# MEASUREMENT OF MASS AND LIFETIME OF $\Lambda_b$

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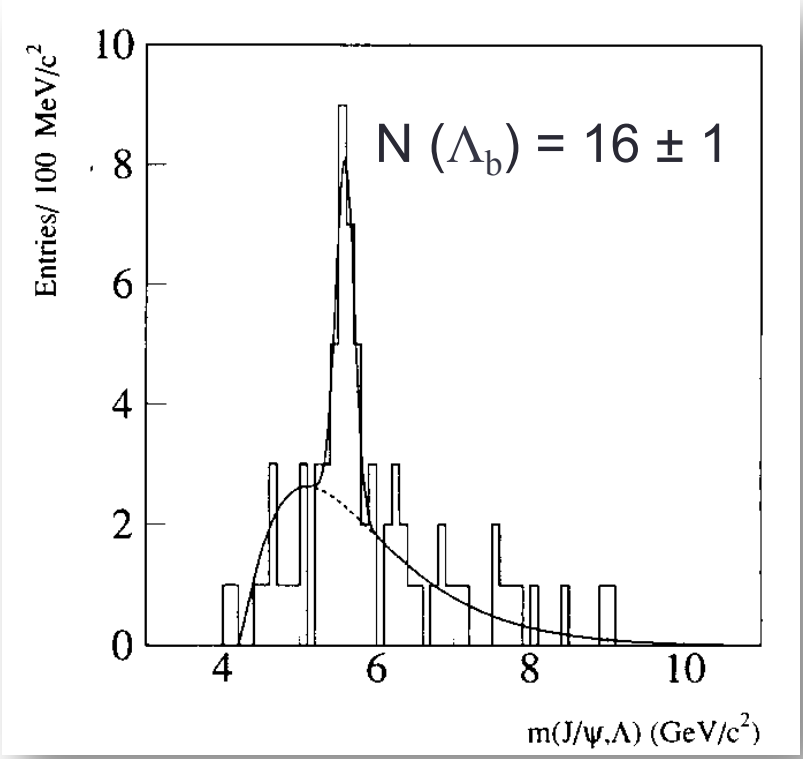
# Outline

- Quick overview of $\Lambda_b$
- Recent lifetime measurement at the Tevatron experiments
- The ATLAS detector
  - 2010 - 2012 data taking
  - Reconstruction performance relevant for B physics
  - Triggers for B-physics
- $\Lambda_b$ mass and lifetime measurements
  - How to measure lifetime?
  - Selection of $\Lambda_b \rightarrow J/\psi\Lambda$ candidates
  - Background and Signal Modeling
  - Systematic uncertainties
  - Results
- Conclusions

# Overview on the $\Lambda_b$

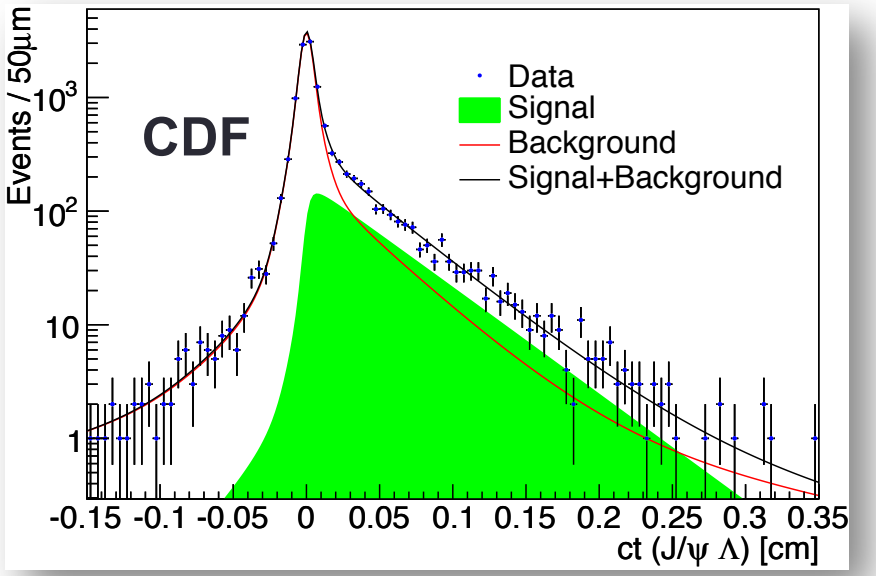
- Lightest b baryon (udb)
- First observed by UA1 in 1991 in the decay channel $\Lambda_b \rightarrow J/\psi\Lambda$
- First lifetime measurement from LEP experiments (1992) using the semileptonic decays
- First lifetime measurement in the fully reconstructed channel at the Tevatron experiments
- Produced in high statistics at LHC
  - Lifetime and mass measurements at the ATLAS and LHCb experiments



# Recent lifetime measurements at Tevatron

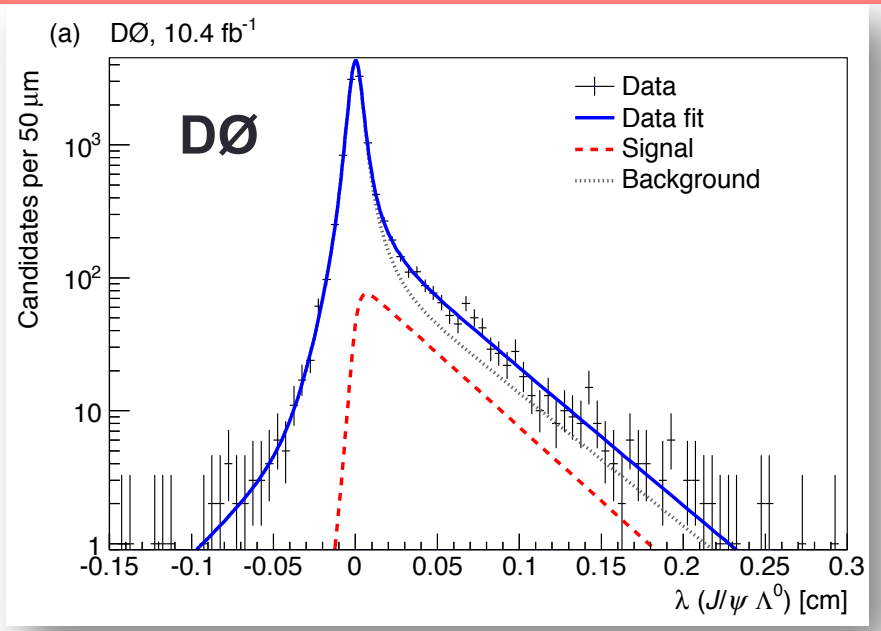
- There is a more then 2σ discrepancy between two recent CDF lifetime measurements: $\Lambda_b \rightarrow J/\psi\Lambda$ and $\Lambda_b \rightarrow \Lambda_c\pi$ decay channels
- There is a more then 2σ discrepancy between recent CDF and DØ results in the same channel: $\Lambda_b \rightarrow J/\psi\Lambda$

$$\tau(\Lambda_b) = 1.537 \pm 0.045(stat) \pm 0.014(syst)\, ps$$




Phys. Rev. Lett. 106, 121804 (2011)

$$\tau(\Lambda_b) = 1.303 \pm 0.075(stat) \pm 0.035(syst)\, ps$$

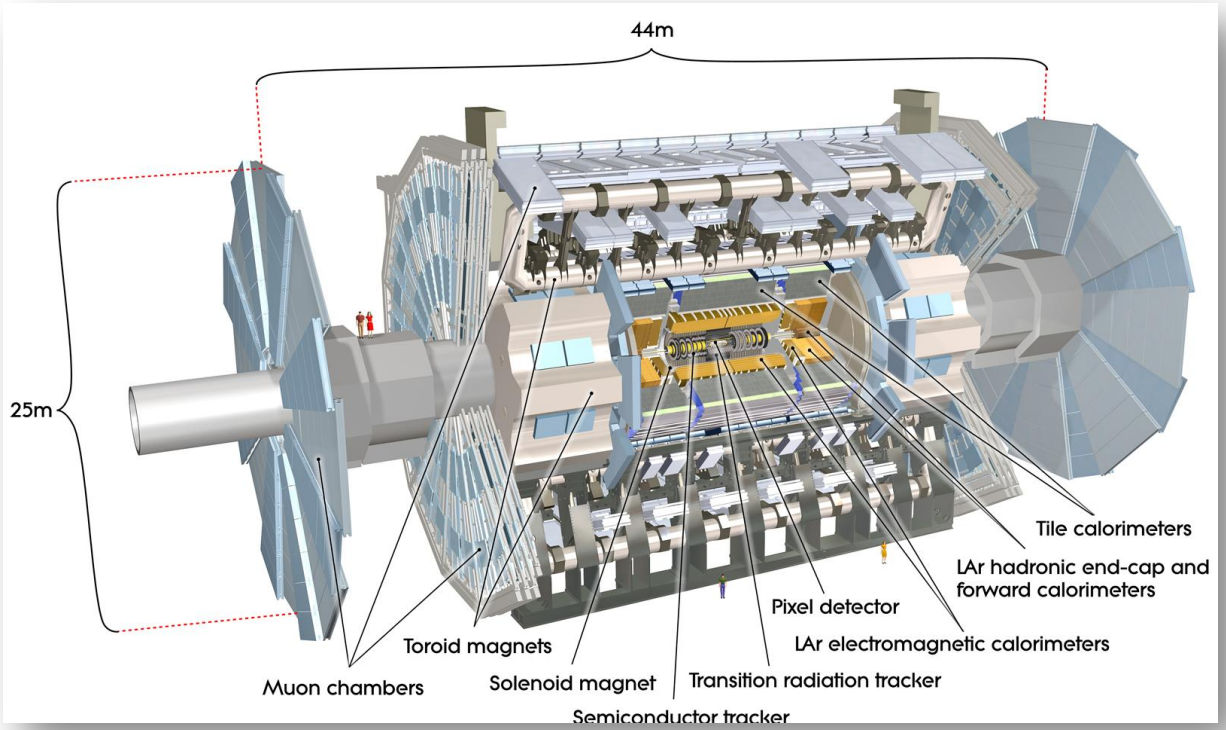



arXiv:1204.2340 [hep-ex]

# The ATLAS detector

B physics measurements require excellent tracking capabilities and muon identification

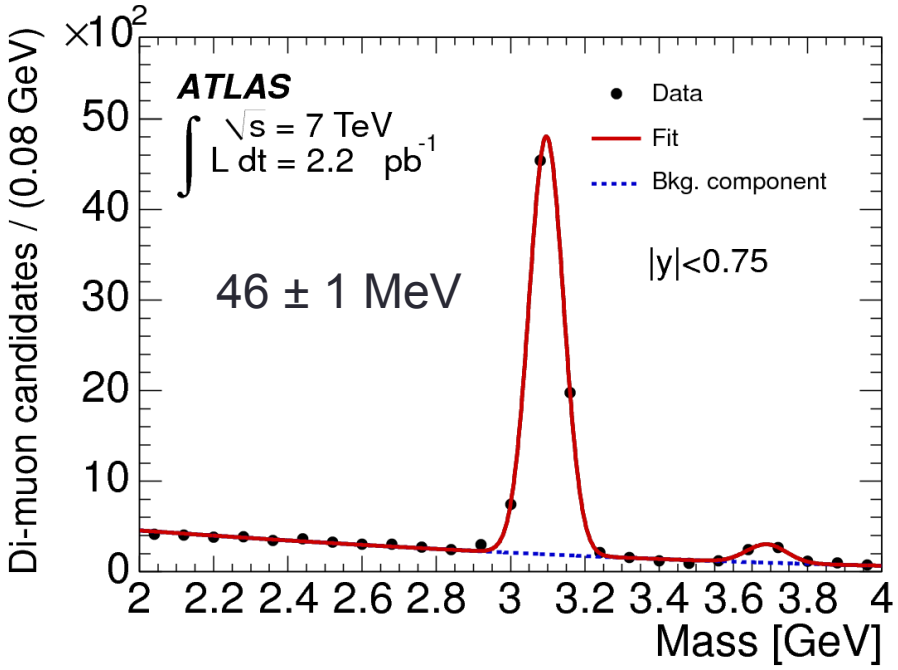
- Inner Detector ($|\eta| < 2.5$)
  - Silicon pixels and strips (SCT) with Transition Radiation Tracker (TRT)
  - 2T Solenoidal field
  - $\sigma_p/p \sim 3 - 5\ \%$
  - Impact parameter resolution ~ 10μm

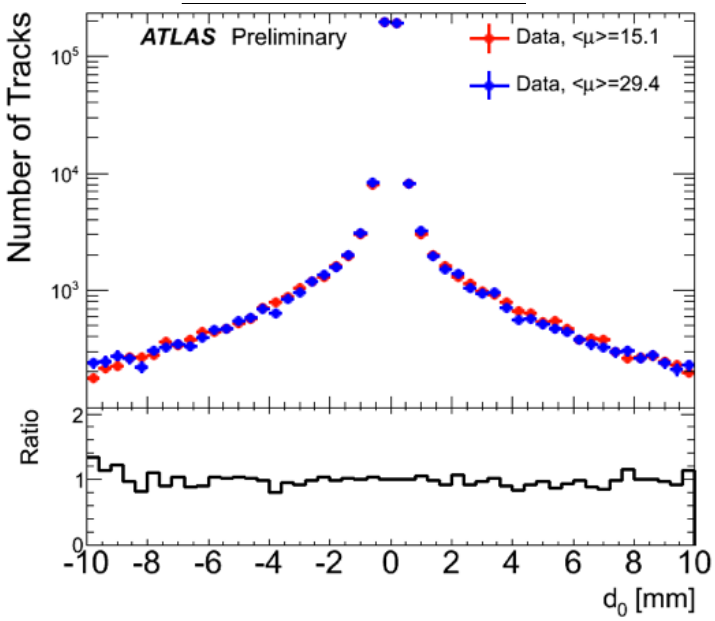


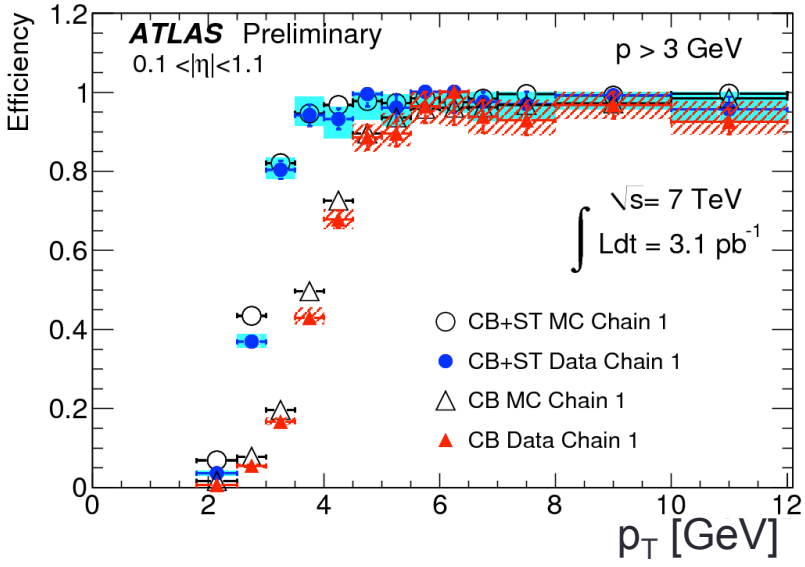

- Muon Spectrometer ($|\eta|<2.7$)
  - 4 detector technologies: dedicated tracking and trigger chambers
  - 0.5 - 2T Toroidal field
  - $\sigma_p/p \sim 5\%$ (for $p_T$ = 10 - 100GeV)

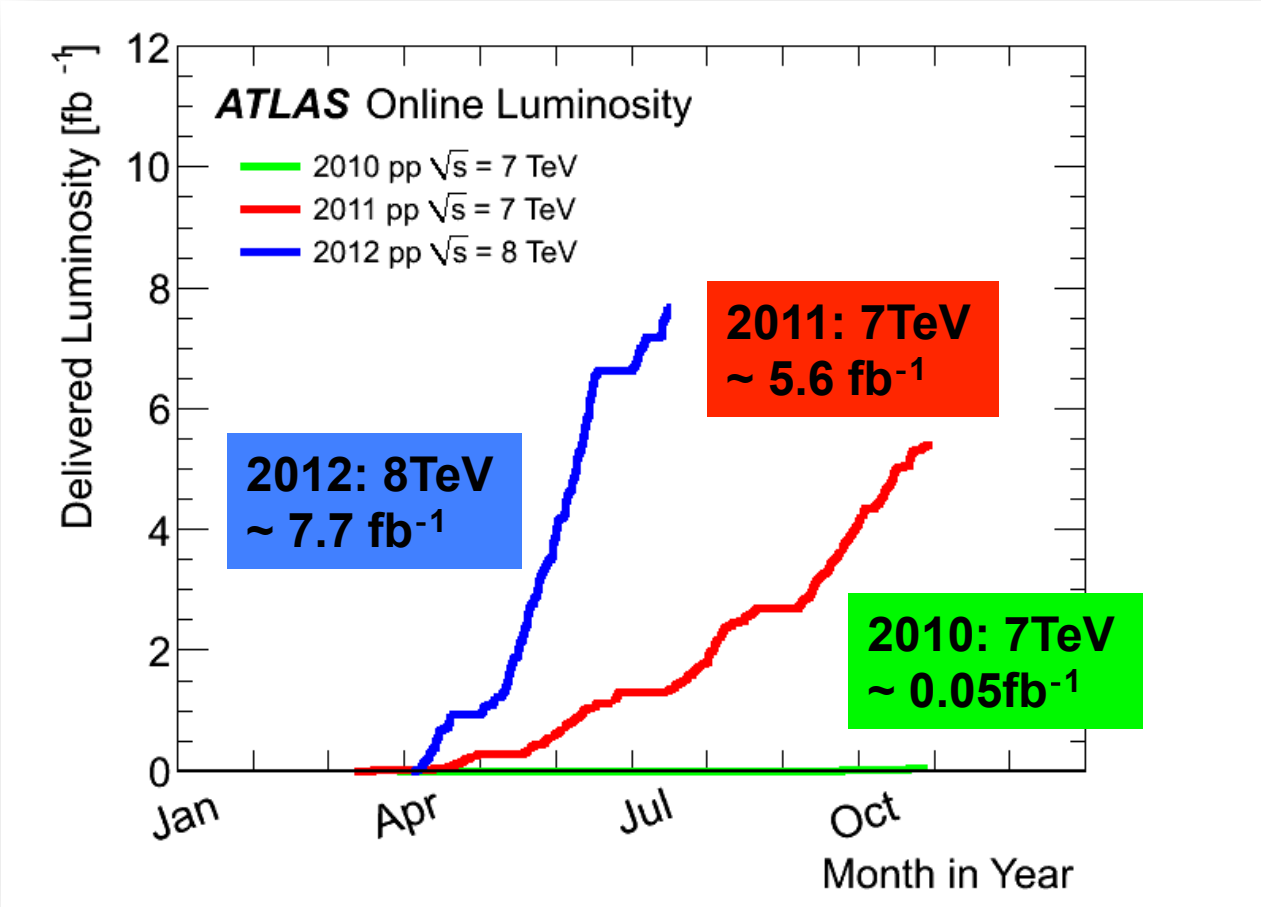
# Performance

- Excellent mass resolution required for good S/B separation
- Transverse impact parameter of the reconstructed tracks with respect to the PV at two different pile-up conditions
- Muon reconstruction efficiency using J/ψ decays





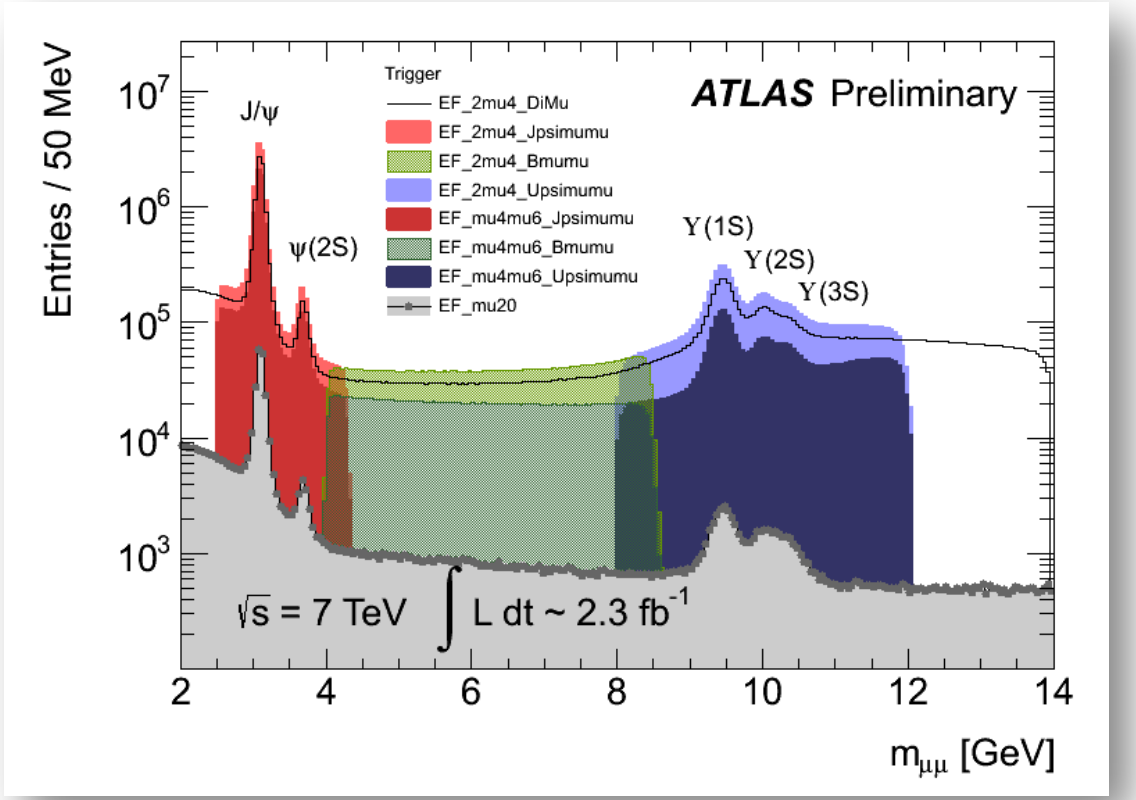

- Luminosity delivered to ATLAS since the beginning
- In this analysis we used ~ 5fb$^{-1}$ collected during 2011

- Status of the ATLAS detector

| *ATLAS* 2011 p–p run | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inner Tracking | | | Calorimeters | | | | Muon Detectors | | | | Magnets | |
| Pixel | SCT | TRT | LAr EM | LAr HAD | LAr FWD | Tile | MDT | RPC | CSC | TGC | Solenoid | Toroid |
| 99.8 | 99.6 | 99.2 | 97.5 | 99.2 | 99.5 | 99.2 | 99.4 | 98.8 | 99.4 | 99.1 | 99.8 | 99.3 |

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √s=7 TeV between March 13th and October 30th (in %), after the summer 2011 reprocessing campaign

# Trigger for B physics




- **EF_mu20**
  a single muon trigger at level 1, confirmed at the high level trigger, passing a threshold of 20GeV
- **EF_mu4mu6_X**
  two muon triggers at level 1, confirmed at the high level trigger, with one objects passing a threshold of 4 and the other 6 GeV

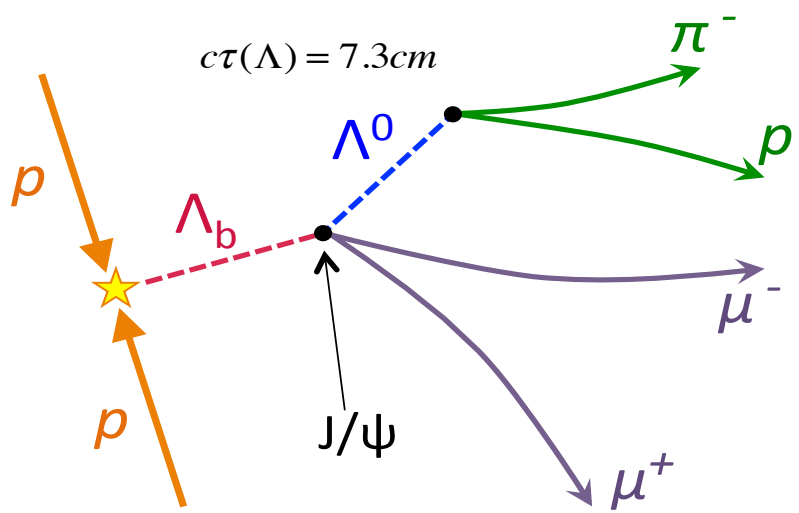
No displaced vertex requirements - advantage for lifetime measurement

# Lifetime measurement

- Measurement method:
  - The proper decay time is calculated for each candidate as:

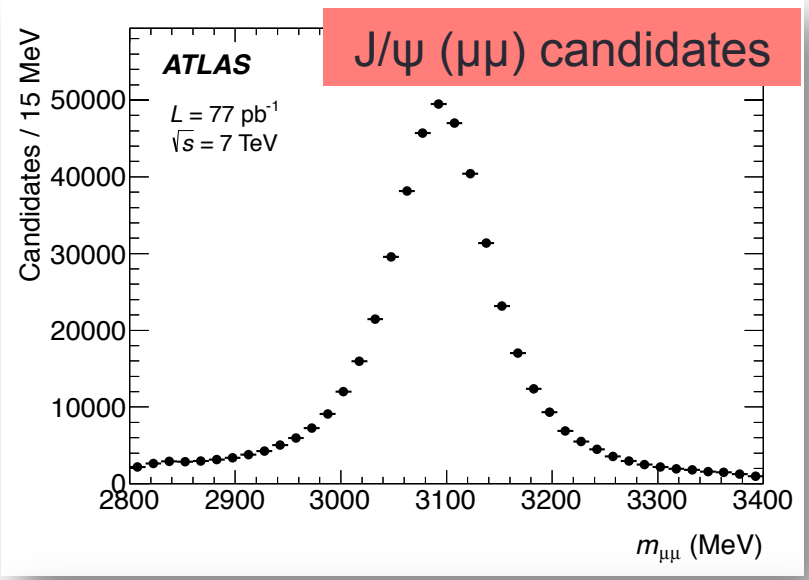
$$\tau = L_{xy} \frac{m(\Lambda_b)}{p_T(\Lambda_b)}$$

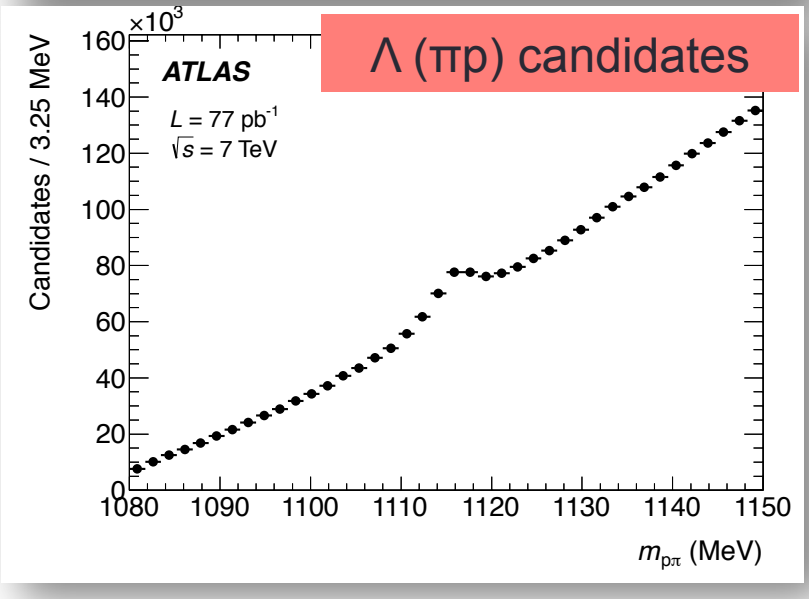
  - $L_{xy}$ is a $\Lambda_b$ transverse decay distance measured from the primary vertex
  - $m(\Lambda_b)$ = 5620.2 MeV
- Measurement procedure:
  - Select signal events
  - Build p.d.f. for
    - Mass and proper decays time
    - Signal and Background
  - Mass and lifetime simultaneously extracted with unbinned likelihood fit



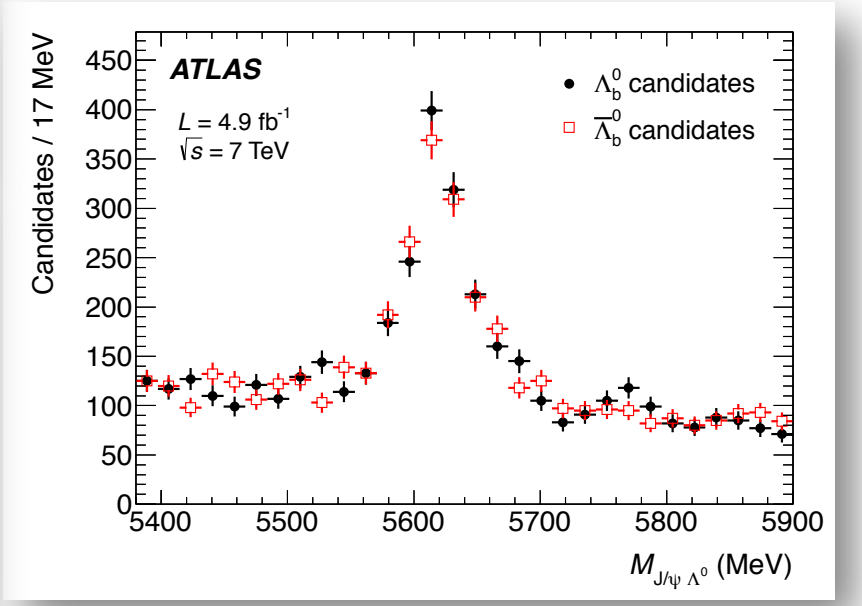

$B^0 \rightarrow J/\psi\ K_S$ is used as a control sample due to its similar topology. The lifetime of $B^0$ is also measured in this analysis. It is used to compute the lifetime ratio $\tau(\Lambda_b)/\ \tau(B^0)$

# Signal Selection



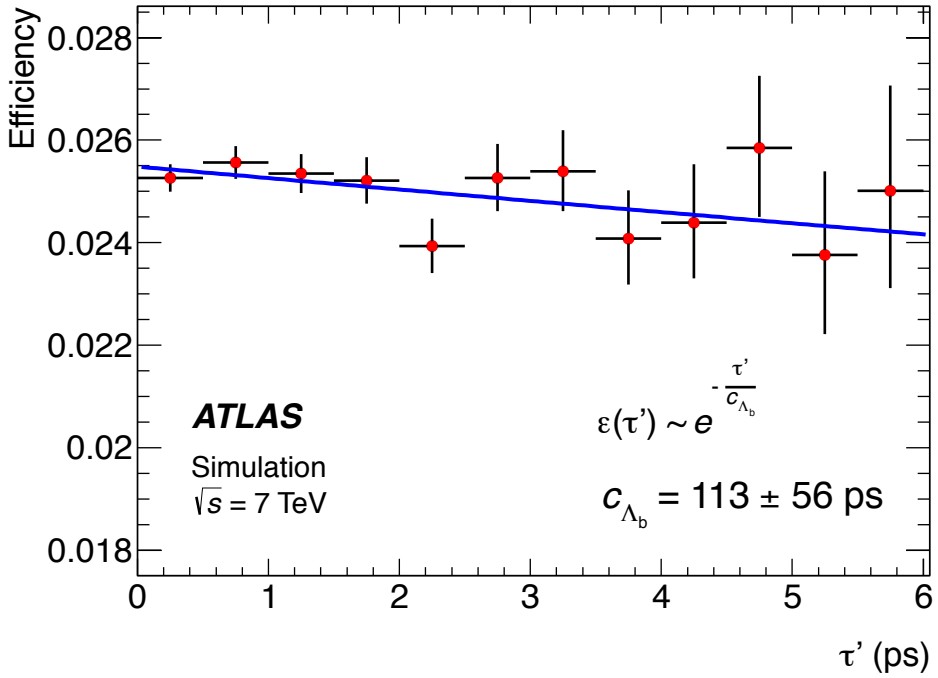

- Selection of $\Lambda_b \rightarrow J/\psi(\mu\mu)\,\Lambda(\pi p)$
  - Perform fit on 4 tracks simultaneously ($\chi^2/N_{dof} < 3$)
  - Transverse decay length ($L_{xy}$) of $\Lambda$ candidate from $\Lambda_b$ vertex is required to be greater than 10mm
  - $p_T$ of refitted $V^0 > 3.5$ GeV
  - 5.38 GeV < $m_{J/\psi\Lambda}$ < 5.9GeV




4074 $\Lambda_b$ and 4081 anti $\Lambda_b$ candidate (including background) were selected

# Background and Signal fit models

- Signal:
  - Proper decay time
    - Exponential and
    - efficiency function →
  - Mass
    - Gaussian function
- Background:
  - Proper decay time
    - Prompt component
    - Non-prompt component
  - Mass
    - Polynomial function



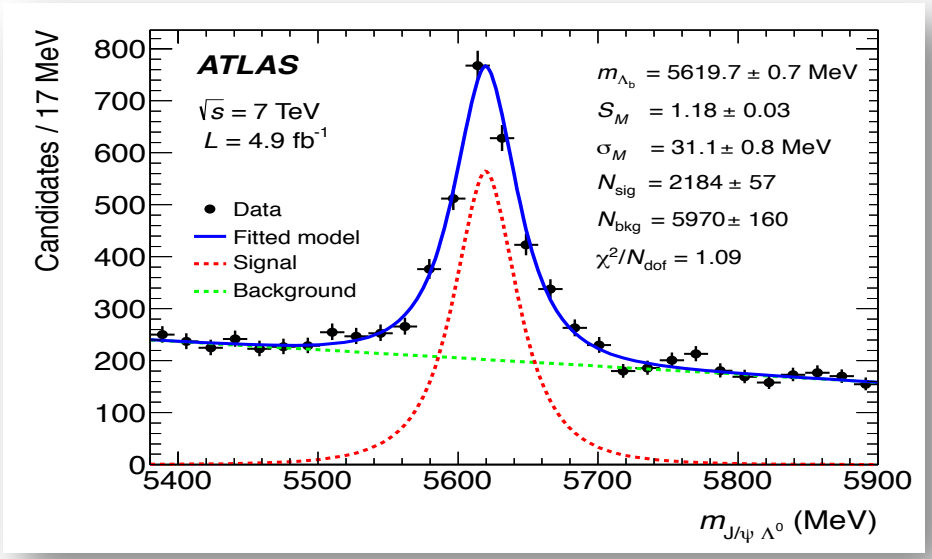

Mass and lifetime simultaneously extracted with unbinned likelihood fit

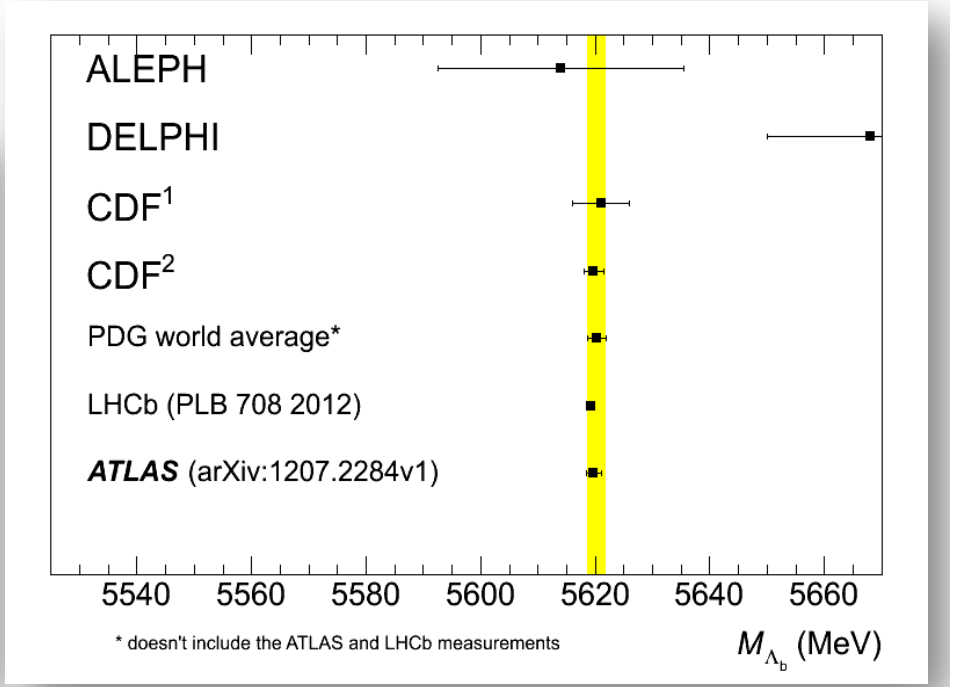
# Systematics of the measurement

| Uncertainty | $\sigma_\tau$ (fs) | $\sigma_m$ (MeV) |
|---|---|---|
| Selection/reconstruction | 12 | 0.9 |
| Background fit models | 9 | 0.2 |
| $B_d$ contamination | 7 | 0.2 |
| Misalignment | 1 | - |
| Extra material | 3 | 0.2 |
| Tracking $p_T$ scale | - | 0.5 |
| Total systematics | 17 | 1.1 |

- Selection:
  - $V^0$ reconstruction
- 82 ± 46 $B_d$ candidates misidentified as $\Lambda_b$

# $\Lambda_b$ mass measurement



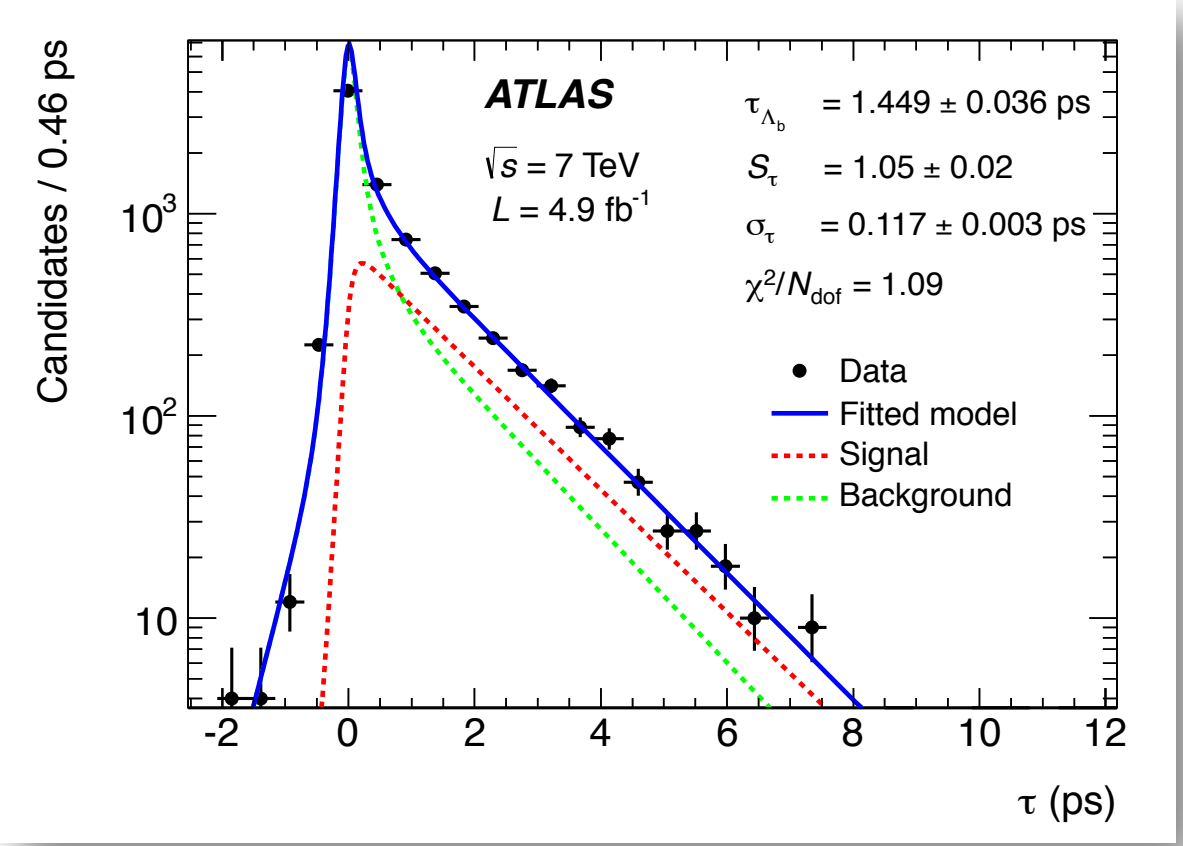




$$m(\Lambda_b) = 5619.7 \pm 0.7(stat) \pm 1.1(syst) MeV$$

N ($\Lambda_b$) = 2184 ± 57

The most precise measurement is from LHCb

# Lifetime measurement results

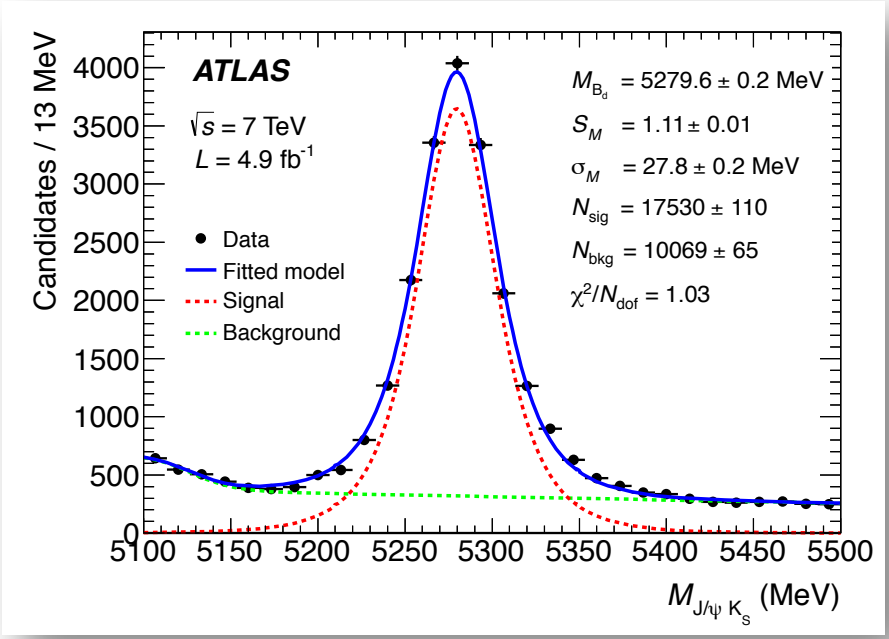


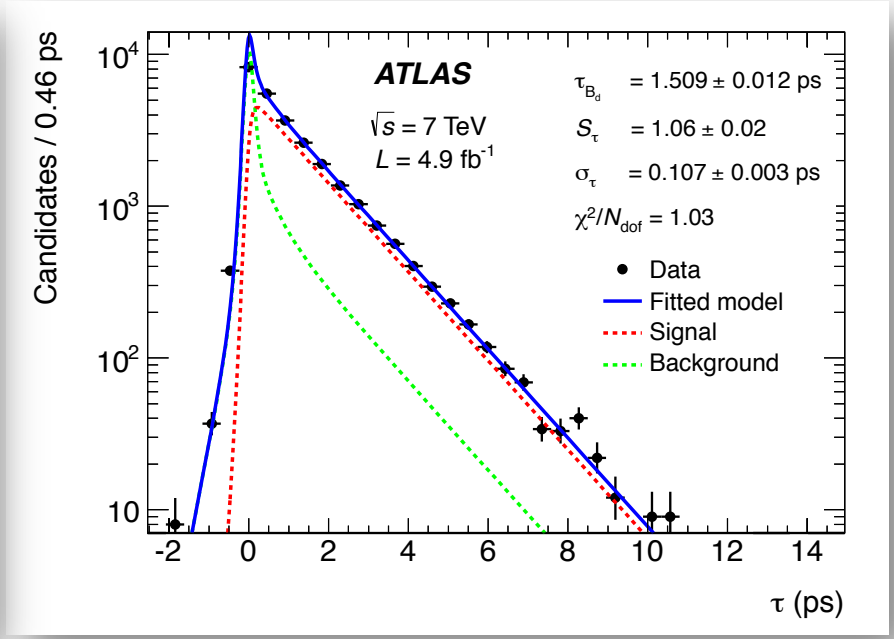

$$\tau(\Lambda_b) = 1.499 \pm 0.036(stat) \pm 0.017(syst)\, ps$$

PDG(2012): $\tau(\Lambda_b) = 1.425 \pm 0.032$ ps

# Cross - check

Same selection and fitting procedure is applied on $B_d \rightarrow J/\psi\, K_s$ candidates!




$$\tau(B_d) = 1.509 \pm 0.012(stat) \pm 0.018(syst)\, ps$$

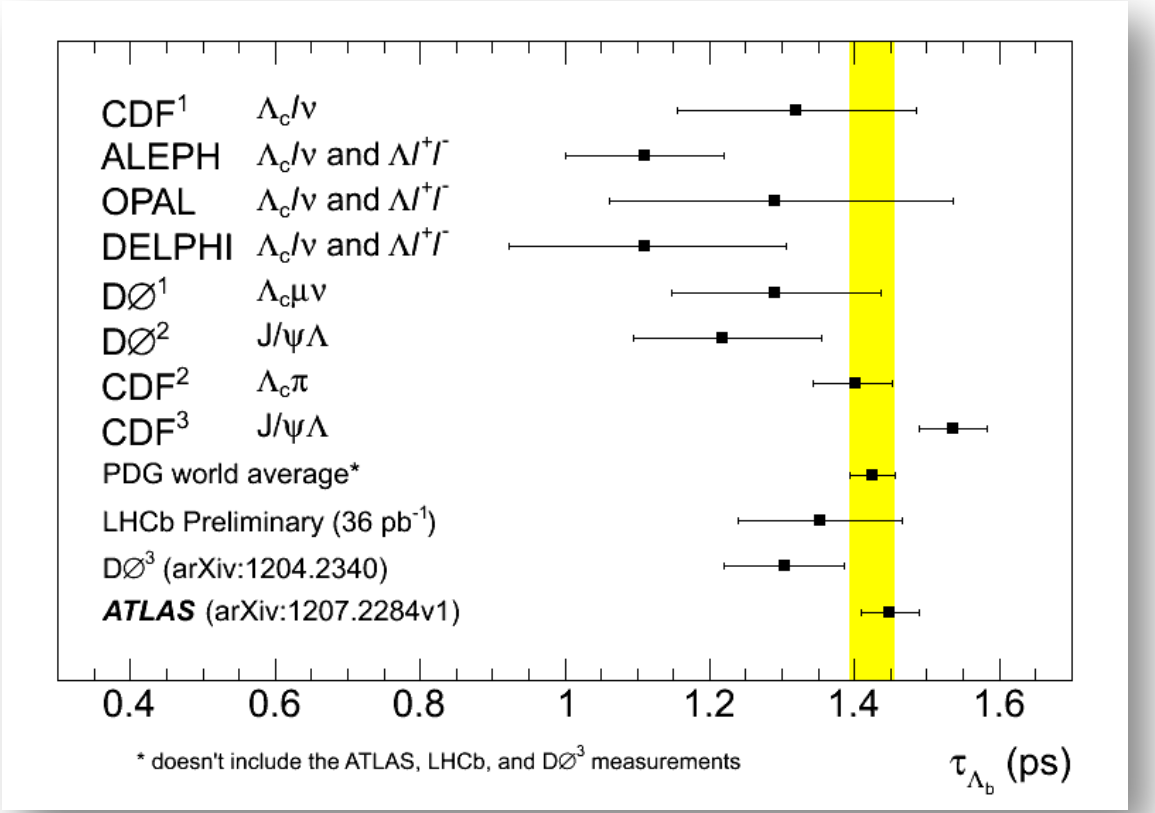
$$m(B_d) = 5279 \pm 0.2(stat) \pm 1.0(syst)\, MeV$$

PDG(2012): $\tau(B_d) = 1.519 \pm 0.007$ ps

$m(B_d) = 5279.5 \pm 0.3$ MeV

# Comparison with other measurements

$$\tau(\Lambda_b) = 1.499 \pm 0.036(stat) \pm 0.017(syst)\, ps$$

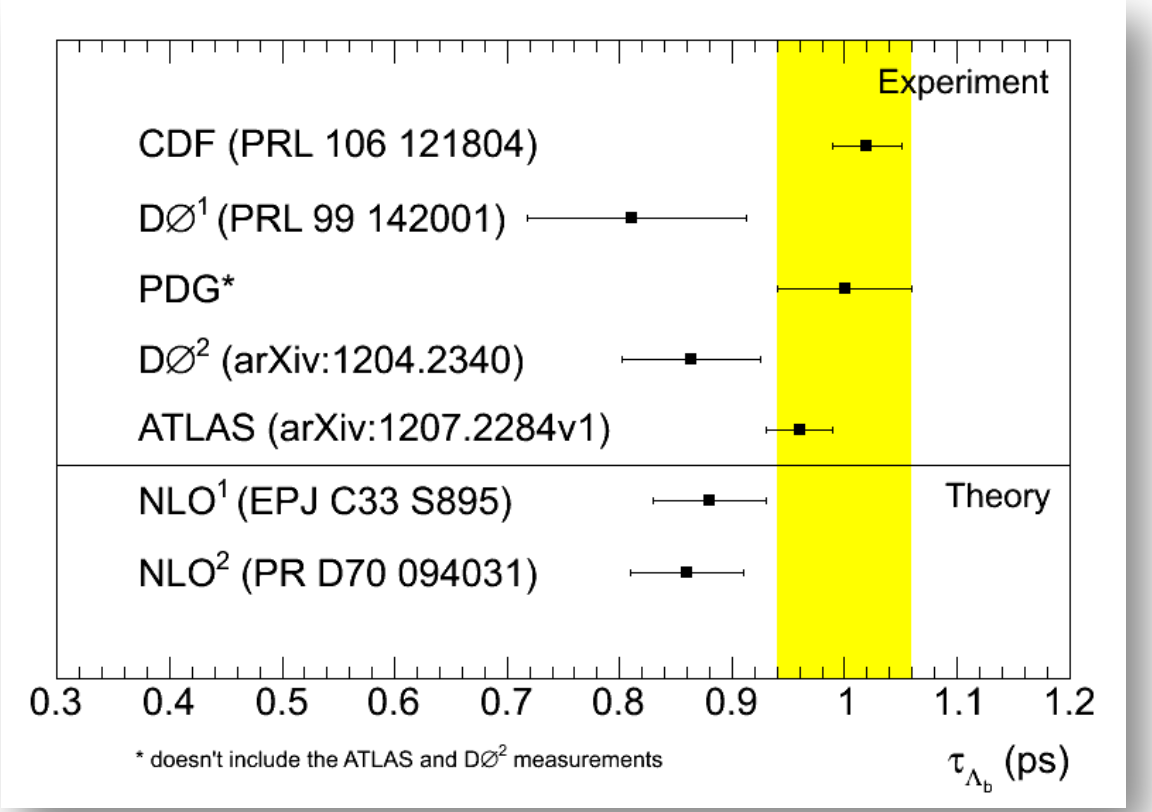



ATLAS lifetime measurement is the most precise $\Lambda_b$ lifetime measurement in the world!

# Ratio

$$\frac{\tau(\Lambda_b)}{\tau(B^0)} = 0.960 \pm 0.025(stat) \pm 0.016(syst)$$

Testing Heavy Quark Expansion (HQE) theory in B hadrons which predicts hierarchy of B hadron lifetimes due to spectator effects on decay of b quark




- Consistent with
  - the world average: 1.00 ± 0.06
  - NLO theoretical predictions 0.86 ± 0.5 and 0.88±0.5
  - recent DØ measurement: 0.864 ± 0.052(stat) ± 0.033 (syst)
  - recent CDF measurement: 1.020 ± 0.030(stat) ± 0.008 (syst)

# Conclusions

- ATLAS has already delivered many important B-physics measurements, and more are on the way
- ATLAS $\Lambda_b$ lifetime measurement is the most precise $\Lambda_b$ lifetime measurement in the world and it is consistent with previous measurements
- The precision of the Λb mass measurement is now the second-best
- Preparations to measure the $\Lambda_b$ polarization are underway