Coherent Nuclear Interactions at RHIC

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When ultrarelativistic nuclei undergo interactions at large impact parameters, the entire nucleus can interact as a single particle, via a coherent electromagnetic (photon) or Pomeronic fields. Collisions between these fields have a broad physics interest.

Two-photon collisions result from the interactions of the electromagnetic fields of the two nuclei. This process can be modelled by the Weizsacker-Williams method as the collision of two almost-real photons; any spin 0 or spin 2 state with internal or external charge is accessible[1]. We have calculated the photon fluxes, collision rates and final state production rates for a variety of final states at RHIC[2]. For final state energies below 1.5 GeV, RHIC will have a higher $\gamma\gamma$ luminosity than e^+e^- colliders such as CESR and LEP II.

Photon-Pomeron and double-Pomeron interactions are also possible. Pomerons are a representation of colorless interactions involving the strong force, such as pp elastic scattering, and having the same quantum numbers as the vacuum. They represent the absorptive part of the interaction cross section. At RHIC, interactions such as $\gamma + P \rightarrow V$, where V is a vector meson will produce large numbers of ρ, ϕ and J/ψ. Double Pomeron interactions can lead to spin 0 or 2 final states, at higher energies than can be produced in $\gamma\gamma$ collisions. These interactions measure the photon-Pomeron and nucleon-Pomeron coupling, and shed light on the nature of the Pomeron.

We have investigated the feasibility of studying these interactions, using two-photon collisions as our model[2]. These interactions have signatures that can be distinguished from backgrounds such as grazing nuclear collisions, beam gas interactions, cosmic rays, and the like. Since the nuclei interact as a single particle, the perpendicular momentum scale $p_\perp$ of the products is determined by the nuclear size R, with $p_\perp = \hbar c/R$, or about 30 MeV/c for gold. In contrast, incoherent background has a $p_\perp$ scale given by QCD, typically 300 MeV/c. For the reactions of interest studied here, there are typically 2 or 4 charged and 0 neutrals, allowing for complete reconstruction of the event, and hence accurate $p_\perp$ determination. Because the photons and Pomerons are both color singlets, the final state should not be accompanied by additional particles, and should be well separated in rapidity space from both beams.

We have simulated $\gamma\gamma$ collisions to a number of final states: $\mu^+\mu^-$, $\tau^+\tau^- \rightarrow l^+l^-$, $\eta_c \rightarrow K^{*0}K^+\pi^-$, η', $f_0(975)$, $f_2(1270)$, and $\rho^0\rho^0 \rightarrow \pi^+\pi^-\pi^+\pi^-$, and found the rates and acceptances in the STAR detector. Rates are high, and, except for the η_c, all states may be seen and studied with good statistics; the η_c is marginal. We have also simulated the backgrounds due to grazing nuclear collisions and beam gas events. Except for the η_c, signal to noise ratios are good.

We have also developed a scheme for STAR to trigger on these events at level 0, 1, 2, and 3. This trigger selects events based on multiplicity and topology in levels 0 through 2, adding tracking information to find the total charge, vertex position and momentum balance at level 3. At each stage, we have demonstrated good acceptance, while using a small fraction of the available bandwidth.

References

[1] S. Klein, "Two-Photon Physics at RHIC", in *Photon '95*, ed. D. J. Miller, S. L. Cartwright and V. Khoze, World Scientific, 1995.

[2] Spencer Klein and Evan Scannapieco, "Two-Photon Physics with STAR, STAR Note 243, March 22, 1996.