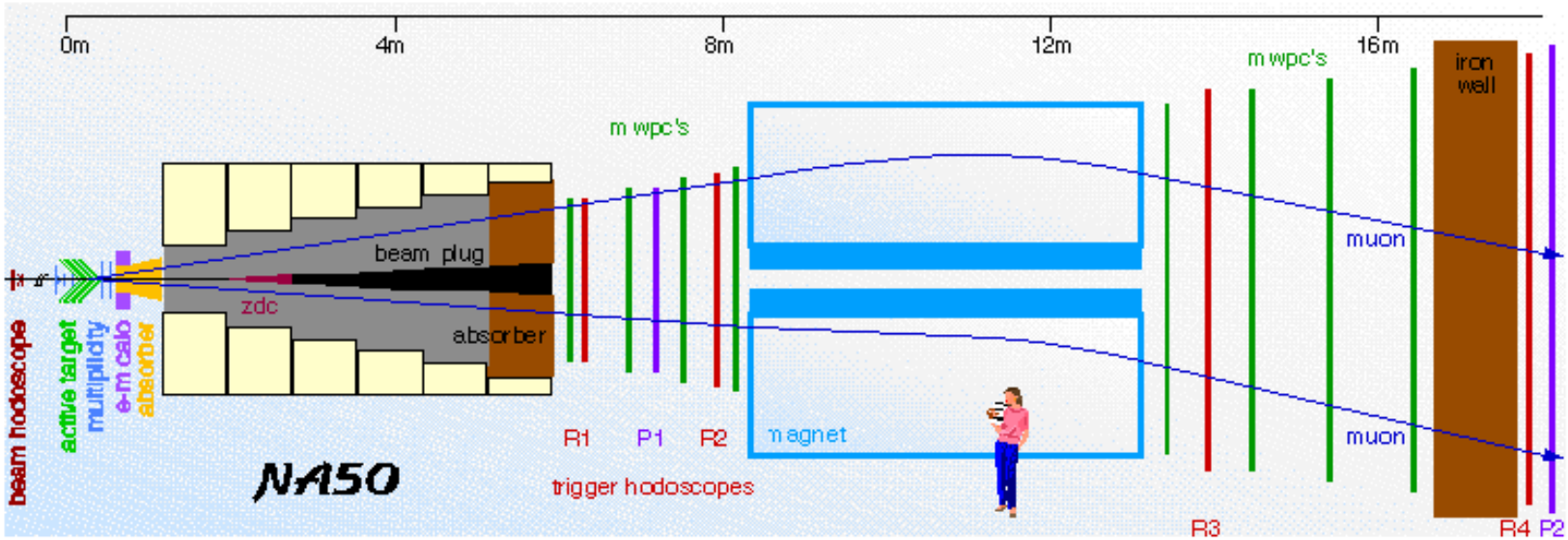
Quarkonium production and suppression in Pb-Pb and p-A collisions at SPS energies

NA50 Collaboration



Luciano Ramello - Università del Piemonte Orientale

Alessandria, Italy

Quark Matter 2005, Budapest, Aug. 4-9, 2005

Outline of the talk

- Results on charmonium production and suppression
  - **new reference** for J/ψ normal nuclear absorption:
    - **using** high statistics **p-A** data at 450, 400 and 200 GeV
    - **excluding S-U** data at 200 GeV
  - J/ψ **anomalous suppression** in Pb-Pb collisions at 158 GeV/nucleon and comparison with lighter systems
  - ψ' **absorption** from p-A to Pb-Pb

- p_T dependence of J/ψ suppression
- J/ψ transverse momentum distributions

$\Rightarrow$ **poster 210 N. Topilskaya**

- Υ production in p-A $\Rightarrow$ **parallel talk 5b/1 Sat. 16:00 P. Cortese**

- Conclusions

Charmonium physics in NA50

- **Charmonium suppression** by QGP color screening: Matsui+Satz 1986

- Measurements by NA38 with **p-A**, **O-U** and **S-U** collisions (1986-1992):
  - observed suppression of J/ψ finally understood as due to absorption in ordinary nuclear matter

- New measurements by **NA50** with **p-A** and **Pb-Pb** collisions:
  - Discovery of **anomalous J/ψ suppression** in central Pb-Pb collisions (1995-1996 data)
  - Last two Pb-Pb data samples collected under improved conditions $\Rightarrow$ **final results**:
    * **single thin target** (1998) $\Rightarrow$ no reinteractions in targets
    * **vacuum** around target (2000) $\Rightarrow$ no Pb-air interactions

L. Kluberg, 20 years of J/ψ suppression at the CERN SPS, Proc. Hard Probes 2004, Ericeira, Portugal

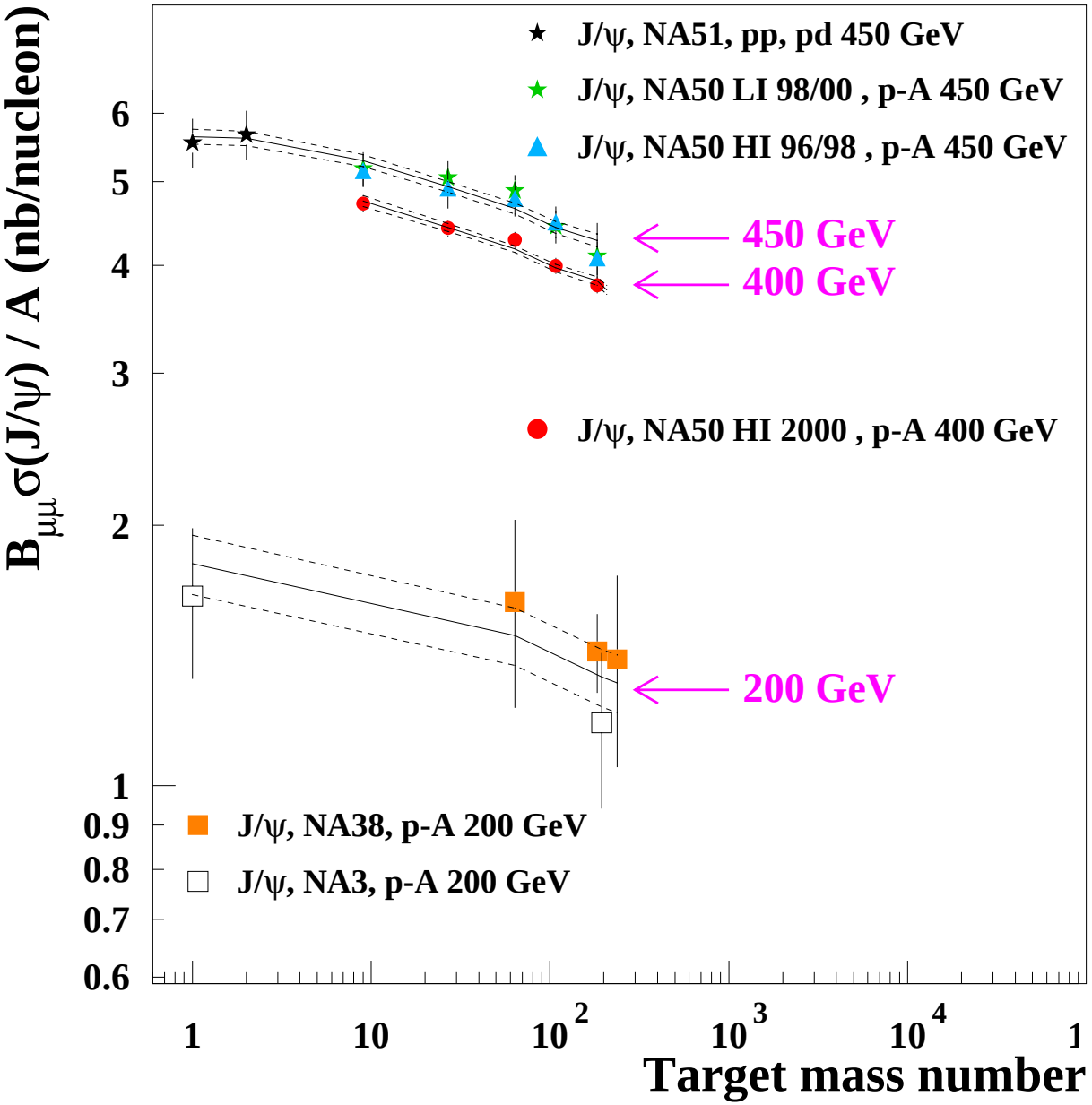
Developments since Q.M. 2004

- Charmonium analysis (ratios of J/ψ and ψ' to Drell-Yan) in Pb-Pb:
  - **Same PDF's** (GRV 94 LO) used for Drell-Yan **in all analyses**

- Reference curve for normal nuclear absorption:
  no available 158 GeV p-A data $\Rightarrow$ use higher energy p-A & rescale:
  - Determine $\sigma_{abs}^{J/\psi}$ from a coherently analyzed set of $(J/\psi)/DY$ **p-A** data at **450** and **400** GeV $\Rightarrow$ shape of absorption curve
  - Determine level of $(J/\psi)/DY$ at **158** GeV without using S-U data but only J/ψ cross-sections from 450, 400 and 200 GeV p-A data, plus calculation for Drell-Yan $\Rightarrow$ normalization of absorption curve
  - Take into account the **neutron halo**
    (different spatial distributions of neutrons and protons in nuclei)
    $\Rightarrow$ affects centrality dependence of absorption curve

Final NA50 results on $(J/\psi)/DY$ in Pb-Pb: Eur. Phys. J. C 39 (2005) 335;
Reference for neutron halo: Phys. Rev. Lett. 87 (2001) 082501.

J/ψ cross-sections in p-A at 450, 400 and 200 GeV



- Glauber fit to $B_{\mu\mu}\sigma(J/\psi)$
  $\Rightarrow \quad \sigma_{abs}^{J/\psi} = 4.48 \pm 0.42$ **mb**
  $N_{200}/N_{450} = 0.320 \pm 0.025$
  $N_{200}/N_{400} = 0.357 \pm 0.027$

  normalizations N_{450}, N_{400} *and* N_{200} **include both energy and kinematical domain changes**

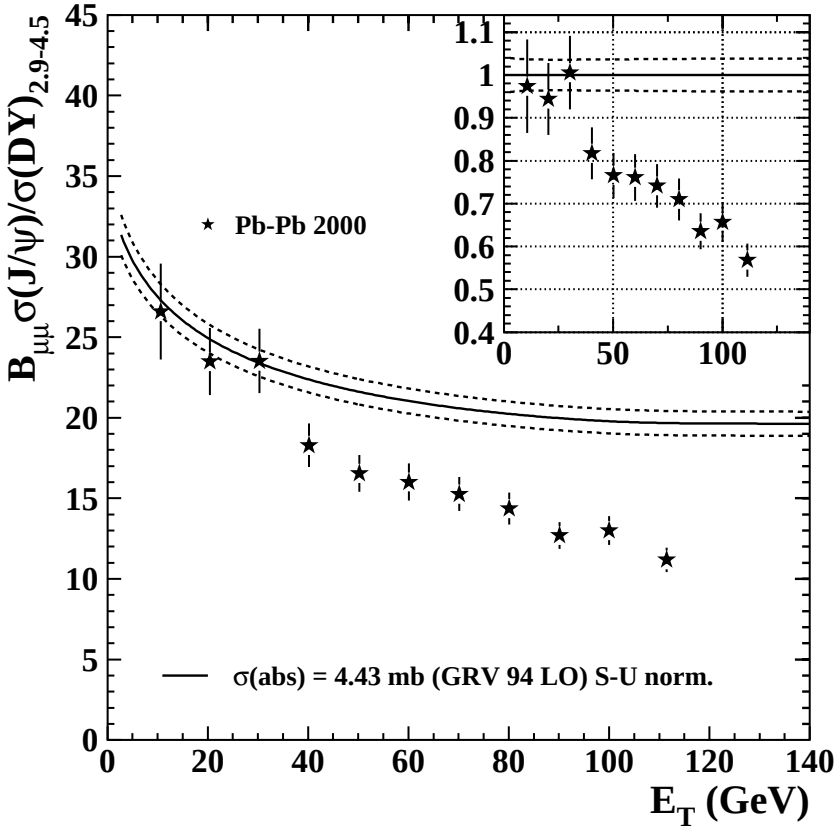
- $(J/\psi)/DY$ ratios (available only at 450, 400 GeV)
  $\Rightarrow \quad \sigma_{abs}^{J/\psi} = 4.18 \pm 0.35$ **mb**

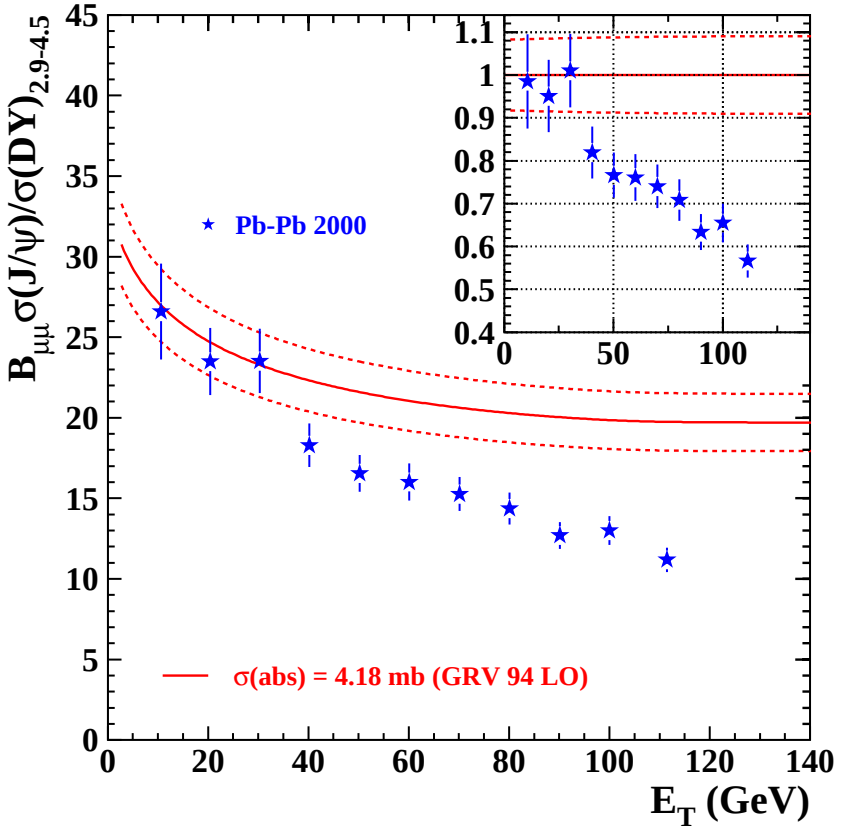
  Fair agreement between both determinations

The absorption curve for $(J/\psi)/DY$ in Pb-Pb

- Start from $(J/\psi)/DY$ **normalization at 450 GeV** (**1.4%** error)
- **Rescale to 200 GeV** using:
  - ♢ *measured* absolute J/ψ cross-sections (**7.8%** error, including syst.)
  - ♢ LO *calculation* for Drell-Yan (**2.5%** error)
- **Rescale to 158 GeV** using:
  - ♢ fit "$\grave{a}$ la $Schuler$" to measured J/ψ cross-sections (**1.5%** error)
  - ♢ LO *calculation* for Drell-Yan (negligible error)
- **Glauber calculation** (including neutron halo) plus experimental smearing to calculate absorption curve vs. observables E_T, E_{ZDC}, N_{ch}
- **Remarks**:
  1. **Main assumption is:**
     J/ψ **normal nuclear absorption cross-section is the same**
     at 158 GeV and in 450, 400 and 200 GeV p-A collisions
  2. Absorption curve **determination completely independent of S-U**
     (used previously to fix normalization of normal nuclear absorption curve at 200 GeV and reduce its error)

$(J/\psi)/DY$ vs. E_T in Pb-Pb (2000 data)



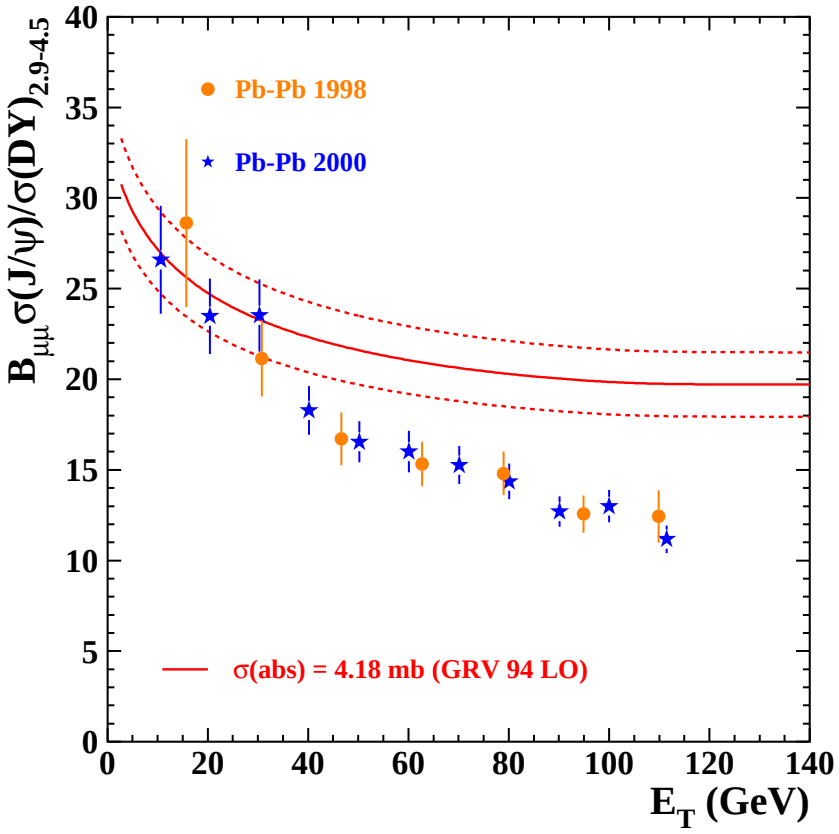


Previous procedure using also S-U data for absorption curve normalization: small error BUT assumes S-U is normal

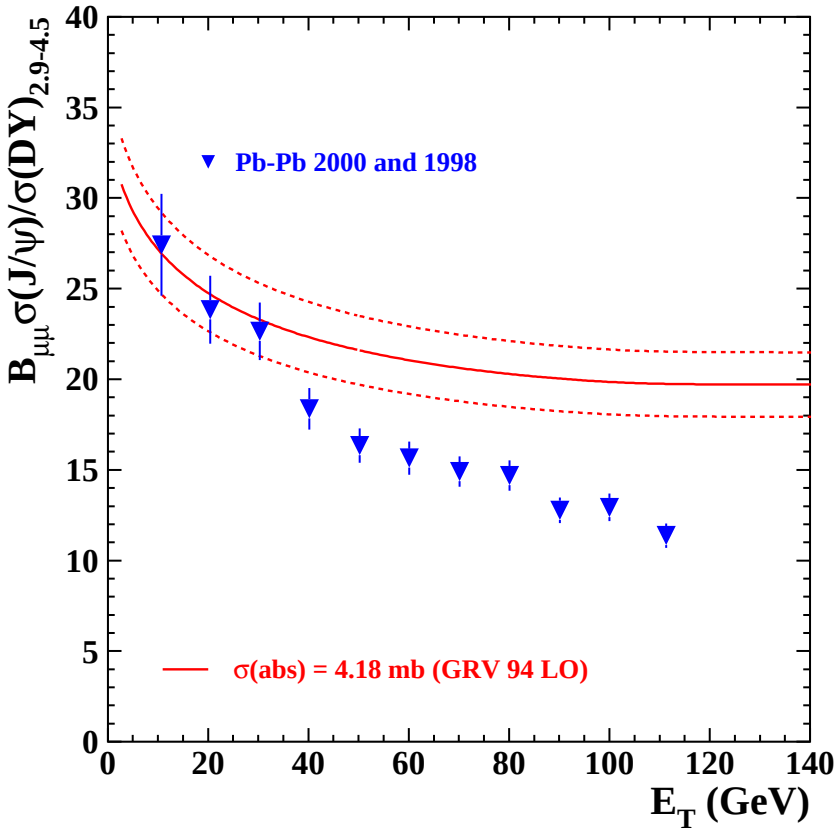
New procedure with absorption curve from p-A data only: larger error BUT free from assumptions on S-U

The absorption curve itself is almost the same with both procedures

Anomalous J/ψ suppression vs. E_T in Pb-Pb



Pb-Pb 1998 and 2000 data . . .



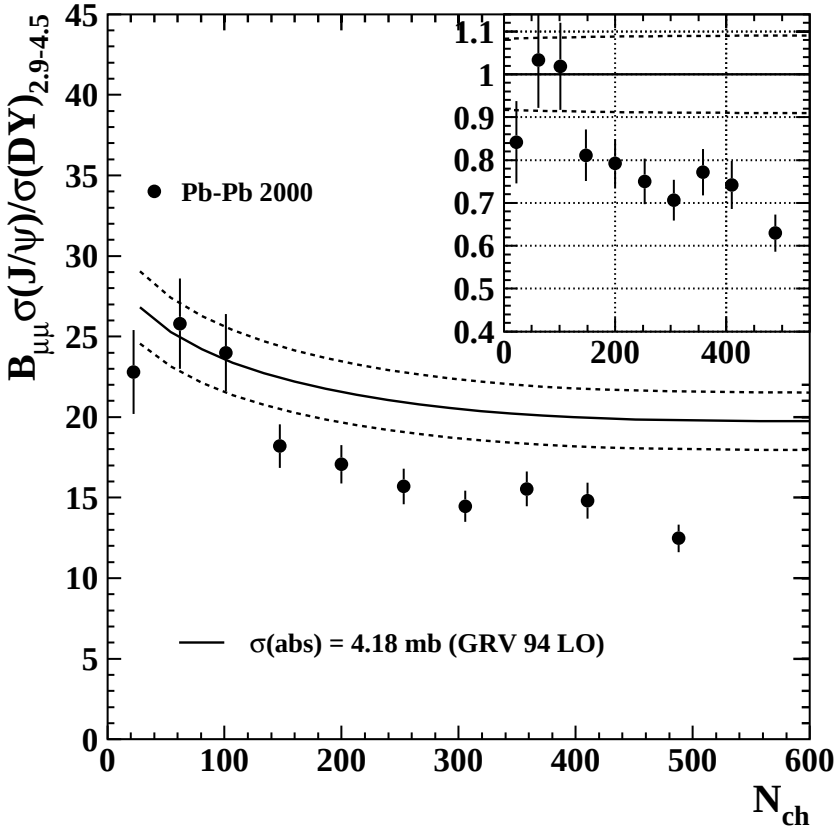
. . . and averaged result

Pb-Pb (1998 + 2000 data):

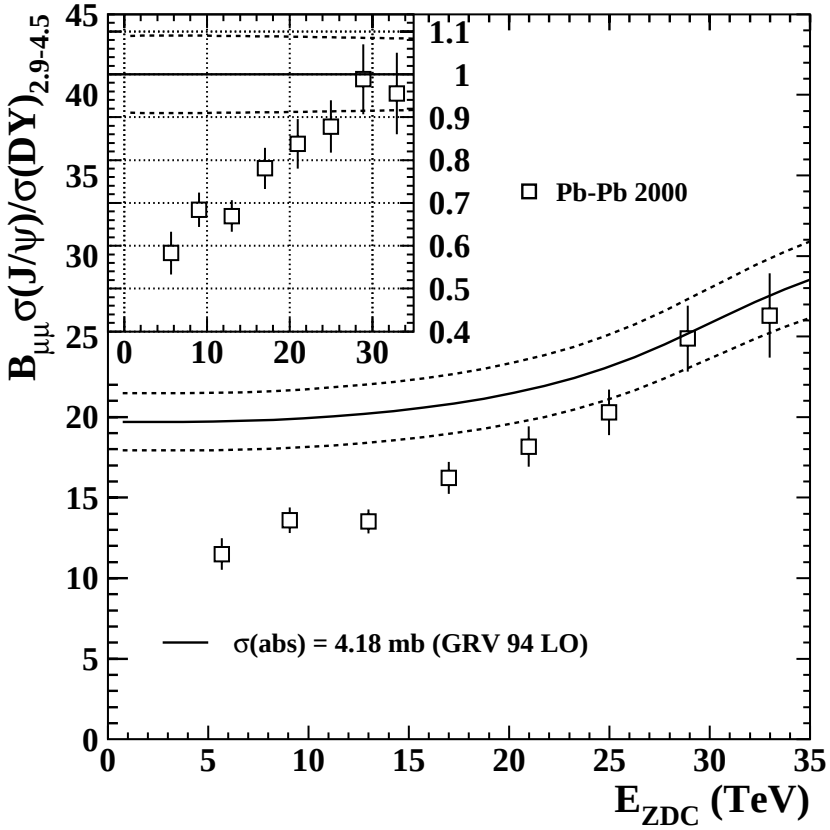
⇒ **departure from normal nuclear absorption at mid-centrality**

⇒ **suppression increases with centrality**

Anomalous J/ψ suppression vs. N_{ch}, E_{ZDC}



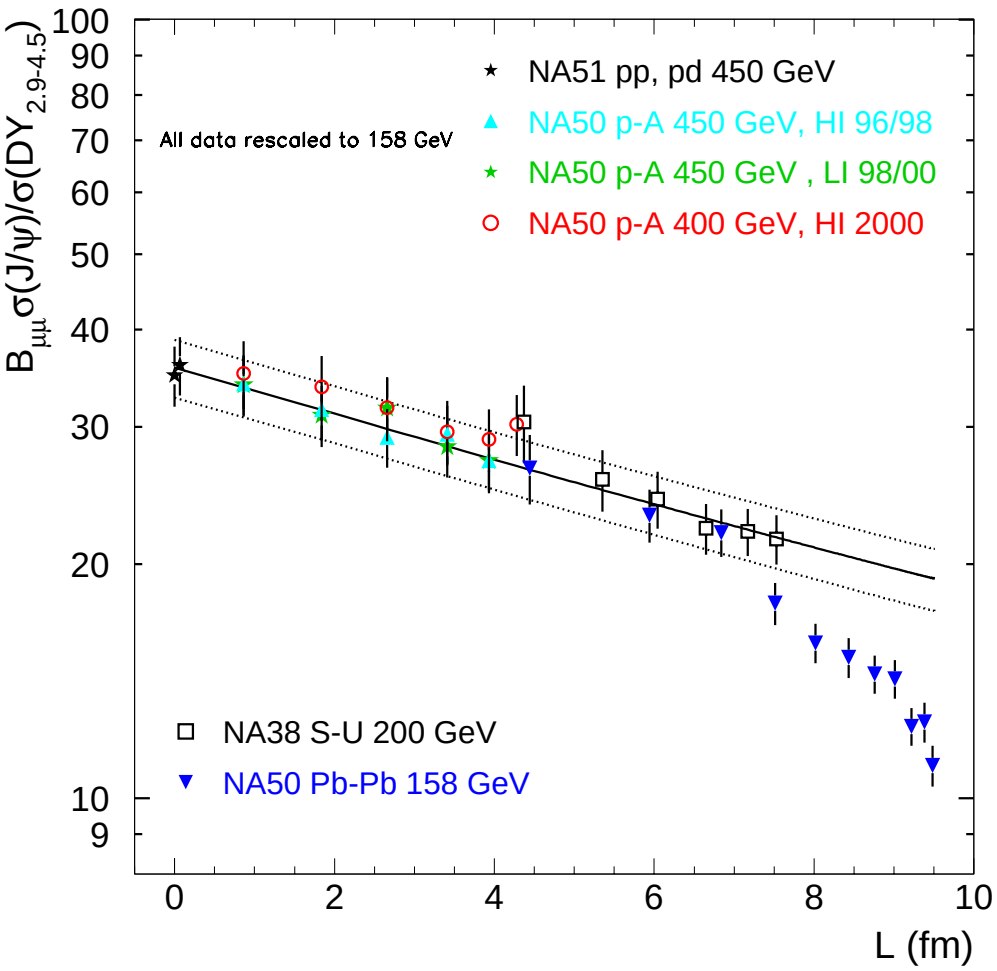
Independent analysis vs. N_{ch} ...



...and vs. forward energy E_{ZDC}

$\Rightarrow$ similar suppression pattern as previously shown vs. E_T

$(J/\psi)/DY$: p-A, S-U and Pb-Pb collisions



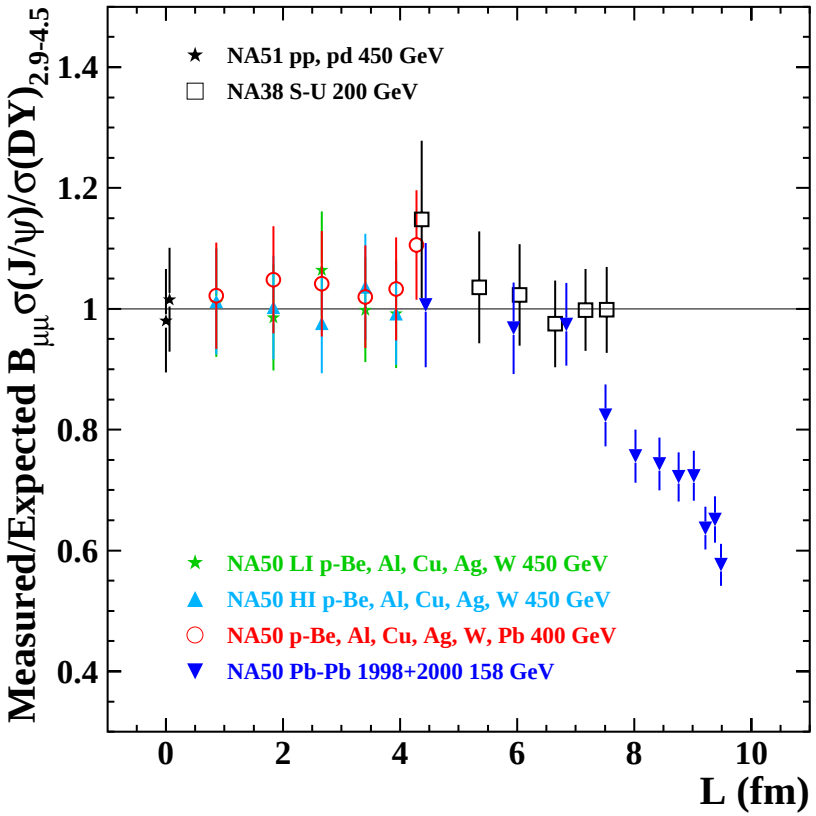
- **Average path L in nuclear matter**: appropriate to visualize nuclear absorption in different systems

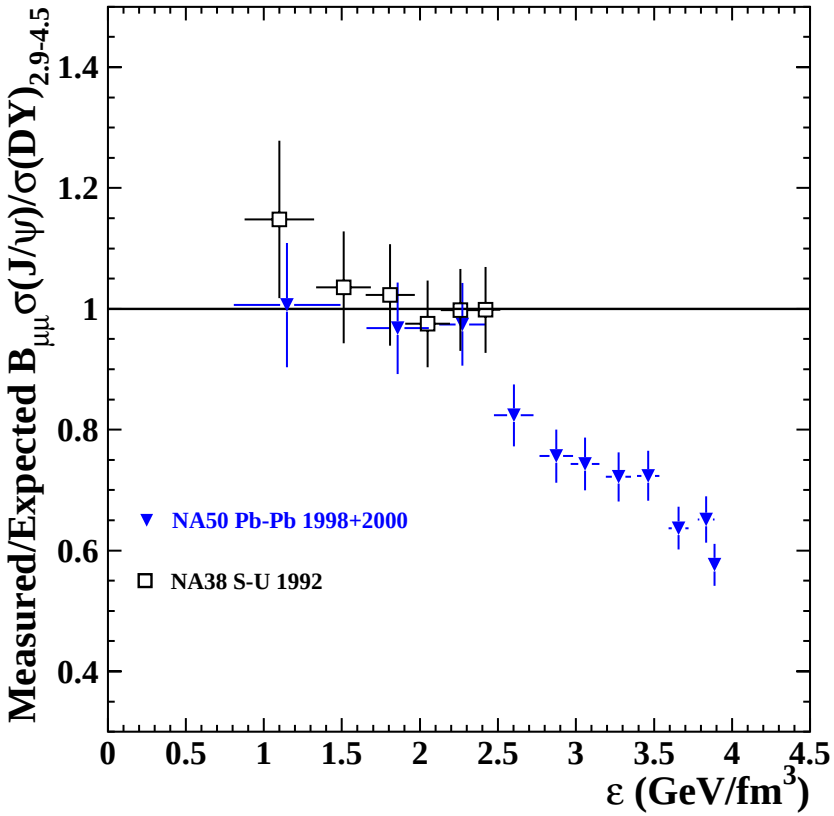
- **Absorption curve from p-A data only**

  $\Rightarrow$ allows new conclusion

- **Peripheral Pb-Pb data points but ALSO all of S-U data points compatible with normal nuclear absorption**

$(J/\psi)/DY$: Measured/Expected in A-B collisions





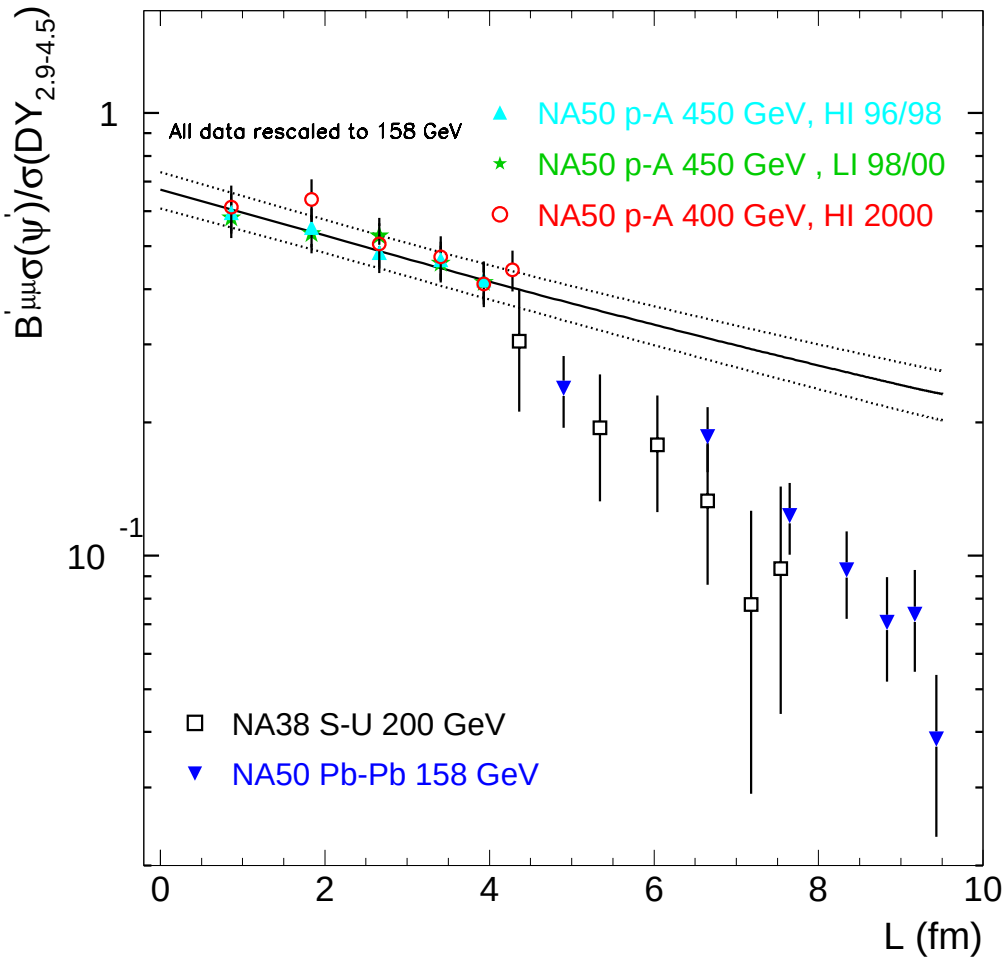
From results of previous slide but here in terms of

"measured/normally expected"

as a function of:

average path L and **energy density** ϵ

ψ'/DY: p-A, S-U and Pb-Pb collisions



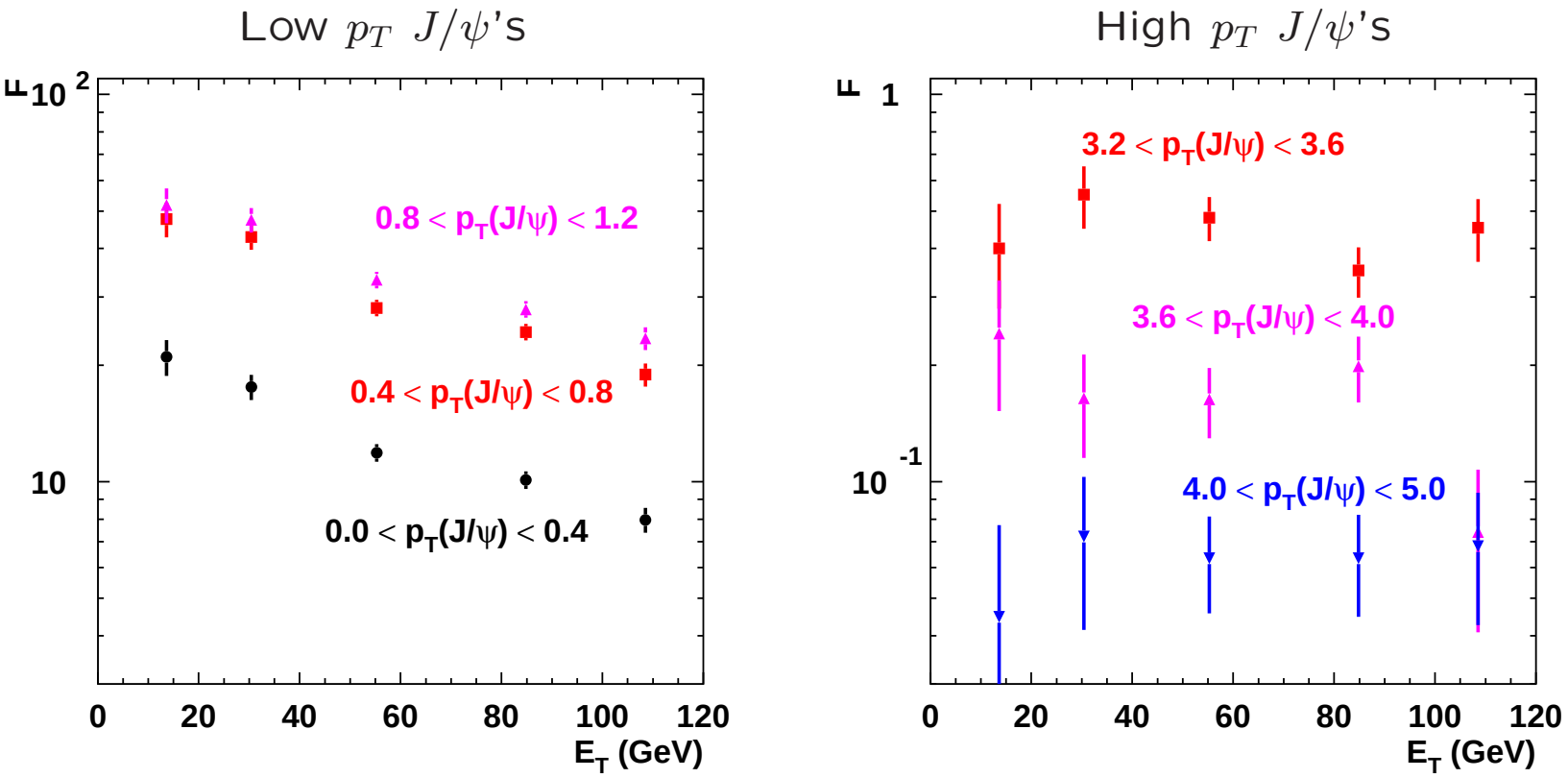
- Glauber fit to p-A ψ'/DY
  $\Rightarrow \sigma^{\psi'}_{abs,pA} = 7.6 \pm 1.1$ **mb**

- **Already in S-U**
  ψ'/DY deviates from p-A behaviour, showing **larger absorption**

- **Pb-Pb and S-U show very similar ψ' absorption larger than observed in p-A**

J/ψ suppression vs. centrality in p_T bins

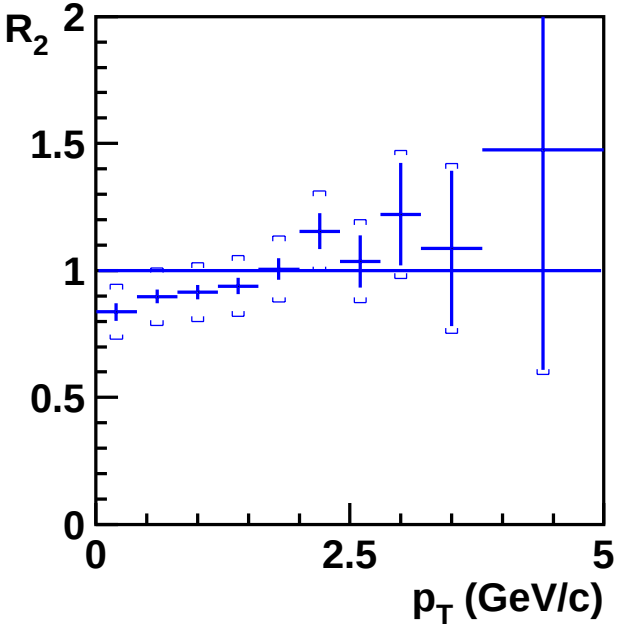
$$F(E_T; p_{Ti}) = N_\psi(E_T; p_{Ti})/N_{DY}(E_T)$$

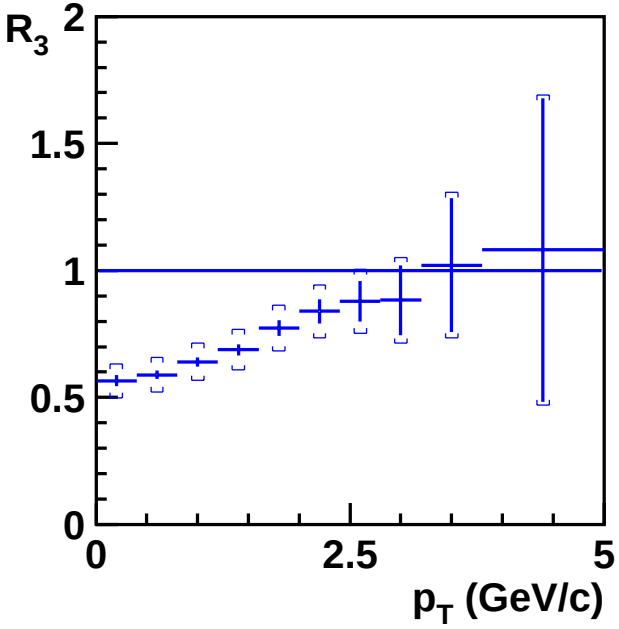


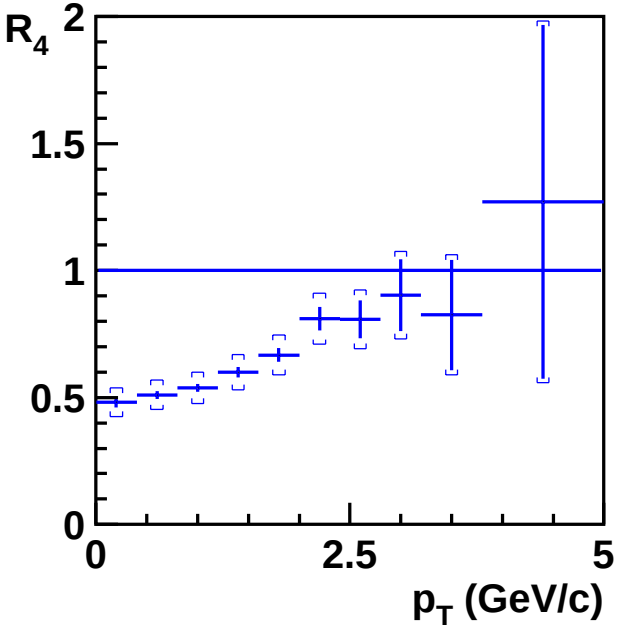
$F(E_T; p_{Ti})$ is the ratio $(J/\psi)/DY$ limited to J/ψ's in a given p_T bin

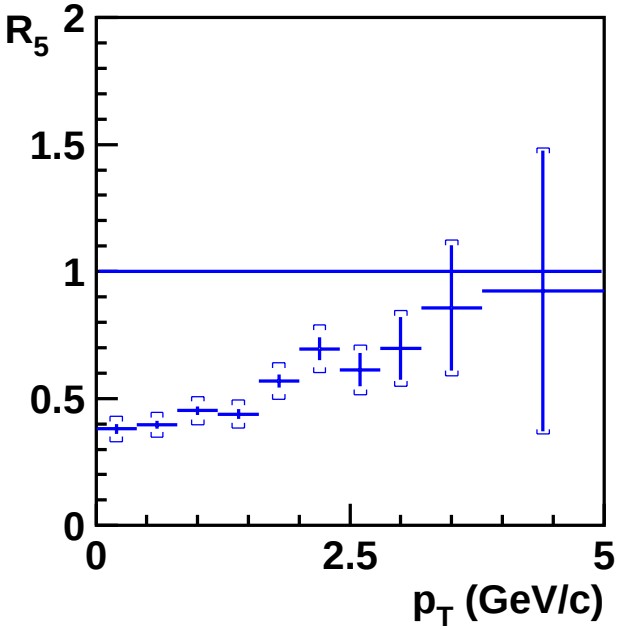
$\Rightarrow$ **Anomalous J/ψ suppression is concentrated at low p_T**

J/ψ central to peripheral ratio "R_{CP}" vs. p_T









The ratios $R^i_{CP}(p_T)$ are defined as:

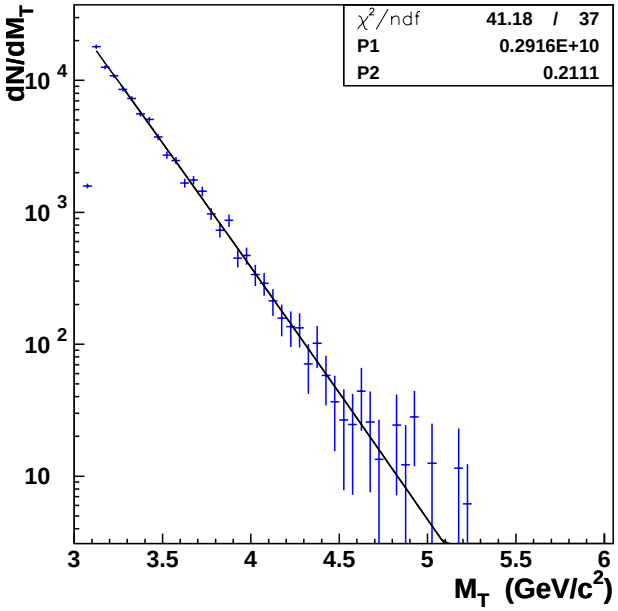
$$\frac{N_{\psi,i}(p_T)}{N_{DY,i}} \Big/ \frac{N_{\psi,1}(p_T)}{N_{DY,1}}$$

with $N_{DY,i}$ prop. to N^i_{coll}

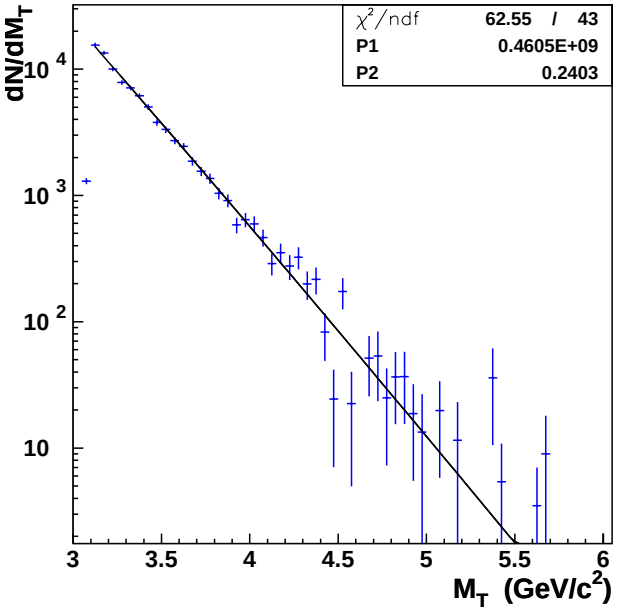
- Central to peripheral ratio R^i_{CP} for centrality bins $i = 2, 5$ where $i = 1$ is the most peripheral bin
- **J/ψ suppression is mainly at low p_T**
- **For $p_T > 3.5$ GeV/c centrality dependence of J/ψ suppression is weak**

J/ψ transverse mass distributions in Pb-Pb

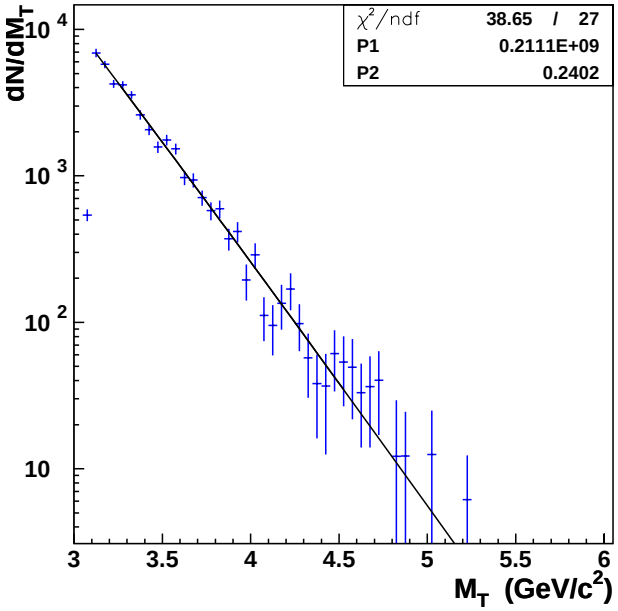
Peripheral



Semi-central



Central



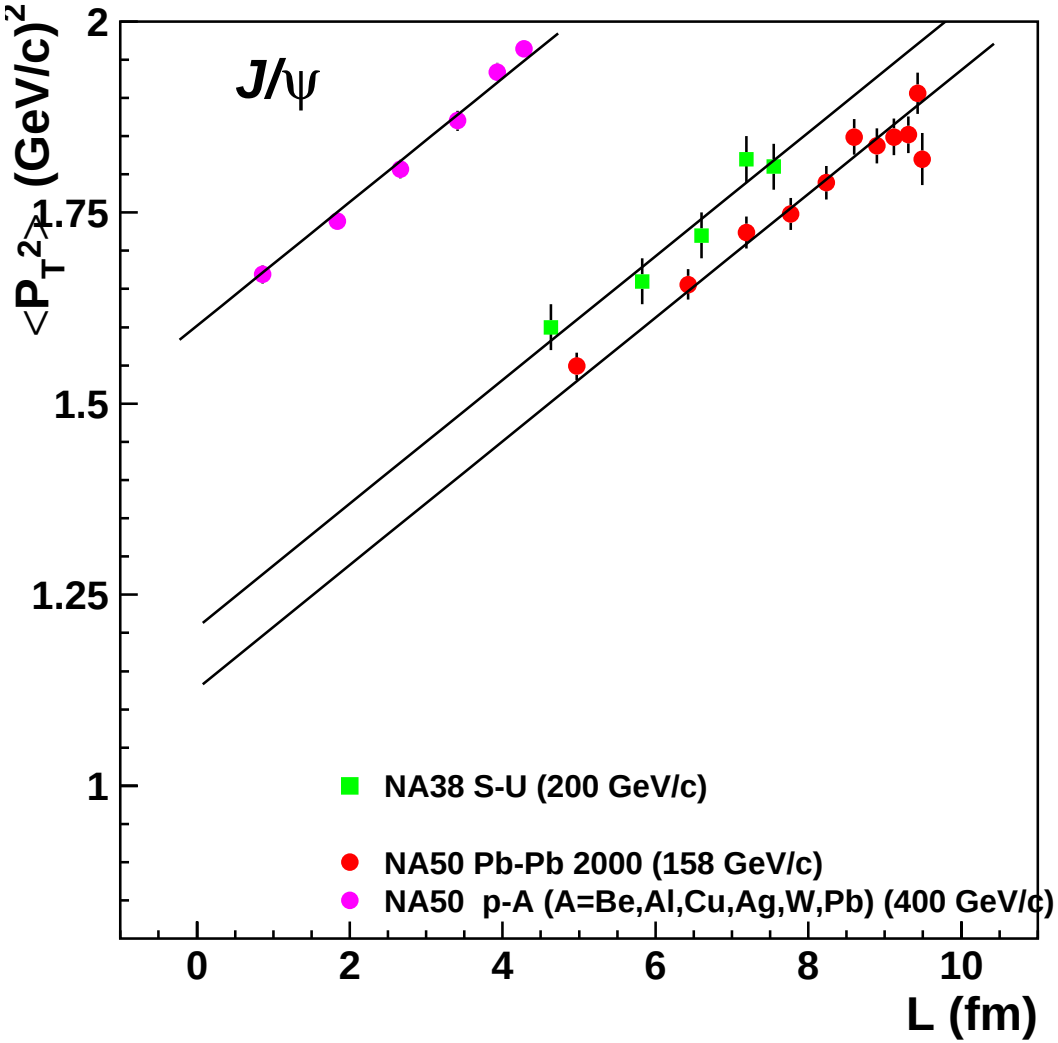
	Peripheral	Semi-central	Central
$T =$	211 ± 2 MeV	240 ± 3 MeV	240 ± 5 MeV
$< p_T^2 >=$	1.55 ± 0.02 GeV^2	1.84 ± 0.02 GeV^2	1.82 ± 0.03 GeV^2

Fit transverse mass distributions dN/dM_T in each centrality bin with thermal model: $M_T^2 K_1(M_T/T)$

Extract effective **temperature** T from fit

note that T and $< p_T^2 >$ are linearly correlated

J/ψ's $< p_T^2 >$ from p-A to Pb-Pb

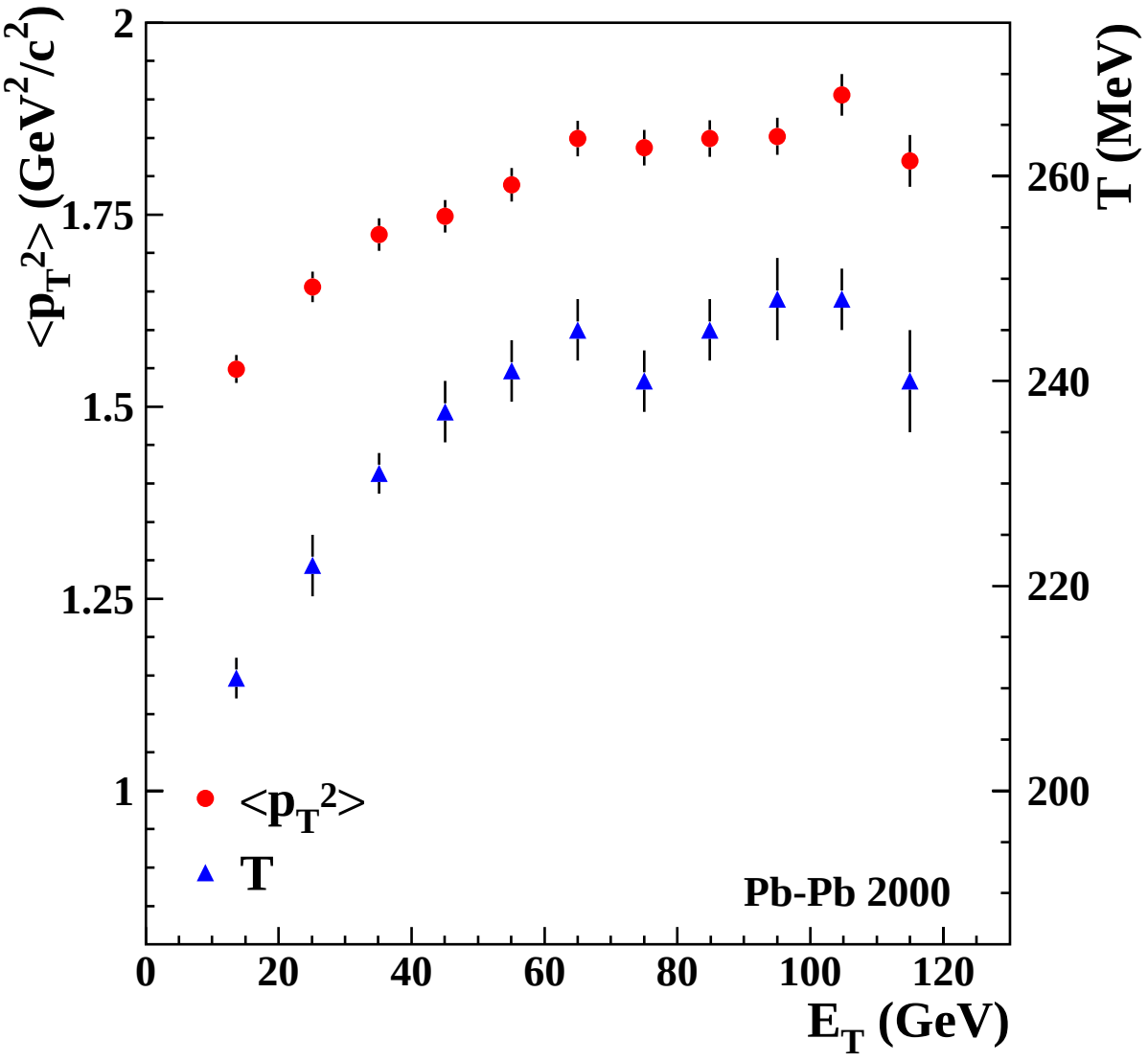


- All systems show that both
  $< p_T^2 >$ **and** T
  are **linearly increasing**
  with average path L

- Attributed to multiple scattering of initial partons (gluons)

- Phenomenological description with the expression:
  $< p_T^2 > (L) = < p_T^2 >_{pp} + \alpha_{gN} L$
  with an energy dependent
  $< p_T^2 >_{pp}$ and a common slope:
  $\alpha_{gN} = 0.081 \pm 0.002$ GeV^2/c^2/fm

$< p_T^2 >$ and T of surviving J/ψ's vs. centrality



- More detailed examination of $< p_T^2 >$ and T in Pb-Pb vs. centrality (here vs. measured E_T)

$\Downarrow$

- **Saturation of:**

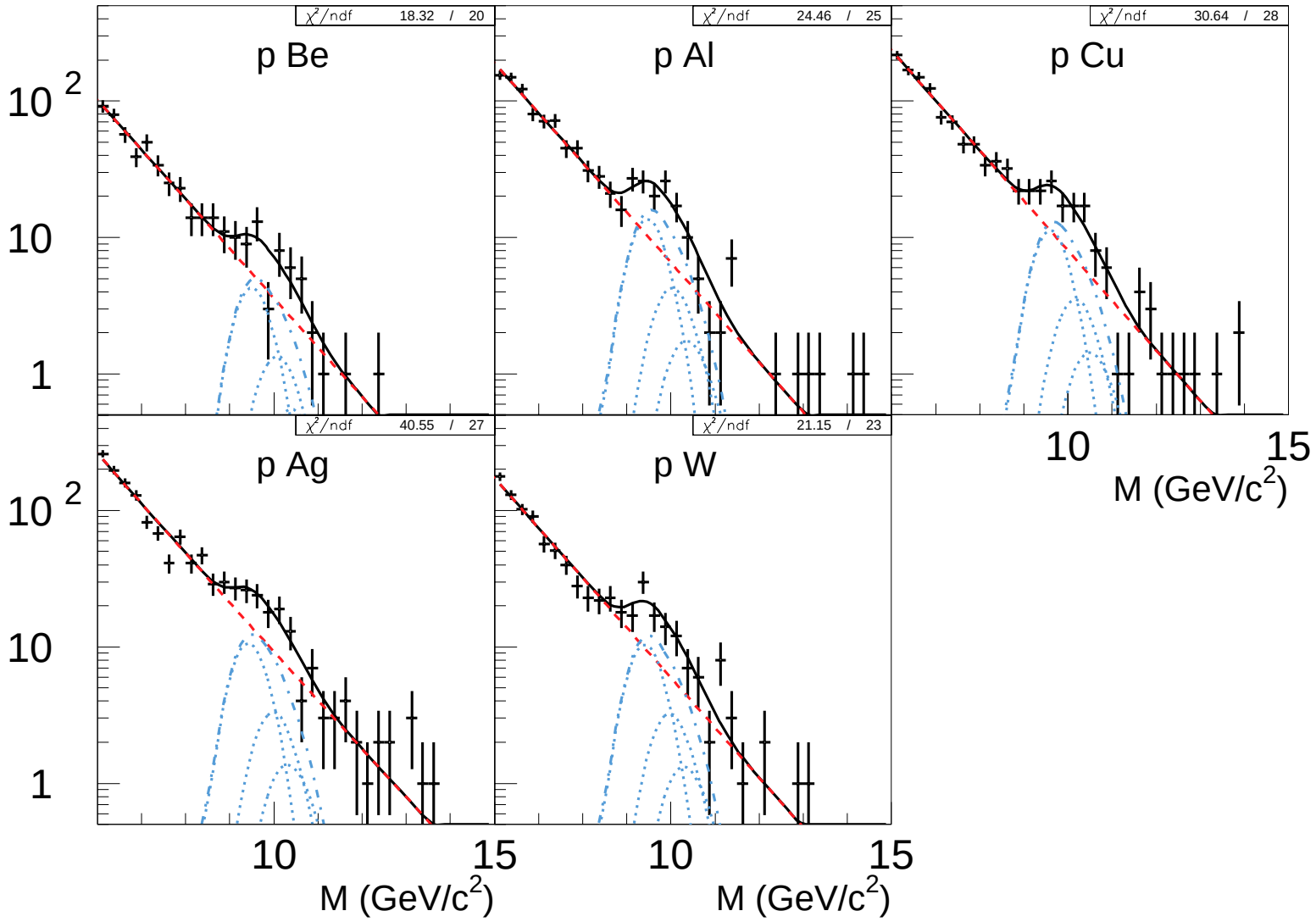
  $< p_T^2 >$ vs. E_T

  is observed for central Pb-Pb collisions

- **Same behaviour for:**

  T vs. E_T

Υ production in p-A collisions



Nuclear dependence of Drell-Yan and Υ production at $\sqrt{s} = 29.1$ GeV

see P. Cortese's talk at parallel session . . .

Conclusions on charmonia

- **Charmonium production and suppression:**
  with **normal** nuclear absorption
  derived from p-A collisions only
  we find in Pb-Pb collisions at 158 GeV/nucleon:
  - $(J/\psi)/DY$:
    - ♢ **Anomalous suppression** in semicentral and **central** collisions
    - ♢ **Peripheral Pb-Pb BUT ALSO ALL OF S-U** production in **agreement with normal** nuclear absorption
    - ♢ **Anomalous suppression** of J/ψ mostly **at low** J/ψ p_T
  - ψ'/DY:
    - ♢ **same suppression pattern in S-U and in Pb-Pb**, **very different from** normal absorption in **p-A collisions**

- J/ψ **transverse momentum distributions:**
  - ♢ **saturation of** $< p_T^2 >$ **and temperature** T **for central Pb-Pb collisions**

The NA50 Collaboration

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