Searching for New Physics through Flavour

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Why do we care about flavour physics now that the high p_T LHC programme is finally underway ?

Flavour physics facilities, past and present

Potential game changers – five decent bets where the New Physics could show itself in the next few years

Conclusions

Flavour Physics is Important

Many of open questions in Standard Model (SM) found in flavour sector:

- Why are there 3 generations ? (and is it only 3 ?)
- What determines the extreme hierarchy of fermion masses?
- What determines the elements of the CKM matrix?
- What is the origin of CP violation (CPV)?

Progress in flavour physics may help understand open questions in cosmology - SM CPV insufficient to explain matter/antimatter asymmetry

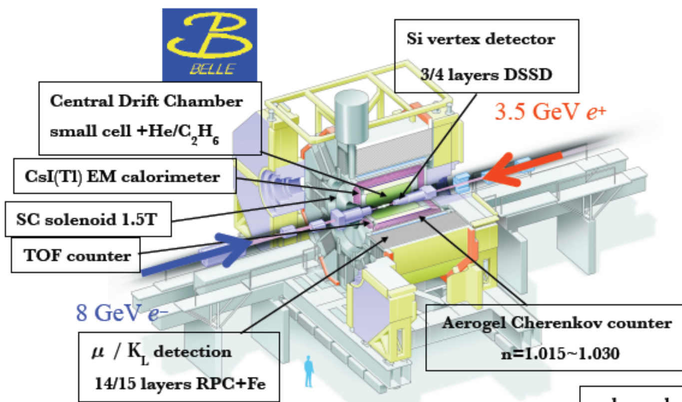
Flavour physics is a proven tool of discovery:

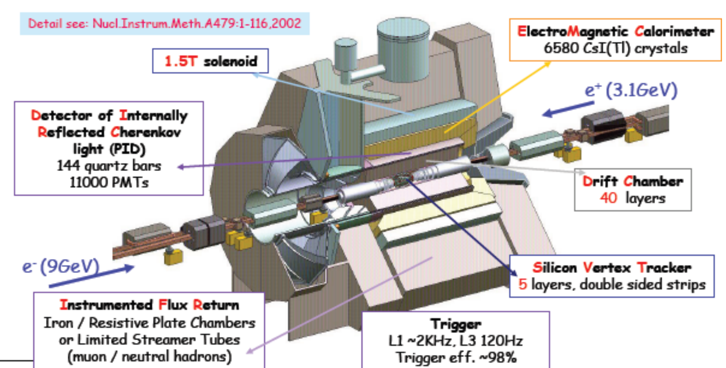
- Kaon mixing, BR($K^0_L \rightarrow \mu\mu$) & GIM → prediction of charm
- CP violation → need for a third generation
- B mixing → mass of top is very heavy
- SUSY parameter space already severely constrained by e.g. $b \rightarrow s\gamma$

Precise studies of flavour observables are an excellent way to look for New Physics!

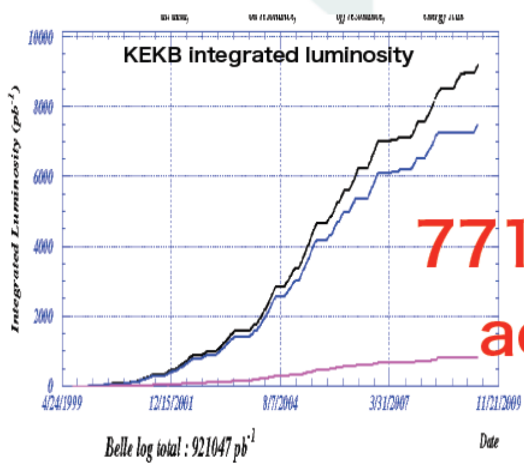
Cast of characters

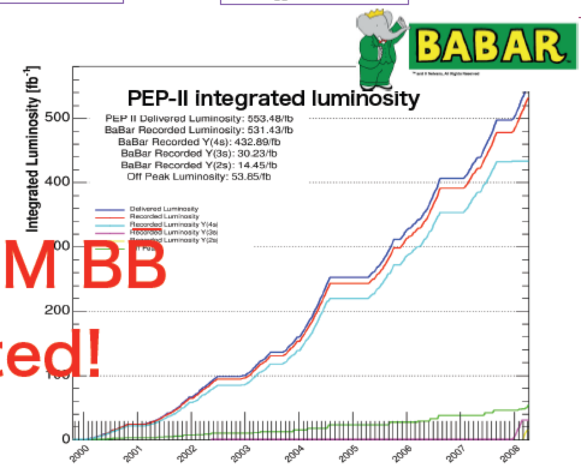
B-factories





- charged particle tracking
- momentum measurement
- particle identification
- e/γ energy measurement
- K_L cluster detection

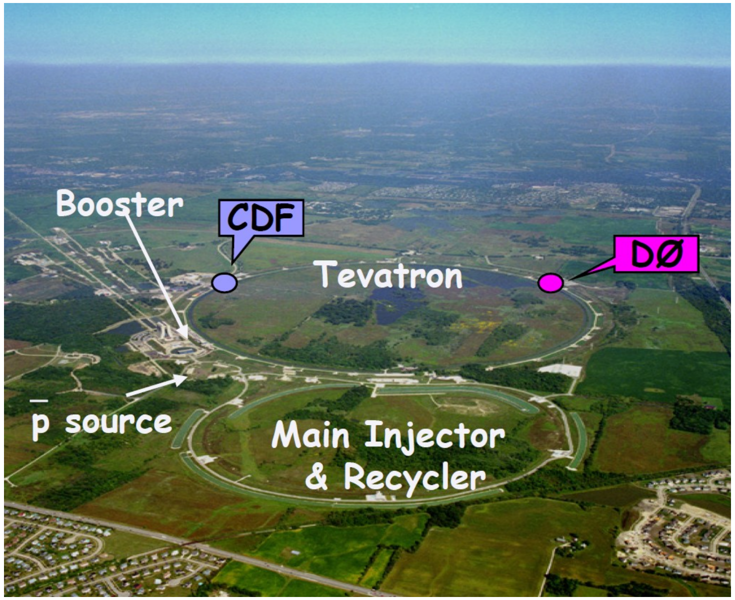


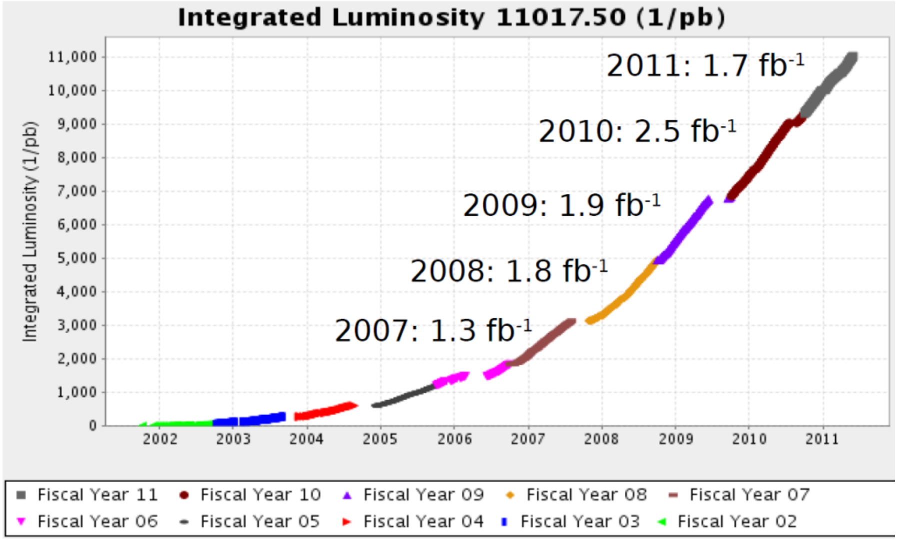


771M + 463M BB accumulated!

Truly *astounding* achievement ! Bulk of data analysed in bulk of analyses.
Still much vital work to be done. But low likelihood of real surprises (?)

State of play at the Tevatron



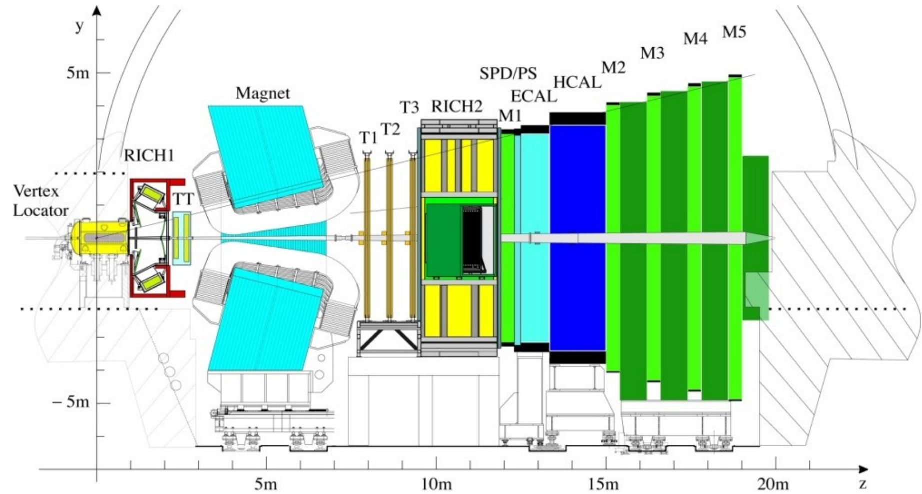


Over 11 fb^{-1} delivered to each experiment, and ~1 fb^{-1} more still to be collected

For many flavour physics analyses, only half of total dataset has been analysed

Still lots of physics to come!

LHCb Essentials

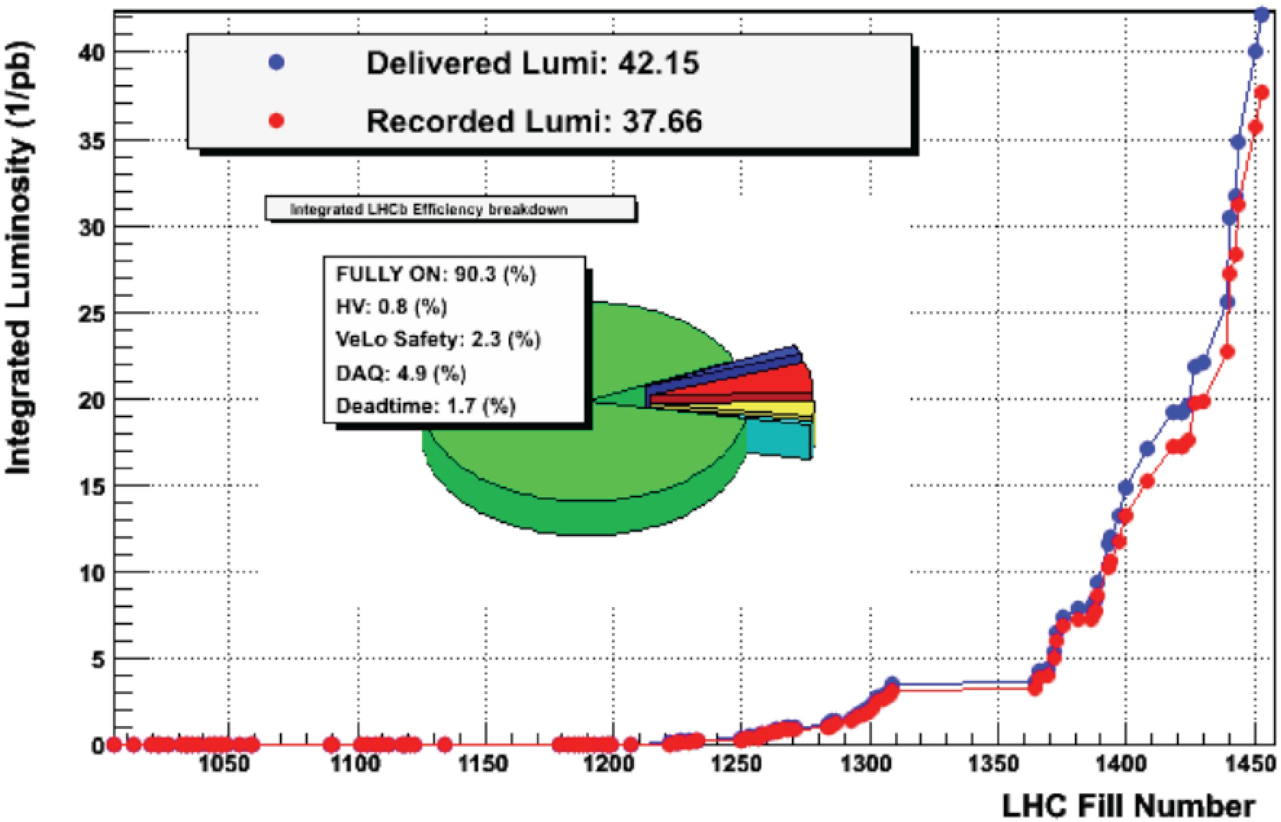


LHCb optimised for flavour physics.
Various attributes distinguish it from
Tevatron detectors + ATLAS/CMS:

- Dedicated heavy flavour trigger
  - L0: hardware trigger firing on high p_t hadrons and muons
  - HLT: software trigger exploiting, in particular, tracking and vertexing. Outputs at 3 kHz

    → Efficient for hadronic B and D decays, as well as leptonic channels
- Very precise vertexing
  - VELO (planes of forward silicon) approach to within 8mm of beam
- Hadron identification
  - Two RICHes provide good π/K separation over $2 < p < 100$ GeV/c
- LHCb design luminosity << maximum design luminosity of machine
  - LHCb already operating at (even above!) design luminosity (2×10^{32} cm^{-2} s^{-1})

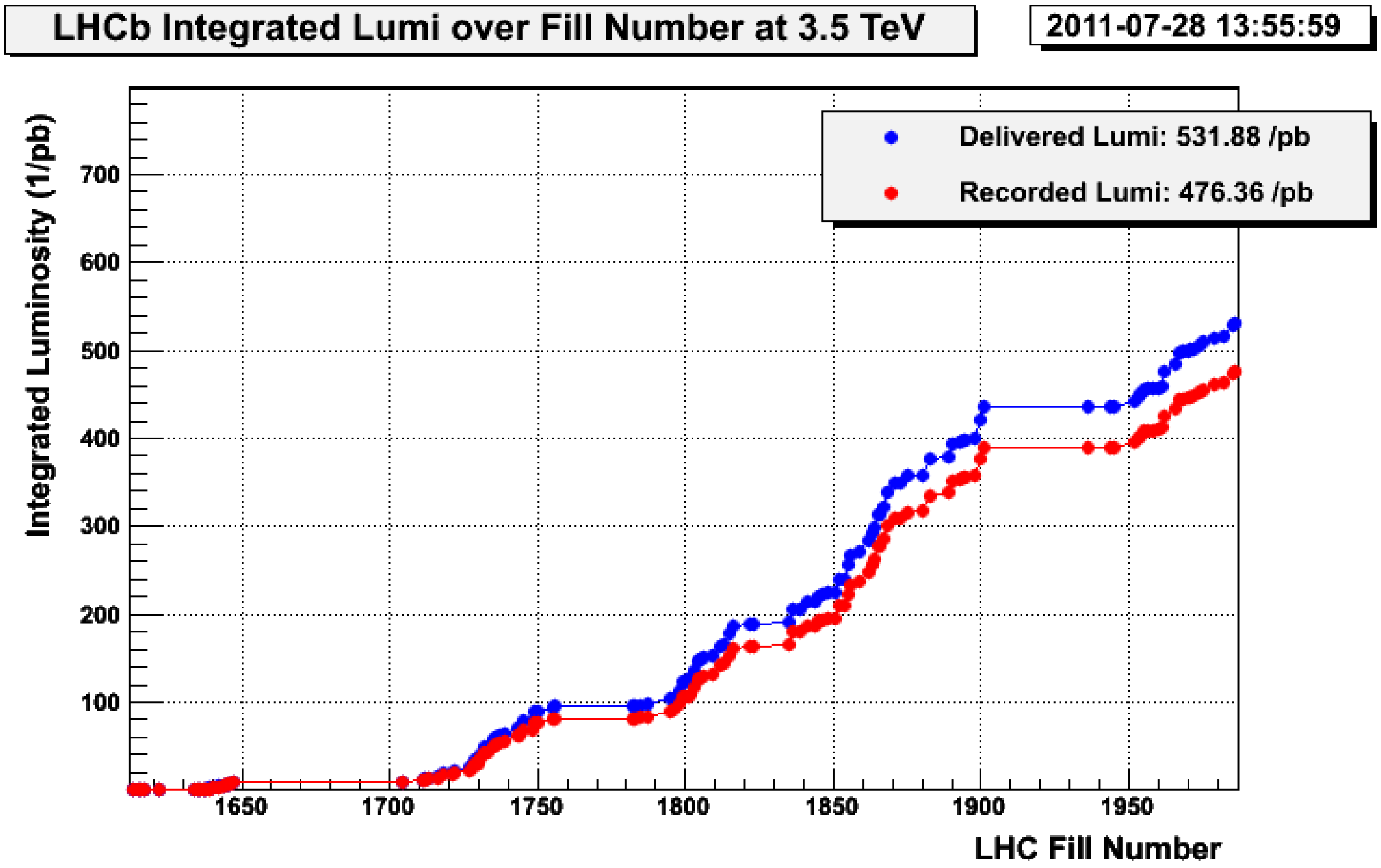
LHCb integrated luminosity in 2010



Design luminosity 2 x 10^{32} cm^{-2} s^{-1}. Almost there at end of run!

Similar amount (~40 pb^{-1}) accumulated by ATLAS and CMS

Integrated luminosity (so far) in 2011

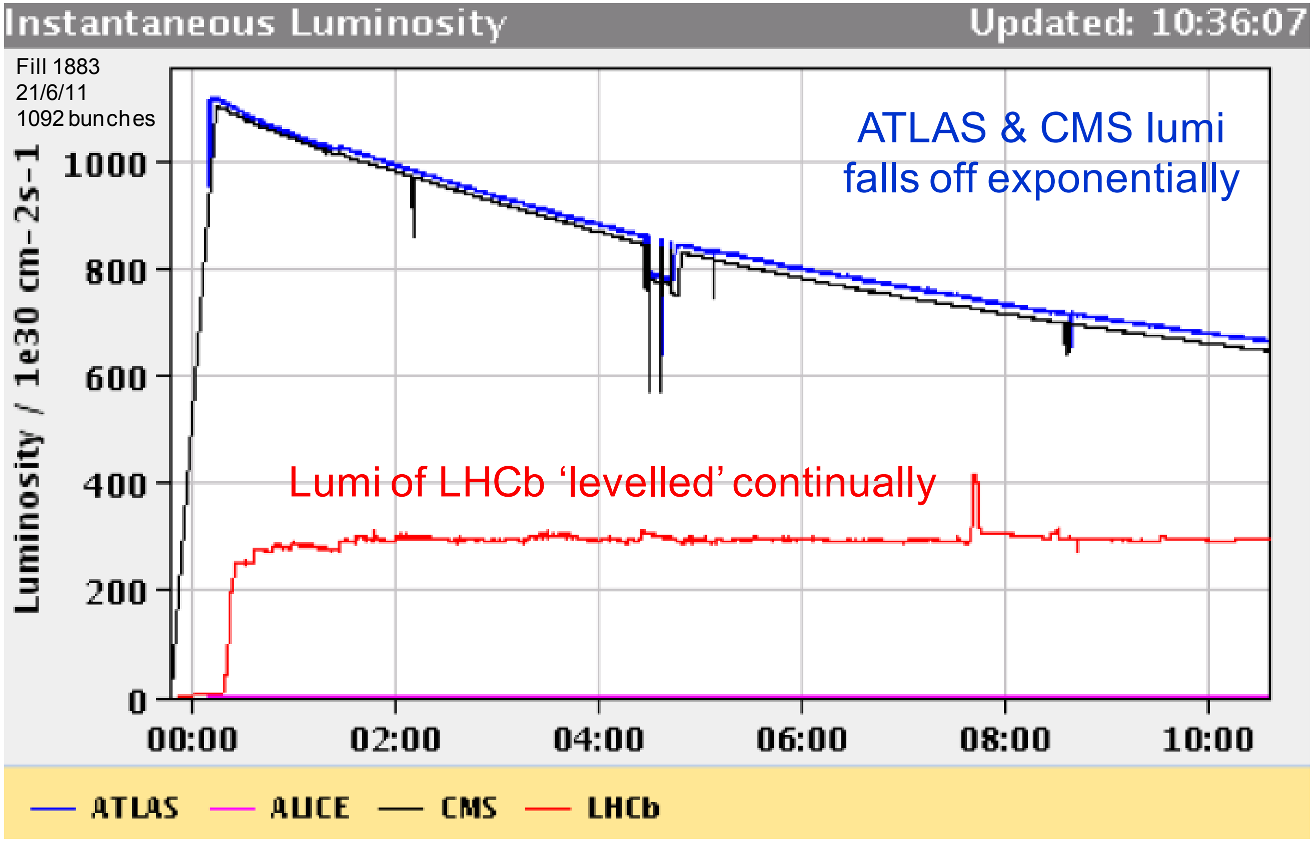


~476 pb^{-1} recorded. On target to accumulate >1 fb^{-1} by end of year.

ATLAS and CMS have collected around 3 times this amount

Running strategy in 2011

Beams at LHCb displaced from head-on, with displacement reduced throughout fill



LHCb lumi choice dictated by event size & complexity, trigger & detector stability

Looking forward...

There exist three approved projects which will bring further step-up in precision...

datataking begins 2015 ?

Belle II

datataking begins 2017 ?

SuperB

datataking begins 2019 ?

...but will not consider these further today, as shall focus on the immediate future

Five potential game-changers – decent bets to lead us to NP in the LHC era

- CP violation searches in charm
- Precise CKM metrology
- Observables in $B^0 \to K^{*0}\mu^+\mu^-$
- CP violation in B_s mixing
- $BR(B_s \to \mu^+\mu^-)$

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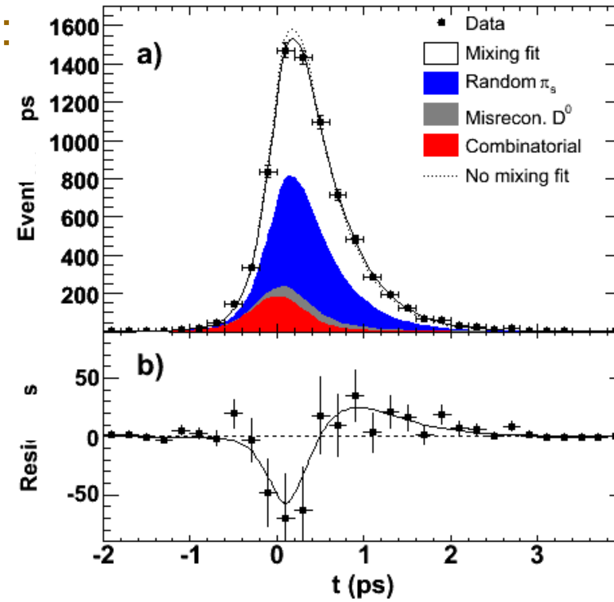
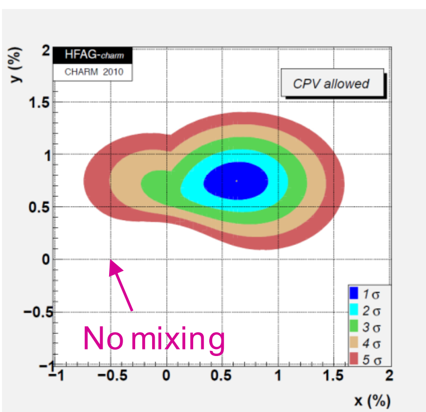
D^0-$\overline{D}^0$ Mixing: Observation

Numerous recent, exciting results on charm mixing:

The most interesting…

- 'Wrong sign' $K\pi$ (x'^2, y')
  - Belle, PRL 96 (2006) 151801
  - BABAR, PRL 98 (2007) 211802
  - CDF, PRL 100 (2008) 121802
- Eigenstate lifetime analyses: y_{CP}
  - BABAR, PRD 80 (2009) 071103
  - Belle, PRL 98 (2007) 211803
- $K_S\pi^+\pi^-$ Dalitz analyses: x,y
  - Belle, PRL 99 (2007) 131803
  - BABAR, PRL 105 (2010) 081803





A whole armada of complementary analyses
Taken *together*, no doubt now that mixing exists…

$$x = 0.63\pm^{0.19}_{0.20}\ \%$$

$$y = 0.75\pm 0.12\ \%$$

(HFAG, Oct 10, CPV allowed)

…but what does it mean?

The next step: CPV in charm

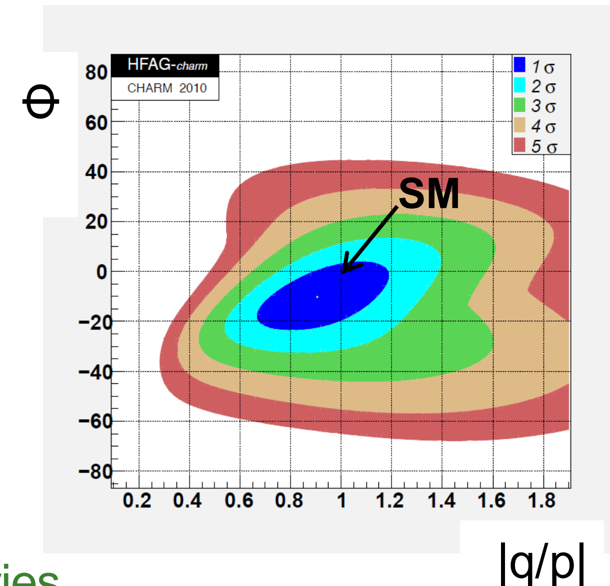
Values of x & y at top end of SM expectation – but *not* inconsistent. Use results to constrain many NP models. See, for example, Golowich et al. PRL 98 (2007) 181801.

'High' values of x & y encourage us to follow lessons of B sector - look for CPV !

In SM Φ=0 and |q/p|=1 is an almost perfect approximation. Looking for deviations from this a powerful NP probe, and one complementary to B / K-sector searches.

$$|q/p| = 0.91 \pm^{0.18}_{0.16}$$

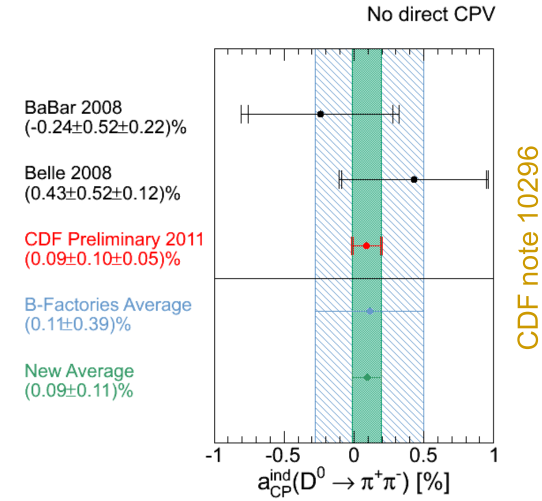
$$\phi = -10.2 \pm^{9.4}_{8.9} \text{ degrees}$$



Further updates possible from CDF and B-factories.
With these, and LHCb order of magnitude improvement possible? Going still further is a strong argument for LHCb upgrade / superflavour factory

For similar reasons, we must intensify the hunt for direct CPV in charm

Grounds for optimisim

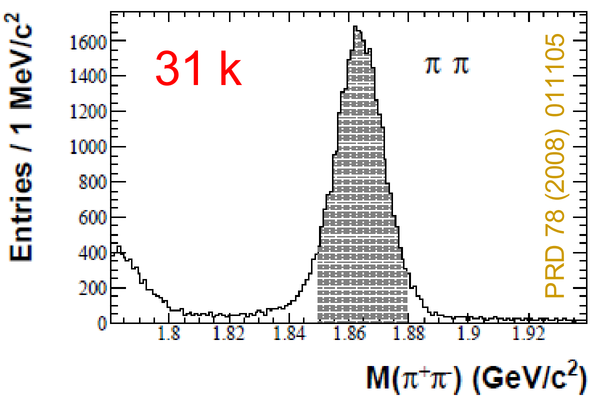


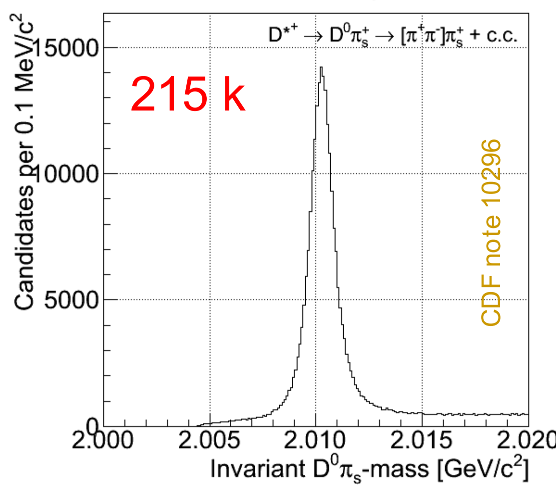
Very large samples of $D^0 \to hh$ events at Tevatron have recently been exploited to give significantly improved constraints beyond (already precise) B-factory results

e.g. $D^* \to D^0(\pi\pi)\pi$

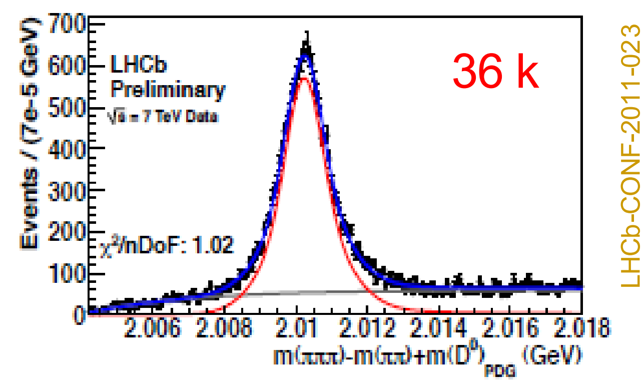
CDF, 5.94 fb^{-1}

BABAR, 384 fb^{-1}





LHCb, 37 pb^{-1}



10 x more decays now on tape

This work will be continue at LHCb, where cross-section is even higher (~6 mb !*) & large fraction of trigger output (~1 kHz) devoted to charm physics

+ LHCb-CONF-2011-023

First (2010) charm results from LHCb

LHCb-CONF-2011-046

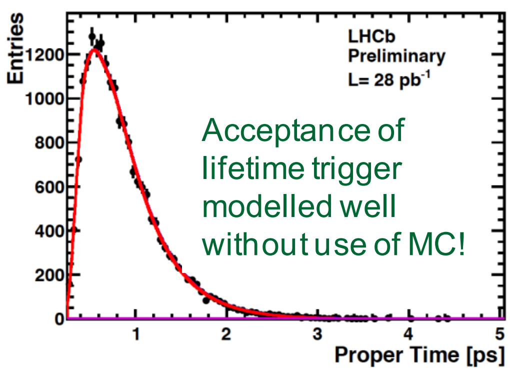
Search for CPV in mixing:

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

which would be indicated by $A_\Gamma \neq 0$

$A_\Gamma = (-0.59 \pm 0.59 \pm 0.21) \times 10^{-2}$

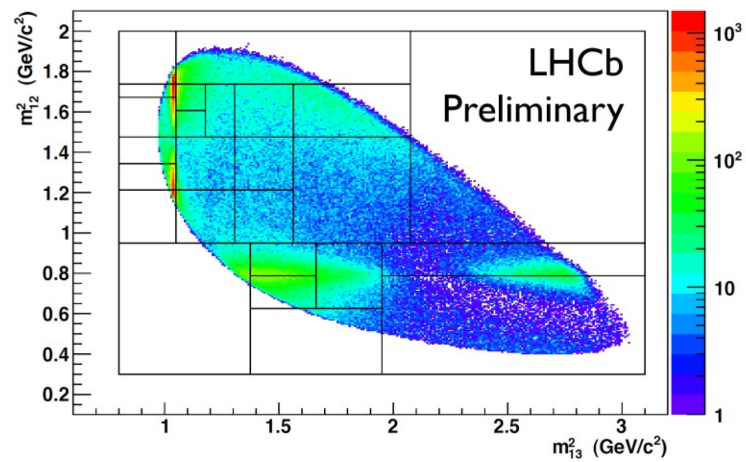
Limited sample (28 pb^{-1}) does not yet allow for improved sensitivity w.r.t. previous measurements...



...but shows that challenges at hadron collider are under control

Search for direct CPV in $D^+ \to K^+K^-\pi^+$

Compare bins of D^+ and D^- Dalitz plot



Paper in preparation

Systematic control provide by:

- ability to invert dipole polarity – check for detector asymmetries
- control channels like $D_s^+ \to K^+K^-\pi^+$ and very abundant $D^+ \to K^-\pi^+\pi^+$

No CPV seen in signal, but *neither* is any fake CPV from control modes !

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- Observables in $B^0 \to K^{*0} \mu^+ \mu^-$
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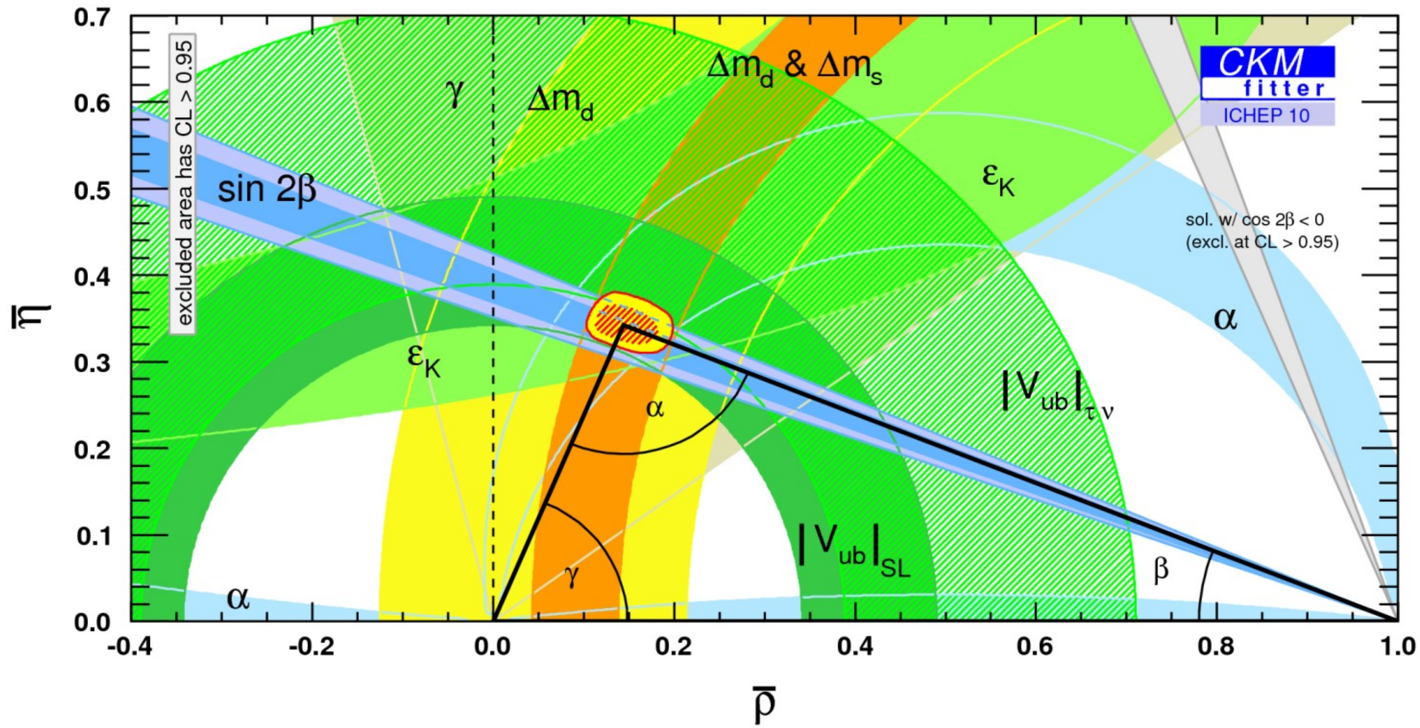
- $BR(B_s \to \mu^+ \mu^-)$

The need for more precise CKM-metrology

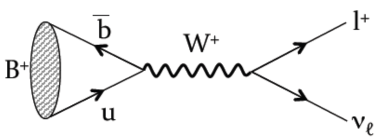
Amazing job by the B-factories (plus kaon experiments [ε_K], plus Tevatron [Δm_s]). Clear that CKM mechanism is dominant driver of CP-violation (in B_d system).



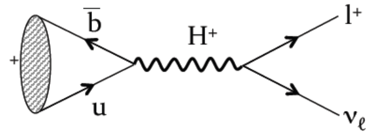
Still possible for NP to be present at ~10% level. And consistency is *not* perfect... Where are current 'tensions', & where are improved measurements needed?

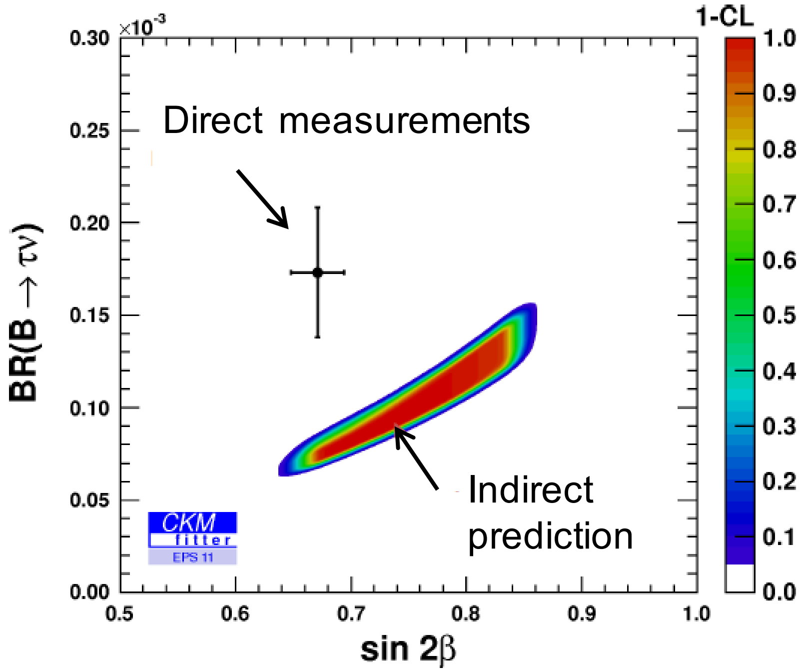
One example of 'tension': B→τν & sin2β

$$\mathcal{B}(B \to \tau\nu) = \frac{G_F^2 m_{B^+} m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_{B^+}^2}\right)^2 |V_{ub}|^2 f_B^2 \tau_{B^+}$$



+ ?





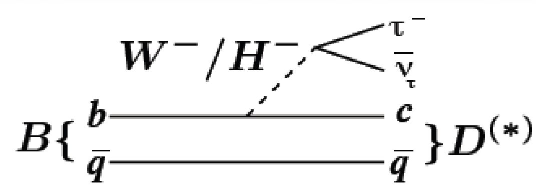
If genuine, this could point to NP in B→τν or sin2β (although sin2β is very well known, it is still *likely* to carry NP at *some* level)

Determination of BR(B→τν) requires full or partial reconstruction of 'other' B.

Presently known to ~20% precision. Need Super-B/Belle-II for significant progress.

Further progress on sin2β will come from LHCb, but will take time...

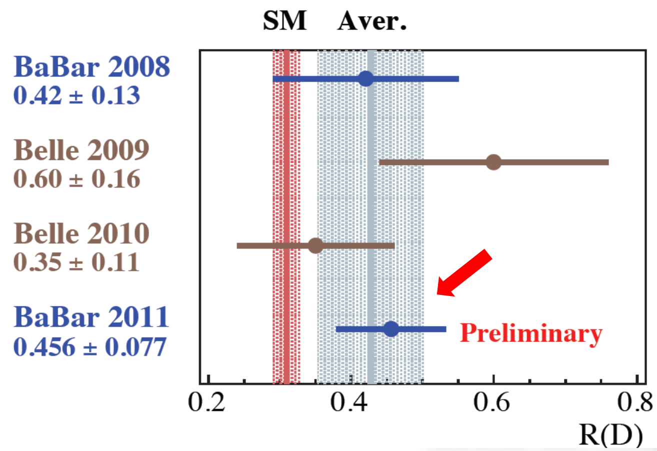
Interesting developments: measurements of B→D(*)τν



Recently new measurements have appeared of the BR of $B\to D^{(*)}\tau\nu$ (or more precisely this BR w.r.t. that of $B\to D^{(*)}l\nu$) – sensitive to same NP as $B\to\tau\nu$

$$R(D^{(*)}) = \frac{\mathcal{B}\left(B \to D^{(*)}\tau\nu_\tau\right)}{\mathcal{B}\left(B \to D^{(*)}\ell\nu_\tau\right)}$$

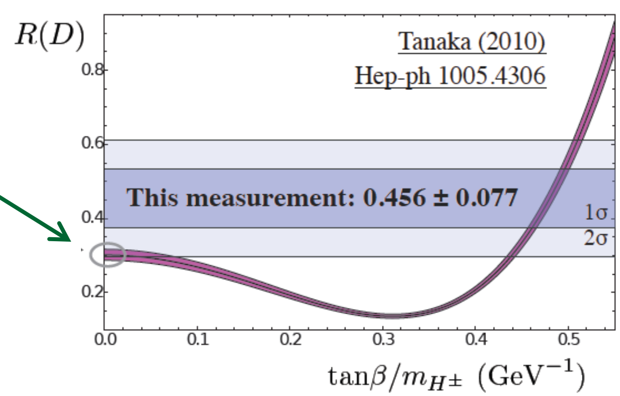
A tendency to be higher than SM seen here too!

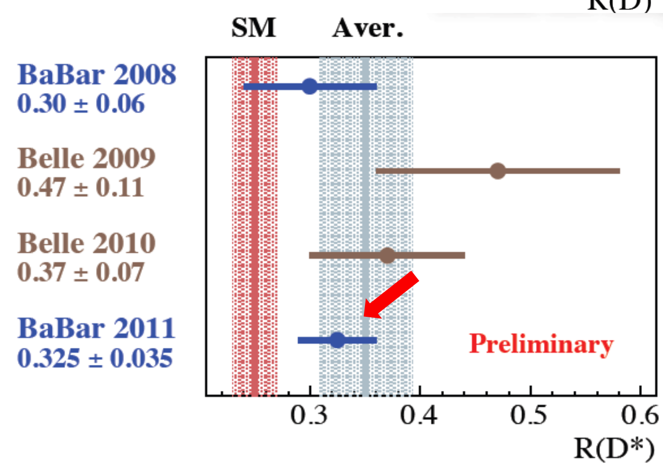


New measurements *not* in average

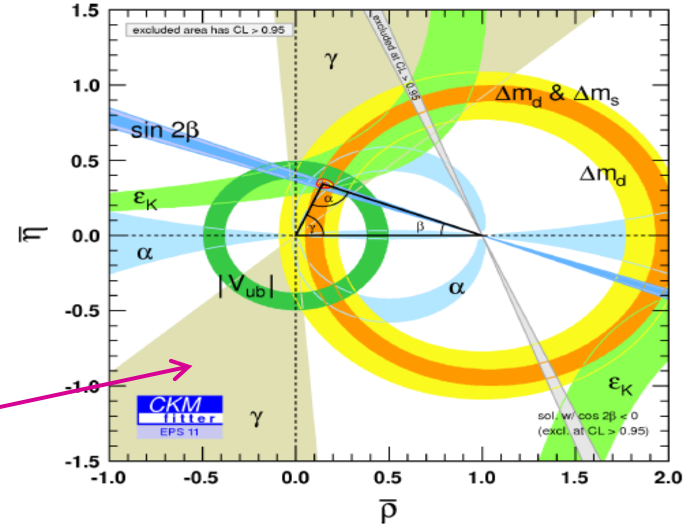
R_D result 1.8 σ higher than SM

Favours high tanβ ?





Precision CKM-metrology: the next challenge



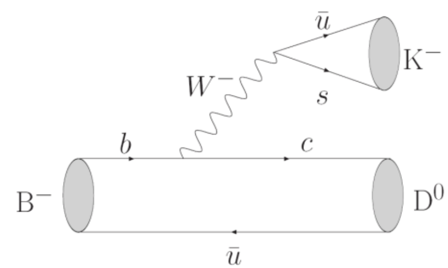
B-factories (& others) have done a great job in mapping out unitarity triangle. But progress needs improved knowledge of angle γ (a.k.a. φ_3)

Look in $B^\pm \to DK^\pm$ decay<u>s</u> using common mode for D^0 & D^0

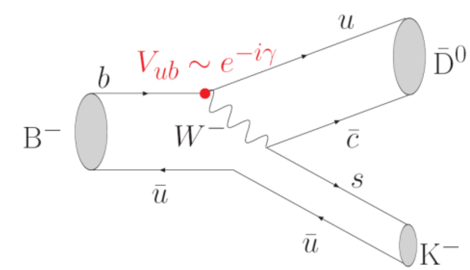
$\to \gamma$ sensitive interference

$\to$ different rates for B^+ & B^- (CPV!)

Favoured



Suppressed



To *maximise* interference look for mode *suppressed* for D^0 & *favoured* for $\bar{D}^0$

e.g. $D^0 \to K^+\pi^-$ (DCS) , $\bar{D}^0 \to K^+\pi^-$ (CF) the 'ADS' method [**A**twood, **D**unietz, **S**oni]

Total visible BR very small (~10^{-7}), and not yet observed (4.1σ signal from Belle).

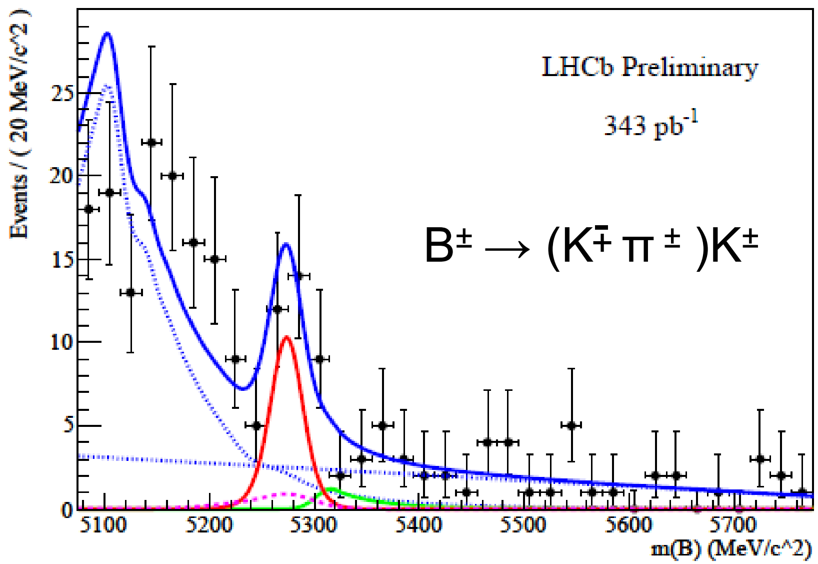
The suppressed 'ADS' mode $B^\pm \to (K^\mp\pi^\pm)K^\pm$ is the gateway to γ !

Evidence for suppressed ADS mode

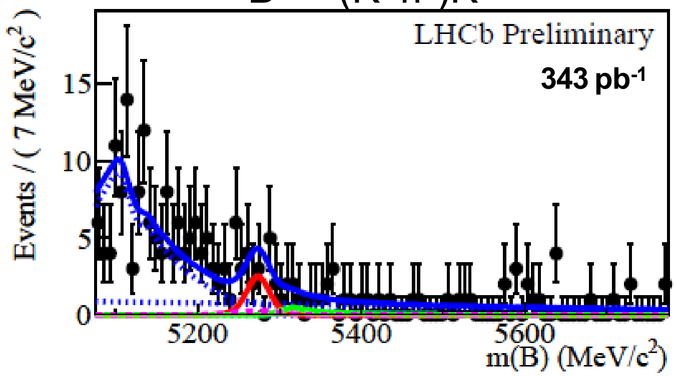
Hint of large CPV effects:

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

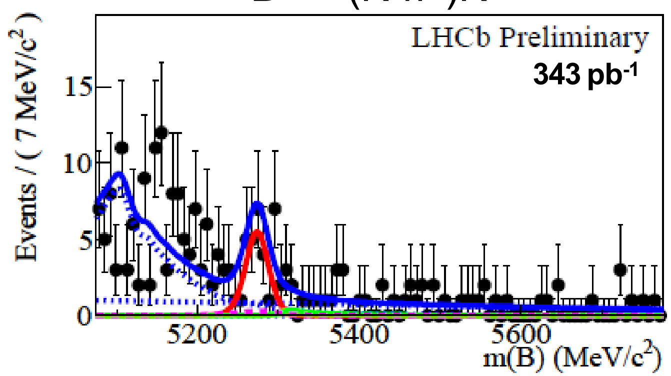
LHCb-CONF-2011-044



$B^- \to (K^+\pi^-)K^-$



$B^+ \to (K^-\pi^+)K^+$



Ratio to favoured mode:

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

World Average (without LHCb) 1.6 ± 0.3

Asymmetry:

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

World Average (without LHCb) -0.58 ± 0.21

Very bright prospects for significant improvement in γ sensitivity soon !

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- CP violation searches in charm
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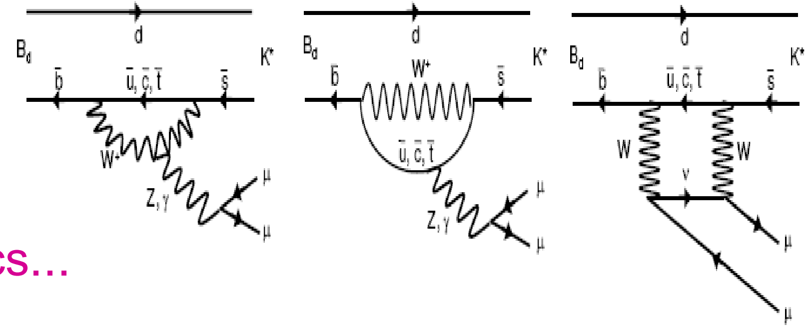
- CP violation in B_s mixing
- BR($B_s \rightarrow \mu^+ \mu^-$)

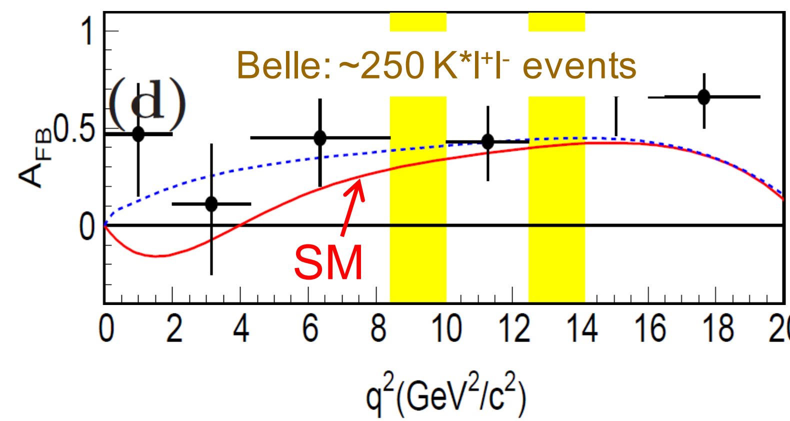
$B^0 \to K^* l^+ l^-$



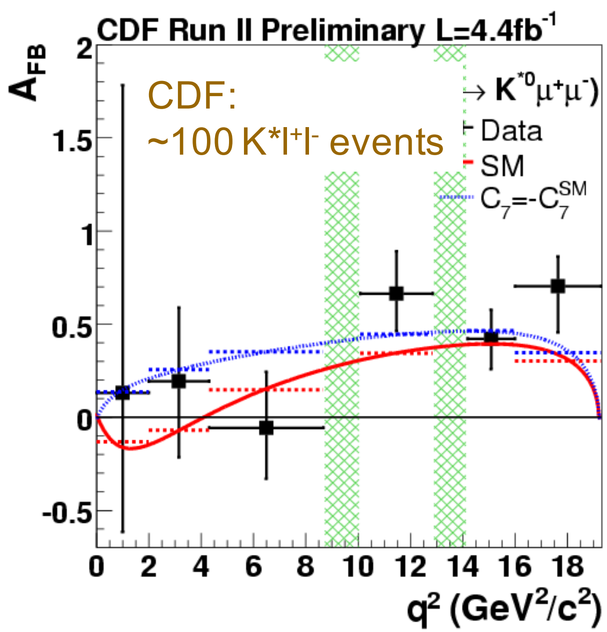
Many observables exist in $B^0 \to K^* l^+ l^-$ to probe helicity structure of any New Physics...

...in particular, forward-backward asymmetry (A_{FB}) of lepton system as a function of lepton invariant mass (q^2).

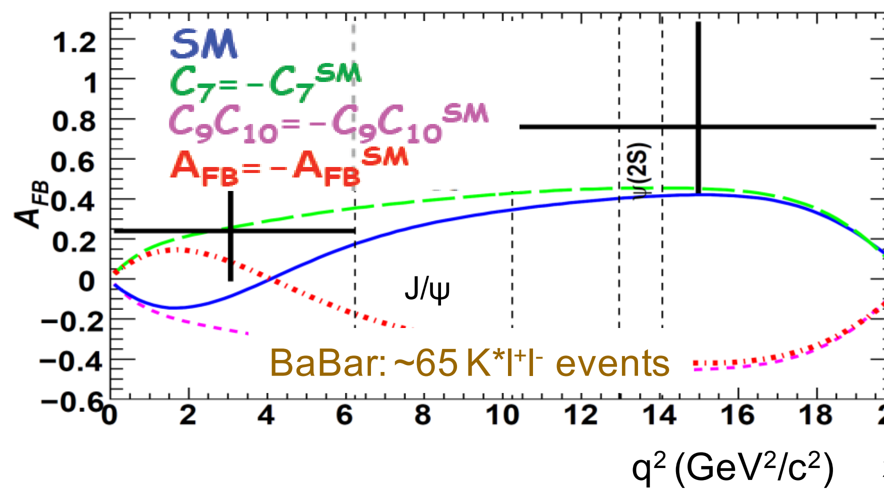
Early results from CDF & B-factories show intriguing behaviour at low q^2, But precision too low yet to speak of an 'anomaly'



PRL 103 (2009) 171801



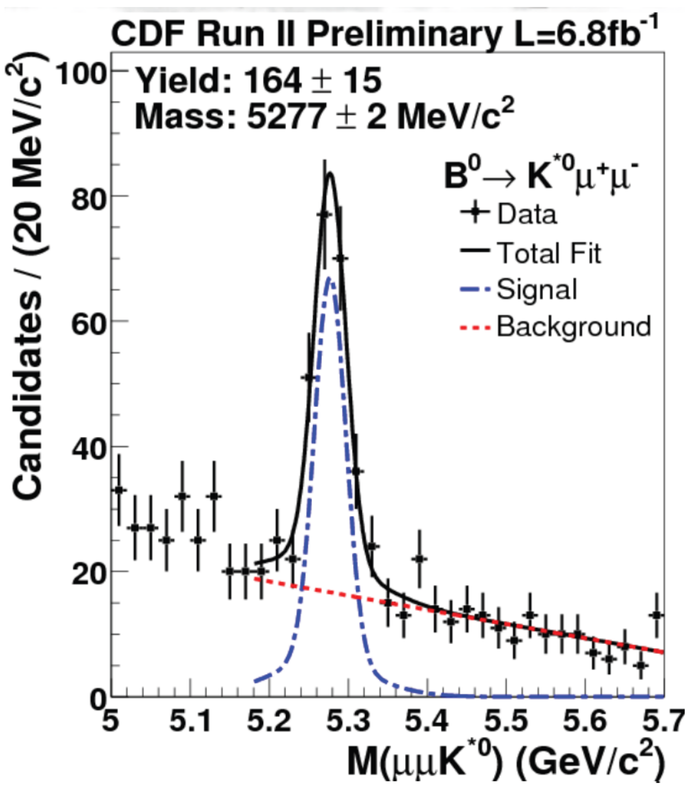
CDF note 10047

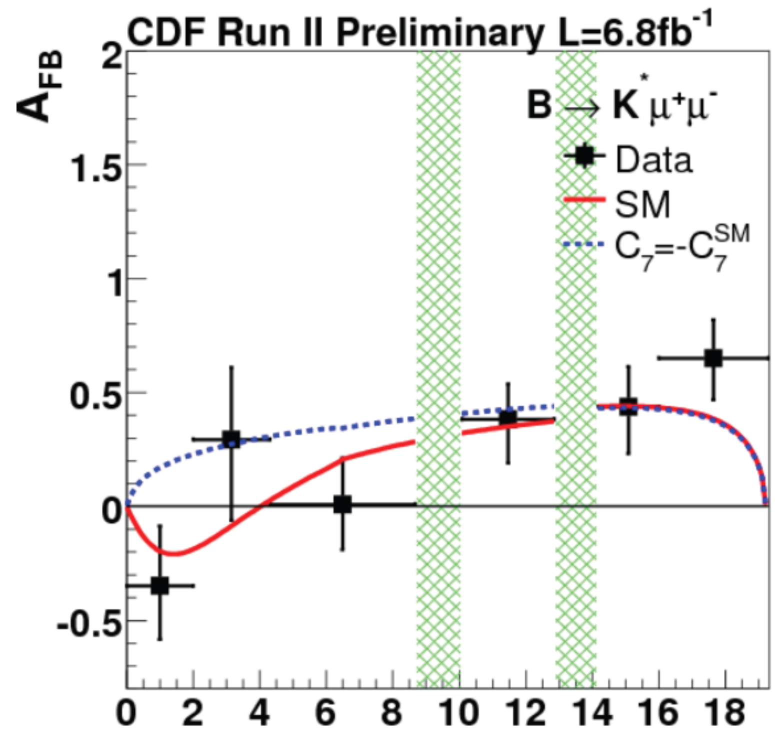


PRD 79 (2009) 031102

$B^0 \to K^* \mu^+ \mu^-$ at CDF: last week's update

CDF has updated its analysis to study of 164 decays. Nothing anomalous here...



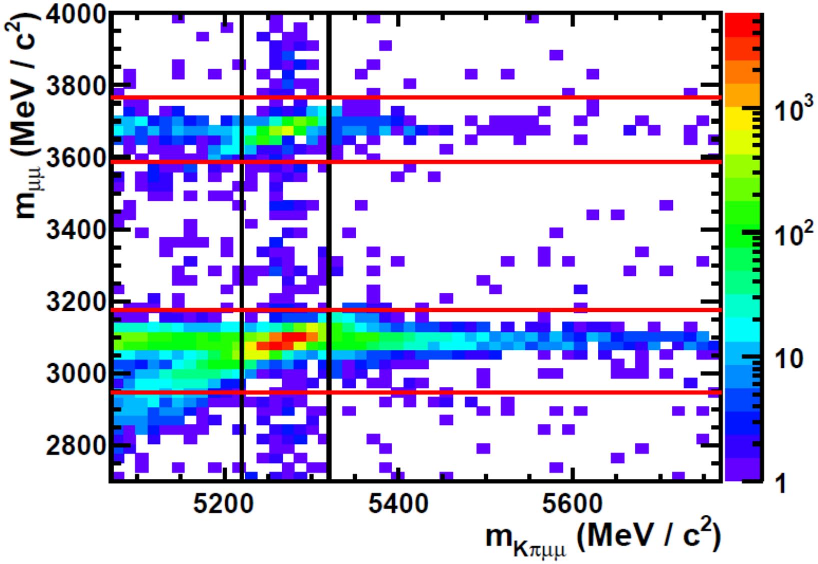


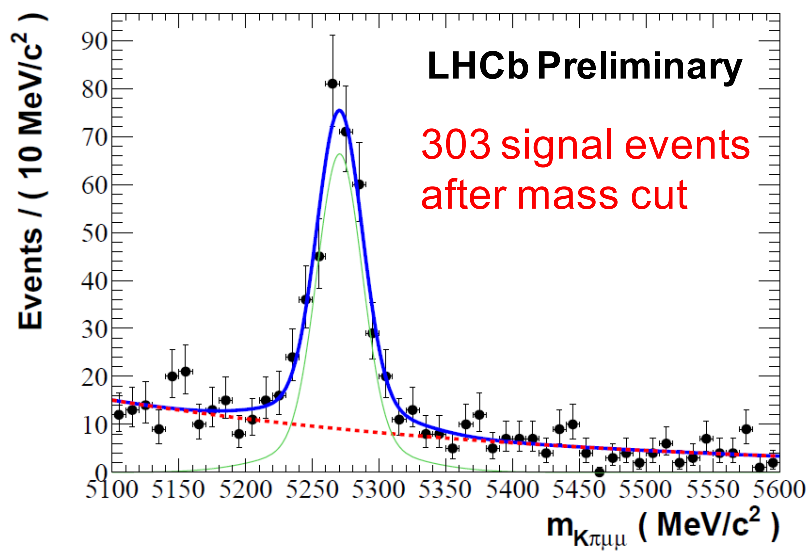
(CDF has also made first measurements of other observables: $A_T^{(2)}$ and A_{im})

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

Select events using Boosted Decision Tree from sample of 309 pb^{-1}

Veto decays in J/Ψ and Ψ(2S) resonance regions





Measure in 6 q^2 bins:

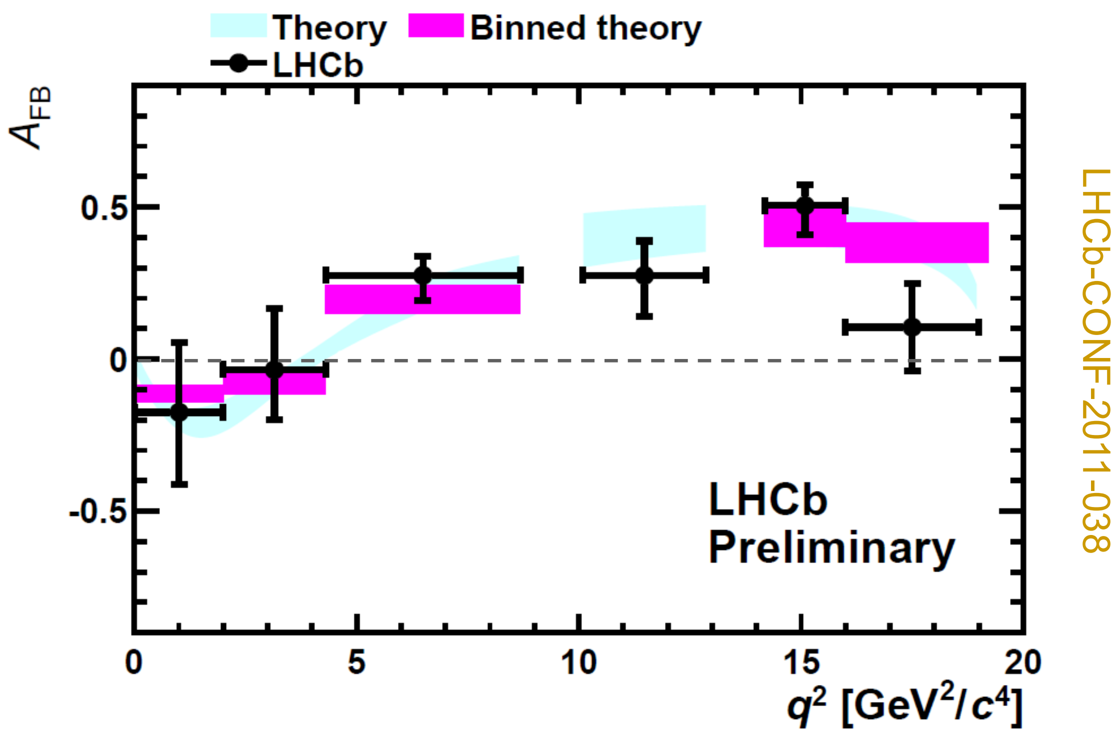
- differential branching fraction, $d\Gamma/dq^2$
- longitudinal polarisation, F_L
- A_{FB}

Simultaneous fit of 1D projections of helicity angles of kaon & lepton

Performance of fit validated on MC and $B^0 \rightarrow J/\Psi K^*$ decays

A_{FB} in $B^0 \rightarrow K^* \mu^+ \mu^-$ in LHCb with 309 pb^{-1}

Systematic uncertainties are small, and generally themselves statistics limited.



Data are consistent with predictions at present sensitivity. Next tasks:

- determine crossing point: sensitive to NP; cleanly predicted in SM
- study other observables, e.g. $A_T^{(2)}$, sensitive to RH currents

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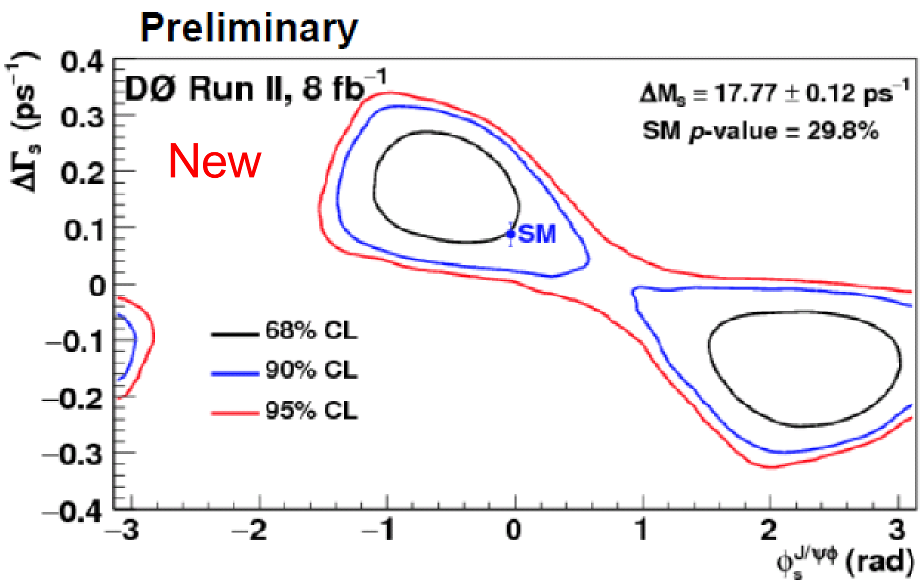
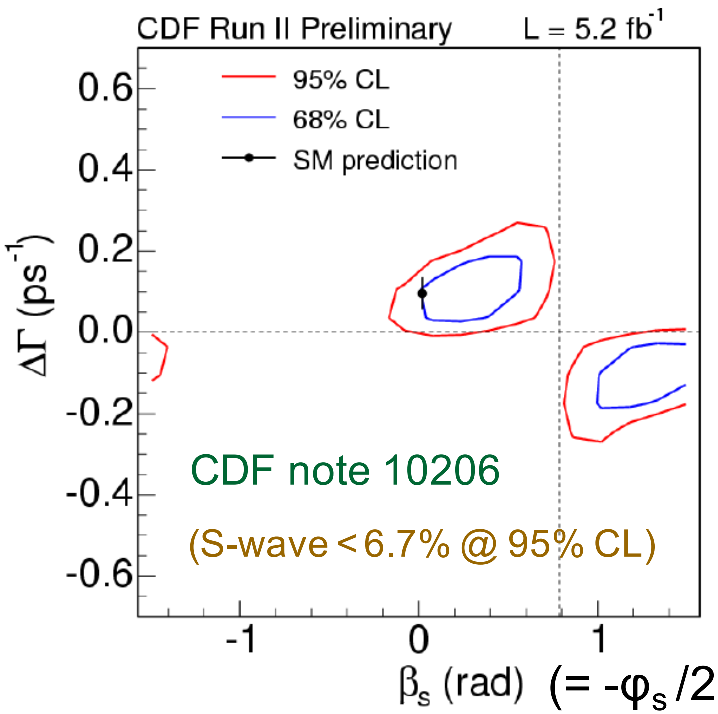
CPV in $B_s \to J/\psi\Phi$ at the Tevatron

CPV phase, φ_s, in B_s mixing-decay interference , e.g. measured in $B_s \to J/\Psi\Phi$, very small & precisely predicted in SM. Box diagram offers tempting entry point for NP!

Tevatron results are intriguing:



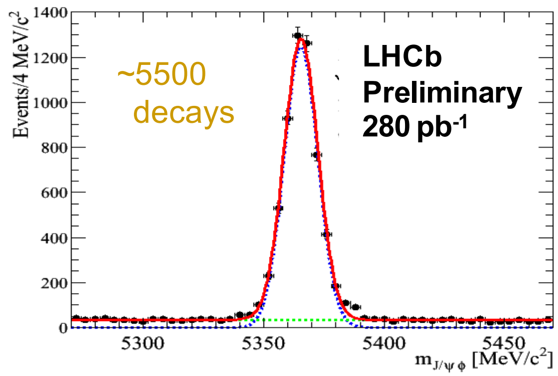


Results are consistent, & both are ~1σ away from SM. 2σ discrepancy observed in combination of the earlier analyses (2.8 fb^{-1}) has diminished (but no new comb. yet)

LHCb prospects for φ_s

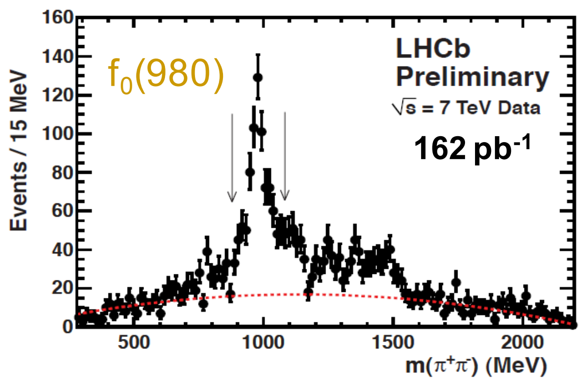
LHCb 37 pb^{-1} result: less precise than Tevatron, but shows the same trend. ~350 pb^{-1} currently under analysis – exciting possibilities await !

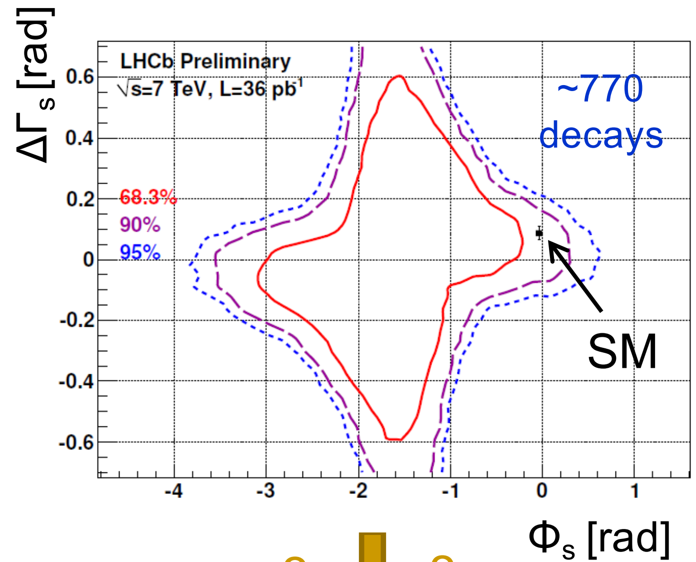
$B_s \rightarrow J/\Psi\varphi$



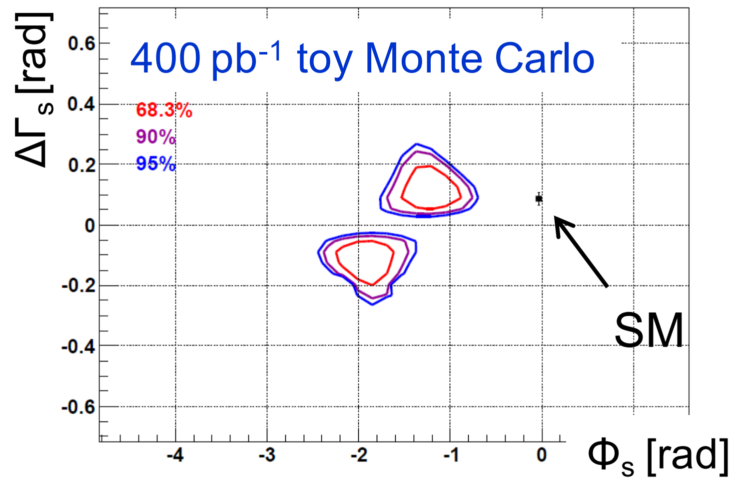
Sensitivity can be improved through inclusion of CP-eigenstate modes such as $B_s \rightarrow J/\Psi f_0(980)$

$\pi\pi$ spectrum in $B_s \rightarrow J/\Psi\pi\pi$





? ?



Assuming identical analysis performance + central values

New physics in a^s_{sl} (&/or a^d_{sl}) ?

If New Physics enhances CP-violation in $B^0_s \to J/\psi\Phi$, it will likely also dominate over the (negligible) SM CP-violation predicted in the like-sign lepton asymmetry.

D0 collaboration saw a striking effect in an analysis of last year [PRL 105 (2010) 081801, PRD 82 (2010) 032001] In a recent update [arXiv:1106.6308] the mystery has deepened...

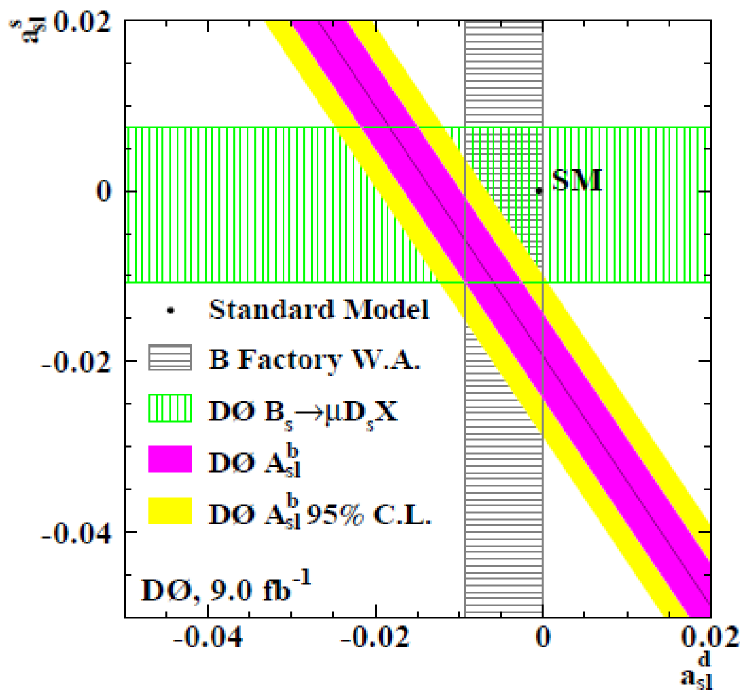
$$A^b_{sl} = (-0.787 \pm 0.172\ (\text{stat}) \pm 0.093\ (\text{syst}))\%$$

$$A^b_{sl}(\text{SM}) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$$

3.9σ tension with SM (was 3.0σ...). New result Includes analysis improvements and cross-checks with impact parameter.

At face value this looks like New Physics! ...

...but very challenging systematics ! D0 'trick' is to exploit correlation in background between single lepton & dilepton samples



Cross-check badly needed from CDF/LHCb..
However If effect is genuine it will likely soon manifest itself in $B^0_s \to J/\psi\Phi$ study.

Five potential game-changers – decent bets to lead us to NP in the LHC era

- CP violation searches in charm
- Precise CKM metrology
- Observables in $B^0 \rightarrow K^{*0}\mu^+\mu^-$
- CP violation in B_s mixing
- $BR(B_s \rightarrow \mu^+\mu^-)$

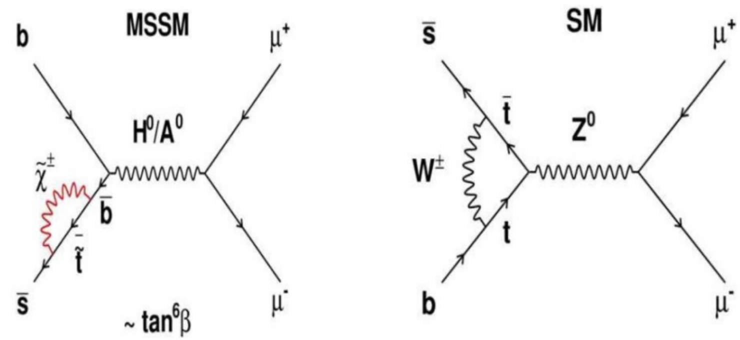
The golden mode: $B_s \to \mu\mu$

B physics rare decay par excellence:

$BR(B_s \to \mu\mu)_{SM} = (3.2 \pm 0.2) \times 10^{-9}$

[A.J.Buras, arXiv:1012.1447]

Precise prediction (which will improve) !

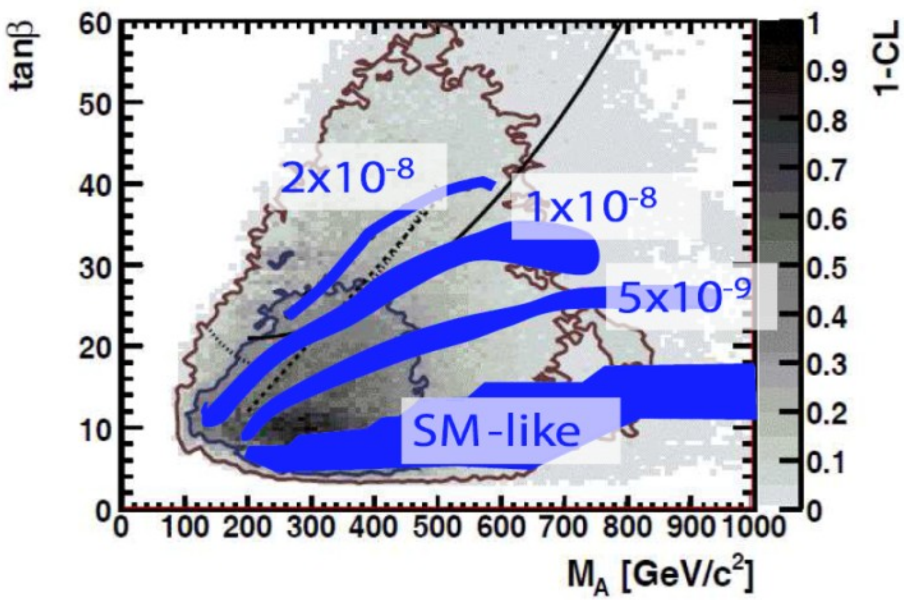


Very high sensitivity to NP, eg. MSSM:

$$Br^{MSSM}(Bq \to l^+ l^-) \propto \frac{m_b^2 m_l^2 \tan^6 \beta}{M_{A0}^4}$$

One example [O. Buchmuller et al, arXiv:0907.5568] : NUHM (= generalised version of CMSSM)

$BR(B_s \to \mu\mu)$ - highly discriminatory



BR UL 95% CL as of Spring 2011:

CDF (3.7 fb^{-1}): $< 4.3 \times 10^{-8}$

D0 (6.1 fb^{-1}): $< 5.1 \times 10^{-8}$

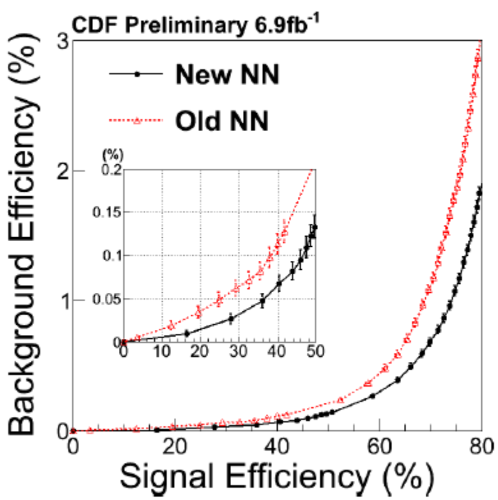
LHCb (37 pb^{-1}): $< 5.6 \times 10^{-8}$

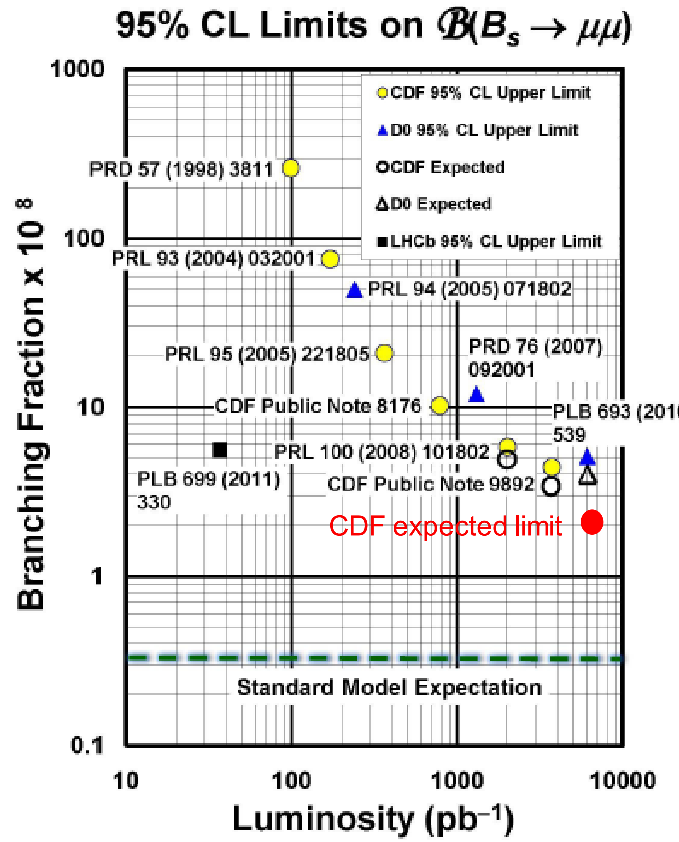
For a long time CDF promised update...

$B_s \rightarrow \mu\mu$ update at CDF – what we expected (Spring 2011)

Told to expect new CDF result with:

- ~7 fb^{-1}, i.e. 2x more data
- increased muon acceptance
- improved neural net





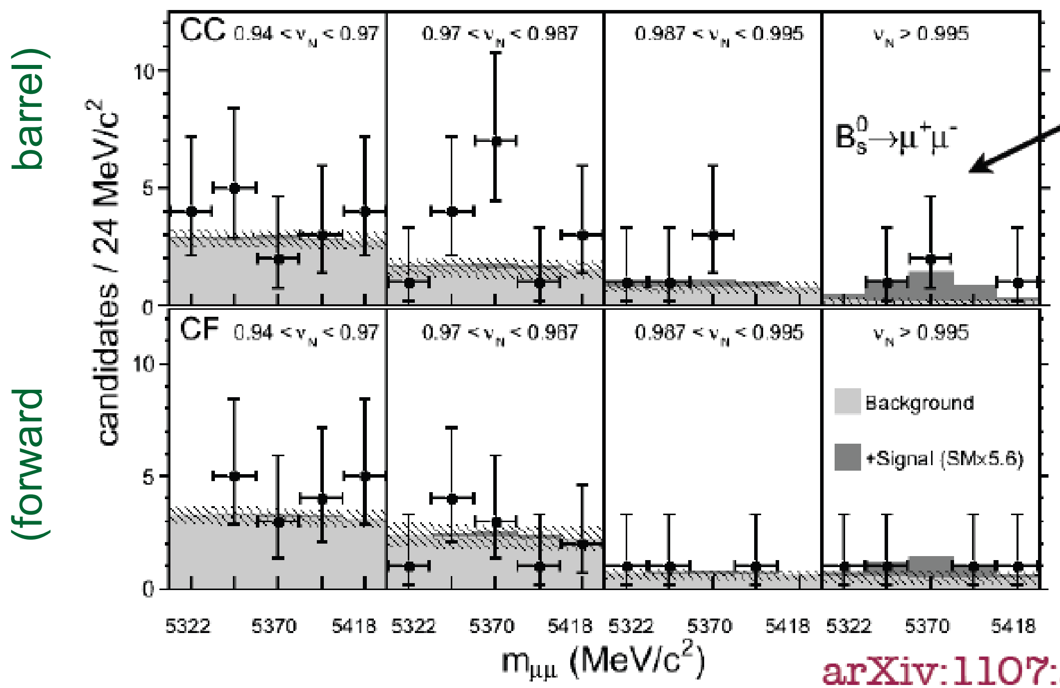
Analysis anticipated setting limit at 2 x 10^{-8} (in fact final sensitivity is 1.5 x 10^{-8})

$B_s \to \mu\mu$ update at CDF – what we got

An excess is seen in most sensitive bins of central analysis – 2.8σ effect overall

(4 bins of neural net output, from least to most sensitive)

Tonelli, EPS



arXiv:1107:2304

Most sensitive bin:
0.9±0.5 exp.
4 observed

$BR = 1.8^{+1.1}_{-0.9} \times 10^{-8}$

[Note also the excess in the 2nd CC bin (certainly not signal!). Studied at length & no systematic cause identified. Excluding bin changes result little.]

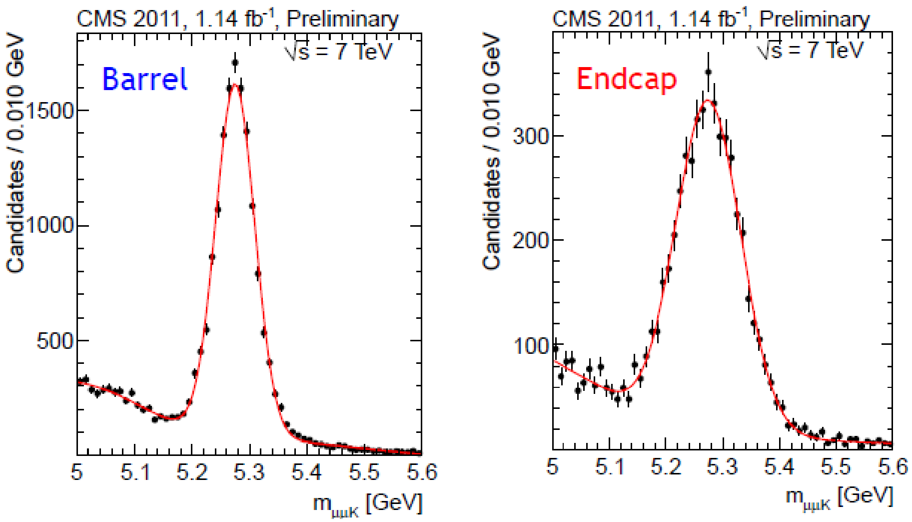
CMS search for $B_{s,d} \to \mu^+\mu^-$ with 1.14 fb^{-1}

Dimuon trigger at L1, with track information added at HLT. Then, offline:

- Cut based analysis, optimised on MC and data sidebands prior to unblinding
- Analysis divided into two geometrical regions

'Barrel'	'Endcap'
Both μ $\|\eta\|<1.4$	At least one μ $\|\eta\|>1.4$

- Selection variables: μ id, 'pointing angle', flight length significance, fit quality, isolation criteria, p_T(μ-max)> 4.5 GeV, p_T(μ-min)> 4.0 GeV, p_T(B)>4 GeV...
- Normalisation & calibration modes:
  - $B^+ \to J/\Psi K^+$ →
  - $B_s \to J/\Psi\varphi$ used to check MC description of B_s fragmentation dependent quantities



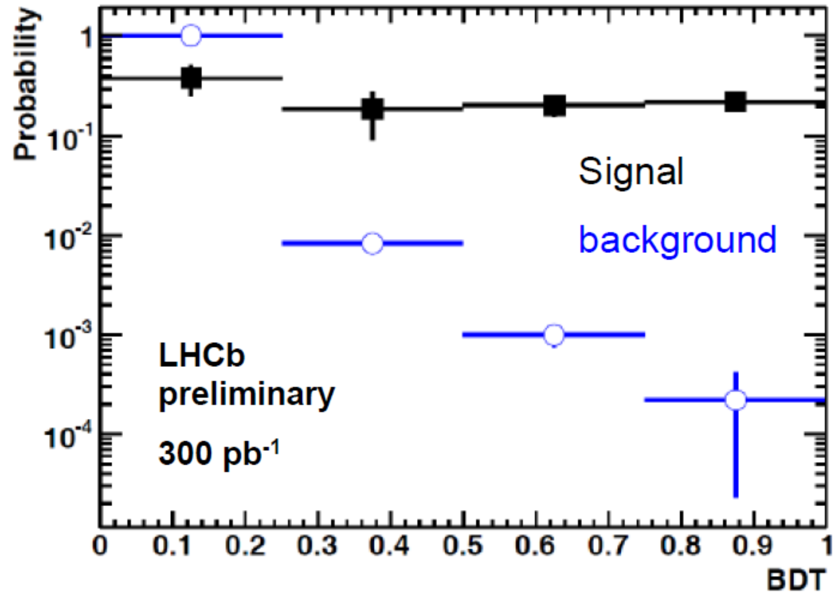
2011 $B_s \to \mu^+\mu^-$ search at LHCb with 300 pb^{-1}

Strategy very similar to 2010 analysis [PLB 699 (2011) 330] After di-μ preselection:

- Build Boosted Decision Tree out of 9 kinematical and topological variables

  Train BDT on MC, but calibrate on data:

  - signal response: use B→hh decays triggered on 'other B' (avoid biases!)
  - background response: use sidebands



- Invariant mass of expected signal parameterised as crystal ball, with scale & resolution (~25 MeV) calibrated from data (dimuon resonances & B→hh)
- Now look in a 6 x 4 grid of $\mu^+\mu^-$ invariant mass vs BDT output
- To obtain relative BR for signal use three normalisation channels: $B^+ \to J/\Psi K^+$, $B_s \to J/\Psi\varphi$ and $B^0 \to K\pi$ – all give consistent results

Does LHC see a peak ?

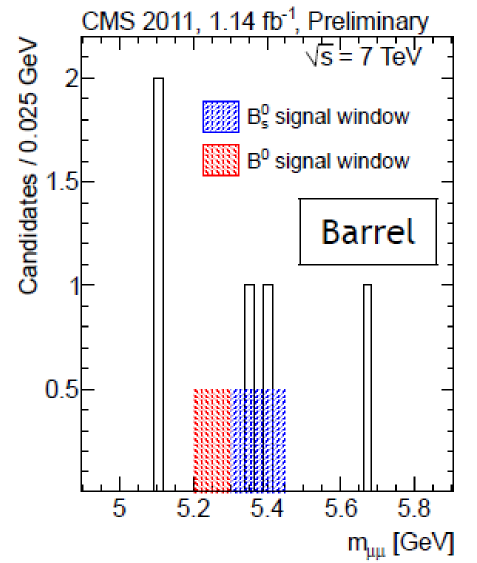
Not exactly…

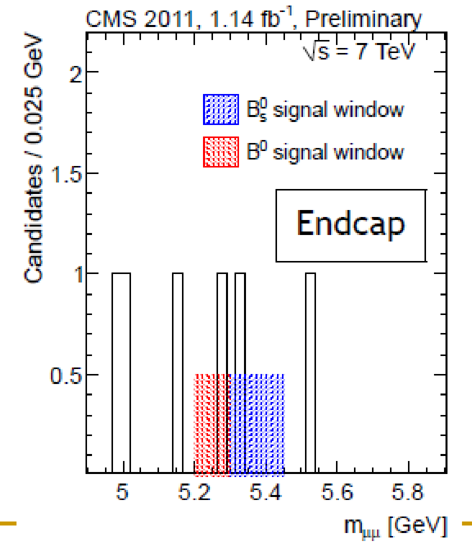
CMS results for $B_s \to \mu^+\mu^-$ search with 1.14 fb^{-1}

No significant excess seen

this is $B \to hh$

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

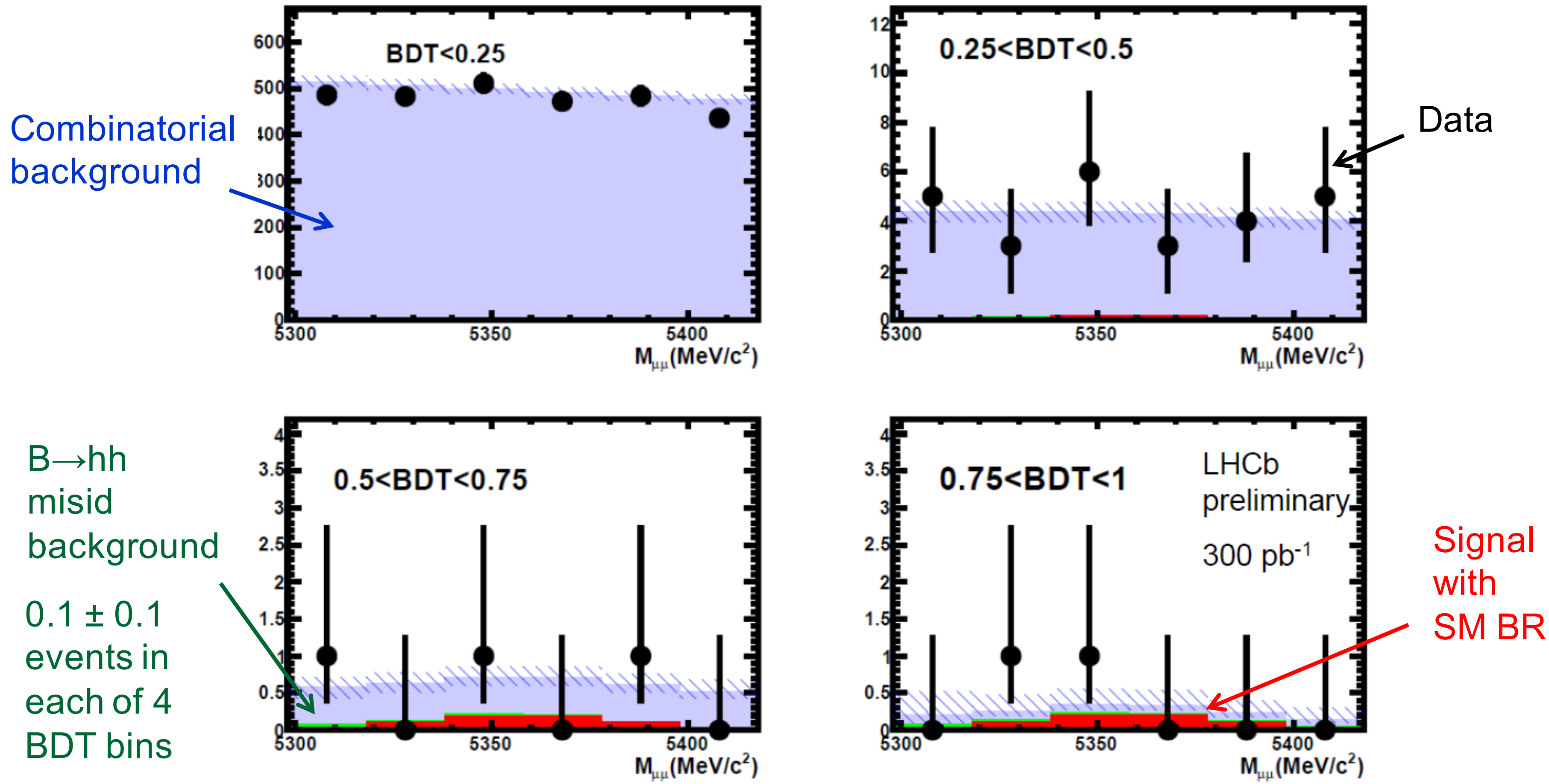




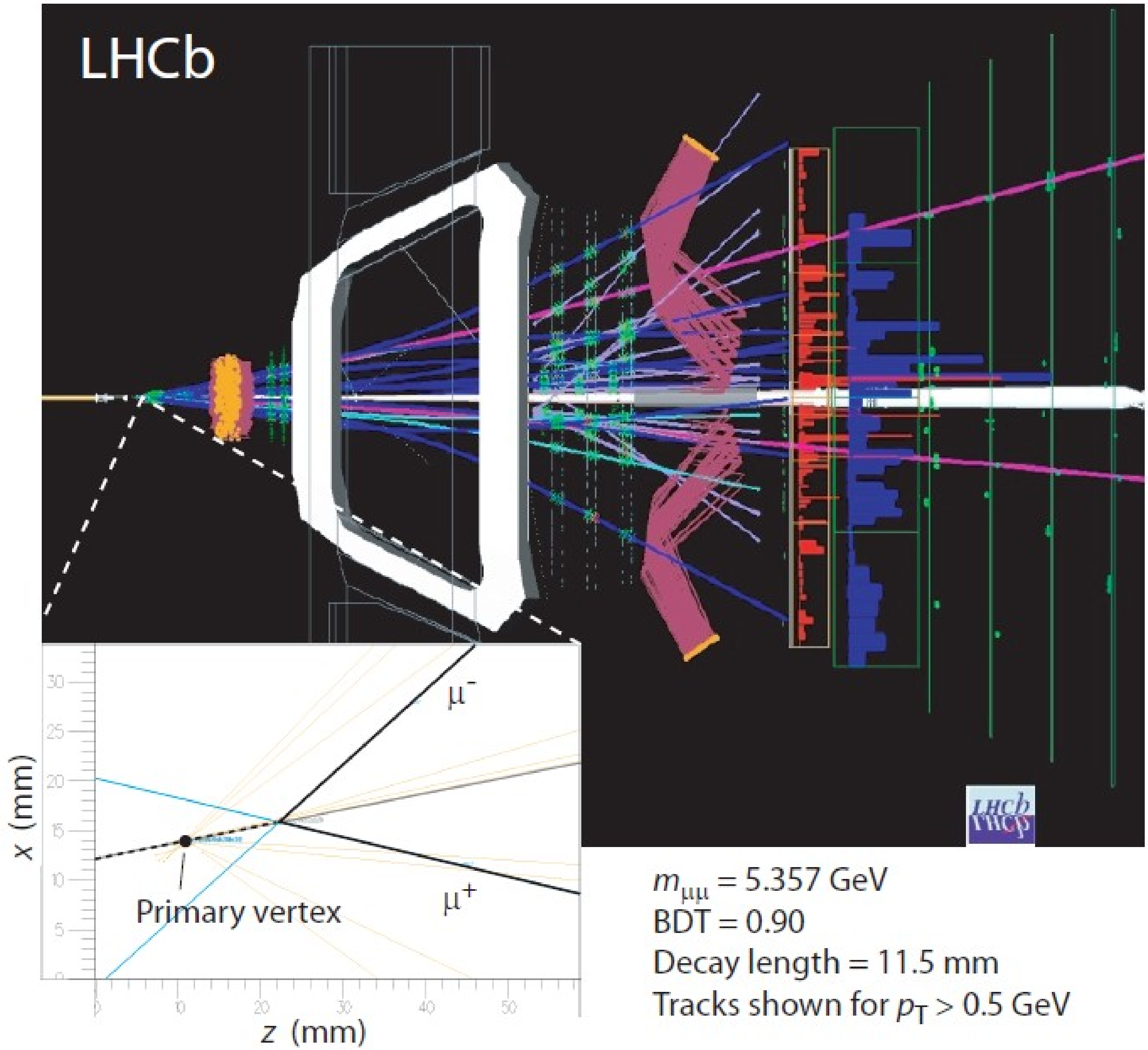
Calculate upper limits using frequentist CLs approach and taking $f_s/f_u = 0.282 \pm 0.037$ [PDG]

Expected limit at 95% C.L. (including presence of SM signal)	1.8×10^{-8}
Observed limit at 95% (90%) C.L.	$1.9\ (1.6) \times 10^{-8}$
p-value of bckgd only hypothesis	11%

LHCb $B_s \to \mu^+\mu^-$ results in B_s mass region with 300 pb^{-1}

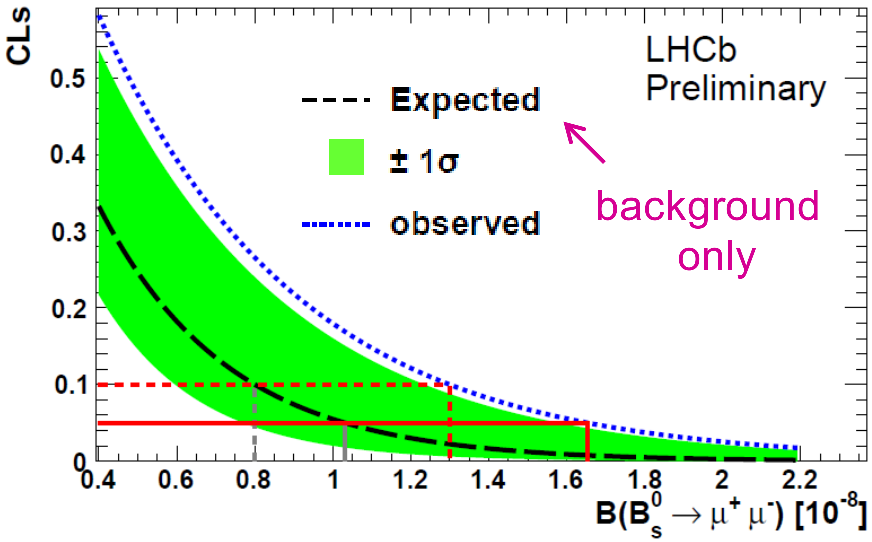


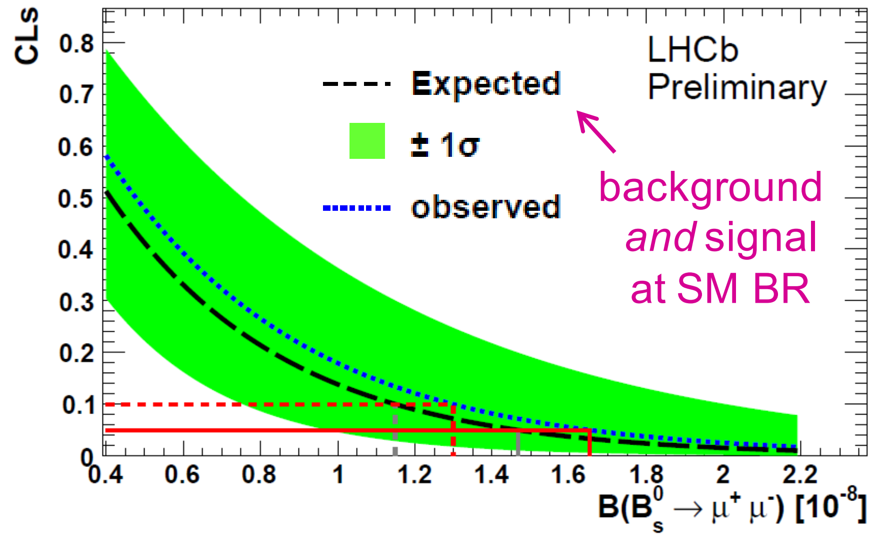
	BDT<0.25	0.25<BDT<0.5	0.5<BDT<0.75	0.75<BDT
Exp.combinatorial	2968 ± 69	25 ± 2.5	2.99 ± 0.89	0.66 ± 0.40
Exp. SM signal	1.26 ± 0.13	0.61 ± 0.06	0.67 ± 0.07	0.72 ± 0.07
Observed	2872	26	3	2


LHCb
μ⁻
μ⁺
Primary vertex
x (mm)
z (mm)
$m_{\mu\mu}$ = 5.357 GeV
BDT = 0.90
Decay length = 11.5 mm
Tracks shown for p_T > 0.5 GeV

LHCb preliminary limit (stat + syst) on $BR(B_s \to \mu^+\mu^-)$

Compute limits using frequentist CLs method and LHCb combined result for f_s/f_d



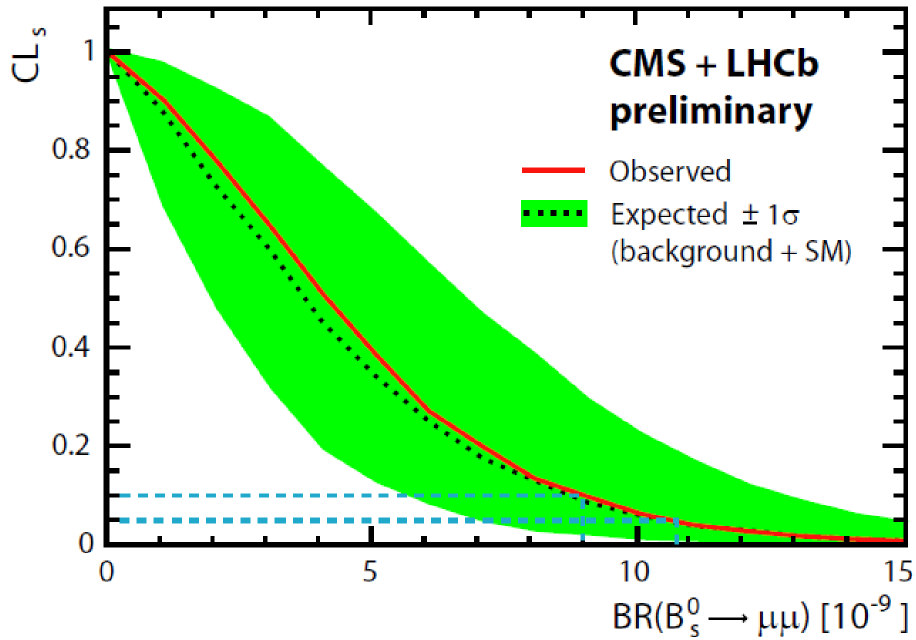


LHCb-CONF-2011-037

	Background only	Background + SM signal
Expected limit at 95% (90%) C.L.	$1.0\ (0.8) \times 10^{-8}$	$1.5\ (1.2) \times 10^{-8}$
Observed limit at 95% (90%) C.L.	$1.6\ (1.3) \times 10^{-8}$	
p-value of bckgd only hypothesis	14%	
Observed limit at 95% (90%) C.L. when combined with 2010 result	$1.5\ (1.2) \times 10^{-8}$	

Preliminary BR($B_s \rightarrow \mu^+\mu^-$) combination

A preliminary CMS-LHCb combination on BR($B_s \rightarrow \mu^+\mu^-$) has been performed, again using the CLs approach, & taking LHCb value of f_s/f_d as common input



Observed limit at 95% (90%): 1.1 (0.9) x 10^{-8}

This is 3.4 times the expected SM value

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

Clear 'tension' with CDF result - await next LHC update!

Summary and outlook

Even though we are, for sure, at the start of the long-awaited high p_T renaissance, we should not forget that flavour physics still has a role to play

Indeed, some of the results from the Tevatron and B-factories provide tantalising hints that New Physics discovery is not far distant

The studies highlighted here are just examples, to my mind the most promising, but there are many others (e.g. gluonic and radiative Penguins)

The LHC is a frontier machine not only in terms of energy, but also in heavy flavour production. We may be pushing on an open door...

...& if it opens, there will be plenty inside for the future experiments to explore

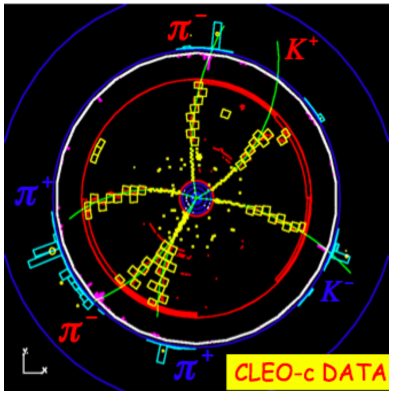
Backups

Threshold charm facilities

$e^+e^- \to \Psi(3770) \to D\bar{D}$ has several attractive features:

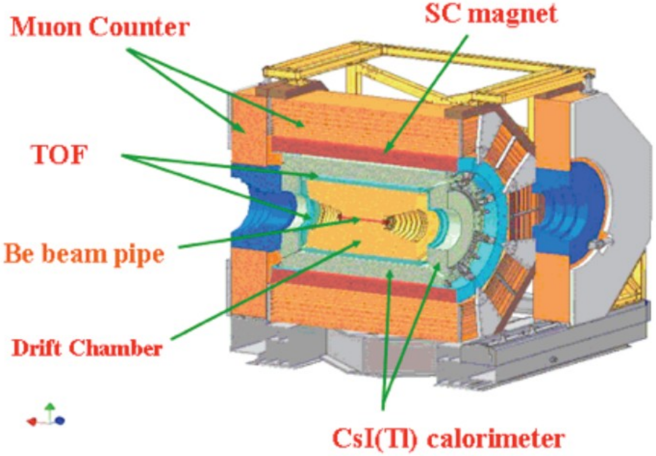
- quantum correlated $D\bar{D}$ system → strong phase measurements and CP violation searches
- no fragmentation particles – very clean environment, plus opportunity to infer unseen particles (e.g. ν and K_L) through kinematics of rest of event

CLEO-c collected 818 pb^{-1} at $\Psi(3770)$



$\psi(3770) \to D^+(K^-\pi^+\pi^+)D^-(K^+\pi^-\pi^-)$

BES-III at BEPCII



Already collected 2.5 fb^{-1} at $\Psi(3770)$

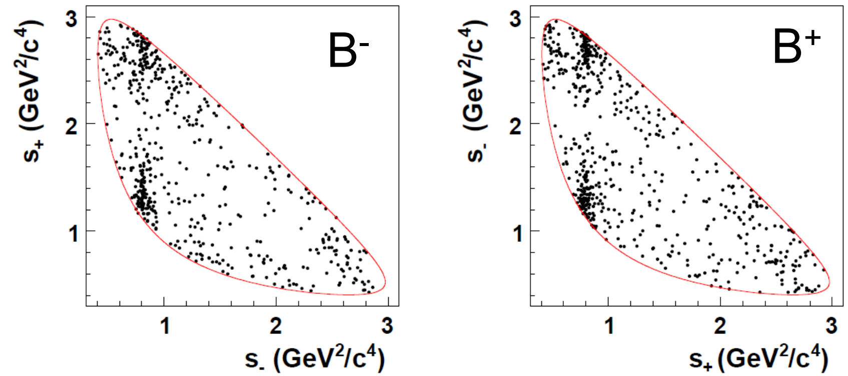
Intention to collect very big $\Psi(3770)$ sample features in plans of Super-B

$B^{\pm} \rightarrow D(K^0_S\pi\pi)K^{\pm}$:a synergy of facilities

Most statistically sensitive method at B-factories is to use $K_S\pi\pi$ as D-final state.

CPV leads to differences in Dalitz plot distributions

Extraction of γ requires we understand variation of strong phase difference between D^0 and $\bar{D}^0$ across Dalitz space

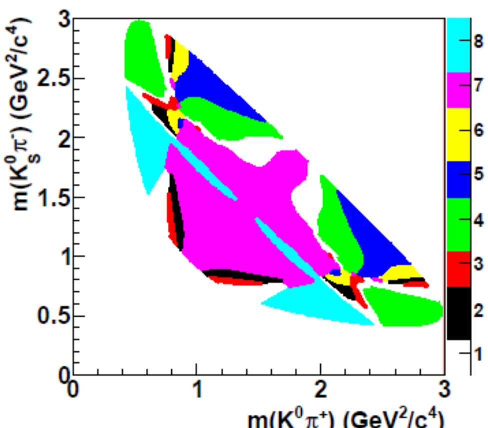


BABAR, PRL 105 (2010) 121801

Either take from amplitude model → incur model error – undesirable

Or use measurements of these phases performed in bins coming from Ψ(3770) decays at CLEO-c [PRD 82 (2010) 112006] Nice demonstration of synergy of facilities!

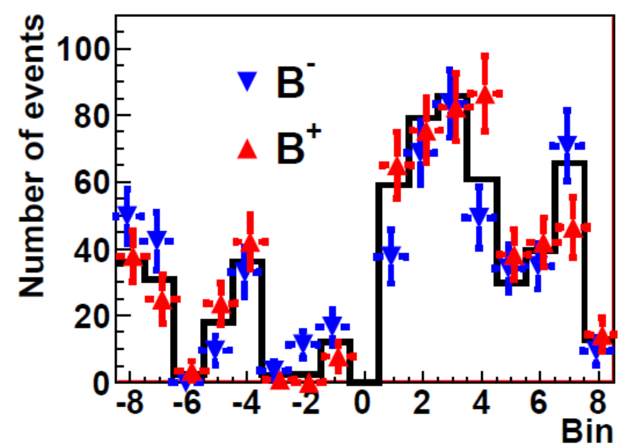
Odd looking bins Chosen to optimise stat precision



Recently applied by Belle

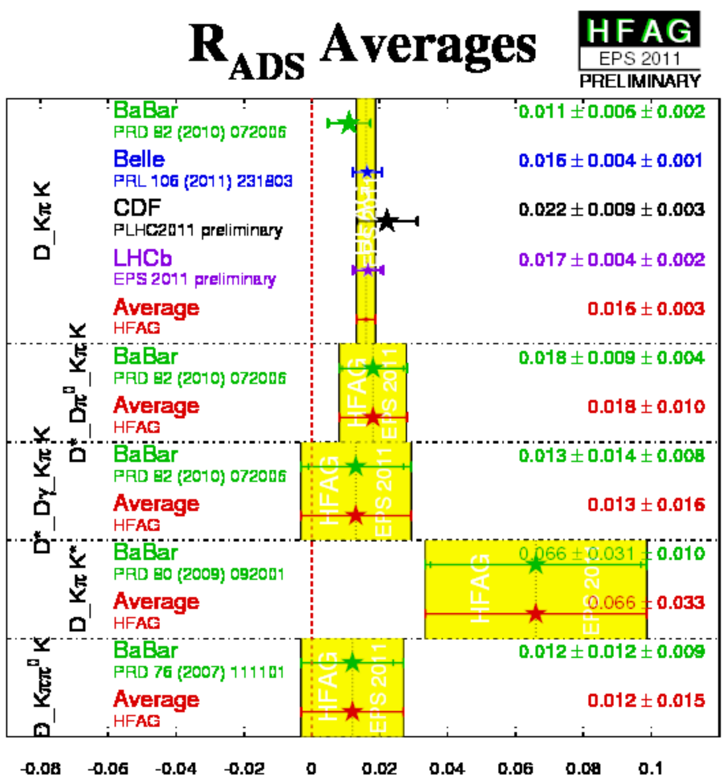
Precision ~ 16°

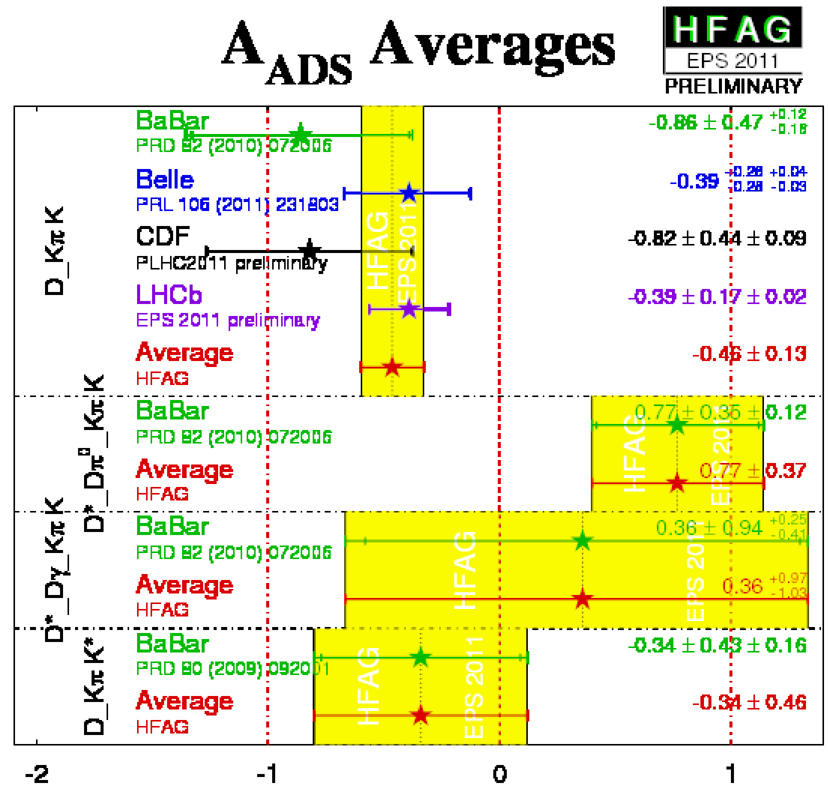
No model error !



Belle, arXiv:1104.4046

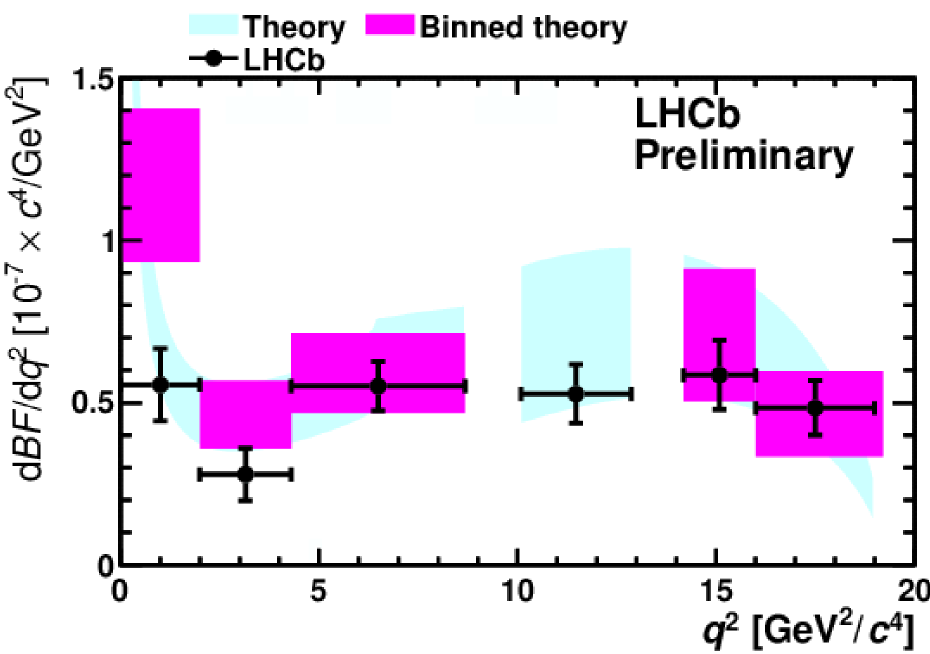
LHCb ADS analysis results in context

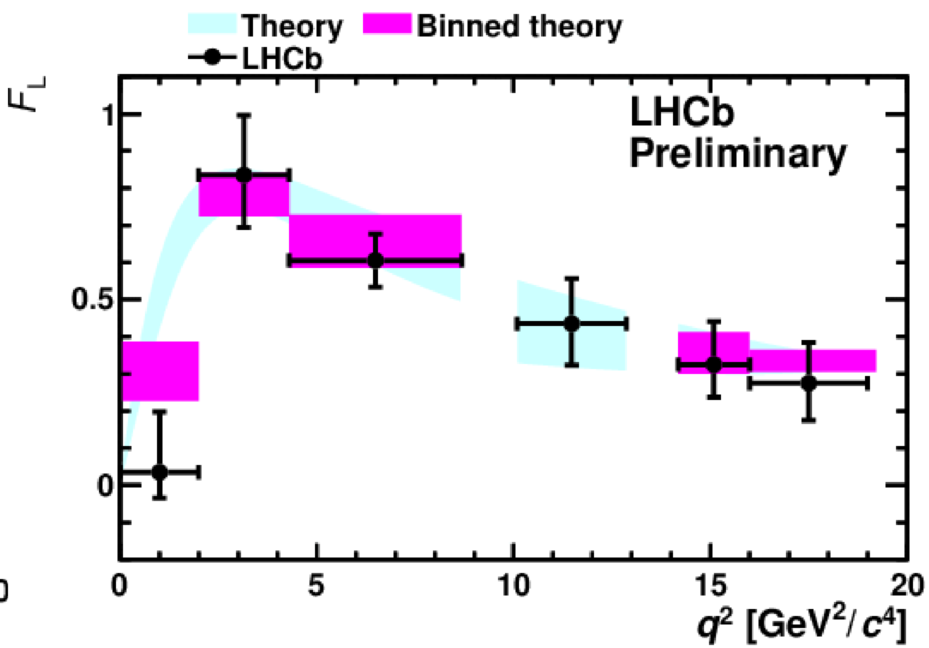




$d\Gamma/dq^2$ and F_L in $B^0 \to K^*\mu^+\mu^-$

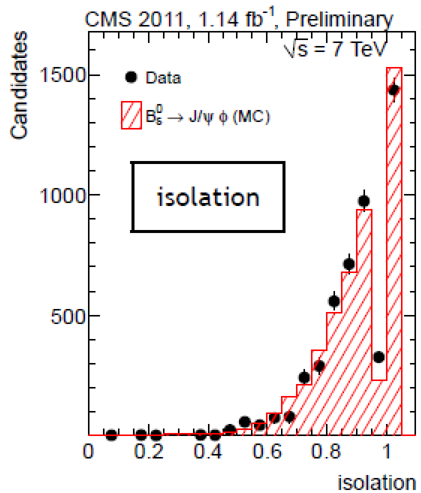
These observables have good consistency with the SM expectations !

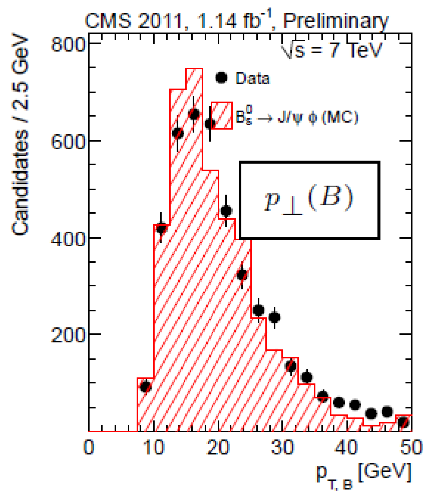


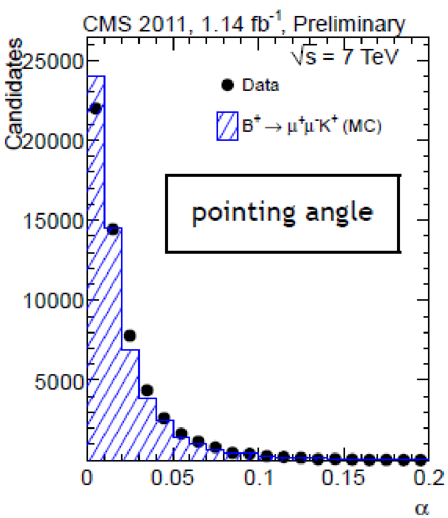


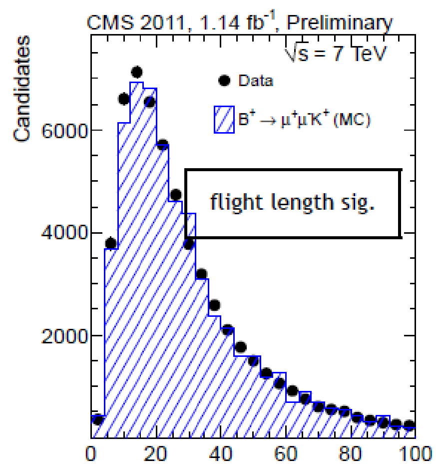
CMS $B_s \to \mu^+\mu^-$ analysis performance

Good agreement found between data and MC for all selection variables.

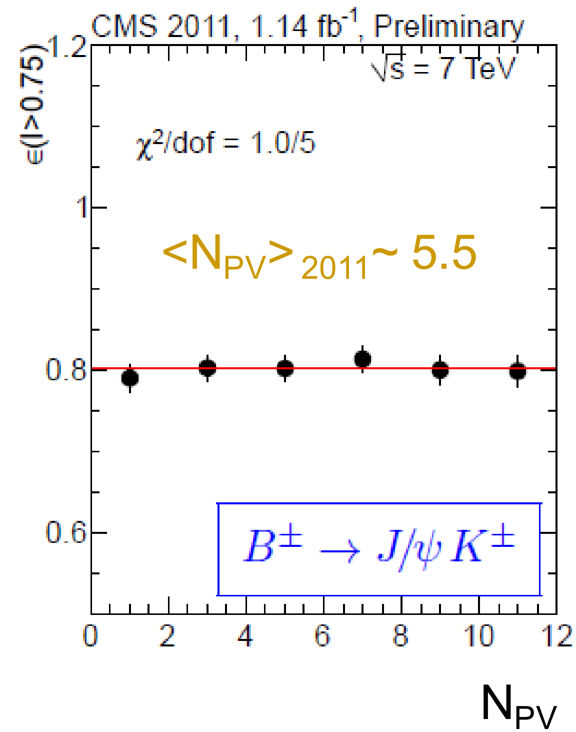








Efficiency of variables potentially sensitive to pileup (e.g. isolation, flight length) checked on data

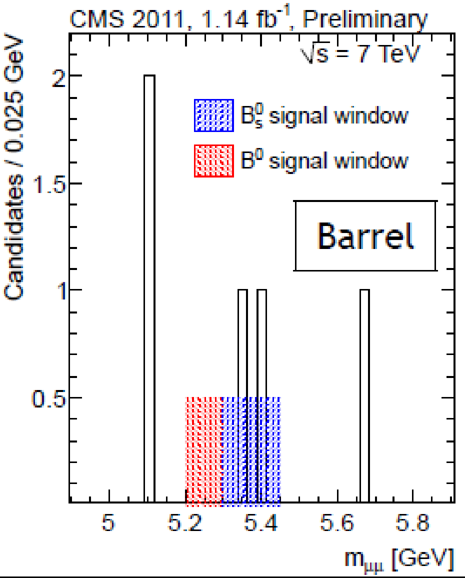


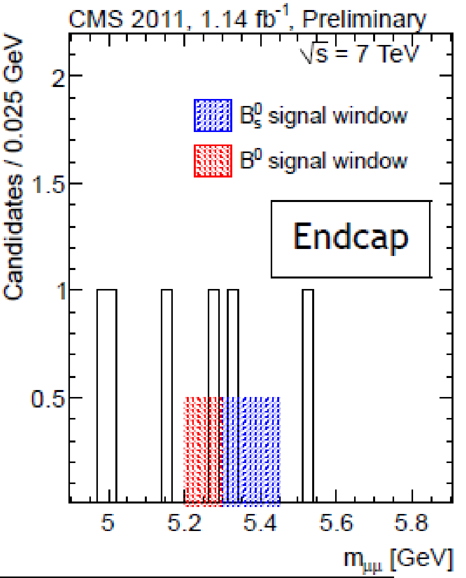
Excellent stability observed – good news for higher luminosity!

CMS $B_{d,s} \to \mu\mu$ results

	Barrel		Endcap	
	$B^0 \to \mu^+\mu^-$	$B^0_s \to \mu^+\mu^-$	$B^0 \to \mu^+\mu^-$	$B^0_s \to \mu^+\mu^-$
Acceptance	$(24.62 \pm 0.99) \times 10^{-2}$	$(24.72 \pm 0.99) \times 10^{-2}$	$(22.61 \pm 0.91) \times 10^{-2}$	$(23.14 \pm 0.93) \times 10^{-2}$
$\varepsilon_{\rm analysis}$	$(2.23 \pm 0.19) \times 10^{-2}$	$(2.22 \pm 0.19) \times 10^{-2}$	$(1.16 \pm 0.10) \times 10^{-2}$	$(1.24 \pm 0.11) \times 10^{-2}$
$\varepsilon_{\rm tot}$	$(0.36 \pm 0.04) \times 10^{-2}$	$(0.36 \pm 0.04) \times 10^{-2}$	$(0.21 \pm 0.02) \times 10^{-2}$	$(0.21 \pm 0.02) \times 10^{-2}$
$N^{\rm exp}_{\rm signal}$	0.065 ± 0.011	0.80 ± 0.16	0.025 ± 0.004	0.36 ± 0.07
$N^{\rm exp}_{\rm bg}$	0.40 ± 0.23	0.60 ± 0.35	0.53 ± 0.27	0.80 ± 0.40
$N^{\rm exp}_{\rm peak}$	0.25 ± 0.06	0.07 ± 0.02	0.16 ± 0.04	0.04 ± 0.01
$N_{\rm obs}$	0	2	1	1

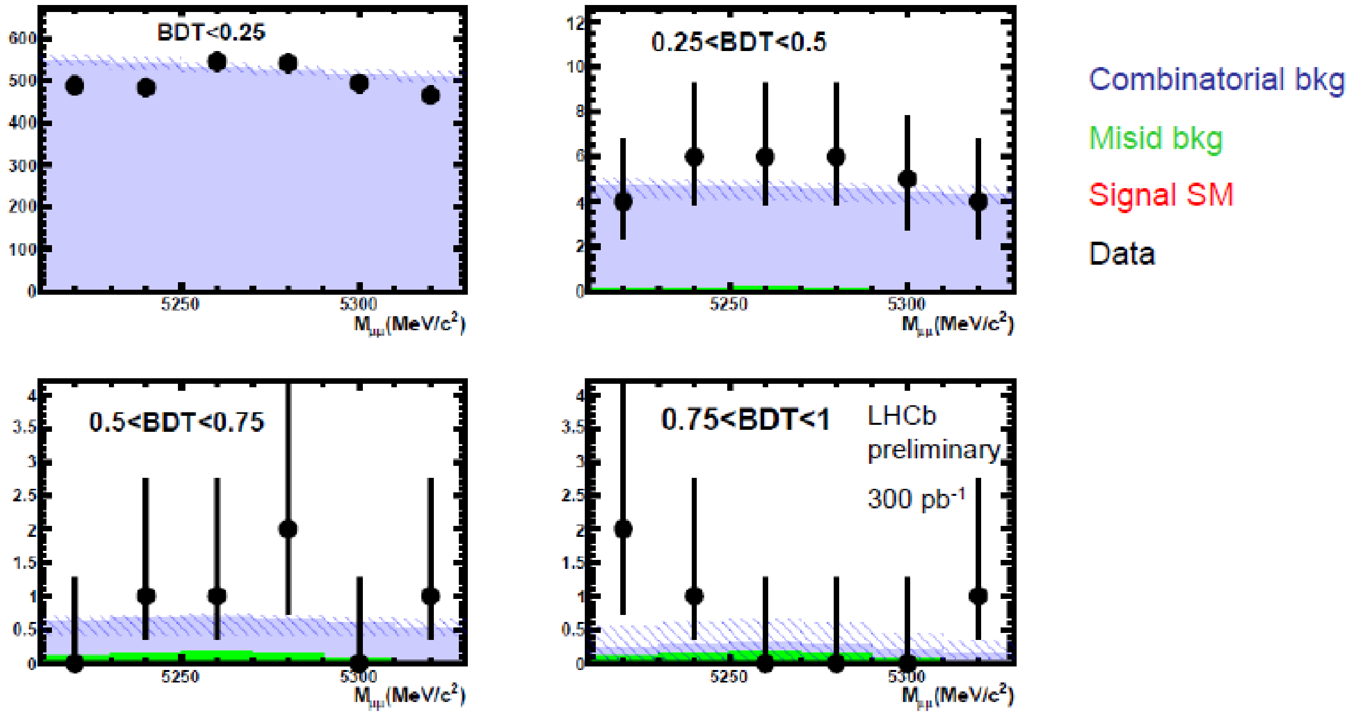
- As expected
  - ▷ based on sidebands
  - ▷ studied with $I < 0.7$
  - → no evidence for anomalous signal
- Expected UL (median)
  $B^0_s \to \mu^+\mu^- : 1.8 \times 10^{-9}$





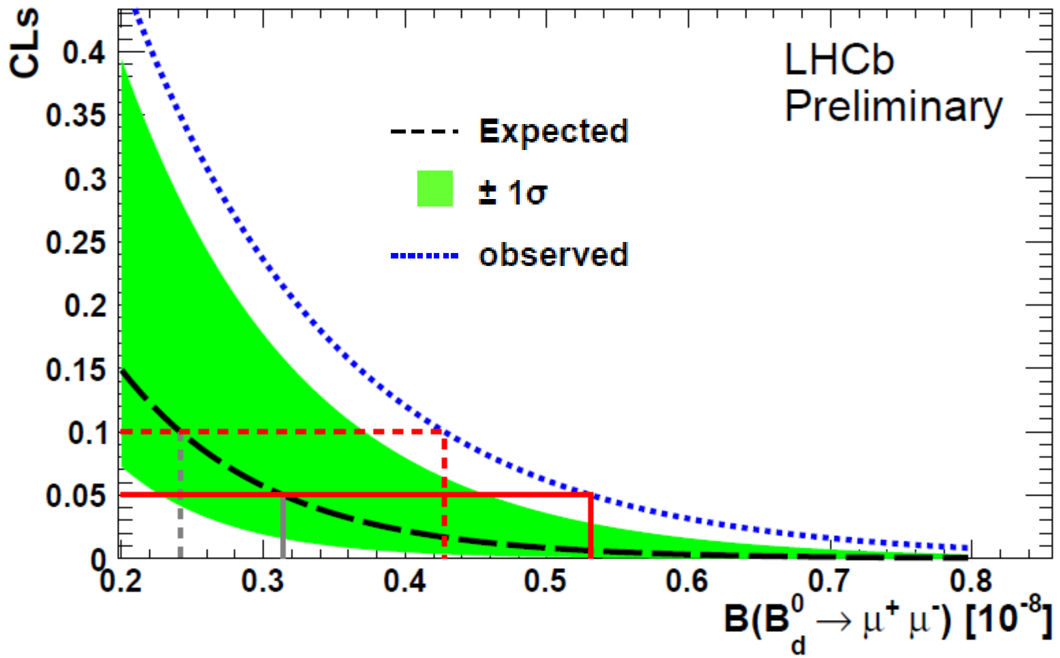
Urs Langenegger — Search for $B^0_{s(d)} \to \mu^+\mu^-$ with the CMS experiment (2011/07/22) — 13

LHCb $B^0_d \to \mu\mu$ results (2011, 300 pb^{-1})



	BDT<0.25	0.25<BDT<0.5	0.5<BDT<0.75	0.75<BDT
Exp.combinatorial	3175 ± 72	26.6 ± 2.5	3.1 ± 0.8	0.7 ± 0.4
Exp. MisID	0.6± 0.1	0.6± 0.1	0.6± 0.1	0.6± 0.1
Observed	3025	31	5	4

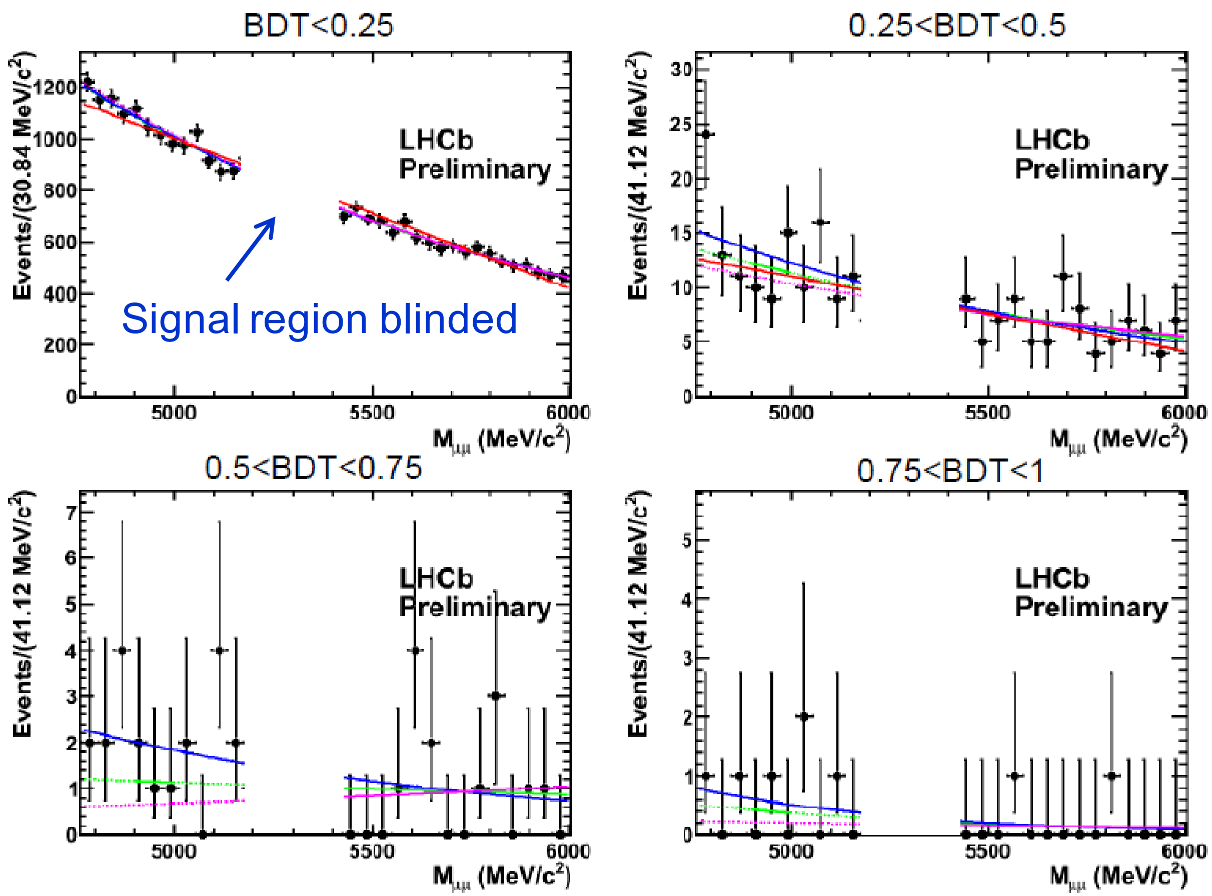
LHCb $B^0_d \to \mu\mu$ results (2011, 300 pb^{-1})



	Bkg only 90(95) %CL	CLb
Expected stat+syst	2.4 (3.1) $\times 10^{-9}$	
Observed stat+syst	4.2 (5.2) $\times 10^{-9}$	0.90

Background description vs $M_{\mu\mu}$ in LHCb

Different parameterisations performed for background shape → systematics



Limits on BR($B_d \rightarrow \mu^+ \mu^-$)

No significant excess seen in $B_d \rightarrow \mu^+ \mu^-$ search

95% (90%) C.L. limits

CMS observed	4.6 (3.7) x 10^{-9}
CMS expected	4.8 x 10^{-9}
LHCb expected	3.1 (2.4) x 10^{-9}
LHCb observed	5.2 (4.2) x 10^{-9}

(NB here LHCb results are 2011 data only)

$B_s \rightarrow \mu^+\mu^-$ – extrapolations performed from 2010 LHCb analysis