LNF 2012 Summer Institute

26th June 2012

LHCb highlights

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on behalf of the LHCb Collaboration

Introduction and summary

LHCb is the **dedicated flavour physics** experiment at the LHC

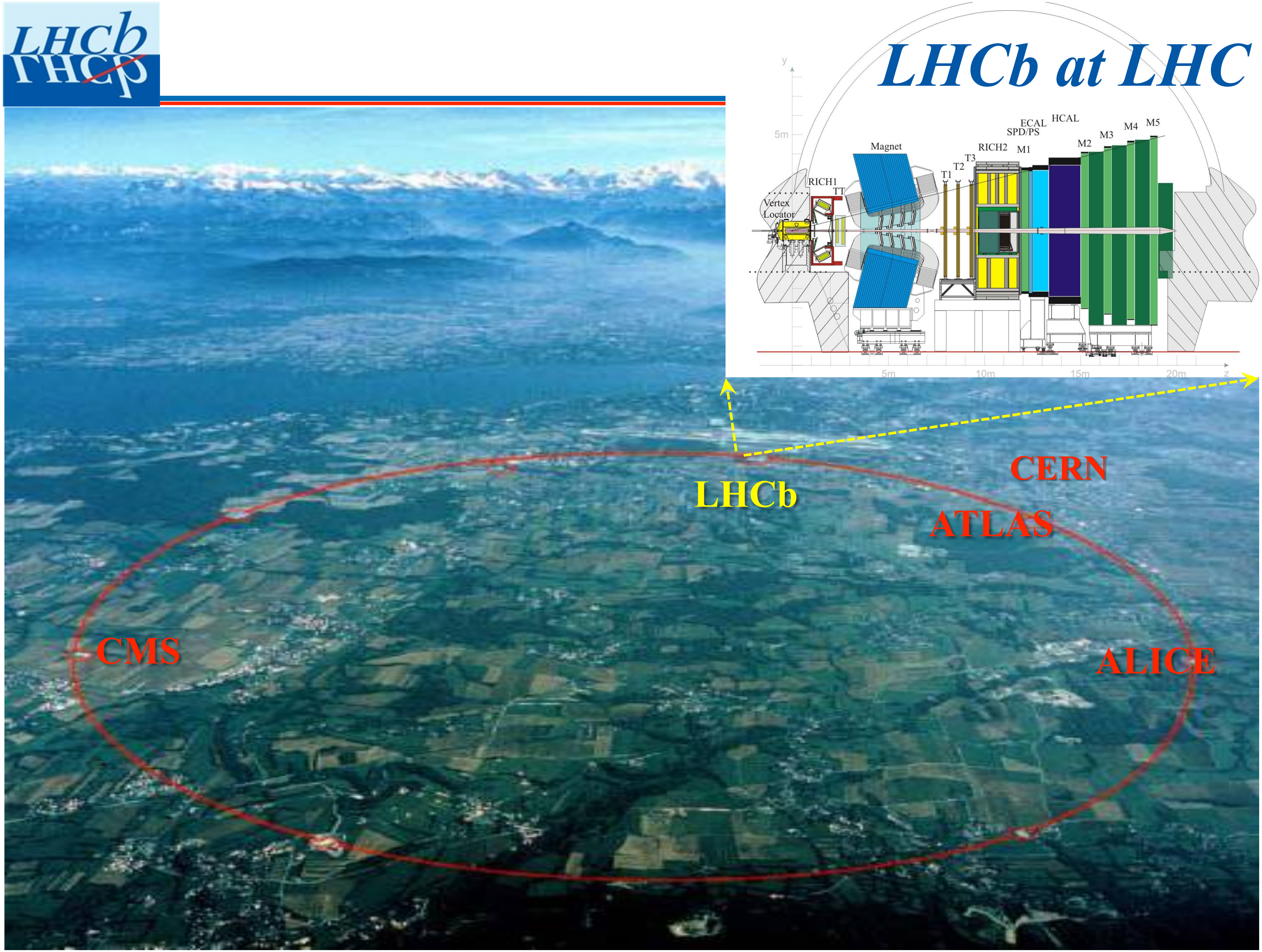
ATLAS and CMS search for the direct production of new states; LHCb is designed to see their indirect effect on **charm** and **beauty** decays via virtual production in loop diagrams.

Wide physics program: **Quarkonia**, heavy flavour production and spectroscopy: b-hadron masses, X(3872), $pp \to p+X+p$,… **CPV**: $B \to Dh$ (γ CKM angle), time dependent B_S studies (ϕ_S), charmless B decays, first evidence in charm,... **Rare B and D decays**: $B_{S,d} \to \mu\mu$, $B \to h\mu\mu$, $D \to \mu\mu$,… **Beyond heavy flavour**: W and Z, inclusive jet and dijet, K_S, Λ, ϕ production

57 physics publications to date, more in pipeline; >80 preliminary results submitted as Conference Papers [LHCb-CONF-xxx, www.cern.ch/lhcb/].

- **Detector and run conditions**
- **Physics results for rare decays and CP violation. A personal (+Luca) selection.**
- **Future plans**

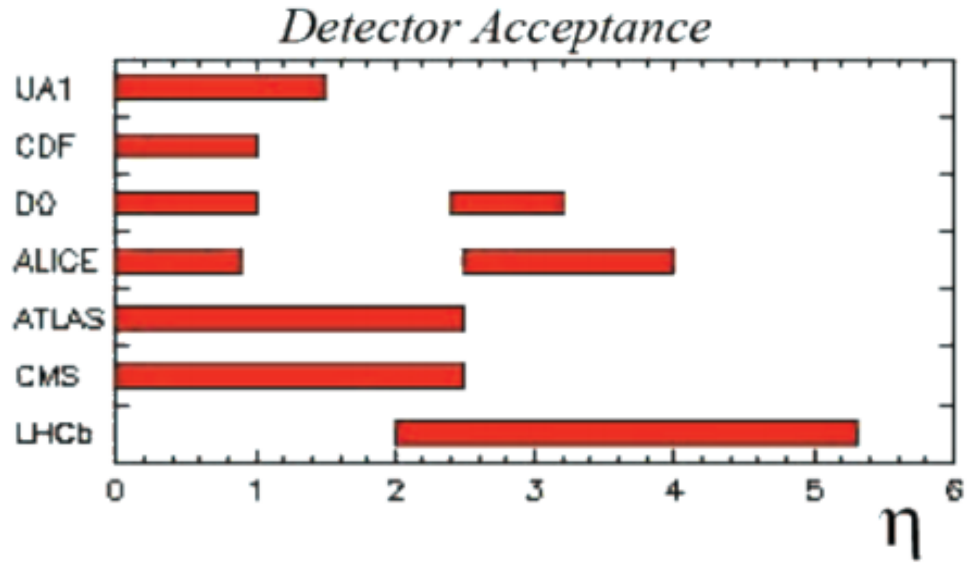
LHCb at LHC



y
5m
Vertex
Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
5m
10m
15m
20m
z
LHCb
CERN
ATLAS
CMS
ALICE

LHCb: acceptance and cross sections

A general purpose, high resolution spectrometer in the forward direction; covers the forward region at the LHC in a unique rapidity range: 2<η<5.



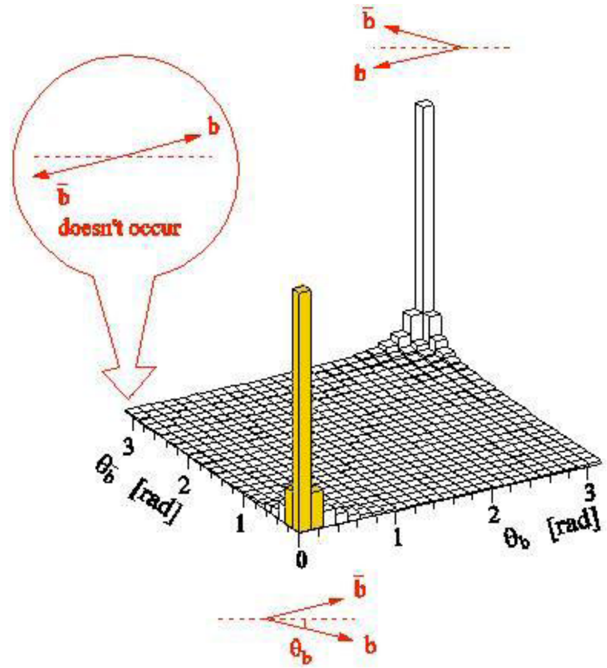
LHCb exploits the strongly forward peaked heavy quark production: covering only 4% of solid angle the acceptance for b-quark production cross section is ~40%.

Large cross sections:

σ(bb) = ~300 μb; ~10^{11} b decays on tape (2011)

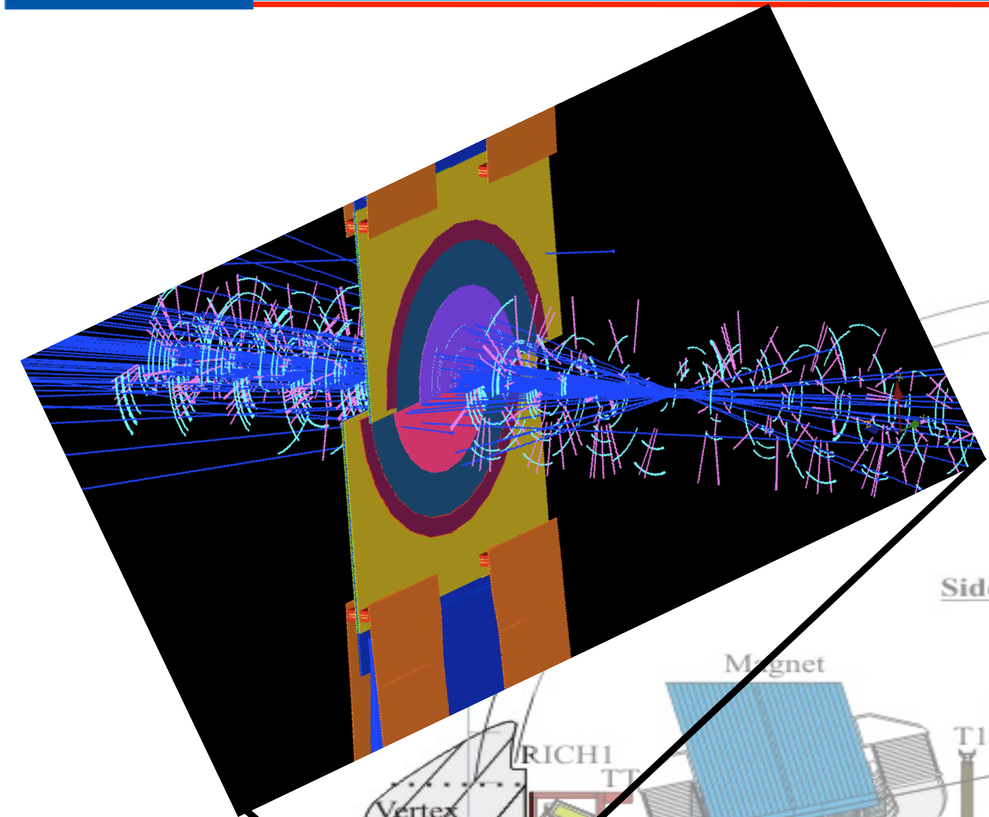
σ(cc) = ~6000 μb; ~10^{12} D decays on tape (2011)

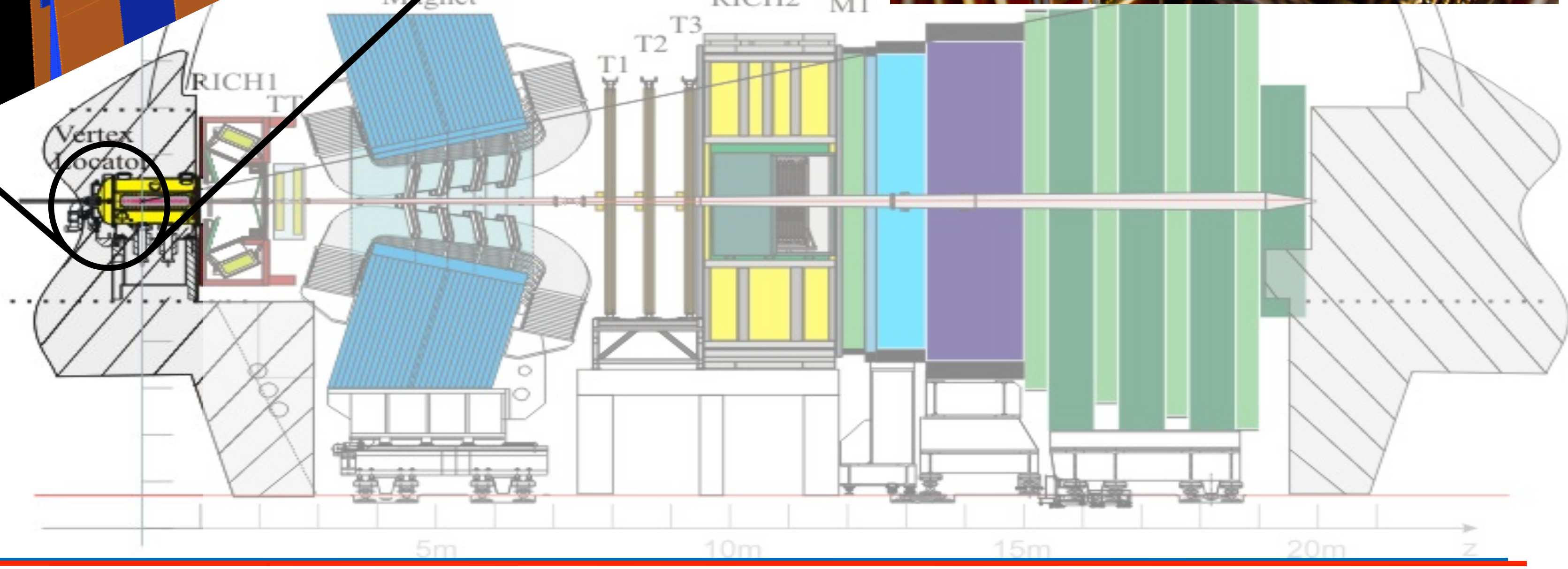
(at 7 TeV, ~15% more at 8 TeV)



Vertex detector: VELO

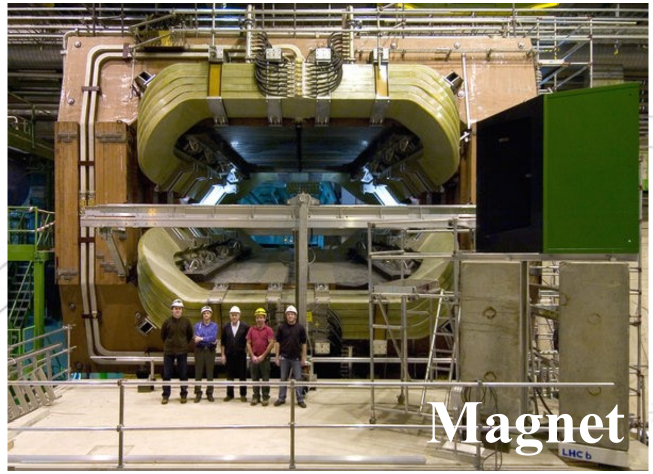
Silicon strip detector with ~ 30 μm impact-parameter resolution



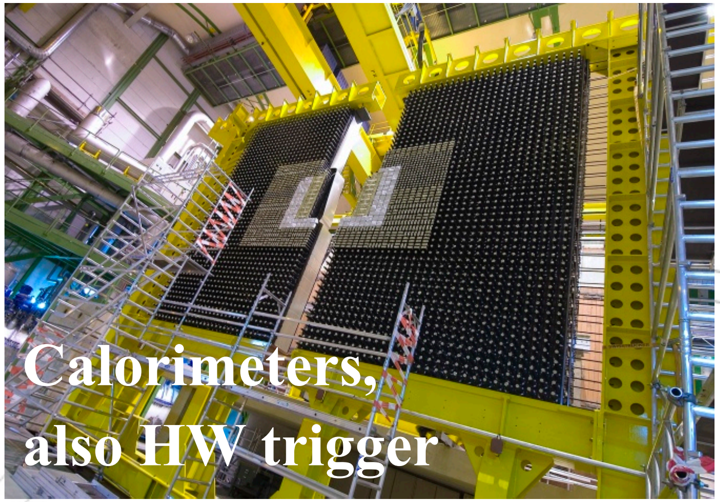


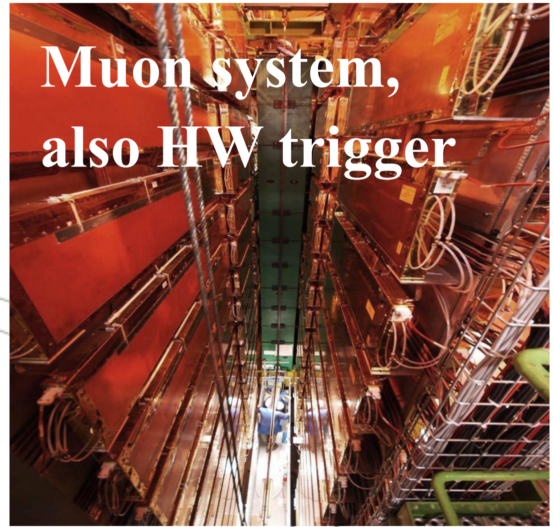
Momentum and mass reconstruction

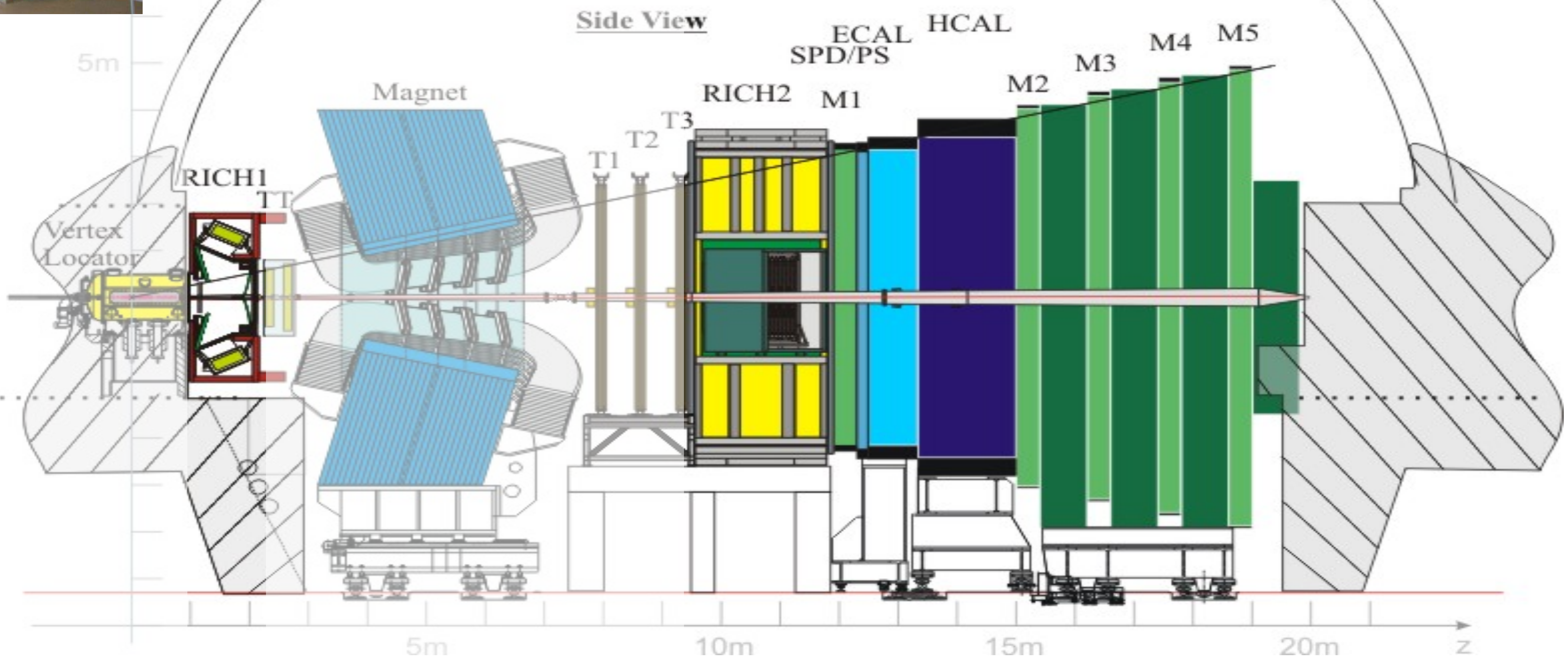
Tracking system and dipole magnet to measure angles and momenta $\Delta p/p \sim 0.5\ \%$, mass resolution, together with VELO ~ 25 MeV (for $B_s \rightarrow \mu\mu$)



Particle identification

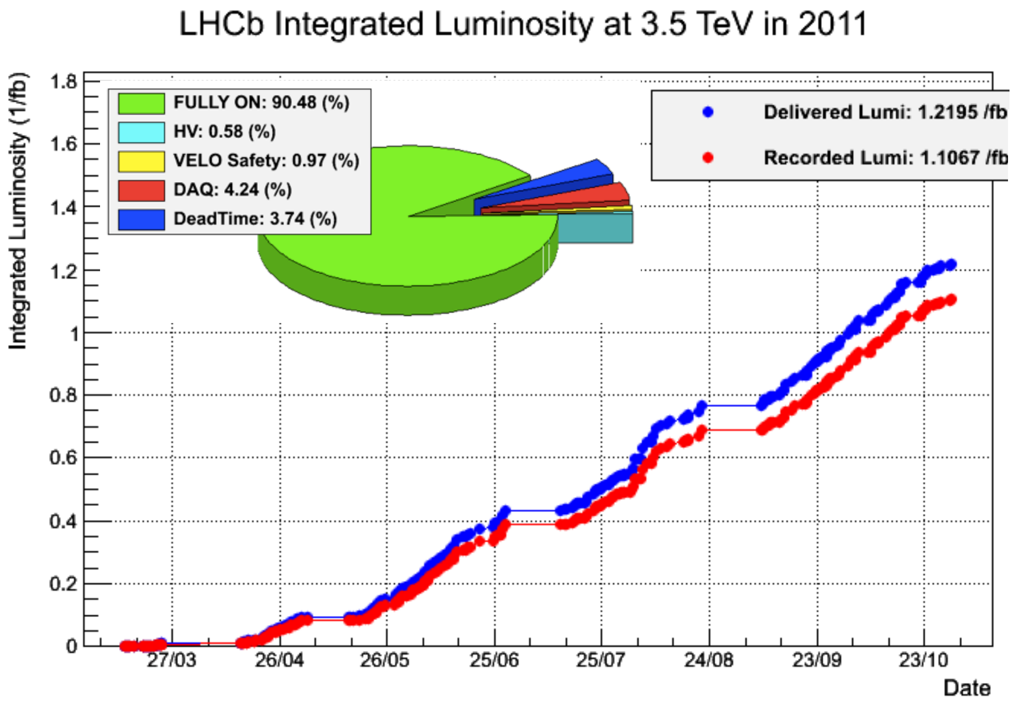


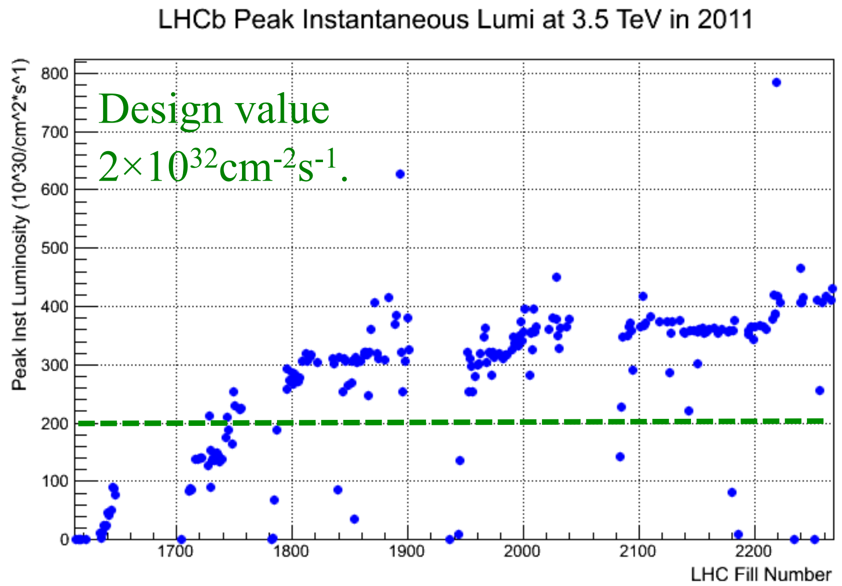


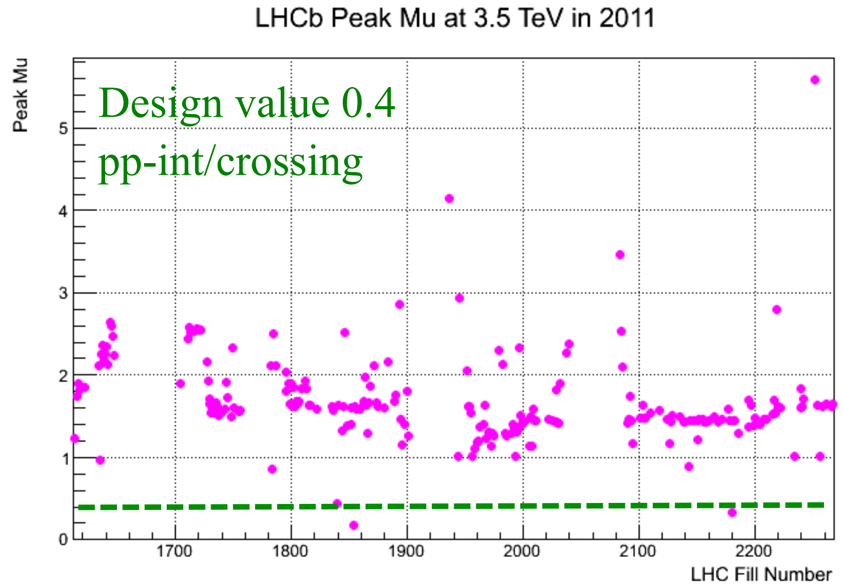


Data taking in 2011 (at 3.5 TeV)

- **1.1 fb^{-1}** acquired in 2011;
- 91% data taking efficiency, including data quality;
- Well **beyond design parameters**.







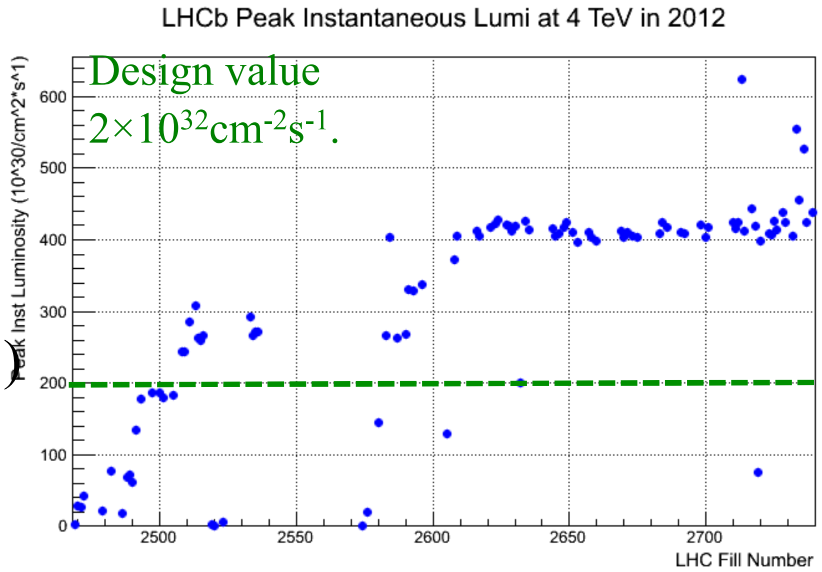
Data taking in 2012 (at 4 TeV)

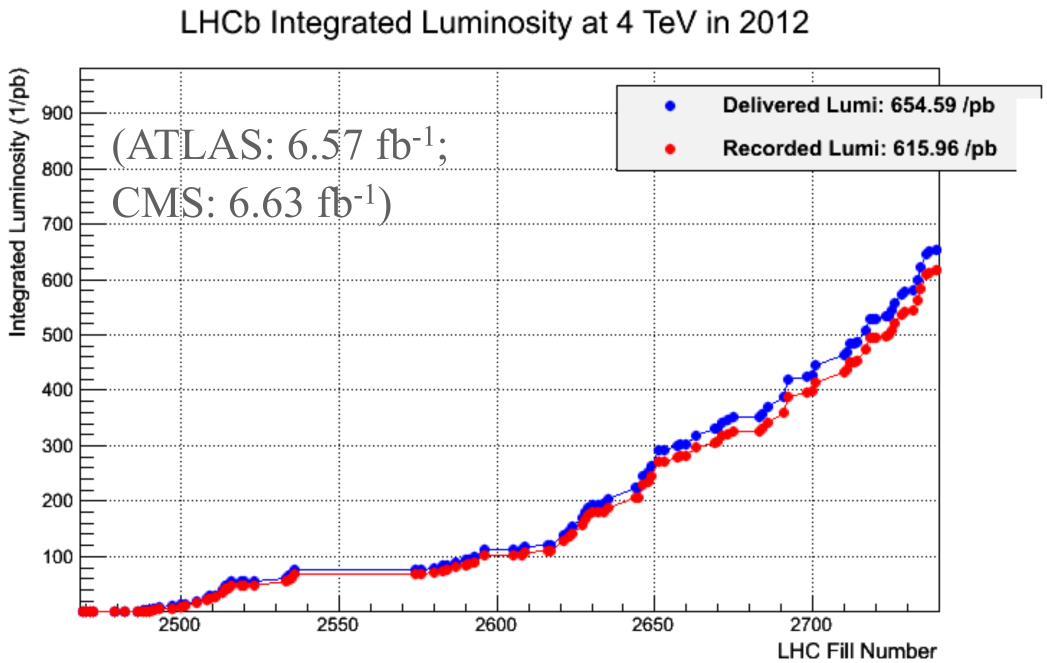
Stable conditions currently are:

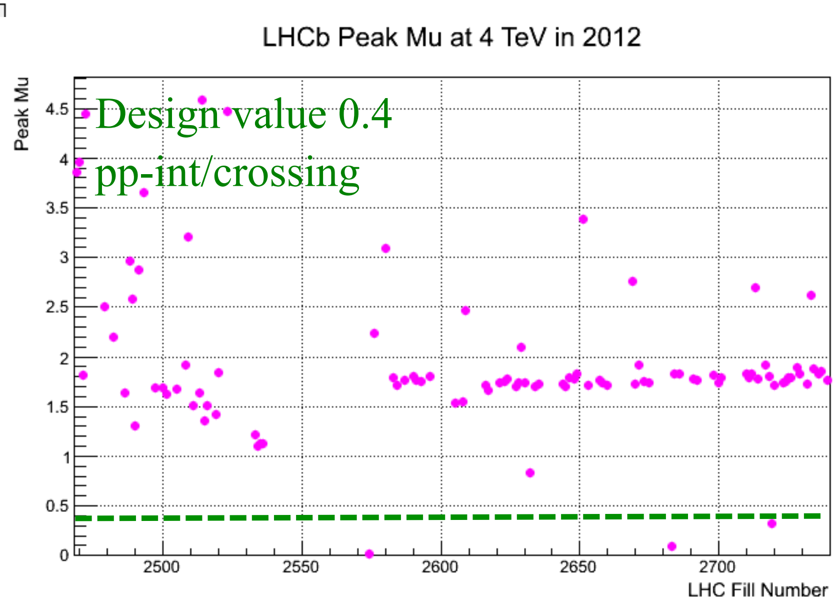
- 1274 colliding bunches,
- ~2 interactions in every non-empty collision
- **>94%** data taking efficiency.

0.62 fb^{-1} acquired so far in 2012 (hope 1.5 fb^{-1})

- instantaneous luminosity $4\times10^{32}cm^{-2}s^{-1}$







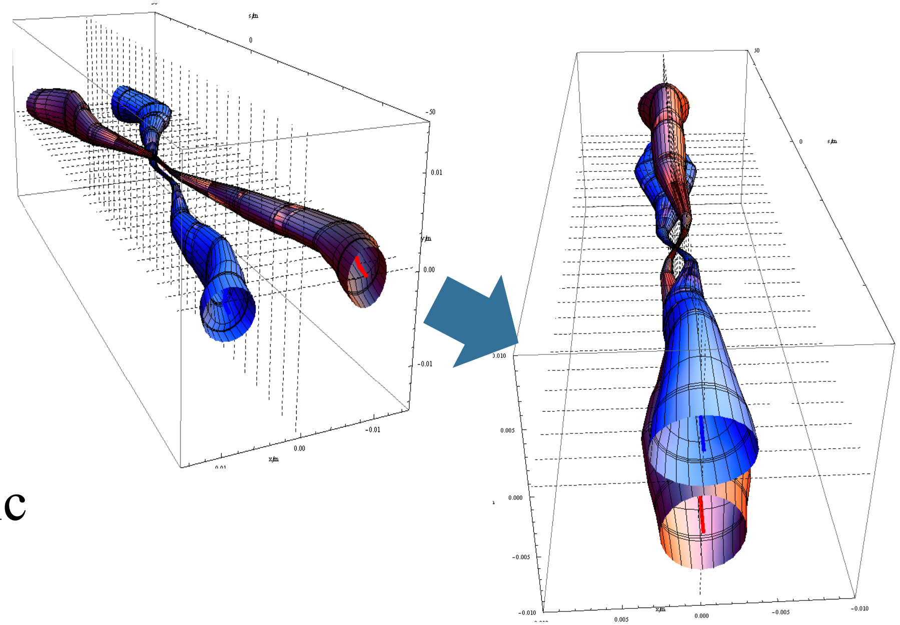
2012 run conditions

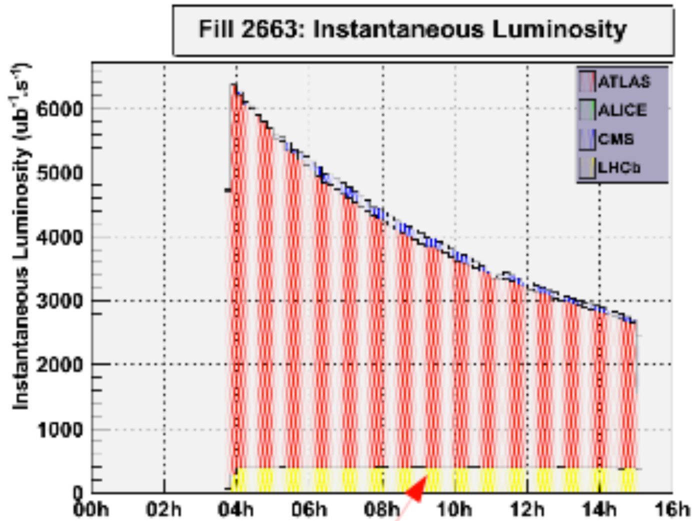
- **Luminosity leveling** at $4\times10^{32}\text{cm}^{-2}\text{s}^{-1}$

Continuously adjust beam overlap in collision region, in harmony with higher luminosity for ATLAS/CMS. Luminosity kept flat at optimal level.

Nicely <u>working with both magnet polarities</u>: polarity regularly switched to cancel systematic effects.

<u>New this year</u>: beam optics changed to decouple crossing angles from LHC (V) and spectrometer magnet (H).





LHCb is flat for 9 hours

- **Triggered** at two levels:

14 MHz → 920 kHz in hardware

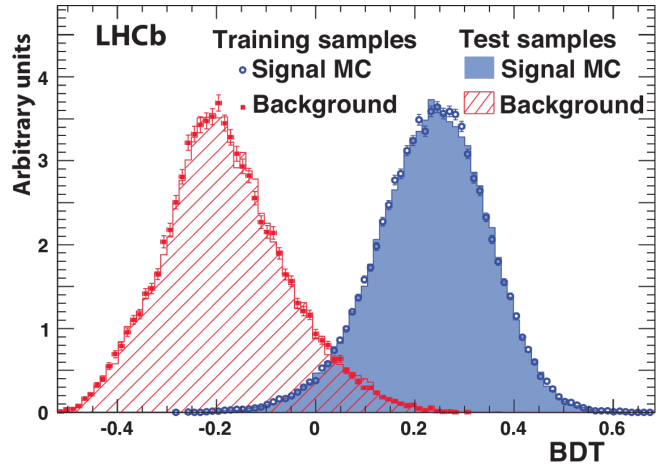
920 kHz → 4.4 kHz in software

2× design, shared equally between <u>beauty</u> and <u>charm</u> triggers

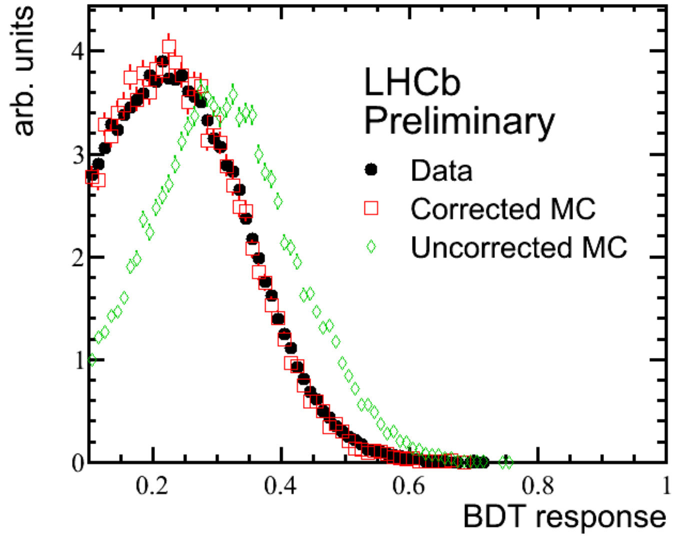
Toolbox - 1

- the use of normalization channels to convert observed number of events in BR **reduces systematic errors, in particular from little known production rates**;

- MVA operators, based on Boosted Decision Tree (**BDT**): combine kinematical and/or geometrical and/or quality information (B vertex position, p_T, $\chi 2$ track fit, PID,…) to **classify events as signal or background**; BDT algorithm, a learning technique: combining "weak" classifiers, achieve a final powerful classifier [arXiv:physics/0408124]; optimized on MC and calibrated on data.



- use of control channels/samples [with geometry/ trigger/selection/… as similar as possible to the signal] to **avoid/reduce dependence on simulation** (angular distributions, charge dependency, time acceptance,…);

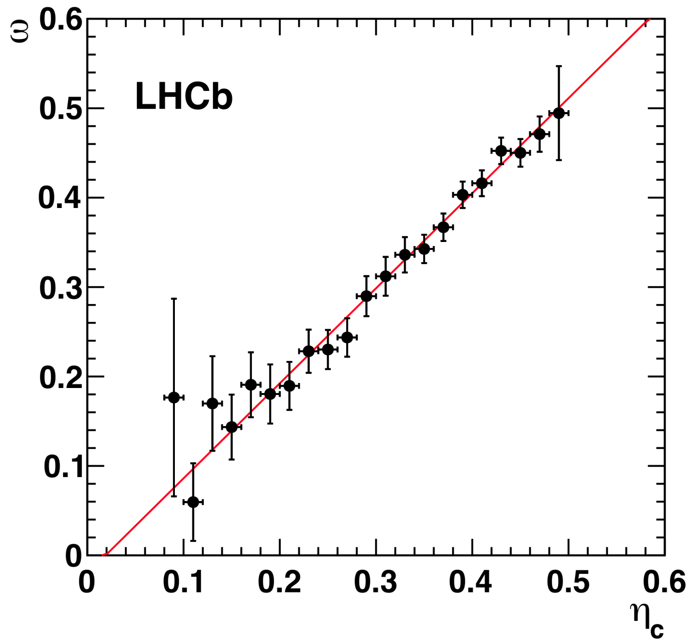


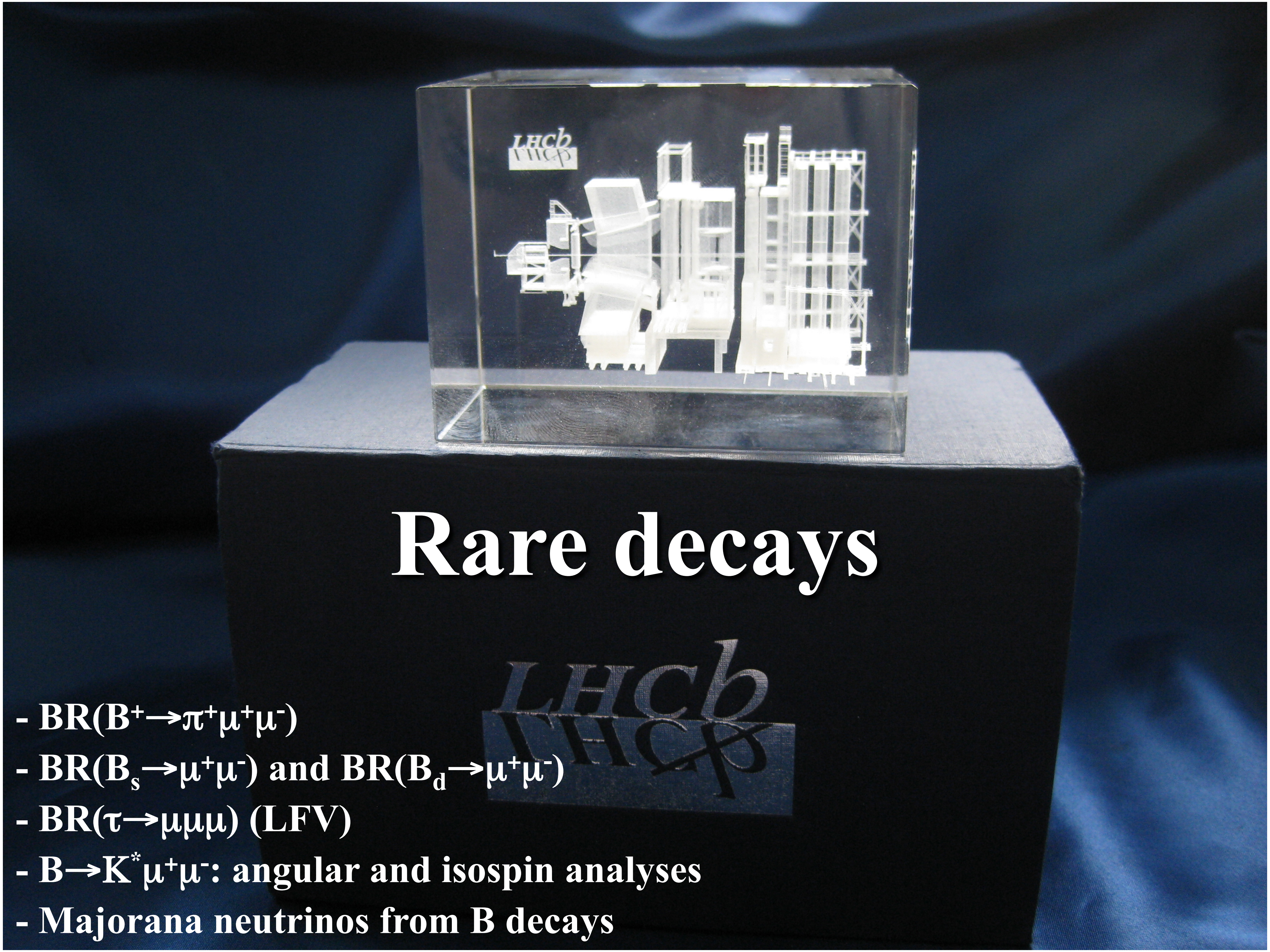
- Very good PID for muons and hadrons; **performance and misID from data**;

- Blind analyses: signal region not looked at until the analyses are frozen.

- Analysis optimization: maximize **relevant differences** e.g. "SM signal plus bkg" and "bkg only" hypotheses, asymmetries sensitivity,…

- Tagging: for measurements that require knowledge of the flavour of the meson at production; exploit flavour specific features of the accompanying (non-signal) hadron; estimate a per-event mis-tag probability, which is calibrated with data from control channels. In particular: "Opposite-side flavour tagging of B mesons" [Eur. Phys. J. C (2012) 72:2022].





Rare decays

- BR($B^+ \to \pi^+\mu^+\mu^-$)
- BR($B_s \to \mu^+\mu^-$) and BR($B_d \to \mu^+\mu^-$)
- BR($\tau \to \mu\mu\mu$) (LFV)
- $B \to K^*\mu^+\mu^-$: angular and isospin analyses
- Majorana neutrinos from B decays

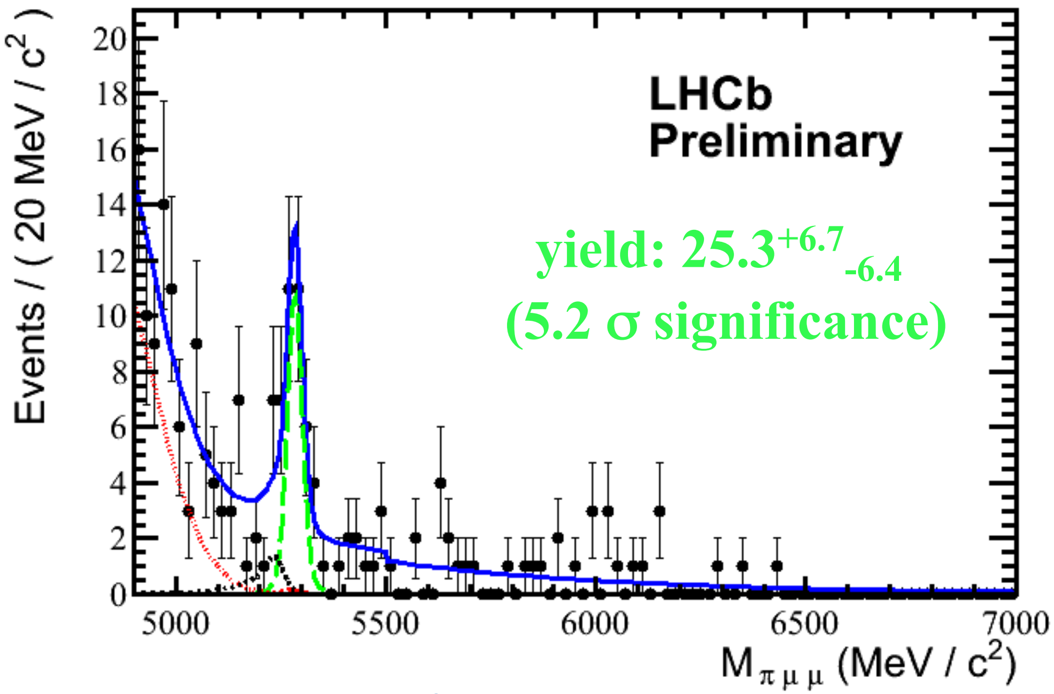
$BR(B^+ \to \pi^+ \mu^+ \mu^-)$

LHCb-CONF-2012-006

In the SM **b→dl⁺l⁻** transitions suppressed by $|V_{td}/V_{ts}|$ wrt the $b \to sl^+l^-$:
$BR_{SM}=(1.96\pm0.21)\times10^{-8}$. [H.Z.Song et alComm. in Th. Phys. 50 (2008) 696]

- Not [necessarily] needed BSM: even with strong experimental constraints from $b \to l^+l^-$, $BR(B^+ \to \pi^+\mu^+\mu^-)$ can be enhanced by NP models.

- Never observed before; expect 21±3 SM events in **1 fb⁻¹**.
- Veto J/ψ and ψ'(2S) in $m_{\mu\mu}$.
- **BDT** signal/bkg rejection.
- Yield from fit to $M_{\pi\mu\mu}$ distribution, bkg **mass shapes from data control channels**: $B^+ \to J/\psi K^+$ and $B^+ \to J/\psi \pi^+$.
- Normalize to $B^+ \to J/\psi K^+$.



$BR(B^+ \to \pi^+\mu^+\mu^-) = (2.4\pm0.6_{STAT}\pm0.2_{SYST})\times10^{-8}$ [preliminary]

$B \to \mu\mu$ introduction

In SM $B_{(d,s)} \to \mu\mu$ is very rare (FCNC process and helicity suppressed); sensitive probe to NP contributions (e.g. in MSSM, BR enhanced by $\tan^6\beta$) fully complementary to direct searches.

Well predicted in SM:

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

$B_d \to \mu\mu = (0.10 \pm 0.01) \times 10^{-9}$.

[Buras et al arXiv:1007.5291, use B_s=1.33±0.06 from HPQCD arXiv:0902.1815]

<u>Entering the precision realm</u>:

- Alternative option, with main uncertainty from f_{Bs} (impressive lattice results)

$B_s \to \mu\mu = (3.1 \pm 0.1) \times 10^{-9}$, *[Buras et al arXiv:1205.5064, use f_{Bs} = 227.7±6.2 MeV]*

$B_s \to \mu\mu = (3.64^{+0.17}_{-0.31}) \times 10^{-9}$, *[CKM fitter arXiv:1106.4041, use f_{Bs} = 231±15 MeV]*

$B_s \to \mu\mu = (3.53 \pm 0.38) \times 10^{-9}$. *[Mohmoudi et al arXiv:1205.1845, use f_{Bs} = 234±10 MeV]*

- Experiments measure time integrated BR, need to consider BBbar mixing:

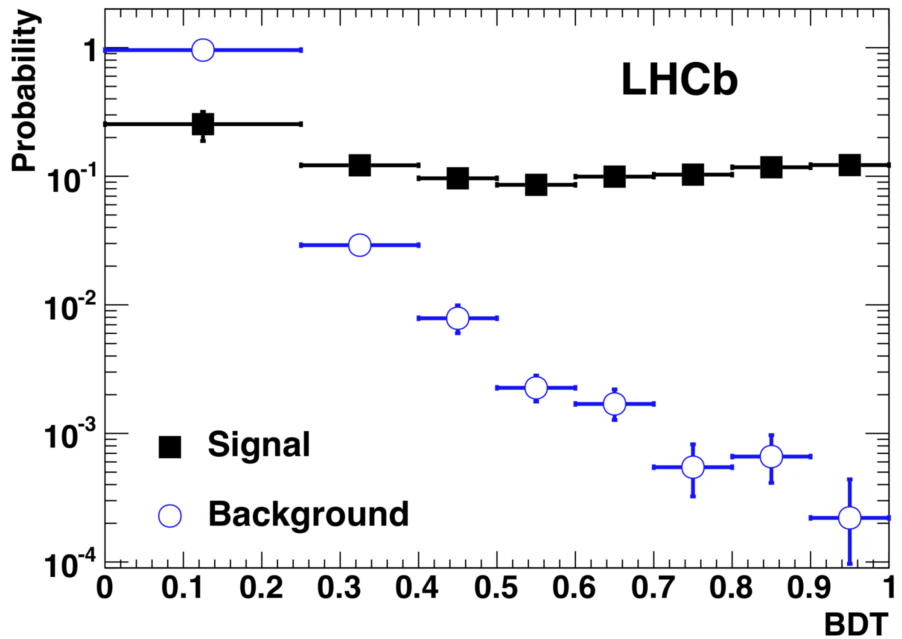
3.2 at $t=0$, becomes 3.5 time integrated

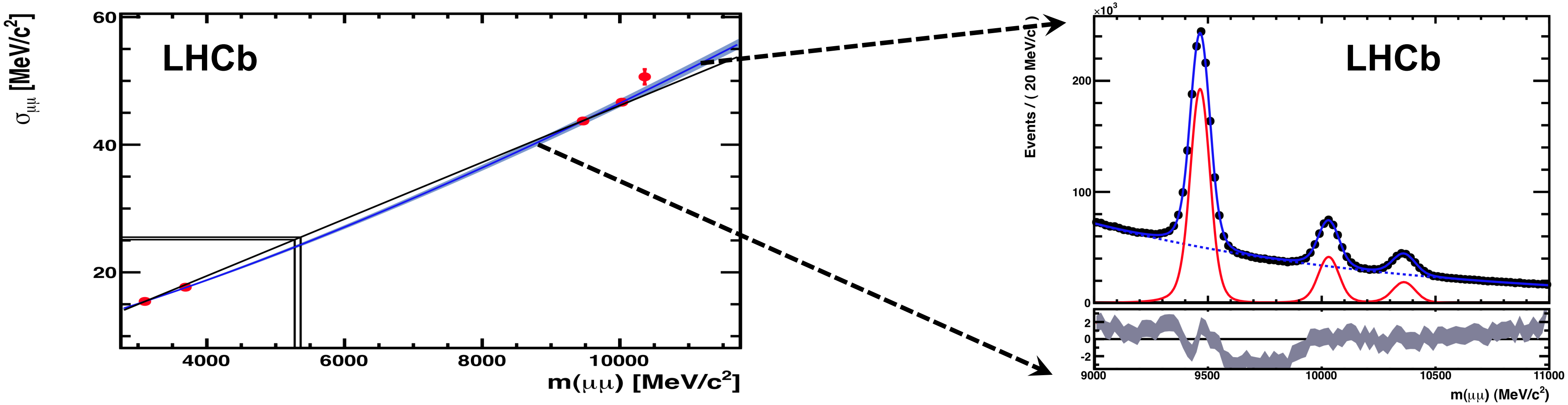
[y_s from LHCb-CONF-2012-002 De Bruyn et al arXiv:1204.1735]

$BR(B_s \to \mu\mu)$ and $BR(B_d \to \mu\mu)$

PRL 108,231801(2012)

- Loose μμ from B preselection
- Classify each event using BDT and invariant m(μμ) mass
- **BDT** optimized on MC but calibrated with data: **signal from B→hh** and **background from sidebands**.
- Mass parameters from B→hh and dimuon resonances.

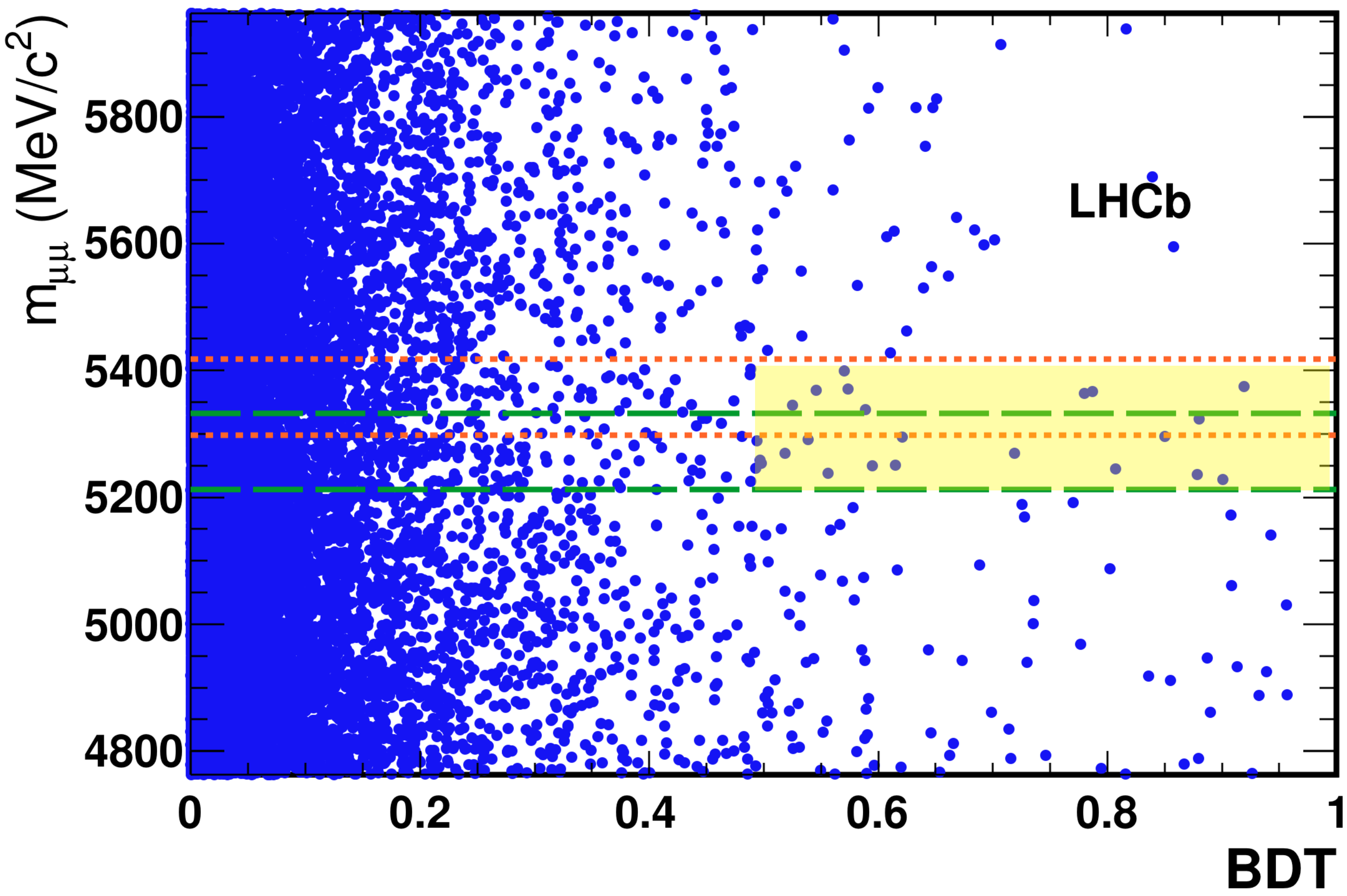




$BR(B_s \to \mu\mu)$ and $BR(B_d \to \mu\mu)$

PRL 108,231801(2012)

1 fb^{-1} data distribution on the **BDT×mass plane**.



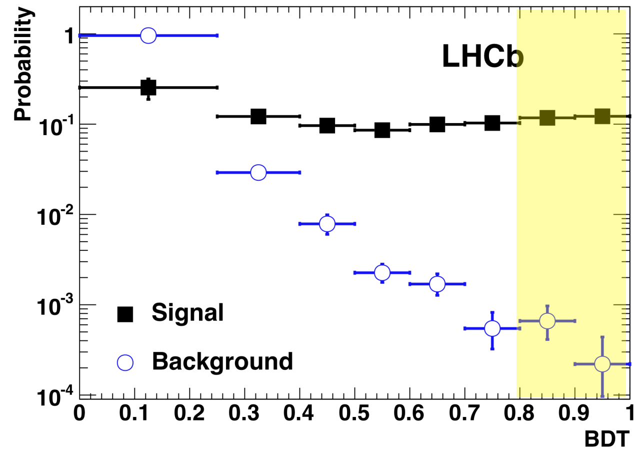
Fit in 8×9 bins on the plane [maximize S/B separation] for each search window, B_s and B_d, separately.

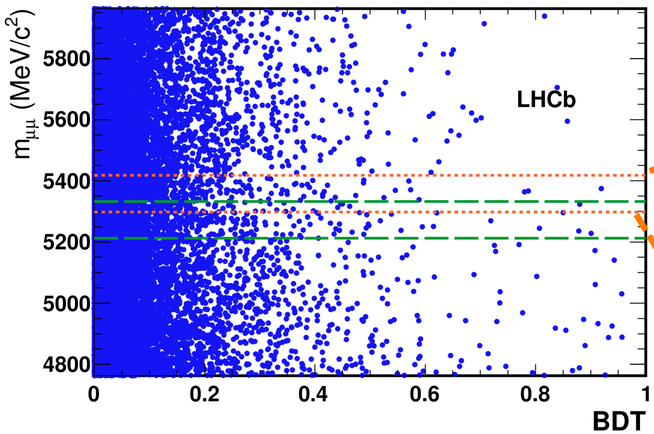
The whole BDT range is used to measure the two limits.

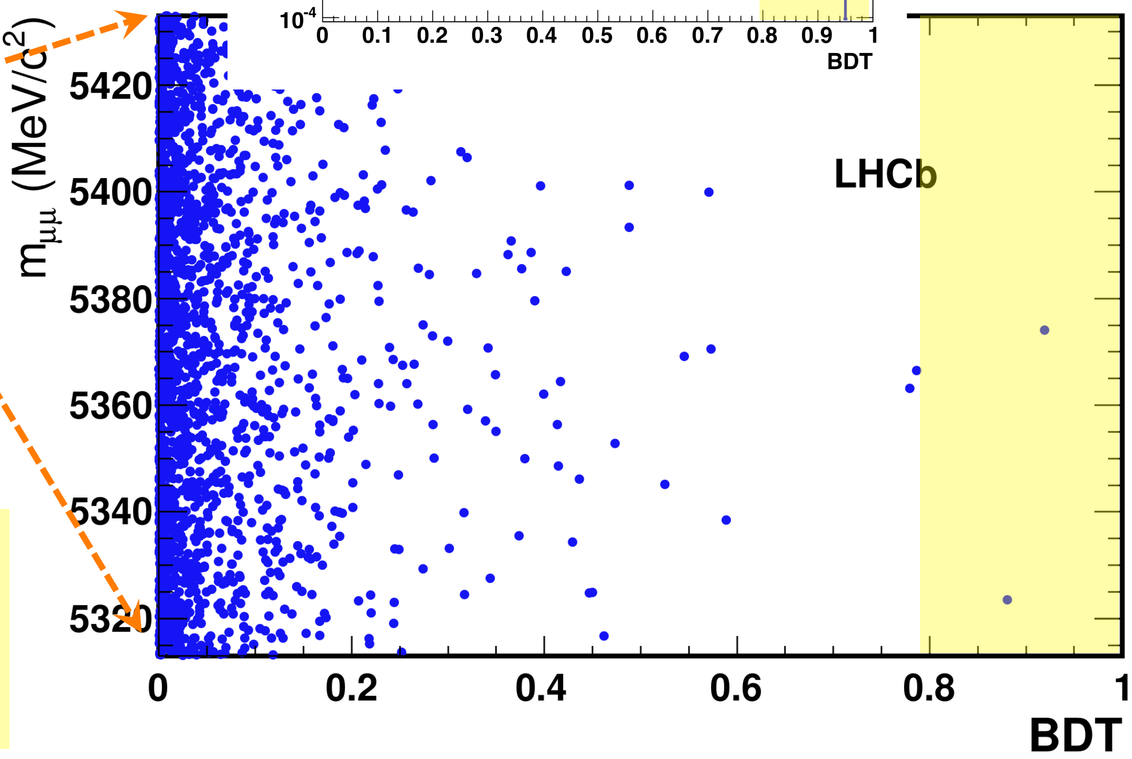
$BR(B_s \to \mu\mu)$ and $BR(B_d \to \mu\mu)$

PRL 108,231801(2012)

1 fb^{-1} data distribution: **zoom the B_s search window**.



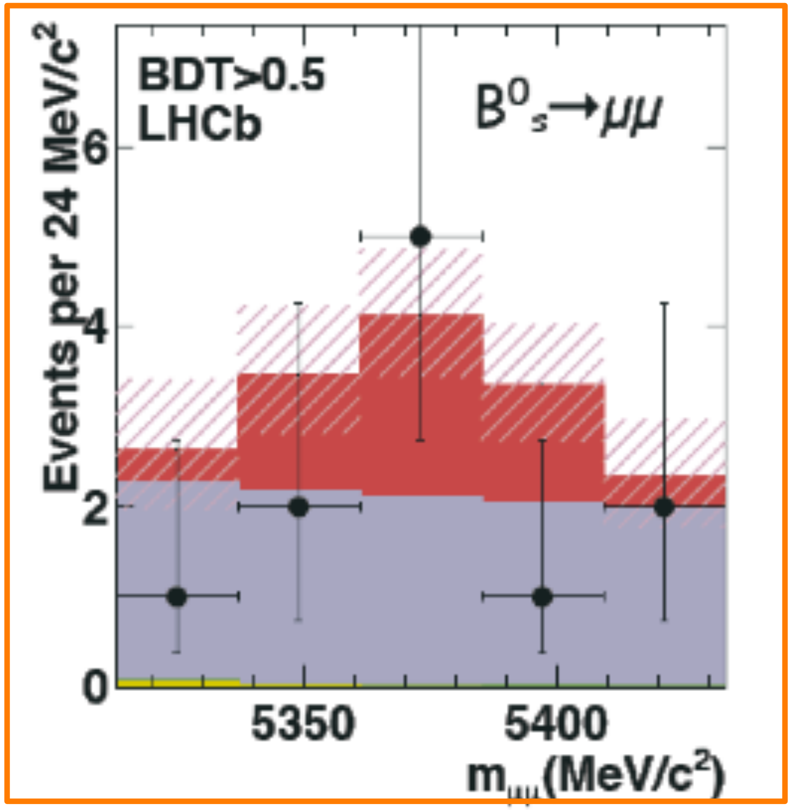


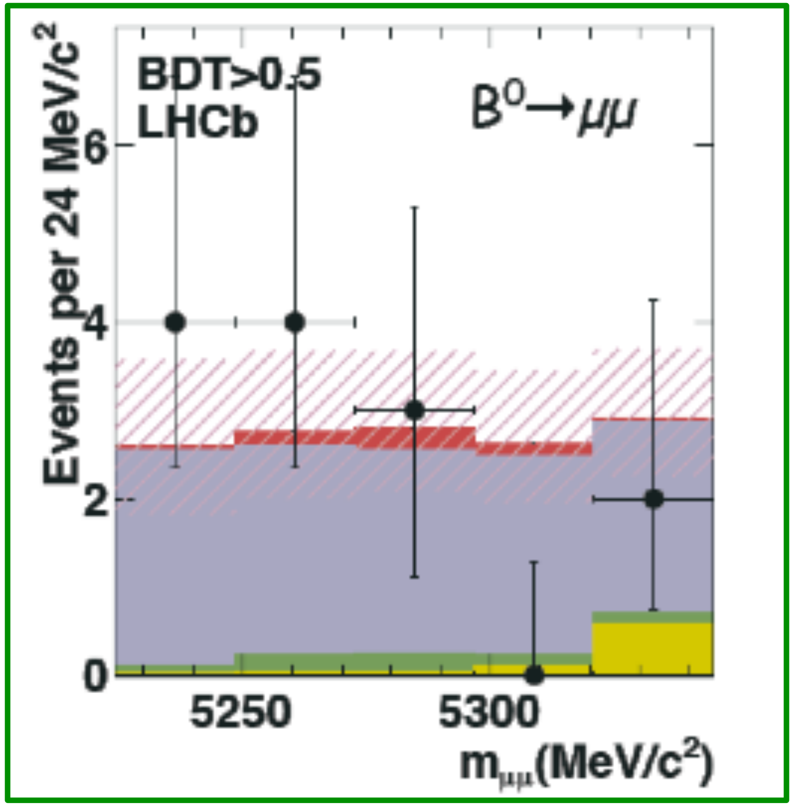


No background in the high BDT region (>0.8) where LHCb is most sensitive to signal.

$BR(B_s \to \mu\mu)$ and $BR(B_d \to \mu\mu)$

PRL 108,231801(2012)





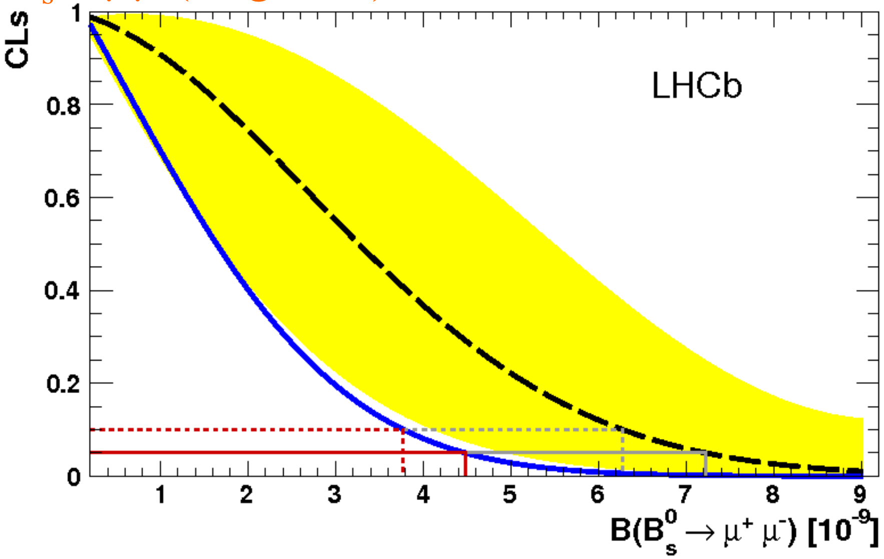
Pictorial synthesis of the events in the all mass bins with BDT>0.5:
expected SM signal, comb. bkg, B→hh bkg, cross-feed between channels.

Number of events translate into BR normalizing to $\mathbf{B_s \to J/\psi\phi}$, $\mathbf{B_d \to J/\psi K^*}$, $\mathbf{B_d \to K\pi}$.

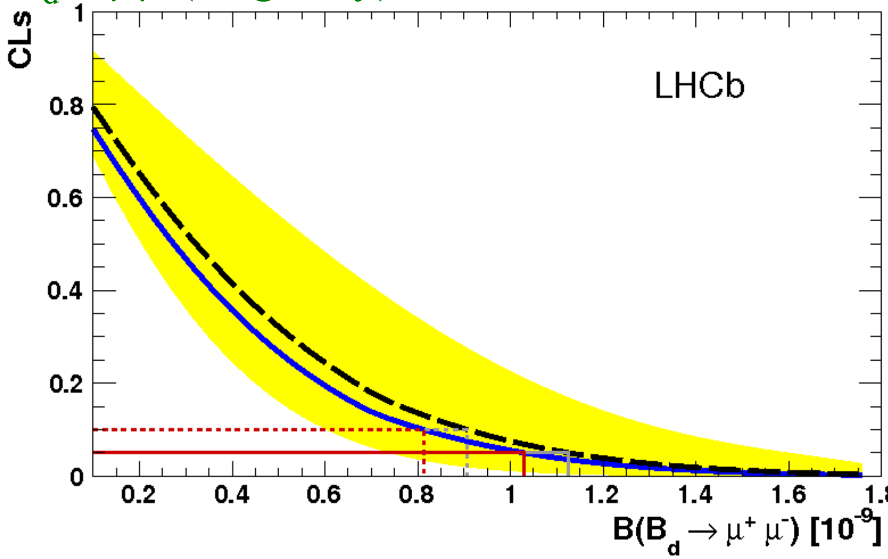
BR($B_s \to \mu\mu$) and BR($B_d \to \mu\mu$)

PRL 108,231801(2012)

$B_s \to \mu\mu$ (Bkg+SM)

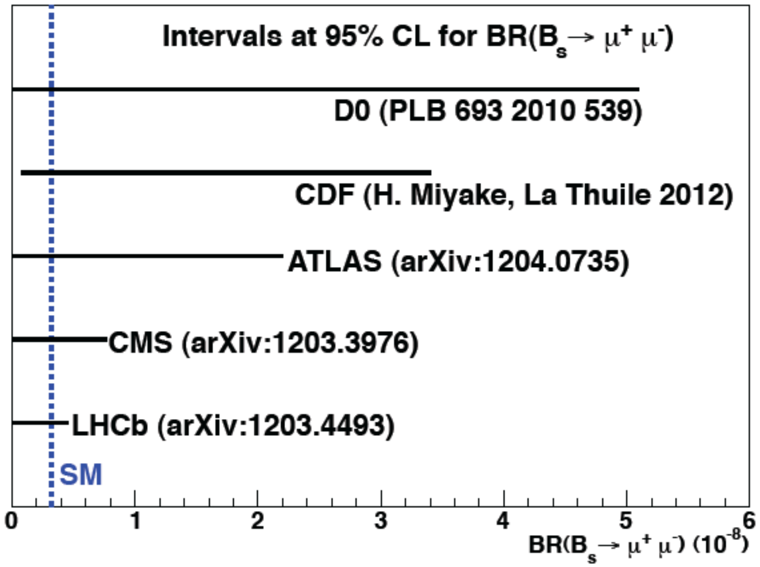


$B_d \to \mu\mu$ (Bkg only)



at 95%CL

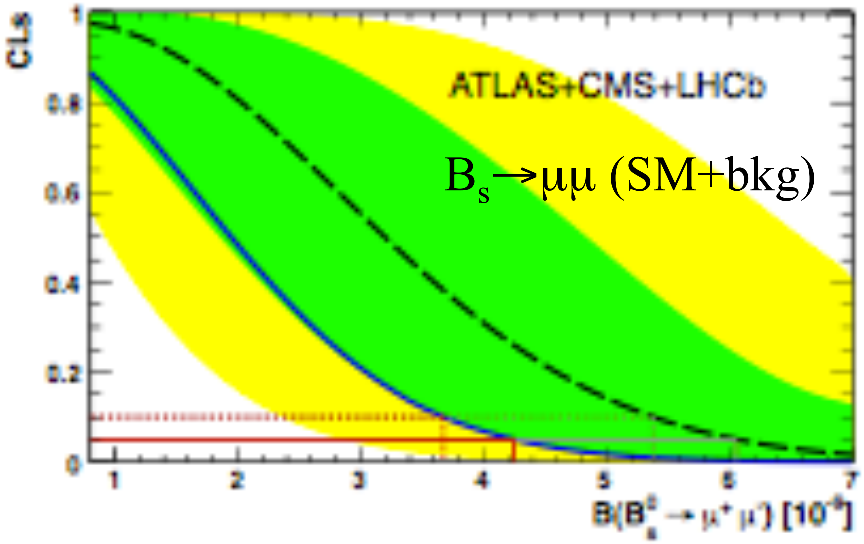
$B_s \to \mu\mu$	**Exp. bkg + SM**	**7.2×10^{-9}**
	Exp. bkg	3.4×10^{-9}
	Observed	**4.5×10^{-9}**
$B_d \to \mu\mu$	**Exp. bkg**	**1.1×10^{-9}**
	Observed	**1.0×10^{-9}**

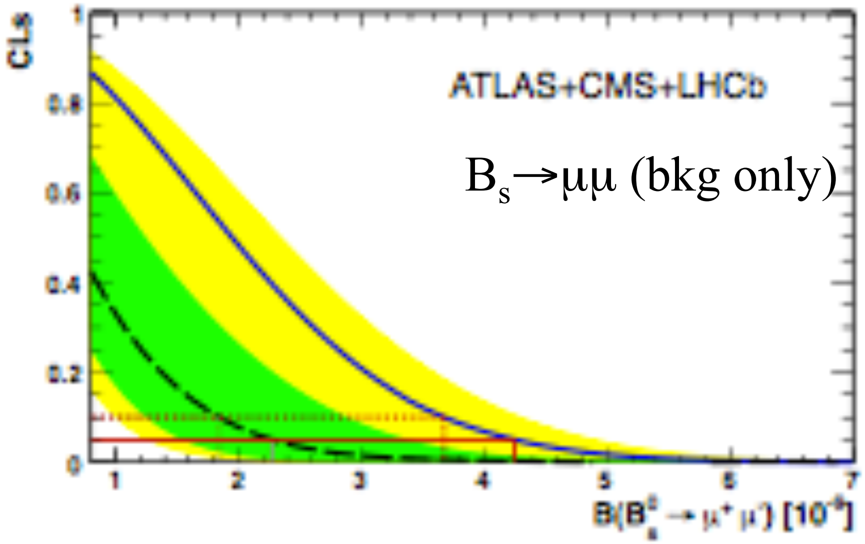


$B_s\mu\mu$ combination and perspectives

arXiv:1204.0735, JHEP 1204(2012) 033, PRL 108,231801(2012), LHCb-CONF-2012-017

New ATLAS, CMS, and LHCb results have been combined [preliminary].

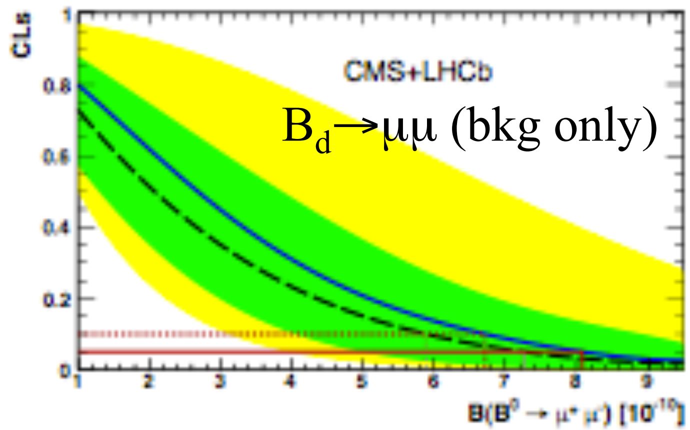




BR($B_s \rightarrow \mu\mu$)<**4.2×10^{-9}** at 95% CL

excess over bkg at 2σ; compatible with SM at 1σ.

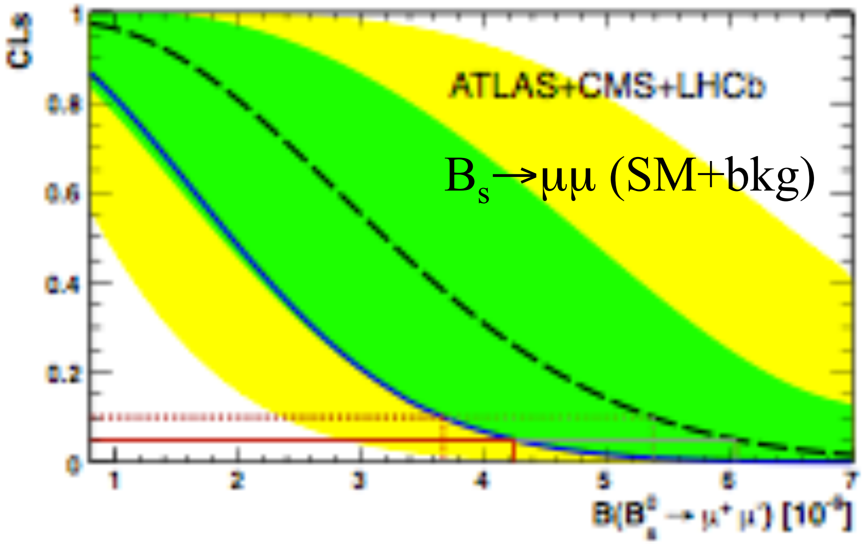
BBR($B_d \rightarrow \mu\mu$) <**0.81×10^{-9}** at 95%)CL

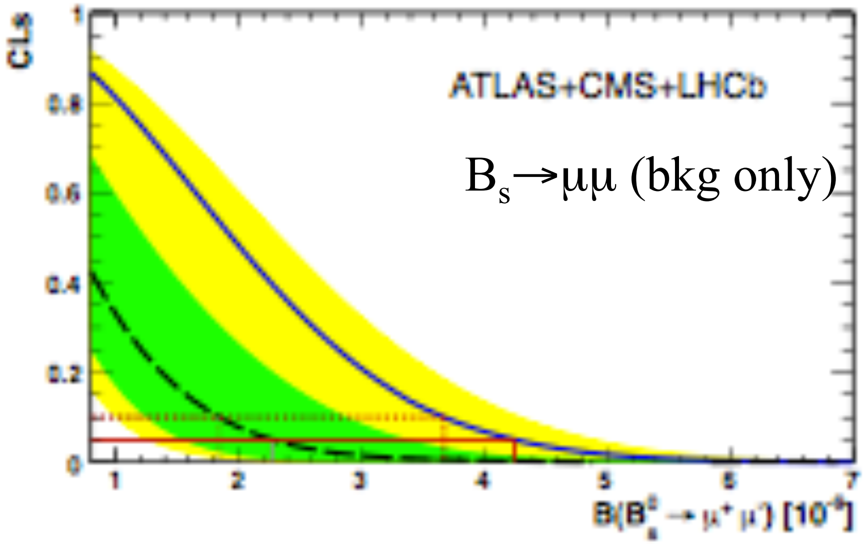


$B_s\mu\mu$ combination and perspectives

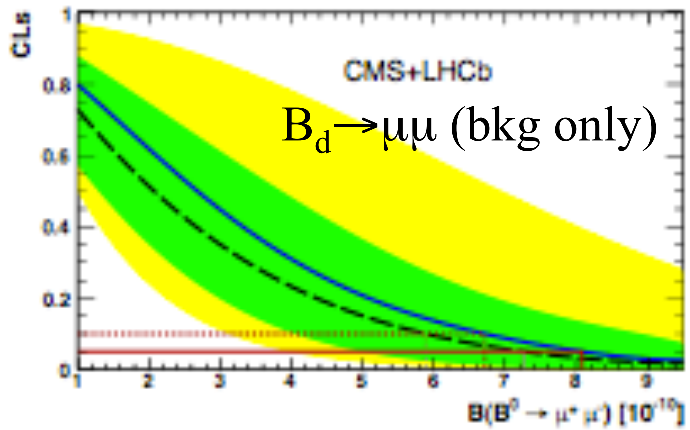
LHCb-CONF-2012-017

SM prediction $(3.2\pm0.2)\times10^{-9}$ [Buras, Acta Phys. Pol. vol 41 (2010)]





- No significant BR($B_s\to\mu\mu$) enhancement.
- $B_s\to\mu\mu$: eating in SM prediction
- Precision measurement of SM $B_s\to\mu\mu$.
- Observation of $B_d\to\mu\mu$.
- Measure the ratio $B_s\to\mu\mu/B_d\to\mu\mu$: test MFV models



$BR(\tau\rightarrow\mu\mu\mu)$

LHCb-CONF-2012-015

Neutrino oscillations implies LFV at some level.

SM+ $\nu_\mu - \nu_\tau$ oscillations predict $BR(\tau\rightarrow\mu\mu\mu)\sim O(10^{-54})$.

In many BSM theories, LFV amplified in τ wrt μ; can predict $BR(\tau\rightarrow\mu\mu\mu)$ experimentally achievable 10^{-8}-10^{-10}.

[e.g. W.Marciano et al Ann.Rev.Nucl.Part.Sci 58 (2008)315]

Best limit $BR(\tau\rightarrow\mu\mu\mu)<2.1\times10^{-8}$ at 90% CL [Belle, PLB687(2010)139].

Large inclusive σ_τ (from B, D_s^- and D^0 mesons).

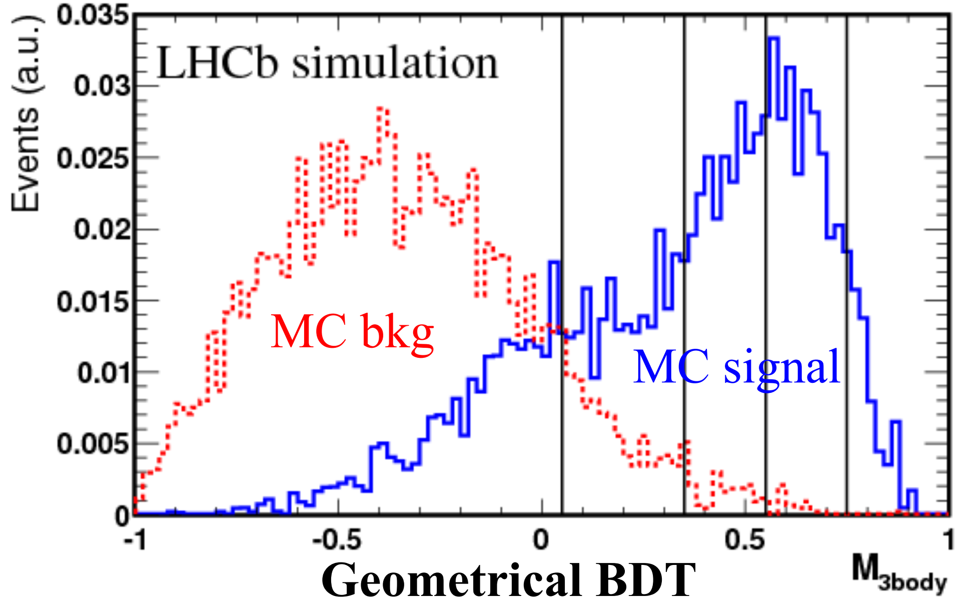
PID and bkg rejection: 3μ easier than $\mu^-\gamma$ or 3e.

Analysis strategy similar to $B_s\mu\mu$.

Signal/bkg discrimination via 3 classifiers:

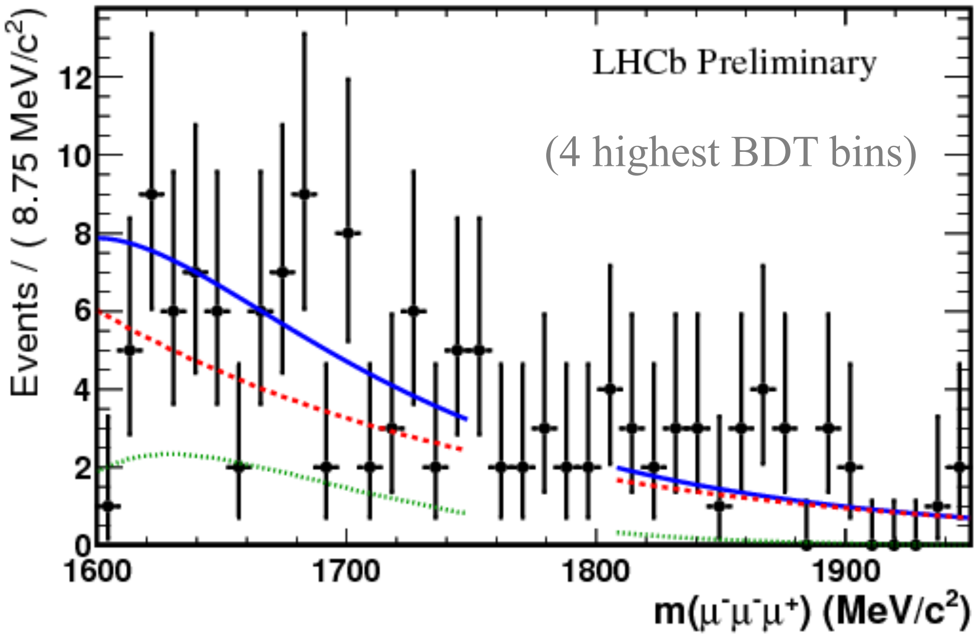
- geometrical BDT (combinatorial bkg)
- PID BDT (μ hypothesis)
- 3 muons invariant mass, $m_{3\mu}$.

Developed using sig and bkg MC.



BR(τ→μμμ)

LHCb-CONF-2012-015



Final signal/bkg classifier **calibrated on $D_s^-\to\phi(\mu\mu)\pi^-$ data**: 5×5 bins with PID and geometrical information.

In each bin, fit $m(\mu^-\mu^-\mu^+)$ distribution.

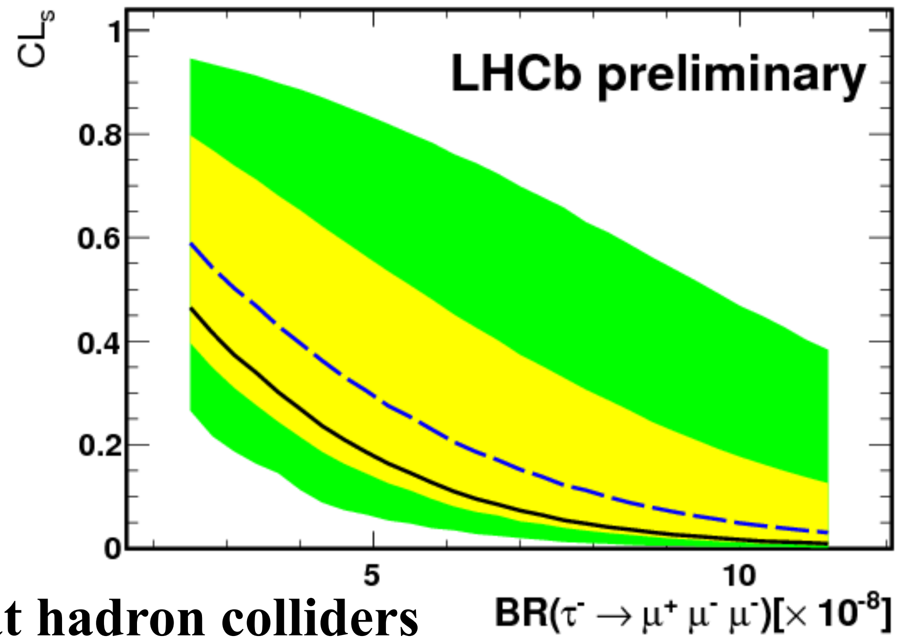
Blind region: $m_\tau \pm 30$ MeV

Normalize to $D_s^-\to\phi(\mu\mu)\pi^-$, in **1 fb^{-1}** data

BR(τ→μμμ) [preliminary]

Expected $<9.7\times10^{-8}$ at 95% CL

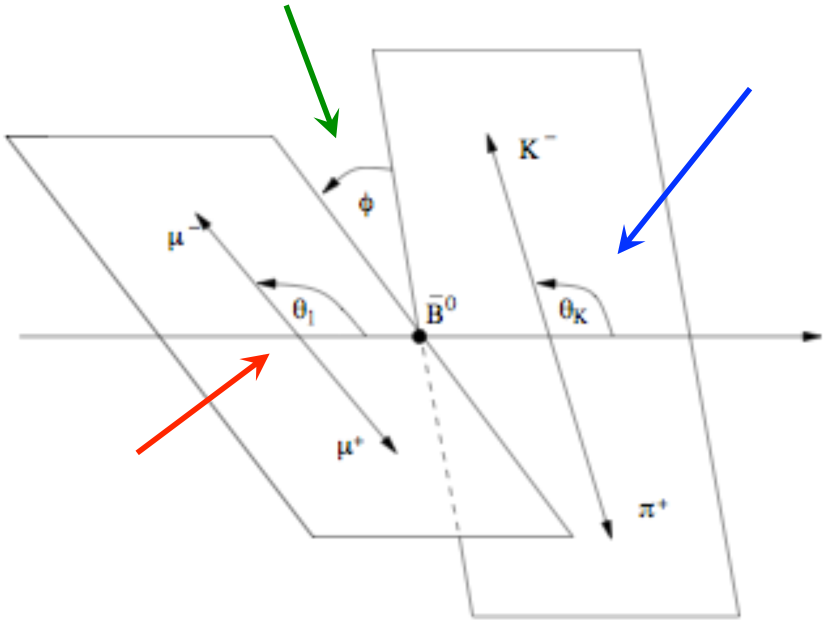
Observed $<7.8\times10^{-8}$ at 95% CL



Proof of principle: can be made at hadron colliders

$B\to K^*\mu^+\mu^-$: angular analysis

LHCb-CONF-2012-008



- The decay is described by three angles (θ_l, θ_K, ϕ) and the μμ invariant mass $\mathbf{q^2}$.

- Can define angular observables, where the hadronic uncertainties are under control and sensitive to NP.
- Full angular PDF:

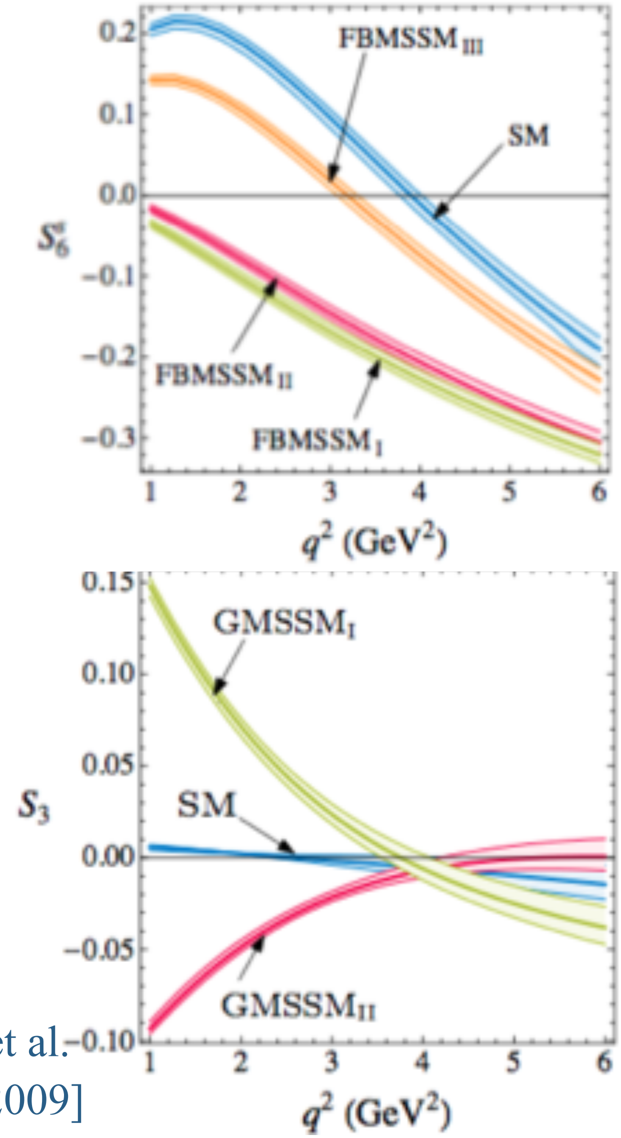
$$\frac{d^4\Gamma}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi\, dq^2} \propto [I_1^s \sin^2\theta_K + I_1^c \cos^2\theta_K + (I_2^s \sin^2\theta_K + I_2^c \cos^2\theta_K)\cos 2\theta_\ell + I_3 \sin^2\theta_K \sin^2\theta_\ell \cos 2\phi + I_4 \sin 2\theta_K \sin 2\theta_\ell \cos\phi + I_5 \sin 2\theta_K \sin\theta_\ell \cos\phi + (I_6^s \sin^2\theta_K + I_6^c \cos^2\theta_K)\cos\theta_\ell + I_7 \sin 2\theta_K \sin\theta_\ell \sin\phi + I_8 \sin 2\theta_K \sin 2\theta_\ell \sin\phi + I_9 \sin^2\theta_K \sin^2\theta_\ell \sin 2\phi\,],$$

None of the experiments has enough statistics to attempt a full angular fit: projection of angles (BaBar, Belle, CDF) or **3D fit, folding $\phi\to\phi+\pi$, if $\phi<0$ (LHCb)**.

$B \to K^* \mu^+ \mu^-$: angular analysis

LHCb-CONF-2012-008

$$\frac{1}{\Gamma}\frac{d^4\Gamma}{d\cos\theta_\ell\, d\cos\theta_K\, d\hat{\phi}\, dq^2} = \frac{9}{16\pi}\Big[F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K) + F_L\cos^2\theta_K(2\cos^2\theta_\ell - 1) + \frac{1}{4}(1-F_L)(1-\cos^2\theta_K)(2\cos^2\theta_\ell - 1) + S_3(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}A_{FB}(1-\cos^2\theta_K)\cos\theta_\ell + A_{Im}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$



The 3D fit in q^2 bins, allows to measure:

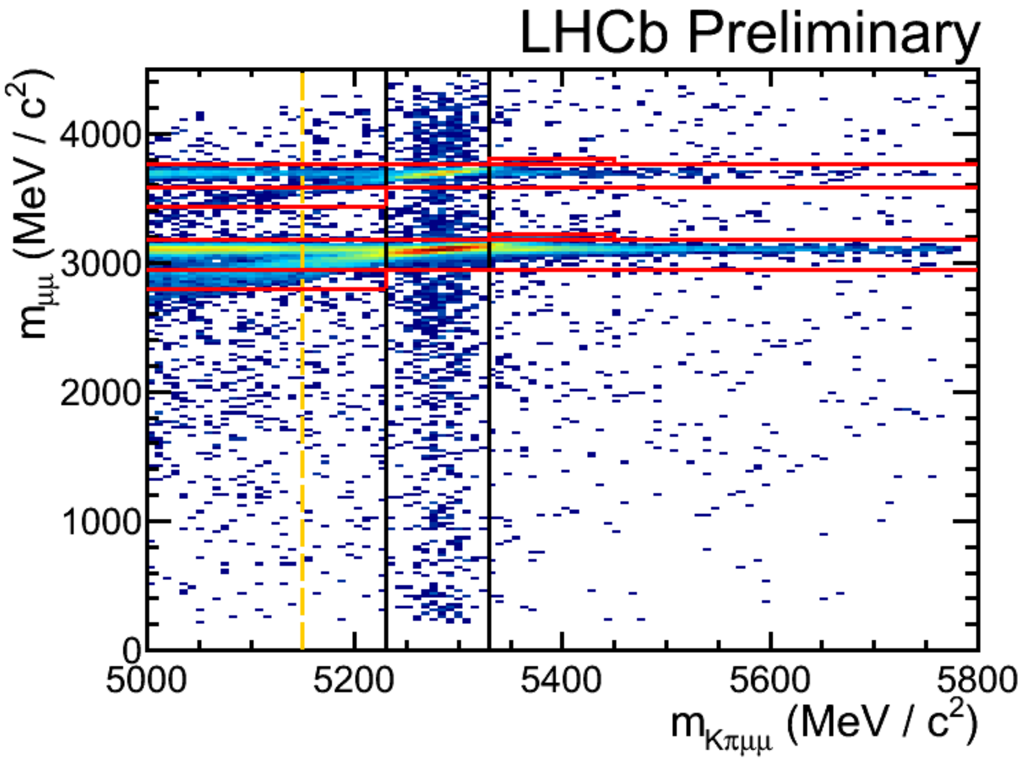
- F_L, K^* longitudinal polarization;
- $S_6 = 4/3 A_{FB}$, the forward-backward asymmetry;
- $S_3 = (1-F_L)A_T^2$, the transverse asymmetry;
- A_{Im}, the T-odd asymmetry.

Better sensitivity and easier (natural) correlations treatment.

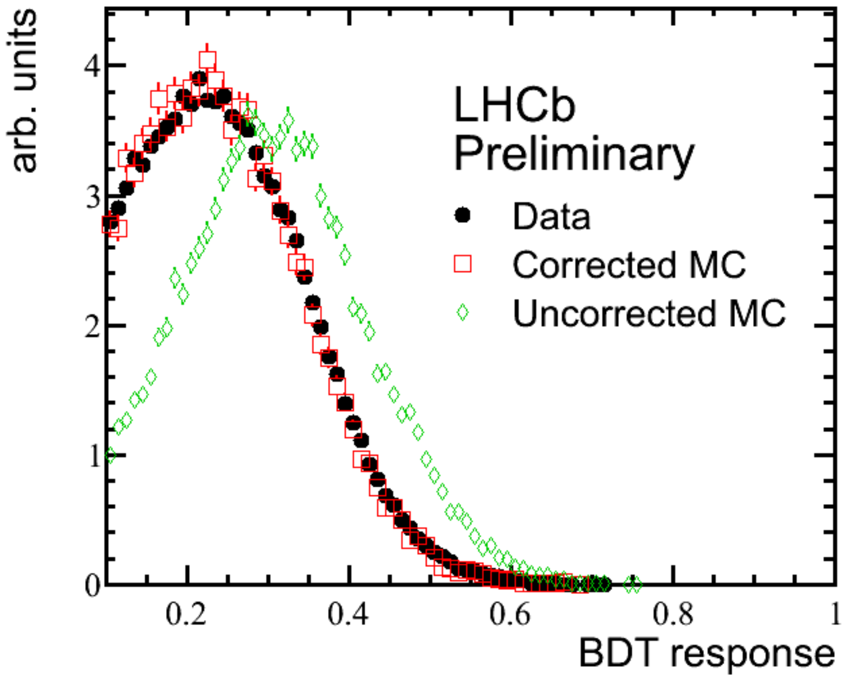
[Altmannshofer et al. JHEP 0901:019,2009]

$B\to K^{*}\mu^{+}\mu^{-}$: angular analysis

LHCb-CONF-2012-008



- Use a **BDT** to select $B\to K^{*}\mu^{+}\mu^{-}$ events.
- Remove J/ψ and $\psi(2S)$ dimuon resonances.

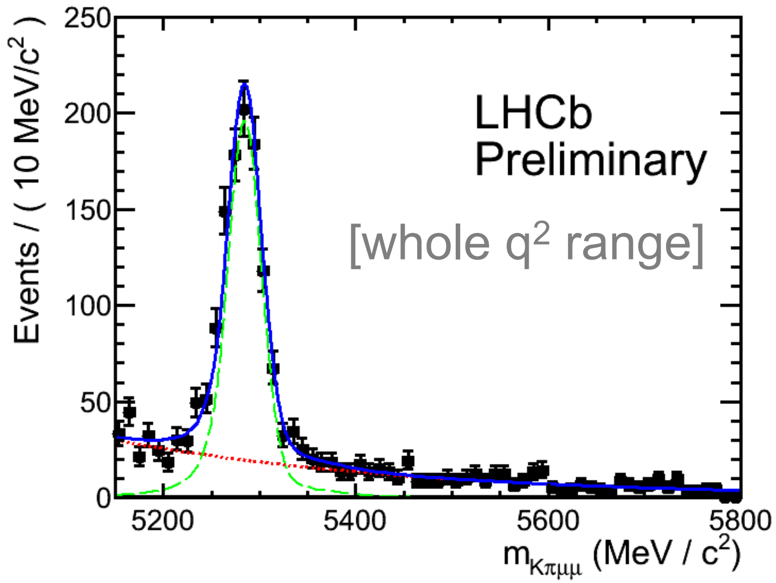


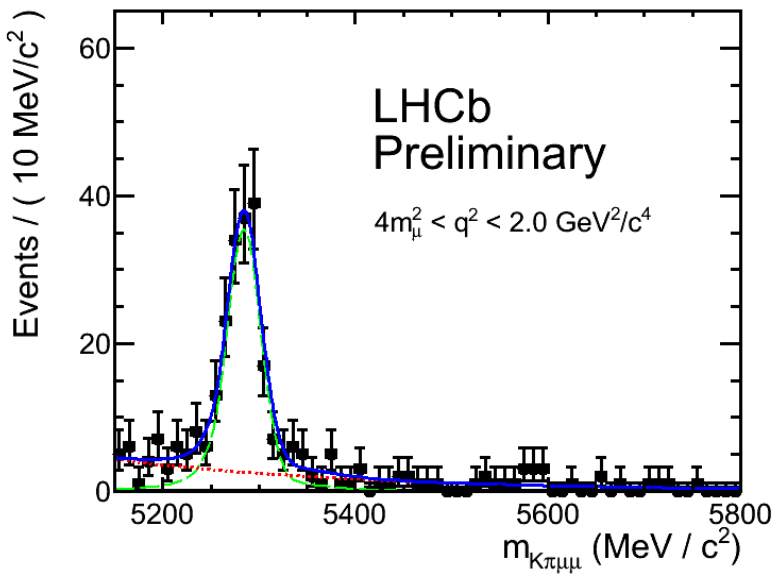
Detector acceptance effects:

- tuning of MC using data driven techniques.
- check MC quality with $B_d\to K^{*}J/\psi$ data control sample.
- **each event is weighted using corrected MC efficiency $\varepsilon(\theta_l, \theta_K, \phi, q^2)$**.

$B \to K^* \mu^+ \mu^-$: angular analysis

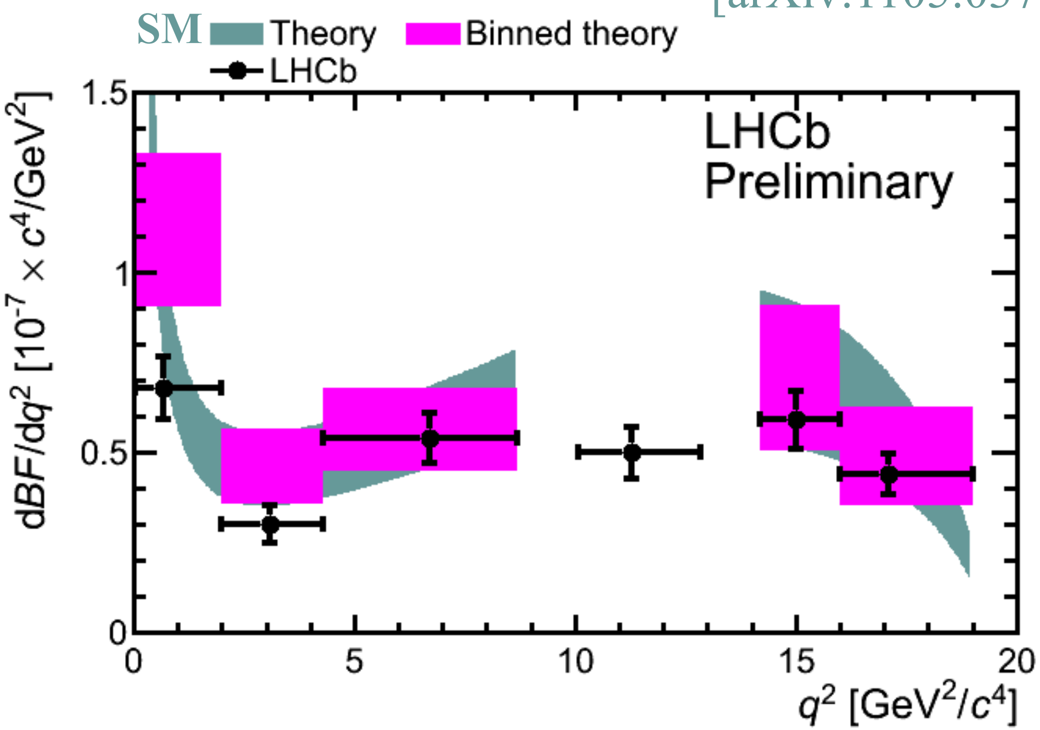
LHCb-CONF-2012-008





- In total, observe 900±34 events in **1 fb^{-1}** data.
- Fitting m($K\pi\mu\mu$) in q^2 bins measure differential BR (normalize to $B \to K^{0*} J/\psi$).
- Compare with **SM predictions**.

[arXiv:1105.0376]



$B \rightarrow K^{*}\mu^{+}\mu^{-}$: angular analysis

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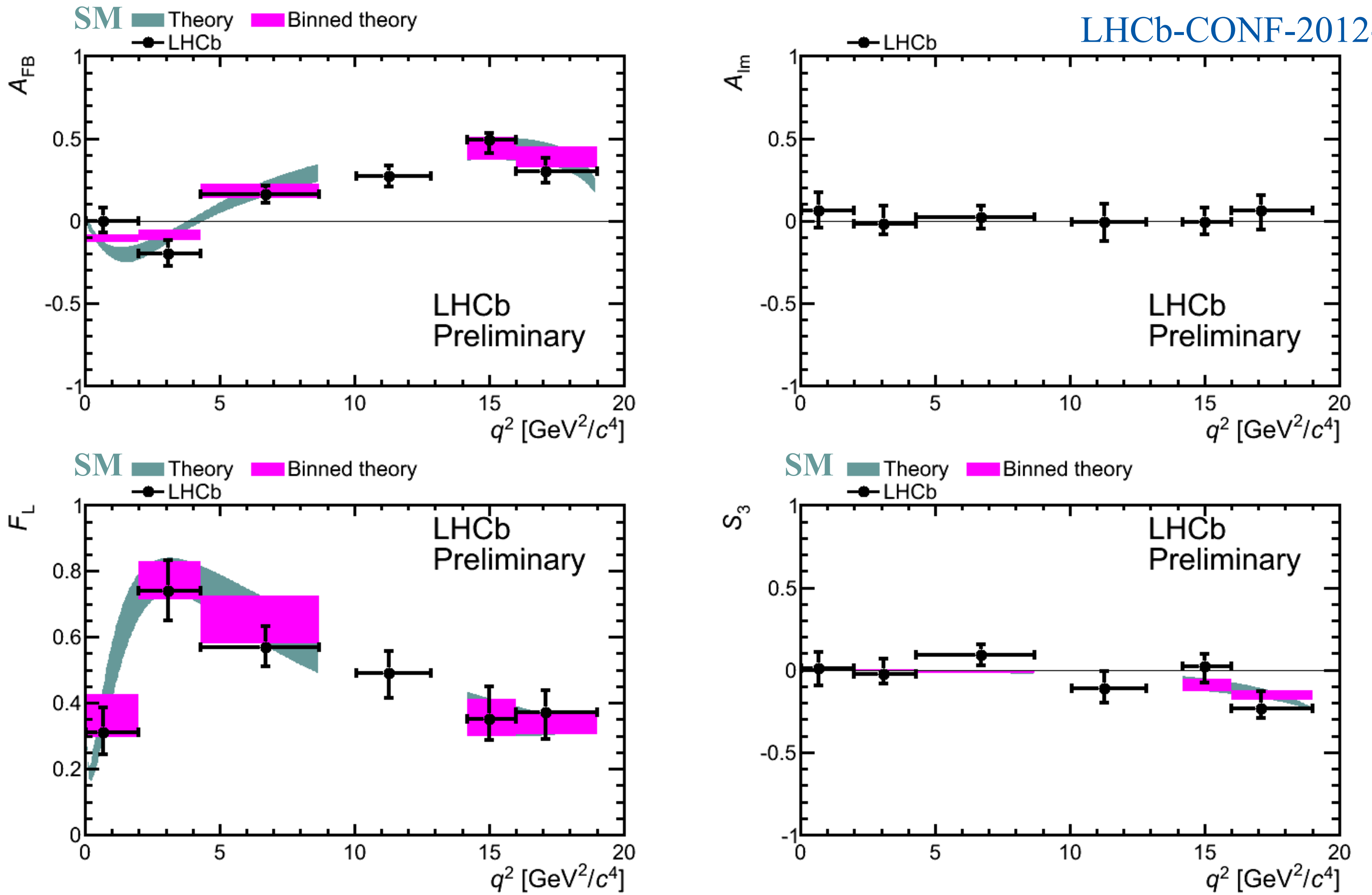
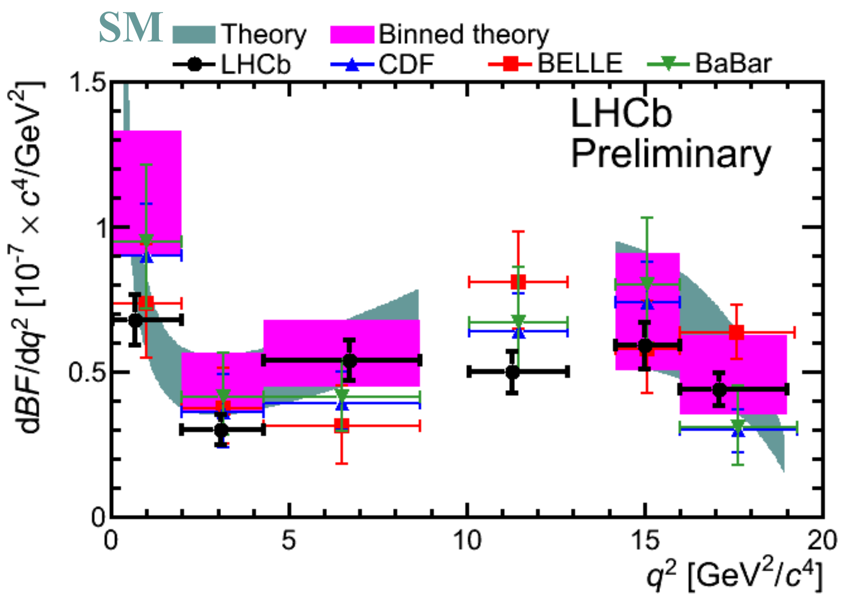
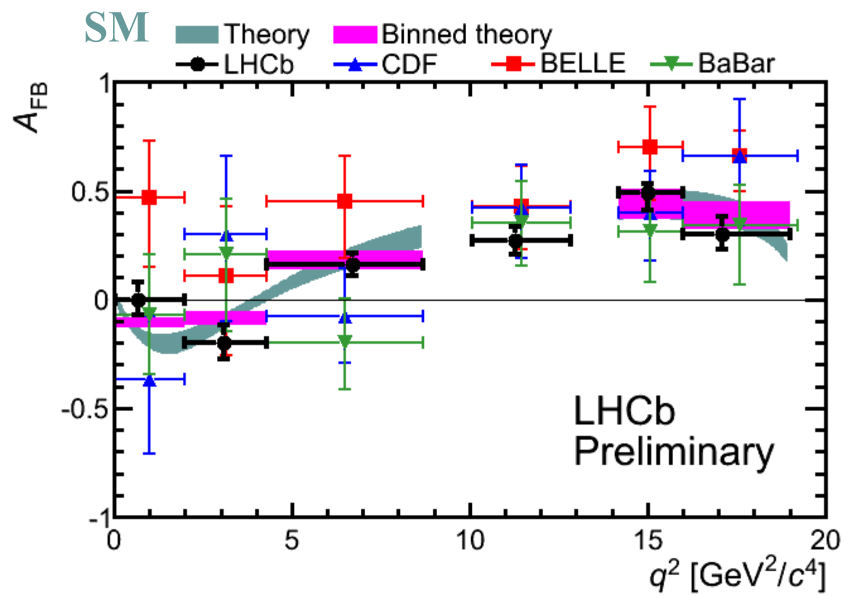
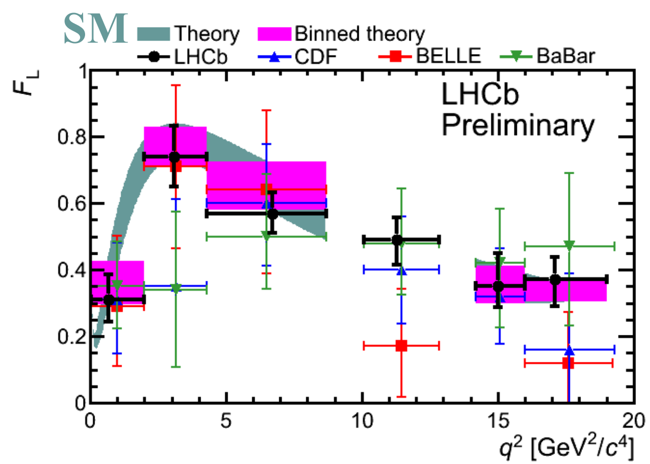


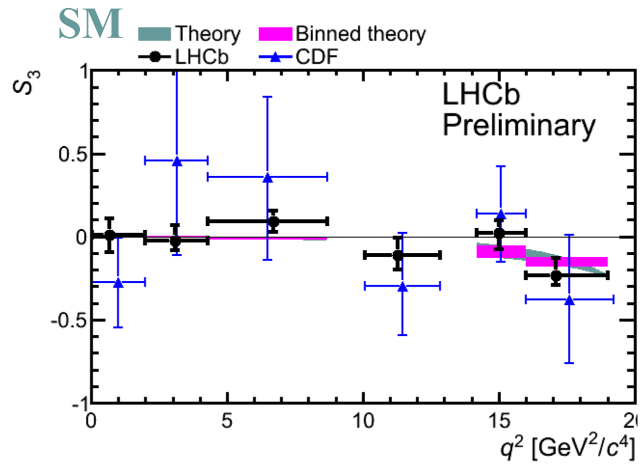
$B \to K^{*}\mu^{+}\mu^{-}$: angular analysis

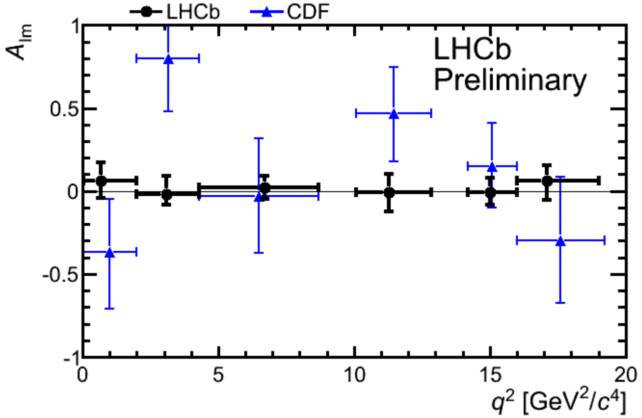
LHCb-CONF-2012-008





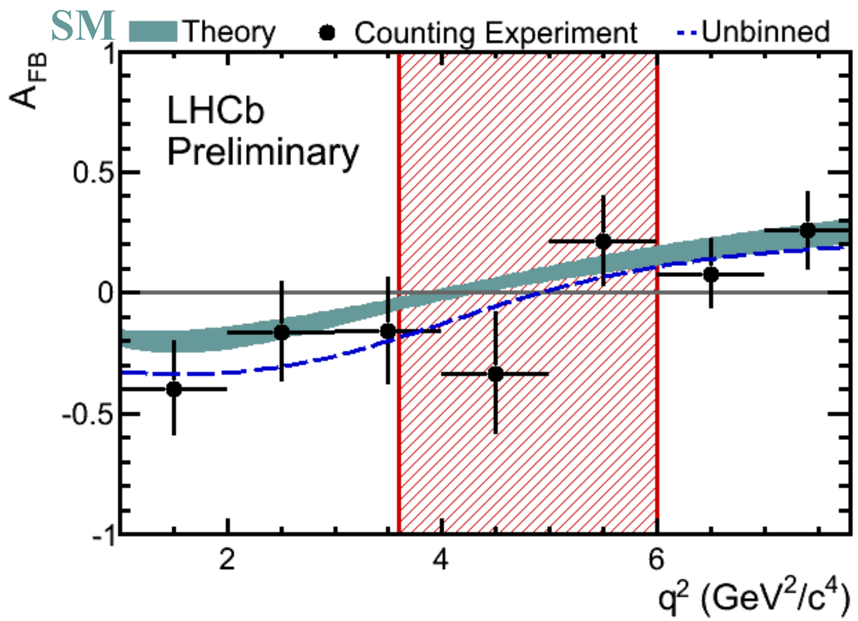


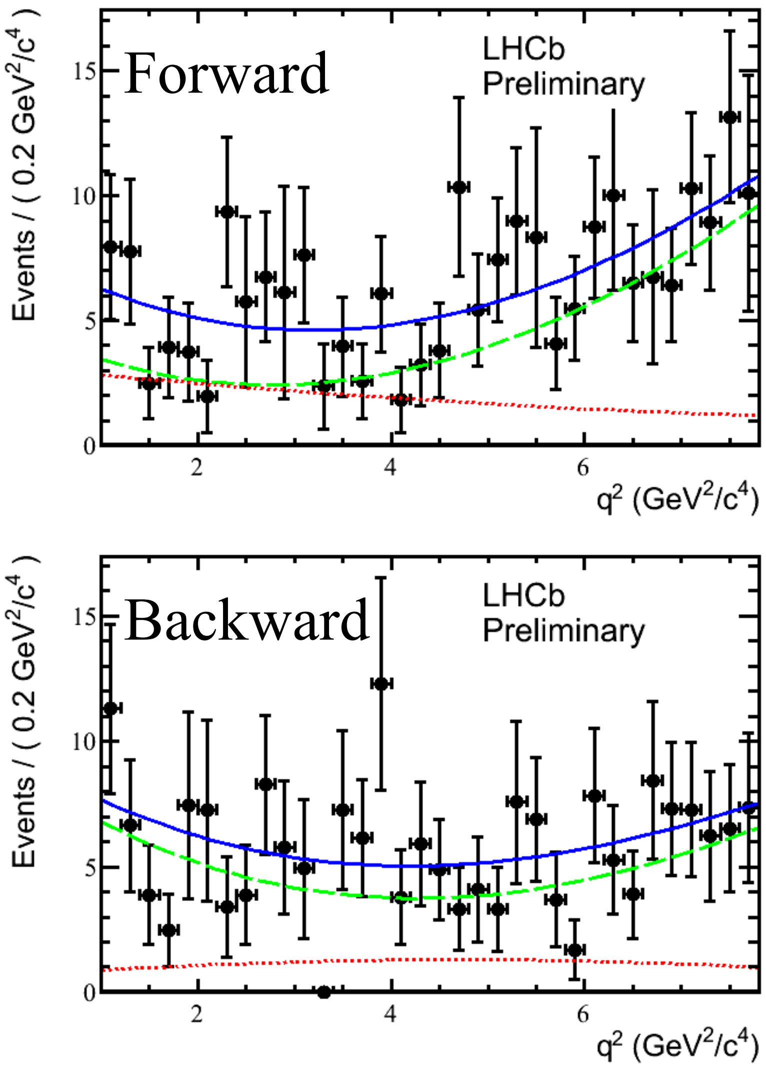




$B \to K^* \mu^+ \mu^-$: angular analysis

LHCb-CONF-2012-008





- In SM A_{FB} changes sign at a well defined q^2 point, predicted with no hadronic uncertainties e.g.: $q_0^2(K^*)=4.36^{+0.33}_{-0.31}$ GeV^2.
[Eur. Phys. J. C 41 (2005) 173-188]

- Extract q_0^2 from a 2D fit to q^2 distribution and the invariant mass M(Kπμμ) of forward and backward events separately: **$4.9^{+1.1}_{-1.3}$ GeV^2** [preliminary]

$B \to K\mu^+\mu^-$: isospin asymmetry

LHCb-PAPER-2012-011, arXiv:1205.3422

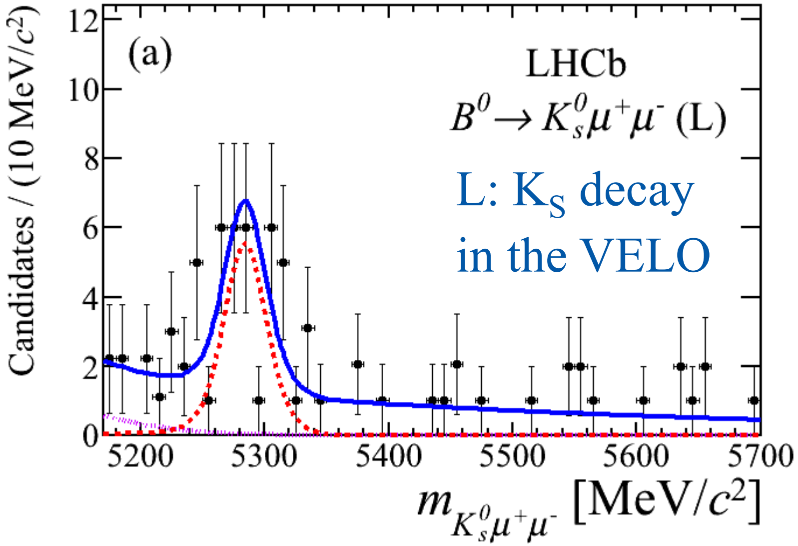
Measure differential BR of four decay modes:

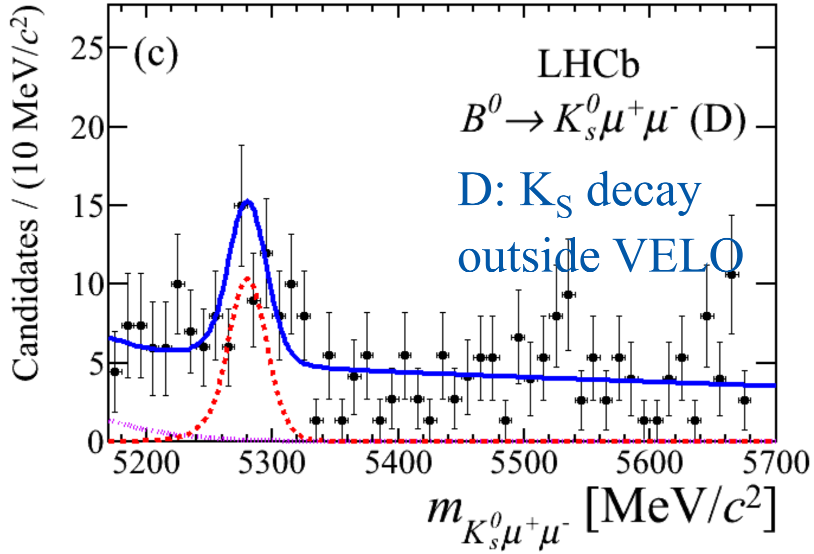
$B^0 \to K_S\mu^+\mu^-$ $B^0 \to (K^{*0} \to K^+\pi^-)\mu^+\mu^-$ $B^+ \to K^+\mu^+\mu^-$ $B^+ \to (K^{*+} \to K_S\pi^+)\mu^+\mu^-$

Predictions for BRs suffer from large hadronic uncertainties; in the asymmetries these contributions cancel at leading order. Define A_I comparing with relevant charged mode:

$$A_I = \frac{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) - \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) + \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}$$

Veto dimuon chamonium resonances; "K_S signal" channel split into L and D categories.





$B \rightarrow K\mu^+\mu^-$: isospin asymmetry

LHCb-PAPER-2012-011, arXiv:1205.3422

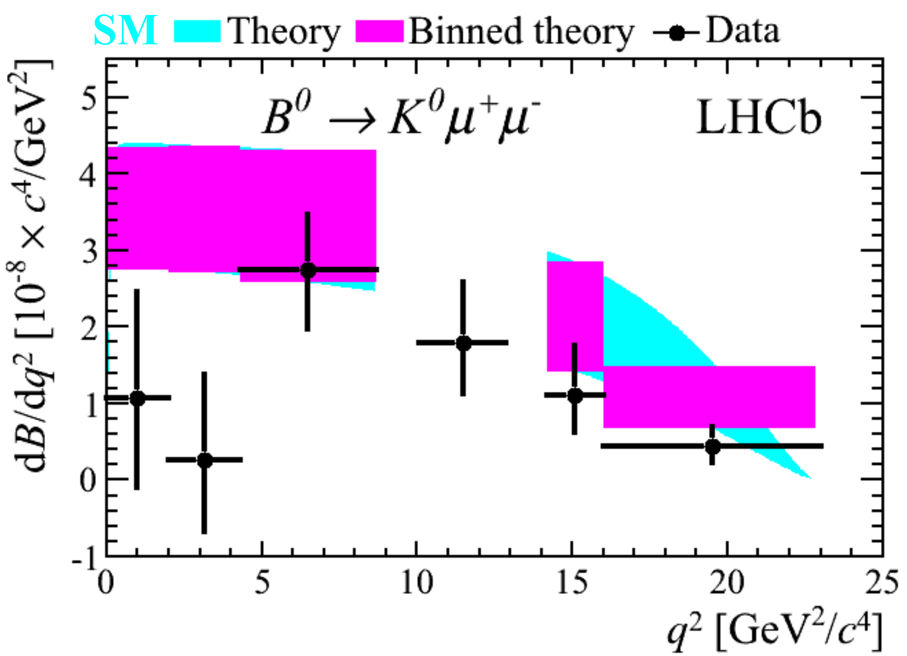
Normalize to $B^0 \rightarrow K^{(*)}(J/\psi \rightarrow \mu^+\mu^-)$ to get BR (stat+syst errors):

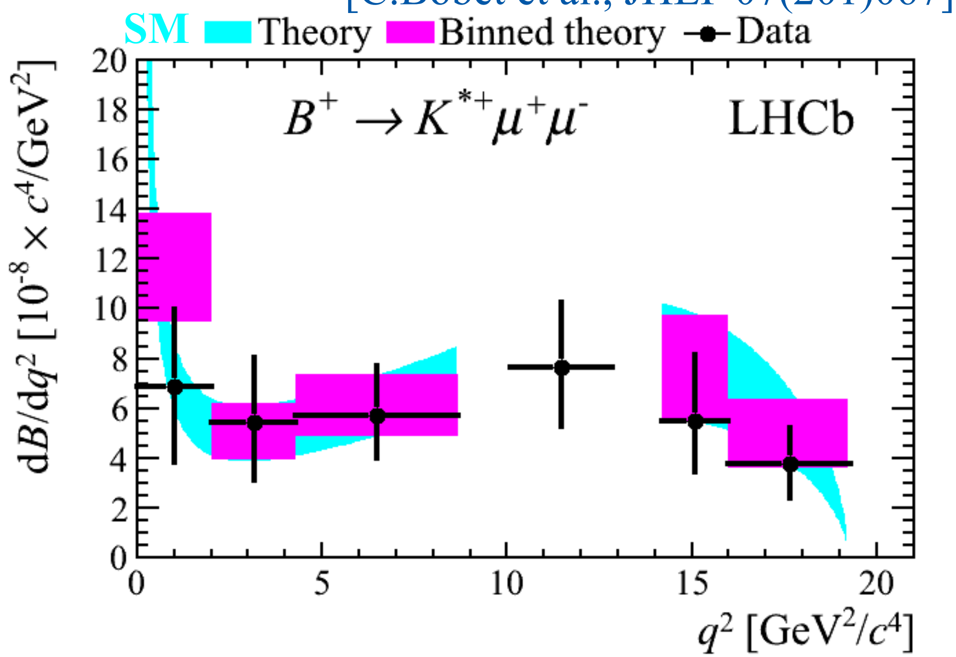
$BR(B^0 \rightarrow K_S\mu^+\mu^-) = (0.31^{+0.07}_{-0.06}) \times 10^{-6}$, **first observation (5.7σ).**

$BR(B^+ \rightarrow K^{*+}\mu^+\mu^-) = (1.16 \pm 0.19) \times 10^{-6}$.

Extract differential BR for $B^0 \rightarrow K_S\mu^+\mu^-$ and $B^+ \rightarrow K^+\mu^+\mu^-$:

[C.Bobet et al., JHEP 07(201)067]



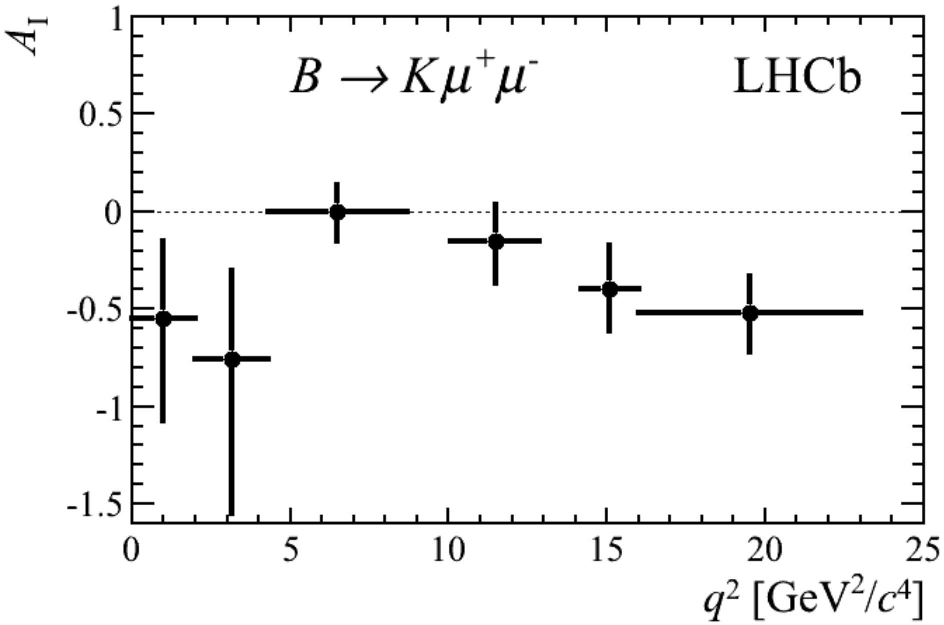


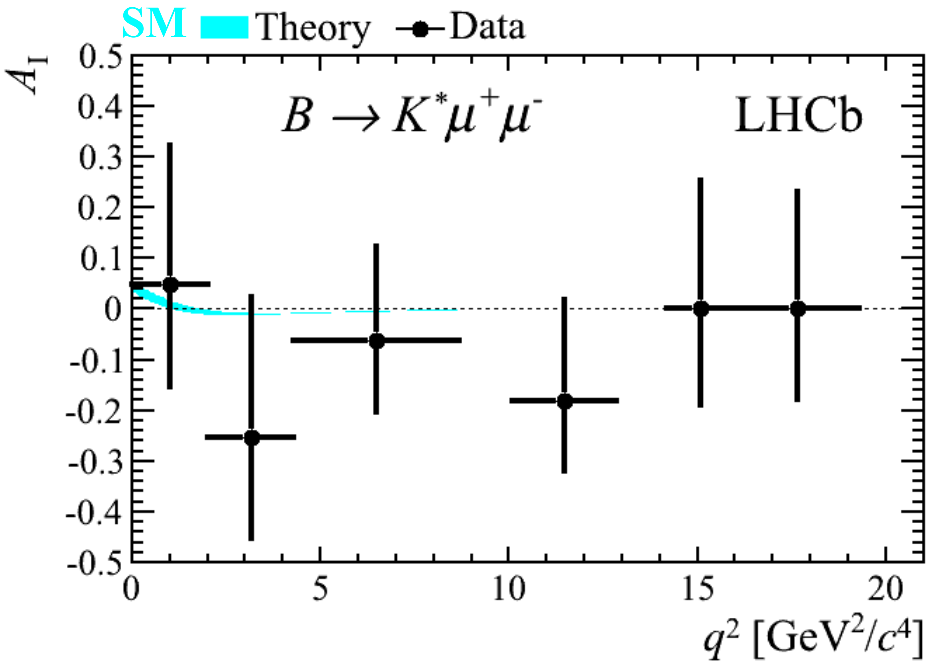
$B \to K\mu^+\mu^-$: isospin asymmetry

LHCb-PAPER-2012-011, arXiv:1205.3422

SM predicts A_I~0; sizable (10%) deviation from 0 only in the low q^2(<1) spectrum.

[T.Feldmann and J.Matias, JHEP 01(2002)074]





Integrated across q^2:

- $A_I(B^+ \to K^{*+}\mu^+\mu^-)$: consistent with zero, as predicted by SM.
- **$A_I(B^0 \to K^0\mu^+\mu^-)$: 4.4σ deviations from zero**;

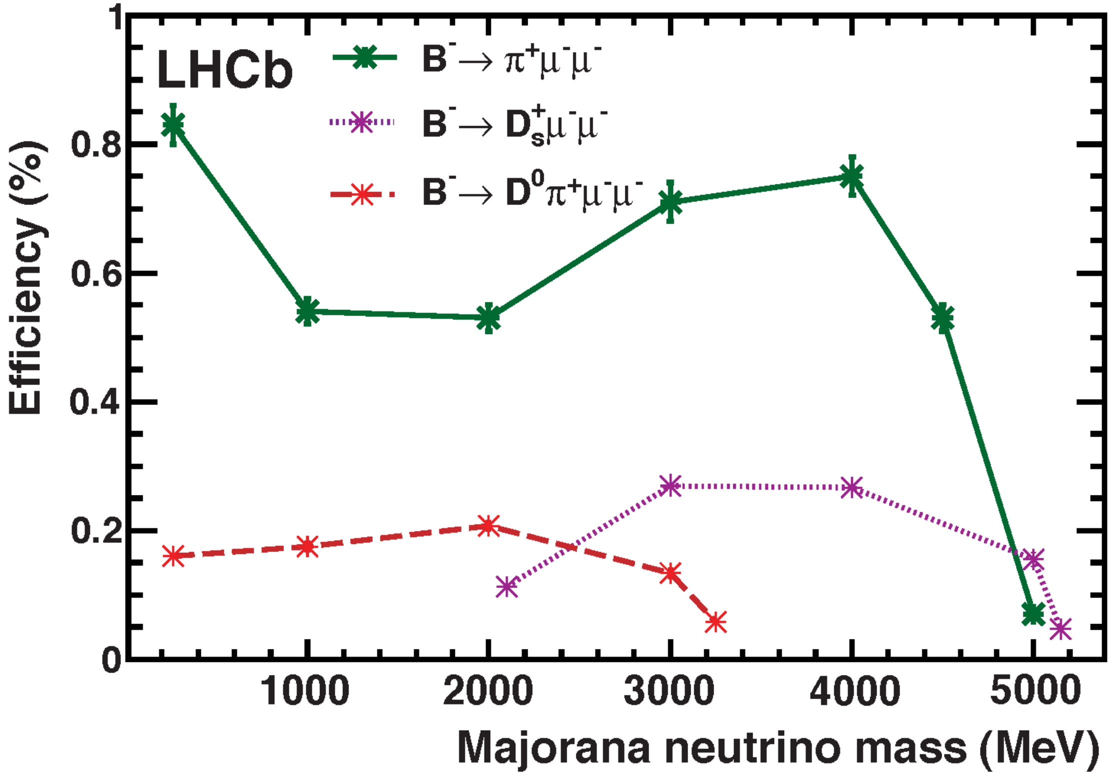
no explanations in or beyond SM.

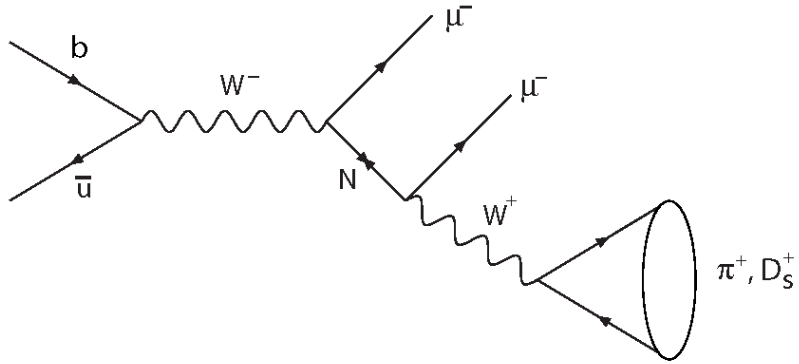
Majorana neutrino from B decays

Phys. Rev. Lett. 108 (2012) 101601, Phys. Rev. D 85, 112004 (2012)

Searches for Majorana neutrinos in $\mathbf{B^+ \to h^- \mu^+ \mu^+}$ or $\mathbf{B^- \to \mu^- \mu^- + hadrons}$:
- $D^{(*)+}\mu^-\mu^-$ final states: mediated by ν_M of any mass;
- final states with π^+, D_s^+ or $D^0\pi^+$: mediated by on-shell ν_M.

Each channel allows to explore different ν_M mass ranges.

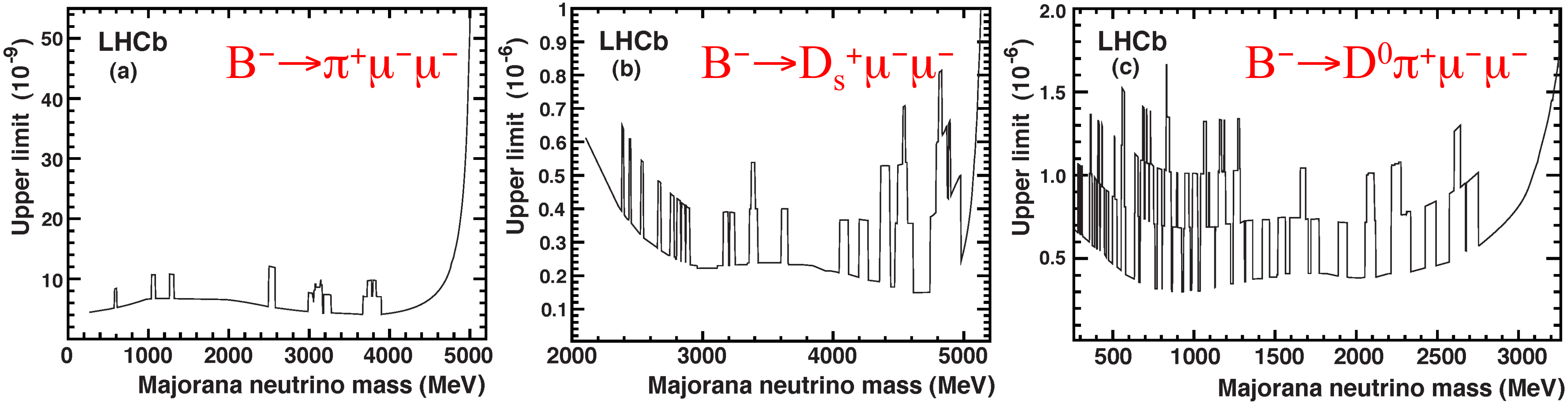




Normalization: channels with same number of muons in the final state and equal track multiplicity

Majorana neutrino from B decays

Phys. Rev. Lett. 108 (2012) 101601, Phys. Rev. D 85, 112004 (2012)

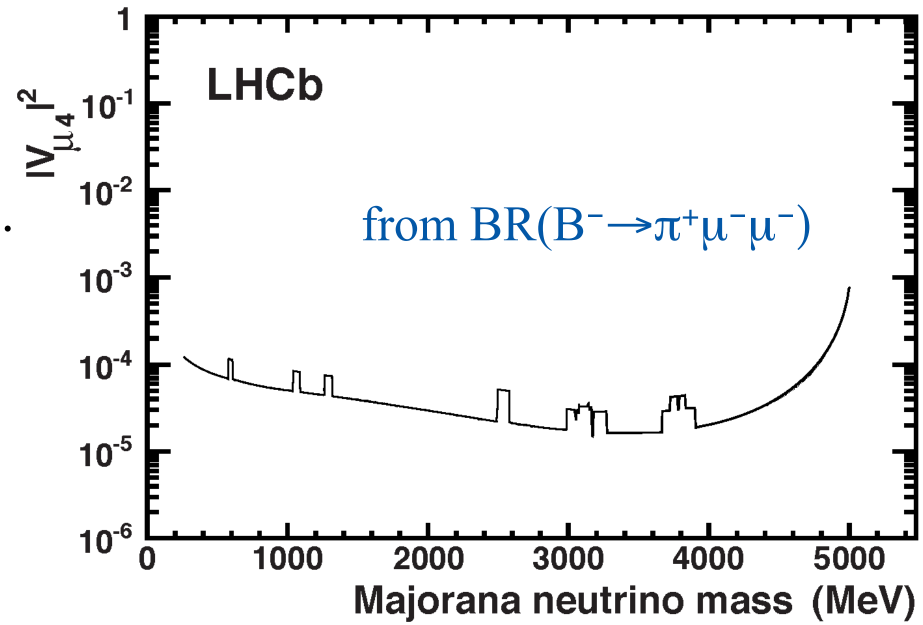


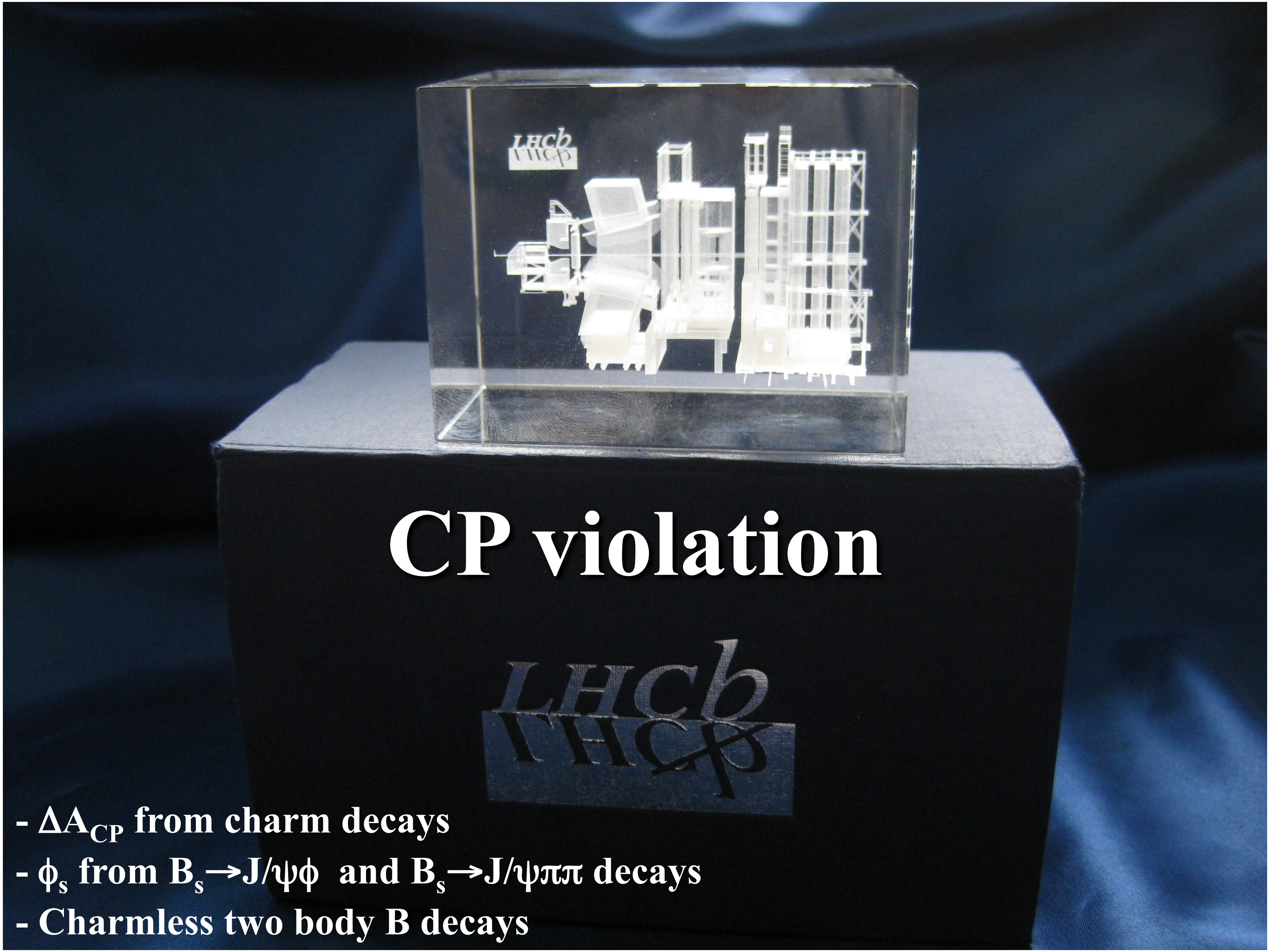
No events found in **0.41 fb^{-1}**.

BR limits at 95% CL: most restrictive to date.

The limit on $B^-\to\pi^+\mu^-\mu^-$ can be used to establish the limits for the coupling $|V_{\mu 4}|$ **complementary to 0vββ searches** which probe (V_{e4}, m_4) plane.

[arXiv: 0901.3589]





CP violation

- ΔA_{CP} from charm decays
- ϕ_s from $B_s \rightarrow J/\psi\phi$ and $B_s \rightarrow J/\psi\pi\pi$ decays
- Charmless two body B decays

Time integrated CP asymmetry: ΔA_{cp}

Measure time integrated CP asymmetries in single Cabibbo suppressed decays: $D \rightarrow \pi^+\pi^-$ and $D \rightarrow K^+K^-$.

PRL 108, 111602 (2012)

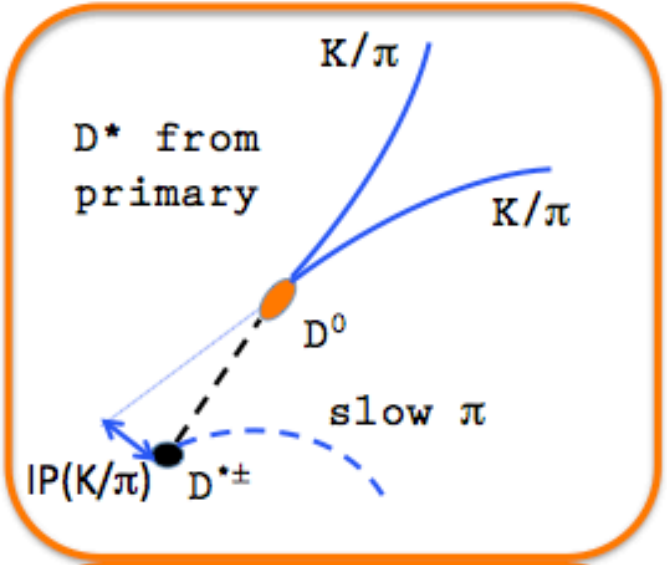
$$\mathcal{A}^f_{CP}(t) = \frac{\Gamma_{D\rightarrow f}(t) - \Gamma_{\overline{D}\rightarrow f}(t)}{\Gamma_{D\rightarrow f}(t) + \Gamma_{\overline{D}\rightarrow f}(t)} \qquad \mathcal{A}^f_{CP} = a^{dir}_{CP}(f) + \frac{\langle t \rangle}{\tau} a^{ind}_{CP}$$

[M.Gersabeck et al. J.Phys. G39 (2012) 045005]

Use **$D^{*\pm} \rightarrow D\pi_s^\pm$ decays**; tag D^0 flavour via "slow pion" charge: $p(\pi_s)$~5 GeV, $p(\pi,K)$~30 GeV.

$$A_{raw}(f) = A_{CP}(f) + A_D(f) + A_D(\pi_s) + A_P(D^{*+})$$

Observed/raw asymmetry includes detector effects and possible D* production asymmetry; **cancel to first order** by measuring difference between $D \rightarrow \pi^+\pi^-$ and $D \rightarrow K^+K^-$:



$$\Delta A_{CP} \equiv A_{raw}(KK) - A_{raw}(\pi\pi) = A_{CP}(KK) - A_{CP}(\pi\pi)$$

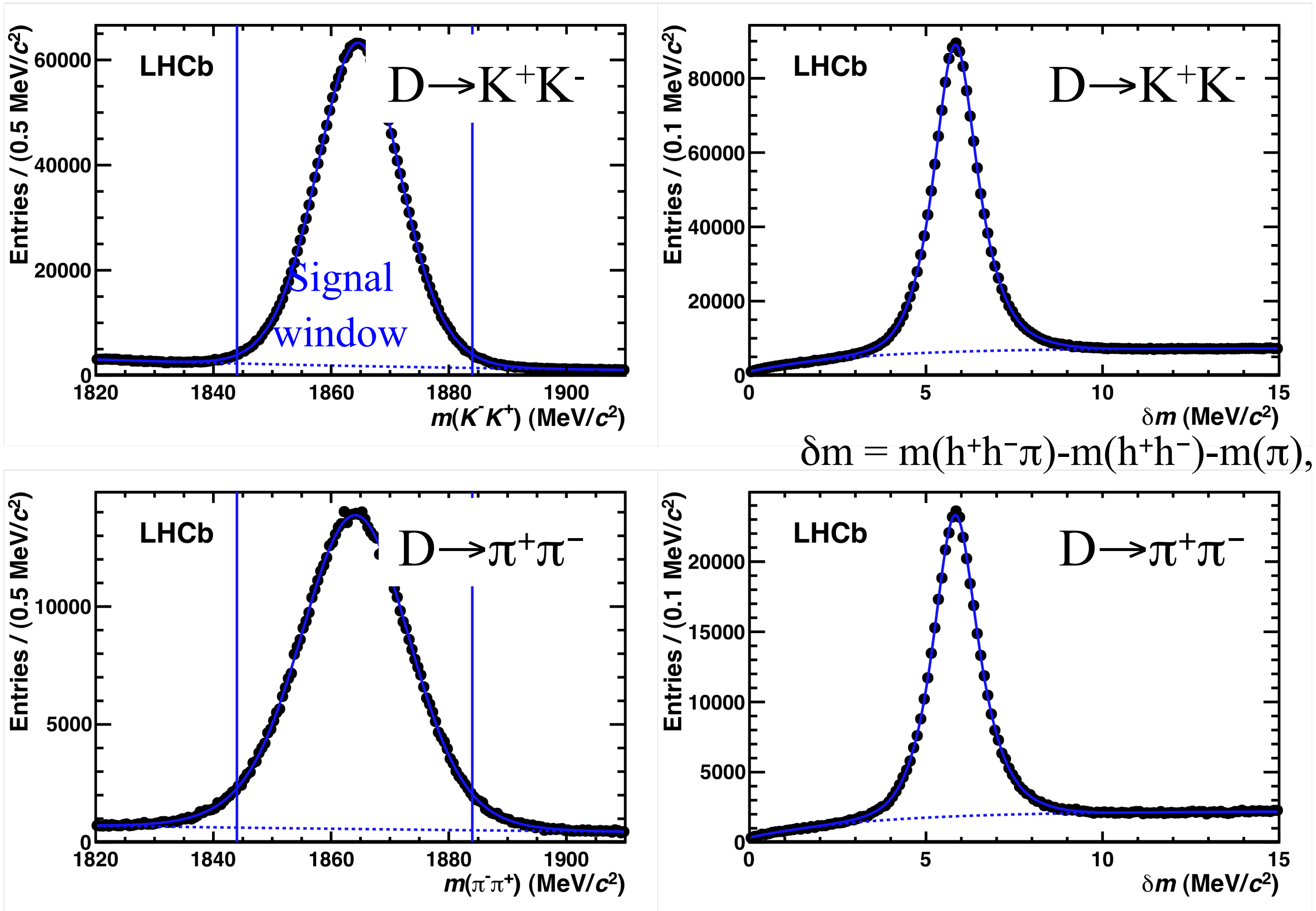
(contribution from possible indirect CPV term are small)

$$= \left[a^{dir}_{CP}(KK) - a^{dir}_{CP}(\pi\pi)\right] + \frac{\Delta\langle t \rangle}{\tau} a^{ind}_{CP}$$

Time integrated CP asymmetry: ΔA_{cp}

PRL 108, 111602 (2012)

From analyzing 2/3 of 2011 data set (0.6 fb^{-1}):
1.4 M $D \to \pi^+\pi^-$ and 0.4M $D \to K^+K^-$ tagged.

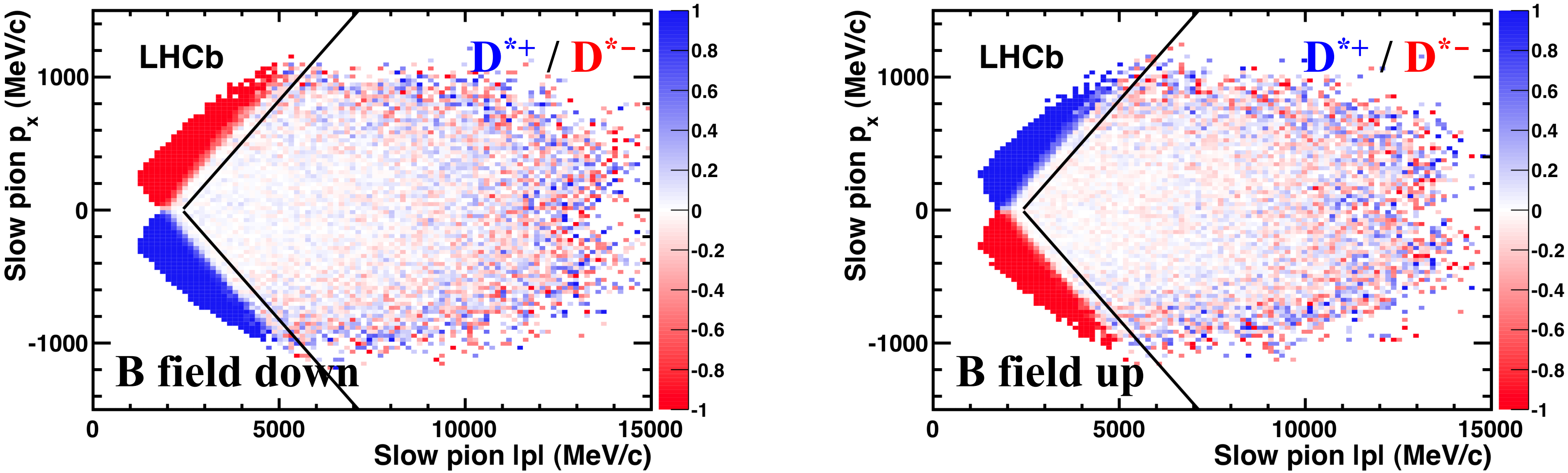


$\delta m = m(h^+h^-\pi) - m(h^+h^-) - m(\pi)$, $h=\pi,K$

ΔA_{cp}: detector asymmetries

PRL 108, 111602 (2012)

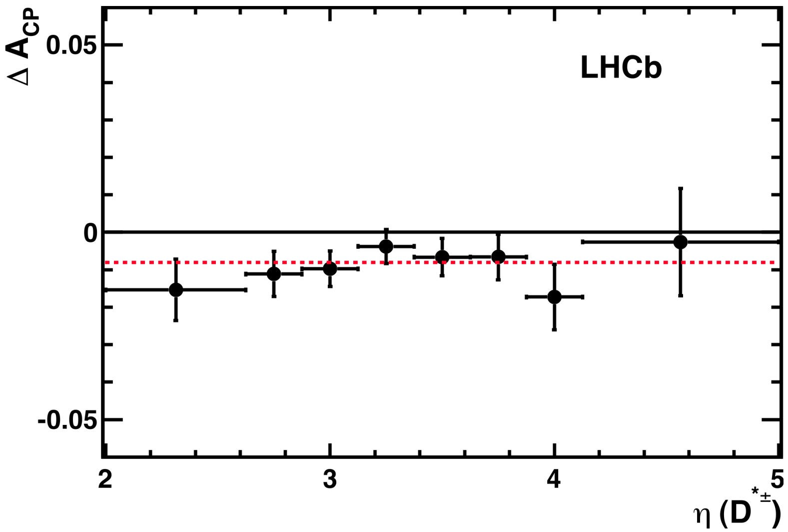
- Analyzing data with both magnet polarities makes detector asymmetries cancel.

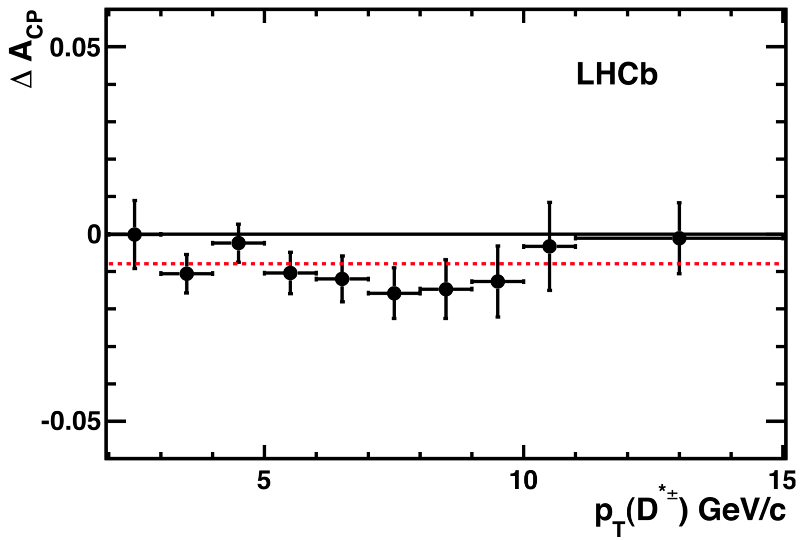


- There are regions of phase space where only D^{*+} or only D^{*-} is kinematically possible; this cause ΔA_{cp}^{RAW} up to 100%.
- Asymmetry independent of D^0 decay mode, but breaks the assumption that raw asymmetries are small (risk of second order effects on efficiency ratio)

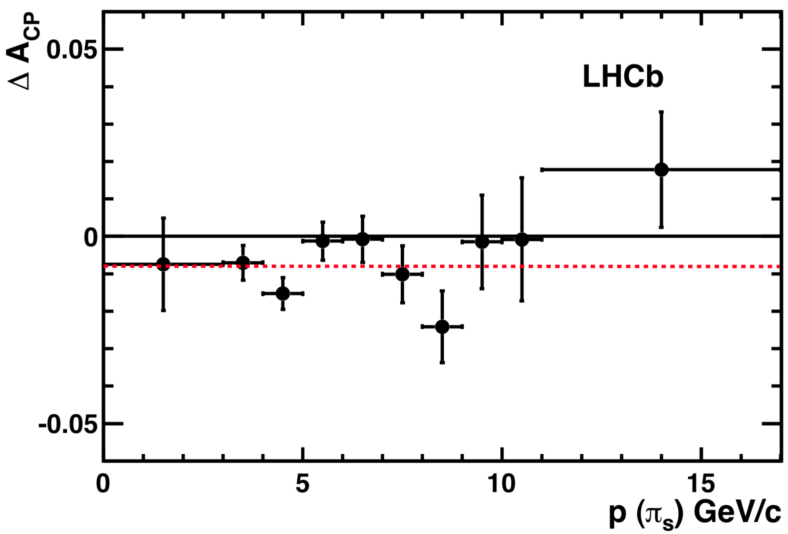
ΔA_{cp}: cross checks

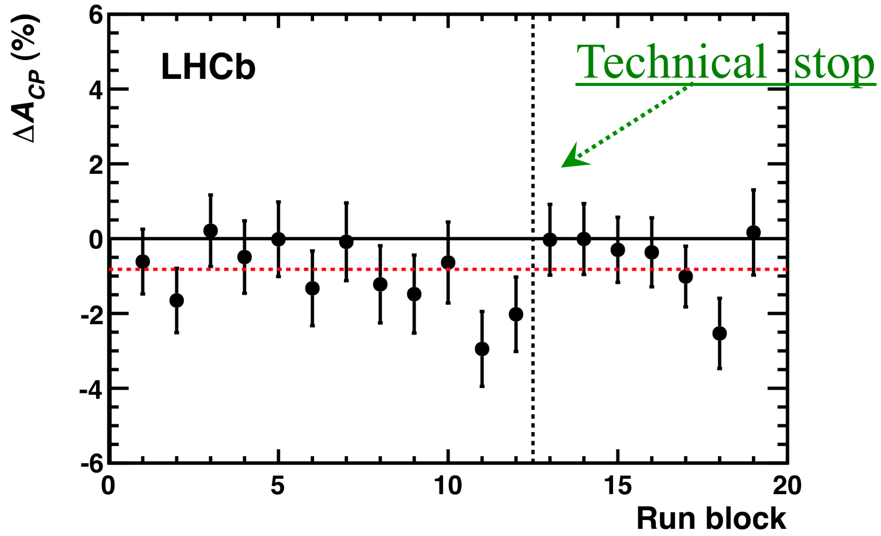
PRL 108, 111602 (2012)





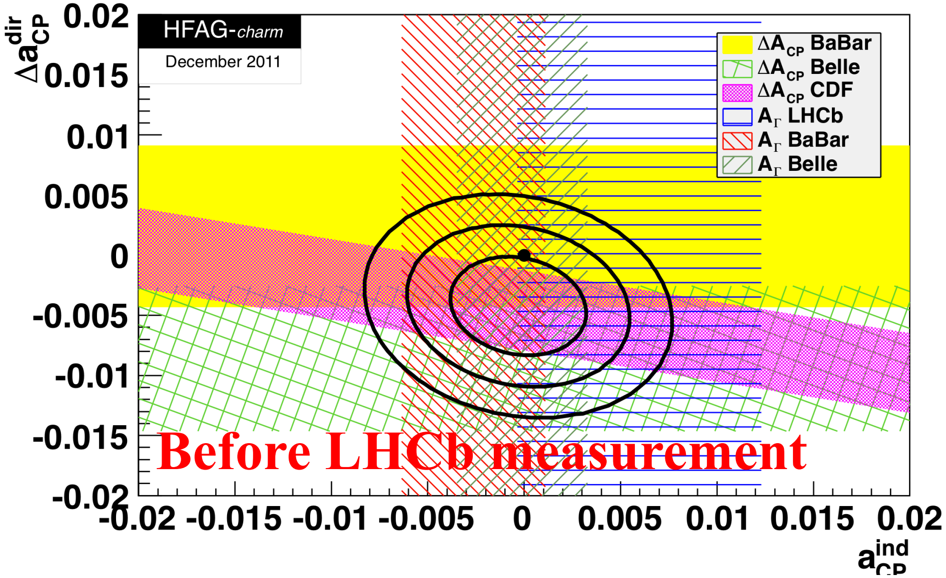
ΔA_{cp} value **should not vary** with kinematics of the D* or along the data taking





ΔA_{cp}: results

PRL 108, 111602 (2012)



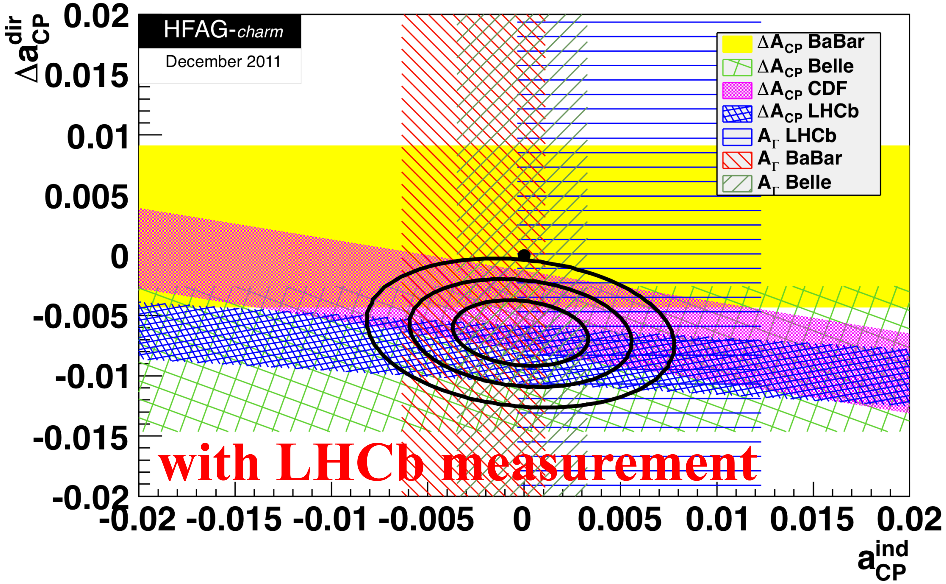
ΔA_{CP} = -0.82±0.21(stat)±0.11(sys) %

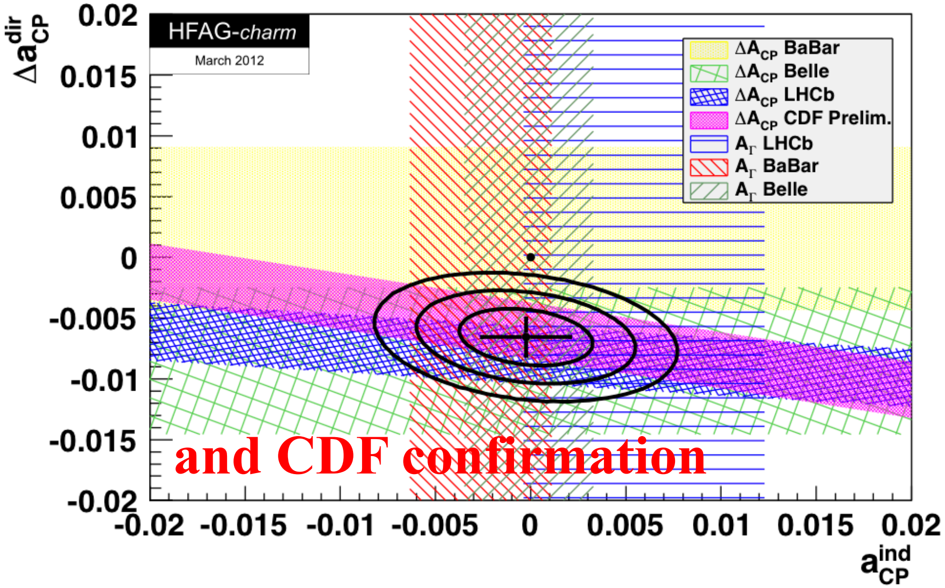
3.5 σ from CP conserving hypothesis

Present WA: CL of (0,0) is 6.1×10^{-5}

ex-ante: too large in SM

ex-post: cannot exclude hadronic uncertainties contributions



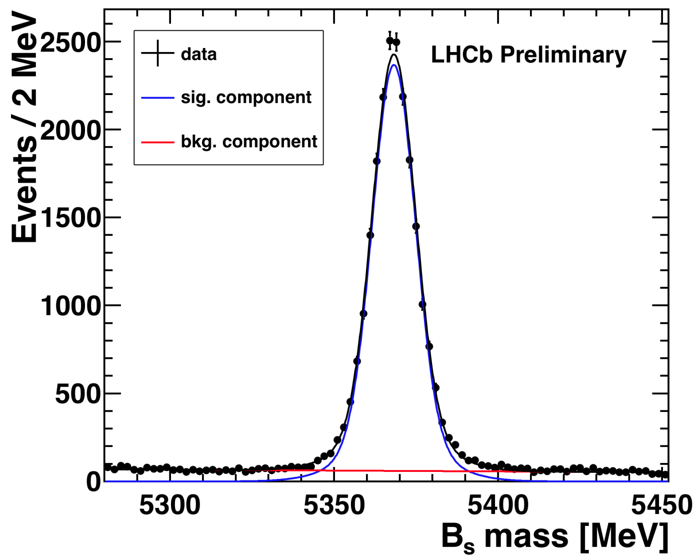


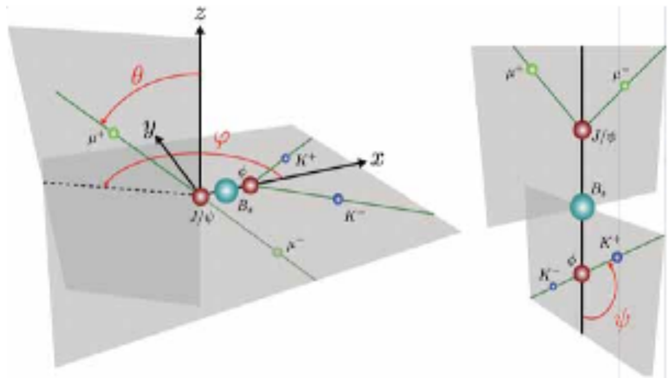
[Plots from HFAG: www.slac.stanford.edu/xorg/hfag/charm/]

CP violation in $B_s \to J/\psi\phi$ decays

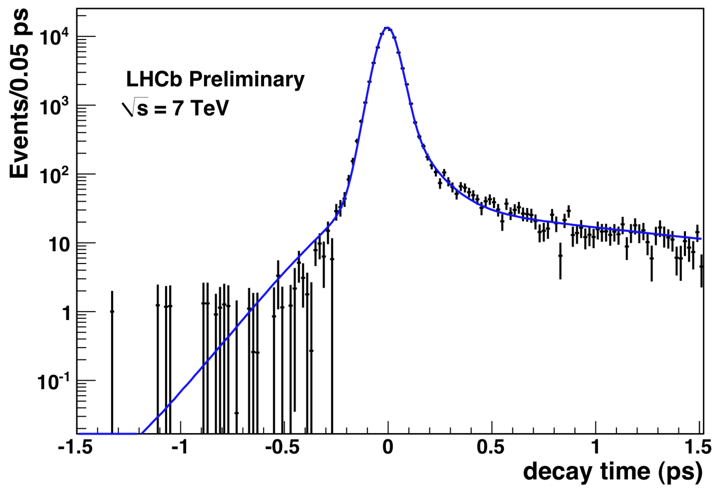
LHCb-CONF-2012-002 (1 fb^{-1} update of arXiv:1112.3183)

- In SM is dominated by tree level diagram; small CPV in SM arises from phase of B^0_s oscillations. NP phases in box diagram could dominate over SM contributions.
- **21200 $B_s \to J/\psi\phi$ candidates** ($J/\psi \to \mu\mu$, $\phi \to KK$).
- Mixture of CP-odd and CP-even components in the final state: full angular analysis (transversity basis).



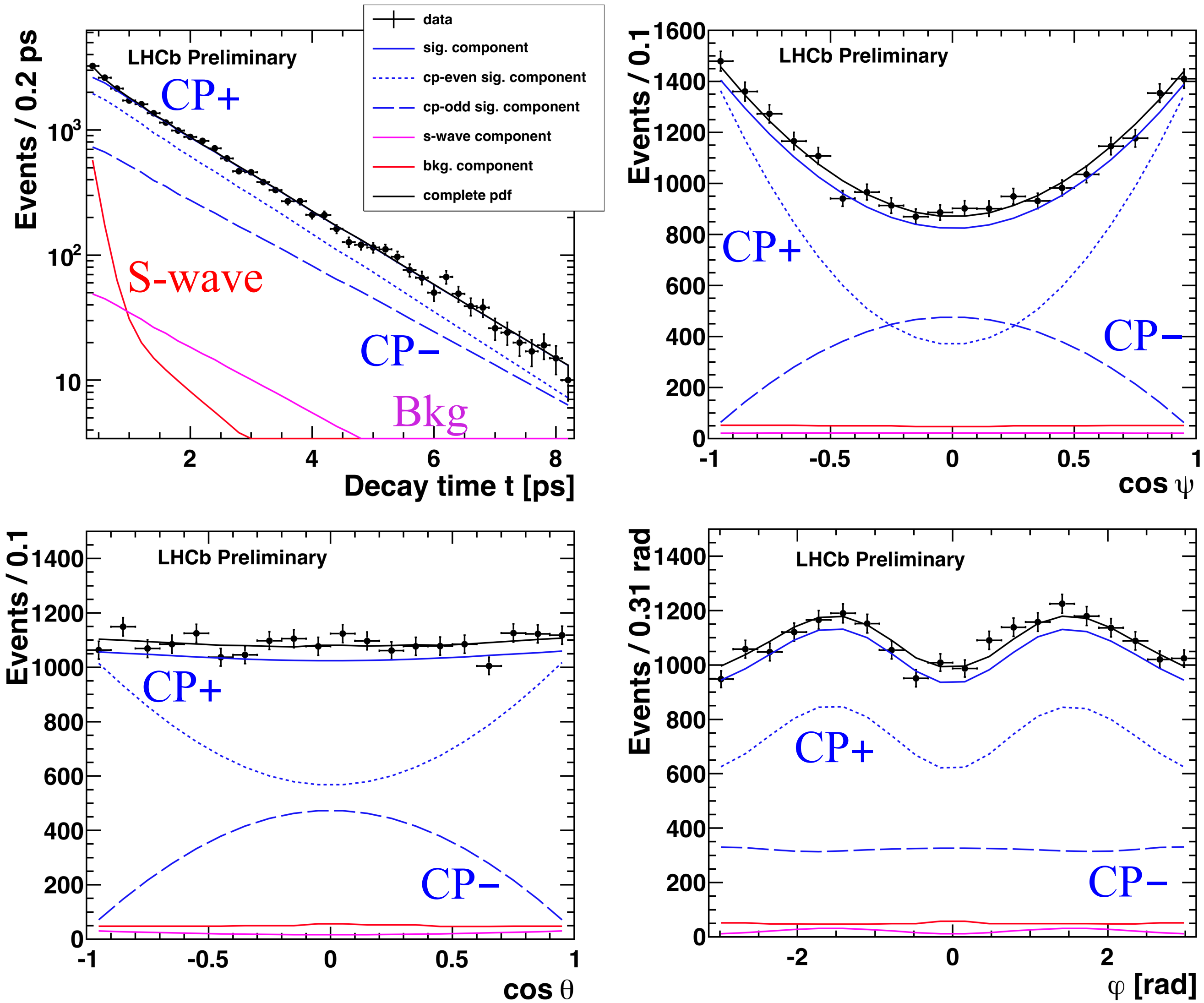


- **Good** understanding of angular acceptance.
- Time acceptance and resolution (~45 fs) <u>from data</u> ($J/\psi \to \mu\mu$ prompt candidates).
- Effective tagging efficiency **from $B \to J/\psi K$ data**.



CP violation in $B_s \to J/\psi\phi$ decays

LHCb-CONF-2012-002



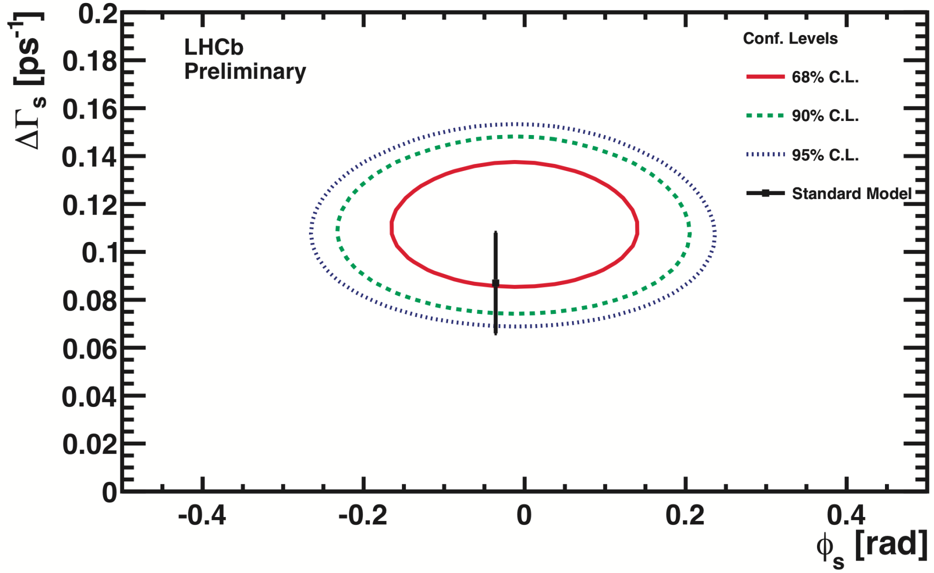
Fit projections for decay time and angles within $m_B \pm 20$ MeV.

Fit results:

Parameter	Value	Stat.	Syst.
Γ_s [ps^{-1}]	0.6580	0.0054	0.0066
$\Delta\Gamma_s$ [ps^{-1}]	0.116	0.018	0.006
$\|A_\perp(0)\|^2$	0.246	0.010	0.013
$\|A_0(0)\|^2$	0.523	0.007	0.024
F_S	0.022	0.012	0.007
$\delta_\perp$ [rad]	2.90	0.36	0.07
$\delta_\parallel$ [rad]	[2.81, 3.47]		0.13
δ_s [rad]	2.90	0.36	0.08
ϕ_s [rad]	-0.001	0.101	0.027

(preliminary)

CP violation in $B_s \to J/\psi\phi$ decays



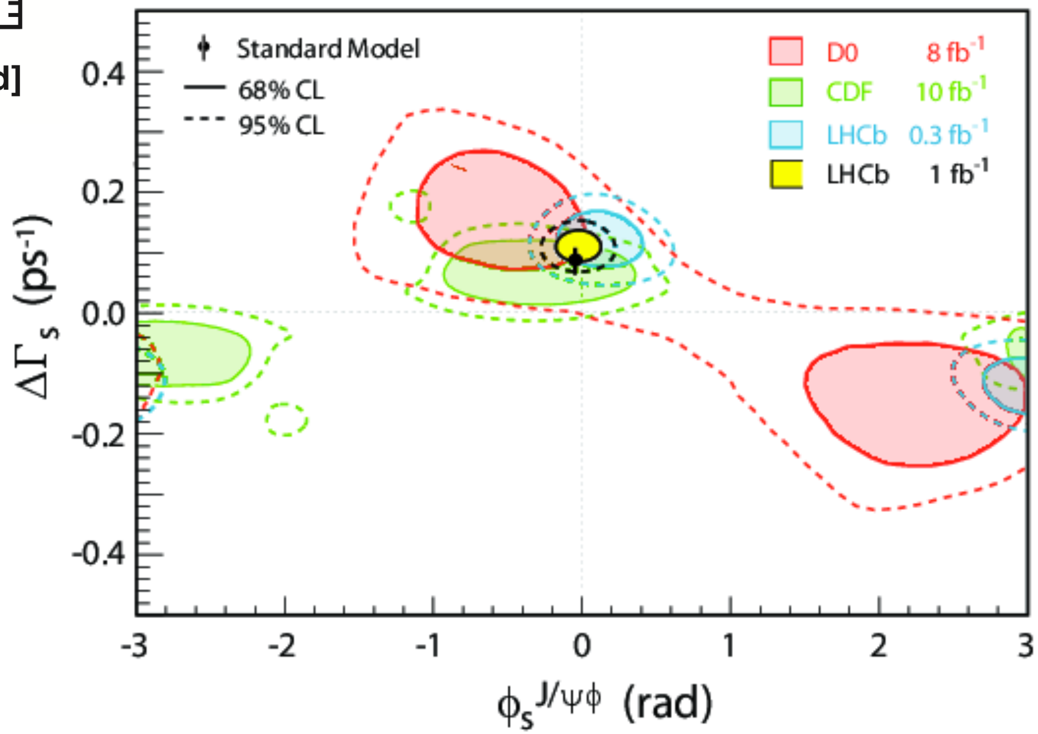
LHCb-CONF-2012-002

$$\phi_s = -0.001 \pm 0.101 \;(\text{stat}) \pm 0.027 \;(\text{syst}) \text{ rad},$$
$$\Gamma_s = 0.6580 \pm 0.0054 \;(\text{stat}) \pm 0.0066 \;(\text{syst}) \text{ ps}^{-1}$$
$$\Delta\Gamma_s = 0.116 \pm 0.018 \;(\text{stat}) \pm 0.006 \;(\text{syst}) \text{ ps}^{-1}$$

(preliminary)

- Measurement with 1 fb^{-1} 2011 data confirms small CPV in B^0_s oscillations.

- Ambiguity for $\phi_s \to \pi-\phi_s$, $\Delta\Gamma_s \to -\Delta\Gamma_s$ + strong phase changes, solved by LHCb

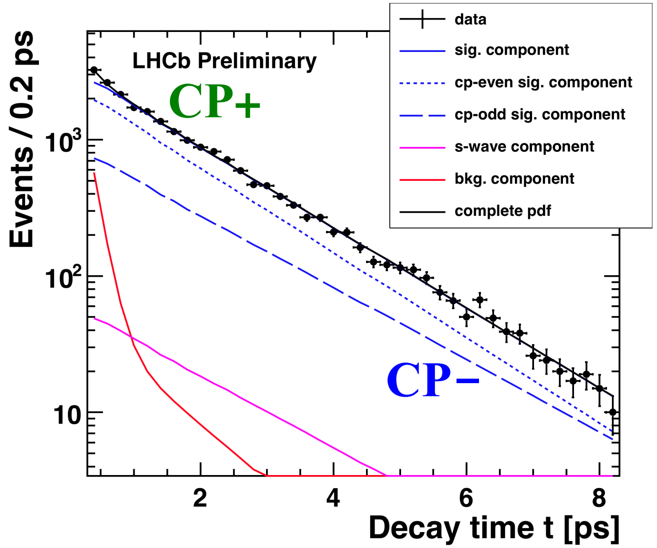


Sign of $\Delta\Gamma_s = \Gamma_L - \Gamma_H$ with $B_s \to J/\psi K^+K^-$

PRL 108 241801 (2012)

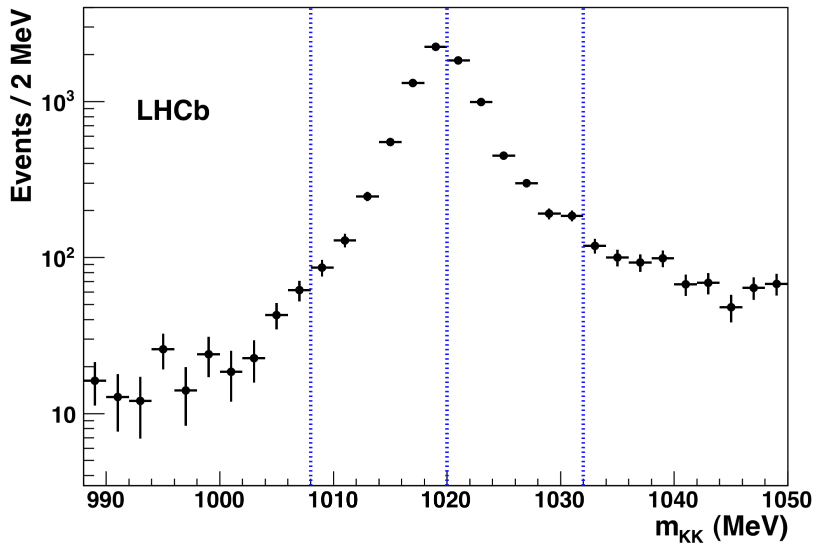
Two solutions for $(\Delta\Gamma_s,\phi_s)$: the time-dependent differential decay rates are invariant under $(\phi_s,\Delta\Gamma_s)\to(\pi-\phi_s,-\Delta\Gamma_s)$ + strong phase transformations.

- τ(**CP+**)<τ(**CP-**): the mass eigenstate ~**CP+** decay faster than ~**CP-**.



Solution I (ϕ_s~0) Light~**CP+** Heavy~**CP-**: $\Gamma_L>\Gamma_H$ $\Delta\Gamma_s>0$.

Solution II (ϕ_s~π) Heavy~**CP+** Light~**CP-**: $\Gamma_H>\Gamma_L$ $\Delta\Gamma_s<0$.

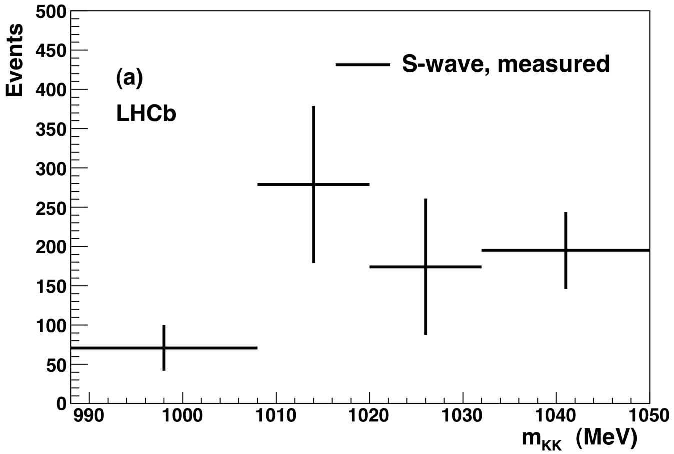


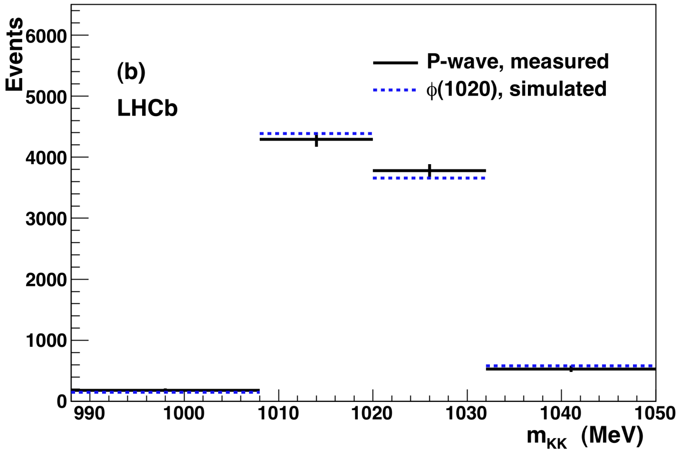
In $B_s\to J/\psi K^+K^-$ decays, the total decay amplitude is a coherent sum of S-wave and P-wave contributions.

Phases behave differently as a function of m_{KK} near $\phi(1020)$ mass region.

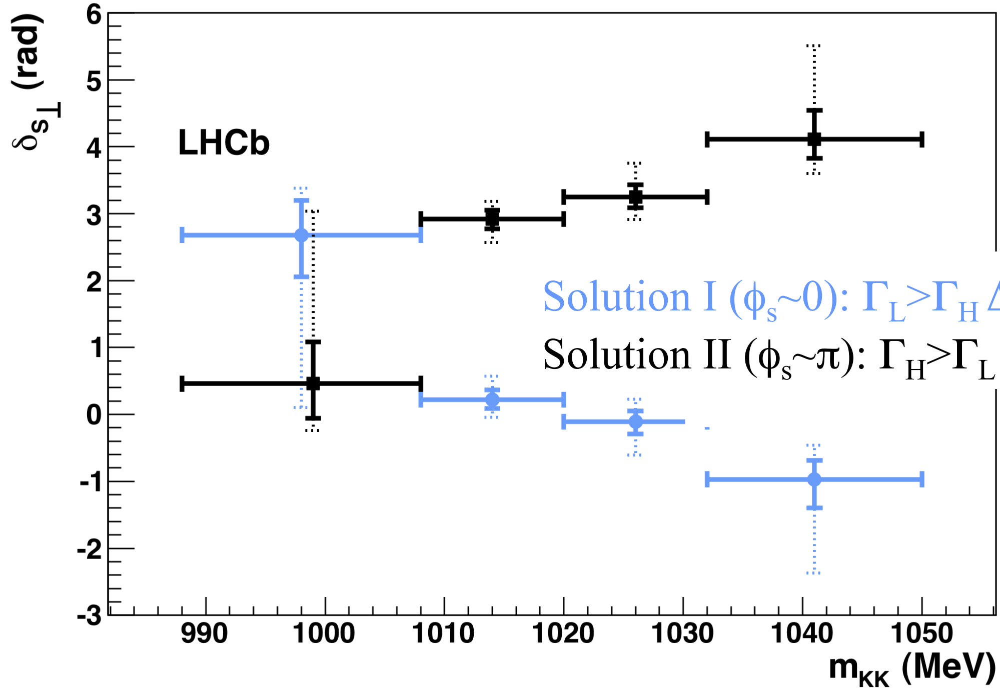
Sign of $\Delta\Gamma_s = \Gamma_L - \Gamma_H$ with $B_s \to J/\psi K^+K^-$

PRL 108 241801 (2012)





For the $(\Delta\Gamma_s,\phi_s)$ physical solution the phase difference, $\delta_{S\text{-}P}$, **decrease** through the $\phi(1020)$ m_{KK} region.



Solution I (ϕ_s~0): $\Gamma_L>\Gamma_H$ $\Delta\Gamma_s>0$

Solution II (ϕ_s~π): $\Gamma_H>\Gamma_L$ $\Delta\Gamma_s<0$

The negative trend of Solution I has 4.7 σ significance.

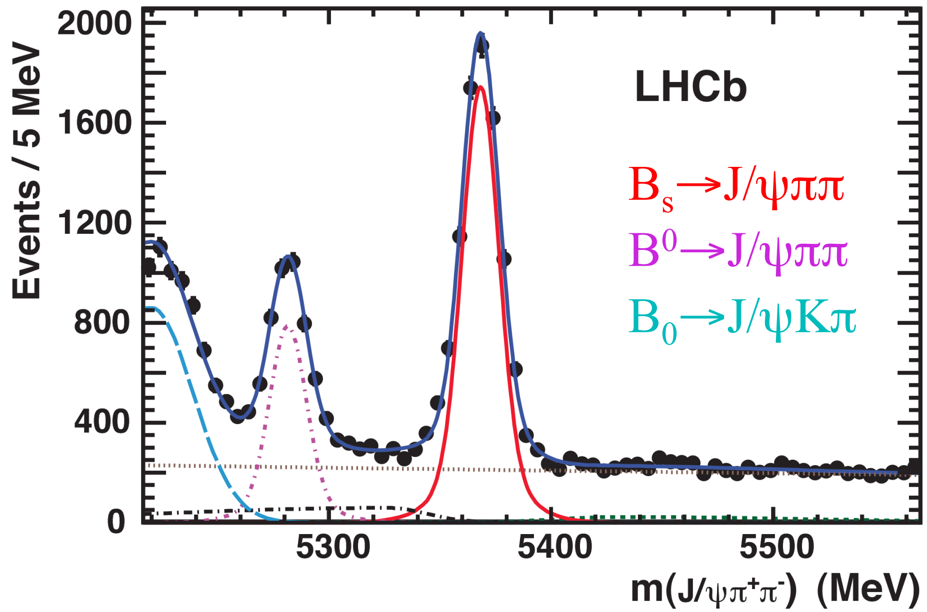
In the B^0_s system the **CP+** mass eigenstate is lighter and decay faster than CP− (similar to neutral K system).

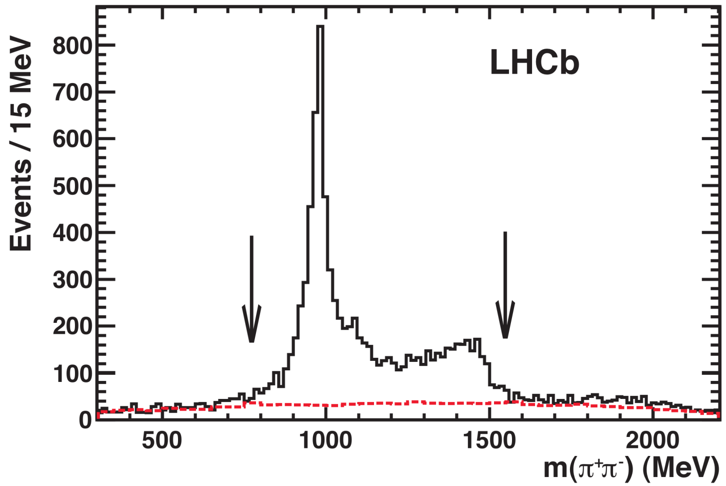
CP violation in $B_s \rightarrow J/\psi\pi\pi$ decays

Previous analysis $B_s \rightarrow J/\psi f_0(980)$. [PLB 707 (2012) 497]

LHCb-PAPER-2012-006, arXiv:1204.5675

- Now use wider $m(\pi\pi)$ range: $B_s \rightarrow J/\psi\pi\pi$.
- BDT selection + maximum likelihood fit to time and mass: **7400 events in 1 fb^{-1}**.
- From Dalitz analysis of resonant $m(\pi\pi)$ structure, measure **almost pure CP-odd** final state (>97.7% at 95%CL).
- Decay time acceptance and resolution from data.





Result: $\phi_s = -0.019^{+0.173+0.004}_{-0.174-0.003}$

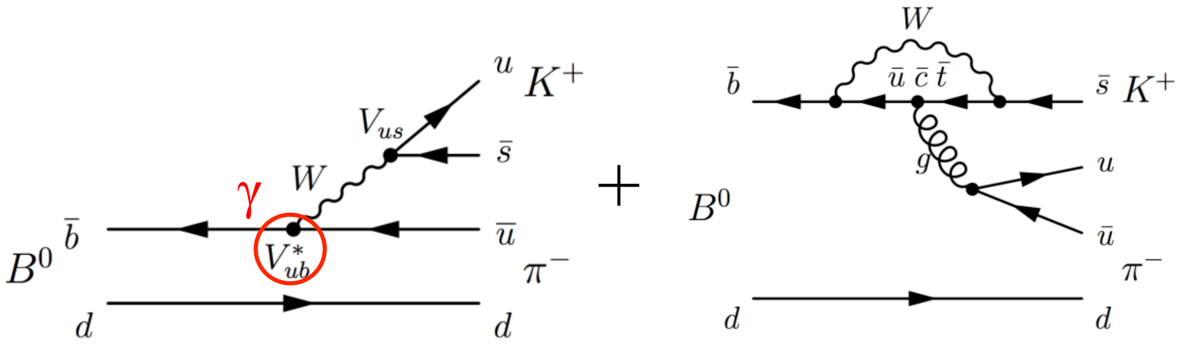
Combining (joint fit to data) with 1 fb^{-1} $B_s \rightarrow J/\psi\phi$ result [LHCb-CONF-2012-002]:

ϕ_s **= -0.002±0.083(stat)±0.027(syst) rad**.

Consistent with SM prediction.

CP Violation in $B_{s,d} \to hh$ decays

PRL 108, 201061 (2012)



- Several diagrams contribute to the decay amplitudes: tree, strong and EW penguins, annihilation and exchange topologies. NP can contribute to penguin loop
- Important interplay among all B→hh channels

Decay mode	Contributing diagrams
$B^0 \to \pi^+\pi^-$	T, P, PA, P^C_{EW}, E
$B^0 \to K^+\pi^-$	T, P, P^C_{EW}
$B^0_s \to \pi^+K^-$	T, P, P^C_{EW}
$B^0_s \to K^+K^-$	T, P, PA, P^C_{EW}, E
$B^0 \to K^+K^-$	PA, E
$B^0_s \to \pi^+\pi^-$	PA, E

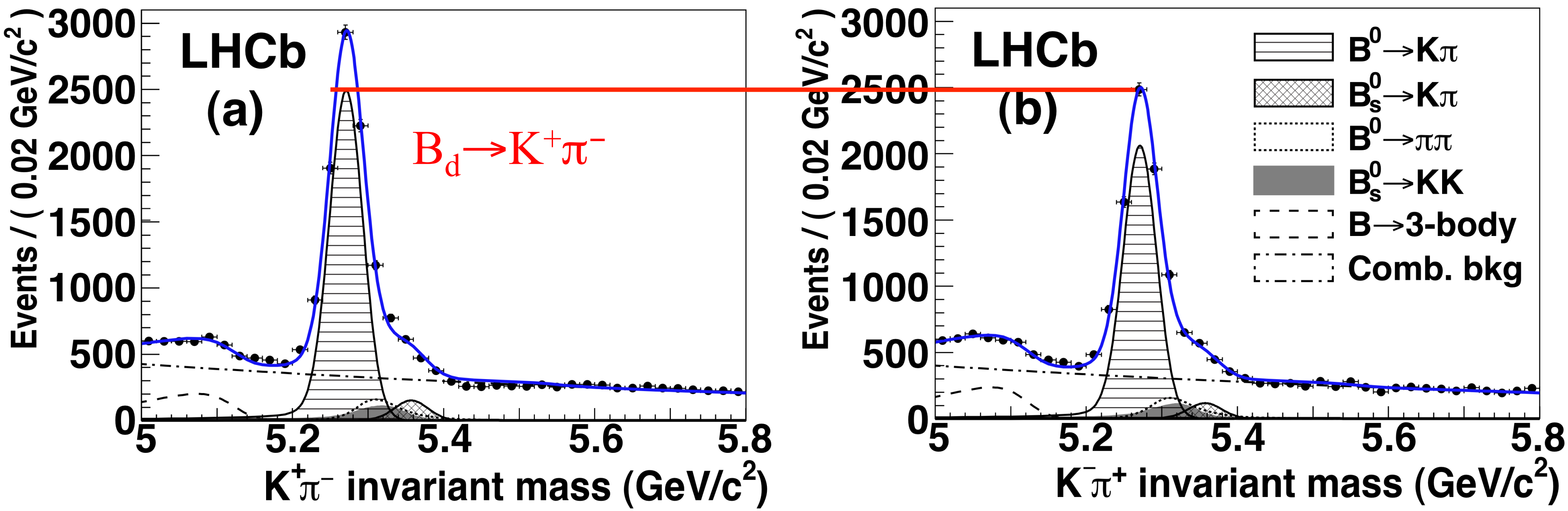
Sensitive to V_{ub} phase (γ CKM angle)

Measure the untagged CP asymmetry for B_d and B_s decays

CP Violation in $B_d \to K\pi$ decays

PRL 108, 201061 (2012)

$$\mathcal{A}_{\mathrm{raw}} = \mathcal{A}_{CP} + \mathcal{A}_{\mathrm{det}} + \kappa \cdot \mathcal{A}_{\mathrm{prod}}$$



Detector asymmetry: determined from D's, 0.2% from reconstruction, suppressed by B field flip, 1% from interaction cross-section

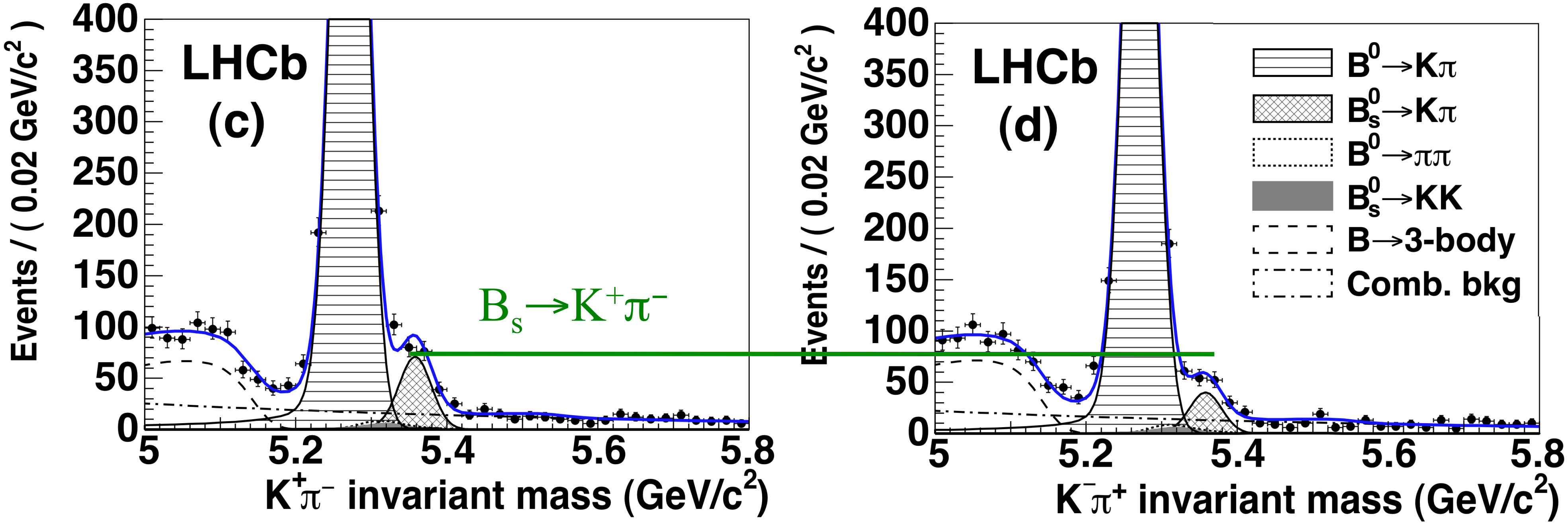
Production asymmetry: measured in $B_d \to J/\psi K^{*0}$, A_{PROD}~1%, diluted (30% in B_d), mixing proper time acceptance, vanish in B_s case

Correction **measured on data**: **$\Delta(B_d \to K^+\pi^-) = -0.007 \pm 0.006$**.

CP Violation in $B_s \to K\pi$ decays

PRL 108, 201061 (2012)

$$\mathcal{A}_{\rm raw} = \mathcal{A}_{CP} + \mathcal{A}_{\rm det} + \kappa \cdot \mathcal{A}_{\rm prod}$$



Detector asymmetry: determined from D's, 0.2% from reconstruction, suppressed by B field flip, 1% from interaction cross-section

Production asymmetry: measured in $B_d \to J/\psi K^{*0}$, A_{PROD}~1%, diluted (30% in B_d), mixing proper time acceptance, vanish in B_s case

Correction **measured on data**: **$\Delta(B_s \to K^+\pi^-) = -0.010 \pm 0.002$**.

CP Violation in $B_{s,d} \to K\pi$ decays: results

PRL 108, 201061 (2012)

$$A_{CP}(B_s^0 \to \pi K) = \frac{\Gamma(\bar{B}_s^0 \to \pi^- K^+) - \Gamma(B_s^0 \to \pi^+ K^-)}{\Gamma(\bar{B}_s^0 \to \pi^- K^+) + \Gamma(B_s^0 \to \pi^+ K^-)}$$

A_{CP}= 0.27 ±0.08(stat) ±0.02(syst) [0.35 fb^{-1}]

First 3σ evidence for CPV in B_s decays.

Systematic dominated by B mass modeling.

$$A_{CP}(B^0 \to K\pi) = \frac{\Gamma(\bar{B}^0 \to K^- \pi^+) - \Gamma(B^0 \to K^+ \pi^-)}{\Gamma(\bar{B}^0 \to K^- \pi^+) + \Gamma(B^0 \to K^+ \pi^-)}$$

A_{CP}= -0.088 ±0.011(stat) ±0.008(syst) [0.35 fb^{-1}]

Most precise (5σ) observation for CPV in hadronic machine.

Systematic dominated by correction of production and detector asymmetry

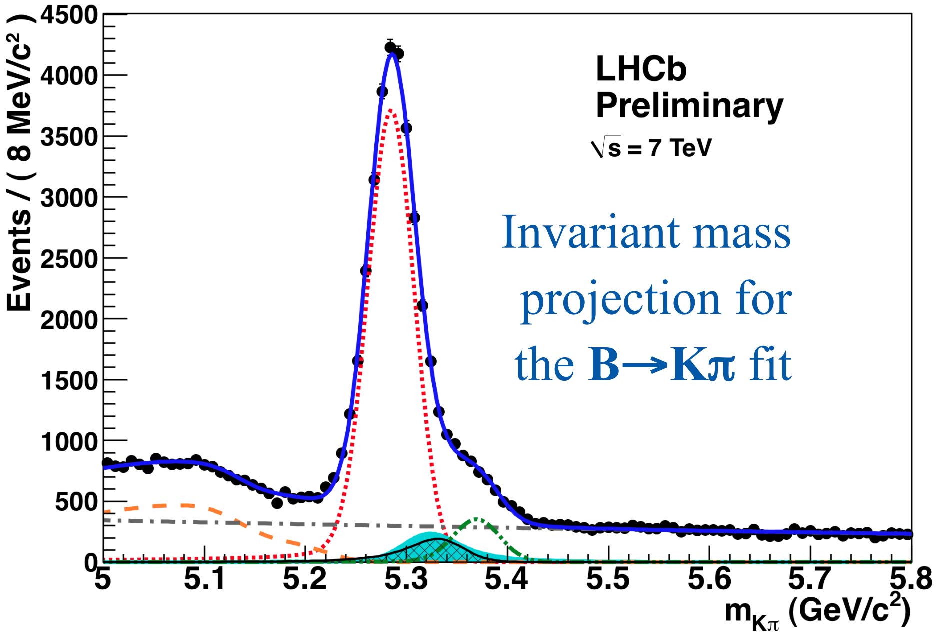
Time dependent CPV in $B_{s,d} \to hh$ decays

- First measurement of time dependent CPV in $B^0 \to \pi^+\pi^-$ and $B^0_s \to K^+K^-$ at LHCb.
- Experimental knowledge not clear for $B^0 \to \pi^+\pi^-$ (measured by **BaBar** and **Belle**) never measured for $B^0_s \to K^+K^-$.

LHCb-CONF-2012-007

$$\mathcal{A}_{CP}(t) = \frac{A_f^{\mathrm{dir}}\cos(\Delta m t) + A_f^{\mathrm{mix}}\sin(\Delta m t)}{\cosh\left(\frac{\Delta\Gamma}{2}t\right) - A_f^{\Delta\Gamma}\sinh\left(\frac{\Delta\Gamma}{2}t\right)}$$

Experiment	$A_{\pi\pi}^{\mathrm{dir}}$	$A_{\pi\pi}^{\mathrm{mix}}$	$\rho(A_{\pi\pi}^{\mathrm{dir}}, A_{\pi\pi}^{\mathrm{mix}})$
BABAR	$0.25 \pm 0.08 \pm 0.02$	$-0.68 \pm 0.10 \pm 0.03$	0.06
Belle	$0.55 \pm 0.08 \pm 0.05$	$-0.61 \pm 0.10 \pm 0.04$	0.15
HFAG average	0.38 ± 0.06	-0.65 ± 0.07	0.08



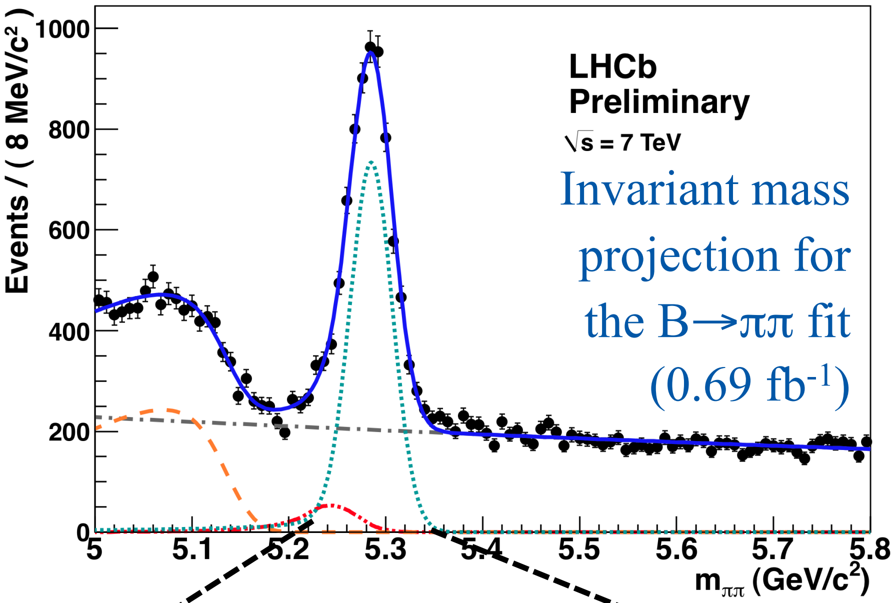
Invariant mass projection for the **B→Kπ** fit

From an unbinned maximum likelihood 2D (mass and time) determine decay time, final state and flavour tagging: **$B^0 \to K\pi$**, **$B_s \to K\pi$**, combinatorial, **3-body**, **$B^0 \to \pi\pi$ and $B_s \to KK$ cross-feed**.

From large stat. $B \to K\pi$ sample, determine **tagging performance** (efficiencies and mistag rates) and **production asymmetries**.

Time dependent CPV in $B_d \to \pi^+\pi^-$ decays

LHCb-CONF-2012-007

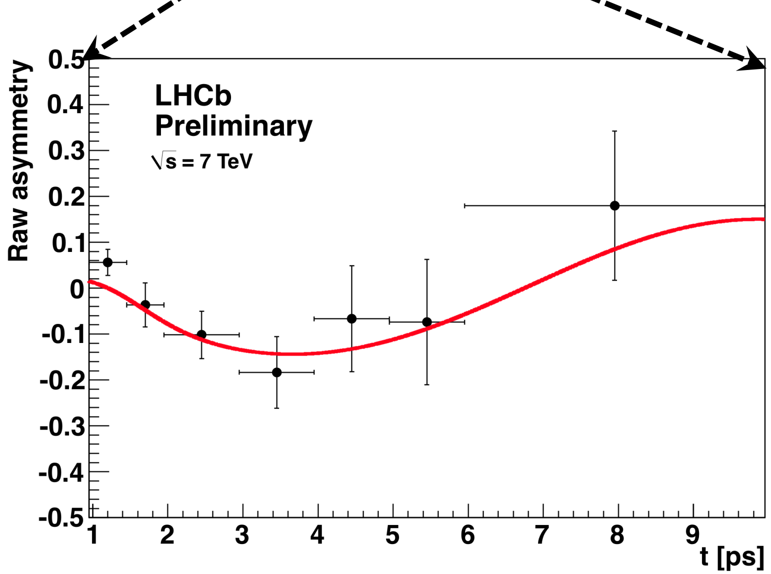


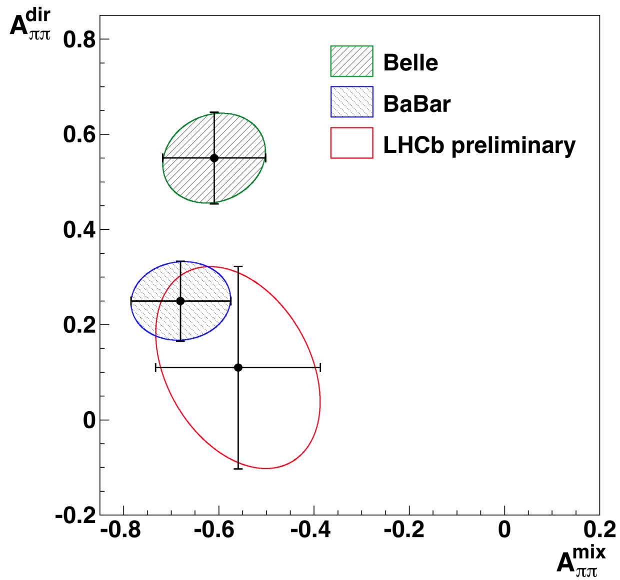
From fit ($B^0 \to \pi\pi$ **signal**, $B^0 \to K\pi$ **cross-feed**, combinatorial, **3-body**)

measure:

$$A^{dir}_{\pi\pi} = 0.11 \pm 0.21 \pm 0.03$$
$$A^{mix}_{\pi\pi} = -0.56 \pm 0.17 \pm 0.03$$
$$\rho(A^{dir}_{\pi\pi}, A^{mix}_{\pi\pi}) = -0.34.$$

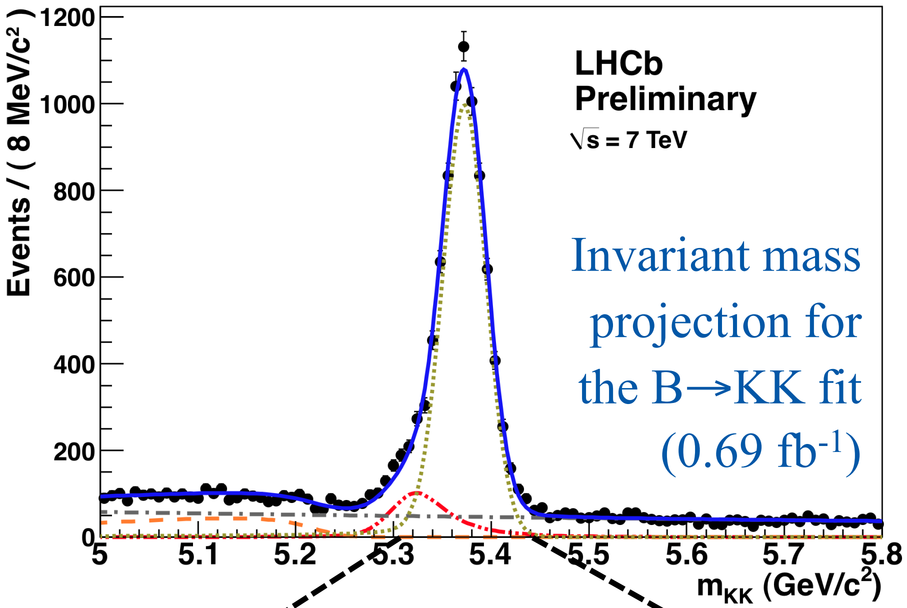
A_{mix}: first evidence of mixing-induced CPV at hadron collider (3.2σ).

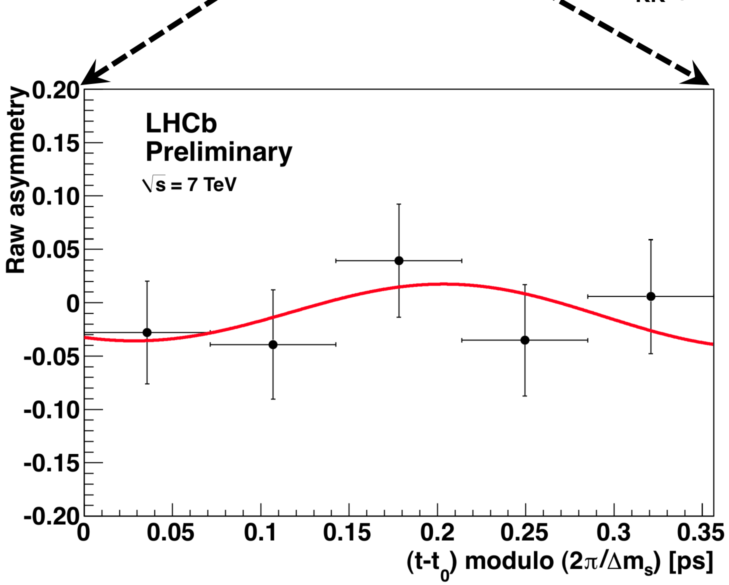




Time dependent CPV in $B^0_s \to K^+K^-$ decays

LHCb-CONF-2012-007





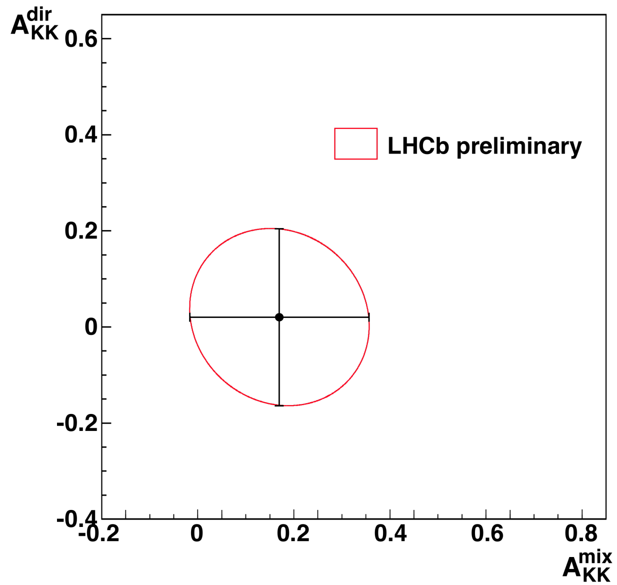
From fit (**$B^0 \to \pi\pi$ signal**, **$B^0 \to K\pi$ cross-feed**, combinatorial, **3-body**)

measure:

$$A^{\rm dir}_{KK} = 0.02 \pm 0.18 \pm 0.04$$
$$A^{\rm mix}_{KK} = 0.17 \pm 0.18 \pm 0.05$$
$$\rho(A^{\rm dir}_{KK},\, A^{\rm mix}_{KK}) = -0.10.$$

- **First measurement ever of time-dependent CPV of $B^0_s \to K^+K^-$ decay**.

- Large statistical error, will benefit of SSK tagging.

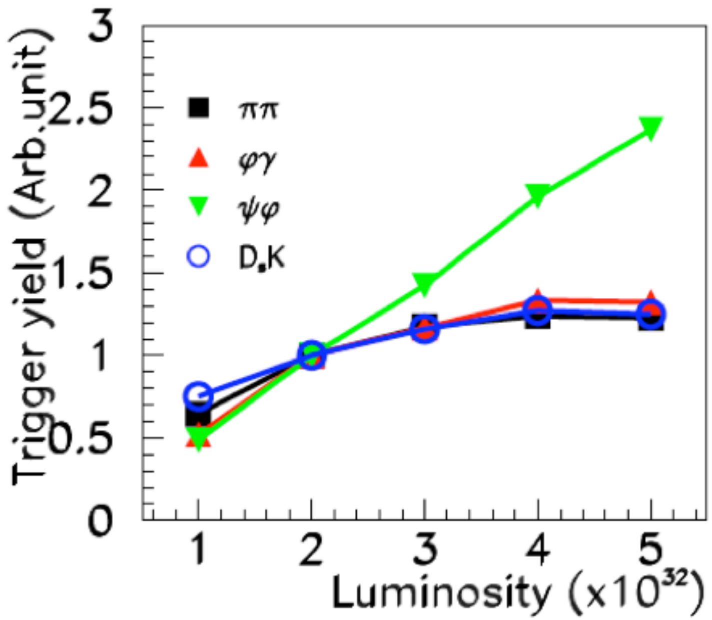


Future plans

Future plans and LHCb upgrade

Up to now, New Physics hide behind SM interactions.

Expect to **double dataset by end of this year**; after long shutdown, **further doubling in 2015-17** (plus increase of cross-sections with energy): **total 5-7 fb^{-1}**.



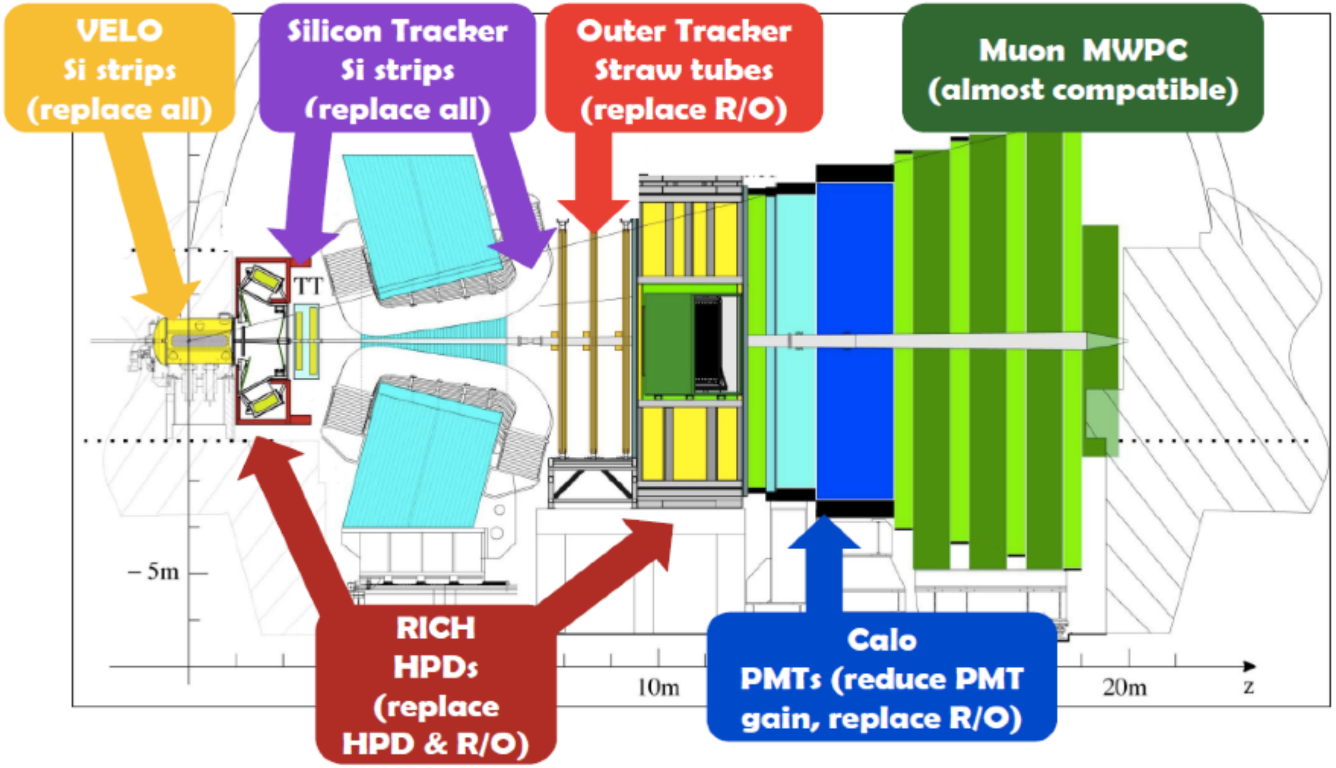
Main limitation that currently prevent exploiting higher luminosity is the **hardware trigger**: keeping output rate <1MHz requires raising of thresholds → hadronic yields reach plateau.

Propose to **remove the hardware trigger and readout LHCb at 40 MHz** crossing rate; flexible software trigger in CPU farm → increase in yields by factor 10-20 at 1-2×10^{33} cm^{-2}s^{-1} (25 ns required)

Requires replacing front-end electronics; planned for the long shutdown in 2018.

Running for ~10 years will give 50 fb^{-1}.

Detector modifications - 1

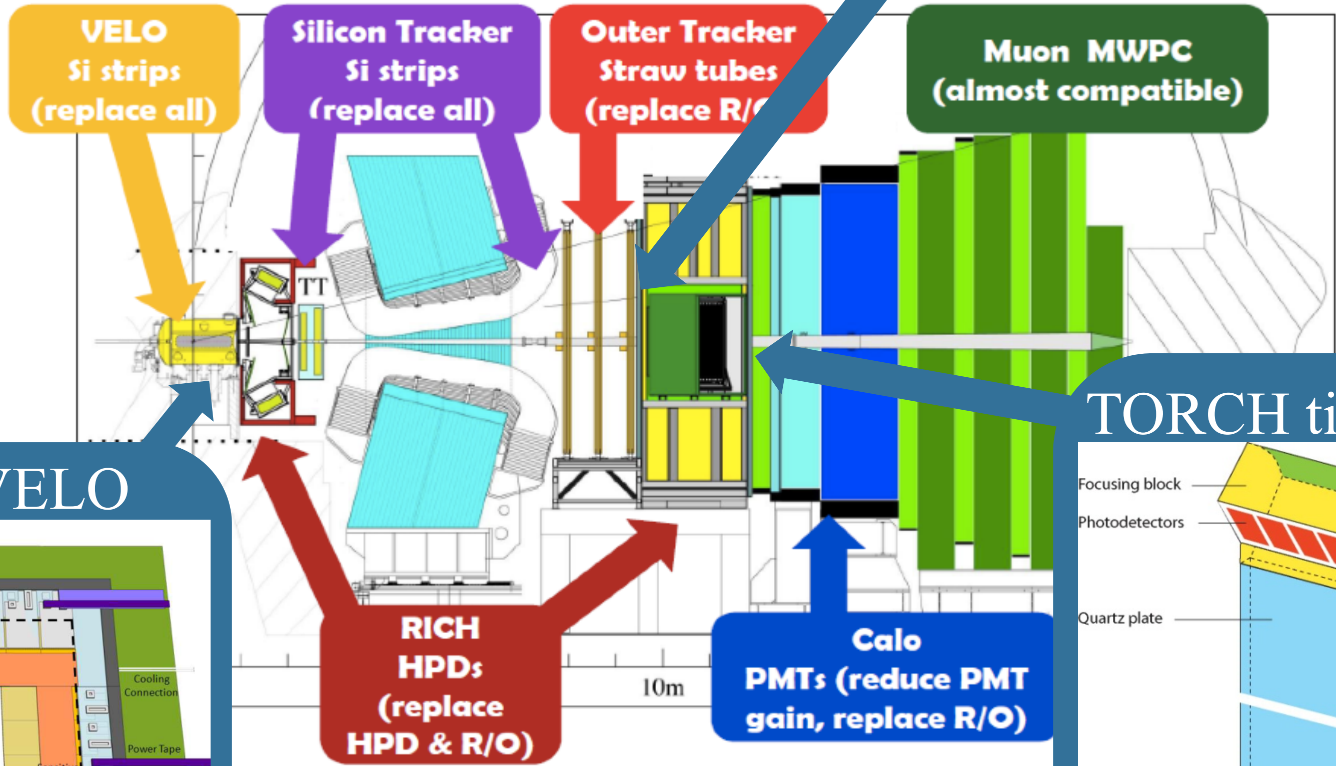


Baseline detector modifications
to allow 40 MHz readout

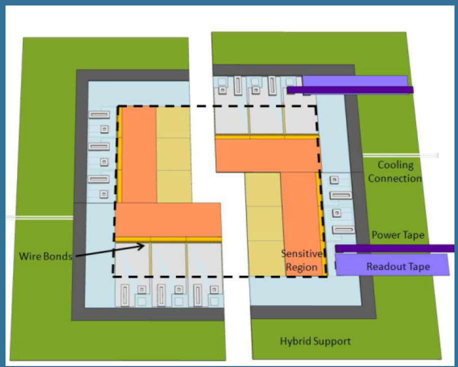
Detector modifications - 2

R&D on possible detector upgrades

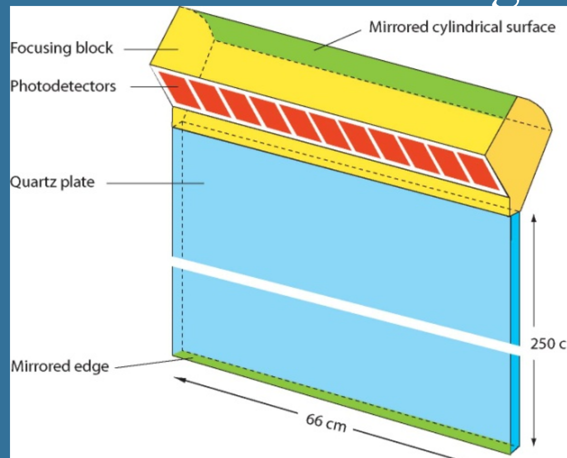
e.g. Scintillating-fibre tracker



Pixel VELO



TORCH time-of-flight

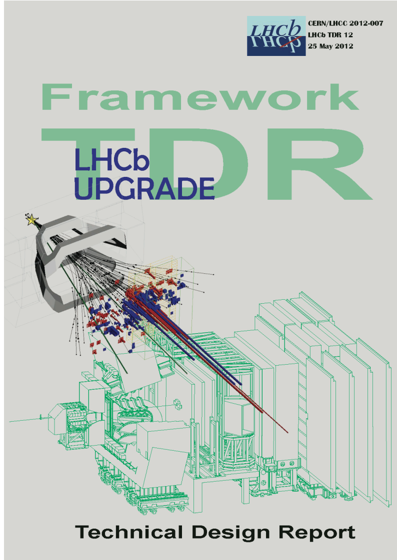


Baseline detector modifications
to allow 40 MHz readout

Future plans and LHCb upgrade

Letter of Intent for upgrade submitted to LHCC [LHCC-2012-007] last year: encouraged to proceed to Technical Design Report

Framework TDR just submitted (25 May): schedule and cost of subsystems, institute interests.



Update of physics case and expected performance:

Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,\text{fb}^{-1}$)	Theory uncertainty
B^0_s mixing	$2\beta_s$ ($B^0_s \to J/\psi\ \phi$)	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s$ ($B^0_s \to J/\psi\ f_0(980)$)	0.17 [10]	0.045	0.014	~ 0.01
	$A_{\text{fs}}(B^0_s)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta^{\text{eff}}_s(B^0_s \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta^{\text{eff}}_s(B^0_s \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\text{eff}}(B^0 \to \phi K^0_S)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta^{\text{eff}}_s(B^0_s \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\text{eff}}(B^0_s \to \phi\gamma)/\tau_{B^0_s}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\ A_{\text{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_{\text{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B^0_s \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B^0_s \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	γ ($B \to D^{(*)}K^{(*)}$)	~ 10–$12°$ [19, 20]	4°	0.9°	negligible
	γ ($B^0_s \to D_s K$)	–	11°	2.0°	negligible
	β ($B^0 \to J/\psi\ K^0_S$)	0.8° [18]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

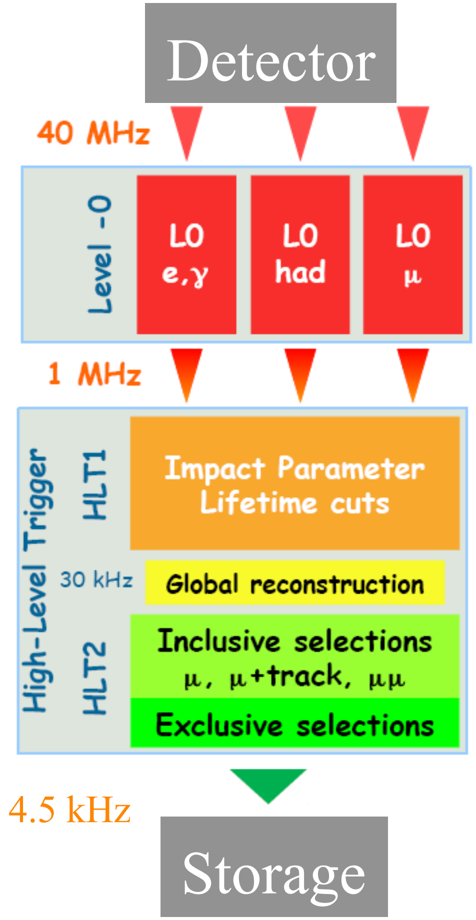
Timeline (tight!)

- 2011 Letter of Intent
- 2012 Framework TDR
  R&D ongoing
- 2013 Subsystem TDRs
- 2014-16 Production
- 2017 Acceptance testing
- 2018 Installation
- 2019 Data taking


LHCb beautifully demonstrated the power of LHC in the flavour physics.
SM still describes observations well: be prepared to observe tiny NP effects.
The LHCb Experiment
1:300 scale model engraved in optical glass
LHCb is one of the four major particle physics experiments operating at the LHC proton collider at CERN. It searches for new physics by studying CP violating effects in particles containing beauty and charm quarks and by measuring very rare processes. This photograph shows the LHCb underground cavern as it looks today. Hidden behind the scaffolding is the forward spectrometer, as displayed in the enclosed glass engraving.
http://lhcb-public.web.cern.ch
LHCb: ideally suited for this!

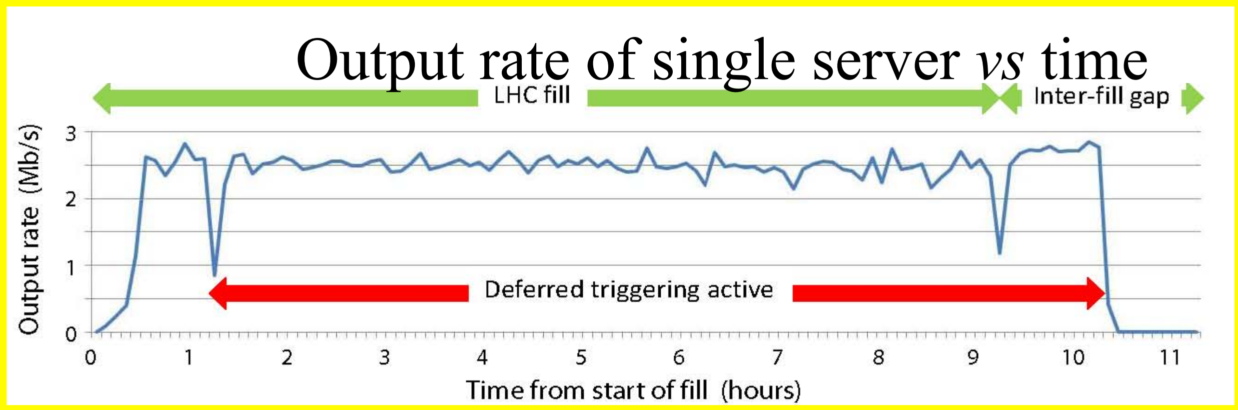
Data processing

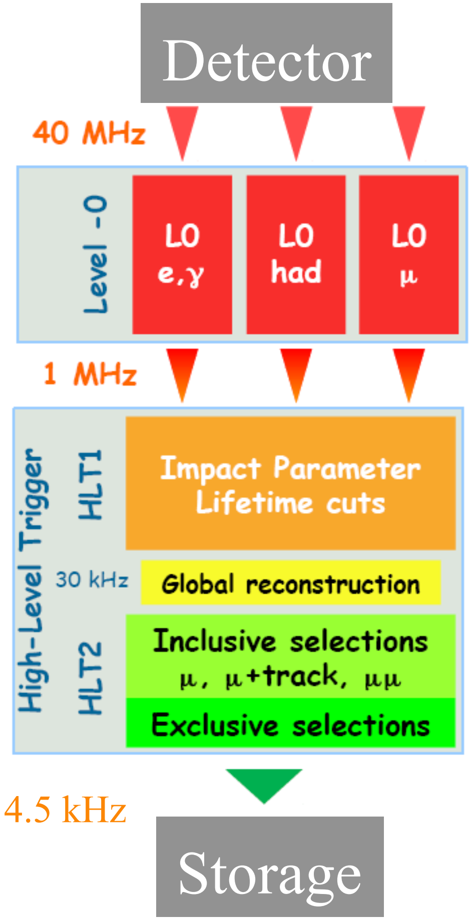
- Trigger in two steps: **Level-0** in hardware
  p_T of e, μ, and hadron (thresholds ~ 1–3 GeV)
  → reduce rate to 1 MHz
- Then all detectors read out into large CPU farm (~1500 servers) **High Level Trigger** in software
- *New this year:*
  - **Output rate** increased to 4.5 kHz to provide data sample for analysis during shutdown (events are relatively small ~ 60 kB)
  - **Deferred triggering:** fraction of events written to local storage of CPUs and processed during inter-fill gap ~10% increase in effective power



- $O(10^{10})$ events recorded per year: centralized "stripping" selection to reduce to samples of $< \sim 10^7$ events for individual analysis: ~ 800 selections!

Data processing





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Detector details

Forward spectrometer (running in pp collider mode)
Inner acceptance 10 mrad from conical beryllium **beam pipe**

Vertex locator around the interaction region
Silicon strip detector with ~ 30 μm impact-parameter resolution

Tracking system and dipole magnet to measure angles and momenta $\Delta p/p$ ~ 0.5 %, mass resolution, together with VELO ~ 25 MeV (for $B_s \rightarrow \mu\mu$)

Two **RICH** detectors for charged hadron identification

Calorimeter system to identify electrons, hadrons and neutrals.
Important for the first level of the trigger

Muon system to identify muons, also used in first level of trigger

BR(B→μμ): entering the precision realm

1) $\mathcal{B}(B_q \to \mu^+\mu^-) = 4.36 \cdot 10^{-10} \frac{\tau_{B_q}}{\hat{B}_q} \frac{Y^2(v)}{S(v)} \Delta M_q$ Buras, Physics Letters B 566 (2003)

used so far $BR(B_s \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$ (6.3%) Buras, Acta Phys. Pol. vol. 41 (2010)

which makes use of Bs=1.33 ± 0.06 (4.5%) Gamiz et al. (HPQCD), arXiv:0902.1815

2)
$$BR(B_s \to \mu^+\mu^-) = \frac{G_F^2 \alpha^2}{64\pi^2} f_{B_s}^2 m_{B_s}^3 |V_{tb} V_{ts}^*|^2 \tau_{B_s} \sqrt{1 - \frac{4m_\mu^2}{m_{B_s}^2}} \times \left\{ \left(1 - \frac{4m_\mu^2}{m_{B_s}^2}\right) |C_{Q_1} - C'_{Q_1}|^2 + \left| (C_{Q_2} - C'_{Q_2}) + 2(C_{10} - C'_{10}) \frac{m_\mu}{m_{B_s}} \right|^2 \right\}. \quad (2.4)$$

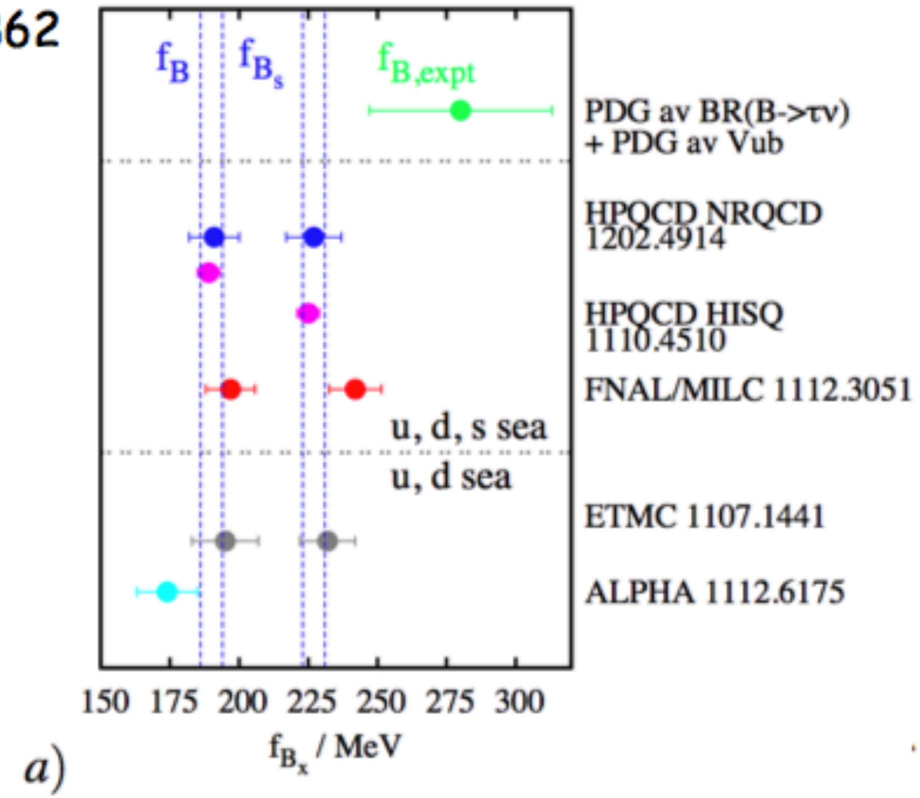
main uncertainty from fBs, but impressive lattice results -> all authors agree this is best option for the future

$BR(B_s \to \mu^+\mu^-) = (3.1 \pm 0.2) \times 10^{-9}$	Buras, arXiv:1204.5064	use f_{Bs}= (227.7 ± 6.2) MeV
$= (3.64\ ^{+0.17}_{-0.31}) \times 10^{-9}$	CKM fitter, arXiv:,1106.4041	use f_{Bs} = (231 ± 15) MeV
$= (3.53 \pm 0.38) \times 10^{-9}$	Mahmoudi, arXiv:,1205.1845	use f_{Bs} = (234 ± 10) MeV

BR(B→μμ): entering the precision realm

plot from C. Davies review

arXiv:1203.3862



make your choice!

arXiv:1205.1845 (Mahmoudi et al.)

HPQCD-NRQCD + FNAL/MILC + ETMC

f_{Bs} = (234 ± 10) MeV

=> BR =(3.53 ± 0.38)×10^{-9}

arXiv:1203.3862 (Davies)

HPQCD-NRQCD + HPQCD-HISQ + FNAL/MILC

f_{Bs} = (227 ± 4) MeV

=> BR = (3.32 ± 0.25)×10^{-9}

all other inputs from Mahmoudi

new results will come, and a more clear strategy for getting an average, too: FLAG-2, 1st review end of 2012 (FPCP 2012, El-Khadra)

$BR(B_s \to \mu^+\mu^-\mu^+\mu^-)$ and $BR(B_d \to \mu^+\mu^-\mu^+\mu^-)$

- Strongly suppressed in SM; contributions from: $B \to J/\psi(\mu^+\mu^-)\phi(\mu^+\mu^-) = \mathbf{2.3(9)\times10^{-8}}$

  $B \to \mu^+\mu^- \gamma^*(\mu^+\mu^-) \sim \mathbf{10^{-10}\text{-}10^{-11}}$

  [Phys. Rev. D 70(2004)114028]

- possible enhancement in BSM, with new particles decaying in $\mu^+\mu^-$.

  [S.Demidov, D.Gorbunov arXiv:1112.5230]

- cut based analysis to maximize S/B, tuned on $B \to J/\psi(\mu^+\mu^-)\phi(\mu^+\mu^-)$ decays.

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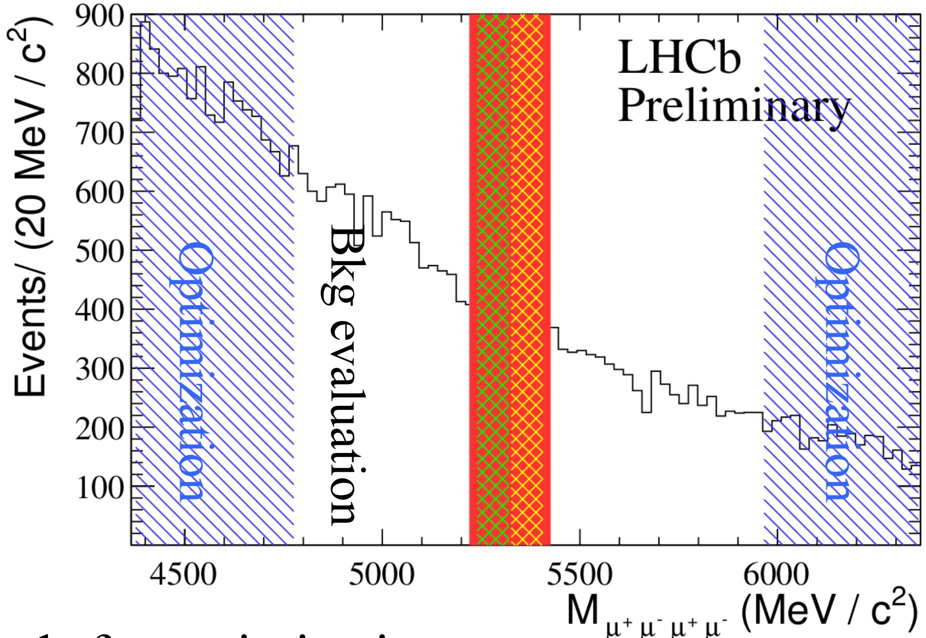
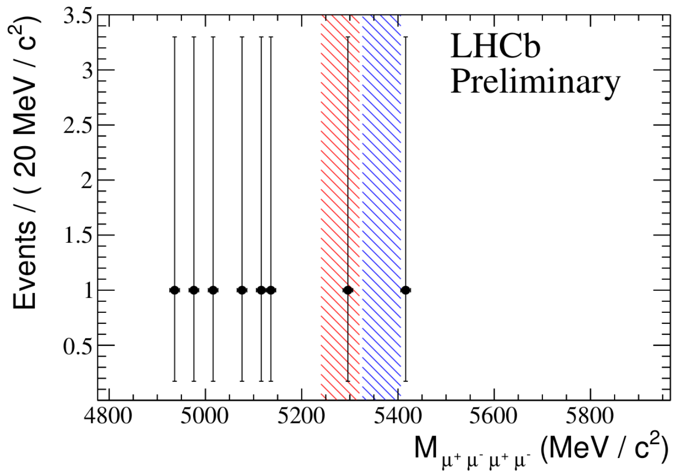




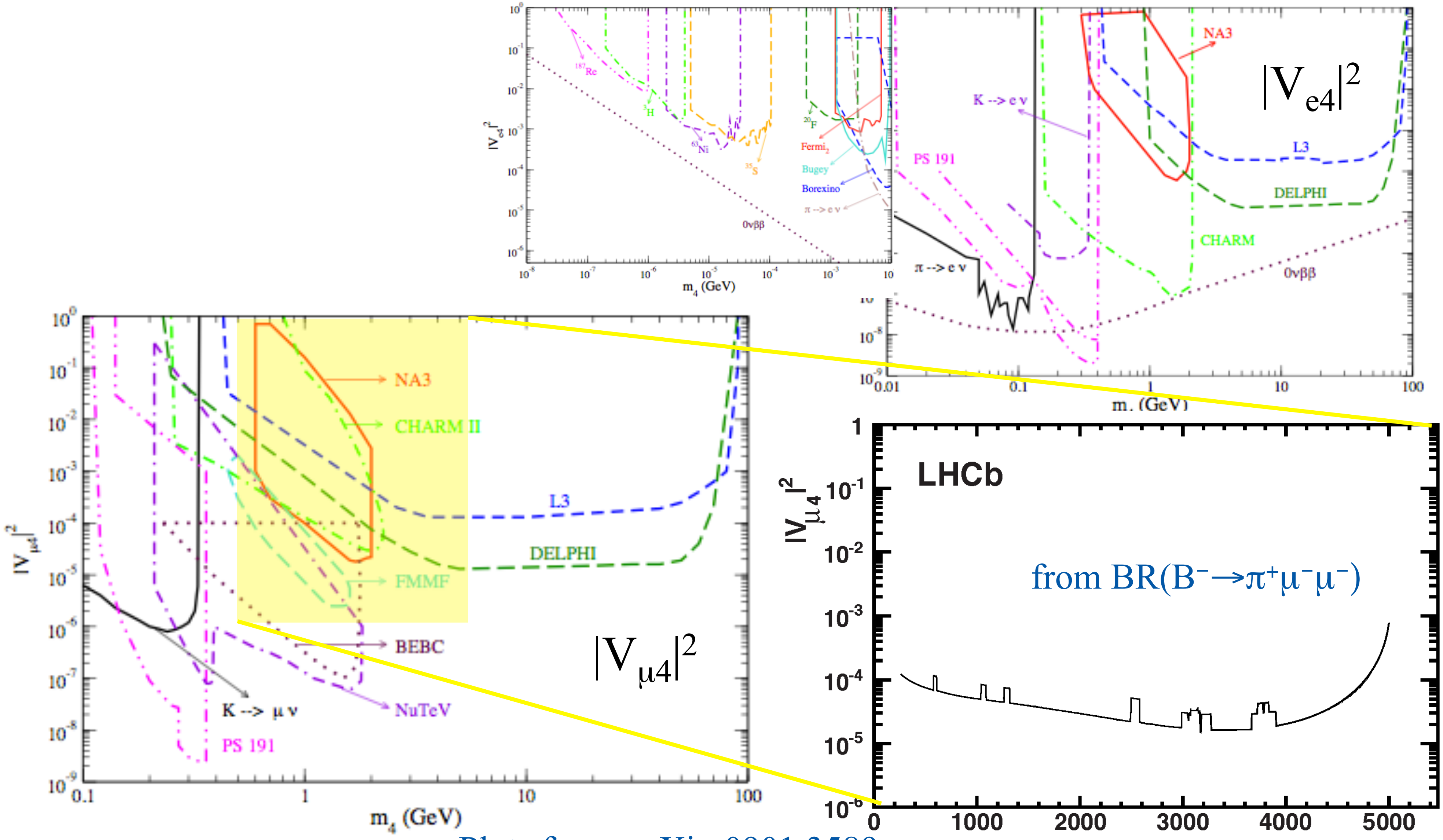
- Side bands for optimizations and background evaluation.
- Check on resonant bkg: SM compatible.
- Unblind **non resonant** region $M_{4\mu}$ for **1 fb^{-1}**:

1 B_d and **0 B_s** events in signal window.

Normalize to $B \to J/\psi(\mu^+\mu^-)K^{*0}(K^+\pi^-)$

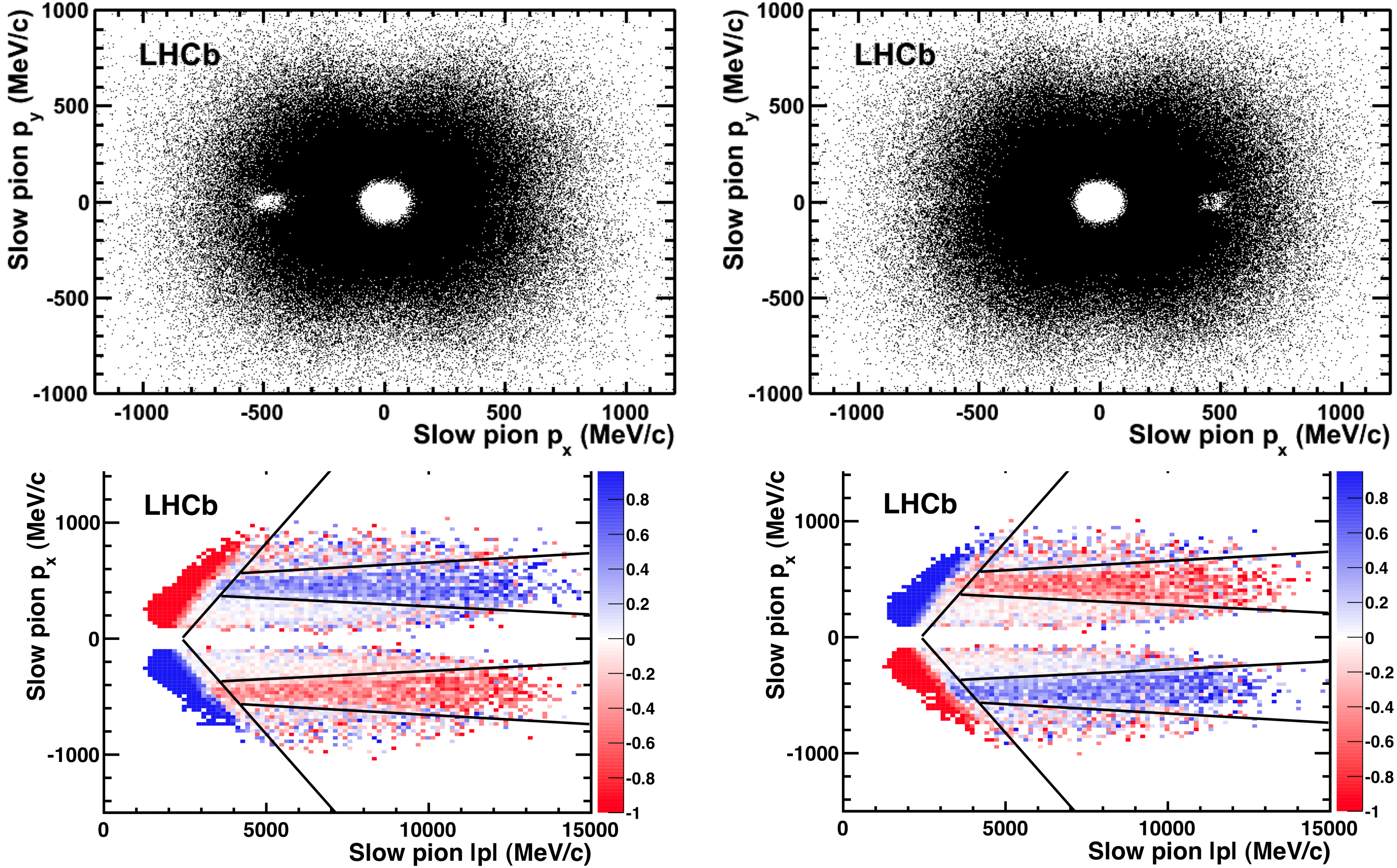
$BR(B_s \to \mu^+\mu^-\mu^+\mu^-) < 1.3\times10^{-8}$ and $BR(B_d \to \mu^+\mu^-\mu^+\mu^-) < 5.4\times10^{-9}$ [preliminary]

Majorana neutrino from B decays



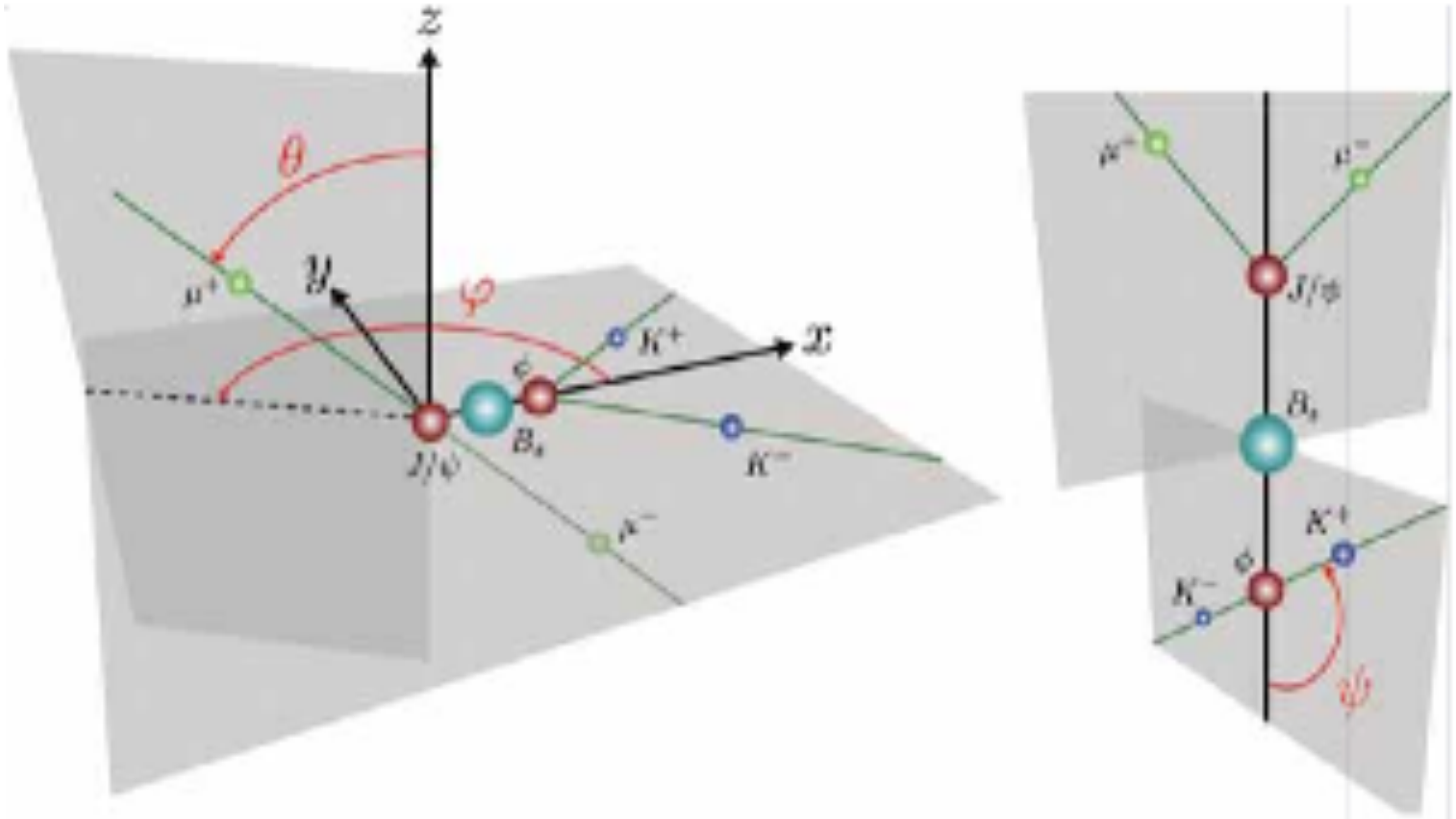
Plots from: arXiv:0901.3589

ΔA_{cp}


LHCb
Slow pion p_y (MeV/c)
Slow pion p_x (MeV/c)
1000
500
0
-500
-1000
LHCb
Slow pion p_y (MeV/c)
Slow pion p_x (MeV/c)
LHCb
Slow pion p_x (MeV/c
Slow pion |p| (MeV/c)
0
5000
10000
15000
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-1
LHCb
Slow pion p_x (MeV/c
Slow pion |p| (MeV/c)

CP violation in $B_s \rightarrow J/\psi\phi$ decays

Transversity basis:



Time dependent CPV in $B_{s,d} \to K\pi$ decays

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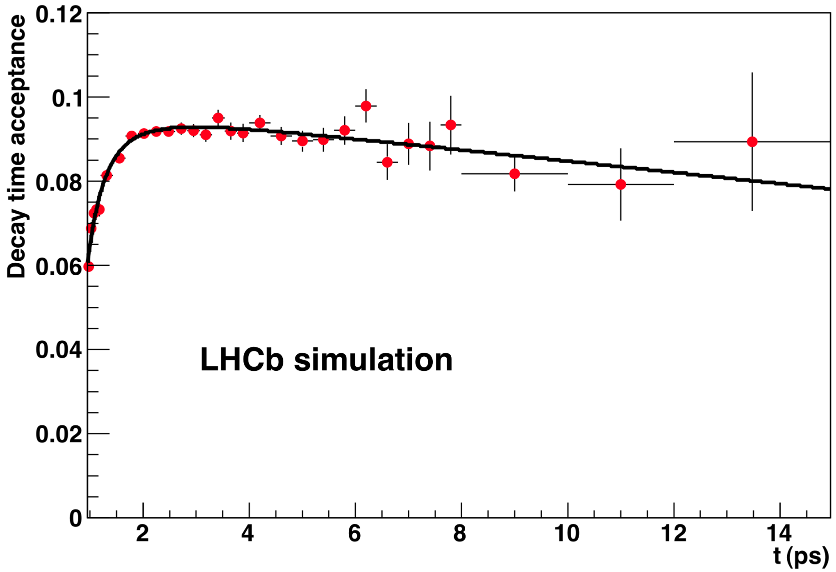

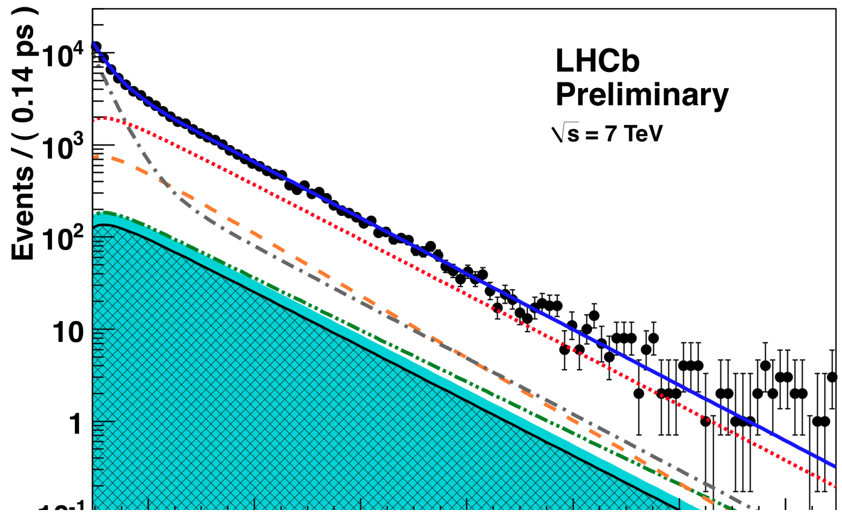

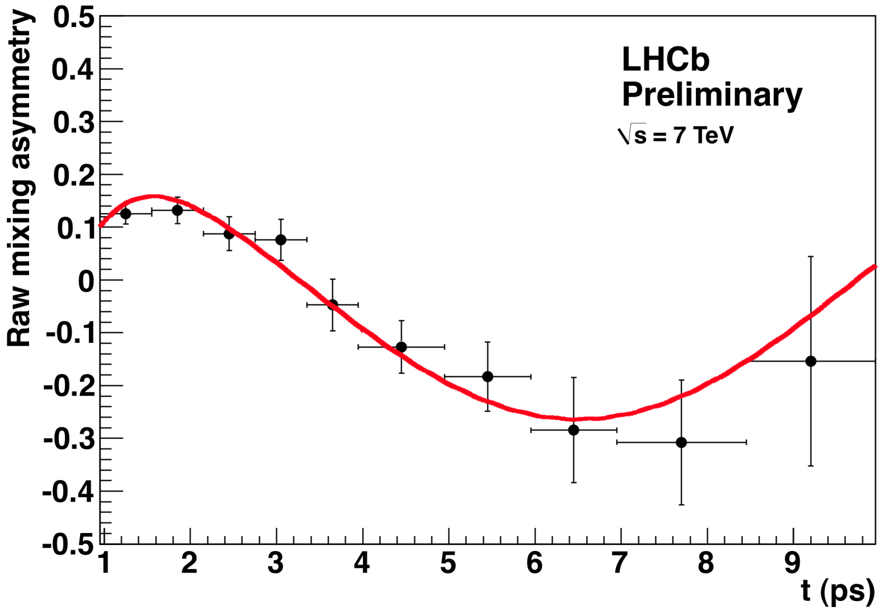

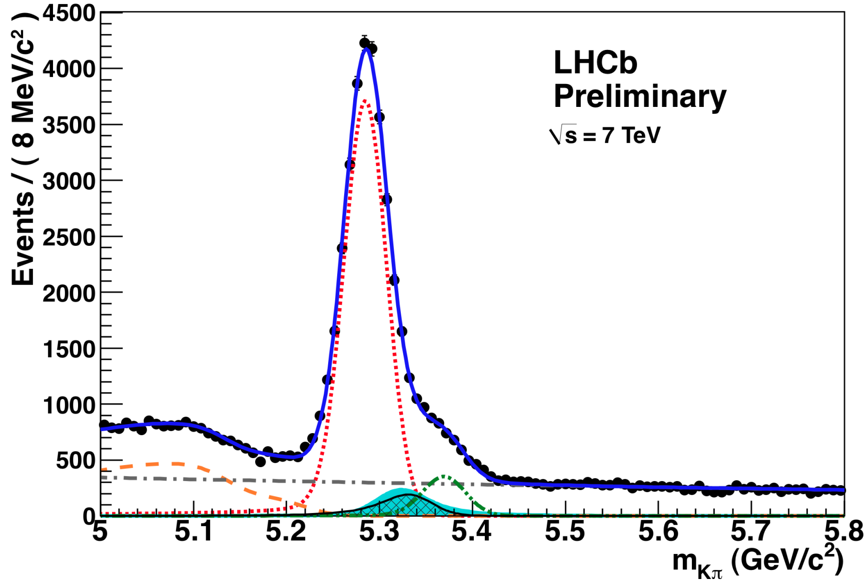

Time dependent CPV in B→hh decays

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