LHCb Status Report

Marianna Fontana on behalf of the LHCb collaboration

INFN Cagliari and CERN

LHCC open session

CERN, Geneva, 13 September 2017

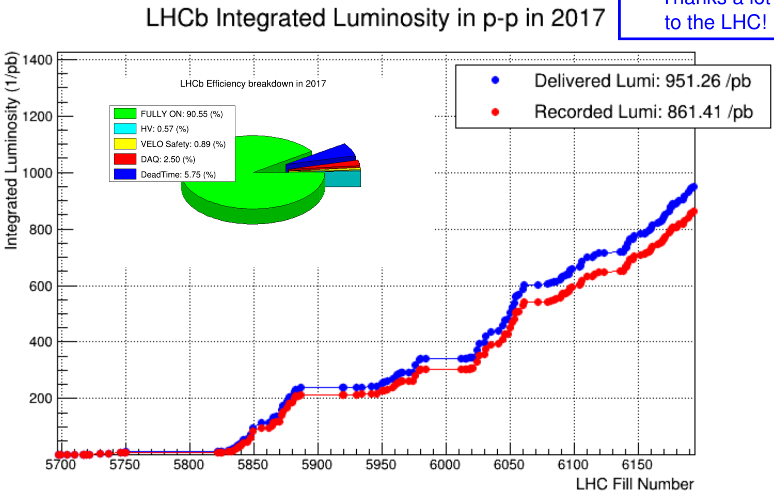
Outline

- Operations: 2017 data taking
- Physics: highlights from the summer conferences
- Upgrade: status and plans
- Conclusions

Status of 2017 data taking

Excellent start of 2017 data taking

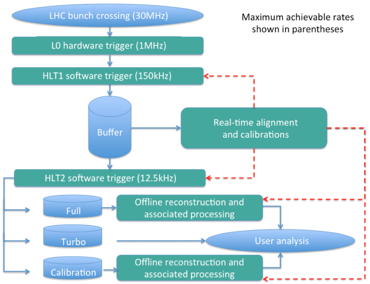
Thanks a lot to the LHC!



Trigger

Run 2 strategy

- L0 bandwidth optimized for the wide physics programme: retuned for 2017 and updated according to the latest LHC forecasts
- Buffer data on disk after HLT1
- Real-time alignment and calibration evaluation
- Data processed by HLT2 asynchronously



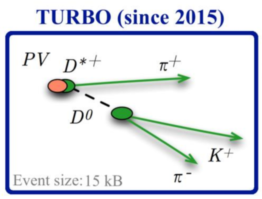
Disk buffer ∼ 10 PB

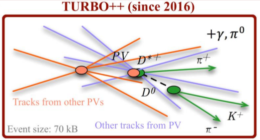
- Two HLT1 configurations have been prepared: loose and tight. Started with loose configuration
- Simulations are made to estimate the disk buffer occupancy up to end of the year
- With current LHC performance, unlikely to exhaust the buffer this year: keep loose configuration

Trigger

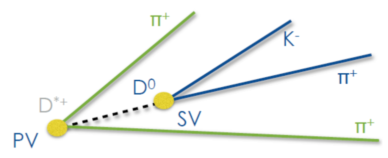
Turbo stream

- Novel approach in Run 2 that exploits the LHCb real-time alignment capabilities
- Crucial for analyses with large statistics
- Great disk space saving
- Fast data availability for physics analyses



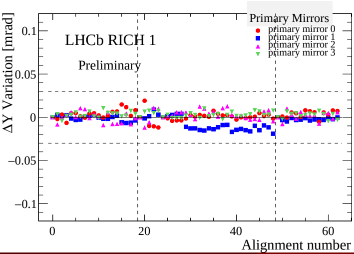


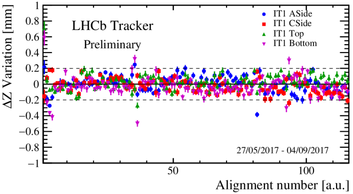
- **New** intermediate solution for Turbo in 2017: **Turbo SP (Selective Persistence)** that allows to save candidates and a subset of the reconstruction
- Allows particles nearby the PV to be chosen for further analysis
- Utility to help select interesting particles

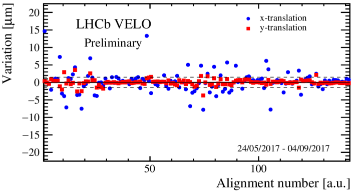


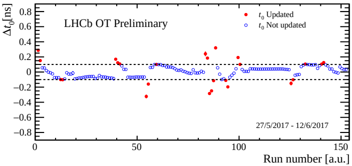
Alignment and calibration

- Real-time alignment per fill
  - Alignment of the full tracking system: VELO, TT, T stations
  - Alignment of PID detector: RICH mirrors and Muon chambers
- Real-time calibration per run or per fill
  - RICH calibration
  - OT time calibration
  - Calorimeter calibration
- Full automatization of Rich mirror alignment and improved Calo calibration





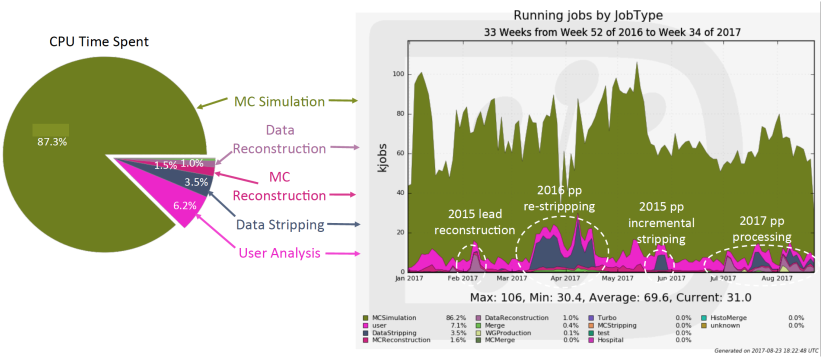




Offline computing

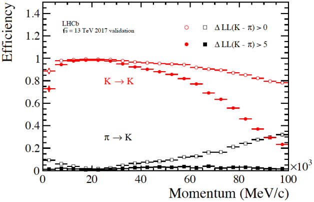
Maximum use of computing resources to process all type of data

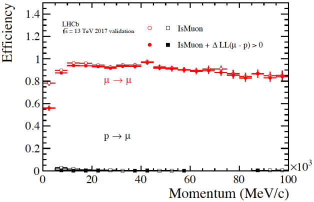
- New stripping of Run 2 data, including Pb-Pb data
- processing of 2017 data
- MC productions
- Development of different fast simulation options to save resources
    - Re-decay signal N times, re-using same underlying event
    - Fully simulate only part of the detector, e.g. tracker only

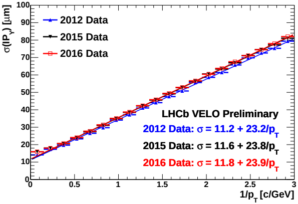


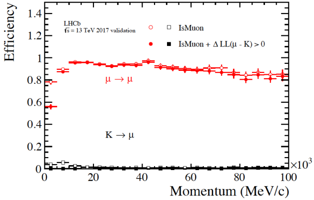
Performance

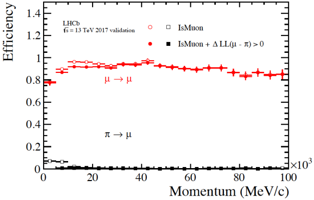
Excellent performance of the tracking and PID detectors

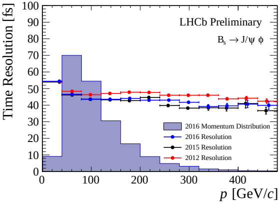




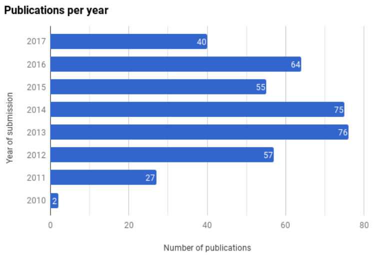








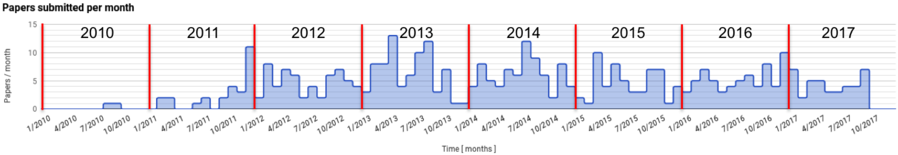
Paper status



20 new papers submitted since last LHCC week

In summary

- 396 papers in total
- 40 papers in 2017
- Other 10 papers to be submitted shortly



Paper status

2016-065: Updated search for long-lived particles decaying to jet pairs; arXiv:1705.07332; EPJC
2017-007: Study of charmonium production in b-hadron decays and first evidence for the decay $B^0_s \to \phi\phi\phi$; arXiv:1706.07013; EPJC
2017-009: Improved limit on the branching fraction of the rare decay $K^0_S \to \mu^+\mu^-$; arXiv:1706.00758; EPJC
2017-010: Updated branching fraction measurements of $B^0_{d,s} \to K^0_S h^+ h'^-$ decays; arXiv:1707.01665; JHEP
2017-013: Test of lepton universality with $B^0 \to K^{*0}\ell^+\ell^-$ decays; arXiv:1705.05802; JHEP
2017-014: Prompt and nonprompt J/ψ production and nuclear modification in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV; arXiv:1706.07122; PLB
2017-015: Study of prompt D^0 meson production in pPb collisions at $\sqrt{s_{NN}} = 5$ TeV; arXiv:1707.02750; JHEP
2017-016: Measurement of the shape of the $\Lambda^0_b \to \Lambda^+_c \mu^- \overline{\nu}_\mu$ differential decay rate; arXiv:1709.01920; PRD
2017-017: Measurement of the ratio of the $B^0 \to D^{*-}\tau^+\nu_\tau$ and $B^0 \to D^{*-}\mu^+\nu_\mu$ branching fractions using three-prong τ-lepton decays; arXiv:1708.08856; PRL
2017-018: Observation of the doubly charmed baryon Ξ^{++}_{cc}; arXiv:1707.01621; PRL
2017-019: Observation of D^0 meson decays to $\pi^+\pi^-\mu^+\mu^-$ and $K^+K^-\mu^+\mu^-$ final states; arXiv:1707.08377; PRL
2017-020: Study of $b\bar{b}$ correlations in high energy proton-proton collisions; arXiv:1708.05994; JHEP
2017-021: Measurement of CP observables in $B^\pm \to D^{(*)0}K^\pm$ and $B^\pm \to D^{(*)0}\pi^\pm$ decays; arXiv:1708.06370; PLB
2017-022: First observation of the rare purely baryonic decay $B^0 \to p\bar{p}$; arXiv:1709.01156; PRL
2017-023: Search for baryon-number-violating Ξ^0_b oscillations; arXiv:1708.05808; PRL
2017-024: Measurement of forward $Z \to b\bar{b}$ production in pp collisions at $\sqrt{s} = 8$ TeV; arXiv:1709.03458; PLB
2017-025: Bose-Einst. corr. of same-sign charged pions in the forward region in pp collisions at $\sqrt{s} = 7$ TeV; arXiv:1709.01769; JHEP
2017-028: Measurement of the Υ polarization in pp collisions at $\sqrt{s} = 7$ and 8 TeV; arXiv:1709.01301; JHEP
2017-029: Measurement of CP violation in $B^0 \to J/\psi(e^+e^-)K^0_S$ and $B^0 \to \psi(2S)(\mu^+\mu^-)K^0_S$ decays; arXiv:1709.03944; JHEP
2017-036: Precise measurement of the χ_{c1} and χ_{c2} resonance parameters with the decay $J/\psi\mu^+\mu^-$; arXiv upcoming; PRL

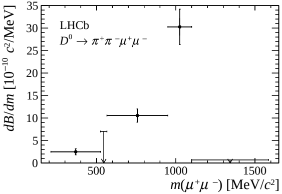
2017-030: Measurement of CP observables in $B^\pm \to DK^{*\pm}$ decays using two- and four-body D-meson final states PRELIMINARY
2017-031: Search for the lepton flavour violating decays $B^0_{(s)} \to e^\pm\mu^\mp$ PRELIMINARY
2017-035: Study of the semitauonic decay $B^+_c \to J/\psi\tau^+\nu_\tau$ PRELIMINARY
2017-038: Search for dark photons produced in 13 TeV pp collisions PRELIMINARY

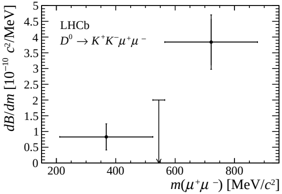
First observation of $D^0 \to h^+ h^- \mu^+ \mu^-$

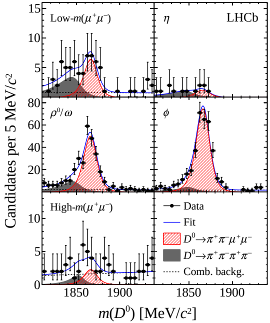
LHCb-PAPER-2017-019

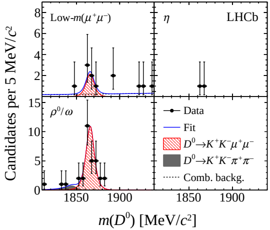
- First observation of D^0 mesons decaying into $\pi^+\pi^-\mu^+\mu^-$ and $K^+K^-\mu^+\mu^-$
- Data set: 2 fb^{-1} at 8 TeV
- Normalisation decay: $D^0 \to K^-\pi^+[\mu^+\mu^-]_{\rho^0/\omega}$
- Signal in almost every $q^2 = m^2(\mu\mu)$ bin

- Differential BF investigated









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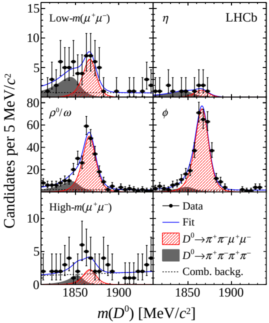
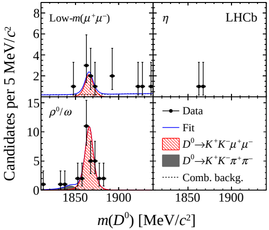
- Normalisation decay: $D^0 \to K^-\pi^+[\mu^+\mu^-]_{\rho^0/\omega}$
- Signal in almost every $q^2 = m^2(\mu\mu)$ bin

- Total BF (Long-Distance dominated) in agreement with SM predictions
- Expected to tighten constraints on possible short distance contributions

$$\mathcal{B}(D^0 \to \pi^-\pi^+\mu^+\mu^-) = (9.64 \pm 0.48 \pm 0.51 \pm 0.97) \times 10^{-7}$$
$$\mathcal{B}(D^0 \to K^-K^+\mu^+\mu^-) = (1.54 \pm 0.27 \pm 0.09 \pm 0.16) \times 10^{-7}$$

Rarest charm decays measured to date





Search for the decays $B^0_{(s)} \to e^\pm \mu^\mp$ NEW

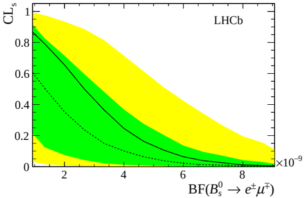
LHCb-PAPER-2017-031

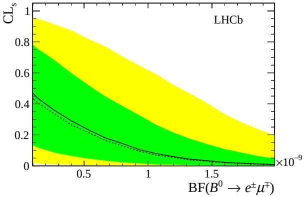
- Lepton-flavour violating decays
- No excess of signal observed wrt background
- Put a limit to the BF

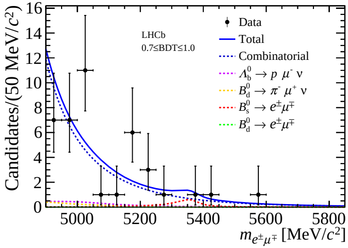
$$\mathcal{B}(B^0_s \to e^\pm \mu^\mp) < 5.4\ (6.3) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to e^\pm \mu^\mp) < 1.0\ (1.3) \times 10^{-9}$$
at 90 (95)% CL

- Best upper limits to date and a factor 2-3 better than the previous results from LHCb

- Data sample: 1.0 (7 TeV) + 2.0 (8 TeV) fb^{-1}



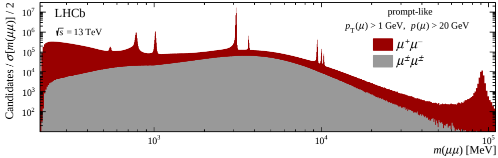


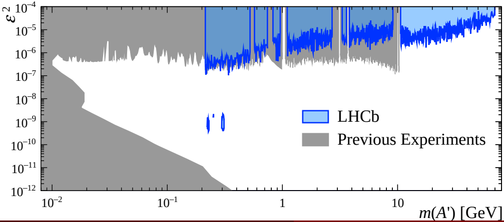


Search for dark photons NEW

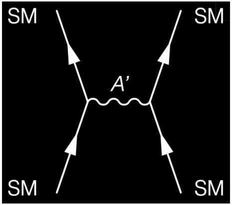
LHCb-PAPER-2017-038

- Search for $A' \to \mu^+\mu^-$ decay in 2016 data (1.5 fb^{-1})
- Output of Turbo stream
- **Prompt-like search**: $\mu\mu$ threshold up to 70 GeV
- **Long-lived search**: $214 < m(A') < 350$ MeV





Dark sector



- Possible coupling via kinetic mixing between the SM hypercharge and A' field strength tensors
- Dark photons may be produced if kinematically allowed

- No evidence for dark photons
- Same sensitivity as BaBar
- First limits above 10 GeV
- Most stringent constraints for $10.6 < m(A') < 70$ GeV
- First exclusion limits to long-lived dark photons at a non-beam-dump experiment

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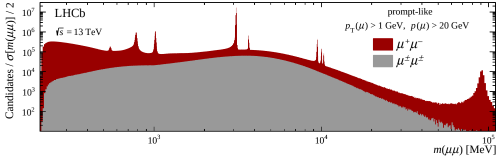
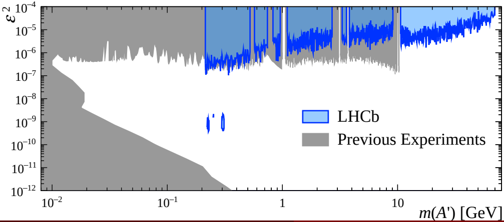
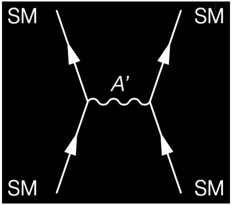




Dark sector



- Possible coupling via kinetic mixing between the SM hypercharge and A' field strength tensors
- Dark photons may be produced if kinematically allowed

Prospects

- **2017**: big improvements in the software-trigger efficiency for low-mass dark photons
- **Run 3**: removal of the hardware-trigger $\to$ access to $\mathcal{O}(100-1000)$ times more decays than 2016

J/ψ production in pPb collisions

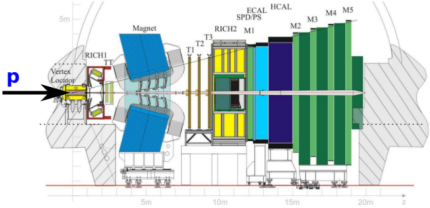
LHCb-PAPER-2017-014

Data samples recorded in 2016 ($\times$10 2013 sample):

- pPb collisions: 13.6 nb^{-1}
- Pbp collisions: 20.8 nb^{-1}

Energy: $\sqrt{s_{NN}} = 8.16$ TeV

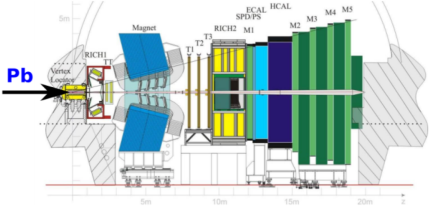
First LHC result with this sample!!



Forward

$1.5 < y^* < 4.5$

$y^* = y_{lab} - 0.465$



Backward

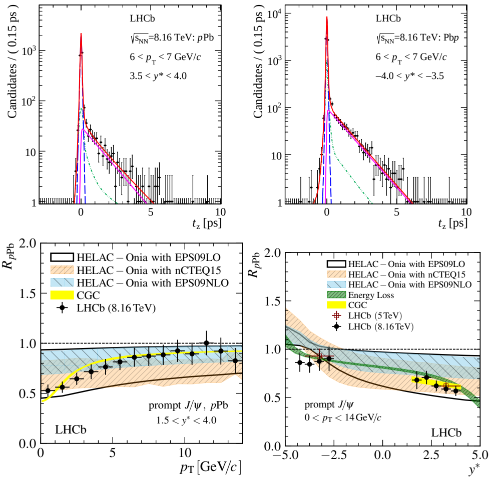
$-5.5 < y^* < -2.5$

$y^* = -(y_{lab} + 0.465)$

J/ψ production in pPb collisions

LHCb-PAPER-2017-014

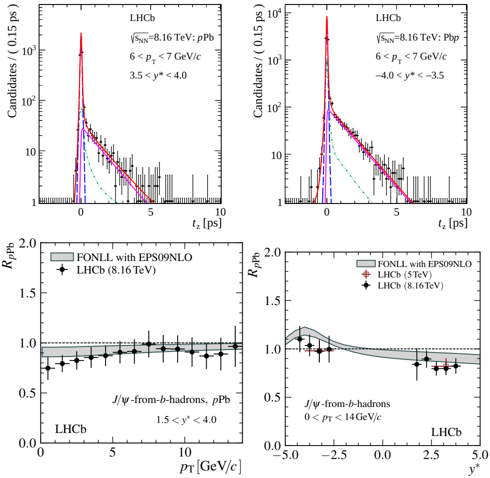
- J/ψ prompt and from b-hadrons cross-section
- Production relative to *pp* collisions, scaled by the Pb mass number



J/ψ production in pPb collisions

LHCb-PAPER-2017-014

- Theoretical calculations can account for the majority of observed dependences
- First beauty-hadron production measurement down to $p_T = 0$ in pPb and Pbp collisions at LHC



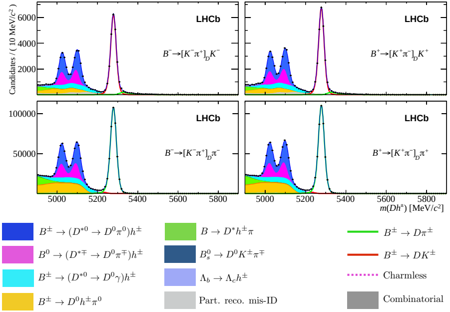
γ from $B^{\pm} \to (D^{*0} \to D^0\pi^0/\gamma)K^{\pm}$

LHCb-PAPER-2017-021

- γ is the least well known angle of the unitarity triangle
- Look for the New Physics comparing tree level and loop level decays

- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- $B^+ \to D^{*0}K^+$ with $D^{*0} \to D^0\gamma/\pi^0$: experimentally challenging due to the low efficiency
- Partial reconstruction of D^*

$$
\begin{aligned}
A_K^{K\pi} &= -0.019 \pm 0.005\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_\pi^{KK} &= -0.008 \pm 0.003\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_K^{KK} &= +0.126 \pm 0.014\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_\pi^{\pi\pi} &= -0.008 \pm 0.006\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_K^{\pi\pi} &= +0.115 \pm 0.025\ (\text{stat}) \pm 0.007\ (\text{syst})\\
R^{KK} &= 0.988 \pm 0.015\ (\text{stat}) \pm 0.011\ (\text{syst})\\
R^{\pi\pi} &= 0.992 \pm 0.027\ (\text{stat}) \pm 0.015\ (\text{syst})\\
R_{K/\pi}^{K\pi} &= (7.768 \pm 0.038\ (\text{stat}) \pm 0.066\ (\text{syst})) \times 10^{-2}
\end{aligned}
$$



World's best measurement!!

γ from $B^{\pm} \to (D^{*0} \to D^0\pi^0/\gamma)K^{\pm}$

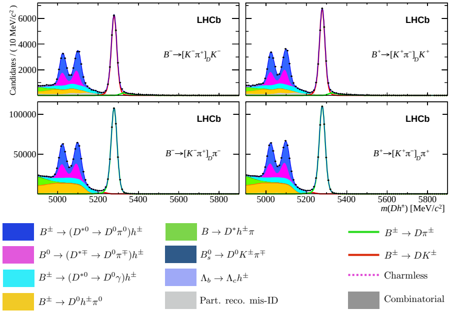
LHCb-PAPER-2017-021

- γ is the least well known angle of the unitarity triangle
- Look for the New Physics comparing tree level and loop level decays

- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- $B^+ \to D^{*0}K^+$ with $D^{*0} \to D^0\gamma/\pi^0$: experimentally challenging due to the low efficiency
- Partial reconstruction of D^*

$$
\begin{aligned}
A_K^{K\pi,\gamma} &= +0.001 \pm 0.021\ (\text{stat}) \pm 0.007\ (\text{syst})\\
A_\pi^{K\pi,\gamma} &= +0.000 \pm 0.006\ (\text{stat}) \pm 0.001\ (\text{syst})\\
A_K^{K\pi,\pi^0} &= +0.006 \pm 0.012\ (\text{stat}) \pm 0.004\ (\text{syst})\\
A_\pi^{K\pi,\pi^0} &= +0.002 \pm 0.003\ (\text{stat}) \pm 0.001\ (\text{syst})\\
A_K^{CP,\gamma} &= +0.276 \pm 0.094\ (\text{stat}) \pm 0.047\ (\text{syst})\\
A_\pi^{CP,\gamma} &= -0.003 \pm 0.017\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_K^{CP,\pi^0} &= -0.151 \pm 0.033\ (\text{stat}) \pm 0.011\ (\text{syst})\\
A_\pi^{CP,\pi^0} &= +0.025 \pm 0.010\ (\text{stat}) \pm 0.003\ (\text{syst})\\
R^{CP,\gamma} &= 0.902 \pm 0.087\ (\text{stat}) \pm 0.112\ (\text{syst})\\
R^{CP,\pi^0} &= 1.138 \pm 0.029\ (\text{stat}) \pm 0.016\ (\text{syst})\\
R_{K/\pi}^{K\pi,\pi^0/\gamma} &= (7.930 \pm 0.110\ (\text{stat}) \pm 0.560\ (\text{syst})) \times 10^{-2}\\
\mathcal{B}(D^{*0} \to D^0\pi^0) &= 0.636 \pm 0.002\ (\text{stat}) \pm 0.015\ (\text{syst})\\
\mathcal{B}(B^- \to D^{*0}\pi^-) &= (4.664 \pm 0.029\ (\text{stat}) \pm 0.268\ (\text{syst})) \times 10^{-3}
\end{aligned}
$$

- The γ modes with comparable precision to the world average
- The π^0 modes substantially improve the world averages



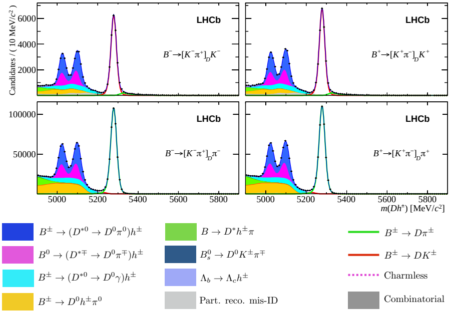
γ from $B^\pm \to (D^{*0} \to D^0\pi^0/\gamma)K^\pm$

LHCb-PAPER-2017-021

- γ is the least well known angle of the unitarity triangle
- Look for the New Physics comparing tree level and loop level decays

- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- $B^+ \to D^{*0}K^+$ with $D^{*0} \to D^0\gamma/\pi^0$: experimentally challenging due to the low efficiency
- Partial reconstruction of D^*

$$
\begin{aligned}
A_K^{K\pi,\gamma} &= +0.001 \pm 0.021\ (\text{stat}) \pm 0.007\ (\text{syst})\\
A_\pi^{K\pi,\gamma} &= +0.000 \pm 0.006\ (\text{stat}) \pm 0.001\ (\text{syst})\\
A_K^{K\pi,\pi^0} &= +0.006 \pm 0.012\ (\text{stat}) \pm 0.004\ (\text{syst})\\
A_\pi^{K\pi,\pi^0} &= +0.002 \pm 0.003\ (\text{stat}) \pm 0.001\ (\text{syst})\\
A_K^{CP,\gamma} &= +0.276 \pm 0.094\ (\text{stat}) \pm 0.047\ (\text{syst})\\
A_\pi^{CP,\gamma} &= -0.003 \pm 0.017\ (\text{stat}) \pm 0.002\ (\text{syst})\\
A_K^{CP,\pi^0} &= -0.151 \pm 0.033\ (\text{stat}) \pm 0.011\ (\text{syst})\\
A_\pi^{CP,\pi^0} &= +0.025 \pm 0.010\ (\text{stat}) \pm 0.003\ (\text{syst})\\
R^{CP,\gamma} &= 0.902 \pm 0.087\ (\text{stat}) \pm 0.112\ (\text{syst})\\
R^{CP,\pi^0} &= 1.138 \pm 0.029\ (\text{stat}) \pm 0.016\ (\text{syst})\\
R_{K/\pi}^{K\pi,\pi^0/\gamma} &= (7.930 \pm 0.110\ (\text{stat}) \pm 0.560\ (\text{syst})) \times 10^{-2}\\
\mathcal{B}(D^{*0} \to D^0\pi^0) &= 0.636 \pm 0.002\ (\text{stat}) \pm 0.015\ (\text{syst})\\
\mathcal{B}(B^- \to D^{*0}\pi^-) &= (4.664 \pm 0.029\ (\text{stat}) \pm 0.268\ (\text{syst})) \times 10^{-3}
\end{aligned}
$$



- Evidence for CP violation in $B^- \to (D\pi^0)K^-$ at 4.3 σ

γ from $B^{\pm} \to (D^{*0} \to D^0\pi^0/\gamma)K^{\pm}$

LHCb-PAPER-2017-021

- γ is the least well known angle of the unitarity triangle
- Look for the New Physics comparing tree level and loop level decays

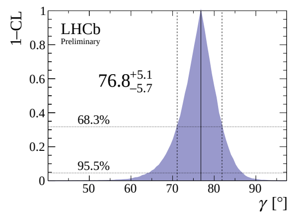
- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- $B^+ \to D^{*0}K^+$ with $D^{*0} \to D^0\gamma/\pi^0$: experimentally challenging due to the low efficiency
- Partial reconstruction of D^*

LHCb γ combination [LHCb-CONF-2017-004]

Notably including the following updates:

- $B^{\pm} \to D^0K^{*\pm}$ [LHCb-CONF-2016-014]
- $B^{\pm} \to D^{*0}K^{*\pm}$ [LHCb-PAPER-2017-021]
- $B_s^0 \to D_s^{\mp}K^{\pm}$ [LHCb-CONF-2016-015]
- $B^{\pm} \to D^0K^{\pm}$ [LHCb-PAPER-2017-021]

$$\gamma = (76.8^{+5.1}_{-5.7})^{\circ}$$

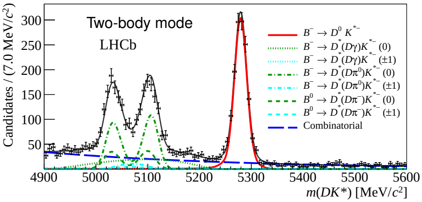


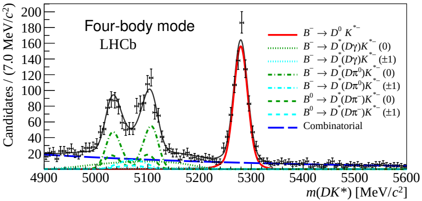
$B^{\pm} \to DK^{*\pm}$

LHCb-PAPER-2017-030

Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
Look at 2 and 4 body D^0 decay modes

$$
\begin{aligned}
A_{K\pi} &= -0.004 \pm 0.023\,(\text{stat}) \pm 0.008\,(\text{syst})\\
A_{KK} &= 0.06 \pm 0.07\,(\text{stat}) \pm 0.01\,(\text{syst})\\
A_{\pi\pi} &= 0.15 \pm 0.13\,(\text{stat}) \pm 0.02\,(\text{syst})\\
R_{KK} &= 1.22 \pm 0.09\,(\text{stat}) \pm 0.01\,(\text{syst})\\
R_{\pi\pi} &= 1.08 \pm 0.14\,(\text{stat}) \pm 0.03\,(\text{syst})\\
R^{+}_{K\pi} &= 0.020 \pm 0.006\,(\text{stat}) \pm 0.001\,(\text{syst})\\
R^{-}_{K\pi} &= 0.002 \pm 0.004\,(\text{stat}) \pm 0.001\,(\text{syst})\\
A_{K\pi\pi\pi} &= -0.013 \pm 0.031\,(\text{stat}) \pm 0.009\,(\text{syst})\\
A_{\pi\pi\pi\pi} &= 0.02 \pm 0.11\,(\text{stat}) \pm 0.01\,(\text{syst})\\
R_{\pi\pi\pi\pi} &= 1.08 \pm 0.13\,(\text{stat}) \pm 0.03\,(\text{syst})\\
R^{+}_{K\pi\pi\pi} &= 0.016 \pm 0.007\,(\text{stat}) \pm 0.003\,(\text{syst})\\
R^{-}_{K\pi\pi\pi} &= 0.006 \pm 0.006\,(\text{stat}) \pm 0.004\,(\text{syst})
\end{aligned}
$$





- CP asymmetries in the GLW modes consistent with and more precise than the previous ones
- Limited sensitivity to γ

Signal significance:

- Two-body ADS: 4.2 σ First evidence
- Four-body ADS: 2.8 σ

CPV in $B^0 \to [c\bar{c}]K^0_S$

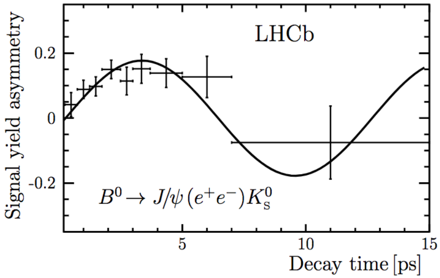
LHCb-PAPER-2017-029

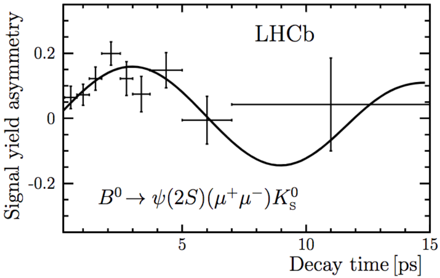
- Decay-time-dependent CP violation in $B^0 \to J/\psi(e^+e^-)K^0_S$ and $B^0 \to \psi(2S)(\mu^+\mu^-)K^0_S$

$$A_{CP}(t) = \frac{S\sin(\Delta m t) - C\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2) + A_{\Delta\Gamma}\sinh(\Delta\Gamma t/2)} \overset{\Delta\Gamma=0}{\approx} S\sin(\Delta m t) - C\cos(\Delta m t)$$

- Data sample: 1.0 (7 TeV) + 2.0 (8 TeV) fb^{-1}

$$S_{J/\psi K^0_S} \approx \sin 2\beta$$





$C = 0.12^{+0.07}_{-0.07}$ (stat) $+ 0.02$ (syst)
$S = 0.83^{+0.07}_{-0.08}$ (stat) $+ 0.01$ (syst)

$C = -0.05^{+0.10}_{-0.10}$ (stat) $+ 0.01$ (syst)
$S = 0.84^{+0.10}_{-0.10}$ (stat) $+ 0.01$ (syst)

CPV in $B^0 \to [c\bar{c}]K^0_S$

LHCb-PAPER-2017-029

- Decay-time-dependent CP violation in $B^0 \to J/\psi(e^+e^-)K^0_S$ and $B^0 \to \psi(2S)(\mu^+\mu^-)K^0_S$

$$A_{CP}(t) = \frac{S\sin(\Delta mt) - C\cos(\Delta mt)}{\cosh(\Delta\Gamma t/2) + A_{\Delta\Gamma}\sinh(\Delta\Gamma t/2)} \overset{\Delta\Gamma=0}{\approx} S\sin(\Delta mt) - C\cos(\Delta mt)$$

- Data sample: 1.0 (7 TeV) + 2.0 (8 TeV) fb^{-1}

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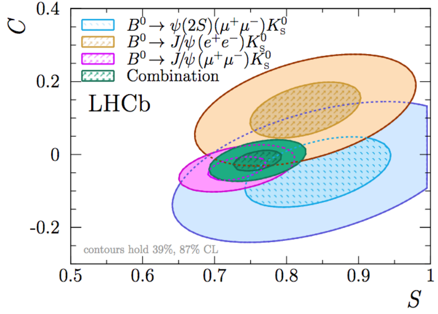


LHCb average

of all charmonium modes $J/\psi(ee, \mu\mu)$, $\psi(2S)(\mu\mu)$

$$C(B^0 \to [c\bar{c}]K^0_S) = -0.017 \pm 0.029$$
$$S(B^0 \to [c\bar{c}]K^0_S) = 0.760 \pm 0.034$$

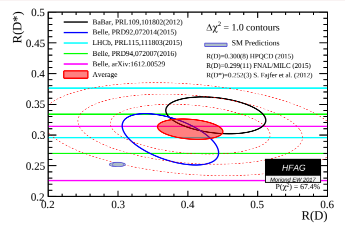
- $\sin 2\beta$ improved by 20%
- Expected to improve the precision of the world average
- Consistent with CKM prediction of $\sin 2\beta = 0.740^{+0.020}_{-0.025}$

Lepton Flavor Universality: $R(D^*)$

LHCb-PAPER-2017-017

- In SM amplitudes for processes involving e, μ, τ must be identical up to effects depending on lepton mass
- Comparison between semitauonic and semimuonic decays sensitive to NP

$$R(D^*) = \frac{\mathcal{B}(B^0 \to D^{*-}\tau^+\nu)}{\mathcal{B}(B^0 \to D^{*-}\mu^+\nu)}$$



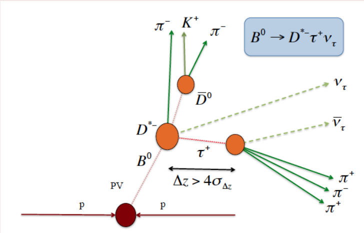
- $R(D^*)$ in tension with SM at 3.4 σ
- $R(D)$ and $R(D^*)$ combination in tension with SM at the level of 3.9 σ

- In LHCb $R(D^*)$ with hadronic 3-prong τ decays:

$$R(D^*) = K(D^*) \times \frac{\mathcal{B}(B^0 \to D^{*-}3\pi)}{\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)}$$

$$K(D^*) = \frac{\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)}{\mathcal{B}(B^0 \to D^{*-}3\pi)}$$

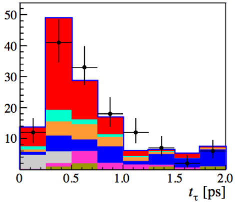
- Separating secondary and tertiary vertices with excellent resolution

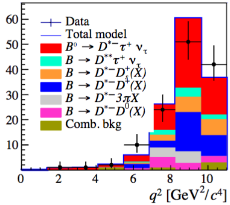


- Dataset: Run 1 data
- Measurement in bins of q^2, t_τ, BDT

Lepton Flavor Universality: $R(D^*)$

LHCb-PAPER-2017-017

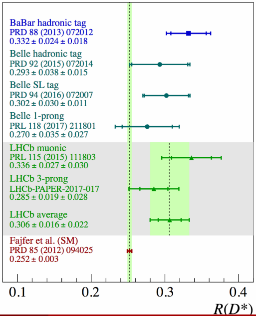




$N_{D^*\tau\nu} = 1300 \pm 85$
$K(D^*) = (1.93 \pm 0.13 \pm 0.17)$

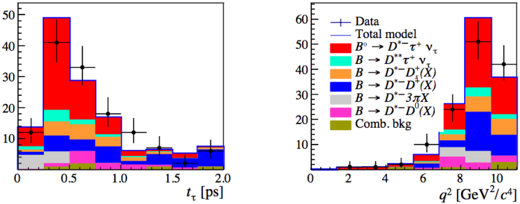
$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau) = (1.39 \pm 0.09 \pm 0.12 \pm 0.06)\%$

- **LHCb hadronic**
  $R(D^*) = 0.285 \pm 0.019 \pm 0.025 \pm 0.013$
- LHCb muonic
  $R(D^*) = 0.336 \pm 0.027 \pm 0.030$
- Preliminary LHCb average
  $R(D^*) = 0.306 \pm 0.027$
- New world average
  $R(D^*) = 0.304 \pm 0.015$ (3.4 σ above SM)



Lepton Flavor Universality: $R(D^*)$

LHCb-PAPER-2017-017



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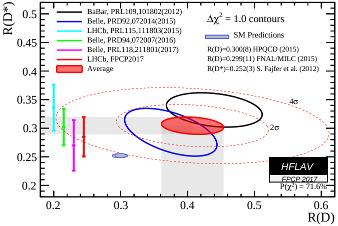


$R(D)$ and $R(D^*)$ combination at 4.1 σ from SM

Lepton Flavor Universality: $R(J/\psi)$ NEW

LHCb-PAPER-2017-035

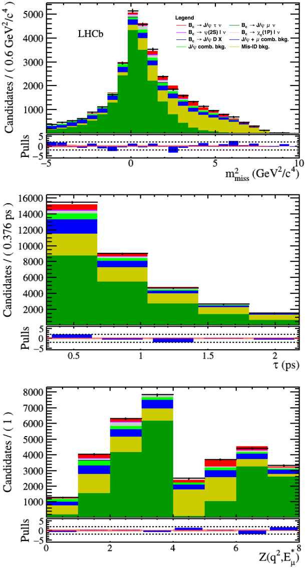
- Generalization of $R(D^*)$ to the B_c sector

$$R(J/\psi) = \frac{\mathcal{B}(B_c^+ \to J/\psi\tau^+\nu_\tau)}{\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)}$$

- B_c decay form factors unconstrained experimentally: theoretical prediction not yet precise 0.25-0.28
- Reconstruct signal with $\tau \to \mu\nu_\mu\nu_\tau$ (17%)
- Dataset: Run 1 (3 fb^{-1})

$$R(J/\psi) = 0.71 \pm 0.17 \pm 0.18$$

(about 2 σ from SM)



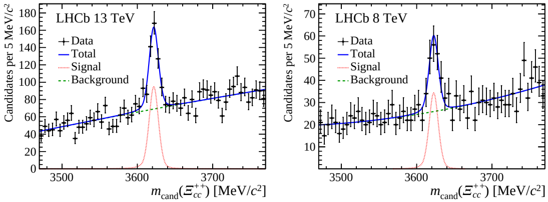
Excellent future prospects:

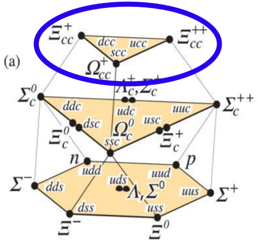
- Run I + Run II data with extra MC allow finer binning in missing mass
- Form factors systematics reduced by LQCD work + dedicated form factor study
- Only LHCb can perform this measurement

Observation of Ξ_{cc}^{++}

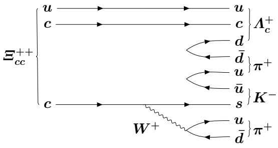
LHCb-PAPER-2017-018

- Doubly charmed baryons predicted by quark model
- Observation of Ξ_{cc}^{+} claimed by SELEX [Phys. Lett. B 628 (2005) 18-24]
- No evidence observed by BaBar, FOCUS, Belle and LHCb
- Search in LHCb for $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^-$
- Data sample: 2.0 (8 TeV) + 2.0 (13 TeV) fb^{-1}





Lattice QCD calculations
$m(\Xi_{cc}^{++}) = 3606 \pm 11 \pm 8$ MeV$/c^2$
[arXiv: 1704.02647]



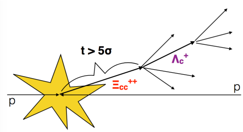
- Highly significant peak: 7.6 σ (2012), 12.9 σ (2016)
- Combined yield: 426 $\pm$ 39
- The mass is measured with the 2016 sample

$$m(\Xi_{cc}^{++}) = 3621 \pm 0.72\ (\text{stat}) \pm 0.31\ (\text{syst})\ \text{MeV}/c^2$$

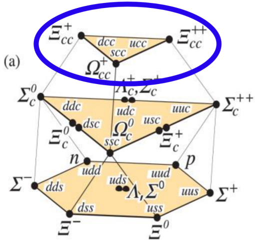
Observation of Ξ_{cc}^{++}

LHCb-PAPER-2017-018

- Doubly charmed baryons predicted by quark model
- Observation of Ξ_{cc}^{+} claimed by SELEX [Phys. Lett. B 628 (2005) 18-24]
- No evidence observed by BaBar, FOCUS, Belle and LHCb
- Search in LHCb for $\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^-$
  - Significant displacement consistent with a weak decay



  - Inconsistent with SELEX measurement



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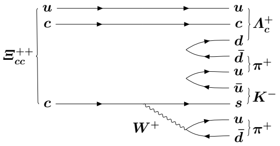


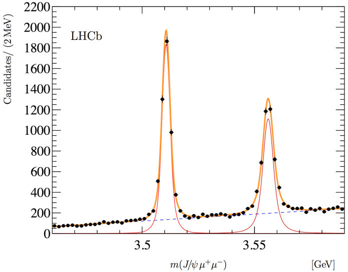
Next steps

- Study of the production mechanisms
- Precise lifetime measurement
- Branching fraction and production rate measurements
- Searches in additional decay modes
- Search for other states, i.e. Ξ_{cc}^{+}, double-heavy beauty barions

Studies of χ_c Dalitz decays NEW

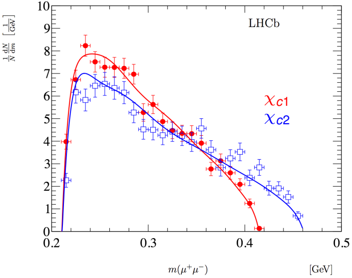
LHCb-PAPER-2017-036

- Observation of $\chi_{c1,2} \to J/\psi\mu^+\mu^-$
- Relevant breakthrough in the χ_c spectroscopy



4755 and 3969 candidates

- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- Event topology with four muons in the final state provides a clean signature

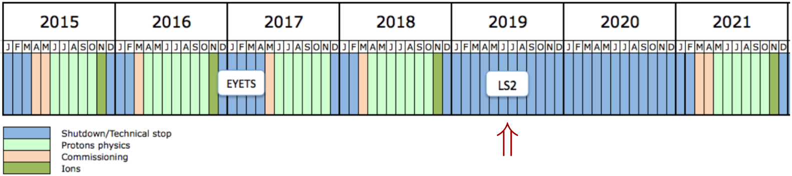


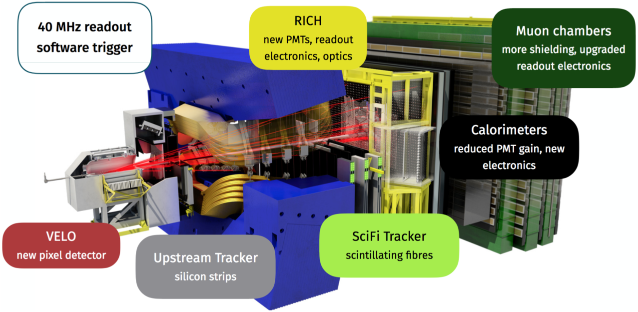
Background subtracted dimuon mass distributions agree well with the theoretical expectation of photon-mediated amplitudes

$m(\chi_{c1}) = 3510.71 \pm 0.04\ (\text{stat}) \pm 0.09\ (\text{syst})\ \text{MeV}/c^2$
$m(\chi_{c2}) = 3556.10 \pm 0.06\ (\text{stat}) \pm 0.11\ (\text{syst})\ \text{MeV}/c^2$
$m(\chi_{c1}) - m(\chi_{c2}) = 45.39 \pm 0.07\ (\text{stat}) \pm 0.03\ (\text{syst})\ \text{MeV}/c^2$
$\Gamma(\chi_{c2}) = 2.10 \pm 0.20\ (\text{stat}) \pm 0.02\ (\text{syst})\ \text{MeV}$

Results consistent with and have similar precision to current world averages

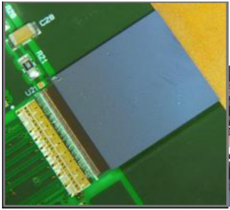
LHCb Upgrade

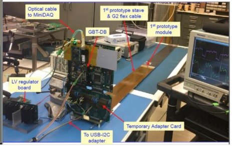


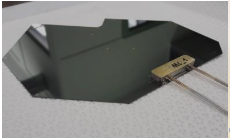


Upgrade status

- Upgrade construction phase ongoing
  - Key front-end ASICs (VeloPix v2 and UT SALT) submitted and expected by end of September
  - SciFi front-end final ASIC (PACIFIC5) received and successfully tested
  - First VELO microchannel soldered
  - The MiniDAQ2 production is completed
- Test-beam at the SPS North area for:
  - **UT**: first test of full size 10x10 cm^2 sensor
  - Final test of n-type sensor before submitting production order
  - **RICH**: first Ring from a complete Photon Detector Module, Mini-DAQ1 and Online Presenter in a Test Beam
- First 20 modules of SciFi arrived in August at the Pit







Conclusions

- LHCb operation
  - Excellent performance during the 2017 data taking
  - Detector fully commissioned and operational
  - Optimal and dynamic use of resources to maximise the physics output
- LHCb physics program
  - 20 papers submitted since the last LHCC report
  - Many new and important results over the summer, some of them shown here for the first time
- LHCb upgrade is progressing well
  - Huge progress over the past few months
  - First pieces of the new detector arrived at Pit

Backup