# Results on ψ' Production in Nucleus-Nucleus Collisions at CERN/SPS

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for the NA50 Collaboration

# Physics Motivations

- **Charmonia production in pp, pA, AA collisions**

- $c\bar{c}$ **states suppressed by**

    - ◆ normal absorption in nuclear matter

        - ▫ nuclear absorption

        - ▫ absorption by hadron gas

    - ◆ anomalous suppression

        - ▫ Debye colour screening

➡ Need for a systematic study
with different systems

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# The NA50 Experiment
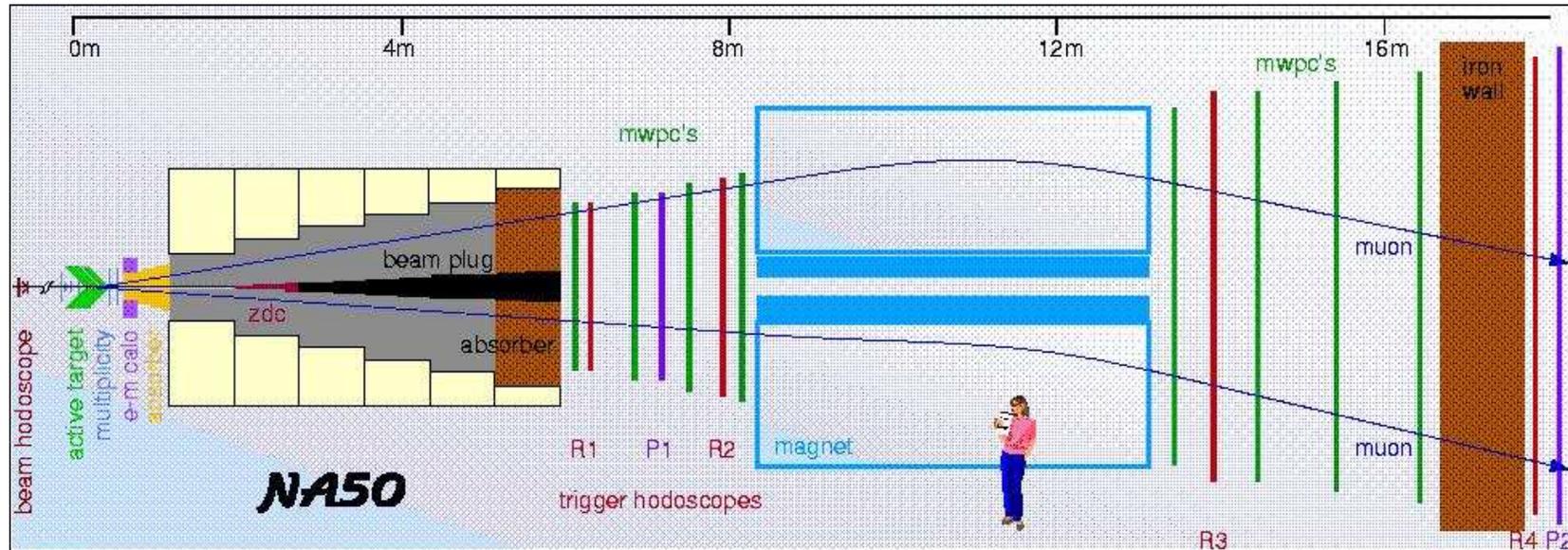


Charmonia detection via dimuon decay

$J/\psi$ , $\psi' \rightarrow \mu^+ \mu^-$

Dimuon detection in

$$2.92 \leq y_{lab} < 3.92 \quad \text{and} \quad |\cos \theta_{CS}| < 0.5$$

Typical acceptances: $A_{J/\psi} = 13.5\%$ , $A_{\psi'} = 14.8\%$

# The Target Region
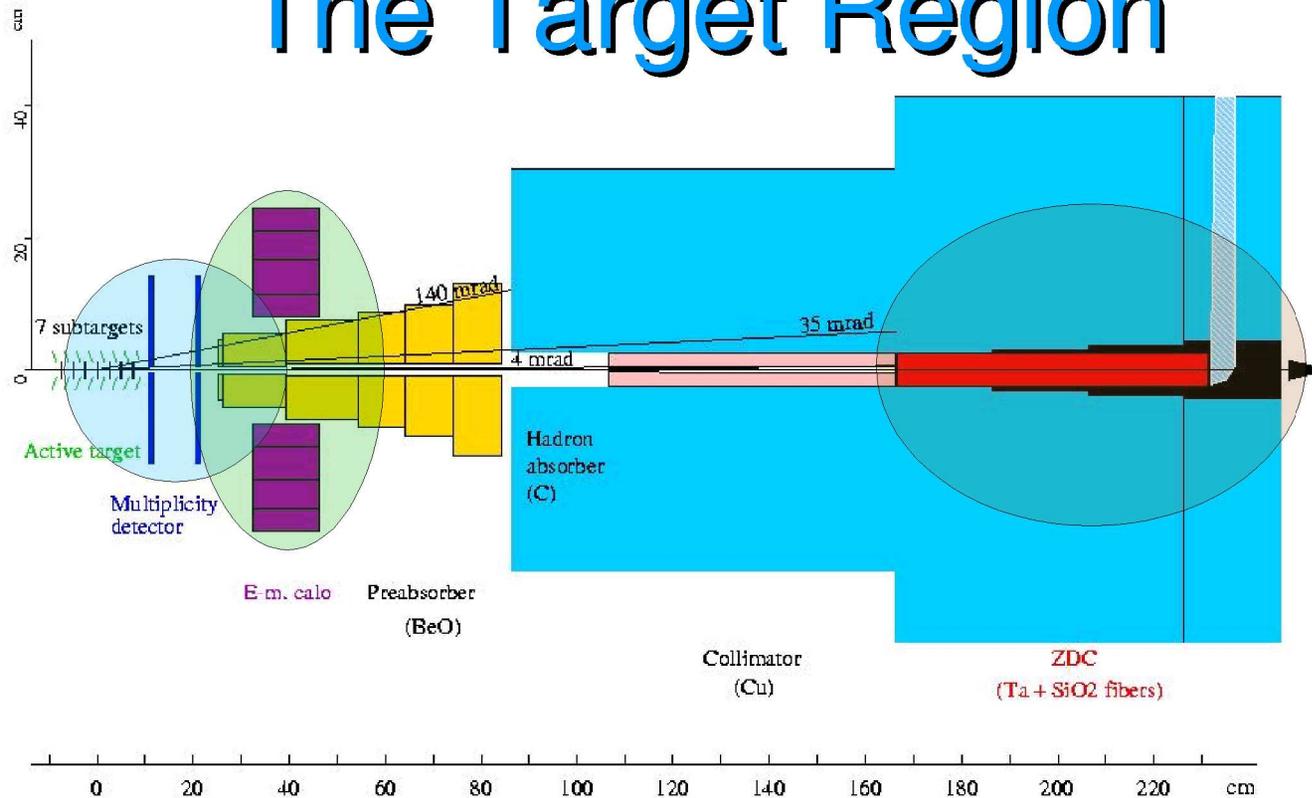


**Multiplicity Detector**
measures charged particles in
$1.9 \leq \eta_{lab} < 4.2$

**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
$\eta_{lab} > 6.3$

# Data Collection

NA50 uses proton and lead beams colliding on different fixed targets

## Data samples in Pb-Pb collisions

| Data taking period | Target thickness | Number of subtargets | Beam intensity (ions/burst) | Number of J/$\psi$ | Number of $\psi'$ |
|---|---|---|---|---|---|
| 1995 | 17% $\lambda_I$ | 7 (in air) | $3 \times 10^7$ | 50000 | |
| 1996 | 30% $\lambda_I$ | 7 (in air) | $5 \times 10^7$ | 190000 | |
| 1998 | 7% $\lambda_I$ | 1 (in air) | $5.5 \times 10^7$ | 49000 | 380 |
| 2000 | 9.5% $\lambda_I$ | 1 (in vacuum) | $7 \times 10^7$ | 129000 | 905 |

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# Data Selection

- Upstream interactions in Beam Hodoscope rejected by dedicated detectors

- Rejection of interaction pileup

- Target interactions 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 is obtained
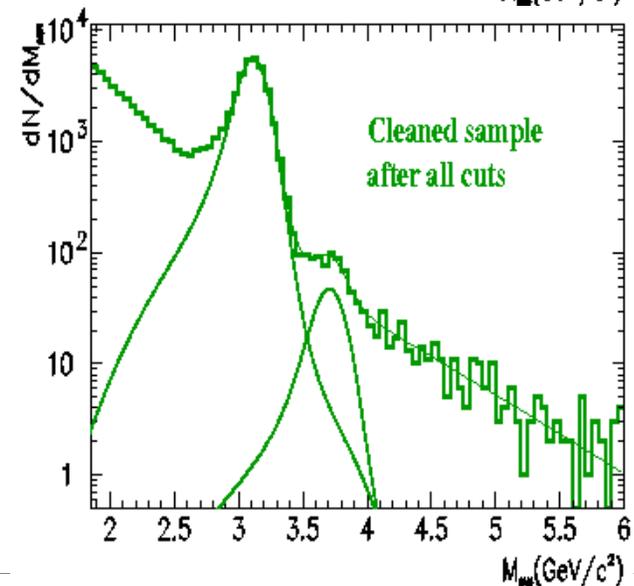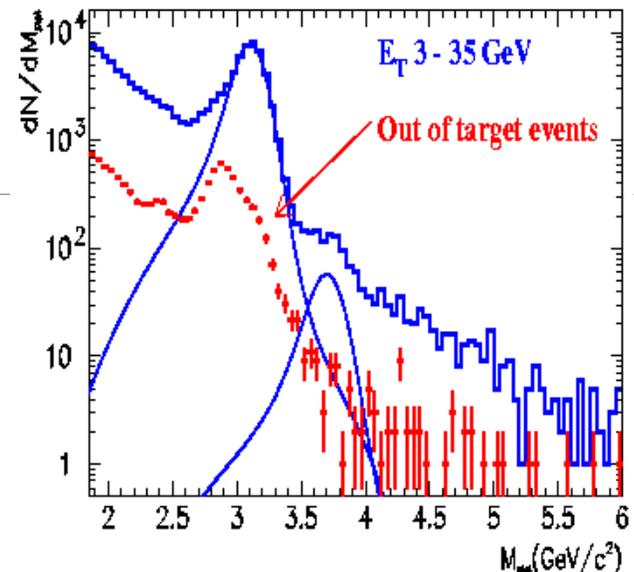
# Analysis Method

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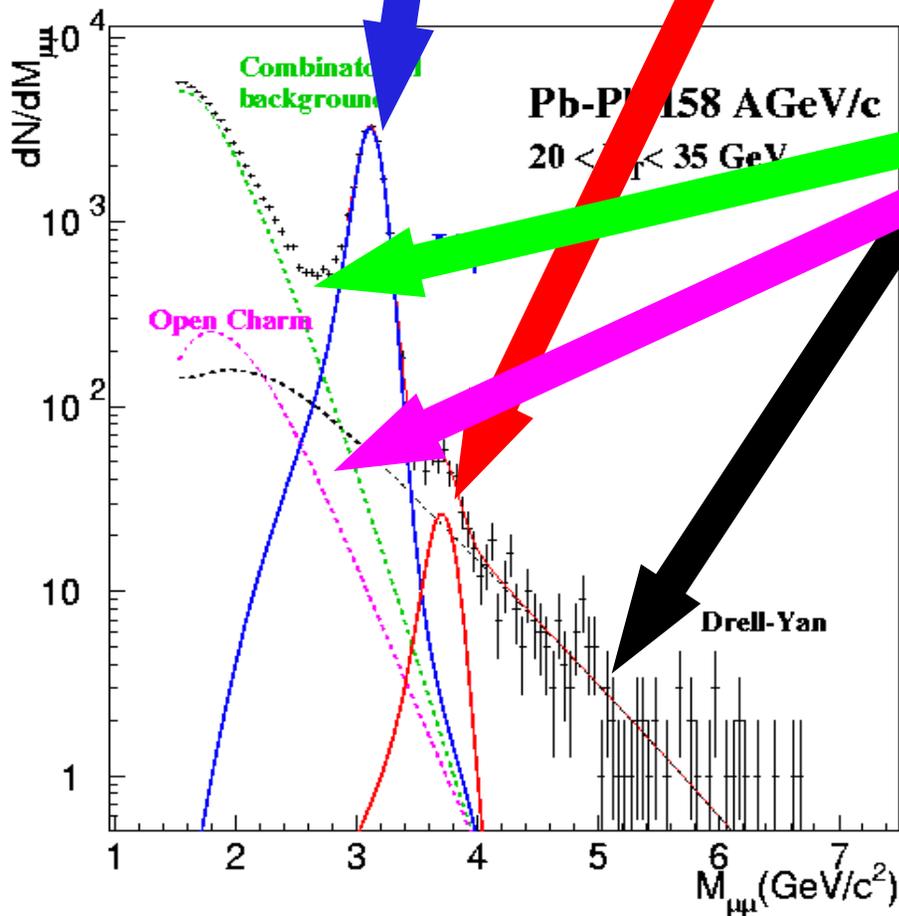


- $J/\psi$, $\psi'$, DY and Open Charm shapes are generated by MonteCarlo and reconstructed as real data

- $J/\psi$ and $\psi'$ mass resolutions ~100MeV

- Combinatorial Background, mostly from $\pi$ and $K$ decays, is extracted from measured like-sign pairs

- Final fit performed for M > 2.9 GeV/c$^2$

- DY(4.2–7.0) is used as reference (proportional to the number of nucleon-nucleon interactions in all systems)

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# The *J/ψ* Suppression

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

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

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

No clear flattening of *J/ψ / DY* at high $E_T$
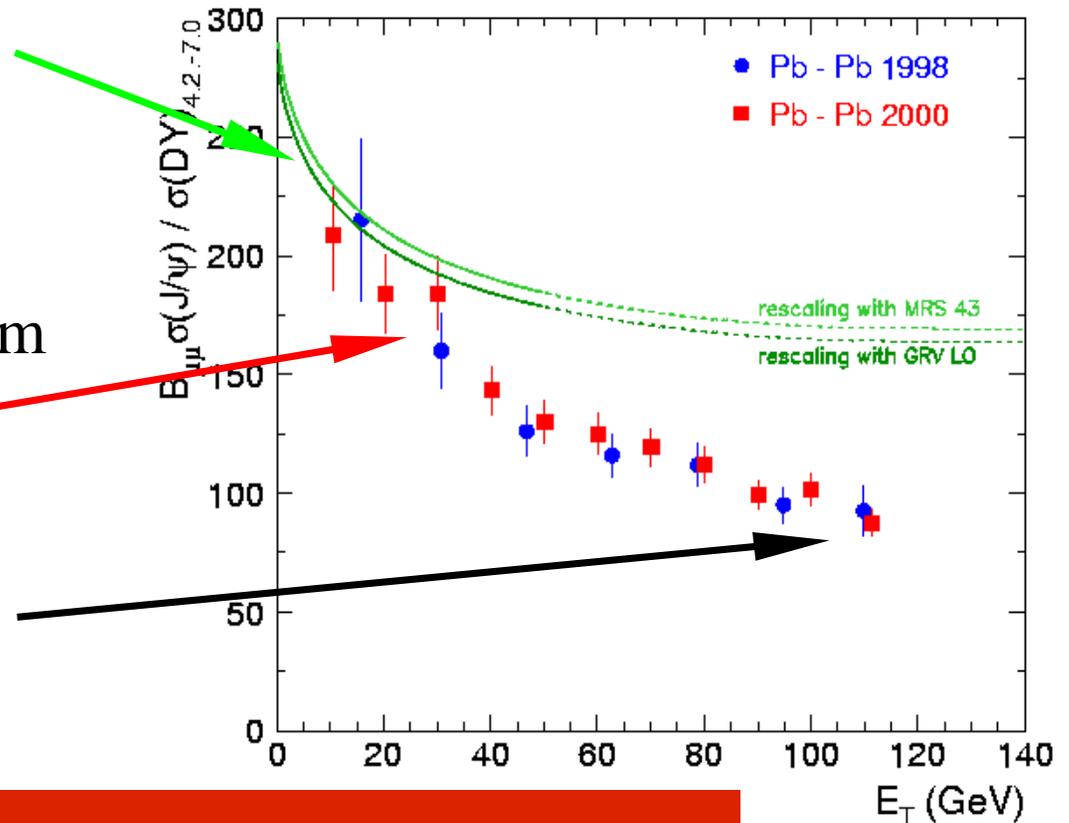


*J/ψ* is anomalously suppressed !

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# The ψ' Study
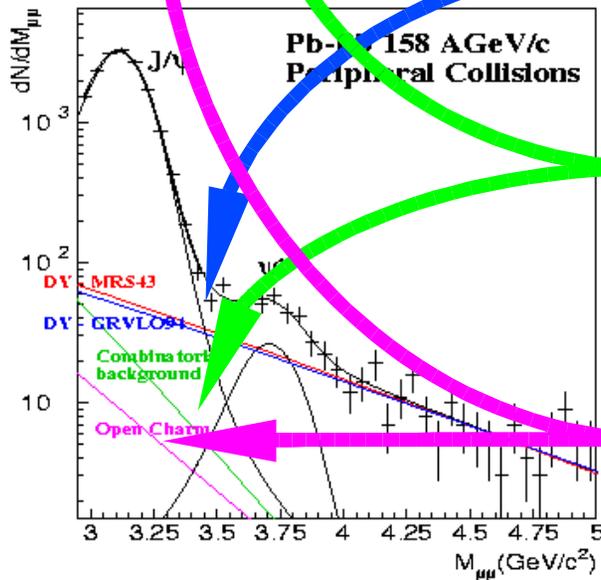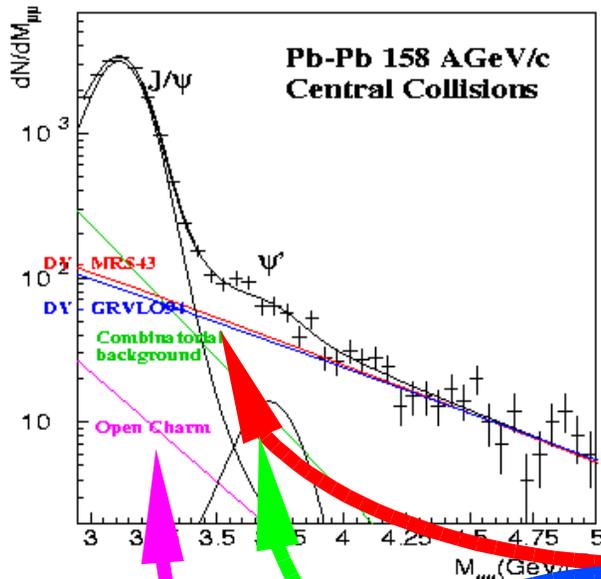
Challenging due to
- ✓ small dimuon cross section
- ✓ large suppression
- ✓ overlap of several dimuon sources

Different structure functions (GRV LO or MRS LO) chosen to simulate Drell-Yan can induce a 10% difference in ψ' normalization

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$_{4.2\text{-}7.0}$ as a function of E$_T$

The transverse energy E$_T$ is used as the collision centrality estimator
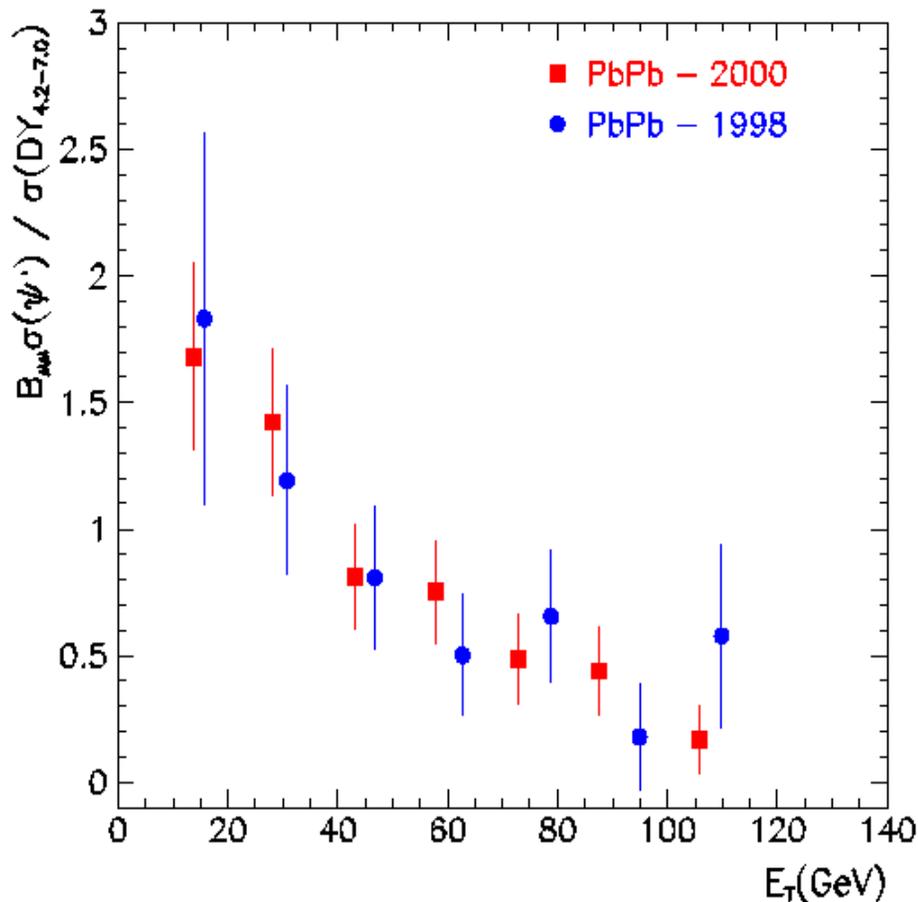


- $\psi'$ is increasingly suppressed with respect to Drell-Yan

- Good compatibility between Pb-Pb 2000 and Pb-Pb 1998 data

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# $\psi'/\psi$ as a function of $E_T$

The transverse energy $E_T$ is used as the collision centrality estimator
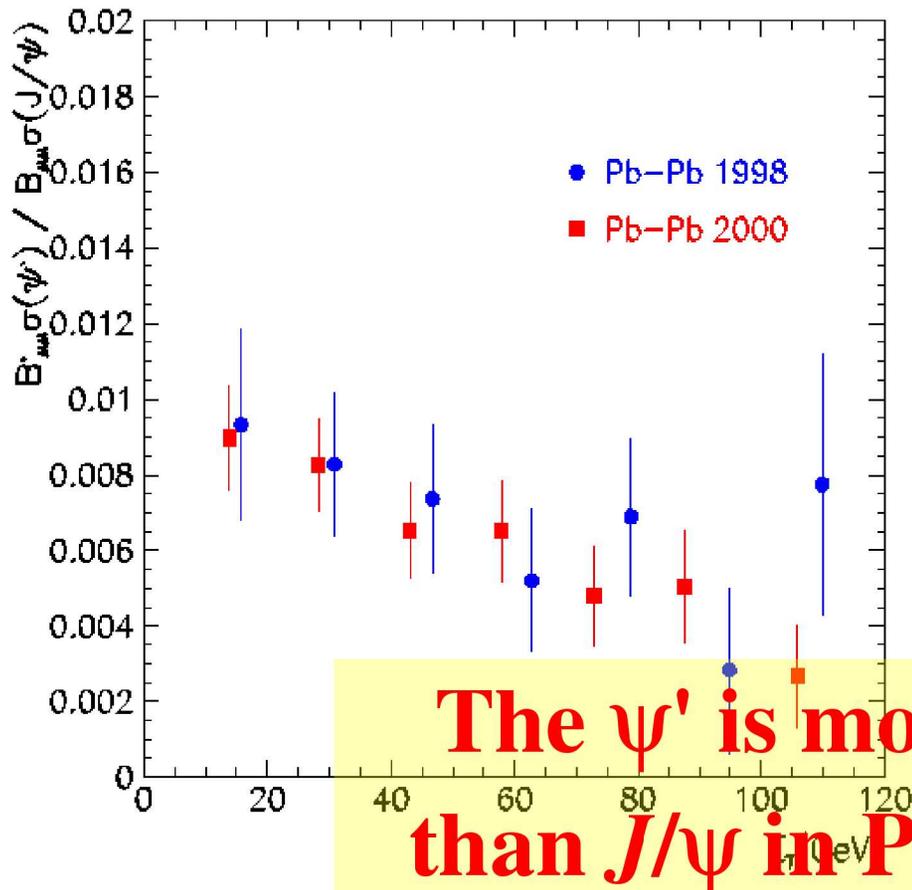


The ratio of the two charmonia states decreases with centrality by a factor of 2.5 between peripheral and central collisions

**The $\psi'$ is more suppressed than $J/\psi$ in Pb-Pb collisions**

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# $\psi'/\psi$ as a function of $A_{proj}B_{targ}$

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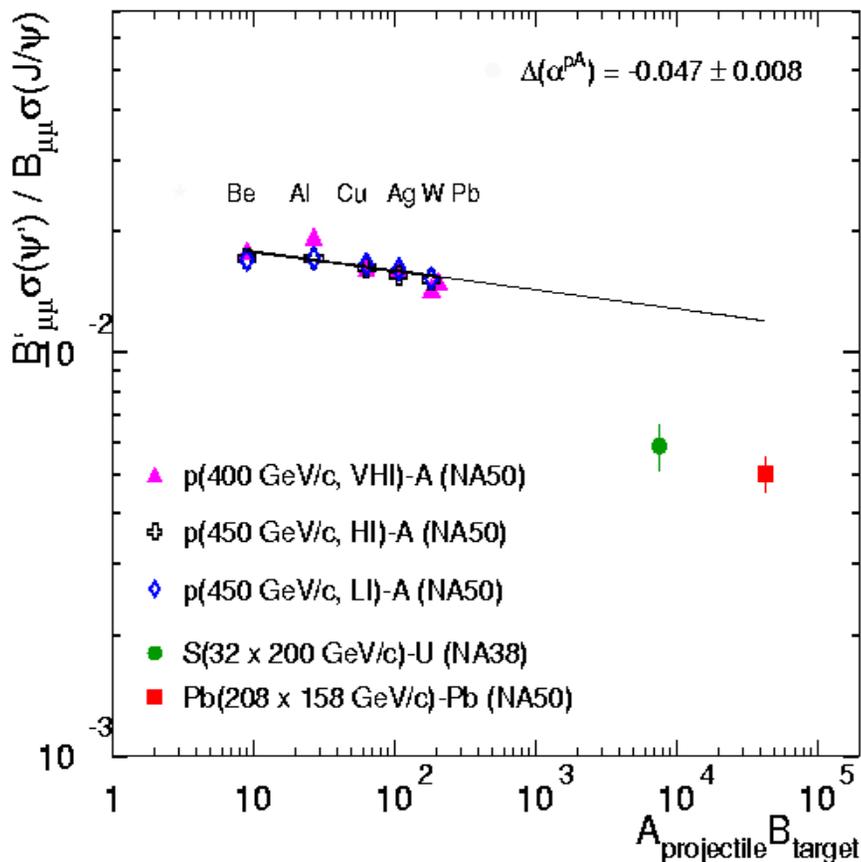


- The ratio $B'_{\mu\mu}\sigma(\psi')/B_{\mu\mu}\sigma(J/\psi)$ can be parametrized with a power law like $A^{\Delta\alpha}$

- $\psi'$ is more suppressed than $J/\psi$ already in p-A collisions

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

- $\psi'$ is even more suppressed in ion-ion interactions

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# $\psi'$/DY$_{4.2-7.0}$ as a function of $L$

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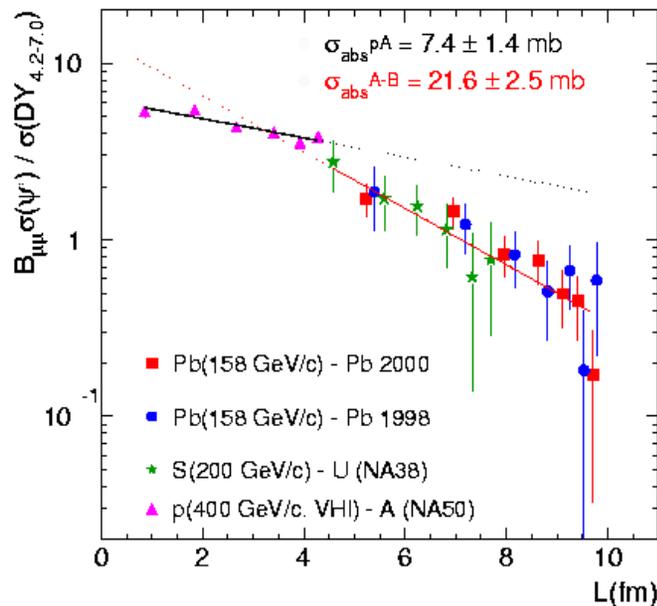


Using an exponential parametrization

$$\sigma_0\exp(-<\rho L>\sigma_{abs})$$

in p-A collisions for $\psi'$ we have

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

and in S-U and Pb-Pb 2000 fitted simultaneously

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

- Different behaviour between p-A and A-B collisions

- Strong suppression of $\psi'$ between peripheral and central A-B interactions

- The $\psi'$ suppression is the same in S-U and Pb-Pb collisions as a function of $L$

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# $\psi'/DY_{4.2-7.0}$ as a function of $N_{part}$
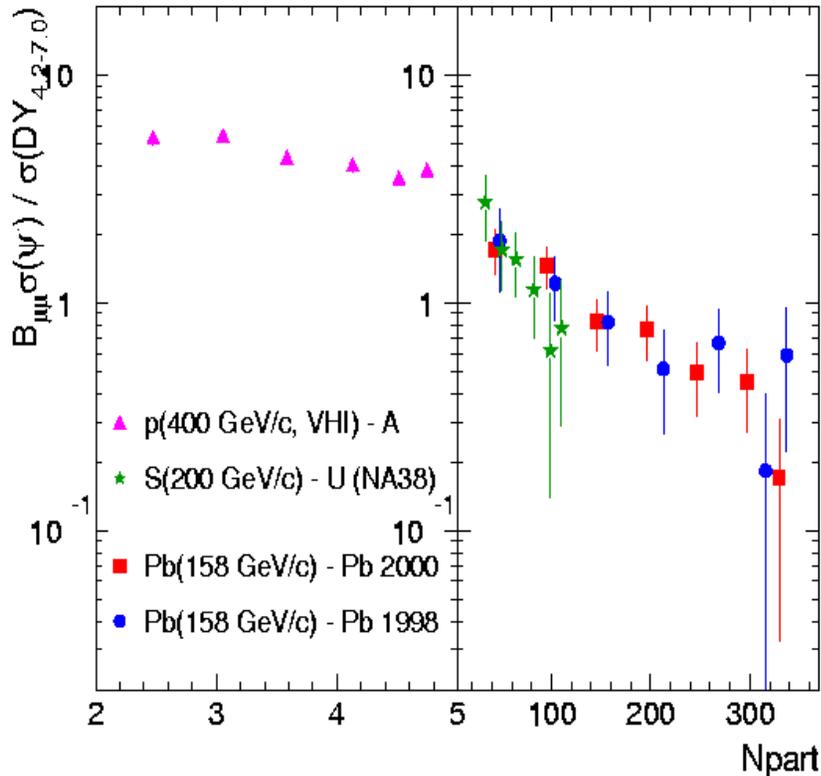


The centrality estimator $N_{part}$ is calculated from the measured transverse energy

$$< E_T(b) > = q\ N_{part}(b)$$

where $q$ is the mean energy per participant deposited in the E.M. calorimeter

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

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# *J/ψ* and ψ' "measured" over "expected"
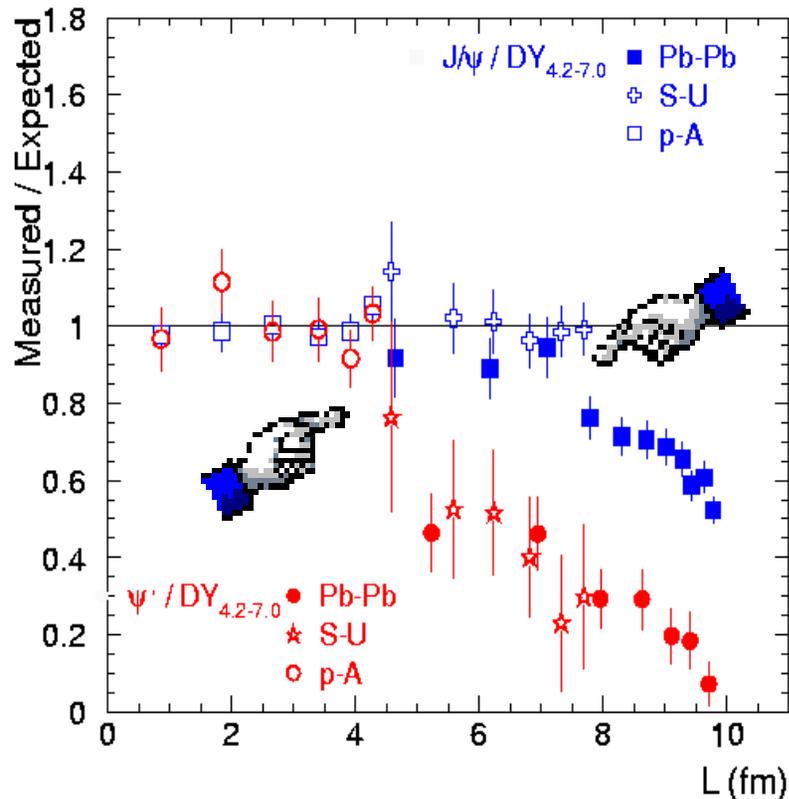


Ratio measured over normal absorption, obtained from full Glauber calculation with

$$\sigma_{abs} = 4.3 \pm 0.3 \text{ mb}$$

for *J/ψ* (from p-A and S-U) and

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

for ψ' (from p-A only)

**In A-B collisions the ψ' departs from the expected absorption curve for lower *L* values with respect to the *J/ψ***

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# Conclusions

- For Pb-Pb collisions:

  ◆ $\psi'$ is suppressed as a function of centrality w.r.t. Drell-Yan by a factor 7 between peripheral and central collisions

  ◆ the ratio $\psi'/\psi$ decreases with centrality by a factor 2.5 between peripheral and central collisions

- Comparing with lighter systems

  ◆ $\psi'$ is much more suppressed in A-B (already in S-U) than in p-A reactions

  ◆ $\psi'$ pattern suppression is the same in S-U and in Pb-Pb as a function of $L$ and $N_{part}$

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# 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 and INFN, Cagliari, Italy

- CERN, Geneva, Switzerland

- LIP, Lisbon, Portugal

- INR, Moscow, Russia

- IPN, Univ. de Paris-Sud and CNRS-IN2P3, Orsay, France

- Lab. Leprince-Ringuet, Ecole Polytechnique and CNRS-IN2P3, Palaiseau, France

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