Round Table Discussion - Future (Near-term) Opportunities

❑ P_T Spectrum – Factorization:

$$\frac{d\sigma}{dy dp_T^2}$$ – NRQCD? So far, the most successful one

If $p_T^2 \gg m_V^2$, two-step factorization: pQCD + NRQCD or SCET + NRQCD

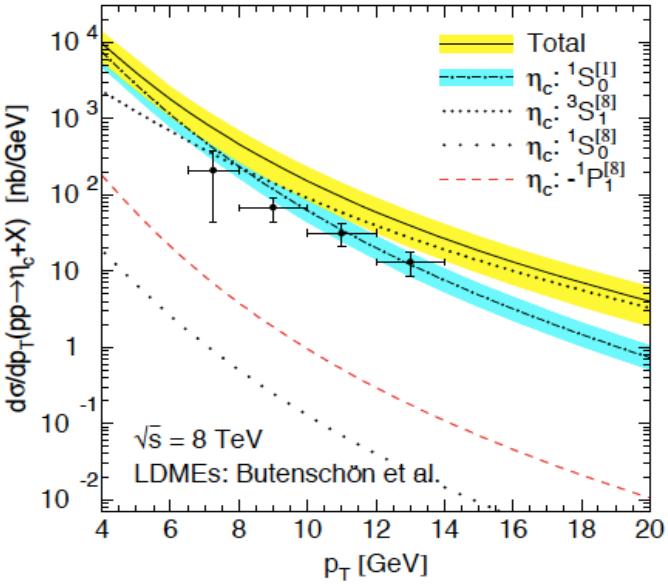
What about low p_T regime?

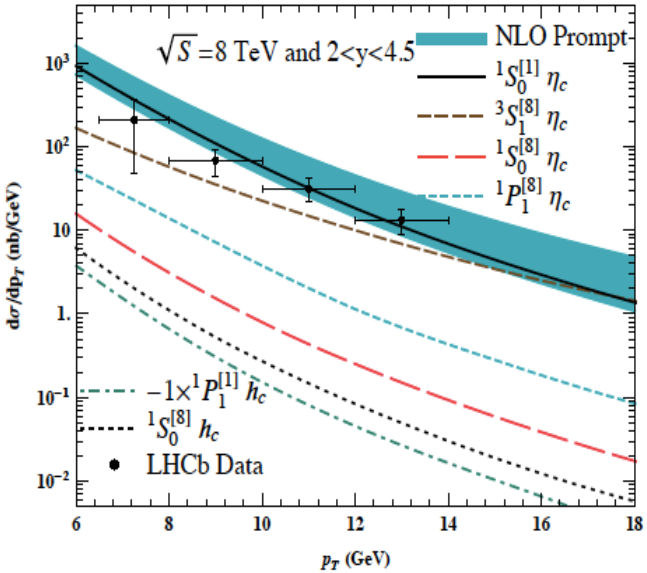
✧ Opportunities:

LHC, Belle-II on the yield of various quarkonium states: $J/\psi, \psi', \eta_c, \chi_c, \Upsilon, \ldots$

➡ Test the "Evolution of scale" (pQCD, SCET, …), jet structure, …
Test the "HQ Spin Symmetry" (NRQCD, …)

Round-table on Monday





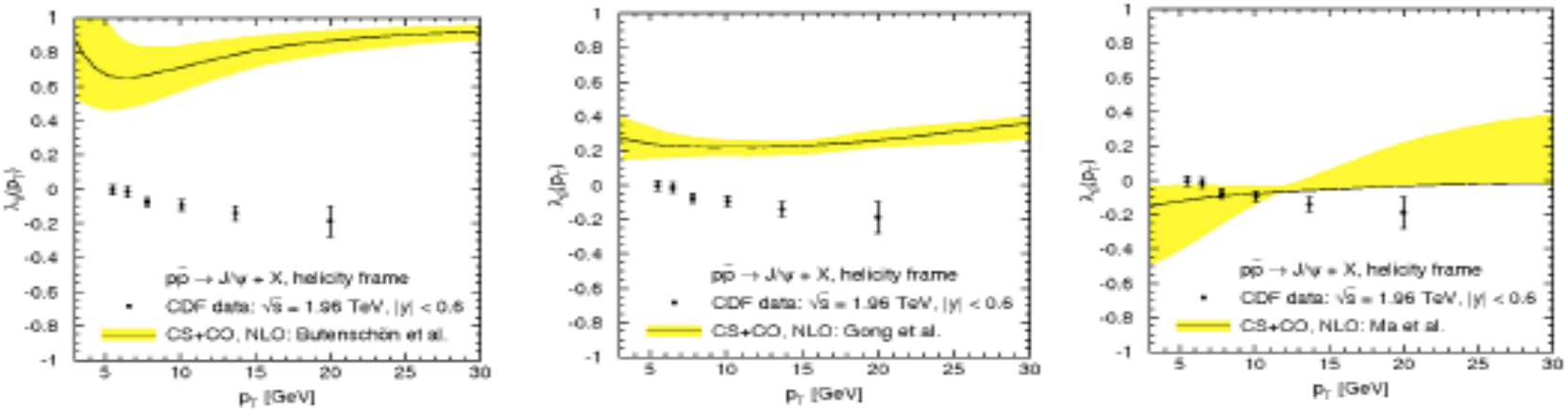
Exp: $p\bar{p}$

Any possible interference contribution from resonance and continuum?

Round Table Discussion - Future (Near-term) Opportunities

❑ Polarization – Factorization:

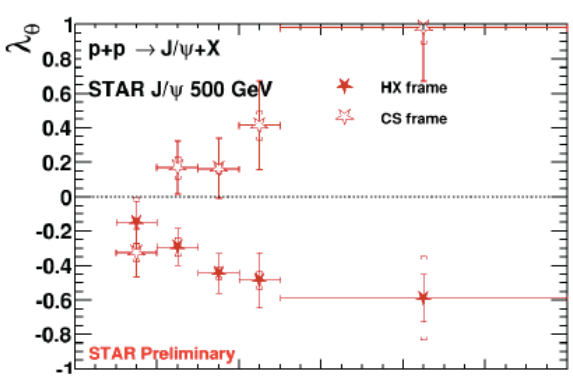
$$\frac{d\sigma}{dy dp_T^2 d\Omega}$$ – Role of physics at O(P_T) vs O(M_V)? "hadronization vs polarization"

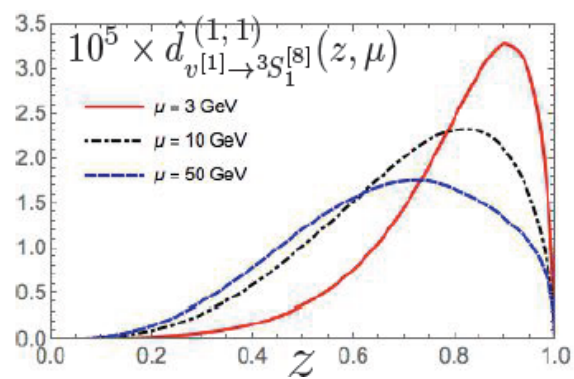


✧ Opportunities:

LHC, RHIC, Belle-II on the polarization at different scale

– Evolution of polarized FFs – octet evolves fast!





Round Table Discussion - Future (Near-term) Opportunities

❑ Total rate – Factorization:

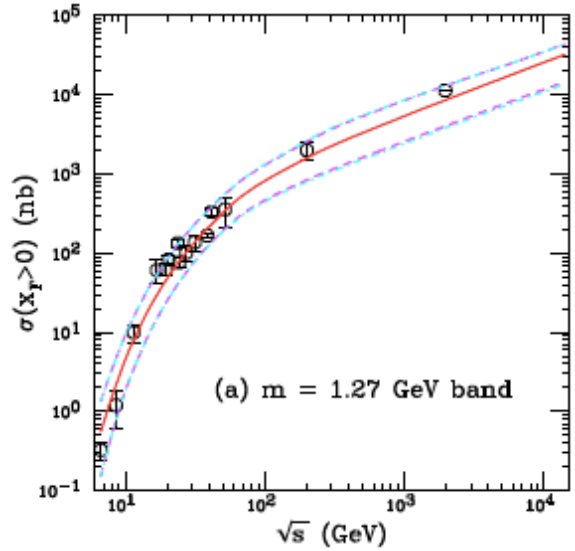
$$\frac{d\sigma}{dy},\ \sigma_{\rm total}(s)$$ – CEM

✧ Opportunities: s-dependence

LHC, Belle-II, BESIII, …

✧ Challenges:

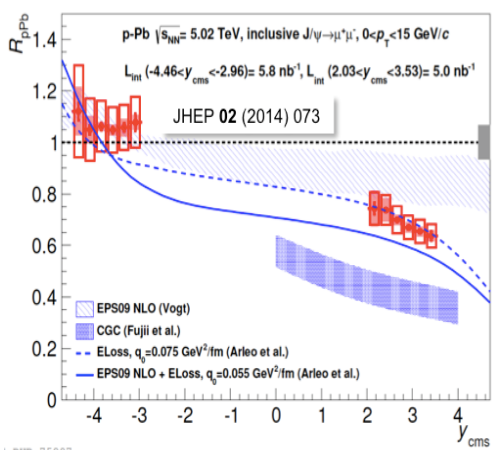
Calculate total rate in NRQCD, … ?

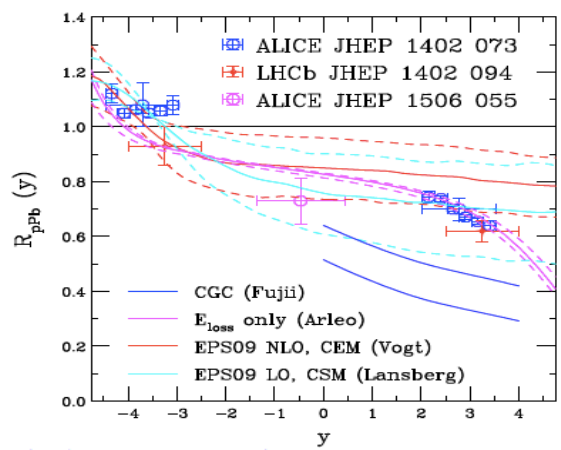


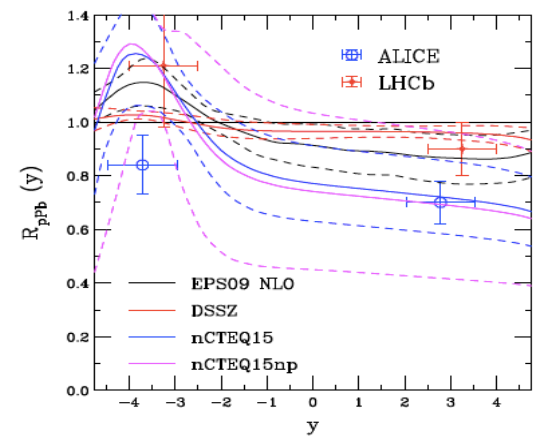
❑ Impact on "in Medium":

$$\frac{d\sigma^{pA}}{dy}\ \left(\text{or}\ \frac{d\sigma^{pA}}{dx_F}\right),$$

– Reliability of calculation – quark-pair vs quarkonium?
Formation of "quarkonium" inside vs outside medium?





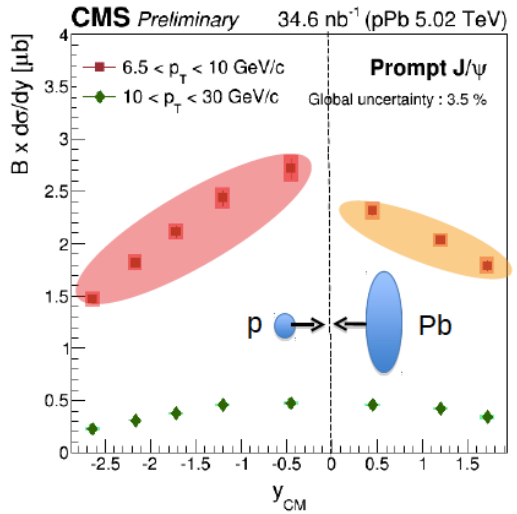


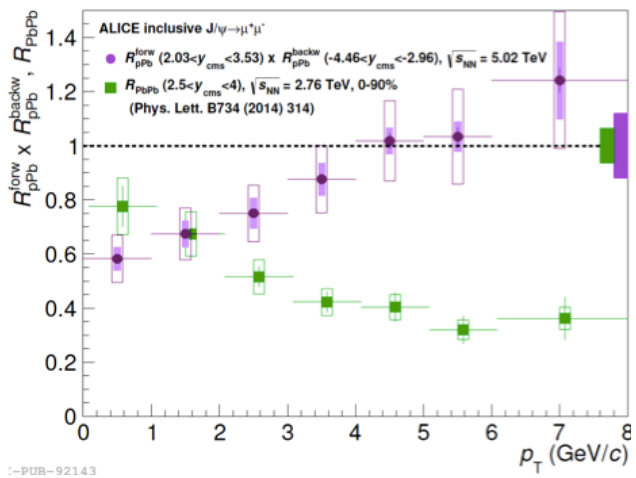
Round Table Discussion - Future (Near-term) Opportunities

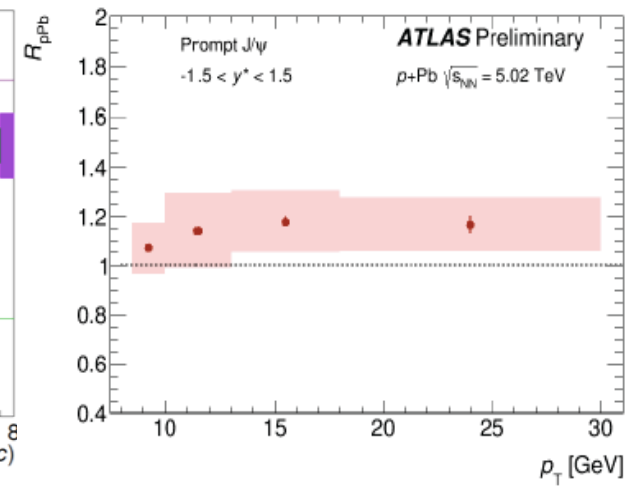
❑ In Medium – Nuclei as filters:

$$\frac{d\sigma^{pA}}{dy dp_T^2}$$

– Can p_T help improve the reliability of calculation, as well as the isolation of production mechanism(s)?





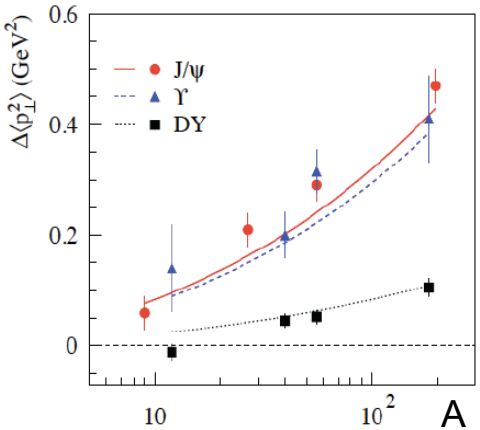


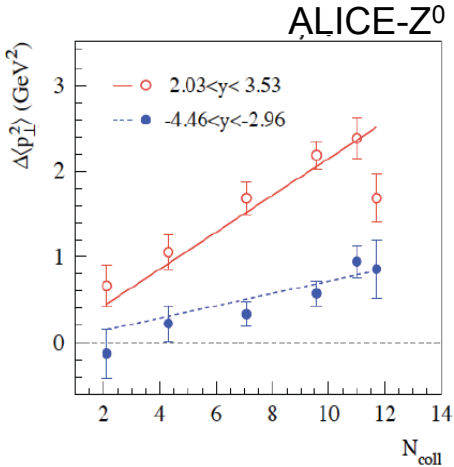
✧ Opportunities:

Existing data on pA from LHC, RHIC, …
LHC – fixed target (LHCb, After,…), …

✧ Challenges:

Validity of theory at low p_T, …
P_T-moments of the spectrum, …?





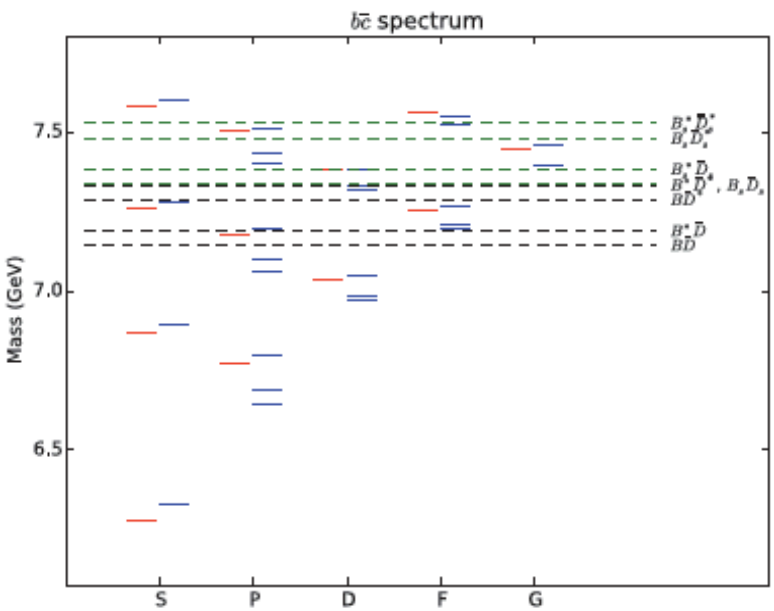
Estia's wish list – I

Round-table on Thursday

- The dynamics of the new states is likely a cocktail of the models so far proposed. Lattice QCD may provide some answers. More experimental data will also clarify the situation:
  - Resolve the status of (cc) new exotic states only seen by one experiment.
  - HQS predicts the expectations (cc) -> (bb) within a given model. Provides a test for various models.
  - e+e- -> $(j_l^P = \frac{1}{2}^-)_{HL}$ + X: Measure $M_X(s)$ for s < [4.6 (D); 5.42(D_s); 11.43 (B); 12.0 (B_s)]
- We see enhancements (resonances) at two heavy-light meson thresholds for I=1 channels. What about the rest of the SU(3) nonet?
  - For strange heavy-light meson pair thresholds: Resonances and hadronic transitions with single η and ϕ light hadrons?
    - No wide $j^P = \frac{1}{2}^+$ heavy-light mesons in charm or bottom systems -> no sequential transitions (as in the Υ(5S) system).
    - $M(D_s^+ D_s^{-*}) = 4{,}081$; $M(D_s^{+*} D_s^{-*}) = 4{,}225$; $M(2^3P_1) = 4{,}310$ MeV -> no analogy of X(3872).
    - Narrow $D_P(\frac{1}{2}^+) + D_S(\frac{1}{2}^-)$ thresholds? (and B analogs) - This is answered now
    - Also possible in decays of B mesons - D D_s*, D* D_s ,D*D_S* states.D D_s*

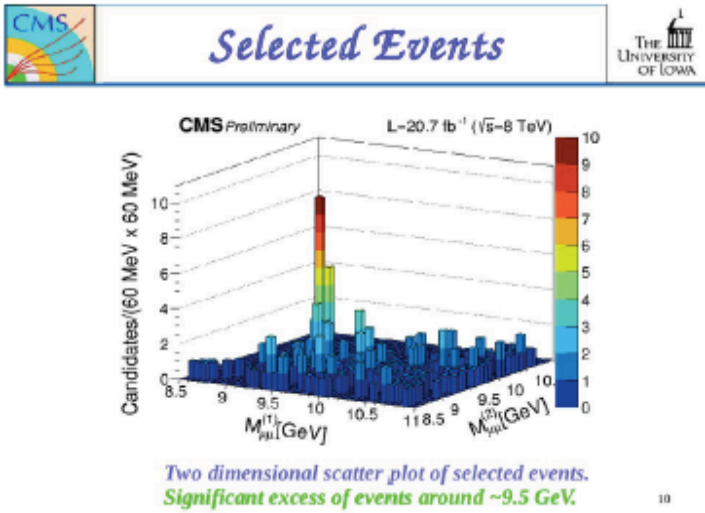
Estia's wish list – II

- Double heavy baryons - (ccq), (cbq), (bbq). Both HQET and NRQCD play a role in the excitation spectra.
  - double expansion
  - NRQCD for the two heavy quarks and HQET expansion for the heavy core (QQ) - light quark system.
  - In leading order in $1/m_Q$: Excitation spectrum for the light quark is same as for heavy-light mesons (HQET)
- B_c - a rich excitation spectrum of states.
  - Atlas observed: Bc(2S) -> Bc(1S) +ππ. The first radially excited state.
  - Many states observable at the LHC and a future TevaZ factory.
  - B_c is the unique heavy-heavy meson that only has weak direct decays.
  - Opportunities to study CKM and BSM physics.



Estia's wish list – III

- CMS at $\sqrt{s}$ = 8 TeV observes double Υ production in the $\mu^+ \mu^- \mu^+ \mu^-$ final state:
  - $\sigma(\bar{p}\bar{p} \to \Upsilon\Upsilon) = 68.8 \pm 12.7\,(\text{stat}) \pm 7.4\,(\text{syst})$ pb for $|y| < 2.0$ and $p_T^{\Upsilon} < 50$ GeV
  - Possible to search for heavy quark hadrons $(c\bar{c}c\bar{c})$, $(c\bar{b}b\bar{c})$, $(b\bar{b}b\bar{b})$
  - Quarkonium states increasingly bound as heavy quark mass increases. What about tetraquark states?

Are there any narrow deeply bound tetraquark states?

Maksat Haymyradov: APS April meeting