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Study of J/ψ production with jet activity in the STAR experiment

Hao Huang for the STAR collaboration

National Cheng Kung University

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APS physics

Introduction and motivation

➢ J/ψ meson

- The J/ψ production involves both perturbative and non-perturbative processes.

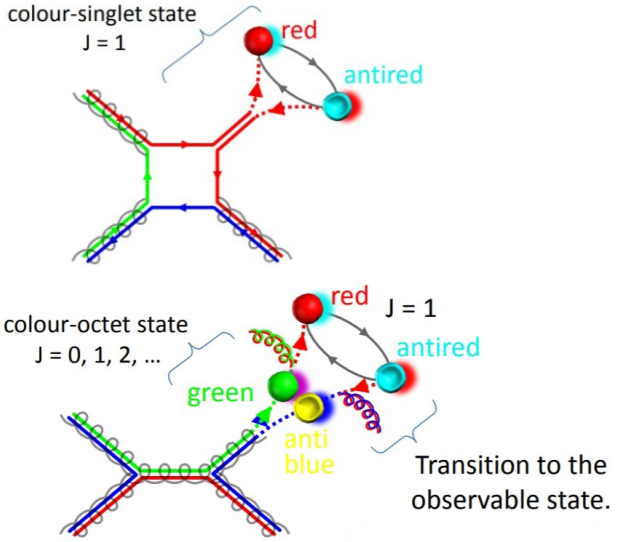
  ➡ Provide fruitful information on Quantum Chromodynamics (QCD)

- The production cross section of J/ψ can be well described by non-relativistic QCD (NRQCD) framework (CMS Collaboration, J. High Energ. Phys. 2012, 11 (2012))
- However, the almost zero polarization of J/ψ from the measurements is not consistent with the NRQCD prediction (CMS Collaboration, Phys. Lett. B 727, 381 (2013))

➢ J/ψ production associated with jet activity

- Quarkonium production from the Color Singlet Model (CSM) should result in a larger jet activity (number of jets per event) than that from the Color Octet Mechanism (COM) (Physics Reports, 889, 1 (2020))

  ➡ An alternative way to distinguish CSM and COM

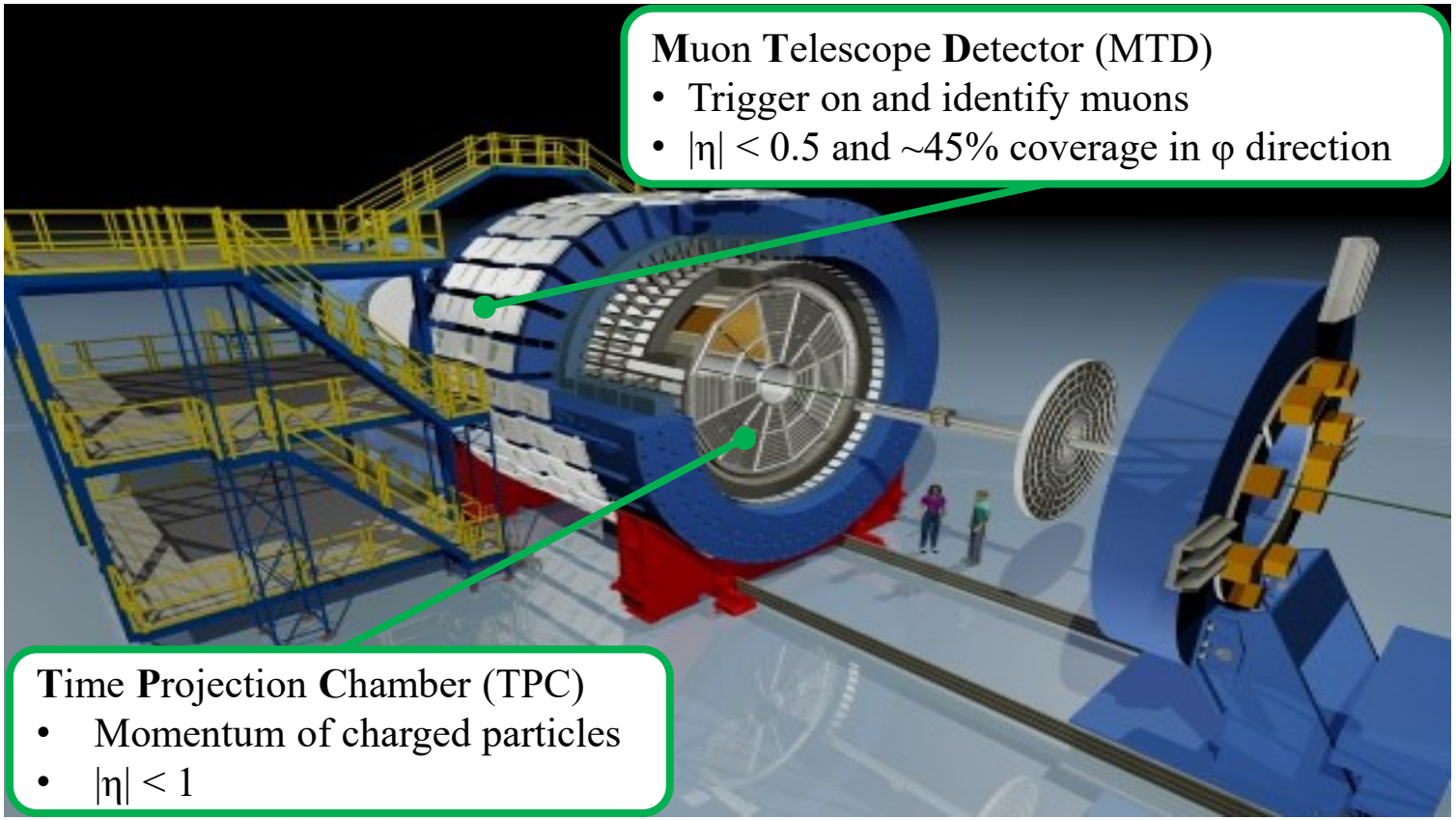


(Pietro Faccioli, Course on Physics at the LHC (2013))

- Color Singlet Model (CSM) and Color Octet Mechanism (COM)

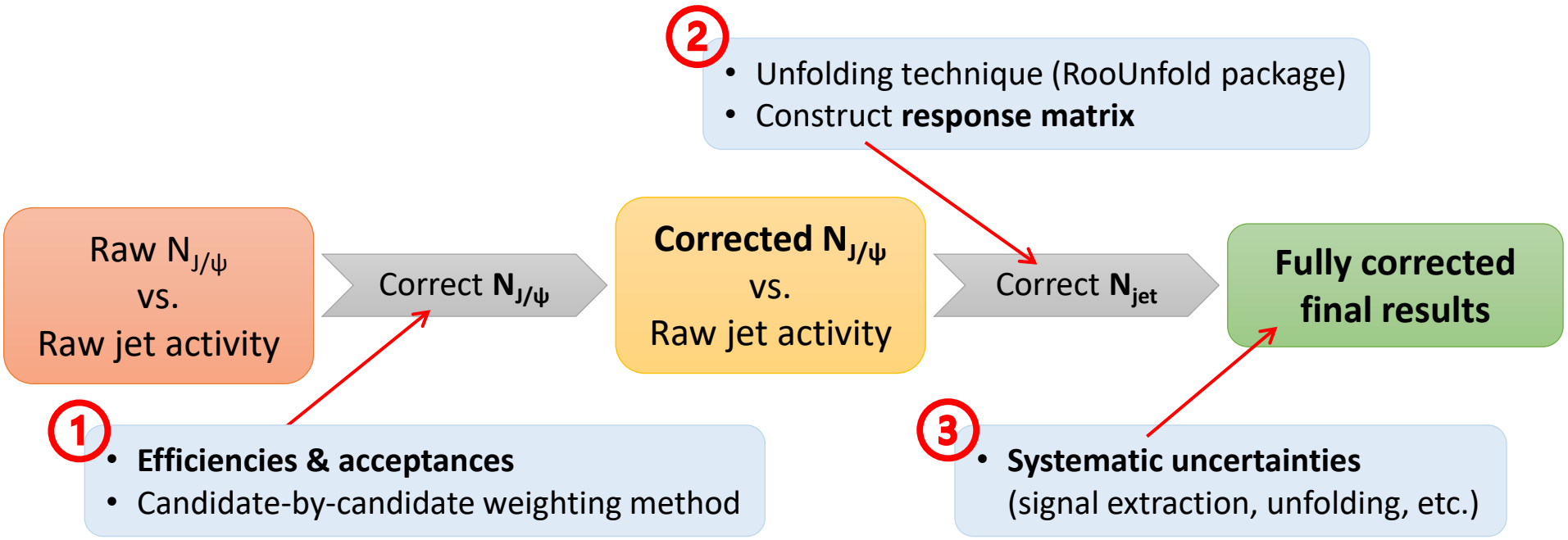
The Solenoid Tracker At RHIC

- Location: Brookhaven National Laboratory on Long Island, New York
- Coverage: full azimuthal angle and mid-rapidity ($|\eta| < 1$)



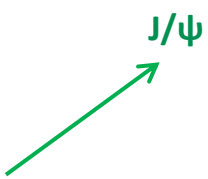
Analysis procedure

- Observable: J/ψ production cross section as a function of jet activity
- Data set: p+p collisions at $\sqrt{s}$ = 200 GeV in 2015

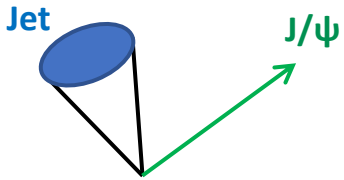


Raw J/ψ signal extraction in different jet activity categories

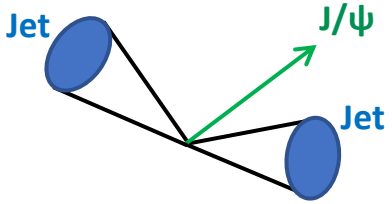
- J/ψ mesons are reconstructed via dimuon decay channel
- Charged jets are reconstructed using anti-k_T algorithm
  - J/ψ candidates and their daughter muons are not included as jet constituents
- Two jet radii are considered: R = 0.4 and R = 0.6



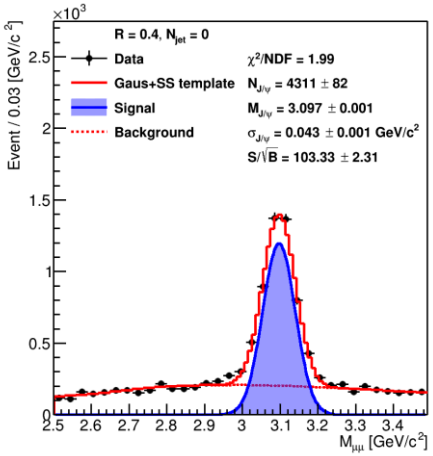
• J/ψ with 0 jet

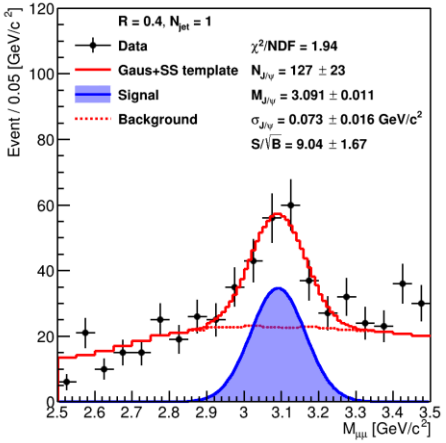


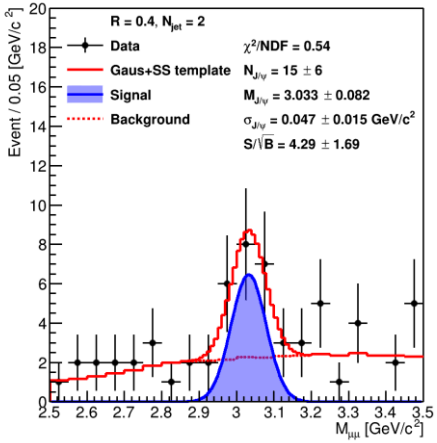
• J/ψ with one jet



• J/ψ with two jets



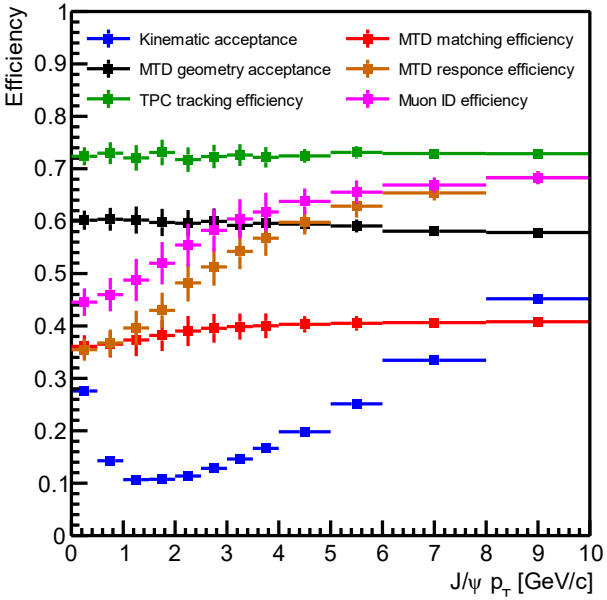




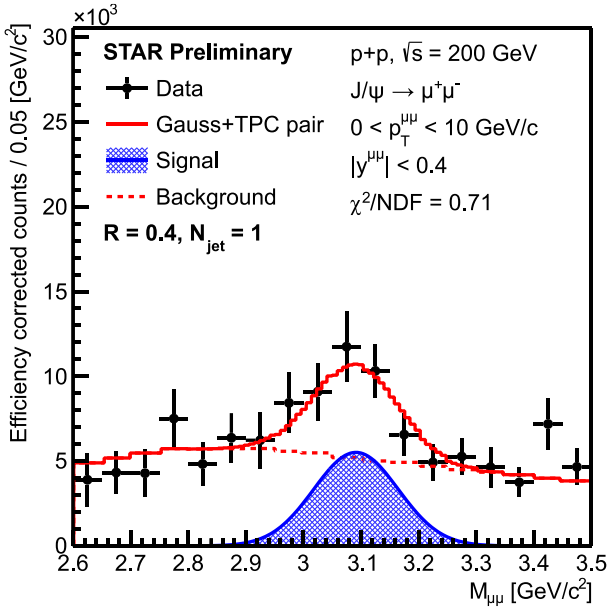
• Raw J/ψ signal in different jet activity (R = 0.4)

Correction for the number of J/ψ

- Candidate-by-candidate weighting method
  - $N_{J/\psi}^{corrected} = \sum_{1}^{N_{J/\psi}} w_i$, where $w_i = (\varepsilon_{reco} \times A)^{-1}$
  - ε_{reco}: total reconstruction efficiency
  - A: total acceptance (kinematic and MTD geometry)



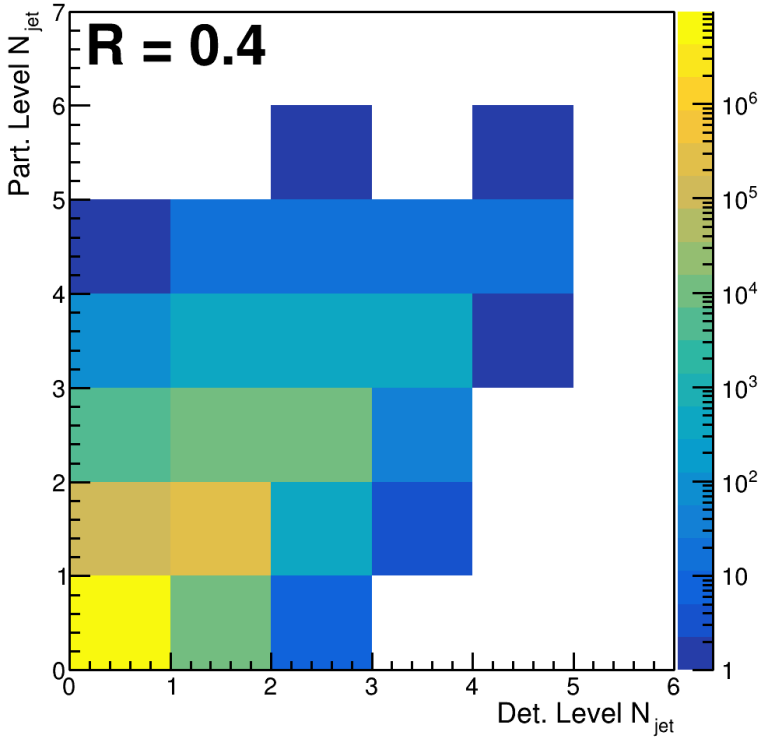
- Efficiencies and acceptances as a function of J/ψ p_T



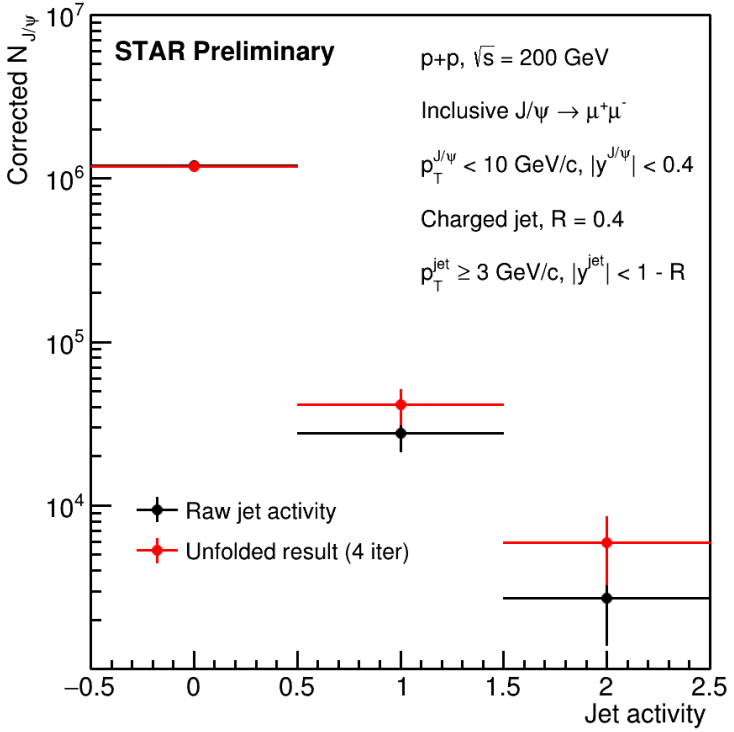
- Corrected J/ψ signal with $N_{jet} = 1$, R = 0.4

Correction for the jet activity

- Unfolding with RooUnfoldBayes algorithm in RooUnfold package
- Response matrices are built using PYTHIA8 events with detector effects



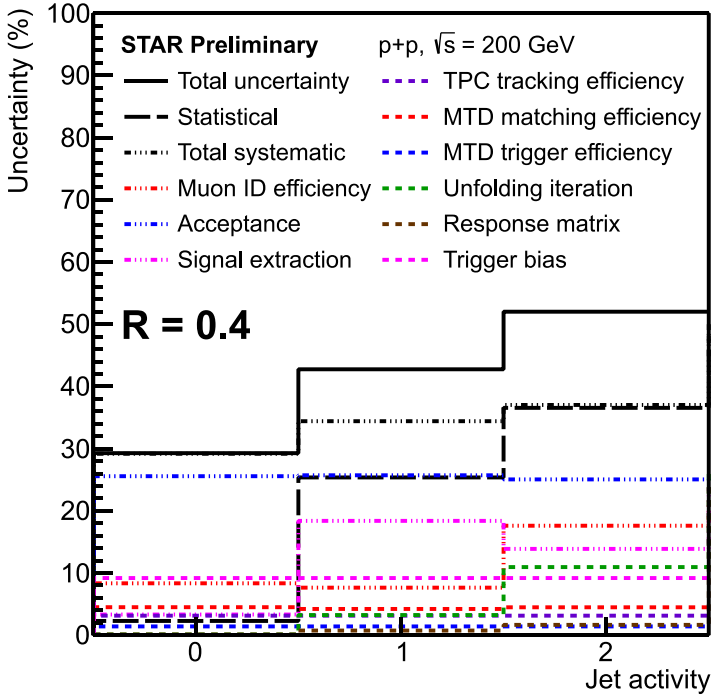
- Response matrix (R = 0.4)



- Results of raw and unfolded jet activity (R = 0.4)

J/ψ cross section and uncertainties

- The J/ψ production cross section as a function of jet activity:
  - $Br(J/\psi \to \mu^+\mu^-) \times \frac{d\sigma}{dN_{jet}} = \frac{1}{\Delta N_{jet}} \times \frac{N^{corrected}_{J/\psi \to \mu^+\mu^-}}{\int L\, dt}$
  - ΔN_{jet} denotes the bin width of each N_{jet} bin, which equals to 1
- Various uncertainties are included
  - Statistical uncertainty
  - Systematic uncertainties
    - Signal extraction
    - Efficiencies
    - Acceptance
    - Unfolding procedure
    - Response matrix

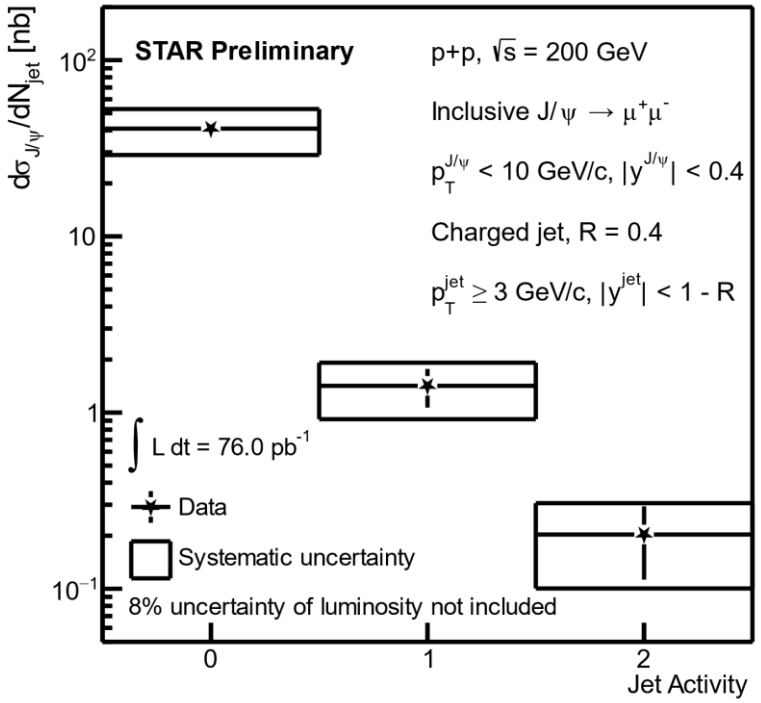


- Statistical, systematic, and total uncertainties

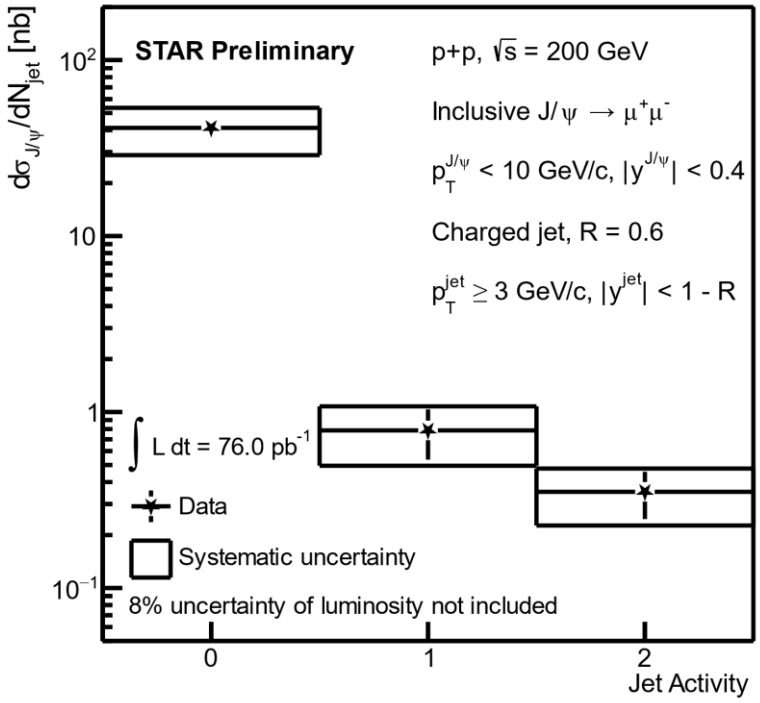
Results

- First results of J/ψ production cross section as a function of jet activity in p+p collisions at $\sqrt{s} = 200$ GeV
- J/ψ $p_T < 10$ GeV/c and charged jet $p_T \geq 3$ GeV/c

R = 0.4



R = 0.6

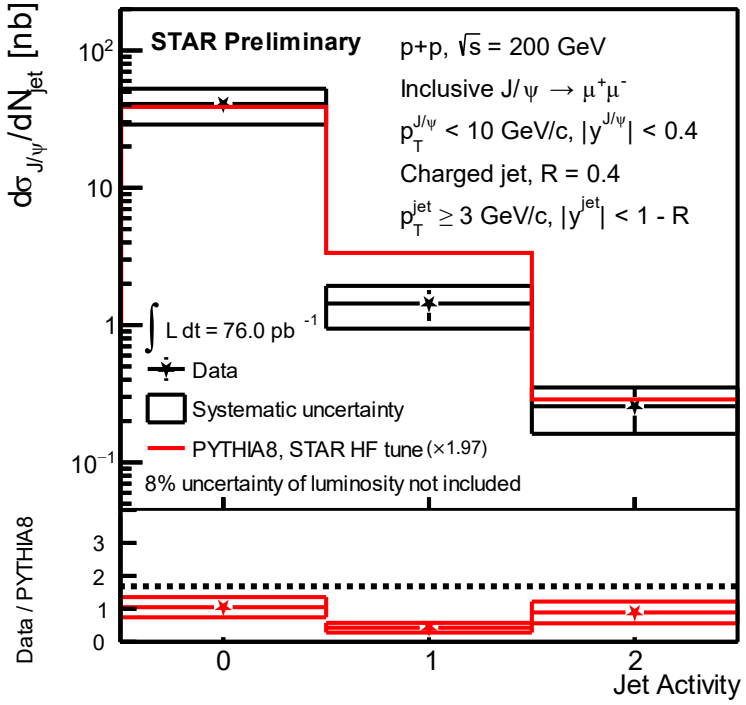


• J/ψ cross section as a function of jet activity with jet radius R = 0.4 (left) and 0.6 (right)

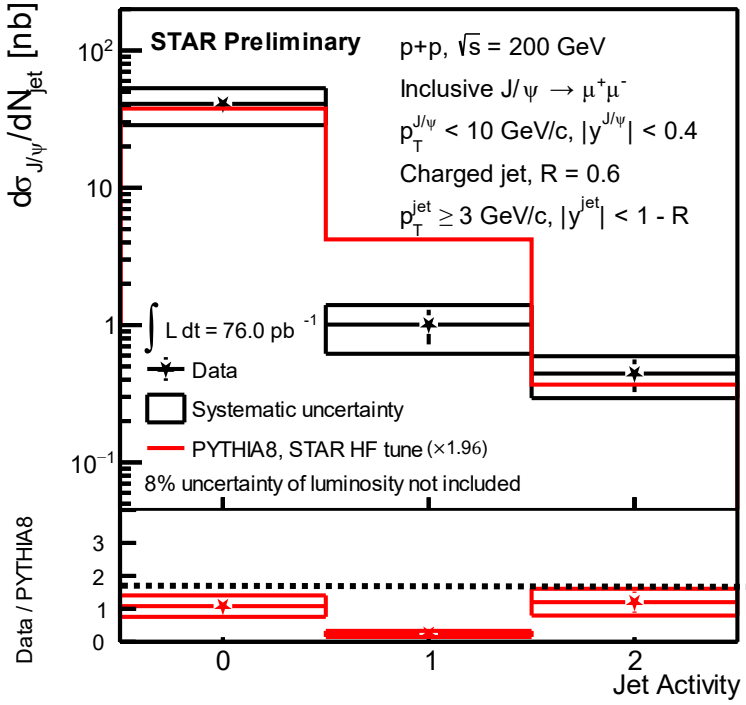
Comparison to PYTHIA

- Compare to PYTHIA8 predictions (scaled by ~×2 for shape comparison):
  - The result for R = 0.4 jet has a small discrepancy in shape (p-value = 0.18)
  - The result for R = 0.6 jet shows an inconsistency in shape (p-value = 0.01)
  - Larger fraction of J/ψ are produced associated with jets than in data

R = 0.4



R = 0.6



• J/ψ cross section as a function of jet activity with jet radius R = 0.4 (left) and 0.6 (right)

Summary

- First results of J/ψ production cross section as a function of jet activity in p+p collisions at $\sqrt{s}$ = 200 GeV
  - Detector effects are corrected, and systematic uncertainties are estimated
- Differences between data and the PYTHIA8 predictions:
  - Inconsistency in shape (p-value = 0.01) with jet R = 0.6
  - Larger fraction of J/ψ are produced associated with jets in PYTHIA8 than data
- A new observable to constrain different models and provide more understanding of quarkonium production
- Theorical calculations are welcomed