NA38/NA50 experiments

Recent results on intermediate mass dimuon production

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Outline

- **introduction**
- **data analysis**
  - ✓ p-A
  - ✓ S-U and Pb-Pb
- **comparison with models**
  - ✓ charm enhancement
  - ✓ D-mesons rescattering
  - ✓ thermal dimuons
- **conclusions**

Introduction

❖ NA50 has shown that the p-A dimuon mass spectra in the mass range 1.5 to 2.5 GeV/c^2 is correctly reproduced by a superposition of DY and $D\bar{D}$ dimuons

❖ a linear extrapolation of p-A sources to nucleus-nucleus collisions underestimate data [Euro.Phys.J.**C14**(2000)443]

❖ new development on this subject using a 4-dimensional unfolding method [NIM.**A405**(1998)139]

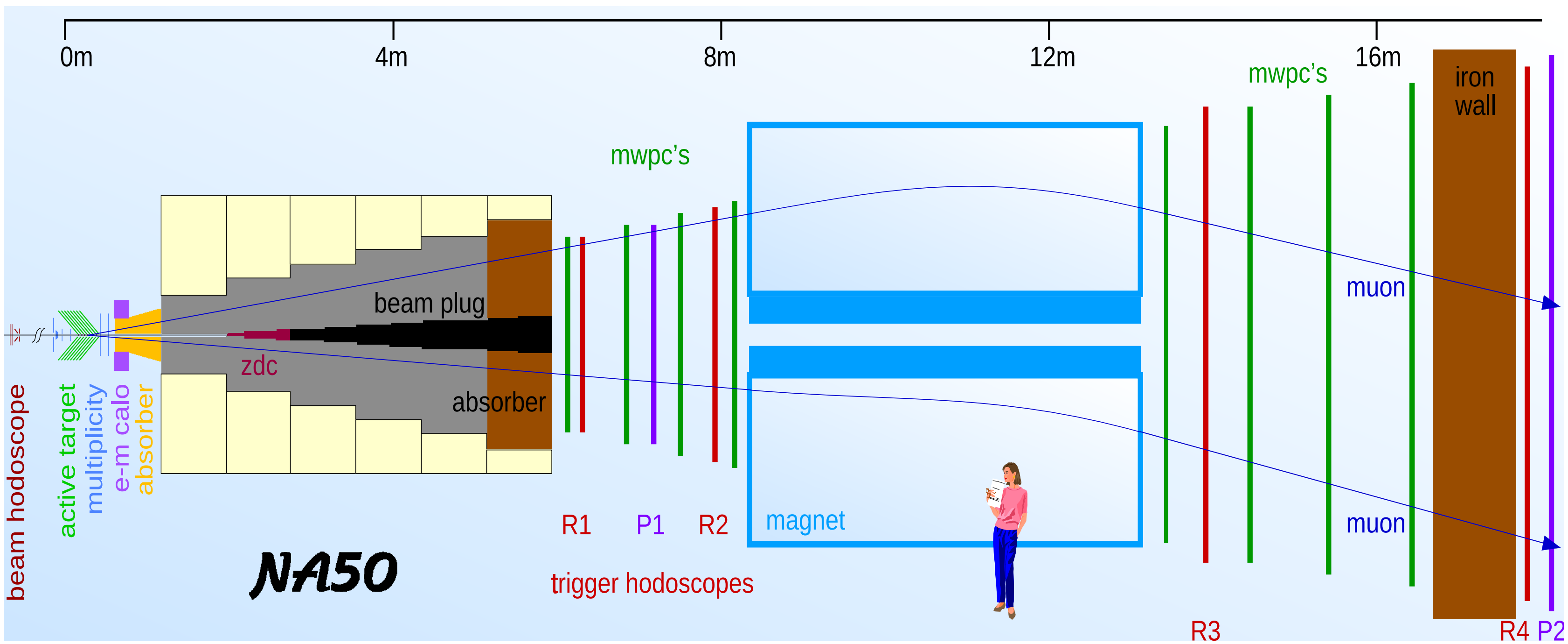
❖ NA50 apparatus

- ➔ detect opposite sign ($\mu^+\mu^-$) muon pairs
- ➔ centrality detection

❖ record the like sign pairs $\mu^+\mu^+$ and $\mu^-\mu^-$

- ➔ combinatorial background

NA50 Experiment



Unfolding method

- detector effects → acceptance and resolution

acceptance $A(x)$ x : set of kinematical variables describing
resolution $S(x'|x)$ the dimuon → M, p_T, Y_{cm}, $\cos(\theta_{cs})$

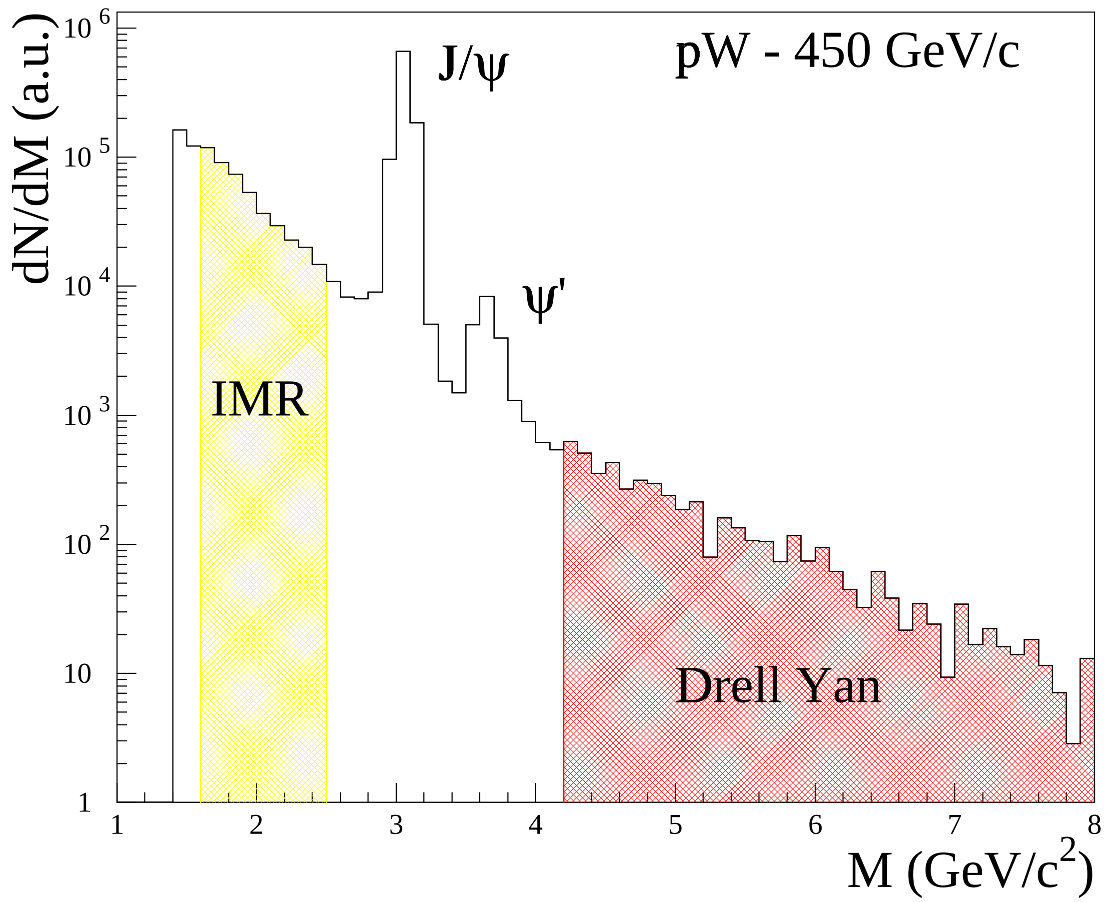
$$D(x') = \int S(x'|x)\; A(x)\; \Phi(x)\; dx$$

⇨ extract the physical distribution Φ from the measured one D

- 4-D unfolding method [NIM **A405**(1998)139]

  - ✓ 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

Dimuon mass spectrum



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

Mass spectra analysis

fit 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
- 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

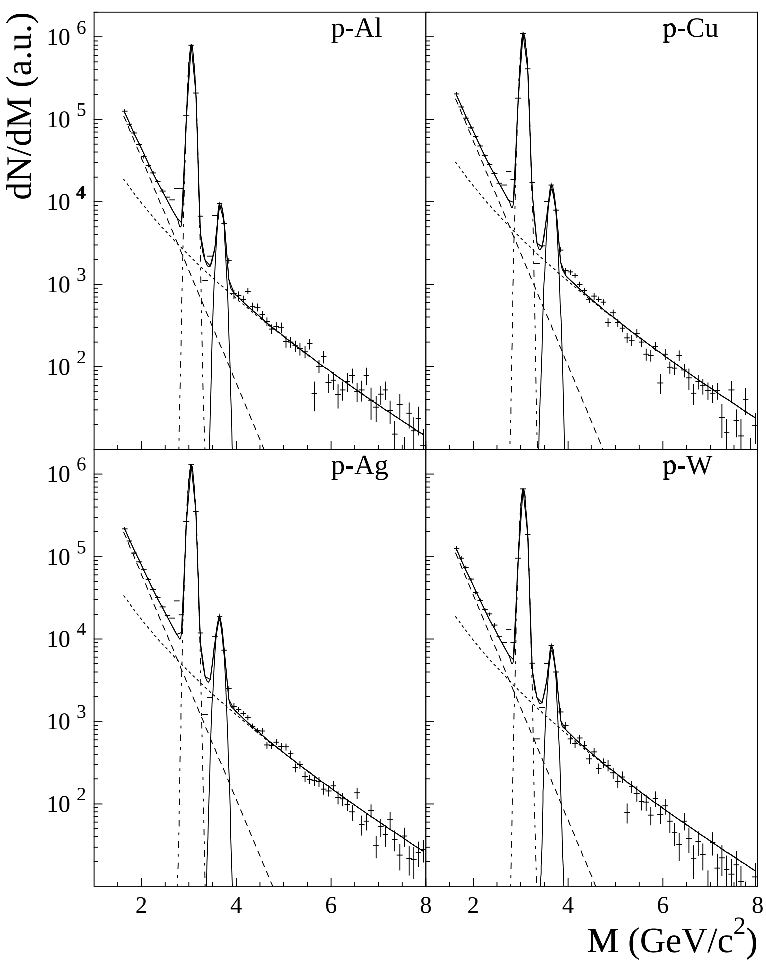
$$\sigma_{k_T}^{DY} = 0.8 \text{ GeV/c}$$ [NA51 pp collisions]

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

  - ✓**MRS A** set of PDF's
- 7 parameters fit

p-A results - 450 GeV

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



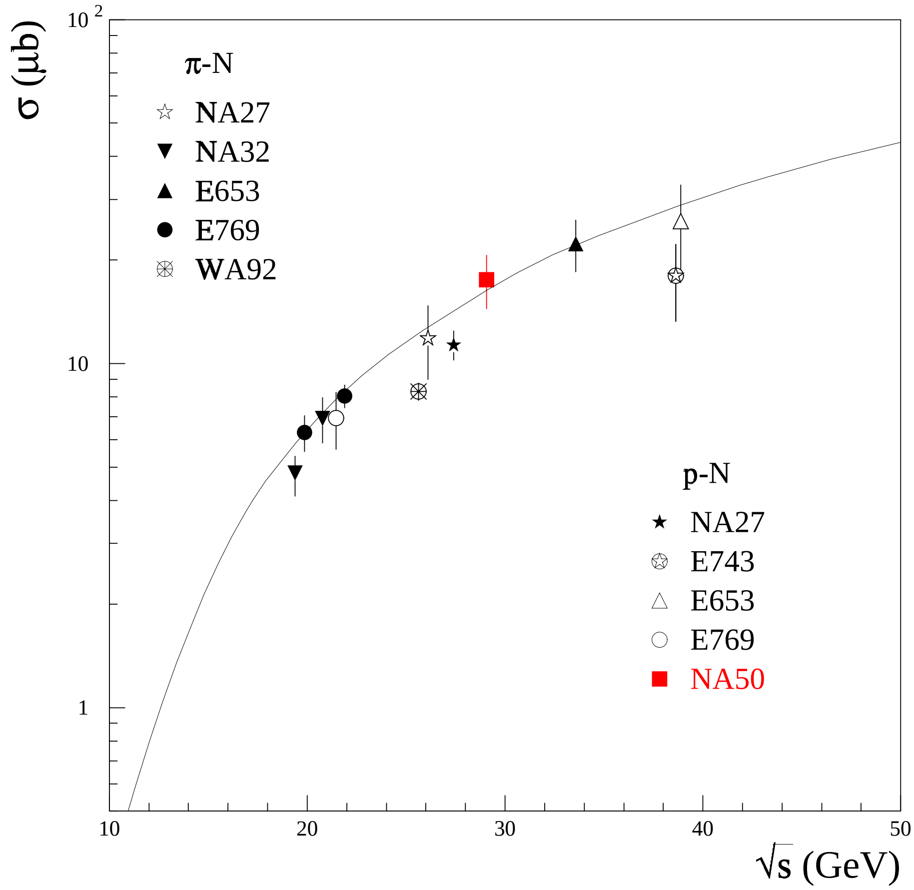
$$\left.\frac{D\bar{D}}{DY}\right|_{pp,450} = 4.13 \pm 0.15$$

in $1.6 < M < 2.5$ GeV/c^2

Open charm cross section

- the open charm cross section @ 450 GeV is deduced in the following way :

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



- the value is compatible with other direct measurements

Ion mass spectra

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

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

❖ data unfolded in the following kinematical domain

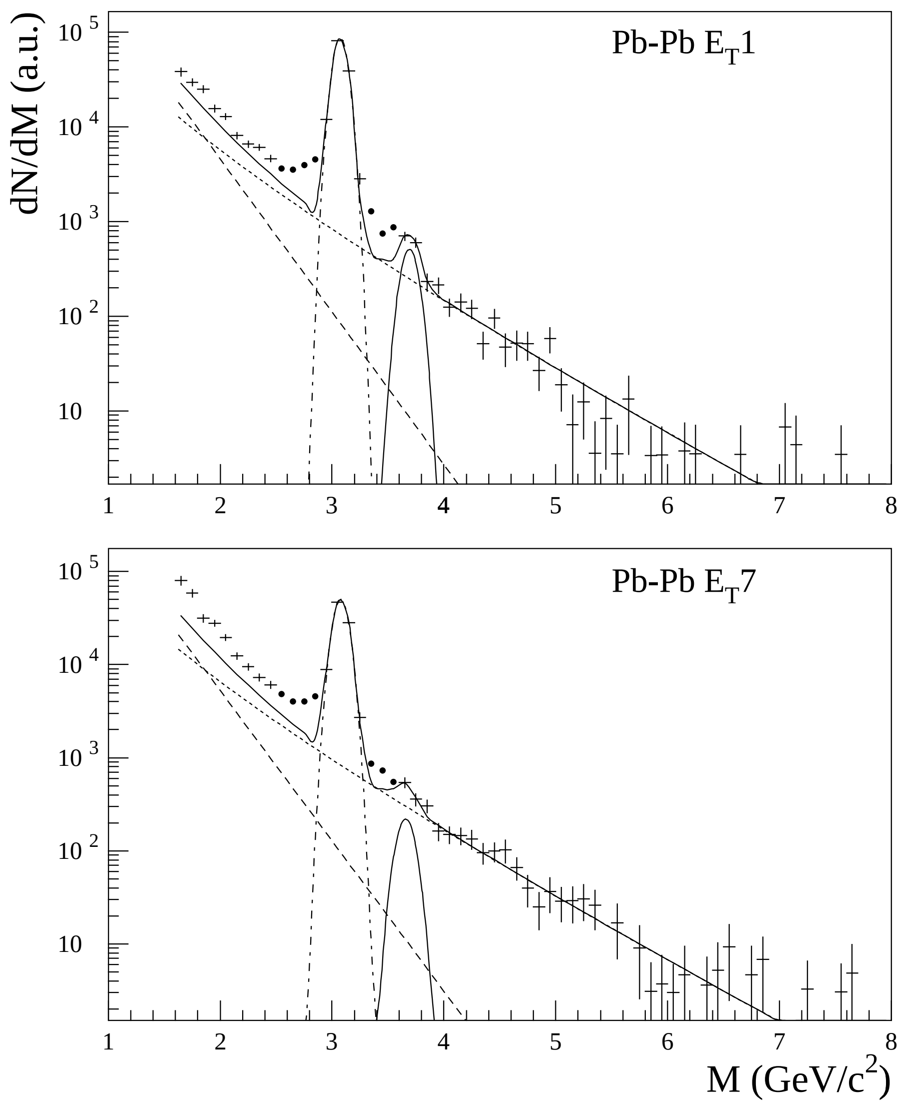
$$\begin{cases} M > 1.6\ \mathrm{GeV}/c^2 \\ 0.2 < Y_{cm} < 0.8 \\ -0.3 < \cos(\theta_{cs}) < 0.3 \end{cases}$$

❖ for ion collisions, the DY and $D\bar{D}$ processes are extrapolated linearly from NN yields, as expected for hard processes

❖ NN open charm and DY cross sections have been deduced from the p-A 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

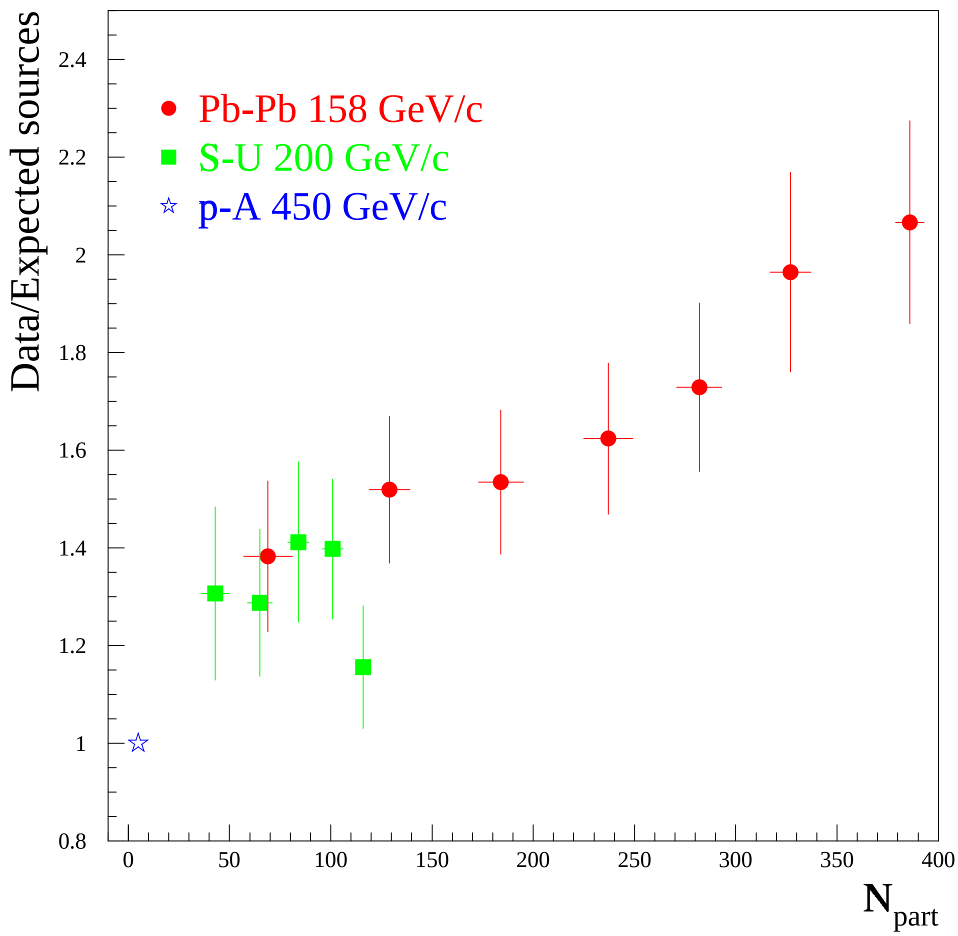


➔ in the IMR, data are higher than the expected sources

data/expected sources

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

↳ plot data/expected sources vs N_{part} in $1.6 < M < 2.5$ GeV/c^2



❖ the IMR excess increases as a function of centrality

Charm enhancement

❖ hypothesis : excess behaves as open charm
[C.Y. Wong and Z.Q. Wang, Phys.Lett.**B367**(96)50]

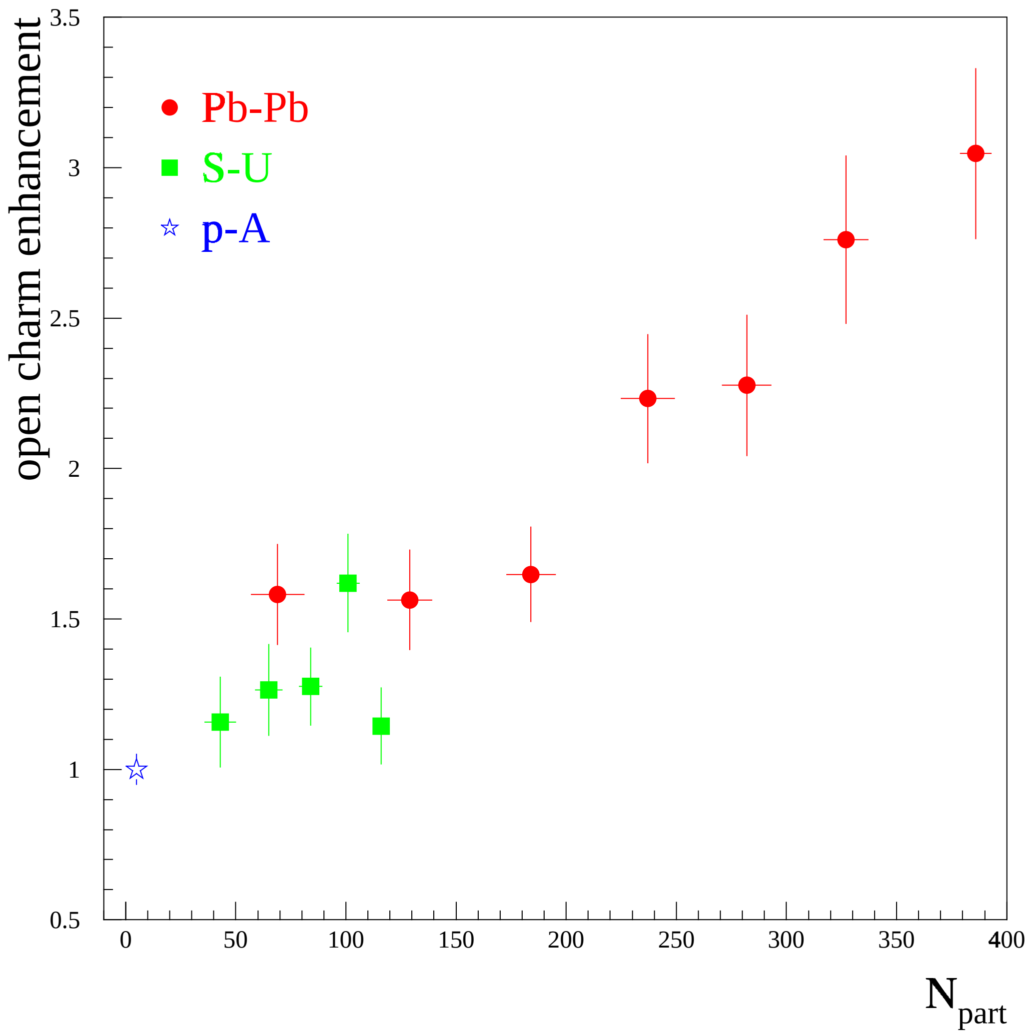
→ fit the IMR ion mass spectra with a superposition of DY and $D\bar{D}$ and extract the ratio $(D\bar{D}/DY)_{measured}$

→ calculate the expected ratio $(D\bar{D}/DY)_{expected}$ from p-A

❖ plot the enhancement factor E as a function of centrality

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

Charm enhancement



✓ charm-like enhancement : factor ~3 in central Pb-Pb with respect to p-A

✓ linear increase with N_{part}

D-mesons rescattering

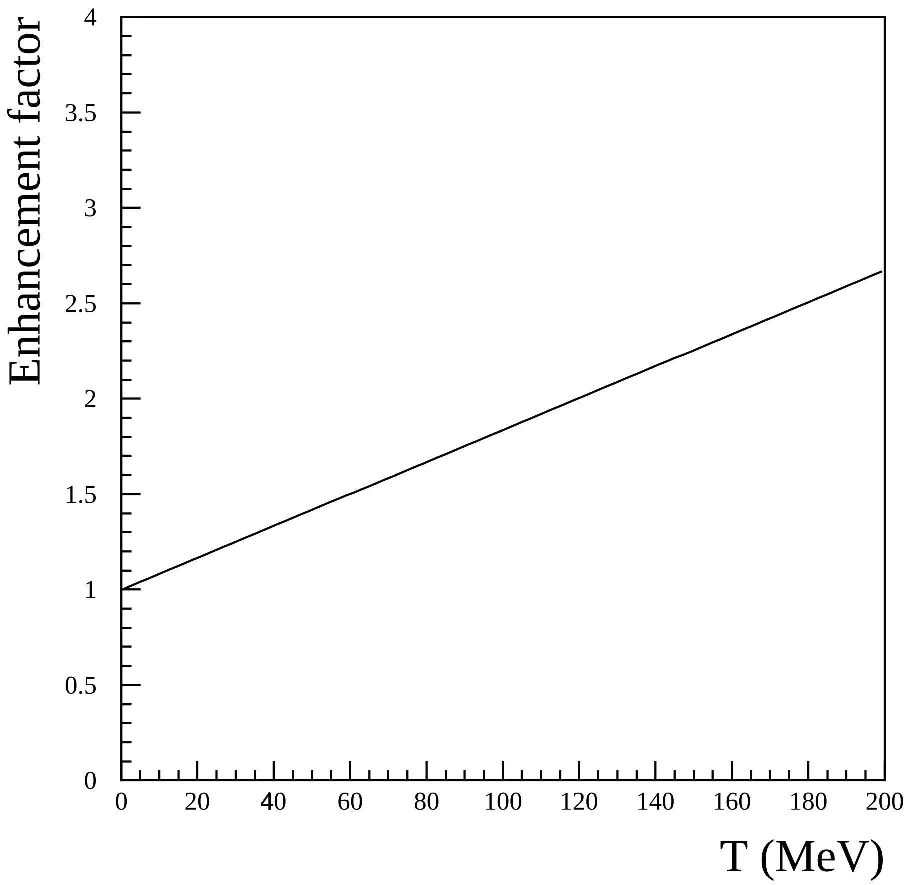
❖ several theoretical models have been proposed to explain the observed IMR charm excess

❖ Z. Lin and X.N. Wang [Phys.Lett.**B444**(98)245] associate the observed excess to D-mesons rescattering in nuclear matter which leads to an enhancement in the limited phase space of the NA50 experiment

❖ D and $\bar{D}$ rescattering is described by a thermal distribution depending on a temperature parameter T

D-mesons rescattering

❖ the enhancement factor in NA50 phase space is calculated as the ratio of the number of dimuons observed at temperature T and at T=0

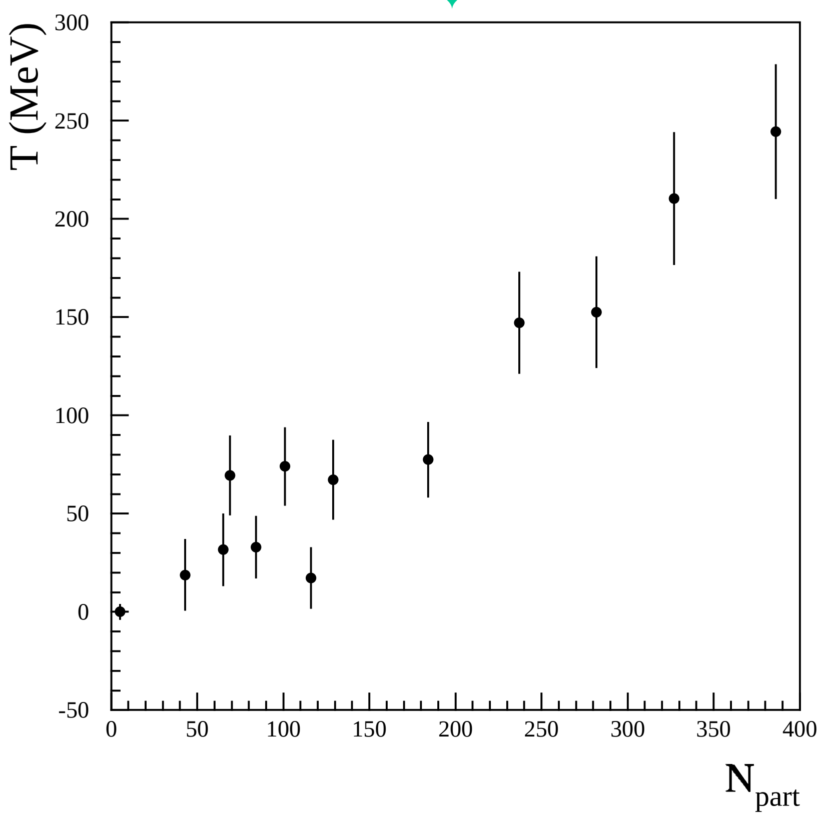


with MRS A
and
m_c = 1.5 GeV/c^2

D-mesons rescattering

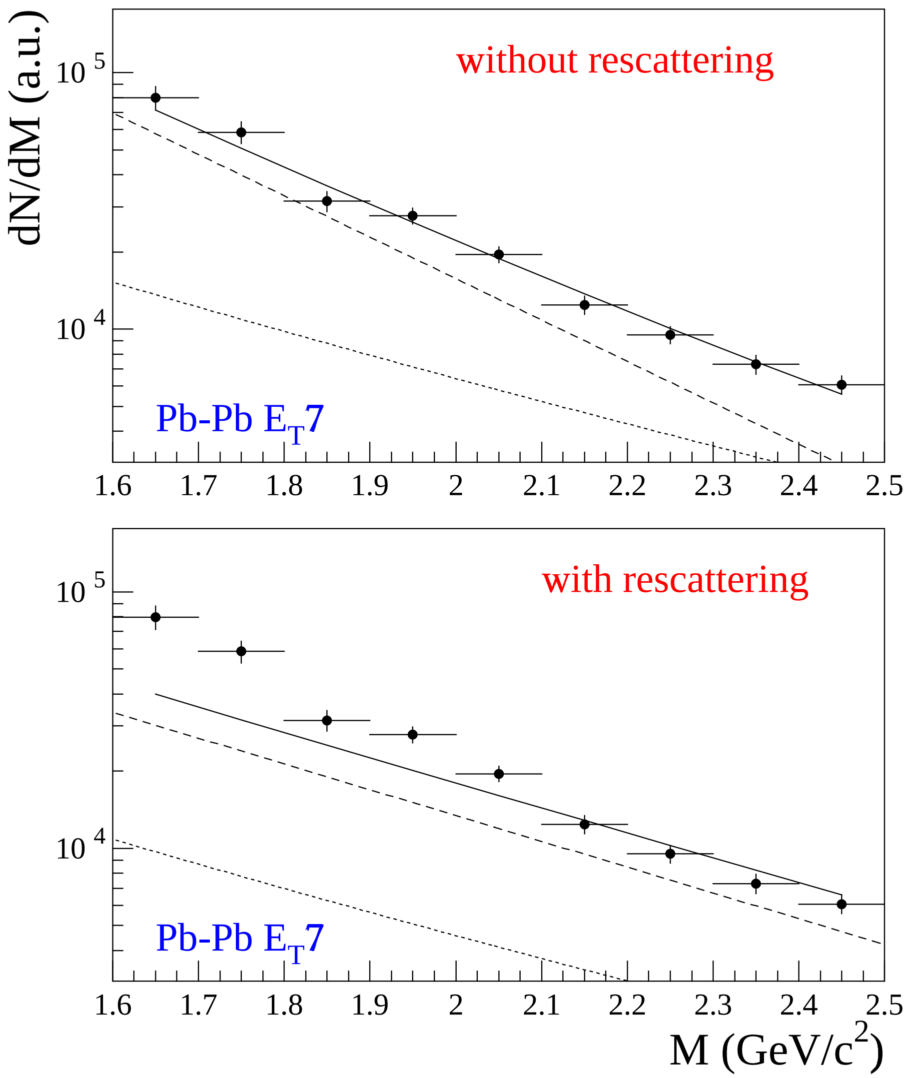
❖ from the experimental value of the enhancement the corresponding temperature can be obtained for each of the centrality bins

E_{data} (N_{part}) and E_{model} (T)



❖ the shape of the dimuon mass distribution from $D\bar{D}$ decays is then calculated with the corresponding temperature

D-mesons rescattering



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

Thermal dimuons

- model developped by Rapp and Shuryak
  [Phys.Lett.**B473**(2000)13]

→ $\mu\mu$ yield based on $q\bar{q}$ annihilation rate

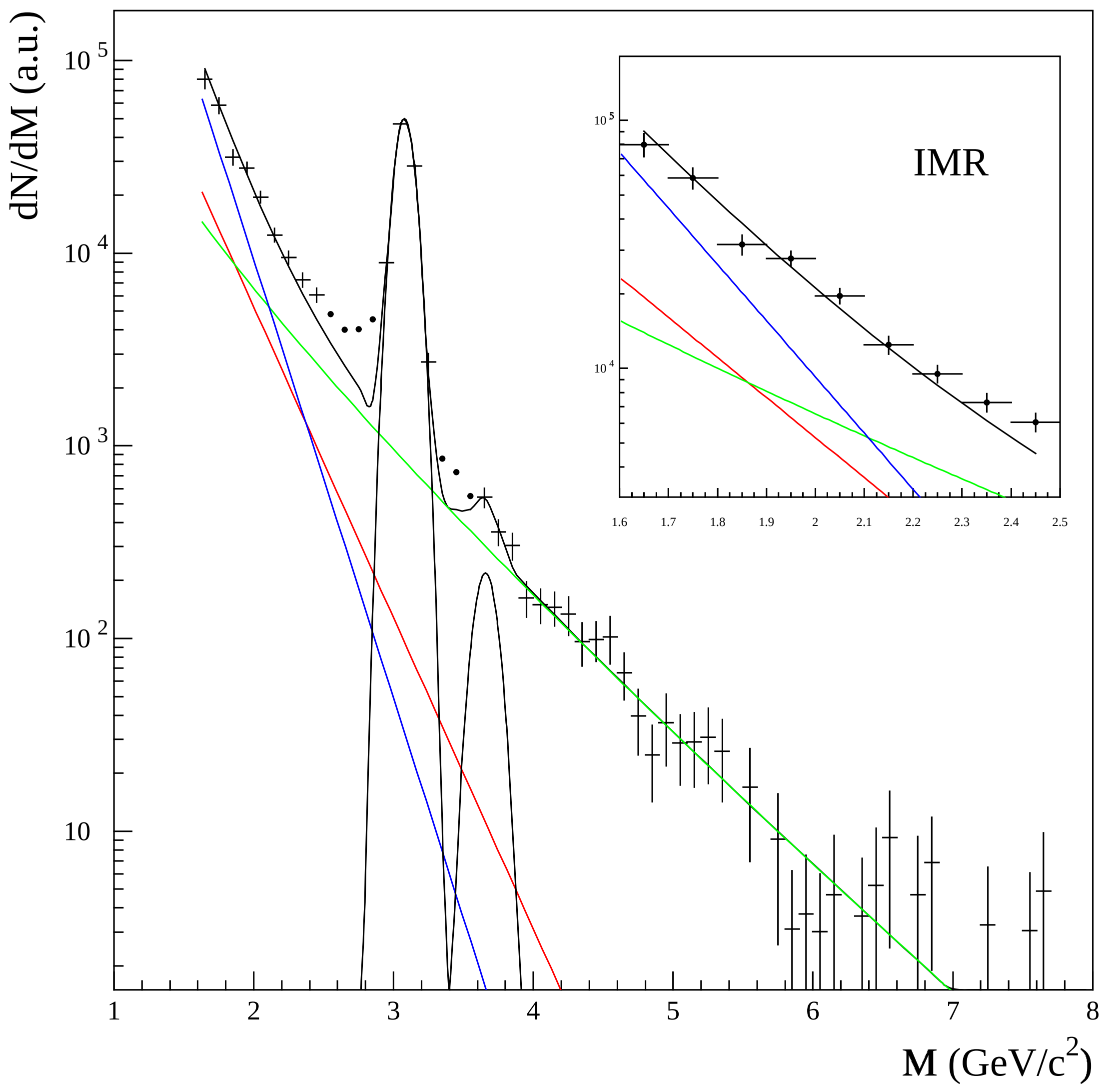
→ integration over space-time history

→ central collisions only

→ parameters :
- fireball lifetime : 14 fm/c
- initial temperature : T_i = 192 MeV

→ explicit introduction of a QGP phase
- critical temperature : T_c = 175 MeV

Thermal dimuons



➔ the IMR excess can be well accounted for by thermal radiation when combined with DY and open charm

Conclusions

❖ the $\sigma_{c\bar{c}}$ cross section extracted from the p-A data agrees with direct measurements of other experiments

❖ the ion data are in excess of the DY+D$\bar{D}$ superposition extrapolated from p-A

❖ this excess increases linearly with N_{part}

❖ the mass distribution cannot be reproduced by a model assuming D and $\bar{D}$ rescattering

❖ two possible explanations of the observed excess :

✓ the data can be described under the hypothesis of an enhancement of charm production

✓ the central Pb-Pb mass distribution can be reasonably well reproduced by the thermal model