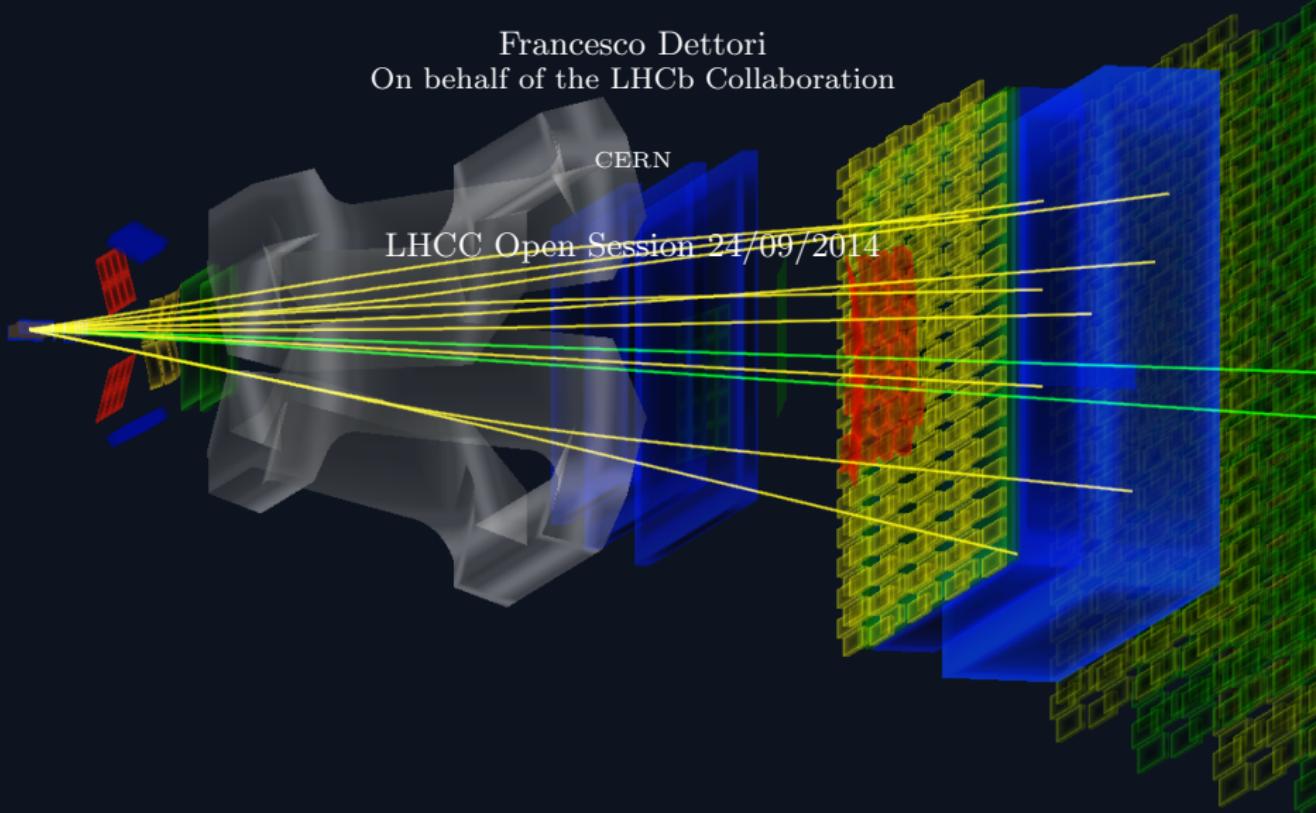


LHCb Status Report

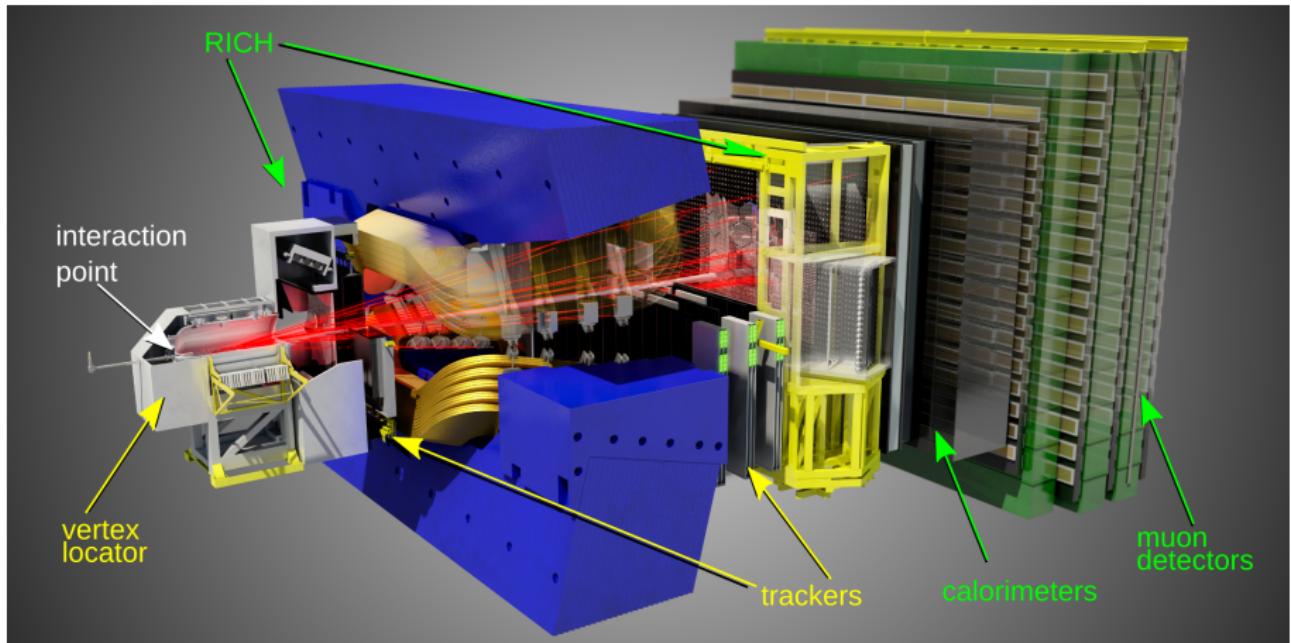
Francesco Dettori
On behalf of the LHCb Collaboration

LHCC Open Session 24/09/2014

CERN



LHCb experiment recent news



- As of September 2014: 1075 members, from 68 institutes in 17 countries
- *Beautiful, charming, strange* physics program

Articles submitted since last LHCC

A stable physics output rate!

PAPER-2014-018 Search for CP violation in $D_s^\pm \rightarrow K_S^0 K^\pm$ and $D_s^\pm \rightarrow K_S^0 \pi^\pm$ decays
 [LHCb, to appear in JHEP, arXiv:1406.2624]

PAPER-2014-022 Observation of Z production in proton-lead collisions at LHCb
 [LHCb, submitted to JHEP, arXiv:1406.2885]

PAPER-2014-023 First measurement of the charge asymmetry in beauty-quark pair production
 [LHCb, to appear in Phys. Rev. Lett., arXiv:1406.4789]

PAPER-2014-024 Test of lepton universality using $B^+ \rightarrow K^+ \ell^+ \ell^-$ decays
 [LHCb, to appear in Phys. Rev. Lett., arXiv:1406.6482]

PAPER-2014-011 Effective lifetime measurements of the $B_s^0 \rightarrow K^+ K^-$, $B^0 \rightarrow K^+ \pi^-$ and $B_s^0 \rightarrow \pi^+ K^-$ decays
 [LHCb, Phys. Lett. B736 (2014) 446, arXiv:1406.7204]

PAPER-2014-025 Measurement of the ratio of the B_c^+ branching fractions to $J/\psi \pi^+$ and $J/\psi \mu^+ \nu_\mu$
 [LHCb, Phys. Rev. D90 (2014) 032009, arXiv:1407.2126]

PAPER-2014-026 Measurement of CP violation in $B_s^0 \rightarrow \phi \phi$ decays [LHCb, to appear in Phys. Rev. D, arXiv:1407.2222]

PAPER-2014-037 Measurement of the B_s^0 lifetime in $D_s^+ \pi^-$ decays [LHCb, to appear in Phys. Rev. Lett., arXiv:1407.5873]

PAPER-2014-034 Evidence of CP violation in $B^+ \rightarrow p\bar{p}K^+$ decays [LHCb, to appear in Phys. Rev. Lett., arXiv:1407.5907]

PAPER-2014-027 Observation of charmonium pairs produced exclusively in $p\bar{p}$ collisions [LHCb, to appear in J. Phys. G, arXiv:1407.5973]

PAPER-2014-038 Measurement of CP asymmetry in $B_s^0 \rightarrow D_s^\mp K^\pm$ decays [LHCb, submitted to JHEP, arXiv:1407.6127]

PAPER-2014-017 Measurement of CP violation and constraints on the CKM angle γ in $B^\pm \rightarrow DK^\pm$ with $D \rightarrow K_S^0 \pi^+ \pi^-$ decays [LHCb, to appear in Nucl. Phys. B, arXiv:1407.6211]

PAPER-2014-035 Observation of overlapping spin-1 and spin-3 $D^0 K^-$ resonances at mass 2.86 GeV/ c^2 [LHCb, to appear in Phys. Rev. Lett., arXiv:1407.7574]

PAPER-2014-043 Observation of $B_s^0 \rightarrow K^\pm K^\mp$ and evidence of $B_s^0 \rightarrow K^{*-} \pi^+$ decays [LHCb, submitted to New J. Phys., arXiv:1407.7704]

PAPER-2014-036 Dalitz plot analysis of $B_s^0 \rightarrow \bar{D}^0 K^- \pi^+$ decays [LHCb, to appear in Phys. Rev. D, arXiv:1407.7712]

PAPER-2014-031 Study of χ_b meson production in $p\bar{p}$ collisions at $\sqrt{s}=7$ and 8 TeV and observation of the decay $\chi_b \rightarrow \Upsilon(3S)\gamma$ [LHCb, to appear in Eur. Phys. J. C, arXiv:1407.7734]

PAPER-2014-028 Measurement of CP violation parameters in $B^0 \rightarrow DK^{*0}$ decays [LHCb, submitted to Phys. Rev. D, arXiv:1407.8136]

PAPER-2014-042 Measurement of the $B^0 - B^0$ and $B_s^0 - B_s^0$ production asymmetries in $p\bar{p}$ collisions at $\sqrt{s}=7$ TeV [LHCb, submitted to Phys. Lett. B, arXiv:1408.0275]

PAPER-2014-039 First observation of a baryonic B_c^+ decay [LHCb, to appear in Phys. Rev. Lett., arXiv:1408.0971]

PAPER-2014-032 Measurement of CP asymmetries in the decays $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ and $B^+ \rightarrow K^+ \mu^+ \mu^-$ [LHCb, submitted to Phys. Rev. Lett., arXiv:1408.0978]

PAPER-2014-030 First observations of the rare decays $B^+ \rightarrow K^+ \pi^+ \pi^- \mu^+ \mu^-$ and $B^+ \rightarrow \phi K^+ \mu^+ \mu^-$ [LHCb, to appear in JHEP, arXiv:1408.1137]

PAPER-2014-046 Search for CP violation using T -odd correlations in $D^0 \rightarrow K^+ K^- \pi^+ \pi^-$ decays [LHCb, to appear in JHEP, arXiv:1408.1299]

PAPER-2014-041 Measurement of the CKM angle γ using $B^\pm \rightarrow DK^\pm$ with $D \rightarrow K_S^0 \pi^+ \pi^-$, $K_S^0 K^+ K^-$ decays [LHCb, submitted to JHEP, arXiv:1408.2748]

DP-2013-002 Measurement of the track reconstruction efficiency at LHCb [LHCb, submitted to JINST, arXiv:1408.1251]

PAPER-2014-033 Measurement of the forward W boson cross-section in $p\bar{p}$ collisions at $\sqrt{s}=7$ TeV [LHCb, submitted to JHEP, arXiv:1408.4354]

PAPER-2014-045 Determination of γ and $-2\beta_s$ from charmless two-body decays of beauty mesons [LHCb, submitted to Phys. Lett. B, arXiv:1408.4368]

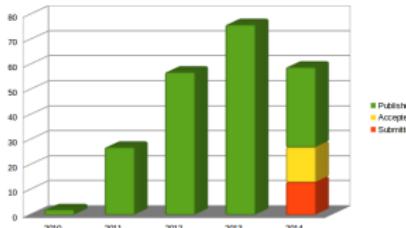
PAPER-2014-044 Measurements of CP violation in three-body phase space of charmless B^\pm decays [LHCb, submitted to Phys. Rev. D, arXiv:1408.5373]

PAPER-2014-040 Measurement of the $\chi_b(3P)$ mass and of the relative rate of $\chi_{b1}(1P)$ and $\chi_{b2}(1P)$ production [LHCb, submitted to JHEP, arXiv:1409.1408]

PAPER-2014-029 Measurement of the $\eta_c(1S)$ production cross-section in proton-proton collisions via the decay $\eta_c(1S) \rightarrow p\bar{p}$ [LHCb, submitted to Eur. Phys. J. C, arXiv:1409.3612]

PAPER-2014-051 Measurement of the CP -violating phase ϕ_s in $\overline{B}_s^0 \rightarrow D_s^+ D_s^-$ decays [LHCb, submitted to PRL, arXiv:1409.4619]

Published papers



Outline

- LS1 activities and Run II preparation
 - ★ Run II Data taking
- Upgrade
- Summary of recent articles
 - ★ Cross-sections, spectroscopy and particle properties
 - ★ CP Violation and CKM matrix
 - ★ Rare decays



LS1 activities

Recent LS1 activities

- Beam pipe: new support and tension monitor systems installed
- Precise re-evaluation of the magnet field map
- HeRSCheL: installation of detectors for forward physics
- Construction of new control room in good progress
- Trigger upgrade: works for fibres installation proceeding
- Maintenance of RICH photo-detectors



LS1 activities are progressing well in parallel with >19k visitors
LHCb will be ready for new data taking in 2015!

LHCb data taking in Run II: do more and better

Run I Data Taking

40 MHz bunch crossing rate

L0 Hardware Trigger : 1 MHz readout, high E_T/P_T signatures

450 kHz
 h^\pm

400 kHz
 $\mu/\mu\mu$

150 kHz
 e/γ

Defer 20% to disk

Software High Level Trigger

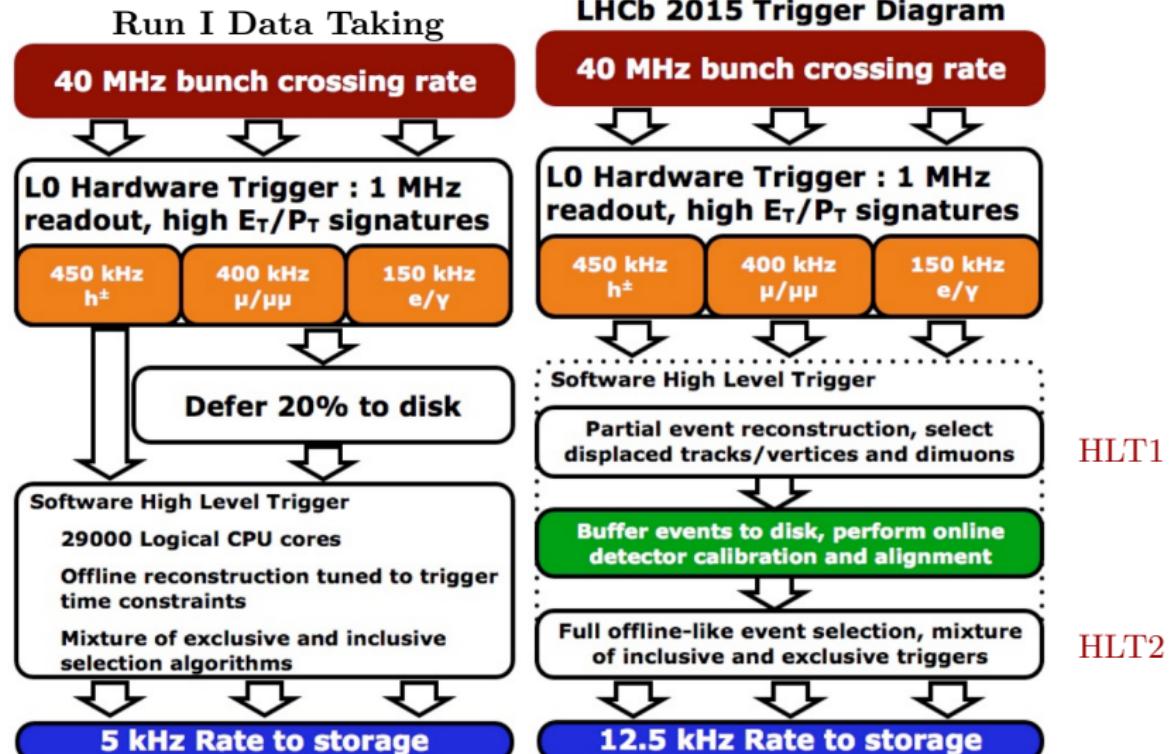
29000 Logical CPU cores

Offline reconstruction tuned to trigger time constraints

Mixture of exclusive and inclusive selection algorithms

5 kHz Rate to storage

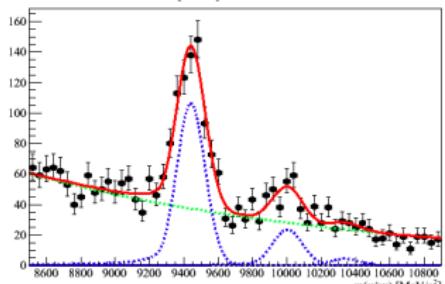
LHCb data taking in Run II: do more and better



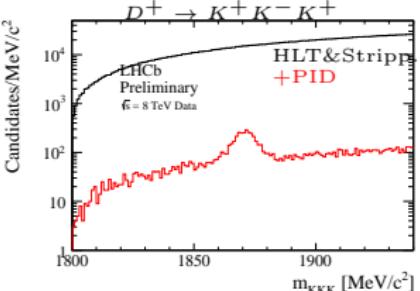
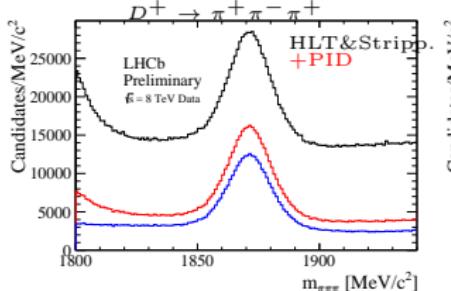
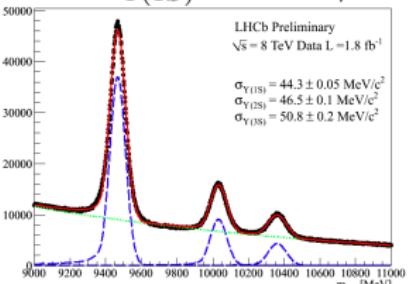
Defer trigger after HLT1 instead of L0. Perform calibration and alignment before HLT2 in real-time.

Real-time calibration and alignment

$$\sigma_{Y(1S)} = 86 \text{ MeV}/c^2$$



$$\sigma_{Y(1S)} = 44 \text{ MeV}/c^2$$



- Alignment performances equal to offline improve background rejection
- PID selection can improve purity for suppressed channels
- Some physics analyses can be done directly on HLT output

Trigger streams division in Run II

12.5 kHz to storage

Full Stream
5 kHz

Parked Stream
5 kHz

Turbo Stream
2.5 kHz

Similar processing
to 2012

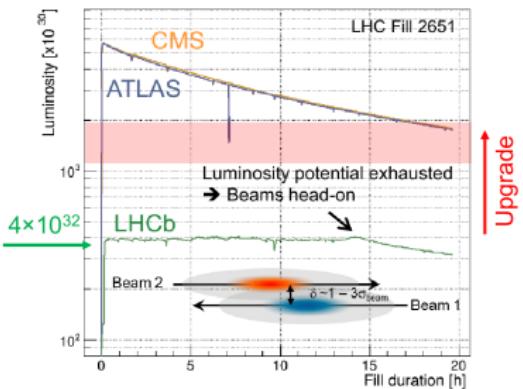
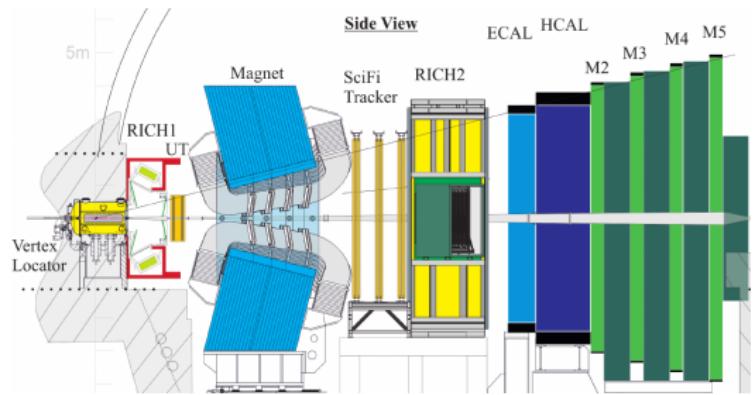
Processed during
LS2

Physics analysis
on HLT

- Full stream to offline reconstruction as Run I
- Parked stream to be processed after data taking
- Turbo stream for immediate data analysis out of HLT processing

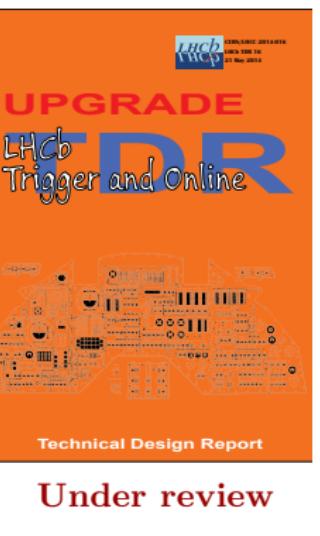
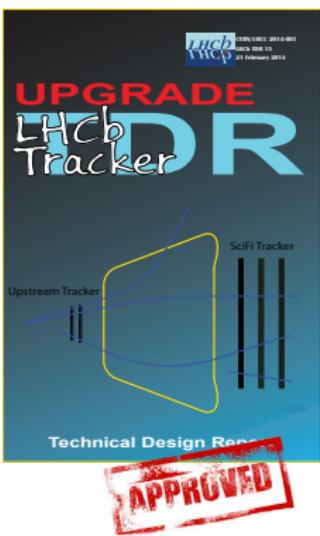
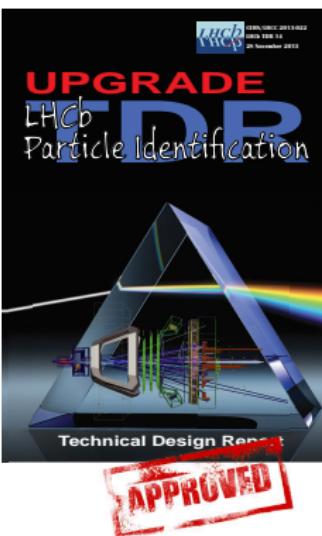
The LHCb upgrade

- Increase levelled luminosity up to $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Fully flexible software trigger up to 40 MHz
- Record 20 to 100 kHz
- Upgrade VELO and Tracker



A word on the LHCb upgrade status

- TDRs ready: Trigger TDR under review
- Milestones have been defined for each project
- The division of resource allocation is being finalised and will be presented to the October RRB





Cross-sections, spectroscopy and particle properties

Precision luminosity measurements at the LHC

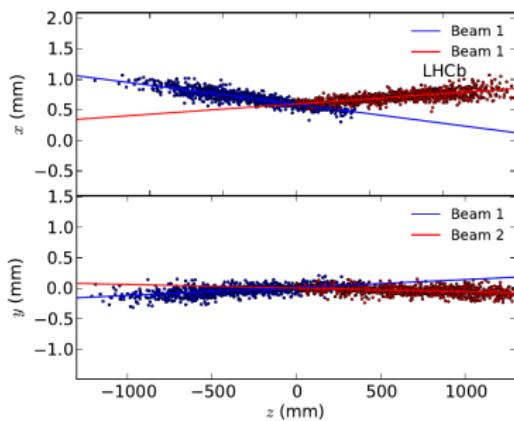
LHCb-PAPER-2014-047 - Submitted to JINST

Calibration of instantaneous luminosity fundamental for cross-section measurements

$$L = N_1 N_2 \nu_{\text{rev}} 2c \int \rho_1(x, t, z, t) \rho_2(x, t, z, t) dx dy dz dt$$

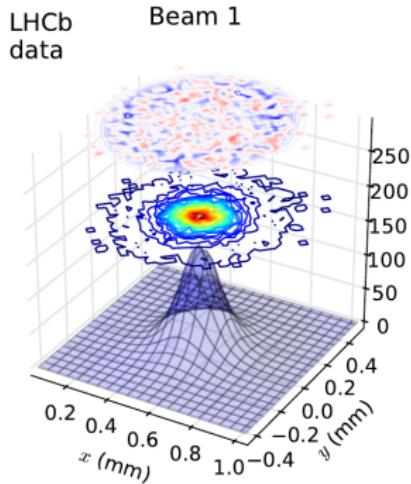
Two independent methods:

- van der Meer scan
- Beam Gas Imaging: unique to LHCb



Observed not factorizability of beam density profile

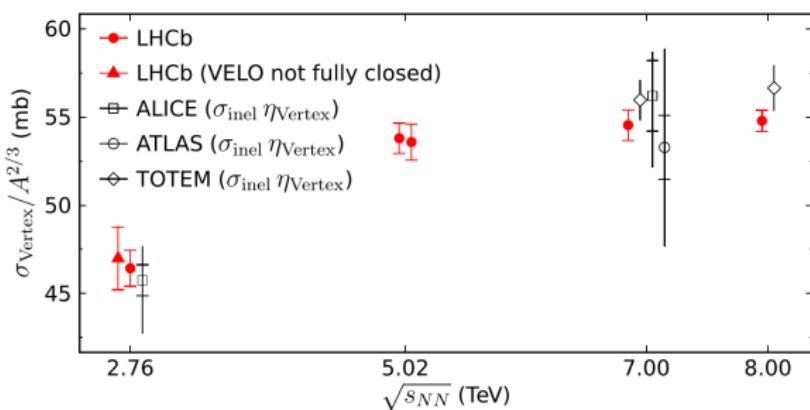
2D fit with improved description



Precision luminosity measurements at the LHC

LHCb-PAPER-2014-047 - Submitted to JINST

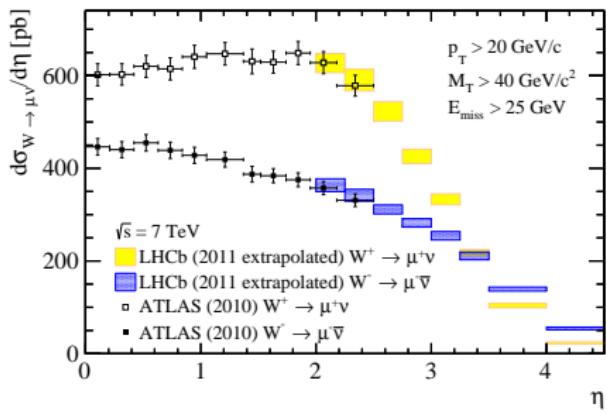
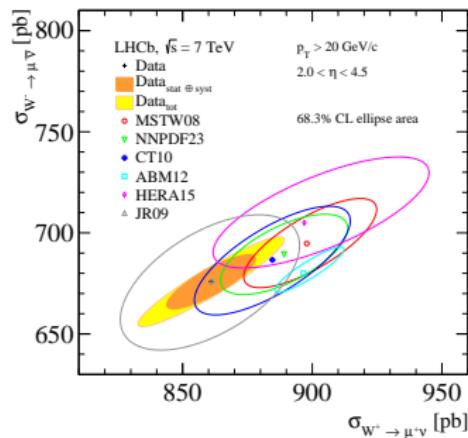
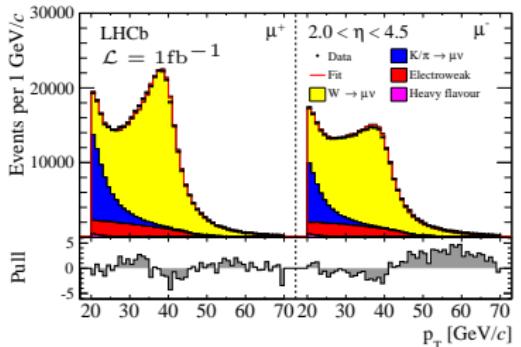
- Visible cross-sections measured at different energies and beams
 - The two methods have similar precision and mostly uncorrelated systematics
 - Precision on the average reference cross-section of 1.12% (1.16%) without (with) propagation to physics data.
- Most precise luminosity calibration at a bunched-beam hadron collider



Measurement of the forward W boson cross-section in pp collisions at $\sqrt{s} = 7$ TeV

LHCb-PAPER-2014-033 - Submitted to JHEP

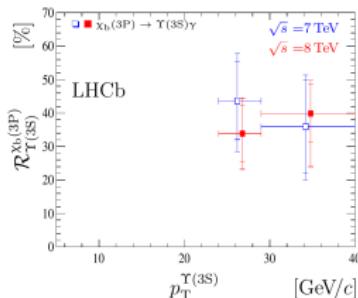
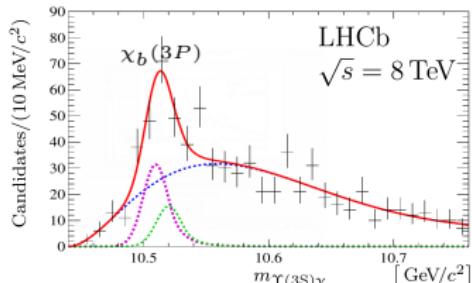
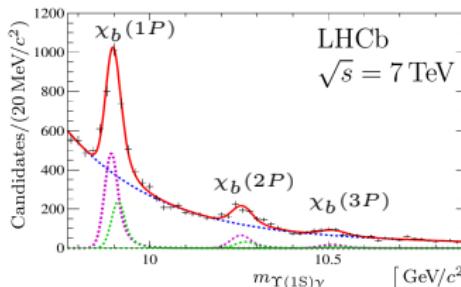
- Inclusive $W \rightarrow \mu\nu$ cross-section in forward region
- Probes low x values where theoretical uncertainties are larger
- Pseudorapidity $2 < \eta < 5$
- Compatible with and complementary to GPD



First observation of the decay $\chi_b(3P) \rightarrow \Upsilon(3S)\gamma$

LHCb-PAPER-2014-031 - Accepted by EPJC

- Study of χ_b meson production in pp collisions at $\sqrt{s} = 7$ and 8 TeV
- Quarkonia states production described by NRQCD
- Measurement of production ratio $\mathcal{R}_{\Upsilon(nS)}^{\chi_b(mP)} \equiv \sum_{i=1,2} \frac{\sigma(pp \rightarrow \chi_{b,i}(mP)X \rightarrow \Upsilon(nS)\gamma X)}{\sigma(pp \rightarrow \Upsilon(nS)X)}$
- First observation of the $\chi_b(3P) \rightarrow \Upsilon(3S)\gamma$, previously neglected in theory predictions



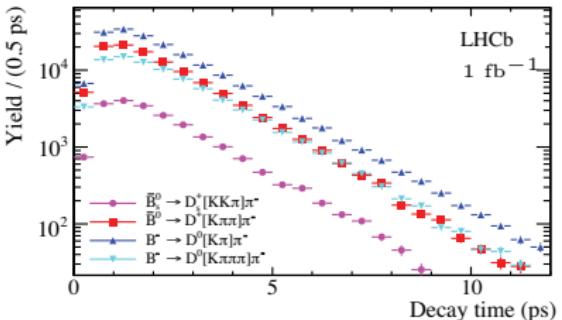
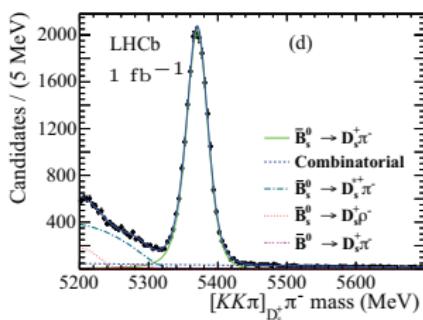
Precision measurement of $\chi_{b1}(3P)$ mass also performed:
 $m_{\chi_{b1}(3P)} = 10511 \pm 1.7 \pm 2.5 \text{ MeV}/c^2$

Important inputs to quarkonia production
and as references for ion collisions

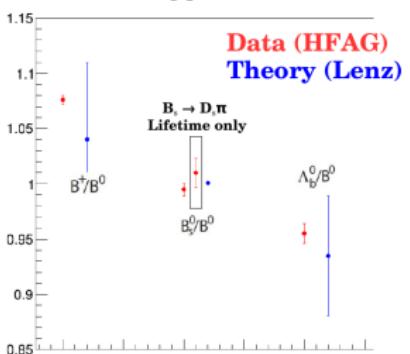
Measurement of the \bar{B}_s^0 meson lifetime in $D_s^+\pi^-$ decays

LHCb-PAPER-2014-037 - Accepted by PRL

- Measurement of flavour specific (fs) lifetime of \bar{B}_s^0 using $D_s^+\pi^-$ final state
- Due to fast mixing, equal admixture of heavy and light mass eigenstates
- Normalised to $\bar{B}^0 \rightarrow D^+\pi^-$ and $B^- \rightarrow D^0\pi^-$ decays



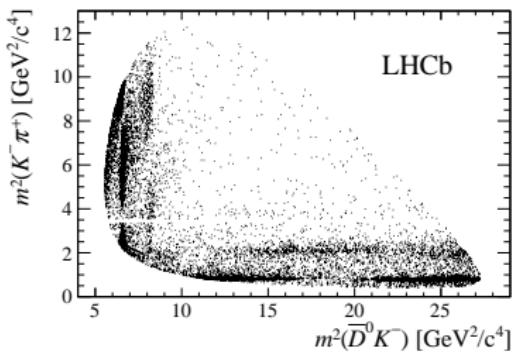
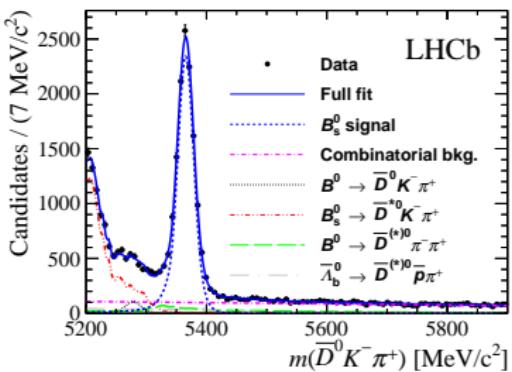
- $\tau_{fs} = (1.535 \pm 0.015 \pm 0.012 \pm 0.007) ps$
Most precise measurement to date and consistent with previous measurements!
- The ratio of lifetimes is measured to be:
 $\tau(\bar{B}_s^0)/\tau(\bar{B}^0) = 1.010 \pm 0.010 \pm 0.008$
In perfect agreement with HQE predictions for Γ_s/Γ_d .



Observation of overlapping spin-1 and spin-3 $\bar{D}^0 K^-$ resonances at mass 2.86 GeV/c^2

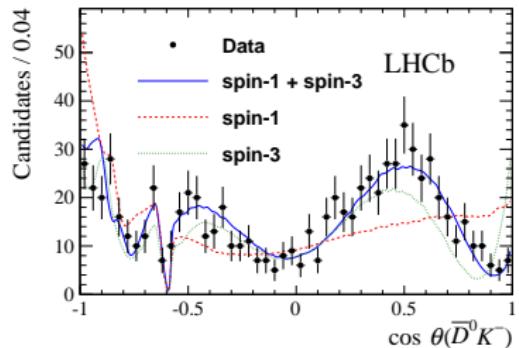
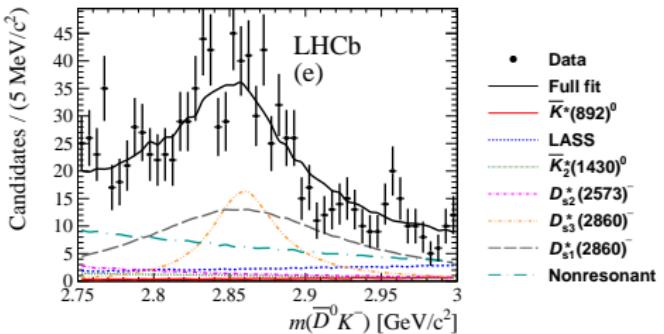
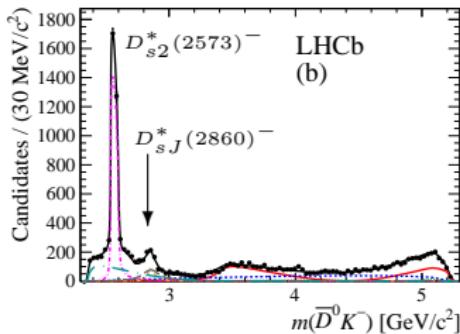
LHCb-PAPER-2014-035 and 36 - Accepted by PRL and PRD

- Study of the Dalitz plot of $B_s^0 \rightarrow D^0 K^- \pi^+$ decays using 3.0fb^{-1} of pp collisions
- Angular analysis to study quantum numbers of previously observed D_{sJ}^* resonances



Observation of overlapping spin-1 and spin-3 $\bar{D}^0 K^-$ resonances at mass 2.86 GeV/c^2

LHCb-PAPER-2014-035 and 36 - Accepted by PRL and PRD



- $D_{sJ}^*(2860)^-$ is composed of two states one of spin 1 and one of spin 3 both observed with more than 10σ significance
- First observation of spin 3 states in B decays and of a heavy flavour state with spin 3

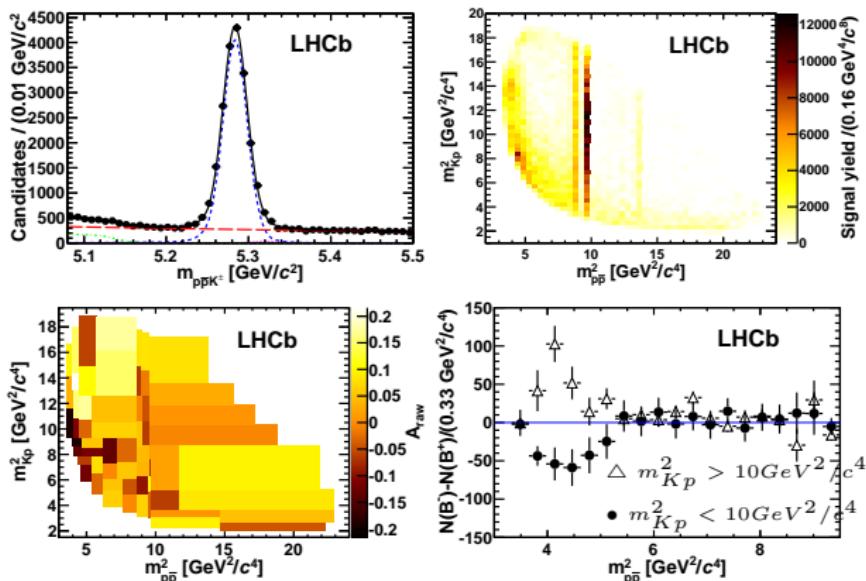


CP Violation and CKM matrix

First evidence of CP violation in b-hadron decays with baryons in the final state

LHCb-PAPER-2014-034 - Accepted to PRL

- Search for CP asymmetry in Dalitz plane of $B^+ \rightarrow p\bar{p}K^+$ decays with 3fb^{-1}
- Large asymmetries observed in $B \rightarrow hhh$: probe strong phase due to rescattering
- Baryons can have different behaviour



$$A(m_{p\bar{p}} < 2.85 \text{ GeV}/c^2, m_{K^0 p}^2 < 10 \text{ GeV}^2/c^4) = -0.036 \pm 0.023 \pm 0.004$$

$$A(m_{p\bar{p}} < 2.85 \text{ GeV}/c^2, m_{K^0 p}^2 > 10 \text{ GeV}^2/c^4) = +0.096 \pm 0.024 \pm 0.004 \quad (\text{Significance of } 4\sigma)$$

Measurement of the semileptonic CP asymmetry in B^0 decays

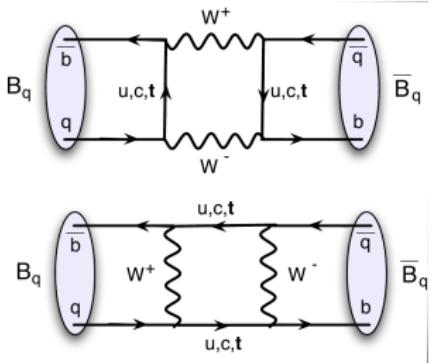
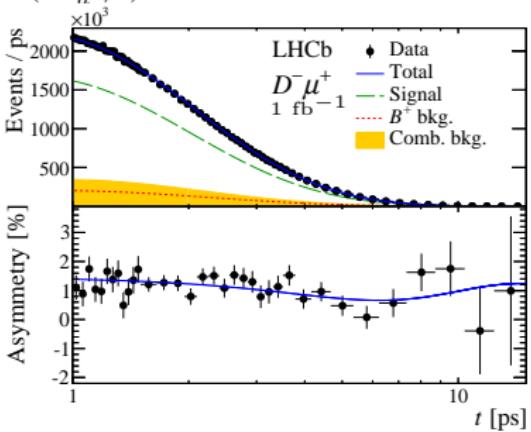
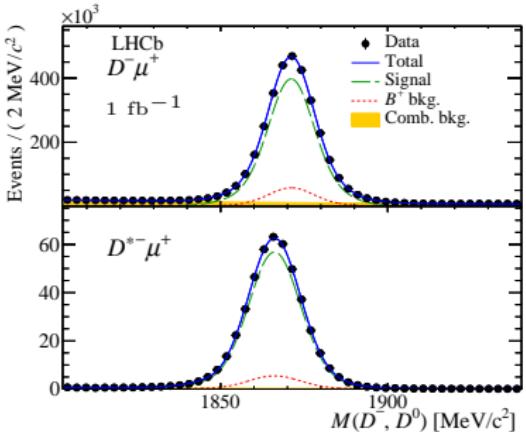
LHCb-PAPER-2014-053 - To be submitted to PRL

- Measurement of CP violation in mixing through flavour specific $B^0 \rightarrow D^{(*)-} \mu^+ X$ decays

$$a_{sl}^d \equiv \frac{\Gamma(\bar{B} \rightarrow B \rightarrow f) - \Gamma(B \rightarrow \bar{B} \rightarrow \bar{f})}{\Gamma(\bar{B} \rightarrow B \rightarrow f) + \Gamma(B \rightarrow \bar{B} \rightarrow \bar{f})}$$

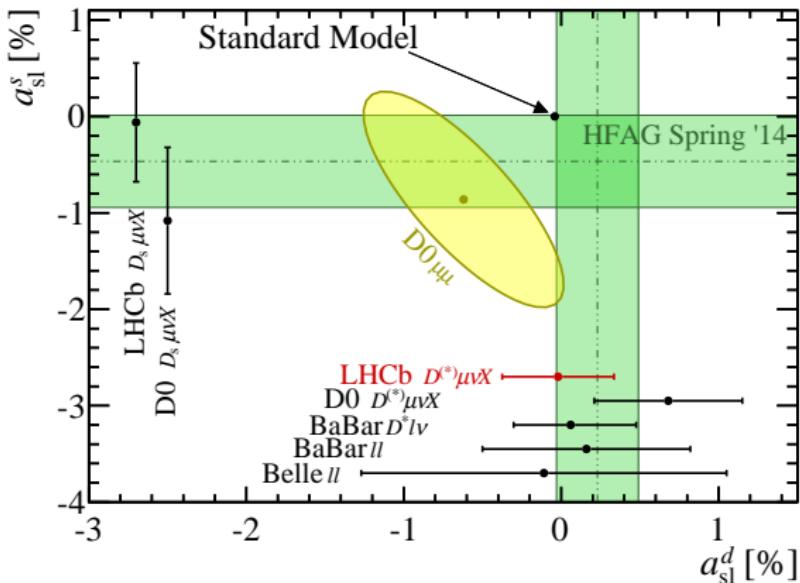
- $a_{sl}^d = (-4.1 \pm 0.6) \times 10^{-4}$ in the Standard Model
- D0 experiment observed a discrepancy w.r.t. the SM
- Exploit untagged time dependent rate:

$$A_{meas}(t) = \frac{a_{sl}^d}{2} + A_D - (A_P + a_{sl}^d) \frac{\cos(\Delta m_d t)}{\cosh(\Delta \Gamma_d t/2)}$$



Measurement of the semileptonic CP asymmetry in B^0 decays

LHCb-PAPER-2014-053 - To be submitted to PRL



Measurement of CP asymmetry

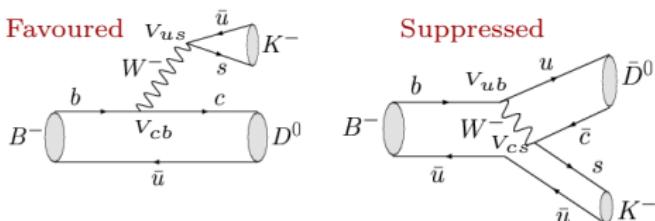
$$a_{sl}^d = (-0.02 \pm 0.19 \pm 0.30)\%$$

most precise measurement to date and compatible with the SM prediction and earlier measurements

The equivalent measurement for B_s^0 mesons is coming soon

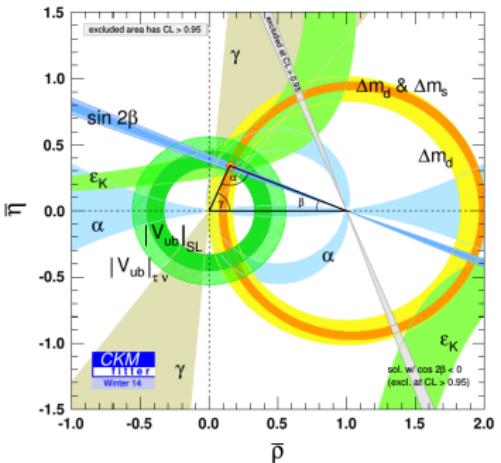
Measurement of the CKM matrix angle γ

- Cabibbo-Kobayashi-Maskawa angle
 $\gamma \equiv \arg \left(-\frac{V_{ud} V_{ub}^*}{V_{cd} V_{cb}^*} \right)$
- Measured at tree level from interference of $b \rightarrow c \bar{u} s$ and $b \rightarrow u \bar{c} s$ amplitudes
- Precision test of SM:
 $\gamma = (69.5 \pm 3.9)^\circ$ from unitarity



Can be measured in B decays

- $B^- \rightarrow D^0 K^-$ and $B^- \rightarrow \bar{D}^0 K^-$ with common D final state
- Weak phase difference is γ
- Strong phase difference δ_B
- $r_B = \frac{|A_{\text{suppressed}}|}{|A_{\text{favoured}}|}$



Various methods

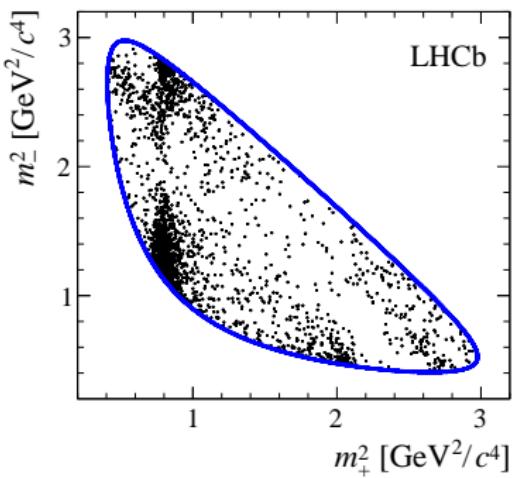
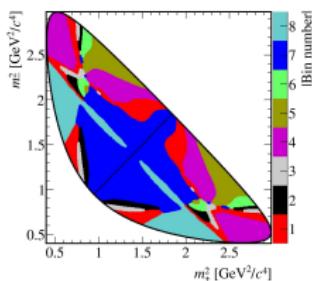
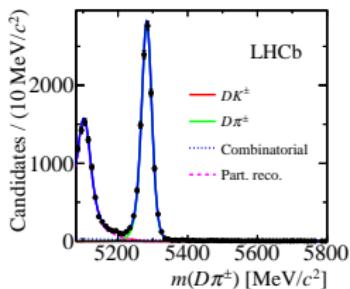
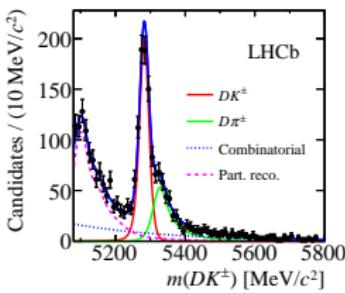
- ADS: flavour specific final state
- GLW: CP eigenstate final state
- GGSZ: Dalitz plot analysis
- GLS: Single Cabibbo suppressed
- Time dependent

Measurement of the CKM angle γ using $B^\pm \rightarrow DK^\pm$

LHCb-PAPER-2014-041 - Submitted to JHEP

- $D^0 \rightarrow K_S h h$ Dalitz plane distribution depends on interference:

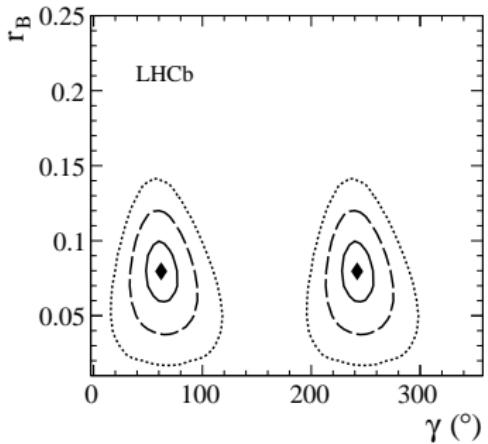
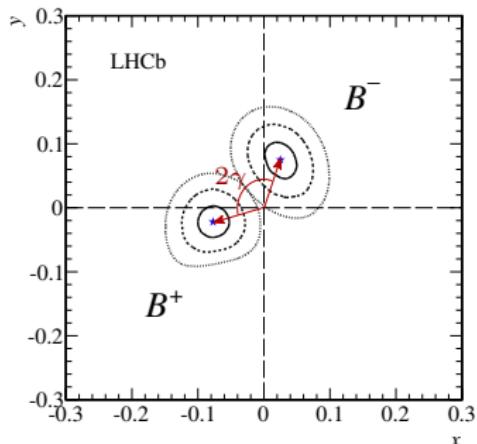
$$A_B(m_-^2, m_+^2) \propto A + r_B e^{i(\delta_B - \gamma)} \bar{A}$$
- Model independent binned method
- Strong phase variation from CLEO-c measurements (Phys. Rev. D82 (2010) 112006)
- Full dataset of 3fb^{-1}
- Improved analysis using $B \rightarrow D^* \mu \nu X$ decays to cross-check efficiency profile



Measurement of the CKM angle γ using $B^\pm \rightarrow DK^\pm$

LHCb-PAPER-2014-041 - Submitted to JHEP

Distribution described in terms of $x_\pm \equiv r_B \cos(\delta_B \pm \gamma)$ and $y_\pm \equiv r_B \sin(\delta_B \pm \gamma)$



$$\begin{aligned}x_+ &= (-7.7 \pm 2.4 \pm 1.0 \pm 0.4) \times 10^{-2} \\x_- &= (+2.5 \pm 2.5 \pm 1.0 \pm 0.5) \times 10^{-2} \\y_+ &= (-2.2 \pm 2.5 \pm 0.4 \pm 1.0) \times 10^{-2} \\y_- &= (+7.5 \pm 2.9 \pm 0.5 \pm 1.4) \times 10^{-2}\end{aligned}$$

$$\begin{aligned}r_B &= 0.080^{+0.019}_{-0.021} \\ \delta_B &= (134^{+14}_{-15})^\circ \\ \gamma &= (62^{+15}_{-14})^\circ\end{aligned}$$

consistent with world average and previous measurements.

Most precise single measurement of γ

Improved constraints on γ : CKM2014 update

LHCb-CONF-2014-004

Combination of LHCb results on the CKM angle γ .

- $B^+ \rightarrow Dh^+$, $D \rightarrow hh$, GLW/ADS, 1 fb^{-1} , Phys. Lett. B712 (2012) 203,
- $B^+ \rightarrow Dh^+$, $D \rightarrow K\pi\pi\pi$, ADS, 1 fb^{-1} , Phys. Lett. B723 (2013)
- $B^+ \rightarrow DK^+$, $D \rightarrow K_S^0 hh$, model-independent GGSZ, 3 fb^{-1} , arXiv:1407.6211, submitted to Nucl. Phys. B.
- $B^+ \rightarrow DK^+$, $D \rightarrow K_S^0 K\pi$, GLS, 3 fb^{-1} , Phys. Lett. B733 (2014) 36,
- $B^0 \rightarrow DK^{*0}$, $D \rightarrow hh$, GLW/ADS, 3 fb^{-1} , arXiv:1407.8136, submitted to Phys. Rev. D.
- $B_s^0 \rightarrow D_s^\pm K^\mp$, time-dependent, 1 fb^{-1} , arXiv:1407.6127, submitted to JHEP.

- $D^0 \bar{D}^0$ mixing and CP violation taken into account
- Auxiliary measurements on hadronic parameters
- Full combination and *robust* ($B \rightarrow DK$ only) combination
- Frequentist Feldman-Cousins method with “plug-in” treatment of nuisances and bayesian cross-check

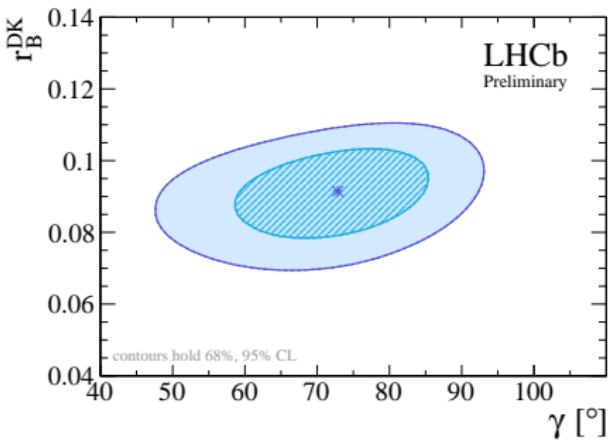
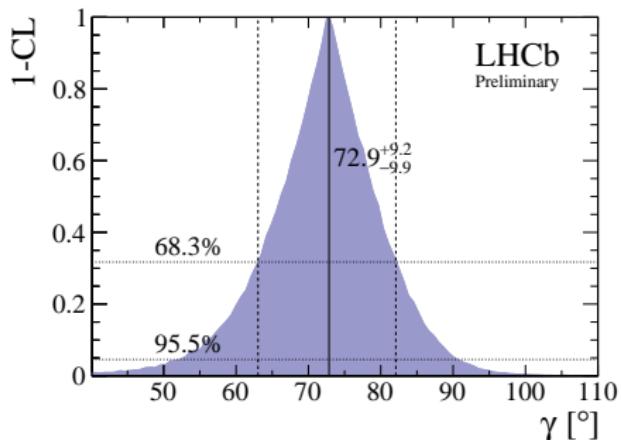
Improved constraints on γ : CKM2014 update

LHCb-CONF-2014-004

- Robust combination:

$$\gamma = (73^{+9}_{-10})^\circ$$

more precise than the B factories combination and more updates yet to come





Rare Decays

Observation of the rare $B_s^0 \rightarrow \mu^+ \mu^-$ decay from the combined analysis of CMS and LHCb data

LHCb-PAPER-2014-049 - CMS-BPH-13-007 - To be submitted to Nature

- One of the most sensitive decays to look for physics beyond the SM
- FCNC and helicity suppressed, precise theoretical predictions:

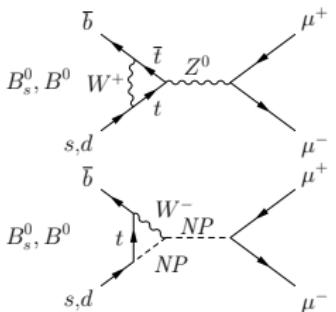
$$\begin{aligned}\mathcal{B}^{SM}(B_s^0 \rightarrow \mu^+ \mu^-) &= (3.66 \pm 0.23) \times 10^{-9} \\ \mathcal{B}^{SM}(B^0 \rightarrow \mu^+ \mu^-) &= (1.06 \pm 0.09) \times 10^{-10} \\ \mathcal{R} &= 0.0295^{+0.0028}_{-0.0025}\end{aligned}$$

LHCb [Phys.Rev.Lett. 111 (2013) 101805]

$$\begin{aligned}\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) &= \left(2.9^{+1.1}_{-1.0} \right) \times 10^{-9} \quad (4.0\sigma) \\ \mathcal{B}(B^0 \rightarrow \mu^+ \mu^-) &= \left(3.7^{+2.4}_{-2.1} \right) \times 10^{-10} \quad (2.0\sigma)\end{aligned}$$

CMS [Phys.Rev.Lett. 111 (2013) 101804]

$$\begin{aligned}\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) &= \left(3.0^{+1.0}_{-0.9} \right) \times 10^{-9} \quad (4.3\sigma), \\ \mathcal{B}(B^0 \rightarrow \mu^+ \mu^-) &= \left(3.5^{+2.1}_{-1.8} \right) \times 10^{-10} \quad (2.0\sigma),\end{aligned}$$



Observation of the rare $B_s^0 \rightarrow \mu^+ \mu^-$ decay from the combined analysis of CMS and LHCb data

LHCb-PAPER-2014-049 - CMS-BPH-13-007 - To be submitted to Nature

- Full combination with simultaneous fit of the two datasets
- Shared common parameters: $\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-)$, $\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-)$, $\mathcal{B}(B^+ \rightarrow J/\psi K^+)$, f_d/f_s
- Small variations to original publications:
 - LHCb: $\Lambda_b^0 \rightarrow p\mu^-\nu$ background included in default fit
 - CMS: corrected $\mathcal{B}(\Lambda_b^0 \rightarrow p\mu^-\nu)$ and q^2 , included lifetime bias correction
- Full frequentist Feldman-Cousins procedure for $\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-)$

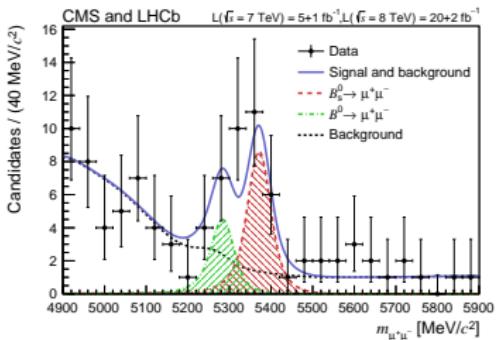
Results

$$\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) = (2.8^{+0.7}_{-0.6}) \times 10^{-9} \quad (6.2\sigma)$$

First observation of the $B_s^0 \rightarrow \mu^+ \mu^-$ decay

$$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-) = (3.9^{+1.6}_{-1.4}) \times 10^{-10} \quad (3.0\sigma[FC])$$

First evidence for an excess of events in the search for the $B^0 \rightarrow \mu^+ \mu^-$ decay.
Both branching fractions are compatible with the SM.



Observation of the rare $B_s^0 \rightarrow \mu^+ \mu^-$ decay from the combined analysis of CMS and LHCb data

LHCb-PAPER-2014-049 - CMS-BPH-13-007 - To be submitted to Nature

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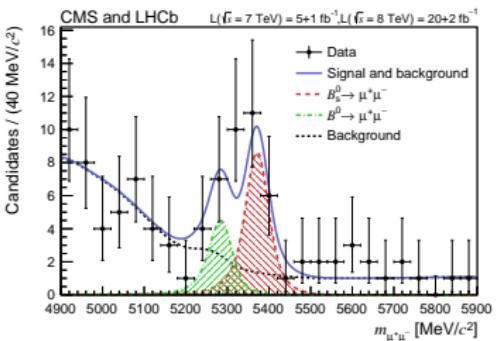
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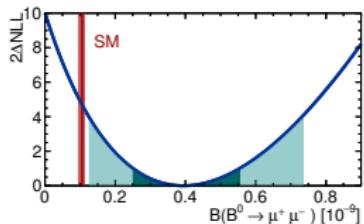
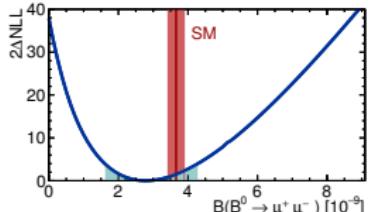
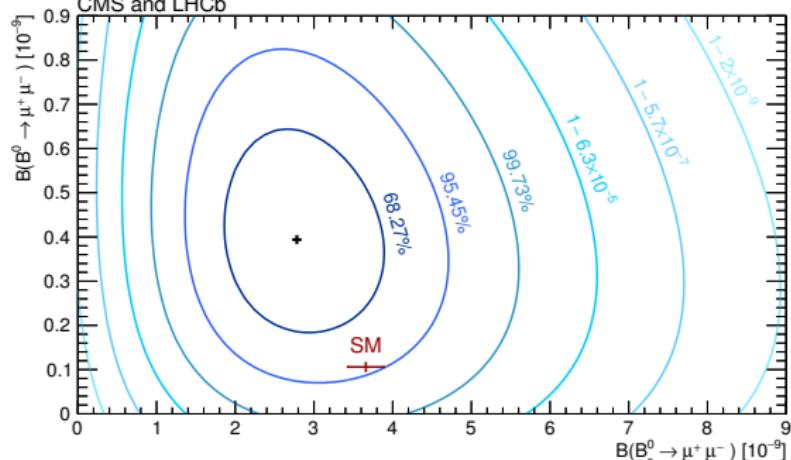
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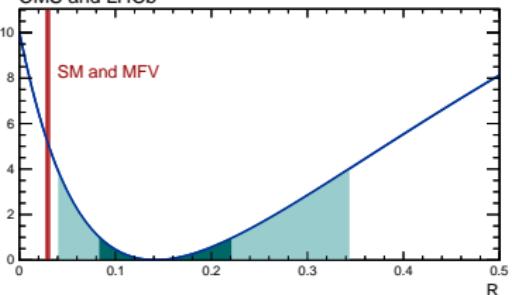
Observation of the rare $B_s^0 \rightarrow \mu^+ \mu^-$ decay from the combined analysis of CMS and LHCb data

LHCb-PAPER-2014-049 - CMS-BPH-13-007 - To be submitted to Nature

CMS and LHCb



CMS and LHCb

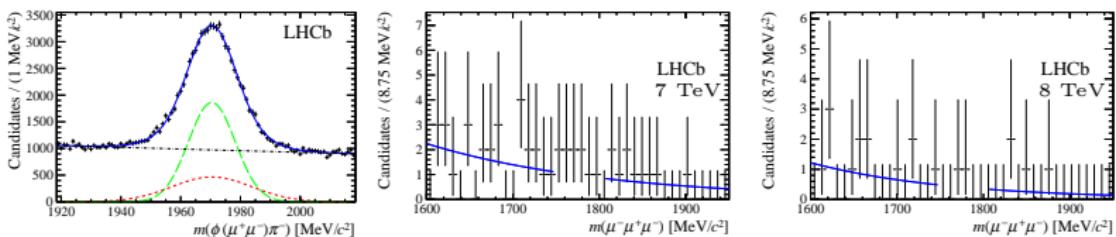


- Ratio of branching fractions, sensitive to MFV also measured: $\mathcal{R} = \frac{\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-)} = 0.14^{+0.08}_{-0.06}$
- Compatibility with SM at 2.3σ level
- First LHC combined analysis bore fruits!
- Precision measurement expected in the upgrade

Search for the lepton flavour violating decay $\tau^- \rightarrow \mu^- \mu^+ \mu^-$

LHCb-PAPER-2014-052 - To be submitted to JHEP

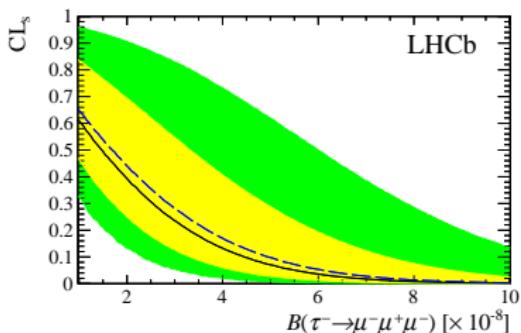
- LFV $\tau^- \rightarrow \mu^- \mu^+ \mu^-$ decays would be unambiguous signs of New Physics
- Large τ production ($85\mu b$ at 7 TeV) mainly from heavy quark decays
- Updated search with 3fb^{-1}
- Normalized to $D_s \rightarrow \phi(\rightarrow \mu\mu)\pi$: $\mathcal{B}(\tau^- \rightarrow \mu^- \mu^+ \mu^-) = \frac{\mathcal{B}(D_s^- \rightarrow \phi(\rightarrow \mu^+ \mu^-)\pi^-)}{\mathcal{B}(D_s^- \rightarrow \tau^- \bar{\nu}_\tau)} f_\tau^{D_s} \frac{\varepsilon_{cal}}{\varepsilon_{sig}} \frac{N_{sig}}{N_{cal}}$



No excess observed, upper limit with CLs method:

$$\mathcal{B}(\tau^- \rightarrow \mu^- \mu^+ \mu^-) < 4.6(5.6) \cdot 10^{-8} \text{ at } 90 \text{ (95) \% CL}$$

Helps to improve world limit together with B factories



Conclusions

- LHCb experiment in good shape: exploiting the full statistics of Run I
- Wide range of physics topics: from large cross-sections to rare decays
- Stable physics output rate and many interesting results yet to come
- Many leading results but still room for NP in precision measurements
- Looking forward to the exciting Run II
- Upgrade program on track, ready for detector construction

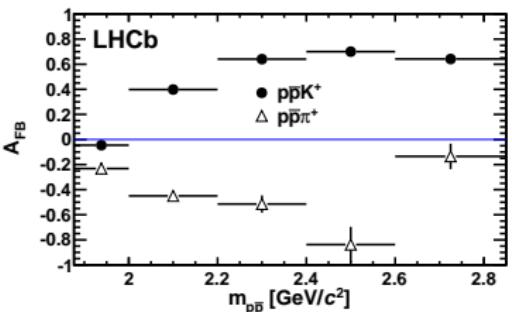
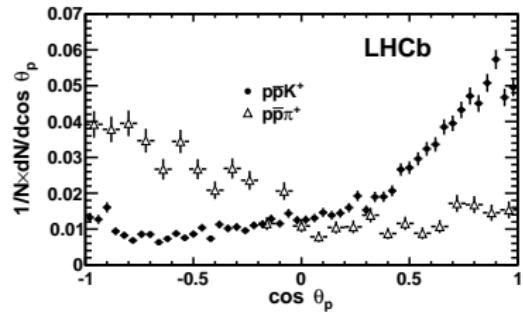
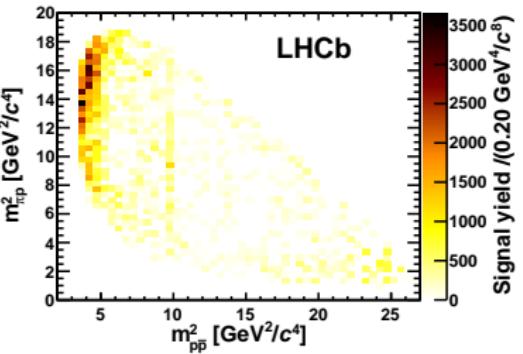
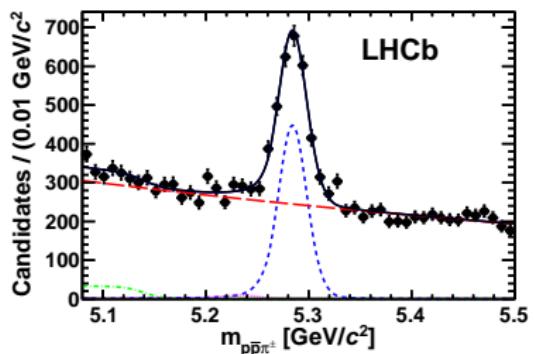


Additional material

Evidence for CP violation in $B^+ \rightarrow p\bar{p}K^+$ + decays

LHCb-PAPER-2014-034 - Submitted to PRL

Forward-Backward asymmetry also studied in $B \rightarrow p\bar{p}h$ decays



Measurements of CP violation in the three-body phase space of charmless B^\pm decays

LHCb-PAPER-2014-044

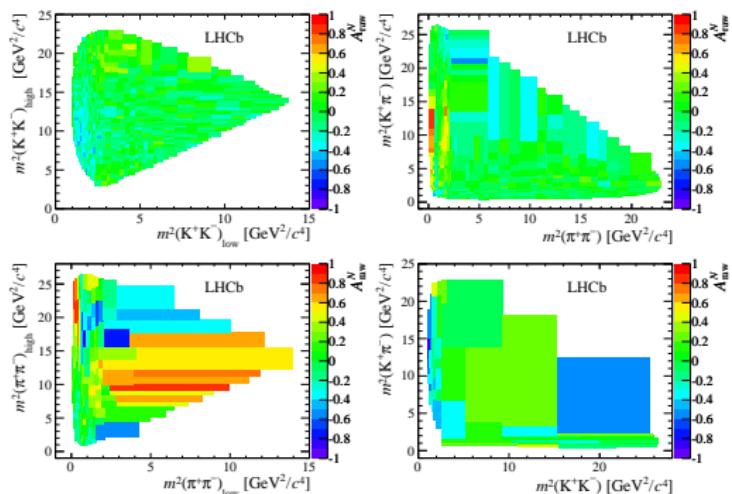
- Search for CP asymmetry in $B \rightarrow hhh$ decays with 3fb^{-1}
- Integrated asymmetries measured

$$A_{CP}(B^\pm \rightarrow K^\pm \pi^+ \pi^-) = +0.025 \pm 0.004 \pm 0.004 \pm 0.007 \quad (2.8\sigma)$$

$$A_{CP}(B^\pm \rightarrow K^\pm K^+ K^-) = -0.036 \pm 0.004 \pm 0.002 \pm 0.007 \quad (4.3\sigma)$$

$$A_{CP}(B^\pm \rightarrow \pi^\pm \pi^+ \pi^-) = +0.058 \pm 0.008 \pm 0.009 \pm 0.007 \quad (4.2\sigma)$$

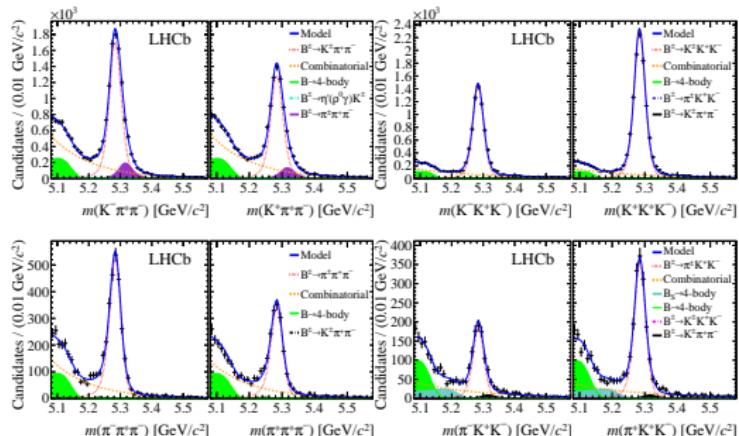
$$A_{CP}(B^\pm \rightarrow \pi^\pm K^+ K^-) = -0.123 \pm 0.017 \pm 0.012 \pm 0.007 \quad (5.6\sigma)$$



Measurements of CP violation in the three-body phase space of charmless B^\pm decays

LHCb-PAPER-2014-044

- Different asymmetries for $\pi\pi$ and KK final states probably due to rescattering
- Contributions also due to interference of partial waves
- Full angular analysis needed to disentangle



Decay	N_S	A_{CP}
$B^\pm \rightarrow K^\pm \pi^+ \pi^-$	$15\,562 \pm 165$	$+0.121 \pm 0.012 \pm 0.017 \pm 0.007$
$B^\pm \rightarrow K^\pm K^+ K^-$	$16\,992 \pm 142$	$-0.211 \pm 0.011 \pm 0.004 \pm 0.007$
$B^\pm \rightarrow \pi^\pm \pi^+ \pi^-$	4329 ± 76	$+0.172 \pm 0.021 \pm 0.015 \pm 0.007$
$B^\pm \rightarrow \pi^\pm K^+ K^-$	2500 ± 57	$-0.328 \pm 0.028 \pm 0.029 \pm 0.007$