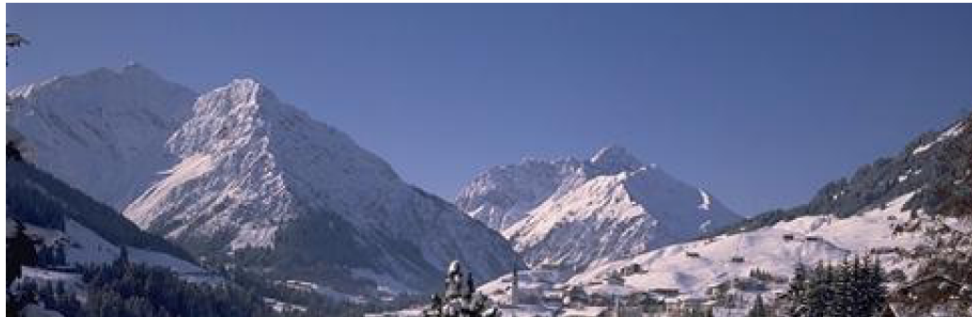


J/ψ and ψ' productions in nucleus-nucleus collisions at the CERN-SPS

Helena Santos, LIP-Lisbon
NA50 Collaboration

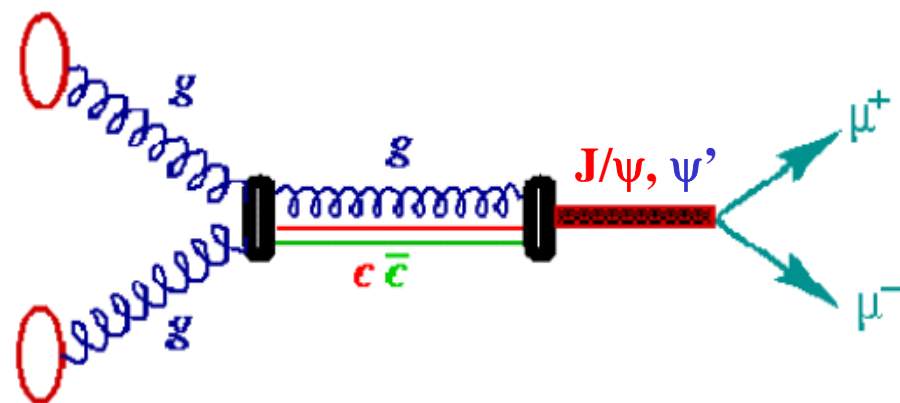
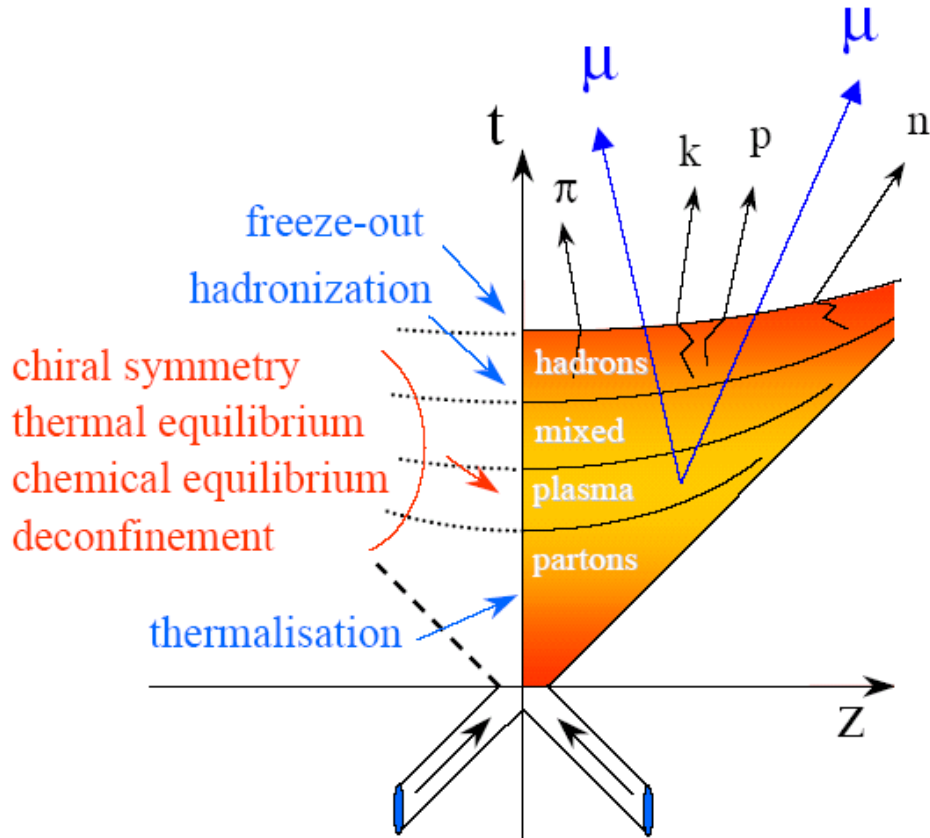
Outline

- Introduction
- NA50 experiment overview
- Analysis procedure
- Results in Pb-Pb collisions
- Results in lighter systems and comparisons
- Conclusions



Phenomenology of the Heavy Ion Collisions

Evolution of interacting matter

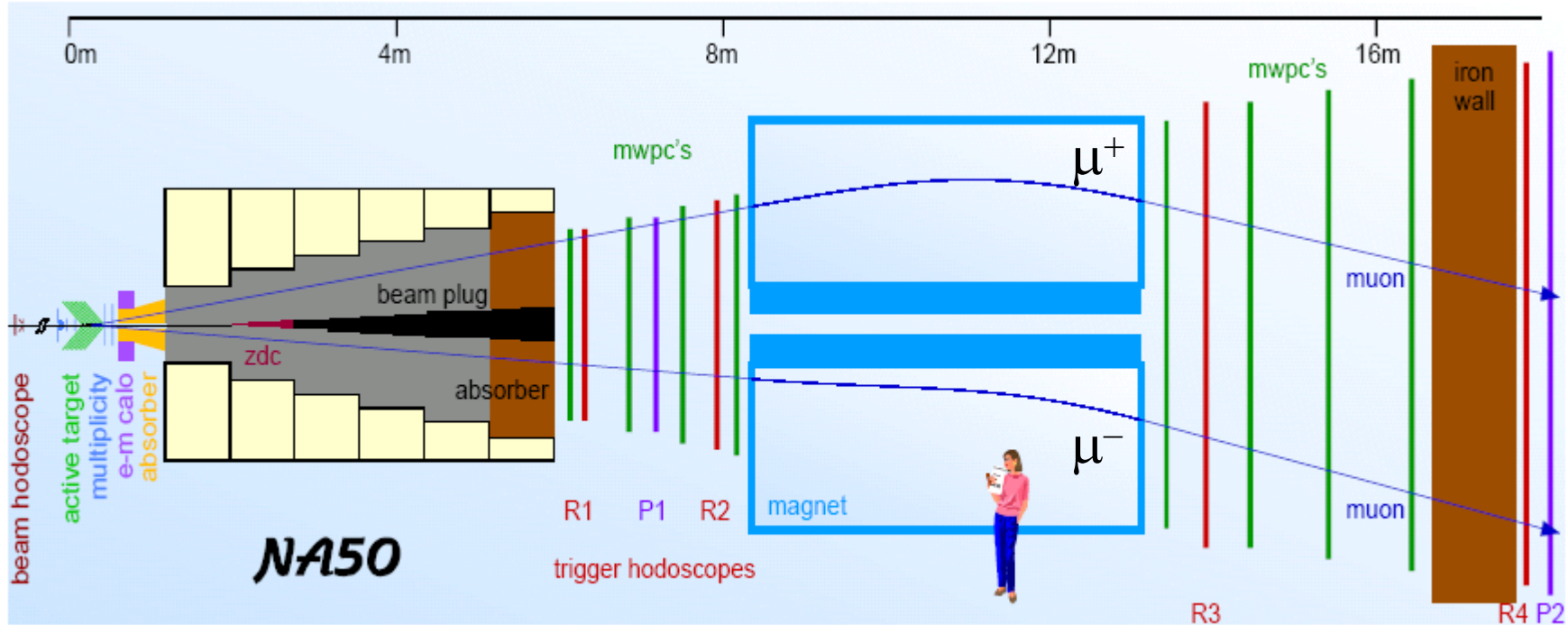


- Pre-equilibrium partonic system
- **Quark Gluon Plasma**
- Hadronization and freeze-out

J/ψ suppression by
Debye colour screening
is a strong signature of

QGP

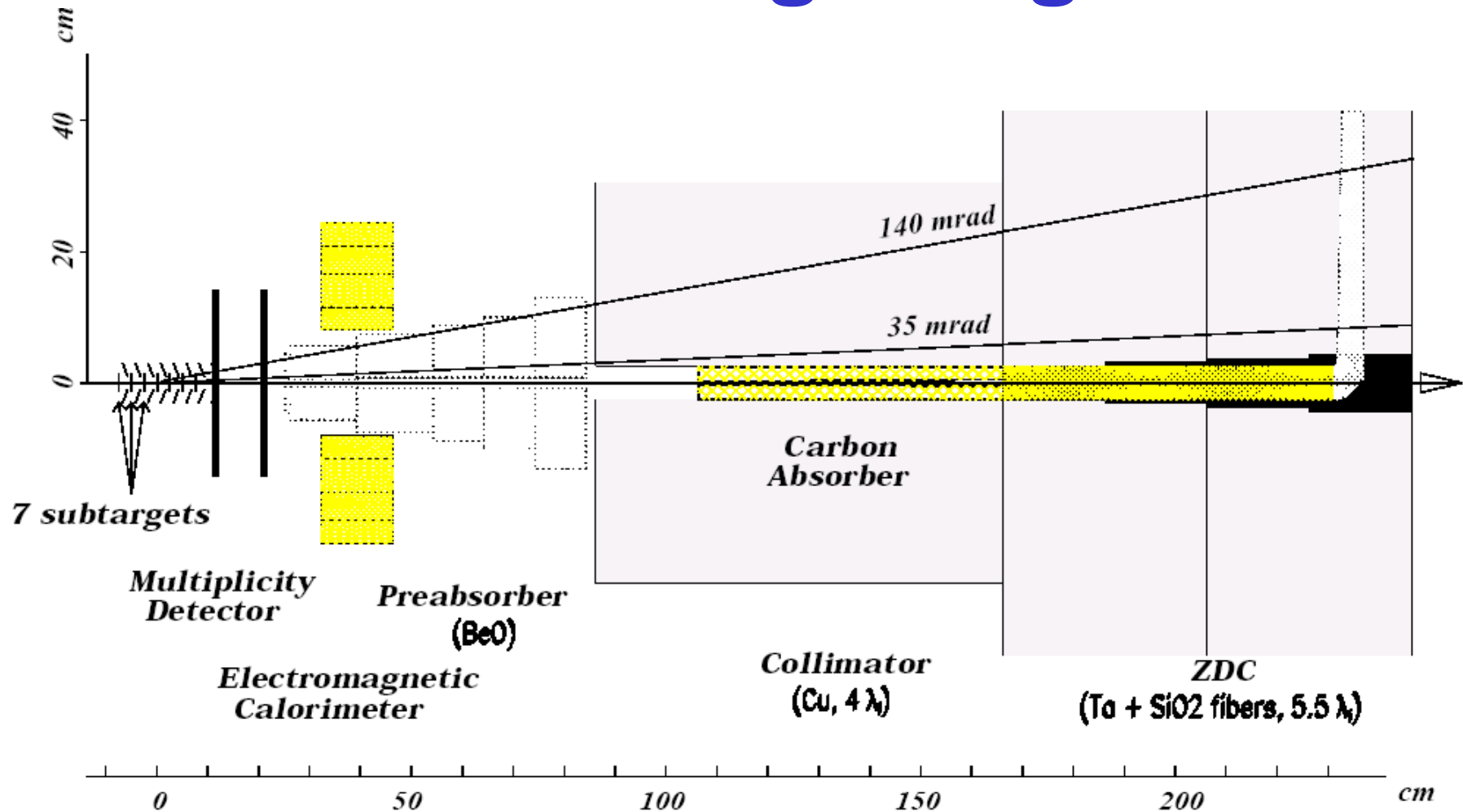
The NA50 Experiment



Acceptances

J/ψ	$12.42 \pm 0.02 \pm 0.17 \%$
ψ'	$14.77 \pm 0.03 \pm 0.26 \%$
$DY_{2.9-4.5}$	$13.79 \pm 0.05 - 0.16 \%$

The NA50 target region



Acceptance: $1.9 \leq \eta_{\text{lab}} \leq 4.2$ for the Multiplicity Detector

$1.1 \leq \eta_{\text{lab}} \leq 2.3$ for the Electromagnetic Calorimeter

$\eta_{\text{lab}} \geq 6.3$ for the Zero Degree Calorimeter

Data samples review

NA50 uses proton and lead beams colliding on fixed targets.

The spectrometer is almost the same used in the previous **NA38** experiment (study of p-A, O-Cu, O-U and S-U systems)

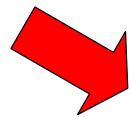
Data samples in Pb-Pb collisions

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

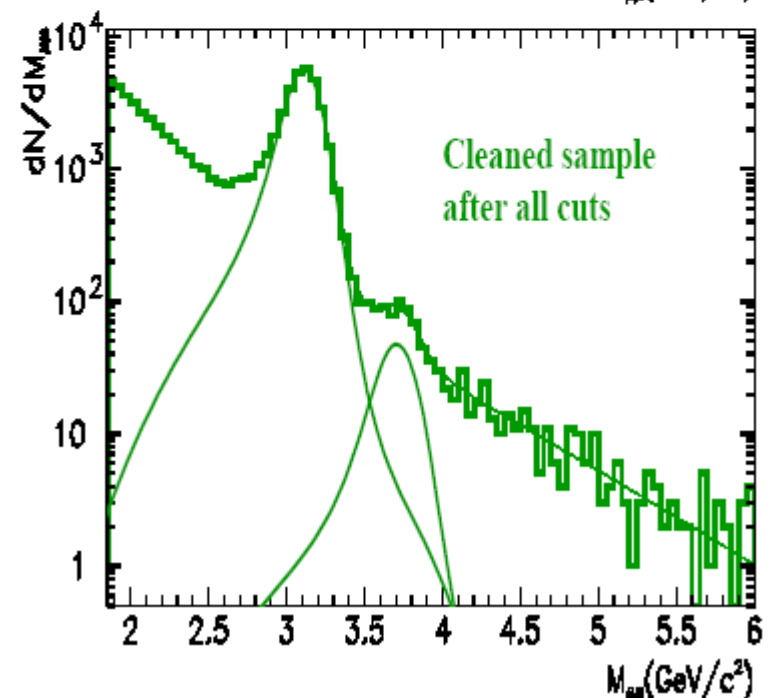
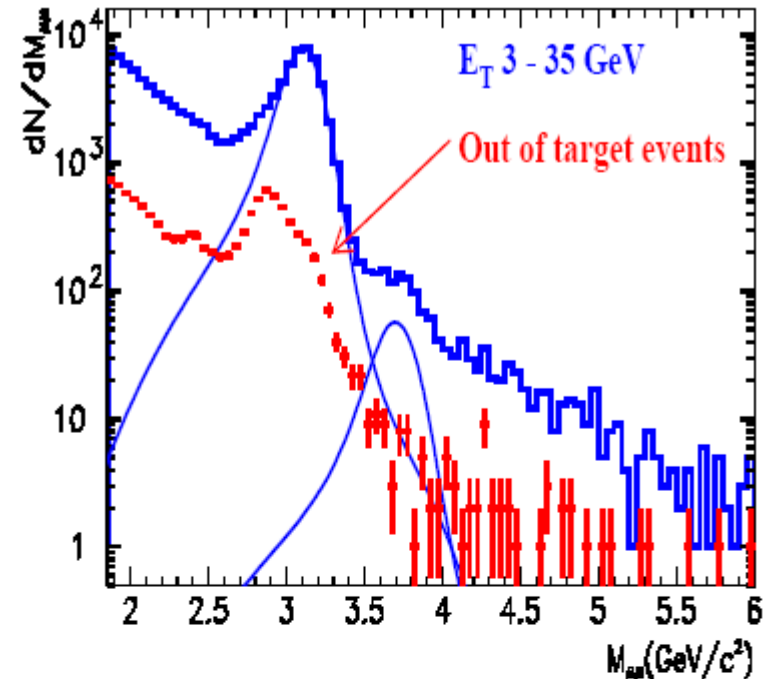
- Upstream interactions in the **beam hodoscope** are rejected by dedicated detectors
- Interaction pileup is rejected
- In-target interactions are identified using the **Multiplicity Detector**:

✓ No Pb-air contamination in peripheral interactions



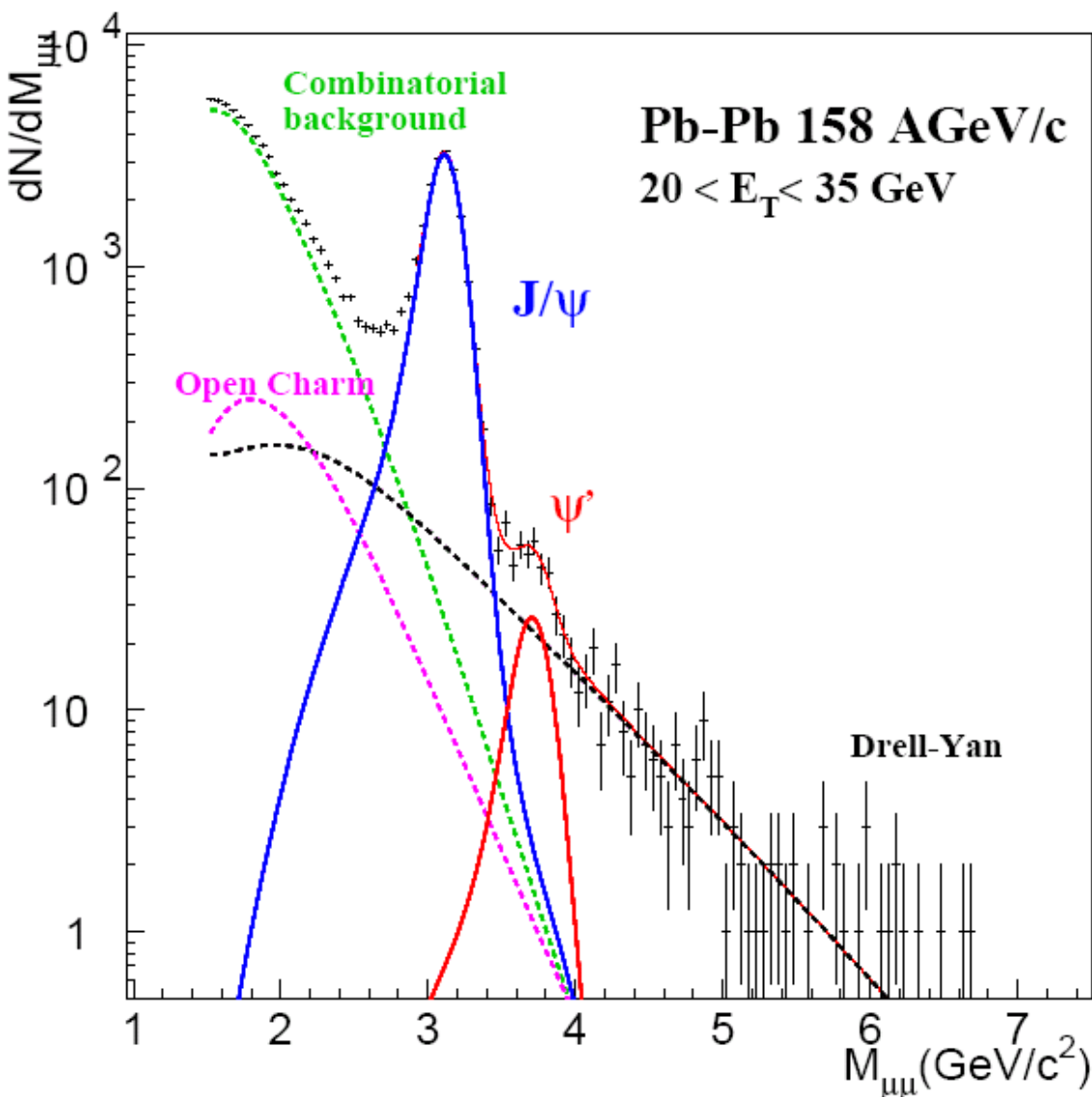
Re-analysis of **Pb-Pb 1998** data

✓ Efficient primary vertex in-target identification



The analysis method

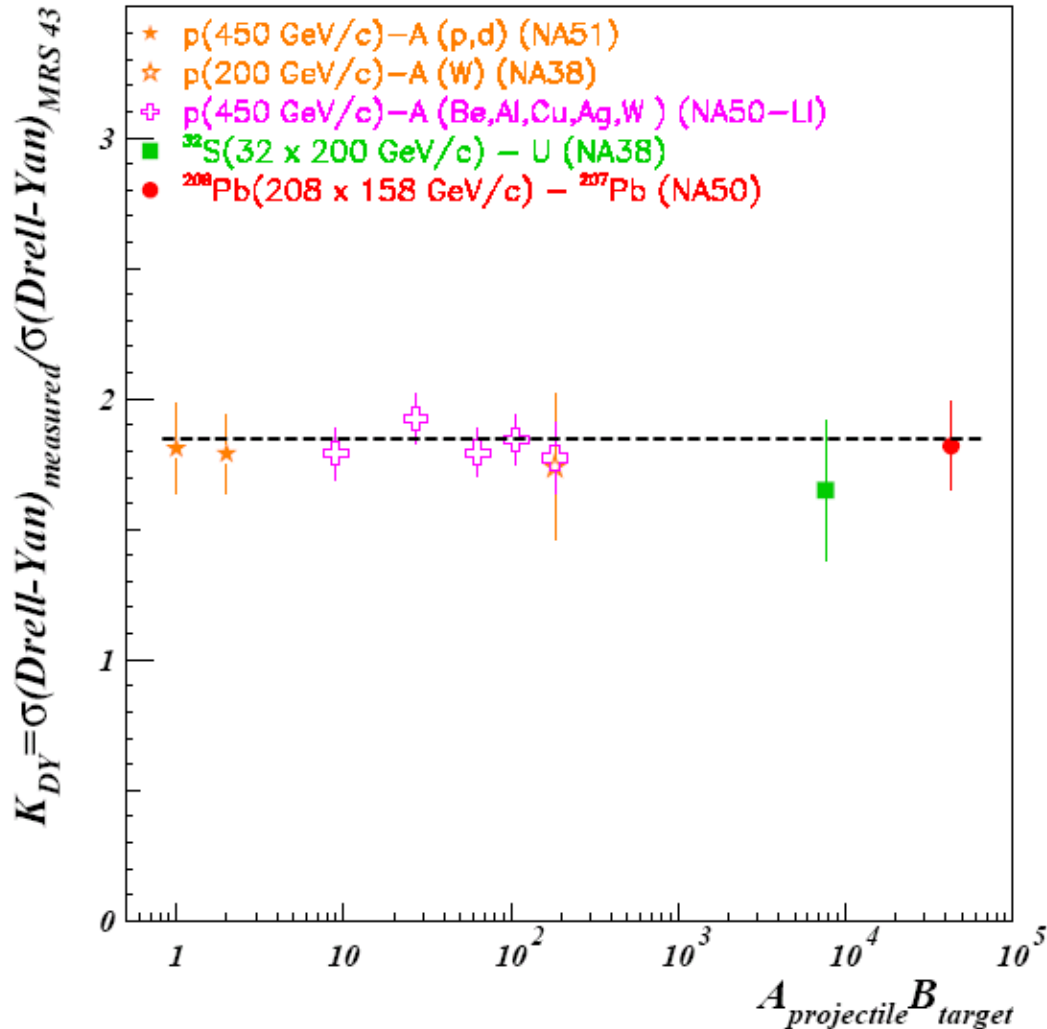
$$\frac{dN^{+-}}{dM} = A_{J/\psi} \frac{dN_{J/\psi}}{dM} + A_{\psi'} \frac{dN_{\psi'}}{dM} + A_{DY} \frac{dN_{DY}}{dM} + A_{D\bar{D}} \frac{dN_{D\bar{D}}}{dM} + \frac{dN_{BG}}{dM}$$



- J/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

Reference for charmonia production

Drell-Yan



Advantages:

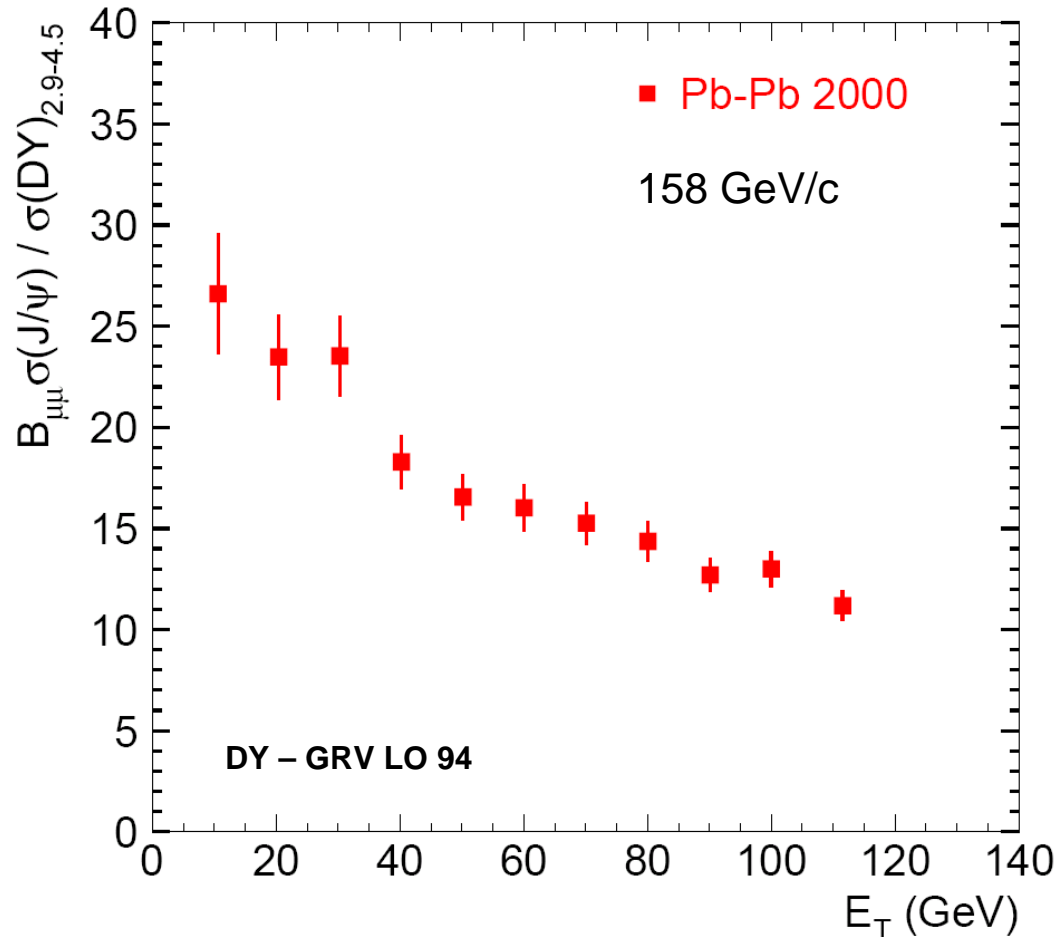
- $\sigma(\text{DY})$ is proportional to the number of nucleon-nucleon collisions from p-p up to Pb-Pb (in the NA50 phase space, at least)
- Same selection criteria
- Same eventual biases and inefficiencies

→ Good normalization for J/ψ and ψ'

Drawback: relatively poor statistics

The J/ψ suppression

Results on $B_{\mu^+\mu^-} \sigma(J/\psi) / \sigma(DY_{2.9-4.5})$ as a function of E_T for **Pb-Pb 2000** data



- The ratio of cross-sections decreases from peripheral to central collisions by a factor of ~ 2.5

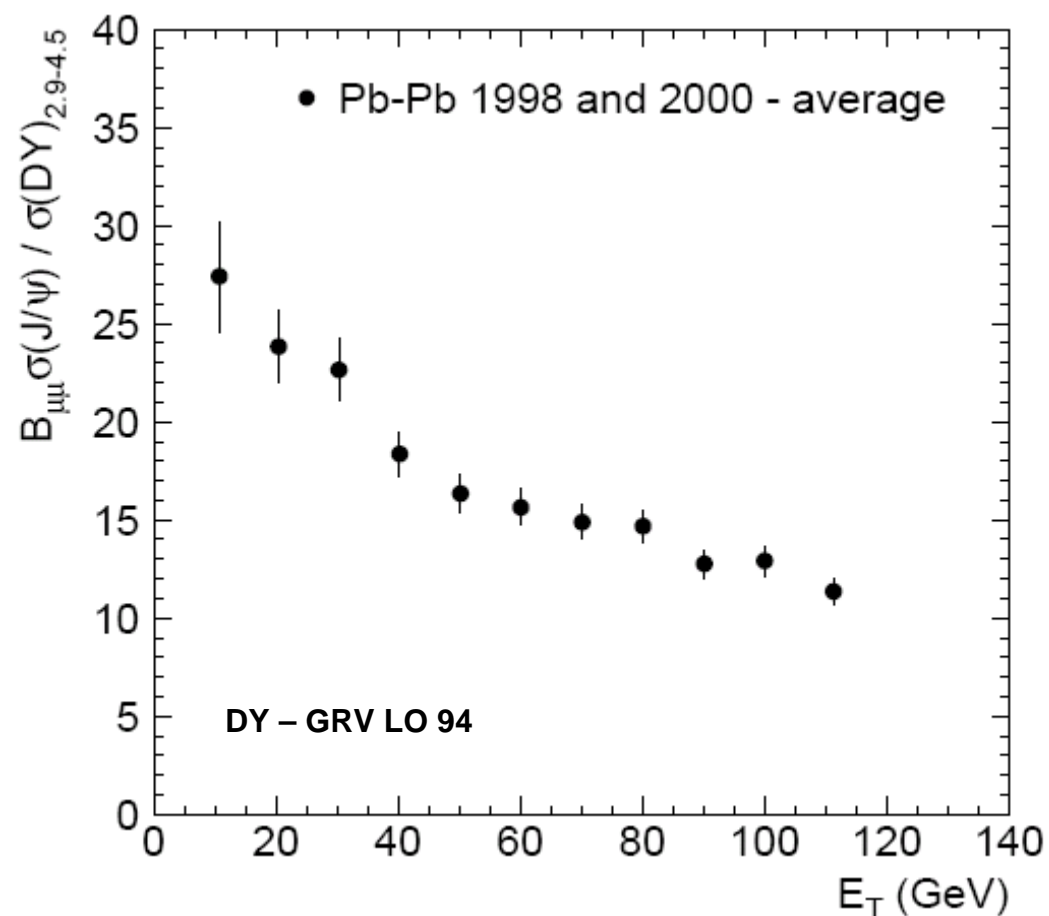
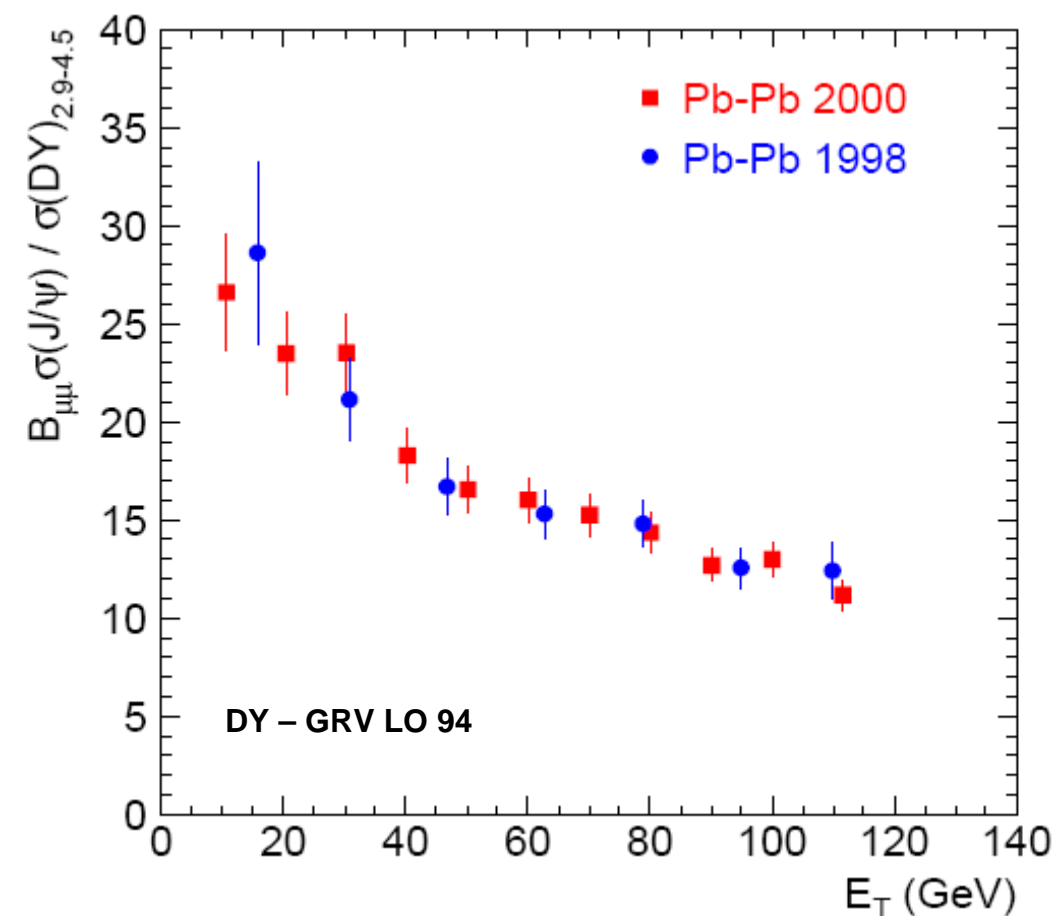
- No saturation is seen for the most central reactions

✓ Statistical errors varying between 9% and 7%

✓ The overall systematic error stands between -1.4% and +3.8%

The J/ψ suppression

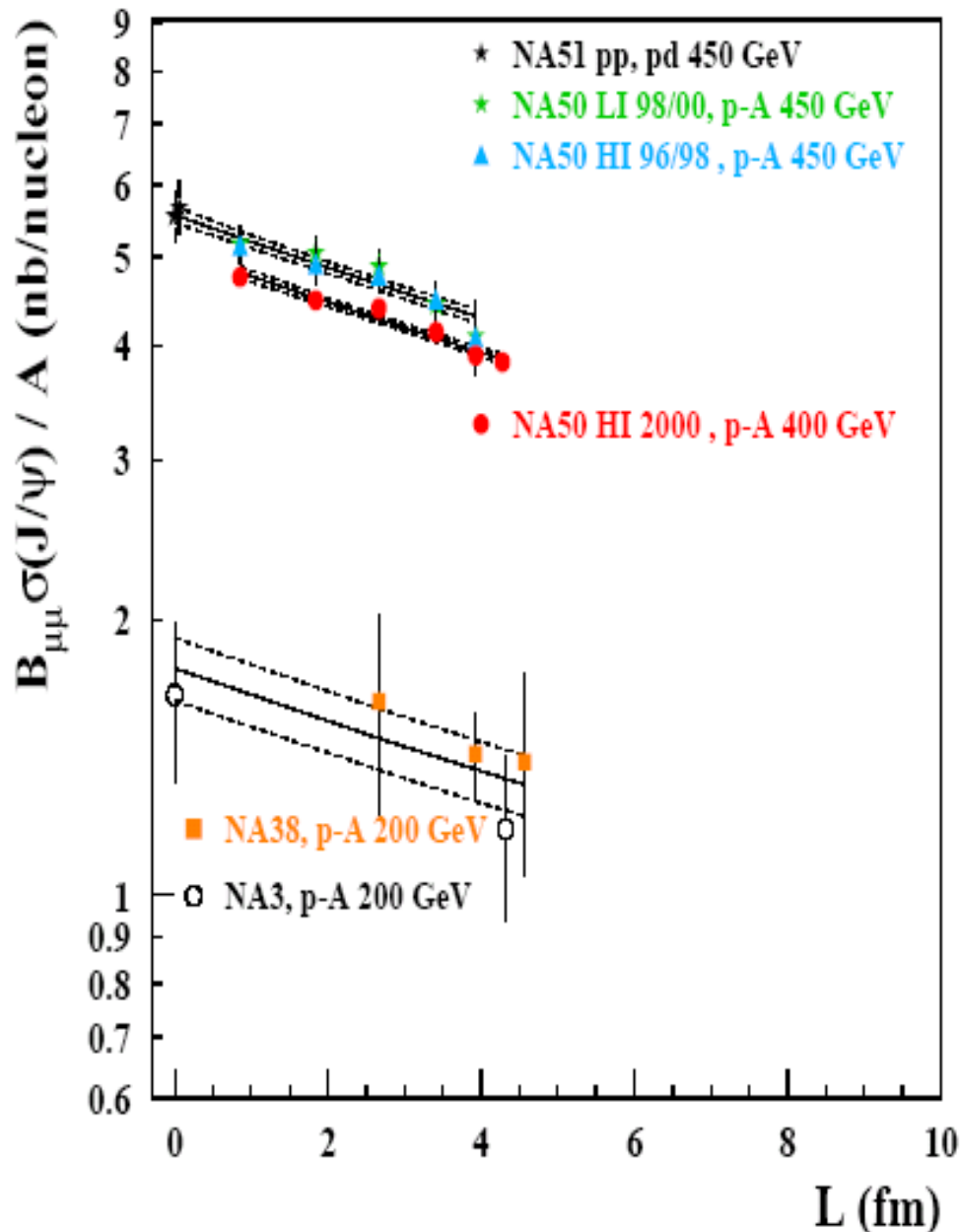
Results on $B_{\mu^+\mu^-} \sigma(J/\psi) / \sigma(DY_{2.9-4.5})$ as a function of E_T for **Pb-Pb 2000** and **1998** data



- Very good compatibility between the results from the two samples
- Systematics under control \longrightarrow average \longrightarrow **better accuracy**

The normal nuclear absorption

Determine absorption reference at 158 GeV from p-A

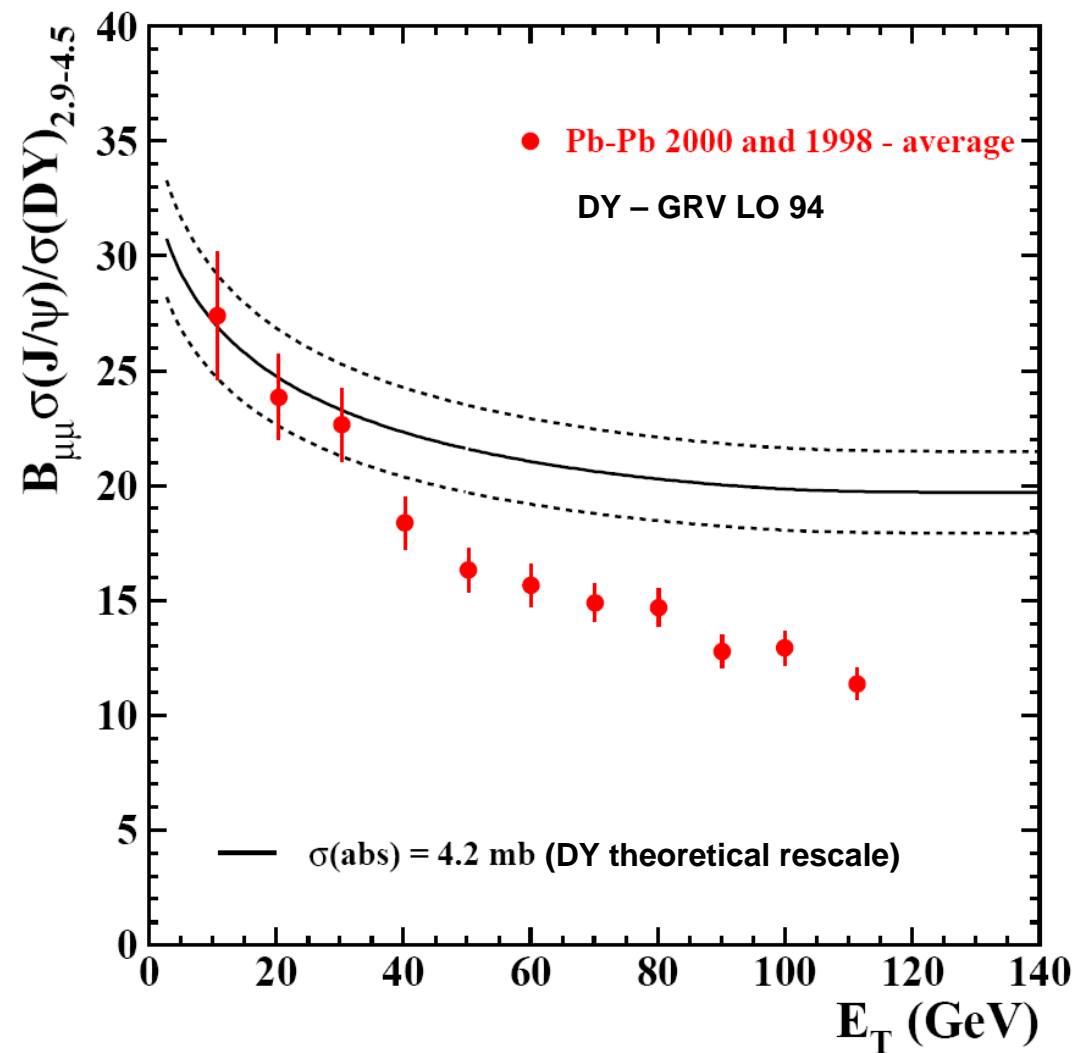


Data from:

- **NA50** p-A at 400/450 GeV
- NA51 p-p and p-d at 450 GeV
- All available 200 GeV data (**NA38**) + p-p and p-Pt (NA3)

- Absolute J/ψ cross sections
- Independent fits are fully compatible
- Simultaneous fit leads to $\sigma_{abs} = 4.1 \pm 0.4$ mb and rescaling factor from 450 to 200 GeV
- Theoretical rescale from 200 to 158 GeV

$J/\psi/DY$ in Pb-Pb with p-A reference as a function of E_T



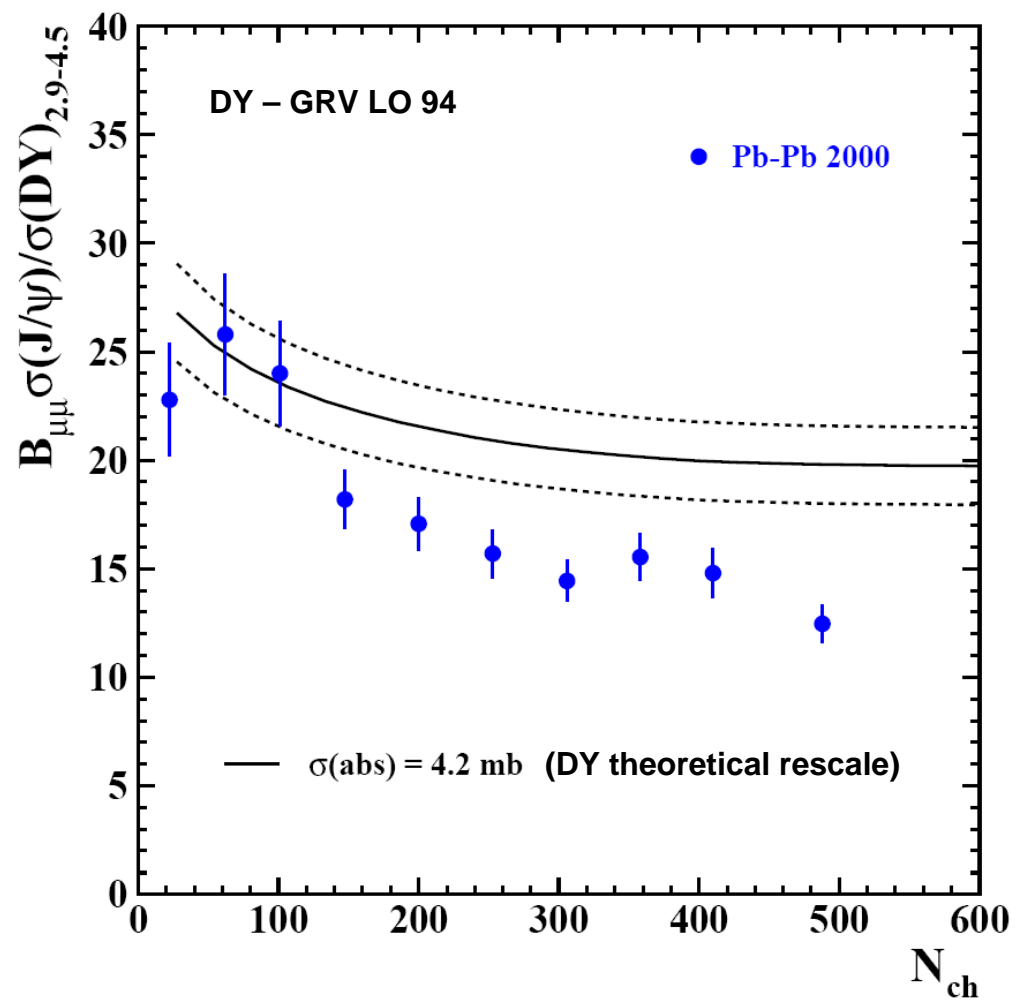
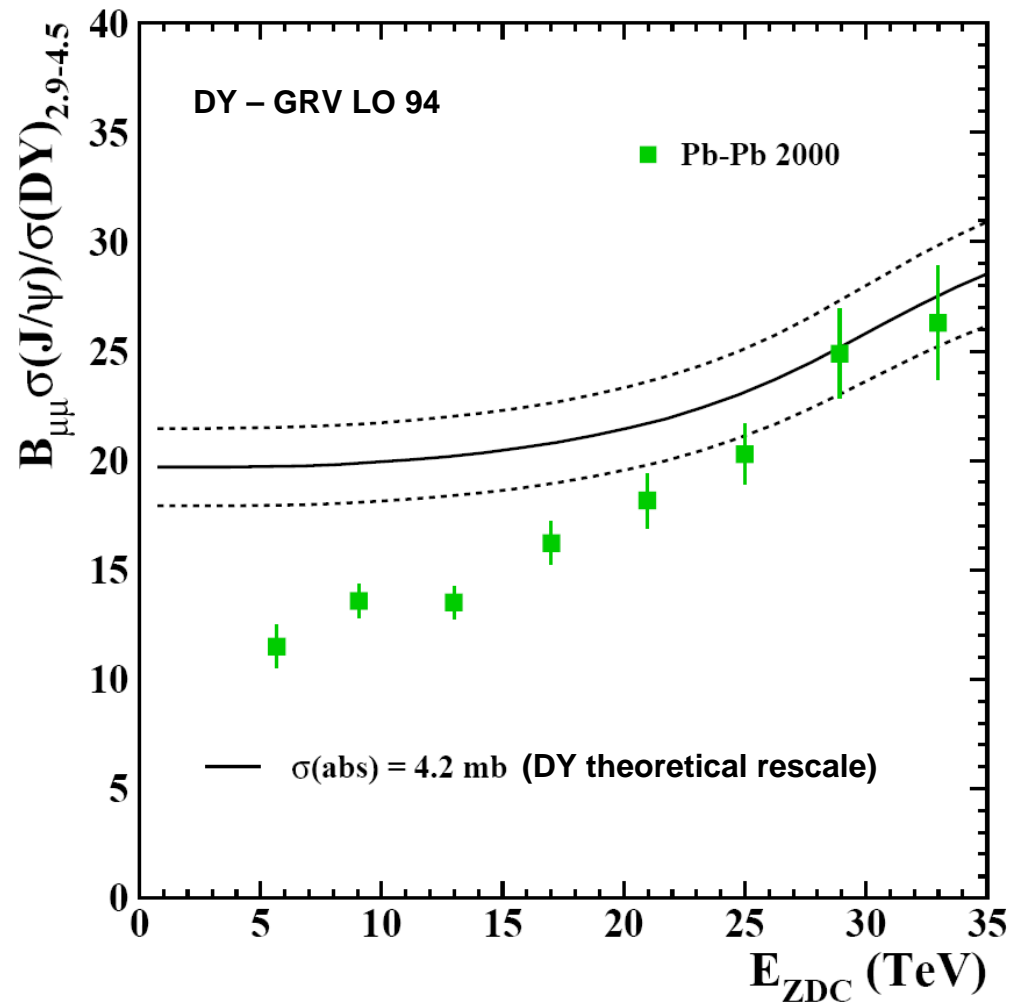
The ratio $\sigma(J/\psi)/\sigma(DY)$:

- Behaves “as p-A” for peripheral collisions

- Departs from the normal absorption at $E_T \approx 35 \text{ GeV}$

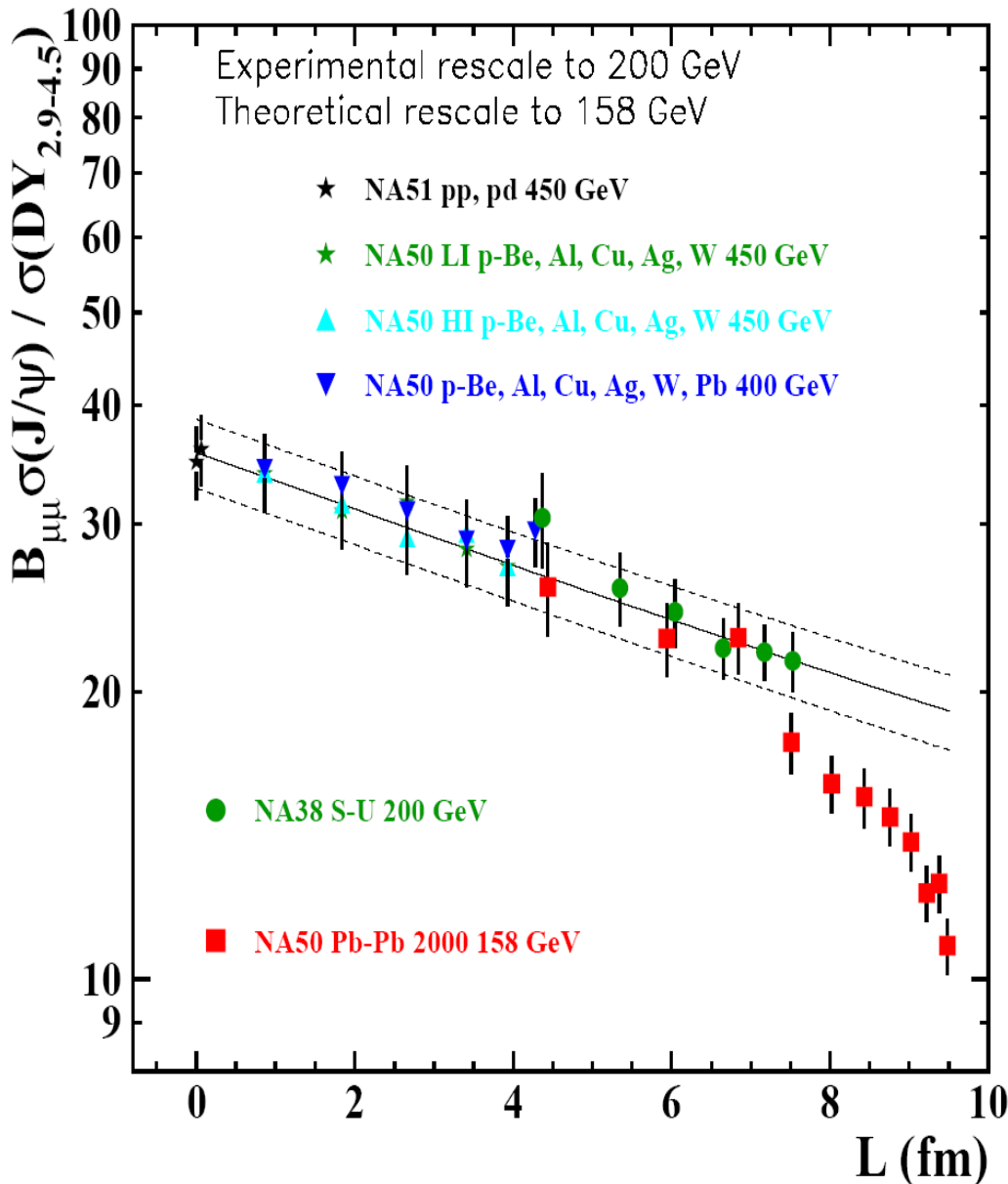
- Becomes more and more abnormal for more and more central collisions

$J/\psi/DY$ as a function of forward energy and charged multiplicity



3 independent estimators, E_T , E_{ZDC} and N_{ch} , confirm the same **anomalous J/ψ suppression pattern**

J/ψ/DY from p-p to Pb-Pb systems as a function of L



J/ψ suffers:



**Normal
suppression in
S-U and
peripheral Pb-Pb**



**Anomalous
suppression in
central Pb-Pb**

The ψ' study

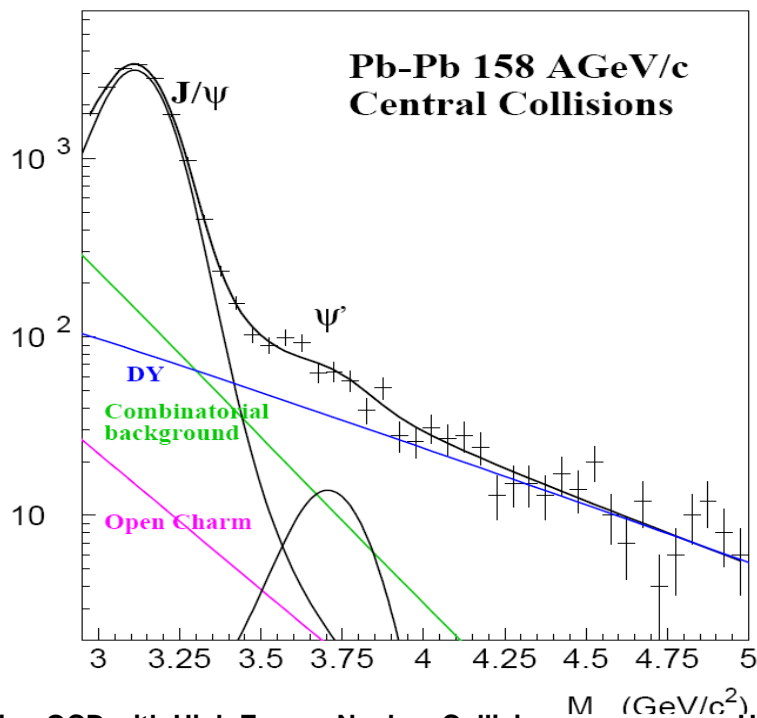
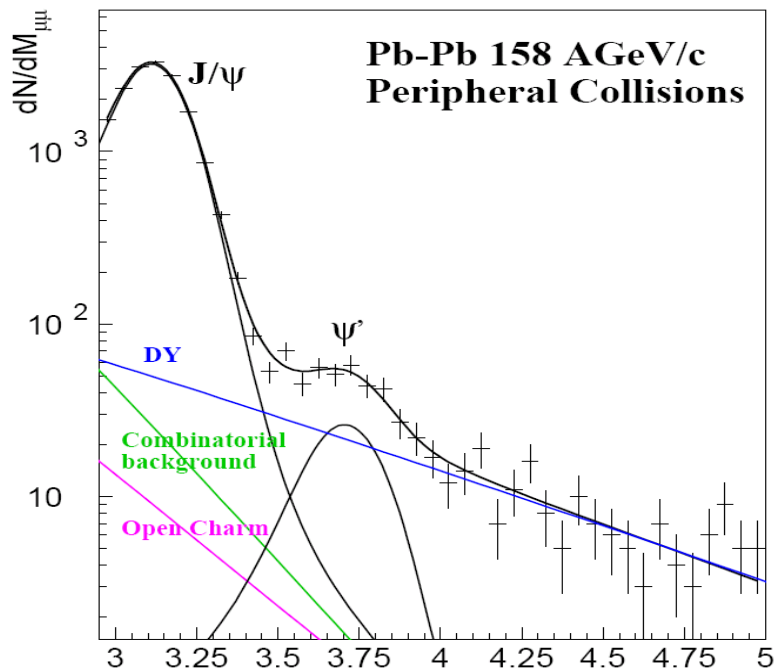
Challenging due to:

- small dimuon cross section
- large suppression
- several dimuon sources overlap

◇ Structure functions chosen to simulate **Drell-Yan** induce up to 7% difference in ψ' normalizations

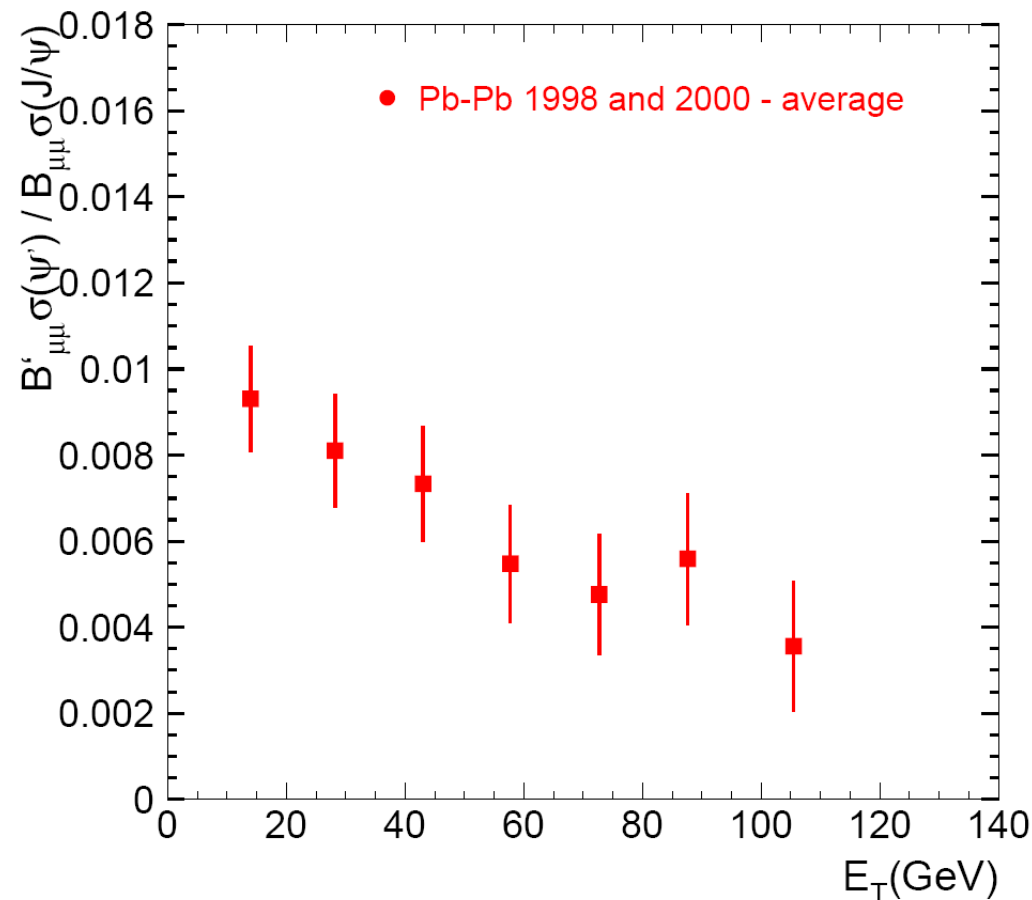
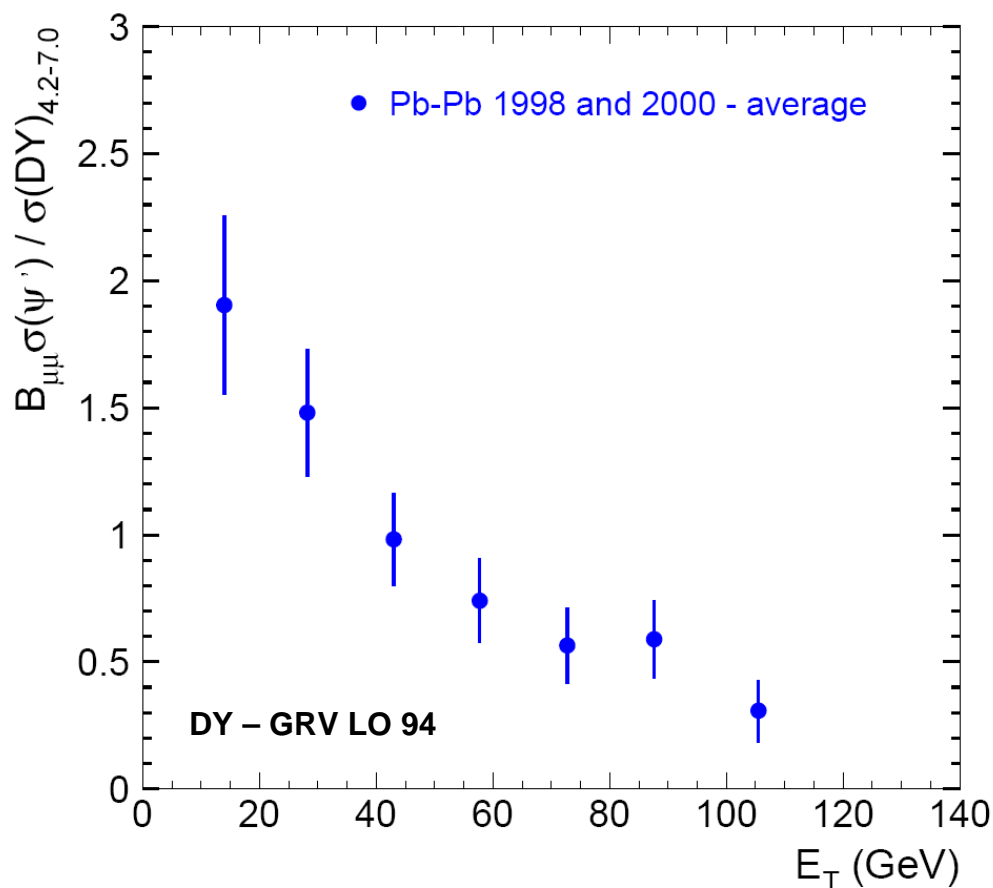
◇ **Combinatorial Background** is accurately measured from like-sign sample in each centrality region

◇ The uncertainty due to **Open Charm** semi-leptonic decays is $< 1.5\%$



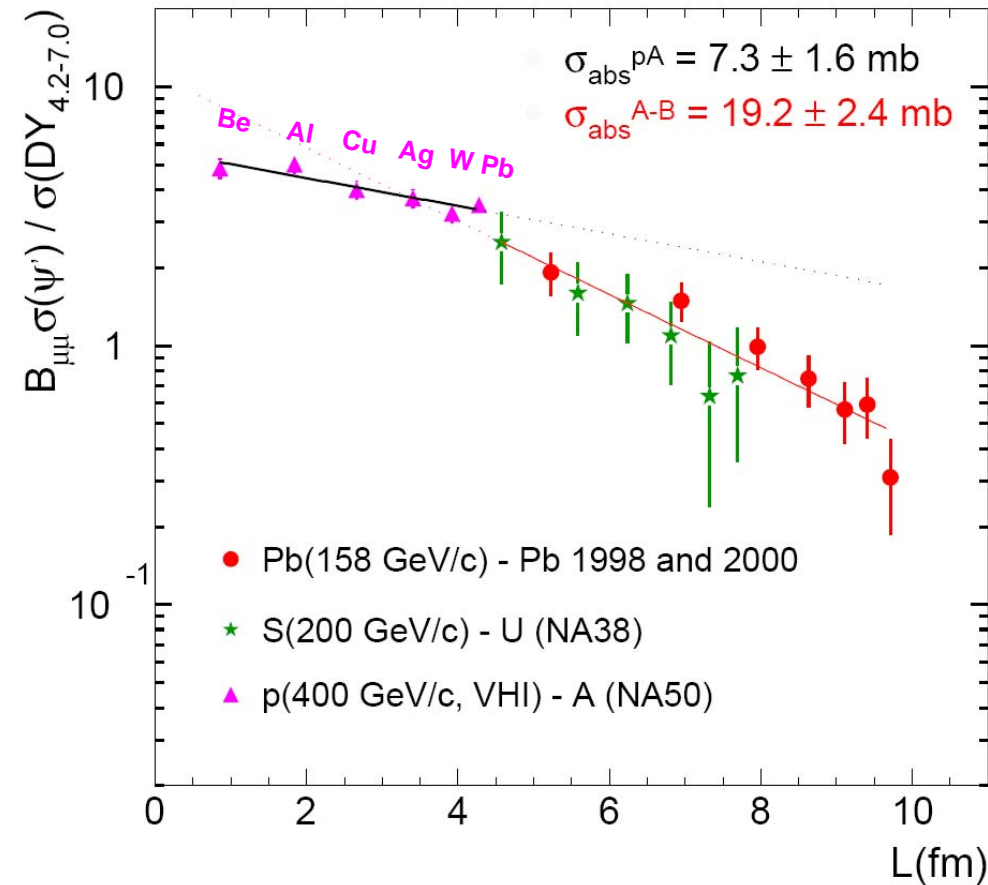
The ψ' suppression

$B_{\mu^+\mu^-}\sigma(\psi')/\sigma(DY_{4.2-7.0})$ and $B'_{\mu^+\mu^-}\sigma(\psi')/B_{\mu^+\mu^-}\sigma(J/\psi)$ as a function of E_T – Average between Pb-Pb 2000 and 1998



- ψ' is increasingly suppressed with respect to **Drell-Yan**
- The ratio of the **two charmonium states** decreases with centrality by a factor of 2.5 between peripheral and central collisions

ψ'/DY in p-A, S-U and Pb-Pb systems as a function of L



Using an exponential parametrization:

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

One obtains in p-A collisions for ψ'

$$\sigma_{\text{abs}}^{\text{p-A}} = 7.3 \pm 1.6 \text{ mb}$$

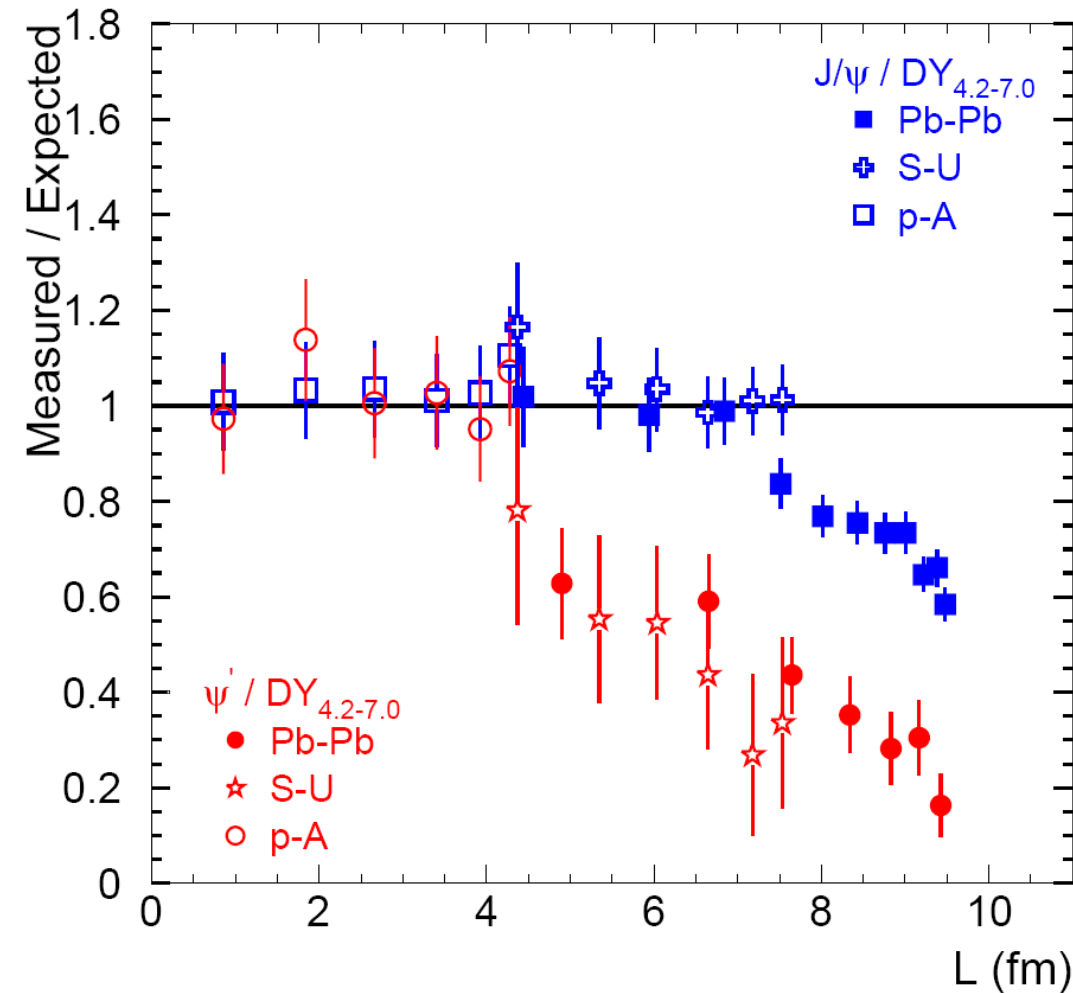
and

$$\sigma_{\text{abs}}^{\text{A-B}} = 19.2 \pm 2.4 \text{ mb}$$

for S-U e Pb-Pb collisions fitted simultaneously

- Different behaviours between p-A and A-B collisions
- Strong suppression of ψ' between peripheral and central A-B interactions
- Same ψ' suppression in S-U e Pb-Pb collisions as a function of centrality

J/ψ and ψ' – measured over expected



Expected: absorption model
(full Glauber calculation) with

$$\sigma_{\text{abs}}^{J/\psi} = 4.2 \pm 0.4 \text{ mb}$$

$$\sigma_{\text{abs}}^{\psi'} = 7.6 \pm 1.2 \text{ mb}$$

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

Conclusions – J/ψ

1. $\sigma(\text{DY})$ is proportional to the number of nucleon-nucleon collisions from **p-p** up to **Pb-Pb**
2. The measurement of J/ψ production in **p-A** collisions at 450, 400 and 200 GeV provides reliable predictions of nuclear absorption cross section, $\sigma_{\text{abs}}^{J/\psi}(\text{p-A})$, at 158 GeV
3. For **S-U** and peripheral **Pb-Pb** collisions, the ratio $\sigma(J/\psi)/\sigma(\text{DY})$ follows the normal nuclear absorption (like **p-A**)
4. For **Pb-Pb** central collisions, J/ψ production departs from this normal behaviour. It exhibits an abnormal suppression, which increases with increasing centrality

Conclusions - ψ'

1. ψ' is strongly suppressed relatively to **Drell-Yan** as a function of E_T by a factor of 7 between peripheral and central collisions
2. A steady decrease of the ratio between the **two charmonium states** as a function of E_T is observed, reaching a factor of 2.5
3. The ψ' suppression pattern is the same in **S-U** and **Pb-Pb** collisions, and not compatible with the one exhibited in **p-A** reactions

A comparison between ψ' and **J/ ψ** suppressions, normalized to the suppression expected, shows that the ψ' anomalous suppression sets in earlier than for **J/ ψ**