Diffractive Production of Glueballs

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This contribution is based on the work with John Ellis [1], in which we link the unexpected azimuthal dependence of the production of scalar glueball candidate observed recently by the WA91 and WA102 Collaborations to the broken scale invariance of QCD.

Confinement and the non-Abelian structure of QCD imply the existence of bound states of gluons. Clearly, finding and recognizing such glueball states is very important. One intriguing possibility is to identify the observed $f_0(1500)$ state with the lightest scalar glueball [2]. To verify the gluonic nature of this state, one has to check in particular if the mechanisms of its production are consistent with those expected for glueball states. This suggests in particular that one looks for its production in gluon-rich environments. It was suggested long time ago [3] that the glueballs should be produced copiously in the central production process

$$pp \to p_f X p_s \tag{1}$$

This may be dominated by double-Pomeron exchange when the final-state protons carry large fractions of the initial-state proton momenta in the centre-of-mass frame. In fixed-target experiments, this requires the presence of fast (p_f) and slow (p_s) protons in the final state.

Recently, a big step in the investigation of this process has been taken by the WA91 and WA102 Collaborations, which have reported remarkable kinematical dependences of central meson production [4,5]. Specifically, it was observed [5] that the the production of glueball candidates depends strongly on the relative transverse momenta of the final-state protons p_f and p_s. The variable suggested in [5,6] was the difference between the transverse momenta $\vec{p\prime}_t$ and $\vec{q\prime}_t$ of the final-state protons:

$$dP_t = |\vec{p_t}\prime - \vec{q_t}\prime|. \tag{2}$$

The dependence of central meson production on this variable appears to be very non-trivial: namely, it was found that at small dP_t the production of glueball candidates, in particular the $f_0(1500)$, was significantly enhanced over the production of conventional $\bar{q}q$ mesons. It was proposed [6] that this remarkable feature of central production could be related to the intrinsic structure of glueball states, and that the selection of events with small dP_t could act effectively as a glueball filter. So far, no dynamical explanation of this important empirical observation has been suggested, so the challenge for theory is to understand the dynamics behind this glueball filter.

We have proposed [1] the following form for the coupling responsible for scalar glueball production in Pomeron-Pomeron collisions:

$$Ł \sim \Theta(x) G_a^{\mu\nu}(x) G_{\mu\nu}^a(x), \tag{3}$$

In momentum space, this coupling leads to an amplitude that is proportional to the square of the scalar product of the four-momenta of the colliding gluons g_1 and g_2:

$$\mathcal{M} \sim (g_1.g_2 g^{\mu\nu} - g_1^\mu g_2^\nu)(g_1.g_2 g_{\mu\nu} - g_{1\mu} g_{2\nu}) \sim (g_1.g_2)^2. \tag{4}$$

This form of the coupling, and the Pomeron flux factors, imply [1] that the production of the scalar glueball should be most efficient when the two protons scatter in parallel directions in the transverse plane, in agreement with the experimental observations.

Our findings support the idea that the azimuthal dependence in double diffractive production provides a valuable way to single out the scalar glueballs and to understand their properties. It would be extremely interesting to extend these studies to collider energies, where the dominance of the Pomeron exchange is much better justified.

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