Martina Franca, 17 June 2001
Workshop on QCD

CHARMONIA STATES SUPPRESSION AND TRANSVERSE MOMENTUM DISTRIBUTION IN PB – PB COLLISIONS AT THE CERN SPS

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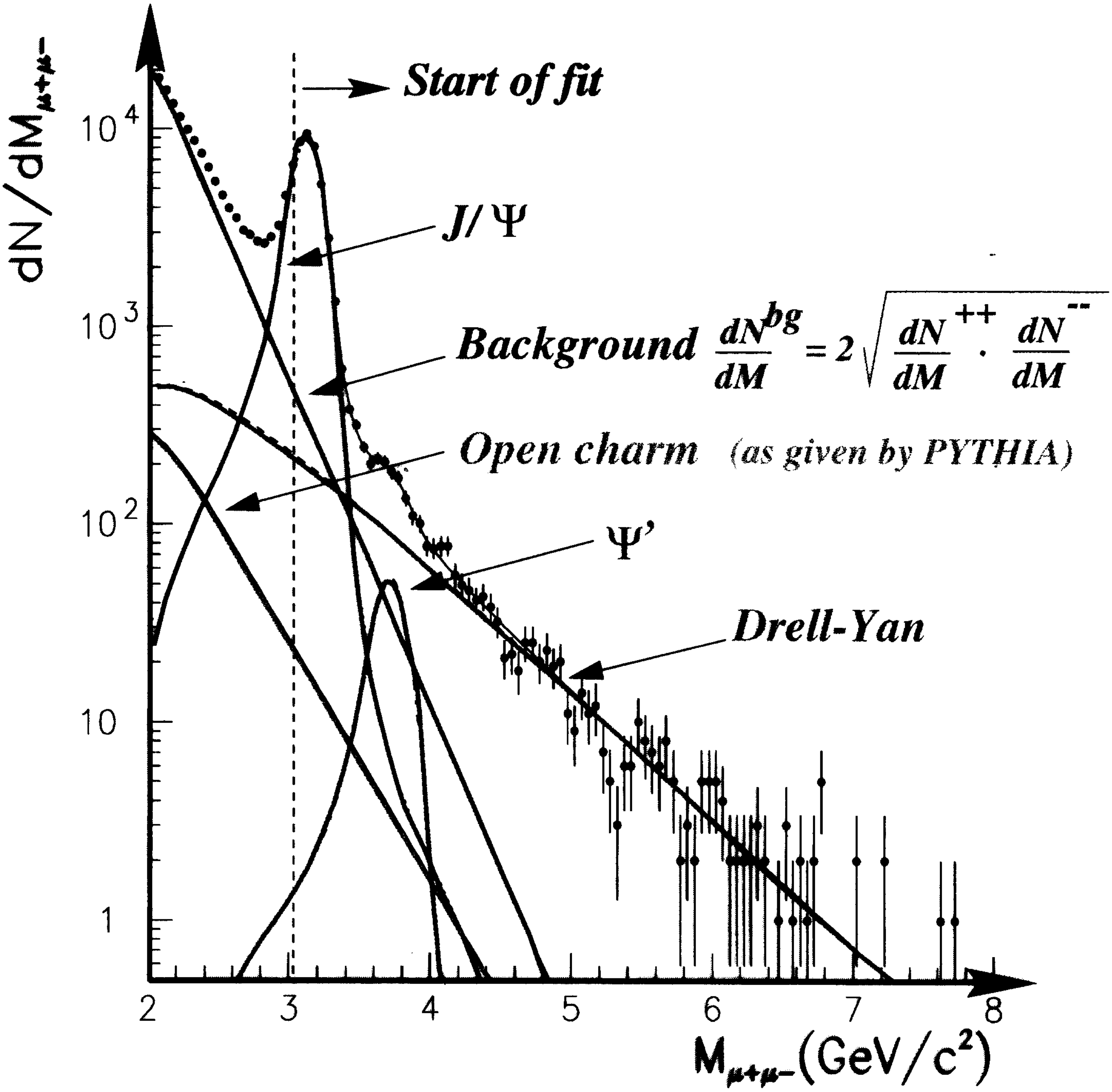
1. Introduction. History of charmonium production experiments at CERN
2. Ordinary and anomalous charmonium suppression
3. Hadronic and quark-gluon plasma interpretation of the experimental data on anomalous charmonia states suppression
4. Transverse momentum distribution and centrality dependence
5. Conclusions

Example of fit of a mass spectrum (1995 Pb-Pb data)

$$\frac{dN}{dM} = A_{J/\Psi}\frac{dN^{J/\Psi}}{dM} + A_{\Psi'}\frac{dN^{\Psi'}}{dM} + A_{DY}\frac{dN^{DY}}{dM} + \frac{dN^{D\bar{D}}}{dM} + \frac{dN^{bg}}{dM}$$

5 free parameters : $A_{J/\Psi}$, $A_{\Psi'}$, A_{DY} , $M_{J/\Psi}$, $\sigma_{J/\Psi}$



VARIABLES

- **Electromagnetic transverse energy**

  $E_T = E(\gamma,\pi^0) * \sin\theta \qquad \pi^0 \Rightarrow \gamma\gamma$

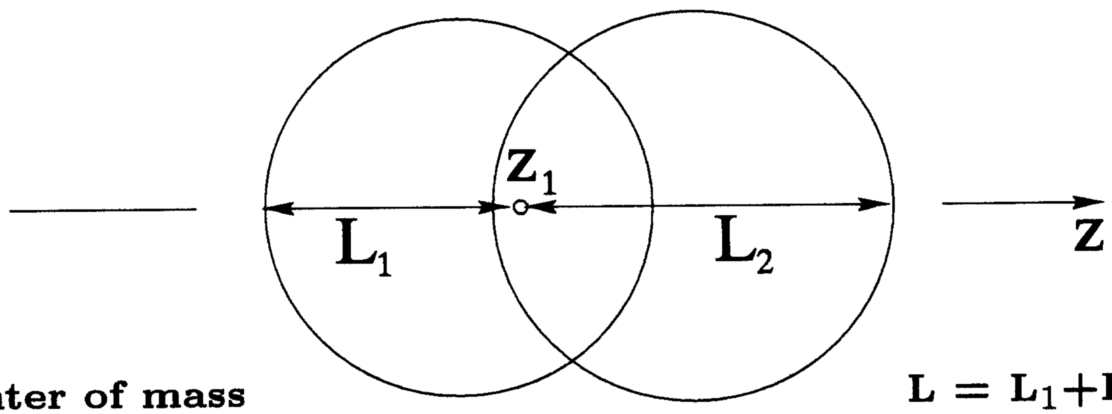
  Measurements for η = [1.1-2.3] ($y_{beam}/2 \simeq 2.93$)

  centrality cuts ⇔ b (impact parameter) = f(E_T)

- **Average length of the (c,$\bar{c}$) path through nuclear matter**

  L = geometrical variable
  E_T ⇒ b (impact parameter) ⇒ L

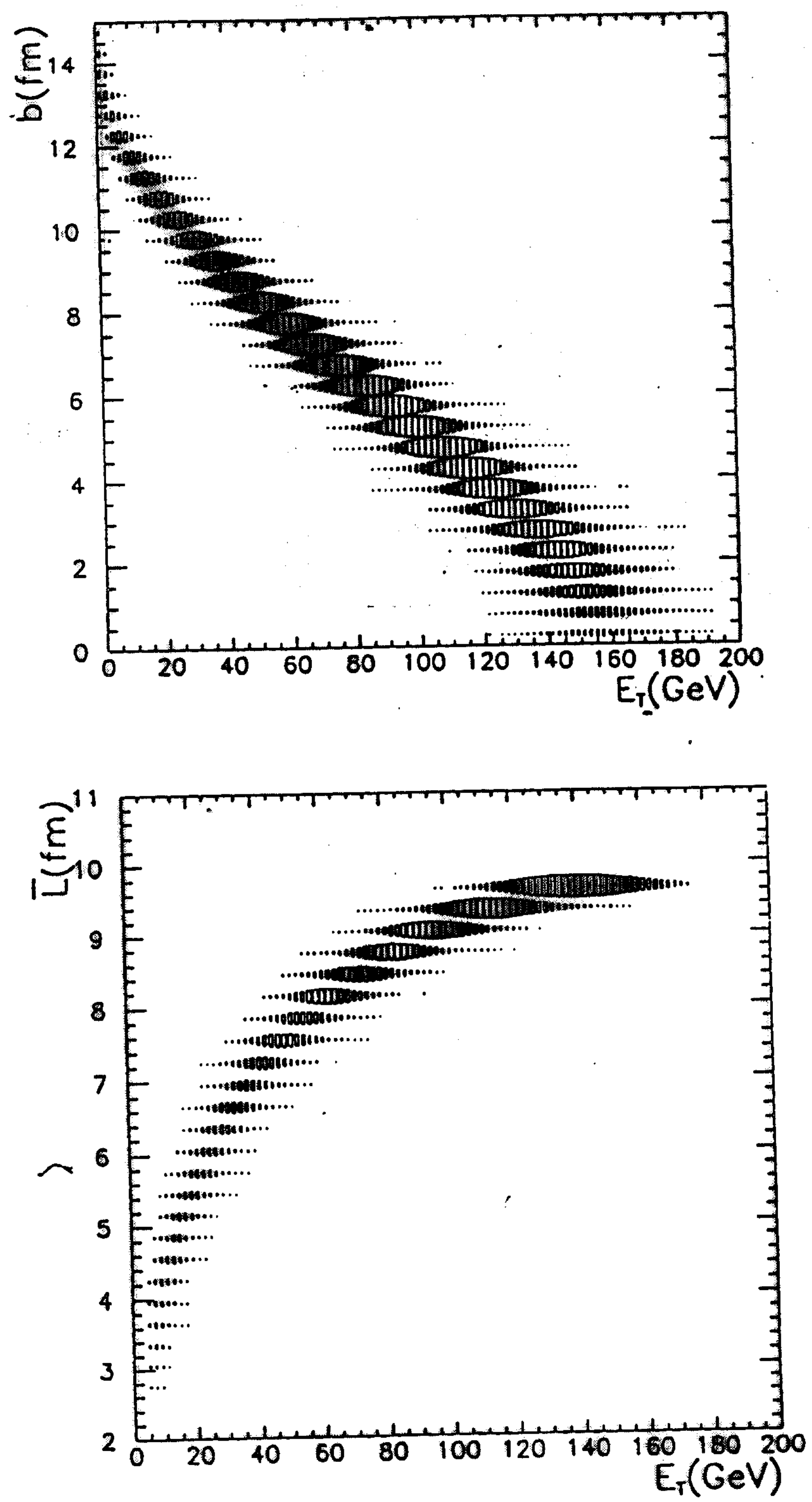
  example: b = 0 fm, (c,$\bar{c}$) produced at (0,0,z1)



center of mass **L = L_1+L_2**

Absorption ⇒ $N_{OUT} = N_{IN} * e^{-\rho_0 . L . \sigma_{absorption}}$
ρ_0 = nuclear density

$b \Leftrightarrow E_T \Leftrightarrow L$ correlations



Centrality determination by Zero Degree Calorimeter

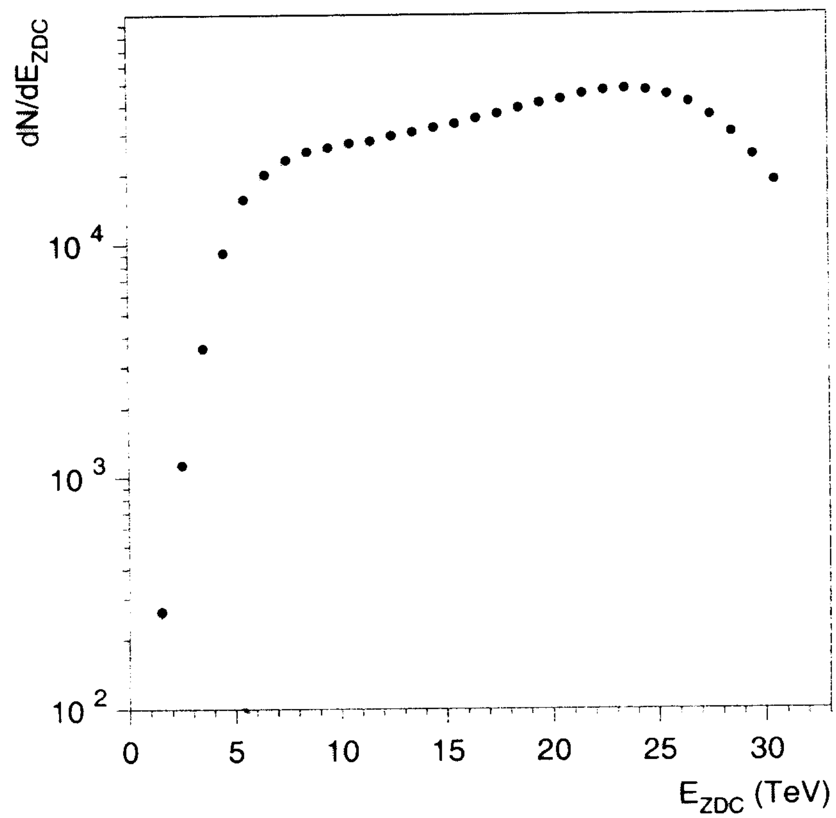
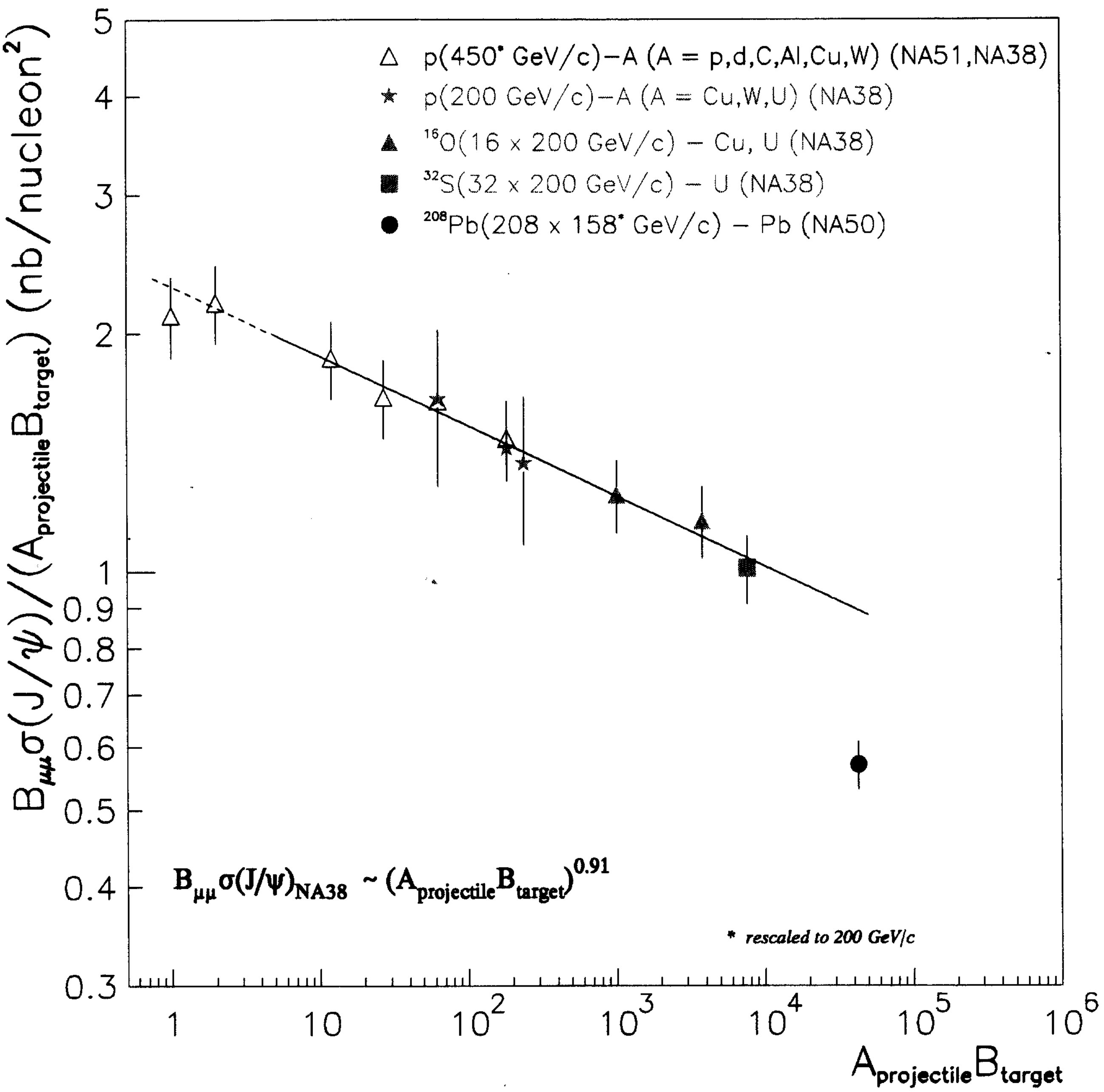
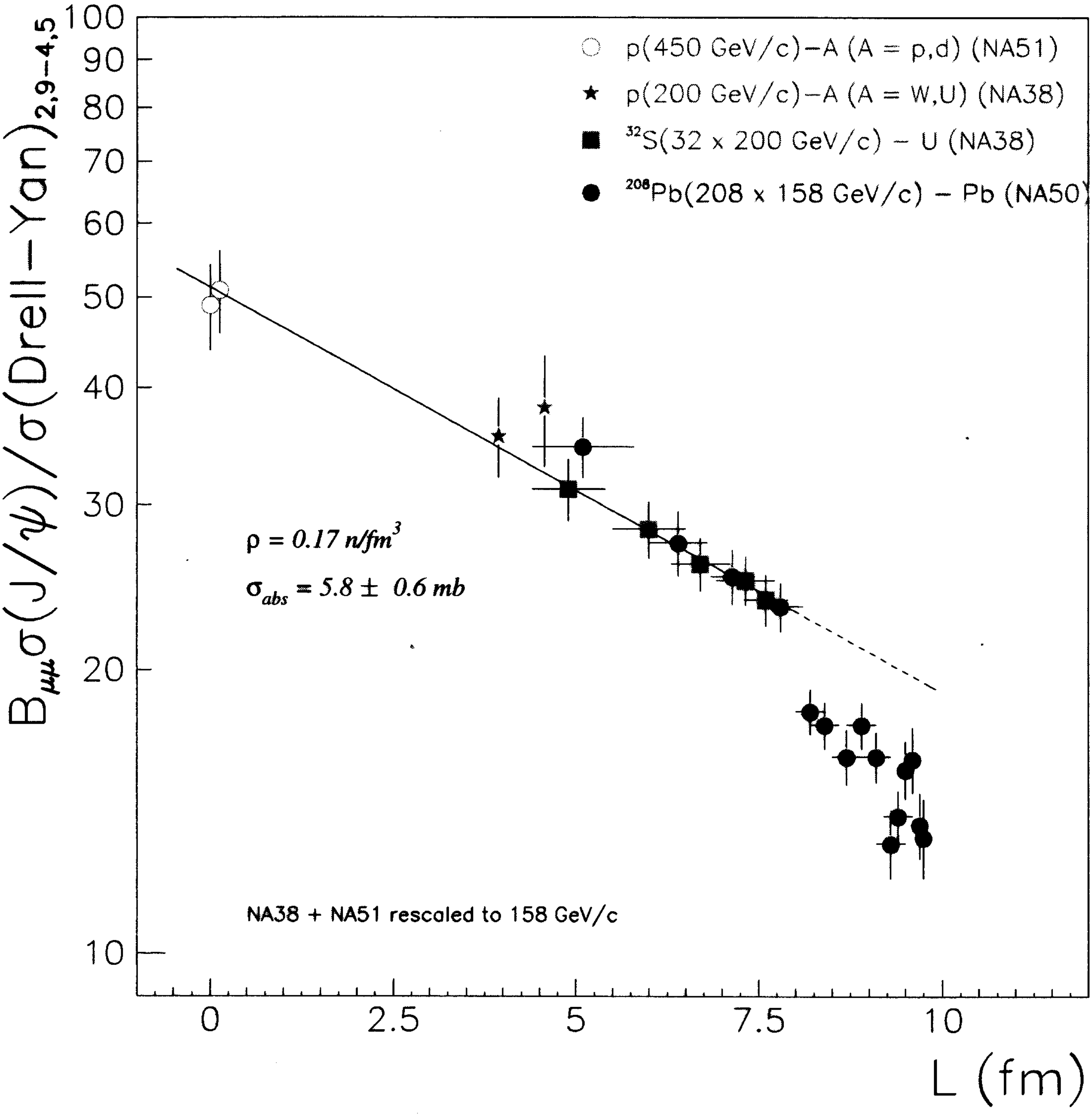


Figure 2: E_{ZDC} spectrum measured in 1998 with the minimum bias trigger. The data are not corrected for the efficiency of the target algorithm and the contribution from secondary particles has not been subtracted.

$$N_{part} = 208 - \frac{E_{ZDC}}{158\ GeV}$$

J/ψ cross-sections





p(450 GeV/c)−A (A = p,d) (NA51)
p(200 GeV/c)−A (A = W,U) (NA38)
^{32}S(32 x 200 GeV/c) − U (NA38)
^{208}Pb(208 x 158 GeV/c) − Pb (NA50)
$\rho = 0.17\ n/fm^3$
$\sigma_{abs} = 5.8 \pm\ 0.6\ mb$
NA38 + NA51 rescaled to 158 GeV/c
$B_{\mu\mu}\sigma(J/\psi)/\sigma(\text{Drell-Yan})_{2,9-4,5}$
L (fm)
0
2.5
5
7.5
10
10
20
30
40
50
60
70
80
90
100

Survival probability

$$S^{pA}_{Glauber} = \frac{\sigma(pA \to \psi)}{A\,\sigma(pN \to \psi)} =$$

$$= \int d^2b\, dz\, \rho_A(b,z) \exp\left(-(A-1)\int_z^{\infty} dz'\, \rho_A(b,z')\,\sigma_{abs}\right)$$

$$\sigma_{abs} = 7.3 \pm 0.6 \text{ mb}$$

D. Kharzeev, C. Lourenço, M. Nardi, H. Satz
Z. Phys C74 (1997) 307

preresonant state $c\bar{c} - g$:

D. Kharzeev and H. Satz
Phys. Lett. B 366 (1996) 316

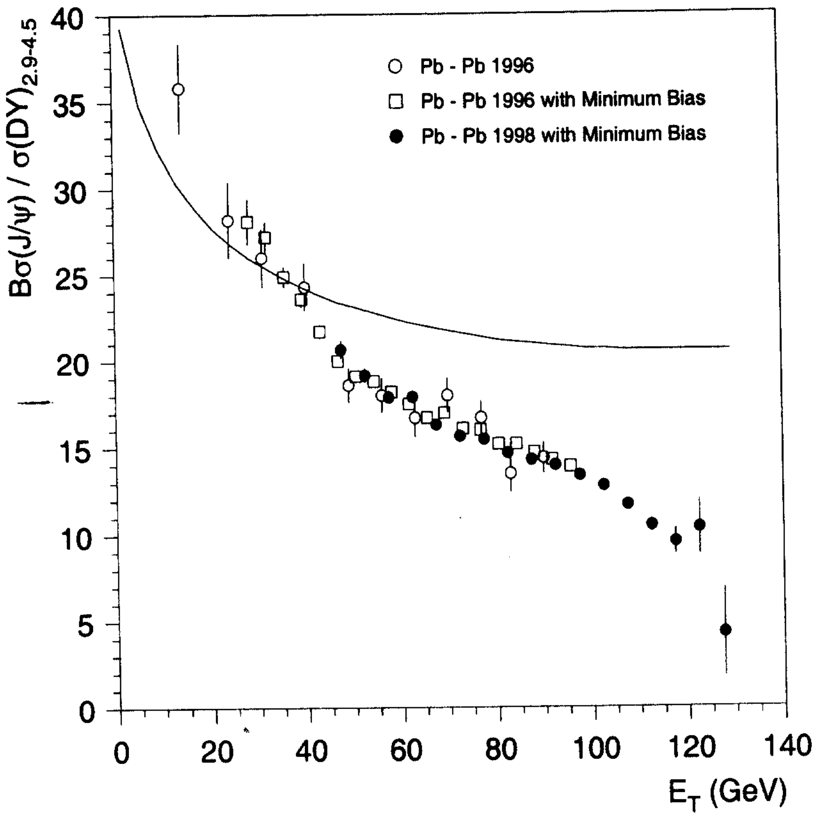


Figure 4: $\sigma_\psi/\sigma_{\rm DY}$ ratio as a function of $E_{\rm T}$, obtained with the standard and minimum bias analyses of the 1996 and 1998 data samples. The curve represents the J/ψ suppression due to ordinary nuclear absorption.

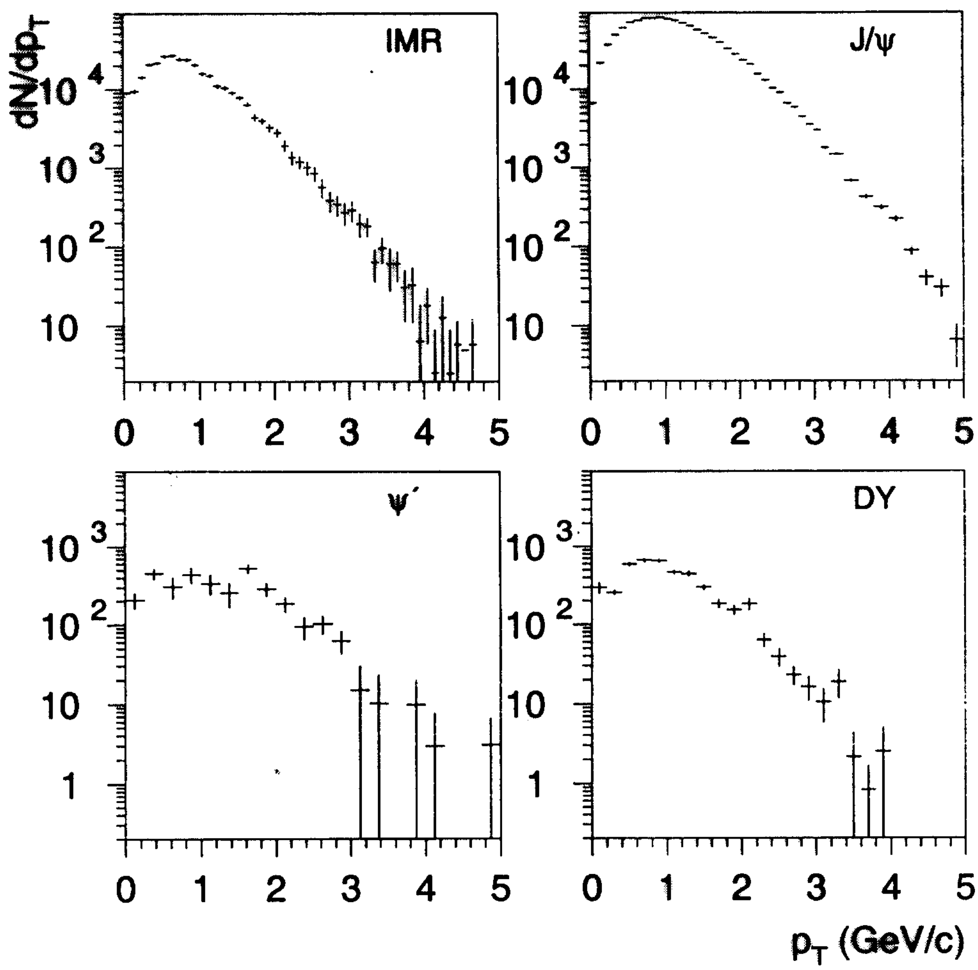


Figure 2: p_T distributions for several muon pair mass intervals. IMR stands for the mass range $2.1 < M < 2.7$ GeV/c^2 and DY stands for $M > 4.2$ GeV/c^2.

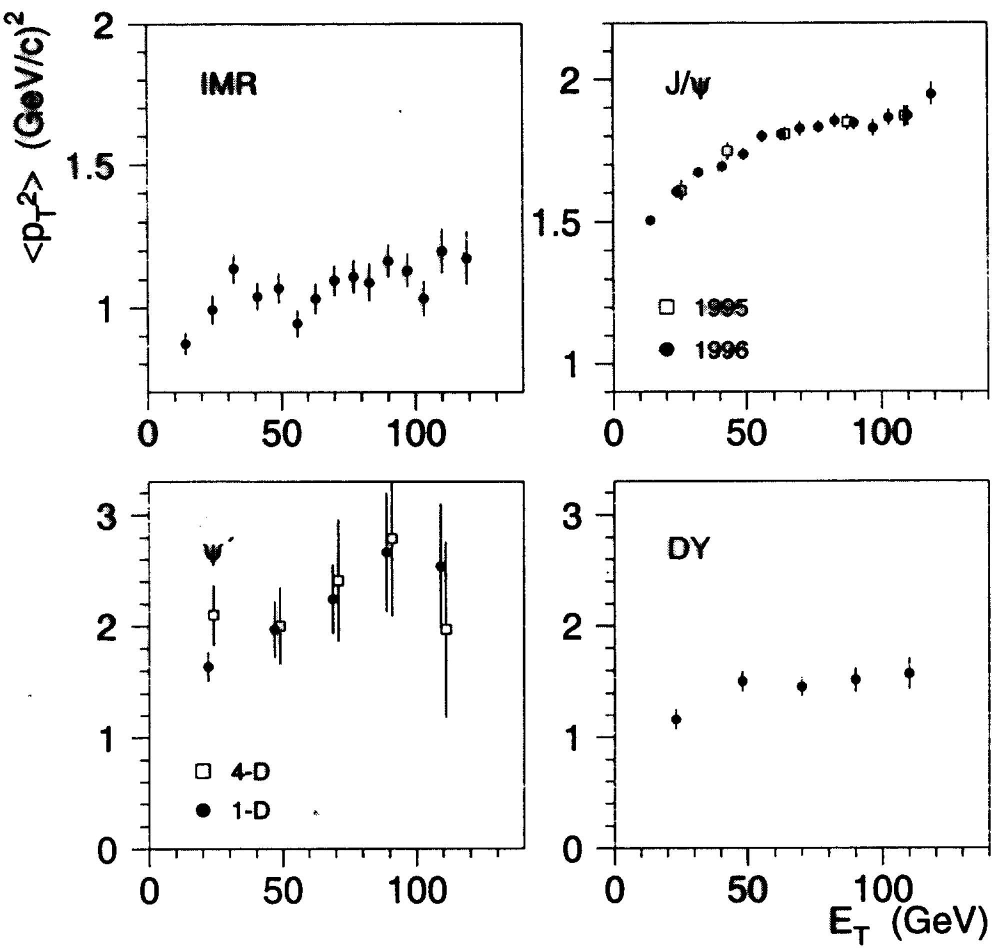


Figure 4: $\langle p_T^2 \rangle$ as a function of the transverse energy for several muon pair mass intervals. For the J/ψ, the 5 open squares correspond to the 1995 data sample. The error bars are only statistical. For the ψ', both the 1-D and 4-D deconvolution results are shown.

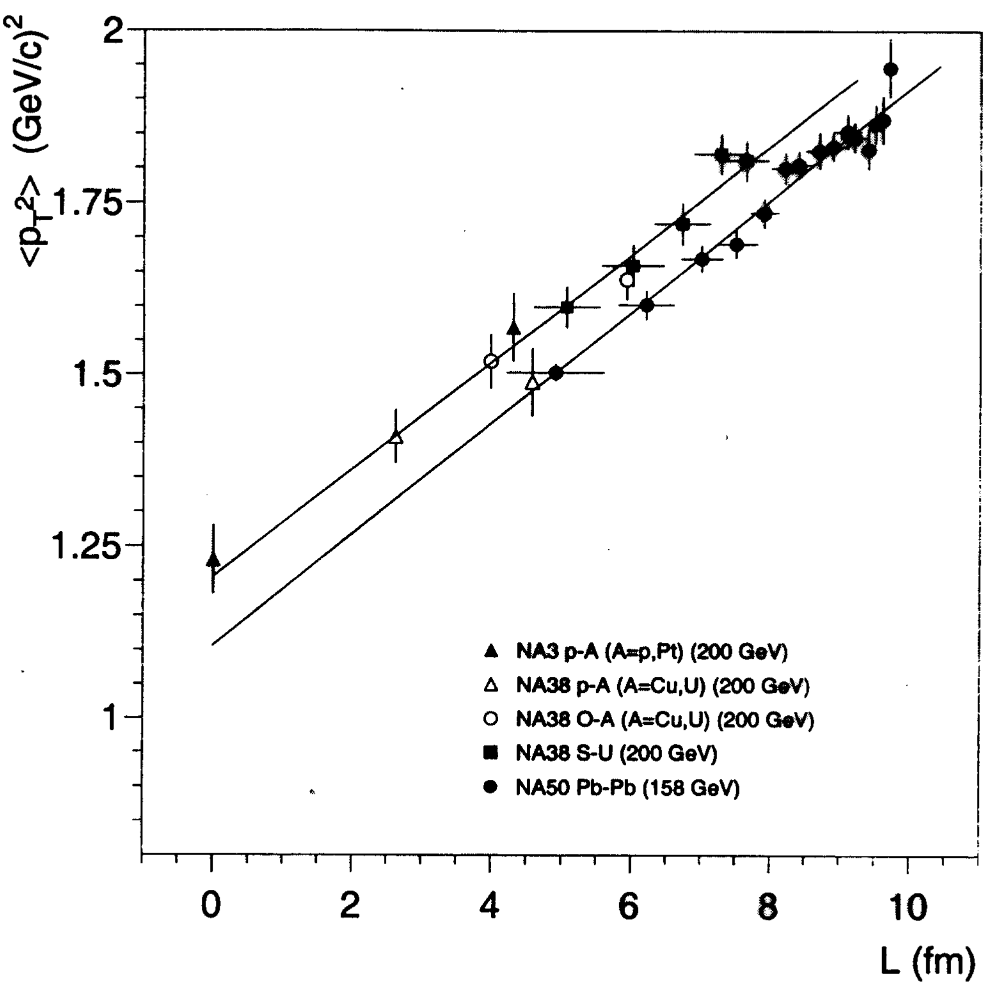


Figure 5: $\langle p_{\mathrm{T}}^2 \rangle$ values of the J/ψ as a function of L. The measurements performed at 200 GeV/nucleon are also included. The lines are linear fits to the data points, one for each beam energy.

$$\langle p_T^2 \rangle (E_T) = \langle p_T^2 \rangle_{pp} + a_{gN} L(E_T)$$

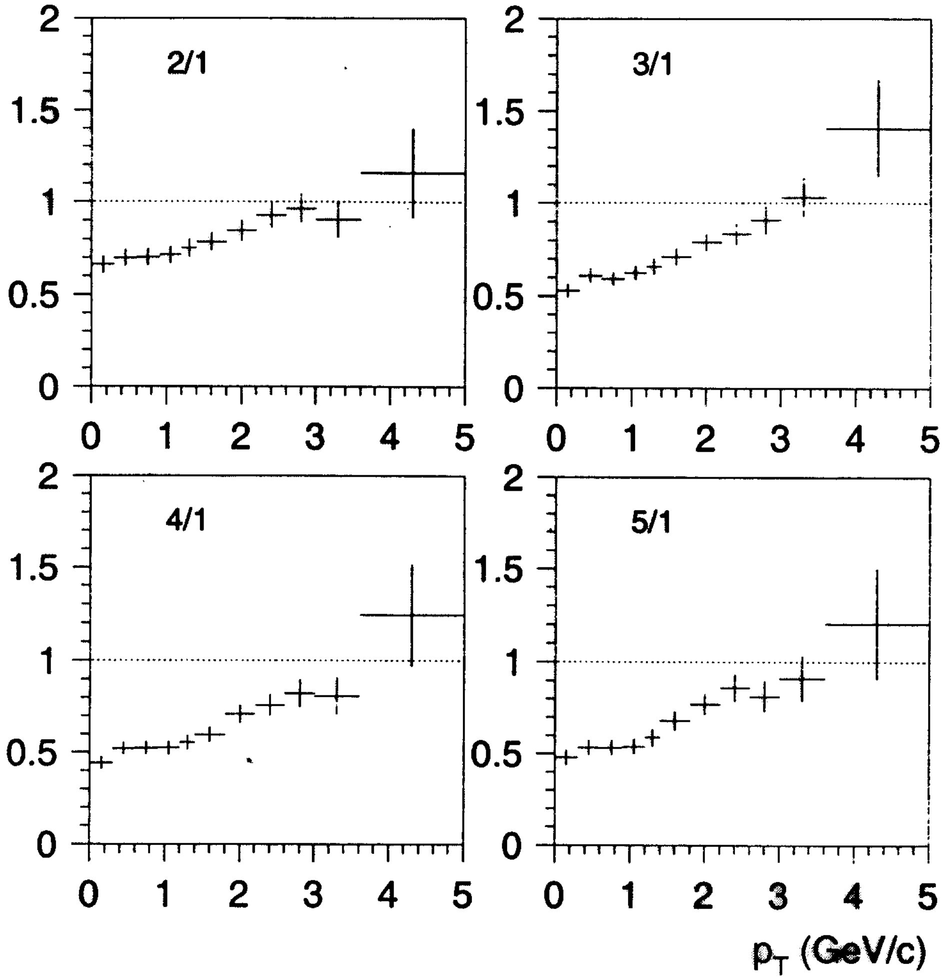


Figure 6: Ratios between the J/ψ p_{T} distributions in the E_{T} bin i ($i = 2, 3, 4, 5$) and in the first E_{T} bin, $R_i(p_{\mathrm{T}})$.

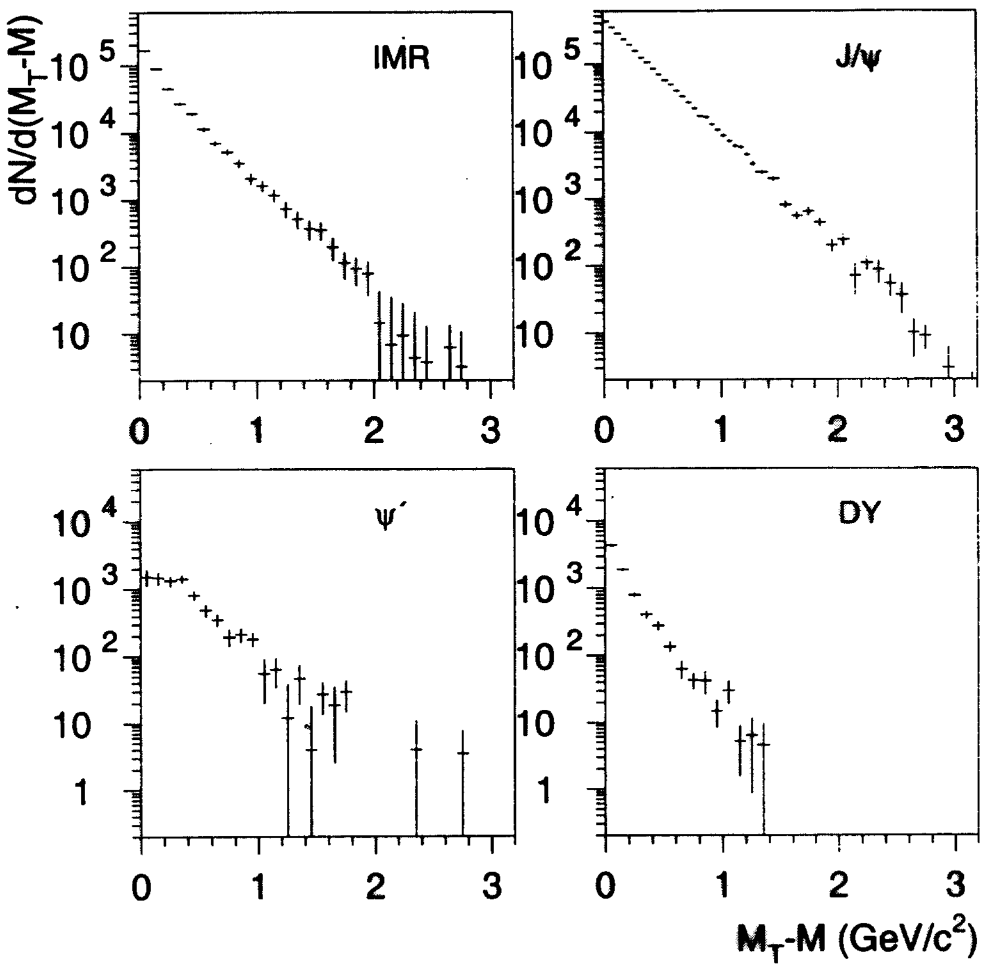


Figure 7: $M_\mathrm{T} - M$ distributions for several muon pair mass intervals.

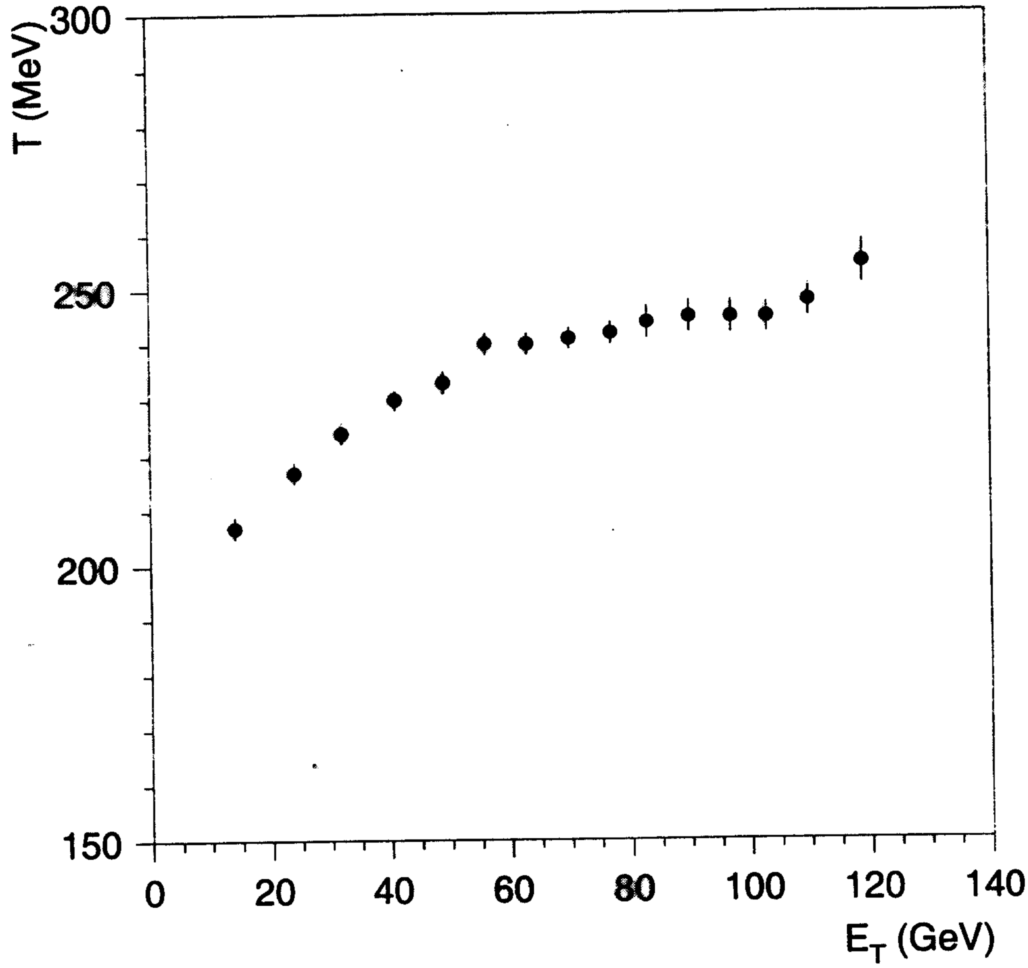


Figure 8: Inverse slope parameter, T, of the J/ψ transverse mass distributions, plotted as a function of the transverse energy.

I. Initial state parton multiple scattering (Increase of $\langle p_T^2 \rangle$ with centrality and then saturation)

S. Gavin, M. Gyulassy (1988)
J.P. Blaizot, J.Y. Ollitrault (1989)
J. Hüfner, Y. Kurihara, H. Pirner (1988)

II. Formation of QGP

1. Increase of $\langle p_T^2 \rangle$ with centrality – high-p_T J/ψ's escape without being suppressed by the plasma

J.P. Blaizot, J.Y. Ollitrault (1989)
M.C. Chu, T. Matsui (1988)

2. Decrease of $\langle p_T^2 \rangle$ due to reduction of detected J/ψ's

D. Kharzeev, M. Nardi, H. Satz (1997)

Comovers

A. Capella, A. Kaidalov, A.K. Akil, C. Gerschel

Phys.Lett. B 393 (1997) 431 Phys.Rev. C59 (1999) 395

S. Gavin and R. Vogt Phys.Rev.Lett. 78 (1997) 1006

J. Geiss et al. Phys.Lett. B447 (1999) 31

C. Spieles et al. Phys.Rev C60 (1999) 054901

D. Kahana and S.Kahana Prog.Part.Nucl.Phys. 42 (1999) 269

Deconfinement

D. Kharzeev and H. Satz Z.Phys. C74 (1997) 307

J.P. Blaizot and J.Y. Ollitraunlt Phys.Rev.Lett. 77

(1996) 1703

C.Y. Wong Phys.Rev. C55 (1997) 2621

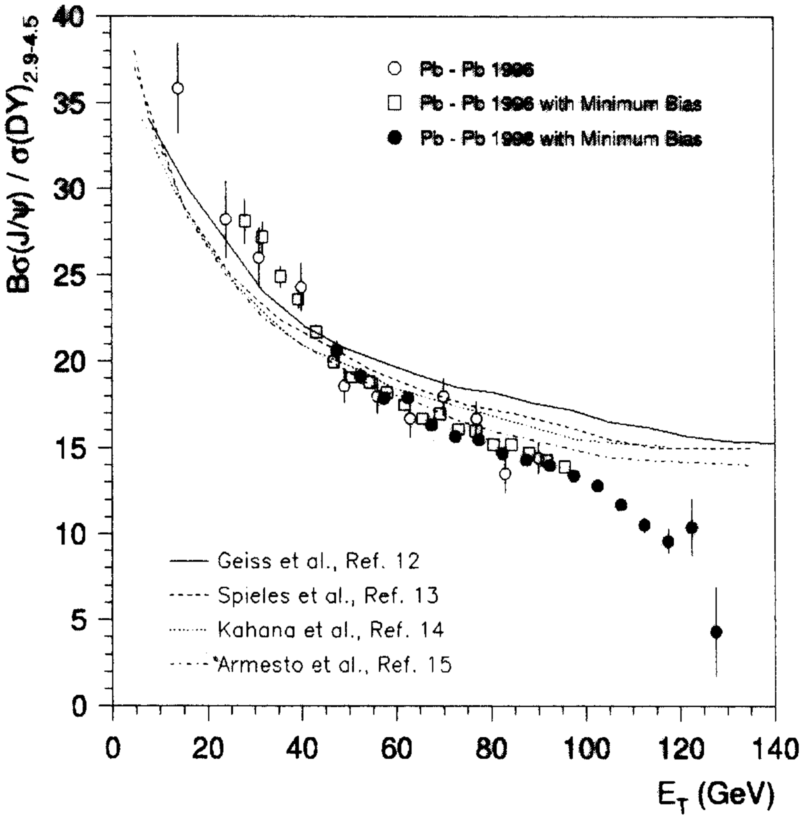


Figure 6: Comparison between our data and several conventional calculations of J/ψ suppression.

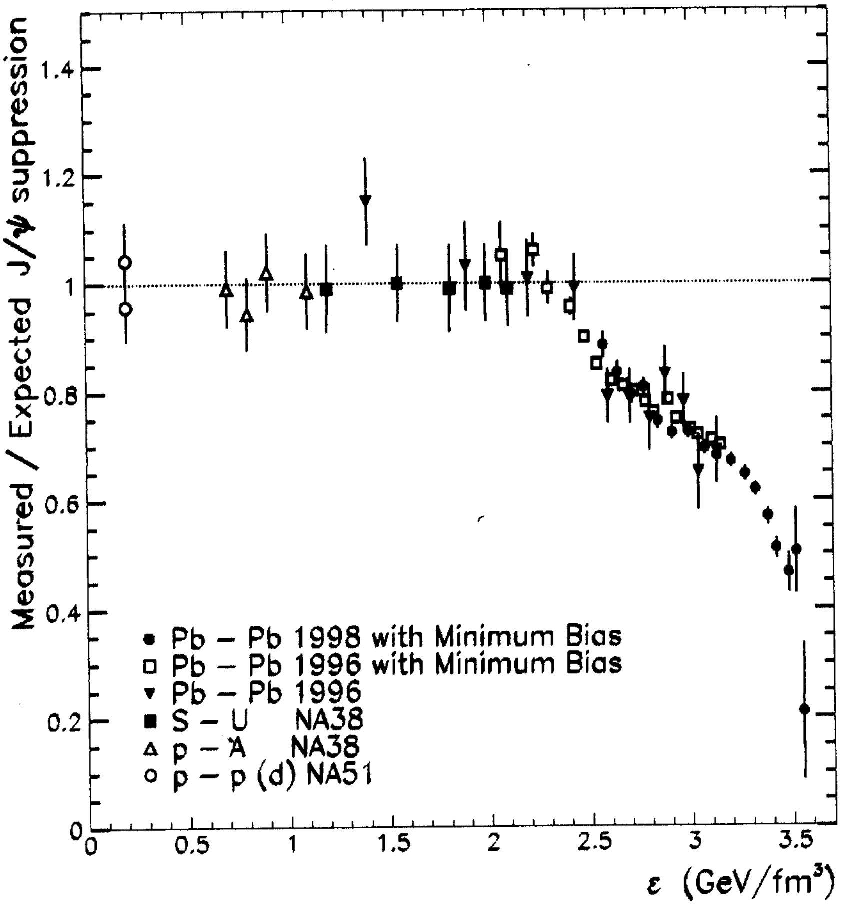


Figure 6: Measured J/ψ production yields, normalised to the yields expected assuming that the only source of suppression is the absorption by the nuclear medium. The data is shown as a function of the energy density reached in the several collision systems.

Conclusions

1. New effect of anomalous charmonium suppression in central Pb – Pb collisions was observed in NA50 experiment at CERN

2. The threshold onset of anomalous suppression could be more reliable explained by Debye color screening in deconfined quark – gluon matter

3. Combined analysis of charmonia production and transverse momentum dependence on centrality needs more theoretical work to be done.