“20th anniversary of J/Ψ suppression” Workshop, BNL, May 9, 2006

J/Ψ suppression: where are we now, and where are we going?

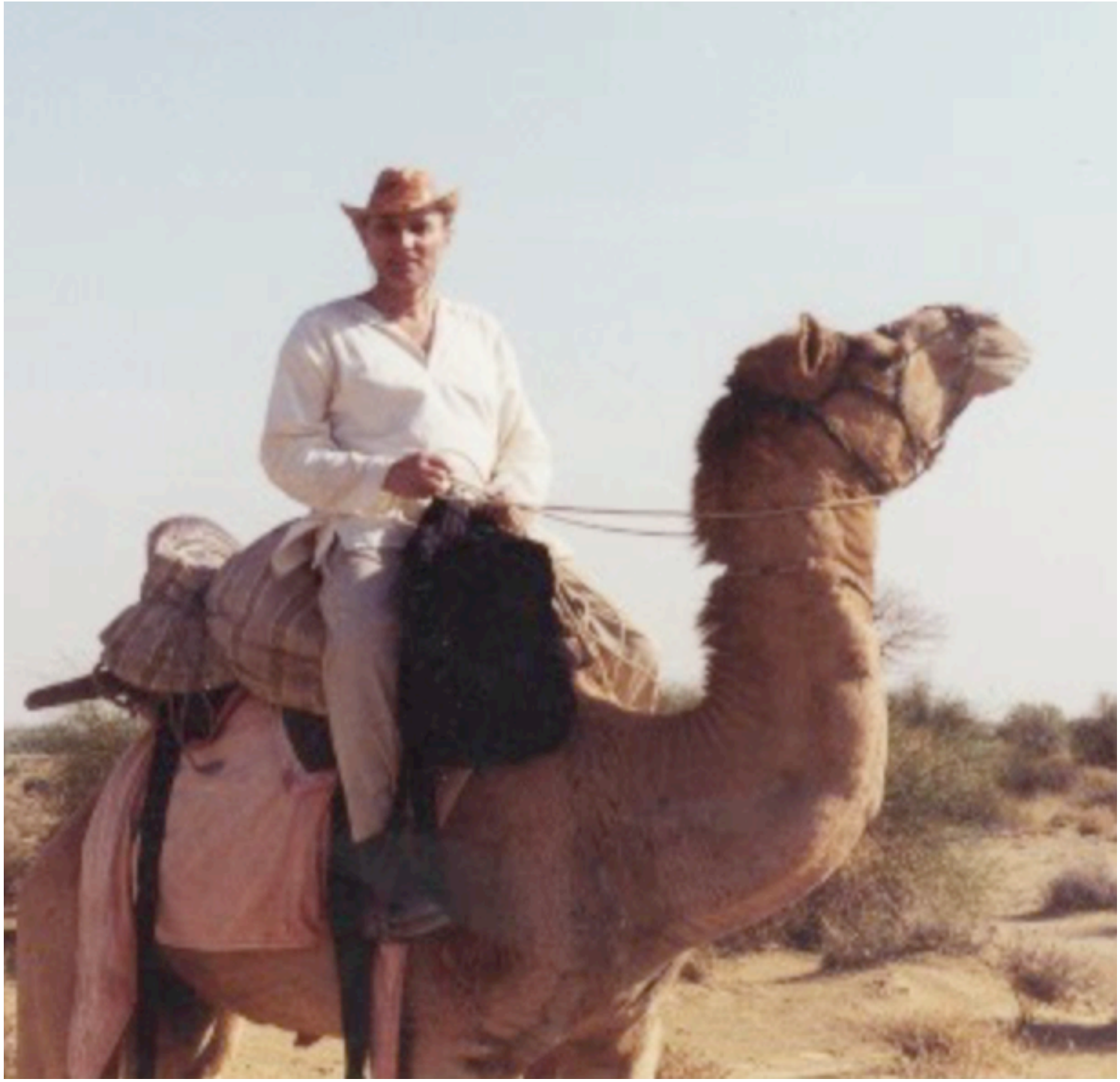
D. Kharzeev

BNL

BROOKHAVEN NATIONAL LABORATORY

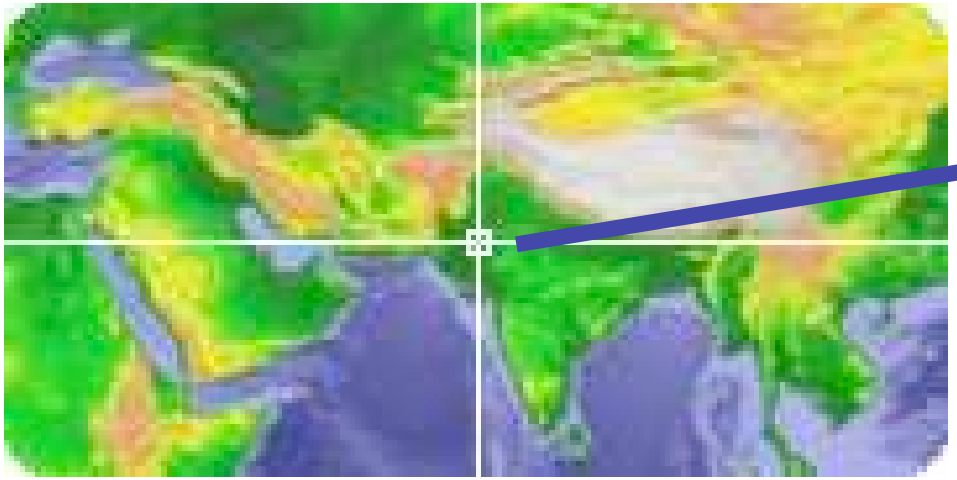
Helmut:
Tall in the Saddle

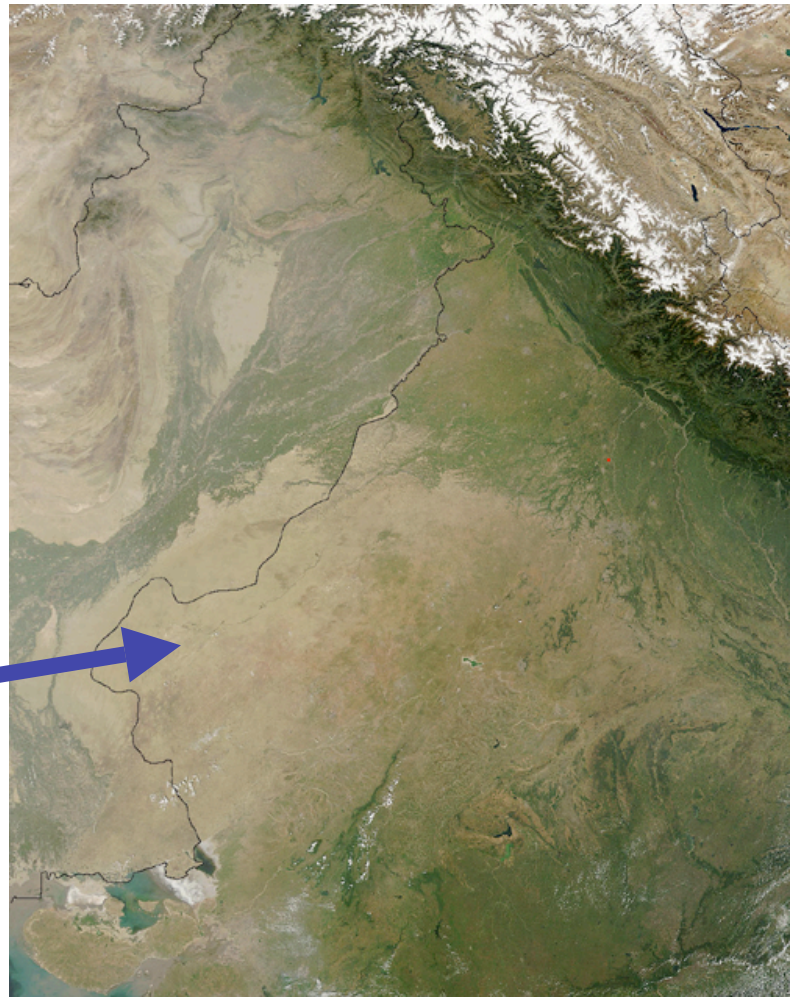
Helmut:
Tall in the Saddle



Helmut:
Exploring the remote parts of the World and of the QCD phase diagram

Thar desert at the border of India and Pakistan





November revolution:

VOLUME 33, NUMBER 23 PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

Experimental Observation of a Heavy Particle J†

J. J. Aubert, U. Becker, P. J. Biggs, J. Burger, M. Chen, G. Everhart, P. Goldhagen, J. Leong, T. McCorriston, T. G. Rhoades, M. Rohde, Samuel C. C. Ting, and Sau Lan Wu
Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

and

Y. Y. Lee
Brookhaven National Laboratory, Upton, New York 11973
(Received 12 November 1974)

We report the observation of a heavy particle J, with mass $m = 3.1$ GeV and width approximately zero. The observation was made from the reaction $p + \mathrm{Be} \rightarrow e^+ + e^- + x$ by measuring the e^+e^- mass spectrum with a precise pair spectrometer at the Brookhaven National Laboratory's 30-GeV alternating-gradient synchrotron.

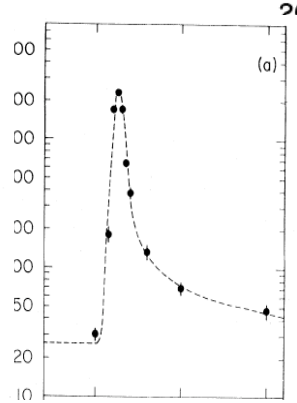
Discovery of a Narrow Resonance in e^+e^- Annihilation*

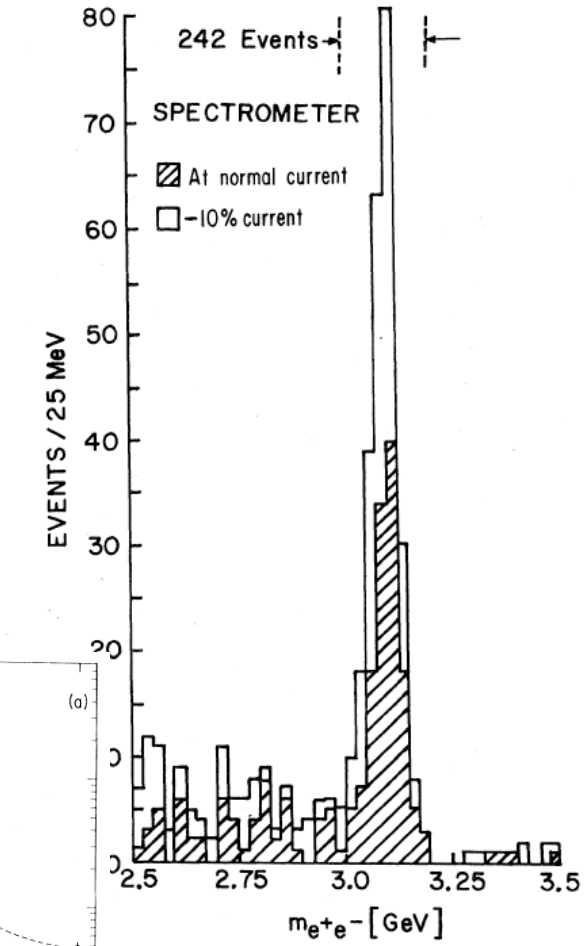
J.-E. Augustin,† A. M. Boyarski, M. Breidenbach, F. Bulos, J. T. Dakin, G. J. Feldman, G. E. Fischer, D. Fryberger, G. Hanson, B. Jean-Marie,† R. R. Larsen, V. Lüth, H. L. Lynch, D. Lyon, C. C. Morehouse, J. M. Paterson, M. L. Perl, B. Richter, P. Rapidis, R. F. Schwitters, W. M. Tanenbaum, and F. Vannucci‡
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

and

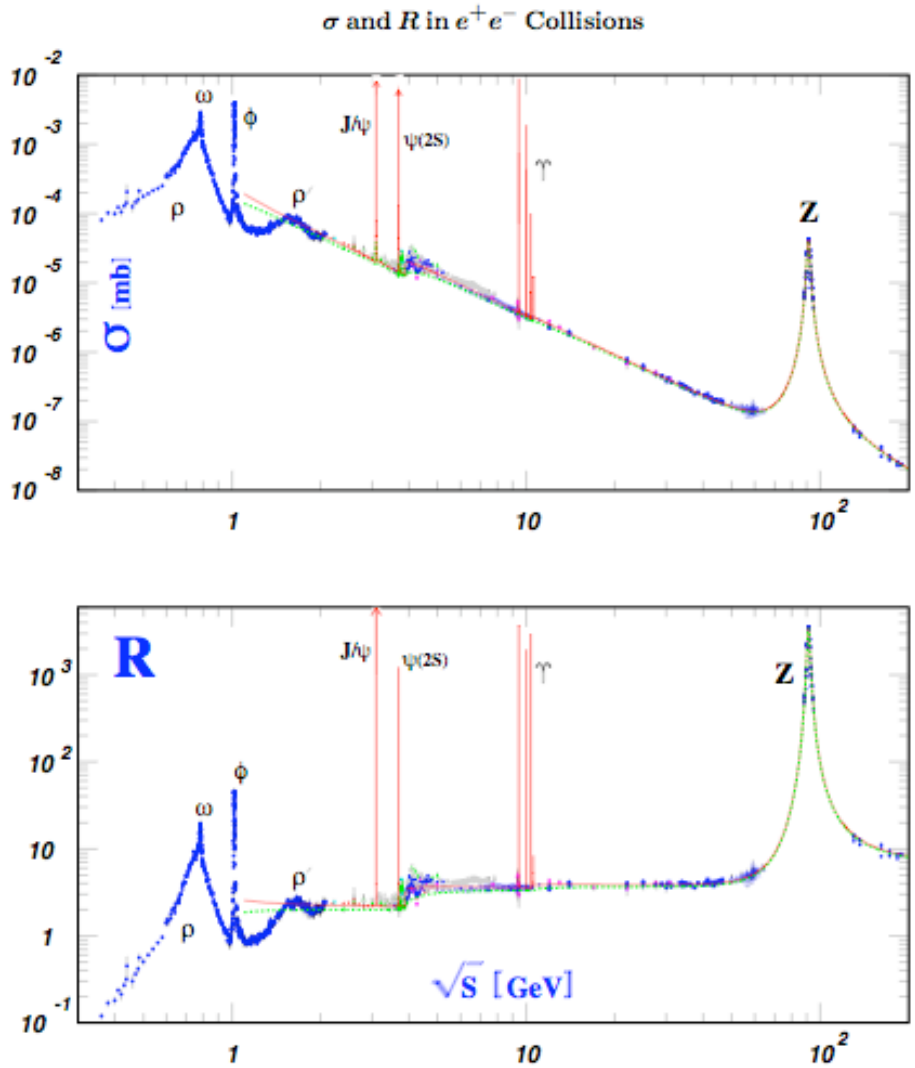
G. S. Abrams, D. Briggs, W. Chinowsky, C. E. Friedberg, G. Goldhaber, R. J. Hollebeek, J. A. Kadyk, B. Lulu, F. Pierre,§ G. H. Trilling, J. S. Whitaker, J. Wiss, and J. E. Zipse
Lawrence Berkeley Laboratory and Department of Physics, University of California, Berkeley, California 94720
(Received 13 November 1974)

We have observed a very sharp peak in the cross section for $e^+e^- \rightarrow$ hadrons, e^+e^-, and possibly $\mu^+\mu^-$ at a center-of-mass energy of 3.105 ± 0.003 GeV. The upper limit to the full width at half-maximum is 1.3 MeV.





Why is heavy quarkonium so narrow?

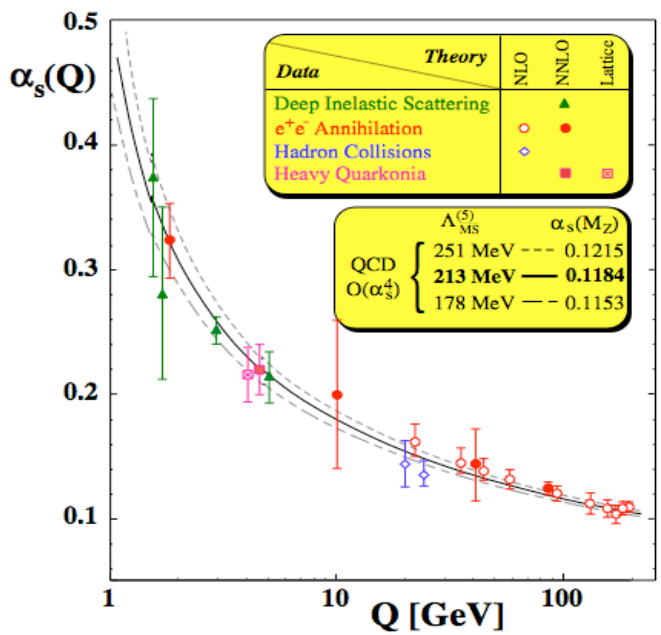


Why are heavy quarks so important?

Heavy quark masses M_H are generated at the electroweak scale, and are external parameters in QCD;

Heavy quarks are "heavy" because their masses are large on the typical QCD scale of Λ_{QCD}:

$$M_H >> \Lambda_{QCD}$$



$$\alpha_s(M_H) \ll 1$$

$$\frac{\langle \alpha_s G^2 \rangle}{M_H^4} \ll 1$$

Putting J/Ψ to work:

Volume 178, number 4 PHYSICS LETTERS B 9 October 1986

J/ψ SUPPRESSION BY QUARK–GLUON PLASMA FORMATION ☆

T. MATSUI
Center for Theoretical Physics, Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

and

H. SATZ
Fakultät für Physik, Universität Bielefeld, D-4800 Bielefeld, Fed. Rep. Germany and Physics Department, Brookhaven National Laboratory, Upton, NY 11973, USA

Received 17 July 1986

If high energy heavy ion collisions lead to the formation of a hot quark–gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, the temperature dependence of the screening radius, as obtained from lattice QCD, is compared with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. It is concluded that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark–gluon plasma formation.

Matsui & Satz:

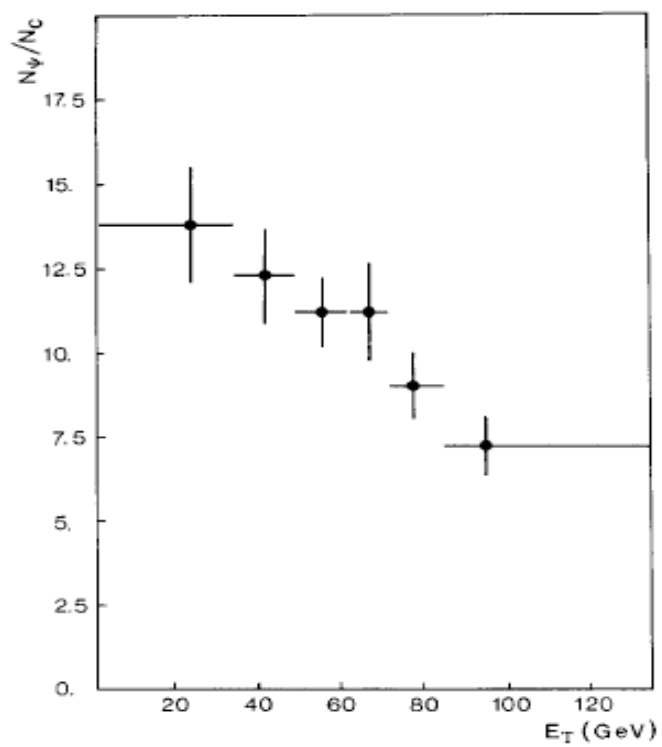
We thus conclude, that there appears to be no mechanism for J/ψ suppression in nuclear collisions except the formation of a deconfining plasma, and if such a plasma is produced, there seems to be no way to avoid J/ψ suppression.

NA38: the first observation of J/Ψ suppression

6 April 1989

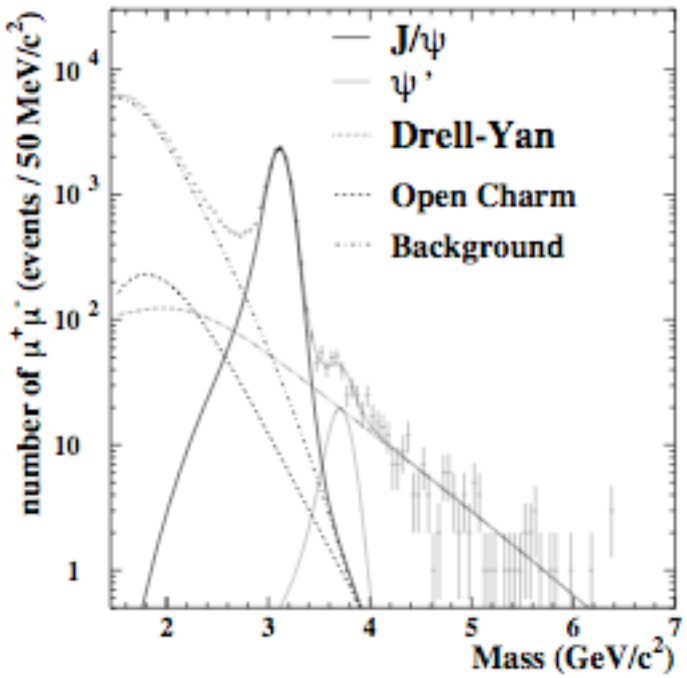
THE PRODUCTION OF J/Ψ IN 200 GeV/NUCLEON OXYGEN–URANIUM INTERACTIONS

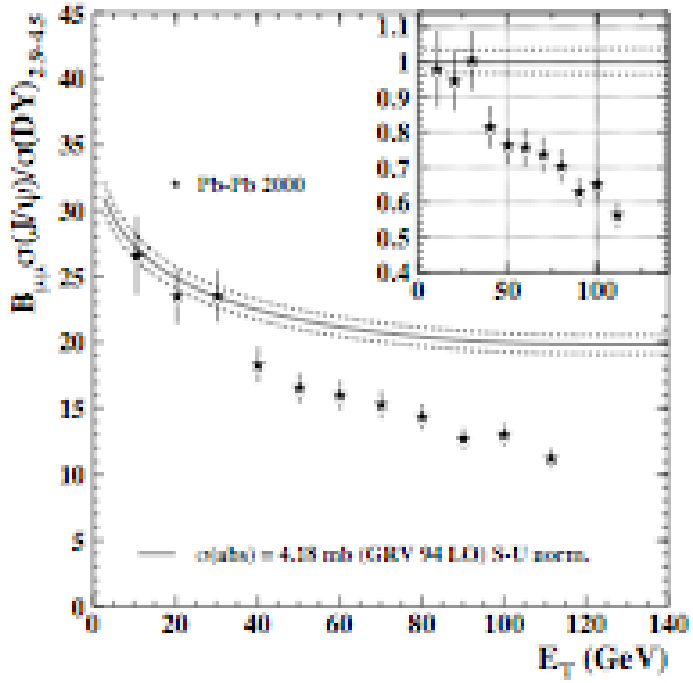
NA38 Collaboration



Experimental information

CERN: NA38/50/60 experiments





NA50 Coll., hep-ex/0412036

J/Ψ suppression in the plasma

Heavy quarkonia are very sensitive to the properties of QCD matter; when Debye length becomes smaller than the size of quarkonium,

$$R_{Debye}(T) \sim 1/(gT) < R_{Quarkonium} \sim 1 / (\alpha_s M_H),$$

quarkonia are screened out of existence T. Matsui & H. Satz '86
this happens when $T \sim g\, M_H$

(what is the corresponding formula for strong coupling?)

However, even before that, when $T \sim \varepsilon \sim \alpha_s^2 M_H$, quarkonia can be dissociated due to thermal activation

What is the mechanism of dissociation?

In cold matter, dissociation rate is relatively small due to the softness of gluon distributions in confined matter, but it is large, O(1 fm^{-1}), in hot QCD matter

DK & H. Satz '94

Dissociation mechanism - gluo-effect

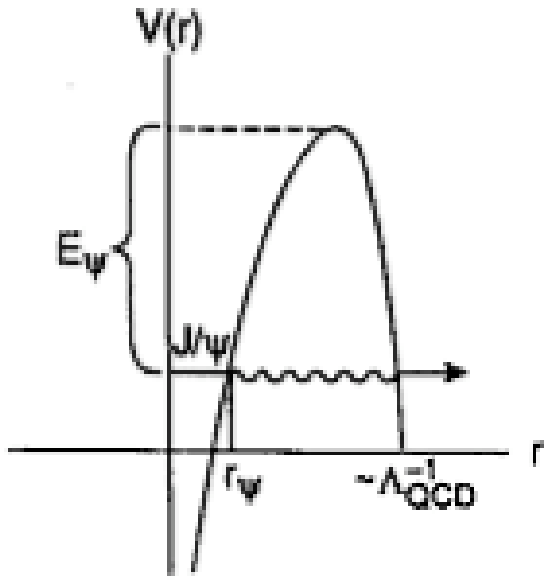
E.Shuryak '78
G.Bhanot, M.Peskin '79

dominates if $\frac{\epsilon}{T} \gg 1$ (strong coupling regime)

Screening dominates if $\frac{\epsilon}{T} \ll 1$ (weak coupling)

What mechanism is more important?

DK, L.McLerran, H.Satz
hep-ph/9504338



$$R_{act} = \frac{1}{Z(T)} \frac{V}{L} \left(\frac{c}{\pi^2} MT^2 \right) e^{\frac{-E_{J/\psi}}{T}}$$

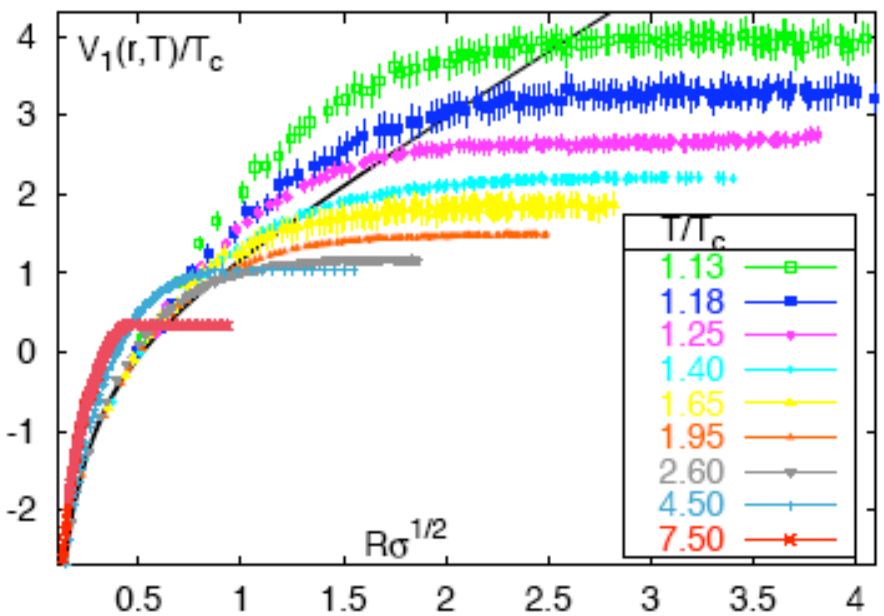
Weak coupling:

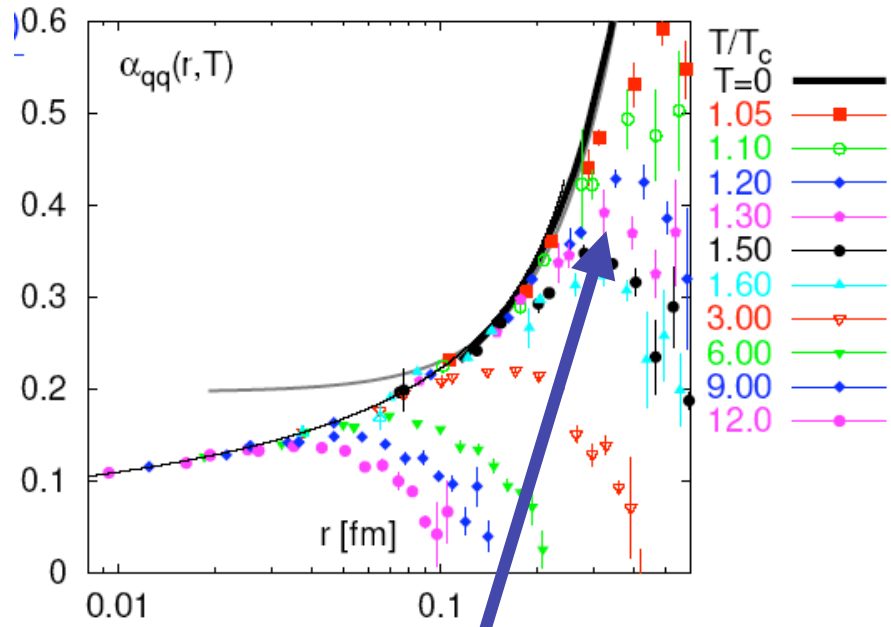
$$R_{act} = \frac{4}{L} \sqrt{\frac{T}{2\pi M}} = \frac{v(T)}{L}$$

Strong coupling:

$$R_{act} = \frac{(LT)^2}{3\pi} M e^{-E_{J/\psi}/T}$$

Heavy quark internal energy and screening: lattice QCD results

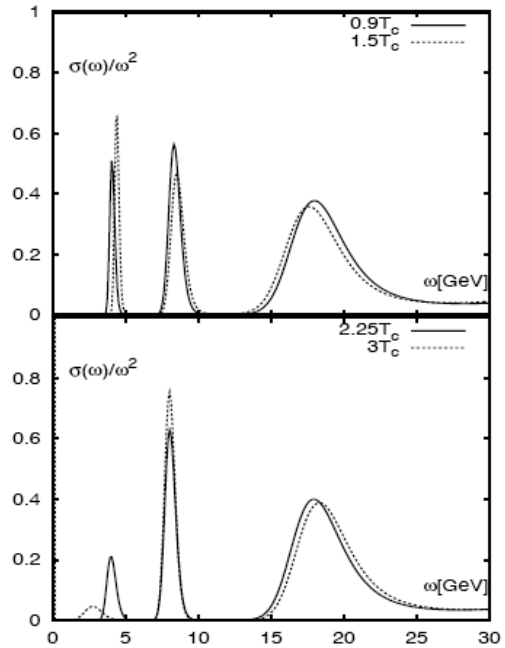




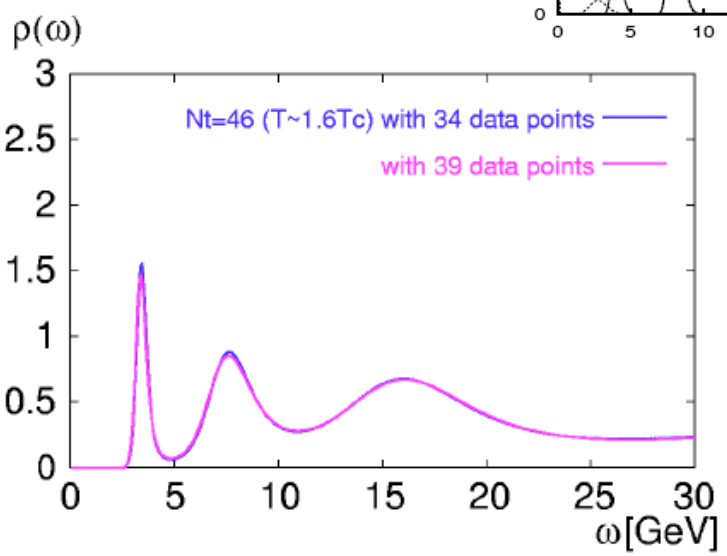
O.Kaczmarek, F. Karsch, P.Petreczky, F. Zantow, hep-lat/0309121

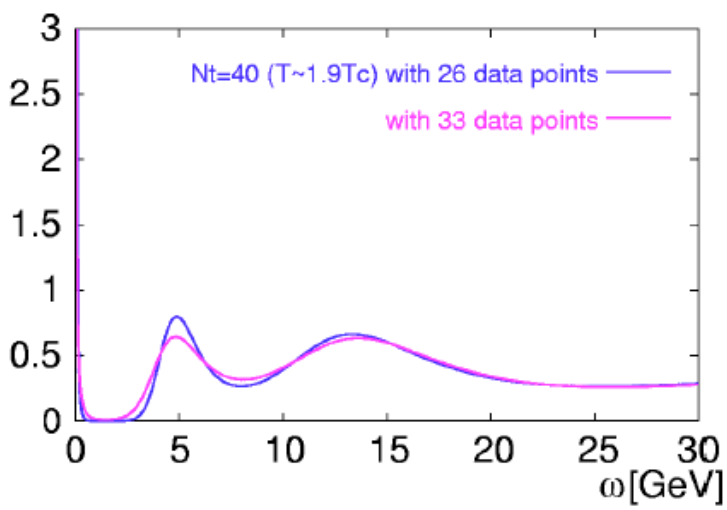
Interaction energy exceeds the temperature - strong coupling!

J/Ψ above T_c: alive and well?



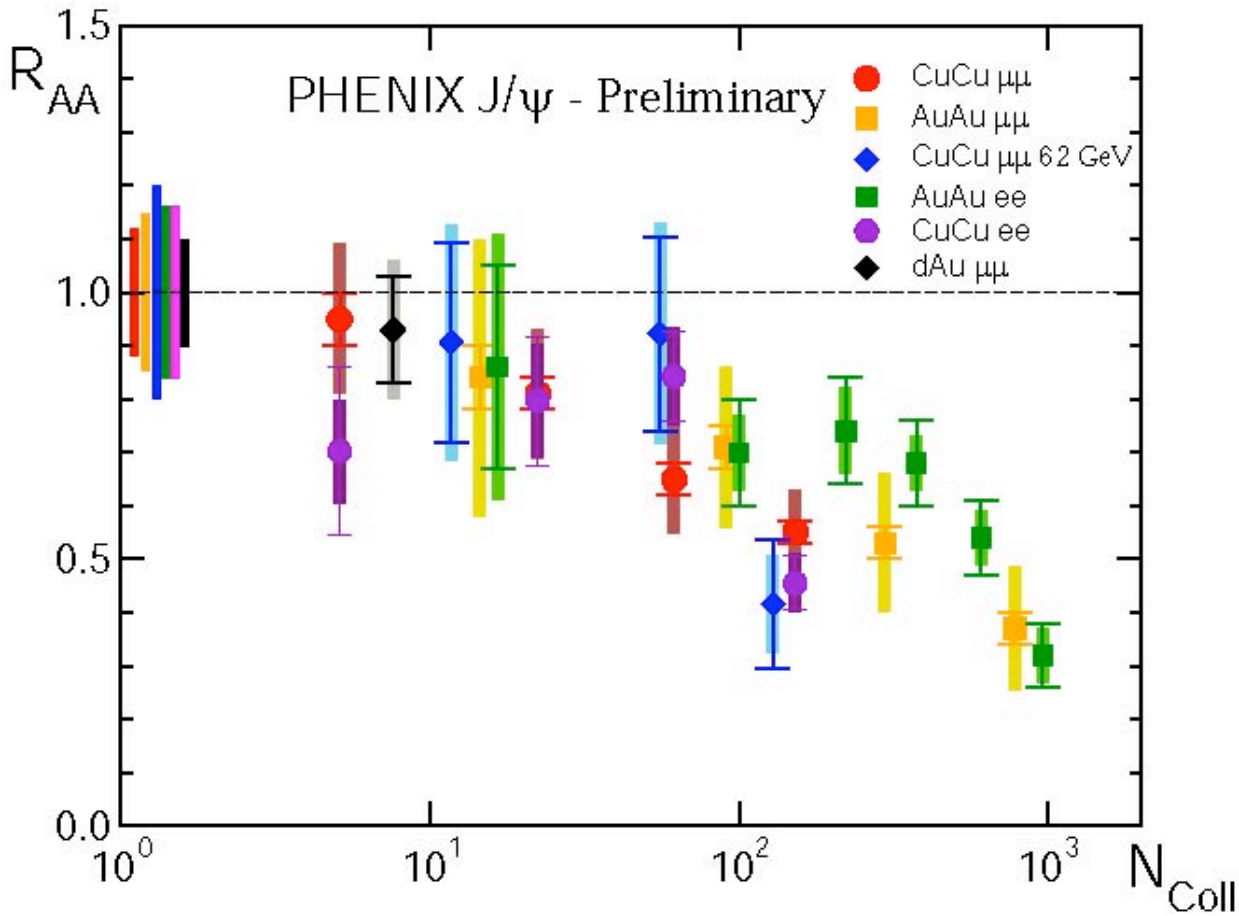
S.Datta,
F.Karsch,
P.Petreczky,
I.Wetzorke





M.Asakawa,
T.Hatsuda

J/ψ suppression at RHIC



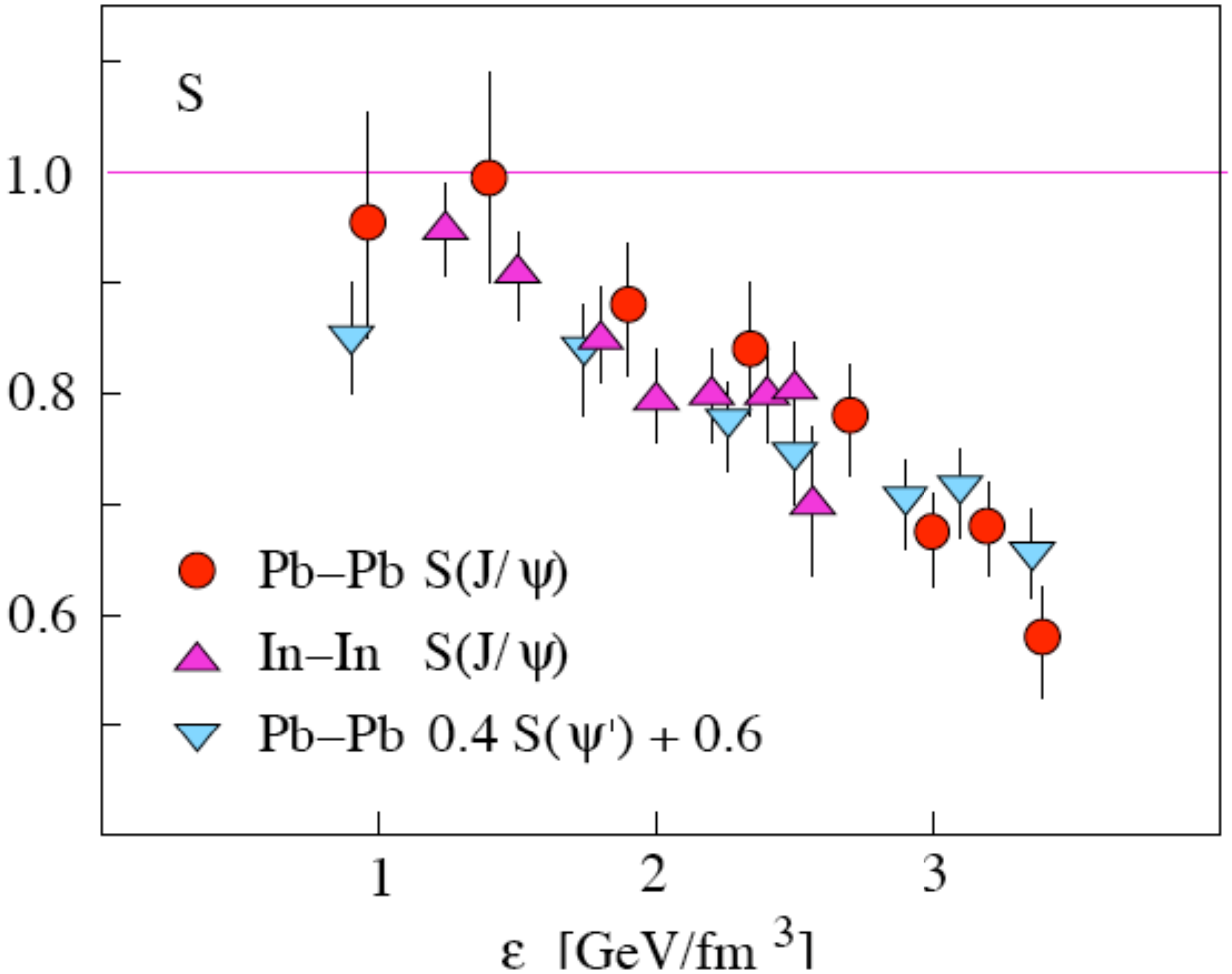
"same as at SPS"?

Sequential charmonium dissociation

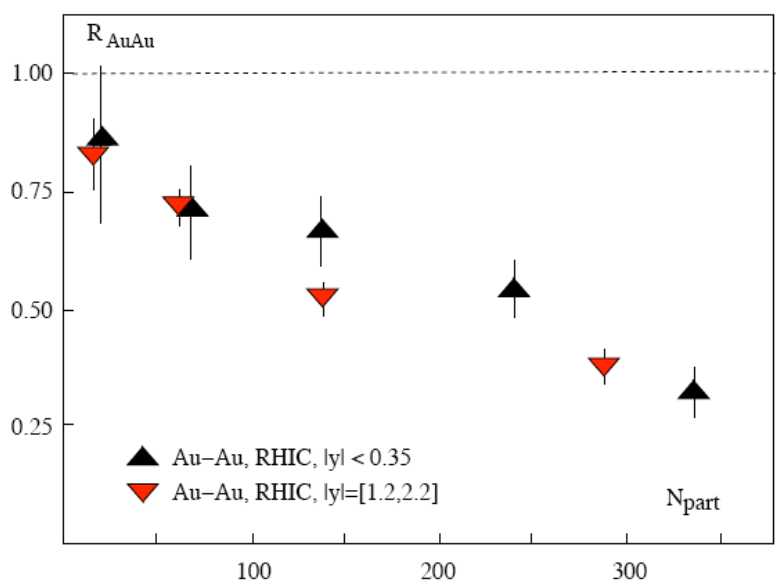
Both the absence of J/ψ suppression up to ~ 2 T_c and the apparent similarity of the magnitude of suppression at RHIC and SPS are puzzling;
However, the two puzzles may be consistent with each other

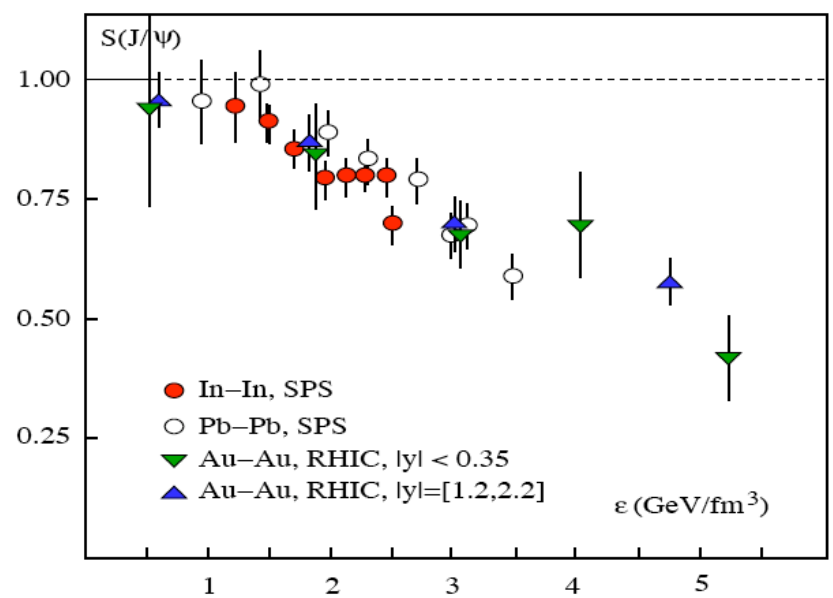
F.Karsch, DK, H.Satz,
hep-ph/0512239

Is there a "direct" J/ψ suppression at SPS?



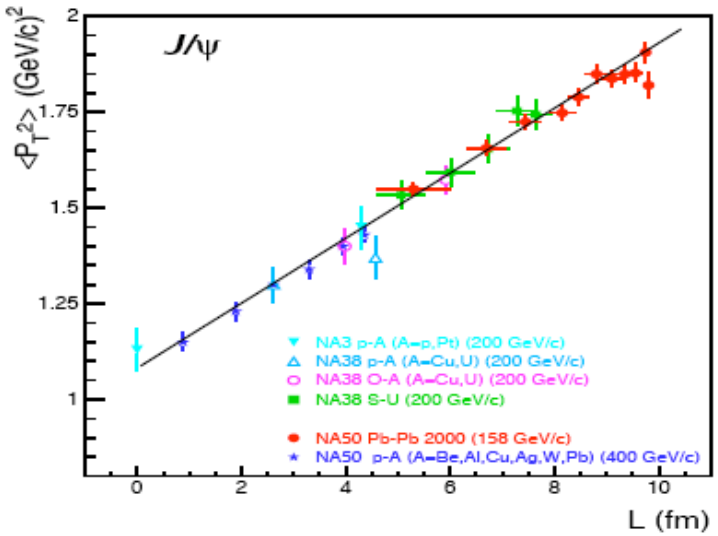
Is there a "direct" J/ψ suppression at RHIC?

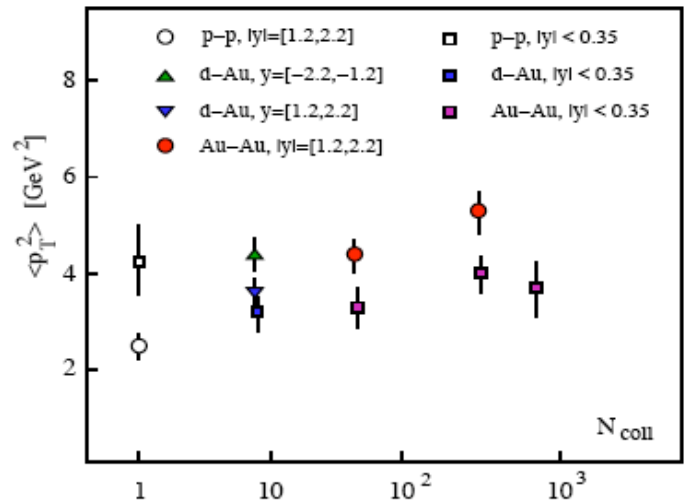


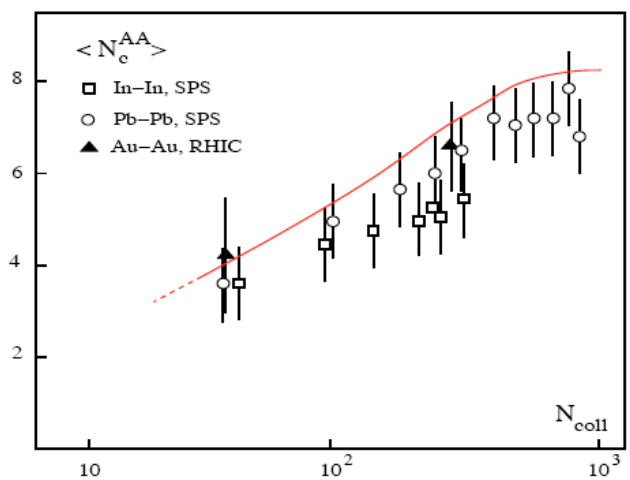


Data: PHENIX, NA50, NA60

Transverse momentum distributions



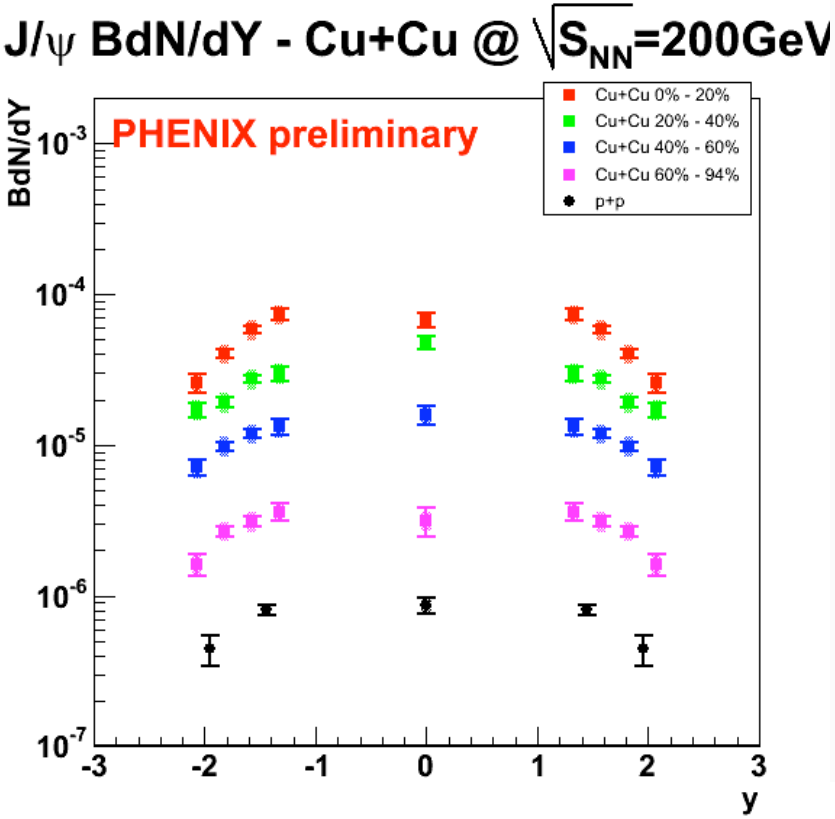


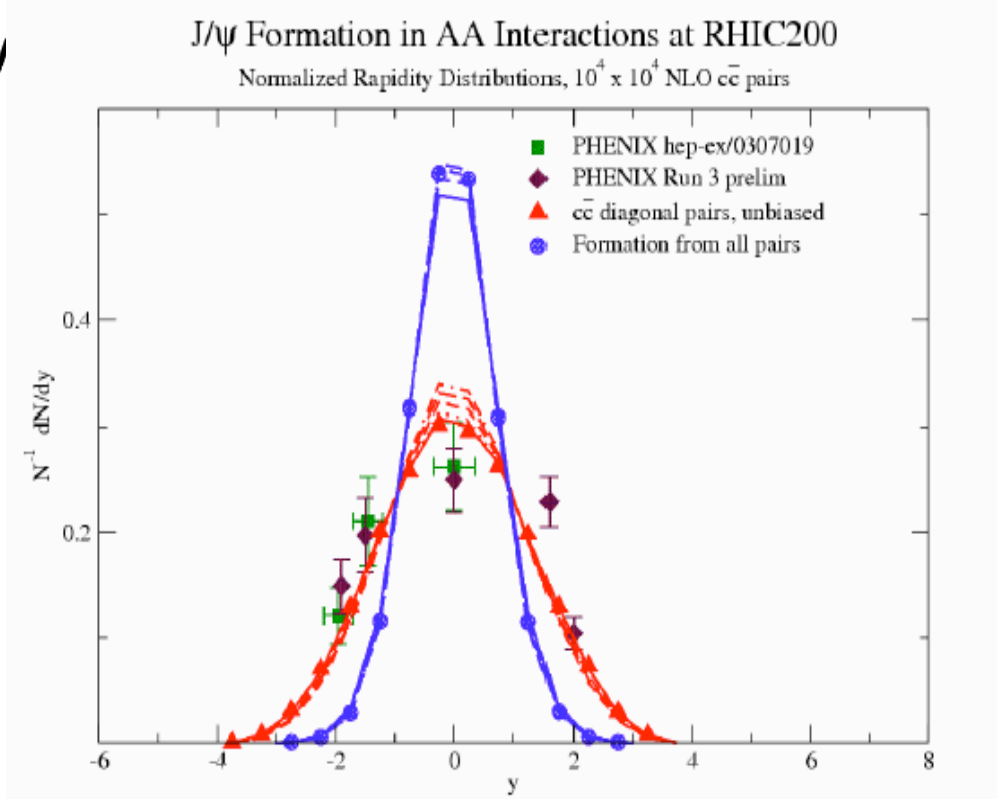


Glauber model analysis

Recombination of charm quarks?

Talk by R.Thews





R.Thews

Recombination narrows the rapidity distribution; is this seen?
Are high p_t charmonia suppressed stronger than open charm?

Summary

1. 20 years after, the problem of J/ψ behavior in quark-gluon plasma remains in the focus of attention

2. This problem may well keep the key to understanding the strongly coupled plasma, much like the surprising properties of J/ψ were central to understanding QCD

More work has to be done…