

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 lighter systems

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

- Conclusions

NEW !!!

UPGRADE !!!



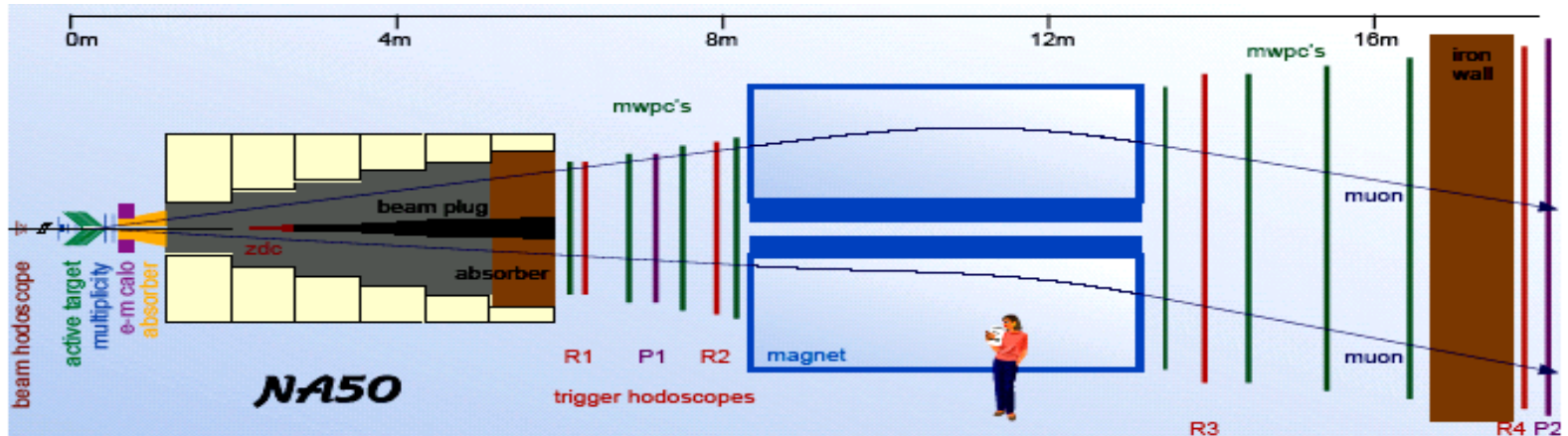
Developments since Moriond 2004

- 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.**

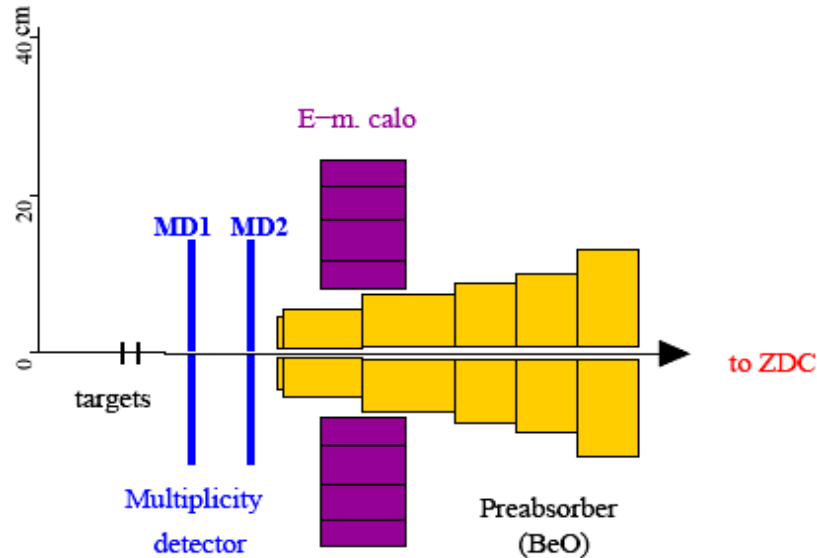
- The reference:
 - **Coherent comparison between all NA50 p-A data samples to extract the absorption cross section.**
 - **Purely determined using p-A nucleus collisions.**
 - Previously, S-U results were also included under the assumption that they were behaving normally.
 - **Inclusion of the neutron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



NA50 Dimuon spectrometer



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



Kinematical domain

- $2.92 \leq Y_{\text{LAB}} < 3.92$
- $|\cos(\theta_{\text{CS}})| < 0.5$

Acceptances

- J/ψ : 12.42 ± 0.02 (0.17%)
- ψ' : 14.77 ± 0.03 (0.26%)
- $DY_{2.9-4.5}$: 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_1	3×10^7	50
1996	158	7 (in air)	30 % λ_1	5×10^7	190
1998	158	1 (in air)	7 % λ_1	5.5×10^7	49
2000	158	1 (in vacuum)	10 % λ_1	7×10^7	129

□ 1998 data sample

- 1 thin target avoids reinteractions and confirms charmonia production behaviour for central collisions.

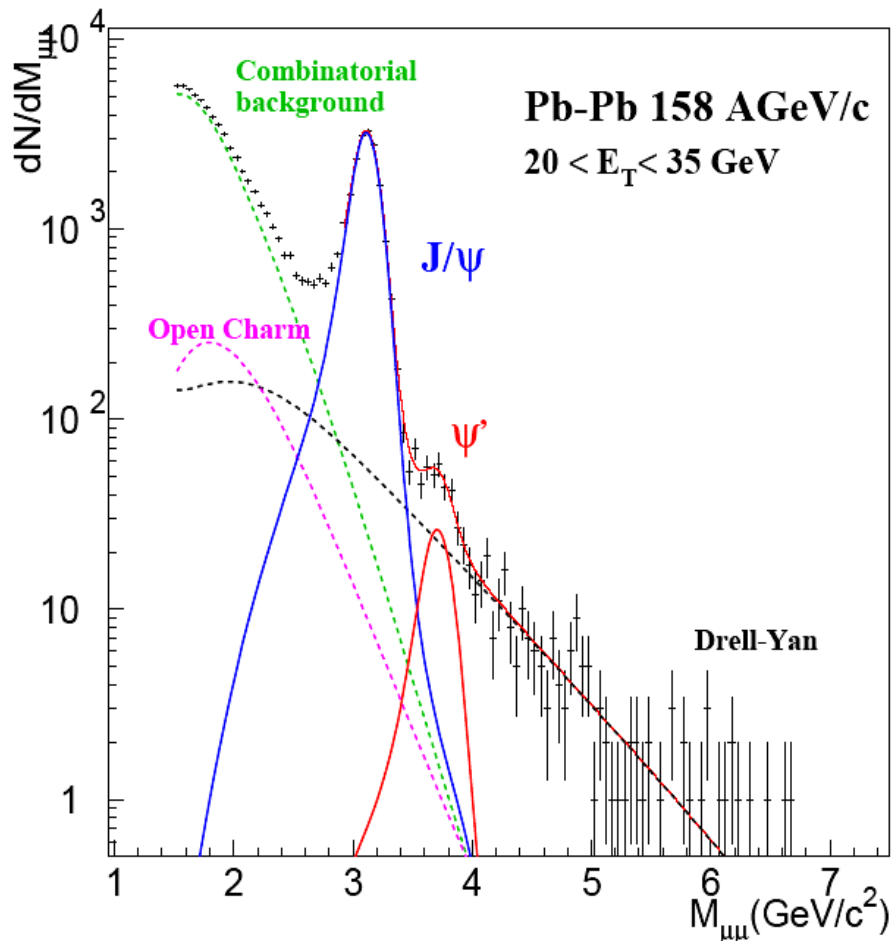
□ 2000 data sample

- 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/c² of mass resolution).

- **Combinatorial background** is built from the measured like sign dimuon distributions.



Importance of p-A measurements

- J/ψ production in lighter 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 its **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_1	4.0 - 13	350:800
98/00	450	Be, Al, Cu, Ag, W	26-39 % λ_1	0.8 - 2.5	80:180
2000	400	Be,Al,Cu,Ag,W,Pb	26-39 % λ_1	9.0 - 13	38:68

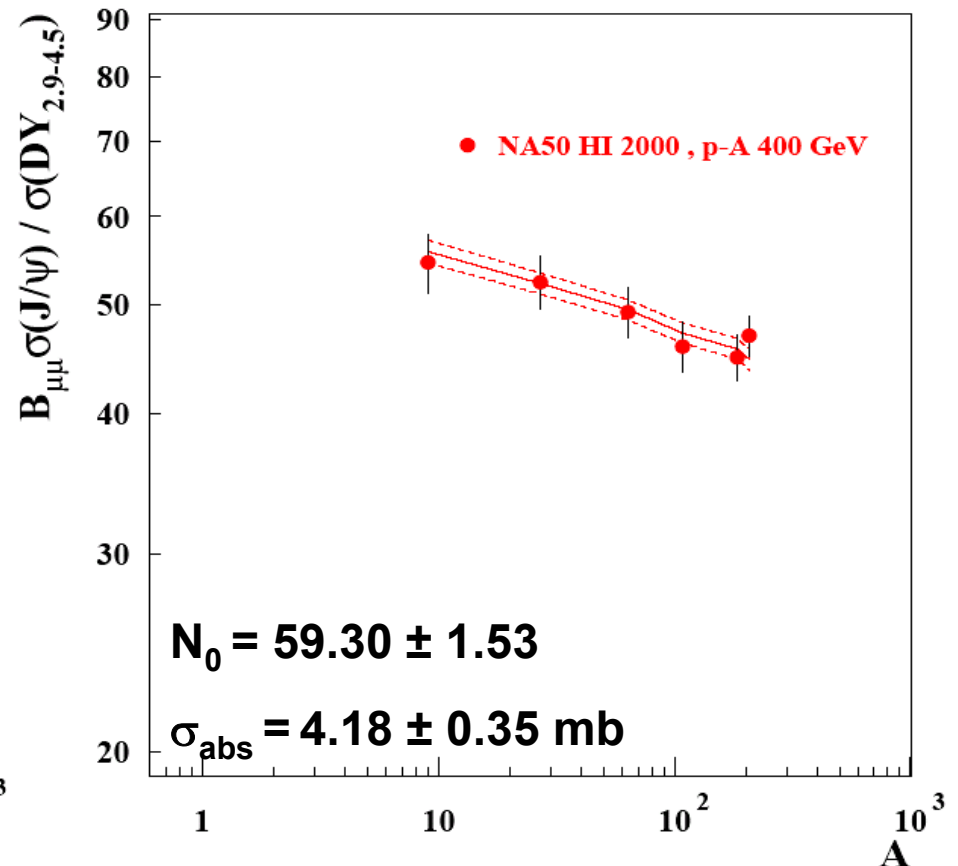
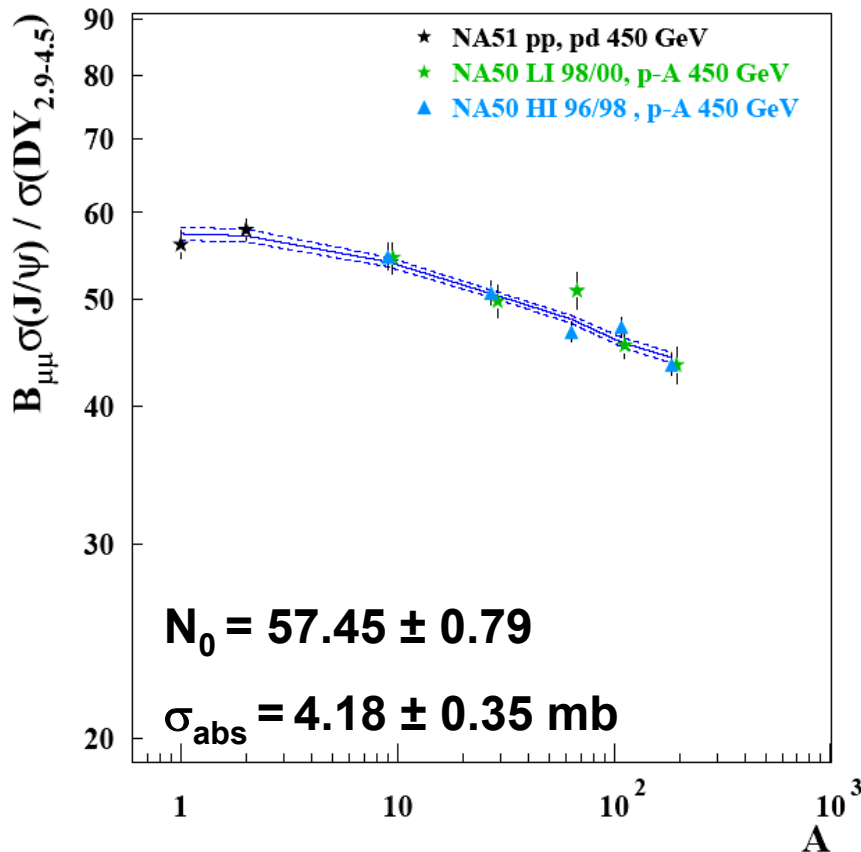
- **Large improvement in statistics** compared to previous NA38 p-A data samples.
- Last NA50 p-A runs were taken in **a very short period of time with frequent target changes**
 - Allows to minimize possible systematic errors on the luminosity ammounting different targets.



J/ψ production in p-A collisions (I)

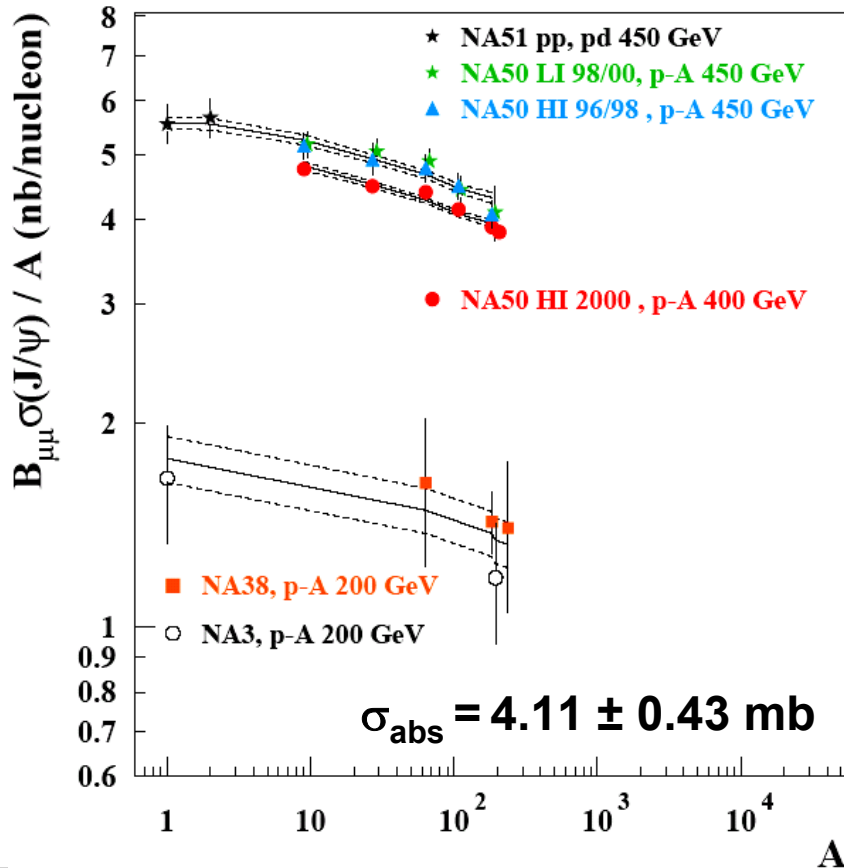
- Use the high statistics NA50 $B_{\mu\mu} \sigma(J/\psi) / \sigma(DY_{2.9-4.5})$ results, at 450 and 400 GeV, together with pp, pd from NA51 data:

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



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.

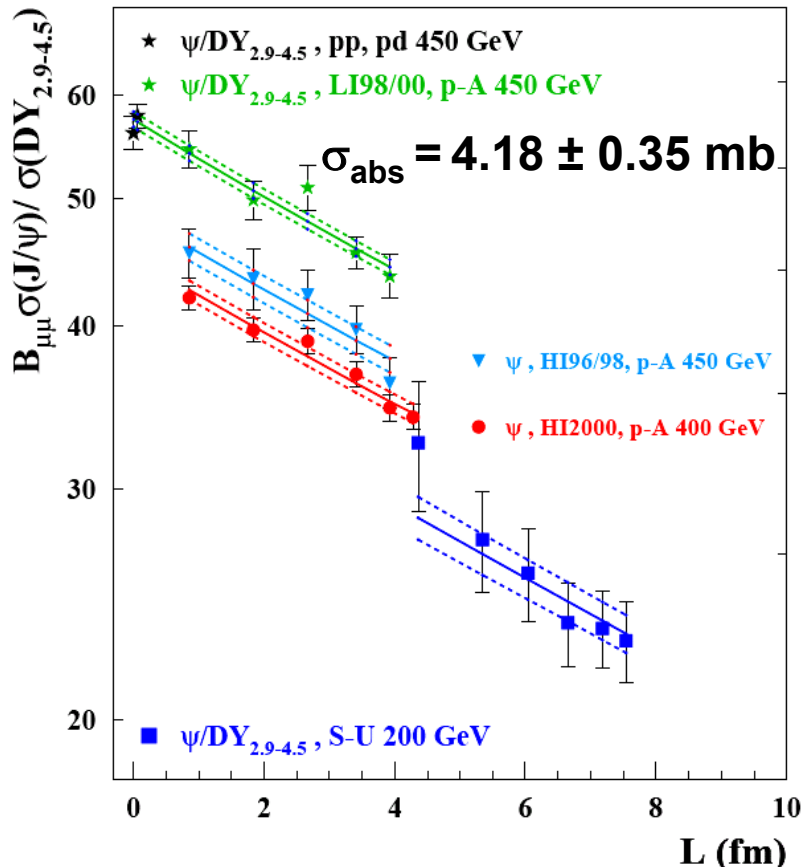


- Data sets (at a given energy) present compatible σ_{abs} values.
- A simultaneous fit provides the J/ψ experimental rescaling factors to 200 GeV:
 - $N_{200} / N_{450} = 0.319 \pm 0.025$
 - $N_{200} / N_{400} = 0.348 \pm 0.027$
- The small rescaling which brings J/ψ from 200 to 158 GeV is done using 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** $B_{\mu\mu} \sigma(J/\psi) / \sigma(DY_{2.9-4.5})$ results (alone):
 $\sigma_{\text{abs}}(\text{S-U}) = 7.05 \pm 3.03 \text{ mb}$



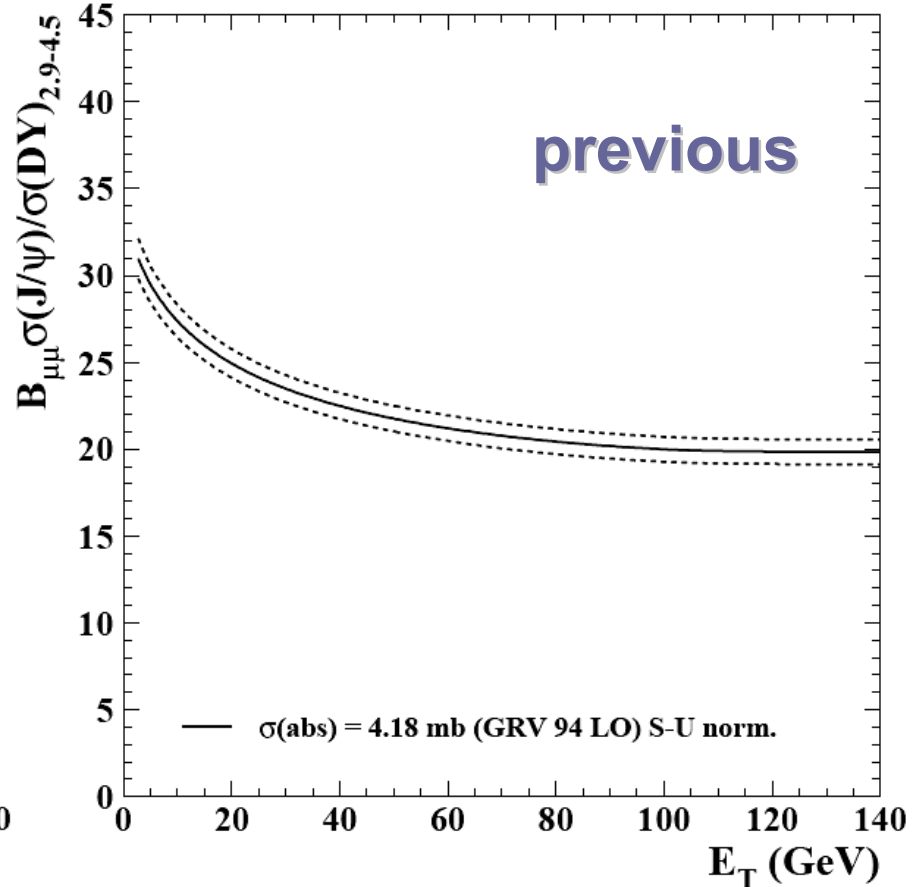
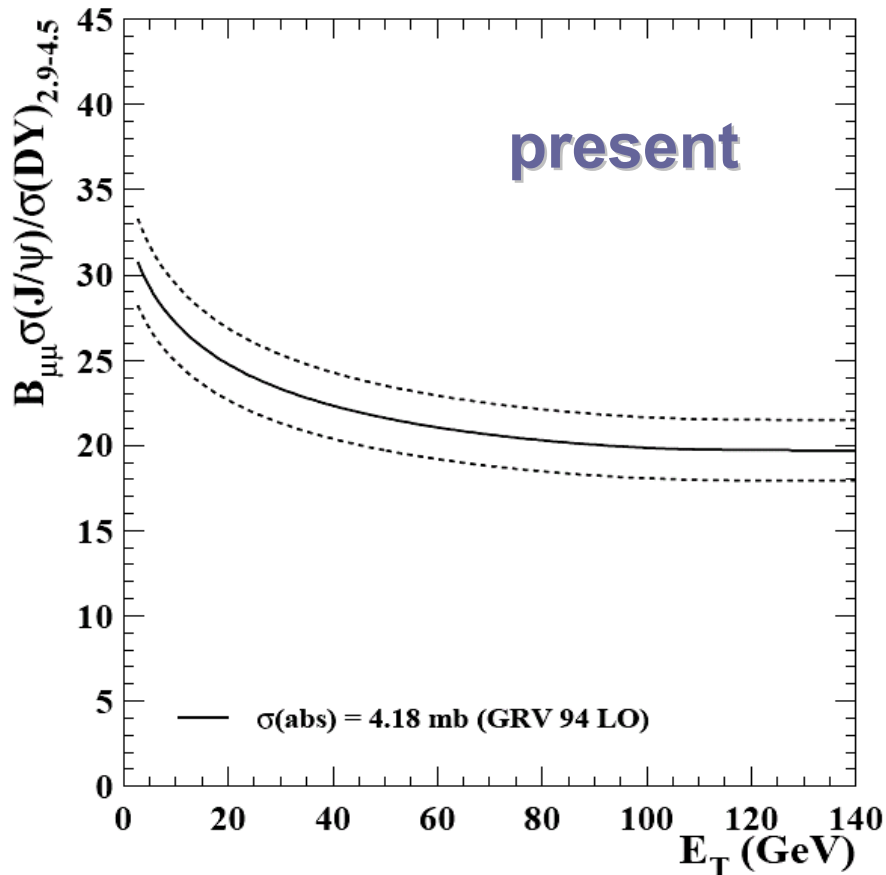
- Under the assumption that **S-U** was behaving normally:

- It was included with p-A results in a simultaneous Glauber fit
 $\sigma_{\text{abs}} = 4.18 \pm 0.35 \text{ mb}$.
- 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.



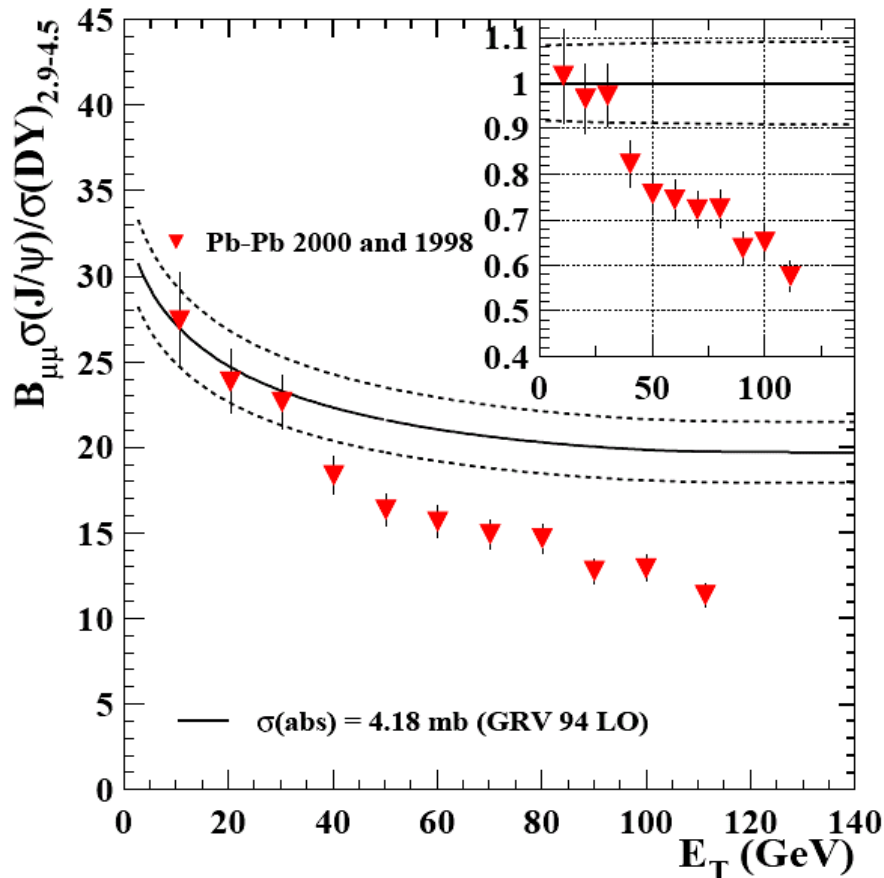
Present vs previous estimation

- 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

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

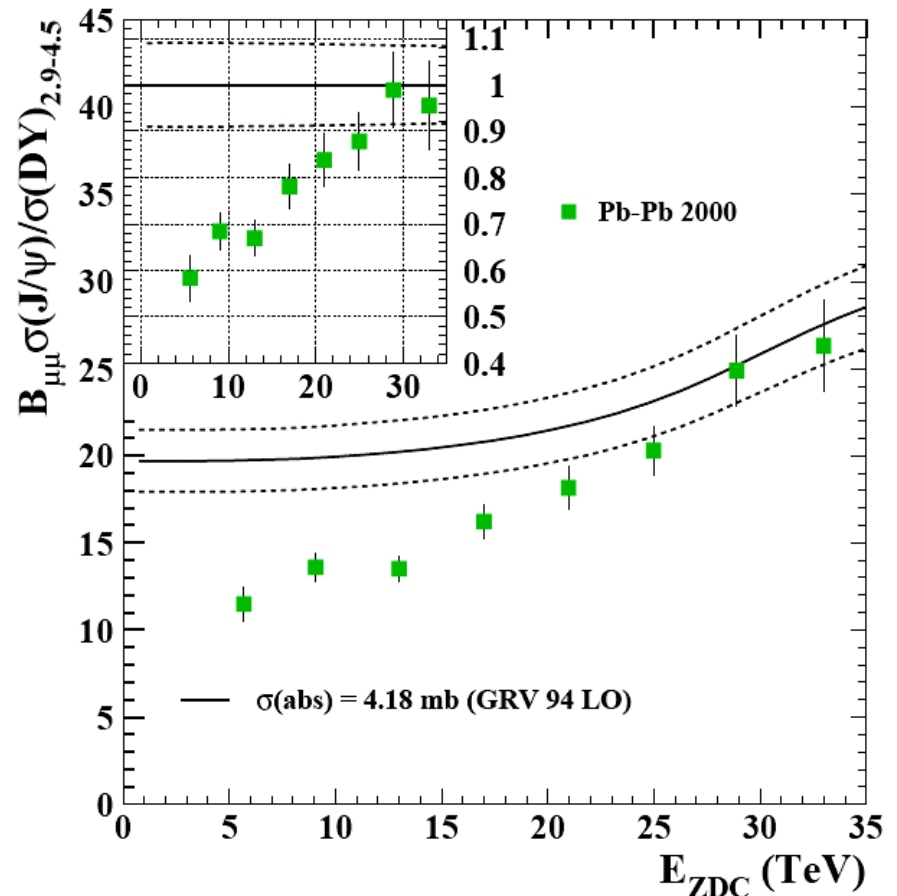
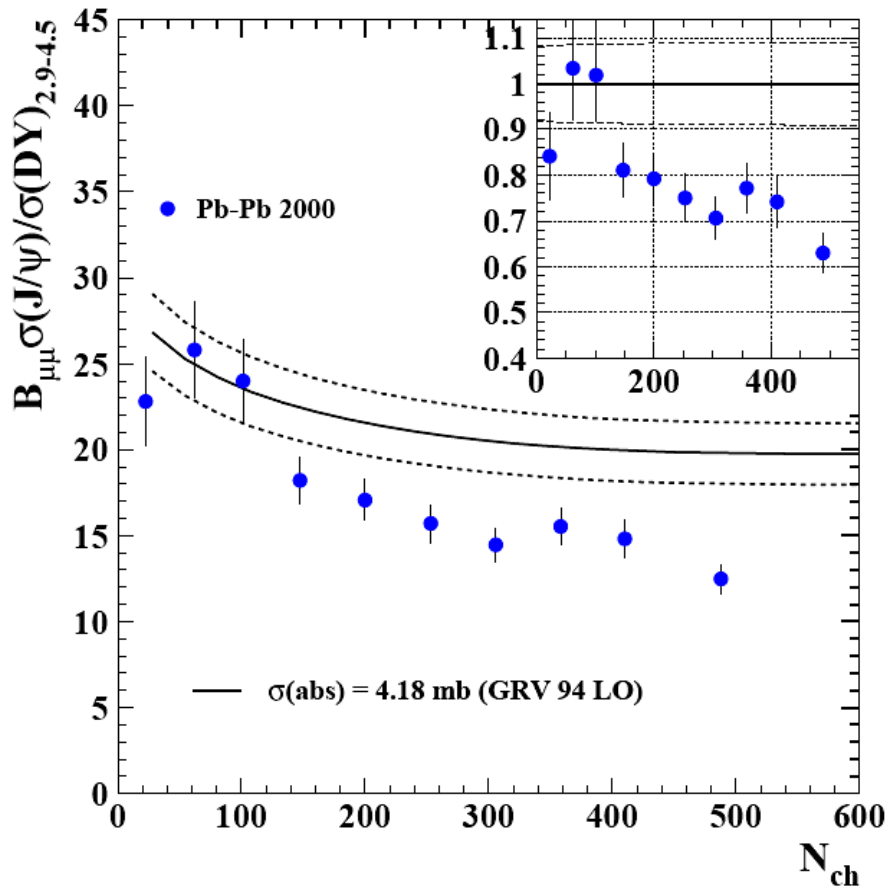


- **Peripheral collisions:**
 - Compatible with the normal nuclear absorption.
- **Mid – centrality:**
 - Departure from the normal nuclear absorption.
- **Central collisions:**
 - No saturation at high centralities.



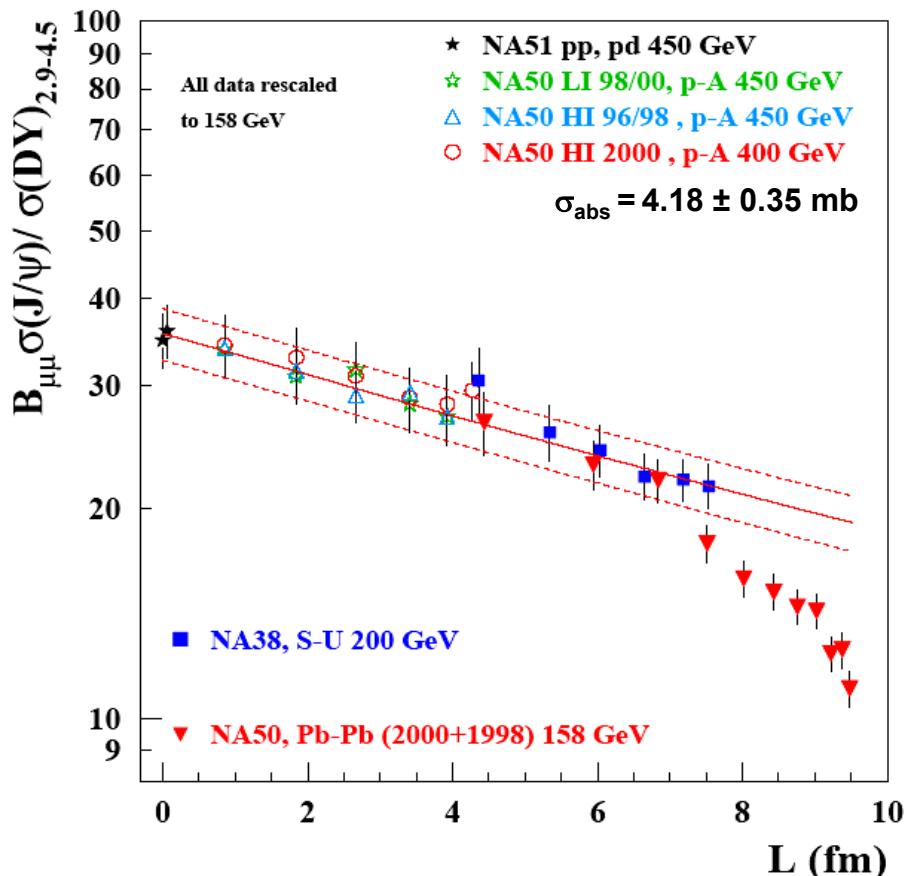
Other centrality estimators

- 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)



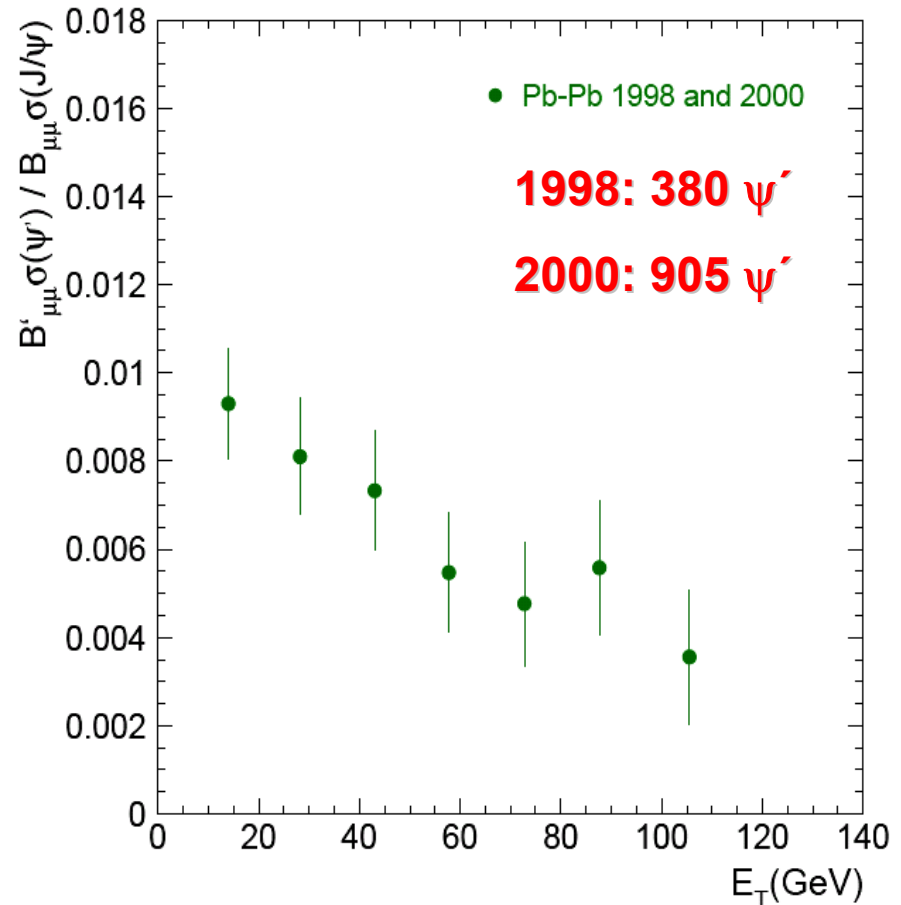
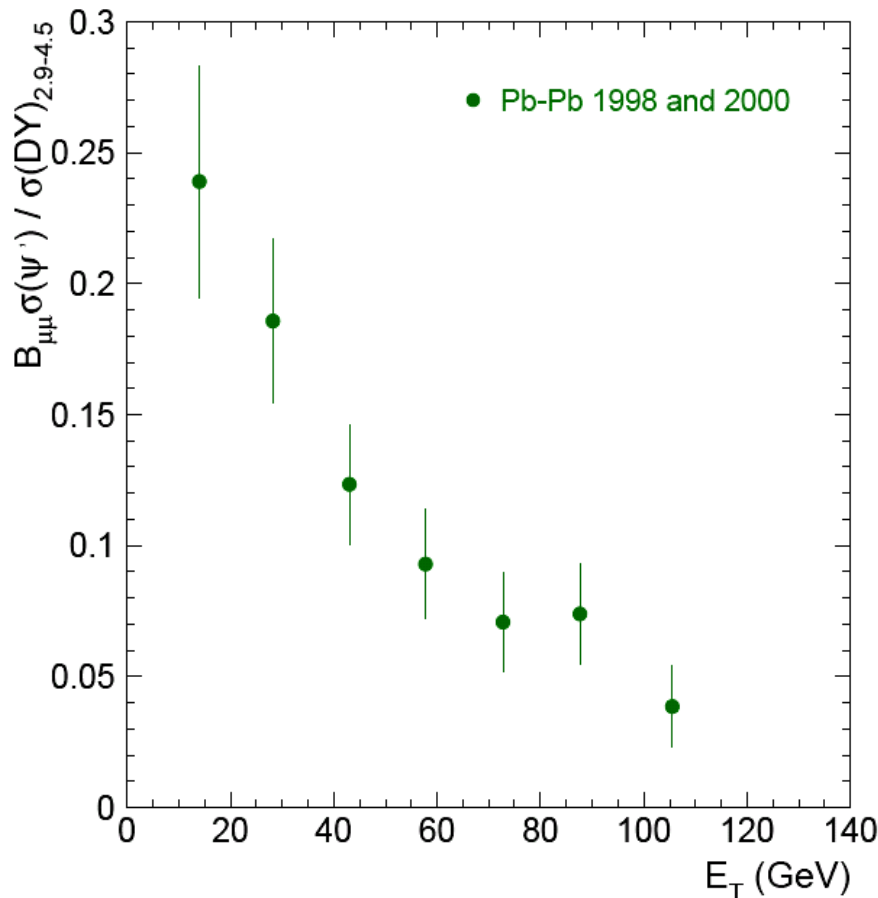
□ L variable

- 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.



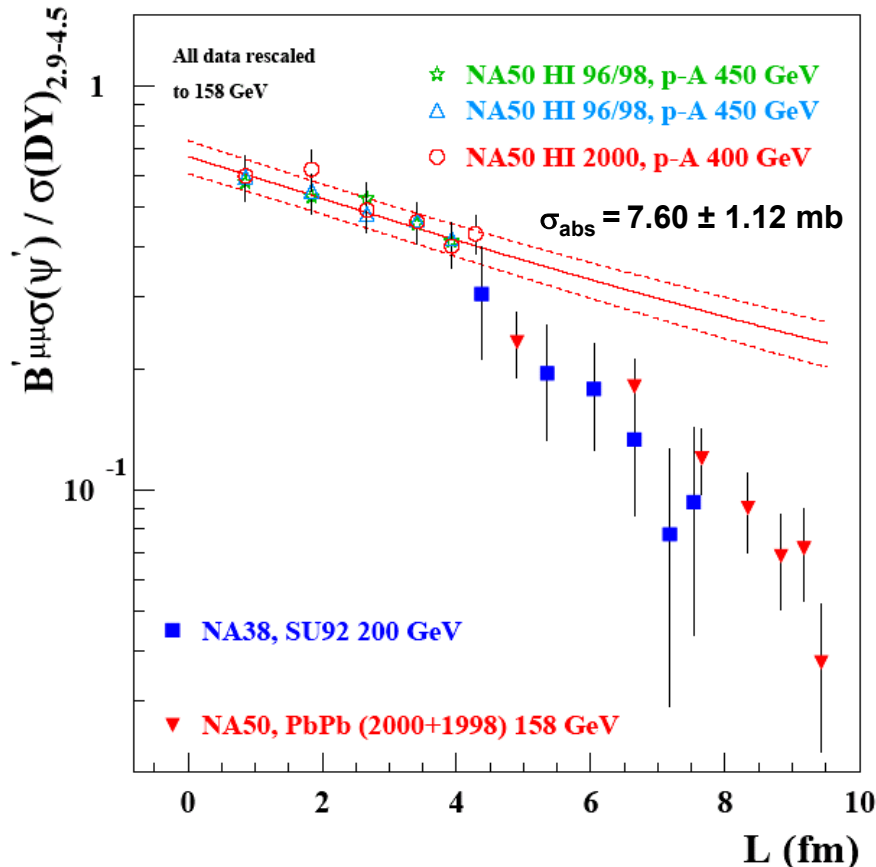
ψ'/DY and $\psi'/\text{J}/\psi$ vs E_T : Pb-Pb results

- 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 $B'_{\mu\mu} \sigma(\psi') / \sigma(DY_{2.9-4.5})$ p-A results:
 - Deduce an absorption curve with $\sigma_{\text{abs}} = 7.60 \pm 1.12$ 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.

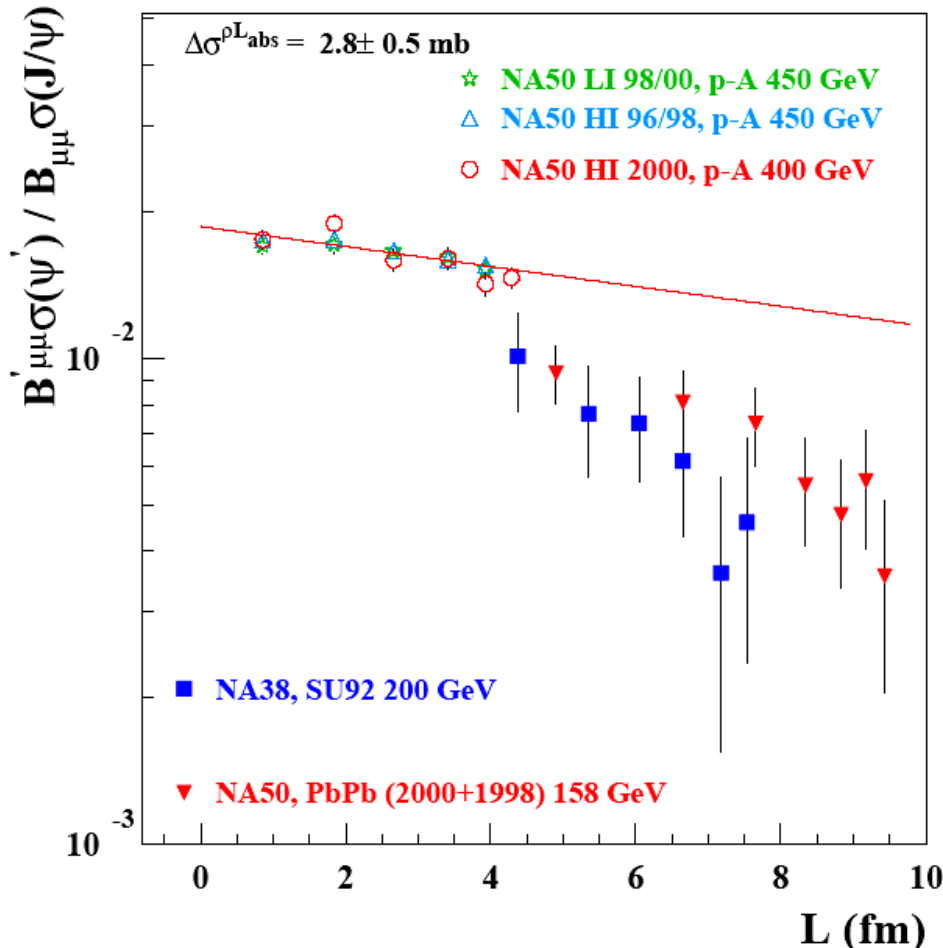


$\psi' / J/\psi$ vs L

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

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

$$\Delta\sigma_{abs}^{\rho L} = 2.8 \pm 0.5 \text{ mb}$$



- The difference between full Glauber calculations is:

$$\begin{aligned} \Delta\sigma_{abs}^{Glb} &= \sigma_{abs}(\psi') - \sigma_{abs}(J/\psi) \\ &= 3.4 \pm 0.6 \text{ mb} \end{aligned}$$

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

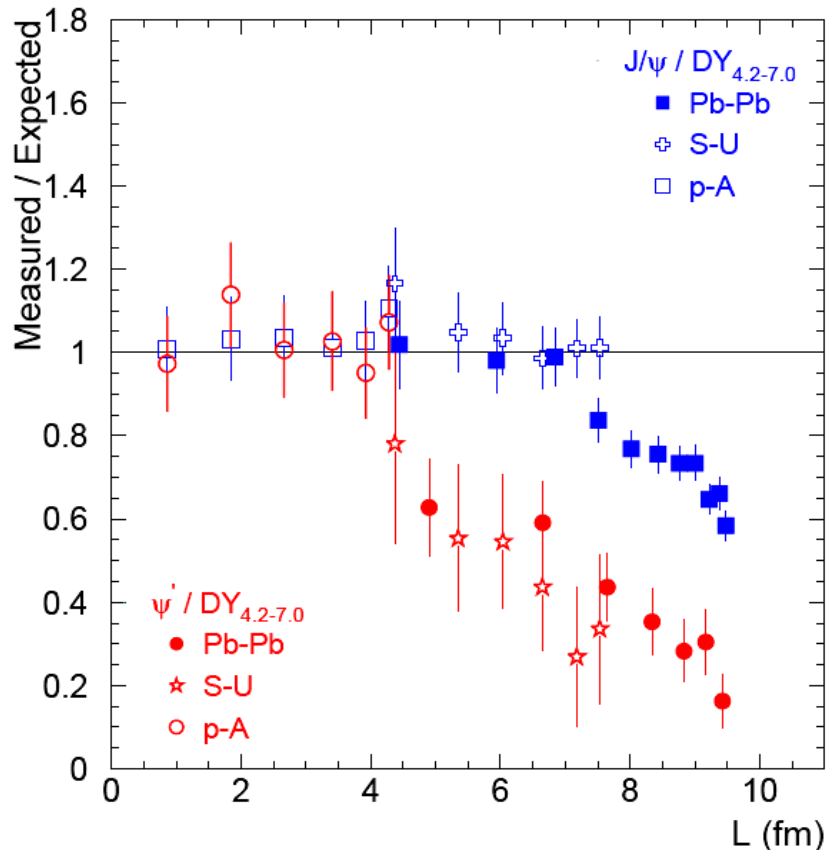


Charmonia results: Conclusions

Expected = Glauber absorption model

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

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



- **S-U** and **peripheral Pb-Pb** $(\text{J}/\psi)/\text{DY}$ results follow the absorption curve extrapolated from p-A measurements.
- **Pb-Pb central collisions** show an **anomalous $(\text{J}/\psi)/\text{DY}$ 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.

