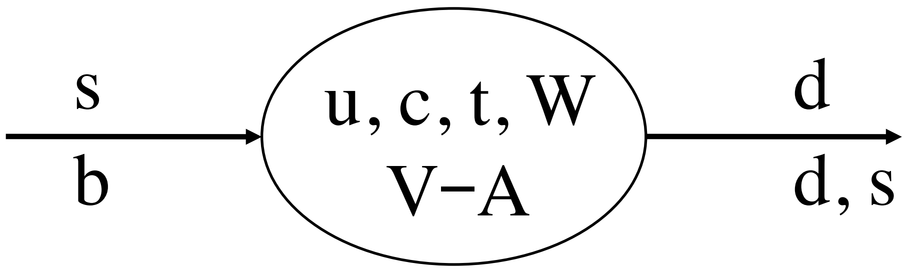
Flavour Physics and Recent Results from the LHCb Experiment

The Zürich Phenomenology Workshop
Higgs search confronts theory
Zürich, Switzerland, 9-11 January 2012

T. Nakada
EPFL-LPHE
Lausanne, Switzerland

Evolution of Flavour physics (I)

- Quark flavour physics, has been successfully uncovering physics at much higher scale than directly accessible, e.g. quark family structure and 3rd generation of quark family. Using the quantum fluctuations in the loop diagram



Examples

- Δm_K and Br($K_L \to \mu^+\mu^-$) $\Rightarrow$ m_c Lee&Gaillard (1974)
  charm discovery Aubert et al., Augustin et al., 1974 (Niu et al. 1971?)
- CP: 1964, J.H. Christenson et al., Br($K^0{}_L \to \pi^+\pi^-$) $\neq$ 0
  $\Rightarrow$ Third family Kobayashi&Maskawa (1973)
- B^0-$\overline{B}^0$ oscillations (Δm_B): ARGUS (1987)
  $\Rightarrow$ m_t > 50 GeV/c^2 (NB: UA1 1984 20<m_t<50 GeV/c^2)
  top discovery by CDF and D0 in 1995 (m_t = 171.2±2.1 GeV/c^2)
- They were done before the direct discovery of c, b and t quarks
- Establishing the KM phase as the major source of CP violation
- Flavour Physics made crucial contributions to establish the flavour structure of the SM

First charm?

Prog. Theor. Phys. Vol. 46 (1971), No. 5

A Possible Decay in Flight of a New Type Particle

Kiyoshi NIU, Eiko MIKUMO and Yasuko MAEDA*

Institute for Nuclear Study University of Tokyo
**Yokohama National University*

August 9, 1971

1971
emulsion exposed in
a JAL Jet cargo plane

one event of
$X \to \pi^0$ + one charged hadron

hypo.	$\pi^0\pi^{charged}$	$\pi^0 p$
τ(s)	2.2×10^{-14}	3.6×10^{-14}
m(GeV)	1.78	2.95

Possibly, the first observation of $D\to K\pi^0$ decay in 1971

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Top quark mass?

UA1, 1984

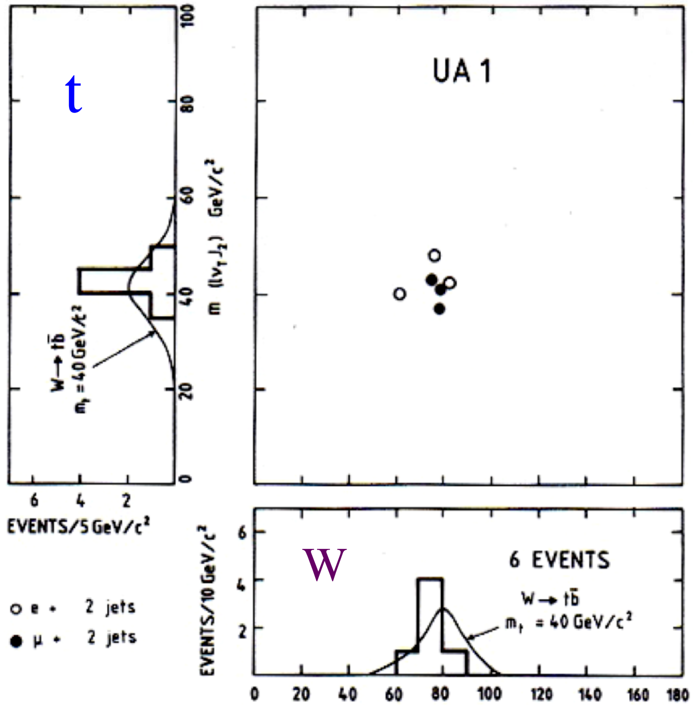
$p\bar{p} \rightarrow W^{+} + X$

↳ $t\,\bar{b}$ ⟶ jet

↳ $b l \nu$

↳ jet

$m_t = 30 \sim 50$ GeV/c^2



Phys. Lett. 147B (1984) 493

Phys. Lett. B 192 (1987) 245

ARGUS, 1987

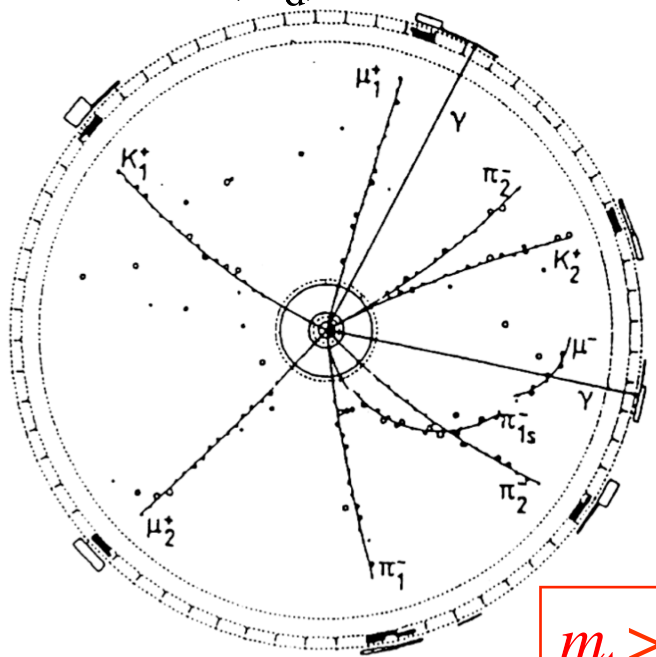
$\Upsilon(4S) \rightarrow B_d^0 \overline{B}_d^0$

$\rightarrow B_d^0 B_d^0$ or $\overline{B}_d^0 \overline{B}_d^0$

$\rightarrow \ell^+\ell^+$ or $\ell^-\ell^-$

24.8±7.6±3.8

$\Delta m(B_d) \sim 100 \times \Delta m(K^0)$



$m_t > 50$ GeV/c^2

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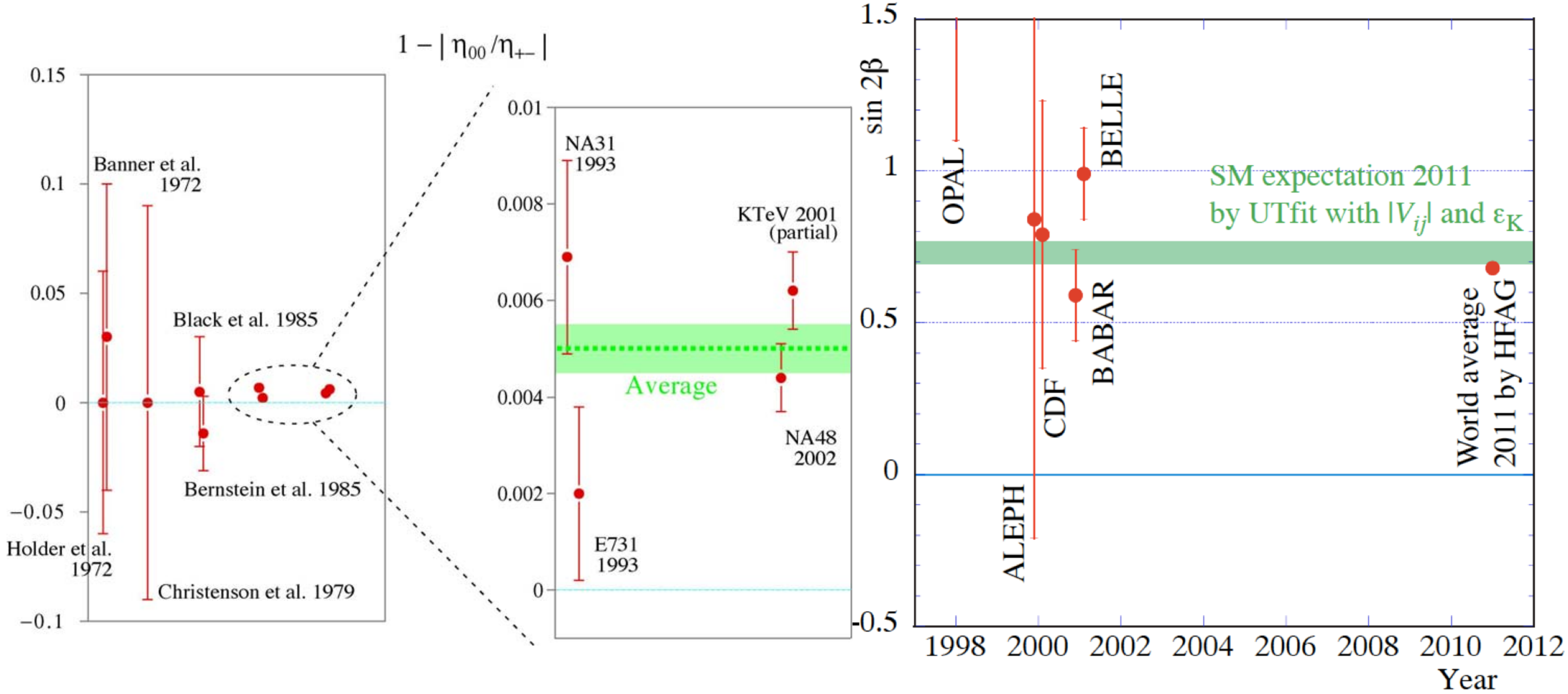
CPV within the SM framework?

- In 2001
  - Superweak model ruled out by $\mathrm{Re}(\varepsilon'/\varepsilon) \neq 0$ in K^0
  - CPV in $B \rightarrow J/\psi K_S$ is in very good agreement with the SM prediction



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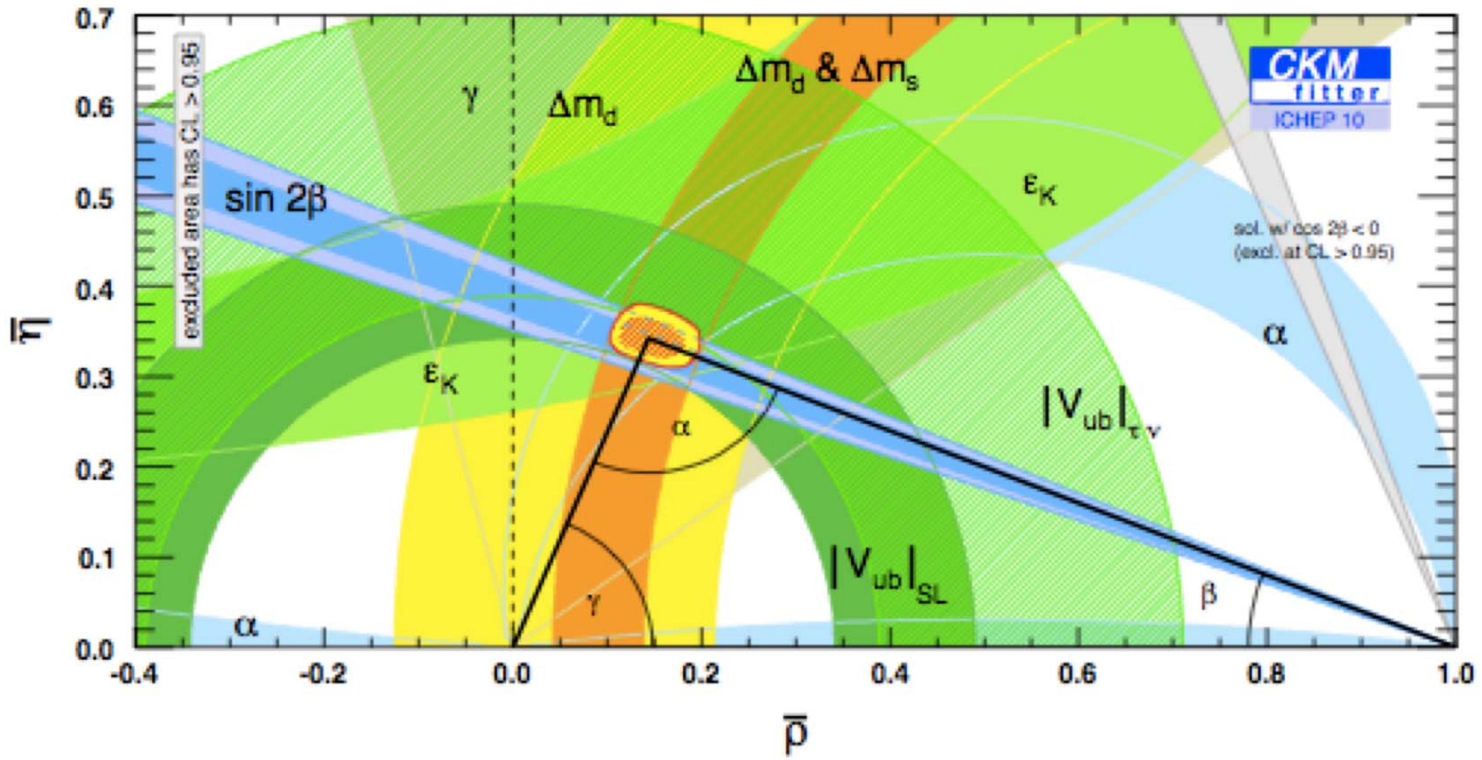
Flavour physics agreement with SM

- All the flavour changing processes are described by the four parameters of the CKM mass mixing matrix (λ, A, ρ, η)



- However from this plot, we know already either new physics energy scale is >> TeV (far beyond LHC) or the flavour structure of new physics is very special.

Evolution of Flavour physics (I)

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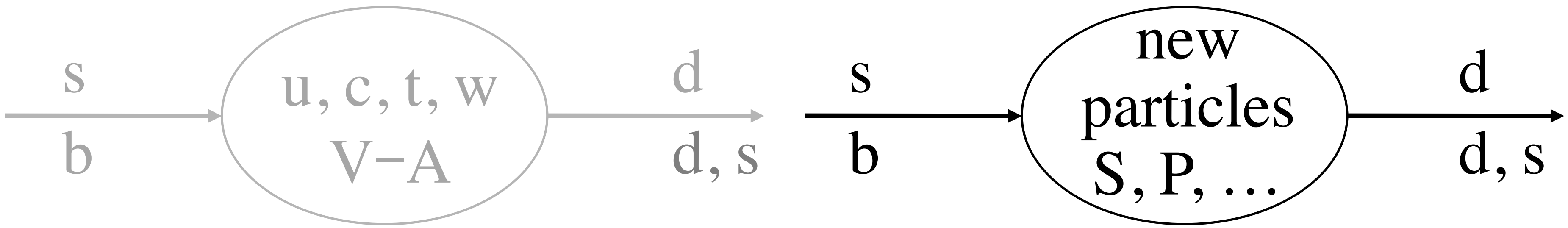


amplitude: $A = A_{SM} + A_{NP}$

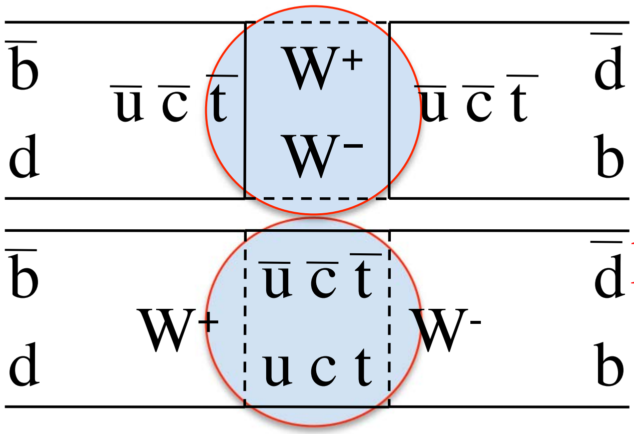
|A|: rare decays, Δm

arg A: CP violation

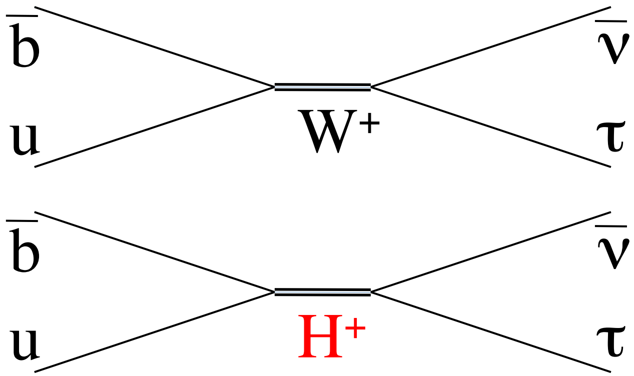
Lorentz structure of A: "photon" polarization via final state angular distribution or mixing-decay CP violation

Where are the sign of new physics?

- If one looks closer, there exists hint of discrepancies…
  - "sin 2β" extracted from CPV in $B_d \rightarrow J/\psi K_S$ somewhat small
  - $|V_{ub}|$ extracted from $B \rightarrow \tau\nu$ decays larger than $|V_{ub}|$ extracted from the semileptonic decays.
- This could be due to
  1. Problem with extracting $|V_{ub}/V_{cb}|$ due to the hadronic uncertainties
     OR
  2. New Physics in B^0-$\overline{B}^0$ oscillations and charged Higgs in $B \rightarrow \tau\nu$



+ new particles



Where are the sign of new physics?

- For many processes, current experimental limits on new physics are still very large, up to ~$O(10)$ above the SM values:
  - $B_s \rightarrow \mu^+\mu^-$
  - CPV in $B_s \rightarrow J/\psi\phi$
  - Lorentz structure in b→s radiative decays, $B^0 \rightarrow K^{*0}\mu^+\mu^-$, CPV in $B \rightarrow \phi\gamma$, etc.
  - CP violation in D system
- Comparison of (ρ, η) determined from the tree processes, i.e. $|V_{ub}|$ and γ (B→DK), and (ρ, η) from the loop processes, i.e. ε_K, β, Δm_d and Δm_s.

Swiss thought about B factory in 80's

- Swiss option
  - SIN in 1986 with $L > 5\times10^{32}$ cm^{-2}s^{-1} symmetric energy
  - PSI Proposal (1988), $L > 10^{33}$ cm^{-2}s^{-1} modest asymmetric energy option

Was quite a pioneering effort, but no B factory was constructed in Europe

PR-86-13

SIN

Motivation and Design Study
for a B-Meson Factory with High Luminosity

R.Eichler[1], T.Nakada[2], K.R.Schubert[3], S.Weseler[3], and K.Wille[4]

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2) Schweizerisches Institut für Nuklearforschung (SIN)
CH-5234 Villigen, Switzerland
3) Institut für Hochenergiephysik, Universität Heidelberg
D-6900 Heidelberg, Germany
4) Institut für Physik, Universität Dortmund
D-4600 Dortmund, Germany

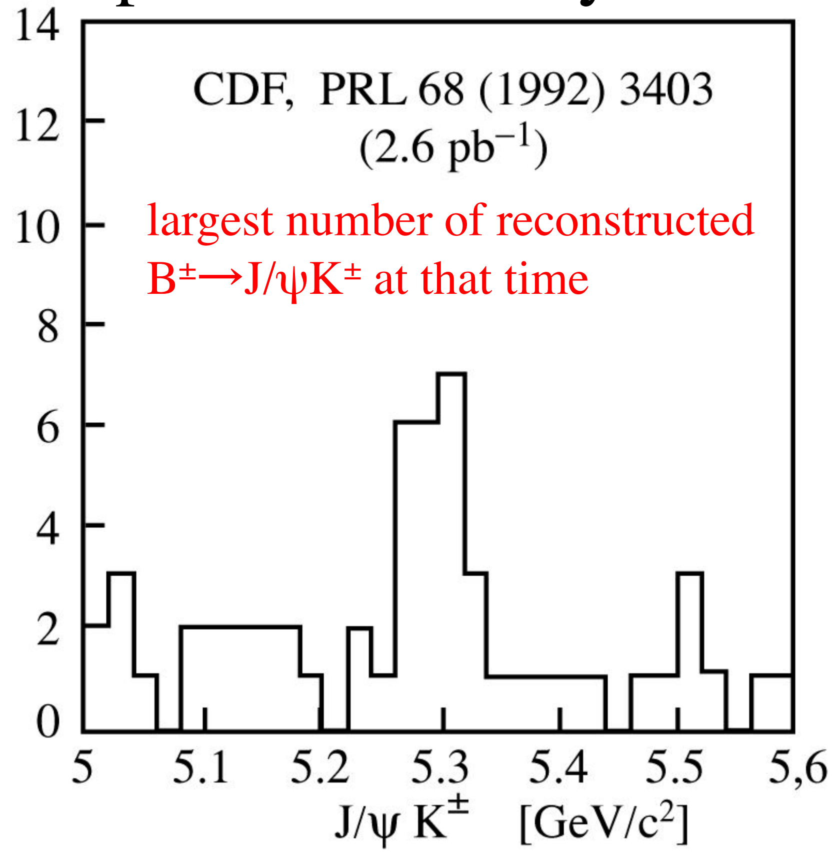
November 24, 1986

Swiss Institute
for Nuclear Research

CH-5234 Villigen
Switzerland

Hadron colliders also interesting

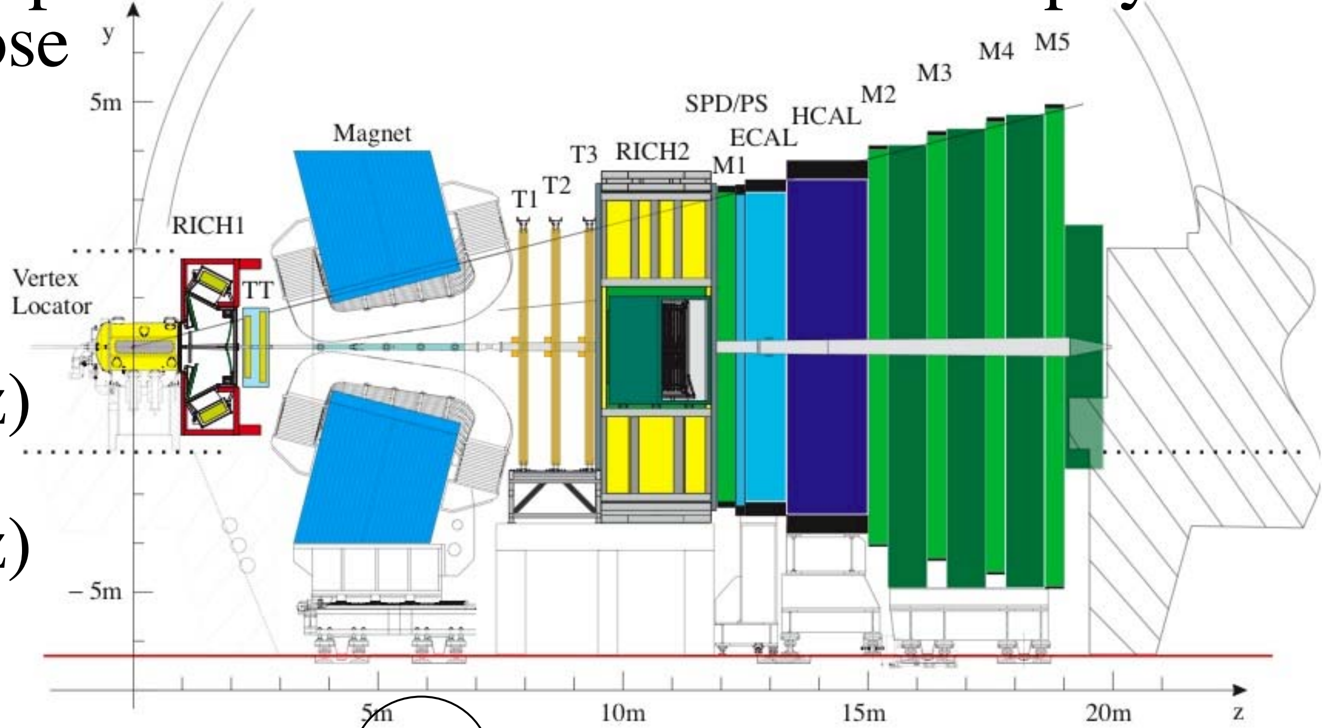
- Tevatron started in 1988, showed its potential already during Run I, thanks to large $\sigma_{b\bar{b}}$
- Three EoI's at the Evian workshop 1992 (before the B factory approvals), followed by three LoI's.
- Unified experiment, LHCb approved in 1998.

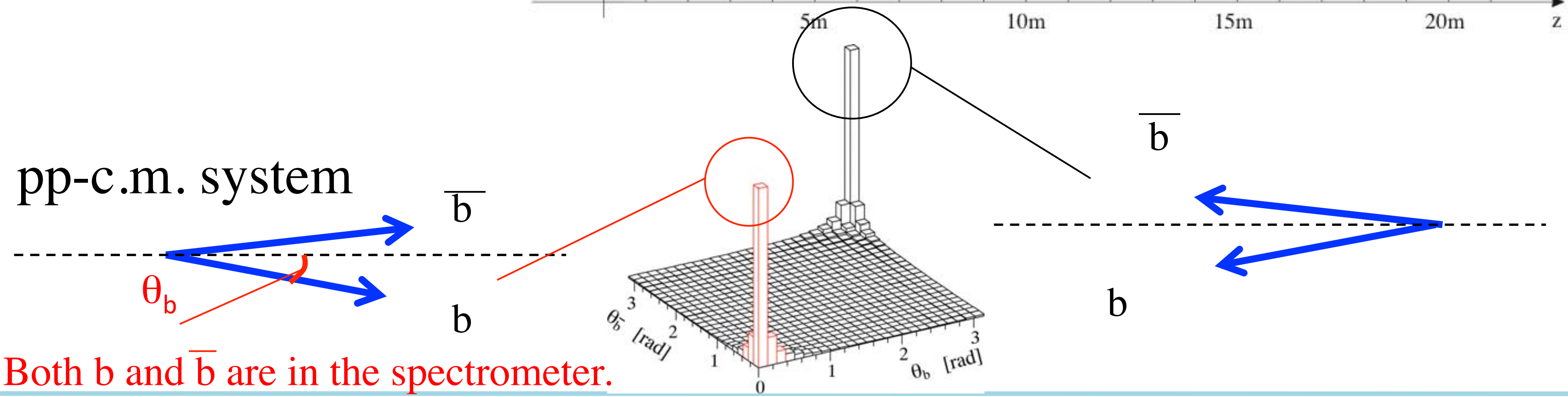


Quick reminder for LHCb

LHCb is a forward spectrometer dedicated for flavour physics

- -Vertex detector close to the beam
- -RICH for PID
- -High rate readout for software trigger (~1 MHz)
- -High rate data logging (~3 kHz)





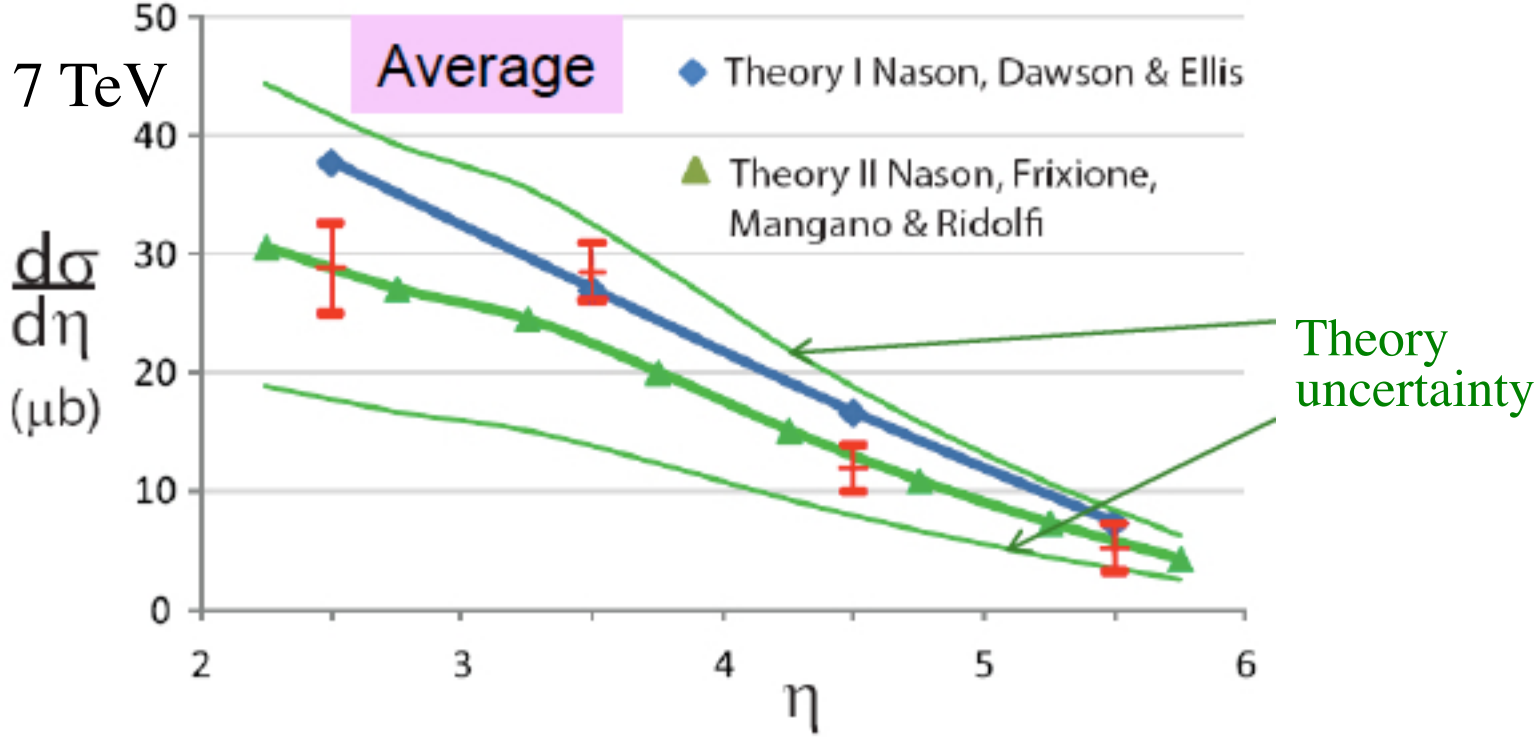
Both b and $\bar{b}$ are in the spectrometer.

Very rapid start of the experiment

- As ALICE, ATLAS, and CMS, LHCb was ready for physics right from the first collision in 2010 at $\sqrt{s}$ = 7 TeV
  e.g. $\sigma_{b\bar{b}}$ $B \to \mu D(\to K\pi)X$ and $B \to J/\psi(\to \mu\mu)X$

LHCb PLB2010

pp $\sqrt{s}$ = 7 TeV
25 nb^{-1}



Real demonstration of LHCb in 2010

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
  - cleanly reconstructed B_s

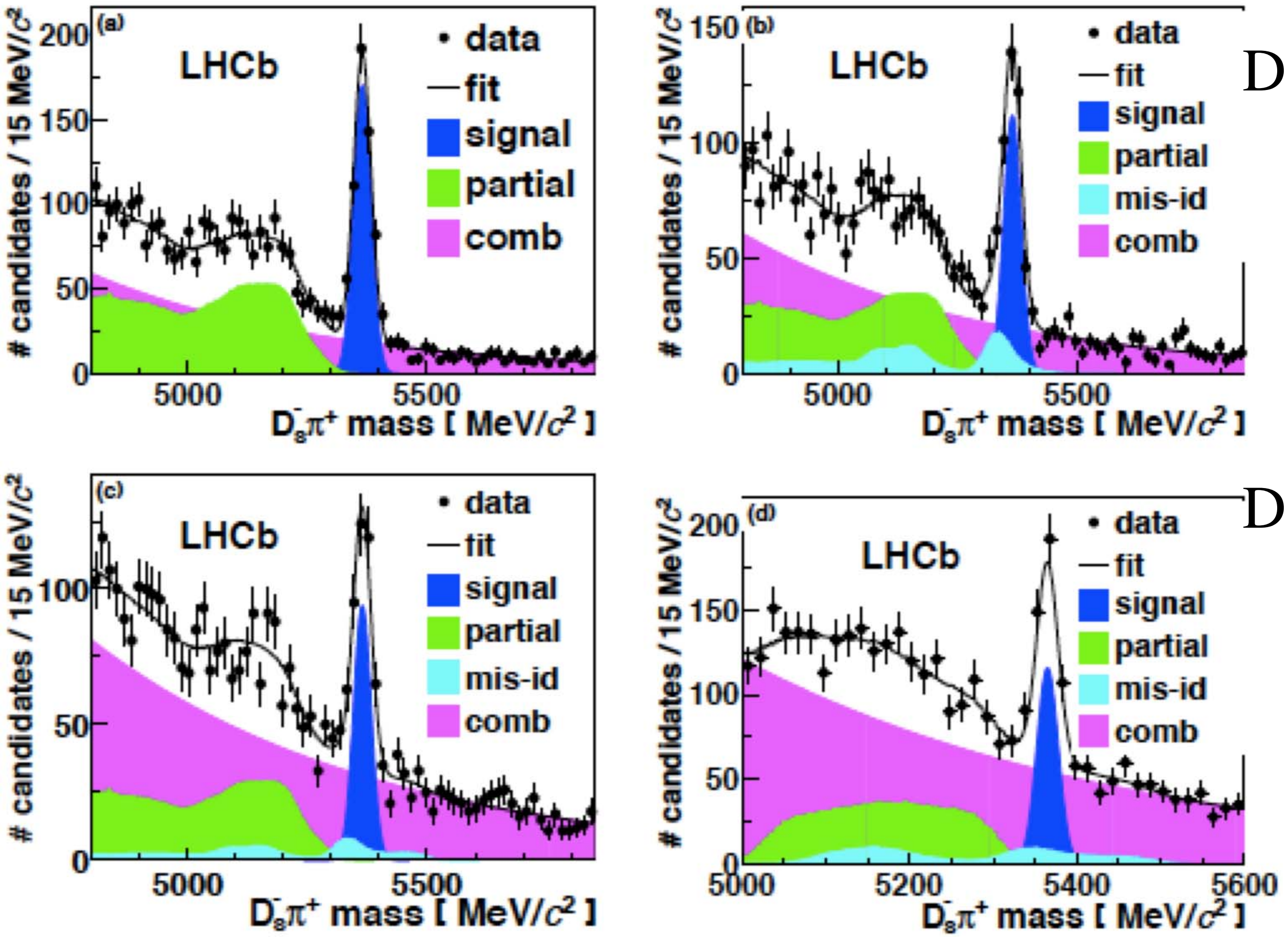
submitted for publication

$D_s(\phi\pi)\pi$

$D_s(K^*K)\pi$

$D_s(KK\pi)\pi$

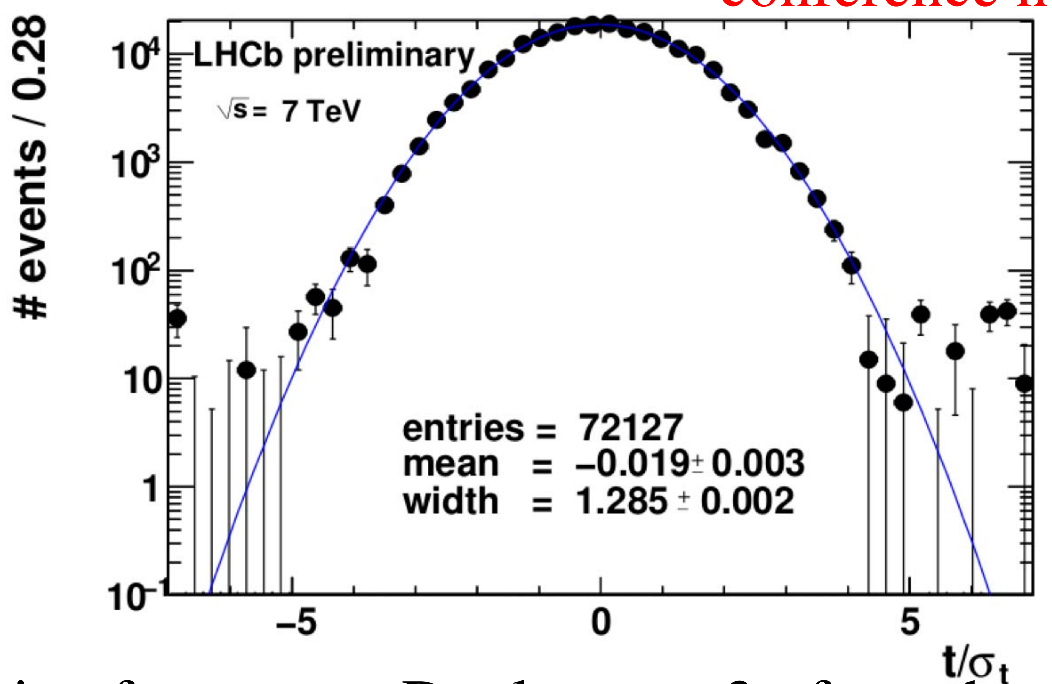
$D_s3\pi$



Real demonstration of LHCb in 2010

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
  - cleanly reconstructed B_s
  - good momentum and vertex resolutions → decay time resolution σ_t = 44 fs for $D_s\pi$ and 36 fs for $D_s 3\pi$

conference note



Pull distribution for prompt D_s plus π or 3π from the primary vertex making B_s mass, i.e. fake B_s at $t = 0$

Real demonstration of LHCb in 2010

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
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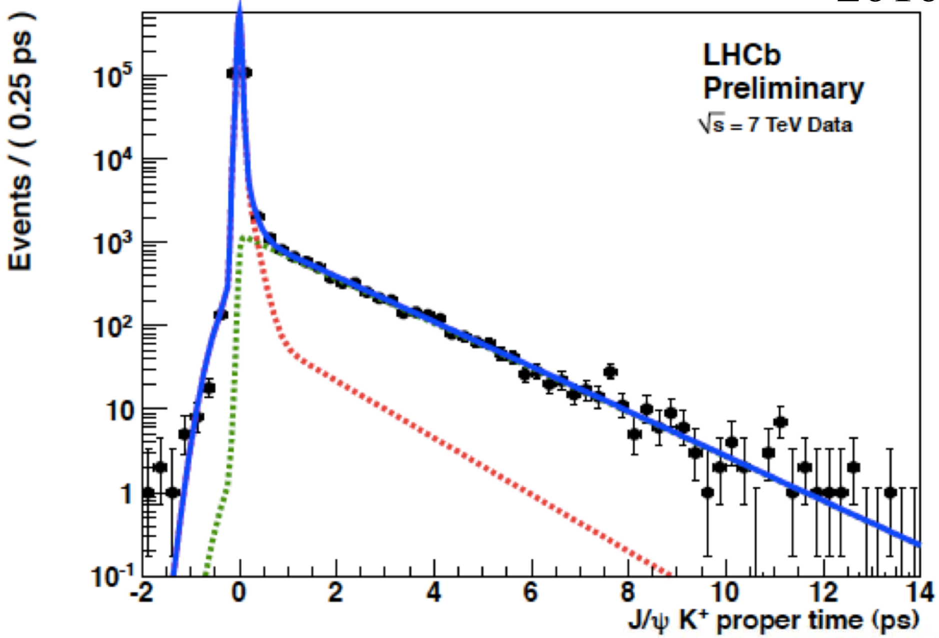
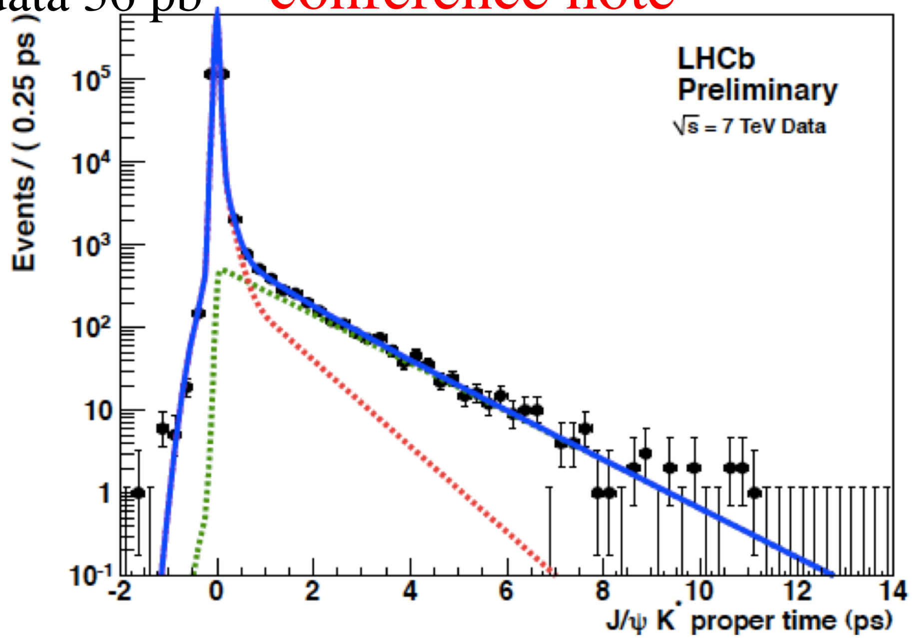
  - well calibrated absolute scale of decay time

B lifetime measurements 2010 data 36 pb^{-1} conference note





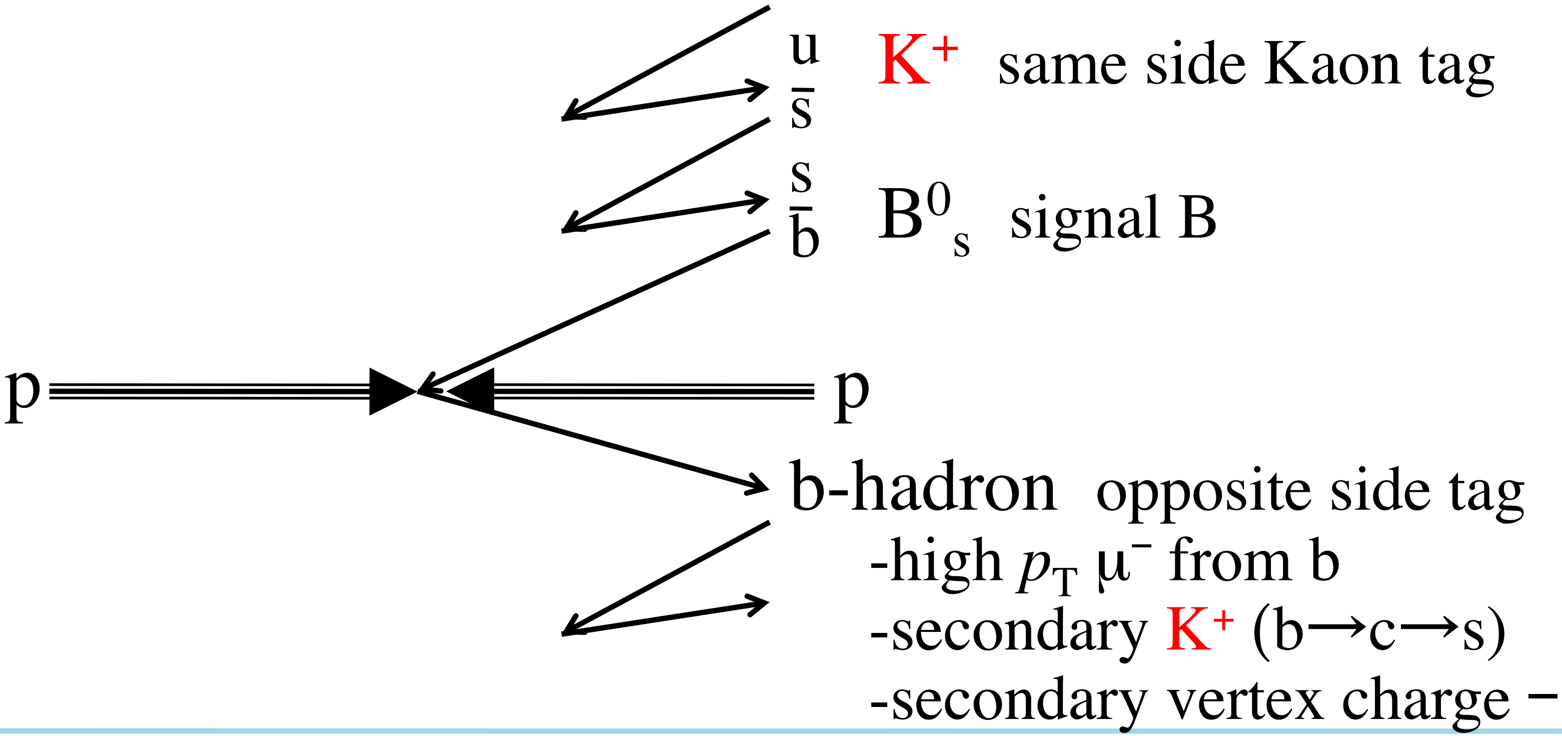
$$\tau(B^+ \to J/\psi K^+) = 1.689 \pm 0.022 \pm 0.047 \text{ ps}$$
$$\tau(B^0 \to J/\psi K^{*0}) = 1.512 \pm 0.032 \pm 0.042 \text{ ps}$$
$$\tau(B^0 \to J/\psi K^0_S) = 1.558 \pm 0.056 \pm 0.022 \text{ ps}$$

PDG 1.641 ± 0.008 ps

PDG 1.519 ± 0.007 ps

Real demonstration of LHCb in 2010

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
  - cleanly reconstructed B_s
  - good momentum and vertex resolutions → decay time resolution
  - well calibrated absolute scale of decay time
  - efficient and clean initial flavour tag
    hadron PID of LHCb



Real demonstration of LHCb in 2010

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
  - cleanly reconstructed B_s
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  - well calibrated absolute scale of decay time
  - efficient and clean initial flavour tag
  - high statistics

submitted for publication

With 2010 data 36 pb^{-1}

Decay mode (+c.c)	Signal yield
$B_s^0 \to D_s^-(\phi\pi^-)\pi^+$	515 ± 25
$B_s^0 \to D_s^-(K^*K^-)\pi^+$	338 ± 27
$B_s^0 \to D_s^-(K^+K^-\pi^-)\pi^+$	283 ± 27
$B_s^0 \to D_s^- 3\pi$	245 ± 46
Total	1381 ± 65

Real demonstration of LHCb in 2010

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  - cleanly reconstructed B_s
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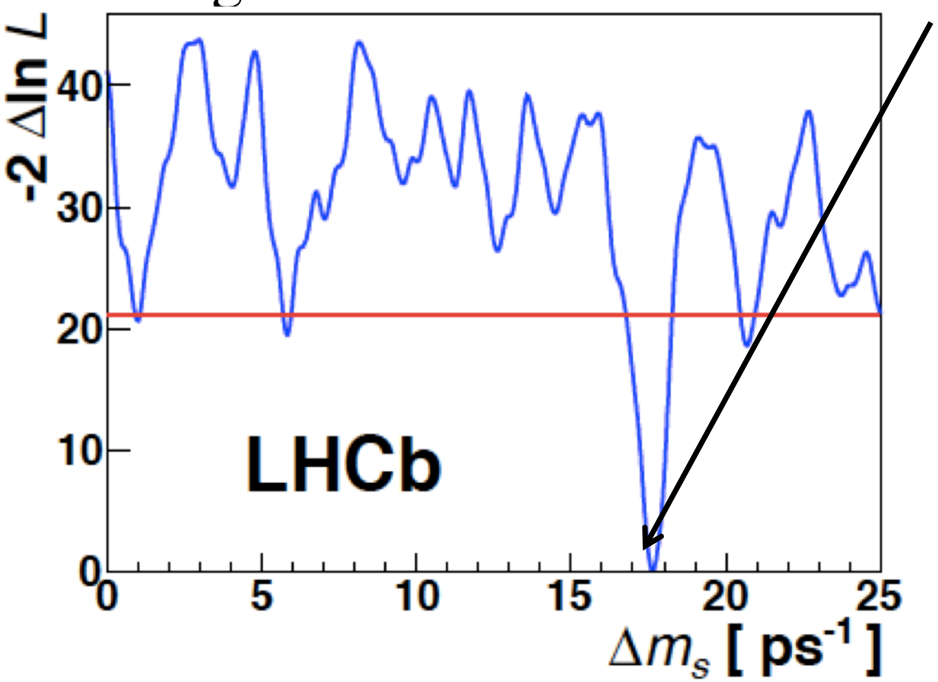


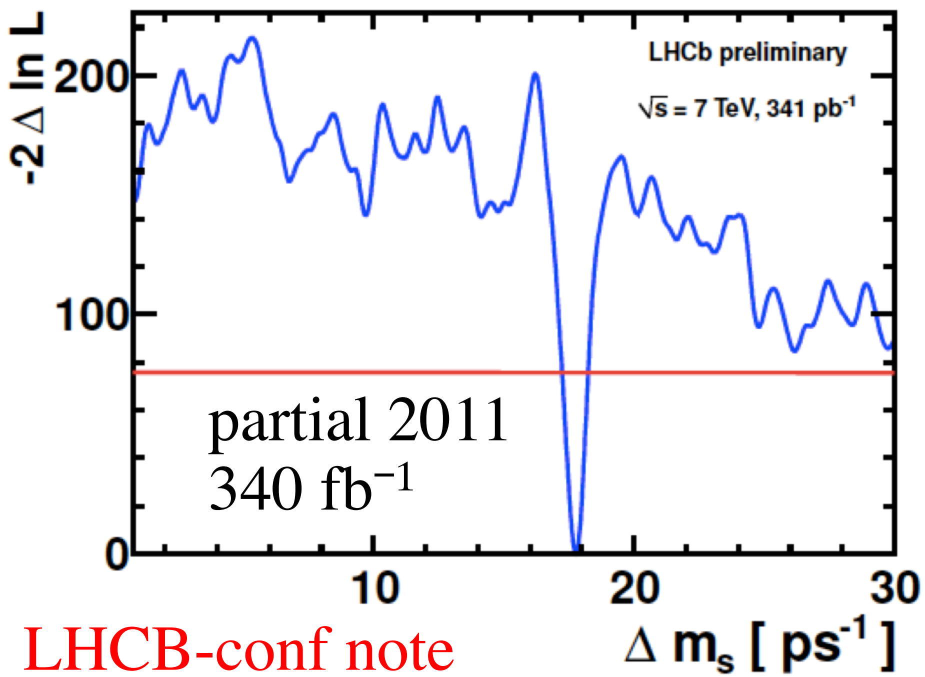
submitted for publication

$\Delta m_s = 17.63 \pm 0.11 \pm 0.02\ \mathrm{ps}^{-1}$
with full 2010 data 36 pb^{-1}
opposite side tag only

c.f. CDF
$\Delta m_s = 17.77 \pm 0.10 \pm 0.07\ \mathrm{ps}^{-1}$
with 1 fb^{-1} data (PRL 2006)

Real demonstration of LHCb now

- B_s-$\overline{B}_s$ oscillation frequency (Δm_s) measurement
  - cleanly reconstructed B_s
  - good momentum and vertex resolutions → decay time resolution
  - well calibrated absolute scale of decay time
  - efficient and clean initial flavour tag
  - high statistics



LHCB-conf note

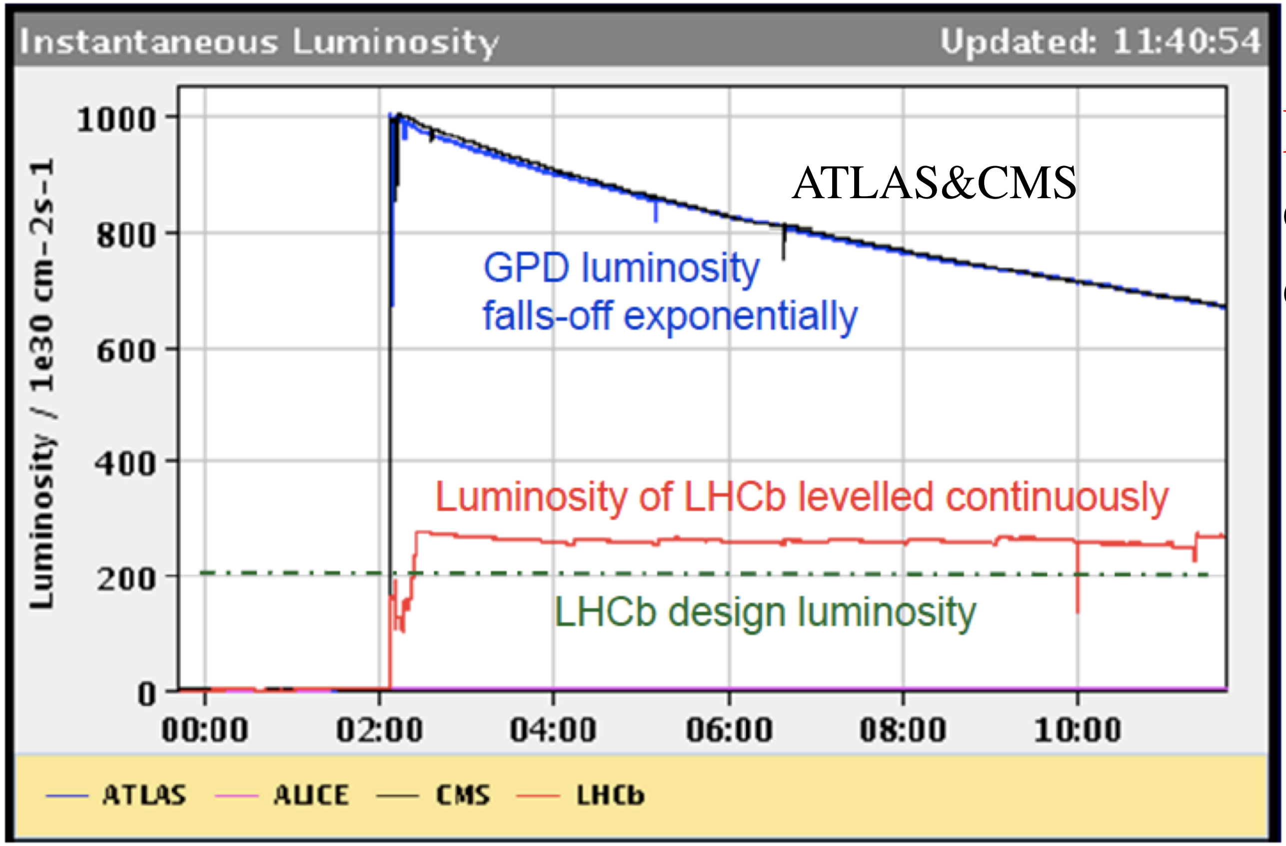
$\Delta m_s = 17.63 \pm 0.11 \pm 0.02\ \mathrm{ps}^{-1}$
with full 2010 data 36 pb^{-1}
opposite side tag only

$\Delta m_s = 17.725 \pm 0.041 \pm 0.026\ \mathrm{ps}^{-1}$
with partial 2011 data 340 fb^{-1}
same + opposite sides tag

c.f. CDF
$\Delta m_s = 17.77 \pm 0.10 \pm 0.07\ \mathrm{ps}^{-1}$
with 1 fb^{-1} data (PRL 2006)

LHC pp at $\sqrt{s}$ =7 TeV in 2011

- pp run in 2011 finished
  $\int L\, dt$: ATLAS/CMS ~5 fb^{-1} and LHCb ~1fb^{-1} data
- ATLAS/CMS running at maximum luminosities
  LHCb running at constant luminosity



Luminosity at LHCb IR controlled by displacing the beams

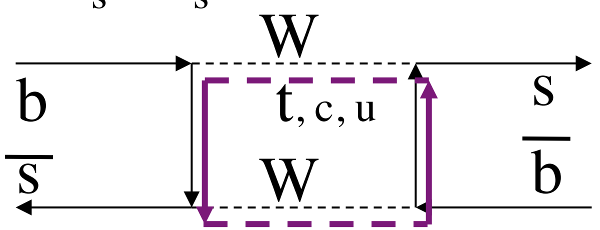
LHCb running luminosity 2011

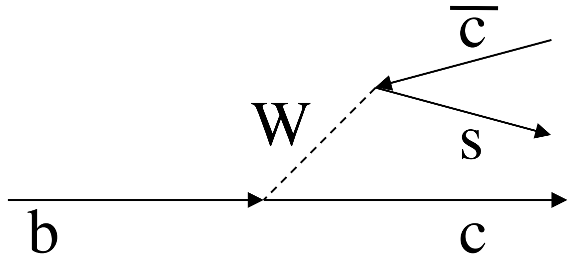
- LHCb has been running beyond the designed performance
  - LHCb designed luminosity:
    $L = 2\times10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ with 25 nsec
  - LHCb actual running luminosity in 2011:
    $L \approx 3\times10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ with 50 nsec
    i.e. 1.5 more peak luminosities with 1/2 the bunch crossing rate
  - 3 times higher number of pp interactions per event
    ⇒ challenge for both trigger and analysis
    more CPU installed for the event filter farm
    designed safety margin of the detector
    LHCb fully exploiting this running condition
    ⇒ good prospect for the upgrade

LHCb results with 2011 partial data

- CP violation in $B_s \to J/\psi\phi$ (370 pb^{-1}) submitted for publication

B_s^0-$\overline{B}_s^0$ oscillations

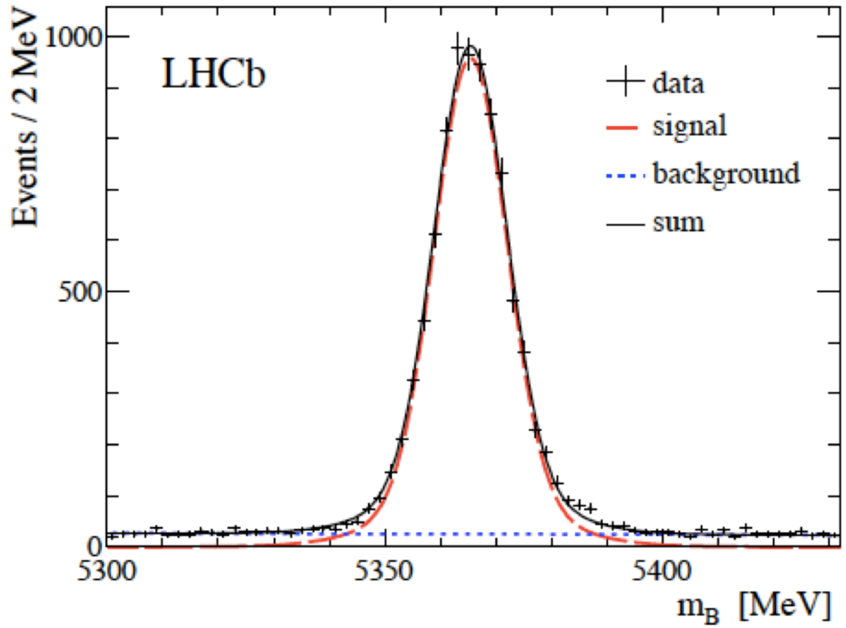




$\phi_s^{J/\psi\phi}$: phase difference

In the SM $2\lambda^2\eta$

+ New Physics phase



Clean $B_s \to J/\psi\phi$ signal
~8500 (untagged)

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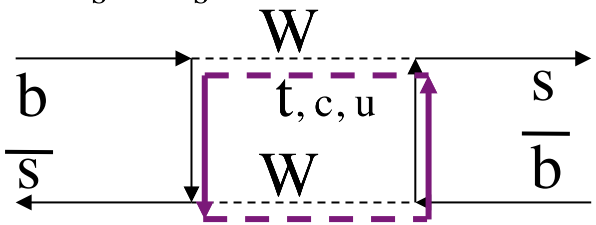
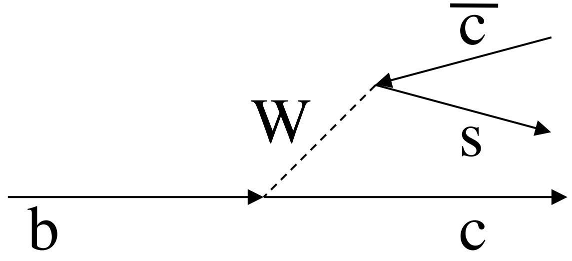
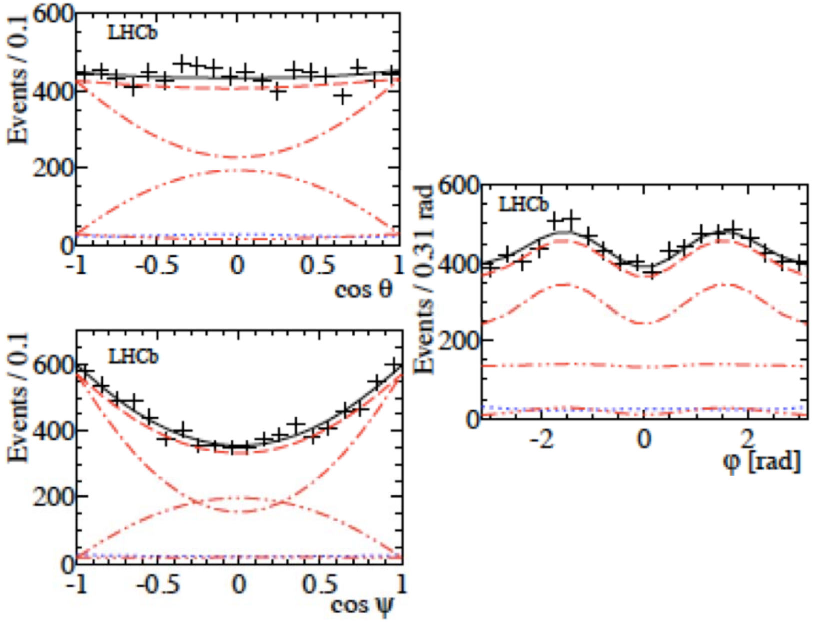
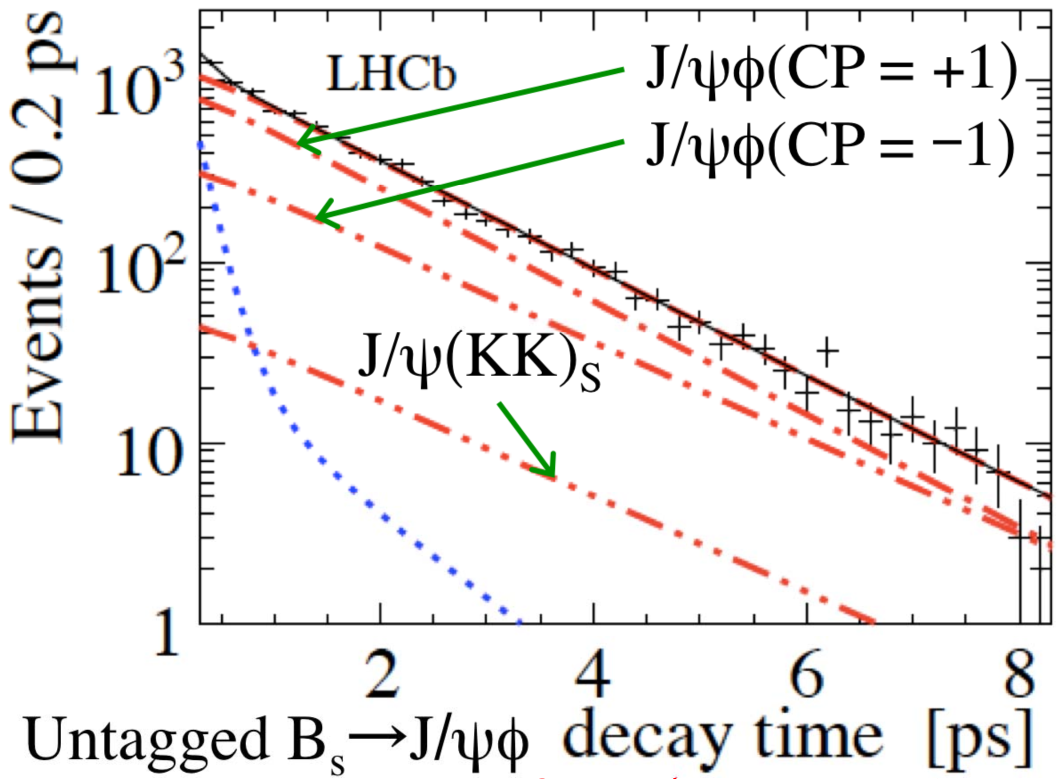




$\phi_s^{J/\psi\phi}$: phase difference
In the SM $2\lambda^2\eta$
+ New Physics phase



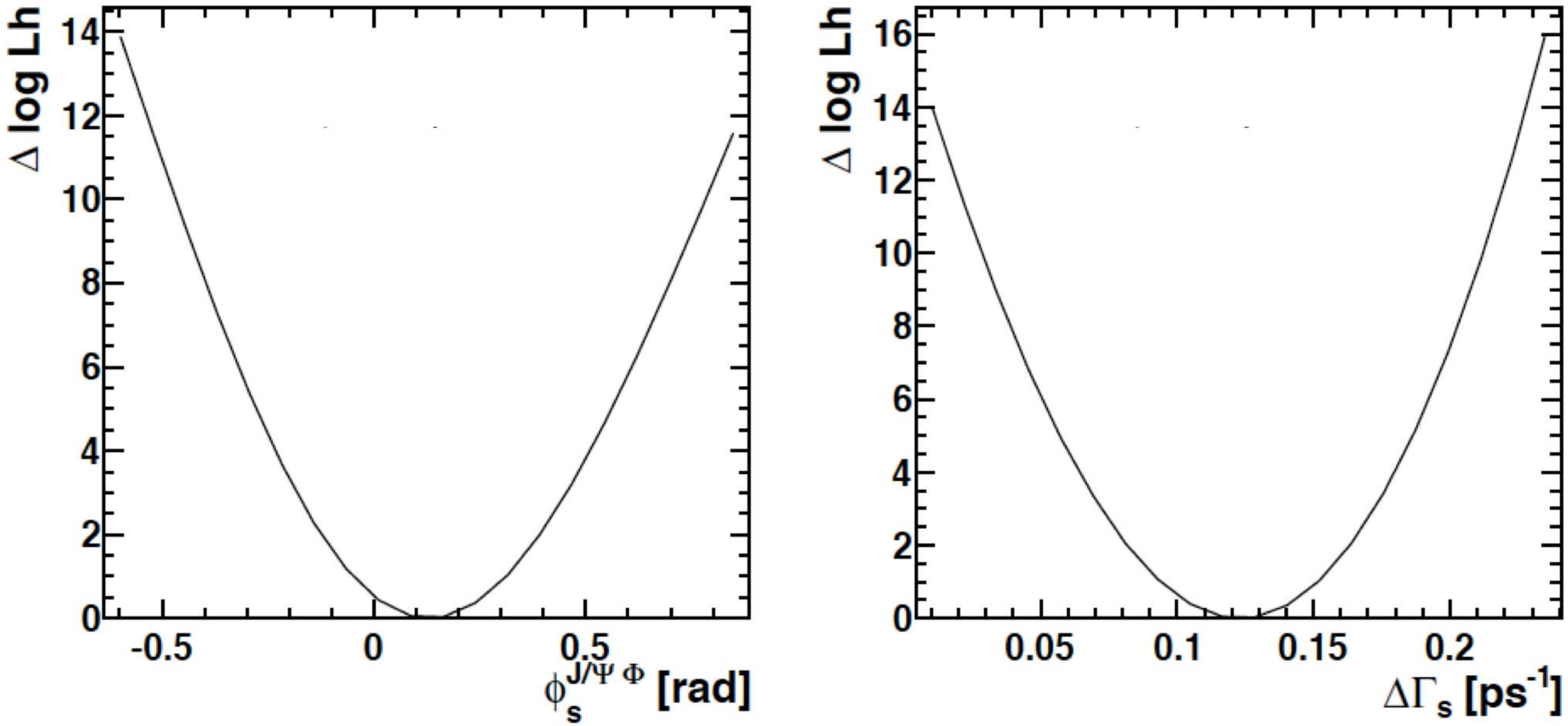
simultaneous fit to the decay angle distributions



NB: CP of $J/\psi(KK)_S = -1$

LHCb results with 2011 partial data

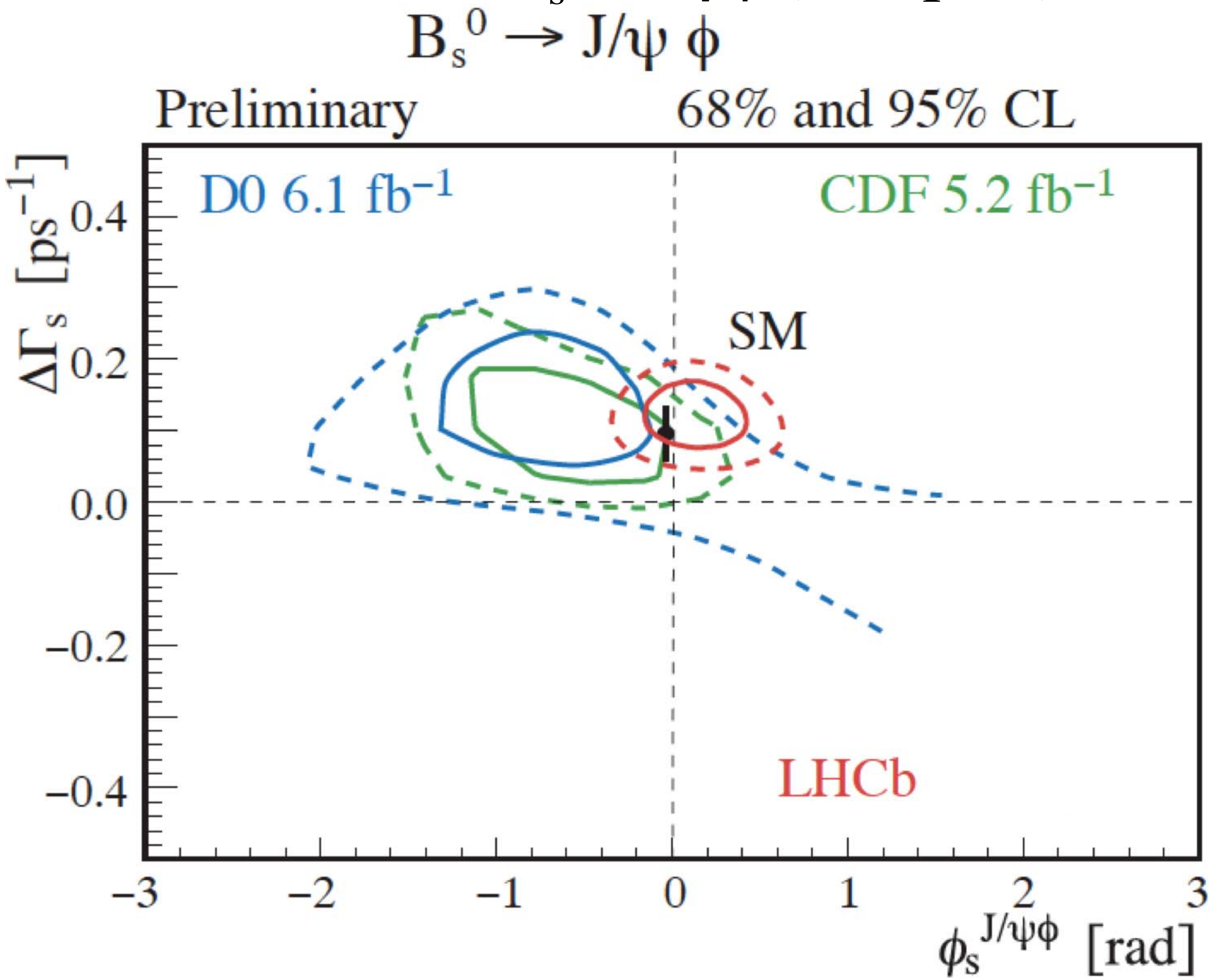
- CP violation in $B_s \rightarrow J/\psi\phi$ (370 pb^{-1})
  - opposite side tag only
  - K^+-K^- S-wave contribution included:
  - tagged sample, very good fit behaviour



LHCb results with 2011 partial data

- CP violation in $B_s \rightarrow J/\psi\phi$ (370 pb^{-1})

submitted for publication



(ambiguity resolved by a separate analysis using the strong phase difference between K-K P-wave and S-wave, $\delta_P - \delta_S$)

LHCb results with 2011 partial data

- CP violation in $B_s \to J/\psi\phi$ (370 pb^{-1}) submitted for publication
  - $\Gamma_s = 0.657 \pm 0.009 \pm 0.008$ ps^{-1}
    The world best measurement
  - $\Delta\Gamma_s = 0.123 \pm 0.029 \pm 0.011$ ps^{-1}
    A clear evidence for non-zero $\Delta\Gamma$
  - $\phi_s^{J/\psi\phi} = 0.15 \pm 0.18 \pm 0.06$ rad
    The world best measurement
    By combining with the LHCb
    $B_s \to J/\psi f_0 \Rightarrow 0.07 \pm 0.17 \pm 0.06$

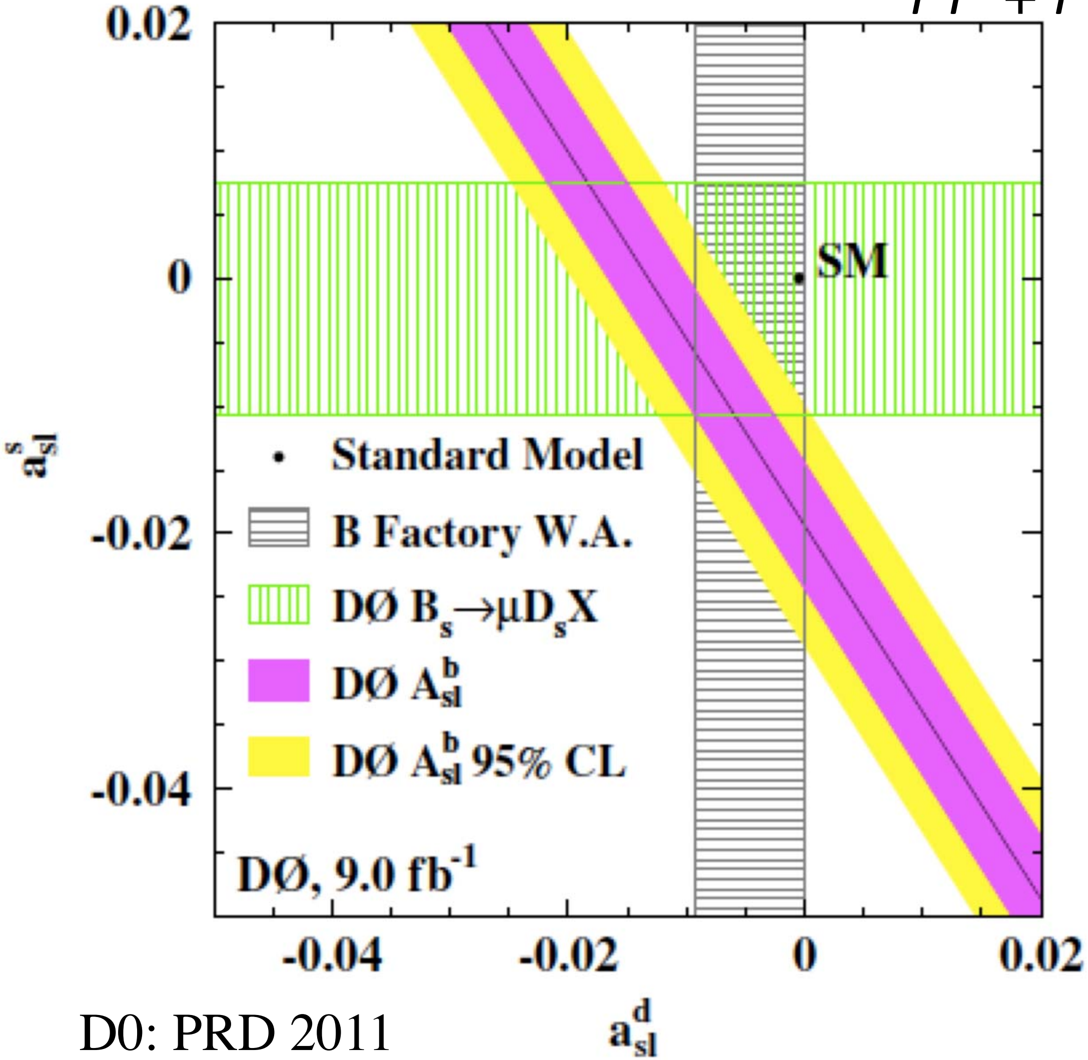
Good agreement with the Standard Model
$\Delta\Gamma_s = 0.096 \pm 0.039$ ps^{-1}
$\phi_s^{J/\psi\phi} = 0.0366\,^{+0.0016}_{-0.0015}$ rad
(Lentz and Nierste, Badin et al., Charles et al.)

- $\Delta\Gamma_s/\Gamma_s = 0.187$
- $\Delta\Gamma_s/\Delta m_s = 0.0069 \pm 0.0017$
  constraint for the CPV in B_s-$\overline{B}_s$ oscillations
  $a_{sl} = \Delta\Gamma/\Delta m \arctan(\phi_\Gamma - \phi_M)$
  D0 A_{sl} means $\phi_\Gamma - \phi_M \approx 45°$ too big even with new physics

$a_{\rm sl}$ from D0

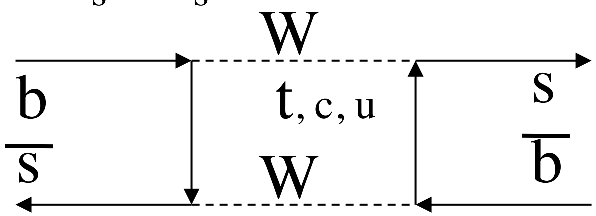
- CP violation in $B \leftrightarrow \overline{B}$

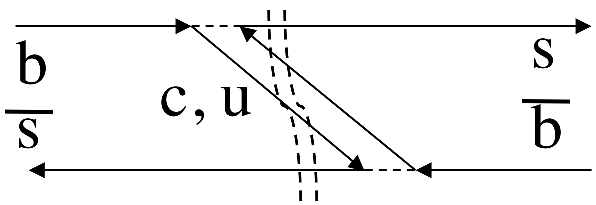
$$\frac{l^+l^+ - l^-l^-}{l^+l^+ + l^-l^-}$$



D0: PRD 2011

B_s^0-$\overline{B}_s^0$ oscillations





$$\frac{\Pr(\overline{B}\rightarrow B) - \Pr(B\rightarrow \overline{B})}{\Pr(\overline{B}\rightarrow B) + \Pr(B\rightarrow \overline{B})}$$

$=\mathrm{Im}(\Gamma_{12}/M_{12})$

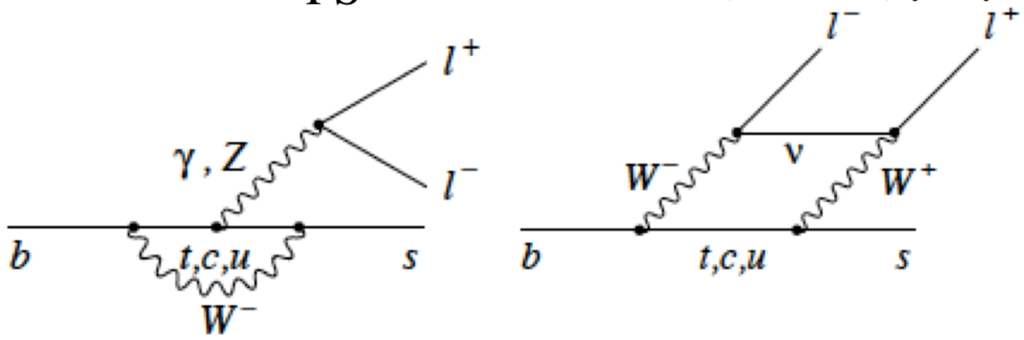
In the SM

$\sim 6\times 10^{-4}$ (B_d)

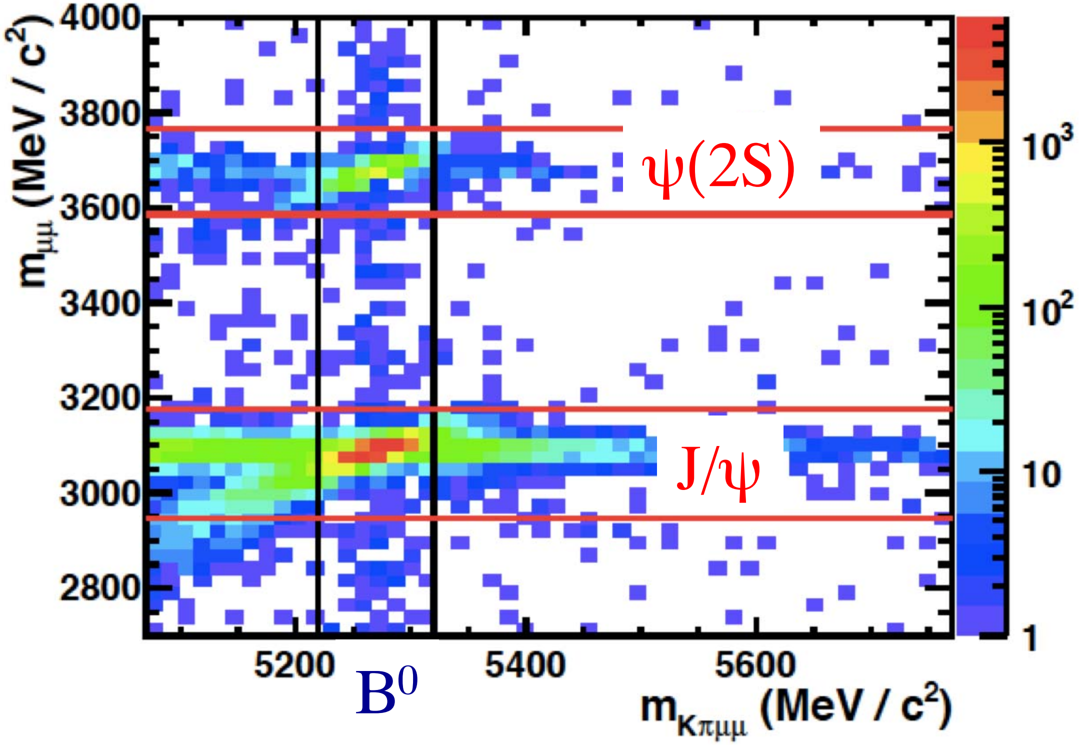
$\sim 2\times 10^{-5}$ (B_s)

LHCb results with 2011 partial data

- Muon A_{FS} in $B^0 \rightarrow K^{*0}(K^+\pi^-)\mu^+\mu^-$ (370 pb^{-1})



Asymmetry in the l^+l^- angular distribution through the interference: modified if new physics with different Lorentz structure

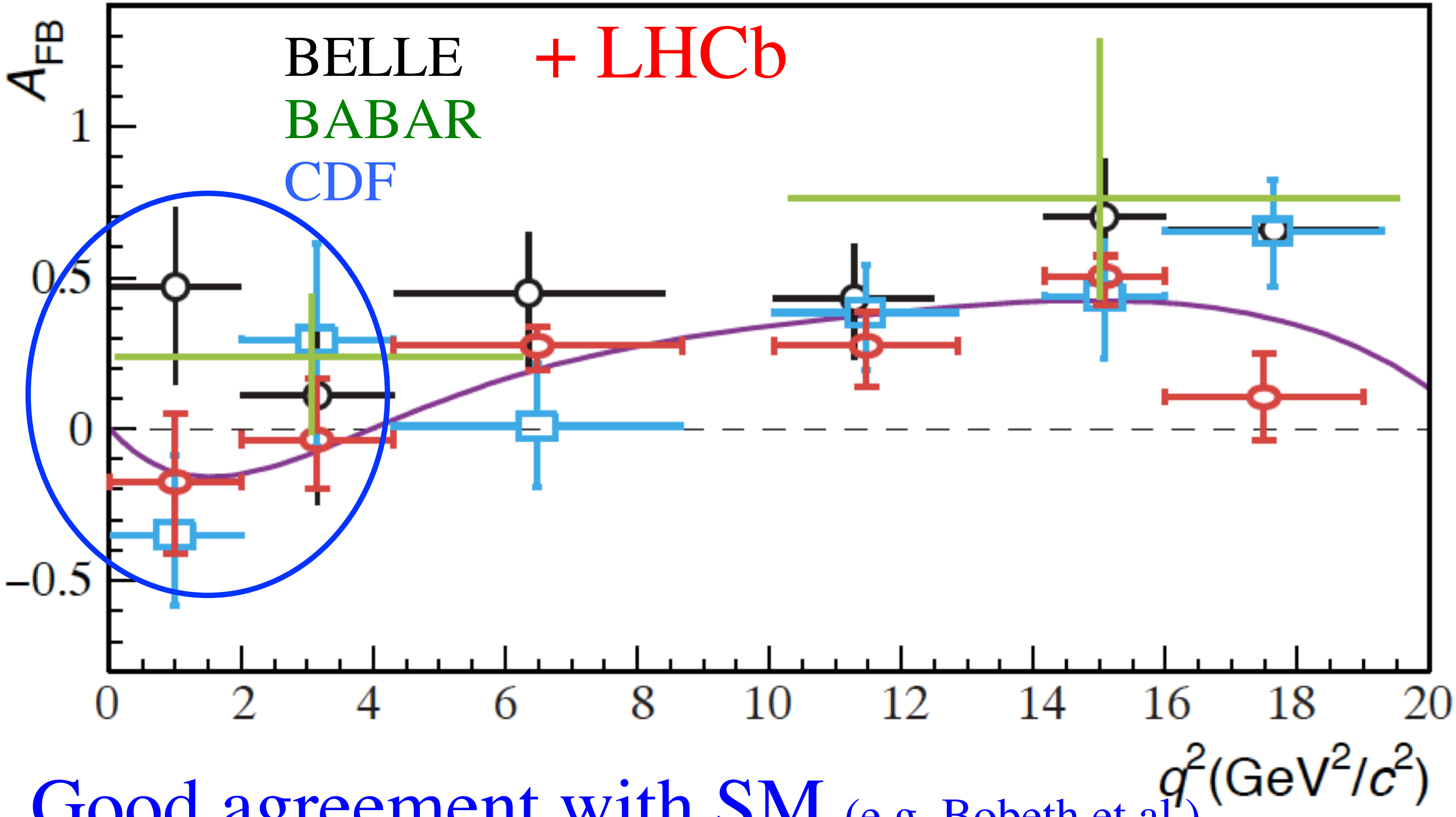


~340 signal events

LHCb results with 2011 partial data

- Muon A_{FS} in $B^0 \rightarrow K^{*0}(K^+\pi^-)\mu^+\mu^-$ (370 pb^{-1})

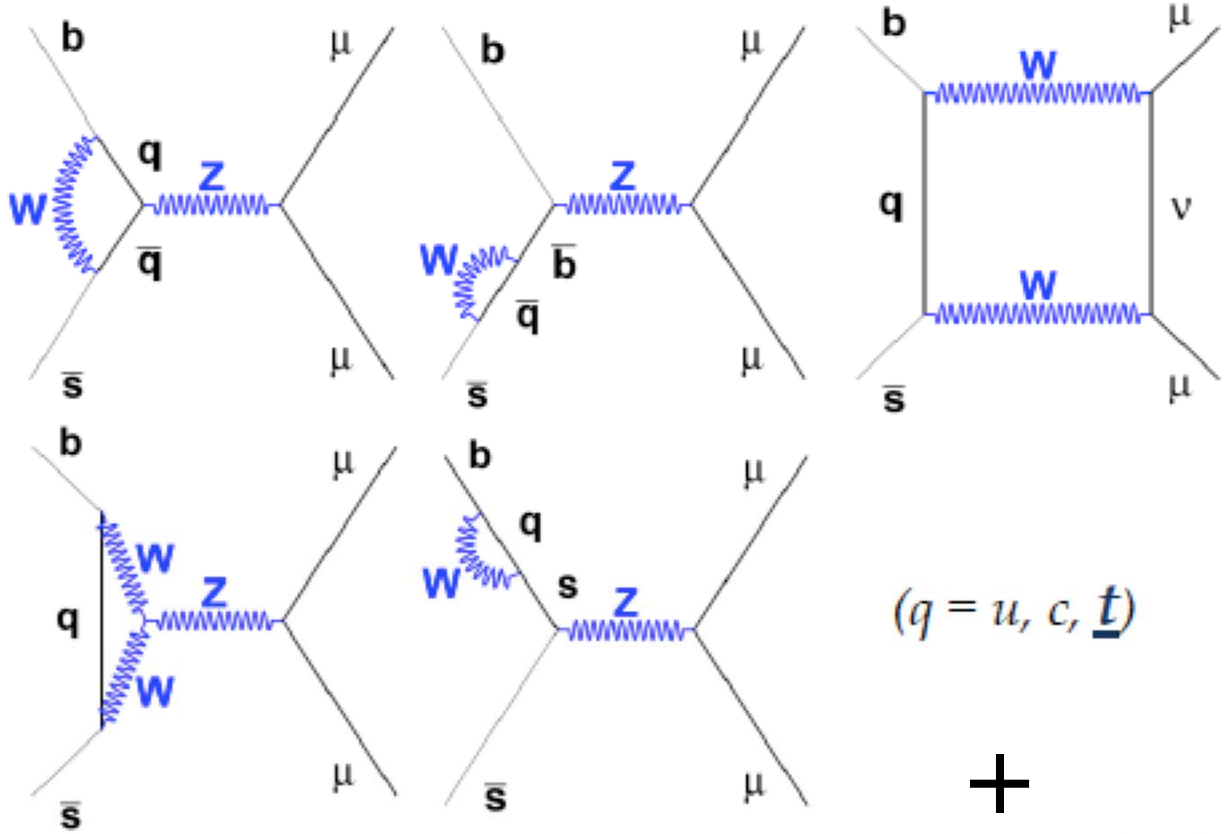
submitted for publication



Good agreement with SM (e.g. Bobeth et al.)

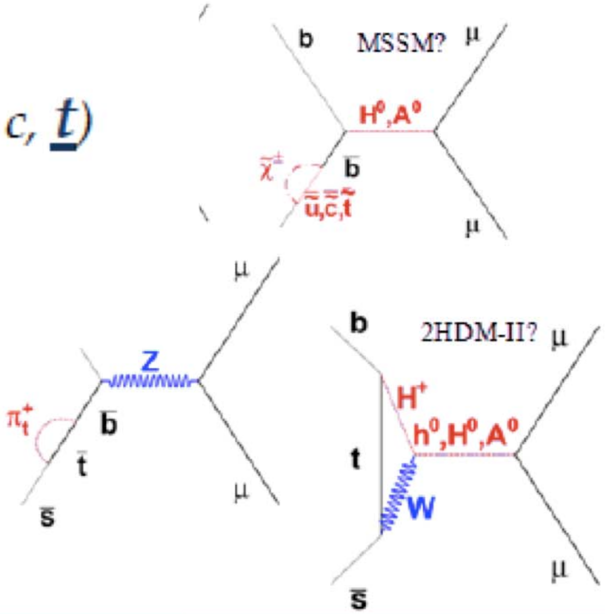
LHCb results with 2011 partial data

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



$(q = u, c, t)$

+



?

LHCb results with 2011 partial data

- $B_s^0 \to \mu^+\mu^-$ submitted for publication

  LHCb results with 370 pb^{-1} data distribution based analysis

  $Br(B_s \to \mu^+\mu^-) < 1.3\ (1.6) \times 10^{-8}$ @ 90% (95%) C.L.

  $Br(B_d \to \mu^+\mu^-) < 3.0\ (3.6) \times 10^{-9}$ @ 90% (95%) C.L.

  CMS: $Br(B_d \to \mu^+\mu^-) < 1.9 \times 10^{-8}$ @ 90% C.L.

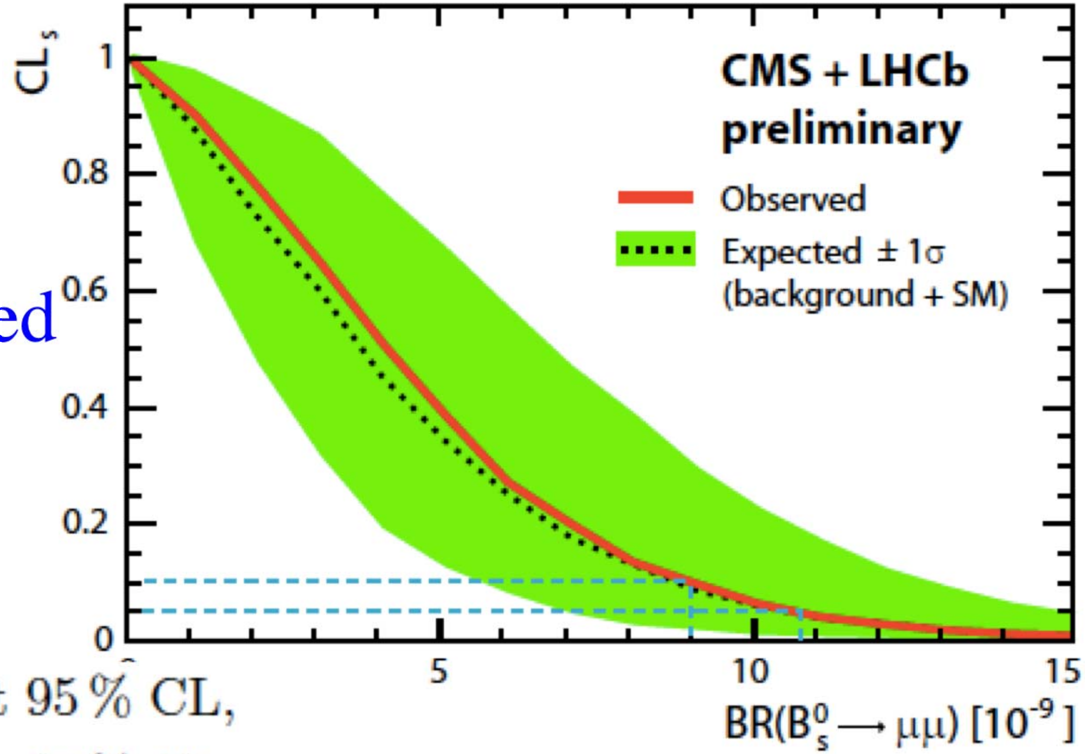
- CMS + LHCb

  CDF results not confirmed

  Consistent with SM

  B_s: $(3.2 \pm 0.2) \times 10^{-9}$

  (Buras et al.)



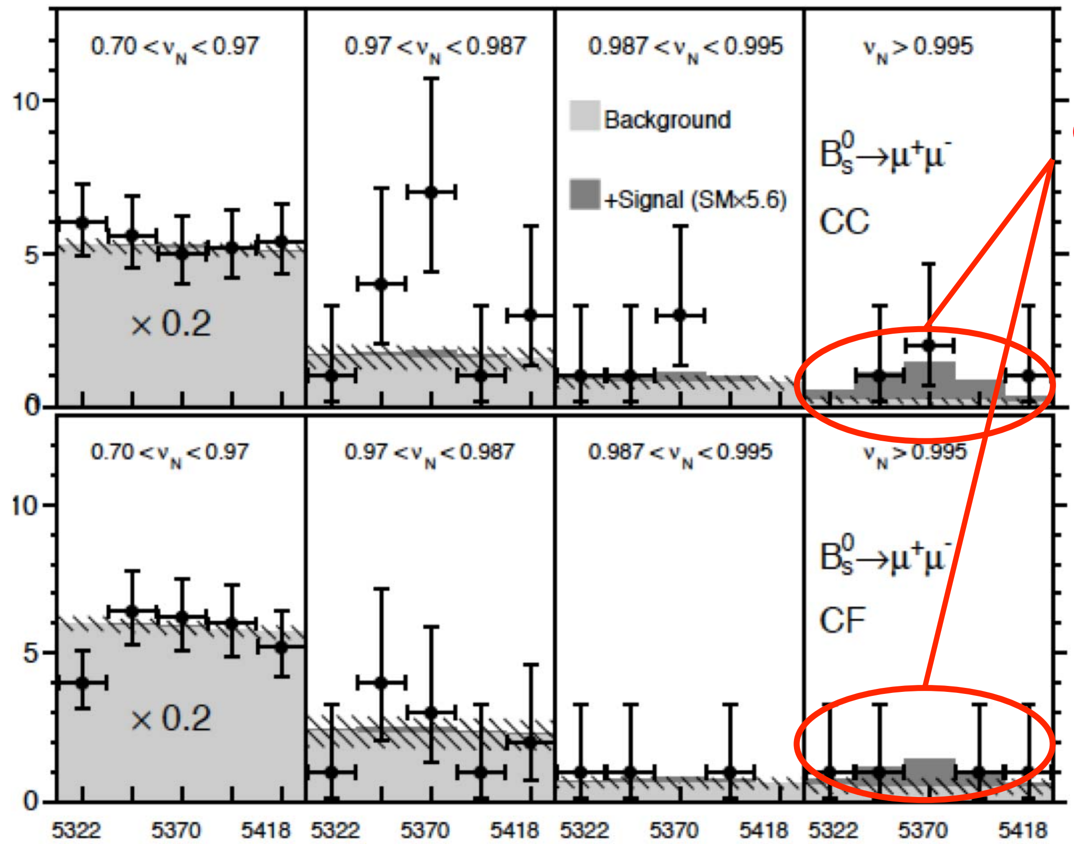
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 1.08 \times 10^{-8} \text{ at } 95\,\% \text{ CL},$$
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 0.90 \times 10^{-8} \text{ at } 90\,\% \text{ CL},$$

CDF results on $B_s \to \mu^+\mu^-$

- Interests were generated by CDF results with 7 fb^{-1} data

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (1.8^{+1.1}_{-0.9}) \times 10^{-8}$$

Hypothesis of background fluctuation: p-value of 0.27%



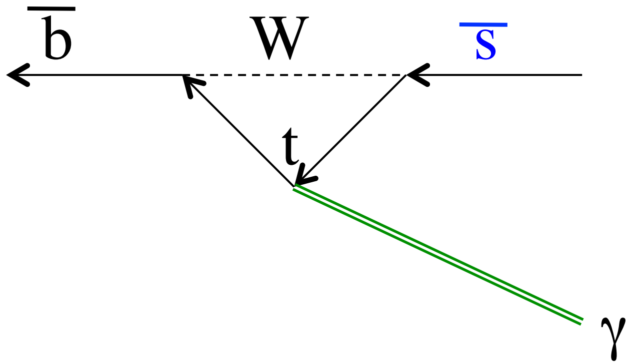
excess over the background and SM prediction?

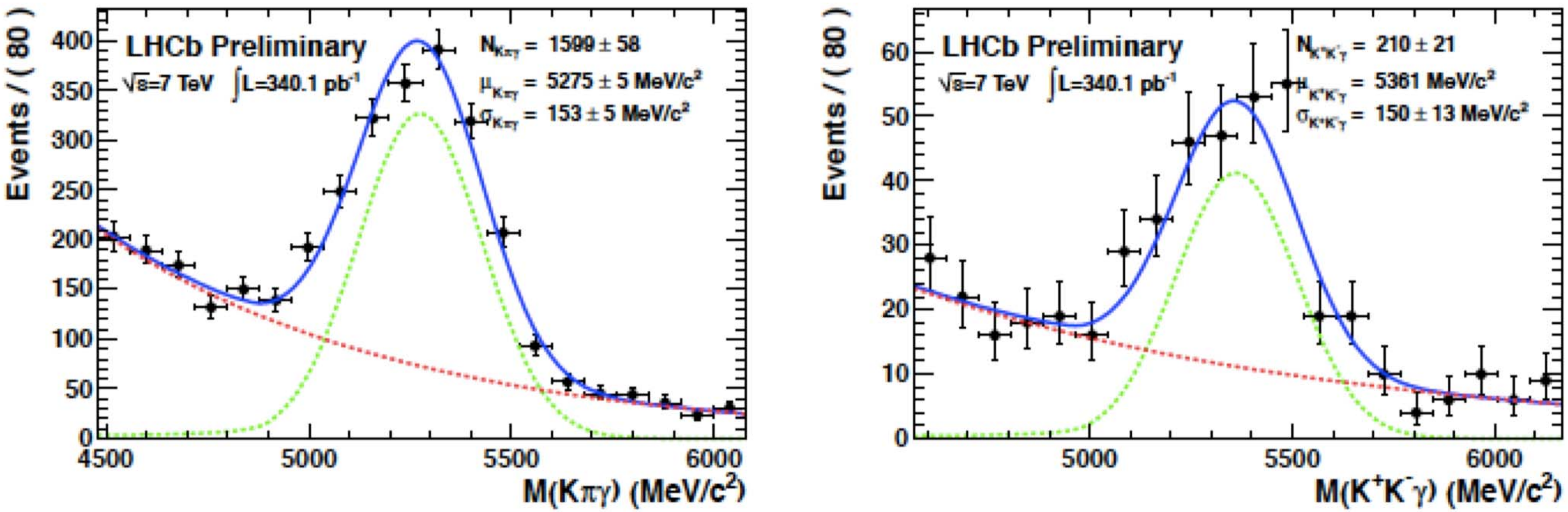
CDF PRL2011

LHCb results with 2011 partial data

- $B_d \to K^{*0}\gamma$ and $B_s \to \phi\gamma$

LHCb Conf-note

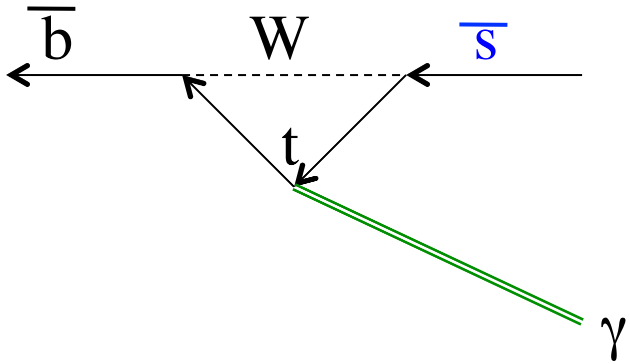




LHCb results with 2011 partial data

- $B_d \to K^{*0}\gamma$ and $B_s \to \phi\gamma$

LHCb Conf-note



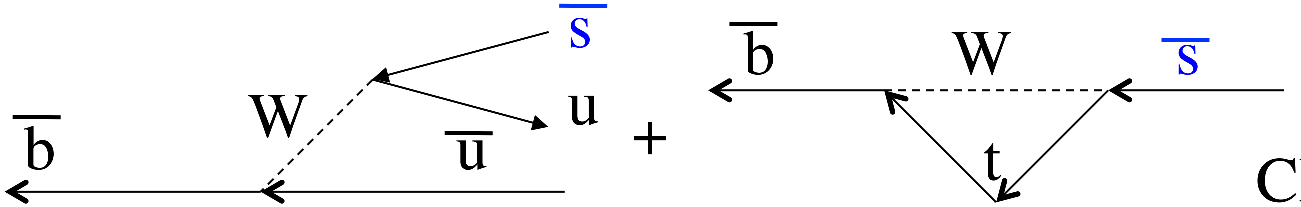
$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B_s^0 \to \phi\gamma)} = 1.52 \pm 0.14(\text{stat}) \pm 0.10(\text{syst}) \pm 0.12(f_s/f_d)$$

370 pb^{-1} World best measurement
cf: PDG average 0.7 ± 0.3

Final goal for $B_s \to \phi\gamma$: to study decay time dependent CP asymmetry

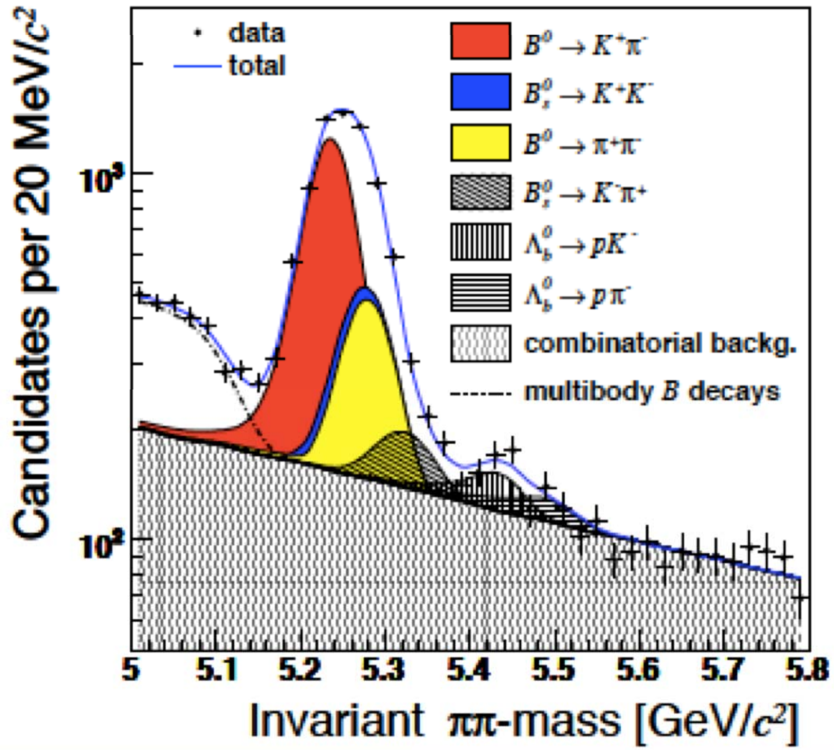
LHCb results with 2011 partial data

- B→hh decays
  - CP violation in the decay amplitudes:
    $\overline{B}^0 \to K^-\pi^+$ vs $B^0 \to K^+\pi^-$



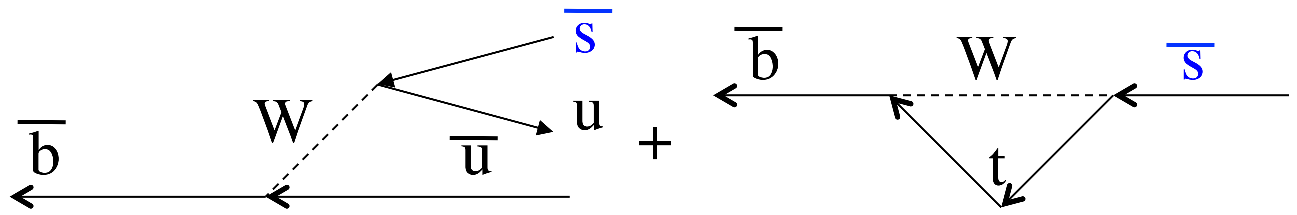
	$A_{CP}(B^0 \to K\pi)$	
BaBar	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	PRL2008
Belle	$-0.094 \pm 0.018 \pm 0.008$	
CLEO	$-0.04 \pm 0.16 \pm 0.02$	
CDF	$-0.086 \pm 0.023 \pm 0.009$	PRL2011
HFAG Average	$-0.098^{+0.012}_{-0.011}$	

CDF 1 fb^{-1}

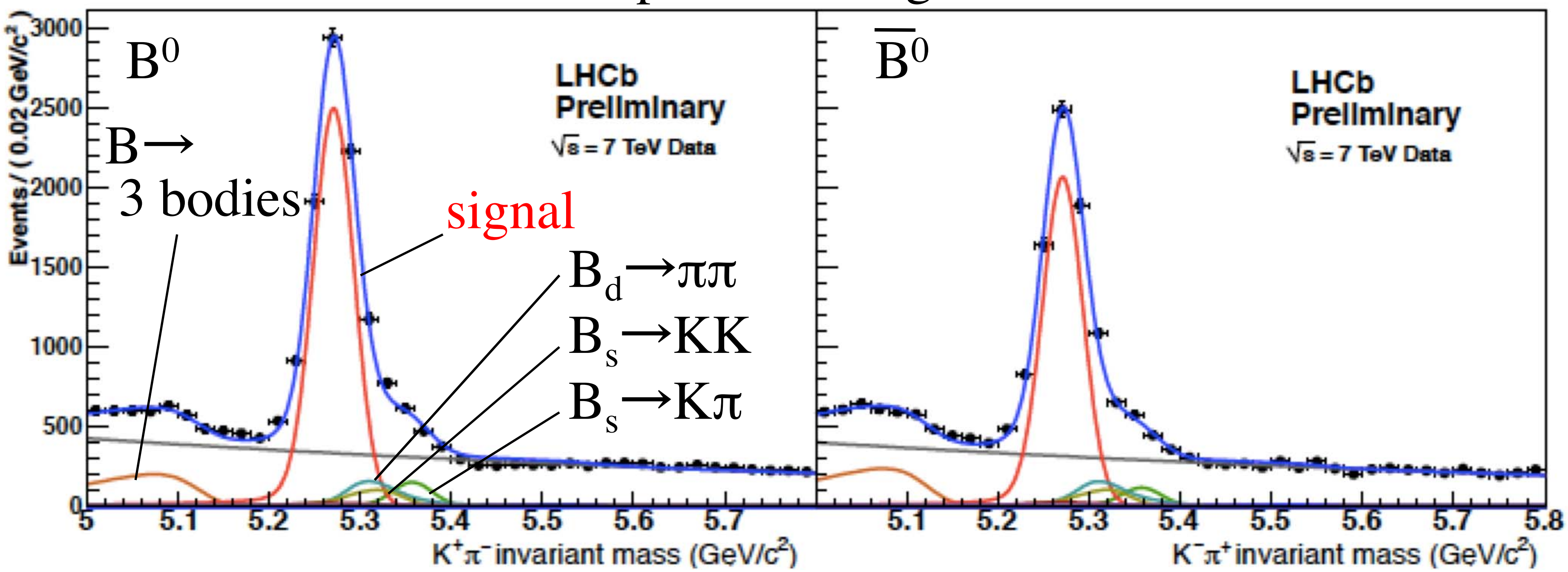


LHCb results with 2011 partial data

- $B \to hh$ decays LHCb Conf-note
  - CP violation in the decay amplitudes:
    $\overline{B}^0 \to K^- \pi^+$ vs $B^0 \to K^+ \pi^-$



LHCb 370 pb^{-1} clean signal due to PID

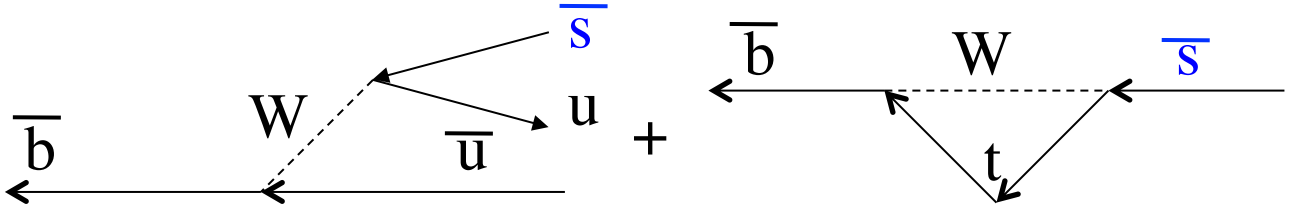


LHCb results with 2011 partial data

- B→hh decays

LHCb Conf-note

  – CP violation in the decay amplitudes:
    $\overline{B}^0 \to K^-\pi^+$ vs $B^0 \to K^+\pi^-$



	$A_{CP}(B^0 \to K\pi)$
BaBar	$-0.107 \pm 0.016^{+0.006}_{-0.004}$
Belle	$-0.094 \pm 0.018 \pm 0.008$
CLEO	$-0.04 \pm 0.16 \pm 0.02$
CDF	$-0.086 \pm 0.023 \pm 0.009$
HFAG Average	$-0.098^{+0.012}_{-0.011}$

LHCb (preliminary) 370 pb^{-1}

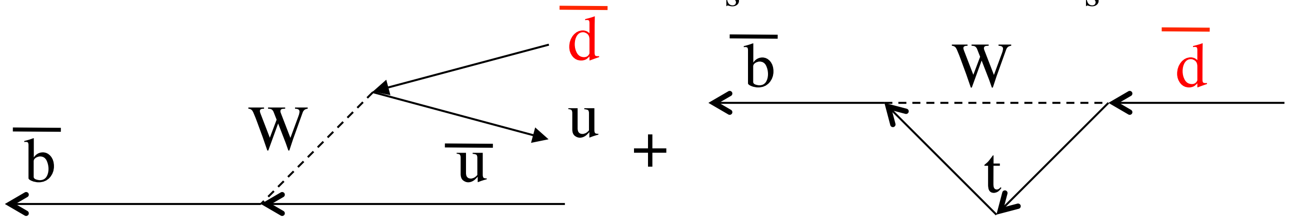
$$A_{CP}(B^0 \to K\pi) = -0.088 \pm 0.011 \pm 0.008$$

World best measurement

LHCb results with 2011 partial data

- $B \to hh$ decays — LHCb Conf-note
  - CP violation in the decay amplitudes:

$\overline{B}^0 \to K^-\pi^+$ vs $B^0 \to K^+\pi^-$ $\quad$ $\overline{B}_s^0 \to K^+\pi^-$ vs $B_s^0 \to K^-\pi^+$



	$A_{CP}(B^0 \to K\pi)$	$A_{CP}(B_s^0 \to \pi K)$
BaBar	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	-
Belle	$-0.094 \pm 0.018 \pm 0.008$	-
CLEO	$-0.04 \pm 0.16 \pm 0.02$	-
CDF	$-0.086 \pm 0.023 \pm 0.009$	$0.39 \pm 0.15 \pm 0.08$
HFAG Average	$-0.098^{+0.012}_{-0.011}$	0.39 ± 0.17

LHCb (preliminary) 370 pb^{-1}

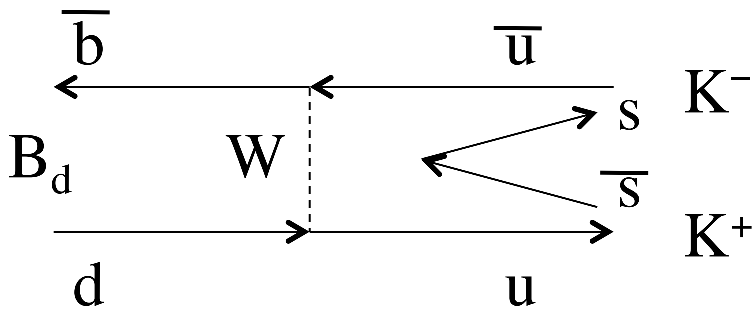
$A_{CP}(B^0 \to K\pi) = -0.088 \pm 0.011 \pm 0.008 \quad A_{CP}(B_s^0 \to \pi K) = 0.27 \pm 0.08 \pm 0.02$

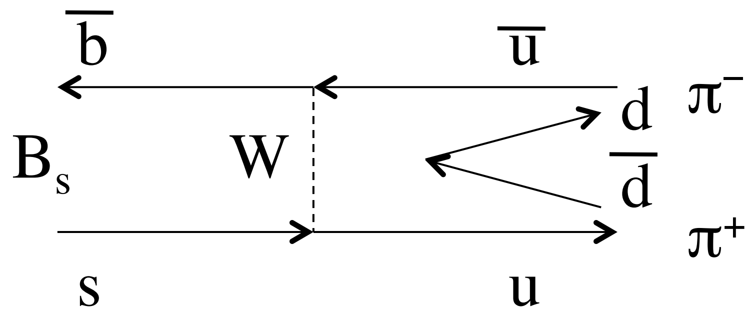
World best measurement

May be, B_s CP asymmetry is larger and opposite sign

LHCb results with 2011 partial data

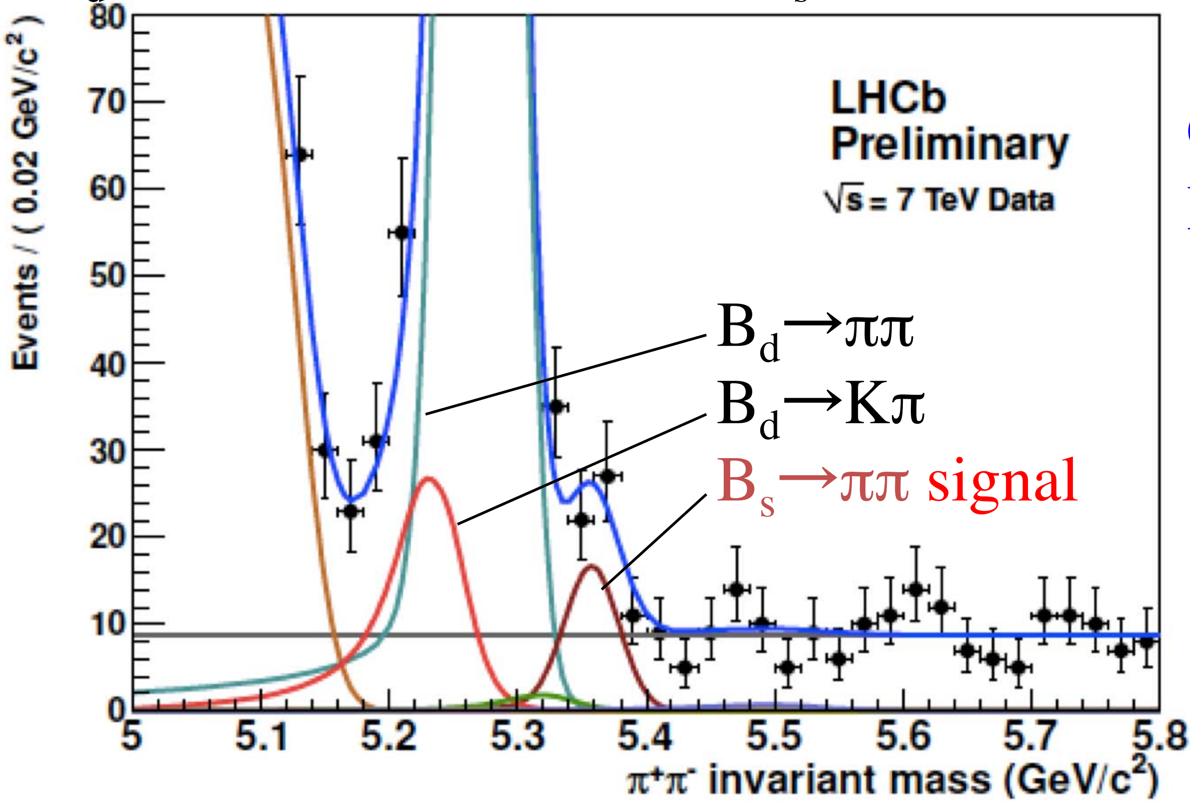
- $B \to hh$ decays
  - CP violation in the decay amplitudes:
    $\overline{B}^0 \to K^-\pi^+$ vs $B^0 \to K^+\pi^-$ $\qquad$ $\overline{B}_s^0 \to K^+\pi^-$ vs $B_s^0 \to K^-\pi^+$
  - W-exchange diagramme
    $B_d \to K^+K^-$ $\qquad$ $B_s \to \pi^+\pi^-$





LHCb results with 2011 partial data

- $B\to hh$ decays — LHCb Conf-note
  - CP violation in the decay amplitudes:
    $\overline{B}^0\to K^-\pi^+$ vs $B^0\to K^+\pi^-$ $\overline{B}_s{}^0\to K^+\pi^-$ vs $B_s{}^0\to K^-\pi^+$
  - W-exchange diagramme
    $B_d\to K^+K^-$ $B_s\to\pi^+\pi^-$



Good mass resolution
Particle ID

LHCb results with 2011 partial data

- $B \rightarrow hh$ decays

LHCb Conf-note

  – CP violation in the decay amplitudes:
  $\overline{B}^0 \rightarrow K^- \pi^+$ vs $B^0 \rightarrow K^+ \pi^-$ $\overline{B}_s^0 \rightarrow K^+ \pi^-$ vs $\overline{B}_s^0 \rightarrow K^- \pi^+$
  – W-exchange diagramme
  $B_d \rightarrow K^+ K^-$ $B_s \rightarrow \pi^+ \pi^-$

$$\mathcal{BR}(B^0 \rightarrow K^+ K^-) = (0.13^{+0.06}_{-0.05} \pm 0.07) \times 10^{-6}$$

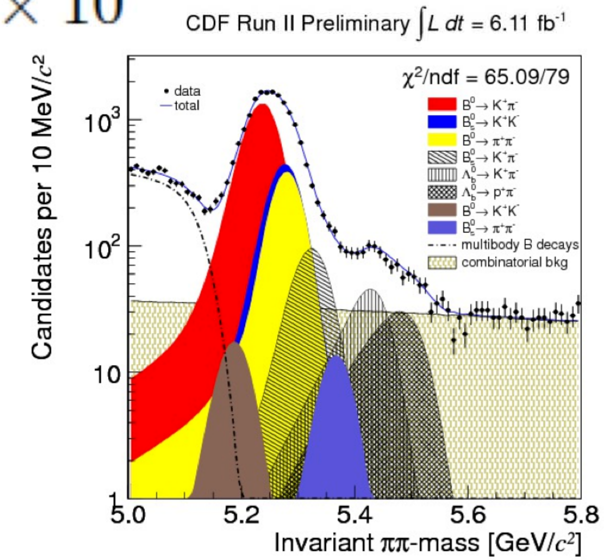
$$\mathcal{BR}(B^0_s \rightarrow \pi^+ \pi^-) = (0.98^{+0.23}_{-0.19} \pm 0.11) \times 10^{-6}$$

Measurements with 370 pb^{-1}

cf: CDF measurements: (6 fb^{-1})

$B_d \rightarrow K^+ K^- = (0.23 \pm 0.10 \pm 0.10) \times 10^{-6}$

$B_s \rightarrow \pi^+ \pi^- = (0.57 \pm 0.15 \pm 0.10) \times 10^{-6}$



Are the B_d and B_d branching fractions same or not?

D physics with LHCb in 2011

- Time integrated CP violation in $D \rightarrow K^+K^-$ and $\rightarrow \pi^+\pi^-$
  Decay time integrated CP asymmetries: A_{CP}^{KK} and $A_{CP}^{\pi\pi}$

$$\frac{D^0_{initial} \rightarrow f - \overline{D}^0_{initial} \rightarrow f}{D^0_{initial} \rightarrow f + \overline{D}^0_{initial} \rightarrow f}$$

  and CP asymmetry difference: $\Delta_{CP} = A_{CP}^{KK} - A_{CP}^{\pi\pi}$

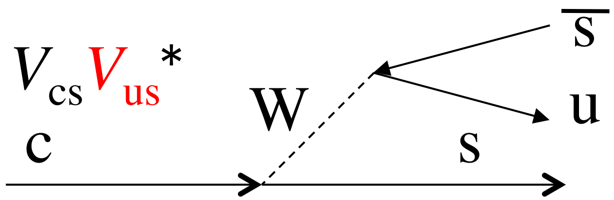
D physics with LHCb in 2011

- Time integrated CP violation in $D \to K^+K^-$ and $\to \pi^+\pi^-$
  Decay time integrated CP asymmetries: A_{CP}^{KK} and $A_{CP}^{\pi\pi}$

$$\frac{D^0_{\text{initial}} \to f - \overline{D}^0_{\text{initial}} \to f}{D^0_{\text{initial}} \to f + \overline{D}^0_{\text{initial}} \to f}$$

and CP asymmetry difference: $\Delta_{CP} = A_{CP}^{KK} - A_{CP}^{\pi\pi}$

KK



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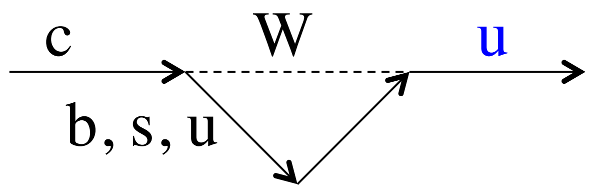


$$V_{ub}V_{cb}^* \{F(m_b) - F(m_d)\}$$
$$+ V_{cs}V_{us}^* \{F(m_s) - F(m_d)\}$$

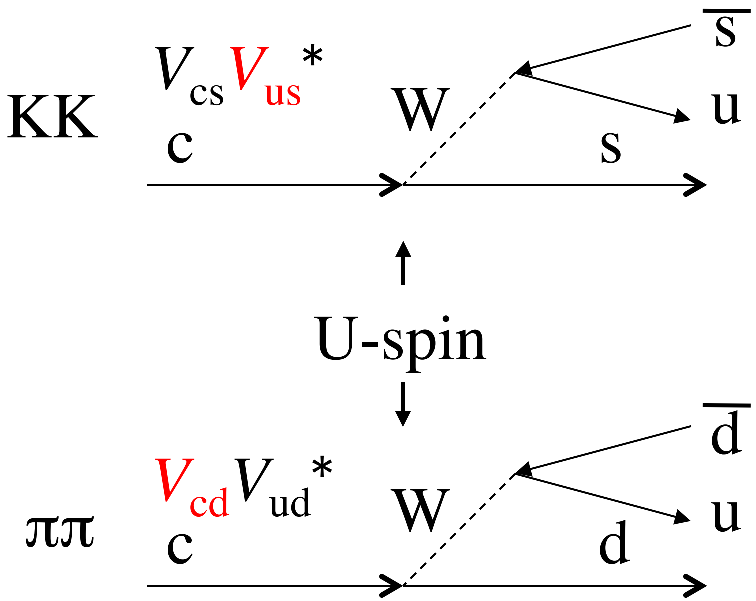
D physics with LHCb in 2011

- Time integrated CP violation in $D \to K^+K^-$ and $\to \pi^+\pi^-$

  Decay time integrated CP asymmetries: A_{CP}^{KK} and $A_{CP}^{\pi\pi}$

$$\frac{D^0_{\text{initial}} \to f - \overline{D}^0_{\text{initial}} \to f}{D^0_{\text{initial}} \to f + \overline{D}^0_{\text{initial}} \to f}$$

  and CP asymmetry difference: $\Delta_{CP} = A_{CP}^{KK} - A_{CP}^{\pi\pi}$



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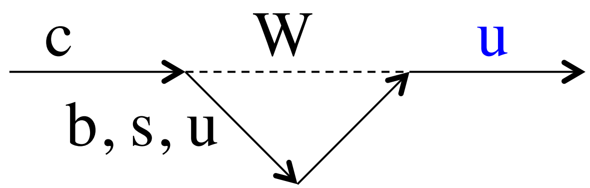


$$V_{ub}V_{cb}^* \{F(m_b) - F(m_d)\} + V_{cs}V_{us}^* \{F(m_s) - F(m_d)\}$$

KK and ππ: tree weak amplitudes are with opposite signs
if U-spin symmetry holds, **interference terms have opposite signs**

D physics with LHCb in 2011

- Time integrated CP violation in $D \rightarrow K^+K^-$ and $\rightarrow \pi^+\pi^-$
  Decay time integrated CP asymmetries: A_{CP}^{KK} and $A_{CP}^{\pi\pi}$

$$\frac{D^0_{initial} \rightarrow f - \overline{D}^0_{initial} \rightarrow f}{D^0_{initial} \rightarrow f + \overline{D}^0_{initial} \rightarrow f}$$

  and CP asymmetry difference: $\Delta_{CP} = A_{CP}^{KK} - A_{CP}^{\pi\pi}$

  World average $\Delta_{CP} = -\,0.0043 \pm 0.0036$ dominated by CDF

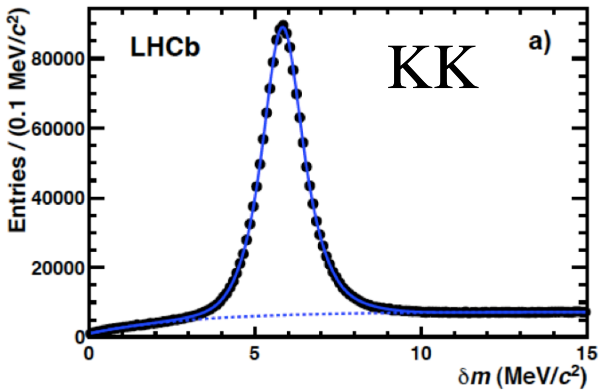
D physics with LHCb in 2011

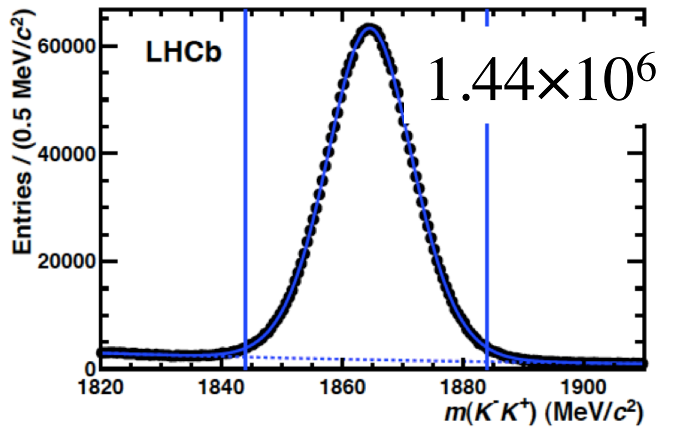
- Time integrated CP violation in $D \to K^+K^-$ and $\to \pi^+\pi^-$
  At LHC, large $\sigma_{c\bar{c}} \approx 6$ mb ≈ 20 times $\sigma_{b\bar{b}}$
  Initial tag: $D^{*+} \to D^0\pi^+$ and $D^{*-} \to \bar{D}^0\pi^-$

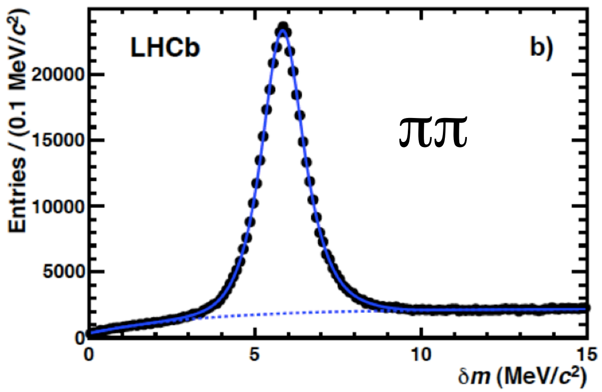
$m(D^{*+} - D^0)$

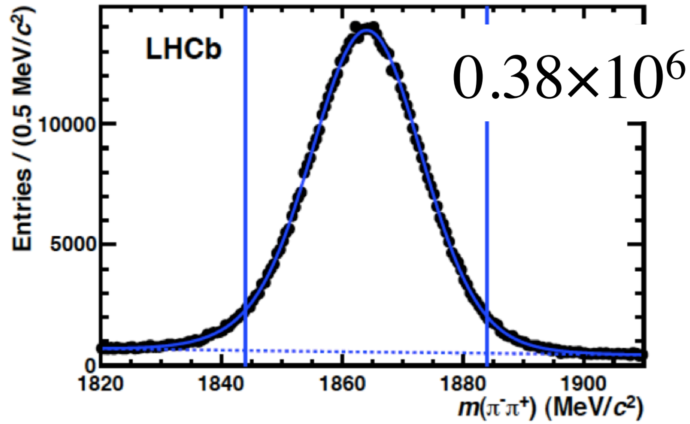
D^0 mass

620 pb^{-1}









D physics with LHCb in 2011

- Time integrated CP violation in $D \to K^+K^-$ and $\to \pi^+\pi^-$

  LHCb with 620 pb^{-1} submitted for publication
  $\Delta_{CP} = -0.0082 \pm 0.0021 \pm 0.0011 = -0.0082 \pm 0.0024$
  - World best measurement
  - SM prediction difficult, but expected to be at most $O(10^{-3})$
  - Interesting to see how it develops with more statistics
  - A_{CP}^{KK} and $A_{CP}^{\pi\pi}$ separately in the future
  - Time dependent study in the future
  - Other D-$\overline{D}$ mixing and CPV parameters have been measured, but not the world best yet (2010data, 29 pb^{-1})). This will change soon!
    submitted for publication

What I could not show…

- Preparation for the CKM parameter measurements, e.g. γ;
  reconstruction of $B_{u,d}\to DK$, $B_s\to D_sK$, …
- Rare and SM forbidden B and D decays;
  reconstruction of B, D$\to$ $e\mu$, $\mu^+\mu^+$+c.c., …
- Spectroscopy with b-quarks;
  excited B's, b-baryons, …
- Exotic states with c (and b in future);
  X, Y, Z, …
- PDF and QCD measurements;
  $d\sigma^2/dy\,dp_T$ for W and Z
- Soft QCD

⋮

Conclusions

- At LHC, new physics is now searched both directly and indirectly.
- LHCb is running with a higher luminosity than designed, thank to the flexible trigger.
- LHCb starts to provide the world best measurements in many B and D decays already with ~370 fb^{-1} of data.
- So far, CP violation and rare decay measurements are in agreement with the Standard Model predictions.
- LHCb collected ~1 fb^{-1} of data this year. Results expected for the coming conferences.
- Forward acceptance, particle ID, flexible trigger and high data logging rate allow LHCb to perform a wide range of physics programme.

My standard joke of the past years…

My hope, expectation and possible realities
matrix for 2014 at LHC

ATLAS CMS high p_T physics	BSM	Only SM	BSM	
LHCb flavour physics	Only SM	BSM	BSM	
Particle Physics	☺	☺	☺	

Oh, no more space left…