Measurement of J/ψ Production in Proton–Proton Collisions by the PHENIX Experiment

Nichelle Bruner

University of New Mexico

for the PHENIX Collaboration

HEP2003 – July 19, 2003

Outline

First results from PHENIX for $pp \rightarrow J/\psi$ at $\sqrt{s} = 200$ GeV will be presented.

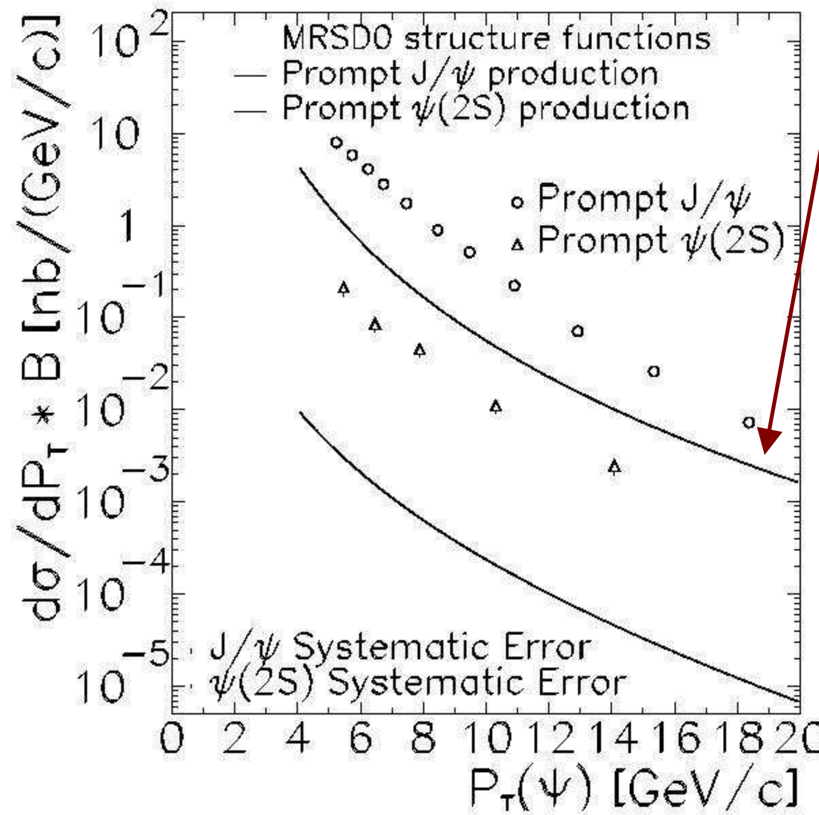
- Why is this measurement important?
- RHIC and the PHENIX detector
- Analysis procedure
- Results for $pp \rightarrow J/\psi$ Production
- Outlook for future measurements

Motivation: Understanding J/ψ Production Mechanisms

- Fixed target data have provided J/ψ σ_{TOTAL} and $\langle p_T \rangle$ for $\sqrt{s}$ = 7–38.8 GeV
- Results from collider energies, with limited reach in η and p_T, have raised interest in various models:
  - Color Singlet Model
  - Color Octet Model (NRQCD)
  - Color Evaporation Model (phenomenological)

Systematic studies at RHIC energies with wide η and p_T coverage are needed.

CDF J/ψ cross section is greater than Color Singlet Model prediction PRL **79** 572 (1997)



Motivation: Baseline for RHIC Heavy Ion and Spin Programs

- Baseline for pA and AA. Comparisons between various collision species are needed to resolve competing J/ψ production signatures of quark gluon plasma.
  - pA: "normal nucleus effects"
  - AA: "medium effects"
- Understand J/ψ polarization
- Baseline for components of spin program which rely on heavy flavor.

PHENIX

12 Countries; 57 Institutions; 460 Participants*

Brazil University of São Paulo, São Paulo

China Academia Sinica, Taipei, Taiwan
China Institute of Atomic Energy, Beijing
Peking University, Beijing

France LPC, University de Clermont–Ferrand, Clermont–Ferrand
Dapnia, CEA Saclay, Gif–sur–Yvette
IPN–Orsay, Universite Paris Sud, CNRS–IN2P3, Orsay
LLR, Ecòle Polytechnique, CNRS–IN2P3, Palaiseau
SUBATECH, Ecòle des Mines at Nantes, Nantes

Germany University of Münster, Münster

Hungary Central Research Institute for Physics (KFKI), Budapest
Debrecen University, Debrecen
Eötvös Loránd University (ELTE), Budapest

India Banaras Hindu University, Banaras
Bhabha Atomic Research Centre, Bombay

Israel Weizmann Institute, Rehovot

Japan Center for Nuclear Study, University of Tokyo, Tokyo
Hiroshima University, Higashi–Hiroshima
KEK, Institute for High Energy Physics, Tsukuba
Kyoto University, Kyoto
Nagasaki Institute of Applied Science, Nagasaki
RIKEN, Institute for Physical and Chemical Research, Wako
RIKEN–BNL Research Center, Upton, NY
University of Tokyo, Bunkyo–ku, Tokyo
Tokyo Institute of Technology, Tokyo
University of Tsukuba, Tsukuba
Waseda University, Tokyo

S. Korea Cyclotron Application Laboratory, KAERI, Seoul
Kangnung National University, Kangnung
Korea University, Seoul
Myong Ji University, Yongin City
System Electronics Laboratory, Seoul Nat. University, Seoul
Yonsei University, Seoul

Russia Institute of High Energy Physics, Protovino
Joint Institute for Nuclear Research, Dubna
Kurchatov Institute, Moscow
PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
St. Petersburg State Technical University, St. Petersburg

Sweden Lund University, Lund

USA Abilene Christian University, Abilene, TX
Brookhaven National Laboratory, Upton, NY
University of California – Riverside, Riverside, CA
University of Colorado, Boulder, CO
Columbia University, Nevis Laboratories, Irvington, NY
Florida State University, Tallahassee, FL
Georgia State University, Atlanta, GA
University of Illinois Urbana Champaign, Urbana–Champaign, IL
Iowa State University and Ames Laboratory, Ames, IA
Los Alamos National Laboratory, Los Alamos, NM
Lawrence Livermore National Laboratory, Livermore, CA
University of New Mexico, Albuquerque, NM
New Mexico State University, Las Cruces, NM
Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
Oak Ridge National Laboratory, Oak Ridge, TN
University of Tennessee, Knoxville, TN
Vanderbilt University, Nashville, TN

*as of July 2002

PHENIX Muon Arms – Run 2 Configuration

Muon Arms

Track stubs from Muon Identifiers used to seed tracks in the Muon Tracker

Muon Tracker

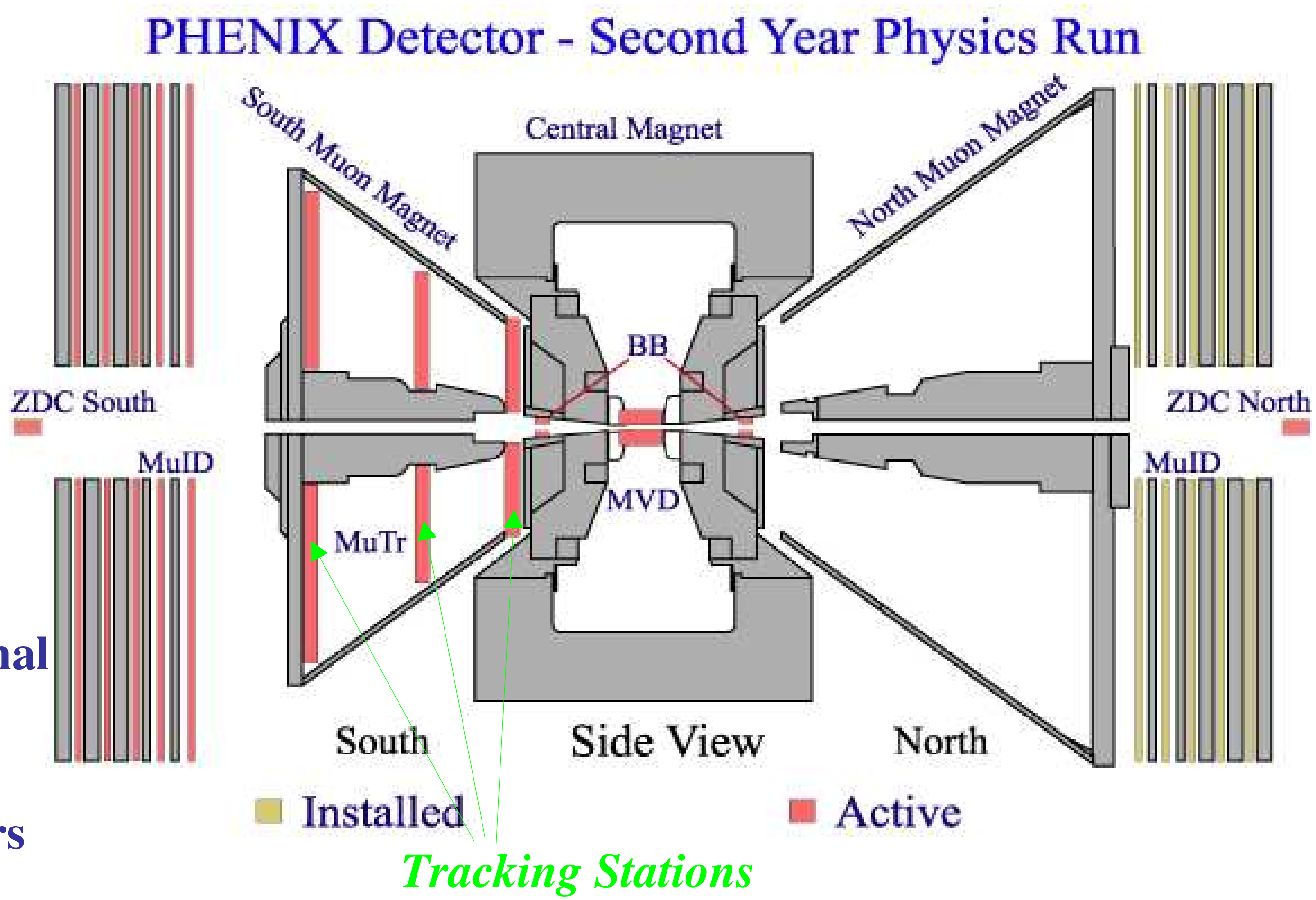
3 stations of cathode strip chambers per arm

$-1.2 > \eta > -2.2$ (south)

$1.2 < \eta < 2.4$ (north)

$-\pi < \phi < \pi$

position resolution ~ 100μm



Muon Identifier

5 layers of plastic proportional (Iarocci) tubes per arm

–transversely oriented

–separated by steel absorbers

$p(\mu) > 2$ GeV/c

π/μ rejection = 2.5×10^{-4}

N. Bruner Univ. of New Mexico

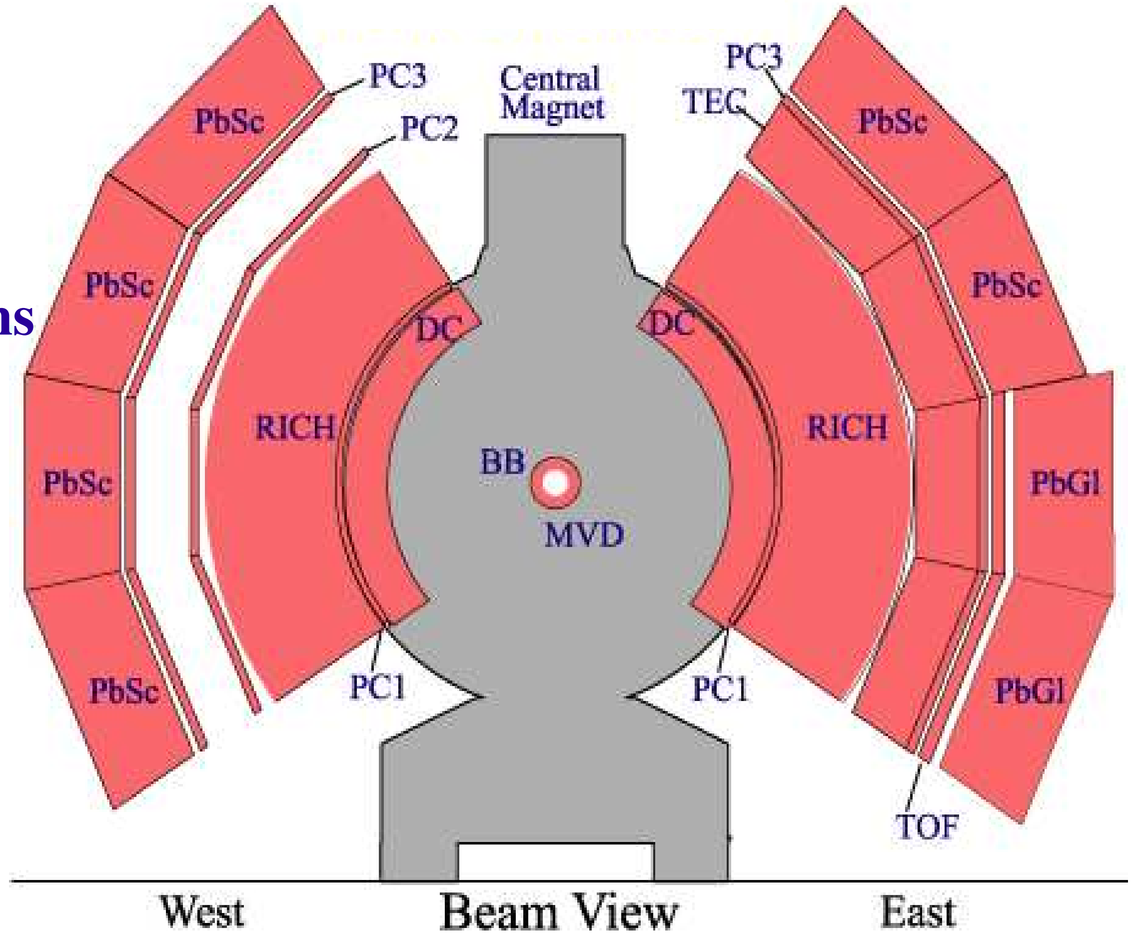
Central Arms

<u>**Coverage**</u>

$-0.35 < \eta < 0.35$

$30^o < |\varphi| < 120^o$ (East & West)

Charged hadrons, Electrons, Photons



<u>**Electrons**</u>

- **Tracks** (Beam–Beam, Drift Chambers, Pad Chambers)**+**
- **RICH rings +**
- **EM Calorimeter clusters**

<u>**Resolution**</u>

- **π/e rejection $< 10^{-4}$**
- **TOF: K/π separation up to 2.5 GeV/c**
- **$\delta p/p = 0.7\% + 1.0\% \times p$ [GeV/c]**

<u>**Global Subsystems**</u>

MVD: $-2.5<\eta<+2.5$

Beam–Beam Counter

Zero–Degree Calorimeter

$pp \to J/\psi + X \to l^+l^- + X$ Analysis

RHIC Run 2

- pp collisions at $\sqrt{s}$ =200 GeV
- transversely polarized, max pol. = 25%
- RHIC delivered 700 nb^{-1}
- PHENIX sampled 156 nb^{-1}
- 67 nb^{-1} used in $J/\psi \to \mu^+\mu^-$
- 82 nb^{-1} used in $J/\psi \to e^+e^-$

J/ψ triggers = minimum bias & level 1

minimum bias trigger = at least one hit in each Beam–Beam counter

- offline vertex cut = $|Z| \leq 35$ cm (e^+e^-) and $|Z| \leq 38$ cm ($\mu^+\mu^-$)
- electron level 1 trigger = EMCal tower 2×2 tile with > 0.75 GeV *or* 4×4 tile with > 2.1 GeV
- muon level 1 trigger = 1 deep muon + 1 deep or shallow muon in the muon identifier

Analysis Continued

$$B_{ll}\frac{d^2\sigma}{dy\,dp_T} = \frac{N_{J/\psi}}{\int \mathcal{L}dt\ \Delta y \Delta p_T}\frac{1}{\varepsilon_{lvl1}\varepsilon_{minbias}}\frac{1}{A\varepsilon_{rec}}$$

$\int \mathcal{L}dt$ = 67 nb^{-1} ($\mu^+\mu^-$) and 82 nb^{-1} (e^+e^-) ± 9.6%

$A\varepsilon_{rec} \times \varepsilon_{lvl1}$ varied for electrons and muons as a function of y and p_T

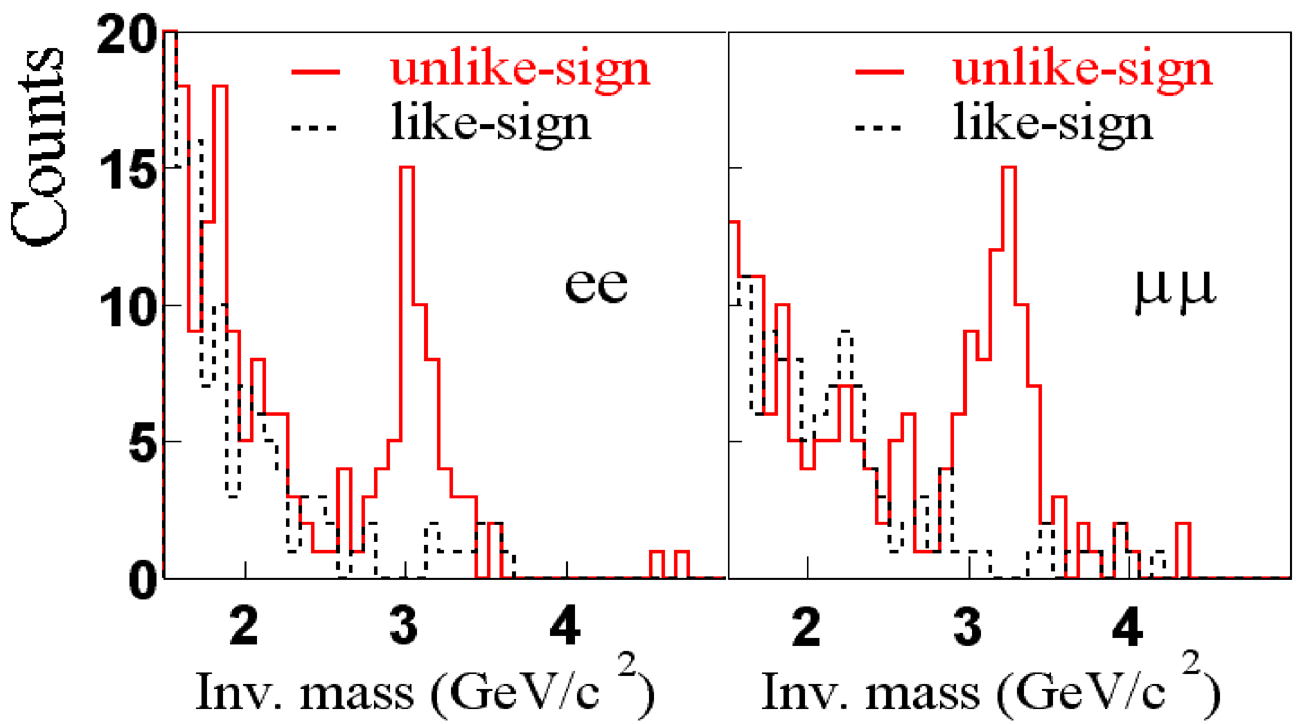
$\mu^+\mu^-$: $A\varepsilon_{rec} \times \varepsilon_{lvl1}$ = 0.038 –0.017 ± 13%

e^+e^-: ε_{lvl1} 2×2 = 0.87–0.90 ± 5%, 4×4 = 0.30–0.74 ± 36%

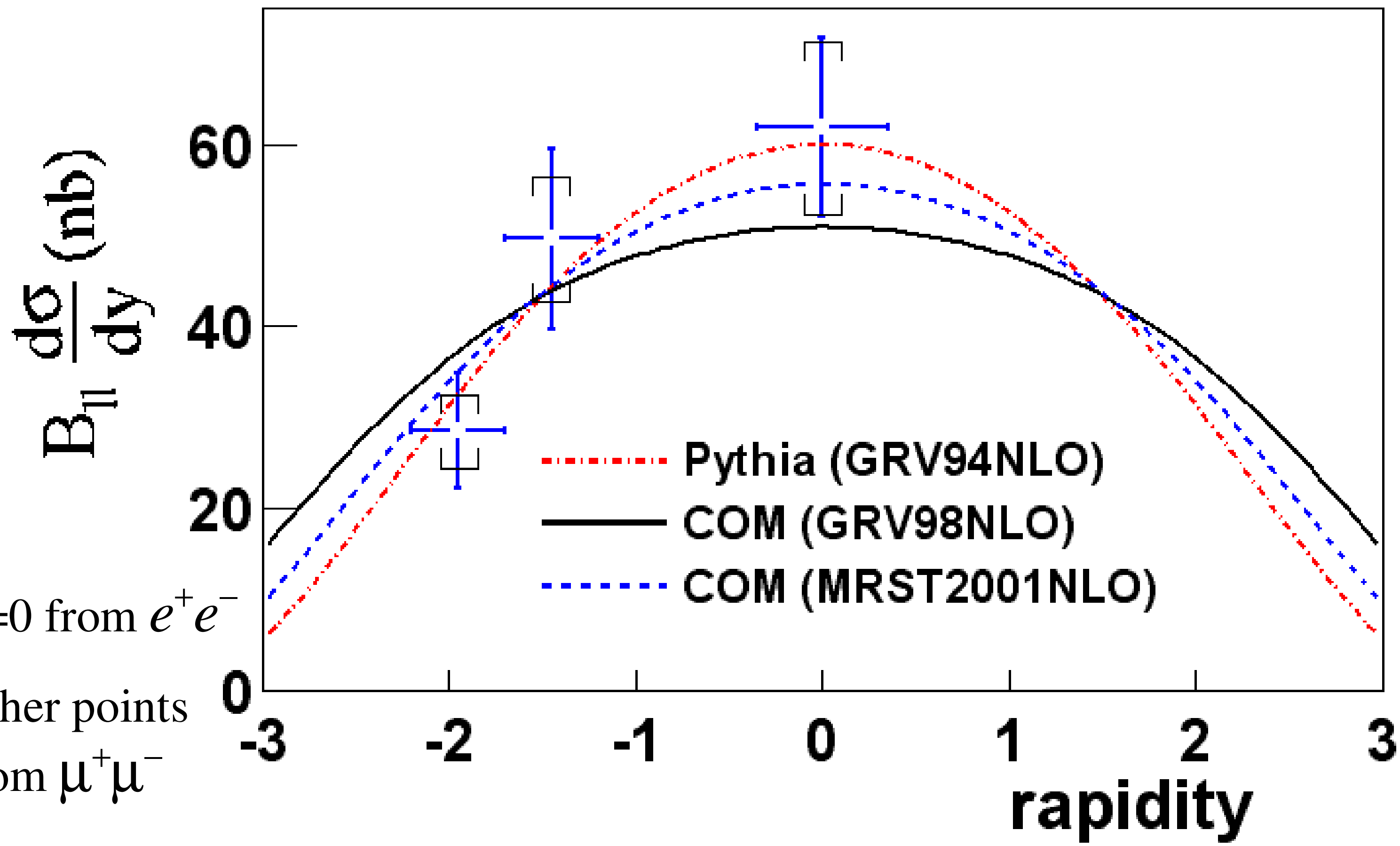
e^+e^-: $A\varepsilon_{rec}$ = 0.026–0.010 ± 13%

$\varepsilon_{minbias}$ = 0.75 ± 3%

$N_{J/\psi}$ is determine by like–sign subtraction



pp → J/ψ Rapidity Distribution



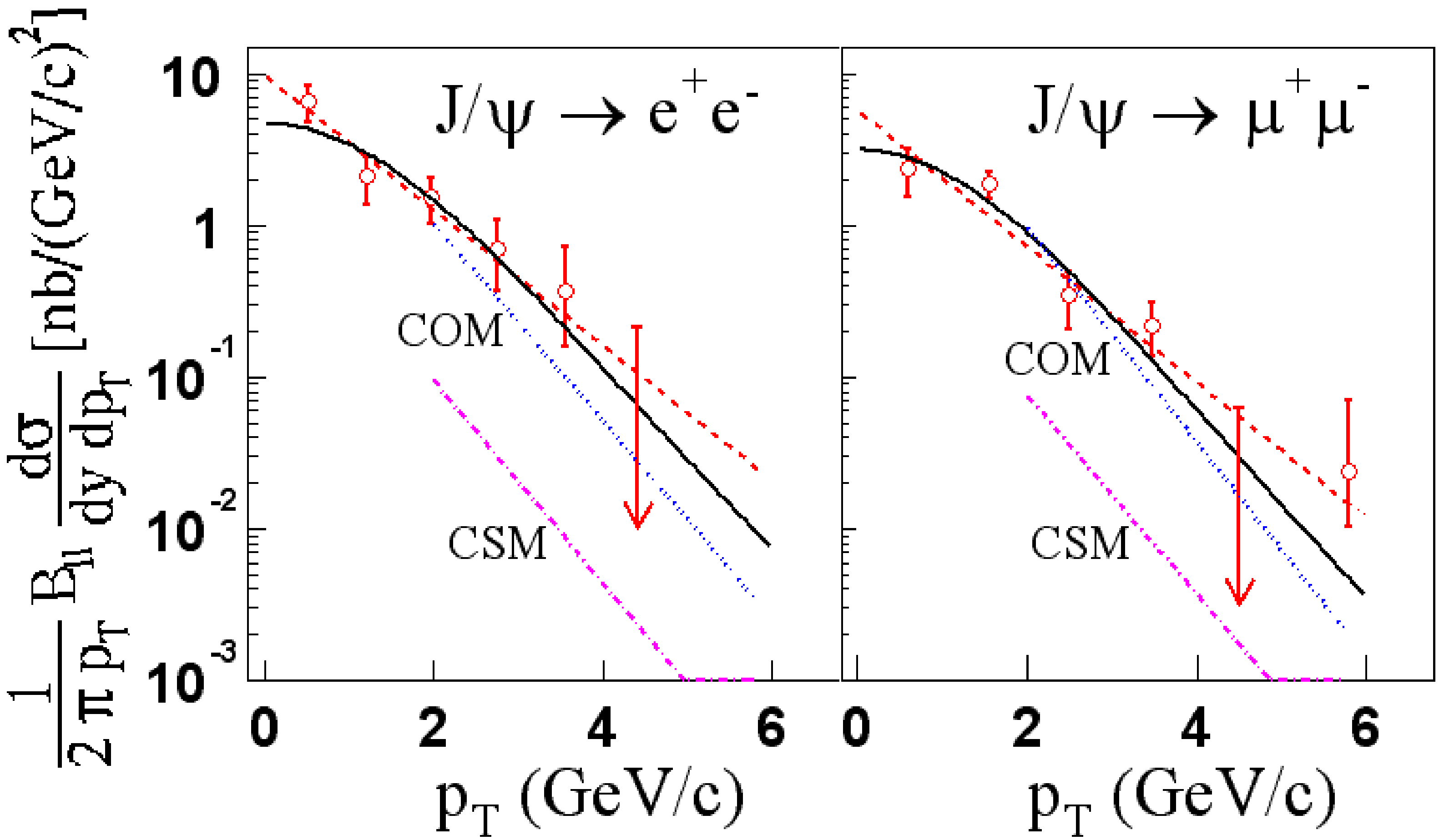
y=0 from e^+e^-

other points from $\mu^+\mu^-$

Gluon fusion dominates production in all models, therefore y shape depends on gluon distribution function.
More data are needed to constrain PDF.

All curves are normalized to data.
Brackets represent systematic uncertainty.
The Pythia shape was used to determine σ.

PHENIX pp → J/ψ Momentum Distribution



Dashed line is an exponential fit.

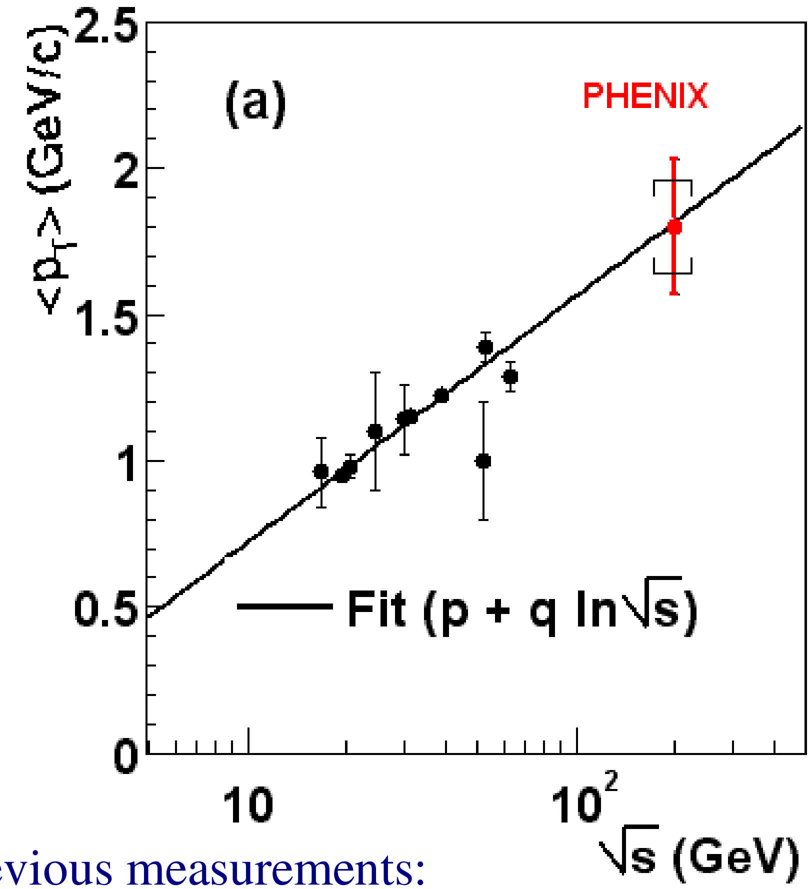
Solid line is a fit to $1/(2\pi p_T)\, d\sigma/dp_T = A\,(1+(p_T/B)^2)^{-6}$

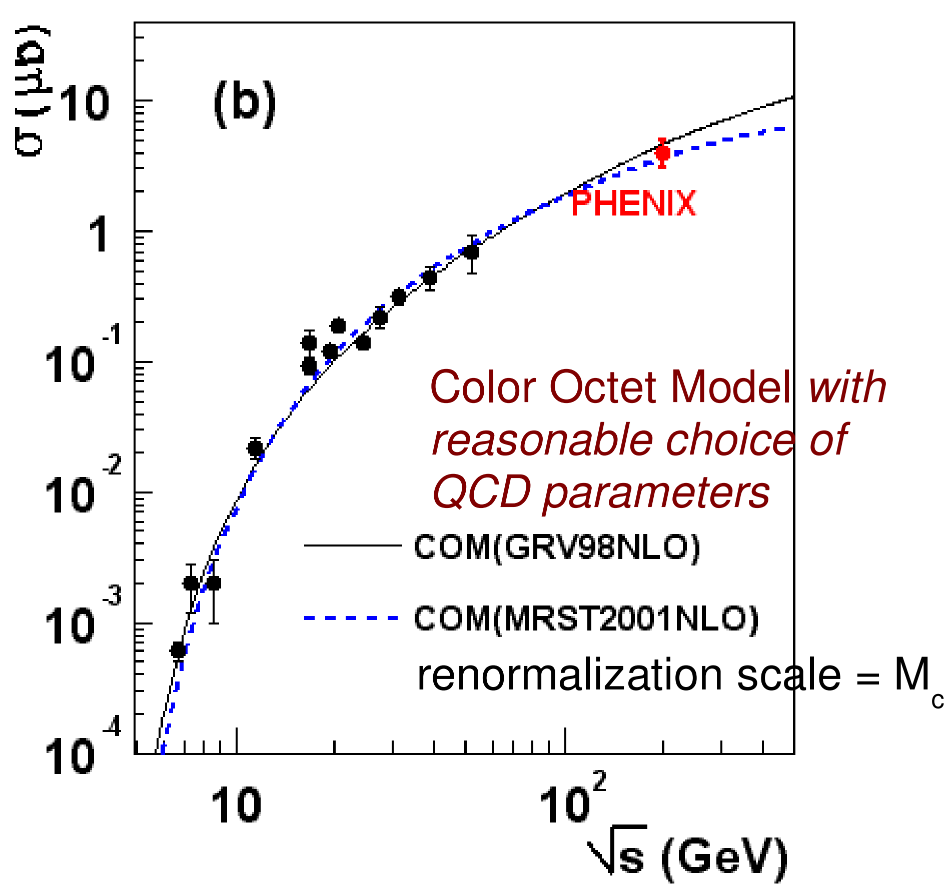
(phenomenological fit from fixed target data)

$pp \rightarrow J/\psi$ Mean P_T and Cross Section

$\langle p_T \rangle = 1.80 \pm 0.23(\mathrm{stat}) \pm 0.16(\mathrm{sys})\,\mathrm{GeV}/c$

$\sigma_{tot}(pp \rightarrow J/\psi) = 3.99 \pm 0.61(\mathrm{stat}) \pm 0.58(\mathrm{sys}) \pm 0.40(\mathrm{abs})\ \mu\mathrm{b}$





fit to previous measurements:
p= 0.53, q = 0.19

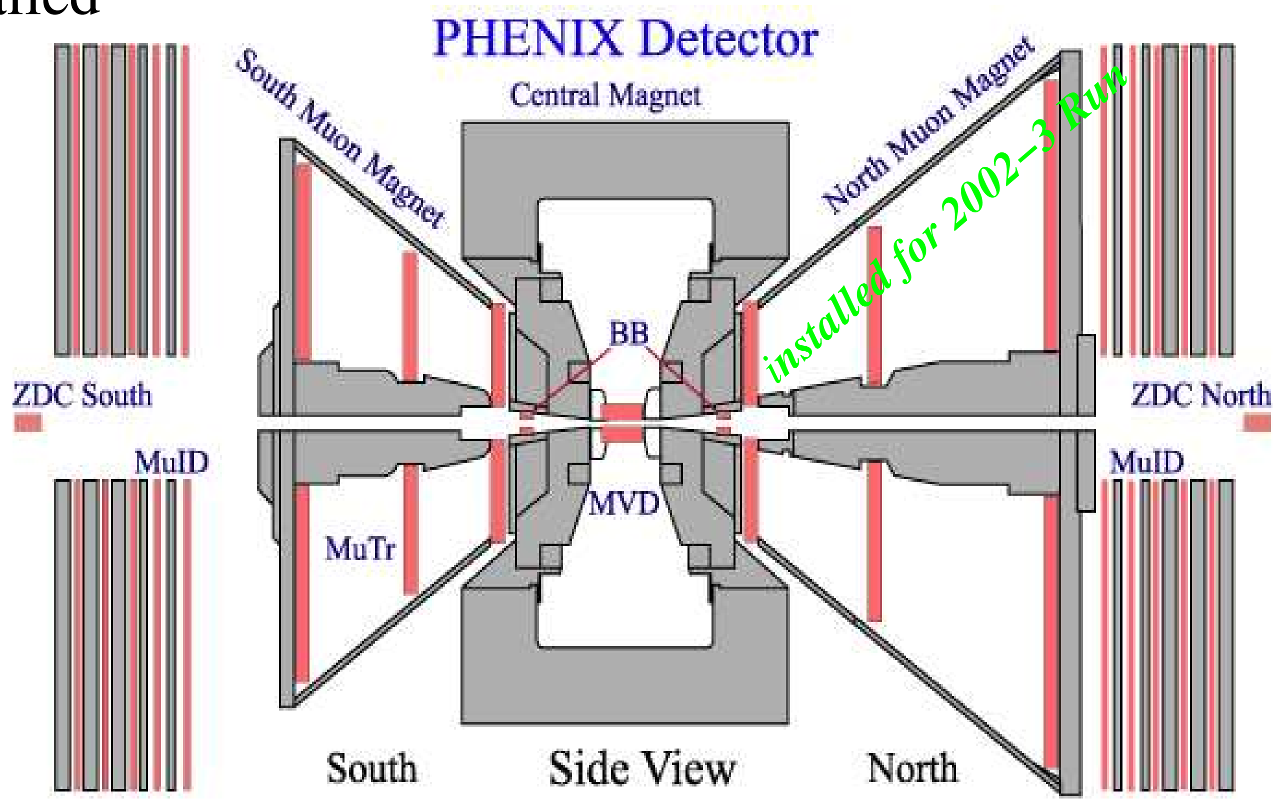
Conclusion

- PHENIX has measured J/ψ production p–p collisions at $\sqrt{s} = 200$ GeV over a wide y and p_T range.
- $\sigma_{tot}(pp \rightarrow J/\psi) = 3.99 \pm 0.61(stat) \pm 0.58(sys) \pm 0.40(abs)\ \mu b$.
- $\langle p_T \rangle = 1.80 \pm 0.23(stat) \pm 0.16(sys)$ GeV/c.
- With current statistics, y shape is consistent with most available PDFs.
- Color Octet Model is consistent with our p_T distributions above 2 GeV/c and $\sqrt{s}$ dependence of σ.

Outlook

This measurement is the first in a program.

- Run 2 Au–Au results for J/ψ production have been submitted to PRL.
- RHIC Run 3 completed in May 2003.
  - 2.7 nb^{-1} of d–Au at 200 GeV
  - 0.35 pb–1 of p–p at 200 GeV
- Both Muon Arms now installed
  $\Rightarrow$ increased y coverage
  $-2.2<y<-1.2$ & $1.2<y<2.4$
- Future runs at higher $\sqrt{s}$



Relativistic Heavy Ion Collider

Heavy ions ⇒ quark–gluon plasma

Polarized protons ⇒ nucleon spin structure