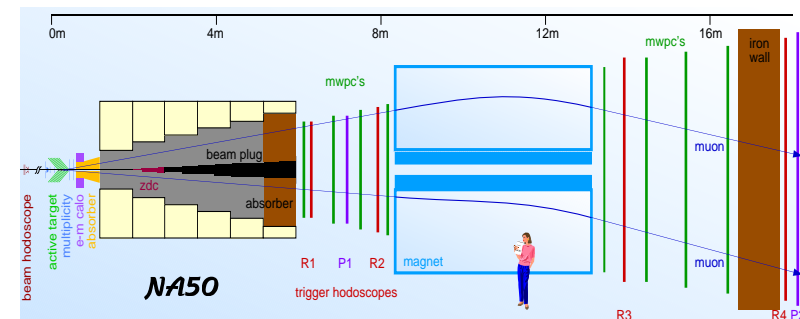


ψ' production in nucleus-nucleus collisions at the CERN/SPS

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



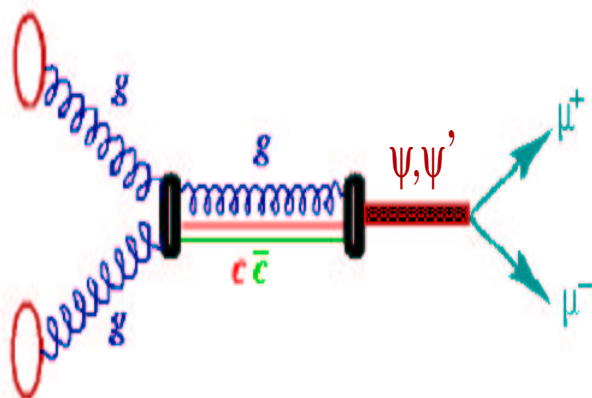
The charmonia study

charmonia cross-sections

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

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



$$E_{binding}(\psi') \sim 50 \text{ MeV}$$

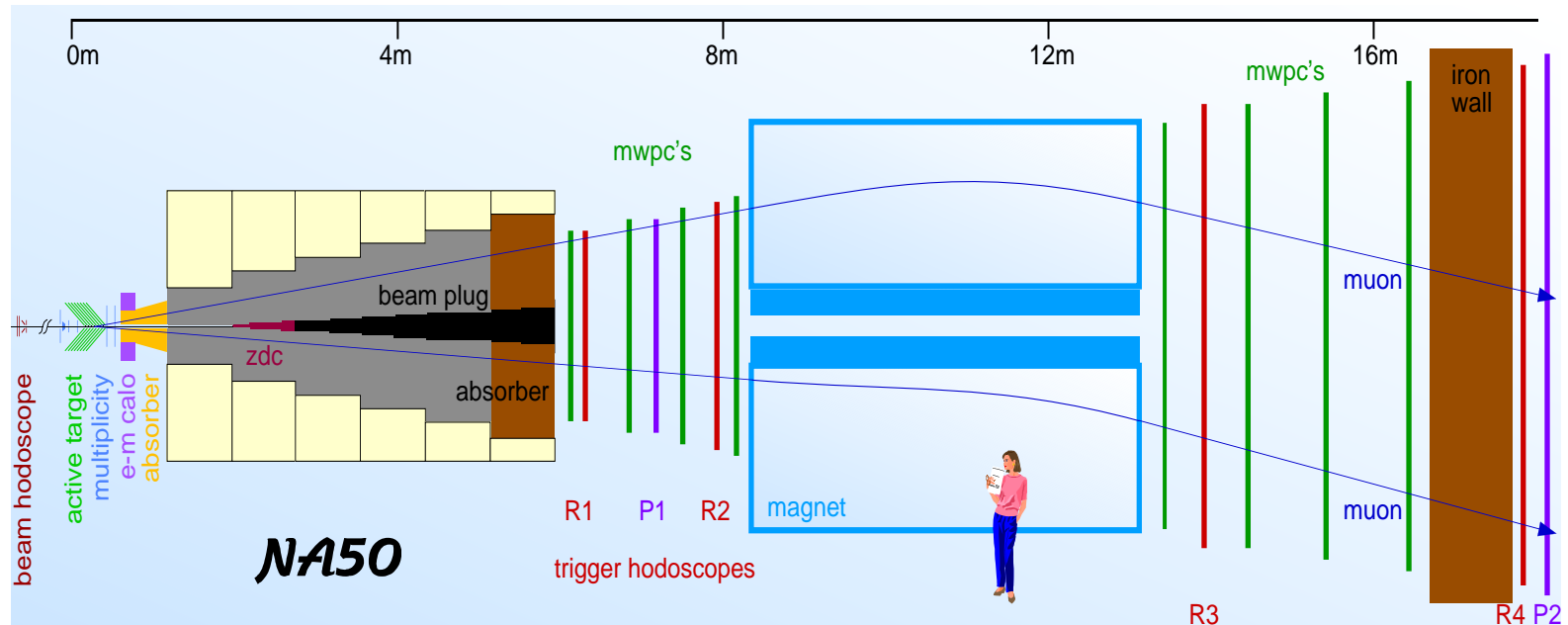
$$E_{binding}(\chi_c) \sim 200 \text{ MeV}$$

$$E_{binding}(J/\psi) \sim 640 \text{ MeV}$$

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**

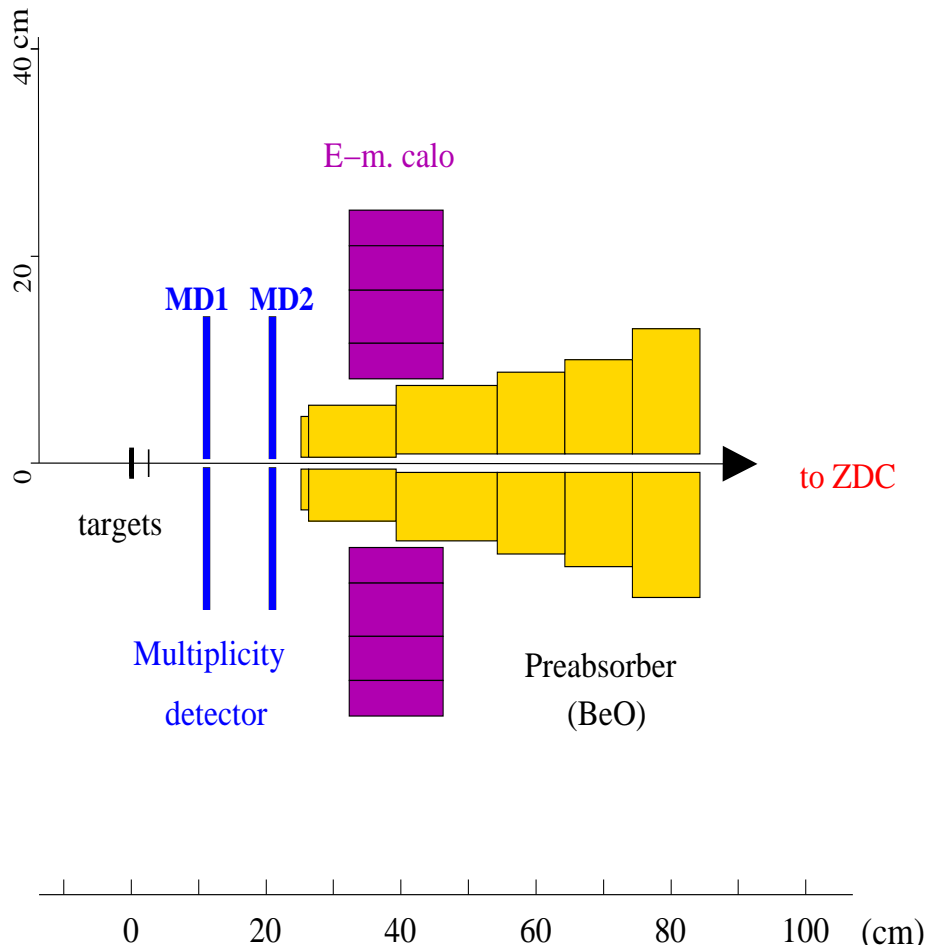


Kinematical Domain: $2.92 \leq y_{lab} < 3.92$, $|\cos\theta_{CS}| < 0.5$

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

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

Target region detectors



◇ 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

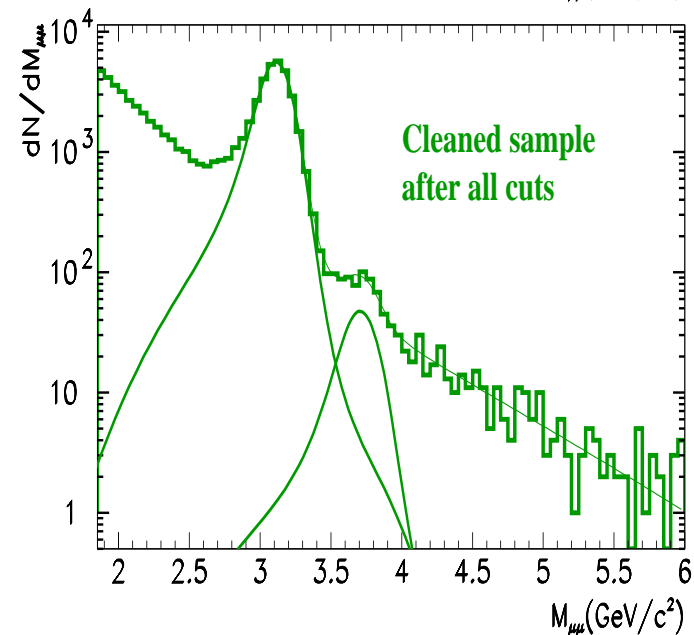
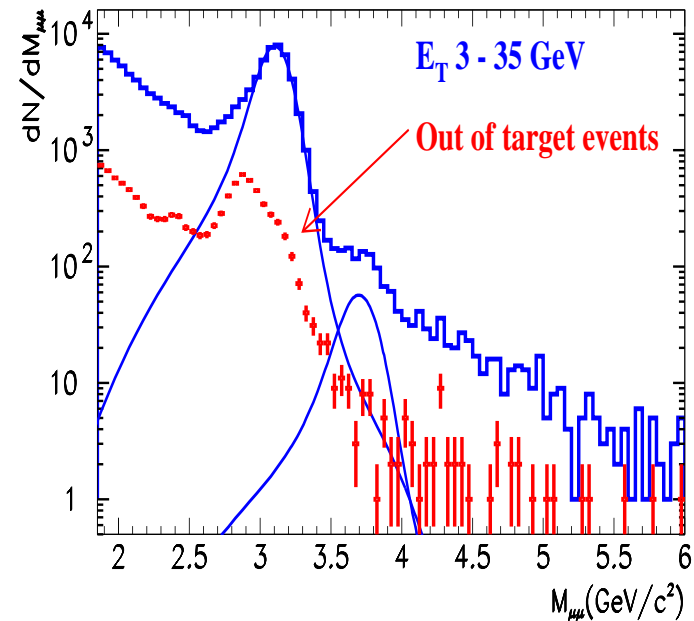
data sample	total target thickness	number of sub-targets	beam intensity (ions/burst)	number of J/ψ	number of ψ'
1995	17% λ_I	7 (in air)	3×10^7	50000	
1996	30% λ_I	7 (in air)	5×10^7	190000	
1998	7% λ_I	1 (in air)	5.5×10^7	49000	380
2000	9.5% λ_I	1 (in vacuum)	7×10^7	129000	905

Data selection

- 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

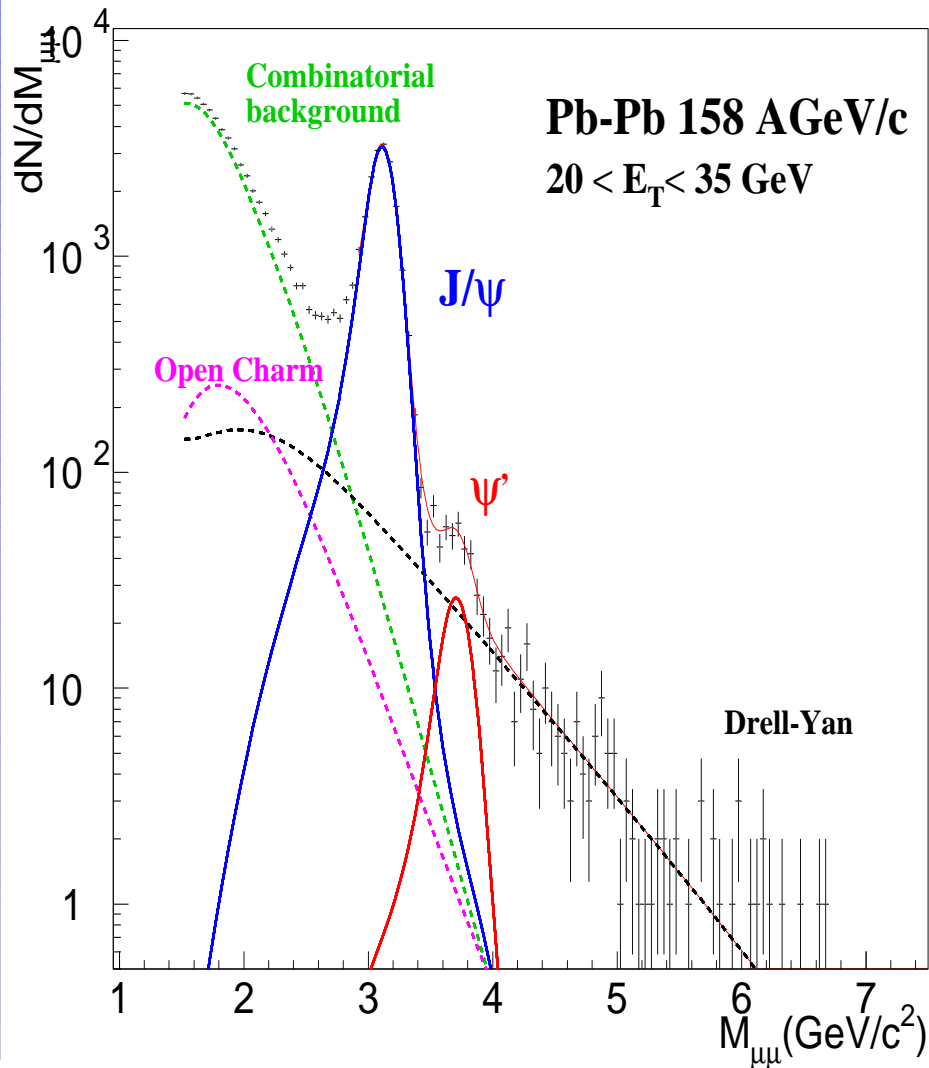
J/ψ produced outside target pollutes the ψ' mass region

After all cuts, a clean sample for analysis is obtained



Analysis Procedure

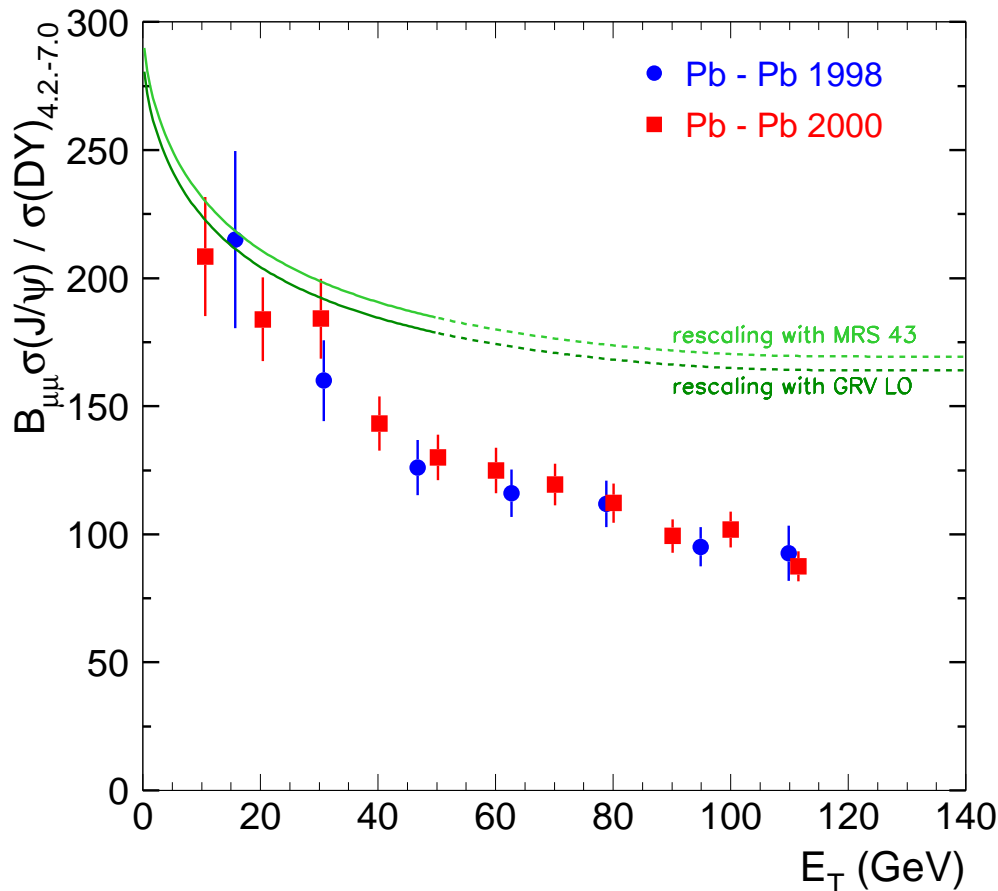
$$\frac{dN^{+-}}{dM} = A_{J/\psi} \frac{dN_{J/\psi}}{dM} + A_{\psi'} \frac{dN_{\psi'}}{dM} + A_{DY} \frac{dN_{DY}}{dM} + A_{D\bar{D}} \frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$



- 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 ~ 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/c²

The J/ψ suppression

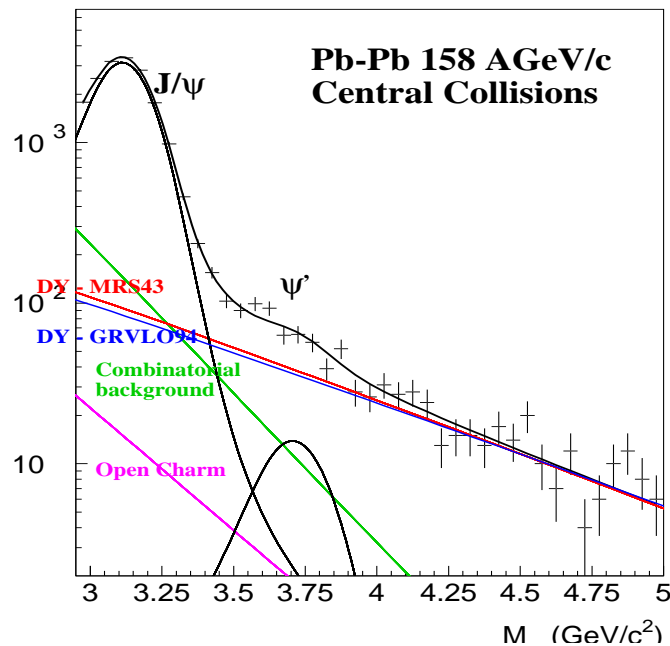
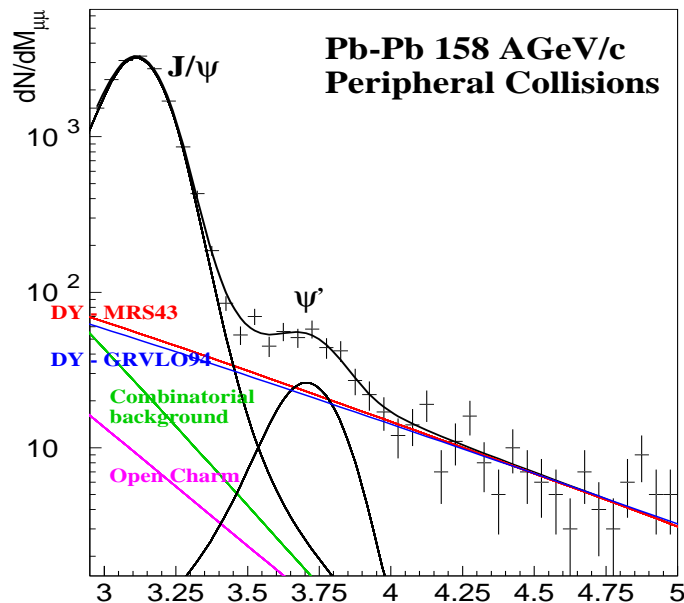
Results on $B_{\mu+\mu-} \sigma(J/\psi) / \sigma(DY_{4.2-7.0})$ as a function of E_T



- 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



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

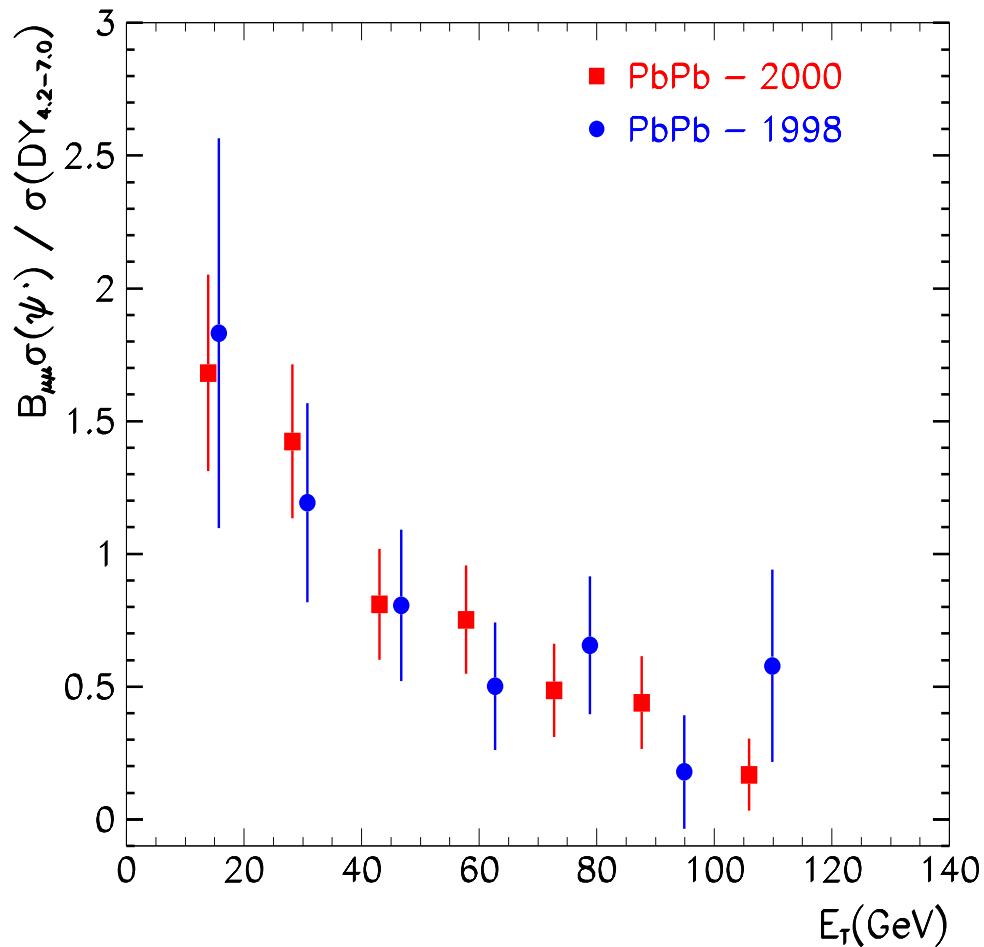
◇ Combinatorial Background is

accurately measured from like-sign
sample in each centrality region

◇ The uncertainty due to Open Charm
semi-leptonic decays is negligible

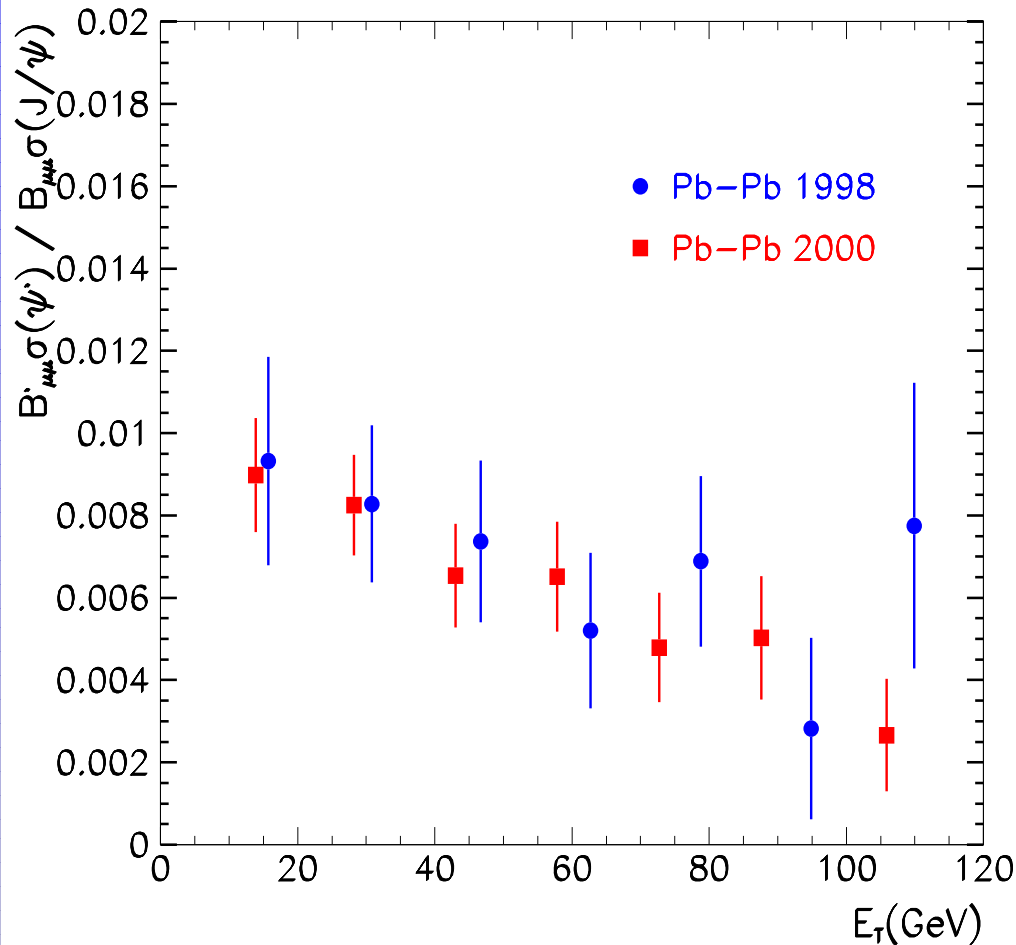
$\psi' / DY_{4.2-7.0}$ as a function of E_T

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

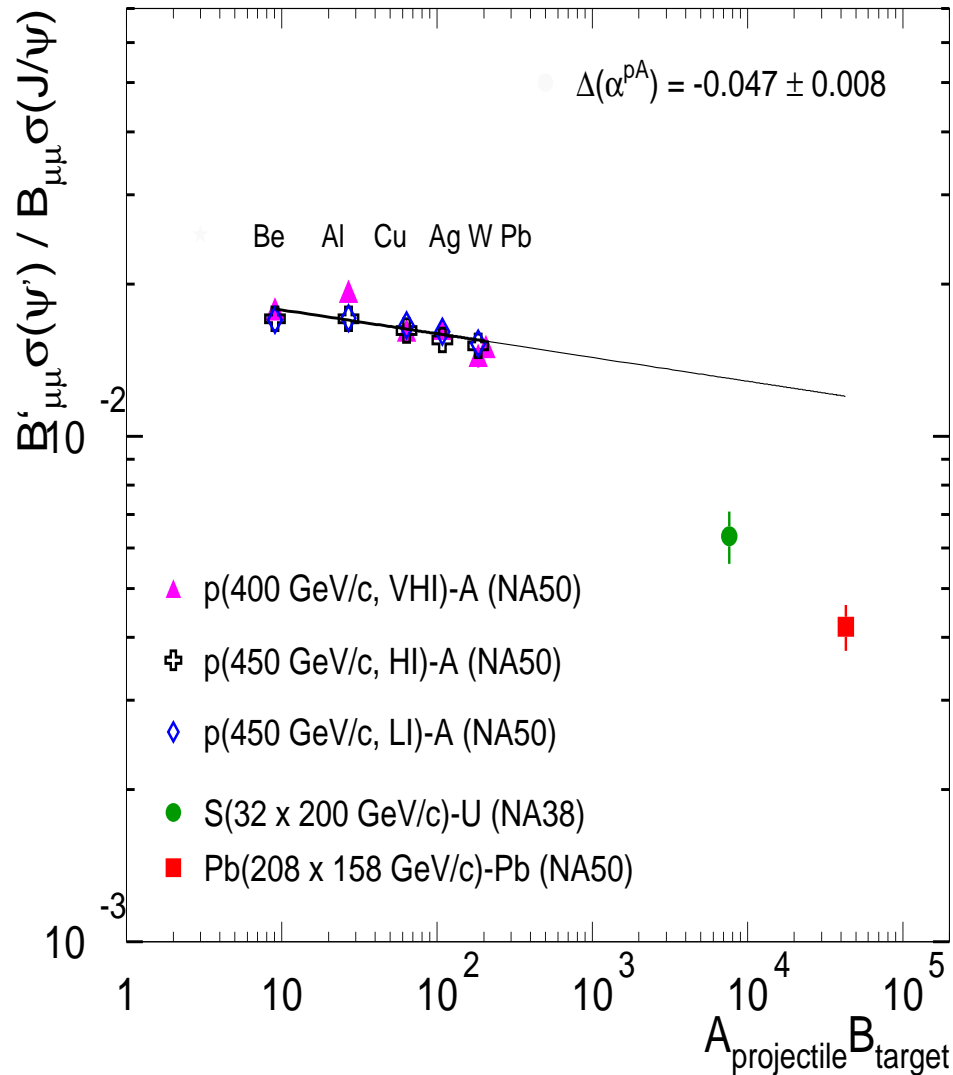
ψ' / ψ as a function of E_T



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

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

- ψ' is even more suppressed in ion induced interactions

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

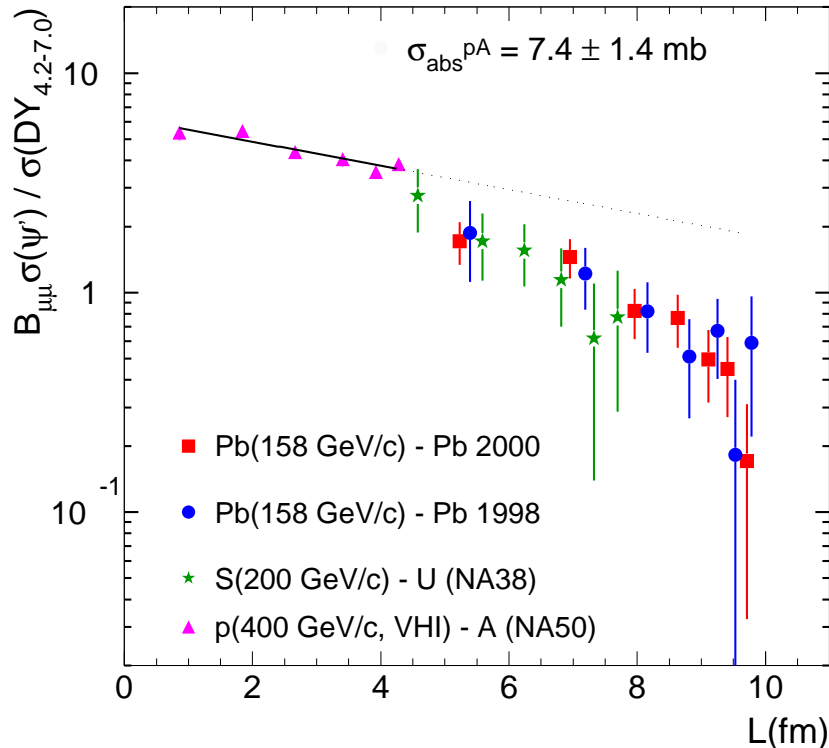
L is the mean free path crossed by the $c\bar{c}$ pair in the nuclear matter

Using an exponential parametrization:

$$\sigma_0 e^{-\langle \rho L \rangle} \sigma_{abs}$$

one obtains in p-A collisions for ψ'

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



- 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

$\psi' / DY_{4.2-7.0}$ 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:

$$\sigma_0 e^{-\langle \rho L \rangle} \sigma_{abs}$$

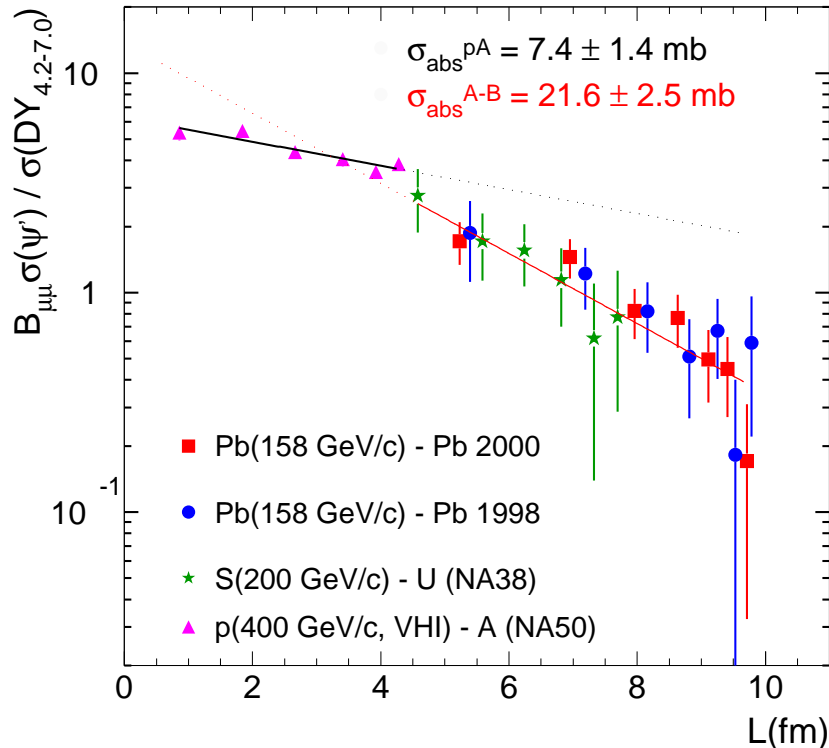
one obtains in p-A collisions for ψ'

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

and

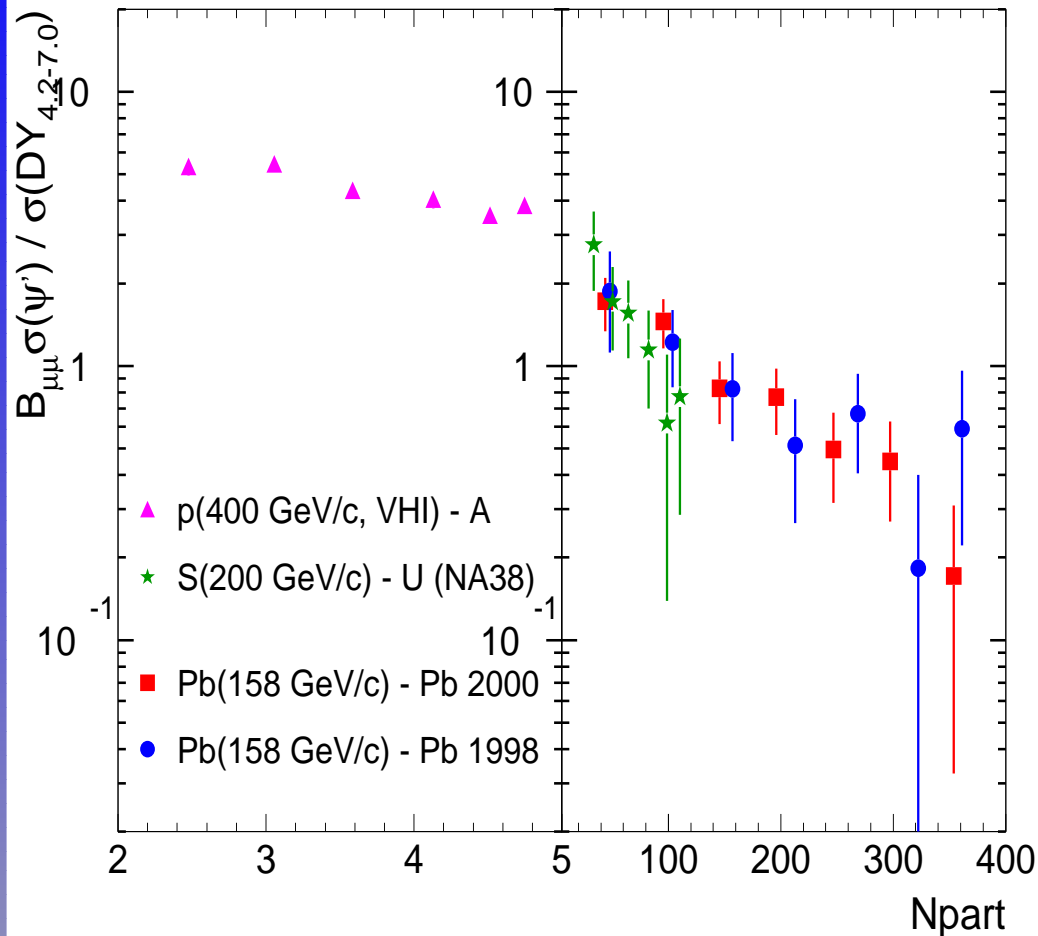
$$\sigma_{abs}^{AB} = 21.6 \pm 2.5 \text{ mb}$$

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}



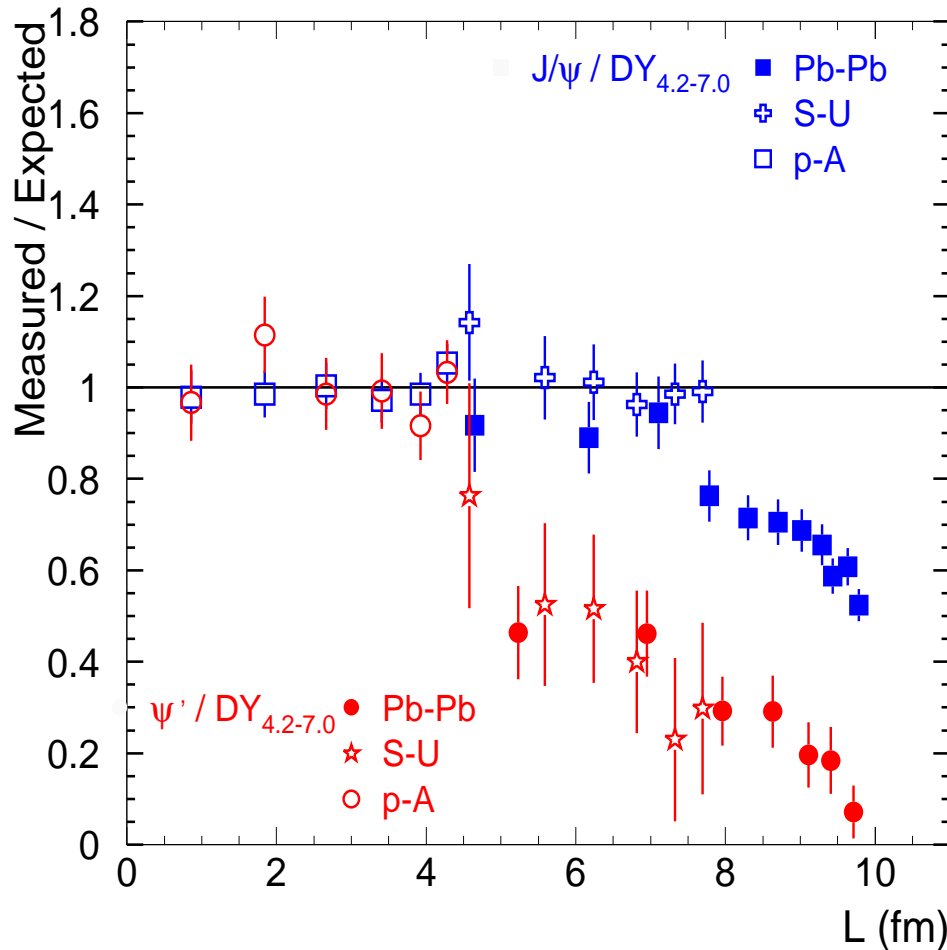
- The centrality estimator N_{part} is calculated from the measured **transverse energy**:

$$\langle E_T(b) \rangle = q N_{part}(b)$$

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

J/ψ and ψ' measured over expected



Expected: absorption model (full Glauber calculation) with

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

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

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

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

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- **IFA, Bucharest, Romania**
- **Università di Cagliari/INFN, Cagliari, Italy**
- **CERN, Geneva, Switzerland**
- **LIP, Lisbon, Portugal**
- **INR, Moscow, Russia**
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