Transverse momentum distributions of J/ψ produced in Pb−Pb and p−A interactions at the CERN SPS

NA50 Collaboration

N.Topilskaia − INR, Moscow

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NA50 Collaboration

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Outline

J/ψ transverse momentum distributions:

- dN/dp_T distributions and $\langle p_T^2 \rangle$ as a function of E_T
- $\langle p_T^2 \rangle$ as a function of L :

  beam energy dependence of $\langle p_T^2 \rangle$ parameters

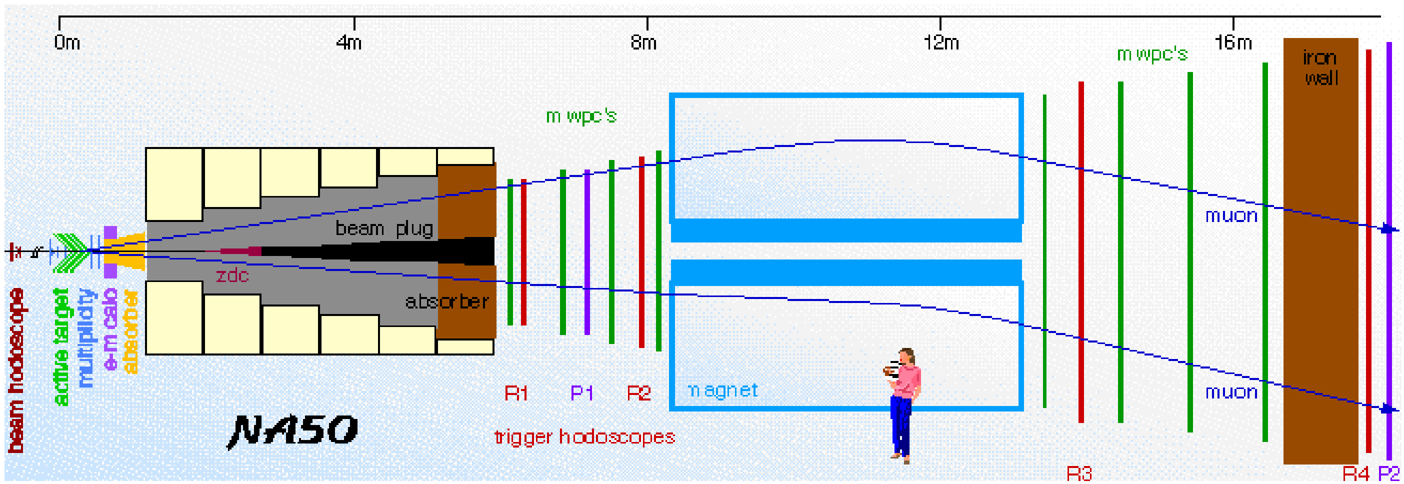
J/ψ transverse mass distributions:

- dN/dM_T distributions and T as a function of E_T
- T as a function of energy density :

  beam energy dependence of T parameters

T as a function of particle mass

Experimental Setup



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

- **Dimuon spectrometer :**
  - $2.92 < y_{lab} < 3.92$
  - $|\cos\theta_{CS}| < 0.5$
- **Centrality detectors :**
  - EM calorimeter $(1.1 < \eta_{lab} < 2.3)$
  - ZDC calorimeter $(\eta_{lab} > 6.3)$
  - Multiplicity detector $(1.5 < \eta_{lab} < 3.5)$

Pb−Pb 158 Gev/c (1995, 1996, 2000)

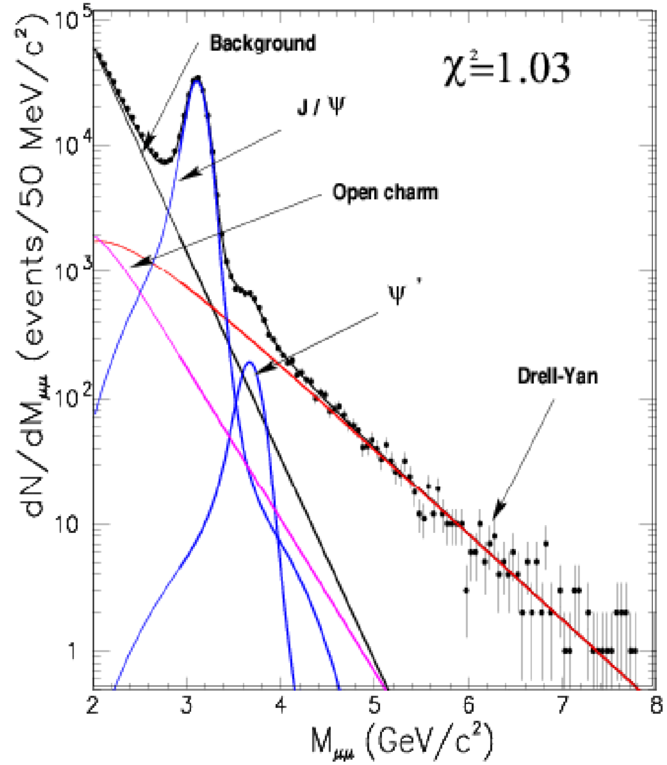
Data period	Subtargets	Number of J/ψ
1995	7	50000
1996	7	190000
2000	1 in vacuum	110000

p − A 400 Gev/c (2000)

Target	Number of J/ψ
Be	40000
Al	50000
Cu	47000
W	51000
Pb	71000

Fit to the mass spectrum

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

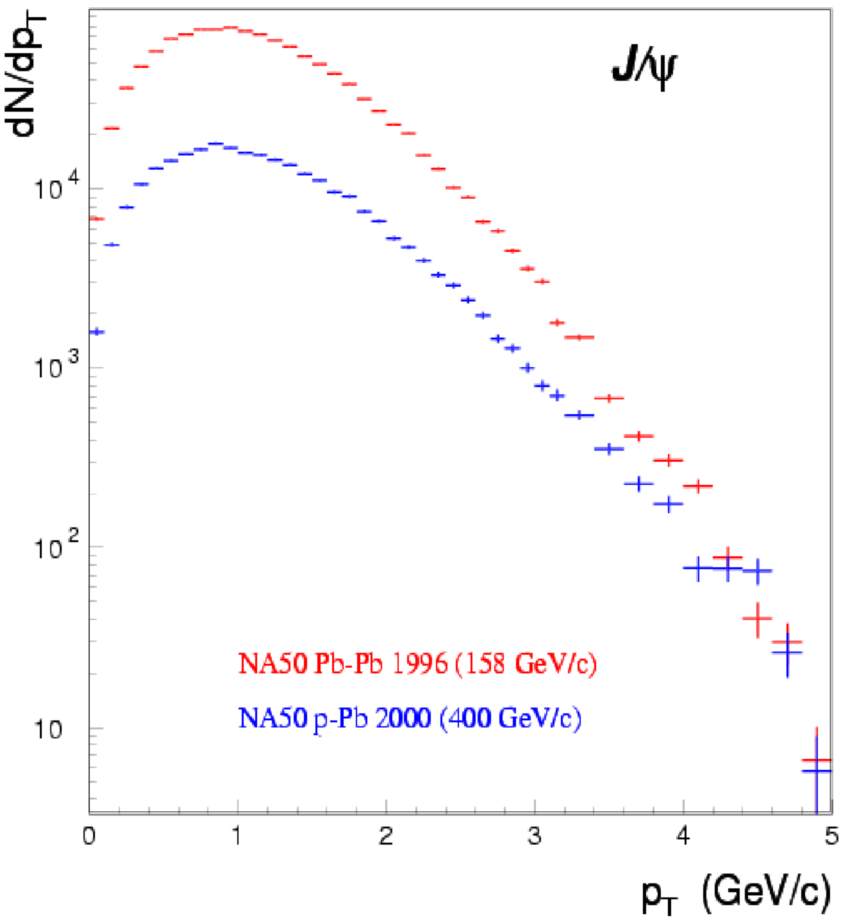


For p_T calculations J/ψ − events in the (2.7−3.5) GeV/c^2 (1995−1996) or (2.9−3.3) GeV/c^2 (1996−2000) mass region

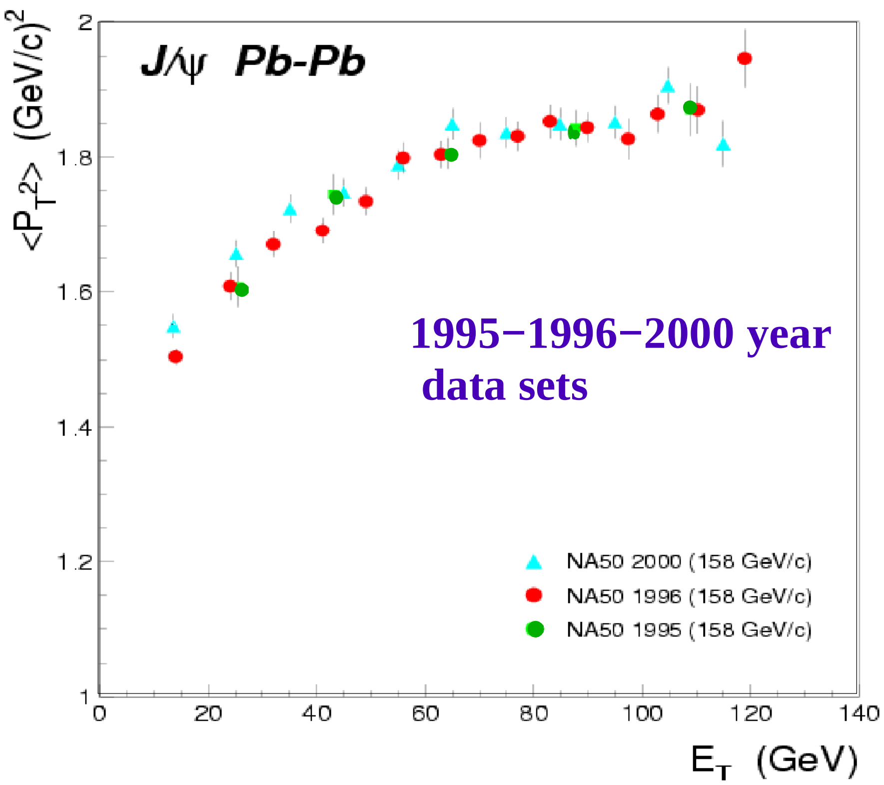
Number of continuum contribution from the mass fit is less 8%(3%), is mainly DY

Correction of the J/ψ transverse momentum distributions for the continuum p_T contribution is made

J/ψ transverse momentum distribution

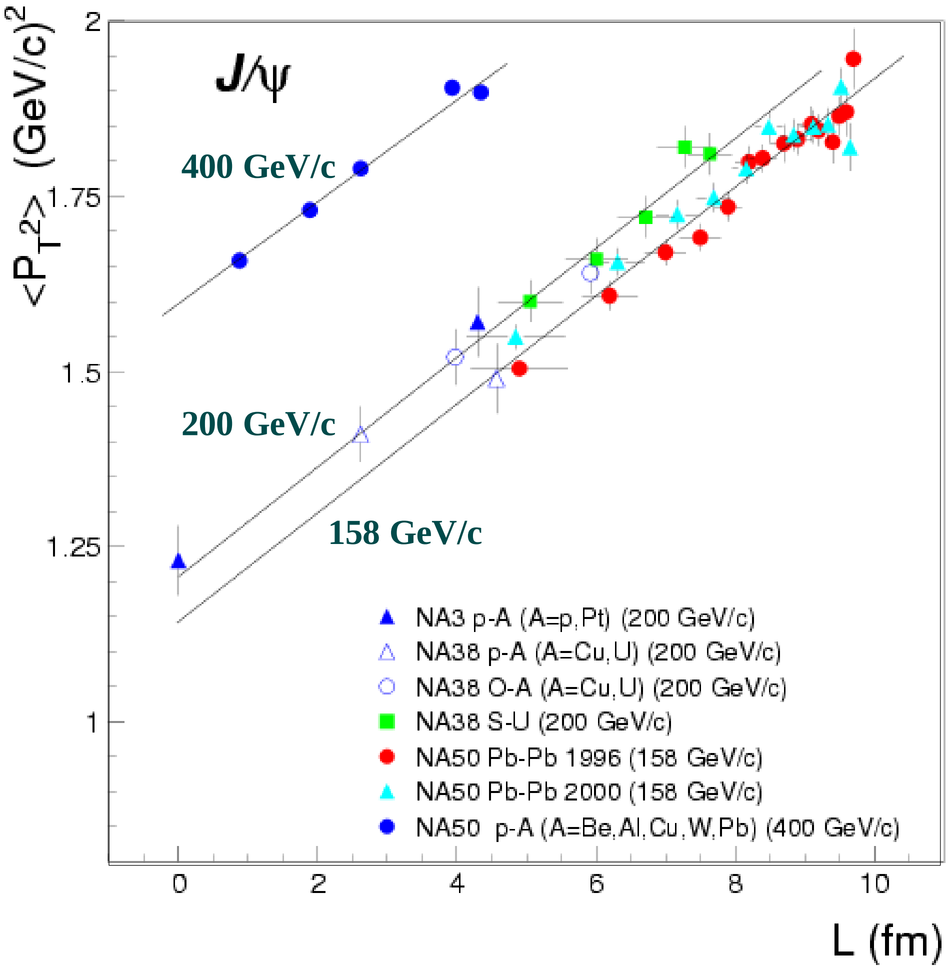


$\langle p_T^2 \rangle$ as a function of transverse energy



For the Pb−Pb collisions $\langle p_T^2 \rangle$ shows an increase followed by a saturation for the central events

$\langle p_T^2 \rangle_{J/\psi}$ as a function of L (1)



L − geometric length of matter crossed by the $c\bar{c}g$ state.

Fit according to:

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

158 GeV/c: $\alpha_{gN} = 0.078 \pm 0.003$ **GeV²/c²fm⁻¹** $\tilde{\chi}^2 = 1.22$

200 GeV/c: $\alpha_{gN} = 0.078 \pm 0.006$ **GeV²/c²fm⁻¹** $\tilde{\chi}^2 = 0.76$

400 GeV/c: $\alpha_{gN} = 0.073 \pm 0.004$ **GeV²/c²fm⁻¹** $\tilde{\chi}^2 = 1.91$

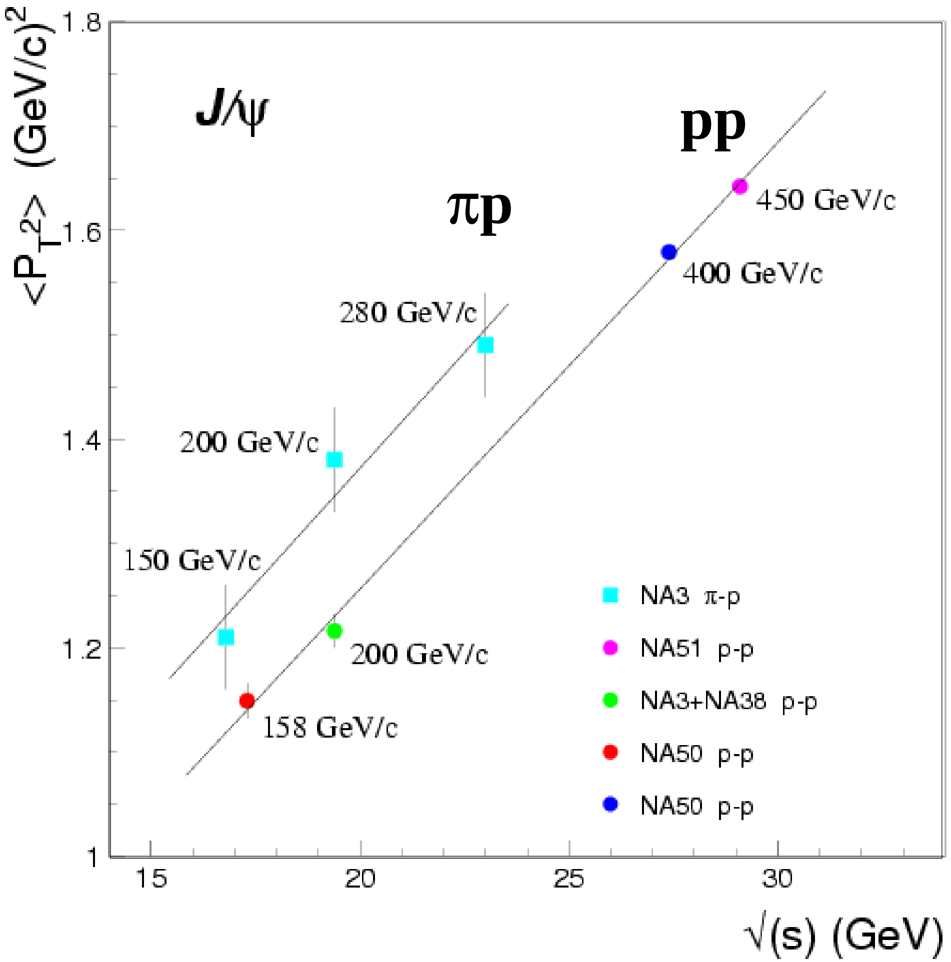
Fit with a common slope:

$\alpha_{gN} = 0.077 \pm 0.002$ **GeV²/c²fm⁻¹** $\tilde{\chi}^2 = 3.43$

In the SPS energy range: α_{gN} − **has weak or no beam energy dependence**

$\langle p_T^2 \rangle_{pp}$ − **depends on beam energy**

Energy dependence of $\langle p_T^2 \rangle_{pp}$



$\langle p_T^2 \rangle_{pp}$ as a function of $\sqrt{s}$

Fit according to:

$$\langle p_T^2 \rangle_{pp} = a + b*\sqrt{s}$$

$a = 0.40 \pm 0.04$ GeV^2/c^2 $\quad$ **$\tilde{\chi}^2 = 0.96$**

$b = 0.043 \pm 0.002$ GeV/c^2

is compatible with

$\langle p_T^2 \rangle_{\pi p}$ behaviour measured by NA3

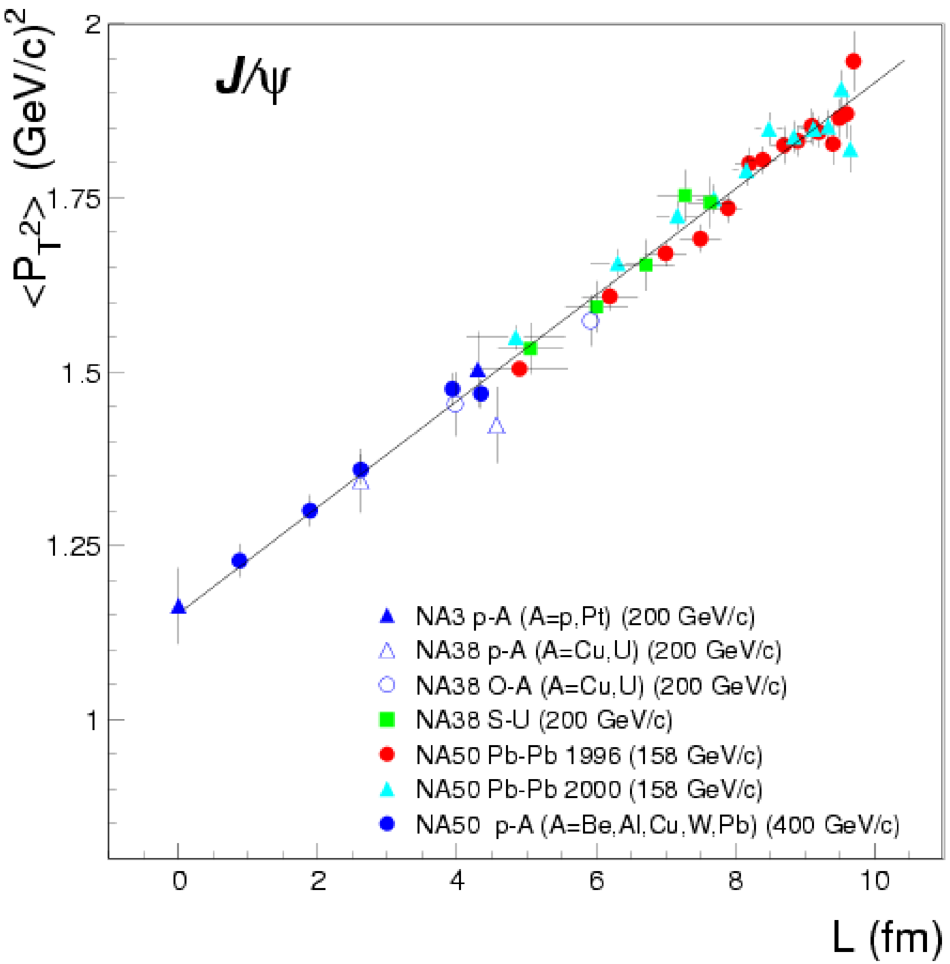
$$\langle p_T^2 \rangle_{\pi p} = a + b*\sqrt{s}$$

$a = 0.44 \pm 0.23$ GeV^2/c^2 $\quad$ **$\tilde{\chi}^2 = 0.78$**

$b = 0.047 \pm 0.012$ GeV/c^2

In the SPS energy range the $\langle p_T^2 \rangle_{pp}$ grows linearly as a function of $\sqrt{s}$, total energy in the NN center of mass

$\langle p_T^2 \rangle_{J/\psi}$ as a function of L (2)



NA3 + NA38 (200 GeV/c) +
NA50 (400 GeV/c)
are rescaled to 158 GeV/c

Fit according to:

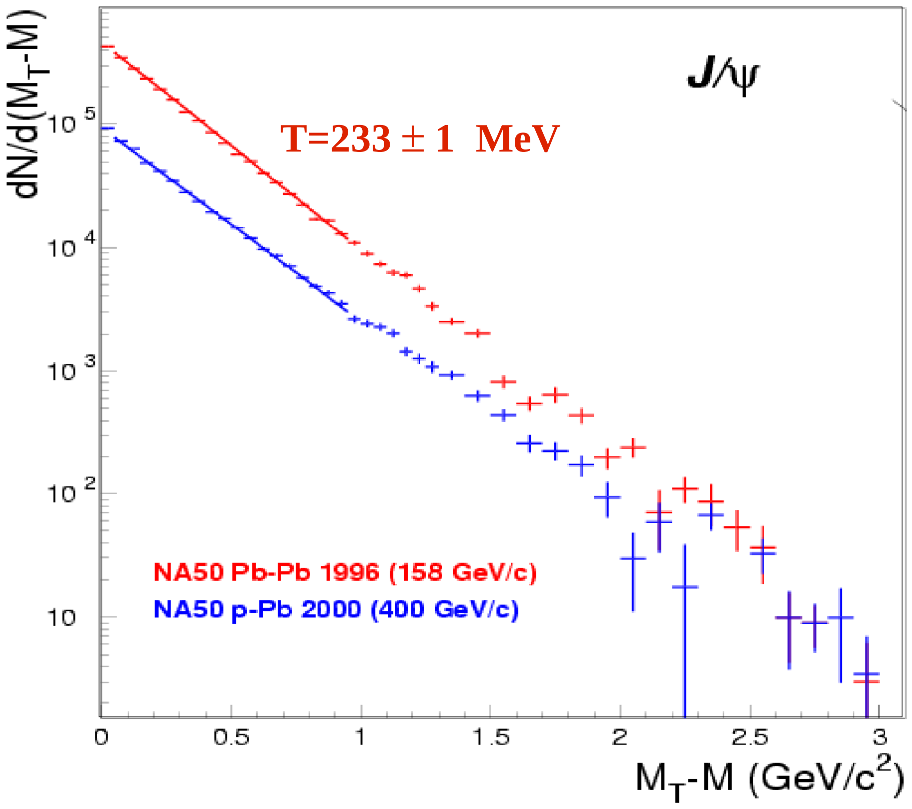
$$\langle p_T^2 \rangle(L) = \langle p_T^2 \rangle_{pp} + \alpha_{gN} \cdot L$$

$\langle p_T^2 \rangle_{pp} = 1.15 \pm 0.02$ GeV^2/c^2 $\tilde{\chi}^2 = 0.91$

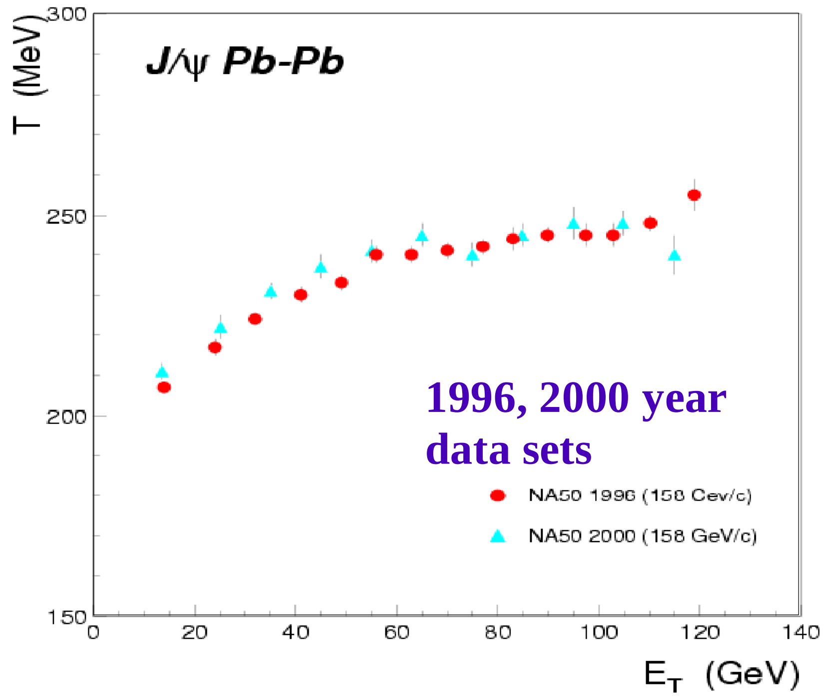
$\alpha_{gN} = 0.076 \pm 0.002$ GeV^2/c^{2}fm^{-1}

The observed dependence could simply result from parton initial state multiple scattering

J/ψ transverse mass distribution



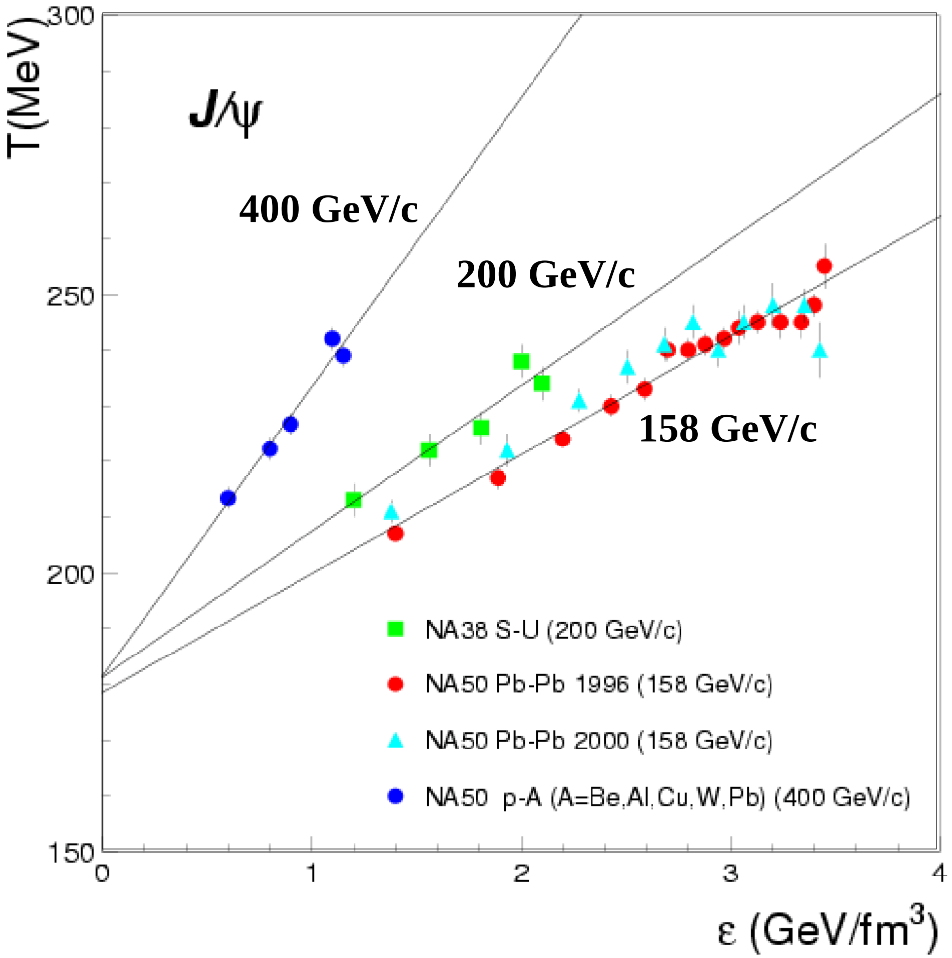
$T_{J/\psi}$ as a function of transverse energy



Fit M_T distribution with a modified Bessel Function $M_T^2K_1(M_T/T)$ gives inverse slope parameter T − effective temperature of the system in thermal models

The inverse slope parameter T shows an increase followed by saturation for the central events. The T behaviour is similar $<p_T^2>$ as a function of E_T

$T_{J/\psi}$ as a function of ε (1)



ε− energy density reached in the collision

Fit with a linear function:

$T_{J/\psi}(\varepsilon) = T(\varepsilon=0) + Tslope * \varepsilon$

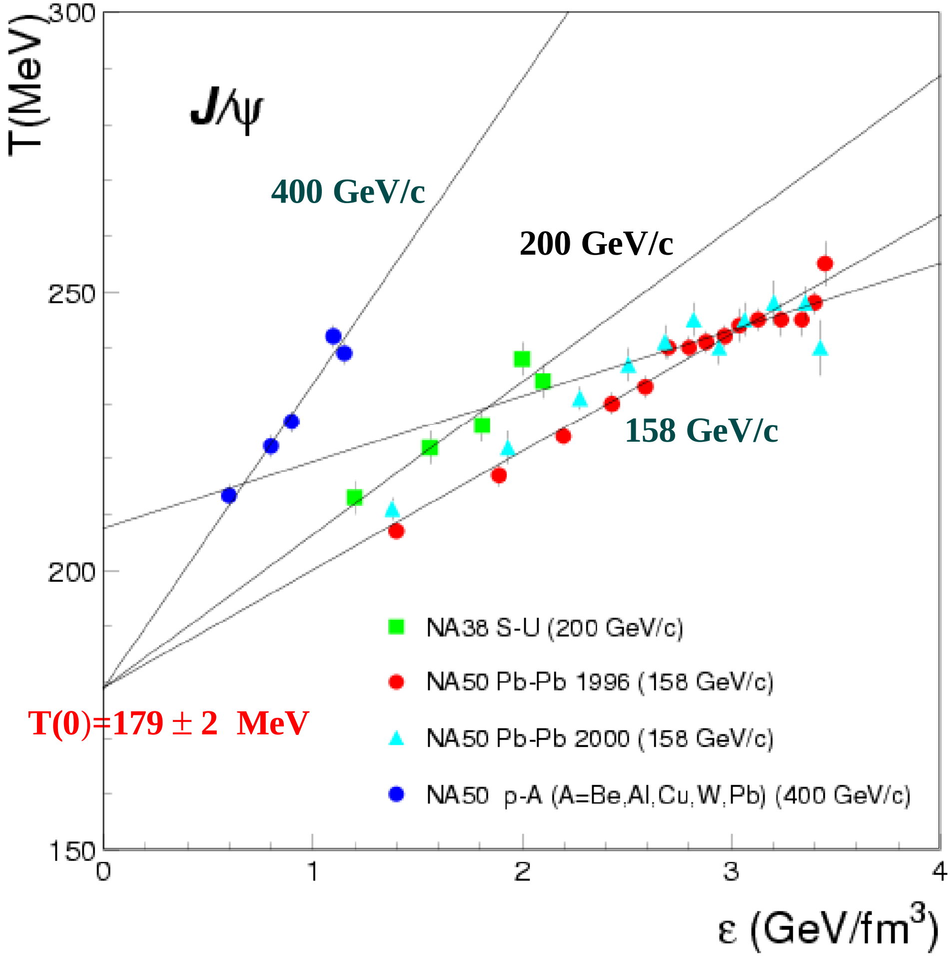
gives compatible initial $T(\varepsilon=0)$ values for 3 data sets.

158 GeV/c: $T(\varepsilon=0) = 178 \pm 2$ MeV
200 GeV/c: $T(\varepsilon=0) = 181 \pm 7$ MeV
400 GeV/c: $T(\varepsilon=0) = 181 \pm 4$ MeV

Tslope depends on beam energy

For all colliding systems $T_{J/\psi}$ grows as a function of energy density

$T_{J/\psi}$ as a function of ε (2)



Fitting with a common initial value for 3 data sets gives

$T(\varepsilon=0) = 179 \pm 2$ MeV
and beam energy dependent Tslope

158 GeV/c: Tslope = $(21 \pm 1) \cdot 10^{-3}$ fm^3
200 GeV/c: Tslope = $(27 \pm 1) \cdot 10^{-3}$ fm^3
400 GeV/c: Tslope = $(55 \pm 2) \cdot 10^{-3}$ fm^3

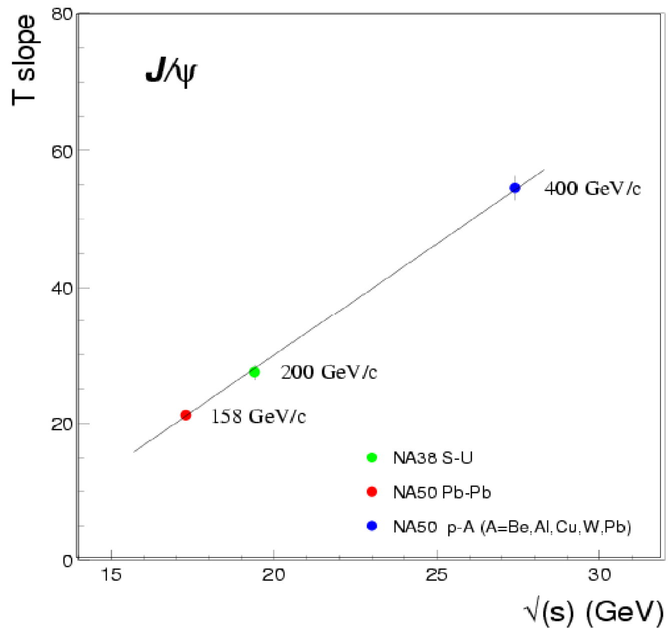
For central Pb−Pb collisions

158 GeV/c: Tslope = $(12 \pm 3) \cdot 10^{-3}$ fm^3

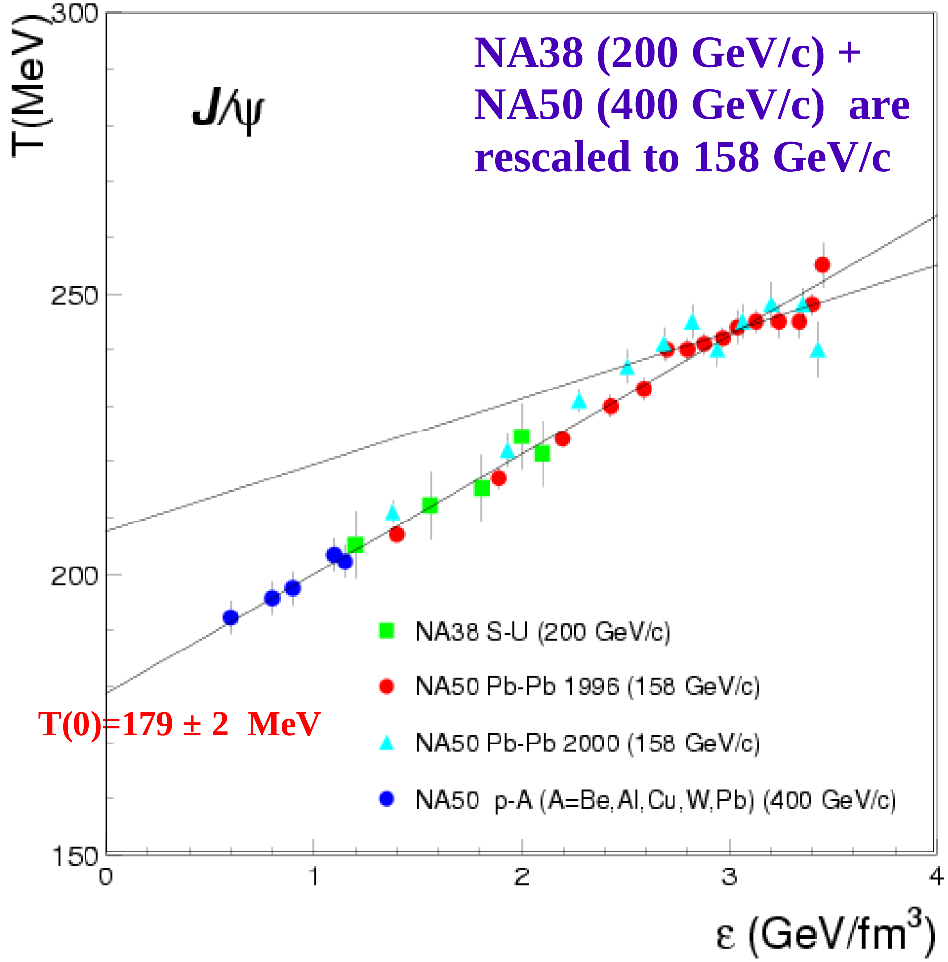
The behaviour is quit similar for all colliding systems except for the most central Pb−Pb collisions

$T_{J/\psi}$ as a function of ε (3)

Tslope energy dependence



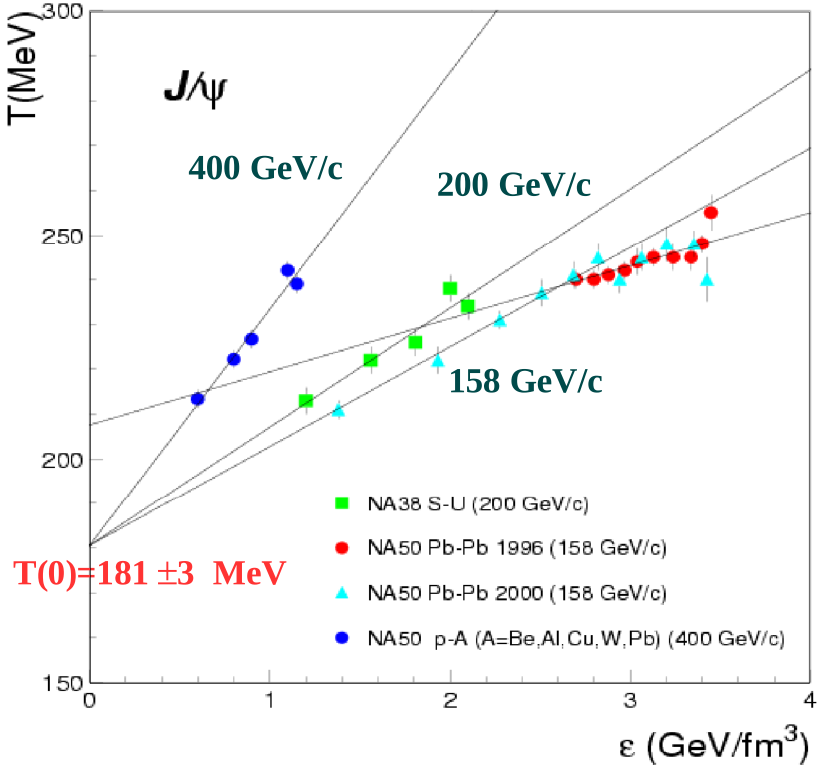
Tslope grows linearly as a function of $\sqrt{s}$

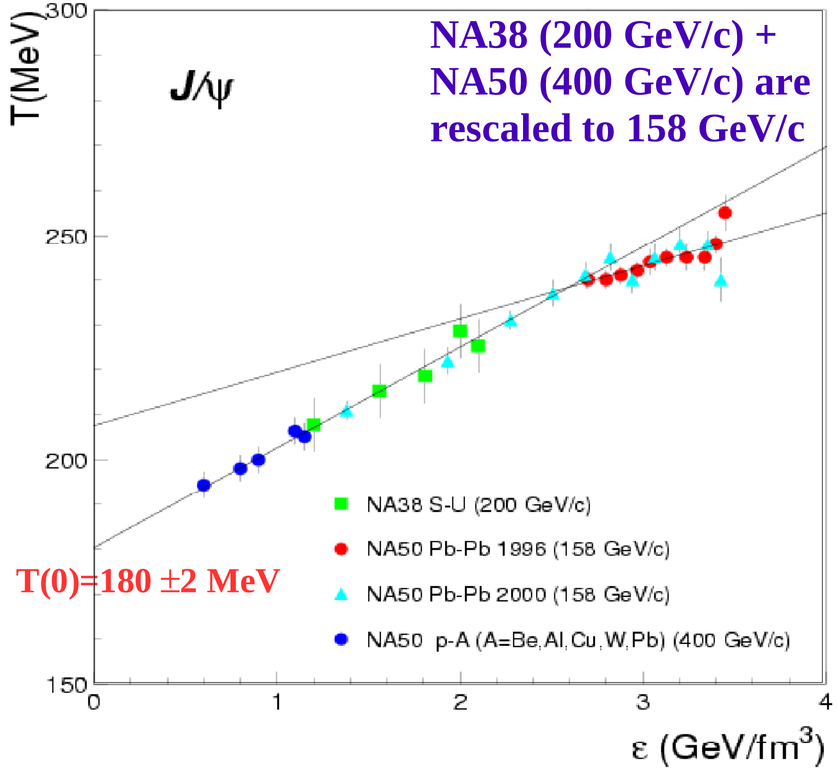


The behaviour is quit similar for all the colliding systems. For the most central Pb−Pb collisions more flat energy dependence could be seen.

$T_{J/\psi}$ as a function of ε (4)

For Pb−Pb 158 GeV/c data set only peripheral Pb−Pb 2000 year data were used for fitting with common initial $T(\varepsilon=0)$ value





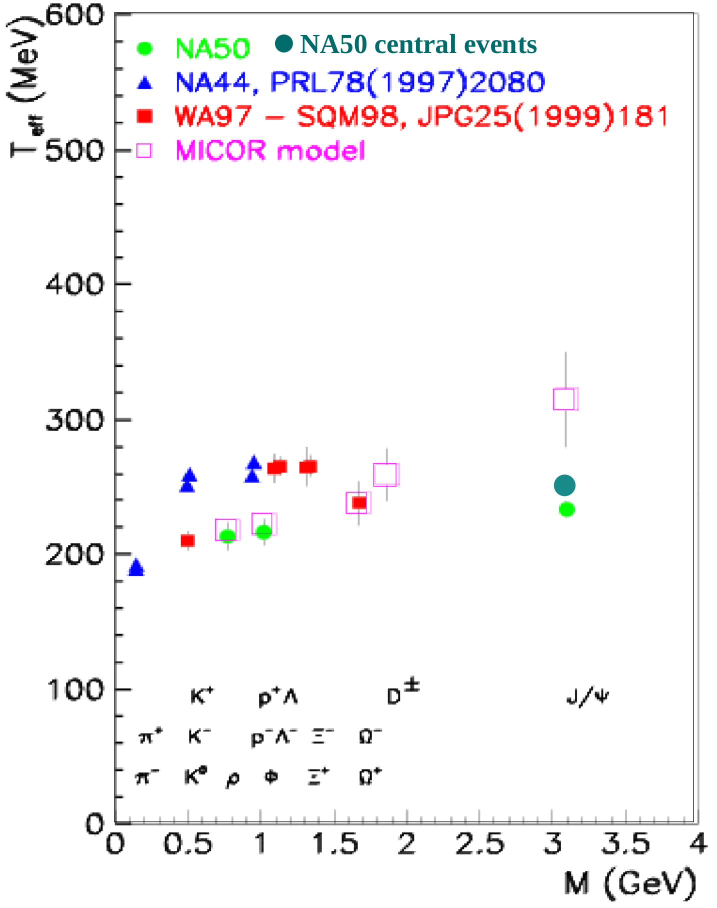
Tslope = $(22 \pm 1) \cdot 10^{-3}\,\mathrm{fm}^3$ $\quad \tilde{\chi}^2 = 1.06$

Tslope(central Pb−Pb) = $(12 \pm 3) \cdot 10^{-3}\,\mathrm{fm}^3$ $\quad \tilde{\chi}^2 = 0.68$

In the SPS energy range for all colliding systems $T_{J/\psi}$ grows linearly with the energy density.

For the most central Pb−Pb collisions more flat behaviour could be seen.

T as a function of particle mass



T for J/ψ– NA50, PRL B499(2001)85

Inverse slope parameter T obtained by fitting M_T distributions with $M_T^{3/2}\exp(-M_T/T)$ function

$T = T_{f-o} + 2/\pi\, M \langle v_T^{f-o}\rangle^2$ K.Bugaev et al.(PLB 523(2001) 255)

For J/ψ experimental T value is smaller than expected on the base of

pion freese–out

H.Appelshauser et al., NA49 Coll.,Eur.Phys.J.C2(1998)661

$T_{f-o}(\pi)$ = 120 ± 12 MeV, $\langle v_T^{f-o}\rangle = 0.5 \pm 0.12$

and MICOR model

P.Csizmadia, P.Levai, Phys.Rev. C61 (2000)031903

$T^H(J/\psi) = 175 \pm 10$ MeV, $\langle v_T^H\rangle = 0.19 \pm 0.05$

Conclusions

J/ψ transverse momentum distributions:

- For all colliding systems $\langle p_T^2 \rangle$ grows linearly as a function of L .
- The observed dependence of $\langle p_T^2 \rangle$ as a function of centrality could result from parton initial state multiple scattering.

J/ψ transverse mass distributions:

- The inverse slope T grows linearly as a function of energy density.
- All colliding systems have the same initial T value at $\varepsilon=0$.
- For the central Pb−Pb collisions a more flat ε dependence could be seen.

T as a function of particle mass :

- For the J/ψ effective temperature T is smaller than expected.