Searching for QGP:
the J/ψ probe in the NA50/CERN experiment

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The NA50 Collaboration

Alessandria, Annecy, Bucharest, Cagliari, CERN, Clermont-Ferrand, Lisbon, Lyon, Moscow, Orsay, Palaiseau, Strasbourg, Torino, Yerevan

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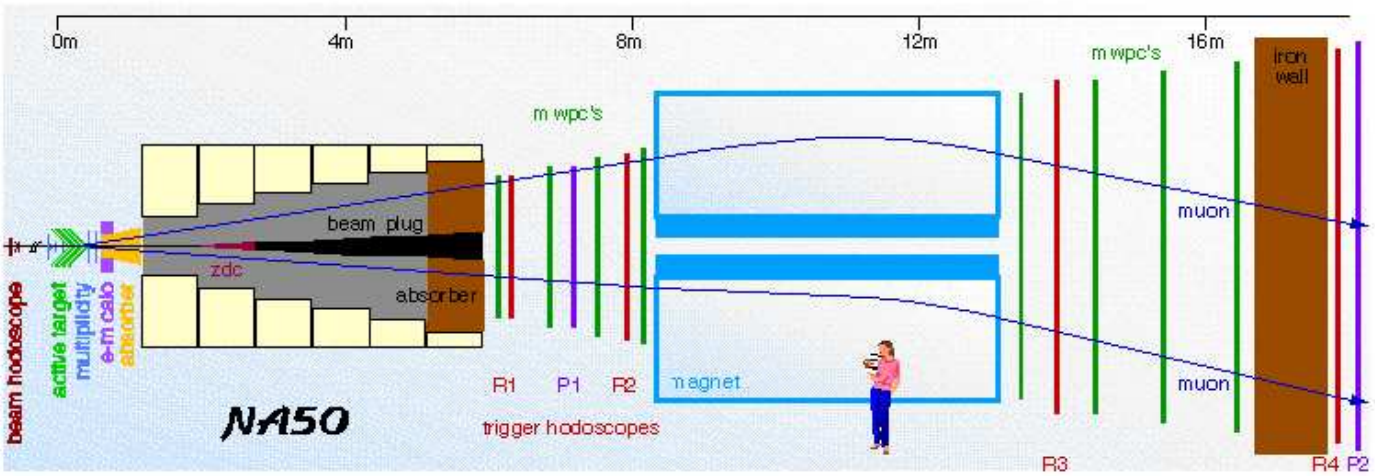
Experimental Setup



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 $(1.5 < \eta_{lab} < 3.5)$

Event selection

Standard selection criteria applied to all periods:

- dimuon trigger (or ZDC trigger for Minimum Bias events)
- cuts on pileup and beam halo events; rejection of interactions originating in the beam hodoscope
- target algorithm identification and/or Et-Ezdc countour cut applied
- quality cuts on muon tracks

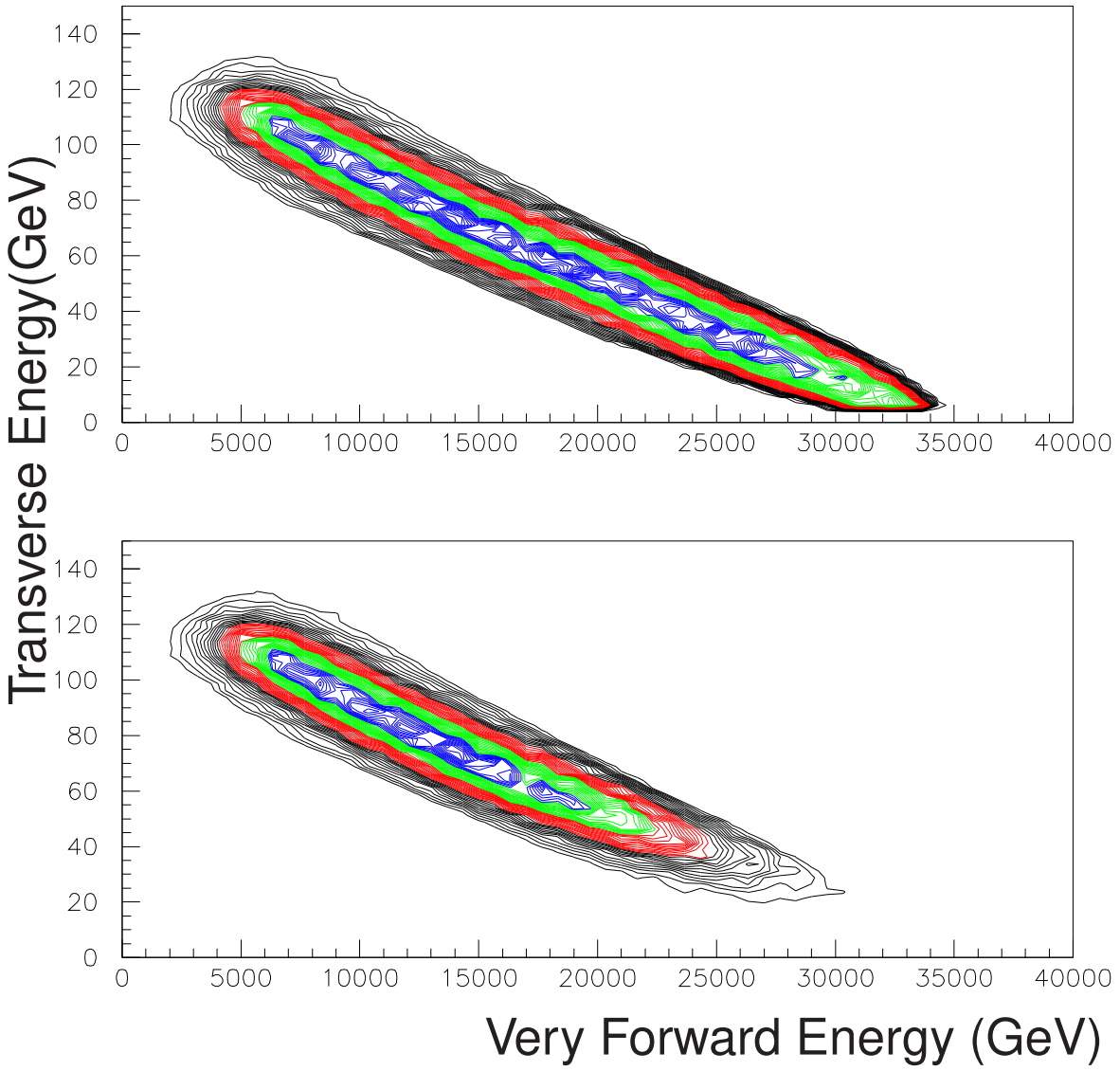
Very similar setup in 1995, 1996 and 1998, except for the target

Data Conditions

Data period	1995	1996	1998
Target thickn. λ_{int}	17 %	30 %	7 %
Nb. subtargets	7	7	1
Beam intensity	$3 \cdot 10^7$	$5 \cdot 10^7$	$5.5 \cdot 10^7$
Number of J/ψ	50 000	190 000	40 000
Vertex identif.	target algorithm	target algorithm *or* countour cut	Target algorithm
Minimum bias analysis	no	yes	yes

- **1996:** high statistics; increase selection on peripheral events
- **1998:** avoid Pb-air interactions; select $E_T >$ 40 GeV

Identification of Pb-Pb interactions



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

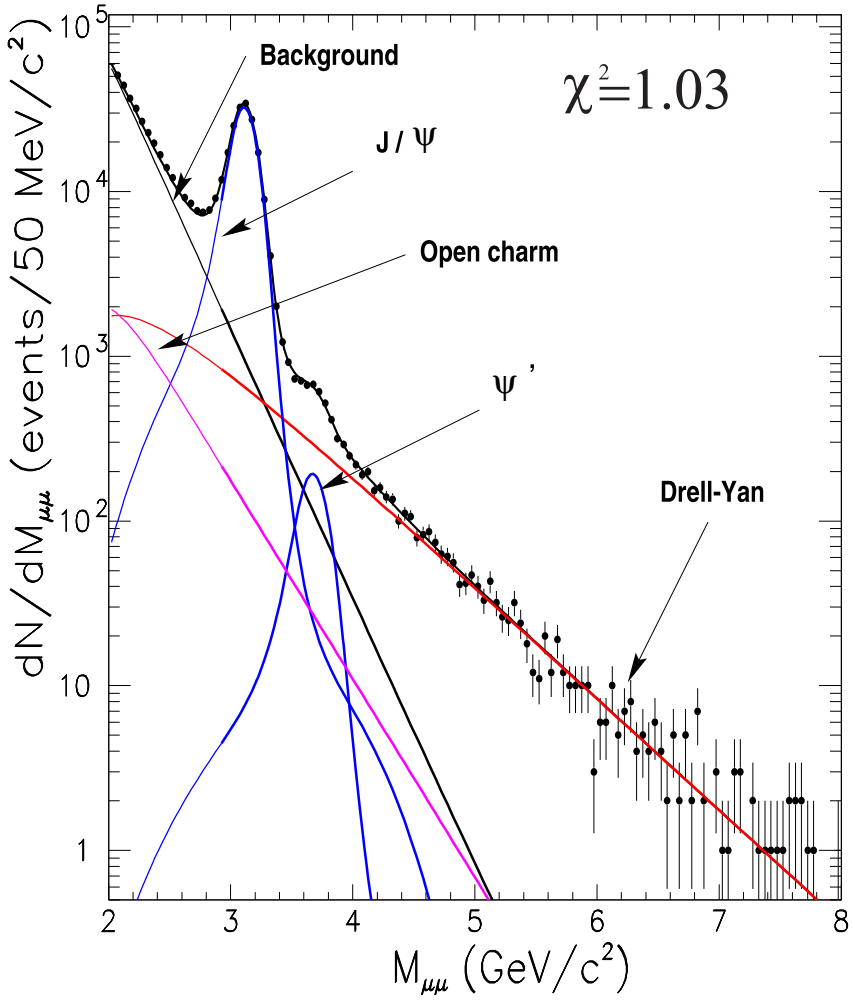
statistics increased for peripheral events

Target Algorithm:

based on quartz blade Čerenkov counters

Fit to the mass spectrum

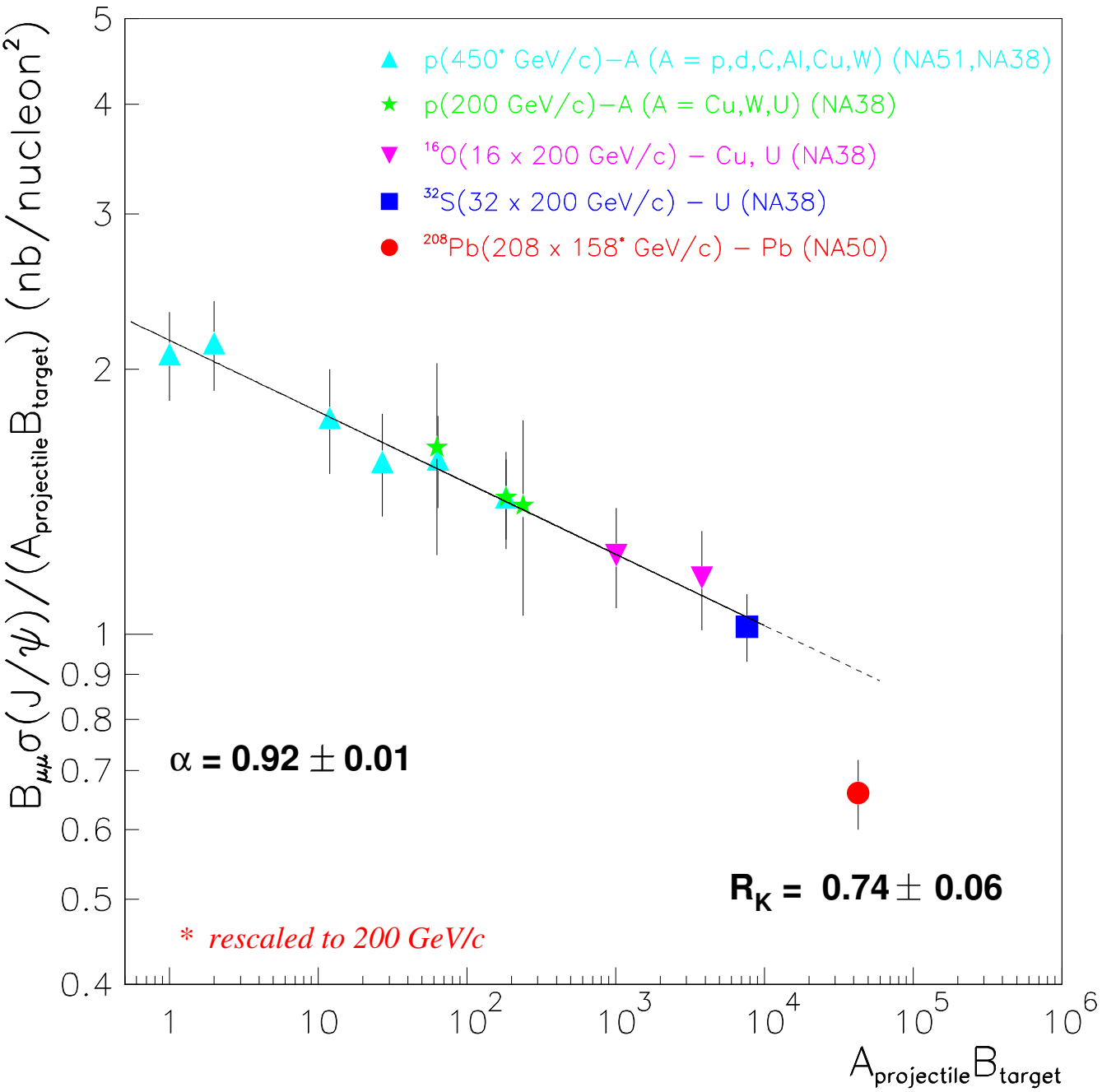
$$\frac{dN}{dM} = A_{J/\psi}\frac{dN_{J/\psi}}{dM} + A_{\psi'}\frac{dN_{\psi'}}{dM} + A_{DY}\frac{dN_{DY}}{dM} + \frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$



• 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 and reconstructed chain

ψ/AB as a function of $A_{projectile}$ B_{target}



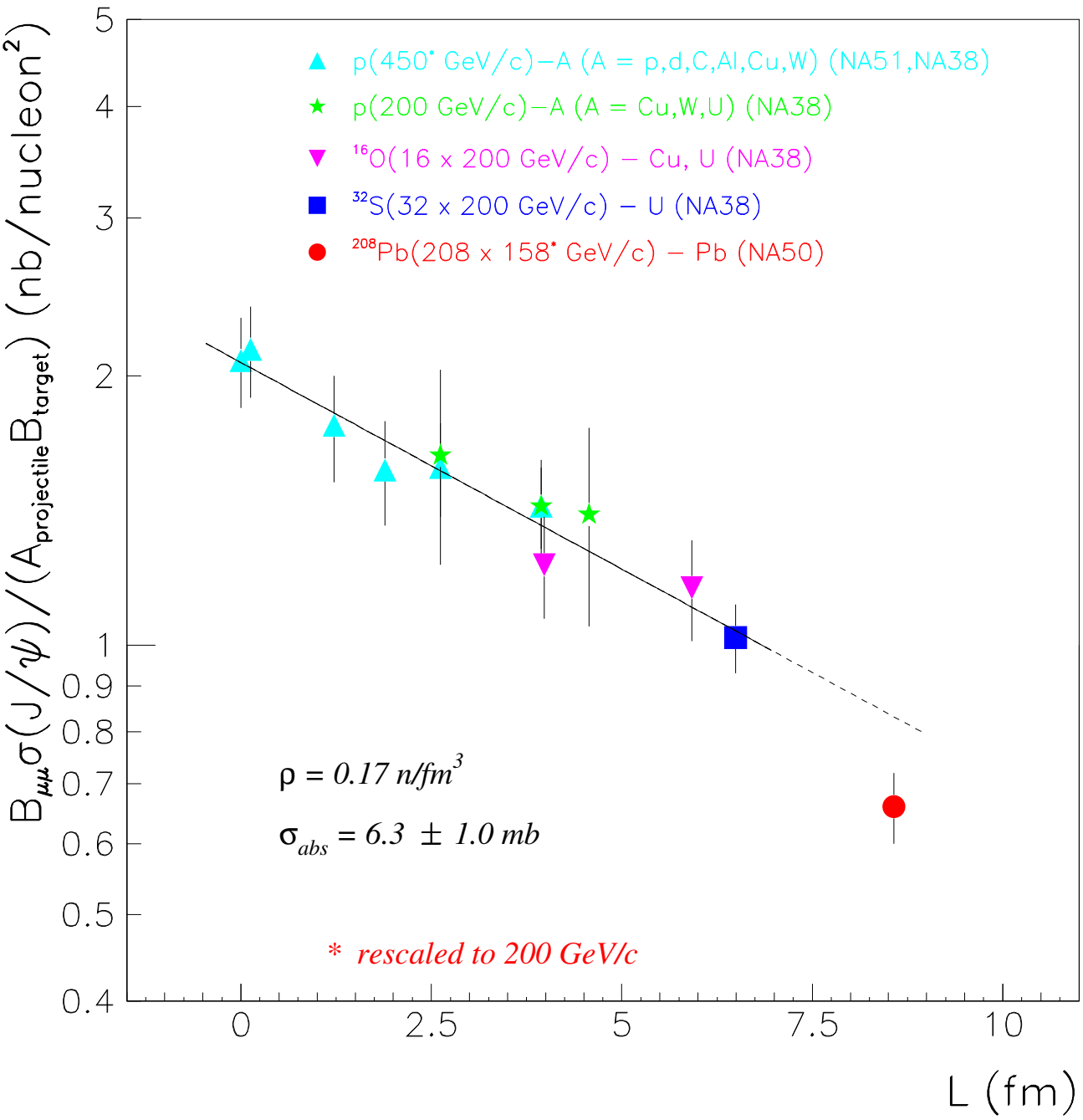
J/ψ production can be parametrized as:

$$\sigma^{\psi} \propto (A\ B)^{\alpha} \quad \Rightarrow \quad \alpha = 0.92 \pm 0.01$$

In Pb-Pb collisions J/ψ is anomalously suppressed as compared to other reactions.

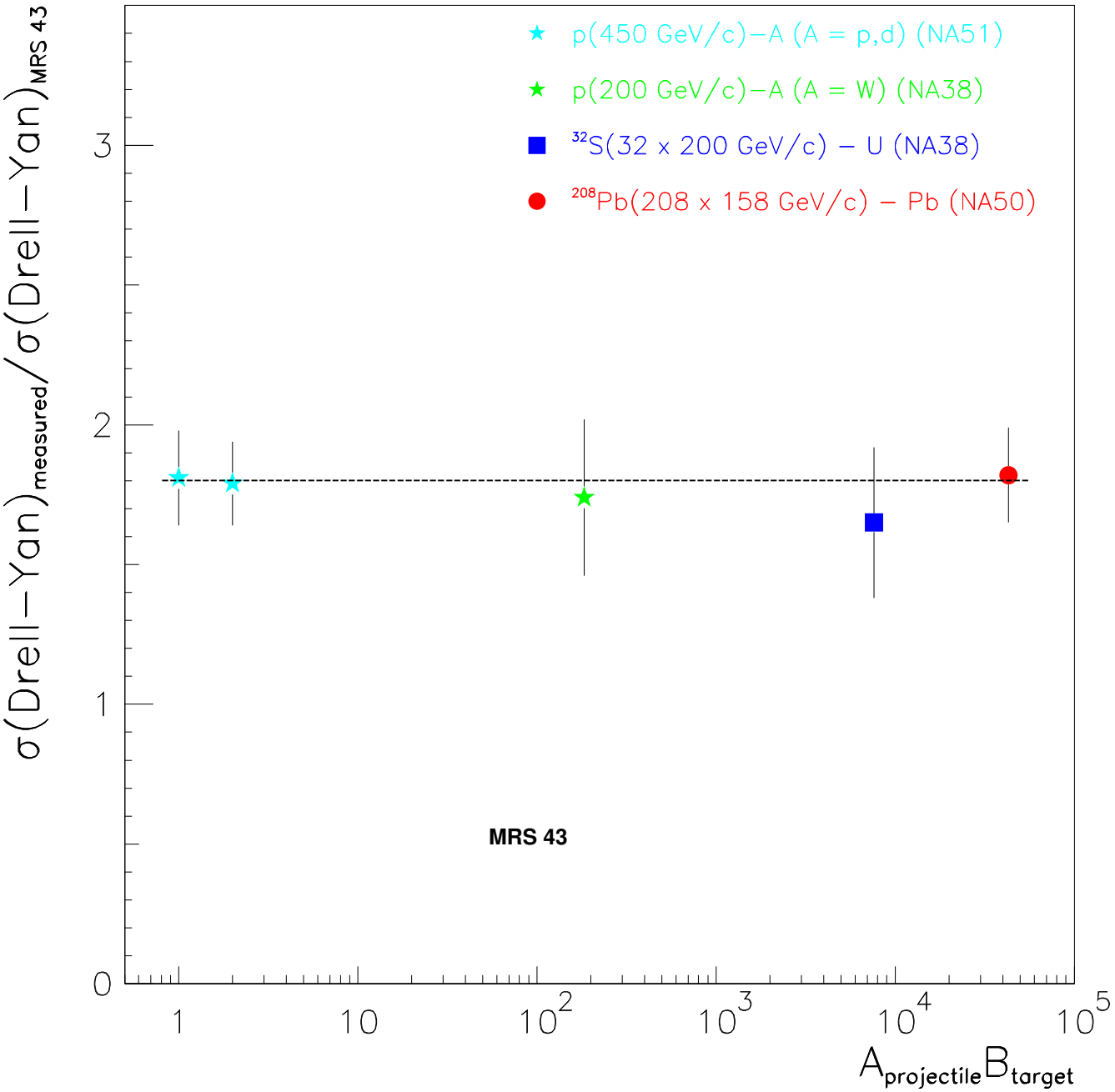
ψ/AB as a function of L

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



$$\frac{B_{\mu\mu}\sigma^{\psi}}{A\ B} \propto e^{-\rho L \sigma_{abs}} \Rightarrow \sigma_{abs} = 6.3 \pm 1.0\ mb$$

Drell-Yan: Experimental K factor

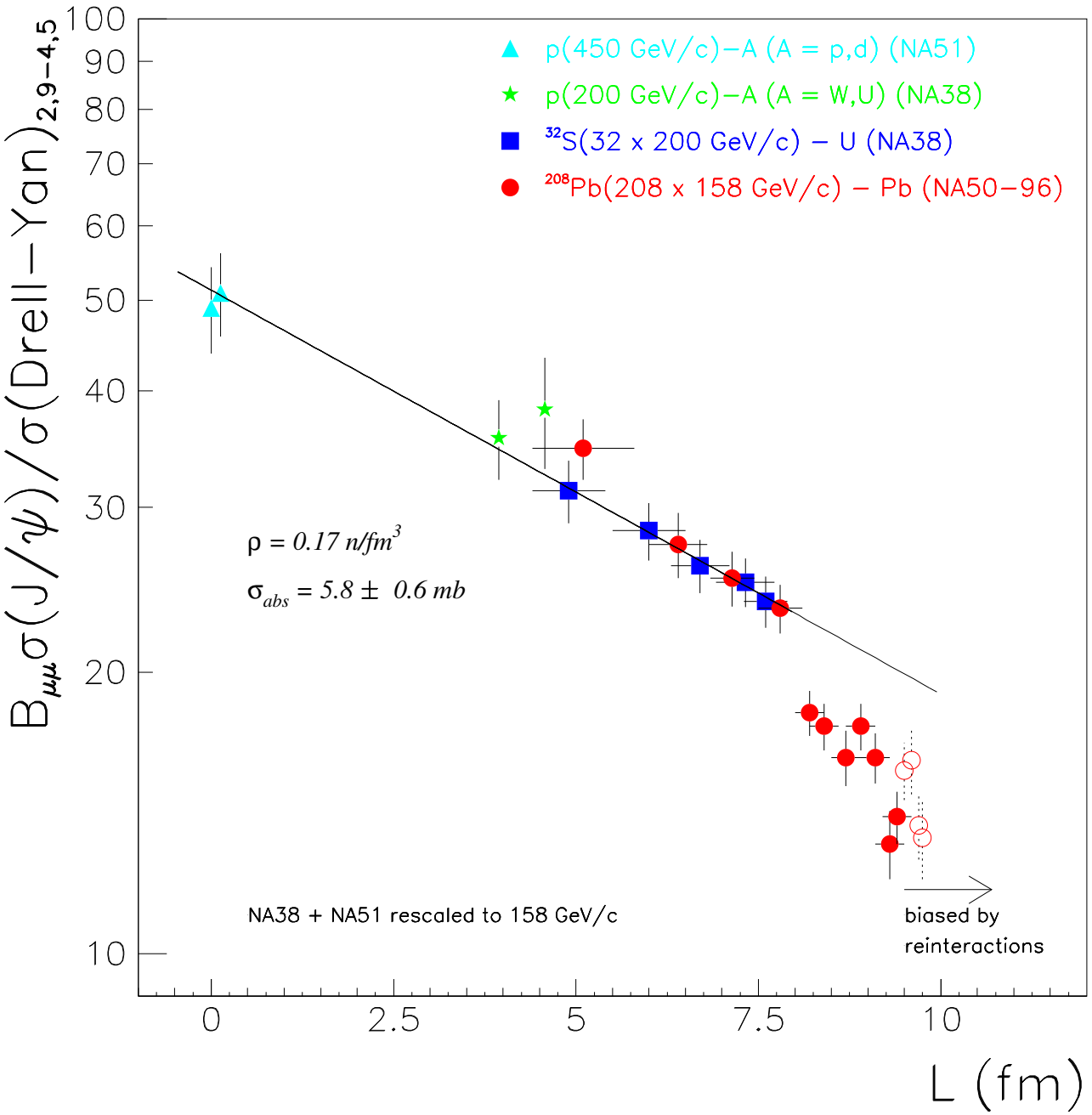


Drell-Yan is proportional to the number of collisions A·B, that is, it scales as expected:

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

ψ/DY as a function of L

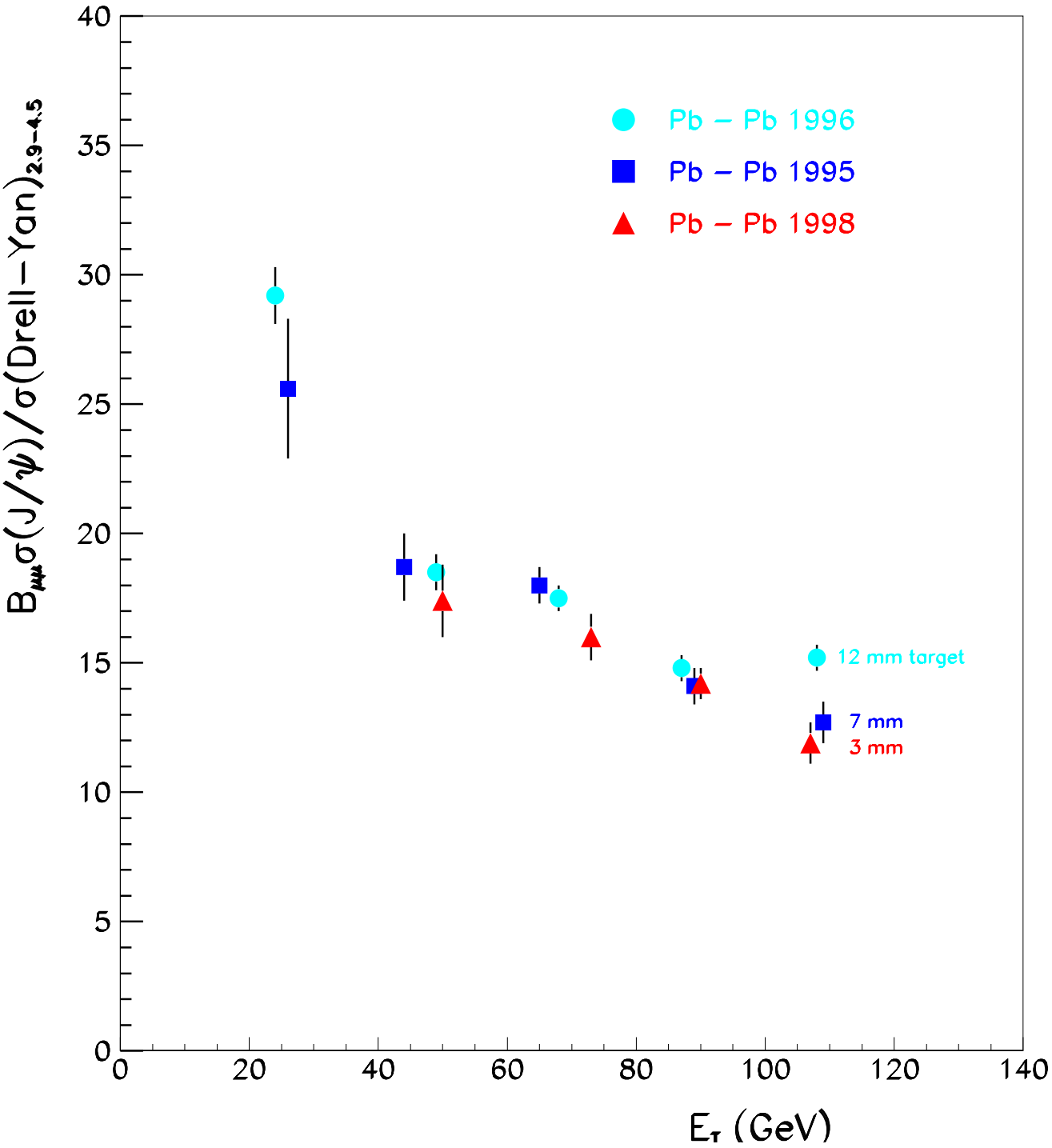
L - path length of the pre-resonant $c\bar{c}g$ state in nuclear matter



$$\frac{B_{\mu\mu}\sigma^{\psi}}{\sigma^{DY}} \propto e^{-\rho L \sigma_{abs}} \Rightarrow \sigma_{abs} = 5.8 \pm 0.6\ mb$$

Sudden 20% drop at L = 8 fm

ψ/DY as a function of E_T



The 3 data samples are compatible, but the highest E_T bin is affected by reinteractions occurring in thicker targets (12 mm $\Leftrightarrow$ 30% λ_{int})

"Minimum bias" analysis

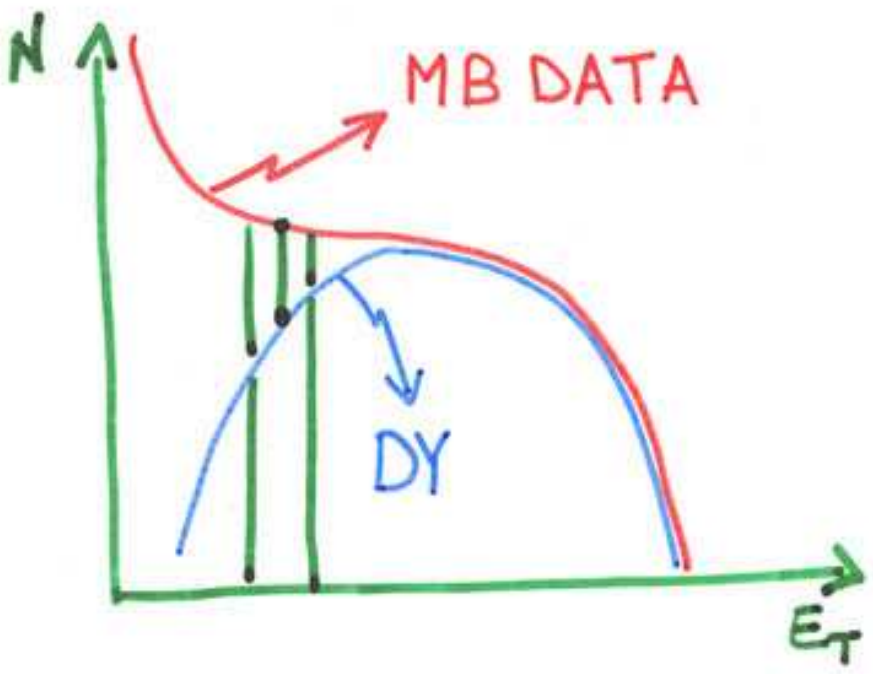
Using the sample of events collected with a "minimum bias" (ZDC) trigger as an estimator for the Drell-Yan in the ratio $J/\psi/DY$:

- Statistical error reduced
- Independent sample
- Target algorithm selection for all the 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

Minimum bias: the method



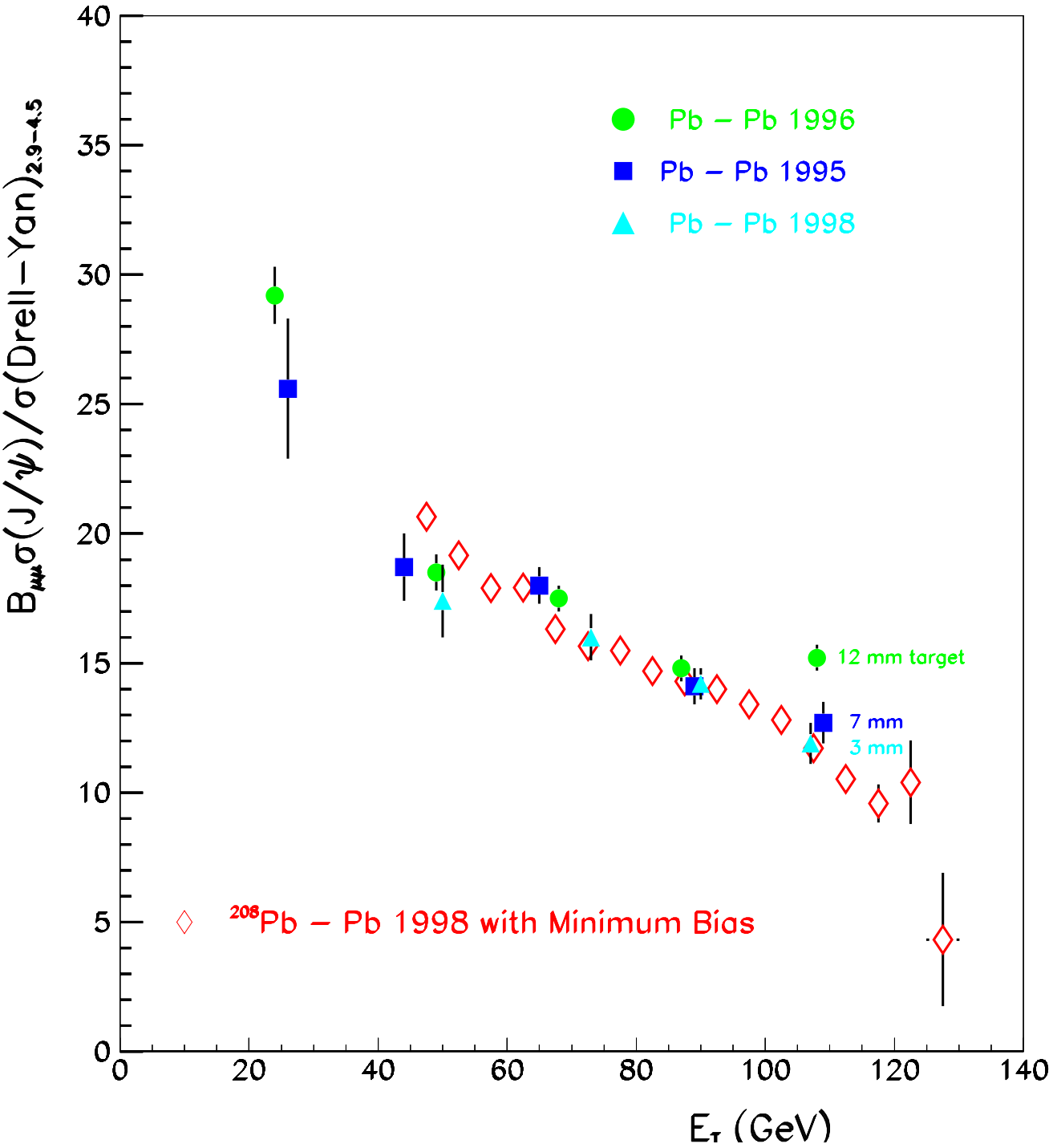
$N_{AB}(b)$: number of collisions for a given impact parameter b (Glauber model)

$$\frac{N_{DY}(E_T)}{N_{MB}(E_T)} \sim N_{AB}(E_T)$$

$$N_{DY^\star}(E_T) = N_{MB}^{exp}(E_T) \times N_{AB}(E_T)$$

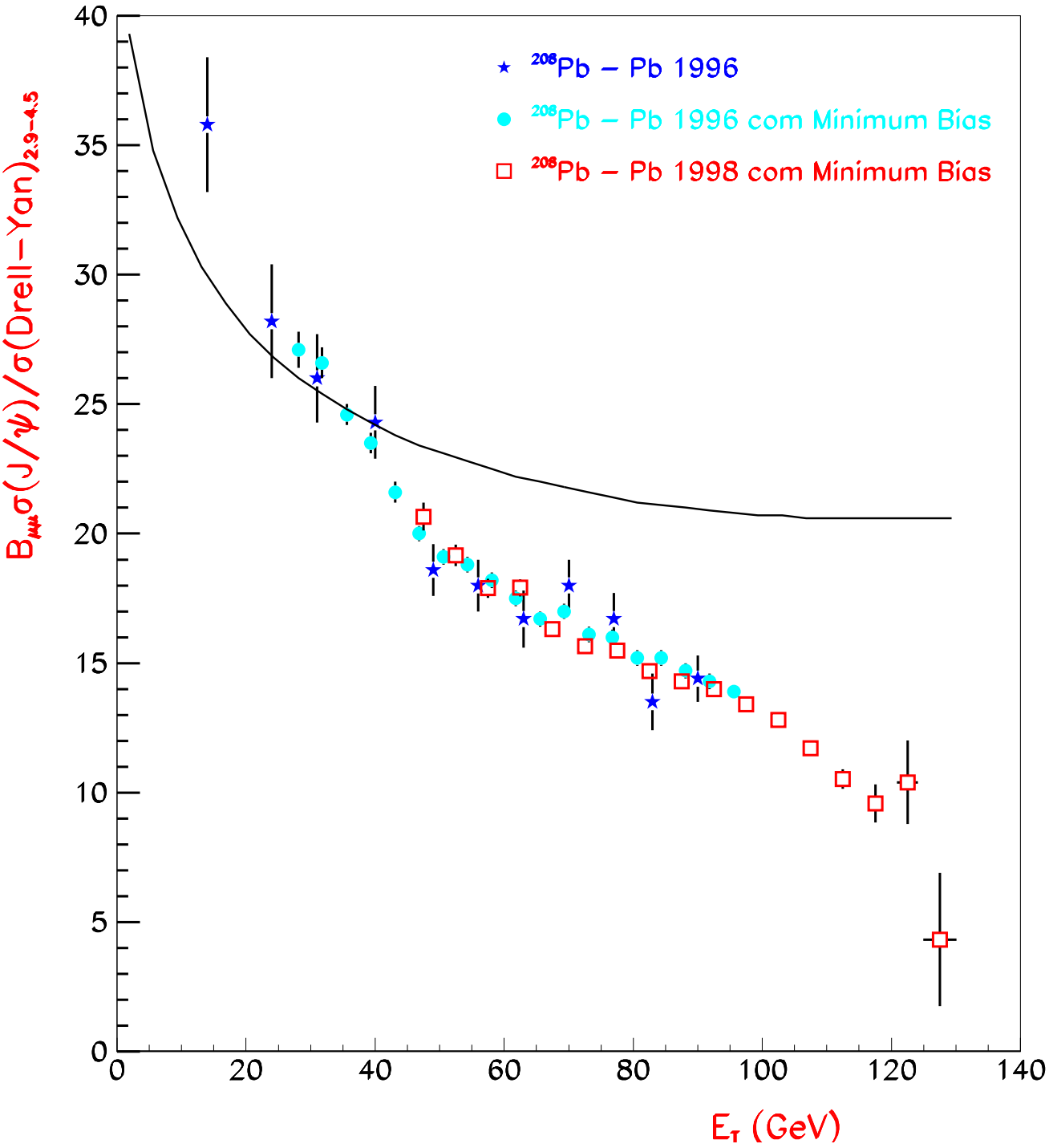
$$\frac{N_\psi(E_T)}{N_{MB}(E_T)} \rightarrow \frac{N_\psi(E_T)}{N_{DY}(E_T)}$$

ψ/DY as a function of E_T



The Minimum Bias analysis exhibits the same behaviour as the Standard analysis

ψ/DY as a function of E_T

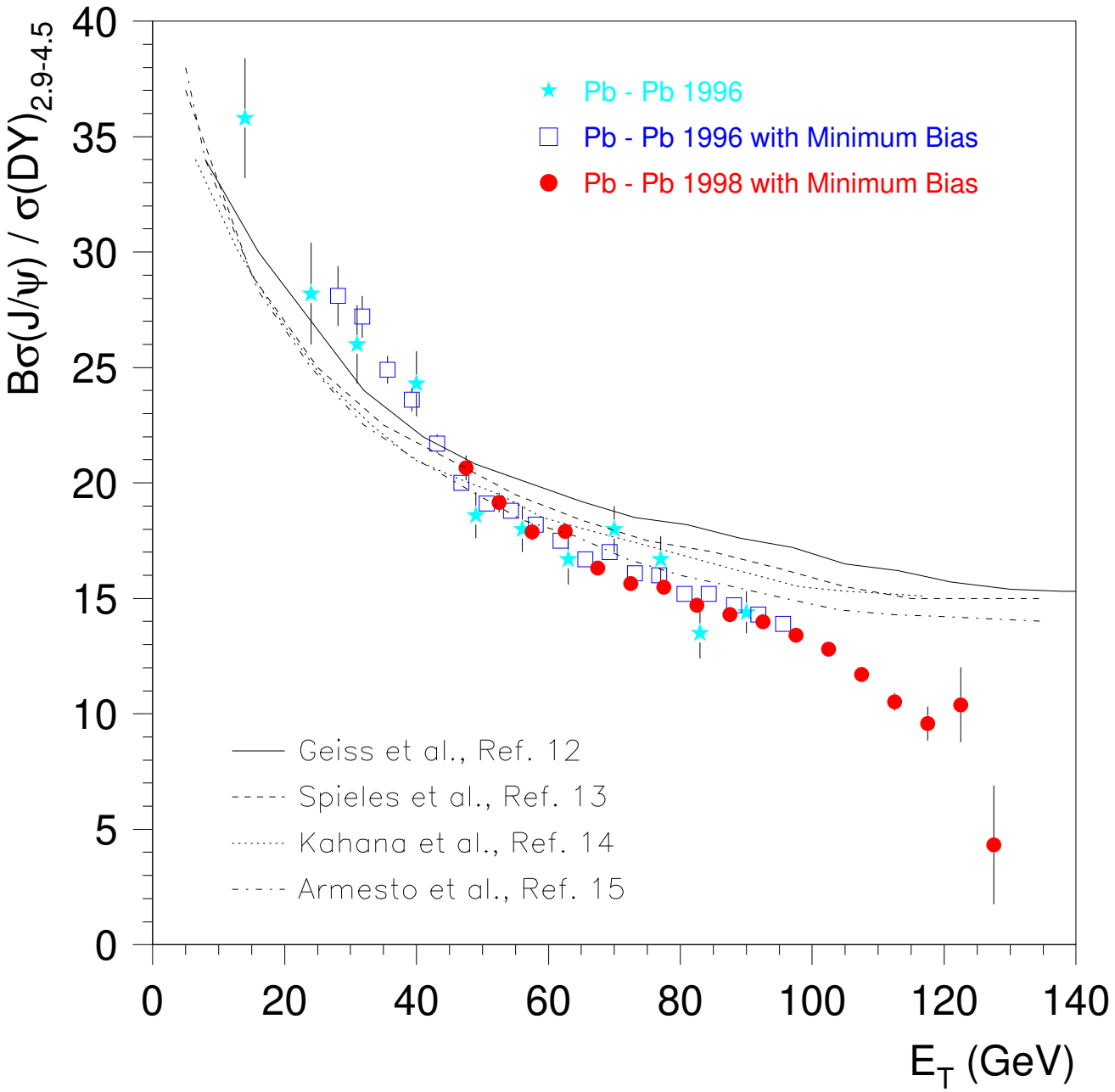


Solid line: exponential parametrization as obtained from light systems (NA38 + NA51)

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

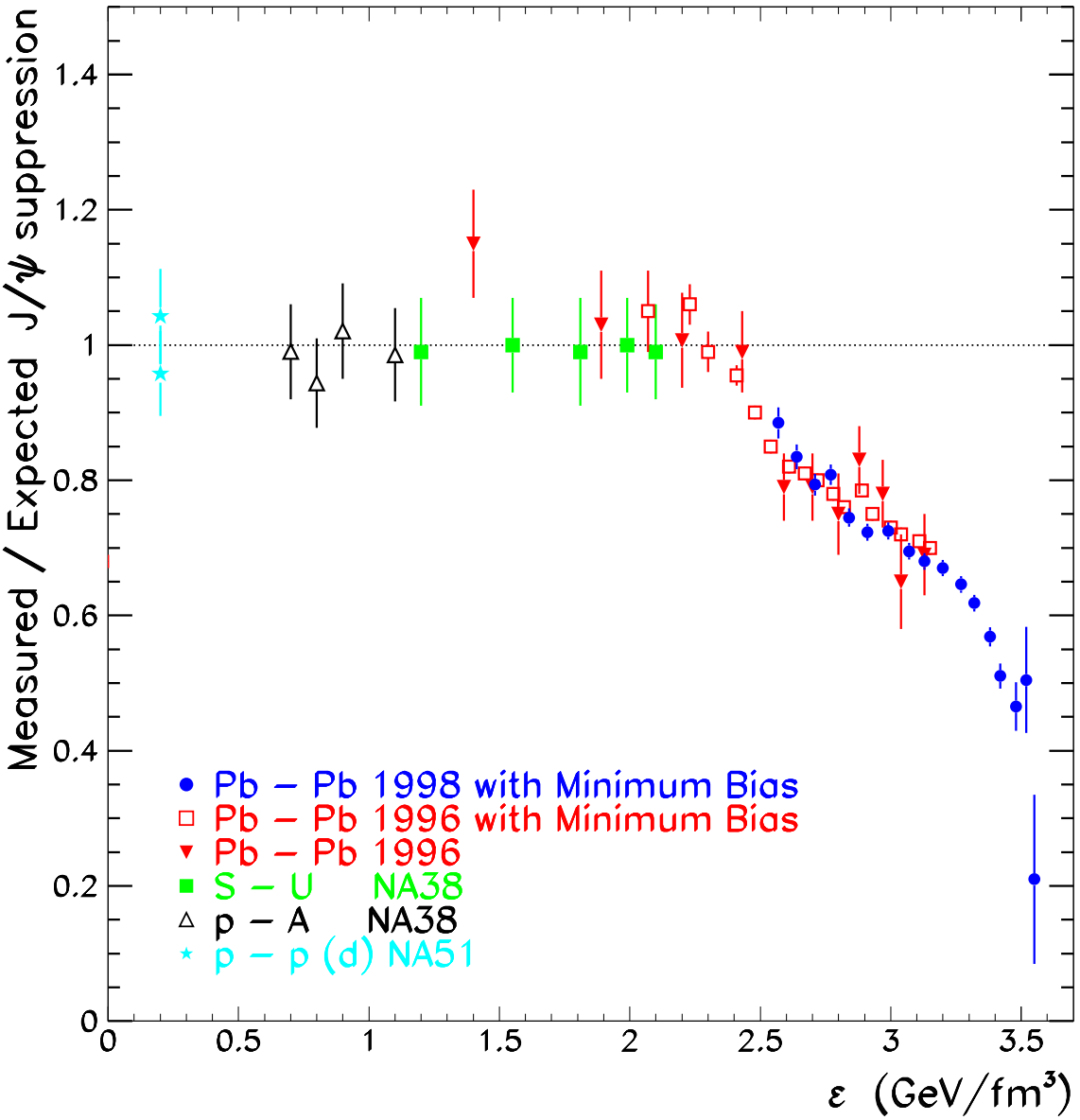
ψ/DY as a function of E_T

Comparision with conventional (hadronic) models



The stepwise suppression pattern rules out any of these conventional models

ψ suppression as a function of ϵ



Pattern shows a sudden drop at 2.3 GeV/fm^3 and an inflexion point at 3.1 GeV/fm^3 followed by a steady steepy decrease.

It can be naturally explained in the framework of quark-gluon plasma formation as successive melting of χ , then ψ , charmonium states.