# $J/\psi$ Normal and Anomalous suppression

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# *Outline*

- On J/Ψ
- Looking J/ψ in Pb-Pb collisions
- Drell-Yan processes
- Normal suppression in nuclear matter
- Anomalous suppression
- Conclusions

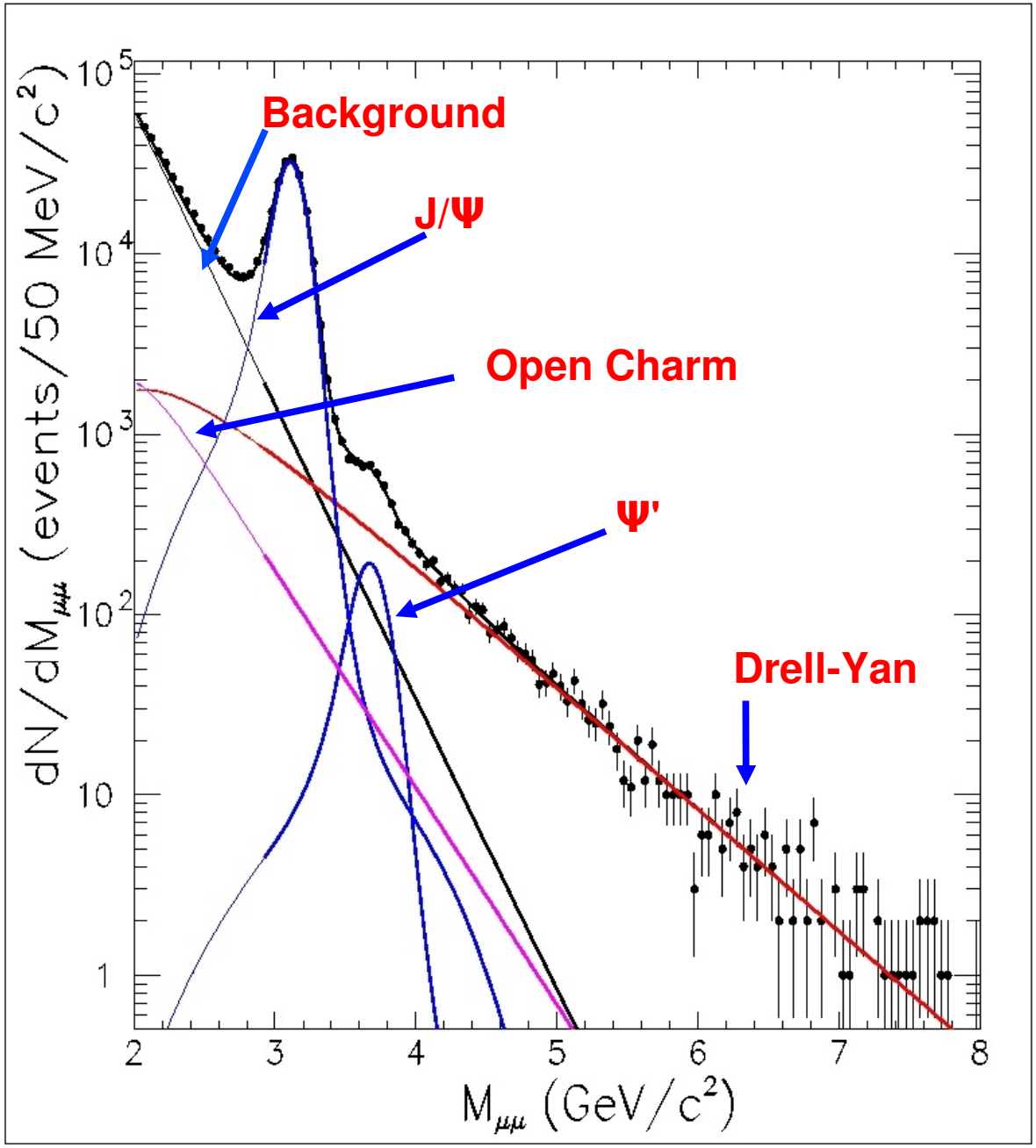
# On J/Ψ Particle, (discovery in 1976)

The 1976 Nobel Prize in physics was shared by a Massachusetts Institute of Technology researcher who used Brookhaven's Alternating Gradient Synchrotron (AGS) to discover a new particle and confirm the existence of the charmed quark. Samuel C.C. Ting was credited for finding what he called the "J" particle, the same particle as the "psi" found at nearly the same time at the Stanford Linear Accelerator Center (SLAC) by a group led by Burton Richter. The particle is now known as the J/Ψ.

Ting's experiment took advantage of the AGS's high-intensity proton beams, which bombarded a stationary target to produce showers of particles that could be detected by complex detectors. A strong peak in electron and positron production at an energy of 3.1 billion electron volts (GeV) led Ting to suspect the presence of a new particle, the same one found by Richter.

**Within 10 days of the first discovery, a second resonance peak was observed: Ψ' or Ψ(3685)**

# Looking J/Ψ in Pb-Pb collisions



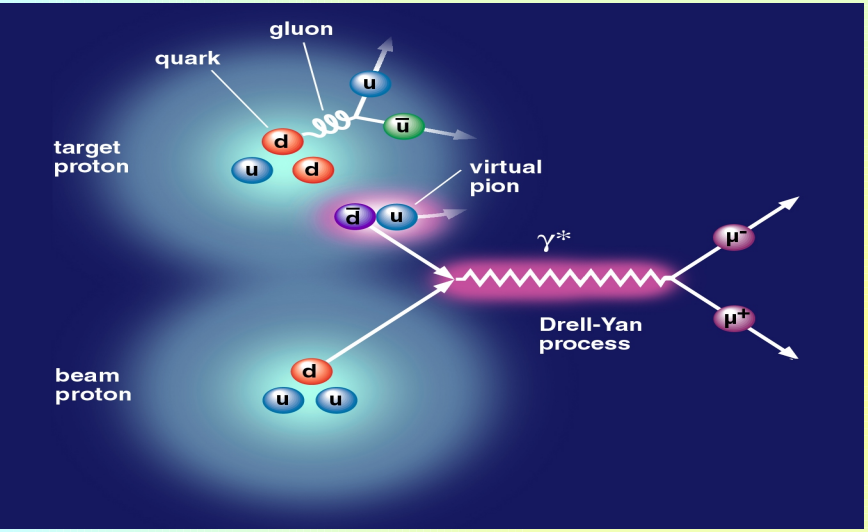

- **J/Ψ -> μ$^+$ μ$^-$ (e$^+$ e$^-$)**

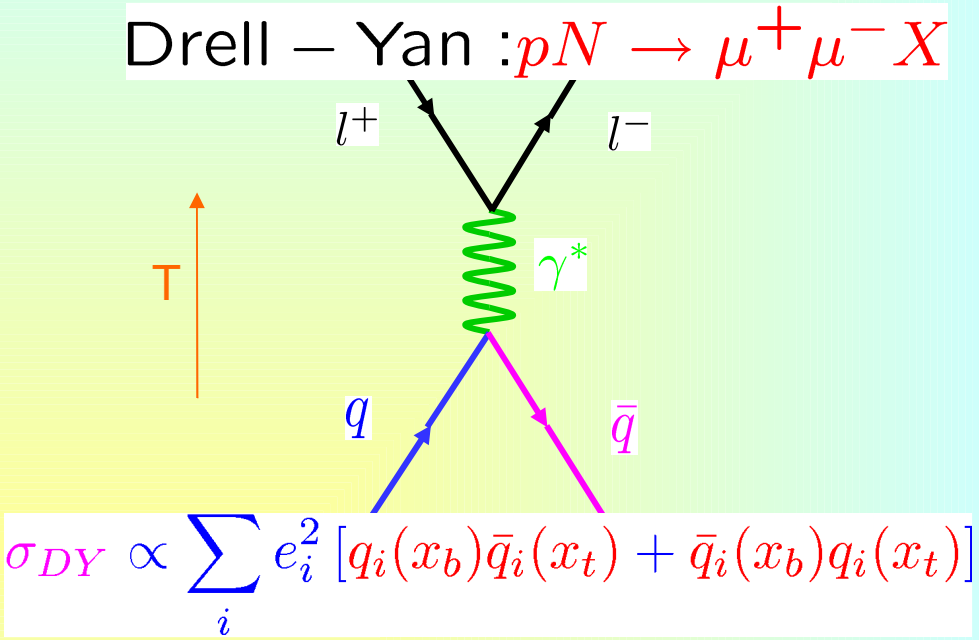
**Final invariant mass spectrum** of the opposite-sign pairs obtained from the whole sample of events collected in 1996 by NA50 Pb-Pb at 158 GeV/c.

Five contribution:

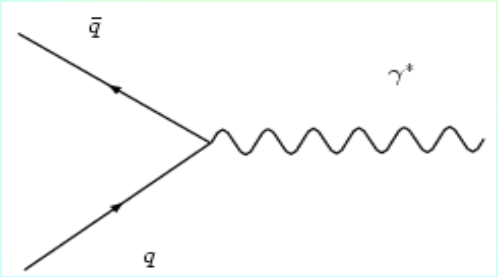
- **Combinatorial background**
- **Open Charm (DDbar)**
- **J/psi**
- **Psi**
- **Drell-Yan**

**Drell-Yan process:** a quark from one hadron and a antiquark from another hadron annihilate creating a virtual photon or Z boson which then decay into a pair of oppositely charged leptons



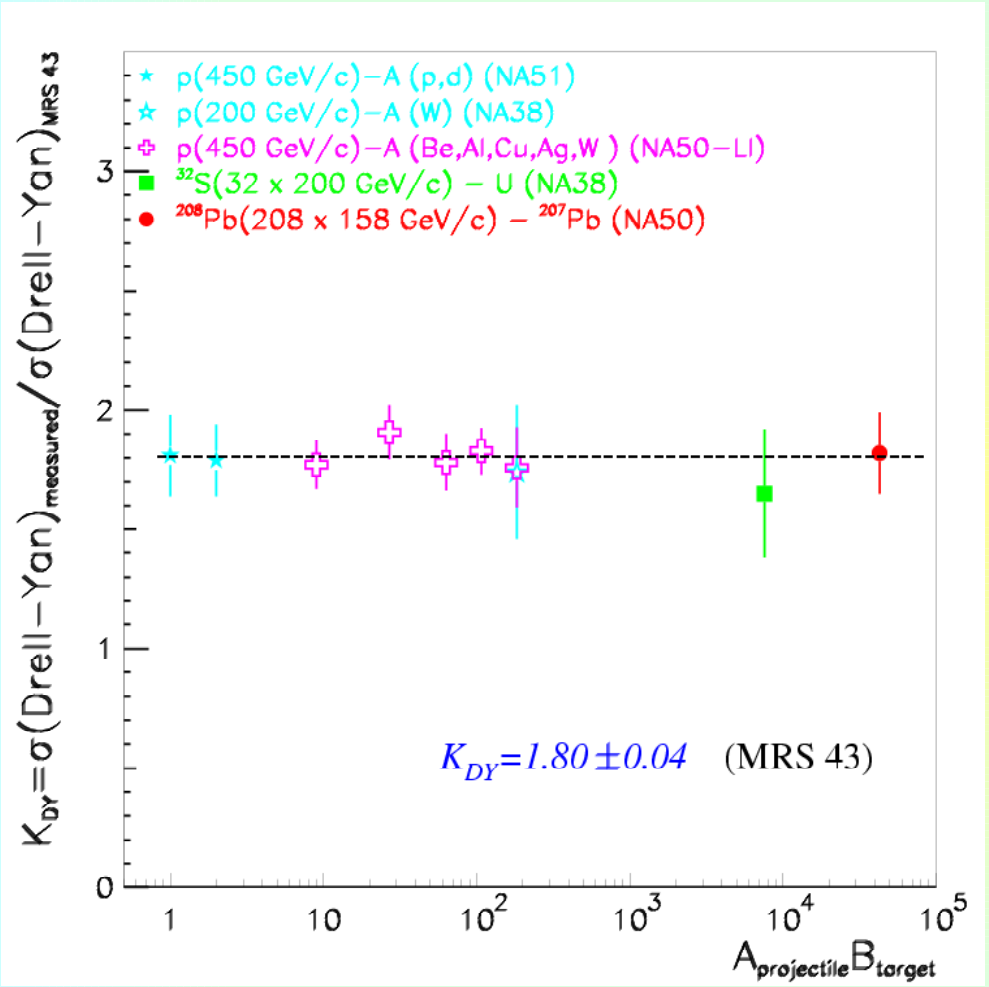




$$\left(\frac{d\sigma_0^{AB\to l^+l^-}}{d^4q}\right)_{Born} = \sum_{ab} \frac{1}{s} \hat{f}_{a/A}(x_a)\, \hat{f}_{b/B}(x_b)\, \hat{\sigma}_0^{ab\to l^+l^-}$$




$$\hat{\sigma}_0^{q\bar{q}\to l^+l^-} = \frac{4\pi\alpha^2 e_q}{9q^2} \longrightarrow \alpha_s^0 \text{ order}$$

# The Drell-Yan reference

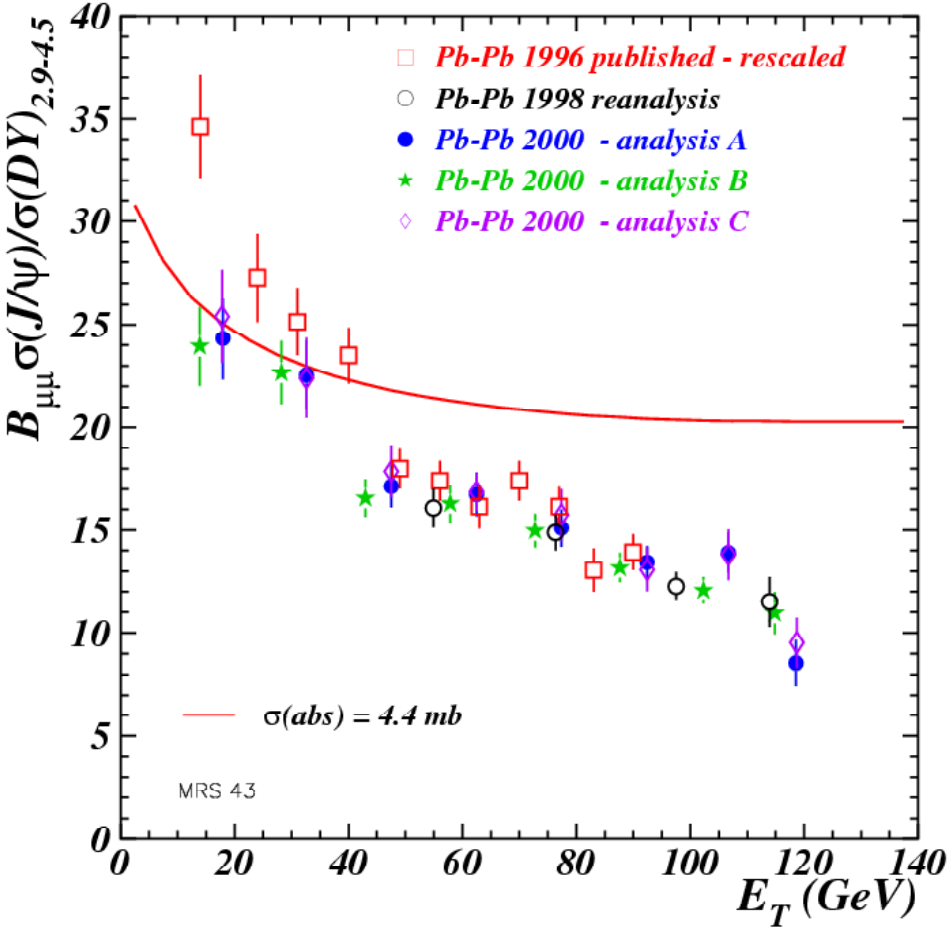



**The Drell-Yan yield is proportional to the number of nucleon-nucleon collisions from p-p to Pb-Pb**

**It is a good normalization for the J/ψ yield**

**The <u>centrality dependence</u> of the cross section ratio $\sigma_{J/\psi} / \sigma_{DY}$ (2.9-4.5) in Pb-Pb must be compared with precise measurement of the same ratio in lighter systems (p-A)**

# The 2000 results vs $E_T$ (with MRS43)




The analysis is affected by a systematic uncertainty coming from the set of p.d.f. used for calculation of DY cross section in the mass range 2.9-4.5 GeV/$c^2$

**The curve represents the ordinary nuclear absorption fitted to the NA51 and NA38 results (PLB410(1997) 327).**

In order to estimate this effect, the analysis of the 2000 data vs $E_T$ has been done also with the set MRS43.

**The same pattern vs. $E_T$ is observed, as in the analysis with GRV LO, but slightly different absolute values of the cross-section ratio.**

## summary

**Preliminary results** from the **most recent NA50 data**:

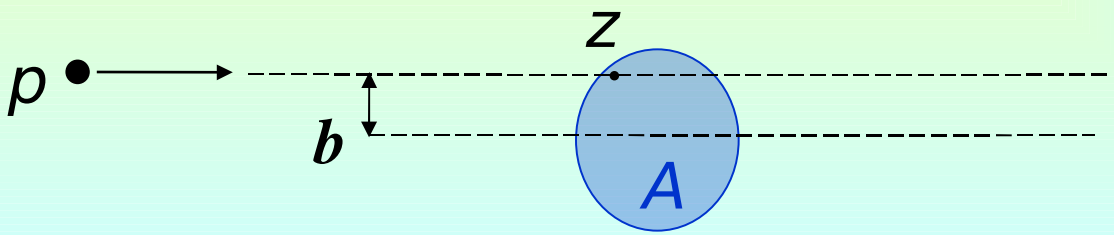
- confirm the J/ψ suppression pattern: a threshold effect followed by
a steady decrease for the most central Pb-Pb collisions;
- confirm the departure from a normal nuclear absorption (newly
determined from p-A and S-U data);
- indicate that the most peripheral Pb-Pb interactions (b>8.5 fm)
indeed follow the normal nuclear absorption pattern.

# Normal suppression

- General definition : $S_{AB} = \sigma_{AB} / (AB\sigma_{pN})$

- J/ψ suppression in p-A collisions is well described by a probabilistic formula

$$S_{pA} = \int d^2b \int_{-\infty}^{\infty} dz \rho_A(b,z) \exp\left\{ -(A-1) \int_{z}^{\infty} dz' \rho_A(b,z') \sigma_{abs} \right\}$$



# … Normal suppression

- From a fit of experimental p-A data (NA38,NA50):
  $\sigma_{abs}$=4.18 +- 0.35 mb (**Eur.Phys.J.C39 (2005),335**)
- In S-U collisions the same suppression is observed
- **The J/Ψ yield** is suppressed with respect to DY one. The ratio shows an exponential behavior when plotted as a function of the mean length of the nuclear matter crossed by the ccbar pair. This is interpreted in terms of nuclear absorption of the ccbar pair before the J/Ψ (Ψ' or χ) formation. Preresonance absorption.

# *Anomalous suppression*

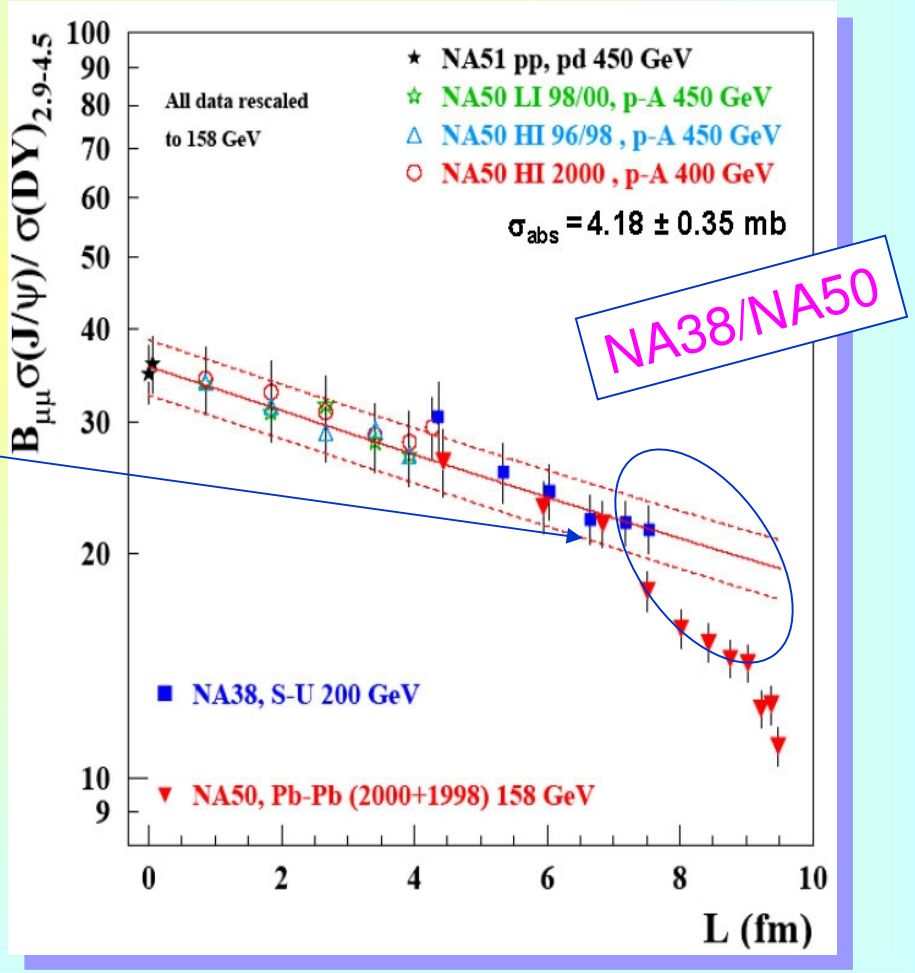
**In 1996 was discovery the anomalous J/psi suppression in Pb-Pb collision at Super Proton Synchrotron (SPS)** (**M.C. Abreu, et al (Nucl.Phys. A610 (1996)404c** ).

In peripheral Pb-Pb collisions the (J/ψ )/DY ratio is consistent with the normal suppression pattern

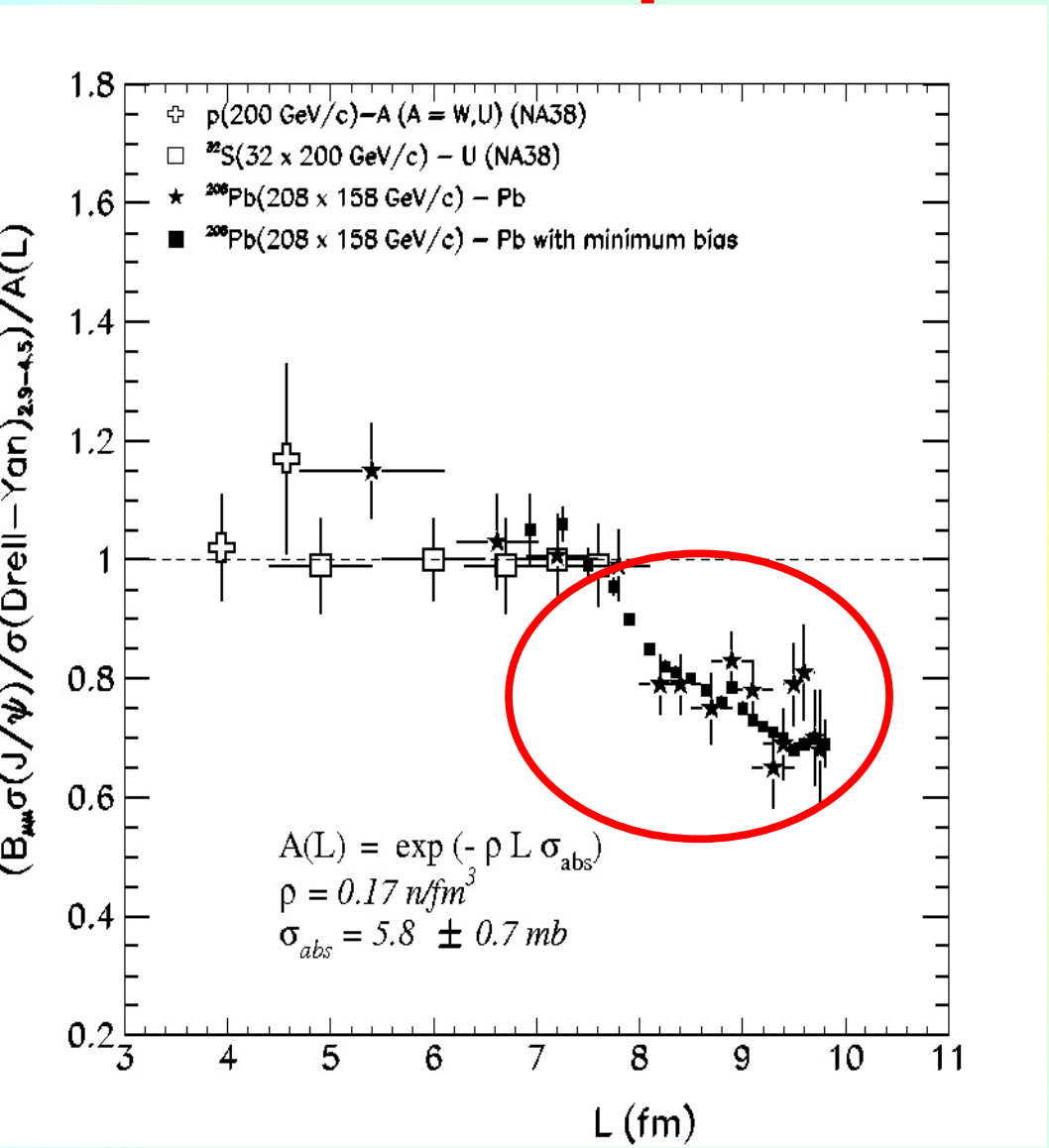
In central Pb-Pb collisions (b<8-8.5 fm) a much stronger suppression is observed:

Anomalous suppression

New In-In data follow the same pattern ! (NA60)



# ...J/ψ Anomalous suppression




**NA50 Collaboration:**
**Phys. Lett. B 450 (1999) 456.**

- **Charmonium suppression is expected to sign the phase transition between normal and deconfined nuclear matter predicted by lattice QCD.**
- **The sudden change of behavior observed in our data suggest that the observed abnormal suppression results from a discontinuity in the state of nuclear matter**

# *Models:*

## *suppression by hadron interactions*

- *Dual Parton Model*
- *Dissociation*
- *Percolation*
- 
- 
- 
- *Xitzel will continue next meeting*

# *Conclusions*

The observed J/ψ suppression at SPS is qualitatively very similar to the pattern expected by deconfinement models.

- None of the models so far is completely satisfactory in the comparison with data; new effects: finite size, life-time, surface…
- RHIC data : recombination or higher states suppression ?

*Thank you !*

# Feed-down corrections

**Only a fraction (~60%) of the observed J/ψ 's are directly produced. The rest come from the decay of higher excited states (~30% from χ , ~10% from ψ ').**

**The feed-down has been studied in pN and π N interactions.**

**The medium (confined / deconfined) affects differently the different charmonium states.**

**Different properties (binding energy, size,…) implies different dissociation temperatures or different cross-sections for interactions with hadrons.**

$$S_{J/\psi} = 0.6 S^{dir}_{J/\psi} + 0.3 S^{dir}_{\chi} + 0.1 S^{dir}_{\psi'}$$