J/Psi Production at RHIC in a QGP

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*Review of Deconfinement Signal

*Extension to RHIC

*New Formation Mechanism in a Deconfined Region -> ***Enhancement***

hep-ph/0004041, Phys. Rev. C62: 024905 (2000)
hep-ph/0007323, hep-ph/0009090

- **Color Deconfinement -> Screening**
- SPS Energies, c cbar in 20% of Central Coll.
- Normal Vacuum, J/Psi fraction x = O (1%)
- Suppression in p-A, O-U, S-U, Pattern Suggests Nuclear Origin
- **NA50 "anomalous" Suppression**
- Drell-Yan Normalization, Centrality Dependence - Final State Effect?
- **S_final due to:**
  - Deconfinement
  - Hadronic Co-Movers
  - Coherent Partonic Interactions

Magnitudes Similar
Look for Patterns and Details

WHAT IS DIFFERENT AT HIGH ENERGIES?

$$\overline{N_0} = T_{AA}(b)\,\sigma_{pp \to ccbarX}$$

Energy	c cbar	b bbar
SPS	0.2	1/30,000
RHIC	10	.05
LHC	200	6

- In a Region of Deconfinement, the c and cbar quarks are mobile
- Each can "find" a partner not restricted to its production antiparticle

- New Production Mechanism
- Initial Rate Proportional to

$$\left(\overline{N_0}\right)^2 !$$

- This Feature Avoids the Matsui-Satz Condition that Additional Heavy Quarks are Rarely Available

Model for J/Psi Formation in QGP

- Free Thermal Quarks and Gluons
- Gluon Density - Chemical Equil.
- Charm Density - Initial Production
- 1-d Isentropic Expansion
- $V(\tau_0) = \pi R^2 \tau_0$; $VT^3 = \text{constant}$
- Parameters: T_0, R, τ_0, $\langle N_0 \rangle$
- Average over Initial Conditions:

$$N_{J/Psi}\,(t=0) = x\, N_c\,(t=0)$$

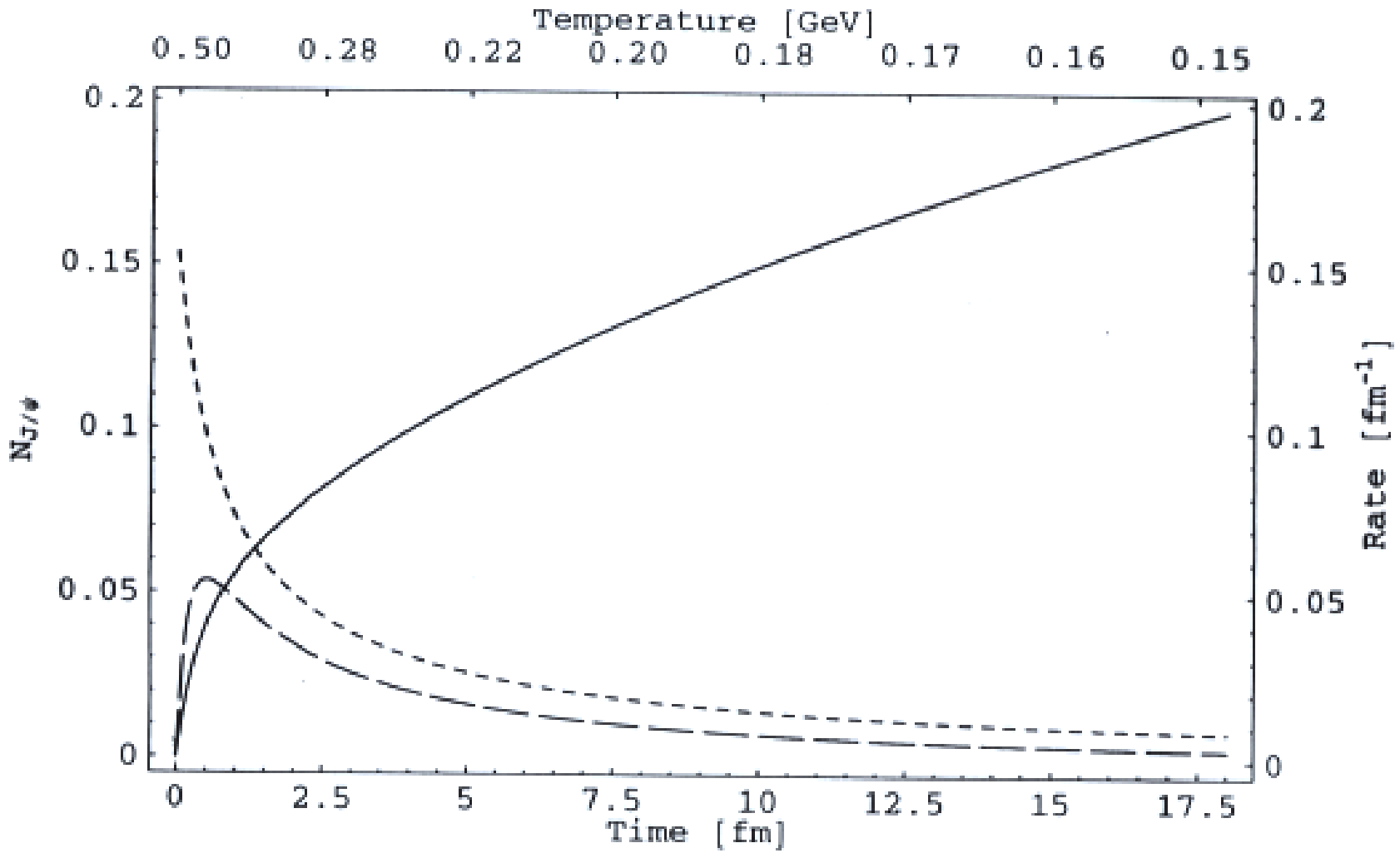
$$N_c = N_{cbar}\,,\ \text{charm conservation}$$

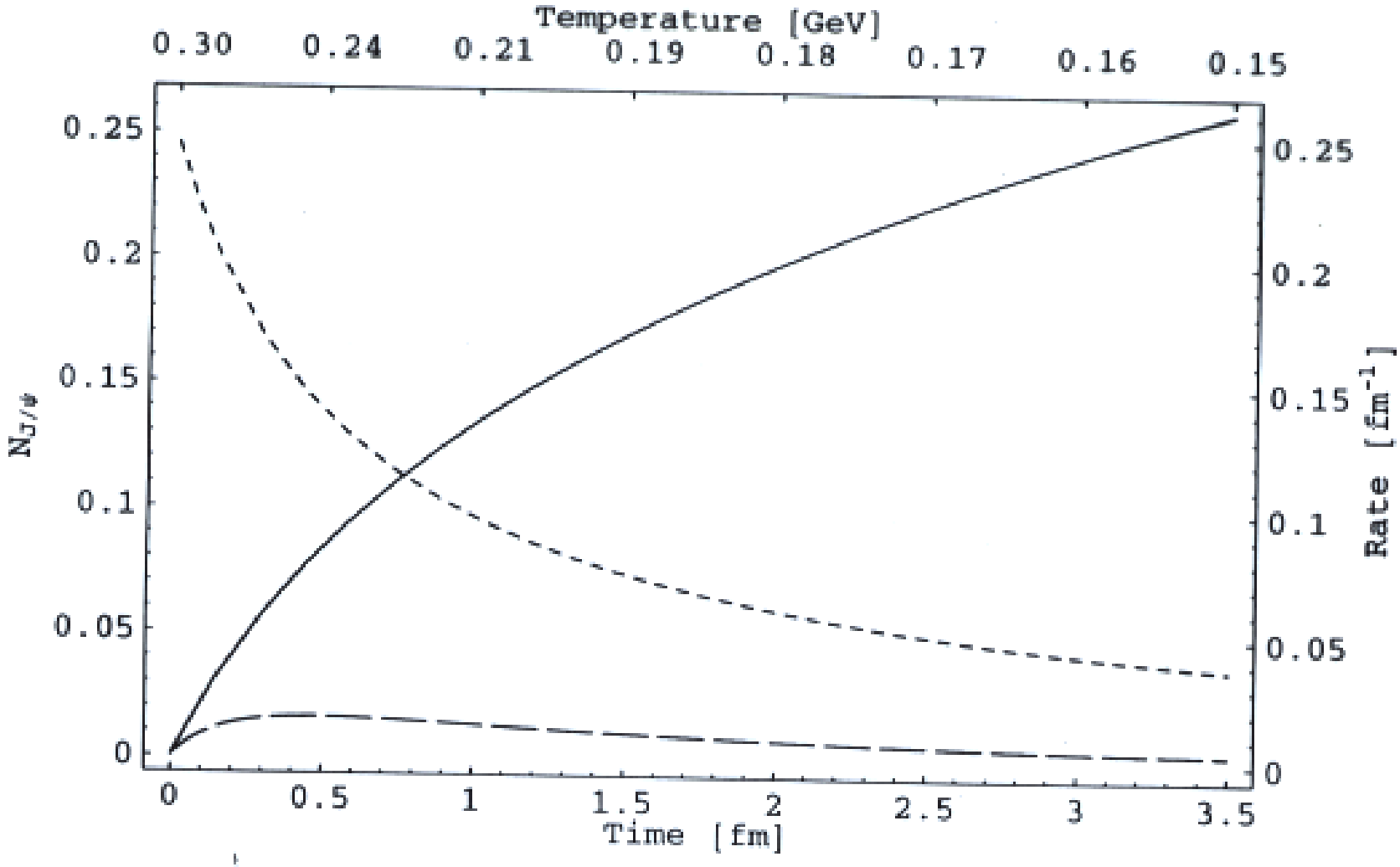
Kinetic Rate Equations for J/Psi Formation and Dissociation

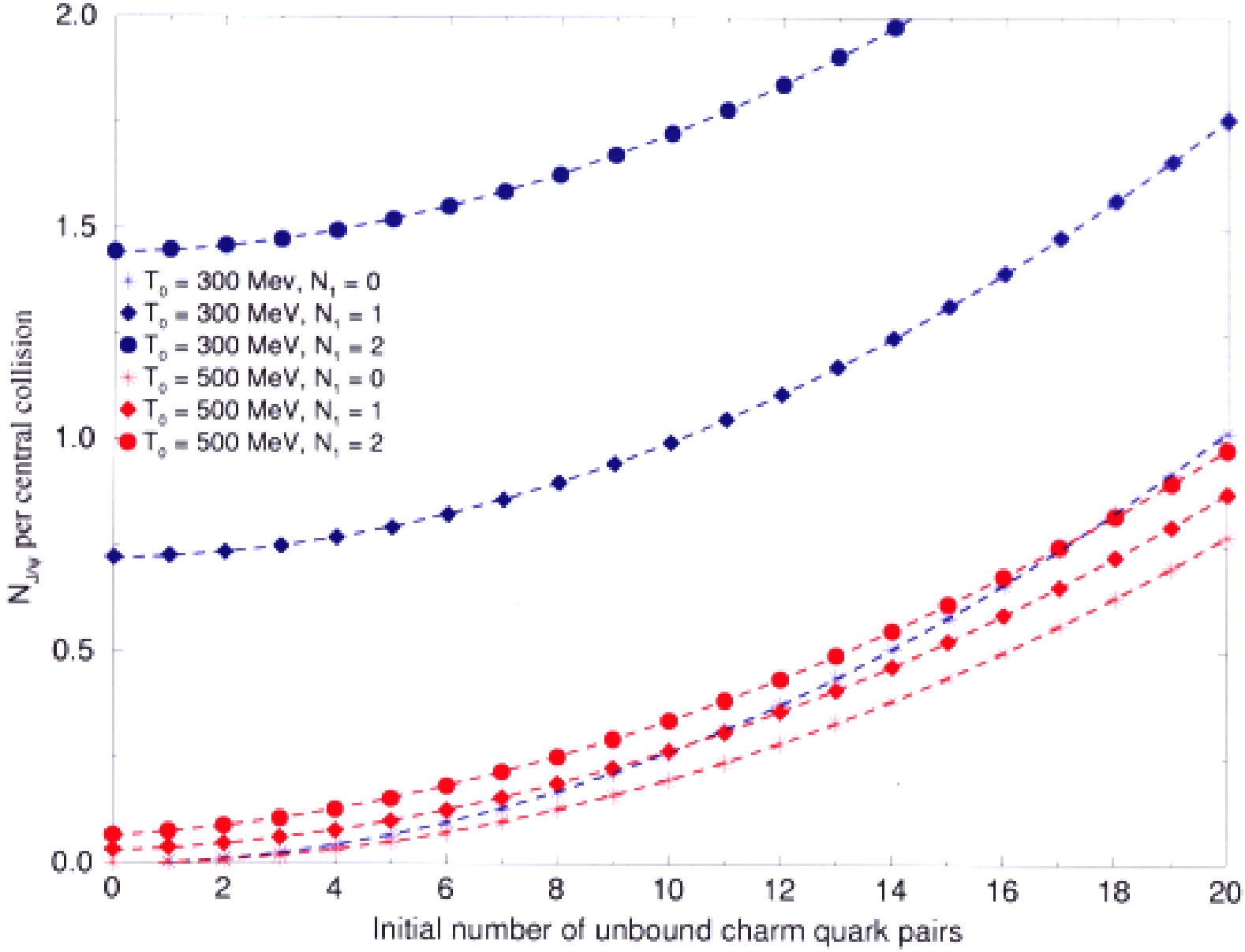
$$\frac{dN_{J/\psi}}{d\tau} = \langle v\sigma_F \rangle \rho_c N_c - \langle v\sigma_D \rangle \rho_g N_{J/\psi}$$

- Reaction Rates from OPE-based Gluon Interaction with Color Dipole of Non-Relativistic Quarkonium Bound States

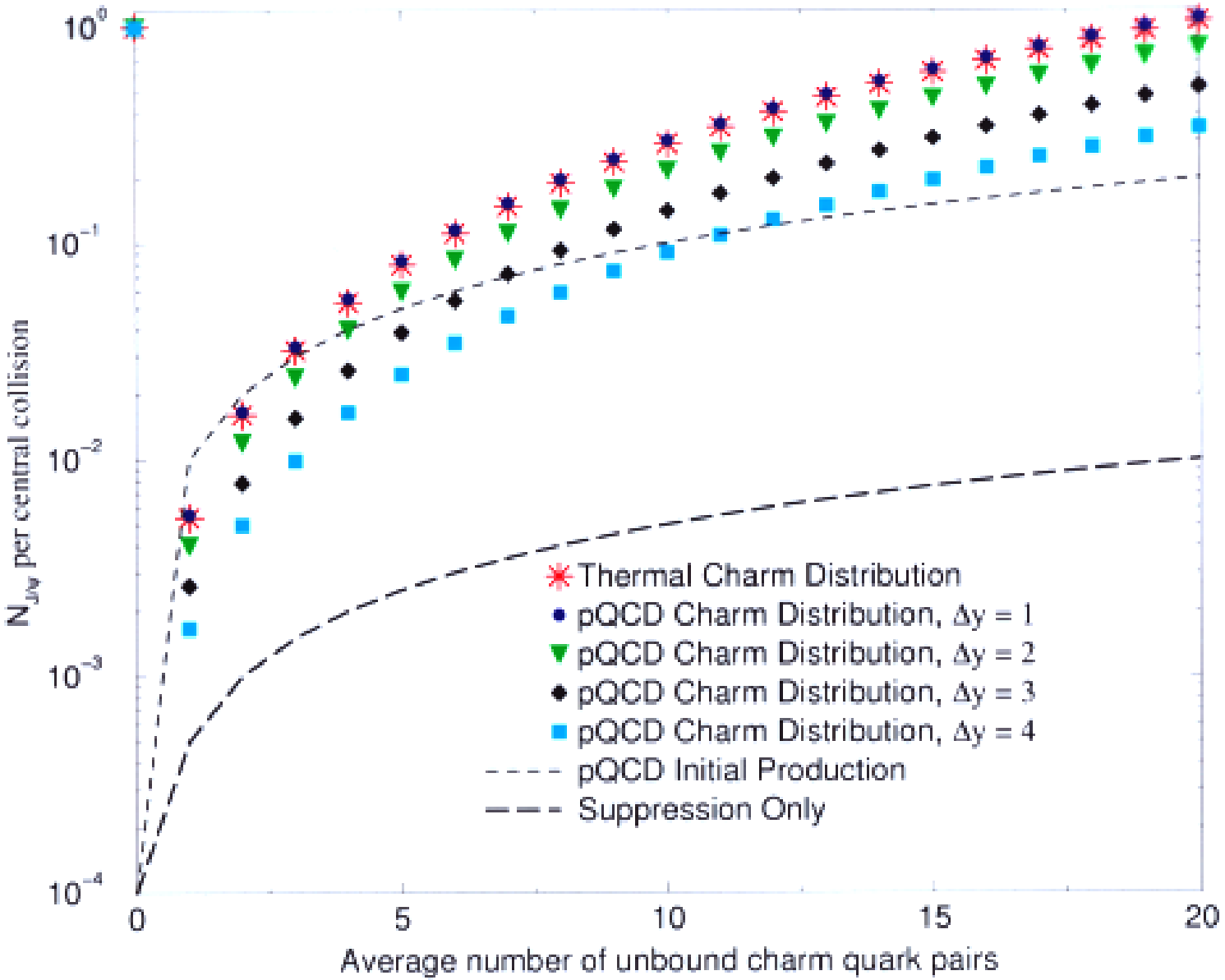
$$\sigma_D = \left(\frac{32}{3}\right)^2 \cdot \frac{\pi}{6\mu^2} \left(\frac{2\mu}{\varepsilon_0}\right)^{1/2} \frac{(k/\varepsilon_0 - 1)^{3/2}}{(k/\varepsilon_0)^5}$$


Temperature [GeV]
0.50
0.28
0.22
0.20
0.18
0.17
0.16
0.15
0.2
0.15
0.1
0.05
0
$N_{J/\psi}$
0.2
0.15
0.1
0.05
0
Rate [fm^{-1}]
0
2.5
5
7.5
10
12.5
15
17.5
Time [fm]


Temperature [GeV]
0.30
0.24
0.21
0.19
0.18
0.17
0.16
0.15
0.25
0.2
0.15
0.1
0.05
0
$N_{J/\psi}$
0.25
0.2
0.15
0.1
0.05
0
Rate [fm^{-1}]
0
0.5
1
1.5
2
2.5
3
3.5
Time [fm]


2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
16
18
20
$N_{J/\psi}$ per central collision
Initial number of unbound charm quark pairs
T_0 = 300 Mev, N_1 = 0
T_0 = 300 MeV, N_1 = 1
T_0 = 300 MeV, N_1 = 2
T_0 = 500 MeV, N_1 = 0
T_0 = 500 MeV, N_1 = 1
T_0 = 500 MeV, N_1 = 2

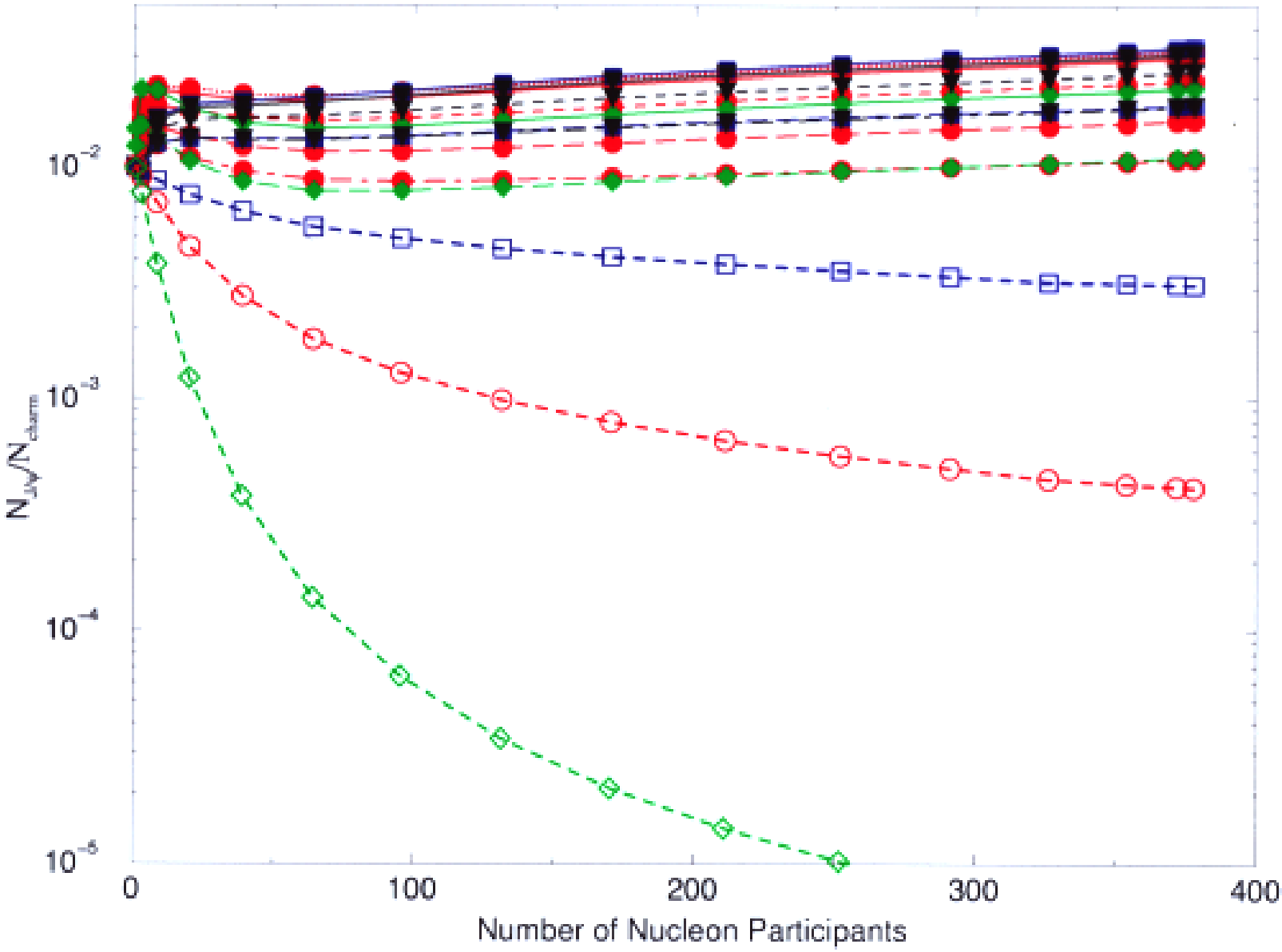
J/ψ Formation Dependence on Charm Distribution



CENTRALITY DEPENDENCE

- Use Participant Number as a Measure: $E_T = q\, N_P(b)$
- Use Participant Density as a Measure of Energy Density to find b-dependence of T_0
- Ratio Defines Initial Transverse Area of QGP
- $T_{AA}(b)$ Determines $\langle N_0 \rangle (b)$

- Normalize $N_{J/\psi}/N_{charm}$


10^{-2}
10^{-3}
10^{-4}
10^{-5}
$N_{J/\psi}/N_{charm}$
0
100
200
300
400
Number of Nucleon Participants

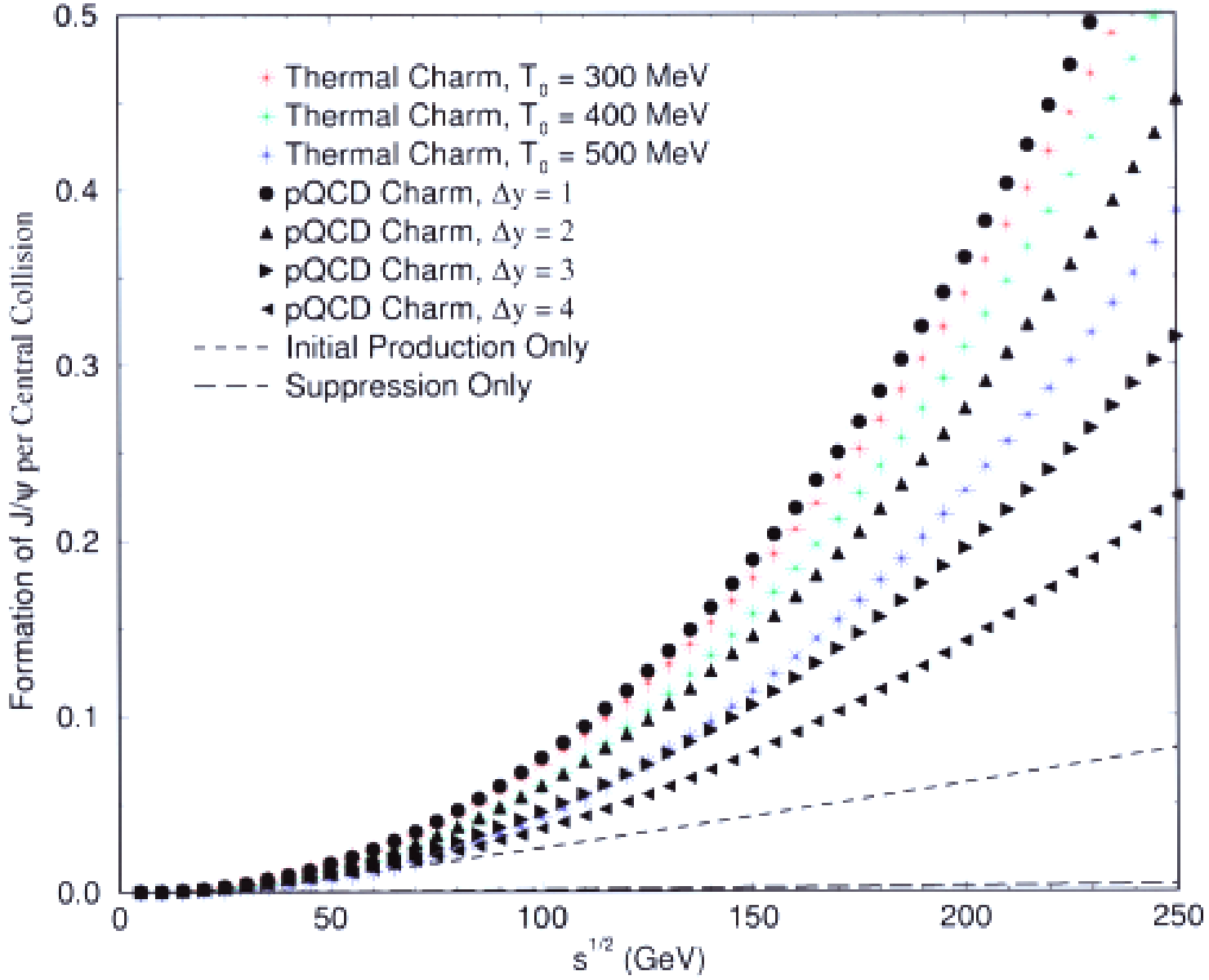
Sensitivity to Parameters

- Gluon Shadowing
- Chemical Saturation for Gluons
- In-Medium Properties
- Transverse Expansion
- Cross sections and Rates
- Mixed Phase and Production in Hadronic Gas

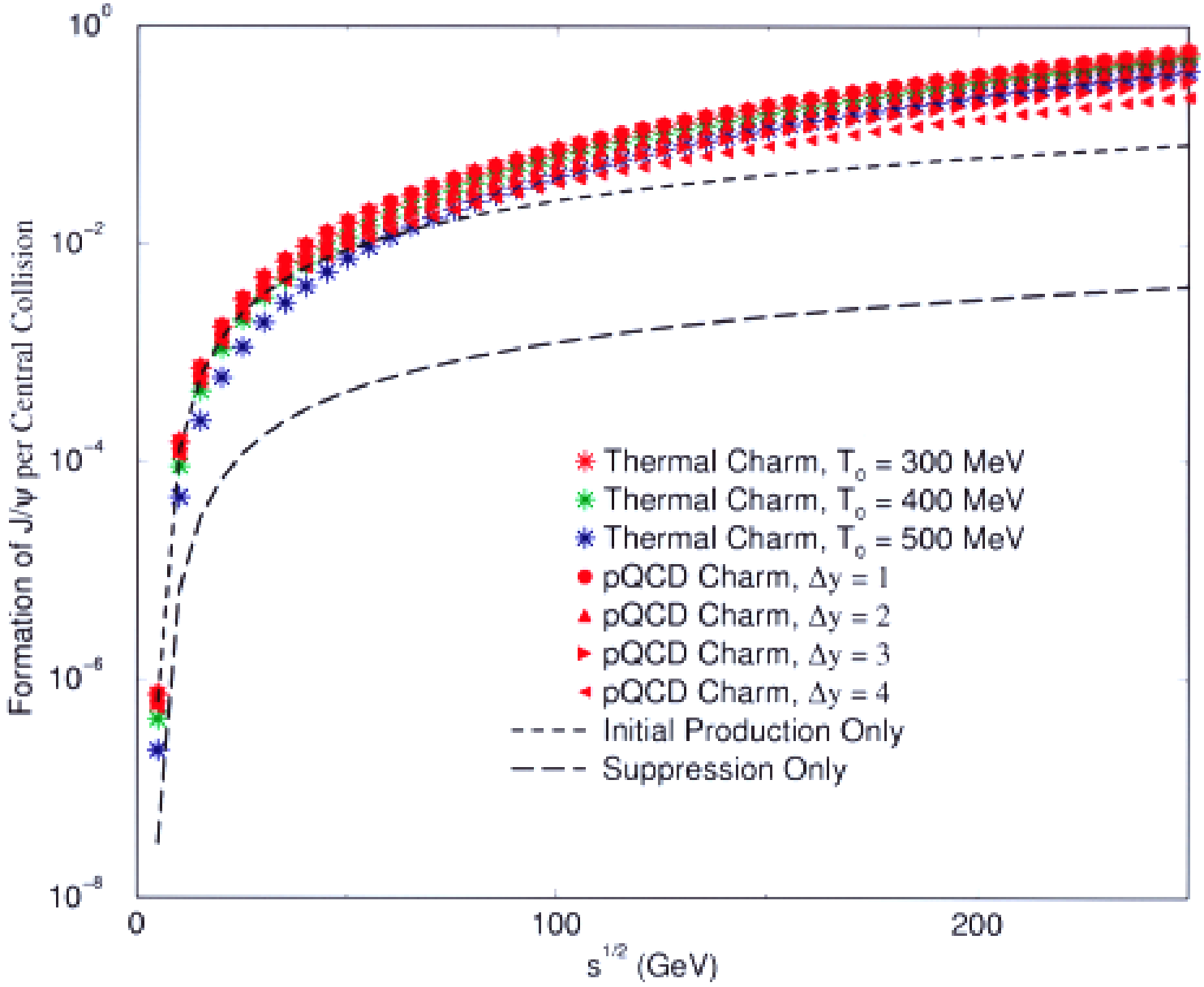
ENERGY DEPENDENCE

- $\sigma(s)$ from pQCD NLO
- Central Collisions, fixed T_0
- Track $N_0(s)$, similar to $N_0(b)$
- New Formation Quadratic in N_0
- Average becomes Linear at Small N_0
- Contrast with Suppression Only

Formation Mechanism Energy Dependence



Formation Mechanism Energy Dependence



SUMMARY

- At RHIC (and LHC) Energies, Multiple Pairs of Heavy Quarks can Probe Deconfinement
- J/Psi ***ENHANCEMENT*** Predicted in Kinetic Model
- Ratio J/Psi to Initial Charm Provides a **Unique Centrality Dependence**
- Energy and A - Dependence can Track the Quadratic *FORMATION RATE*