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PRODUCTION OF G(1590) IN 300 GeV CENTRAL π^-N COLLISIONS

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(Joint CERN – IHEP experiment)

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Abstract

Significant production of G(1590), a scalar glueball candidate, is observed in a study of η pairs produced in π^-N central collisions at 300 GeV/c.

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First results on the production of pairs of η-mesons in central collisions of pions on nucleons are reported in the present letter. The interest in this process comes because it is dominated by double Reggeon exchange (at high energies, double Pomeron exchange DPE) [1] which may enhance glueball production [2]. A large glueball cross section in the central region is predicted by a mechanism proposed by S.Gershtein and A.Logunov [3] which relates the rise of total cross section with increasing energy to the exchange of glueballs in the t-channel or to the collision of the soft gluon seas of the interacting particles.

Eta pairs, amongst other neutral final states, are observed with 300 GeV/c incident negative pions in the exclusive reaction :

$$\pi^- N \to M^0 \pi^- N \qquad (1)$$
$$\hookrightarrow \eta\eta \to 4\gamma$$

where the longitudinal momentum of M^0 is small ($x_F \approx 0$). In such a reaction, the signal from glueballs may be enhanced in two ways, first by DPE, second by observing the $\eta\eta$ decay mode as predicted by the decoloration mechanism [4]. The study of this reaction at high energy has been proposed as an efficient means to find glueballs or mesons with a large gluonic component [3]. Accordingly, as a glueball candidate, G(1590) [5, 6] is expected to be produced in this reaction. Another advantage of this process is its characteristic kinematics [7].

The measurements have been made at the CERN SPS with the experimental setup shown on fig. 1. The energy and coordinates of the photons from the η decays are measured with the multiphoton hodoscope Cerenkov calorimeter GAMS-4000 [6]. The target is located at a distance of 12 meters upstream of GAMS. It is made of 16 plastic scintillators, 5 mm thick each and separated by 20 mm. It is surrounded by a guard system of counters. A magnetic spectrometer is placed downstream of GAMS, to measure the momentum of the forward scattered pion which proceeds from the target through the central hole of the calorimeters. Its deflection in a nine Tesla·m magnetic field is determined by multi-wire proportional chambers with 2 mm wire spacing placed before and after the magnets. The energy of these forward scattered pions is also measured in the nine-cell hadron calorimeter, MHC-9. The data acquisition system and the calibration procedures for the calorimeters and other components of the apparatus have been described earlier [6, 8, 9].

The fast trigger decision requires : (1) a minimum of 10 GeV energy deposition in GAMS, measured with a fast analog dynode adder system, (2) the presence in the wire chambers of the magnetic spectrometer of one and only one charged track whith a momentum in the range 150 − 285 GeV/c as determined by a fast processor, (3) a minimum of 100 GeV energy deposition in MHC−9, (4) the absence of a signal in the scintillator guard system and (5) the absence of a signal in the lead−scintillator sandwiches that define the GAMS aperture.

A total flux of $2{\cdot}10^{10}$ pions on the target have been collected for the study of reaction (1). Off−line analysis first rejects events which do not satisfy total energy balance before and after collision. The spectrum of $E_{tot} = E_{\pi^-} + \Sigma E_{\gamma i}$, the sum of the energies of the pion and of all gammas in GAMS, shows a narrow peak with a σ_E of 5 GeV, the instrumental resolution. The noise under the peak is less than 15 %. Events with E_{tot} in a $\pm 2\sigma_E$ range were kept for further analysis.

Shower reconstruction programs for the determination of energy and coordinates of each gamma in GAMS are similar to those used in former experiments [6, 9, 10]. Events are sorted out according to the number of gammas observed.

The events that contain four gammas are used in the remaining analysis. The large majority of such events is made of π^0's which are rejected by excluding all events which contain a γ pair with an invariant mass in the range 90 MeV $< M_{2\gamma} <$ 200 MeV [6].

The remaining events are submitted to a 2−C fit. The nucleon mass is fixed, as well as the mass of one γ−pair identified as an η−meson; the invariant mass of the second gamma pair is left free. The spectrum of the latter is shown in fig. 2c. The background below the η−peak is seen to depend on the mass of the η−pair, $M_{\eta\eta}$. It is large near threshold, it decreases sharply with increasing $M_{\eta\eta}$ and it becomes negligible above 1400 MeV (fig. 2d) where most η−pairs may be found (fig. 3). This background has been determined through fitting individual spectra, like those of fig.2, plotted for each mass interval $M_{\eta\eta}$, with an η−peak and a polynomial.

The final spectrum with background subtracted is plotted in fig. 3. A significant peak due to the central production of a meson with mass and width :

$$M = (1610 \pm 20)\ \text{MeV} \qquad \Gamma = (170 \pm 40)\ \text{MeV} \tag{2}$$

is observed. This peak cannot be explained by kinematical reflections as the mass spectra of the $\eta\pi^-$ and $M^0\pi^-$ combinations concentrate above 2.5 GeV and do not show any structure.

The distribution of η pairs in this peak as a function of the cosine of the angle θ^* between the momentum of one η and the momentum transferred to the pion ("Reggeon momentum") in the rest frame of M^0 (similar to the Gottfried–Jackson angle) is isotropic (fig. 4) pointing to a spin–zero meson. The decay mode fixes then the other quantum numbers : $I^G J^{PC} = 0^+ 0^{++}$. This meson may be identified with G(1590), the glueball candidate that was discovered in $\pi^- p$ charge–exchange reactions at 40 GeV and 100 GeV decaying into $\eta\eta$, $\eta'\eta$ and $4\pi^0$ [5,6].

The x_F distribution of the G(1590) events (fig. 5) shows that most of these mesons are concentrated in the range $x_F \lesssim 0.25$ (rapidity $\lesssim$ 1). The dashed curve represents the shape of the setup acceptance which is zero for $x_F < 0$ and reaches a maximum at $x_F \approx 0.2$. The G(1590) events are distributed as expected for mesons that are produced in central collisions [12].

The 300 GeV production cross section of G(1590) in the range $0 < x_F < 0.3$ is $\sigma(\pi^- N \rightarrow \pi^- NG) \cdot BR(G \rightarrow \eta\eta) = (30 \pm 10)$ nb (the number of effective nucleons in the scintillator target has been taken proportional to $A^{2/3}$). In this case, taking 0.12 as the value of $BR(G \rightarrow \eta\eta)$ [4, 5, 11] one gets a central production cross section $\sigma(\pi^- N \rightarrow \pi^- NG)$ of (0.2 ± 0.1) μb.

The G(1590) central production rate is significant compared to that of a meson like f(1270) which is observed through its $\pi^0\pi^0$ decay mode. The cross–section ratio $\sigma(\pi^- N \rightarrow \pi^- NG)/\sigma(\pi^- N \rightarrow \pi^- Nf)$ of about 1/2 is to be compared to this ratio for the same particles in peripheral charge–exchange reactions wich is an order of magnitude smaller [5, 6]. This is another argument pointing towards the glueball nature of G(1590).

Central collision processes have been studied earlier at $\sqrt{s}$ energies from 10 to 62 GeV [12] in similar reactions, but in a search for states decaying into π and K mesons, channels which are known not to be favored by G(1590).

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FIGURE CAPTIONS

Fig. 1 Experimental setup (NA12/2). GAMS−4000: hodoscope electromagnetic calorimeter made of lead−glass cells; MHC−240: modular hadron calorimeter; S_{1-5}: scin−tillation counters; $H^{b}_{1,2}$ − beam hodoscopes; T: live target; GS: guard system (scintillation and lead−glass counters); A,AH: scintillation counters; SW: aperture defining sandwich counters. Magnetic spectrometer: Magnets and $MPWC_{1-4}$: multiwire proportional chambers; MHC−9 and GAMS−64: hadron and photon hodoscope calorimeters.

Fig. 2 a) Invariant mass spectrum of all γ−pairs in 4−γ events ($i,k = 1$ to 4, $i \neq k$).

b) Idem for the events with a total mass above 1.4 GeV.

c) Invariant mass spectrum of the second pair of photons in 4−γ events after the first pair has been identified with an η.

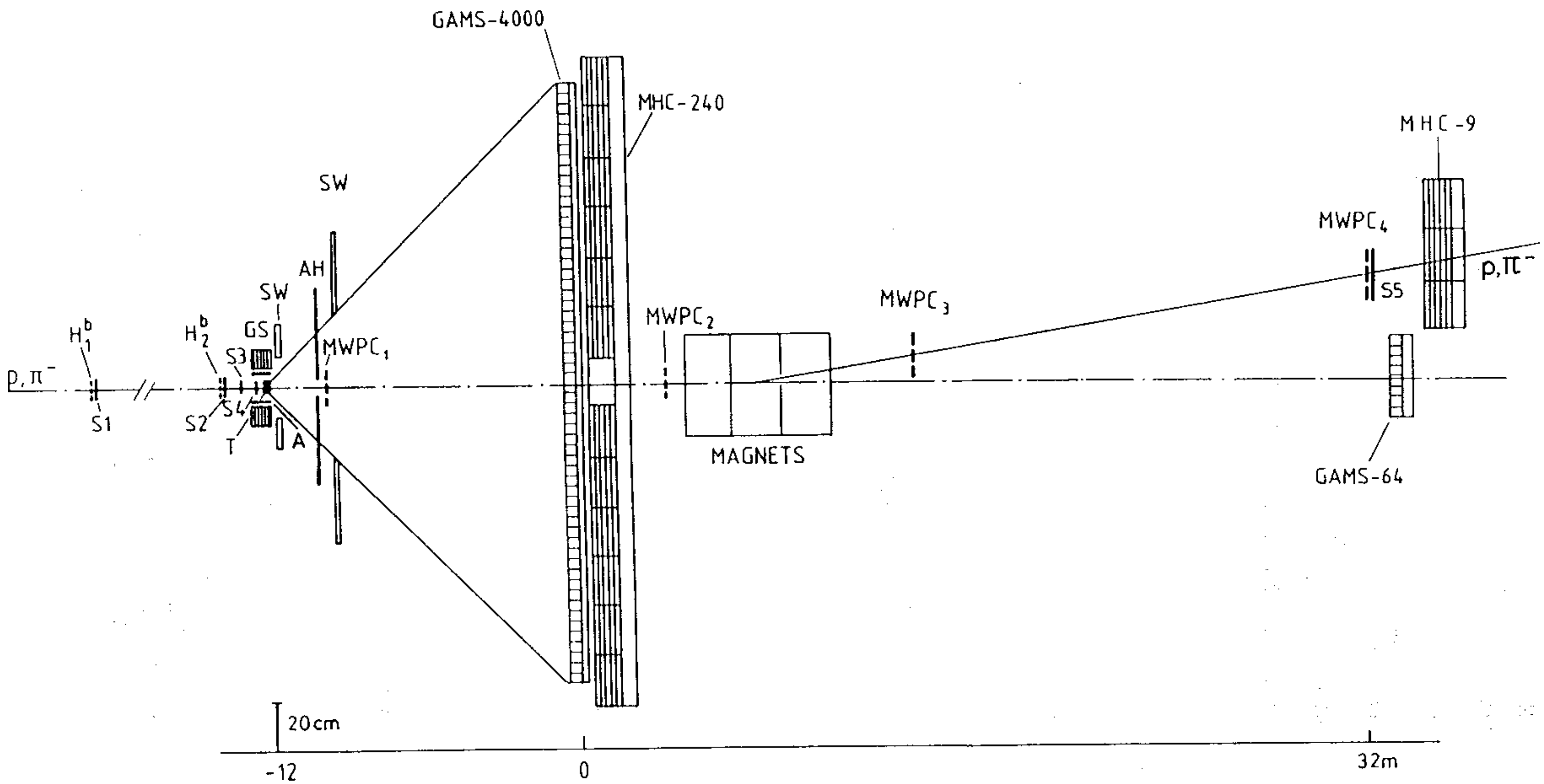
d) Idem for events with a mass $M_{\eta\eta} > 1.4$ GeV.

The arrows point to the tabulated value of the η mass.

Fig. 3 Invariant mass of $\eta\eta$−systems (after background subtraction) showing clearly the production of G(1590) in reaction (1). The arrow points to the tabulated value of the G mass.

Fig. 4 Angular distribution of the decay products in the rest frame of the $\eta\eta$−systems for events in the G(1590)−peak.

Fig. 5 Distribution of G(1590)−mesons produced in reaction (1) versus the Feynman variable x_F. The dashed curve represents the x_F acceptance of the setup (norma−lized to the maximum of the experimental distribution).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MHC-240
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SW
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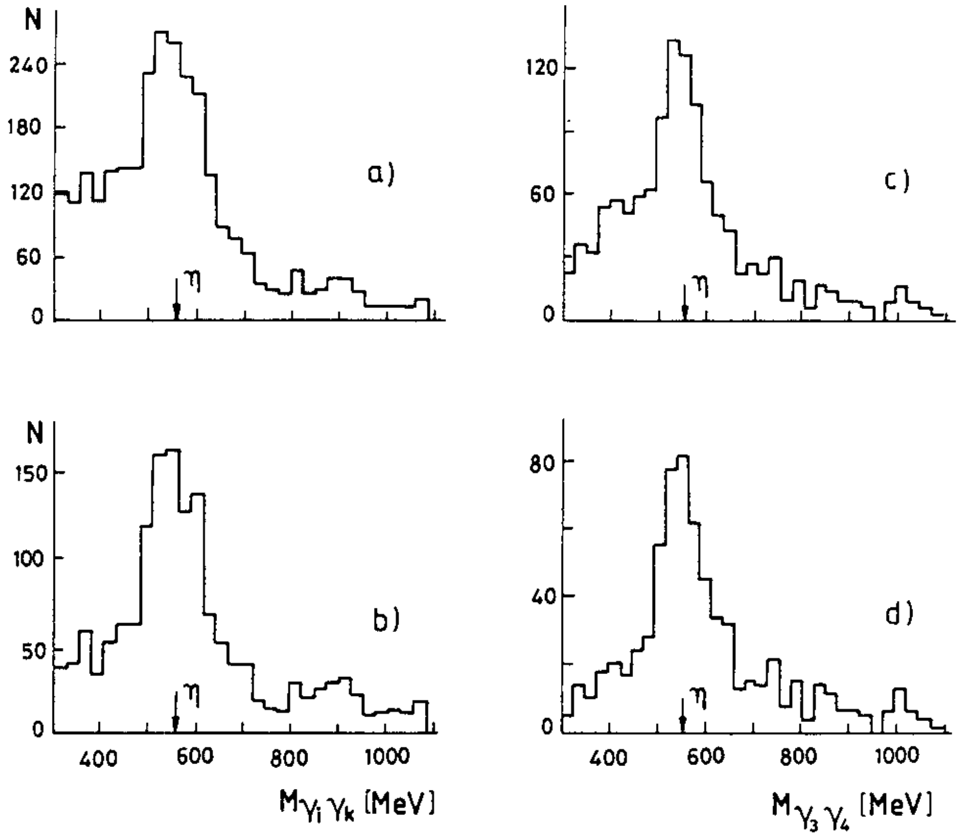
H_1^b
H_2^b
S3
MWPC$_1$
MWPC$_2$
MWPC$_3$
MWPC$_4$
p, π^-
S1
S2
S4
T
A
MAGNETS
S5
p, π^-
GAMS-64
20cm
-12
0
32m

Fig. 1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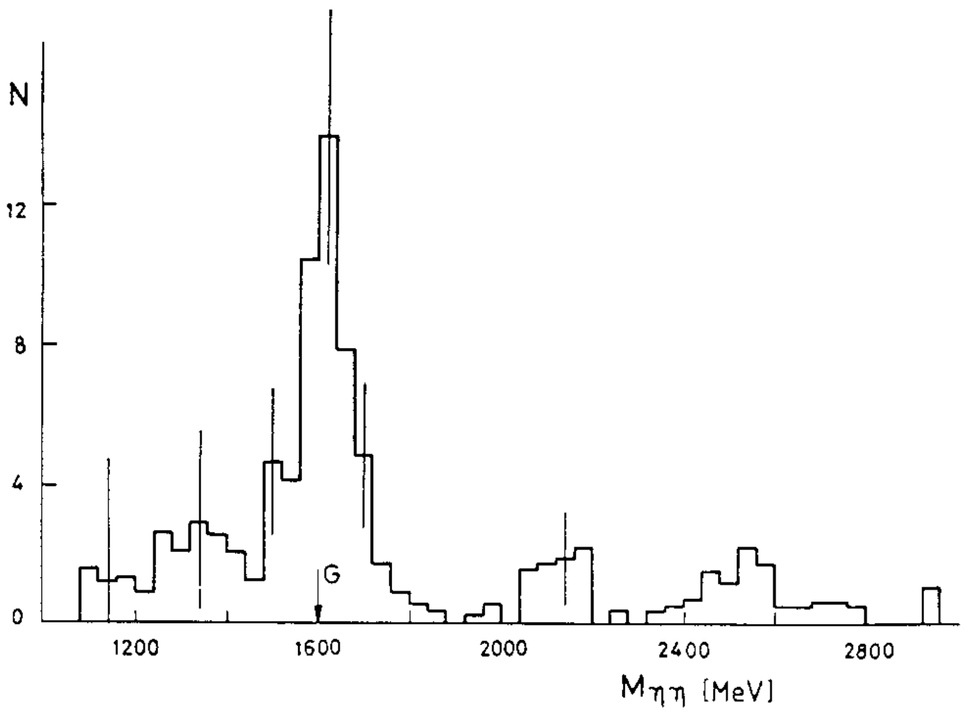
240
180
120
60
0
a)
η
120
60
0
c)
η
N
150
100
50
0
b)
η
400
600
800
1000
$M_{\gamma_i \gamma_k}$ [MeV]
80
40
0
d)
η
400
600
800
1000
$M_{\gamma_3 \gamma_4}$ [MeV]

Fig. 2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4
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G
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1600
2000
2400
2800
$M_{\eta\eta}$ [MeV]

Fig. 3

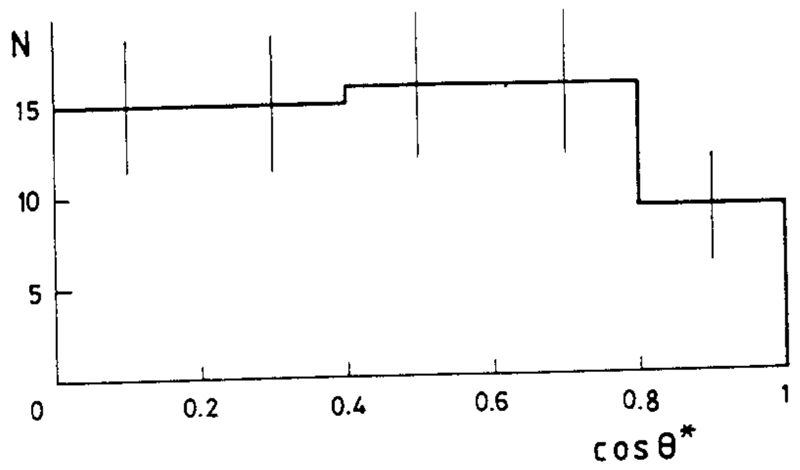

Fig. 4

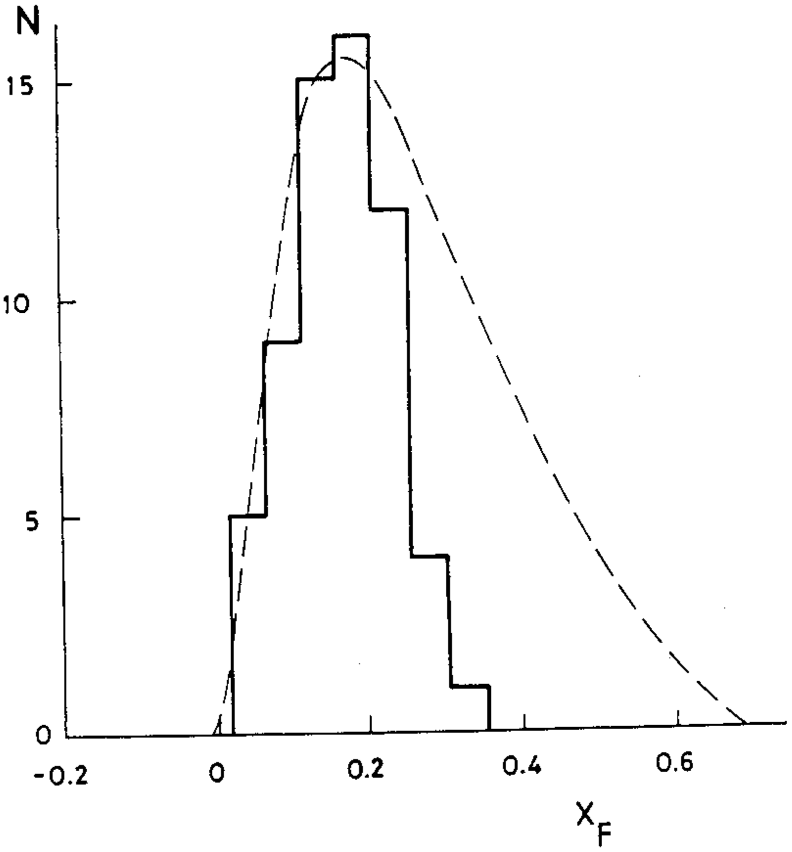

Fig. 5