Recent heavy-flavor and quarkonium measurements with the ATLAS detector

Alexandre Lebedev for the ATLAS collaboration

IS2021

The VI[th] International Conference on the

INITIAL STAGES OF HIGH-ENERGY NUCLEAR COLLISIONS

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Israel, Weizmann Institute of Science, The David Lopatie Conference Centre

Why heavy flavor?

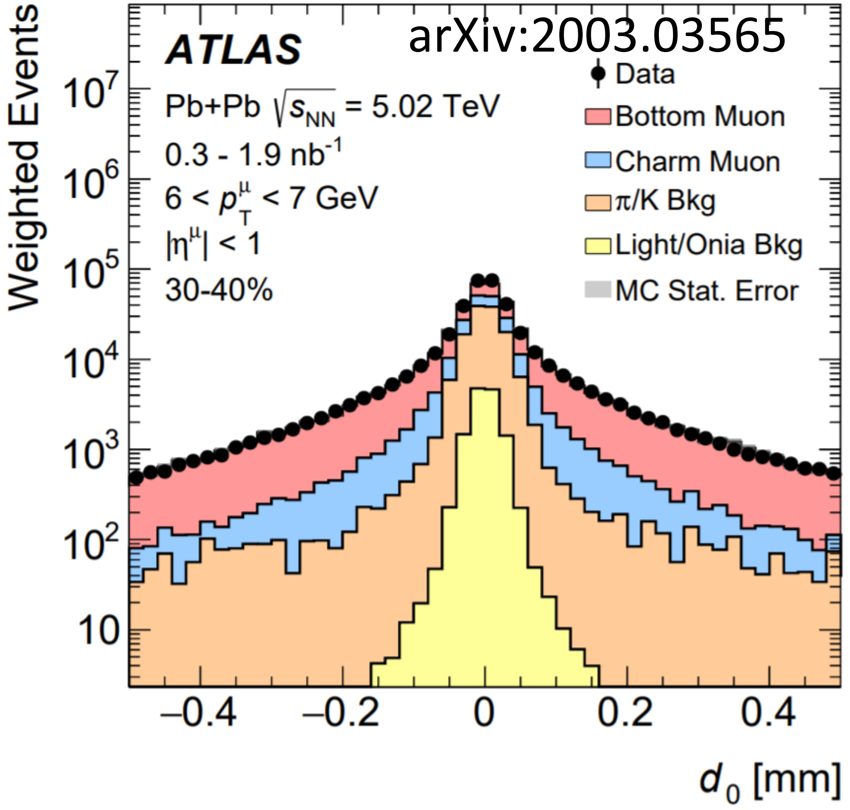
- Heavy quarks are produced in initial hard scatterings
  - carry information about all stages of the collision
  - production can be calculated with pQCD ($m_b > m_c > \Lambda_{QCD}$)
- Probe QGP through energy loss mechanisms
  - collisional + radiative
  - mass hierarchy, flavor dependence.
- Keep identity after hadronization

Heavy flavor signal extraction

Open charm and beauty are separated from light flavors using

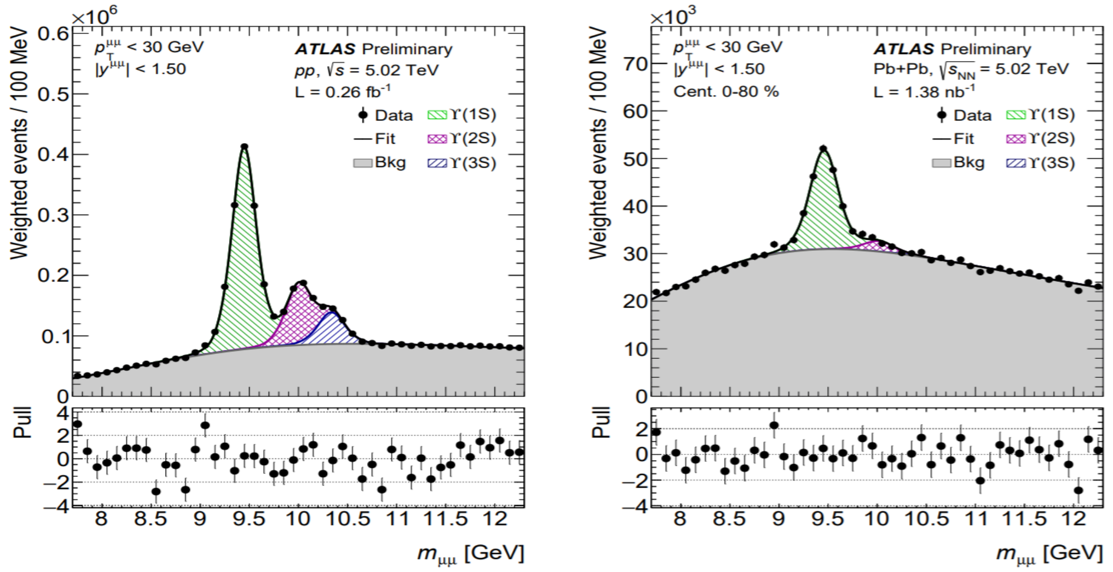
a) Momentum imbalance between n the measurements in the tracking detector and in the muon spectrometers.

b) Distance of Closest Approach (DCA) distribution unfolding with templates obtained from MC. (based on difference of lifetimes for charm and beauty mesons).

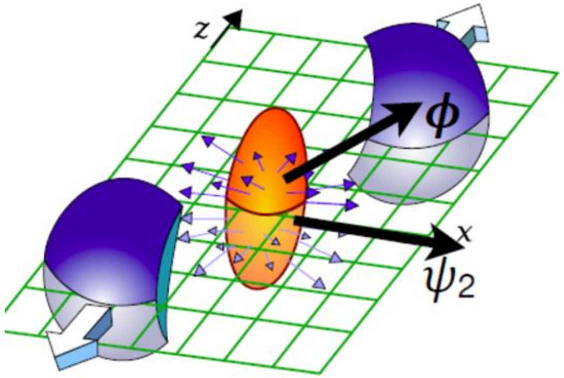


Upsilons are identified using di-muon invariant mass distributions

ATL-COM-PHYS-2019-965

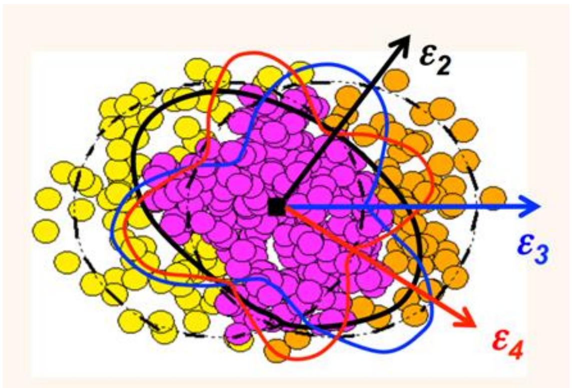


Flow phenomenon



Spatial asymmetry represented by eccentricity ε_n

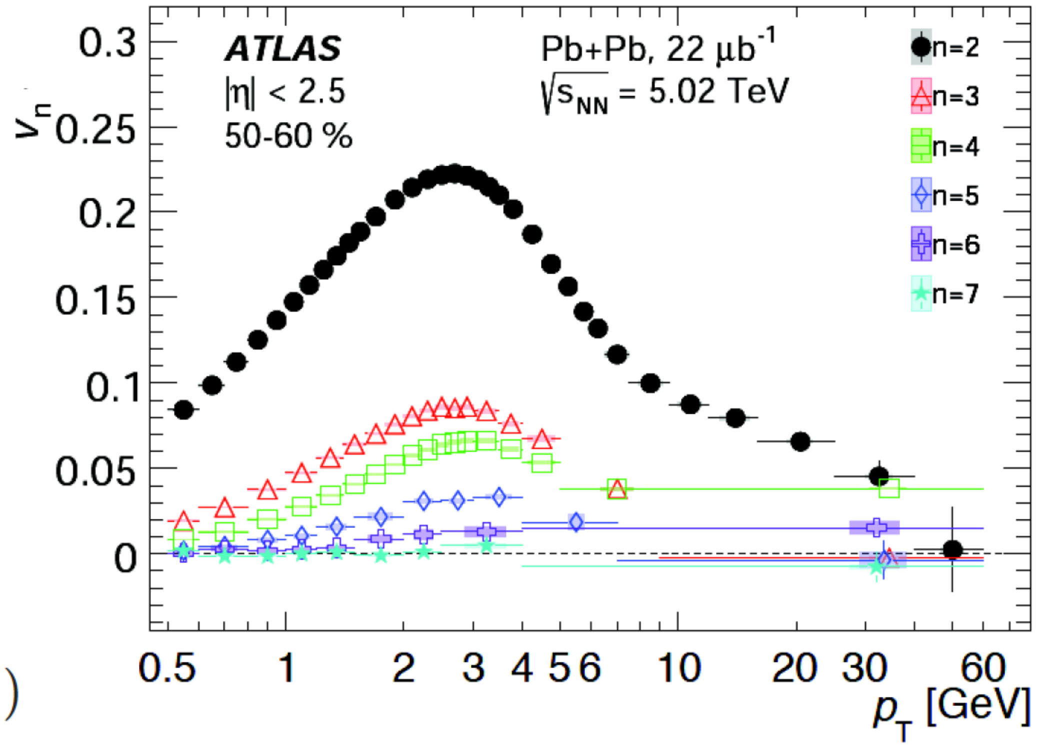
$$\varepsilon_n = \frac{\sqrt{\langle r^n \cos(n\phi)\rangle^2 + \langle r^n \sin(n\phi)\rangle^2}}{\langle r^n\rangle}$$



translates into momentum flow described by Fourier transform coefficients v_n

$$\frac{dN}{d\phi} \propto 1 + \sum_n 2v_n\left(p_T\right)\cos\left(n\left(\phi - \psi_n\right)\right)$$

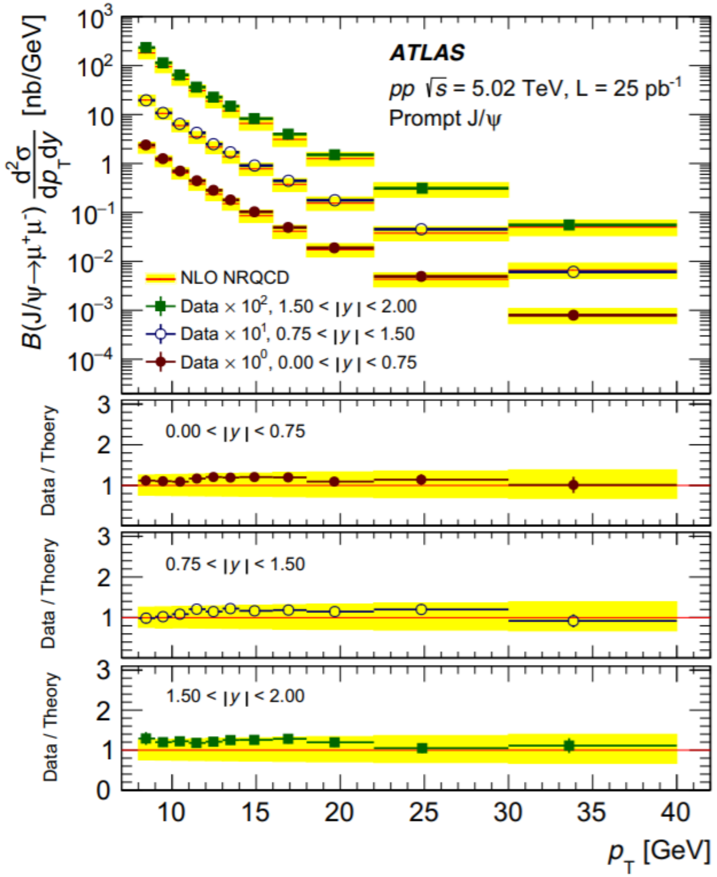
EPJC 78 (2018) 997



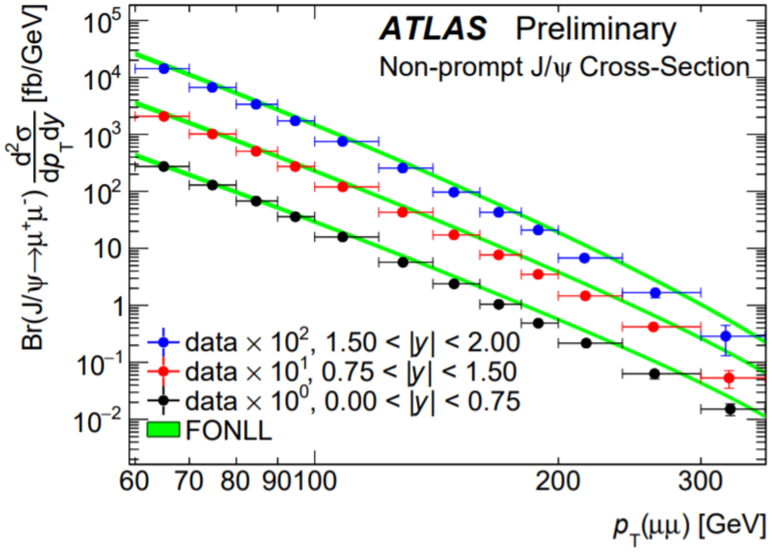
- HF flow can be used to discriminate between models of heavy-quark energy loss and constrain heavy-quark transport coefficients in the QGP.
- Observed in high multiplicity p+p collisions too.
- ATLAS made precision measurements reaching high p_T and high n available.

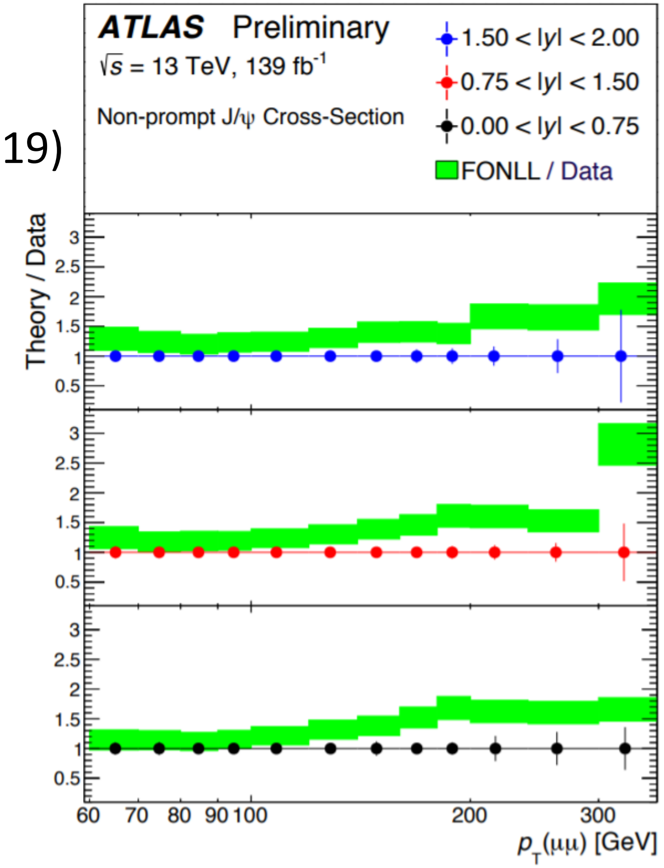
Heavy flavor in p+p

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



ATLAS-CONF-2019-047 (October 2019)





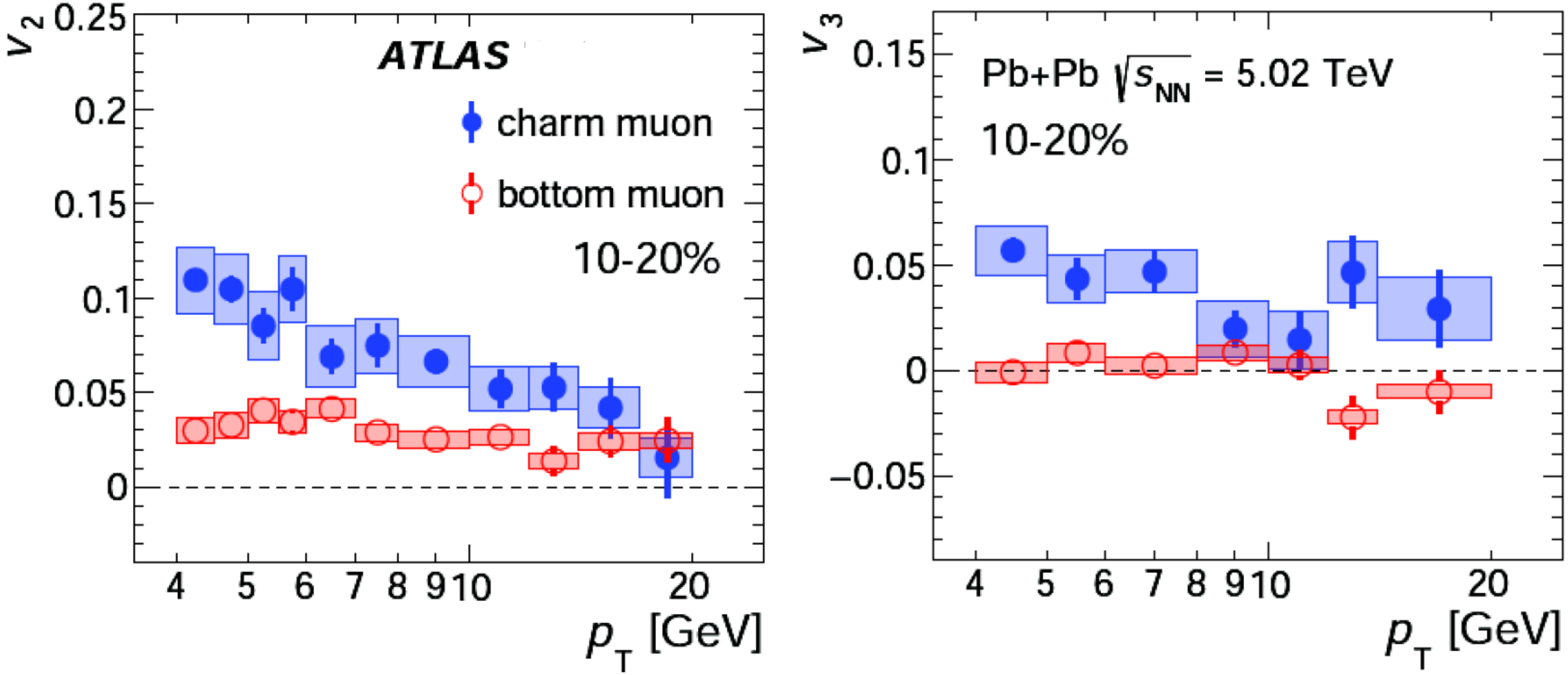
- General features of heavy flavor production are more-or-less well understood in p+p, although theory uncertainties are rather large.
- Baseline for nucleus-nucleus collisions study

Open heavy flavor

Charm and beauty flow in Pb+Pb

Muons from HF decays

Phys.Lett.B 807 (2020) 135595

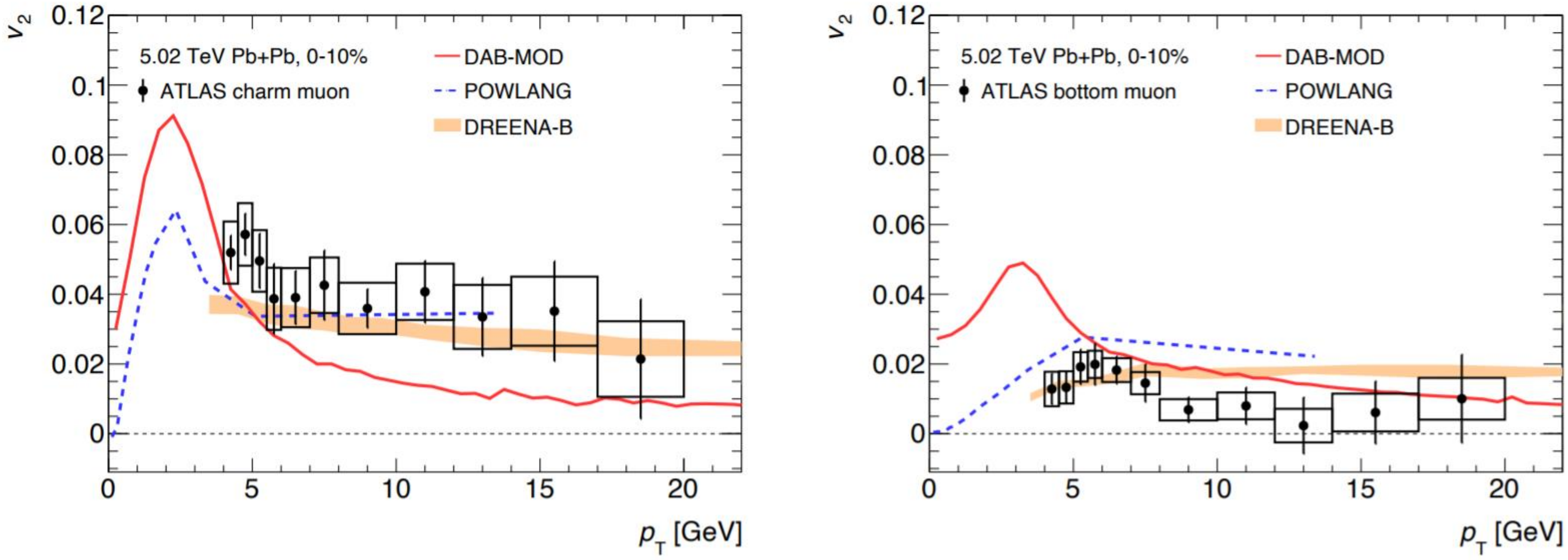


- Charm: non-zero v_2 and v_3 up to 20 GeV/c
- Beauty: smaller but non-zero v_2
- First measurement of beauty v_3 consistent with zero at all centralities.

Theory comparison v_2

DAB-MOD arXiv:1906.10768
POWLANG arXiv:1712.00588
DREENA-B arXiv:1805.04786
Data points arXiv:2003.03565

charm **bottom**



- Good matching for DREENA-B *(dynamic energy loss in 1+1D expanding QCD medium)*
- POWLANG *(transport model based on Langevin equation with collisional Eloss)* shows worse matching for beauty
- DAB-MOD does not describe well charm at low p_T *(2D+1 viscous hydrodynamic expansion with event-by-event fluctuations)*

Theory comparison v_3

DAB-MOD arXiv:1906.10768
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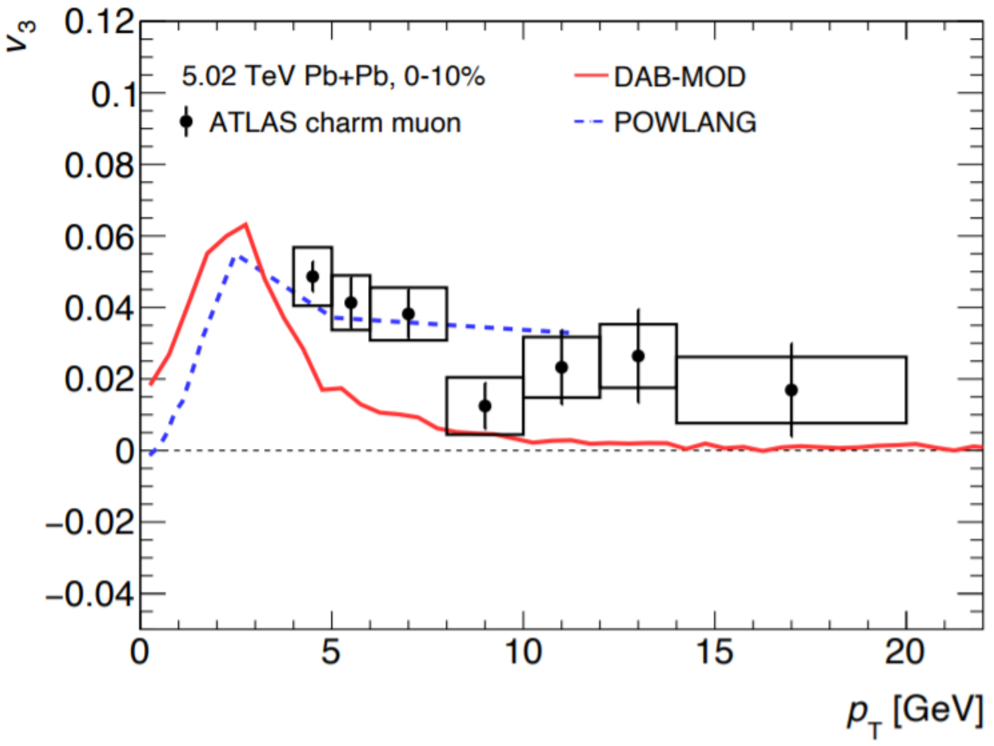
Data points arXiv:2003.03565

charm



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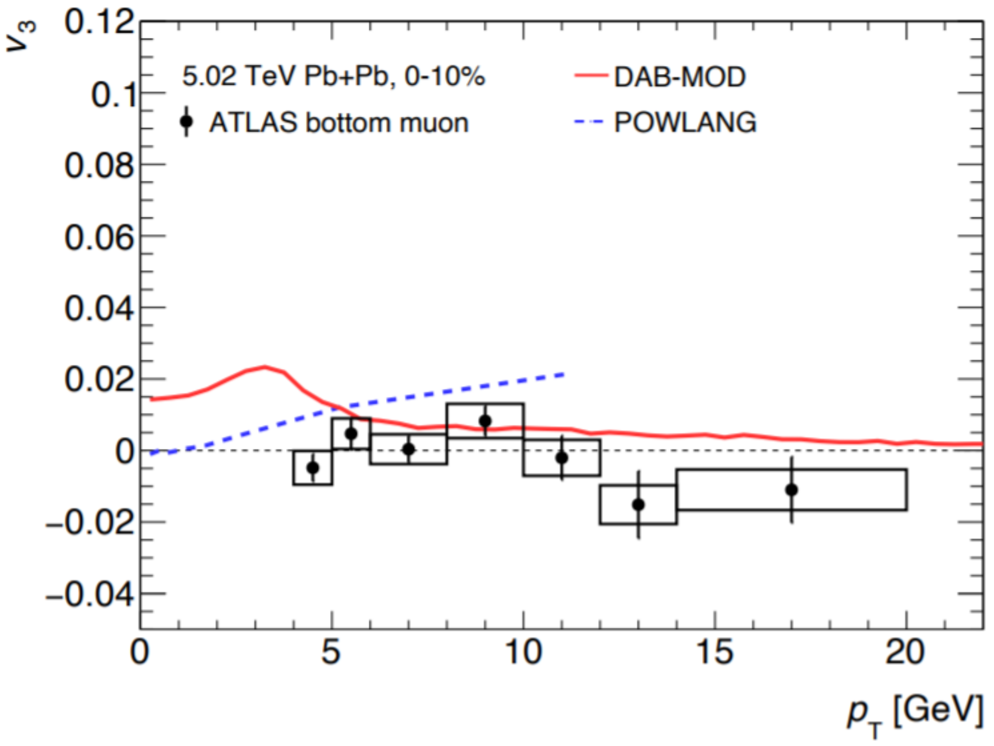
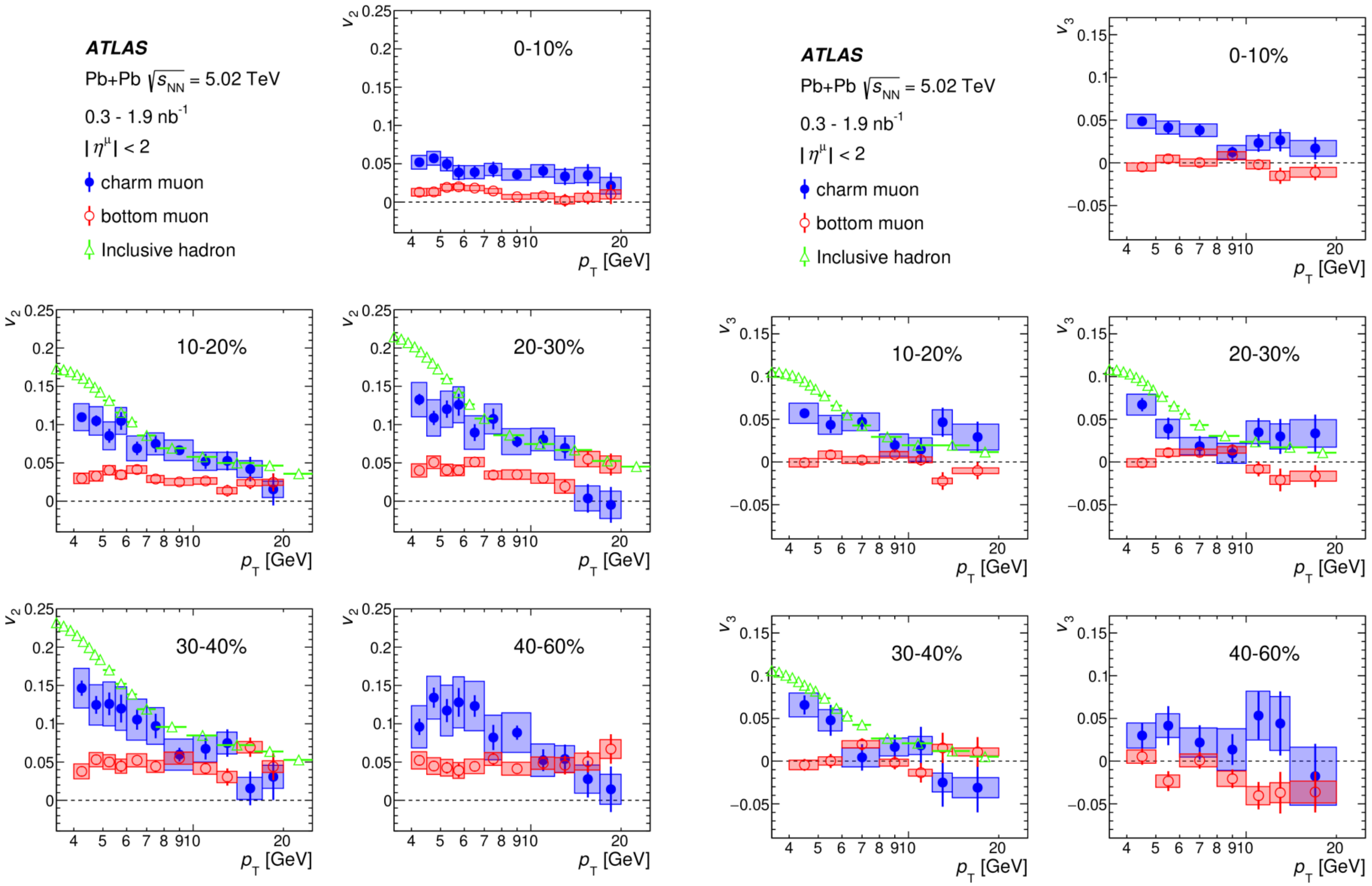


Similar model behavior for v_3

Comparison to light flavors

Phys. Lett. B 807 (2020) 135595

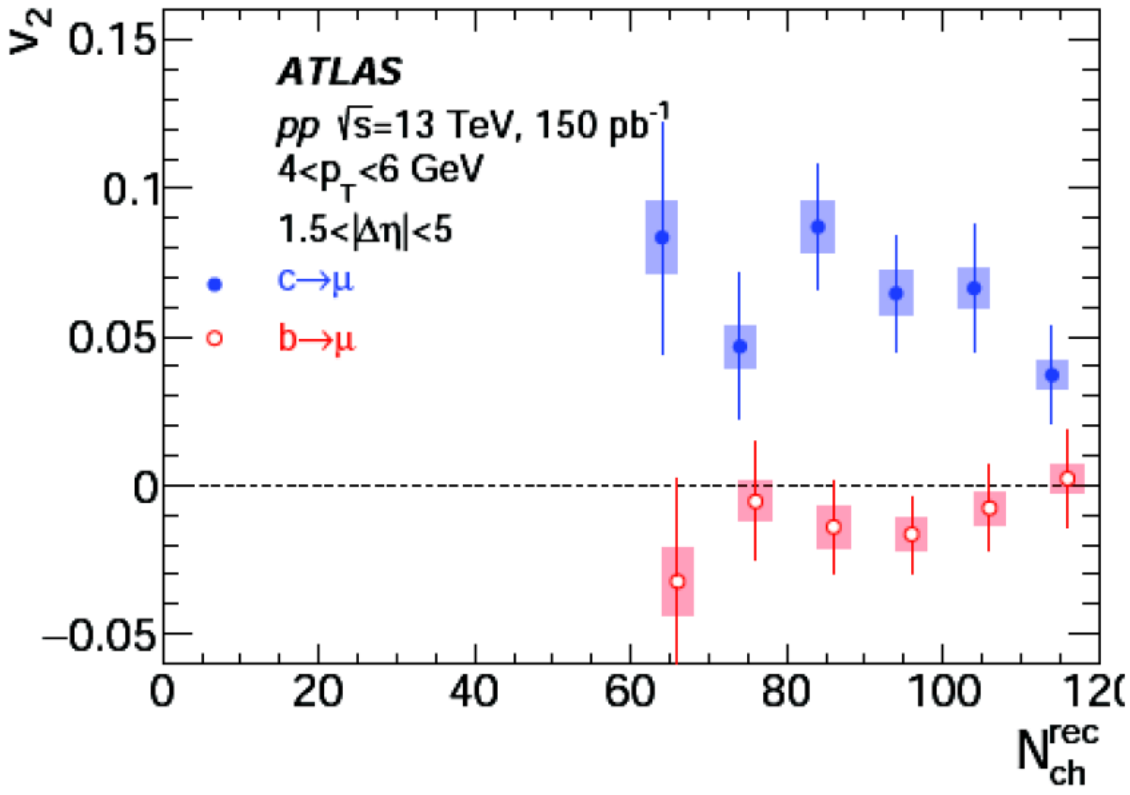


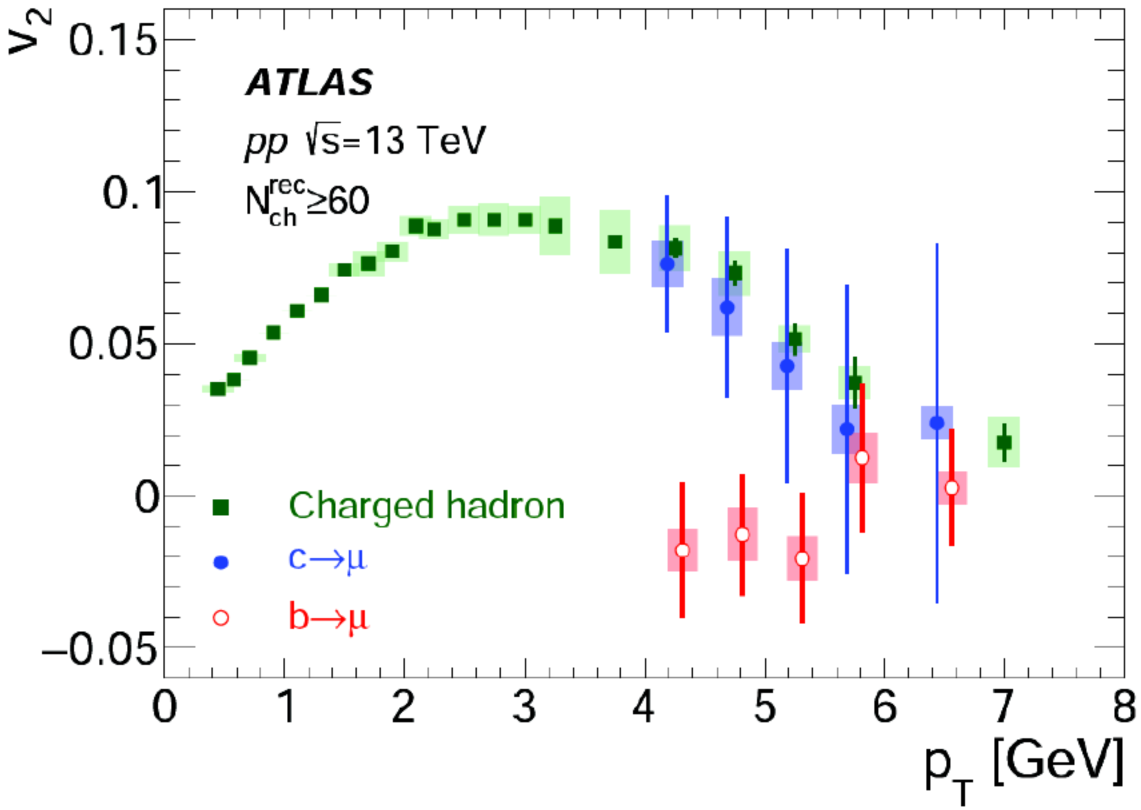
For both v_2 and v_3 charm flow is similar to light flavors, while beauty flows significantly less

Charm and beauty flow in p+p

Muons from HF decays

PRL **124** 082301 (2020)



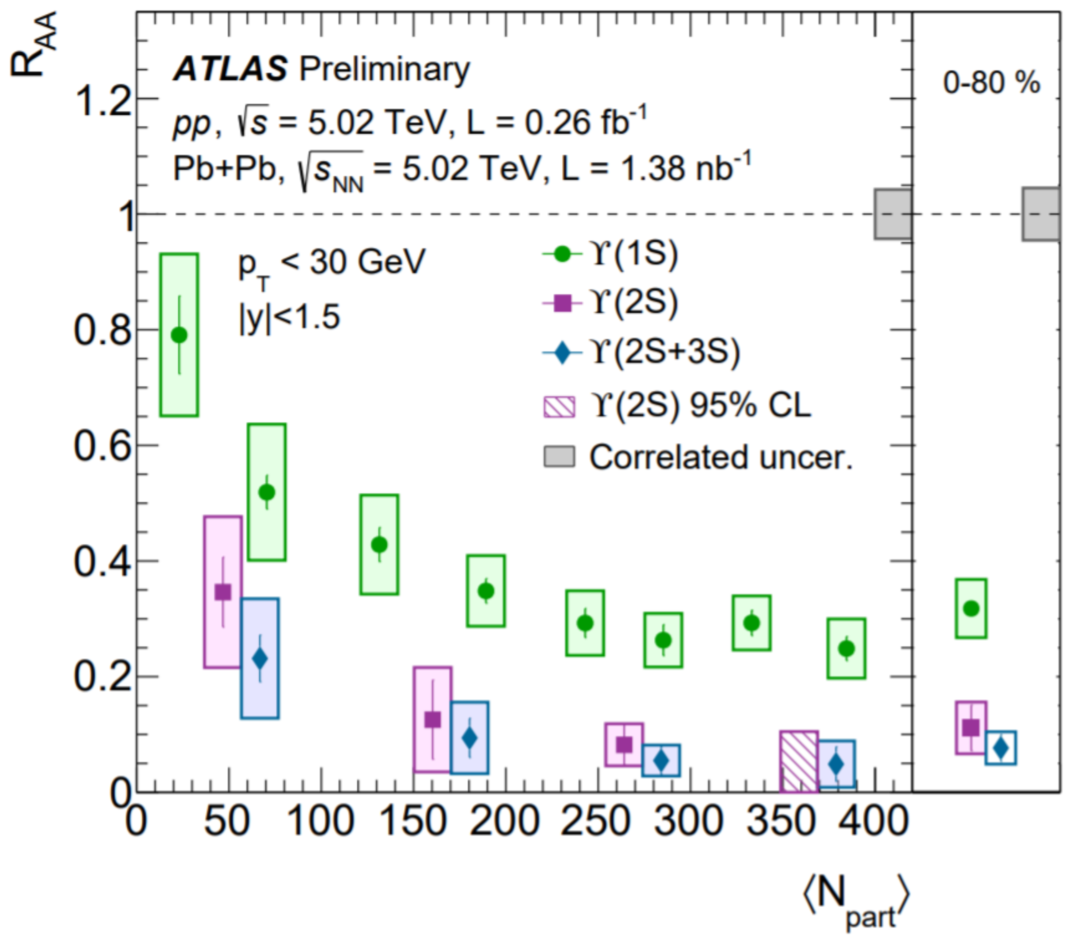


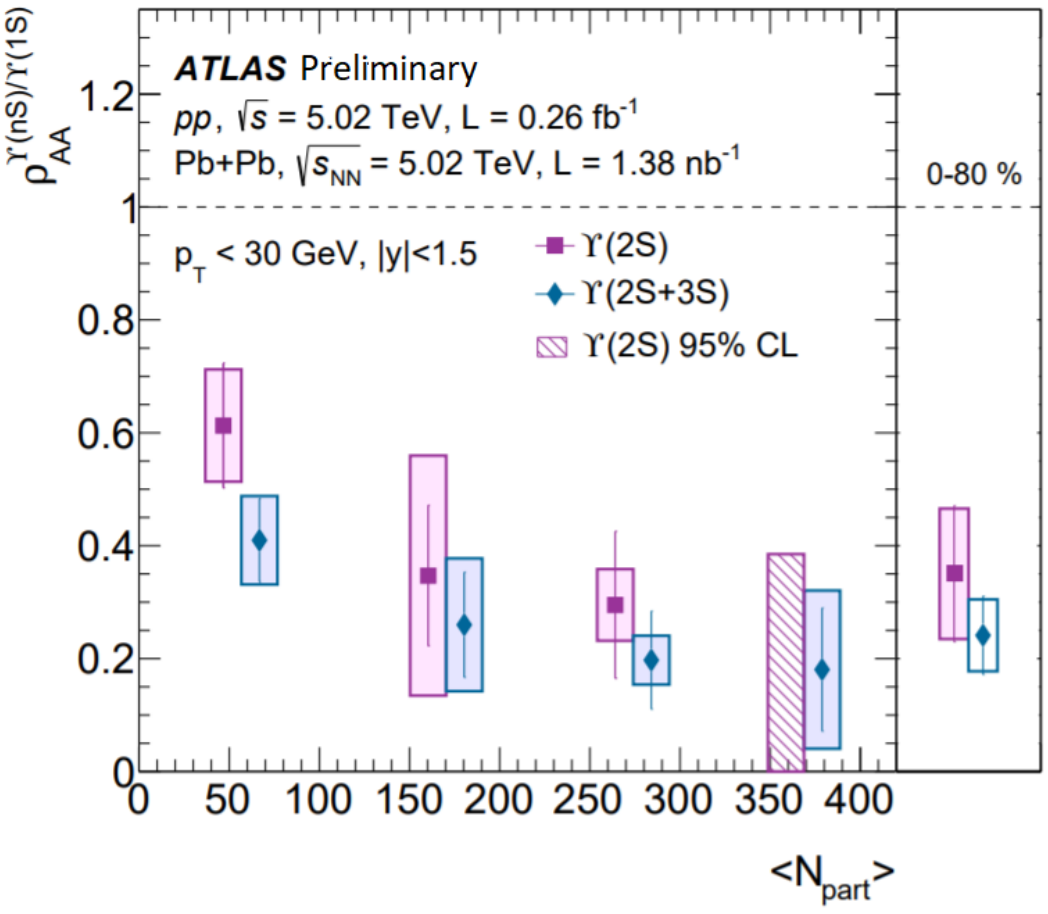
- Flow observed in high multiplicity p+p collisions too
- Charm flow the same as light quark flow.
- No beauty flow

Quarkonia

Upsilon suppression in Pb+Pb

ATLAS-CONF-2019-054

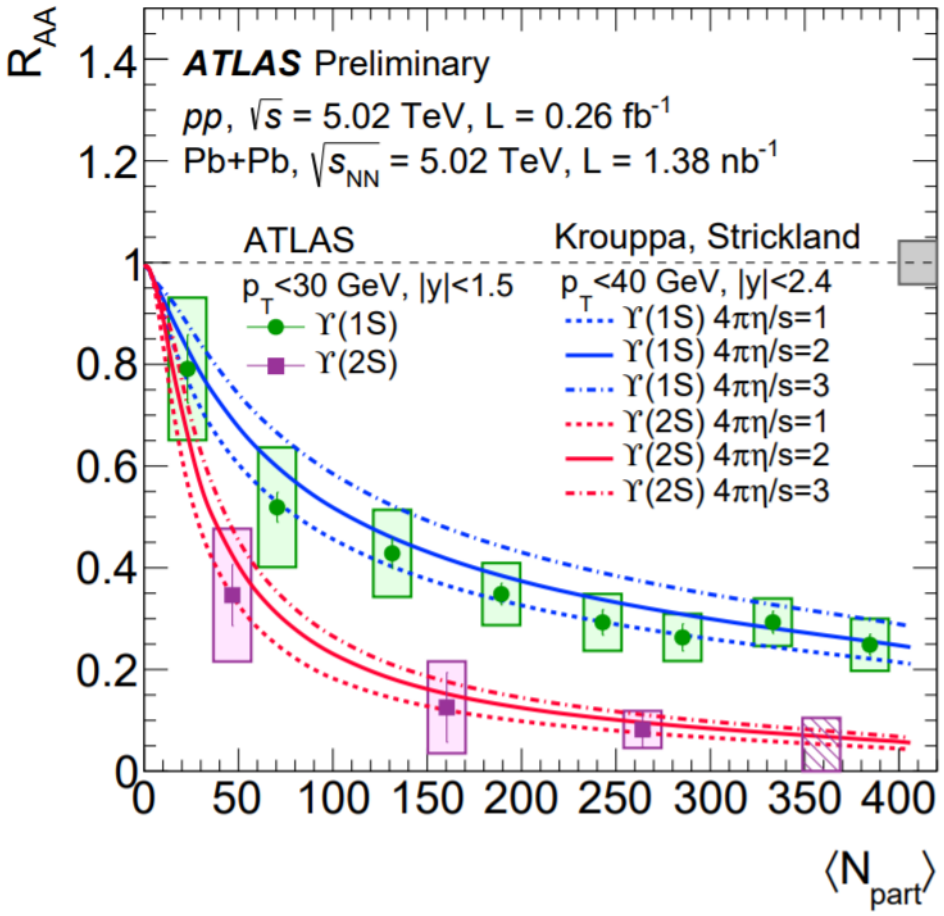


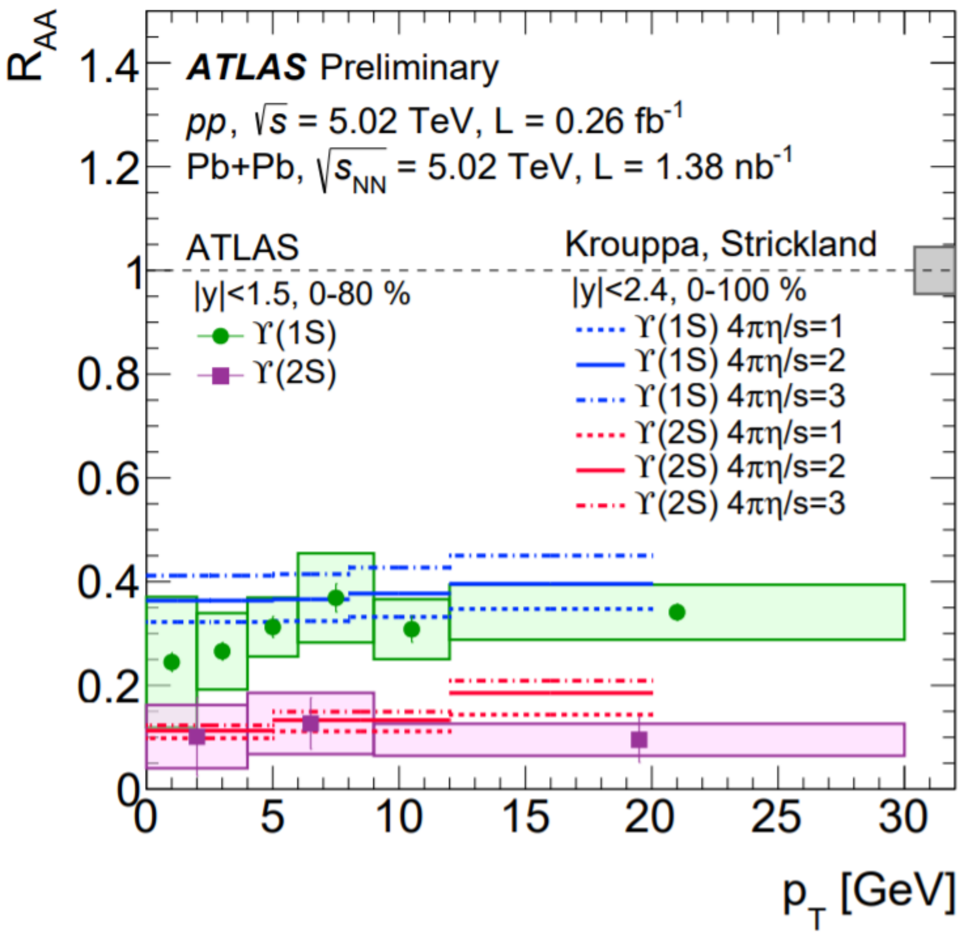


Expected order of suppression, larger suppression in central collisions.

Theory comparison

ATLAS-CONF-2019-054



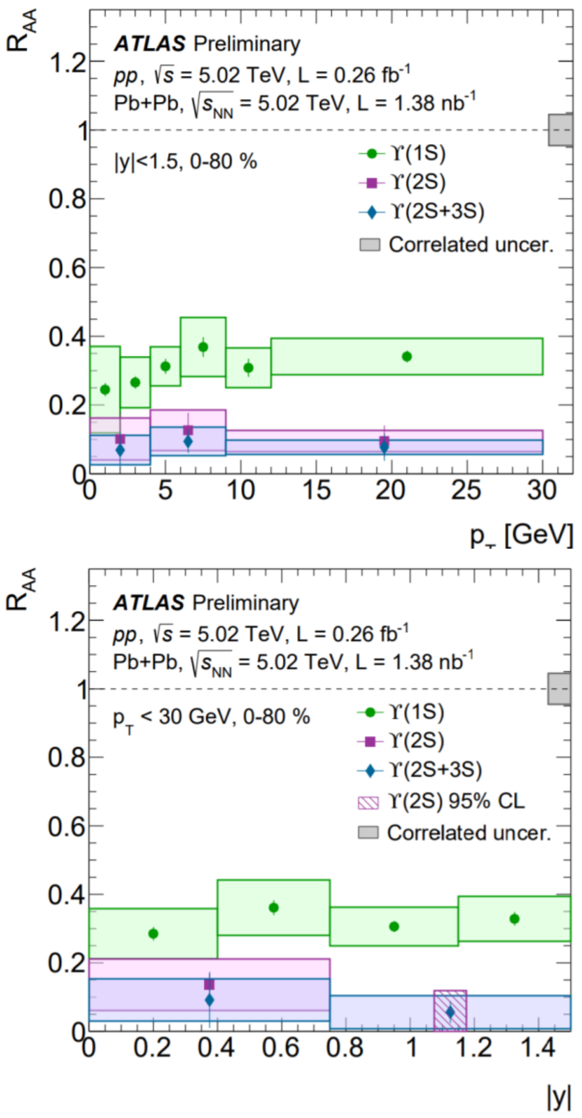


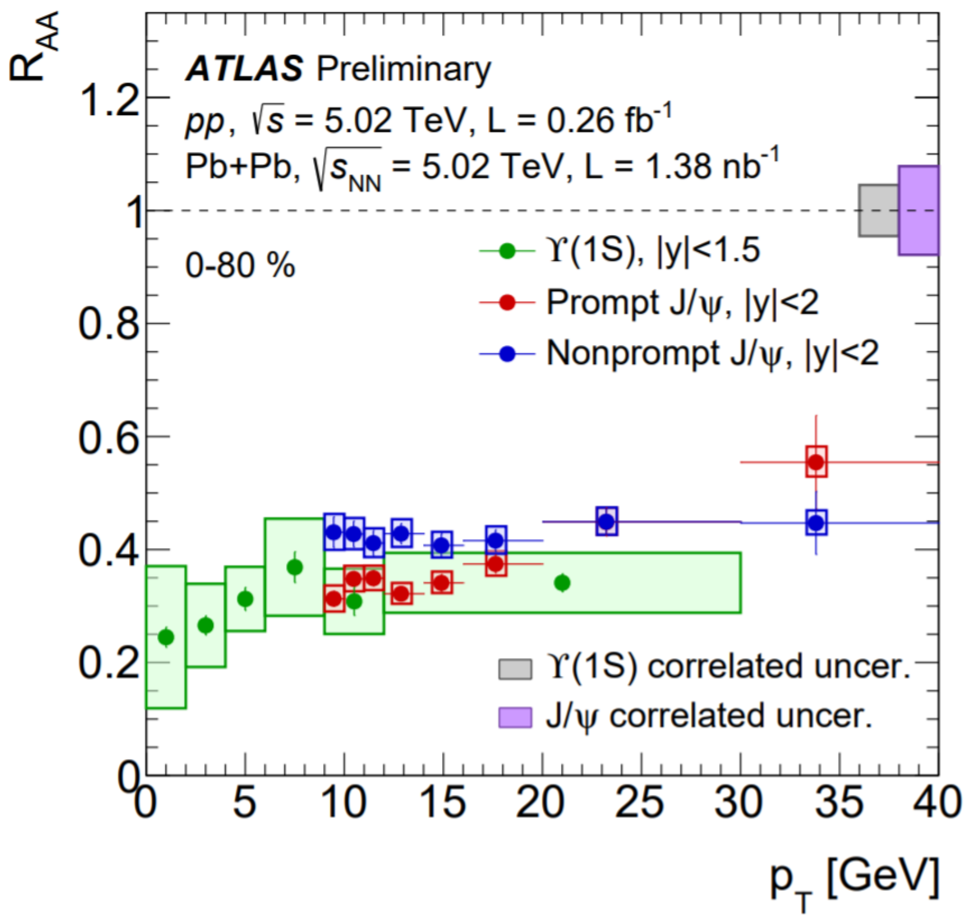
Krouppa, Strickland, (Universe 2 (2016) 16):

- Includes color screening and feed-down. Temperature range: 629-641 MeV

Upsilon suppression in more details

ATLAS-CONF-2019-054





Prompt J/ψ (charm) is consistent with Y(1S) despite different binding energy

⇨ different regeneration?

Non-prompt J/ψ (beauty) less suppressed than prompt, but still consistent with Y(1S).

⇨ many competing mechanisms?

No p_T or rapidity dependence for suppression

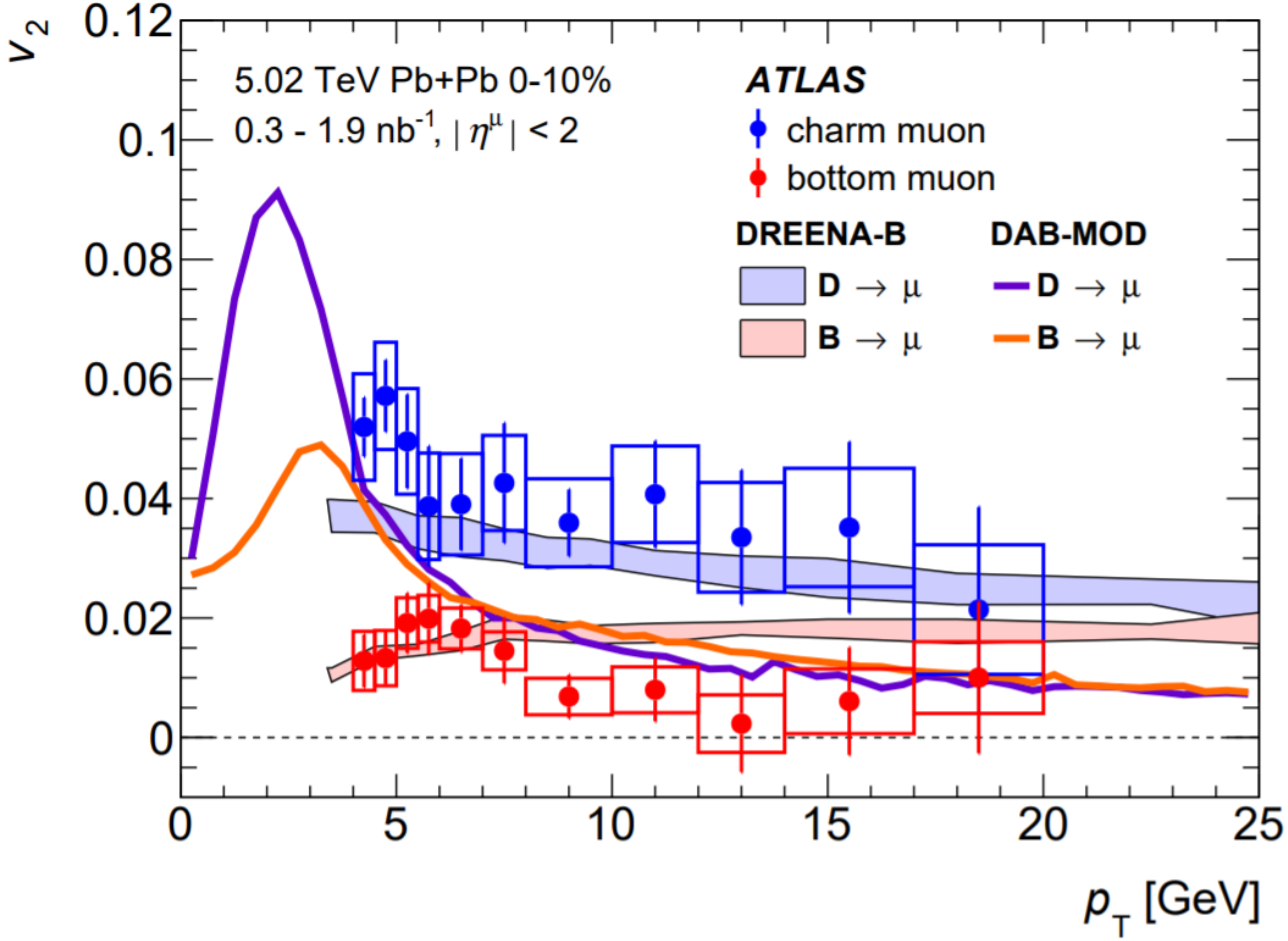
Conclusions

- General features of heavy flavor production in p+p collisions are reasonably well understood theoretically and can serve as a baseline for HI studies.
- In HI collisions both charm and beauty flow, with larger anisotropies for charm.
- Beauty v_3 is zero in HI collisions.
- In high multiplicity p+p collisions open charm flow is similar to light flavors, but no beauty flow..
- Upsilon suppression in Pb+Pb exhibits expected order, well described by theory.
- Comparison to J/ψ indicates importance of regeneration, many competing processes

Backup slides

Theory comparison for Pb+Pb

arXiv:2003.03565



Good matching of theory to data for DREENA-B (*PLB 791 (2019) 236*). *(dynamic energy loss in 1+1D expanding QCD medium)*

Matching of DAB-MOD (*Phys. Rev. C 96, 064903*) worse for the flow from charm. *(2D+1 viscous hydrodynamic expansion with event-by-event fluctuations)*