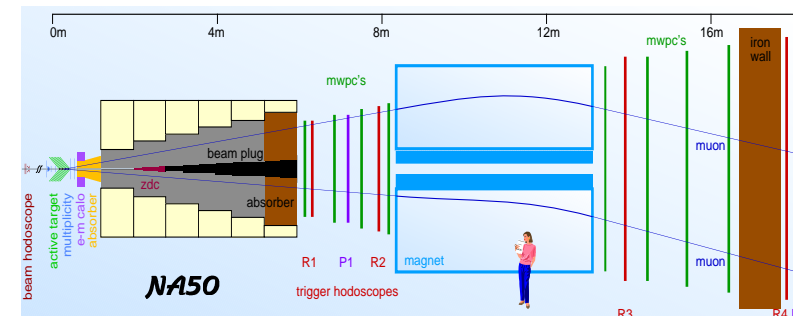# ψ' production in nucleus-nucleus collisions at the CERN/SPS

H. Santos, LIP-Lisbon, for the
NA50 Collaboration

Outline

- **NA50 experiment overview**

- **Analysis procedure**

- ψ'/DY **and** ψ'/ψ **results in Pb-Pb collisions**

- **Comparison with lighter systems (p-A and S-U)**
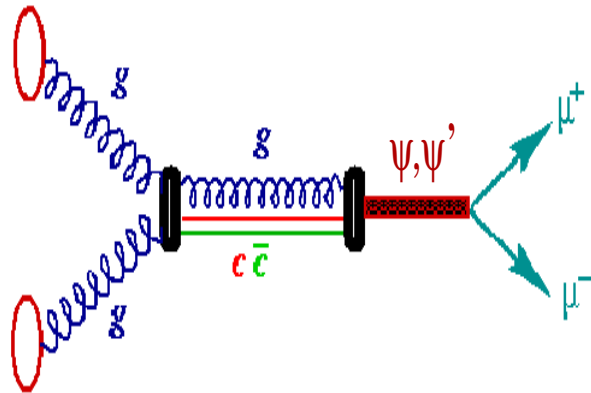
- **Conclusions**

The charmonia study

charmonia cross-sections

$$B'_{\mu^+\mu^-}\sigma(\psi') << B_{\mu^+\mu^-}\sigma(J/\psi)$$

Processes suppressing the charmonium states

- **Nuclear absorption of charmonia production**

- **Absorption by a hadron gas ("comovers")**

- **Debye colour screening on the $c\bar{c}$ pair potential**
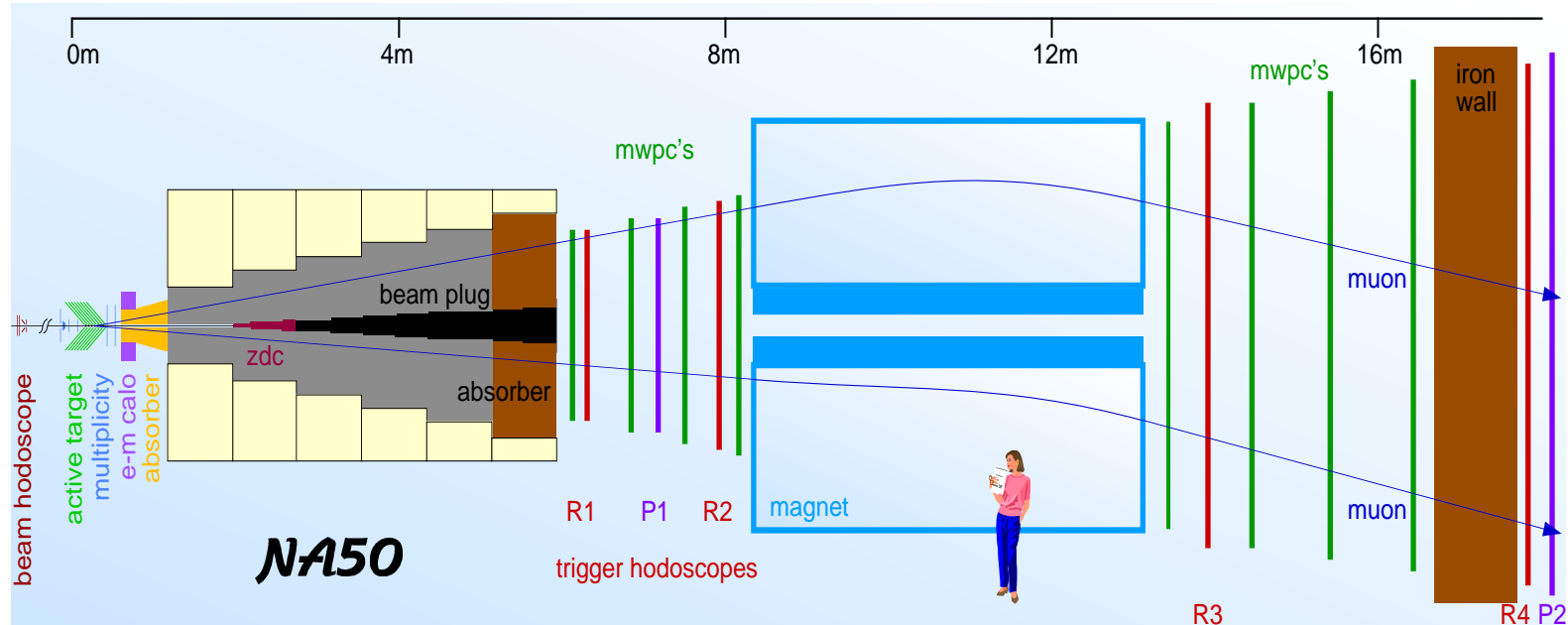
$$E_{binding}(\psi') \quad \sim \quad 50\, MeV$$
$$E_{binding}(\chi_c) \quad \sim 200\, MeV$$
$$E_{binding}(J/\psi) \sim 640\, MeV$$

The ψ' is a much weaker bound state than the J/ψ

The NA50 Experiment

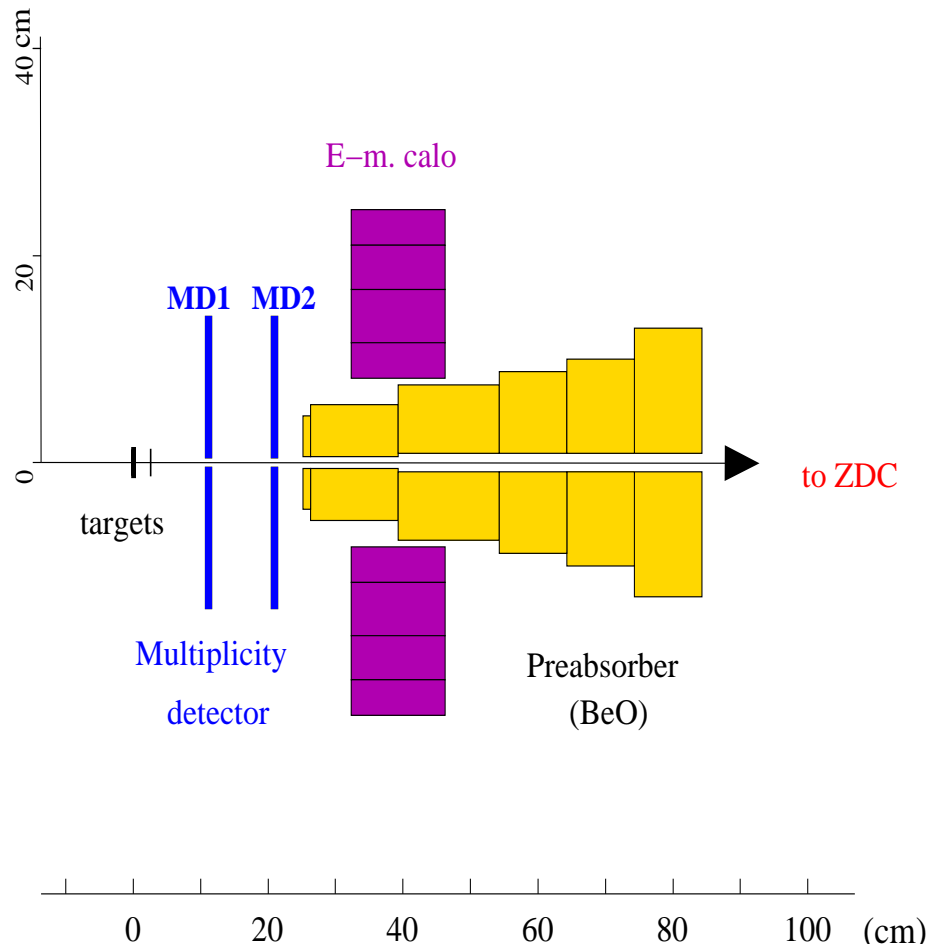**NA50 measures charmonia production via dimuon decays searching for signatures of quark and gluon deconfinement**

Kinematical Domain: $2.92 \leq y_{lab} < 3.92, \quad \mid cos\theta_{CS} \mid < 0.5$

Acceptances: $Acc(J/\psi) = 13.5\%$

$Acc(\psi') \quad = 14.8\%$

40 cm

20

0

E–m. calo

MD1 MD2

targets

to ZDC

Multiplicity

detector

Preabsorber

(BeO)

| 0 | 20 | 40 | 60 | 80 | 100 (cm) |

◇ **E.M. Calorimeter**

measures the neutral

transverse energy in

$$1.1 \leq \eta_{lab} < 2.3$$

◇ **Zero Degree Calorimeter**

measures the beam ion

spectators energy in

$$\eta_{lab} > 6.3$$

◇ **Multiplicity Detector**

measures charged

particles in

$$1.9 \leq \eta_{lab} < 4.2$$

NA50 is an upgrade of the previous **NA38** experiment (study of p-A and S-U systems) and uses proton and lead beams colliding on fixed targets
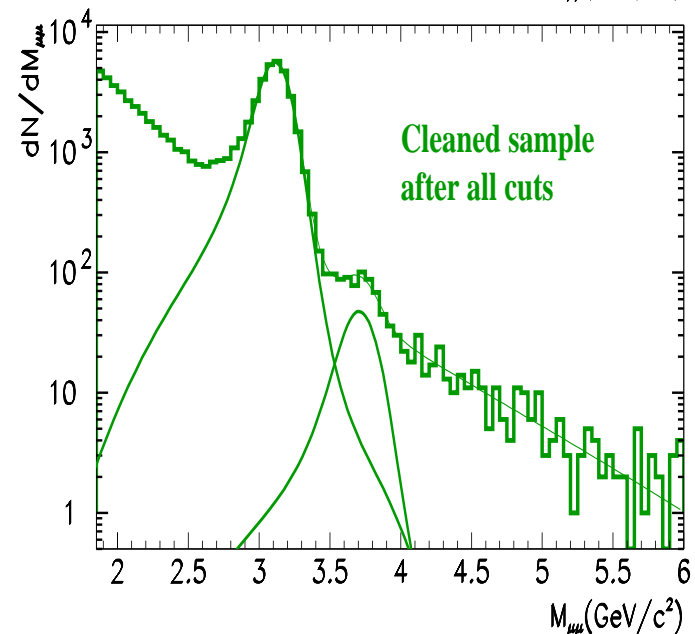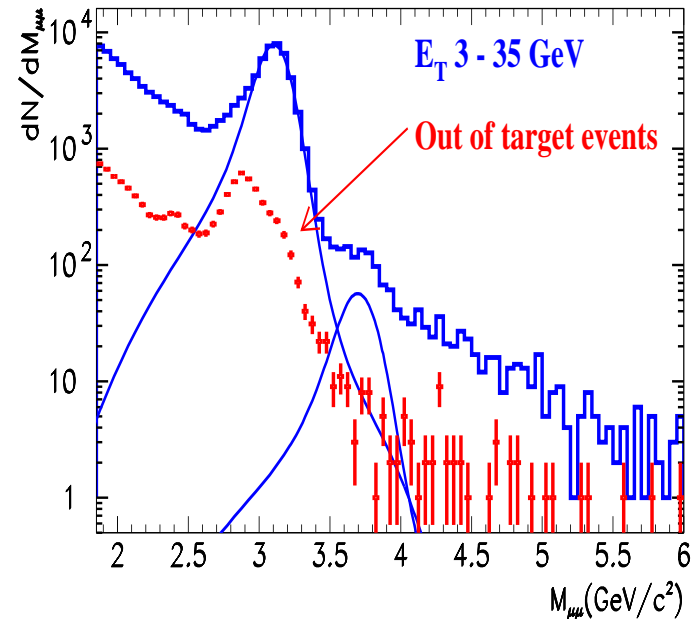
Data samples in Pb-Pb collisions

data sample	total target thickness	number of sub-targets	beam intensity (ions/burst)	number of J/ψ	number of ψ'
1995	17% λ_I	7 (in air)	3×10^7	50000	
1996	30% λ_I	7 (in air)	5×10^7	190000	
1998	7% λ_I	1 (in air)	5.5×10^7	49000	380
2000	9.5% λ_I	1 (in vacuum)	7×10^7	129000	905

- **Upstream interactions in Beam Hodoscope are rejected by dedicated detectors**

- **Interaction pileup is rejected**

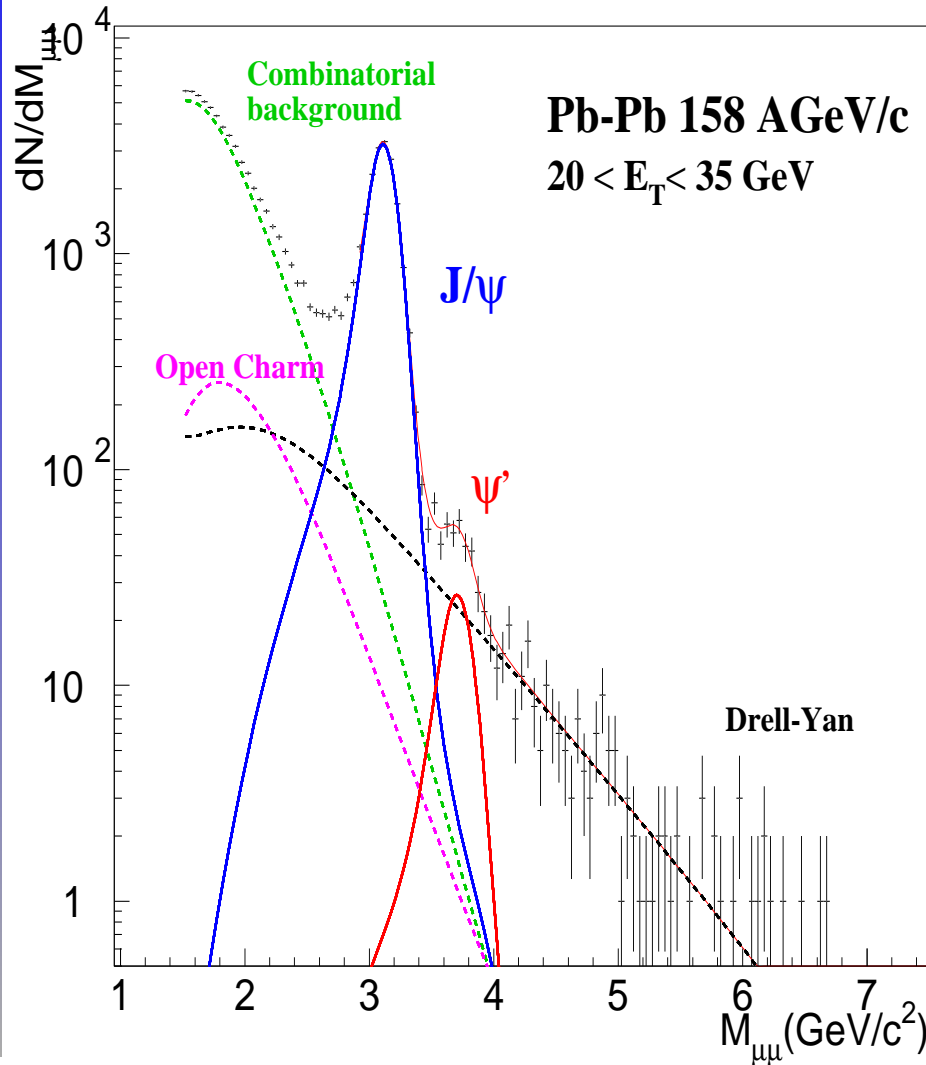- **In-target interactions are identified using the Multiplicity Detector and track quality cuts**

J/ψ **produced outside target pollutes the ψ' mass region**

After all cuts, a clean sample for analysis is obtained

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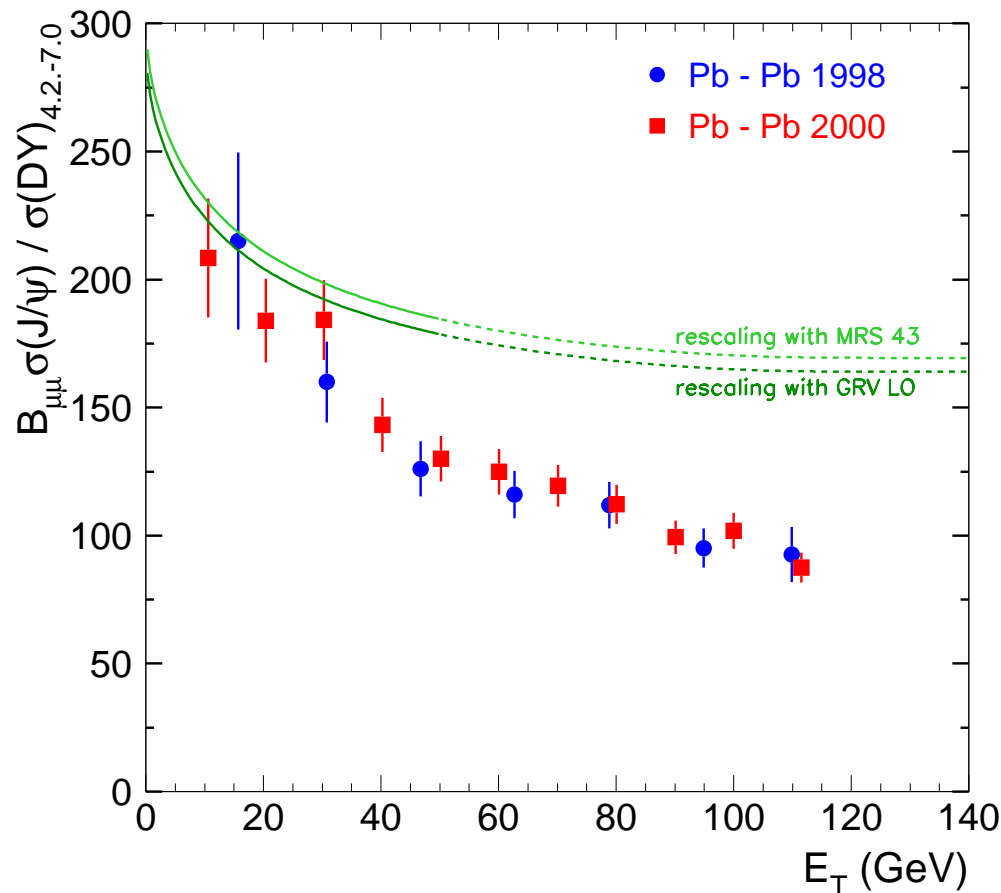
$$\frac{dN^{+-}}{dM} = A_{J/\psi}\frac{dN_{J/\psi}}{dM} + A_{\psi'}\frac{dN_{\psi'}}{dM} + A_{DY}\frac{dN_{DY}}{dM} + A_{D\bar{D}}\frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$

- J/ψ, ψ', DY and $D\bar{D}$ shapes are generated by Monte Carlo and reconstructed as real data

- J/ψ and ψ' mass resolutions are $\sim$100 MeV

- **Combinatorial background**, mostly from pion and kaon decays, is extracted from measured like-sign pairs

- Final fit performed for **M > 2.9 GeV/c^2**
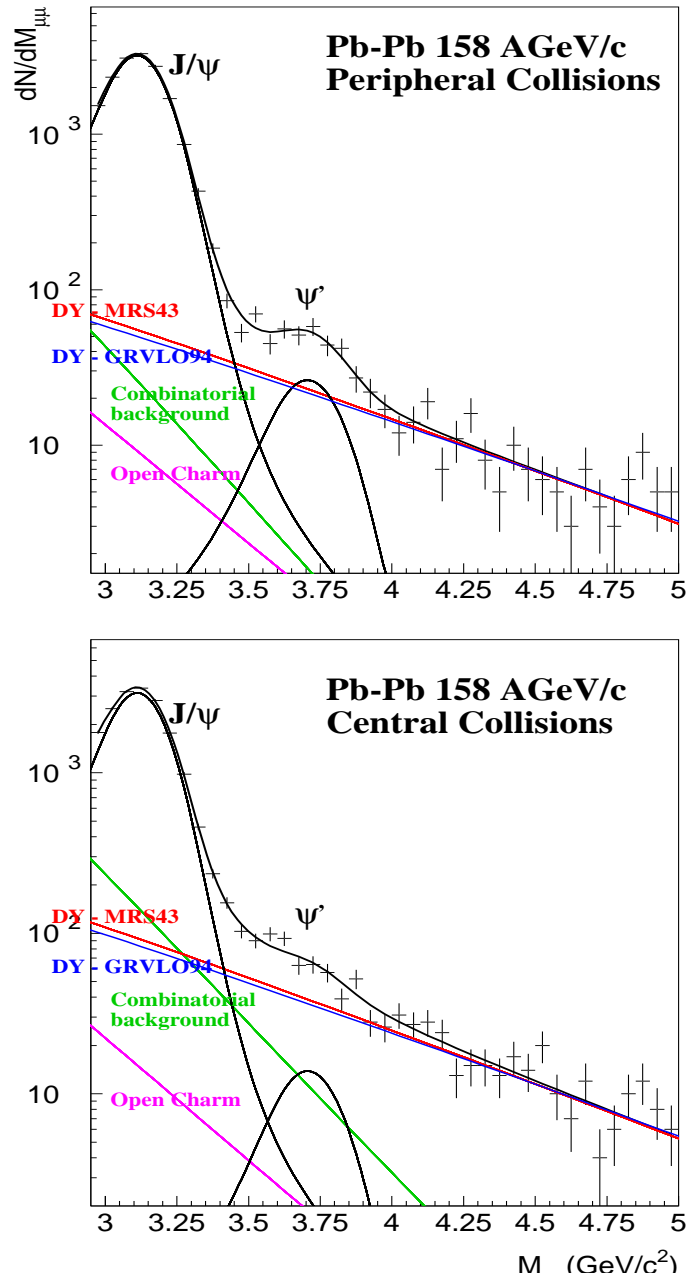
The J/ψ suppression

Results on $B_{\mu^+\mu^-}\sigma(J/\psi)/\sigma(DY_{4.2-7.0})$ **as a function of** E_T

- **The absorption curve fits our lighter systems: p-A (NA50) and S-U (NA38)**

- **Departure of** $J/\psi/DY$ **from the absorption curve at** $E_T \approx$ **40 GeV**

- **No saturation of** $J/\psi/DY$ **at high** E_T

J/ψ **is anomalously suppressed**

The ψ' study

Pb-Pb 158 AGeV/c Peripheral Collisions

Pb-Pb 158 AGeV/c Central Collisions

Challenging due to:

- **small dimuon cross section**
- **large suppression**
- **several dimuon sources overlap**

◇ **GRV LO** or **MRS NLO** structure functions chosen to simulate **Drell-Yan** induce 10% difference in ψ' normalizations
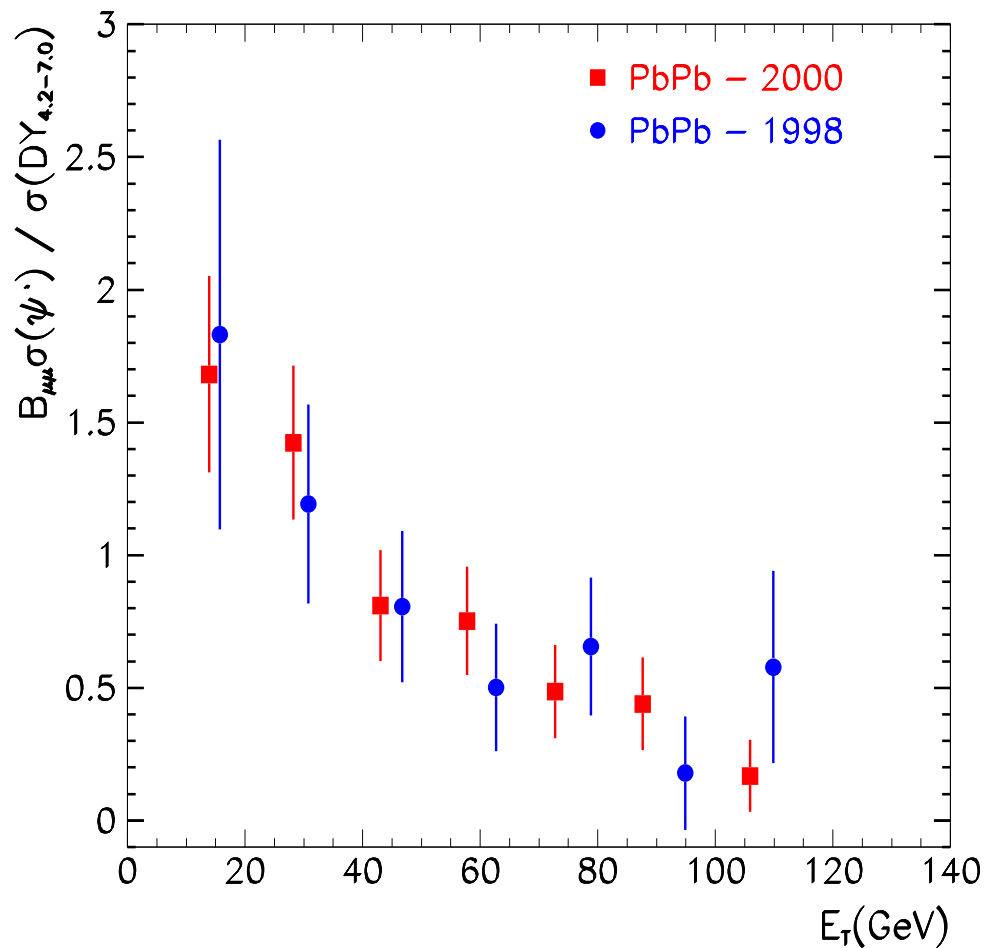
◇ **Combinatorial Background** is accurately measured from like-sign sample in each centrality region

◇ The uncertainty due to **Open Charm** semi-leptonic decays is negligible
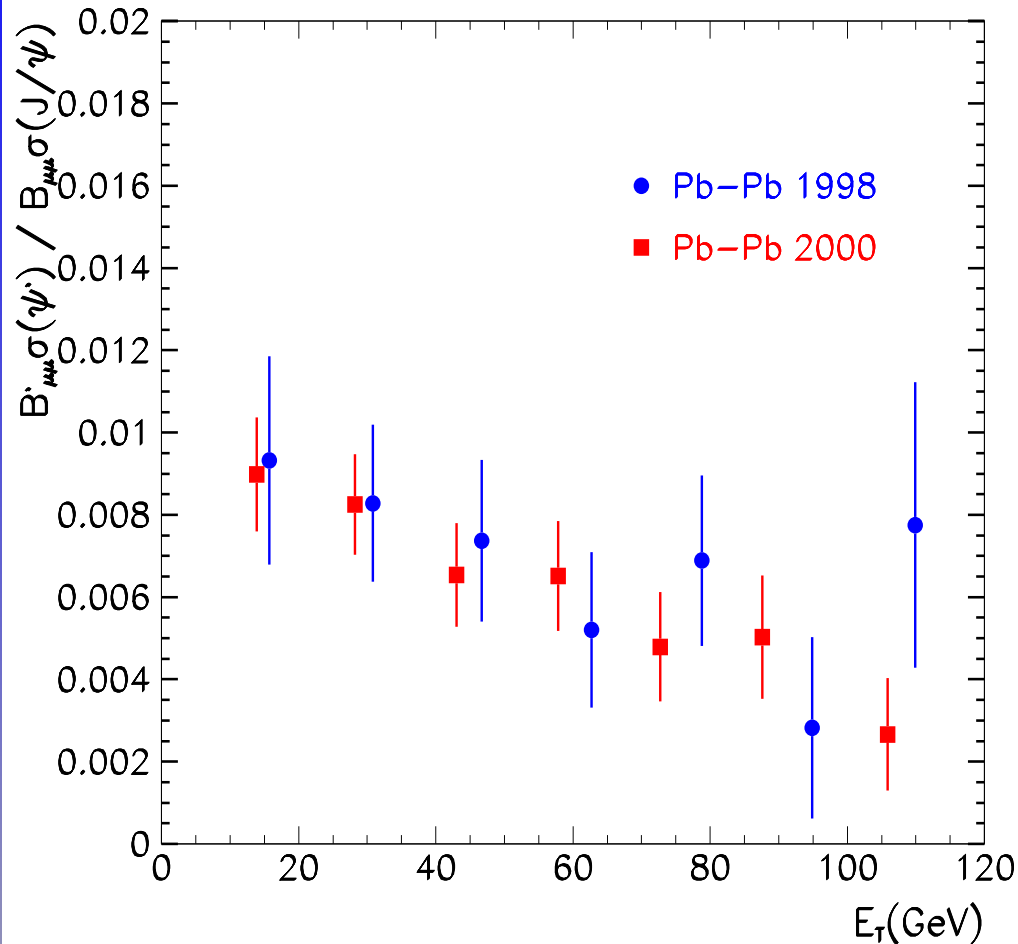
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$\psi'/DY_{4.2-7.0}$ as a function of E_T

Transverse energy, E_T, used as the collision centrality estimator

- ψ' **is increasingly suppressed with respect to Drell-Yan**

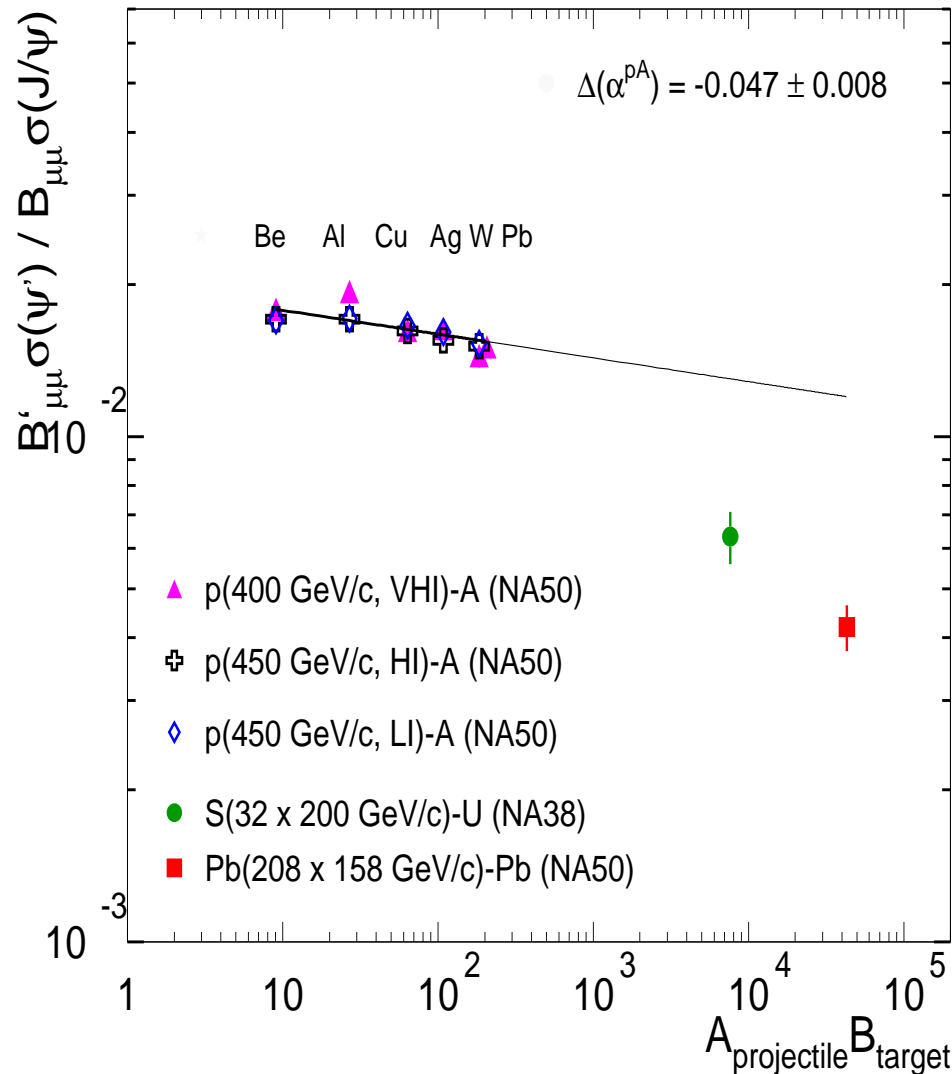- **Good compatibility between Pb-Pb 2000 and Pb-Pb 1998 results**

ψ'/ψ as a function of E_T

The ratio of the two charmonium states decreases with centrality by a factor of 2.5 between peripheral and central collisions

The ψ' is more suppressed than the J/ψ in Pb-Pb collisions

ψ'/ψ in p-A, S-U and Pb-Pb systems as a function of $A_{proj}B_{targ}$

- $B'_{\mu^+\mu^-}\sigma(\psi')/B_{\mu^+\mu^-}\sigma(\psi)$ **parametrized with a power law:** $A^{\Delta\alpha}$

- ψ' **is more suppressed than** J/ψ**, already in** **p-A** **collisions**

$$\alpha_{\psi'} - \alpha_{\mathbf{J}/\psi} = -0.047 \pm 0.008$$

- ψ' **is even more suppressed in** **ion induced** **interactions**

Inside figure:

$\Delta(\alpha^{pA}) = -0.047 \pm 0.008$

Be   Al   Cu Ag W Pb

▲ p(400 GeV/c, VHI)-A (NA50)

✚ p(450 GeV/c, HI)-A (NA50)

◇ p(450 GeV/c, LI)-A (NA50)

● S(32 x 200 GeV/c)-U (NA38)

■ Pb(208 x 158 GeV/c)-Pb (NA50)

$B'_{\mu\mu}\sigma(\psi') / B_{\mu\mu}\sigma(J/\psi)$

$A_{projectile}B_{target}$

$\psi'/DY_{4.2-7.0}$ in p-A, S-U and Pb-Pb systems as a function of L

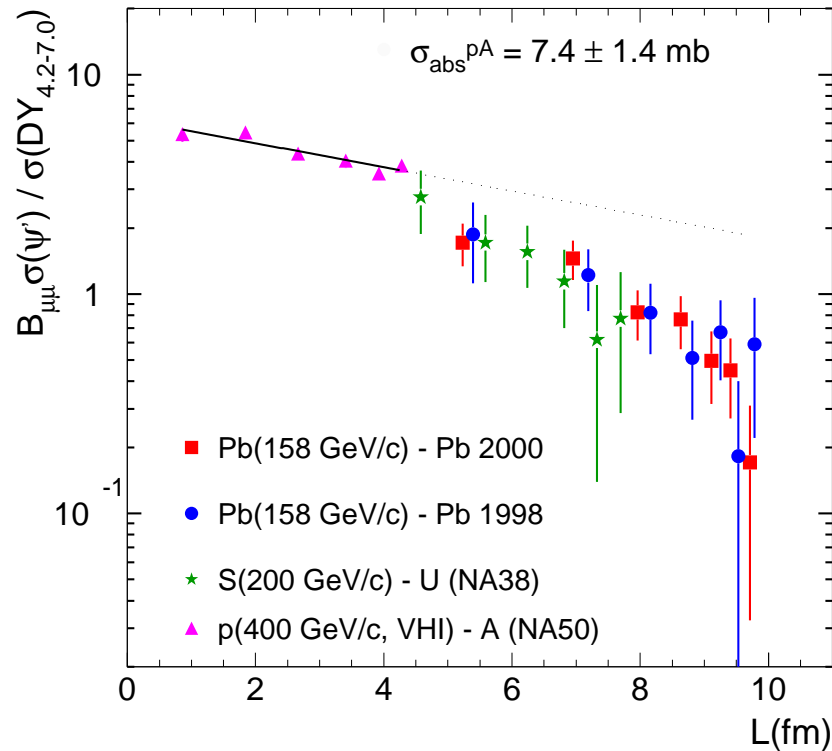L **is the mean free path crossed by the** $c\bar{c}$ **pair in the nuclear matter**

Using an exponential parametrization:

$$\sigma_{\mathbf{o}}\mathbf{e}^{-<\rho \mathbf{L}>\sigma_{\mathbf{abs}}}$$

one obtains in p-A collisions for ψ'

$$\sigma_{abs}^{pA} = 7.4 \pm 1.4 \ \mathbf{mb}$$

- **Different behaviours between p-A and A-B collisions**

- **Strong suppression of** ψ' **between peripheral and central A-B interactions**

- **The** ψ' **suppression is the same in S-U and Pb-Pb collisions as a function of centrality**

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L **is the mean free path crossed by the** $c\bar{c}$ **pair in the nuclear matter**

σ$_{abs}$^{pA} = 7.4 ± 1.4 mb

σ$_{abs}$$^{A\text{-}B}$ = 21.6 ± 2.5 mb

- Pb(158 GeV/c) - Pb 2000
- Pb(158 GeV/c) - Pb 1998
- S(200 GeV/c) - U (NA38)
- p(400 GeV/c, VHI) - A (NA50)

Using an exponential parametrization:

$$\sigma_{\mathbf{o}}\mathbf{e}^{-<\rho \mathbf{L}>\sigma_{\mathbf{abs}}}$$

one obtains in p-A collisions for ψ'

$$\sigma_{abs}^{pA} = 7.4 \pm 1.4 \ \mathbf{mb}$$
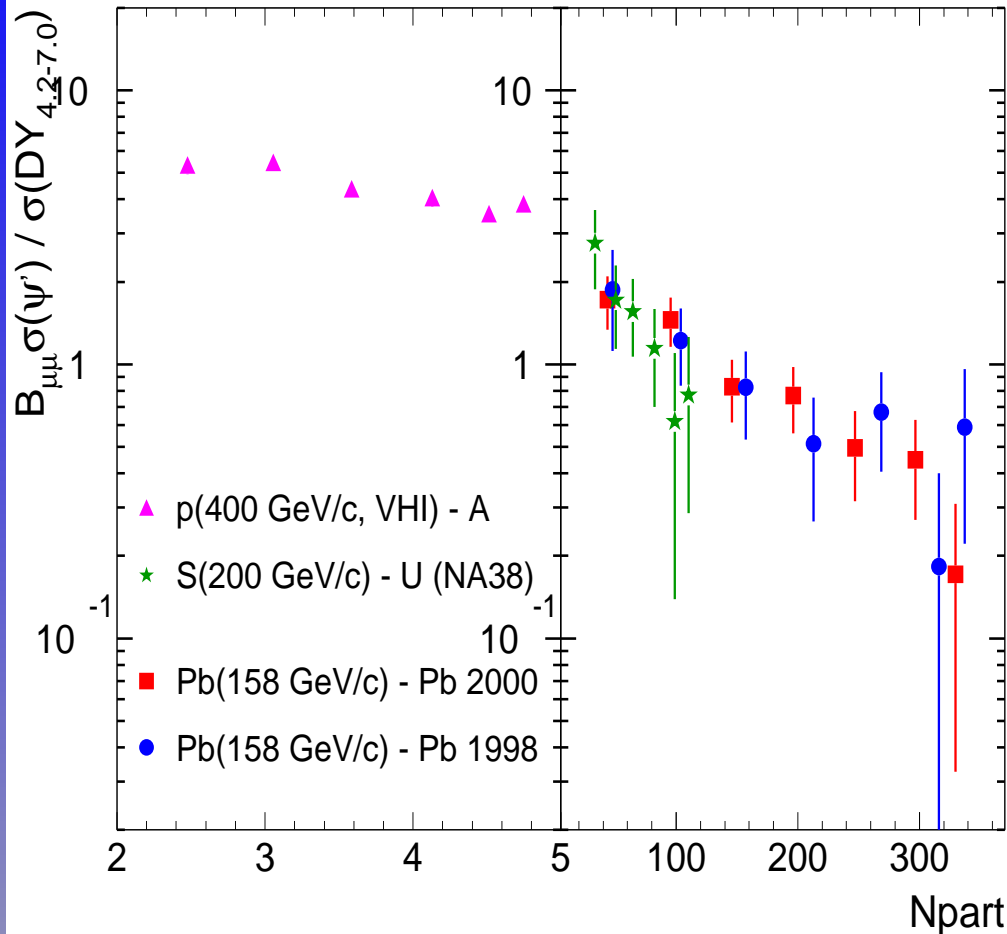
and

$$\sigma_{abs}^{AB} = 21.6 \pm 2.5 \ \mathbf{mb}$$

for S-U and Pb-Pb 2000 collisions fitted simultaneously

- **Different behaviours between p-A and A-B collisions**

- **Strong suppression of** ψ' **between peripheral and central A-B interactions**

- **The** ψ' **suppression is the same in S-U and Pb-Pb collisions as a function of centrality**

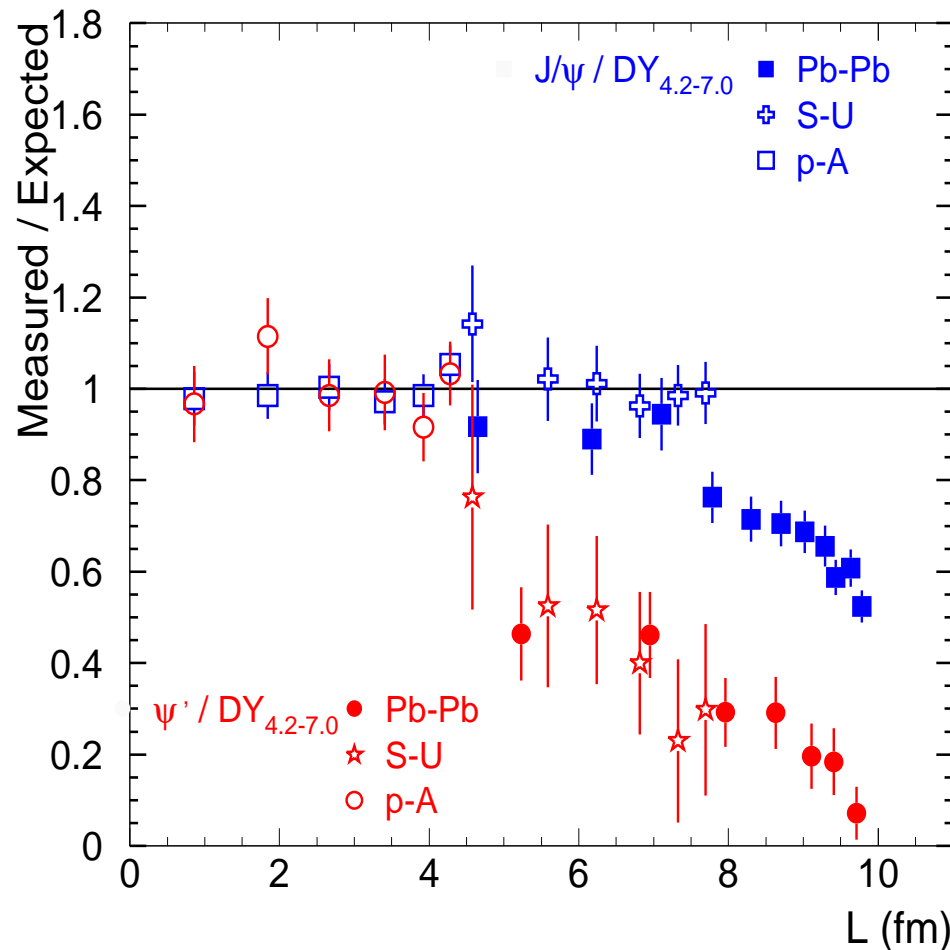# $\psi'/DY_{4.2-7.0}$ in p-A, S-U and Pb-Pb systems as a function of N_{part}

- **The centrality estimator N_{part} is calculated from the measured transverse energy:**

$$< E_T(b) > = qNpart(b)$$

q **is the mean energy per participant deposited in the electromagnetic calorimeter**

The $B_{\mu\mu}\sigma(\psi')/\sigma(DY_{4.2-7.0})$ **behaviour, as a function of the number of participants in the collision, exhibits again the ψ' strong suppression in A-B interactions**

Expected: absorption model (full Glauber calculation) with

$$\sigma_{\mathbf{abs}}^{\mathbf{J}/\psi} = 4.3 \pm 0.3 \ \mathbf{mb}$$

$$\sigma_{\mathbf{abs}}^{\psi'} = 7.9 \pm 0.6 \ \mathbf{mb}$$

In A-B collisions, the ψ' departs from the absorption curve for less central reactions w.r.t. the J/ψ

Conclusions

For Pb-Pb collisions:

- ψ' is suppressed as a function of centrality w.r.t. **Drell-Yan** by a factor of **7** between **peripheral** and **central** collisions

- The ratio of ψ'/ψ decreases with centrality by a factor of **2.5** between **peripheral** and **central** collisions

Comparison with lighter systems:

- ψ'/**DY** is much more suppressed in **A-B** than in **p-A** reactions and its pattern suppression is the same in **S-U** and **Pb-Pb** as a function of centrality

- The ψ' anomalous suppression sets in earlier than for J/ψ

NA50 Collaboration Institutions

- **Università del Piemonte Orientale, Alessandria and INFN-Torino, Italy**

- **LAPP, CNRS-IN2P3, Annecy-le-Vieux, France**

- **LPC, Univ. Blaise Pascal and CNRS-IN2P3, Aubière, France**

- **IFA, Bucharest, Romania**

- **Università di Cagliari/INFN, Cagliari, Italy**

- **CERN, Geneva, Switzerland**

- **LIP, Lisbon, Portugal**

- **INR, Moscow, Russia**

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