Charmonia production at the CERN/SPS

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NA50 Collaboration

L I P

Outline

- NA50 experiment overview
  - Experimental setup
  - Analysis procedure

- J/ψ normal nuclear absorption: **The Reference**
- Pb-Pb anomalous suppression: **Final results**
  - Comparison with ligther systems

NEW !!!

- The ψ' absorption
  - Pb-Pb $B_{\mu\mu}\sigma(\psi')$ / σ(DY) results
  - Pb-Pb $B_{\mu\mu}\sigma(\psi')$ / $B_{\mu\mu}\sigma(J/\psi)$ results
  - Lighter systems comparison

UPGRADE !!!

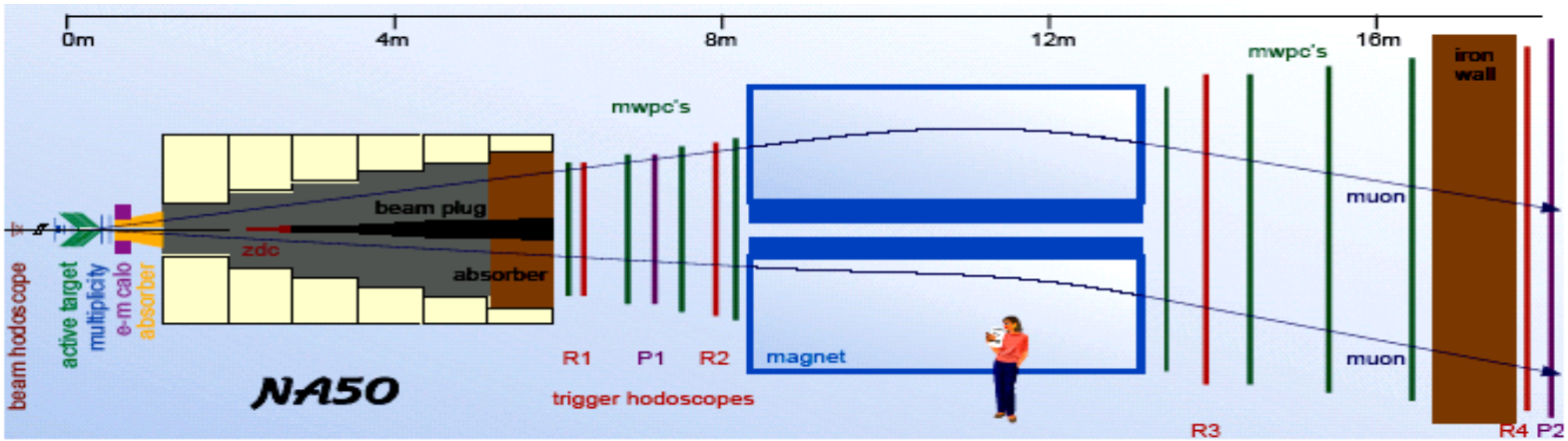
- Conclusions

Developments since Moriond 2004

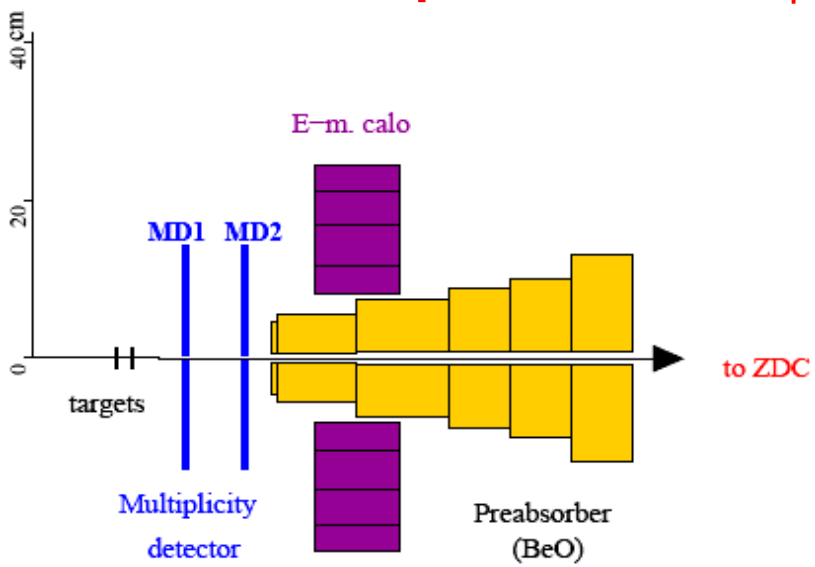
- Charmonia Pb-Pb data analysis:
  - **All results analysed using GRV 94 LO set of PDFs.**
    - Consistent computation of the Drell-Yan shape
  - **Average between 1998 and 2000 results.**

- The reference:
  - **Coherent comparison between all NA50 p-A data samples to extract the absorption cross section.**
  - **Purely determined using p-A nucleus collisions.**
    - Previously, S-U results were also included under the assumption that they were behaving normally.
  - **Inclusion of the neutron halo effect.**
    - Neutrons inside a Pb nucleus have different spatial distributions from protons → **DY cross-section will sligtly depend on centrality**.

NA50 Dimuon spectrometer



Optimized for $J/\psi \rightarrow \mu^+\mu^-$ detection



- **Kinematical domain**
  - $2.92 \leq Y_{LAB} < 3.92$
  - $|\cos(\theta_{CS})| < 0.5$
- **Acceptances**
  - J/ψ : 12.42 ± 0.02 (0.17%)
  - ψ' :14.77 ± 0.03 (0.26%)
  - $DY_{2.9\text{-}4.5}$:13.79 ± 0.05 (0.16%)

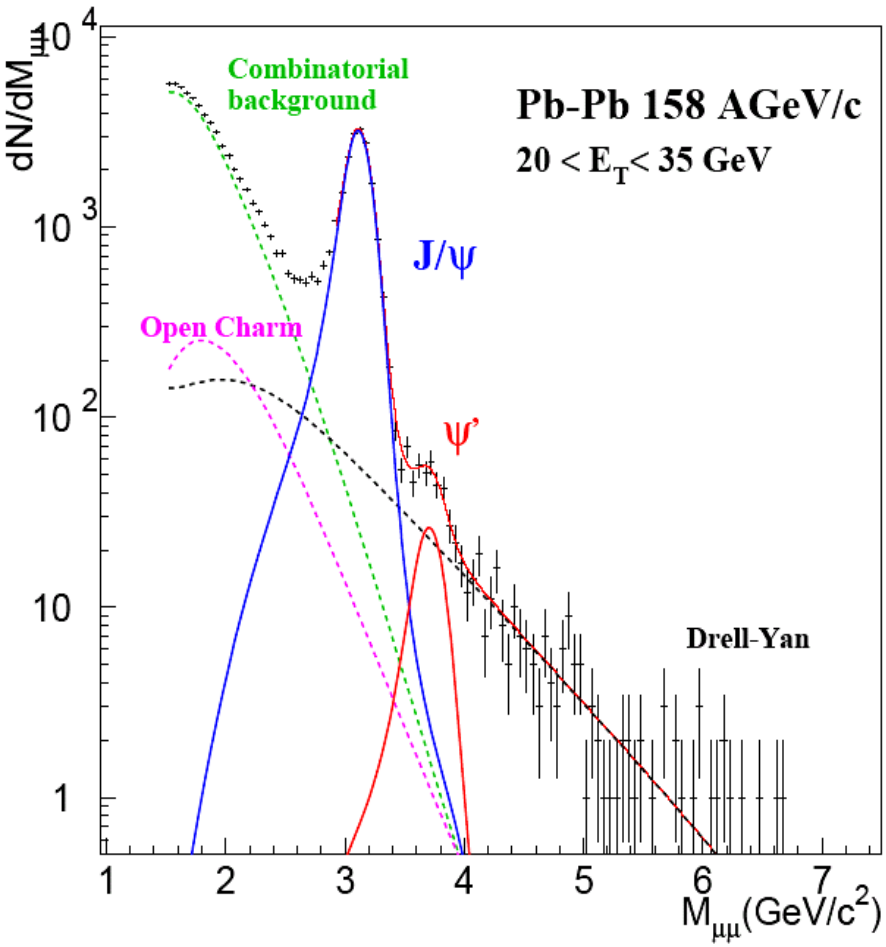
NA50 Pb-Pb data samples

Year	Energy (GeV)	Sub-targets	Target thickness	Intensity (10^7 ions/b)	J/ψ (10^3)
1995	158	7 (in air)	17 % λ_I	3 x 10^7	50
1996	158	7 (in air)	30 % λ_I	5 x 10^7	190
1998	**158**	**1 (in air)**	**7 % λ_I**	**5.5 x 10^7**	**49**
2000	**158**	**1 (in vacuum)**	**10 % λ_I**	**7 x 10^7**	**129**

- **1998 data sample**
  - 1 thin target avoids reinteractions and confirms charmonia production behaviour for central collisions.
- **2000 data sample**
  - 1 thin target in vacuum avoids Pb-Air interactions and confirms charmonia production behaviour for peripheral collisions.

The analysis method

- Fit invariant mass spectrum for each centrality region.



- **Signal functional forms** are obtained through Monte-Carlo generation and spectrometer simulation:
  - **DY** and **Open-Charm** shapes from PYTHIA input with **GRV 94 LO PDFs**.
  - **J/ψ** and **ψ'** shapes are dominated by experimental effects (~ 100 MeV/c^2 of mass resolution).
- **Combinatorial background** is built from the measured like sign dimuon distributions.

Importance of p-A measurements

- J/ψ production in ligther systems is crucial.
  - Are there abnormal effects in heavier systems?

- J/ψ is already considerably absorbed in p-A collisions **(normal nuclear absorption):**
  - Systematically measure of J/ψ yield as a function of nuclear size and determine it's **surviving probability**.

- Build an absorption curve:
  - Use a Glauber model to evaluate the expected number of J/ψ as a function of centrality in **158 GeV Pb-Pb interactions.**
  - **Compare with Pb-Pb measurements**.

NA50 p-A data samples

Year	Energy (GeV)	Targets	Target thickness	Intensity (10^8 p/s)	J/ψ (10^3)
96/98	450	Be,Al,Cu,Ag,W	26-39 % λ_I	4.0 - 13	350:800
98/00	450	Be, Al, Cu, Ag, W	26-39 % λ_I	0.8 - 2.5	80:180
2000	400	Be,Al,Cu,Ag,W,Pb	26-39 % λ_I	9.0 - 13	38:68

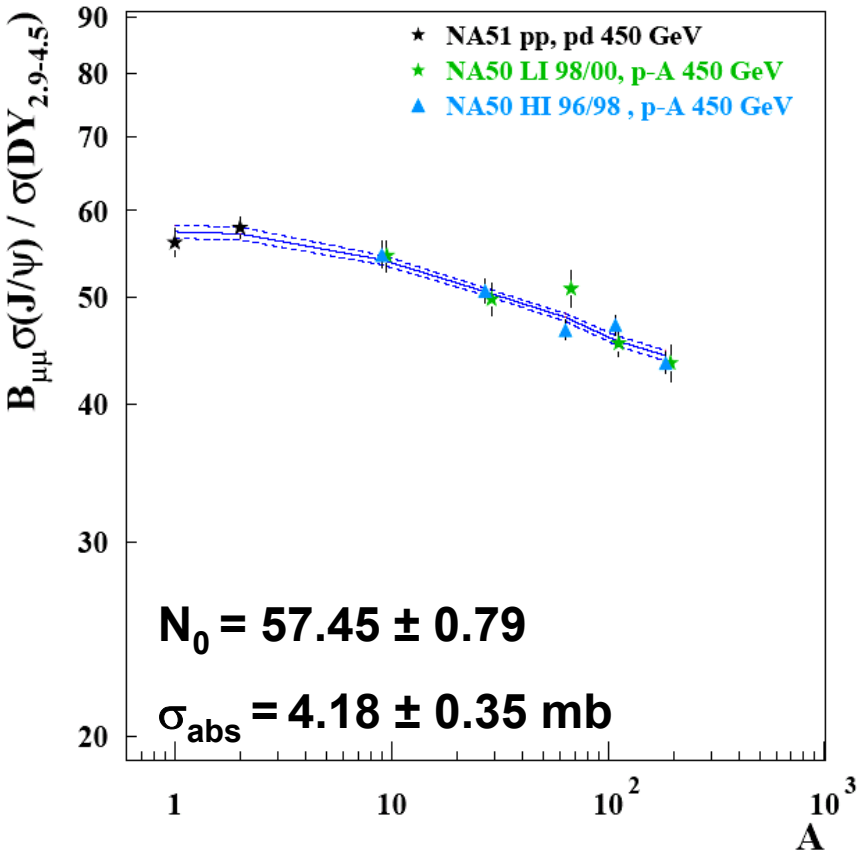
- **Large improvement in statistics** compared to previous NA38 p-A data samples.

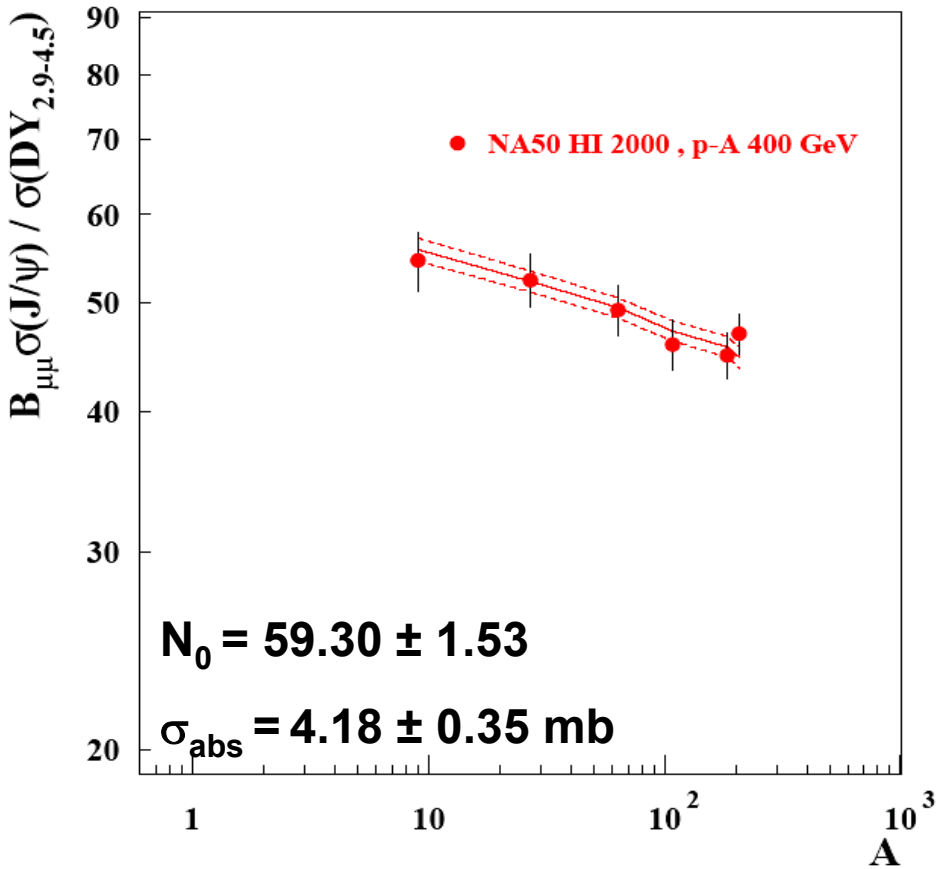
- Last NA50 p-A runs were taken in **a very short period of time with frequent target changes**
  - Allows to minimize possible systematic errors on the luminosity ammoung different targets.

J/ψ production in p-A collisions (I)

- Use the high statistics NA50 $B_{\mu\mu}\sigma(J/\psi)$ / $\sigma(DY_{2.9\text{-}4.5})$ results, at 450 and 400 GeV, together with pp, pd from NA51 data:

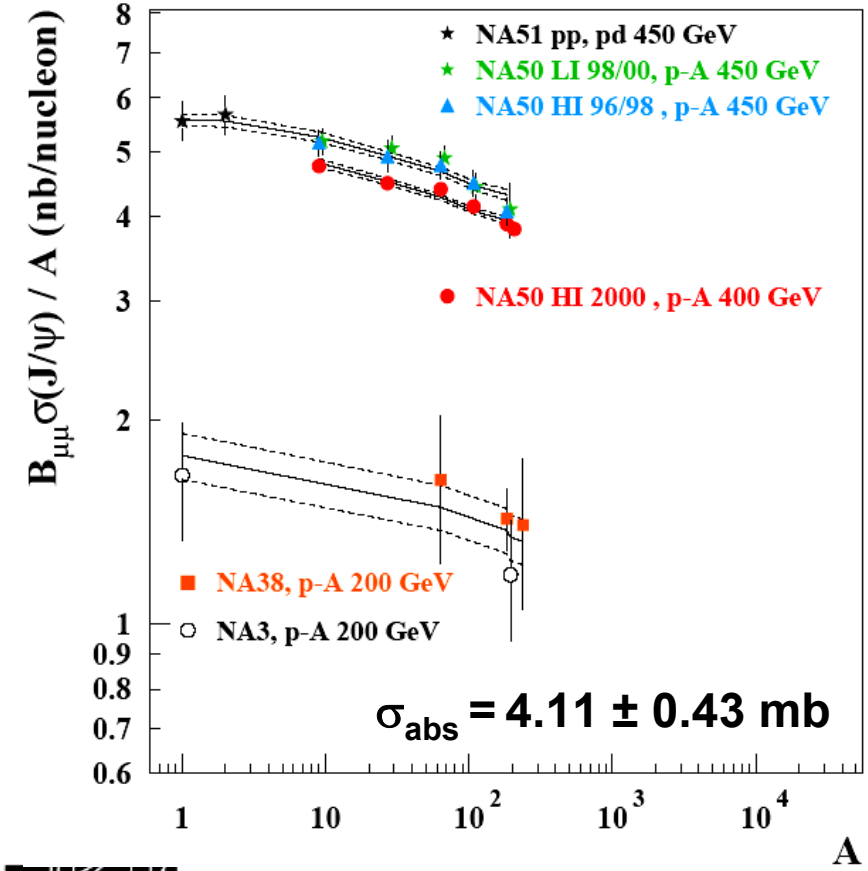
$$\sigma_{abs} = 4.18 \pm 0.35 \text{ mb}$$





J/ψ production in p-A collisions (II)

- NA50 only has p-A data at higher energies than 158 GeV:
  - Study $B_{\mu\mu}\sigma(J/\psi)/A$ results at different energies from NA51, NA50, NA38 (same dimuon spectrometer) and NA3 experiments.

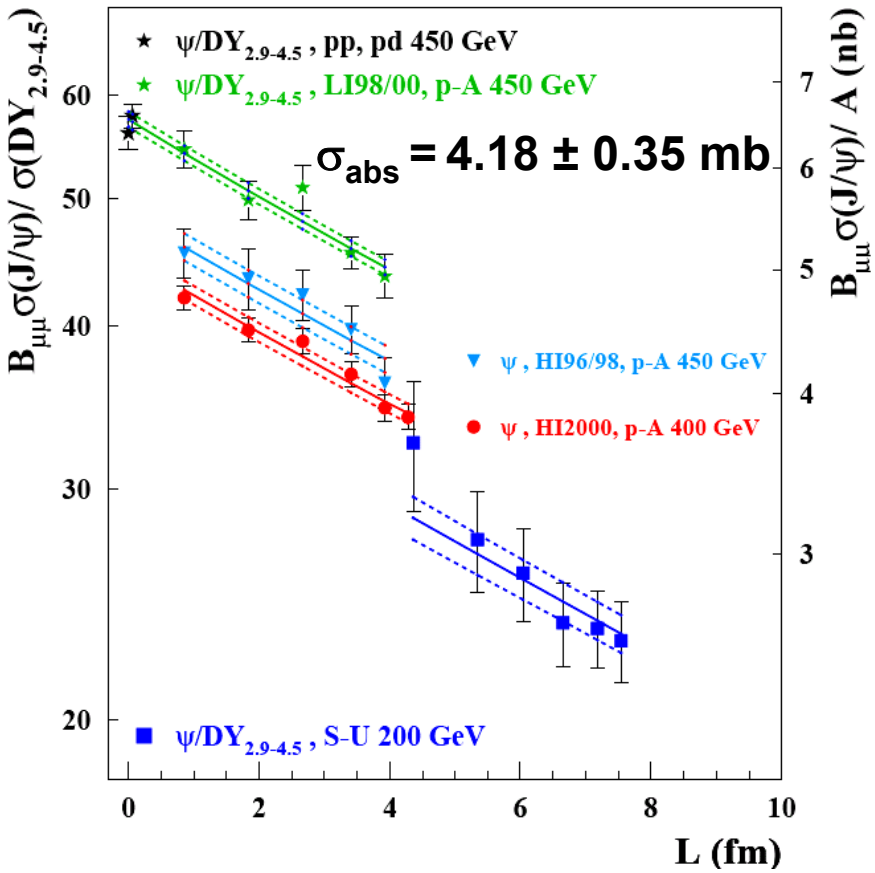


- Data sets (at a given energy) present compatible σ_{abs} values.
- A simultaneous fit provides the J/ψ experimental rescaling factors to 200 GeV:
  - $N_{200} / N_{450} = 0.319 \pm 0.025$
  - $N_{200} / N_{400} = 0.348 \pm 0.027$
- The small rescaling which brings J/ψ from 200 to 158 GeV is done using the Schuler parametrization.
- DY is rescaled theoretically from 450 / 400 to 158 GeV using LO calculations.

Our previous σ_{abs} determination

- NA38 200 GeV **S-U** $B_{\mu\mu}\sigma(J/\psi) / \sigma(DY_{2.9\text{-}4.5})$ results (alone):

$$\sigma_{abs}(\textbf{S-U}) = 7.05 \pm 3.03 \text{ mb}$$

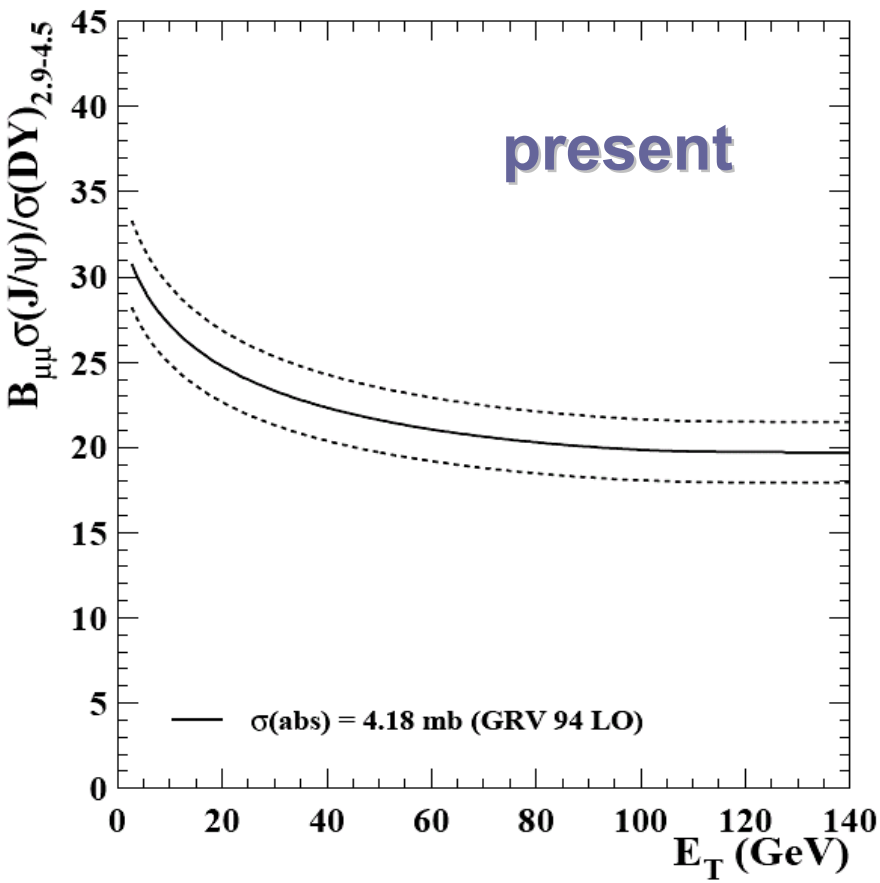


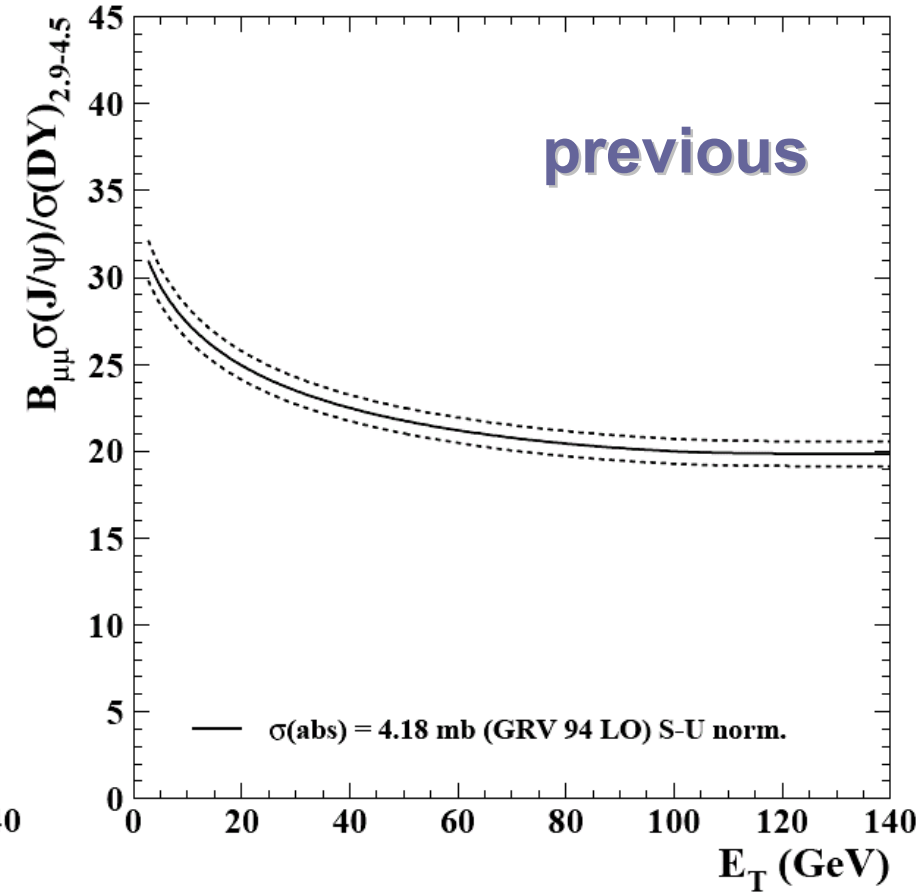
- **Under the assumption that S-U was behaving normally:**
  - It was included with p-A results in a simultaneous Glauber fit

    $\sigma_{abs} = 4.18 \pm 0.35$ mb.
  - Absorption curve **normalization** was given by S-U 200 GeV data.
  - The factor which brings J/ψ from 200 to 158 GeV was obtained using Schuler parametrization.
  - DY was rescaled theoretically from 200 to 158 GeV using LO calculations.

Present vs previous estimation

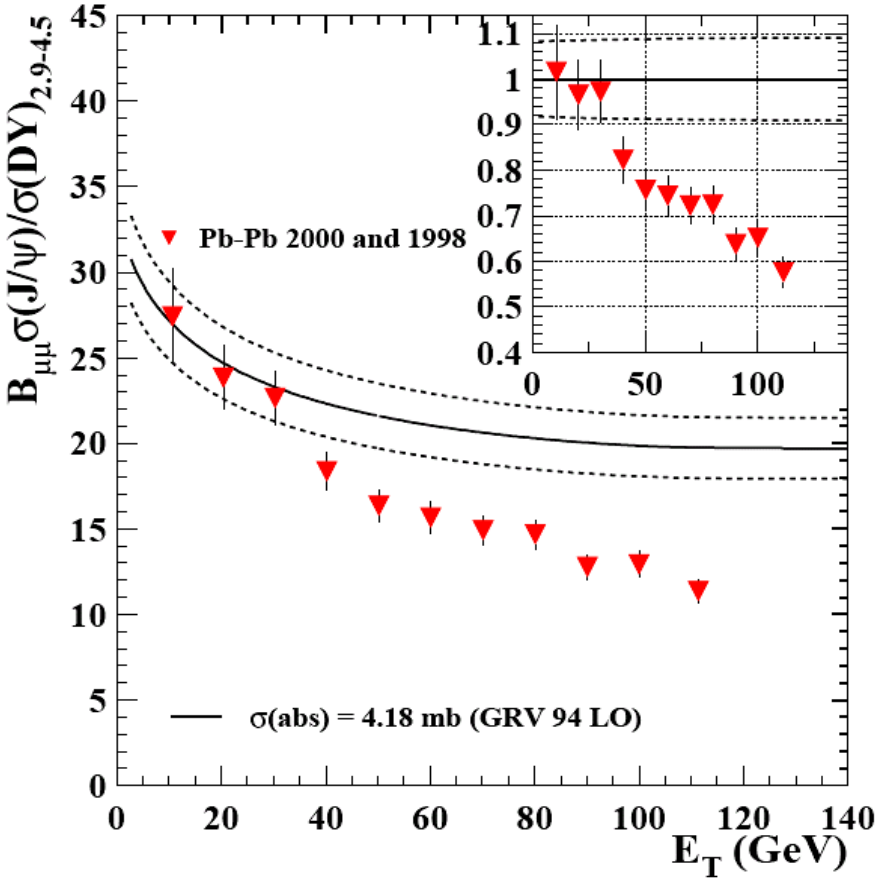
- Normal nuclear absorption curve doesn't change:
  - The much larger systematic error bar in our present estimation is imposed by the uncertainty of p-A $B_{\mu\mu}\sigma(J/\psi)$ normalizations at 200 GeV.





The J/ψ anomalous suppression

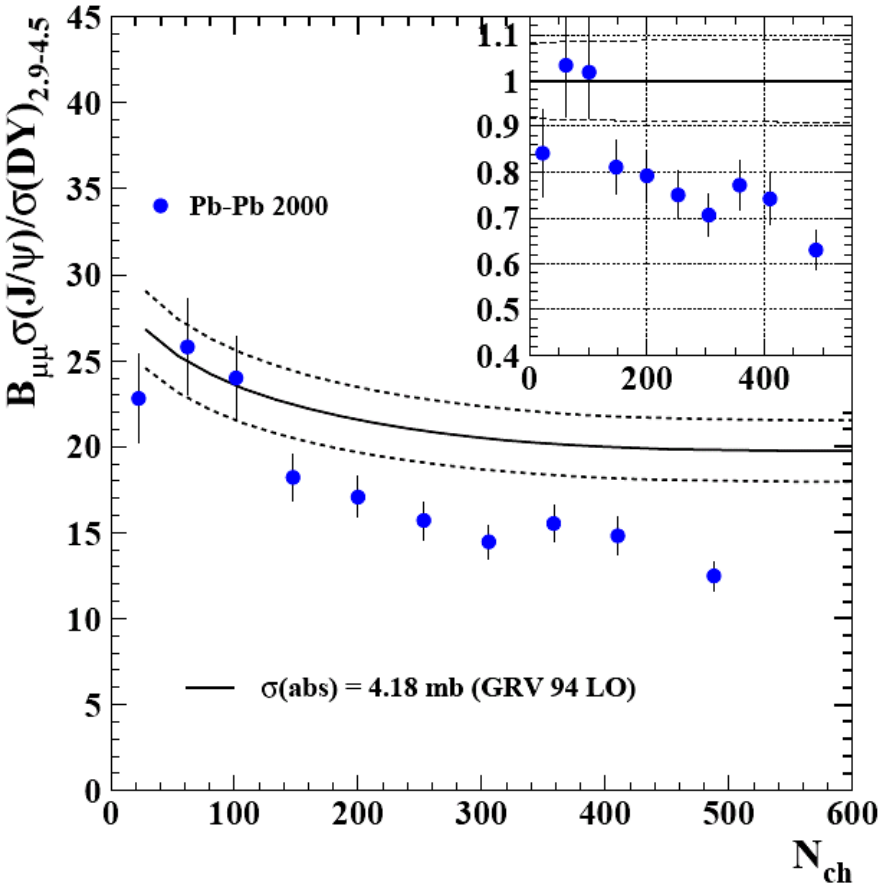
- $B_{\mu\mu}\sigma(J/\psi) / \sigma(DY_{2.9\text{-}4.5})$ **Pb-Pb** results do not follow the normal absorption as extrapolated from p-A systems.

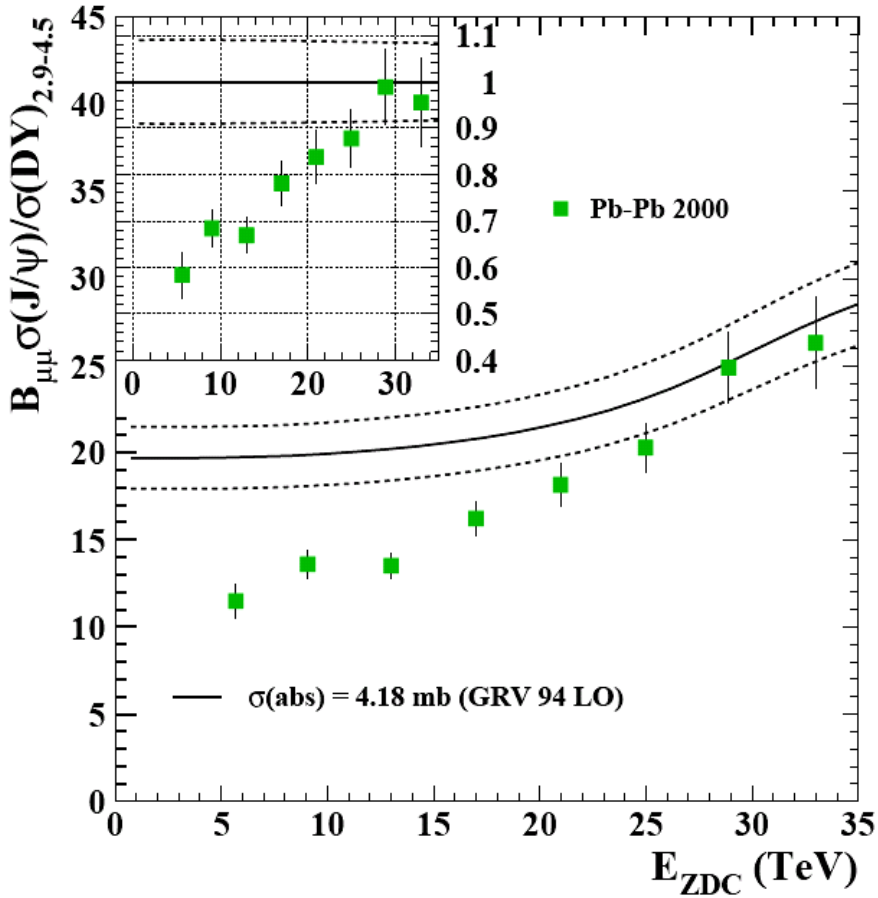


- **Peripheral collisions:**
  - Compatible with the normal nuclear absorption.
- **Mid – centrality:**
  - Departure from the normal nuclear absorption.
- **Central collisions:**
  - No saturation at high centralities.

Other centrality estimators

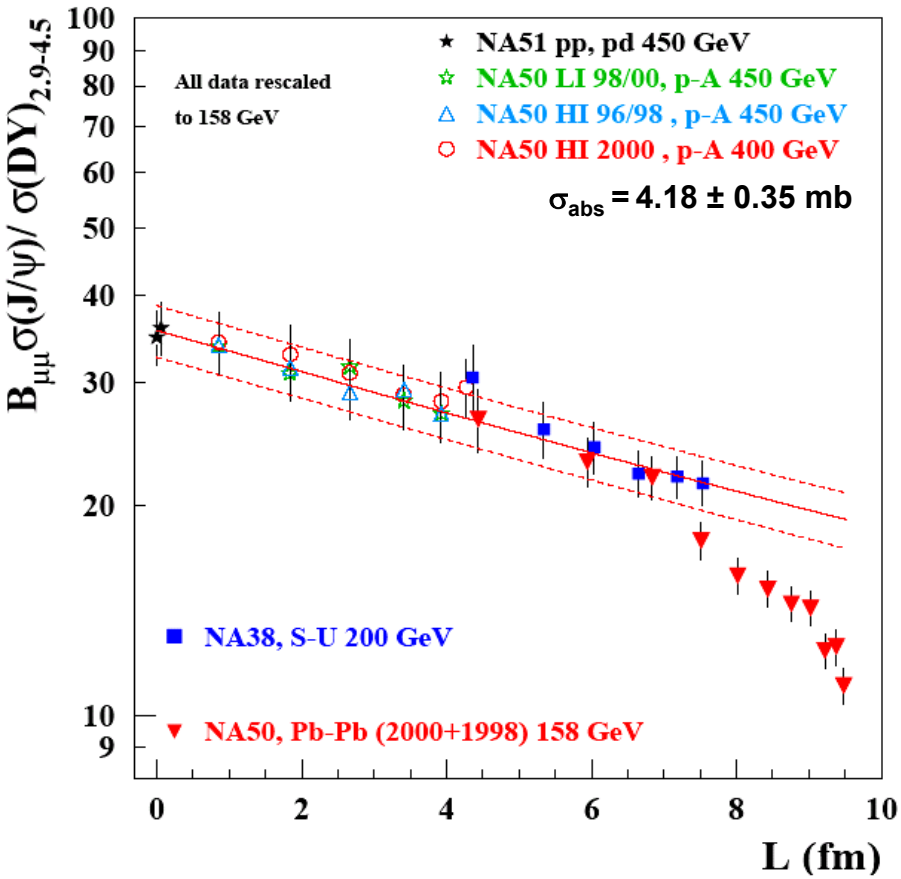
- Same behaviour is observed as a function of other centrality estimators (N_{ch} and E_{ZDC}).





J/ψ/DY vs L: From pp to Pb-Pb

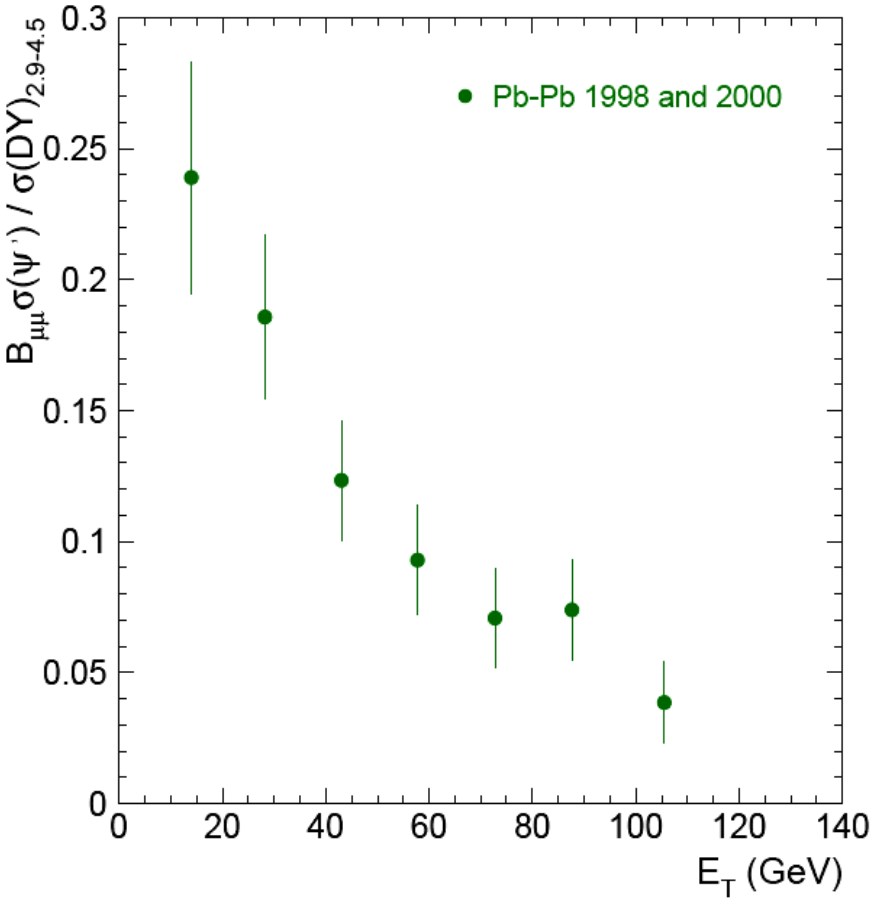
- 20 years of J/ψ results from SPS experiments:
  - NA38, NA51 and NA50 (using same dimuon spectrometer)

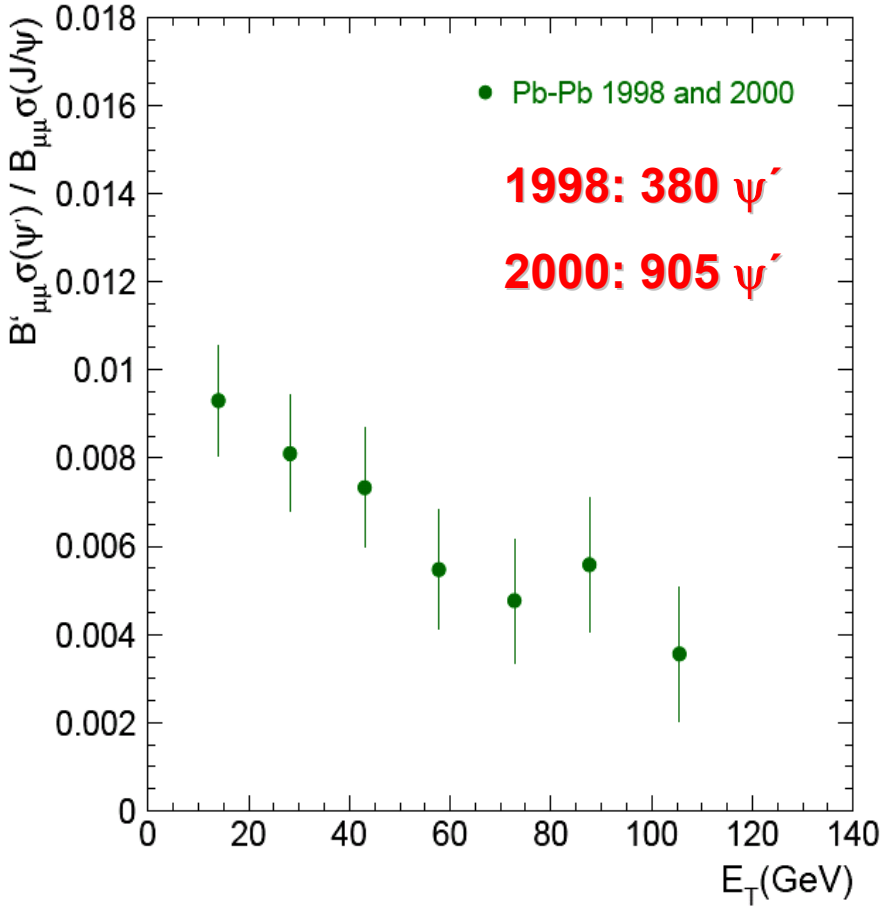


- **L variable**
  - Mean free path crossed by J/ψ in nuclear matter. Good variable to compare p-A and A-B data (at different centralities)
- **S-U collisions show good compatibility with the normal absorption curve**
- **Pb-Pb collisions depart from normal absorption curve at mid centralities.**

ψ'/DY and ψ'/J/ψ vs E_T : Pb-Pb results

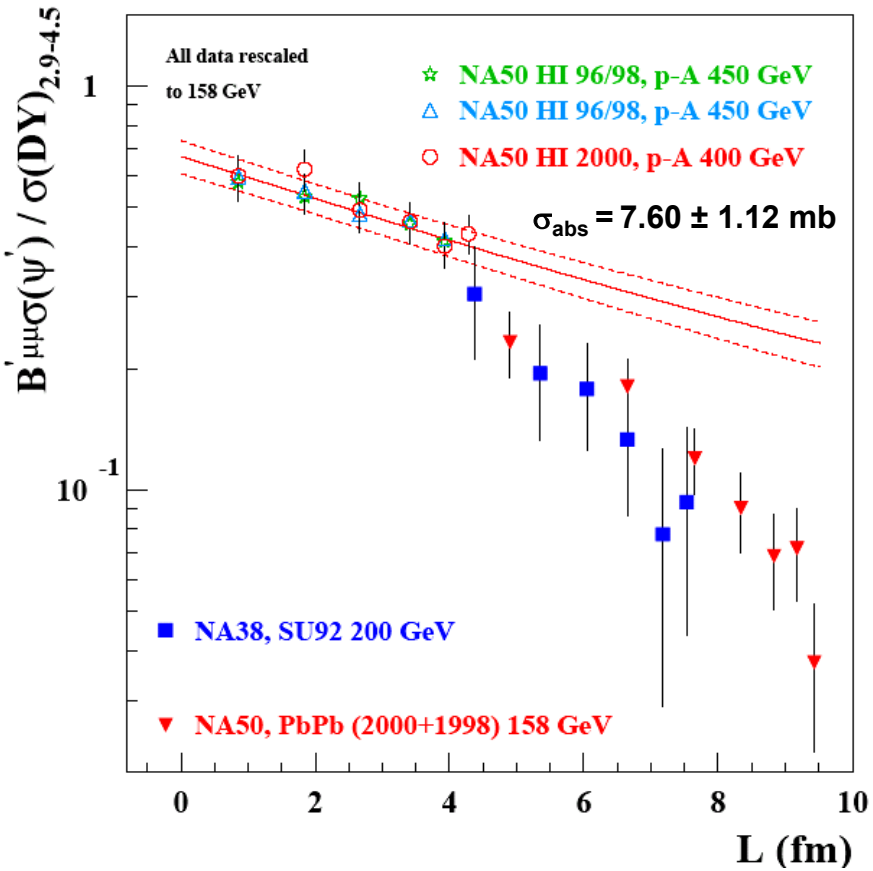
- Strong ψ' suppression w.r.t. DY as a function of centrality.
- Charmonia ratio decreases by a 2.5 factor from peripheral to central collisions.





ψ' / DY vs L

- From $B'_{\mu\mu}\sigma(\psi')$ / $\sigma(DY_{2.9\text{-}4.5})$ p-A results:
  - Deduce an absorption curve with σ_{abs} = 7.60±1.12 mb.
  - Same rescales to 158 GeV as used for J/ψ absorption curve.



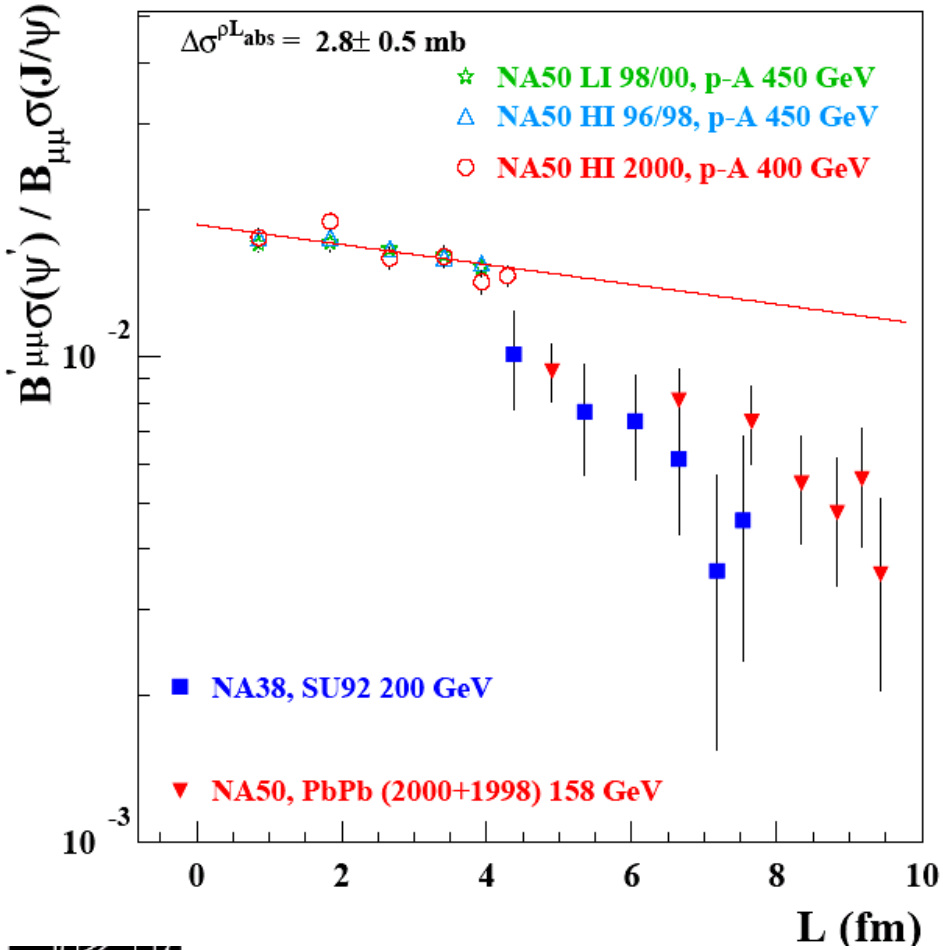
- **Different behaviour between p-A and A-B collisions.**
- **Strong ψ' absorption from peripheral to central A-B interactions.**
- **Compatible ψ' suppression between S-U and Pb-Pb collisions.**

ψ' / J/ψ vs L

- If a simple exponential parametrization is used to quantify the charmonia absorption difference in p-A data:

$$\sigma_0 \exp(-\rho \cdot L \cdot \Delta\sigma_{abs}^{\rho L})$$

$\Delta\sigma^{\rho L}_{abs}$ = 2.8 ± 0.5 mb



- The difference between full Glauber calculations is:

$\Delta\sigma^{Glb}_{abs} = \sigma_{abs}(\psi') - \sigma_{abs}(J/\psi)$
$= 3.4 \pm 0.6$ mb

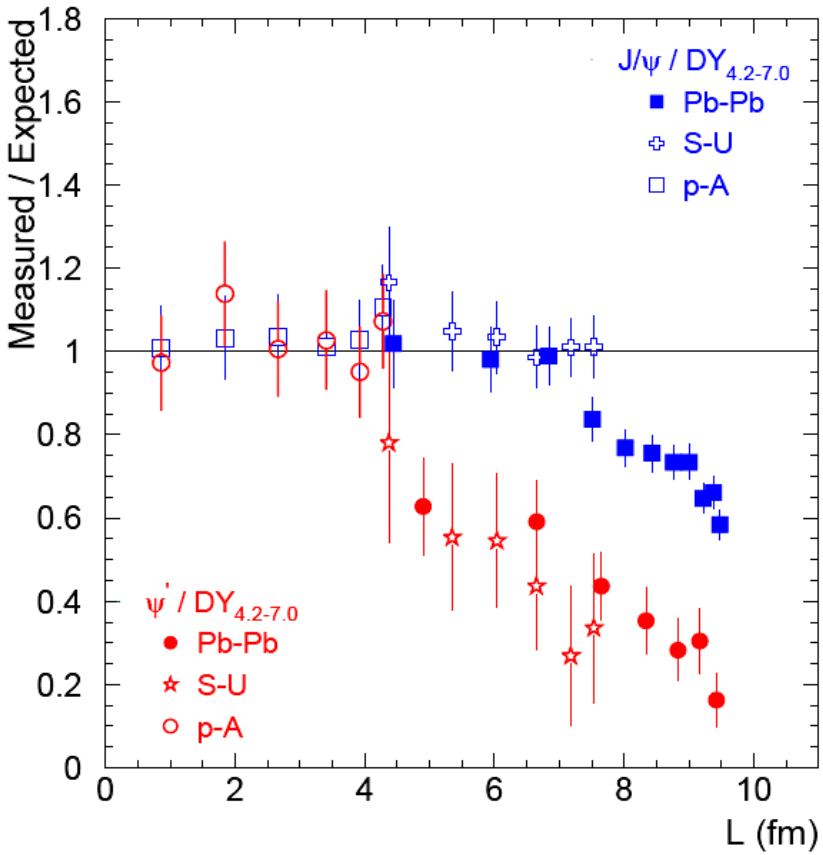
- **The relative absorption between J/ψ and ψ' resonances is different from p-A to A-B data.**

Charmonia results: Conclusions

Expected = Glauber absorption model

$\sigma_{abs}(J/\psi) = 4.18 \pm 0.35$ mb

$\sigma_{abs}(\psi') = 7.60 \pm 1.12$ mb



- **S-U** and **peripheral Pb-Pb (J/ψ)/DY** results follow the absorption curve extrapolated from p-A measurements.
- **Pb-Pb central** collisions show an **anomalous (J/ψ)/DY suppression** with respect to p-A behaviour.
- **ψ'/DY** behaviour is the same in **S-U** and **Pb-Pb** interactions and not compatible with the one observed in p-A collisions.
- **ψ' anomalous suppression** sets in earlier than the J/ψ one.

NA50 passport

- **Who are we?**
  - NA50 is a fixed target experiment from CERN/SPS.
- **What do we measure?**
  - J/ψ yields in light (p-A and S-U) and heavy (Pb-Pb) systems interactions.
- **Why do we measure it?**
  - J/ψ suppression was predicted as a clear signature for **Quark Gluon Plasma formation.**
- **What do we observe?**
  - A strong and increasing suppression of J/ψ yield in Pb-Pb collisions as a function of centrality w.r.t. the expected behaviour deduced from lighter systems.