LHCb Status Report

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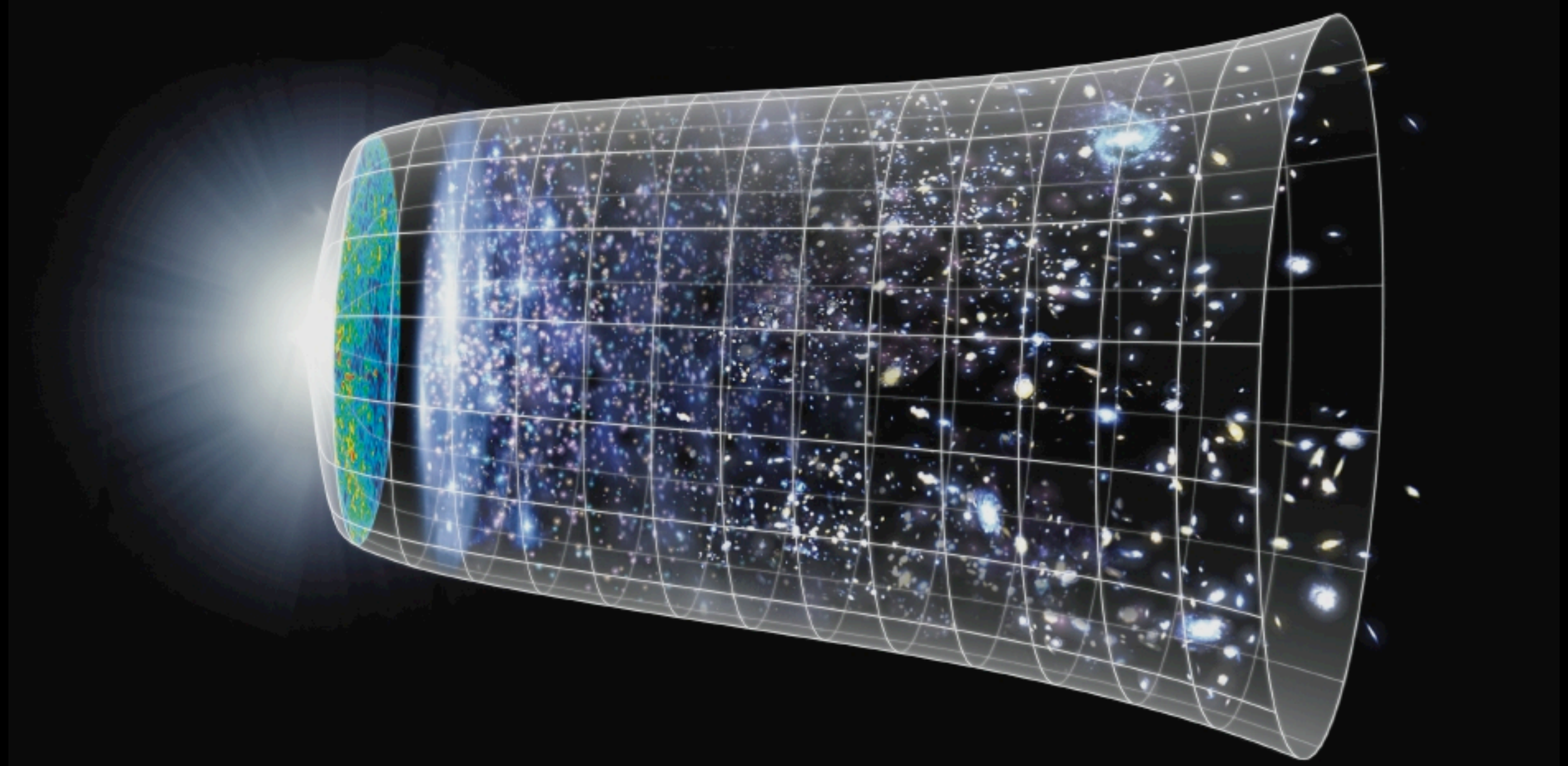
on behalf of the LHCb Collaboration
Department of Physics & Laboratory for Nuclear Science
Massachusetts Institute of Technology

LHCC Open Session
June 4, 2014

Outline

- Brief summary of LHCb papers submitted since March.
- LS1 activities
- Preparation for Run 2.
- Looking forward to Run 3.

The LHCb physics program has been expanding rapidly over the past few years and now includes vibrant activity in exotic spectroscopy, pA collisions, and many other areas that were not part of our original “road map”.



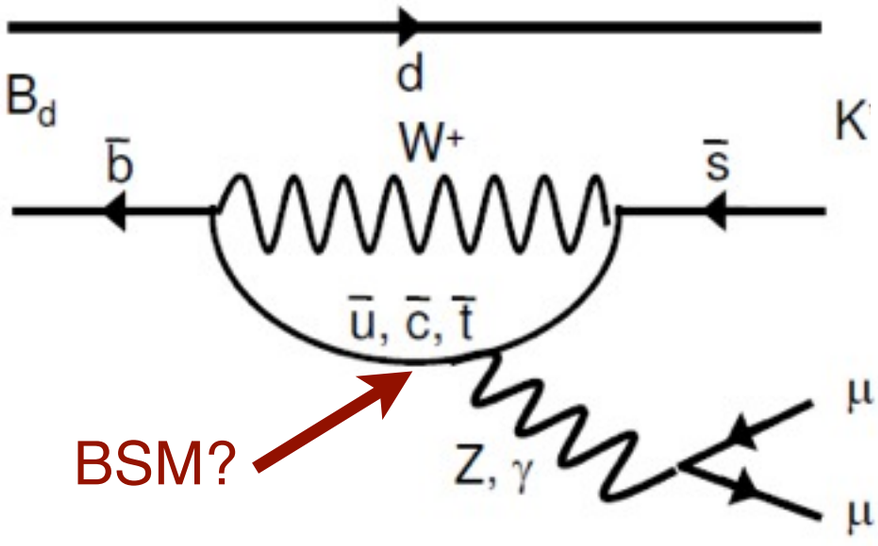
We have submitted 17 papers for publication since the previous LHCC meeting in March. First I will summarize (some of) these recent results ...

Rare & CP-Violating Decays

Excellent laboratories to search for BSM by performing precision tests of the SM. Many of these “indirect” searches are sensitive to mass scales higher than has been accessible to date in “direct” searches.

LHCb-PAPER-2014-006

The b→s penguin decays are sensitive to BSM contributions in the loop:



Rates @ large q^2 lower than SM. Some authors explain this as a ~5 TeV Z' ... but could also be unexpected QCD effect.

updated to 3/fb

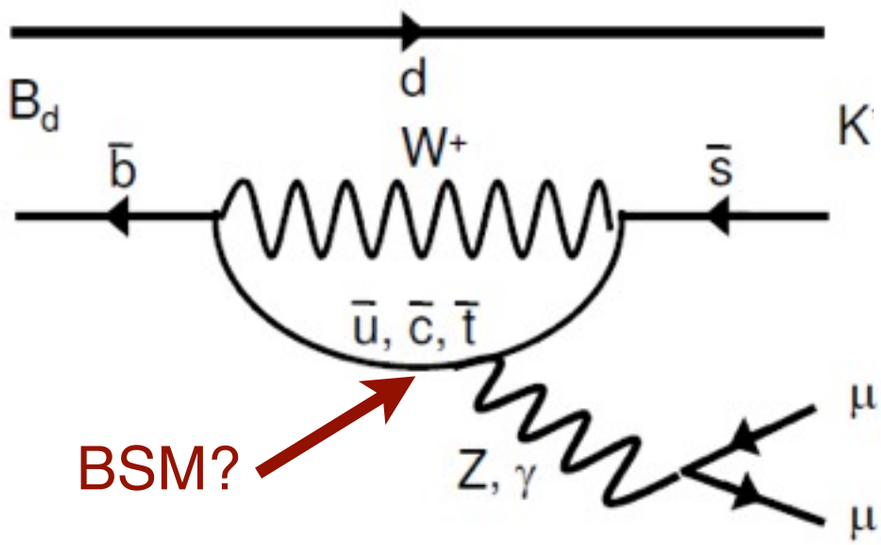
Decay mode	Measurement	Prediction
$B^+ \to K^+\mu^+\mu^-$	$8.5 \pm 0.3 \pm 0.4$	10.7 ± 1.2
$B^0 \to K^0\mu^+\mu^-$	$6.7 \pm 1.1 \pm 0.4$	9.8 ± 1.0
$B^+ \to K^{*+}\mu^+\mu^-$	$15.8\ ^{+3.2}_{-2.9} \pm 1.1$	26.8 ± 3.6

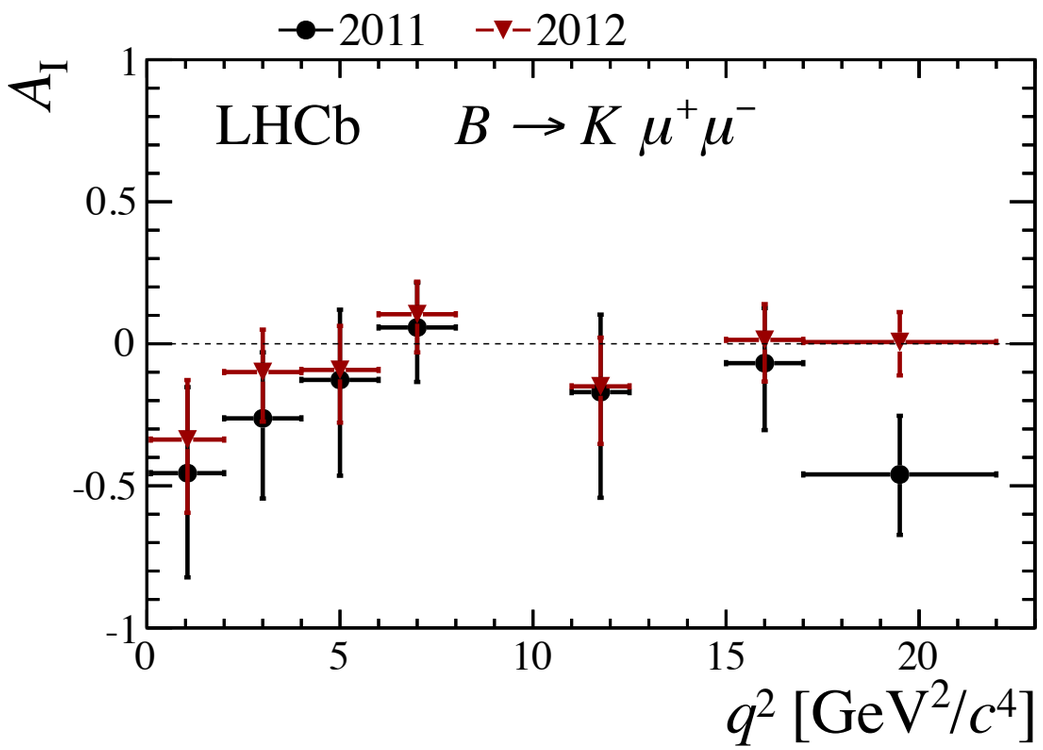
expect update soon

Several important measurements still to be updated to 3/fb so experimental picture will become shaper soon. Hopefully theory picture does as well.

LHCb-PAPER-2014-006

The b→s penguin decays are sensitive to BSM contributions in the loop:

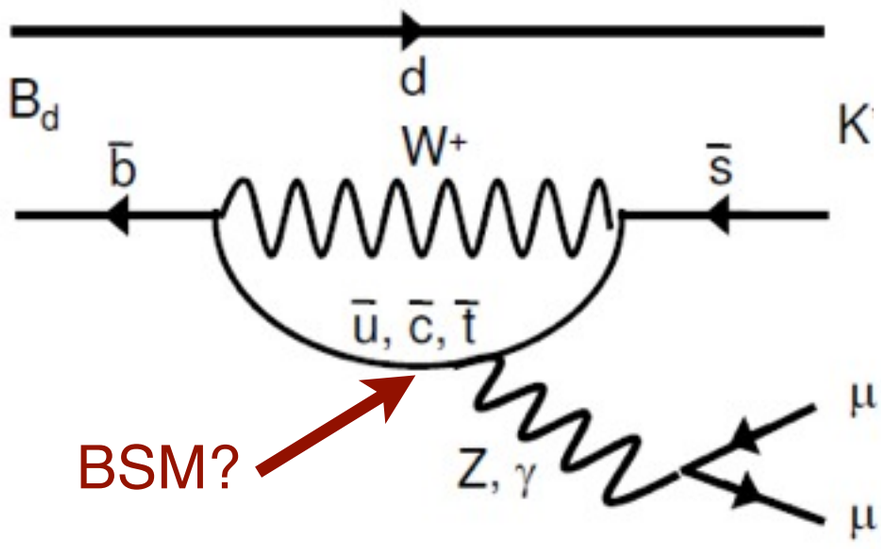




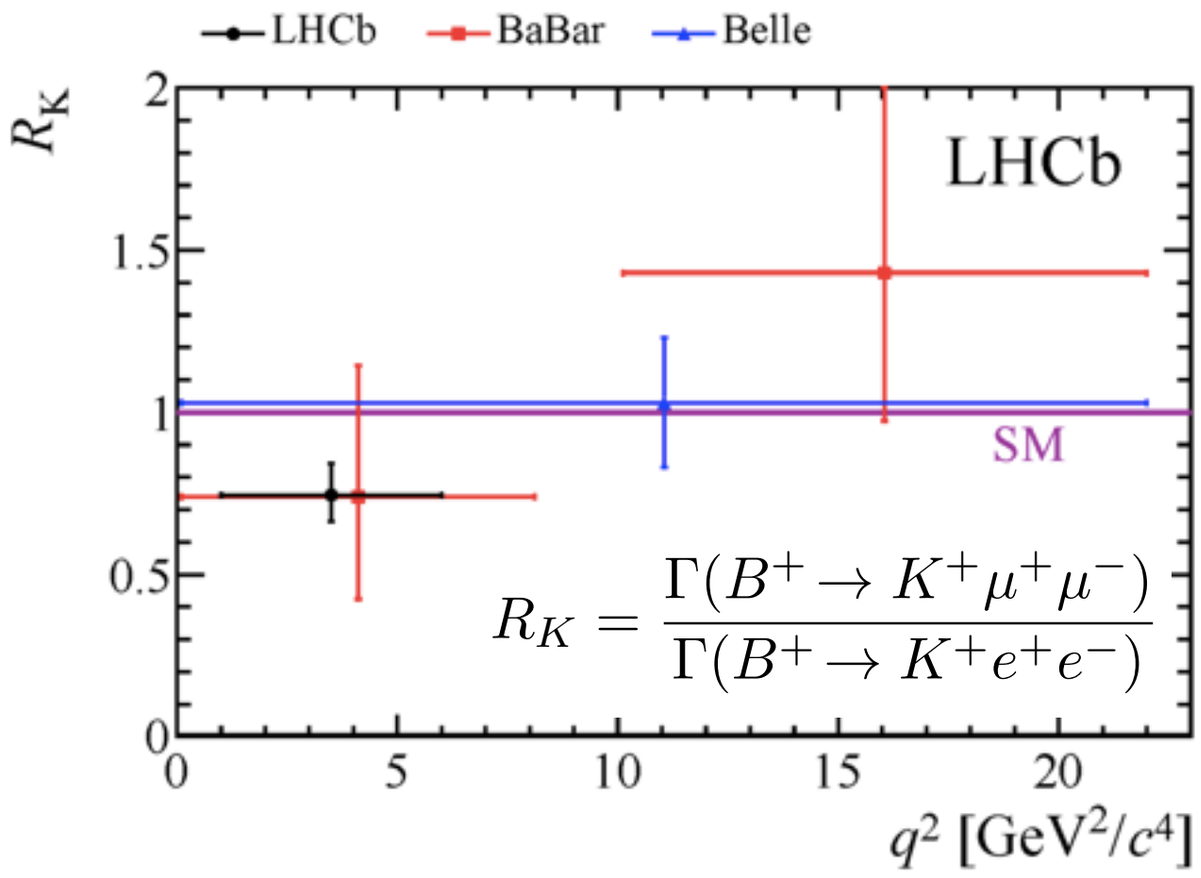
New isospin asymmetry results are consistent with the SM (they are also consistent with our previous results) as are angular observables in LHCb-PAPER-2014-007 (K*μμ updated angular observables soon).

Lepton Universality

The b→s penguin decays are sensitive to BSM contributions in the loop:



LHCb-PAPER-2014-024 (upcoming)

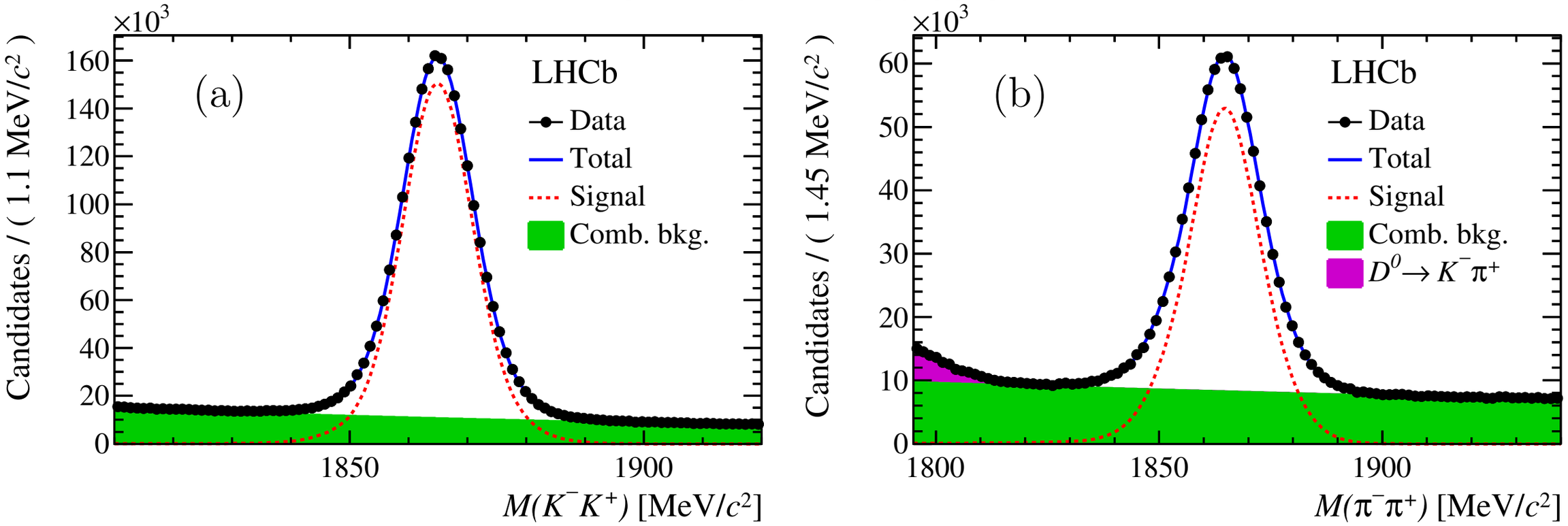


$$R_K = 0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{sys})$$

Expect something very close to one in the SM (result about 2.5σ away).

CP violation in D^0 decays tagged in semileptonic B decays:

2011+2012 LHCb data



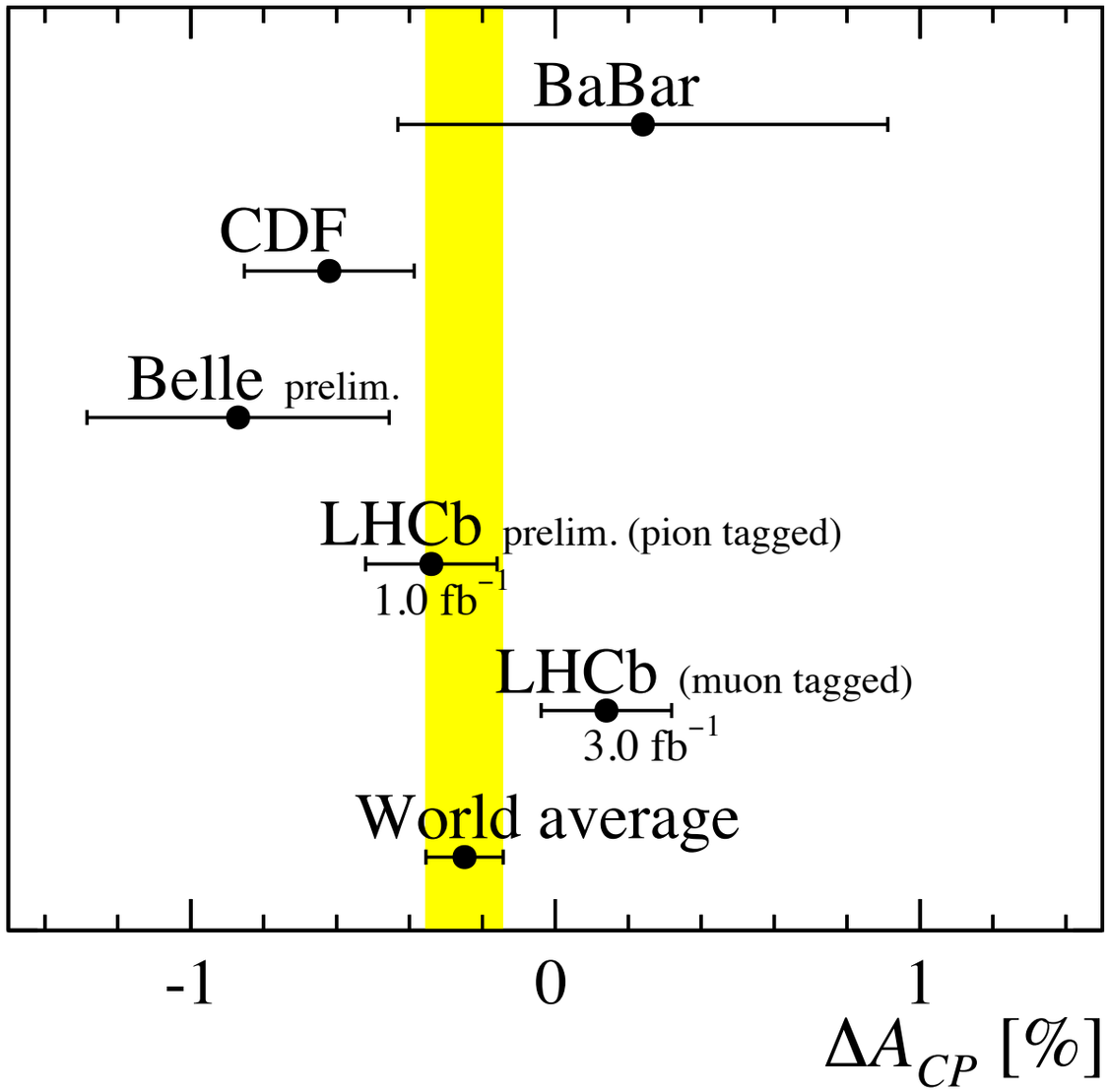
$$\Delta A_{CP} = A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+) = (+0.14 \pm 0.16\,(\text{stat}) \pm 0.08\,(\text{syst}))\% \ .$$

$$A_{CP}(K^-K^+) = (-0.06 \pm 0.15\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$$

$$A_{CP}(\pi^-\pi^+) = (-0.20 \pm 0.19\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$$

LHCb results are the most precise to date and show no significant evidence of CP violation (consistent with SM expectations).

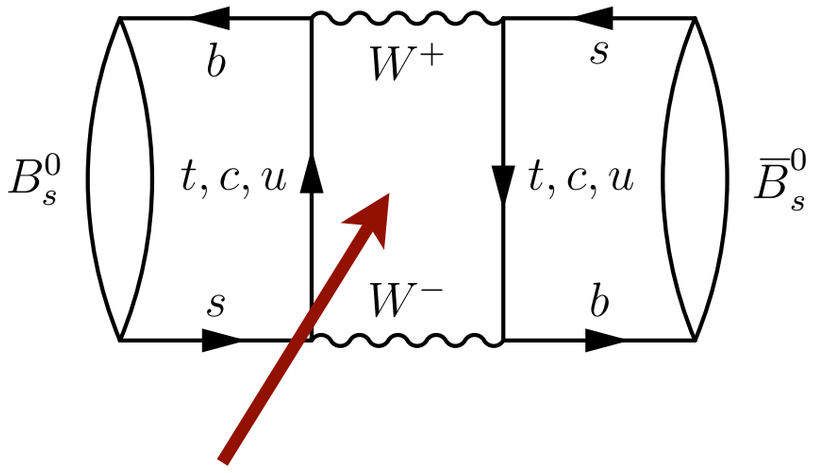
Summary of the World's data:



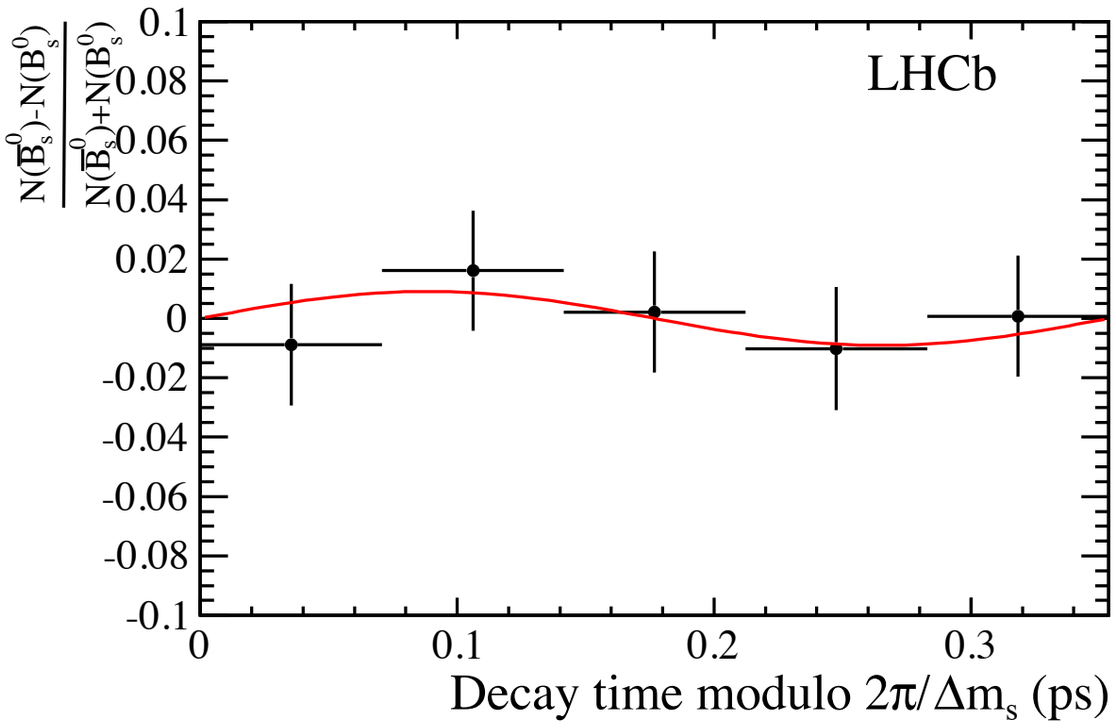
LHCb-PAPER-2014-019

Precision measurement of the B_s mixing phase ϕ_s using $B_s \to J/\Psi\pi\pi$

A time-dependent amplitude analysis is used to determine ϕ_s



2011+2012 data



Obtain $\phi s = 70 \pm 68 \pm 8$ mrad which is the most precise for this decay mode, c.f. $\phi s = 70 \pm 90 \pm 10$ mrad from 1/fb of $B_s \to J/\Psi KK$ (SM: -36.3±1.6 mrad).

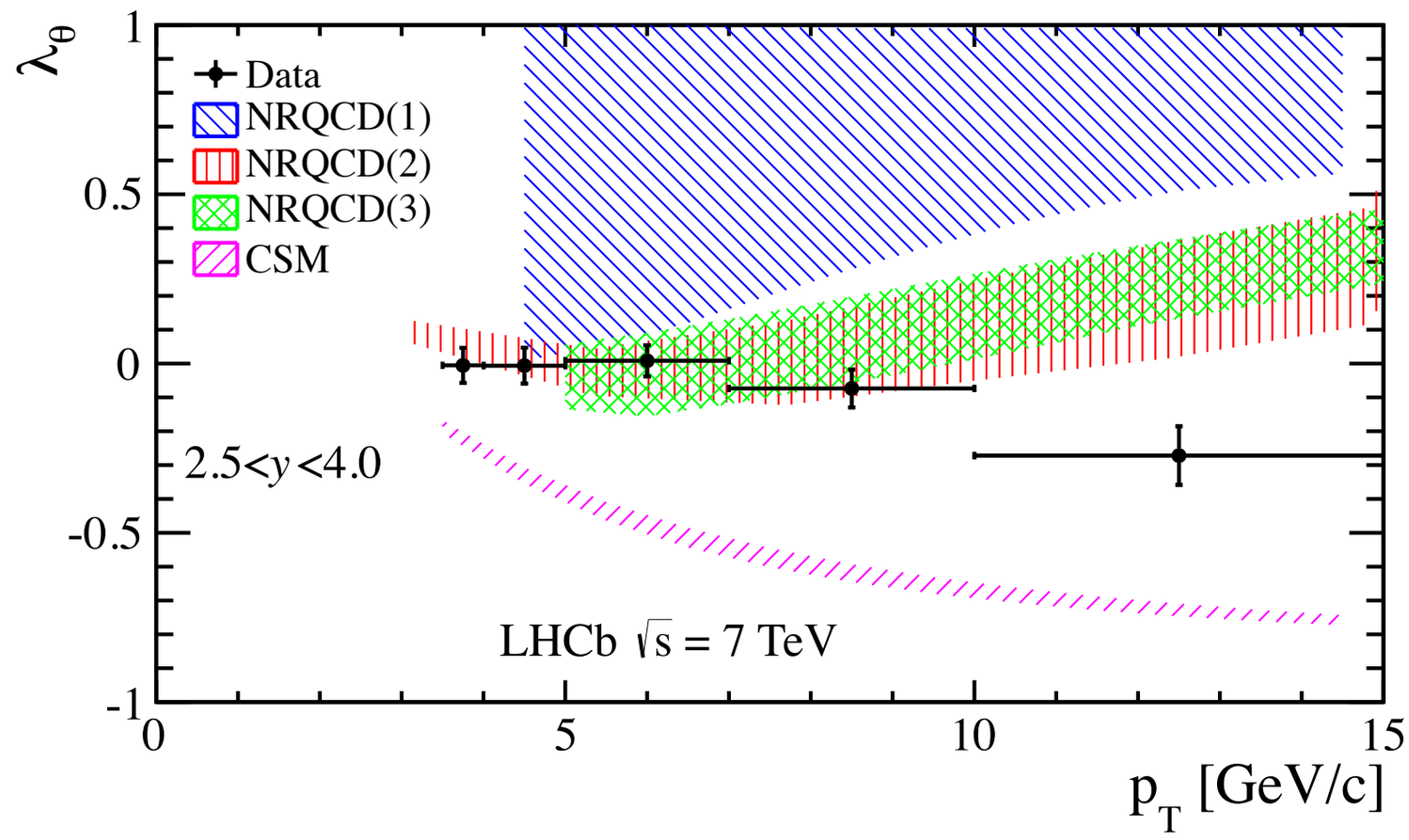
Production Measurements

Useful for testing fragmentation, hadronization and for improving MC generators. Production quantities often required as input for BSM searches. LHCb is now also studying cold nuclear matter effects in p-Pb.

LHCb-PAPER-2013-067

Theoretical models fail to reproduce both the cross section and polarization of heavy quarkonium at hadron colliders.

2011 LHCb data: ψ(2S) polarization

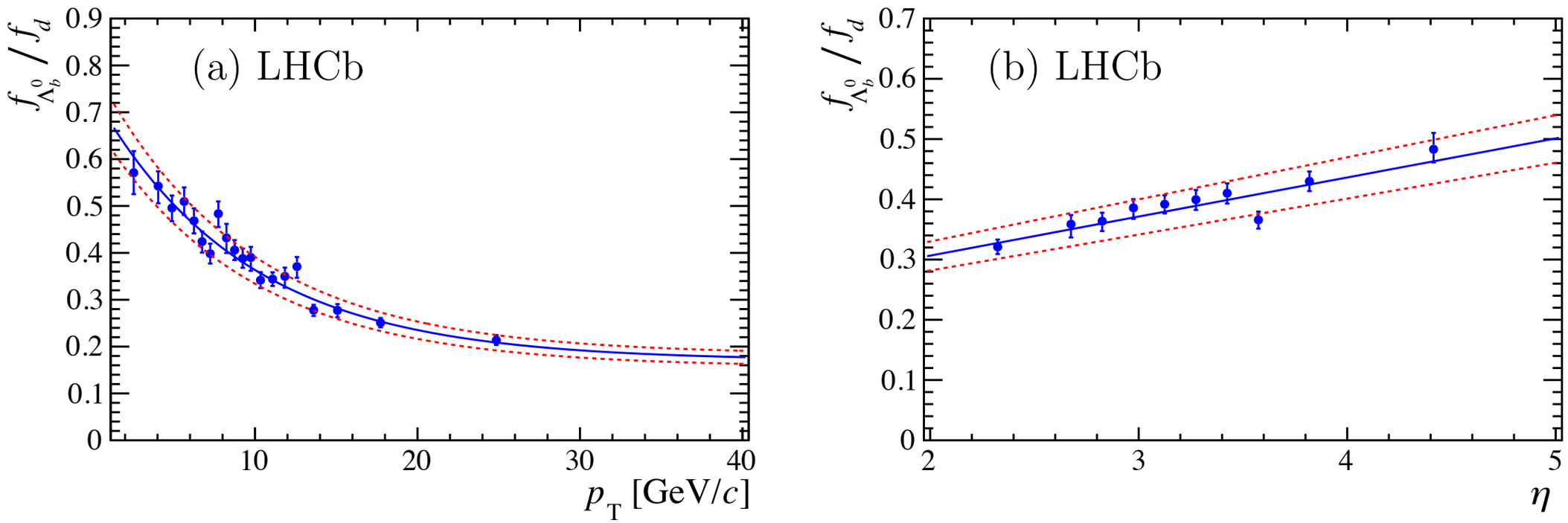


LHCb results (small polarization everywhere) do not agree with theory.

LHCb-PAPER-2014-004

Study of kinematic dependence of beauty baryon production:

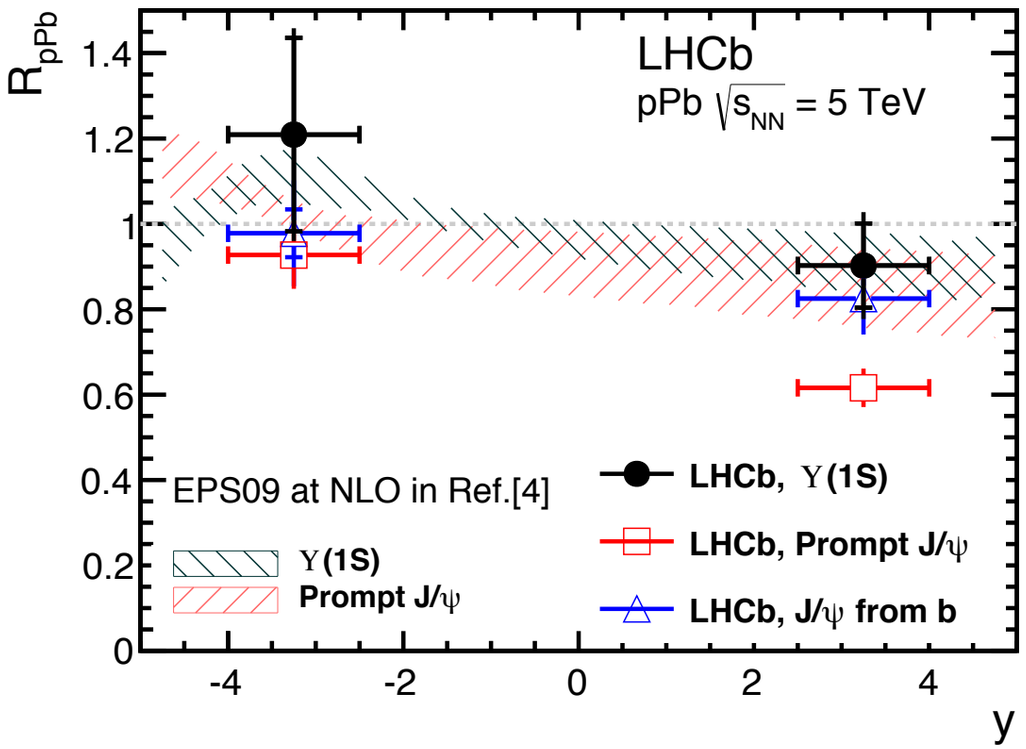
2011 LHCb data

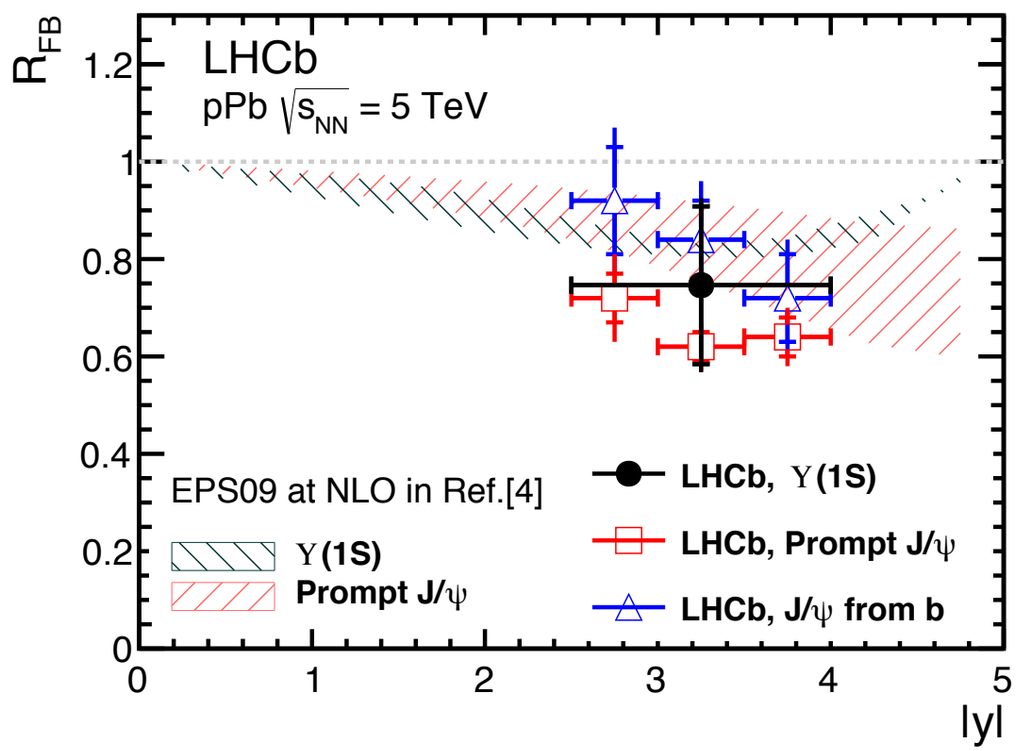


These are the most precise measurements to date of the PT and η dependence of b-baryon production.

LHCb-PAPER-2014-015

Study of cold nuclear matter effects in p-Pb collisions:





LHCb results agree with theory predictions.

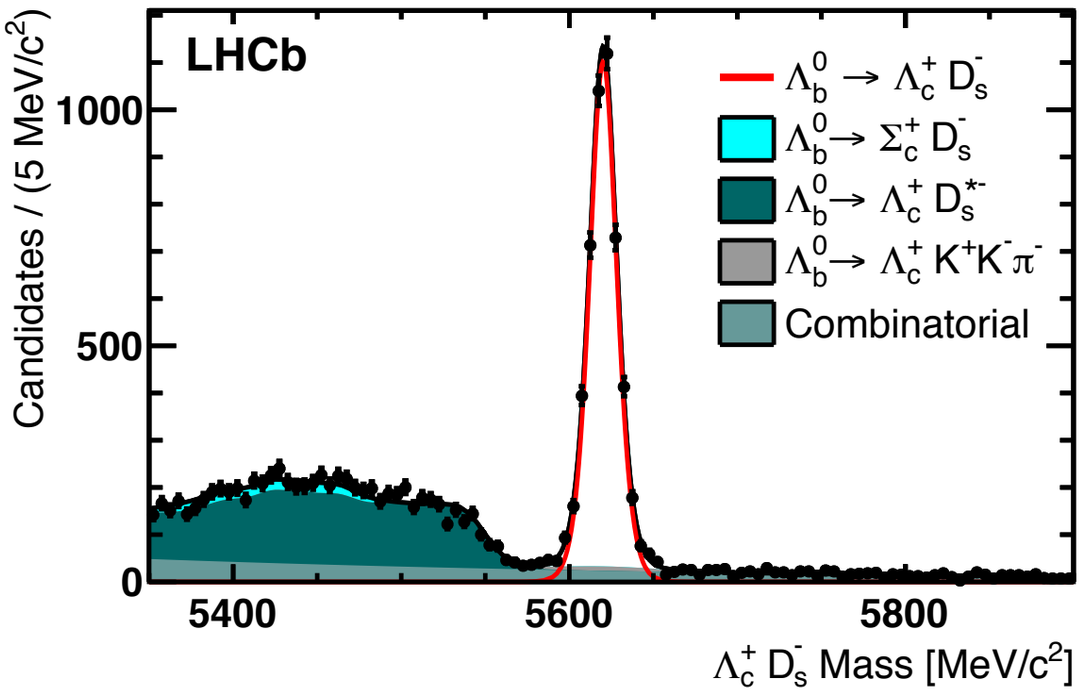
Properties of Beauty Hadrons

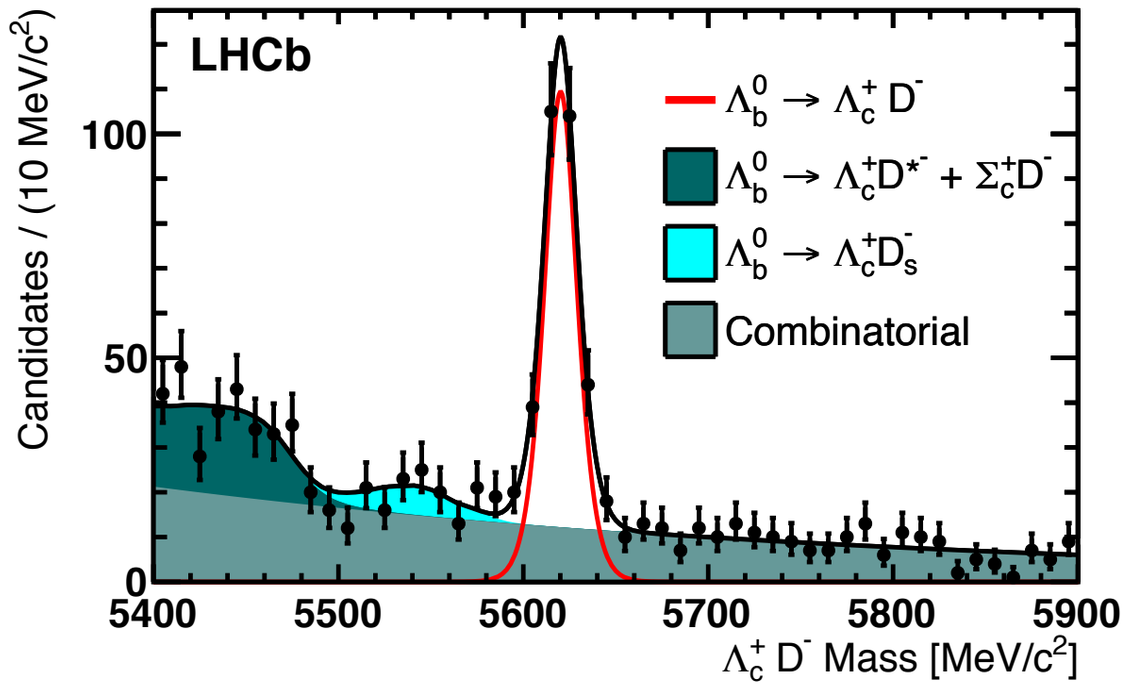
Tests of non-perturbative QCD and QCD factorization. Hadron masses and lifetimes are important inputs to QCD models, which in turn are important for BSM searches.

LHCb-PAPER-2014-002

First observation of decays of beauty baryons into pairs of charm hadrons:

2011+2012 LHCb data: $\Lambda_b \to \Lambda_c D_{(s)}$

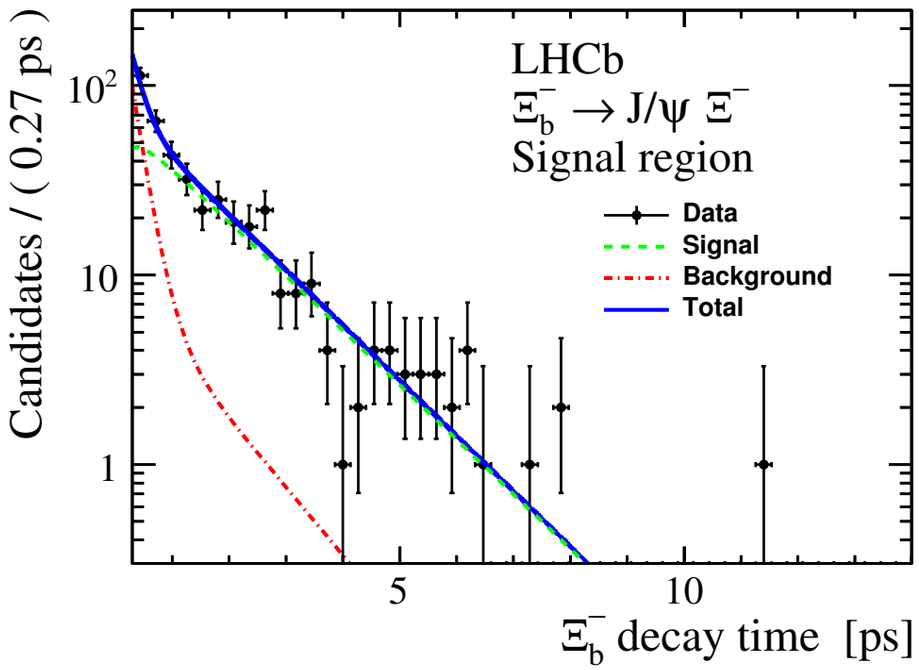


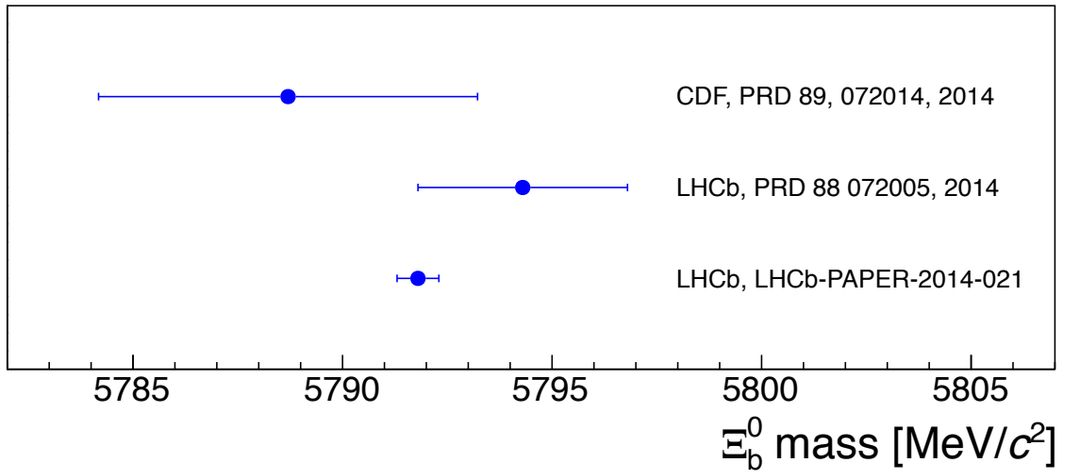


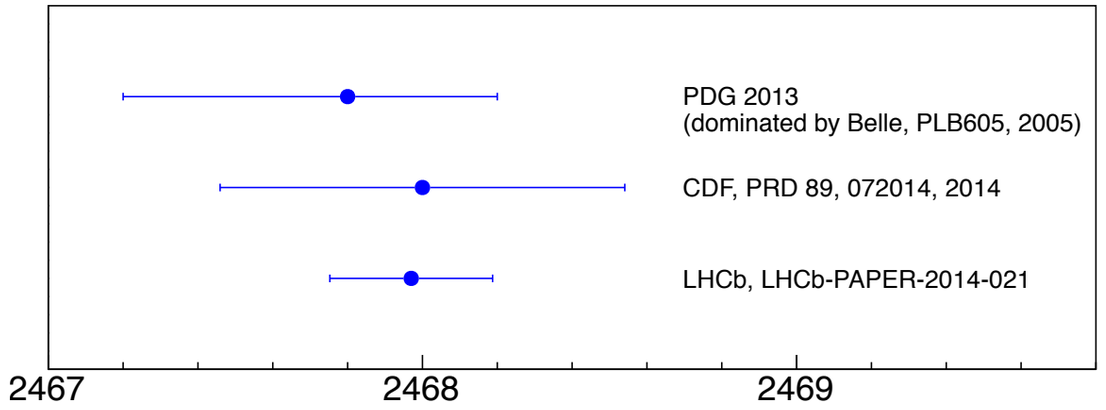
Most precise measurement of any beauty baryon mass (also improves other b baryon masses measured relative to Λb). Also measured several decay rate ratios useful for testing QCD factorization (results agree with factorization).

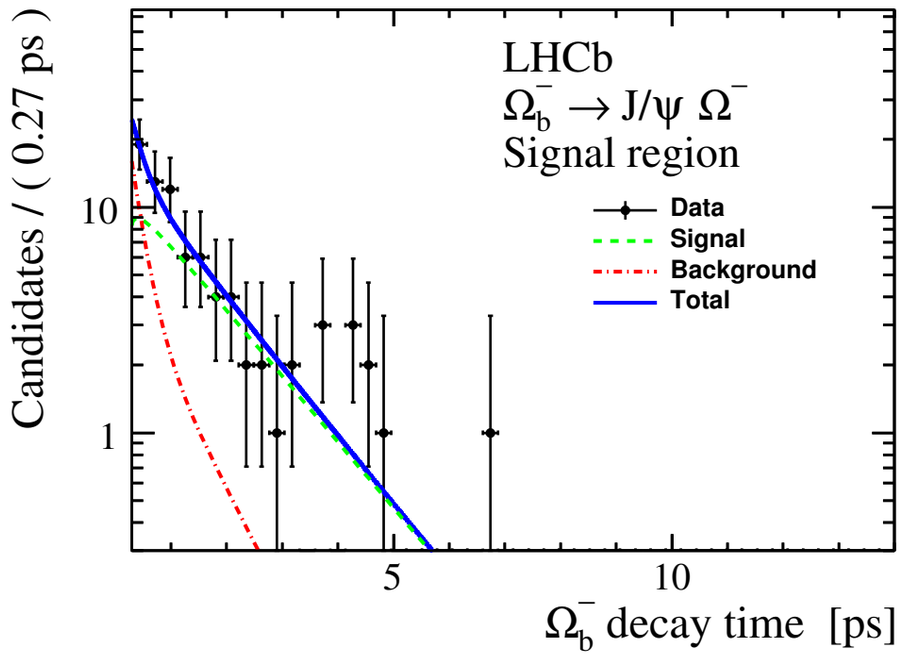
LHCb-PAPER-2014-0(10,21)

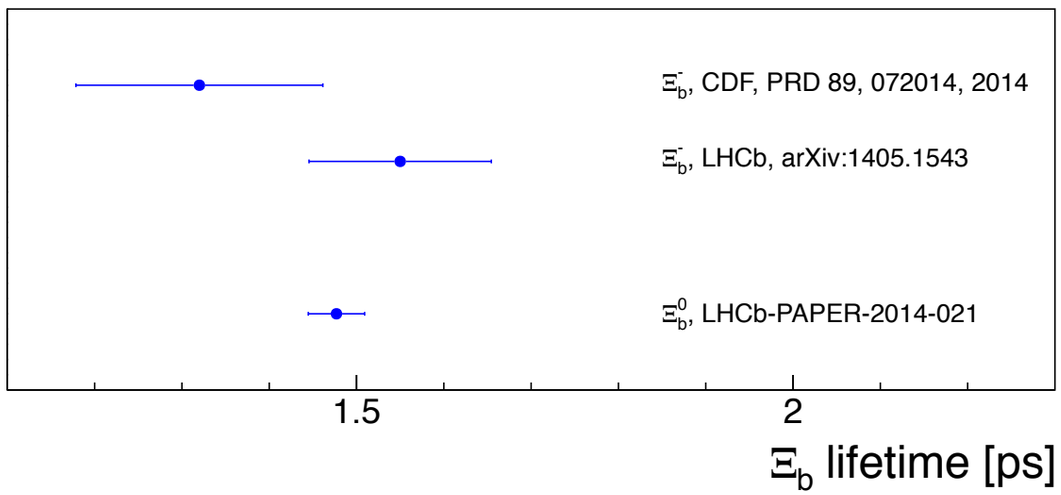
Precision studies of the Ξ_b, Ξ_c and Ω_b baryons:











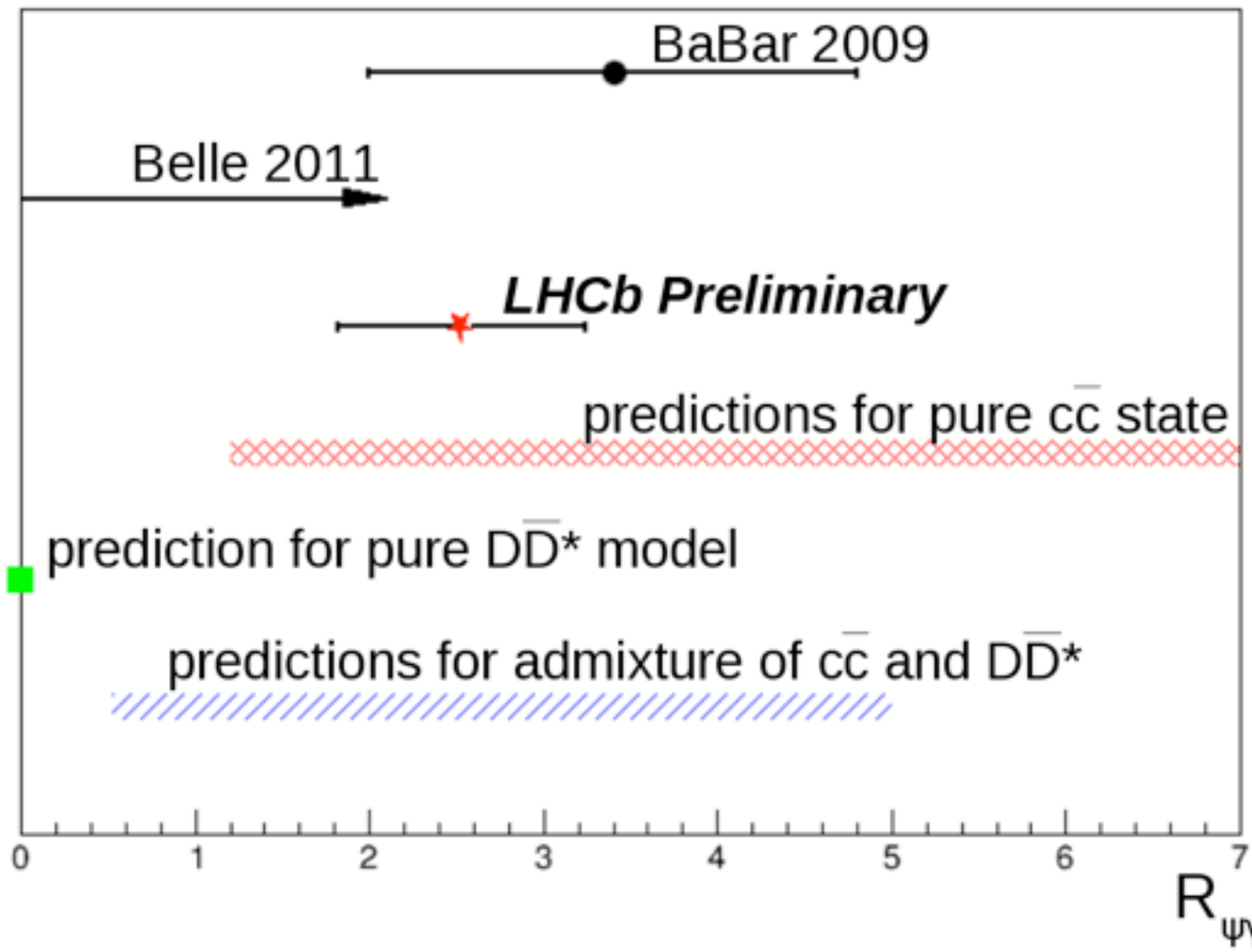
Exotic Spectroscopy

“Baryons can now be constructed from quarks using the combinations qqq, qqq$\bar{q}$q, etc, while mesons are made out of q$\bar{q}$, q$\bar{q}$q$\bar{q}$, etc.” --Gell Mann. QCD phenomenology is still not well understood 50 years later.

LHCb-PAPER-2014-008

The ratio $\Gamma(X\to\psi(2S)\gamma)/\Gamma(X\to J/\psi\gamma)$ is a good probe of the internal structure of the exotic X(3872) particle.

2011+2012 LHCb data



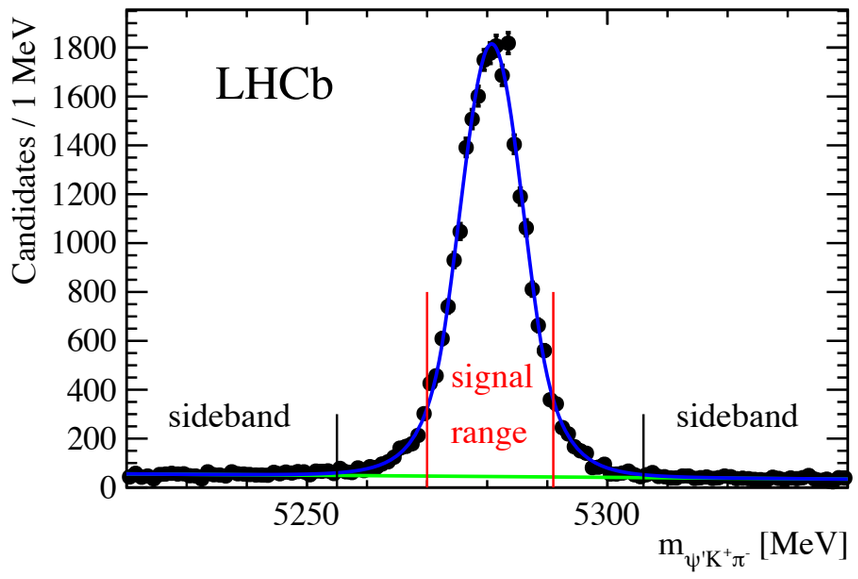
M(X) = 3871.68±0.17 MeV
M(D*)+M(D)=3871.85±0.20 MeV.

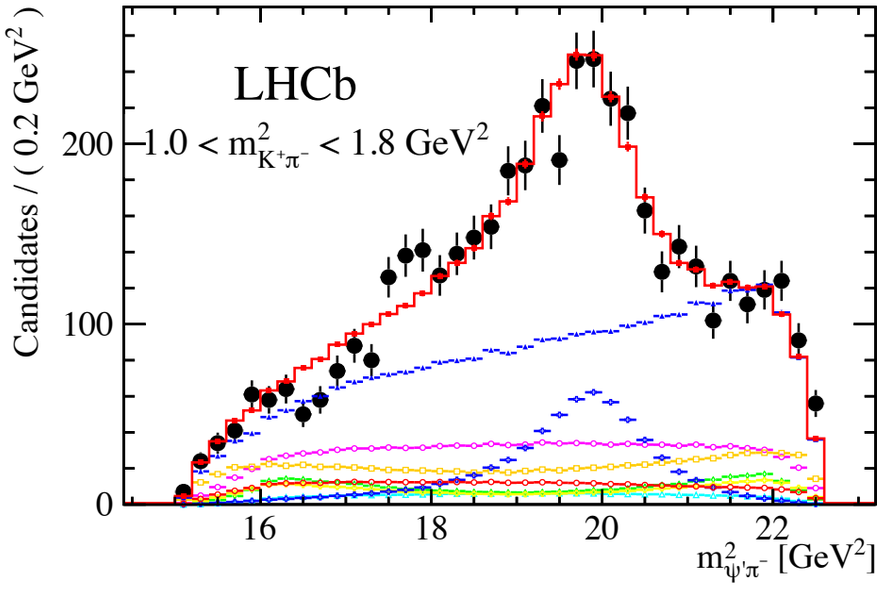
LHCb result rules out the pure D*D molecule interpretation. Unlikely to be a tetraquark (where charged partners?), most likely cc + molecule/cusp.

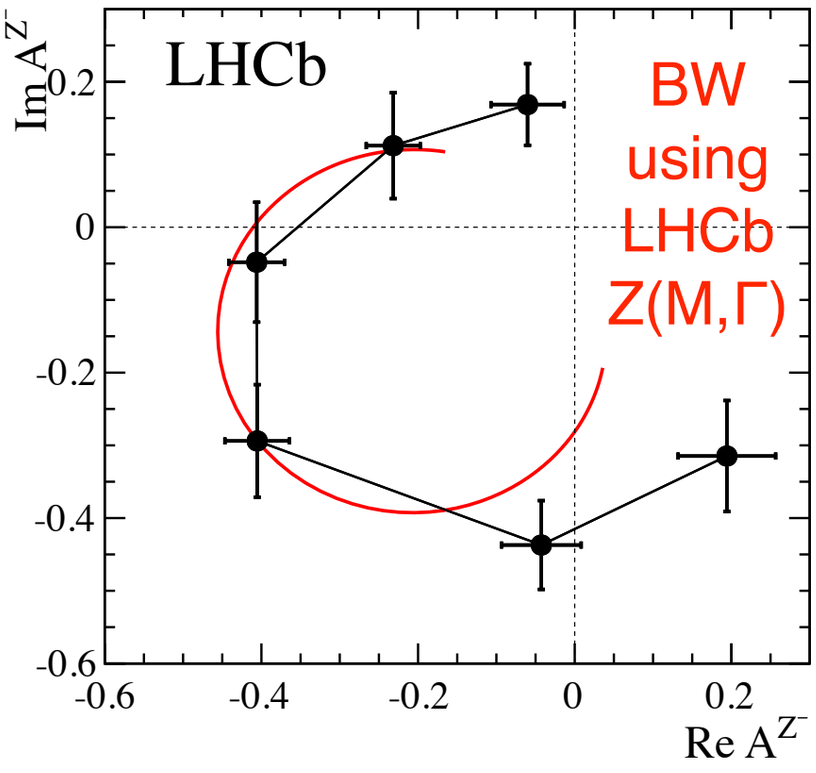
LHCb-PAPER-2014-014

The Z(4430) state was first seen by Belle but not confirmed by BaBar. It has manifestly exotic quark content ... but is it a particle?

2011+2012 LHCb data (12x stats of Belle and BaBar)



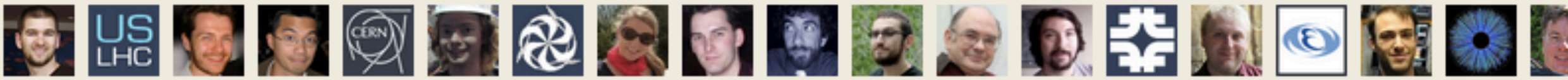




4-D angular analysis determines Z to have $J^P=1^+$.

Model-independent Argand diagram strongly supports 4-quark particle.

Net quark content (and charge) rules out cc, J^P rules out cusp ... 4-quark!



« Grosse moisson de trèfles à quatre feuilles

On the Shoulders of... »

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Major harvest of four-leaf clover

The LHCb Collaboration at CERN has just confirmed the unambiguous observation of a very exotic state, something that looks strangely like a particle being made of four quarks. As exotic as it might be, this particle is sternly called Z(4430)$^-$, which gives its mass at 4430 MeV, roughly four times heavier than a proton, and indicates it is has a negative electric charge. The letter Z shows that it belongs to a strange series of particles that are referred to as XYZ states.

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Quarks bonding differently at LHCb

Time To Open the Gates of Hell? CERN: Large Hadron Collider Discovers 'Very Exotic Matter' That Challenges Traditional Physics! (Must-See Videos)

The Large Hadron Collider beauty collaboration has confirmed the existence of exotic hadron with two quarks, two anti-quarks.

"The last time they fired it up, it was almost openining dimensional portals like a stargate! There were reports that people were seen coming in and out of different dimensions!" —*Hagmann and Hagmann Report*

بازنویسی فیزیک نوین با کشف ذره جدید چهار کوارکی

» سرویس: علمي و فناوري - علم و فناوري جهان

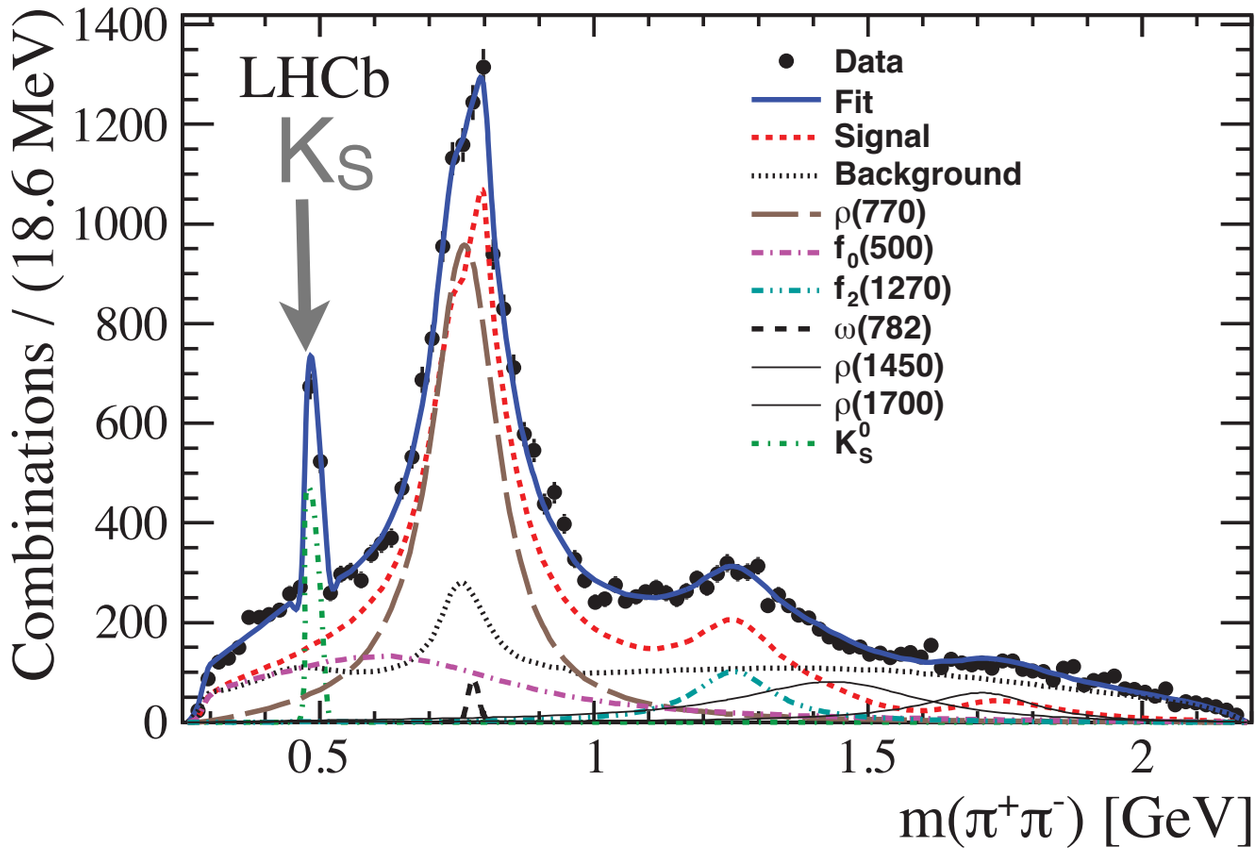
کد خبر: 93012911697
جمعه ۲۹ فروردین ۱۳۹۳ - ۰۹:۰۸

دانشمندان مرکز سرن در سوئیس با استفاده از آشکارساز زیبایی برخورددهنده بزرگ هادرونی(LHCb) وجود یک ذره عجیب را تائید کرده‌اند.

به گزارش سرویس علمی خبرگزاری دانشجویان ایران(ایسنا)، این ذره ملقب به Z(4430) ابتدا در سال 2007 کشف شده بود، اما

Use relative rates of B decays to study internal structure of light-quark states:

4-D amplitude analysis projection:



$$r_\sigma^f = \left(1.1^{+1.2+6.0}_{-0.7-0.7}\right) \times 10^{-2} < 0.098 \quad \text{at } 90\% \text{ C.L}$$

LHCb results rule out the simple tetraquark picture r=1/2 is expected.

Run 2 & 3 Preparation

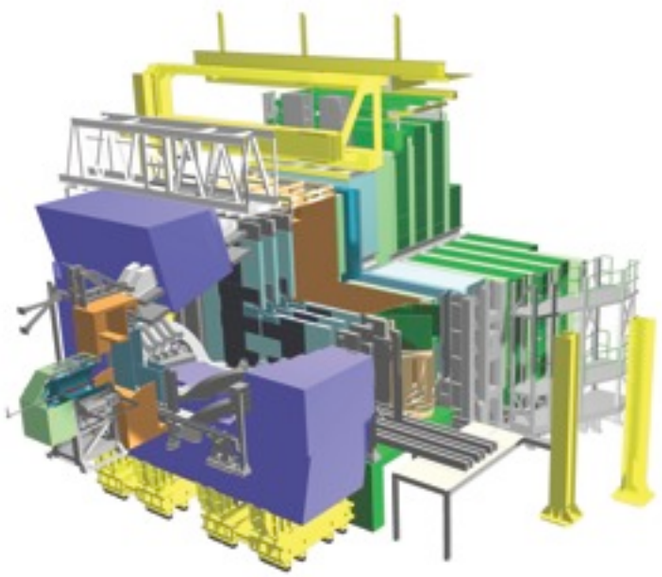
LS1 Status

- Consolidation work on MUON and CALOs in progress.
- RICH 2 A side: some HPDs replaced
- RMS back in place
- Maintenance of mechanics (detector movement) and detector alignment
- Preparation for Upgrade: installation of optical link from Detector to Surface
- Herschel counter installation in the tunnel: in progress
- Dipole magnet tested to nominal current

LS1 program progressing well and LHCb will be ready for startup in Jan 2015

Run I Trigger

LHCb Trigger Group, JINST 8, P04022 [arXiv:1211.3055]



15 MHz

1 MHz

5 kHz

“deferral”

pass

partial reconstruction

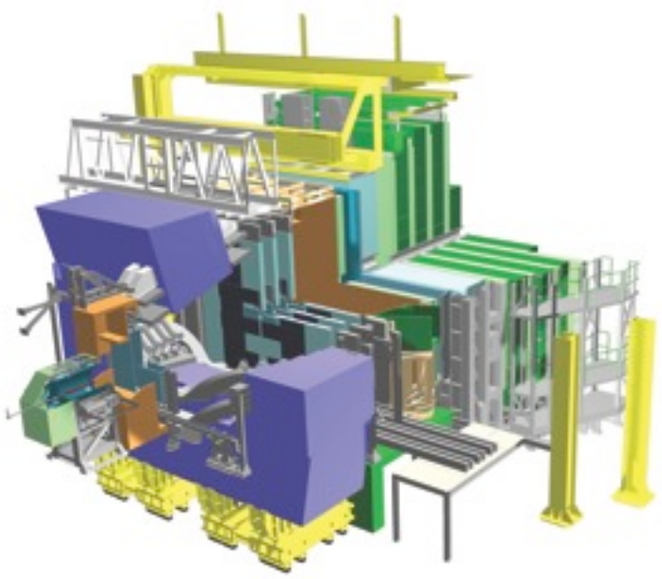
full reconstruction

pass

fail

fail

Run II Trigger



30 MHz

1 MHz

12.5 kHz

partial reconstruction

pass

fail

full reconstruction

pass

fail

Online Calibration

Huge effort towards getting “real time” calibration ready for 2015.

RICH

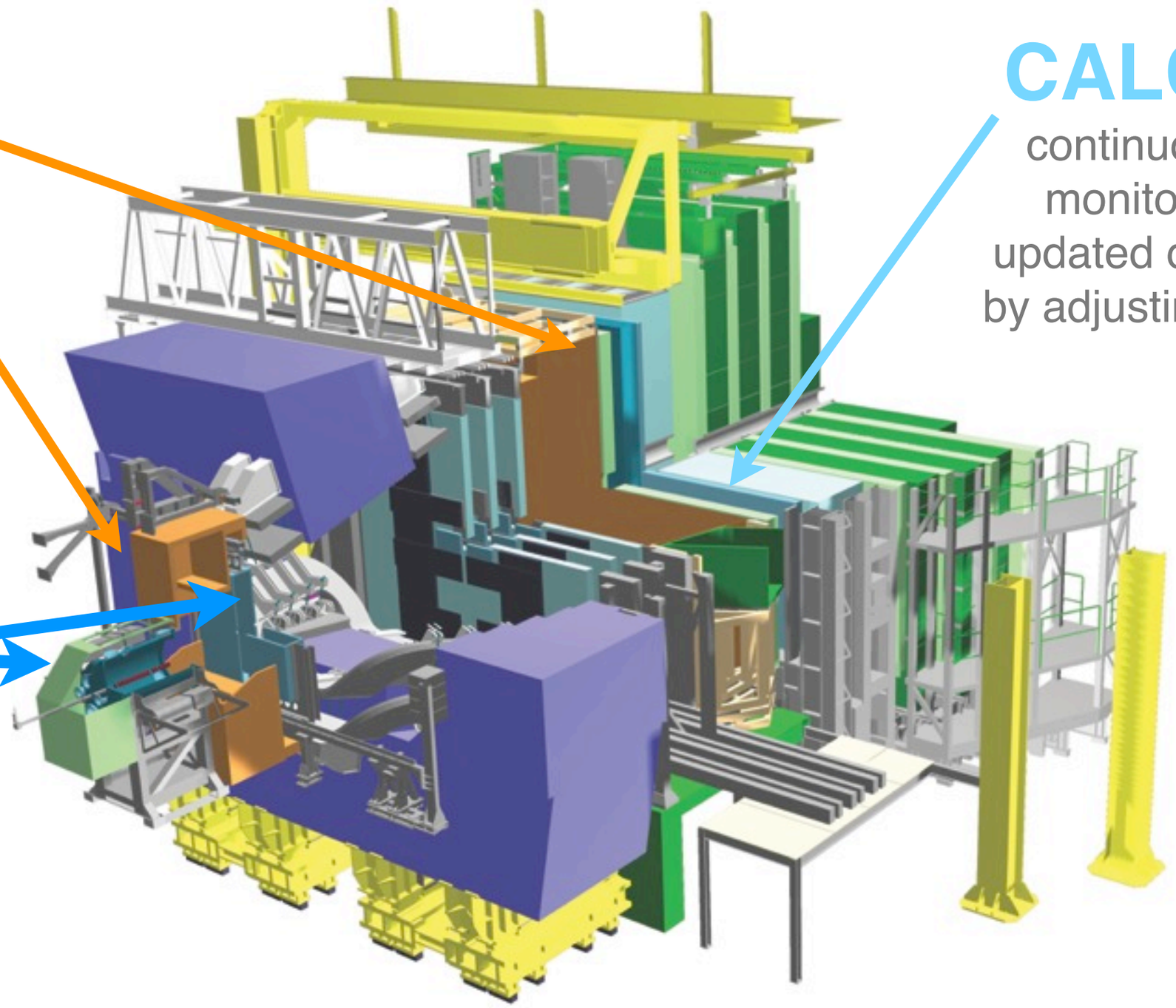
calibrate run-by-run to determine index of refraction, etc.

CALO

continuously monitored/ updated directly by adjusting gain

VELO +Tracker

align fill-by-fill but online update DB when exceed tolerance



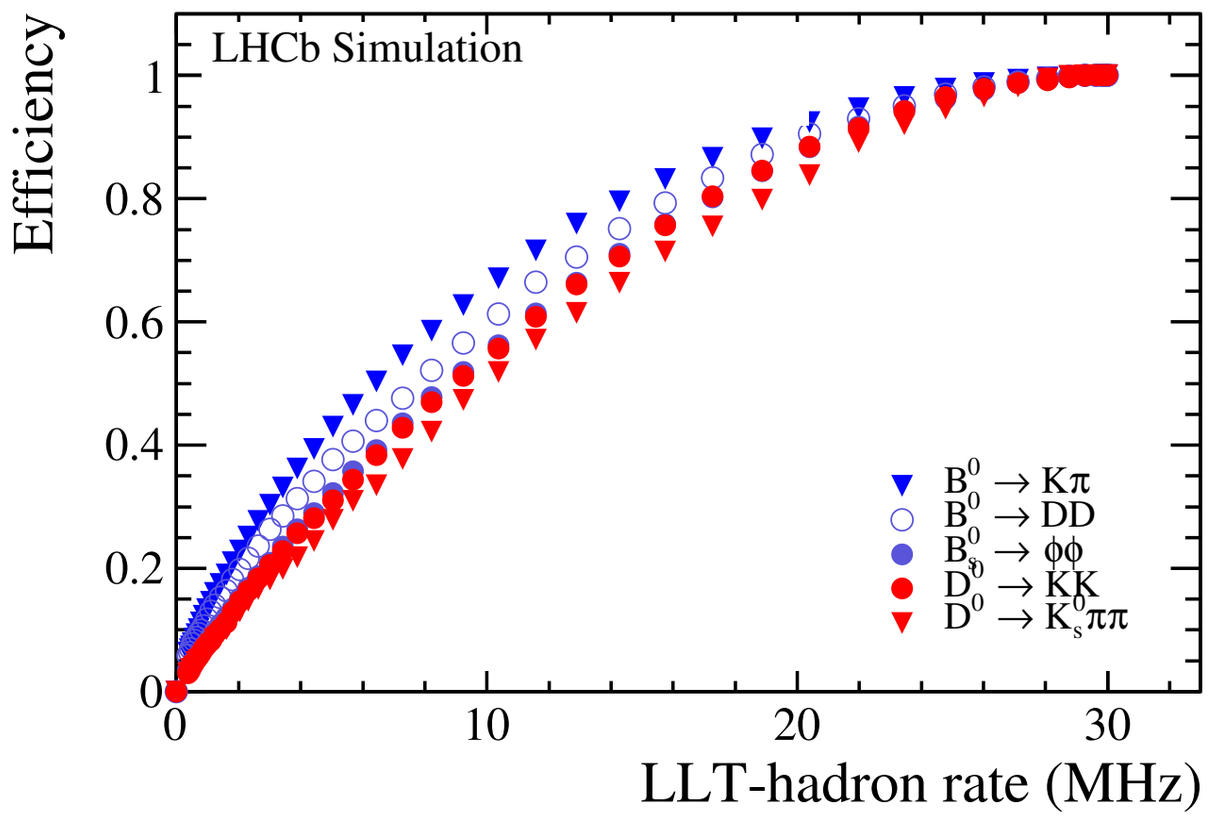
Run III Trigger

LHCb trigger works amazingly well, but the hardware stage is inefficient for many decays and only gets worse at higher luminosity.

LHCb Upgrade:

- Run at 5X Run 1 Lumi.
- $\sigma_{b,c} \sim$ 2X higher @ 14 TeV.

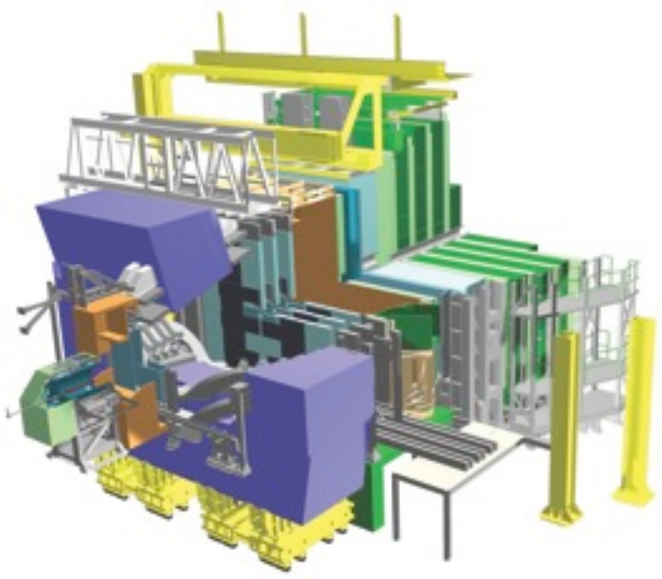
hardware trigger efficiency for hadronic decays in upgrade conditions



Detector upgrade to allow triggerless readout and a full-software trigger.

Run III Trigger

Triggerless readout & full software trigger:



30 MHz

20-100 kHz

full reconstruction

pass

fail

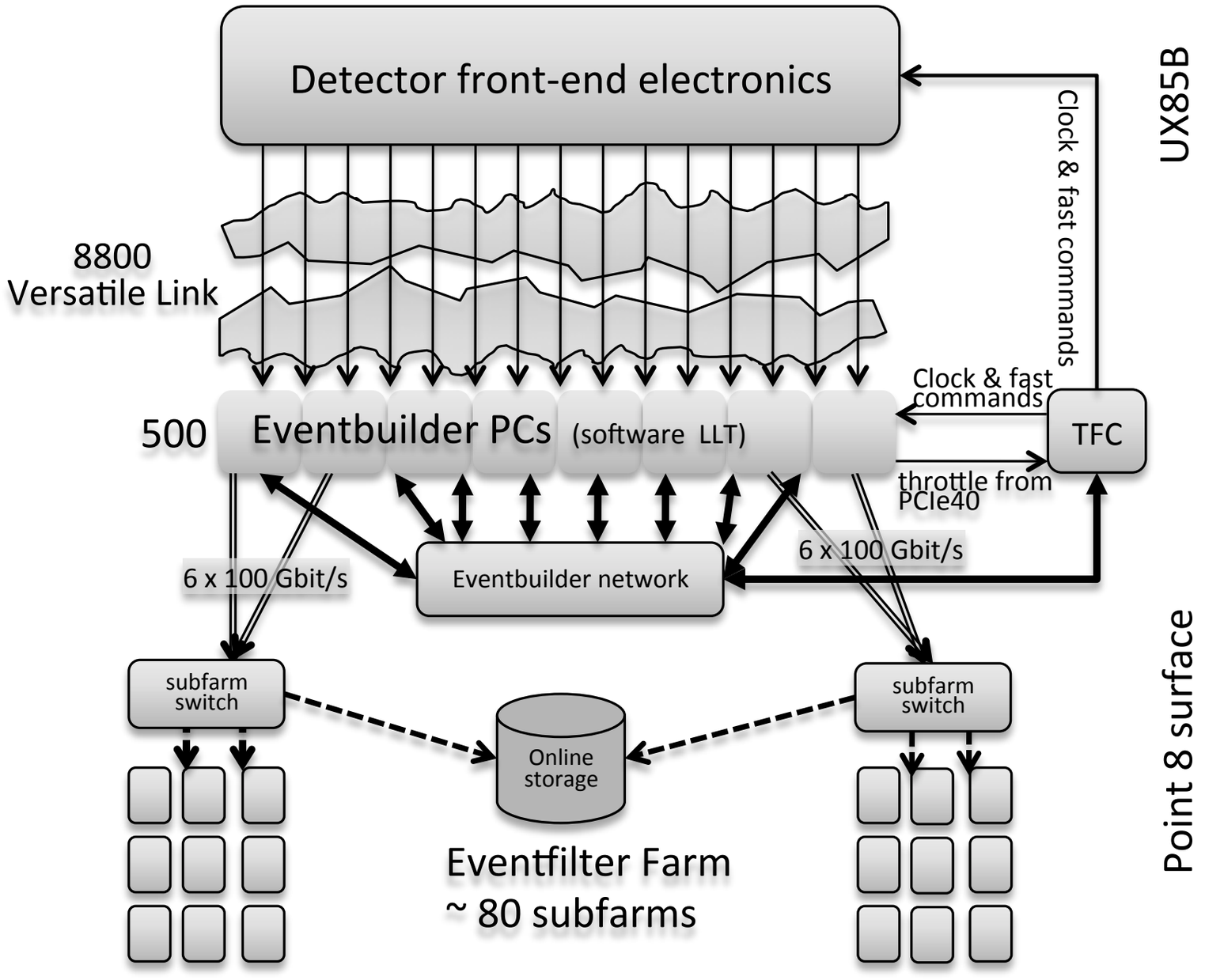
full reconstruction

pass

fail

Run III Online

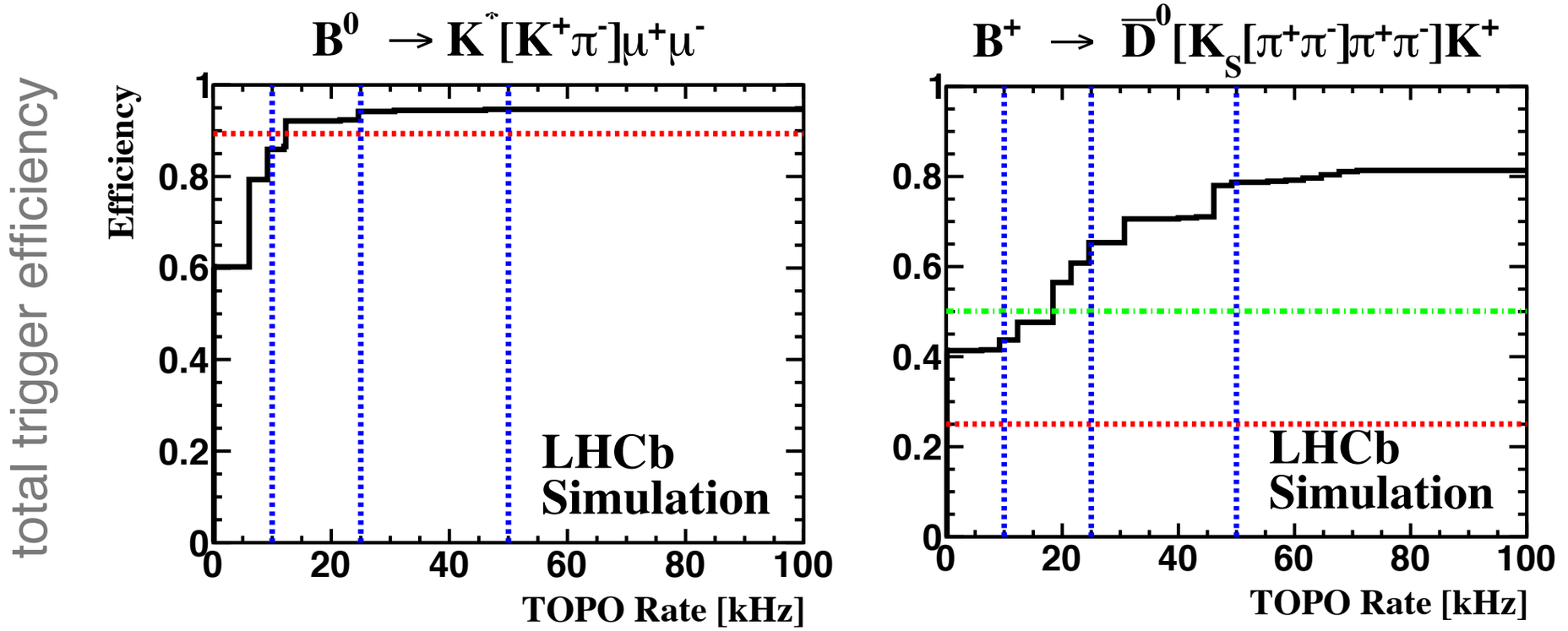
"Natural" evolution of the current LHCb online system:



Most cost-effective solution is to move everything to surface.

Run III Trigger

Inclusive b-hadron trigger efficiencies for the upgrade:

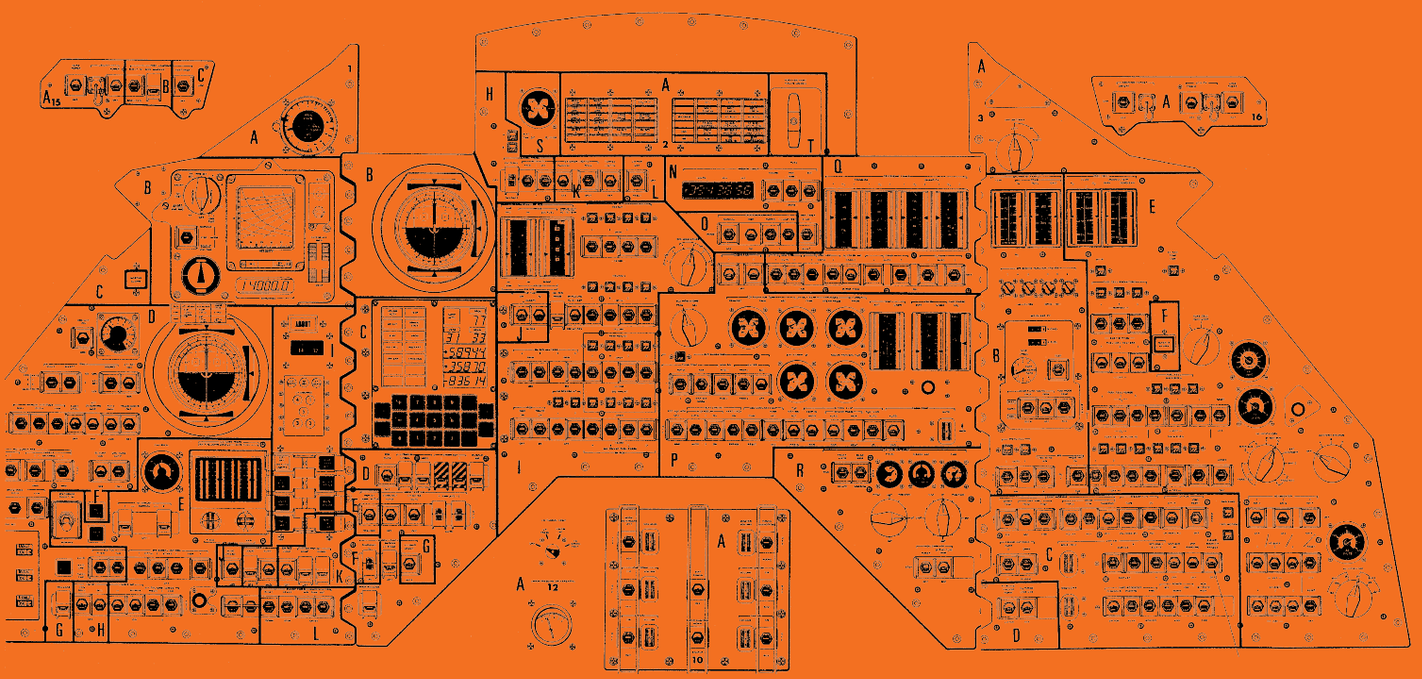


Full software trigger also allows non-lifetime-biasing, exclusive beauty and charm, inclusive di-muon, EW, ... flexibility!

CERN/LHCC 2014-016
LHCb TDR 16
21 May 2014

UPGRADE

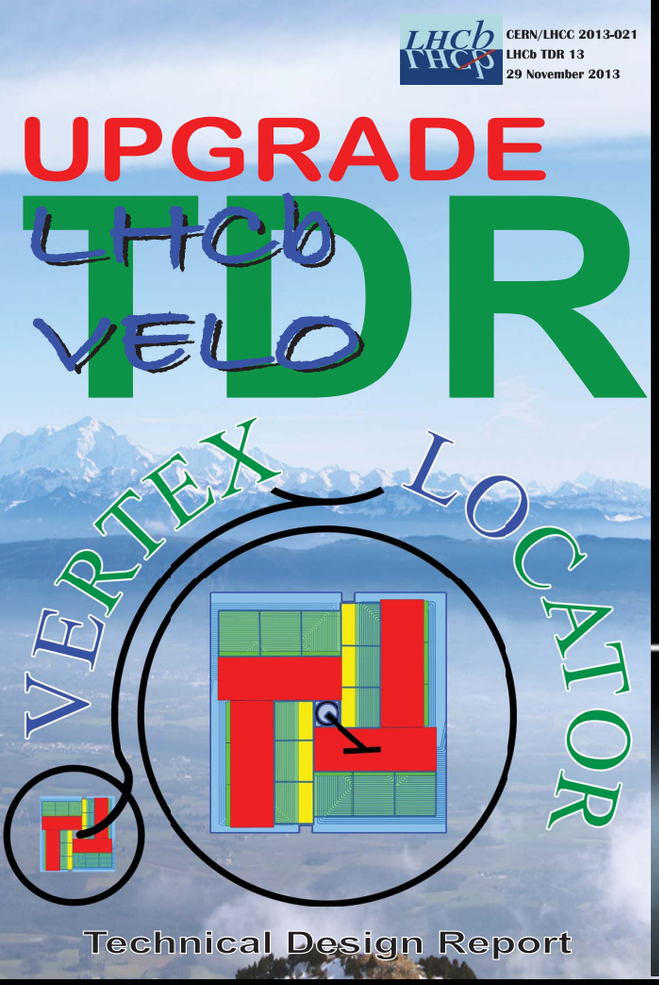
LHCb Trigger and Online TDR

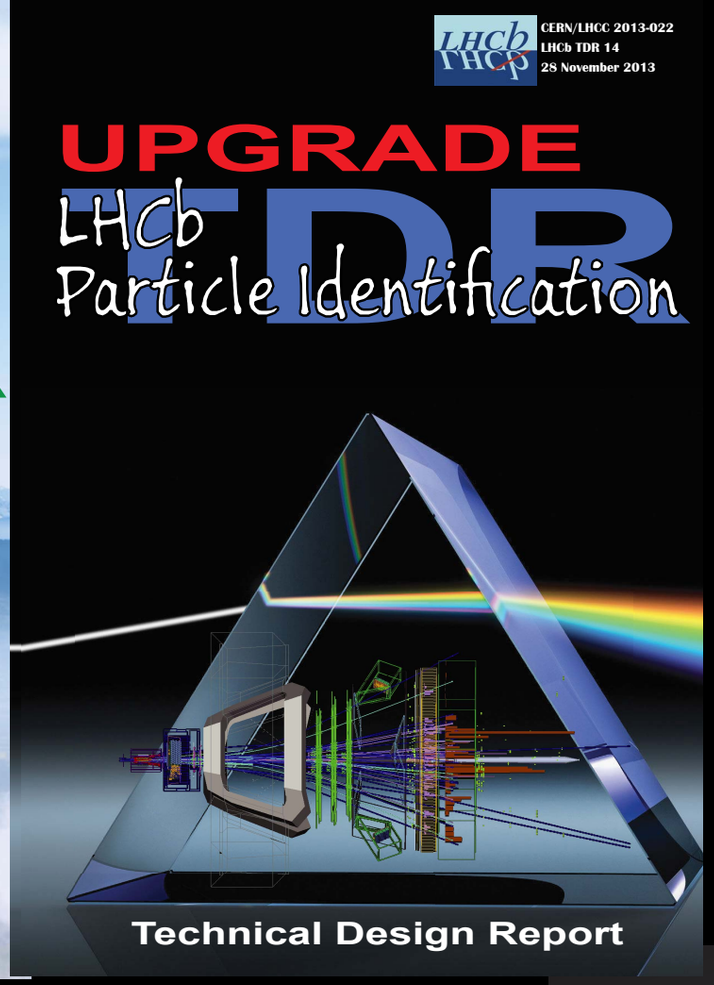


Technical Design Report

The final LHCb Upgrade TDR delivered to the LHCC on May 22.

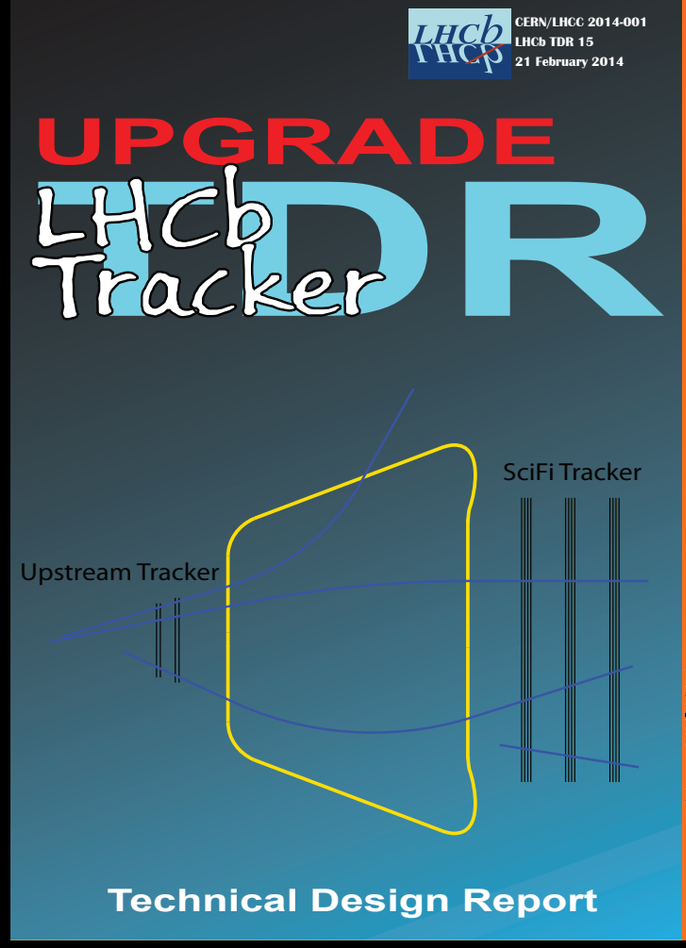
Proposal for a triggerless readout followed by a full software trigger!

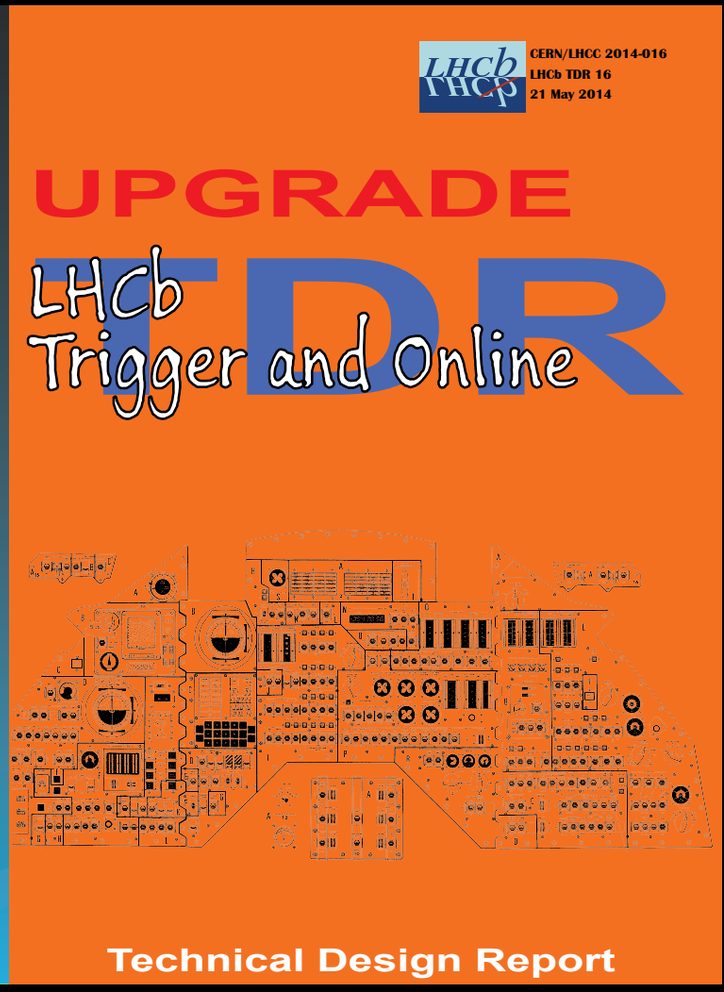




The full-software trigger is only made possible by the shared vision implemented in all LHCb subdetector TDRs.

We are still churning out Run 1 results. Run 2 prep work is progressing nicely and Run 3 TDRs are done ... the future is bright @ LHCb.

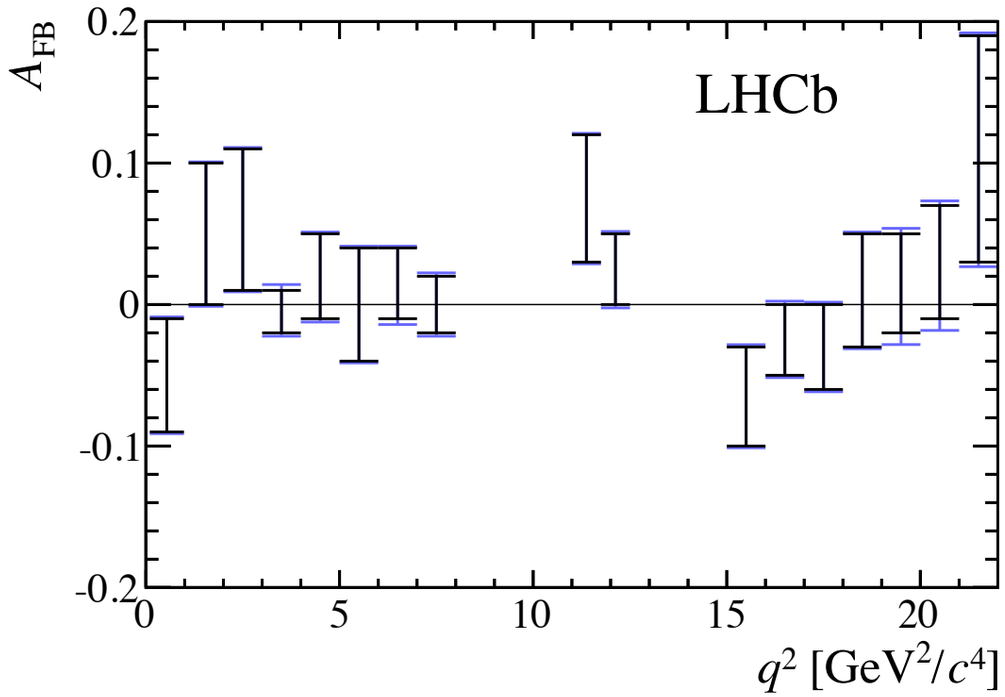


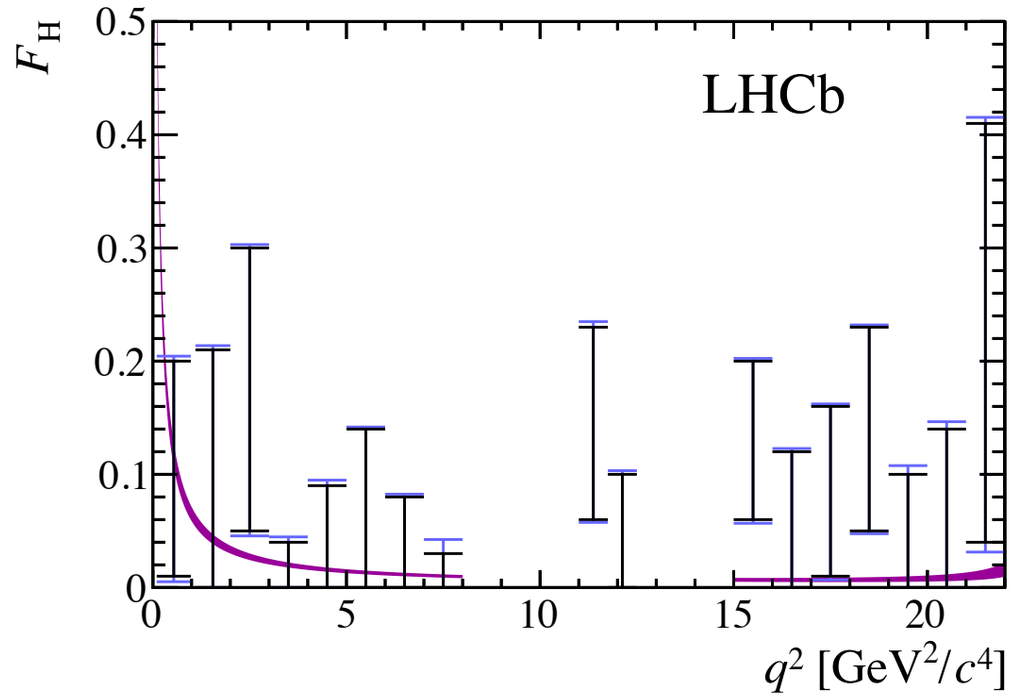


LHCb-PAPER-2014-007

The b→s penguin decays are sensitive to BSM contributions in the loop:

2011+2012 LHCb data

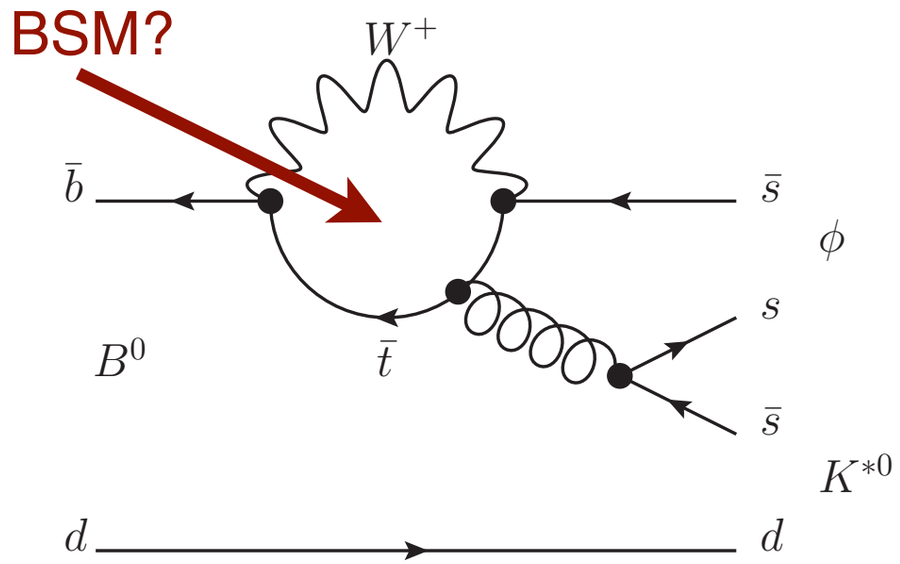




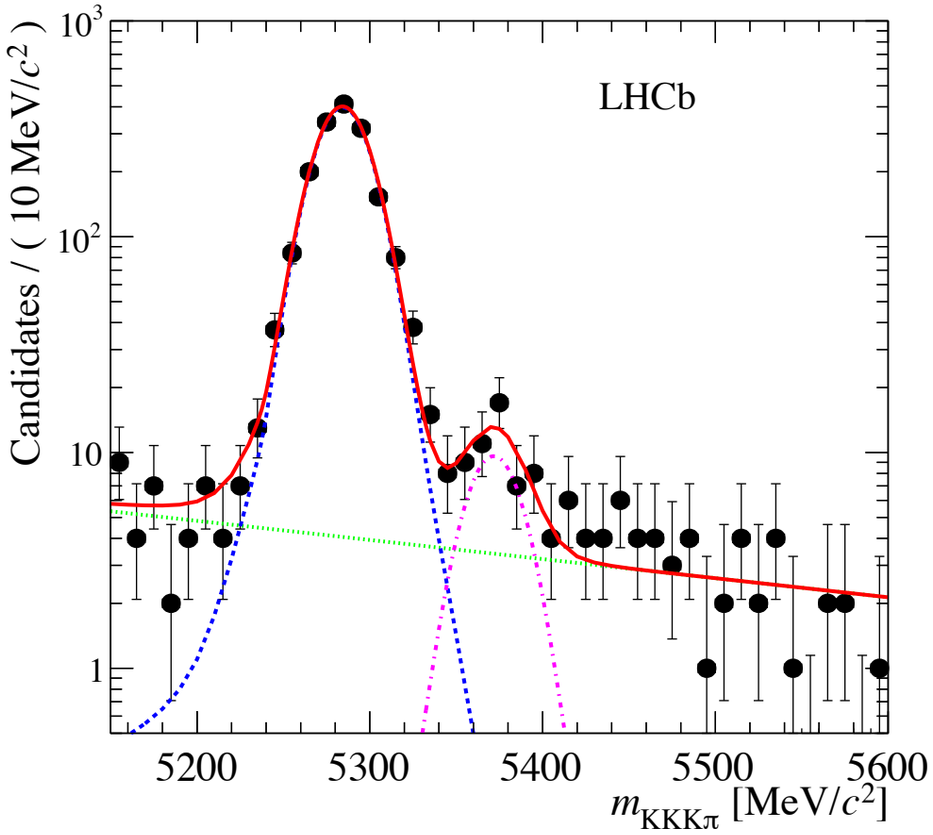
B→Kμμ angular analysis results are consistent with the SM. These measurements place strong constraints on BSM (pseudo)scalar and tensor amplitudes (the latter were previously poorly constrained).

LHCb-PAPER-2014-005

The b→s penguin decays are sensitive to BSM contributions in the loop:



2011 LHCb data: $B^0 \to \phi K^*$



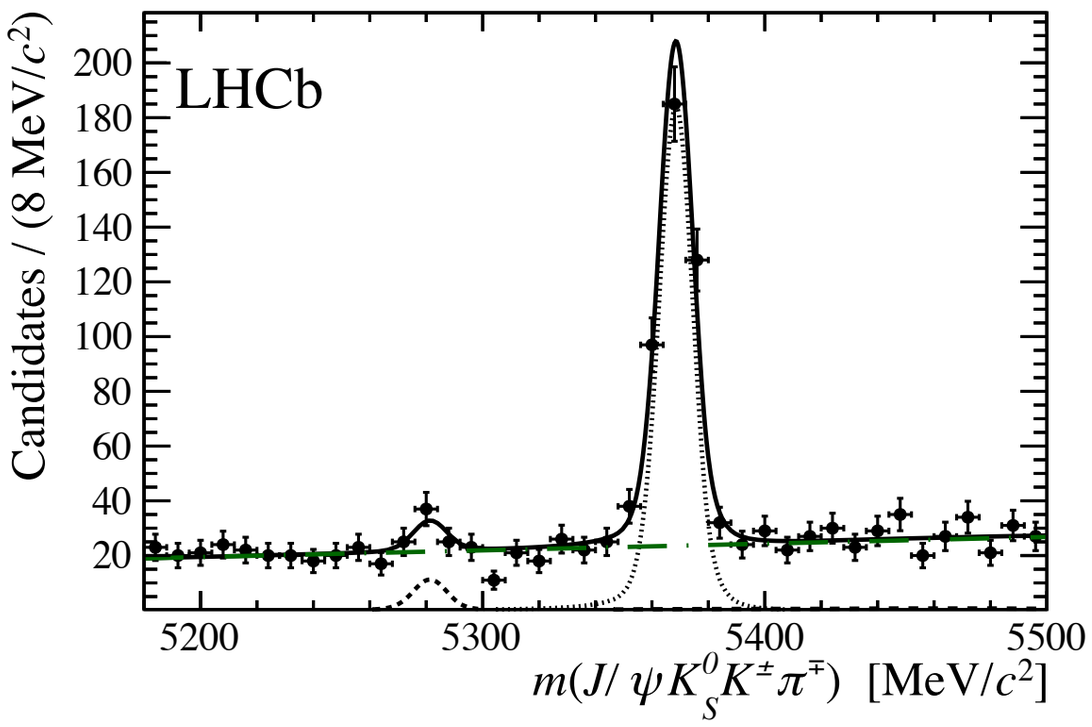
5-D angular analysis performed

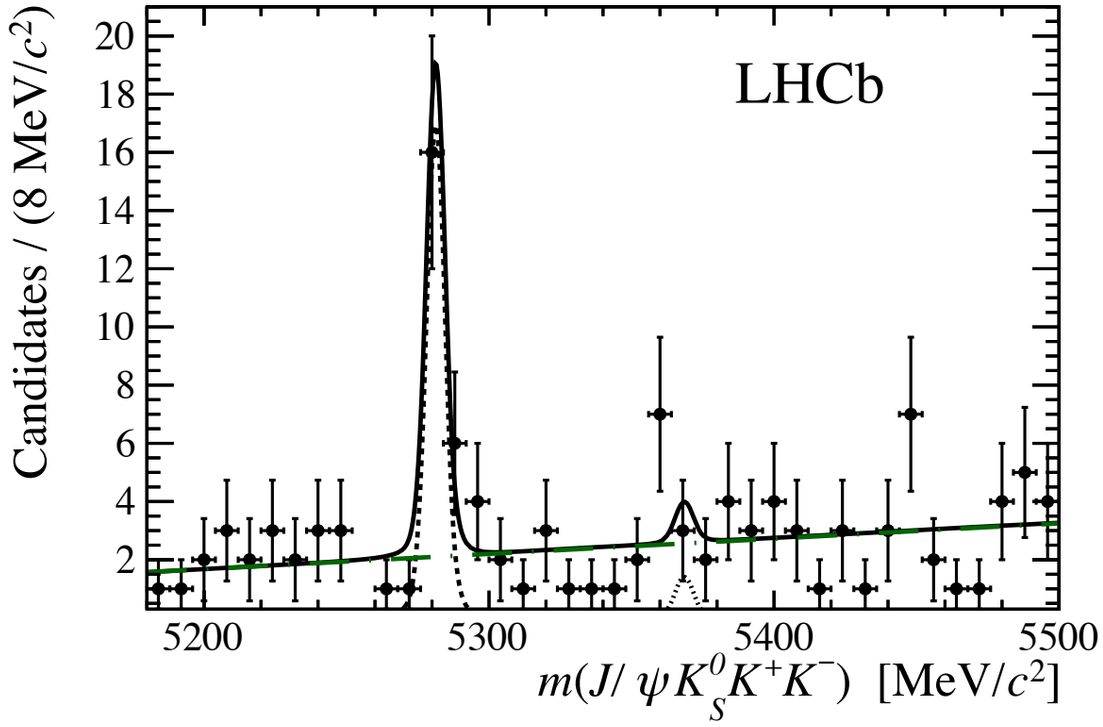
LHCb most precise polarization amplitude, strong phase difference and CP violation measurements. Results consistent with SM expectations.

LHCb-PAPER-2014-016

Decays of the type $B_{(s)} \to J/\psi K_S h h^{(')}$ ($h=\pi,K$) can be used to test isospin symmetry in exotic spectroscopy.

2011 LHCb data



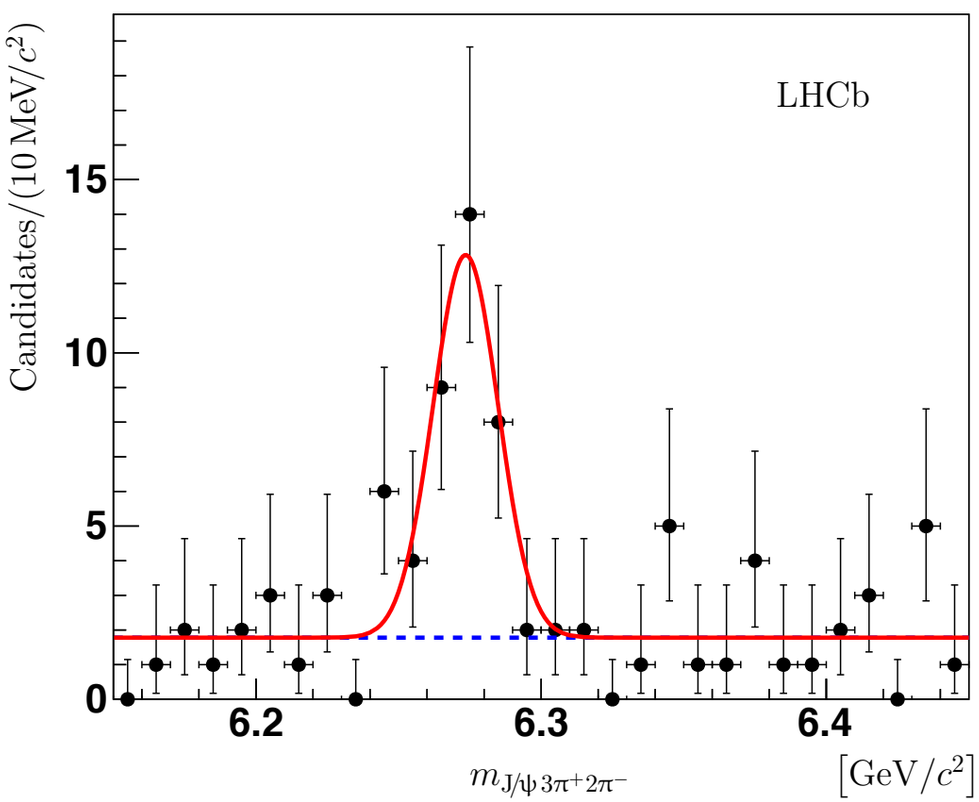


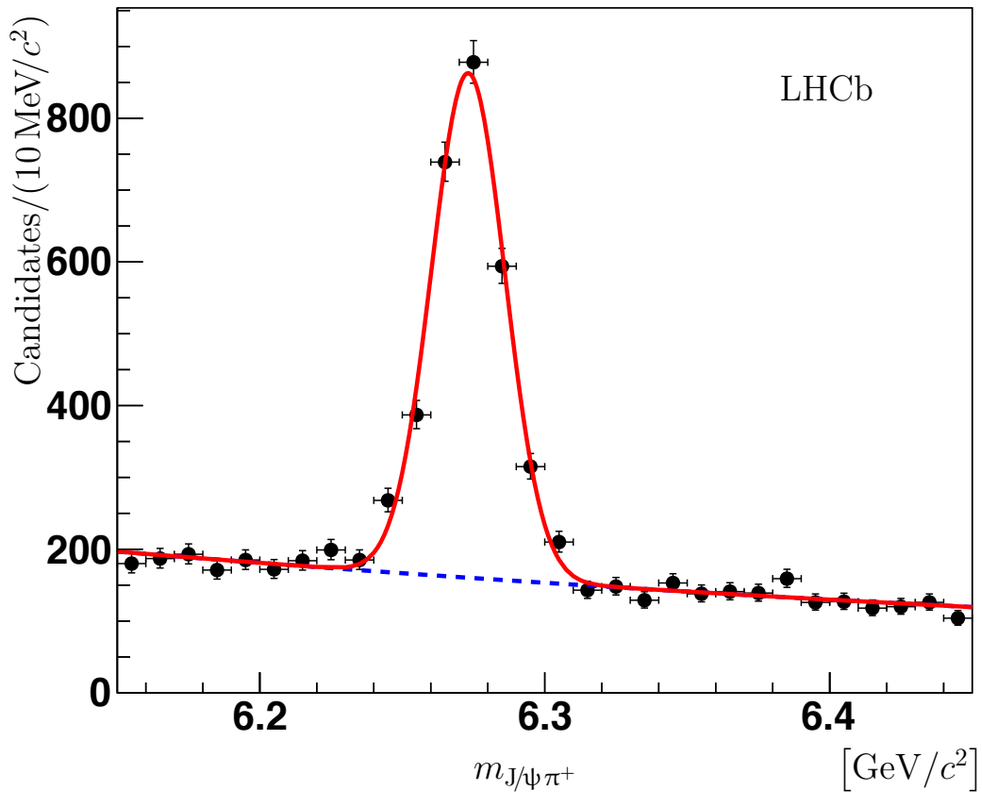
LHCb results contain 2 first observations, along with several other “most precise” results. No evidence for any exotic hadrons (need more stats).

LHCb-PAPER-2014-009

The Bc is the only known bc meson. Much still to learn about it.

2011+2012 LHCb data





$$\frac{\mathcal{B}\left(\mathrm{B_c^+} \to \mathrm{J/\psi}\, 3\pi^+ 2\pi^-\right)}{\mathcal{B}\left(\mathrm{B_c^+} \to \mathrm{J/\psi}\, \pi^+\right)} = 1.74 \pm 0.44 \pm 0.24.$$

LHCb results agree with expectations assuming factorization.