Study of deconfinement in NA50

NA50 Collaboration

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NA50 COLLABORATION

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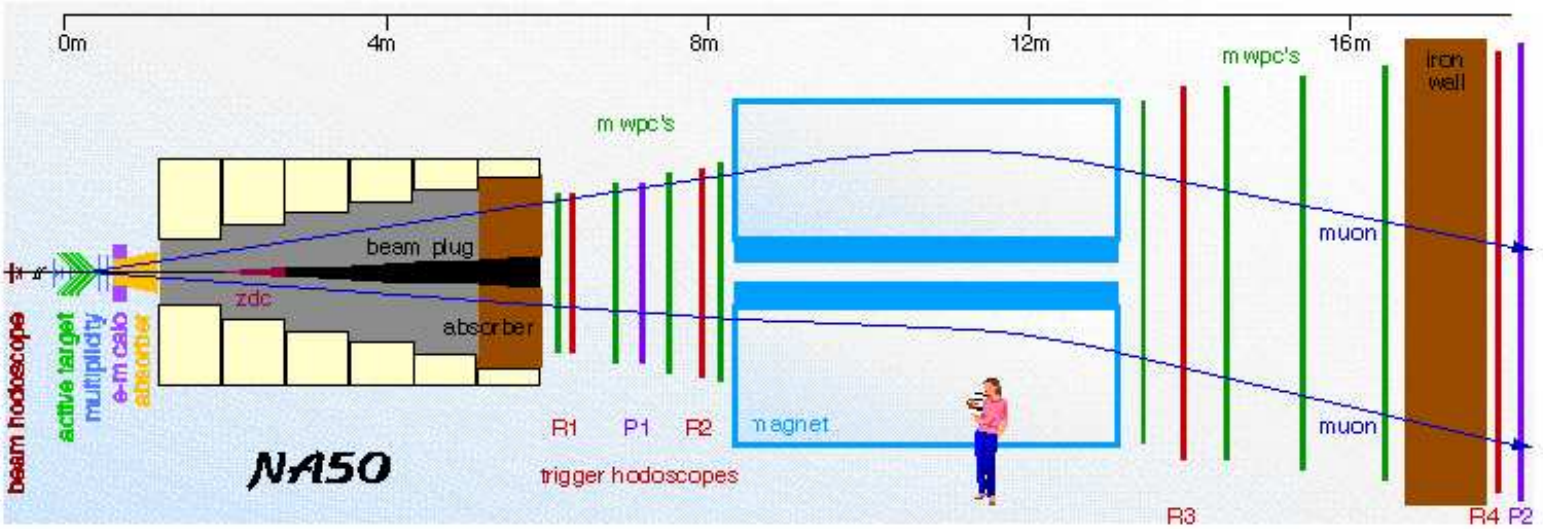
Outline

QGP Probe: J/ψ Suppression

- **Baseline: J/ψ production in light systems**
  - **New proton data (p - Be, Al, Cu, Ag, W)**
  - **p-p, p-d (NA51) and S-U (NA38)**
- **Study of $J/\psi/DY$ as a function of:**
  - **L** – **path length of $c\bar{c}g$ through nuclear matter**
  - E_T – **neutral transverse energy**
  - ϵ – **energy density**
- **Other J/ψ analyses**
  - **Minimum Bias analysis**
  - **ZDC analysis**
- **Comparison with models**
  - **Hadronic models**
  - **QGP formation models**
- **Summary**

Experimental Setup



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

- **Dimuon spectrometer:**

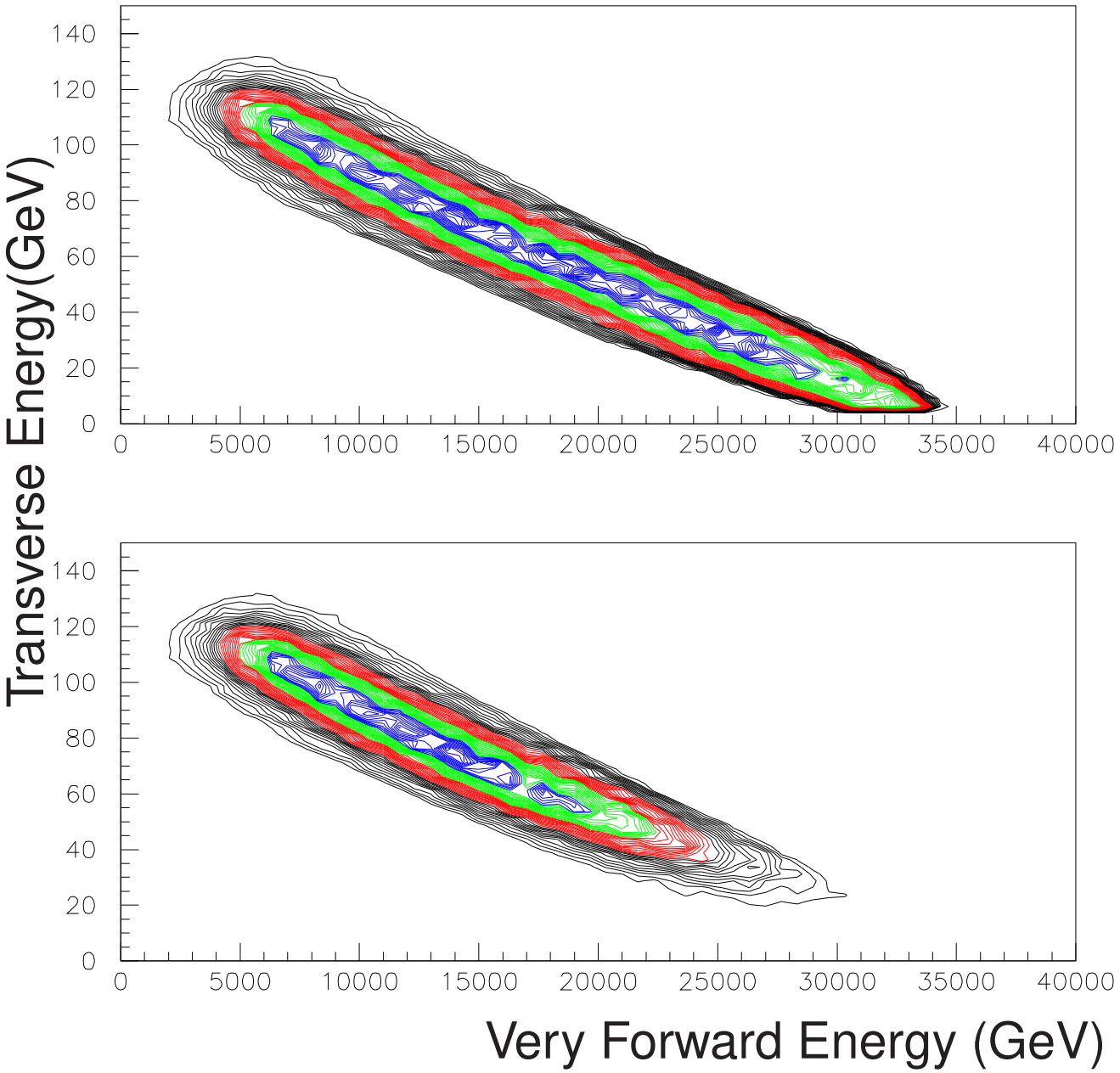
$0 < y_{CM} < 1 \quad (2.92 < y_{Lab} < 3.92) \quad |\cos\theta_{CS}| < 0.5$

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 $(1.9 < \eta_{lab} < 4.1)$

Identification of Pb-Pb interactions

Pb – Pb 1996



Contour cut on the E_T - E_{ZDC} correlation:

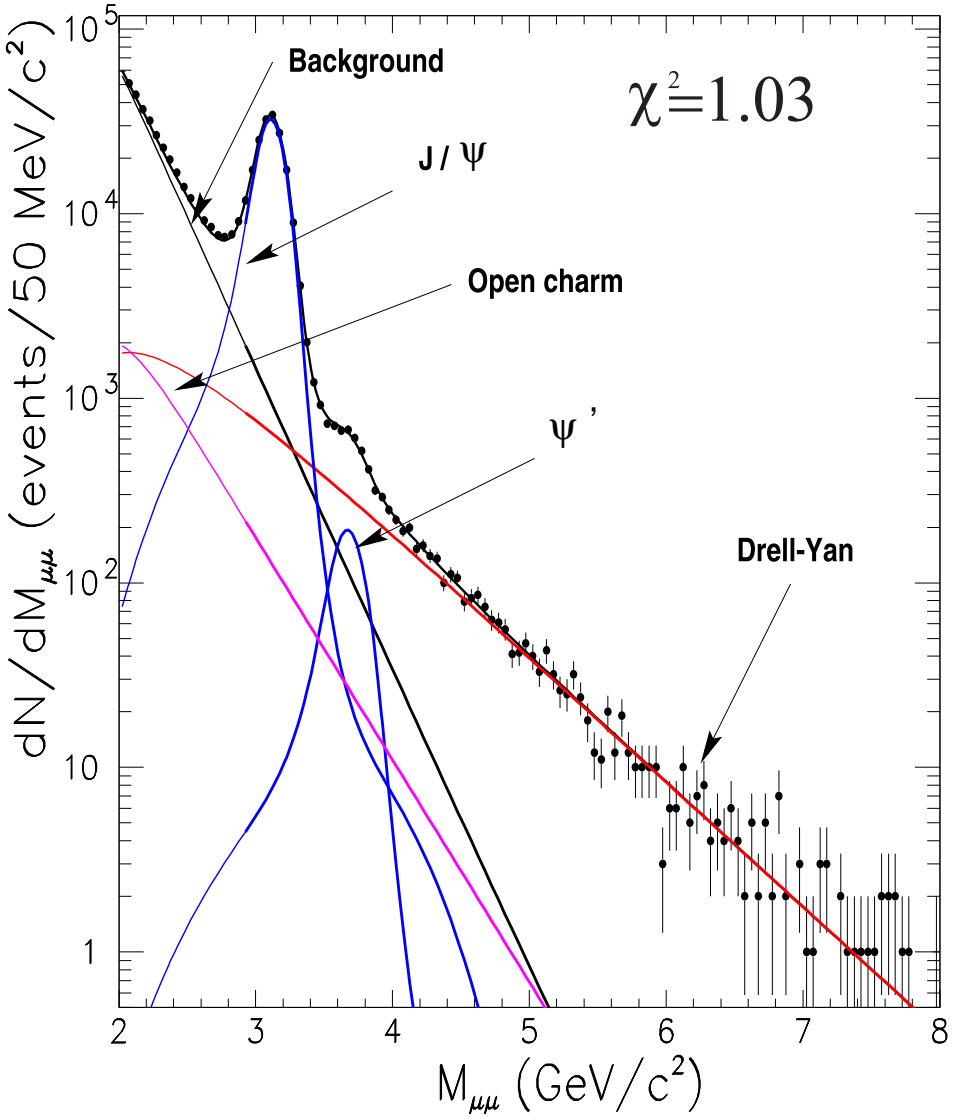
statistics increased for peripheral events

Target Algorithm:

based on quartz blade Čerenkov counters

Fit to the mass spectrum

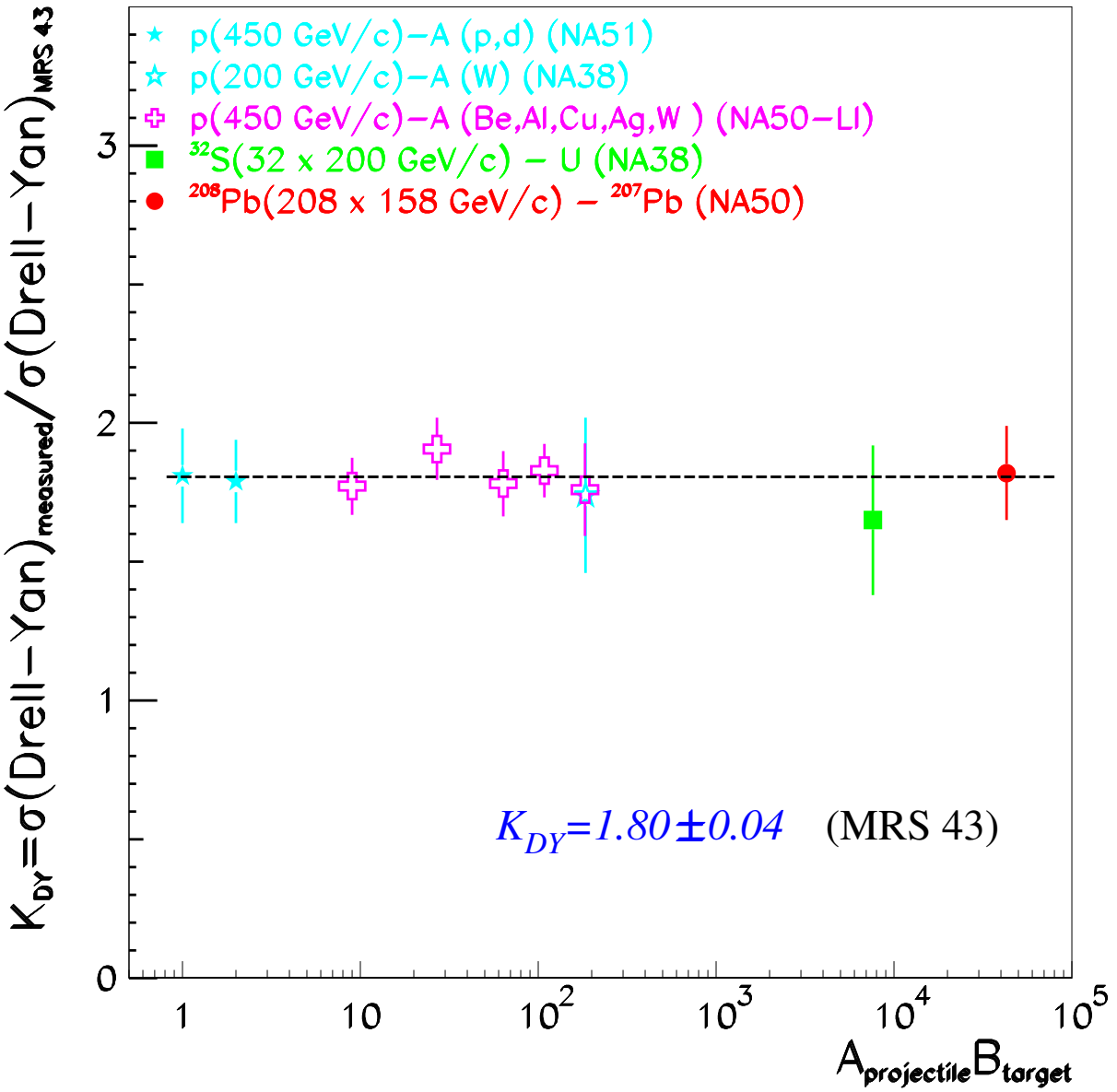
$$\frac{dN}{dM} = A_{J/\psi}\frac{dN_{J/\psi}}{dM} + A_{\psi'}\frac{dN_{\psi'}}{dM} + A_{DY}\frac{dN_{DY}}{dM} + \frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$



• 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 plus reconstruction chain

Drell-Yan: Experimental K factor



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

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

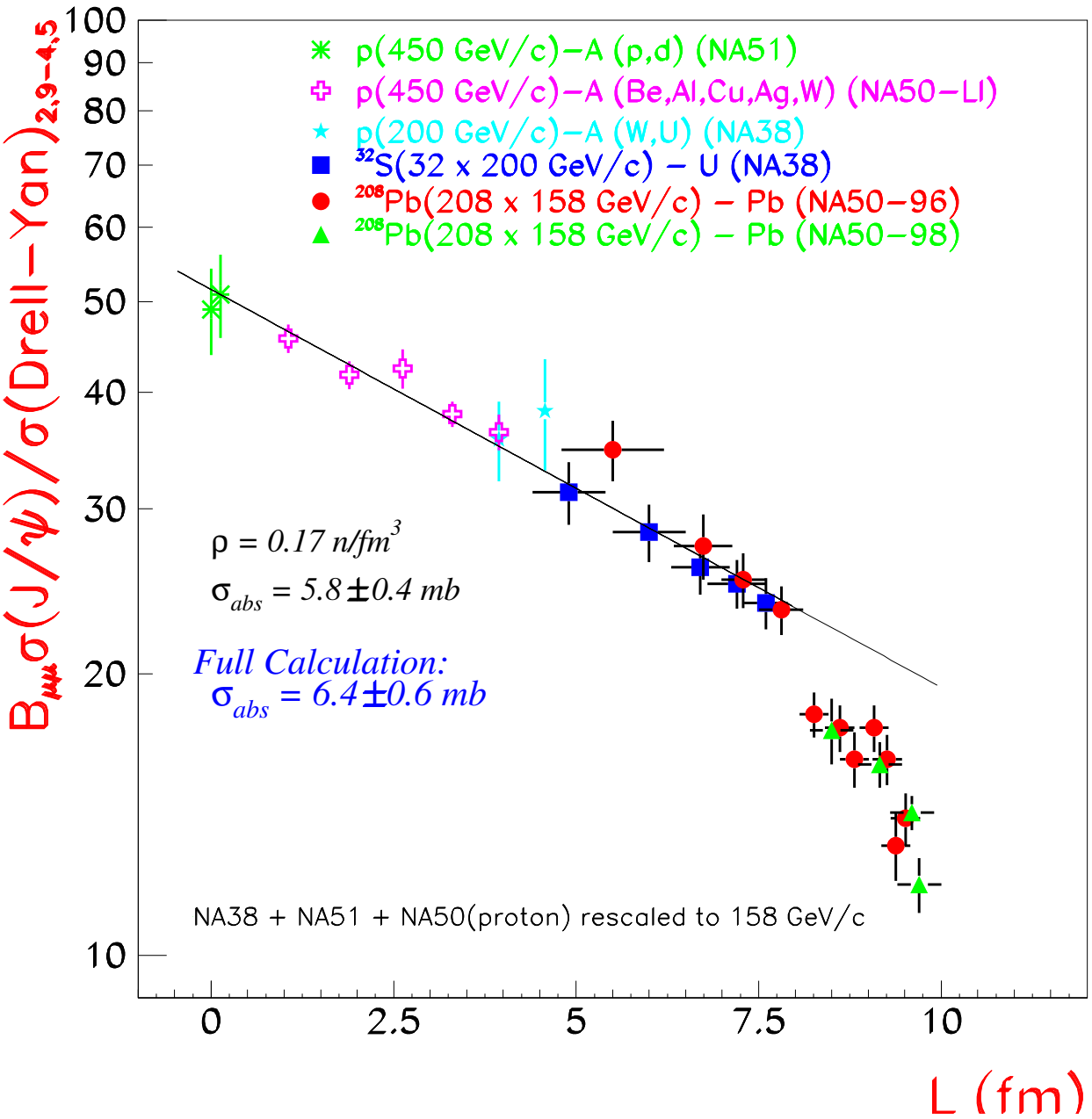
Data energy dependence is very well described by DY(LLA) with MRS43

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

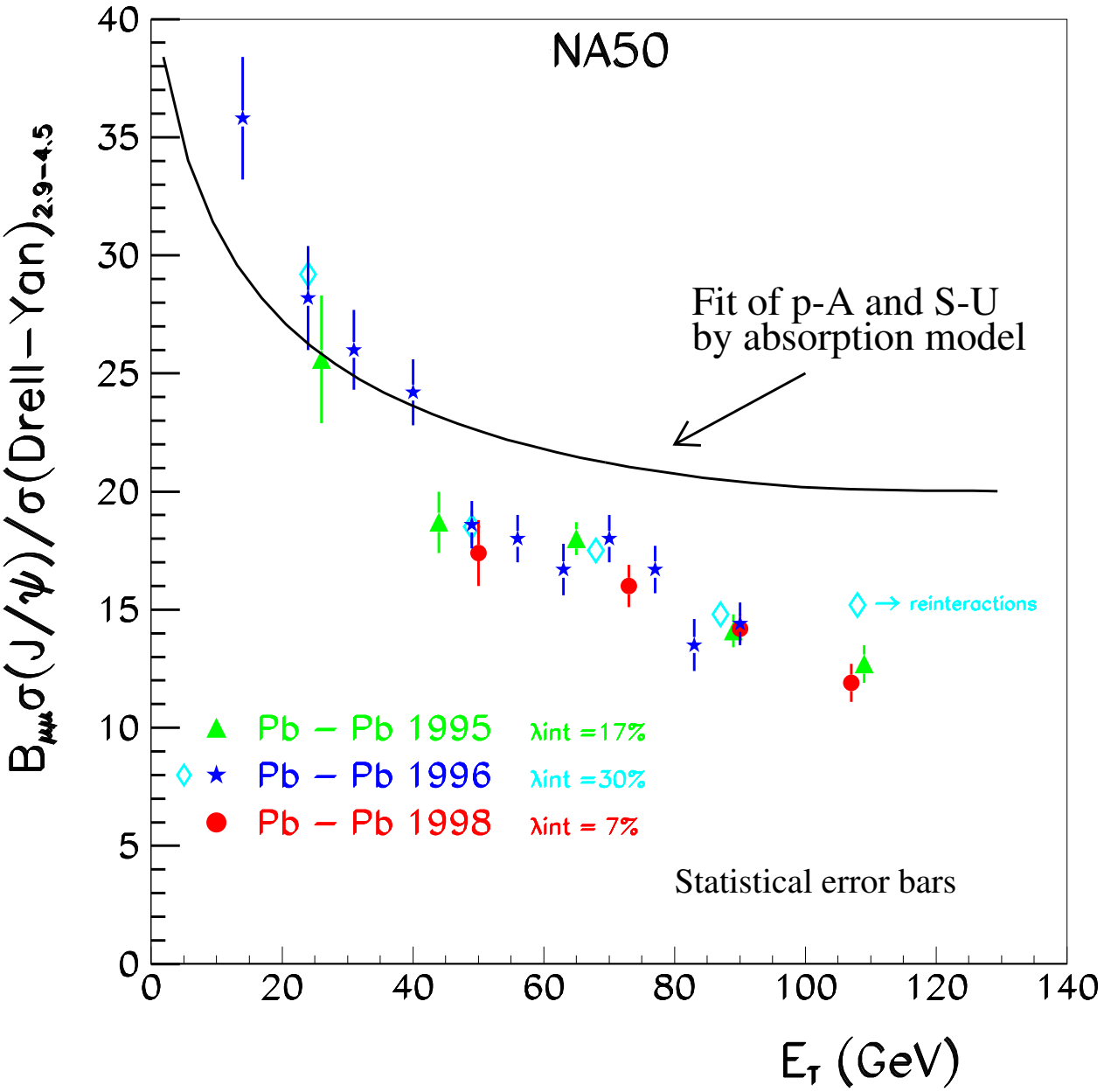


Fit including new proton data (full calculation):

$$\frac{B_{\mu\mu}\sigma^{\psi}}{\sigma^{DY}} \propto e^{-\rho L \sigma_{abs}} \Rightarrow \sigma_{abs} = 6.4 \pm 0.6 \ mb$$

Sudden 20% drop at L = 8 fm

ψ/DY as a function of E_T (1)



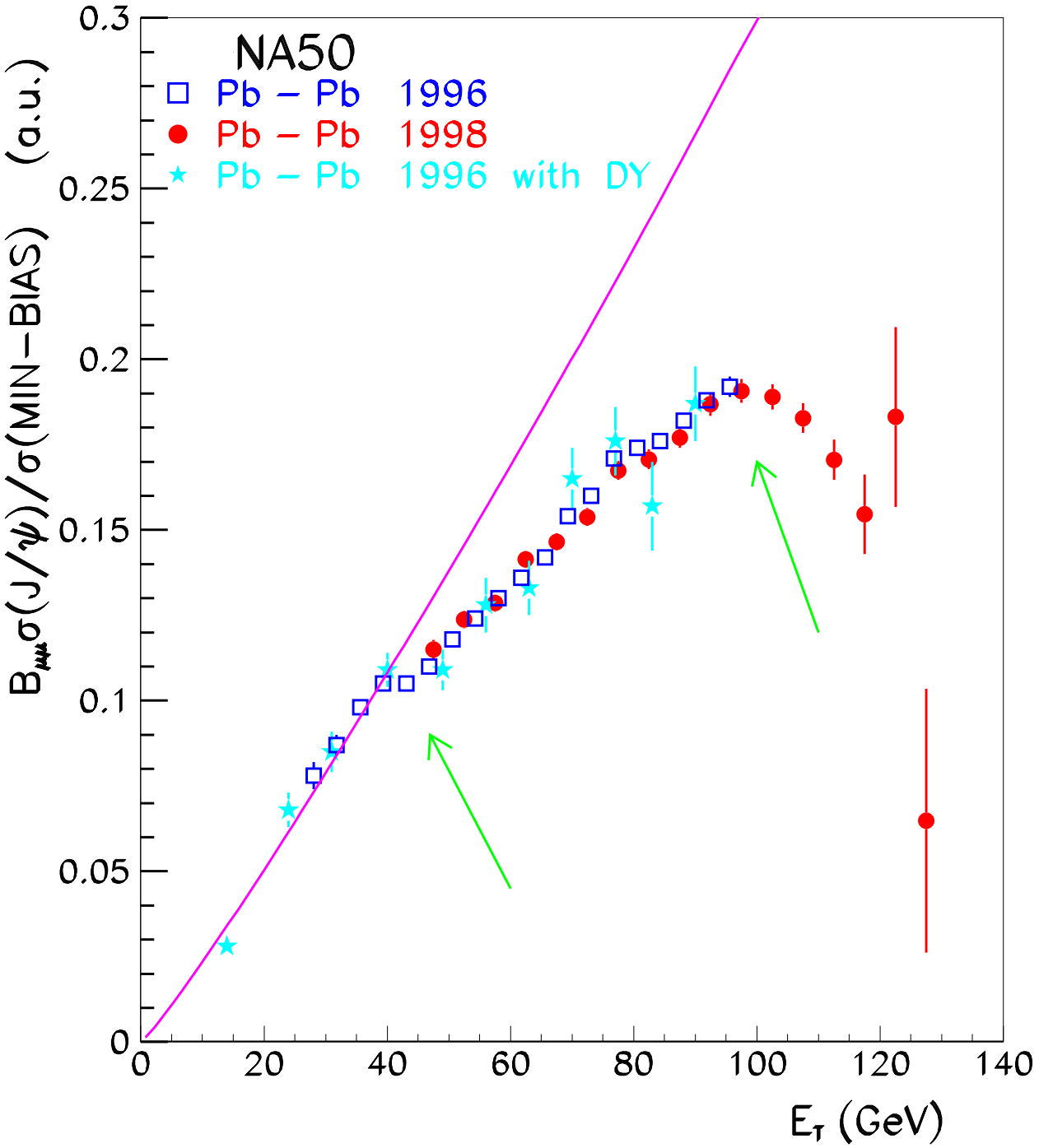
Solid line: Glauber parameterization as obtained from fit to light systems – S-U (NA38), p-p, p-d (NA51) and p-A (NA50)

Results from 3 year's data sets are in agreement

$\Rightarrow$ Systematics are under control

A sudden drop is seen around 40 GeV, followed by a continuous decrease

ψ/Minimum Bias as a function of E_T



Solid line: Absorption model with $\sigma_{abs} = 6.4 \pm 0.6\ mb$ **as obtained from fit to p-A and S-U data (NA50 + NA38 + NA51) with full calculation**

Pattern exhibits 2 "accidents"

$J/\psi/DY$ Minimum Bias analysis

Using the sample of events collected with a "minimum bias" (ZDC) trigger as an estimator for the Drell-Yan in the ratio $J/\psi/DY$:

- **Statistical error reduced**
- **Independent sample**
- **Target algorithm selection for all events**
- **Counting technique: no fits to the mass spectra**

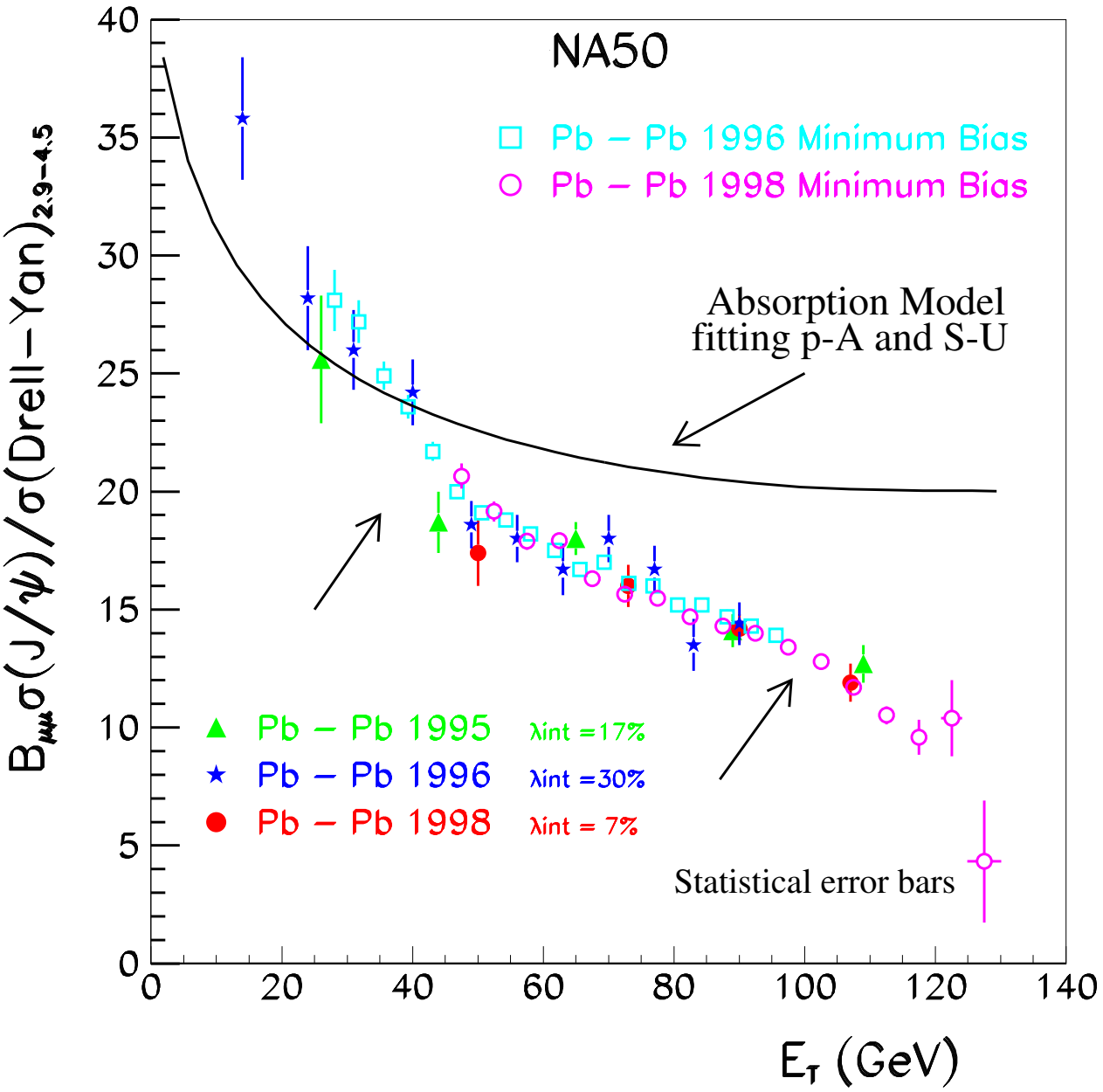
Different systematic effects:

- **Minimum bias trigger based on ZDC**
- **No selection on the muon tracks**
- **Empty target contamination at low E_T**
- **Low target efficiency at low E_T**

$\Rightarrow$ **Bigger systematic error**

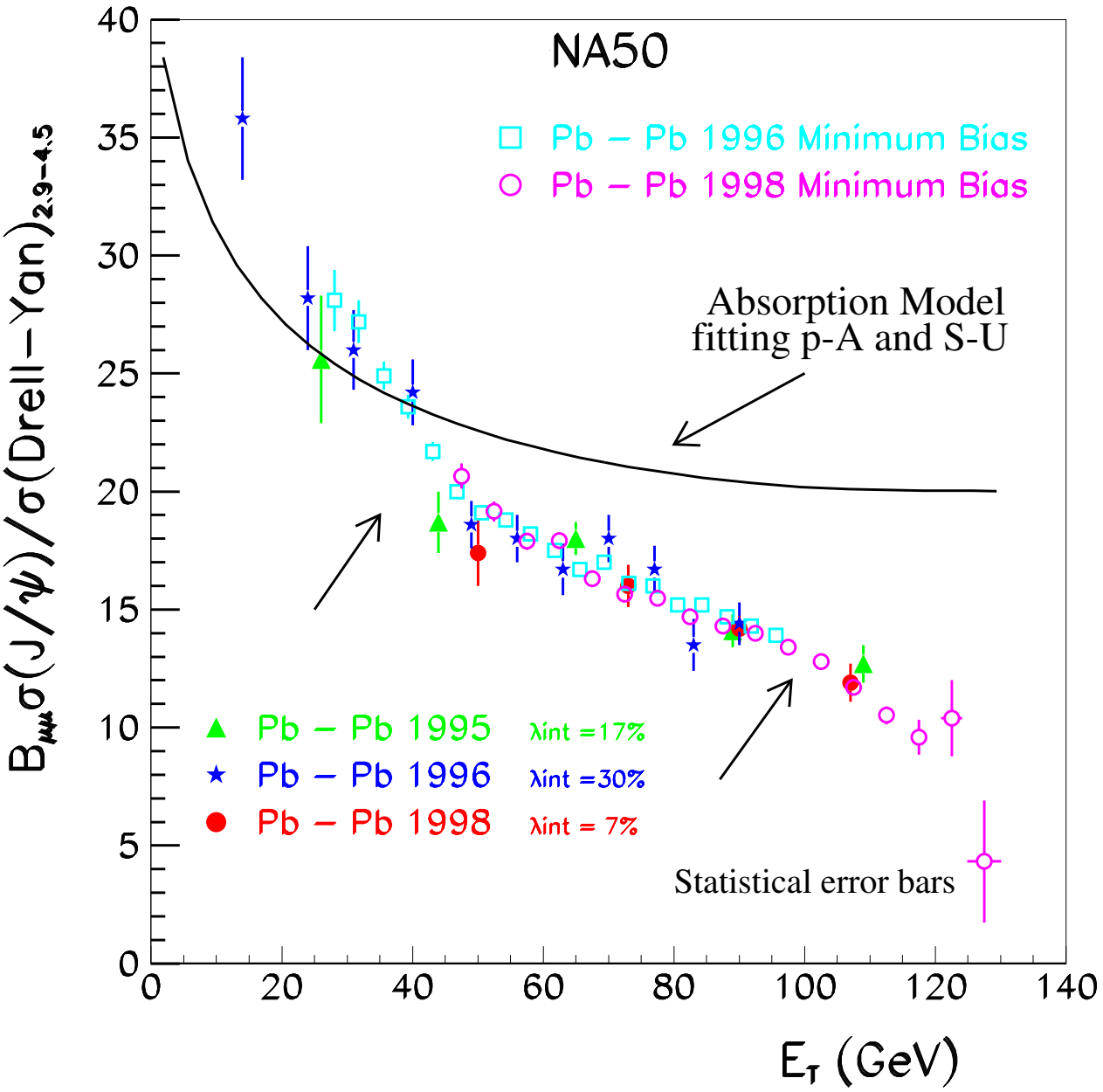
(not totally estimated)

ψ/DY as a function of E_T (2)



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

ψ/DY as a function of E_T (3)



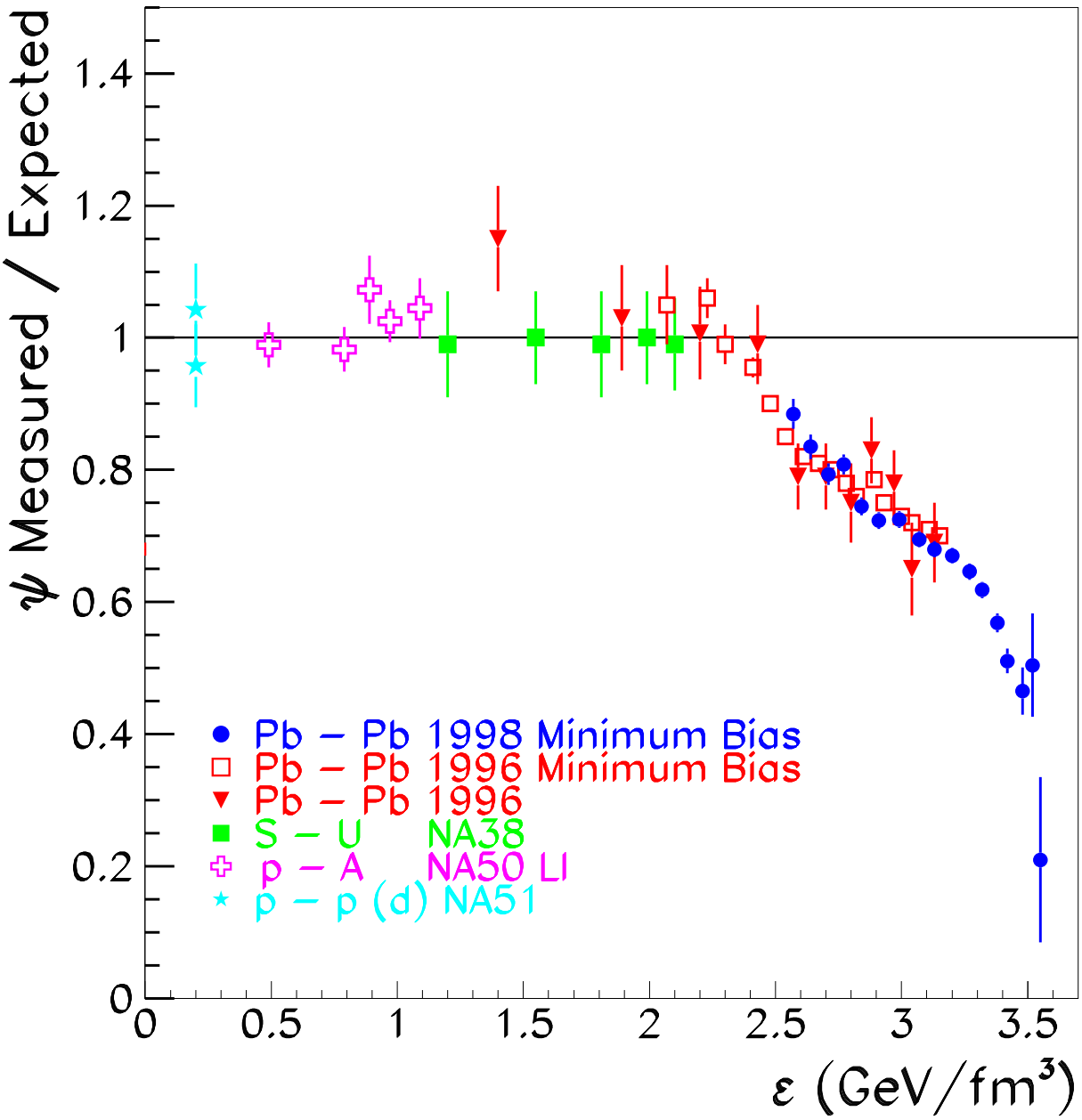
Min. Bias and Standard analyses are in agreement, even for most central collisions

$\Rightarrow$ **systematic errors for high E_T are negligible**

For low E_T maybe systematics are not negligible:

- due to Pb-air interactions
- due to small efficiency of target algorithm

ψ Measured/Expected as a function of ϵ

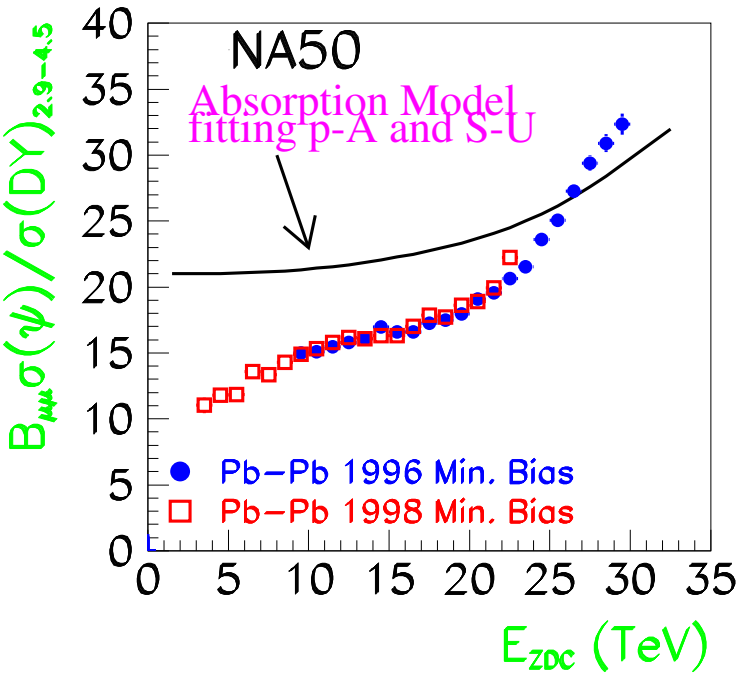


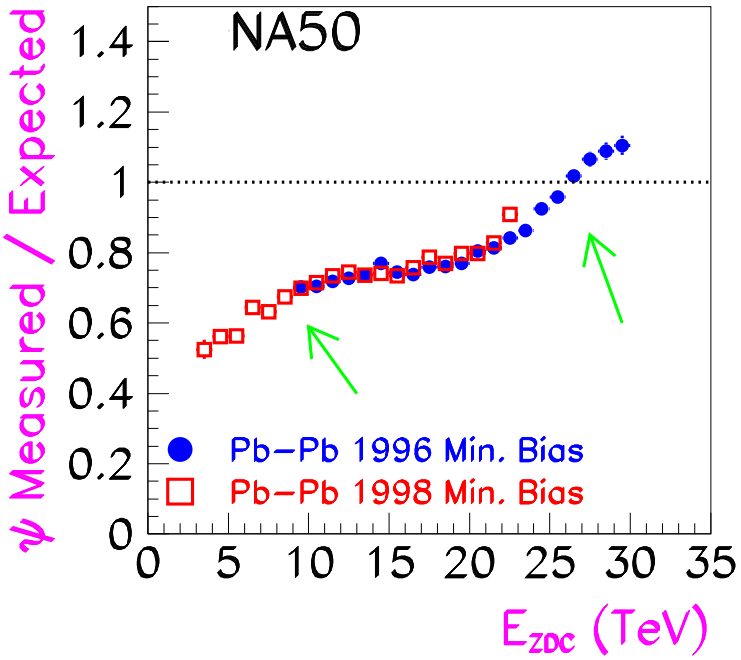
Expected: **absorption model as obtained from fit to light systems (p-A and S-U)**

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

ψ/DY as a function of ZDC

Using another detector: ZDC, for centrality ψ studies



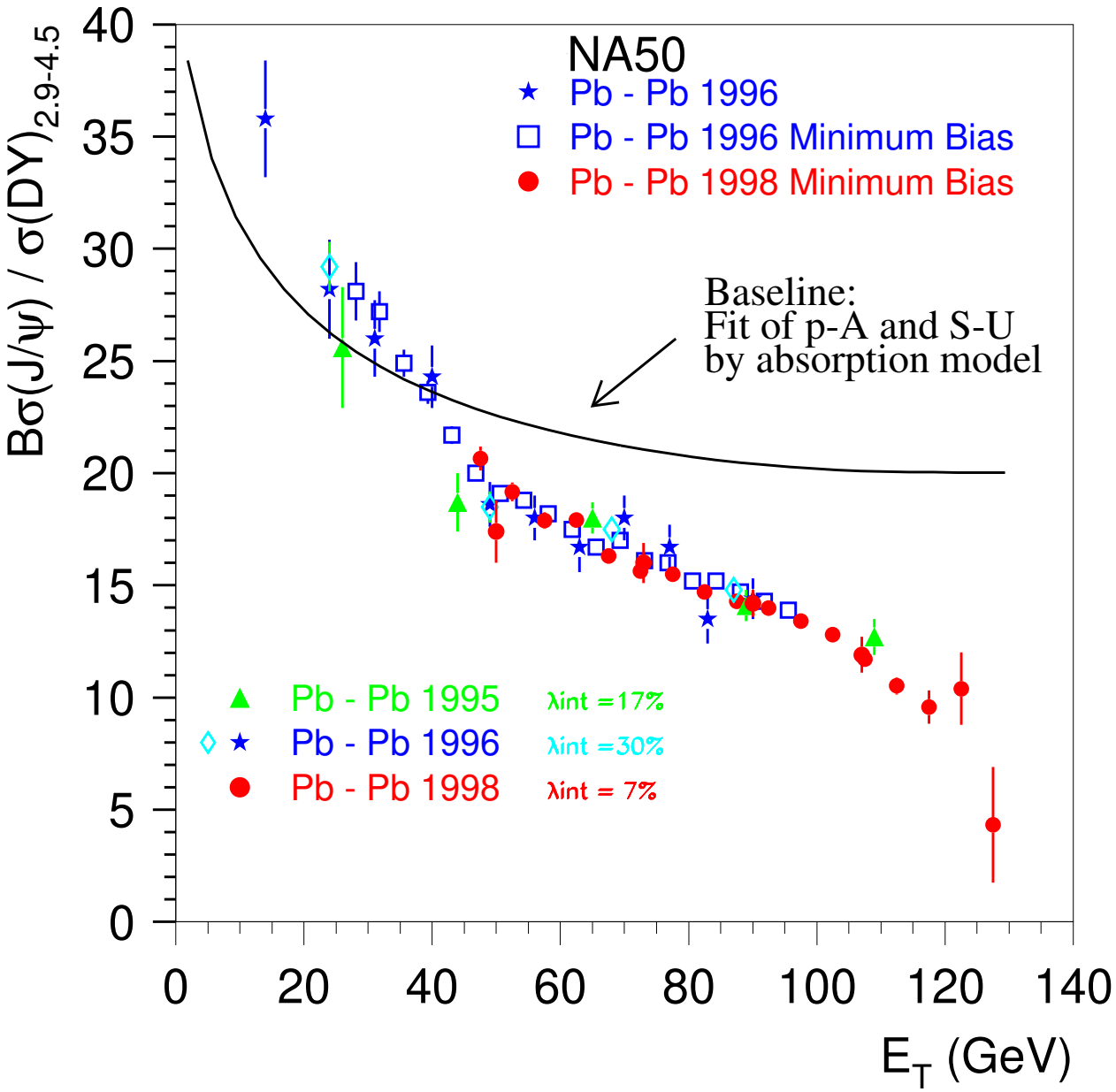


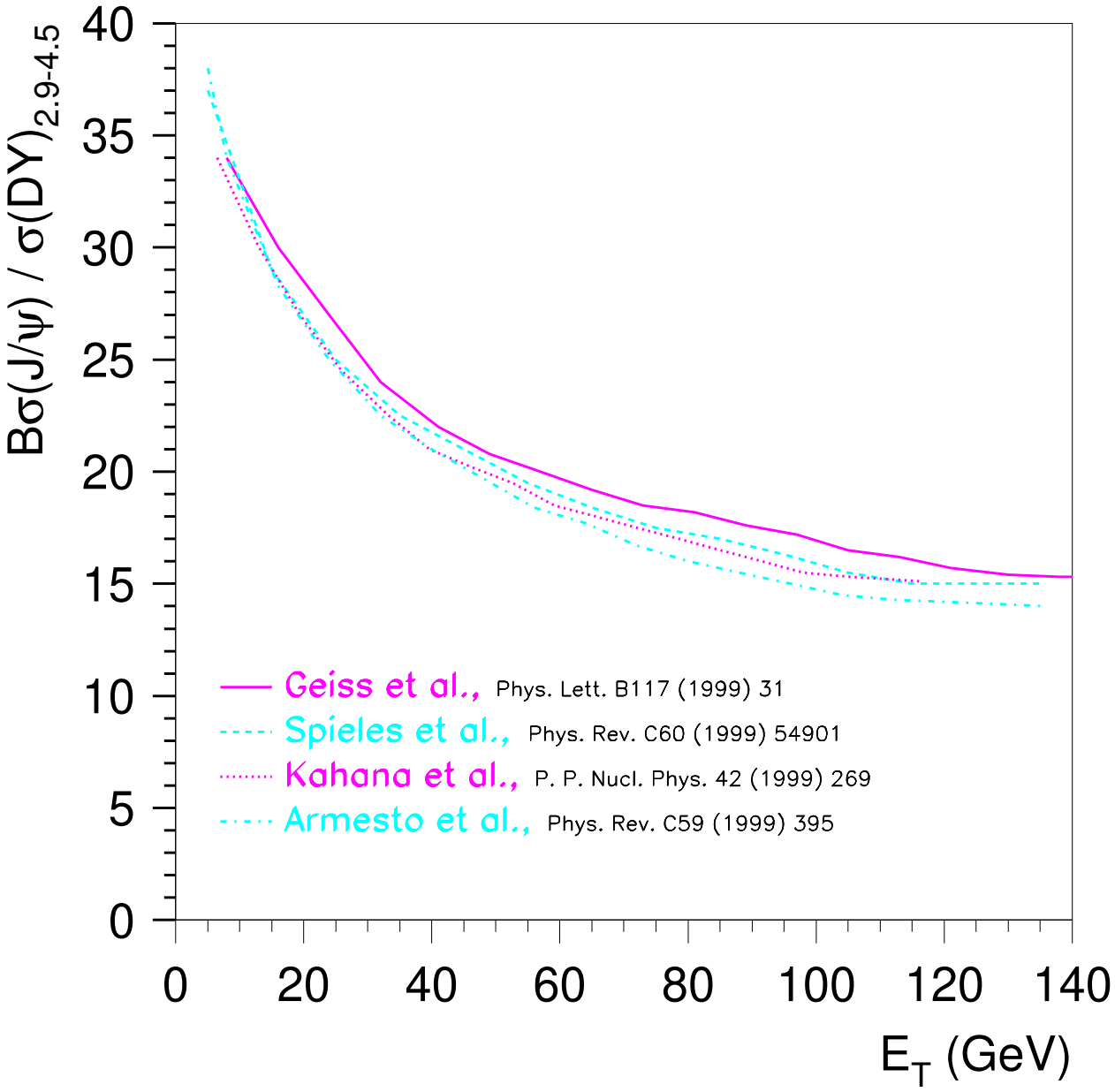
Solid line and Expected: absorption model as obtained from fit to light systems (p-A and S-U)

Observation of the 2 discontinuities in ψ suppression

ψ/DY as a function of E_T (4)

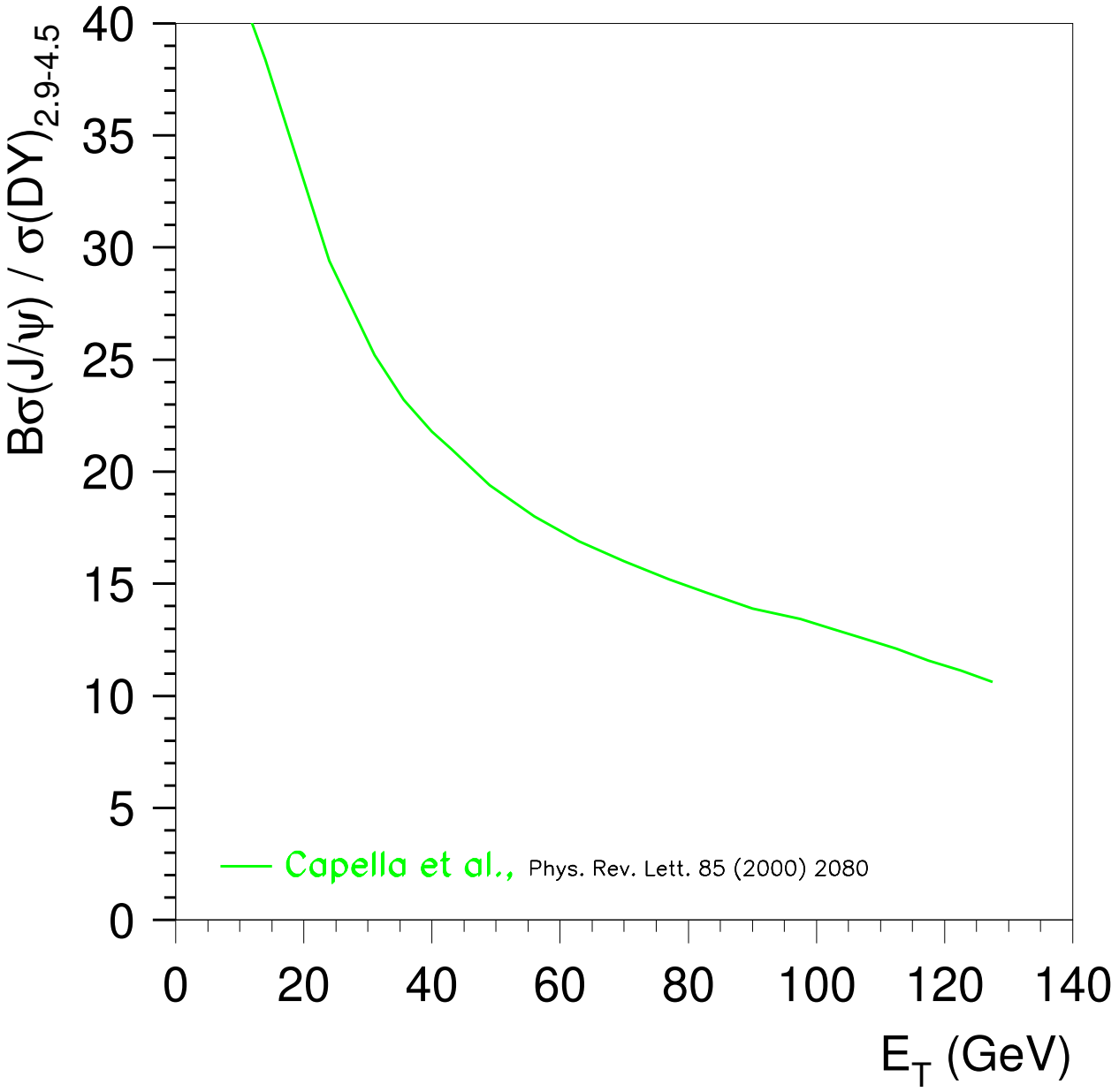
Comparison with conventional (hadronic) models





Problems:

- **No sharp decrease**
- **Saturation for central collisions**

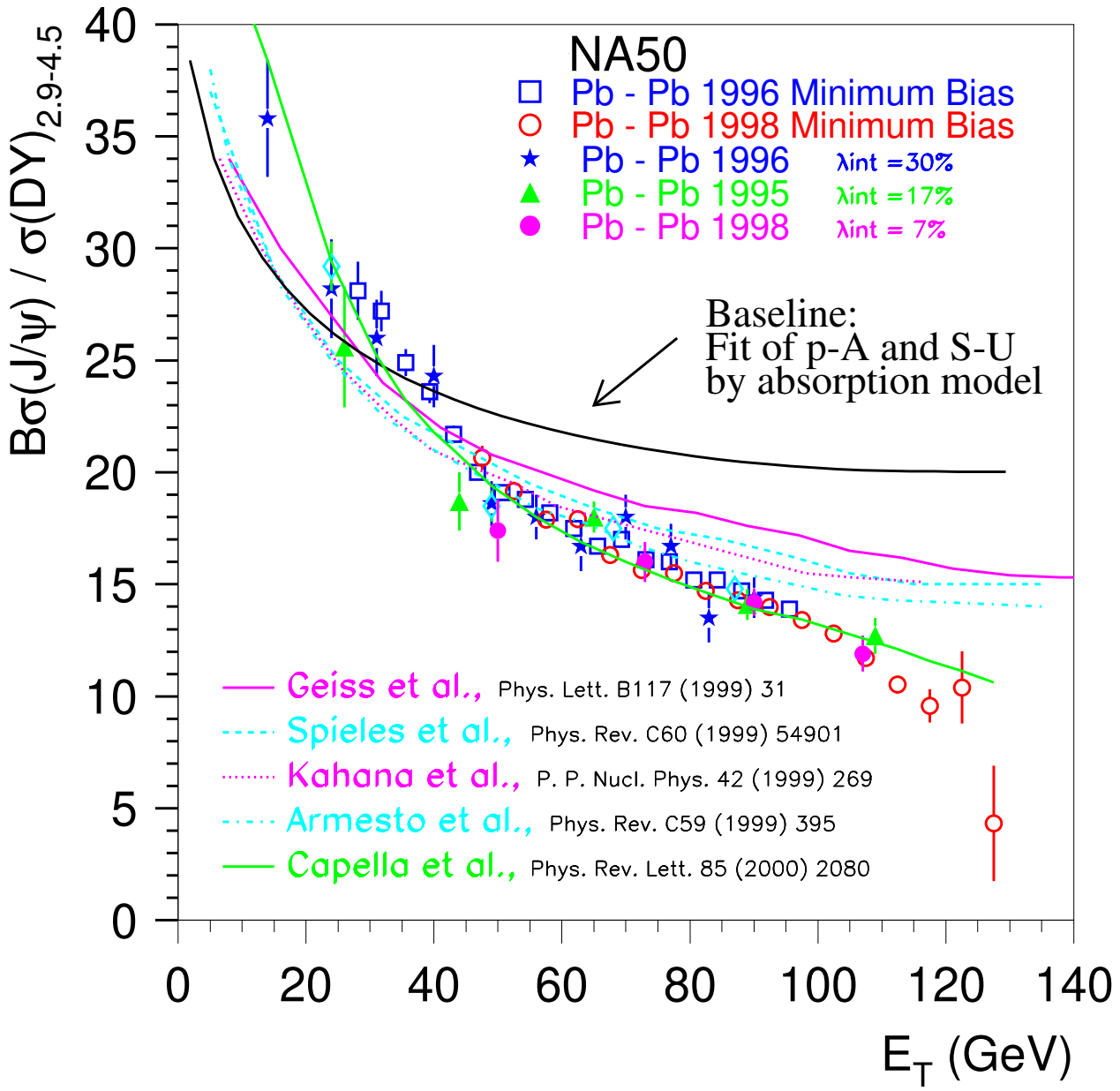


Problems:

- **Doesn't describe p-A and S-U interactions**
- **Fluctuations in hadronic model are not enough to describe high E_T data**

ψ/DY as a function of E_T (5)

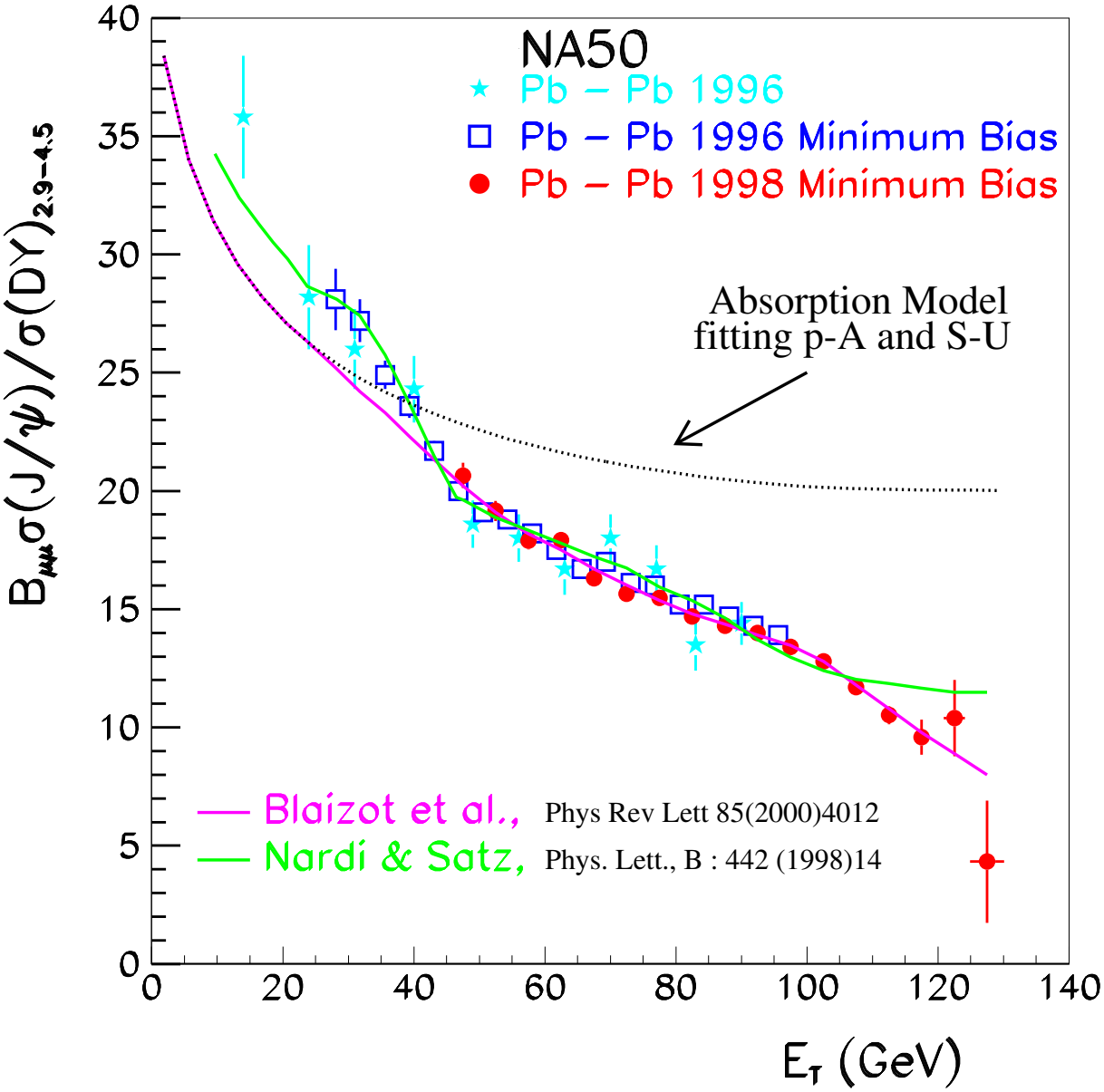
Comparison with conventional (hadronic) models



The stepwise suppression pattern rules out any of these conventional models

ψ/DY as a function of E_T (6)

Comparison 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

seems necessary to describe the data

Recent model developments

From recent calculations in lattice (Karsh et al.),

new approximative models:

S. Digal et al. and C.Y. Wong

give the possibility of charmonia dissociation (T_d) states (namely the χ_c) in hot nuclear matter, before deconfinement (T_c)

$T_d < T_c$ **for** χ_c

$T_d > T_c$ **for** J/ψ (S. Digal et al.)

$T_d < T_c$ **for** J/ψ (C.Y. Wong)

$\Rightarrow$ **need of:**

— **complete calculation**

— **give predictions as a function of measured variables**

NA50 Latest Run

To clarify and to measure peripheral collisions without any bias and with reduced error bars:

2000 Run :

$\geq$ 100 000 J/ψ

- **with target placed in vacuum**
  $\Rightarrow$ **no Pb-air interactions**
- **two different detectors for minimum bias sample**
  $\rightarrow$ **zero degree calorimeter**
  $\rightarrow$ **beam hodoscope**
- **development of new target algorithm**
  with higher efficiency at low E_T (use of MD)

$\Rightarrow$ **Results coming soon**

Summary

- New accurate and extensive study of J/ψ production in proton-nucleus interactions:

  p-Be, p-Al, p-Cu, p-Ag, p-W

  Together with p-p, p-d (NA51) and S-U (NA38) results, give comprehensive understanding of J/ψ normal absorption

- 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 inflection point followed by a steady steep decrease

- Hadronic models with comovers fail to interpret the stepwise pattern

- This can be interpreted by successive melting of charmonium bound states (χ_c, J/ψ) as predicted by Quark-Gluon Deconfinement or by a dissociation of χ_c in hot matter and the melting of J/ψ

  $\Rightarrow$ Theory needs to stabilize

- Results from new high precision data, with the target placed in vacuum are coming soon