.0013^{+0.0004}_{-0.0003}$	$0.0016^{+0.0004}_{-0.0002}$
	Observed	67	0	0	0
[−20, 0]	Exp. bkg.	$59.0^{+1.1}_{-1.1}$	$1.40^{+0.18}_{-0.17}$	$0.315^{+0.077}_{-0.067}$	$0.020^{+0.022}_{-0.012}$
	Exp. sig.	$0.0045^{+0.0017}_{-0.0017}$	$0.0030^{+0.0014}_{-0.0011}$	$0.00219^{+0.00067}_{-0.00054}$	$0.00280^{+0.00060}_{-0.00045}$
	Observed	56	2	0	0
[0, 20]	Exp. bkg.	$58.1^{+1.1}_{-1.1}$	$1.36^{+0.18}_{-0.16}$	$0.300^{+0.073}_{-0.064}$	$0.019^{+0.021}_{-0.011}$
	Exp. sig.	$0.0045^{+0.0017}_{-0.0017}$	$0.0030^{+0.0014}_{-0.0011}$	$0.00219^{+0.00067}_{-0.00054}$	$0.00280^{+0.00060}_{-0.00045}$
	Observed	60	0	0	0
[20, 40]	Exp. bkg.	$57.3^{+1.1}_{-1.1}$	$1.33^{+0.17}_{-0.16}$	$0.287^{+0.070}_{-0.061}$	$0.017^{+0.019}_{-0.010}$
	Exp. sig.	$0.0026^{+0.0009}_{-0.0009}$	$0.0017^{+0.0008}_{-0.0006}$	$0.0013^{+0.0004}_{-0.0003}$	$0.0016^{+0.0004}_{-0.0002}$
	Observed	42	2	1	0
[40, 60]	Exp. bkg.	$56.4^{+1.1}_{-1.1}$	$1.29^{+0.17}_{-0.16}$	$0.274^{+0.067}_{-0.058}$	$0.016^{+0.018}_{-0.009}$
	Exp. sig.	$0.0009^{+0.0003}_{-0.0003}$	$0.0006^{+0.0003}_{-0.0002}$	$0.0004^{+0.0001}_{-0.0001}$	$0.0006^{+0.0002}_{-0.0001}$
	Observed	49	2	0	0