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HEAVY ION PHYSICS

First measurement of the strange particles $R_{\rm CP}$ nuclear modification factors in heavy-ion collisions at the SPS

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Abstract. The NA57 experiment has measured the p_T distributions of $\rm K^0_S$, Λ, and $\overline{\Lambda}$ particles in fixed-target Pb–Pb interactions at $\sqrt{s_{\rm NN}} = 17.3$ GeV, as a function of the collision centrality. In this paper we study the central-to-peripheral nuclear modification factors and compare them to other measurements and to theoretical predictions.

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1. Introduction

At the Relativistic Heavy Ion Collider (RHIC), the central-to-peripheral nuclear modification factor

$$R_{\rm CP}(p_T) = \frac{\langle N_{\rm coll}\rangle_{\rm P}}{\langle N_{\rm coll}\rangle_{\rm C}} \times \frac{{\rm d}^2 N^{\rm C}_{\rm AA}/{\rm d}p_T{\rm d}y}{{\rm d}^2 N^{\rm P}_{\rm AA}/{\rm d}p_T{\rm d}y} \qquad (1)$$

has proven to be a powerful tool for the study of parton propagation in the dense QCD medium expected to be formed in nucleus–nucleus collisions (see, e.g., [1]). At high p_T (> 7 GeV/c), $R_{\rm CP}$ is found to be suppressed by a factor 3–4 with respect to unity (at $\sqrt{s_{\rm NN}} = 200$ GeV), for all particle species; this is interpreted as a consequence of parton energy loss in the medium, prior to fragmentation outside the medium [2]. Energy loss would predominantly occur due additional gluon radiation, with a probability that depends on the density of colour charges in the medium [3, 4]. High-p_T partons are then believed to fragment in a similar fashion as in pp collisions ($p_T^{\rm hadron} = z\, p_T^{\rm parton}$; $z < 1$). At intermediate transverse momenta

(2–5 GeV/c), instead, after energy loss, partons would hadronize 'inside' the dense partonic system via the mechanism of parton coalescence [5]: a quark-antiquark pair or three (anti)quarks, close in phase-space, would coalesce into a meson or baryon, with $p_T^{\text{meson(baryon)}} \approx 2(3)\, p_T^{\text{quark}}$. This is predicted to originate a pattern of larger R_{CP} for baryons relative to mesons. The pattern has been observed, for instance, by the STAR Collaboration for Λ, Ξ, and Ω relative to K^0_S, $\text{K}^{0\star}$, and ϕ [1, 6, 7].

The study of R_{CP} and of its particle-species dependence, in particular the meson/baryon dependence, at top SPS energy allows to test for these phenomena at an energy smaller by about one order of magnitude ($\sqrt{s_{\text{NN}}} = 17.3$ GeV). While measurements of the π^0 R_{CP} by the WA98 Collaboration, supporting the presence of parton energy loss effects, were published already in 2002 [8], the first results on the particle-species dependence (unidentified negatively charged hadrons, K^0_S, Λ, and $\overline{\Lambda}$) have been reported by the NA57 Collaboration in [9].

2. Data analysis

Strange particles are reconstructed using their decay channels into charged particles, measured in the NA57 silicon pixel telescope: $\text{K}^0_\text{S} \to \pi^+\pi^-$, $\Lambda \to \pi^-\text{p}$, and $\overline{\Lambda} \to \pi^+\overline{\text{p}}$. The selection procedure is described in detail in [9]. The main criteria are the following: (a) the two decay tracks are compatible with the hypothesis of having a common origin point; (b) the reconstructed secondary vertex is well separated from the target; (c) the reconstructed candidate points back to the primary vertex position. The acceptance covers about one unit of rapidity around mid-rapidity.

The collision centrality is determined from the charged particle multiplicity N_{ch}, measured by a dedicated silicon detector [10, 11]. The sample of collected events is subdivided in centrality classes, with N_{ch} limits corresponding to given fractions of the Pb–Pb inelastic cross section. The covered centrality range is 0–53% $\sigma^{\text{Pb}-\text{Pb}}$. For each class the average number of participants, $\langle N_{\text{part}} \rangle$, and of binary collisions, $\langle N_{\text{coll}} \rangle$ are calculated from the Glauber model, after a wounded-nucleon model fit ($N_{\text{ch}} \propto N_{\text{part}}$) to the N_{ch} distribution [10].

3. Results and comparisons

Figure 1 shows the results for 0–5%/40–55% and 30–40%/40–55% R_{CP} nuclear modification factors. At low-p_T R_{CP} scales with the number of participants for all particles except the $\overline{\Lambda}$. With increasing p_T, K^0_S mesons reach values of $R_{\text{CP}} \approx 1$: for the most central class we do not observe the enhancement above unity that was measured in proton–nucleus relative to pp collisions (Cronin effect [12]). An enhancement is, instead, observed for strange baryons, Λ and $\overline{\Lambda}$, that reach $R_{\text{CP}} \simeq 1.5$ at $p_T \simeq 3$ GeV/c. The results are in qualitative agreement with those presented by NA49 [13] for charged pions, charged kaons and protons plus antiprotons.

In Fig. 2 (left) we compare our K^0_S data to predictions (X.N. Wang) obtained

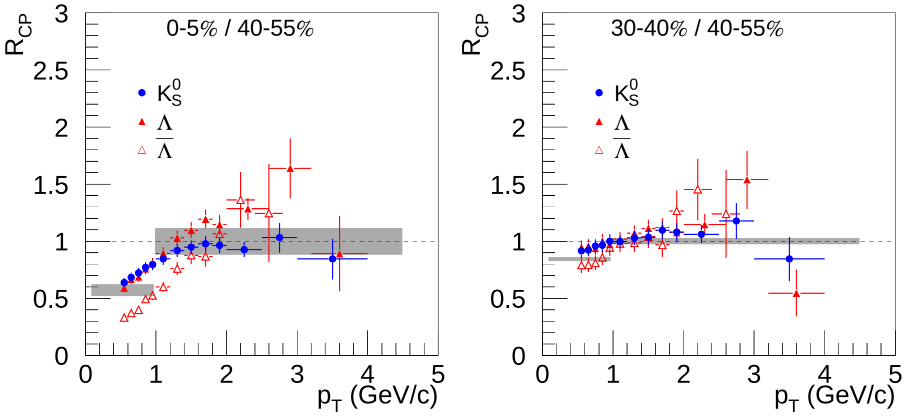

Fig. 1. R_{CP} ratios for singly-strange particles in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 17.3$ GeV [9]. Shaded bands centered at $R_{\mathrm{CP}} = 1$ represent the systematic error due to the uncertainty in the ratio of the values of $\langle N_{\mathrm{coll}} \rangle$ in each class; shaded bands at low p_T represent the values expected for scaling with the number of participants, together with their systematic error.

from a perturbative-QCD-based calculation [14], including (thick line) or excluding (thin line) in-medium parton energy loss. The initial gluon rapidity density of the medium was scaled down, from that needed to describe RHIC data, according to the decrease by about a factor 2 in the charged multiplicity. The data are better described by the curve that does include energy loss. In agreement with the value reached at high-p_T by the data is also the prediction of a second model of parton energy loss (PQM) that describes several energy-loss-related observables at RHIC energies [15].

Figure 2 (right) shows the ratio of Λ R_{CP} to $\mathrm{K}^0_{\mathrm{S}}$ R_{CP}, as measured from our data and by STAR at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV [1, 16] (note that $\Lambda + \overline{\Lambda}$ are considered by STAR and that the centrality range used for the peripheral class is slightly different in the two experiments). The similarity of the Λ–K pattern to that observed at RHIC may be taken as an indication for coalescence effects at SPS energy.

4. Conclusions

We have presented the first results on central-to-peripheral nuclear modification factors for strange particles at the SPS energy $\sqrt{s_{\mathrm{NN}}} = 17.3$ GeV. The comparisons of our data to theoretical calculations and STAR data at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV suggest a scenario with moderate in-medium partonic energy losses and a recombination-induced baryon/meson effect, similar to that observed at RHIC energy.

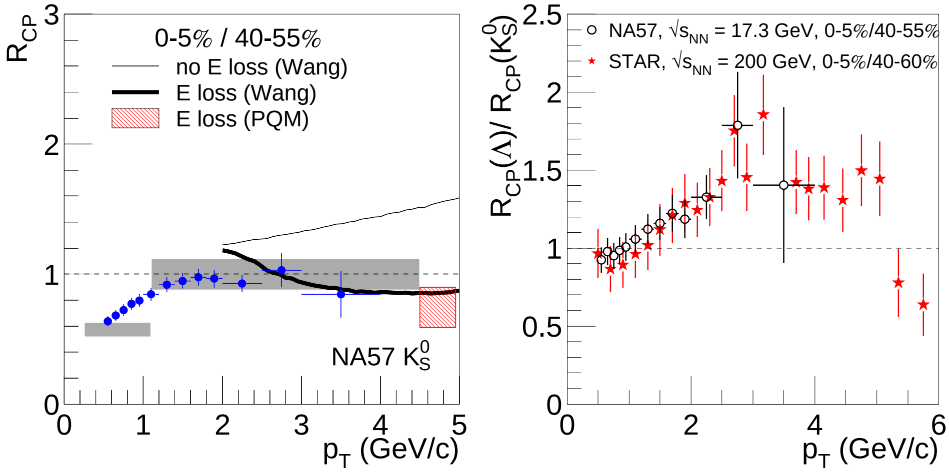

Fig. 2. Left: K^0_S $R_{CP}(p_T)$ compared to predictions [14, 15] with and without energy loss. Right: ratio of Λ R_{CP} to K^0_S R_{CP}, as a function of p_T, at the SPS (NA57 at $\sqrt{s_{NN}} = 17.3$ GeV) and at RHIC (STAR at $\sqrt{s_{NN}} = 200$ GeV [1, 16]).

References

1. J. Adams *et al.*, STAR Coll., *Phys. Rev. Lett.* **92** (2004) 052302.
2. I. Arsene *et al.*, BRAHMS Coll., *Nucl. Phys.* **A757** (2005) 1; K. Adkox *et al.*, PHENIX Coll., *Nucl. Phys.* **A757** (2005) 184; B.B. Back *et al.*, PHOBOS Coll., *Nucl. Phys.* **A757** (2005) 28; J. Adams *et al.*, STAR Coll., *Nucl. Phys.* **A757** (2005) 102.
3. M. Gyulassy and X.N. Wang, *Nucl. Phys.* **B420** (1994) 583.
4. R. Baier *et al. Ann. Rev. Nucl. Part. Sci.* **50** (2000) 37.
5. R.C. Hwa and C.B. Yang, *Phys. Rev.* **C67** (2003) 064902; R.J. Fries *et al.*, *Phys. Rev.* **C68** (2003) 044902; V. Greco *et al.*, *ibidem* 034904.
6. K. Schweda *et al.*, STAR Coll., *J. Phys.* **G30** (2004) (2004) s693.
7. X.Z. Cai *et al.*, STAR Coll., *Nucl. Phys.* **A** (QM2005 proceedings), *in print.*
8. M.M. Aggarwal *et al.*, WA98 Coll., *Eur. Phys. J.* **C23** (2002) 225.
9. F. Antinori *et al.*, NA57 Coll., *Phys. Lett.* **B623** (2005) 17.
10. F. Antinori *et al.*, NA57 Coll., *Eur. Phys. J.* **C18** (2000) 57.
11. F. Antinori *et al.*, NA57 Coll., *J. Phys.* **G31** (2005) 321.
12. J. Cronin *et al.*, *Phys. Rev.* **D11** (1975) 3105.
13. C. Höhne *et al.*, NA49 Coll., *Nucl. Phys.* **A** (QM2005 proceedings), *in print.*
14. X.N. Wang, *Phys. Rev.* **C61** (2000) 064910; private communication.
15. A. Dainese *et al.*, *Eur. Phys. J.* **C38** (2005) 461; private communication.
16. M.A.C. Lamont, poster presentation at QM2005, *Acta Phys. Slov. in print.*