Recent results on J/ψ from NA50

NA50 Collaboration

P. Bordalo – LIP-Lisbon

Stony Brook, January 15-20, 2001

NA50 COLLABORATION

M.C. Abreu[6,a], B. Alessandro[10], C. Alexa[3], R. Arnaldi[10], M. Atayan[12], C. Baglin[1], A. Baldit[2], M. Bedjidian[11], S. Beolè[10], V. Boldea[3], P. Bordalo[6,b], G. Borges[6], A. Bussière[1], L. Capelli[11], J. Castor[2], B. Chaurand[9], B. Cheynis[11], E. Chiavassa[10], C. Cicalò[4], T. Claudino[6], M.P. Comets[8], S. Constantinescu[3], P. Cortese[10], J. Cruz[6,c], N. De Marco[10], A. De Falco[4], G. Dellacasa[10,d], A. Devaux[2], S. Dita[3], O. Drapier[11], L. Ducroux[11], B. Espagnon[2], J. Fargeix[2], P. Force[2], M. Gallio[10], Y.K. Gavrilov[7], C. Gerschel[8], P. Giubellino[10], M.B. Golubeva[7], M. Gonin[9], A.A. Grigorian[12], J.Y. Grossiord[11], F.F. Guber[7], A. Guichard[11], H. Gulkanyan[12], R. Hakobyan[12], R. Haroutunian[11], M. Idzik[10,e], D. Jouan[8], T.L. Karavitcheva[7], L. Kluberg[9], A.B. Kurepin[7], Y. Le Bornec[8], C. Lourenço[5], P. Macciotta[4], M. Mac Cormick[8], A. Marzari-Chiesa[10], M. Masera[10], A. Masoni[4], S. Mehrabyan[12], M. Monteno[10], A. Musso[10], P. Petiau[9], A. Piccotti[10], J.R. Pizzi[11], F. Prino[10], G. Puddu[4], C. Quintans[6], H. Santos[6], S. Ramos[6,b], L. Ramello[10,d], P. Rato Mendes[6], L. Riccati[10], A. Romana[9], P. Saturnini[2], E. Scomparin[10] S. Serci[4], R. Shahoyan[6,f], S. Silva[6], M. Sitta[10,d], P. Sonderegger[5,b], X. Tarrago[8], N.S. Topilskaya[7], G.L. Usai[4], E. Vercellin[10], L. Villatte[8], N. Willis[8]

[1] LAPP, CNRS-IN2P3, Annecy-le-Vieux, France.
[2] LPC, Univ. Blaise Pascal and CNRS-IN2P3, Aubière, France.
[3] IFA, Bucharest, Romania.
[4] Università di Cagliari/INFN, Cagliari, Italy.
[5] CERN, Geneva, Switzerland.
[6] LIP, Lisbon, Portugal.
[7] INR, Moscow, Russia.
[8] IPN, Univ. de Paris-Sud and CNRS-IN2P3, Orsay, France.
[9] LPNHE, Ecole Polytechnique and CNRS-IN2P3, Palaiseau, France.
[10] Università di Torino/INFN, Torino, Italy.
[11] IPN, Univ. Cl. Bernard Lyon-I and CNRS-IN2P3, Villeurbanne, France.
[12] YerPhI, Yerevan, Armenia.

Outline

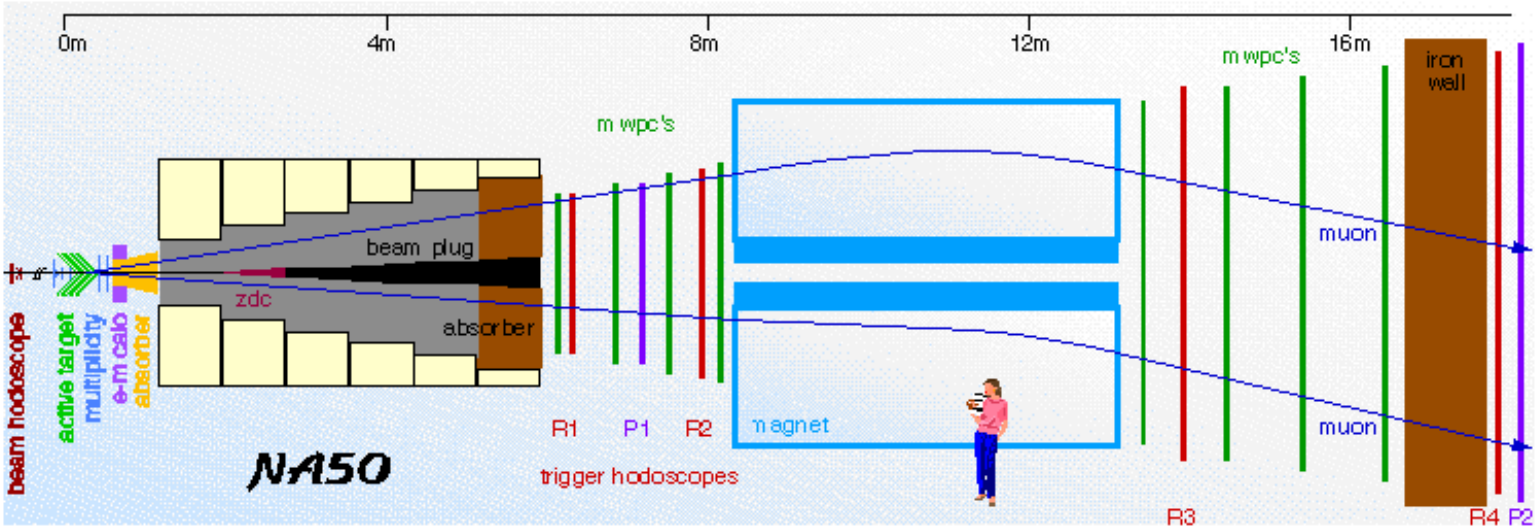
J/ψ Production:

- $J/\psi/DY$ as a function of E_T, L and ϵ
- New proton data
- Minimum Bias analysis
- ZDC analysis
- Comparision with models

J/ψ Transverse distributions:

- dN/dM_{T} distributions
- $\langle p_{\mathrm{T}} \rangle$ and $\langle p_{\mathrm{T}}^2 \rangle$ as a function of E_{T} and L
- Inverse slope parameter T
- dN/dp_{T} ratios for different centralities

Experimental Setup



The J/ψ is detected via its decay into muon pairs

- **Dimuon spectrometer:**

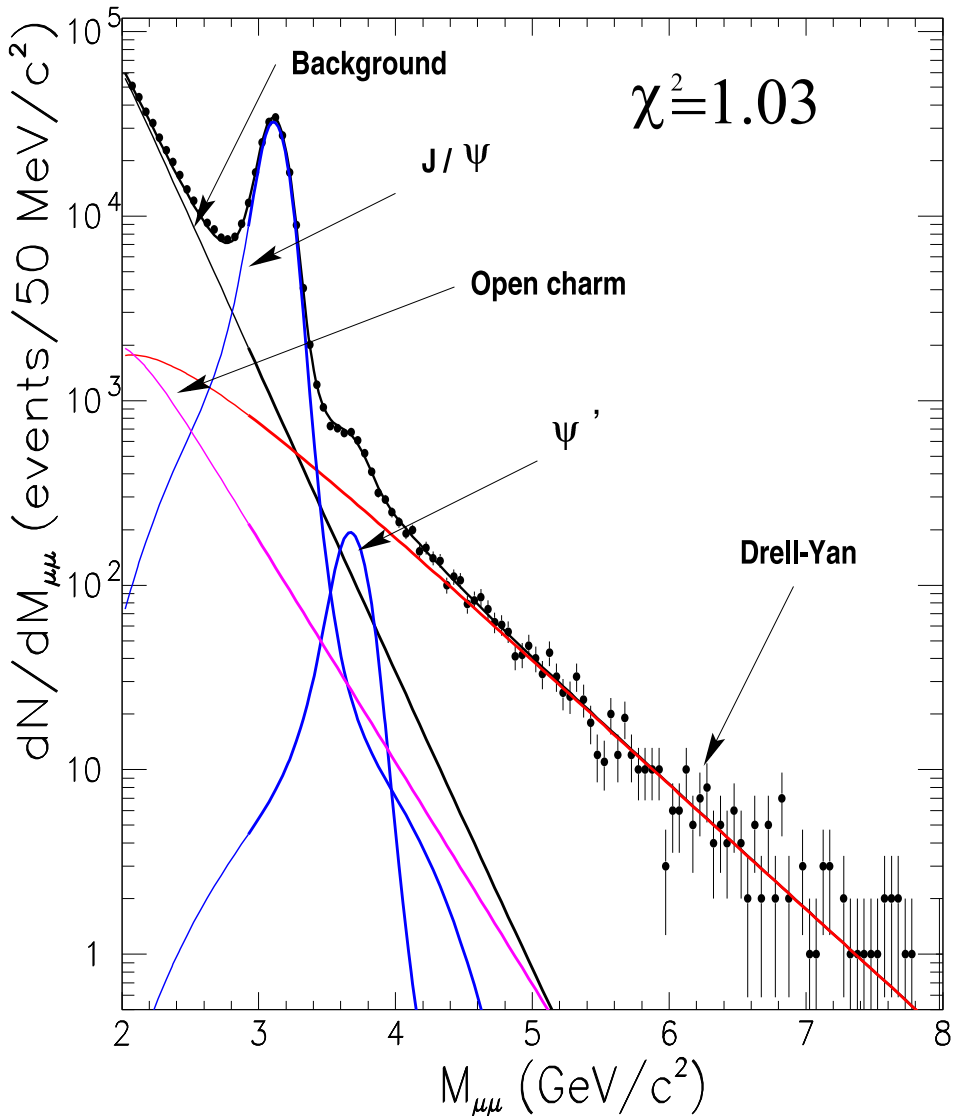
$0 < y_{CM} < 1 \quad (2.92 < y_{Lab} < 3.92) \quad |\cos\theta_{CS}| < 0.5$

Acceptance	J/ψ	13.5%
	DY$(2.9 - 4.5)$	15.1%
	DY $(2.9 - 8.0)$	15.4%

- **Active target:** Čerenkov counter blades
- **Centrality detectors:**
  - ▷ E.m. calorimeter $(1.1 < \eta_{lab} < 2.3)$
  - ▷ Zero Degree Calorimeter $(\eta_{lab} > 6.3)$
  - ▷ Multiplicity detector $(1.5 < \eta_{lab} < 3.5)$

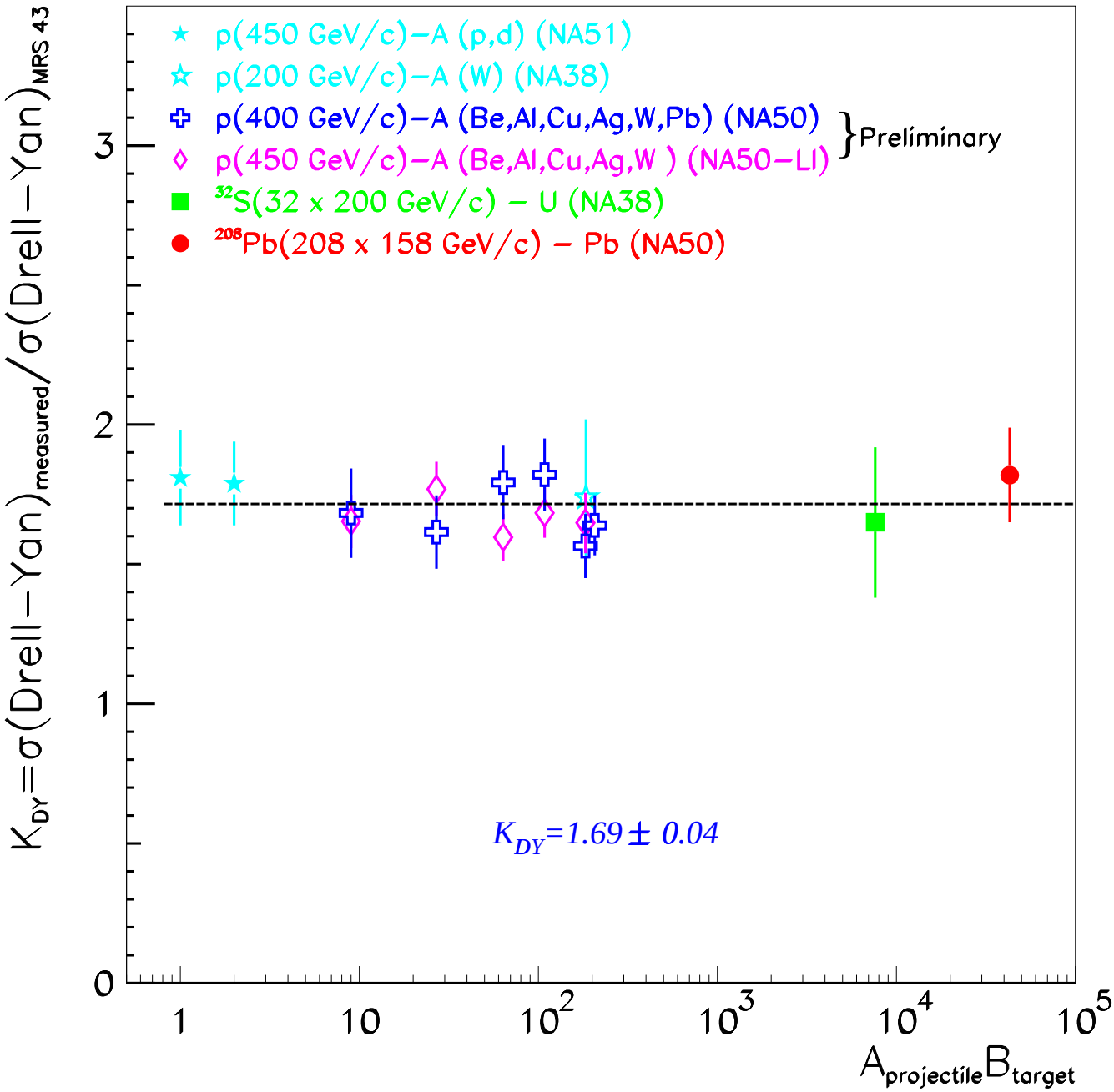
Fit to the mass spectrum

$$\frac{dN}{dM} = A_{J/\psi}\frac{dN_{J/\psi}}{dM} + A_{\psi'}\frac{dN_{\psi'}}{dM} + A_{DY}\frac{dN_{DY}}{dM} + \frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$



- Combinatorial background, due to π and K decays, is estimated from like-sign pairs: $N_{BG} = 2\sqrt{N^{++}N^{--}}$
- J/ψ, ψ', $D\bar{D}$ and Drell-Yan shapes from simulation and reconstructed chain

Drell-Yan: Experimental K factor



Drell-Yan is proportional to the number of collisions A·B, that is, it scales as expected:

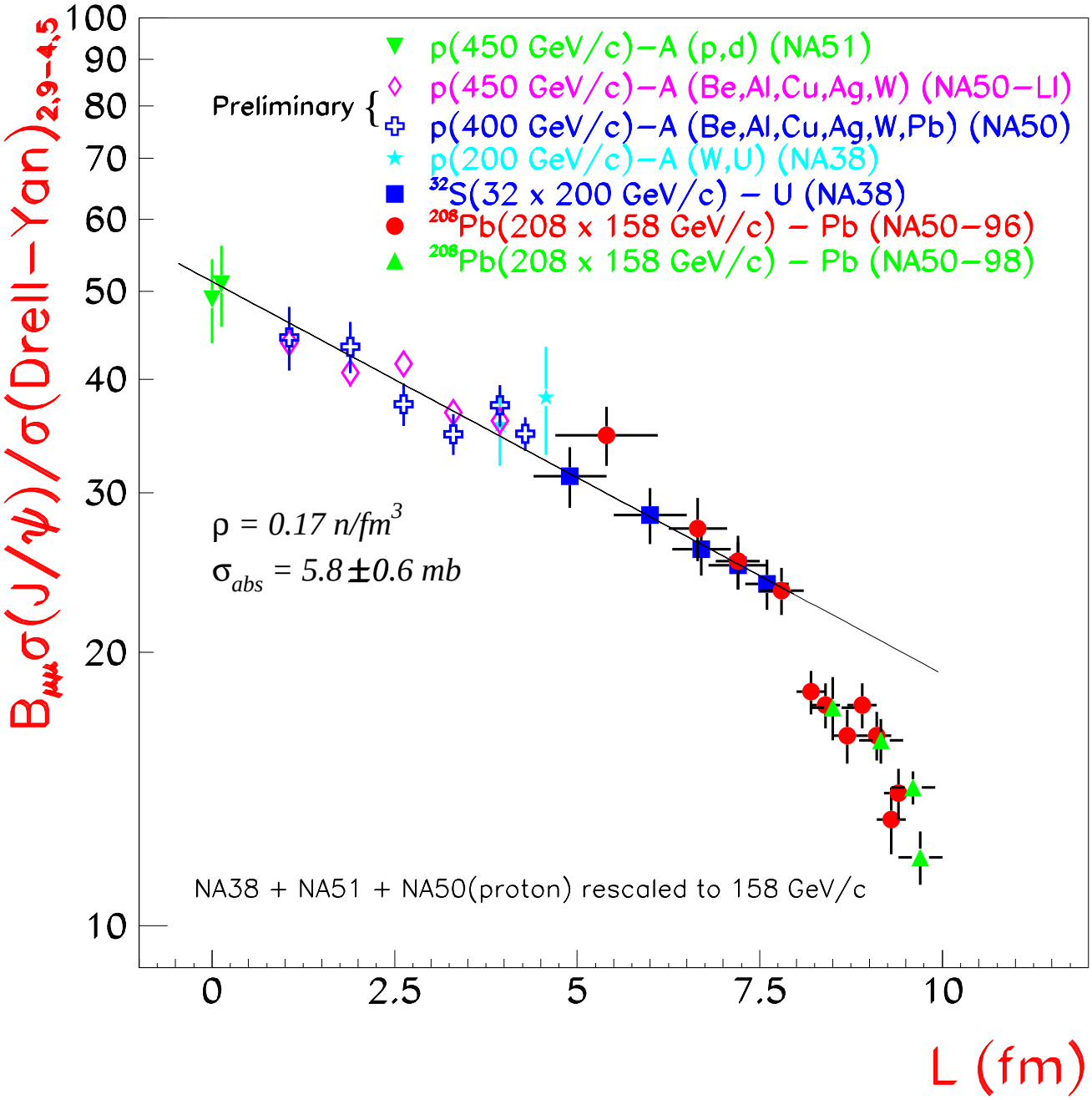
$$\sigma^{DY} \propto (A\ B)^{\alpha} \quad with \quad \alpha = 1$$

Previous K factor (excluding new proton data):

$$K_{DY} = 1.78 \pm 0.08$$

ψ/DY as a function of L

L - path length of the pre-resonant $c\bar{c}g$ state in nuclear matter

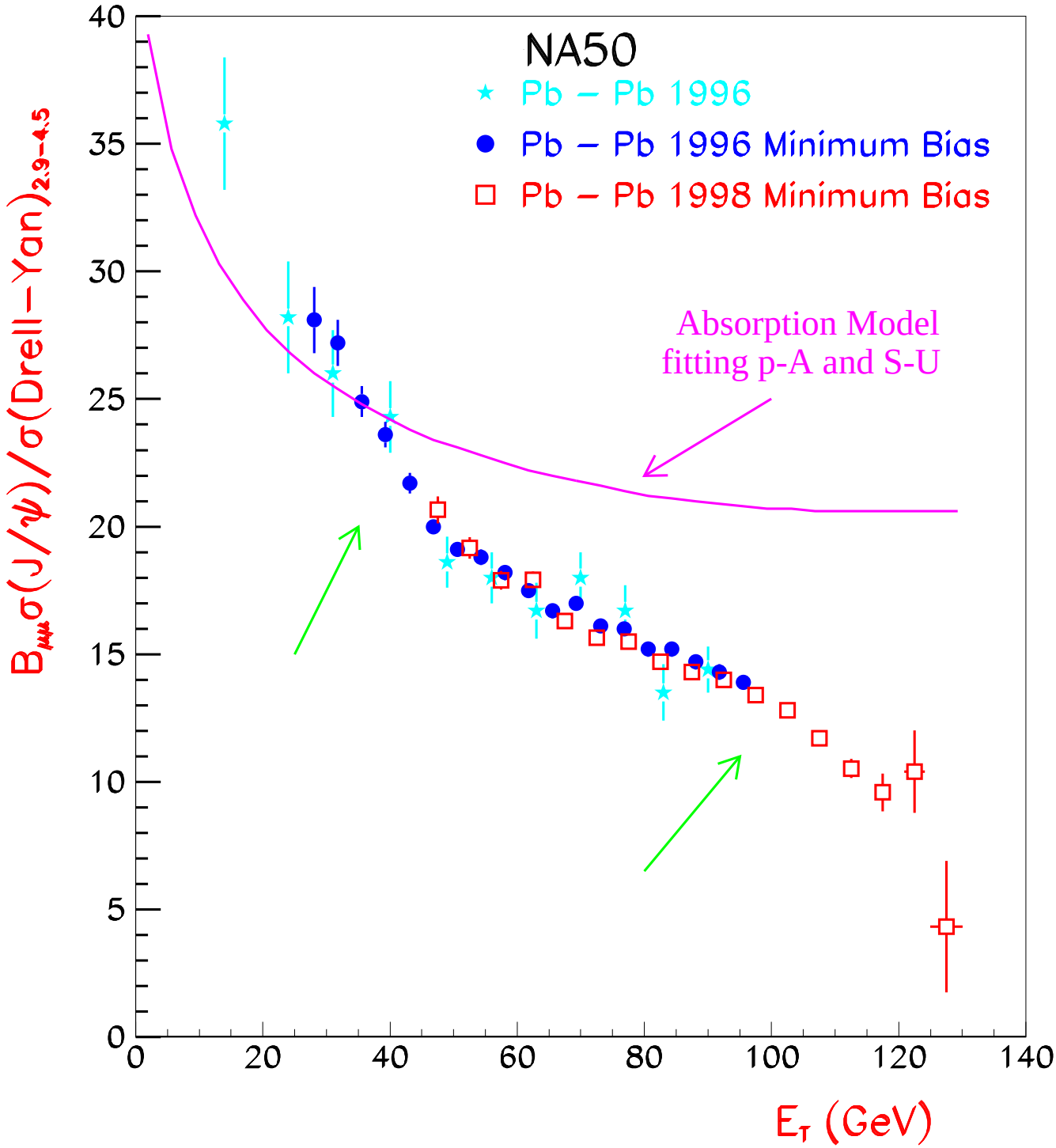


Fit including new proton data:

$$\frac{B_{\mu\mu}\sigma^{\psi}}{\sigma^{DY}} \propto e^{-\rho L \sigma_{abs}} \Rightarrow \sigma_{abs} = 5.4 \pm 0.4\ mb$$

Sudden 20% drop at L = 8 fm

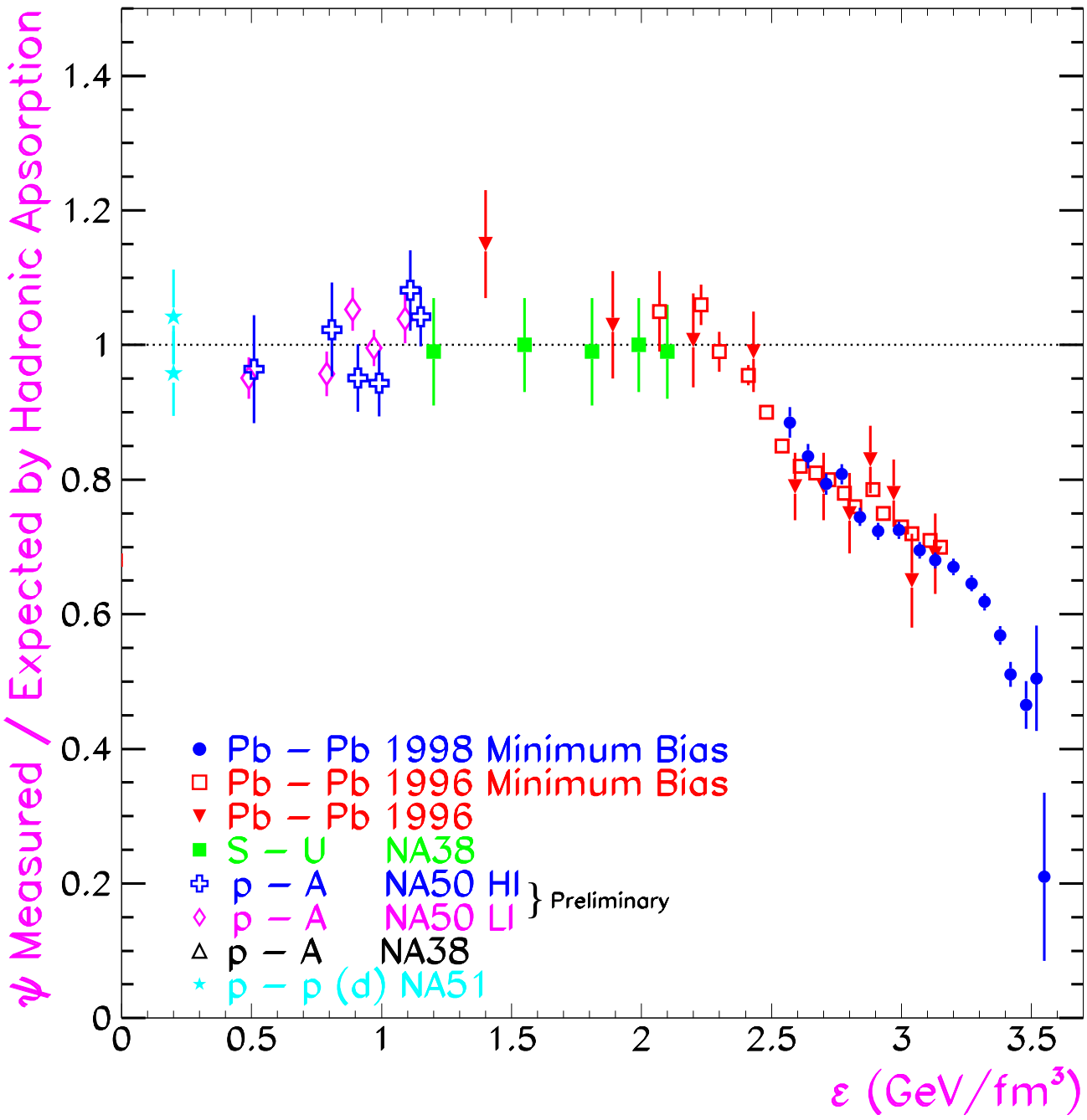
ψ/DY as a function of E_T



Solid line: **exponential parametrization as obtained from fit to light systems (NA38 + NA51)**

20% drop at 40 GeV and an inflexion point at 90 GeV followed by a steady steep decrease

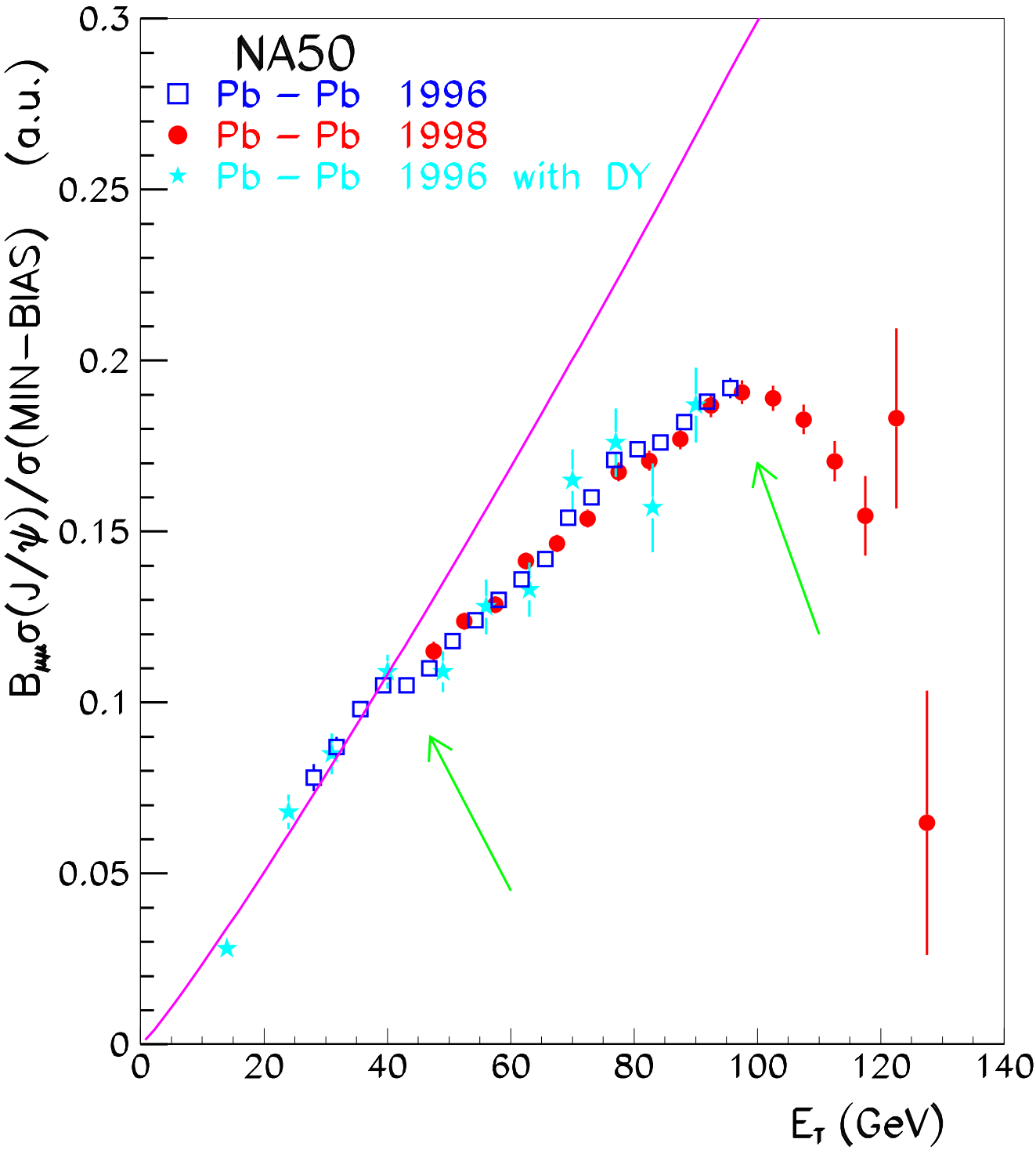
ψ Measured/Expected as a function of ϵ



Expected: **Absorption Model as obtained from fit to light systems (p-A and S-U)**

Stepwise Pattern: 2 threshold values for J/ψ suppression, $\simeq$ 2.4 and $\simeq$ 3.2 GeV/fm^3

ψ/Minimum Bias as a function of E_T

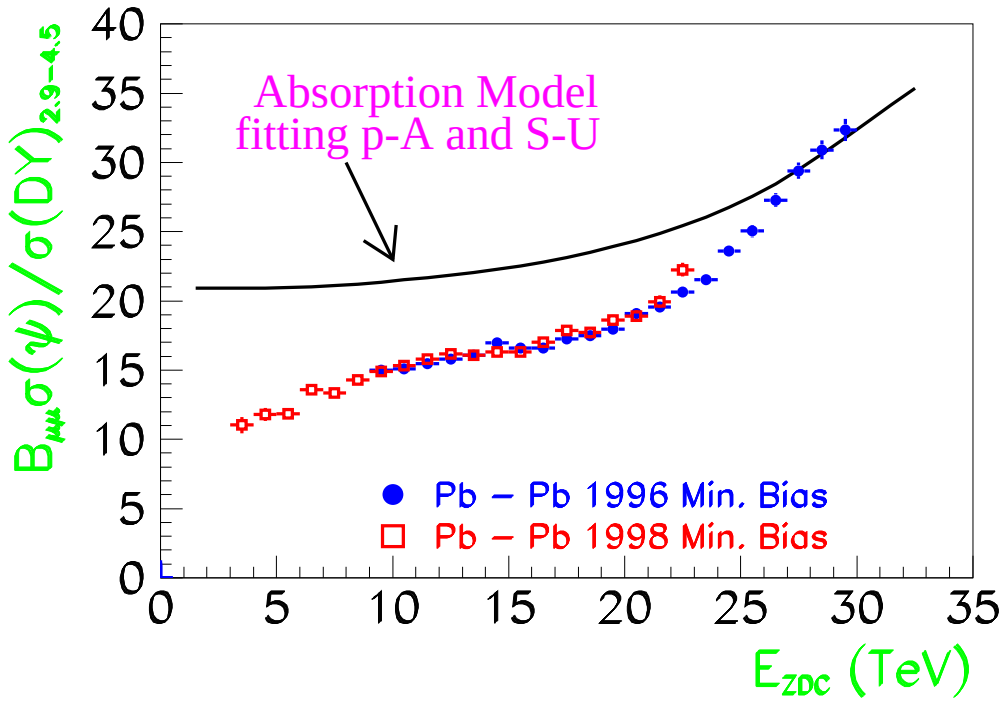


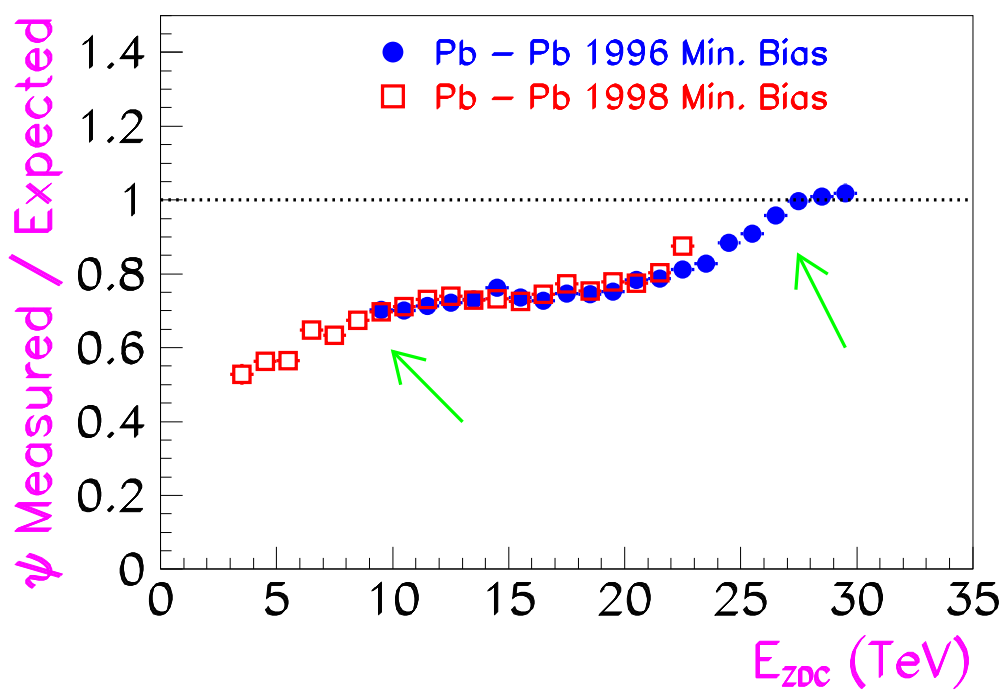
Solid line: Absorption Model with $\sigma_{abs} = 6.4 \pm 0.8\ mb$ **as obtained from fit to p-A and S-U data (NA38 + NA51) with full calculation**

Pattern exhibits 2 "accidents"

ψ/DY as a function of ZDC

Using another detector: ZDC, for centrality ψ studies



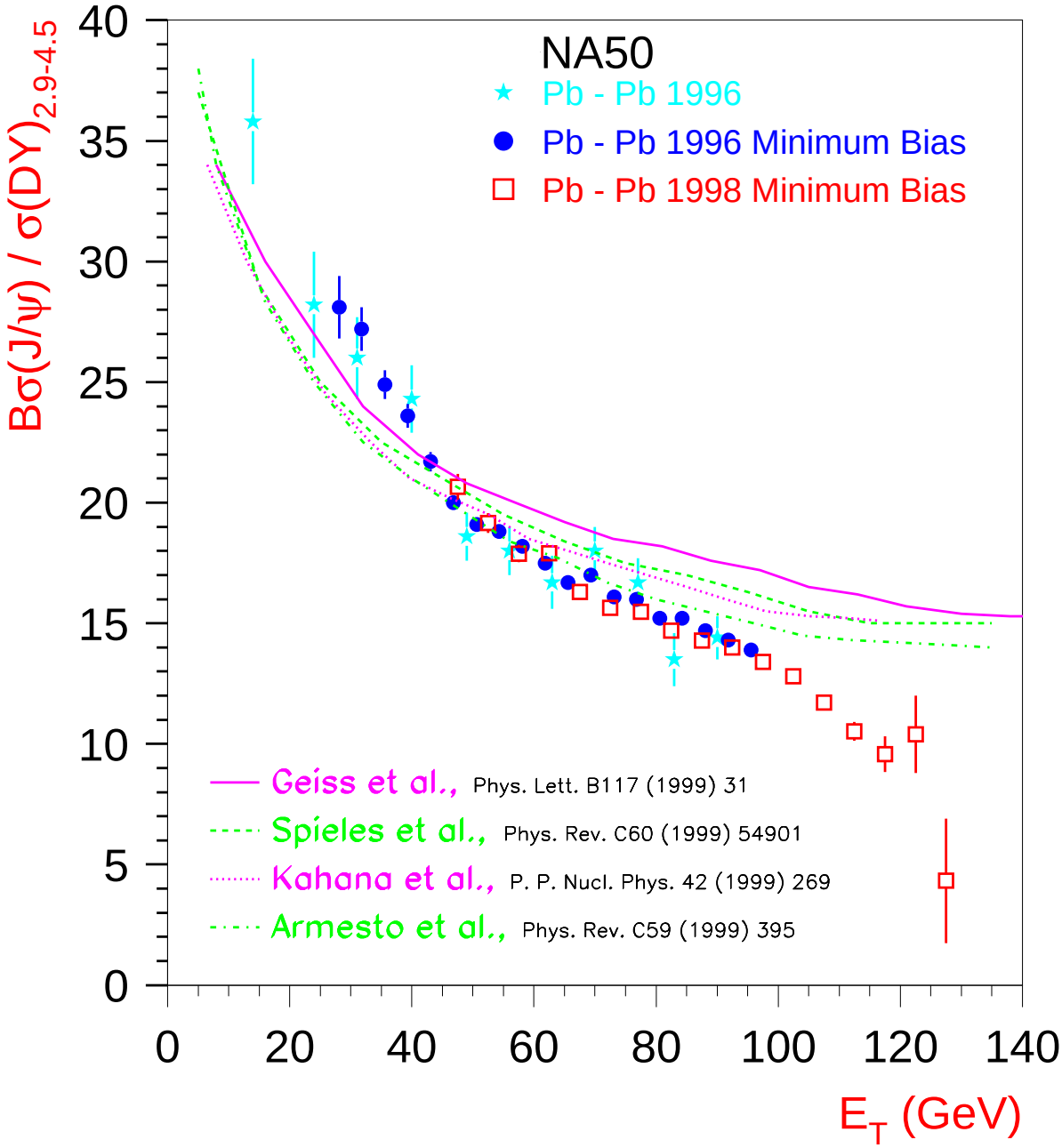


Solid line and Expected: Absorption Model as obtained from fit to light systems (p-A and S-U)

Observation of the 2 discontinuities in ψ suppression

ψ/DY as a function of E_T

Comparision with conventional (hadronic) models

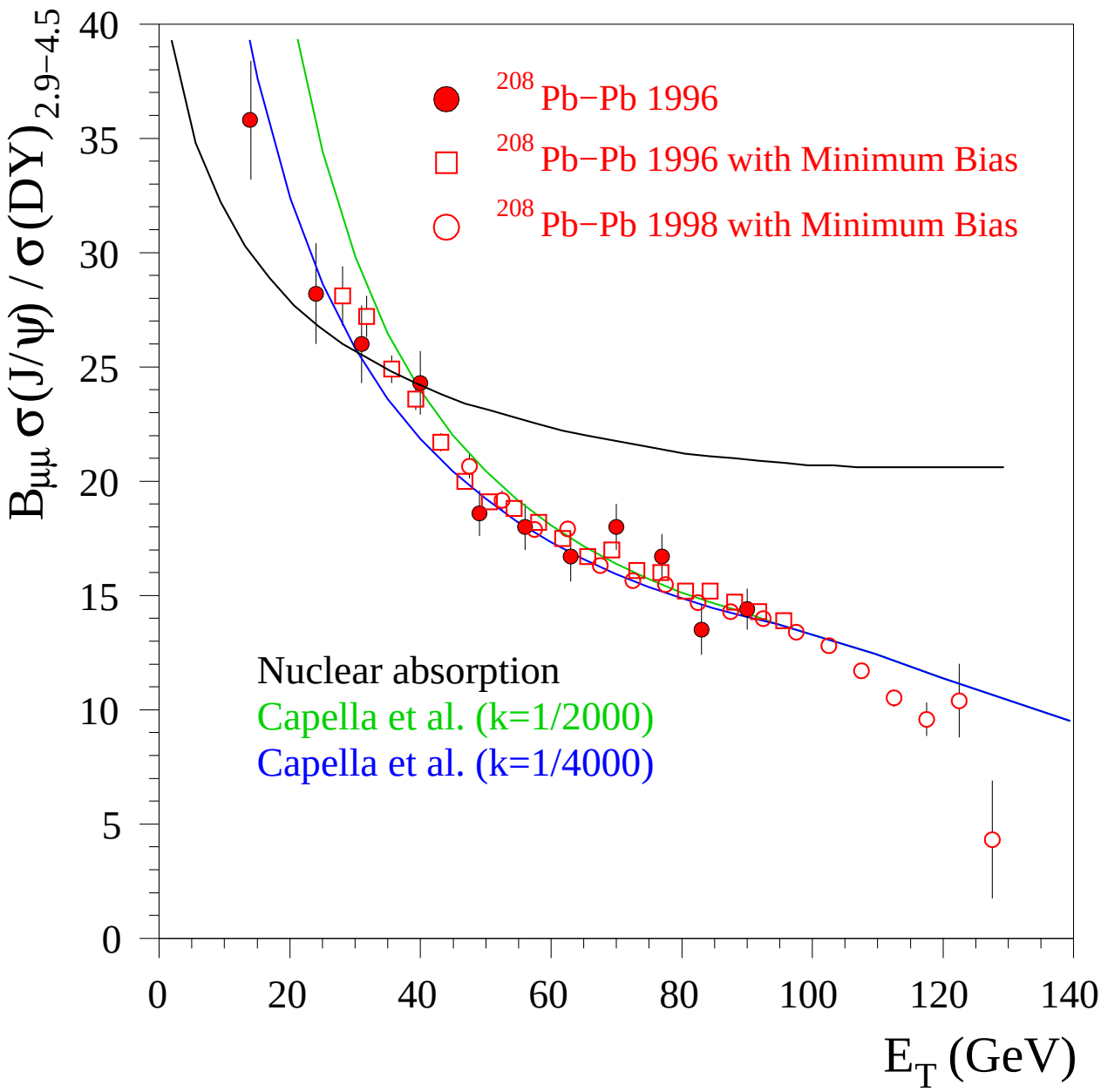


The stepwise suppression pattern rules out any of these conventional models

ψ/DY as a function of E_T

Comparision with modified Capella's hadronic model (E_T fluctuations included)

(Phys. Rev. Lett. 85 (2000) 2080)

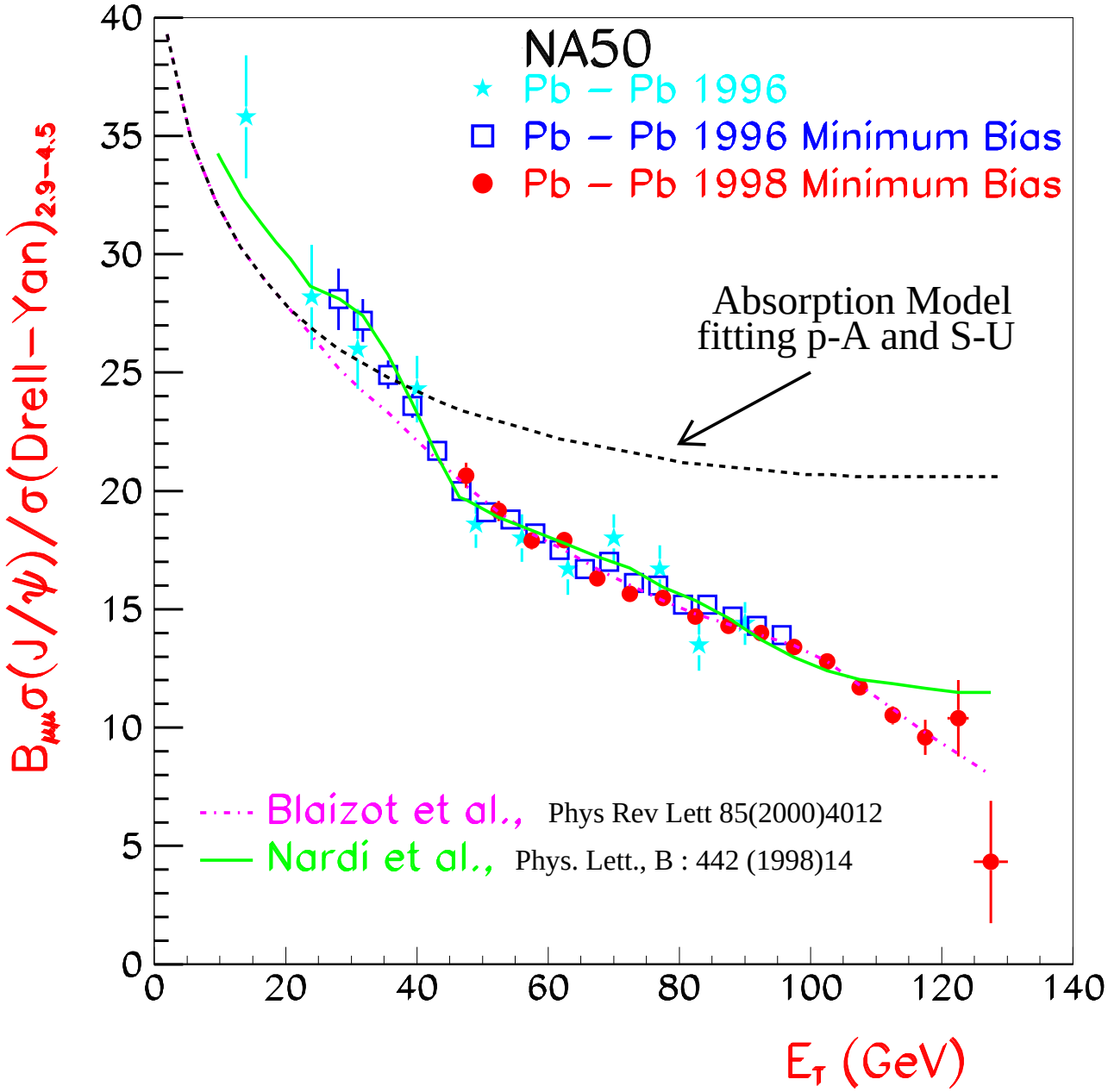


The model does not describe:

- ▷ **the normal absorption as observed in p-A and S-U interactions (black line)**
- ▷ **the steady decrease for central Pb-Pb collisions**

ψ/DY as a function of E_T

Comparision with models assuming QGP



Magenta line: with gradual J/ψ suppression and E_T fluctuations

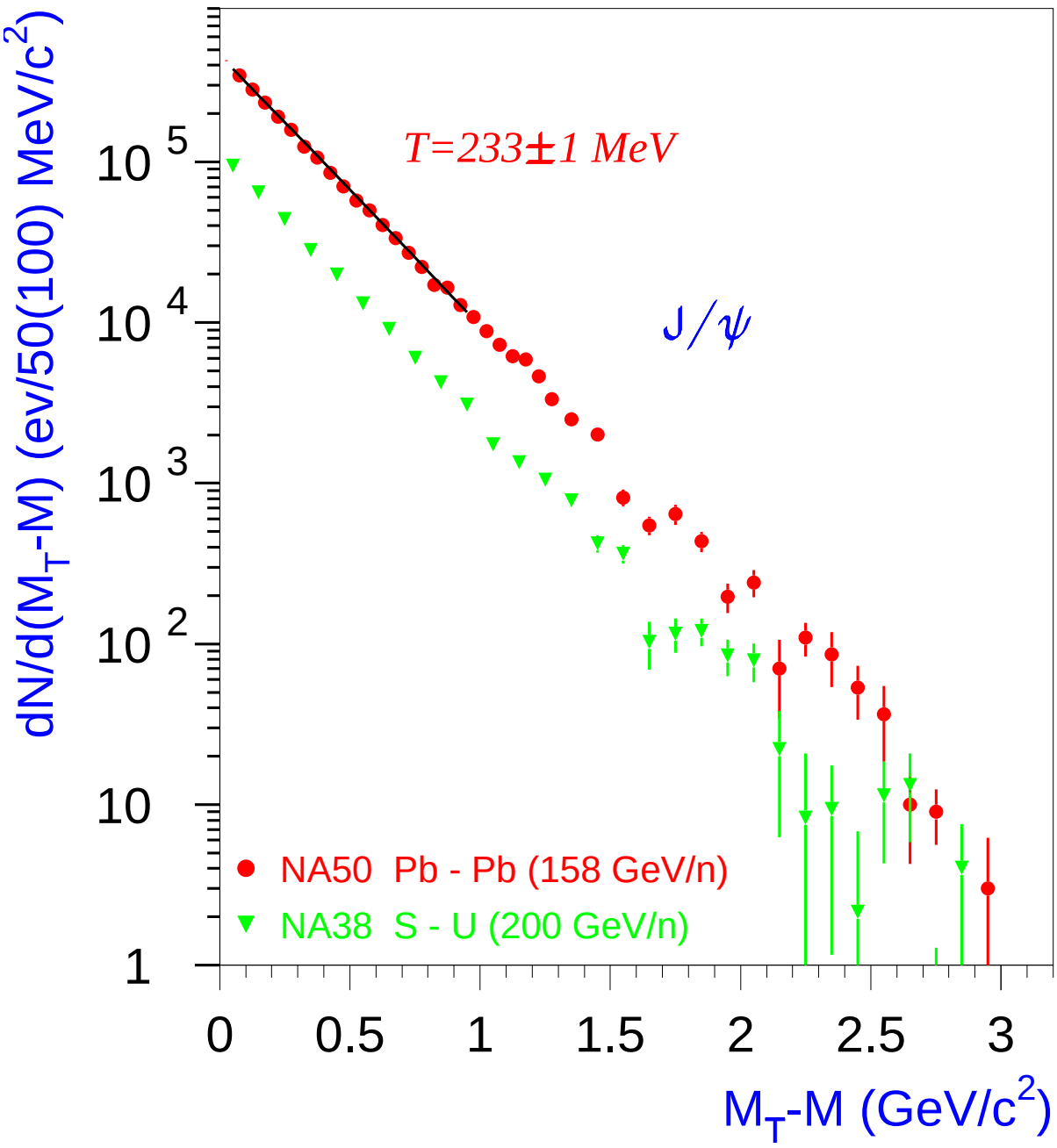
Green line: with two thresholds, corresponding to the χ and the J/ψ melting points, but no E_T fluctuations

Quark and Gluon Deconfinement

with 2 melting points plus E_T fluctuations

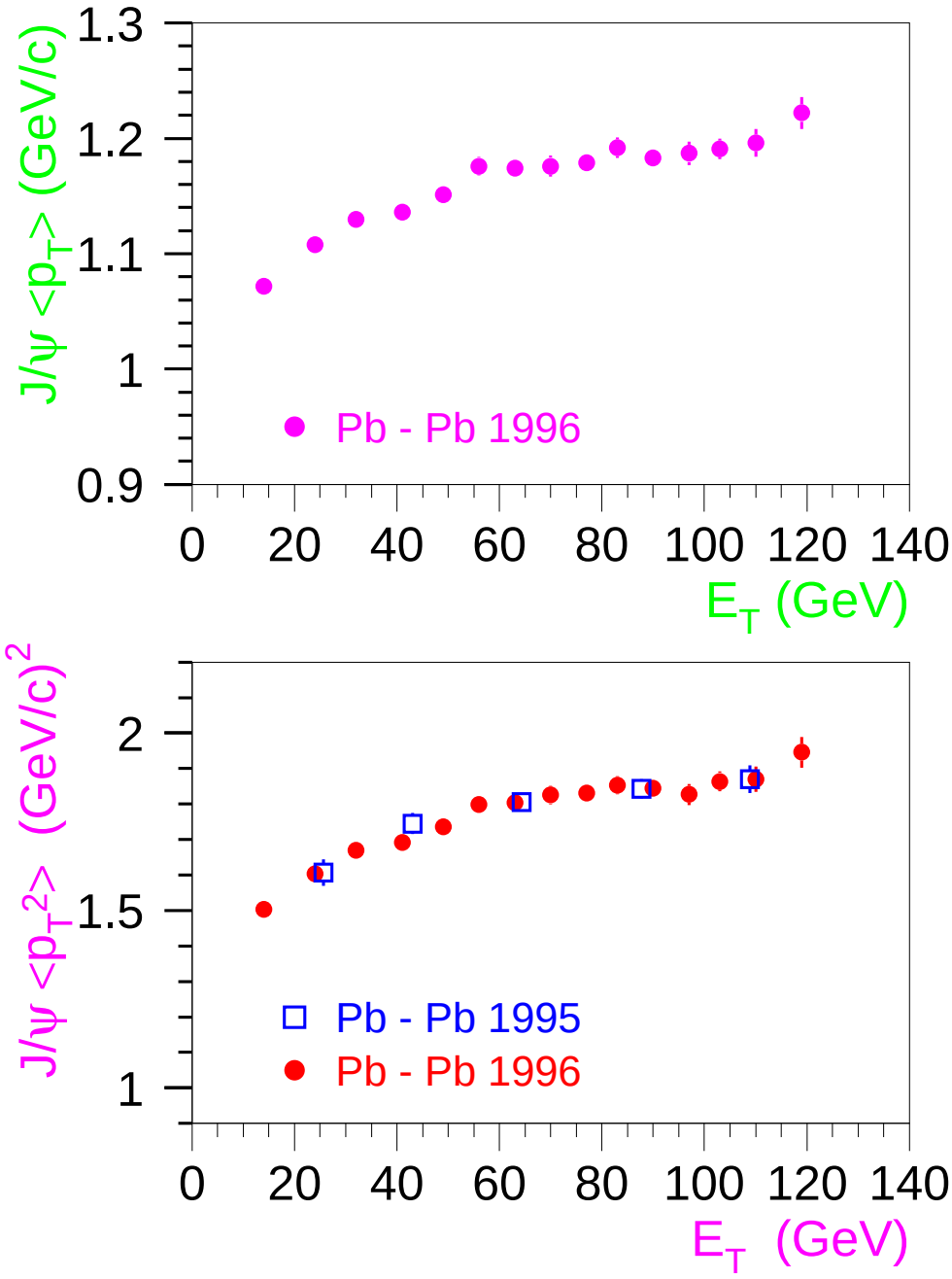
seem necessary to describe the data

ψ Transverse Mass Distribution



Solid line: Fit with modified Bessel Function gives an inverse slope parameter $T = 233 \pm 1\ MeV$ for Pb-Pb collisions at 158 GeV/nucleon

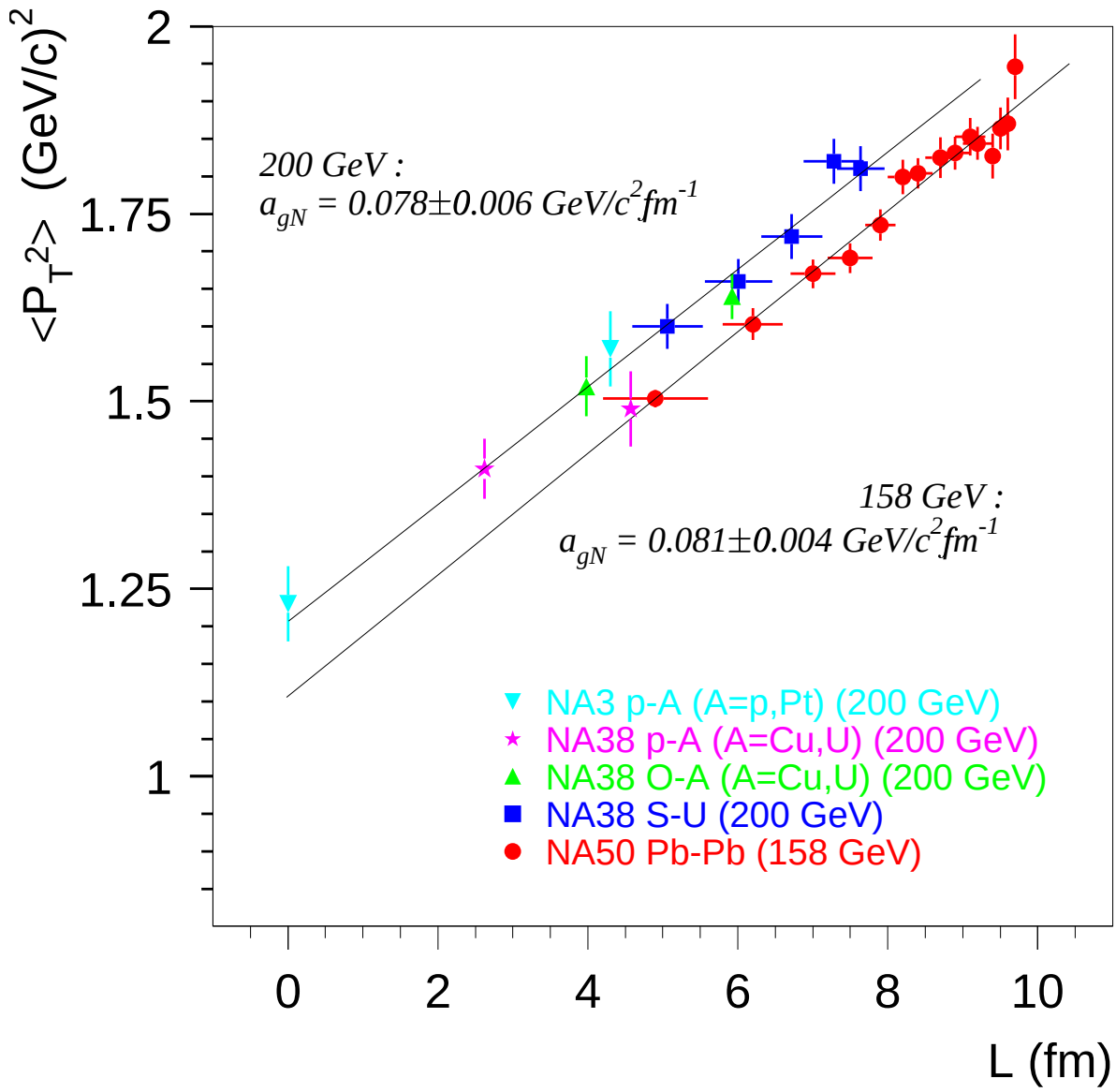
$\langle p_{\mathrm{T}} \rangle_\psi$ and $\langle p_{\mathrm{T}}^2 \rangle_\psi$ as a function of E_T



Both $\langle p_{\mathrm{T}} \rangle$ and $\langle p_{\mathrm{T}}^2 \rangle$ show an increase followed by a saturation

$\langle p_{\rm T}^2 \rangle_\psi$ as a function of L

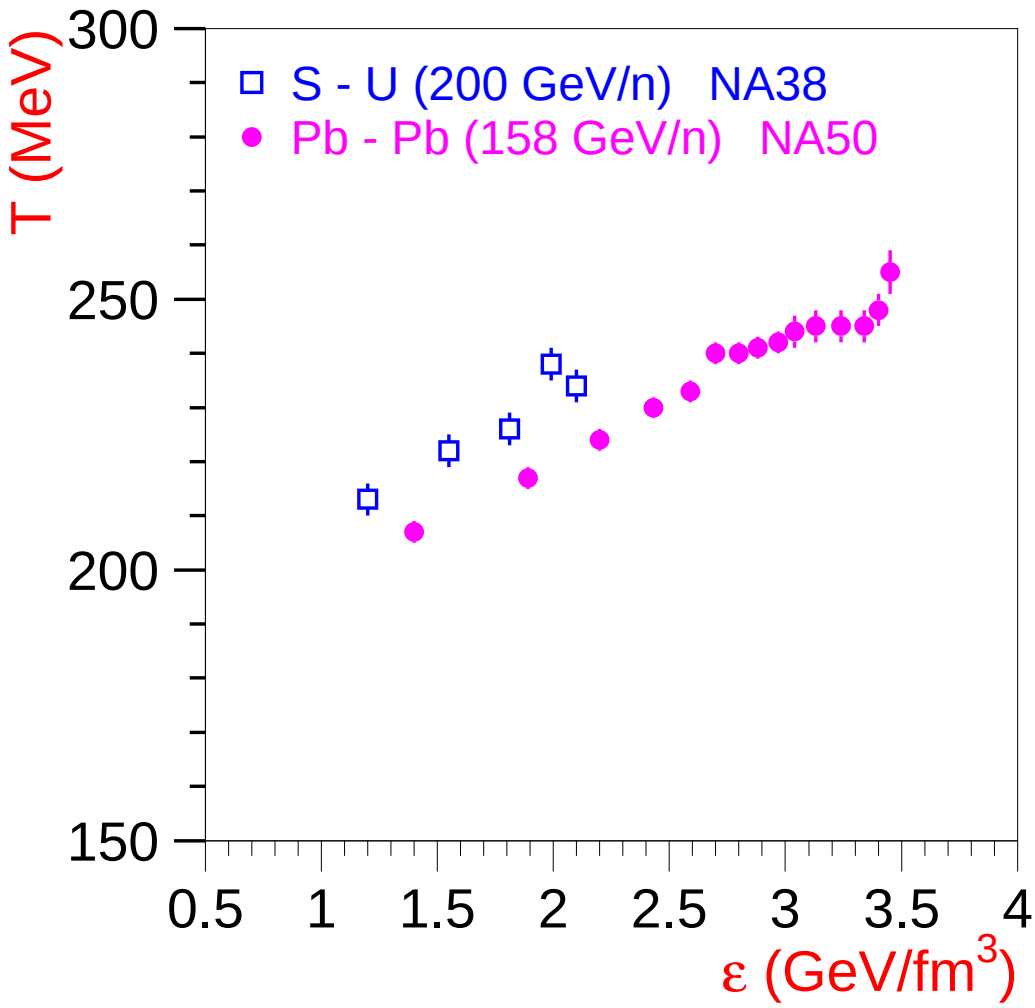
Study of the initial state interactions effect: $\langle p_{\rm T}^2 \rangle$ as a function of L, the geometric length of matter crossed by the $c\bar{c}$ state



- **Fits according to: $\langle p_{\rm T}^2 \rangle (E_{\rm T}) = \langle p_{\rm T}^2 \rangle_{pp} + a_{gN}\ L(E_{\rm T})$ give compatible slopes for proton, Sulfur and Lead induced reactions. Fit with common slope: $a_{gN} = 0.080 \pm 0.003\ GeV^2/c^2 fm^{-1}$ with $\chi^2/ndf = 0.65$**

- **$\langle p_{\rm T}^2 \rangle$ depends on the beam energy**

T_ψ as a function of ϵ

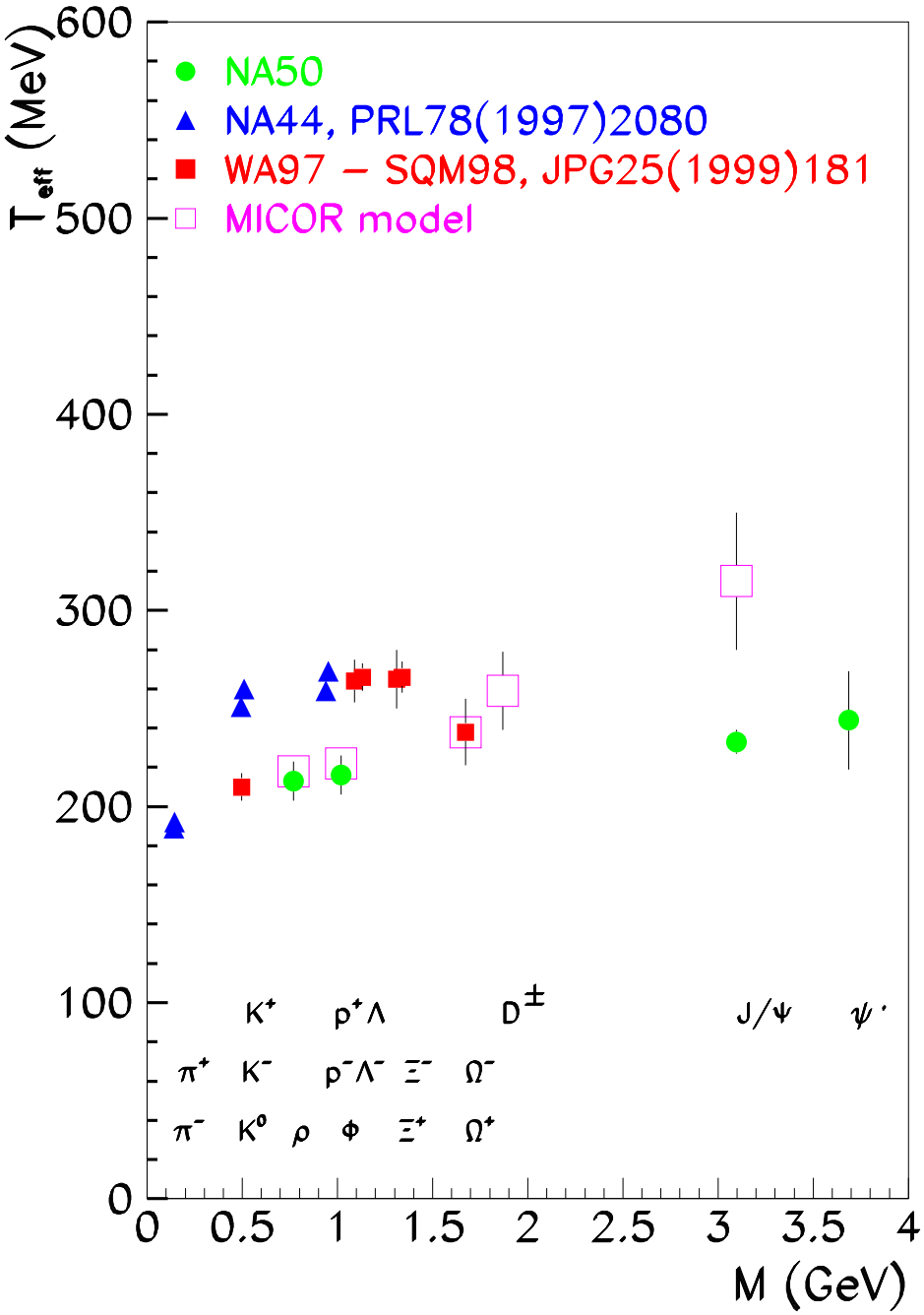


The inverse slope parameter T for Pb-Pb as a function of energy density shows an increase, followed by a saturation and a final increase(?)

The T parameter depends also on beam energy

T as a function of Particle Mass

Determining T parameter by fitting $d\sigma_{\rm part}/dM_T$ distributions with $M_T^{3/2} exp(-M_T/T)$

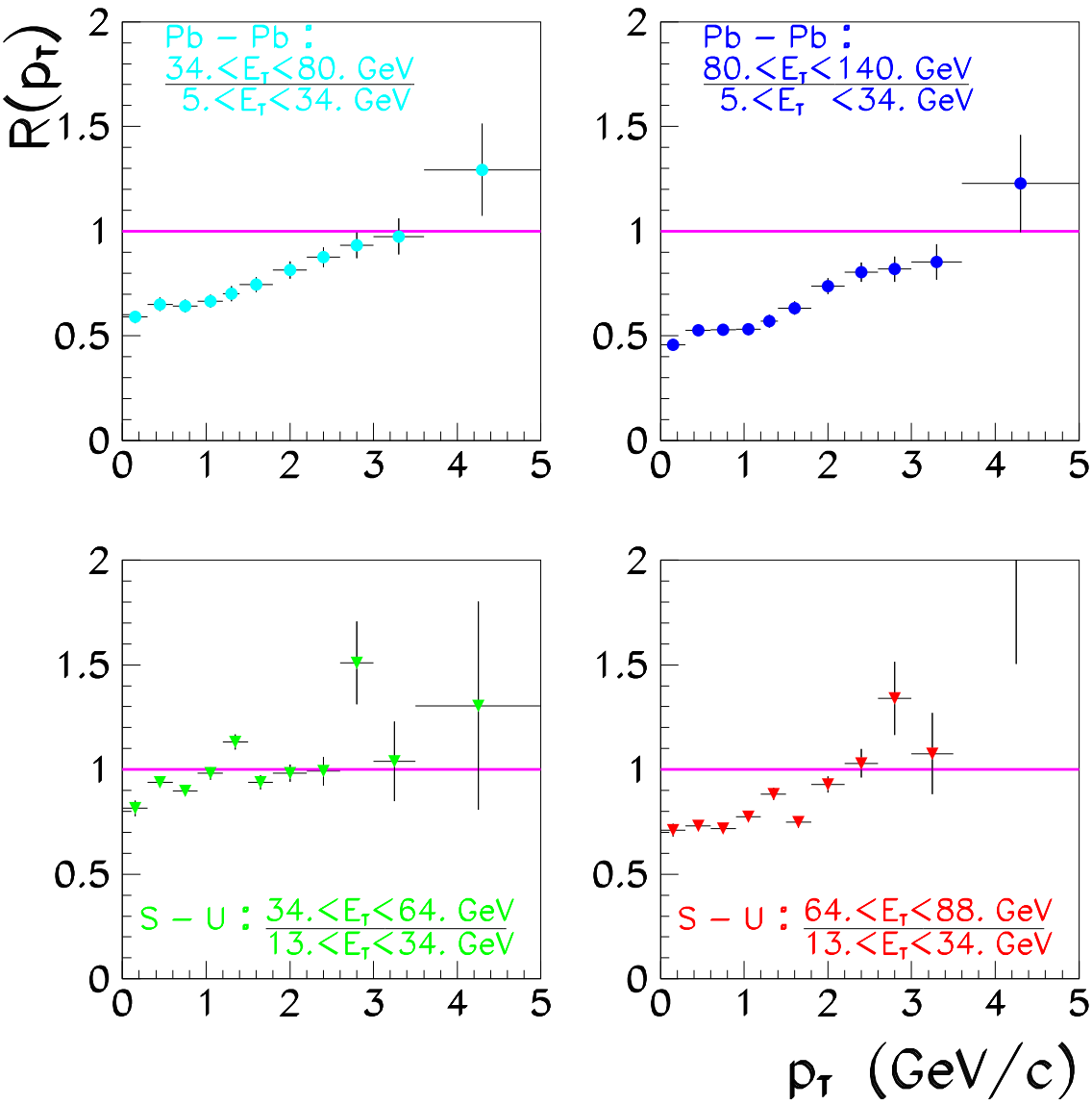


The rise of T with Particle Mass is smoother than the expected

Ratio $R(p_{\mathrm{T}})$

$R(p_{\mathrm{T}})$ **is the ratio of** ψ p_{T} **distributions for a given** E_{T} **region with respect to the lowest** E_{T} **region, normalized to the ratio of the corresponding** DY **events:**

$$R(p_{\mathrm{T}}) \equiv \frac{\frac{dN_\psi}{dp_{\mathrm{T}}}/N_{\mathrm{DY}} \quad (high\ E_{\mathrm{T}})}{\frac{dN_\psi}{dp_{\mathrm{T}}}/N_{\mathrm{DY}} \quad (low\ \ E_{\mathrm{T}})}$$



In Pb-Pb central collisions $R(p_{\mathrm{T}})$ **seems to saturate at high** p_{T}

Conclusions

J/ψ Suppression:

- **Different analyses (E_T, MB, ZDC) agree with the observed stepwise pattern of the anomalous J/ψ suppression: a drop of about 20% and an inflexion point followed by a steady steep decrease**
- **This can be interpreted by successive melting of charmonium bound states (χ, J/ψ) as predicted by Quark-Gluon Deconfinement**

J/ψ Transverse Distributions:

- **J/ψ is more suppressed at low p_T**
- **p_T distributions of formed J/ψ studied as a function of centrality show a rise followed by a saturation**
- **In Pb-Pb central collisions the ratio $R(p_T)$ seems to saturate at high p_T**