HF Spectroscopy and New States with ATLAS

Leonid Gladilin (MSU / JINR)
on behalf of the ATLAS Collaboration

LHC Heavy Flavour WG meeting, 10 November 2015

Outline :

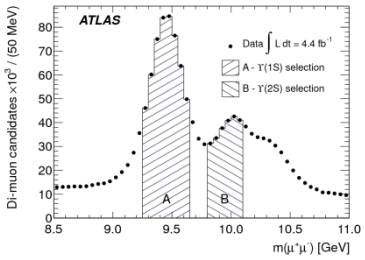
$\chi_b(3P)$ observation in $\chi_b(3P) \rightarrow \Upsilon(1/2\,S)\,\gamma$	PRL 108 (2012) 152001
Branching fraction of $B^+ \rightarrow \chi_{c1} K^+$	JHEP 07 (2014) 154
Observation of excited B_c ($\rightarrow B_c\pi^+\pi^-$)	PRL 113 (2014) 212004
Search for X_b ($\rightarrow \Upsilon(1S)\,\pi^+\pi^-$)	PLB 740 (2015) 199
Observation of $\Lambda_b \rightarrow \psi(2S)\,\Lambda^0$	PLB 751 (2015) 63
Summary & Prospects	

Back-up : ATLAS @ LHC

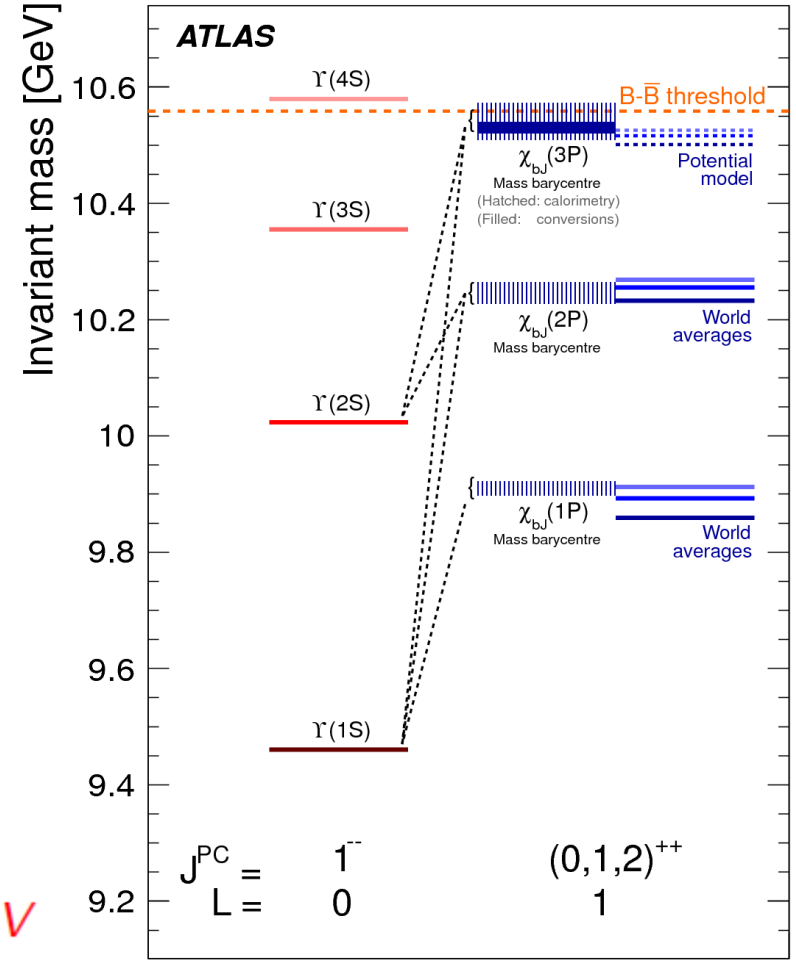
Λ_b mass and lifetime $\Lambda_b \rightarrow J/\psi\,\Lambda^0$	PRD 87 (2013) 032002
Study of $B_c \rightarrow J/\psi\,D_s^{(*)+}$	arXiv:1507.07099

$\chi_b(3P)$ observation in $\chi_b(3P) \rightarrow \Upsilon(1/2\,S)\,\gamma$

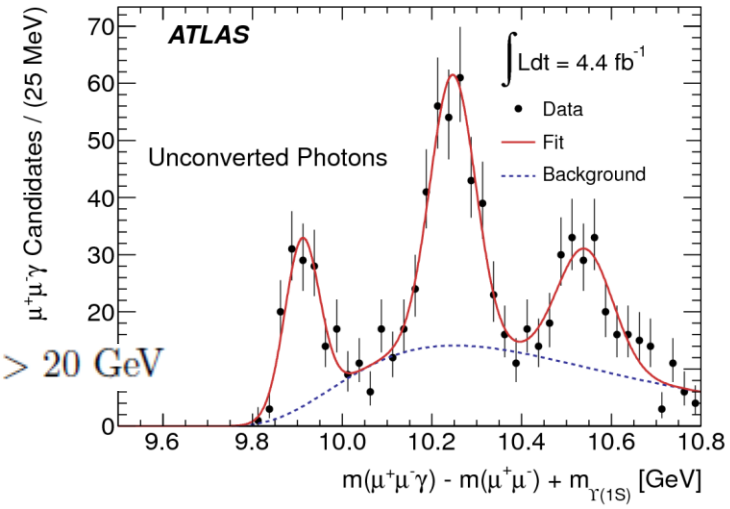
PRL 108 (2012) 152001



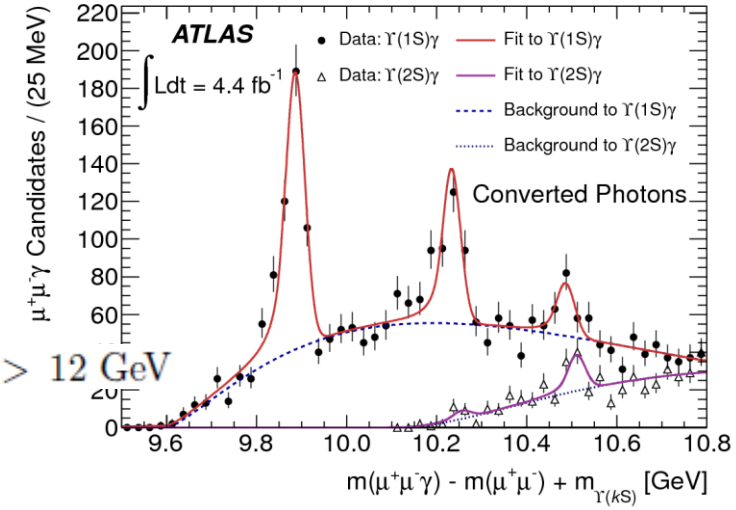
Observed bottomonium radiative decays in ATLAS, L = 4.4 fb^{-1}



$p_T(\mu^+\mu^-) > 20$ GeV



$p_T(\mu^+\mu^-) > 12$ GeV

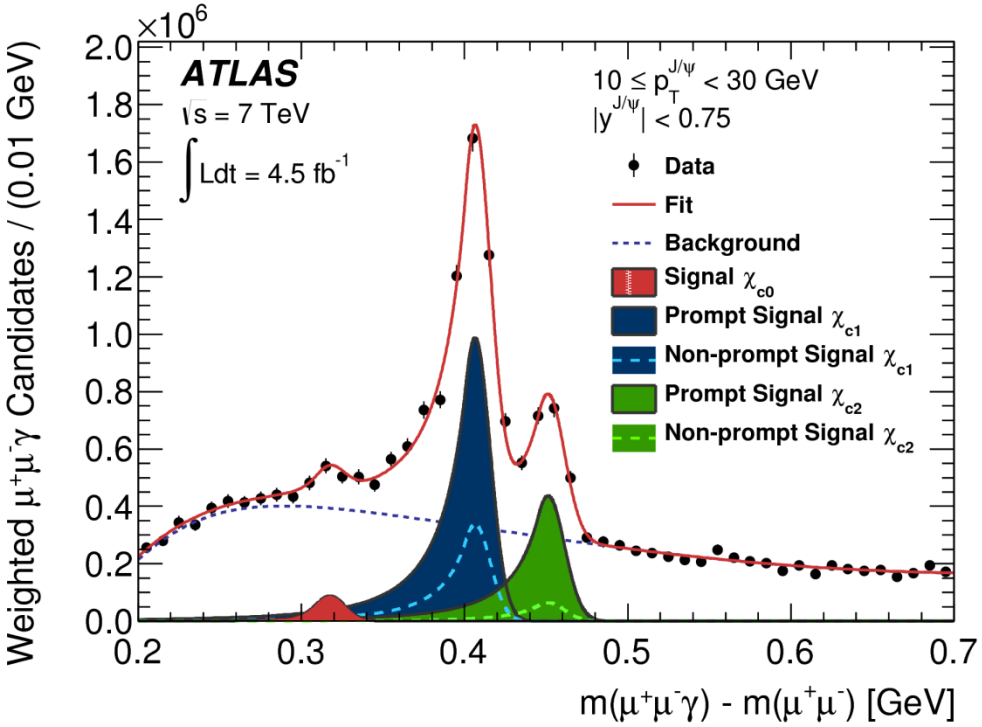


$$m_{\chi_b(3P)} = 10.530 \pm 0.005(stat) \pm 0.009(syst)\,GeV$$

LHCb: $m_{\chi_b(3P)} = 10.535 \pm 0.010(stat)$ GeV (LHCb-CONF-2012-020)

D0: $m_{\chi_b(3P)} = 10.551 \pm 0.014(stat) \pm 0.017(syst)$ GeV (arXiv:1203.6034)

Branching fraction of $B^+ \longrightarrow \chi_{c1} K^+$



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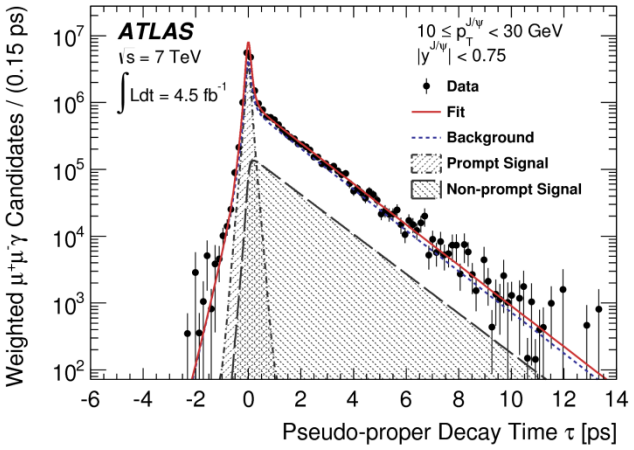
only converted photons

$$p_{\mathrm{T}}^{\gamma} > 1.5 \text{ GeV and } |\eta^{\gamma}| < 2.0$$

$$2.95 < m\,(\mu^+\mu^-) < 3.25 \text{ GeV}$$



To separate prompt and non-prompt (from B decays) production pseudo-proper lifetime is used

$$\tau = \frac{L_{xy} \cdot m_{J/\psi}}{|\vec{p_T}|} \qquad L_{xy} = \frac{\vec{L} \cdot \vec{p_T}}{|\vec{p_T}|}$$

used primarily to study pQCD aspects of $\chi_{c1/2}$ *production*

Branching fraction of $B^+ \to \chi_{c1} K^+$

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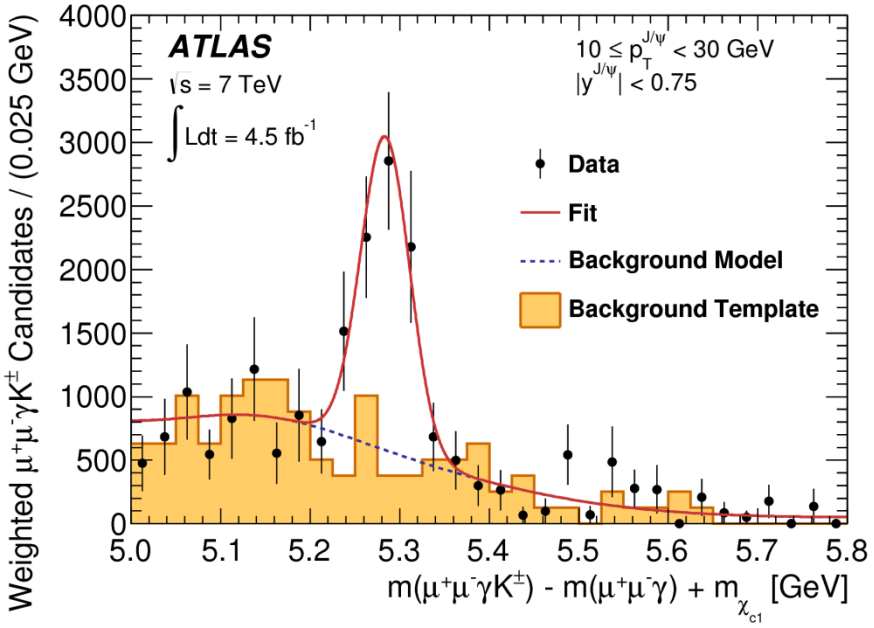
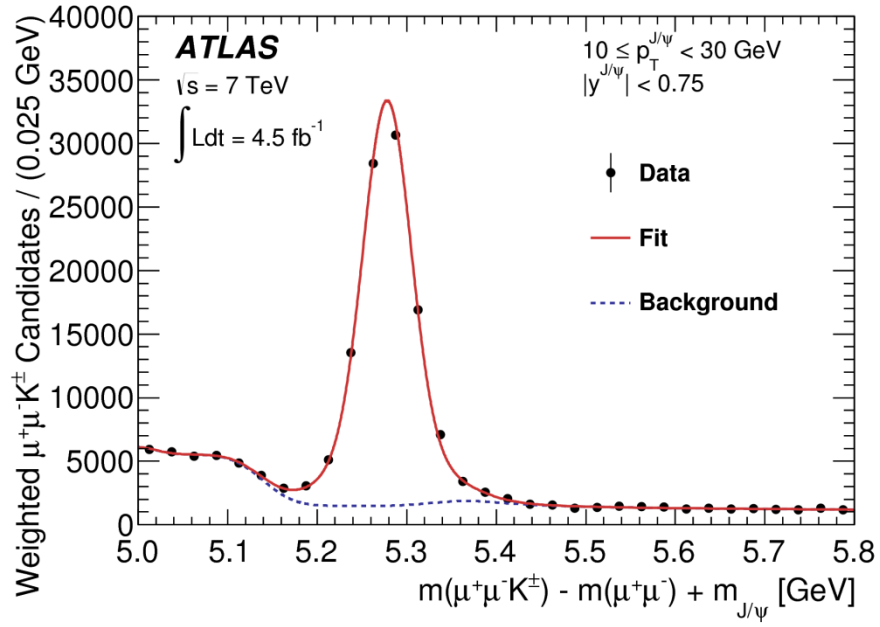
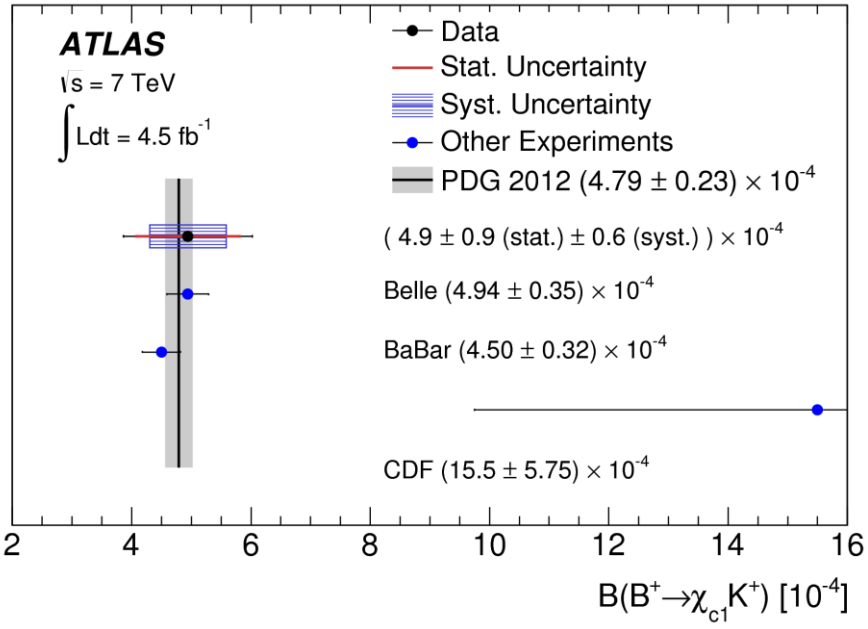




$$0.32 < m(\mu^+\mu^-\gamma) - m(\mu^+\mu^-) < 0.43 \text{ GeV}$$

$L_{xy} > 300\ \mu m$

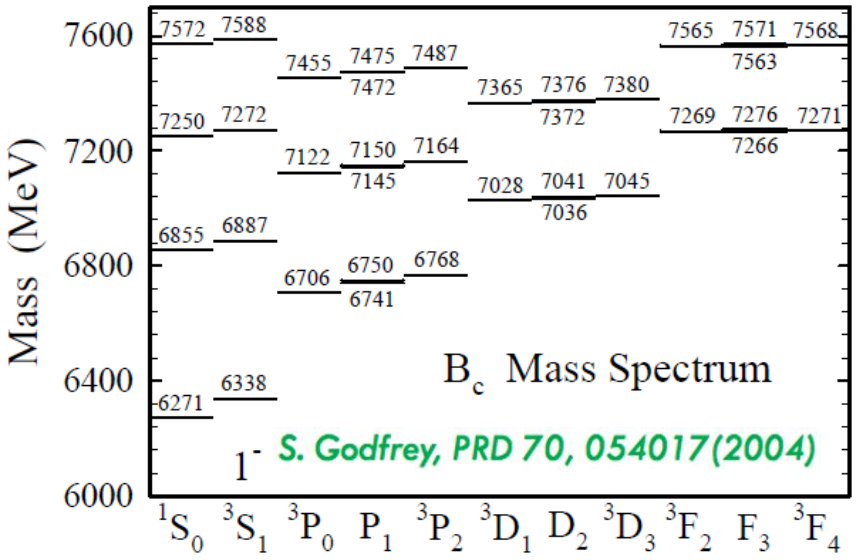
$$\mathcal{B}(B^\pm \to \chi_{c1} K^\pm) = \mathcal{A}_B \cdot \frac{N^B_{\chi_{c1}}}{N^B_{J/\psi}} \cdot \frac{\mathcal{B}(B^\pm \to J/\psi K^\pm)}{\mathcal{B}(\chi_{c1} \to J/\psi\,\gamma)}$$



much better than other measurements in hadron collisions

Observation of excited B_c ($\rightarrow B_c\pi^+\pi^-$)

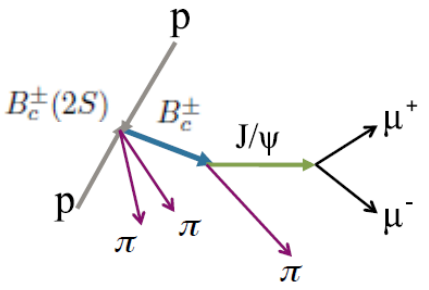
PRL 113 (2014) 212004



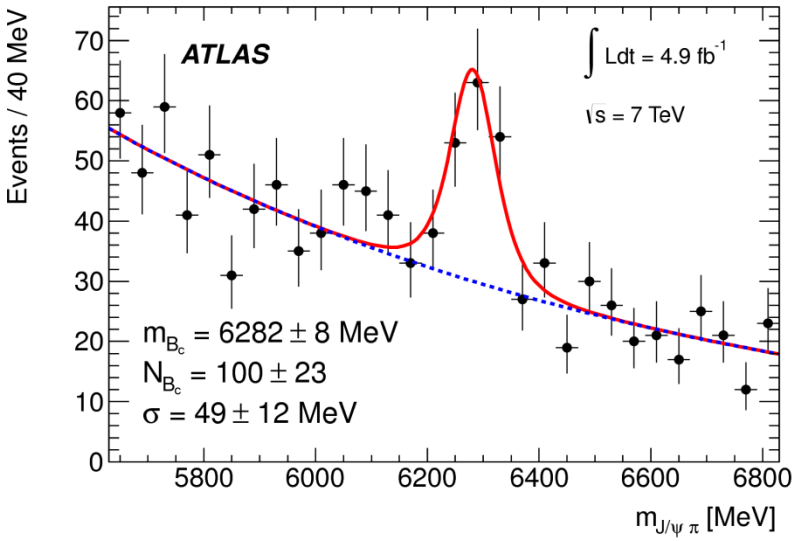
Large B_c family is expected although only ground state has been known until today

$B_c^{\pm}(2S)$ 6835–6917 MeV

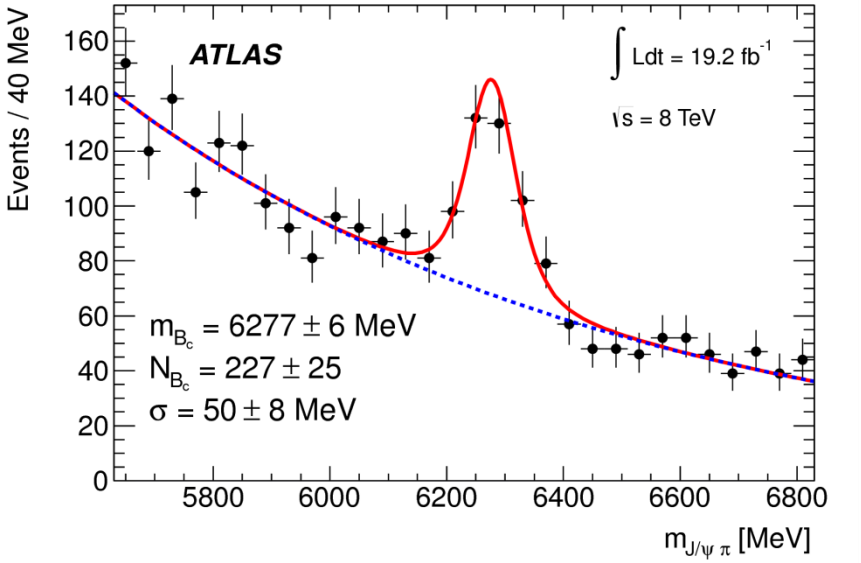
$2S/1S \simeq 0.6$ $\quad 2^1S_0 \rightarrow 1^1S_0 + \pi\pi$



$p_T(\pi) > 4$ GeV, $m(J/\psi)$ constrained to PDG



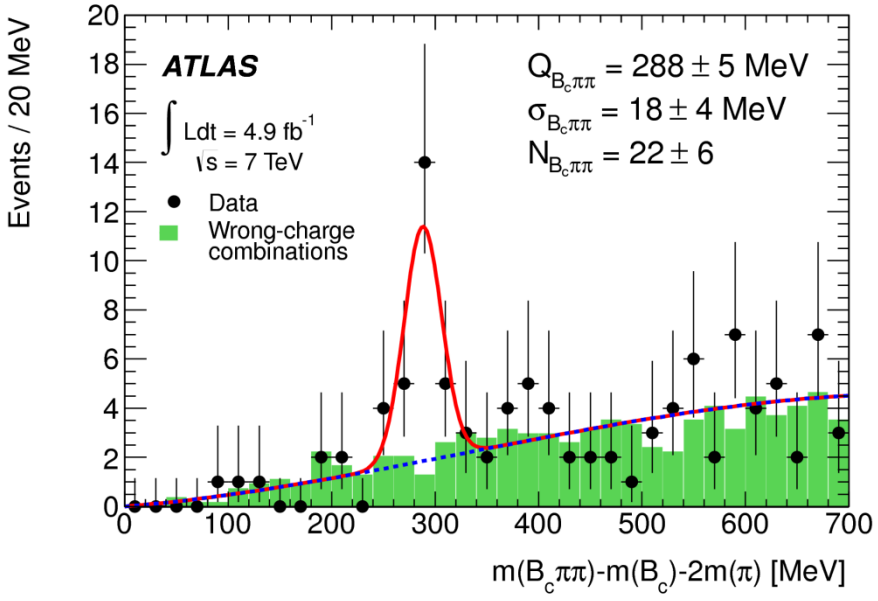
$p_T(B_c) > 15$ GeV

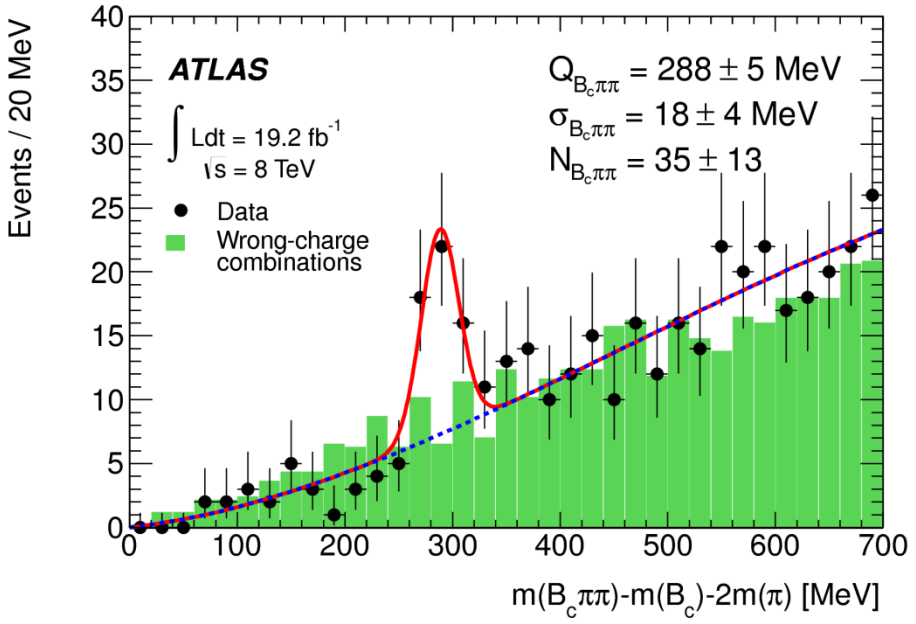


$p_T(B_c) > 18$ GeV

Observation of excited B_c ($\rightarrow B_c\pi^+\pi^-$) PRL 113 (2014) 212004

$p_T(\pi^\pm) > 400$ MeV, $m(J/\psi)$ constrained to PDG





Significance from $\Delta \ln L$ of pseudo-experiments: 5.4 σ (local)

5.2 σ ("look elsewhere")

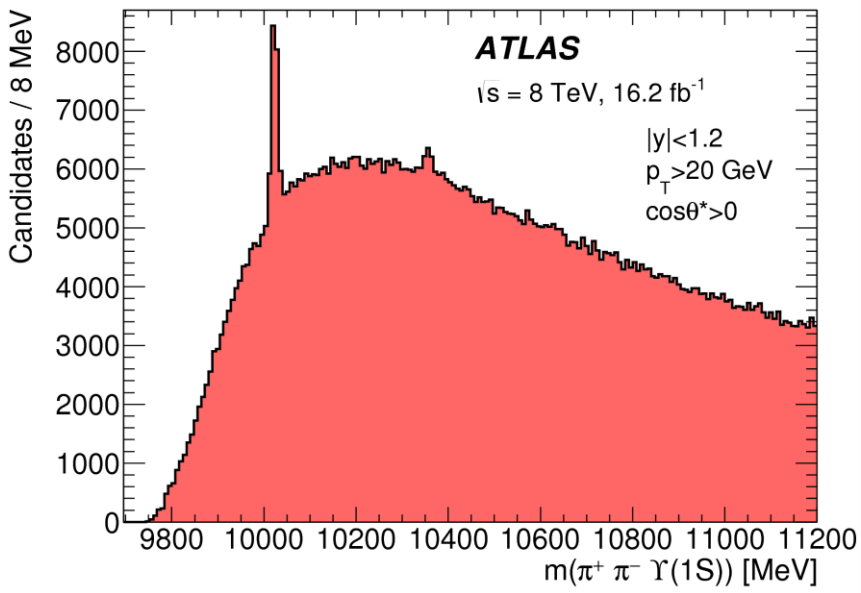
Q = 288.3 ± 3.5 ± 4.1 MeV

M = 6842 ± 4 ± 5 MeV

Both mass value and decay mode agree with expectations for $B_c^{\pm}(2S)$

Search for X_b ($\rightarrow \Upsilon(1S)\,\pi^+\pi^-$)

PLB 740 (2015) 199

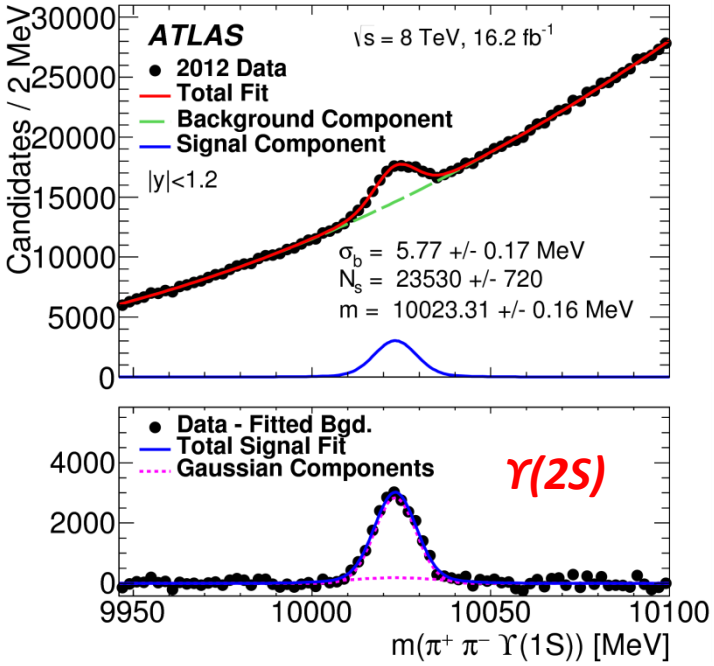


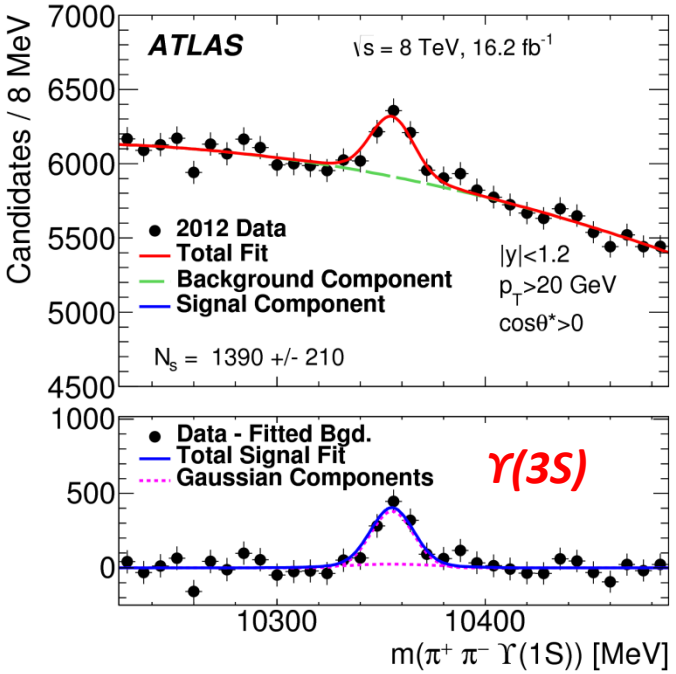
X_b - counterpart of X(3872)
Most of predictions: 10.4-10.9 GeV

~1×10^6 $\Upsilon(1S)\rightarrow\mu^+\mu^-$
~2×10^5 $\Upsilon(2S)\rightarrow\mu^+\mu^-$

$p_T(\pi^{\pm}) > 0.4$ GeV

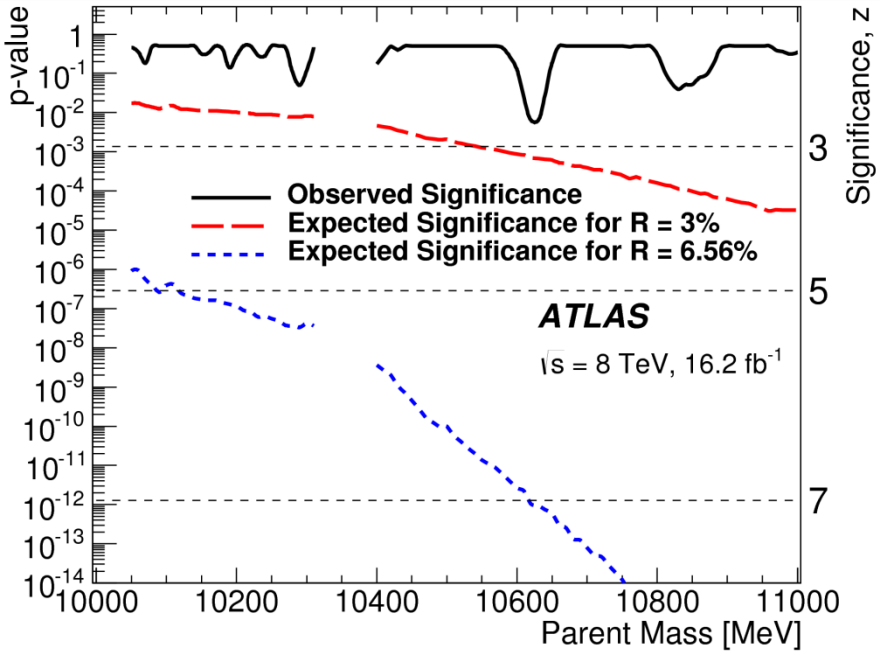
Θ* - angle between the di-pion momentum in the parent rest frame and the lab-frame parent momentum

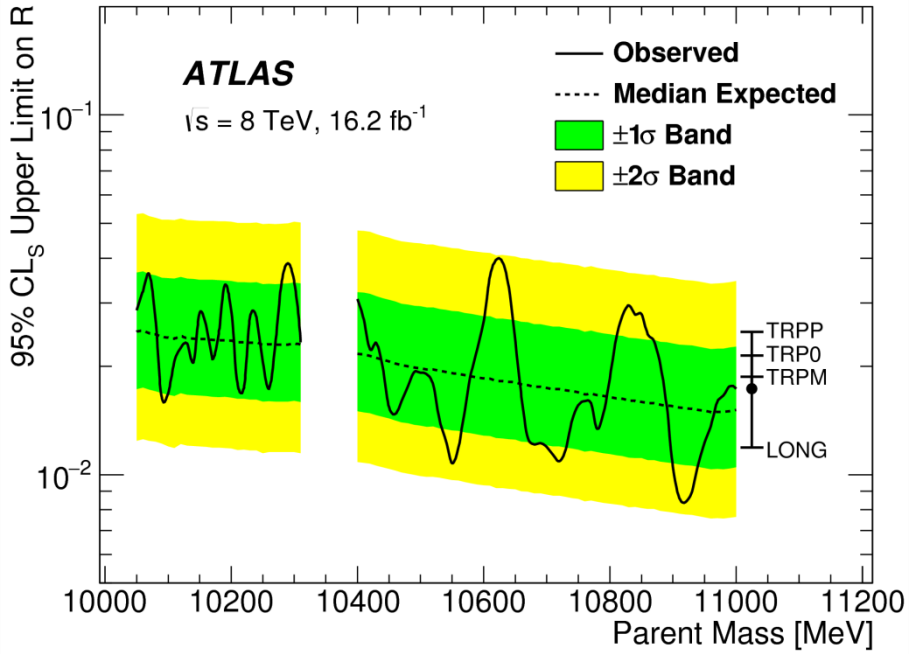




Search for X_b ($\rightarrow \Upsilon(1S)\,\pi^+\pi^-$)

PLB 740 (2015) 199

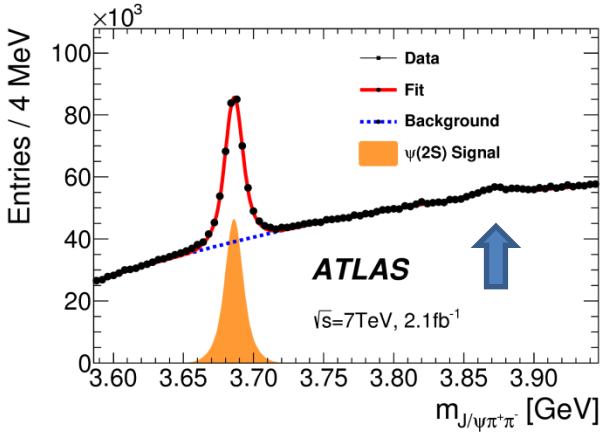




$$R \equiv (\sigma\mathcal{B})/(\sigma\mathcal{B})_{2S} \qquad N = N_{2S} \cdot R \cdot \frac{\mathcal{A}}{\mathcal{A}_{2S}} \cdot \frac{\epsilon}{\epsilon_{2S}}$$

X_b witn R ≥ 6.56% (analogous ratio for X(3872)) are excluded for 10.05-10.31 GeV and 10.4 -11.0 GeV

Dedicated fits for $\Upsilon(1^3D_J)$ triplet and broad $\Upsilon(10860)$ and $\Upsilon(11020)$ reveal no signals



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Observation of $\Lambda_b \rightarrow \psi(2S)\,\Lambda^0$

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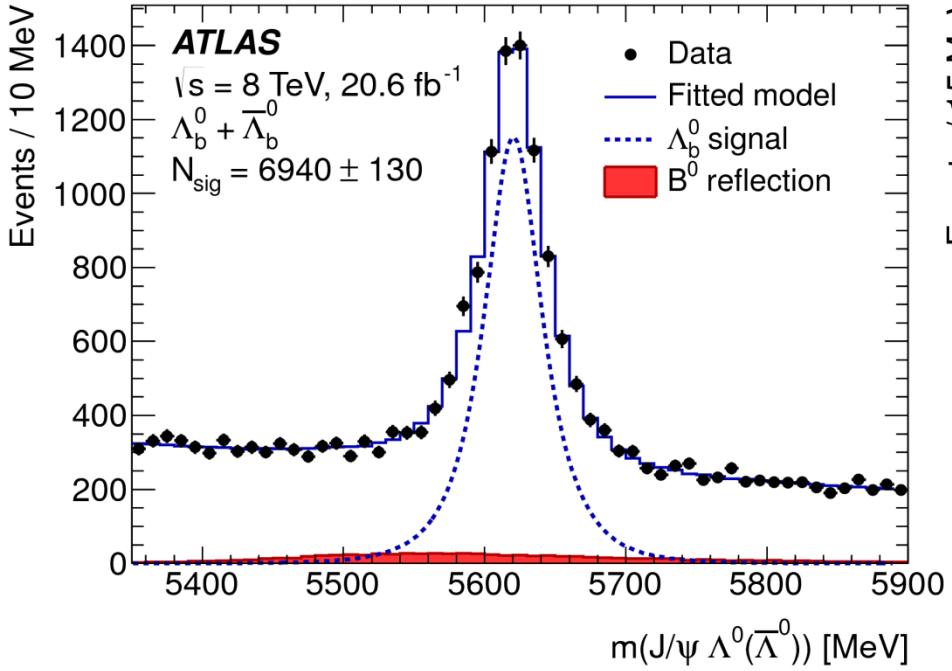

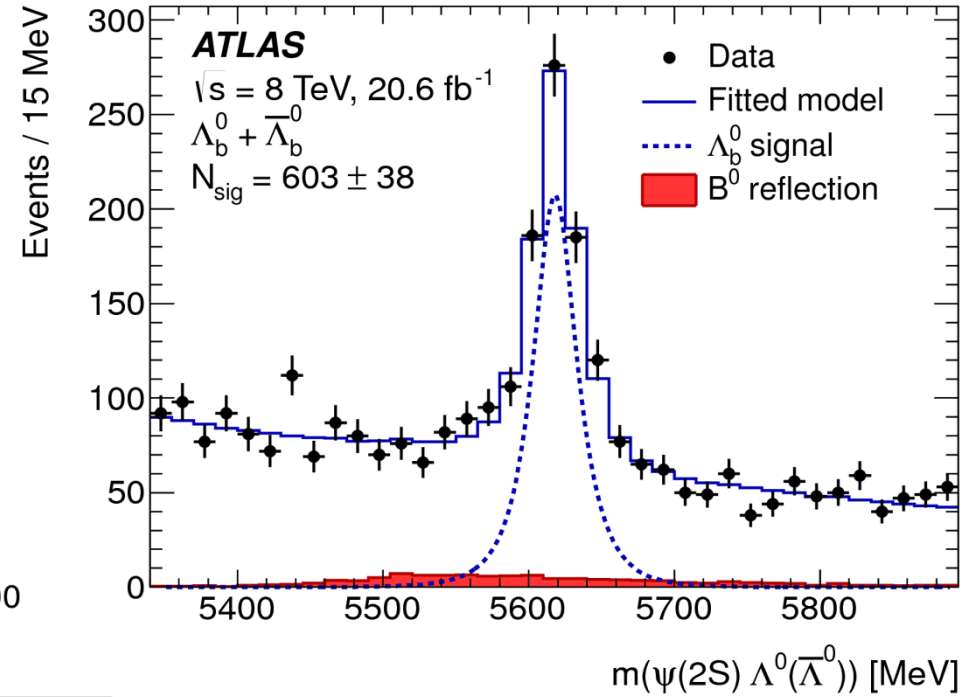

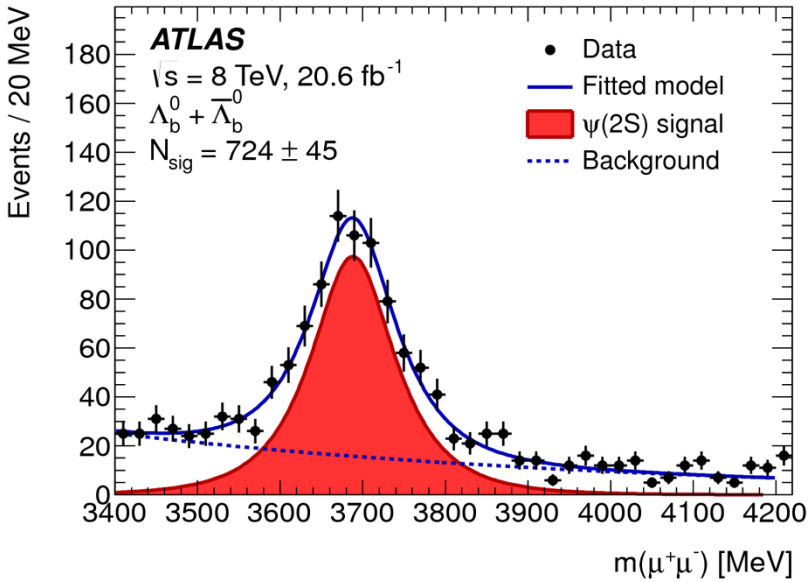

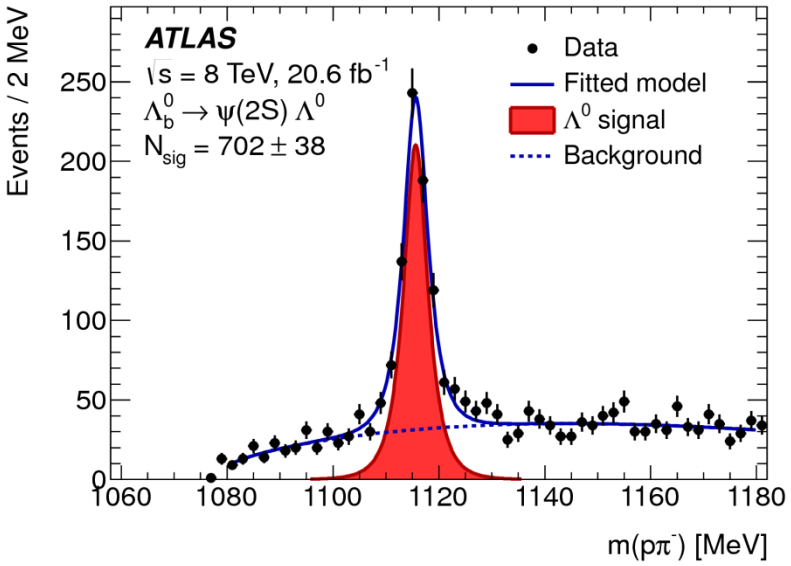

Observation of $\Lambda_b \rightarrow \psi(2S)\,\Lambda^0$

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$$\frac{\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)}{\Gamma(\Lambda_b^0 \rightarrow J/\psi\,\Lambda^0)} = 0.501 \pm 0.033(\text{stat}) \pm 0.016(\text{syst}) \pm 0.011(\mathcal{B})$$

In comparison with covariant quark model prediction (0.8 ± 0.1)

T. Gutsche et al., Phys. Rev. D 88 (2013) 114018, arXiv:1309.7879 [hep-ph].

Lies in the range 0.5-0.8 measured for the branching ratios of analogous B meson decays [PDG].

Summary

- Observation of $\chi_b(3P)$ (in $\chi_b(3P) \rightarrow \Upsilon(1/2\,S)\,\gamma$)
- Best measurements of $Br(B^+ \rightarrow \chi_{c1} K^+)$ in hadron collisions
- Observation of excited B_c ($\rightarrow B_c\pi^+\pi^-$)
  The mass (6842 ± 4 ± 5 MeV) and decay mode agree with $B_c(2S)$
- Search and upper limits for X_b ($\rightarrow \Upsilon(1S)\,\pi^+\pi^-$)
- Observation of $\Lambda_b \rightarrow \psi(2S)\,\Lambda^0$ *and its relative branching measurement*

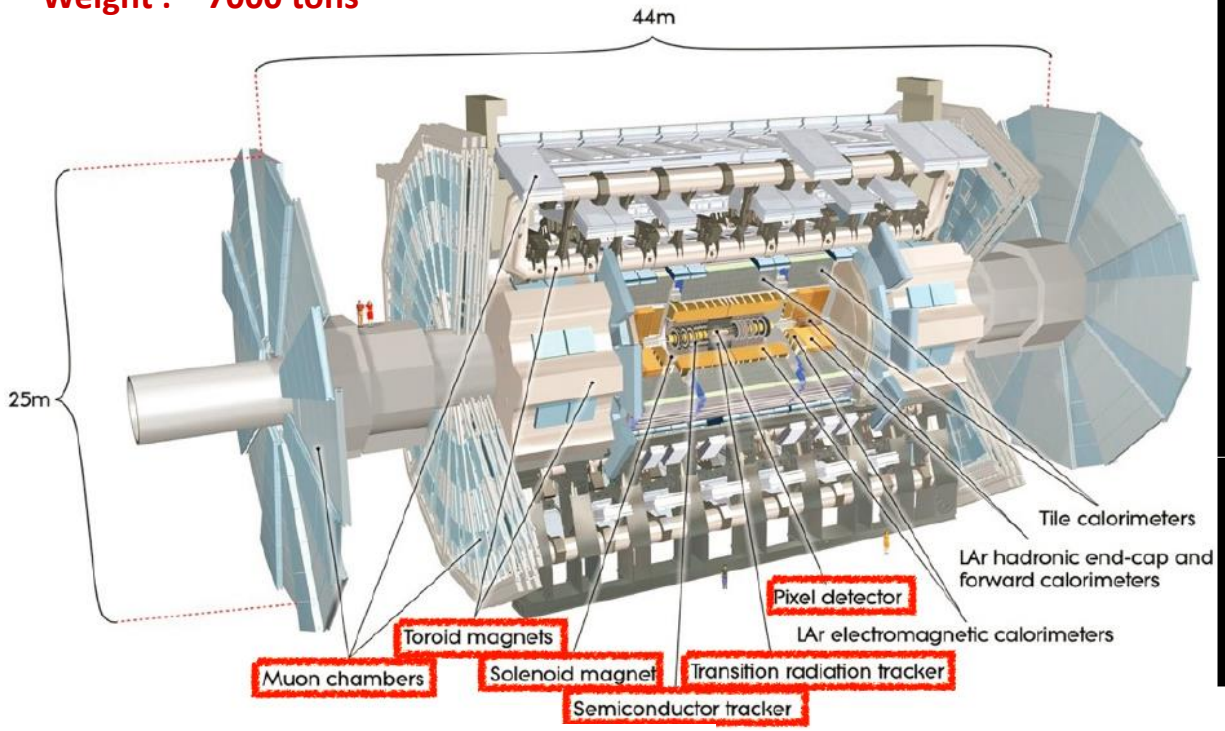
Prospects

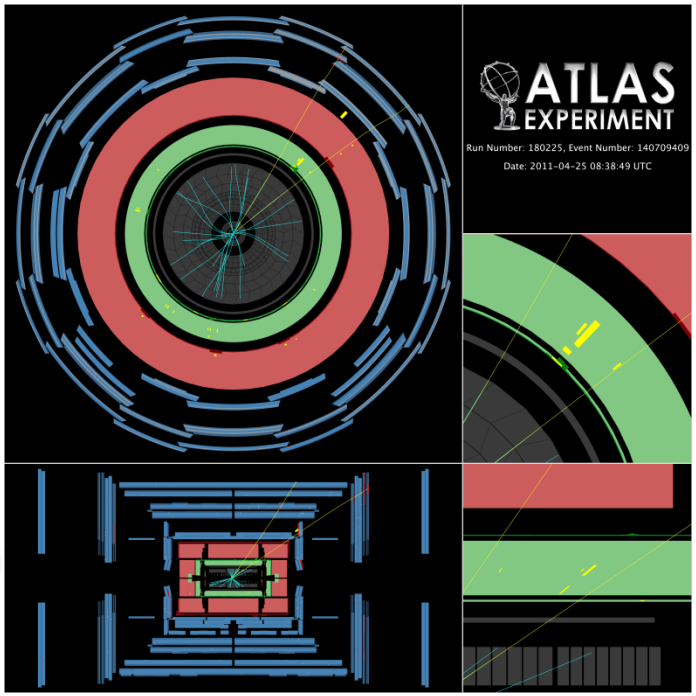
- ~25 fb^{-1} in 2011-2012 at $\sqrt{s}$ = 7-8 TeV
  ~4 fb^{-1} in 2015 at $\sqrt{s}$ = 13 TeV
  can expect up to 100 fb^{-1} in 2016-2018 at $\sqrt{s}$ = 13 TeV
- Improved lifetime resolution due to insertable B-layer
  Improved tracking in high-level trigger
- Plan to improve precision of our Run I results
- Plan to check observations of other collaborations,
  in particular, PQ's from LHCb and Ξ_b^{*0} from CMS
- And, hopefully, something new

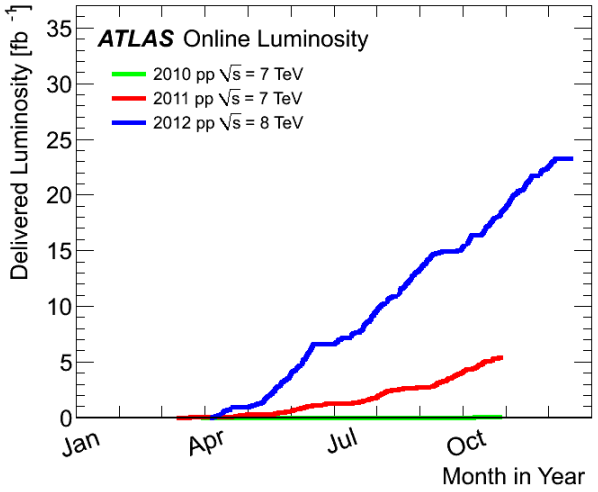
Back-up Slides

ATLAS @ LHC

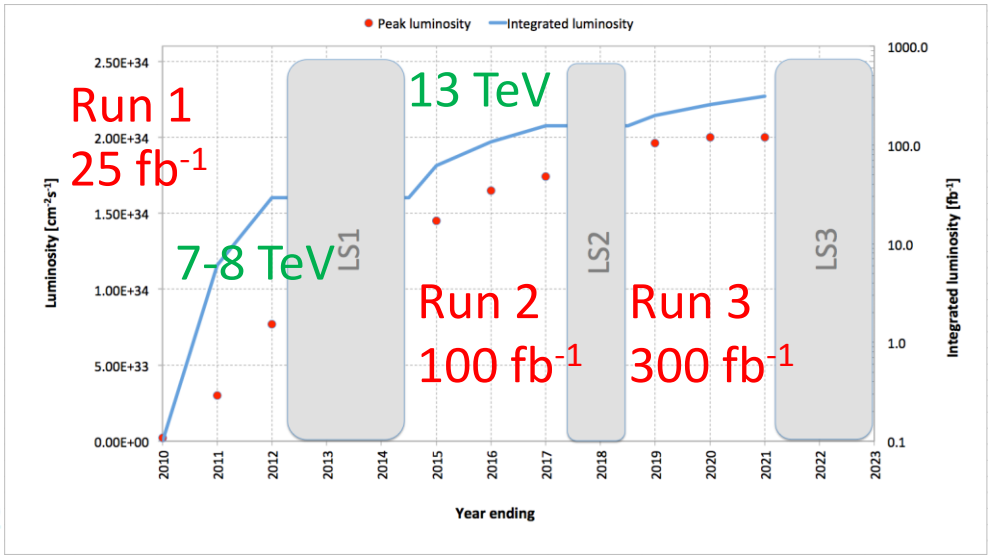
Weight : ~ 7000 tons





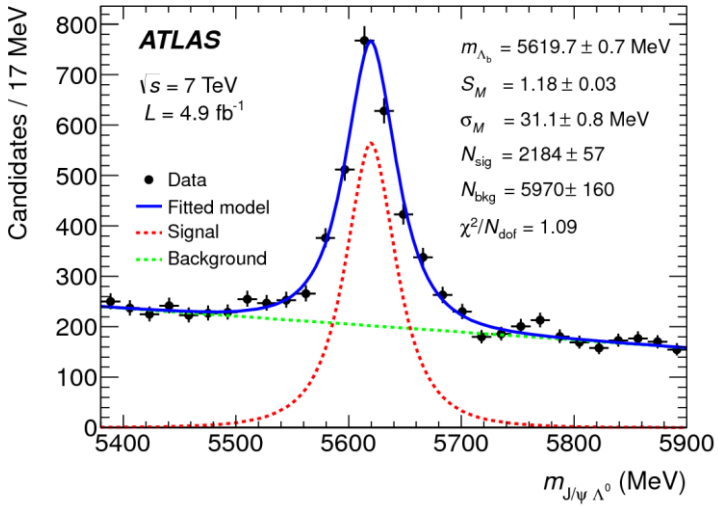


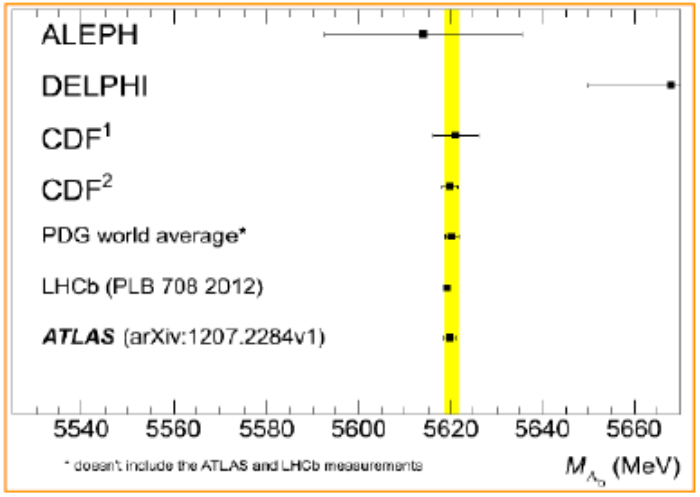
Peak Lumi: 6.76×10^{33} cm^{-2}



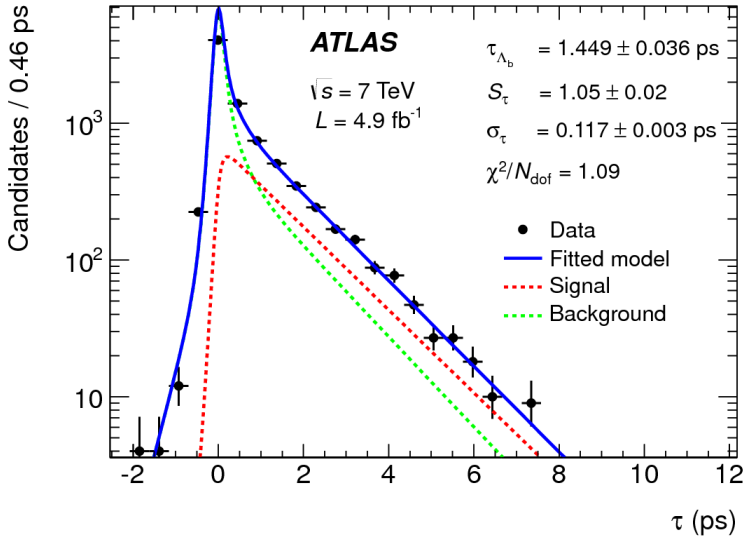
Run 4
HL-LHC
3000 fb^{-1}

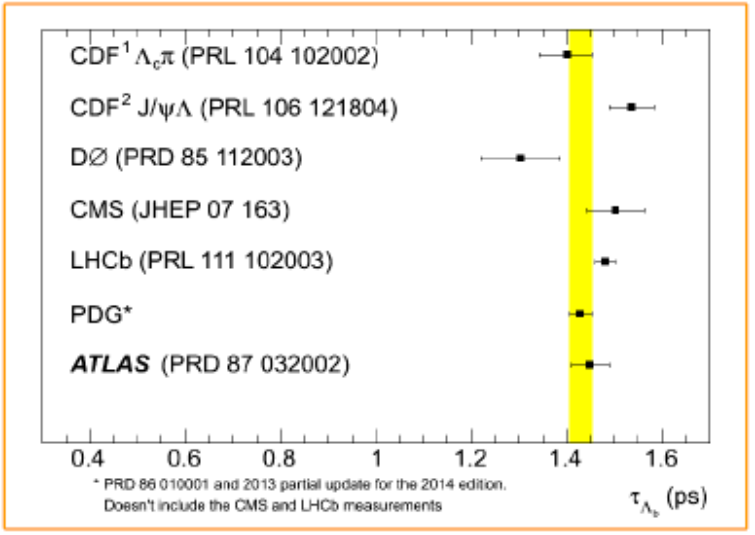
Λ_b mass and lifetime from $\Lambda_b \rightarrow J/\psi\, \Lambda^0$





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





$$\tau(\Lambda_b) = 1.499 \pm 0.036(\text{stat}) \pm 0.017(\text{syst})\ \text{ps}$$

PRD 87 (2013) 032002

Study of $B_c \rightarrow J/\psi\, D_s^{(*)+}$

arXiv:1507.07099