What's new at LHCb
(LHCb Overview)

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on behalf of the LHCb Collaboration

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1. Overview

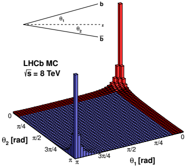
Overview

- LHCb Experiment — $3\,\text{fb}^{-1}$ [arXiv:1412.6352]
- Rare Decays
  - $B_s^0 \to \mu^+\mu^-$ (combination with CMS) — $3\,\text{fb}^{-1}$ [arXiv:1411.4413]
  - $B^0 \to K^{*0} e^+ e^-$ - — $3\,\text{fb}^{-1}$ [arXiv:1501.03038]
  - Lepton universality with $B^+ \to K^+\ell^+\ell^-$ (R_K) — $3\,\text{fb}^{-1}$ [PRL 113, 151601 (2014)]
  - $B^0 \to K^{*0}\mu^+\mu^-$ (P_5') — $1\,\text{fb}^{-1}$ [PRL 111, 191802 (2013)]
  - $B_s^0 \to \pi^+\pi^-\mu^+\mu^-$ and $B^0 \to \pi^+\pi^-\mu^+\mu^-$ — $3\,\text{fb}^{-1}$ [arXiv:1412.6433]
- CKM matrix and CP violation
  - β angle measurements — $1\,\text{fb}^{-1}$ [PLB 721 (2013) 24-31]
  - γ angle measurements and combination — $1\text{-}3\,\text{fb}^{-1}$ [arXiv:1411.4600]
  - Mixing induced CP violation (ϕ_s) - $B_s^0 \to J/\psi\,\phi$ — $3\,\text{fb}^{-1}$ [arXiv:1411.3104]
  - Semileptonic CP asymmetry in B mixing (A^s_{SL},A^d_{SL}) — $3\,\text{fb}^{-1}$ [arXiv:1409.8586]
- Selected others
  - Lumi measurement — $3\,\text{fb}^{-1}$ [2014 JINST 9 P12005]
  - Search for long lived to jet pairs — $0.6\,\text{fb}^{-1}$ [arXiv:1412.3021]
  - Measurement of B_c^+ lifetime — $3\,\text{fb}^{-1}$ [PLB 742 (2015) 29-37]
- The future
  - Prospects for Run2
  - LHCb Upgrade — [CDS LHCb Reports]

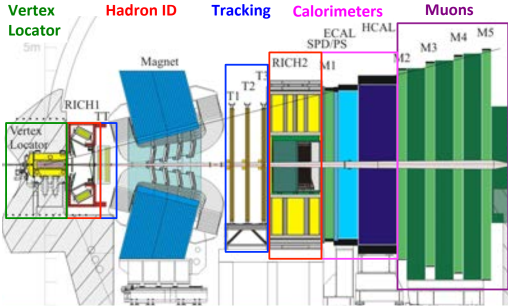
2. LHCb Experiment

The LHCb Detector

- A single arm forward spectrometer - unique pseudorapidity (η) range
- pp collisions in Run 1:
  - 2011: $\sqrt{s}$ =7 TeV, L=1 fb^{-1}
  - 2012: $\sqrt{s}$ =8 TeV, L=2 fb^{-1}
- High $b\bar{b}$ and $c\bar{c}$ production cross section:
  - $\sigma(pp \to b\bar{b}) = 286\mu\text{b}$ at 7 TeV
  - $\sigma(pp \to c\bar{c}) \approx$ 20 times larger

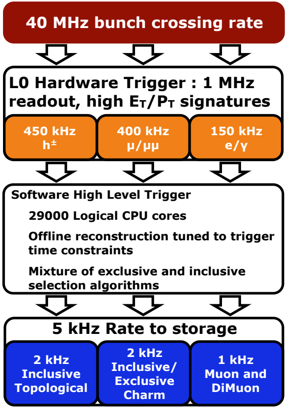


- Recent detector performance paper using data from 2010-2012 - [arXiv:1412.6352]



The LHCb Experiment II

- Detector sub-systems:
  - Tracking system
    - IP resolution $\approx 20\mu$m
    - p resolution $\approx 0.5\%$
    - τ resolution ≈ 45 fs
  - RICH sub-detectors
    - Good $K - \pi$ separation for momentum range $2 < p < 100$ GeV/c
  - Calorimeters
    - Identification of $\gamma,\ e,\ \pi^0$
  - Muon detectors
    - Identification of μ
  - All complimented with a sophisticated trigger system
    - Allows high readout rate
    - High efficiency for a broad range of physics topics
    - Considerable improvement in the HLT for 2015 and beyond (more later)
- Integrated luminosity
  - $\sqrt{s} = 7$ TeV $L = 1\,\text{fb}^{-1}$ 2011
  - $\sqrt{s} = 8$ TeV $L = 2\,\text{fb}^{-1}$ 2012
  - $\sqrt{s} = 13$ TeV $L = 7 - 8\,\text{fb}^{-1}$ 2015-2017
- Instaneous luminosity (levelled)
  - Can cope with anything $\approx 1 - 4 \times 10^{32}$ cm^{2}s^{-1} before detector occupuncies become very high



LHCb Physics

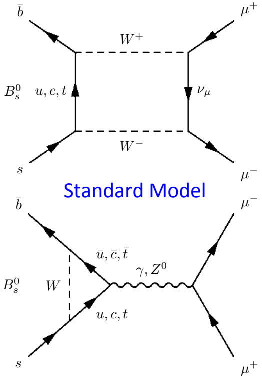
- Many aspects to LHCb physics program
- Mostly indirect searches for new physics
  - Rare decays
  - CP violation
  - Historically indirect approach gives success
    - Z^0 inferred a decade before direct observation
    - t quark inferred 3 decades before direct observation
- Measurement of SM CKM parameters
  - γ, β, ϕ_s
  - Can also offer hints of new physics
- Spectroscopy
- Charm physics
- QCD measurements
- EW measurements
- Exotica searches

At the institute of particle physics

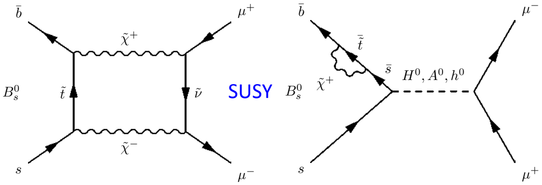
3. Rare Decays

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

- Very rare decay strongly suppressed in the SM
- Theoretically well understood
- Predicted BRs:
  - $B_s^0 \to \mu^+\mu^- = (3.65 \pm 0.23) \times 10^{-9}$
  - $B^0 \to \mu^+\mu^- = (1.06 \pm 0.09) \times 10^{-10}$
  - [arXiv:1311.0903]
- Highly sensitive to new physics
- LHCb result based on full Run 1 luminosity ($3\,\text{fb}^{-1}$)
- Recent combination with CMS ($25\,\text{fb}^{-1}$) submitted to Nature - [arXiv:1411.4413]

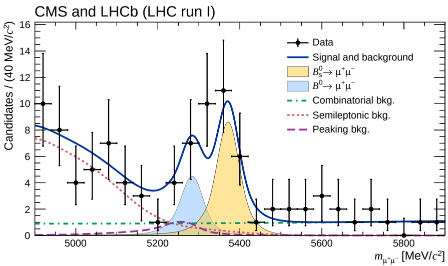


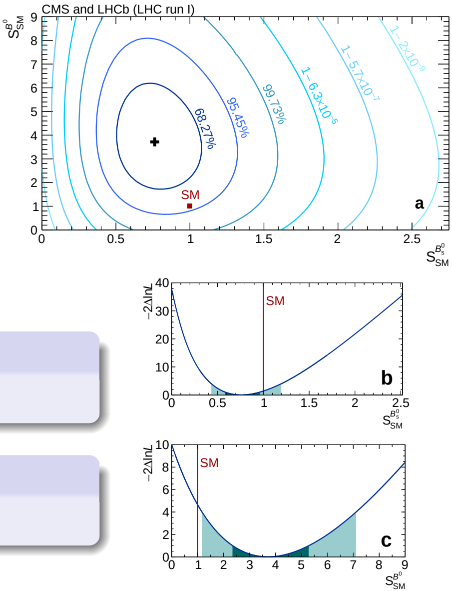
Standard Model



SUSY

$B_s^0 \to \mu^+\mu^-$, $B^0 \to \mu^+\mu^-$ combination with CMS





$B_s^0 \to \mu^+\mu^-$ 6.2σ - first observation

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

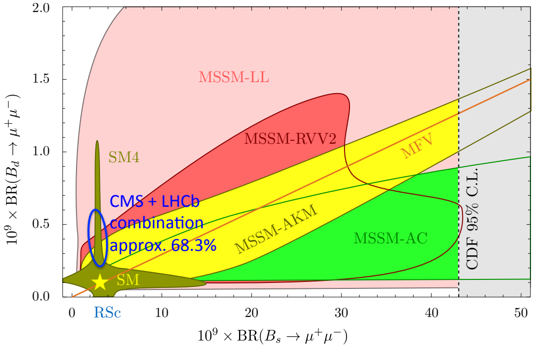
$B^0 \to \mu^+\mu^-$ 3.2σ

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.9^{+1.6}_{-1.4}) \times 10^{-10}$$

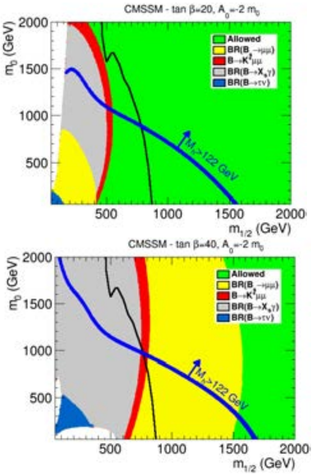
$B_{s(d)} \to \mu^+\mu^-$ implications

- Provides strong constraints on many new physics models
  - particularly at large $\tan\beta$

[arXiv:1107.0266]

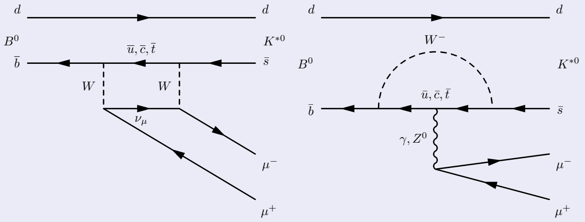


[arXiv:1401.2145]

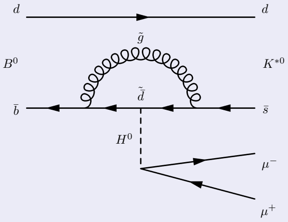


FCNC decays $B^0 \to K^{*0}\ell^+\ell^-$

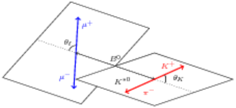
Standard Model



SUSY



- Sensitive to NP contributions in the loops
- Express differential decay rate with angular observables which are form factor independent
- Decay of $B^0 \to K^{*0}\mu^+\mu^-$ at LHCb with $1\,\mathrm{fb}^{-1}$ ($3\,\mathrm{fb}^{-1}$ update coming soon)
- Recently published result of $B^0 \to K^{*0}e^+e^-$ in low q^2 region



(a) θ_K and θ_ℓ definitions for the B^0 decay

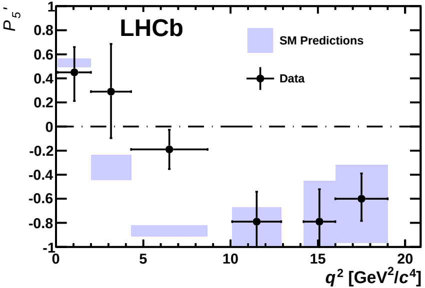
$B^0 \to K^{*0} \mu^+ \mu^-$

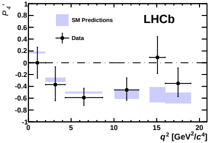
- Complicated angular fit
- Use observables with small form factor uncertainties

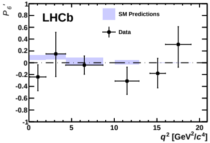
$$\frac{1}{\mathrm{d}\Gamma/dq^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi\,\mathrm{d}q^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K + \frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_\ell$$
$$- F_\mathrm{L}\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi$$
$$+ S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi$$
$$+ S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$
$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

$$P'_{i=4,5,6,8} = \frac{S_{j=\mathbf{4,5,7,8}}}{\sqrt{F_L(1-F_L)}}$$

- Discrepany with SM, local significance of 3.7σ, in 3rd bin of P'_5
- After LEE correction this goes down to $\approx 3\sigma$
- Possibly NP contribution to EW penguin?
- Are the theory errors reliable?
- Result with $1\,\mathrm{fb}^{-1}$ of data - [PRL 111, 191802 (2013)]
- Update with full Run 1 data coming soon

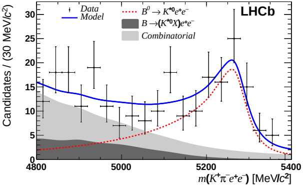




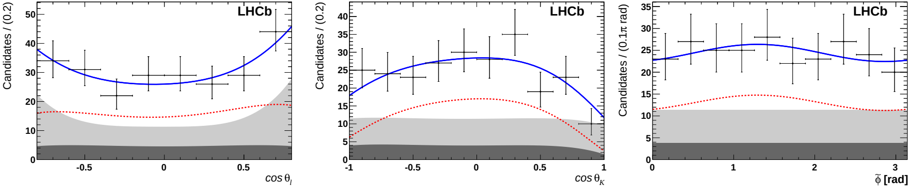


$B^0 \to K^{*0} e^+ e^-$

- New result - [arXiv:1501.03038]
- Similar concept to $B^0 \to K^{*0}\mu^+\mu^-$
- Measure angular observables in low q^2 region: $0.002 < q^2 < 1.120\ \text{GeV}^2/c^4$
- Using full $3\,\text{fb}^{-1}$ of Run 1 data
- *Results are consistent with SM predictions*

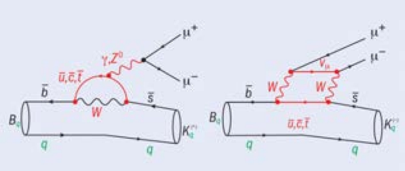


Variable	Fit value ± (stat) ± (syst)	Relation
F_L	$0.16 \pm 0.06 \pm 0.03$	Related to K^{*0} polarisation and lepton forward-backward asymmetry
A_T^{Re}	$0.10 \pm 0.18 \pm 0.05$	
$A_T^{(2)}$	$-0.23 \pm 0.23 \pm 0.05$	Sensitive to the photon polarisation
A_T^{Im}	$0.14 \pm 0.22 \pm 0.05$	

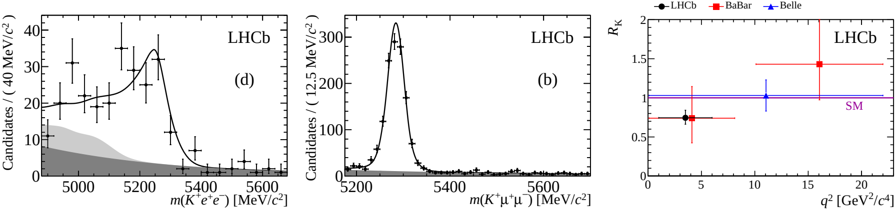


Lepton universality in $B^+ \to K^+\ell^+\ell^-$

- In the SM expect that:
  $R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+e^+e^-)} = 1 \pm \mathcal{O}(10^{-3})$
- Sensitive to lepton flavour violating NP
- Electrons are difficult for LHCb



- Use double ratios with $B^+ \to K^+ J/\psi(\to \ell^+\ell^-)$ to cancel systematics
  - assumes lepton universality for the J/ψ
  - [PRL 113, 151601 (2014)]



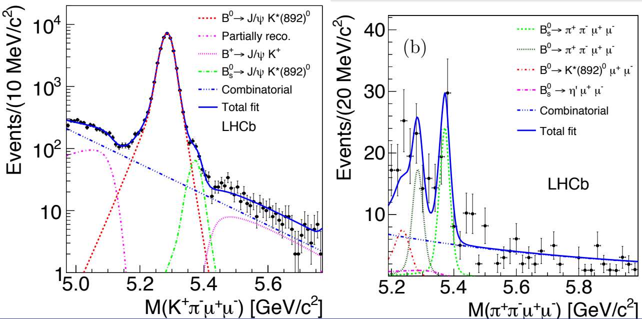
Find R_K compatible with SM at 1% level

$R_K = 0.745^{+0.090}_{-0.074}\,(\text{stat}) \pm 0.036\,(\text{syst})$

$B_{s(d)} \to \pi^+\pi^-\mu^+\mu^-$

- New result using $3\,\mathrm{fb}^{-1}$ of data - [arXiv:1412.6433] - submitted to Phys. Lett. B
- First observation of the decay $B_s^0 \to \pi^+\pi^-\mu^+\mu^-$ at 7.3σ
- First evidence of the decay $B^0 \to \pi^+\pi^-\mu^+\mu^-$ at 4.8σ
- Use the $B \to J/\psi\, K^*$ decay for normalisation
- Veto non-resonant $\mu^+\ \mu^-$ and require $0.5 < m(\pi^+\pi^-) < 1.3\ \mathrm{GeV}/c^2$

$$\mathcal{B}(B_s^0 \to \pi^+\pi^-\mu^+\mu^-) = (8.6 \pm 1.5 \pm 0.7 \pm 0.7) \times 10^{-8}$$
$$\mathcal{B}(B^0 \to \pi^+\pi^-\mu^+\mu^-) = (2.11 \pm 0.51 \pm 0.15 \pm 0.16) \times 10^{-8}$$

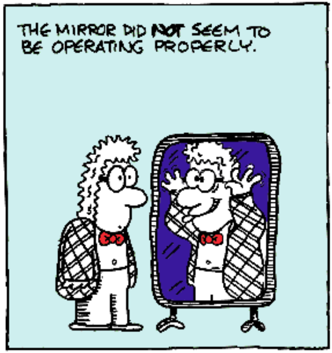


4. CKM matrix

CP violation at LHCb

"CP violation in B and D systems at LHCb"

- More details in Marta Calvi's talk later today
- A brief description and selected highlights here



Quark mixing and the CKM matrix

- Quark mixing in the SM described by the CKM matrix

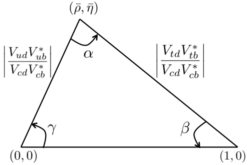
CKM matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

- ~ 1, ~ 0.2, ~ 0.04, $\sim 0.004 - 0.008$
- Further from diagnoal, the weaker the couplings (hierachy)
- Unitarity requires that $VV^\dagger = \mathbb{1}$
- Imposes 6 conditions (off diagonals of $VV^\dagger = 0$) - unitarity triangles

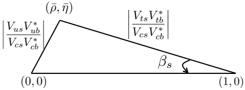
"B^0 unitarity triangle"

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



"B_s^0 unitarity triangle" (much more squeezed)

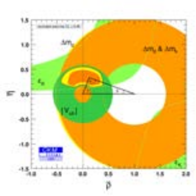
$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0$$



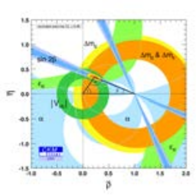
The B^0 unitarity triangle

- CKM picture now well verified - any discrepancies could be of great importance

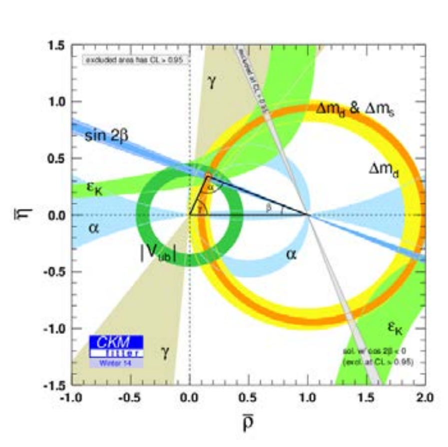
1995



2004



2014



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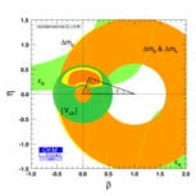
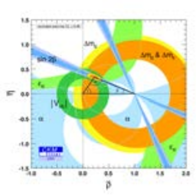
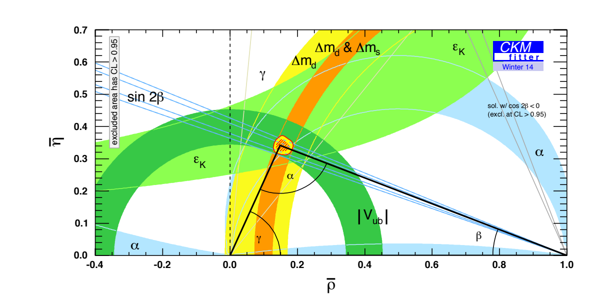


2004



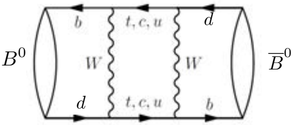
2014 - zoom

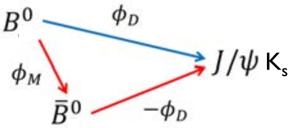


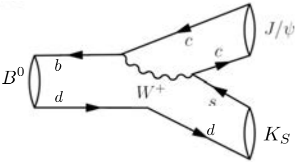
Measuring angle β

- *Interference* between mixing (via $B\overline{B}$ oscillation) and decay (to $J/\psi\ K^0_S$) gives a CP violating phase:

$$\phi = \phi_M - 2\phi_D = 2\beta$$



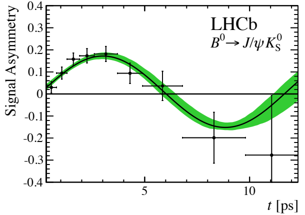




- Measure decay asymmetry to get $\sin(2\beta)$

$$\mathcal{A}(t) = \frac{\Gamma(\overline{B}^0(t) \to J/\psi\, K^0_S) - \Gamma(B^0(t) \to J/\psi\, K^0_S)}{\Gamma(\overline{B}^0(t) \to J/\psi\, K^0_S) + \Gamma(B^0(t) \to J/\psi\, K^0_S)}$$

- Current analysis with $1\,\mathrm{fb}^{-1}$- [PLB 721 (2013) 24-31]
  - Result: $\sin(2\beta) = 0.73 \pm 0.07 \pm 0.04$
  - $3\,\mathrm{fb}^{-1}$ coming soon (precision comparable with B factories)



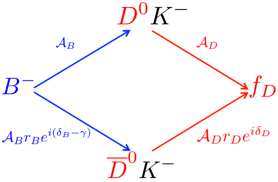
World average (HFAG Winter 2014)

$\sin(2\beta) = 0.68 \pm 0.02$

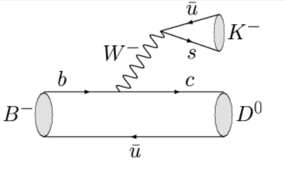
Measuring angle γ from trees

- Use interference between tree decays of $B^{\pm} \to DK^{\pm}$ and $D\pi^{\pm}$ which lead to the same final state
  - Inteference between *"suppressed"* and *"favoured"* decays
  - Combine results of many modes with different methodologies:

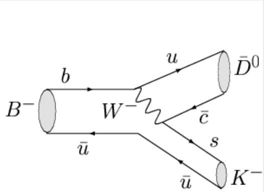
Method	Decay	Reference
GGSZ	$D \to K^0_S\pi^{\pm}\pi^{\mp}$, $D \to K^0_S K^{\pm}K^{\mp}$	[arXiv:1408.2748]
K3π	$D \to \pi^{\pm}K^{\mp}\pi^{\pm}\pi^{\mp}$, $D \to K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}$	[arXiv:1203.3662]
ADS	$D \to \pi^{\pm}K^{\mp}$	[arXiv:1203.3662]
GLW	$D \to K^{\pm}K^{\mp}$, $D \to \pi^{\pm}\pi^{\mp}$	[arXiv:1203.3662]



Favoured



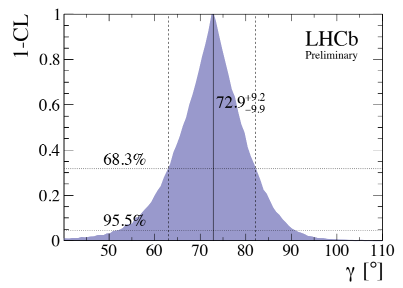
Suppressed



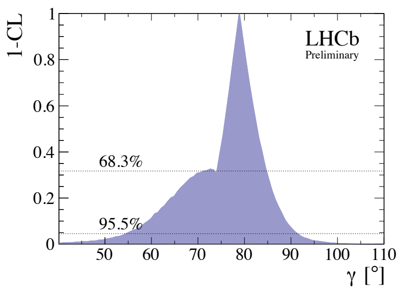
LHCb combination of angle γ from trees

- Nominal result: $\gamma = (72.9^{+9.2}_{-9.9})^\circ$ - [arXiv:1411.4600]
- World average (direct measurement): $\gamma = (73.2^{+6.3}_{-7.0})^\circ$
- Uncertainty $< 10^\circ$ is better than combined B factories
- Many Run 1 modes still to be published with $3\,\text{fb}^{-1}$
- Continued improvement expected with larger statistics of Run 2 and beyond:
  - Hope to get near $\sim 3^\circ$ precision (current indirect precision)

Result combining $B \to DK$ decays

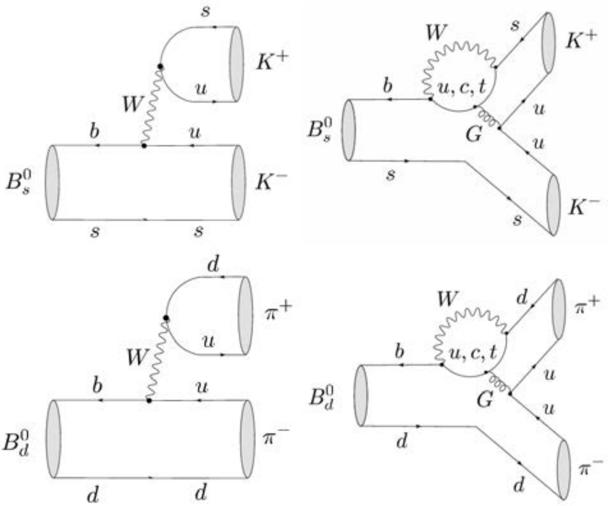


Result combining $B \to DK$ and $B \to D\pi$ decays



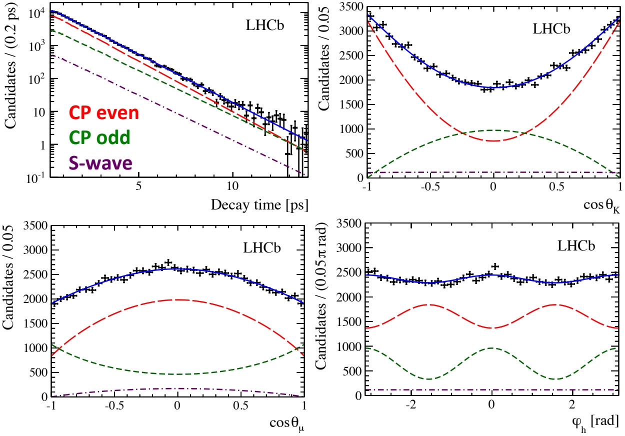
Measuring angle γ from loops

- Make use of decays: $B^0 \to K^+K^-$, $B^0 \to \pi^+\pi^-$, $B^+ \to \pi^+\pi^0$, $B^0 \to \pi^0\pi^0$
- Result compatible with γ from trees $\gamma = (63.5^{+7.2}_{-6.7})^\circ$ - [arXiv:1408.4368]



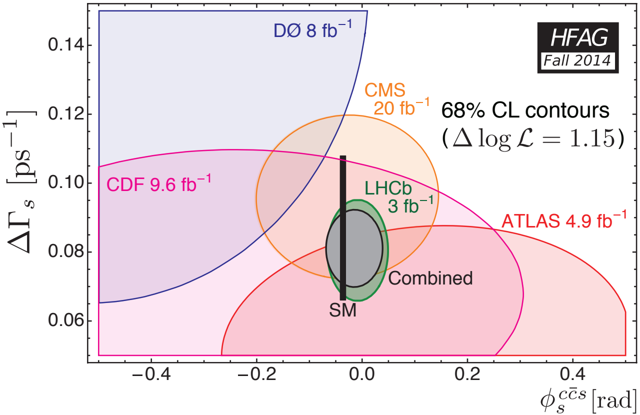
CP violation in the B_s^0 system

- Interference between decay ($B_s^0 \to J/\psi\,\phi$) and mixing (via $B\overline{B}$ oscillation)
- CP violating phase $\phi_s = -2\beta_s$ in SM
  - Very small and precisely predicted in SM
  - Early Tevatron results were tantalising
- LHCb (and also ATLAS/CMS) have clarified this picture
  - $B_s^0 \to J/\psi\,\phi$ analysis with $\sim 20\times$ precision of Tevatron
  - Augmented with complementary analysis of $B_s^0 \to J/\psi\,\pi^+\pi^-$
- Final LHCb Run1 results recently made public - [arXiv:1411.3104]



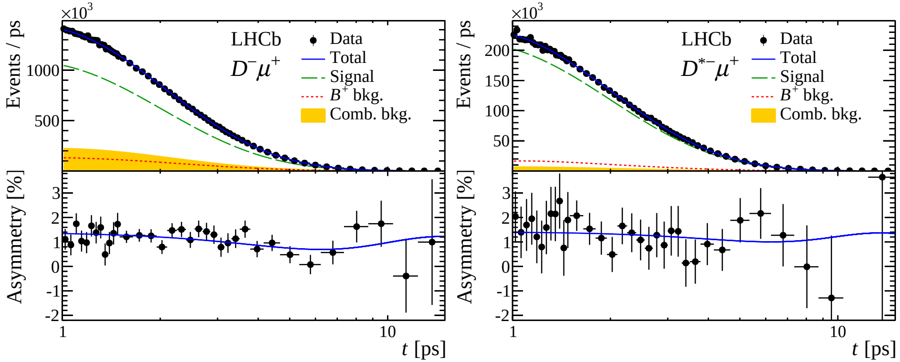
HFAG combination of ϕ_s and $\Delta\Gamma_s$

- SM wins out again!
- Still, these observable are very sensitive to non-SM contributions
- Improved precision is a long term aim
- World average $\phi_s = -0.015 \pm 0.035$ - [arXiv:1412.7515]
  - Precision dominated by LHCb



Semileptonic CP asymmetry in $B\overline{B}$ mixing

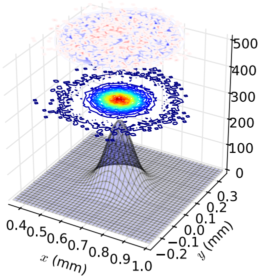
- Reconstruct $B^0 \to D^-\mu^+$ and $B^0 \to D^{*-}\mu^+$ where $D^- \to K^+\pi^-\pi^-$ and $D^{*-} \to \bar{D}\pi^-$
- Measure asymmetry between the number of $D^{(*)-}\mu^+$ and $D^{*+}\mu^-$ decays
- Result consistent with SM $a_{\rm sl}^d = (-0.02 \pm 0.19 \pm 0.30)\%$ - [arXiv:1409.8586]

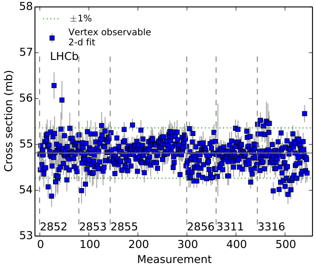


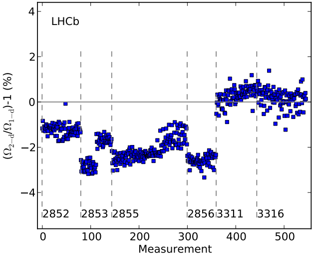
5. Selected others

Luminosity measurement

- Precise luminosity measurement required to reduce uncertainty as much as possible when measuring cross sections and yields
- LHCb now has the most precise lumi measurement at a bunched hadron collider
- Luminosity uncertainty now at 1.1% level for Run 1 data - [2014 JINST 9 P12005]
  - Introduced two-dimensional description of the beam density profile
  - Use of both *"van der Meer scan"* and *"beam gas imaging"* methods

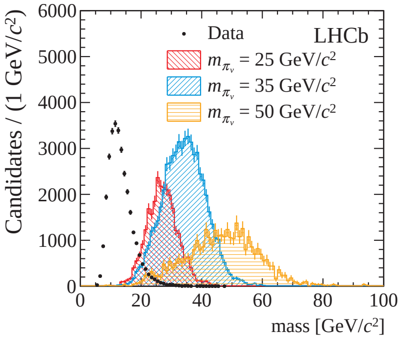


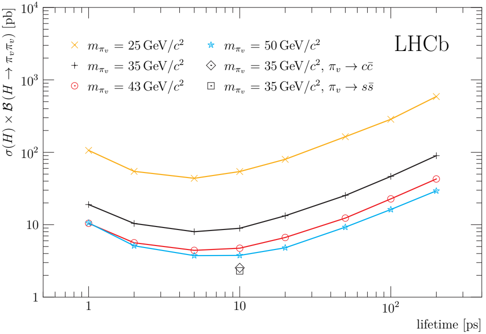




Search for long-lived particles decaying to jet pairs

- Search for long lived particles with $25 < m_{jj} < 50$ GeV$/c^2$ and $1 < t < 200$ ps
  - Pair-produced from SM-like Higgs
- Using just first 0.62 fb^{-1} of data at $\sqrt{s}$ =7 TeV - [arXiv:1412.3021]
- See no excess above background
- Exclude some hidden valley scenarios





Measurement of the B_c^+ lifetime using $B_c^+ \to J/\psi\,\pi^+$

- Study the time evolution of $B_c^+ \to J/\psi\,\pi^+$ and $B^+ \to J/\psi\,K^+$ decays - [PLB 742 (2015) 29-37]
- Measure the partial width difference (ratio of decay times) of the two to extrapolate the B_c^+ lifetime
- Indepdent of the complimentary measurement with the semileptonic $B_c^+ \to J/\psi\,\mu^+\nu_\mu X$ decay

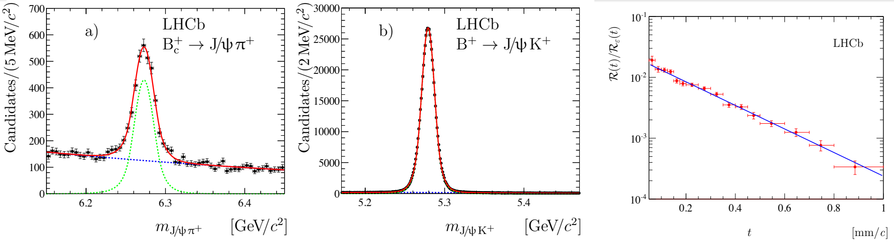
$B_c^+ \to J/\psi\,\pi^+$ lifetime

$\Delta\Gamma = \Gamma_{B_c^+} - \Gamma_{B^+} = 4.46 \pm 0.14 \pm 0.07\ \mathrm{mm}^{-1}c$

$\tau_{B_c^+ \to J/\psi\,\pi^+} = 513.4 \pm 11.0 \pm 5.7$ fs

Combined $B_c^+ \to J/\psi\,\pi^+$ and $B_c^+ \to J/\psi\,\mu^+\nu_\mu X$

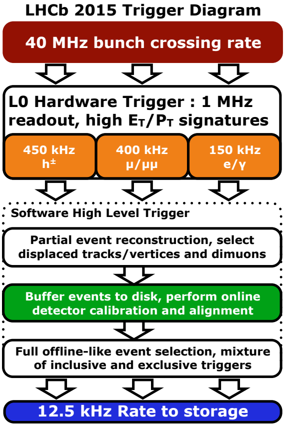
$\tau_{\mathbf{B_c^+}} = \mathbf{511.4 \pm 9.3}$ **fs**



6. The Future

Preparing for Run 2

- Run 2 now only a few months away!
- Nominal running at $\sqrt{s}$ =13 TeV
  - $b\overline{b}$ cross section increased by ~ 1.6
  - Expect total integrated luminosity of $\sim 6-8\,\mathrm{fb}^{-1}$
- Considerable improvements to trigger system will facilitate new challenges
- Improvements
  - Systematics from size of control samples
  - Detector induced asymmetries
  - PID calibration
  - Lifetime biasing cuts in trigger
- Objectives
  - There are many!
  - Improved precision in CKM paramters
  - Improved knowledge of rare processes e.g. $B_{s(d)} \to \mu^+\mu^-$ and $B^0 \to K^{*0}\ell^+\ell^-$
  - More spectroscopy
  - New ideas!
- Full explotation of Run 1 data still ongoing

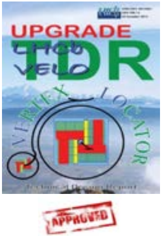


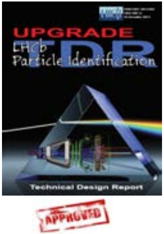
And beyond....

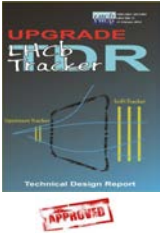
- Huge improvements planned for 2019 and beyond with the LHCb upgrade
- Operational lumi will increase to $2 \times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - Aim to collect $50\,\mathrm{fb}^{-1}$ in total
- Upgrade all detector subsystems:

VELO	41M $55\mu\mathrm{m}\times 55\mu\mathrm{m}$ Si pixels very close to beam
PID	Upgrades to RICH1, Calorimeters and Muon system
Tracking	Si based upstream tracker and scintillating fibre downstream tracking system

- Limitations of current L0 hardware trigger will be completely removed
- Will read out the full detector at 40 MHz!
- Full software trigger - running on large CPU farm
- All upgrade projects have been approved by CERN research board
  - Final R&D ongoing







LHCb Upgrade expected performance - CERN-LHCC-2012-007

Type	Observable	Current precision	LHCb 2018	Upgrade (50 fb^{-1})	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\ \phi)$	0.035	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\ f_0(980))$	0.17	0.045	0.014	~ 0.01
	$A_{\mathrm{fs}}(B_s^0)$	6.4×10^{-3}	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\phi)$	–	0.17	**0.03**	0.02
	$2\beta_s^{\mathrm{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\mathrm{eff}}(B^0 \to \phi K_S^0)$	0.17	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\mathrm{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.08	0.025	0.008	0.02
	$s_0\ A_{\mathrm{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 %	6 %	2 %	7 %
	$A_{\mathrm{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.25	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 %	8 %	2.5 %	$\sim$ 10 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9}	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	$\sim$ 100 %	$\sim$ 35 %	$\sim$ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim$ 10–12°	4°	**0.9°**	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\ K_S^0)$	0.8°	0.6°	0.2°	negligible
Charm CP violation	A_Γ	2.3×10^{-3}	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3}	0.65×10^{-3}	0.12×10^{-3}	–

Summary

- LHCb has performed incredibly well Run 1
- Have produced a wide variety of informative results with $3\,\mathrm{fb}^{-1}$
  - First observations of new decays
  - Observations of new particles
  - Precision physics measurements of many parameters of interest (β, γ)
- So far results in CPV consistent with SM CKM matrix
- Some interesting deviations in rare decays
  - P_5' in $B \to K^* \mu^+ \mu^-$
  - Lepton universality in $B^0 \to K^{*0} \ell^+ \ell^-$
  - Need more data to confirm or deny

"WE CAN SEE HERE THAT THE AGREEMENT WITH THEORY IS EXCELLENT"

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- Much more still to come from Run 1 and much of it in the near future
- Exciting prospects in Run 2 (and beyond) to add new measurements and improve existing ones with more statistics

Thanks for your attention!