B and Λ_b lifetimes at ATLAS and CMS

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on behalf of ATLAS and CMS collaborations

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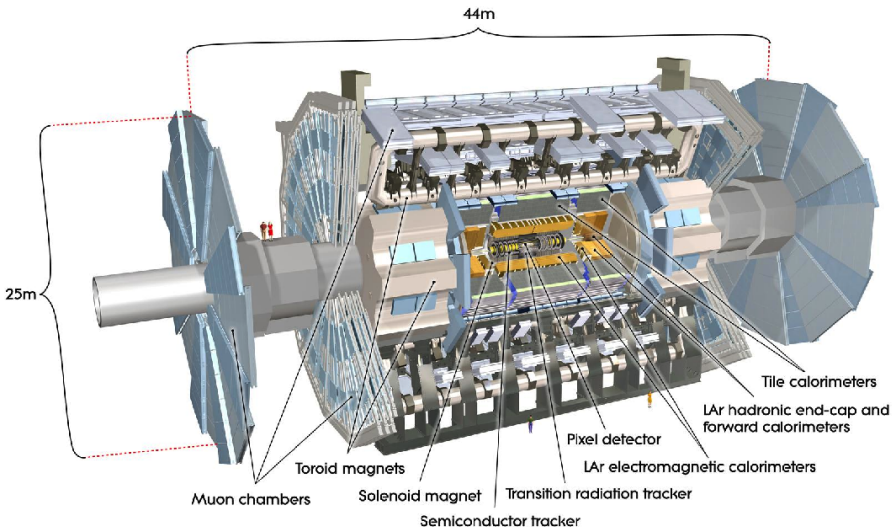
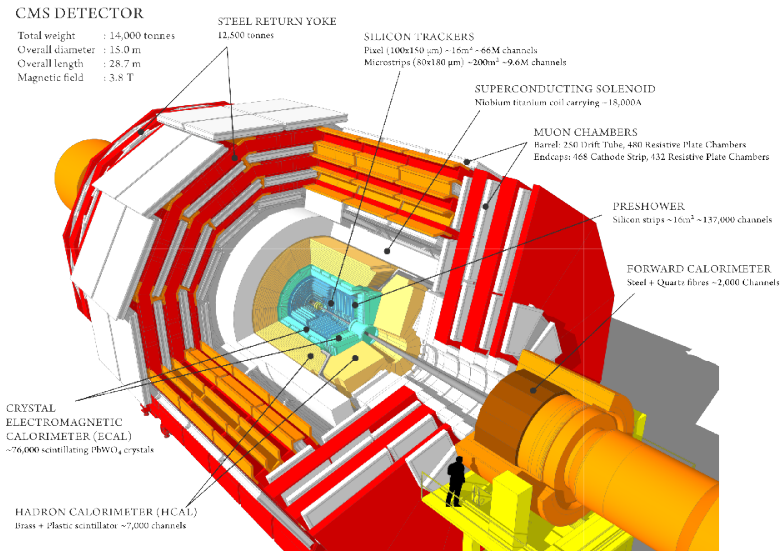
Outline

The ATLAS and CMS detectors



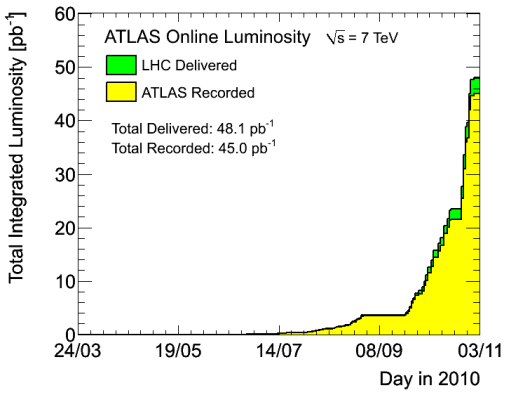


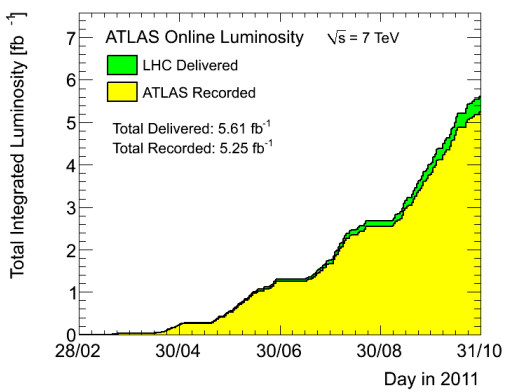
Two experiments devoted to large specturm searches, from Standard Model studies to searches of expected or unexpected New Physics phenomena
Detectors designed to be of general purpose and implemented with complementary technologies where applicable

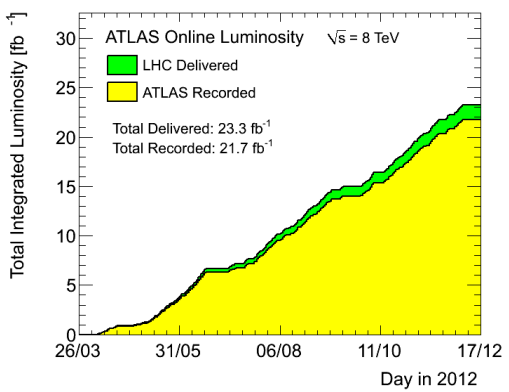
The B-physics results presented in this talk are mainly based on:
- trigger selection and offline reconstruction of muons, down to 3/4 GeV
- reconstruction of charged tracks in the inner silicon detectors, down to 0.5/1 GeV

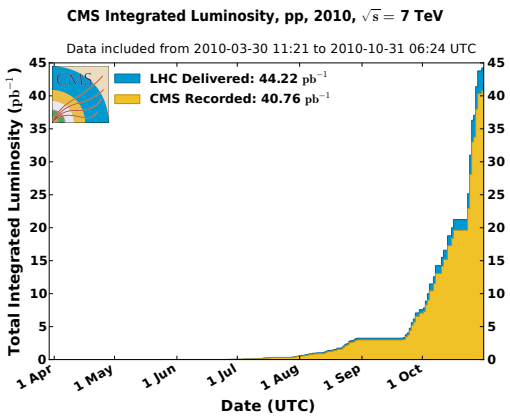
The two detectors have shown no major performance differences in these fields

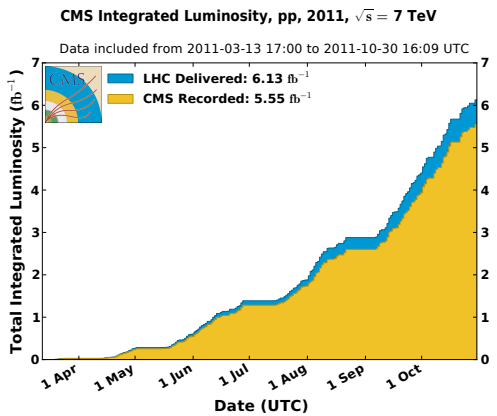
Integrated luminosity for pp collisions

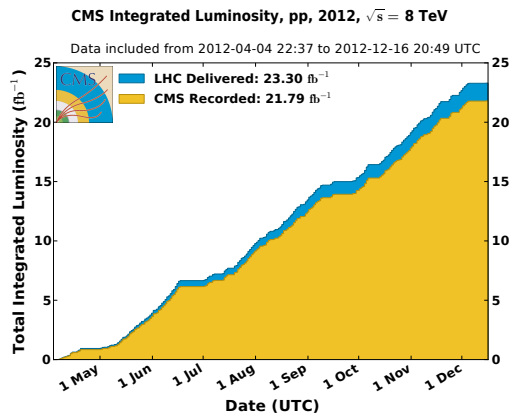






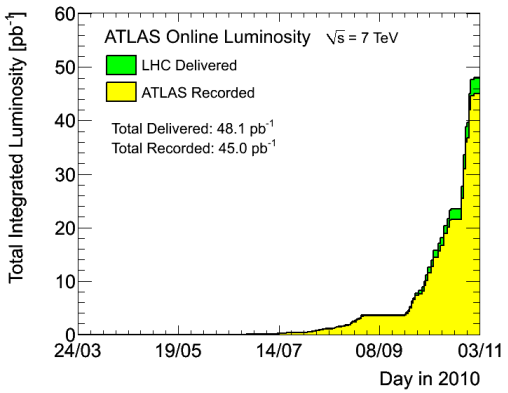


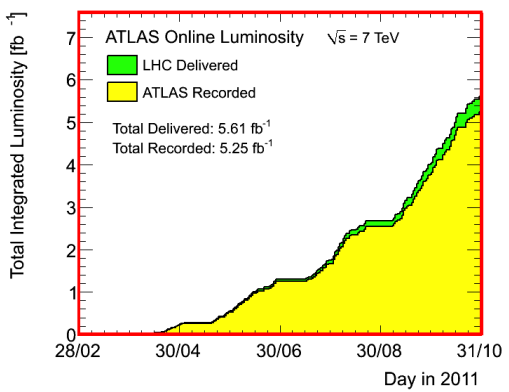


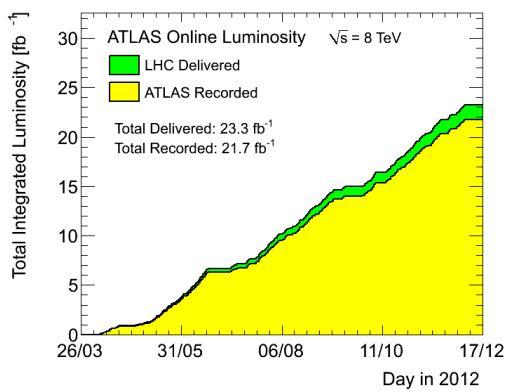


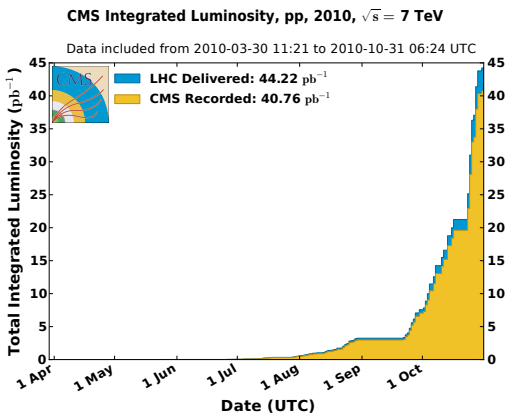
Impressive evolution of luminosity delivered by LHC, from 40 pb^{-1} to 20 fb^{-1}!
Very high detector efficiency and stability: above 95% for all subsystems
Stable and reliable DAQ and trigger systems: data-taking efficiency above 93%
Performance very close for both experiments

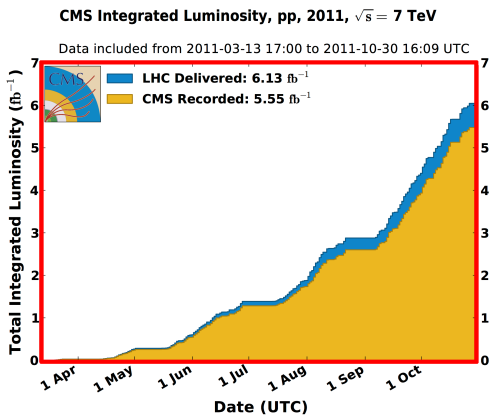
Integrated luminosity for pp collisions

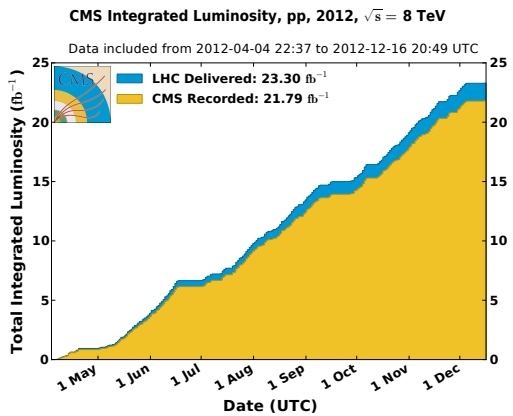






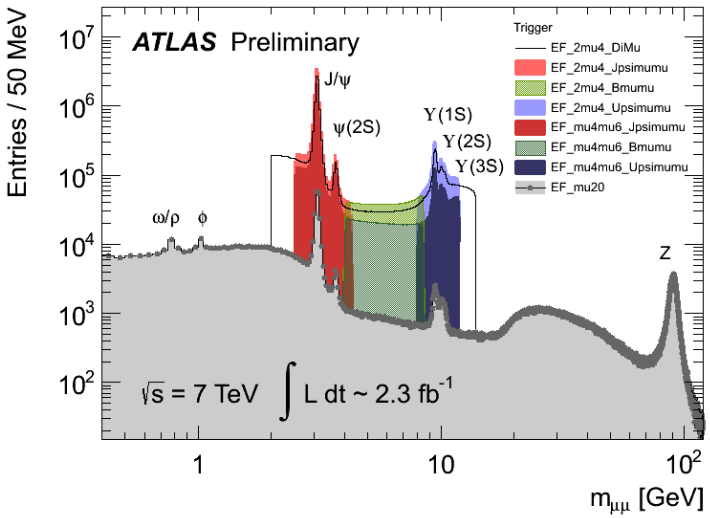


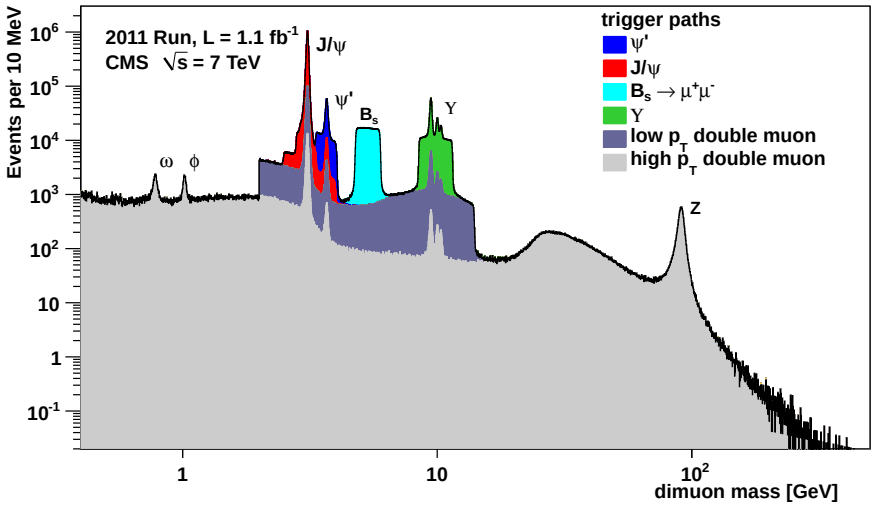




Results presented in this talk will focus on the analysis of 2011 data

Trigger selections for B-physics





Both experiments implemented trigger selections specific to B-physics studies, to complement single and double muon triggers (both plots based on 2011 data)

Additional dimuon invariant mass selection windows for different objects: J/Ψ, Υ, B
Grant affordable rates, without raising muon thresholds or applying prescales

Large acceptance gain w.r.t. single muon triggers, limited by high thresholds
Only difference among experiments: ATLAS never applies cuts on the displaced vertex

B_s^0 lifetime measurement

Both ATLAS and CMS experiments measured the B_s^0 lifetime in the decay channel

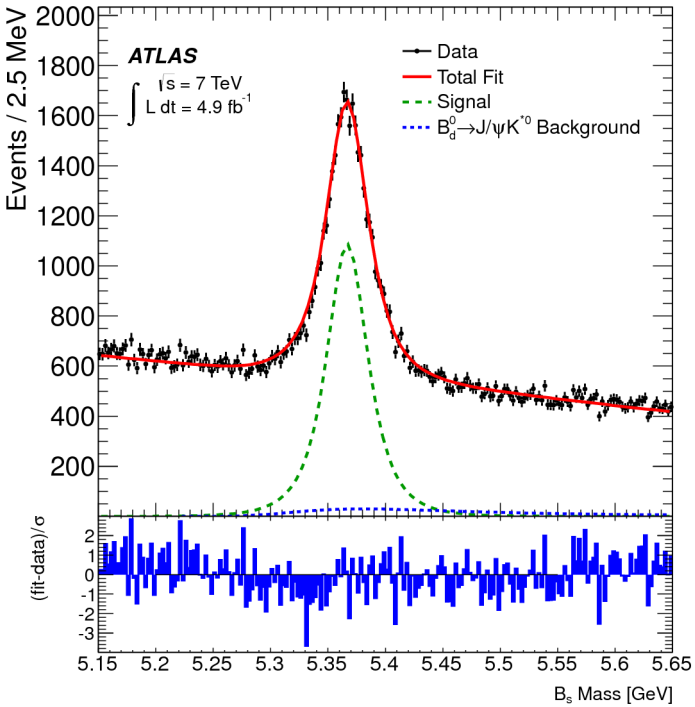
$$B_s^0 \to J/\Psi\,\phi \quad \text{with} \quad J/\Psi \to \mu^+\mu^- \quad \text{and} \quad \phi \to K^+K^-$$

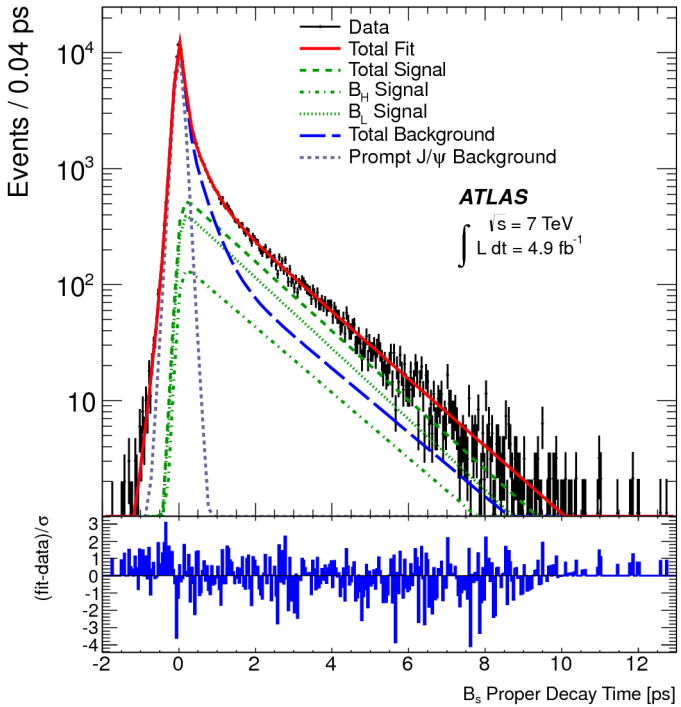
Allows to measure the B_s^0 mixing phase: covered by Claudio Heller in this conference
In this talk: focus on measurement of average lifetime between heavy and light states, seen as a validation of reconstruction and fit

The reconstruction of candidates is based on:
- single muon, dimuon and J/Ψ triggers
- two opposite-sign muons with p_T above 3/4 GeV, matching J/Ψ mass
- two opposite-sign tracks with p_T above 0.5/0.7 GeV, matching ϕ mass
- dimuon invariant mass constrained to the nominal J/Ψ mass
- track quadruplet fit to a common vertex, adding χ^2 requests

The measurement of the B_s^0 lifetime is extracted with:
- unbinned maximum likelihood fit of B_s^0 mass and proper decay time (ATLAS 2010)
- unbinned maximum likelihood fit of B_s^0 mass, proper decay time and three decay angles (ATLAS/CMS 2011)

B_s^0 lifetime: ATLAS

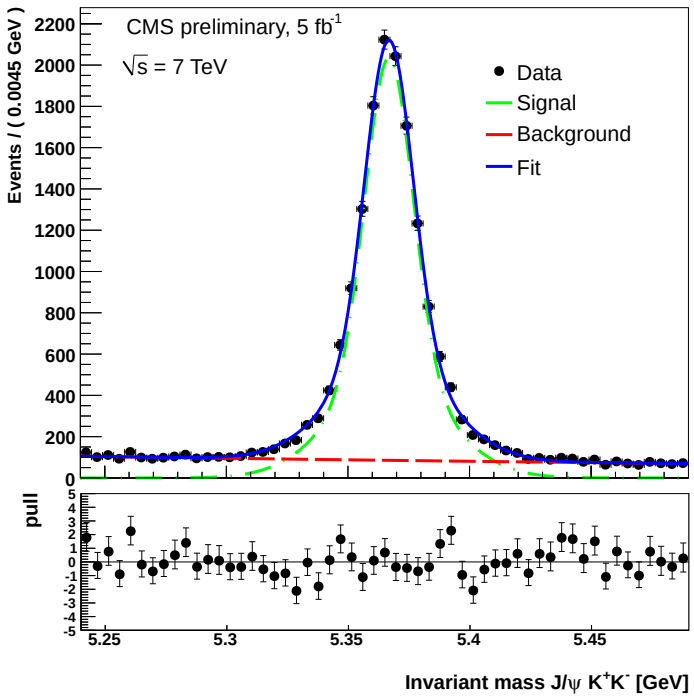


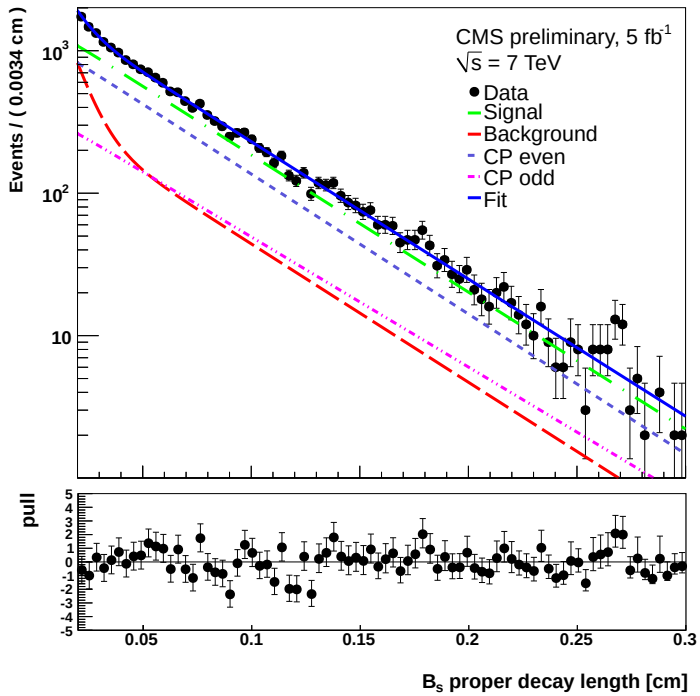


2011 result from JHEP 12 (2012) 072: time-dependent angular analysis
Plots correspond to projections of a five-dimensional likelihood
$\Gamma_s = 0.677 \pm 0.007$ (stat) ± 0.004 (syst) ps^{-1}

2010 result from ATLAS-CONF-2011-092: validation of the method
$\tau(B_s^0) = 1.41 \pm 0.08$ (stat) ± 0.05 (syst) ps

B_s^0 lifetime: CMS

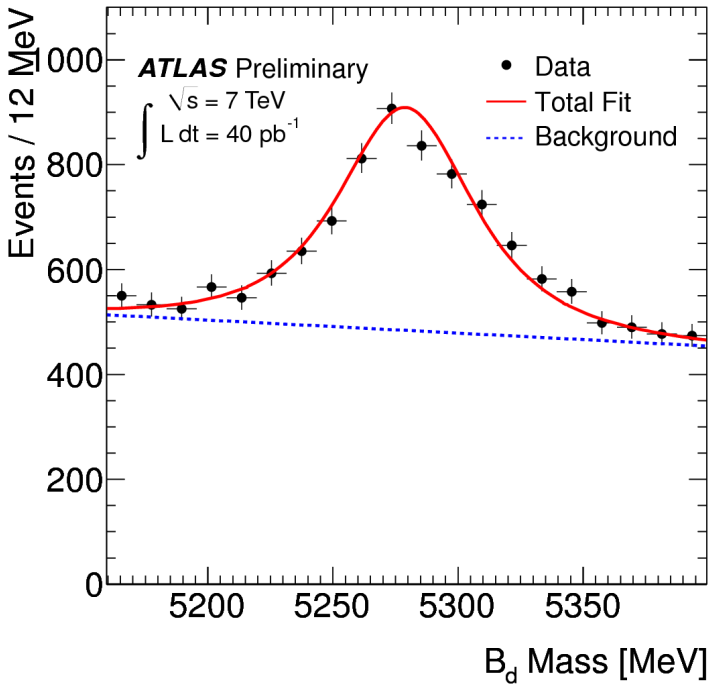


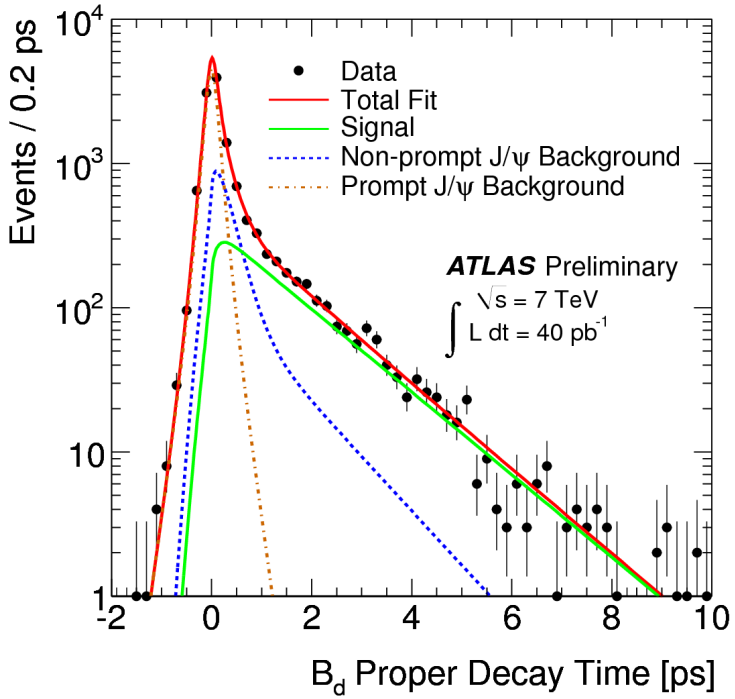


2011 result from CMS-PAS-BPH-11-006: time-dependent angular analysis
Plots correspond to projections of a five-dimensional likelihood
$c\tau(B_s^0) = 0.04580 \pm 0.00059\ (\text{stat}) \pm 0.00022\ (\text{syst})$ cm

ATLAS and CMS measurements mutually compatible and compatible with PDG
Equivalent precision for the two experiments

B_d^0 lifetime: ATLAS





ATLAS also studied the $B_d^0 \to J/\Psi\, K^*$ channel (2010)

first test for measurements of $B_s^0 \to J/\Psi\, \phi$, having equivalent topology, similar helicity structure of final states, but higher statistics

Result from ATLAS-CONF-2011-092

$\tau(B_d^0) = 1.51 \pm 0.04\ (\text{stat}) \pm 0.04\ (\text{syst})$ ps

Average B lifetime: ATLAS

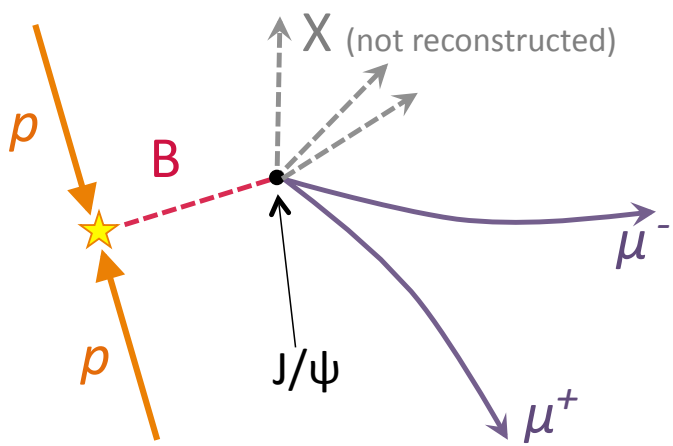
Another ATLAS result in this sector is the lifetime measurement in inclusive decays

$$B \to J/\Psi X \quad \text{with} \quad J/\Psi \to \mu^+\mu^-$$

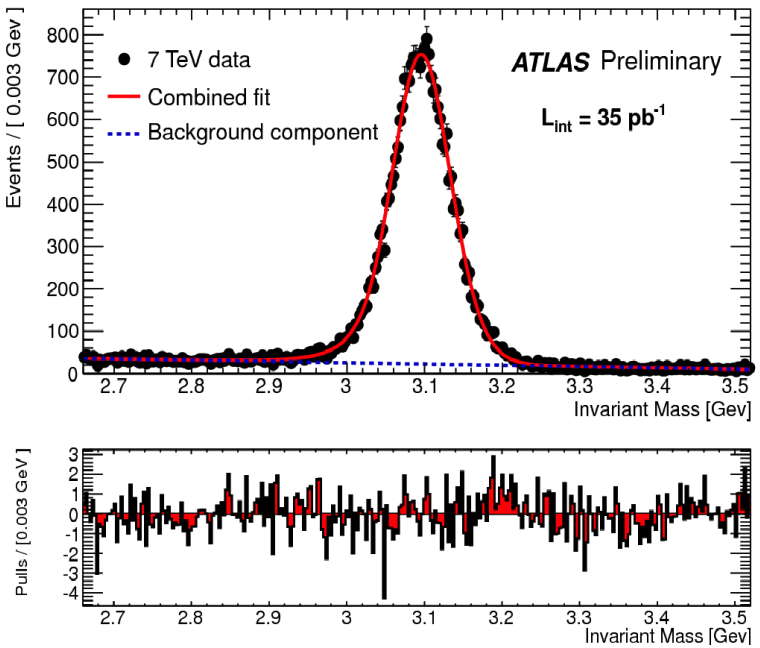
These decays allow to measure the average lifetime of the admixture of B-hadrons produced in LHC proton-proton collisions and decaying to final states including a J/Ψ

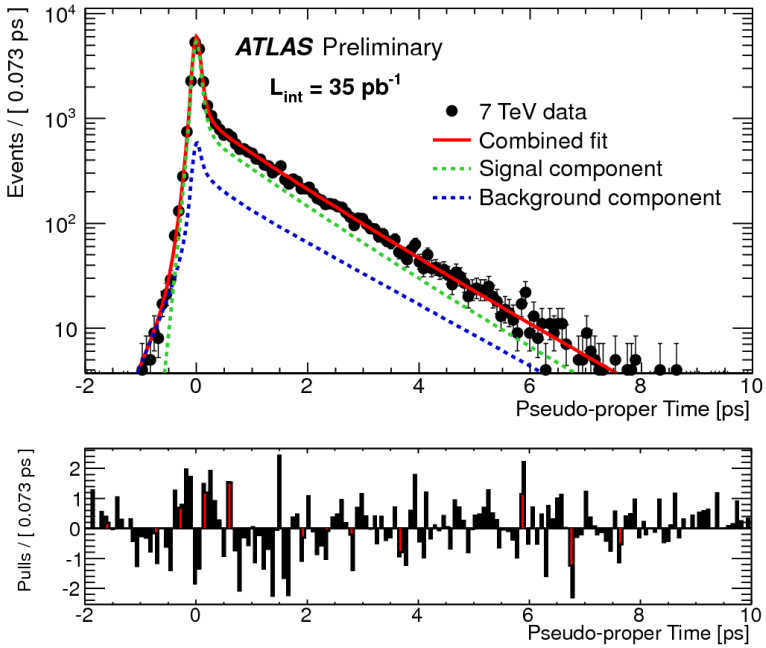
Study performed on 2010 data, to prepare precision measurements of B-hadron lifetimes, understanding detector and reconstruction on a high-statistics sample

Reconstruction and fit procedures
- reconstruction of J/Ψ candidates as before, with tighter p_T cuts (6 GeV)
- separation of B-hadron J/Ψ candidates from prompt production or $c\bar{c}$ decays based on decay vertex displacement
- no B-hadron transverse momentum, approximated with J/Ψ transverse momentum (pseudo-proper time)
- correction factor for the consequent smearing evaluated on simulated data



Average B lifetime: ATLAS





Fit procedure: unbinned maximum likelihood fit of J/Ψ mass and pseudo-proper time

Result from ATLAS-CONF-2011-145

$< \tau_b > = 1.489 \pm 0.016$ (stat) $\pm$ 0.043 (syst) ps

To be compared with PDG

$< \tau_b >_{PDG} = 1.544 \pm 0.014$ ps

Λ_b^0 lifetime: motivation and previous results

Both ATLAS and CMS experiments measured the Λ_b^0 lifetime in the decay channel

$$\Lambda_b^0 \to J/\Psi\,\Lambda^0 \quad \text{with} \quad J/\Psi \to \mu^+\mu^- \quad \text{and} \quad \Lambda^0 \to p + \pi^-$$

The study of this baryon can be performed only at hadron colliders, since it is not produced at B-factories, given its high mass

Recent CDF and D0 measurements show a 2σ discrepancy
This pushes LHC experiments to provide a more precise measurement

CDF: $\tau(\Lambda_b^0) = 1.537 \pm 0.045$ (stat) ± 0.014 (syst) ps
D0: $\tau(\Lambda_b^0) = 1.303 \pm 0.075$ (stat) ± 0.035 (syst) ps

Furthemore, the lifetime ratio $\tau(\Lambda_b^0)/\tau(B_d^0)$ can be theoretically predicted
It is interesting to confront Heavy Quark Expansion (HQE) and perturbative QCD (pQCD) predictions with experimental results

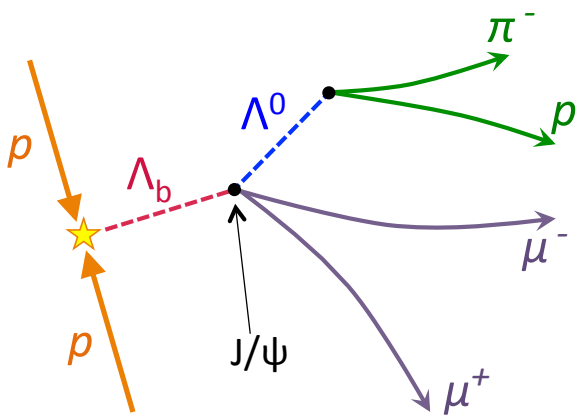
HQE: $\tau(\Lambda_b^0)/\tau(B_d^0)$ between 0.88 and 0.97
pQCD: $\tau(\Lambda_b^0)/\tau(B_d^0)$ between 0.86 and 0.88 (± 0.05)
CDF: $\tau(\Lambda_b^0)/\tau(B_d^0) = 1.020 \pm 0.030$ (stat) ± 0.008 (syst) ps
D0: $\tau(\Lambda_b^0)/\tau(B_d^0) = 0.864 \pm 0.052$ (stat) ± 0.033 (syst) ps

Λ_b^0 lifetime: selection of candidates and fits

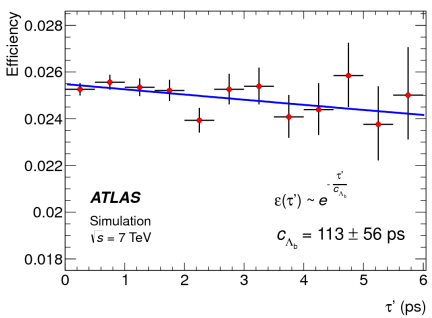
Reconstruction and fit procedures

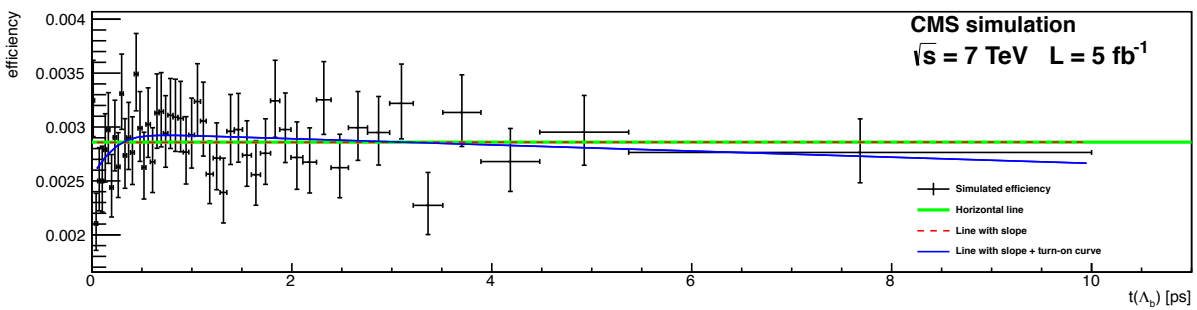
- single muon, dimuon and J/Ψ triggers
- two opposite-sign muons, matching J/Ψ mass
- two opposite-sign tracks, matching Λ^0 mass
- dimuon mass constrained to J/Ψ mass
- track quadruplet fit to a cascade vertex
- vertex χ^2 requests and Λ^0 decay length cut
- test comparison with B_d^0 hypothesis
- unbinned maximum likelihood fit of Λ_b^0 mass

and proper decay time is performed

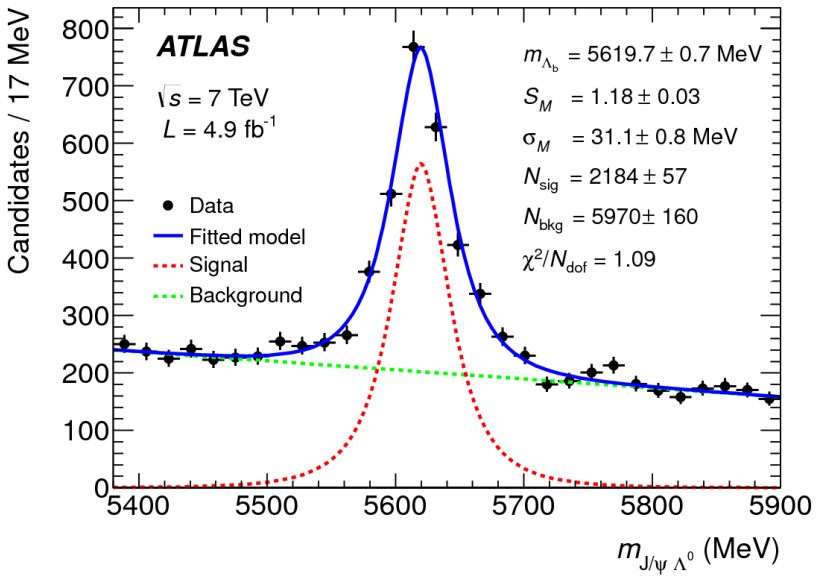


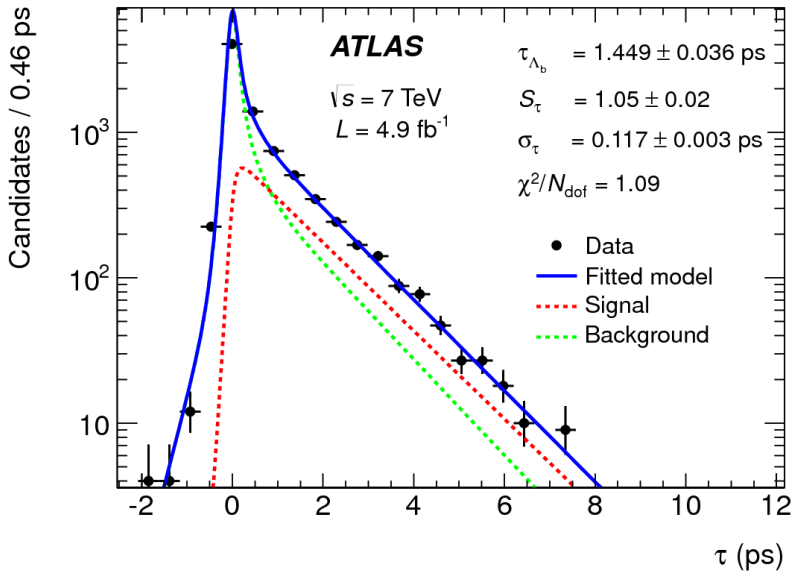
The Λ_b^0 efficiency correction as a function of its decay length is taken into account





Λ_b^0 lifetime: ATLAS





Result from Phys. Rev. D 87 (2013) 032002

$m(\Lambda_B^0) = 5619.7 \pm 0.7$ (stat) $\pm$ 1.1 (syst) MeV

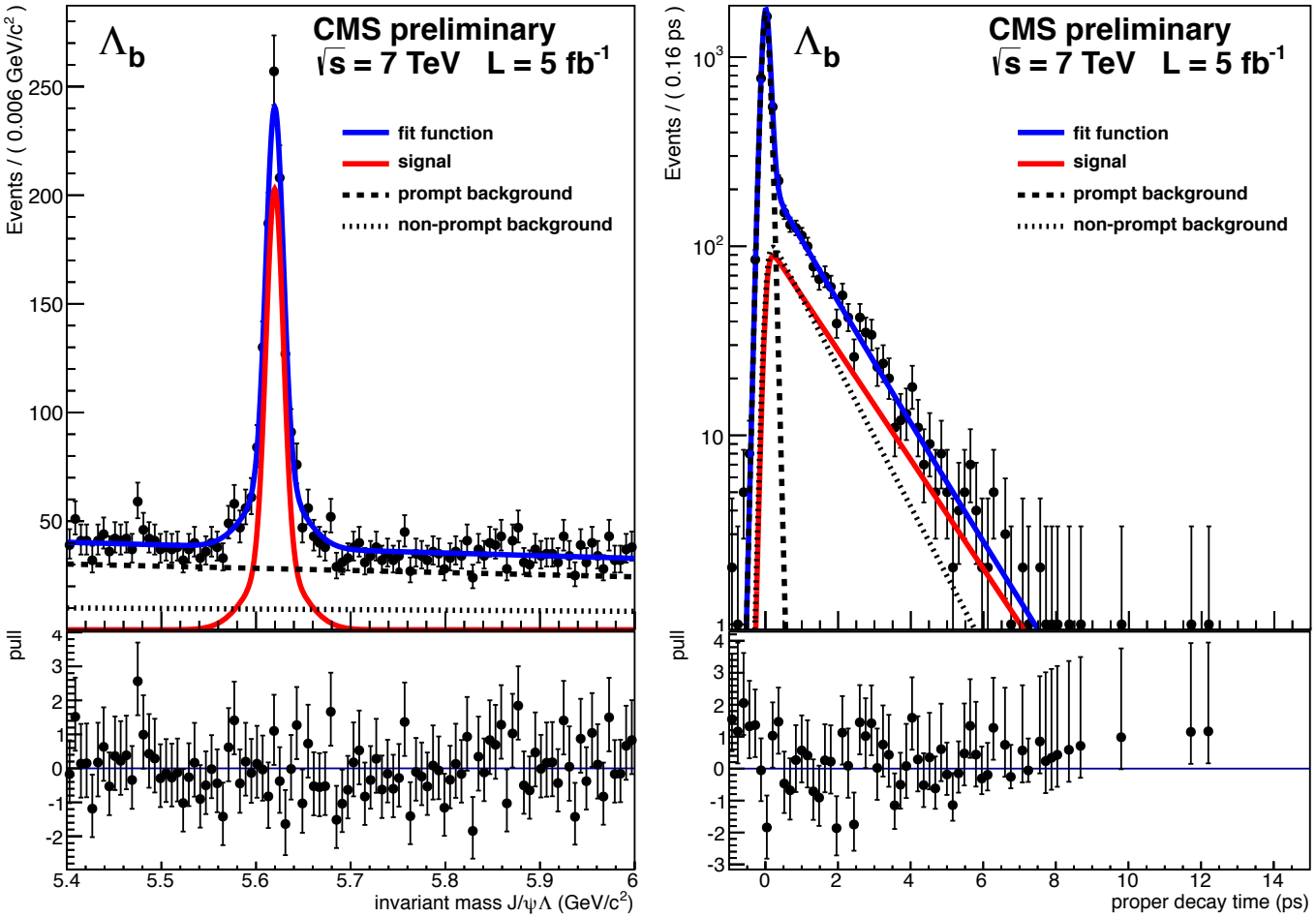
$\tau(\Lambda_B^0) = 1.449 \pm 0.036$ (stat) $\pm$ 0.017 (syst) ps

$\tau(\Lambda_b^0)/\tau(B_d^0) = 0.960 \pm 0.025$ (stat) $\pm$ 0.016 (syst)

The $m(\Lambda_b^0)$ and $\tau(\Lambda_b^0)$ results are compatible with PDG world averages and LHCb

The result for $\tau(\Lambda_b^0)/\tau(B_d^0)$ is placed between CDF and D0 values, favors and agrees with HQE and is compatible with pQCD

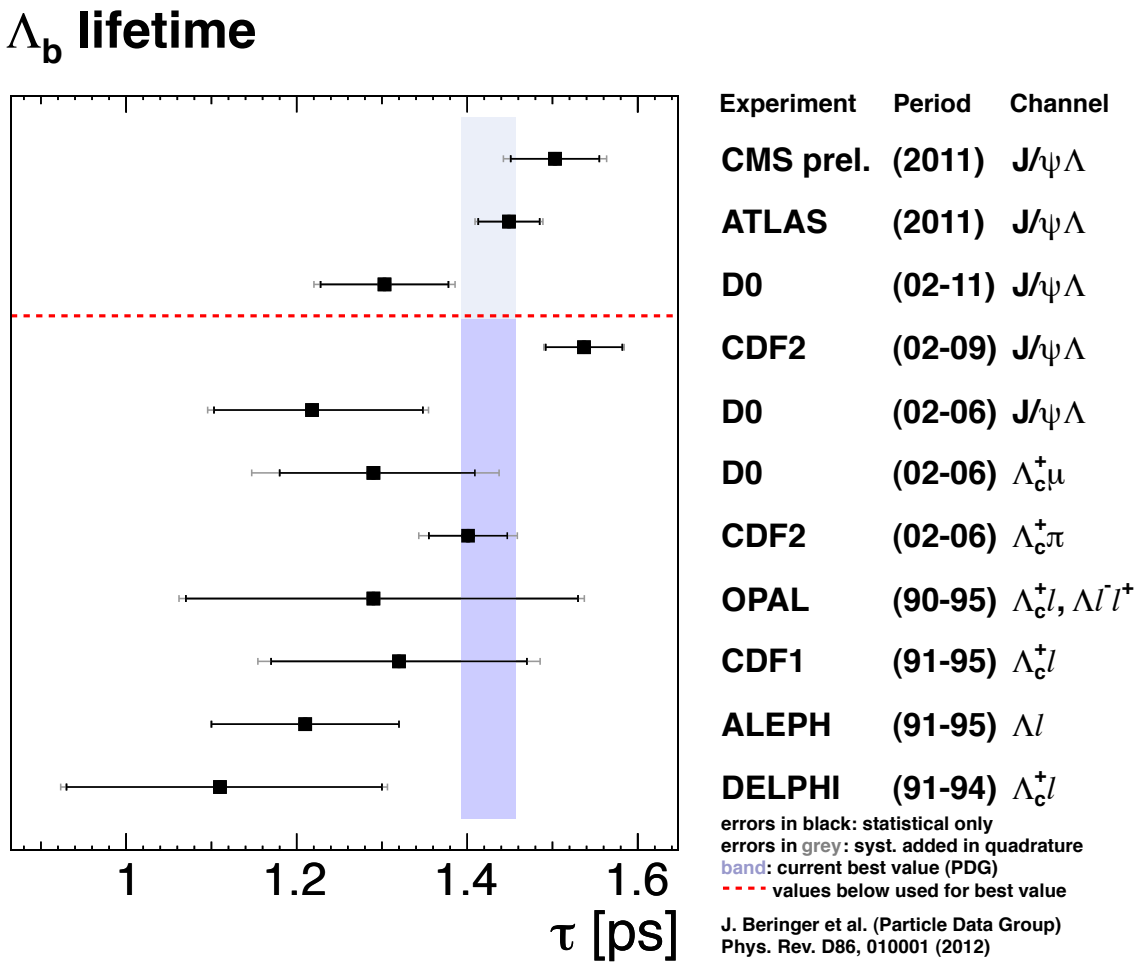
Λ_b^0 lifetime: CMS



Result from CMS-BPH-11-013

$\tau(\Lambda_B^0) = 1.503 \pm 0.052\ (\text{stat}) \pm 0.031\ (\text{syst})$ ps

Λ_b^0 lifetime: overall compatibility



LHCb (2011): $\tau(\Lambda_B^0) = 1.353 \pm 0.108$ (stat) ± 0.035 (syst) ps
Old result based on 2010 data; result update in preparation, not yet public

Conclusions

The overall performance of LHC and the ATLAS and CMS experiments has been very good and stable over the last two/three years

Both ATLAS and CMS are deeply involved in delivering high-quality B-physics measurements; some reported in this talk, but more already available and yet to come

The study of B-hadron masses and lifetimes provides a solid proving ground for more complex studies, such as time dependent analyses; all results in this field are compatible with PDG world averages

Precision measurements of the Λ_b^0 lifetime and its ratio to B_d^0 lifetime have been provided, shedding some light on discrepancies between CDF and D0 and on theoretical predictions

More results underway in this sector: an example is Λ_b^0 polarization, further probing the agreement between QCD predictions and experimental results