New results from WA102 experiment

Alexander Singovski
LAPP, Annecy-le-Vieux

1. Glueball search by WA102 experiment:
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   - what?
   - how?
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Glueballs.

Experimental point of view

1. Glueballs and other non-$q\bar{q}$ states are clearly predicted by QCD.
   Although observability of a pure gg state is not mandatory.

2. Glueballs masses are predicted by models.
   For example, Lattice Gauge calculations give
   $M(0^{++})$ = 1500 - 1700 MeV
   $M(2^{++})$ = 2000 - 2200 MeV

3. The lowest lying 0^{++} glueball should be the easiest to observe once it is expected in rather well experimentally studied mass region but it is mixed with his scalar $q\bar{q}$ neighbors and probably cannot be observed as a separate physical state.

4. The scalar glueball search task is essentially a study of the exotic properties of already well known mesons, looking for inconsistency with their $q\bar{q}$ nature.

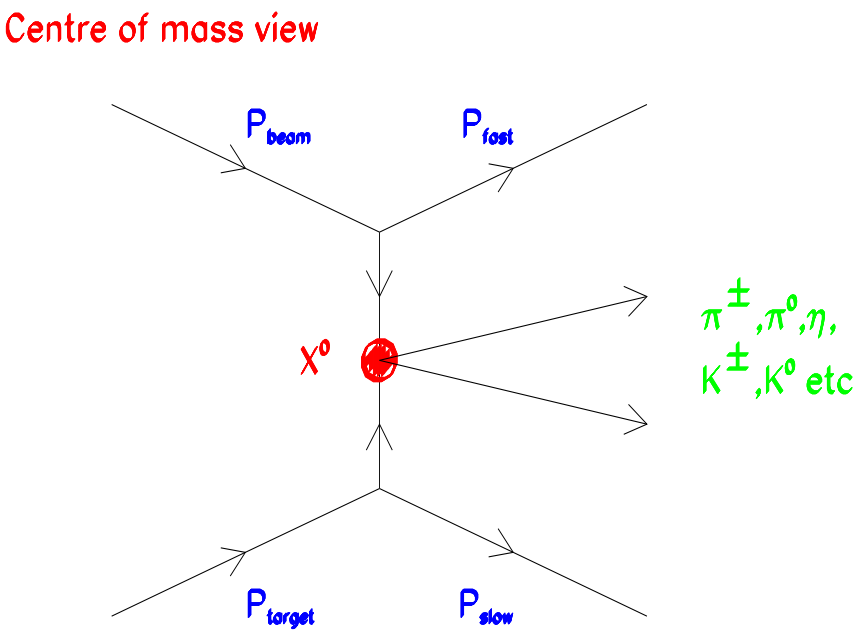
Glueballs.

Experimental point of view

An ideal glueball search experiment:

- should be universal with high acceptance, good tracking, EM calorimetry and particle ID;
- should use gluon rich production process: radiative J/ψ decays, central pp interactions, $p\bar{p}$ annihilations;
- should perform a complete study of the given mass region, detect all states in all decay modes, define their quantum numbers (PWA);
- should find a quantitative deviation from the quark model prediction and extract information about the glue content of the meson states.

WA102 experiment. New results in central production.

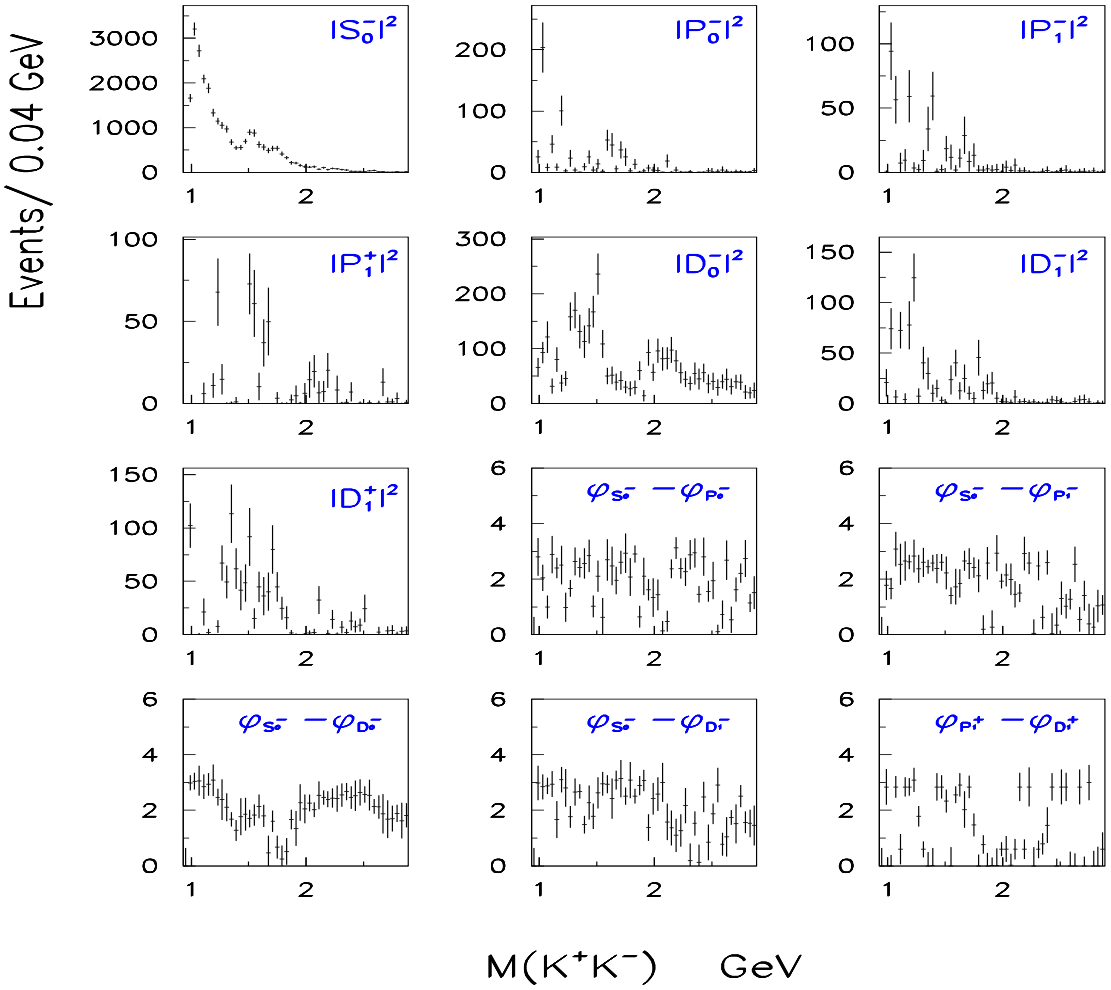


Experiment WA102 has studied exclusive final states in the reaction:

$$pp \rightarrow p_f p_s(x^0)$$

at 450 GeV/c which is predicted to be a source of gluonic final states via double Pomeron exchange.

$pp \rightarrow p_f p_s(K^+K^-)$, the physical solution



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

5 solutions P-wave dominant at threshold.

1 solution D-wave dominant at threshold.

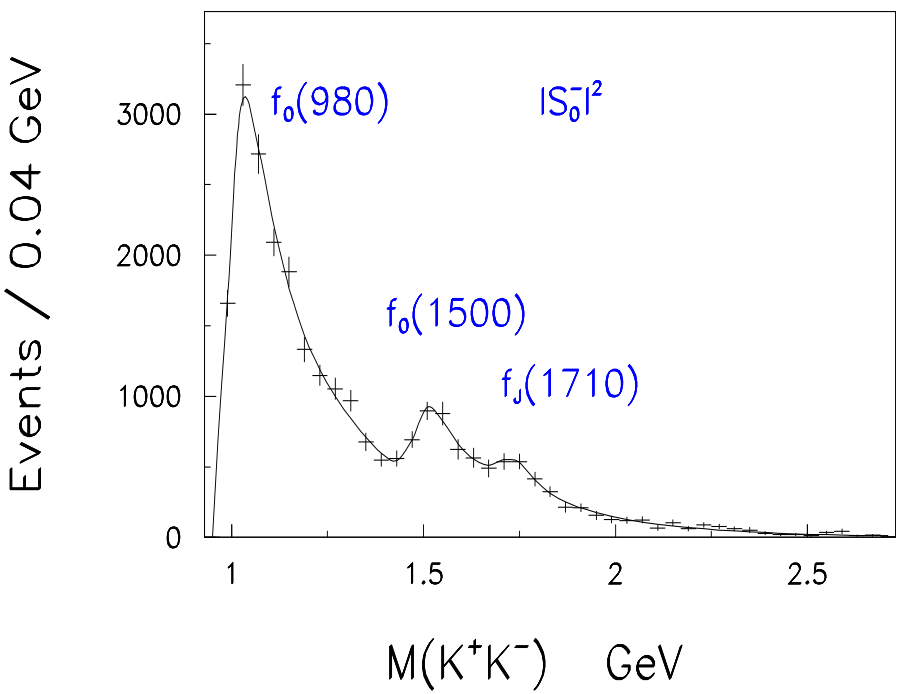
1 solution equal S and P-wave at threshold.

One unambiguous physical solution.

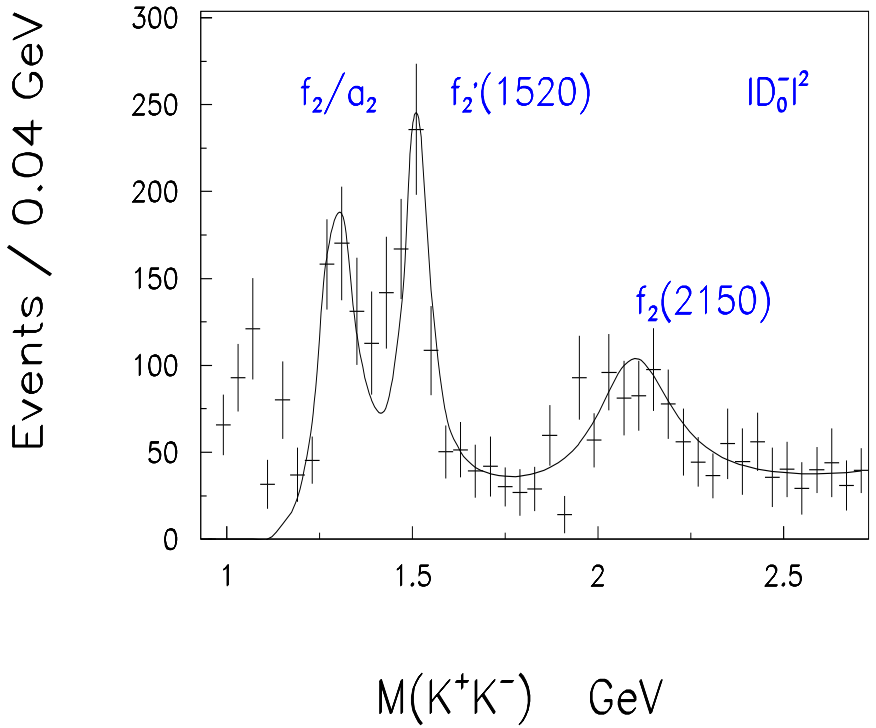
WA102 experiment. New results in central production.

$pp \rightarrow p_f p_s(K^+K^-)$, S- and D-wave

The S-wave



The D-wave



Summary of the K^+K^- analysis

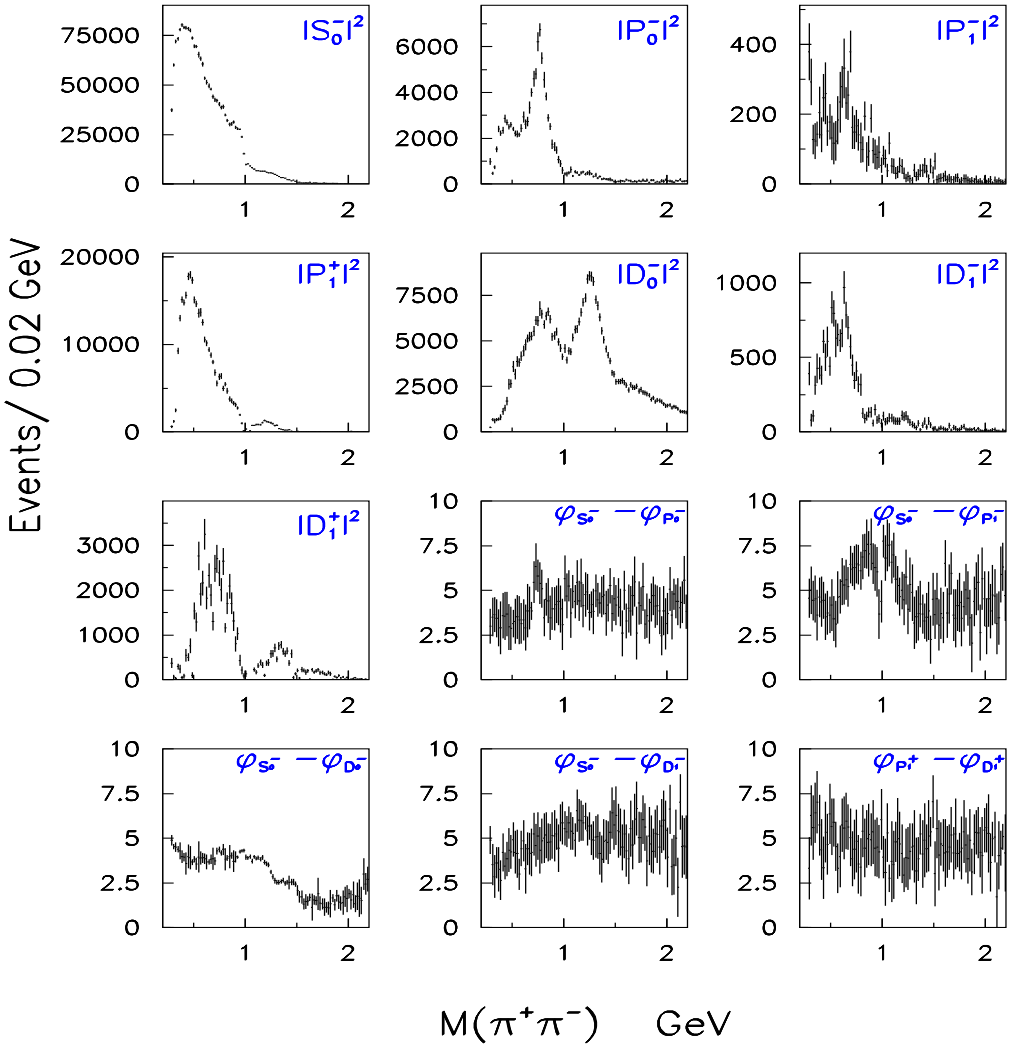
An unambiguous physical solution has been found from a partial wave analysis of the centrally produced K^+K^- system.

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 region.

WA102 experiment. New results in central production.

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



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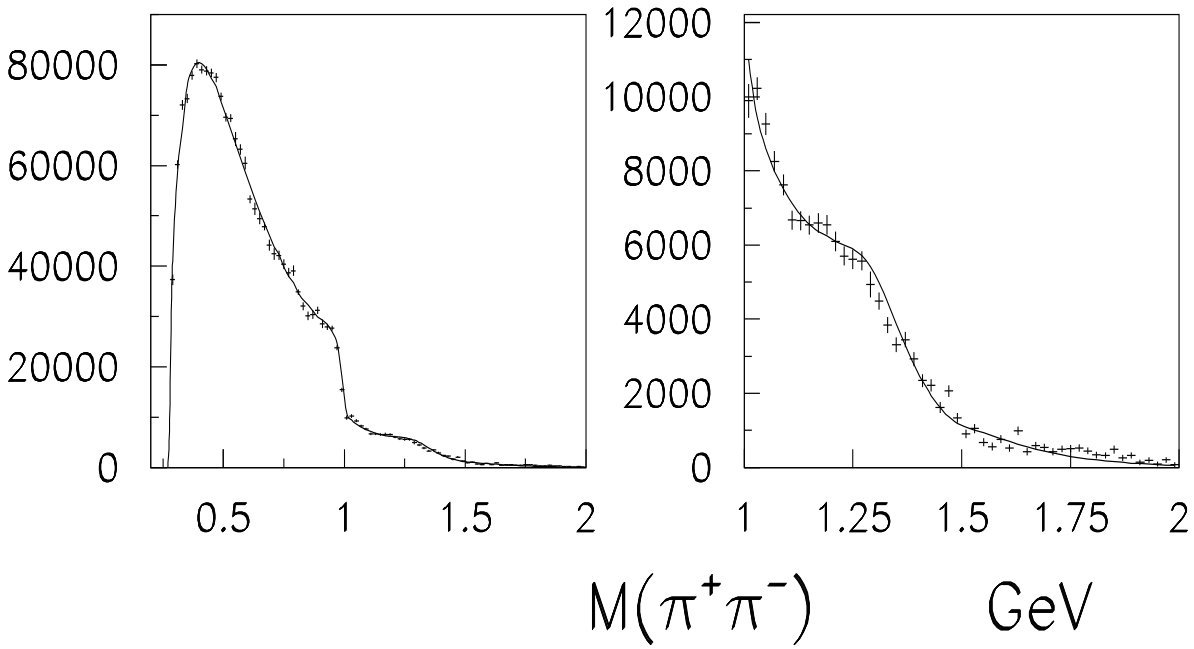
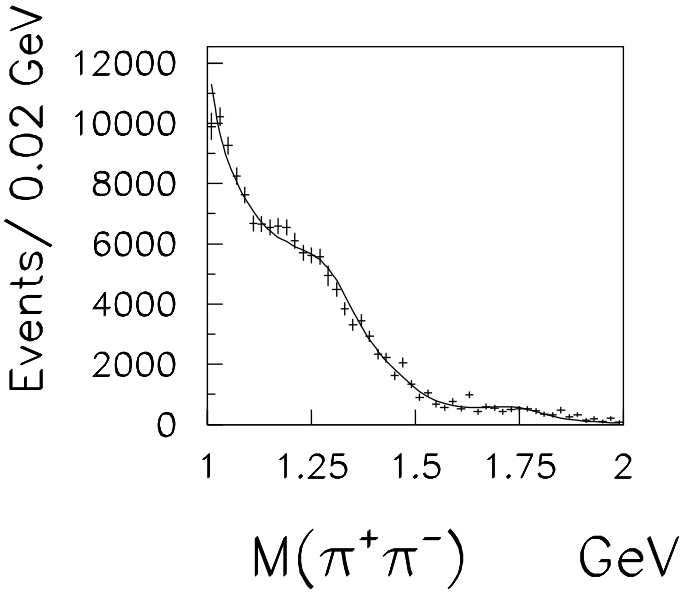
WA102 experiment. New results in central production.

$pp \rightarrow p_f p_s(\pi^+\pi^-)$, the S-wave



A fit using three interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1370)$ and $f_0(1500)$



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

Summary of the $\pi^+\pi^-$ analysis

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

Evidence is found for the $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_j(1710)$ with j=0 in 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

A coupled channel analysis of the K^+K^- and $\pi^+\pi^-$ channels

A coupled channel analysis has been performed in order to determine the pole positions and branching ratios of the resonances observed.

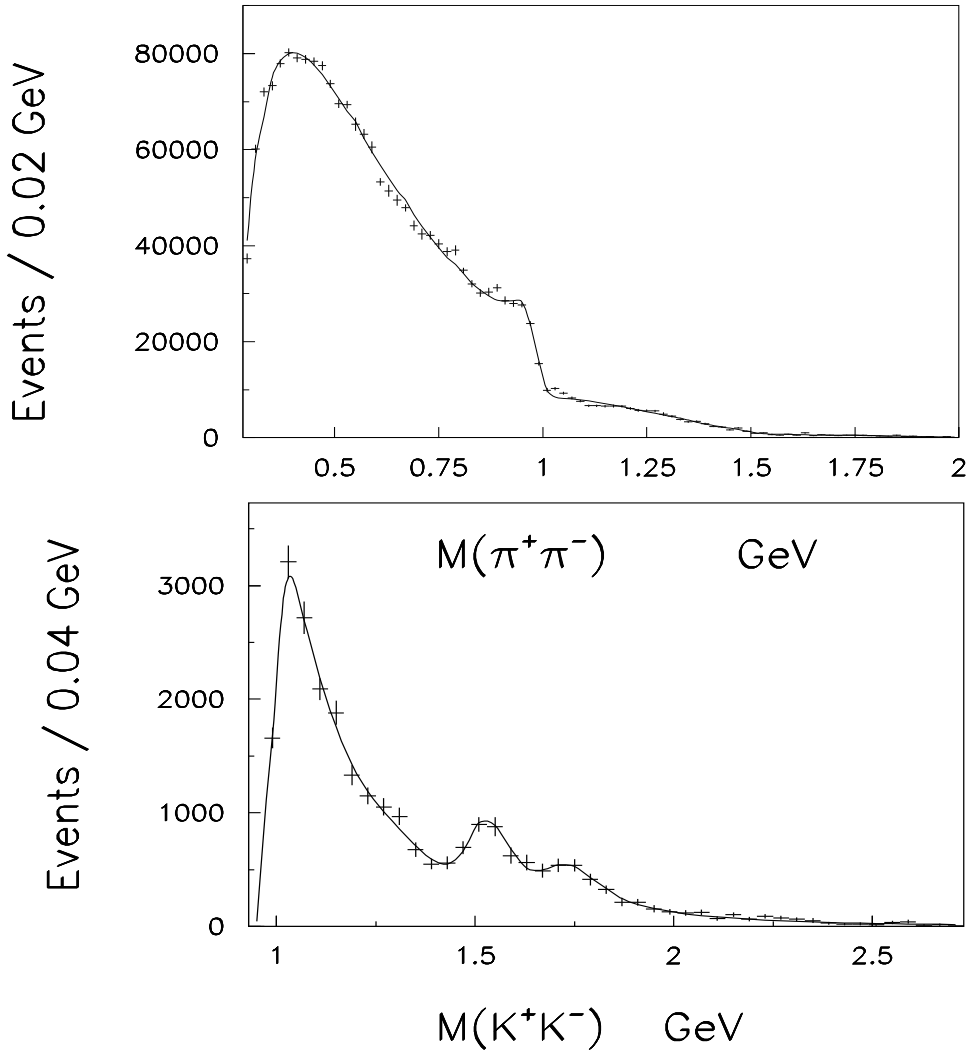
Three methods of fitting the data have been used:

1. Interfering Breit-Wigners
2. T-Matrix analysis
3. K-matrix analysis

The pole positions and branching fractions found from the three methods are found compatible.

WA102 experiment. New results in central production.

A coupled channel analysis of the K^+K^- and $\pi^+\pi^-$ channels



A mean value of the three methods is quoted and the spread between methods is used to calculate a systematic error.

The pole positions are:

$f_0(980)$ M=(987 ± 6 ± 6) -i(48 ±12 ±8)MeV

$f_0(1370)$ M=(1312 ±25±10) -i(109±22±15)MeV

$f_0(1500)$ M=(1520 ±12±10) -i(49± 9± 8)MeV

$f_0(1710)$ M=(1727 ±12±11) -i(63± 8± 9)MeV

Branching ratios:

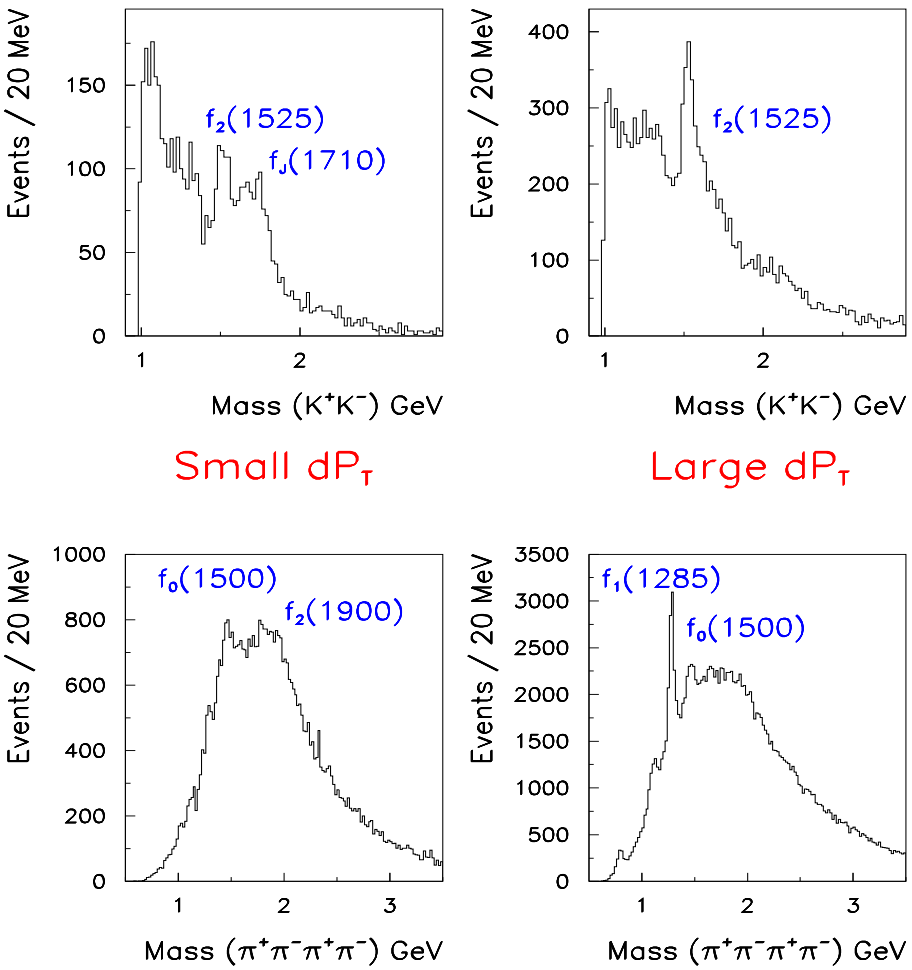
$$\frac{f_0(1370)\to K\bar{K}}{f_0(1370)\to \pi\pi} = 0.46\pm0.15 \pm0.11$$

$$\frac{f_0(1500)\to K\bar{K}}{f_0(1500)\to \pi\pi} = 0.33\pm0.03\pm0.07$$

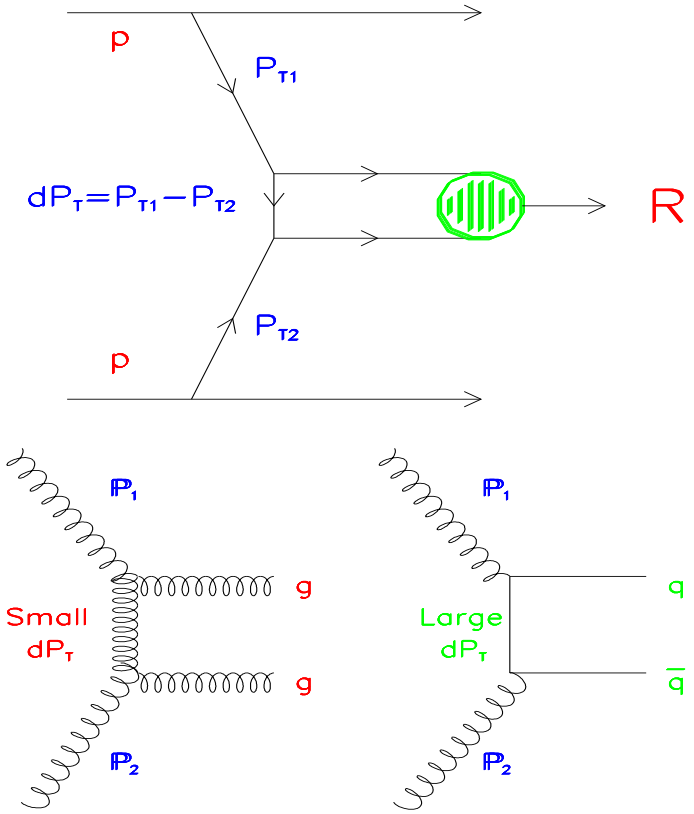
$$\frac{f_0(1710)\to K\bar{K}}{f_0(1710)\to \pi\pi} = 5.0\pm0.6 \pm0.9$$

WA102 experiment. New results in central production.

An update of the central production dynamics



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



WA102 experiment. New results in central production.

Ratio of number of events at small dP_T to large dP_T

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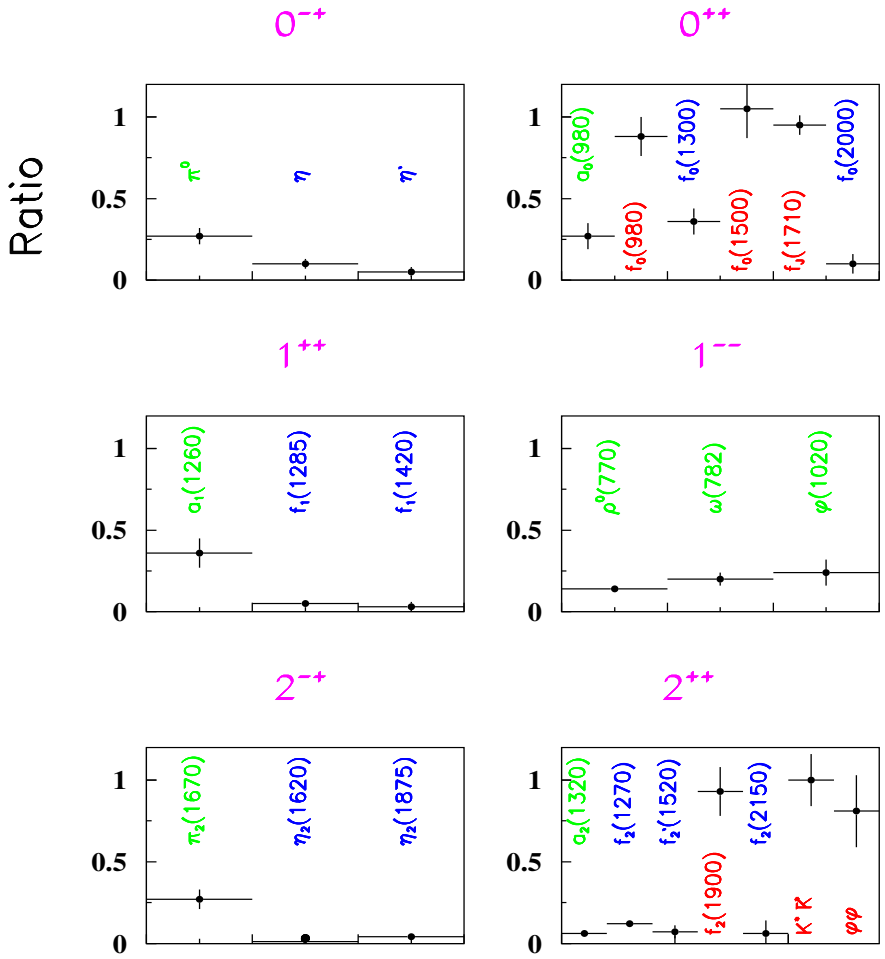


Ratio of number of events at small dP_T to large dP_T

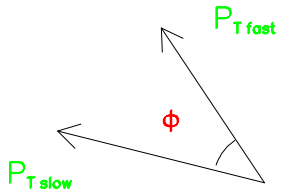
The dP_T glueball filtering data support the model of the scalar glueball spread over several scalar states:

$f_0(980)$, $f_0(1300)$, $f_0(1500)$ and $f_0(1710)$

with the value of small dP_T to large dP_T ratio acting as a "glue indicator"

An update of the central production dynamics

The azimuthal angle ϕ between the outgoing protons



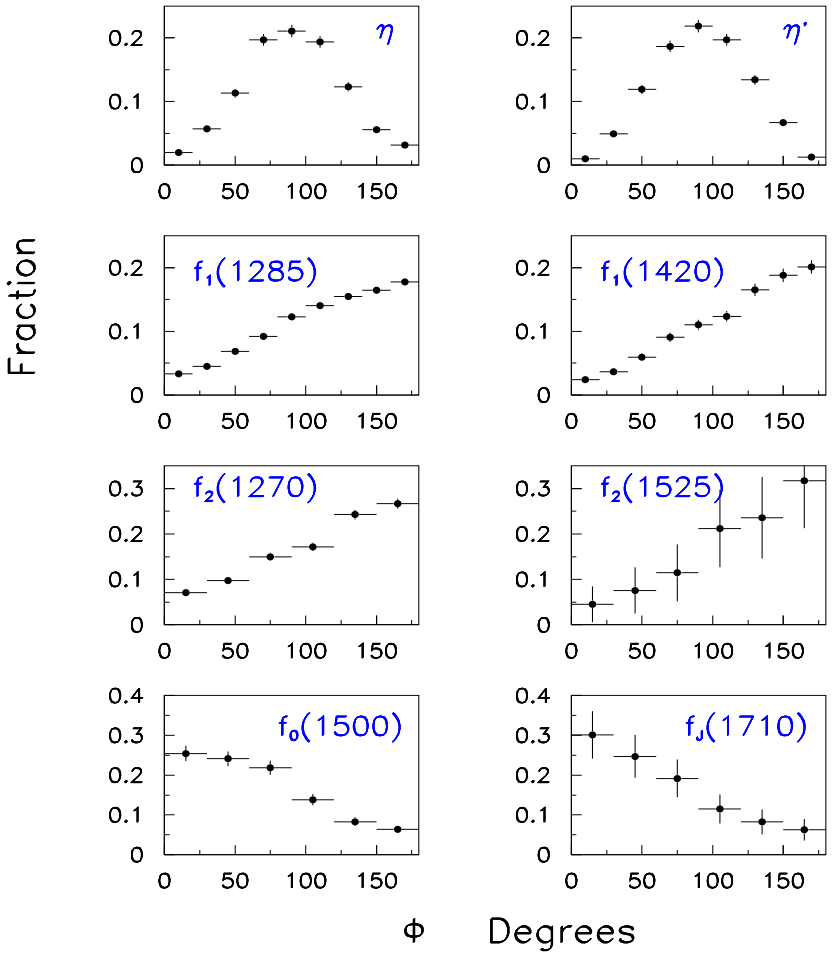
There is a correlation between ϕ and dP_T

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

therefore some ϕ dependence reflecting dP_T one can be expected.

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

Resonance production as a function of ϕ



Progress on understanding the central production dynamics effects

Several theoretical papers have been published on dP_T and ϕ effects.

All agree that the exchange particle (Pomeron) must have $J>0$ and that $J=1$ is the simplest explanation. (Supported by the $\pi\pi$ D-wave spectrum.)

Summary

An analysis of the centrally produced K^+K^- and $\pi^+\pi^-$ systems have been performed.

K^+K^-: evidence for the $f_0(980)$, $f_0(1500)$ and $f_0(1710)$ is found in the S-wave

$\pi^+\pi^-$: evidence for the $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$ is found in the S-wave.

In both cases $f_J(1710)$ is clearly seen in S-wave with J=0, no evidence for this state is found in D-wave.

The branching ratios for $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$ to K^+K^- and $\pi^+\pi^-$ have been determined.

There is evidence for a kinematical filter (dP_T) which selects glue-exotics candidates from known $q\bar{q}$ states.

There is an interesting effect in the azimuthal angle of the two scattering protons. The explanation of this effect could be that the exchange particle (Pomeron) have J>0.