Recent results on intermediate mass dimuon production

NA38/NA50 Collaboration

L.Capelli - IPN Lyon

Charm production in nucleus nucleus collisions workshop

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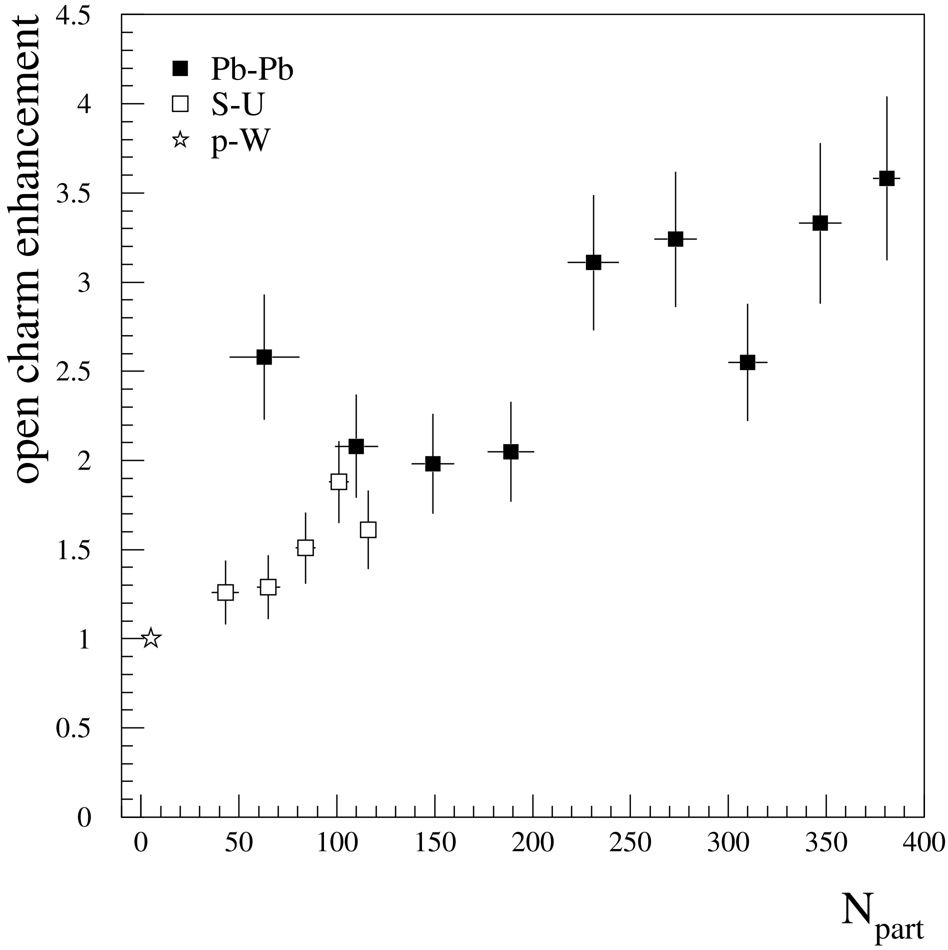
outline

- introduction
- data analysis
  - mass distributions
  - P_T distributions
- comparison with models

Introduction

- an excess has been shown to exist in the dimuon mass range 1.5 to 2.5 GeV/c^2 [Nucl.Phys.**A610**(1996)331c]



- NA50 apparatus
  - muon spectrometer
  - centrality detection

Unfolding methods

- detector effects $\rightarrow$ acceptance and resolution

acceptance $\mathcal{A}(x)$ x : set of kinematical variables describing
resolution $\mathcal{S}(x'|x)$ the dimuons ➡ M, P_T, Y_{cm}, $\cos(\Theta_{cs})$

$$\mathcal{D}(x') = \int \mathcal{S}(x'|x)\ \mathcal{A}(x)\ \phi(x)\ dx$$

➩ extract the physical distribution $\phi(x)$ from the measured one $\mathcal{D}(x')$

- 1-D unfolding method

  - assume separability between the different kinematical variables
  - assume the shapes of the distributions of each variable
  - unable to disentangle correlation between variables due to the detector or/and to the physics

4-D unfolding method

- based on image restoration methods extended to 4-D
- accounts for detector correlation
- preserve physics correlations
- no need to assume specific shapes for distribution
- iterative method [NIM **A405**(1998)139]

$$\rightarrow \qquad \phi^n(j) = O^n(j) / \mathcal{A}(j)$$

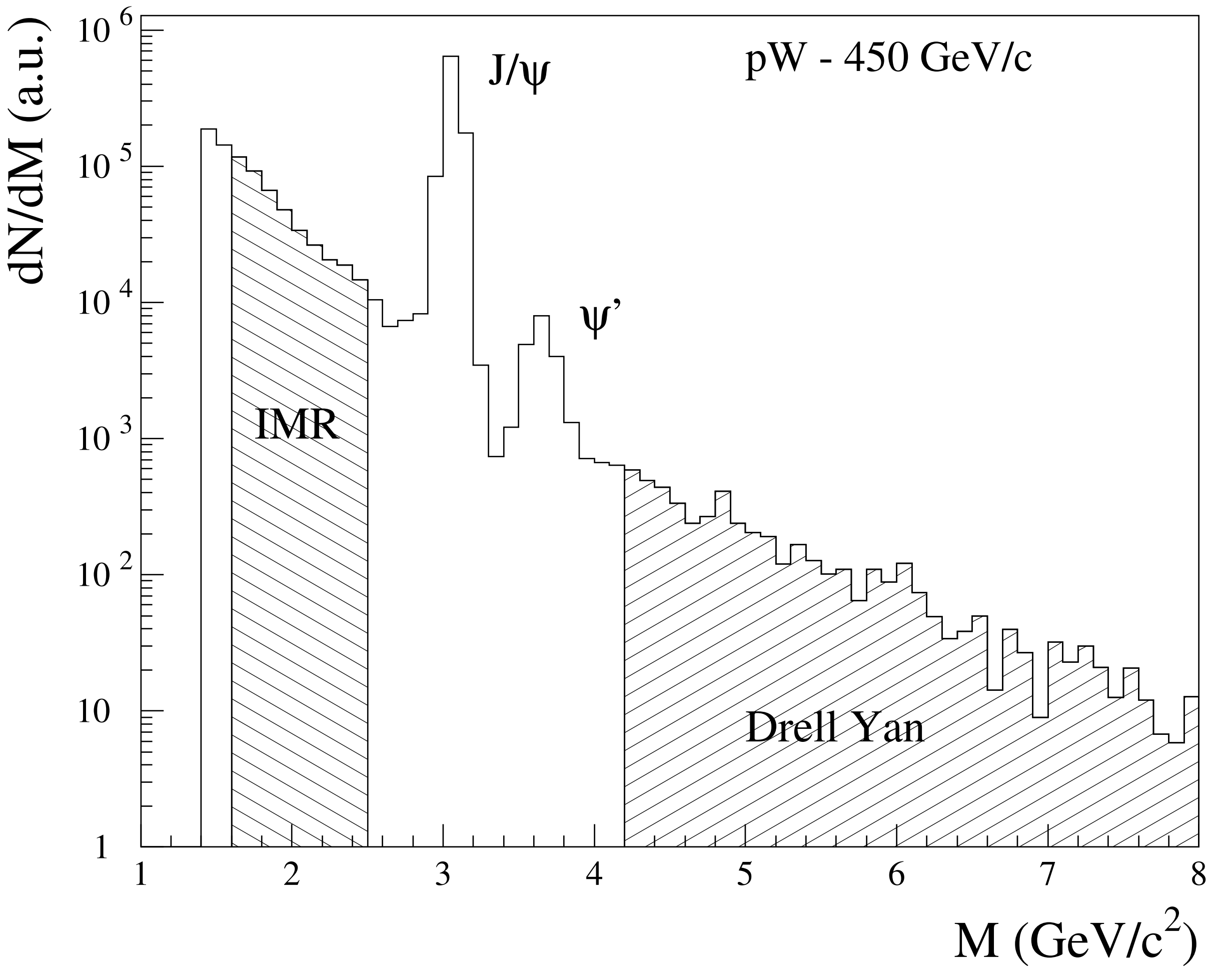
with $$O^n(j) = O^{n-1}(j) \sum_i \mathcal{S}(i|j) \frac{\mathcal{D}(i)}{I^{n-1}(i)}$$

$$I^{n-1}(i) = \sum_j \mathcal{S}(i|j) \; O^{n-1}(j)$$

$\mathcal{S}$ (i|j) computed from single muon characteristics

Dimuon mass spectra

Between the ϕ and J/ψ resonances $\rightarrow$ Intermediate Mass Region (IMR)
$1.6 < M < 2.5$ GeV/c^2



- Known sources
  - Drell Yan : $q\bar{q} \rightarrow \mu^+\mu^-$
  - Resonances decay : J/ψ, $\psi' \rightarrow \mu^+\mu^-$
  - Charmed meson (and baryon) decays as $D \rightarrow \mu X$

Mass spectra analysis

- fit of data in the mass range $1.6 < M < 8.0$ GeV/c^2 assuming

$$\frac{dN}{dM} = n_1 \frac{dN^{D\bar{D}}}{dM} + n_2 \frac{dN^{DY}}{dM} + n_3 \frac{dN^{\psi}}{dM} + n_4 \frac{dN^{\psi'}}{dM}$$

  - gaussian shapes for the J/ψ and ψ' resonances :
    - free J/ψ and ψ' position and $\sigma_{\psi'} = \sigma_{J/\psi}\, M_{\psi'}/M_{J/\psi}$
  - shapes of DY and $D\bar{D}$ obtained from PYTHIA 6.1 with :
    - c quark mass ➡ $\mathbf{m_c = 1.5}$ GeV/c^2
    - Intrinsic transverse momentum

$\sigma_{k_T}^{DY}$ = **0.8** GeV/c [NA51 pp collisions]

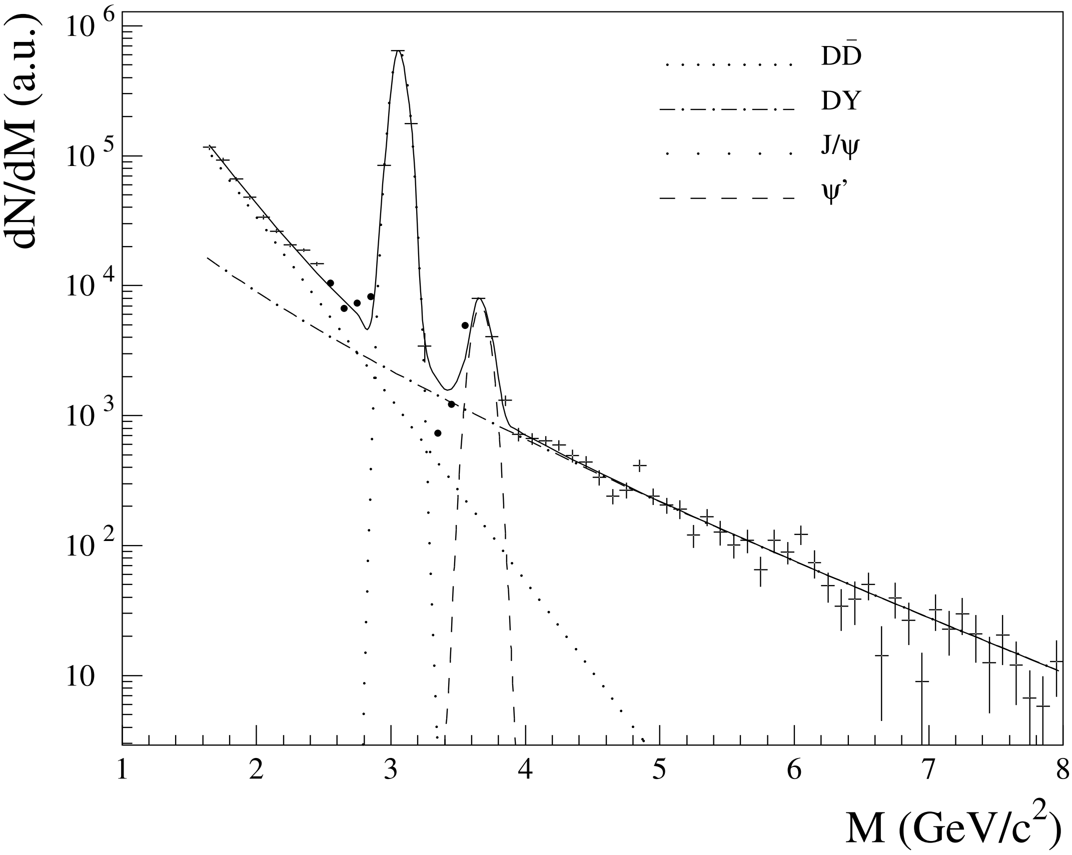
$\sigma_{k_T}^{D\bar{D}}$ = **1.0** GeV/c [Eur.Phys.J.**C1**(98)123]

    - **MRS A** set of PDF's

  - 7 parameters fit

pW results - 450 GeV/c

- measured data unfolded in the following kinematical domain : $M > 1.6$ GeV/c^2, $-0.2 < Y_{cm} < 0.4$ and $-0.3 < \cos(\Theta_{cs}) < 0.3$



- $$\left(\frac{D\bar{D}}{DY}\right)_{pW,\,450} = 4.48 \pm 0.15$$

$$\text{in} \quad \begin{array}{l} 1.6 < M < 2.5 \text{ GeV/c}^2 \\ -0.2 < Y_{cm} < 0.4 \\ -0.3 < \cos(\Theta_{cs}) < 0.3 \end{array}$$

Open charm cross section

- $\sigma^{\mathbf{DY}}_{pp,\,450}$ = (25.3 ± 1.9) pb [NA51,Phys.Lett.**B438**(98)35]
has been measured in the phase space domain :

  $M > 4.3$ GeV/c^2
  $-0.4 < Y_{cm} < 0.6$
  $-0.5 < \cos(\Theta_{cs}) < 0.5$

- with PYTHIA $\sigma^{DY}_{HM} \rightarrow \sigma^{DY}_{IMR}$

- from the ratio $\left(\frac{D\bar{D}}{DY}\right)_{pW,\,450}$

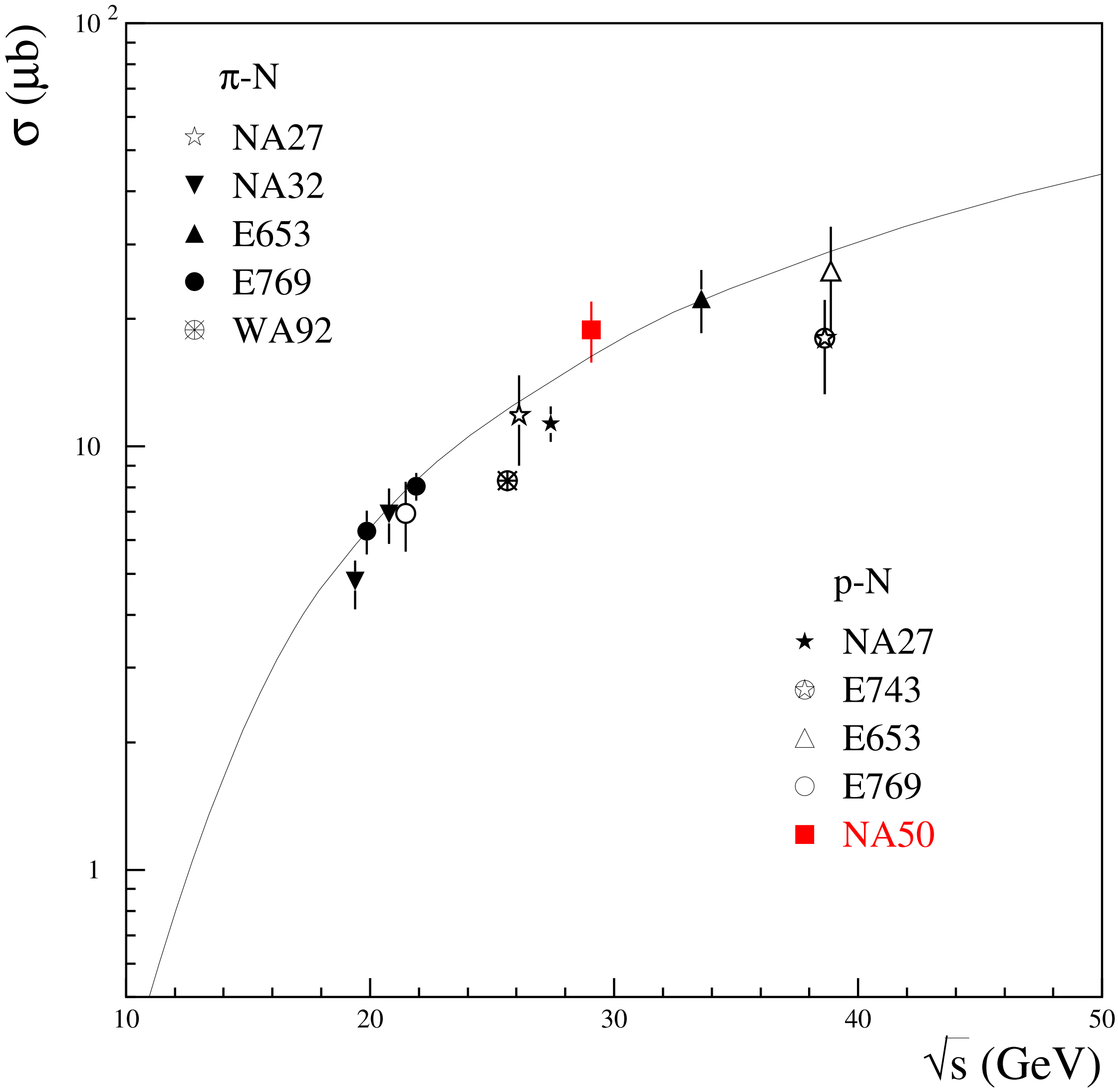
➥ the open charm cross section at 450 GeV can be deduced in the following way :

$$\sigma^{450}_{c\bar{c}} = \sigma^{DY}_{IMR} \times \left(\frac{D\bar{D}}{DY}\right)_{pp,\,450} \times (\text{phase space factor}) \times \frac{1}{BR(D \rightarrow \mu)^2}$$

$$\sigma^{450}_{c\bar{c}} = (\mathbf{37.7} \pm \mathbf{6.2})\ \mu b$$

Open charm cross section

- comparison with other experiments



- NA50 value is compatible with other direct measurements

- influence of the choice of the PDF :
  same analysis with GRV94 LO leads to 12% higher $\sigma^{450}_{c\bar{c}}$

S-U and Pb-Pb mass spectra analysis

- data unfolded in the following kinematical domain :

  $M > 1.6$ GeV/c^2
  $0.2 < Y_{cm} < 0.8$
  $-0.3 < \cos(\Theta_{cs}) < 0.3$

- analysis as a function of centrality based on electromagnetic transverse energy E_T :

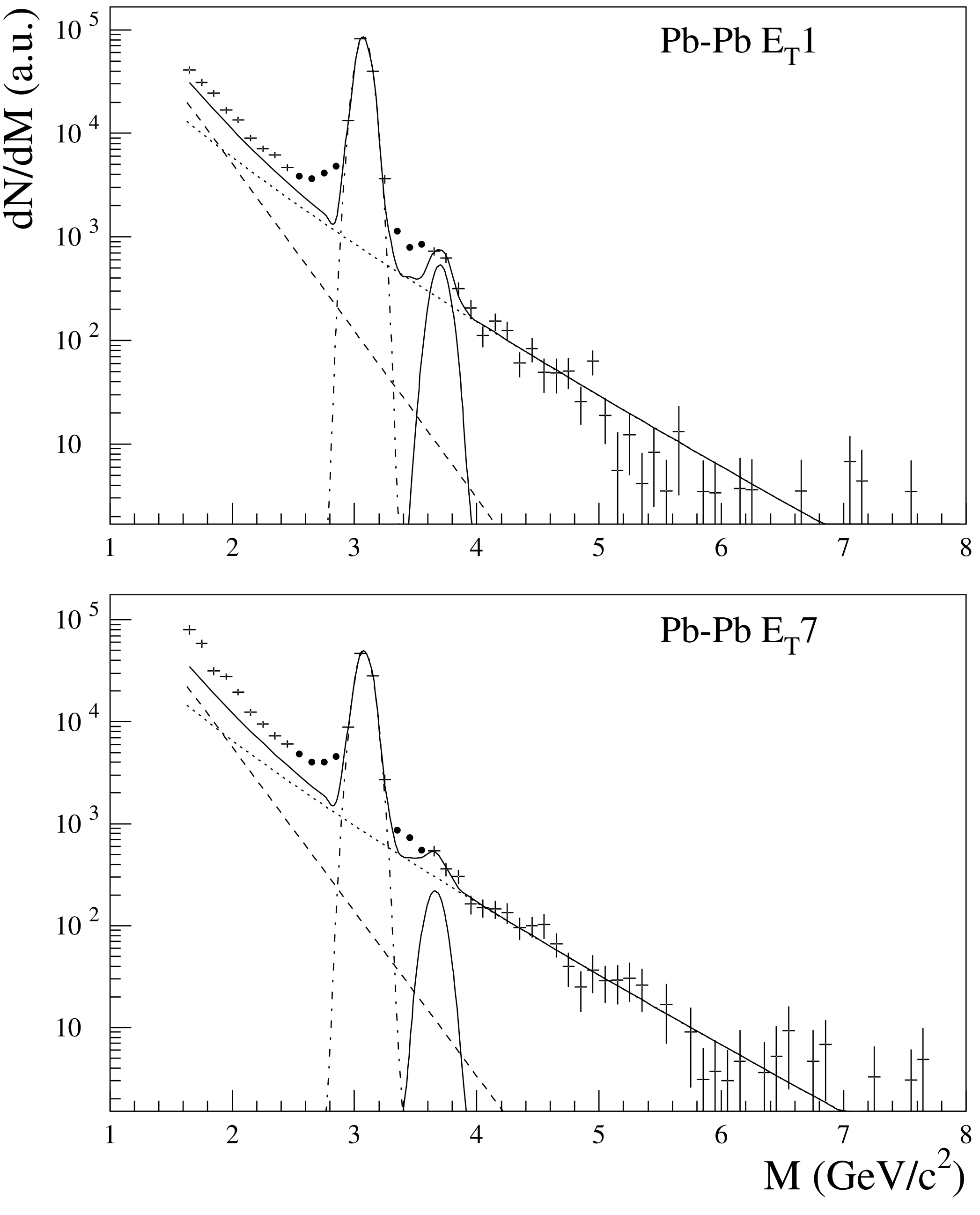
  - 5 bins for S-U
  - 7 bins for Pb-Pb

- for S-U and Pb-Pb collisions, the DY and $D\overline{D}$ processes are extrapolated linearly from NN yields, as expected for hard processes.

- NN open charm and DY cross sections have been deduced from the pW 450 GeV/c value using the $\sqrt{s}$-dependence given by PYTHIA

- the isospin correction has been taken into account for DY

Pb-Pb mass spectra



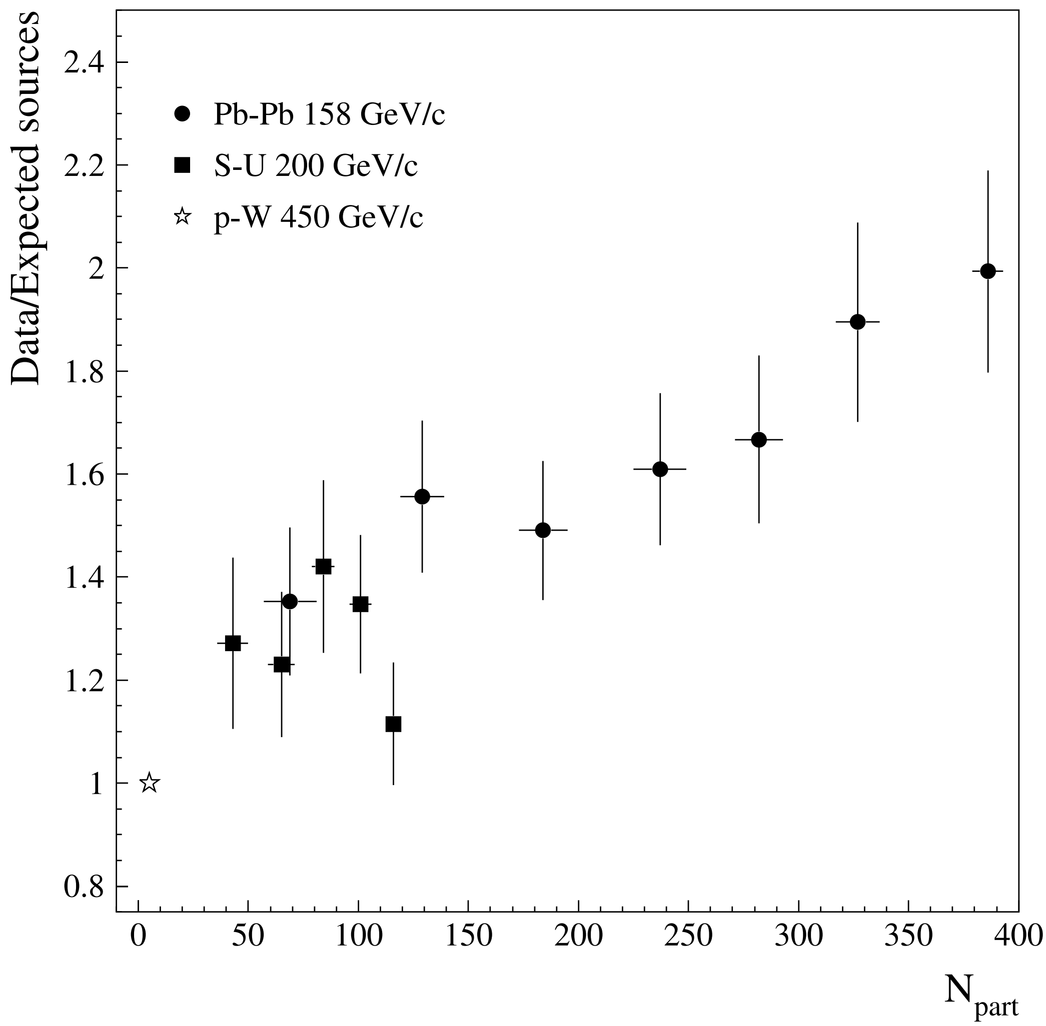
→ Data are higher than the expected sources

Data / expected sources

- quantify the difference between data and expected sources as a function of centrality :

➥ plot data/expected sources (D/S) vs N_{part} in $1.6 < M < 2.5$ GeV/c^2

(Npart computed from E_T in the frame of the Glauber model with 2 parameter Woods-Saxon density profiles)



- the IMR excess increases as a function of centrality

Nuclear effects in the PDF

- PDF are affected by nuclear medium (EMC)
- Modification of PDF calculated by Eskola, Kolhinen and Salgado (EKS) [Nucl.Phys.**B535**(98)351]

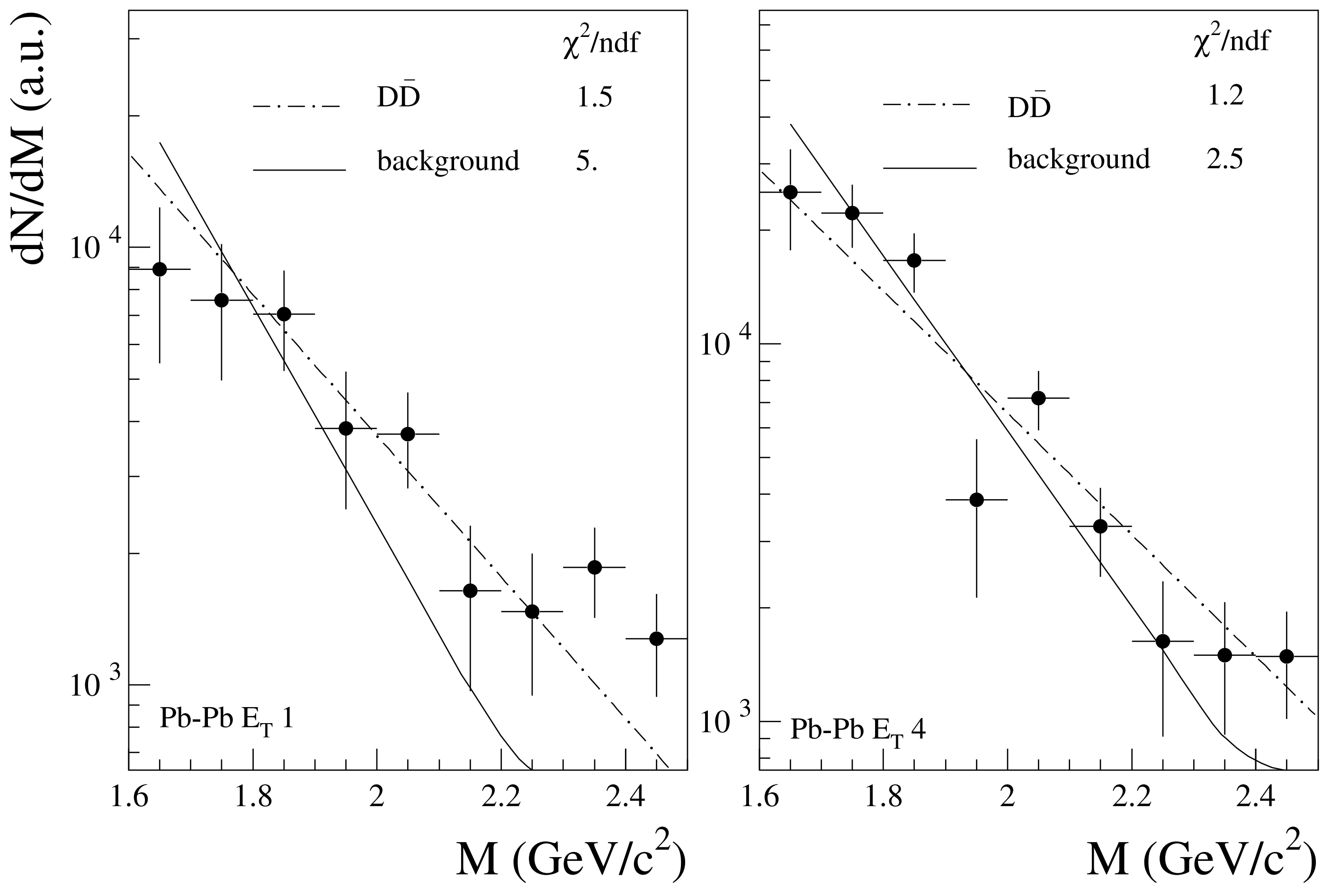
$$f_i^A(x, Q^2) = R^A(x, Q^2) f_i^p(x, Q^2) \qquad \text{EKS} \rightarrow R^A(x,Q^2)$$

- D/S computed with MRS structure function modified by medium effects
- the excess decreases by 10-15% at most

Hypothesis on the nature of the excess

- underestimation of the combinatorial background

→ compare the excess mass distribution with open charm and background shape



- excess mass shape differs from background shape and is similar to open charm shape

Charm enhancement hypothesis

- Hypothesis : excess behave as open charm

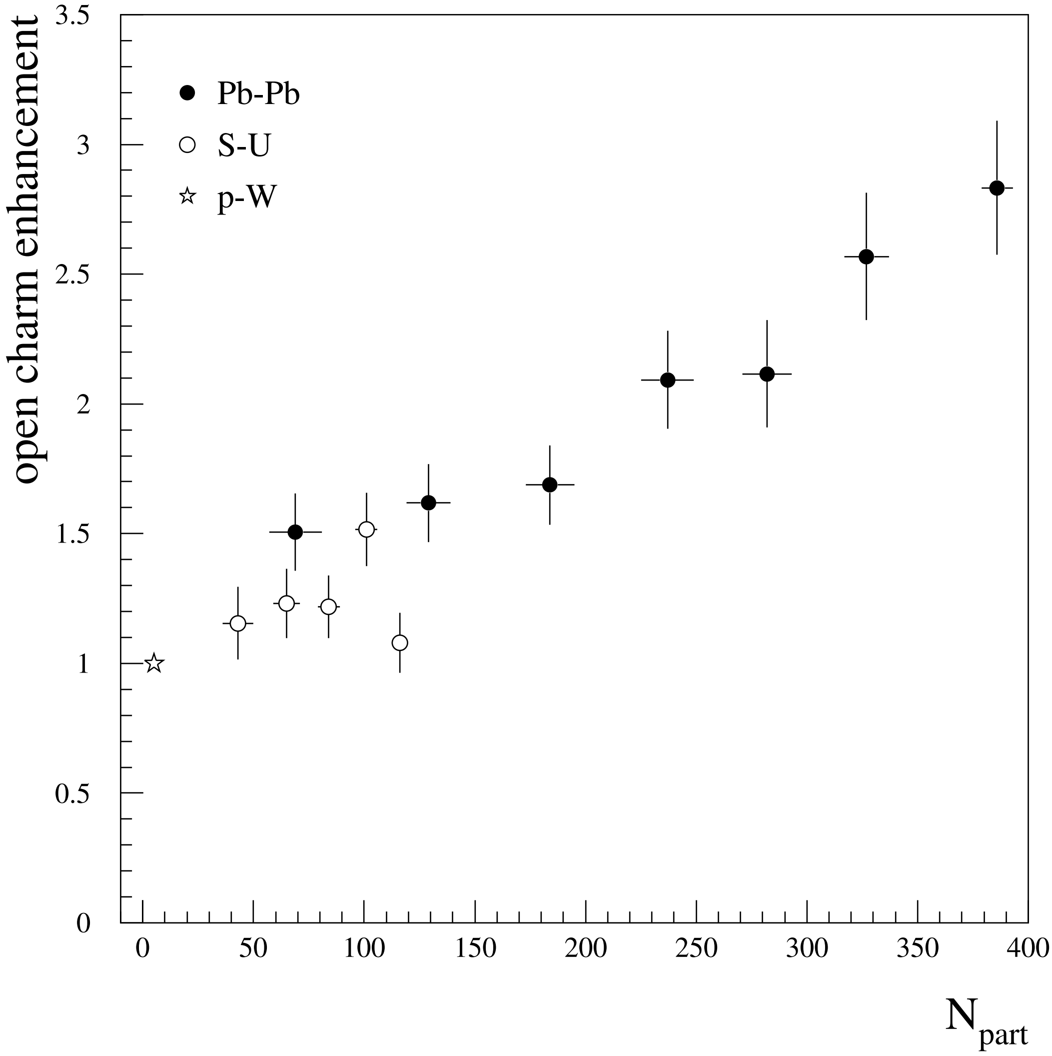
→ fit the IMR S-U and Pb-Pb mass spectra with a superposition of DY and $D\bar{D}$ and extract the ratio $(D\bar{D}/DY)_{measured}$

→ calculate the expected ratio : $(D\bar{D}/DY)_{expected}$ from pW

- plot the enhancement factor E as a function of centrality :

$$E = \frac{(D\bar{D}/DY)_{measured}}{(D\bar{D}/DY)_{expected}}$$

Charm enhancement hypothesis



- charm-like enhancement : factor ~3 in central Pb-Pb with respect to pW
- linear increase with N_{part}

Comparison with 1-D analysis

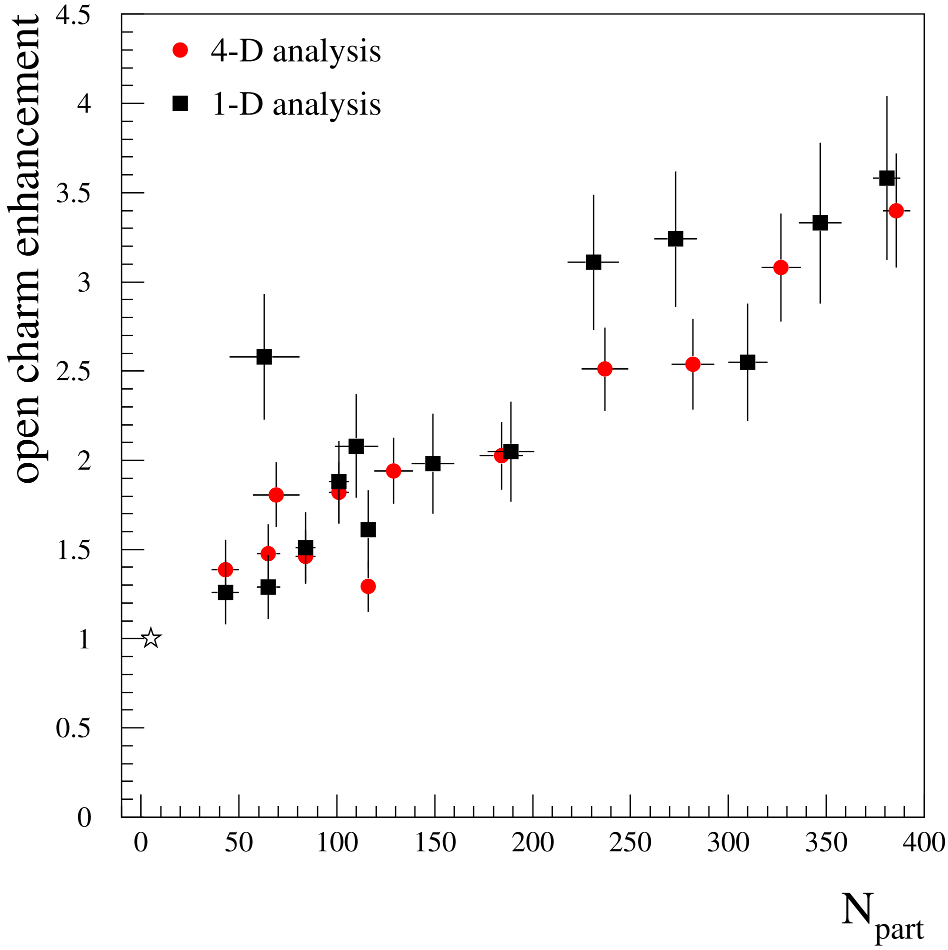
- 1-D results in domain :

$1.5 < M < 2.5$ GeV/c^2, $0 < Y_{cm} < 1$ and $-0.5 < \cos(\Theta_{cs}) < 0.5$

- 4-D results in domain :

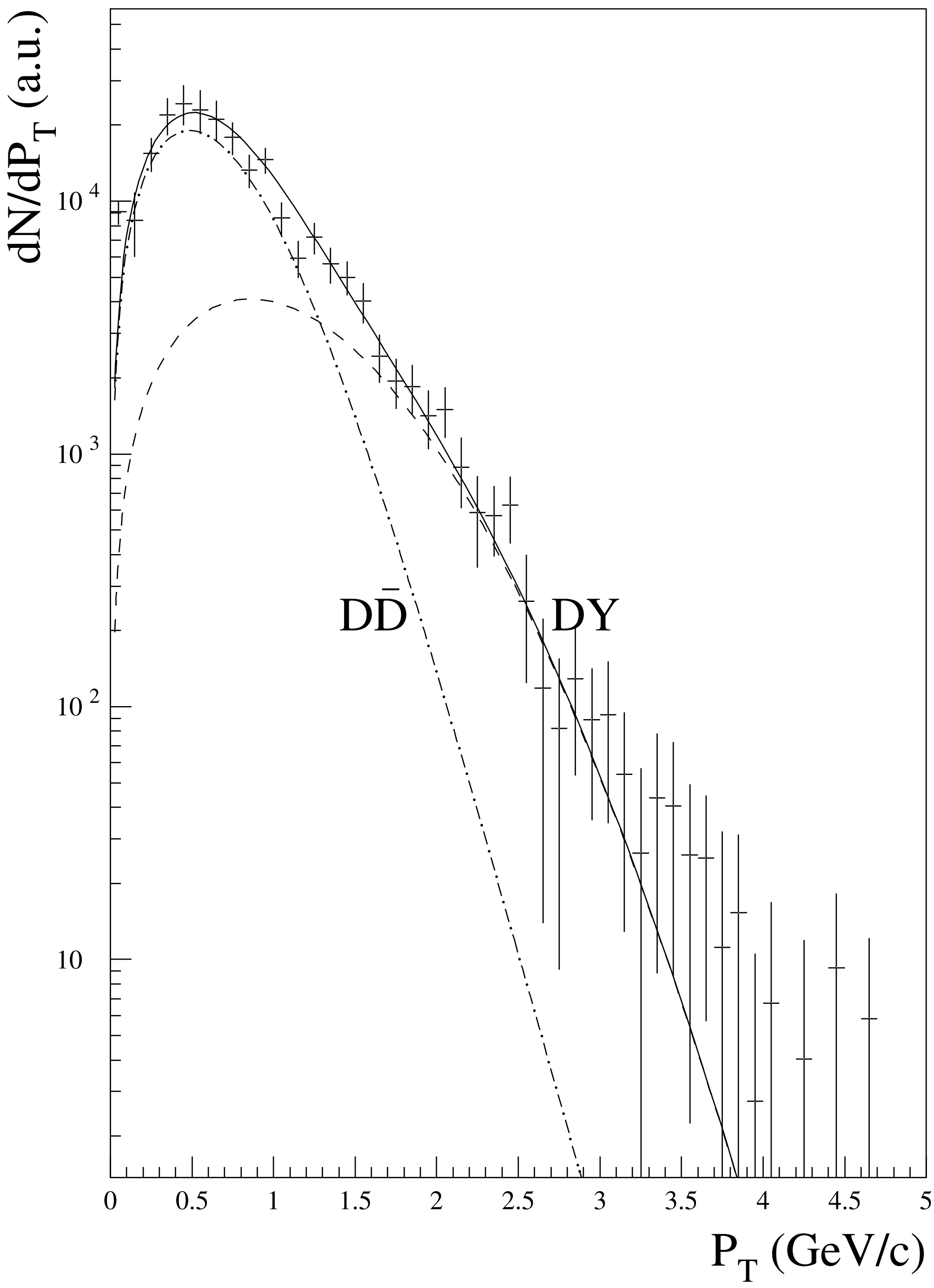
$1.6 < M < 2.5$ GeV/c^2, $0.2 < Y_{cm} < 0.8$ and $-0.3 < \cos(\Theta_{cs}) < 0.3$

→ phase space correction from 4-D domain to 1-D domain given by PYTHIA



- agreement satisfactory

P_T distributions of IMR Pb-Pb events



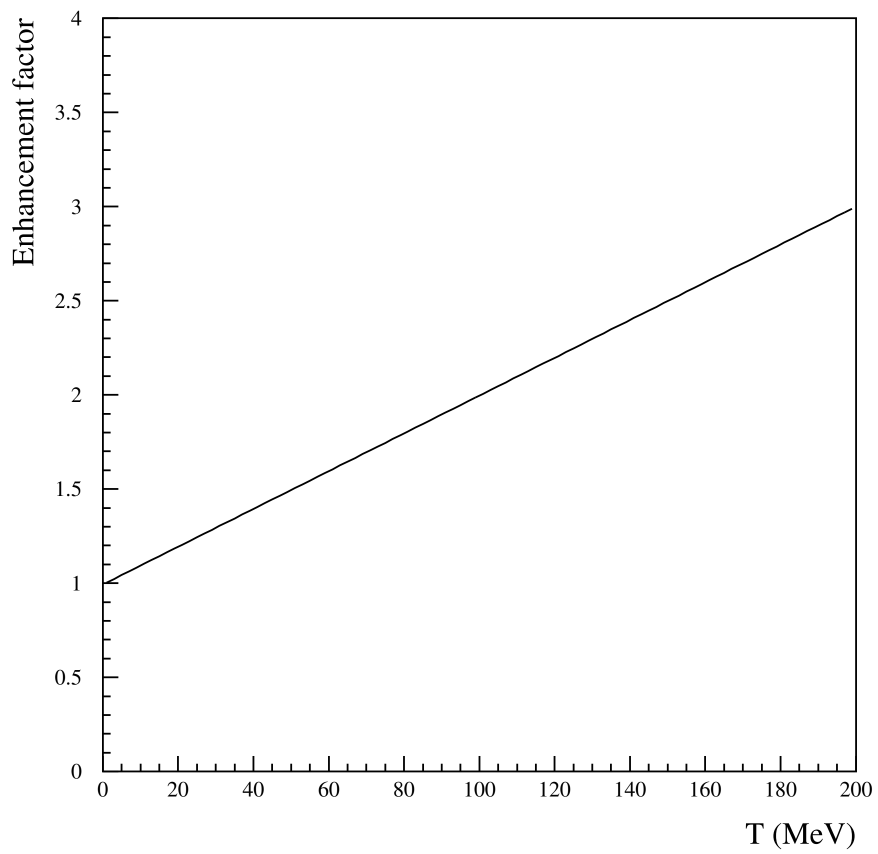
- the superposition of the DY and $D\overline{D}$ distributions reproduces reasonably well the data

D-meson final state rescattering

- several theoretical models have been proposed to explain the observed IMR charm excess
- Lin and Wang [Phys.Lett.**B444**(98)245] associate the observed excess to D-meson rescattering in nuclear matter which leads to an enhancement in the limited phase space of the NA50 experiment
- D and $\overline{\text{D}}$ rescattering is described by a thermal distribution depending on a temperature parameter T

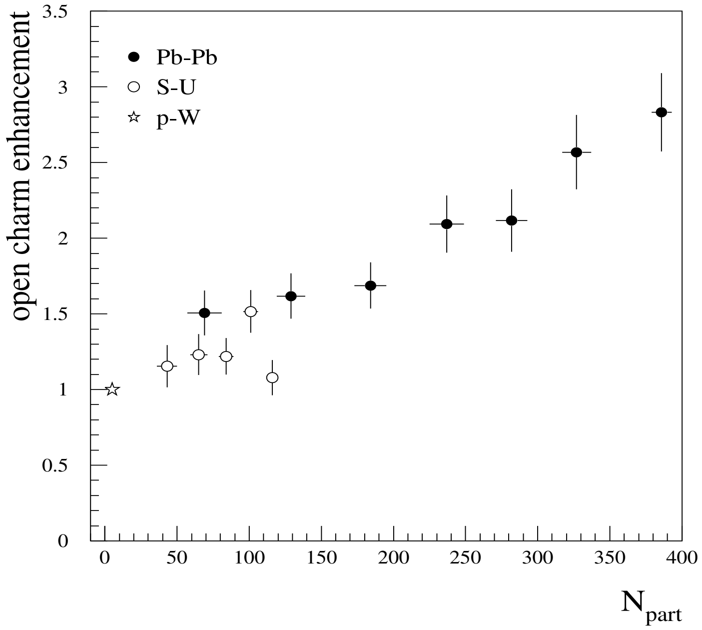
→ the enhancement factor in our phase space is calculated as the ratio of the number of dimuons observed at temperature T and at T=0

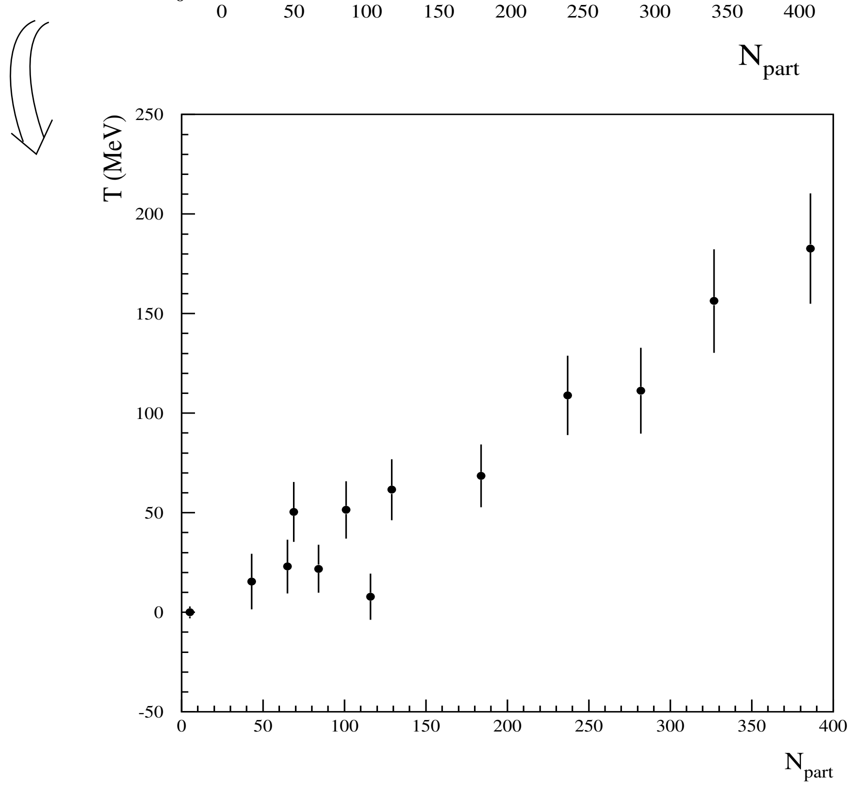
(with MRS A and m_c = 1.5 GeV/c^2)



D-meson final state rescattering

- from the experimental value of the enhancement, the corresponding temperature can be obtained for each of the centrality bins

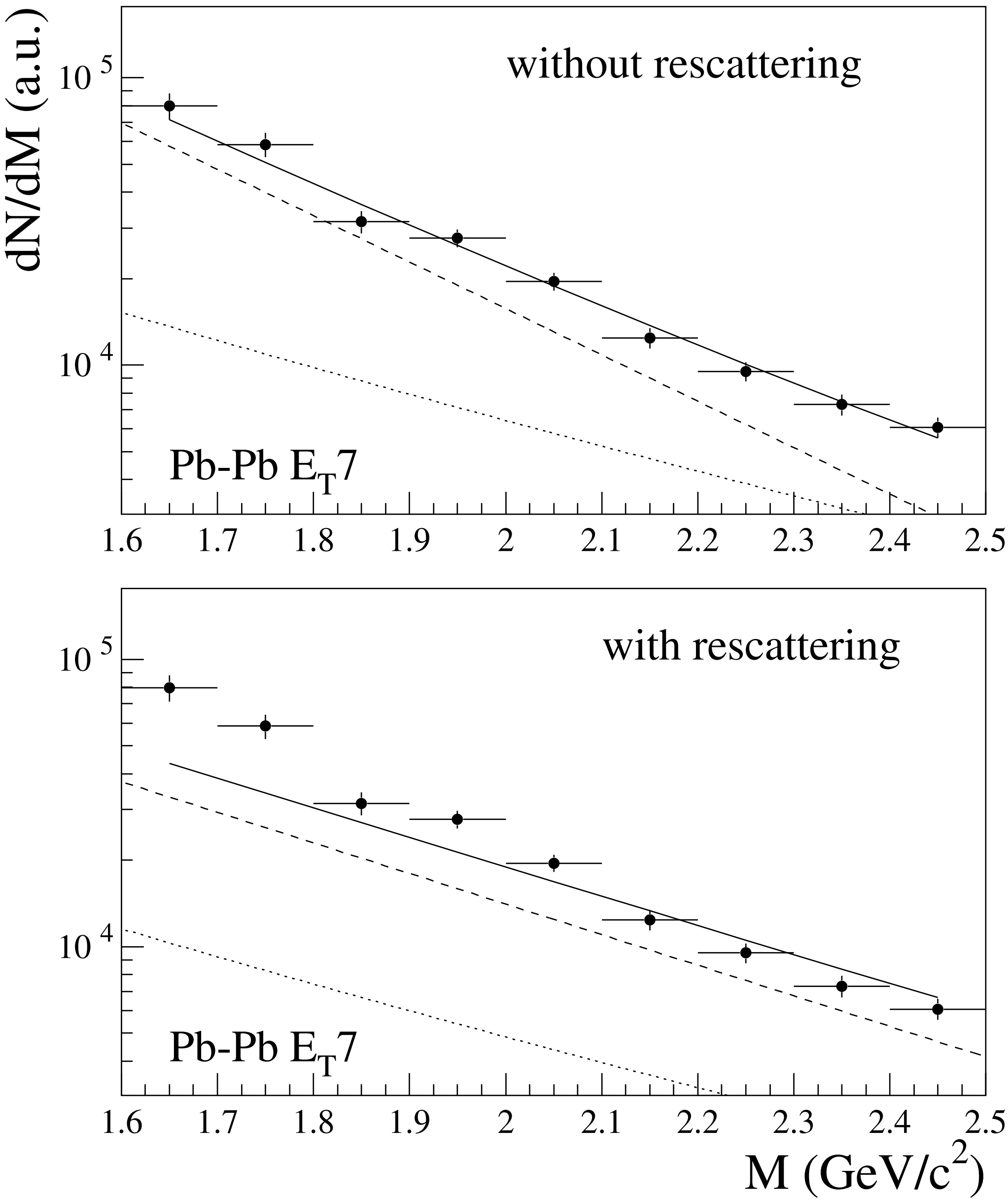




- the shape of the dimuon mass distributions from $D\overline{D}$ decays is then calculated with the corresponding temperature

D-meson final state rescattering

Mass distributions

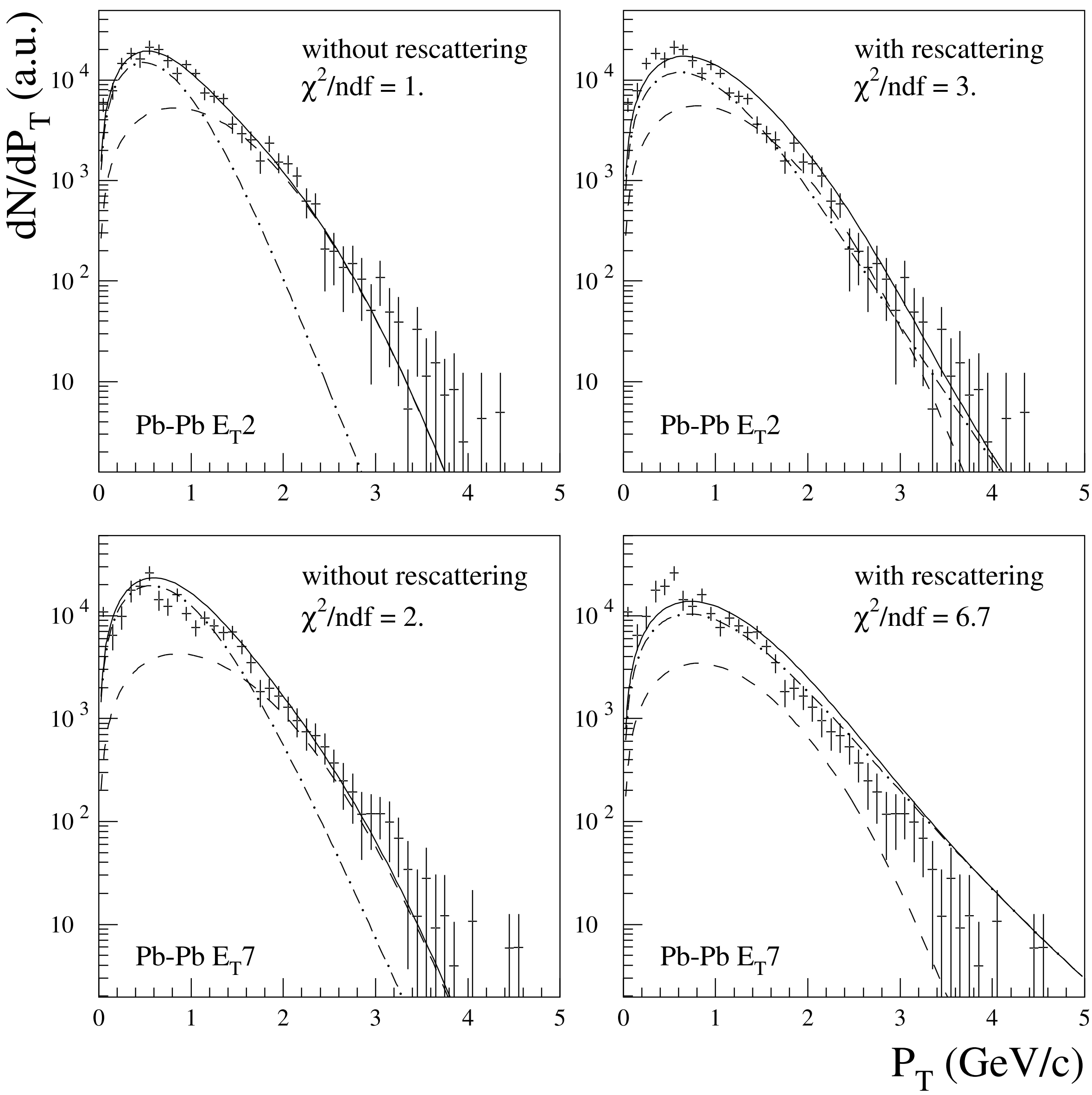


- the mass shape calculated with this model fails to reproduce the IMR mass spectra in central Pb-Pb collisions

D-meson final state rescattering

P_T distributions

- absolute normalization fixed from the mass spectra
- shape of $D\overline{D}$ P_T distributions computed using the corresponding temperature



Conclusions

- the $\sigma_{c\bar{c}}$ cross section extracted from the p-W data agrees with direct measurements of other experiments
- the ion data are in excess of the DY + $D\overline{D}$ superposition extrapolated from pW
- This excess increases linearly with N_{part}
- medium effects on the parton distribution functions reduce the excess by 15% at most
- the data can be described under the hypothesis of an enhancement of charm production
- the mass and P_T distributions cannot be reproduced by a model assuming D and $\overline{D}$ rescattering