EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PRODUCTION OF 3.1 GeV/c^2 RESONANCE WITH 24 GeV/c PROTONS

F. Binon*), C. Bricman*), P. Duteil†), M. Gouanère**), J. Jansen*), G. Massas††), J.P. Lagnaux*), J.P. Peigneux**), D. Sillou**), M. Spighel**), J.P. Stroot*) and P. Vilain†††)

IISN (Belgium)-LAPP(Annecy) Collaboration

ABSTRACT

The production of 3.1 GeV/c^2 resonance with 24 GeV/c protons has been measured with a symmetric bispectrometer through its decay into e^+e^- pairs.

(Submitted to Physics Letters B)

Geneva - 26 January 1976

*) IISN, Belgium, visitor at CERN.

**) LAPP, Annecy, France, visitor at CERN.

†) CERN, Geneva, Switzerland.

††) CERN Fellow, on leave from LAPP.

†††) CERN Fellow, on leave from IISN.

The production of e^+e^- pairs with an invariant mass around 3 GeV/c^2 has been measured at the CERN PS with a beam of 24 GeV/c protons. The principle of the measurement was to search for pairs of electrons and positrons, each with a large transverse momentum, which would result from the decay of a heavy mass object produced at rest (or nearly so) in the c.m. of the collision. For masses of the decay products rather smaller than the parent one, their angle of emission in a transverse decay depends on the velocity of the c.m. only ($\cos\theta = \beta_{cm}$, i.e. θ = 278 mrad at 24 GeV/c) and their momentum is proportional to the mass of the parent particle.

The experimental set-up is a symmetric focusing bispectrometer. Each arm consists of a triplet of quadrupole lenses to obtain a parallel beam and a vertical bending magnet to create the dispersion necessary for momentum analysis. This part is totally embedded in iron and concrete shielding. A carbon target was used with a length of 3 cm, a height of 2 mm, and a width of 5 mm. It was positioned with the help of thin bronze strings in a vacuum box at the entrance of an auxiliary horizontal bending magnet.

The angle of the spectrometer arms with respect to the incoming proton direction is 195 mrad. The angle of the particles accepted by the spectrometer is 265 mrad with the use of the auxiliary magnet. The solid angle of acceptance of each arm is 1.1×10^{-3} sr.

All detectors are kept outside the main shielding structure. Immediately behind the concrete are placed the scintillation hodoscopes and multiwire proportional chambers, with 1 mm wire spacing for determining the position and the angle of emission of the particles. Behind these, threshold Čerenkov counters are used for particle identification. They are supplemented by lead-glass shower counters to improve rejection in the determination of electron events. Data taking is triggered by the left-right coincidence between defining scintillation counters. Precise timing is obtained by a slower TAC-ADC chain operating on specially designed counters with a FWHM resolution of 0.6 nsec. Details of the complete detection system will be published elsewhere.

Incident proton beam intensity during a e^+e^- search of about one hundred hours was 3×10^{11} per burst of 0.4 sec duration. The primary proton beam intensity is monitored with a calibrated secondary emission chamber. The number of interactions in the target is continuously monitored with two directional scintillator telescopes.

The calibration of beam monitors, and the evaluation of efficiencies and solid angles of acceptance of the bispectrometer, have been globally ascertained by a measurement of the elastic scattering cross-section at 265 mrad of 7.85 GeV/c protons on the hydrogen of a polyethylene target. The agreement with existing data is better than 30%.

Twenty three coincidences over a window of 10 nsec have been registered. These had satisfied the following requirements in each arm:

a) the electron threshold counter is triggered;

b) the energy deposited by each particle in the shower counters is larger than 4 GeV.

Of these events, 19 were grouped in a time bin of less than 1 nsec. Events outside this range indicate a probability of about half an accidental coincidence per nanosecond bin. Further analysis shows:

a) the momentum of each particle is well inside the spectrometer acceptance;

b) all pairs come from the target;

c) the pairs are emitted with a small longitudinal momentum in agreement with the fact that the mean observation angle in each spectrometer arm is 265 mrad and not 278 mrad, which would be the value for pairs produced at rest in the centre of mass.

The invariant mass distribution of these events is shown in Fig. 1, together with the mass acceptance of the set-up. This acceptance is 350 MeV/c^2 FWHM. Seventeen out of nineteen events are grouped around 3.08 GeV/c^2 with a standard deviation of 37 MeV/c^2. The invariant differential cross-section for the production of the 3.1 GeV/c^2 resonance [1] with a mean longitudinal momentum $\langle p_L \rangle_{cm}$ of 0.14 GeV/c and a zero mean transverse momentum, has been evaluated to be

$$\frac{E}{\pi} \cdot \frac{\partial^3\sigma(p + N \to 3.1)}{\partial p_L \, \partial p_T^2} = \left(3.03^{+1.20}_{-0.86}\right) \times 10^{-34} \; cm^2/GeV^2/c^3 \text{ per free nucleon}$$

using 0.069 as the value for the branching ratio ($3.1 \to e^+e^-/3.1 \to$ all) [2].

The total production cross-section has been obtained by using an $e^{-1.6\,p_T^2}$ transverse momentum distribution as measured by the MIT-BNL group [3] and a longitudinal momentum distribution which is constant up to x = 0.3 and which varies like e^{-6x} for larger x, as measured in Serpukhov [4]. It amounts to

$$\sigma_T(p + N \to 3.1 + \ldots) = 1.27^{+0.50}_{-0.36} \; 10^{-33} \; cm^2 \text{ per free nucleon },$$

the scaling factor used between C target and free nucleon being 9.5, the ratio of total absorption cross-sections of protons on C and H. The quoted errors do not include the possible effect of the hypothesis on the phase-space distribution of the 3.1 resonance.

All available data for production in proton interactions are plotted as a function of $\sqrt{s}$ in Fig. 2. As the value of the 28.5 GeV/c cross-section [1, 3] is given as an order of magnitude only, with no correction for efficiency, no error is quoted [4]. All other data have been recalculated using the hypotheses described above, in particular the same phase-space distribution and the same nuclear to free nucleon scaling factor. The curve typically shows a threshold region and something like a saturation region. It does not allow a sufficiently accurate determination of the threshold between 5 GeV/c^2 and 7.5 GeV/c^2 total energy to decide about a possible associate production phenomenon. From a study of the influence of Fermi motion on the cross-section below threshold [5], it can be estimated that a cross-section reduction by a factor of 10^2 would be observed at a nominal c.m. energy about 0.7 GeV/c^2 lower than the threshold energy. Taking this reduction factor as the maximum compatible with the data, the upper limit of the threshold energy for 3.1 production is found to be (about) 7.5 GeV/c^2. This value excludes the production of a mass larger than 2.5 GeV/c^2 in association with the 3.1 GeV/c^2 resonance and two nucleons.

We thank the CERN PS operation group for its help during the installation of the experiment and for a very careful and reliable tuning of the proton beam.

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Figure captions

Fig. 1 : Mass distribution of e^+e^- pairs. The curve shows the relative mass acceptance of the set-up.

Fig. 2 : Available data on nucleon production of 3.1 GeV/c resonance:

1. the present work;
2. no error quoted, Refs. 1 and 3;

3 to 8. Refs. 6 to 11.

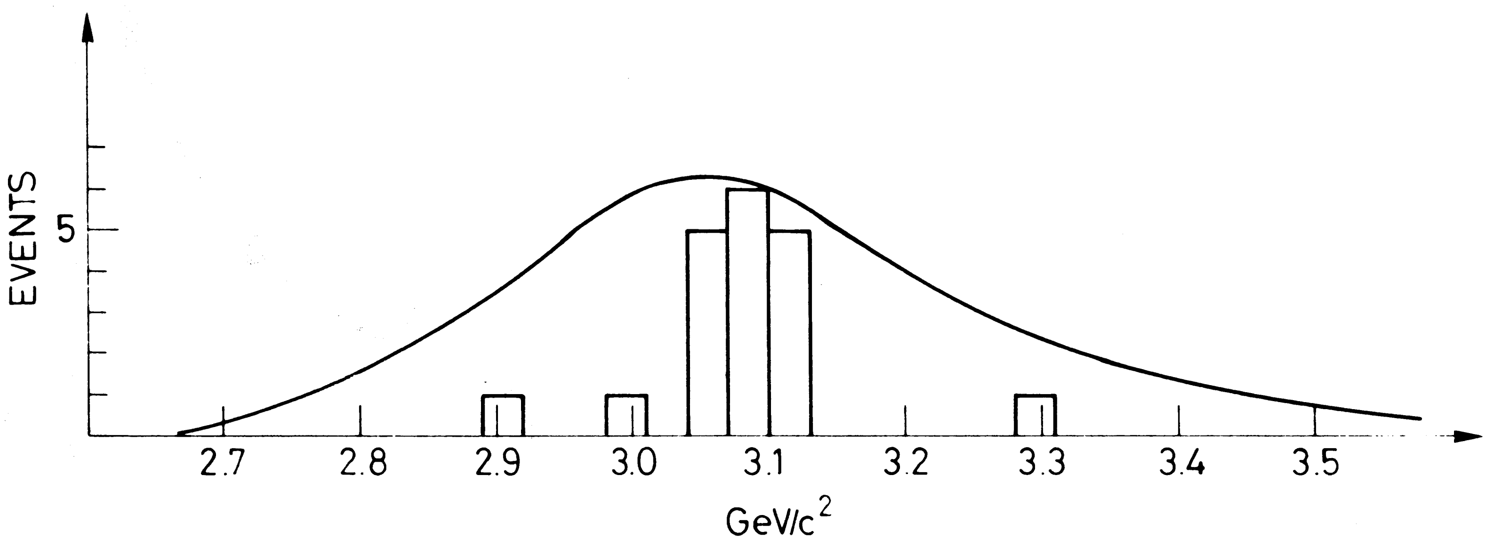

Fig. 1

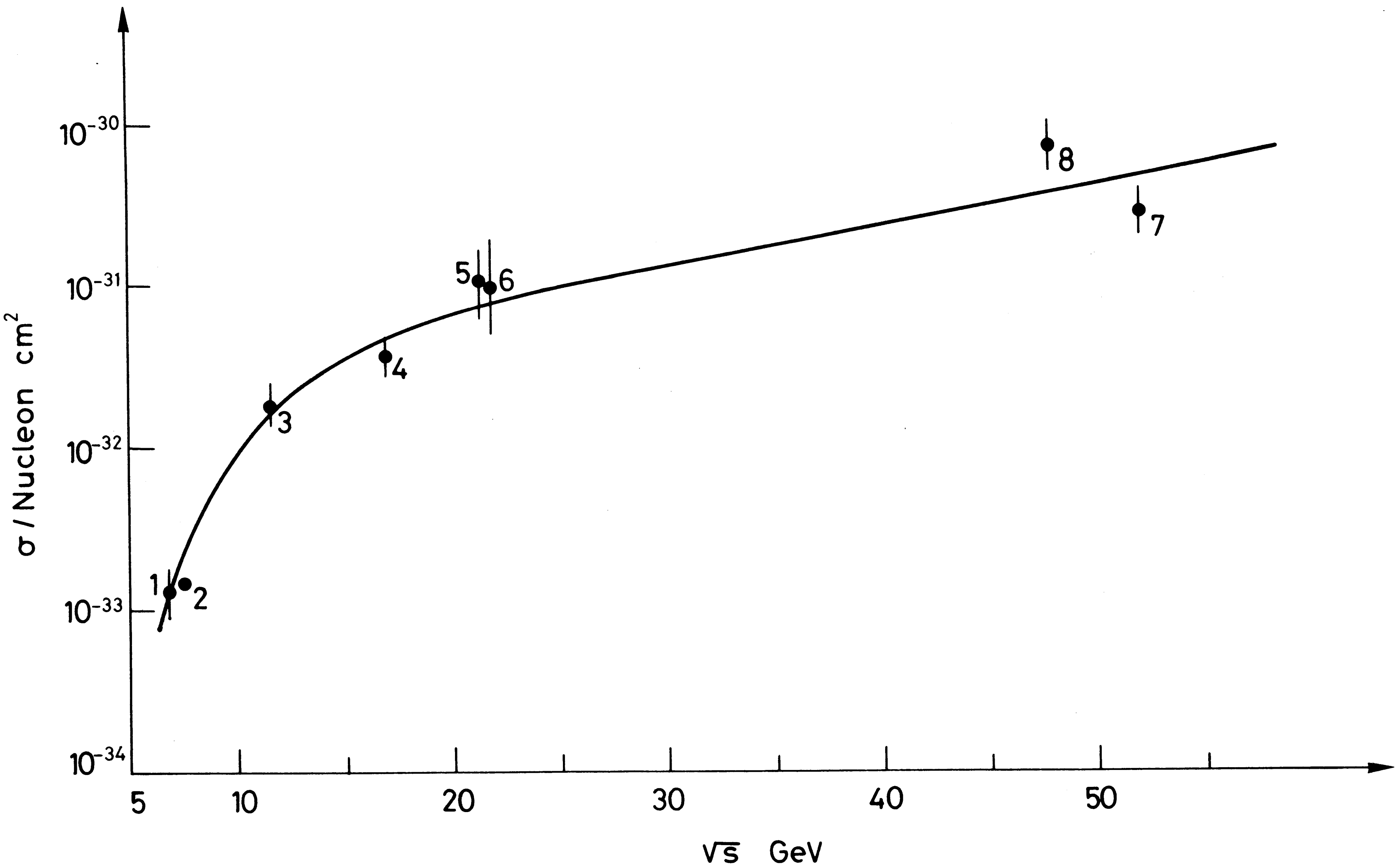
σ / Nucleon cm²
10⁻³⁰
10⁻³¹
10⁻³²
10⁻³³
10⁻³⁴
5
10
20
30
40
50
√s GeV
1
2
3
4
5
6
7
8

Fig. 2