b baryon physics in CMS

S. Polikarpov (on behalf of the CMS Collaboration's B-Physics Analysis Group)

b-baryon fest

5-6 November 2020

5 November 2020

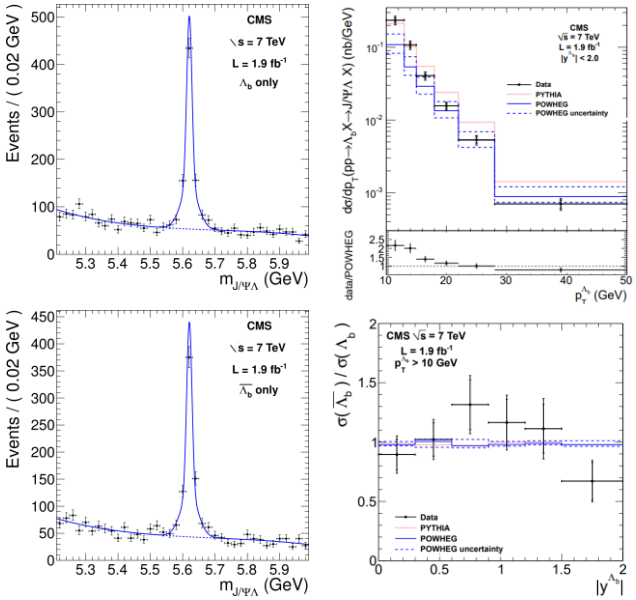
Outline

- Previous CMS results on b baryons
- b-parking at CMS
- Prospects for future CMS analyses with beauty baryons

CMS results in b-baryon sector

Λ_b^0 production, lifetime and polarization measurements

Phys. Lett. B 714 (2012) 136

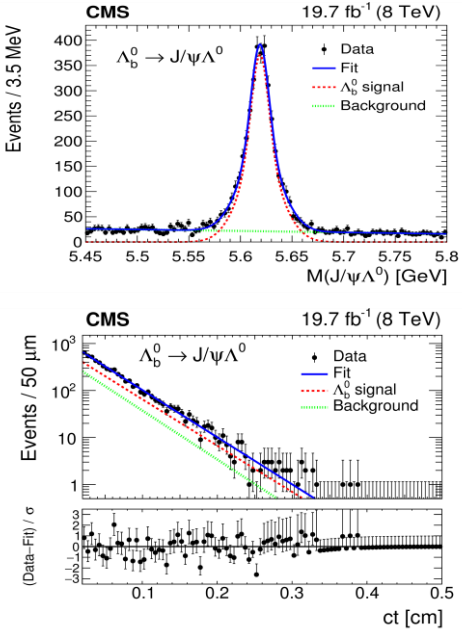


$$\sigma(\mathrm{pp} \to \Lambda_\mathrm{b} X) \times \mathcal{B}(\Lambda_\mathrm{b} \to \mathrm{J}/\psi\Lambda)$$

$$1.16 \pm 0.06 \pm 0.12 \text{ nb}$$

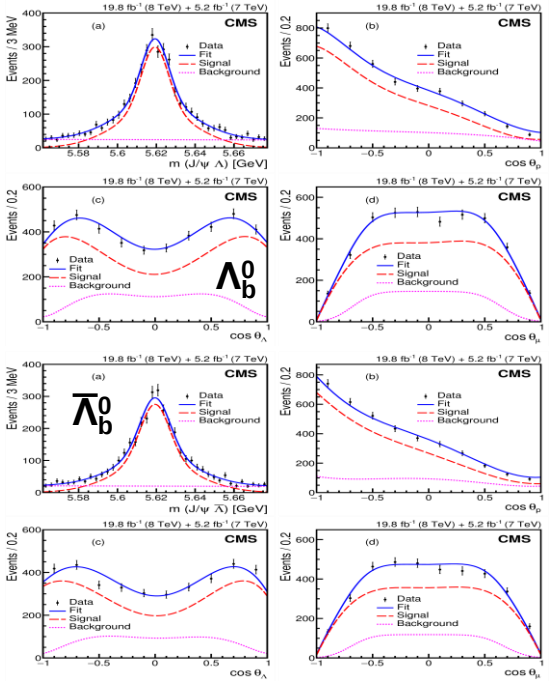
for $p_\mathrm{T}^{\Lambda_\mathrm{b}} > 10\,\mathrm{GeV}$ and $|y^{\Lambda_\mathrm{b}}| < 2.0$

JHEP 07 (2013) 163



$$c\tau_{\Lambda_\mathrm{b}^0} = 442.9 \pm 8.2\,(\mathrm{stat}) \pm 2.8\,(\mathrm{syst})\ \mu\mathrm{m}$$

PRD 97 (2018) 072010



Polarization $P = 0.00 \pm 0.06\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})$

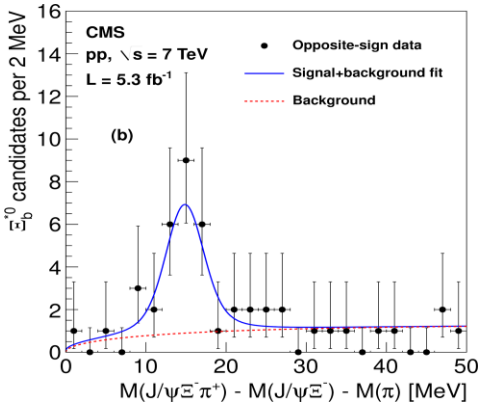
Parity-violating asymmetry $\alpha_1 = 0.14 \pm 0.14\,(\mathrm{stat}) \pm 0.10\,(\mathrm{syst})$

CMS results in b-baryon sector

Beauty baryon spectroscopy: excited states and new decays

PRL 108 (2012) 252002

Observation of Ξ_b^{*0}



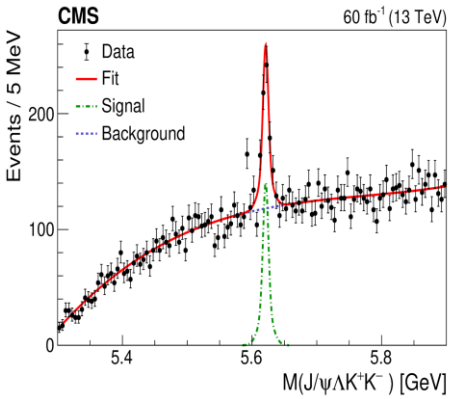
Mass of the new state

$5945.0 \pm 0.7\,(\text{stat.}) \pm 0.3\,(\text{syst.}) \pm 2.7\,(\text{PDG})\ \text{MeV}$

Confirmed later by LHCb

PLB 802 (2020) 135203

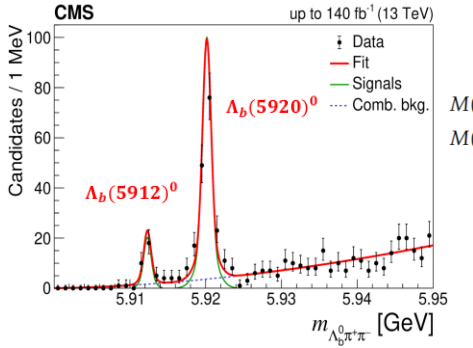
Observation of $\Lambda_b^0 \to J/\psi\Lambda\varphi$



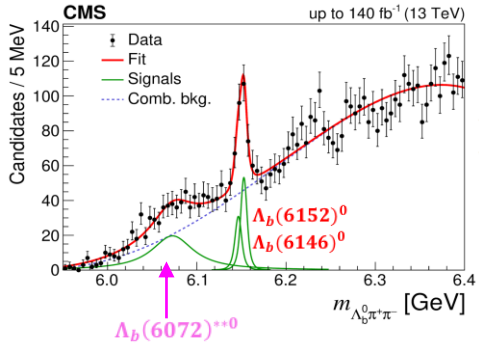
$$\frac{\mathfrak{B}(\Lambda_b^0 \to J/\psi\Lambda\varphi)}{\mathfrak{B}(\Lambda_b^0 \to \psi(2S)\Lambda)} = (8.26 \pm 0.90_{(\text{stat})} \pm 0.68_{(\text{syst})} \pm 0.11_{(\mathfrak{B})})\%$$

PLB 803 (2020) 135345

Measurements of excited Λ_b^0 states



$M(\Lambda_b(5912)^0) = 5912.32 \pm 0.12 \pm 0.01 \pm 0.17\,\text{MeV}$,
$M(\Lambda_b(5920)^0) = 5920.16 \pm 0.07 \pm 0.01 \pm 0.17\,\text{MeV}$,



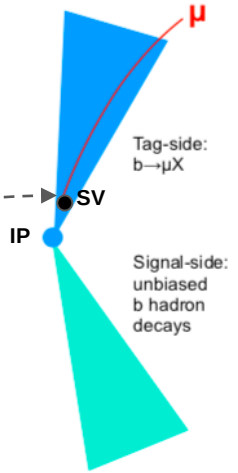
$M(\Lambda_b(6146)^0) = 6146.5 \pm 1.9 \pm 0.8 \pm 0.2\,\text{MeV}$
$M(\Lambda_b(6152)^0) = 6152.7 \pm 1.1 \pm 0.4 \pm 0.2\,\text{MeV}$

Evidence for a broad state, confirmed later by LHCb

Additional physics capabilities: b-parking

- The B-physics parking campaign has recorded ~**10^{10}** ***unbiased*** **decays of beauty hadron** during the Run-2018 **exploiting the flexibility of CMS data taking model (**as luminosity drops in the fill the L1 rate is kept ~constant & the HLT rate increased towards the end of each fill).
- **Trigger/tag-side requires a muon coming from a displaced vertex** *(very likely it is from semileptonic b decay)*

  We finished to reconstruct these 12B events at the end of 2019 [http://cds.cern.ch/record/2704495] and we have on tape:



Mode	N_{2018}	f_B
	Generic b hadrons	
B_d^0	4.0×10^9	0.4
$B^{\pm}$	4.0×10^9	0.4
B_s	1.2×10^9	0.1
b baryons	1.2×10^9	0.1
B_c	1.0×10^7	0.001
Total	1.0×10^{10}	1.0

- **Probe side** will have an unbiased b hadron from the second b quark
- **B-parked data set opens several prospects for b baryon studies**
- The possibility to continue B-parking efforts in Run-3 is currently under discussion

CMS prospects in b baryon physics

- b baryon production measurements in the phase-space complementary to LHCb (pp) and ALICE (HI)
  - *Observation of Λ_b^0 (Ξ_b) production in HI collisions after Run3/4 ?*
- Rare decays with charmonium in the decay products (observations, Branching Fractions)
- Precision measurements with known decays (mass / lifetime / production / BF)
- New and improved spectroscopy measurements can be done in [Λ_b^0 /Ξ_b/Ω_b^-] + track(s)/γ final states
  - Measurements of J^{PC} of the known excited states
  - By using converted photons, where CMS is very precise and competitive, we can also study radiative transitions
- Searches for Ξ_{bc} baryons in various final states
- Some radiative decays, when resolution is not crucial, can be measured exploring the usage of calorimeter photons in addition to conversions
  - $\Lambda_b^0 \to \Lambda\gamma$? $\Xi_b^- \to \Xi^-\gamma$? (via FCNC b→sγ)
- b→s*ll* transitions in baryon sector can also be studied, but are difficult to trigger (especially with electrons)
  - $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ and $\Lambda_b^0 \to \Lambda e^+e^-$ decays ($R(\Lambda)$) can be studied/searched for using parked data
  - $\Lambda_b^0 \to pK\ell^+\ell^-$ very challenging without hadron identification *(even for $\Lambda_b^0 \to J/\psi pK$ purity is low)*
  - With more data, also $\Xi_b^- \to \Xi^-\mu^+\mu^-$, $\Xi_b^- \to \Xi^- e^+e^-$ ($R(\Xi^-)$)?

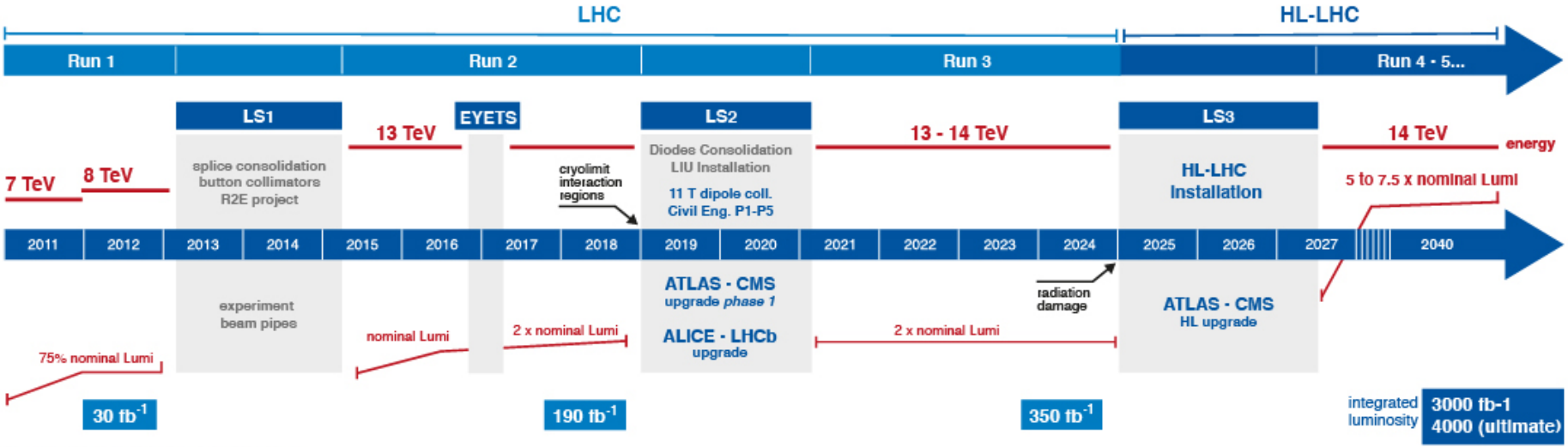
Summary

- CMS has provided important results in b baryon physics in the past, observing new states and decays and measuring Λ_b^0 properties
- Studies of spectroscopy, properties, and rare decays of beauty baryons will be continued
- The B-parking data set collected in 2018 provides additional opportunities
  - For example b→sll transitions, in particular with electrons, can be accessed
  - It is considered to continue b-parking in Run-3

Thank you !

Backup

Run-3 & Phase-II (HL-LHC) scenario

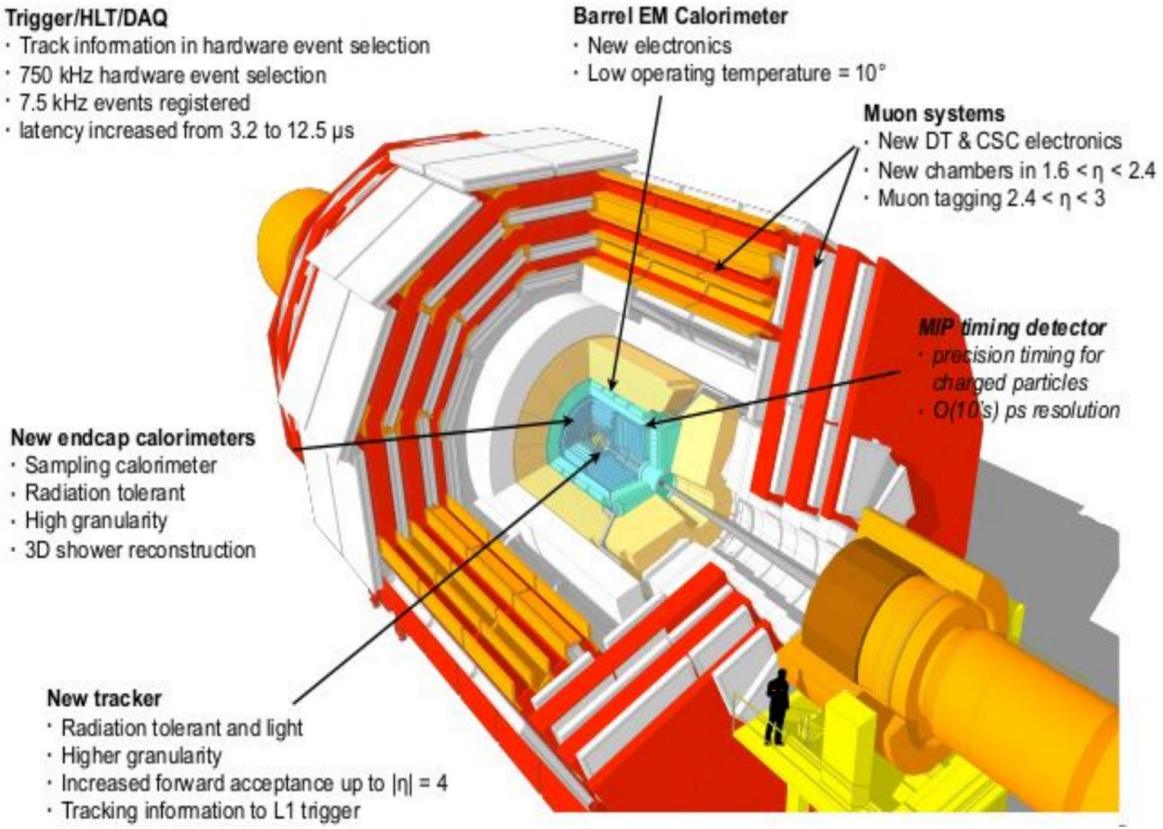


Run-3 target (2022-2024): ~double the statistics collected so far
Phase-II /HL-LHC (from 2027): increase the statistics by a factor ~10 (i.e. 3-4ab^{-1})

Plan to access rare SM processes & perform precision measurements in the Flavour sector.
Heavy Flavour potential (based on low-pT signatures) will suffer from the HL-LHC pileup conditions (<PU> ~140-200)

Availability of **tracking information al L1-trigger** is crucial to retain the full physics potential in this harsh environment

CMS Phase-II Upgrade (overview)



CMS Phase-II upgrades include:

- a new tracker with improved p_T resolution and radiation hardness, lower material budget, extended coverage
- increased muon coverage
- a new forward calorimeter with high granularity and resolution
- addition of the MIP timing detector (MTD)
- increased trigger bandwidth & latencies
- inclusion of tracking information at L1 trigger
- replacement of electronics