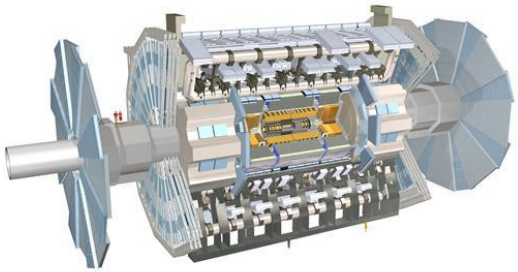


ATLAS Heavy Flavor production and decay properties

Lidia Smirnova
on behalf of the ATLAS Collaboration
(Lomonosov Moscow State University, Moscow, Russia)

St. Petersburg, 31 August 2015

Outline

- ATLAS detector in Run2
- First Run2 HF results:
  - J/ψ non-prompt production fraction in pp collisions at 13 TeV

    atlas-conf-2015-030
- New Run1 HF results:
  - Prompt and non-prompt J/ψ mesons and Z boson associated production at $\sqrt{s}$ = 8TeV

    Eur.Phys.J.C (2015) 75:229
  - Measurement of *b*-quark fragmentation fractions f_s/f_d

    arXiv:1507.08925, subm. to PRL
  - Observation and branching fraction of $\Lambda^0_b \rightarrow \psi(2S)\Lambda^0$ decay

    arXiv:1507.08202, subm.to PLB

More ATLAS HF results in presentations:

- *CP violation and rare B decays*

  V.Nikolaenko talk

- *ATLAS HF spectroscopy and exotic states*

  S.Turchikhin talk

- *Study of the $B_c^+ \rightarrow J/\psi D_s^+$ and $B_c^+ \rightarrow J/\psi D_s^{*+}$ with the ATLAS detector*

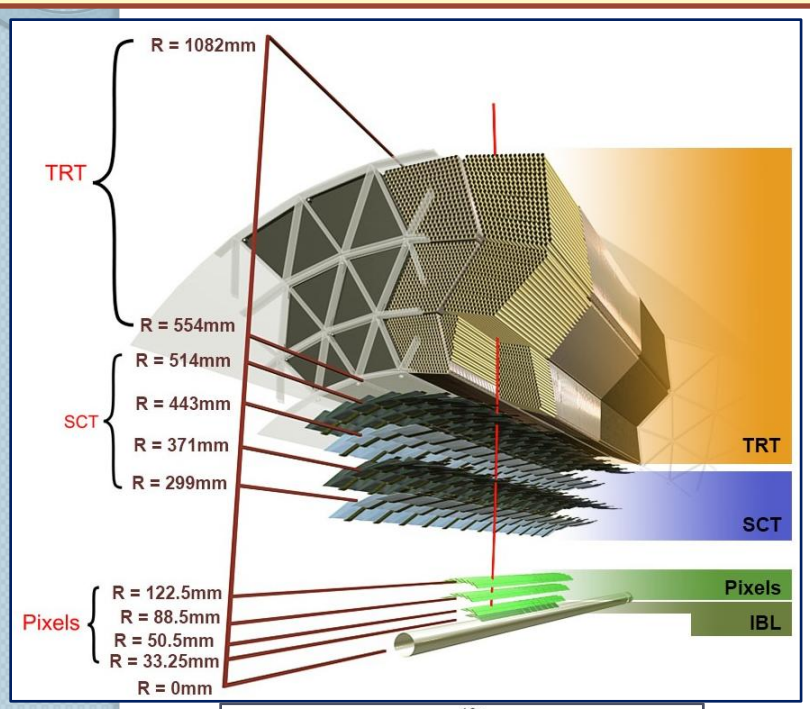
  S.Turchikhin poster

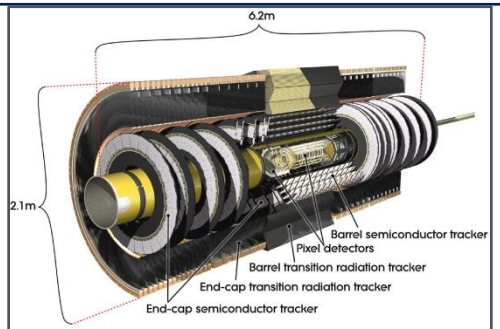
- *Flavour tagged time dependent angular analysis of the Bs->J/psi phi decay on Run 1 data in ATLAS*

  A.Maevskiy poster

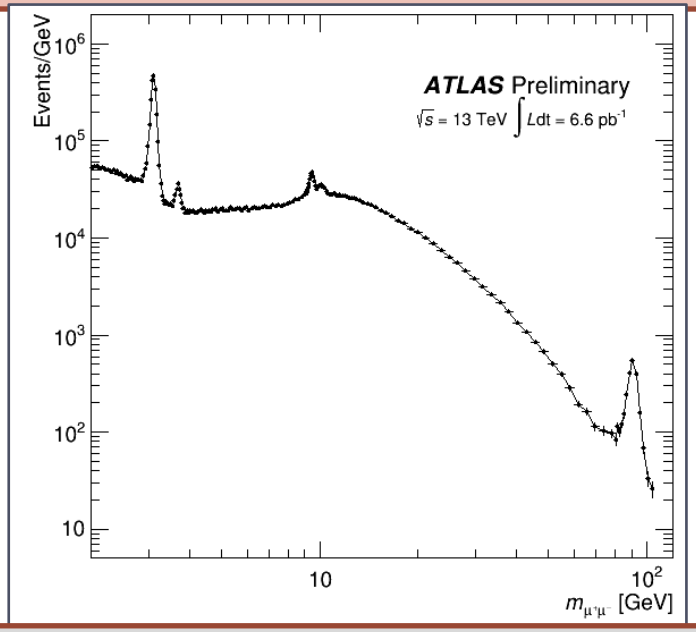
ATLAS detector in Run2

New pixel IBL with R = 33.25 mm in the Inner Detector improves vertex reconstruction resolution





Invariant mass of two oppositely charged muons with $p_T > 4$ GeV/c

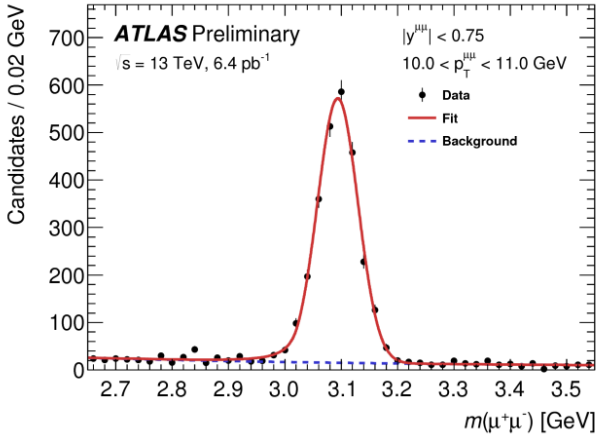


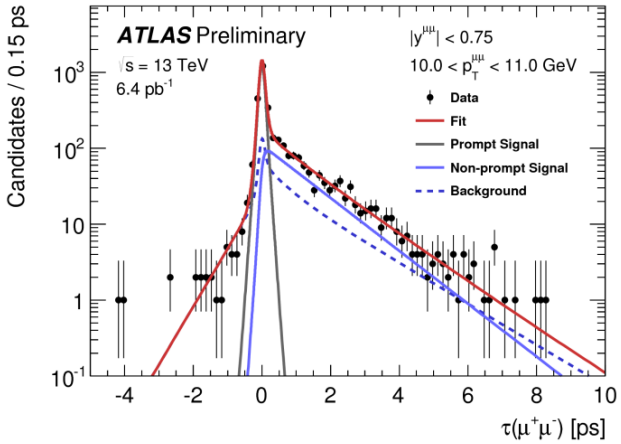
J/Ψ, Ψ′, Υ resonances and Z are clearly visible in two muons invariant mass $m_{\mu\mu}$ spectrum at $|\eta| < 2.5$ in pp collisions at $\sqrt{s} = 13$ TeV with integrated luminosity 6.6 pb^{-1}

J/ψ non-prompt production fraction in pp collisions at 13 TeV

atlas-conf-2015-030

- Integrated luminosity 6.4 pb^{-1};
- Two triggers: two oppositely charged muons, each with $p_T^{\mu} > 4$ GeV, and a single muon with $p_T^{\mu} > 14$ GeV;
- J/ψ candidates: each muon has $p_T^{\mu} > 4$ GeV and $|\eta^{\mu}| < 2.3$; dimuon pair has $p_T > 8$ GeV and $|\eta| < 2$;
- Pseudo-proper decay time calculated $\tau = L_{xy} m_{J/\psi}^{PDG} / p_T$;
- No geometric acceptance corrections
- About 70,000 di-muon candidates with $2.5 < m(\mu^+\mu^-) < 4.2$ GeV





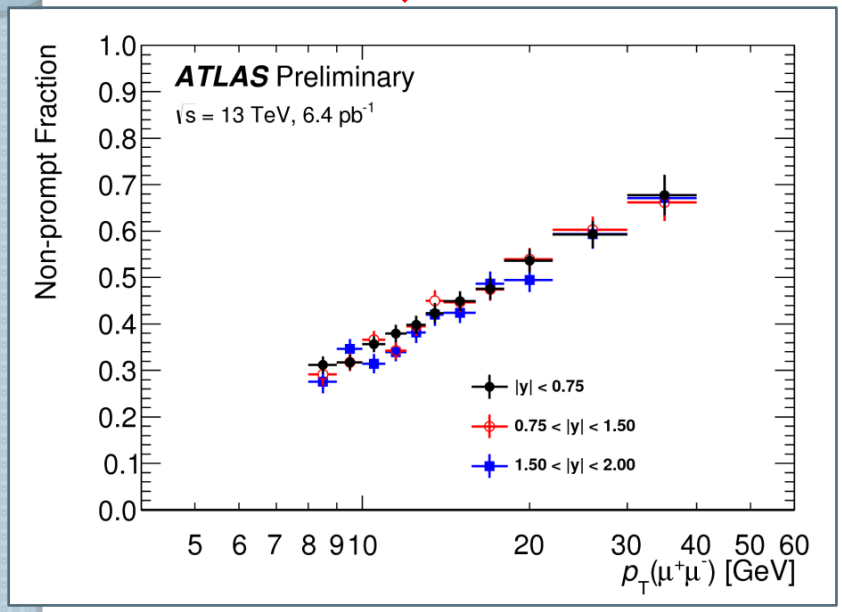
Fit results for dimuon mass $m(\mu^+\mu^-)$ distribution (left) and $\tau(\mu^+\mu^-)$ (right) for $10 < p_T < 11$ GeV and $|y| < 0.75$ intervals

An unweighted two-dimensional maximum likelihood fit for muon pairs with $2.65 < m(\mu^+\mu^-) < 3.55$ GeV and $-5.0 < \tau(\mu^+\mu^-) < 15.0$ ps used to distinguish prompt and non-prompt J/ψ production and eliminate background in 11 intervals of p_T in range 8 - 40 GeV and three intervals in rapidity: $|y|<0.75$; $0.75<|y|<1.5$; $1.5<|y|<2.0$

J/ψ non-prompt production fraction in pp collisions at 13 TeV

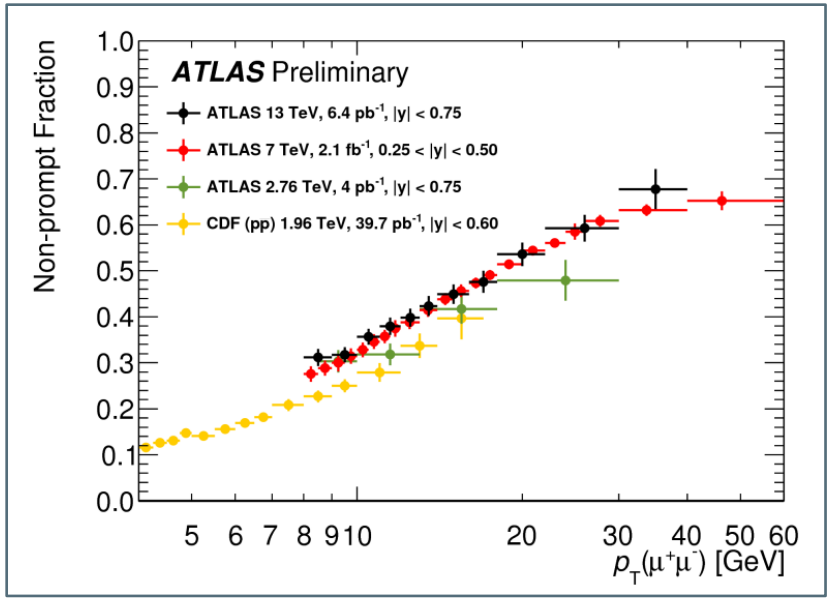
$$f_b^{J/\psi} \equiv \frac{pp \to b + X \to J/\psi + X'}{pp \xrightarrow{\text{Inclusive}} J/\psi + X'} = \frac{N_{J/\psi}^{\text{NP}}}{N_{J/\psi}^{\text{NP}} + N_{J/\psi}^{\text{P}}}$$

$f_b^{J/\psi}$ in different rapidity intervals



Non-prompt J/ψ production fraction increases from 0.25 at p_T 8 GeV to 0.65 at 40 GeV with no observed variation in rapidity

and compared with other measurements at |y|< 0.75



No significant change in non-prompt fraction from 7 to 13 TeV, contrary to the significant difference between 7 TeV and lower energies

Prompt and non-prompt J/ψ mesons and Z boson associated production in pp collisions at 8 TeV

First observation

Eur. Phys. J.C (2015) 75:229

Measurements are important for many processes:

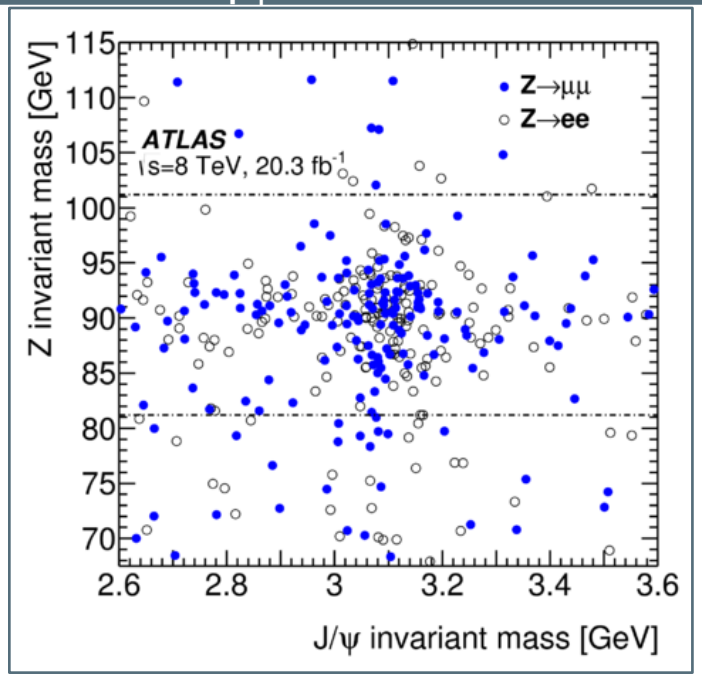
a) $ZZ^* \rightarrow Z(Z^* \rightarrow c\bar{c})$;

b) Bkg to $Z \rightarrow l^+l^- J/\psi$; $H \rightarrow ZZ^*$

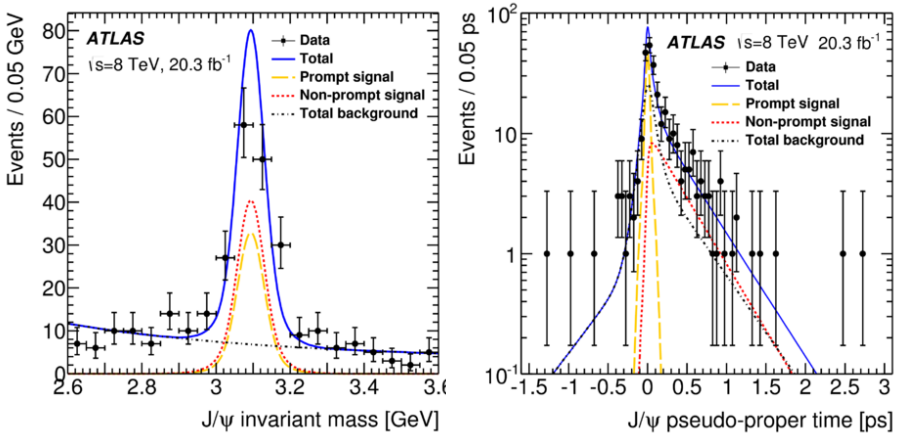
c) Higgs boson charm coupling and CP properties;

and are sensitive to DPS

Total integrated luminosity 20.3 fb^{-1}
Trigger: at least one lepton with $p_T > 24$ GeV



Prompt and non-prompt J/ψ contributions



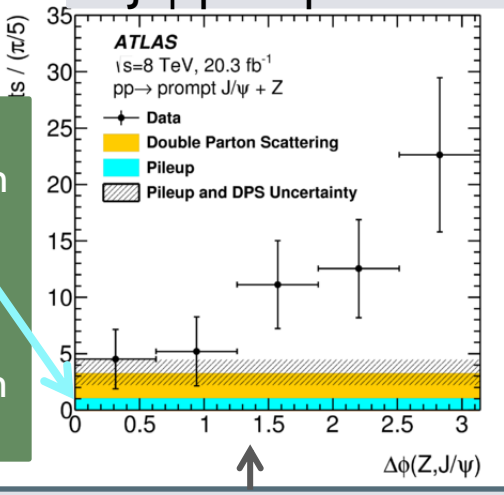
$J/\psi(\mu^+\mu^-)$ candidates: 8.5< pT < 100 GeV, |y| < 2.1

Selected 290 Z and J/ψ events with 139 Z→μμ and 151 Z→ ee.
Bkg. only hypothesis excluded at 5σ

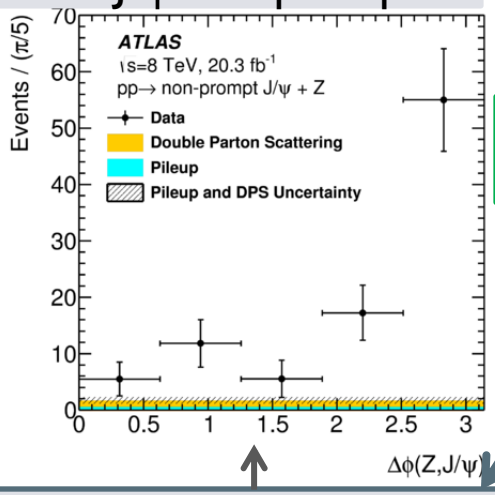
DPS in Z + J/ψ (is counted as part of the signal)

Δϕ between Z and J/ψ :

J/ψ prompt



J/ψ non-prompt



$$P^{ij}_{J/\psi|Z} = \sigma^{ij}_{J/\psi}/\sigma_{\rm eff}$$

$$\sigma_{\rm eff} = 15 \pm 3\,({\rm stat.})^{+5}_{-3}\,({\rm sys.})\,{\rm mb}$$

ATLAS Collab., New J. Phys. 15, 033038 (2013), (DPS xsec. from W+2jets)

SPS at Δϕ ≈ π

Pile-up contribution estimated and subtracted bin-by-bin in final xsec

Both SPS and DPS contribute to Z+J/ψ

$R_{Z+J/\Psi}$ = $Br(J/\Psi \to \mu\mu) \cdot (\sigma(pp \to Z+J/\Psi)/\sigma(pp \to Z))$

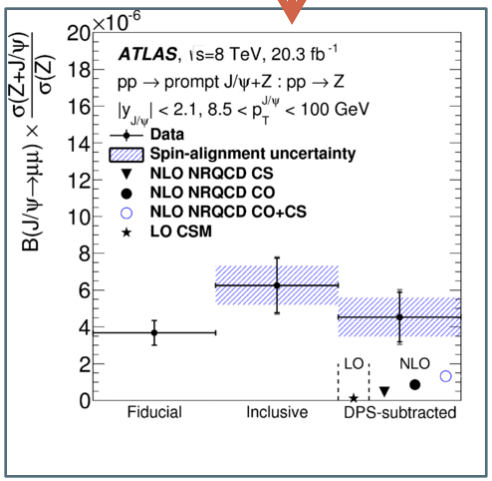
DPS estimation $11.1^{+5.7}_{-5.0}$ and $5.8^{+2.8}_{-2.6}$ ev. flat

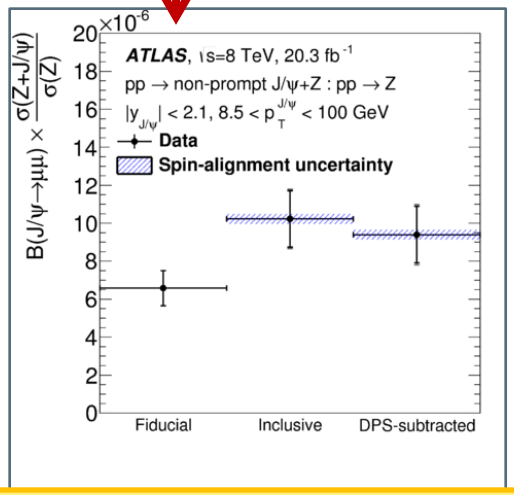
$R^{\rm fid}_{Z+J/\psi}$ $R^{\rm incl}_{Z+J/\psi}$ DPS-subtracted

$y_{J/\psi}$	Fiducial [$\times 10^{-7}$] value ± (stat) ± (syst)	Inclusive [$\times 10^{-7}$] value ± (stat) ± (syst) ± (spin)	DPS-subtracted [$\times 10^{-7}$] value ± (stat) ± (syst) ± (spin)
Prompt cross-section ratio			
$\lvert y_{J/\psi}\rvert < 1.0$	7.6 ± 2.1 ± 0.5	13.9 ± 4.6 ± 0.8 ± 3.4	9.4 ± 4.6 ± 1.1 ± 3.4
$1.0 < \lvert y_{J/\psi}\rvert < 2.1$	9.8 ± 2.2 ± 1.3	15.8 ± 4.5 ± 2.1 ± 3.5	12.0 ± 4.5 ± 2.7 ± 3.5
Non-prompt cross-section ratio			
$\lvert y_{J/\psi}\rvert < 1.0$	18.0 ± 3.3 ± 0.6	29.9 ± 5.0 ± 0.9 ± 1.1	27.8 ± 5.0 ± 1.0 ± 1.1
$1.0 < \lvert y_{J/\psi}\rvert < 2.1$	13.5 ± 2.9 ± 1.9	19.3 ± 5.0 ± 2.1 ± 0.8	17.5 ± 5.0 ± 2.1 ± 0.8

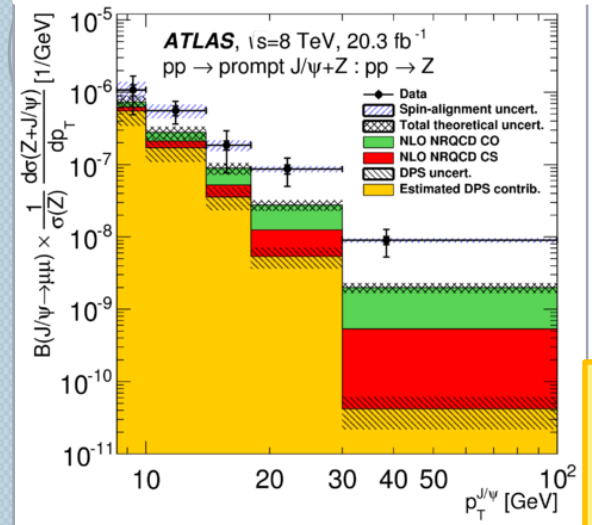
Z+J/Ψ ratios *R*

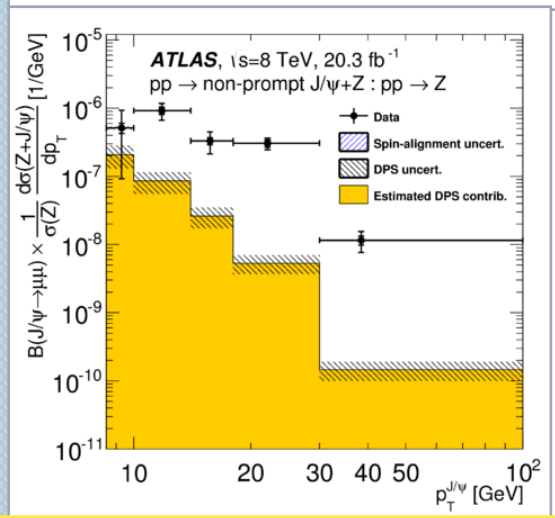
Fid., incl. and DPS subst. Ratios for prompt and non-prompt J/Ψ +Z





Differential Ratios





DPS contribution is softer than data

- Z+ prompt J/ψ is compared to LO color singlet (CS) mechanism (B.Gong et al., JHEP 1303, 115 (2013)) and NLO NRQCD for CS + color-octet (CO) contributions (S.Mao et al., JHEP 1102, 071 (2011)) : expected CS+CO xsection is lower than the data by a factor from 2 to 5 at $8<p_T^{J/\psi}<100$ GeV

$$R^{incl} = (63 \pm 13_{stat} \pm 5_{syst} \pm 10_{spin}) \cdot 10^{-7}$$

DPS contribution is (29±9)%;

- Z+ non-prompt J/ψ

$$R^{incl} = (102 \pm 15 \pm 5 \pm 3) \cdot 10^{-7},$$

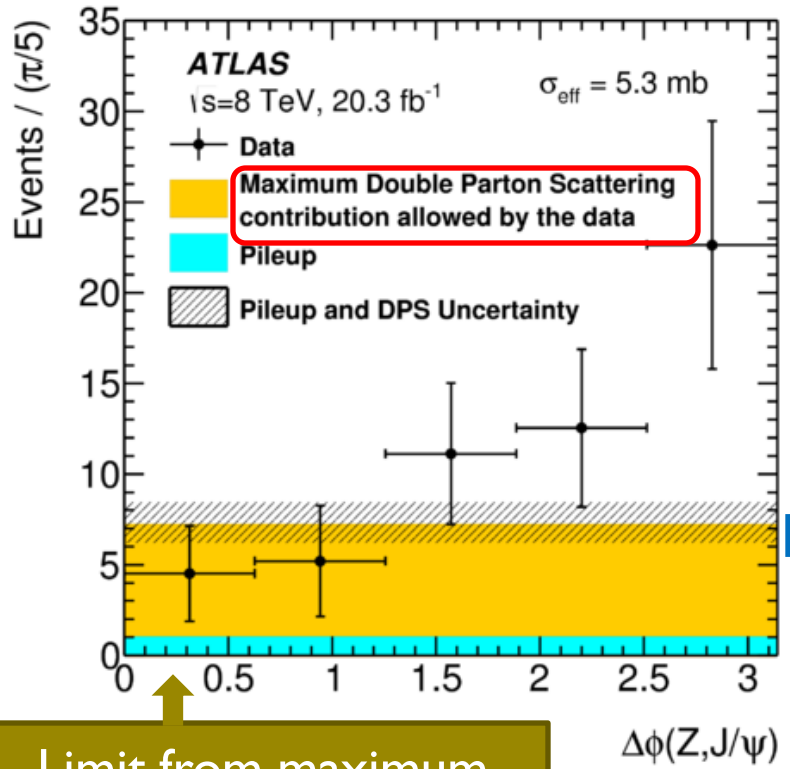
(spin-alignment uncertainty is shown in Figs)

DPS contribution is (8±2)%

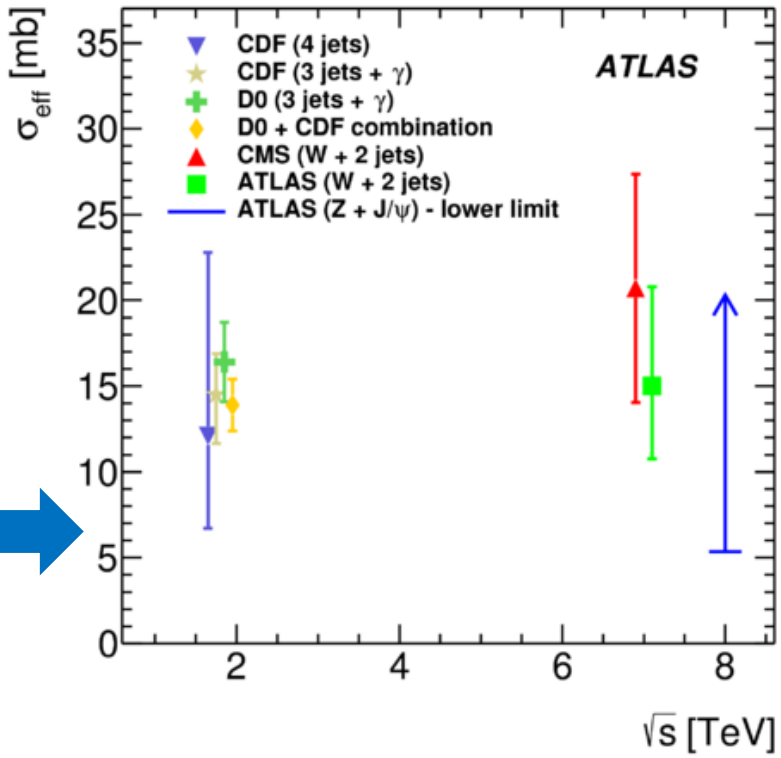
DPS σ_{eff} estimation from Z + prompt J/Ψ

σ_{eff} lower limit from maximal DPS contribution in Z+prompt J/Ψ found to be 5.3mb (3.7) at 68% (95% CL

$(N_{DPS} \uparrow, \sigma_{eff} \downarrow)$



Limit from maximum event number in 1st bin



Measurement of *b*-quark fragmentation fractions f_s/f_d

arXiv:1507.08925

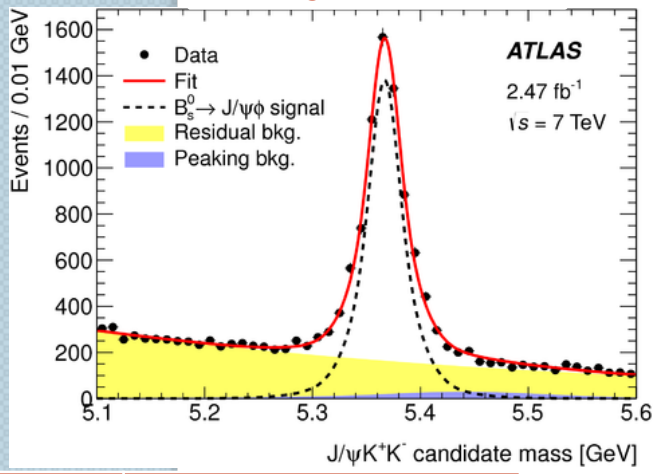
Precise knowledge of f_s/f_d is essential for measurement of $Br(B^0_s \to \mu\mu)$ and sensitivity of searches for New Physics BSM

pp 7 TeV

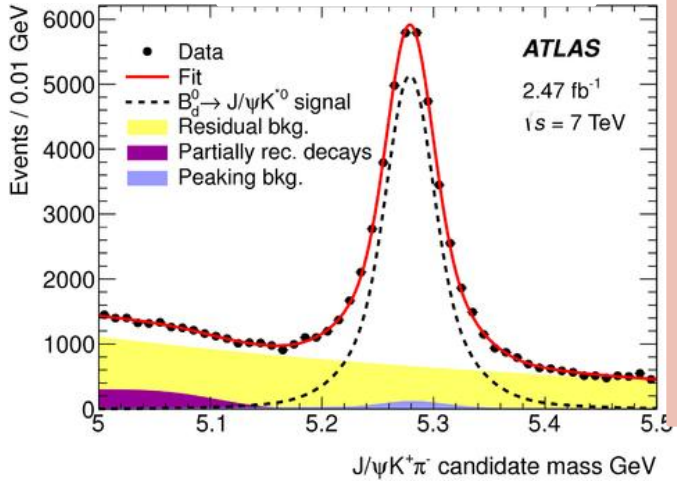
$L = 2.47\ fb^{-1}$

$f_s/f_d \cdot (Br(B^0_s \to J/\Psi\phi)/ Br(B^0_d \to J/\Psi K^{*0})) = 0.199 \pm 0.004_{Stat.} \pm 0.010_{Sys.}$

$B^0_s \to J/\Psi\phi$



$B^0_d \to J/\Psi K^{*0}$



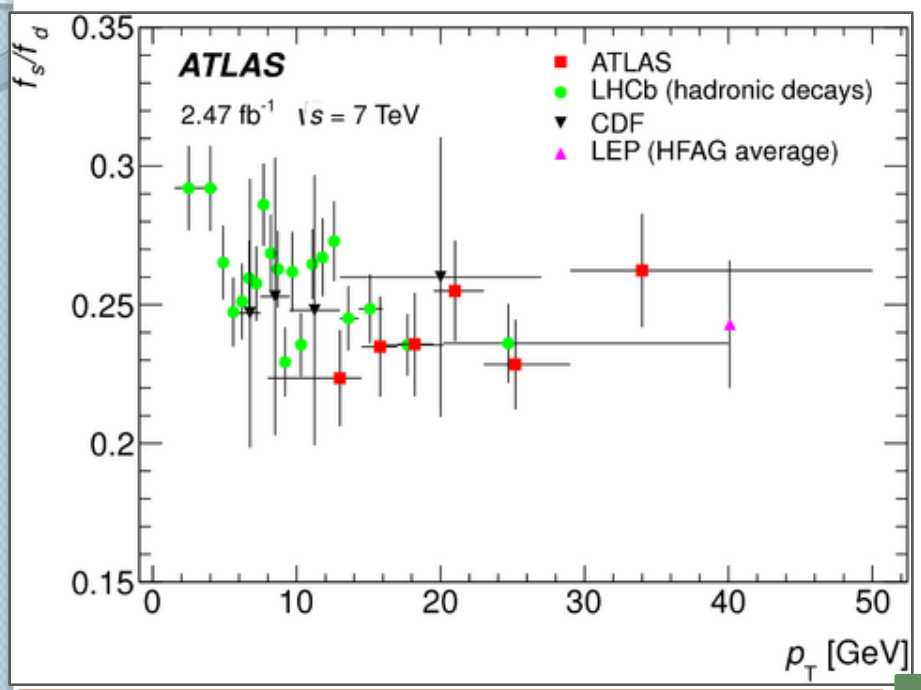
N B^0_s	6640 ± 100 ± 220
N B^0_d	36290 ± 320 ± 650

With Br ratio from X. Liu et al., PRD 89 (2014) 052007

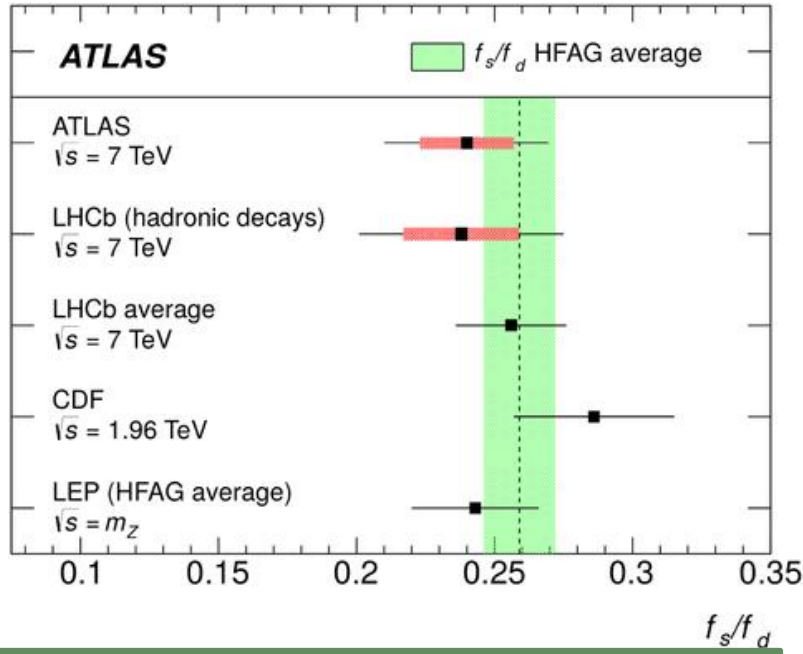
$f_s/f_d = 0.240 \pm 0.004_{st} \pm 0.013_{sys} \pm 0.017_{th}$

b-quark fragmentation fractions f_s/f_d

f_s/f_d in dependence on B p_T



f_s/f_d in comparison with LEP data at $\sqrt{s} \approx m_Z$



The ATLAS data show no f_s/f_d dependence on p_T nor on |y| within $8 < p_T < 50$ GeV and $|y| < 2.5$

ATLAS result agrees with the LEP average (arXiv:1412.7515), LHCb (JHEP04(2013)001) and CDF (pub. note 10795, 2012)

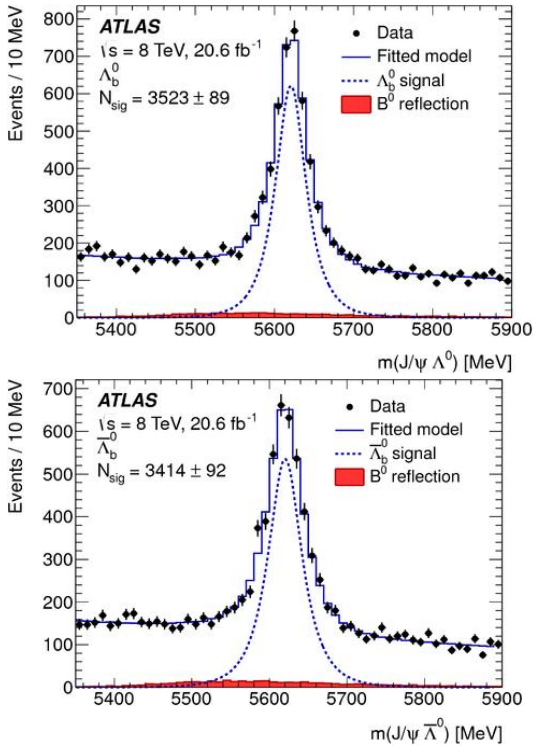
Observation and branching fraction of $\Lambda^0_b \to \psi(2S)\Lambda^0$ decay

pp 8 TeV with 20. 6fb^{-1}

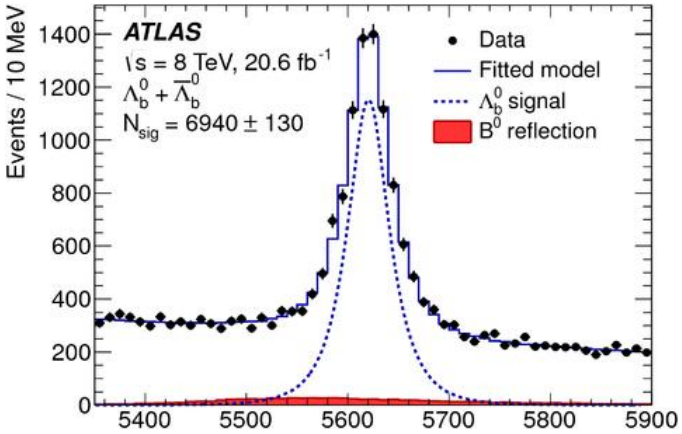
Event selection:

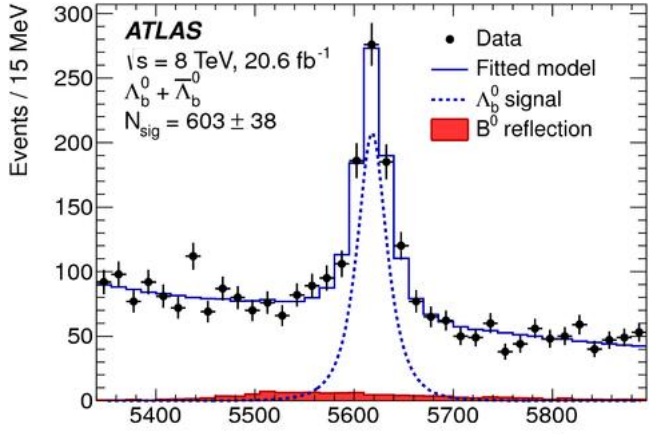
- 3 dimuon triggers: both $p_T > 4$ GeV; muon $p_T > 4$ and $p_T > 6$ Gev; both $p_T > 6$ GeV and $2.5 < m(\mu\mu) < 4.3$GeV
- Two muons with inv. mass within 200 MeV of the J/Ψ or Ψ mass, two additional tracks form Λ candidate with high-p_T track assigned proton hypothesis;
- To control B^0 reflection, dimuon mass refitted with dihadrons as $K^0_s(\pi^+\pi^-)$;
- To suppress comb. and B^0 bkgs additional requirements used.

m(J/ΨΛ) (top) and m(J/Ψ$\bar{\Lambda}$) distributions in selected events with B reflections: N(Λ) ≈ N($\bar{\Lambda}$)



Ratio $\Gamma(\Lambda^0_b \to \psi(2S)\Lambda^0) / \Gamma(\Lambda^0_b \to J/\Psi\Lambda^0)$





Signals extraction:

m(J/ΨΛ/Λ̄), MeV

m(Ψ(2S)Λ/Λ̄), MeV

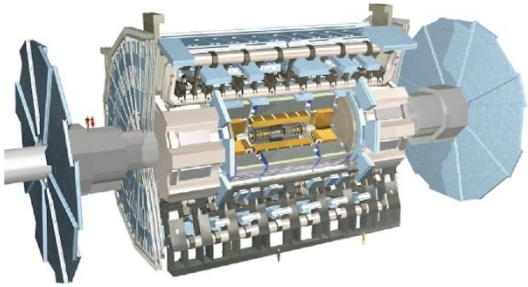
	$\Lambda_b^0 \to J/\psi\Lambda^0$	$B^0 \to J/\psi K_S^0$	$\Lambda_b^0 \to \psi(2S)\Lambda^0$	$B^0 \to \psi(2S)K_S^0$
$N_{\rm sig}$	6940 ± 130	854 ± 84	603 ± 38	124 ± 28
$m_{\rm sig}$ [MeV]	5620.4 ± 0.4	5274.7 ± 2.3	5618.2 ± 1.2	5272.4 ± 4.9
$\sigma_{\rm sig}$ [MeV]	19.7 ± 0.5	19.2 ± 2.2	14.3 ± 1.1	16.7 ± 4.1

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

Ratio is lower than theoretical prediction 0.8 ± 0.1 from covariant quark model

(T. Gutsche et al., Phys. Rev. D 88 (2013) 114018)

Conclusions

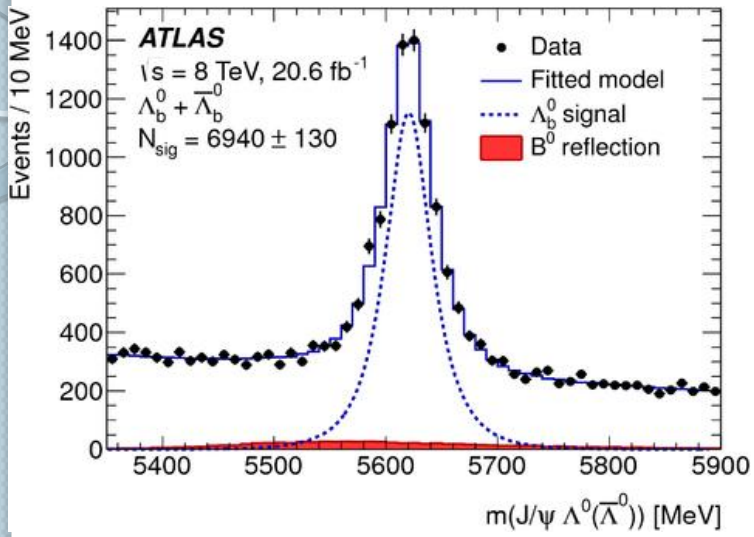


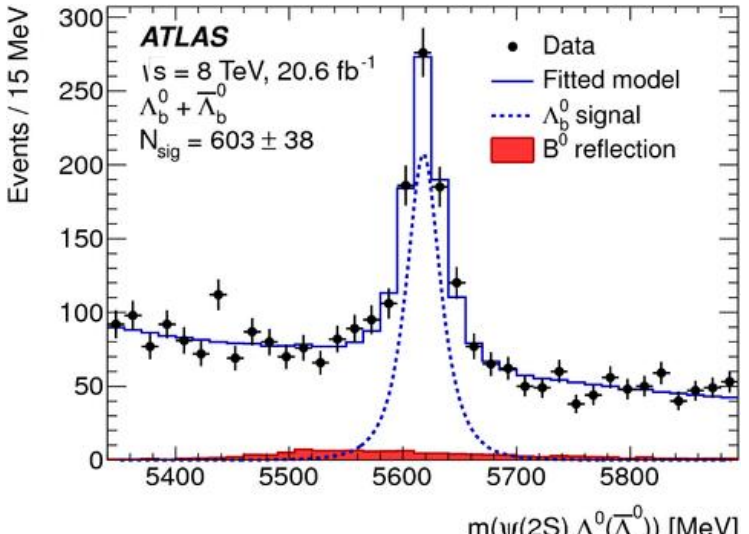
- The ATLAS detector starts operation in Run2 at $\sqrt{s}$ =13 TeV successfully
- First Run2 HF measurements are presented
- New results for HF production and decay properties with Run1 data are shown
- They continue list of results for B, Bs, Bc and Λb hadrons in wide p_T regions from the ATLAS detector presented in

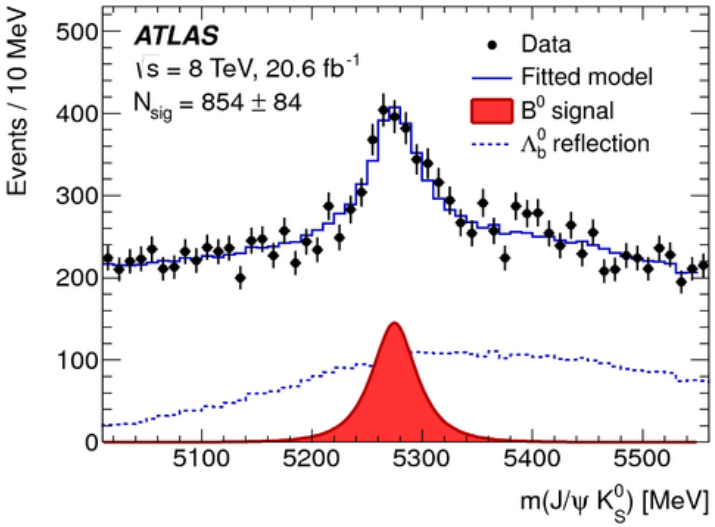
  https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysPublicResults
- New results will follow

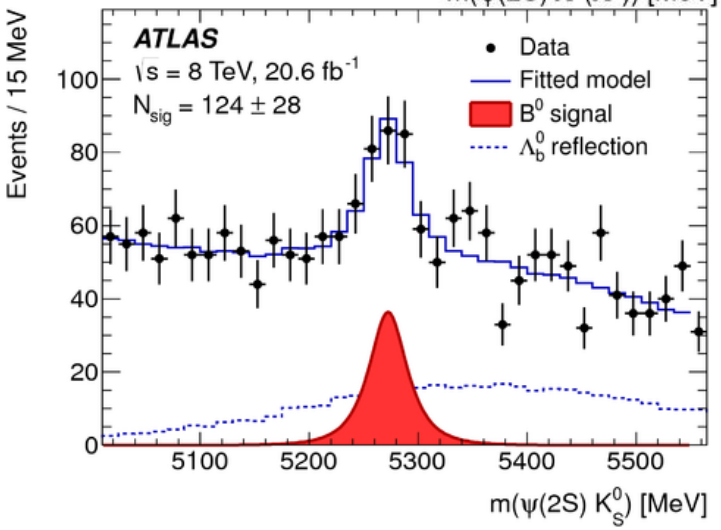
Back-up slides

$\Lambda^0_b \to J/\Psi \Lambda^0$ and $\Lambda^0_b \to \psi(2S)\Lambda^0$ decays









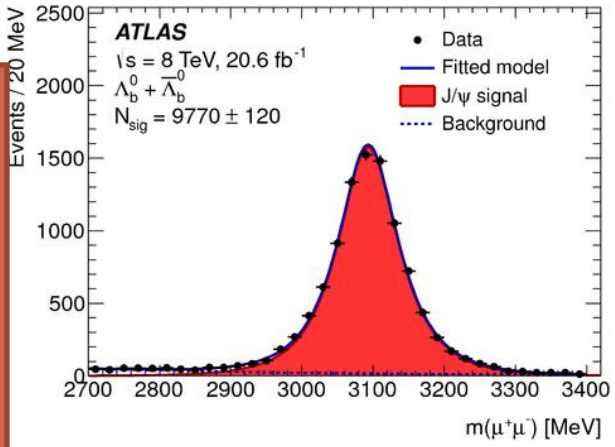
B meson signals (bottom)used for reflection estimations in Λ_b decays (top)

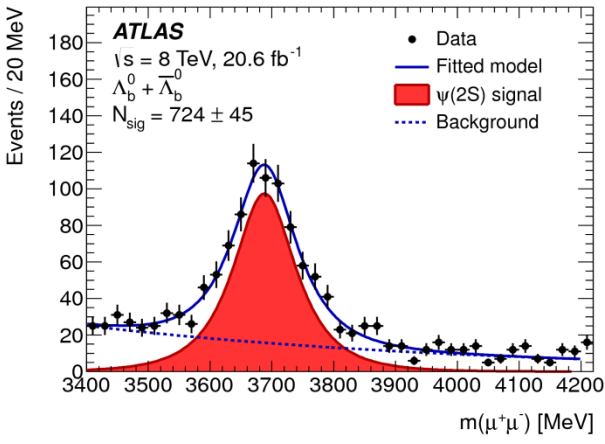
$\Lambda^0_b \to J/\Psi \Lambda^0$ and $\Lambda^0_b \to \psi(2S)\Lambda^0$ decays

Additional bkg and B suppression requirements:

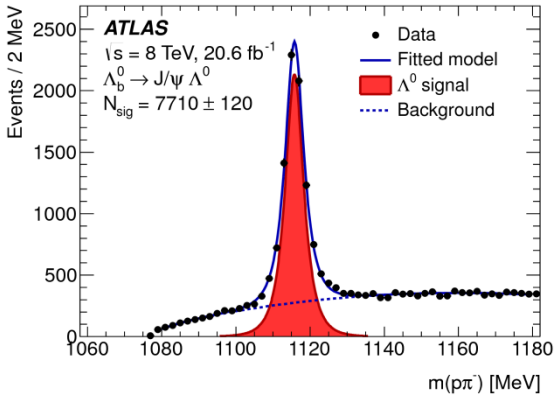
1) $\chi^2(\Lambda_b)/N_{dof} < 3$, $N_{dof} = 6$;
2) $L_{xy}(\Lambda)$. 10 mm;
3) $p_T(\Lambda) > 2.5$ GeV;
4) $p_T(\pi^-) > 0.45$ GeV;
5) $\tau(\Lambda_b) > 0.35$ ps
6) Prob(Λ_b) > Prob(B)

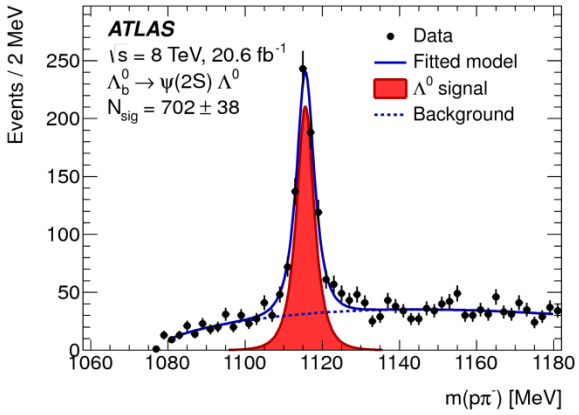
J/Ψ and Ψ(2S) signals in selected Λ_b decays





$\Lambda(p\pi^-)$ signals in selected Λ_b decays





Summary from presented results

- J/Ψ non-prompt production fraction in pp collisions at 13 Tev is presented; no change from 7 to 13 TeV in contrary to change from the lower energies to 7 TeV is observed;
- First observation for associated J/Ψ and Z production in pp collisions at 8 TeV, some tension with theory expectations;
- Results for fs/fd agree with LEP and other experiments and show no dependence on B p_T and rapidity;
- Ratio $\Gamma(\Lambda^0_b \to \psi(2S)\Lambda^0) / \Gamma(\Lambda^0_b \to J/\Psi\Lambda^0) < 0.8$ $(\pm 0.1)_{th}$ is measured.