A glueball-$q\overline{q}$ filter in central production ?

Andrew Kirk

University of Birmingham

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An introduction to glueballs

Quantum ChromoDynamics, the field theory describing strong interactions, not only describes how quarks and antiquarks interact by the exchange of gluons to form mesons

- it also predicts a rich spectrum of non-$q\bar{q}$ states

Glueballs gg, ggg

Hybrids $q\bar{q}g$

Mass estimates

Lattice Gauge calculations predict that the mass of the lightest glueball has $J^{PC} = 0^{++}$ and

$$M(0^{++}) = 1500 \text{ - } 1700 \text{ MeV}$$

Where to look for glueballs

Glueballs should be preferentially produced in gluon rich interactions:

Radiative J/ψ decays, central pp interactions, $p\bar{p}$ annihilations

but should be suppressed in

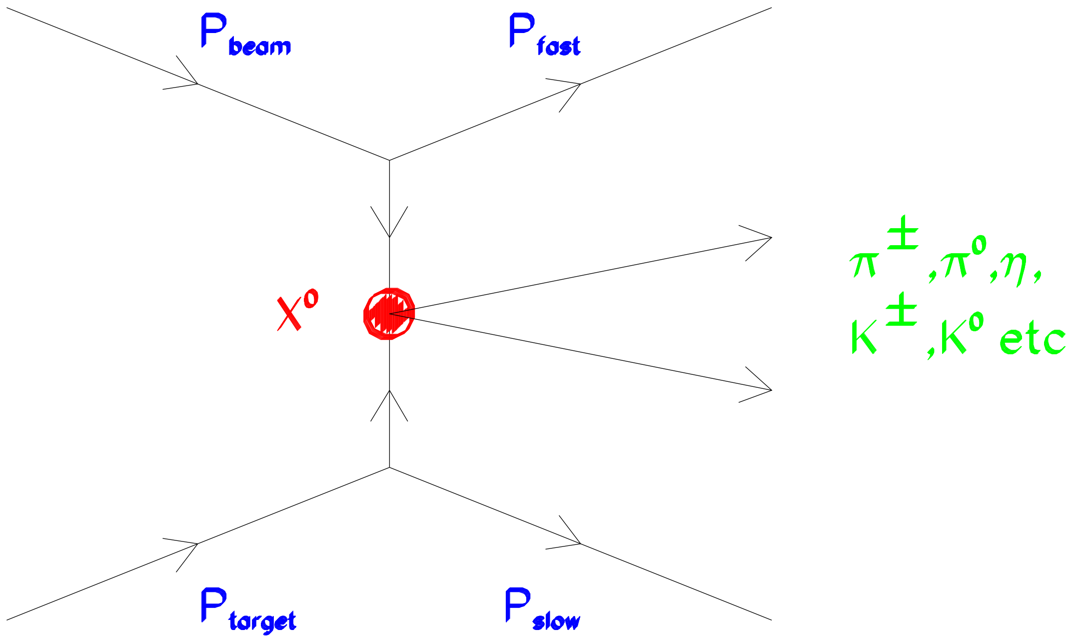
Normal hadronic interactions and $\gamma\gamma$ collisions.

Experiment WA102 has studied exclusive final states in the reaction

$$pp \to p_f p_s (X^0)$$

at 450 GeV/c

Centre of mass view

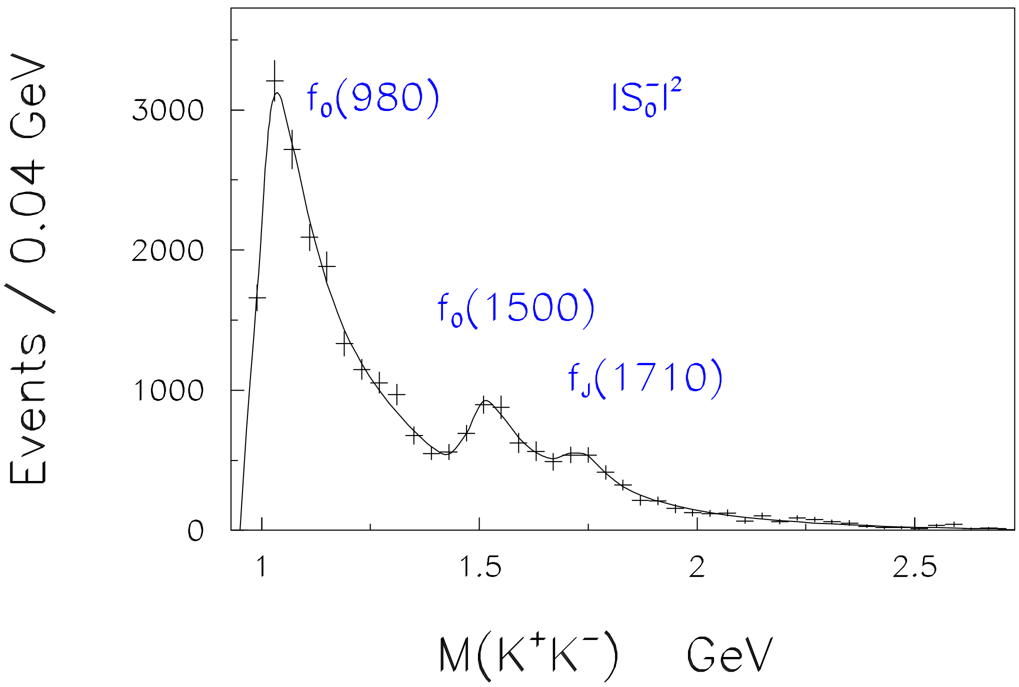


which is predicted to be a source of gluonic final states via double Pomeron exchange.

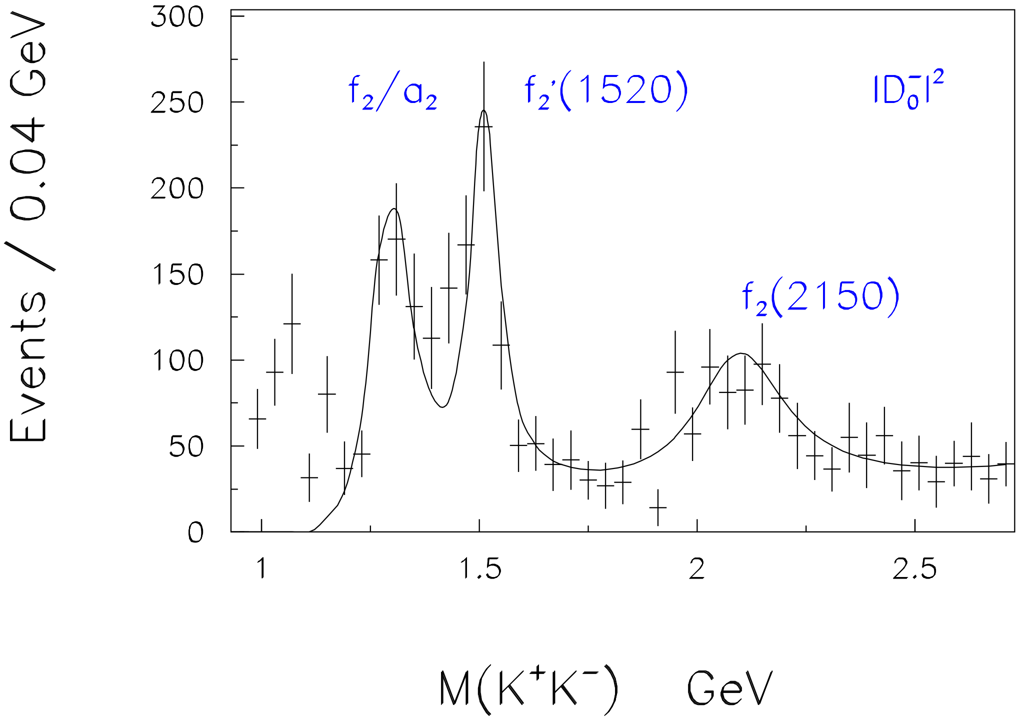
The spin of the $f_J(1710)$

D. Barberis et al.; Phys. Lett. B453 (1999) 305

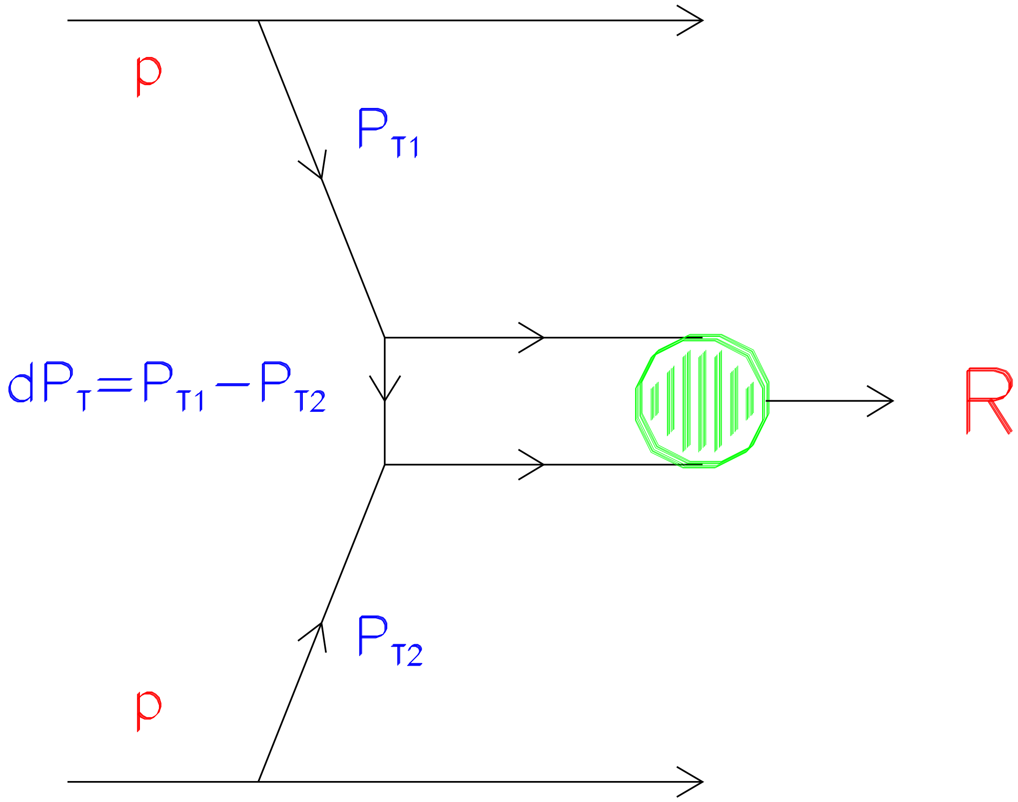
The K^+K^- S-wave

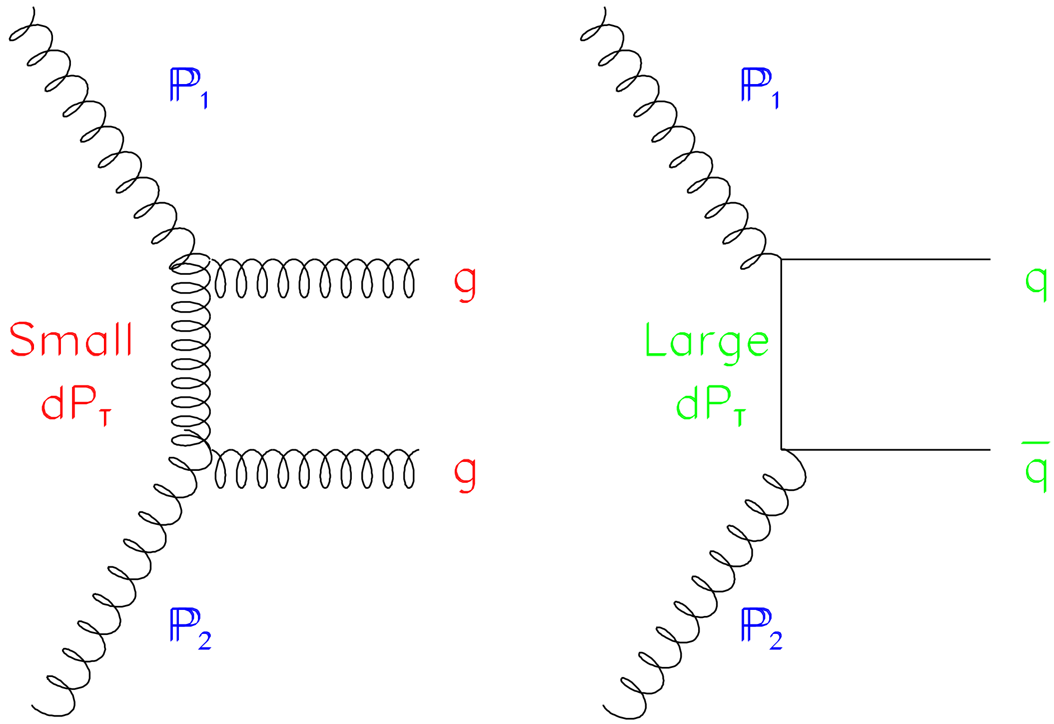


The K^+K^- D-wave

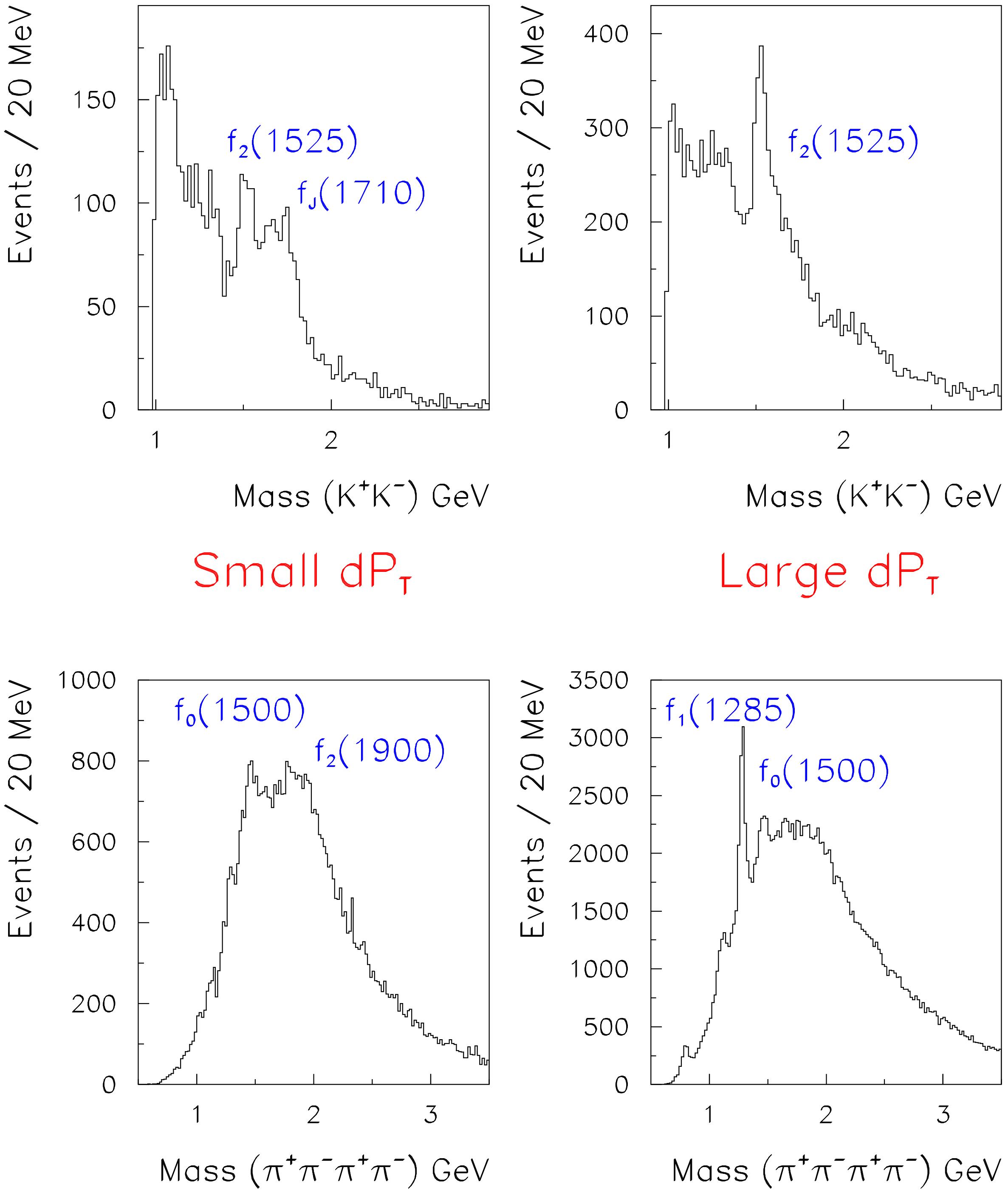


An update on the glueball-$q\bar{q}$ filter

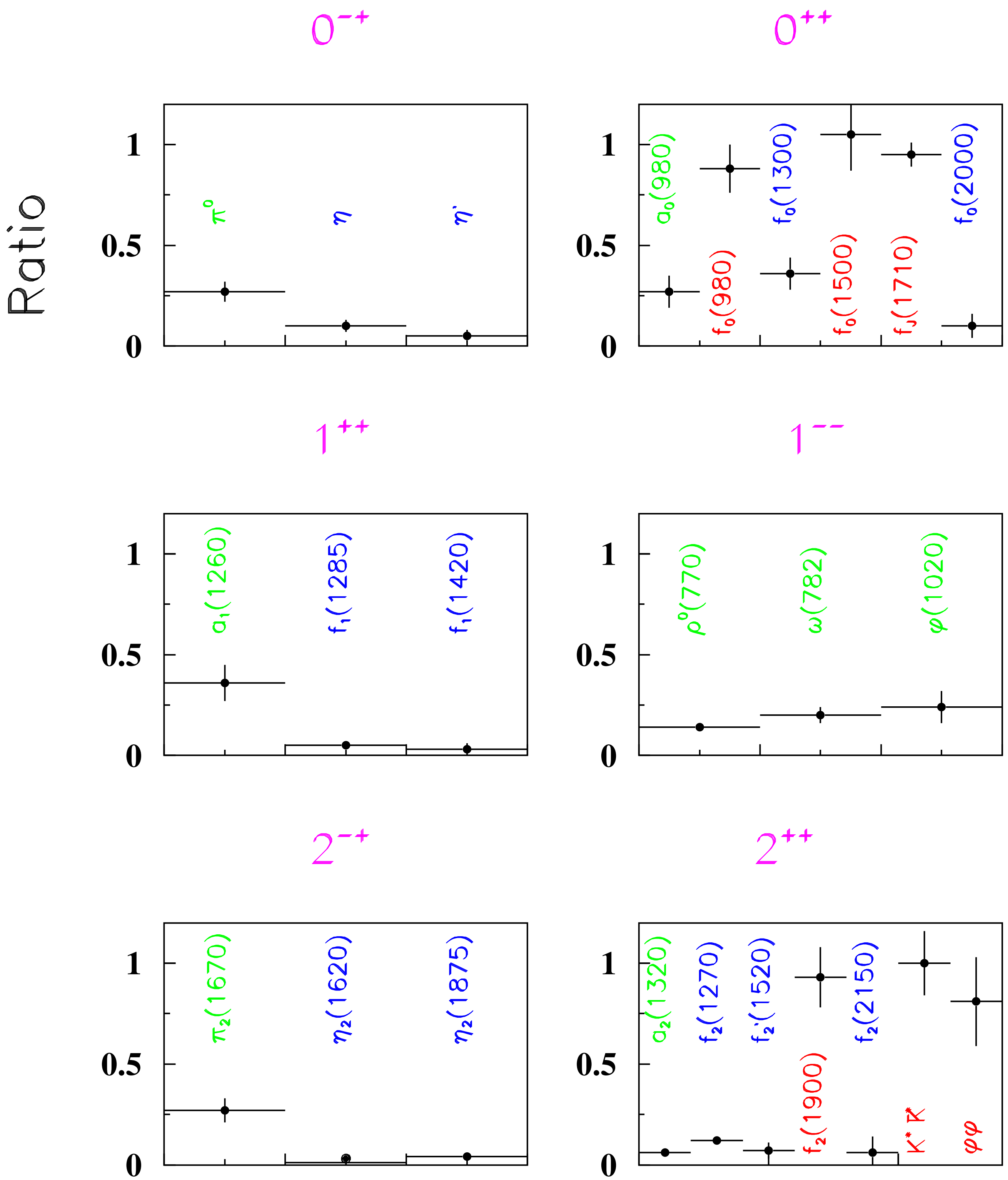




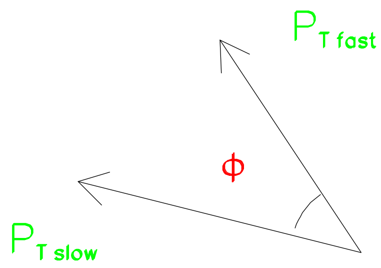
Examples of the glueball-$q\bar{q}$ filter



Ratio of number of events at small dP_T to large dP_T



The azimuthal angle ϕ between the outgoing protons



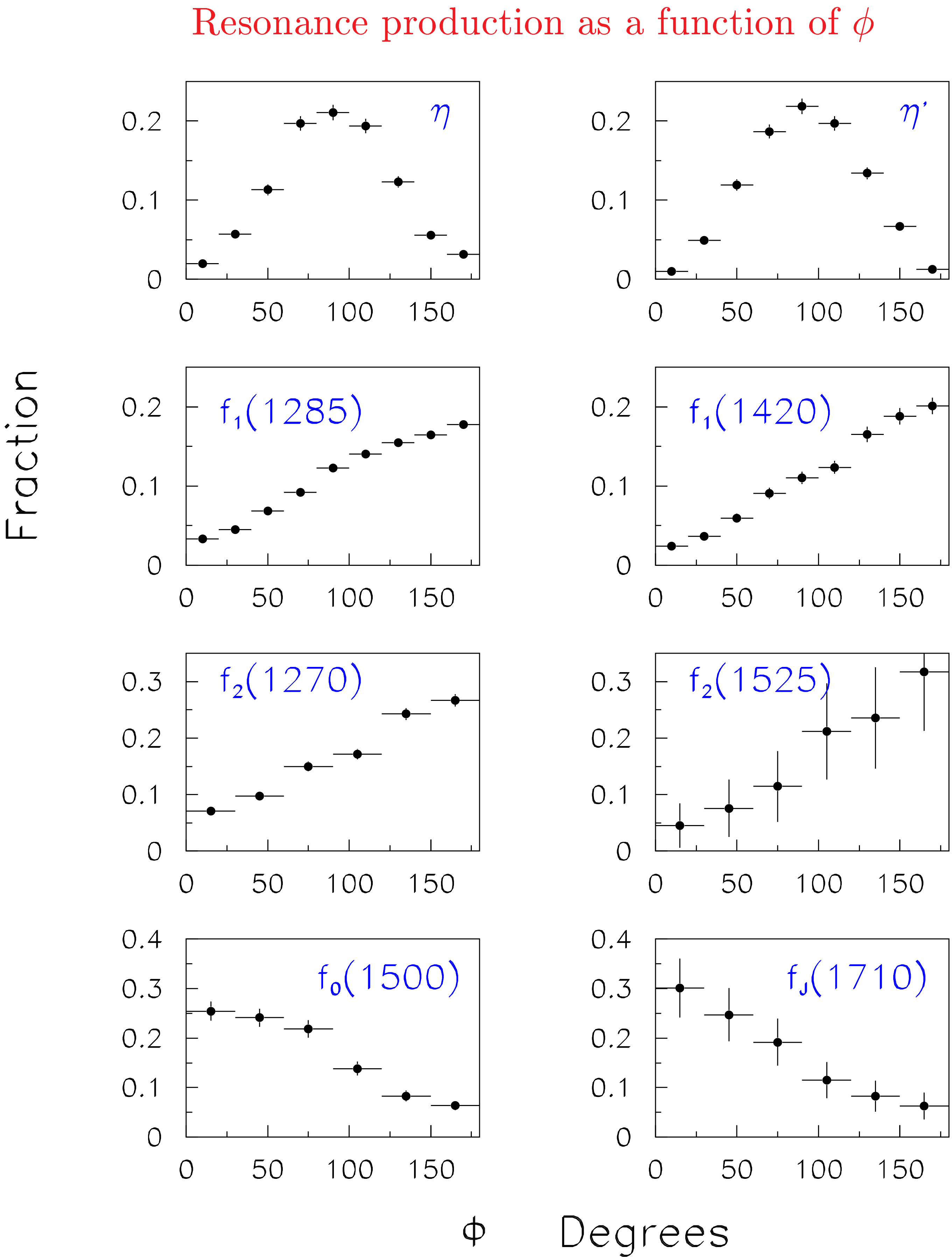
Naively expect a flat ϕ distribution.

There is a correlation between ϕ and dP_T

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

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
η
η'
$f_1(1285)$
$f_1(1420)$
$f_2(1270)$
$f_2(1525)$
$f_0(1500)$
$f_J(1710)$
Fraction
ϕ Degrees

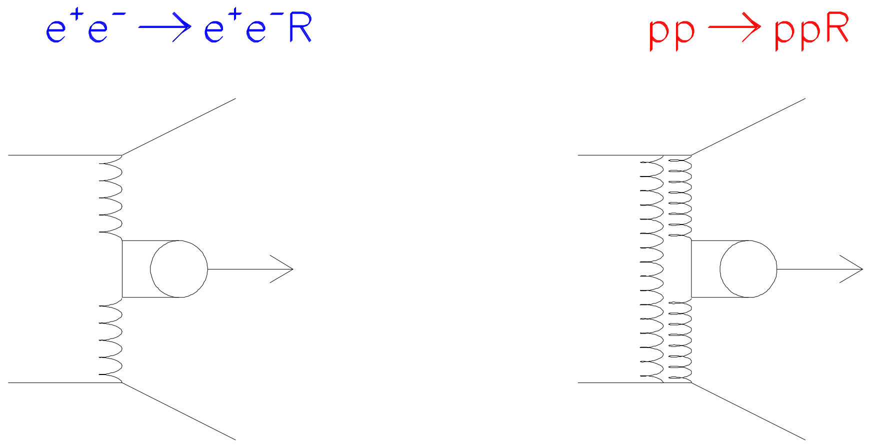
Progress on understanding these effects

Several theoretical papers have been published on these effects

- ‘A Glueball-$q\bar{q}$ filter in central hadron production’ F.E. Close and A. Kirk Phys. Lett. **B397** (1997) 333-338.
- ‘Filtering glueball from $q\bar{q}$ production in proton proton or double tagged $e^+e^- \to e^+e^- R$ and implications for the spin structure of the Pomeron’ F.E. Close Phys. Lett. **B419** (1998) 387.
- ‘Central pseudoscalar production in pp scattering and the gluon contribution to the proton spin’ P. Castoldi, R. Escribano and J.-M. Frere, Phys. Lett. **B425** (1998) 359.
- ‘The glueball filter in central production and broken scale invariance’ J. Ellis and D. Kharzeev hep-ph/9811222
- ‘Unusual properties of the central production of glueballs and instantons’ N. I. Kochelev hep-ph/9902203
- ‘Central production of mesons: Exotic states versus pomeron structure’ F.E. Close and G. Schuler hep-ph/9902243
- ‘Pomeron fusion and central η and η' meson production’ N. I. Kochelev, T. Morii and A.V. Vinnikov hep-ph/9903279
- ‘Evidence that the Pomeron transforms as a non-conserved vector current’ F.E. Close and G. Schuler hep-ph/9905305

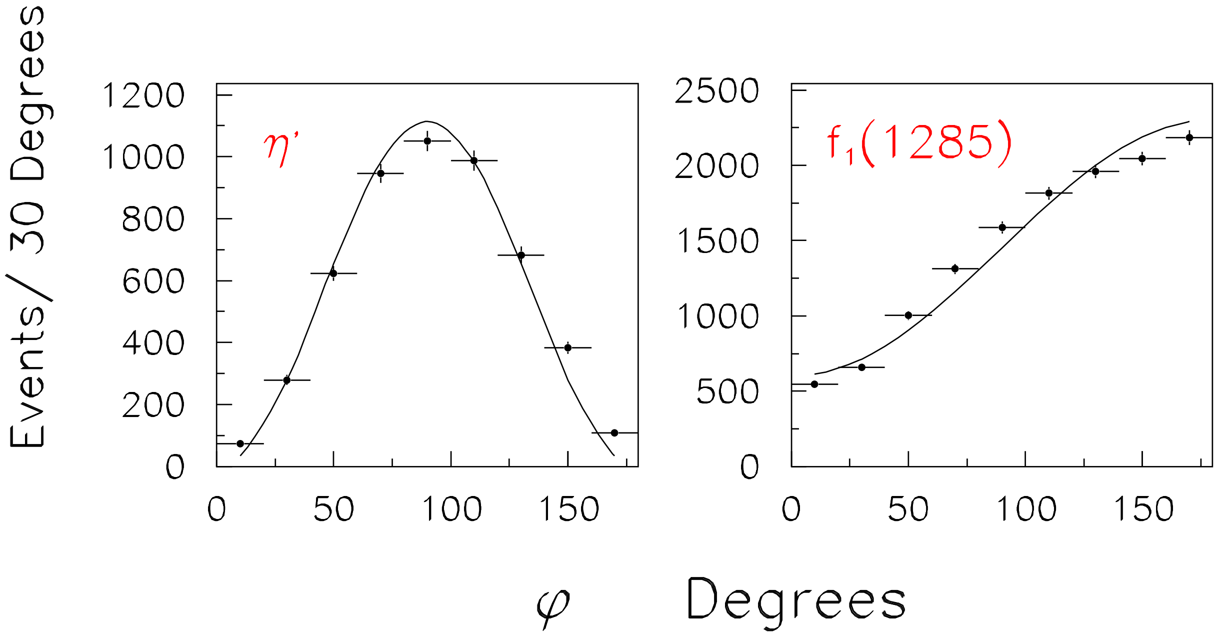
All agree that the exchanged particle (Pomeron) must have $\mathrm{J} > 0$ and that $\mathrm{J} = 1$ is the simplest explanation

Using $\gamma^*\gamma^*$ collisions as an analogy



Close and Schuler have calculated the ϕ dependencies for the production of resonances with different J^{PC}s.

Predict: 0^{-+} $sin^2(\phi)$ 1^{++} $\alpha + sin^2(\phi/2)$



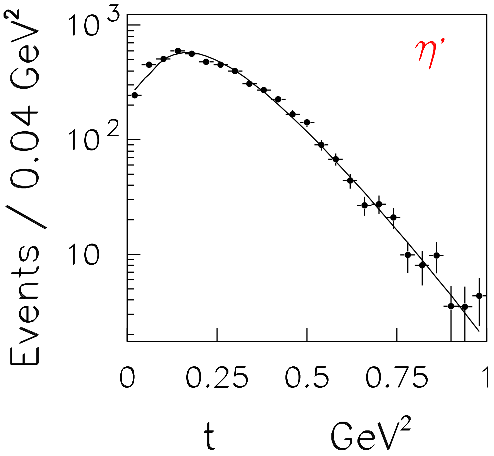
good agreement

Further predictions

Predict: 0^{-+}

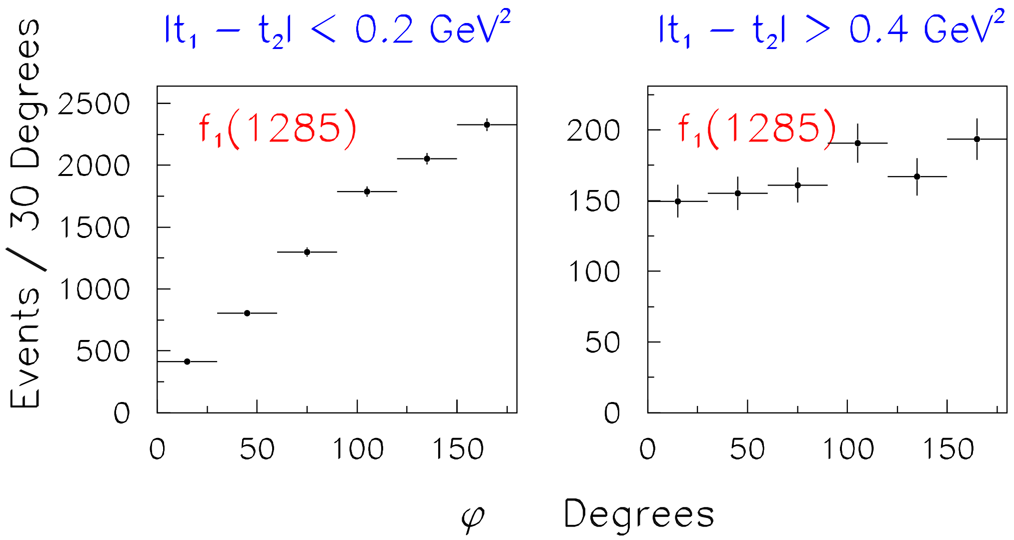
$d\sigma/dt_1t_2 \propto t_1t_2$

good agreement



Predict: 1^{++} $J_Z = 1$ Dominant Observed

$d\sigma/dt_1t_2 \propto \sqrt{t_1t_2}sin^2(\phi/2) + (\sqrt{t_2} - \sqrt{t_1})^2$



After understanding the Pomeron we then want to go on to understand how we can use this to extract the structure of the produced mesons

Summary

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

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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