DOE Grant # DE-SC0023491

Production of J/ψ vs Multiplicity

In $\sqrt{s} = 510\,GeV$ p+p Collisions with STAR at RHIC

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for the STAR Collaboration

LEHIGH UNIVERSITY STAR Brookhaven National Laboratory U.S. DEPARTMENT OF ENERGY

Preliminary Request

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- Supervisor email address: **ank220@lehigh.edu**

Physics Motivation: Existing measurements from STAR and ALICE that show a faster-than-linear rise in J/ψ production vs. event multiplicity. Complementing this pQCD calculable process is a new high precision measurement that affords investigation of the influence of multi-parton interactions as an underlying or contributing mechanism.

- Dataset: **pp510GeV**
- Year: **2017**
- Production Tag: **P20ic.SL22b**
- Triggers Used: **MB.BBC (570006)**
  BHT1.VPD30 (570214)

- Embedding Request ID: 20225101

https://drupal.star.bnl.gov/STAR/starsimrequests/2022/Dec/21/Jpsi-ee-pp-510-GeV-2017-BHT1-Trigger

- Good/Bad Run Lists: Drupal Blog

https://drupal.star.bnl.gov/STAR/blog/bschaefer/QA-BHT1-and-BHT2-datasets

- QA (before) after: (595M) 382M

- Triggers Used: **MB.VPD30 (570001)**
  BHT1.VPD30 (570214)
- ProductionTag: **P20ic.SL22b**

- dsmHotTowers **1, 101, 480, 556, 741, 769, 1086, 1143, 1221, 1239, 1281, 1314, 1476, 1880, 2164, 2165, 2301, 2304, 2314, 2846, 2866, 3494, 3832, 3833, 3834, 3835, 3836, 3839, 3840, 3850, 3856, 3857, 3859, 3876, 3877, 3879, 3880, 3894, 3895, 3899, 3900, 3913, 3914, 3916, 3917, 3920, 3933, 3934, 3935, 3953, 3958, 3959, 3977, 3979, 3980, 3985**

Analysis Procedure

- ✓ 1. Dataset Preparation
  - ✓ a. QA
  - ✓ b. event/track selection
- ✓ 2. Signal Extraction
- ✓ 3. Systematic Uncertainties
  - ✓ a. tracking selection
  - ✓ b. PID cut variations
  - ✓ c. E/p cut variations
  - ✓ d. trigger cut variation
  - ✓ e. signal fitting
  - ✓ f. background variation
  - ✓ g. trig eff. fit vs bin value

Event Requirements	
	-40 Vz < 40 cm
	VtxRanking > 0

Track Requirements:

p_T	0.2 -> 50 GeV/c
eta	-1.0 -> 1.0
DCA	0 -> 1.5 cm
nHitsFit	20+
nHitsdEdx	11+
nHitsRatio	0.52
E_{TOW}/E_{CLU}	> 0.5
$n\sigma$Electron	-1.9 -> 3.0

Associate Electron:

1/beta	0.97 -> 1.03
|mTOFlocalY|	< 2.0
OR	
E/p	0.67 ->3.33
mDSMADC>>4	>=18

Trigger Electron:

E/p	0.67 -> 3.33
mDSMADC>>4	>= 18

TOF Multiplicity:

nHitsFit	≥ 15
DCA	< 1.5 cm
eta	-1.0 -> 1.0
p_T	> 0.2GeV/c
tofMatchFlag	1

Analysis Procedure

- ✓ 1. Dataset Preparation
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  - ✓ c. E/p cut variations
  - ✓ d. trigger cut variation
  - ✓ e. signal fitting
  - ✓ f. background variation
  - ✓ g. trig eff. fit vs bin value
- 4. Corrections
  - ✓ a. Luminosity correction
  - ✓ b. Unfolding correction
  - ✓ c. BBC·MB trigger efficiency
  - ✓ d. VPD·MB trigger efficiency
  - ✓ e. Vertex ranking efficiency
  - f. Pythia6 variants
  - ✓ g. Apply VPD trigger eff.
  - ✓ h. Numerical crosschecks
  - i. Plot beautification

2017 STAR p+p 510 GeV
(79.5 pb-1)

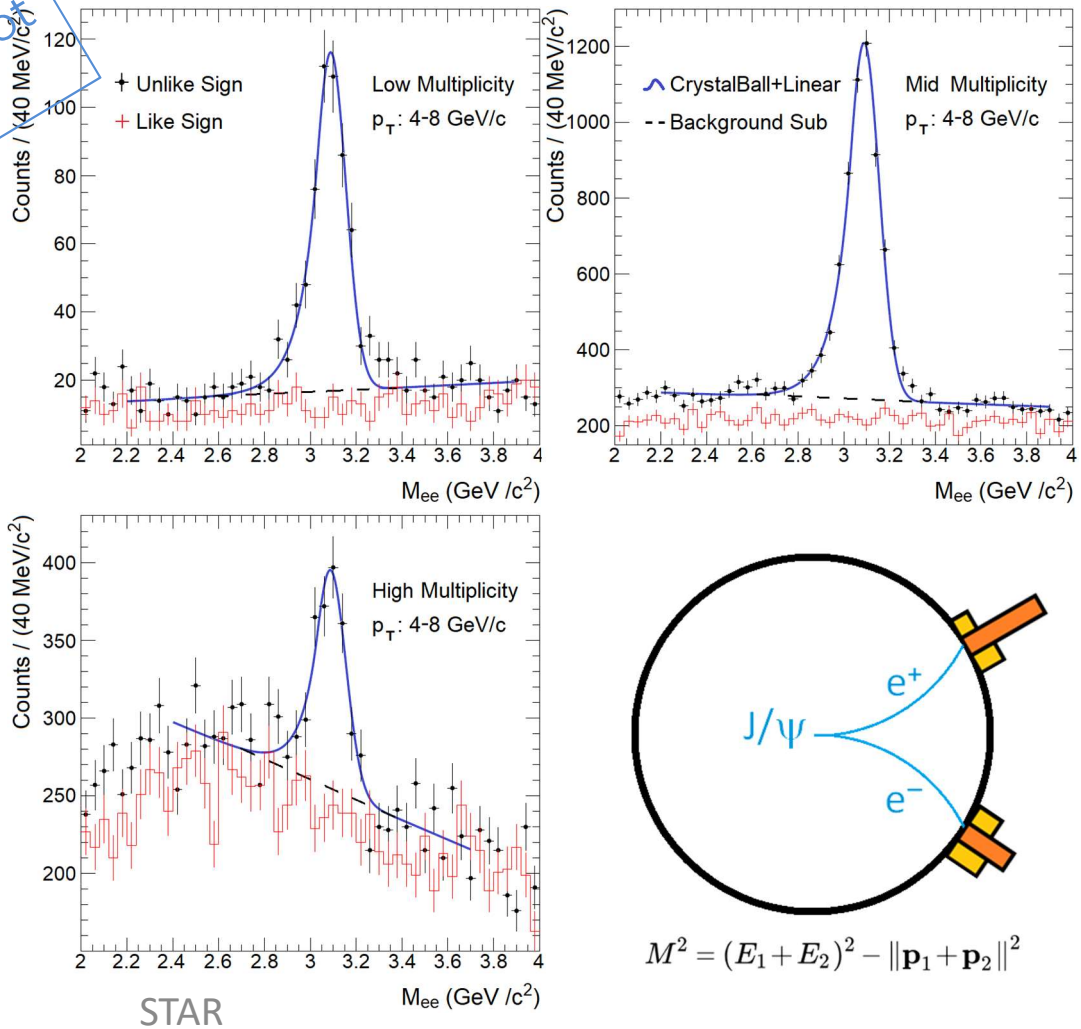
4x increase in luminosity
above 200 GeV p+p

Triggering on events with
4.2 GeV/c EMCal electron

Associate tracks from TOF
or EMCal-E/p requirement

Centroid of C.B. core fixed
to PDG world ave, width
is variable in fit

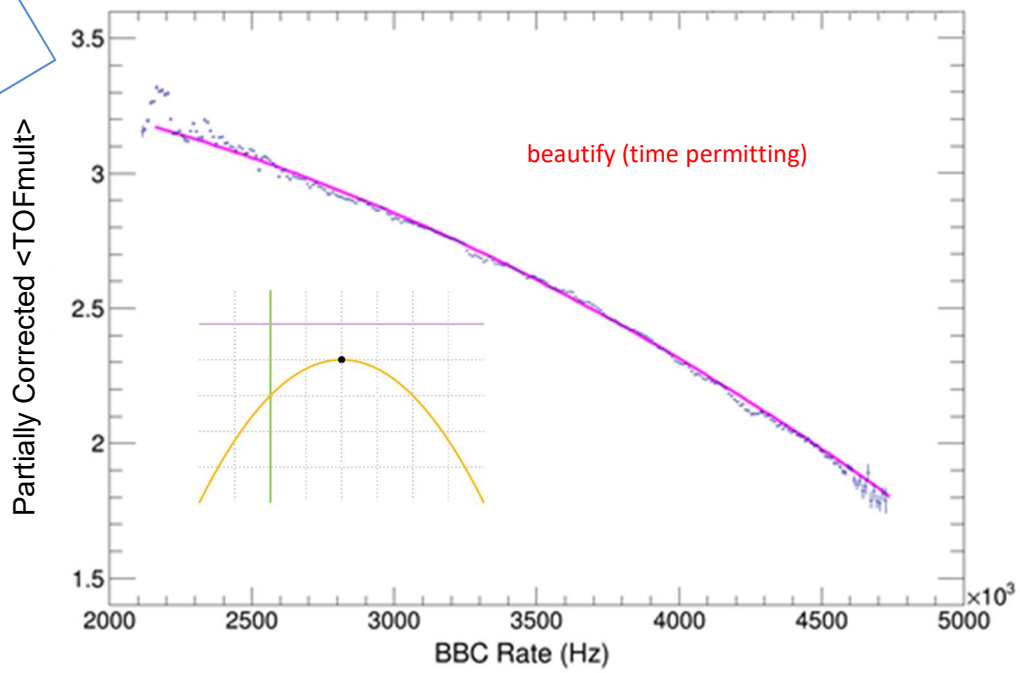
Performance plot request



$$M^2 = (E_1+E_2)^2 - \|\mathbf{p}_1+\mathbf{p}_2\|^2$$

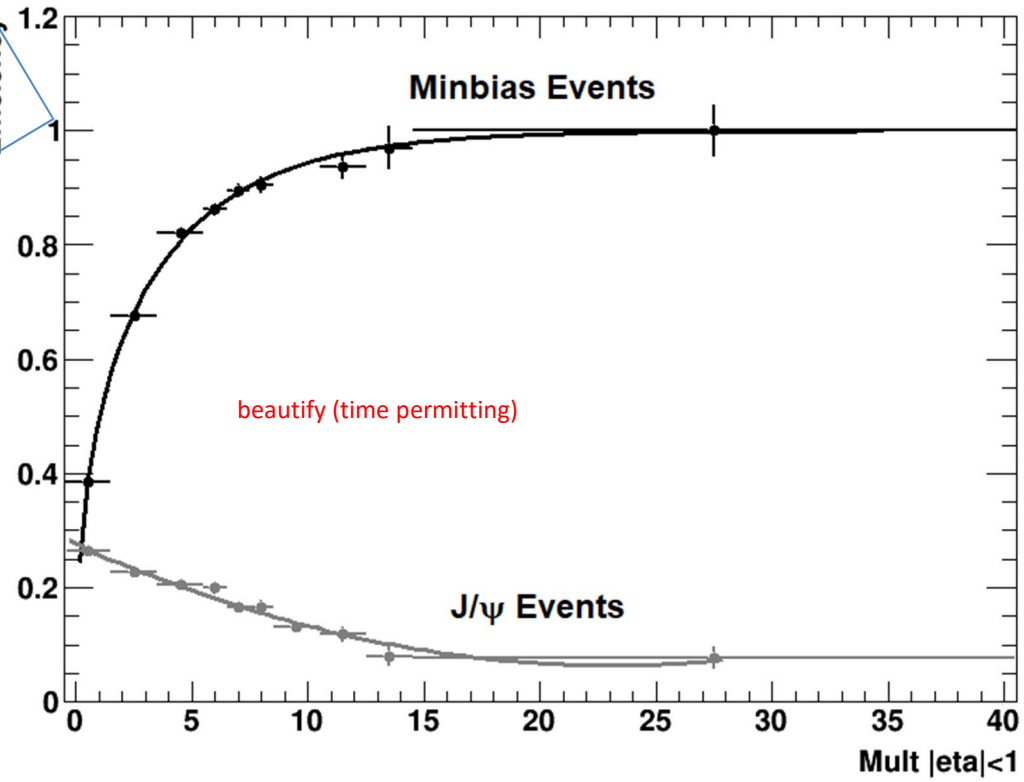
A correction is necessary to account for the varied tracking efficiencies from occupancy effects accompanying the luminosity rate

Performance plot request



Separate efficiency vs multiplicity event selection corrections are necessary for the J/ψ and min-bias distributions

Performance plot request



Pythia events

- STAR HF Tune
- MB

embedded into zerobias and reconstructed

REFINE

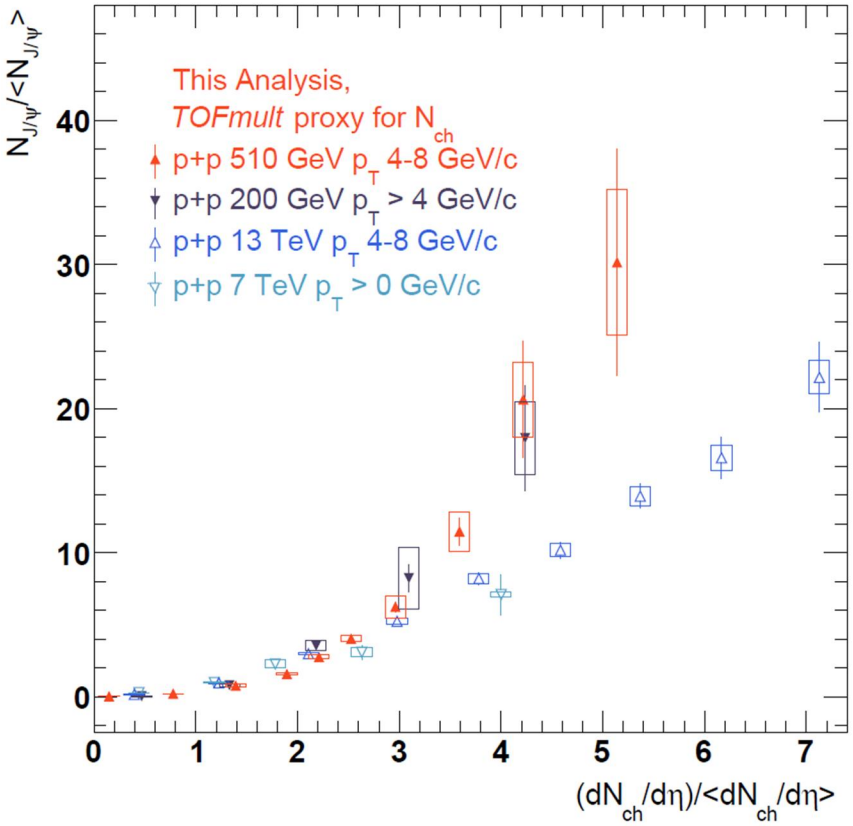
Mult range extended

Improved granularity

510 consistent with 200

Hint of splitting between RHIC and LHC energies

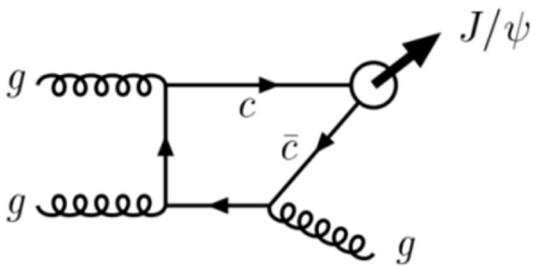
Beautify



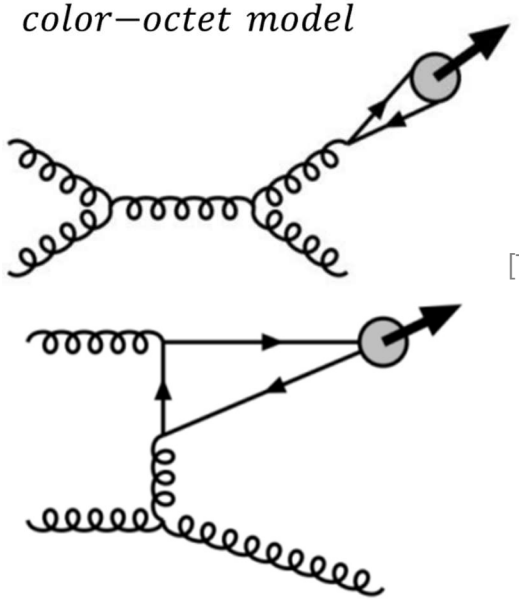
Accompanying model calculations for J/ψ production, are coinciding predictions for the underlying events.

$$d\sigma \sim f(x_1) \otimes f(x_2) \otimes \hat{\sigma}^{x_1 + x_2 \to [c\bar{c}] + X} \otimes H^{[c\bar{c}] \to J/\psi}$$

color−singlet model



color−octet model

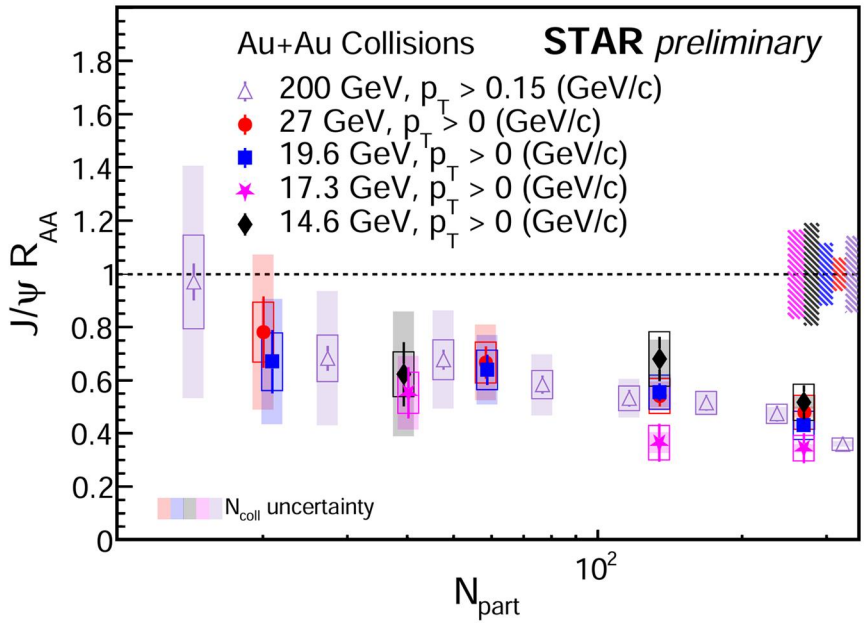


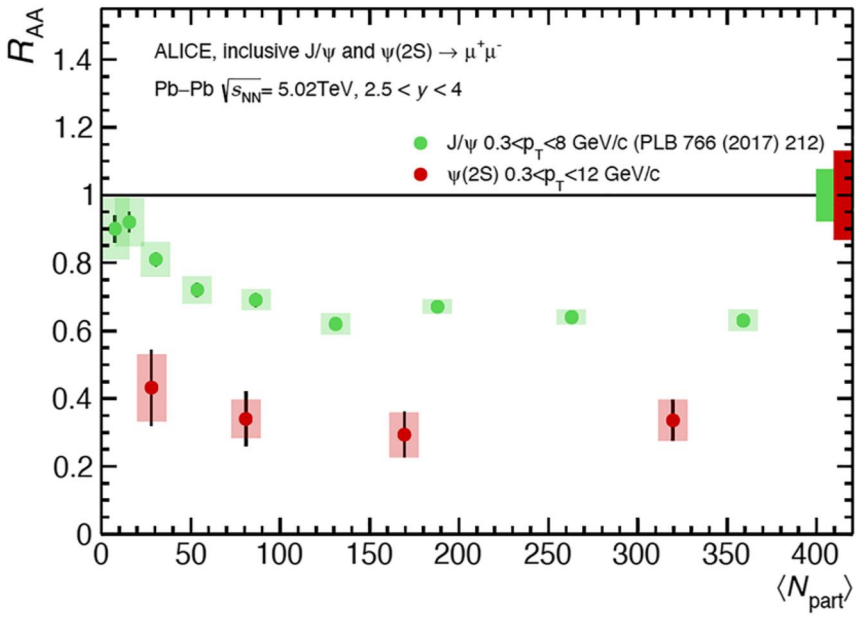
[1]

Suppression of J/ψ is seen more in central than peripheral A+A collisions

Also suppressed in high compared to low multiplicity p+p?

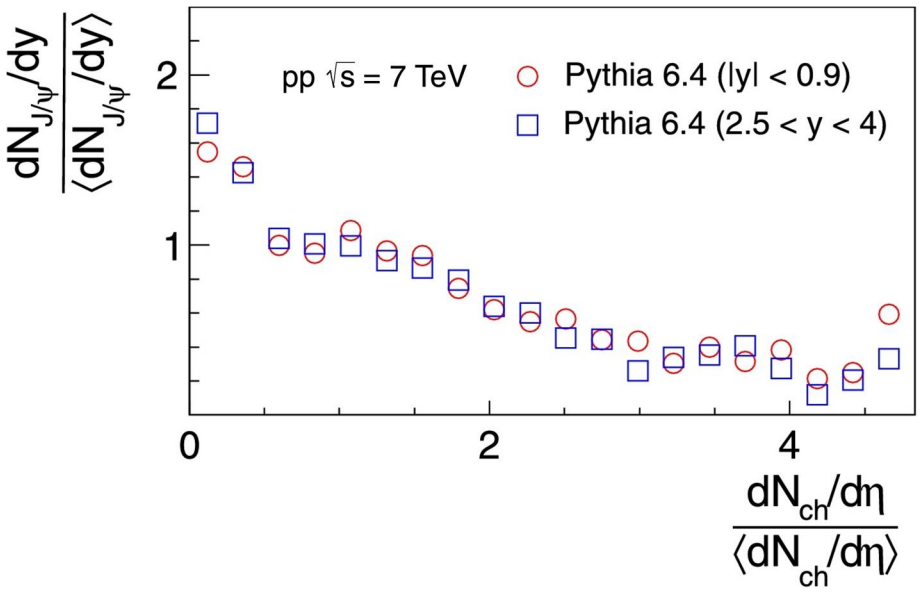
as seen in Wei Zhang's talk tomorrow





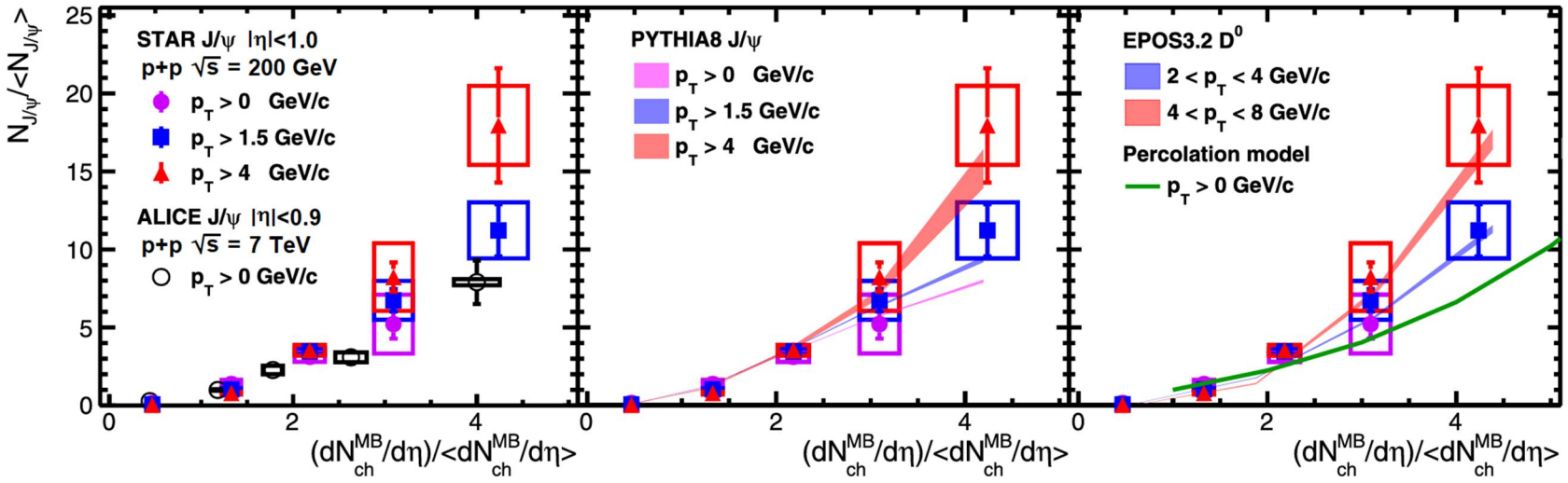
[2]

Early predictions from model calculations



[5]

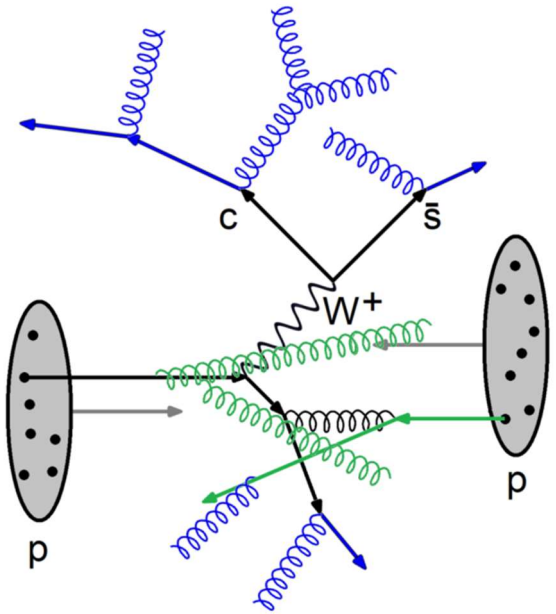
A faster than linear rise in J/ψ production has been found with respect to event multiplicity, consistent across multiple energies.

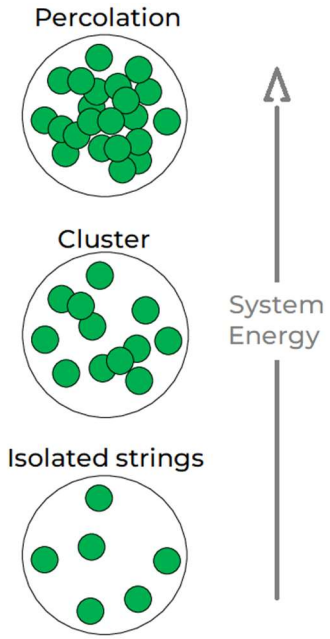


[3]

Events that feature more numerous multi-parton interactions (left) may also enhance J/ψ production due to small b̄ of opposing partons and hence hard scattering

Percolation of color strings (right) may similarly contribute by diminishing soft hadron production





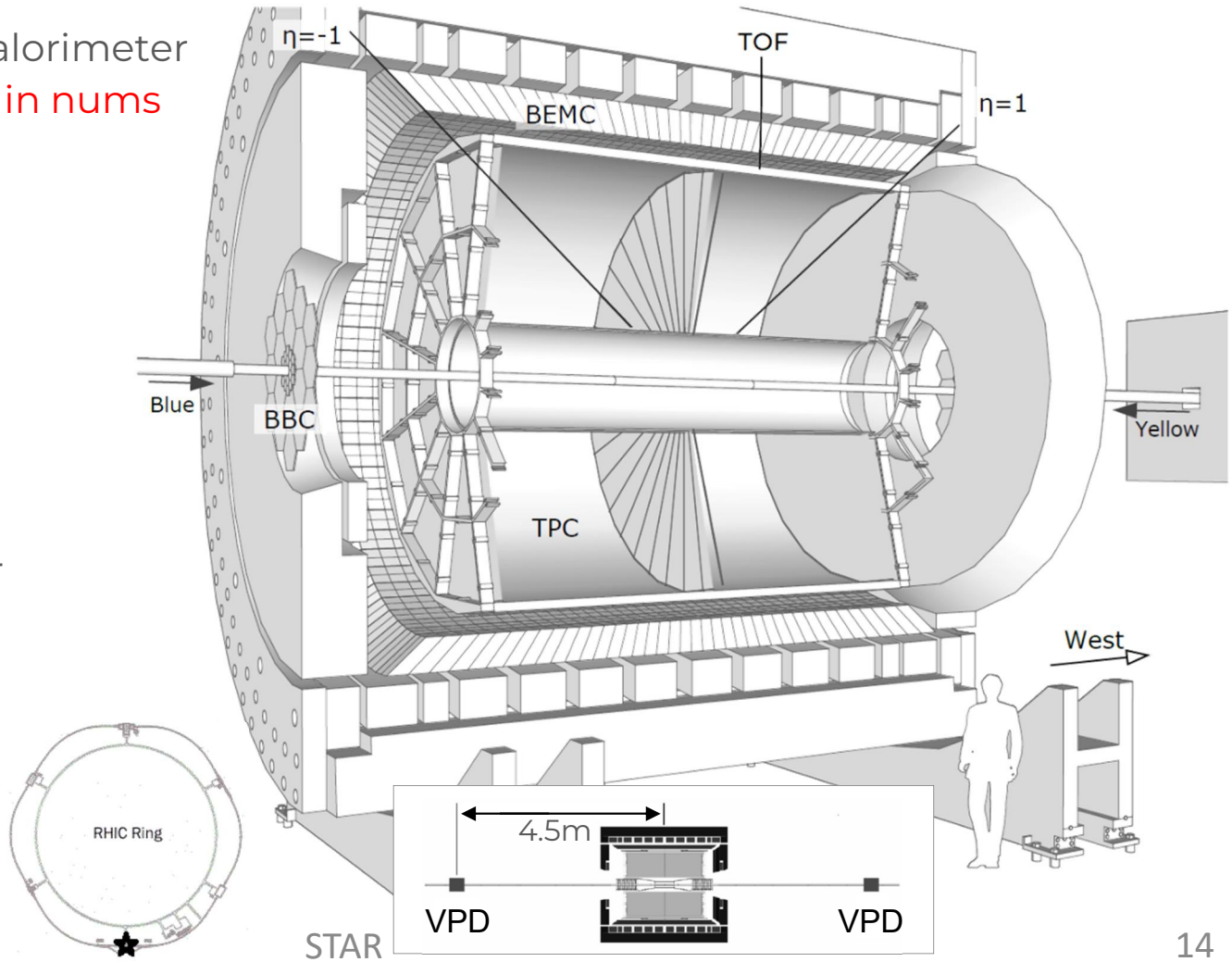
Barrel Electromagnetic Calorimeter
physical characteristics in nums

Time of Flight
radius
timing res

Beam-Beam Counter
eta range

Time Projection Chamber
list volume

Vertex Position Detector
eta range



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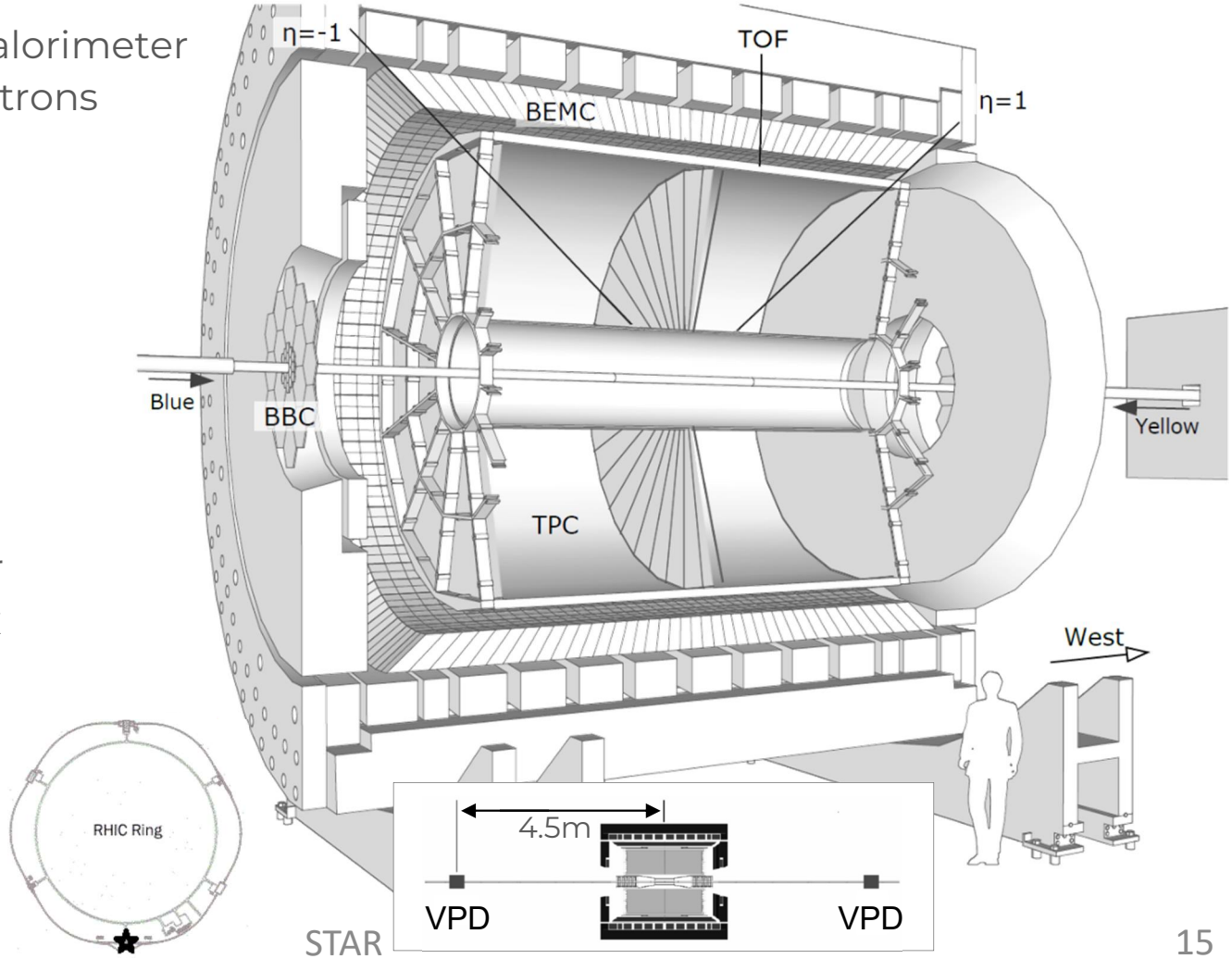
Barrel Electromagnetic Calorimeter
Trigger on, identify electrons

Time of Flight
Pileup track rejection
Slow non-$e^{\pm}$ veto

Beam-Beam Counter
Min-bias trigger

Time Projection Chamber
Momentum and dE/dx

Vertex Position Detector



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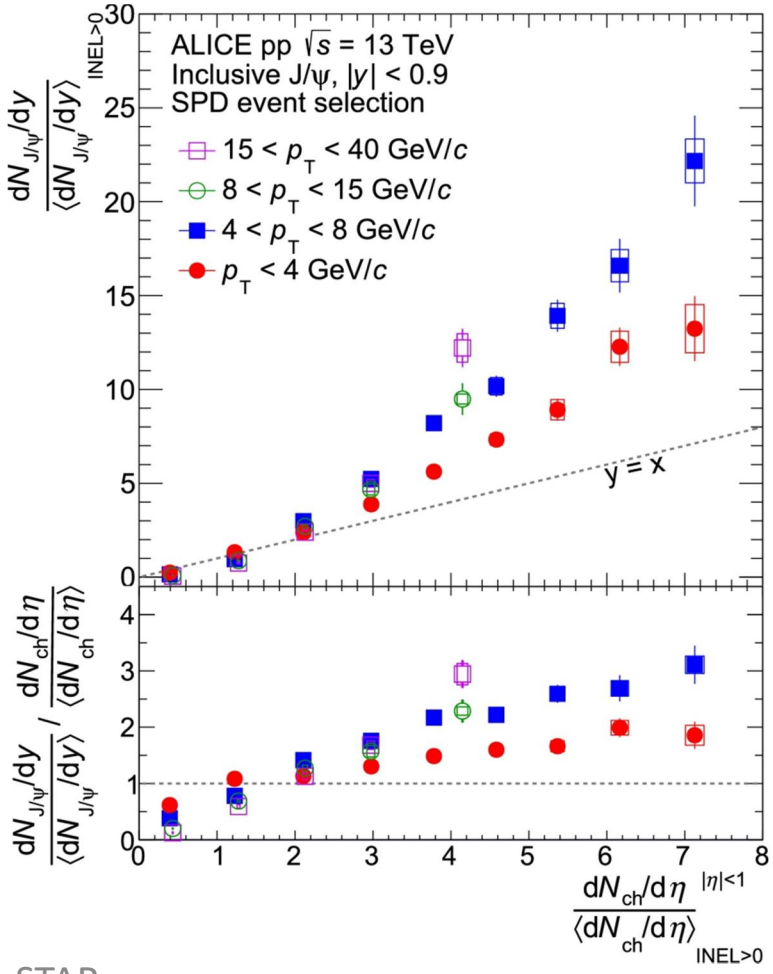
p+p 500,510
performance plot(s)

ideally less than 10 yrs old

ideally TOF beta, dEdx

Systematics Table

Print number table with last two sources


ALICE pp $\sqrt{s}$ = 13 TeV
Inclusive J/ψ, |y| < 0.9
SPD event selection
15 < p_T < 40 GeV/c
8 < p_T < 15 GeV/c
4 < p_T < 8 GeV/c
p_T < 4 GeV/c
y = x
$\frac{dN_{J/\psi}/dy}{\langle dN_{J/\psi}/dy \rangle}^{INEL>0}$
$\frac{dN_{J/\psi}/dy}{\langle dN_{J/\psi}/dy \rangle} / \frac{dN_{ch}/d\eta}{\langle dN_{ch}/d\eta \rangle}$
$\frac{dN_{ch}/d\eta}{\langle dN_{ch}/d\eta \rangle}^{|\eta|<1}_{INEL>0}$

[7]

[1] M. Kramer, Quarkonium Production at high-energy colliders, hep-ph/0106120

[2] J. Harris, B. Müller, et al, QGP Signatures revisited Eur. Phys. J. C (2024) 84:247

[3] J. Adam, J /ψ production cross section and its dependence on charged-particle multiplicity in p+p collisi̅ons at √s =200 GeVPhysics Letters B 786 (2018) 87–93

[4] Rubin P, et. al. (CLEO) Observation of the $^1P_1$ state of charmonium, Phys Rev D, 72 092004, 2005

[5] B. Abelev et. al. (ALICE) , J/ψ production as a function of charged particle multiplī̅city in pp collisions at √s = 7 TeV, Physics Letters B, 712 (2012) 165–175

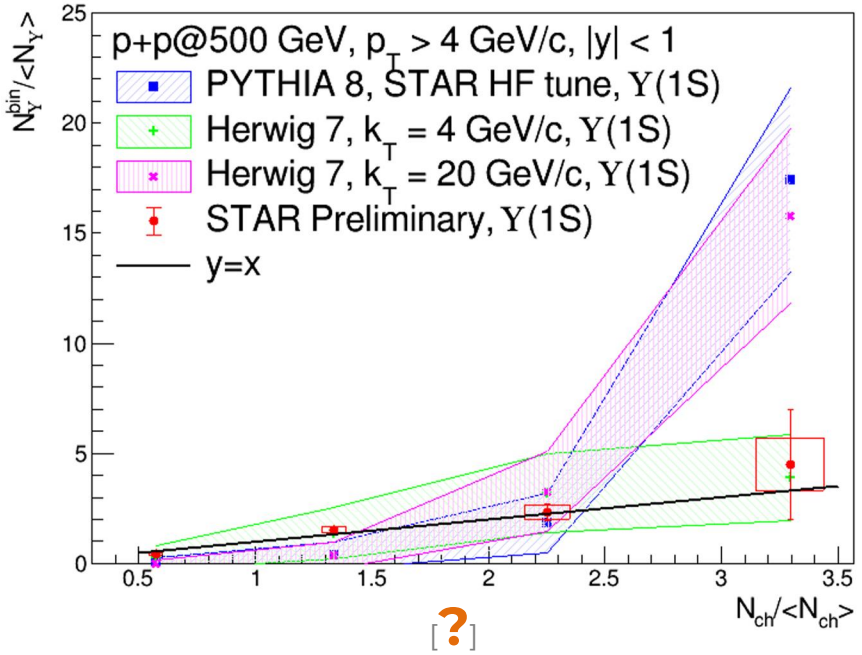
[6] B. Martin, G. Shaw,, Nuclear and Particle Physics, 3rd Ed, p. 190

[7] S. Acharya, et al. (ALICE) Multiplicity dependence of inclusive J/ψ production at √s = 13 TeV, Phys. Lett. B 810 (2020) 135758

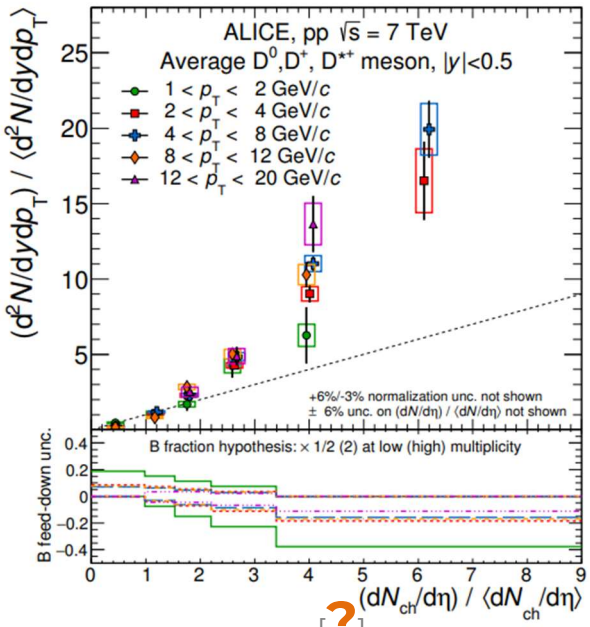
[8] S. Weber, et al. Elucidating the multiplicity dependence of J/ψ production in proton-proton collisions with PYTHIA8, Eur. Phys. J. C (2019) 79:36

Backup

Comparable event activity featured in production of other open and hidden heavy flavor hadrons

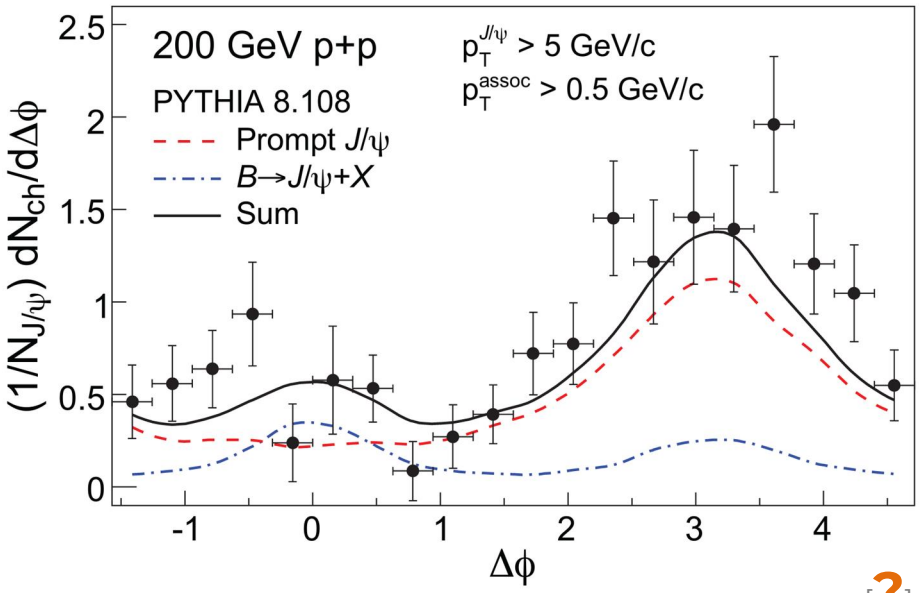


[?]

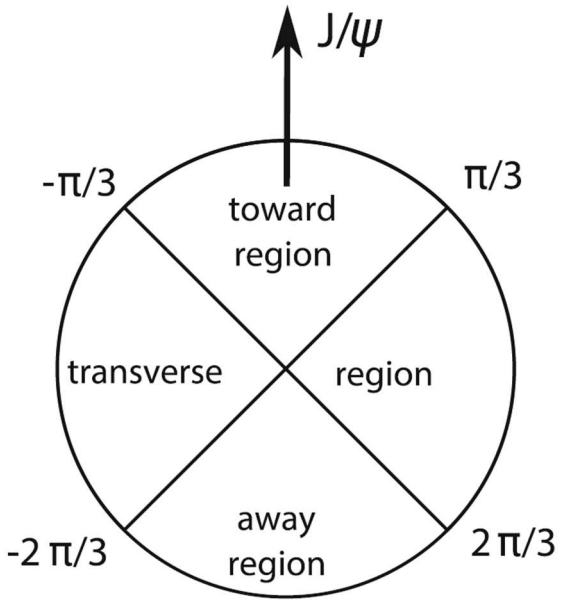


[?]

Backup


200 GeV p+p
PYTHIA 8.108
Prompt J/ψ
B→J/ψ+X
Sum
$p_T^{J/\psi}$ > 5 GeV/c
p_T^{assoc} > 0.5 GeV/c
$(1/N_{J/\psi})\, dN_{ch}/d\Delta\phi$
Δφ
2.5
2
1.5
1
0.5
0
-1
0
1
2
3
4

[?]


J/ψ
-π/3
π/3
toward region
transverse
region
away region
-2 π/3
2 π/3