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ATLAS recent results on production, spectroscopy and exotica in Quarkonia and Heavy Flavour

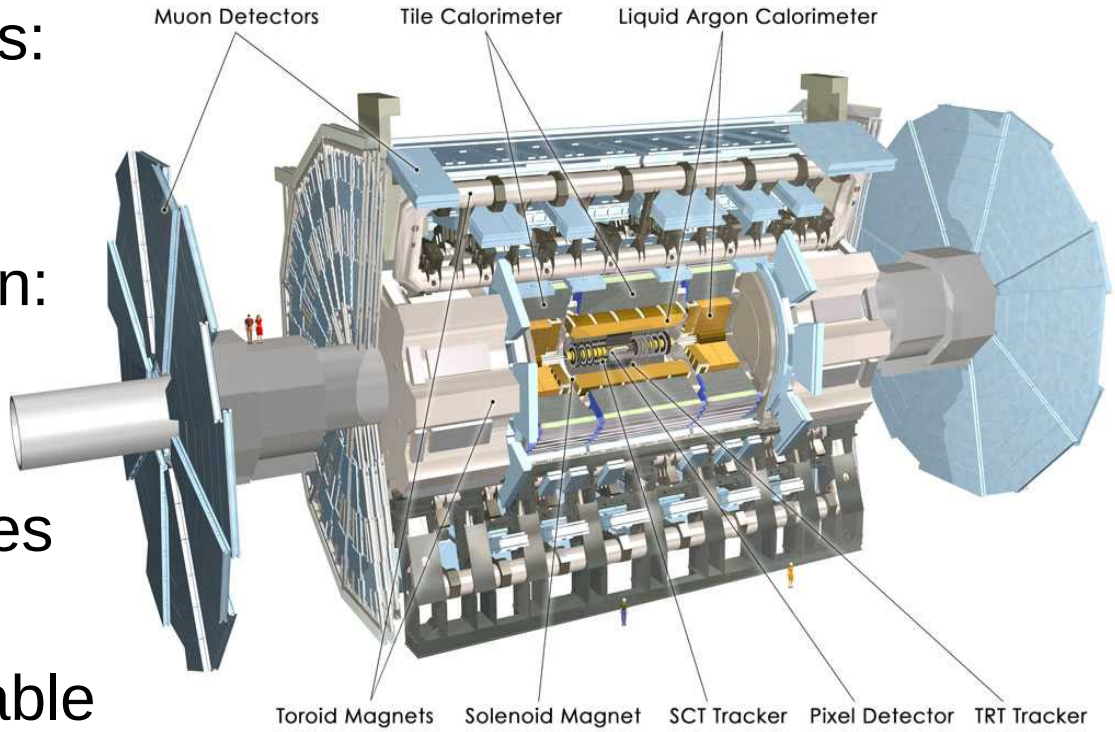
Talk at QCD@Work 2018 – International workshop on QCD Theory and Experiment, Matera, Italy, 25-28 June

Outline

- Search for Tetraquarks in B^0_s π final states
- Study of b-pair production with J/ψ +μ
- X(3872) production
- Quarkonia production in pp and pA at 5 TeV
- B → K* μμ

ATLAS B-Physics Programme

- Precision measurements: rare decays b-hadron decay properties, CPV
- Heavy flavour production: b-hadrons, (associated) quarkonia production
- Spectroscopy: new states and decay modes
- Mostly fully reconstructable exclusive decays with typically two muons in final state → Trigger effectively on low-pt objects



Inner tracker

$$\frac{\sigma(p_T)}{p_T} \approx 0.05\%\ p_T \oplus 1\%$$

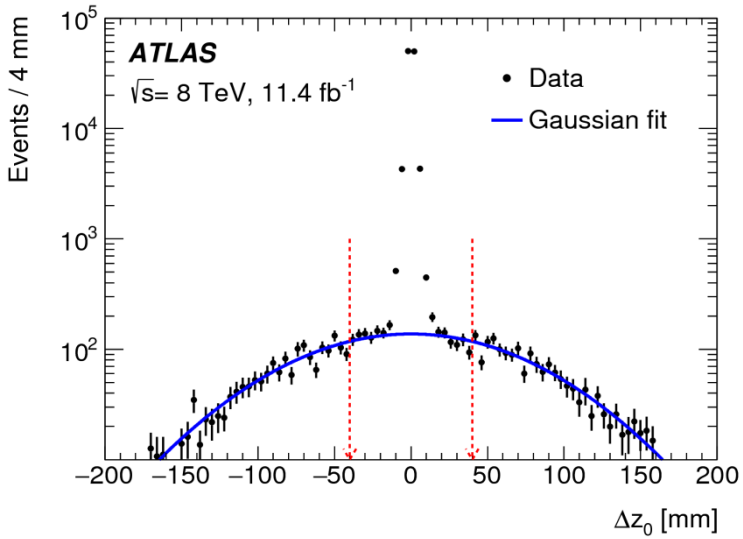
Muon spectrometer

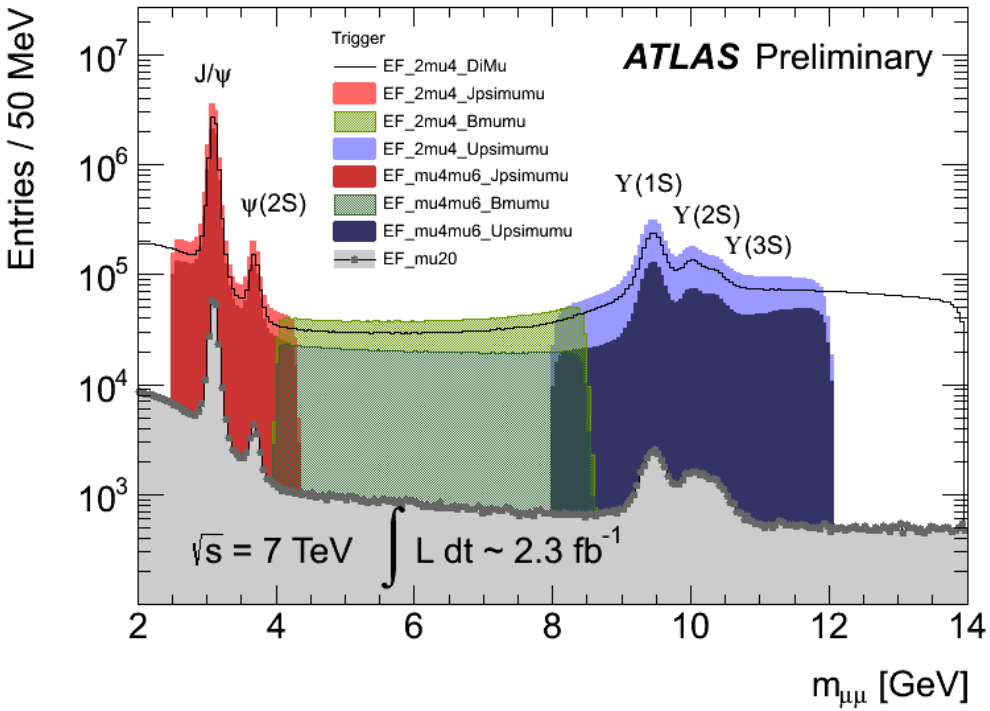
$$\frac{\sigma(p_T)}{p_T} \approx 2\% \quad \text{@50 GeV :}$$

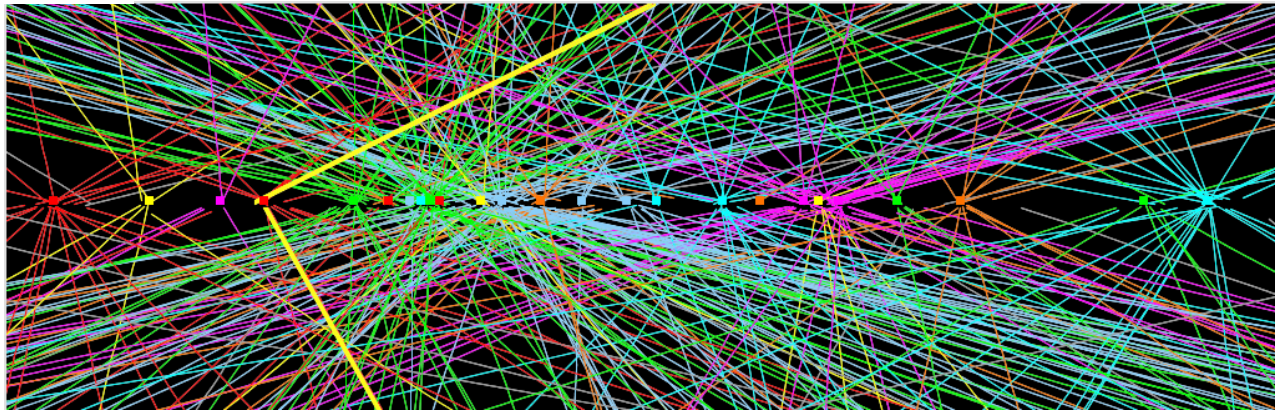
$$\frac{\sigma(p_T)}{p_T} \approx 10\% \quad \text{@ 1 TeV}$$

Datasets + Basic Signals

- 7 TeV: 5 fb^{-1}, 5-15 evts. pile-up
- 8 TeV: 20 fb^{-1},10-35 pile-up







μμ-pair event (Z0) with
25 reconstructed vertices

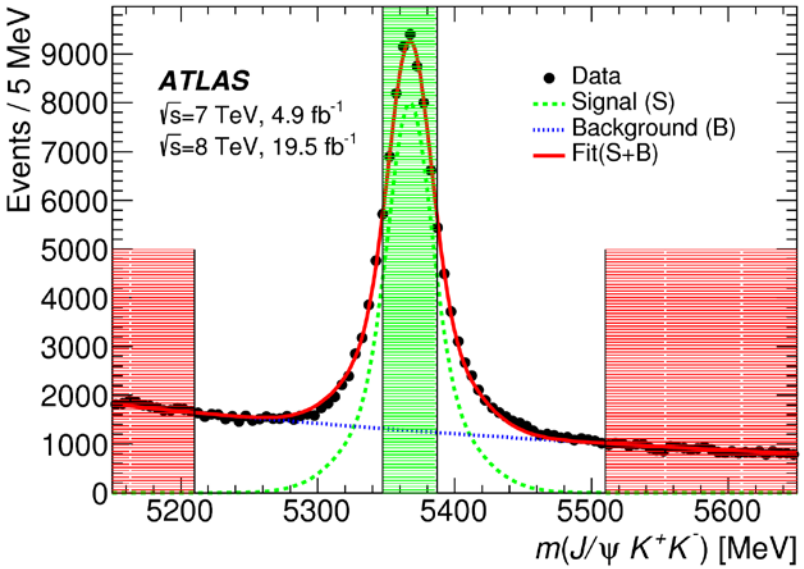
Search for Tetraquarks in $B^0_s \pi^\pm$

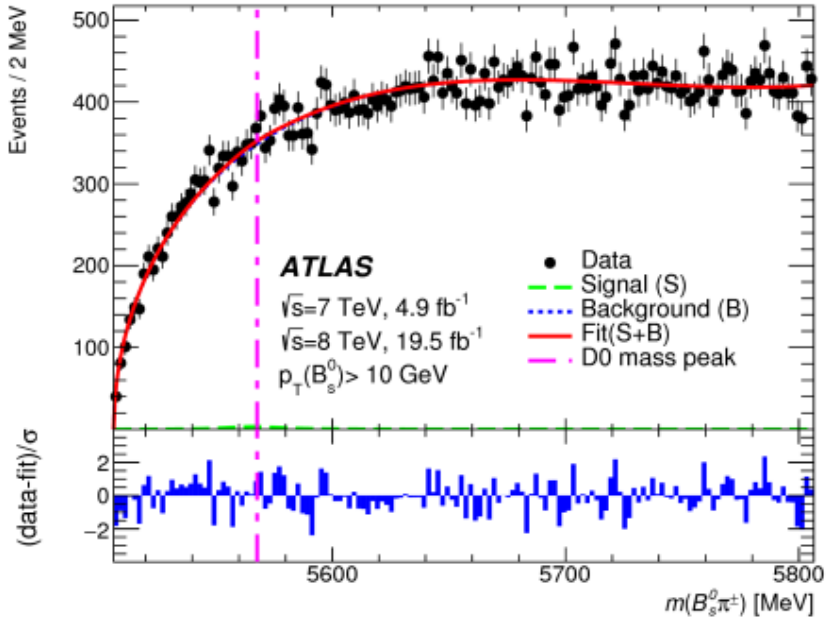
PRL 120 (2018) 202007

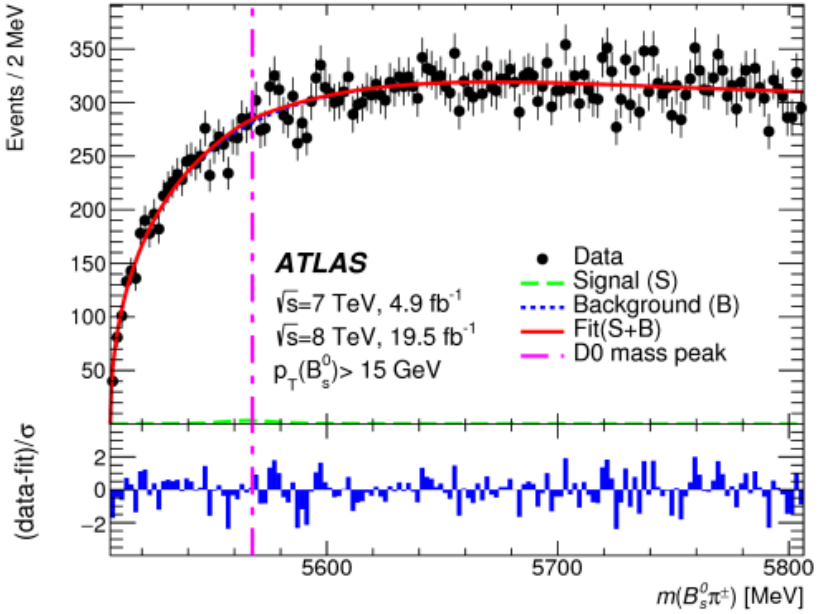
- Structure first observed by **DØ** in 2015, not observed by other experiments so far
- Particle decaying to $B^0_s \pi^\pm$

can only be Tetraquark if it exists

- No signal observed



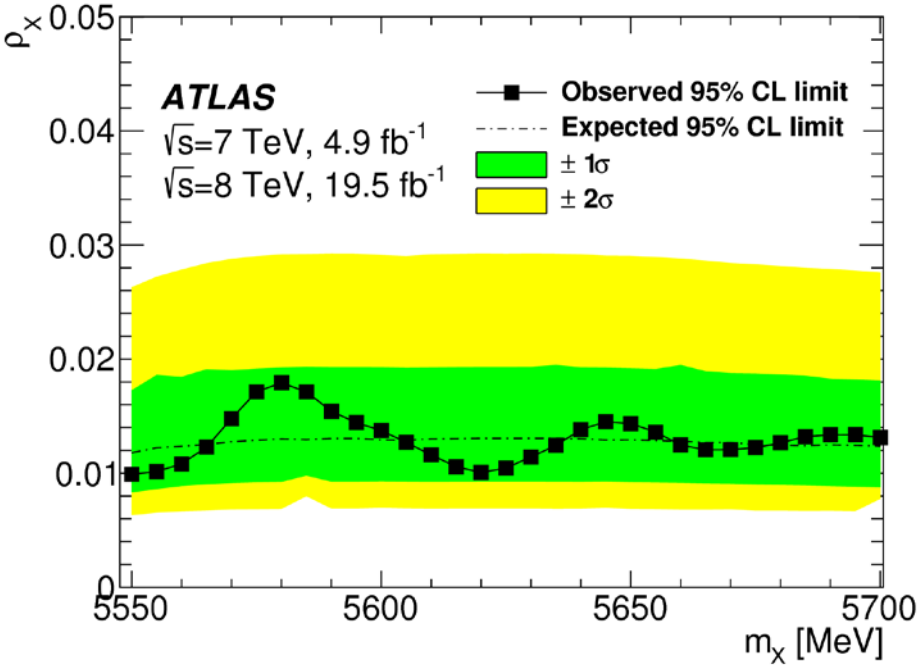




Search for Tetraquarks in $B^0_s \pi^\pm$

- Comparison to other experiments simplified by ρ_X: fraction of X-particle relative to all B^0_s in that final state.
- Exclusion limits in ρ_X
- D0 observed a ρ_X close to 10%. Unlikely to be compatible with ATLAS result.
- Null result confirmed by CDF, CMS, LHCb

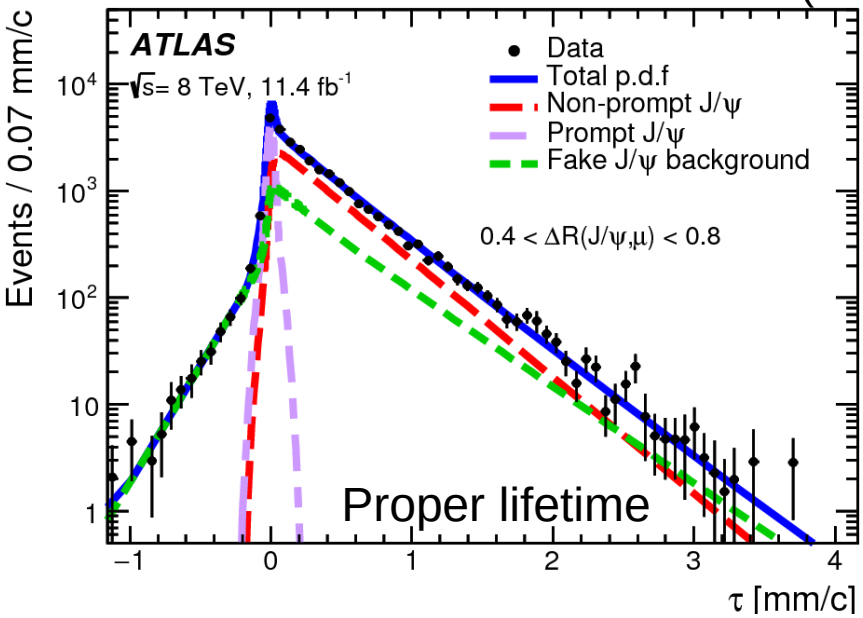
$N(B_s^0)/10^3$	$p_T(B_s^0) > 10$ GeV	52.75 ± 0.28
	$p_T(B_s^0) > 15$ GeV	43.46 ± 0.24
$N(X)$	$p_T(B_s^0) > 10$ GeV	60 ± 140
	$p_T(B_s^0) > 15$ GeV	-30 ± 150
$\epsilon^{rel}(X)$	$p_T(B_s^0) > 10$ GeV	0.53 ± 0.09
	$p_T(B_s^0) > 15$ GeV	0.60 ± 0.10

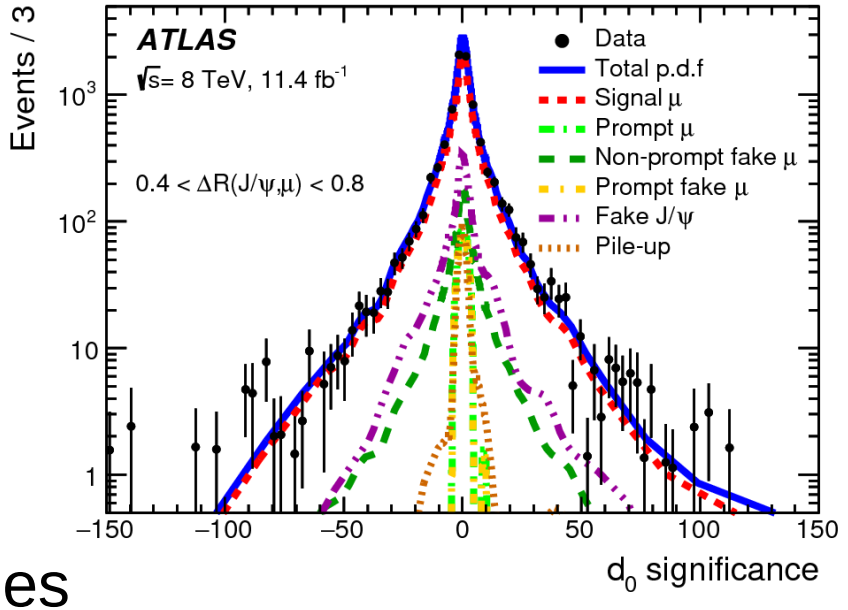


b-Hadron Pair Production @ 8 TeV

JHEP 11 (2017) 62

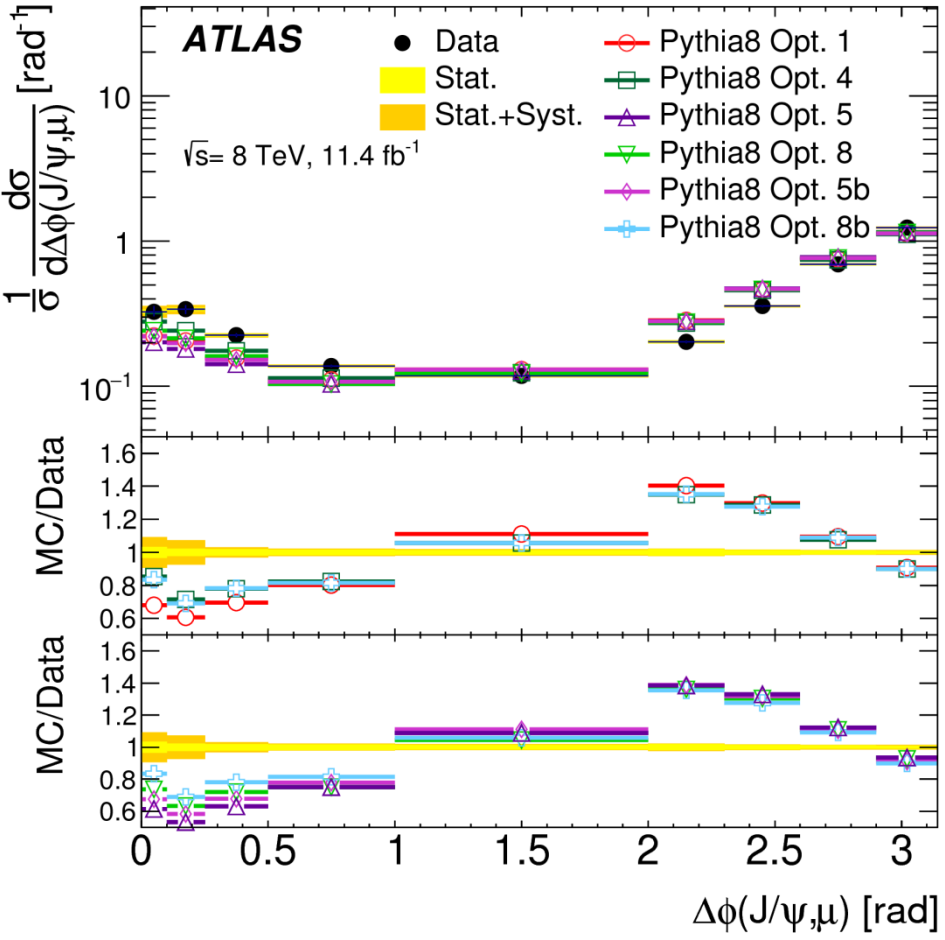
- Charmonia: unique window for QCD studies
- Prompt production: produced directly or through strong decays
- Non-Prompt: produced in decays of b-hadrons, can be separated due to the long b-hadron lifetime
- B-pairs selected by selecting J/ψ + μ final state
- Require:
  - non-prompt J/Psi (ct>0.25 mm)
  - μ compatible with b-origin
- Final ML fit based on 2 variables

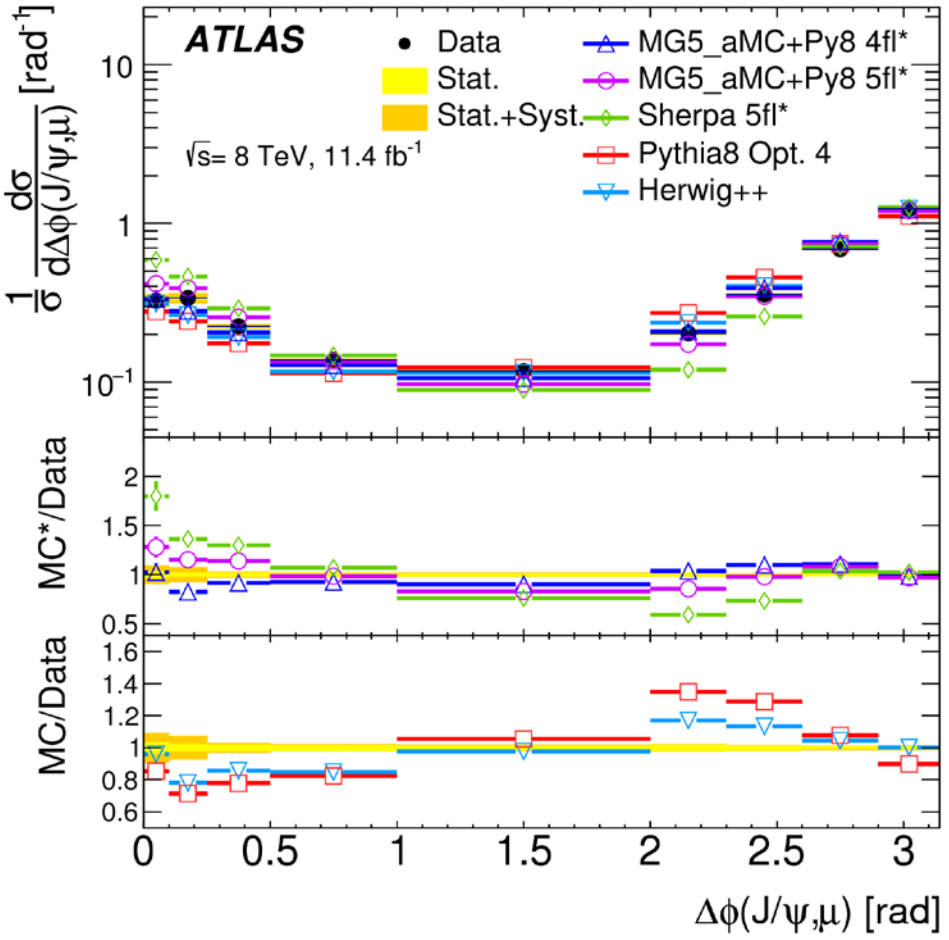




b-Hadron Pair Production @ 8 TeV: Results

- Presented method is jet-independent: Tuned Pythia8 not very successful in describing results. Best match with Madgraph5

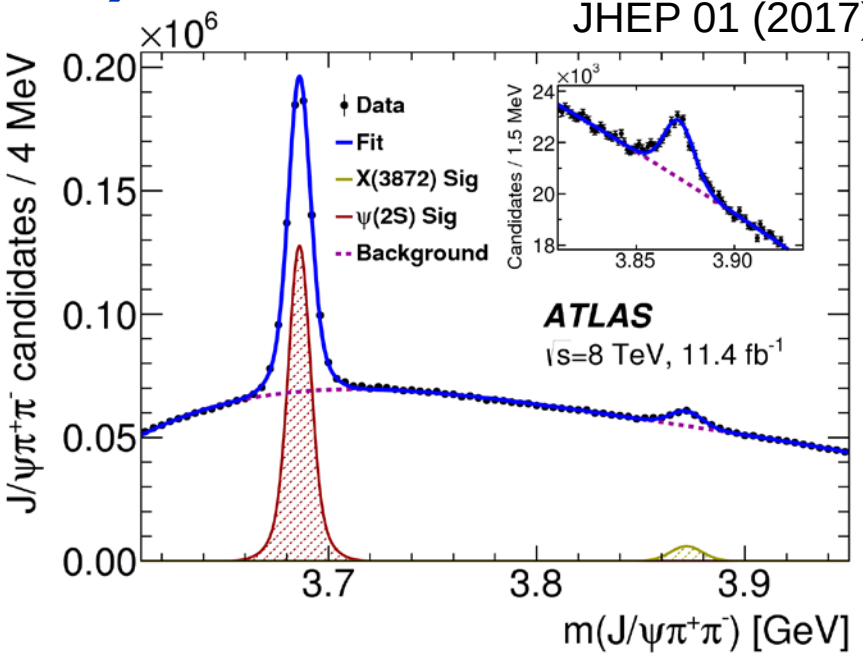


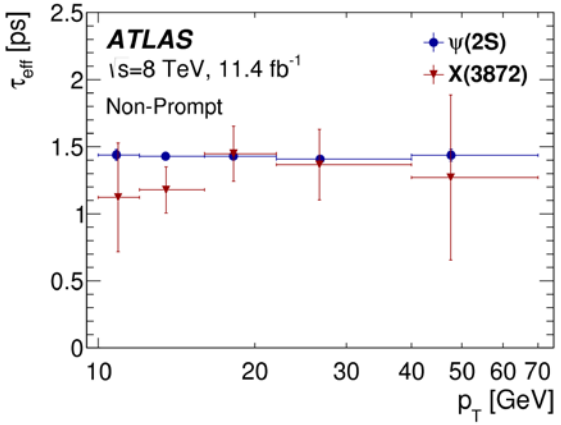


Production of X(3872) @ 8 TeV

- X(3872) unusually narrow charmonium-like state. Too narrow to be compatible with regular cc-state
- Study of properties simplified by comparing to ψ(2S)
- Investigation of origin shows prompt and non-prompt contributions
- Fit of proper lifetime distribution simplified by assuming a single “effective” b-lifetime

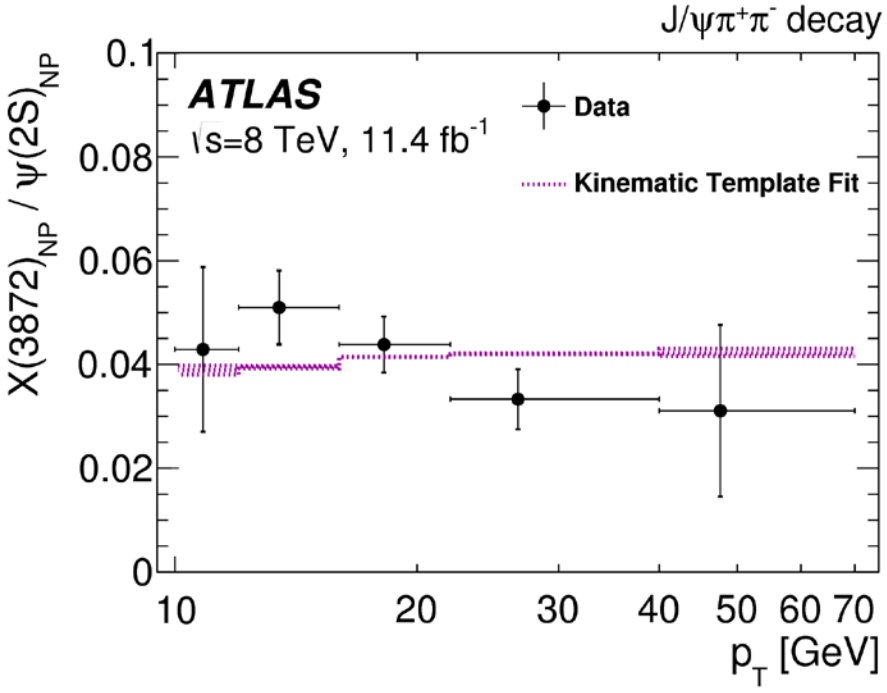
JHEP 01 (2017) 117

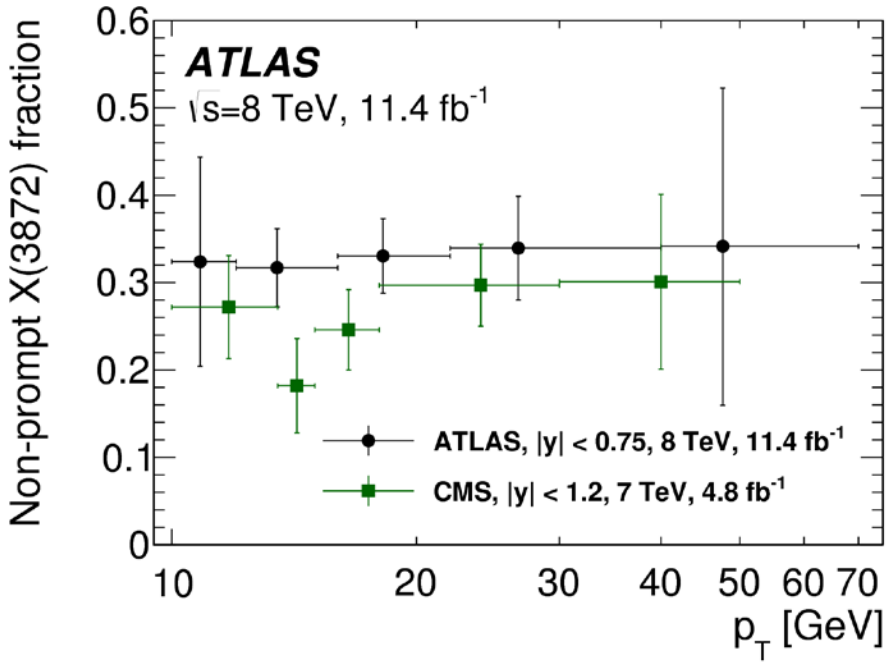




$$R_B = \frac{\mathcal{B}(B\to X(3872)+\text{any})\mathcal{B}(X(3872)\to J/\psi\pi^+\pi^-)}{\mathcal{B}(B\to\psi(2S)+\text{any})\mathcal{B}(\psi(2S)\to J/\psi\pi^+\pi^-)} = (3.95 \pm 0.32(\text{stat}) \pm 0.08(\text{sys})) \times 10^{-2}$$

Production of X(3872) @ 8 TeV: Results





- Non-prompt X(3872) component similar to ψ(2s)
- Possibly some contribution to X(3872) from B_c decays
- $$\frac{\sigma(pp \to B_c)\mathcal{B}(B_c \to X(3872))}{\sigma(pp \to \text{non-prompt } X(3872))} = (25 \pm 13(\text{stat}) \pm 2(\text{sys}) \pm 5(\text{spin}))\%$$
- Non prompt fraction ~ 30%. Similar results as for CMS

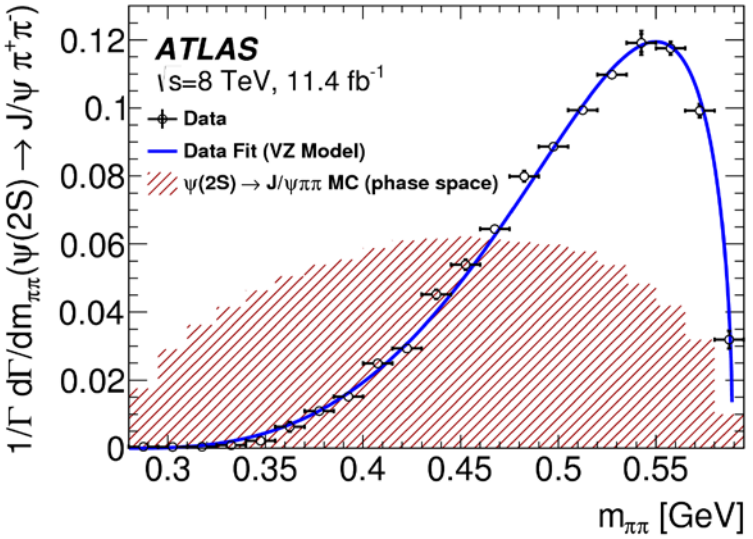
Di-Pion Structure of X(3872)

Di-pion in ψ(2S) → J/ ππ transitions described by Voloshin-Zakharov function:

$$\frac{1}{\Gamma}\frac{d\Gamma}{dm_{\pi\pi}} \propto \left(m_{\pi\pi}^2 - \lambda m_{\pi}^2\right)^2 \times \mathrm{PS}$$

We found λ = 4.16 ± 0.06(stat) ± 0.03(syst)

Matches previous results.

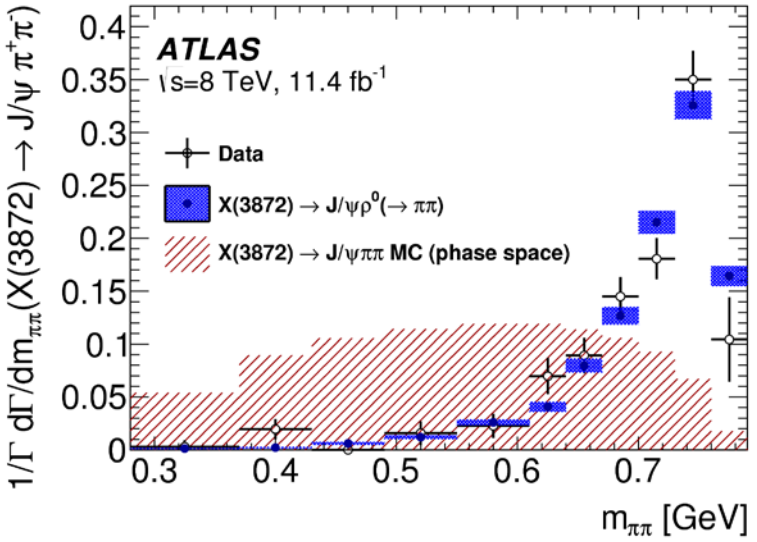


Applied to X(3872) decays

Peaks even sharper at high masses.

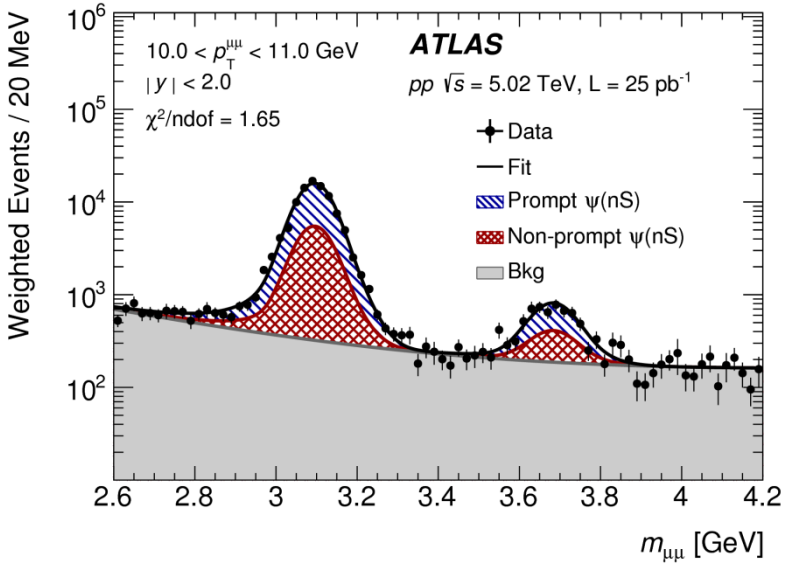
In agreement with X(3872)→ J/ψ ρ^0 (→ππ)

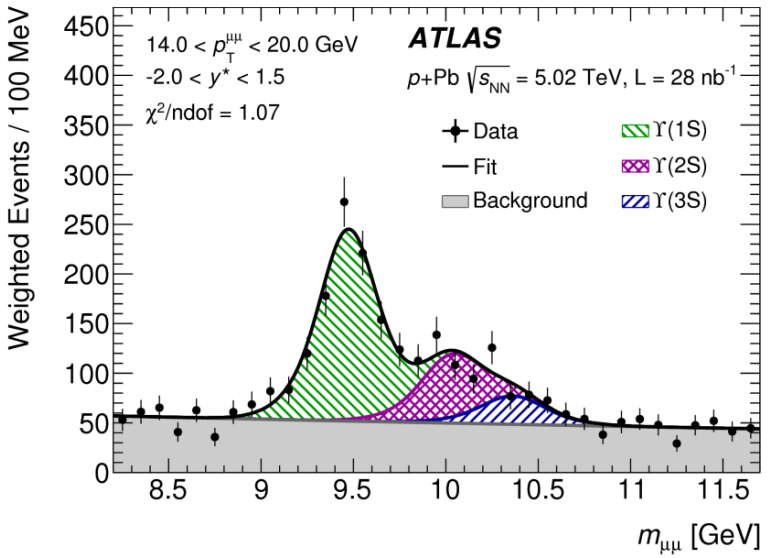
And in agreement with previous results



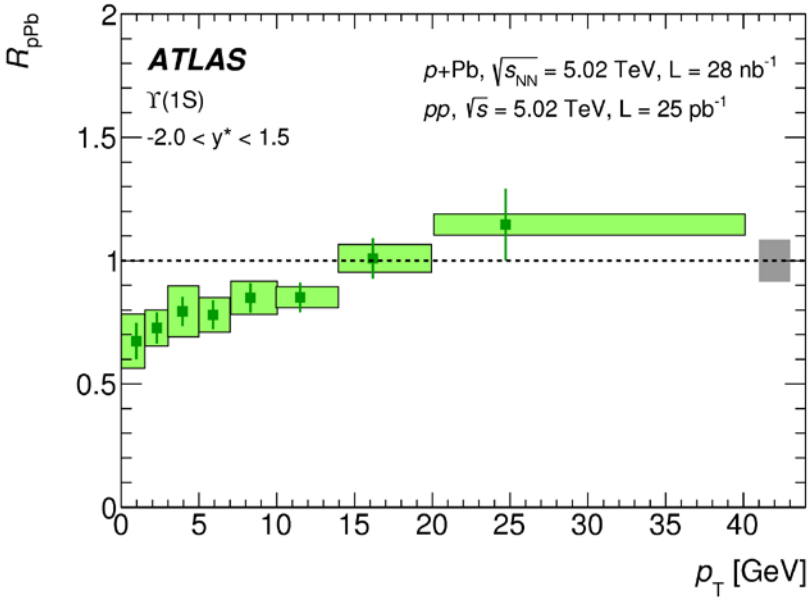
Quarkonium Production in pp + pPb @ 5TeV

Eur. Phys. J. C 78 (2018) 171



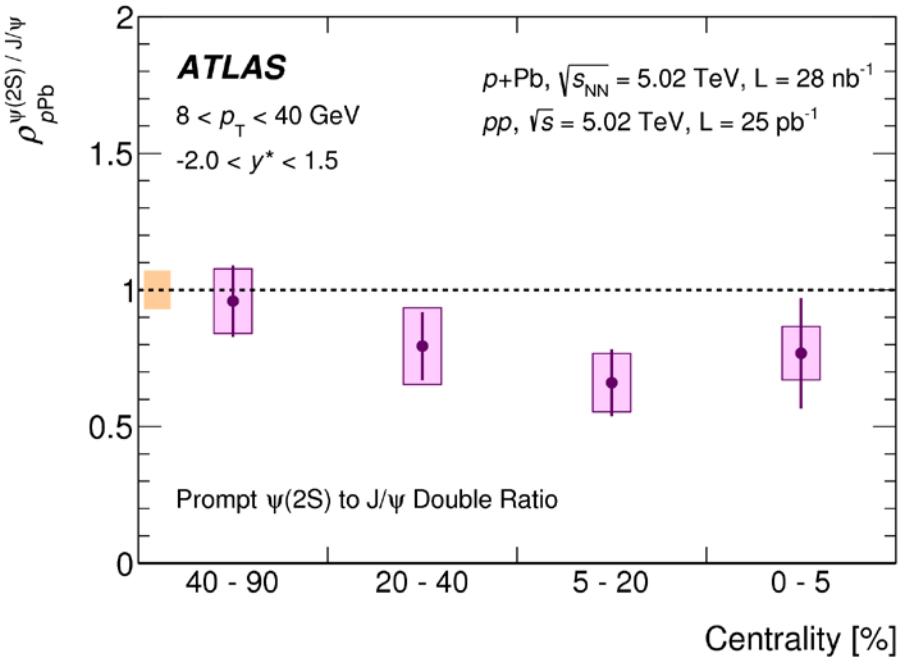


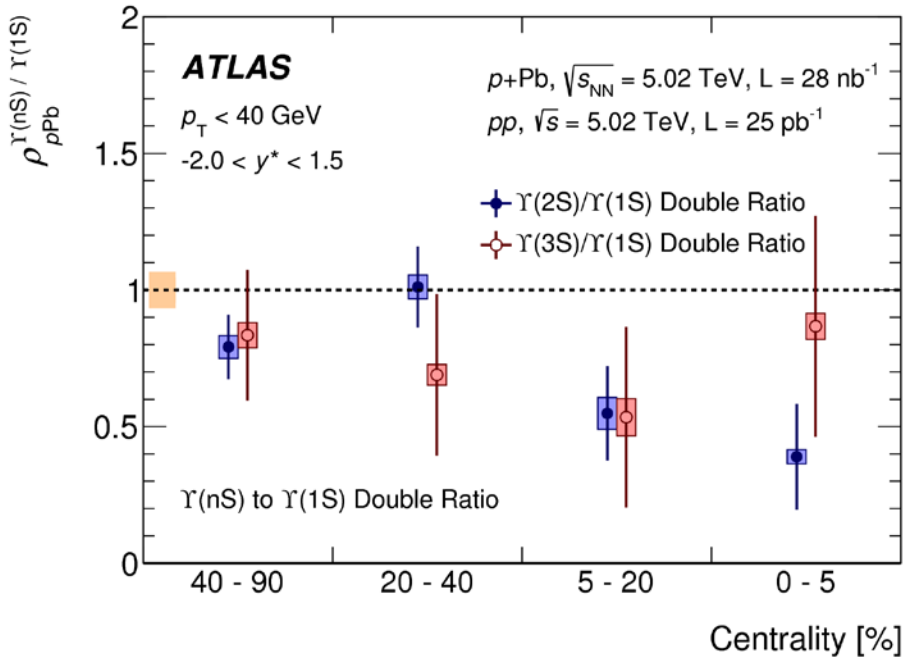
- nuclear modification factors R_{pPb} normalized ratio of σ_{pPb} / σ_{pp}
- R_{pPb} describe effects of cold nuclear matter
- Vital factors for analysis of QGP
- $R_{pPb}(\Upsilon(1S))$ suppressed at low pT
- $R_{pPb}(J/\psi)$ consistent with 1.



Quarkonium Production in pp + pPb collisions @ 5TeV

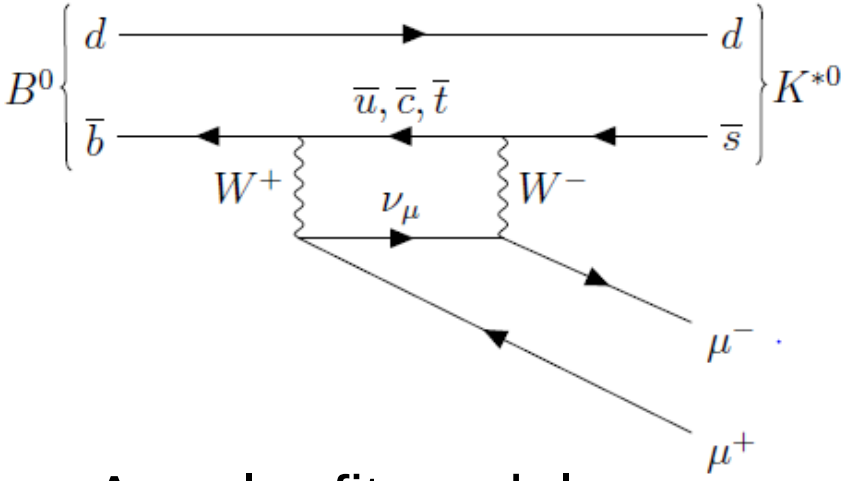
- Form double ratios from nuclear modification factors between excited and ground state quarkonium
- Double ratios: Production of excited Quarkonium states is found to be suppressed relative to ground states in pPb collisions
- More statistics to clearly discern centrality dependence

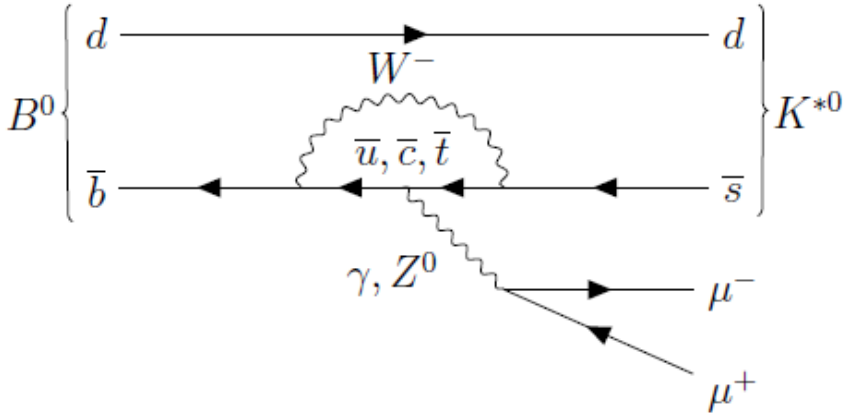




Angular Analysis of B0→K* μμ

arXiv:1805.04000
20.3 fb^{-1} @ 8 TeV



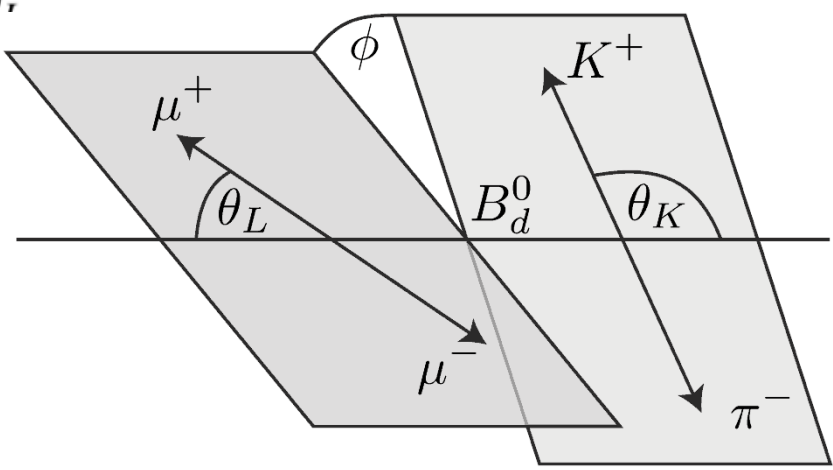


- Angular fit model

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_L\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi\,\mathrm{d}q^2} =$$

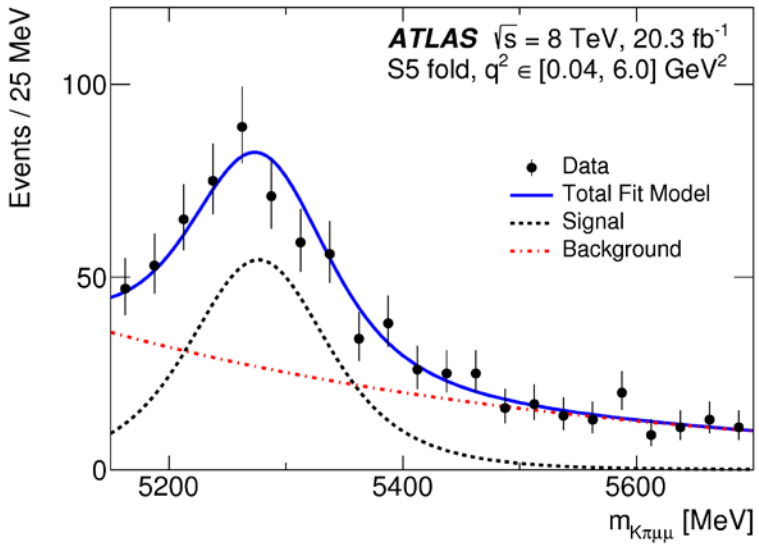
$$\frac{9}{32\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_L\right.$$
$$-F_L\cos^2\theta_K\cos 2\theta_L + S_3\sin^2\theta_K\sin^2\theta_L\cos 2\phi$$
$$+S_4\sin 2\theta_K\sin 2\theta_L\cos\phi + S_5\sin 2\theta_K\sin\theta_L\cos\phi$$
$$+S_6\sin^2\theta_K\cos\theta_L + S_7\sin 2\theta_K\sin\theta_L\sin\phi$$
$$\left.+S_8\sin 2\theta_K\sin 2\theta_L\sin\phi + S_9\sin^2\theta_K\sin^2\theta_L\sin 2\phi\right].$$

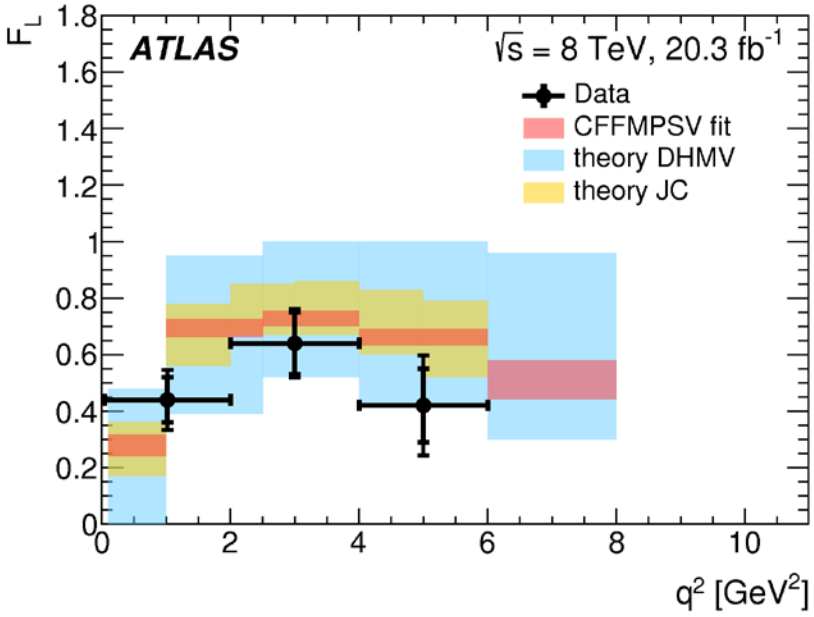
q^2: di-μ inv. mass

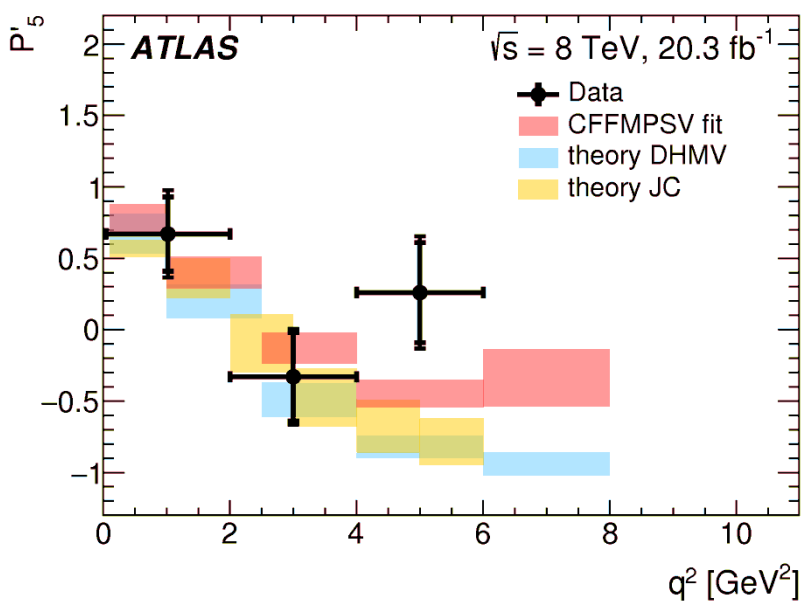


Angular Analysis of B0→K* μμ decays (8 TeV)

- Control region: B→ ψ(nS) K*
- Results of fit in q^2 region below ψ peak, q^2 in [0.04-6.0 GeV^2]
- Results in agreement with predictions and with other experiments.







Summary

- ATLAS has active B physics program
- No signal observed in search for Tetraquarks in $B^0_s \pi^{\pm}$ final state in agreement with other expts.
- Jet-independent b-pair production compared to MC generators
- Study of non-prompt X(3872) production
- Investigation of cold nuclear matter effects in pp, pPb collissions. Measured nuclear modification factors
- Angular analysis of B→K* μμ
- Thank you for your attention!

Additional Slides