New results from the WA102 experiment:

A partial wave analysis of the centrally produced $K\overline{K}$ and $\pi\pi$ systems

Andrew Kirk

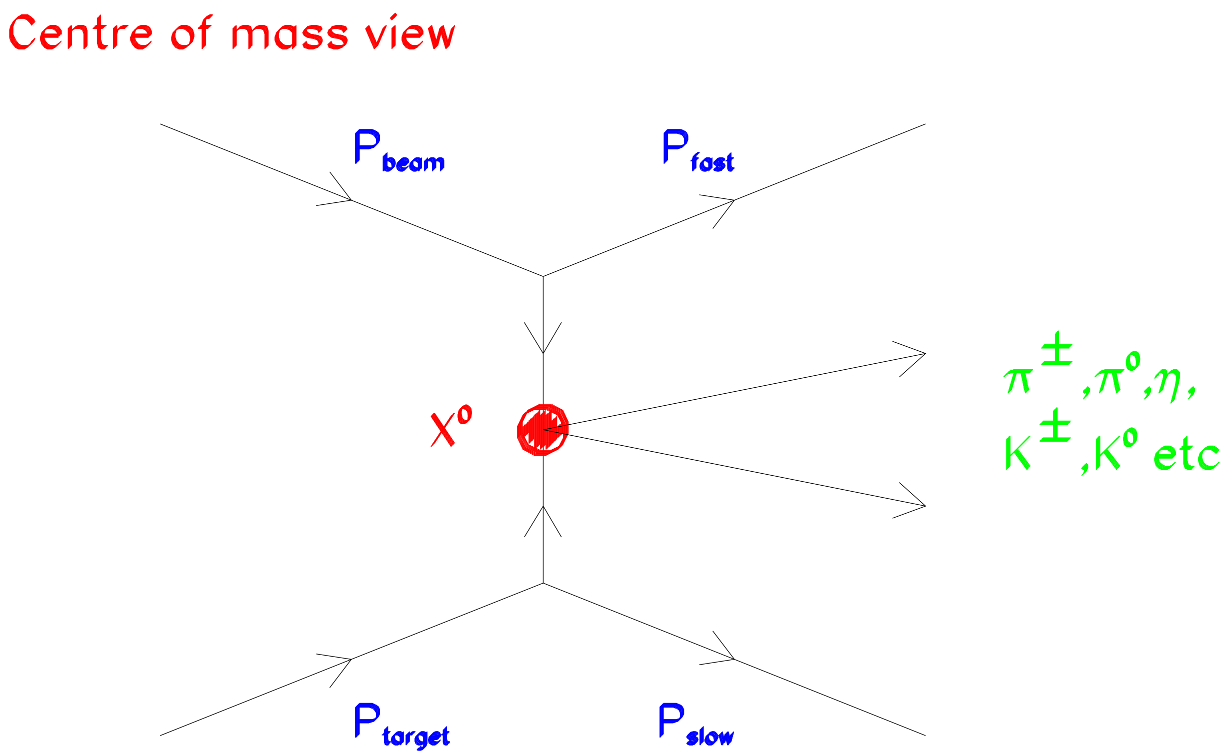
University of Birmingham

1. An introduction to the WA102 experiment
2. A partial wave analysis of K^+K^- and $K^0_SK^0_S$
3. A partial wave analysis of $\pi^+\pi^-$ and $\pi^0\pi^0$
4. An update of the glueball-$q\overline{q}$ filter
5. Summary

Experiment WA102 has studied exclusive final states in the reaction

$$pp \to p_f p_s (X^0) \tag{1}$$

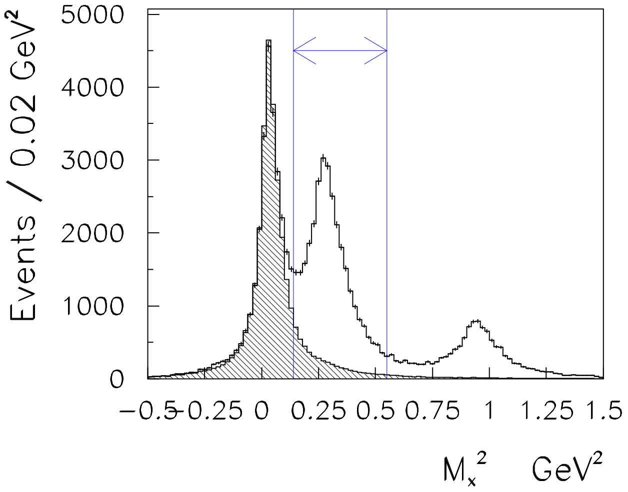
at 450 GeV/c



which is predicted to be a source of gluonic final states via double Pomeron exchange.

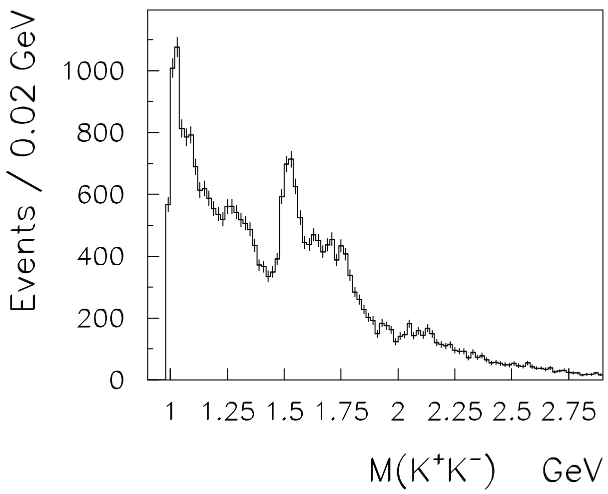
Selection of the reaction $pp \to p_f p_s (K^+K^-)$

The K^+K^- channel is selected using Cerenkov information and energy balance



The residual contamination from the $\pi^+\pi^-$ channel is small and does not effect the results.

The K^+K^- mass spectrum

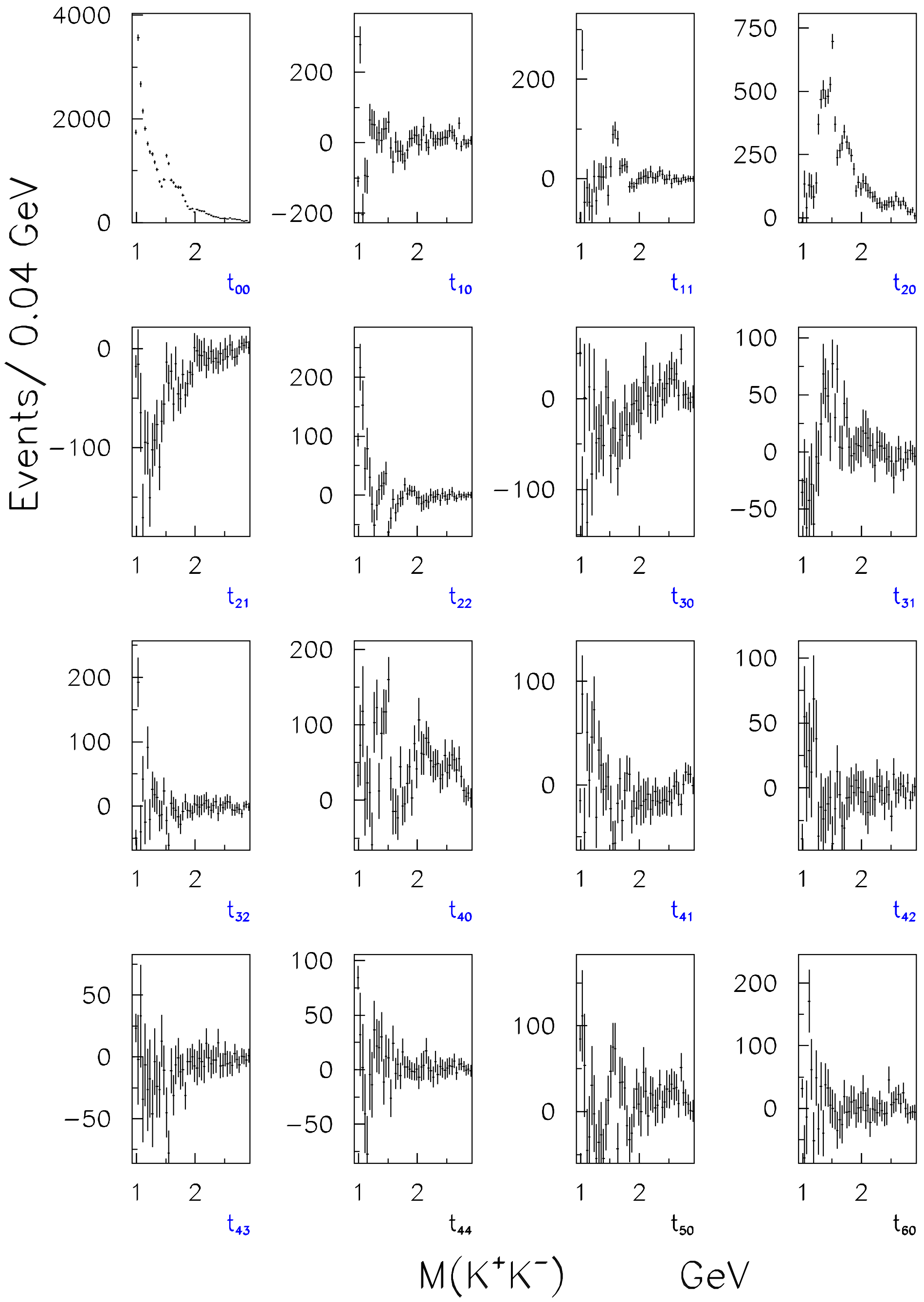


PWA of $pp \to p_f p_s(K^+K^-)$

The acceptance corrected moments, defined by

$$I(\Omega) = \sum_L t_{L0} Y_L^0(\Omega) + 2 \sum_{L,M>0} t_{LM} Re\{Y_L^M(\Omega)\} \qquad (2)$$

have been calculated



PWA in the reflectivity basis

S, P and D waves with $m = 0, 1$ and reflectivity $\varepsilon = \pm 1$

Expressions relating the moments and the waves

$$
\begin{aligned}
\sqrt{4\pi}t_{00} &= |S_0^-|^2 + |P_0^-|^2 + |P_1^-|^2 + |P_1^+|^2 + |D_0^-|^2 + |D_1^-|^2 + |D_1^+|^2 \\
\sqrt{4\pi}t_{10} &= 2|S_0^-||P_0^-|cos(\phi_{S_0^-} - \phi_{P_0^-}) + \tfrac{4}{\sqrt{5}}|P_0^-||D_0^-|cos(\phi_{P_0^-} - \phi_{D_0^-}) \\
&\quad + \tfrac{2\sqrt{3}}{\sqrt{5}}\{|P_1^-||D_1^-|cos(\phi_{P_1^-} - \phi_{D_1^-}) + |P_1^+||D_1^+|cos(\phi_{P_1^+} - \phi_{D_1^+})\} \\
\sqrt{4\pi}t_{11} &= \sqrt{2}|S_0^-||P_1^-|cos(\phi_{S_0^-} - \phi_{P_1^-}) - \tfrac{\sqrt{2}}{\sqrt{5}}|P_1^-||D_0^-|cos(\phi_{P_1^-} - \phi_{D_0^-}) \\
&\quad + \tfrac{\sqrt{6}}{\sqrt{5}}|P_0^-||D_1^-|cos(\phi_{P_0^-} - \phi_{D_1^-}) \\
\sqrt{4\pi}t_{20} &= \tfrac{2}{\sqrt{5}}|P_0^-|^2 - \tfrac{1}{\sqrt{5}}(|P_1^-|^2 + |P_1^+|^2) + \tfrac{\sqrt{5}}{7}(2|D_0^-|^2 + |D_1^-|^2 + |D_1^+|^2) \\
&\quad + 2|S_0^-||D_0^-|cos(\phi_{S_0^-} - \phi_{D_0^-}) \\
\sqrt{4\pi}t_{21} &= \tfrac{\sqrt{6}}{\sqrt{5}}|P_1^-||P_0^-|cos(\phi_{P_1^-} - \phi_{P_0^-}) + \tfrac{\sqrt{10}}{7}|D_1^-||D_0^-|cos(\phi_{D_1^-} - \phi_{D_0^-}) \\
&\quad + \sqrt{2}|S_0^-||D_1^-|cos(\phi_{S_0^-} - \phi_{D_1^-}) \\
\sqrt{4\pi}t_{22} &= \tfrac{\sqrt{3}}{\sqrt{10}}(|P_1^-|^2 - |P_1^+|^2) + \tfrac{\sqrt{15}}{7\sqrt{2}}(|D_1^-|^2 - |D_1^+|^2) \\
\sqrt{4\pi}t_{30} &= -\tfrac{6}{\sqrt{35}}\{|P_1^-||D_1^-|cos(\phi_{P_1^-} - \phi_{D_1^-}) + |P_1^+||D_1^+|cos(\phi_{P_1^+} - \phi_{D_1^+})\} \\
&\quad + \tfrac{6\sqrt{3}}{\sqrt{35}}|P_0^-||D_0^-|cos(\phi_{P_0^-} - \phi_{D_0^-}) \\
\sqrt{4\pi}t_{31} &= \tfrac{6}{\sqrt{35}}|P_1^-||D_0^-|cos(\phi_{P_1^-} - \phi_{D_0^-}) + \tfrac{4\sqrt{3}}{\sqrt{35}}|P_0^-||D_1^-|cos(\phi_{P_0^-} - \phi_{D_1^-}) \\
\sqrt{4\pi}t_{32} &= \tfrac{\sqrt{6}}{\sqrt{7}}\{|P_1^-||D_1^-|cos(\phi_{P_1^-} - \phi_{D_1^-}) - |P_1^+||D_1^+|cos(\phi_{P_1^+} - \phi_{D_1^+})\} \\
\sqrt{4\pi}t_{40} &= \tfrac{6}{7}|D_0^-|^2 - \tfrac{4}{7}(|D_1^-|^2 + |D_1^+|^2) \\
\sqrt{4\pi}t_{41} &= \tfrac{2\sqrt{15}}{7}|D_0^-||D_1^-|cos(\phi_{D_0^-} - \phi_{D_1^-}) \\
\sqrt{4\pi}t_{42} &= \tfrac{\sqrt{10}}{7}(|D_1^-|^2 - |D_1^+|^2)
\end{aligned}
$$

Overall phase for each reflectivity is indeterminate

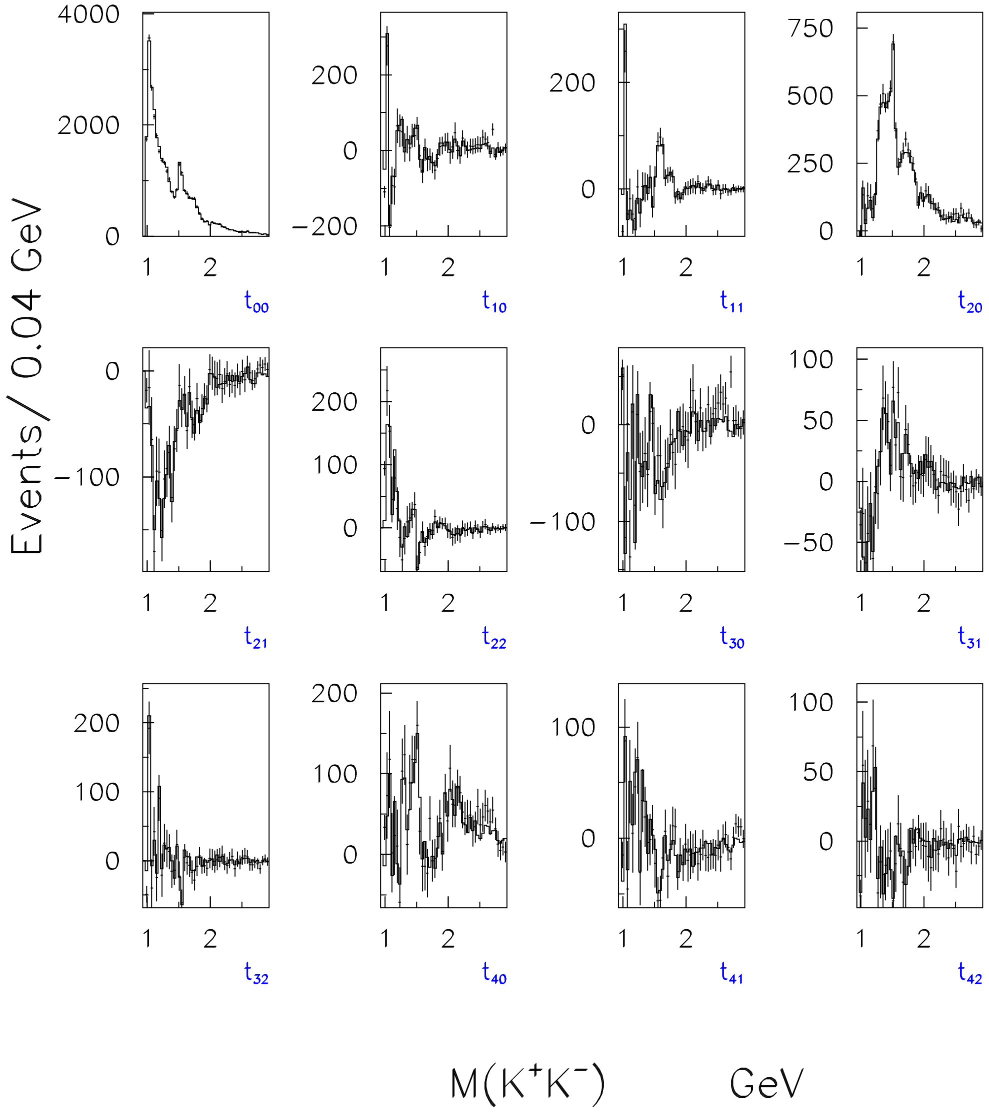
Therefore, $\phi_{S_0^-}$ and $\phi_{P_1^+}$ have been set to zero

12 parameters to be determined

Results of the PWA

The PWA analysis has been performed in 40 MeV mass bins using an event-by-event maximum likelihood method.

The moments calculated from the partial amplitudes are shown superimposed on the experimental moments.

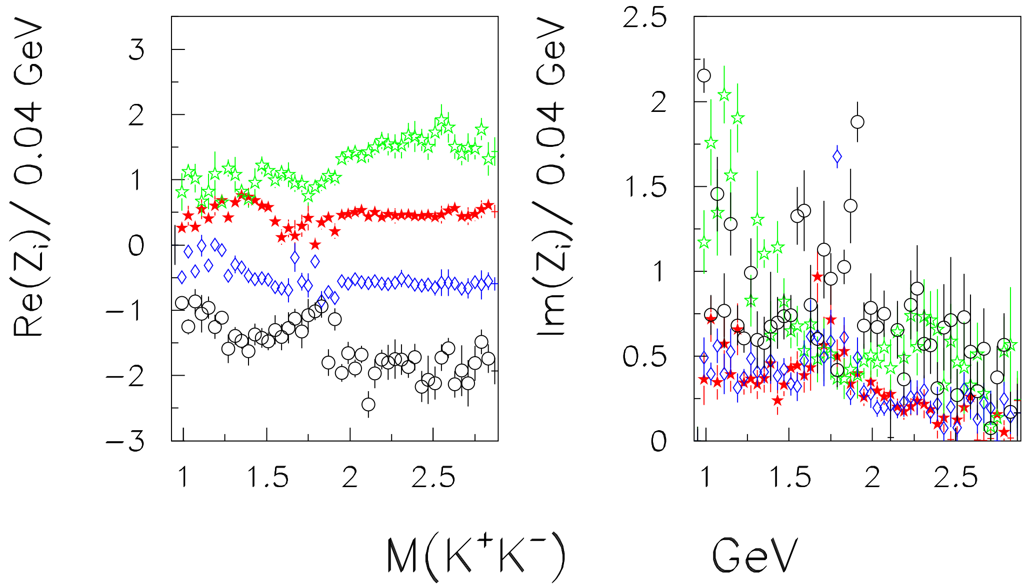


The results of the PWA reproduce well the moments.

Ambiguities

For S, P and D waves there are eight solutions.

The four complex roots, Z_i, after the linking procedure



Imaginary parts give little help in the linking procedure.

Real parts are well separated in most places.

Possible to identify unambiguously all the PWA solutions in the whole mass range.

If swap roots in 1.8 GeV region S-wave $\leftrightarrow$ P-wave and mass spectra look unphysical.

Zeros do not cross the real axis $\rightarrow$ no bifurcation of the solutions.

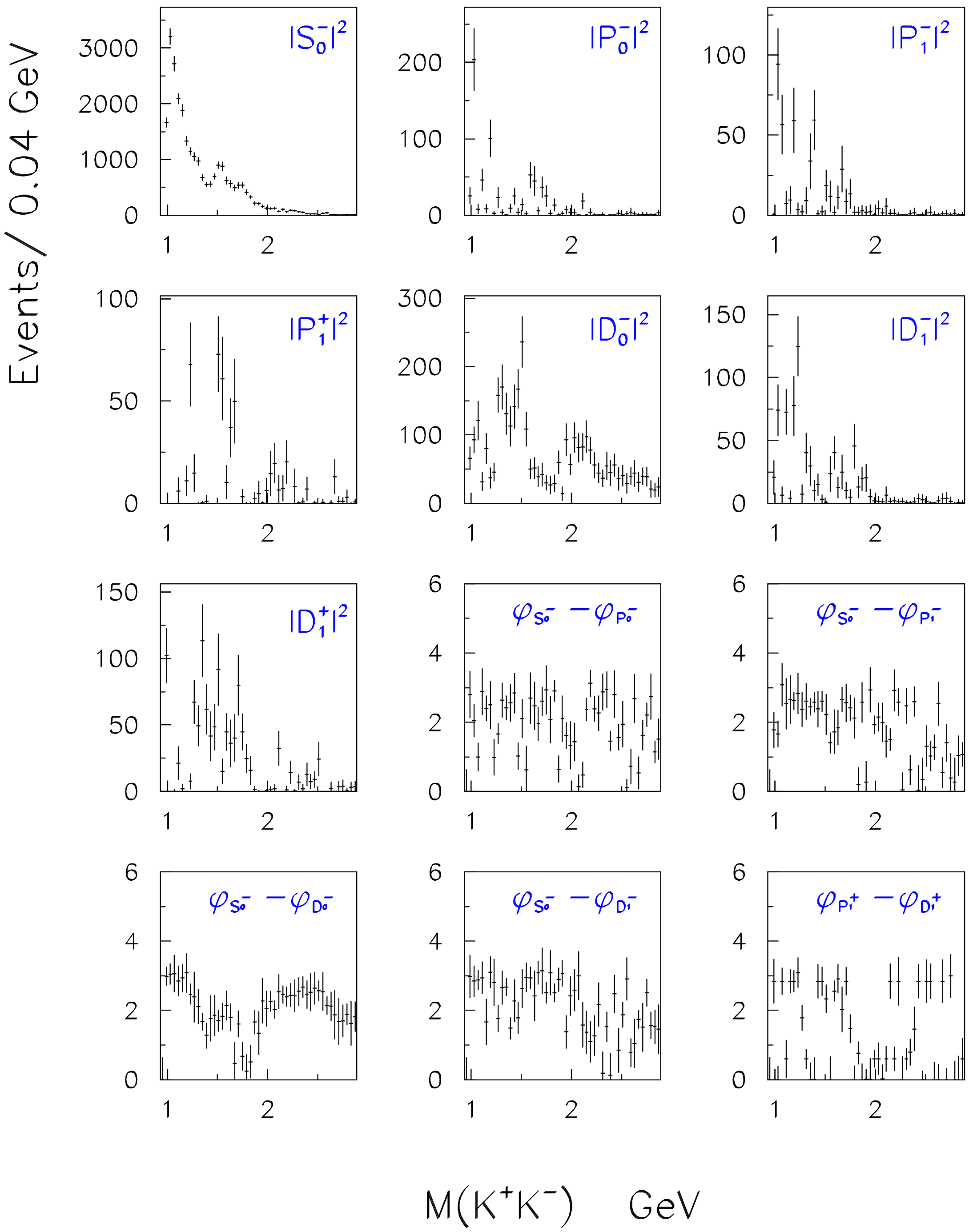
The waves

5 Solutions P-wave dominant at threshold

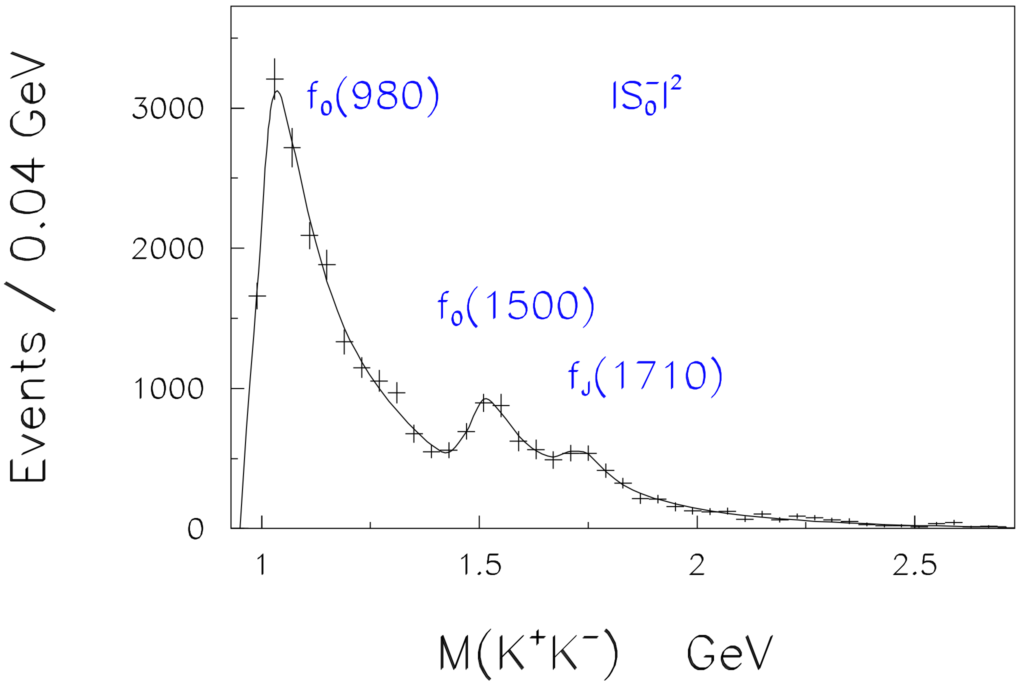
1 Solution D-wave dominant at threshold

1 Solution equal S and P-wave at threshold

The physical solution



The S-wave



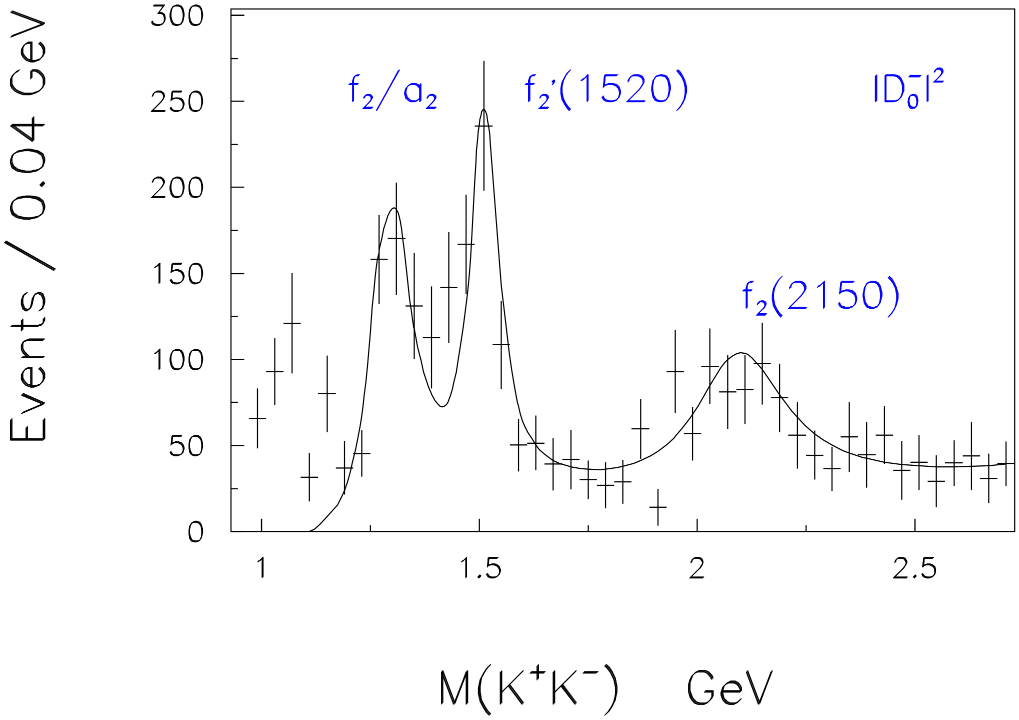
A fit using three interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1500)$ and $f_J(1710)$ and a background gives

$$f_0(980) \quad M = 985 \pm 10 \text{ MeV}, \quad \Gamma = 65 \pm 20 \text{ MeV}$$

$$f_0(1500) \quad M = 1497 \pm 10 \text{ MeV}, \quad \Gamma = 104 \pm 25 \text{ MeV}$$

$$f_0(1710) \quad M = 1730 \pm 15 \text{ MeV}, \quad \Gamma = 100 \pm 25 \text{ MeV}$$

The D-wave



A fit using three relativistic Breit-Wigners to describe the $f_2(1270)/a_2(1320)$, $f_2'(1525)$ and the peak at 2.2 GeV and a background gives

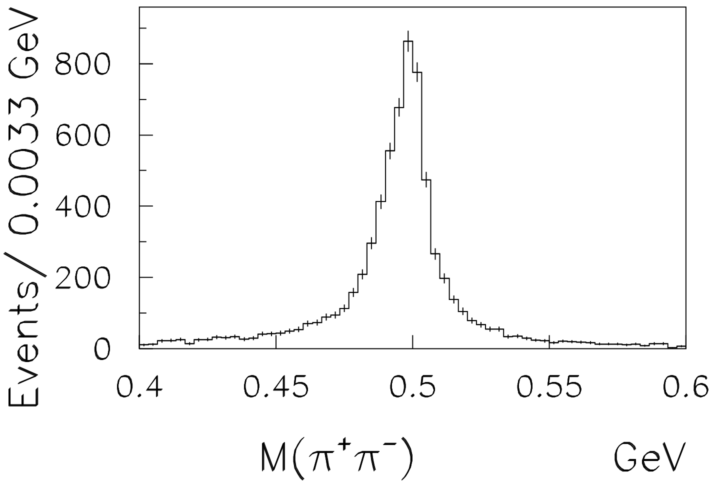
$$f_2/a_2 \quad M = 1305 \pm 20 \text{ MeV}, \quad \Gamma = 132 \pm 25 \text{ MeV}$$

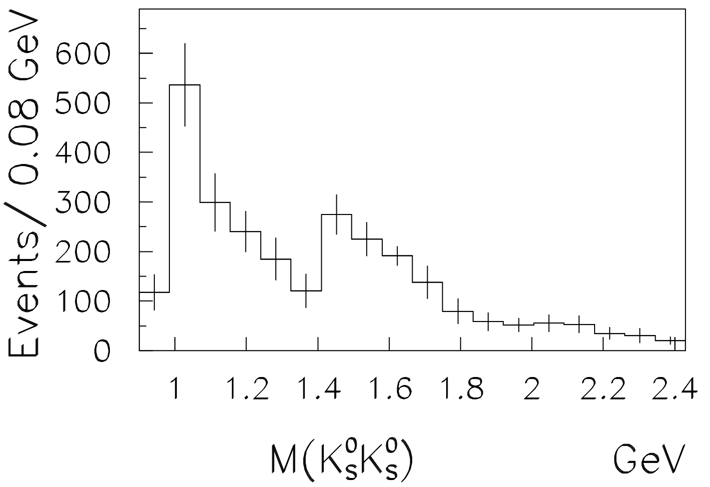
$$f_2'(1525) \quad M = 1515 \pm 15 \text{ MeV}, \quad \Gamma = 70 \pm 25 \text{ MeV}$$

$$f_2(2150) \quad M = 2130 \pm 35 \text{ MeV}, \quad \Gamma = 270 \pm 50 \text{ MeV}.$$

PWA of the reaction $pp \to p_f p_s(K_S^0 K_S^0)$

The $K_S^0 K_S^0$ channel is selected from events with two V^0s.



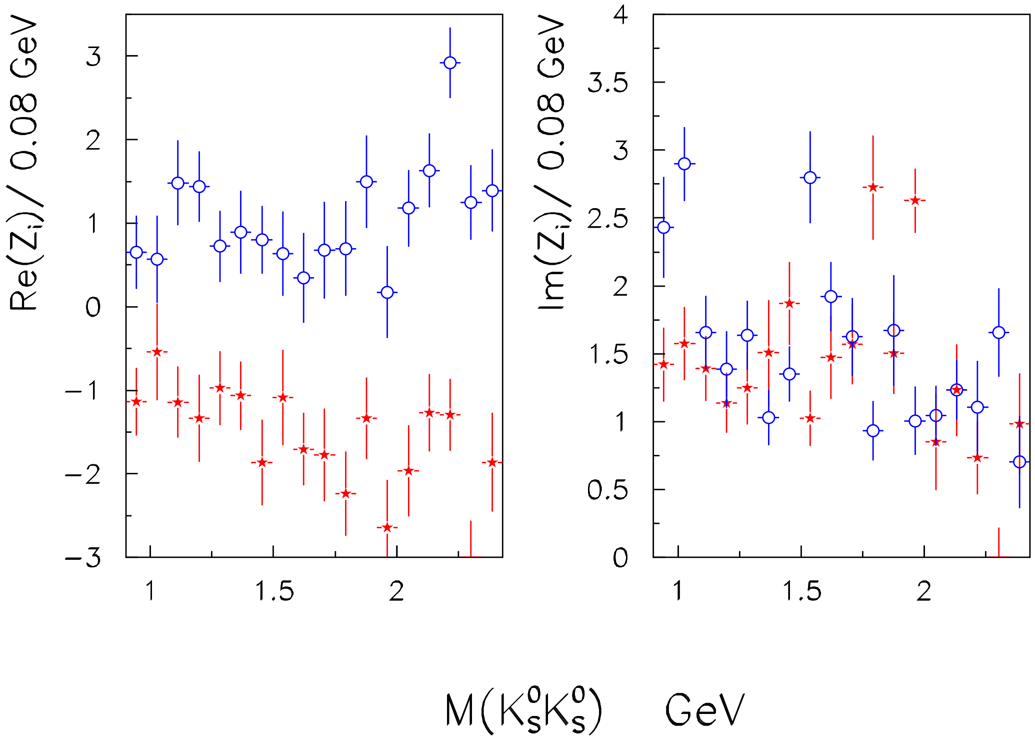


The $K_S^0 K_S^0$ mass spectrum

Ambiguities

For S and D waves there are two solutions.

The two complex roots, Z_i, after the linking procedure



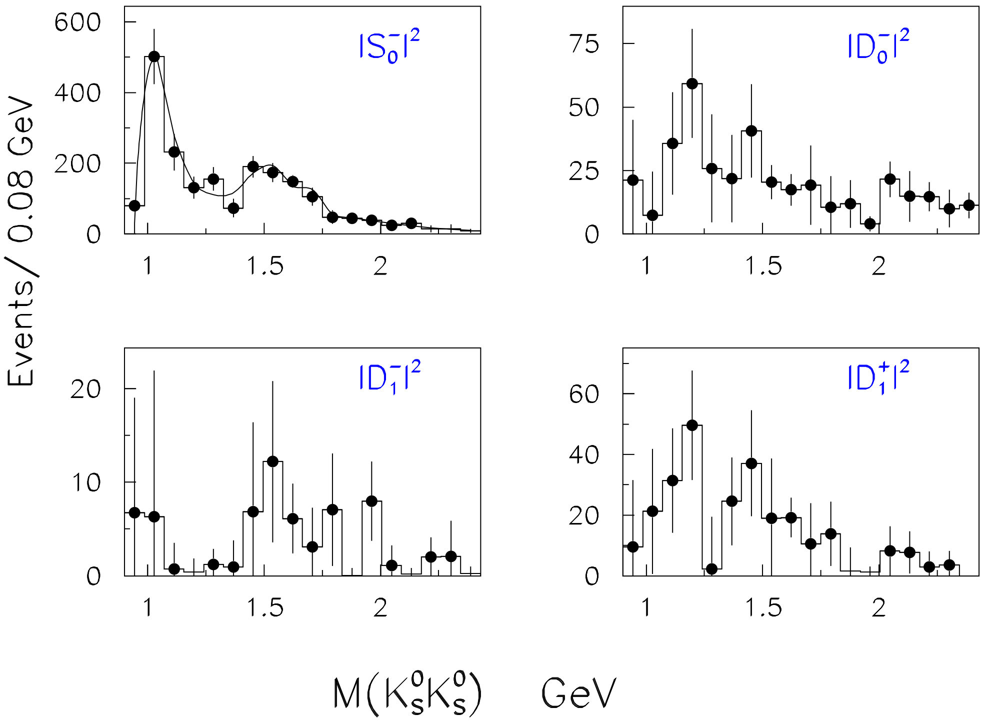
Imaginary parts give little help in the linking procedure.

Real parts are well separated in most places.

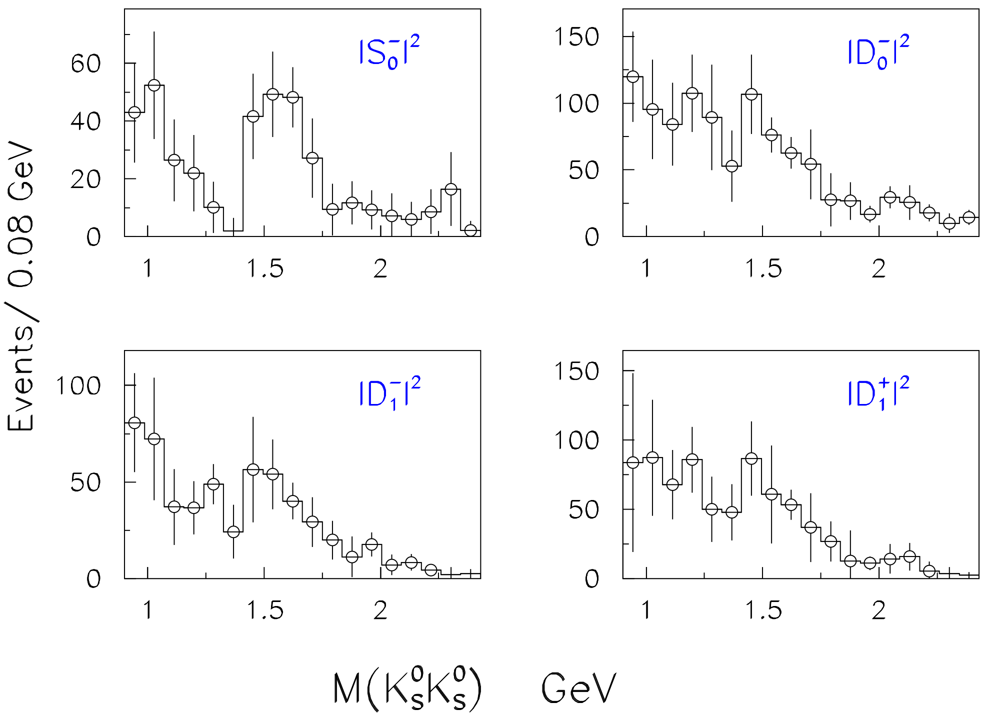
Possible to identify unambiguously the two PWA solutions in the whole mass range.

Zeros do not cross the real axis $\rightarrow$ no bifurcation of the solutions.

The physical solution



The unphysical solution



Summary of the $K\overline{K}$ analysis

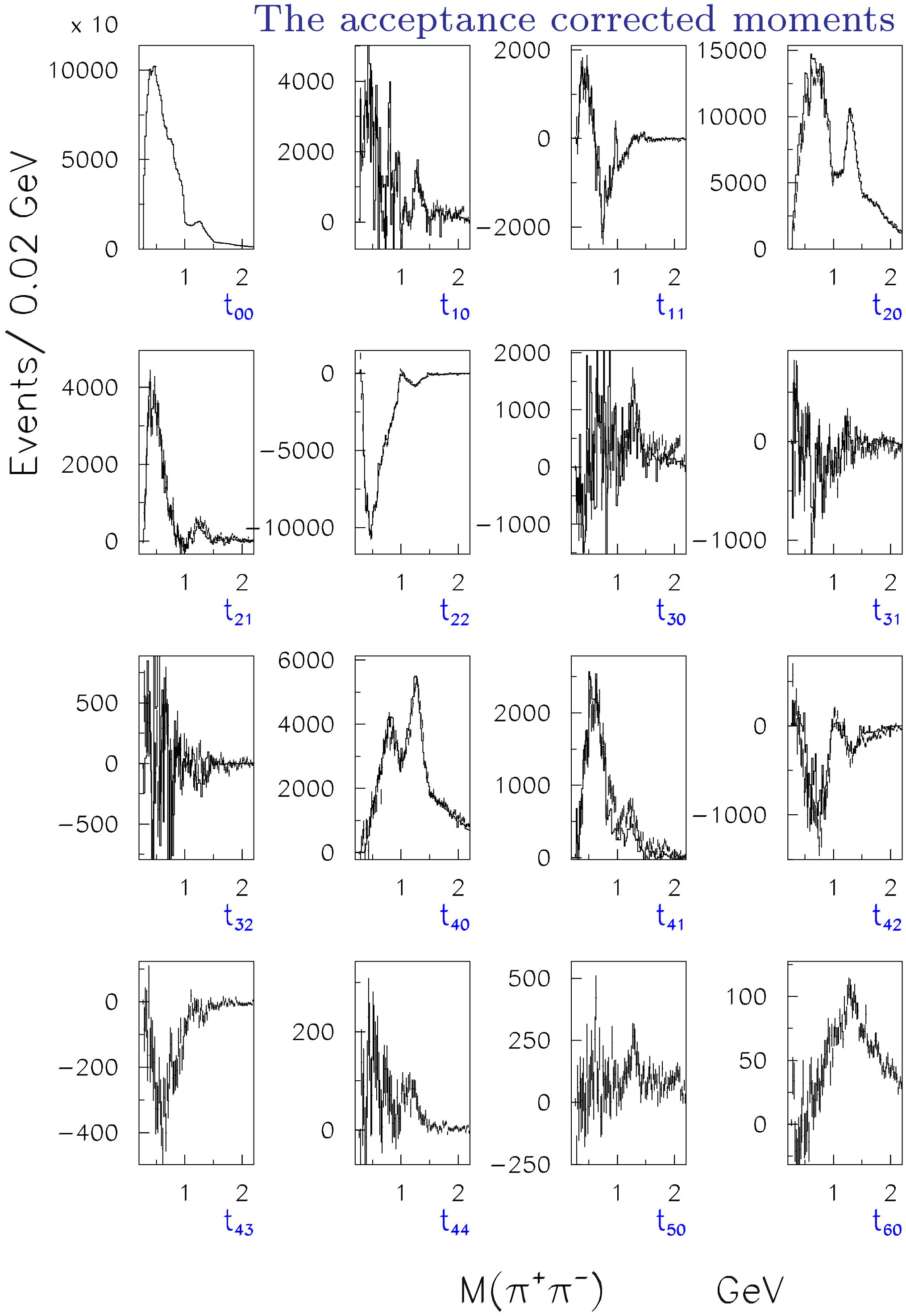
An unambiguous physical solution has been found from a partial wave analysis of the centrally produced K^+K^- and $K^0_S K^0_S$ systems.

The striking feature is the observation of peaks in the S-wave corresponding to the $f_0(1500)$ and $f_J(1710)$ with $J = 0$.

The D-wave shows evidence for the $f_2(1270)/a_2(1320)$, the $f_2'(1525)$ and the $f_2(2150)$ but there is no evidence for a statistically significant contribution in the D-wave in the 1.7 GeV mass region.

PWA of $pp \to p_f p_s(\pi^+\pi^-)$

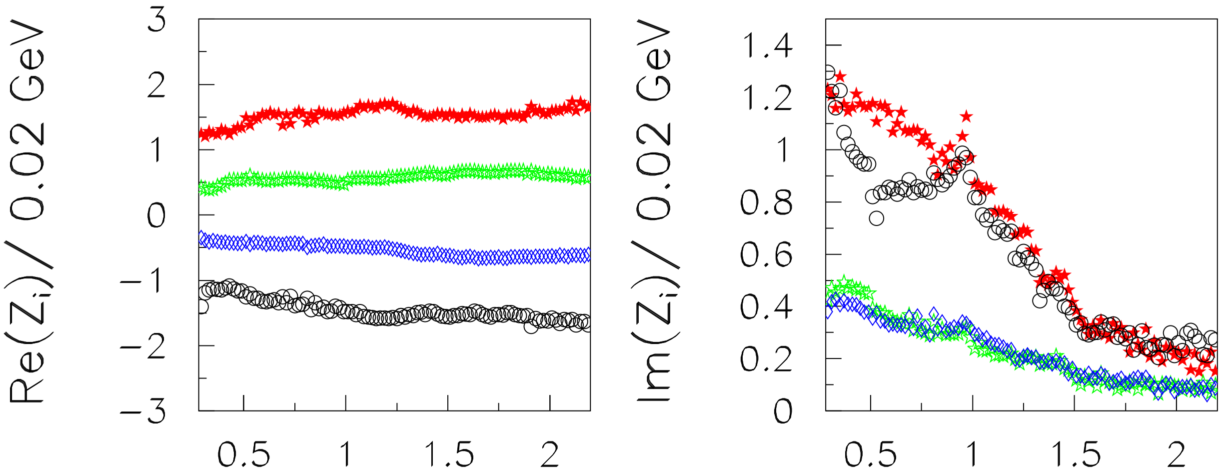
The acceptance corrected moments



Ambiguities

For S, P and D waves there are eight solutions.

The four complex roots, Z_i, after the linking procedure



Real parts are well separated.

Possible to identify unambiguously all the PWA solutions in the whole mass range.

Zeros do not cross the real axis → no bifurcation of the solutions.

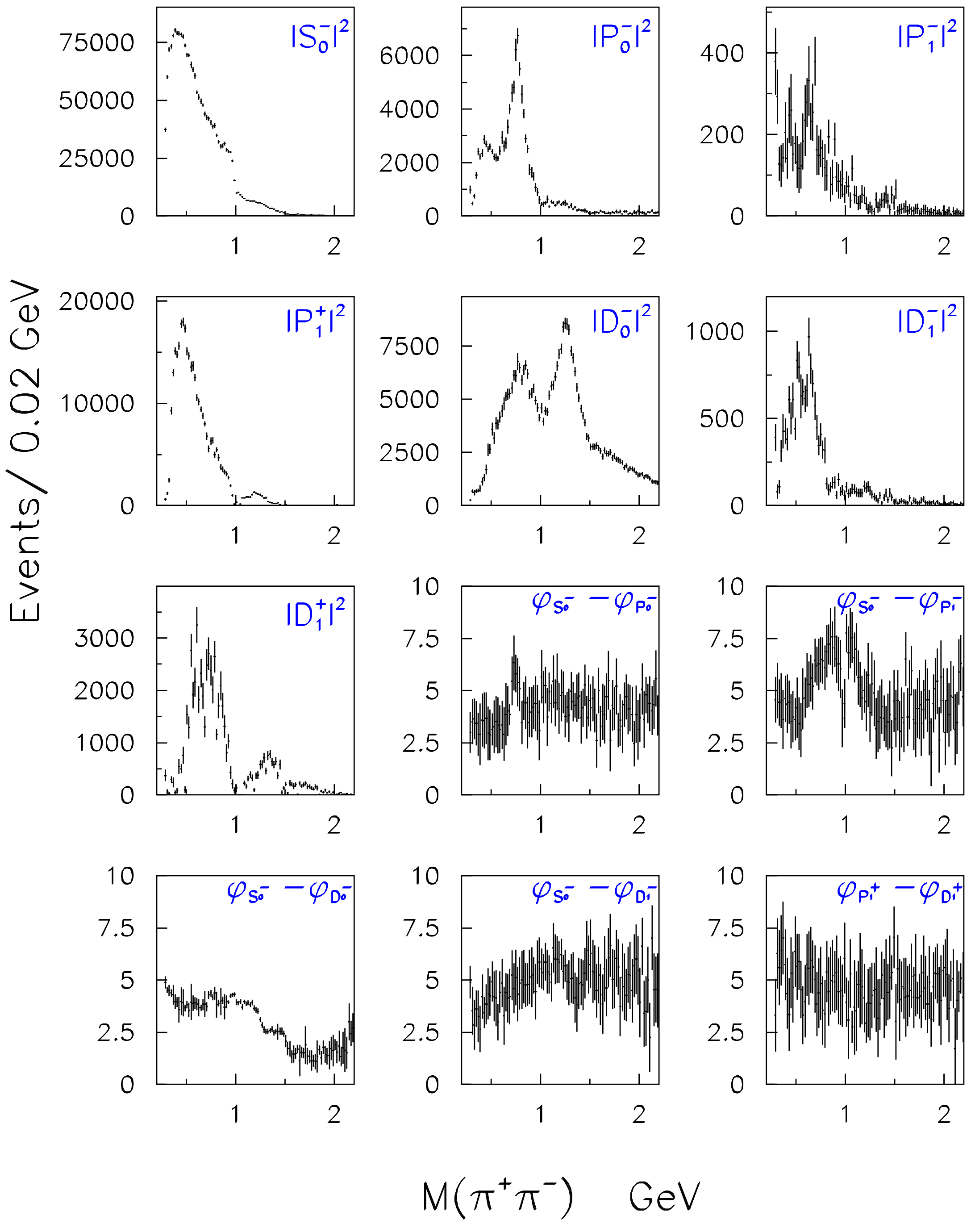
The waves

5 Solutions P-wave dominant at threshold

1 Solution D-wave dominant at threshold

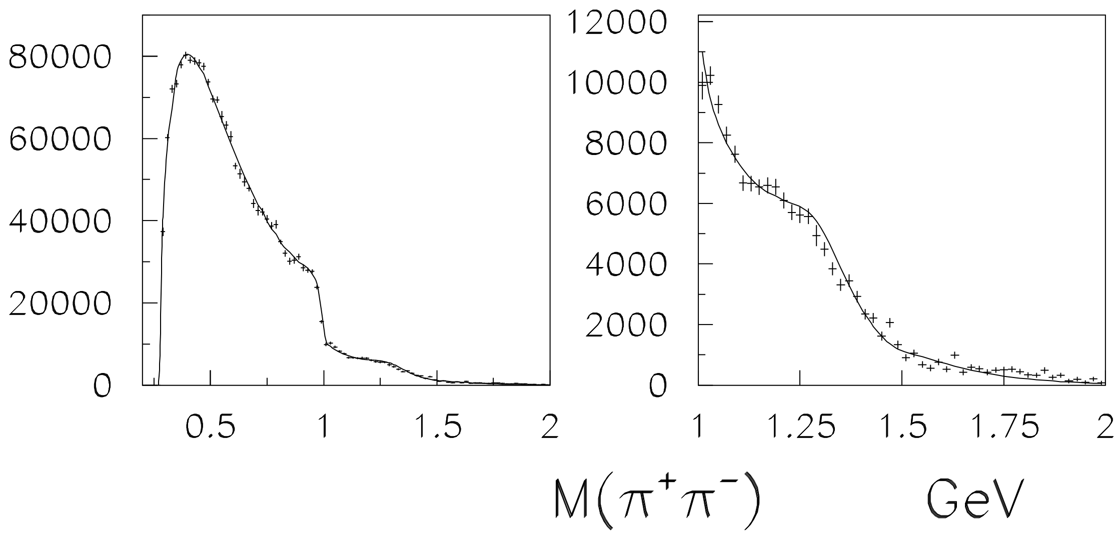
1 Solution equal S and P-wave at threshold

The physical solution

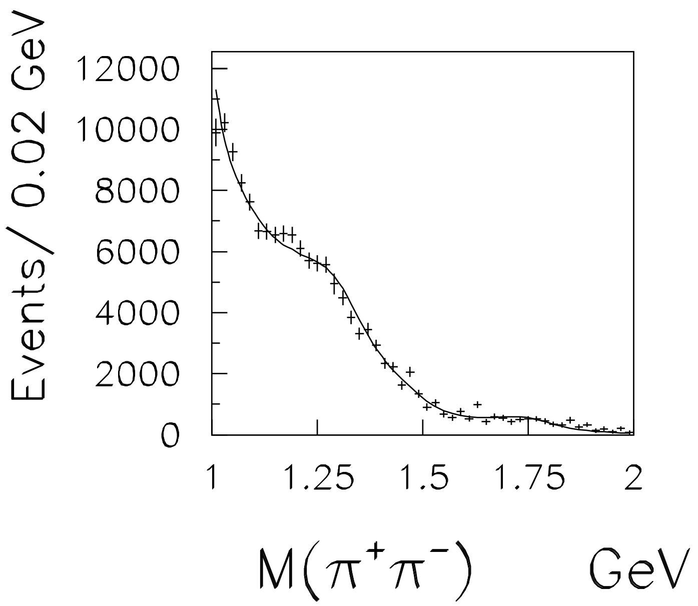


The S-wave

A fit using three interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1300)$ and $f_0(1500)$



adding a Breit-Wigner to describe the $f_J(1710)$



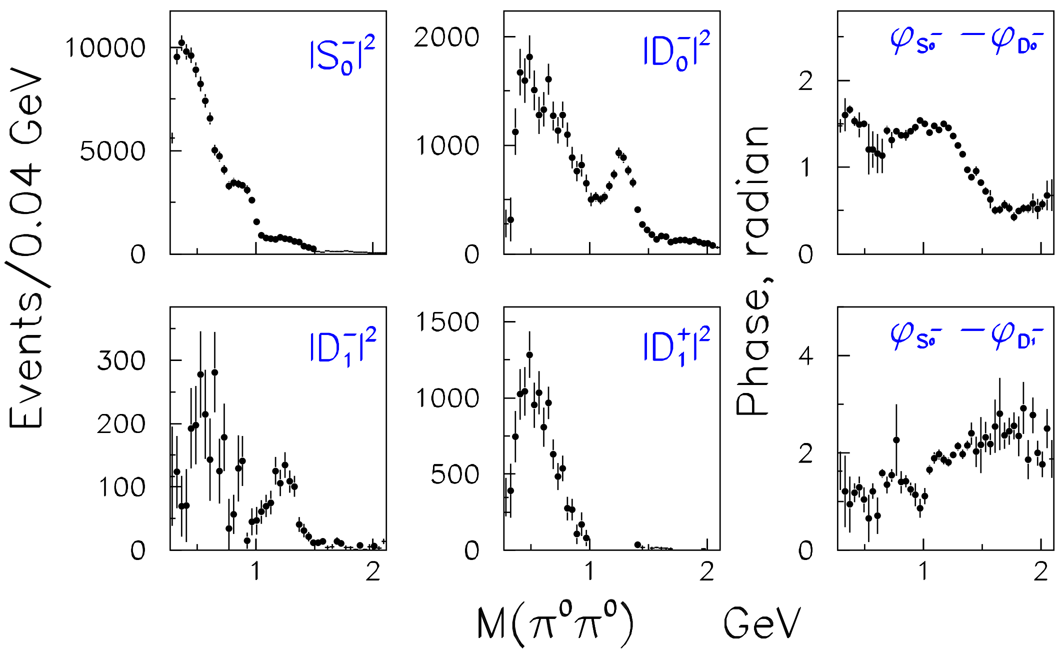
Parameters from the fit to the S-wave

A fit using four interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1300)$, $f_0(1500)$ and $f_J(1710)$ and a background gives

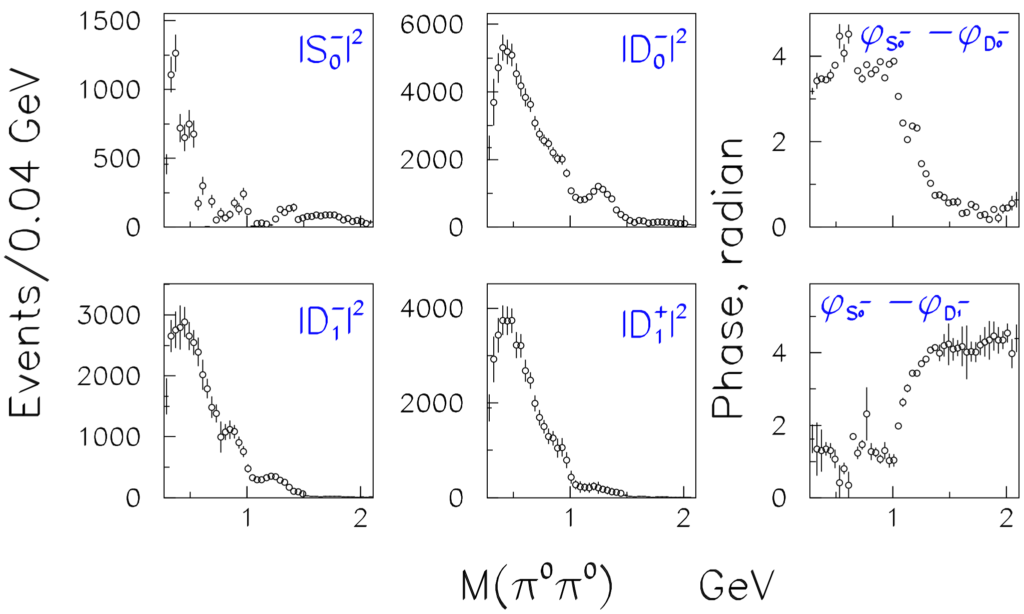
$f_0(980)$	$M = 982 \pm 3$ MeV,	$\Gamma = 80 \pm 10$ MeV
$f_0(1300)$	$M = 1308 \pm 10$ MeV,	$\Gamma = 222 \pm 20$ MeV
$f_0(1500)$	$M = 1502 \pm 10$ MeV,	$\Gamma = 131 \pm 15$ MeV
$f_0(1710)$	$M = 1750 \pm 20$ MeV,	$\Gamma = 160 \pm 30$ MeV

PWA of $pp \to p_f p_s(\pi^0\pi^0)$

The physical solution



The unphysical solution



Summary of the $\pi\pi$ analysis

An unambiguous physical solution has been found from a partial wave analysis of the centrally produced $\pi^+\pi^-$and $\pi^0\pi^0$ systems.

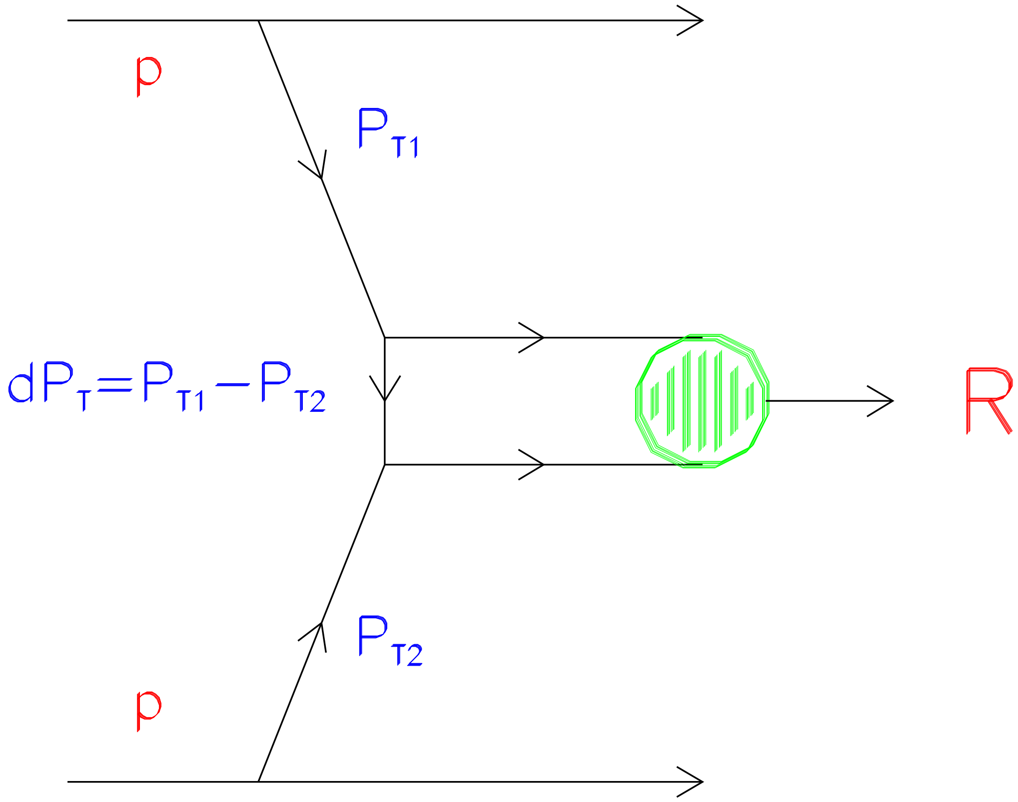
Evidence is found for the $f_0(980)$, $f_0(1300)$, $f_0(1500)$ and $f_J(1710)$ with J = 0 in the the S-wave.

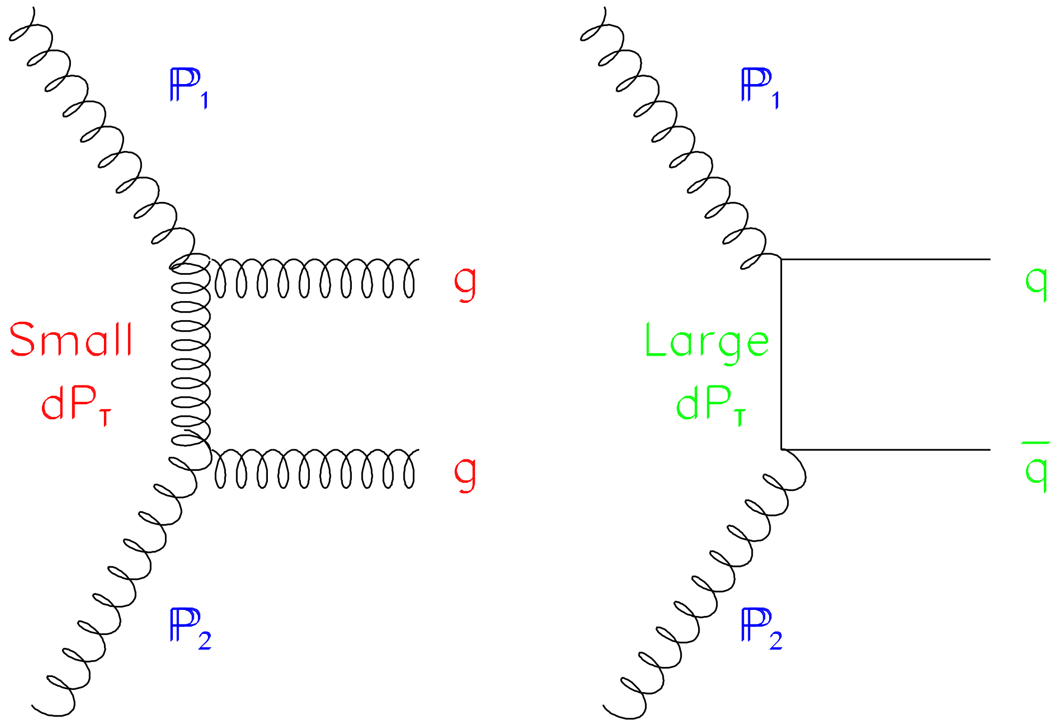
The $\rho(770)$ is observed dominantly in the P_0^--wave.

The $f_2(1270)$ is observed dominantly in the D_0^--wave.

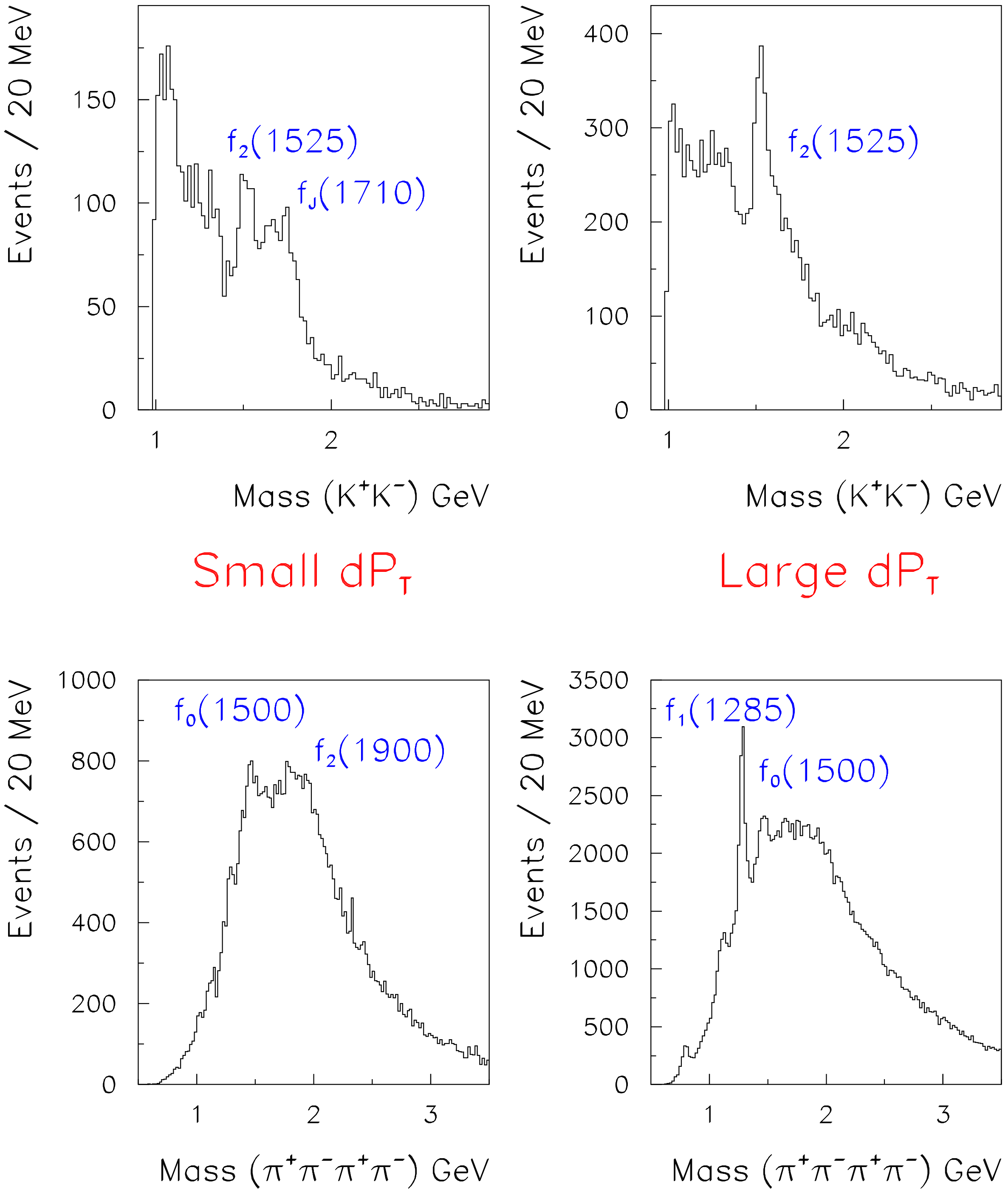
There is evidence for a broad enhancement in the D-wave below 1 GeV.

An update on the glueball-$q\bar{q}$ filter

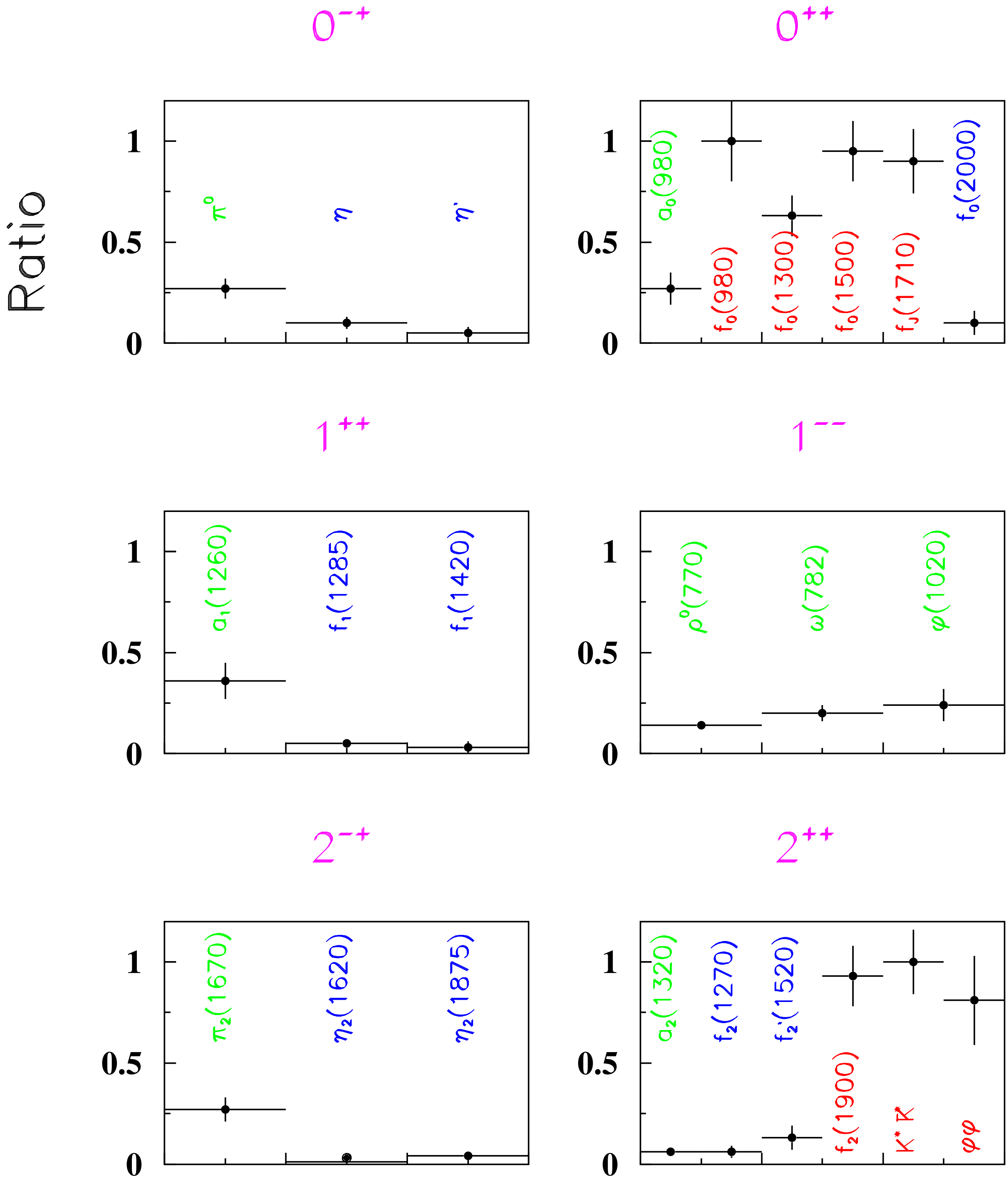




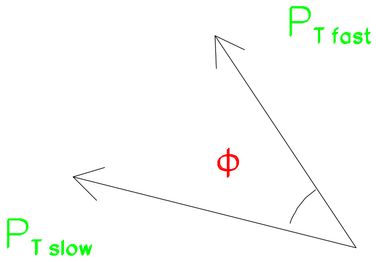
Examples of the glueball-$q\bar{q}$ filter



Ratio of number of events at small dP_T to large dP_T



The azimuthal angle ϕ between the outgoing protons



Naively expect a flat ϕ distribution.

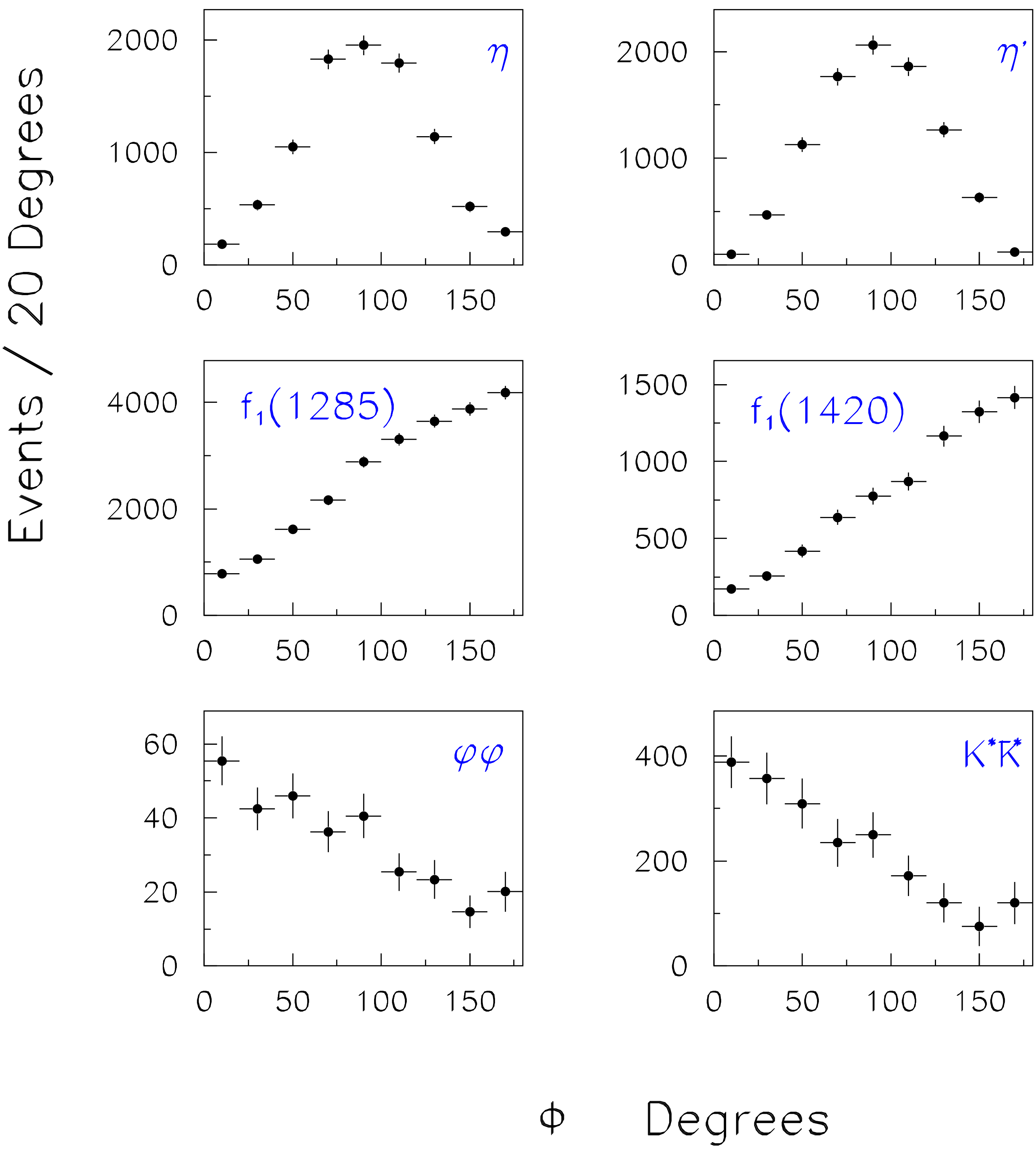
There is a correlation between ϕ and dP_T

$$cos(\phi) = \frac{dP_T^2 - P_T^2}{4t_s t_f} \tag{3}$$

therefore may expect some ϕ dependence.

The observed ϕ distributions are more complex than this and are resonance dependent.

Resonance production as a function of ϕ



Summary

A partial wave analysis of the centrally produced K^+K^-, $K^0_SK^0_S$, $\pi^+\pi^-$and $\pi^0\pi^0$ systems has been performed.

In the $K\overline{K}$ systems evidence is found for the $f_0(980)$, $f_0(1500)$ and $f_J(1710)$ with J = 0 in the the S-wave.

In the $\pi\pi$ systems evidence is found for the $f_0(980)$, $f_0(1300)$, $f_0(1500)$ and $f_J(1710)$ with J = 0 in the the S-wave.

There is evidence for a kinematical filter (dP_T) which selects out glueball candidates from known $q\overline{q}$ states.

There is also a interesting effect in the azimuthal angle of the two scattered protons which may give information on the nature of the Pomeron.

Possibilities for a future study

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE/98-45
3 November 1998

A study of Double Pomeron Exchange in ALICE

A. Kirk
and
O. Villalobos Baillie

School of Physics and Astronomy, University of Birmingham, Birmingham, U.K.

Abstract

The non-Abelian nature of QCD suggests that particles that have a gluon constituent, such as glueballs or hybrids, should exist. Experiments WA76, WA91 and WA102 have performed a dedicated search for these states in central production using the CERN Omega Spectrometer. New results from central production show that there is a kinematical filter which can select out glueball candidates from known $q\overline{q}$ states. A further study of this at high energies is essential in order to get information on the $M(X^0) > 2$ GeV region. This paper describes how this could be done using the the ALICE detector at the LHC.

For further information please contact:
ak@hep.ph.bham.ac.uk