How Omega helped to establish the existence of

non−$q\bar{q}$ mesons

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Outline

1) An introduction to non−$q\bar{q}$ mesons

2) An introduction to the Omega experiments

3) The non−$q\bar{q}$ states observed at Omega

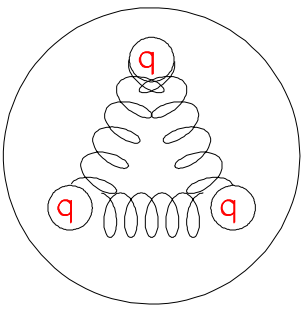
4) Summary

An introduction to $q\bar{q}$ mesons

Originally the quark model predicted that only two types of quark configurations were required to account for all strongly interacting particles

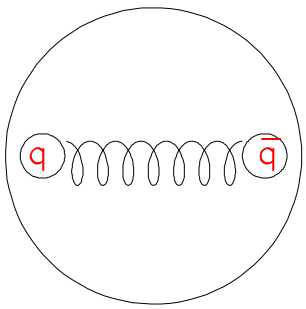
Baryons

qqq



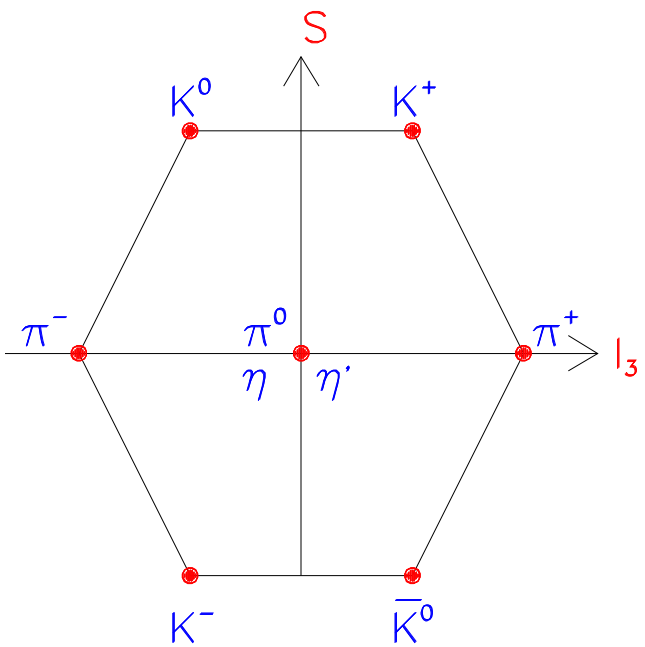
Mesons

$q\bar{q}$



This description was found to be very successful in grouping the particles into multiplets of a given spin parity

For example the ground state 0^{-+} meson nonet

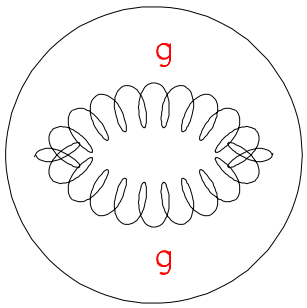


An introduction to non−$q\bar{q}$ mesons

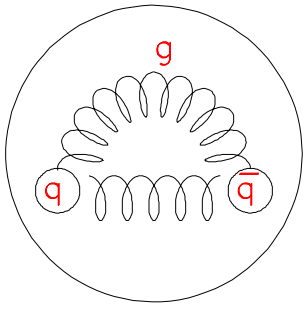
Quantum Chromo Dynamics the field theory describing strong interactions not only describes how quarks and antiquarks interact by the exchange of gluons to form mesons

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

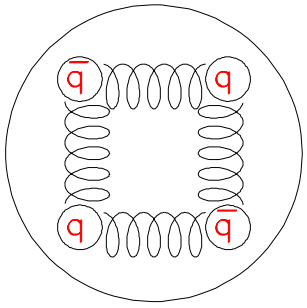
Glueballs gg, ggg



Hybrids $q\bar{q}\,g$



4−quark states $q\bar{q}\,q\bar{q}$



Mass estimations

Naive estimates from the Bag model a few years ago predicted

$$M_{gg}(0^{++}) = 1 \text{ GeV}$$

However, new Lattice Gauge calculations

$$M(2^{++})/M(0^{++}) = 1.5$$

and that depending on the choice of constant

$$M(0^{++}) = 1500 - 1750 \text{ MeV}$$

The ggg states are higher in mass and the lightest $q\bar{q}$ hybrid has

$$M(q\bar{q}\,g) > 1.9 \text{ GeV}$$

How to look for non–$q\bar{q}$ mesons ?

1) Look for Oddballs

– states with J^{PC} not allowed for $q\bar{q}$ states

2) Look for extra states

– states with quantum numbers of an already completed nonet

3) Look for states with unusual branching ratios

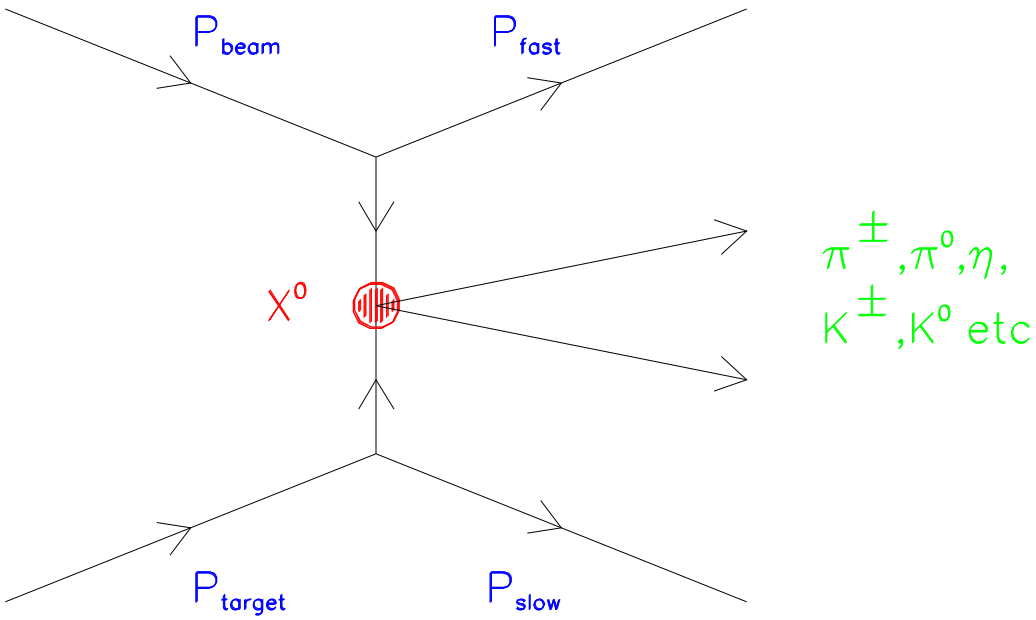
4) Look for states preferentially produced in gluon rich processes

Experiments WA76, WA91 and WA102 have studied exclusive final states in the reactions

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

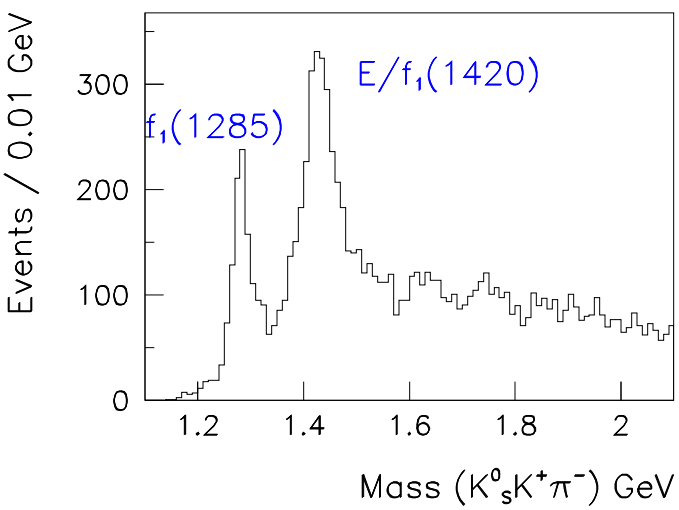
at 85, 300 and 450 GeV/c

Centre of mass view



Some non–$q\bar{q}$ candidates from experiments WA76 and WA91

The $E/f_1(1420)$



Only observed decaying to $K^*\bar{K}$

Dalitz plot analysis $\rightarrow$ $J^{PG} = 1^{++}$

Observation in $K^0_S K^0_S \pi^0$ $\rightarrow$ $I = 0$

and hence $I^G J^{PC} = 0^+ 1^{++}$

The E/f_1(1420) was thought to be the $s\bar{s}$
member of the 1^{++} nonet

However it was not observed in K^-p reactions
where $s\bar{s}$ states should be observed
Instead another state the f_1(1530) was observed

Therefore the E/f_1(1420) is an extra state
which only decays to $K^*\bar{K}$near to
$K^*\bar{K}$threshold

Whatever its classification there are
10 states where the $q\bar{q}$ nonet would
predict that there should only be 9

Summary on $\vartheta/f_J(1720)$

The $\vartheta/f_J(1720)$ is predominantly observed in gluon rich production mechanisms

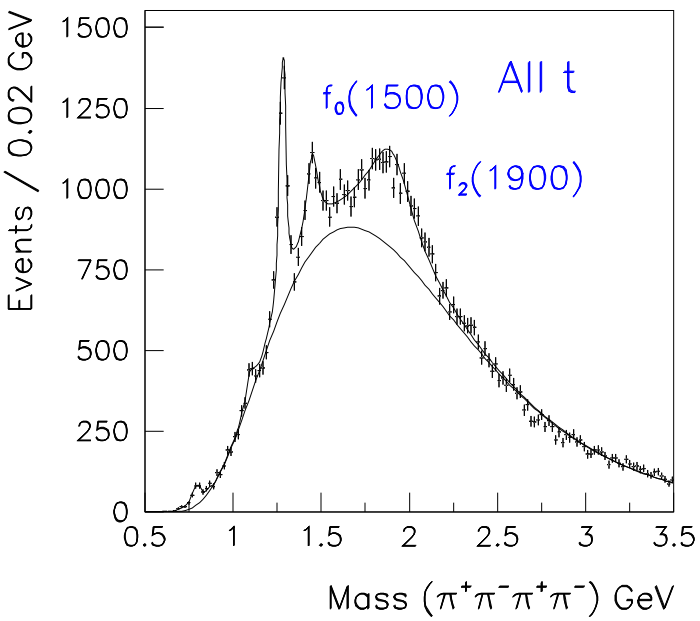
Inspite of its dominant $K\bar{K}$ decay mode it is not produced in K^-p interactions

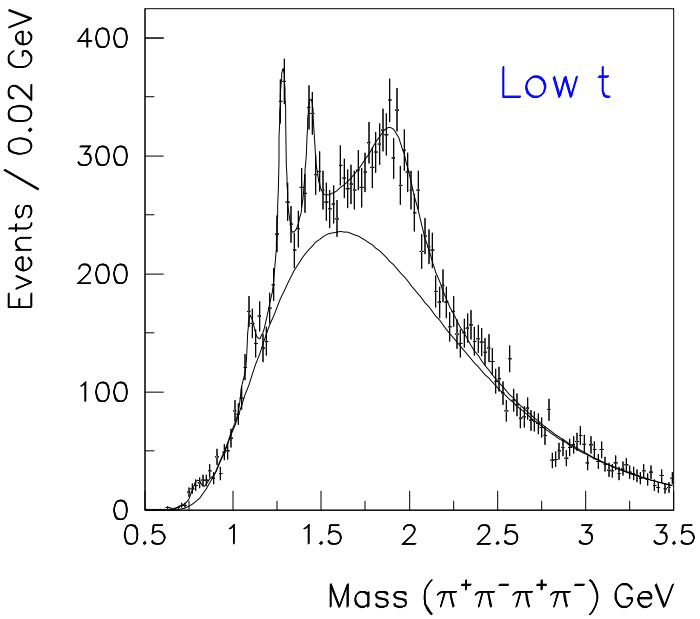
Nor is it produced in $\gamma\gamma$ collisions

Its J^{PC} needs to be confirmed $J^{PC} = 0^{++}$ or 2^{++}

It can not be explained as being a normal $q\bar{q}$ meson

The $f_0(1500)$ and $f_2(1900)$





$f_0(1500)$ and $f_2(1900)$ were first observed by experiment
WA76 in the 300 GeV/c run (not observed in 85 GeV/c data)

Both observed at high energy and low t as would
be expected for states produced by double Pomeron exchange

The $f_0(1500)$ is a narrow scalar which is observed
in central production, $p\bar{p}$ annihilation and
radiative J/ψ decay

It has all the characteristics of being a glueball

Summary

WA76, WA91 and WA102 have performed a dedicated search
for non–$q\bar{q}$ mesons in central production
and several candidates have been observed

$E/f_1(1420)$ $\quad J^{PC} = 1^{++}$

$\vartheta/f_J(1720)$ $\quad J^{PC} = 0^{++}$ or 2^{++}

$f_0(1500)$ $\quad J^{PC} = 0^{++}$

$f_2(1900)$ $\quad J^{PC} = 2^{++}$

None of these states can easily be classified
in $q\bar{q}$ nonets

Gluonium 95

The status of the search for non–$q\bar{q}$ mesons
was discussed by representatives of all the major
experiments at a workshop called Gluonium 95

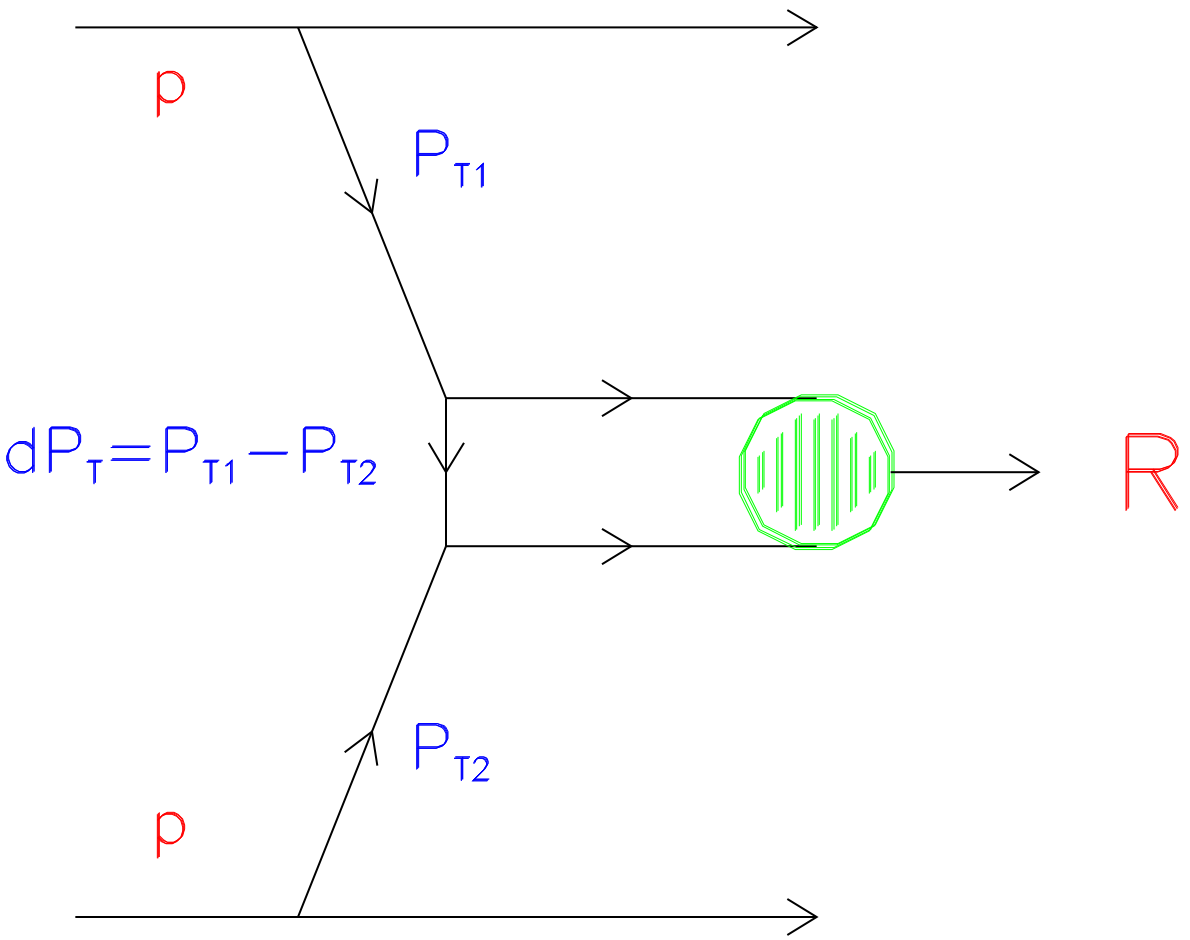
The consensus of this meeting was that
There are too many gold–plated states
for the $q\bar{q}$ nonet scheme

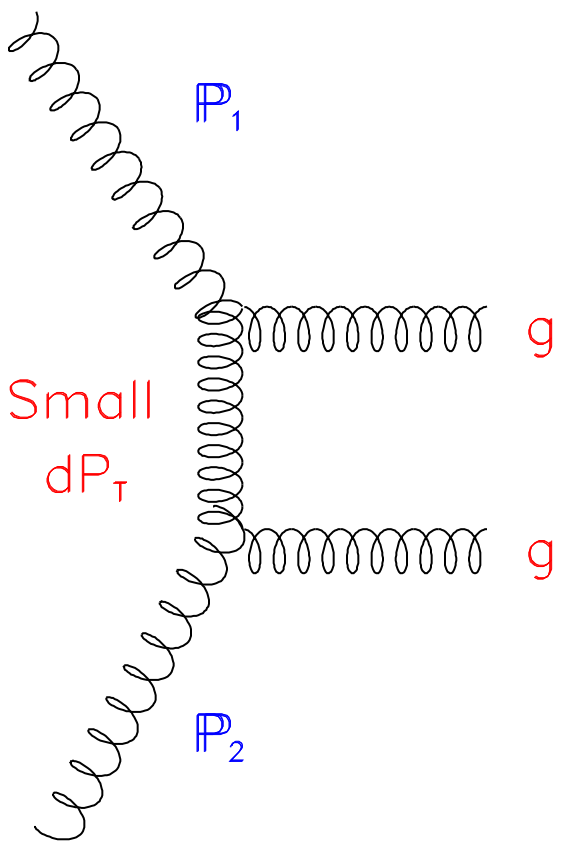
We definitely have

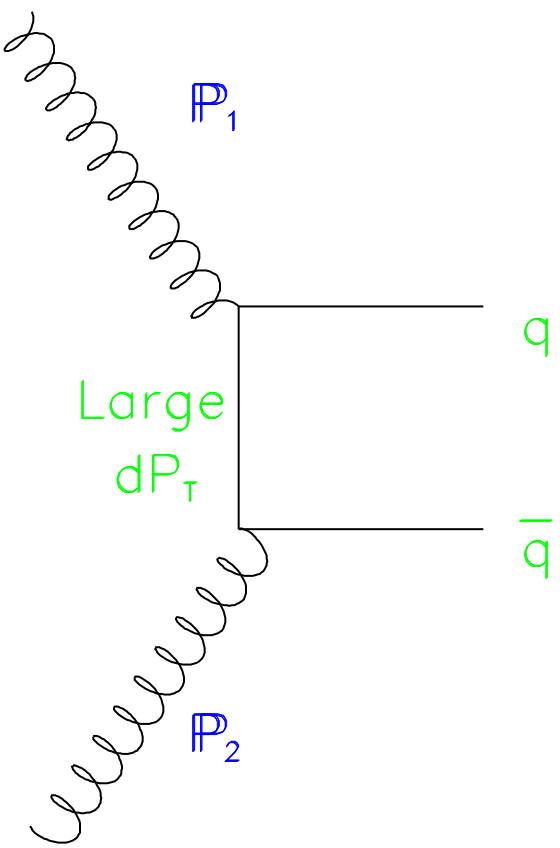
Evidence for non–$q\bar{q}$ mesons

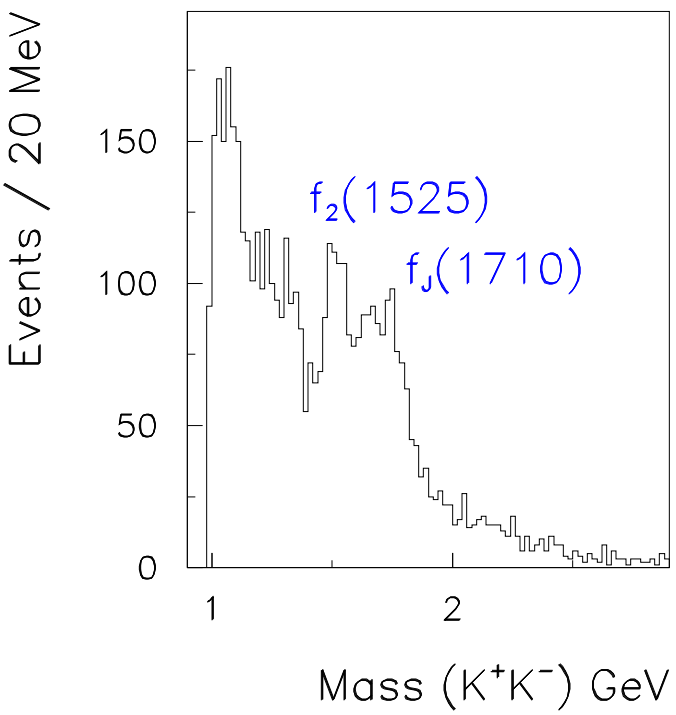
The aim now is to understand the composition of these states
and hence to identify the glueballs

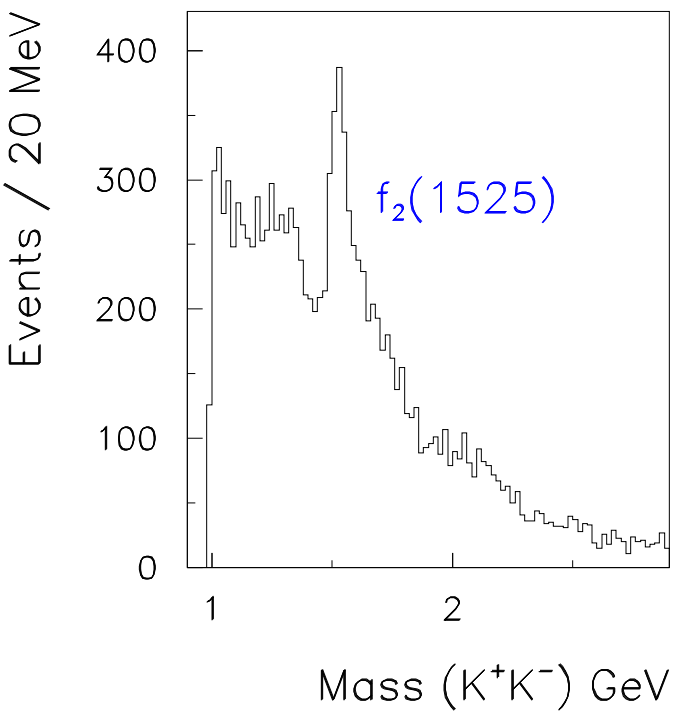
A Glueball – $q\bar{q}$ filter ?





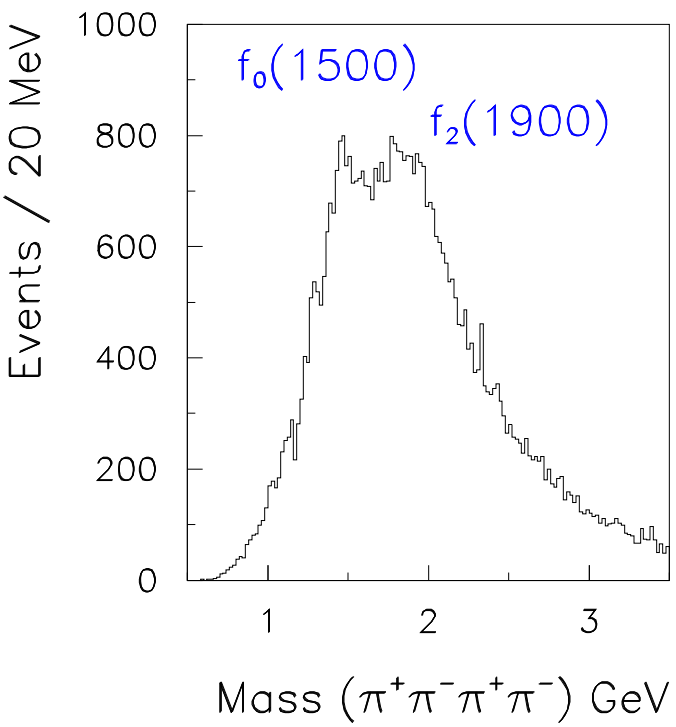


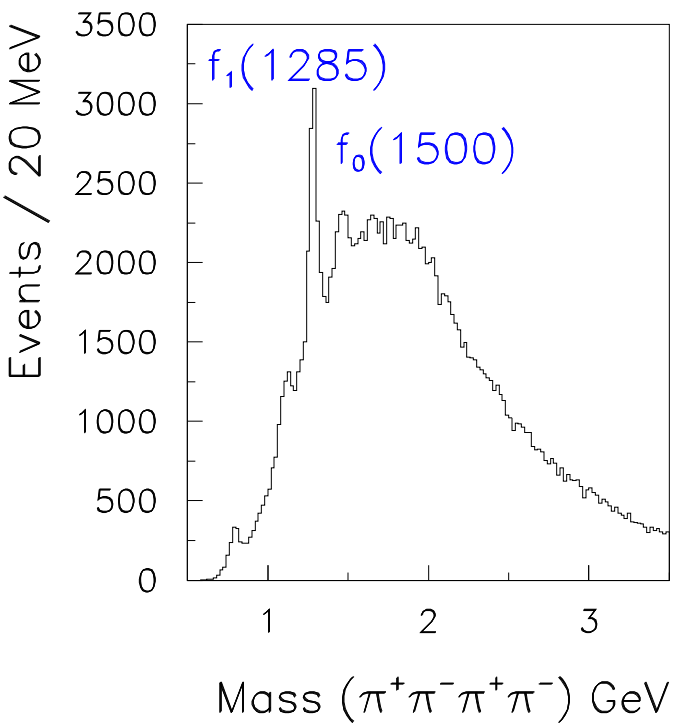




Small dP_T

Large dP_T





Conclusions

Omega has played an essential role in the establishment of the existence of non–$q\bar{q}$ mesons

Several non–$q\bar{q}$ states have been isolated

Preliminary results show that there is the possibility of a glueball–$q\bar{q}$ filter mechanism in central production

We are hopeful that with the data collected at Omega we will be able to answer the question

Where are the glueballs ?