Polarized secondary particles in unpolarized high energy hadron-hadron collisions?

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In this short note I speculate on some consequences of the high energy collision picture in which the orbital angular momentum of the colliding hadrons can be converted into secondary particle angular spin momentum via some spin-orbital interaction. In particular I discuss a possibility to observe a non-zero polarization of secondary particles (e.g. hyperons) at midrapidity ($x_F = 0$) and at low transverse momentum. I also speculate that such effects could contribute to the produced particle directed and elliptic flow observed in relativistic nuclear collisions.

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In a course of high energy hadron-hadron or nuclear collision the orbital angular momentum of colliding particles can be converted into the spin angular momentum of produced particles. In this case the produced particles would become polarized along the initial orbital angular momentum of the colliding particles. One particular mechanism of such a conversion is considered in a recent paper [1] discussing non-central nuclear collisions. I would totally concur with the results presented in this paper. Here, I discuss a few ideas beyond those already mentioned in [1]. Note, that the possibility of the transfer of the orbital momentum into spin is not surprising, e.g. consider the ρ resonance decaying into two pions, which must have the orbital momentum equal to the spin of the ρ. The backward process should be also possible, and if the colliding pions have a particular direction of their orbital momentum, the spin of ρ would point that very direction.

In this short note I would like to point out that such a conversion of the orbital momentum into spin (and, in principle, wise versa) can be relevant not only for $A+A$ collisions but also could lead to important observable effects in hadron-hadron collisions. In particular I try to relate it to such phenomena as the hyperon polarization in unpolarized hadron collisions and single-spin asymmetries in transversely polarized proton collisions. Both these effect arguably are related to the orbital momentum of the quark-gluon matter inside the constituent quarks [2, 3]. I speculate that one can consider 'elementary' $p+p$ collision similar to that of a non-central nuclear collision, namely, introducing the notion of the reaction plane - the plane perpendicular to the orbital momentum, and considering particle production and their polarization relative to that plane (alternatively, to the direction of the orbital momentum). In that approach, for example, the hyperons could have non-zero polarization even at $x_F = 0$ and/or small transverse momenta.

Recall that the hyperon polarization is usually measured with respect to the plane spanned by the hyperon's and projectile momenta, the so-called production plane. It has been observed that the polarization strongly (almost linearly) depends on the fraction of the projectile longitudinal momentum carried, x_F, and also strongly depends on the particle transverse momentum, exhibiting a saturation at about $p_t \sim 1$ GeV/c. In our picture the polarization of the produced particles would be correlated mainly to the direction of the orbital momentum of the colliding hadrons. Then, if measured with respect to the hyperon production plane, the polarization would be non-zero only because the production plane itself is correlated to the "reaction plane" (the orientation of the orbital momentum). In this case, the observed dependence of the polarization on x_F and p_t is due not to the loss of 'actual' polarization, but due to the fact that the hyperon's transverse momentum direction becomes less and less correlated with the "reaction plane". Such a sensitivity would be totally lost at $x_F = 0$.

In order to observe the 'actual' polarization one has to know the direction of the orbital angular momentum of the colliding hadrons. For that purpose we propose to use the azimuthal distribution of particles in the forward rapidity region, similar to the procedure used in the analysis of directed flow in nuclear collisions. One could also think about this procedure from the point of view of single-spin asymmetries. When one selects the events with a particular particle azimuthal distribution, suppose events with preferential particle emission along the x axis, it means that in these particular events the angular momentum of the system is preferentially pointing along the y axis. In its turn it would lead to the hyperon polarization along the y axis and can be observed as correlation between hyperon polarization and the particles azimuthal distribution in the forward region.

The entire picture of $p+p$ collision would look very similar to that of the directed flow in nuclear collision. One could speculate even further: the directed flow of the produced particles observed in high energy nuclear collision could have a significant contribution from the same very physics that is responsible for the single-spin asymmetries. The nuclear collision would be considered just as "coherent" superposition of elementary nucleon-nucleon collisions with strong correlation of the angular momentum in each of them.

Also important that in both, $p+p$ and $A+A$, collisions the particle produced at midrapidity could be strongly polarized. For example, vector resonances, would have their spin pointing along the initial orbital momentum. Then, the decay products of such resonances would have angular distribution $\propto \sin^2\theta$, where θ is the angle relative to the spin direction (in the resonance rest frame), and consequently $\propto \cos(2\phi)$, where the angle ϕ is now the azimuthal angle with respect to the reaction plane, and thus would contribute to the elliptic flow (modulo distortions due to transformation from the resonance rest frame). Such an additional contribution could probably explain the very strong elliptic flow observed at RHIC (recall, that in transverse momentum region, $p_t \sim 3$ GeV/c elliptic flow at RHIC can not be explained by any model [4]).

Finally I note that the effect of strong correlation between the polarization of hyperons produced in nuclear collisions may complicate the analysis aimed on testing a possibility of the parity violation [5] in such collisions. As hyperon polarization would be along the total orbital momentum of the system, and due to the parity violation in their decays, it would lead to the preferential emission of the daughters of their decay along (or opposite) to the system orbital momentum direction. The difference from the effect discussed in [5] would be only in the constant alignment of the particle emission with the orbital momentum compared to event-by event fluctuation in sign (parallel and anti-parallel to the orbital momentum) in the original effect. The fluctuations in the hyperon production could mask the real parity violation effect and special precautions should be taken to avoid this problem.

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