Production and spectroscopy of hadrons containing b quark at ATLAS

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On behalf of ATLAS collaboration

ATLAS detector

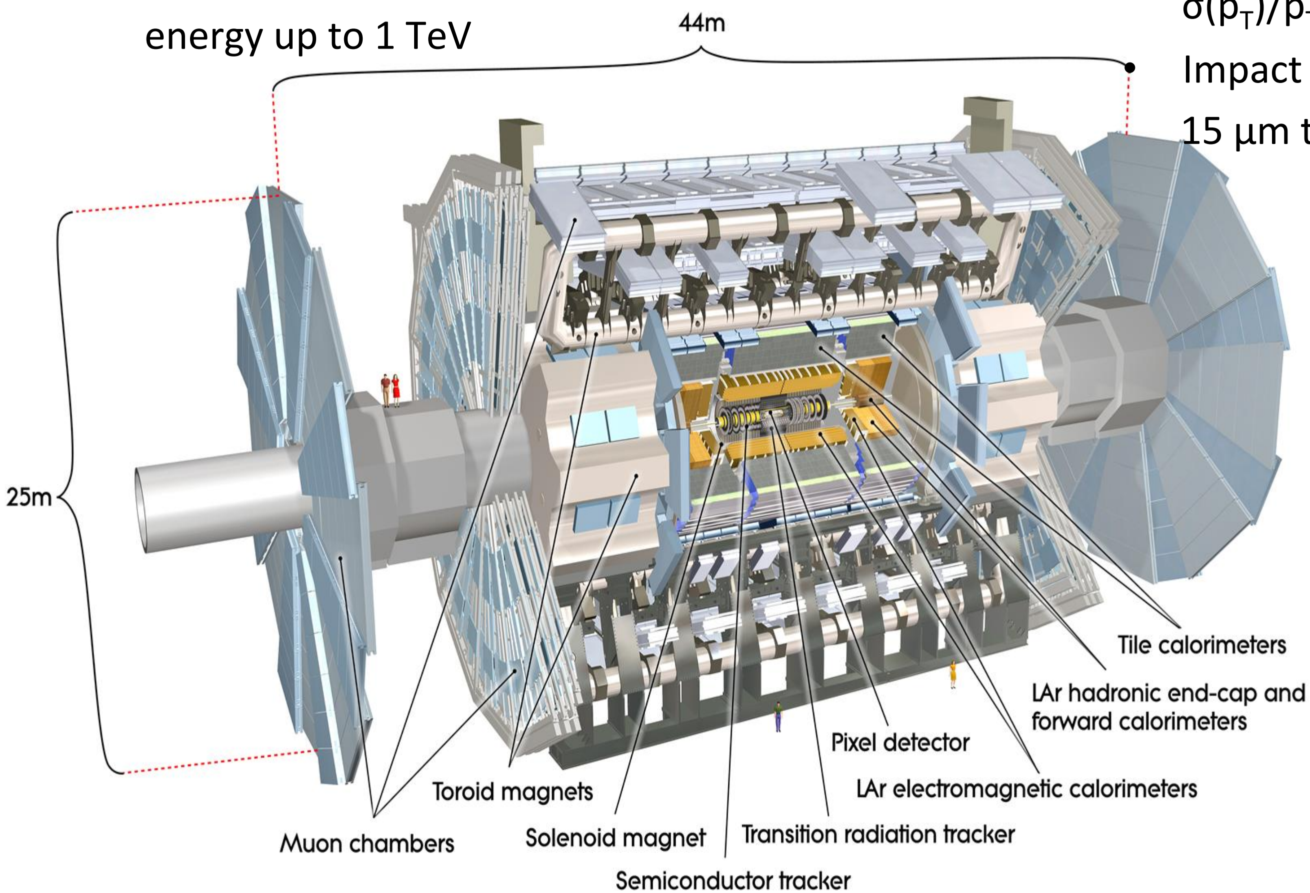
Multipurpose detector at LHC, optimized for high p_T physics and instantaneous luminosity up to 10^{34} $cm^{-2}s^{-1}$

Muon Spectrometer $|\eta|<2.7$

- Momentum resolution: $\sigma(p_T)/p_T<10\%$ for muons with energy up to 1 TeV

Inner Detector (PIX, SCT, TRT) $|\eta|<2.5$

- Momentum resolution: $\sigma(p_T)/p_T = 5 \times 10^{-4} p_T (GeV) \oplus 1.5\%$
- Impact parameter resolution: 15 µm transverse, 100 µm longitudinal



EM calorimeter $|\eta|<3.2$

- Measure the total energy of e^+, e^- and γ.
- E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$ (GeV)

B physics triggers

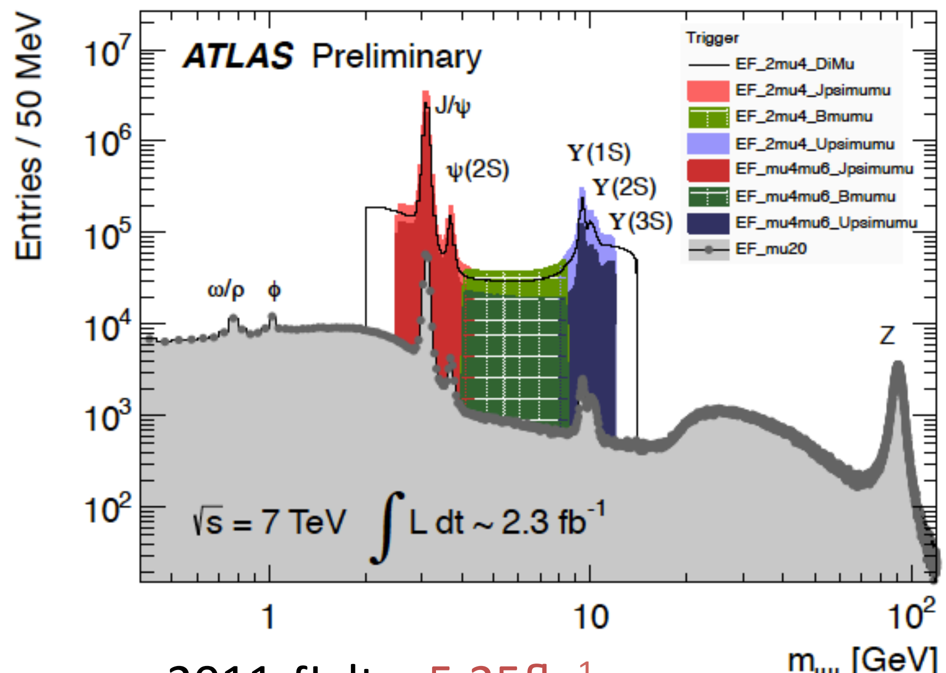
- ATLAS has 3-level trigger system (L1 - hardware, L2 and Event Filter (EF) – High level trigger (HLT))
- Dedicated B-physics triggers are based on both single muons and di-muons with different thresholds and mass ranges.

- Topological triggers process two L1 muon and refine results in the HLT with a good vertex fit and mass cut.

Topology	Mass window
Jpsimumu	2.5-4.3GeV
Upsimumu	8-12 GeV
Bmumu	4-8.3 GeV

- TrigDiMuon triggers require one L1 muon and then search for a second muon in inner detector tracks.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysPublicResults#Stand_alone_plots



- 2011 $\int Ldt = 5.25 fb^{-1}$
- 2012 $\int Ldt = 21.7 fb^{-1}$

$J/\psi \rightarrow \mu^{+}\mu^{-}$ topology

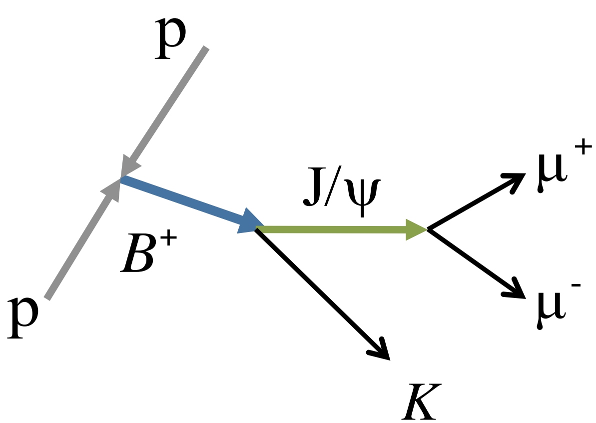
B^+ production cross-section

(ATLAS-CONF-2013-008)

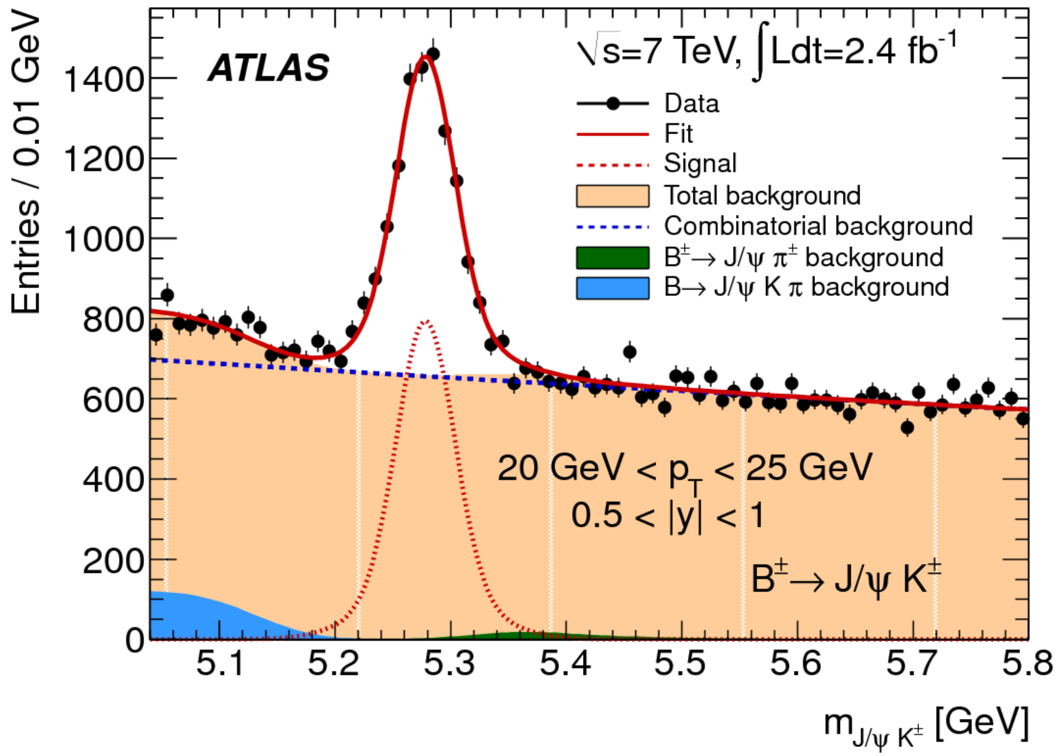
$B^+ \to J/\psi(\mu^+\mu^-)K^+$

- Early 2011 data, 2.4fb^{-1} at 7TeV.
- Di-muon triggers with p_T>4GeV.
- VTX fit with J/ψ mass constraint,

  $p_T(B^+)$>9GeV, $|y(B^+)|$<2.3



Signal: double Gaussian *(fixed from MC)*

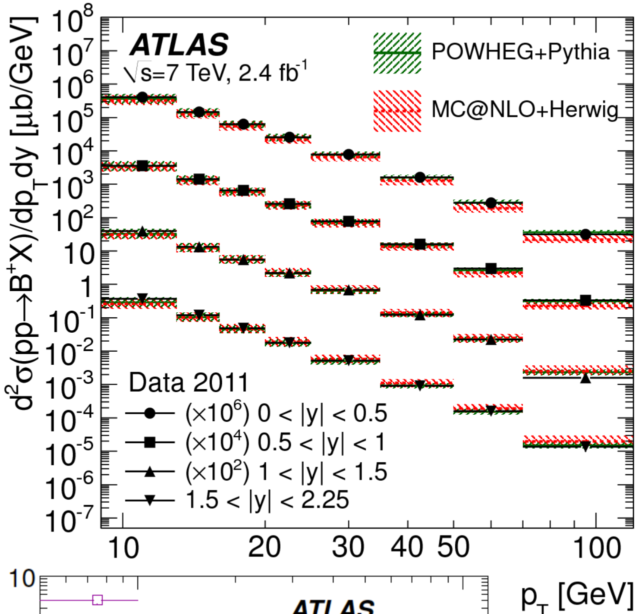


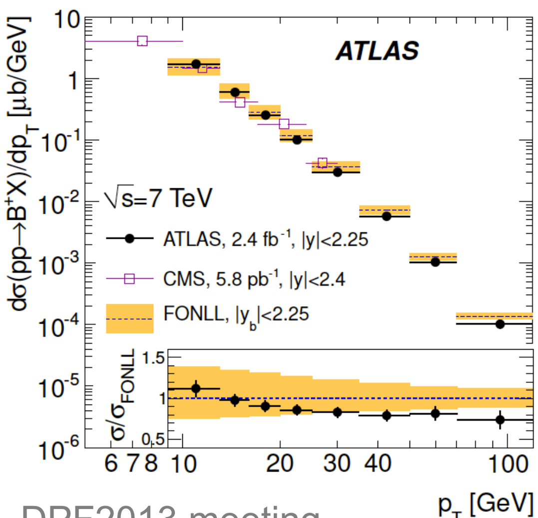
Combinatorial background: single exponential

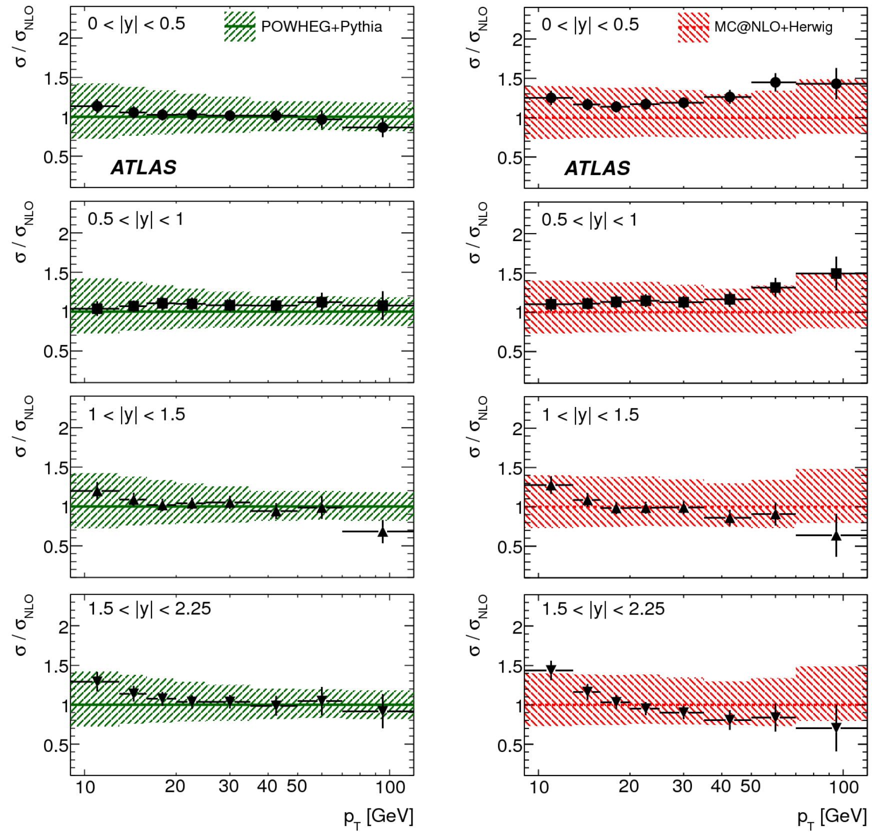
B^+ production cross-section

(ATLAS-CONF-2013-008)

8 p_T bines and 4 y bins in the full kinematic range 9GeV<p_T<120GeV and |y|<2.25







- Powheg+Pythia: good agreement, both cross section and shape.
- MC@NLO+Herwig: lower cross section and softer p_T spectrum in low y, harder p_T spectrum in high y.
- FONLL: good agreement especially with p_T<30GeV, compatible in high p_T

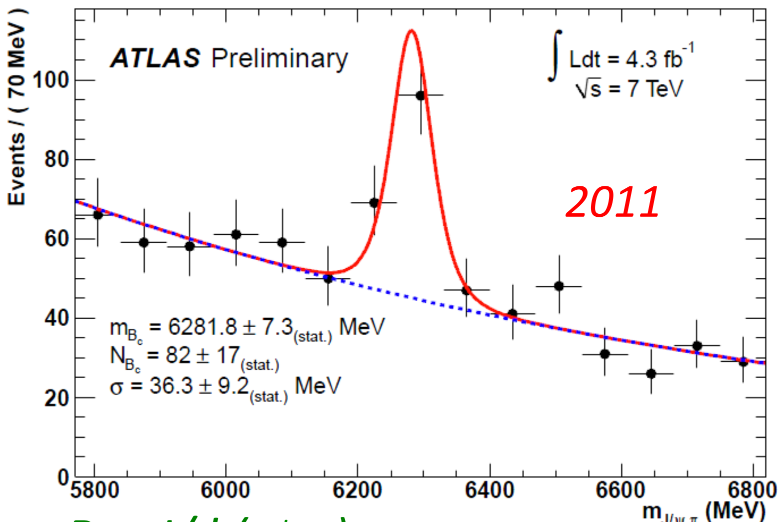
B_c->J/ψπ observation

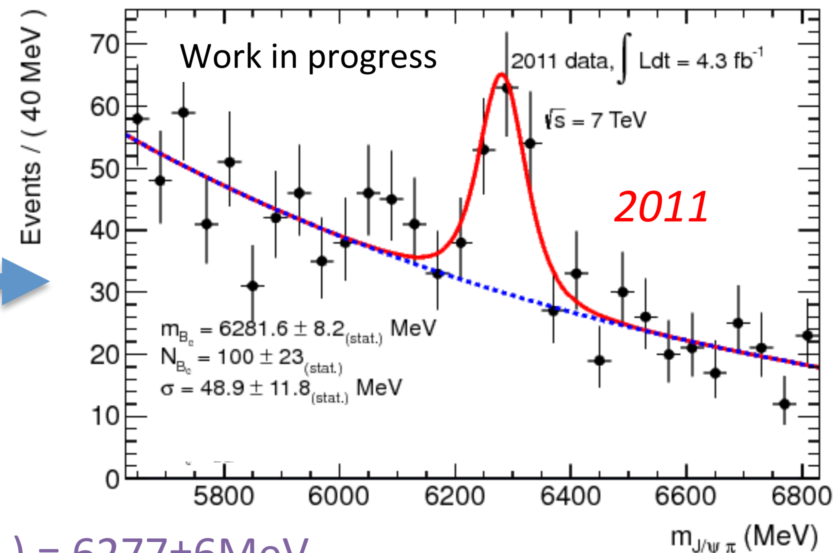
[(ATLAS-CONF-2012-028)](ATLAS-CONF-2012-028)

B_c meson -> bound state of b, c quark.

- Gives an access of information unable to be obtained from charmonium and bottomonium.

Track selection criteria have been optimized according to the higher pileup condition of the second half of 2011 data taking, to reduce the fake hadron tracks.

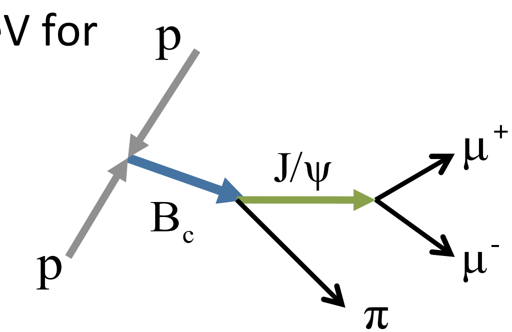




- *B_c->J/ψ($\mu^+\mu^-$)π*

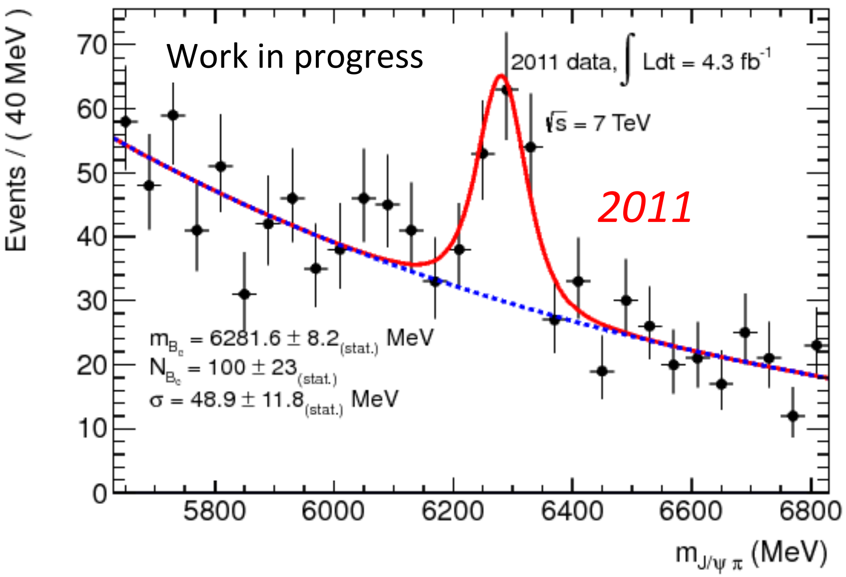
PDG(B_c) = 6277±6MeV

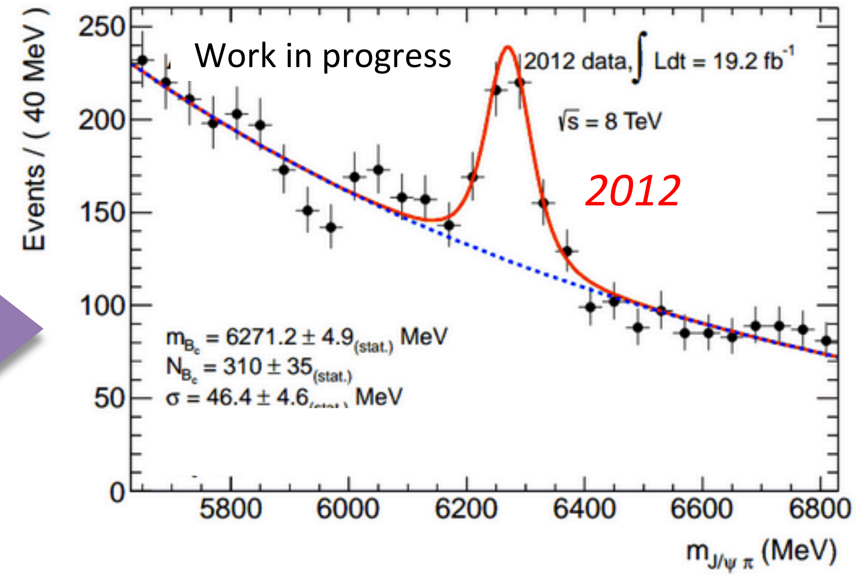
  - Full 2011 7TeV data, 4.3fb^{-1}. Di-muon trigger with p_T>4GeV for the first half and p_T>(6,4)GeV for the second half.
  - Unbinned maximum likelihood fit. Signal – Gaussian; Background – Exponential.
  - $p_T(B_c)$>15GeV, |η|<2.5, VTX constrained to J/ψ mass.



B_c->$J/\psi\pi$ observation

(ATLAS-CONF-2012-028)





- B_c->$J/\psi(\mu^+\mu^-)\pi$
  - Full 2012 8TeV data, 19.2fb^{-1}. Di-muon trigger with p_T>(6,4)GeV.
  - Fit in wide range to minimize the effects from in the left sideband.
  - Frozen cuts from 2011 data -> to be tuned for 2012 conditions.
  - Much higher pileup in 2012, 7TeV->8TeV.

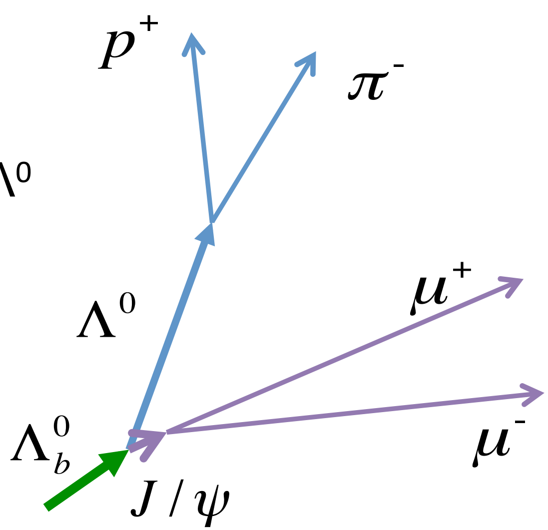
Λ_B lifetime and mass

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

- Λ_b^0 -> ground state heavy b-baryon, $J^P = 1/2$
  - Lifetime still have large experimental uncertainty (2-3%).
  - Discrepancy between CDF and D0 measurements (1.8σ)
- $\Lambda_b^0 \to J/\psi(\mu^+\mu^-)\Lambda^0,\ \Lambda^0 \to p^+\pi^-$

Λ^0 candidates

- 1.08 GeV<m(pπ)<1.15 GeV
- VTX fit constrained to the Λ^0 mass, m=1115.68MeV
- Pointing to J/ψ vertex



J/ψ candidates

- 2.8 GeV<m(μμ)<3.4 GeV
- VTX fit constrained to the J/ψ mass, m=3069.92MeV
- Di-muon trigger with p_T>4GeV.

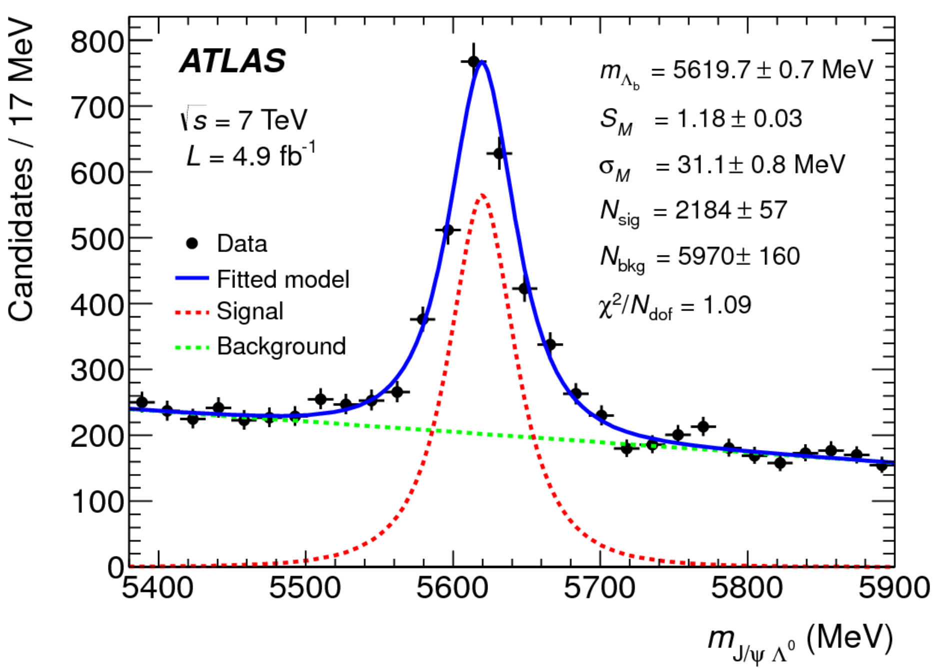
Λ_b^0 candidates

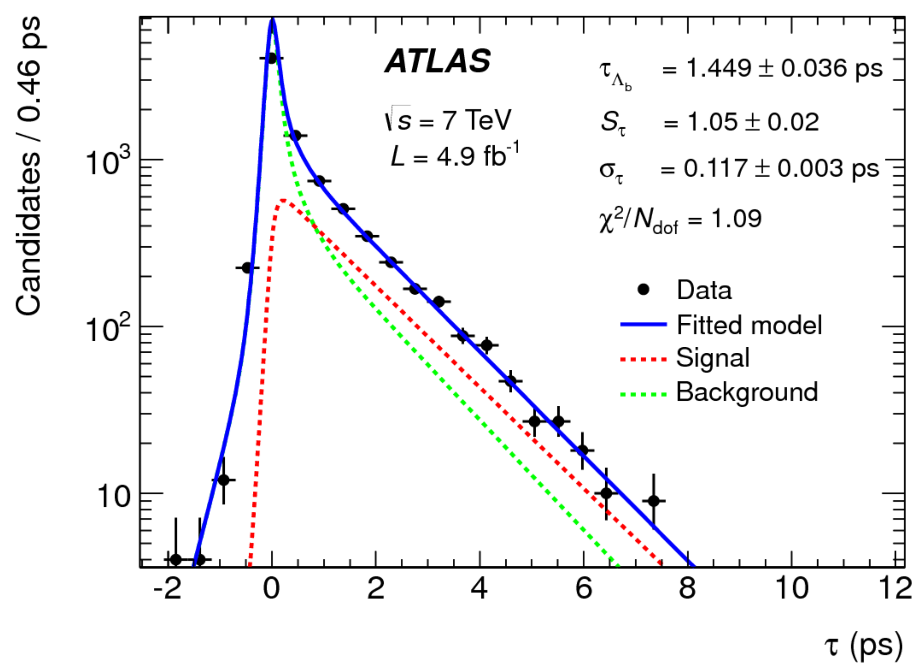
- Cascade topology fit applied to p^+, π^-, μ^+ and μ^- with constraints

Λ_B lifetime and mass

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

- Full 2011 7TeV data, $4.9 fb^{-1}$.
- Proper decay time $\tau = (L_{xy} m_{PDG}(\Lambda_b))/p_T$, $m_{PDG}(\Lambda_b) = 5619.4$MeV
- Simultaneous unbinned likelihood fit to m and τ with per event error.



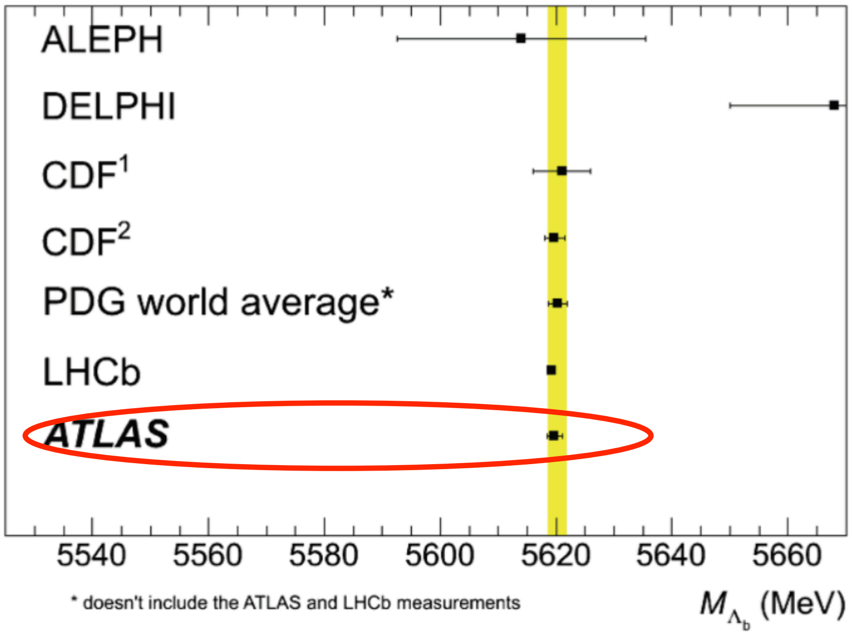


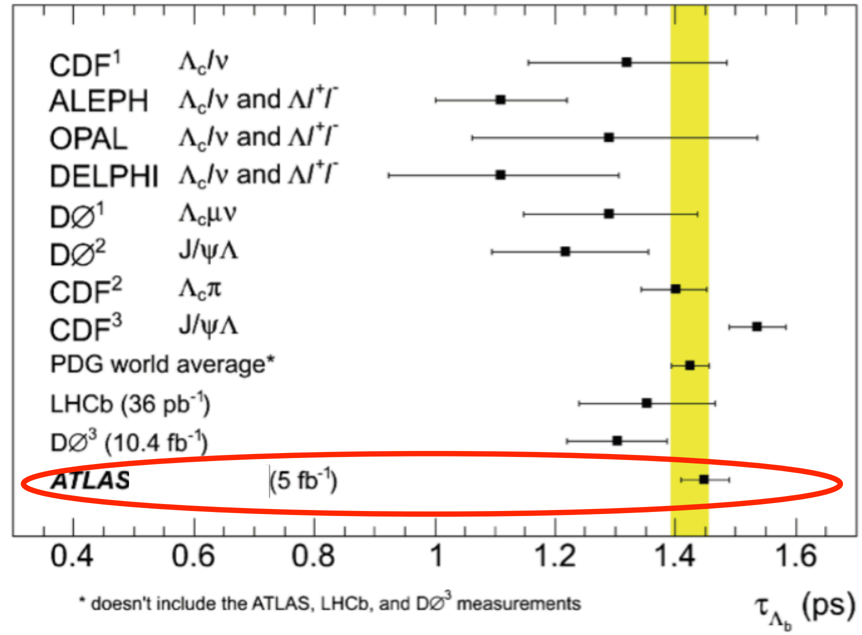
Λ_B lifetime and mass

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

m = 5619.7 ± 0.7 (stat) ± 1.1 (syst) MeV

τ = 1.449 ± 0.036(stat) ± 0.017(syst) ps





- Analysis was cross-checked with $B_d \to J/\psi(\mu^+\mu^-)K_S^0(\pi^+\pi^-)$ *(τ measured with good precision, $\tau(B_d)_{PDG}$ = 1.519±0.007ps, $\tau(B_d)_{measured}$ = 1.509±0.012(stat)±0.018(syst) ps)*
- Lifetime ratio Measured:

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

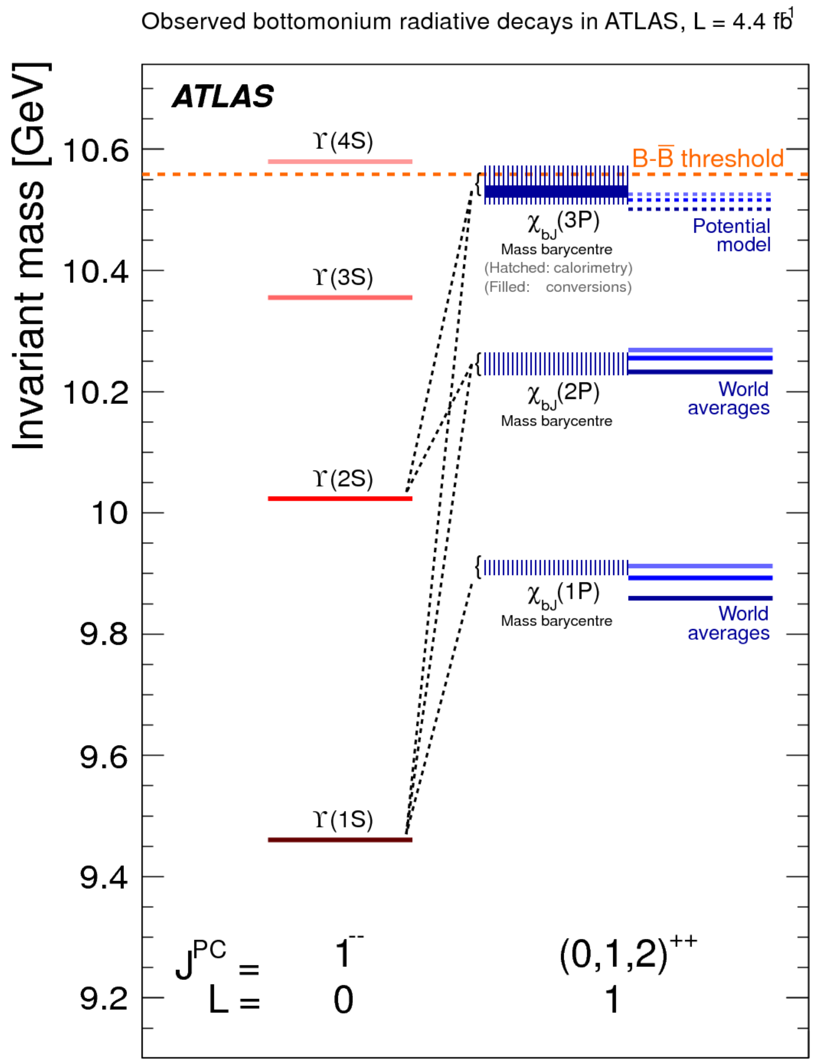
- Agree with D0 *(0.864±0.052(stat)±0.033(syst))*, CDF *(1.020±0.030(stat)±0.008(syst))* and heavy quark expansion calculations *(0.88 - 0.97)*, compatible with the NLO *(0.86-0.88 ±0.05)*.

$\Upsilon \rightarrow \mu^+\mu^-$ *topology*

Observation of a New χ_b State

Phys. Rev. Lett. 108 (2012) 152001

- b quarkonium $\chi_b(1P)$, $\chi_b(2P)$ states have been observed through the radiactive decay modes
  - $\chi_b(1P) \rightarrow \Upsilon(1S)\gamma$ with m = 9.90GeV
  - $\chi_b(2P) \rightarrow \Upsilon(1S,2S)\gamma$ with m = 10.26GeV
- The $\chi_b(3P)$ has not been observed before
  - Predicted mass: ~10.52 GeV
  - Hyperfine splitting: 10-20MeV
  - $\chi_b(3P) \rightarrow \Upsilon(1S,2S)\gamma$
- Search though $\chi_b(nP) \rightarrow \Upsilon(1S,2S)\gamma$.

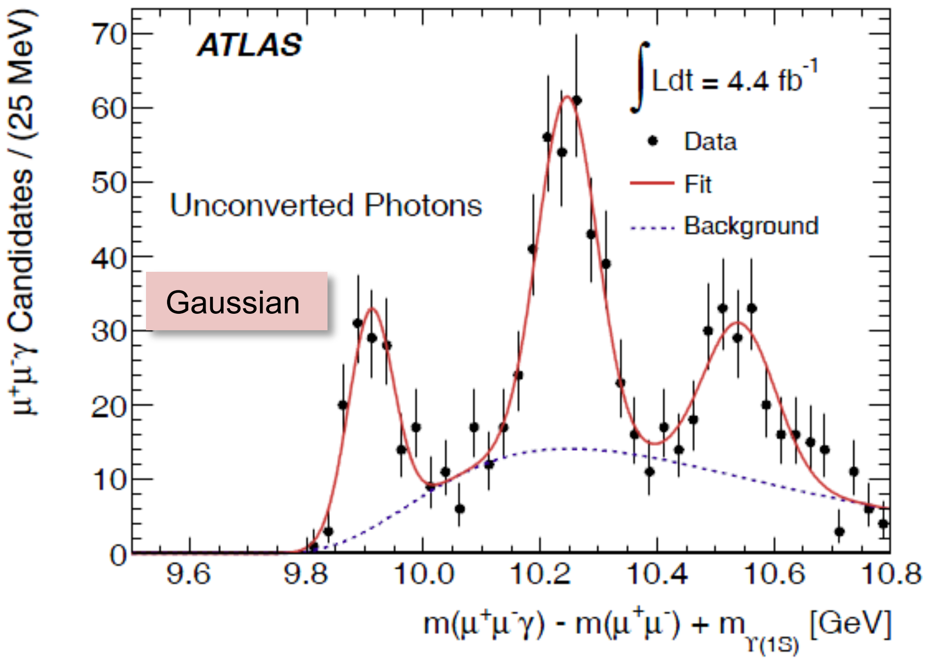


Observation of a New χ_b State

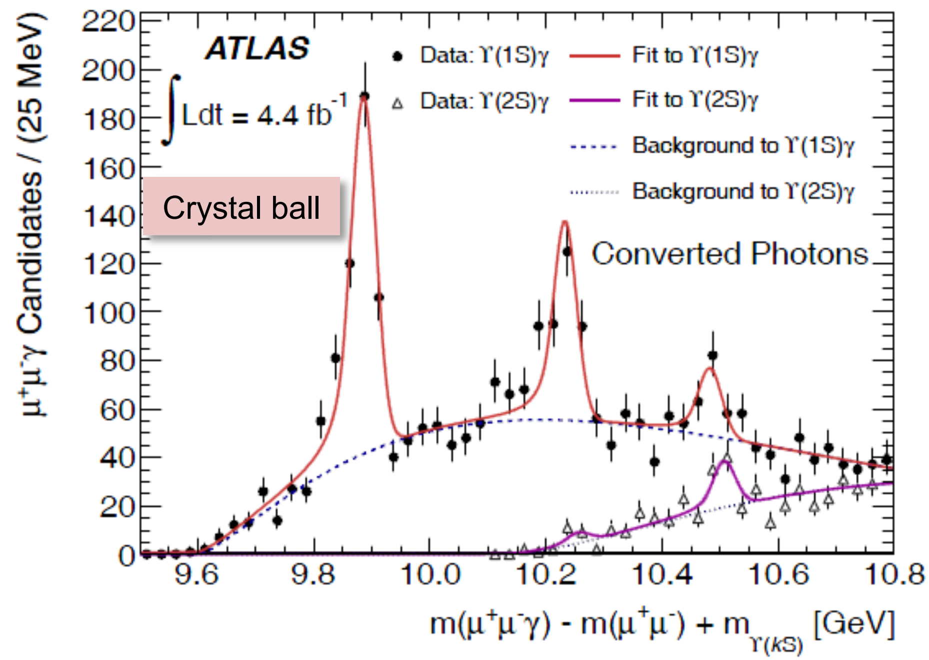
Phys. Rev. Lett. 108 (2012) 152001

Unbinned maximum likelihood fit

Calo. based photon



Tracker based photon



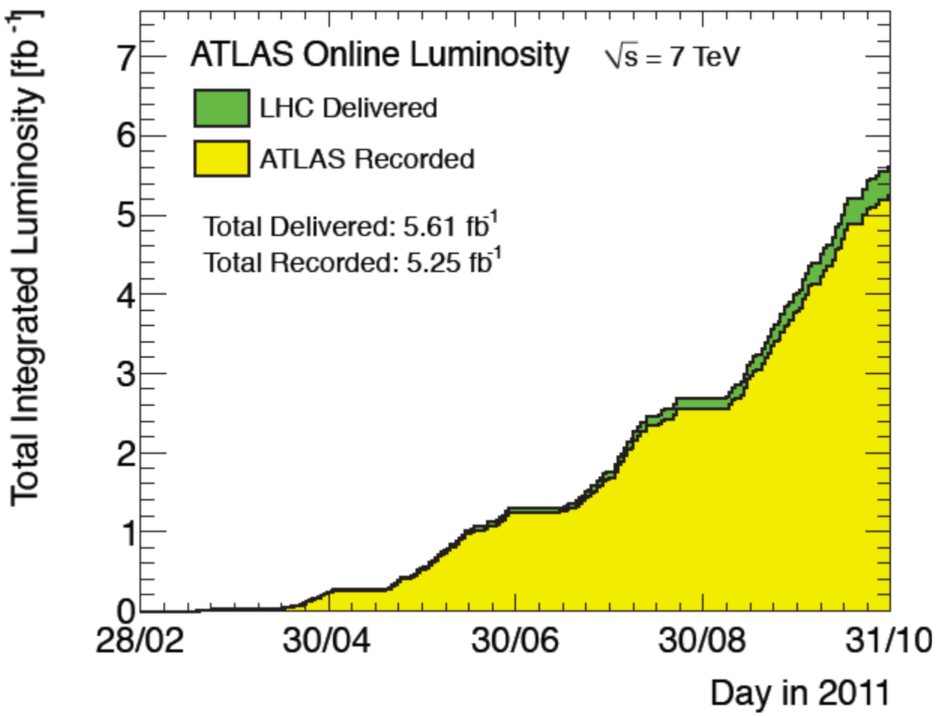
- Search in mass difference $m(\mu^+\mu^-\gamma)-m(\mu^+\mu^-)+m(\Upsilon_{PDG})$ to minimize the muon resolution effects.
- 2011 7TeV data, 4.4 fb^{-1}
- New structure observed at $m = 10.530 \pm 0.005_{(stat.)} \pm 0.009_{(syst.)}$ GeV
- Significance $\sqrt{-2\log(L/L^0)} > 6\sigma$ in two statistically independent samples.

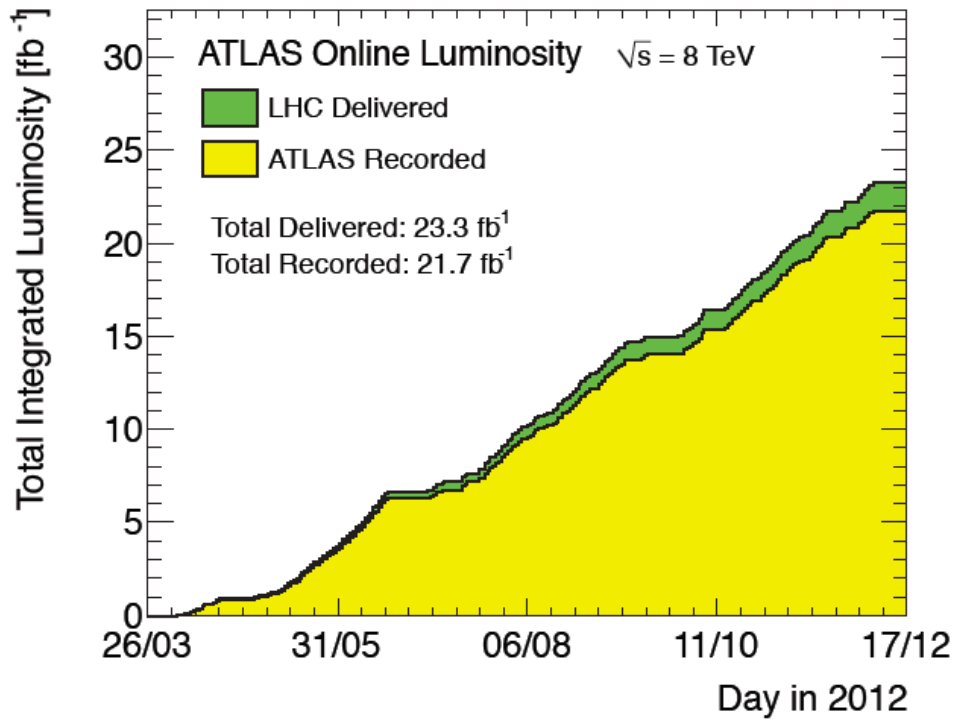
Summary

- B^+ production cross-section has been measured
  - $B^+ \to J/\psi(\mu^+\mu^-)K^+$
  - $9GeV < p_T < 120GeV$ and $|y|<2.25$
  - Powheg+Pythia gives a good description while MC@NLO+Herwig is lower and softer in low y and harder in high y compare to the data .
  - FONLL agree with data especially with $p_T<30GeV$.
- B_c has been observed using full 2011 and 2012 data
  - $B_c \to J/\psi(\mu^+\mu^-)\pi^+$
- Λ_b^0 mass and lifetime have been measured
  - $\Lambda_b^0 \to J/\psi(\mu^+\mu^-)\Lambda^0$, $\Lambda^0 \to p^+\pi^-$
  - m = 5619.7 ± 0.7 (stat) ± 1.1 (syst) MeV
  - τ = 1.449 ± 0.036(stat) ± 0.017(syst) ps
  - Agree with LHCb and PDG, best uncertainty.
- New particle $\chi_b(3P)$ has been first observed at ATLAS
  - $\chi_b(3P) \to \Upsilon(1S,2S)\gamma$
  - $m = 10.530 \pm 0.005_{(stat.)} \pm 0.009_{(syst.)}$ GeV
  - Significance > 6 σ

Backup

Integrated luminosity





https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults

- Record luminosity in 2011: 5.25fb^{-1}, uncertainty 1.8%
- Record luminosity in 2012: 21.7fb^{-1}, preliminary uncertainty 2.8%
- Detector efficiency ≥ 95%

Observation of a New χ_b State

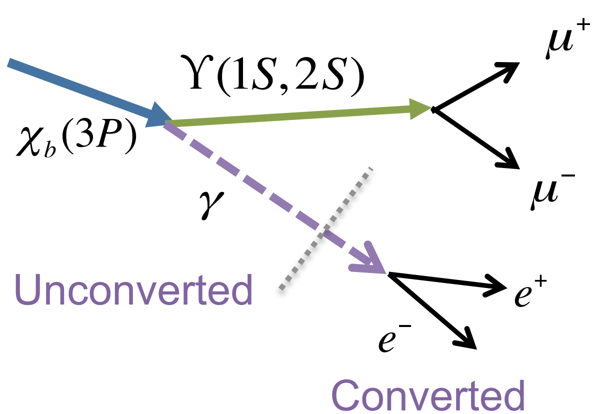
Phys. Rev. Lett. 108 (2012) 152001

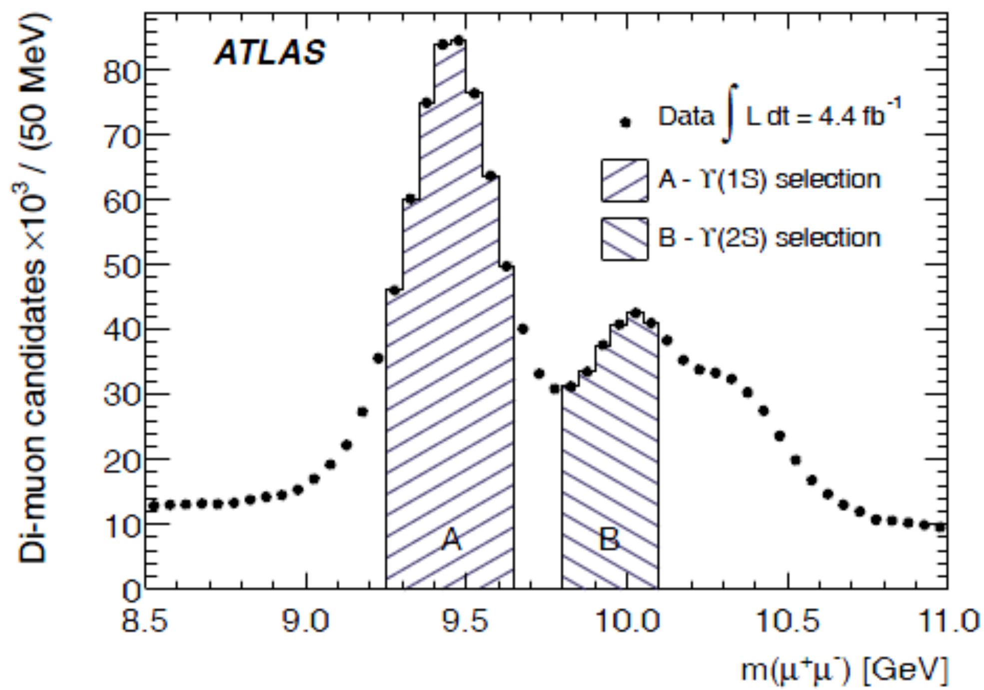
Y(1S,2S) → $\mu^+\mu^-$

- Di-muon tigger with p_T > 4GeV, |η| < 2.3

Photon

- Unconverted photons:
  - EM calorimeter energy deposit
- Converted photons
  - Reconstructed using e tracks.





The asymmetric mass window for Y(2S) is chosen to reduce contamination from the Y(3S) peak and continuum background contributions.