Production and decay of heavy flavour baryons

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on behalf of the LHCb collaboration

presenting also result from Atlas and CMS

INFN - Sezione di Milano

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Outline

- Introduction to *b*-baryon physics
- Experimental results
- Conclusions

Introduction to *b*-baryon physics

Physics motivations

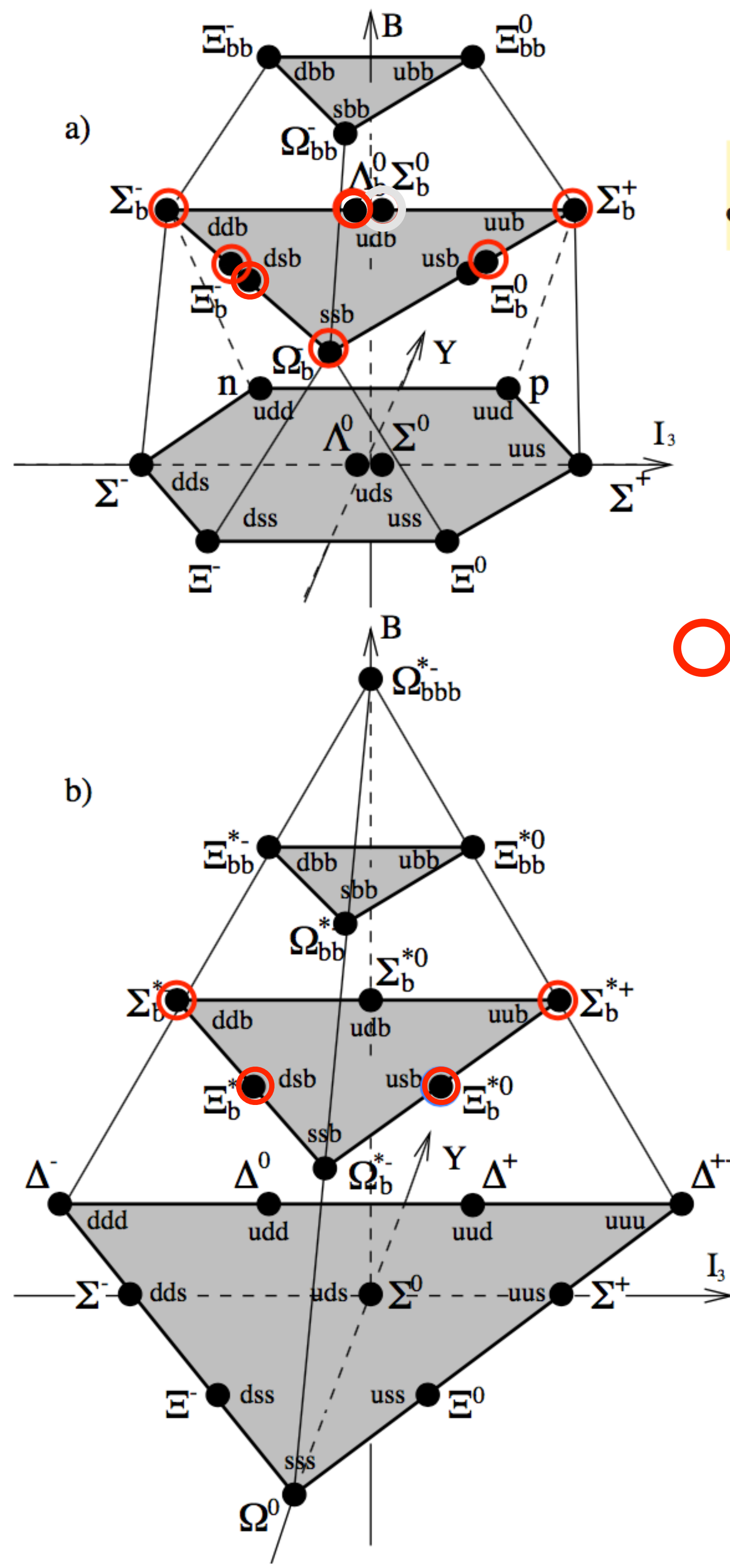
- At LHC *b*-baryons are produced in unprecedented quantities → opens a new field in flavour physics for precision measurements
  - Most precise measurement of $|V_{ub}|$ using $\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu$ decays [arXiv:1504.01568]
  - Mass, lifetimes and branching ratios measurements
- *b*-baryon physics is a relatively unexplored territory:
  - search for physics beyond the Standard Model (SM) in rare decays and *CP* violation
  - useful QCD laboratory in different energy regime with respect to light baryons. Experimental anchor point for QCD models

Beautiful baryons

- Baryons are fermions composed by 3 quarks
- State function antisymmetric under exchange of equal-mass quarks

$$|qqq\rangle_A = |\text{color}\rangle_A \times |\text{space, spin, flavour}\rangle_S$$

- *SU(4)* multiplets for baryons made of (*u,d,s,b*) quarks
  - B= bottomness, Y=hypercharge, I_3= Isospin *z*-component
  - *SU(4)* symmetry heavily broken - large *b*-quark mass
  - particles in *SU(4)* multiplets have same spin and parity



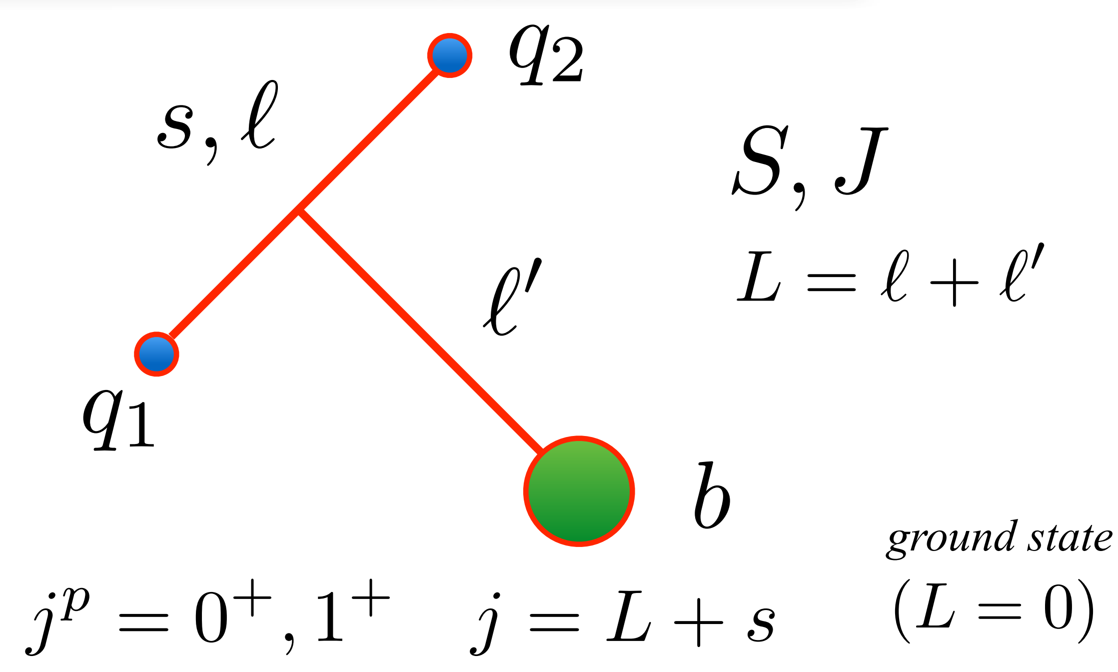
$J^P = \frac{1}{2}^+$

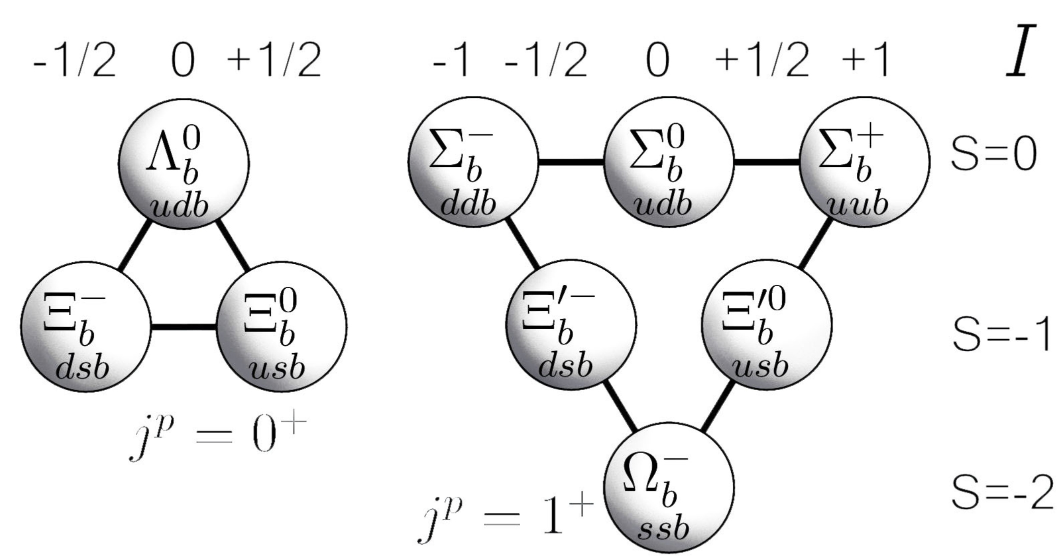
$J^P = \frac{3}{2}^+$

○ observed

b-baryons states

- *b*-baryons (bq_1q_2) as QCD laboratory:
  - $m_b \gg m_{q_1q_2}$ simplified dynamics
    - *b* quark in the limit $m_b \to \infty$
    effective static colour field $(m_b \sim 4.8\text{GeV})$
  - heavy baryon properties determined by dynamics of diquark system in *b*-quark color field
  - Ground state baryons $(L=0)$ with spin-parity $J^P = 1/2^+, 3/2^+$ characterised by the spin-party of the diquark system $j^p = 0^+, 1^+$





$$J^P = \frac{1}{2}^+ \quad (J^P = \frac{3}{2}^+ \text{ not shown})$$

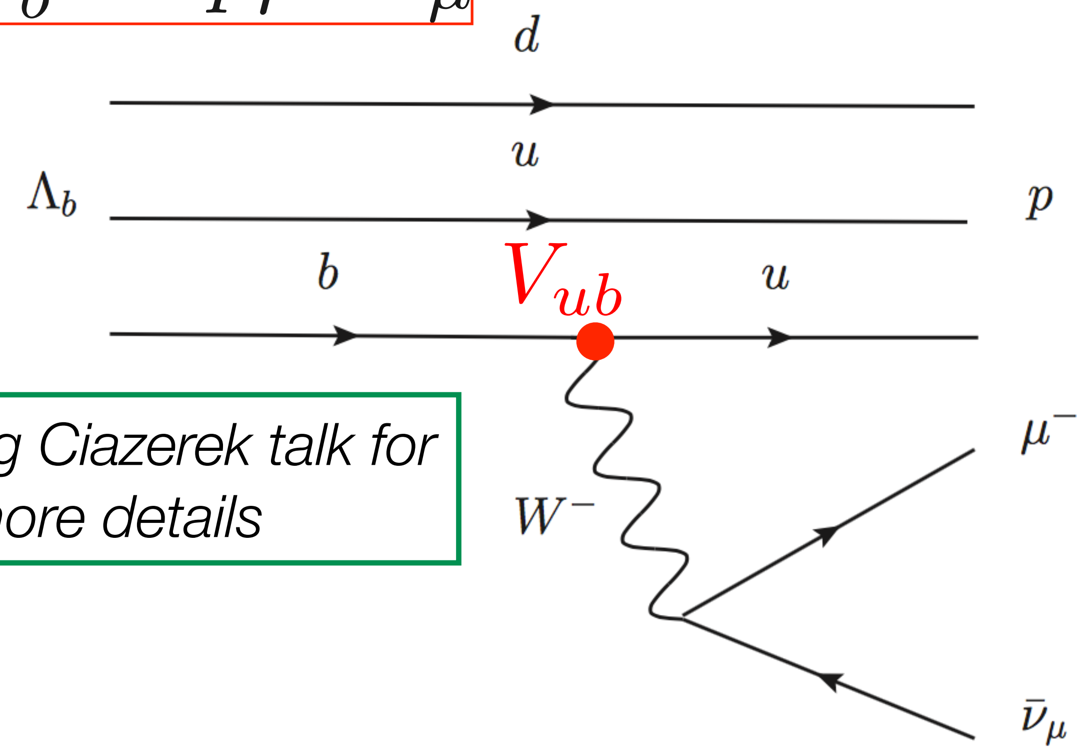
b-baryon rare decays

- Access to $|V_{ub}|$ CKM element, form factors $f(\Lambda_b \to p)$ determined by Lattice QCD. Experimentally very challenging, achieved unprecedented precision

$|V_{ub}| = (3.27 \pm 0.23) \times 10^{-3}$

arXiv:1504.01568, submitted to Nature

$\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu$

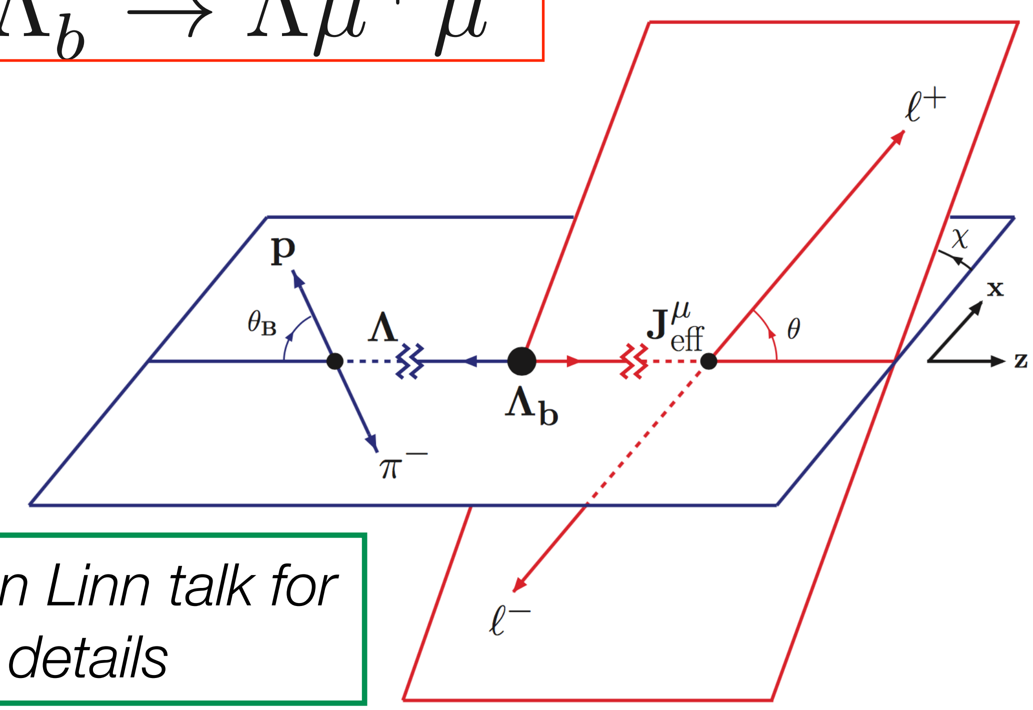


See Greg Ciazerek talk for more details

- Angular analysis of b-baryon flavour-changing neutral current decays, e.g. $b \to s$ transitions, is sensitive to physics beyond Standard Model (SM)

arXiv:1503.07138, submitted to JHEP

$\Lambda_b^0 \to \Lambda\mu^+\mu^-$

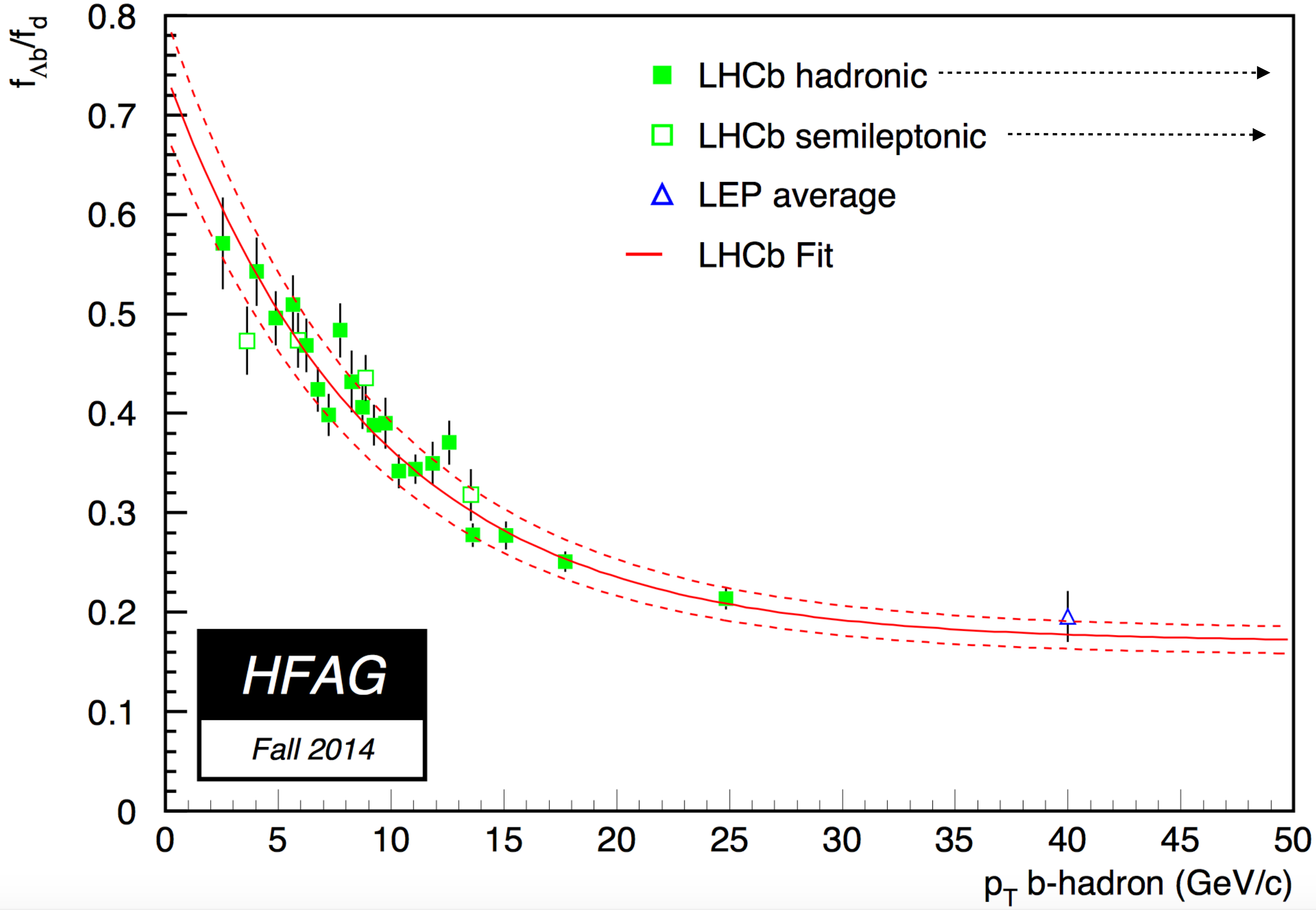


See Christian Linn talk for more details

Experimental results

b-baryon production

- Production cross-section strongly depends on p_T of *b*-hadron :
  - different *b*-quark fragmentation function ratio $f_{\Lambda_b^0}/f_d$ measured at LEP and at LHC, where $f_{\Lambda_b^0} = P(b \to \Lambda_b^0)$ and $f_d = P(b \to B_d^0)$
  - measurement of $f_{\Lambda_b^0}/f_d$ vs p_T of *b*-quark is cleaner to interpret. Expected a slow dependence in that case arXiv:1505.02771



JHEP 08, 143 (2014)

PRD85, 032008 (2012)

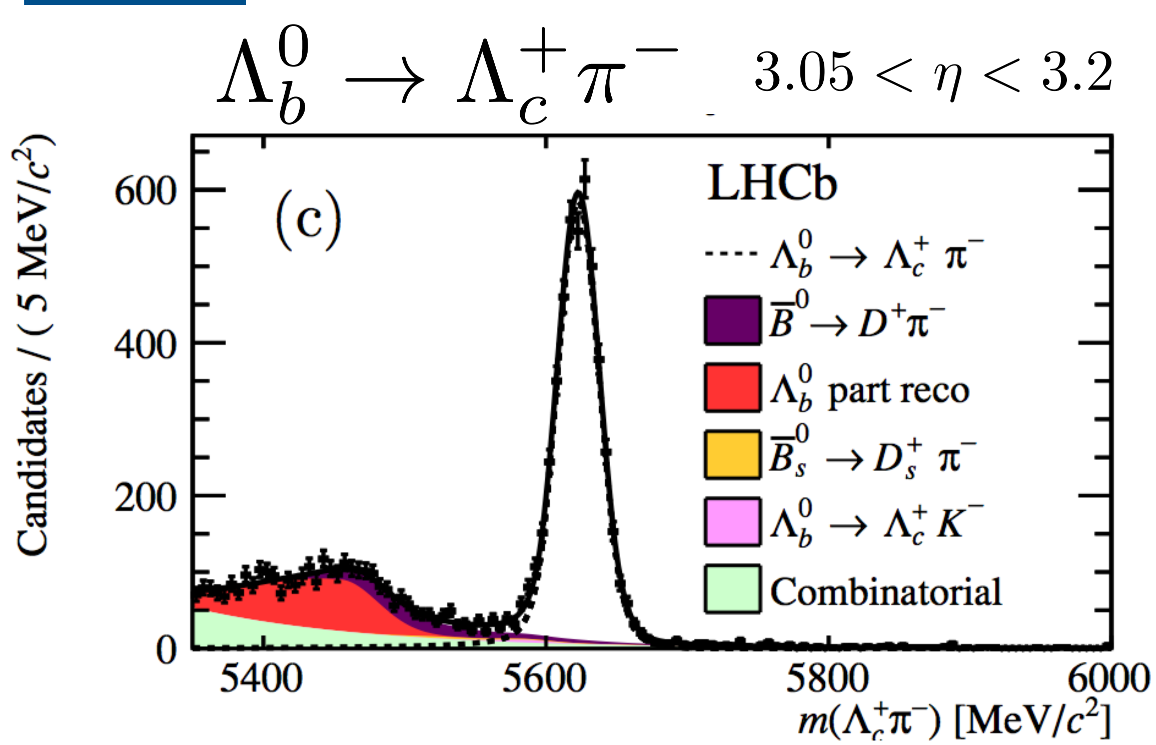
Note: LEP average not included in the fit. LHCb measurements are not independent

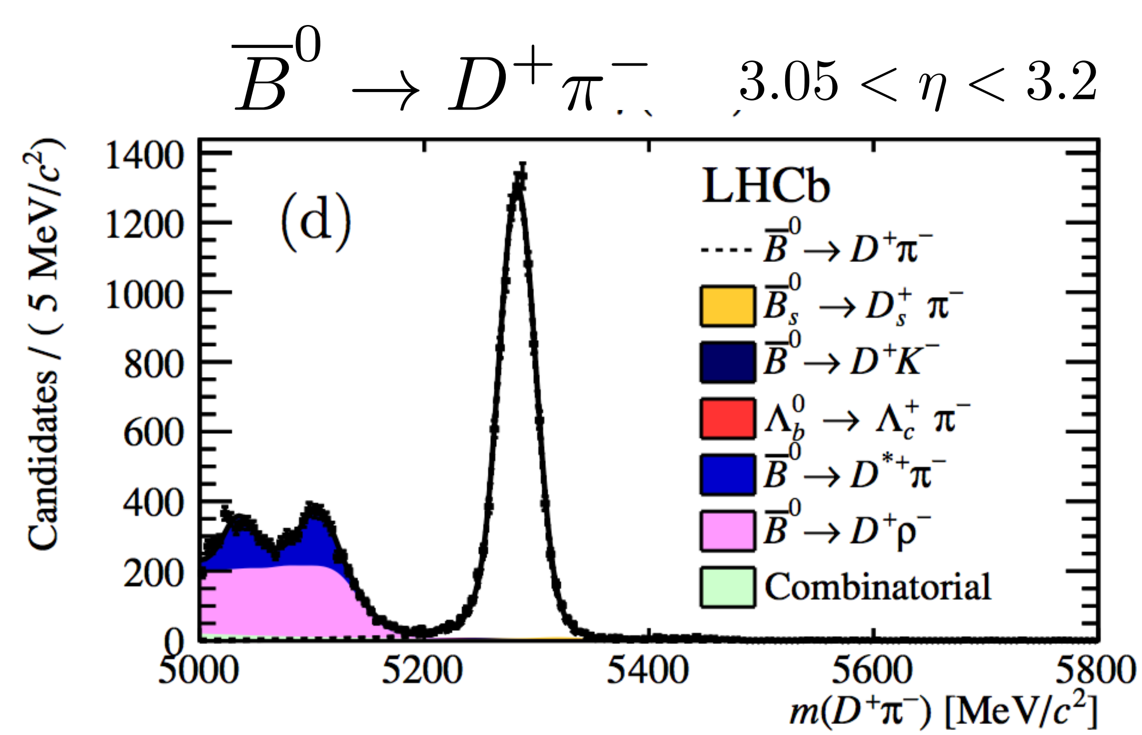
Production kinematic dependence

- Use clean $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ (45K) , $\overline{B}^0 \to D^+\pi^-$ (106K) exclusive decays to measure dependance of $f_{\Lambda_b^0}/f_d$ on *b*-hadron kinematics, e.g. p_T, pseudorapidity η.
- Measure $$\frac{f_{\Lambda_b^0}}{f_d}(x) = \frac{\mathcal{B}\left(\overline{B}^0 \to D^+\pi^-\right)}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-)} \times \frac{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)}{\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)} \times \mathcal{R}(x)$$

where $\mathcal{R}(x) \equiv \frac{N_{\Lambda_b^0\to\Lambda_c^+\pi^-}(x)}{N_{\overline{B}^0\to D^+\pi^-}(x)} \times \frac{\varepsilon_{\overline{B}^0\to D^+\pi^-}(x)}{\varepsilon_{\Lambda_b^0\to\Lambda_c^+\pi^-}(x)}$ and $x = p_T, \eta$

Data sample 1fb[-1] at 7 TeV - JHEP08(2014)143





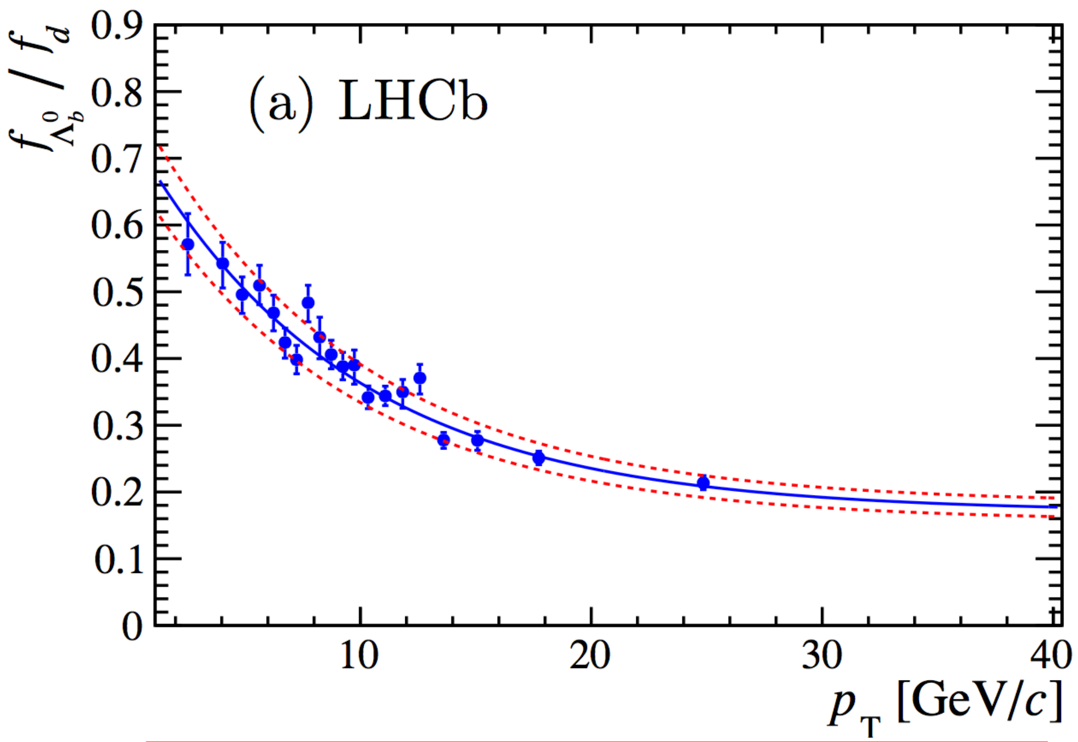
Production kinematic dependence

- Absolute value of $f_{\Lambda_b^0}/f_d$ from LHCb semileptonic analysis
  Phys. Rev. D 85 (2012) 032008
  - obtain most precise branching ratio measurement of *b*-baryon to date (8% precision)

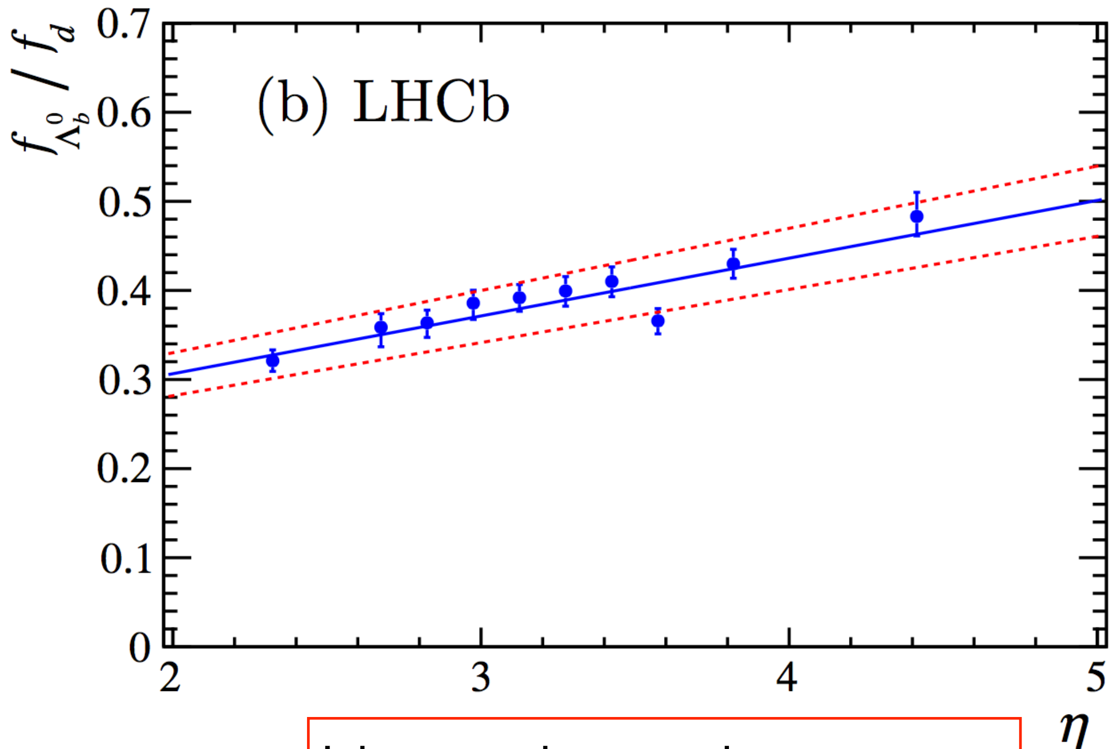
$$\mathcal{B}\left(\Lambda_b^0 \to \Lambda_c^+ \pi^-\right) = \left(4.30 \pm 0.03\ {}^{+0.12}_{-0.11} \pm 0.26 \pm 0.21\right) \times 10^{-3}$$

stat. syst. semileptonic analysis $\mathcal{B}(\overline{B}^0 \to D^+\pi^-)$

JHEP08(2014)143



Exponential dependence vs p_T

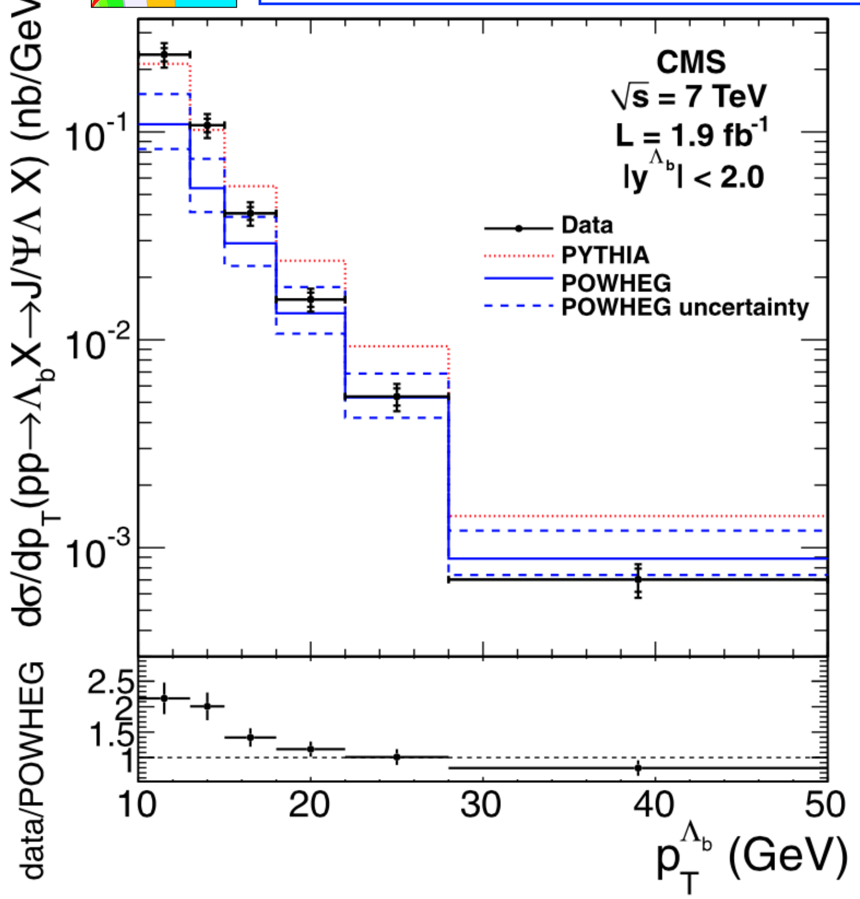


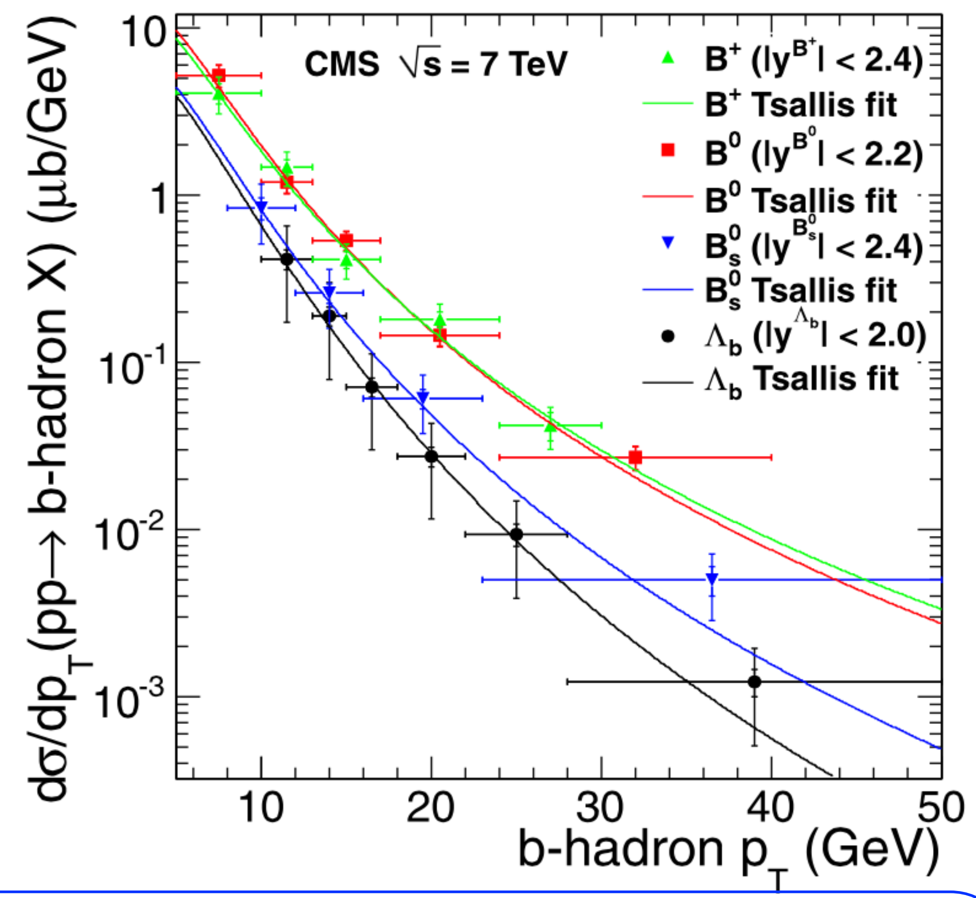
Linear dependence vs η

Λ_b^0 production cross-section

- Measurement of differential production cross-section for Λ_b^0 using $\Lambda_b^0 \to J/\psi\Lambda$ decays with $J/\psi \to \mu^+\mu^-, \Lambda \to p\pi^-$

PLB 714 (2012) 136–157





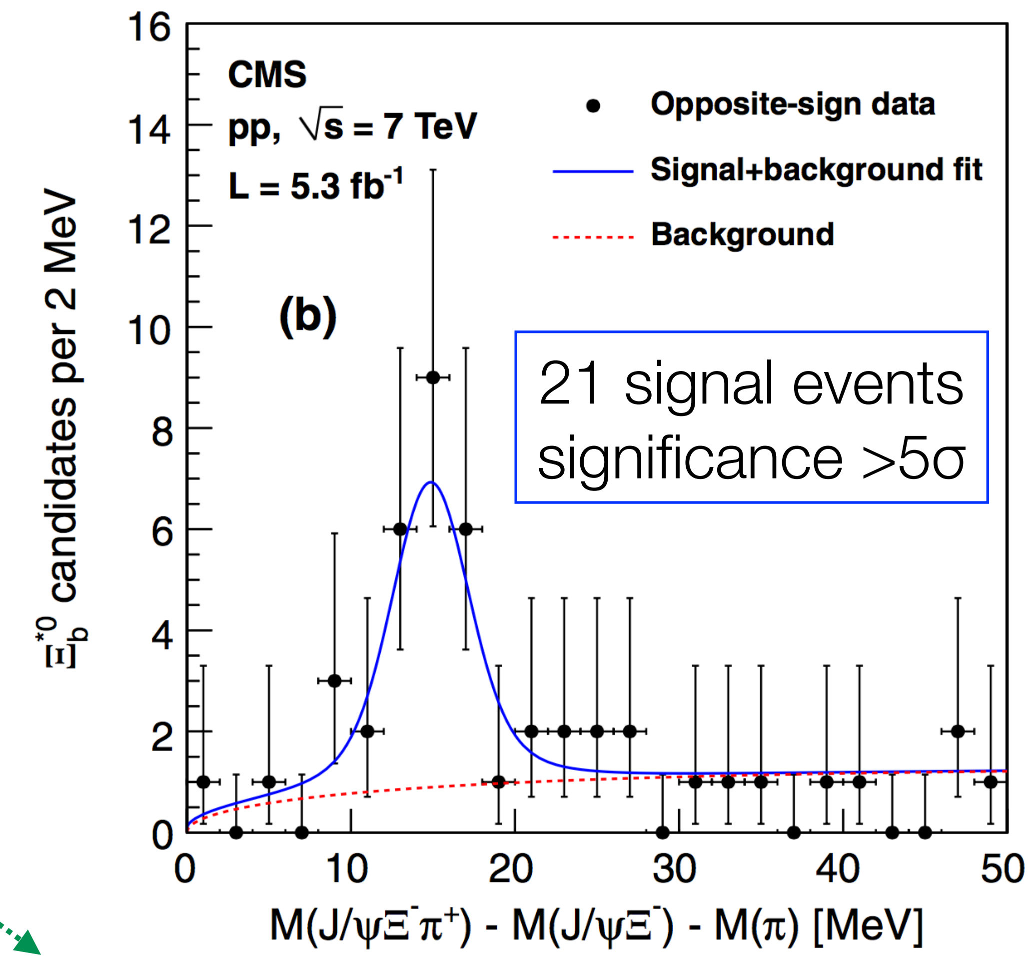
- p_T distribution falls faster than measured *b*-mesons spectra and than predicted spectra from NLO MC POWHEG and leading-order MC PYTHYA
- Cross-section ratio $\sigma(\overline{\Lambda}_b^0)/\sigma(\Lambda_b^0)$ consistent with 1 and constant vs p_T, and rapidity $|y|$

Observation of Ξ_b^{*0}

- New resonant state compatible with

$$\Xi_b^{*0} \quad (usb) \quad J^P = \frac{3}{2}^+, j = 1$$

- Signal reconstruction involves three secondary vertices, Ξ_b^-, Ξ^-, Λ and a dimuon pair
- Theory predicts $m(\Xi_b'^0) - m(\Xi_b^-) < m_{\pi^+}$ no strong decay $\Xi_b'^0 \to \Xi_b^- \pi^+$ consistent with experimental results

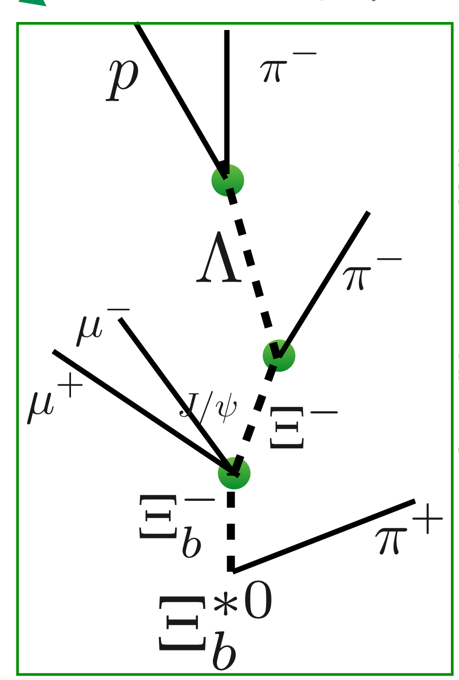


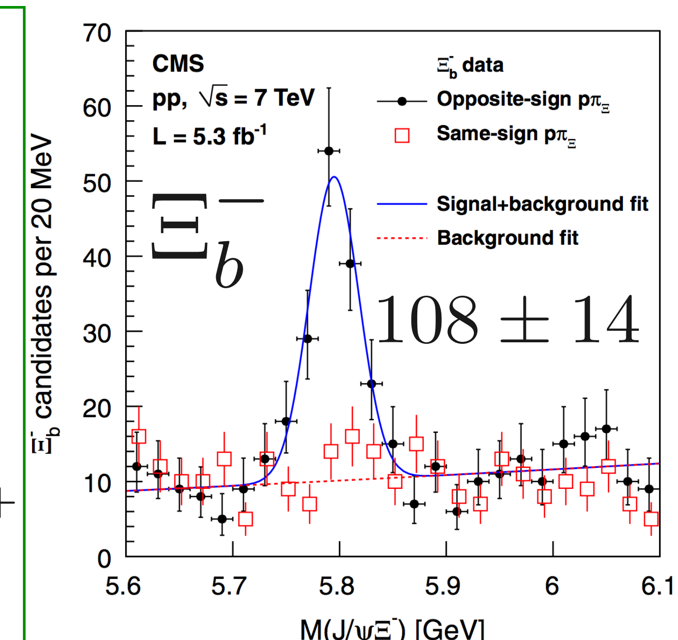
PRL 108, 252002 (2012)

$$\delta m = m(\Xi_b^{*0}) - m(\Xi_b^-) - m_{\pi^+} = 14.84 \pm 0.74 \pm 0.28 \text{ MeV}$$

$$m(\Xi_b^{*0}) = 5945.0 \pm 0.7 \pm 0.3 \pm 2.7(\text{PDG}) \text{ MeV}$$

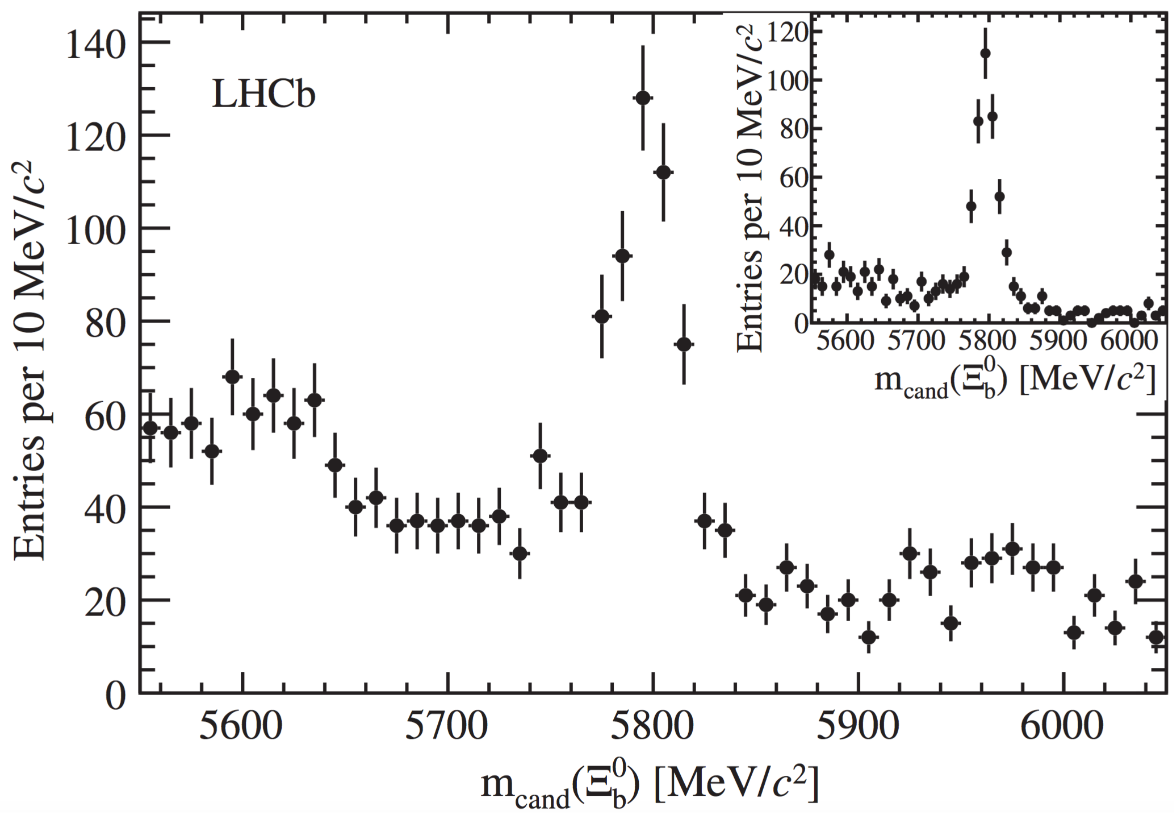
$$\Gamma(\Xi_b^{*0}) = 2.1 \pm 0.74 \text{ MeV}$$

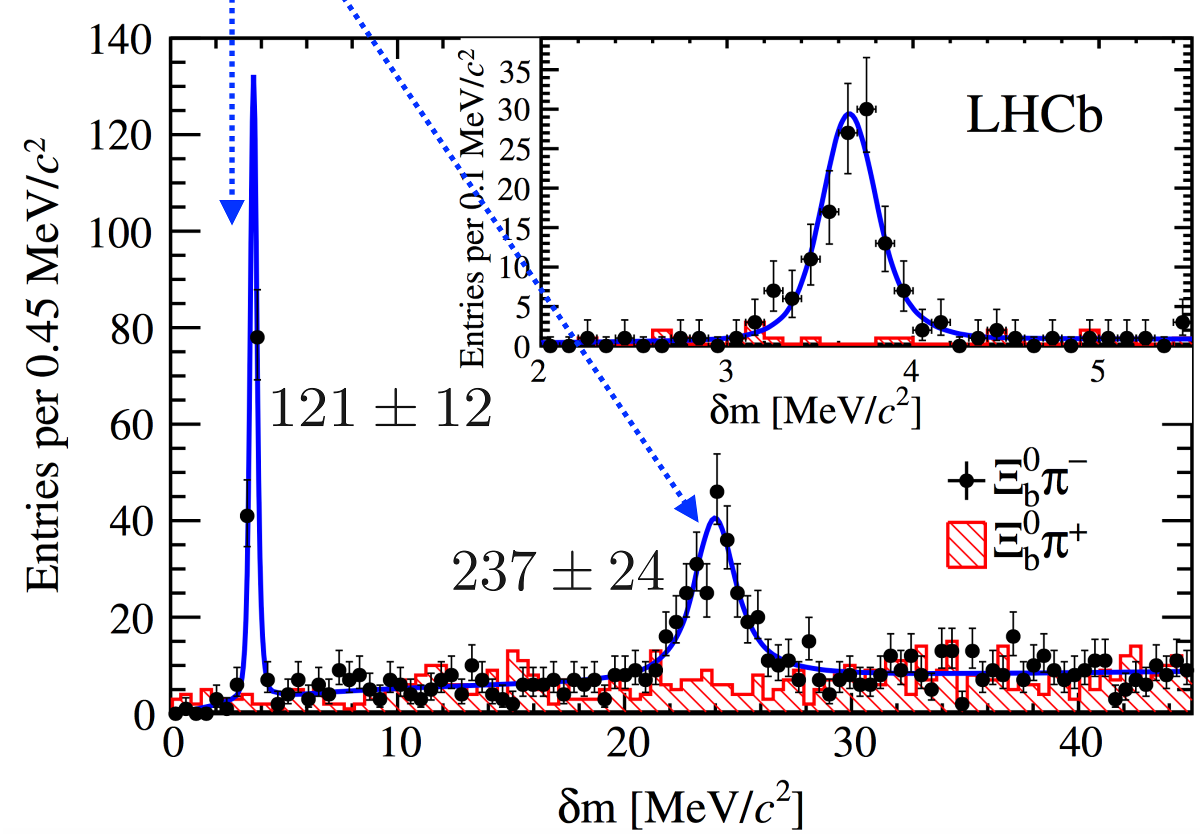




Two new Ξ_b^- baryon resonances

- Study $\Xi_b^0\pi_s^-$ mass spectrum: 2 new resonances consistent with $\Xi_b'^-$ (dsb) $J^P = \frac{1}{2}^+, j=1$ and Ξ_b^{*-} (dsb) $J^P = \frac{3}{2}^+, j=1$





3fb[-1] data at 7-8 TeV - PRL 114, 062004 (2015)

$$\delta m = m(\Xi_b^0\pi^-) - m(\Xi_b^0) - m_{\pi^-}$$

$$\delta m(\Xi_b'^-) = 3.653 \pm 0.018 \pm 0.006 \text{ MeV}/c^2$$

$$\Gamma(\Xi_b'^-) < 0.08 \text{ MeV at } 95\% \text{ C.L.}$$

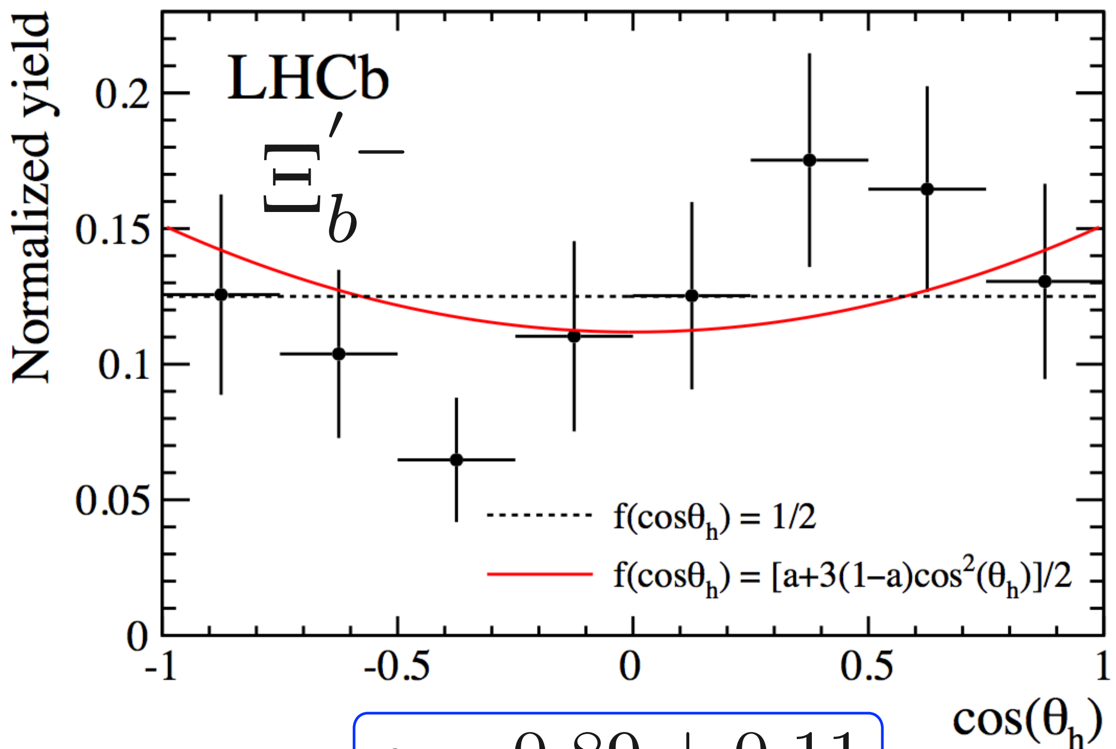
$$\delta m(\Xi_b^{*-}) = 23.96 \pm 0.12 \pm 0.06 \text{ MeV}/c^2$$

$$\Gamma(\Xi_b^{*-}) = 1.65 \pm 0.31 \pm 0.10 \text{ MeV}$$

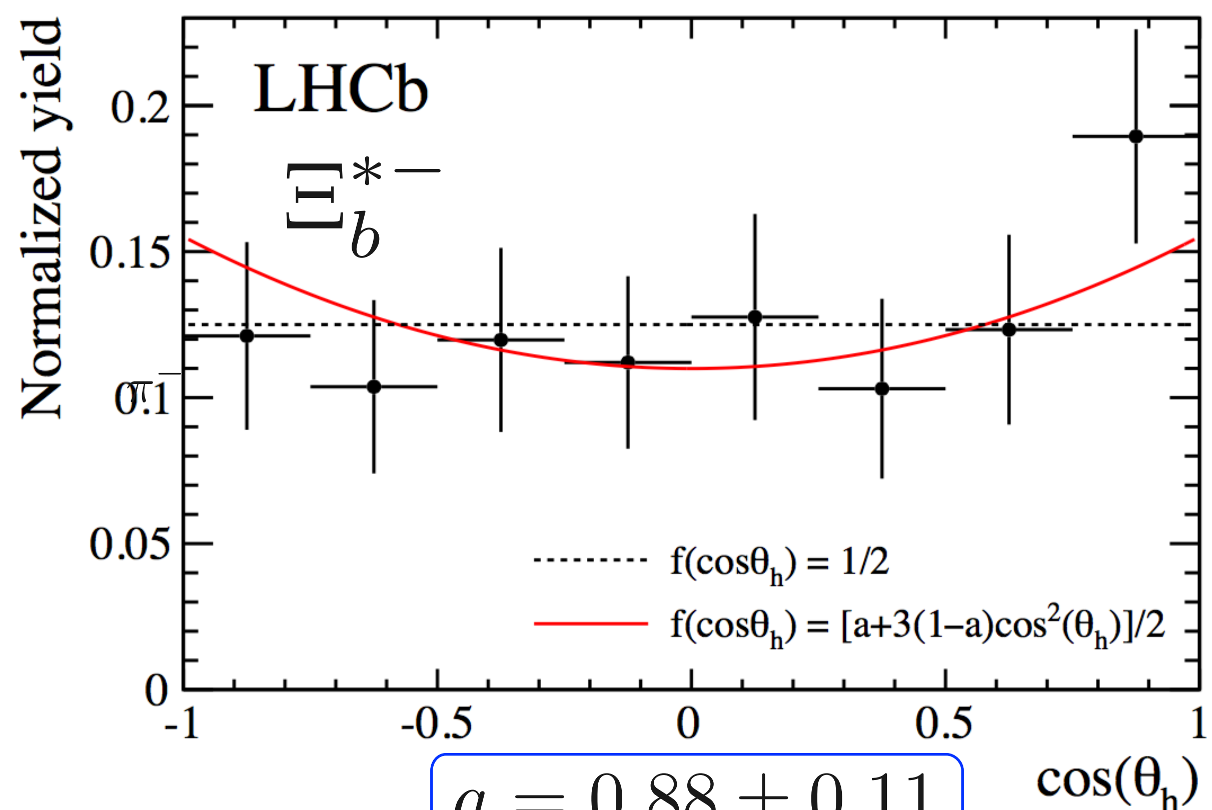
Ξ_b^- helicity angle distributions

- Flat distribution if J=1/2 or J>1/2 but zero longitudinal polarisation
- Cannot determine J value. However, data are consistent with quark model predictions J=1/2 and J=3/2 (if not or weakly polarised)

PRL 114, 062004 (2015)

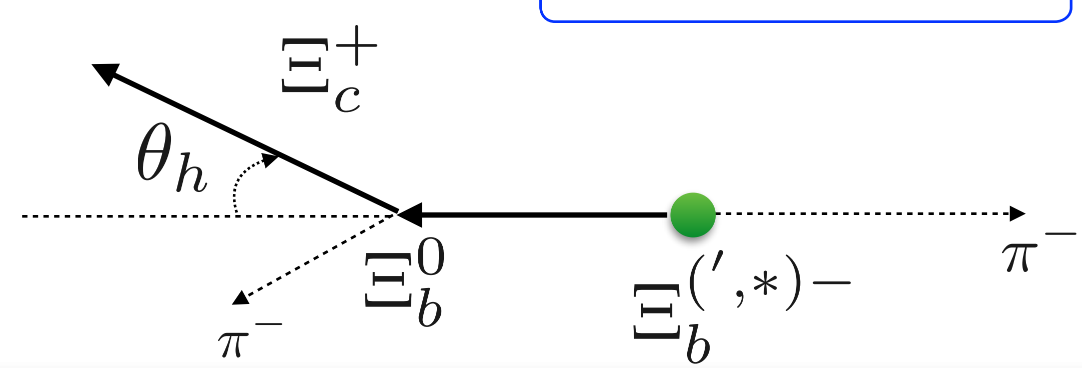


$a = 0.89 \pm 0.11$



$a = 0.88 \pm 0.11$

Helicity angle definition

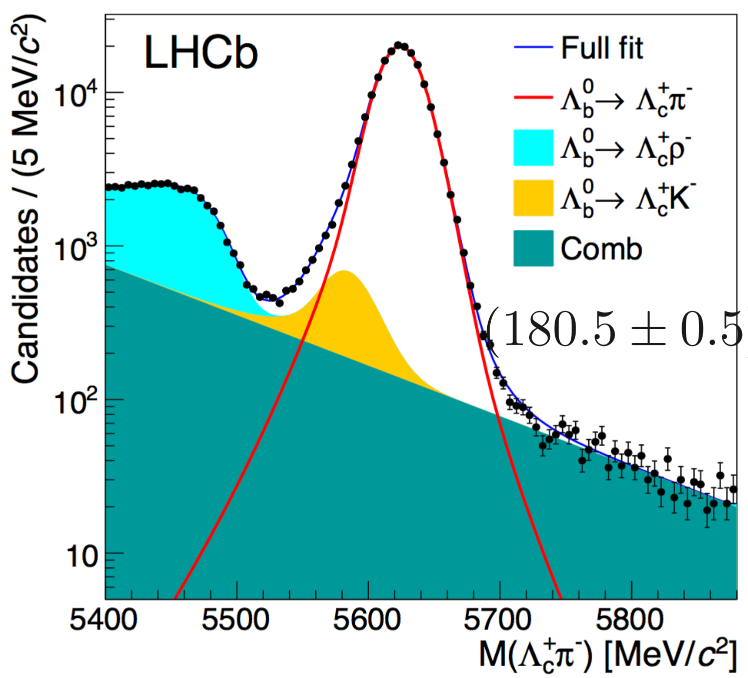


Ξ_b^0 lifetime and mass measurements

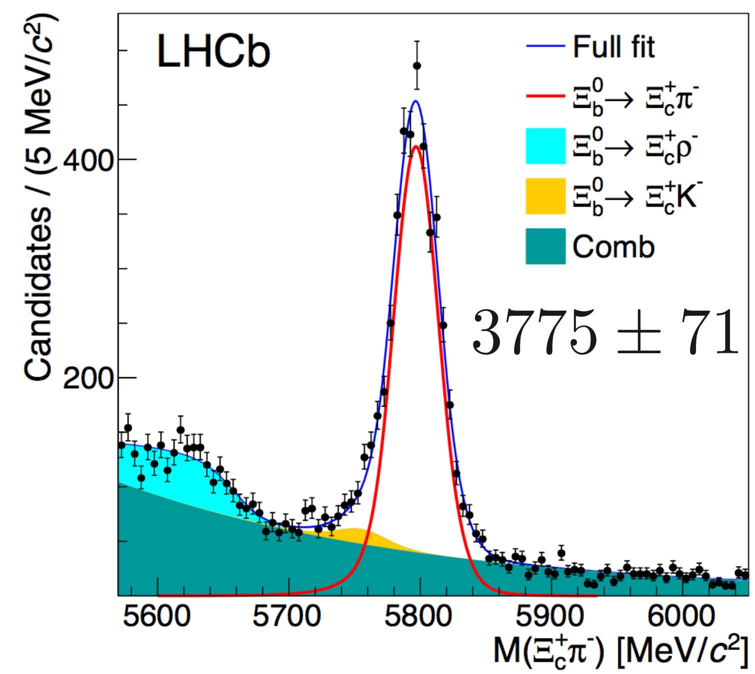
3fb^{-1} data at 7-8 TeV - PRL 113, 032001 (2014)

- Measure lifetime relative to Λ_b^0 and mass difference $m(\Xi_b^0) - m(\Lambda_b^0)$

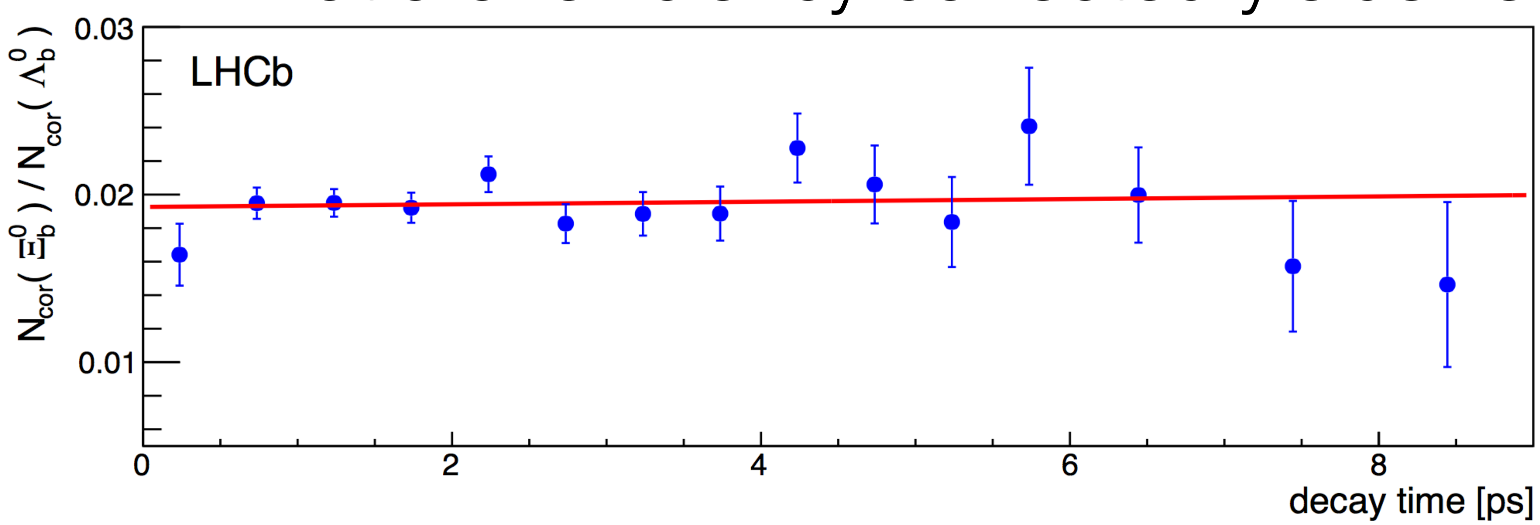
$\Lambda_b^0 \to \Lambda_c^+\pi^-, \Lambda_c^+ \to pK^-\pi^+$



$\Xi_b^0 \to \Xi_c^+\pi^-, \Xi_c^+ \to pK^-\pi^+$



- Ratio of efficiency corrected yields vs time



$$N_{\Xi_b^0}(t)/N_{\Lambda_b^0}(t) = e^{(1/\tau_{\Lambda_b^0} - 1/\tau_{\Xi_b^0})t}$$

Lifetime ratio from a fit using exponential function

Ξ_b^0 lifetime and mass measurements

PRL 113, 032001 (2014)

- Measure $\frac{\tau_{\Xi_b^0}}{\tau_{\Lambda_b^0}} = 1.006 \pm 0.018 \pm 0.010$

  first measurement

Λ_b^0 lifetime measurements

$\tau_{\Lambda_b^0} = 1.479 \pm 0.009 \pm 0.010$ ps

PLB, 734, (2014) 122

$\tau_{\Lambda_b^0} = 1.449 \pm 0.036 \pm 0.017$ ps

PRD 87, 032002 (2013)

$\tau_{\Lambda_b^0} = 1.503 \pm 0.052 \pm 0.031$ ps

JHEP 07 (2013) 163

- Measure $m(\Xi_b^0) - m(\Lambda_b^0) = 172.44 \pm 0.39 \pm 0.17$ MeV$/c^2$

  x4 precision improvement

- Measure relative production rate

$$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \cdot \frac{\mathcal{B}(\Xi_b^0 \to \Xi_c^+ \pi^-)}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^-)} \cdot \frac{\mathcal{B}(\Xi_c^+ \to pK^-\pi^+)}{\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)} = (1.88 \pm 0.04 \pm 0.03) \times 10^{-2}$$

assuming naive Cabibbo factors

$\mathcal{B}(\Xi_b^0 \to \Xi_c^+ \pi^-)/\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^-) \approx 1$ $\mathcal{B}(\Xi_c^+ \to pK^-\pi^+)/\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) \approx 0.1$

obtain $f(\Xi_b^0)/f(\Lambda_b^0) \approx 0.2$

Λ_b^0 mass measurements

$m_{\Lambda_b^0} = 5619.36 \pm 0.26$ MeV

PRL 112, 202001 (2014)

$m_{\Lambda_b^0} = 5619.7 \pm 0.7 \pm 1.1$ MeV

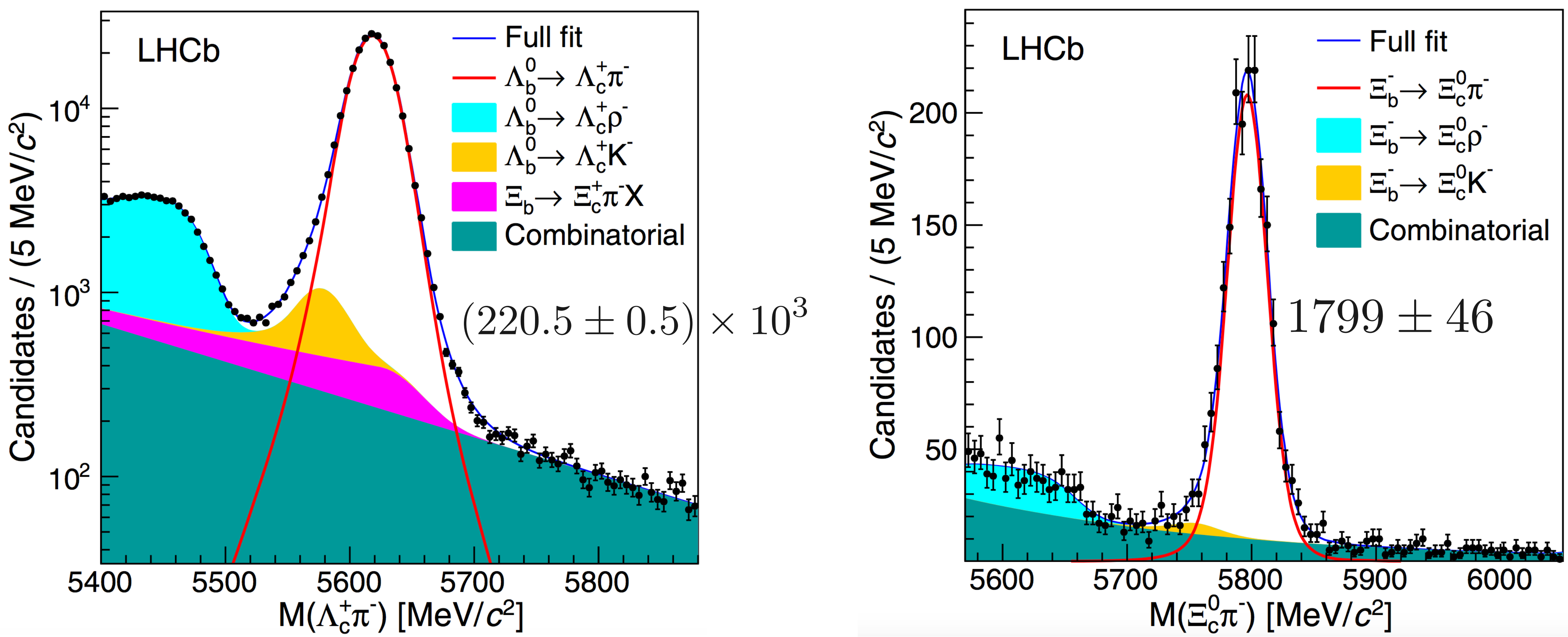
PRD 87, 032002 (2013)

Ξ_b^- lifetime and mass measurements

3fb^{-1} data at 7-8 TeV - PRL 113, 242002 (2014)

- Measure lifetime relative to Λ_b^0 and mass difference $m(\Xi_b^-) - m(\Lambda_b^0)$

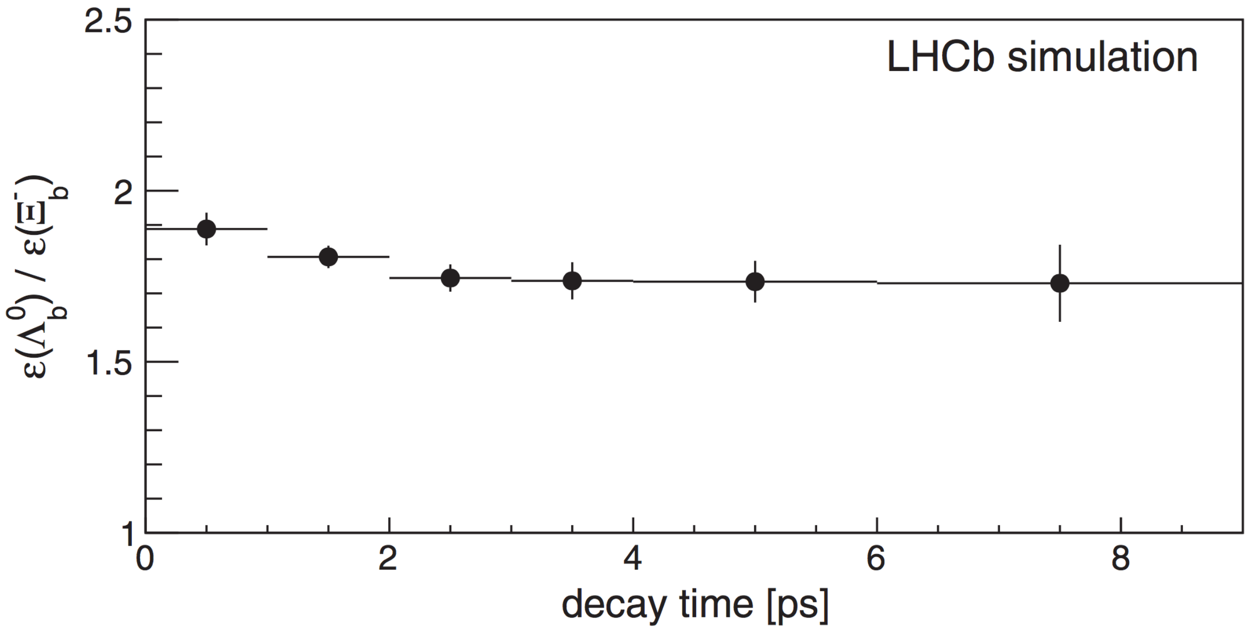
$\Lambda_b^0 \to \Lambda_c^+\pi^-, \Lambda_c^+ \to pK^-\pi^+$ $\qquad$ $\Xi_b^- \to \Xi_c^0\pi^-, \Xi_c^0 \to pK^-K^-\pi^+$



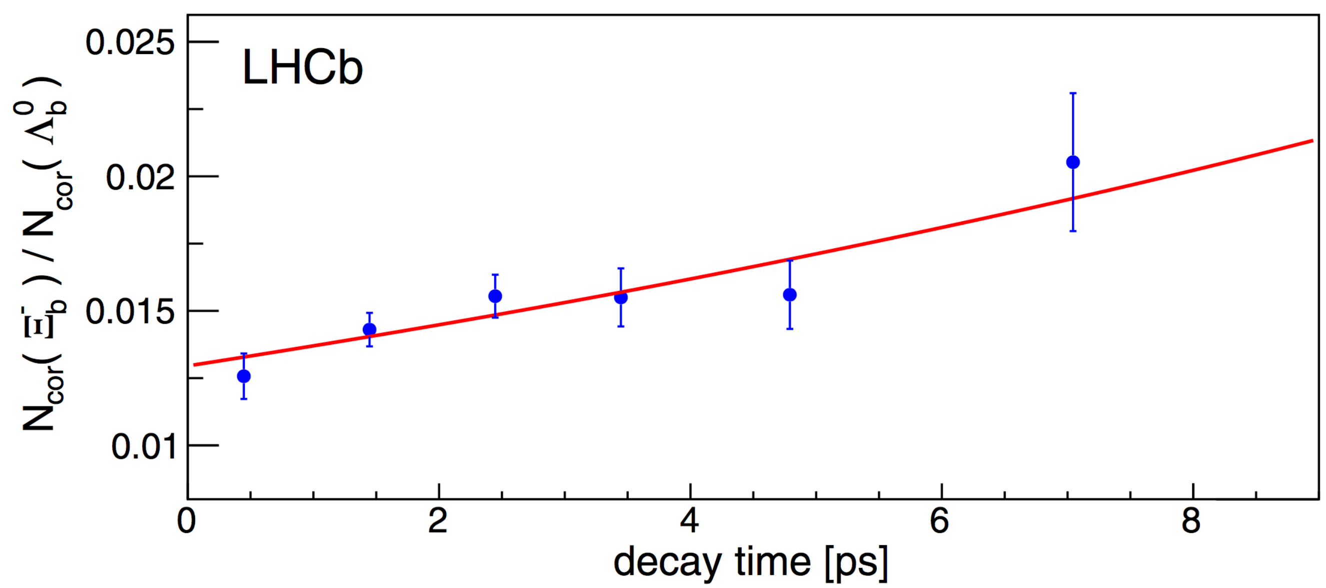
Ξ_b^- lifetime and mass results

PRL 113, 242002 (2014)

Ratio of efficiency vs decay time



Ratio of efficiency corrected yields vs decay time



- Measure $M(\Xi_b^-) - M(\Lambda_b^0) = 178.36 \pm 0.46 \pm 0.16\ \mathrm{MeV}/c^2$

  $$\frac{\tau_{\Xi_b^-}}{\tau_{\Lambda_b^0}} = 1.089 \pm 0.026 \pm 0.011$$

x2 precision improvement

- Using LHCb results relative to Ξ_b^0 we obtain

$$M(\Xi_b^-) - M(\Xi_b^0) = 5.92 \pm 0.60 \pm 0.23\ \mathrm{MeV}/c^2 \qquad \frac{\tau_{\Xi_b^-}}{\tau_{\Xi_b^0}} = 1.083 \pm 0.032 \pm 0.016$$

- Results consistent with predictions from heavy quark expansion (HQE)

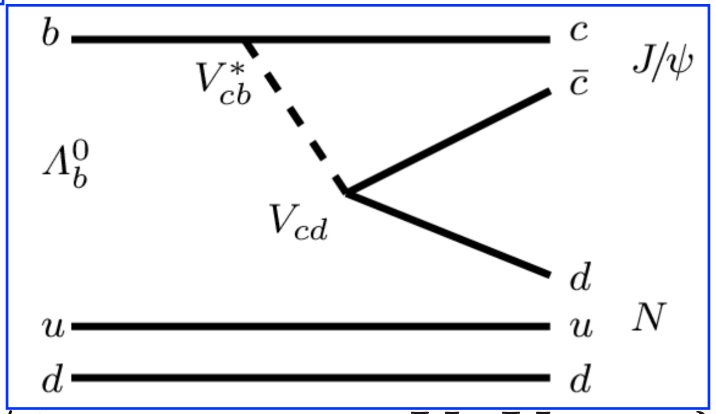
$$\tau_{\Xi_b^-}/\tau_{\Lambda_b^0} = 1.19^{+0.07}_{-0.06} \qquad \tau_{\Xi_b^-}/\tau_{\Xi_b^0} = 1.05 \pm 0.07 \qquad M(\Xi_b^-) - M(\Xi_b^0) = 6.24 \pm 0.21\ \mathrm{MeV}/c^2$$

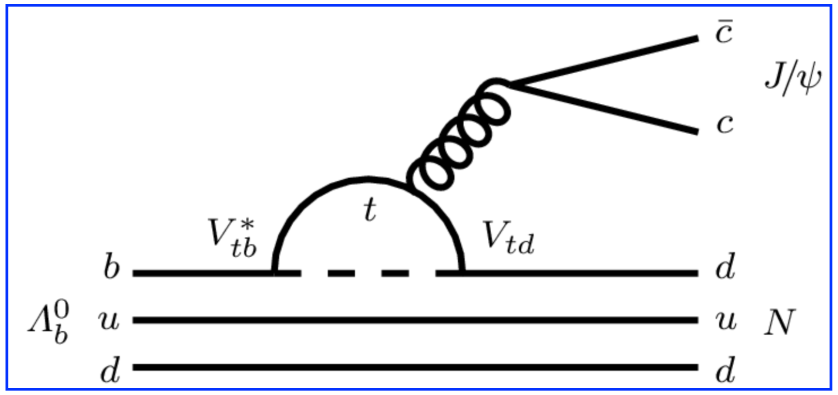
Observation of $\Lambda_b^0 \to J/\psi p \pi^-$ decay

JHEP07(2014)103

- Large interference between tree and penguin amplitudes.

Measure relative BR wrt $\Lambda_b^0 \to J/\psi p K^-$ and search for CPV

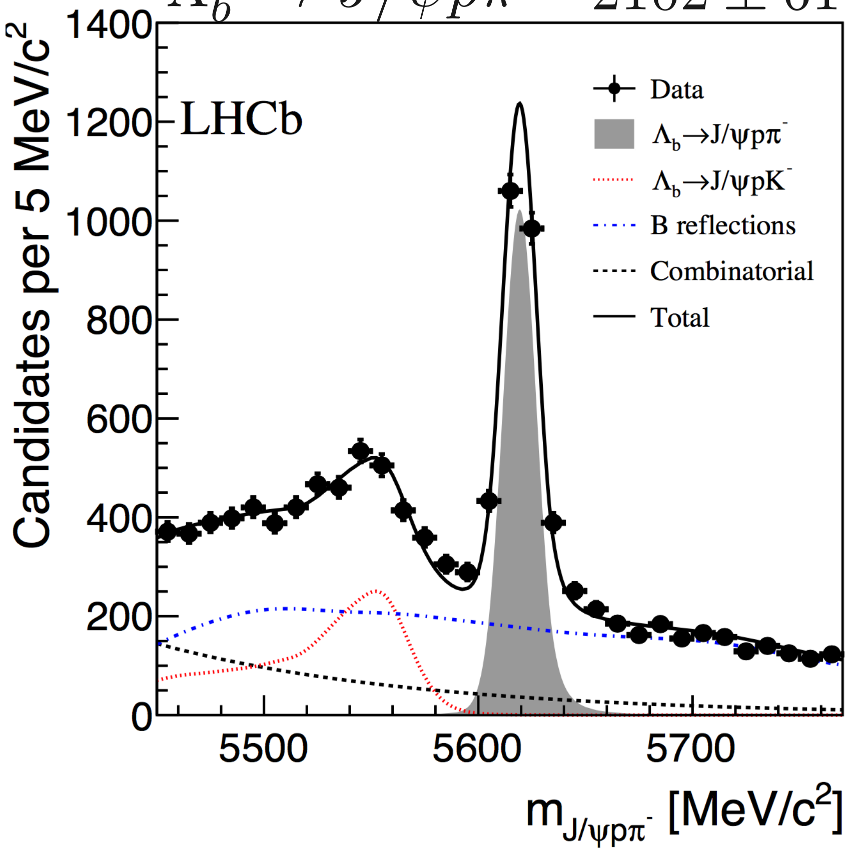




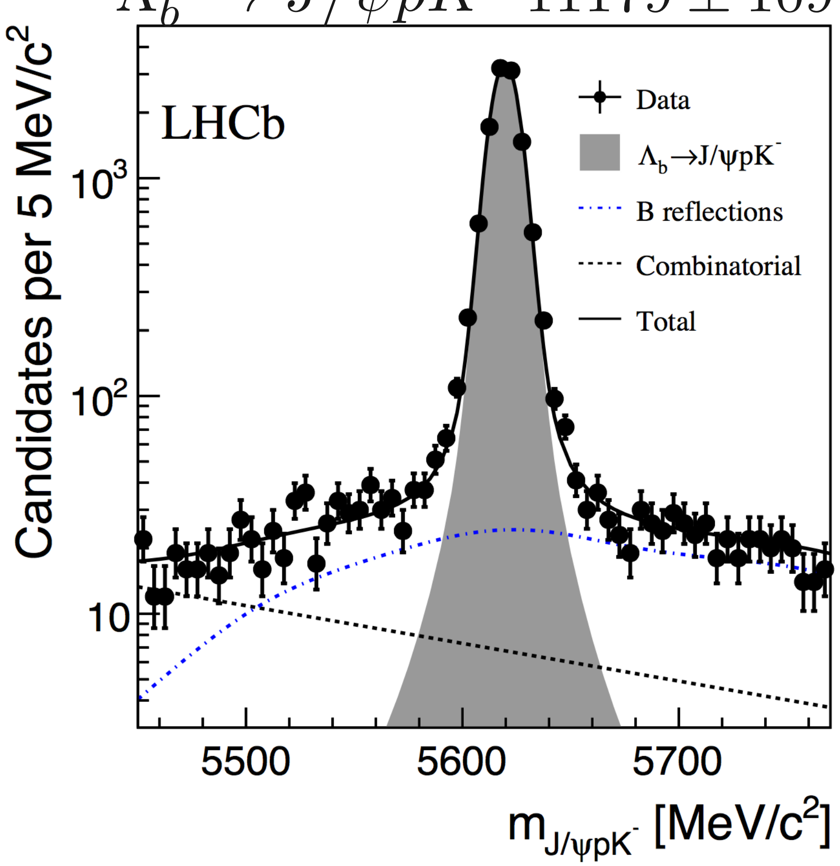
$\Lambda_b^0 \to J/\psi\, p\pi^-$ tree $\propto V_{cb}V_{cd} \sim \lambda^3$

$\Lambda_b^0 \to J/\psi\, p\pi^-$ penguin $\propto V_{tb}V_{td} \sim \lambda^3$ $(|V_{us}| = \lambda)$

$\Lambda_b^0 \to J/\psi p \pi^-$ 2102 ± 61



$\Lambda_b^0 \to J/\psi p K^-$ 11179 ± 109



Search for CP violation

3fb^{-1} data at 7-8 TeV
JHEP07(2014)103

- Measurement of ΔA_{CP} cancel production and proton reconstruction asymmetries

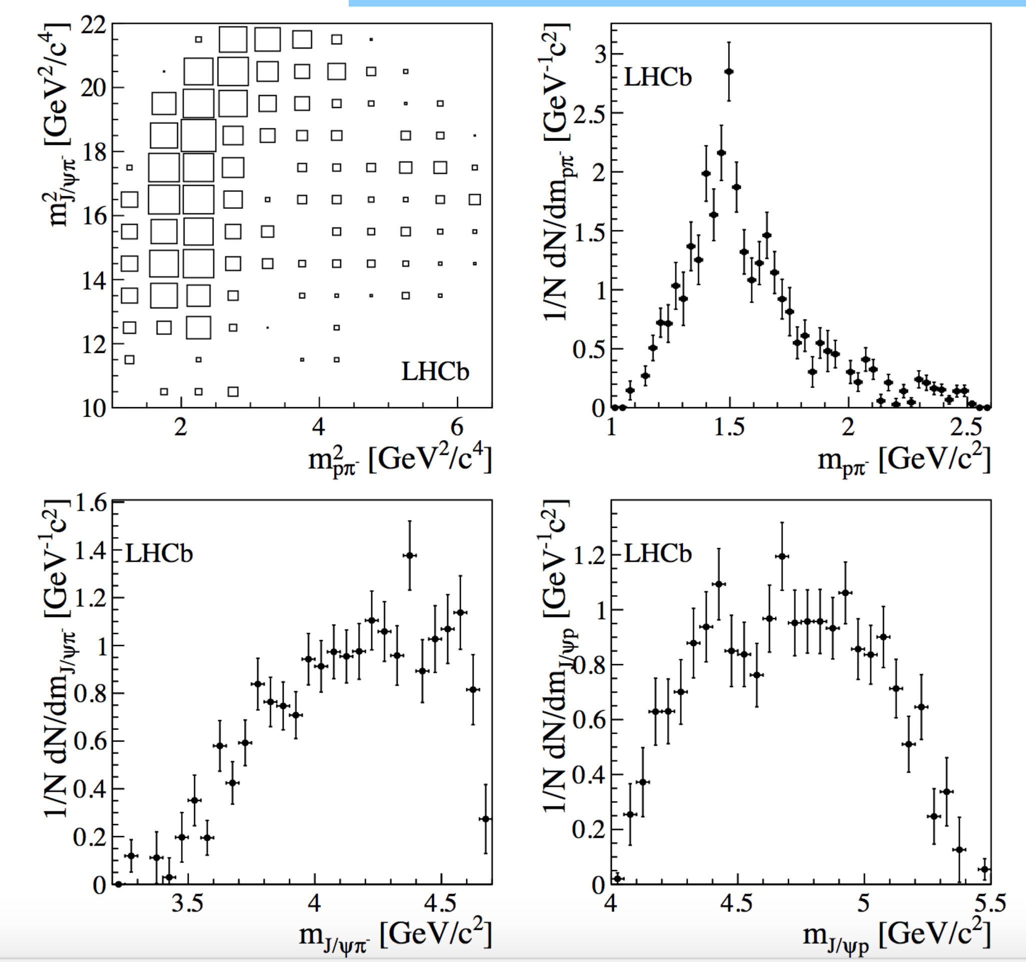
$$\mathcal{A}_{\rm raw}(\Lambda_b^0 \to J/\psi p h^-) = \mathcal{A}_{CP}(\Lambda_b^0 \to J/\psi p h^-) + \mathcal{A}_{\rm prod}(\Lambda_b^0) - \mathcal{A}_{\rm reco}(h^+) + \mathcal{A}_{\rm reco}(p)$$

$$\Delta A_{CP} = \mathcal{A}_{\rm raw}(\Lambda_b^0 \to J/\psi p\pi^-) - \mathcal{A}_{\rm raw}(\Lambda_b^0 \to J/\psi pK^-)$$

$$= \mathcal{A}_{CP}(\Lambda_b^0 \to J/\psi p\pi^-) - \mathcal{A}_{CP}(\Lambda_b^0 \to J/\psi pK^-) + \mathcal{A}_{\rm reco}(\pi^+) - \mathcal{A}_{\rm reco}(K^+)$$

$(5.7 \pm 2.4 \pm 1.2)\%$ 2.2σ from zero

$\approx \mathcal{A}_{\rm raw}(\overline{B}^0 \to J/\psi \overline{K}^{*0}) = (-1.10 \pm 0.32 \pm 0.0.6)\%$



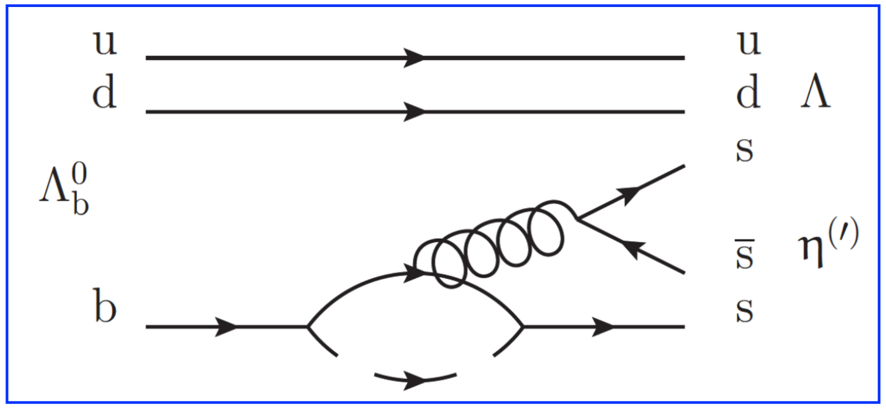
- No indications of large local CP asymmetries in Dalitz plane
- Rich resonant structure in $m(p\pi^-)$, no evidence for exotics in $m(J/\psi p), m(J\psi\pi^-)$
- BR compatible with expected value 0.08: CKM x phase space factor

$$\frac{\mathcal{B}(\Lambda_b^0 \to J/\psi p\pi^-)}{\mathcal{B}(\Lambda_b^0 \to J/\psi pK^-)} = 0.0824 \pm 0.0025\,(\text{stat}) \pm 0.0042\,(\text{syst})$$

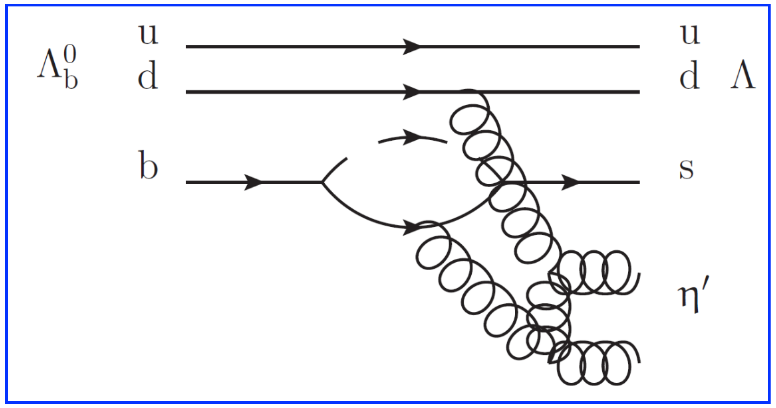
Search for $\Lambda_b^0 \to \Lambda\eta^{(\prime)}$ decays

arXiV:1505.03295
Submitted to JHEP

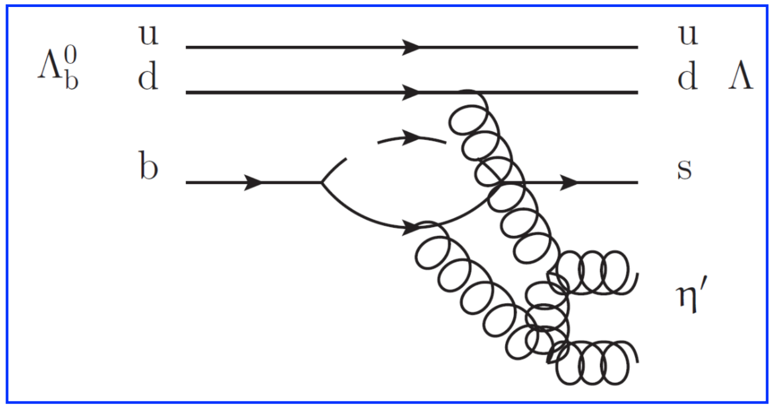
- b-baryons decays to final states with η, η' not yet observed. From BR measurements determine $\eta - \eta'$ mixing



Dominant EW loop diagram



Non-spectator diagram



Anomalous diagram

- Consider η, η' as admixture of light $|\eta_q\rangle = \frac{1}{\sqrt{2}}|u\bar{u} + d\bar{d}\rangle$, strange $|\eta_s\rangle = |s\bar{s}\rangle$ quark states, and gluons $|gg\rangle$:

$$|\eta'\rangle \simeq \cos\phi_G \sin\phi_P|\eta_q\rangle + \cos\phi_G \cos\phi_P|\eta_s\rangle + \sin\phi_G|gg\rangle$$
$$|\eta\rangle \simeq \cos\phi_P|\eta_q\rangle - \sin\phi_P|\eta_s\rangle$$

- Mixing parameters determined in $B^0_{(s)} \to J/\psi\eta^{(\prime)}$ decays

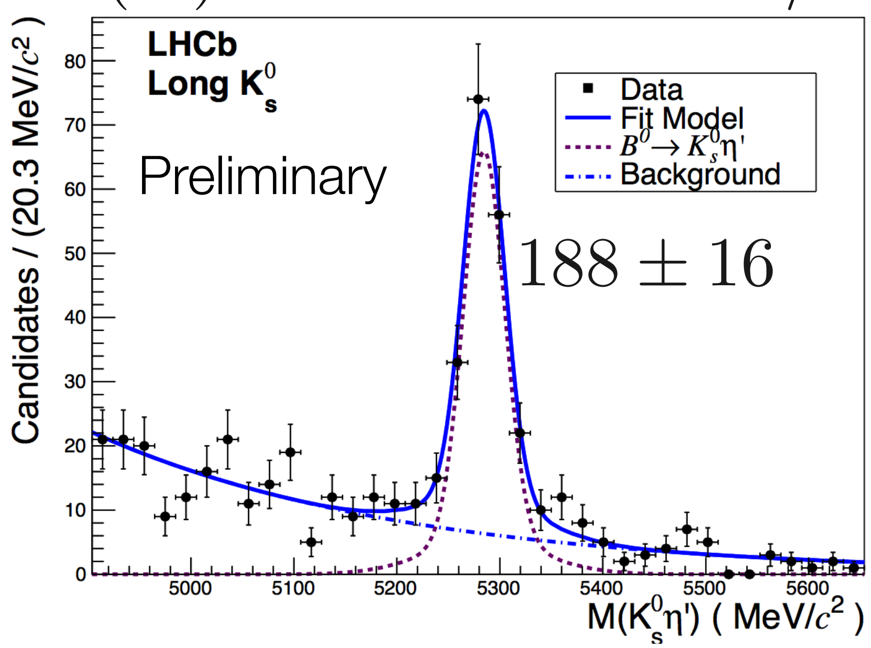
$\phi_P = (43.5^{+1.5}_{-2.8})^\circ$ $\phi_G = (0 \pm 25)^\circ$ JHEP01(2015)024

Analysis strategy and event selection

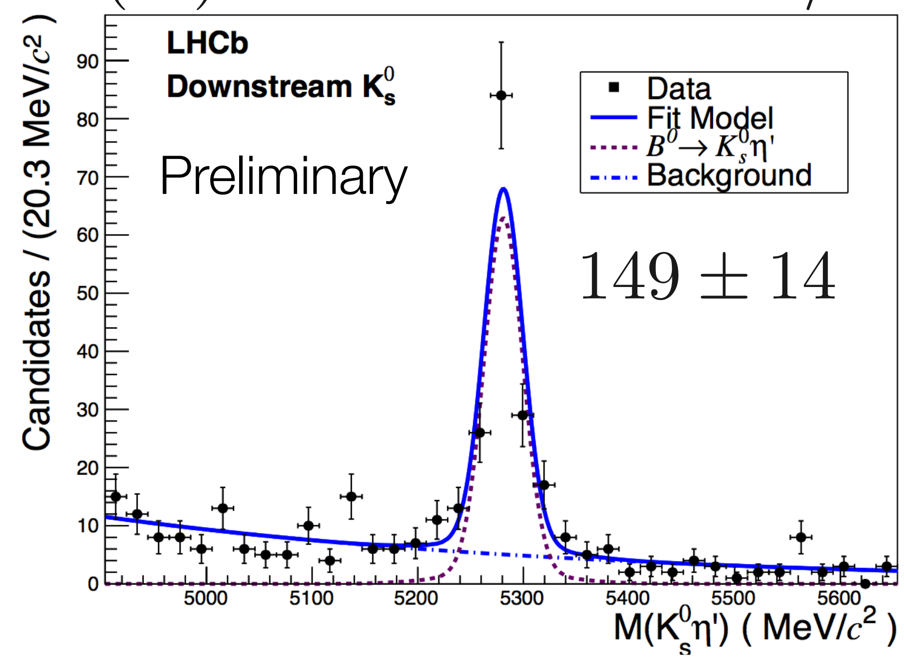
3fb^{-1} data at 7-8 TeV - arXiV:1505.03295, submitted to JHEP

- Measure BR of $\Lambda_b \to \Lambda\eta'_{\pi^+\pi^-(\gamma,\eta_{\gamma\gamma})}$ and $\Lambda_b \to \Lambda\eta_{\pi^+\pi^-\pi^0}$ relative to $B^0 \to K^0_S\eta'_{\pi^+\pi^-\gamma}$
  - Long lived $K^0_S \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$ are divided in Long and Downstream categories if produce hits in the vertex detector or not. Different track resolution and selection optimisation
  - Full decay chain refitted , primary vertex with tracks not from *b*-hadron decays, fix to nominal value the mass of $\Lambda, K^0_S, \eta, \eta'$

$\sigma(m) = 30.0 \pm 1.5\ \mathrm{MeV}/c^2$



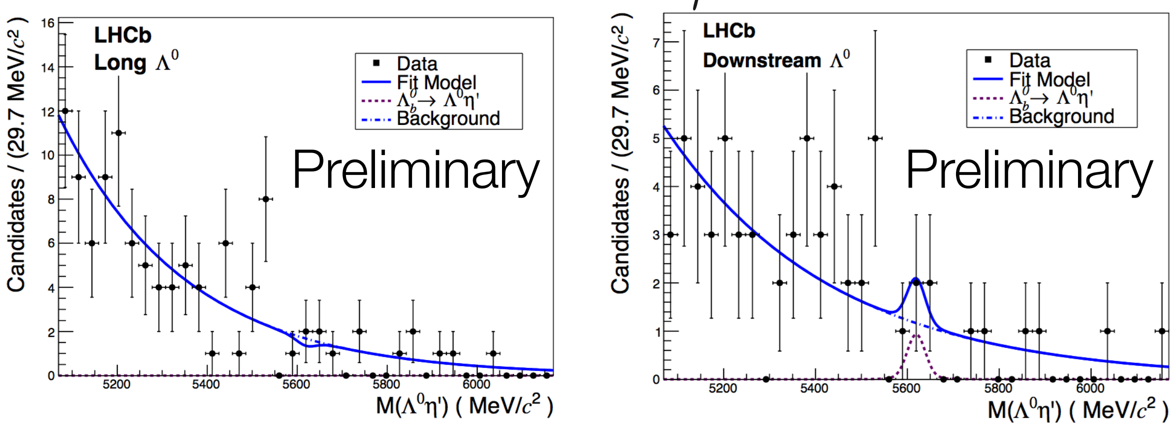
$\sigma(m) = 29.4 \pm 1.3\ \mathrm{MeV}/c^2$



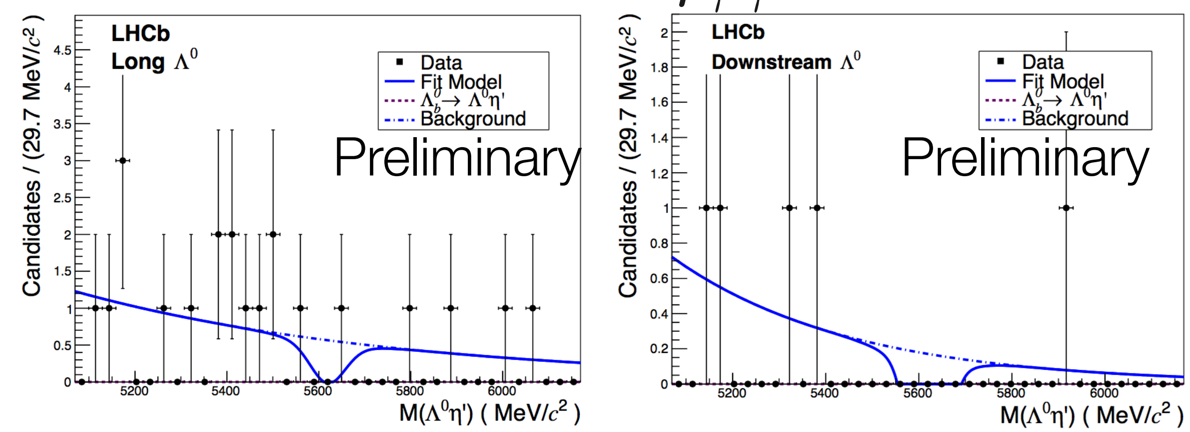
Fit results

3fb^{-1} data at 7-8 TeV - arXiV:1505.03295, submitted to JHEP

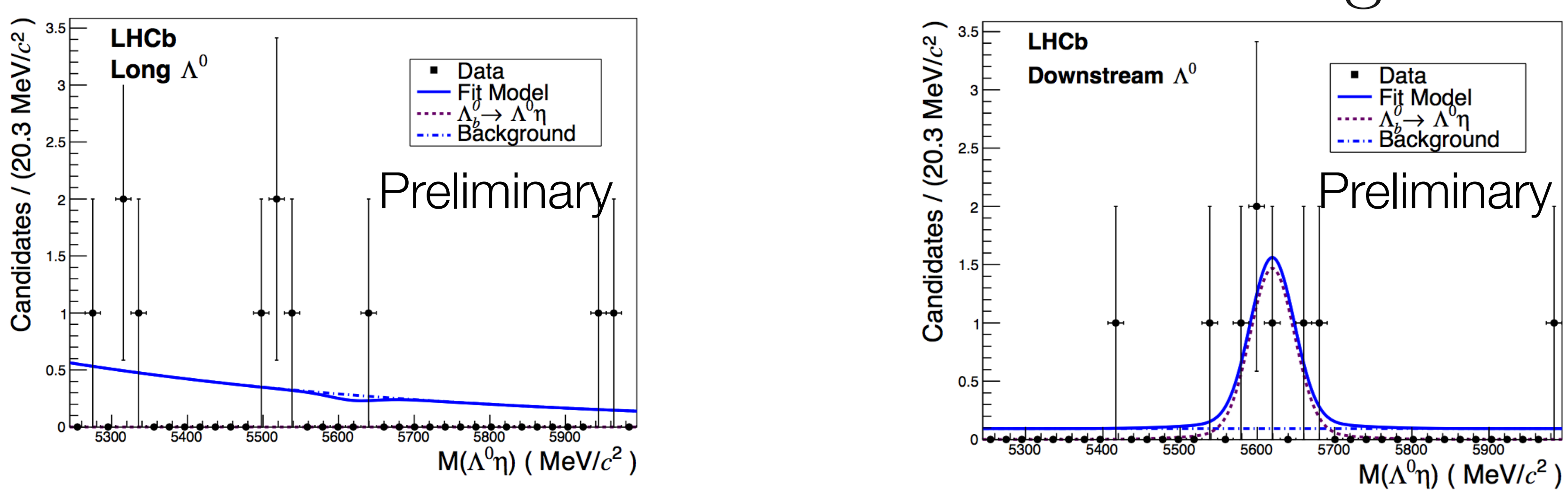
$\Lambda_b \to \Lambda\eta'_{\pi^+\pi^-\gamma}$ 1.0 ± 4.4



$\Lambda_b \to \Lambda\eta'_{\pi^+\pi^-\eta_{\gamma\gamma}}$ -4.2 ± 2.3



$\Lambda_b \to \Lambda\eta_{\pi^+\pi^-\pi^0}$ 5.3 ± 3.8 3σ significance



Use Feldman, Cousins unified method approach for CL Phys. Rev. D57 (1998) 3873

- Measure ratio of BR and use known $\mathcal{B}(B^0 \to K^0_S\eta')$

$$\frac{\mathcal{B}(\Lambda^0_b \to \Lambda\eta')}{\mathcal{B}(B^0 \to K^0\eta')} < 0.047 \text{ at } 90\% \text{ CL} \qquad \mathcal{B}(\Lambda^0_b \to \Lambda\eta') < 3.1 \times 10^{-6} \text{ at } 90\% \text{ CL}$$

$$\frac{\mathcal{B}(\Lambda^0_b \to \Lambda\eta)}{\mathcal{B}(B^0 \to K^0\eta')} = 0.142^{+0.11}_{-0.08} \;\; 68\% \text{ CL} \qquad \mathcal{B}(\Lambda^0_b \to \Lambda\eta) = (9.3^{+7.3}_{-5.3}) \times 10^{-6}$$

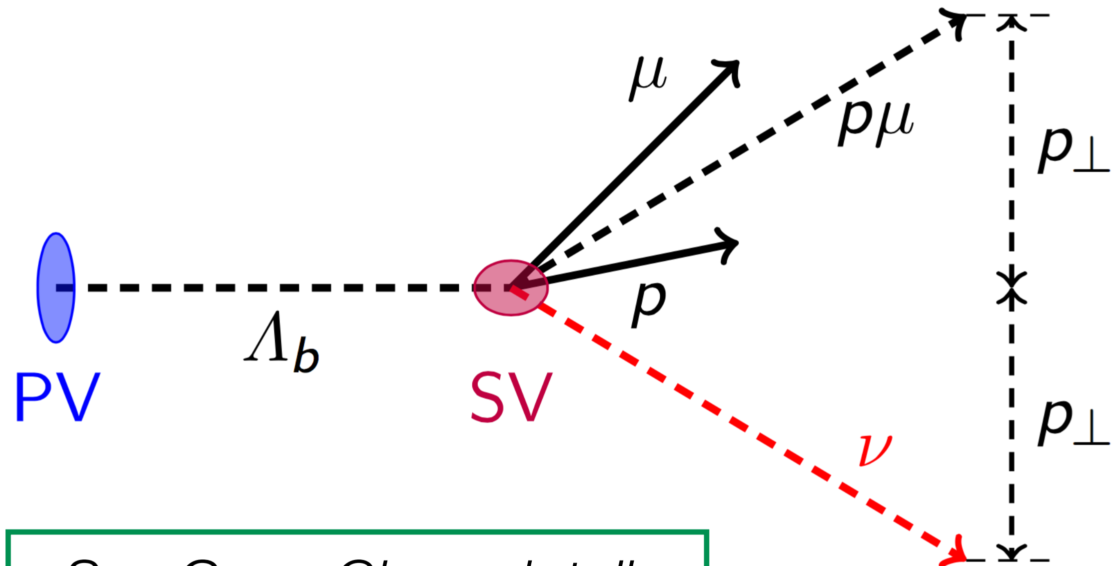
|Vub| measurement with $\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu$

2fb^{-1} data at 8 TeV - arXiv:1504.01568

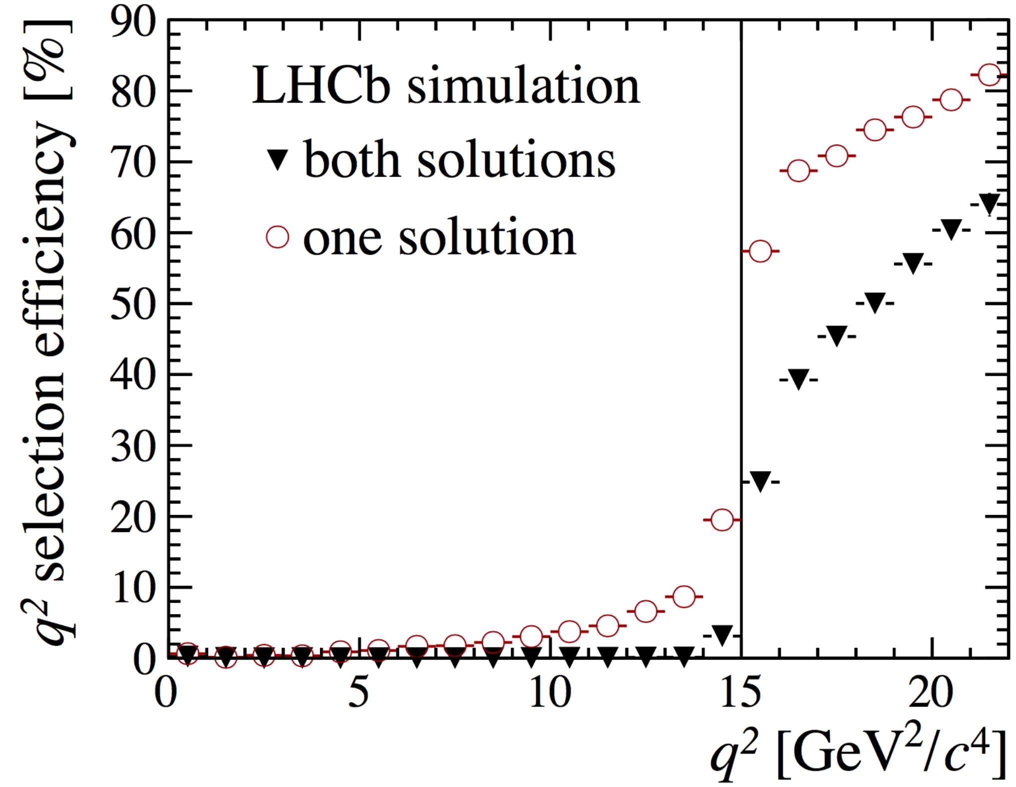
- Normalise yields to $\Lambda_b^0 \to \Lambda_c^+\mu^-\bar{\nu}_\mu$, Vcb mediated decay, cancel many systematic uncertainties
- Apply tight vertex cut, PID on proton and muon, track isolation to reject 90% of background (using boosted decision tree)
- Use corrected mass to reconstruct the signal and retain events with $\sigma(M_{\rm corr}) < 100\rm MeV$

$$M_{corr} = \sqrt{p_\perp^2 + M_{p\mu}^2} + p_\perp$$

- Use Λ_b^0 flight direction and mass to determine q^2 with two-fold ambiguity (neutrino). Require both solutions >15 GeV^2, minimise migration to low q^2



See Greg Ciezarek talk for more details



$|V_{ub}|$ results

2fb^{-1} data at 8 TeV - arXiv:1504.01568

- Measure:

$$|V_{ub}|^2 = |V_{cb}|^2 \frac{\mathcal{B}(\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu)_{q^2>15\mathrm{GeV}^2}}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\mu^-\bar{\nu}_\mu)_{q^2>7\mathrm{GeV}^2}} R_{FF}$$

world average	measured	LQCD [1]
$(39.5 \pm 0.8) \times 10^{-3}$	$(1.00 \pm 0.04 \pm 0.08) \times 10^{-2}$	0.68 ± 0.07

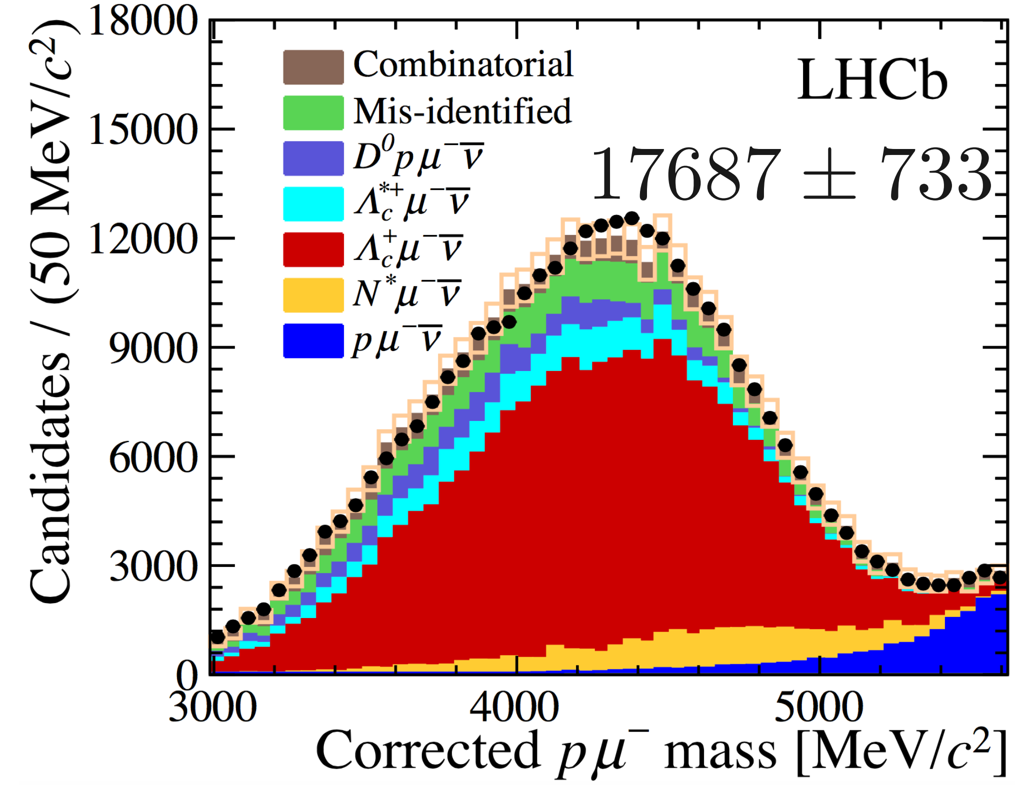
[1] W. Detmold, C. Lehner, and S. Meinel, arXiv:1503.01421

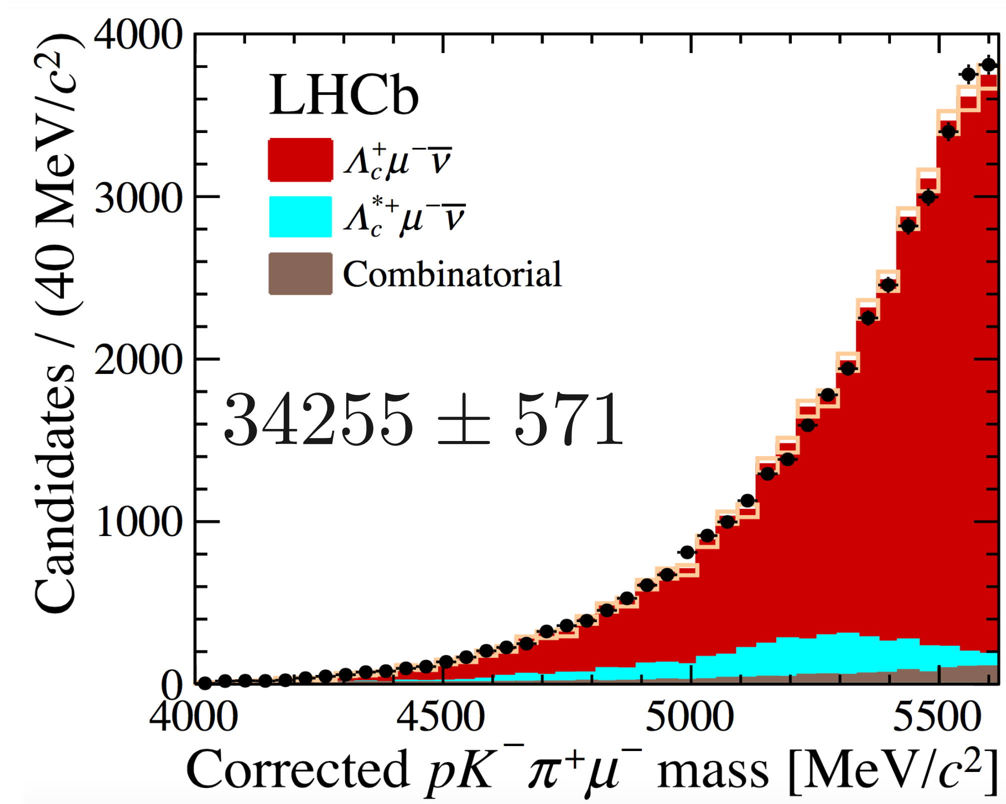
Most precise measurement

$$|V_{ub}| = (3.27 \pm 0.15 \pm 0.17 \pm 0.06) \times 10^{-3}$$

exp. LQCD $|V_{cb}|$

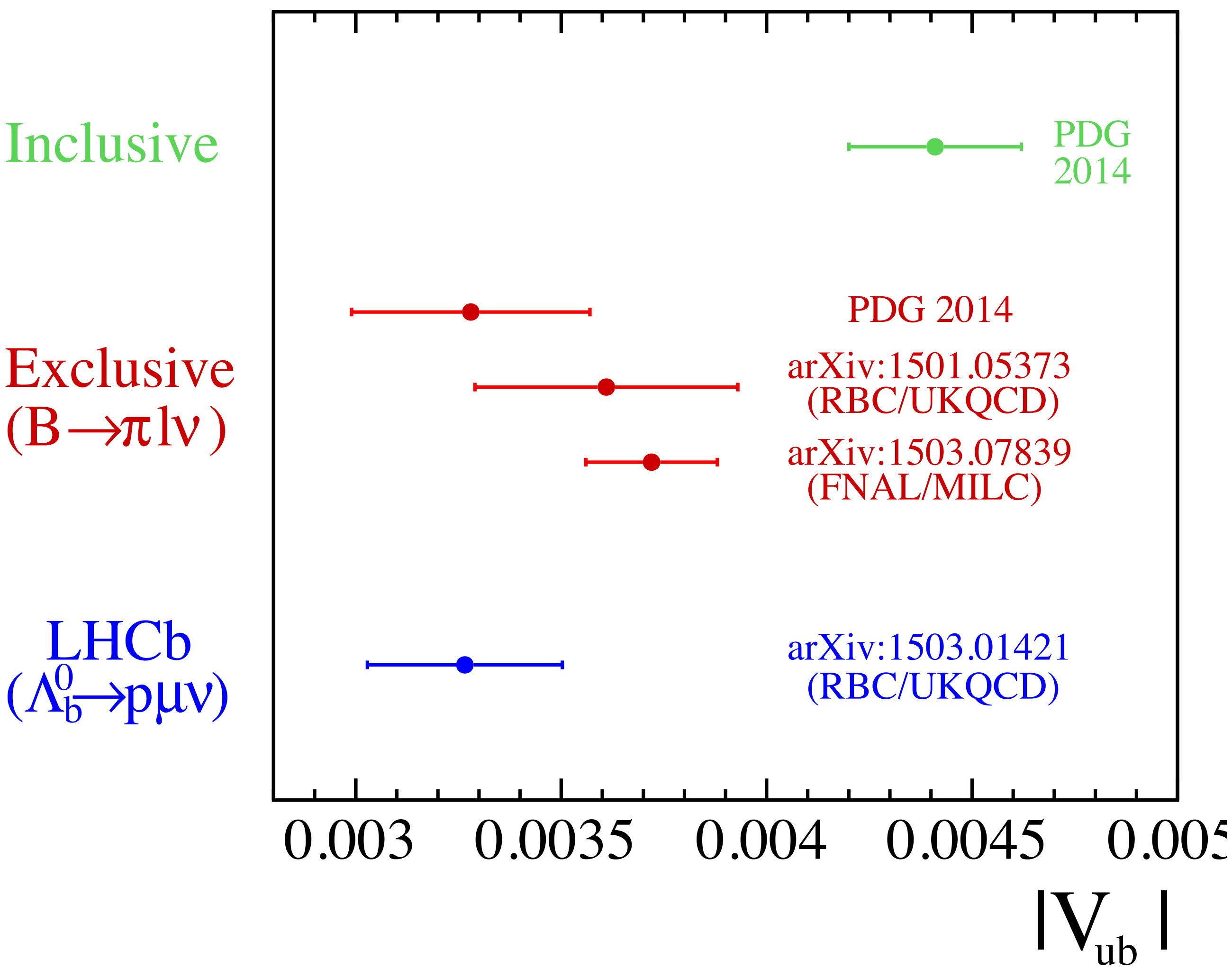
- Background contributions estimated using ad hoc control samples
- Largest exp. uncertainty from $\mathcal{B}(\Lambda_c^+ \to pK^+\pi^-)$



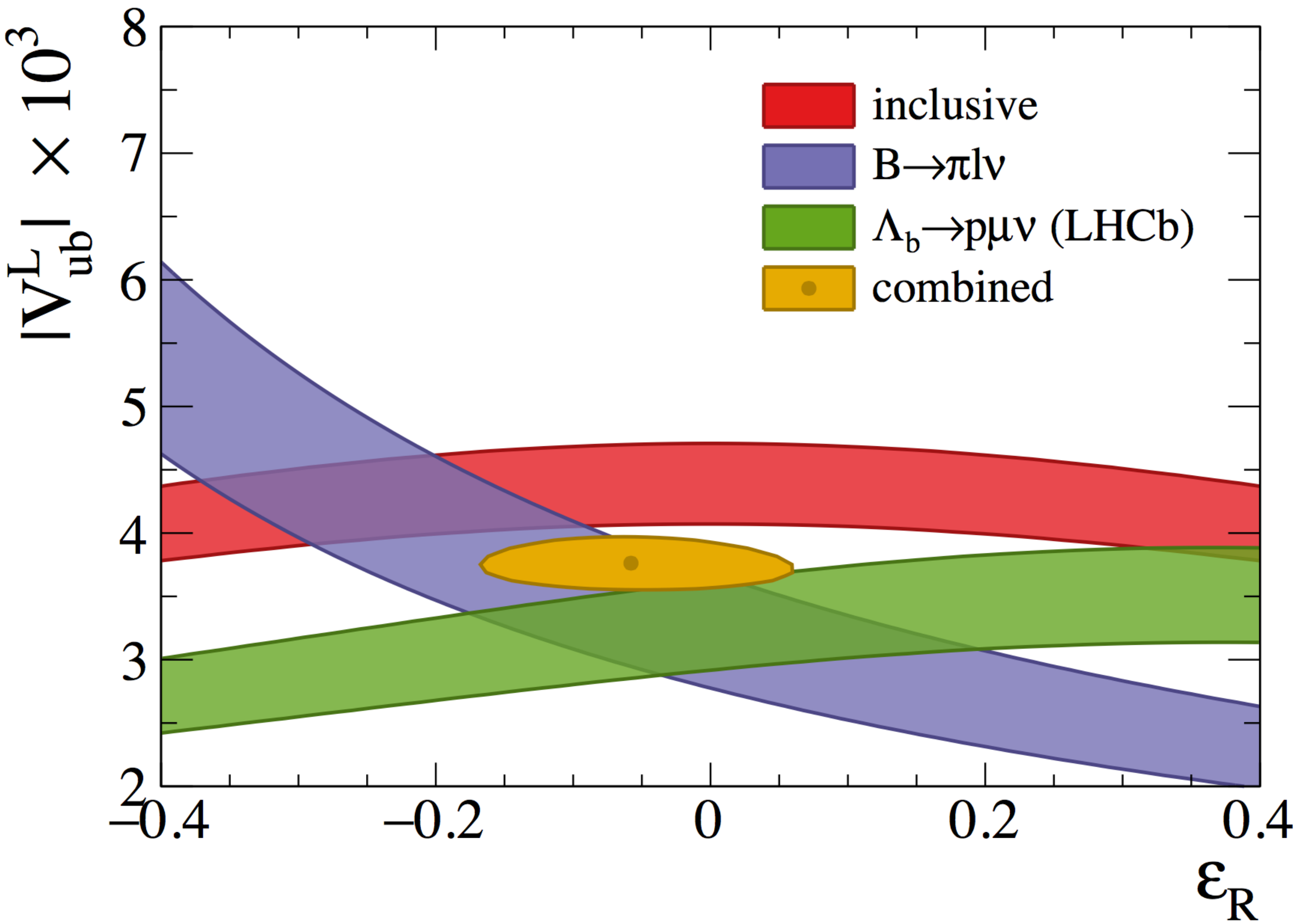


$|V_{ub}|$ puzzle

~3.5σ tension between exclusive and inclusive measurements



LHCb measurement does not support explanation based on right handed current added to SM



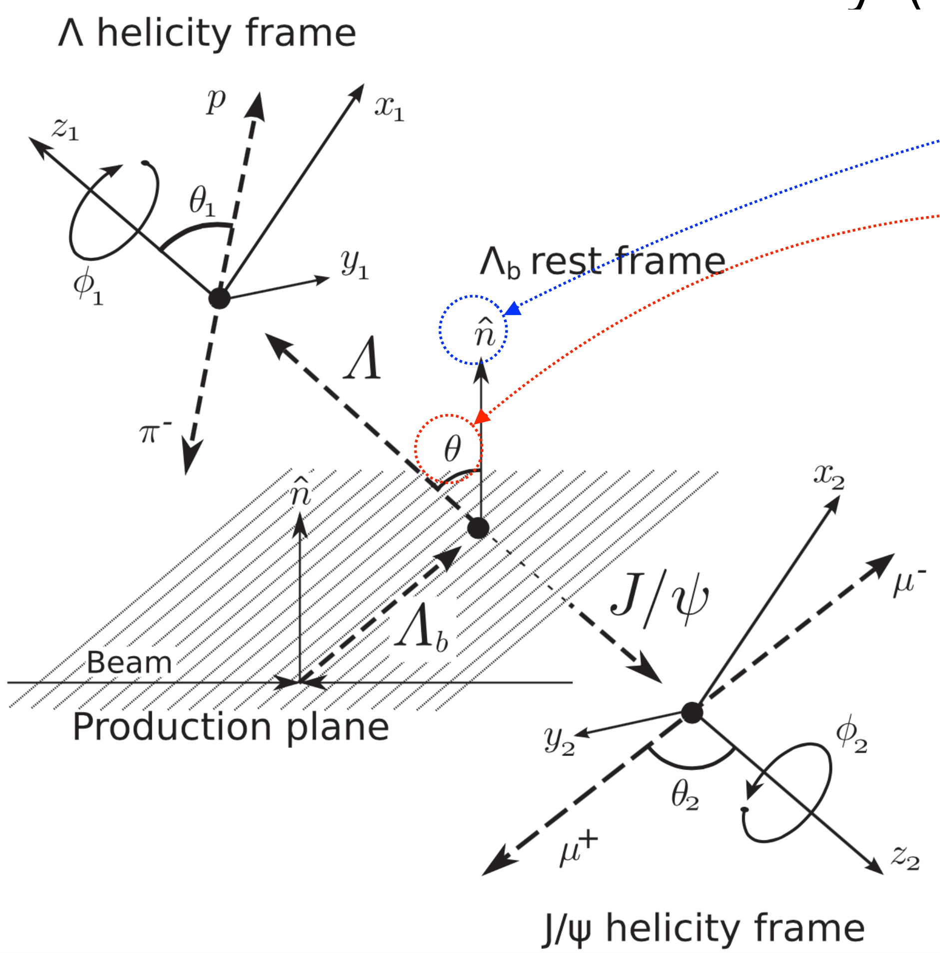
Conclusions

- At the LHC, *b*-baryons represent a new field in flavour physics for precision measurements. However, it is a relatively new territory for experiments and theory
- Precision measurements of mass, lifetimes and BR provide experimental anchor points for theory and QCD models. Rare decays and CPV are sensitive to physics beyond SM
- $|V_{ub}|$ measurement using Λ_b is an outstanding example of advancement of both experimental techniques and LQCD calculations, providing a stringent test of SM. Others are foreseen
- Be prepared to be surprised by *b*-baryon physics in the near future!

Backup slides

Parity violation in $\Lambda_b^0 \to J/\psi\Lambda$

- Parity violation is not maximal in hadron weak decays and depends on hadron constituents. In *b*-baryons can be predicted by perturbative QCD (pQCD) and heavy quark effective theory (HQET)



$$w(\cos\theta) = \frac{1}{2}(1 + \alpha P \cos\theta)$$

polarisation: P; parity-violation: α; angle: $\cos\theta$

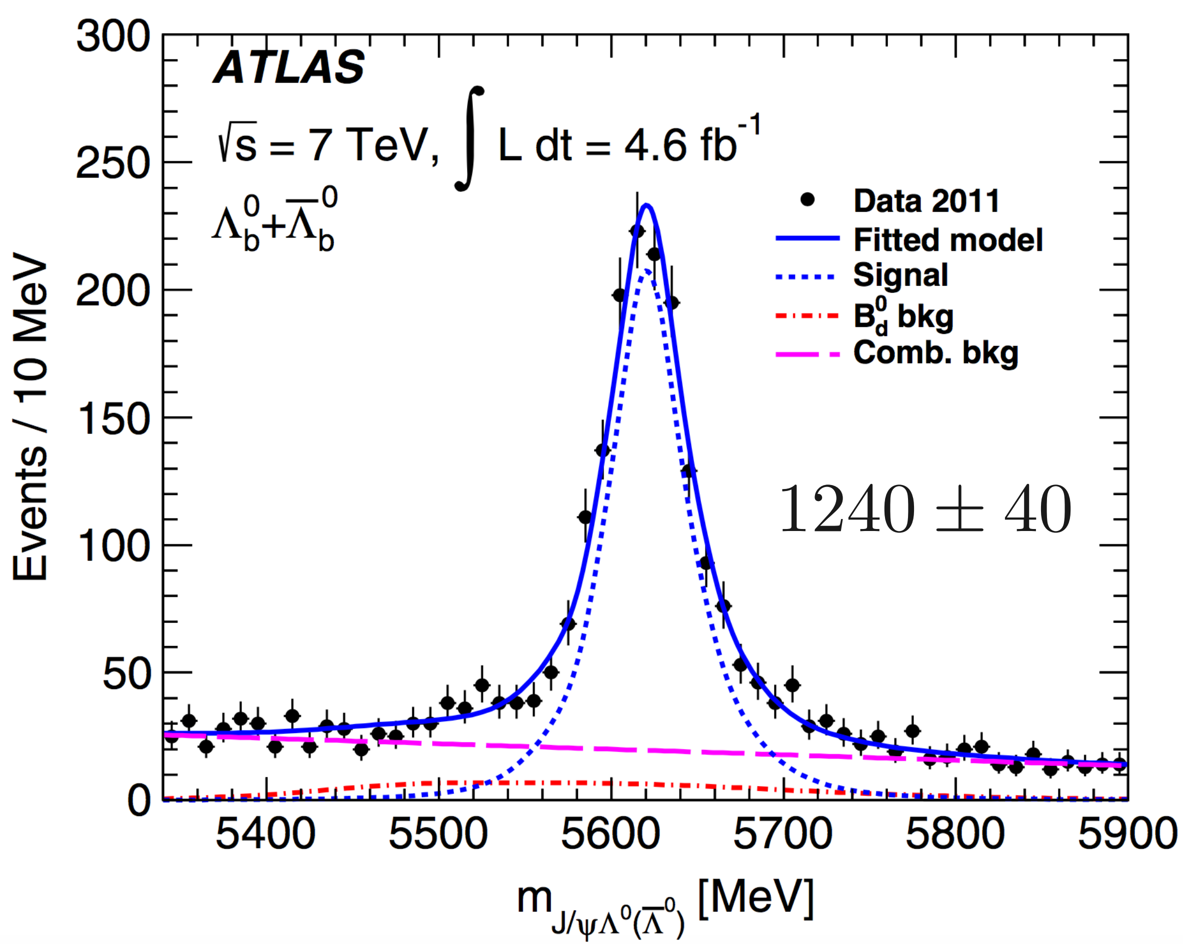
- Λ_b^0 polarisation allowed only to be perpendicular to production plane, due to parity conservation in pp strong interaction

- Use 4 helicity amplitudes to describe the $\Lambda_b^0 \to J/\psi\Lambda$ decay

$$A(\lambda_\Lambda, \lambda_{J/\psi}) : a_+ = A(1/2, 0), a_- = A(-1/2, 0),$$
$$b_+ = A(-1/2, -1), b_- = A(1/2, 1)$$

Parity violation results

ATLAS EXPERIMENT 4.6fb^{-1} data at 7 TeV - PRD 89, 092009 (2014)



Negative helicity states for Λ are preferred.

$$|a_+| = 0.17^{+0.12}_{-0.17}(\text{stat}) \pm 0.09(\text{syst})$$

$$|a_-| = 0.59^{+0.06}_{-0.07}(\text{stat}) \pm 0.03(\text{syst})$$

$$|b_+| = 0.79^{+0.04}_{-0.05}(\text{stat}) \pm 0.02(\text{syst})$$

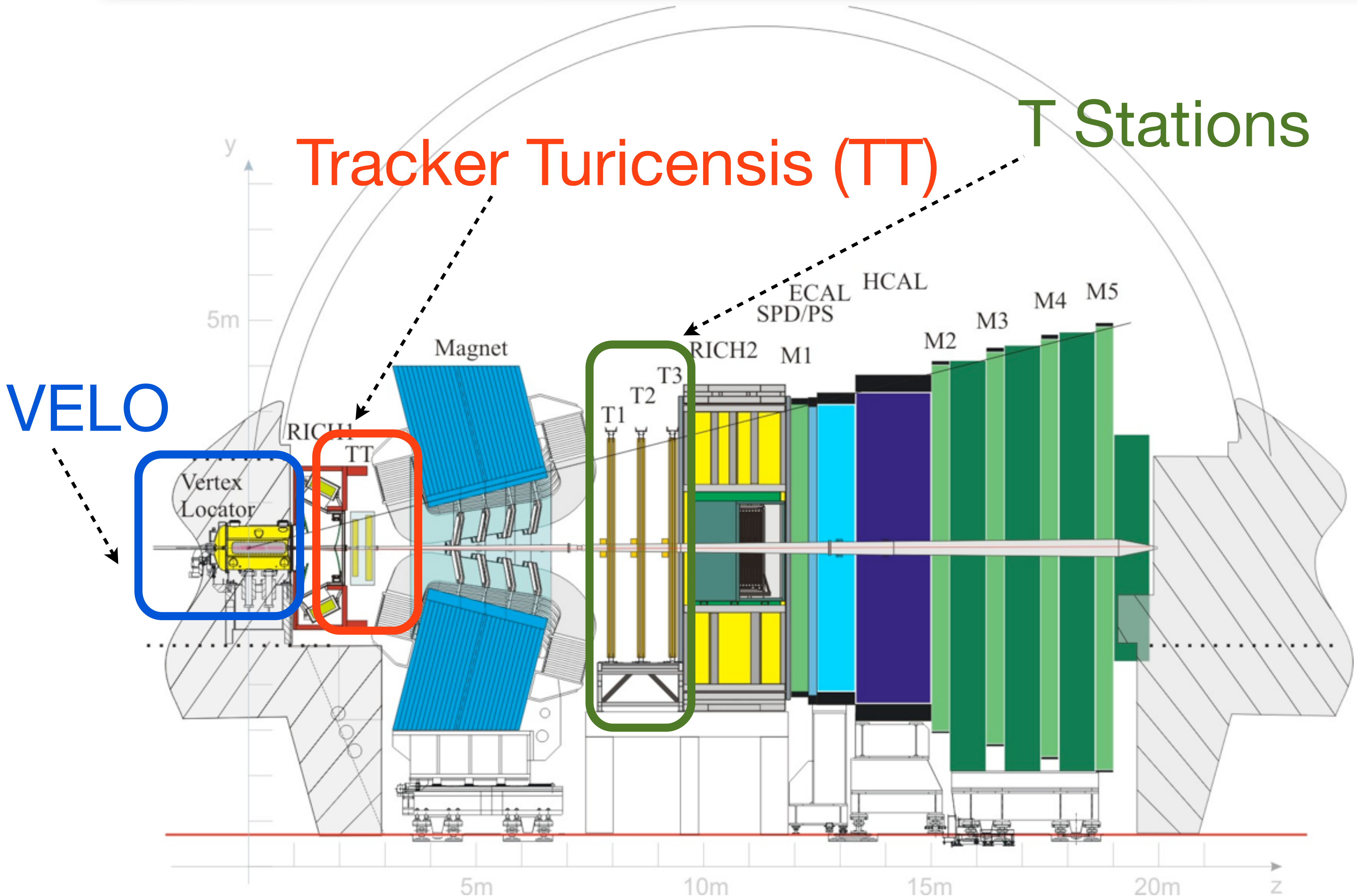
$$|b_-| = 0.08^{+0.13}_{-0.08}(\text{stat}) \pm 0.06(\text{syst})$$

- <P>=0 in a symmetric interval in pseudorapidity
- Assume CP conservation and extract α from a simplified angular analysis with 5 independent parameters

$$\alpha = |a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2$$
$$= 0.30 \pm 0.16 \pm 0.06$$

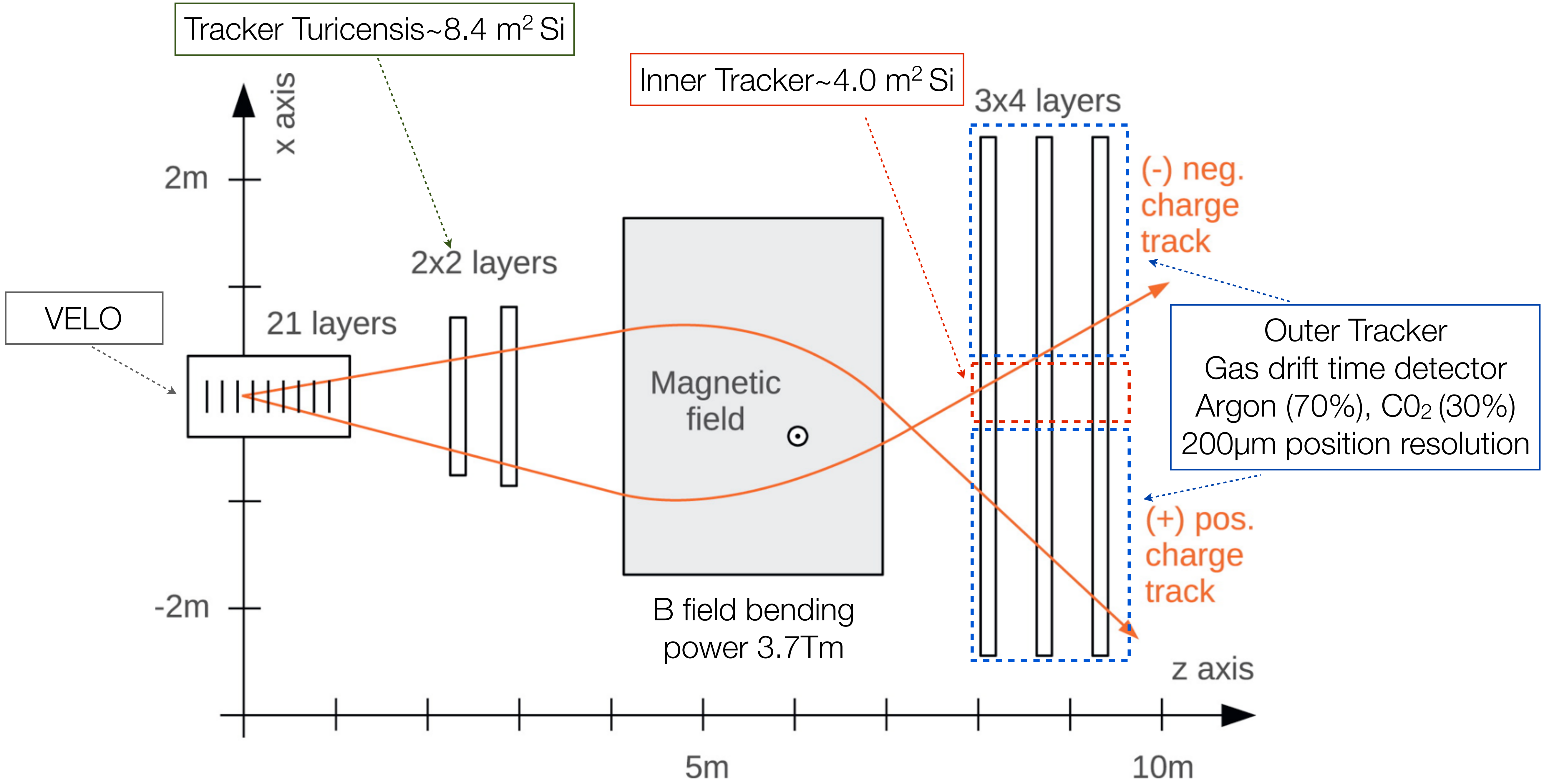
- Consistent with LHCb measurement $\alpha = 0.05 \pm 0.17 \pm 0.07$ PLB 724, 27 (2013) but not with pQCD [-0.17,-0.14] and HQET predictions 0.78
- LHCb measured $P = 0.06 \pm 0.07 \pm 0.02$

LHCb detector

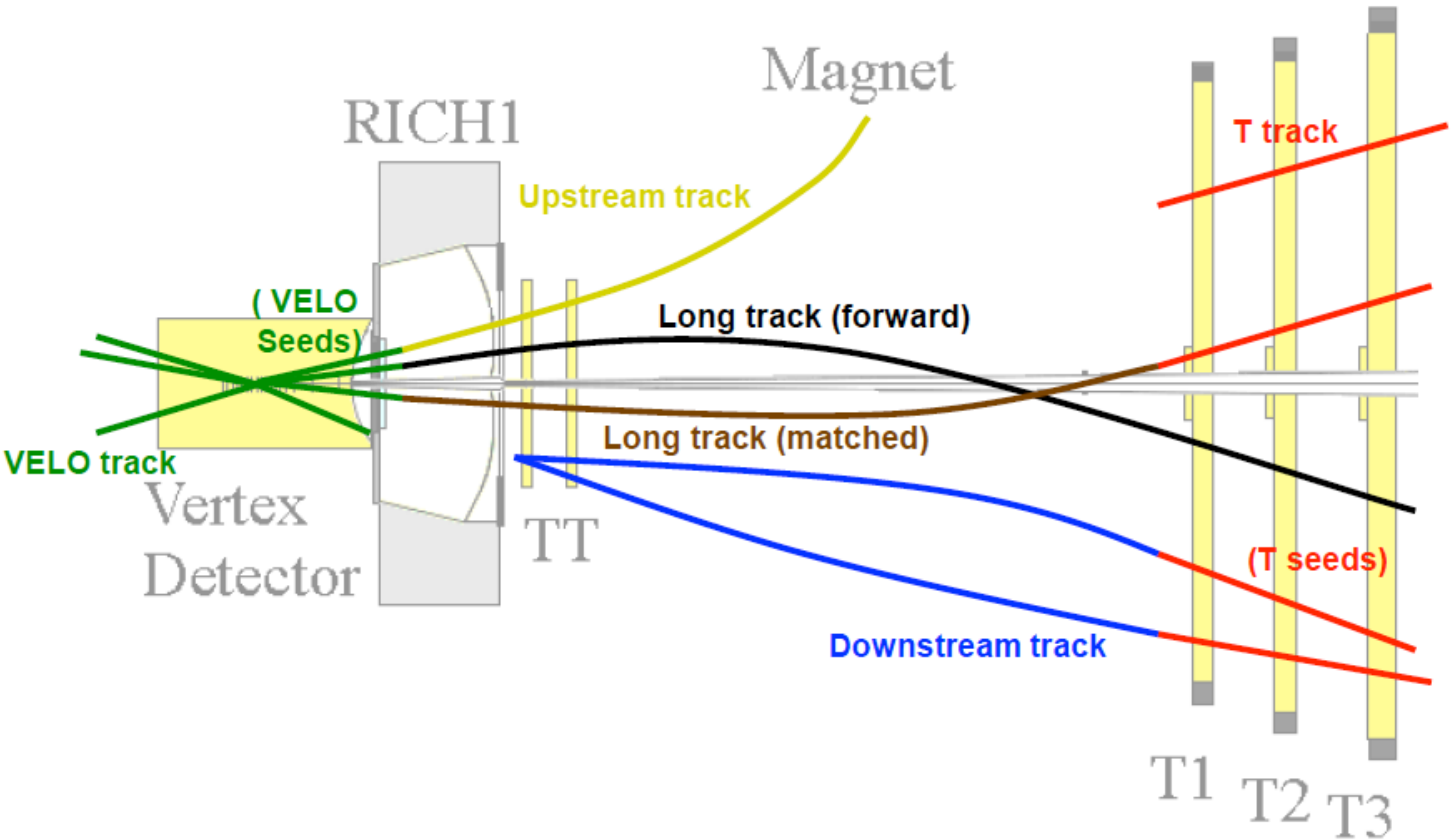


LHCb tracking system

TT: 500μm thick, single sided Si strip detector, pitch~100-200μm, vertical and stereo angle strips arrangement (x-u-v-x)=(0°,-5°,+5°,0°)



Track definitions at LHCb



Ghost track = is a fake track. For example it can be formed by matching a real track segment in the VELO (VELO seed) with a real track segment in the downstream tracker (T seed)