



COHERENT  $A_2^-$  PRODUCTION ON NUCLEI  
OBSERVED IN THE  $K^-K_S^0$  DECAY CHANNEL AT 17.2 GeV/c

*(CERN-Munich Collaboration)*

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ABSTRACT

We have studied  $A_2^-$  production by  $\pi^-$  on a nuclear target in the  $K^-K_S^0$  decay channel, where the  $A_2^-$  is observed above a small background at 17.2 GeV/c incident momentum. Direct confirmation of coherent  $A_2$  ( $J^P = 2^+$ ) production has been found.

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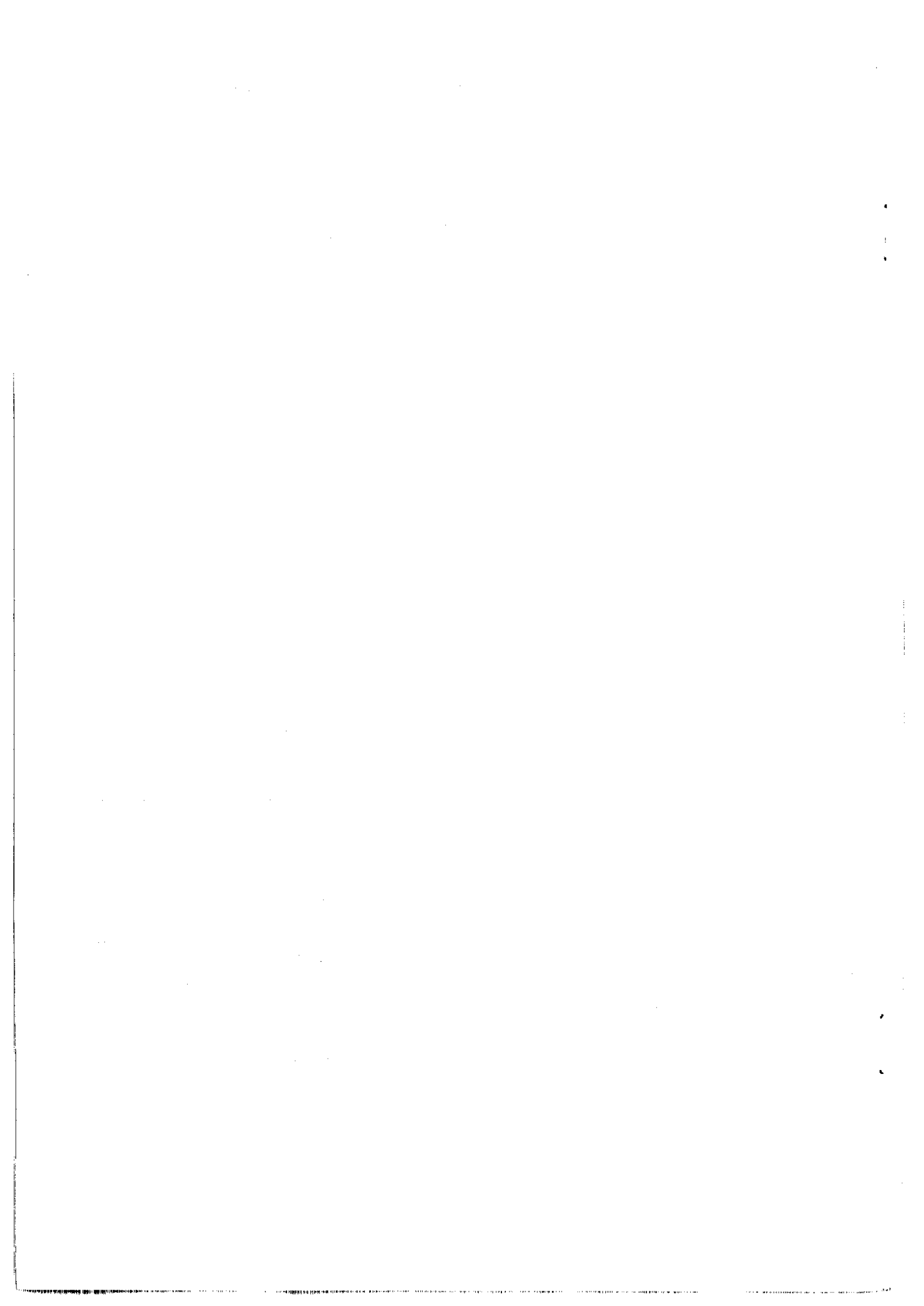
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shower counters F which veto events with  $\pi^0$ 's and charged recoil particle multiplicities above one. A 36-element hodoscope of overlapping scintillation counters measured the azimuthal angle of the recoil proton, thus allowing for  $|t| > 0.08 \text{ GeV}/c^2$  an off-line determination of the coplanarity of the reaction. Multiwire proportional chambers (MWPC) in front of and behind the target improved the accuracy of vertex determination in the magnetic field. The pulse height in a 1 mm thick scintillation counter K directly behind the target allowed the determination of the charged particle multiplicity. The counters V and H in front of and inside the spectrometer magnet (AEG) vetoed events with additional particles missing the spectrometer aperture. A double-layer scintillator hodoscope EG measured the charged particle multiplicity of particles traversing the spectrometer. The multicell Čerenkov counters  $\check{C}_2$  and  $\check{C}_3$  were not used in this analysis.

The trigger for the reaction (1) was: a beam pion defined by signals from the scintillation counters  $B_1 \cdot B_2 \cdot B_3 \cdot \overline{B_4}$  and the Čerenkov  $\check{C}_1$ , a hit from one charged particle in the K-counter, three hits in the EG array, an interaction signalled by a hit in a scintillation counter I -- which has a hole at the position of the beam --, zero or one signal in veto counters F and no hit in the veto counter D. About 500,000 such triggers were collected.

### 3. DATA ANALYSIS

In a geometry reconstruction program events were selected using the following criteria: i) three secondaries of total charge -1; ii) one of the negative secondaries forms a vertex with the beam track inside the target; iii) the other two tracks come from a second vertex downstream of the K-counter. The invariant mass  $m_{\pi^+\pi^-}$  of the latter two particles showed a prominent  $K_S^0$  peak. Events were selected around the  $K_S^0$  peak in the mass interval  $0.486 < m_{\pi^+\pi^-} < 0.510 \text{ GeV}$ . Interpreting the negative track not associated with the  $K_S^0$  as a  $K^-$ , an appropriate cut in the missing mass recoiling to the  $K^-K_S^0$  system is applied, essentially requiring the target nucleus to have the same mass after the interaction. This procedure leaves approximately 5000 events in the mass region  $1.21 \leq m_{K_S^0 K^-} \leq 1.41 \text{ GeV}$ .

The intensity and angular distribution were calculated using a maximum likelihood method to correct for the limited geometrical acceptance of our apparatus as described in Chabaud et al. [4].

#### 4. RESULTS AND DISCUSSION

The distribution of  $K^-K_S^0$  acceptance-corrected invariant mass is plotted in Fig. 2. It is parametrized by a spin-2 Breit-Wigner form on an incoherent linear background contribution. The fit gives a mass =  $1320 \pm 2$  MeV and a width  $\Gamma = 106 \pm 4$  MeV with a  $\chi^2/\text{NDF} = 4.6/7$  in agreement with the resonance parameters compiled by the Particle Data Group [9].

We note the small background contribution which is 14% of the total number of events in the  $1.21 \leq m_{K^-K_S^0} \leq 1.41$  GeV region.

The distribution of  $t' = |t - t_{\min}|$  for all events in the  $A_2$  mass interval 1.21-1.41 GeV (Fig. 3a) exhibits the coherent  $A_2$  production on carbon. It has a dip in the forward direction characteristic of helicity flip  $|\Delta M| = 1$  production; it then increases with  $t'$  and after reaching a maximum falls off with the nuclear form factor as  $e^{-\alpha t'}$ . Above  $t = 0.1$  GeV<sup>2</sup> the incoherent part takes over. We have fitted the data with a two-term form

$$\frac{d\sigma}{dt'} = a t' e^{-\alpha t'} + b t' e^{-\beta t'},$$

where the exponent  $\alpha$  of coherent production is  $\alpha = (43 \pm 2)$  (GeV/c)<sup>-2</sup> and the exponent of incoherent production is  $\beta = (8 \pm 1)$  (GeV/c)<sup>-2</sup>, with  $\chi^2/\text{NDF} = 16.5/15$ . The first term accounts for  $(30 \pm 1)\%$  of the cross-section integrated over  $t'$ .

The exponents of the coherent ( $\alpha$ ) and incoherent ( $\beta$ ) part of the  $t'$  distribution are compatible with the naive expectation for coherent production  $\alpha = \beta A^{2/3}$  and the measurements of the  $A_2^\pm$  production on hydrogen [4,8], respectively.

For  $t' \geq 0.08$  GeV we are able to separate, in our sample, events produced off hydrogen from those produced off carbon and oxygen atoms in the butanol target. This is done by requiring coplanarity between the  $K^-K_S^0$  system and the recoil proton as measured with the coplanarity hodoscope around the target (Fig. 4). For a cut in the coplanarity angle  $\Delta\phi$  of  $\pm 10^\circ$  we estimate a background of  $(48 \pm 7)\%$  from events not coming from free hydrogen.

This background contains events on bound protons, genuine inelastic events, and a very small flat contribution caused by delta-rays accidentally hitting the coplanar hodoscope elements. It is indicated by a dashed line in Fig. 4.

The  $t'$  distribution for events with the  $\pm 10^\circ$   $\Delta\phi$  cut is shown in Fig. 3b; a fit with  $b' e^{-\beta' t'}$  yields  $\beta' = (7.8 \pm 0.2) (\text{GeV}/c)^{-2}$ ,  $\chi^2/\text{NDF} = 2/8$ , in agreement with the incoherent part of the previous distribution.

The simultaneous measurement of  $A_2$  production on hydrogen and on butanol allows us to estimate the cross-section on butanol from earlier measurements of the hydrogen cross-section [8] and the butanol/hydrogen event ratio as observed in this experiment. We obtain  $\sigma_B = (122 \pm 30) \mu\text{b}$  for the  $A_2^-$  production on butanol ( $\text{C}_4\text{H}_9\text{OH}$ ) with a subsequent decay into a  $K^-K_S^0$  channel. Further, assuming that the cross-section on the single oxygen nucleus in the butanol molecule has the value of  $^{16}/_{12}$  times the carbon cross-section, we calculate the following values of the coherent and incoherent  $A_2^-$  production cross-section on carbon

$$\left. \begin{array}{l} \sigma_c^{\text{coh}} = (6.9 \pm 1.7) \mu\text{b} \\ \sigma_c^{\text{inc}} = (13.5 \pm 7.5) \mu\text{b} \end{array} \right\} \text{ for the decay channel } A_2 \rightarrow K^-K^0 \begin{array}{l} \downarrow \\ \rightarrow \pi^+\pi^- \end{array}$$

These values refer to the mass range between 1.2 GeV and 1.42 GeV and to the  $t'$  below  $0.8 \text{ GeV}^2/c^2$ . Comparing the coherent cross-section  $\sigma_c^{\text{coh}}$  with the value  $\sigma_H = 1.1 \text{ mb}$  [4] obtained for the same reaction on a hydrogen target, we see again the ratio of  $\sim 6$  compatible with the naive expectation of  $A^{2/3}$  for the coherent production on carbon.

Correcting for the unobserved decay channels ( $A_2 \rightarrow K^-K_L^0$ ,  $K_S^0 \rightarrow \pi^0\pi^0$ ) and taking the branching ratio of  $(4.7 \pm 0.5)\%$  for  $A_2 \rightarrow \bar{K}K$  from ref. [9], we obtain a considerable cross-section of  $(440 \pm 120) \mu\text{b}$  for the  $A_2$  coherent production on carbon. Let us remember that the cross-section for the  $A_1$  coherent production on carbon is of the order of 1 mb [10].

The t-channel moments of the decay angular distribution  $\langle Y_m^l \rangle = \int (d\sigma/d\Omega) Y_m^l(\Omega) d\Omega$  were determined as a function of  $t'$  averaged over the whole  $A_2$  mass interval  $1.21 < m_{K-K_S^0} < 1.41 \text{ GeV}$  (Fig. 5).  $Y_m^l$  are the spherical harmonics,  $\Omega \equiv (\cos \theta, \phi)$

represents the decay angles of the  $K^-$  in the  $K^-K_S^0$  rest system. In the fit to the data all moments up to  $\ell = 4$  corresponding to angular momentum states  $L = 2$  were allowed. All moments except  $\langle Y_0^2 \rangle$ ,  $\langle Y_2^2 \rangle$ ,  $\langle Y_0^4 \rangle$ , and  $\langle Y_2^4 \rangle$  were compatible with zero and neglected in the final fit. No significant variation with momentum transfer  $t'$  is seen in the four non-zero moments, indicating that the mechanism responsible for coherent and incoherent  $A_2$  production is of the same nature. The same moments measured in  $A_2^-$  production at 9.8 and 18.8 GeV [4] and in  $A_2^+$  production at 12.7 GeV [6] on a hydrogen target are compatible with the values found here for  $|t| \gtrsim 0.1 \text{ GeV}^2$ . This suggests the same production mechanism off nuclei and off hydrogen. A strong coherent production of  $A_2$  indicates that this mechanism has a diffractive component.

## 5. CONCLUSIONS

A strong coherent  $A_2^-$  production by  $\pi^-$  on a nuclear target has been observed in the  $A_2^- \rightarrow K^-K_S^0$  decay channel. The cross-section for coherent  $A_2$  production on a carbon nucleus is estimated to be  $\sigma_c^{\text{coh}} = (0.44 \pm 0.12) \text{ mb}$ . The observed decay angular distribution as a function of  $t'$  suggests the same  $A_2$  production mechanism off nuclei and off hydrogen.

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Figure captions

- Fig. 1 : Schematic view of the apparatus. In the lower part, anticoincidence counters and the coplanarity hodoscope around the target are shown enlarged.
- Fig. 2 :  $K^-K_S^0$  mass spectrum. The solid line is obtained from a fit using a Breit-Wigner form on a linear background contribution which is represented by a dashed line.
- Fig. 3 : Differential cross-sections for  $\pi^-$  nucleus  $\rightarrow (A_2 \rightarrow K^-K_S^0)$  nucleus as a function of  $t'$ :
- a) for all the events in the mass interval  $1.21 \text{ GeV} < m_{\overline{KK}} < 1.41 \text{ GeV}$ ;
  - b) for events in the same mass interval but with a coplanarity cut  $|\Delta\phi| \leq 10^\circ$ .
- The curves are the results of fits to the exponential forms.
- Fig. 4 : The distribution of the coplanarity angle  $\Delta\phi$ .  $\Delta\phi$  is the difference between the azimuth of the missing recoil momentum and the azimuth corresponding to the closest hit in the hodoscope around the target.
- Fig. 5 : Normalized moments,  $\langle Y_m^\ell \rangle$ , as a function of  $t'$ . All moments are normalized such that  $\langle Y_0^0 \rangle = 1/\sqrt{4\pi}$ .

$$\text{TRIGGER} = B \cdot F(\leq 1) \cdot K(=1) \cdot I \cdot \bar{V} \cdot \bar{H} \cdot EG (=3) \cdot \bar{D}$$

$$B = \dot{C}_1 \cdot B_1 \cdot B_2 \cdot B_3 \cdot \bar{B}_4$$

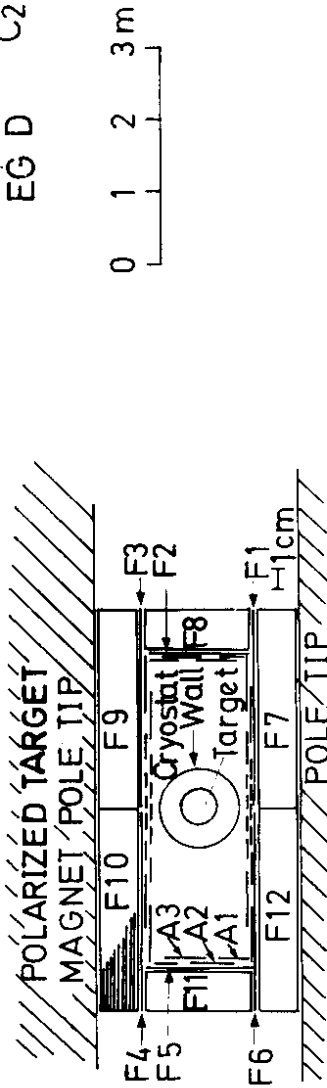
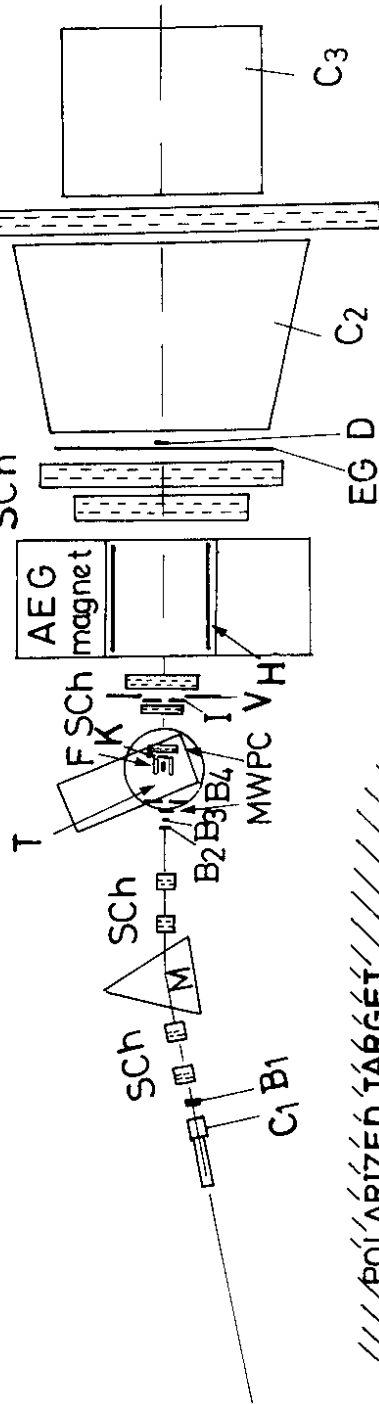


Fig. 1

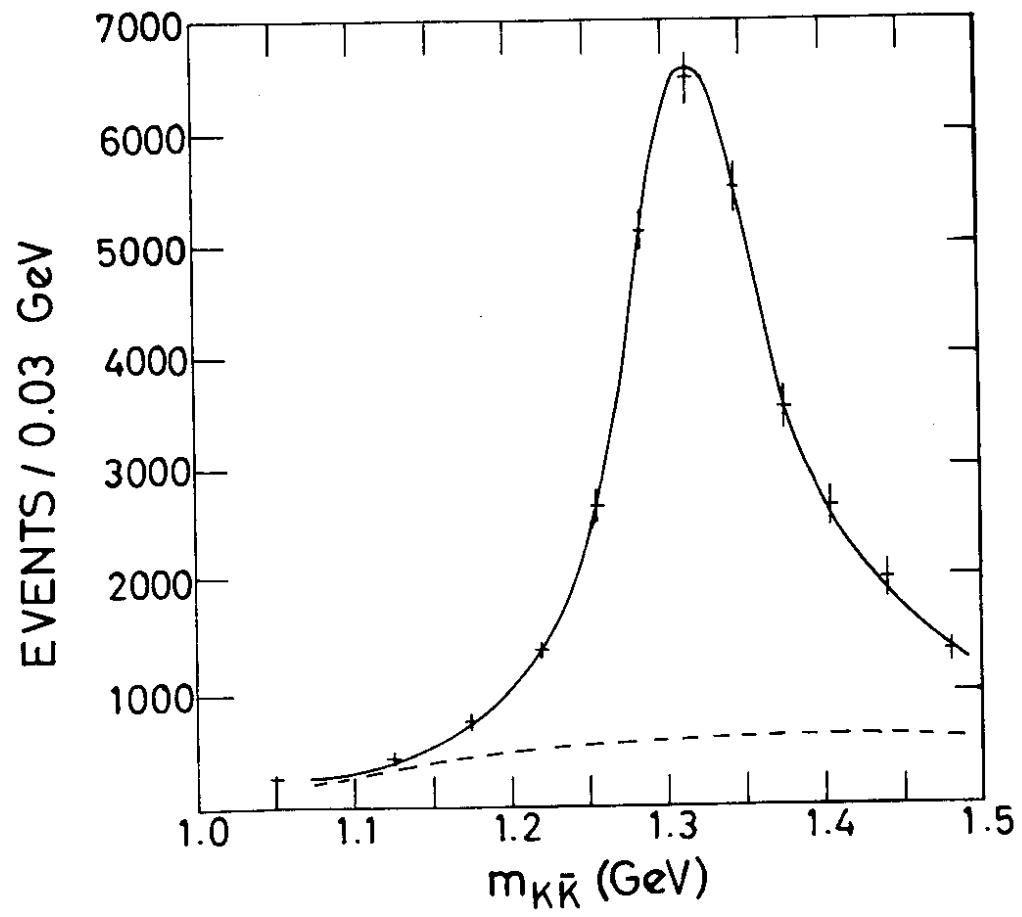


Fig. 2

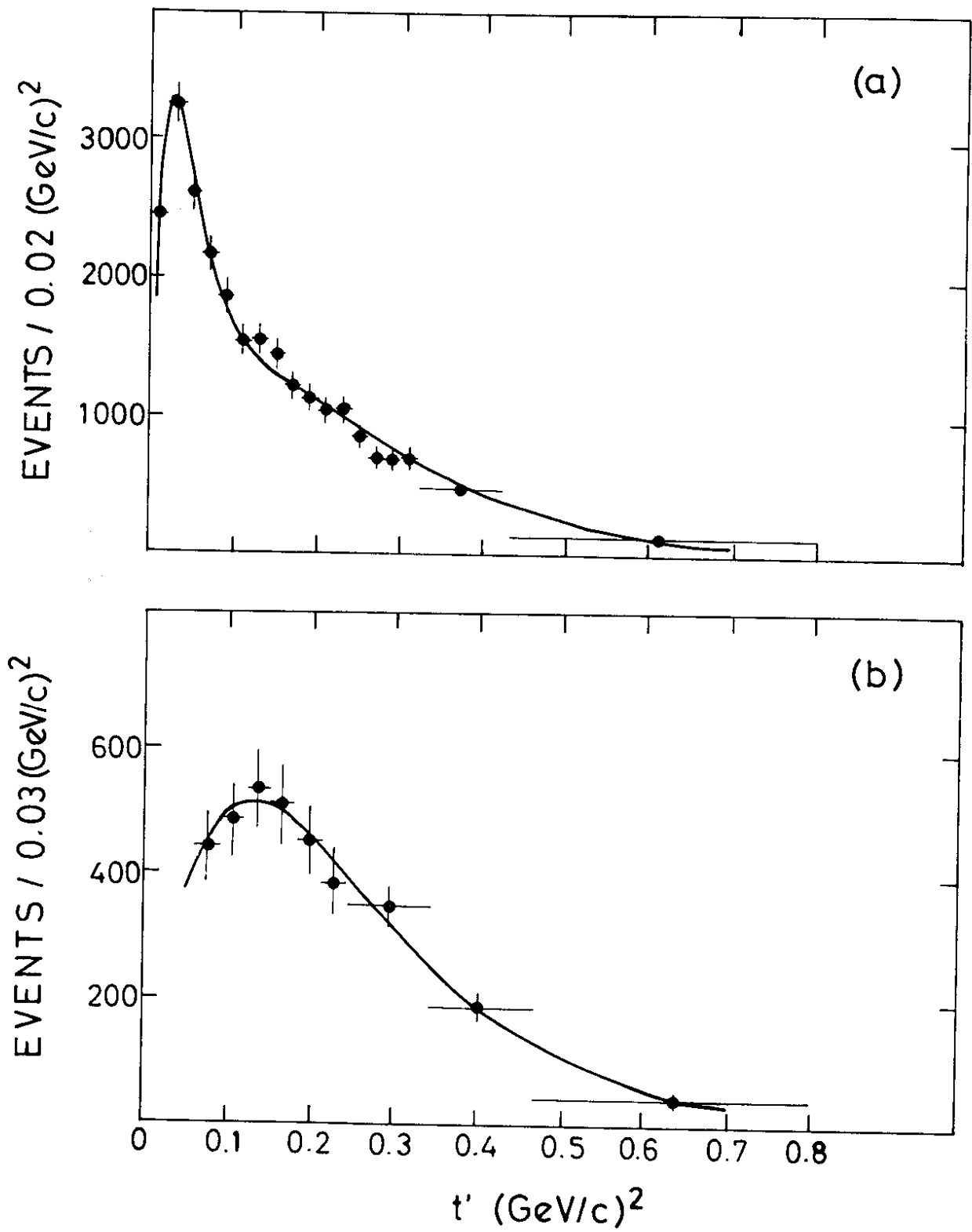


Fig. 3

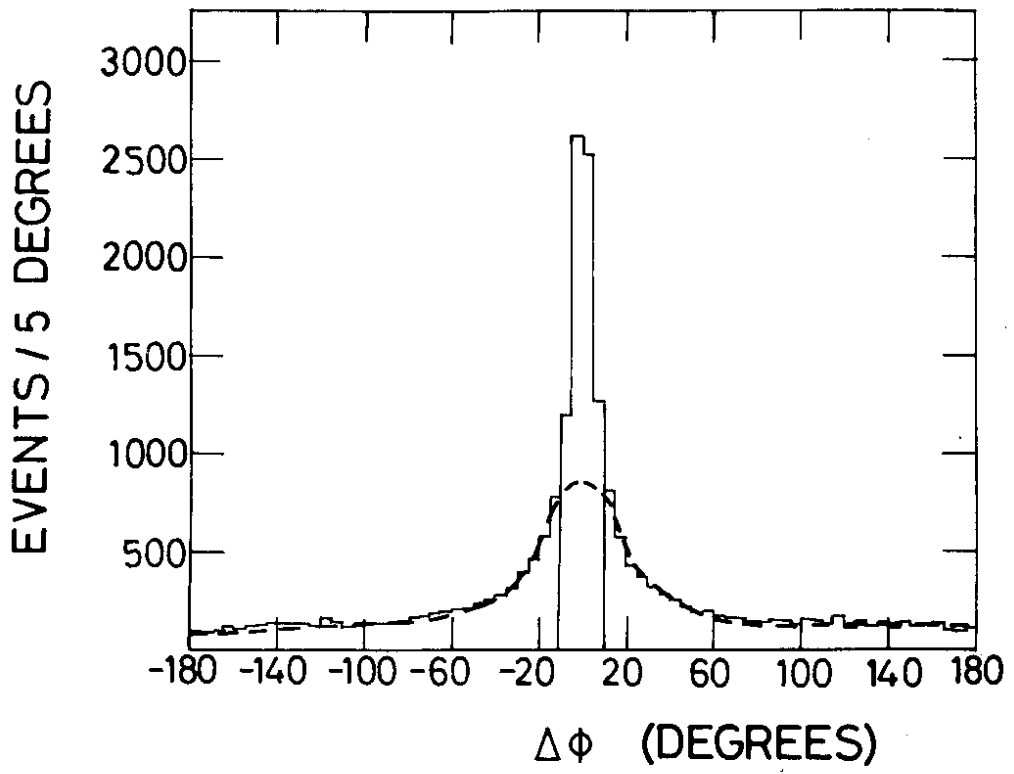


Fig. 4

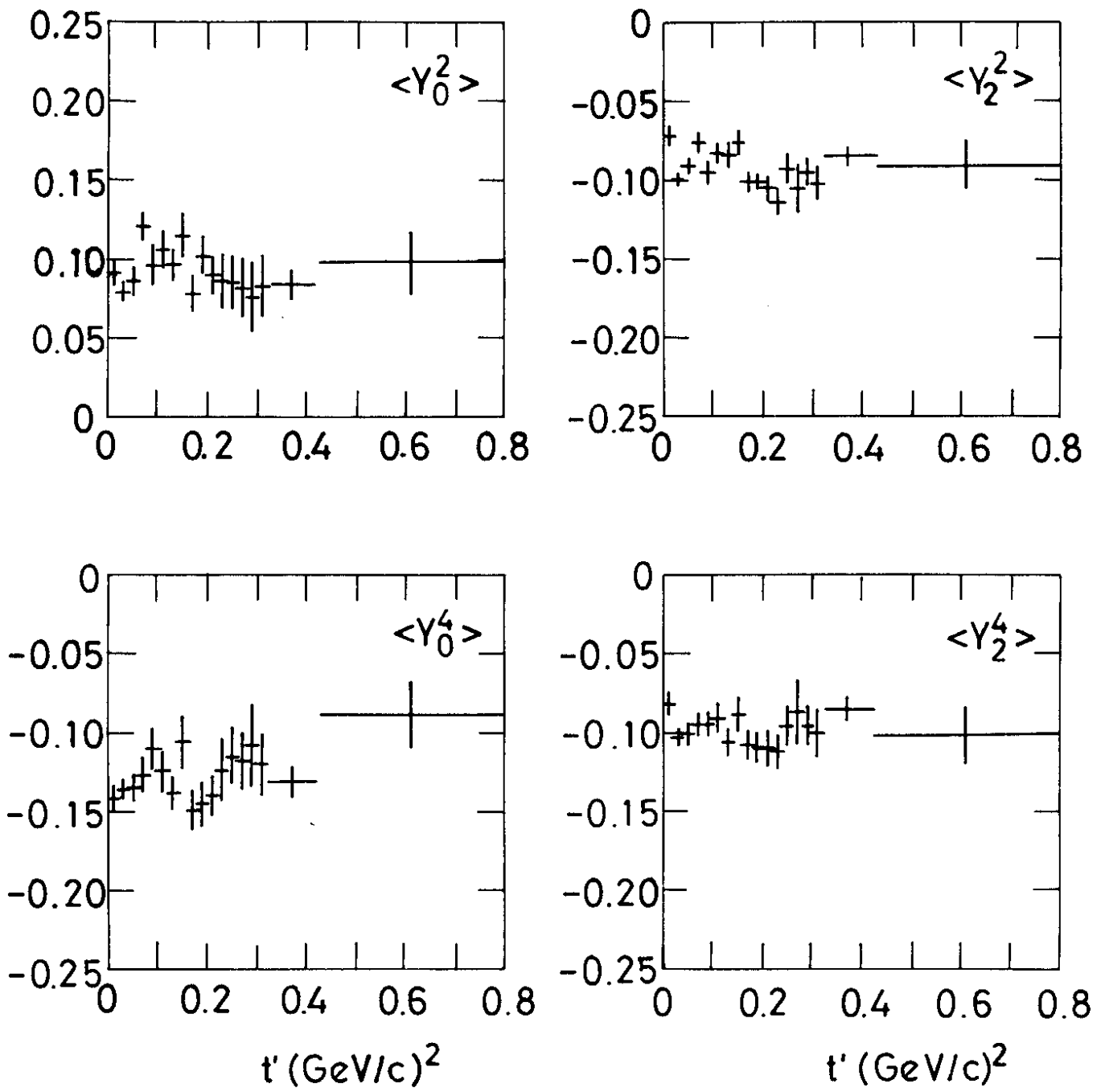


Fig. 5