J/ψ production within a jet in p+p collisions at $\sqrt{s}$ = 500 GeV by STAR

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Outline

- **Motivation**
- **STAR experiment**
- **J/ψ fragmentation function in jet**
- **Summary**

J/ψ production in p+p collisions

- J/ψ is a non-relativistic QCD system(v^2<<1): one of the simplest systems in QCD

Production of the $c\bar{c}$ (large momentum transfer) → Evolution of the $c\bar{c}$ pair into J/ψ (small dynamical scale)

pQCD process **non-pQCD process**

→ Model

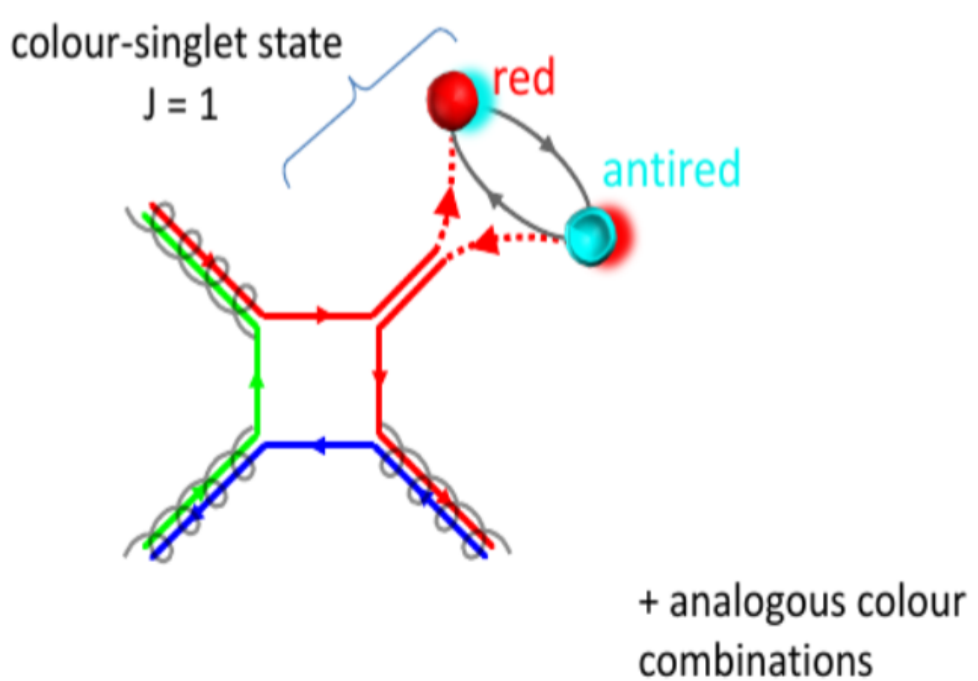
- Difficulty:involving both perturbative and non-perturbative processes

J/ψ production models

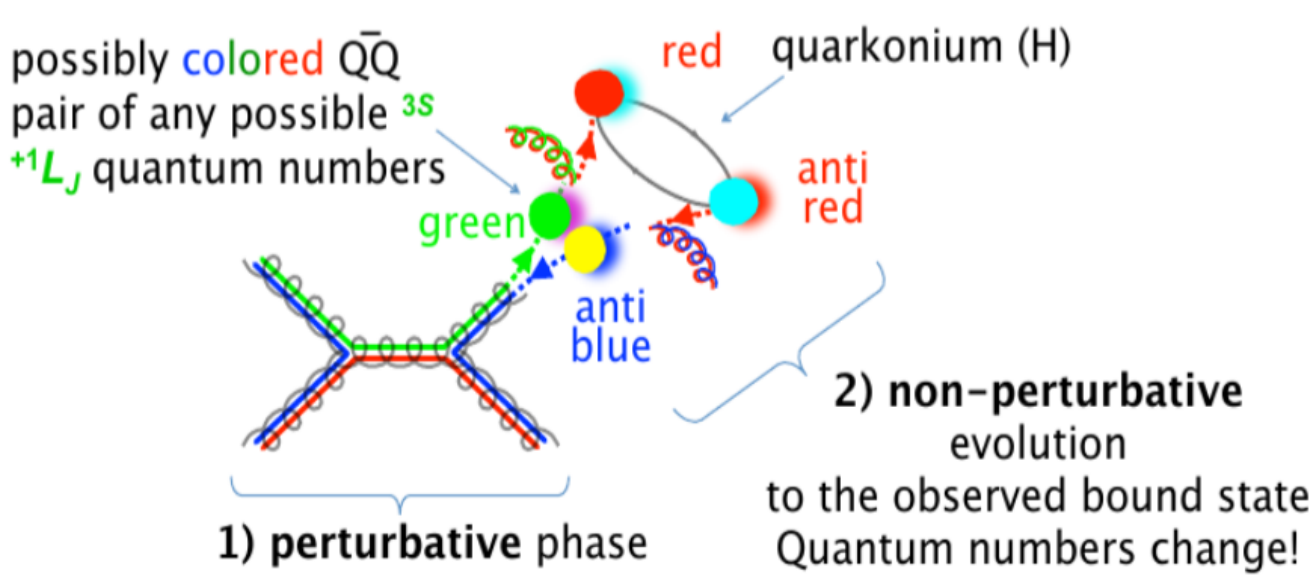
Models differ in the treatment of hadronization:

- Color Singlet Model
- NRQCD approach (CGC+NRQCD at low p_T)
  ➜ Long distance matrix elements (LDMEs)
- Improved Color Evaporation Model et.al

Color-singlet



Color-octet

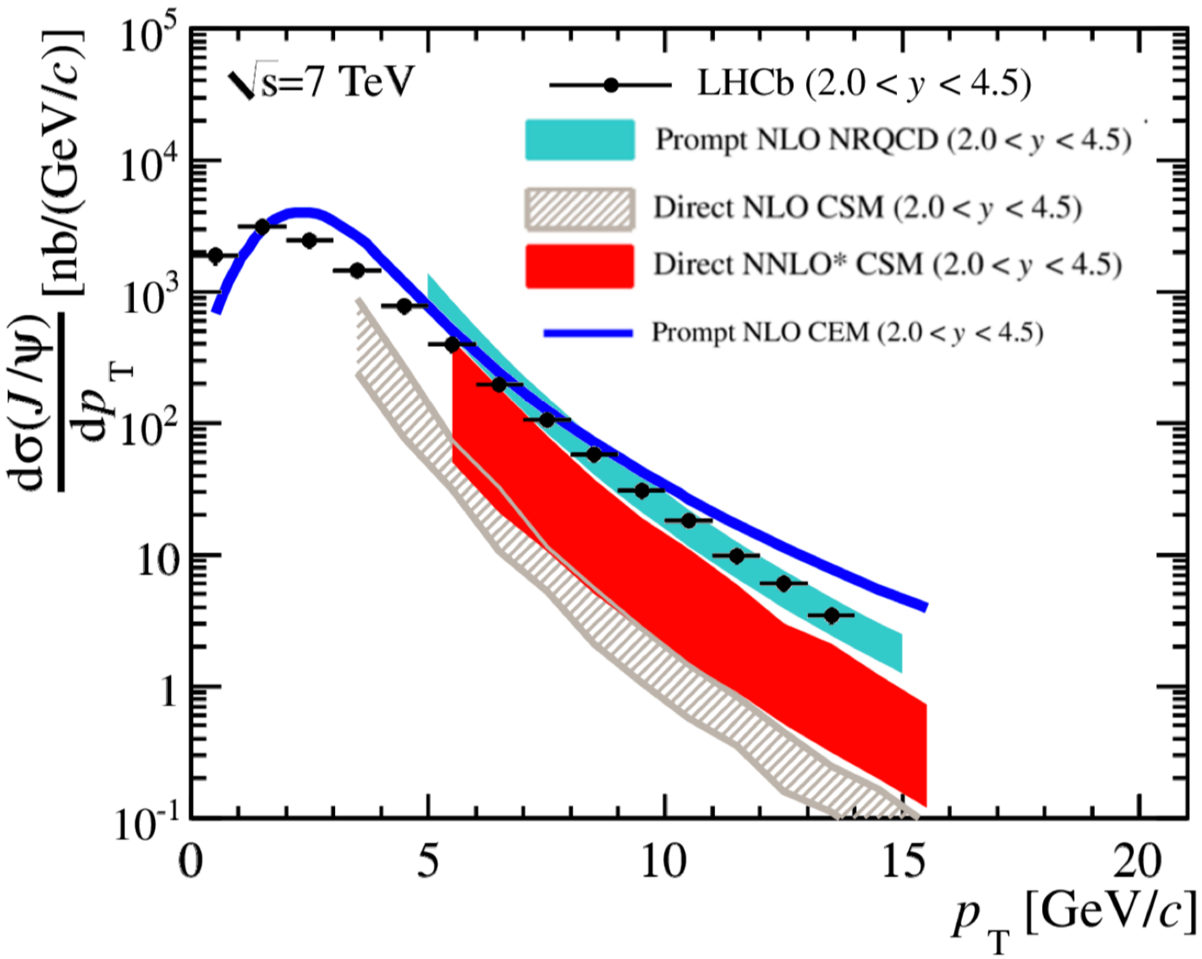


[P. Faccioli, Polarization in LHC physics, Course on Physics at the LHC 2014]

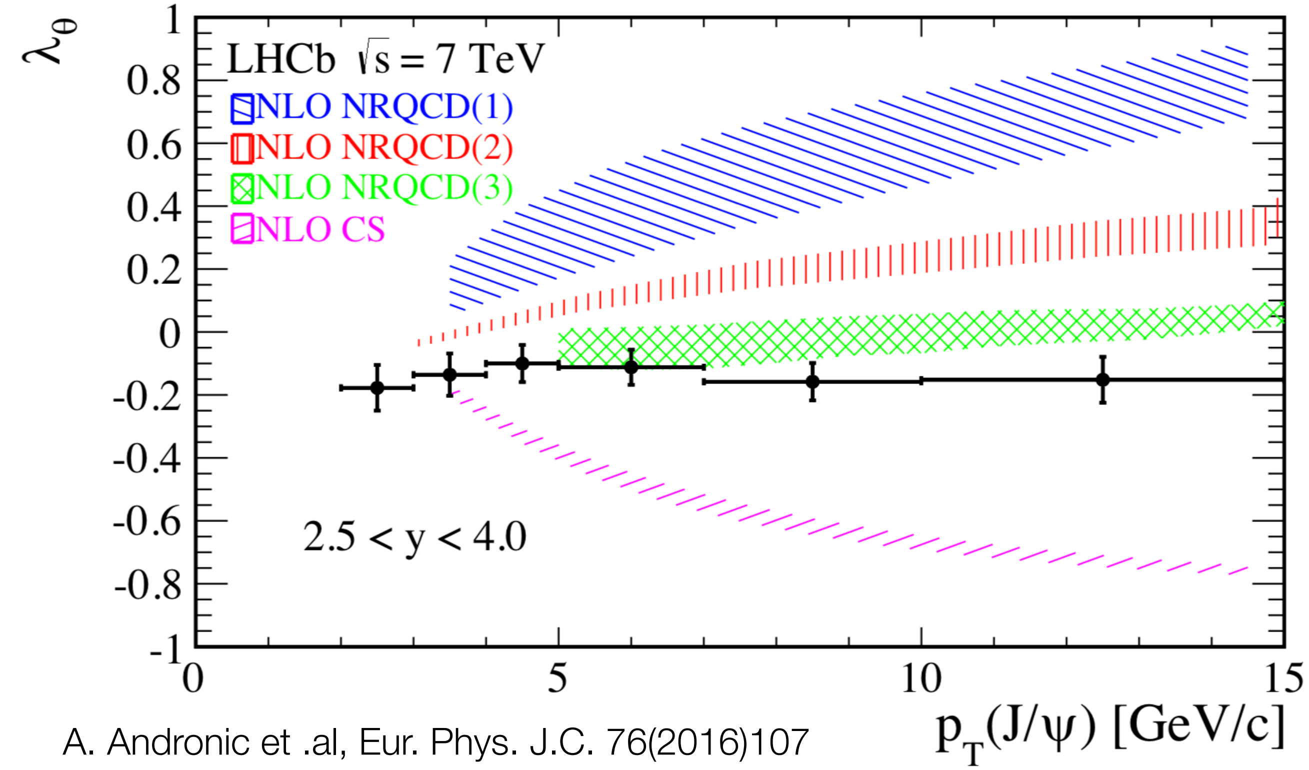
J/ψ production models

J/ψ cross-section and polarization are two key observables to understand the J/ψ production mechanism

Cross-section



Polarization



A. Andronic et .al, Eur. Phys. J.C. 76(2016)107
LHCb, Eur. Phys. J. C 73(2013)2631
LHCb, Eur. Phys. J. C 71(2011)1654

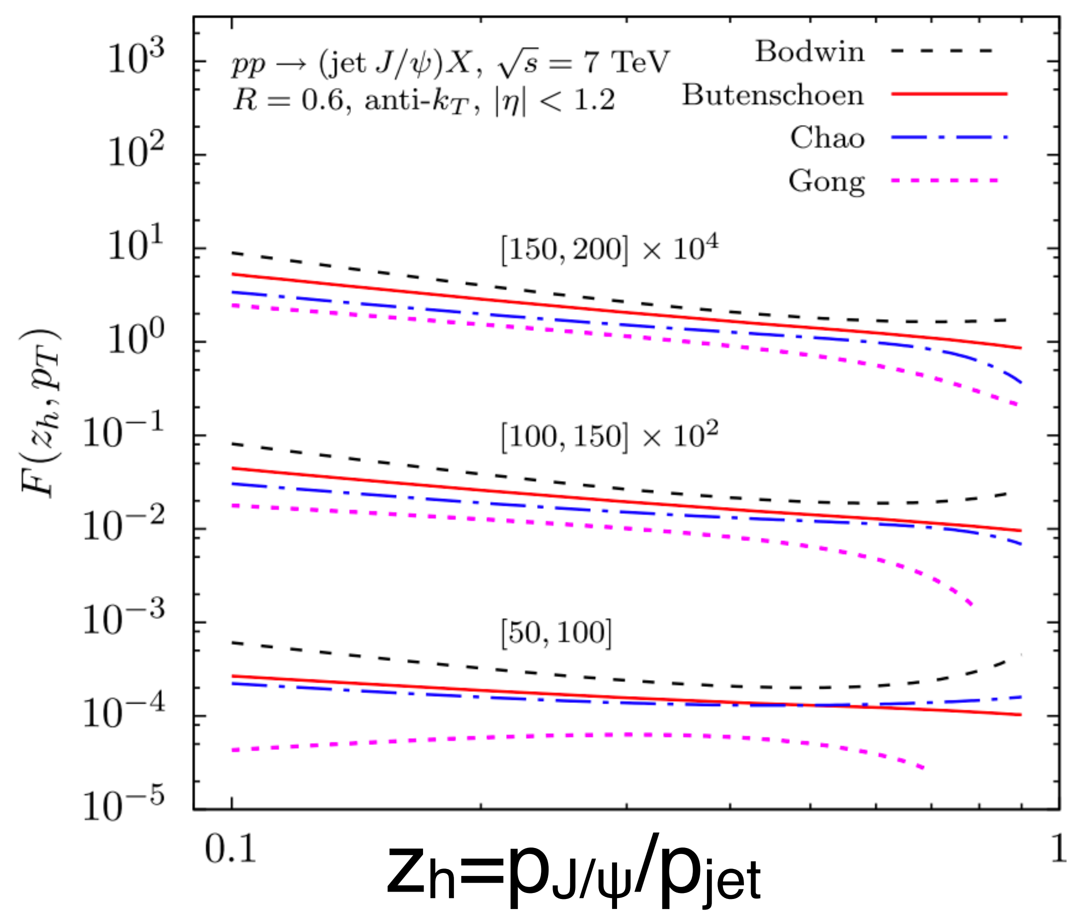
- No consistent descriptions of cross section and polarization
- LDMEs are poorly constrained as to change the nature of the predicted polarization ? → need to further constrain LDMEs

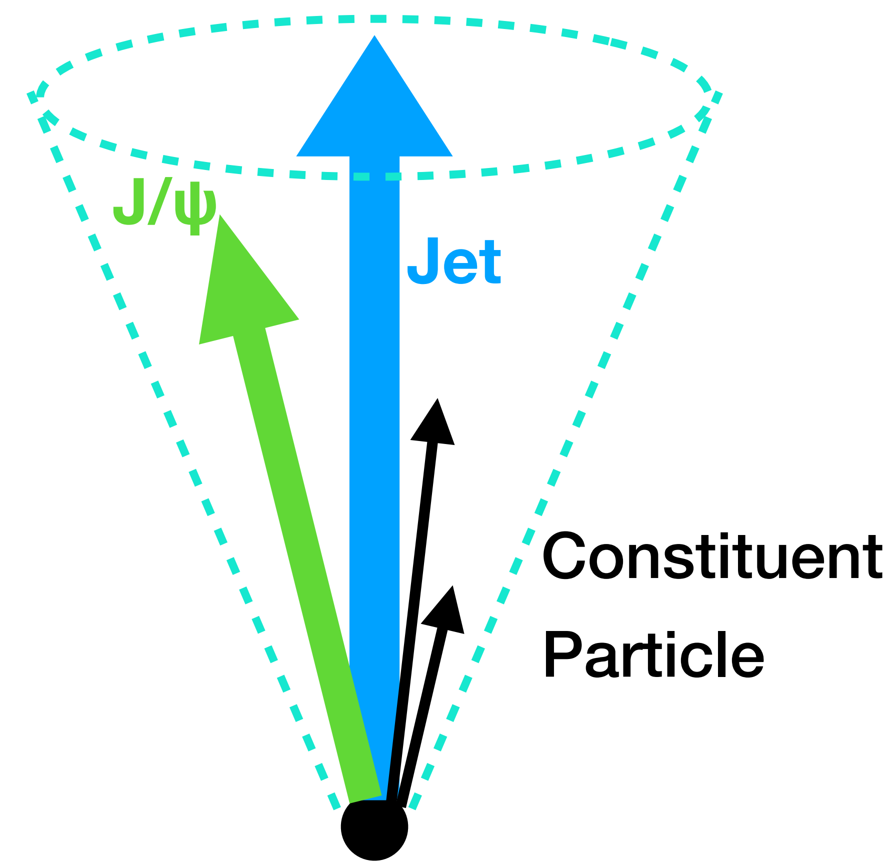
Fragmentation function

J/ψ NRQCD LDMEs from four different groups

	$\langle\mathcal{O}(^3S_1^{[1]})\rangle$ GeV^3	$\langle\mathcal{O}(^1S_0^{[8]})\rangle$ 10^{-2} GeV^3	$\langle\mathcal{O}(^3S_1^{[8]})\rangle$ 10^{-2} GeV^3	$\langle\mathcal{O}(^3P_0^{[8]})\rangle$ 10^{-2} GeV^5
Bodwin	0[a]	9.9	1.1	1.1
Butenschoen	1.32	3.04	0.16	−0.91
Chao	1.16	8.9	0.30	1.26
Gong	1.16	9.7	−0.46	−2.14

Zhong-Bo Kang et .al,
Phys.Rev. Lett. 119 (2017) 032001

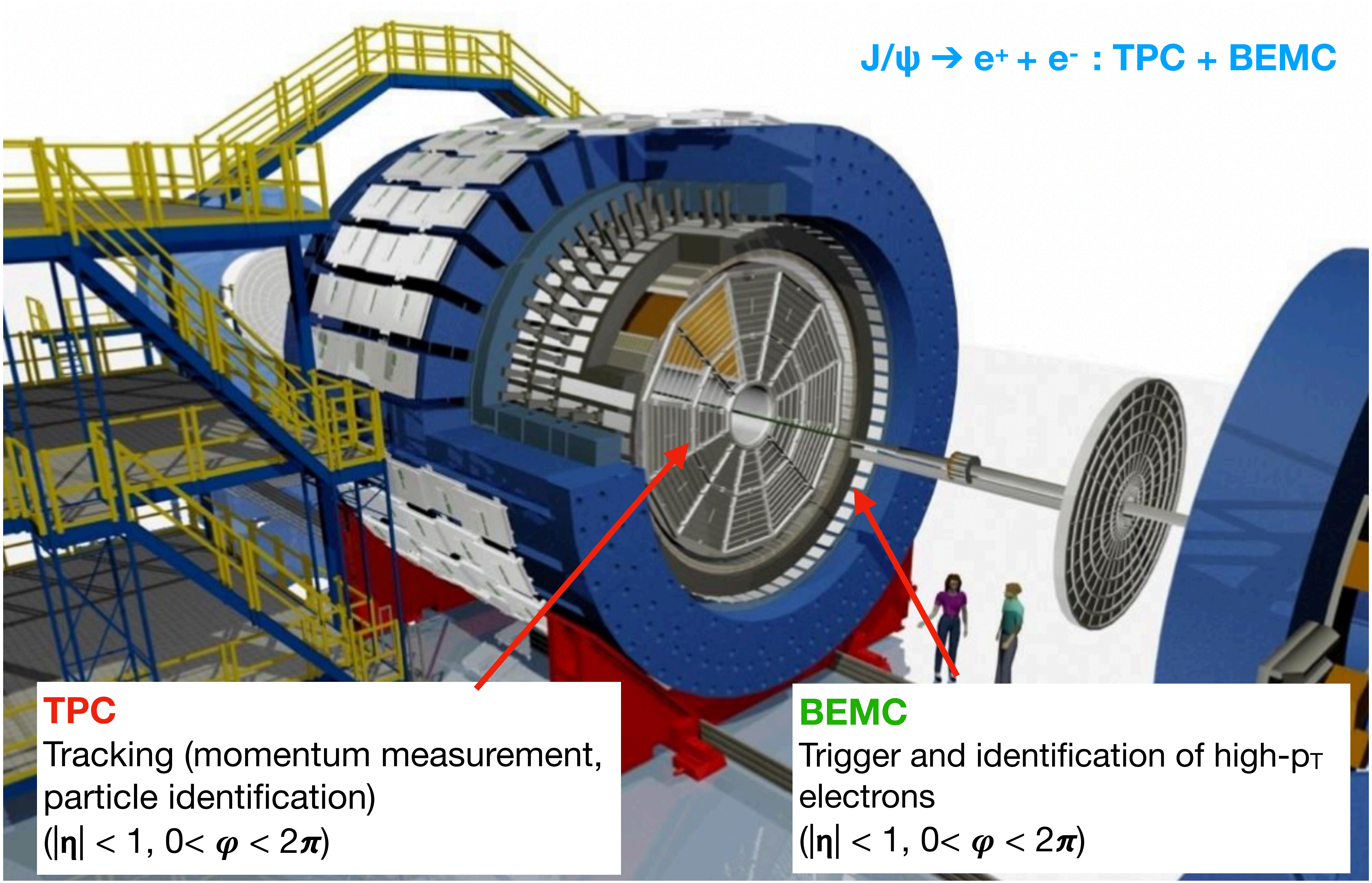




- Fragmentation pattern is different for different production mechanism

The Solenoidal Tracker at RHIC

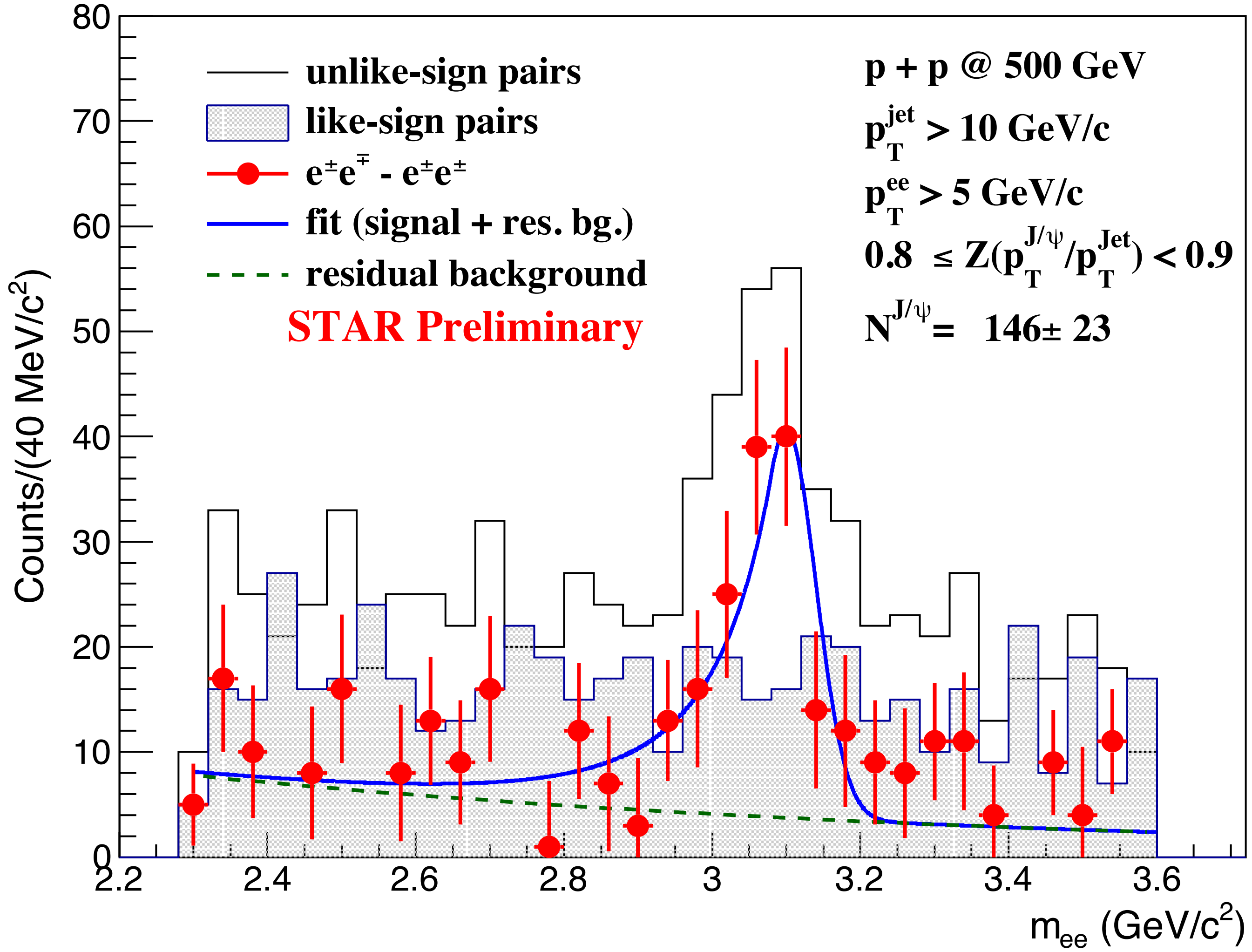
$J/\psi \rightarrow e^+ + e^-$: TPC + BEMC

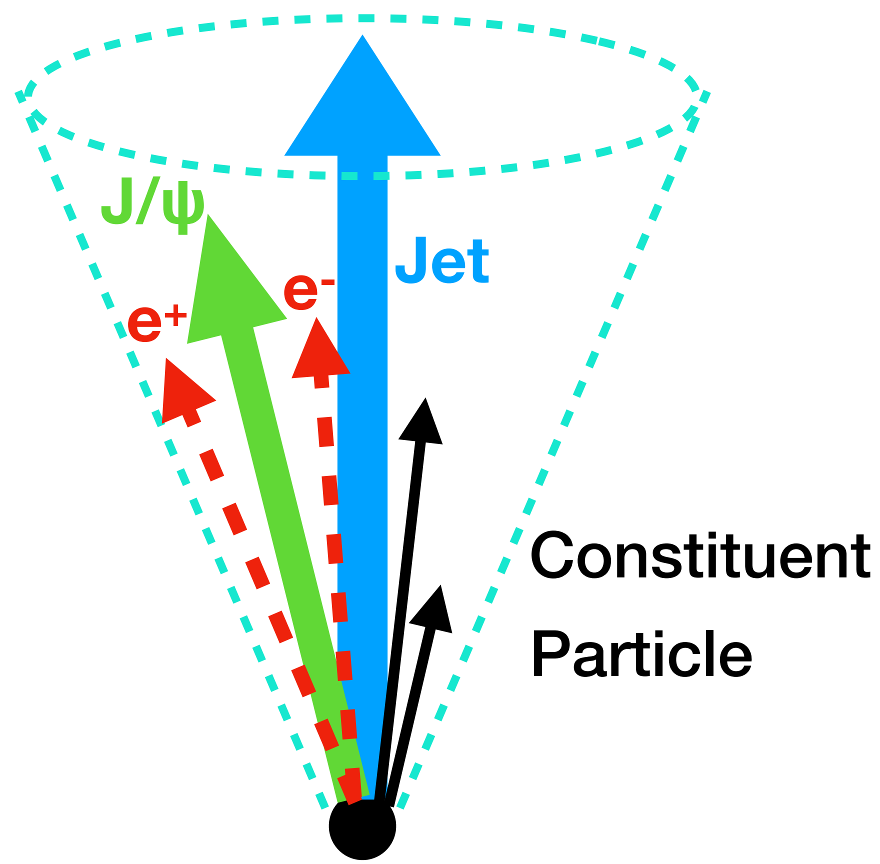


TPC
Tracking (momentum measurement, particle identification)
($|\eta| < 1$, $0 < \varphi < 2\pi$)

BEMC
Trigger and identification of high-p_T electrons
($|\eta| < 1$, $0 < \varphi < 2\pi$)

J/ψ and jet reconstruction

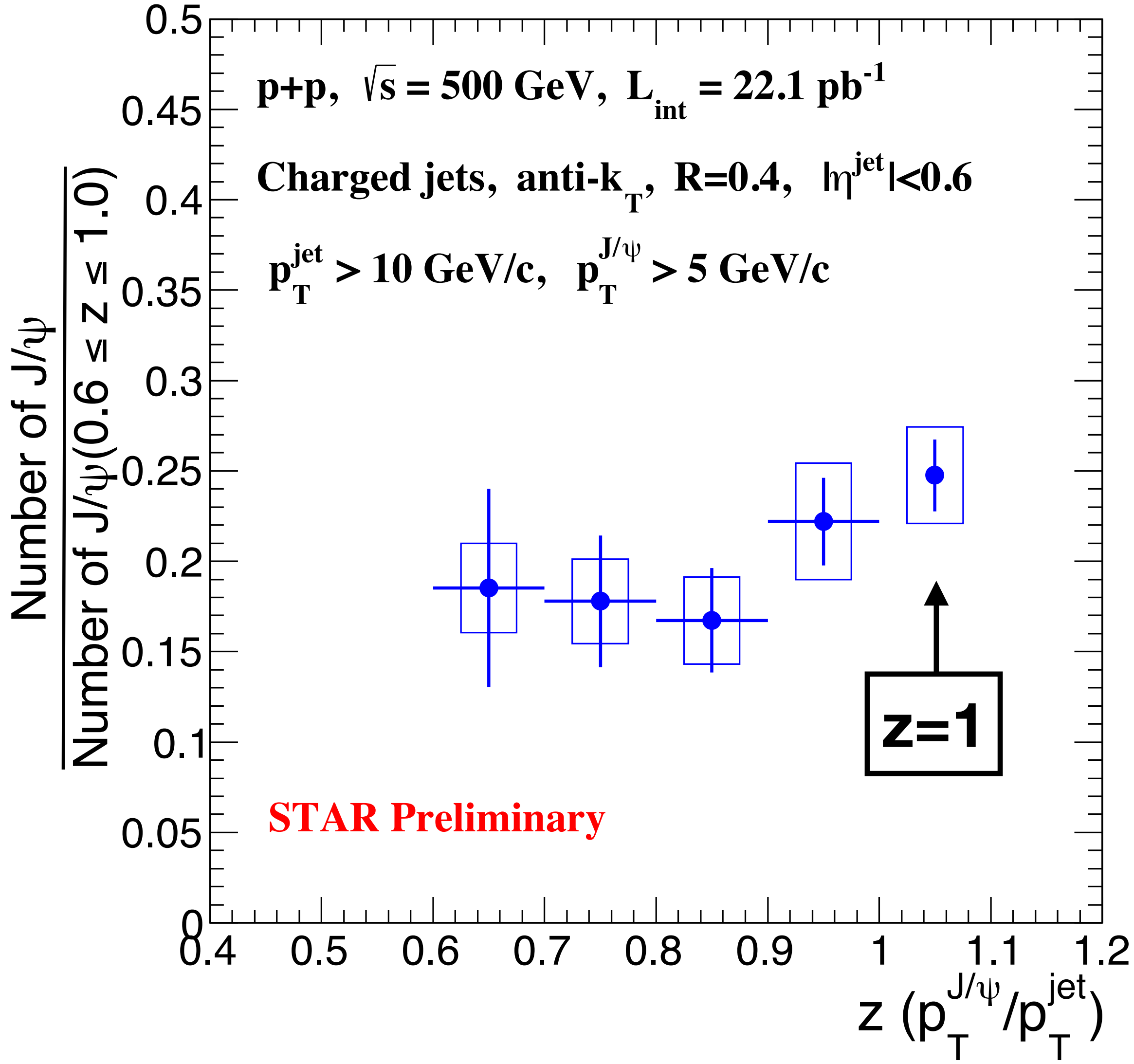




- Combinatorial background: Like-sign method
- Residual background: Drell-Yan, $c\bar{c}$ and $b\bar{b}$ decays
- Crystal-Ball function + exponential function

- Anti-k_T, R =0.4
- Jet: Charged particles + J/ψ candidates

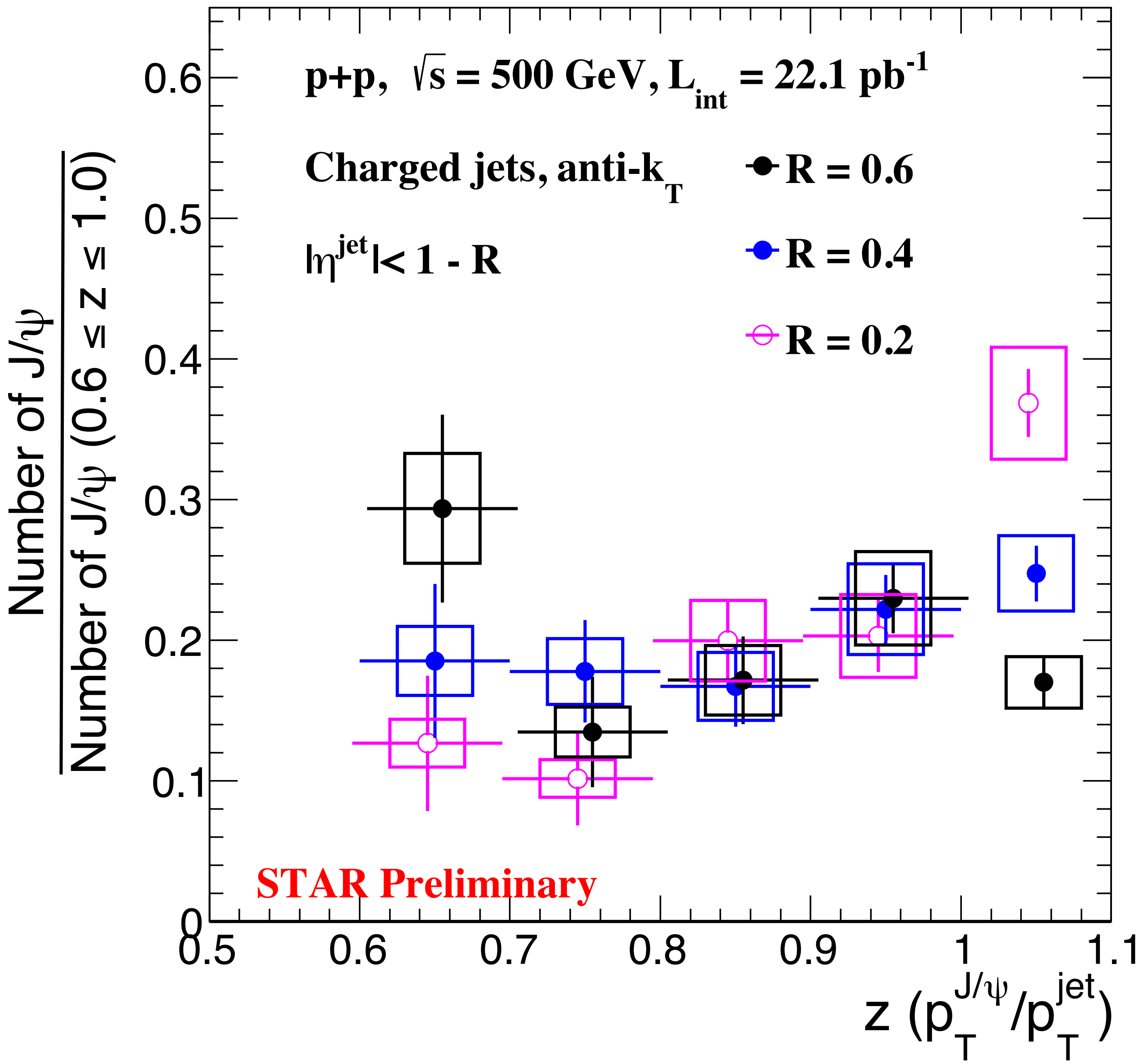
Jet to J/ψ fragmentation function



- z=1 data point (bin-width=0) is moved to 1.05 for visualization
- Major systematic uncertainty sources:
  - Pile-up tracks (~8%)
  - Min-bias vs. J/ψ PYTHIA events used for response matrix (~5%)
  - Tracking efficiency (~12%)

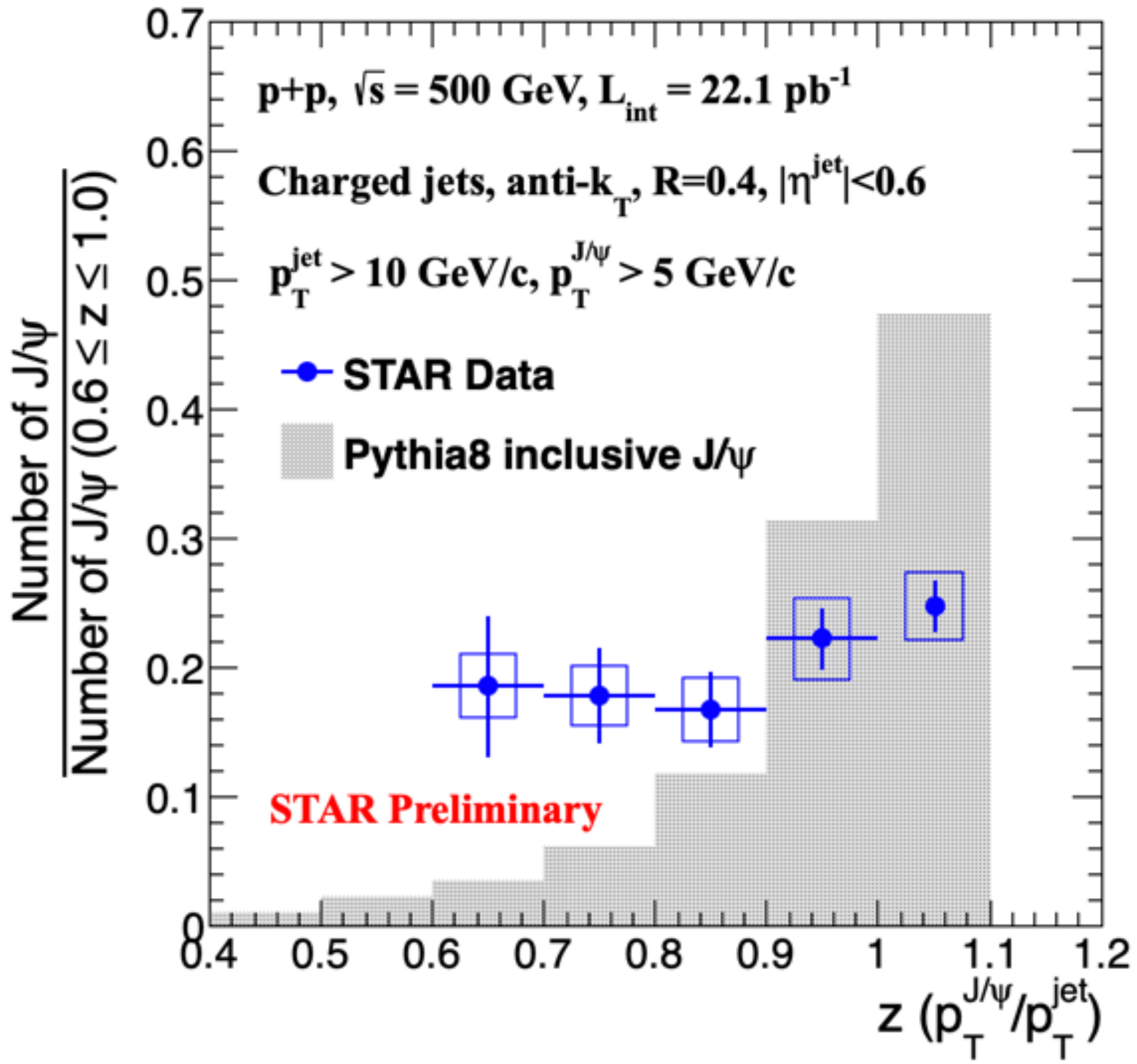
- First measurement of J/ψ production in jets at RHIC
- Detector effects are accounted for via unfolding
- Charged jet to J/ψ fragmentation function :
  - No significant z dependence observed within uncertainties for z <1

Cone size dependence



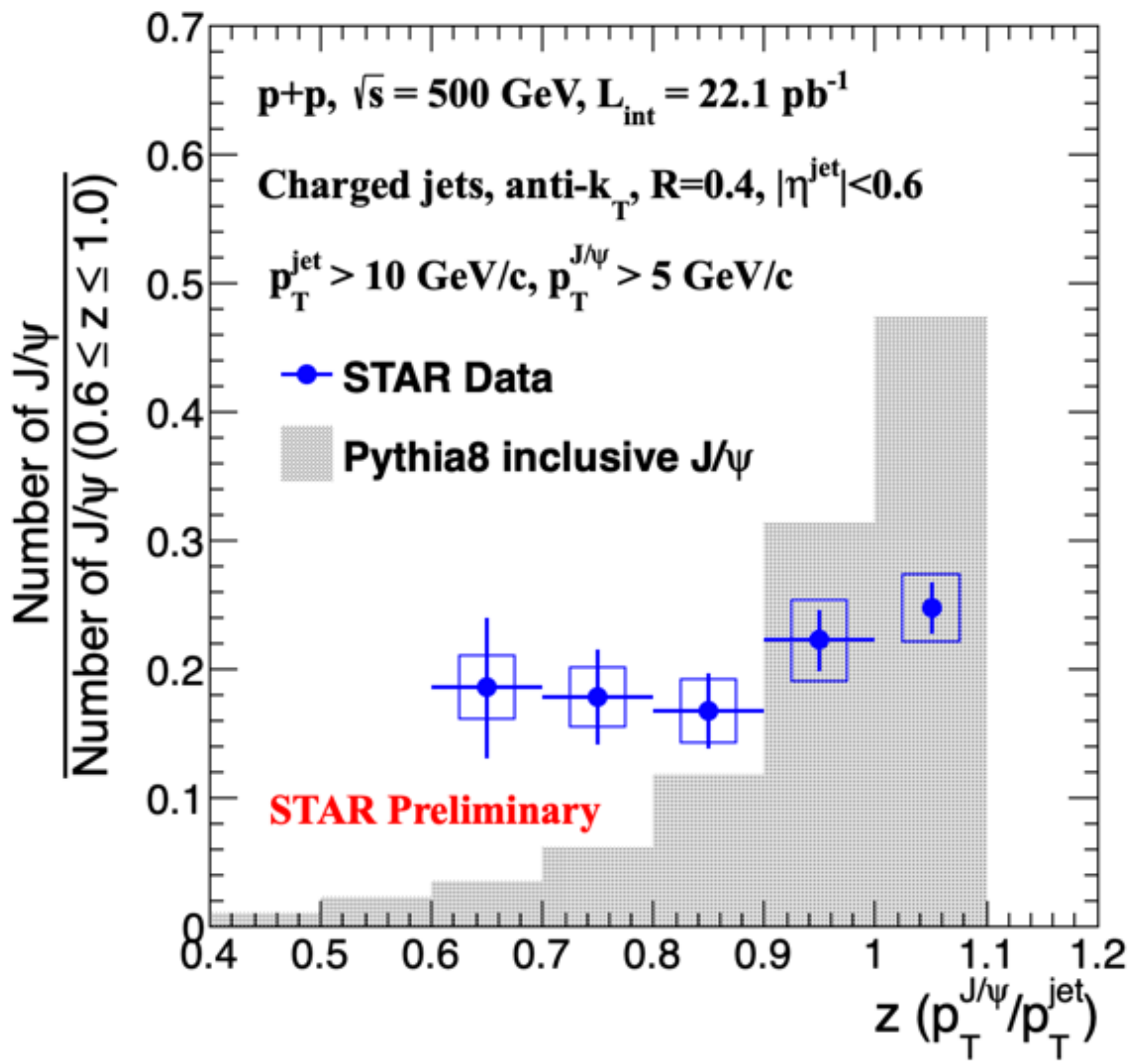
- A hint of R dependence is observed
- Analysis of high statistics data sample from 2017 (L_{int} = 336.4 pb^{-1}) is ongoing
    - ➜More precise measurement

Fragmentation: data vs Pythia8

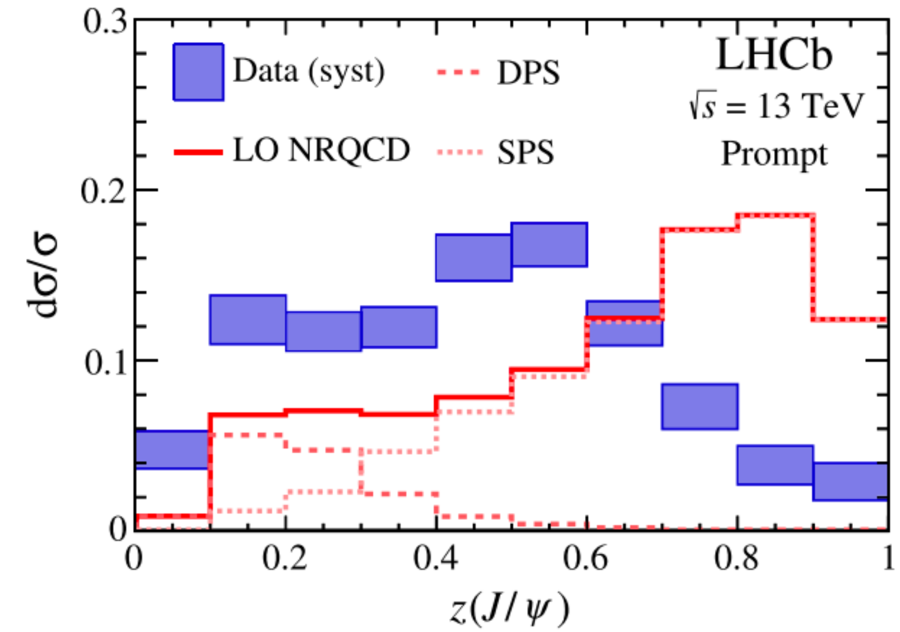


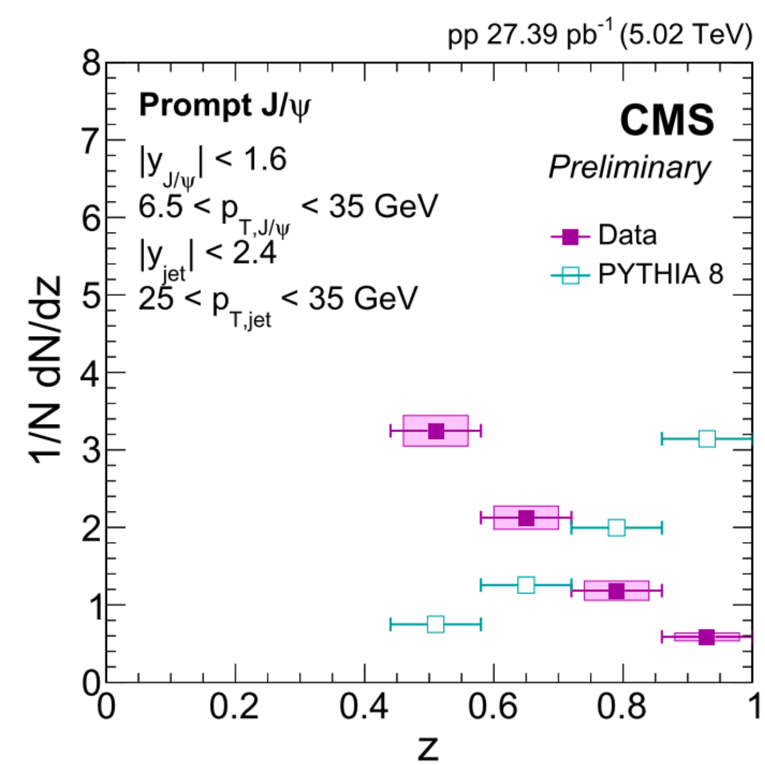
- Different trend and J/ψ production is less isolated in data than in Pythia8
- May help to understand J/ψ polarization
  - Production: parton showers vs parton-parton scattering ?

Fragmentation: RHIC vs LHC



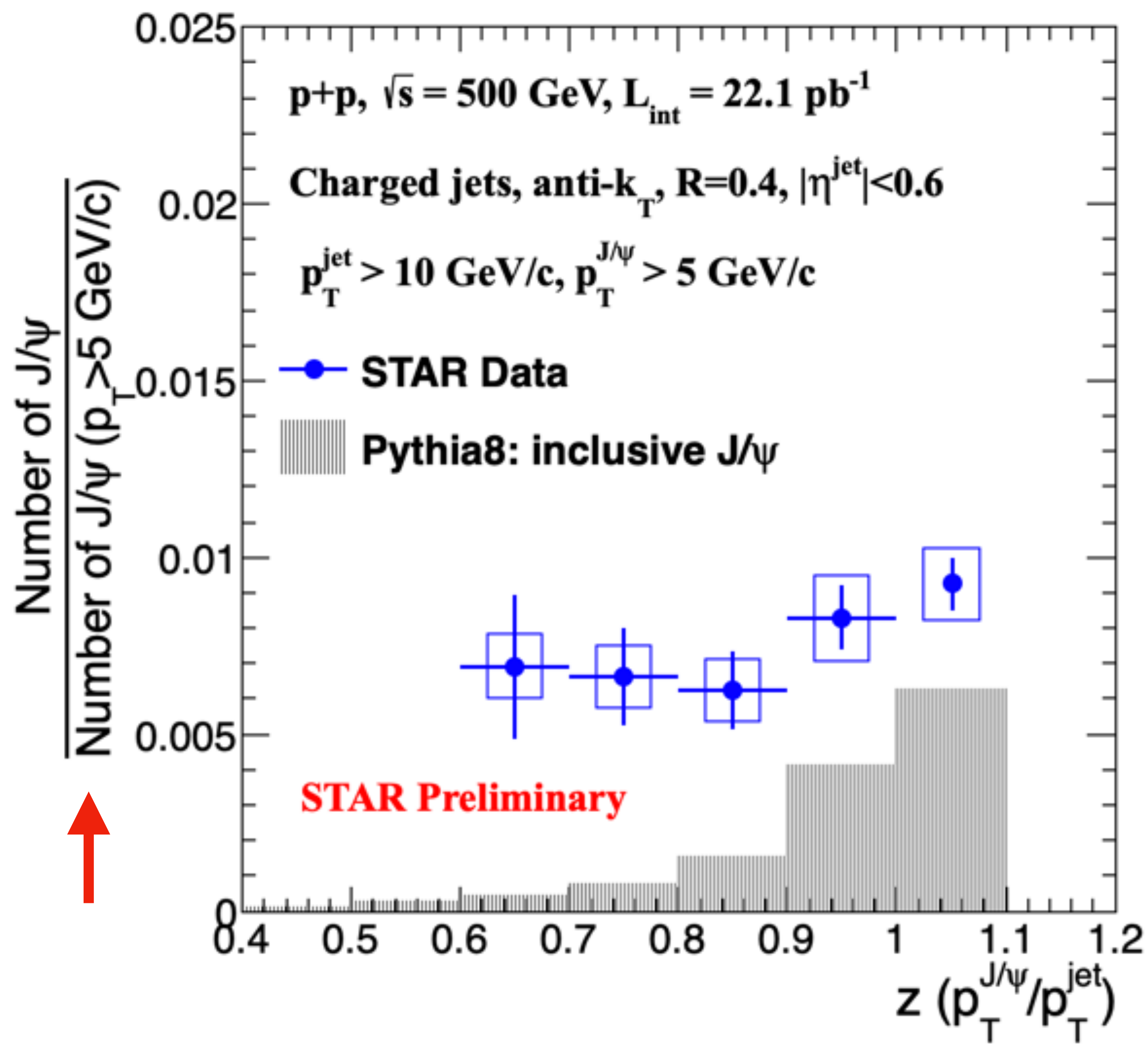
LHCb, PRL 118,(2017) 192001





- Both show a less isolated production scenario
- Different in jet measurements
  - Charged jet at RHIC vs. full jet at LHC
  - Different kinematics range

Fraction of J/ψ produced in jets



STAR, Phys.ReV.D 100(2019) 052009
for p_T > 5 GeV/c J/ψ cross section

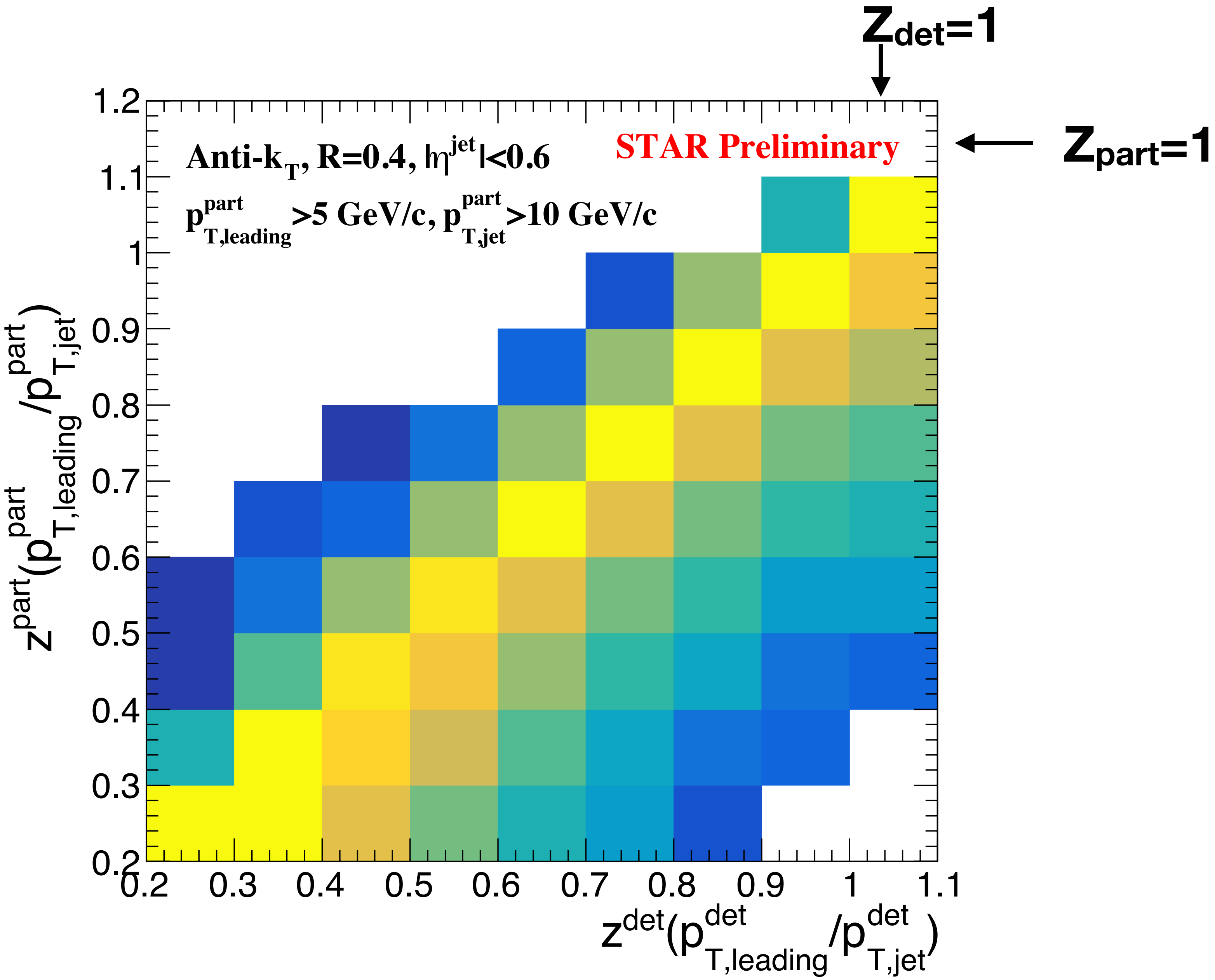
- The probability of producing a J/ψ in charged jet is systematically higher in data than in Pythia8 for the measured kinematics
- The fraction of a $p_T > 5$ GeV/c J/ψ produced in a $p_T > 10$ GeV/c jet is 3.7% ± 0.3% (stat.) ± 0.2%(sys.)

Summary

- First measurement of J/ψ production in jets at RHIC
- No significant z dependence (z<1) of jet to J/ψ fragmentation function is observed for a p_T > 5 GeV/c J/ψ produced in a p_T > 10 GeV/c jet
- Compare to Pythia8
  - Less isolated production in data
  - More J/ψ produced in jets in data
- A hint of R dependence is shown with current uncertainties
- Theory inputs are very welcome

Thanks!

Response matrix



- Response matrix for leading particle
- Leading particle within jet in MB event to mimic J/ψ in jet
- z value is more likely to shift to larger values due to $p_{T,jet}$ (det) < $p_{T,jet}$(part)