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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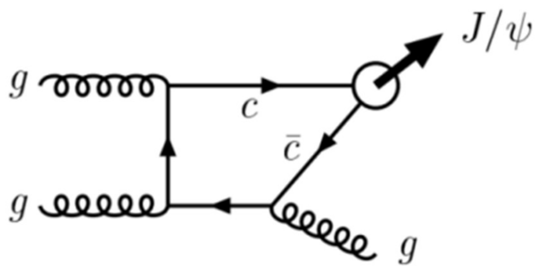
for the STAR Collaboration

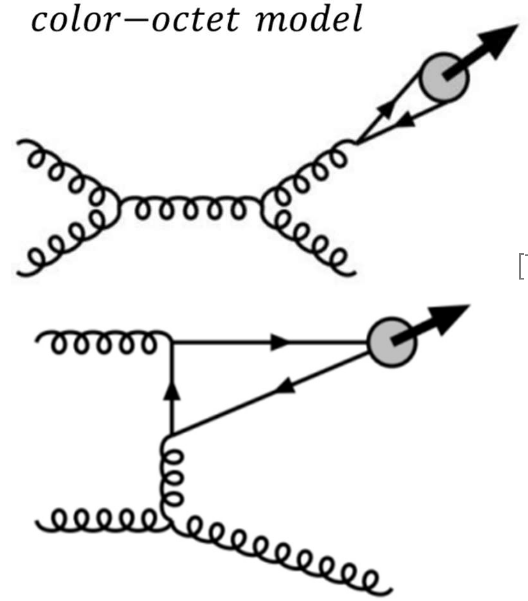
Accompanying model calculations for J/ψ production, are coinciding predictions for the underlying events.

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

color−singlet model



color−octet model

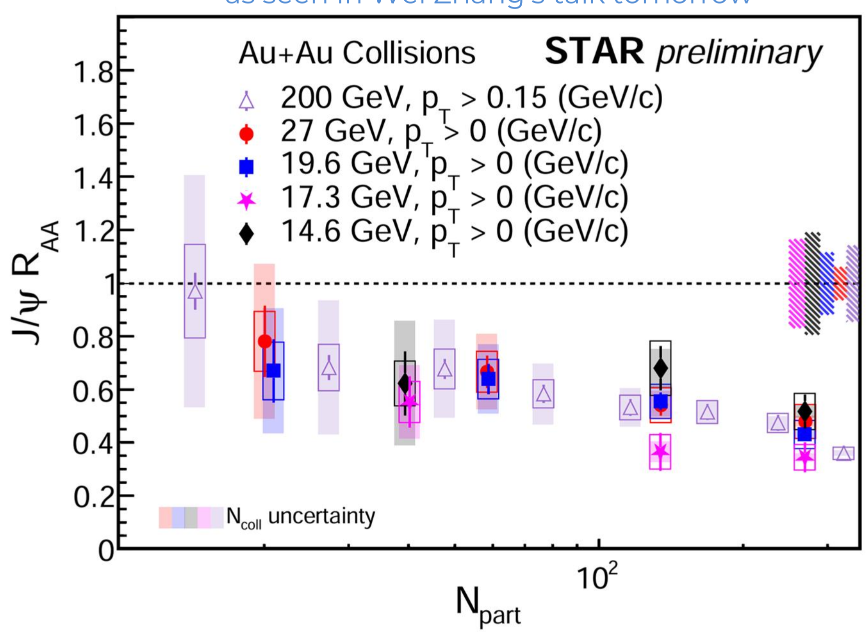


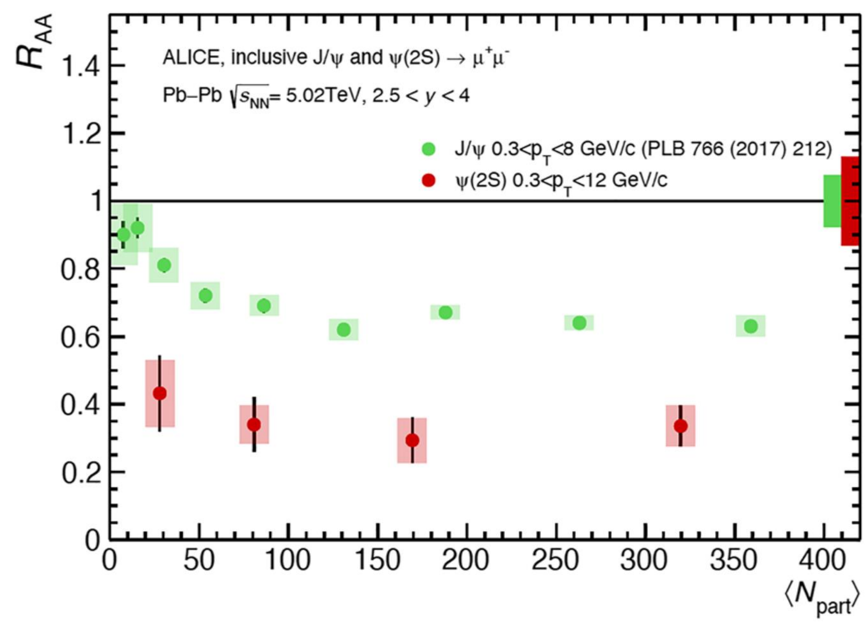
[1]

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

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

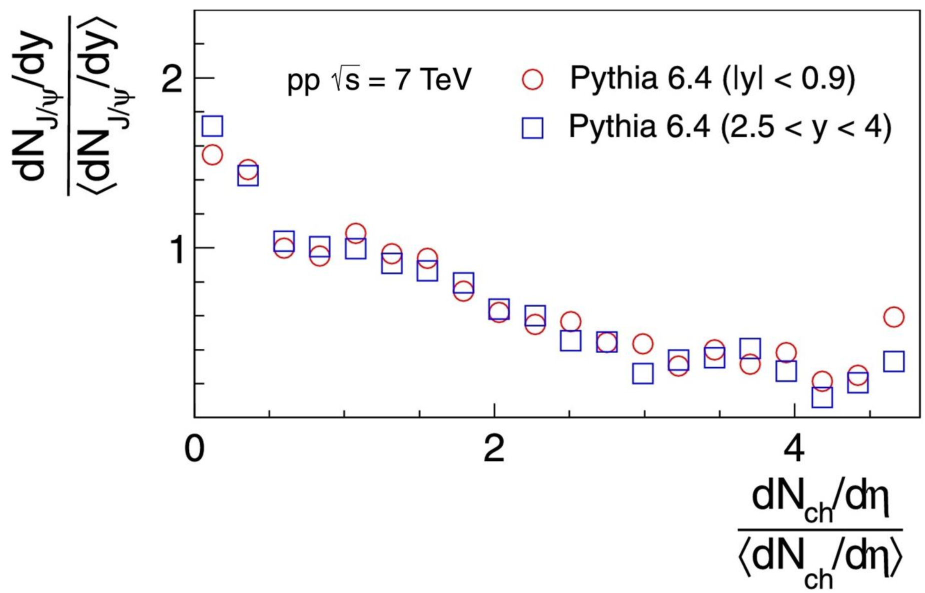
as seen in Wei Zhang's talk tomorrow





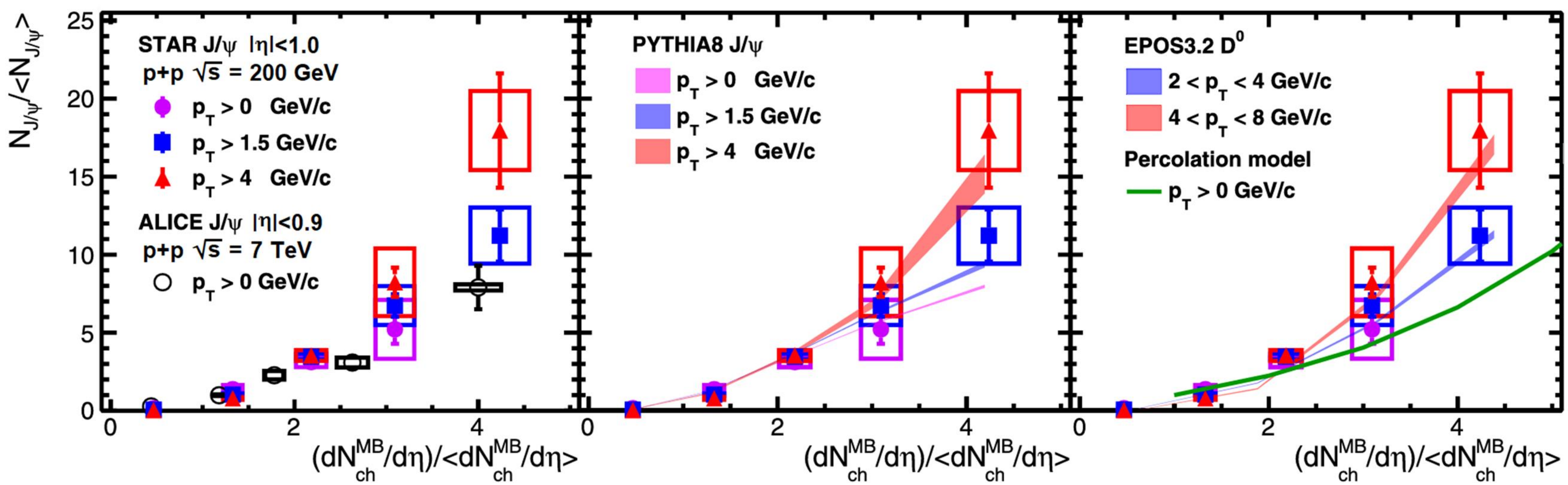
[2]

Early predictions from model calculations



[5]

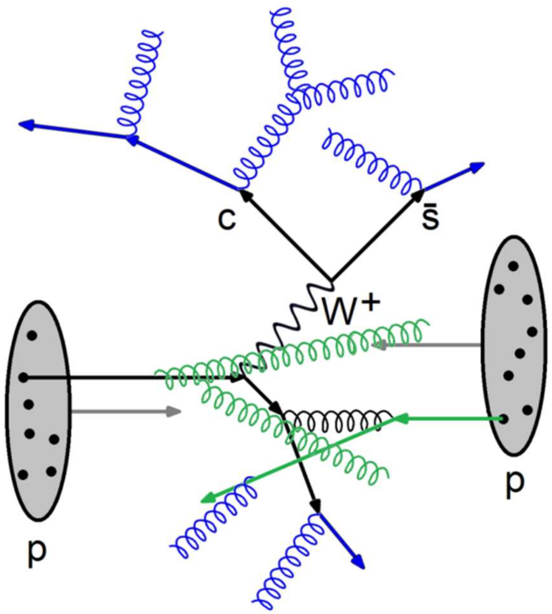
A faster than linear rise in J/ψ production has been found with respect to event multiplicity, consistent across multiple energies.

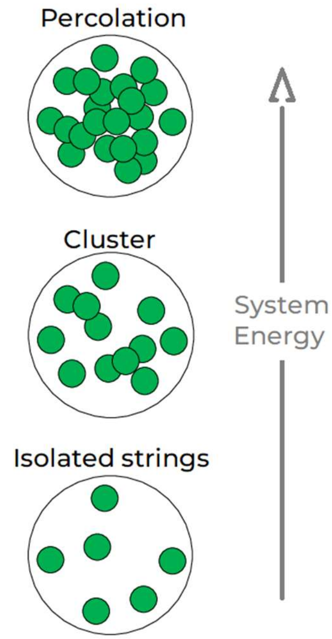


[3]

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





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Barrel Electromagnetic Calorimeter

physical characteristics in nums

Time of Flight

radius

timing res

Beam-Beam Counter

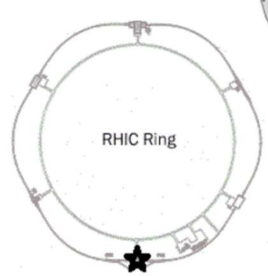
eta range

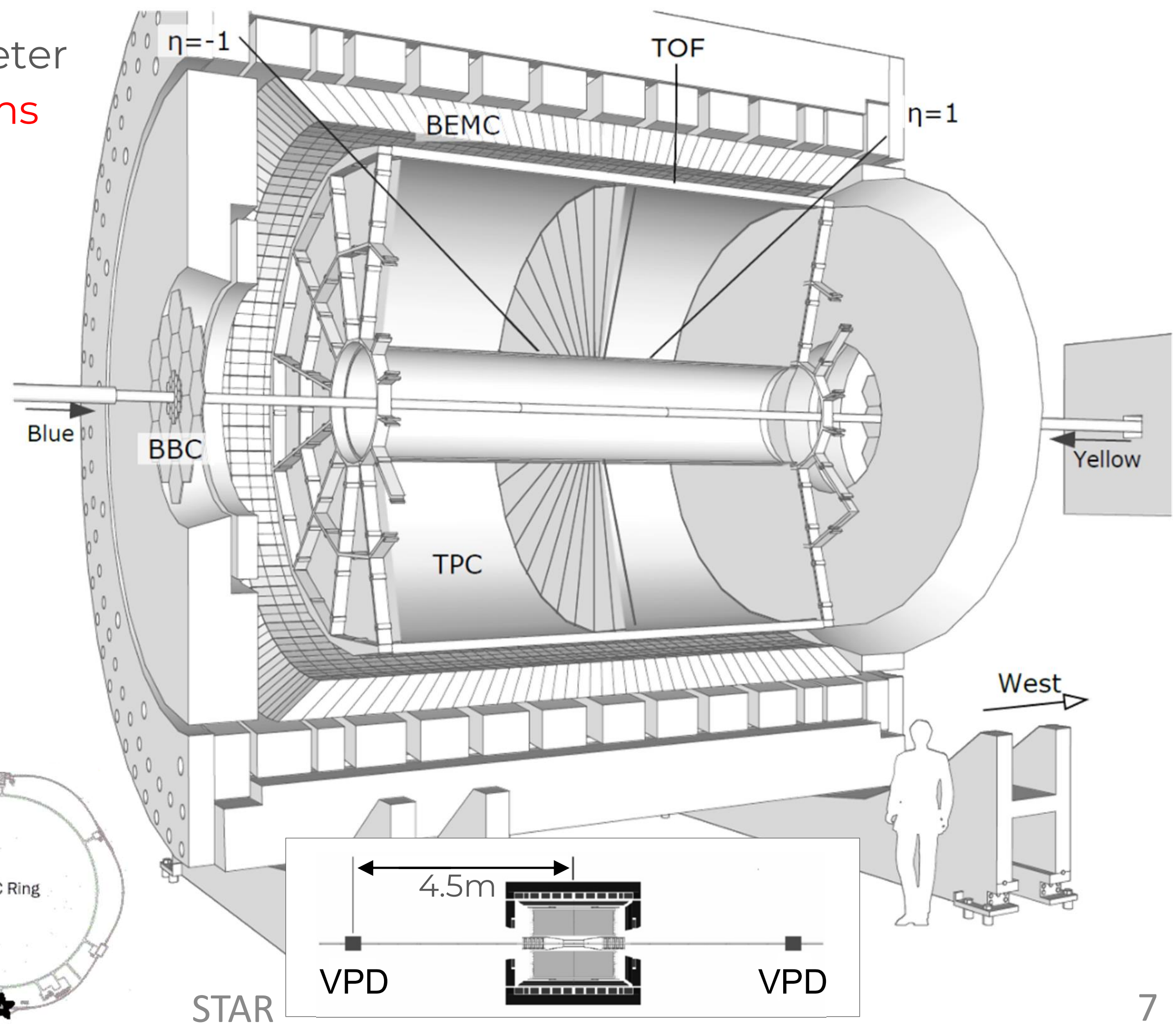
Time Projection Chamber

list volume

Vertex Position Detector

eta range





STAR

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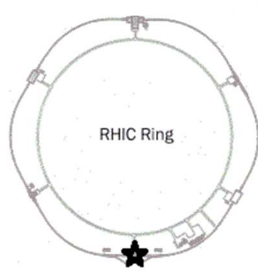
Barrel Electromagnetic Calorimeter
- Trigger on, identify electrons

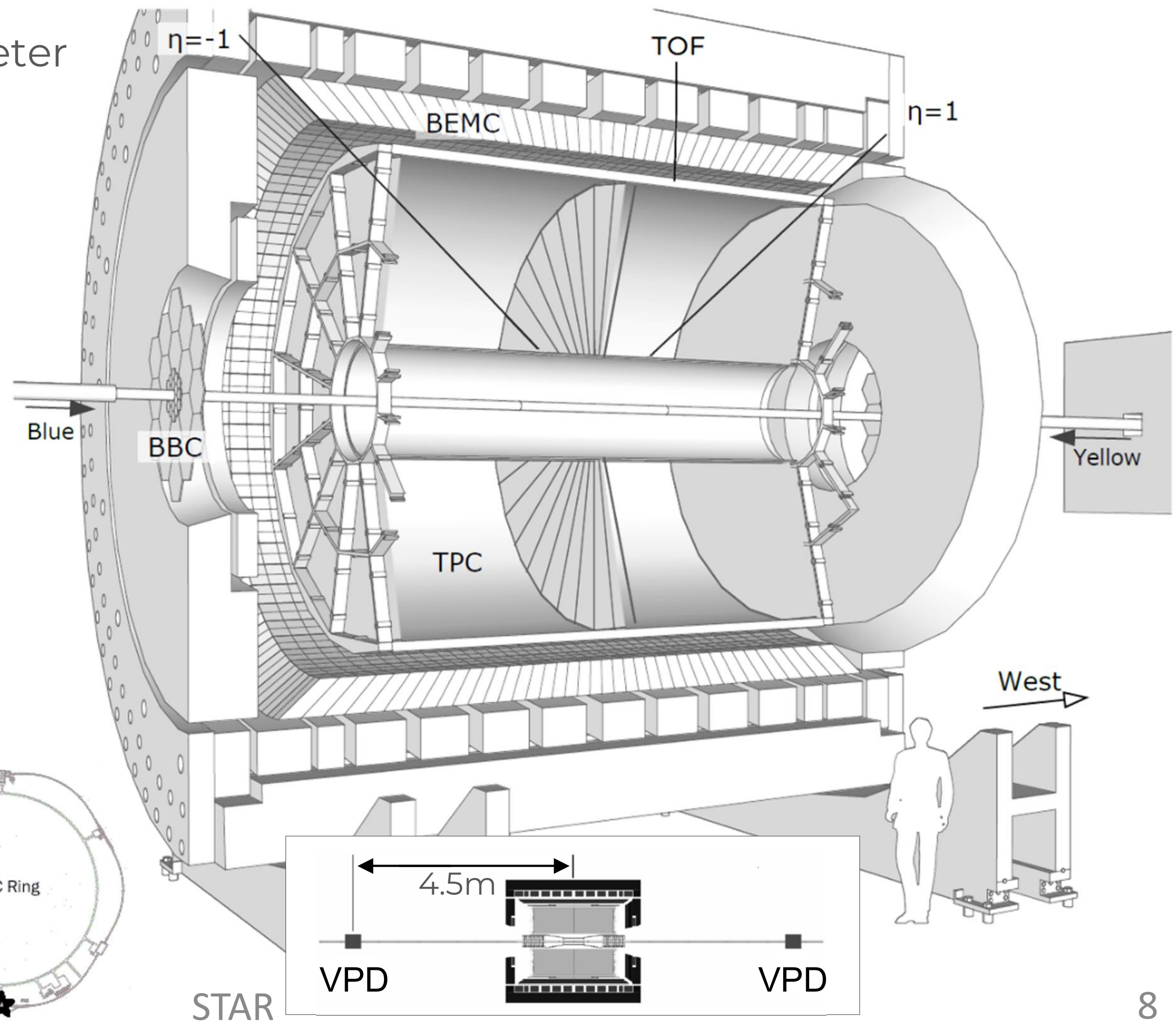
Time of Flight
- Pileup track rejection
- Slow non-$e^{\pm}$ veto

Beam-Beam Counter
- Min-bias trigger

Time Projection Chamber
- Momentum and dE/dx

Vertex Position Detector





STAR

p+p 500,510
performance plot(s)

ideally less than 10 yrs old

ideally TOF beta, dEdx

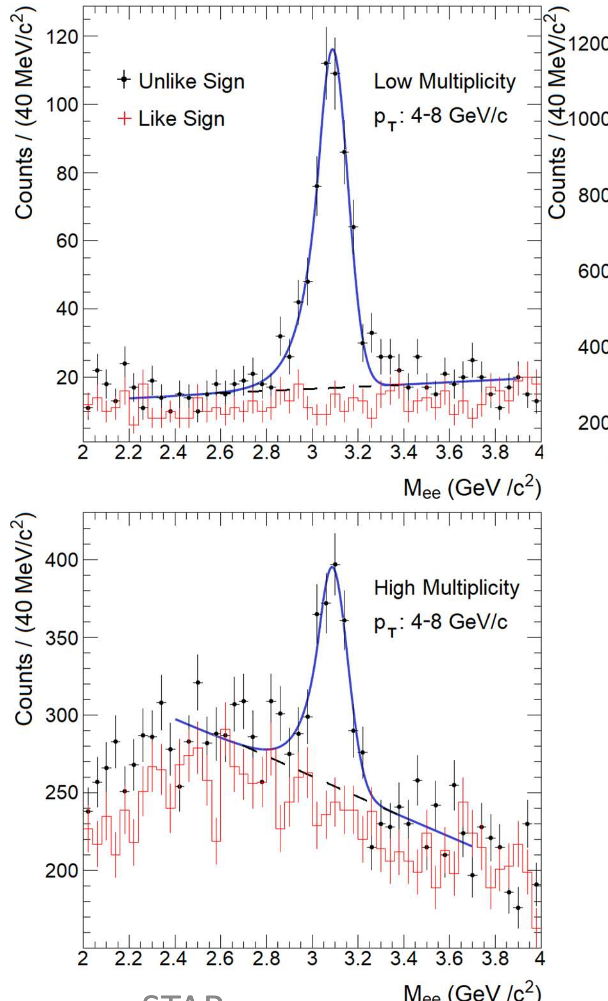
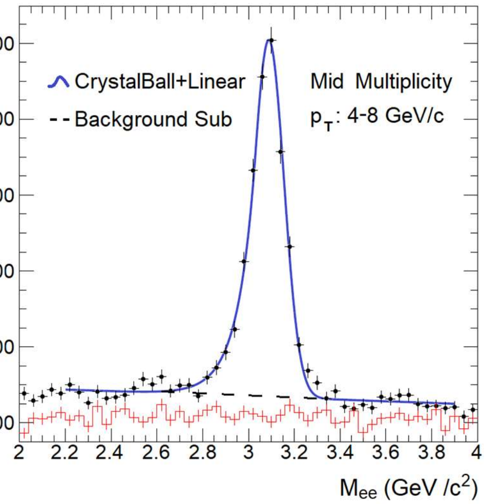
2017 STAR p+p 510 GeV
(79.5 pb-1)

4x increase in luminosity
above 200 GeV p+p

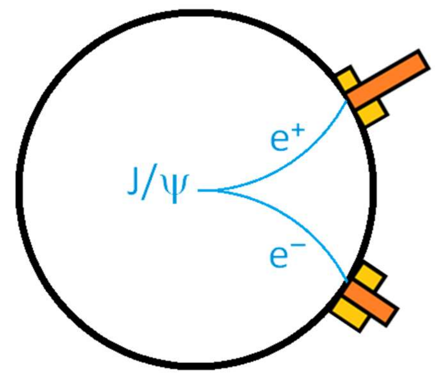
Triggering on events with
4.2 GeV/c EMCal electron

Associate tracks from TOF
or EMCal-E/p window

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

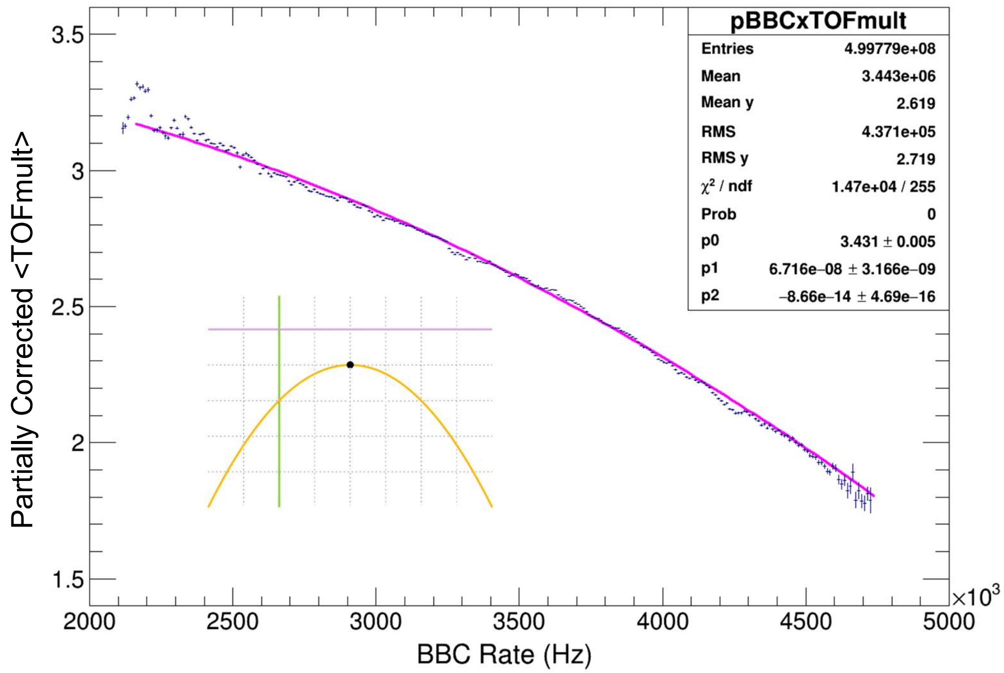



STAR

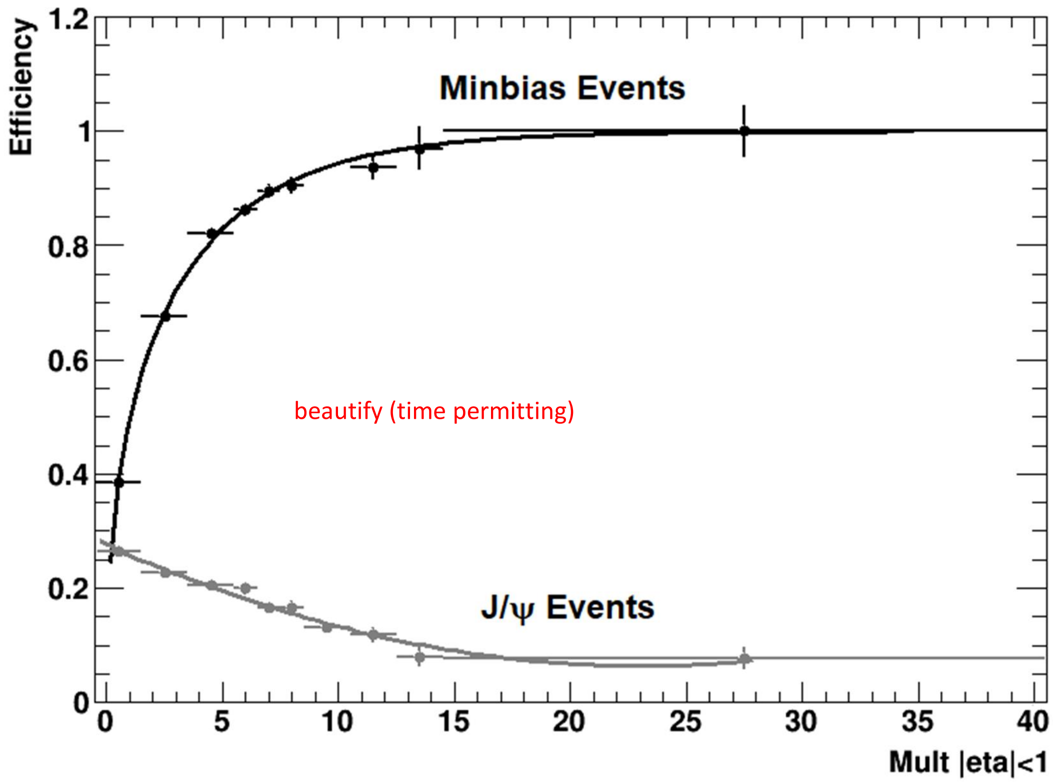


$$M^2 = (E_1 + E_2)^2 - \|\mathbf{p}_1 + \mathbf{p}_2\|^2$$

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



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



Pythia events

- STAR HF Tune
- MB

embedded into zerobias and reconstructed

Systematics Table

Print number table with last two sources

LABELS! Beautify

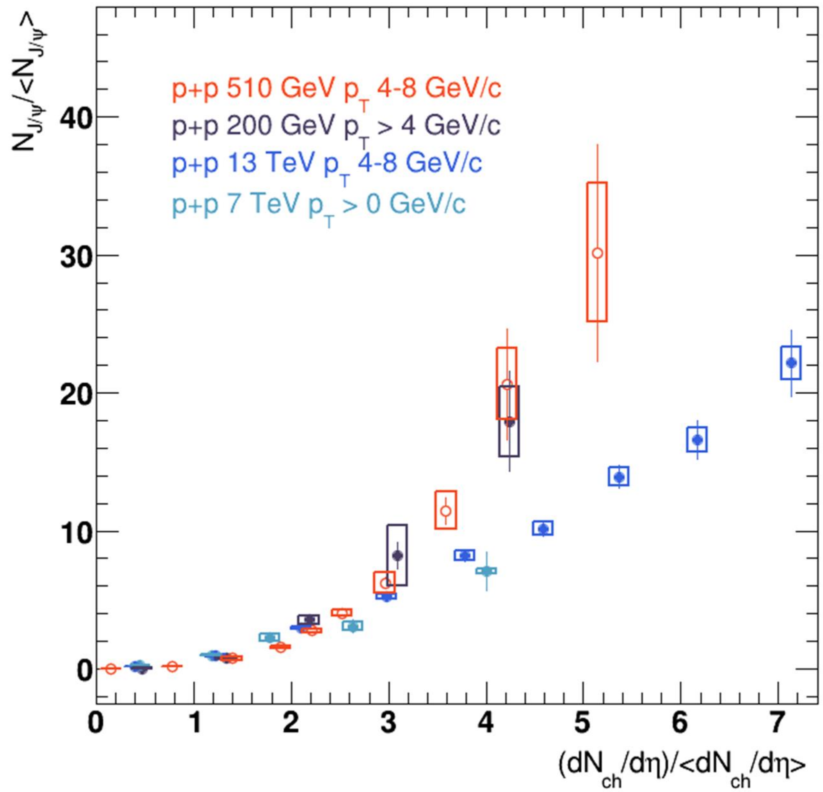
REFINE

Mult range extended

Improved granularity

510 consistent with 200

Hint of splitting between RHIC and LHC energies



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[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 collisions at $\sqrt{s}$ =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 multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV, Physics Letters B, 712 (2012) 165–175

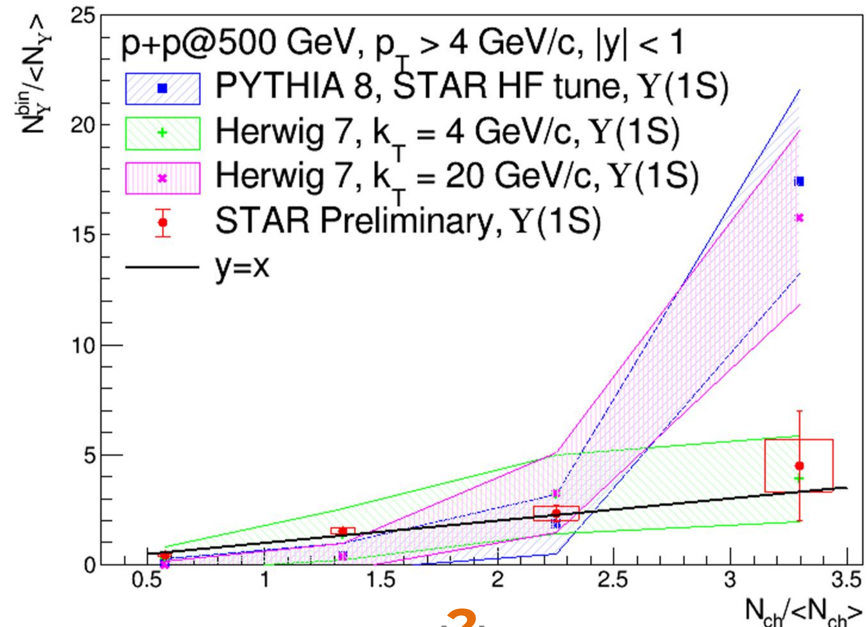
[6] B. Martin, G. Shaw,, Nuclear and Particle Physics, 3rd Ed, p. 190

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

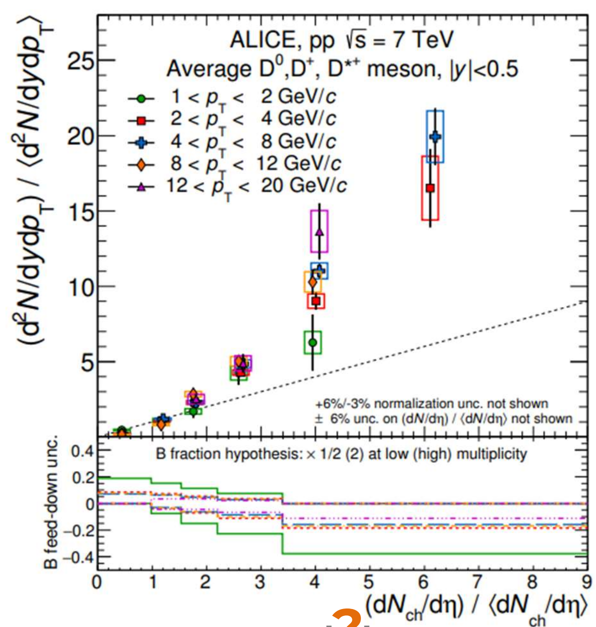
[8] S. Weber, et al. Elucidating the multiplicity dependence of J/ψ production in proton-proton collisions with PYTHIA8, Eur. Phys. J. C (2019) 79:36

Backup

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

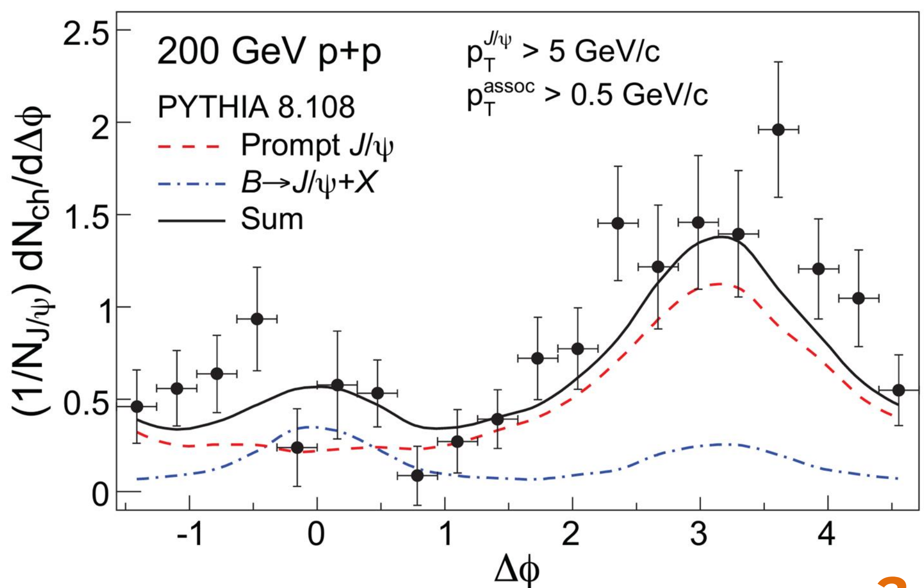


[?]

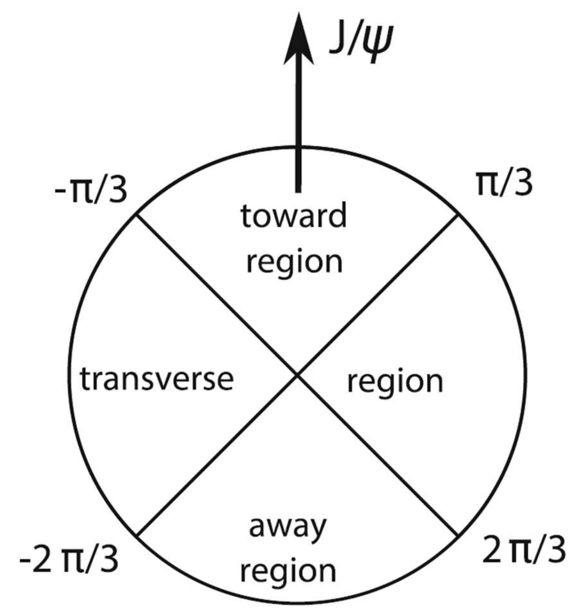


[?]

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$_{ch}$/dΔφ
Δφ

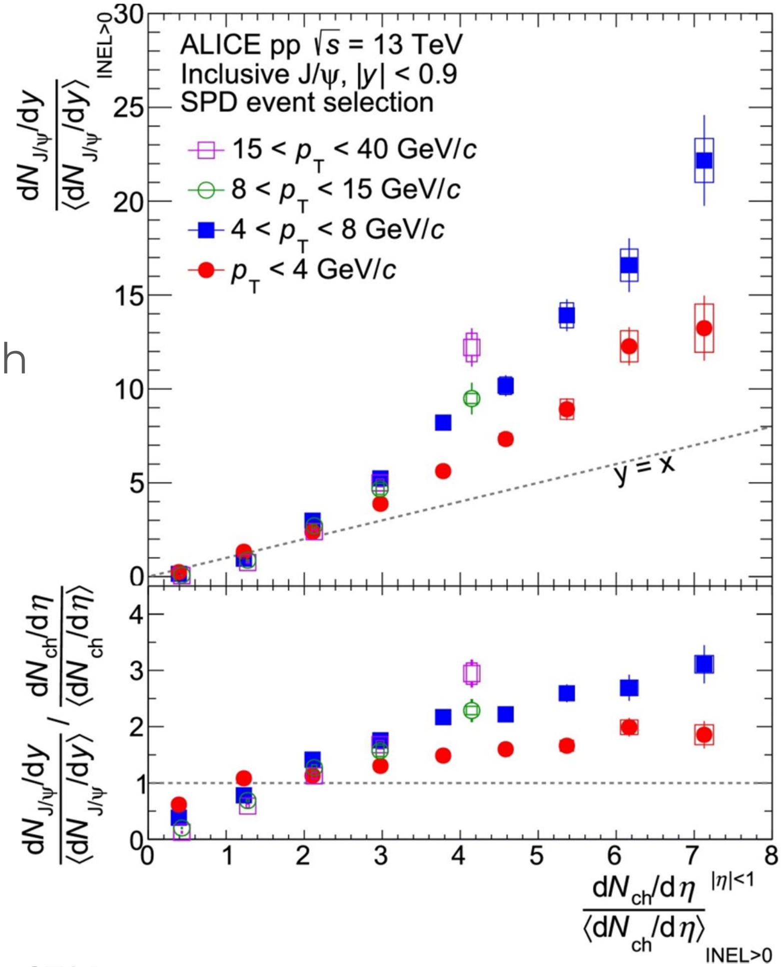
[?]


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

Backup

Extend the reach of STAR with a high multiplicity trigger?/!

[7]



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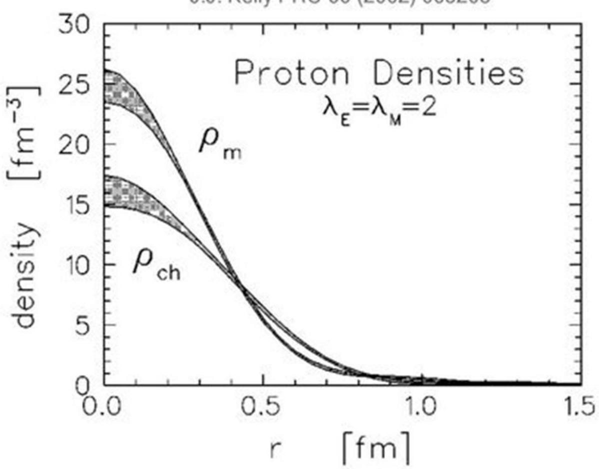
$$F(Q^2) = \frac{G_E^2(Q^2) + \tau G_M^2(Q^2)}{1+\tau} + 2\tau \tan^2\left(\frac{\theta_e}{2}\right) G_M^2(Q^2)$$

- Within a **non-relativistic approach**, electromagnetic **form factors** can be interpreted as the **Fourier transform** of the charge and current **densities** inside the nucleon.

J.J. Kelly PRC 66 (2002) 065203



$$\rho_{ch}(r) = \frac{2}{\pi}\int_0^\infty dQ\, Q^2 j_0\left(Qr/\sqrt{1+\left(Q^2/4M^2\right)}\right) G_E\left(Q^2\right)\left[1+\left(Q^2/4M^2\right)\right]^{\lambda_E}$$

Dipole behaviour

$$\rho(r) = \frac{\lambda^3}{8\pi}\exp[-\lambda r] \quad \rightarrow \quad F(k) = \int \rho(r)\exp[i k \cdot r] d^3 r = \frac{\lambda^4}{\left(k^2+\lambda^2\right)^2}$$

Backup

Further insight into this deviation from linearity can be obtained by investigating the impact parameter dependence of MPI. As mentioned earlier, in PYTHIA the number of MPI per event is related to the matter overlap in the pp collisions and, hence, to the impact parameter b [21]. Figure 3 (left panel) shows the average self-normalized number of MPI per event as a function of the self-normalized b^{-1}. In the most central collisions, the average number of MPI saturates at 3.3 times the mean value. Even higher number of MPI, as

[5]

5.2.1 The strong coupling constant

The strong interaction derives its name from the strong forces acting at distances of order 1 fm that, among other things, bind quarks in hadrons. However, many of the remarkable phenomena discussed in this chapter depend on the fact that the interaction gets weaker at short distances; that is, on asymptotic freedom. Such short-distance interactions are associated with large momentum transfers $|\mathbf{q}|$ between the particles, with

$$|\mathbf{q}| = \mathrm{O}(\hbar/r), \tag{5.6}$$

where $r = |\mathbf{r}|$ is the distance at which the interaction occurs. For example, the amplitude (1.47) for scattering from a spherically symmetric potential $V(r)$ becomes

$$\mathcal{M}(q) = 4\pi \int_0^\infty V(r) \left(\frac{\sin(qr)}{qr} \right) r^2 \mathrm{d}r \tag{5.7}$$

on integrating over all angular directions. The dominant contributions arise from r values of order q^{-1} as asserted, since for smaller r the integrand is suppressed by the factor r^2, while for large r it is suppressed by the average over the rapidly oscillating sine factor. Hence in discussing

[10] The numerical factor multiplying α_s (i.e. $-4/3$ in this case) depends on the colour state chosen, and we will not discuss it further.

[4]