It has been a beauty-ful summer……..

LHCb Status Report

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on behalf of the LHCb Collaboration

LHCC Open Session, September 21st, 2011

…..but what a summer!

Outline:

Detector operation

Computing/offline activities

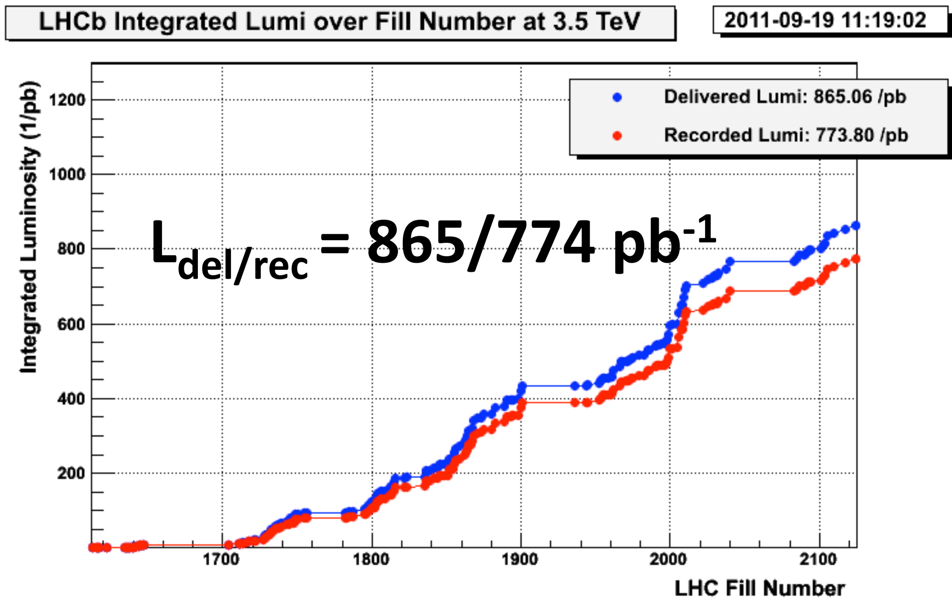
Physics results

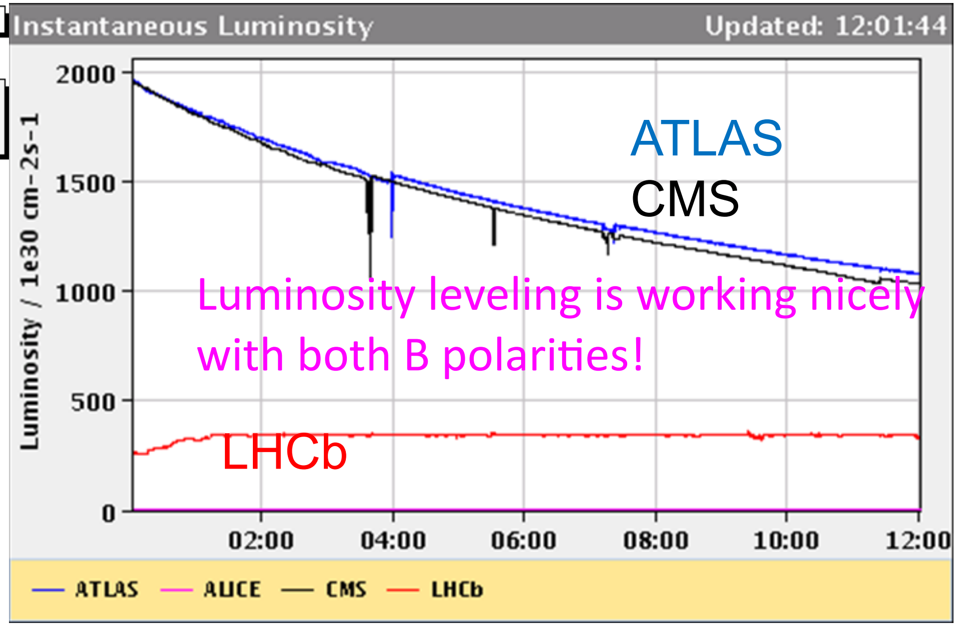
Conclusions and outlook

Detector Operations (1/4)

	L_{inst} [Hz/cm^2]	L0 output rate	μ	Efficiency	L_{int} [pb^{-1}]
April-June	3.0x10^{32}	620 kHz	1.8-2.0	90 %	~350
July-Sept	**3.5x10^{32}**	**850 kHz**	**<1.5**	**90 %**	**~450**

These are the conditions we will keep up to the end of the 2011 run





LHCb is running at ~1.8xL(design) with μ = 3.5x μ(design) well beyond the design parameters (and we are pushing this limit up)

Detector operations (2/4)

Since beginning of August we are running at L_{inst} = $3.5x10^{32}/cm^2/s$
with a L0 output rate of 850 kHz (very close to design)

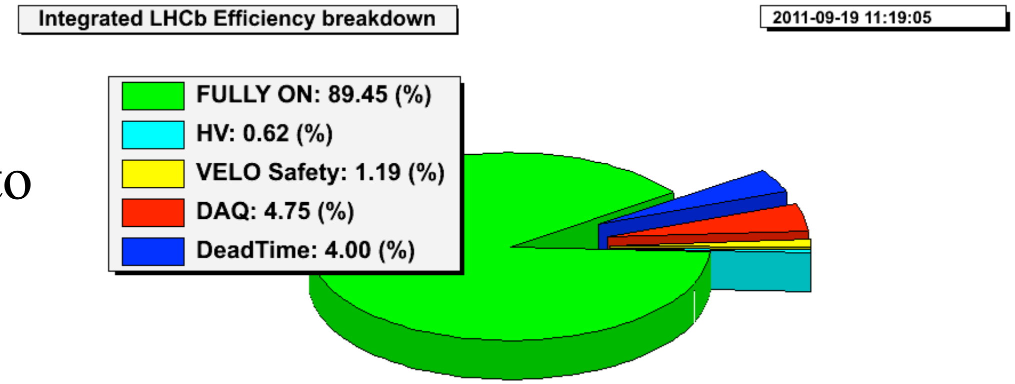
This was possible due to the following improvements:

1. Dead-time due to Tell 1 / UKL1 boards reduced by deploying new firmware.
   → The dead-time due to Tell 1 boards is now <1% (in June was 10% at $3.5x10^{32}$ Hz /cm^2)

2. New online farm installed beginning of August : +20% CPU capacity for HLT
   → added 6x30 nodes to the 1350 already operational

→it was the major source of dead time after the tell1 fixing
→ We are running now at ~90% CPU capacity
→ Margin to increase L without changing trigger

Total dead time now is ~4% (but margin to improve it);



We will do a test at $4x10^{32}$ Hz/cm^2 at the end of the present run

Detector operations (3/4)

The sub-detectors notice we are running at high L:

1. the silicon detectors are showing the first radiation effects:

→but exactly as expected

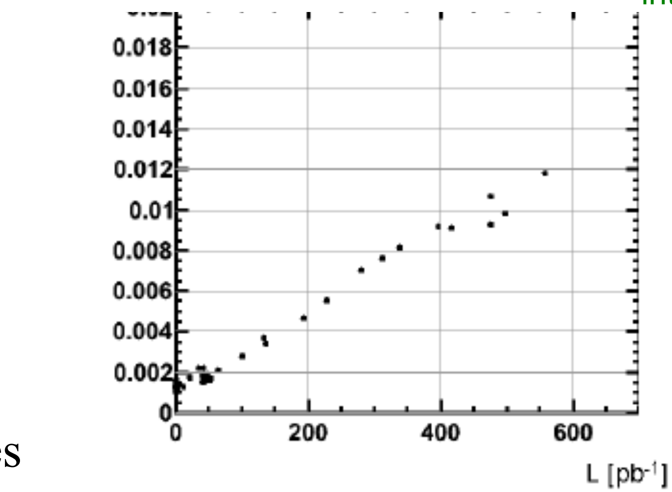
2. the inner zone of HCAL is ageing:

→ but continuously monitored and recalibrated using the Cs source

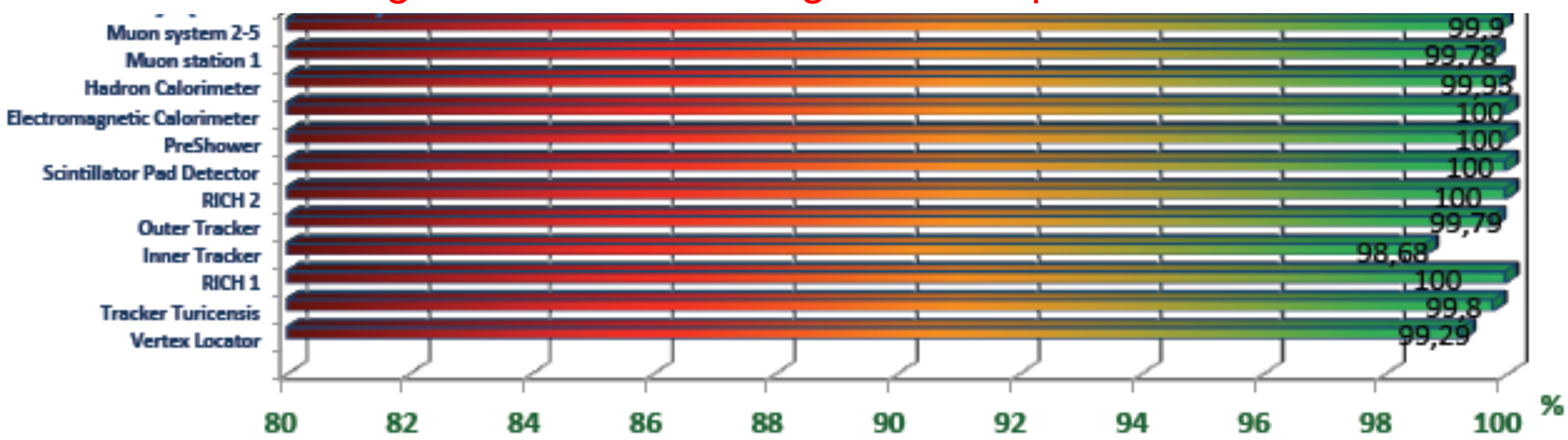
3. RICH: Beam Induced Light Emission (BILE) effect is still there

→but largely reduced by flushing $C0_2$ in the HPD boxes

Current increase for Velo sensors as a function of L_{int}



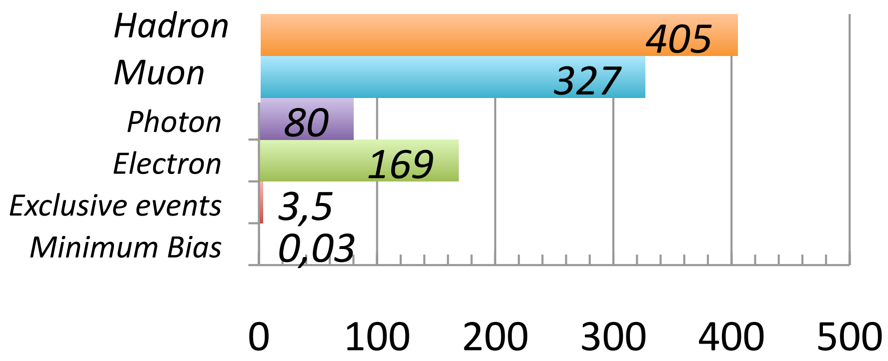
Average fraction of working channels per sub-detector above 98%



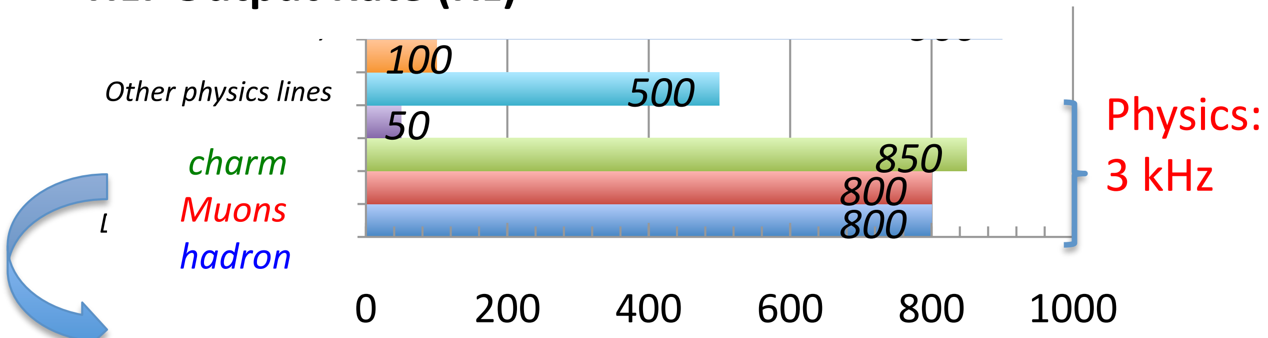
Trigger (4/4)

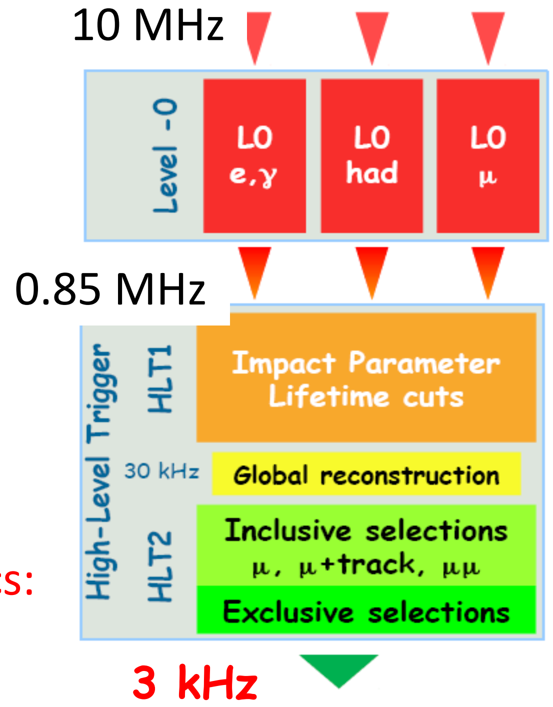
- With 1380 bunches in the LHC, 3.5×10^{32} $cm^{-2}s^{-1}$:
  - Visible crossing rate: 10 MHz
  - L0 output rate: 850 kHz
  - HLT output rate: 3 kHz of physics triggers written on tape
  - HLT Farm CPU busy at ~90 %

L0 Output Rate (kHz, non exclusive)



HLT Output Rate (Hz)





From the bandwidth sharing you see that we are a "catholic" experiment….

Computing/Offline: Virtual Memory (VMEM) and persistency (1/3)

Problem found in spring 2011:
→ unreasonable VMEM usage at TIer1's in reconstruction/stripping process
→ Hit the maximum CPU VMEM of most Tier1 (4 GB) with only 1 raw file per job (60k events).

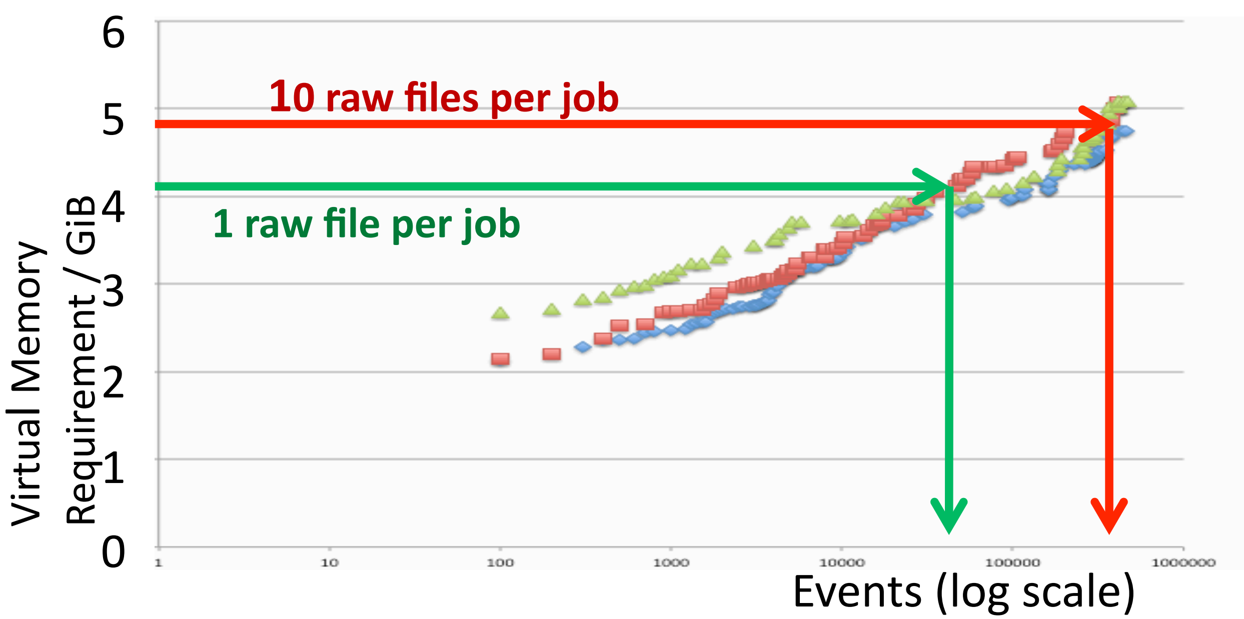
Temporary solution: split 1 raw file in 2 jobs
Price to pay: huge handling of small files during merging phase….
-→ But this allowed us to have data ready for summer conferences!.

Computing/Offline:
Virtual Memory (VMEM) and persistency (2/3)

In parallel setup task force to understand the reason:

1. End of spring reason found:
   → Usage of POOL as intermediate layer between LHCb software and ROOT persistency framework found to be highly inefficient for I/O and VMEM usage

2. End of August: POOL layer removed (huge work but fully transparent for users)
   → Now possible to process 2 raw files per job
   →Aim to reach 10 raw files/job by end of 2012



Computing/Offline:
Disk space and stripping (3/3)

Reconstruction output: 3 kHz with ~130 kB/event → ~ 400 MB/s

Spring 2011:

→ stripping retention too high (~84 MB/s)

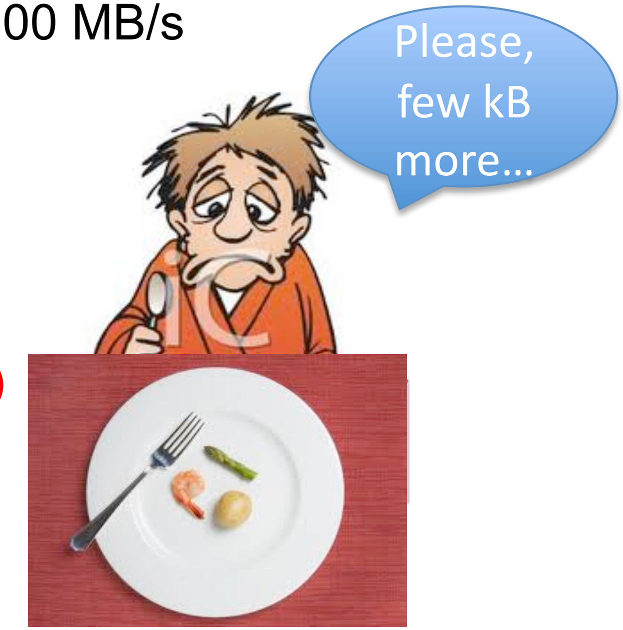
rapidly approaching the LHCb disk space limit.

→Draconian campaign during summer

allowed to pass from 84 MB/s → 34 MB/s (design value)

→Now ready to re-process the full 2011 dataset (~1 fb^{-1}) with the available disk space

(but limited margin for Monte Carlo production)



LHCb stripping lines developer

Reprocessing of 2011 dataset for Winter Conferences will start at the end of September

Physics results

Summer 2011 has been a transition phase for LHCb.

From the calibration of the source…

mostly measurements of cross sections but also observations of new exotic states

…to the heart of the LHCb (and world wide) flavour physics program:

→ 27 new results presented at summer conferences

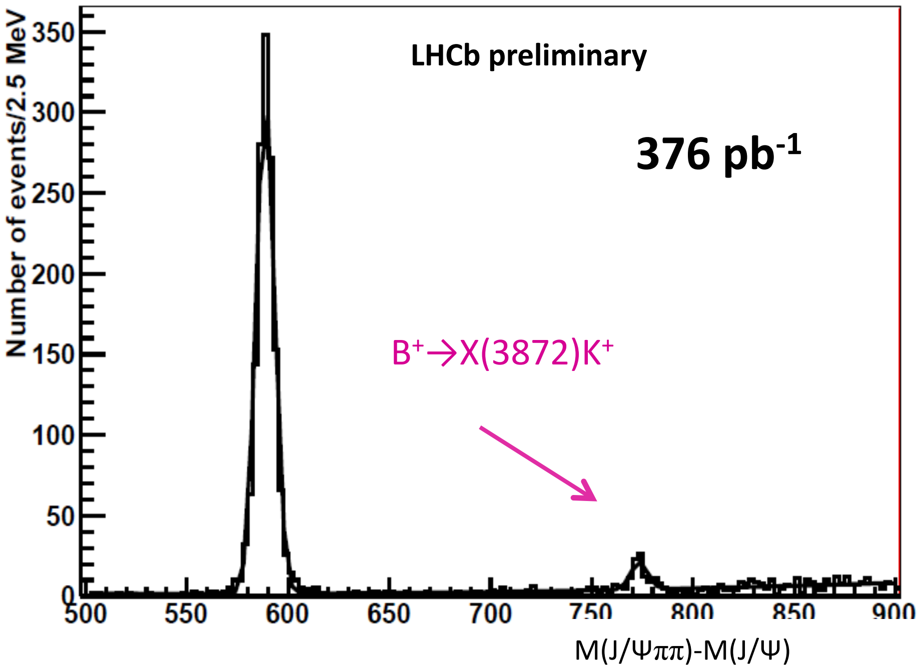
(here possible to cover only some of them):

1. search for NP in $B_d \to K^* \mu\mu$ decays (EPS11, 310 pb^{-1})
2. search for NP in $B_{d,s} \to \mu\mu$ decays (EPS11, 300 pb^{-1})
3. search for NP in the mixing induced CPV phase in B_s (LP11, 340 pb^{-1})
4. search for CPV phase in charm mixing (EPS+LP)
5. constraining the CKM picture: progress toward γ (EPS+LP),

\+ penguins, new states, etc, etc,

Appetizer: exotic state X(3872)

X(3872) was observed by Belle in 2003 (PRL91 (2003) 262001).
LHCb is performing a full study of the X(3872) – observation, xsection & mass.



LHCb inclusive 2010 measurements:

$$M_{X(3872)} = 3871.96 \pm 0.46(\text{stat}) \pm 0.10(\text{syst})\ \text{MeV}/c^2$$

$$\sigma_{X(3872)} \times \mathcal{BR}(X(3872) \to J/\psi\pi^+\pi^-) = 4.74 \pm 1.10(\text{stat}) \pm 1.01(\text{syst})\ \text{nb}$$

LHCb-CONF-2011-021
LHCb-CONF-2011-043

With 2011 data it will be possible to perform very precise mass measurements as well as angular studies* in B→X(3872)K to learn about the J^{PC} of the X(3872)

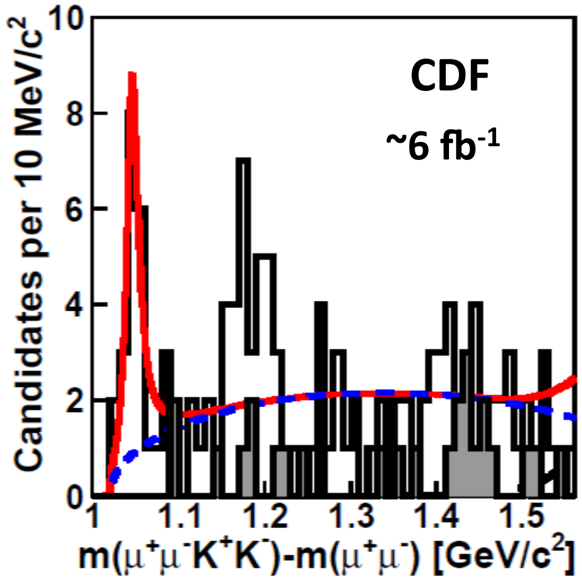
* see LHCb-PUB-2010-003

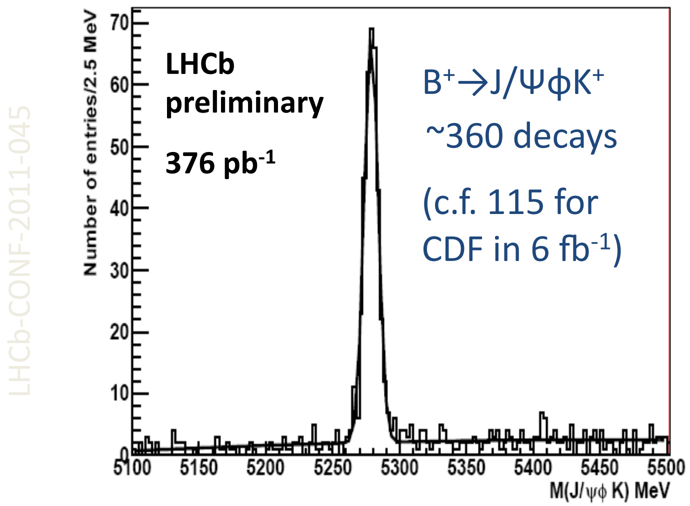
Second appetizer:

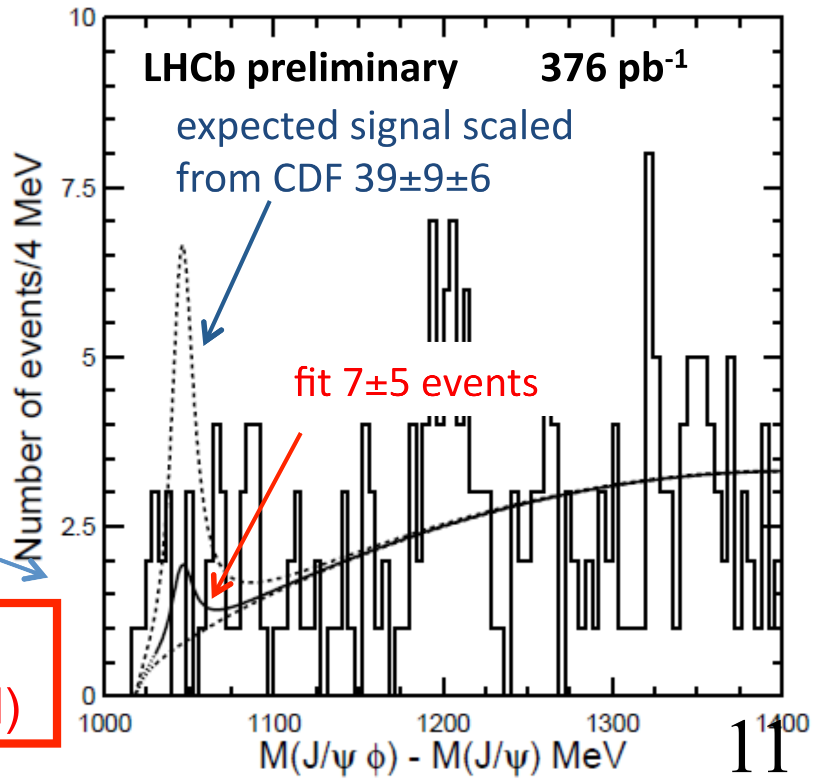
Search for the X(4140)

Studies of other possible exotics are underway.

CDF reported observation of narrow structure, X(4140), in the m(J/ΨK⁺K⁻)-m(J/Ψ) spectrum in $B^+ \to J/\Psi\varphi K^+$ events [arXiv:1101.6058]. LHCb now has a large sample of these decays.







Background model is 3- body phase space convolved with resolution

LHCb does not confirm presence of X(4140).
2.4σ tension with CDF (using this bckgd model)

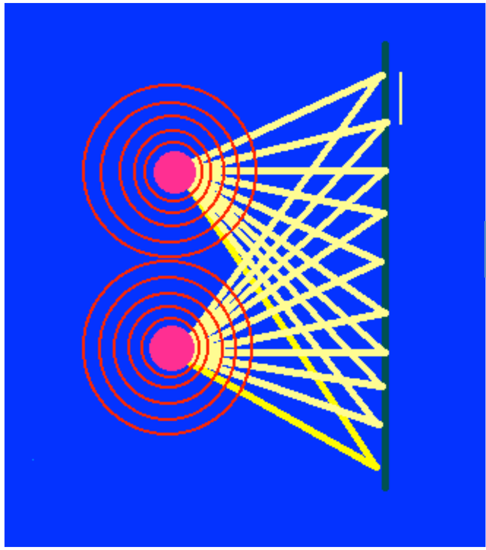
How to search for New Physics @ LHCb?

By studying interference patterns:

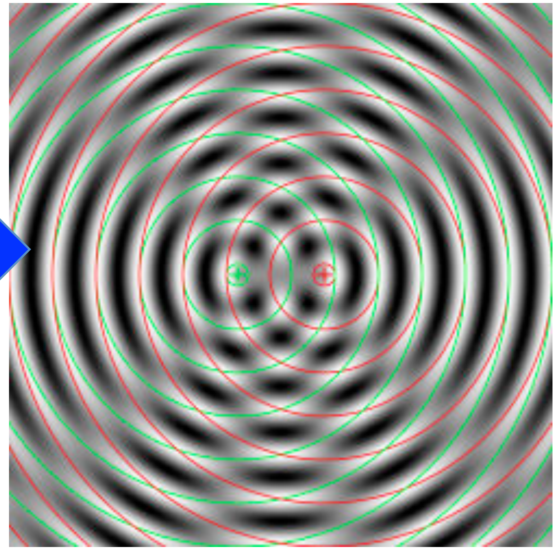
→ Sources with different amplitudes, phases and polarization states will determine different interference patterns

Source 1

Source 2



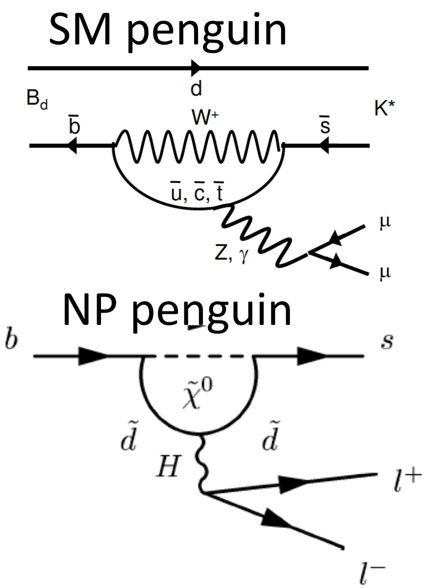
Interference pattern

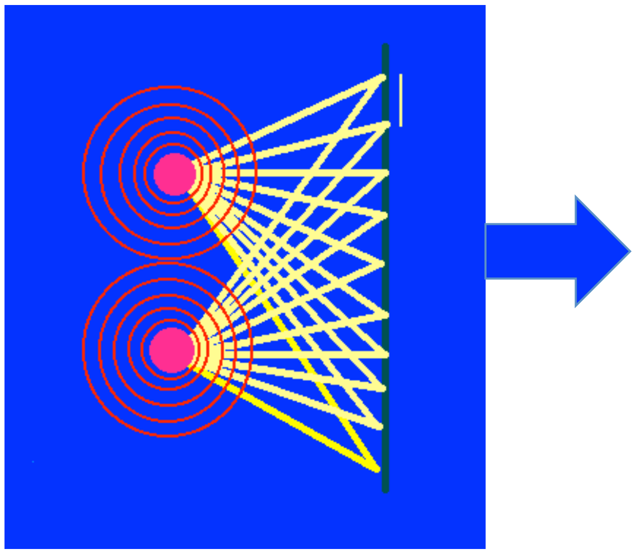


How to search for New Physics @ LHCb?

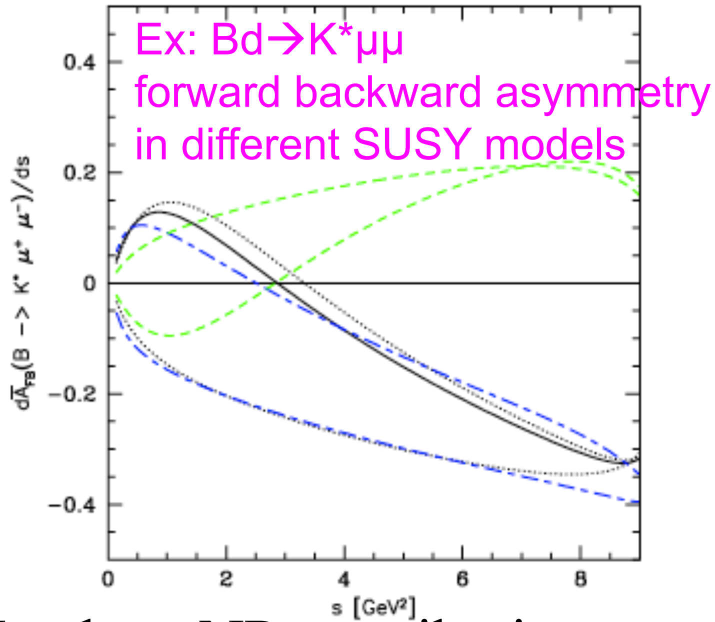
By studying interference patterns..

→ diagrams with different amplitudes (couplings), phases and helicity properties will produce final states with different BR (eg. Bs→μμ) , angular distributions (ex:Bd→K*μμ) and phases (ex. Bs mixing)





Interference pattern:

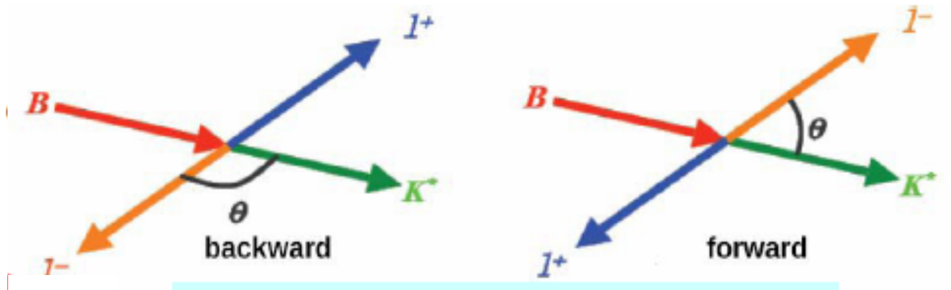


..in FCNC transitions, suppressed in the SM, where NP contributions can be large (in particular in the b→s transitions which are less known)

Search for NP in $B_d \rightarrow K^*\mu^+\mu^-$

Many observables exist to probe the helicity structure of any NP model in particular the forward–backward asymmetry A_{FB} as a function of the dilepton invariant mass (q^2):

$$A_{FB} = \int \frac{d^2 B(B \rightarrow K^* \mu^+ \mu^-)}{d\cos\theta} sgn(\cos\theta)$$

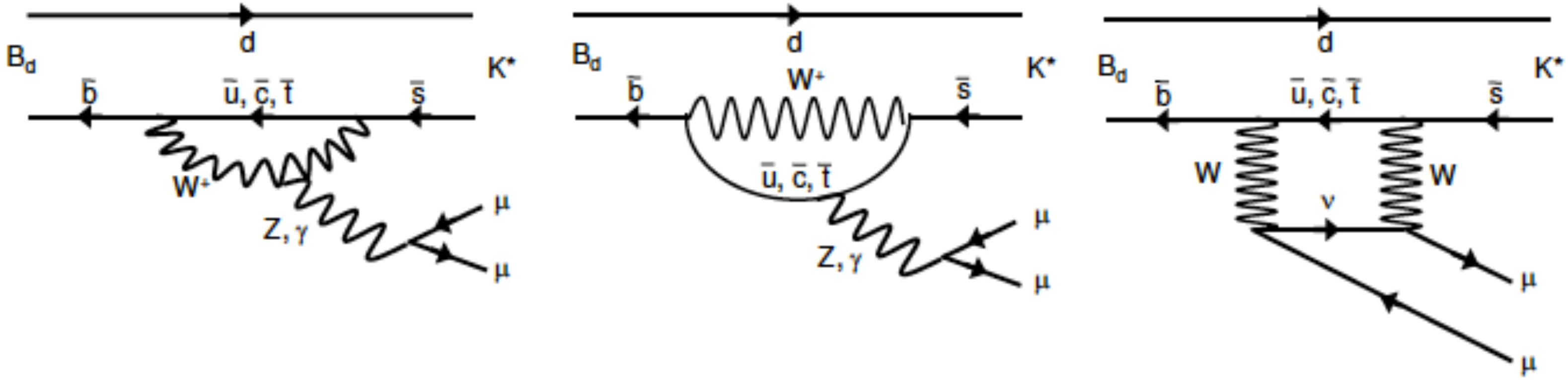


θ = angle between μ^+ & B in the dilepton rest frame

q^2 = dilepton invariant mass

$$A_{FB}\left(s = m^2_{\mu^+\mu^-}\right) = \frac{N_F - N_B}{N_F + N_B}$$

Main SM diagrams



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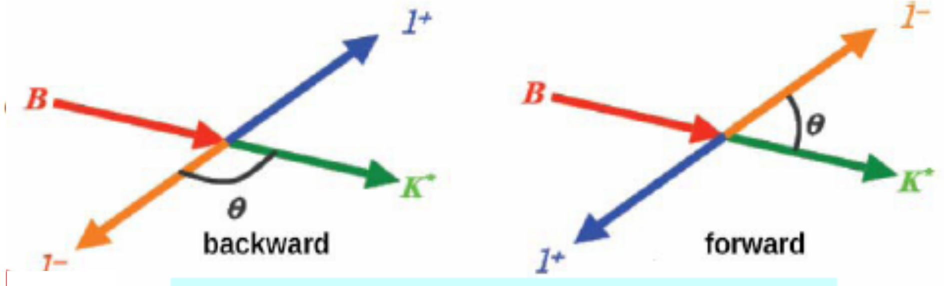

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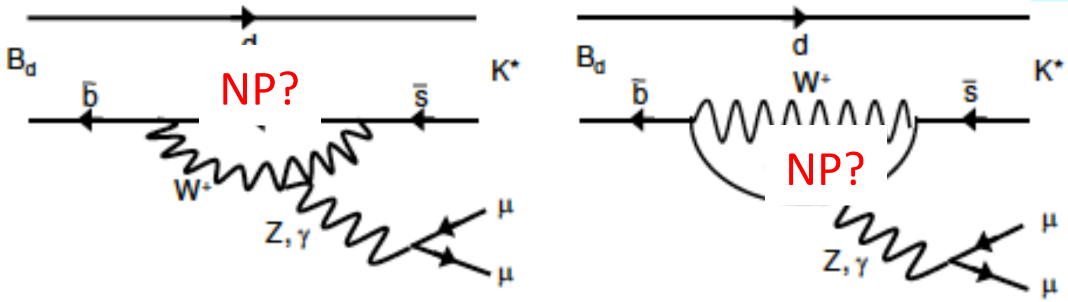
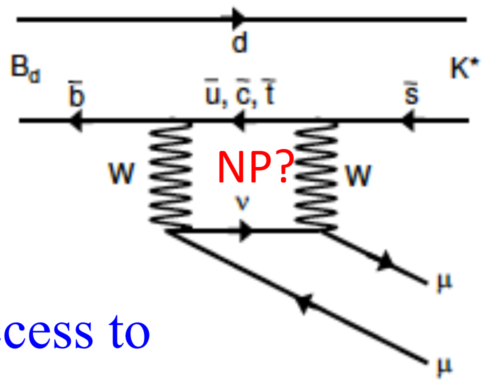




- Interference of axial & vector currents ➔ direct access to relative phases of diagrams involved.
- Uncertainties of hadronic form factors under control in the low-q^2 region.

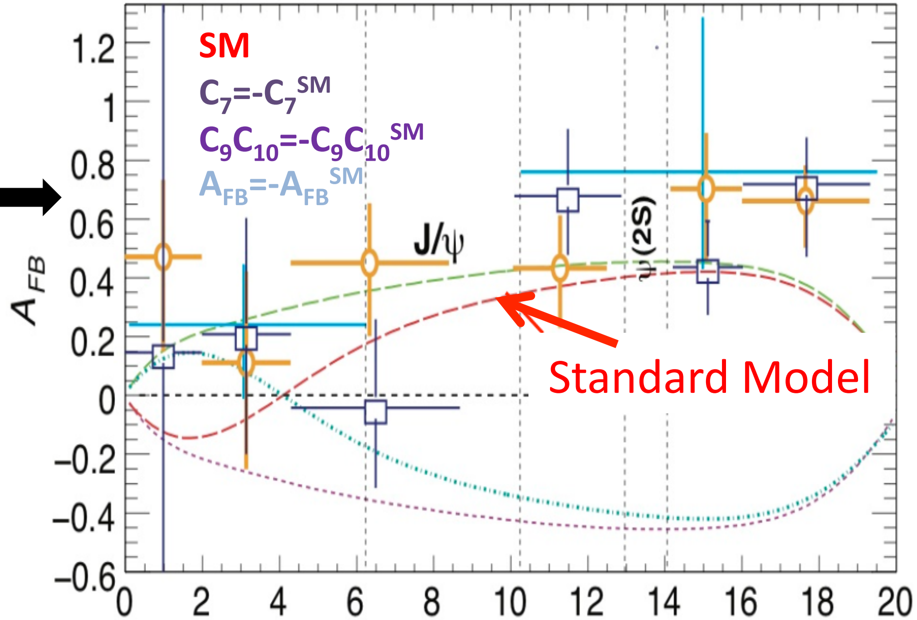
A_{FB} in $B_d \rightarrow K^*\mu\mu$: experimental status

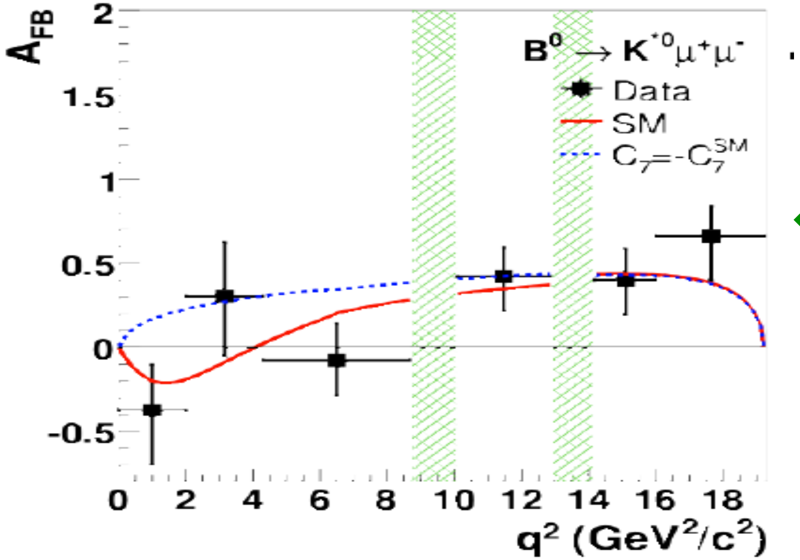
Early results have shown intriguing hints of deviations from SM but statistics too poor to claim any evidence

250 events
[PRL 103 (2009) 171801]

60 events
[PRD 79 (2009) 031102]

100 events
[4.4 fb^{-1}, CDF note 10047]

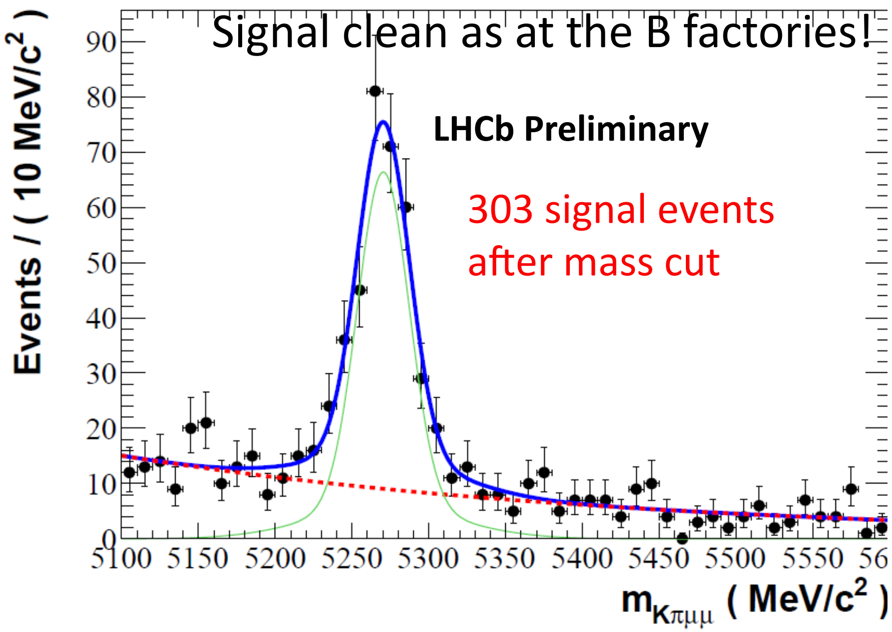


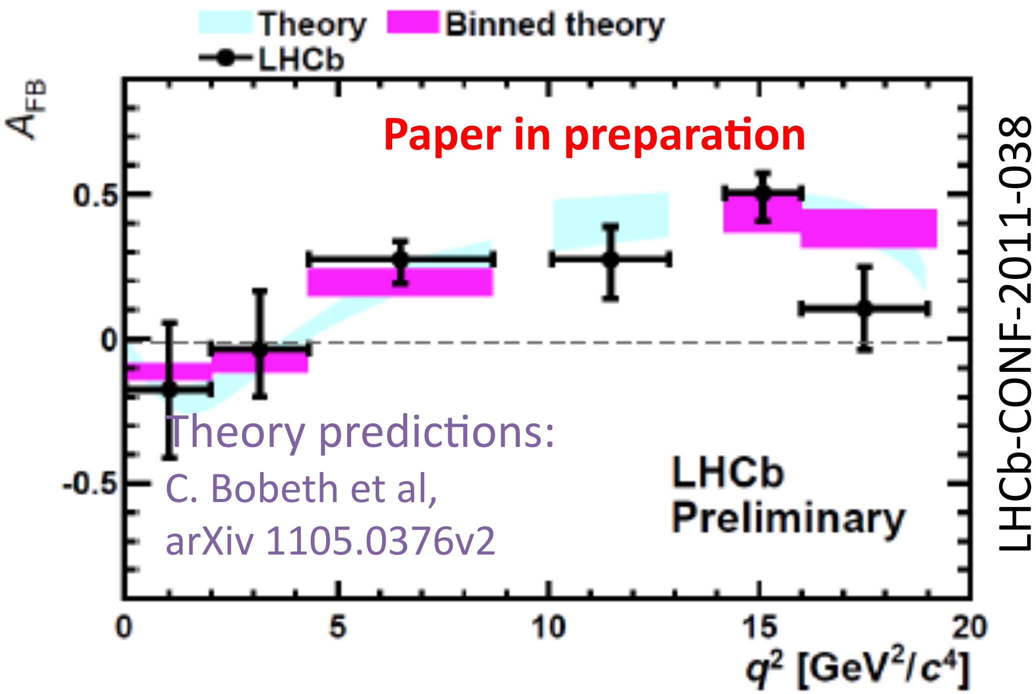


Brand new results from CDF published in August [arXiv:1108.0695] based on 6.8 fb^{-1} and 165 candidates

A_{FB} in $B_d \rightarrow K^*\mu^+\mu^-$: LHCb result (EPS11)

Based on 309 pb^{-1} and 300 candidates
(largest sample in the world and clean as at the B factories)

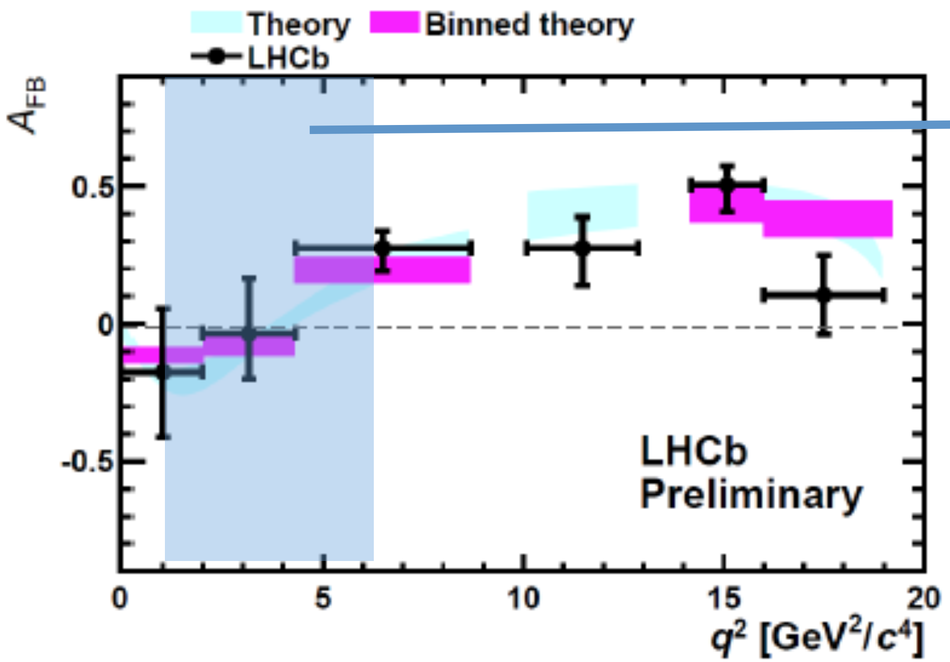




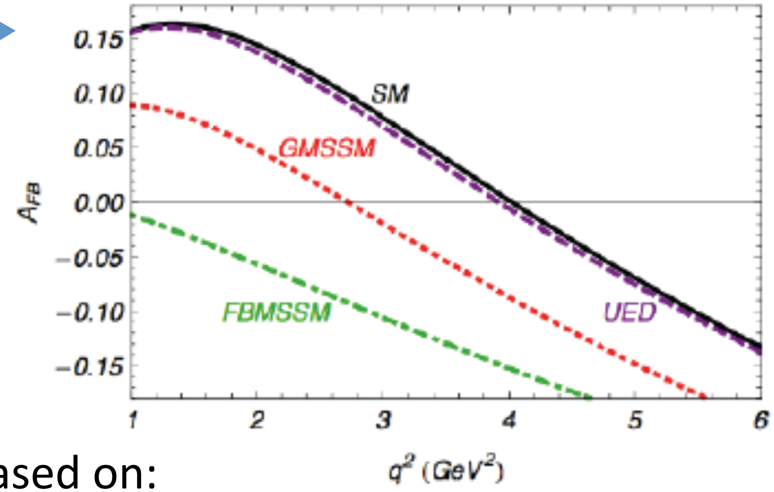
Data are consistent with predictions with present sensitivity
("like a textbook", M. Neubert, EPS2011)

$B_d \to K^*\mu^+\mu^-$: next steps

1.determine the zero crossing point: sensitive to NP and cleanly predicted in SM
→ 2011 data



A_{FB} with flipped sign for $1<q^2<6$:
zero crossing point in different models



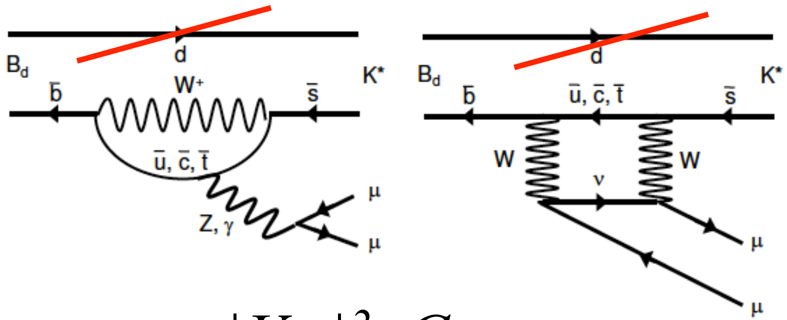
Based on:
W.Altmannshofer et al. [JHEP 0901:019 (2009)]

2. Study other observables by doing the full angular analysis,
eg $A_t^{(2)}$ sensitive to RH currents -→ 2011+2012 dataset

2. Search for NP in $B_{s,d} \rightarrow \mu\mu$ decays

$B_{(d,s)} \rightarrow \mu\mu$ is the best way for LHCb to constrain the parameters of the extended Higgs sector in MSSM, fully complementary to direct searches

Main SM diagrams



$\sim |V_{ts}|^2, C_A$

Double suppressed decay: **FCNC process** and **helicity suppressed**:

→ **very small in the Standard Model but very well predicted:**

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

Buras et al., arXiv:1007.5291 and references therein

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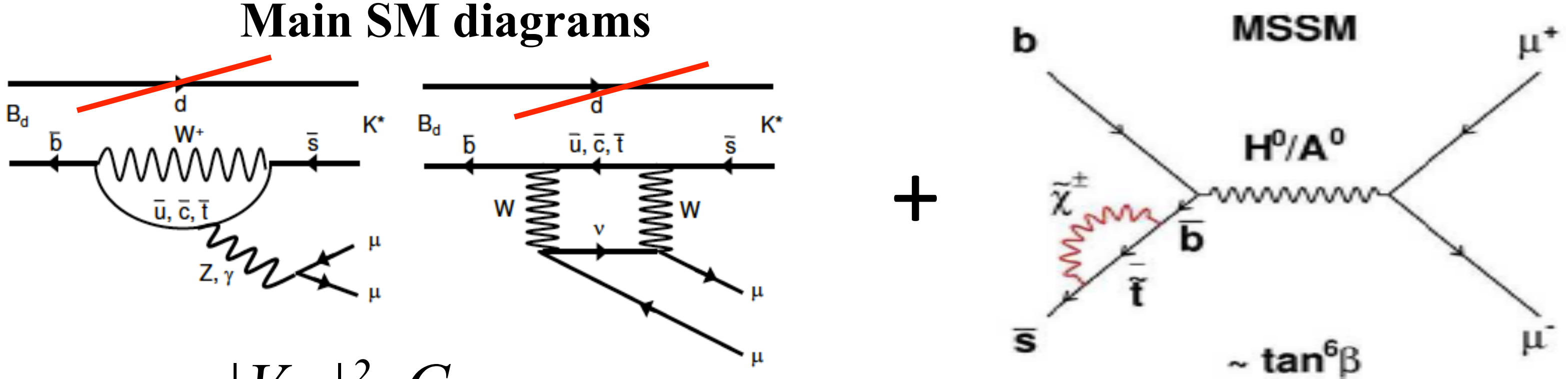

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→**Sensitive to NP contributions in the scalar/pseudo scalar sector:**

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

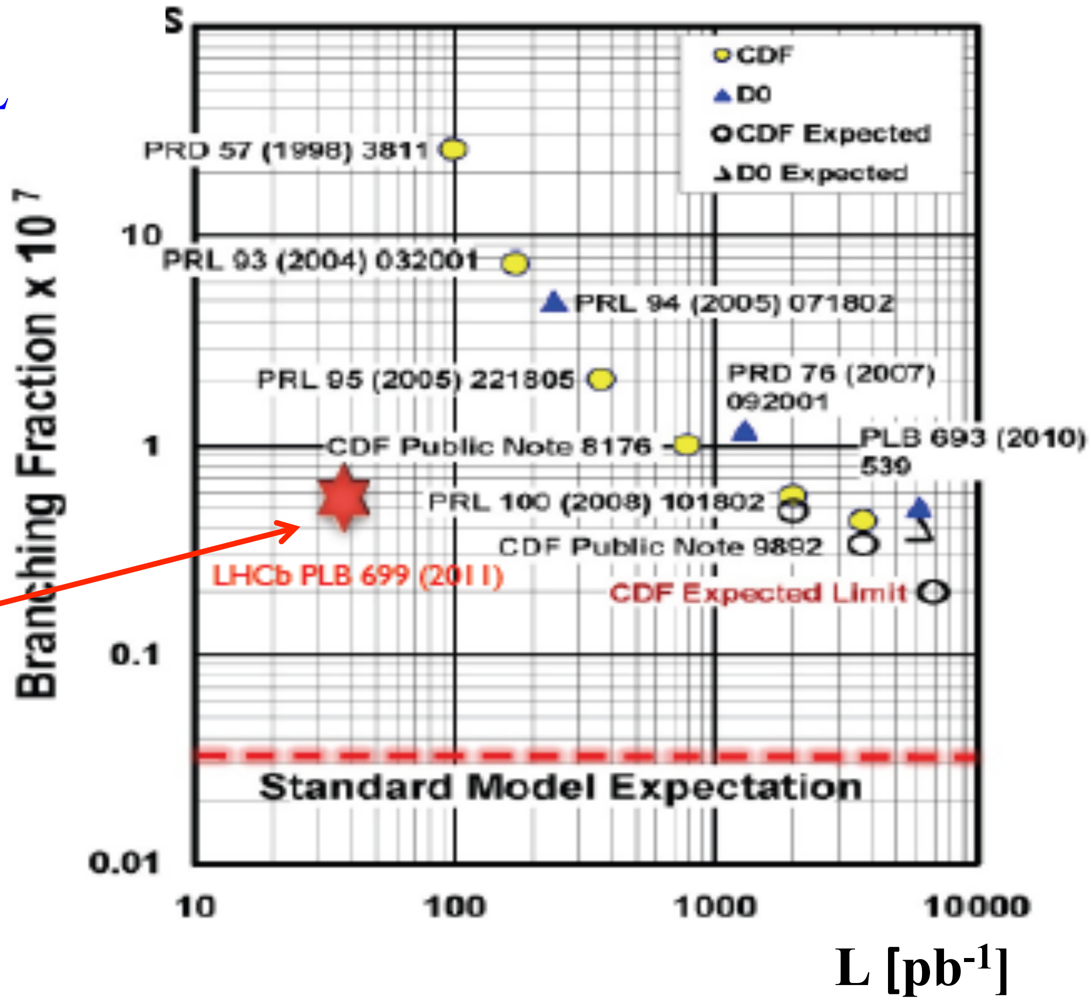
MSSM, large tanβ approximation

Experimental results (before summer 2011)

Published $B_s \rightarrow \mu\mu$ limits @ 95% CL

Experiment	Data set	Limit
CDF	3.7 fb^{-1}	4.3 x 10^{-8}
D0	6.1 fb^{-1}	5.1 x 10^{-8}
LHCb	0.036 fb^{-1}	5.6 x 10^{-8}

LHCb (Phys. Lett. B699 (2011) 330) equivalent to CDF with ~100 times less luminosity



July 2011: CDF observes an excess of $B_s \to \mu\mu$ candidates:

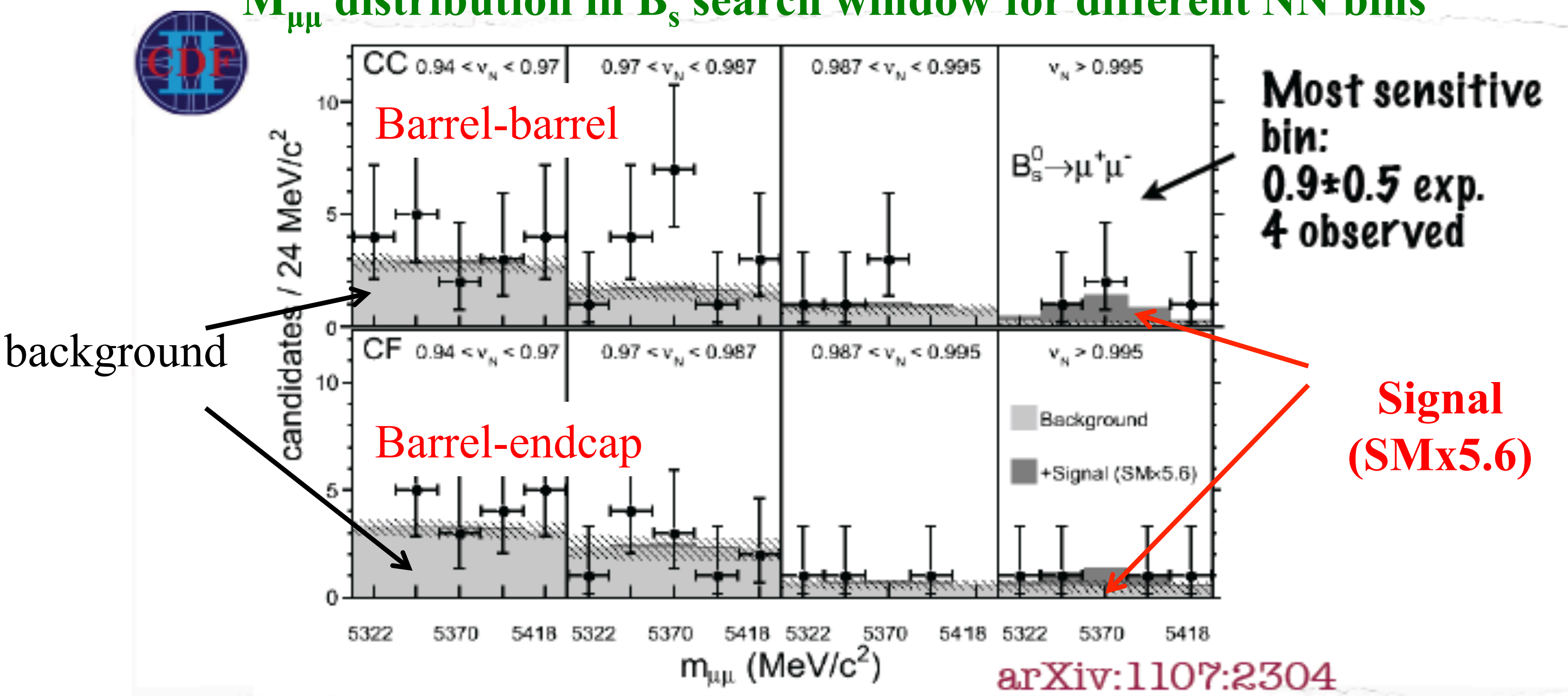
$0.46 \times 10^{-8} < BR < 3.9 \times 10^{-8}$ @ 90% CL or $BR = (1.8^{+1.1}_{-0.9}) \times 10^{-8}$

arXiv:1107.2304

<u>Result based on:</u>

1) double sample size ($3.7\ fb^{-1} \to 7\ fb^{-1}$)
2) +20% acceptance for muons
3) improved Neural Network

$M_{\mu\mu}$ distribution in B_s search window for different NN bins



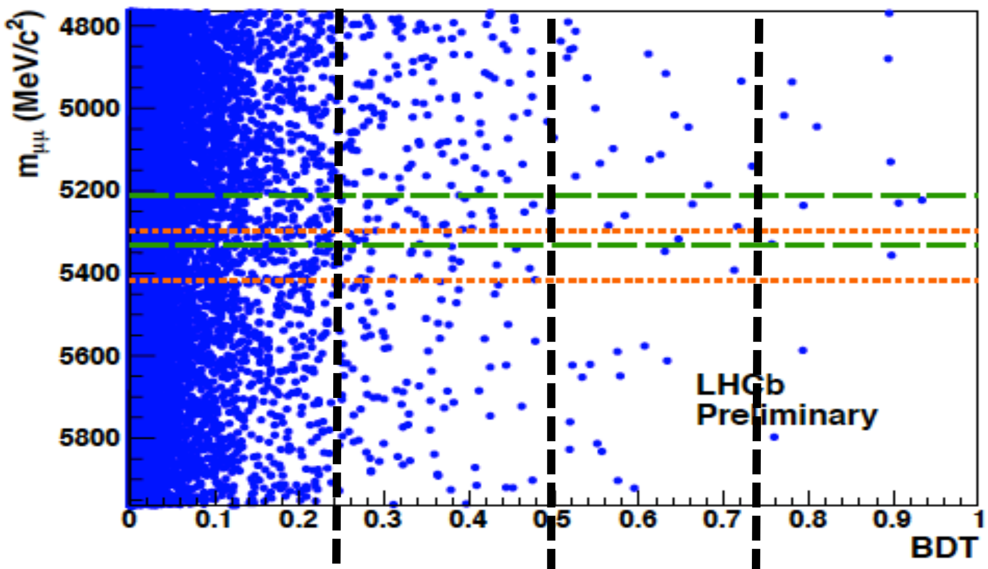
2.8 σ assuming bkg-only hypothesis, 1.9% compatibility with bkg+SM hypothesis

LHCb $B_{sd} \rightarrow \mu\mu$ analysis

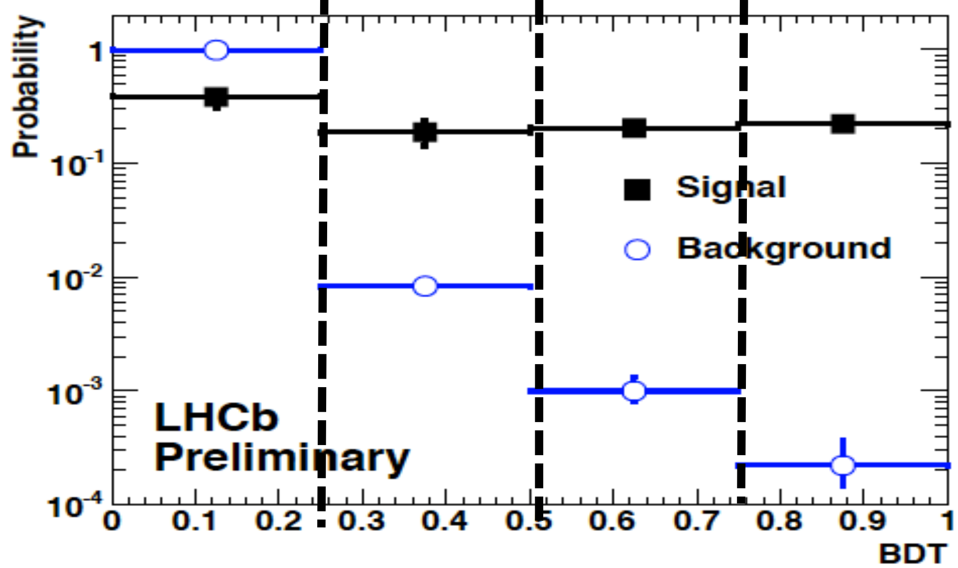
Events are classified in a 2D plane: Invariant mass vs Boosted Decision Tree (BDT)

M(μμ) vs BDT plane
4 BDT bins
6 mass bins

Search windows ($M(B_{s,d}) \pm 60$ MeV



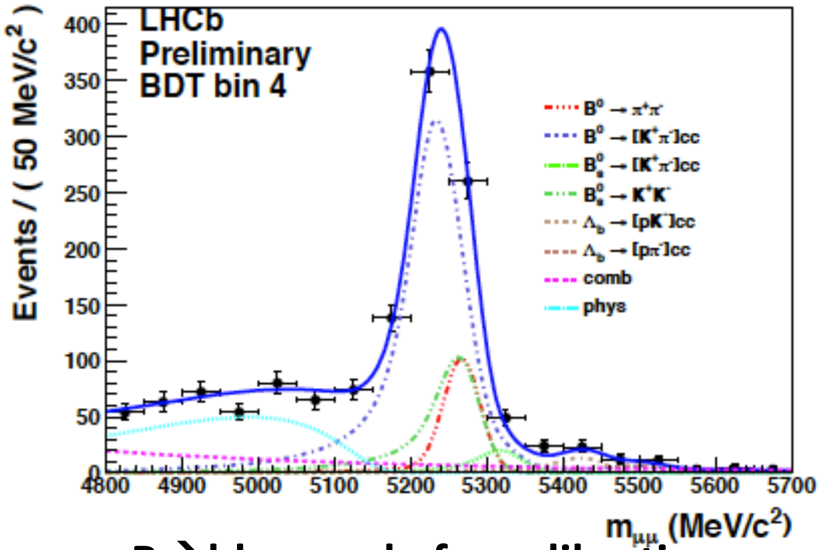
BDT distributions for signal and background



LHCb $B_{sd} \to \mu\mu$ analysis: calibration

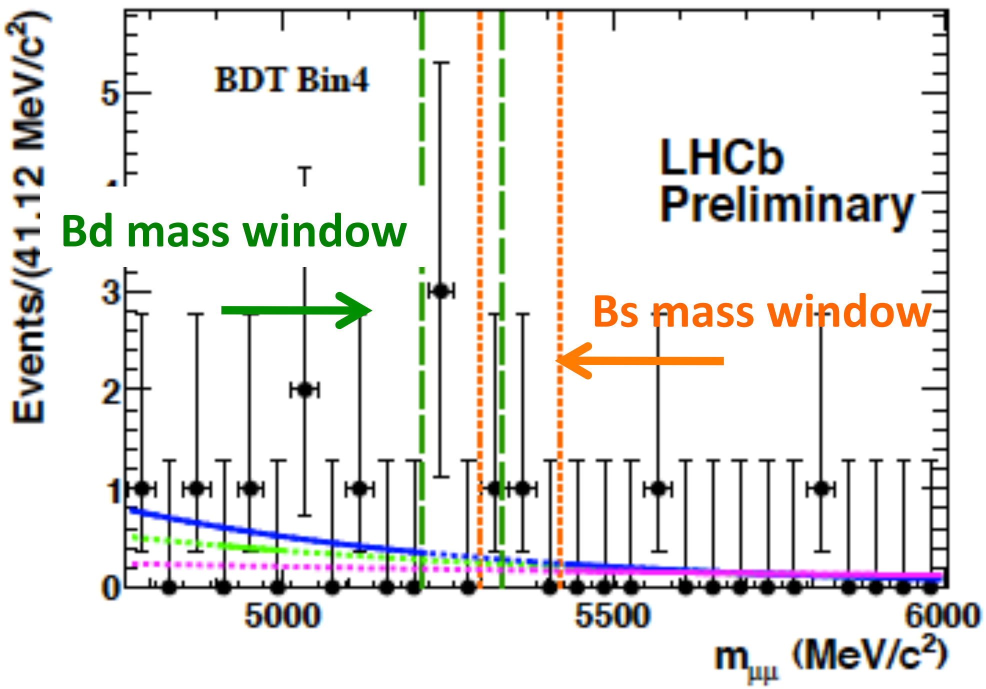
The analysis has been design to extract all the relevant quantities from data

- mass lineshape & BDT shape from $B \to hh$ events



$B \to hh$ sample for calibration

Background in search window



expected background in search windows from fit of data sidebands

LHCb $B_{sd} \rightarrow \mu\mu$ analysis: <u>normalization</u>

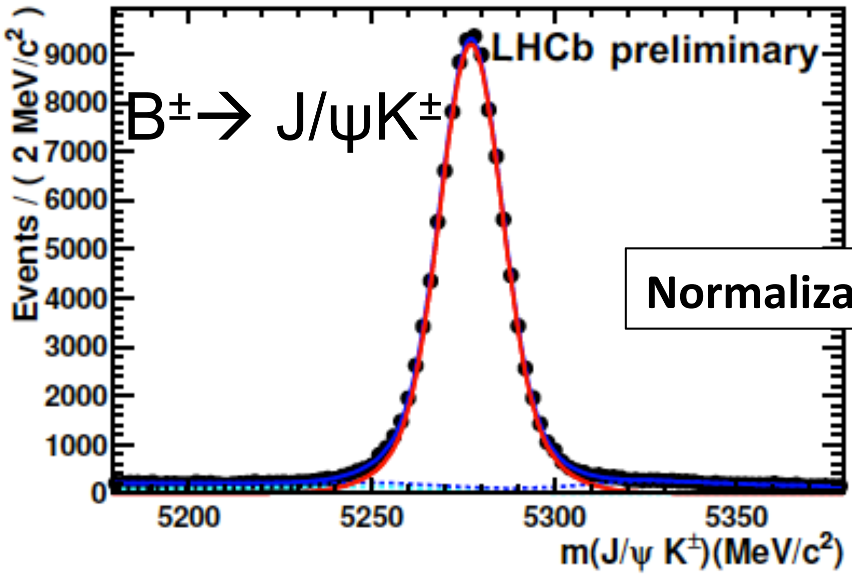
Number of observed events are converted into a BR by normalizing to channels of known BR:

→Use three channels: $B^+ \rightarrow J/\psi\ K^+$, $B_s \rightarrow J/\psi\ \phi$, $Bd \rightarrow K\ \pi$
→Use f_s/f_d LHCb combined result from semi- leptonic and hadronic decays:

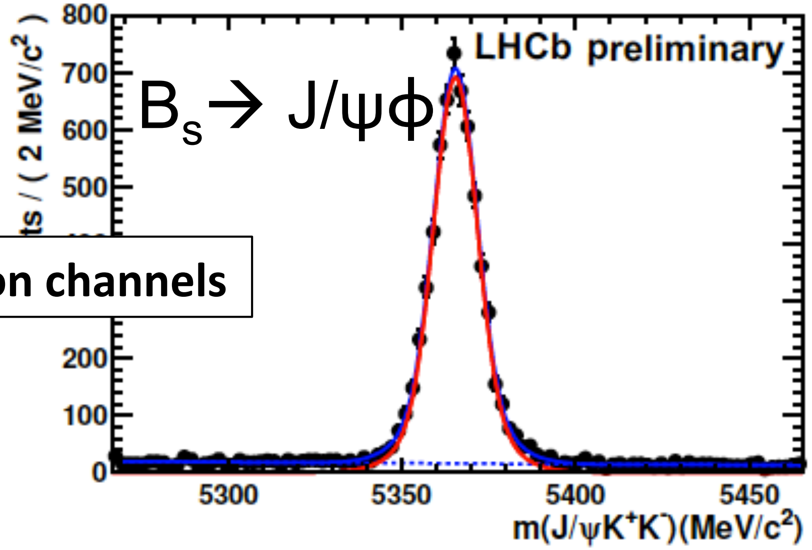
$$f_s/f_d = 0.267\ ^{+0.021}_{-0.020}$$

f_s/f_d not a priori a 'universal' number, but agreement nonetheless seen with other measurements:

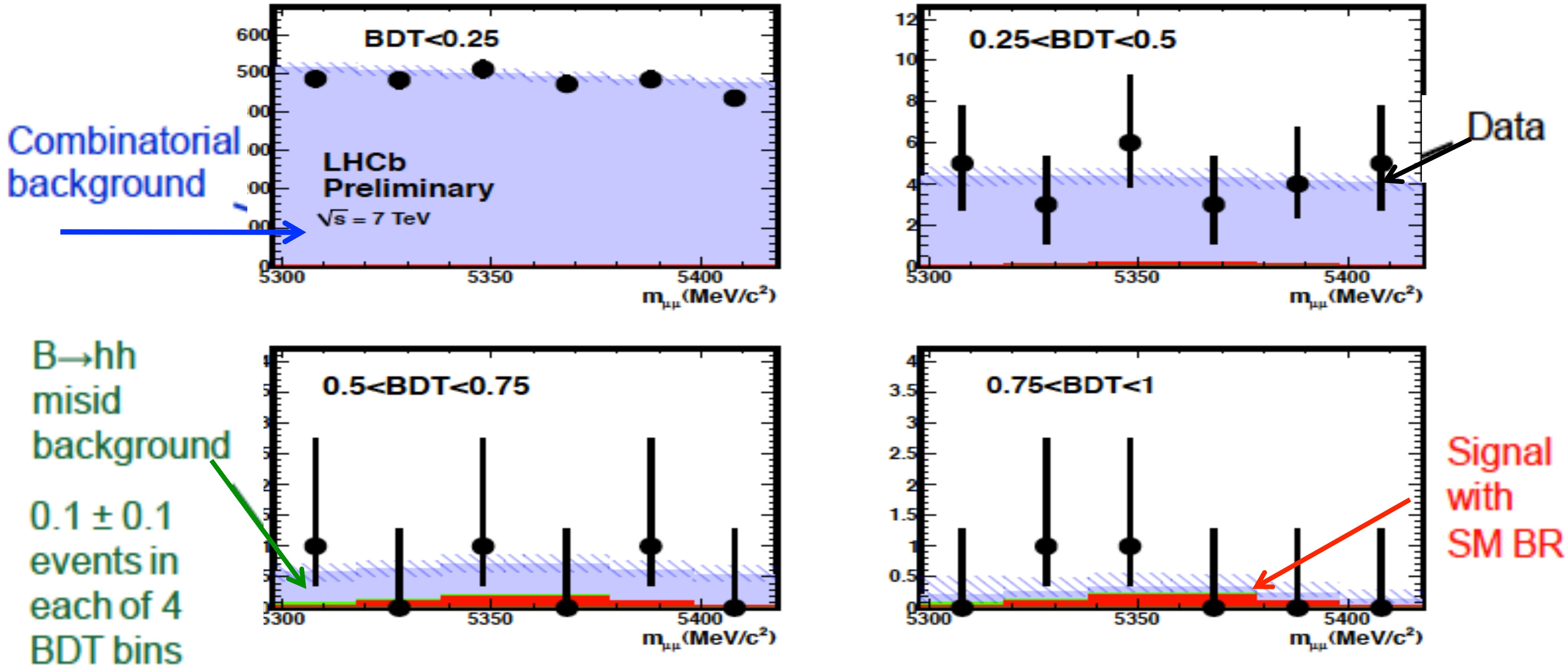
$$\langle f_s / f_d \rangle_{LEP\ Tevatron} = 0.271 \pm 0.027$$



Normalization channels

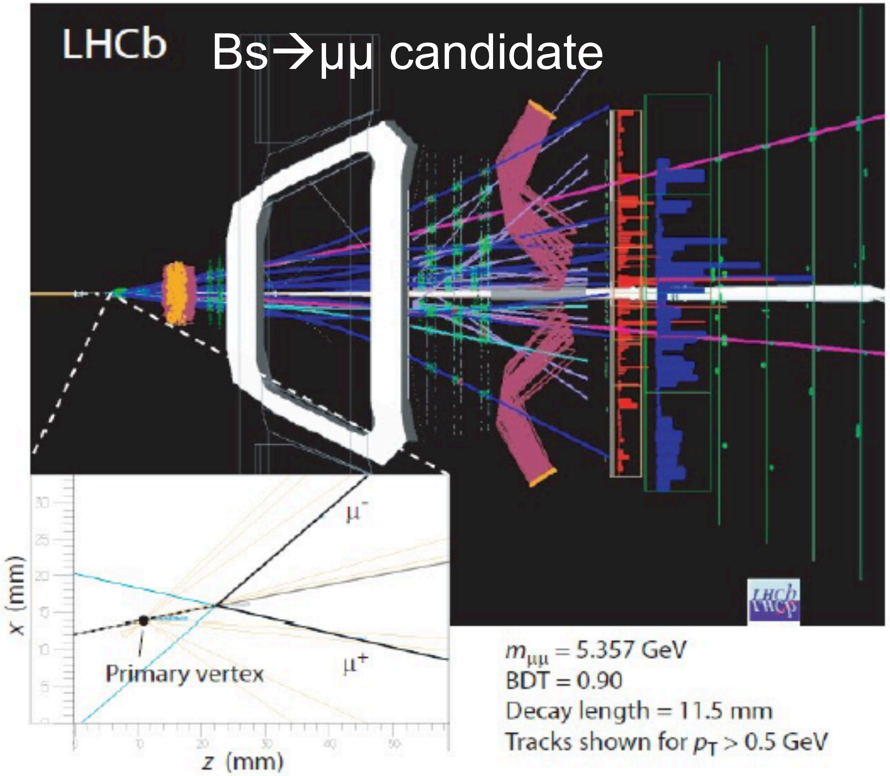


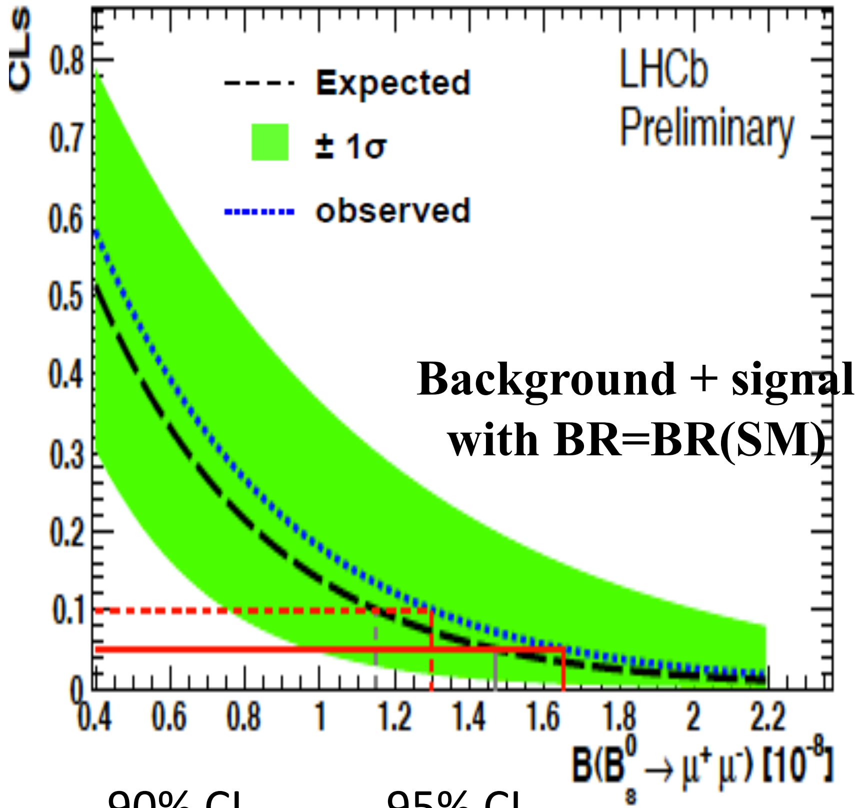
LHCb preliminary result in the B_s mass window with 300 pb^{-1} (no peak, clearly…)



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

LHCb preliminary limit for BR($B_s \to \mu\mu$) with ~340 pb^{-1} (world best)

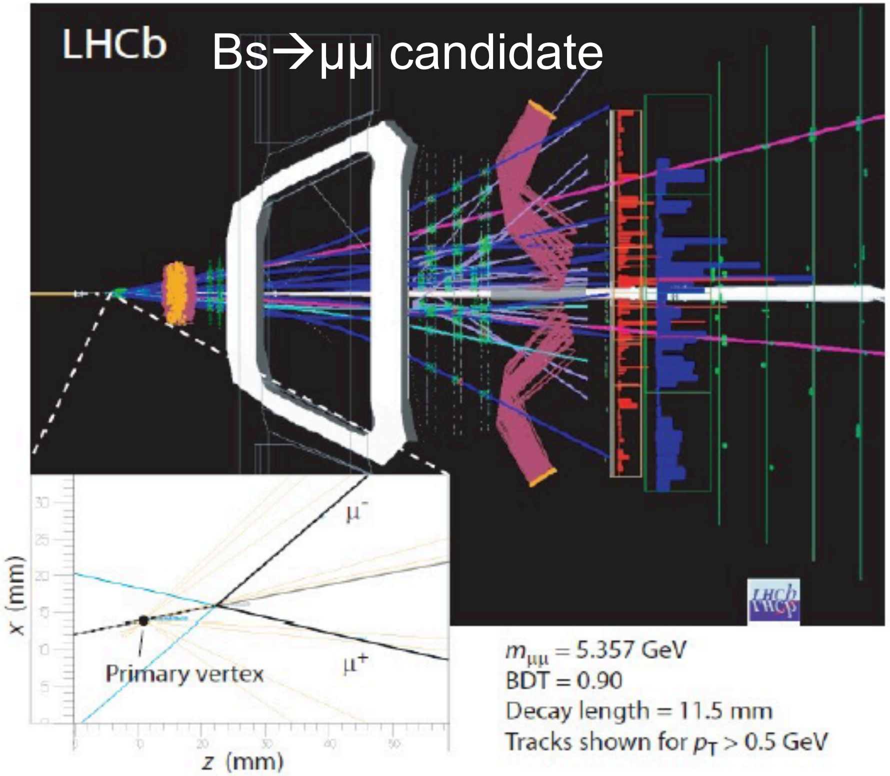


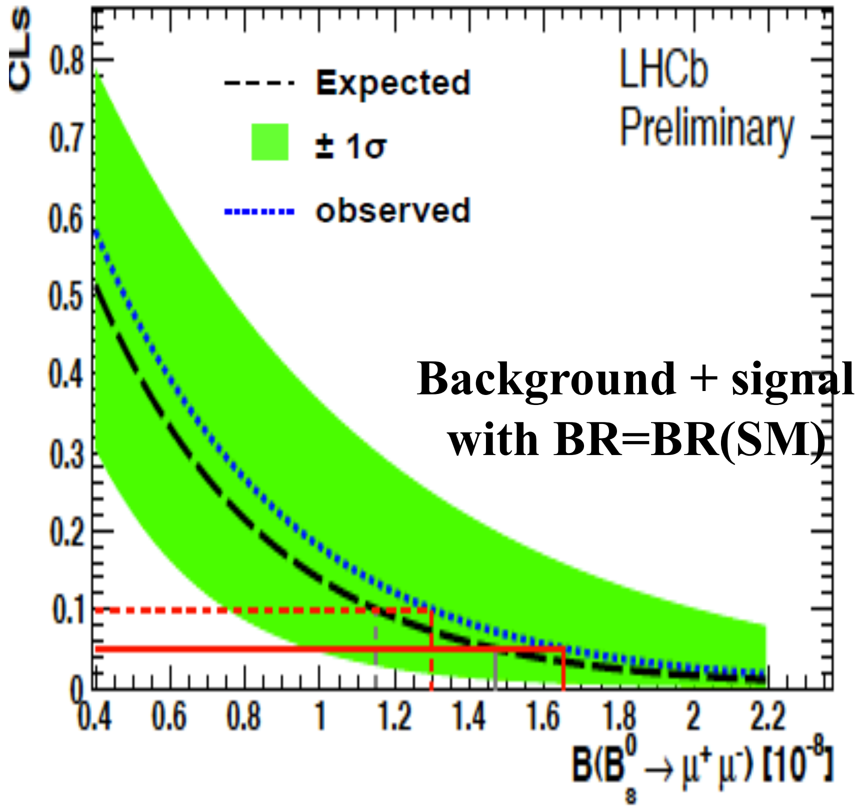


		90% CL	95% CL
	expected limit (bkg+SM hypothesis)	1.2×10^{-8}	1.5×10^{-8}
LHCb 2011 only	observed limit	1.3×10^{-8}	1.6×10^{-8}
LHCb 2010+2011 combined (340 pb^{-1})		**1.2×10^{-8}**	**1.5×10^{-8}**

→ *To be submitted to Phys.Lett.B*

LHCb preliminary limit for BR($B_s \to \mu\mu$) with ~340 pb^{-1} (world best)





	expected limit (bkg+SM hypothesis)	1.2×10^{-8}	1.5×10^{-8}
LHCb 2011 only	observed limit	1.3×10^{-8}	1.6×10^{-8}
→	LHCb 2010+2011 combined (340 pb^{-1})	1.2×10^{-8}	1.5×10^{-8}
	CMS (2011, 1140 pb-1, x3.4 LHCb)	1.6×10^{-8}	1.9×10^{-8}

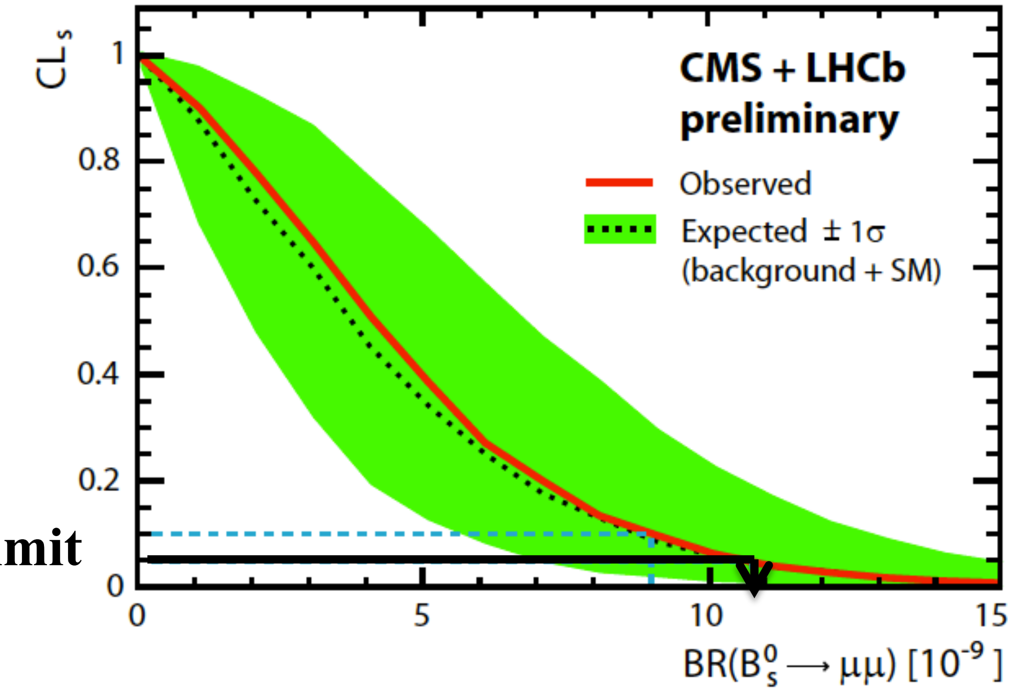
[arXiv:1107.5834v1, CMS-BPH-11-002]

LHCb-CMS combination

[LHCb-CONF-047, CMS-PH-11-019-pas]

- Combination has been performed by LHCb just adding 2 CMS bins (1 for barrel, 1 for endcap):

CMS+LHCb combined



95% exclusion limit

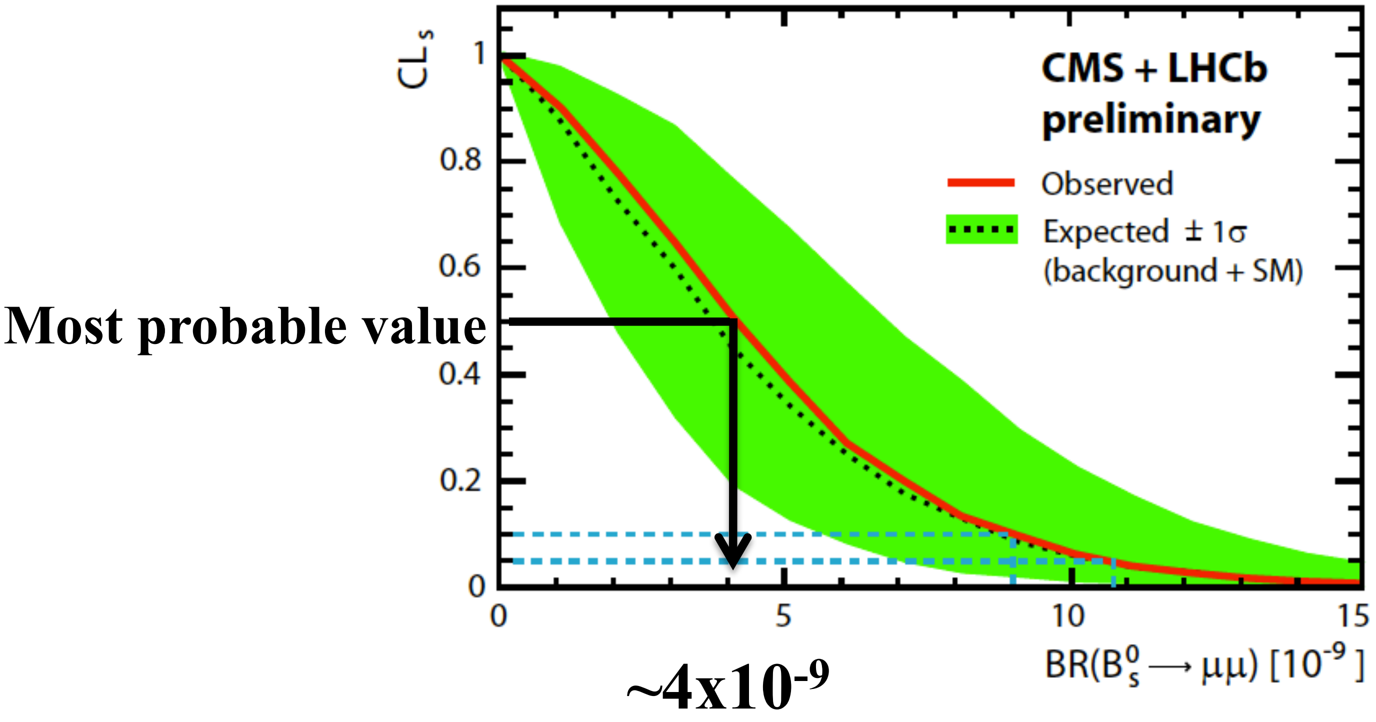
BR($B_s \to \mu\mu$) (LHCb+CMS) < 1.1 x 10^{-8} @ 95% CL (3.4xSM)
Excess seen by CDF not confirmed

LHCb-CMS combination

[LHCb-CONF-047, CMS-PH-11-019-pas]

- Combination has been performed by LHCb just adding 2 CMS bins (1 for barrel, 1 for endcap):

CMS+LHCb combined



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

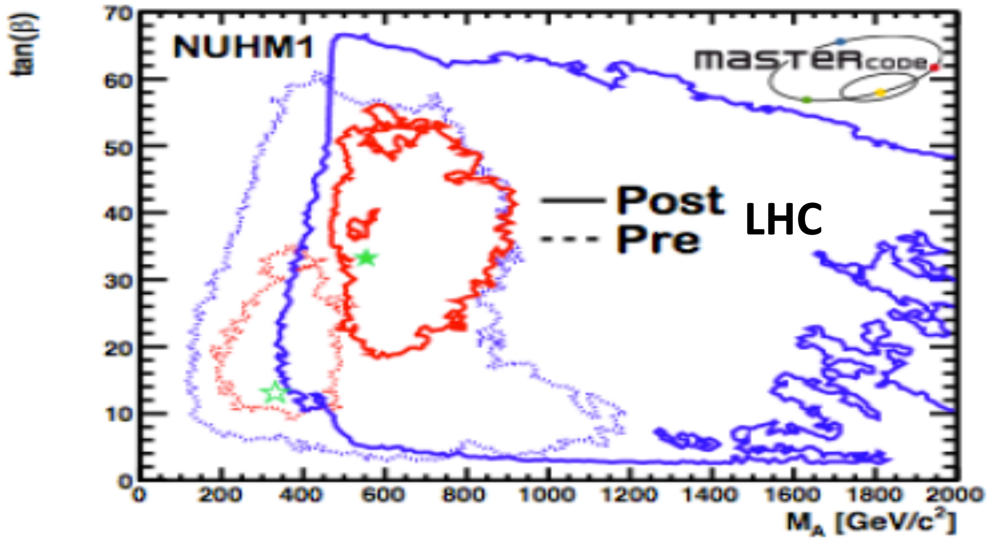
BR($B_s \rightarrow \mu\mu$) and Global Fits

F. *Ronga at the Workshop "LHC results for TeV scale physics", CERN, August 2011*

An example: MasterCode (J. Ellis et al.) (http://www.cern.ch//mastercode)
Goal: perform global fits to measured quantities (including direct searches) and build a χ^2. Compare with prediction from a given model (CMSSM, NUMH1, mSugra, etc.)

Input data: EW observables (largest inpact M_W, A^e_{LR}, A^b_{FB}), Flavour physics observables (largest inpact $b \rightarrow s\,\gamma$, $Bs \rightarrow \mu\mu$), (g-2)μ, Higgs mass, cold dark matter density, LHC direct searches

tanβ vs M_A plane

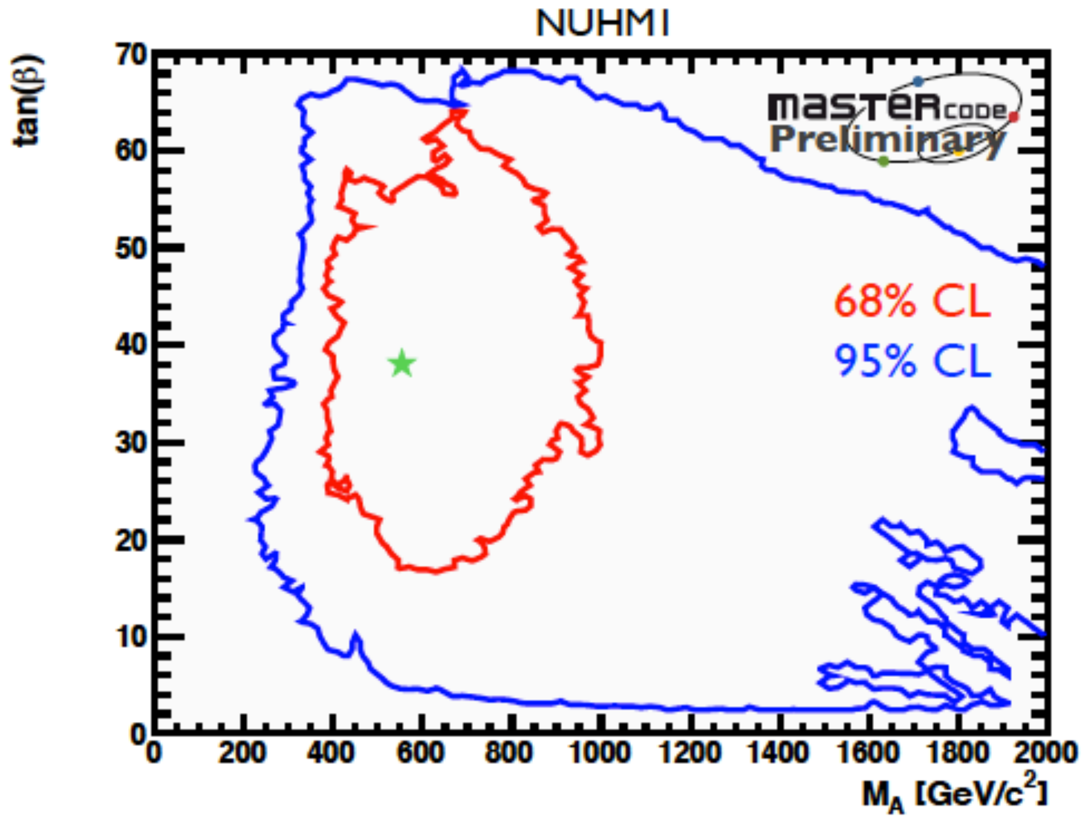


1/fb LHC data push the mass scale up
Low tanβ no longer favoured!

.. Remember that $Bs \rightarrow \mu\mu$ is proportional to $\tan^6\beta$....

Global Fits & $B_s \rightarrow \mu\mu$

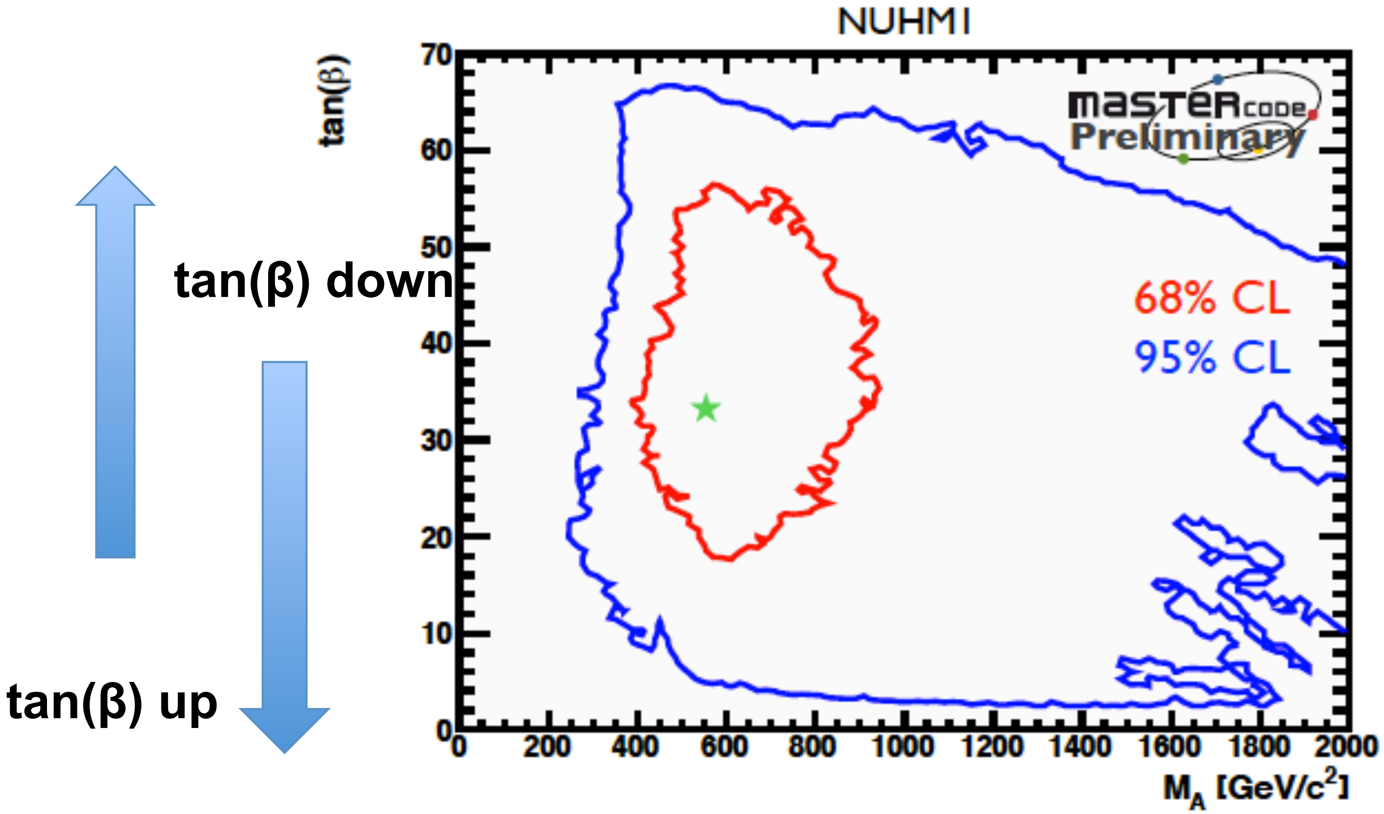
- LHC 2011 MET searches only



tan(β) up

Global Fits & $B_s \rightarrow \mu\mu$

- LHC 2011 MET searches and $B_s \rightarrow \mu\mu$



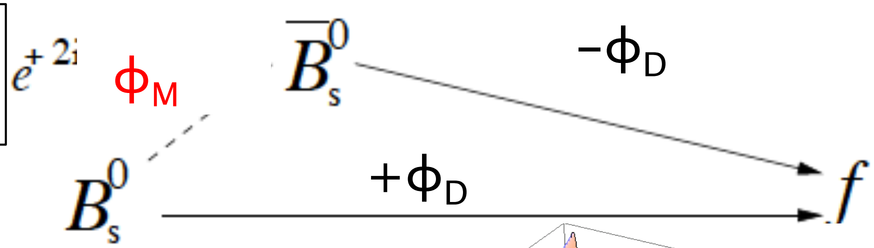
Bs→μμ upper limit pushes tan(β) down
(opposite direction wrt direct searches)

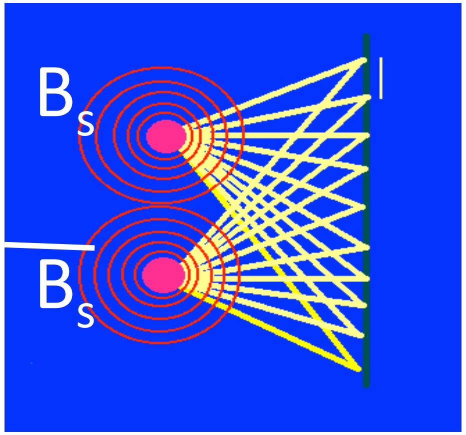
a valuable benchmark of any BSM theory in large tanβ regime

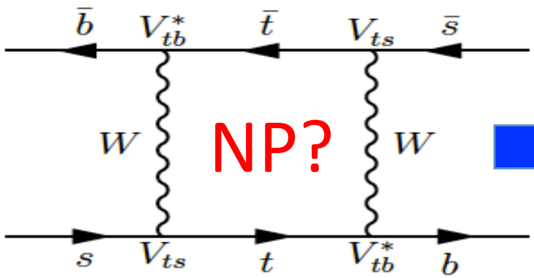
3. Search for NP in B_s mixing phase

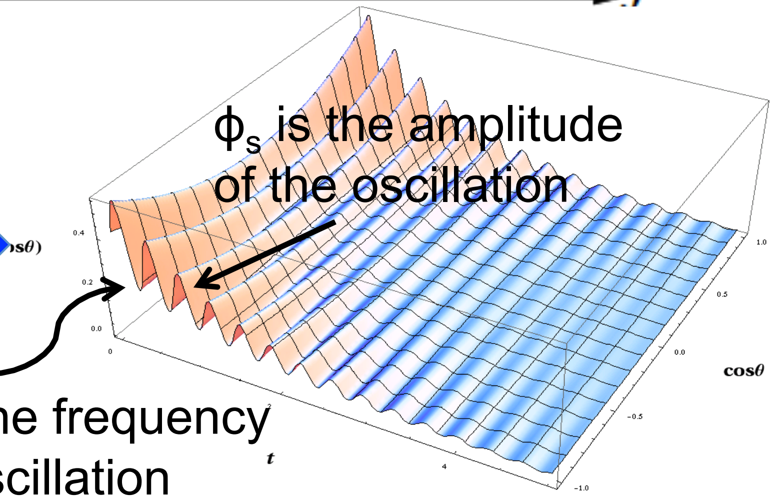
LHCb has measured the B_s mixing phase in $B_s \rightarrow J/\psi\ \phi$ and $B_s \rightarrow J/\psi\ f0$ decays

Measure relative phase difference:
$\phi_S = \phi_M - 2\ \phi_D$





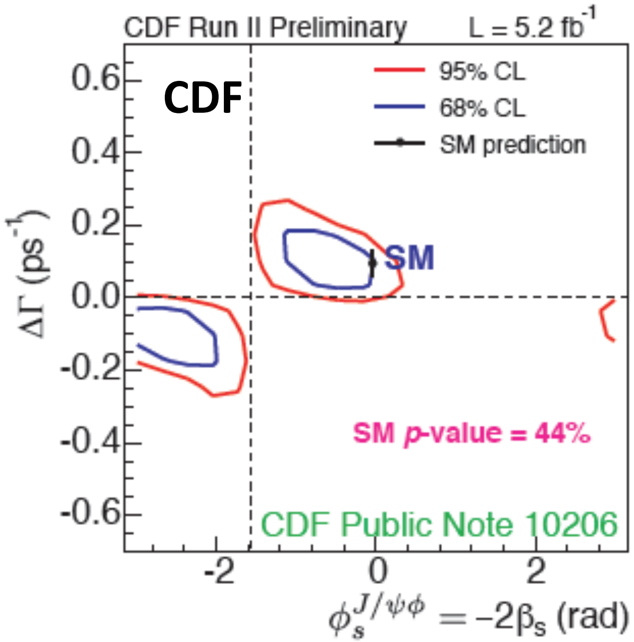


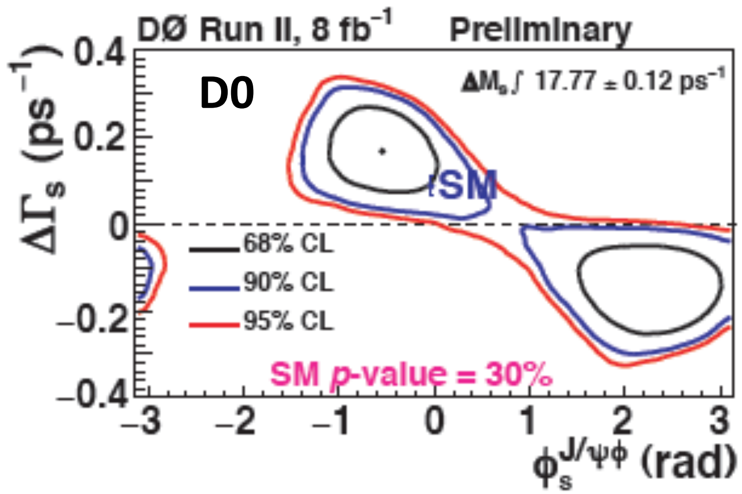


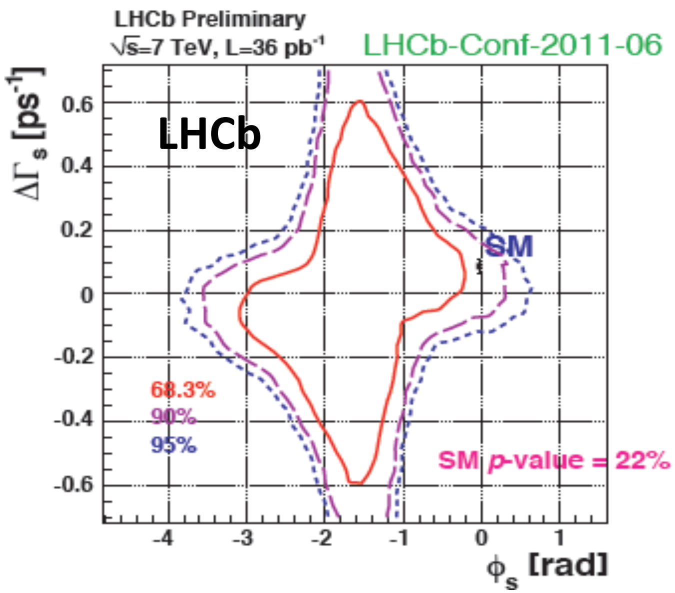
→ In SM $\phi(SM) = \phi(M) = -2\ \beta s^{SM}$ is determined by V_{ts} in the mixing term
$-2\beta s^{SM} = -0.0363 \pm 0.0017$ (CMKFitter)
→ NP can add large phases in the box: $\phi_s = \phi_s(SM) + \phi_s(NP)$

Experimental situation (before Summer 2011)

Results presented before summer 2011 showed compatibility with SM at ~1σ but all experiments with the same trend….





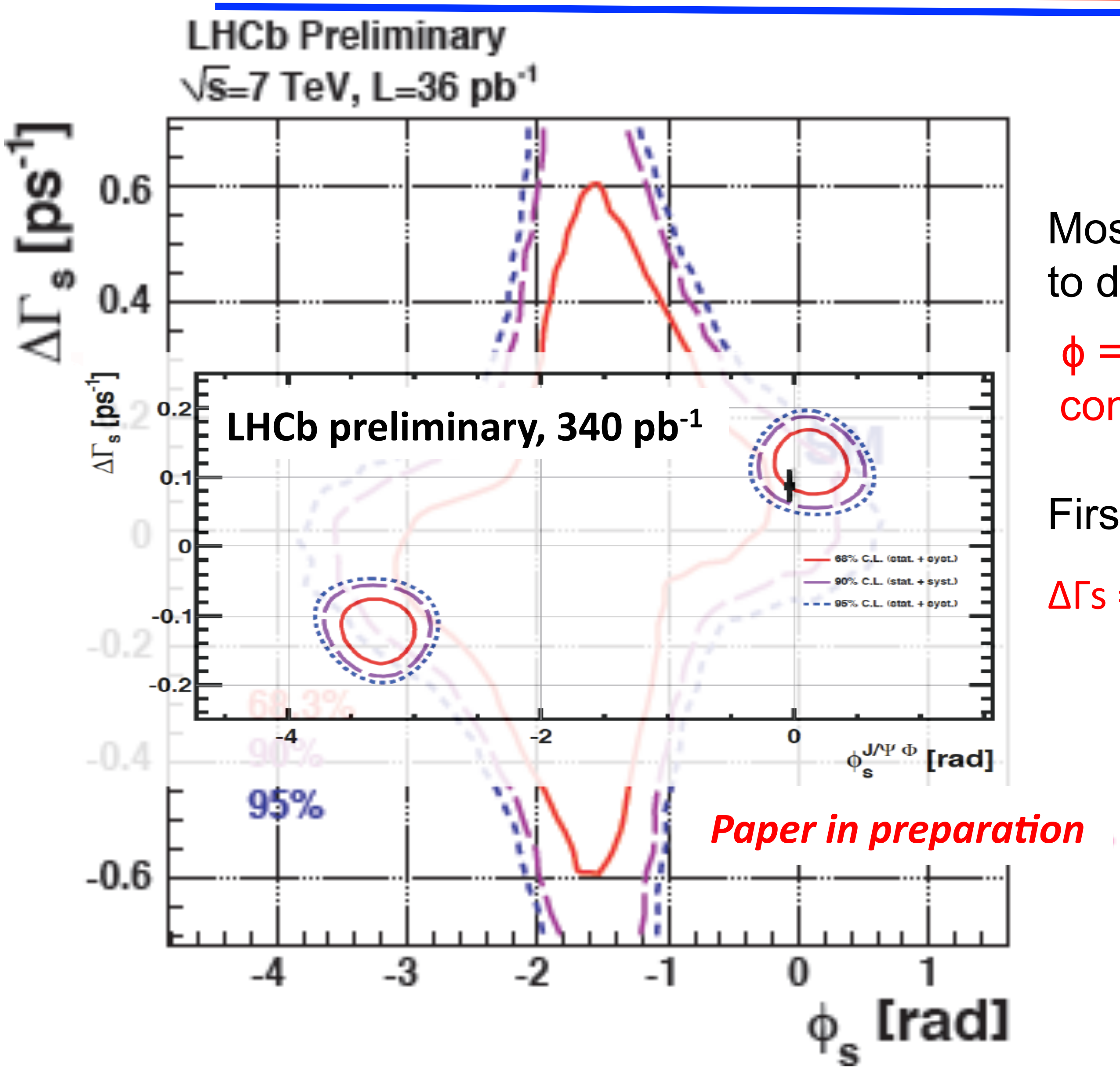


$$\phi_s \in [-3.10, -2.16] \cup [-1.04, -0.04]$$ 68% CL — CDF, 5.2 fb^{-1}

$$\phi_s = -0.55^{+0.38}_{-0.36}$$ D0, 8 fb^{-1}

$$\phi_s \in [-2.7, -0.5]$$ 68% CL — LHCb, 0.035 fb^{-1}

ϕs from $B_s \rightarrow J/\psi\ \varphi$: LHCb with 340 pb^{-1} (2011) (world best)



Most accurate ϕs measurement to date:

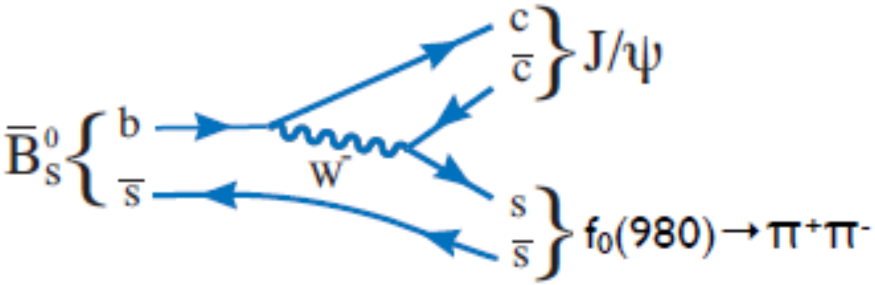
$\phi = 0.13 \pm 0.18(stat) \pm 0.07(syst)$ consistent with SM

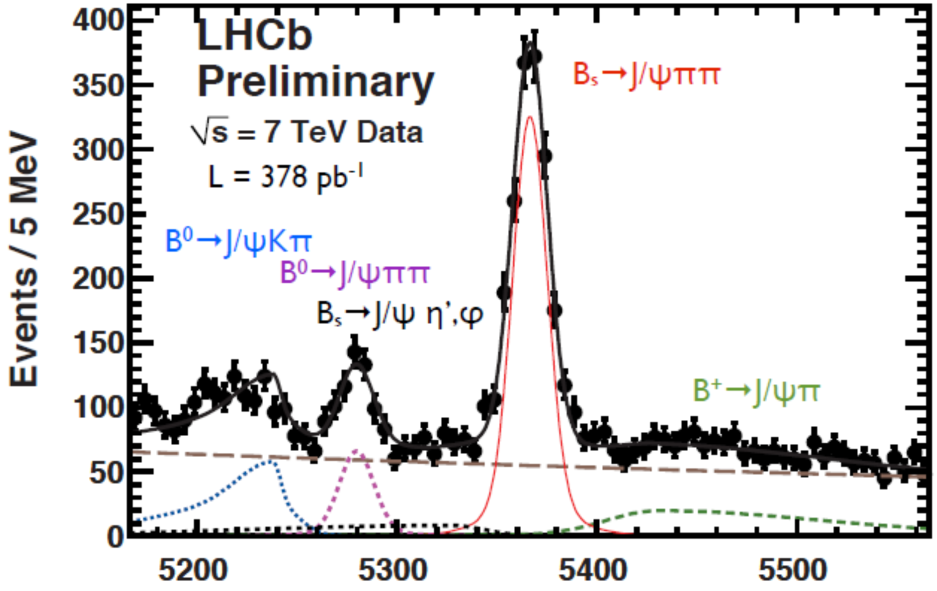
First 4σ evidence of $\Delta\Gamma \neq 0$

$\Delta\Gamma s = 0.123 \pm 0.029(stat) \pm 0.008(syst)$

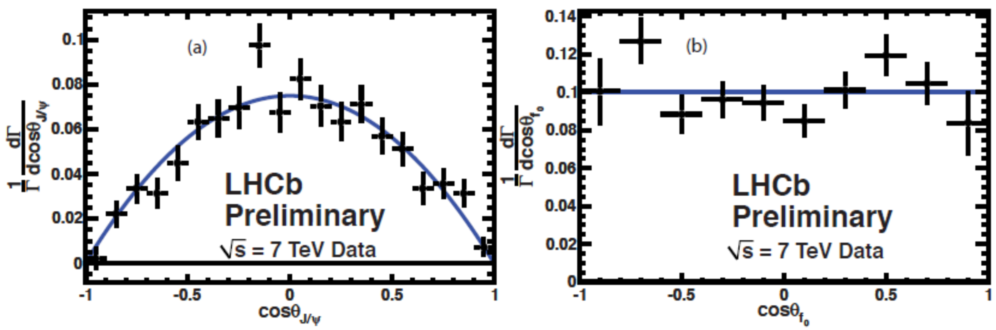
ϕ_s from $B_s \rightarrow J/\psi\ f^0$: LHCb with 380 pb^{-1} (2010+2011)

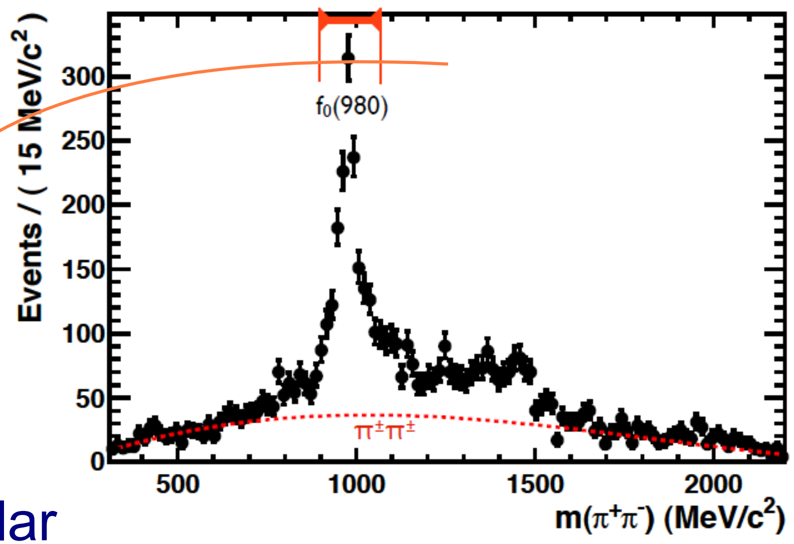
LHCb-CONF-2011-051





- history
  - predicted by Stone, Zhang (2009)
  - first seen by LHCb (PLB689(2011)115)
  - LP2011: first measurement of CPV
- angular distribution of J/ψ and f^0 candidates





candidates in f(980) region look pure scalar
--> no angular analysis needed

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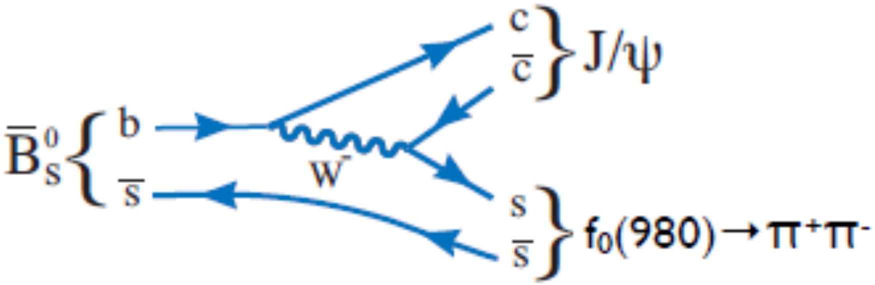
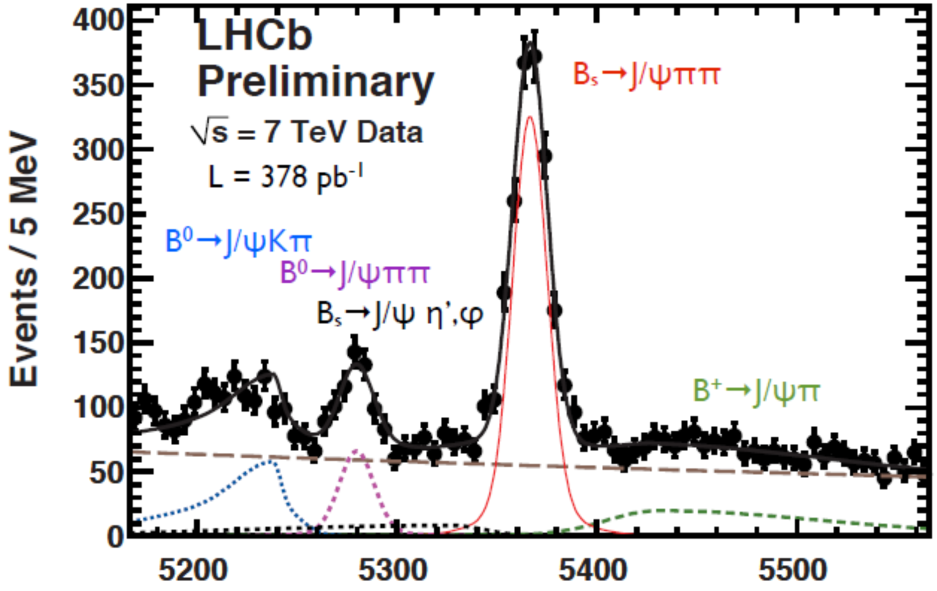
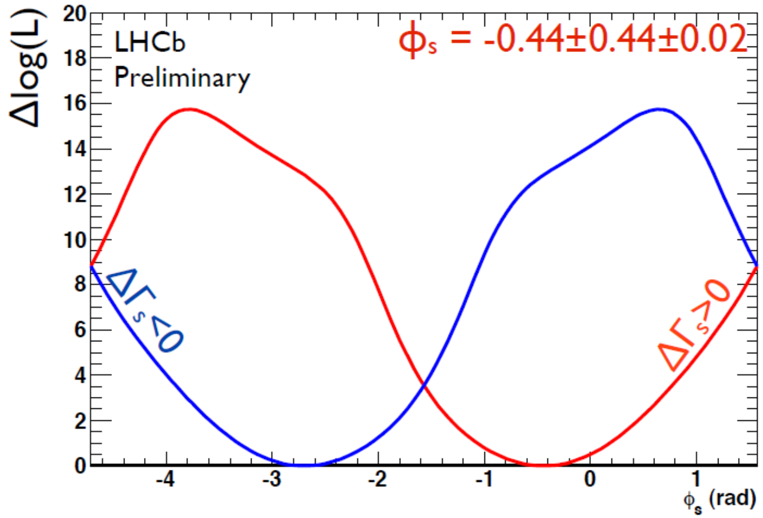
φs from B_s→J/ψ f^0: LHCb with 380 pb^{-1} (2010+2011)

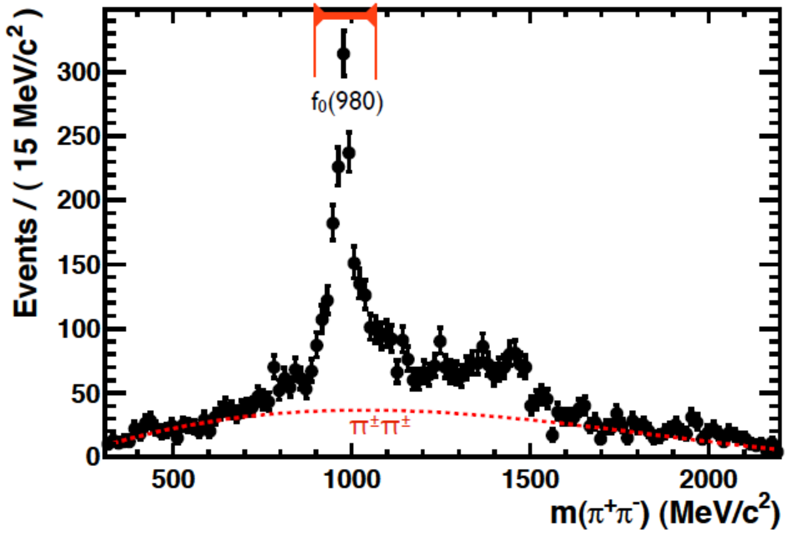
LHCb-CONF-2011-051





- history
  - predicted by Stone, Zhang (2009)
  - first seen by LHCb (PLB689(2011)115)
  - LP2011: first measurement of CPV
- result from the LL fit





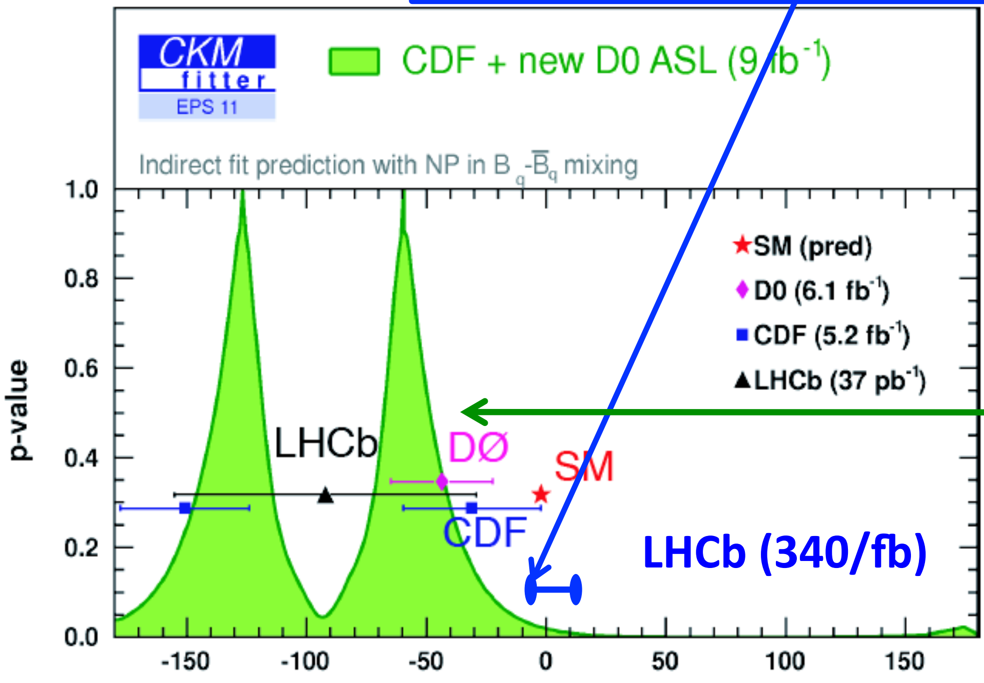
34

B_s mixing phase: combination of J/ψφ and J/ψf^0

- Bs → J/ψ f^0 alone cannot constraint both Γ_s, $\Delta\Gamma_s$ and ϕ_s
  - requires combination with J/ψφ
- simultaneous fit to both samples gives:

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

(LHCb-CONF-2011-056)



ϕ_s predictions from CKMFitter including the new di-muon charge asymmetry measured by D0 with 3.9 σ deviation from SM (EPS2011)

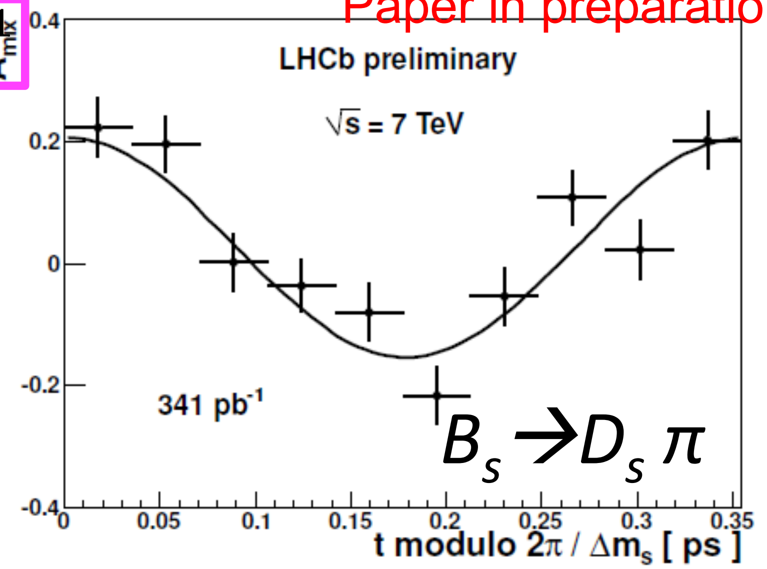
Room for large New Physics contributions highly reduced
(however small deviations from SM still possible)

En passant, B_s mixing frequency ΔM_s (world best)

- LHCb, preliminary result, 341/pb (LHCb-CONF-2011-050)

$$\Delta m_s = 17.725 \pm 0.041 \pm 0.026 \text{ ps}^{-1}$$

Paper in preparation



Compare older results:

CDF (2006) (PRL97,242003 (2006))

$$\Delta m_s = 17.77 \pm 0.10 \pm 0.07 \text{ ps}^{-1}$$

LHCb, 37/pb (LHCb-CONF-2011-005)

$$\Delta m_s = 17.63 \pm 0.11 \pm 0.03 \text{ ps}^{-1}$$

New WA fully dominated by LHCb result and in agreement with SM predictions:

$$\Delta m_s^{\text{WA}} = 17.731 \pm 0.045 \text{ ps}^{-1}$$

$$\Delta m_s^{\text{SM}} = 16.8^{+2.6}_{-1.5} \text{ ps}^{-1}$$

Phys.Rev.D83, 036004 (2011)

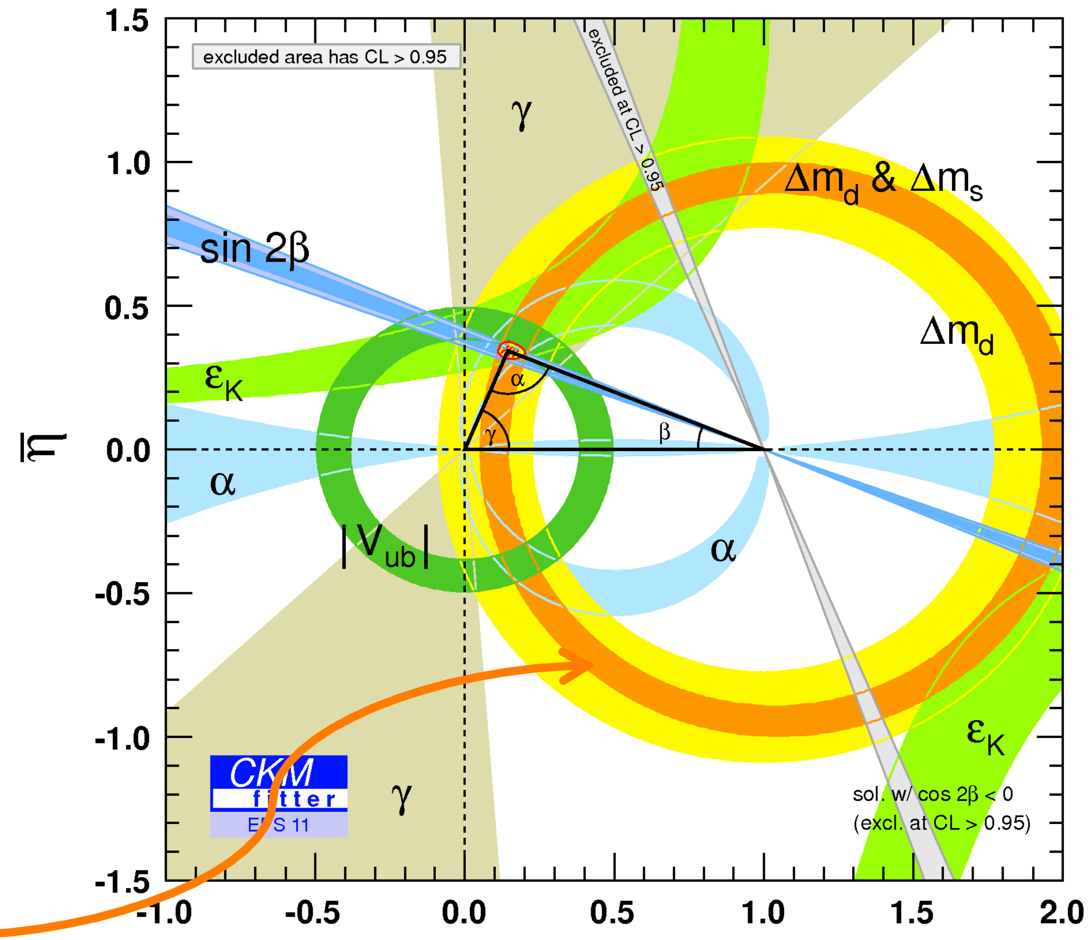
Combined with ΔM_d from B factories:

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.2090 \pm 0.0009 \pm 0.0046$$

exper. lattice

(R. van Kooten, LP2011)

Constraining the CKM picture



$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.2090 \pm 0.0009 \pm 0.0046$$

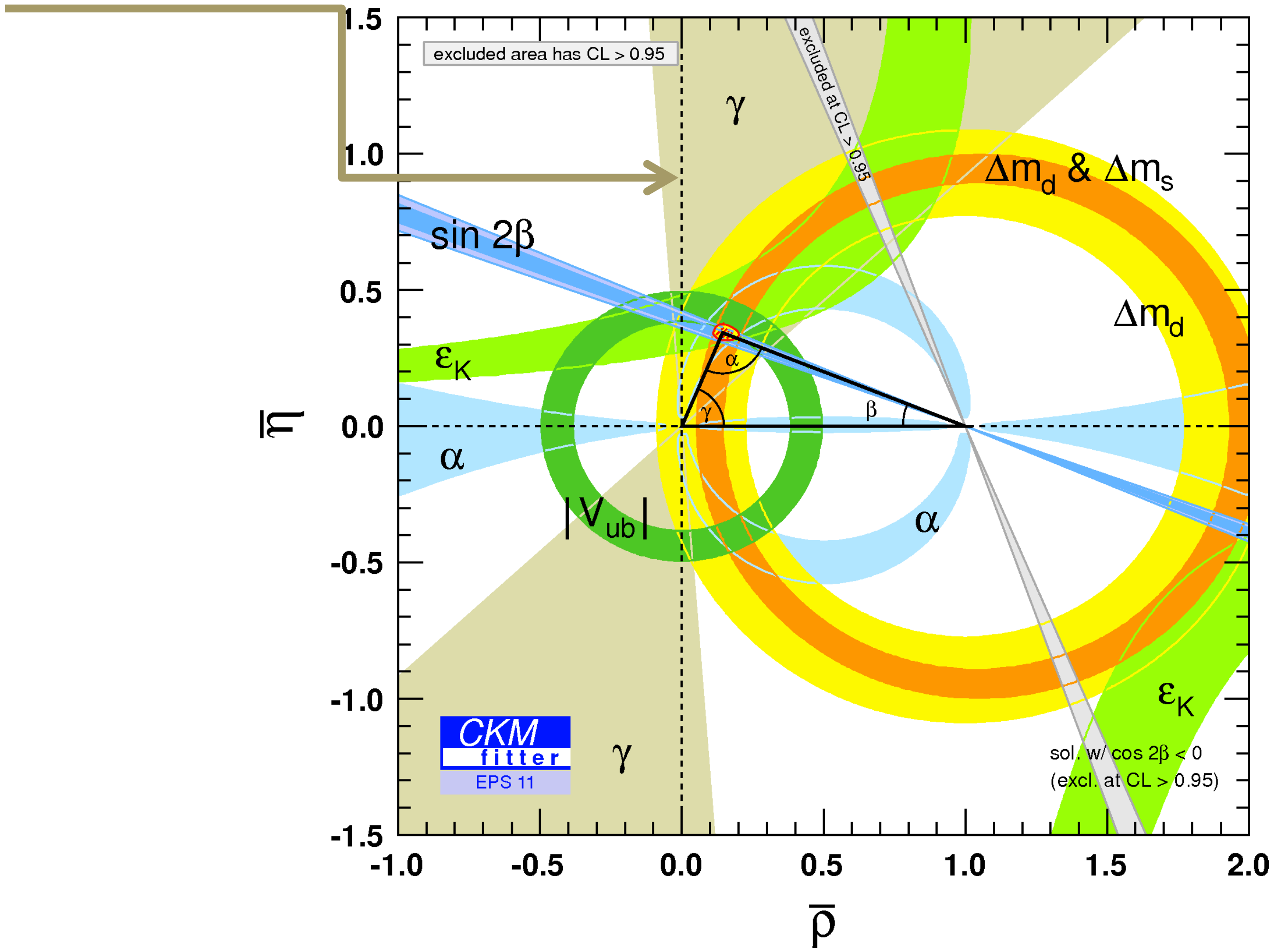
exper. lattice

(R. van Kooten, LP2011)

Error dominated by lattice calculations

Constraining the CKM picture

γ error is still dominated by experimental uncertainties

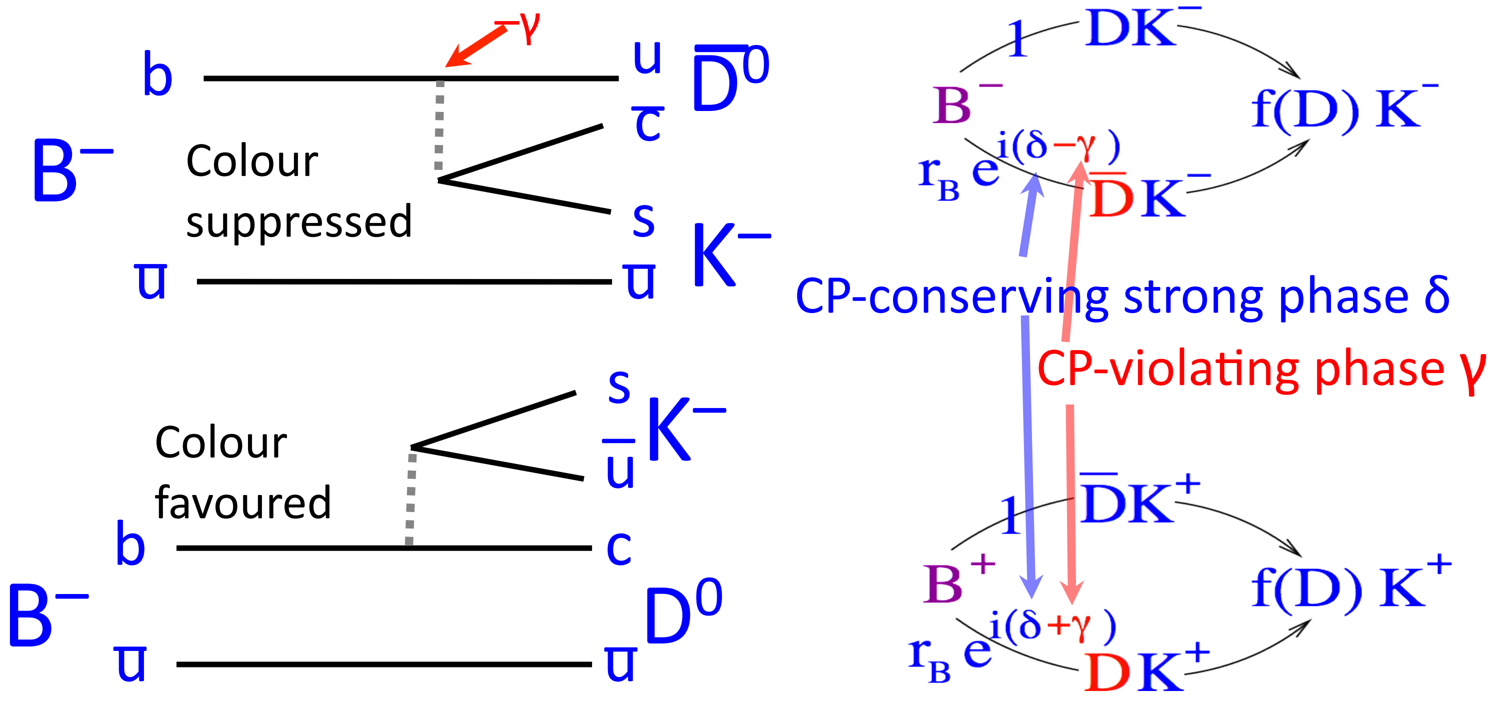


Currently: γ(direct) = 68° ± 13°, dominant error: statistics

Measuring gamma at LHCb: time integrated methods

Another interference pattern:

$B^{\pm} \rightarrow DK^{\pm}$



The interference between color suppressed and color favored diagrams allows to extract the CP-violating phase gamma.

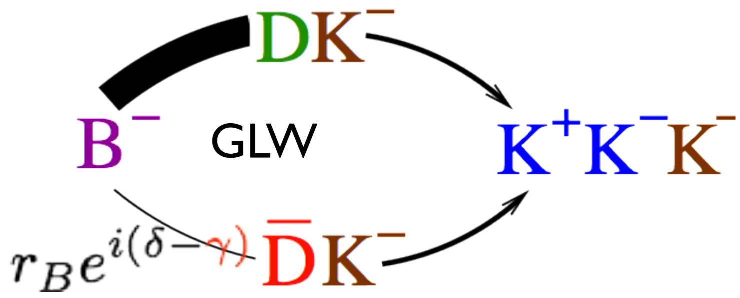
Measuring gamma at LHCb: time integrated methods

Let now the D decay in CP eigenstates and in flavor specific final states and build up the CP violating asymmetries:

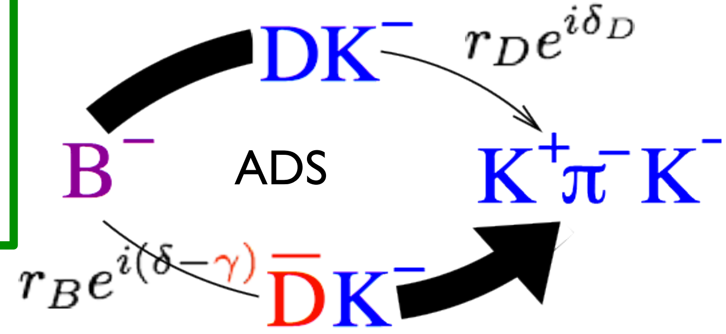
$$A = \frac{\Gamma(B^- \to f_D K^-) - \Gamma(B^+ \to \bar{f}_D K^+)}{\Gamma(B^- \to f_D K^-) + \Gamma(B^+ \to \bar{f}_D K^+)} = 2 r_D r_B \sin(\gamma)\ \cos(\delta_B + \delta_D)\ /\ R$$

where, for GLW, R≡1, r_D≡1 and δ_D≡0. R<1 for ADS.

D→ CP eigenstates (GLW)



D→ flavour specific (ADS)

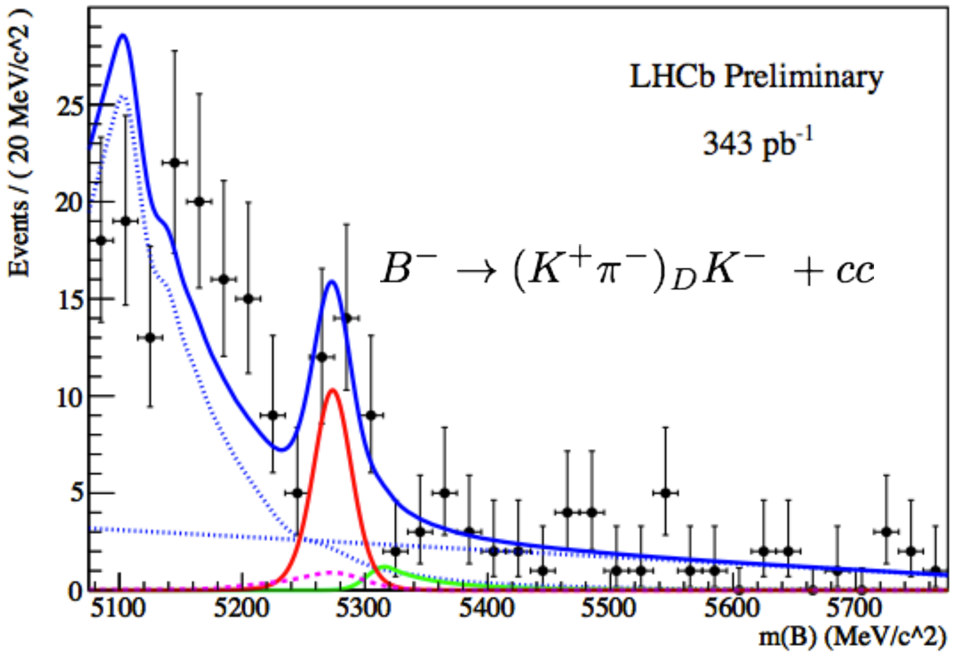


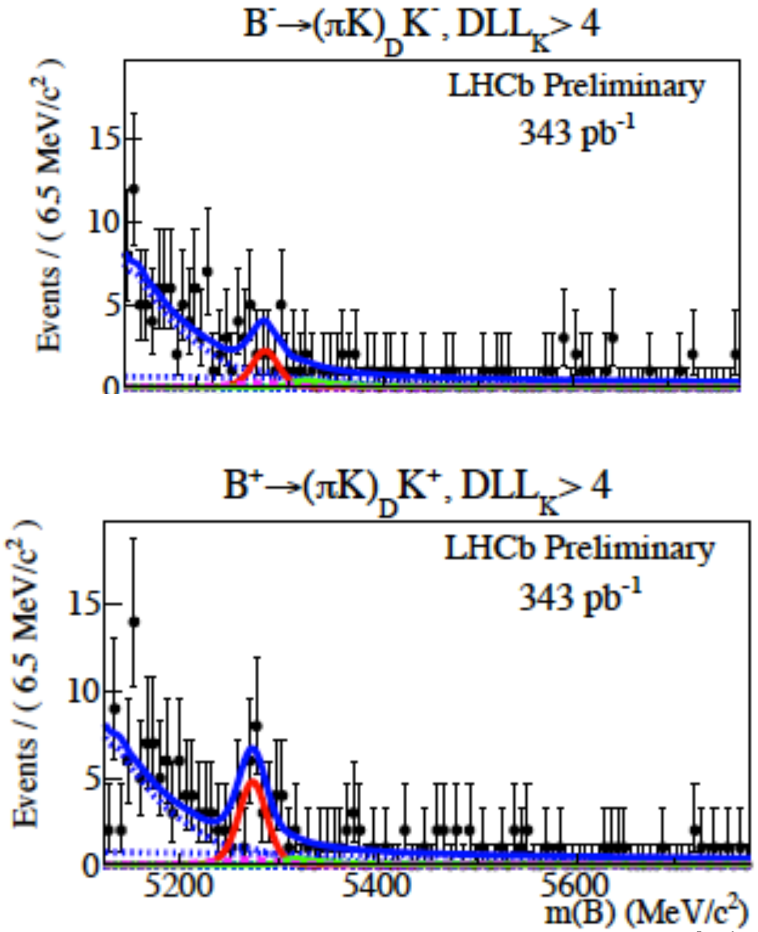
Counting experiment. All parameters can be extracted simultaneously analysing several decay channels (although CLEO-c input for δ_D helps).

Gronau, Wyler Phys.Lett.B265:172-176,1991, (GLW),
Gronau, London Phys.Lett.B253:483-488,1991 (GLW)
Atwood, Dunietz and Soni Phys.Rev.Lett. 78 (1997) 3257-3260 (ADS)

ADS with $B^{\pm} \to D(K\pi)K^{\pm}$ at LHCb

Significant signal (4σ) for suppressed mode in 343/pb.
Same statistics as Belle in all his lifetime but signal cleaner.
The gateway for gamma measurement!



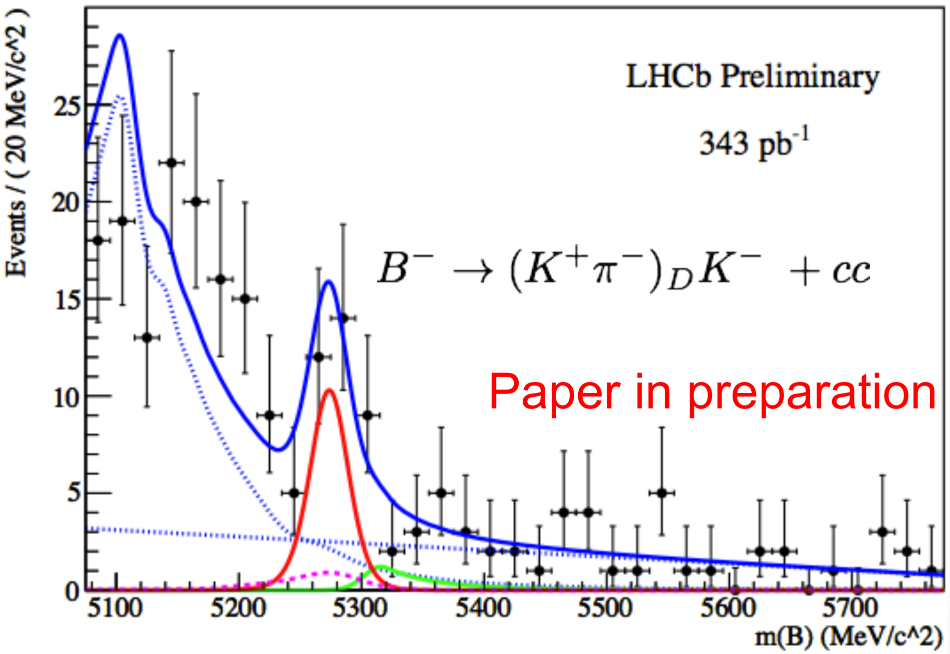


$$A = \frac{\Gamma(B^- \to f_D K^-) - \Gamma(B^+ \to \bar{f}_D K^+)}{\Gamma(B^- \to f_D K^-) + \Gamma(B^+ \to \bar{f}_D K^+)}$$

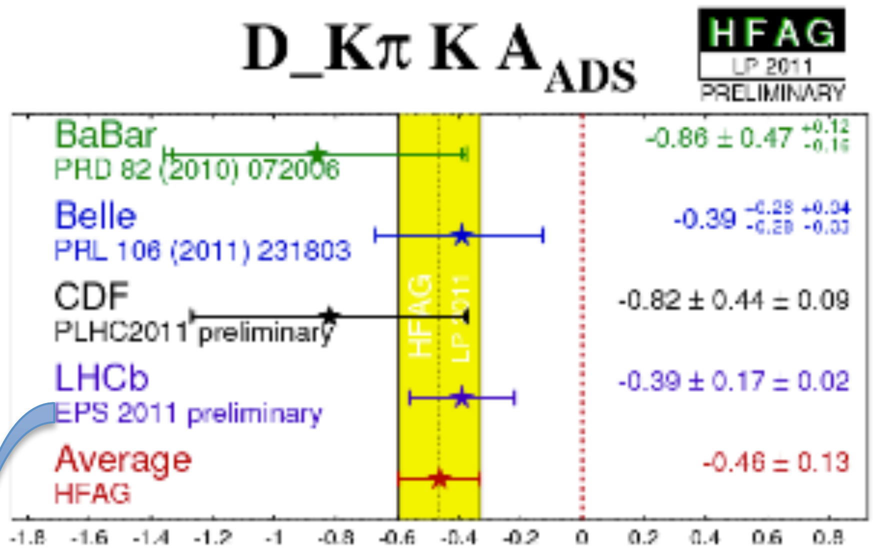
A_{CP} with $B^{\pm} \to D(K\pi)K^{\pm}$ at LHCb (world best)

Significant signal (4σ) for suppressed mode in 343/pb.
Same statistics as Belle in all his lifetime but signal cleaner.
The gateway for gamma measurement!

LHCb-CONF-2011-044



Paper in preparation



Ratio to favoured mode:

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

World Average (without LHCb) $(1.6 \pm 0.3) \times 10^{-2}$

Asymmetry:

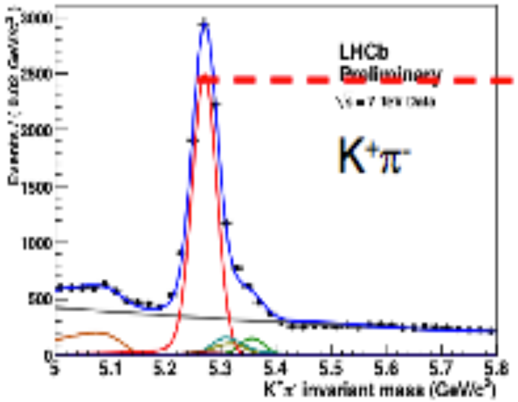
$$A^{DK}_{ADS} = -0.39 \pm 0.17 \pm 0.02$$

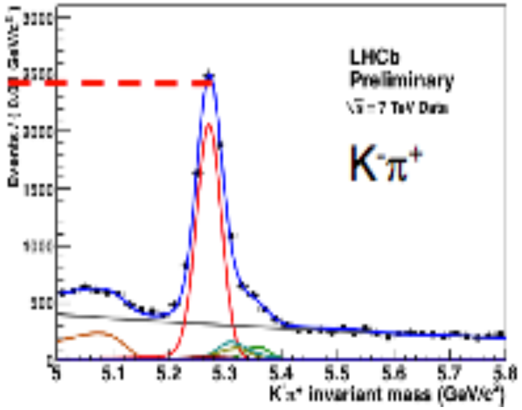
World Average (without LHCb) -0.58 ± 0.21

First step toward γ measurement in loop: direct CPV in $B_{(s)} \to K\pi$

Compare to prev. world-average:

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

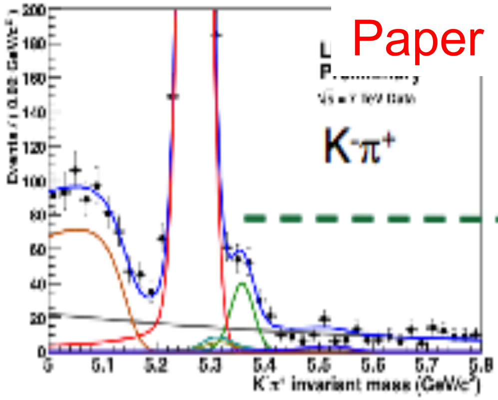


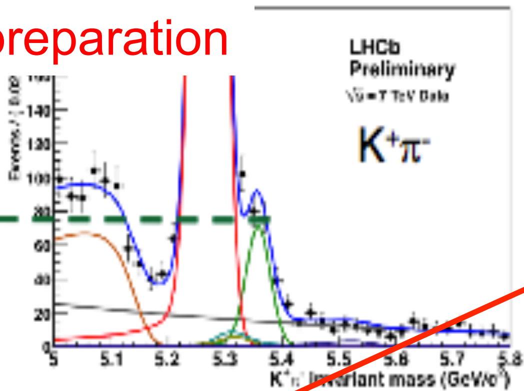


$$A_{CP}\left(\mathrm{B}^0 \to \mathrm{K}^+\pi^-\right) = -0.088 \pm 0.011 \pm 0.008$$

Best single measurement, first 5σ observation at a hadron collider.

Paper in preparation





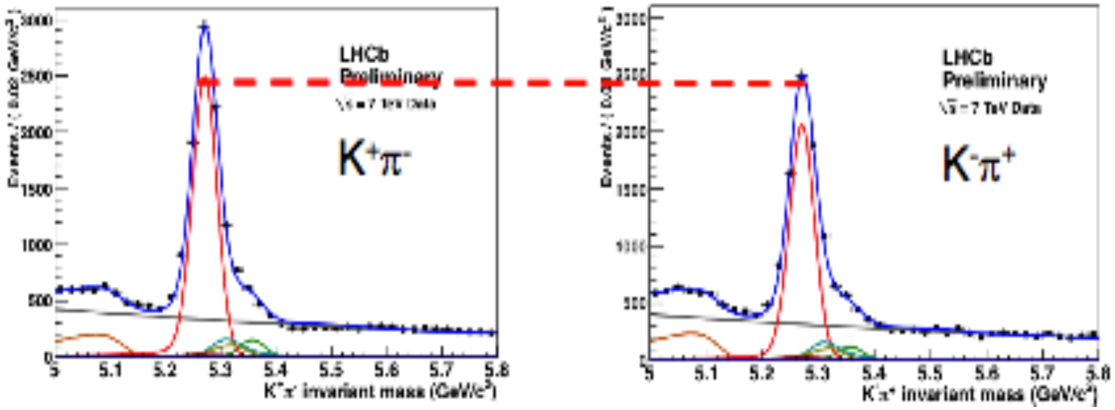
First evidence of CP violation in B_s decays.

$$A_{CP}\left(\mathrm{B}^0_s \to \pi^+\mathrm{K}^-\right) = 0.27 \pm 0.08 \pm 0.02$$

Prev result by CDF:

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

First step toward γ measurement with loops: direct CPV in $B_{(s)} \to K\pi$

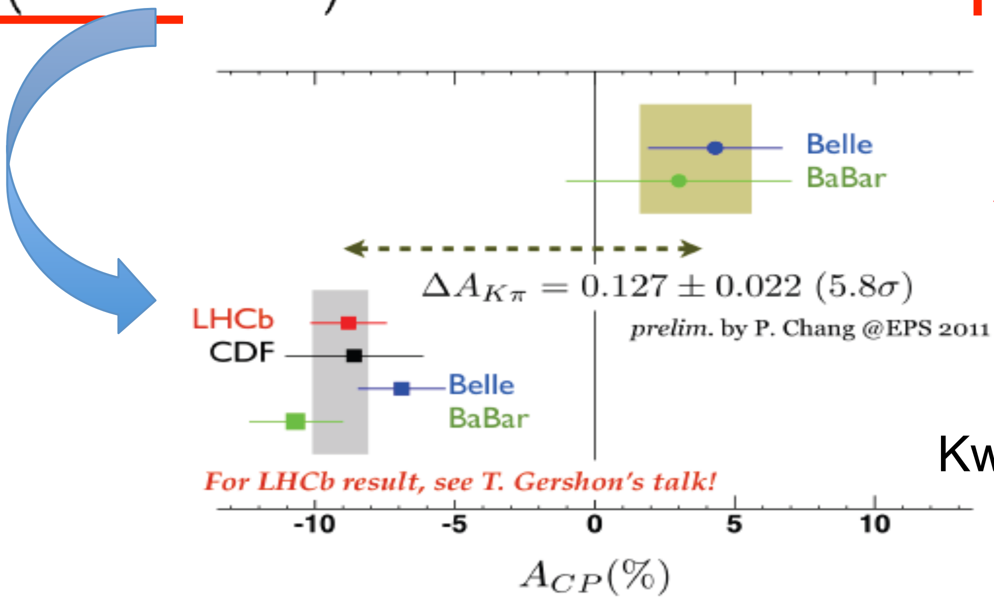


Compare to prev. world-average:

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

Best single measurement, first 5σ observation at a hadron collider

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

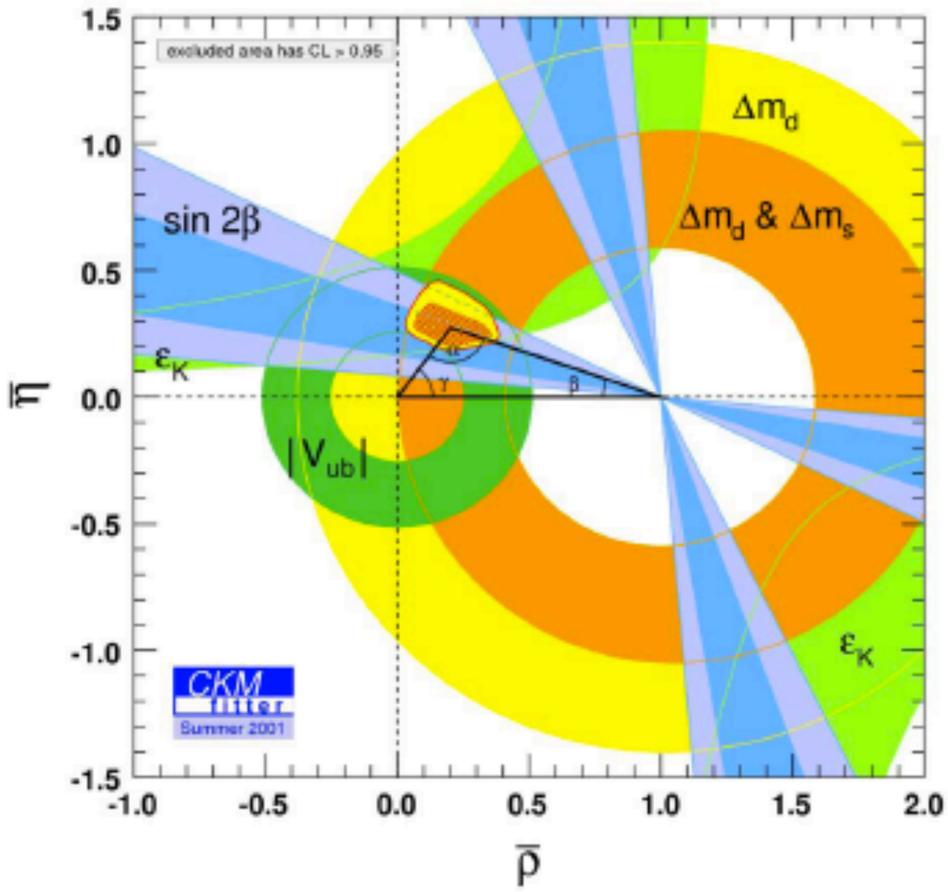


Another point in the A(Kπ) puzzle…..

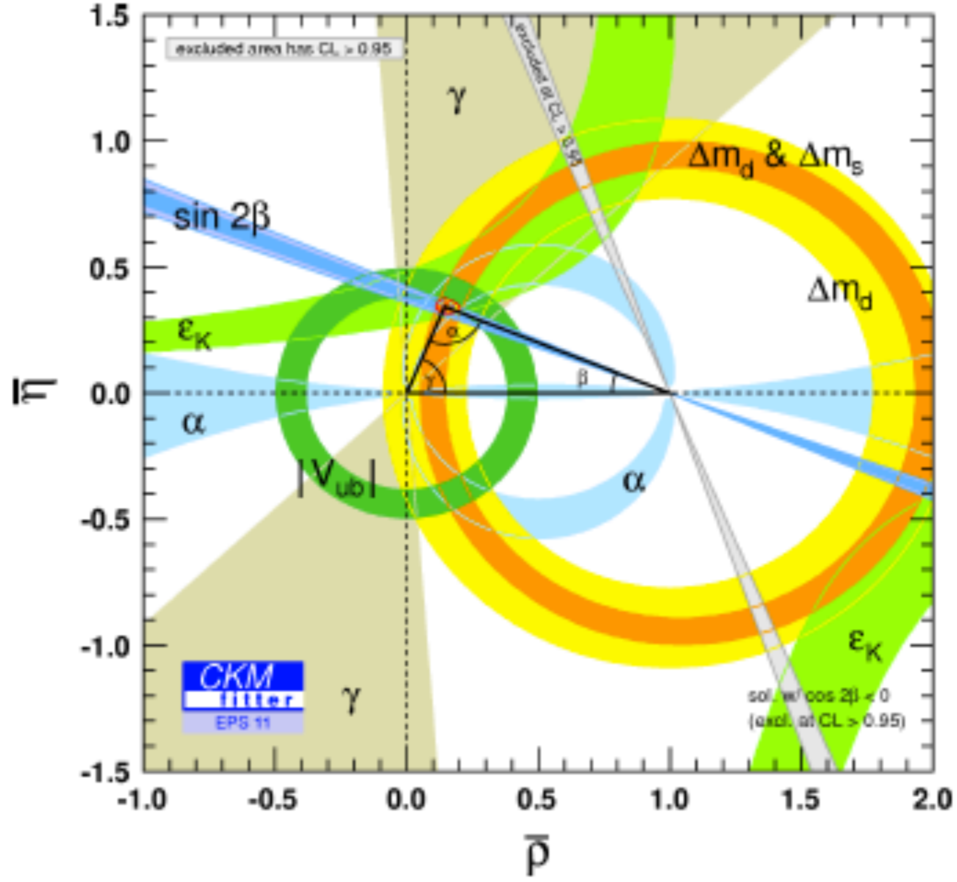
Kwon (LP11)

Evolution in the CKM picture in the last 10 years

EPS 2001

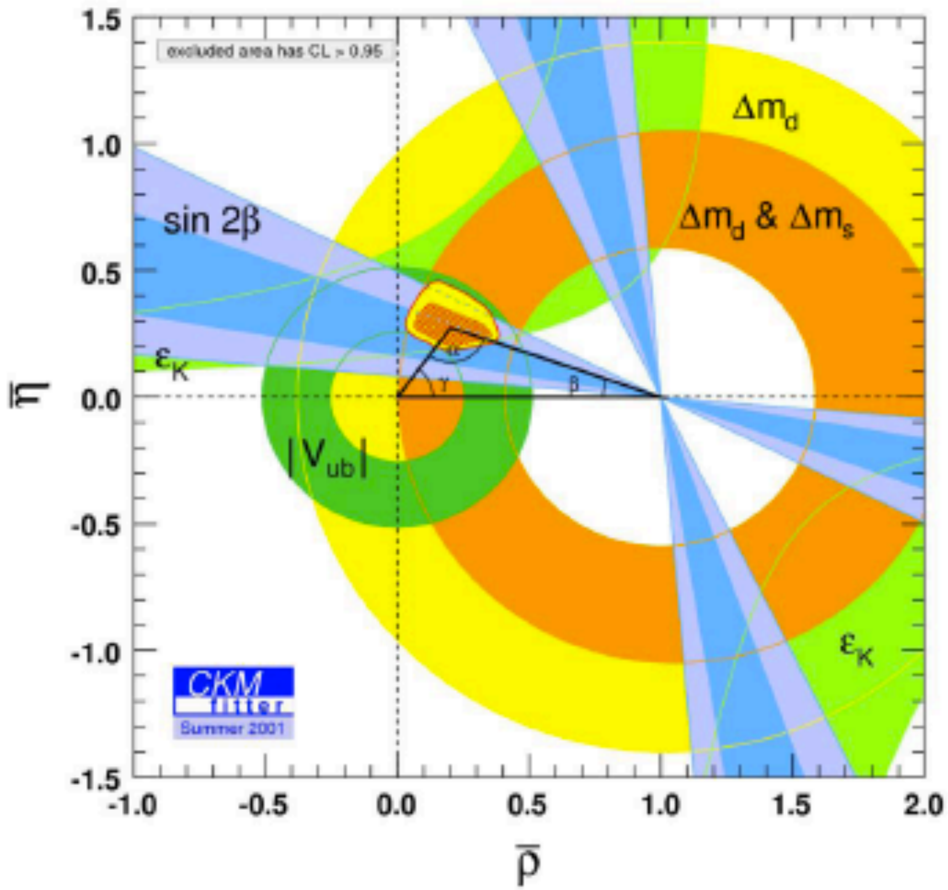


EPS 2011

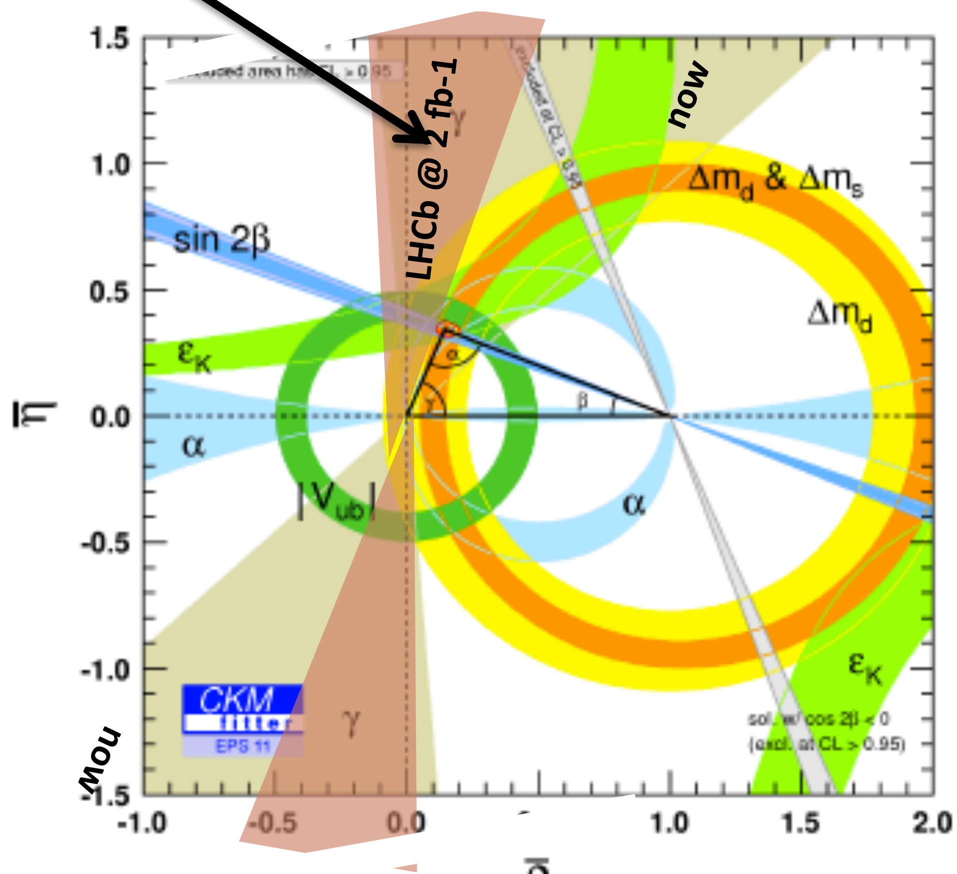


… and adding LHCb contribution:

EPS 2001



LHCb @ end of 2012?



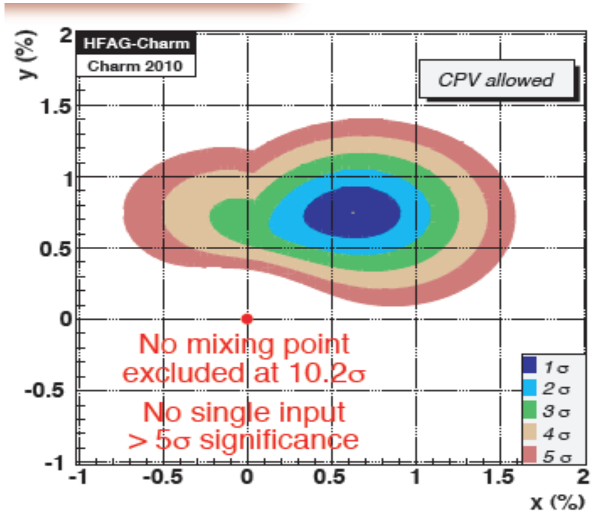
LHCb can pin down the error on gamma to 10°-5° in 2011-2012

The beauty of charm

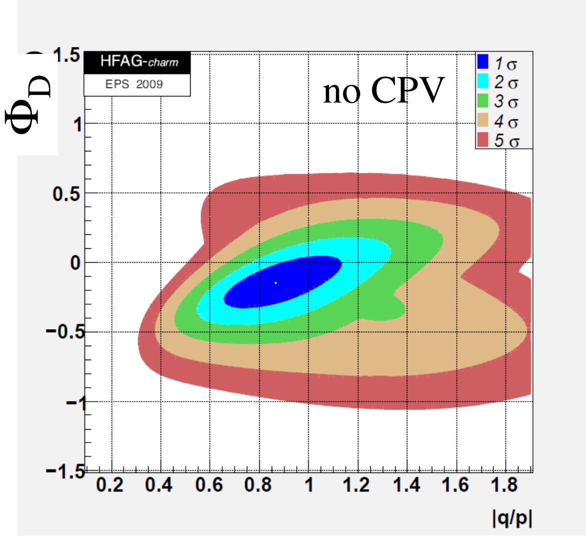
Large $D^0 - \bar{D}^0$ mixing discovered in 2007 and good prospects for the study of CP violation in charm gave new impetus to this field.

LHCb can profit of the huge charm production cross section at the LHC (~6 mb) (almost 1 kHz out of 3 kHz of the HLT output dedicated to charm physics)

"No-mixing" excluded at 10.2 σ:



All measurements consistent with no CPV:



Present constraints on CPV weak because CPV ~ $x_D \sin(2\varphi_D)$ and x_D~1% →required sub-0.1% precision for CPV sensitivity!

The beauty of charm: CPV in mixing

Example mixing analysis is measurement of **"y_{CP}"**, which is D^0 width splitting parameter modified by CP-violating effects. Comparison to pure "y" measurements probes for CP-violation, as does measurement of pure CP-violating observable **A_Γ**

A_Γ: compare D^0 and $D^0 \to KK$ lifetimes [tagged samples]

y_{CP}: compare lifetime of $D^0 \to$CP-eigenstate, eg. KK or ππ, to $D^0 \to$non-eigenstate eg. Kπ [untagged samples]

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

–

$$y_{CP} = \frac{\tau(K^-\pi^+)}{\tau(K^+K^-)} - 1$$

LHCb results presented at EPS, based on 2010 data (~35 pb^{-1}

$$A_\Gamma = (-0.59 \pm 0.59 \pm 0.21)\%$$

c.f. WA of $(0.12 \pm 0.25)\%$

$$y_{CP} = (0.55 \pm 0.63 \pm 0.41)\%$$

c.f. WA of $(1.11 \pm 0.22)\%$

LHCb results with 2011 data will improve the WA
(systematic error is expected to scale with the statistics)

The beauty of charm: CPV in mixing

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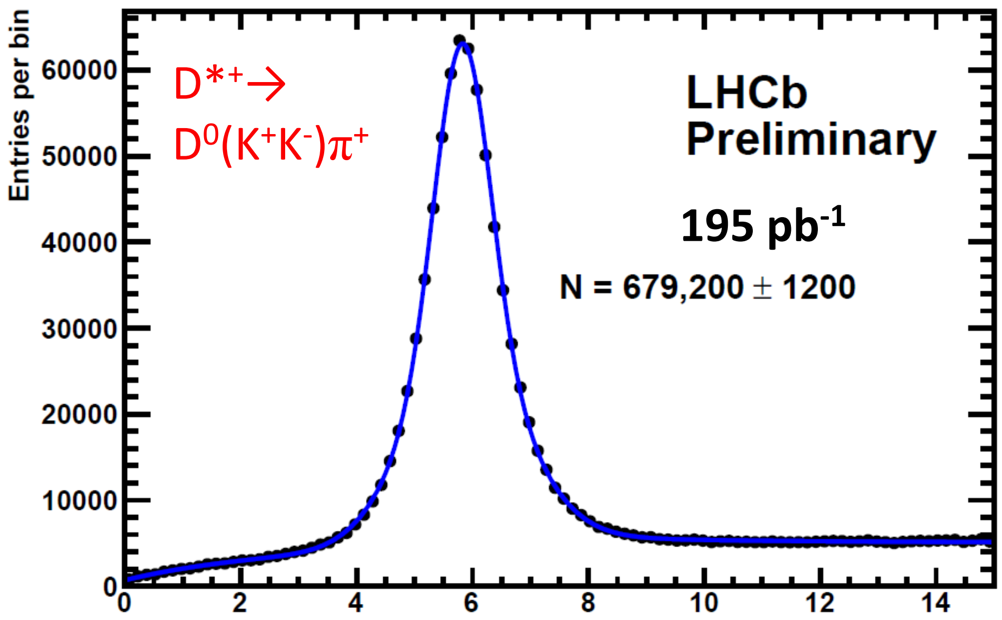


Δm (MeV/c^2)

A_Γ: current WA from Babar+Belle (180k tagged KK)

→ LHCb has ~700k events in 200 pb^{-1}

The beauty of charm: CPV in mixing and direct

CPV in mixing (indirect) can be related to direct CPV via the relation:

$$A_{CP}(h^+h^-) = a_{CP}^{\rm dir}(h^+h^-) + \frac{\langle t\rangle}{\tau} a_{CP}^{\rm ind}(h^+h^-)$$

<t>/τ = 1 at B factories, ~2.5 at CDF (displaced trigger)

Independent of the final state

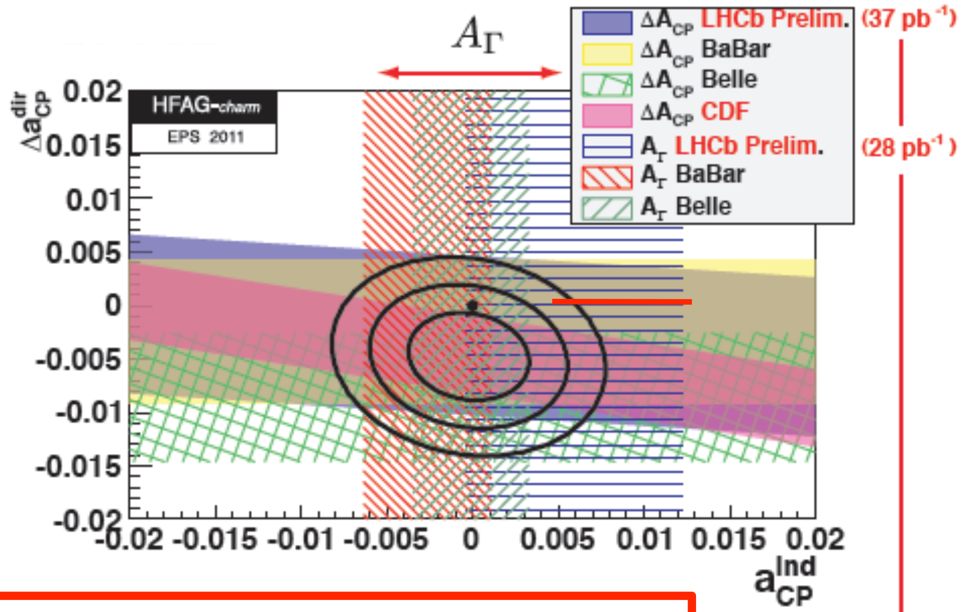
Considering ππ or KK final states we can build the difference:

$A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) =$
$\Delta a_{CP}\,(direct) + \Delta\langle t\rangle/\tau\ \ a_{CP}^{\,ind}$

LHCb measurement with 2010 data

$$A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = (-0.28 \pm 0.70 \pm 0.25)\%$$

together with A_Γ puts an additional constraint in the HFAG plot



Data are consistent with no CP violation at 20% CL

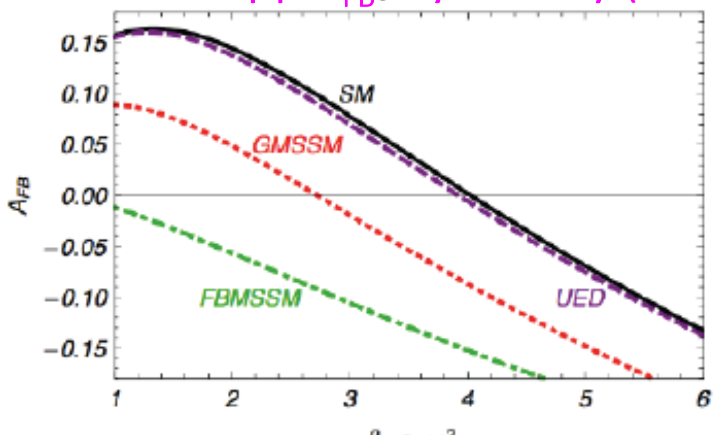
No New Physics…….

No New Physics…… yet!

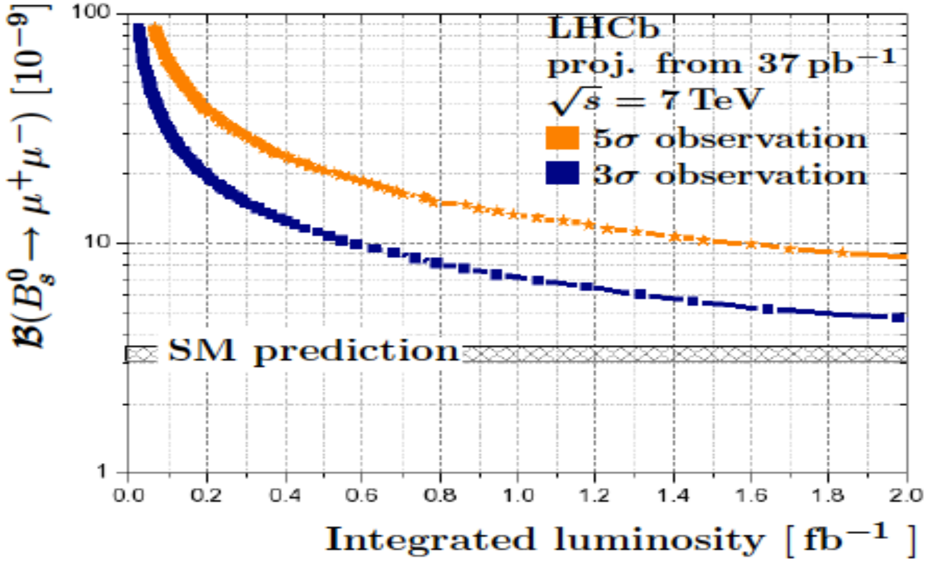
We analyzed only 1/3 of the 2011 dataset
(remember we are sensitive to higher mass scales than direct searches)

LHCb projections for 2012 winter conferences for some selected topics

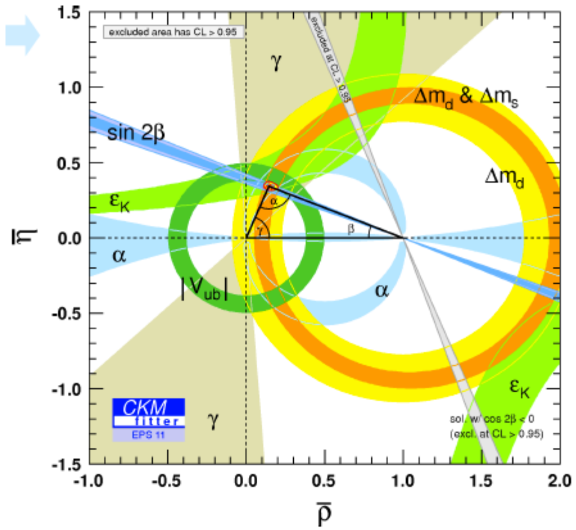
Determination of the zero crossing point
in the Bd→K* μμ A_{FB} asymmetry (2011 data)



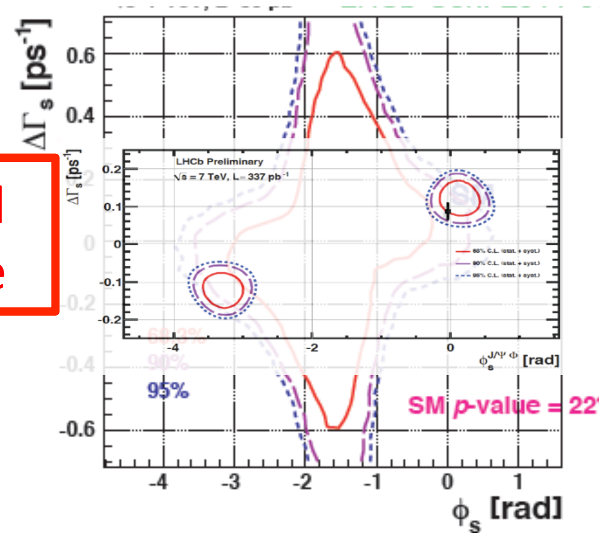
BR(Bs→μμ) projections: 3 σ evidence vs L



W.Alt Gamma measured with
±(5-10)° (2011+2012)



ϕs measured with ±0.1 rad (2011 data)



And many more I had
no time to cover here

It has been a beautiful summer….

ADS suppressed mode
for gamma measurement

POOL→ROOT

Penguin contributions
to sin(2β)

ϕ_s in Bs→J/ψ ϕ
and Bs→J/ψ f0

ΔM_s

Online Farm

CPV in charm

Exotics, new states

Disk Space

$B_{s,d} \to \mu\mu$, A_{FB} in $B_d \to K^*\mu\mu$

Radiative decays

L_{inst} = 3.5×10^{32} Hz/cm^2
throttling of Tell1

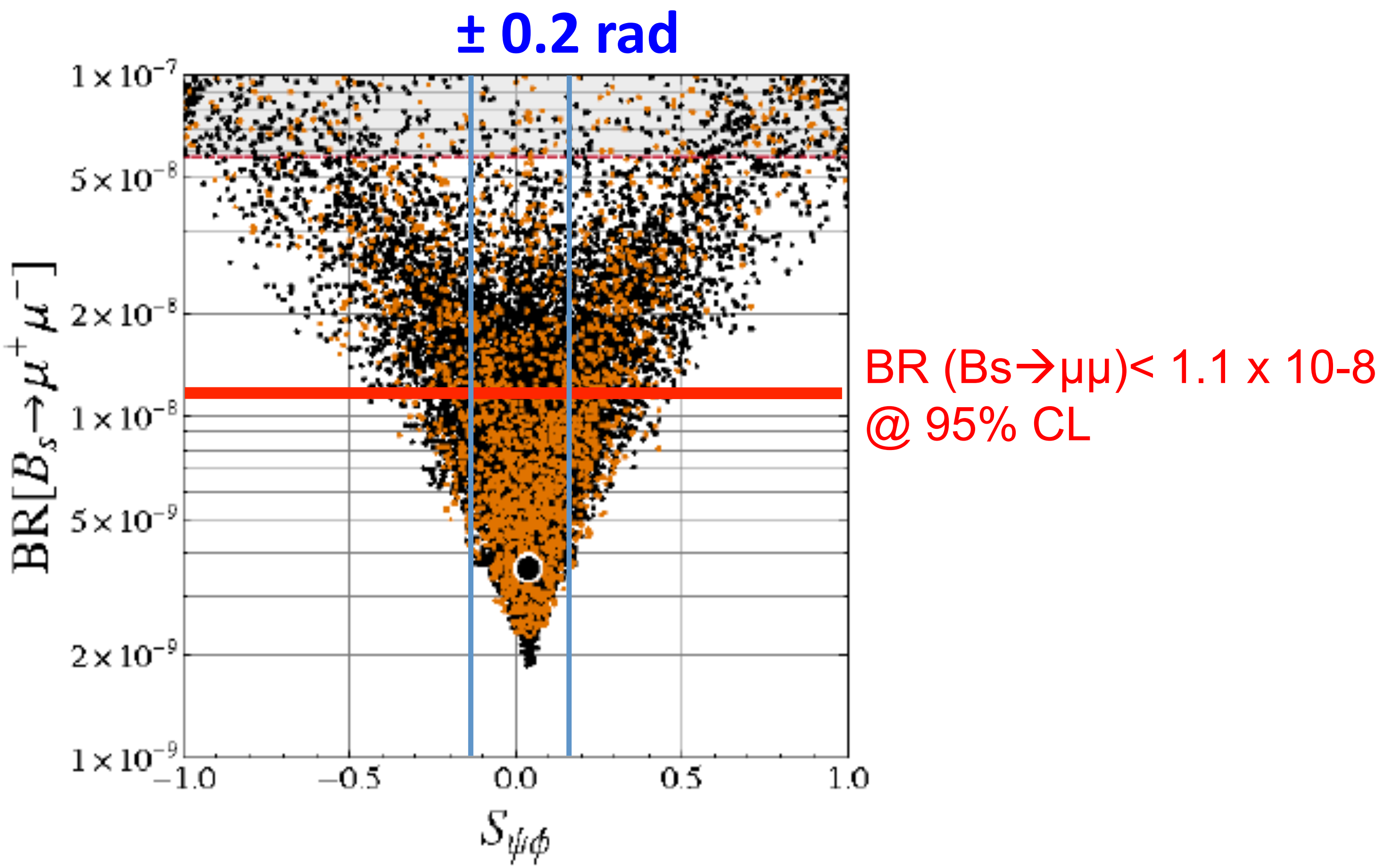
$A_{CP}(K\pi)$


.... and we did enjoy it!


Thanks to the LHC team!
.... and we did enjoy it!

Backup

$B_s \rightarrow \mu\mu$ and ϕ_s in $B_s \rightarrow J/\psi\phi$

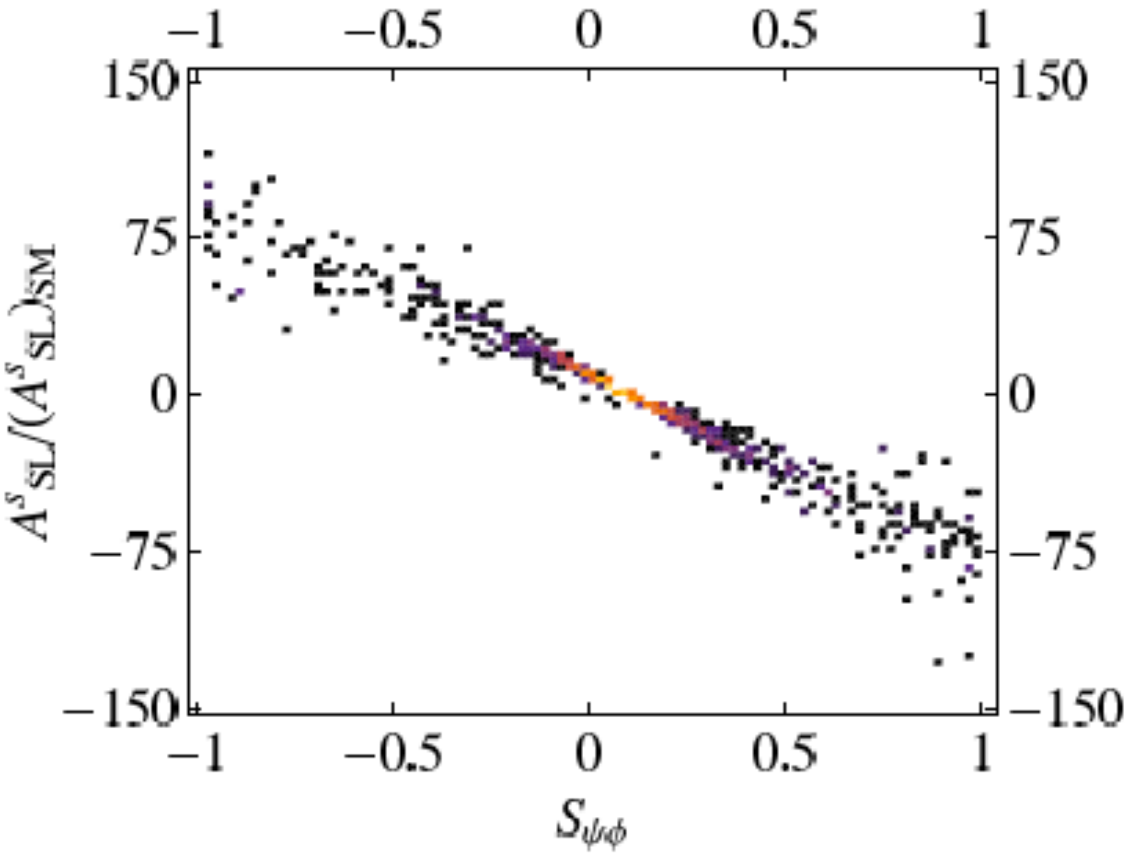


A.J.Buras, arXiv 0910.1032 and references therein

A^s_{SL} and ϕ_s

$$a^s_{fs} = \frac{|\Gamma_{12,s}|}{|M^{SM}_{12,s}|} \cdot \frac{\sin\left(\phi_s^{SM} + \phi_s^{\Delta}\right)}{|\Delta_s|}$$

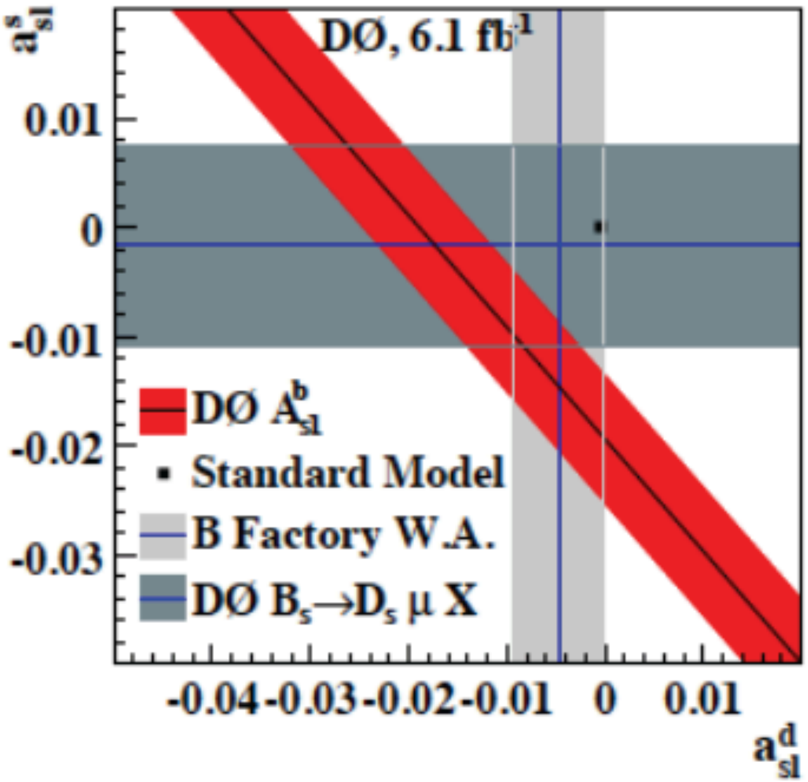
$$\sin(\phi_s^{SM}) \approx 1/240$$



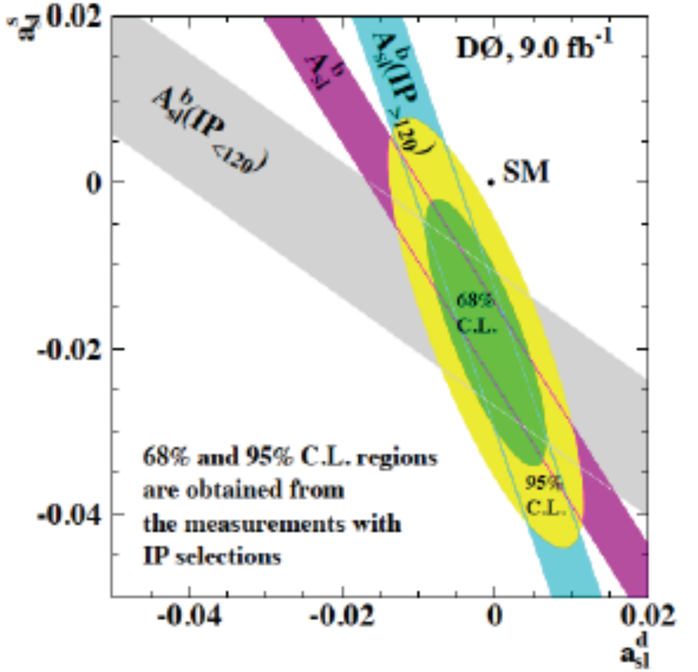
A.J.Buras, arXiv 0910.1032 and references therein

The D0 result

2010



2011 $a^b_{sl} = -(0.787 \pm 0.172 \pm 0.093)\%$



Note: separating samples by muon impact parameter:

$$a^s_{sl} = (-1.81 \pm 1.06)\%$$

$$a^d_{sl} = (-0.12 \pm 1.06)\%$$

Measuring A_{SL}^{s} at LHCb

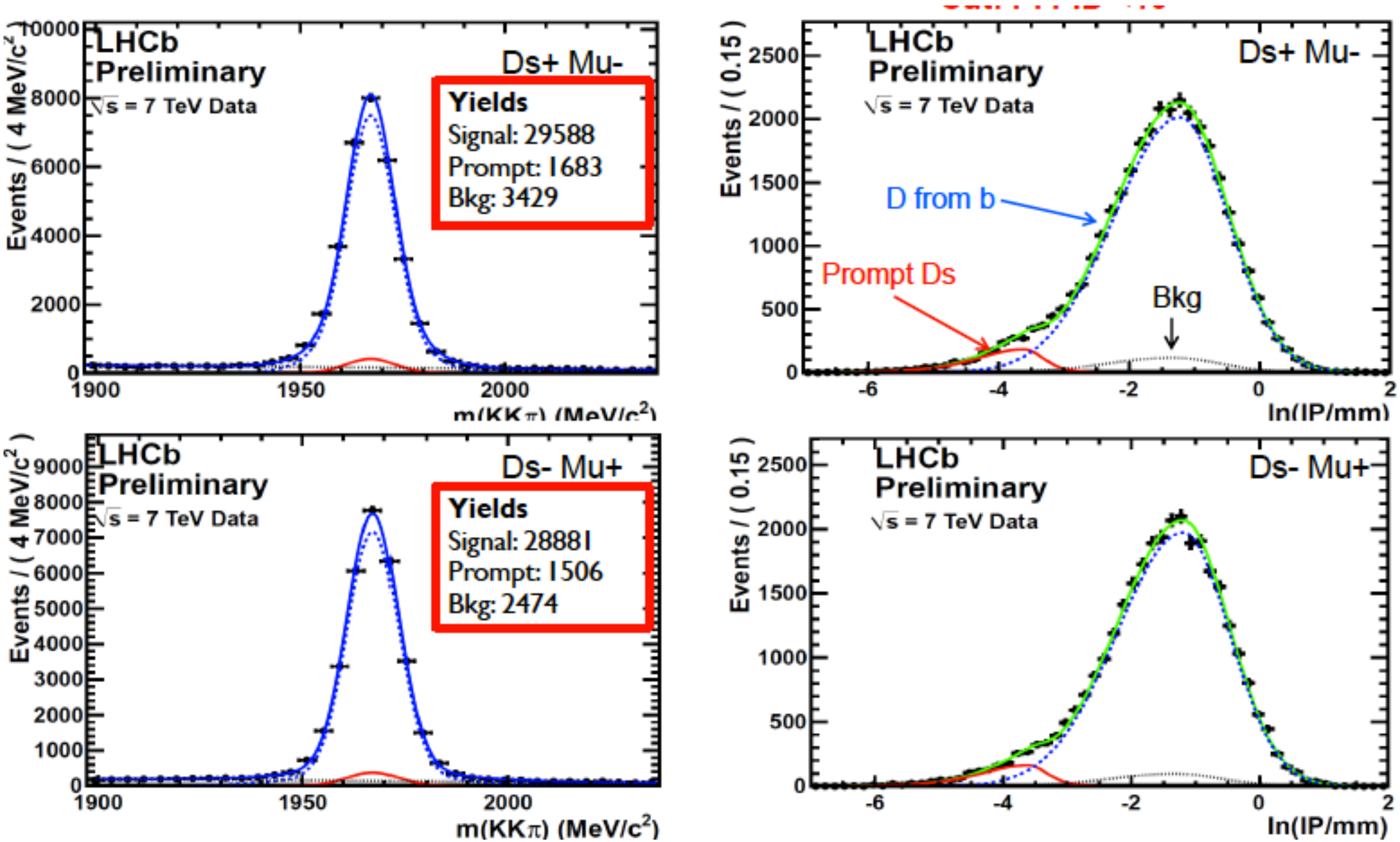
- Time-integrated untagged asymmetry of $B_s \rightarrow D_s(\varphi\ \pi)\ \mu\ X$

  - production asymmetry cancels out at first order due to high oscillation frequency ($<10^{-4}$)

  - $\varphi \rightarrow KK$ is independent of charge asymmetry arising from kaons interacting with detector material

  - π/μ detector asymmetries are measured with high precision using control samples
- Data for both B polarities are analyzed independently and compared
- Signal statistics: ~ 300 pb^{-1}, statistical error on asymmetry with 1 fb^{-1} is 0.15%

Measuring A_{SL}^{s} at LHCb

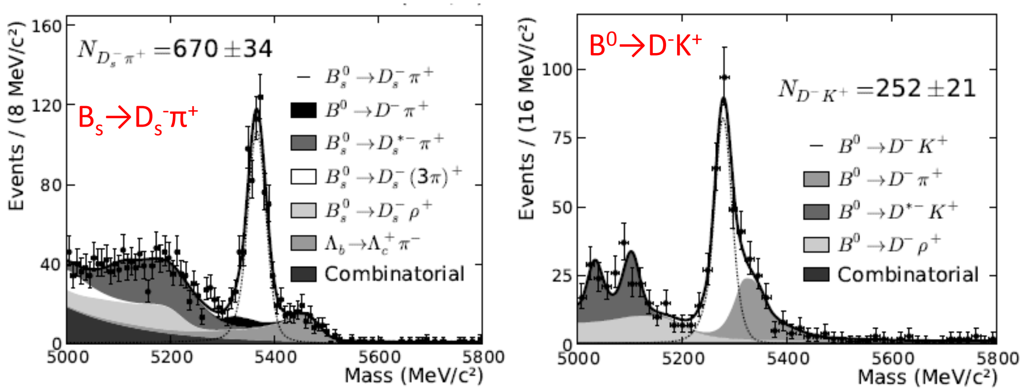


Calibration of the source: fragmentation fractions

LHCb has measured the fragmentation fractions: the relative rates of B^+, B^0, B_s, Λ_b...

Two complementary approaches:

1. ratio of related hadronic decays, e.g. $B^0 \to D^- K^+$ and $B_s \to D_s^- \pi^+$
   [arXiv:1106.4436, sub. to PRL]



2. semi-leptonic analysis with $D^0 \mu X$, $D^+ \mu X$, $D_s \mu X$ & $\Lambda_c \mu X$ events and accounting for cross-feeds [LHCb-CONF-2011-028]

Consistent results for B_s/B^0 fragmentation ratio, f_s/f_d, which thus can be combined:

$$\langle f_s / f_d \rangle_{LHCb} = 0.267 \, ^{+0.021}_{-0.020} \quad *$$

f_s/f_d not a priori a 'universal' number, but agreement nonetheless seen with other measurements:

$$\langle f_s / f_d \rangle_{LEP\ Tevatron} = 0.271 \pm 0.027 \quad x$$

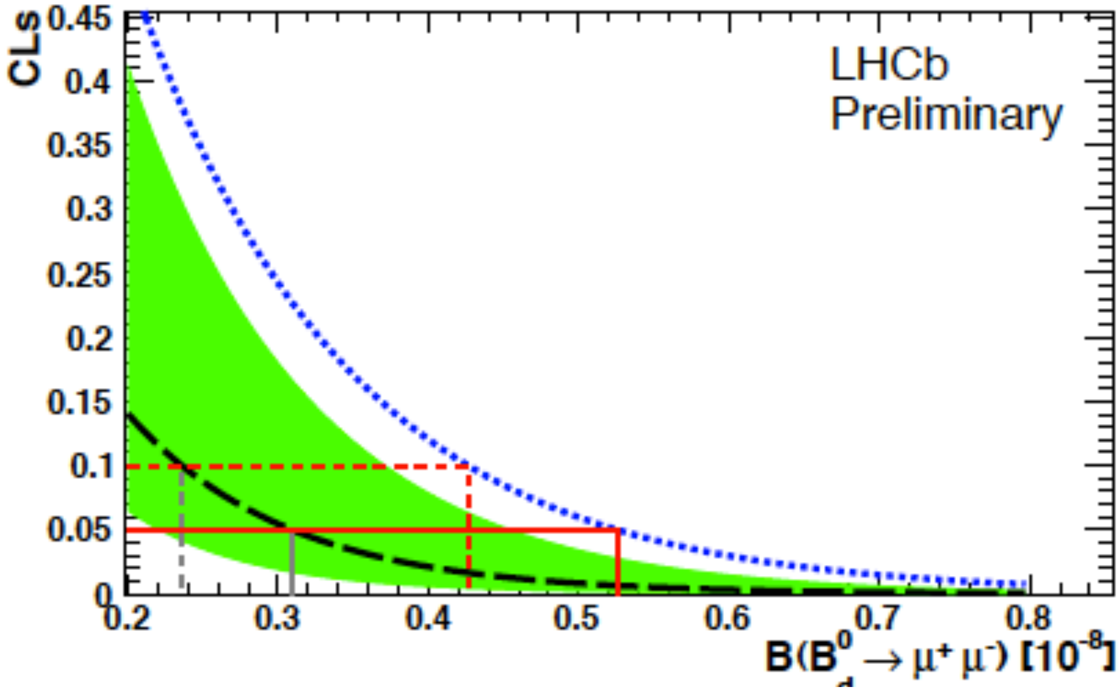
Necessary input for e.g. BR($B_s \to \mu\mu$) !

* LHCb-CONF-2011-034

x courtesy Olivier Schneider

This ratio seems to be independent from energy and pseudo-rapidity

LHCb preliminary limit for BR($B_d \rightarrow \mu\mu$) with 300 pb^{-1}



$B^0 \to \mu^+\mu^-$	at 90% CL	at 95% CL	CL_b
expected limit (bkg only hypothesis)	2.4×10^{-9}	3.1×10^{-9}	
observed limit	4.2×10^{-9}	5.2×10^{-9}	0.79

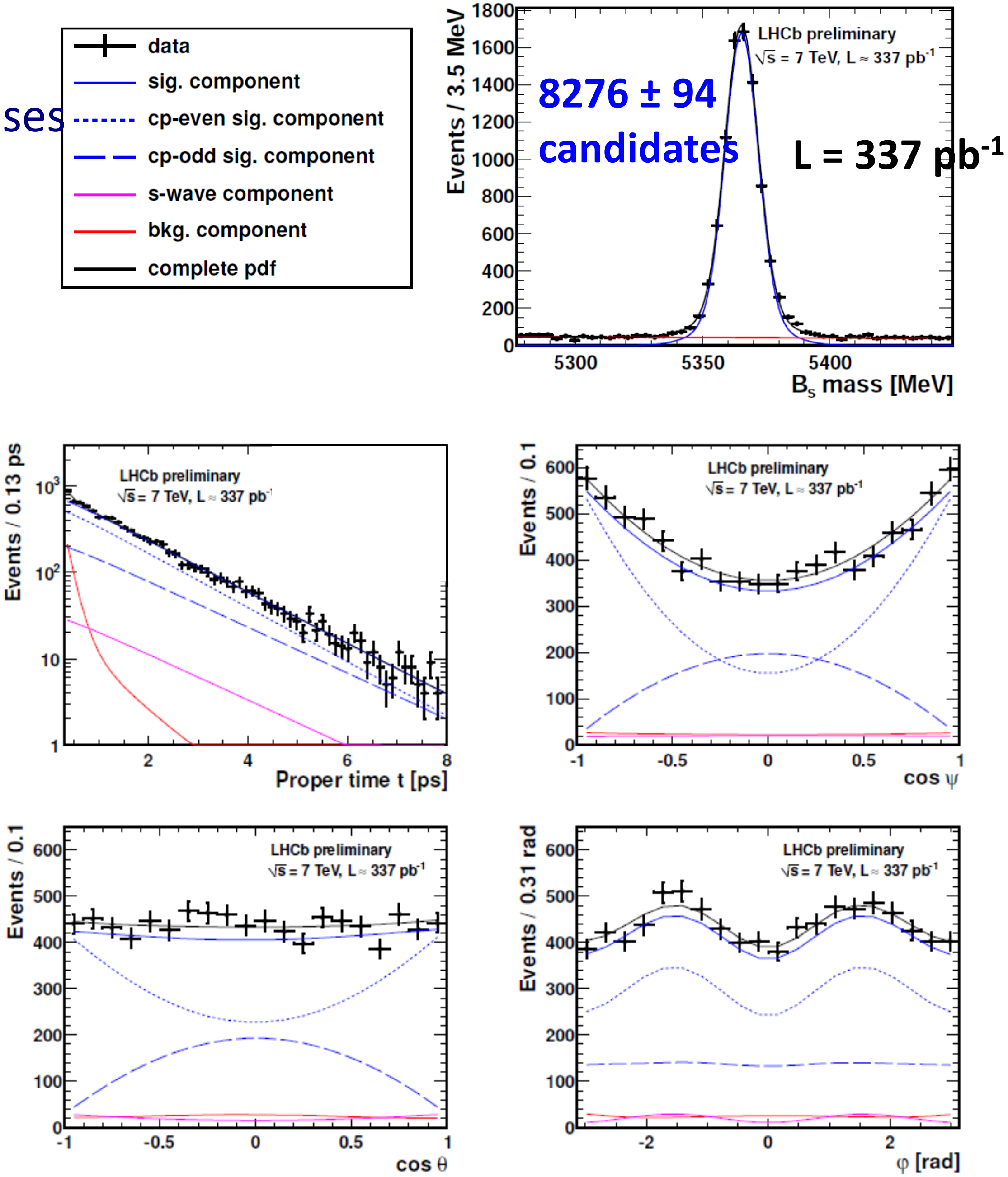
CDF (7 fb^{-1}): 6.0×10^{-9} @ 95% CL

Publication status and plans

Past	SUBMITTED TO / ACCEPTED BY JOURNAL:	10
Present	ANALYSES WITH PAPER DRAFTS CURRENTLY IN COLLABORATION WIDE REVIEW:	7
Future, but still 2011 !	OLDER (2010) ANALYSES AIMED FOR PUBLICATION:	~10
	SUMMER CONFERENCE RESULTS ON ~300 pb^{-1} AIMED FOR PUBLICATION WITH MINIMAL CHANGES:	~17
	SEVERAL NEW ~300 pb^{-1} ANALYSES	
Future, early 2012	MOST ANALYSES WITH FULL REPROCESSED ~1 fb^{-1}	

Maximum Likelihood fit to LHCb data

- ML fit with 10 physics parameters
  - 7 angular amplitudes and phases
  - Γ_s, $\Delta\Gamma_s$, ϕ_s



- proper-time resolution, calibrated on prompt J/psi gives σ(t) ~ 50 fs

- only OS flavour tagging used, calibrated on J/psiK+

$$\varepsilon_{\rm tag}\mathcal{D}^2 = (2.08 \pm 0.41)\%$$

- goodness of fit, using "point-to-point dissimilarity test" (*) gives P-value of 0.44

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

ϕ_s from $B_s \rightarrow J/\psi\ \varphi$: LHCb with 36 pb^{-1} (2010)