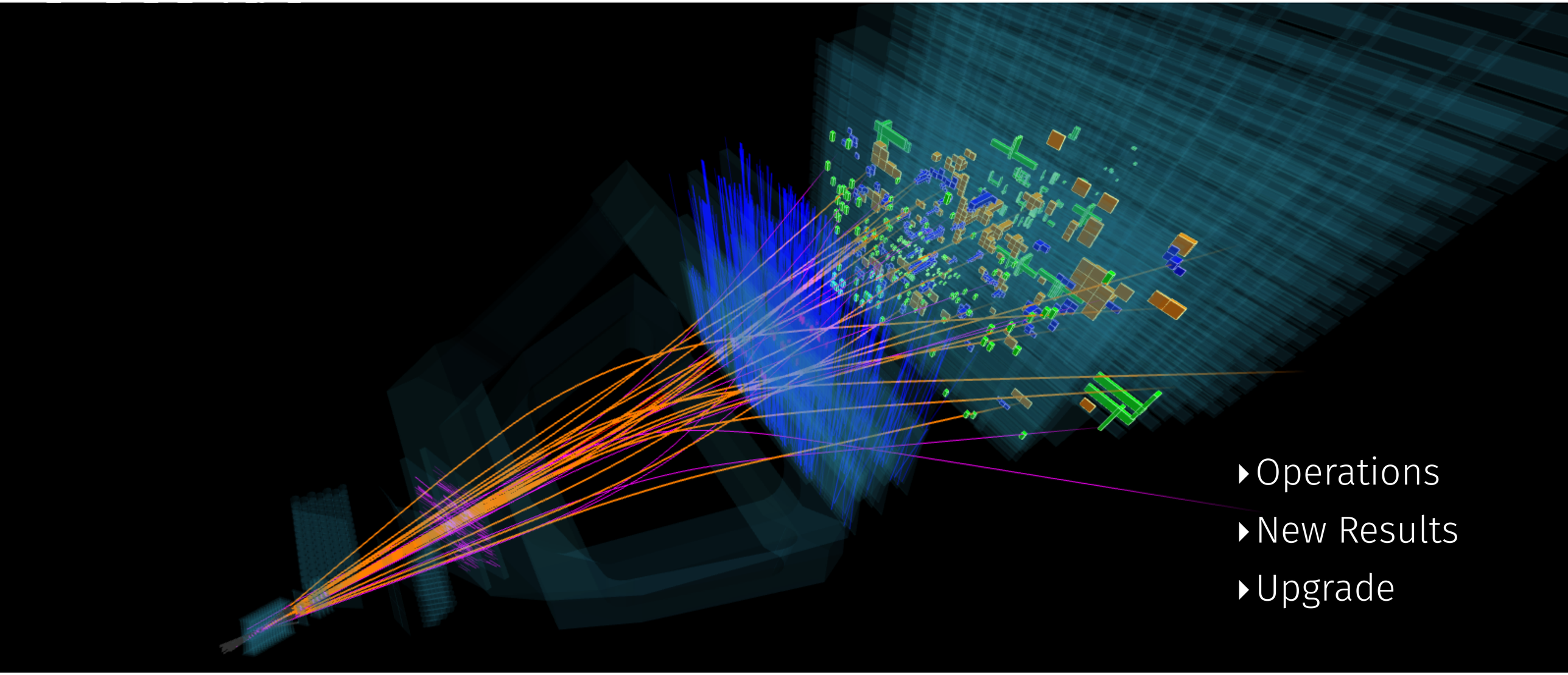
technische universität
dortmund



- Operations
- New Results
- Upgrade

LHCb Status Report

Julian Wishahi on behalf of the LHCb collaboration

127th LHCC Meeting, 21st of September 2016, CERN

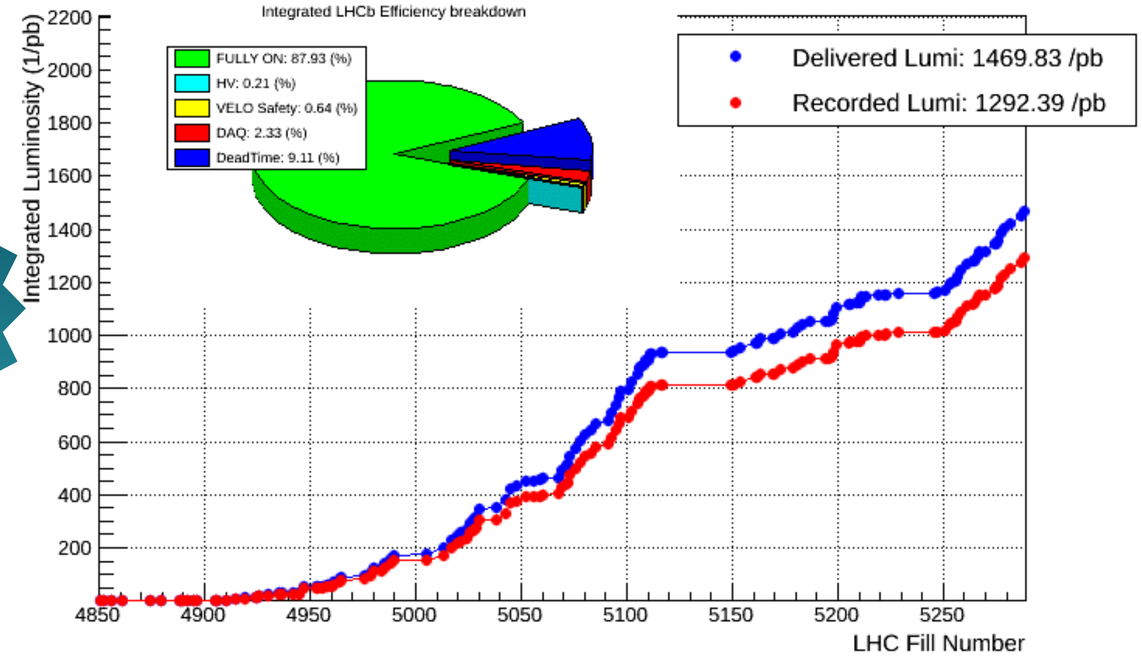
Steve Corey, “Airborne”, CC BY-NC-ND 2.0

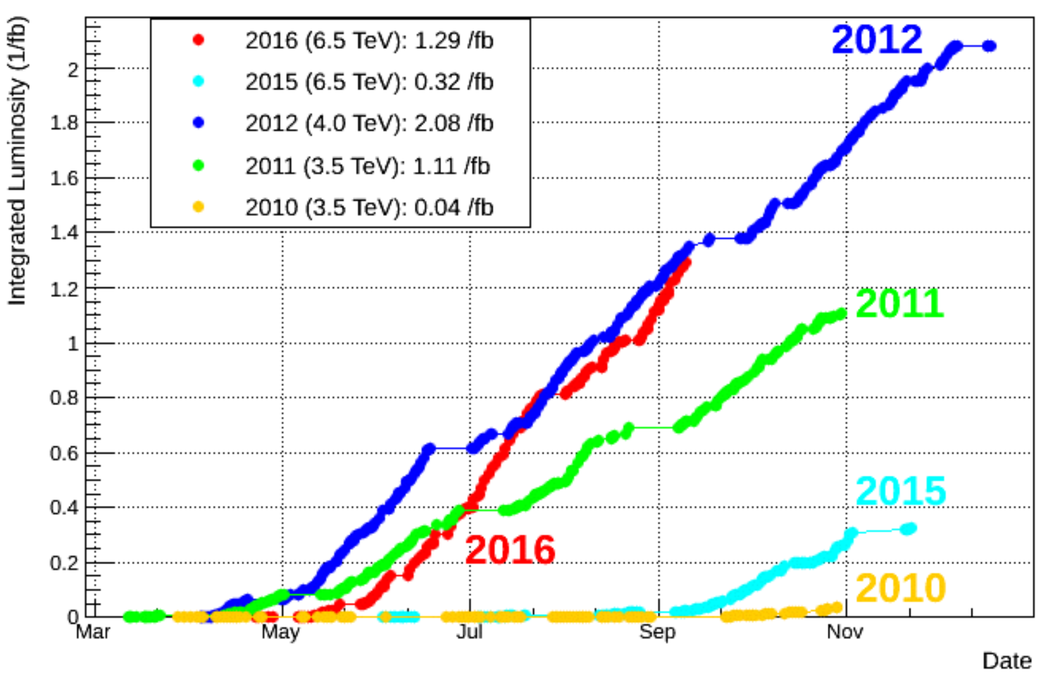
Operations

Data taking status

- amazing LHC performance
  - 80% peak efficiency
  - >50% in stable beams
- great LHCb performance
  - all sub-detectors in good shape
  - data accumulation with ≈90% efficiency
  - collected ≈1.3 fb^{-1} in 2016
  - more *bb*-pairs than in 2012 dataset
- working hard to exploit LHC's record-crunching!
  - originally assumed ≈30% efficiency

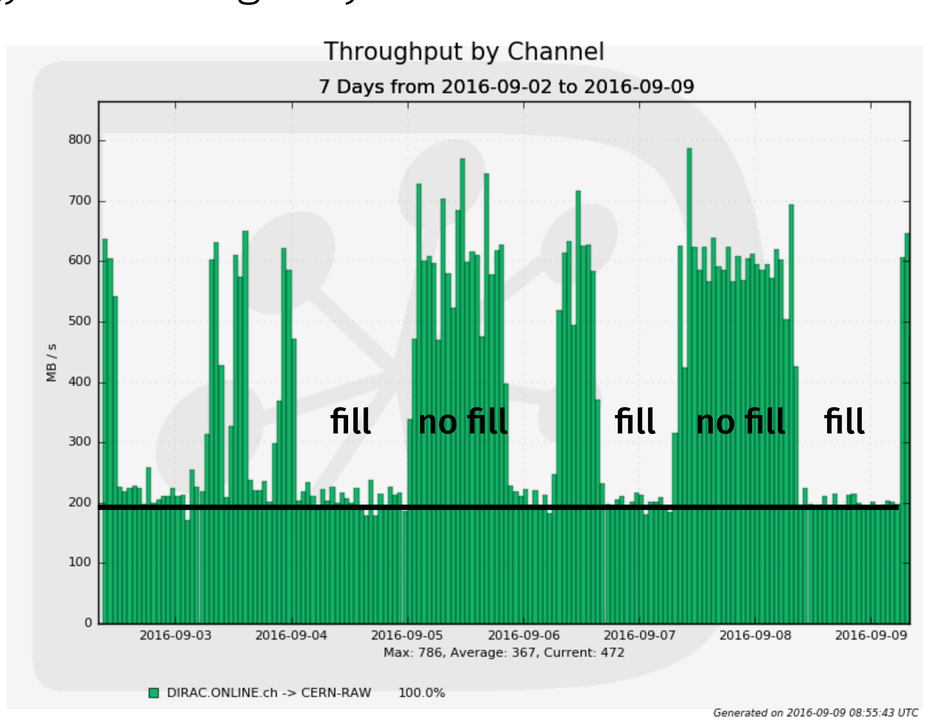
thanks to the accelerator teams!

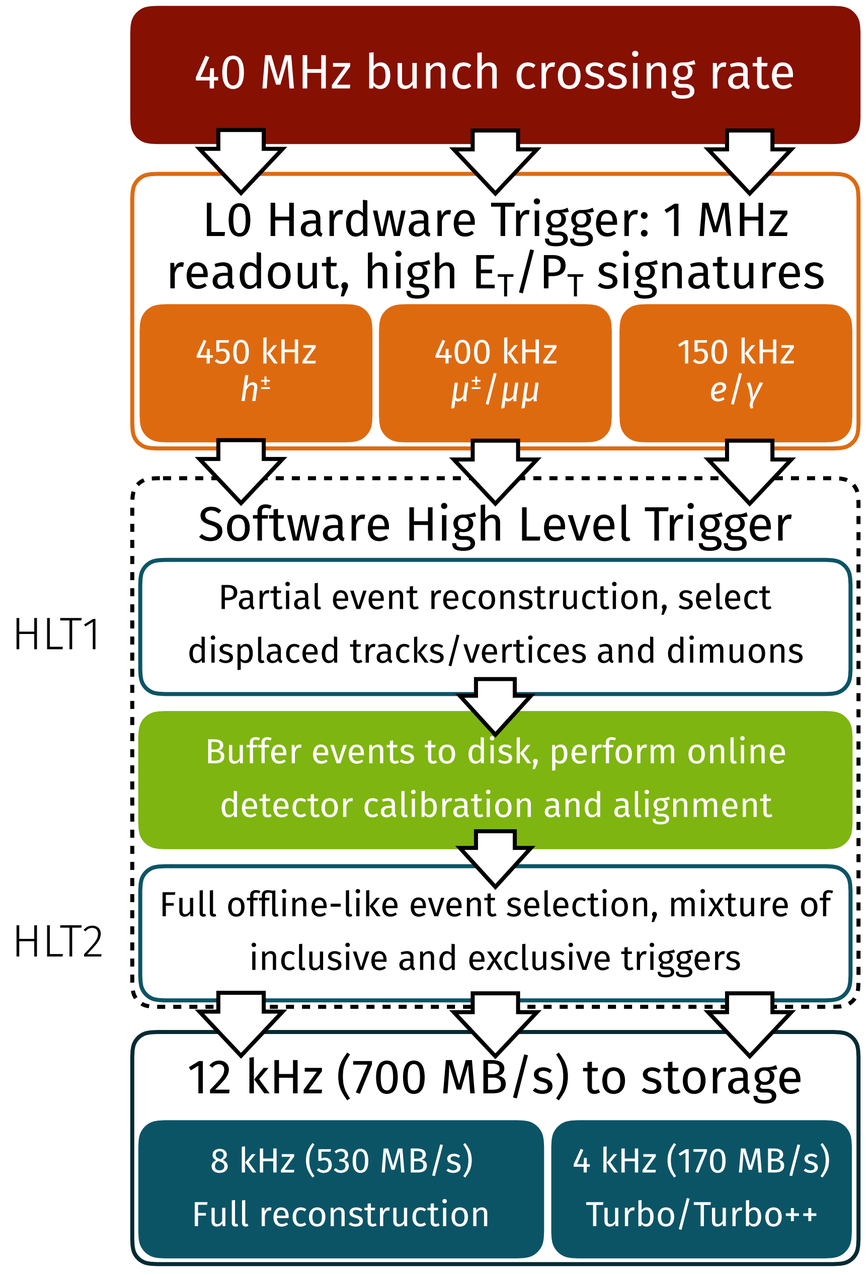




Data taking in Run II – Reminder

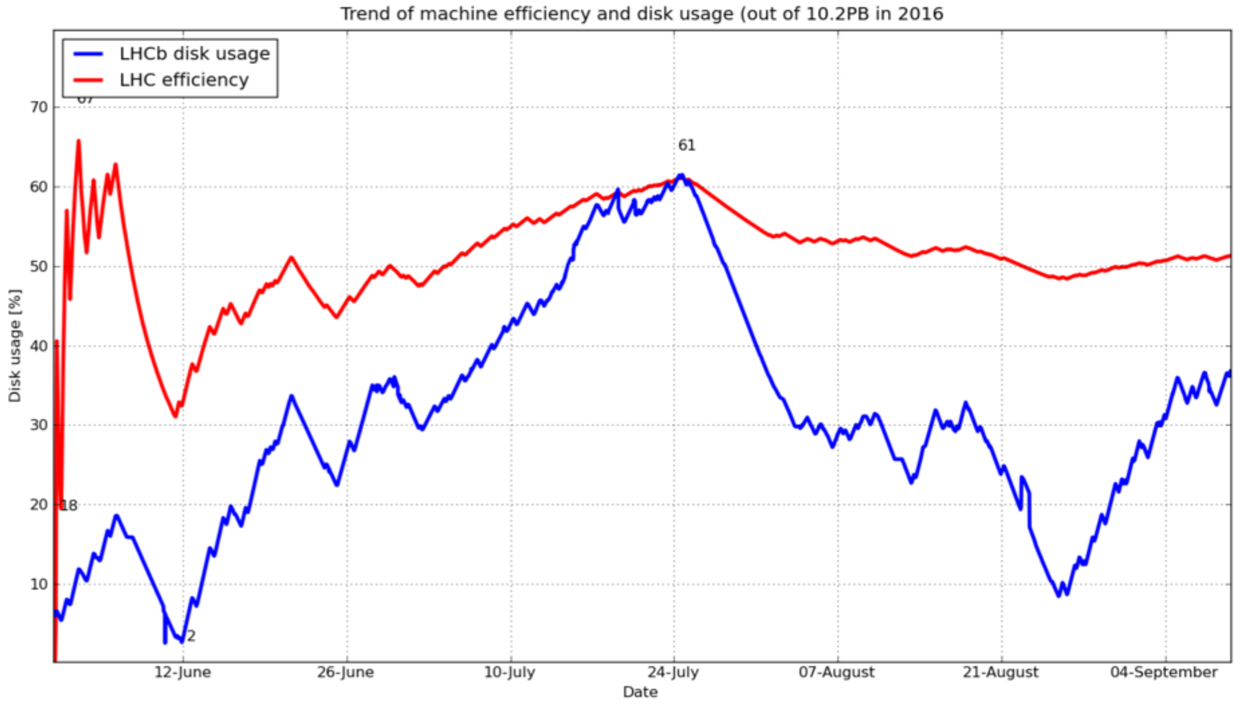
- trigger w. split HLT and automatic alignment
  - buffer data after HLT1
  - perform alignment
  - HLT2 processes data continuously and asynchronously
- HLT1 and HLT2 run on the same farm
- strategy is working very well

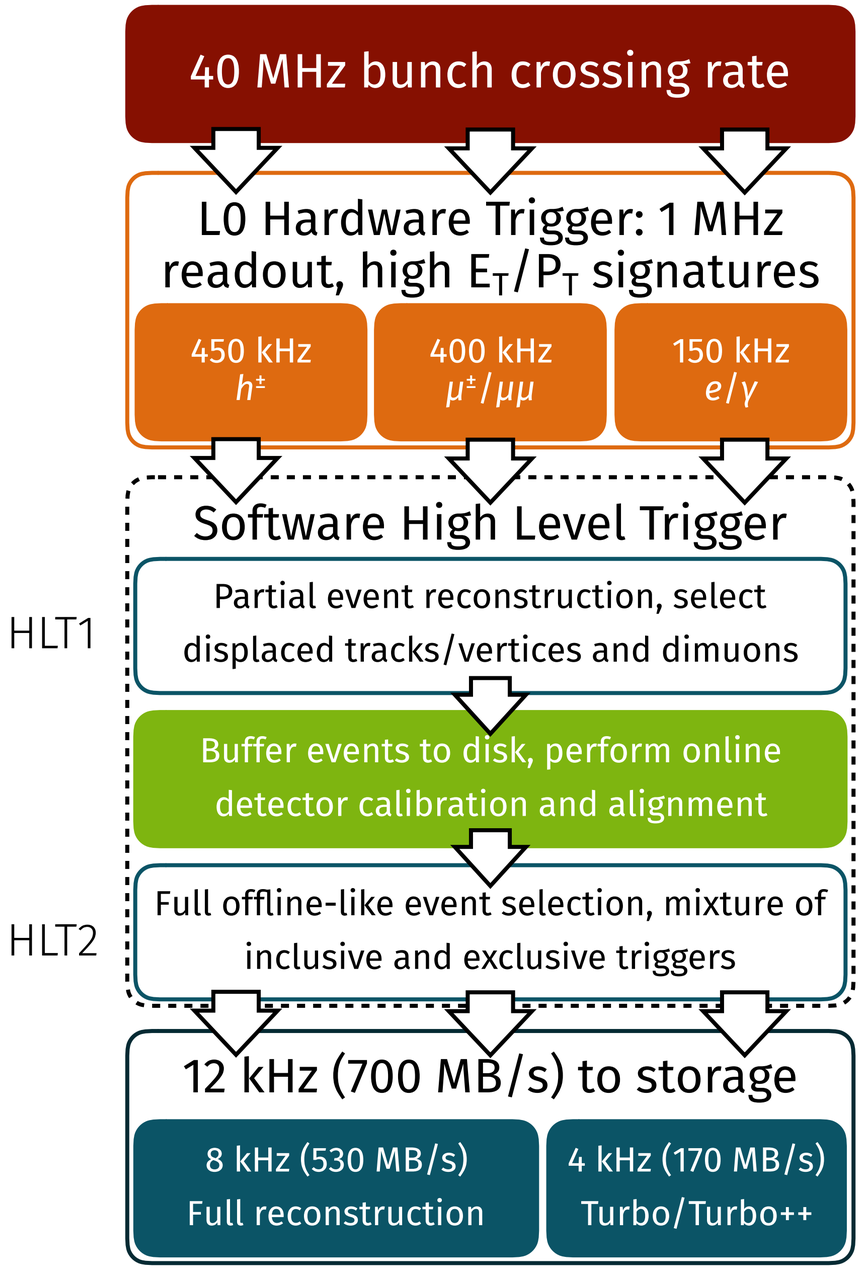




Data taking in Run II – Buffers

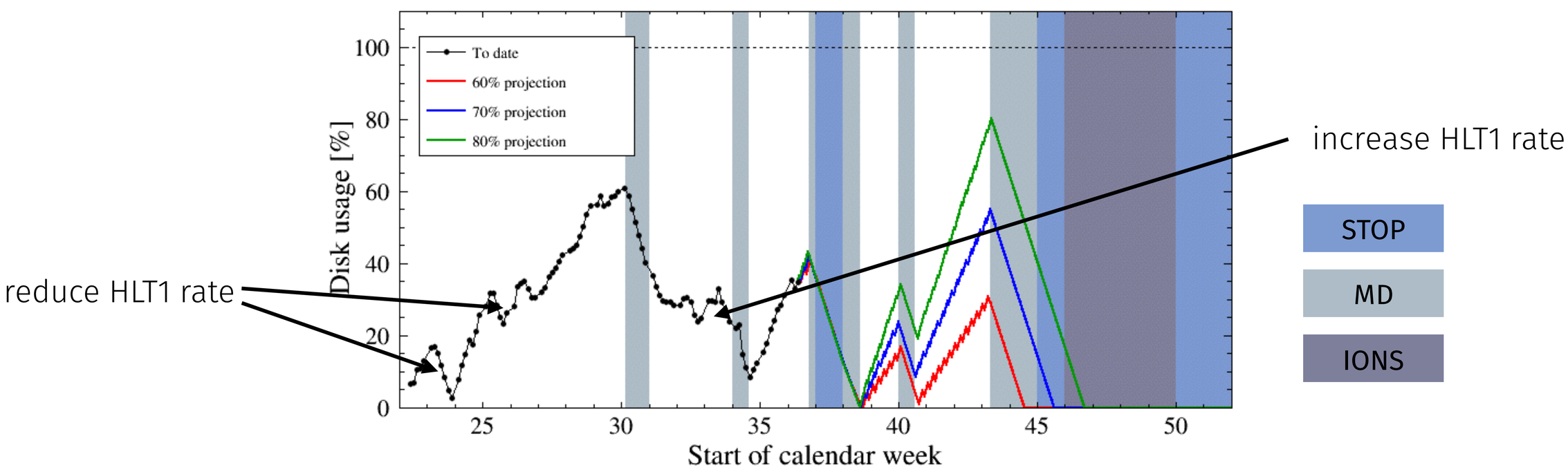
- trigger w. split HLT and automatic alignment
  - buffer data after HLT1
  - perform alignment
  - HLT2 processes data continuously and asynchronously
- HLT1 and HLT2 run on the same farm
- strategy is working very well





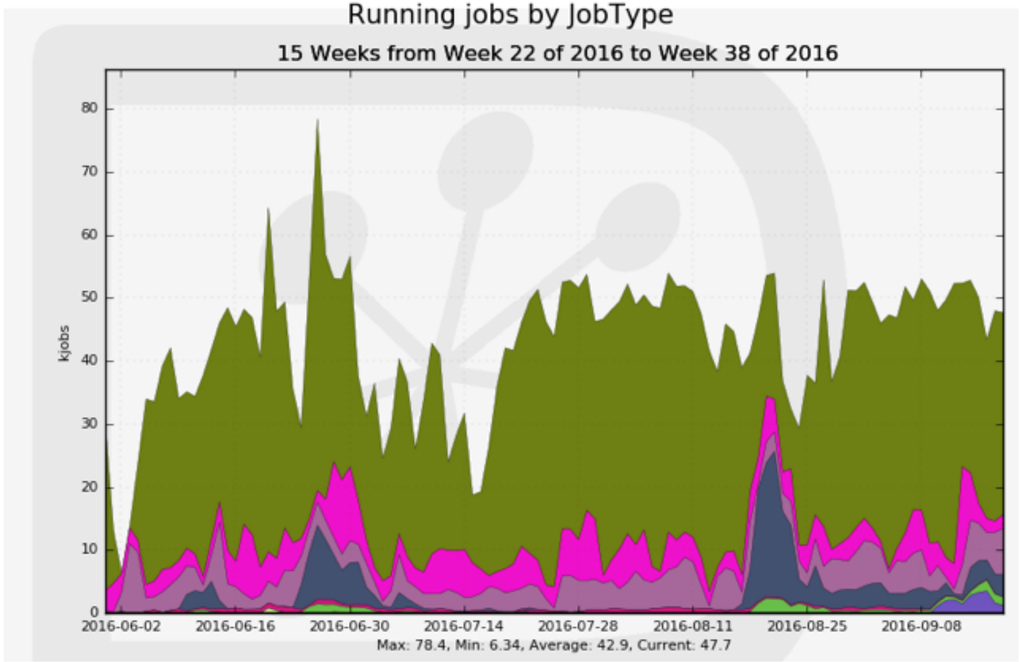
LHC efficiency and LHCb HLT

- defined various scenarios depending on LHCb efficiency and luminosity increase
- monitor status of buffer disks and speed-up the HLT
- small set of trigger configurations for different LHC setups
  - ≈3%/day of disk occupancy decrease when HLT2 running at max
  - increase originally ≈5%/day, can be adjusted by tightening/loosening trigger requirements



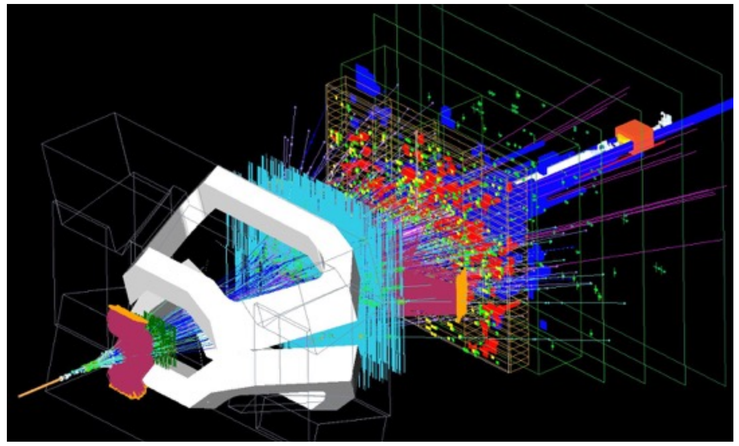
Distributed Data Processing in 2016

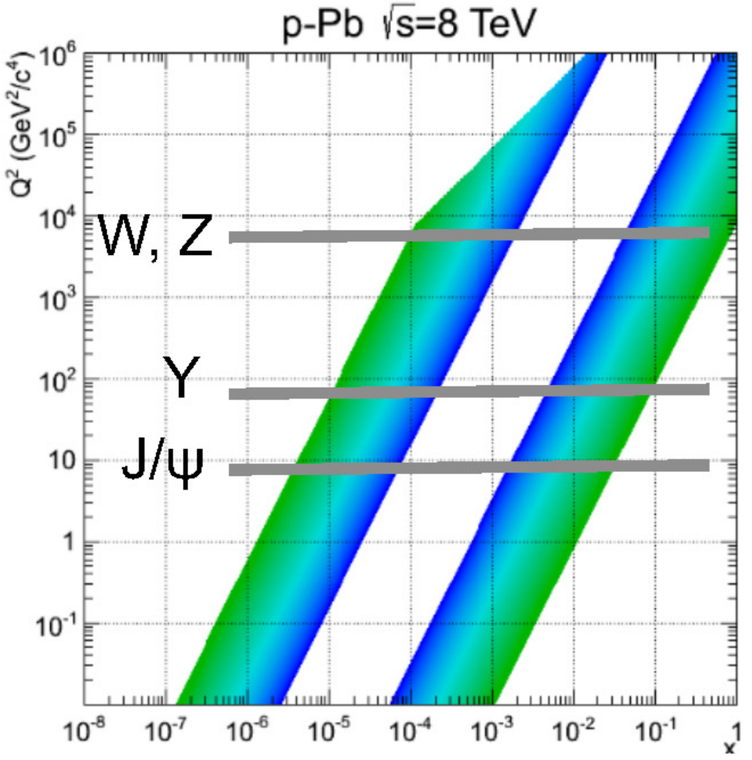
- increased LHC efficiency also affects CPU/disk and tape needs
  - required adaptation of data processing workflows
  - all offline data processing workflows now operational and backlogs processed
- additional strain due to changes in “Turbo”
  - now also contains reconstruction information
  - reduced offline CPU needs
  - increased disk requirements
- additional disk needs mitigated by
  - reduction of disk replicas
  - data popularity to remove unused datasets
  - parking of 1/3 of the Turbo data on tape
- using resources well above pledges



Preparations for the 2016 *p*Pb run

- LHCb will take part to the *p*Pb run at the end of the year
  - it will represent a big step forward for heavy ion physics at LHCb
  - work ongoing to optimise trigger and event reconstruction
  - we aim to get an integrated luminosity of 20 nb^{-1} at $\sqrt{s_{NN}}$ = 8 TeV
  - *p*Pb and Pb*p* configurations split 50/50
- main physics targets
  - J/ψ, $\psi(2S)$, $\Upsilon(nS)$, and Drell-Yan production
    - study cold nuclear matter effects
  - Z, J/ψ, Υ production to improve nuclear PDFs
  - associated heavy flavour production to study contributions from single and double parton scattering
- details in LHCb-PUB-2016-011



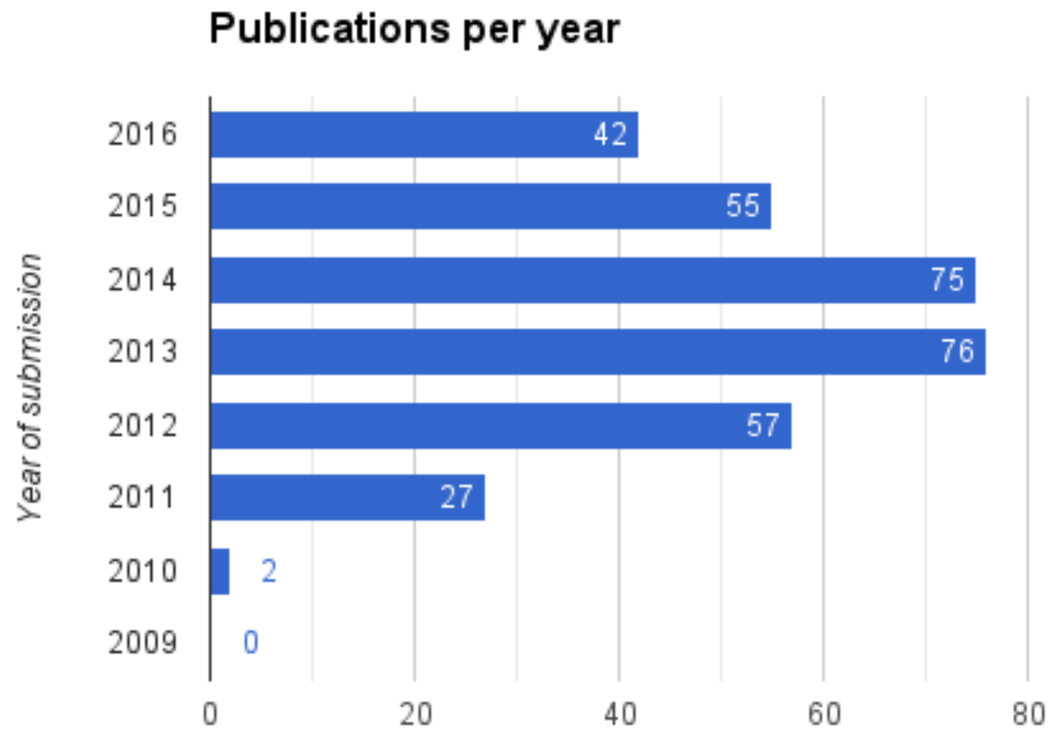


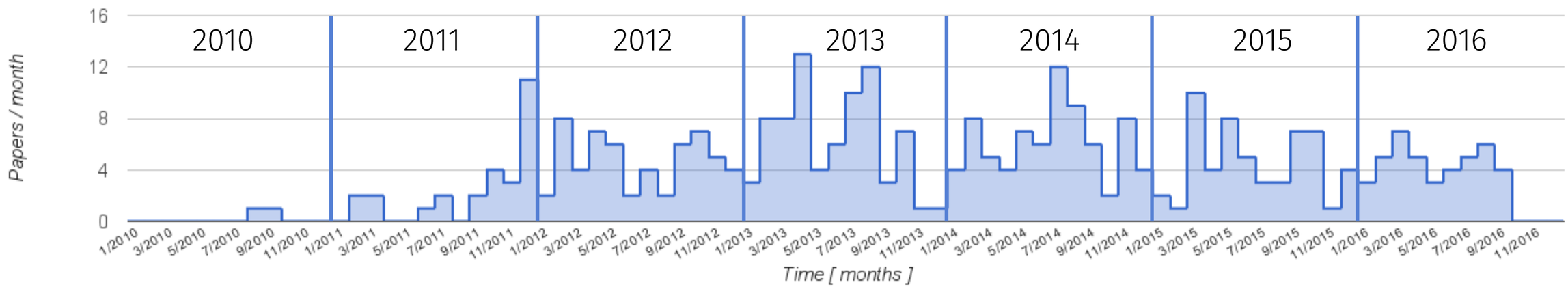
Marty Portier, “newspaper stand”, CC BY-NC-ND 2.0

New results

Publication status

- 334 papers submitted
  - +20 papers w.r.t. last LHCC
  - 7 PRL, 5 JHEP, 4 PLB, 2 PRD, 1 EPJC, 1 Nature Physics
- 15 papers in preparation
- 47 analyses under review





Publications since last LHCC

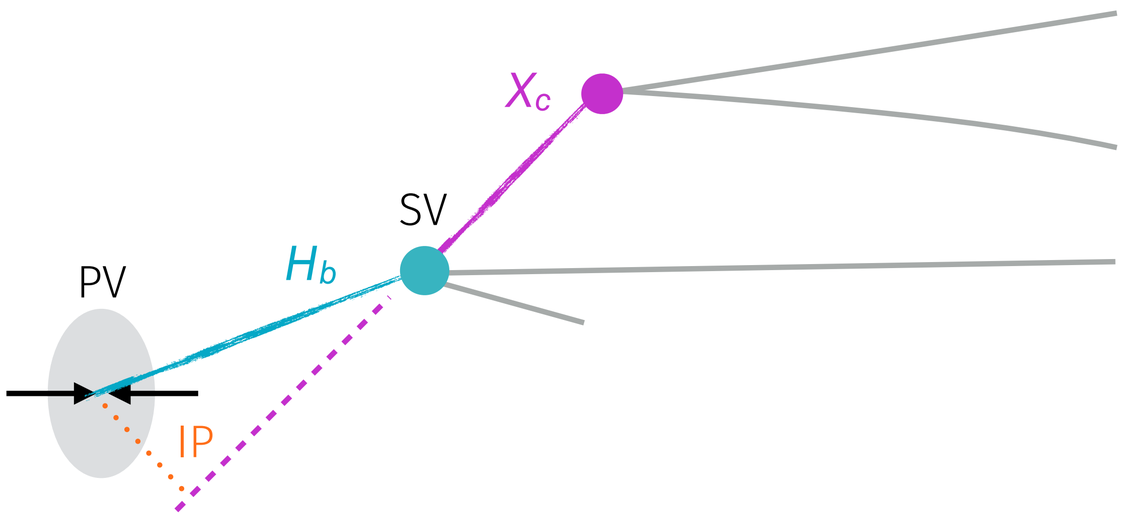
- Probing matter-antimatter asymmetries in beauty baryon decays
- Search for Higgs-like bosons decaying into long-lived exotic particles
- First experimental study of the photon polarization in radiative B_s decays
- Differential branching fraction and angular moments analysis of the decay $B^0 \to K^+ \pi^- \mu^+ \mu^-$ in the $K^*_{0,2}(1430)^0$ region
- Measurement of *CP* violation in $B^0 \to D^+ D^-$ decays
- Measurement of the *CP*-violating phase and decay-width difference in $B_s \to \psi(2S)\varphi$ decays
- Measurement of forward $W \to e\nu$ production in pp collisions at $\sqrt{s}$=8 TeV
- Search for the suppressed decays $B^+ \to K^+ K^+ \pi^-$ and $B^+ \to \pi^+ \pi^+ K^-$
- Amplitude analysis of $B^- \to D^+ \pi^- \pi^-$ decays
- Search for structure in the $B_s \pi^\pm$ invariant mass spectrum

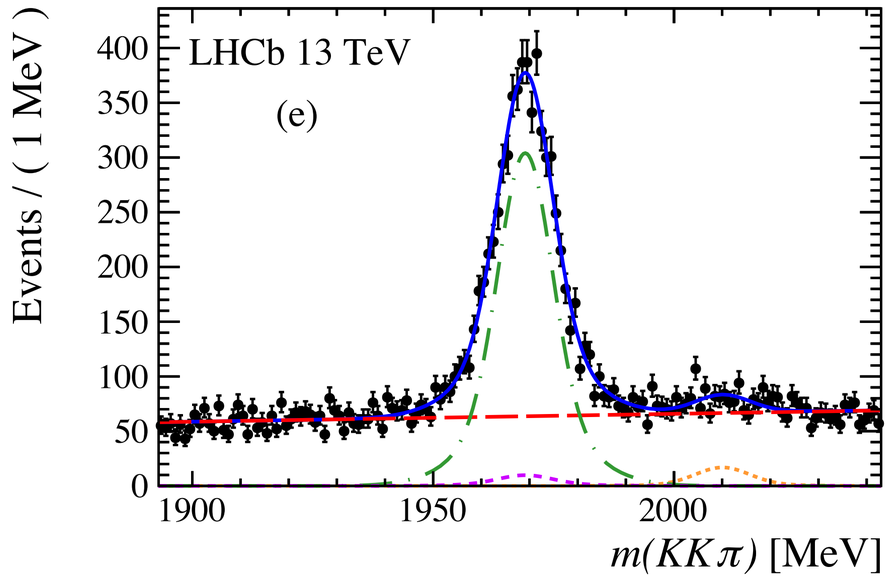
Publications since last LHCC (cont.)

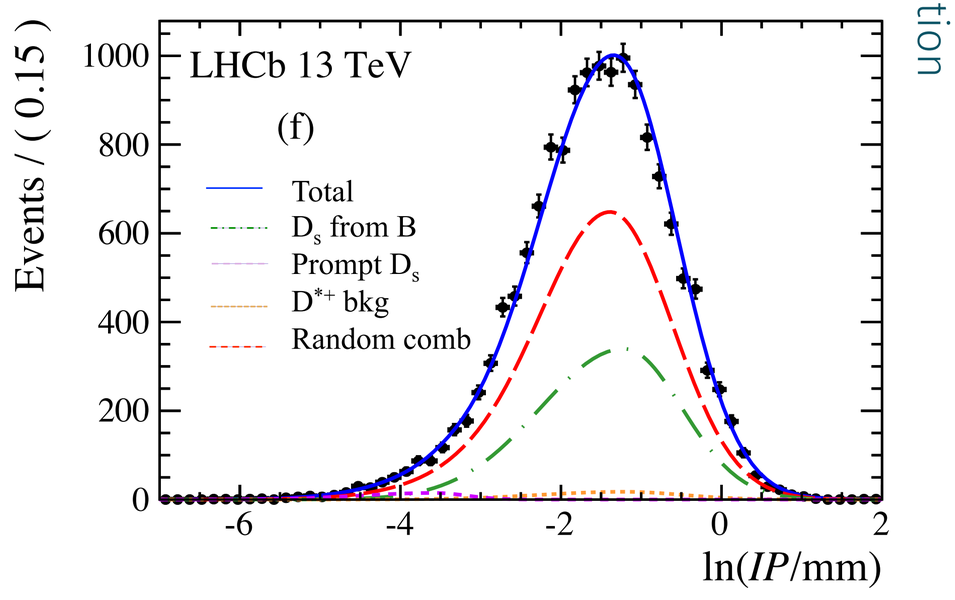
- Measurement of the ratio of branching fractions $\mathrm{Br}(B_c \to J/\psi K^+)/\mathrm{Br}(B_c \to J/\psi \pi^+)$
- Measurement of the forward Z boson production cross-section in pp collisions at $\sqrt{s}$=13 TeV
- Observation of $\eta_c(2S) \to pp$ and search for $X(3872) \to pp$ decays
- Measurement of the $B_s \to J/\psi\eta$ lifetime
- Study of B_c decays to the $K^+K^-\pi^+$ final state and evidence for the decay $B_c \to \chi_c{}^0 \pi^+$
- Amplitude analysis of $B^+ \to J/\psi\varphi \mathrm{K}^+$ decays
- Observation of $J/\psi\varphi$ structures consistent with exotic states from amplitude analysis of $B^+ \to J/\psi\varphi K^+$ decays
- Evidence for exotic hadron contributions to $\Lambda_b \to J/\psi p\pi^-$ decays
- Measurements of the S-wave fraction in $B^0 \to K^+\pi^-\mu^+\mu^-$ decays and the $B^0 \to K^*(892)^0\mu^+\mu^-$ differential branching fraction
- Measurement of the CP asymmetry in B_s mixing

b-quark production cross-section @13 TeV

- strategy: measure inclusive $b \to X_c \mu \nu X$ decays
  - right-sign μX_c combinations, $X_c = \{D^0, D^+, D_s, \Lambda_c\}$
    - form a good secondary vertex (SV)
    - do not point back to the primary vertex (PV)
  - 2D fit to m and ln(IP) distribution to identify non-prompt X_c

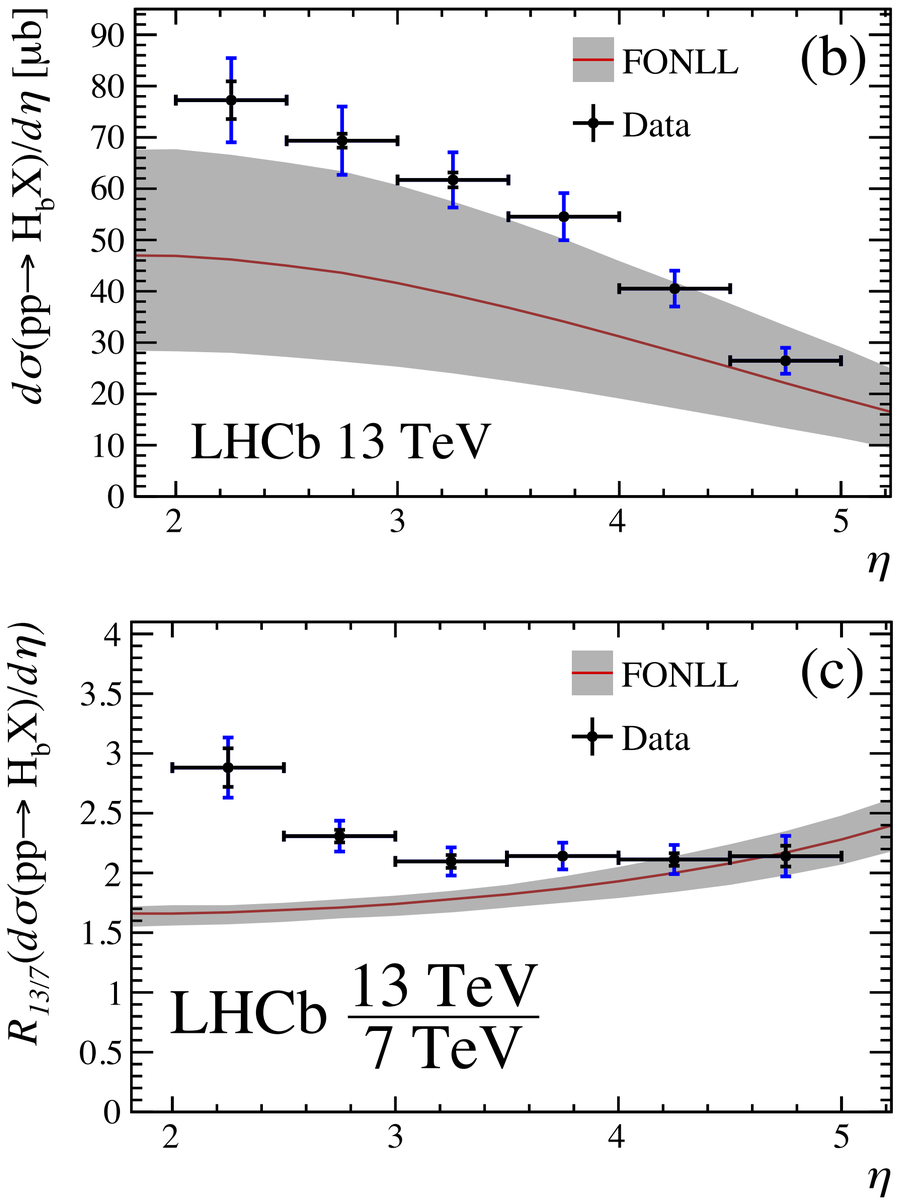






LHCb-PAPER-2016-030, in preparation

b-quark production cross-section



- cross-section in LHCb acceptance
  - σ_{bb} = (164.9 ± 2.3 ± 14.6) μb
  - theory prediction 111^{+51}_{-44} μb from FONLL [arXiv:1507.06197]

- measured ratio
  - $\sigma_{bb}(13\ \text{TeV})/\sigma_{bb}(7\ \text{TeV})$ = 2.30 ± 0.25 ± 0.19
  - theory FONLL predicts $1.70^{+0.21}_{-0.15}$
  - tensions at low η

LHCb-PAPER-2016-030, in preparation

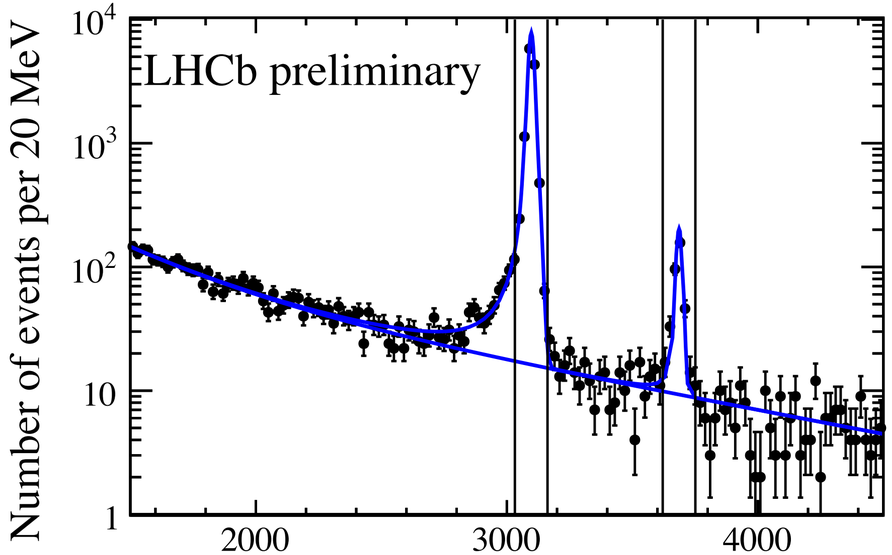
Run II

J/ψ and $\psi(2S)$ production @13 TeV

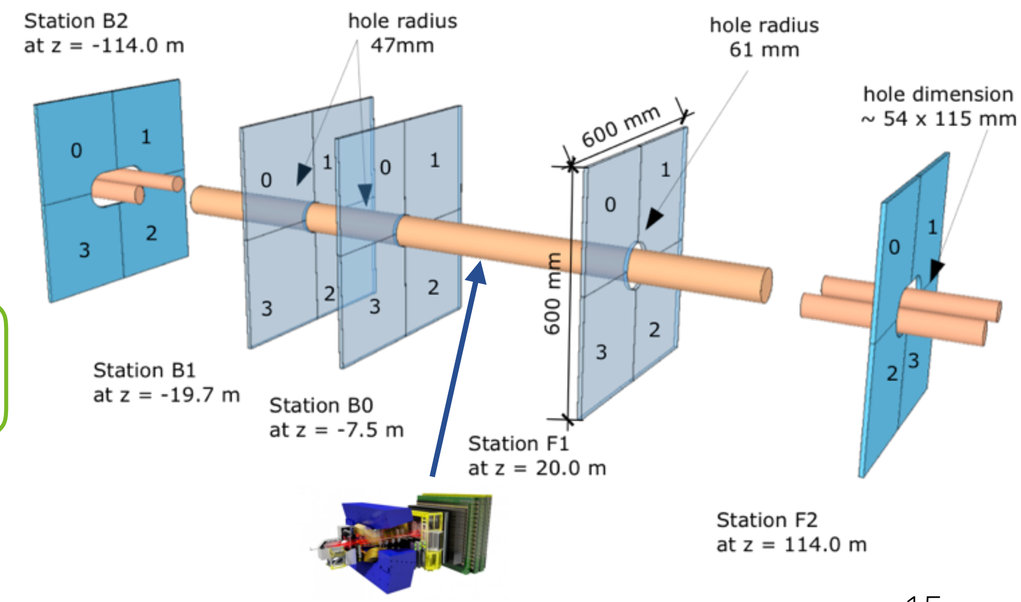
- central exclusive production
  - diffractive process, protons remain intact
  - interaction mediated by pomerons
- cross-section measurements useful for
  - testing QCD
  - description of pomerons
  - probing the gluon PDF, down to $x = 2 \times 10^{-6}$

- first result with the inclusion of HeRSChel!

$$\sigma_{J/\psi\to\mu^+\mu^-}(2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5) = 407 \pm 8 \pm 24 \pm 16 \text{ pb}$$
$$\sigma_{\psi(2S)\to\mu^+\mu^-}(2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5) = 9.4 \pm 0.9 \pm 0.6 \pm 0.4 \text{ pb}$$

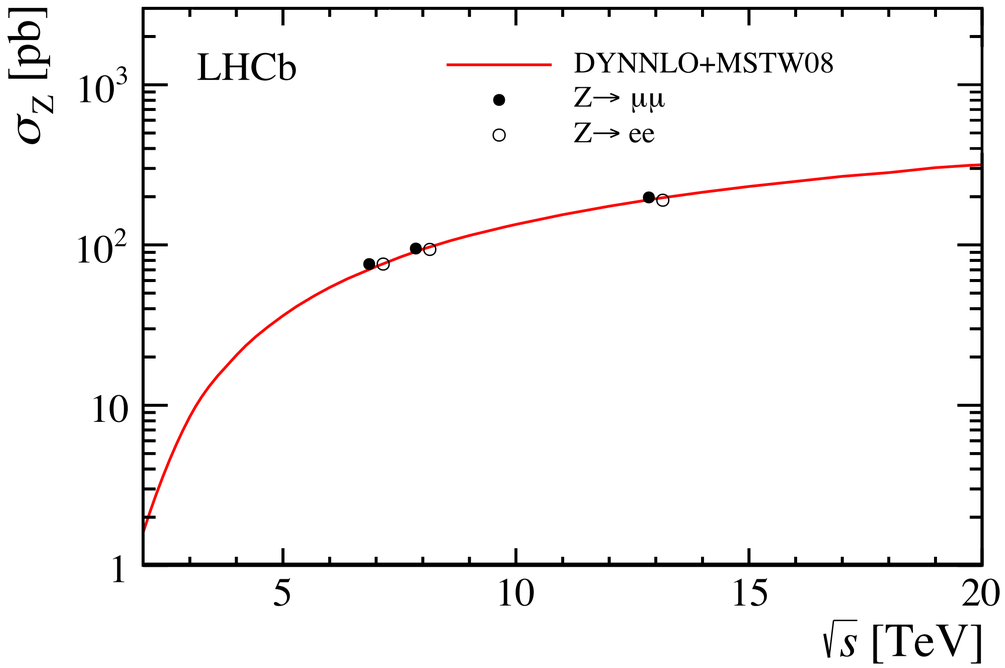


LHCb-CONF-2016-007



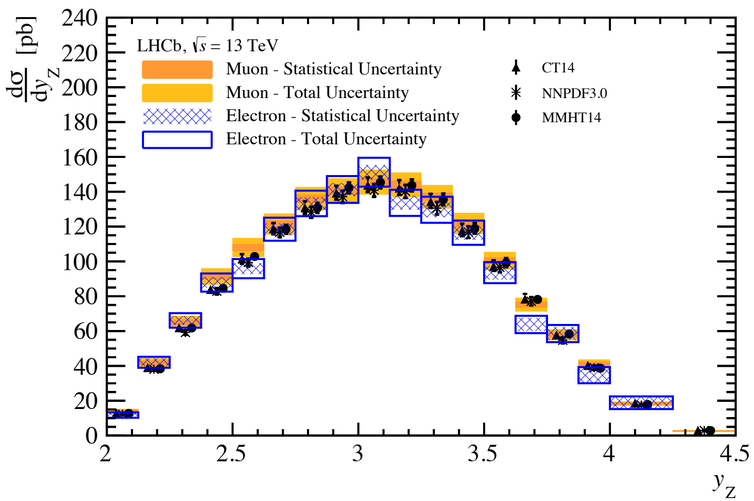
Forward Z boson production at $\sqrt{s}$=13 TeV

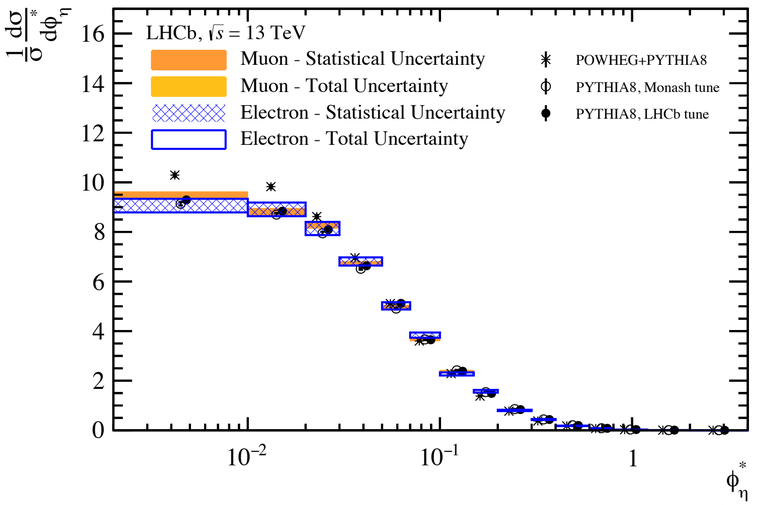
- measure $\sigma(Z \to l^+ l^-)$ with $l^\pm = e^\pm, \mu^\pm$
- probe lower Bjorken-x than in Run I
- good agreement
  - between the two final state cross-sections
  - differential cross-section distributions vs. theory



LHCb-PAPER-2016-021, arXiv:1607.06495

- first step towards further Run II studies
  - great potential for LHCb's electroweak programme





Run I

Photon polarisation in $B_s \to \varphi\gamma$

- decay-time dependent decay rate

$$\Gamma_{B_s^0\to\phi\gamma}(t) \propto e^{-\Gamma_s t}\left[\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma_s t/2)\right]$$

  - photon polarisation parameter

$$\mathcal{A}^{\Delta} \approx \sin 2\psi \cos\varphi_s$$ ← mixing phase

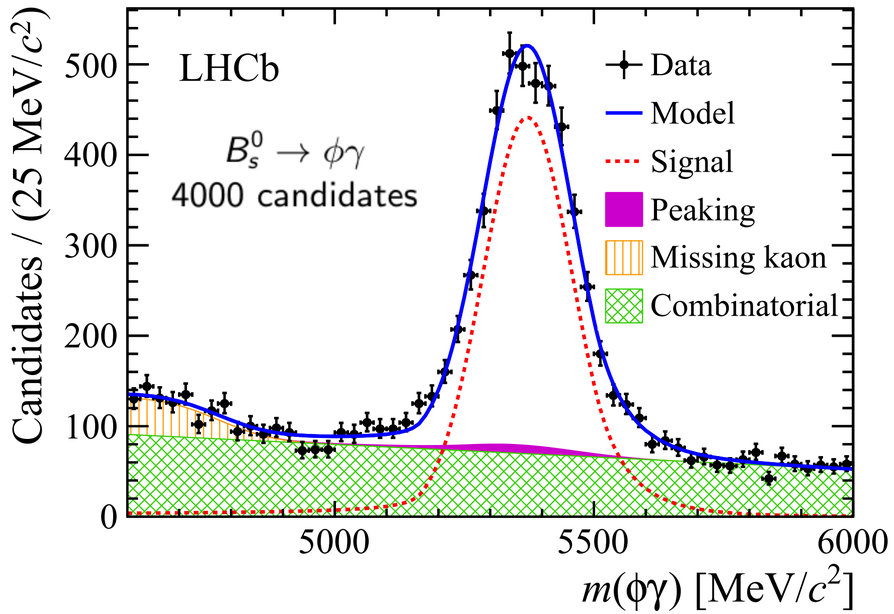
$$\mathcal{A}^{\Delta}{}_{\rm SM} = 0.047^{+0.029}_{-0.025}$$

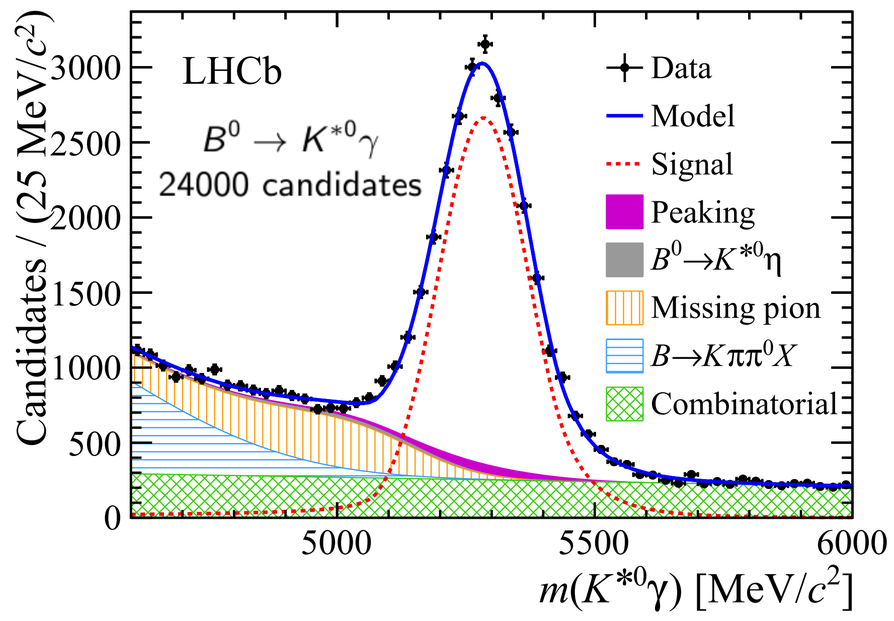
$$\tan\psi \equiv \frac{|A(\bar{B}_s^0 \to \phi\gamma_R)|}{|A(\bar{B}_s^0 \to \phi\gamma_L)|}$$ dominant left-handed polarisation expected

    - angular observables in $B^0 \to K^{*0} e^+ e^-$ also sensitive

  - well measurable due to large decay width difference
    $\Delta\Gamma_s = 0.083 \pm 0.006\ \text{ps}^{-1}$

- use $B^0 \to K^{*0}\gamma$ as control channel
  - here $\Delta\Gamma_d \approx 0$, thus can determine decay-time related effects



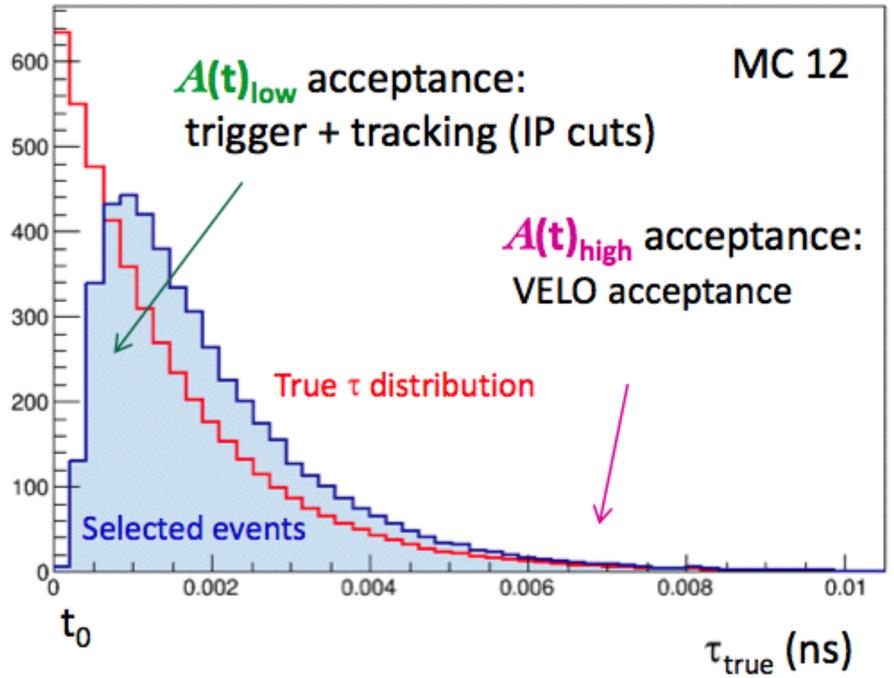


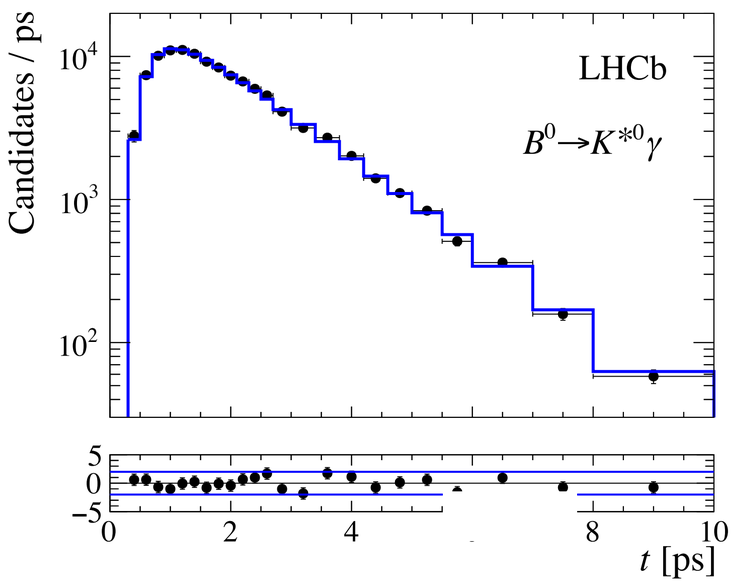
LHCb-PAPER-2016-034, arXiv:1609.02032

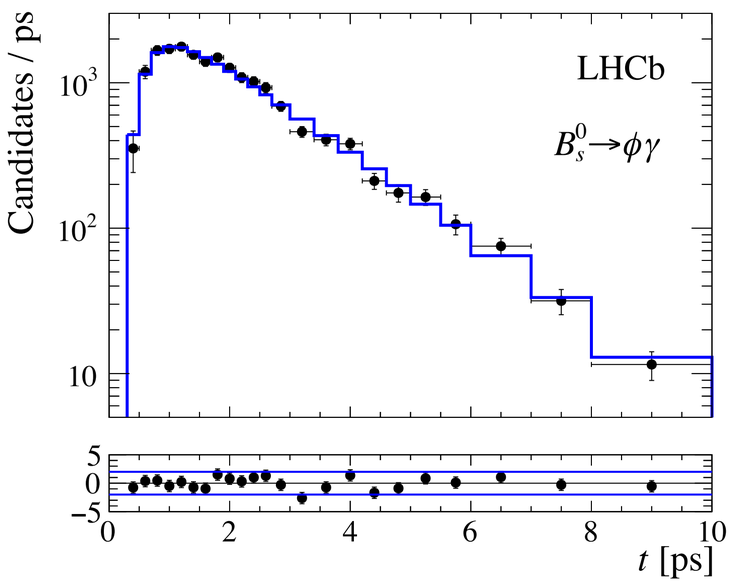
Run I

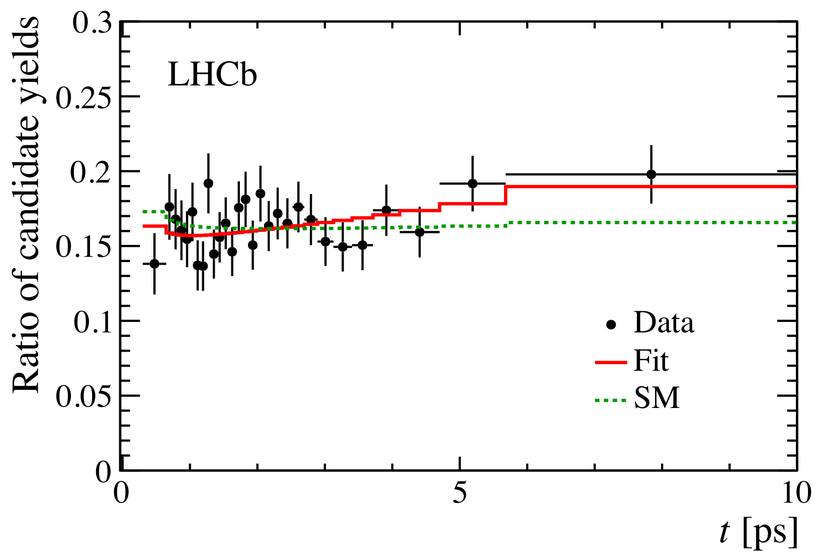
Photon polarisation in $B_s \to \varphi\gamma$

- experimental challenges
  - $\mathcal{P}(t) = [\text{Physics} \times \text{Acceptance}] \otimes \text{Resolution}$
    - resolution from simulations
    - control acceptance by using $B^0 \to K^{*0}\gamma$
  - comb. & partially reconstructed backgrounds
  - peaking backgrounds









LHCb-PAPER-2016-034, arXiv:1609.02032

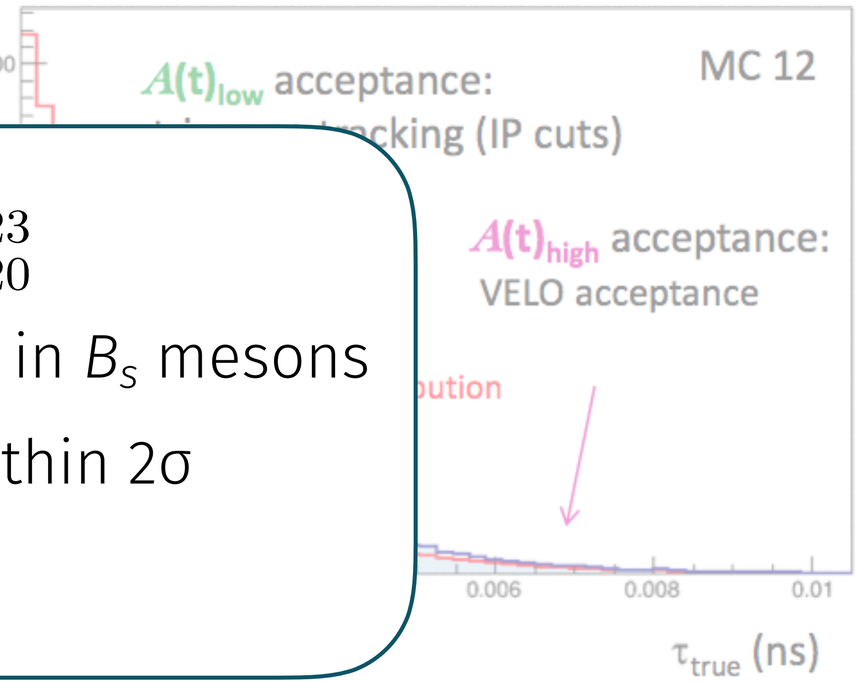
Run I

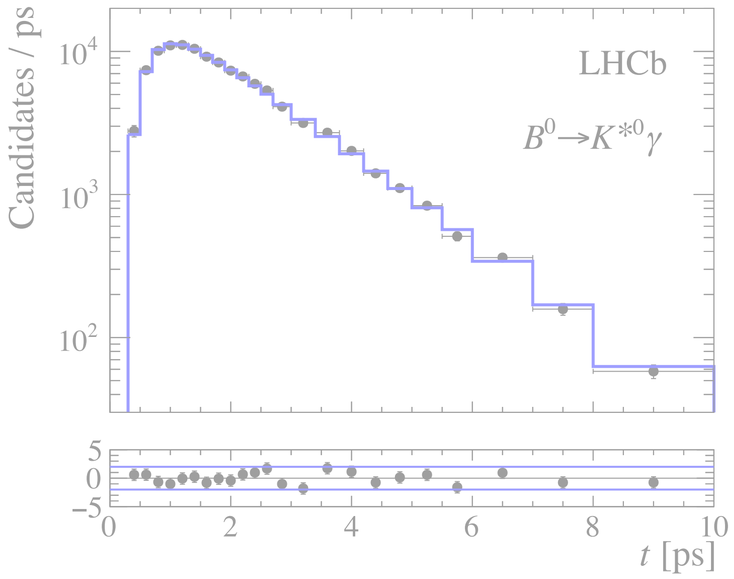
Photon polarisation in $B_s \to \phi\gamma$

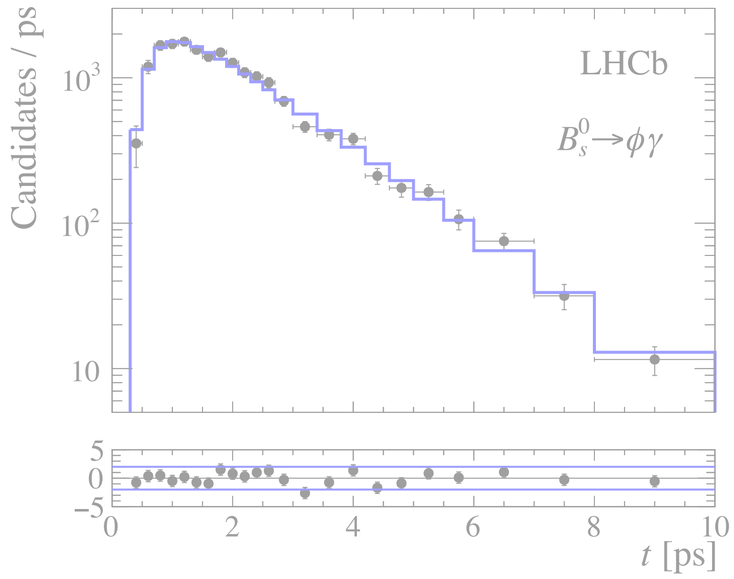
- experimental challenges
  - $\mathcal{P}(t) = [\mathrm{Ph}$
    - resolution
    - control acc
  - comb. & pa
  - peaking bac

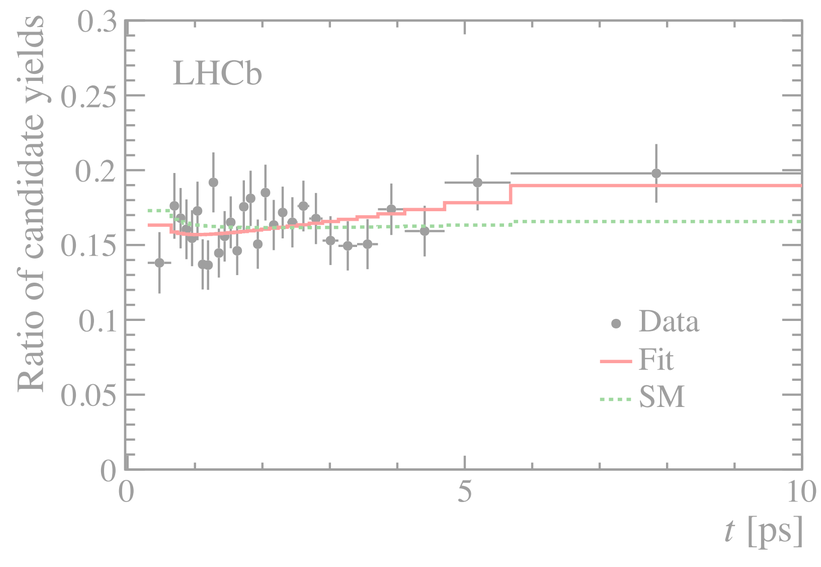
result: $\mathcal{A}^{\Delta} = -0.98\,^{+0.46\,+0.23}_{-0.52\,-0.20}$

- first measurement of polarisation in B_s mesons
- consistent with SM expectation within 2σ
- statistically limited







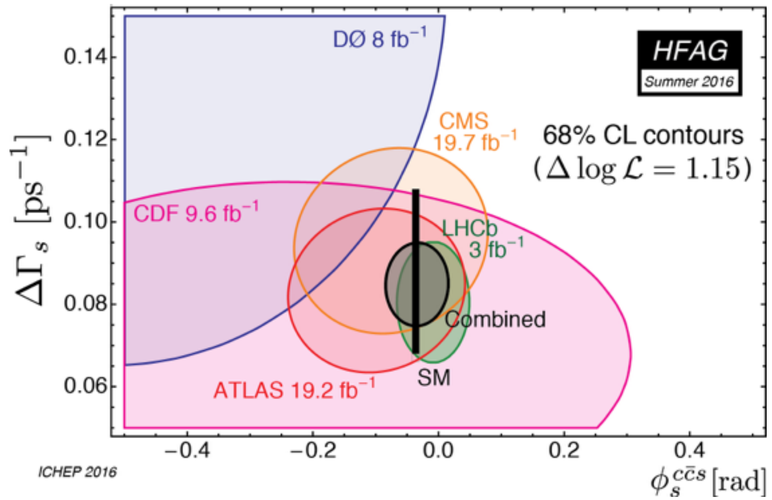


LHCb-PAPER-2016-034, arXiv:1609.02032

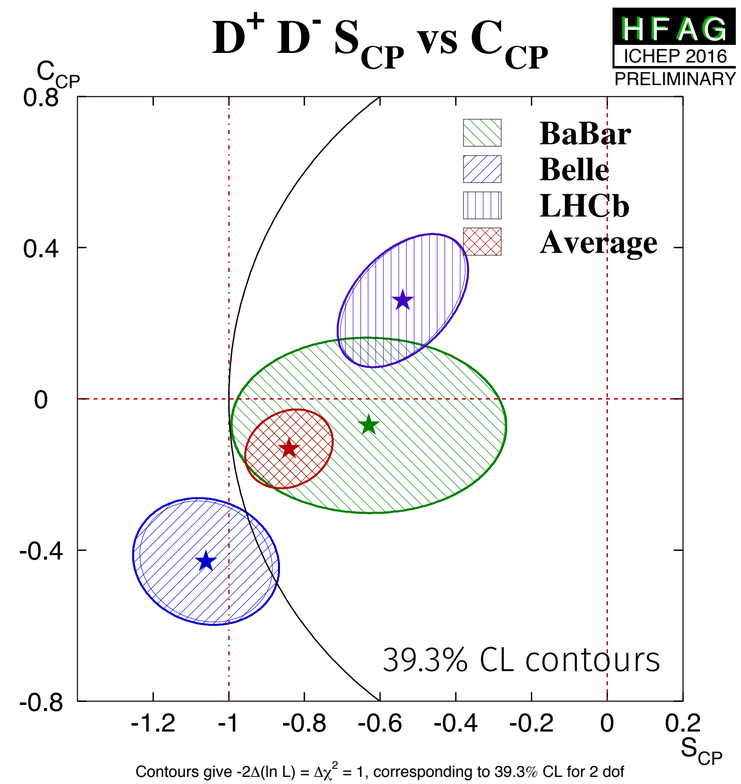
Run I

Flavour tagged analyses

- decay-time dependent *CP* analyses
  - require the knowledge of the initial *B* production flavour
  - flavour tagging algorithms exploit event information
- recent analyses
  - "Measurement of the *CP*-violating phase and decay-width difference in $B_s \to \psi(2S)\phi$ decays"
    - tagging power of 3.9%
  - "Measurement of *CP* violation in $B^0 \to D^+D^-$ decays"
    - precision on CPV significantly improved w.r.t. *B* factories
    - exploiting new tagging algorithms
    - tagging power of 8.1%!



LHCb-PAPER-2016-027

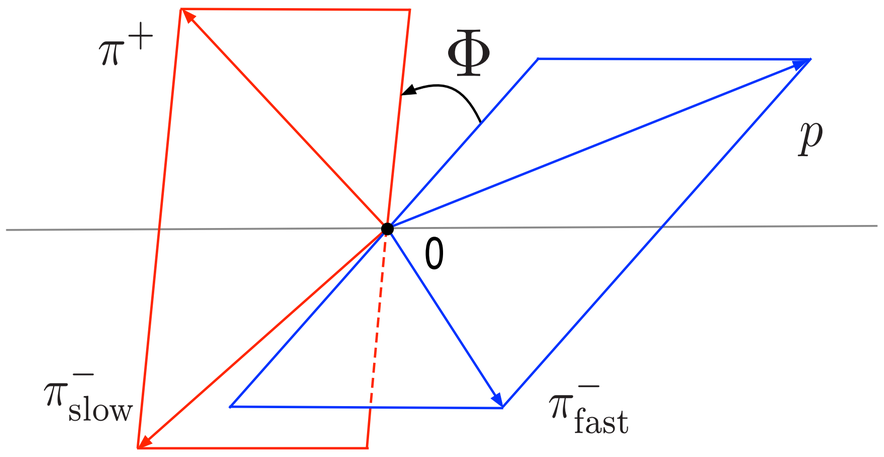


LHCb-PAPER-2016-037

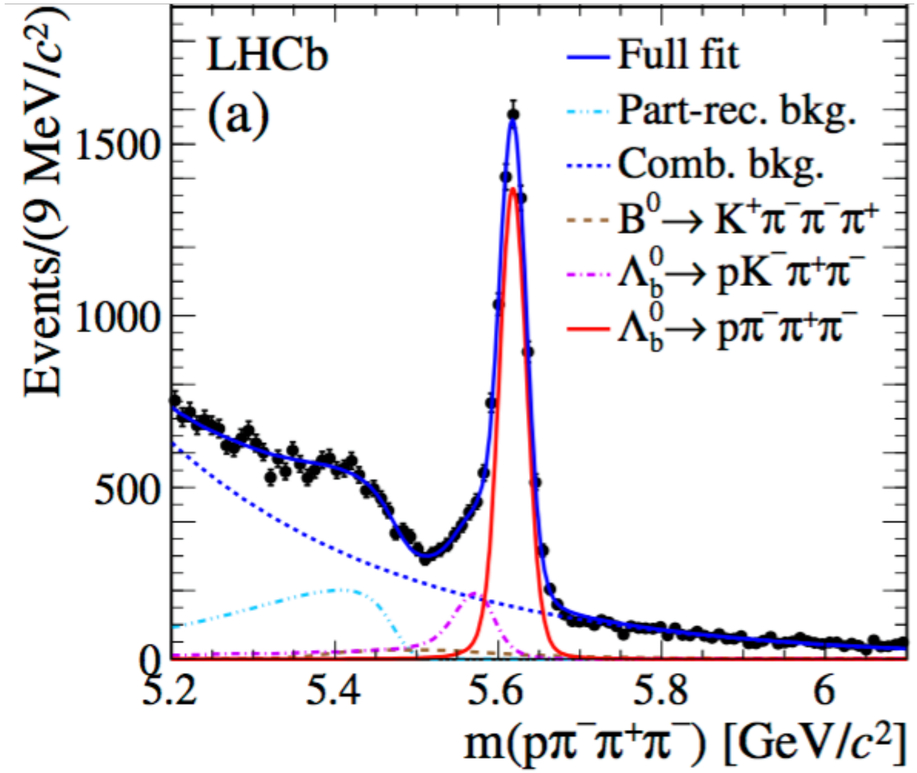
Run I

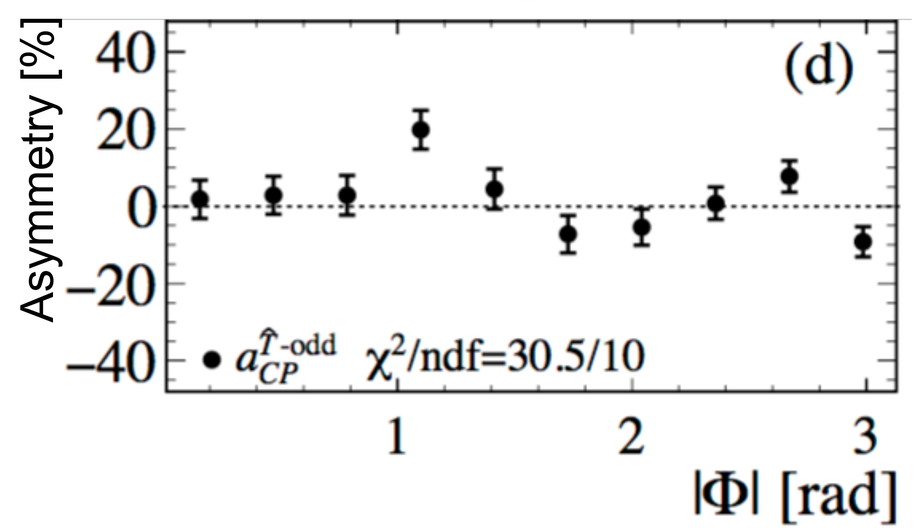
CP violation in *b*-baryons

- strategy: use $\Lambda_b \to p\pi^-\pi^+\pi^-$ decays
  - search for *CP*-violating asymmetries in triple-products of final-state momenta
  - study local CPV as a function of the angle Φ between the $p\pi^-$ and $\pi^+\pi^-$ decay planes



- evidence for *CP* violation at 3.3σ
- first evidence for *CP* violation in baryons!





LHCb-PAPER-2016-031, arXiv:1609.05216

Run I

Search for indirect *CP* violation in D^0 mixing

- decay-time dependent asymmetry in K^+K^- and $\pi^+\pi^-$ final states

$$A_{CP}(t) = \frac{\Gamma(D^0(t) \to f) - \Gamma(\overline{D}^0(t) \to f)}{\Gamma(D^0(t) \to f) + \Gamma(\overline{D}^0(t) \to f)} \approx a_{CP}^{\mathrm{dir}} + \frac{t}{\tau_D} a_{CP}^{\mathrm{ind}}$$

$$A_\Gamma = -a_{CP}^{\mathrm{ind}} \qquad A_\Gamma = \frac{\hat{\Gamma}(D^0 \to f) - \hat{\Gamma}(\overline{D}^0 \to f)}{\hat{\Gamma}(D^0 \to f) + \hat{\Gamma}(\overline{D}^0 \to f)}$$

- analyses
  - use initial $D^{*\pm} \to D^0\pi^\pm$ for tagging the production flavour
  - challenge: avoid experimental biases
    - detector and reconstruction asymmetries
    - non-uniform decay-time acceptance

LHCb-CONF-2016-009, LHCb-CONF-2016-010

Run I

Search for indirect CPV in D^0 mixing

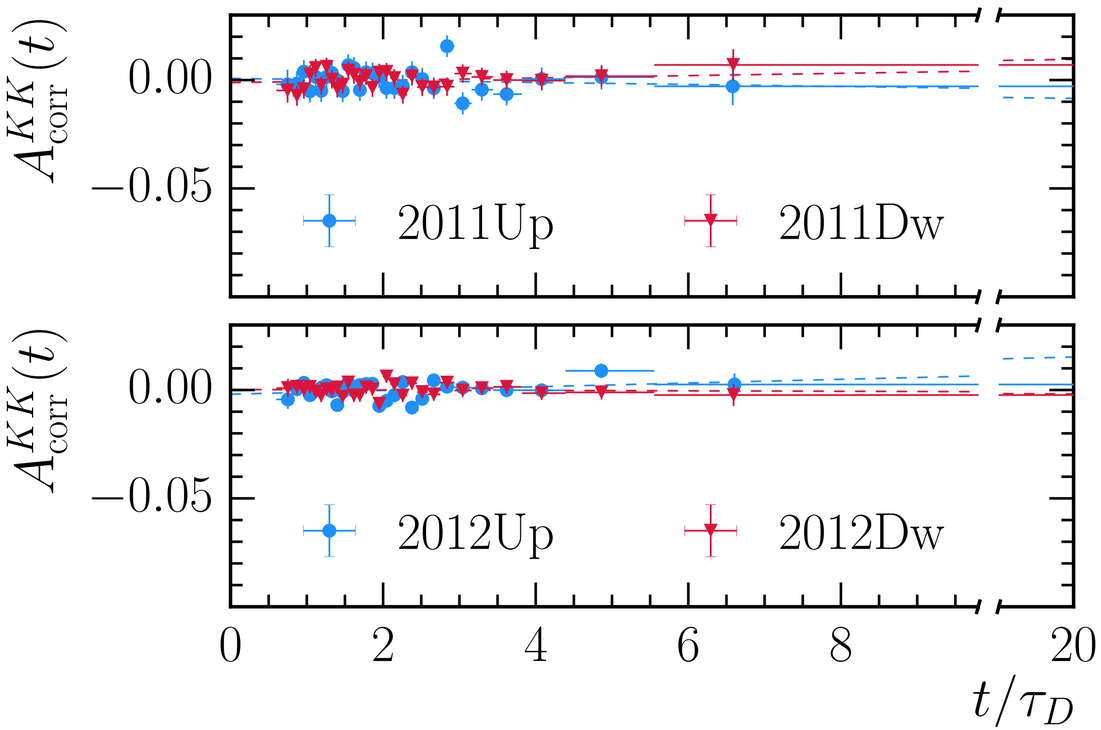
- two independent analyses
  - binned fit [LHCb-CONF-2016-009]
    - perform the analysis in bins of decay time
    - reduces effects from acceptance

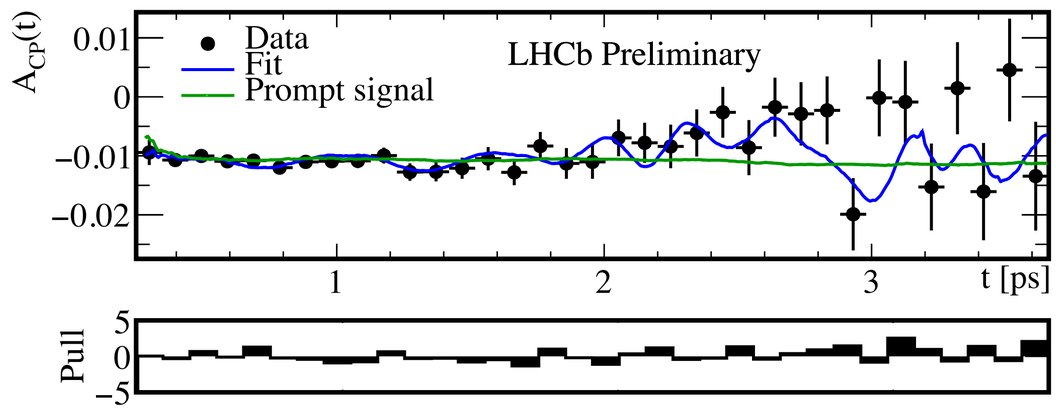
$$A_\Gamma = (-0.12 \pm 0.30) \times 10^{-3}$$

  - unbinned fit [LHCb-CONF-2016-010]
    - evaluate per-event decay-time acceptance function

$$A_\Gamma = (-0.07 \pm 0.34) \times 10^{-3}$$

- consistent within 1σ (incl. correlations)
- world's best measurements!





LHCb-CONF-2016-009, LHCb-CONF-2016-010

Direct *CP* violation in D^0 decays

- measure asymmetry of decay rate $A_{CP}(D^0 \to K^-K^+) \equiv \frac{\Gamma(D^0 \to K^-K^+) - \Gamma(\overline{D}^0 \to K^-K^+)}{\Gamma(D^0 \to K^-K^+) + \Gamma(\overline{D}^0 \to K^-K^+)}$

$$A_{\text{raw}}(D^0 \to f) = \frac{N(D^0 \to f) - N(\overline{D}^0 \to \overline{f})}{N(D^0 \to f) + N(\overline{D}^0 \to \overline{f})}$$

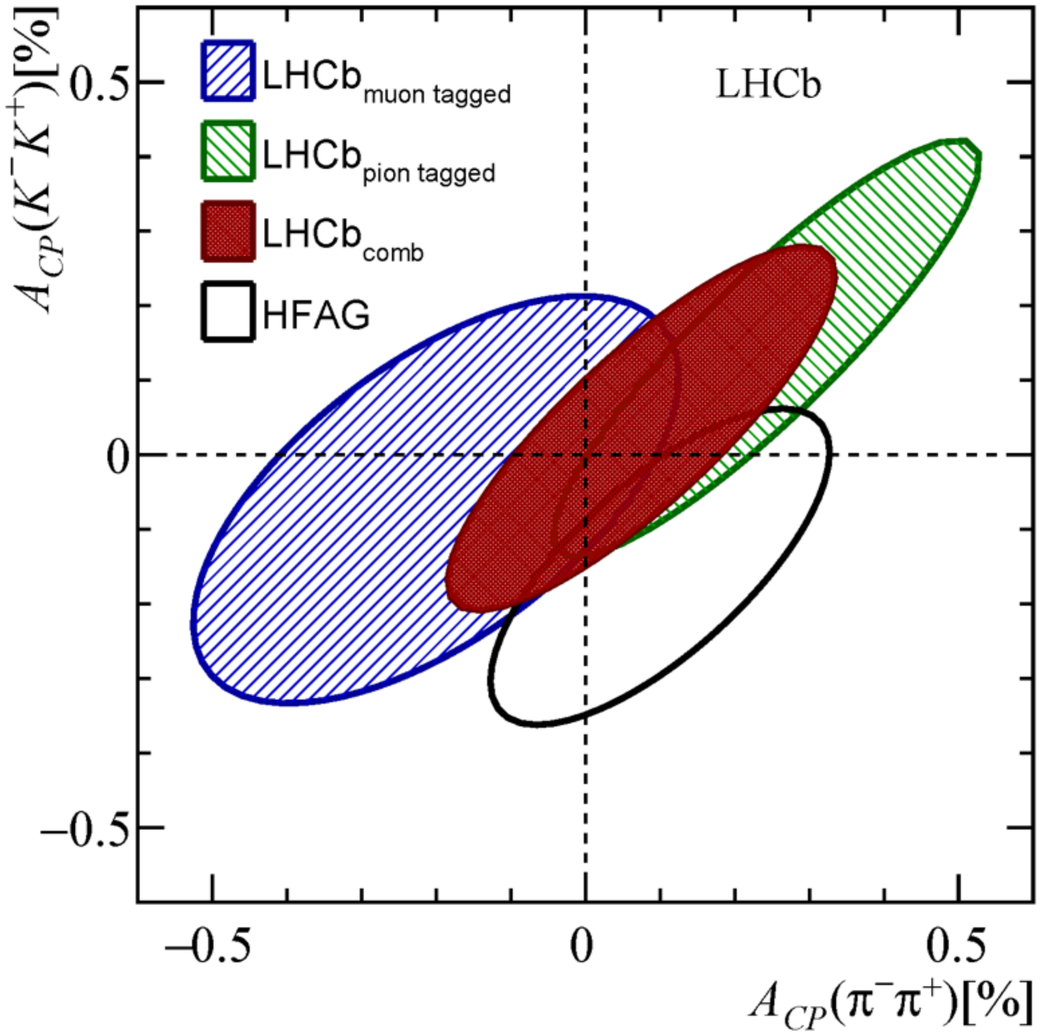
  - expect very small *CP* violation in the SM
  - determine experimental asymmetries from control channels

$$A_{CP}(D^0 \to KK) = A_{\text{raw}}(D^0 \to KK) - A_P(D^{*+}) - A_D(\pi_s^+)$$

- combined results w. previous analyses

$$A_{CP}^{\text{comb}}(KK) = (0.04 \pm 0.12 \pm 0.10)\,\%$$
$$A_{CP}^{\text{comb}}(\pi\pi) = (0.07 \pm 0.14 \pm 0.11)\%$$

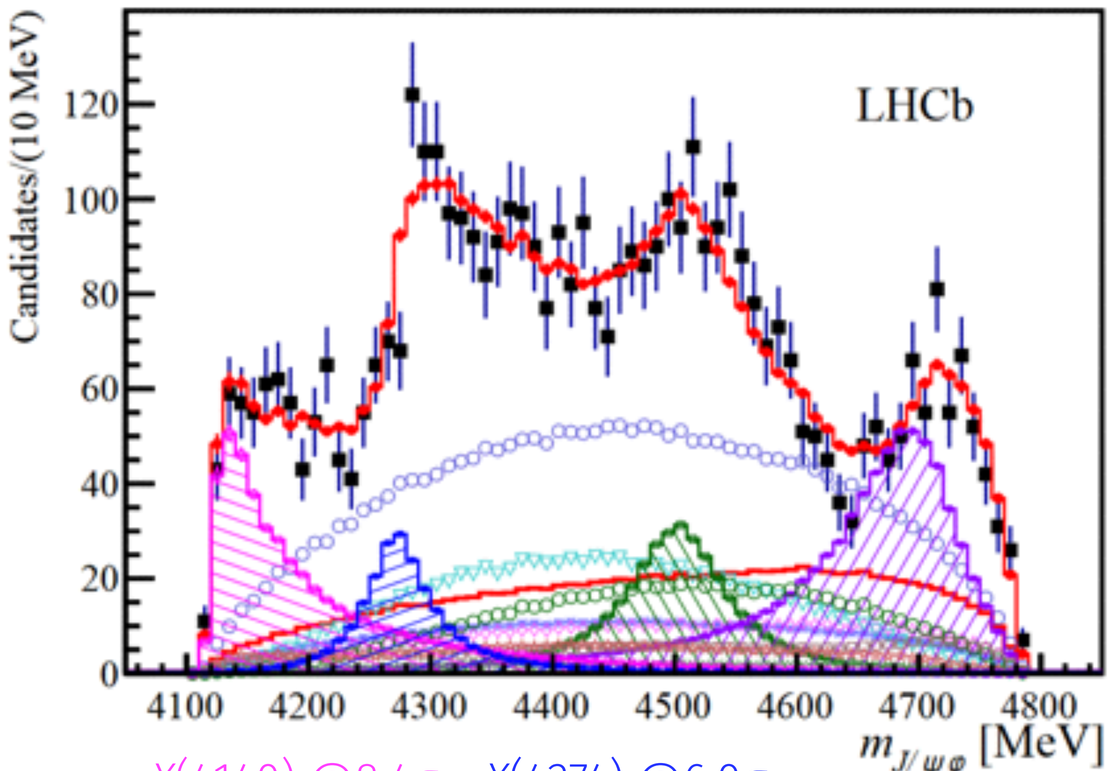
no evidence for CPV



LHCb-PAPER-2016-035, in preparation

Observation of four exotic-like particles

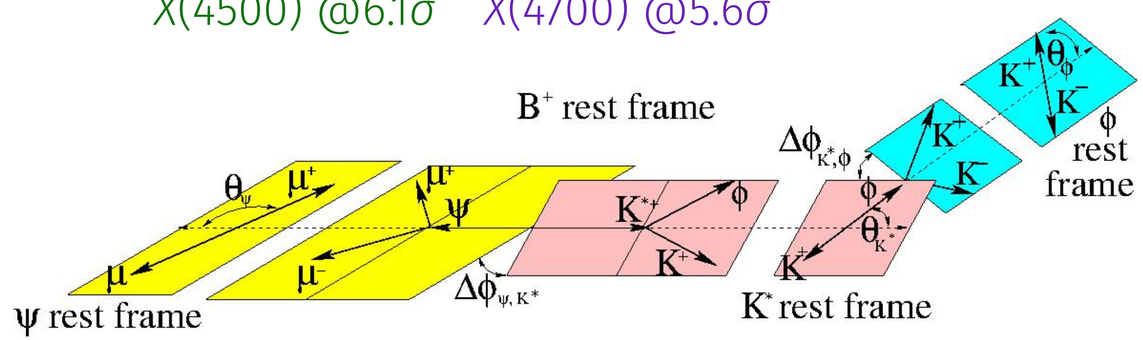
- $X \to J/\psi\varphi$ decays in $B^{\pm} \to J/\psi\varphi K^{\pm}$ decays
- "history"
  - CDF observed a narrow structure, $X(4140)$, and hint for another structure, $X(4274)$
  - exotic: narrow and above $D_s D_s$ threshold
  - also seen by D0 and CMS
- new, unique analysis by LHCb
  - first full amplitude analysis (6D likelihood fit)
  - measurement of quantum numbers
  - $X(4140)$ and $X(4274)$ seen (both $J^{PC}=1^{++}$)
    - $X(4140)$ described as $D_s^{+} D_s^{*-}$ cusp is preferred by fit
  - 2 additional structures, $X(4500)$ and $X(4700)$ (both $J^{PC}=0^{++}$)



LHCb-PAPER-2016-019, arXiv:1606.07898

$X(4140)$ @8.4σ $X(4274)$ @6.0σ

$X(4500)$ @6.1σ $X(4700)$ @5.6σ

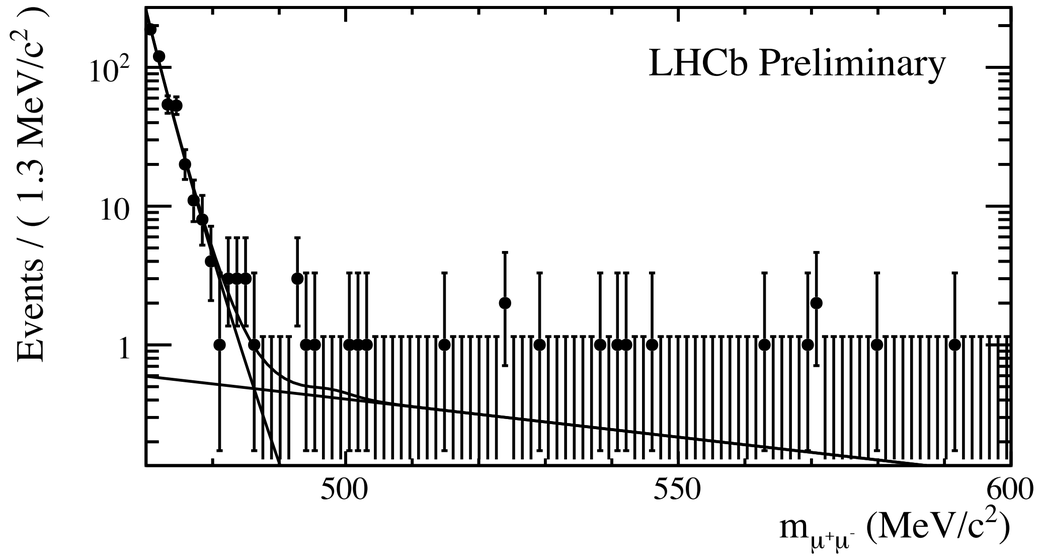


Run I

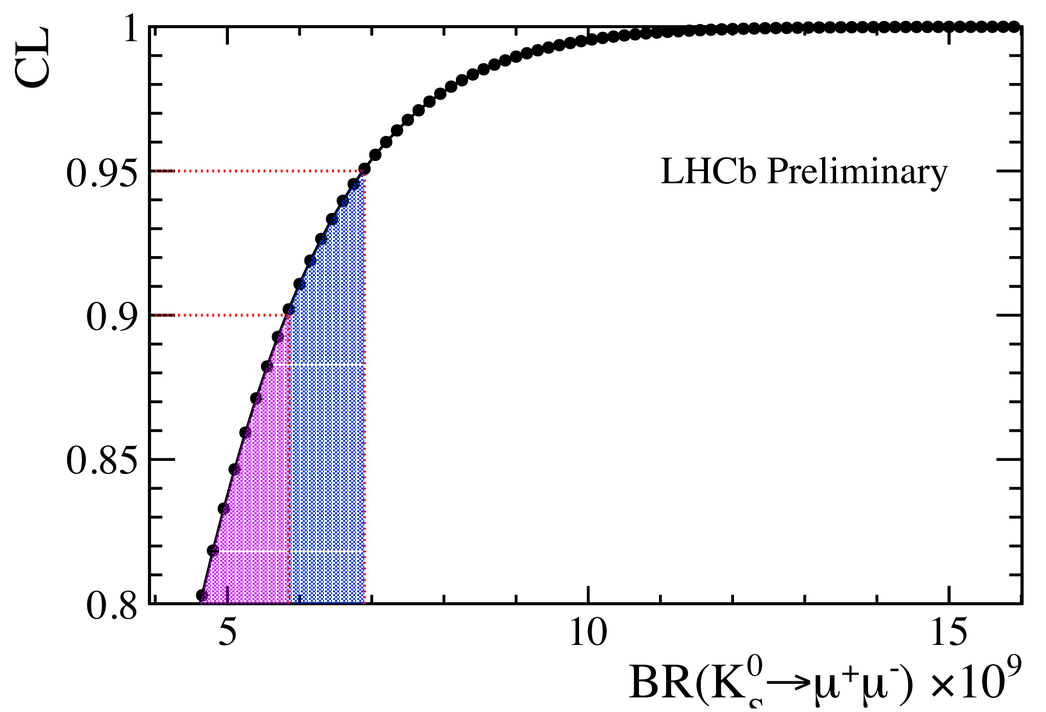
Search for $K_S \to \mu^+\mu^-$ decays

- $K_S \to \mu^+\mu^-$ has not been observed
  - in SM: FCNC transition with additional suppression due to small CPV
    - SM prediction: $BR(K_S \to \mu^+\mu^-) = (5.0 \pm 1.5) \times 10^{-15}$
    - experimental upper limit < 11×10^{-9} @95% CL
- analysis using 2 fb^{-1} of Run I
  - normalisation channel $K_S \to \pi^+\pi^-$
  - fit the kaon mass in bins of trigger selection and MVA output
- preliminary upper limit

$BR(K_S \to \mu^+\mu^-) < 6.9 \times 10^{-9}$ @95% CL



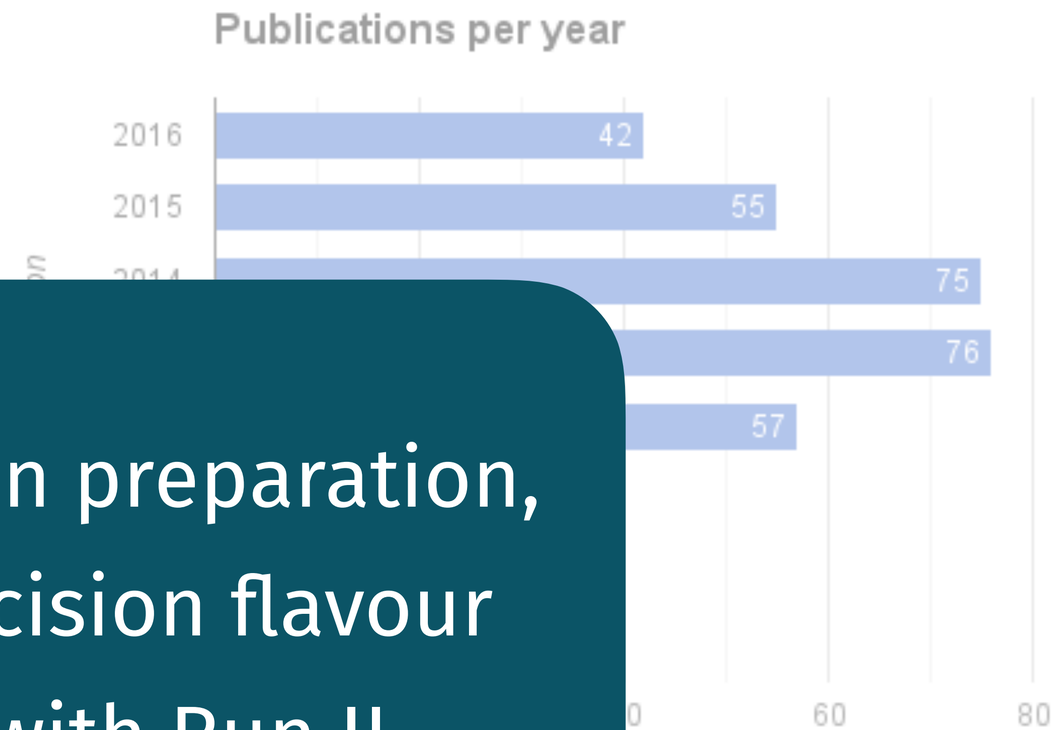
LHCb-CONF-2016-012

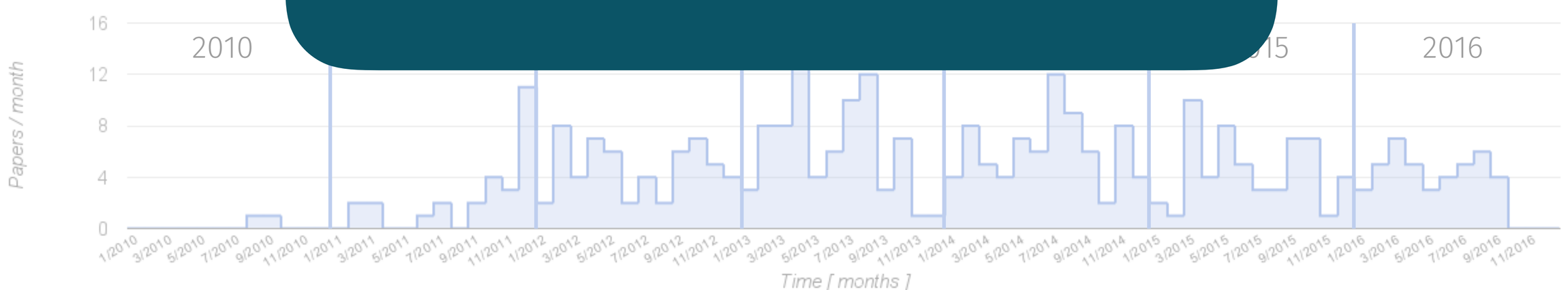


Publication status

- 334 papers submitted
  - +20 papers w.r.t. last LHCC
  - 7 PRL, 5 JHE
    1 EPJC, 1 Na
- 15 papers i
- 47 analyse

many more results in preparation, including high precision flavour physics results with Run II





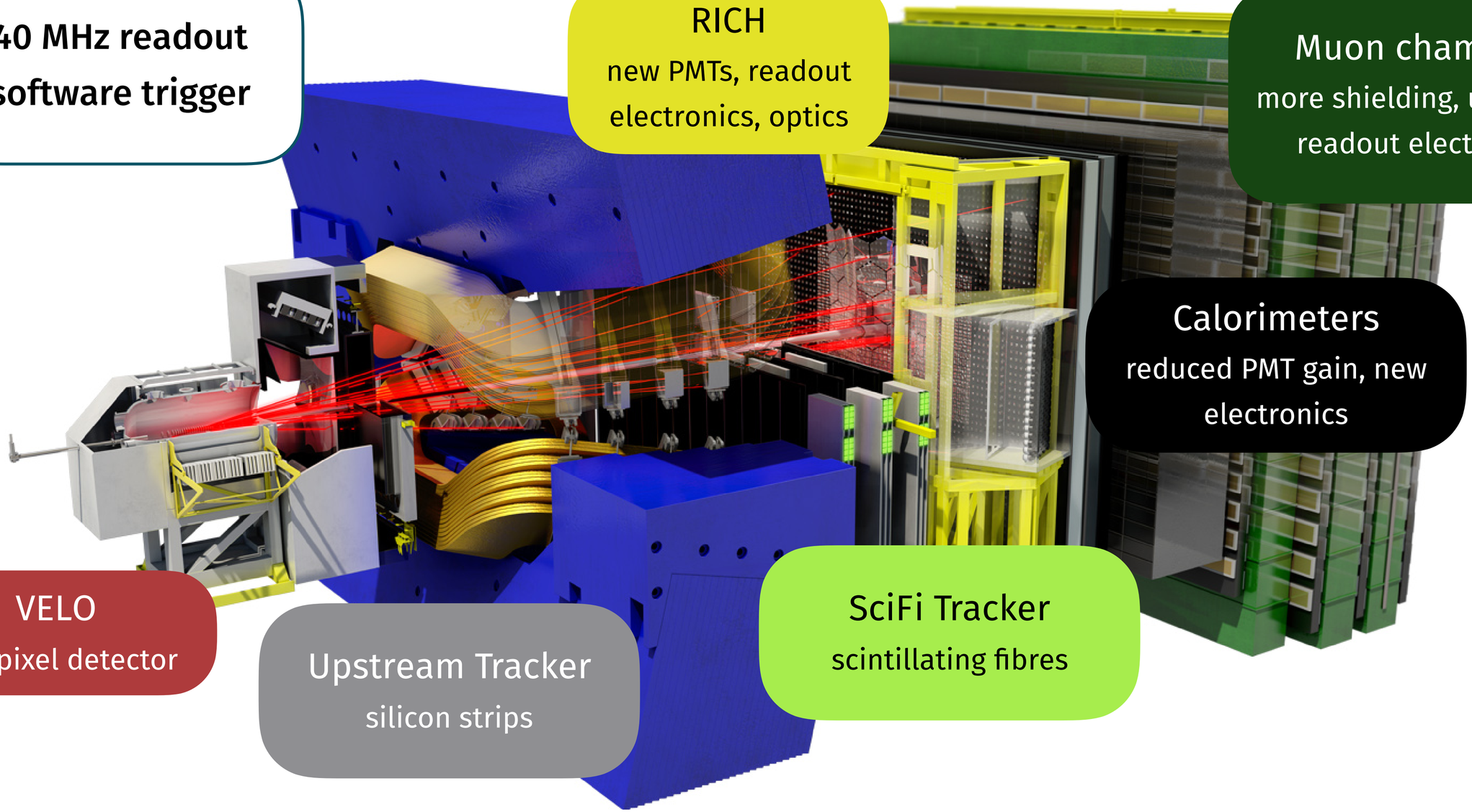
Upgrade

LHCb Upgrade in LS2 – Overview

40 MHz readout
software trigger

RICH
new PMTs, readout electronics, optics

Muon chambers
more shielding, upgraded readout electronics



Calorimeters
reduced PMT gain, new electronics

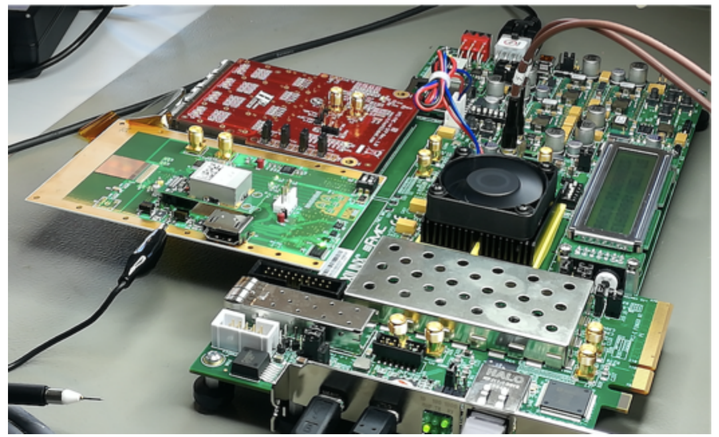
VELO
new pixel detector

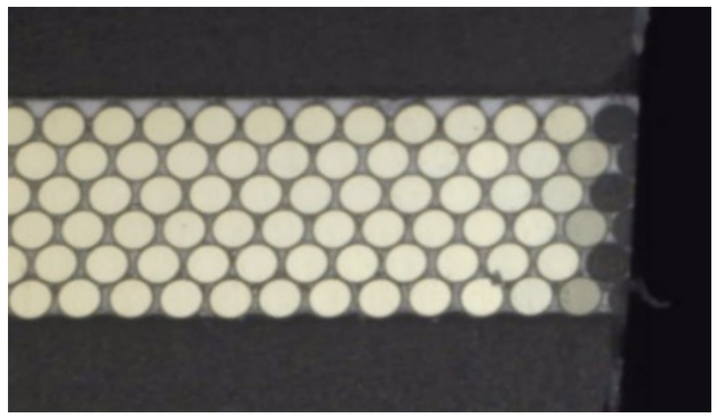
Upstream Tracker
silicon strips

SciFi Tracker
scintillating fibres

LHCb Upgrade in LS2 – Status

- in general a good progress on all subsystems
  - many engineering design and production readiness reviews successfully completed during the summer
  - small delays for some of the milestones
- many detectors entering (pre-)production phase
  - several crucial front-end ASICS successfully submitted and under test
    - VELOPIX for VELO, SALT-128 for Upstream Tracker, CLARO for RICH
  - large component production started
    - delivery of MA-PMTs for RICH started
    - SciFi Tracker fibre delivery on schedule, fibre mat production started
- preparation of LS2 work and worksite organisation is ongoing, profit from EYETS





Peter Jakobs, “Espresso”, CC BY-NC-ND 2.0

Conclusion

Summary & Conclusion

- LHCb's physics program
  - lots of new, diverse results over the summer
  - many long-expected results presented, and many more to come!
- LHCb operation = LHC's superb efficiency + LHCb's flexibility
  - optimal and dynamic use of resources to maximise the physics output
  - effects on computing are under control in 2016
  - already overtook 2012 data taking in terms of *bb*-pairs recorded
  - we are preparing for the *p*Pb runs
- LHCb upgrade is progressing well
  - huge progress over the past few months
  - working hard to keep up with our milestones