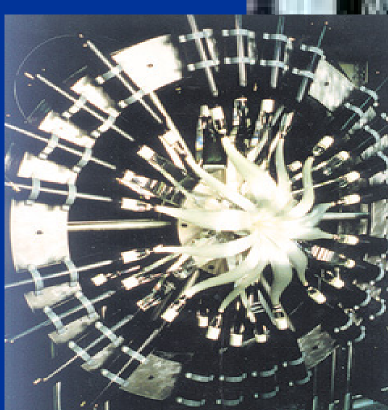
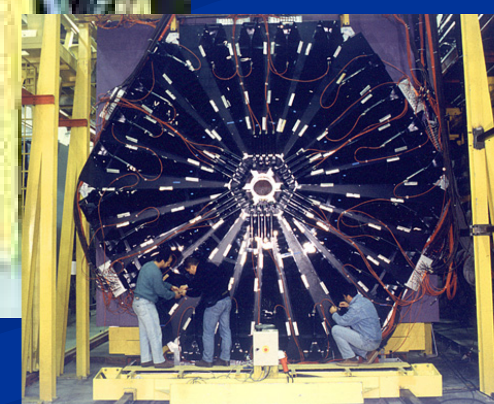
The normal J/ψ nuclear absorption



Gonçalo Borges

NA50 Collaboration

Outline

- The physical motivation
- Data sets and experimental setups
- Data analyses
- Proton-nucleus $B_{\mu\mu}\ \sigma(J/\psi)/A$ results
  - 450 GeV, 400 GeV, 200 GeV
- Comparison with ion $B_{\mu\mu}\ \sigma(J/\psi)/AB$ results
  - 200 GeV O-Cu, O-U, S-U and 158 GeV Pb-Pb
- Comparison with ion $B_{\mu\mu}\ \sigma(J/\psi)\ /\sigma(DY)_{2.9\text{-}4.5}$ results
  - 200 GeV S-U and 158 GeV Pb-Pb
- Conclusions

Motivation

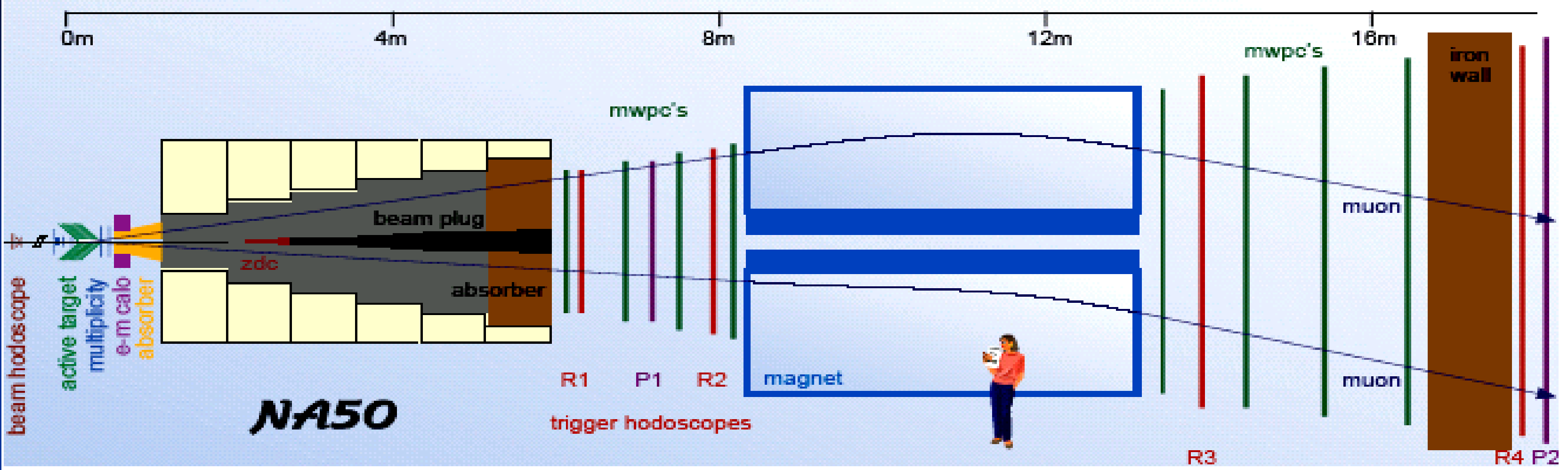
- NA50 studies J/ψ production in Pb-Pb collisions at 158 GeV.
- A very well grounded baseline, describing the normal J/ψ nuclear absorption, has to be established.
  - Study J/ψ production measured in proton collisions with several A targets.
- Extrapolate the expected J/ψ normal nuclear behaviour (as deduced from p-A collisions) to heavier systems.

Available p-A data sets

- Several experiments have measured J/ψ production, in proton-nucleus collisions, at different energies and kinematical domains:
  - NA50 experiment
    - p-A (A = Be, Al, Cu, Ag,W) at 450 GeV
    - p-A (A = Be, Al, Cu, Ag, W, Pb) at 400 GeV
  - NA51 experiment
    - pp, pd at 450 GeV
  - NA38 experiment
    - p-A (A = C, Al, Cu, W) at 450 GeV
    - p-A (A = Cu, W, U) and A-B (O-Cu, O-U, S-U) at 200 GeV
  - NA3 experiment
    - pp, pPt at 200 GeV

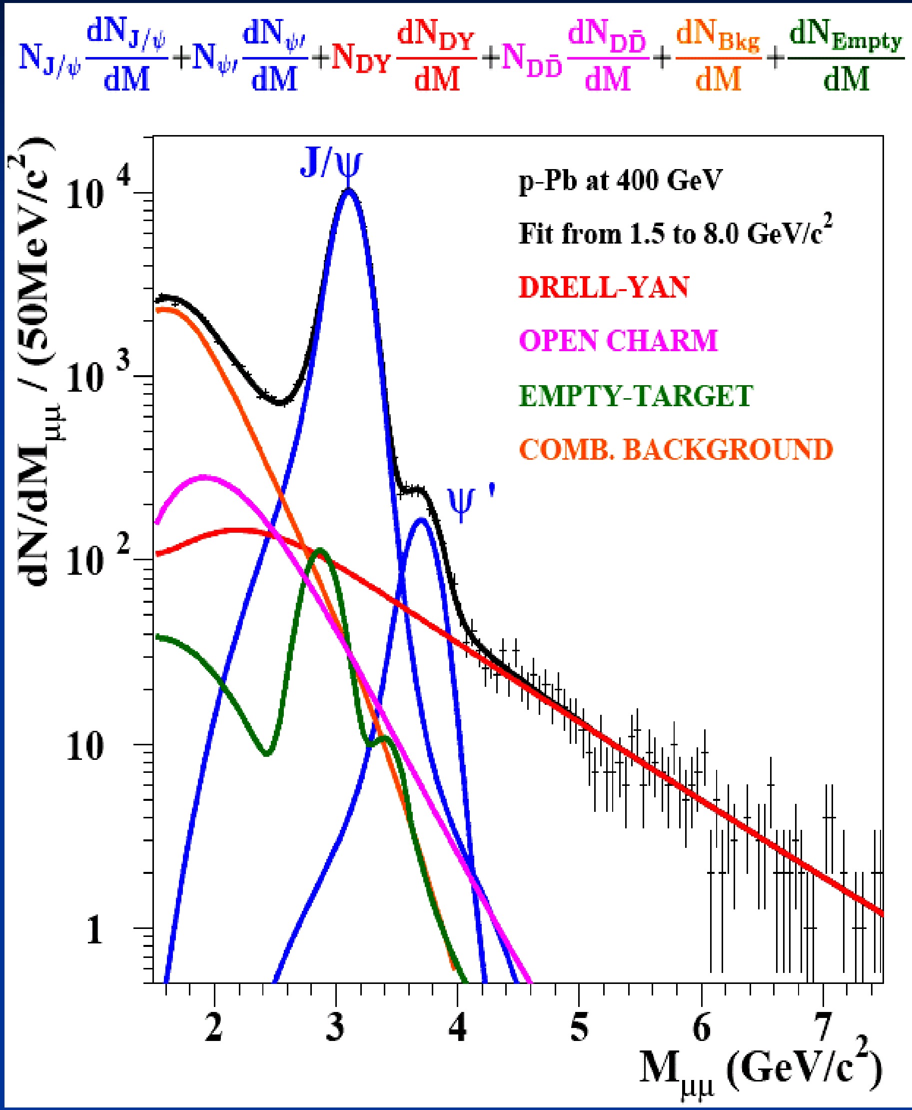
Same Spectrometer

Experimental setups



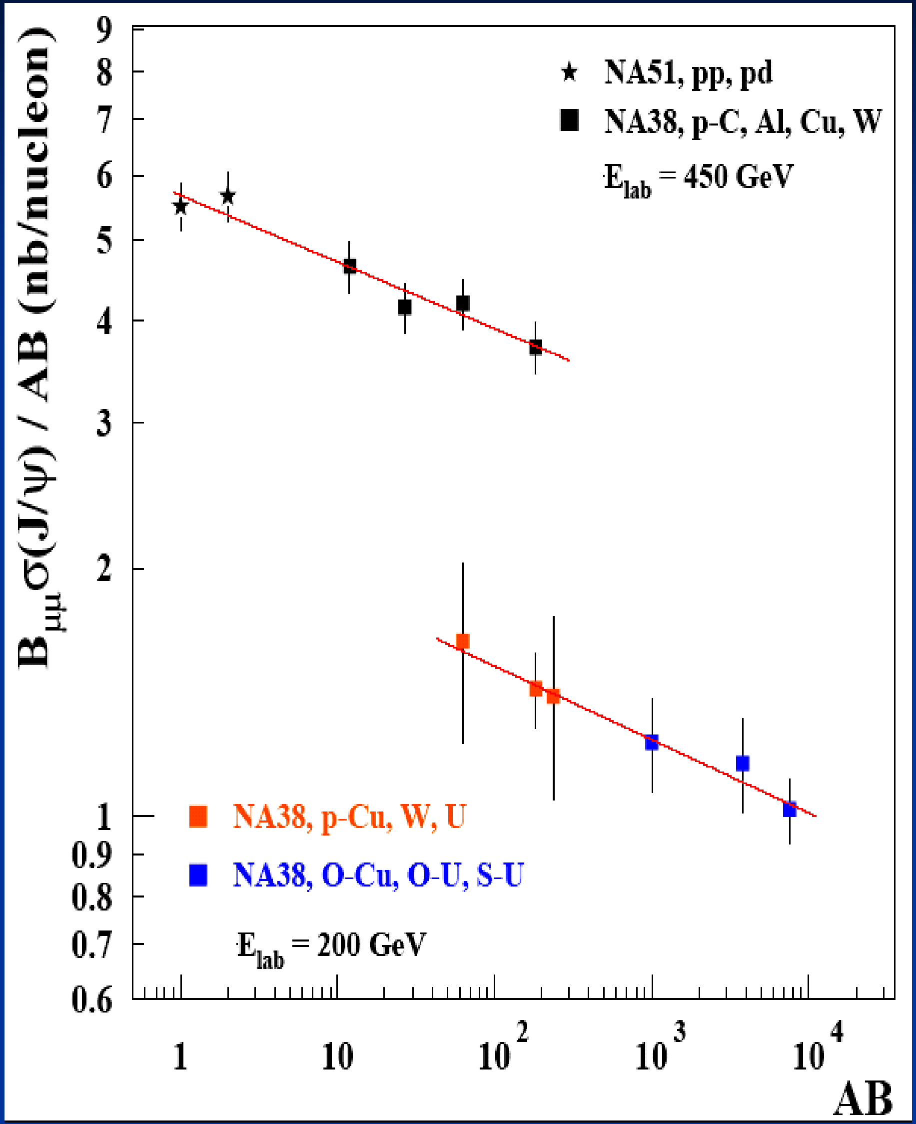
	E_{lab} (GeV)	Data	$Y^*_{\mu\mu}$	$\lvert Cos(\theta_{CS}) \rvert$	Absorber
NA50	450	p-A	-0.50 : 0.50	< 0.5	C, Fe
NA50	400	p-A	-0.45 : 0.55	< 0.5	C, Fe
NA50	158	Pb-Pb	0.00 : 1.00	< 0.5	C, Fe
NA51	450	pp, pd	-0.40 : 0.60	< 0.5	C, Fe
NA38	450	p-A	-0.40 : 0.60	< 0.5	C
NA38	200	p-A	0.00 : 1.00	< 0.5	C
NA38	200	A-B	0.00 : 1.00	< 0.5	C

Data analyses



- NA50, NA51 and NA38 analyses are performed with identical methods.
- The experimental dimuon opposite-sign mass spectrum is analysed through a fit including several ingredients:
  - $J/\psi \rightarrow \mu^+\mu^-$
  - $\psi' \rightarrow \mu^+\mu^-$
  - Drell-Yan process
  - Correlated semileptonic decays of open charm mesons.
  - Combinatorial background

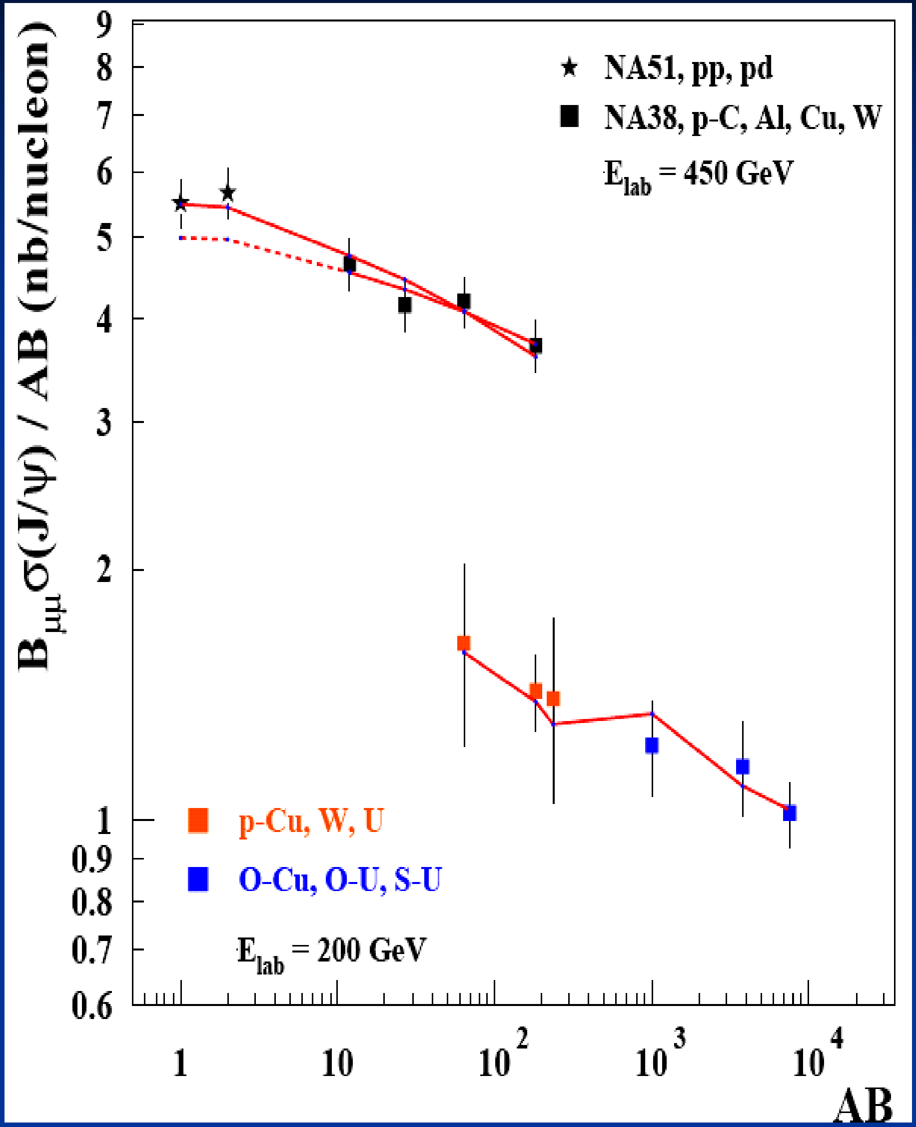
NA51 and NA38 joint α fit



- NA38 has measured J/ψ production in several systems at 450 GeV and 200 GeV.
- NA38 results are compiled in PLB 466 (1999) 408 and analysed together with NA51 450 GeV pp, pd results.
- J/ψ nuclear dependence was parametrized as $\sigma(J/\psi) = \sigma_0 A^{\alpha}$

P_{lab}	N_0 (nb)	$\alpha_{J/\psi}$
450 GeV	5.7±0.3	0.919±0.015
200 GeV	2.3±0.6	0.911±0.034

NA51 and NA38 joint Glauber fit



- A **Glauber Model** was used to describe J/ψ nuclear dependence production

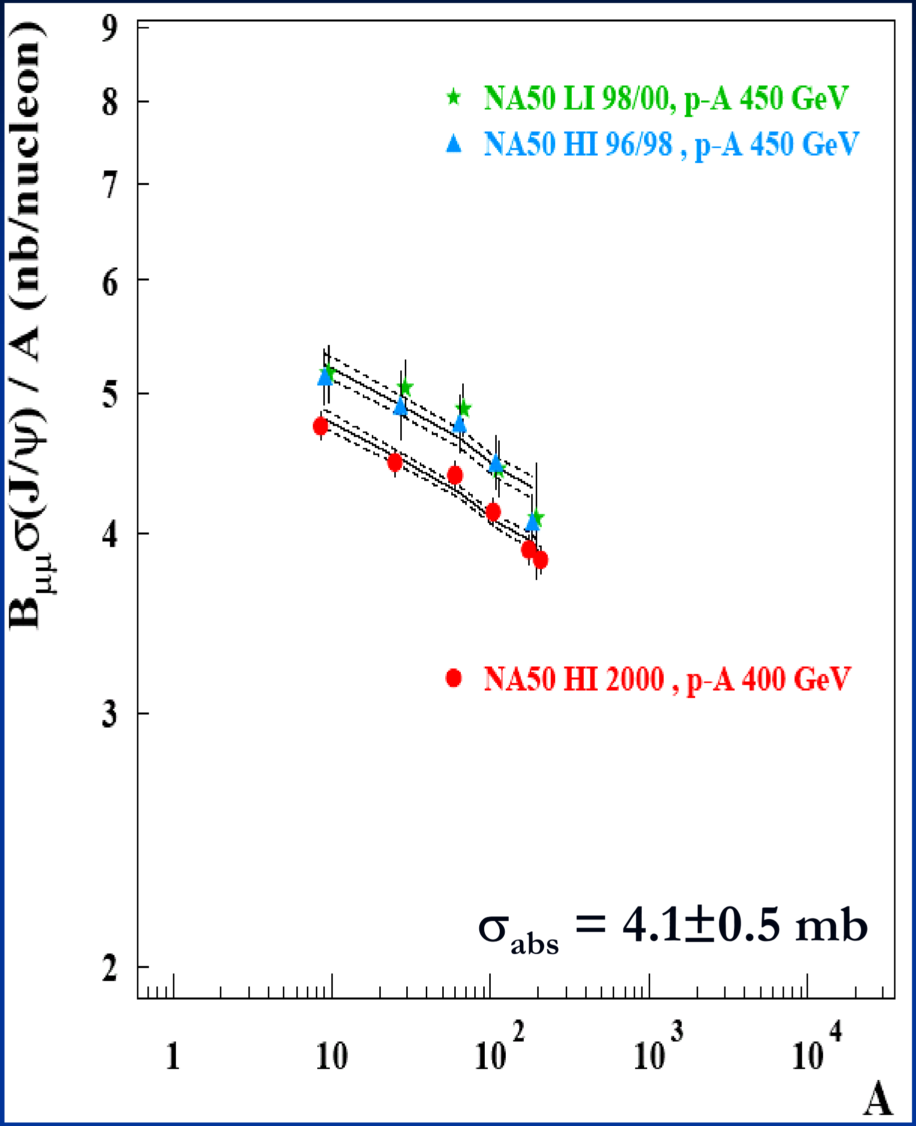
E_{lab}	N_0 (nb)	σ_{abs} (mb)
450 GeV	5.5±0.2	7.1±1.6
200 GeV	2.2±0.5	7.8±3.5

- If NA51 results are excluded from the Glauber fit, we obtain:

E_{lab}	N_0 (nb)	σ_{abs} (mb)
450 GeV	5.0±0.5	4.8±2.6
200 GeV	2.2±0.5	7.8±3.5

► Possible normalization problem between NA51 and NA38 450 GeV p-A results?

NA50 Glauber fit results



- NA50 has 3 different p-A data collections, at 2 different energies and using several targets (A=Be,Al,Cu,Ag,W,Pb)

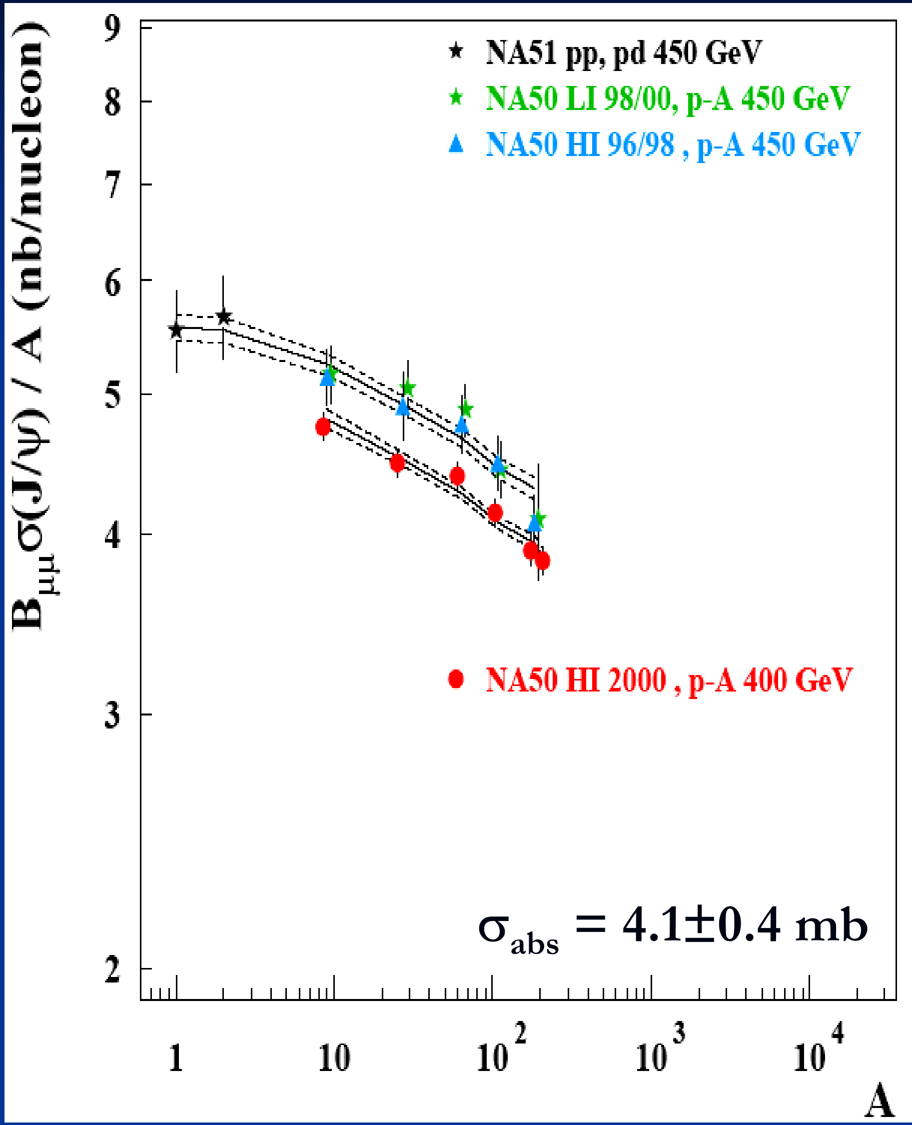
Set	E_{lab}	N_0 (nb)	σ_{abs} (mb)
HI 96/98	450 GeV	5.6±0.3	4.4±1.2
LI 98/00	450 GeV	5.6±0.3	4.0±1.4
HI 2000	400 GeV	5.1±0.1	4.0±0.5

- Results from different data sets are compatible

▶ Perform a simultaneous Glauber fit

E_{lab}	N_0 (nb)	σ_{abs} (mb)
450 GeV	5.6±0.1	4.1±0.5
400 GeV	5.1±0.1	

NA51 and NA50 joint Glauber fit



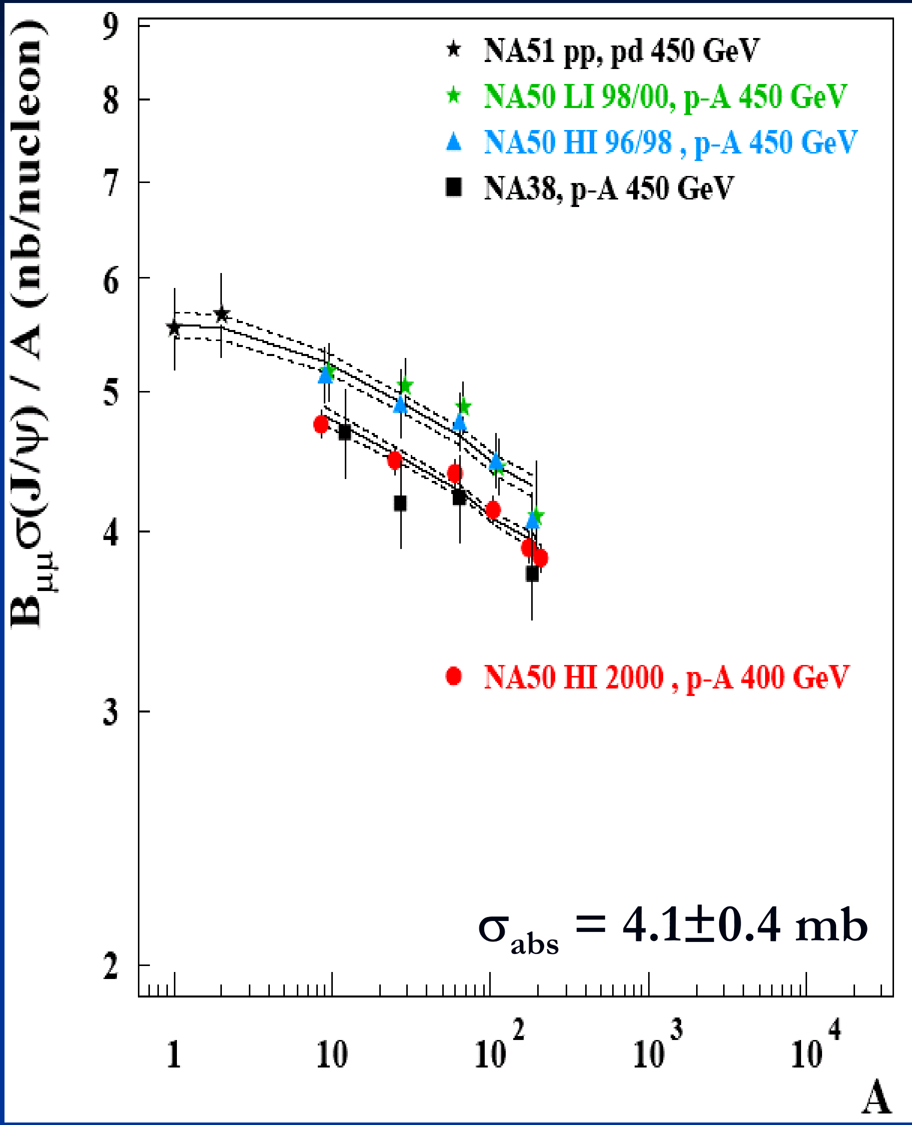
- Glauber fit results including NA51 data

P_{lab}	N_0 (nb)	σ_{abs} (mb)
450 GeV	5.6±0.1	4.1±0.4
400 GeV	5.1±0.1	

- NA51 results are consistent with the extrapolated Glauber behaviour from the NA50 450 GeV p-A results.

► No apparent problem in normalization between NA51 and NA50 450 GeV p-A results.

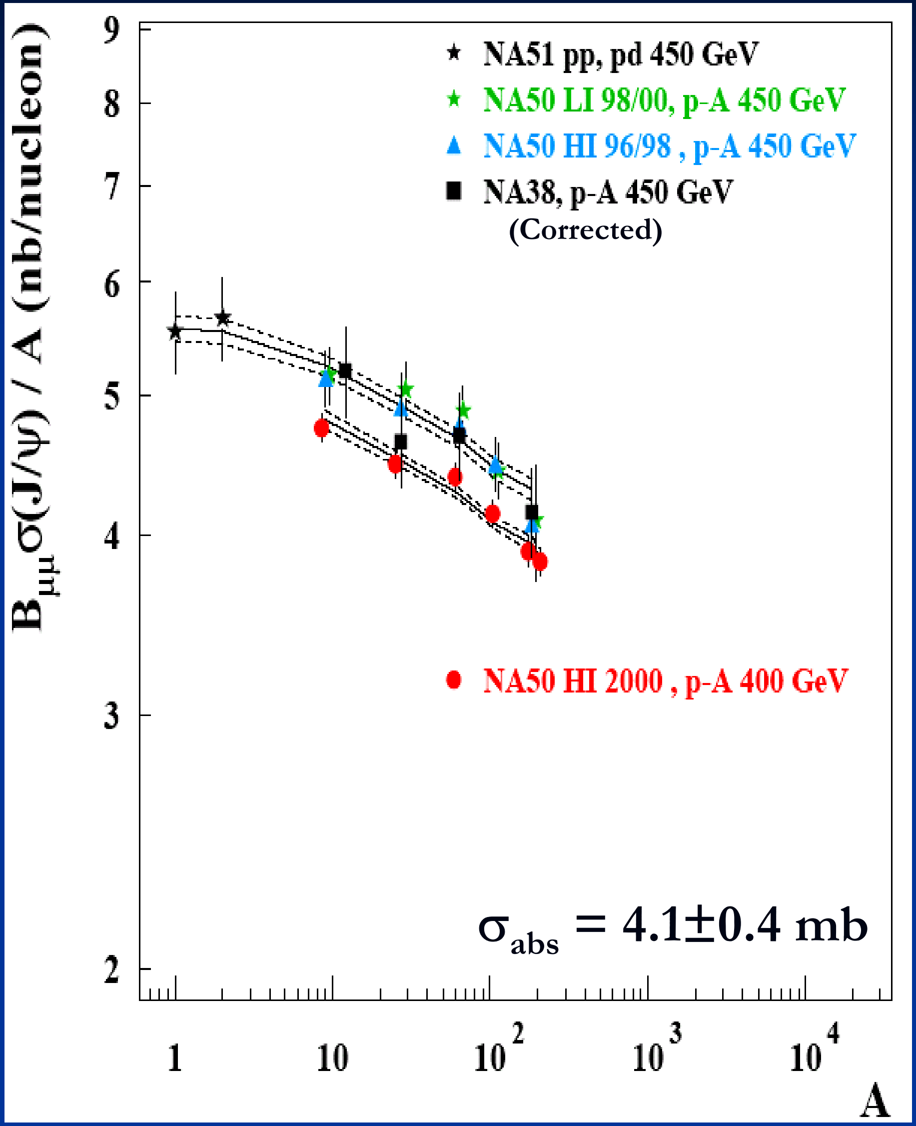
NA51, NA50 and NA38 Glauber fit



- NA50 and NA38 p-A 450 GeV results are not in agreement regarding normalization.
  - Possible systematic problem on NA38 cross-section measurements when compared to NA50.

Set	E_{lab}	N_0 (nb)	σ_{abs} (mb)
NA50	450 GeV	5.6±0.1	4.1±0.4
NA50	400 GeV	5.1±0.1	
NA38	450 GeV	4.9±0.2	

NA51, NA50 and NA38 Glauber fit



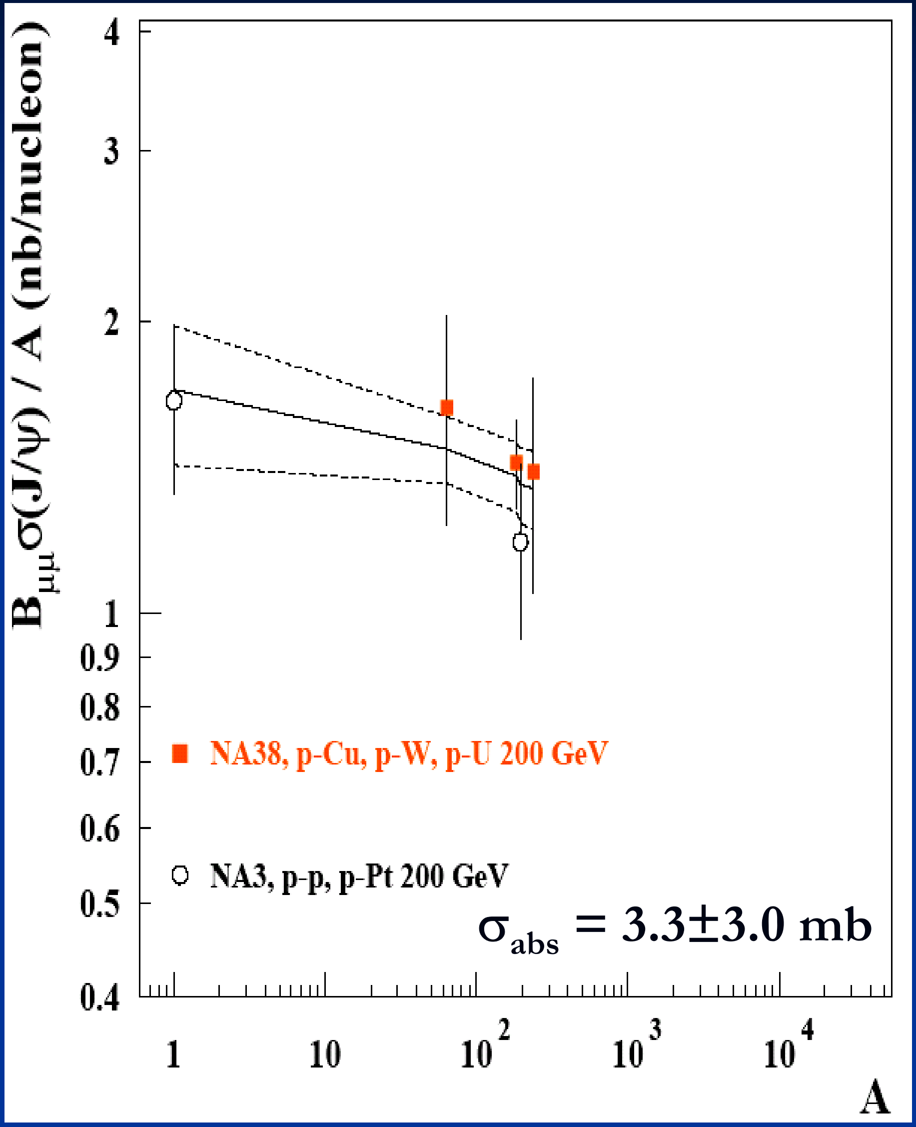
- We revisited the NA38 studies.
  - A problem was found in the NA38 450 GeV p-A reconstruction.
  - This problem does not affect the NA38 p-A 200 GeV results (at much lower intensity beam).
  - An overall ~11% correction has to be applied to the NA38 450 GeV p-A results.

Set	P_{lab}	N_0 (nb)	σ_{abs} (mb)
NA50	450 GeV	5.6±0.1	4.1±0.4
NA50	400 GeV	5.1±0.1	
NA38 (corrected)	450 GeV	5.5±0.2	

NA50 and NA38 comparisons

- The fact that NA50 450 GeV p-A results are now compatible with NA38 450 GeV p-A results (within 2-3%) indicate that:
  - The systematic differences between the two experiments are small and under control;
  - NA50 data at 450/400 GeV can be safely compared with NA38 data at 200 GeV, in terms of slopes and normalizations.

NA38 and NA3 200 GeV Glauber fit



- The 200 GeV NA38 p-A results are not sufficient to extract σ_{abs}.
- NA3 has measured J/ψ production in pp and pPt collisions at 200 GeV. The inclusion of these data in the Glauber fit will constrain the σ_{abs} determination.

E_{lab}	N_0 (nb)	σ_{abs} (mb)
200 GeV	1.7±0.3	3.3±3.0

Comparison of σ_{abs} results

- Glauber fit results to the 450/400 GeV p-A data:

E_{lab}	N_0 (nb)	σ_{abs} (mb)
450 GeV	5.6±0.1	4.1±0.4
400 GeV	5.1±0.1	

- Glauber fit results to the 200 GeV p-A data

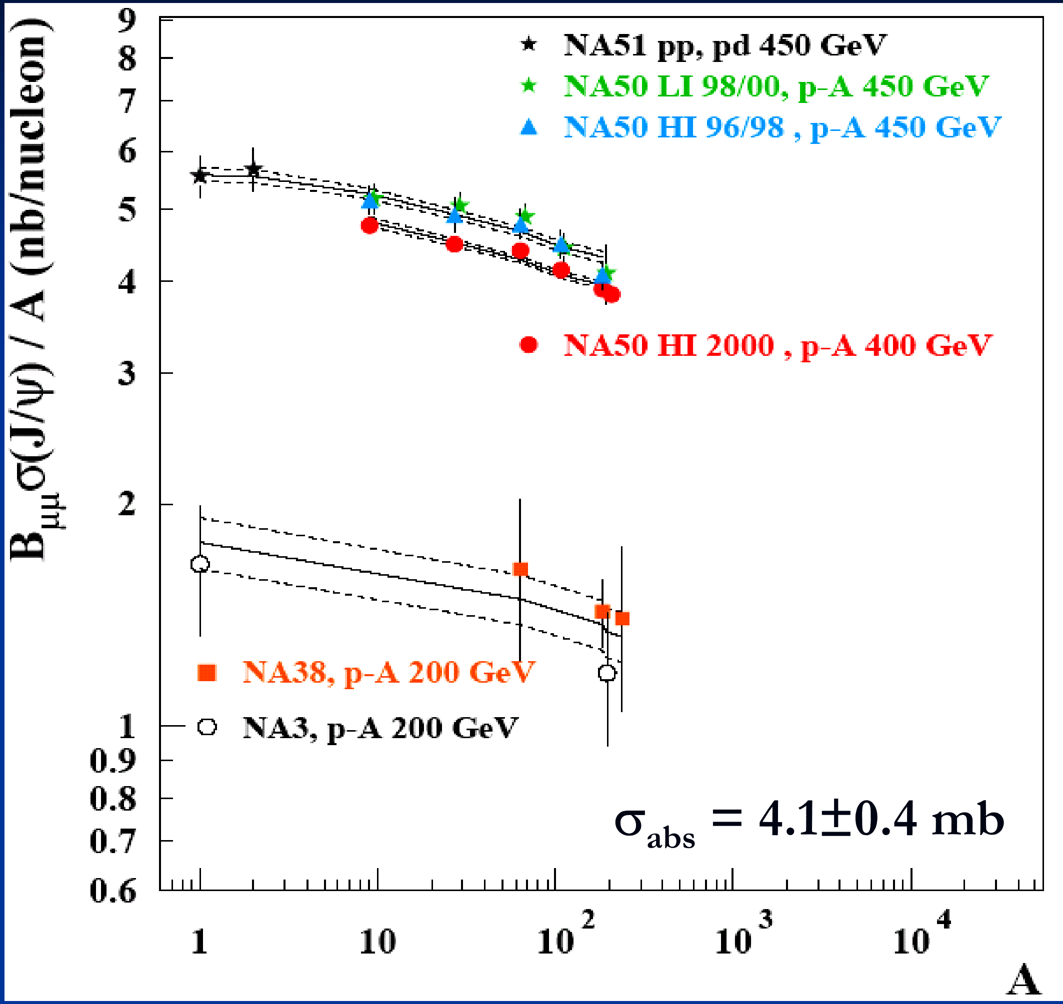
E_{lab}	N_0 (nb)	σ_{abs} (mb)
200 GeV	1.7±0.3	3.3±3.0

- σ_{abs} is determined with bad accuracy at 200 GeV. However, these data are important since they establish the normalization at lower energies.

- σ_{abs} results for the different energies are compatible

  - ► Assume σ_{abs} is constant between 450, 400 and 200 GeV.

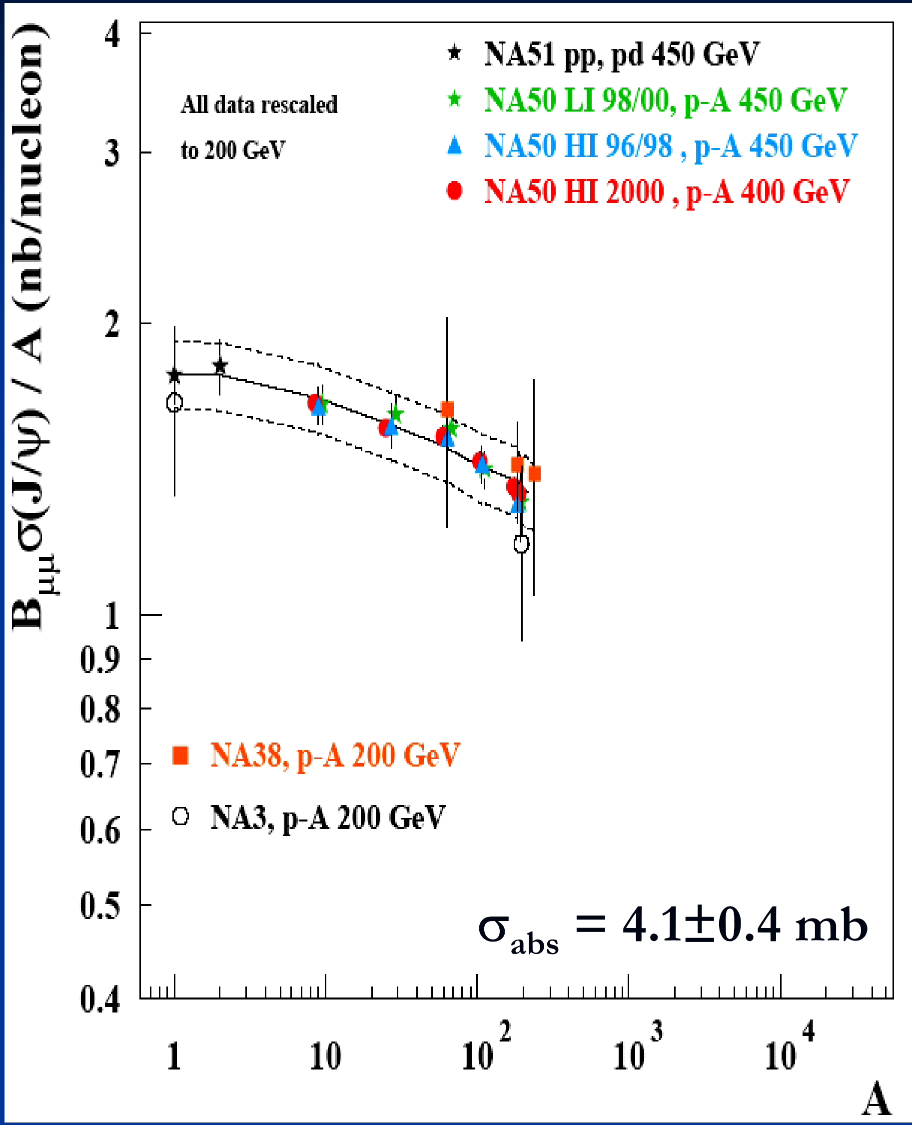
Final σ_{abs} results



- Final results are obtained from a simultaneous Glauber fit performed for the 450/400/200 GeV p-A data

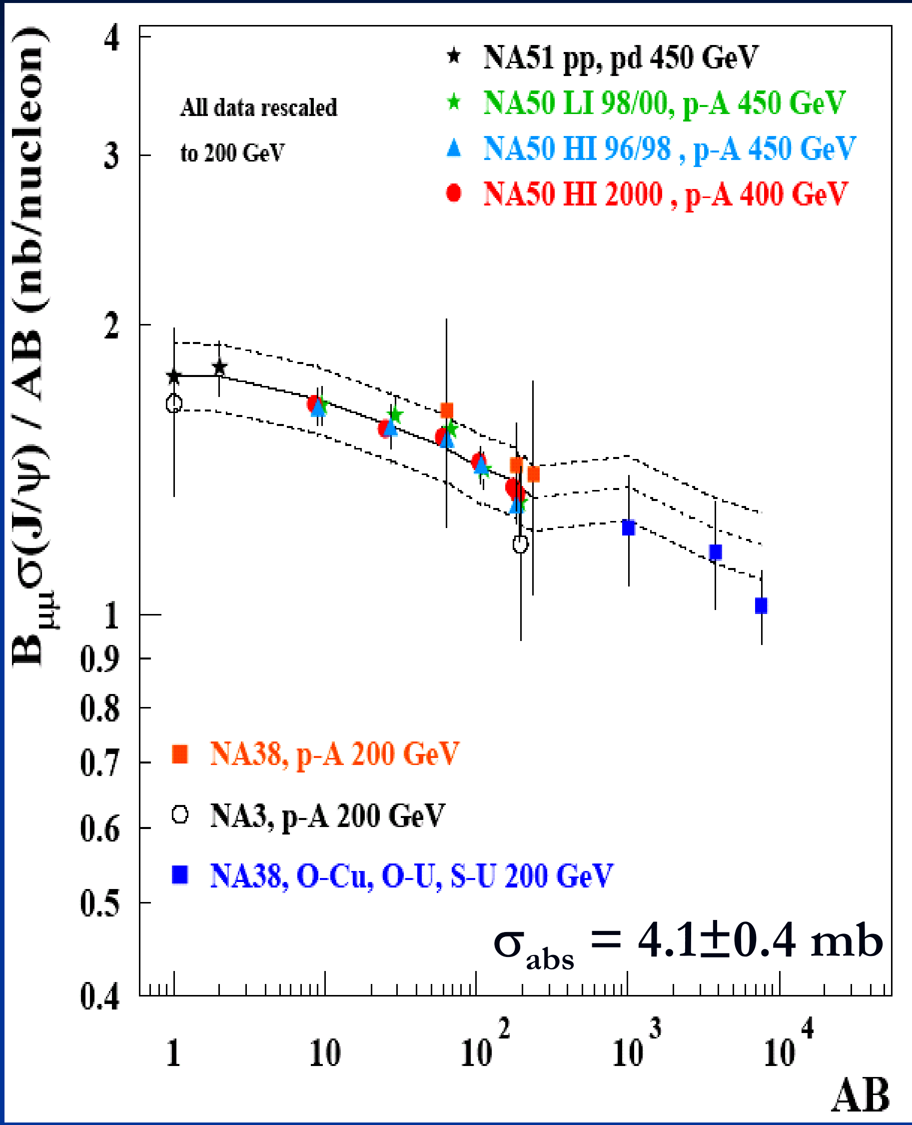
N_0^{200} (nb)	N_0^{400} (nb)	N_0^{450} (nb)	N_0^{200}/N_0^{400}	N_0^{200}/N_0^{450}	σ_{abs} (mb)
1.8±0.1	5.1±0.1	5.6±0.1	0.348±0.027	0.319±0.025	4.1±0.4

Experimental rescaling to 200 GeV



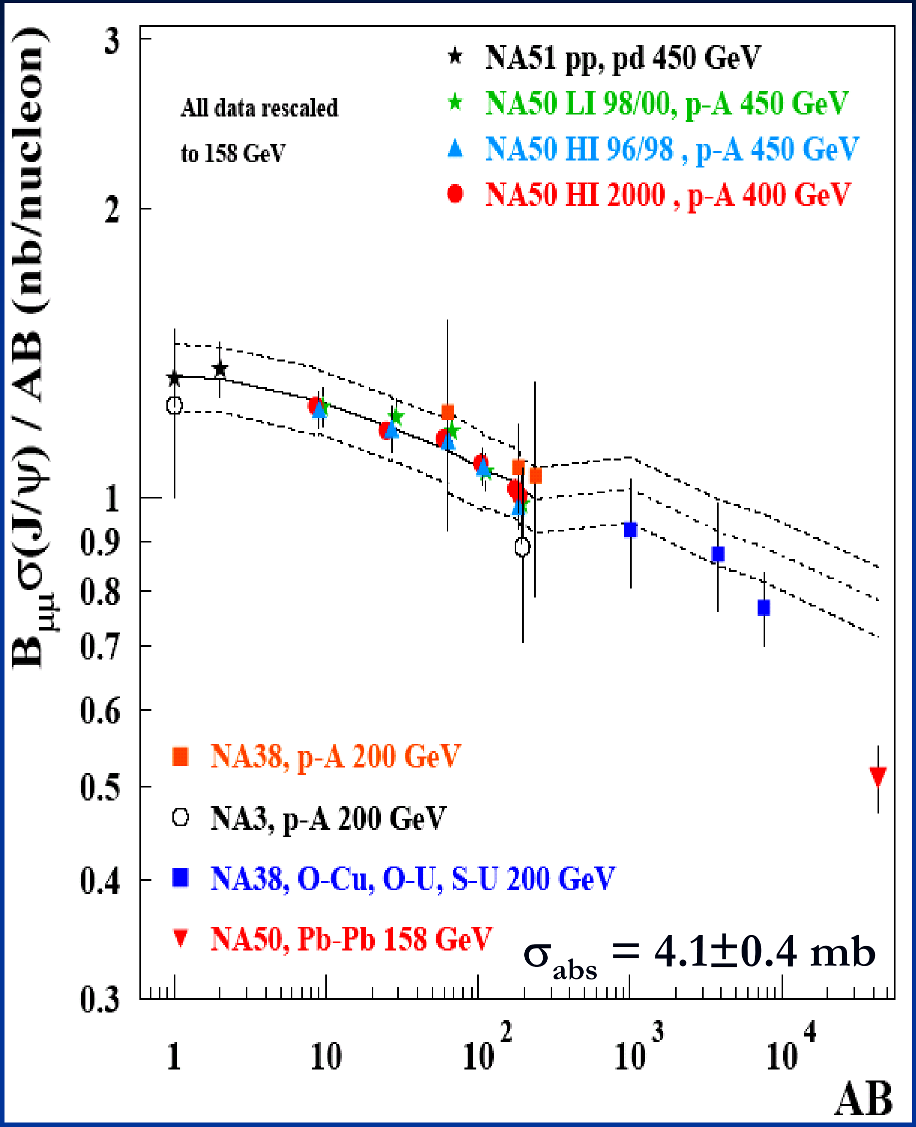
- The ratios N_0^{200}/N_0^{450} and N_0^{200}/N_0^{400} are used to scale down J/ψ absolute cross - sections from higher energies to 200 GeV.
- The rescale systematic error (7.8%) is not included in the data error bars.

Comparison with NA38 light ion data



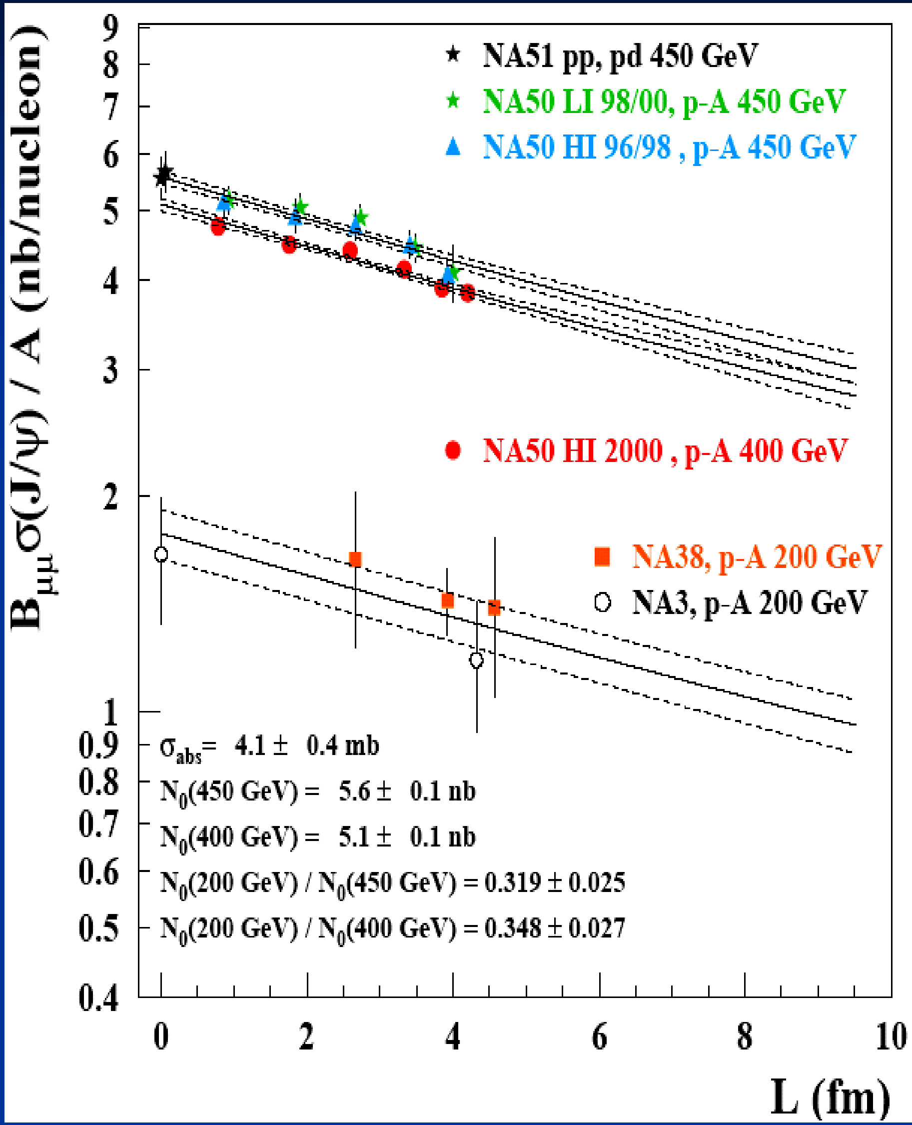
- The A-B data from NA38 are not included in the Glauber fits.
- They are just plotted and compared with the corresponding Glauber estimation deduced from p-A data.

Comparison with NA50 Pb-Pb results



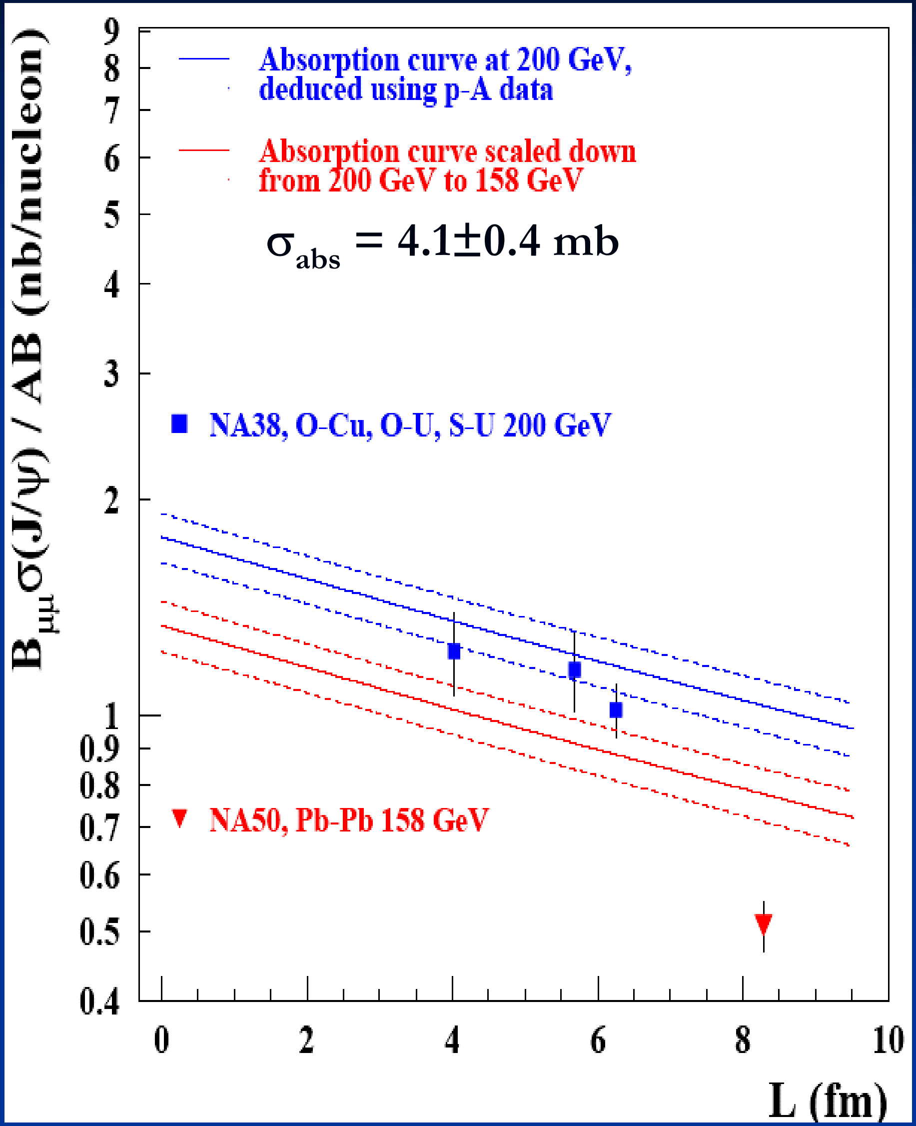
- NA50 has also measured Pb-Pb J/ψ absolute cross-section at 158 GeV.
- The "Schuler parametrization" (in energy and x_F) is used to scale down all data from the 200 GeV kinematical domain to the 158 GeV kinematical domain.
- The Pb-Pb J/ψ production result is compared with the extrapolated Glauber behaviour deduced from p-A data with no assumptions at all regarding A-B results.

ψ absorption curve as a function of L



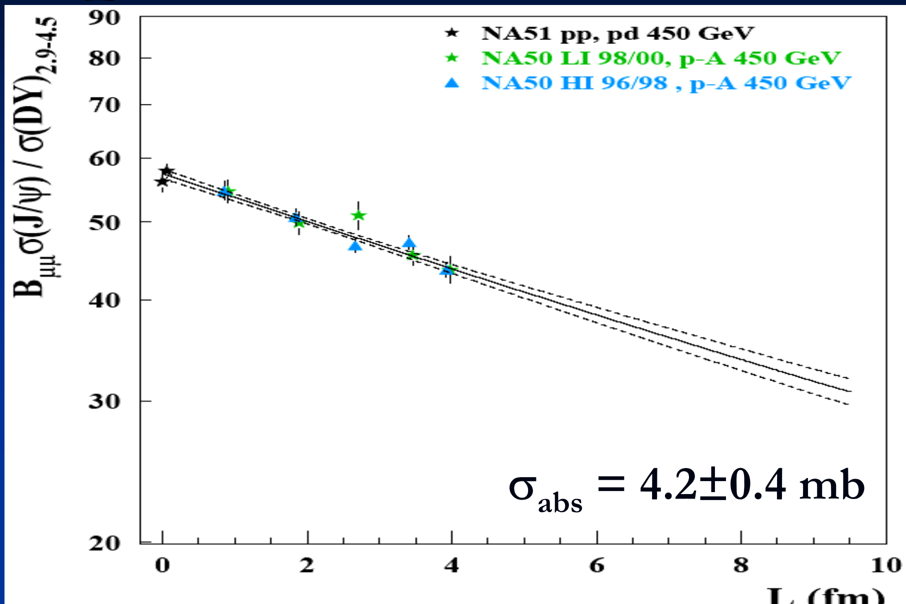
- The same absorption curve, with σ_{abs}=4.1±0.4 mb, is drawn as a function of L, the average path length of J/ψ in nuclear matter, for the 3 different energies:
  - 450 GeV
  - 400 GeV
  - 200 GeV

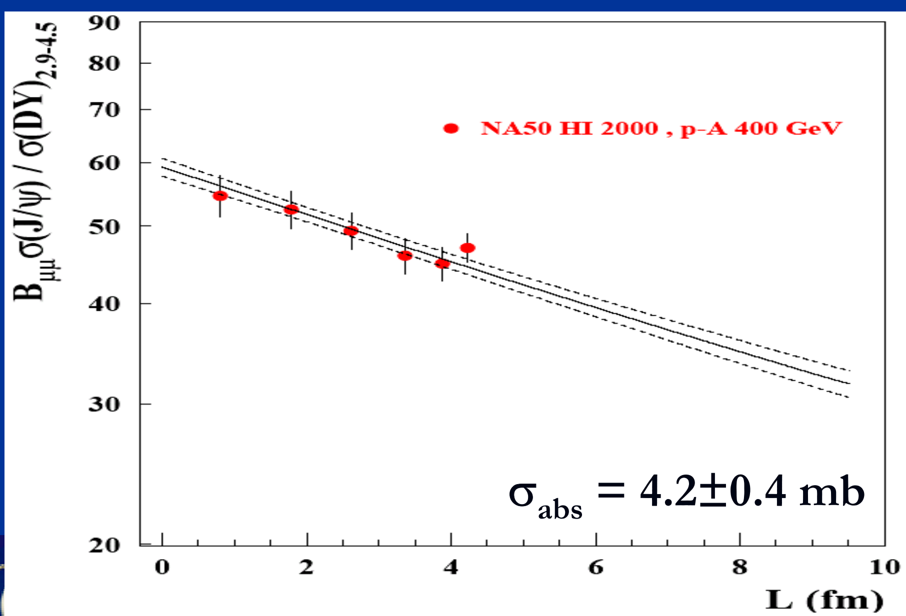
ψ absorption curve as a function of L (2)



- The absorption curve is directly compared with NA38 Bμμ σ(ψ) /AB results at 200 GeV.
- The absorption curve has to be scaled down to the NA50 158 GeV kinematical domain for a direct comparison with Pb-Pb Bμμ σ(ψ) /AB results.

p-A Bμμ σ(ψ) /σ(DY)$_{2.9\text{-}4.5}$ σ_{abs} result



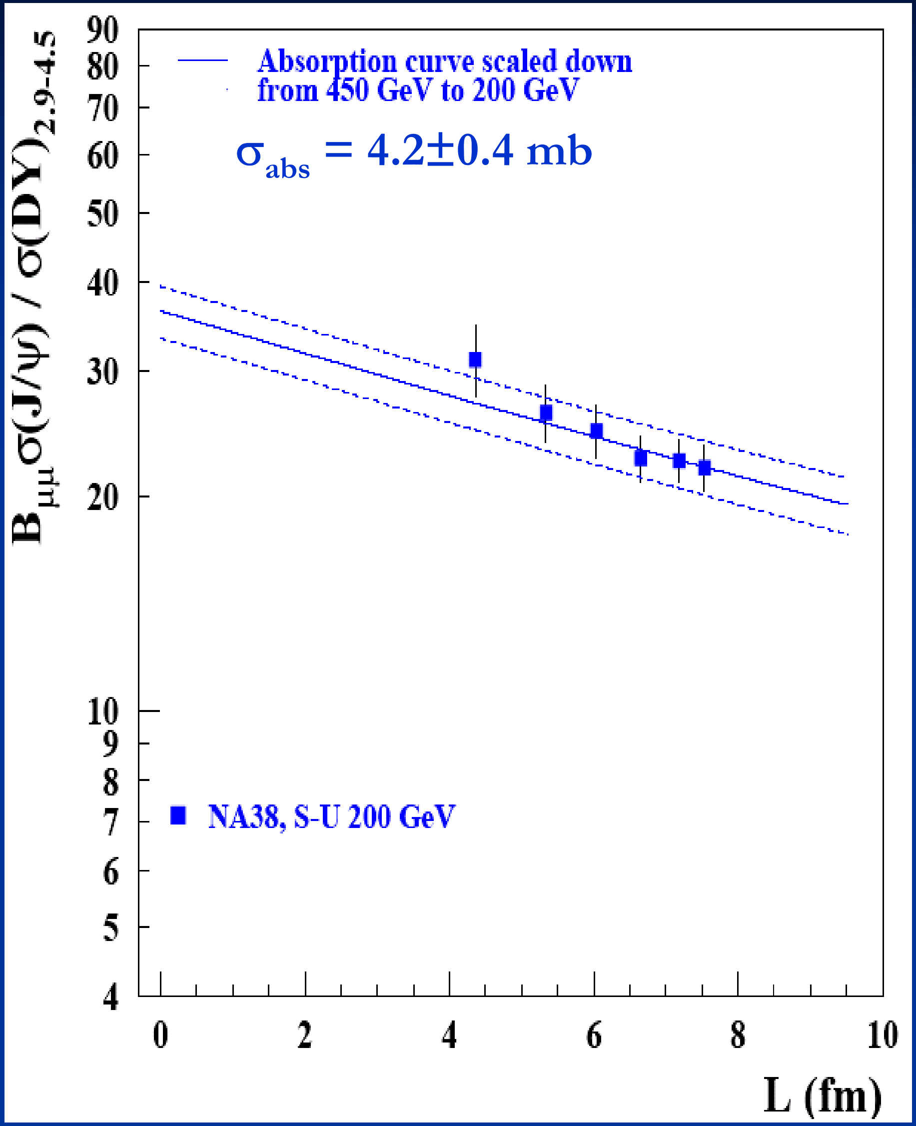


- Bμμ σ(ψ) /σ(DY)$_{2.9\text{-}4.5}$ results in p-A collisions are extracted from NA51 and NA50 data. A Glauber fit is performed using these measurements:

P_{lab}	N_0 (Ψ/DY)	σ_{abs} (mb)
450 GeV	57.5±0.8	4.2±0.4
400 GeV	59.3±1.5	

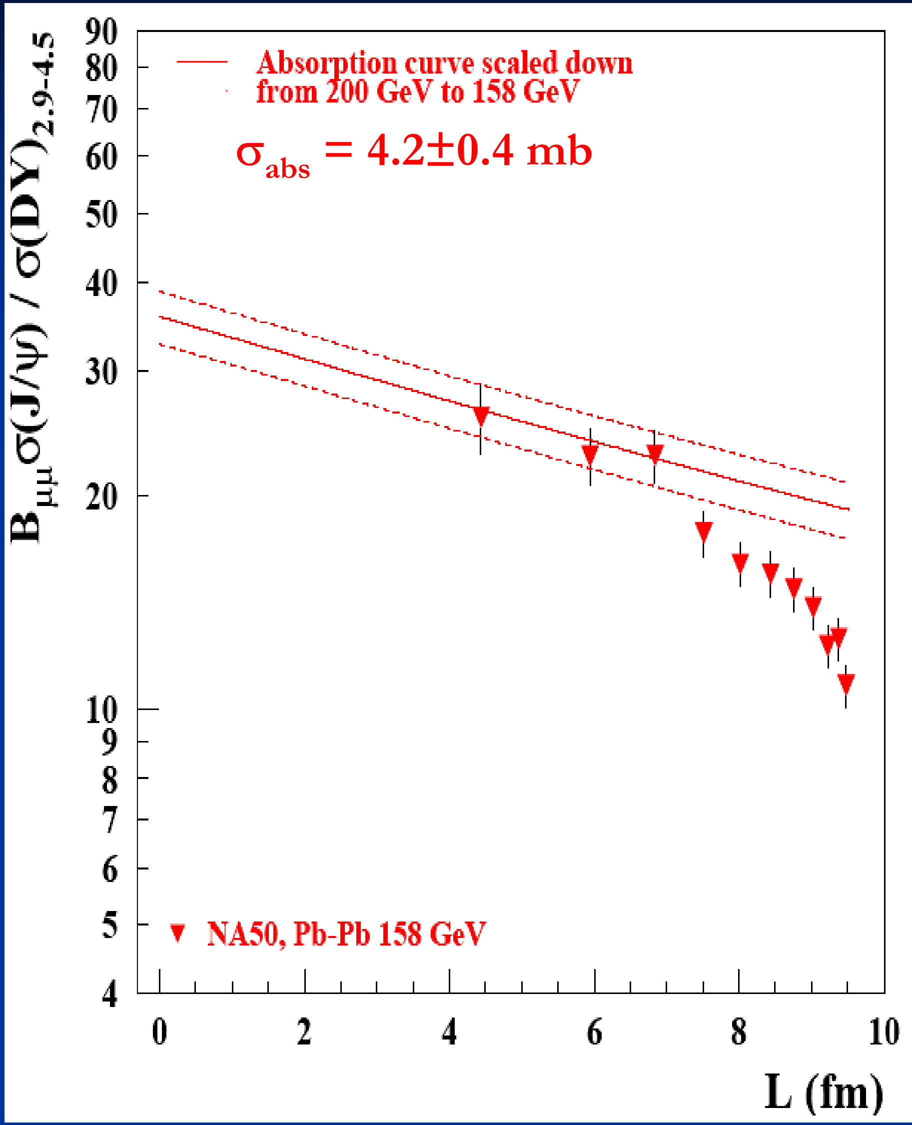
- This σ_{abs} value is in good agreement with the one obtained from Bμμ σ(ψ) /AB results (σ_{abs} = 4.1±0.4 mb).

ψ/DY absorption curve as a function of L



- The ψ/DY absorption curve is **scaled down to 200 GeV using the J/ψ experimental rescales measured in p-A data** and a LO DY calculation.
- S-U $B_{\mu\mu}\ \sigma(\psi) / \sigma(DY)_{2.9\text{-}4.5}$ results at 200 GeV are compared with the absorption curve.

ψ/DY absorption curve as a function of L (2)



- $B\mu\mu\ \sigma(\psi) / \sigma(DY)_{2.9\text{-}4.5}$ Pb-Pb results are compared with an absorption curve scaled down from 200 GeV to 158 GeV using Schuler energy/x_F dependence and a LO DY calculation.

Summary and Conclusions

- J/ψ production was deeply studied using the **available p-A data** at different energies (450, 400 and 200 GeV) from several experiments (NA51, NA50, NA38 and NA3).
- From the J/ψ absolute cross-section used in this study, we have obtained
  - σ_{abs}(450, 400 GeV) = 4.1 ± 0.4 mb
  - σ_{abs}(200 GeV) = 3.3 ± 3.0 mb

  allowing us to assume that σ_{abs} may be the same within the energy range and kinematical domains of the different experiments.

Summary and Conclusions (2)

- **Results from a simultaneous fit to p-A data at the different energies and kinematical domains, give $\sigma_{abs} = 4.1 \pm 0.4$ mb and allow to scale down absolute cross-section from higher energies to 200 GeV.**
- **We observe that the J/ψ NA38 O-Cu, O-U and S-U results lie on top of the absorption curve deduced from p-A data.**
- **Pb-Pb results are systematically below the absorption curve, either in:**
  - $B_{\mu\mu}\,\sigma(\psi)$ /AB measurements
  - $B_{\mu\mu}\,\sigma(\psi)$ /$\sigma(DY)_{2.9\text{-}4.5}$ measurements

More details in analysis metod

- The opposite sign mass spectrum is analysed in a multistep fit procedure:
  - $1.5 \leq M_{\mu\mu} < 8.0$ GeV/c^2 → 1st aproach. Obtain good initial values.
  - $1.5 \leq M_{\mu\mu} < 2.3$ GeV/c^2 → Get R_{BKG}
  - $2.7 \leq M_{\mu\mu} < 4.1$ GeV/c^2 → Precise definition of the ressonance shapes
  - $1.5 \leq M_{\mu\mu} < 8.0$ GeV/c^2 → Get N_{ψ}, $N_{\psi'}$, N_{DY}, N_{DD} contributions
- Acceptances and physical shapes of the different contributions are obtained via MC and spectrometer simulation.
- Background shape is obtained from the like sign mass spectra coming from $\pi^{\pm}$, $K^{\pm}$ uncorrelated decays

$$N^{\pm} = 2\, R_{BKG} \,(N^{++} N^{--})^{1/2}$$

- An empty target contribution is included taking into account dimuons produced upstream and downstrem from the target.

Systematics between NA38 and NA3 ?

- The systematics between NA3 and NA38 data at 200 GeV may exist.
- We have increased NA3 data by a factor 1.21 corresponding to the ratio

$$(\sigma_{pW}/A_W)|_{NA38} \;/\; (\sigma_{pPt}/A_{Pt})|_{NA3}$$

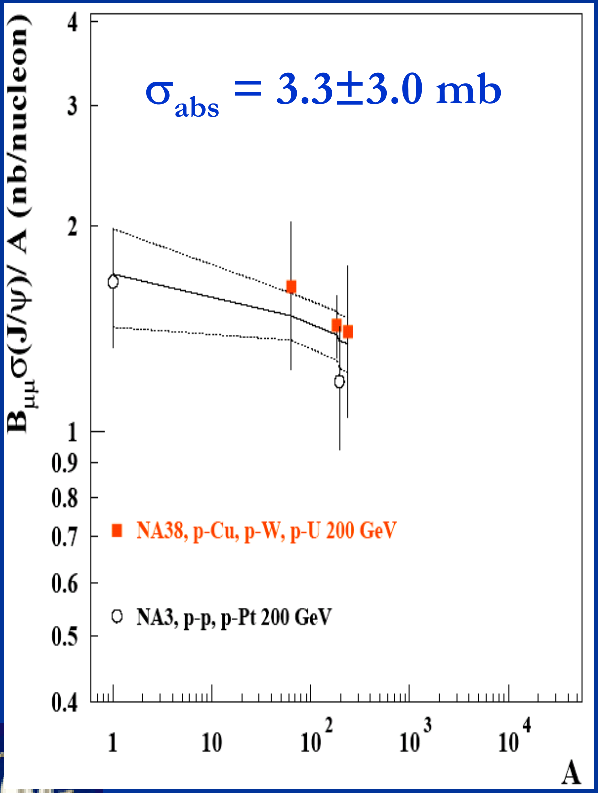
- The simultaneous Glauber calculation was performed as before. We have obtained:

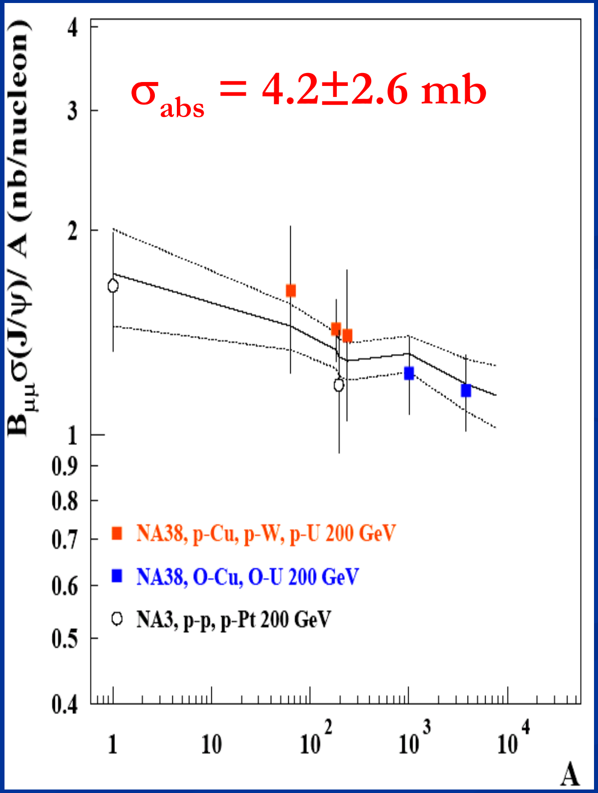
E_{lab}	N_0 (nb)	σ_{abs} (mb)
200 GeV	1.7±0.3	3.3±3.0
200 GeV	2.0±0.4	5.4±3.4

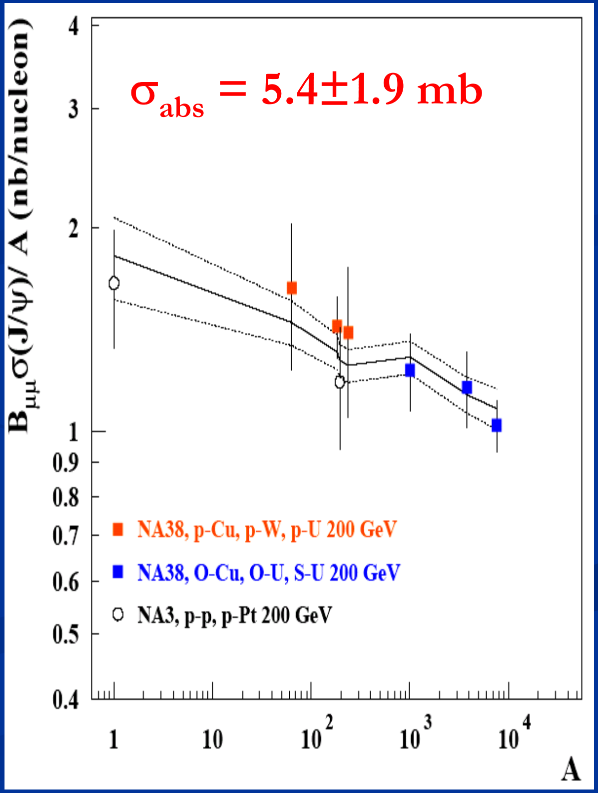
200 GeV A-B Glauber fit results

- Include A-B results in the Glauber fits at 200 GeV

E_{lab}	p-A	O-Cu,U	S-U	N_0 (nb)	σ_{abs} (mb)
200 GeV	√			1.7±0.3	3.3±3.0
200 GeV	√	√		1.7±0.3	4.2±2.6
200 GeV	√	√	√	1.8±0.3	5.4±1.9







From NA3 to NA38 kinematical domain

- NA3 has measured J/ψ production in pp, pPt collisions. Results are obtained to $x_F > 0$ and reported in Z. Phys. C20 (1983) 101.

	$\sigma_{\pi\text{-}A}$ (nb/nuc)	$\sigma_{p\text{-}A} / \sigma_{\pi\text{-}A}$	$\sigma_{p\text{-}A}$ (nb/nuc)
H_2	6.3±0.8	0.58±0.07	3.654±0.640
Pt	4.92±0.77	0.53±0.05	2.608±0.477

- Rescale to NA38 kinematical domain:
  - Divide by a factor 2 (assuming an uniform $|\mathrm{Cos}(\theta_{CS})|$ distribution)
  - Multiply by 0.907±0.084 to rescale to NA38 x_F domain at 200 GeV.
    - $d\sigma/dx_F \sim (1-|x_F|)^d$

	$\sigma_{p\text{-}A}$ (nb/nuc)
H_2	1.657±0.328
Pt	1.182±0.242

"Schuler parametrization" and R.Vogt calculations

- **NA51/NA50/NA38/NA3 experimental rescale**

σ_0 (450 GeV, $-0.5 < Y_{\mu\mu} < 0.5$) / σ_0 (200 GeV, $0.0 < Y_{\mu\mu} < 1.0$) =

0.319 ± 0.025

- **Comparison with other J/ψ production descriptions**

E_{lab}	x_F	Schuler (E, x_F)	R. Vogt (E, x_F)
450 GeV → 200 GeV	[-0.11 : 0.11[→ [0.00 : 0.38[	$(0.460\pm0.009) * (0.866\pm0.139) = 0.398\pm0.064$	0.394 * 0.947 = 0.373
200 GeV → 158 GeV	[0.00: 0.38[→ [0.00: 0.42[	$(0.738\pm0.006) * (1.020\pm0.013) = 0.753\pm0.011$	0.724 * 1.026 = 0.743

- **R.Vogt calculation from**
  - Int. J. Mod. Phys. E12 (2003) 211
  - hep-ph/0311048
- **Schuler parametrizations**
  - $d\sigma/dx_F \sim (1-|x_F|)^d$ with $d = [13.5\pm4.5] / (1 + ([44.9\pm21.9]/s^{1/2}))$
  - $\sigma \sim (1-M/s^{1/2})^n$ with $n = 12.7\pm0.3$