



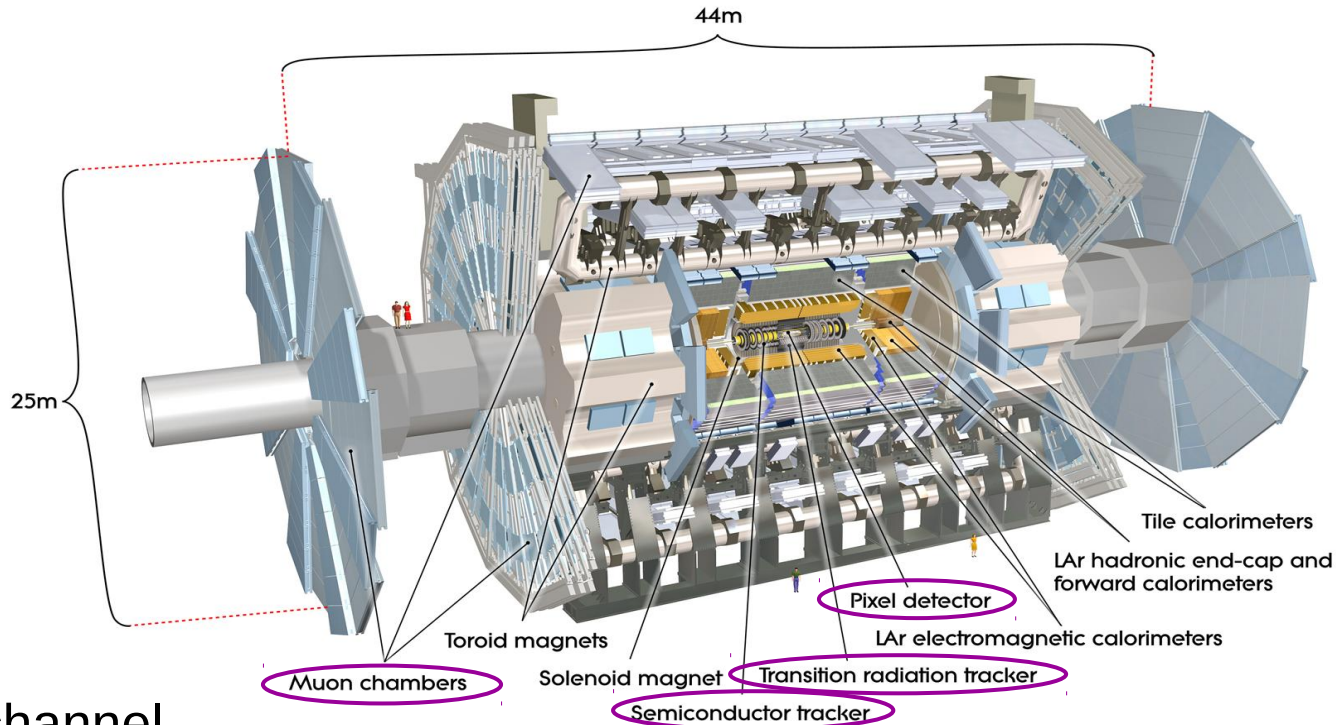
Quarkonium production studies in nuclear collisions at ATLAS

Martin Spousta
for the ATLAS Collaboration

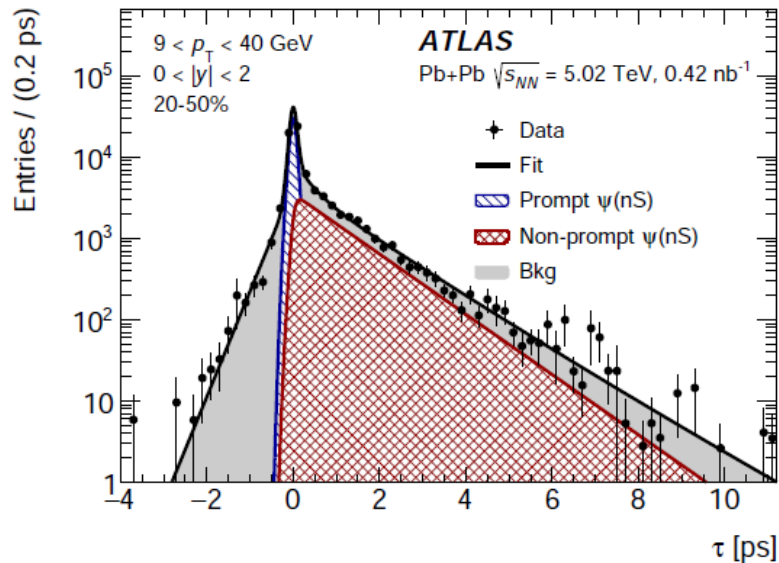
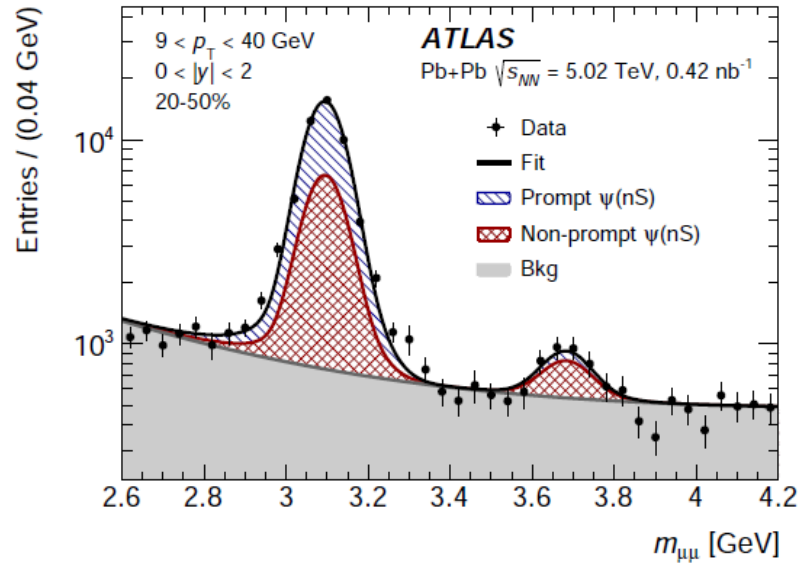
Charles University
Prague

The 14th International Workshop on Heavy Quarkonium (QWG 2021)
UC Davis, 15th - 19th March 2021

Quarkonia in ATLAS



- Dimuon channel.
- Using tracking system + muon spectrometer.
- Measurements of:
 - charmonia and bottomonia production in 5.02 TeV pp, Pb+Pb, and p+Pb collisions
 - charmonia flow in 5.02 TeV Pb+Pb



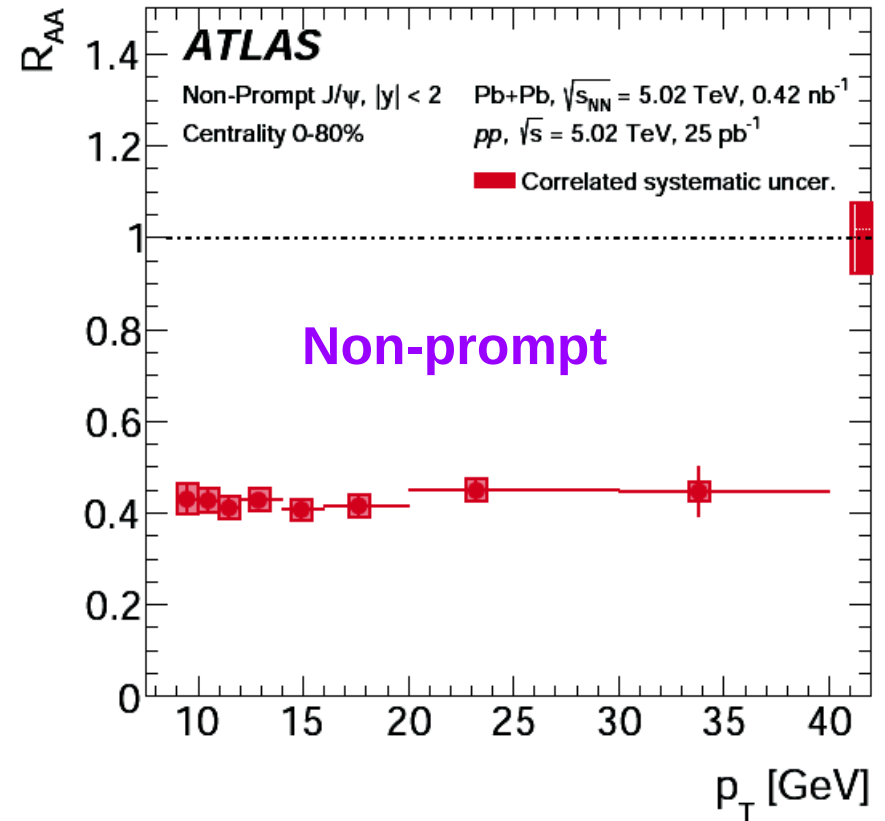
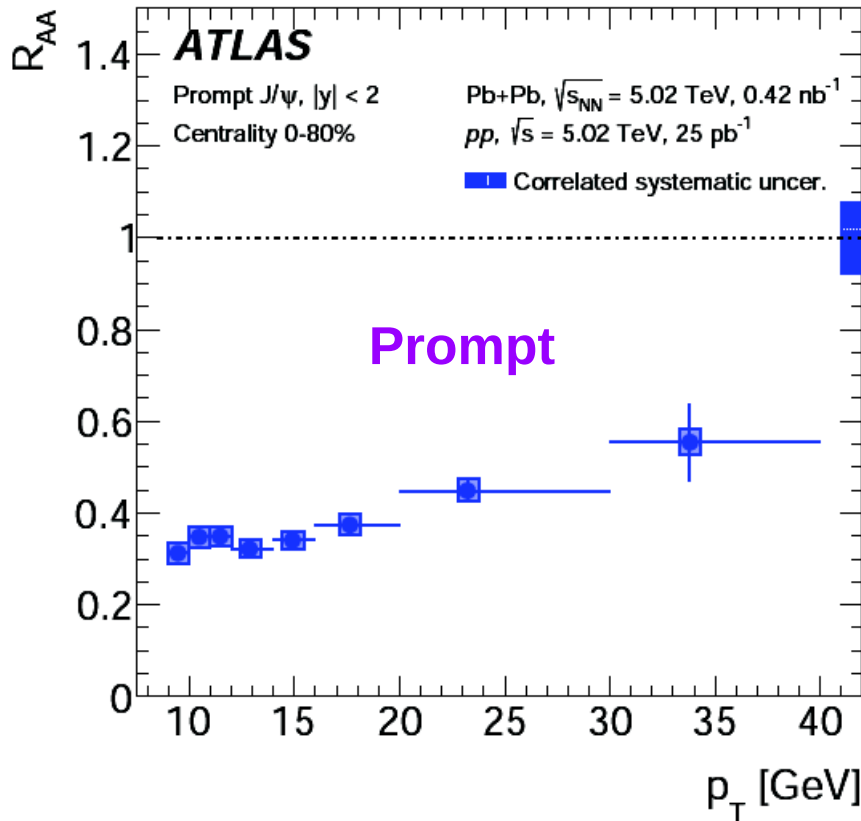
- J/ψ and $\psi(2S)$ in dimuon channel.
- $p_T = 9 - 40$ GeV, $|y| < 2$, $\sqrt{s_{NN}} = 5.02$ TeV.
- Yields from 2D unbinned maximum likelihood fits in $m_{\mu\mu}$ and pseudo-proper decay time τ ,

$$\tau = \frac{L_{xy} m_{\mu\mu}}{p_T^{\mu\mu}}$$

- Prompt and non-prompt (from b-decays) component separated.

Suppression of J/ψ in Pb+Pb

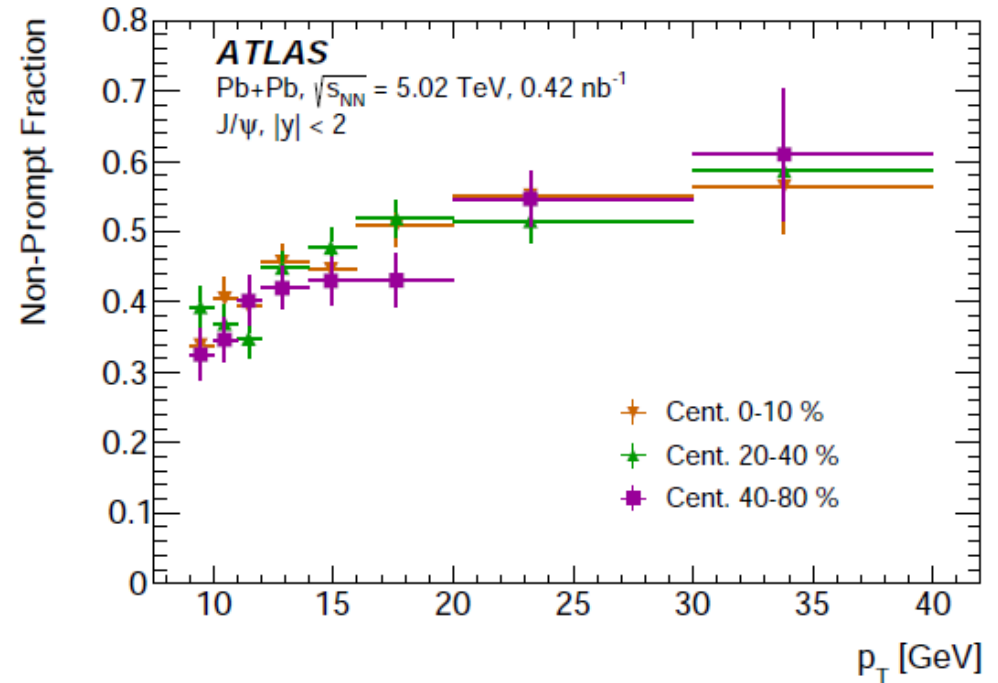
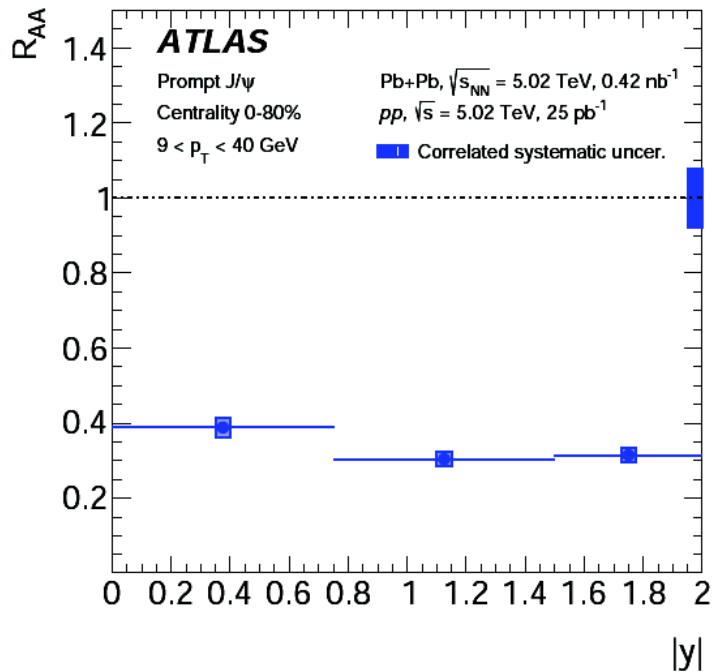
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$$R_{AA} = \frac{N_{AA}}{\langle T_{AA} \rangle \times \sigma_{pp}}$$

- **Similar suppression** of prompt and non-prompt J/ψ .
- **Large suppression** in central collisions:
 $R_{AA} \sim 0.2 - 0.3$ for $p_T = 9 - 40$ GeV

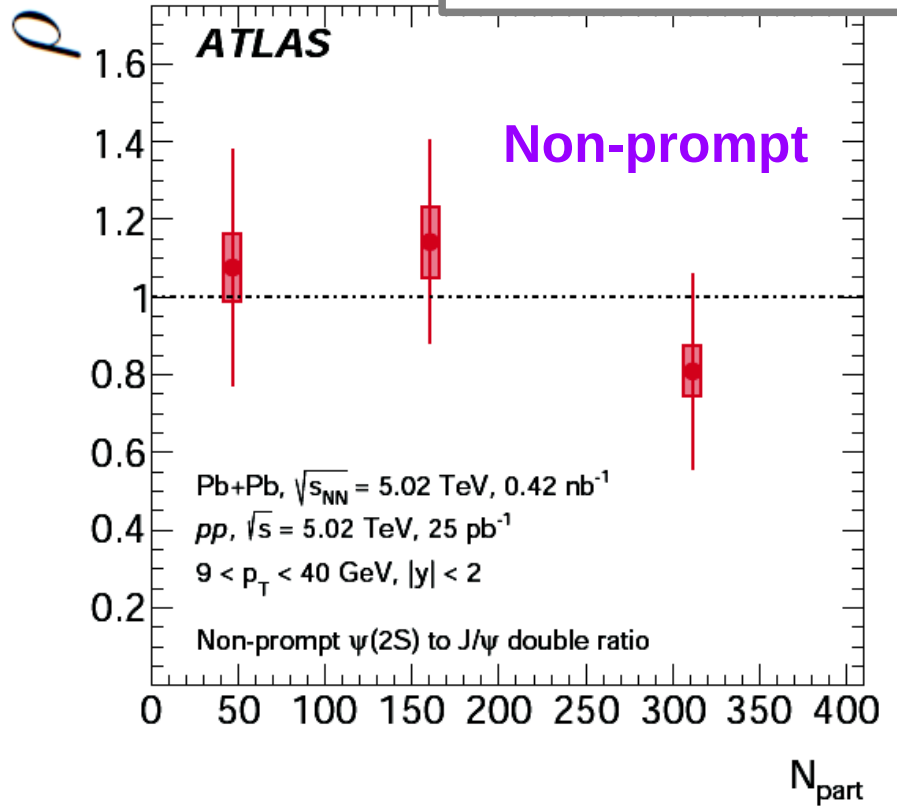
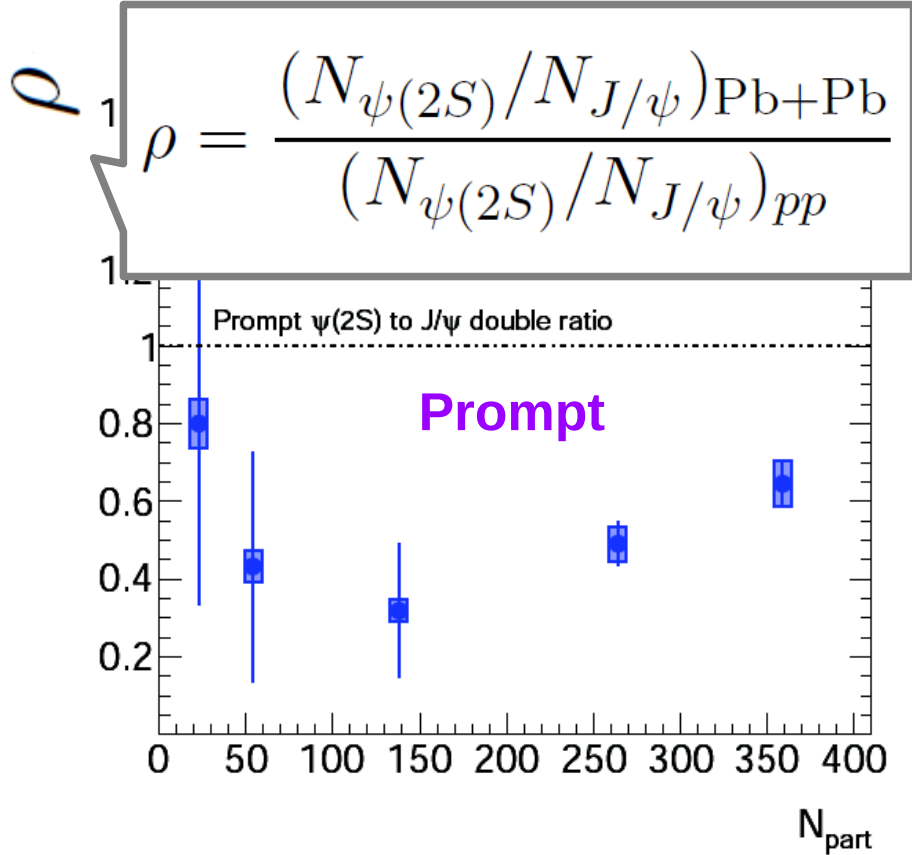
Suppression of J/ψ in Pb+Pb



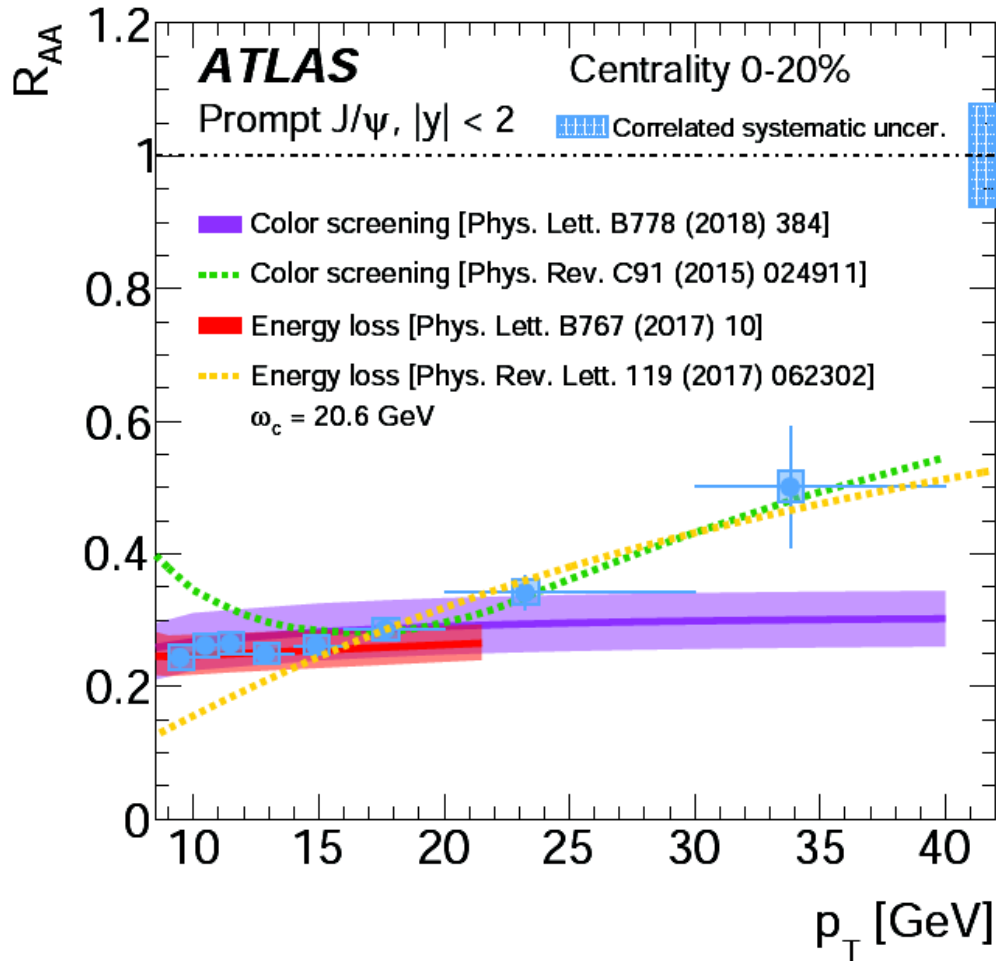
- No significant dependence of suppression on **rapidity** over $|y| < 2$.
- No centrality dependence of **non-prompt fraction**.

Suppression of $\psi(2S)$ in Pb+Pb

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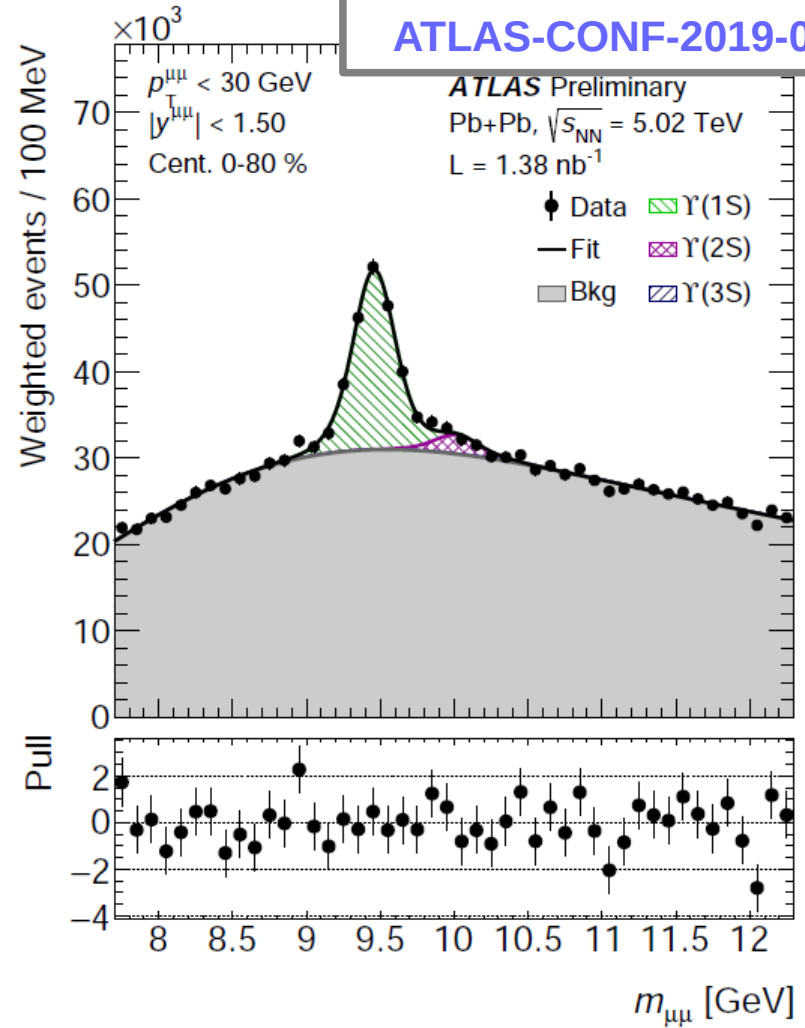
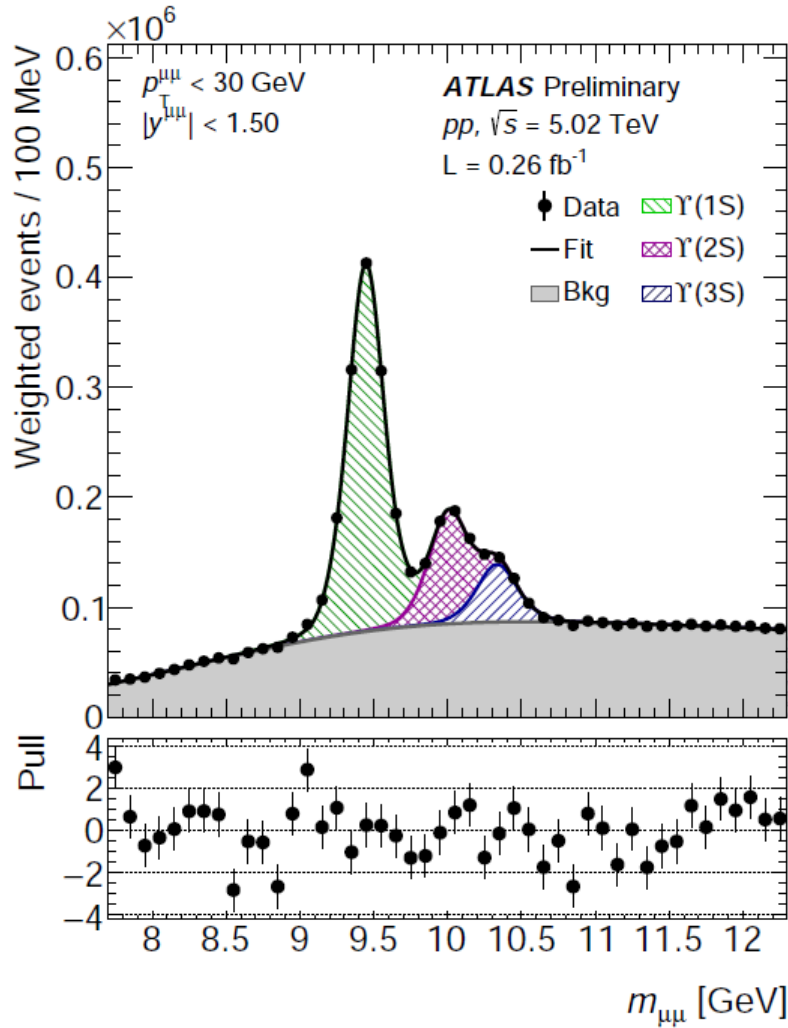
- **Prompt $\psi(2S)$** suppressed by a factor of **~ 2 more** than prompt J/ψ .
(expected e.g. from different binding energies)
- **Non-prompt $\psi(2S)$** exhibits **similar suppression** as non-prompt J/ψ .
(expected e.g. from B-hadron decaying outside of the medium)



- **Color screening versus energy loss.**
- Both of these different mechanisms can reproduce observed suppression, but not in the full range of measurement.
- More precision at high- p_T should allow to discriminate among mechanisms.

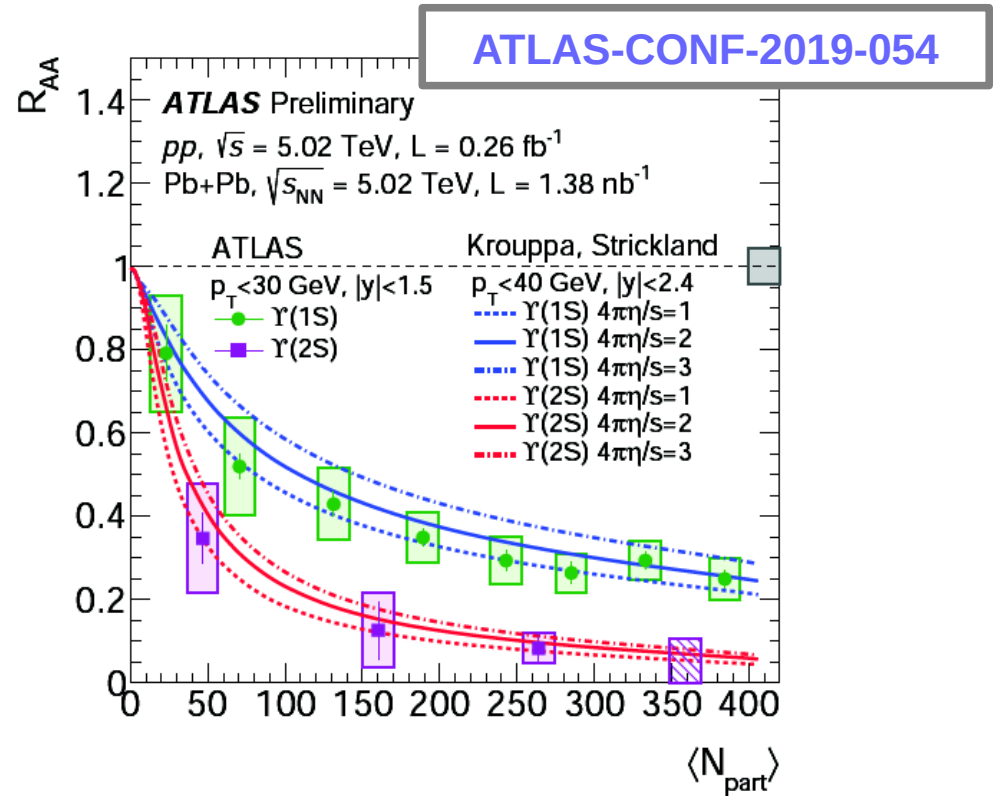
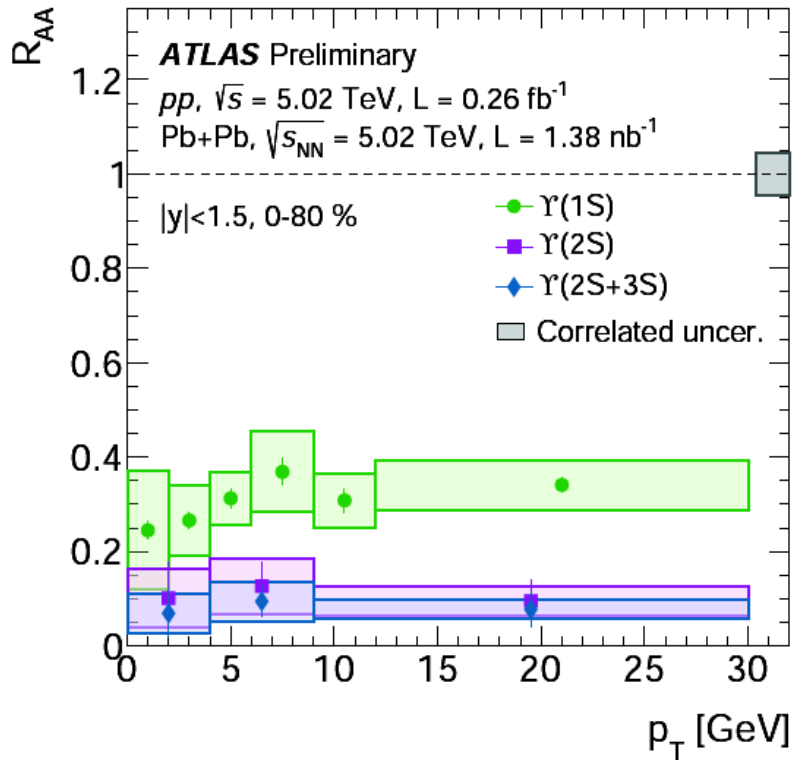
Bottomonia signal in Pb+Pb

ATLAS-CONF-2019-054

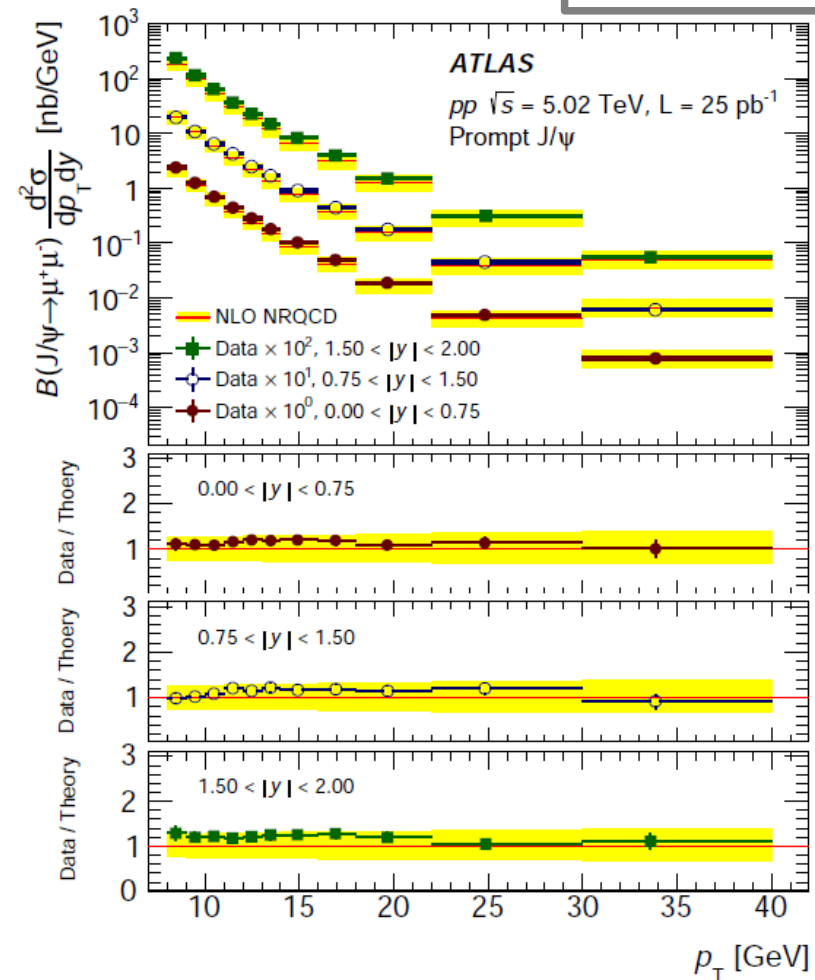
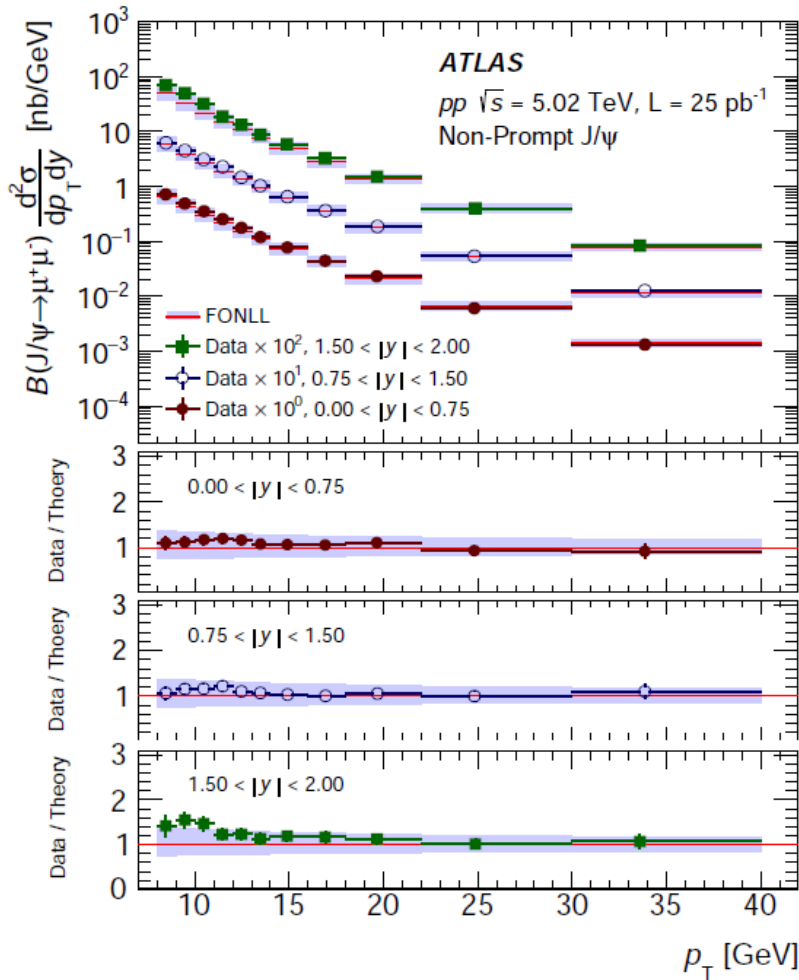


- Left: pp, right: Pb+Pb.
- Strong suppression seen by eye. $\Upsilon(3S)$ not separated.

Bottomonia production in Pb+Pb



- No significant p_T and rapidity dependence.
- $\Upsilon(1S)$ – similar behavior as prompt J/ψ .
- **Expected ordering** observed: $\Upsilon(1S) > \Upsilon(2S) > \Upsilon(2S+3S)$, consistent with theory prediction based on color-screening.



- Reference from measurement in pp collisions.
- Prompt J/ψ and $\psi(2S)$, cross-sections measured in pp collisions **consistent with NRQCD and FONLL predictions, respectively.**

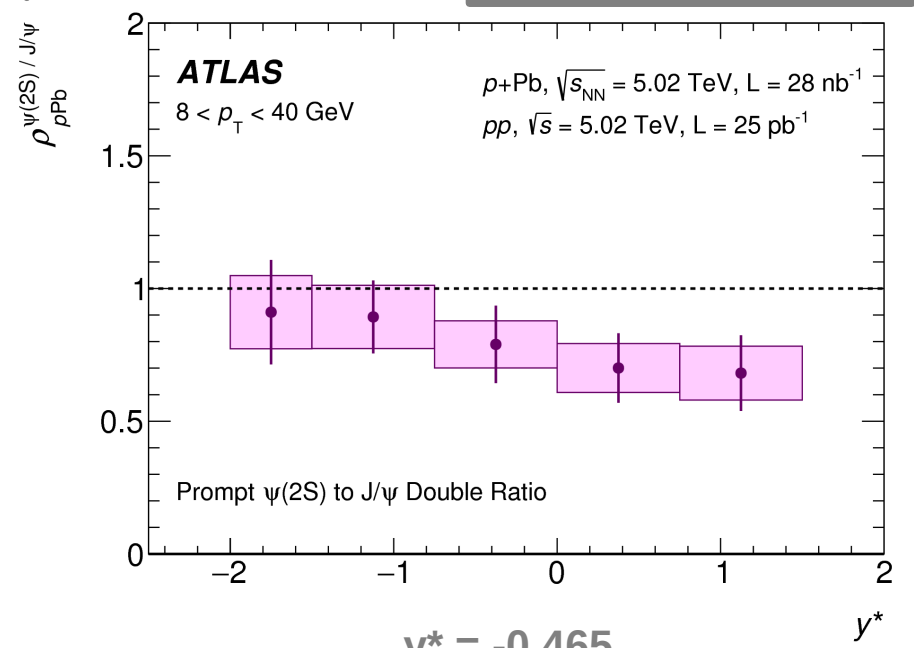
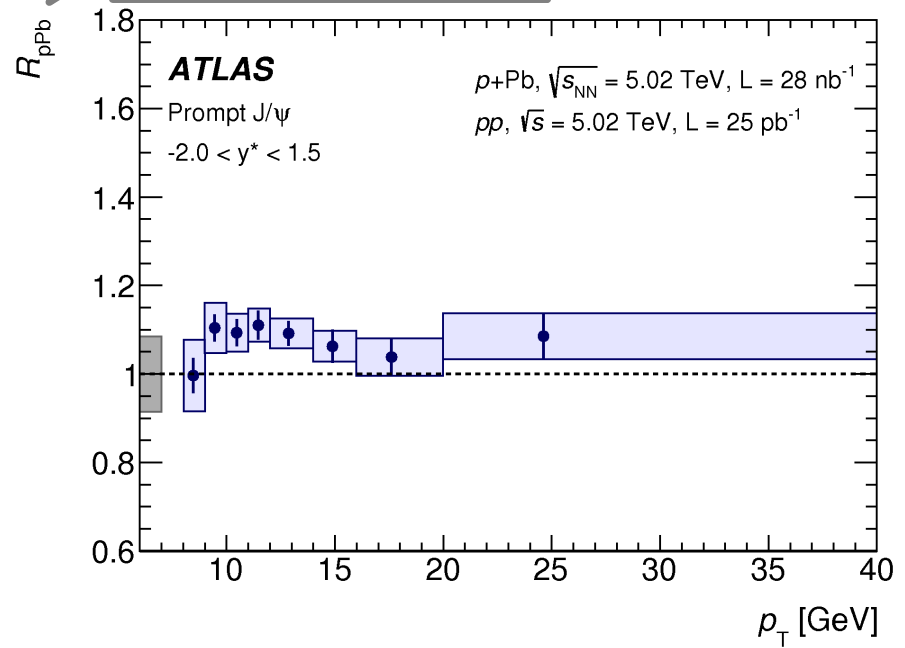
Charmonia production in p+Pb



$$R_{pPb} = \frac{1}{208} \frac{\sigma_{p+Pb}^{O(nS)}}{\sigma_{pp}^{O(nS)}}$$

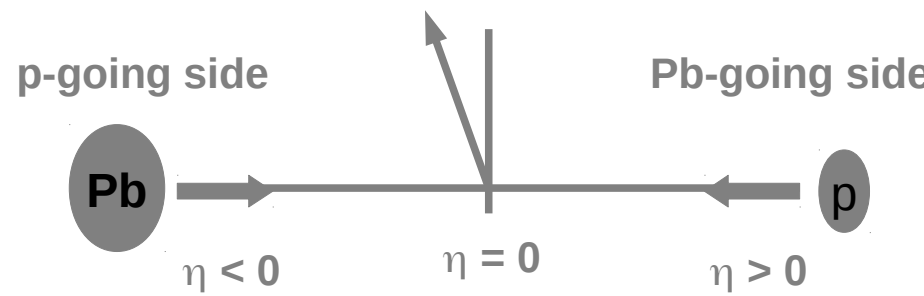
~ ratio of R_{pPb}

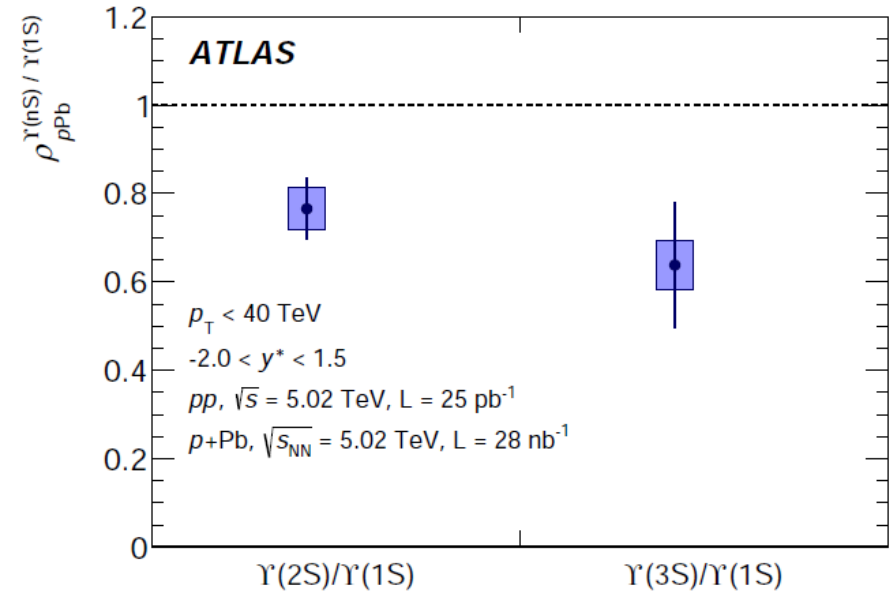
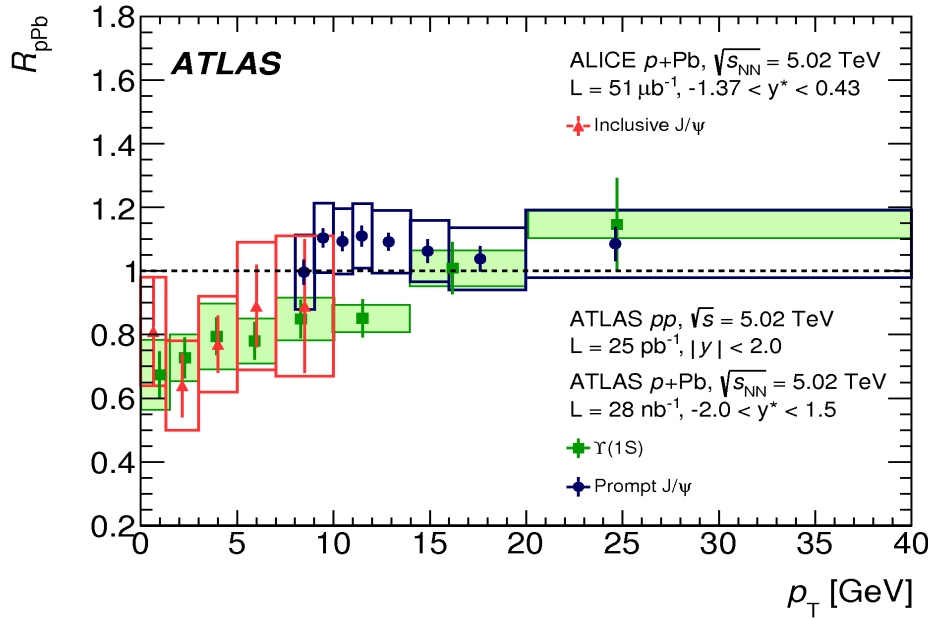
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$y^* = -0.465$

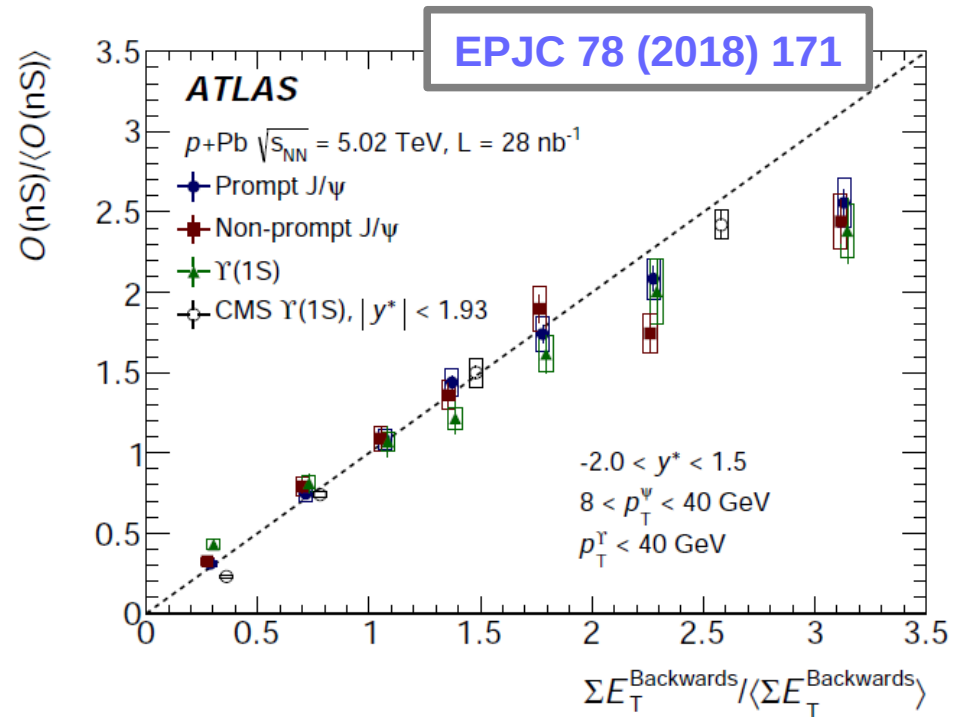
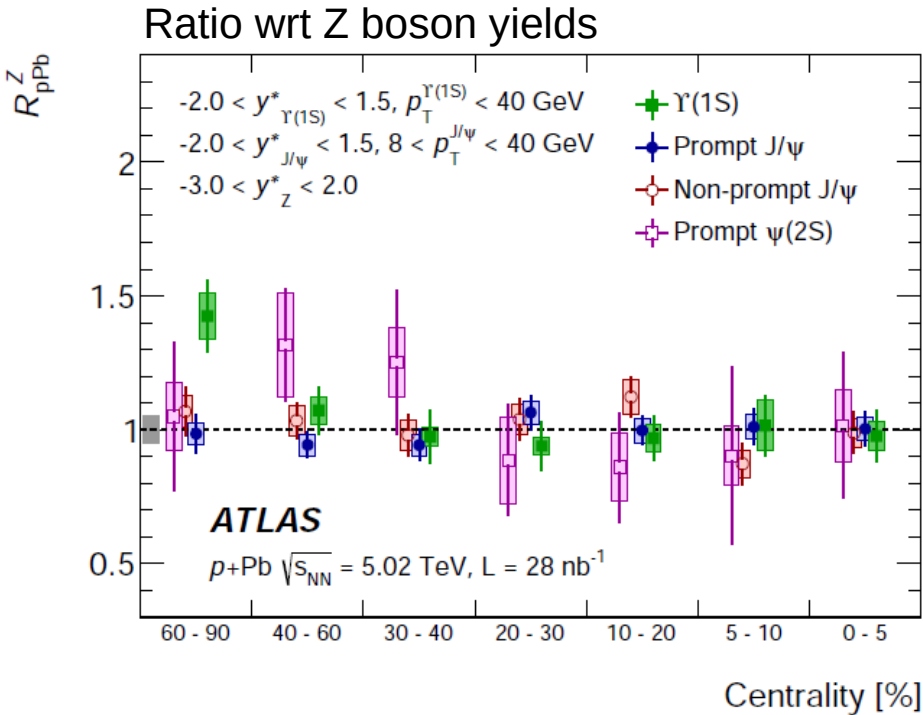
- J/ψ R_{pPb} consistent with unity
- $\psi(2S)$ suppressed wrt J/ψ (1σ) in the Pb-going side





- Y(1S) suppressed at low p_T – suggestive of nPDF effect.
- Y(2S) and Y(3S) suppressed more than Y(1S) by 20 – 30%.

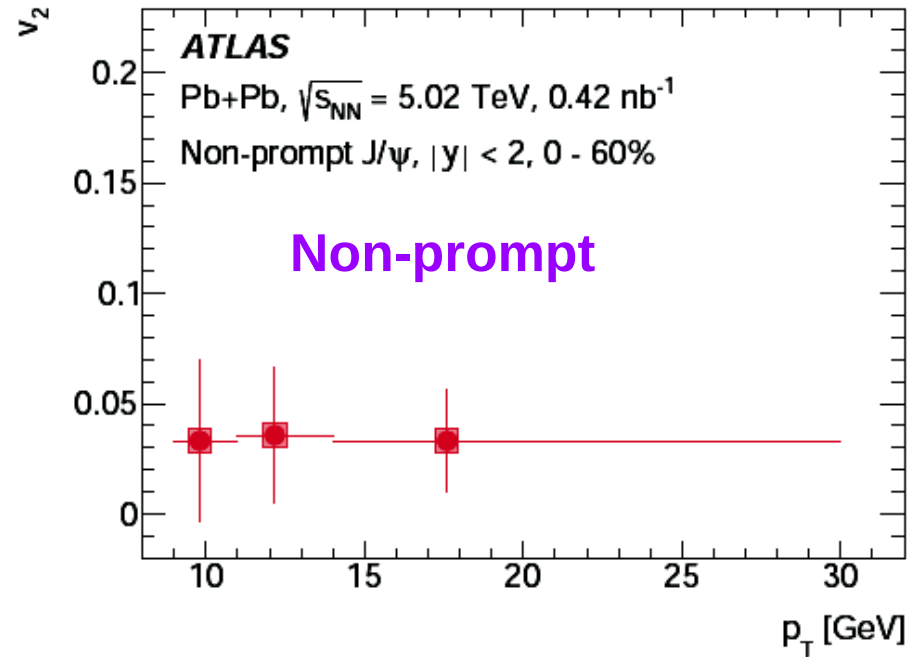
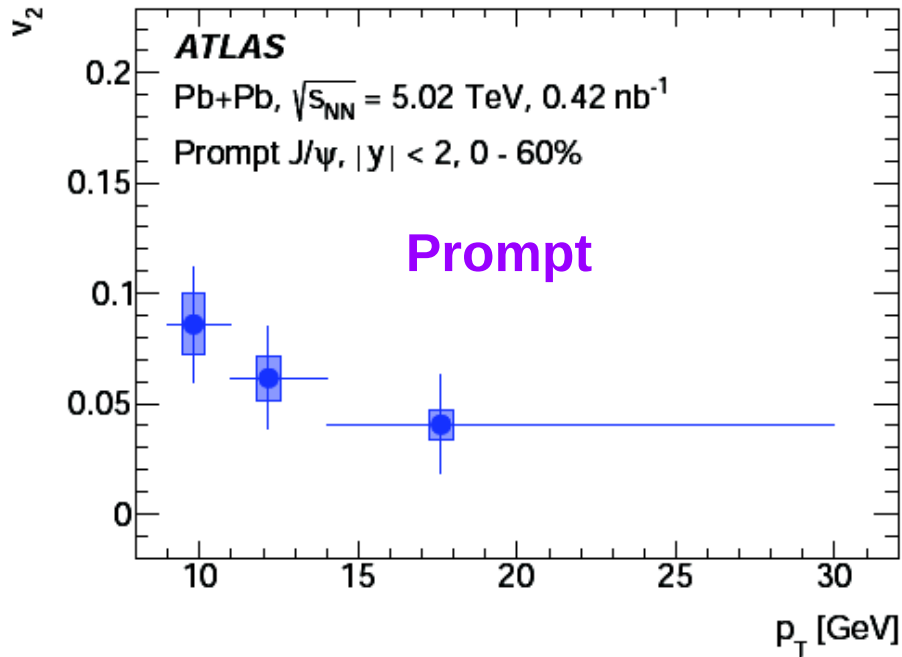
Centrality dependence in p+Pb



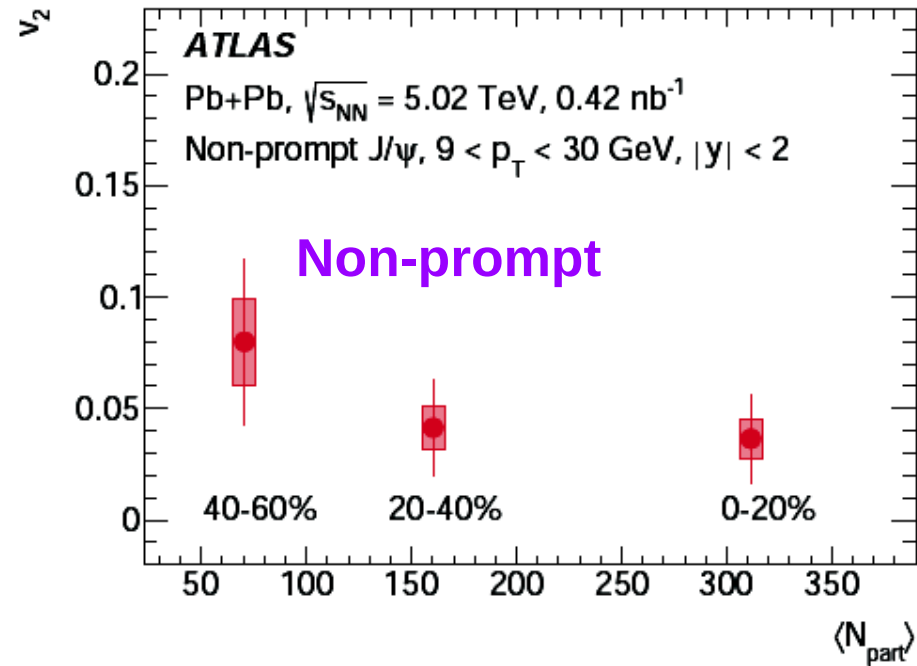
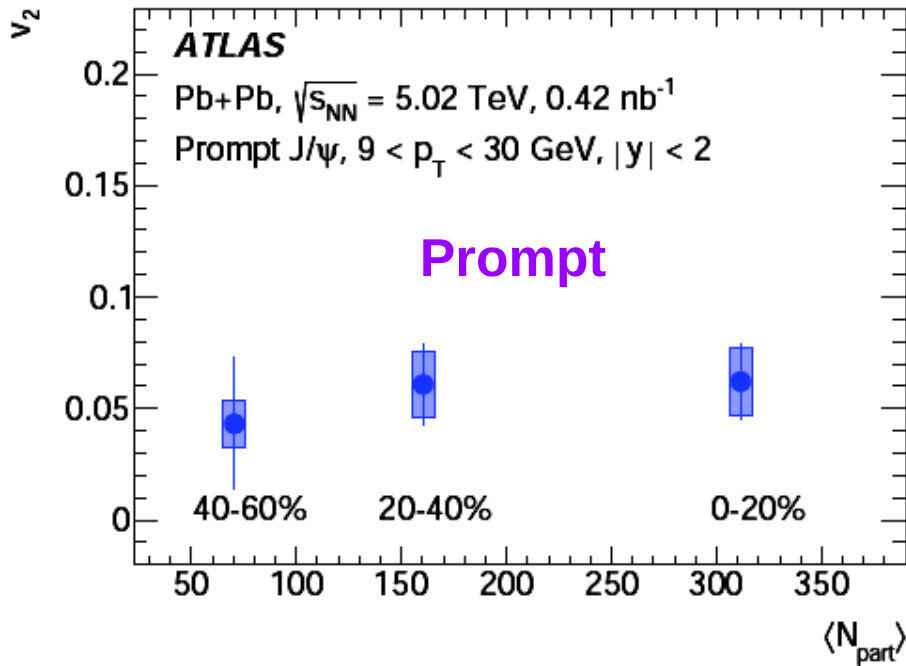
- Z boson found to scale with N_{coll} ,
Y production exhibits **similar behavior** as Z boson production.
- Events with highest activity exhibit **2σ departure** from the linear trend.

$$\frac{O(nS)}{\langle O(nS) \rangle} \equiv \frac{N_{O(nS)}^{\text{cent}} / N_{\text{evt}}^{\text{cent}}}{N_{O(nS)}^{0-90\%} / N_{\text{evt}}^{0-90\%}},$$

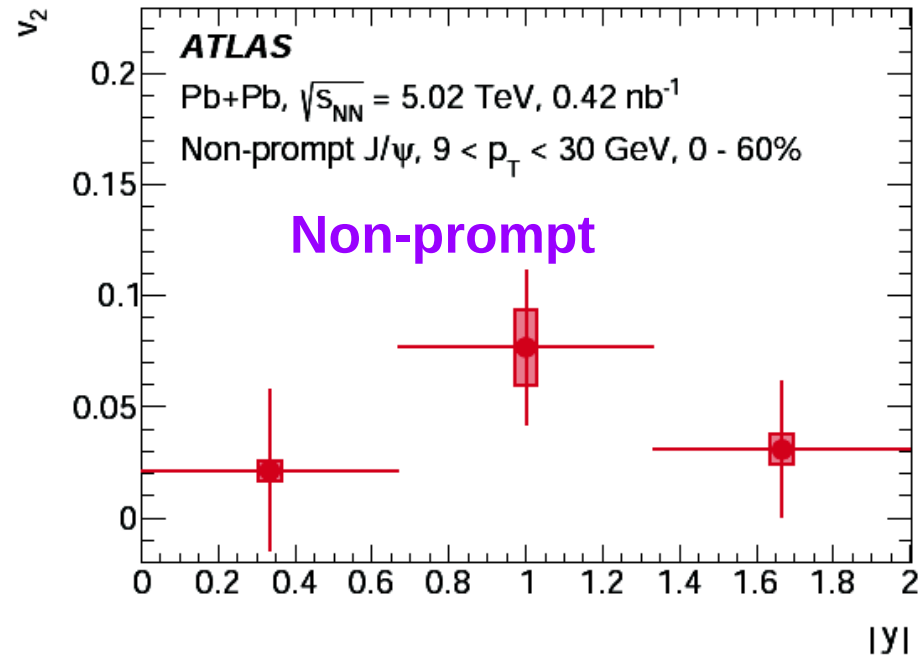
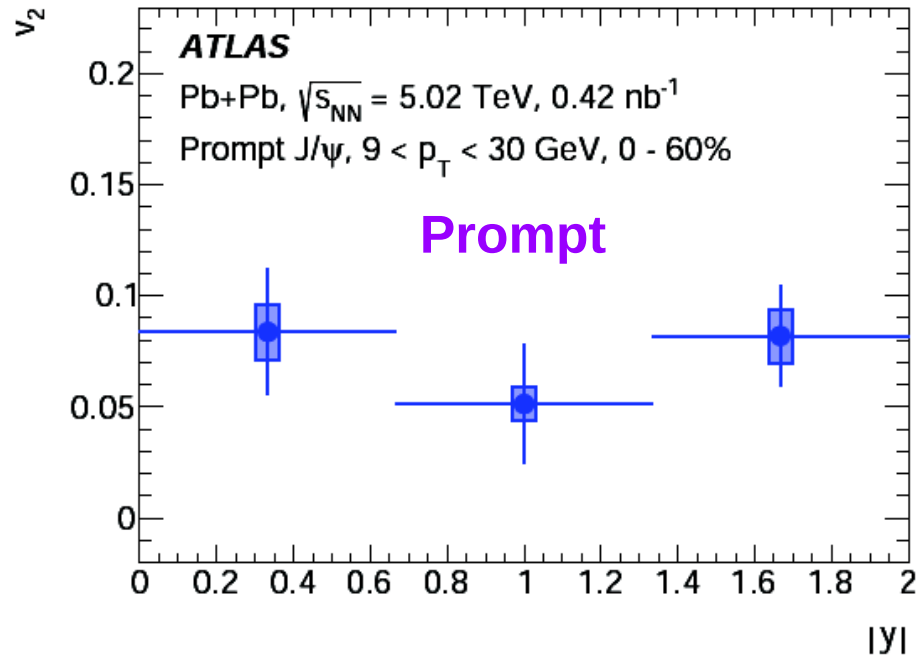
$$\frac{\Sigma E_T^{\text{Backwards}}}{\langle \Sigma E_T^{\text{Backwards}} \rangle} = \frac{\langle \Sigma E_T^{\text{Backwards}} \rangle_{\text{cent}}}{\langle \Sigma E_T^{\text{Backwards}} \rangle_{0-90\%}},$$



- v_2 using event plane method.
- Non-zero flow measured for both prompt and non-prompt J/ψ .
- No significant p_T , centrality, and rapidity dependence.



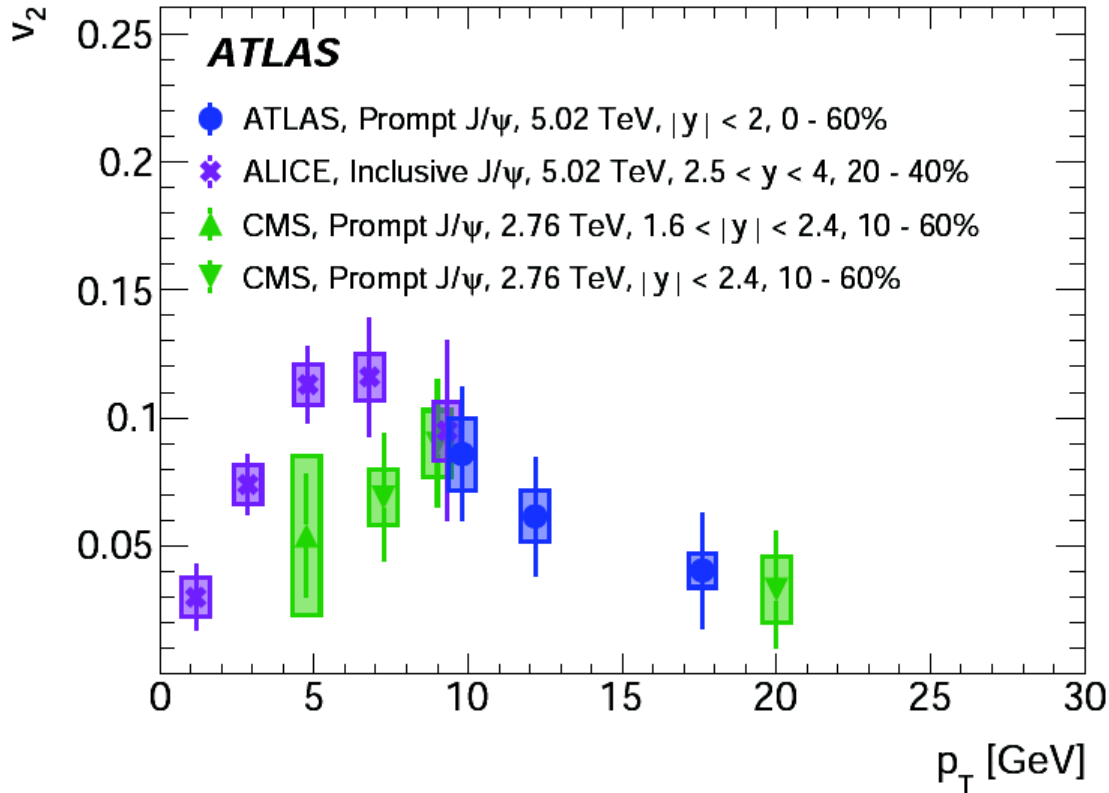
- v_2 using event plane method.
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- v_2 using event plane method.
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Charmonia flow in Pb+Pb

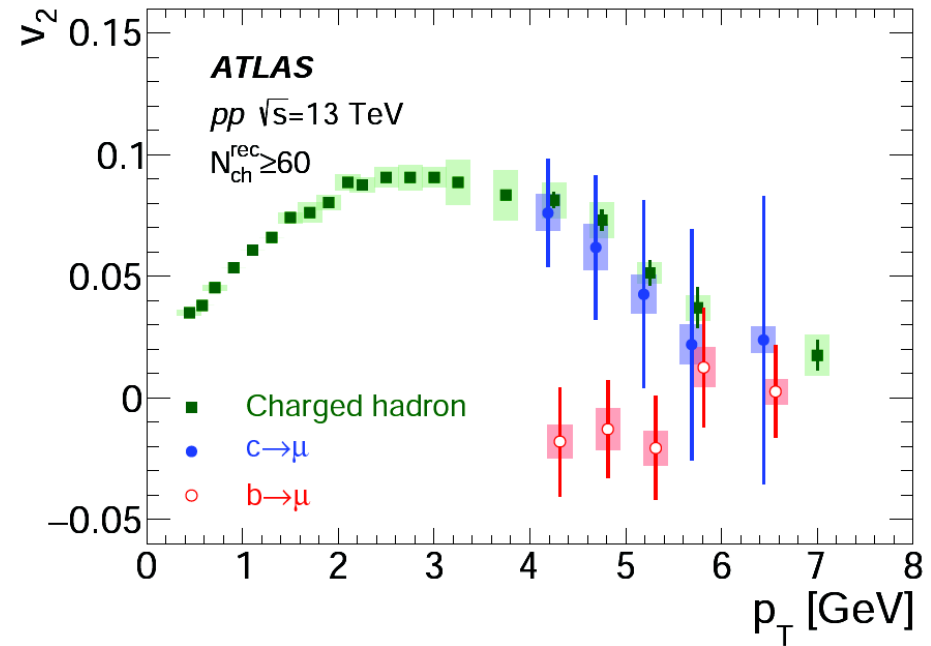
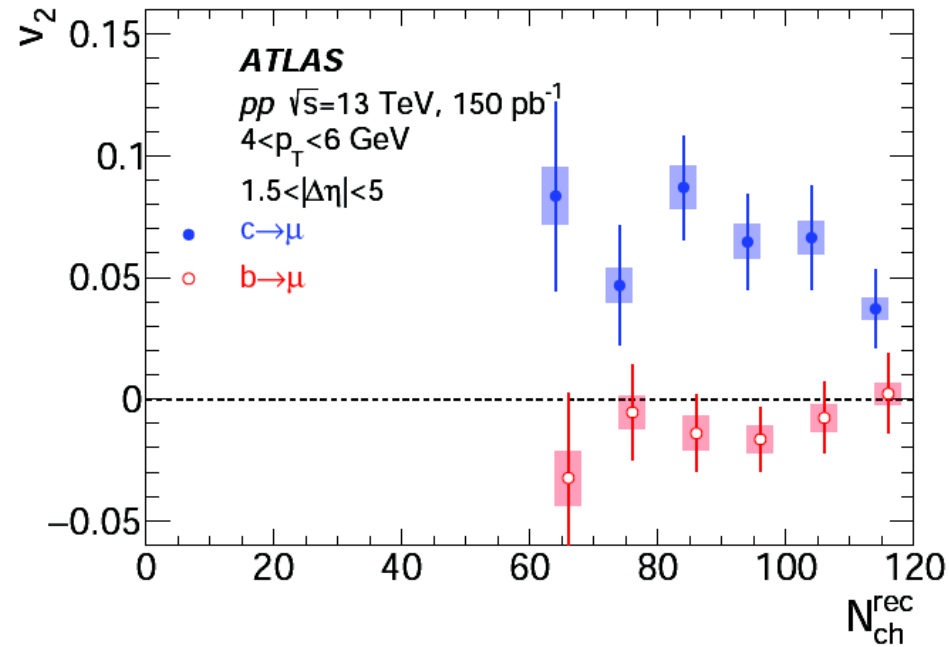
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- Results consistent among LHC experiments exhibiting **typical flow behavior**.

Heavy Flavor: one selected result

PRL 124 (2020) 082301



- Muons from heavy flavor decays, measured in 13 TeV pp collisions.
- μ from **charm**: non-zero v_2 , similar to inclusive **charged hadrons**.
- μ from **beauty**: quark v_2 consistent with zero.
- **Collectivity** in pp does not persist to heavy b-quarks.

Summary of results



- J/Psi elliptic flow in 5.02 TeV Pb+Pb EPJC 78 (2018) 784
 - J/Psi and Psi(2S) production in 5.02 TeV Pb+Pb and pp EPJC 78 (2018) 762
 - Quarkonia production in 5.02 TeV p+Pb and pp EPJC 78 (2018) 171
 - J/Psi production in 5.02 TeV p+Pb PRC 92, 034904 (2015)
 - J/Psi yields and observation of Z production in 2.76 TeV Pb+Pb PLB 697 (2011) 294
 - Measurement of Upsilon production in 5 TeV pp and Pb+Pb ATLAS-CONF-2019-054
- More results on **open heavy flavor** production and flow (not presented):
- HF muon flow in 5.02 TeV Pb+Pb PLB 807 (2020) 135595
 - HF muon+hadron correlations in 13 TeV pp PRL 124 (2020) 082301
 - R_{AA} and v_2 of muons from HF decays in 2.76 TeV Pb+Pb PRC 98 (2018) 044905
 - D meson production in p+Pb collisions ATLAS-CONF-2017-073

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults>

Backup slides

Landscape of the suppression measurements

