M.Calvi, Milano-Bicocca 2 Sep 2011

Highlights on LHCb Physics from summer conferences

NB. Questo non e' il talk per il meeting della CSN1 di Settembre,

With some slides taken from

G.Wilkinson EPS 2011,Grenoble 20-27 July

G.Rhaven LP 2011 Mumbai 22-27 August

LHCb at Summer Conferences

- Main LHCb results on B^0, B_s physics (CPV and NP searches) which surpass previous results obtained at Tevatron, provide new best world measurements …and are all compatible with SM expectations: (all with Italian contributions)

  - $BR(B_{d,s} \rightarrow \mu\mu)$ (EPS) LNF, Firenze
  - A_{FB}, F_L $B^0 \rightarrow K^*\mu\mu$ (EPS) Roma1
  - A_{CP} in $B_{d,s} \rightarrow hh$ (EPS) Bologna
  - B_s mixing phase ϕ_s (LP) Milano,Ferrara

LHCb at Summer Conferences

- And also:
  - Observation of ADS modes towards a γ measurement (EPS)
  - World best Δm_s measurements (LP)
  - BR($B_s \rightarrow D_s K$) world best (LP)
  - $B_s \rightarrow \phi\phi$ TPA (LP)
  - Charm mixing&CPV: y_{CP} and A_Γ (EPS/LP)
  - Excited B** states (LP) Bari, Milano
  - BR $B^\pm \rightarrow ppK^\pm$ (PIC) Genova
  - BR $B \rightarrow V\gamma$ (LP)

……. and more, including EW, up to about 30 new CONF notes

SUMMER - CONFERENCE for notes OUT

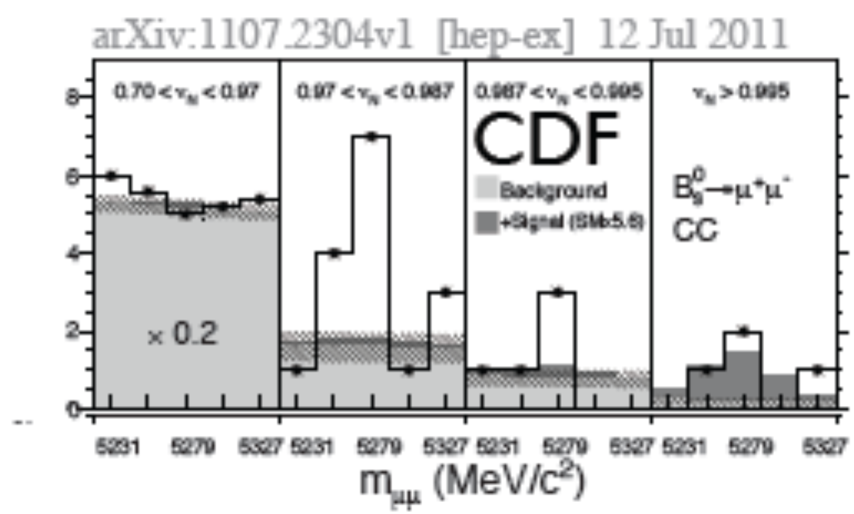
- LHCb-CONF-2011-054 **Measurement of the Charm Mixing Parameter yCP in Two-Body Charm Decays**
- LHCb-CONF-2011-047 **Search for the rare decay $Bs0 \rightarrow \mu+\mu$ at the LHC with the CMS and LHCb experiments. Combination of LHC results of the search for $Bs \rightarrow \mu+\mu-$ decays**
- LHCB-CONF-2011-046 **Measurement of the CP Violation Parameter $A\Gamma$ in Two-Body Charm Decays**
- LHCb-CONF-2011-043 **Inclusive X(3872) production in pp collisions at s=7 TeV**
- LHCb-CONF-2011-041 **ZZ cross-section measurement at s=sqrt{s}=7 TeV using the channel $Z \rightarrow \tau\tau$**
- LHCb-CONF-2011-039 **Updated measurements of WW and ZZ production at sqrt{s} = 7 TeV with the LHCb experiment**
- LHCb-CONF-2011-038 **Angular analysis of $B0 \rightarrow K*0\mu+\mu-$**
- LHCb-CONF-2011-037 **Search for the rare decays $B(s)0 \rightarrow \mu+\mu-$ with 300 pb−1^{-1} at LHCb**
- LHCb-CONF-2011-035 **Analysis of $\bar{B}s0 \rightarrow J/\psi$ ($\pi+\pi-$ and K+K−) and the first observation of $J/\psi f2'(1525)$**
- LHCb-CONF-2011-034 **Average f_s/f_d b-hadron production fraction for 7TeV pp collisions**
- LHCb-CONF-2011-031 **A measurement of the ratio of branching fractions: $B(B\pm \rightarrow DK\pm)/B(B\pm \rightarrow D\pi\pm)$ for $D \rightarrow K\pi$, KKKK, $K\pi\pi\pi$ and $KS0\pi\pi$**
- LHCb-CONF-2011-030 **Measurement of the Ratio of Branching Fractions $B(B\pm \rightarrow J/\psi\pi\pm)/B(B\pm \rightarrow J/\psi K \pm$ at s=7 TeV with the LHCb Detector**
- LHCb-CONF-2011-029 **Time integrated ratio of wrong-sign to right-sign $D0 \rightarrow K\pi$ decays in 2010 data at LHCb**

SUMMER - CONFERENCE notes DRAFT

- LHCB-CONF-2011-057 **Measurement of the relative and absolute branching fractions of the decays Bs0→Ds∓K± and Bs0→Ds−π+**
- LHCB-CONF-2011-051 **Measurement of φs in Bs0→J/ψf0(980)**
- LHCB-CONF-2011-049 **Tagged time-dependent angular analysis of Bs→J/ψφ decays with 337 pb−1 at LHCb**
- LHCB-CONF-2011-048 **Measurement of the Bs0→J/ψKS Branching Fraction**
- LHCB-CONF-2011-045 **Search for X(4140 in B+→J/ψφK+**
- LHCB-CONF-2011-042 **Charmless charged two-body B decays at LHCb with 2011 data**
- LHCB-CONF-2011-040 **First observation of Bc+→J/ψ π+π−π+**
- LHCB-CONF-2011-036 **Studies of beauty baryons decaying to D0pπ- and D0pK-**
- LHCB-CONF-2011-033 **Measurement of the B± cross-section at LHCb**
- **……..**

$B_s \rightarrow \mu\mu$

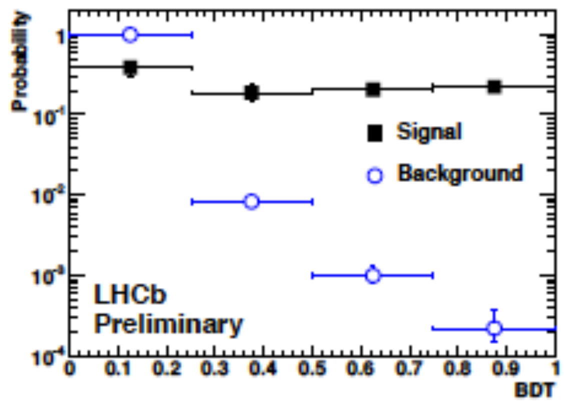
- Very rare in the SM due to GIM & helicity suppression:
  - $Br_{SM}(B_s \rightarrow \mu\mu) = (3.2 \pm 0.2) \times 10^{-9}$
- Large sensitivity to NP, eg:
  - $Br_{MSSM}(B_q \rightarrow \ell^+\ell^-) \propto \frac{M_b^2 M_\ell^2 \tan^6\beta}{M_A^4}$
- CDF recently reported a hint of signal:
  - p-value background + SM Br: 1.9%
  - $Br_{CDF}(B_s \rightarrow \mu\mu) = 1.8^{+1.1}_{-0.9} \times 10^{-8}$

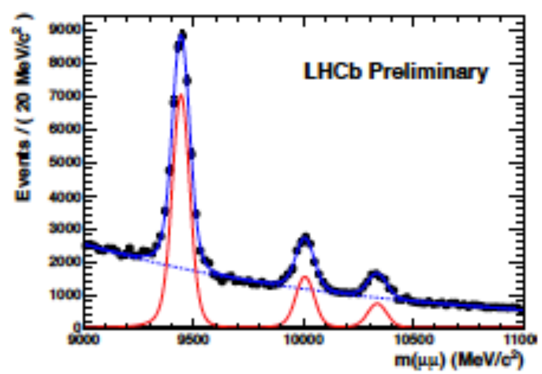


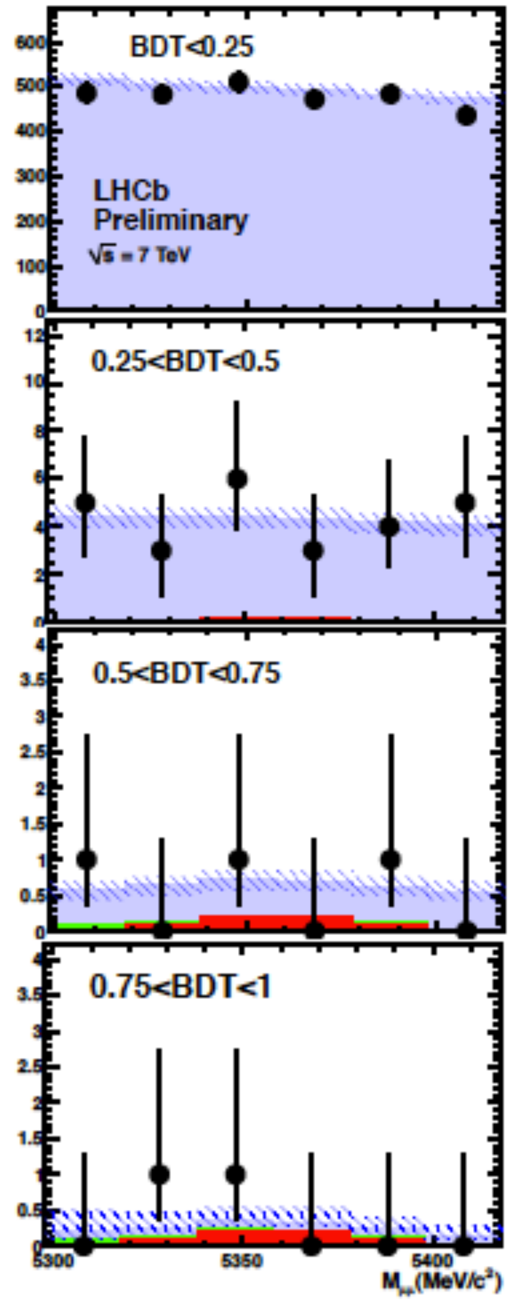
$B_s \rightarrow \mu\mu$ @LHCb

- Analysis of 300/pb using invariant mass & Boosted Decision Tree combining 9 topological & kinematical observables
  - BDT calibrated on $B \rightarrow h^+h^-$ (signal), sidebands (background)
  - Mass resolution obtained by interpolation between $J/\psi \rightarrow \mu\mu$, $\Upsilon(1S) \rightarrow \mu\mu$, shape verified using $B^0 \rightarrow K\pi$, $B_s \rightarrow KK$
- Normalization using $B^+ \rightarrow J/\psi K^+$, $B_s \rightarrow J/\psi\phi$, $B^0 \rightarrow K\pi$, and LHCb result for f_s/f_d

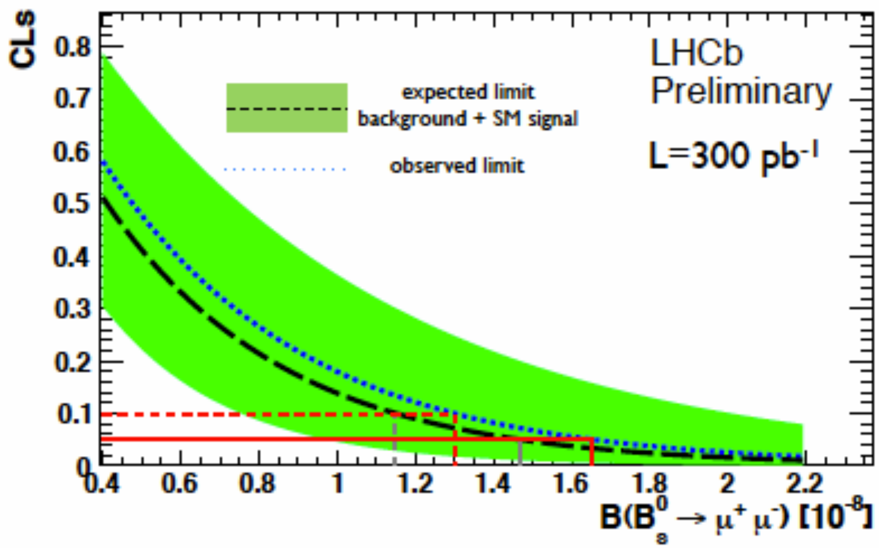
LHCb-CONF-2011-037







$B_s \rightarrow \mu\mu$ LHCb limit

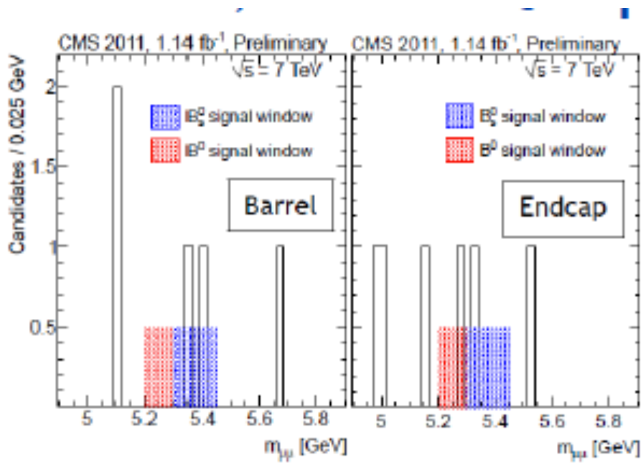


LHCb-CONF-2011-037

- Expected Limit: $<1.5 \times 10^{-8}$ @ 95%CL
- p-value background only: 14%
- Br ($B_s \rightarrow \mu\mu$) $< 1.6 \times 10^{-8}$ @ 95% CL
  - combined with 2010: $<1.5 \times 10^{-8}$ @ 95% CL

$B_s \rightarrow \mu\mu$ LHCb+CMS combined

CMS

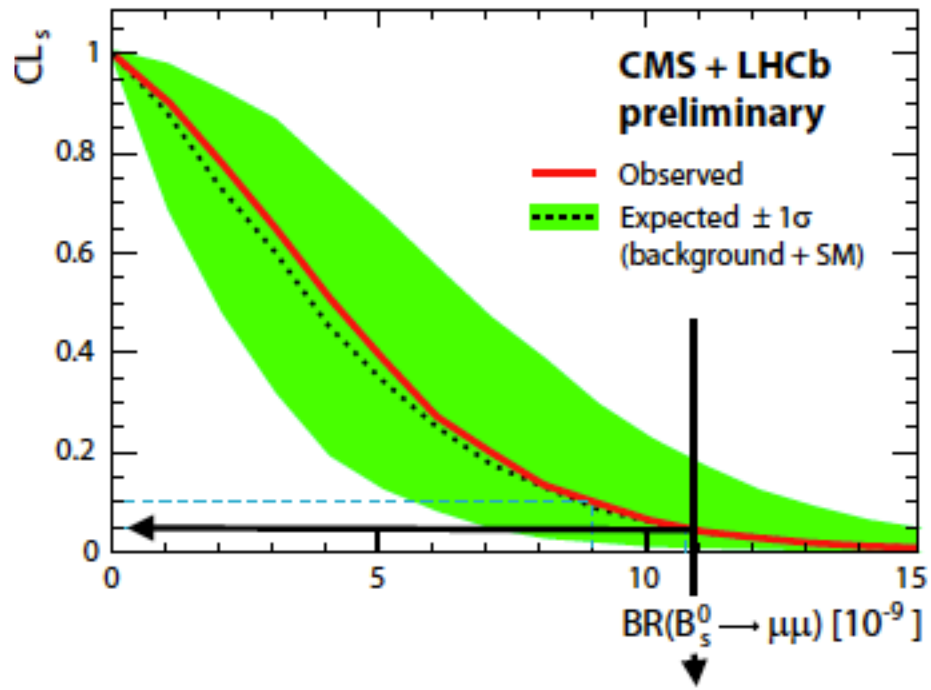


	Barrel	Endcap
N_{signal}^{exp}	0.80 ± 0.16	0.36 ± 0.07
N_{bg}^{exp}	0.60 ± 0.35	0.80 ± 0.40
N_{peak}^{exp}	0.07 ± 0.02	0.04 ± 0.01
N_{obs}	2	1

this is B→hh

CMS-BPH-11-002

- Expected Limit: $< 1.8 \times 10^{-8}$ @ 95%CL
- p-value background only: 11%
- $Br(B_s \rightarrow \mu\mu) < 1.9 \times 10^{-8}$ @ 95% CL
  - using $f_s/f_u = 0.282 \pm 0.037$ [pdg]



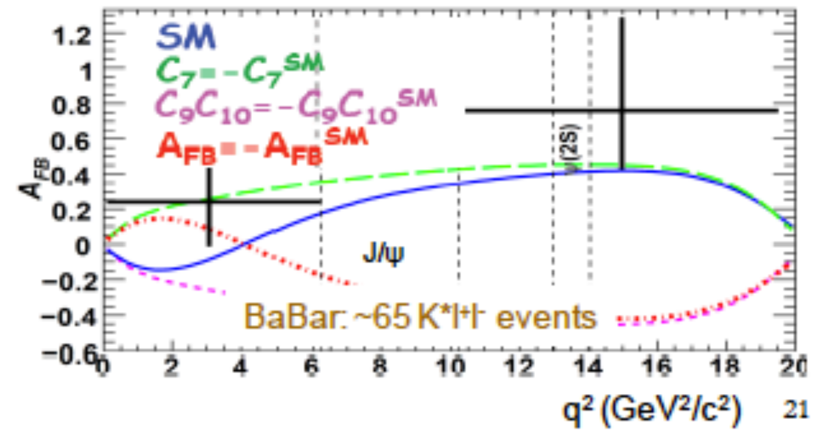
$Br(B_s \rightarrow \mu\mu) < 11 \times 10^{-9}$ @ 95% CL

This is 3.4 times the expected SM value

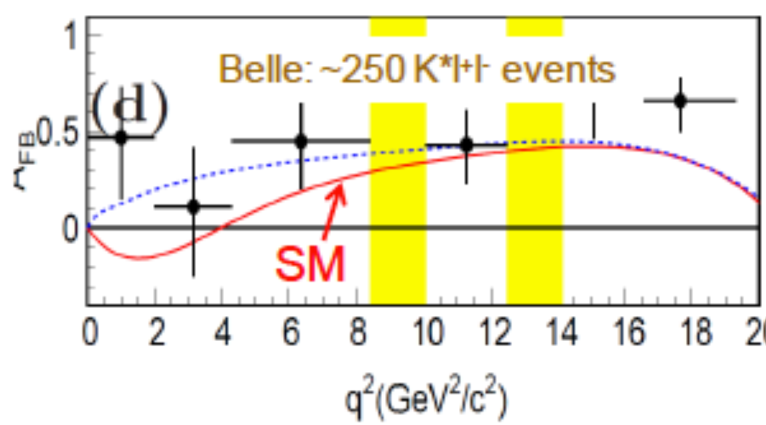
A BR of 1.8×10^{-8} has a CLs value of ~0.3%

$B^0 \rightarrow K^*l^+l^-$

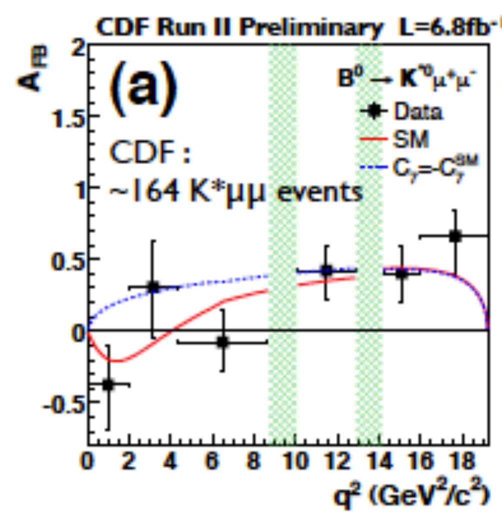
- Flavour changing neutral current decay:
  - $Br(B^0 \rightarrow K^*l^+l^-) = (3.3 \pm 1.0) \times 10^{-6}$
- Described by
  - three angles: θ_l, ϕ, θ_K
  - $\mu\mu$ invariant mass: q^2
- Excellent probe of helicity structure of New Physics
- Esp. lepton forward-backward asymmetry A_{FB} vs. q^2
- Results from B-factories & CDF show hint of peculiar behavior at low q^2 ?



PRD 79 (2009) 031102



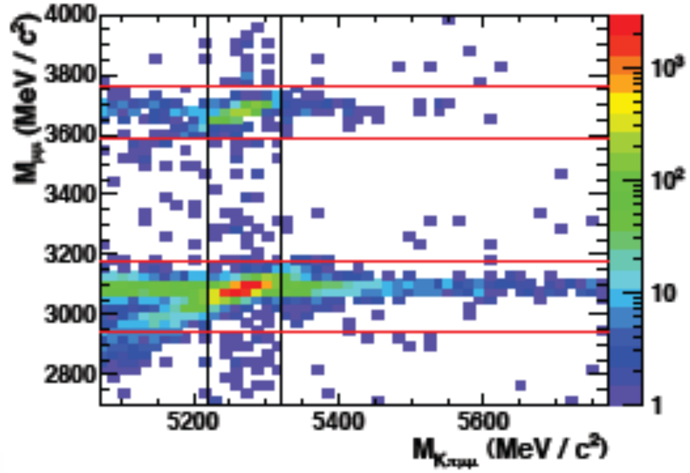
PRL 103 (2009) 171801

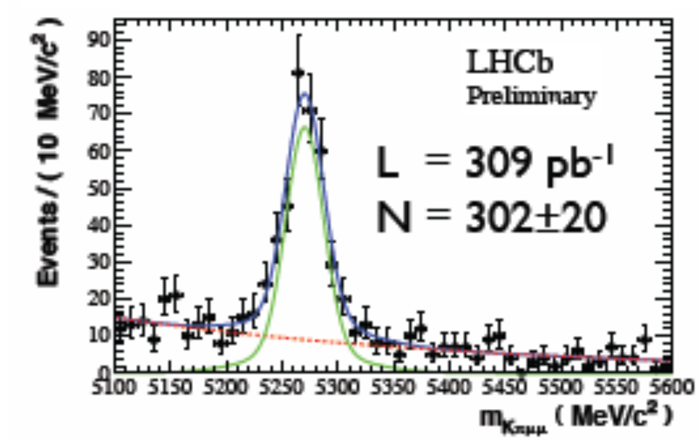


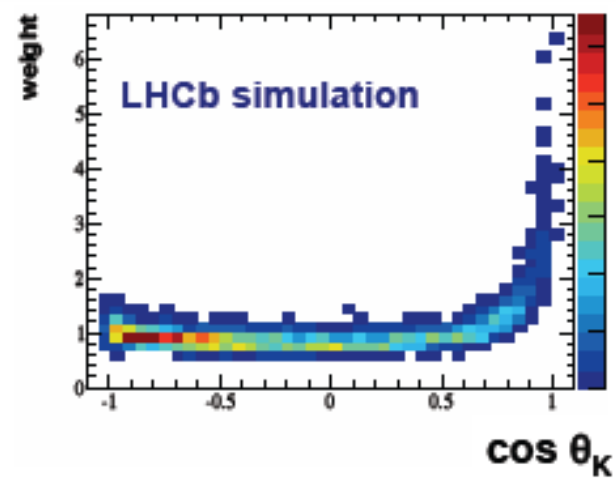
arxiv:1108.0695

B→K*μμ @LHCb

- Select events using a Boosted Decision Tree
- Veto J/ψ and ψ(2S) regions
- Weight events according to ε^{-1}
  - as a function of $(\theta_l, \phi, \theta_K, q^2)$

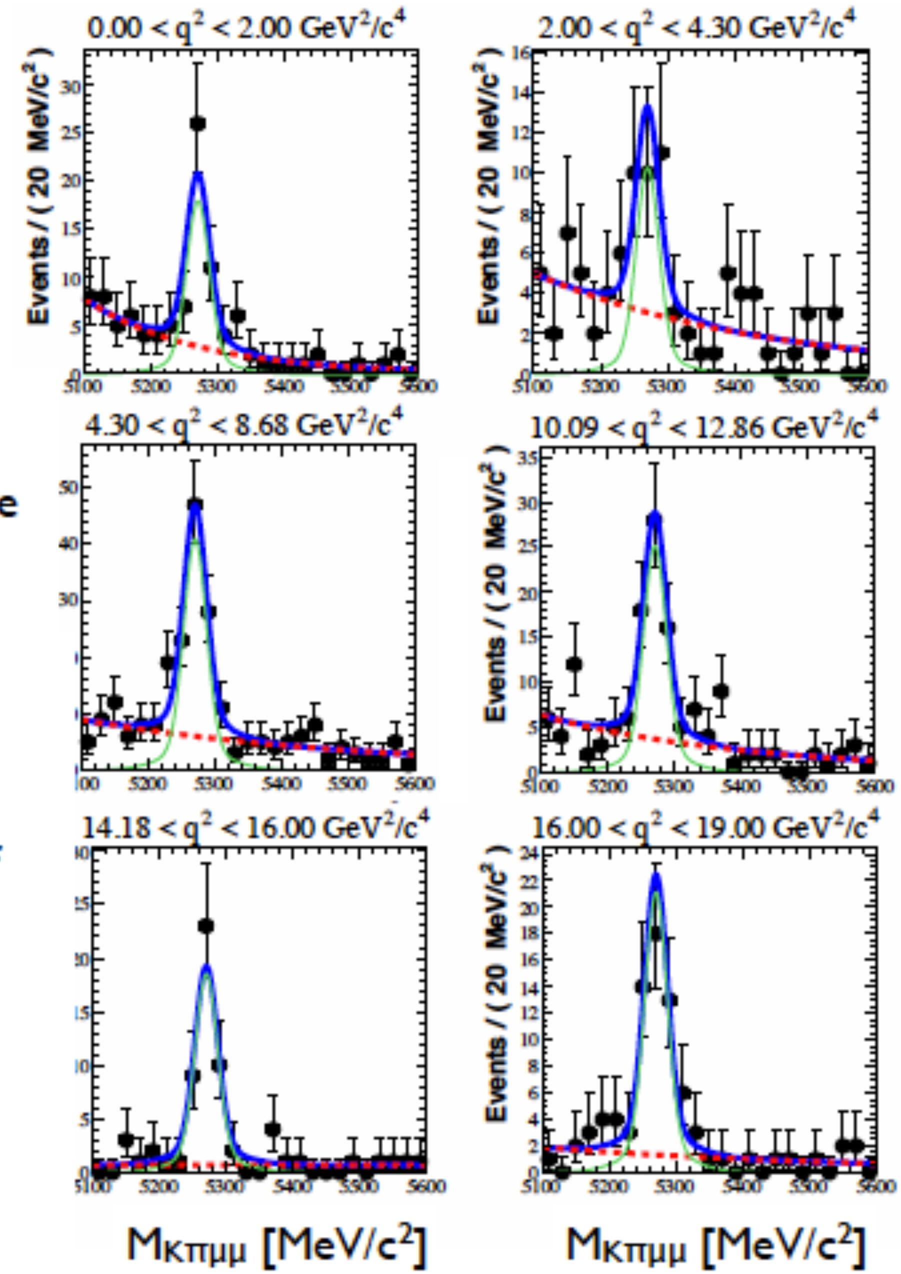




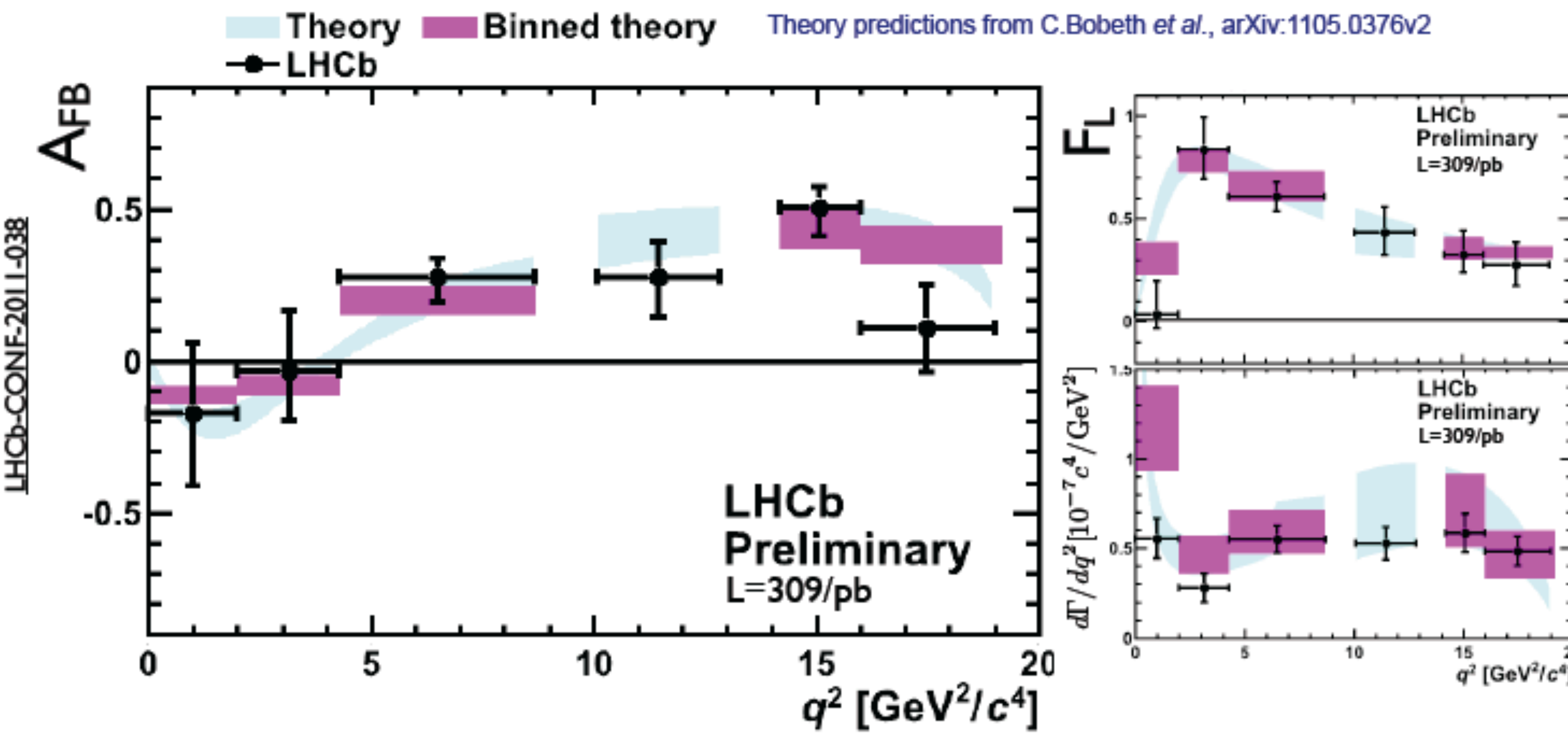


B→K*μμ

- And measure in six q^2 bins:
  - differential branching ratio $d\Gamma/dq^2$ (relative to $B^0 \rightarrow J/\psi\, K^*$)
  - longitudinal polarization, F_L
  - A_{FB}
- using *simultaneous* fit to 1-dim projections of θ_K and θ_l

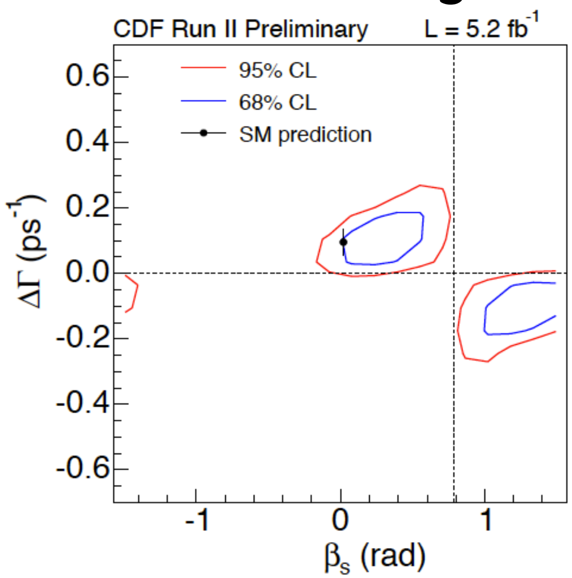


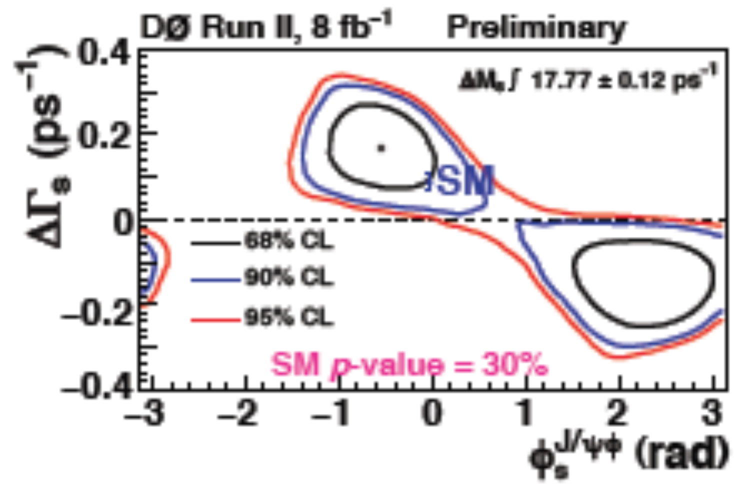
$B^0 \rightarrow K^*\mu^+\mu^-$ at LHC*b*



- Systematic uncertainties small, and generally statistics limited
- Data in excellent agreement with SM predictions at current level of precision.
- Next: add other observables such as $A_T^{(2)}$, sensitive to RH currents

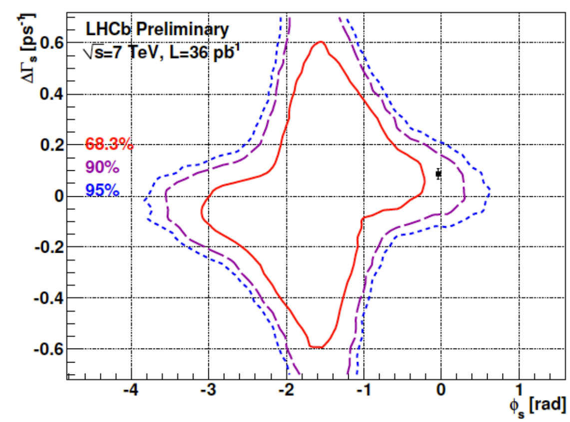
CPV in B_s mixing from $B_s \rightarrow J/\psi\phi$



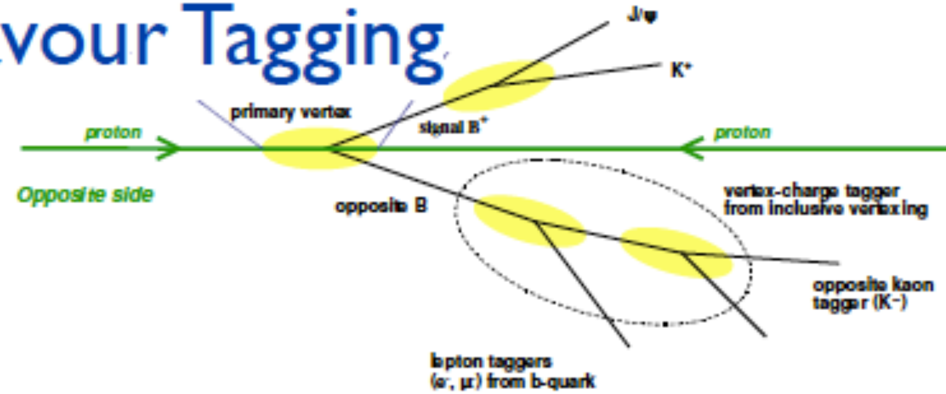


CPV phase in B_s mixing-decay interference, φ_s, measured in $B_s \rightarrow J/\Psi\varphi$ a golden observable for NP

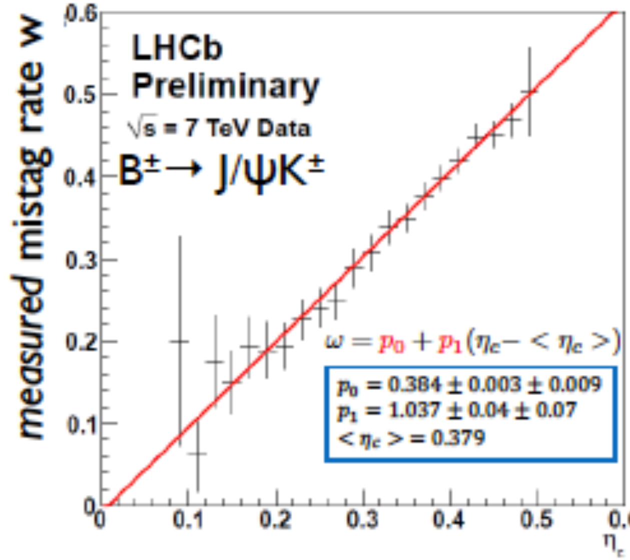
- a priori: unprobed box diagram, phase small in SM
- a posteriori: tension with SM in Tevatron measurements, and synergy with D0 dilepton asymmetry study

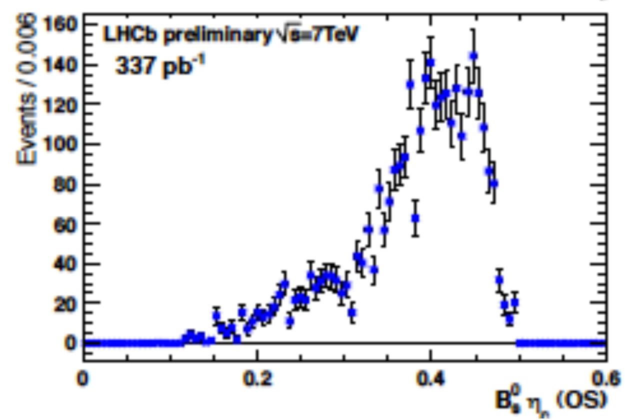


LHC*b*: $B_s \to J/\psi\phi$ - Flavour Tagging



- *Identical* to Δm_s measurement, only use opposite side for now
- Combine 4 observables into an *estimated* wrong tag probability η_c:
  1. high-p_t muons
  2. high-p_t electrons
  3. high-p_t kaons
  4. opposite side vertex charge
- Calibrate on $B^{\pm} \to J/\psi K^{\pm}$ data
- $\langle D_{tag} \rangle = 0.277 \pm 0.011 \pm 0.025$
- Tagging power $\varepsilon D^2 = (2.08 + 0.41)\%$



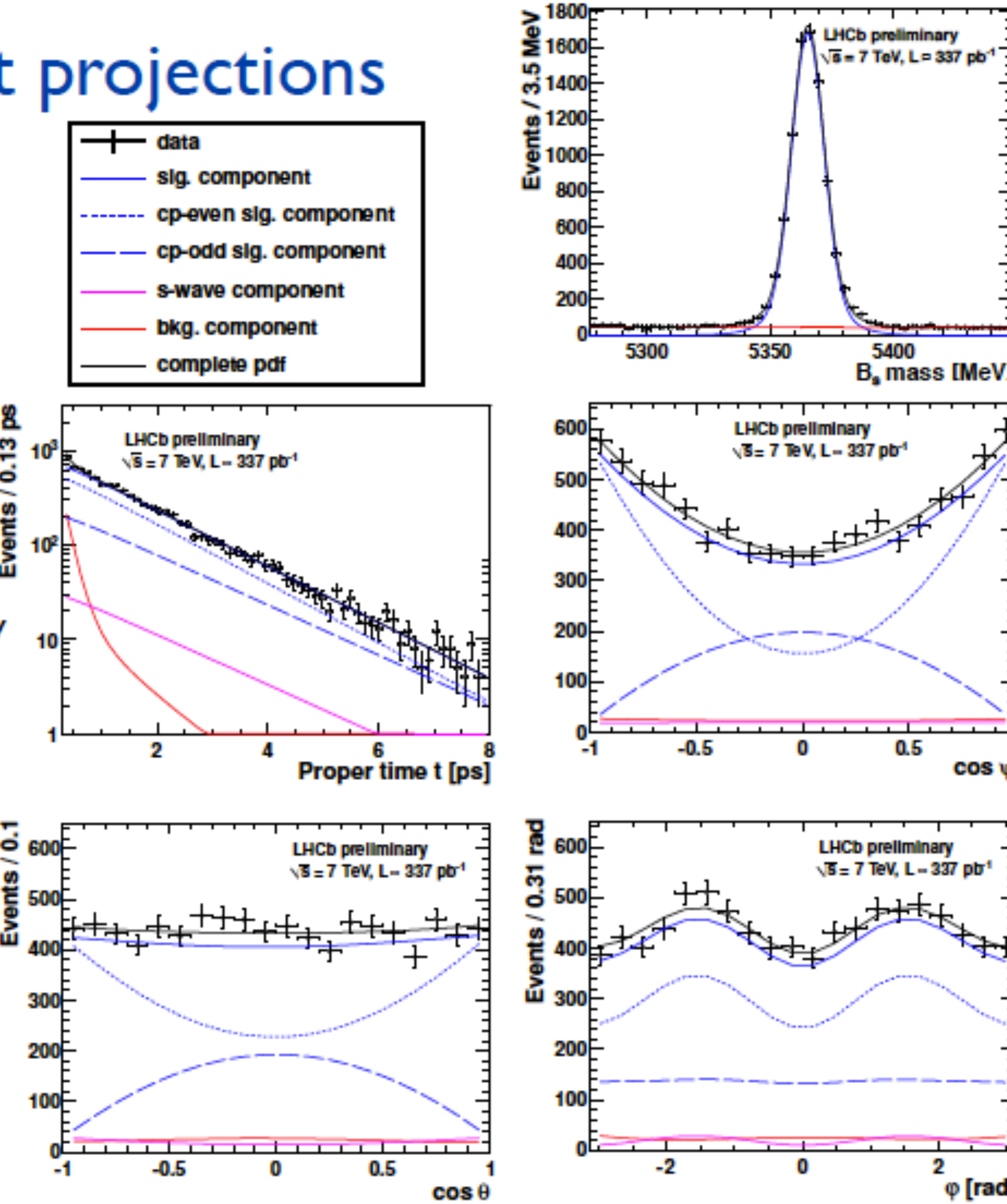


$B_s \to J/\psi\phi$: fit projections

LHCb-CONF-2011-49

N=8276±96
L=337pb^{-1}

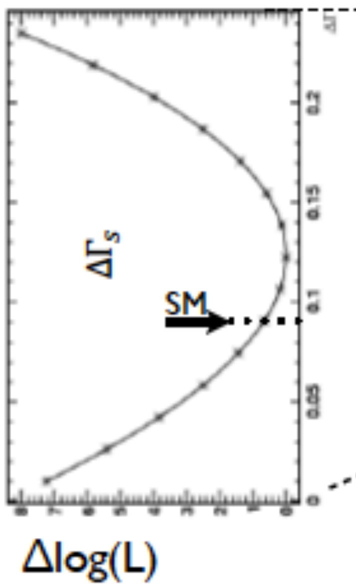
- Projections very well described
- Goodness of fit using point-to-point dissimilarity test statistic(*)
  - p-value: 0.44

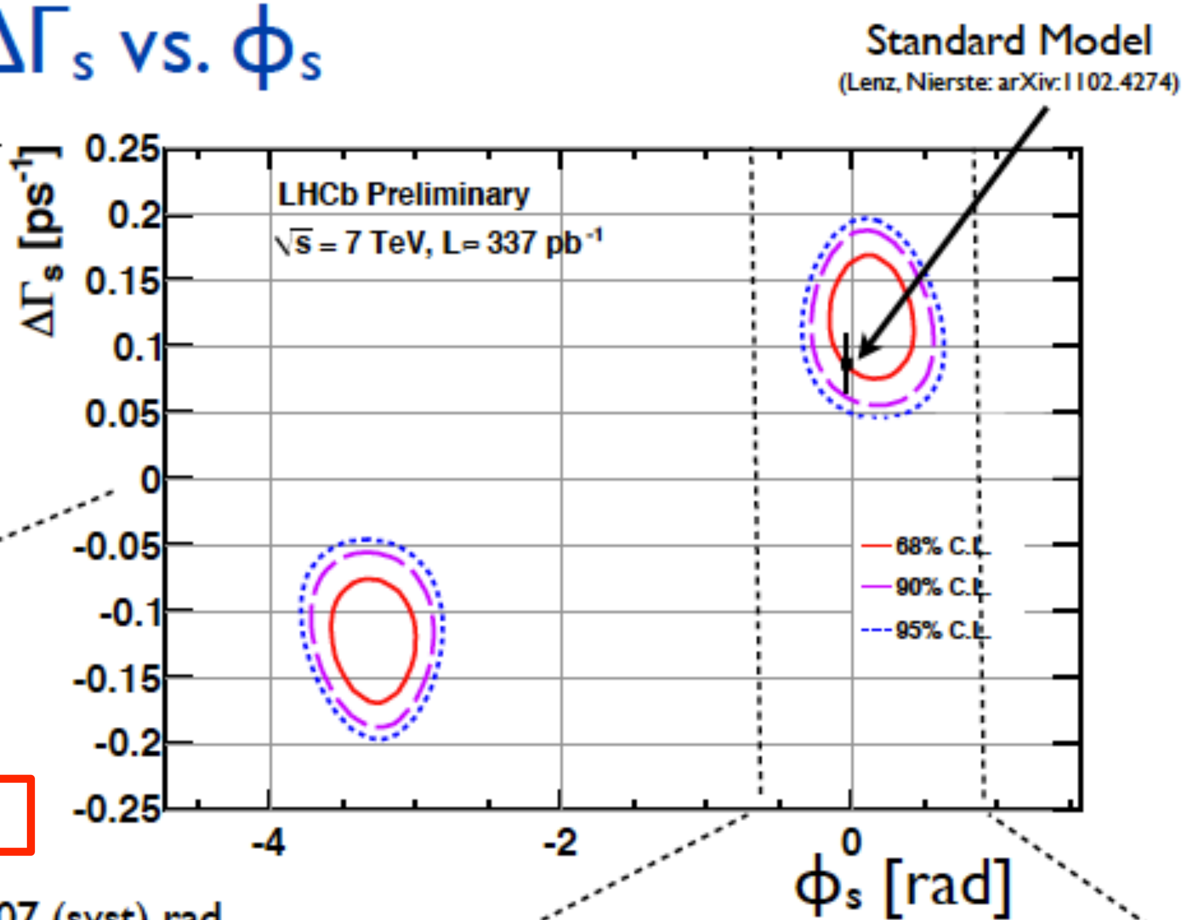


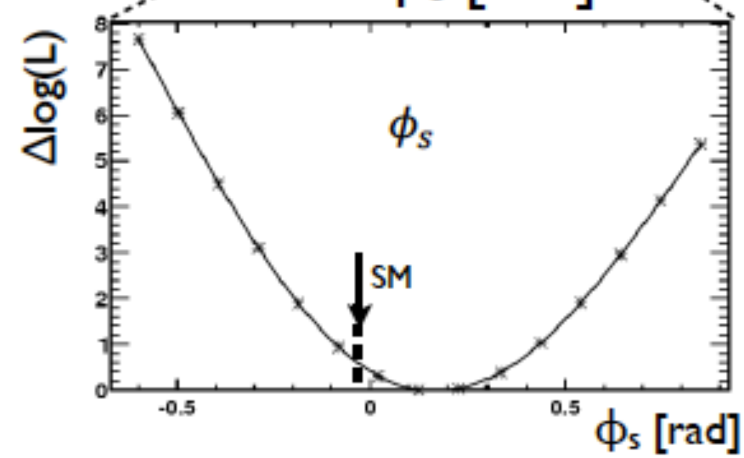
(*) see eg. M. Williams, JINST 5 (2010) P09004
[arXiv:1006.3019 [hep-ex]]

$B_s \to J/\psi\varphi$: $\Delta\Gamma_s$ vs. ϕ_s

LHCb-CONF-2011-49







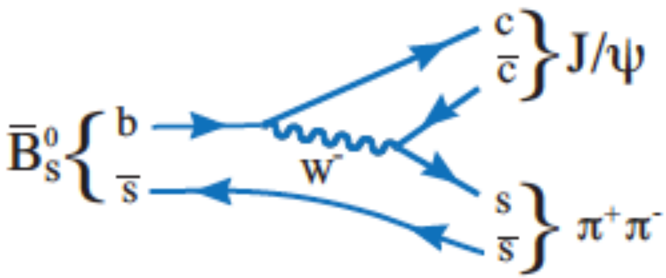
Most precise measurement of ϕ_s

- ϕ_s = 0.13 ± 0.18 (stat) ± 0.07 (syst) rad
- Consistent with SM

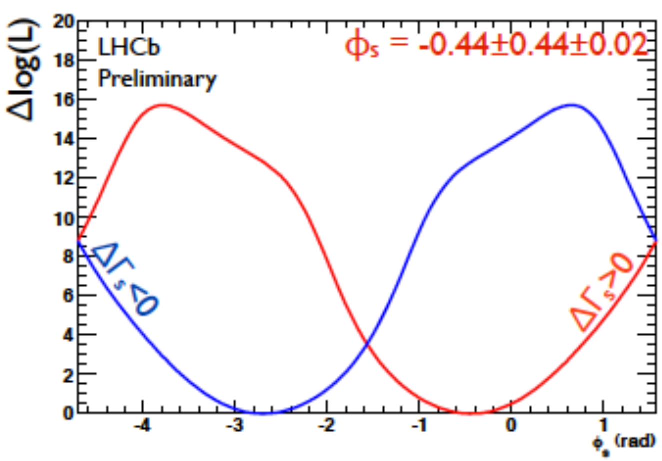
4 σ Evidence for $\Delta\Gamma_s \neq 0$:

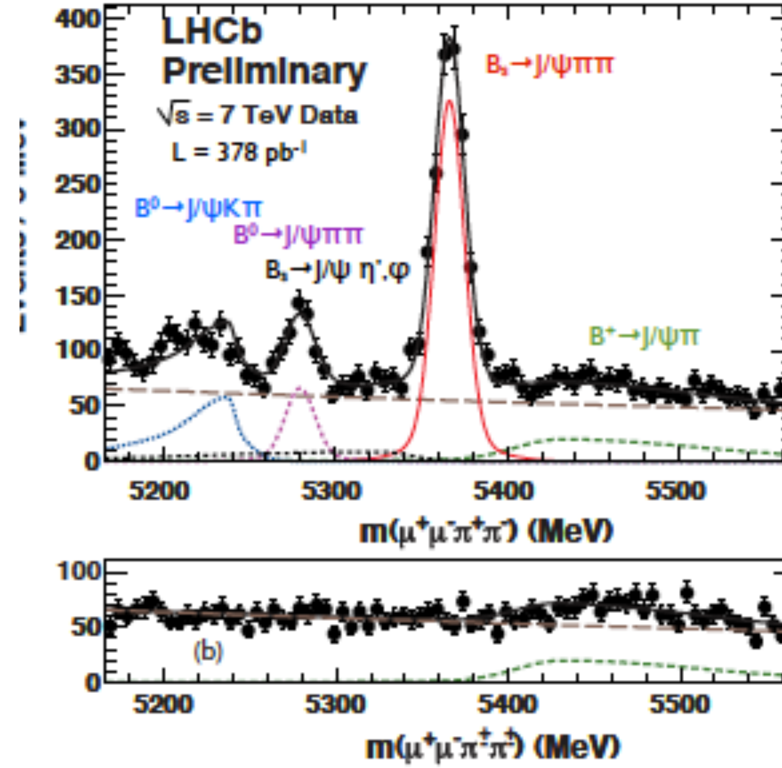
- $\Delta\Gamma_s$ = 0.123 ± 0.029 (stat) ± 0.008 (syst) ps^{-1}
- Γ_s = 0.656 ± 0.009 (stat) ± 0.008 (syst) ps^{-1}

$B_s \to J/\psi f_0$



- $f_0(980)$ is a scalar with an $s\bar{s}$ component
- But decays predominantly into $\pi^+\pi^-$
- The $f_0(980)$ signal region looks pure scalar → purely CP odd → no angular analysis required





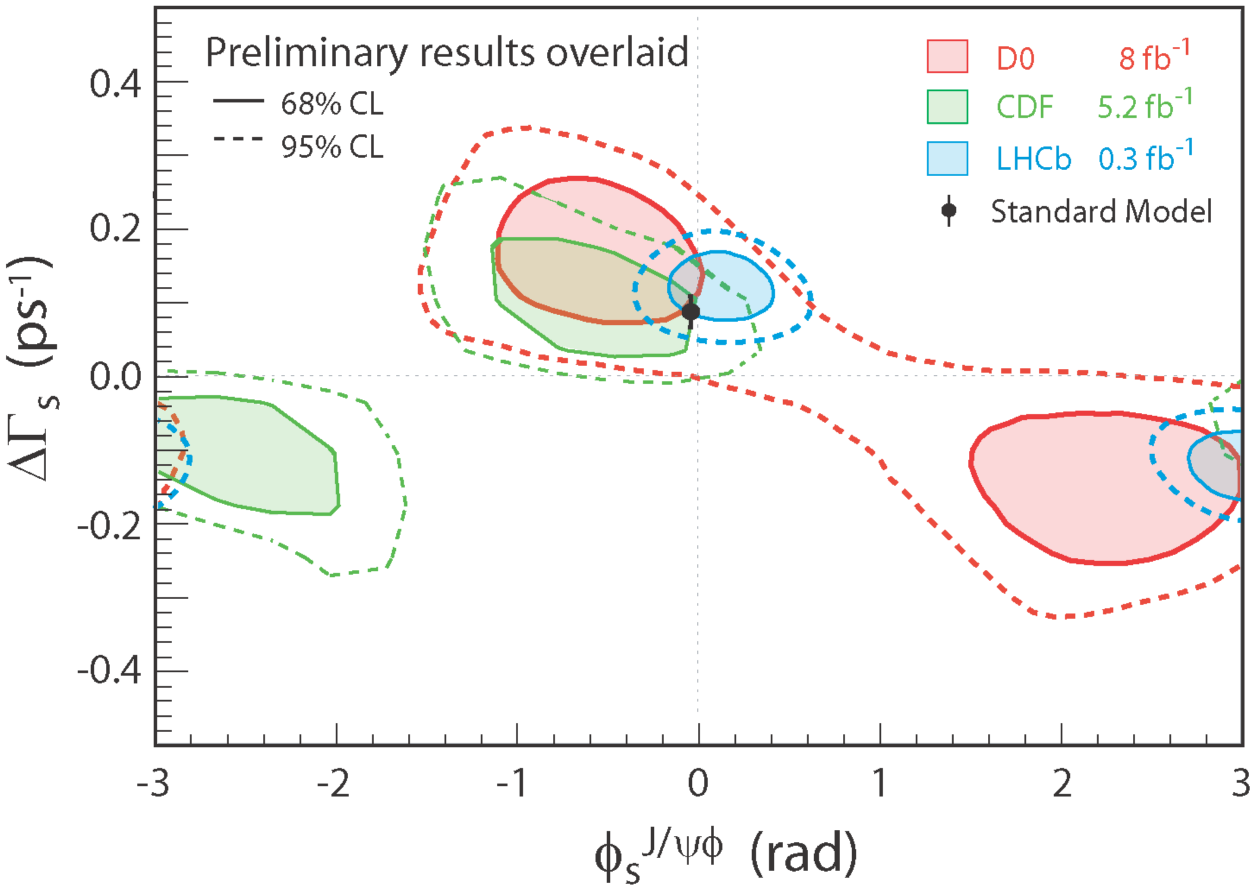
Simultaneous fit to both samples:

LHCb Preliminary

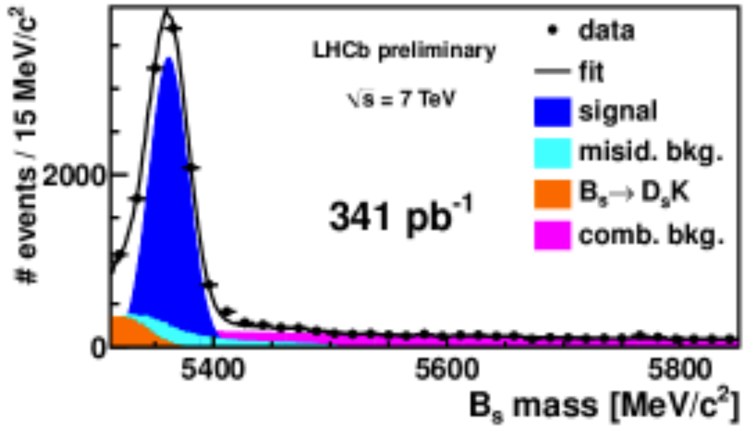
$\phi_s = 0.03 \pm 0.16 \pm 0.07$ rad

With present statistics, no evidence for deviation from the SM.

“Artists impression of overlay” LHCb and CDF, D0



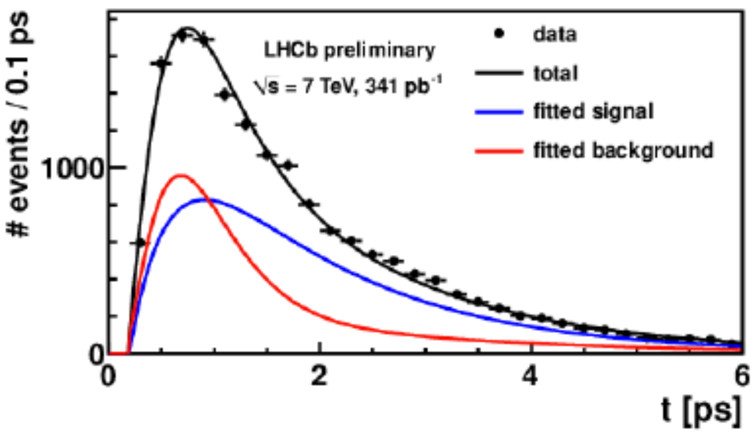
B_s mixing in $B_s \rightarrow D_s^- \pi^+$

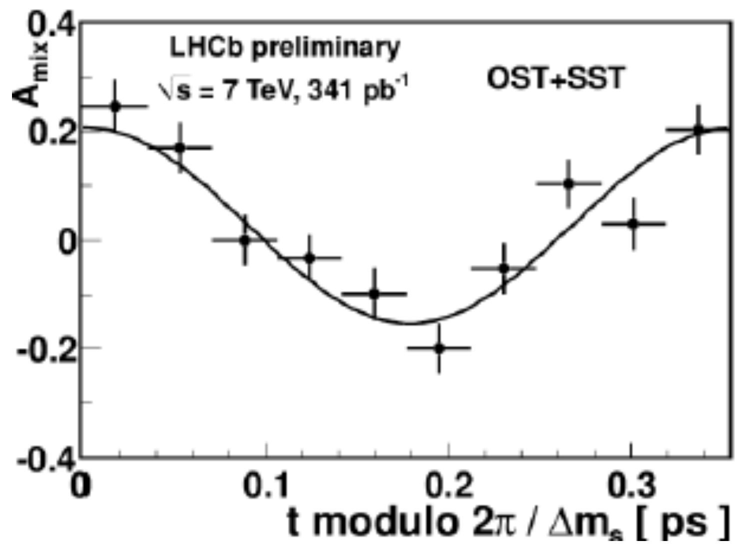


Total of 3 samples: ~9200 events

$$\varepsilon D^2_{SST} = (1.2 \pm 0.4)\%$$

$$\varepsilon D^2_{OST} = (3.1 \pm 0.8)\%$$





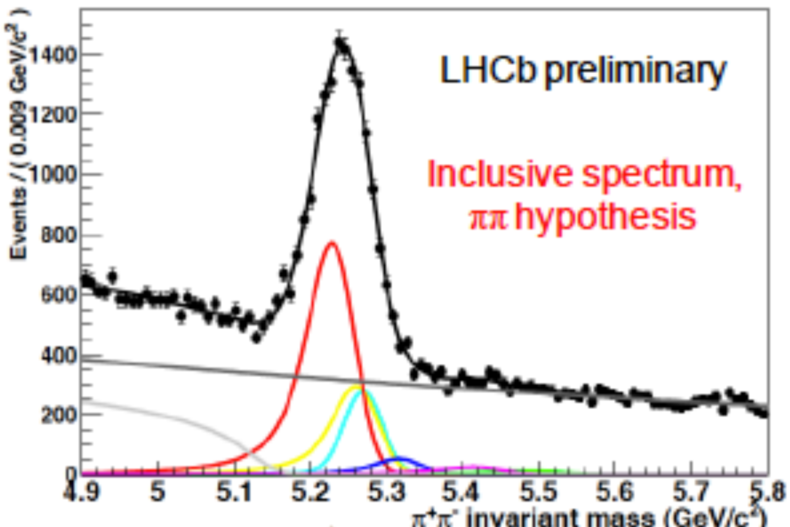
$$\Delta m_s = 17.725 \pm 0.041(stat) \pm 0.025(syst)\ ps^{-1}\ \text{(OST+SST)}$$

CDF, 1 fb^{-1} : $\Delta m_s = 17.77 \pm 0.10\ (\text{stat.}) \ \pm 0.07\ (\text{syst.})\ \text{ps}^{-1}$

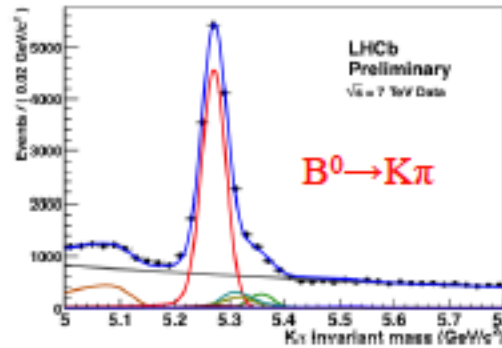
The RICHness of 'B→hh' (h=π,K,p)

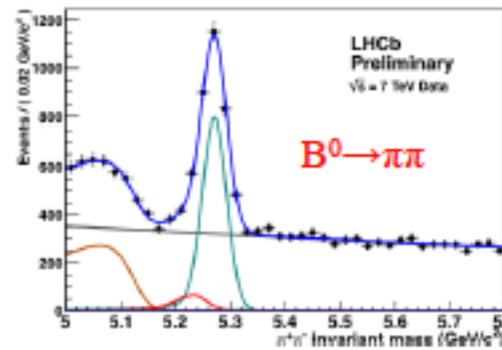
Two-body charmless B decays are central goal of LHCb physics. Significant contribution of Penguin diagrams provides entry point for New Physics

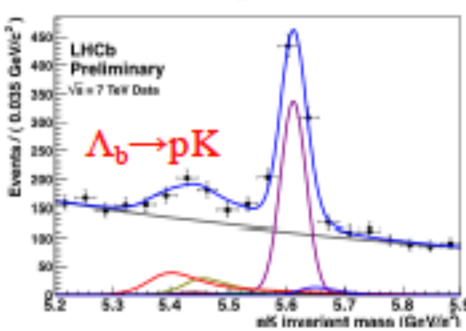
Rely on good performance of trigger and RICH

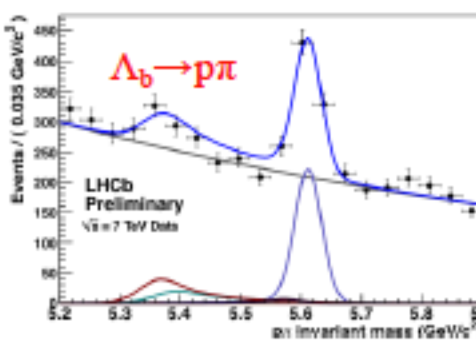


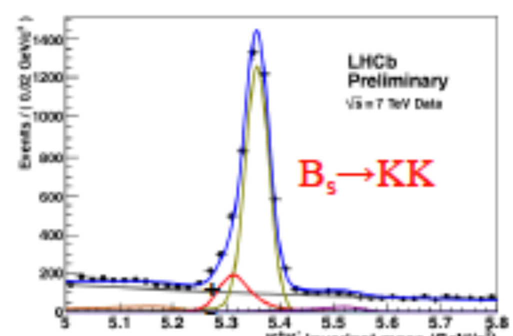
Deploy RICH to isolate each mode !









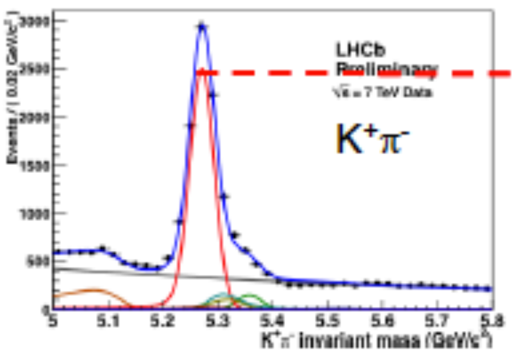


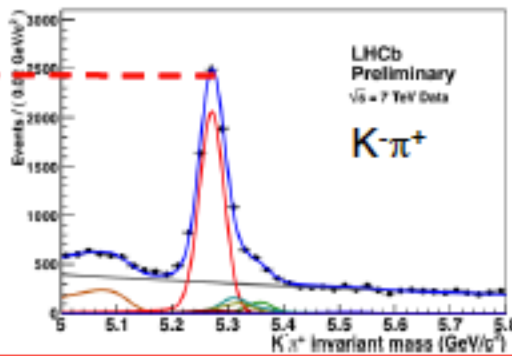
A closer look at $B_{d,s} \to K\pi$: direct CPV

The ultimate goal is to perform time dependent study, particularly of $B_s \to KK$: this will enable New Physics sensitive measurement of γ [e.g. Fleischer, PLB 459 (1999) 306]

First step: look for direct CPV in flavour specific final states [LHCb-CONF-2011-042]:

- Focus on $B^0 \to K\pi$ - here, significant CPV well established





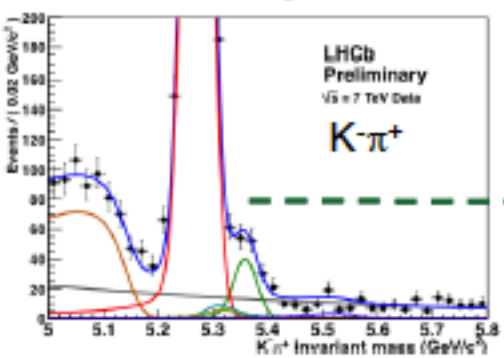
$$A_{CP}(B^0 \to K^+\pi^-) = -0.088 \pm 0.011(\text{stat}) \pm 0.008(\text{syst})$$

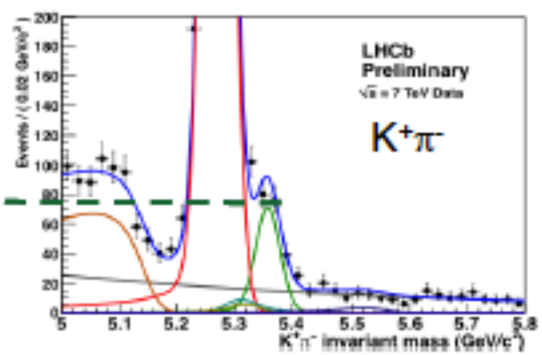
Existing world average:

$$A_{CP}(B^0 \to K^+\pi^-) = -0.098^{+0.012}_{-0.011}$$

Most precise single measurement and first 5σ observation of CPV at a hadron machine !

- Now look at $B_s \to K\pi$





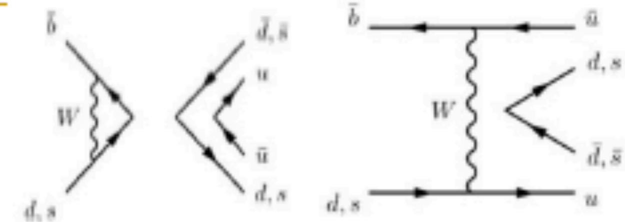
$$A_{CP}(B_s^0 \to \pi^+K^-) = 0.27 \pm 0.08(\text{stat}) \pm 0.02(\text{syst})$$

CDF result:

$$A_{CP}(B_s^0 \to \pi^+K^-) = 0.39 \pm 0.17$$

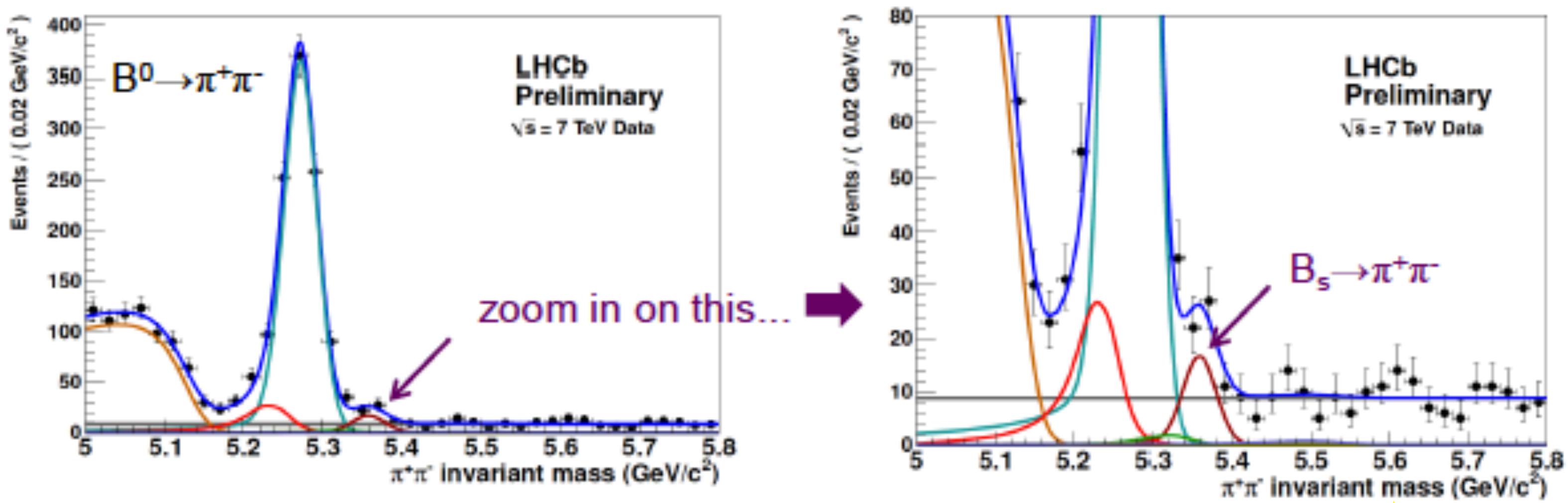
First evidence of CPV in B_s decays !

Search for $B_s \to \pi^+\pi^-$



Possible contribution of suppressed diagrams, e.g.
penguin annihilation, complicates extraction of weak phase info from B→hh decays.

To learn more, look for decays where only suppressed amplitudes contribute,
for example $B_s \to \pi^+\pi^-$. Deploy tight selection:



[LHCb-CONF-2011-042]

Signal observed with 5.2σ significance – this is a first observation

$$\mathcal{BR}(B_s^0 \to \pi^+\pi^-) = (0.98^{+0.23}_{-0.19}(\text{stat}) \pm 0.11(\text{syst})) \times 10^{-6}$$

Consistent with CDF preliminary result: $0.57 \pm 0.15 \pm 0.10 \times 10^{-6}$ [CDF-note-10498]

Towards a precise γ measurement

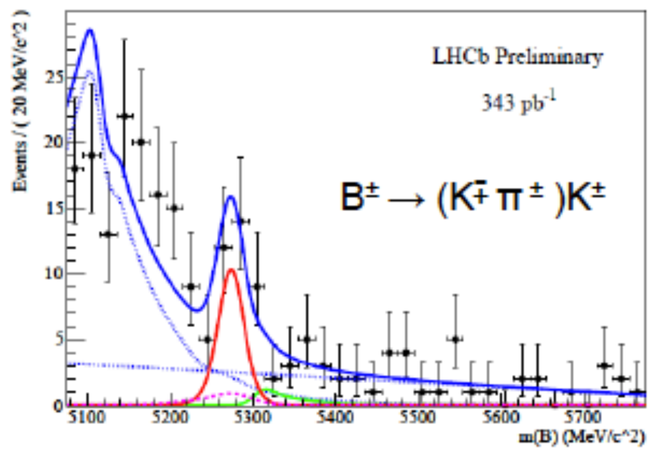
Cleanest way to γ via the interference between $B^{\pm} \rightarrow D^0K^{\pm}$, $B^{\pm} \rightarrow D^0K^{\pm}$ in decays with final states common to D^0,barD^0

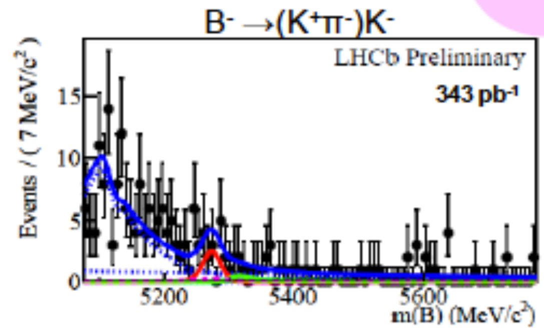
Evidence for suppressed ADS mode

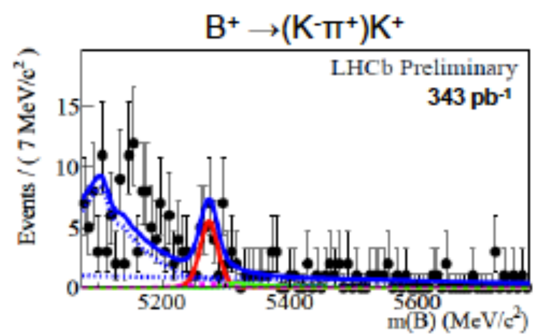
new today!

Signal seen with 4.0σ significance, & hint of asymmetry, consistent with previous results

LHCb-CONF-2011-044







Ratio to favoured mode:

$$R^{DK}_{ADS} = (1.66 \pm 0.39 \pm 0.24) \times 10^{-2}$$

World Average (without LHCb) 1.6 ± 0.3

Asymmetry:

$$A^{DK}_{ADS} = -0.39 \pm 0.17 \pm 0.02$$

World Average (without LHCb) -0.58 ± 0.21

Excited B Spectroscopy

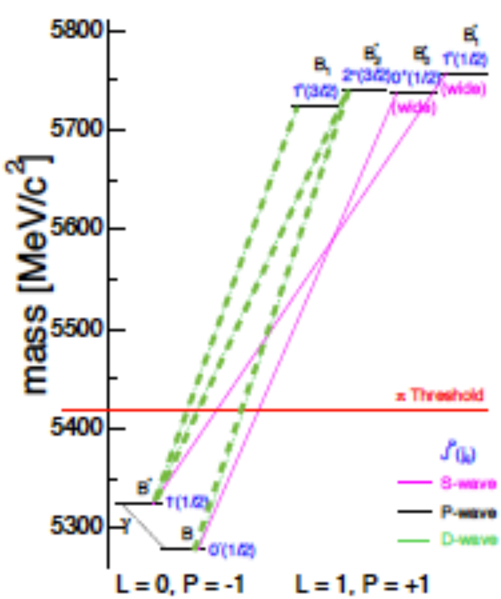
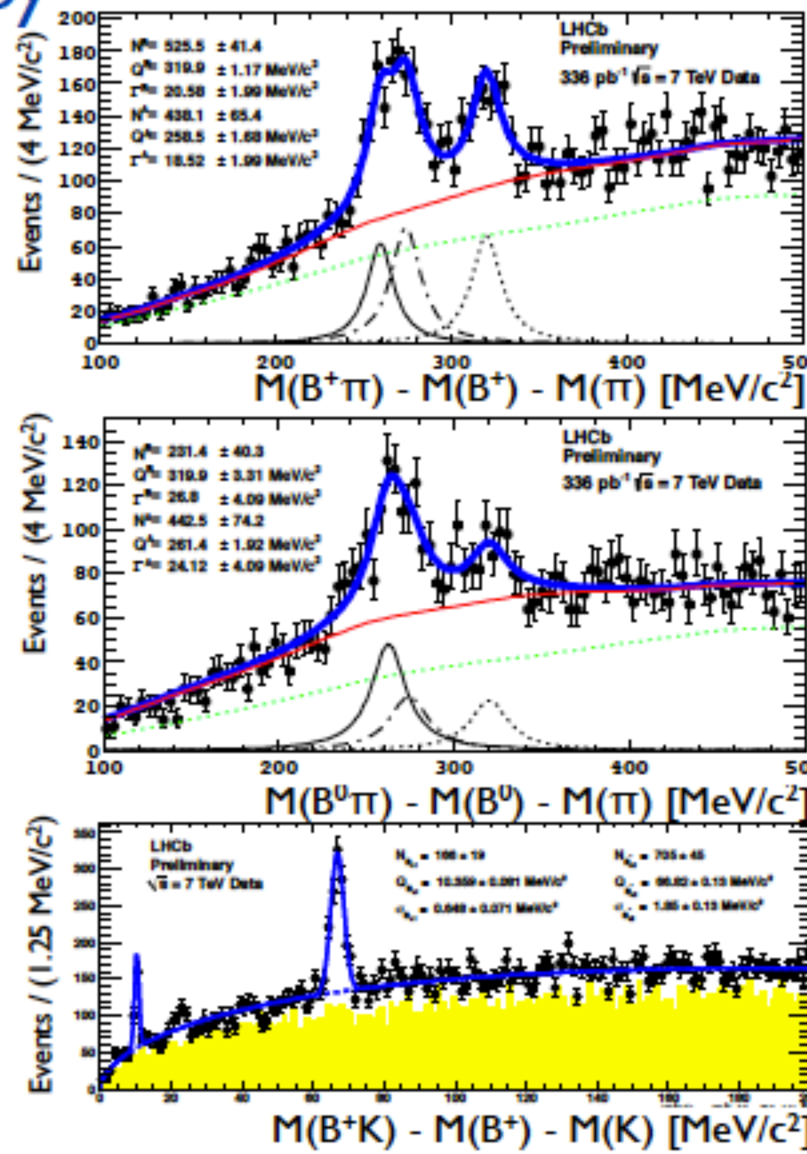


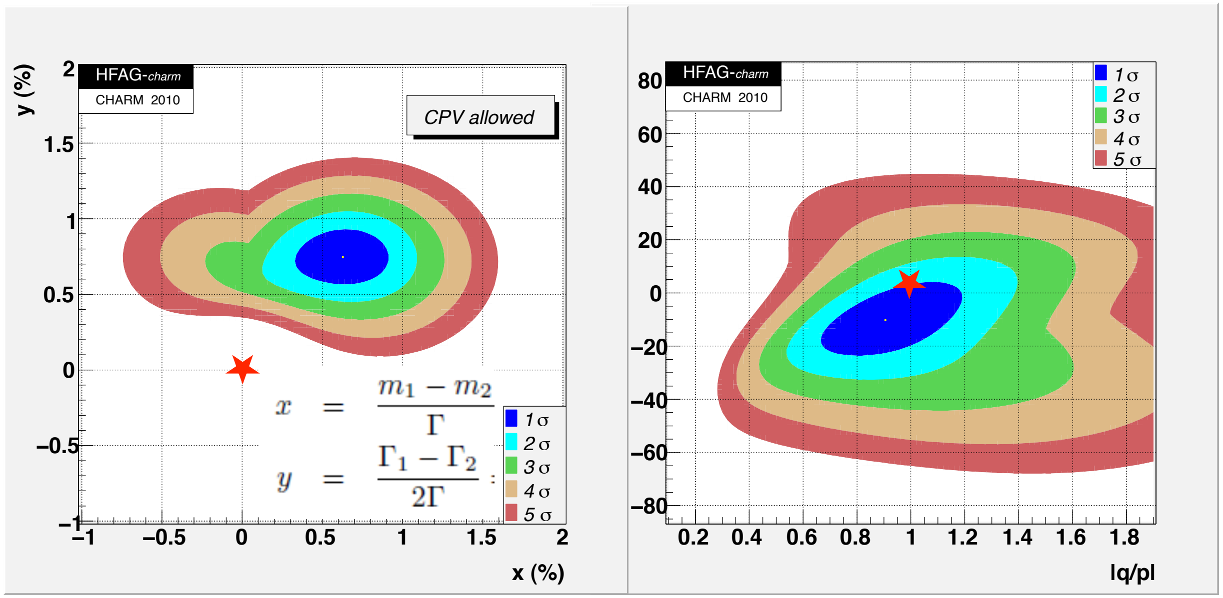
figure courtesy CDF thesis J.Pursley



LHCb-CONF-2011-053

- LHCb takes exclusive $B^0 \to J/\psi K^*$, $D\pi$, $D3\pi$, and $B^+ \to J/\psi K$, $D\pi$, $D3\pi$, and combines them with a π or K from the same primary vertex
- *First observation of the B^{**+} modes*
- Other modes already seen by CDF [PRL**100**(2008)082001), PRL**102**(2009)102003] & D0 [PRL**99**(2007)172001,PRL**100**(2008)082002]

CPV in charm



No mixing point excluded at 10.2σ by combination of several measurements. But no single experiment with 5σ evidence.

No CPV at 1σ.

Two variables for mixing and CPV study:

$$y_{CP} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to K^-K^+)} - 1 \approx y\cos\phi - x\sin\phi\frac{A_m}{2}$$

$$|q/p|^{\pm 2} = 1 \pm A_m$$

$$A_\Gamma = \frac{\tau(\bar{D}^0 \to K^+K^-) - \tau(D^0 \to K^+K^-)}{\tau(\bar{D}^0 \to K^+K^-) + \tau(D^0 \to K^+K^-)} \approx \frac{A_m}{2}y\cos\phi - x\sin\phi$$

New measurements of y_{CP} and A_Γ at LHCb with 2010 data

Measurement of A_Γ at LHCb

new today!

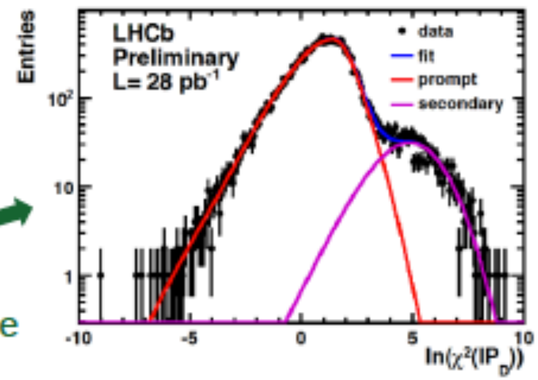
Search for non-zero value of A_Γ is one of most important ways to search of CP-violation in charm mixing

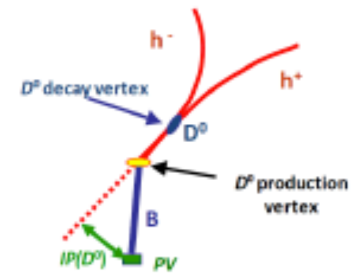
$$A_\Gamma = \frac{\tau(\overline{D}^0 \to K^- K^+) - \tau(D^0 \to K^- K^+)}{\tau(\overline{D}^0 \to K^- K^+) + \tau(D^0 \to K^- K^+)}$$

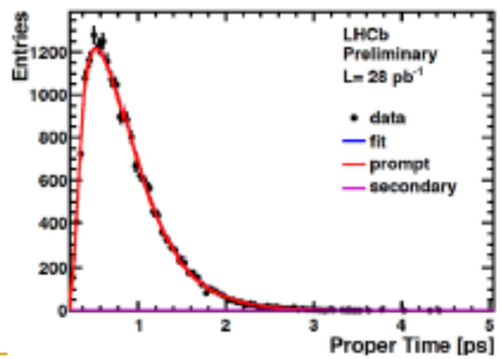
Preliminary A_Γ measurement now available from LHCb using 28 pb^{-1} of 2010 data, using $D^* \to D^0 \pi$, $D^0 \to K^+ K^-$ decays

Two main challenges in time-dependent charm studies at LHC:

- Understand 'pollution' to prompt charm sample coming from $B \to DX$
- Understand lifetime trigger acceptance







Preliminary result:

$28 \pm 3 \ \mathrm{pb}^{-1}$

A_Γ= (- 0.59 ± 0.59 ± 0.21) x 10^{-2}

c.f. world average: 0.12 ± 0.25

Recall this with only fraction of 2010 data...

LHCb-CONF-2011-046

Obtained event-by-event in data !

$$y_{CP} = (5.5 \pm 6.3_{stat} \pm 4.1_{syst}) \times 10^{-3}$$

BaBar:

$$A_\Gamma = (0.1 \pm 3.0 \pm 1.5) \times 10^{-3}$$

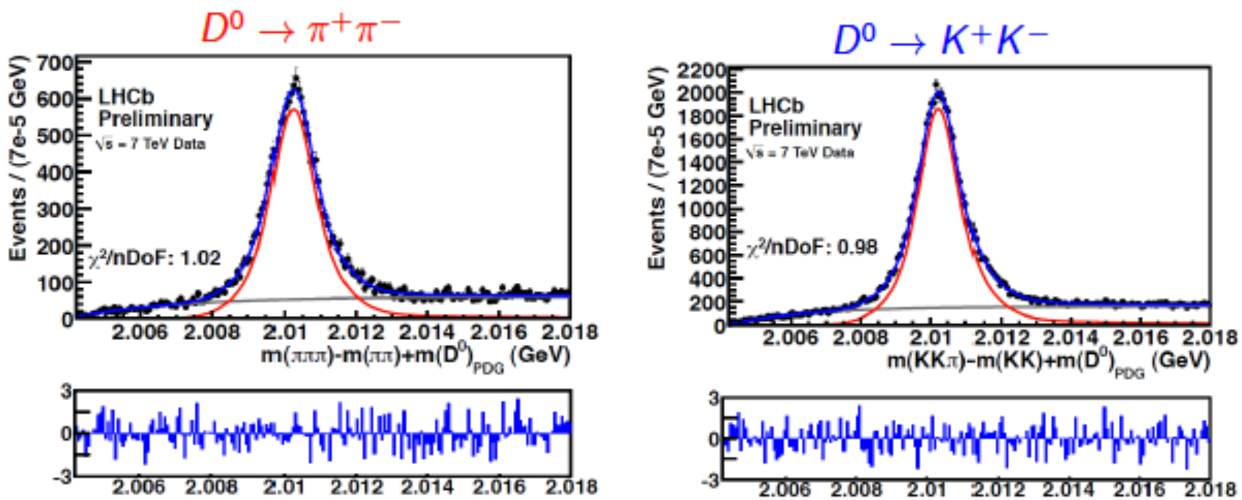
$$y_{CP} = (11.6 \pm 2.2 \pm 1.8) \times 10^{-3}$$

Time-integrated CP Asymmetry in $D^0 \to \pi^+\pi^-, D^0 \to K^+K^-$

- Search for direct CPV. Use $D^{*+} \to D^0\pi^+$ tagged events and difference between two decay channels to cancel effects of detector and production asymmetries:

$$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = A_{CP}^{raw}(K^+K^-) - A_{CP}^{raw}(\pi^+\pi^-)$$

37 pb^{-1}



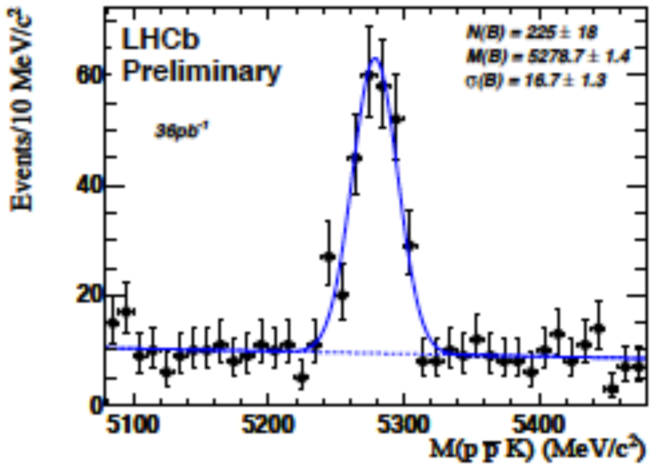
LHCb preliminary

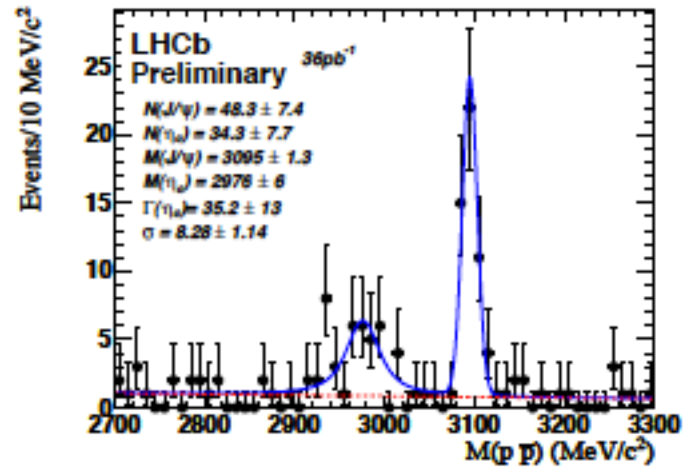
$$\Delta A_{CP} = (-0.28 \pm 0.70 \pm 0.25)\%$$

Will soon be updated with ~300 pb^{-1}.

Relative BR for $B^{\pm} \rightarrow p\bar{p}K^{\pm}$

36 pb^{-1}





Mode	$\mathcal{BR}$ LHCb $[10^{-6}]$	earlier meas. $[10^{-6}]$
J/ψ	-	2.2 ± 0.1
ALL	$10.2 \pm 1.3 \pm 1.0 \pm 0.5$	$10.76^{+0.36}_{-0.33} \pm 0.70$
$M_{pp} < 2.85$	$4.87 \pm 0.91 \pm 0.54 \pm 0.222$	5.12 ± 0.31
η_c	$1.57 \pm 0.43 \pm 0.15 \pm 0.07$	1.54 ± 0.16

Results compatible with measured values at the B-factories.

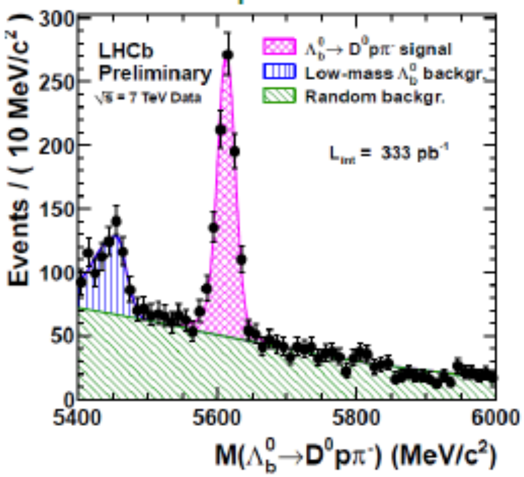
New measurements with b-baryons

new today!

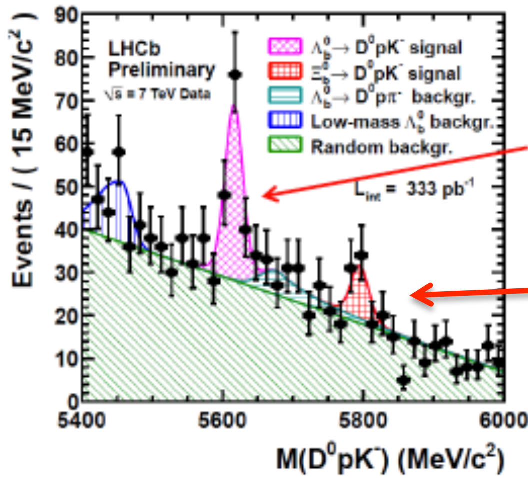
Interesting to look for the decay $\Lambda_b \to D^0pK$, as it is a potentially powerful mode for measuring CKM angle γ. First step is to reconstruct normalisation mode $\Lambda_b \to D^0p\pi$

LHCb-CONF-2011-036

$D^0p\pi^-$



D^0pK^-



$\Lambda_b \to D^0pK$

$\Xi^0_b \to D^0pK$

$\Lambda_b \to D^0pK$ observed for first time with significance of 6.3σ

$$\frac{\mathcal{B}(\Lambda_b^0 \to D^0pK^-)}{\mathcal{B}(\Lambda_b^0 \to D^0p\pi^-)} = 0.112 \pm 0.019^{+0.011}_{-0.014}$$

Measure relative production rate x BR:

$$\frac{f_{b\to\Xi_b^0} \times \mathcal{B}(\Xi_b^0 \to D^0pK^-)}{f_{b\to\Lambda_b^0} \times \mathcal{B}(\Lambda_b^0 \to D^0pK^-)} = 0.29 \pm 0.12 \pm 0.08$$

Measure mass relative to Λ_b:

$$m(\Xi_b^0) - m(\Lambda_b^0) = (181.8 \pm 5.5 \pm 0.5)\ \mathrm{MeV}/c^2$$