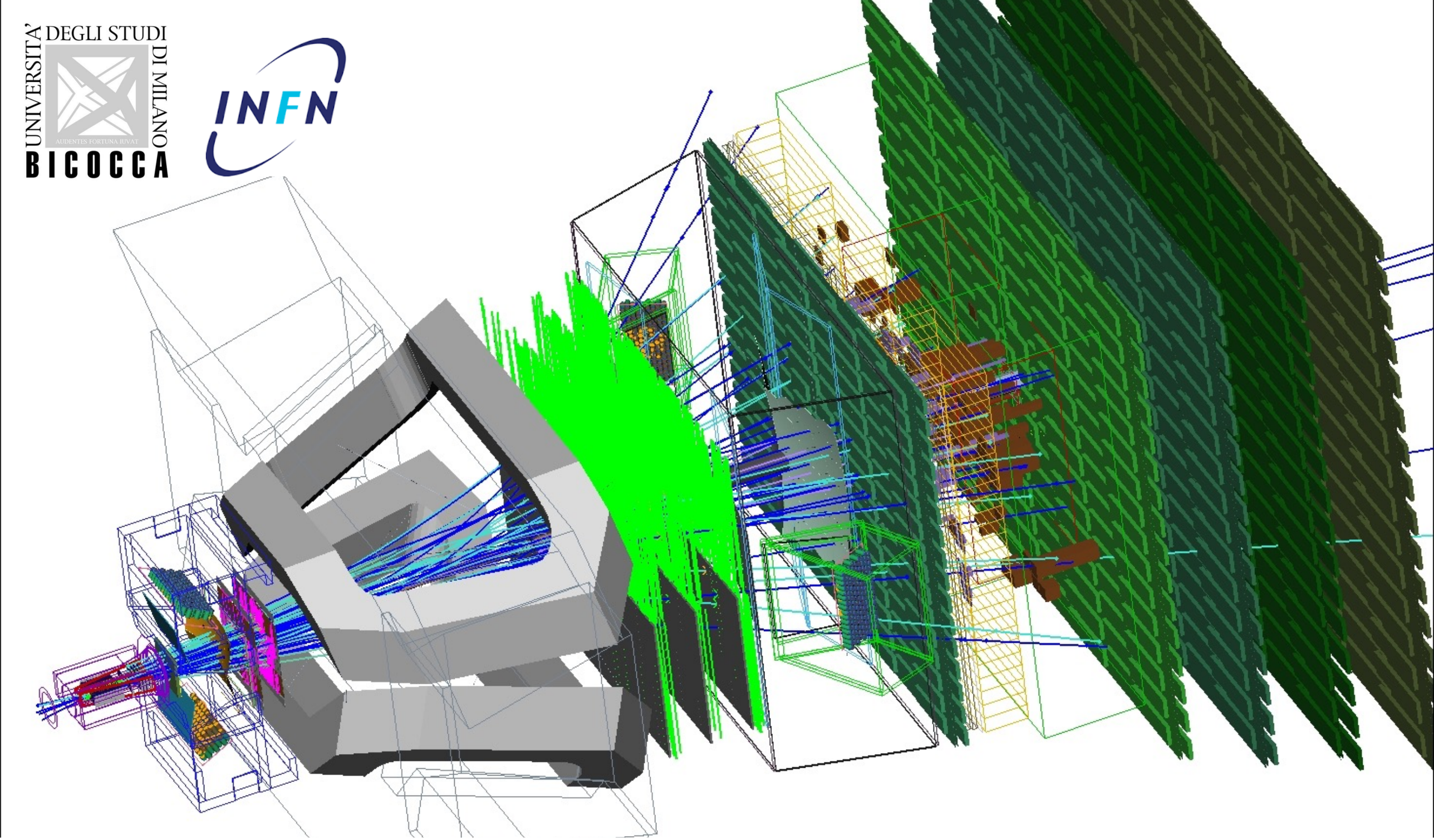


LHCb status report

LHCC open session

Lucia Grillo (Milano-Bicocca)
on behalf of LHCb

Outline

- Operations & EYETS
  - Performance in 2016 during *pp* and *p*Pb data taking
  - Preparation of 2017 data taking
- Physics

  A selection of new published results since last LHCC, including
  - Rare *b*-hadron decays
  - Spectroscopy
  - *CP* violation
  - Fixed target and heavy ion physics
- Upgrade
  - Status and plans
- Expression of Interest for a Phase-II upgrade

First things first

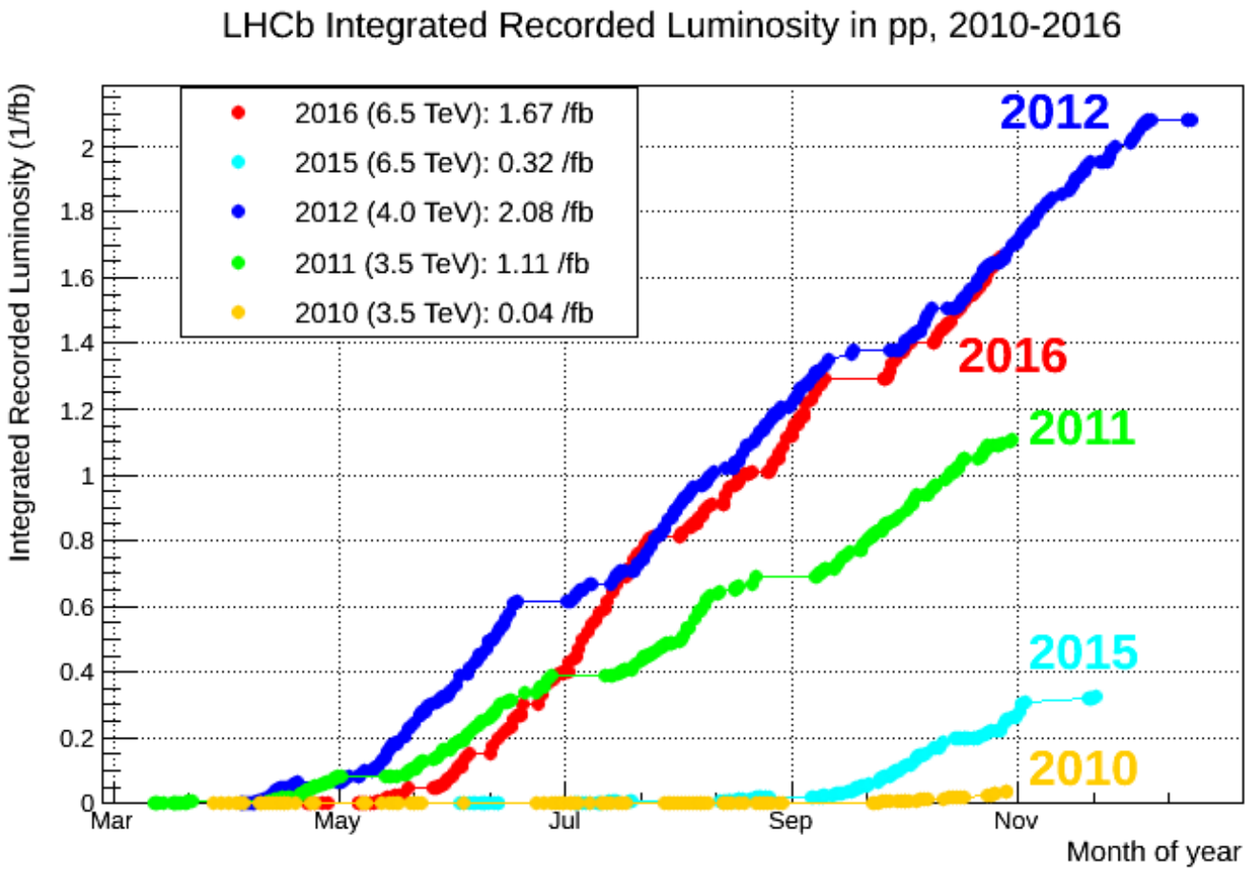
- **Thanks a lot to the LHC for the great performance !!**
- Not only *pp*, but also successful fixed target (SMOG) and *pPb*, *PbPb* program
- LHCb strategy: luminosity leveled at $\sim 4 \times 10^{32} cm^{-2} s^{-1} (\mu = 1.1)$

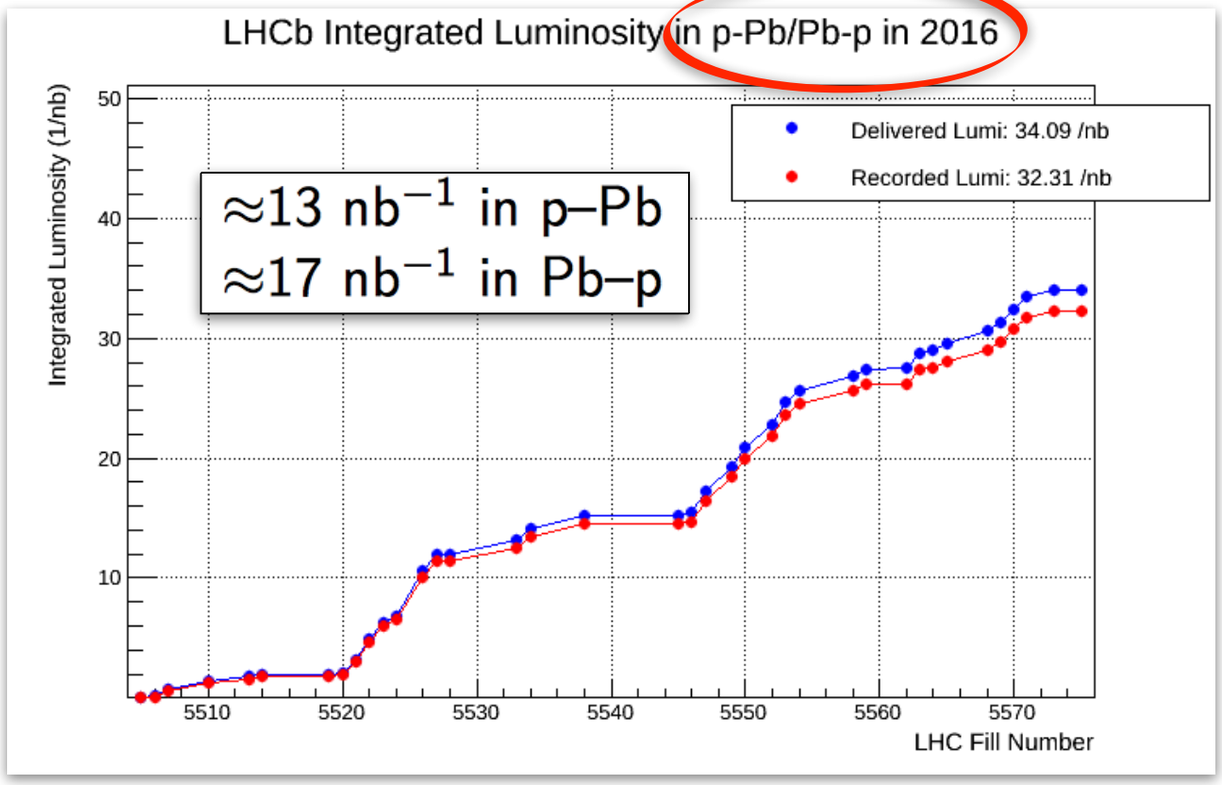
➡ LHCb benefits from maximum number of colliding bunches

➡ LHCb benefits from maximum beam/interfill ratio (i.e. long fills)

- 2017: less *pp* physics days, but more colliding bunches

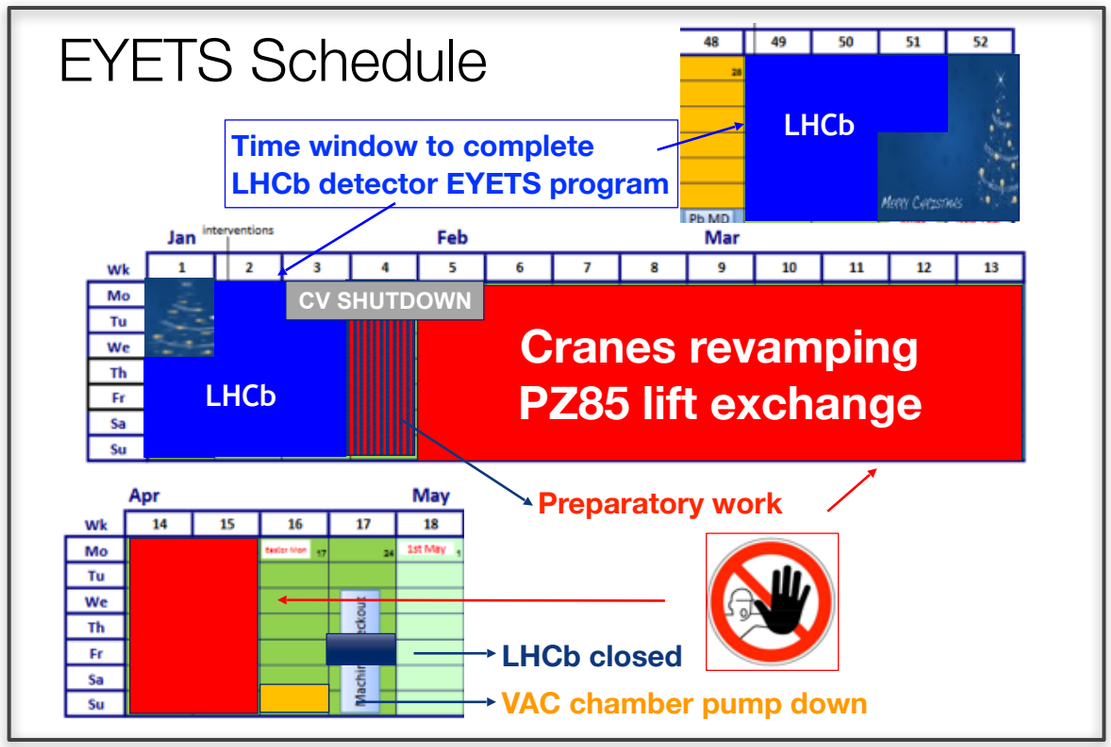
➡ Expected lumi harvest in 2017 similar to 2016

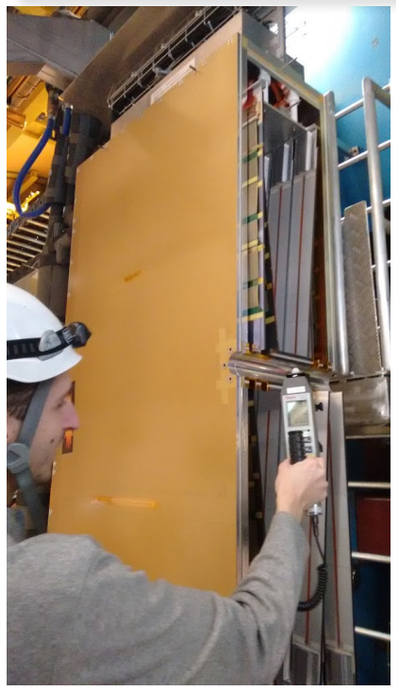


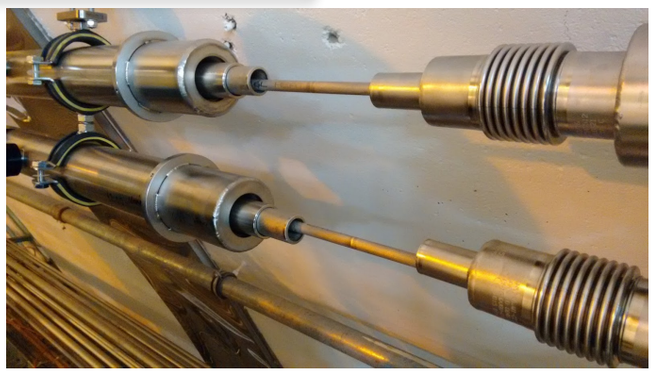


Detectors - 2016 and EYETS program

- ***2016***: only 'standard' minor regular maintenance, radiation tolerance as expected





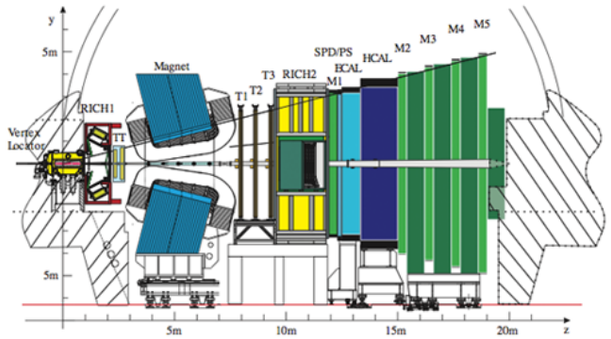


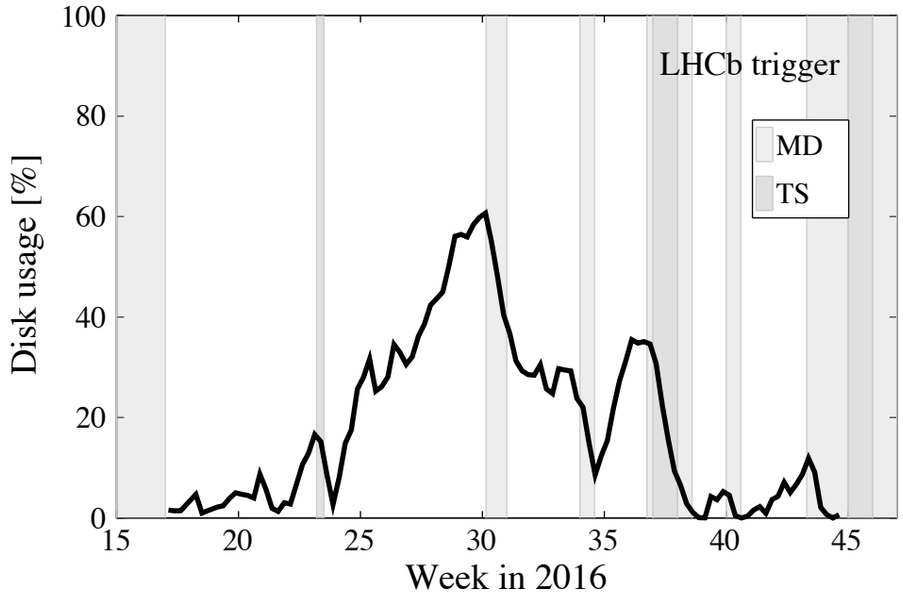
EYETS

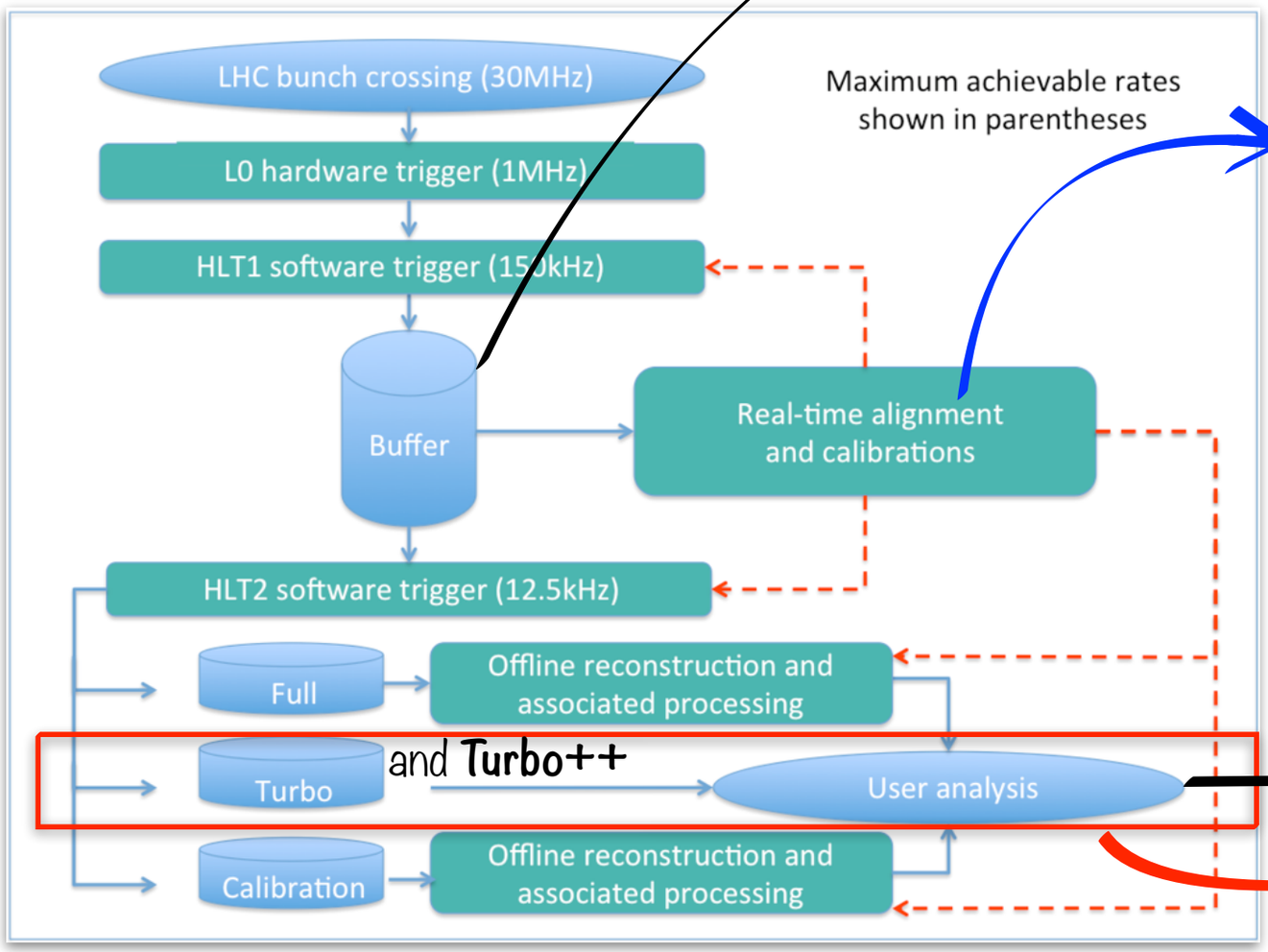
- "**Standard**" maintenance of all detectors and service, typically to fix a few channels or replace broken electronics. Requires to
  - ➢ open Large Detectors (M1, CALO, …)
  - ➢ Venting of the Beam Pipe
  - ➢ Survey
  - ➢ …
- "**Exceptional**" work
  - ➢ CO_2 transfer lines installation (for upgrade)
  - ➢ Repair Silicon Tracker broken bonds
  - ➢ Herschel scintillators replacement
  - ➢ RICH1&2 HPD exchange

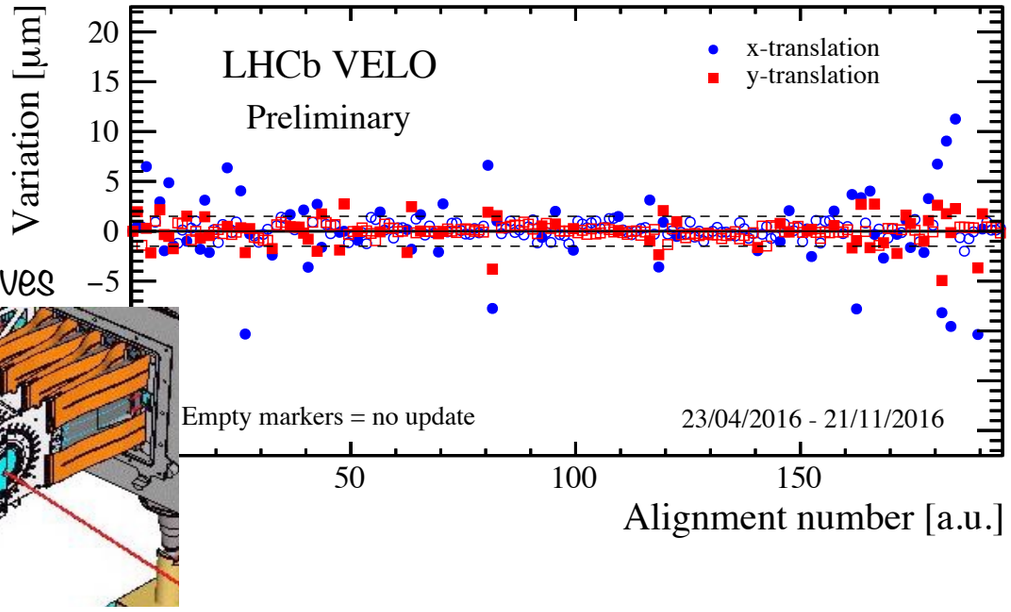
LHCb detector will be ready and in very good shape to resume operation in April 2017.

From the detector to the papers









ARXIV:1701.05116 more in the following slides ...

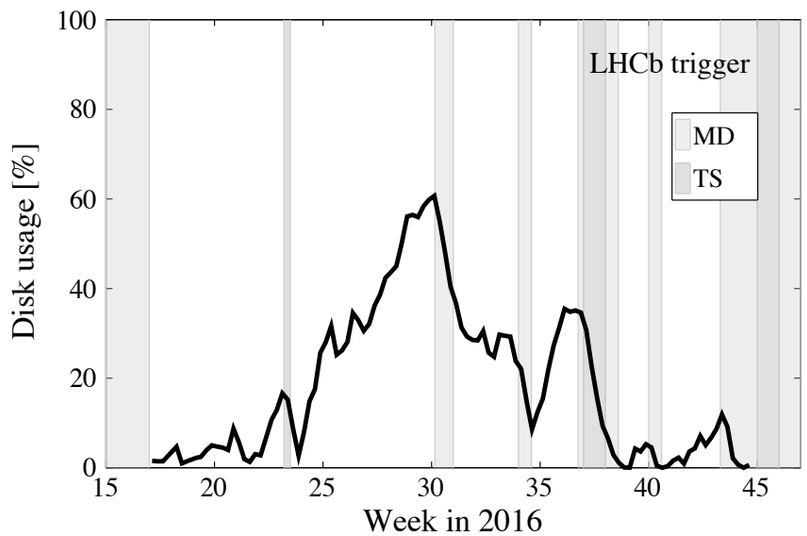
Trigger, Alignment and Calibration

Preparation for 2017
in progress

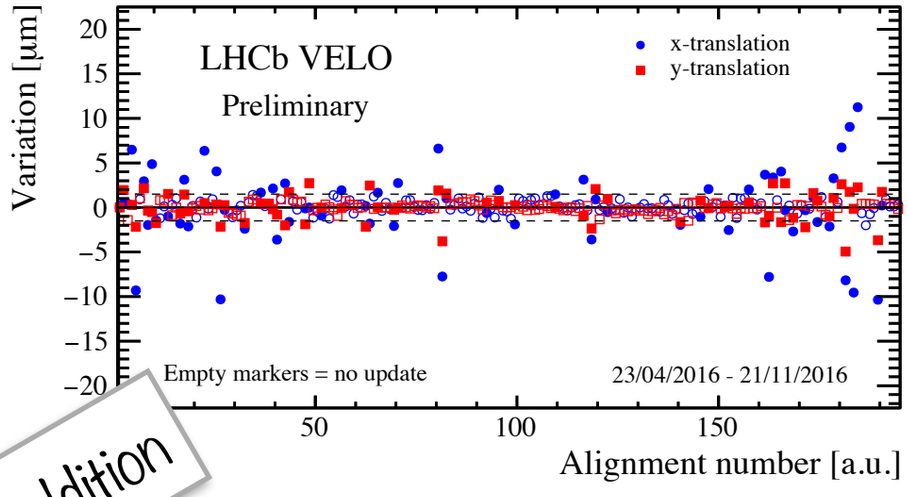
HLT

- Split HLT: write HLT1 output to disk buffer, and then perform best reconstruction in HLT2

➡ Optimize dynamically HLT1 and HLT2 processing to maximize the efficiency and physics output



- New monitoring for HLT and Alignment and Calibration: more flexible and inclusive



Real-time Alignment and Calibration

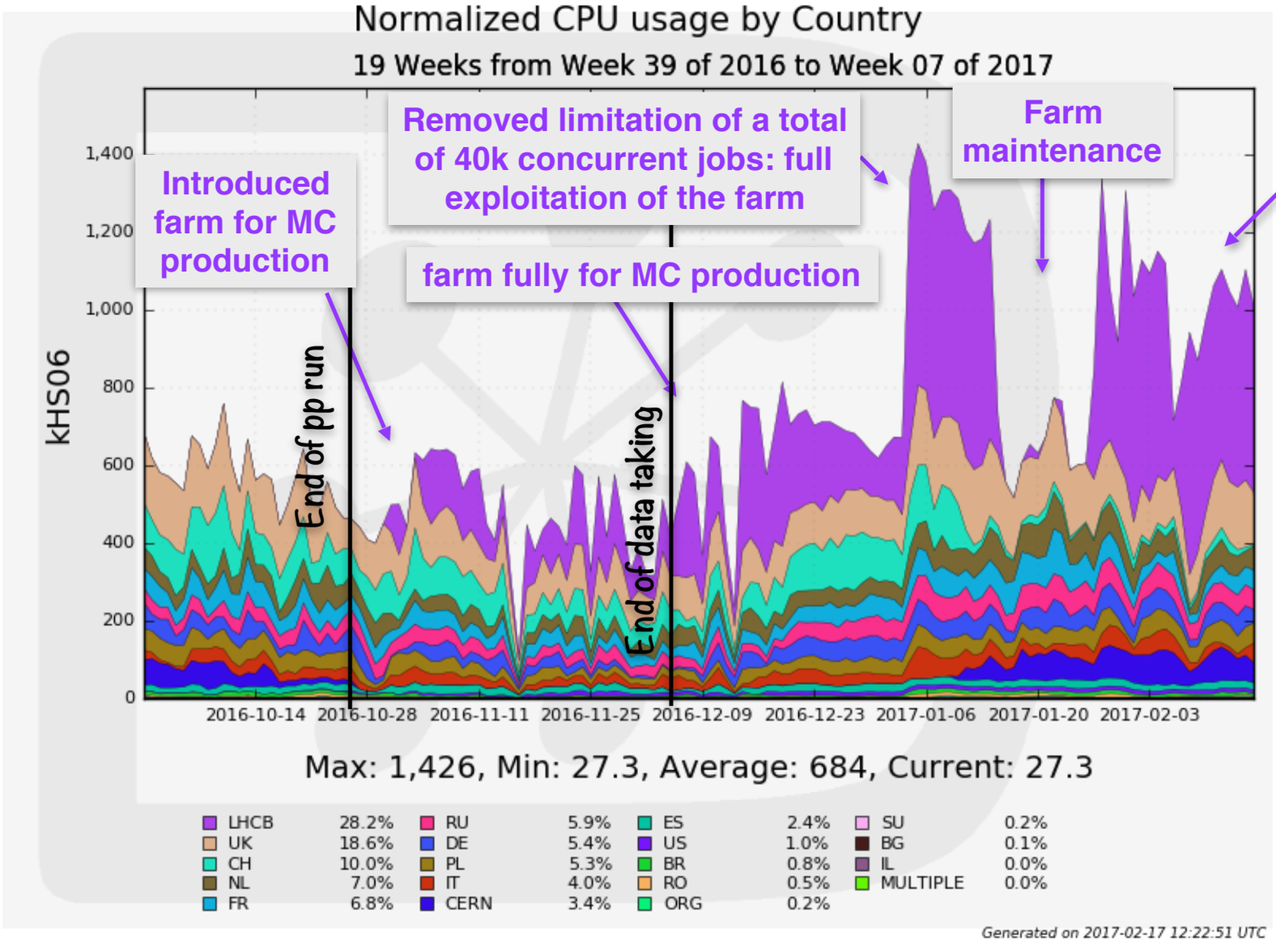
- Towards an even smoother operation: possibility to update more constants in real-time
- Keep improving the system: performance studies, and feasibility of introducing new features

In addition

- Centralized production of samples for calorimeter calibration and tracking efficiency
- New online monitoring for shifters and Simulation DQ, more maintainable and easier to use

EYETS software activities

- Several software upgrades ongoing on the online farm
- Re-stripping of the data ongoing
- Optimal online farm usage for MC production (+ usual grid)
  ~850 million events saved on disk

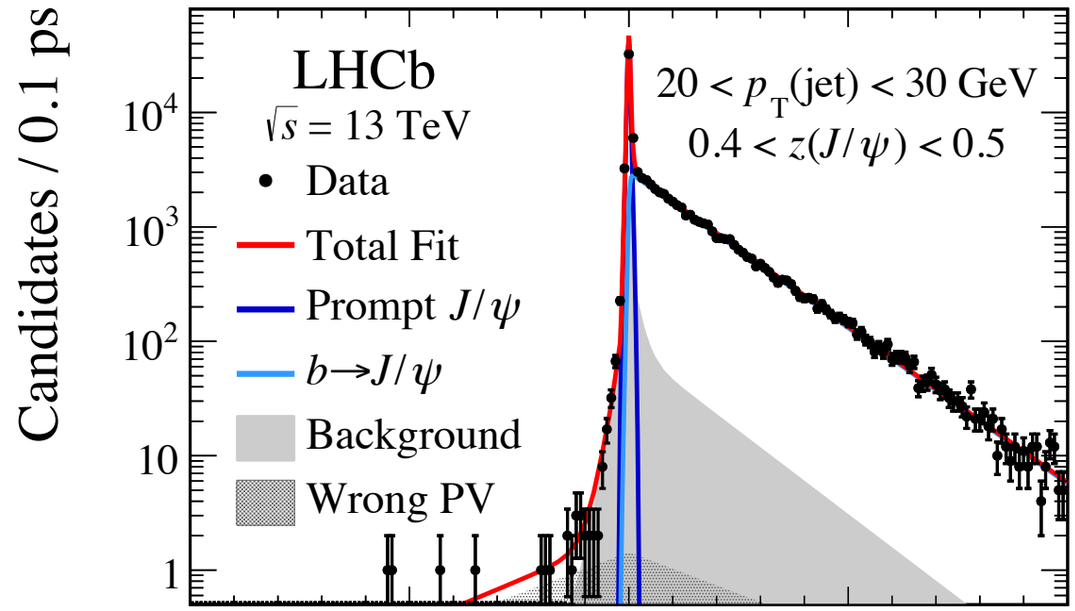


first Turbo++ paper, 2016 data

Real-time analysis: J/ψ production in jets

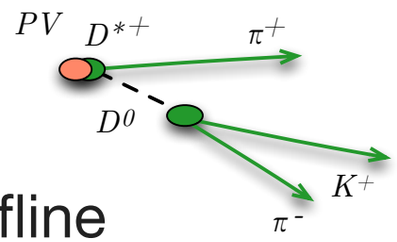
ARXIV:1701.05116

- Aim: study the radiation produced in association with quarkonium states (e.g. J/ψ in jets), different theory predictions available (NRQCD, analytic resummation)
- Measure $z(J/\psi) = p_{\mathrm{T}}(J/\psi)/p_{\mathrm{T}}(\mathrm{jet})$ for J/ψ promptly produced and produced in *b*-hadron decays



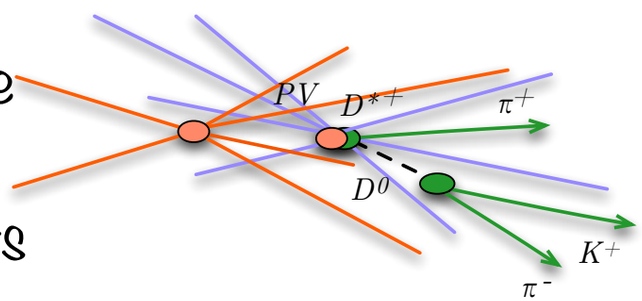
- To access the full z range: need to place no requirements on $p_{\mathrm{T}}(J/\psi)$

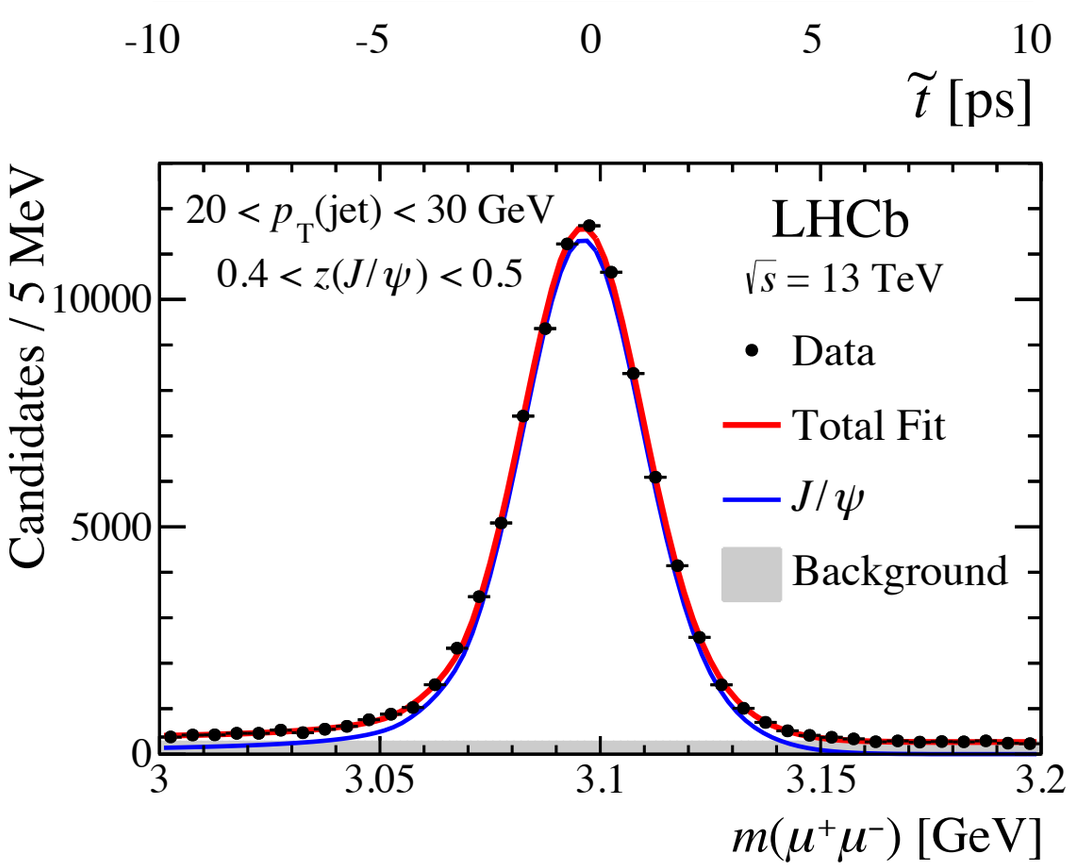
➡ Turbo: save only objects selected by the trigger



- Need to reconstruct jets offline

➡ **Turbo++**: also save all required reconstructed objects



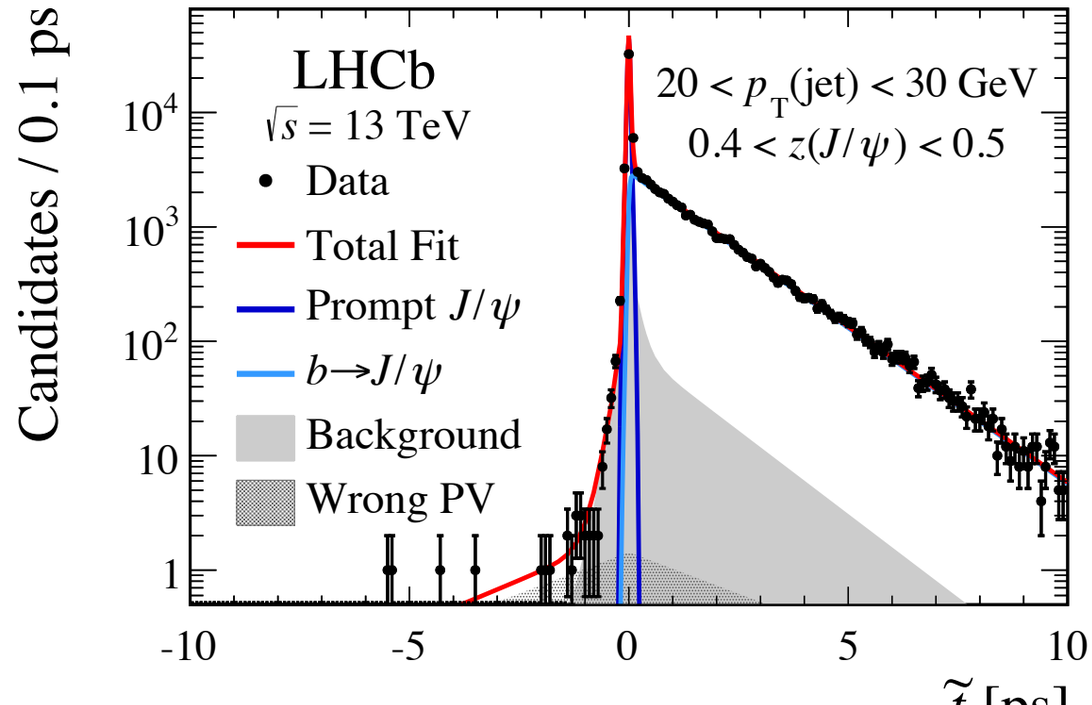


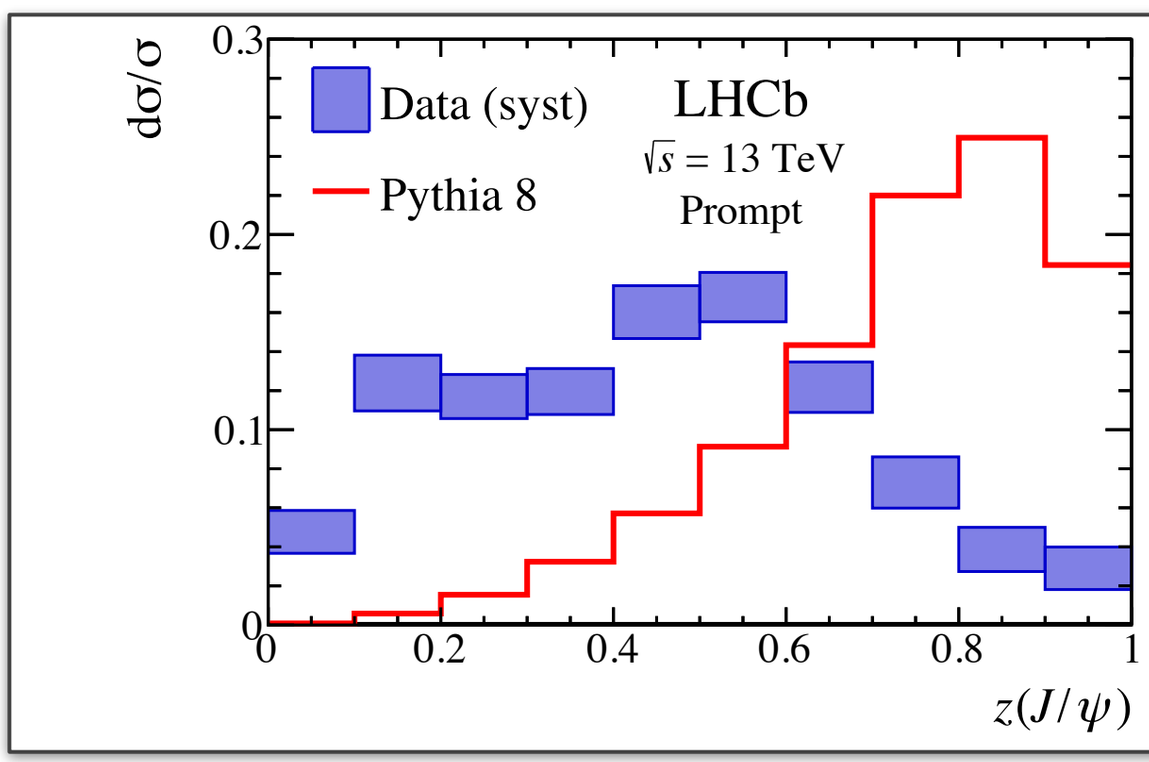
first Turbo++ paper, 2016 data

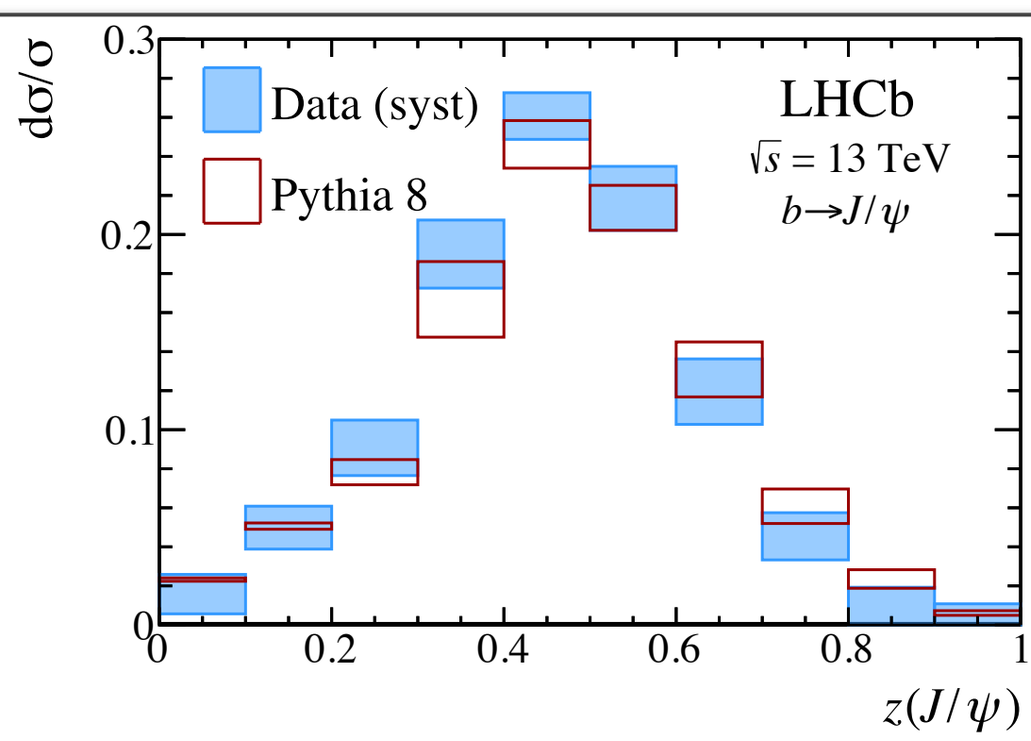
Real-time analysis: J/ψ production in jets

ARXIV:1701.05116

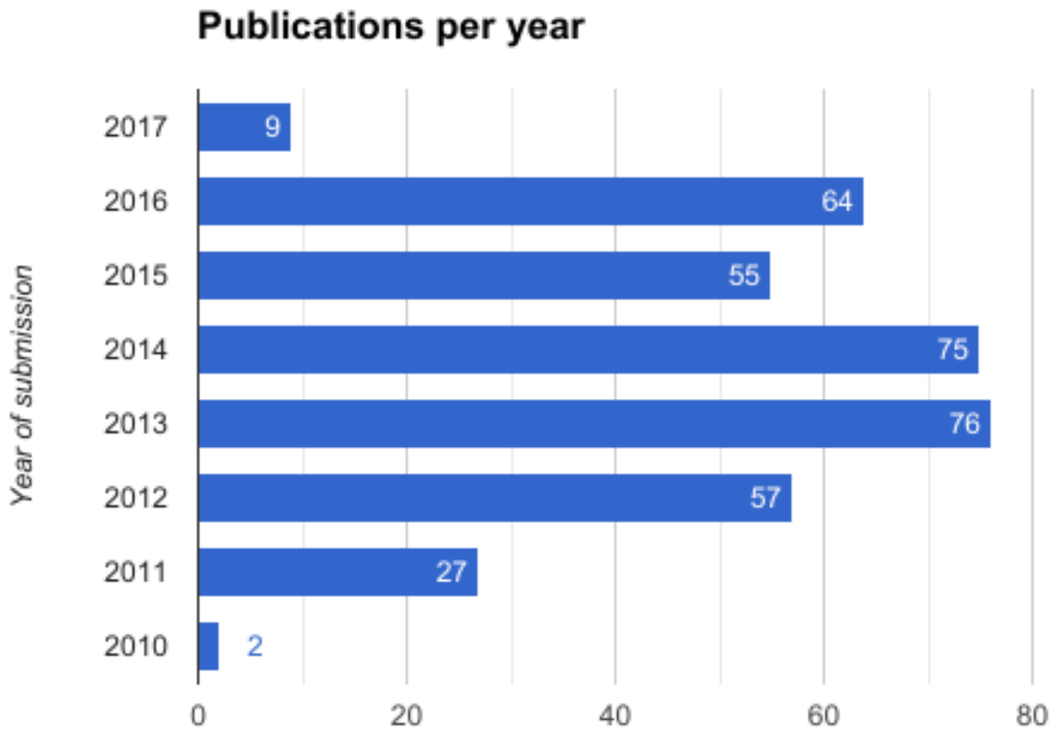
- sample: 2016 *pp*-collision data, fiducial kinematic region applied
- Observed z-distribution for prompt J/ψ does not agree with fixed-order NRQCD implemented in PYTHIA 8
- Observed z-distribution for J/ψ from b-hadron decays in agreement



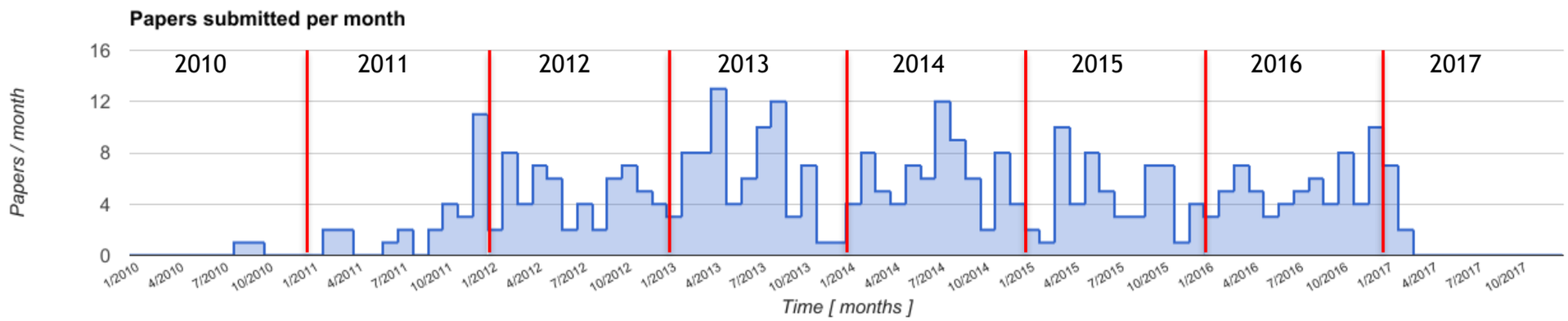




That was one of the 19 papers since last LHCC



- 365 papers
  - 19 papers since last LHCC week
  - 9 papers in 2017
  - 9 further papers being processed within the Editorial Board



Since last LHCC

17 papers + 2 (just submitted)

TITLE	DOCUMENT NUMBER	JOURNAL	SUBMITTED ON
Observation of the suppressed decay $\Lambda_b^0 \to p\pi^-\mu^+\mu^-$	PAPER-2016-049	JHEP ARXIV:1701.08705	30 Jan 2017
Study of the D^0p amplitude in $\Lambda_b^0 \to D^0p\pi^-$ decays	PAPER-2016-061	JHEP ARXIV:1701.07873	26 Jan 2017
Measurement of the $B^\pm$ production asymmetry and the CP asymmetry in $B^\pm \to J/\psi K^\pm$ decays	PAPER-2016-054	PRD	19 Jan 2017
Observation of the $\Xi_b^- \to J/\psi\Lambda K^-$ decay	PAPER-2016-053	PLB	19 Jan 2017
Study of J/ψ production in jets	PAPER-2016-064	PRL ARXIV:1701.05116	18 Jan 2017
Measurement of CP asymmetries in $D^\pm \to \eta'\pi^\pm$ and $D_s^\pm \to \eta'\pi^\pm$ decays	PAPER-2016-041	PLB	07 Jan 2017
Observation of $B_c^+ \to D^0K^+$ decays	PAPER-2016-058	PRL	07 Jan 2017
Search for the $B_s^0 \to \eta'\phi$ decay	PAPER-2016-060	JHEP	23 Dec 2016
Search for long-lived scalar particles in $B^+ \to K^+\chi(\mu^+\mu^-)$ decays	PAPER-2016-052	PRL	22 Dec 2016
Measurement of the J/ψ pair production cross-section in pp collisions at $\sqrt{s} = 13$ TeV	PAPER-2016-057	JHEP	22 Dec 2016
Observation of $B_c^+ \to J/\psi D^{(*)}K^{(*)}$ decays	PAPER-2016-055	PRD	22 Dec 2016
Measurement of the phase difference between short- and long-distance amplitudes in the $B^+ \to K^+\mu^+\mu^-$ decay	PAPER-2016-045	EPJC	20 Dec 2016
Measurement of the ratio of branching fractions and difference in CP asymmetries of the decays $B^+ \to J/\psi\pi^+$ and $B^+ \to J/\psi K^+$	PAPER-2016-051	JHEP	19 Dec 2016
Measurement of the b-quark production cross-section in 7 and 13 TeV pp collisions	PAPER-2016-031	Phys. Rev. Lett. 118 (2017) 052002	15 Dec 2016
Search for CP violation in the phase space of $D^0 \to \pi^+\pi^-\pi^+\pi^-$ decays	PAPER-2016-044	PLB	09 Dec 2016
Observation of the decay $\Xi_b^- \to pK^-K^-$	PAPER-2016-050	PHYS. REV. LETT. 118 071801(2017)	07 Dec 2016
Search for massive long-lived particles decaying semileptonically in the LHCb detector	PAPER-2016-047	EPJC	03 Dec 2016

5 conference reports

TITLE	DOCUMENT NUMBER	SUBMITTED ON
Measurement of J/ψ and D^0 production in pAr collisions at $\sqrt{s_{NN}} = 110$ GeV	LHCB-CONF-2017-001	
Measurement of time-dependent CP-violating asymmetries in $B^0 \to \pi^+\pi^-$ and $B_s^0 \to K^+K^-$ decays at LHCb	LHCB-CONF-2016-018	26 Jan 2017
Measurement of CP asymmetry in $B_s^0 \to D_s^\mp K^\pm$ decays	LHCB-CONF-2016-015	13 Jan 2017
First observation of a baryonic B_s^0 decay	CONF-2016-016	13 Jan 2017
Study of the decay $B^\pm \to DK^{*\pm}$ with two-body D decays	CONF-2016-014	21 Dec 2016

Observation of $B_s^0 \to \mu^+\mu^-$, search of $B^0 \to \mu^+\mu^-$

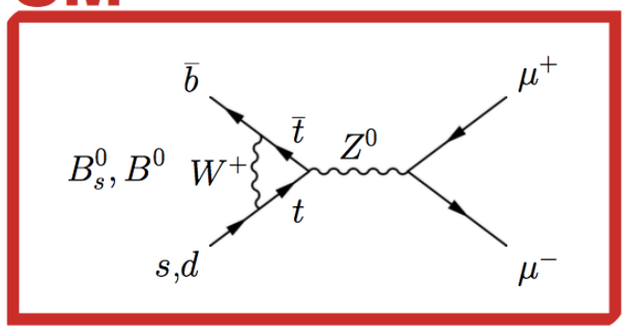
Runl & Runll dataset

- Time integrated branching fractions are predicted in the Standard Model with small uncertainties → sensitive to New Physics effects

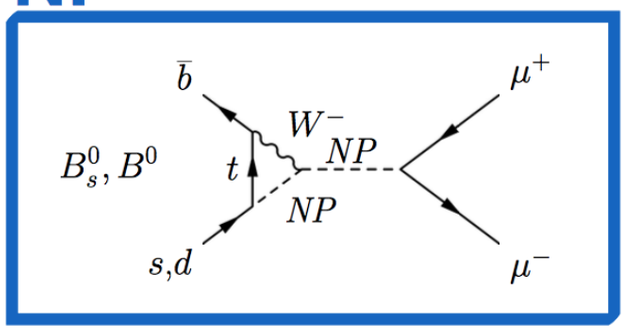
$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.65 \pm 0.23) \times 10^{-9}$

$\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.06 \pm 0.09) \times 10^{-10}$

SM



NP



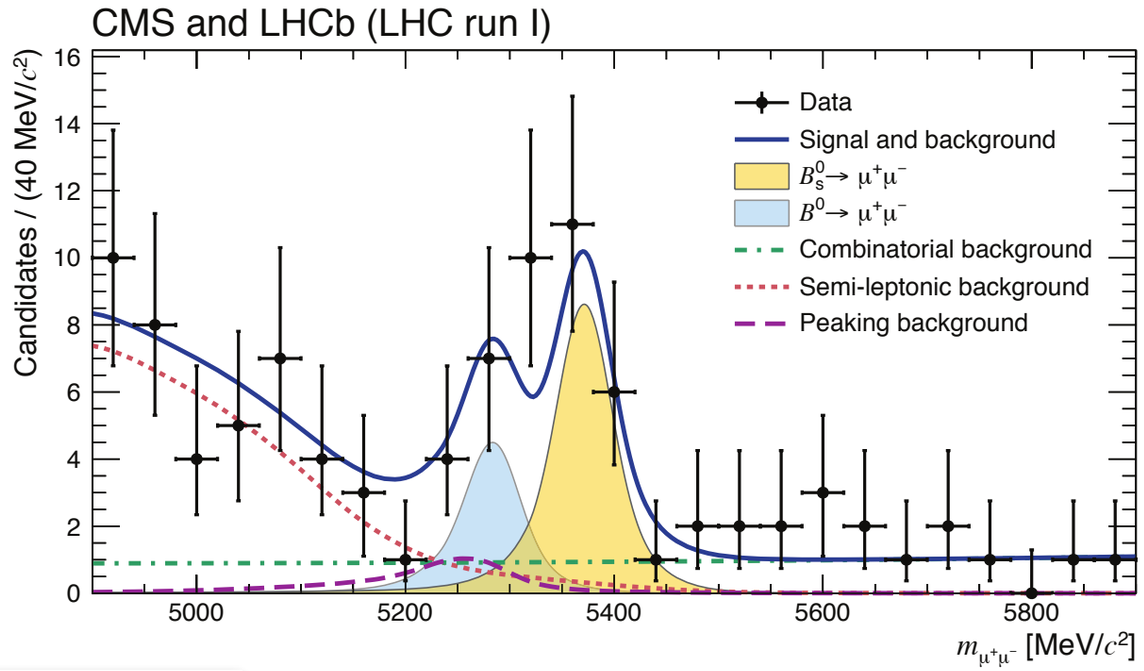
- LHCb-CMS combined analysis
  - Observation of the $B_s^0 \to \mu^+\mu^-$

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

    6.2σ significance observed
    compatibility with SM at 1.2σ level
  - Evidence of the $B^0 \to \mu^+\mu^-$

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

    3.0σ stat. significance compatibility with SM at 2.2σ level



NATURE 522, 68-72 (04 JUNE 2015)

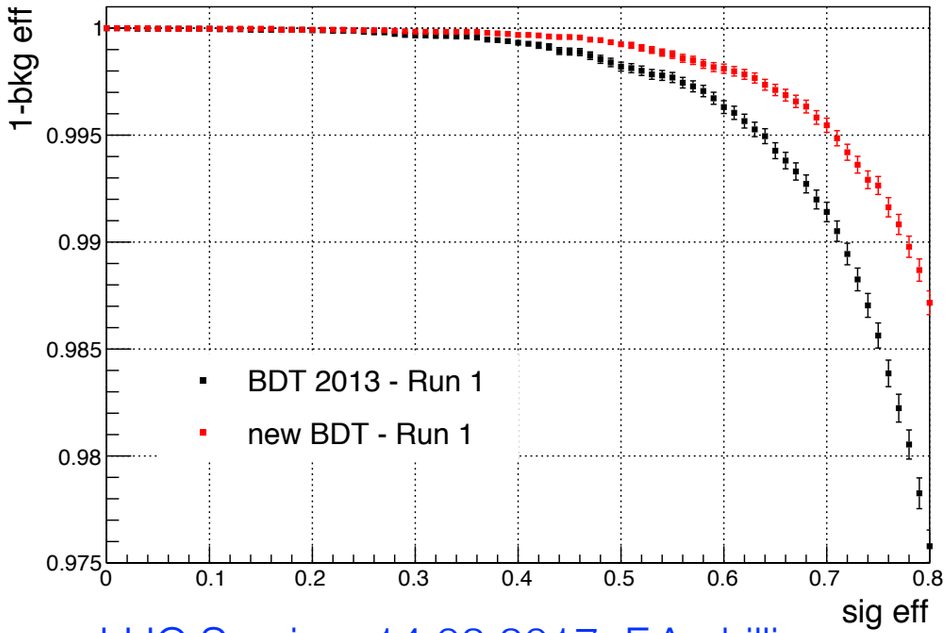
- Further investigation needed

LHCB-PAPER-2017-001

Observation of $B_s^0 \to \mu^+\mu^-$, search of $B^0 \to \mu^+\mu^-$

RunI & RunII dataset

- Adding RunII dataset: $\mathcal{L} = 1.4\text{fb}^{-1}$
- Improvements of the analysis:
  - New multivariate classifier including 2 new isolation variables → +50% background rejection
  - Additional improvements ~20% due to new PID selection



LHC Seminar 14.02.2017, F.Archilli

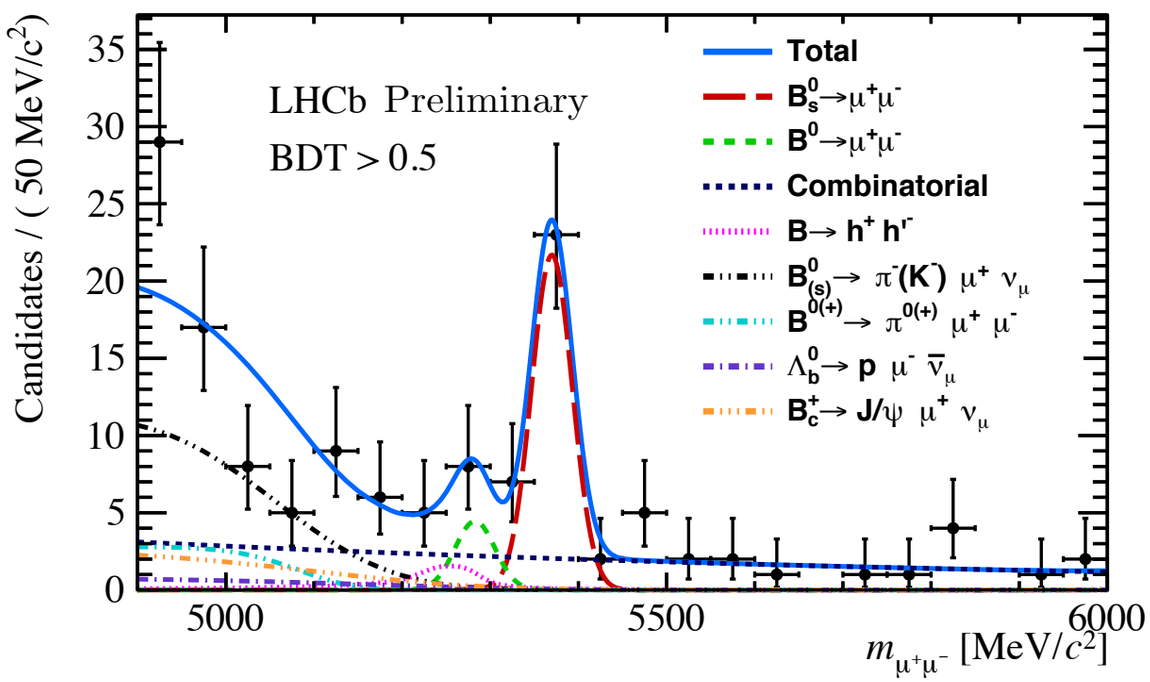
- Results

➡ $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (2.8 \pm 0.6) \times 10^{-9}$
observed with significance 7.8σ

First observation from a single experiment

Compatible with the SM

➡ $\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10}$ @95% CL
no evidence, upper limit

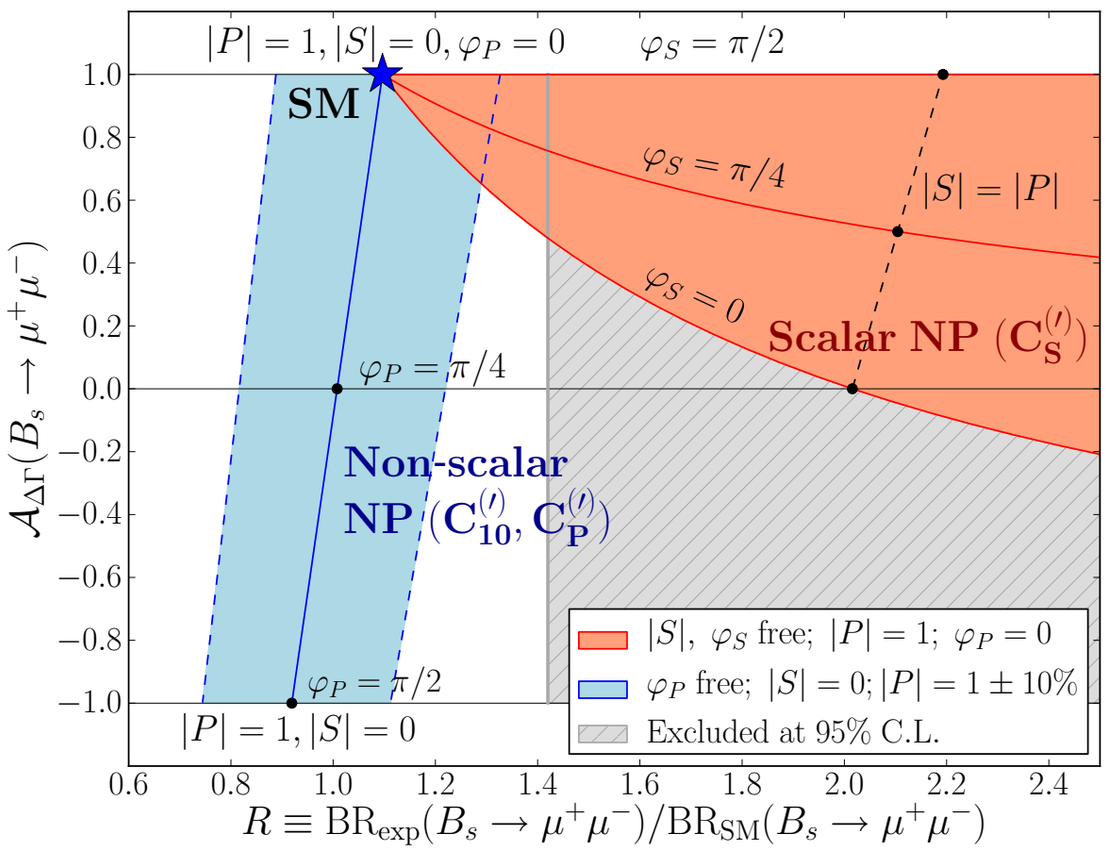


Observation of $B_s^0 \to \mu^+\mu^-$ and effective lifetime

Run1 & Run11 dataset

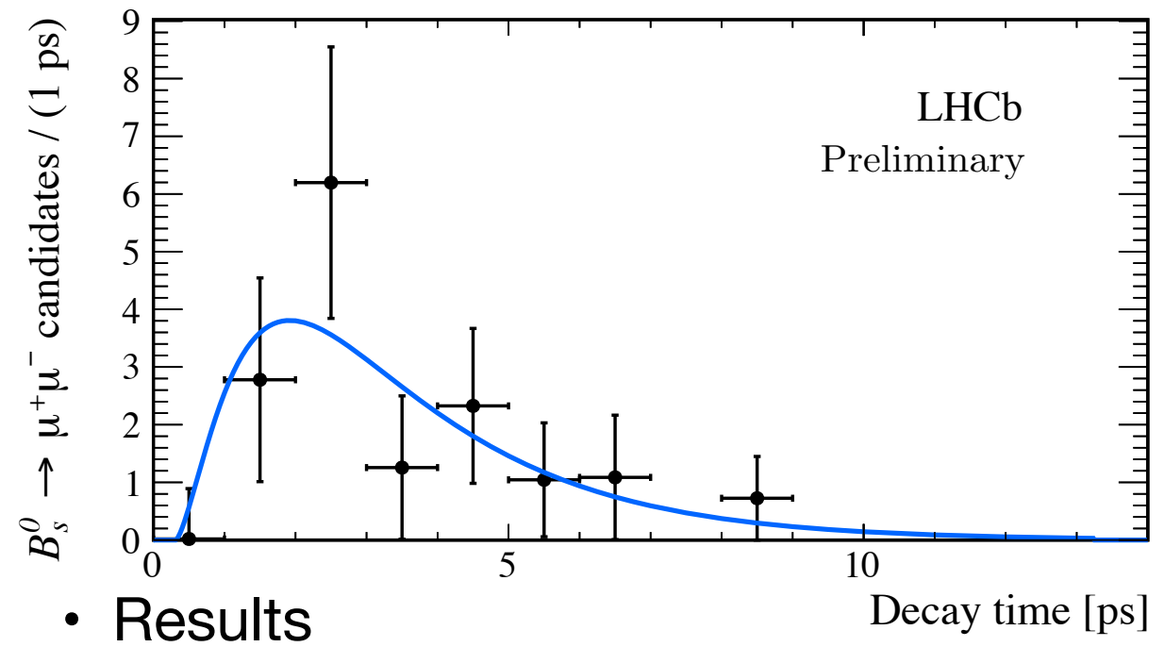
- In the SM only the heavy mass eigenstate of the $B_s^0 - \overline{B}_s^0$ system decays to $\mu^+\mu^-$ but this doesn't necessarily hold for NP scenarios → Effective lifetime clean NP probe, even in the case the BR is close to SM prediction

K. De Bruyn et al. Phys.Rev.Lett. 109 (2012) 041801



$$\tau_{\mu^+\mu^-} = \frac{\tau_{B_s}}{1-y_s^2}\left[\frac{1 + 2A^{\mu^+\mu^-}_{\Delta\Gamma_s} y_s + y_s^2}{1 + A^{\mu^+\mu^-}_{\Delta\Gamma_s} y_s}\right] \quad y_s = \tau_{B_s}\Delta\Gamma_s/2$$

- Effective lifetime: decay time of *Bs* described with a single exponential function



- Results

➡ $\tau(B_s^0 \to \mu^+\mu^-) = 2.04 \pm 0.44 \pm 0.05\mathrm{ps}$

Compatible with the SM

Still large uncertainty, but important proof of concept

LHCB-CONF-2016-11

Search for the rare decays $B^0_{(s)} \to \tau^+\tau^-$

Runl dataset

- FCNC as $B^0_{(s)} \to \mu^+\mu^-$ but less helicity-suppressed, SM predictions:

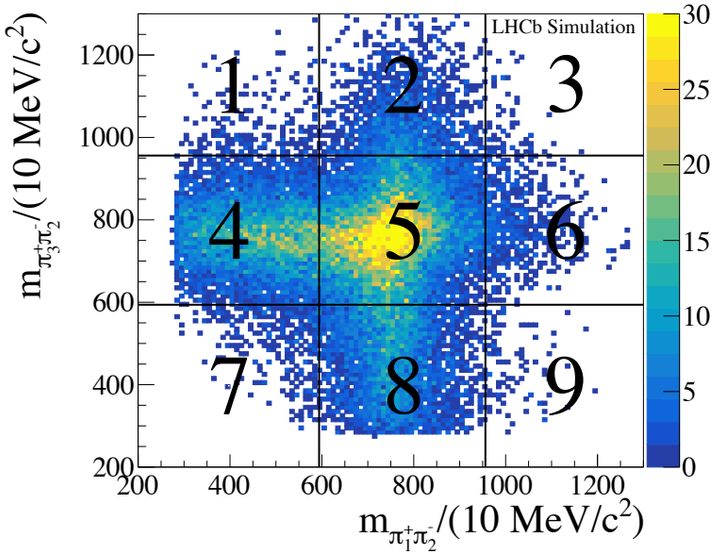
  $\mathcal{B}(B^0 \to \tau^+\tau^-) = (2.22 \pm 0.19) \times 10^{-8}$

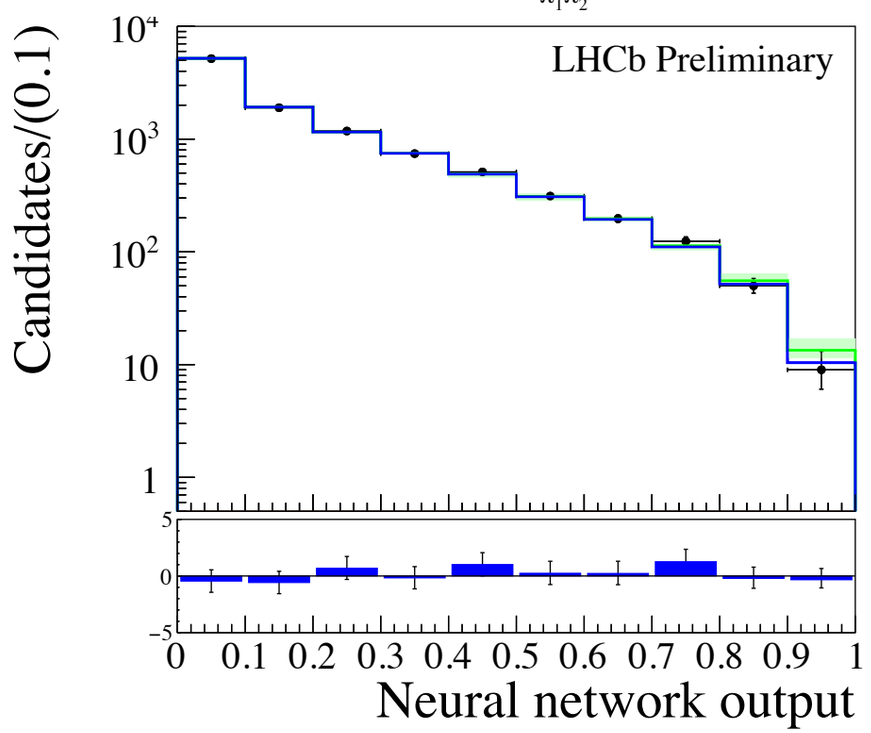
  $\mathcal{B}(B^0_s \to \tau^+\tau^-) = (7.73 \pm 0.49) \times 10^{-7}$

- Test of lepton flavor universality together with $B^0_{(s)} \to \mu^+\mu^-$
- Challenging: at least 2 neutrinos in the final state
- $\boldsymbol{\tau}$ leptons reconstructed as $\tau^+ \to \pi^+\pi^-\pi^+\bar{\nu}_\tau$

  number of signal candidates determined from a fit to a multivariate classifier output using kinematic and topological variables

- Exploit the $\rho^0(770) \to \pi^+\pi^-$ to identify the signal, use $B^0 \to D^+(K^-\pi^+\pi^+)D_s^-(K^-K^-\pi^+)$ as normalization





- **Results**

  Observed upper limit assuming signal fully dominated by B^0_s

  $\mathcal{B}(B^0_s \to \tau^+\tau^-) < 2.4(3.0) \times 10^{-3}$ @90(95)% CL

  Observed upper limit assuming signal fully dominated by B^0

  $\mathcal{B}(B^0 \to \tau^+\tau^-) < 1.0(1.3) \times 10^{-3}$ @90(95)% CL

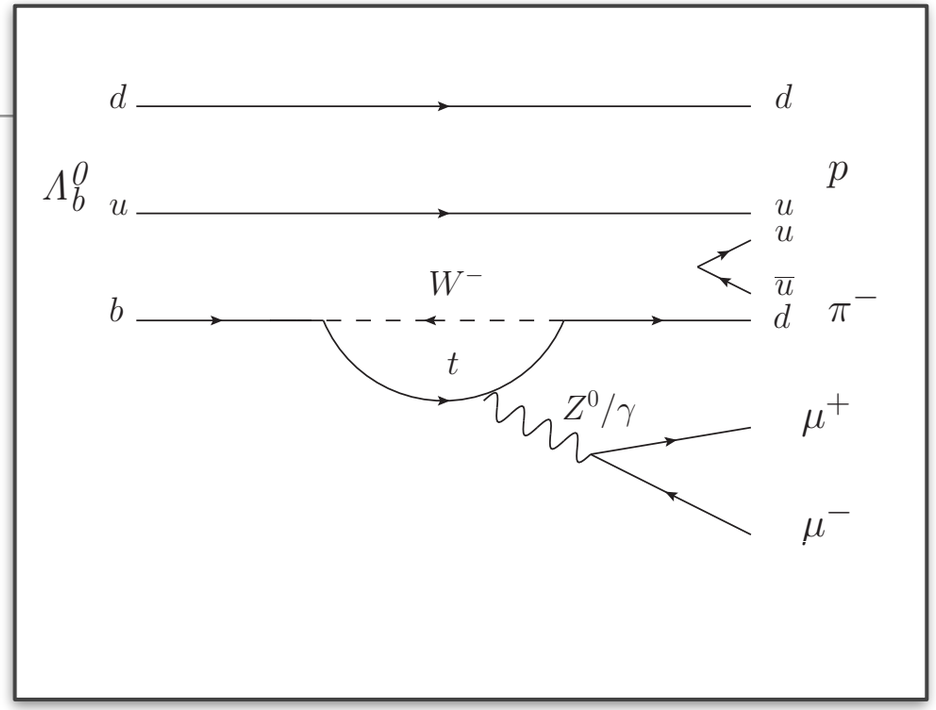
  factor 4 improvement wrt previous BaBar result

ARXIV:1701.08705

Observation of $\Lambda_b^0 \to p\pi^-\mu^+\mu^-$

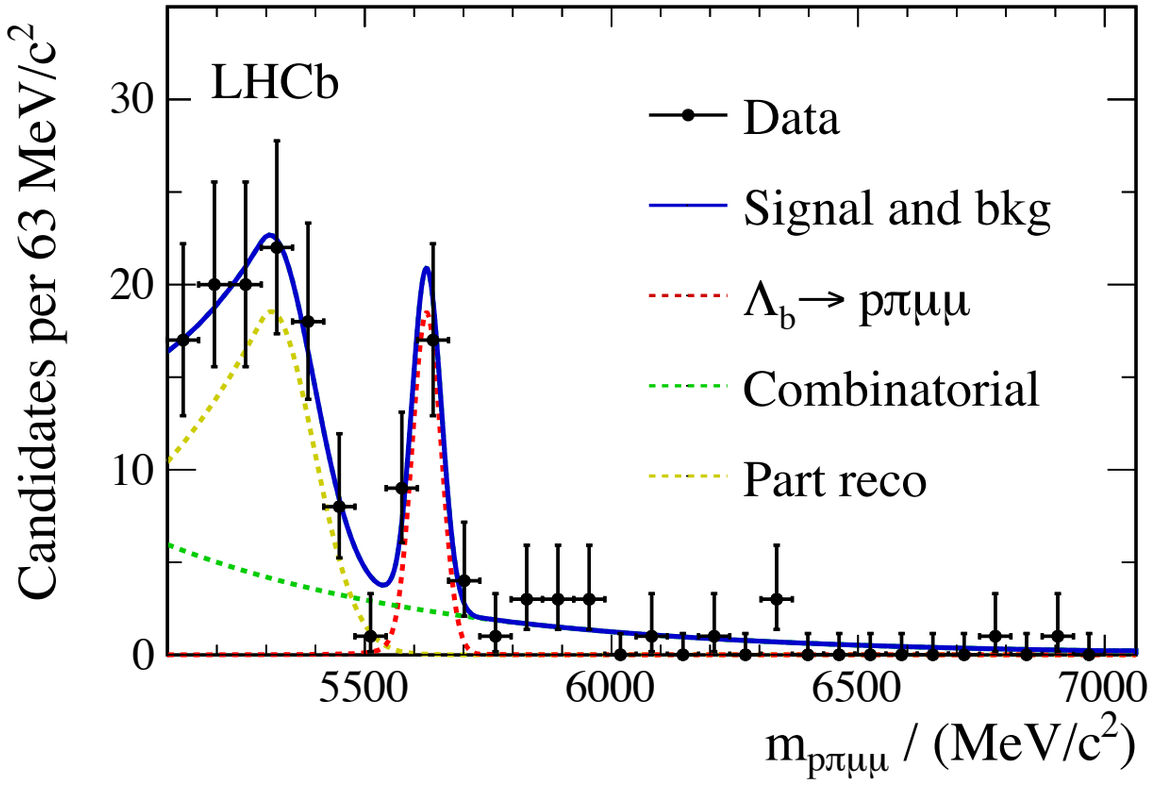
Runl dataset

- Suppression not necessarily present in NP scenarios
- Further perspectives: together with the relevant form factors, the measurement of the BF($\Lambda_b^0 \to pK^-\mu^+\mu^-$) would allow to determine $|V_{td}/V_{ts}|$
- Selection: BDT using kinematic, geometric and proton PID variables



$$\mathcal{B}(\Lambda_b^0 \to p\pi^-\mu^+\mu^-) =$$
$$= \mathcal{B}(\Lambda_b^0 \to J\psi p\pi^-)\mathcal{B}(J\psi \to \mu^+\mu^-)\times$$
$$\frac{N(\Lambda_b^0 \to p\pi^-\mu^+\mu^-)}{N(\Lambda_b^0 \to J\psi p\pi^-)}\frac{\epsilon(\Lambda_b^0 \to J\psi p\pi^-)}{\epsilon(\Lambda_b^0 \to p\pi^-\mu^+\mu^-)}$$
$$= (6.9 \pm 1.9 \pm 1.1^{+1.3}_{-1.0}) \times 10^{-8}$$

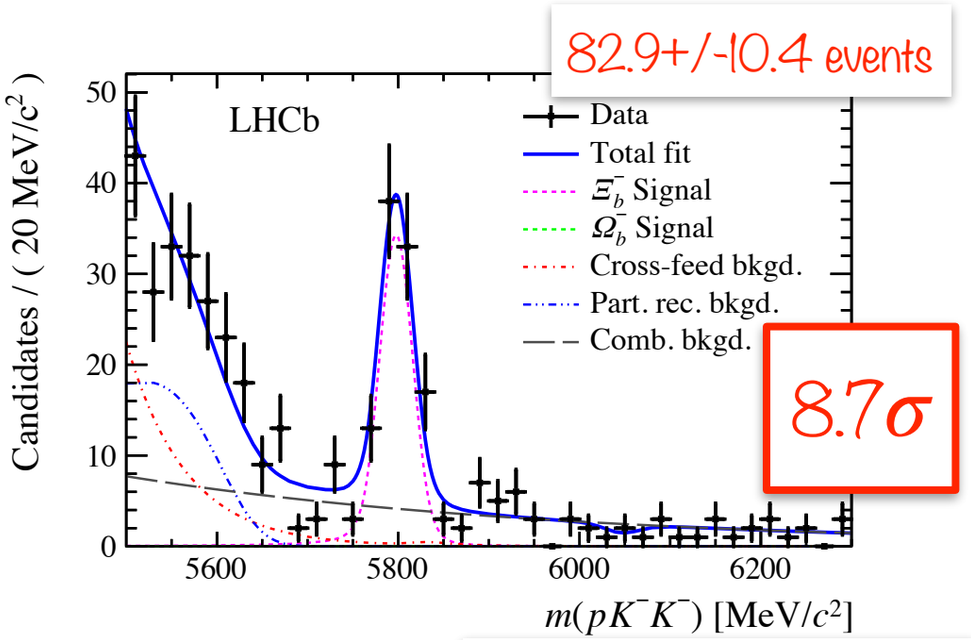
First observation of b→d transition in a baryonic decay, 5.5σ

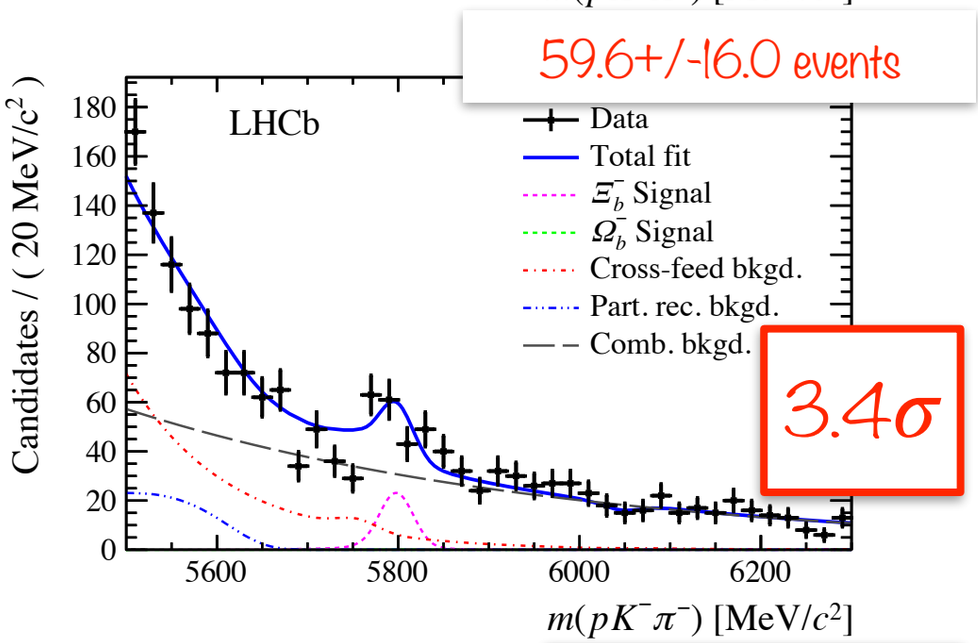


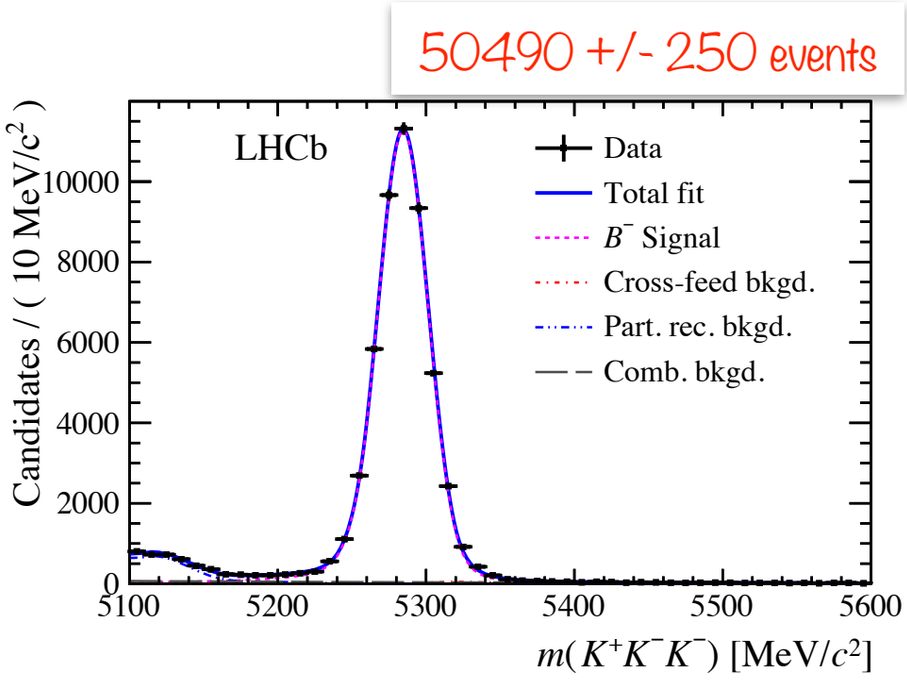
PHYS. REV. LETT. 118 071801 (2017)

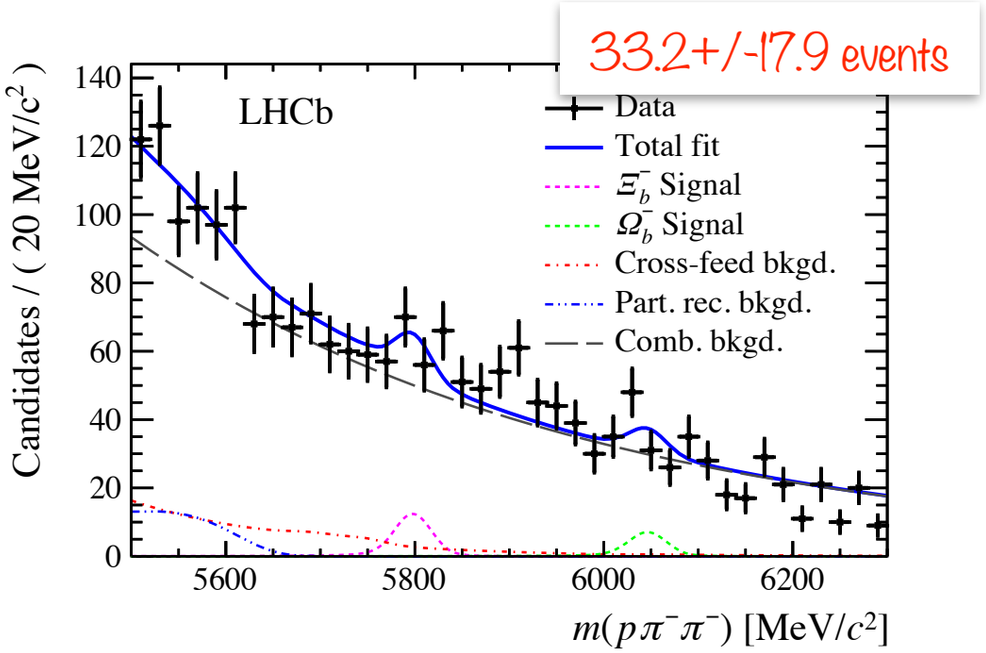
Observation of $\Xi_b^- \to pK^-K^-$

- Search for charmless *b*-baryon (Ξ_b^- and Ω_b^-) decays (final state *phh*) that may be used in the future to investigate *CPV* effects
- Normalization mode: $B^- \to K^+K^-K^-$
- Relative BF x fragmentation fractions obtained from data yields and efficiencies from simulation
- Yield of $\Xi_b^- \to pK^-K^-$ sufficient to be used as normalization for the relative BF of $\Xi_b^- \to pK^-\pi^-$ $\Xi_b^- \to p\pi^-\pi^-$









Runl dataset

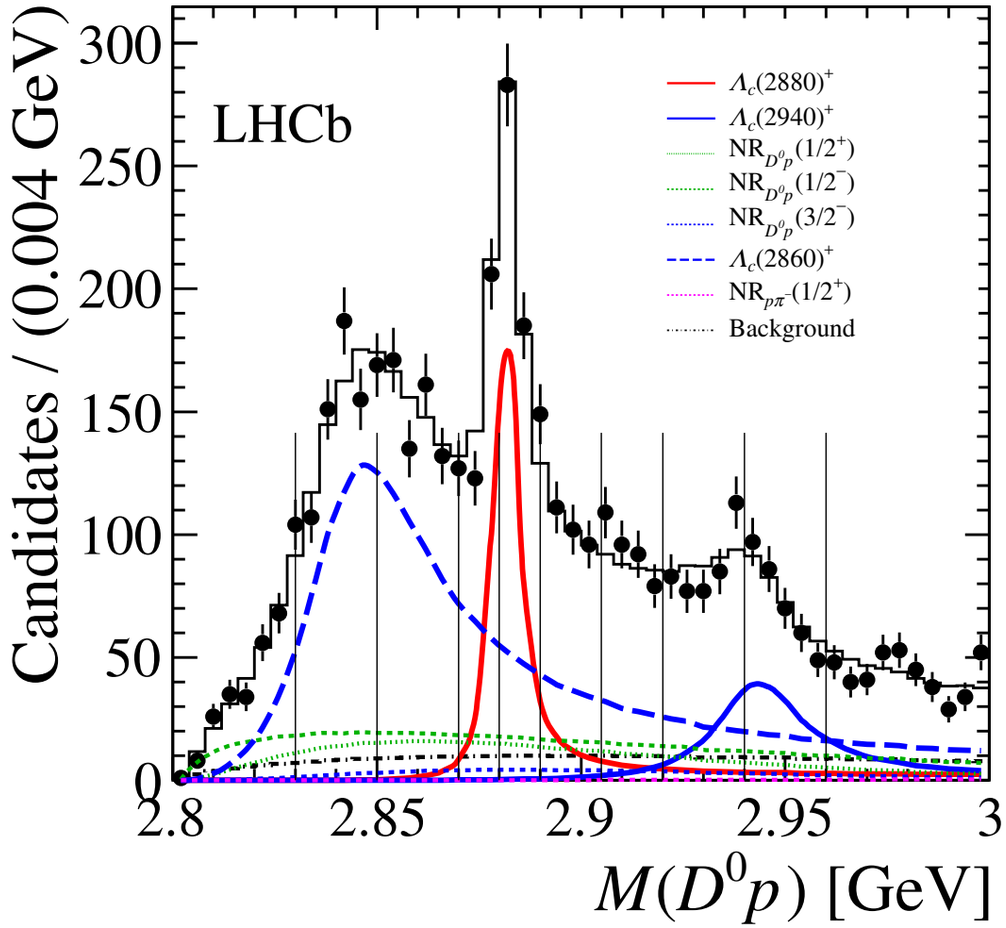
ARXIV:1701.07873

Study of D^0p in $\Lambda_b^0 \to D^0p\pi^-$ decays

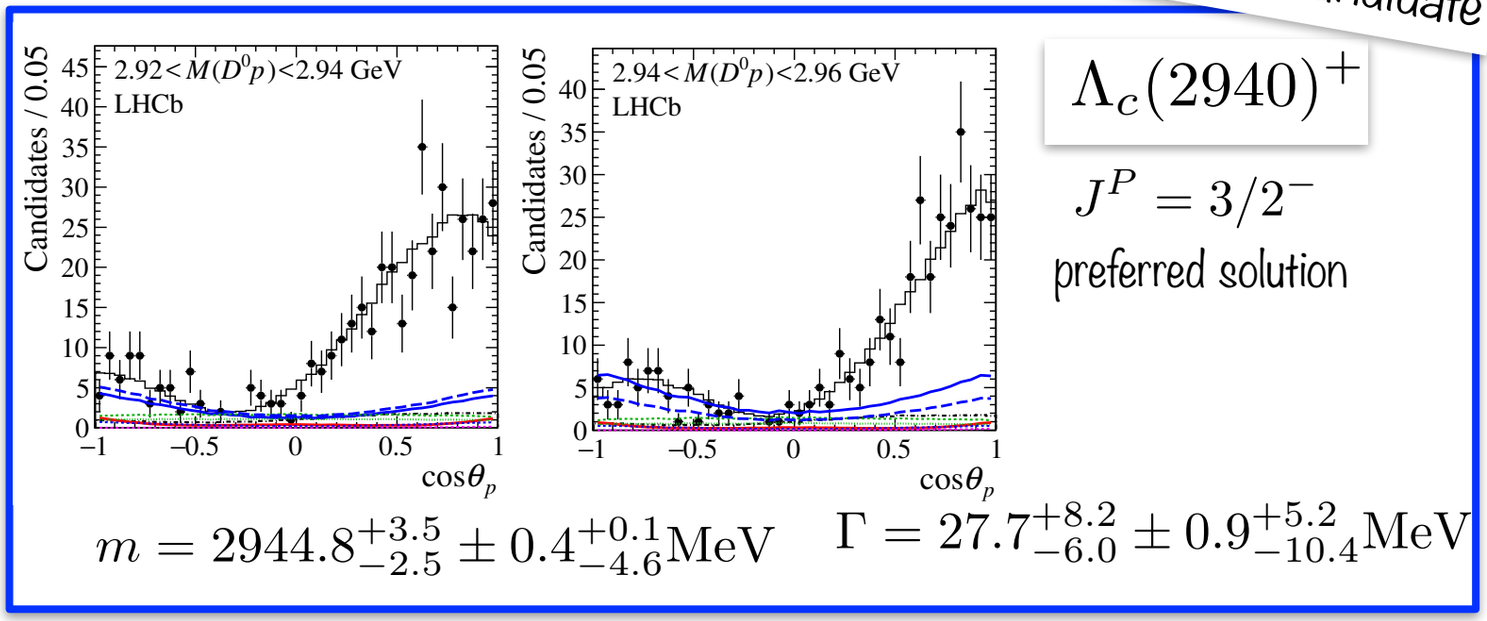
Run1 dataset

*D*⁰*p* amplitude analysis:

- for future *CPV* analysis of $\Lambda_b^0 \to D^0pK^-$ (sensitive to CKM angle γ though $b \to c(u)$ interference like $B \to D^0h$ decays)
- Λ_c^* spectroscopy
- D^0ph accessible also for Ξ_b baryons: a way to study their properties



D*N molecule candidate



$\Lambda_c(2940)^+$

$J^P = 3/2^-$

preferred solution

$m = 2944.8^{+3.5}_{-2.5} \pm 0.4^{+0.1}_{-4.6}\text{MeV}$ $\Gamma = 27.7^{+8.2}_{-6.0} \pm 0.9^{+5.2}_{-10.4}\text{MeV}$

New state

$\Lambda_c(2860)^+$ $J^P = 3/2^+$

$m = 2856.1^{+2.0}_{-1.7} \pm 0.05^{+1.1}_{-5.6}\text{MeV}$ $\Gamma = 67.6^{+10.1}_{-8.1} \pm 1.4^{+5.9}_{-20.0}\text{MeV}$

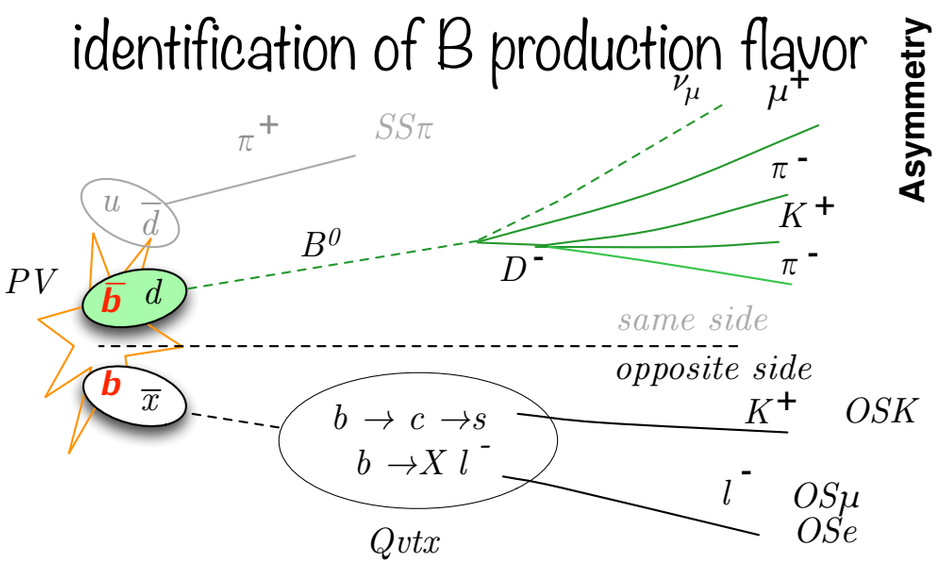
result +/- (stat) +/- (syst) +/- (model)

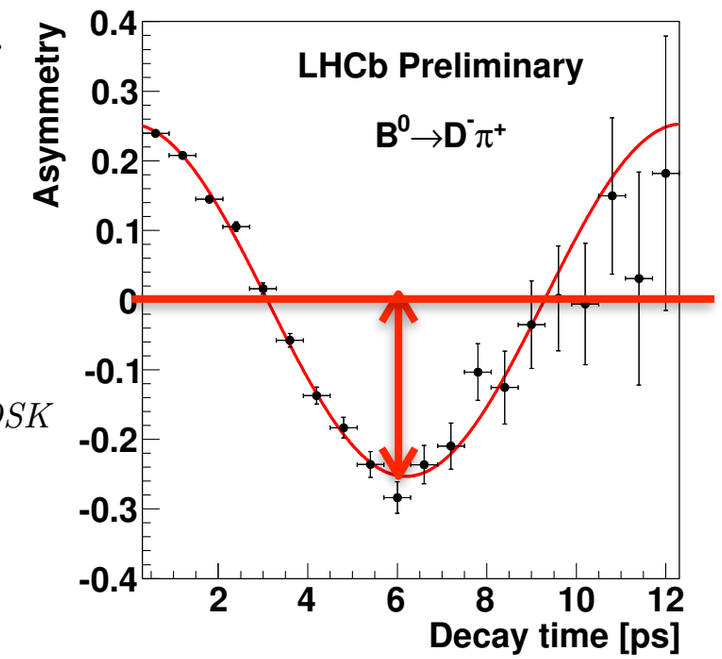
Time dependent *CP* asymmetries

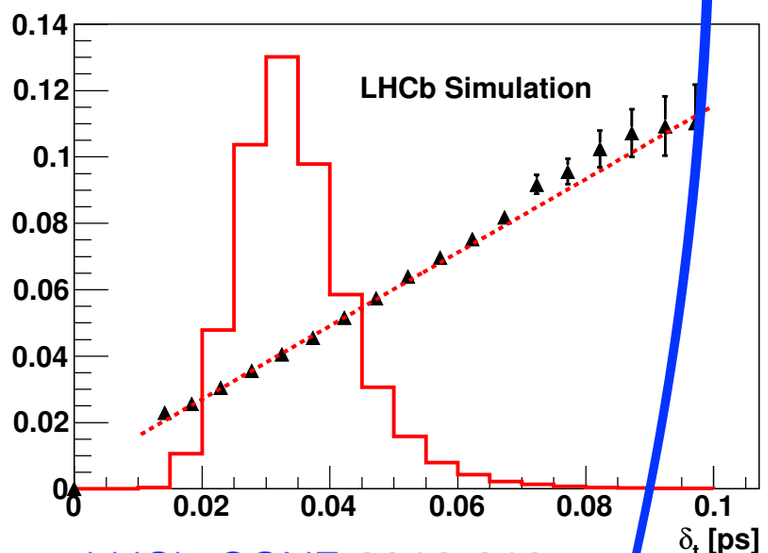
CP observables

$$\frac{\Gamma_{\bar{B}^0_s\to f}(t)-\Gamma_{B^0_s\to f}(t)}{\Gamma_{\bar{B}^0_s\to f}(t)+\Gamma_{B^0_s\to f}(t)} = \frac{-C_f\cos(\Delta m_{d(s)}t)+S_f\sin(\Delta m_{d(s)}t)}{\cosh(\Delta\Gamma_{d(s)}t/2)+A_f^{\Delta\Gamma}\sinh(\Delta\Gamma_{d(s)}t/2)}$$

- Oscillatory term: sensitivity comes from flavor tagged decays only
- Requires: knowledge of mixing frequency $\Delta m_{d(s)}$, flavor tagging, decay time resolution







LHCb-CONF-2016-018

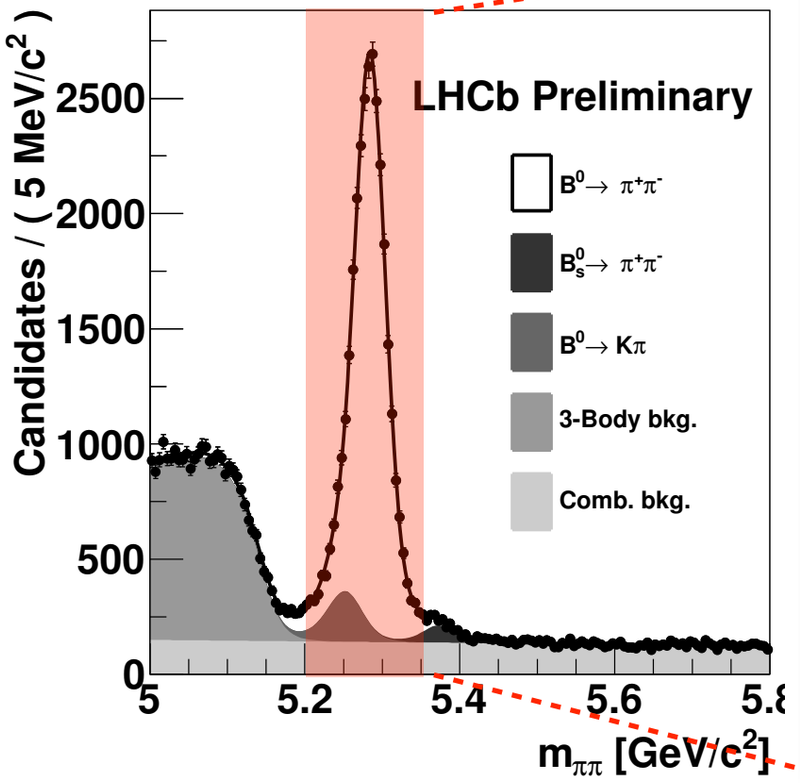
- Hyperbolic term: sensitivity comes from all the events
- Requires: knowledge of width difference in $B^0_{(s)}$ system $\Delta\Gamma_{d(s)}$, lifetime acceptance

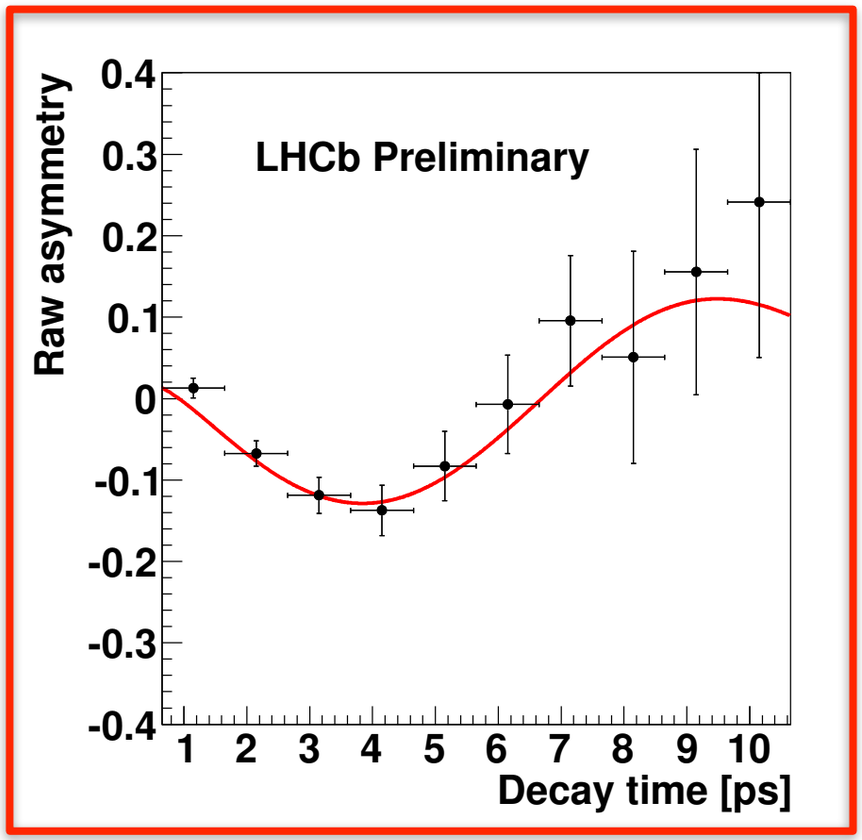
LHCB-CONF-2016-018

Time dependent *CP* asymmetry in $B^0 \to \pi^+\pi^-$ and $B_s^0 \to K^+K^-$

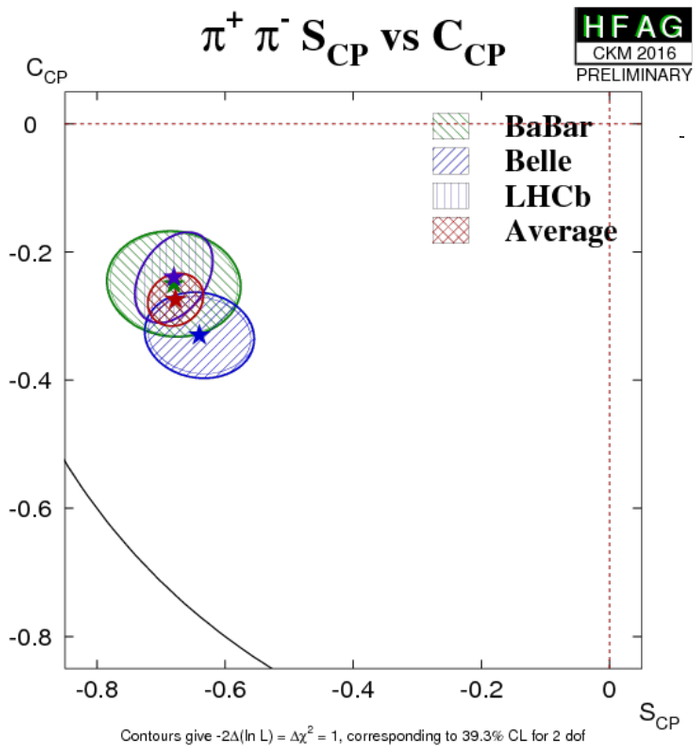
Run1 dataset

- Time dependent *CP* observables are sensitive to CKM angle γ and -2βs
- Tree and penguin decay topologies contribute to *B*→*hh*
- Strategy to extract *CPV* parameters: fit to mass, decay time, per-event mistag probability, per-event decay time error, simultaneously for ππ, KK, Kπ





$$C_{\pi^+\pi^-} = -0.24 \pm 0.07 \pm 0.01$$
$$S_{\pi^+\pi^-} = -0.68 \pm 0.06 \pm 0.01$$



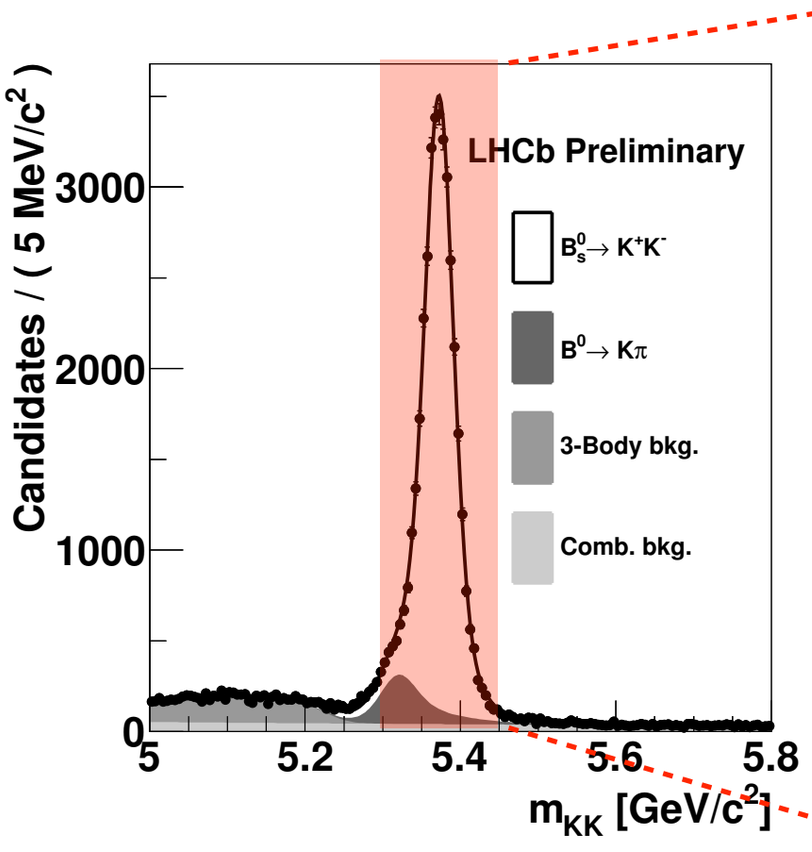
- Best Sππ measurement from a single experiment

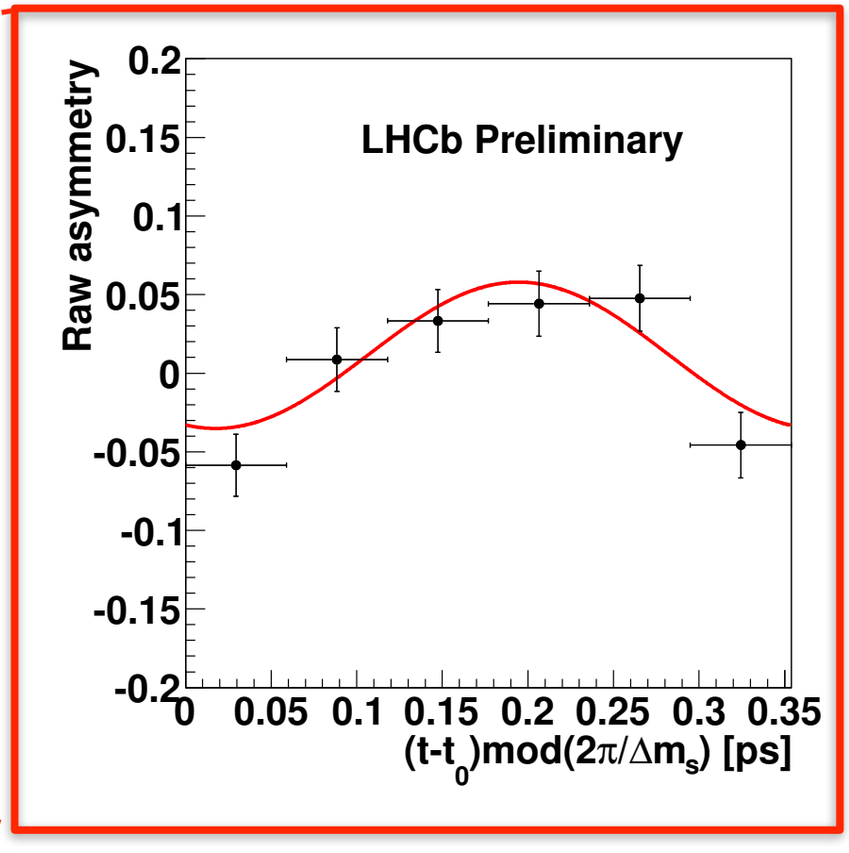
LHCB-CONF-2016-018

Time dependent CP asymmetry in $B^0 \to \pi^+\pi^-$ and $B_s^0 \to K^+K^-$

Run1 dataset

- Time dependent *CP* observables are sensitive to CKM angle γ and -2βs
- Tree and penguin decay topologies contribute to $B \to hh$
- Strategy to extract *CPV* parameters: fit to mass, decay time, per-event mistag probability, per-event decay time error, simultaneously for ππ, KK, Kπ





$$C_{\pi^+\pi^-} = -0.24 \pm 0.07 \pm 0.01$$
$$S_{\pi^+\pi^-} = -0.68 \pm 0.06 \pm 0.01$$
$$C_{K^+K^-} = 0.24 \pm 0.06 \pm 0.02$$
$$S_{K^+K^-} = 0.22 \pm 0.06 \pm 0.02$$
$$A_{K^+K^-}^{\Delta\Gamma} = -0.75 \pm 0.07 \pm 0.11$$

- Best Sππ measurement from a single experiment
- First evidence of CPV in the decay and in the mixing/decay interference in B→KK

LHCB-CONF-2016-015

Time dependent CP asymmetry in $B_s^0 \to D_s^{\mp} K^{\pm}$

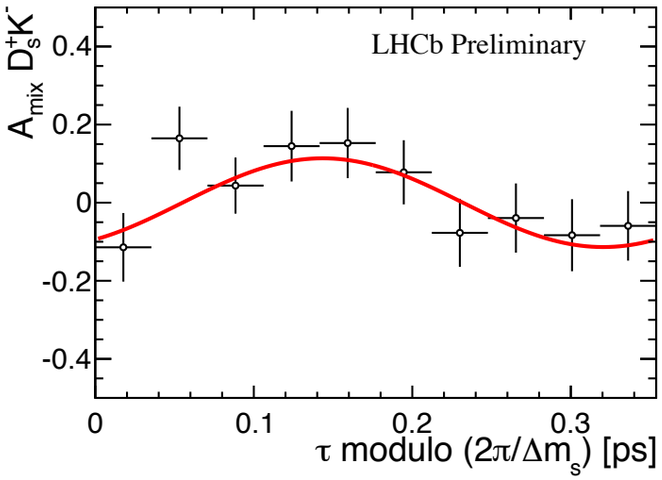
Run1 dataset

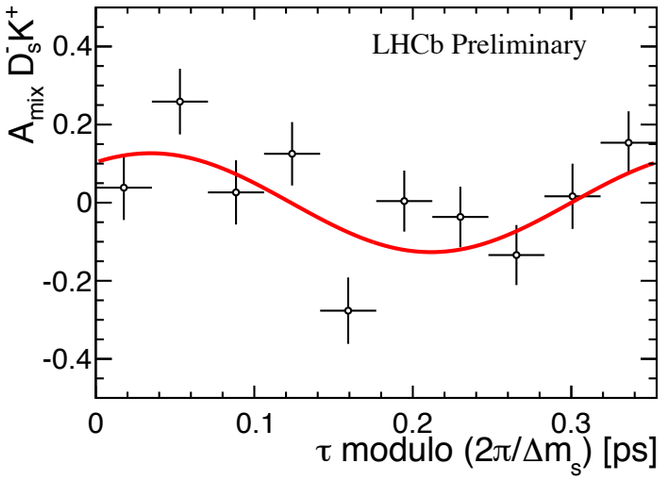
- Signal and background are statistically separated with a 3-dimensional fit to Bs invariant mass, Ds invariant mass and log-likelihood difference between the kaon and pion hypothesis for the companion (B→Dπ for PID efficiency and data/MC diff)
- Decay-time fit to extract *CP*-sensitive parameters
- *CP*-sensitive parameters interpreted in terms of the CKM angle γ

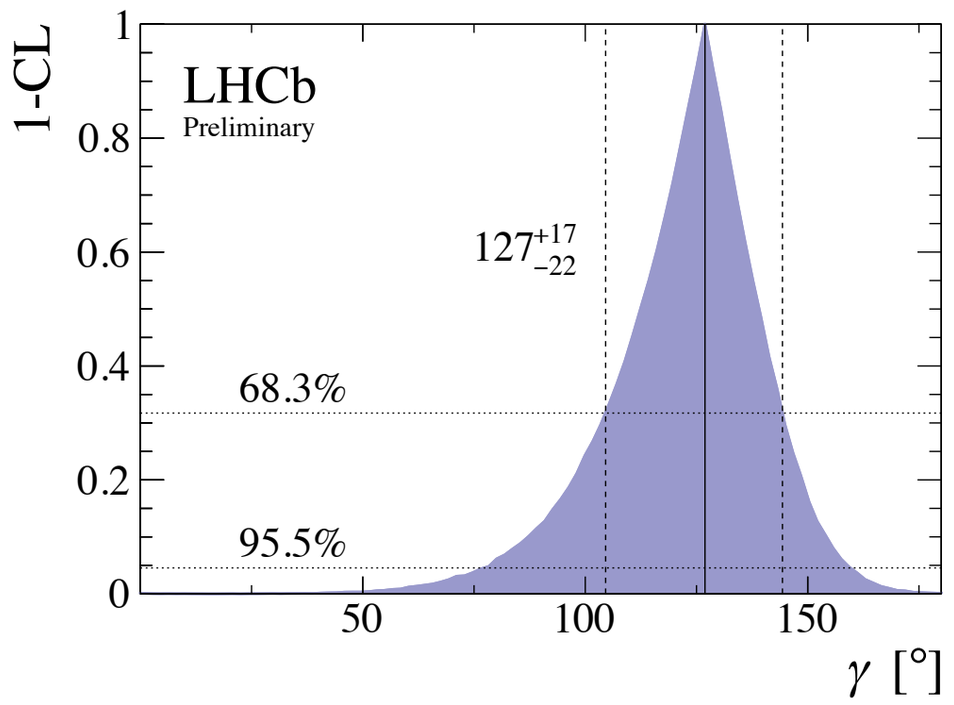
$$C_f = \frac{1 - r_{D_sK}^2}{1 + r_{D_sK}^2},$$

$$A_f^{\Delta\Gamma} = \frac{-2r_{D_sK}\cos(\delta - (\gamma - 2\beta_s))}{1 + r_{D_sK}^2}, \quad A_{\bar{f}}^{\Delta\Gamma} = \frac{-2r_{D_sK}\cos(\delta + (\gamma - 2\beta_s))}{1 + r_{D_sK}^2},$$

$$S_f = \frac{2r_{D_sK}\sin(\delta - (\gamma - 2\beta_s))}{1 + r_{D_sK}^2}, \quad S_{\bar{f}} = \frac{-2r_{D_sK}\sin(\delta + (\gamma - 2\beta_s))}{1 + r_{D_sK}^2}.$$





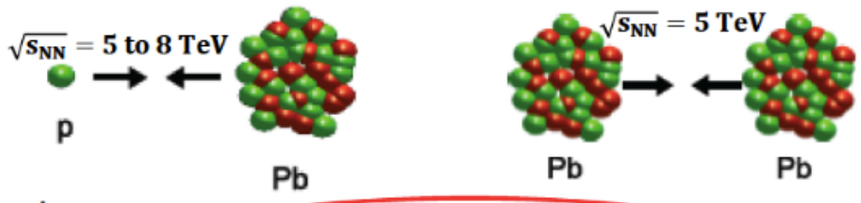


3.6σ Evidence for CP violation in Bs→DsK, with the γ value of $\gamma = (127^{+17}_{-22})^\circ$

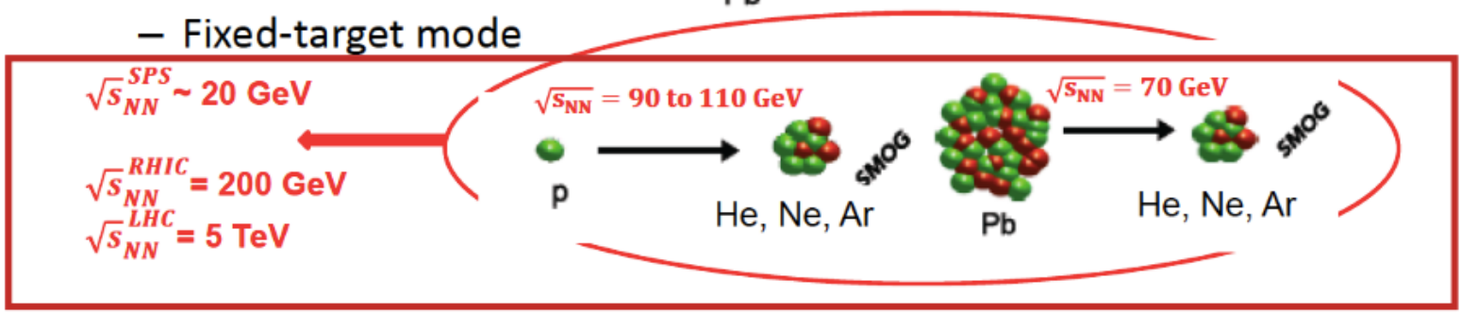
~2σ from LHCb γ combination

Heavy Ions and Fixed Target Physics with LHCb

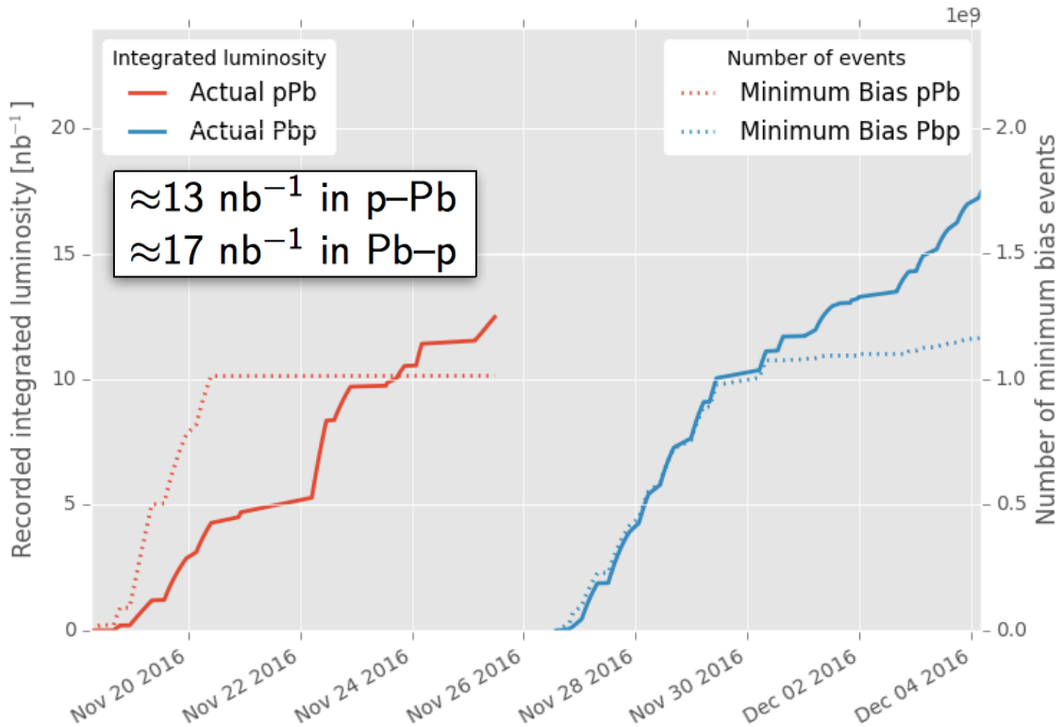
– Collider mode

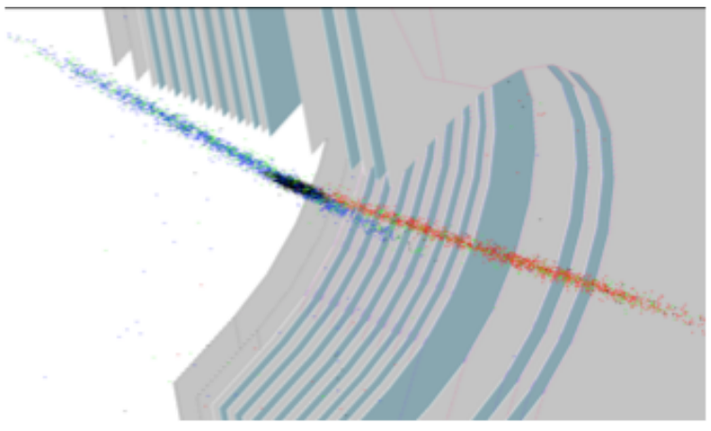


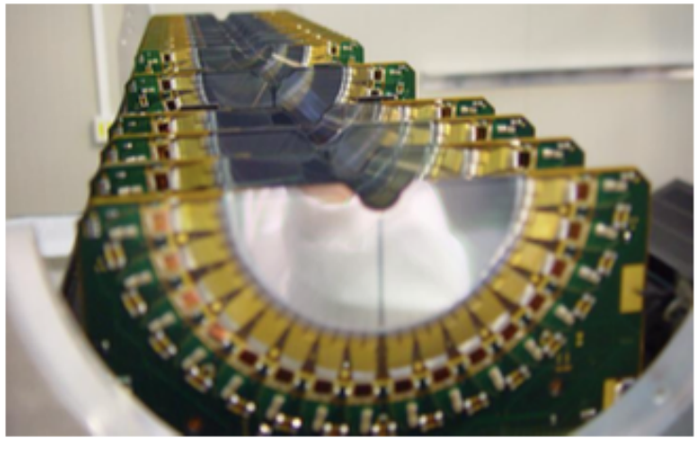
– Fixed-target mode



- Gas (**Neon**, **Ar** and **He**) can be injected inside the LHC vacuum, in the VELO detector
- Used to determine the luminosity but since 2015 is used to also collect physics data (LHCb operated in standard configuration)
- Heavy-ion physics between SPS & RHIC energies towards large rapidities
- Possible measurements that are important to better model backgrounds for collider physics and can have great impact in astroparticle physics



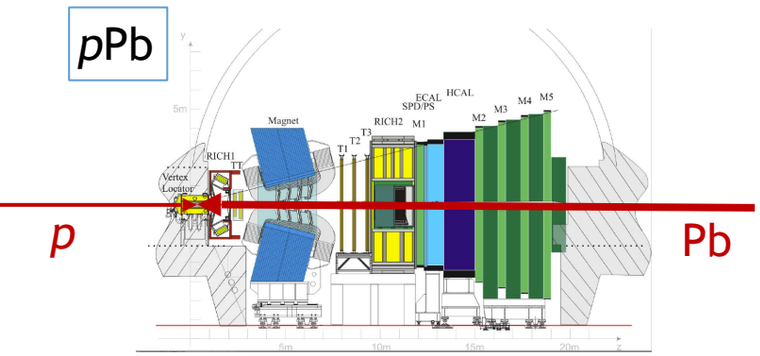




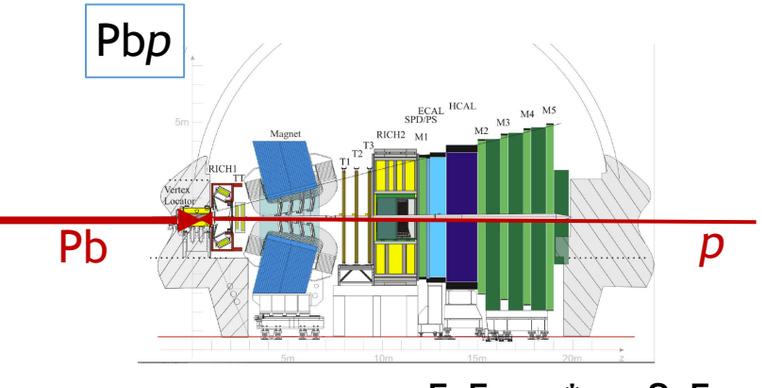
2016 p-Pb and Pb-p run

- Charmonium and open charm baryons

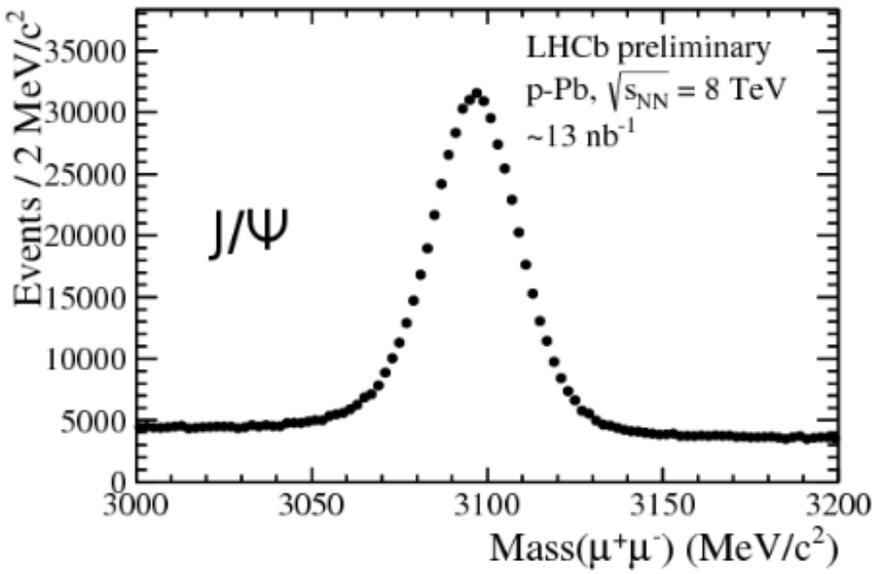
y* = center of mass rapidity

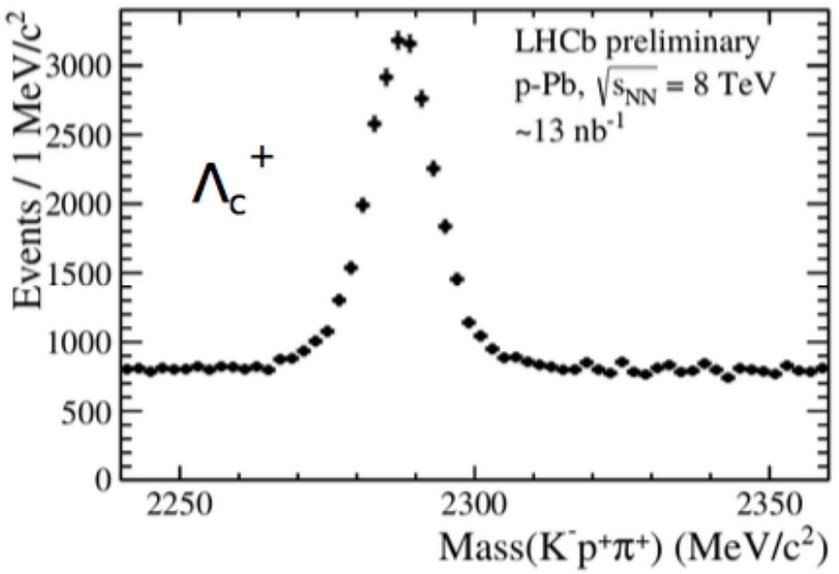


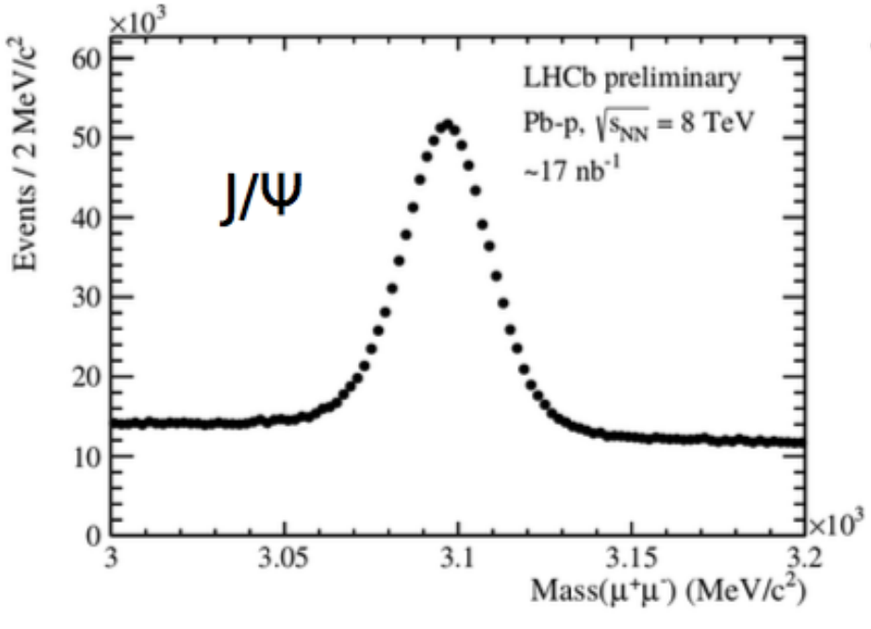
1.5 < *y** < 4.5

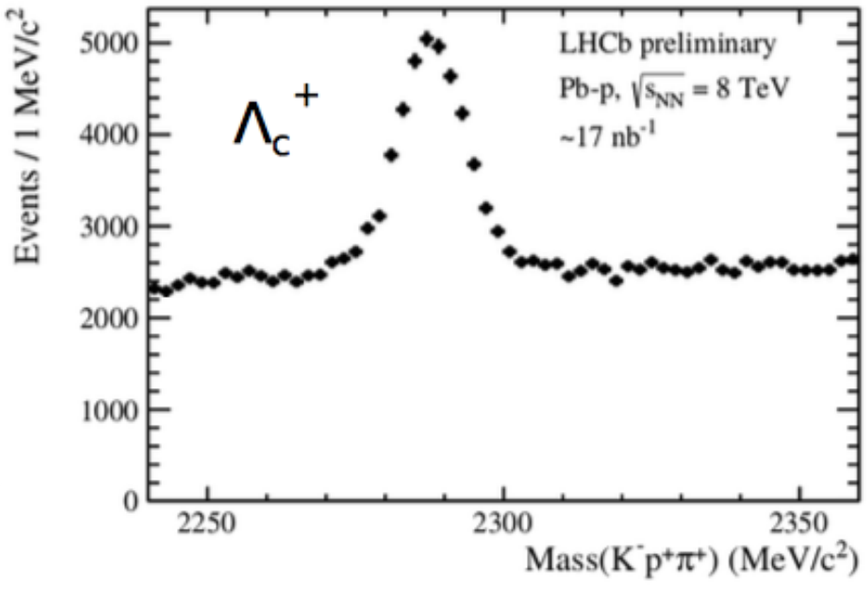


-5.5 < *y** < -2.5



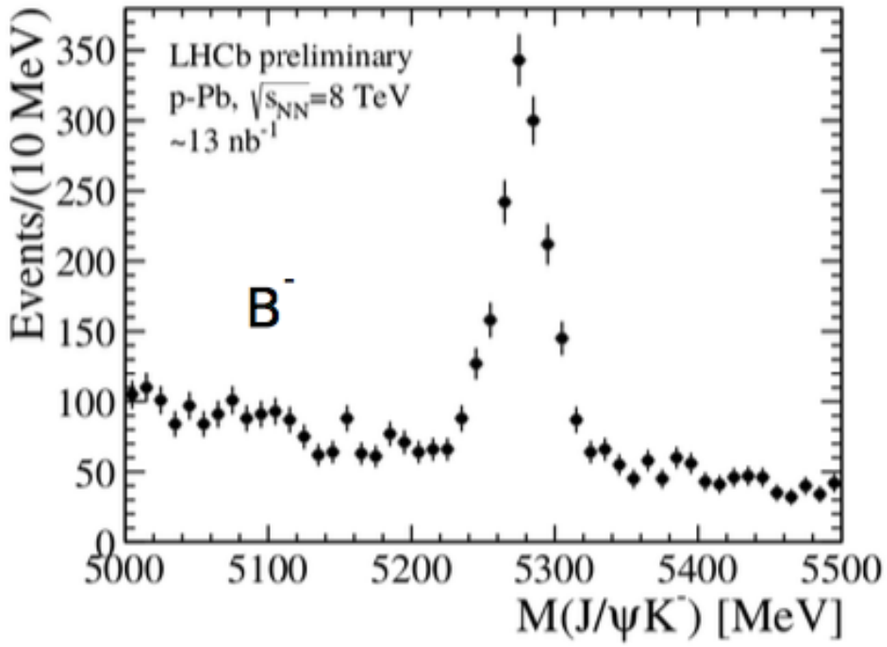


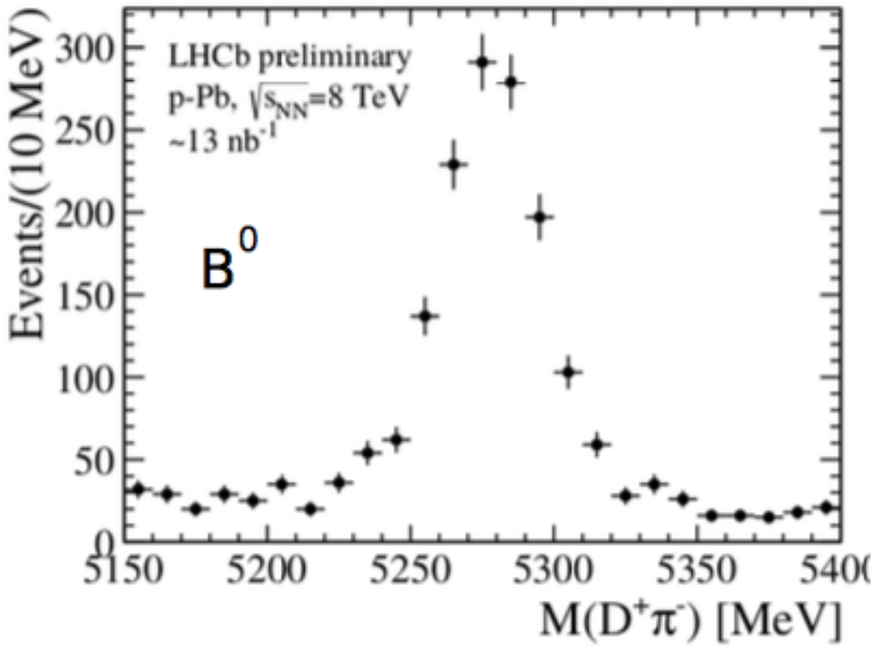


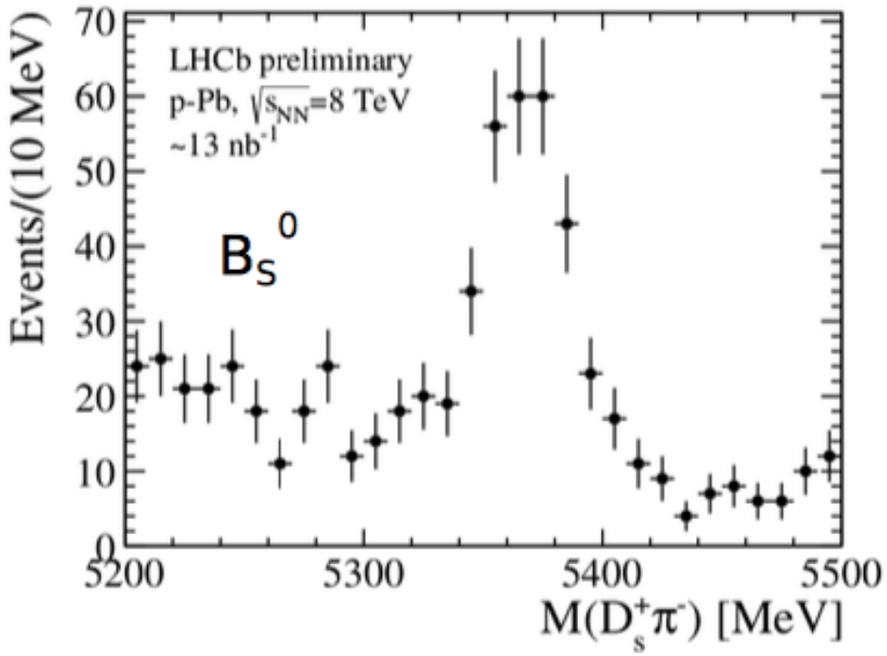


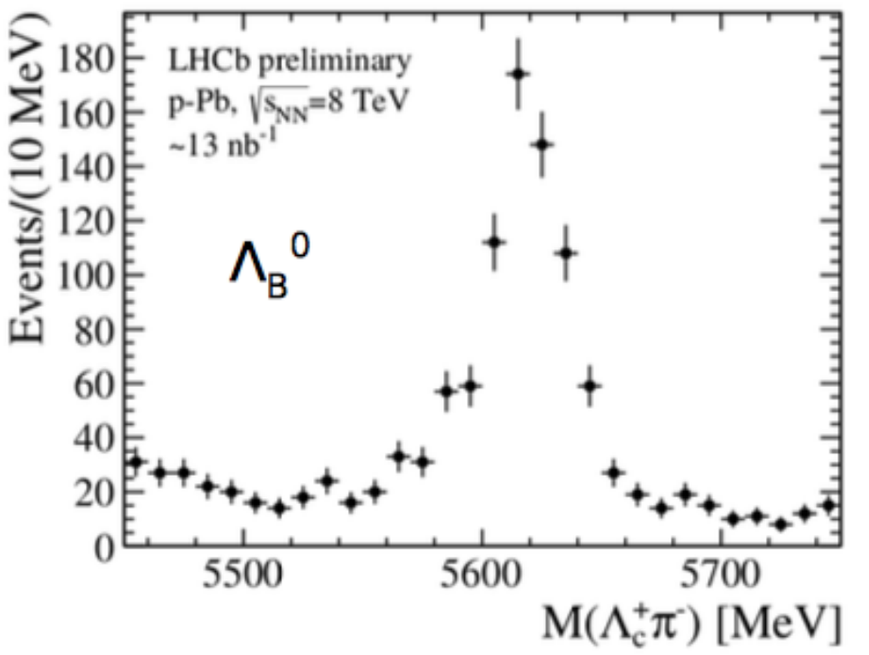
2016 p-Pb run

- Significant samples of beauty meson & baryons down to p_T = 0!



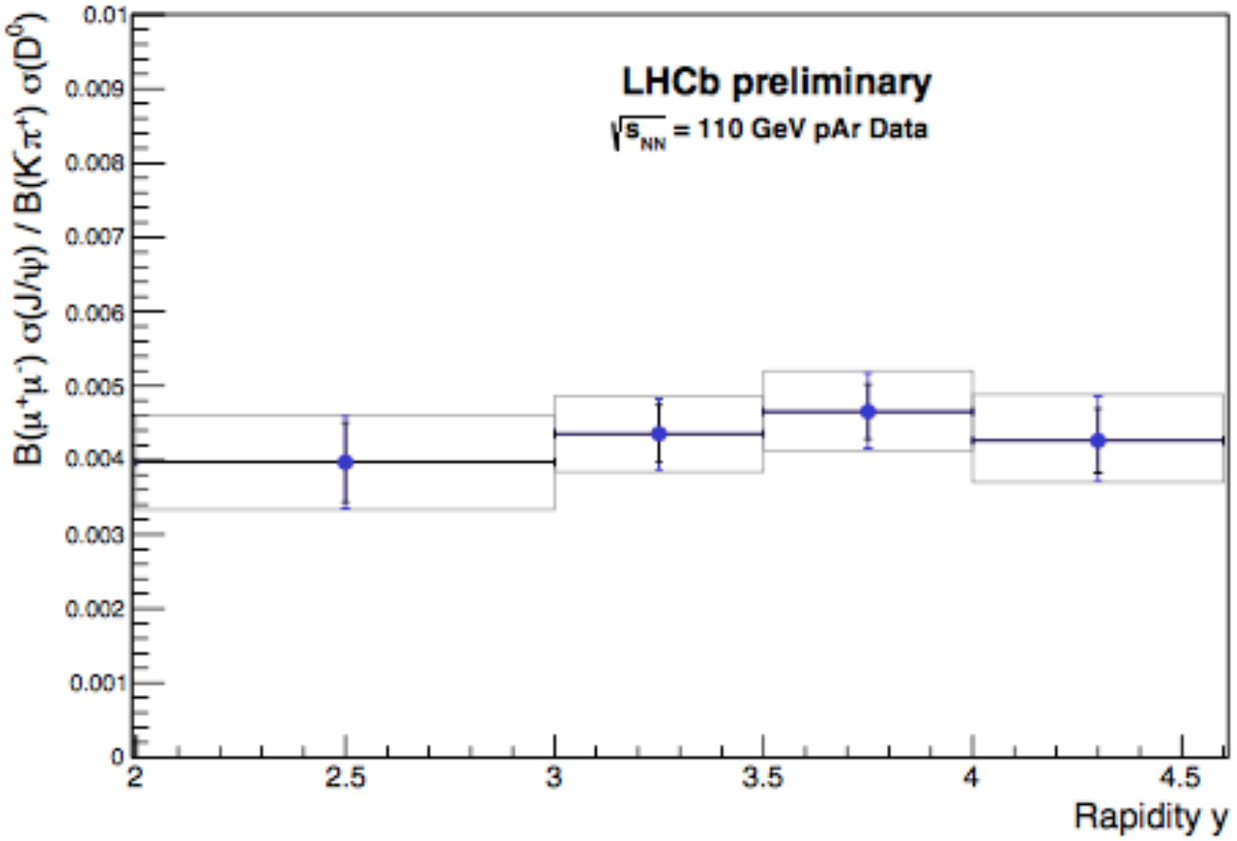


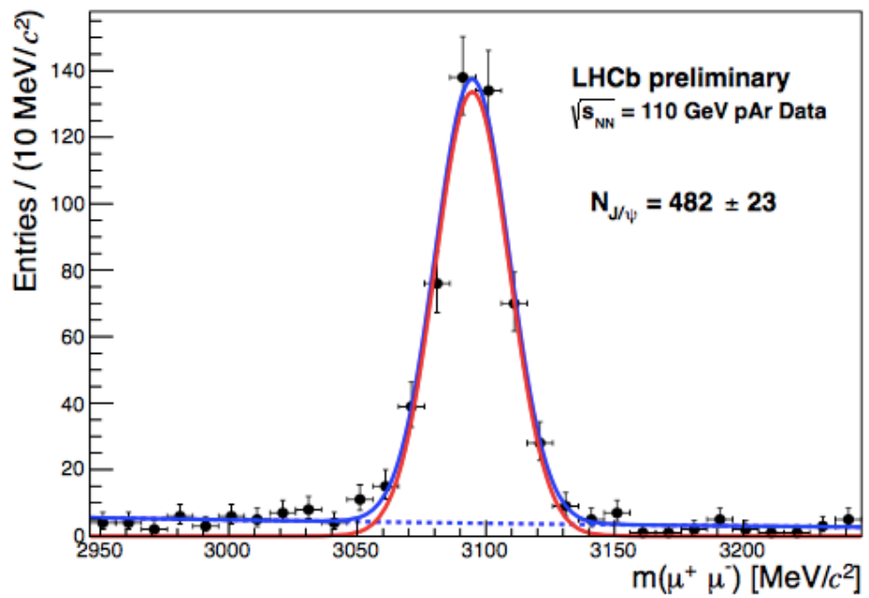


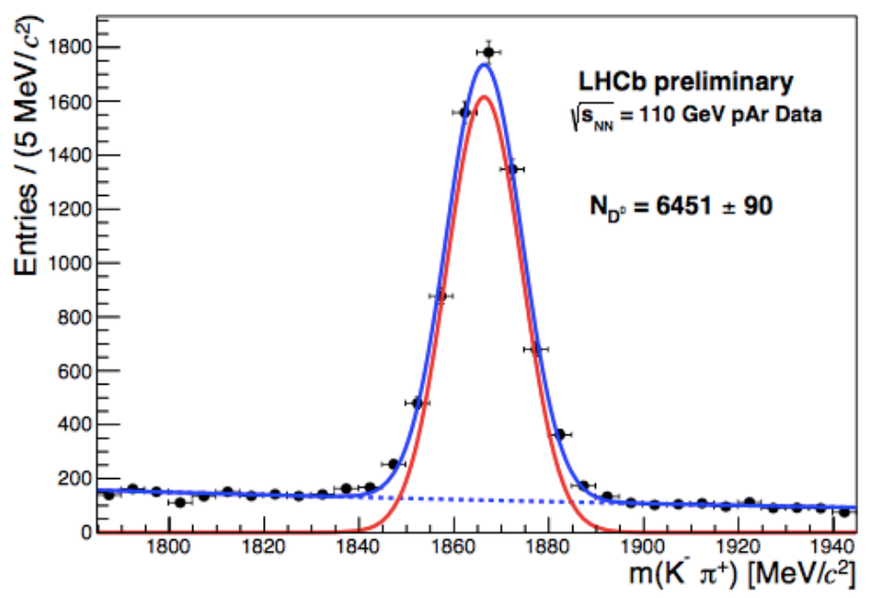


Measurement of J/ψ and D^0 production in pAr

- proton-nucleus collisions at LHCb allow to study effects as parton shadowing (or anti-shadowing) that may suppress (or enhance) the charmonium production, providing information about $c\bar{c}$ pair production kinematics
- ~18h *p*Ar 2015 data taking $\sqrt{s_{NN}}$ = 110GeV, ~4 x 10^{22} protons on target
- comparison of J/ψ and D^0 cross-sections







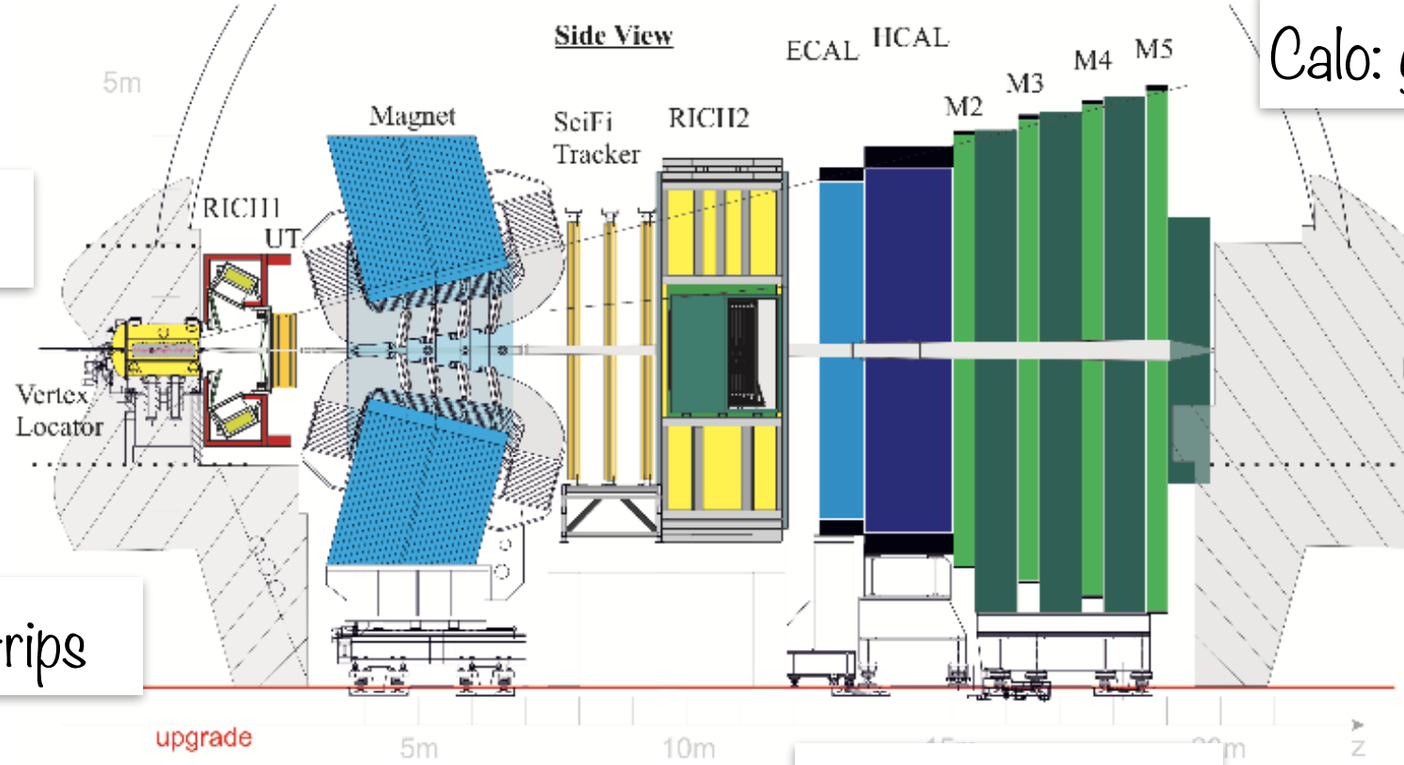
- No strong dependence of the ratio of the cross sections is observed

Coming soon …

- Lepton Flavor Universality tests
  - *R(D*)* measurement exploiting hadronic τ decays
  - Combined *R(D)* and *R(D*)* analysis
  - *R(J/ψ)*
  - R_{K^*}
- New results in heavy flavor production and spectroscopy
- Mixing and *CP* violation in beauty and charm
- Fixed Target and Heavy Ion physics
  - antiproton production in *p*He collisions
  - D^0 production in *p*Pb
  - *J/ψ* production in PbPb
- …

Upgrade

- After LS2, detector read out at 40MHz, software trigger
- Novelties in the detector



Velo: Si pixel

Calo: gain &readout

Muons: shielding & readout

UT: Si strips

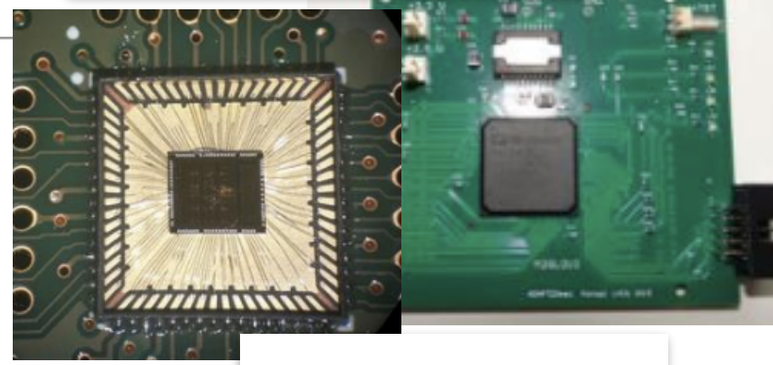
SciFI: scintillating fibre tracker

RICH: photon detectors & optics

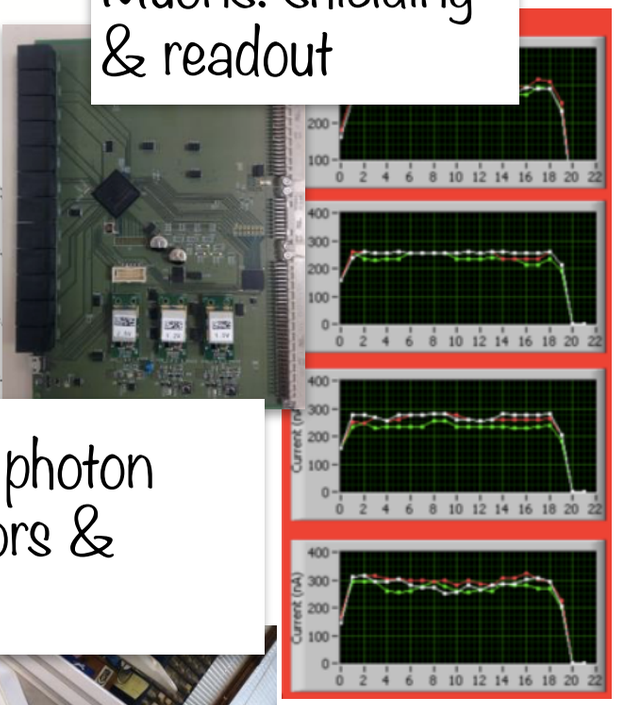
Upgrade

- After LS2, detector read out at 40MHz, software trigger
- Novelties in the detector

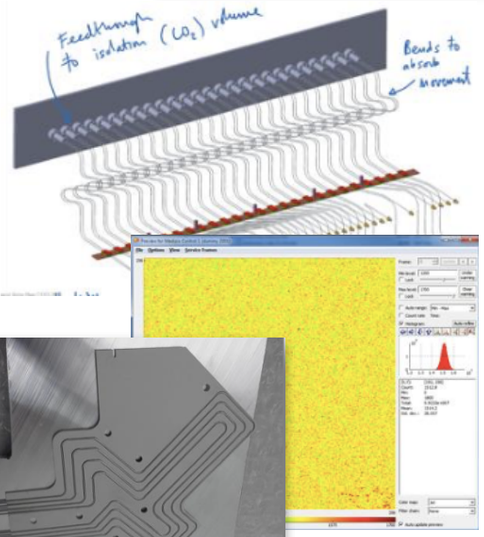
Calo: gain &readout

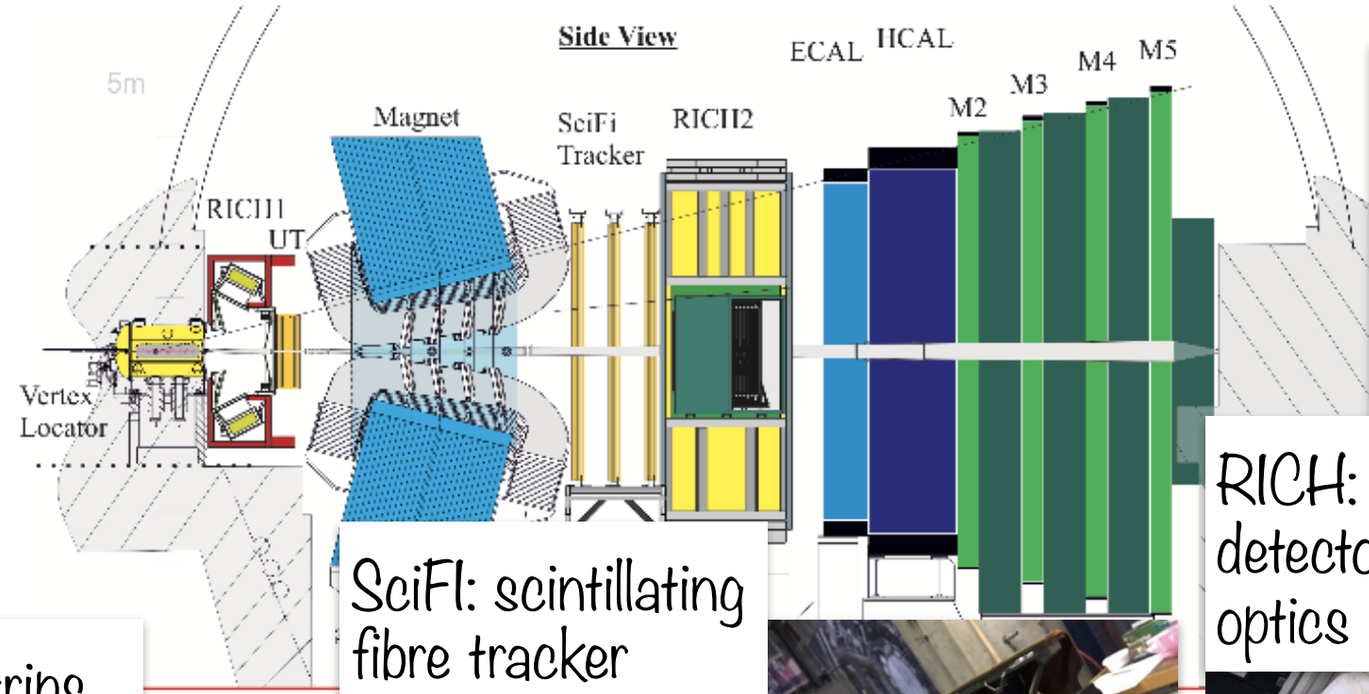


Muons: shielding & readout



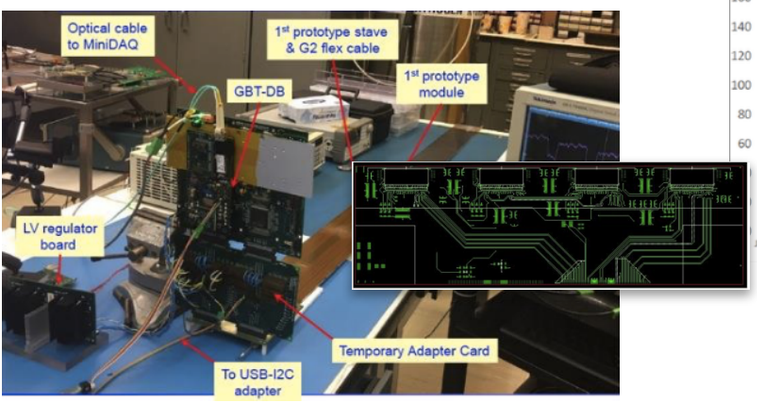
Velo: Si pixel

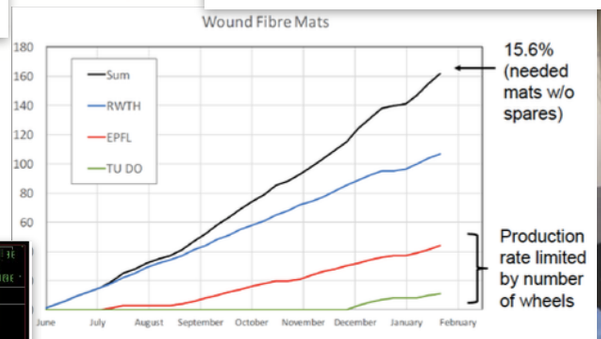


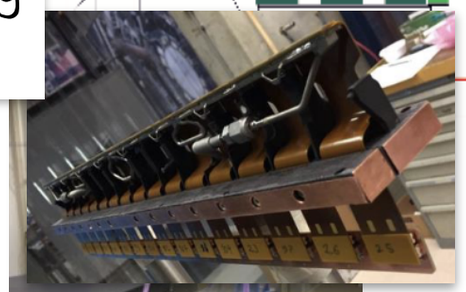


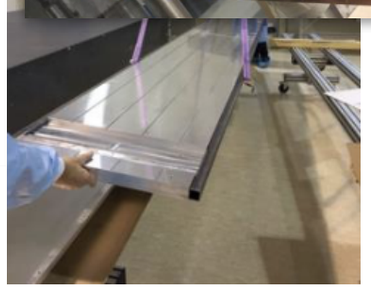
SciFI: scintillating fibre tracker

UT: Si strips

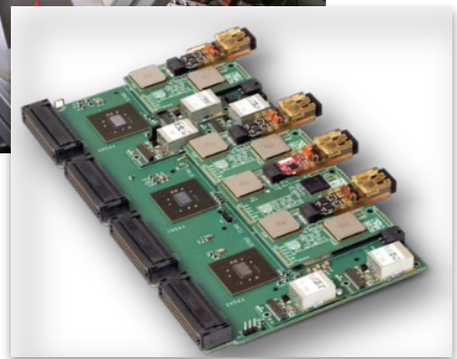








RICH: photon detectors & optics



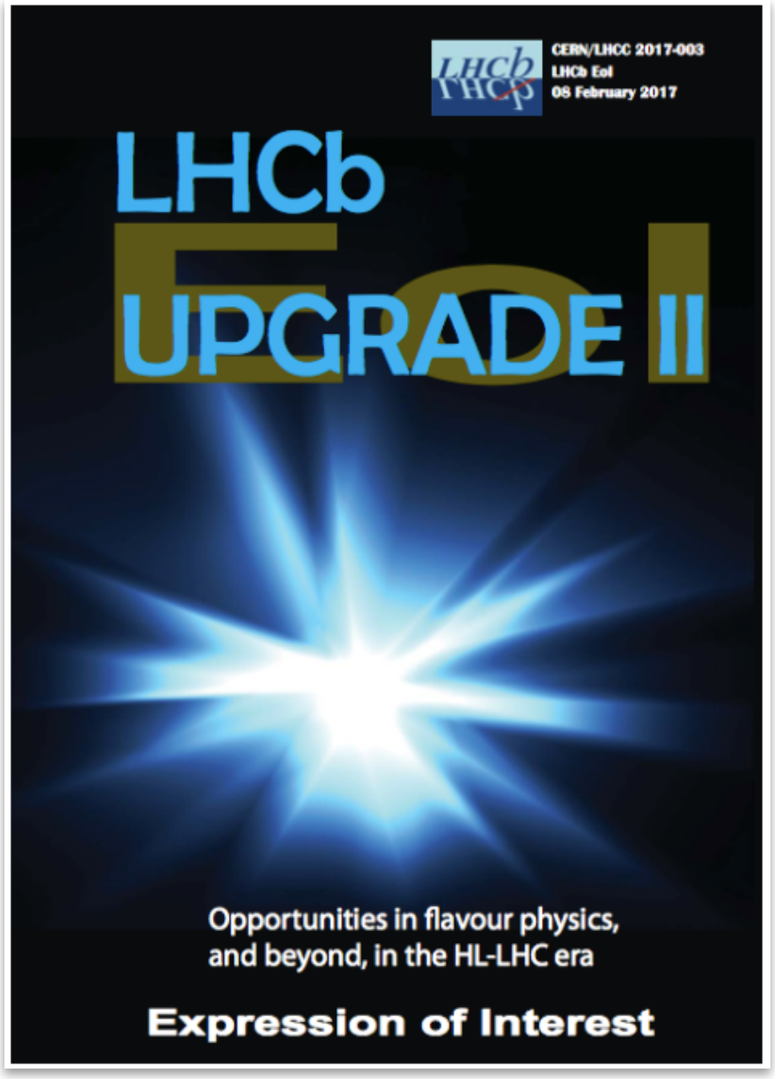
Upgrade

- The upgrade project is progressing at full speed.
- An internal comprehensive review of the upgrade was recently held to optimize the plans towards the installation, evaluate the risks, optimize schedule and discuss strategies for critical items
- A status report of the Computing Project (not under review at this time) was also given, to monitor the preparation of the Computing TDR expected by the end of 2017
- Mass production of key detector components is underway or about to be launched
- Production workflows already well defined in most of the cases
- Details of the installation phase are being worked out in strict collaboration with the Technical Coordination team
- No sign of project will miss the date for being ready for installation.

Expression of Interest for a Phase-II upgrade

	LHC Run	Period of data taking	Maximum $\mathcal{L}$ [$\mathrm{cm^{-2}s^{-1}}$]	Cumulative $\int \mathcal{L}\,dt$ [$\mathrm{fb^{-1}}$]
Current detector	1 & 2	2010–2012, 2015–2018	4×10^{32}	8
Phase-I Upgrade	3 & 4	2021–2023, 2026–2029	2×10^{33}	50
Phase-II Upgrade	5 →	2031–2033, 2035 →	2×10^{34}	300

Physics reach of Phase-II Upgrade: significant improvement in flavor observables already under study and access to new complementary observables



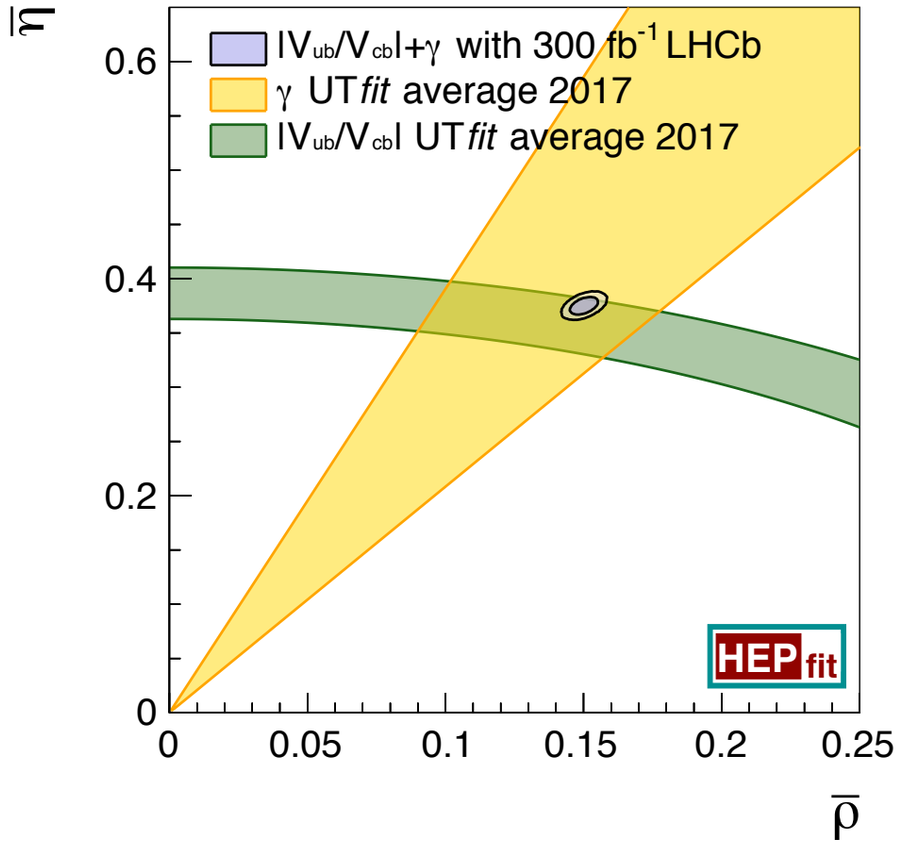
CERN-LHCC-2017-003

Topics and observables	Experimental reach	Remarks
EW Penguins		
Global tests in many $b \to s\mu^+\mu^-$ modes with full set of precision observables; lepton universality tests; $b \to d l^+ l^-$ studies	*e.g.* 440k $B^0 \to K^*\mu^+\mu^-$ & 70k $\Lambda_b^0 \to \Lambda\mu^+\mu^-$; Phase-II $b \to d\mu^+\mu^- \approx$ Run-1 $b \to s\mu^+\mu^-$ sensitivity.	Phase-II ECAL required for lepton universality tests.
Photon polarisation		
$\mathcal{A}^\Delta$ in $B_s^0 \to \phi\gamma$; $B^0 \to K^*e^+e^-$; baryonic modes	Uncertainty on $\mathcal{A}^\Delta \approx 0.02$; $\sim 10k$ $\Lambda_b^0 \to \Lambda\gamma$, $\Xi_b \to \Xi\gamma$, $\Omega_b^- \to \Omega\gamma$	Strongly dependent on performance of ECAL.
$b \to c l^- \bar{\nu}_l$ lepton-universality tests		
Polarisation studies with $B \to D^{(*)}\tau^-\bar{\nu}_\tau$; τ^-/μ^- ratios with B_s^0, Λ_b^0 and B_c^+ modes	*e.g.* 8M $B \to D^*\tau^-\bar{\nu}_\tau$, $\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$ & $\sim 100k$ $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$	Additional sensitivity expected from low-p tracking.
$B_s^0, B^0 \to \mu^+\mu^-$		
$R \equiv \mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$; $\tau_{B_s^0 \to \mu^+\mu^-}$; CP asymmetry	Uncertainty on $R \approx 20\%$ Uncertainty on $\tau_{B_s^0 \to \mu^+\mu^-} \approx 0.03$ ps	
LFV τ decays		
$\tau^- \to \mu^+\mu^-\mu^-$, $\tau^- \to h^+\mu^-\mu^-$, $\tau^- \to \phi\mu^-$	Sensitive to $\tau^- \to \mu^+\mu^-\mu^-$ at 10^{-9}	Phase-II ECAL valuable for background suppression.
CKM tests		
γ with $B^- \to DK^-$, $B_s^0 \to D_s^+K^-$ *etc.*	Uncertainty on $\gamma \approx 0.4°$	Additional sensitivity expected in CP observables from Phase-II ECAL and low-p tracking.
ϕ_s with $B_s^0 \to J/\psi K^+K^-$, $J/\psi\pi^+\pi^-$	Uncertainty on $\phi_s \approx 3$ mrad	
ϕ_s^{sss} with $B_s^0 \to \phi\phi$	Uncertainty on $\phi_s^{sss} \approx 8$ mrad	
$\Delta\Gamma_d/\Gamma_d$	Uncertainty on $\Delta\Gamma_d/\Gamma_d \sim 10^{-3}$	Approach SM value.
Semileptonic asymmetries $a_{\rm sl}^{d,s}$	Uncertainties on $a_{\rm sl}^{d,s} \sim 10^{-4}$	Approach SM value for $a_{\rm sl}^d$.
$\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ with Λ_b^0, B_s^0 and B_c^+ modes	*e.g.* $120k$ $B_c^+ \to D^0\mu^-\bar{\nu}_\mu$	Significant gains achievable from thinning or removing RF-foil.
Charm		
CP-violation studies with $D^0 \to h^+h^-$, $D^0 \to K_S^0\pi^+\pi^-$ and $D^0 \to K^\mp\pi^\pm\pi^+\pi^-$	*e.g.* 4×10^9 $D^0 \to K^+K^-$; Uncertainty on $A_\Gamma \sim 10^{-5}$	Access CP violation at SM values.
Strange		
Rare decay searches	Sensitive to $K_S^0 \to \mu^+\mu^-$ at 10^{-12}	Additional sensitivity possible with downstream trigger enhancements.

Expression of Interest for a Phase-II upgrade

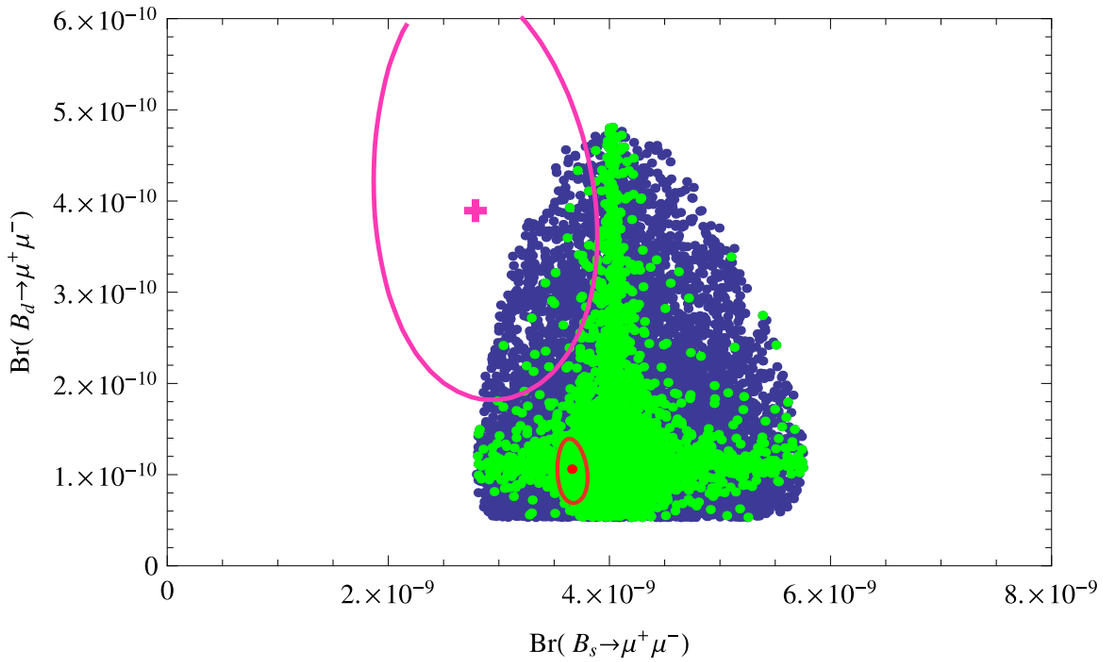
Examples of physics opportunities

- After Phase-II, ~0.4° (conservative extrapolation)
- + |Vub| determination using semileptonic *b*-hadron decays
- Precision tests of the CKM paradigm



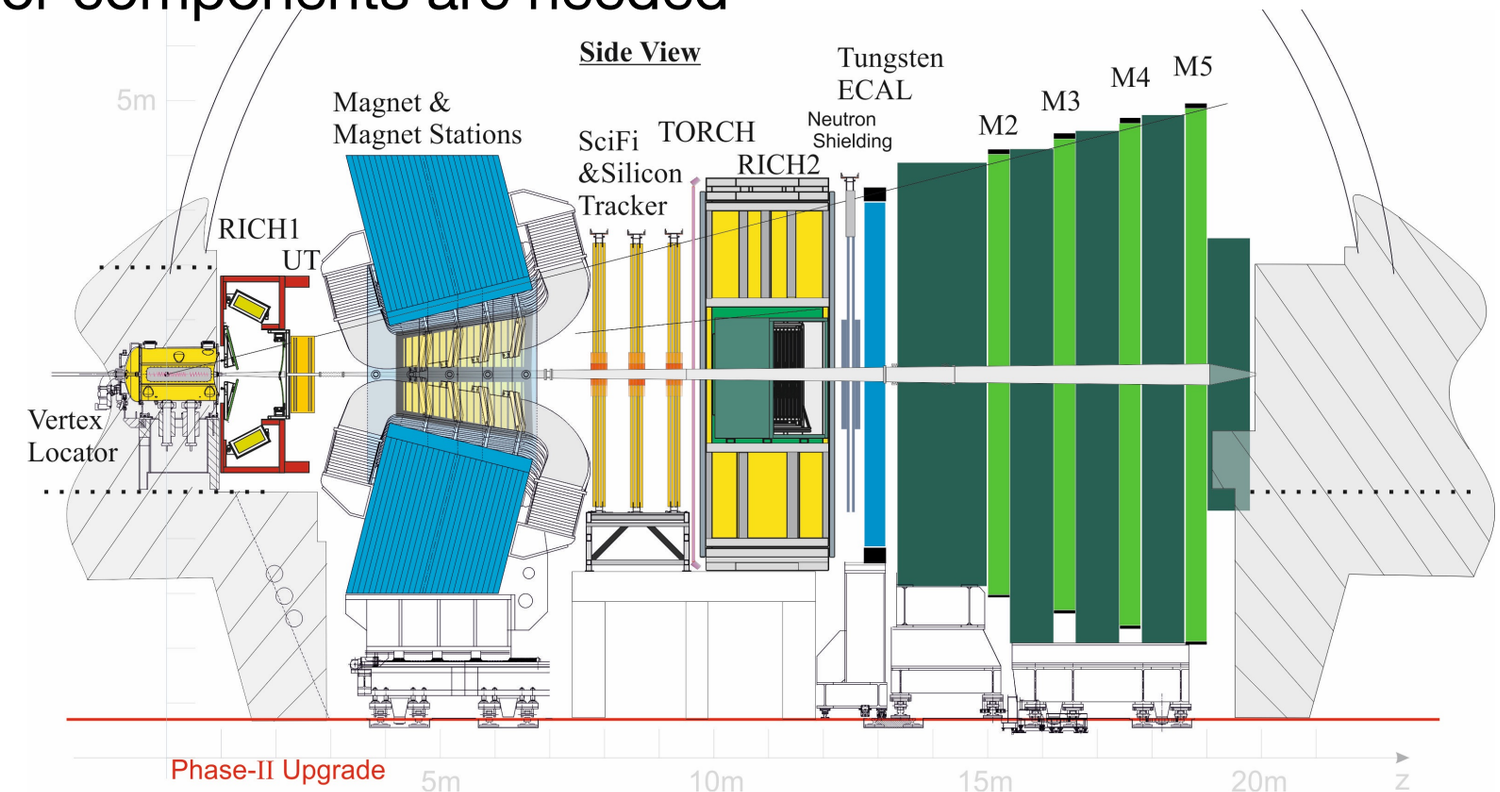
- $R = \mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$
- by end or Run 4, assuming SM prediction, 40% precision on *R*
- After Phase-II, better than 20% precision on *R*
- Additional observables: effective lifetime 30fs precision level and CP-violating observables

- Important to identify NP, if NP effects observed



Expression of Interest for a Phase-II upgrade

- Machine input: studies underway to evaluate the beam-beam effects and the value of β* that could be reached
- New detector components are needed



- Fast timing, radiation hardness, finer granularity
- New calorimeter system: HCAL not needed, ECAL with new technology
- Low momentum tracking
- Possible preparatory work during LS3, e.g. replace innermost part of ECAL with new technology

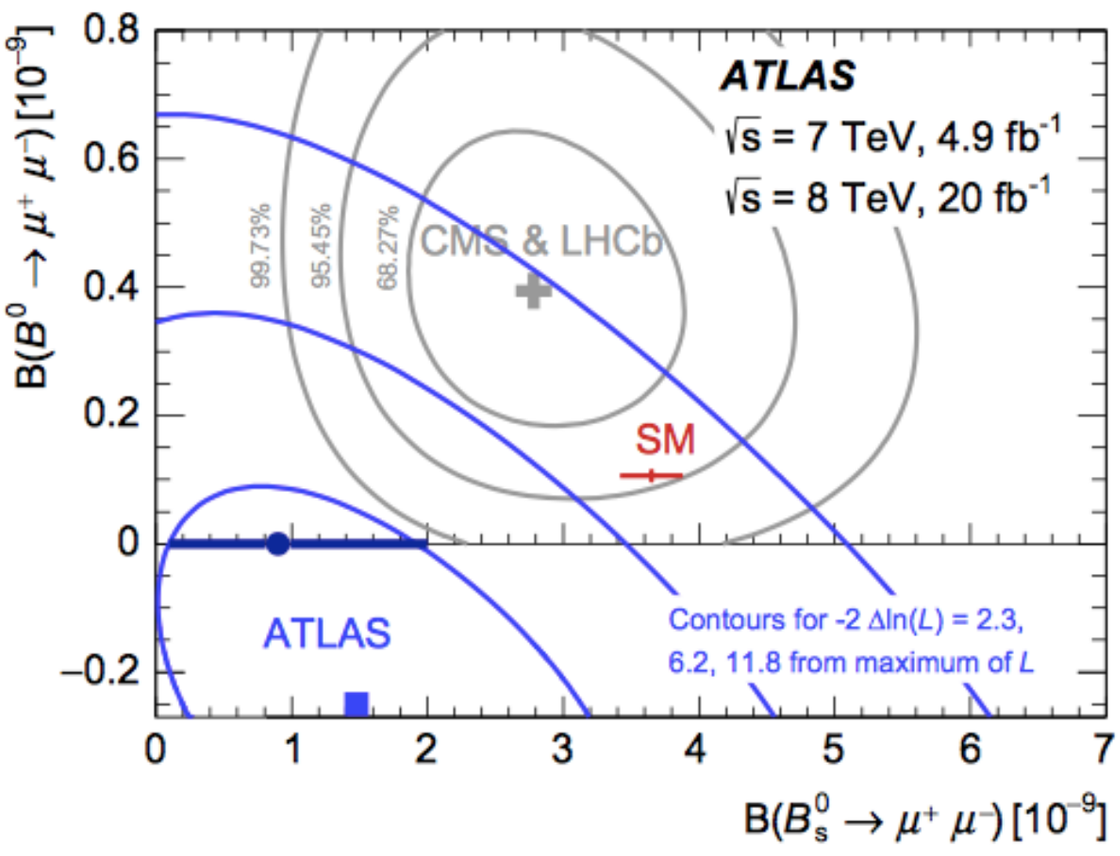
Conclusions

- Operations & EYETS
  - Excellent performance during *pp* and *p*Pb programs
  - Automation makes detector easier to run and allows for broad physics programme
  - “Standard” maintenance and further improvements on the way
- Physics
  - +19 papers + 5 conference notes + several other papers being processed
  - First results with 2016 data
  - Many new results/updates with full Run-I dataset
  - Heavy Ion and Fixed Target program now started deploying the full potential
- Upgrade
  - On track, approaching the installation phase
- Expression of Interest for a Phase-II upgrade
  - Impressive physics opportunities, studies on going

Thanks

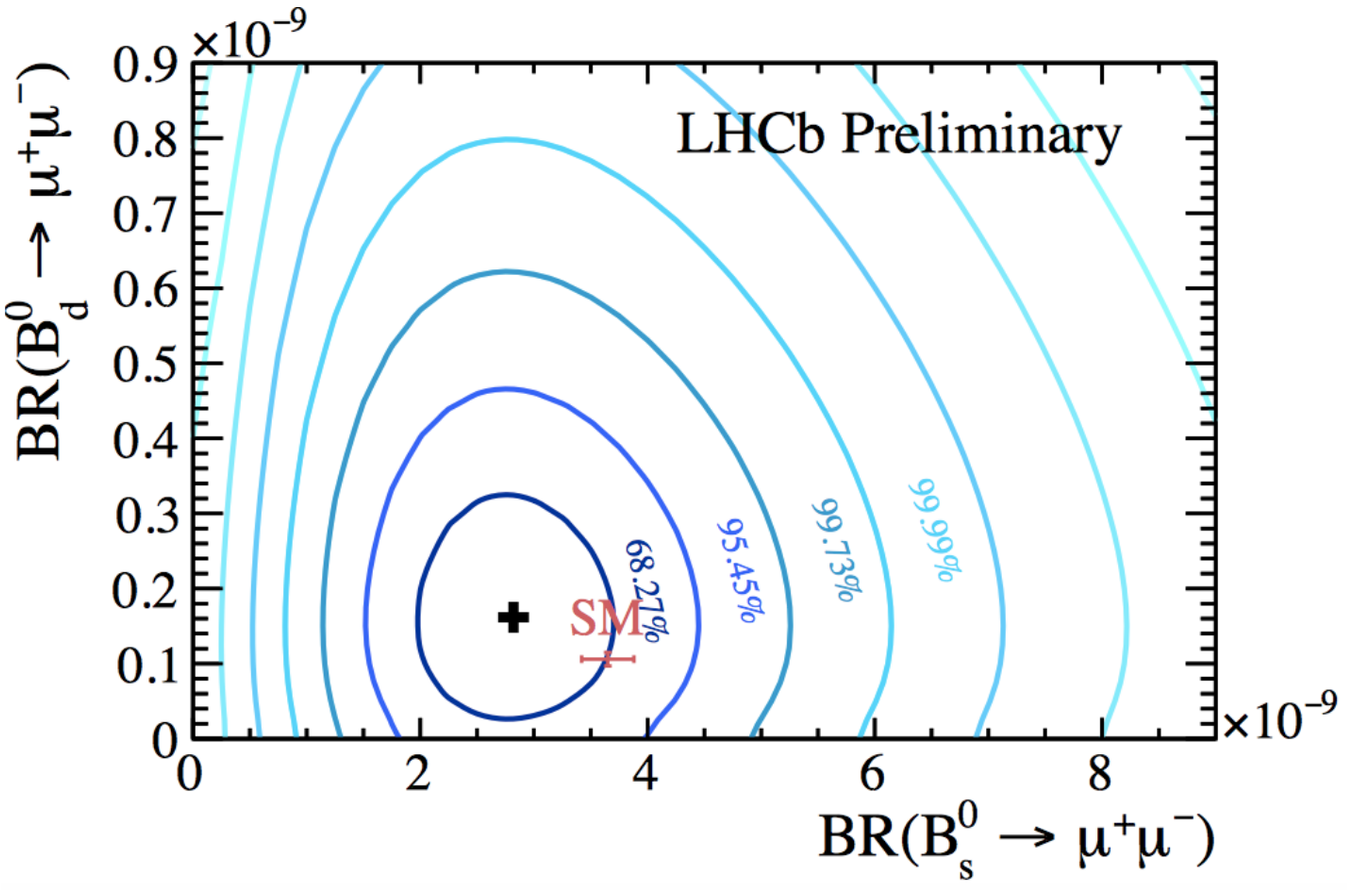
Observation of $B_s^0 \to \mu^+\mu^-$, search of $B^0 \to \mu^+\mu^-$

Run1 & Run1l dataset



NATURE 522, 68-72 (04 JUNE 2015)

+ ATLAS [EPJ C76 (2016) 9, 513]



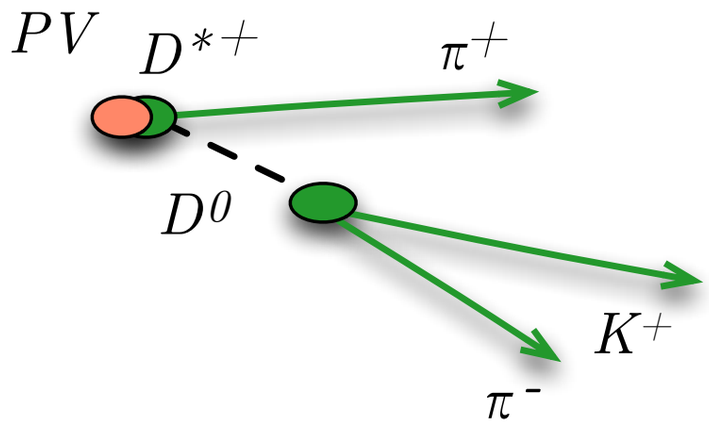
LHCB-PAPER-2017-001

LHC Seminar 14.02.2017, F.Archilli

Turbo and **Turbo++**

new 2016

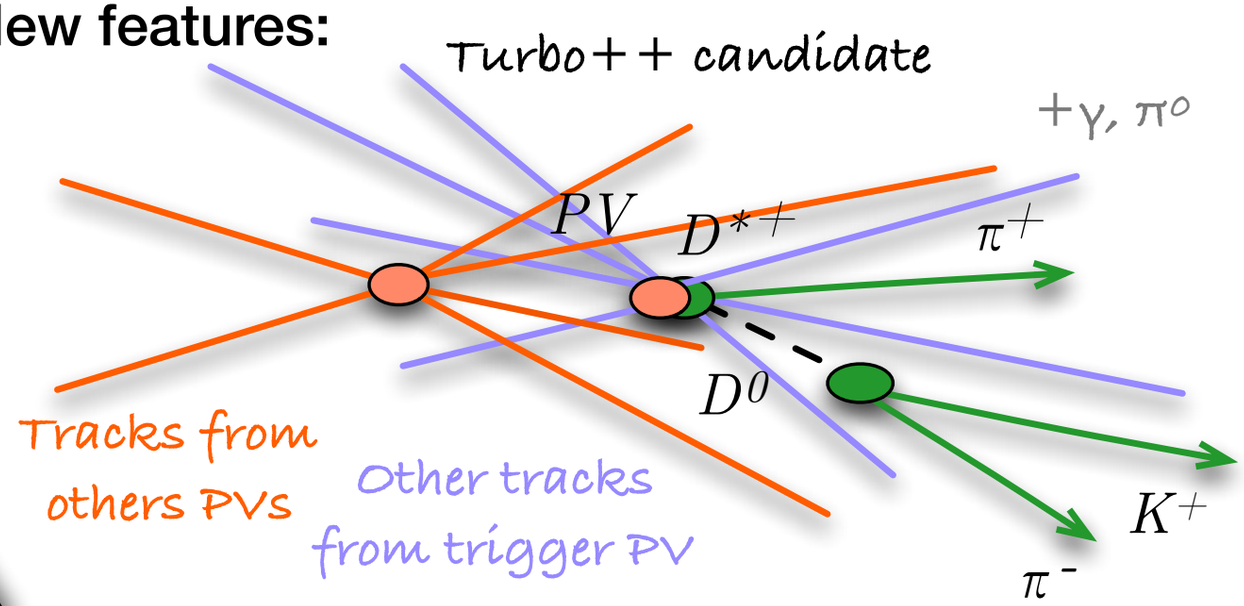
Turbo candidate



- Saves only objects selected by the trigger
- Output limited to a standard set of variables

New features:

Turbo++ candidate



- Allows other reconstructed objects from the event to be saved, in addition to those selected by the trigger
- Allows to create and save new variables (i.e. hits in a cone region around the track)

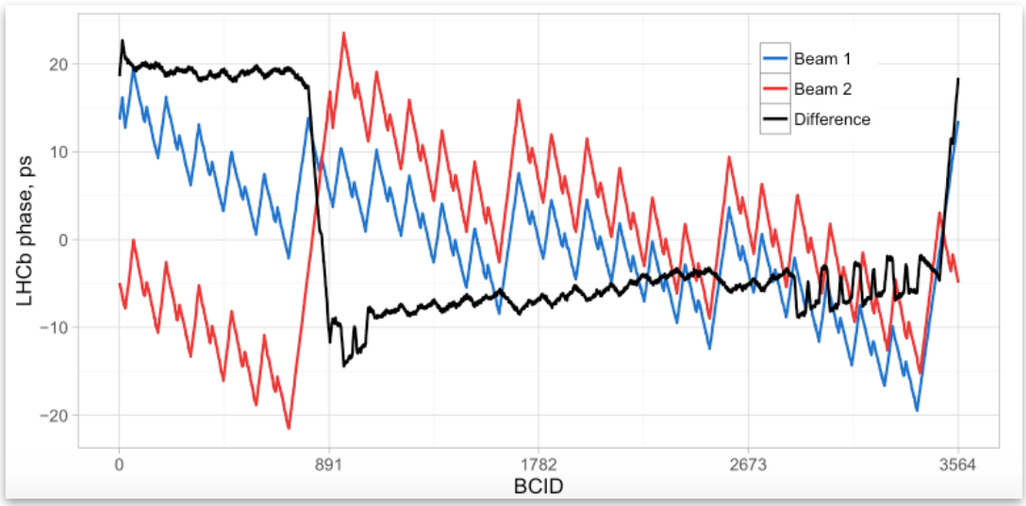
- **Aim:** according to the physics channel and desired measurement, choose how much (and which variables) of the event need to be saved

Even more analyses can be done on the trigger output

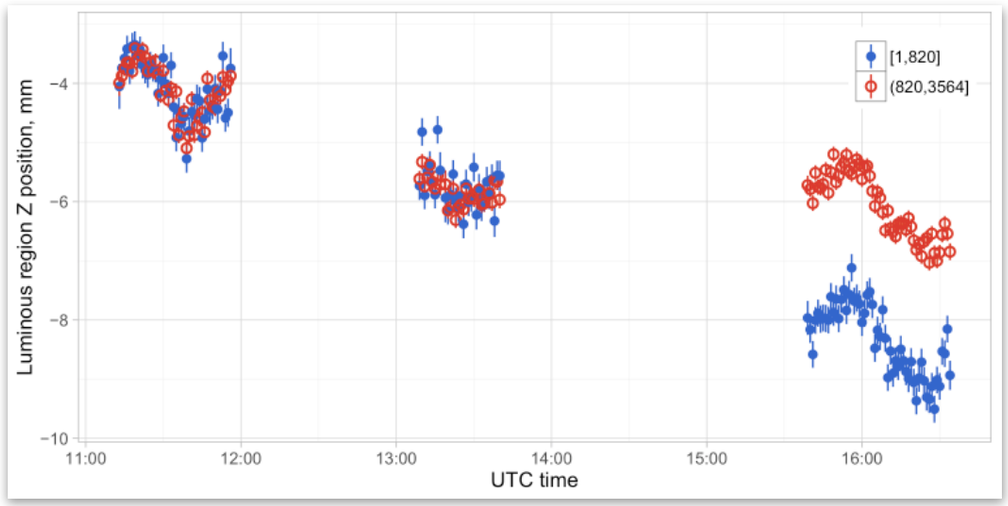
Out of the 420 HLT2 lines in 2016 physics programme, 150 choose Turbo, ~60 new lines wrt 2015

LHC in 2017

- Number of 13 TeV ***pp* physics days** expected to slightly reduce from 146 in 2016 to 134 in 2017
- Number of **colliding bunche**s in LHCb expected to slightly increase from 2036 in 2016 to 2308 in 2017
- Net expected lumi harvest in 2017 similar to 2016
- "Detuning" scheme of LHC will have marginal impact on LHCb operations.



Study on MD 18 Oct 2016



➢ 2 populations of z positions: probably OK, preference for time modulation <~100ps

➢ Smearing tracker drift time ~0.1ns: OK (time-per-track resolution of 0.55ns)