INTERMEDIATE MASS DIMUONS IN NA38/NA50

NA50 collaboration

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IV International Conference on Strangeness in Quark Matter

Padova – July 20-24, 1998

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The NA50 Collaboration

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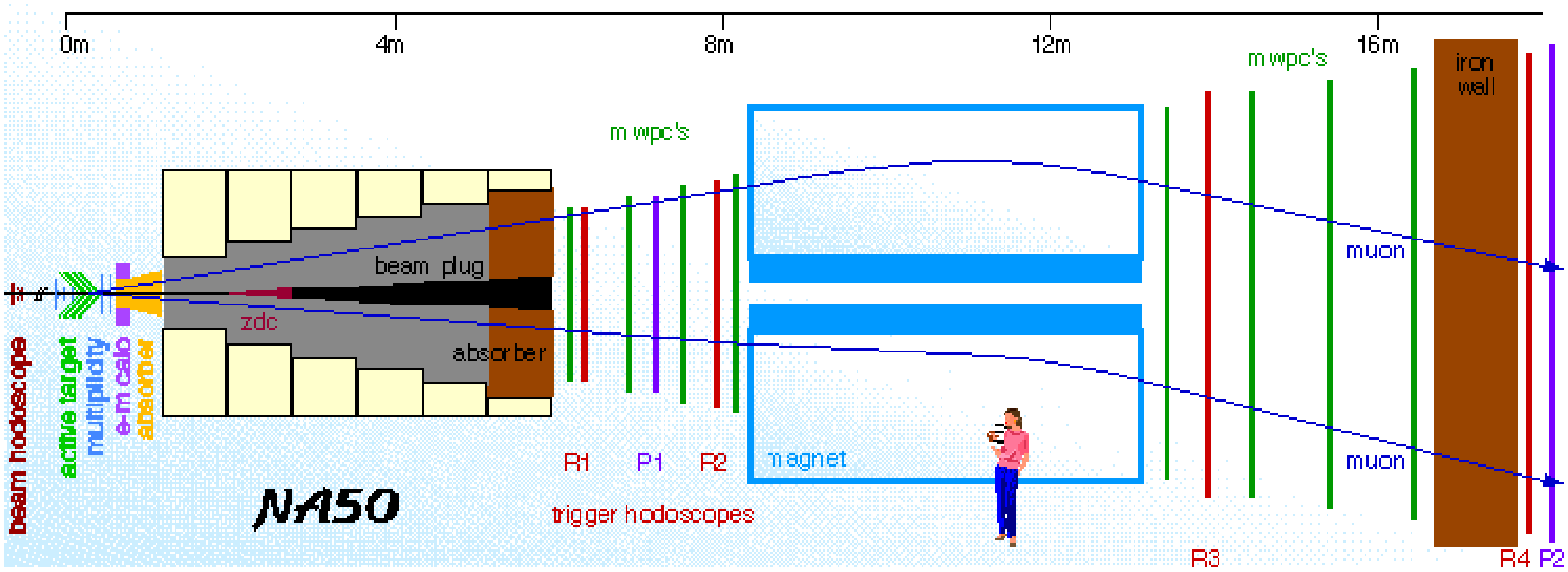
The NA50 experiment



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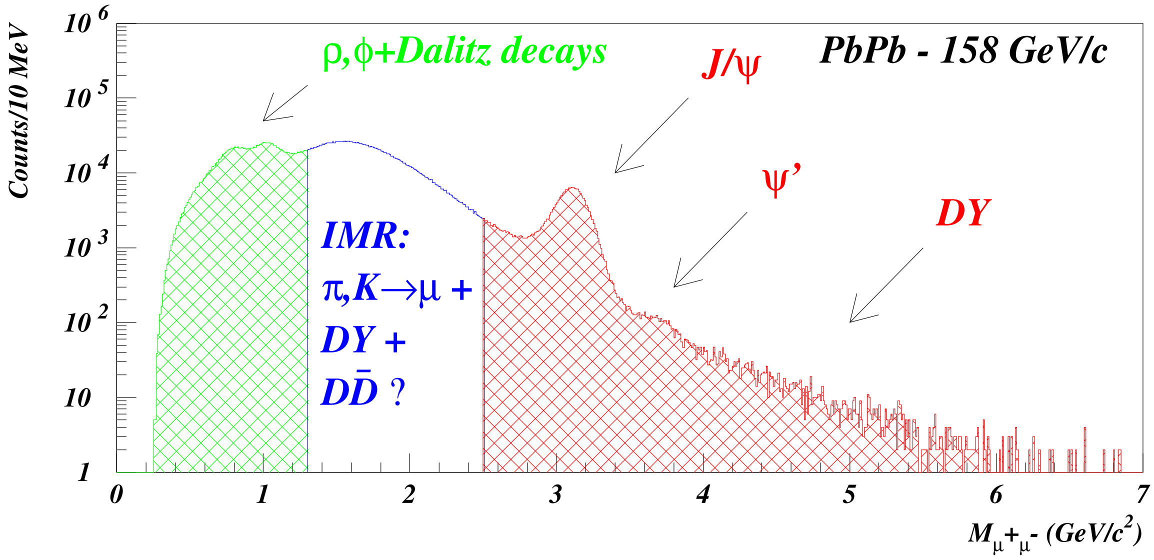
NA38/NA50: p–A, S–U, Pb–Pb

Between the ϕ and the ψ $\rightarrow$ the *Intermediate Mass Region* (IMR)



Physics topics:

- Thermal dileptons;
- Enhancement of known sources.

Goal of this analysis

Describe the IMR spectrum from pA to central PbPb collisions in terms of known sources, i.e.:

- dimuons from π and K decays (comb. background);
- Drell-Yan: $q\bar{q}\rightarrow\gamma^* \rightarrow \mu^+\mu^-$;
- Charmed meson (and baryons) decays, as $D\rightarrow\mu X$.

$\rightarrow$ do not include any thermal dimuon contribution

Preliminary studies:

- C.Lourenco et al.(NA38) N.Phys.A566(1994)77c
- E.Scomparin et al.(NA50) N.Phys.A610(1996)331c

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Description of the known sources

• Dimuons from π and K decays (combinatorial background):

Mass shape:
$\rightarrow$ from measured like-sign dimuon sample with the help (if needed) of mixed-event techniques;

Absolute normalization:
$\rightarrow$ through the usual formula $N^{bck} = 2R\sqrt{N^{++}N^{--}}$

(R parametrizes charge correlation effects)

• DY, semi-leptonic decay of charmed mesons pairs ($D\overline{D}$):

Mass shape:
$\rightarrow$ PYTHIA + detector effects;

Absolute normalization:
$\rightarrow$ through a fit to the experimental (background subtracted) mass distributions; then, compare the results with N-N extrapolations.

What is expected in A–B collisions ?

- DY

Absolute yield expected : $\sigma_{AB}^{DY} = \sigma_{NN}^{DY} \cdot AB$

NA38/NA50 have MEASURED $\sigma_{AB}^{DY} = \sigma_{NN}^{DY} \cdot AB^{\alpha}$,
$\alpha = 1.002 \pm 0.011$
(see also Abreu et al., Phys. Lett. B410(1997) 337)

$\rightarrow$ DY in A–B collisions scales as expected.

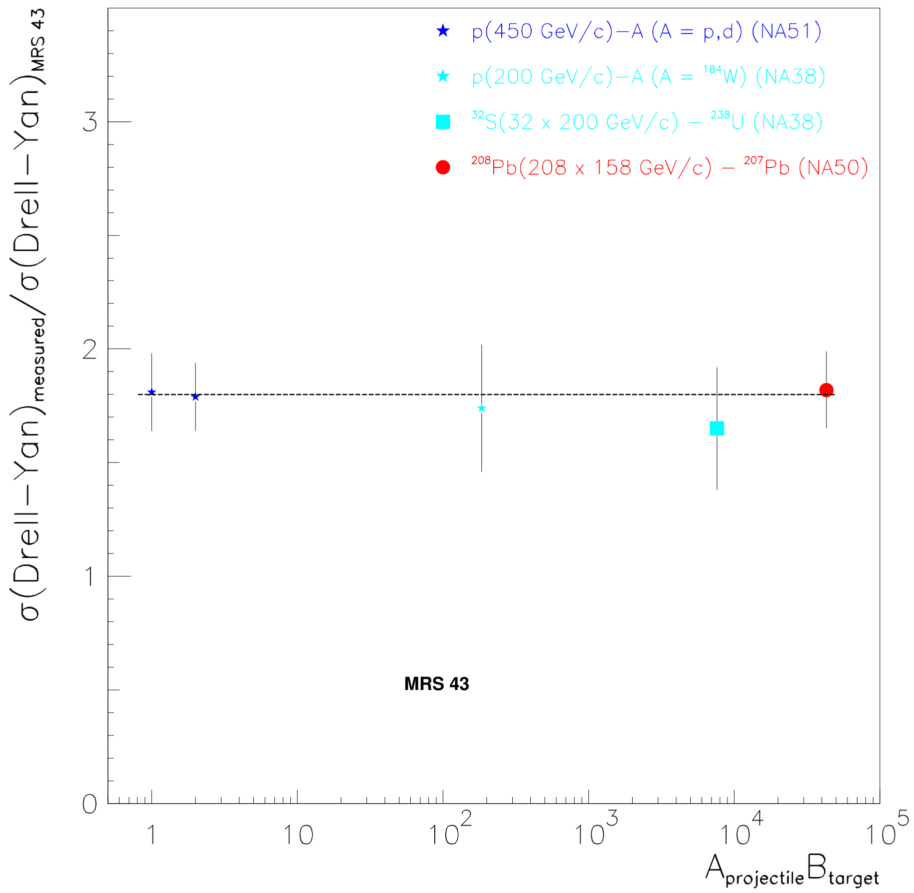
- $D\overline{D}$

Absolute yield expected : $\sigma_{AB}^{D\overline{D}} = \sigma_{NN}^{D\overline{D}} \cdot AB$
Compare with extrapolation of charm production data (CERN,FNAL)

$\rightarrow$ Normally, $\sigma_{AB}^{D\overline{D}} / \sigma_{AB}^{DY}$ should be constant vs AB.

NA38/NA50 results on Drell-Yan (summary)

- From p–p to Pb–Pb collisions σ_{tot}^{DY} scales with the number of $N-N$ collisions;
- DY K–factor with respect to MRS calculations is ~ 1.8 .



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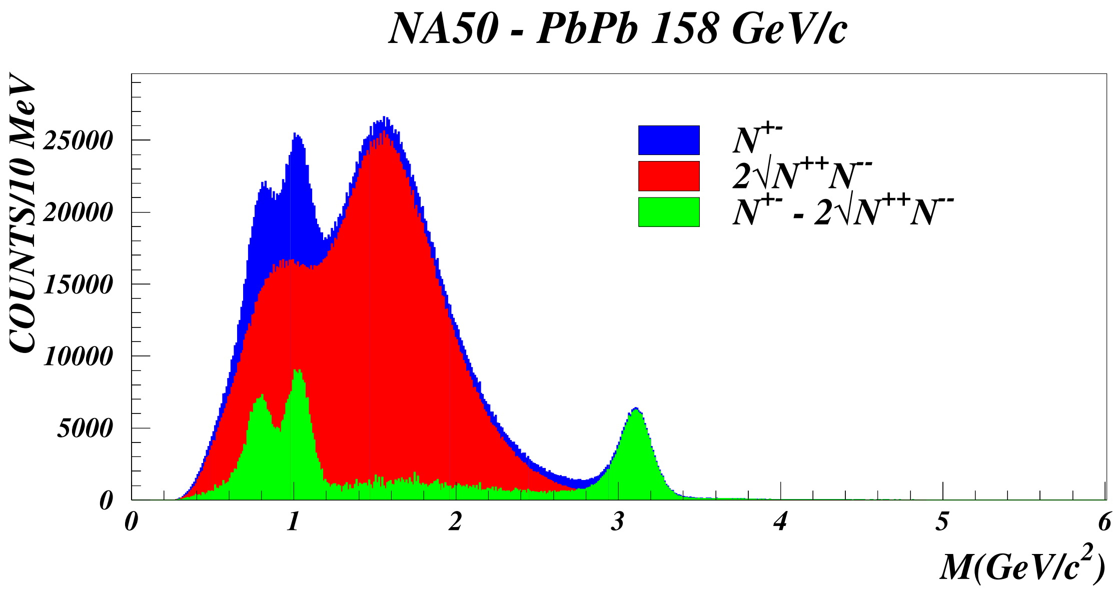
Estimation of the combinatorial background

$$\frac{dN^{bck}}{dM} = 2R\sqrt{\frac{dN^{++}}{dM}\frac{dN^{--}}{dM}}$$



Difficulties:

R=1 only if π,K multiplicity is high and no charge correlation exists

$\longrightarrow$ p–A or peripheral A–B could yield $R > 1$

Since $N^{bck}/N^{+-} \sim 0.8(\mathrm{pA}) \div 0.95(\mathrm{PbPb})$

$\longrightarrow$ Estimation of charge correlation is necessary, use VENUS to get:

$$R = \frac{N^{+-}_{sim}}{2\sqrt{N^{++}_{sim}N^{--}_{sim}}}$$

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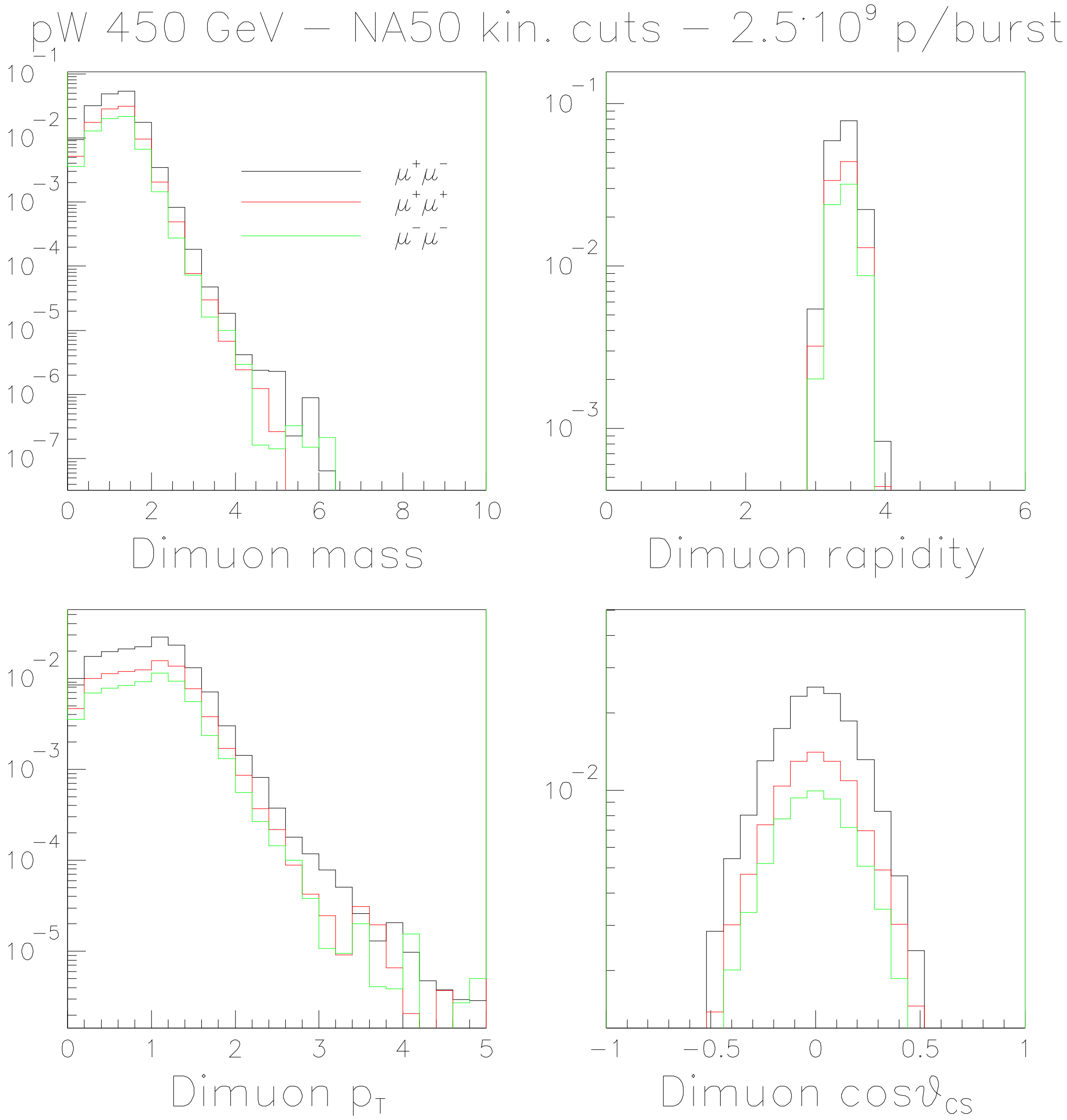
Estimation of the R factor (example)



$$R = \frac{N^{+-}}{2\sqrt{N_{sim}^{++}N_{sim}^{--}}} = 1.05 \pm 0.01$$

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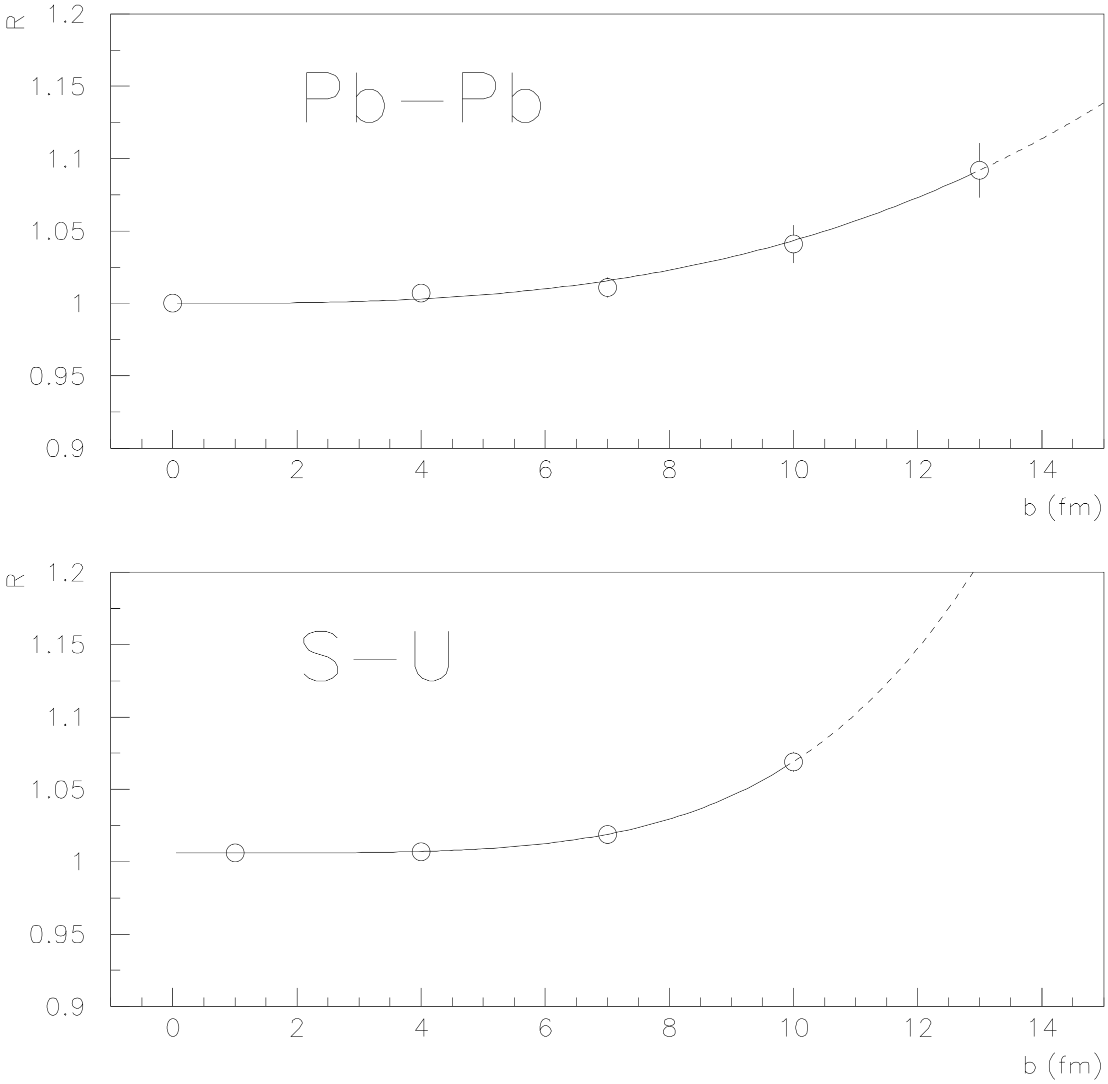
R vs impact parameter b in AB collisions



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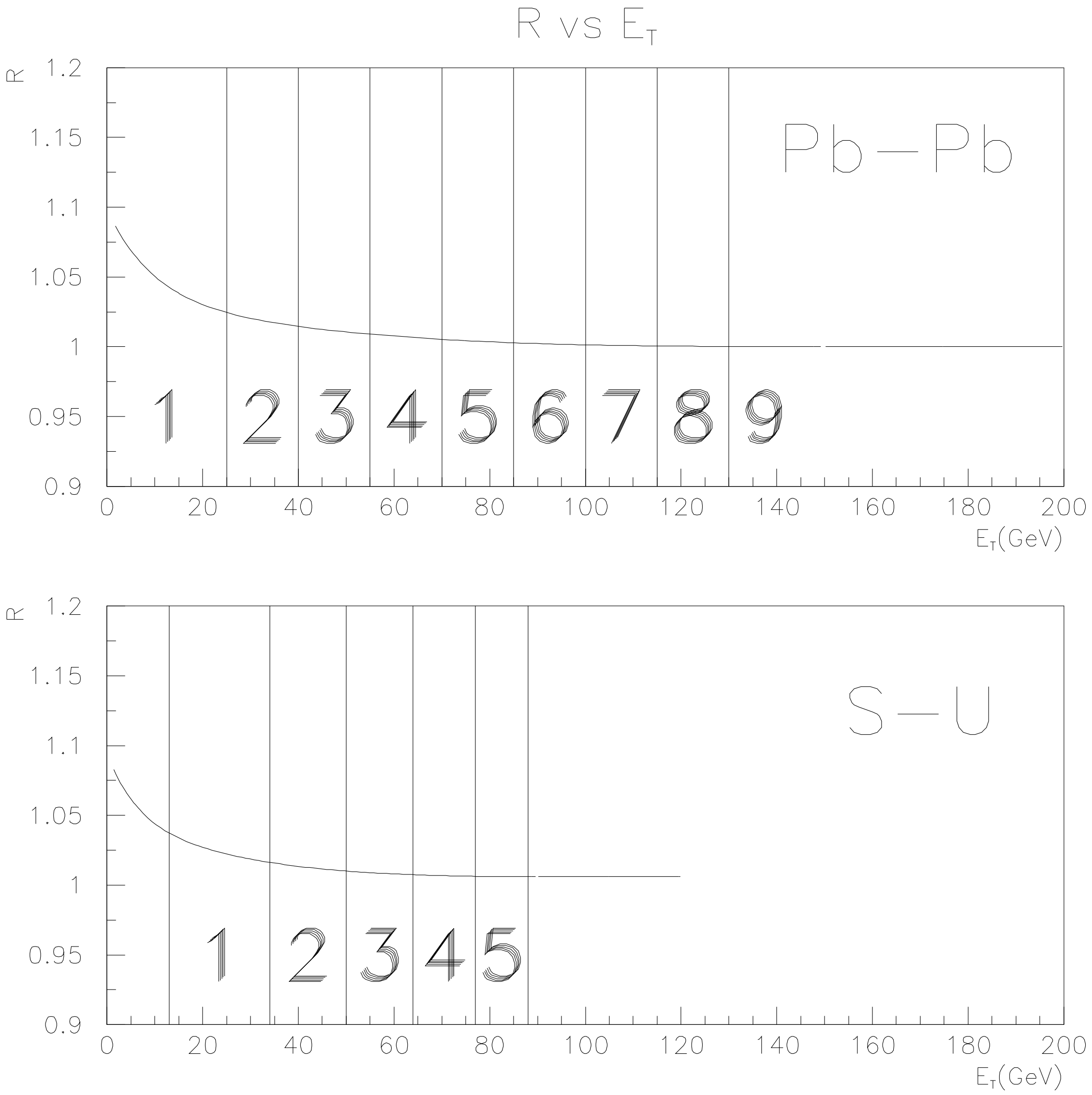
R vs transverse energy E_T in AB collisions



$R > 1$ for peripheral A–B collisions

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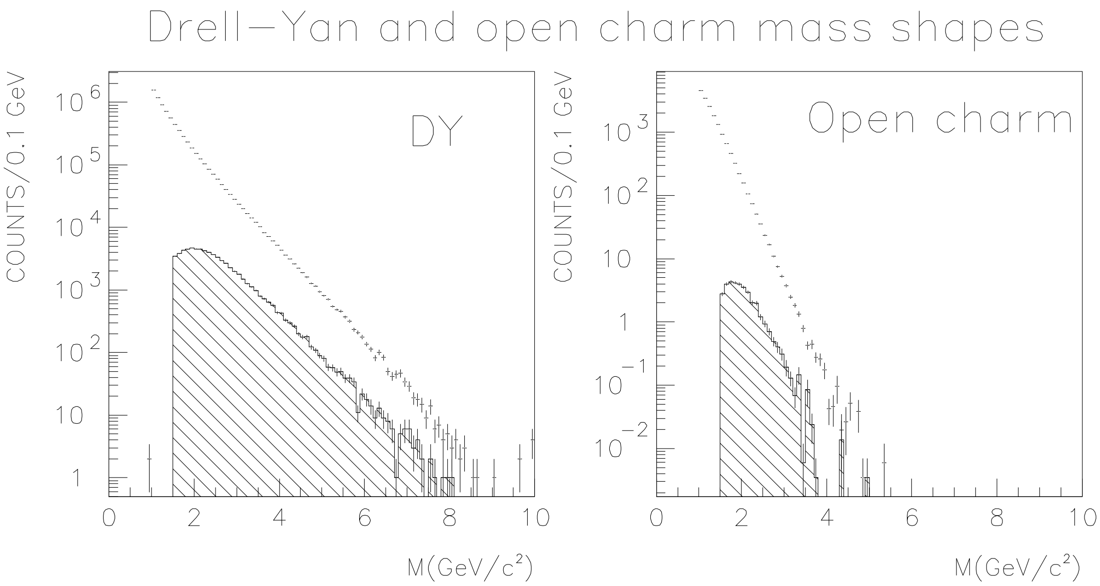
Estimation of the expected sources ($D\overline{D}$, DY)

- Generate dimuons from DY and $D\overline{D}$ using PYTHIA;
- Track dimuons through the apparatus;
- Reconstruct dimuons kinematical variables using the same reconstruction procedure adopted for the experimental data.



- Fit the A–B experimental mass spectra in the region $M > 1.5$ GeV/c^2 with a superposition of the mass shapes of the expected sources, keeping the relative normalizations of the various contributions as free parameters.

$\rightarrow$ Is the description of the mass spectra satisfactory ?

$\rightarrow$ Are the absolute normalizations obtained compatible with N-N extrapolations, which imply $\sigma_{AB}^{D\overline{D}}/\sigma_{AB}^{DY} = const$ vs AB ?

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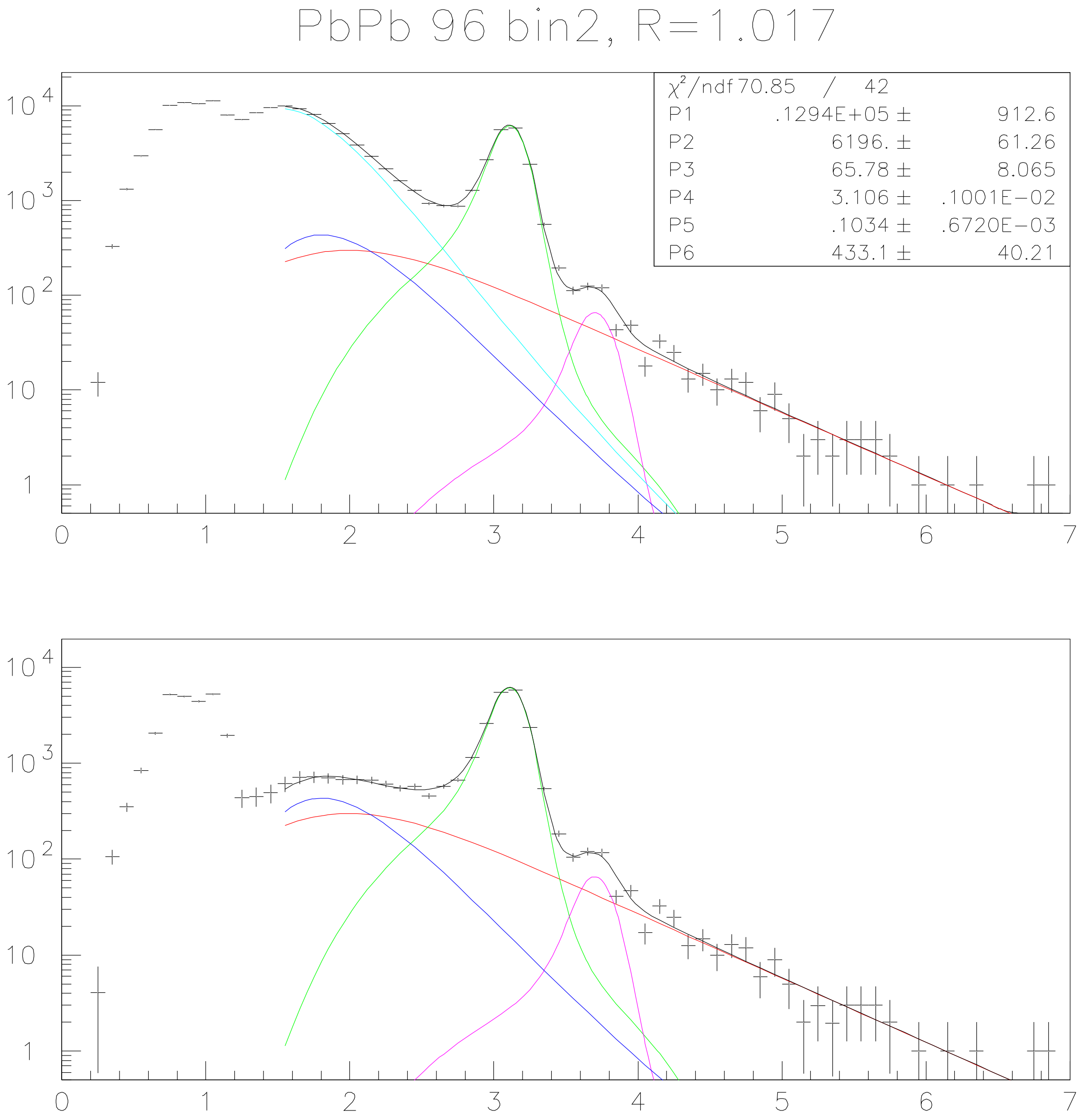
Fit of the mass spectra: peripheral PbPb collisions



R fixed, fit for M>1.5 GeV/c^2

(if the fit starting point is shifted down to M=1.3 GeV/c^2 the results are stable within 2%)

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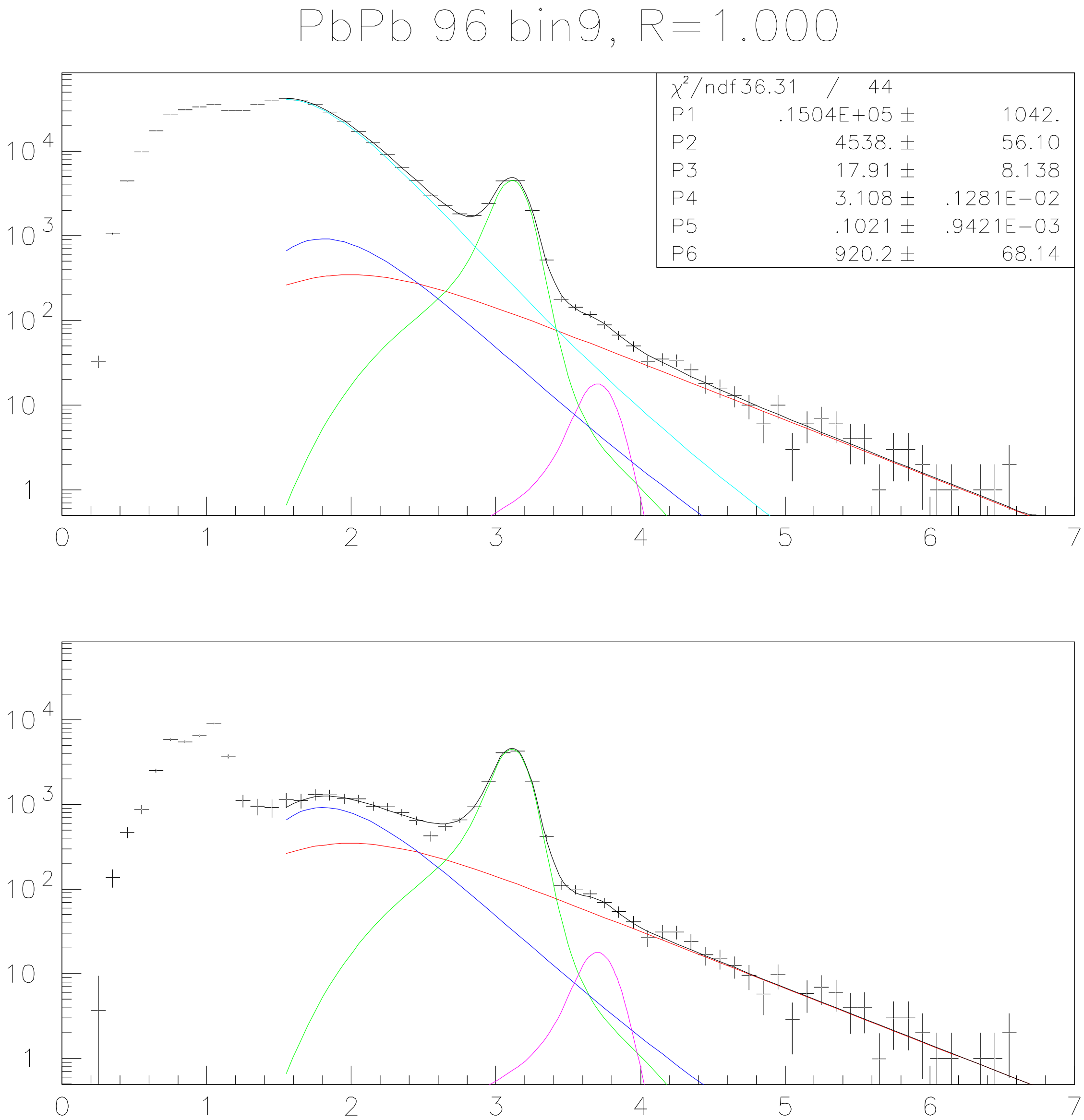
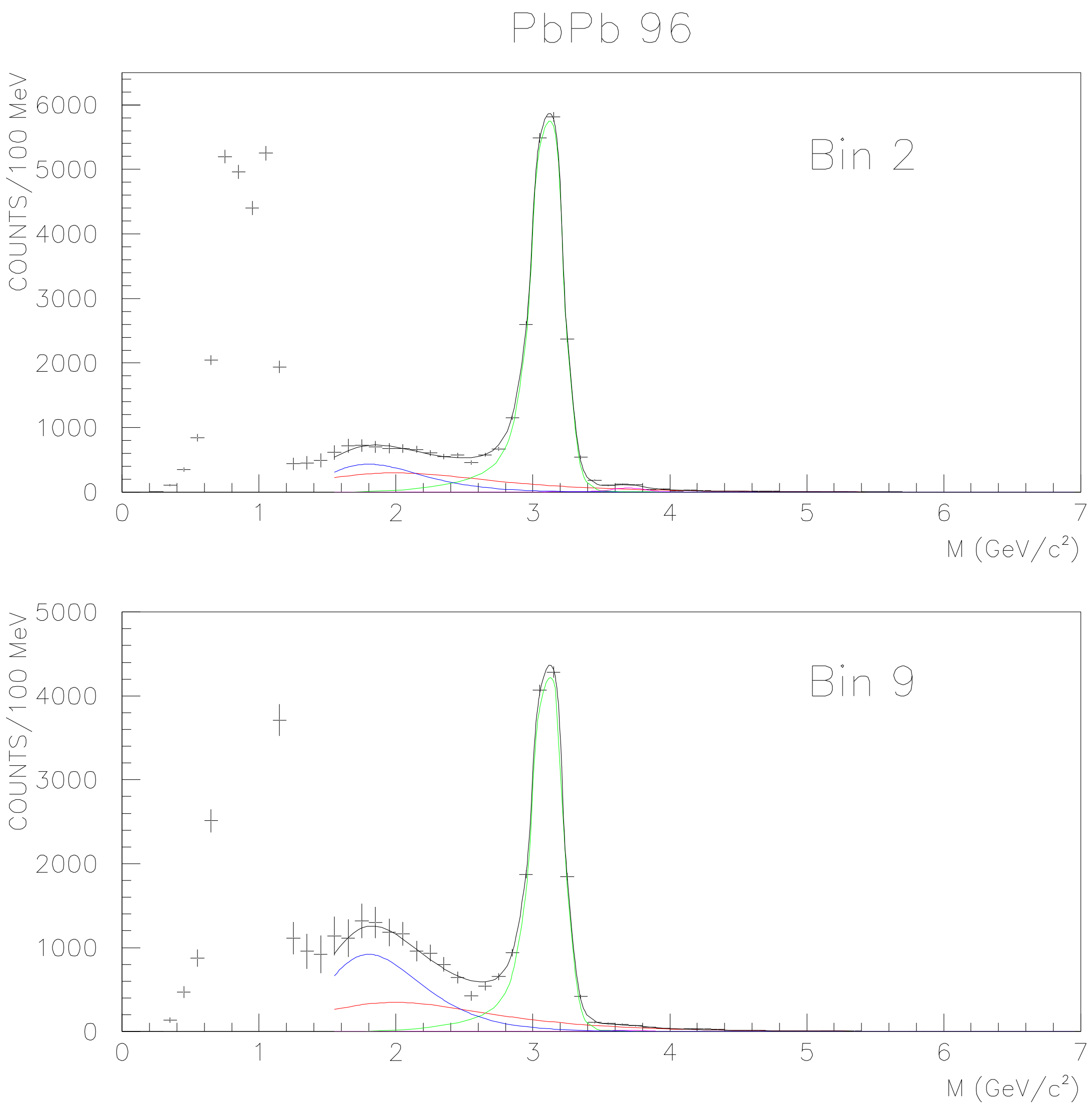
Fit of the mass spectra: central PbPb collisions



R fixed, fit for M>1.5 GeV/c^2

Central vs peripheral Pb–Pb collisions

- We know that the DY exhibits no anomalous behaviour from p–p to Pb–Pb collisions (see Abreu et al., Phys. Lett. B410(1997)337);
- We would expect: $\sigma_{D\overline{D}}/\sigma_{DY} = const.$ vs E_T;



But we see that, in central Pb–Pb collisions, an enhancement of the open charm component, with respect to DY, is necessary in order to describe the mass spectrum $\rightarrow$ **charm–like** enhancement.

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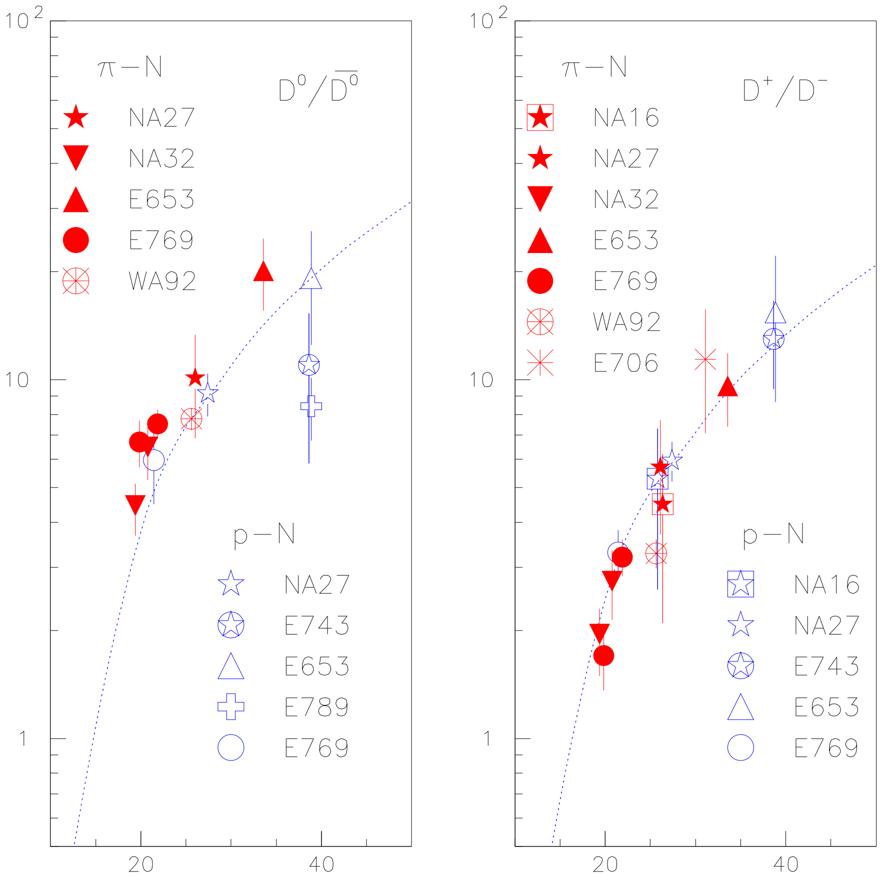
Expected open charm contribution

Introducing an overall up–scale factor PYTHIA reproduces the open charm hadro-production $\sqrt{s}$-dependence and the D-meson differential distributions measured at CERN and FNAL energies; see Braun–Munzinger et al., Eur. Phys. J. C1(1998)123



• Calculate PYTHIA $pp \rightarrow c\bar{c} \rightarrow \mu\mu$, normalizing $D^0/\overline{D^0}$ and D^+/D^- yield to the curves shown in the plots;

• Introduce B.R. D$\rightarrow\mu$;

• Take into account phase space accessible to NA50, i.e.:
$M > 1.5\ GeV/c^2$, $0 < y^* < 1$, $-0.5 < cos\theta < 0.5$

• Introduce nuclear effects ($\alpha_{D\overline{D}} = 1$).

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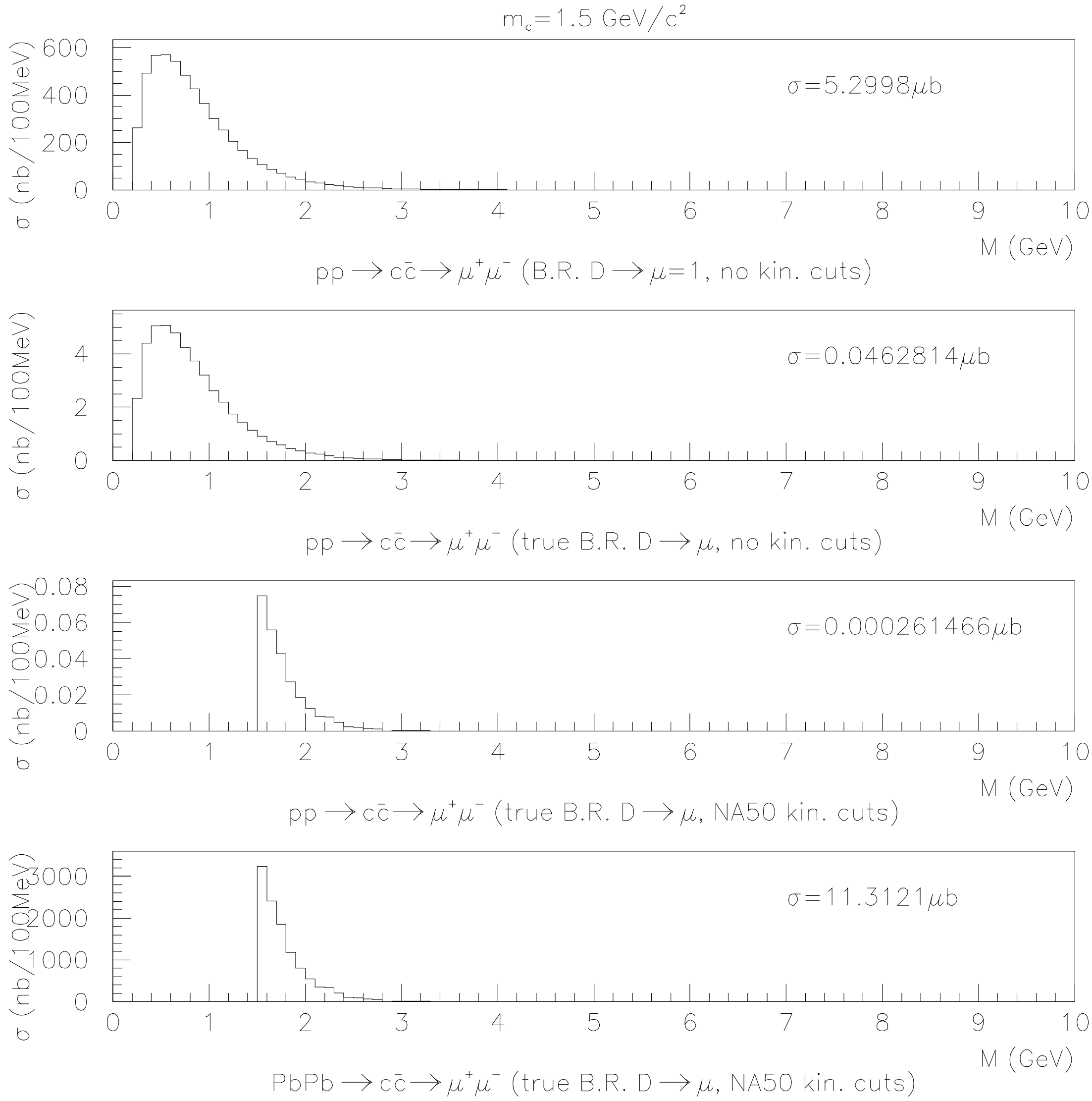
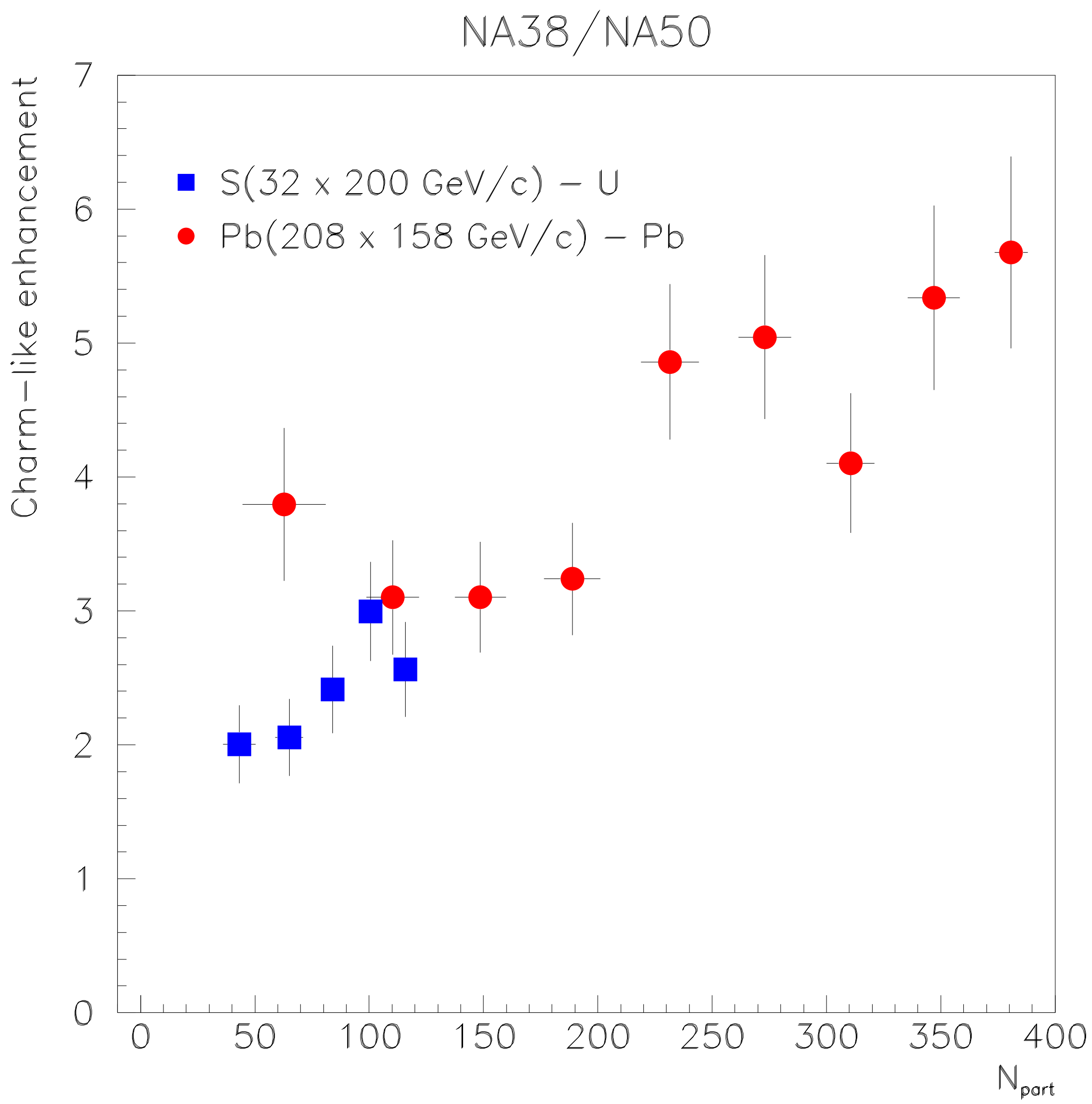
PbPb $\longrightarrow c\bar{c} \longrightarrow \mu^+\mu^-$



m_c=1.35 GeV/c^2 in PYTHIA gives 20% lower cross-section for $PbPb \to c\bar{c} \to \mu^+\mu^-$ ($true\ B.R.\ D \to \mu$, $NA50\ kin.\ cuts$).

Charm–like enhancement vs N_{part}: Pb–Pb, S–U



Pb–Pb

- a factor ∼2 enhancement from peripheral to central collisions;
- first bin to be taken with care (residual non–target background, quality of the fit worse).

S–U

- A factor ∼1.5 enhancement from peripheral to central collisions.

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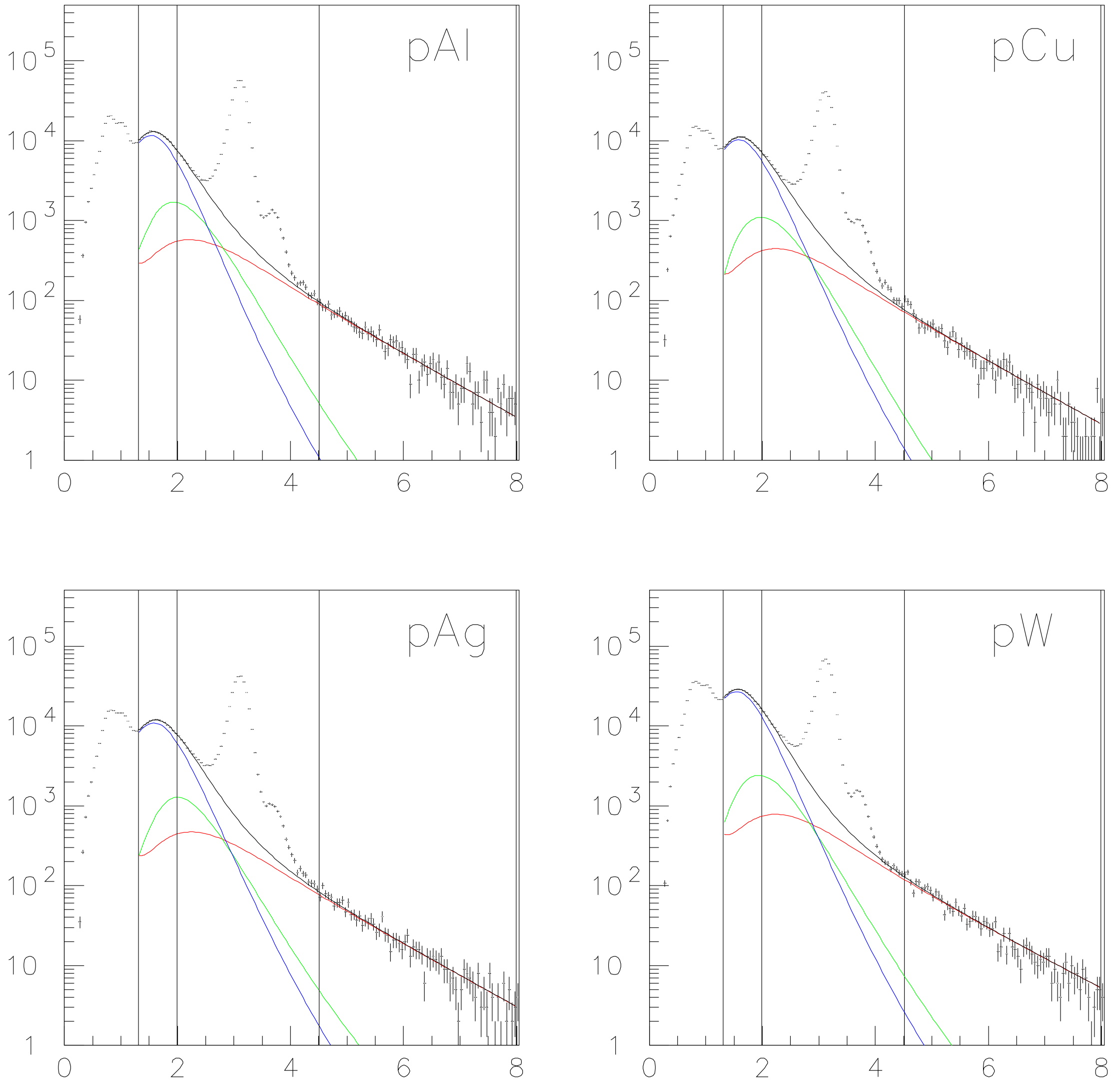
The p–A data

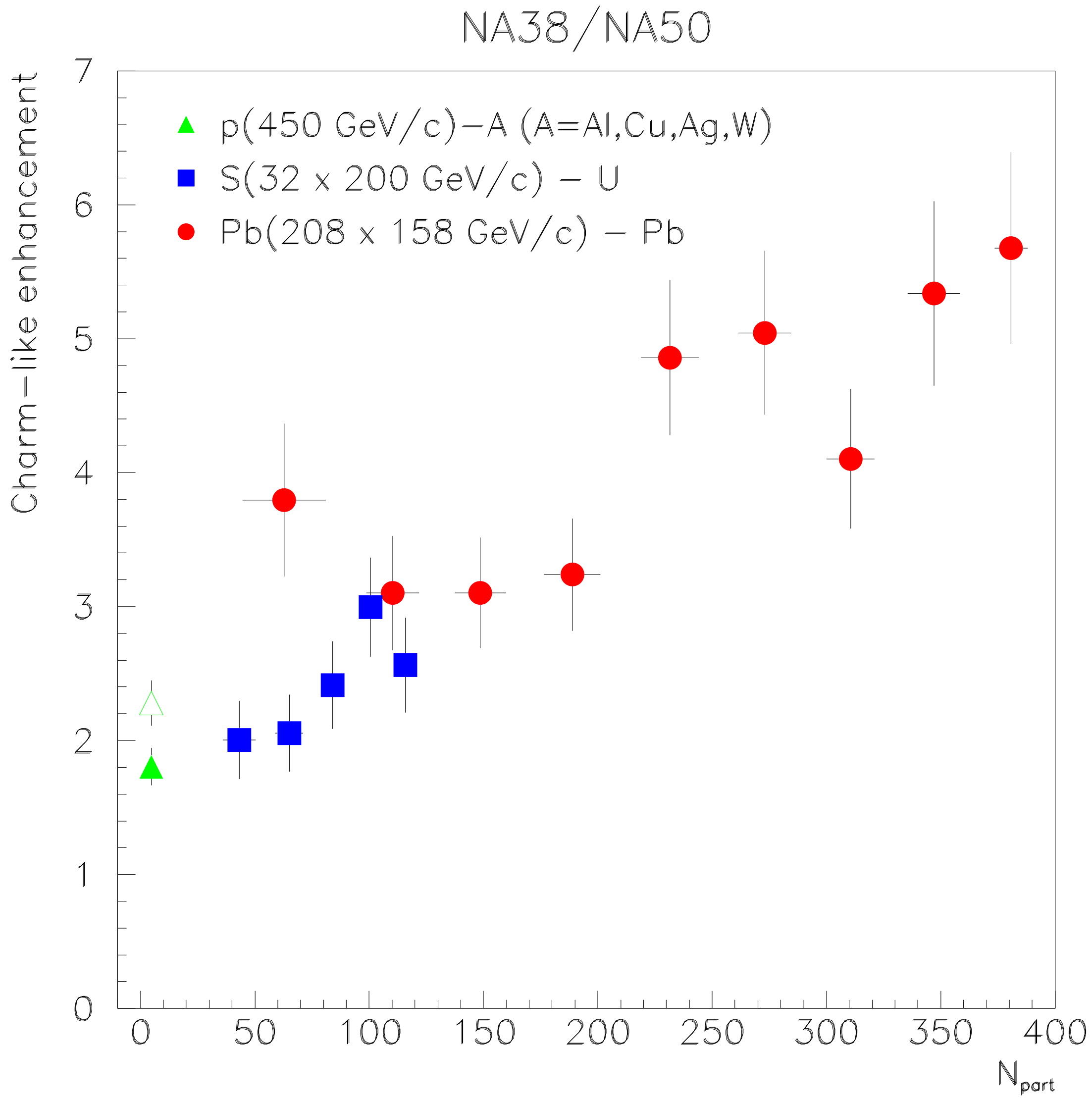
- The charm–like enhancement with respect to PYTHIA extrapolations ranges from ∼2 (peripheral S–U) to ∼6 (central Pb–Pb).
- To check these values, one can look at p–A data, where no enhancement is expected.
- NA50 has taken high–statistics pA data on four nuclear targets (Al, Cu, Ag, W), at 450 GeV/c incident energy ⟶ perform a simultaneous fit of the IMR for the four p–A data samples:
  - Impose $\sigma_{D\overline{D}}/\sigma_{DY} = const.$ from pAl to pW, since both processes should scale with A;
  - Consider the background R-factors as:
    - free parameters;
    - fixed from the VENUS simulation;
  - Fit the data in the regions $1.3 < M < 2.0$ GeV/c^2 and $4.5 < M < 8.0$ GeV/c^2 (exclude the J/ψ region to limit the number of parameters);
  - Compare $D\overline{D}$ yield with the PYTHIA-based calculation.

Fit of the p–A mass spectra



- $\chi^2/n.d.f. = 1.55$
- If the background R–factors are fixed in the fit, a $\sim 20\%$ higher value for $\sigma_{D\overline{D}}/\sigma_{DY}$ is obtained (open triangle in the next plots).

Charm–like enhancement vs N_{part}: p–A, S–U, Pb–Pb



- The charm–like enhancement increases smoothly from p–A to S–U to Pb–Pb
- We should expect an enhancement ~ 1 in p–A

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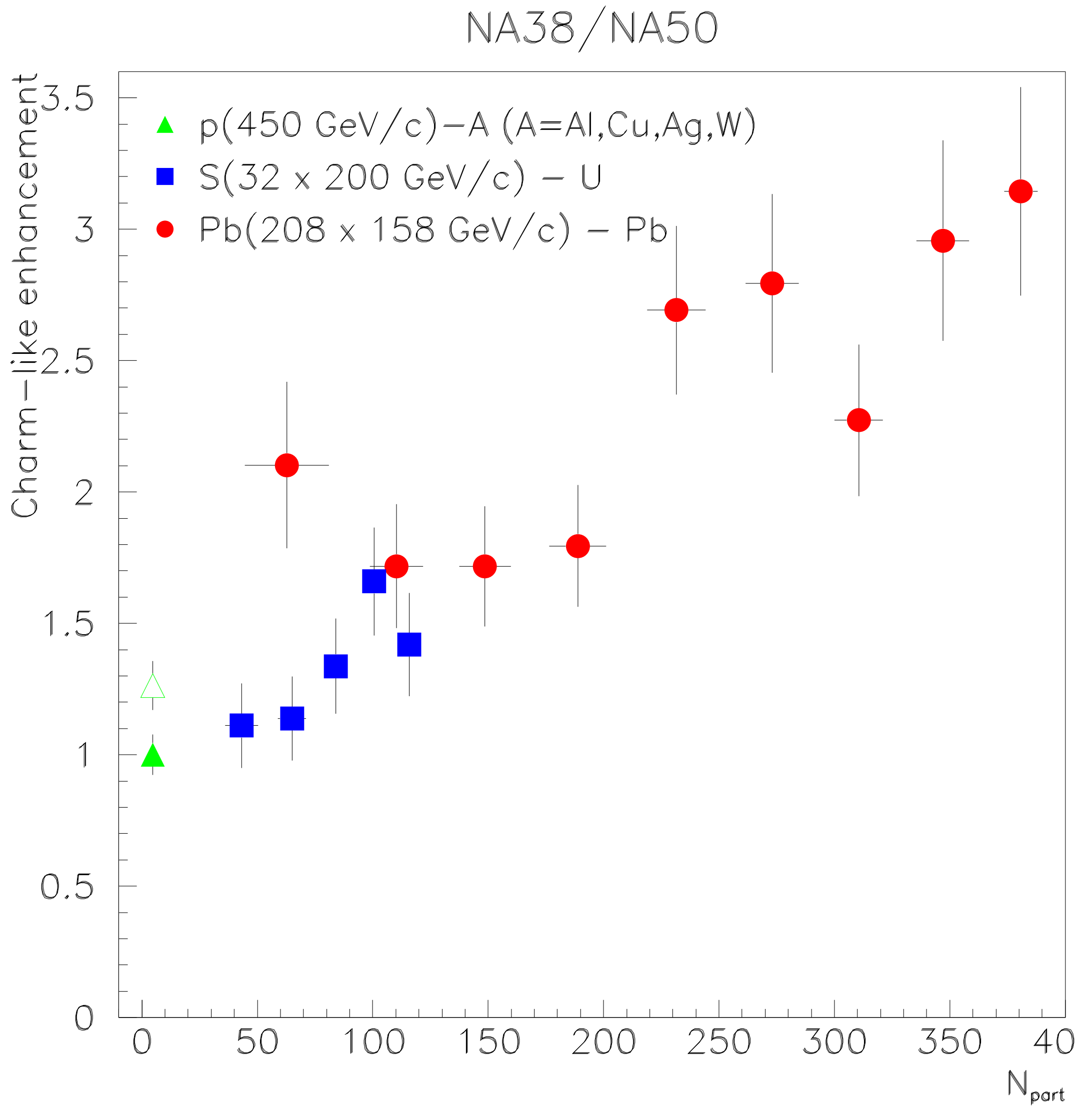
Why is there charm-like enhancement already in pA ?

- The data sets collected in *Braun-Munzinger et al.* exhibit rather large relative uncertainties ($\simeq 2$) between the $D^0/\overline{D^0}$ cross section points.
- Taking into account all possible systematic uncertainties, namely:
  - Absolute cross sections;
  - B.R. $D \to \mu + X$;
  - Dependence of phase space factors on m_c;
- It is reasonable to suppose that no enhancement is present in pA and consequently rescale the AB results.

Charm–like enhancement vs N_{part}: p–A, S–U, Pb–Pb



Charm–like enhancement:

a factor 3 in central Pb–Pb with respect to p–A

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Possible scenarioes

- Additional open charm pairs produced in nucleus–nucleus collisions (but not in p-A), arising from the interactions of gluons produced in different soft-soft baryon-baryon collisions :

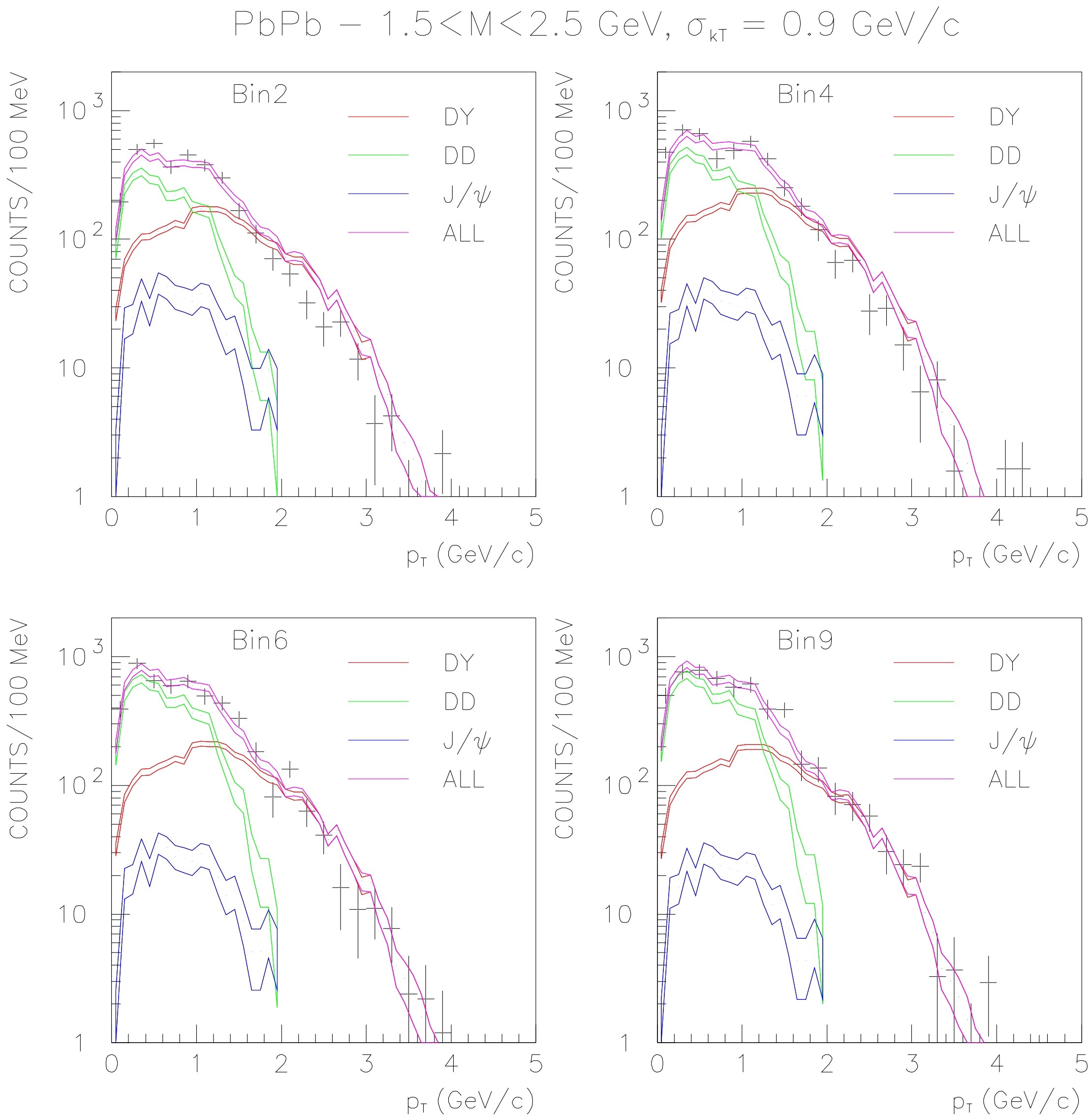
  $\longrightarrow$ C.Y.Wong and Z.Q.Wang, Phys.Lett. B367 (1996) 50

- Gluon anti-shadowing $\rightarrow$ preliminary estimates show that it could only account for a small fraction of the enhancement seen.

- Thermal dimuons production in nucleus–nucleus collisions, if the mass shape of such a contribution happens to be similar to the open charm one.

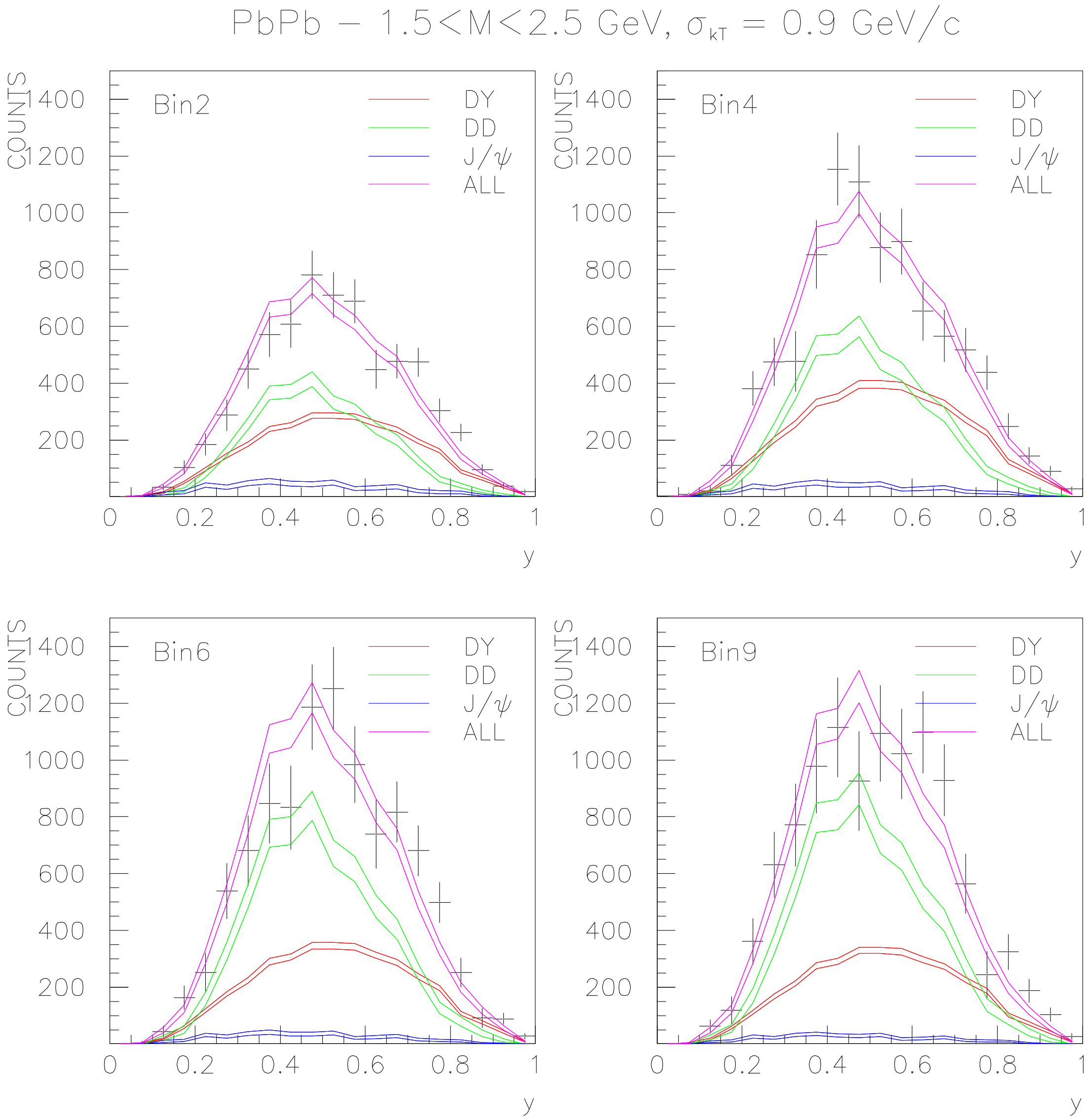
- Parton scattering which distorts the shape of differential distributions in nucleus–nucleus collisions $\rightarrow$ look at p_T distributions in the IMR.

p_T distributions of the Pb–Pb IMR events



- p_T shapes for DY, $D\overline{D}$, J/ψ from PYTHIA + simulation of the detector;
- Absolute normalizations from the fit of the mass spectra;
- Independent evidence that the enhancement is due to a charm–like component.

y distributions of the Pb–Pb IMR events



- y shapes for DY, $D\overline{D}$, J/ψ from PYTHIA + simulation of the detector;
- Absolute normalizations from the fit of the mass spectra;
- Good description of the data, but the y shapes are similar for the various processes in the (narrow) rapidity region covered by NA50.

Conclusions

- From pA to central PbPb collisions a satisfactory description of the mass spectra in the IMR can be achieved in term of known classical sources. Thermal dileptons have not been included in this analysis.

- The charm-like contribution requested to explain the dimuon yield in the IMR in nucleus–nucleus collisions exceeds a linear extrapolation of the charmed mesons production in pA collisions.

- The charm-like contribution enhancement exhibits a steady increase from peripheral SU to central PbPb collisions. In particular, a factor 3 enhancement in the charm-like yield well describes the dimuon production in the IMR for central PbPb collisions.

- The analysis of the p_T spectra of the Pb–Pb IMR events confirms that the excess dimuons come from a charm–like source.