PROCEEDINGS OF SCIENCE

Realistic cross sections for exclusive $\rho^0\rho^0$ production in ultrarelativistic heavy-ion collisions.

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Relativistic heavy–ion collisions at RHIC and LHC represent an intense source for photon induced processes. We present, calculated for the first time, realistic cross sections for exclusive electromagnetic production of two neutral ρ mesons in coherent photon–photon process in the $AA \to A\rho^0\rho^0 A$ reaction

- for $Au-Au$ collisions at $\sqrt{s_{NN}} = 200\ GeV$ (RHIC) and
- for $Pb-Pb$ collisions at $\sqrt{s_{NN}} = 5.5\ TeV$ (LHC).

For low–energy part of the elementary $\gamma\gamma \to \rho^0\rho^0$ process, we use experimental data which were measured by several groups at e^+e^- colliders, while for higher energy, we include vector–dominance–model (VDM)–Regge contribution.
To illustrate the sensitivity of our calculations on details of the form factor, we also compare results with realistic charge density with results for monopole form factor. The cross section is calculated in the equivalent photon approximation.

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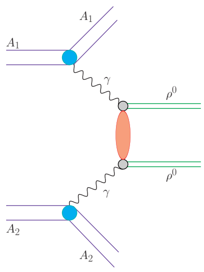

Figure 1: The reaction discussed.

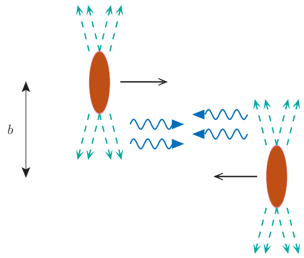

Figure 2: The Weizsäcker–Williams method.

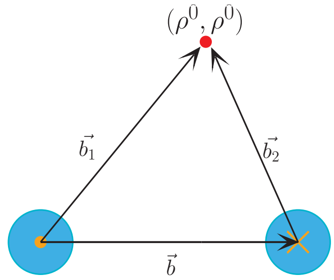

Figure 3: The quantities used in the impact parameter calculation.

The Weizsäcker–Williams method [1] is a standard semi–classical alternative to the Feynman rules for calculating cross sections of electromagnetic interactions. The method is based on the observation that the electric and magnetic fields of a fast–moving charged particle are nearly transverse to the direction of motion.

We consider the process depicted in Fig.1. The corresponding cross section can be written as:

$$\frac{\mathrm{d}\sigma\left(AA \to \rho^0\rho^0 AA; s_{AA}\right)}{\mathrm{d}^2\mathbf{b}} = \mathrm{d}n_{\gamma\gamma}\left(x_1, x_2, \mathbf{b}\right)\hat{\sigma}\left(\gamma\gamma \to \rho^0\rho^0; x_1 x_2 s_{AA}\right) + \dots \,. \tag{1}$$

The effective photon flux

$$\mathrm{d}n_{\gamma\gamma}\left(x_1, x_2, \mathbf{b}\right) = \int \mathrm{d}^2\mathbf{b}_1 \mathrm{d}^2\mathbf{b}_2 S^2_{abs}\left(\mathbf{b}\right)\delta^{(2)}\left(\mathbf{b} - \mathbf{b}_1 + \mathbf{b}_2\right)\frac{\mathrm{d}x_1}{x_1}\frac{\mathrm{d}x_2}{x_2}\frac{1}{\pi^2}|\mathbf{E}\left(x_1, \mathbf{b}_1\right)|^2|\mathbf{E}\left(x_2, \mathbf{b}_2\right)|^2 \tag{2}$$

is expressed through [2, 3] the electric field strengths of the ions. Absorption factor represents the probability that no inelastic interaction between the nuclei occurs. According to Czyż–Maximon [4] approximation absorption factor is given in terms of the optical thickness of the nucleus $T_A\left(\mathbf{b}\right)$:

$$S^2_{abs}\left(\mathbf{b}\right) = exp\left(-\sigma^{tot}_{NN}\int \mathrm{d}^2\mathbf{s}\; T_A\left(\mathbf{b} - \mathbf{s}\right)\; T_A\left(\mathbf{s}\right)\right) \cong \theta\left(\mathbf{b} - 2R_A\right) = \theta\left(|\mathbf{b}_1 - \mathbf{b}_2| - 2R_A\right)\,. \tag{3}$$

Flux of photons in an ultrarelativistic charge moving with the energy γM_A:

$$n\left(\omega\right) \equiv \int \mathrm{d}^2\mathbf{b} N\left(\omega, \mathbf{b}\right) = \frac{1}{\pi}\int \mathrm{d}^2\mathbf{b}|\mathbf{E}\left(x, \mathbf{b}\right)|^2\,, \tag{4}$$

where $x = \frac{\omega}{\gamma M_A}$. Photon energies ω_i are in the nucleus–nucleus center–of–mass; $W^2 = 4\omega_1\omega_2 > 4m^2_\rho$. Additionally we use the $\gamma\gamma$ cms–energy $W_{\gamma\gamma}$ and the rapidity–type variable Y defined through $\omega_1 = \frac{W_{\gamma\gamma}}{2}e^Y$, $\omega_2 = \frac{W_{\gamma\gamma}}{2}e^{-Y} \mapsto \frac{\mathrm{d}\omega_1}{\omega_1}\frac{\mathrm{d}\omega_2}{\omega_2} = 2\frac{\mathrm{d}W_{\gamma\gamma}}{W_{\gamma\gamma}}\mathrm{d}Y$.

Finally one gets:

$$\begin{aligned}\mathrm{d}\sigma\left(AA \to \rho^0\rho^0 AA; s_{AA}\right) &= \int \mathrm{d}^2\mathbf{b}_1 \mathrm{d}^2\mathbf{b}_2 \theta\left(b - 2R_A\right)\frac{\mathrm{d}\omega_1}{\omega_1}\frac{\mathrm{d}\omega_2}{\omega_2}N\left(\omega_1, \mathbf{b}_1\right)N\left(\omega_2, \mathbf{b}_2\right)\\ &\times\; \hat{\sigma}\left(\gamma\gamma \to \rho^0\rho^0; 4\omega_1\omega_2\right)\,.\end{aligned} \tag{5}$$

The Weizsäcker–Williams idea of the equivalent photon flux represents the archetypical parton–model concept.

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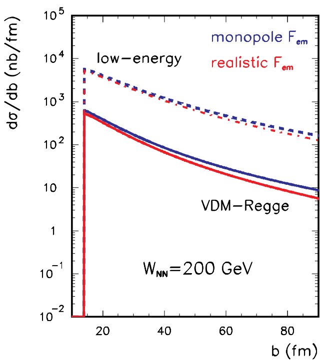

Figure 4: Impact parameter dependence.

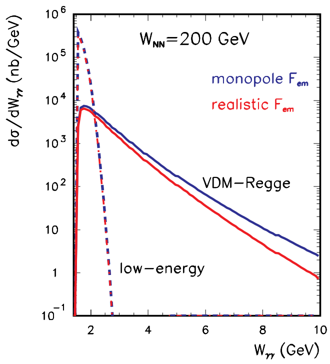

Figure 5: Cross section as a function of $M_{\rho\rho} = W_{\gamma\gamma}$.

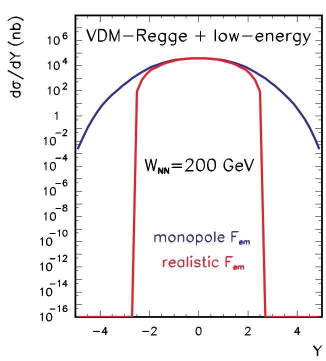

Figure 6: Rapidity (Y) distribution of the $\rho^0\rho^0$ pair.

The low–energy part of the elementary $\gamma\gamma \to \rho^0\rho^0$ process has been parametrized and the parameters have been fitted to the e^+e^+ data [5]. The high–energy part was calculated in VDM–Regge model [6] with parameters which are used to describe other hadronic processes.

In Fig.4 we show the distribution in impact parameter $b = |\mathbf{b_1} - \mathbf{b_2}|$ (see Fig.3). Fig.5 shows cross section as a function of the $\rho\rho$ invariant mass $M_{\rho\rho}$. In Fig.6 we show distribution in rapidity–like variable Y. The figures include both the low–energy component and high–energy VDM–Regge component. We compare results with realistic charge density with results for monopole form factor.

In the present analysis we have concentrated on processes with final nuclei in the ground state. Large nuclear cross sections are obtained. More details about calculations at the RHIC energies can be found in [6]. Fine-grained calculations at the LHC energies will be presented in [7]. We find that both ρ^0 mesons are produced predominantly at midrapidities, both at RHIC and LHC.

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