# Observation of $K_s K_s$ resonances in DIS at HERA

Mauricio Barbi

McGill University

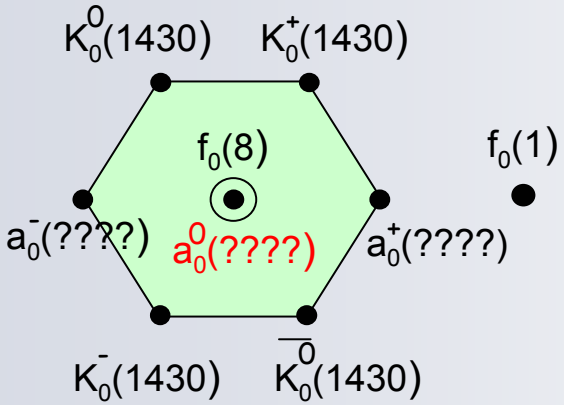
ZEUS Collaboration

*Hadron 2003, Aschaffenburg*
*August 31 – September 6*


1. Introduction / Motivation
2. Event selection
3. Results / Discussions
4. Summary

# Introduction / Motivation

- Scalar meson nonet not well understood; a $s\bar{s}$ state yet to be confirmed, and an excess of candidates for the available positions in the nonet;
- QCD predicts the existence of hadrons made up by gluons (glueballs).
- Lattice QCD predicts lightest glueball with $J^{PC}=0^{++}$ and mass between 1.4-1.8 GeV;




**Scalar $J^{PC}=0^{++}$ Nonet**

$f_0(8)$ → $f_0(1370) \sim \bar{u}u+\bar{d}d$
$f_0(1)$ → $f_0(1500) \sim$ ??
$f_0(1710) \sim$ ??

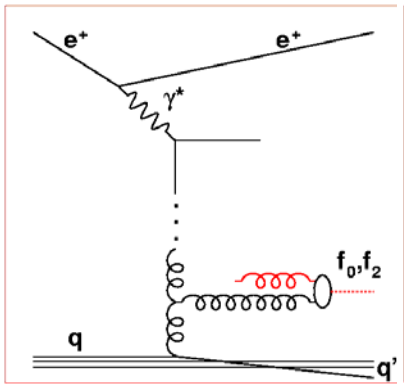
**3 candidates for 2 spots**

**$f_0(1710)$ is a glueball candidate**

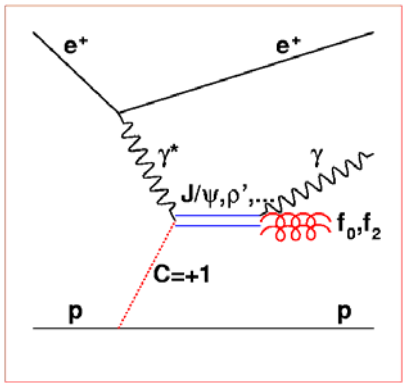
# Introduction / Motivation

- *ep* collisions at HERA as a new environment for resonance studies; gluon rich initial state in *ep* deep inelastic scattering (DIS);
- $K^0_S$ studied at HERA before; clean sample;
- $K^0_S K^0_S$ couples to meson states with $J^{PC}=(\text{even})^{++}$.

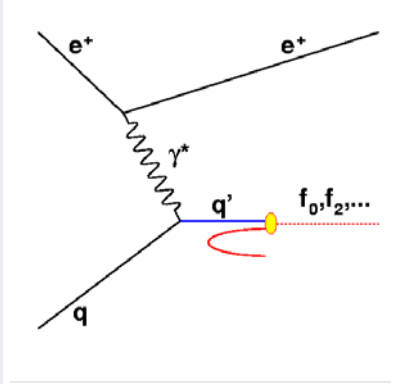
*Some production processes at HERA*



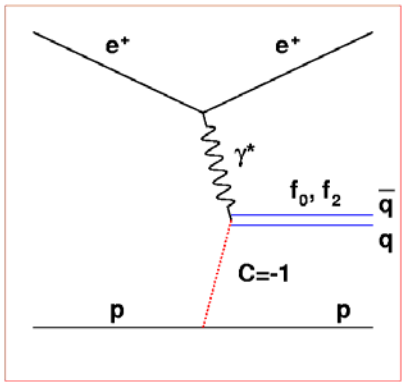

Gluon ladder




Radiative VM decay




Quark jets



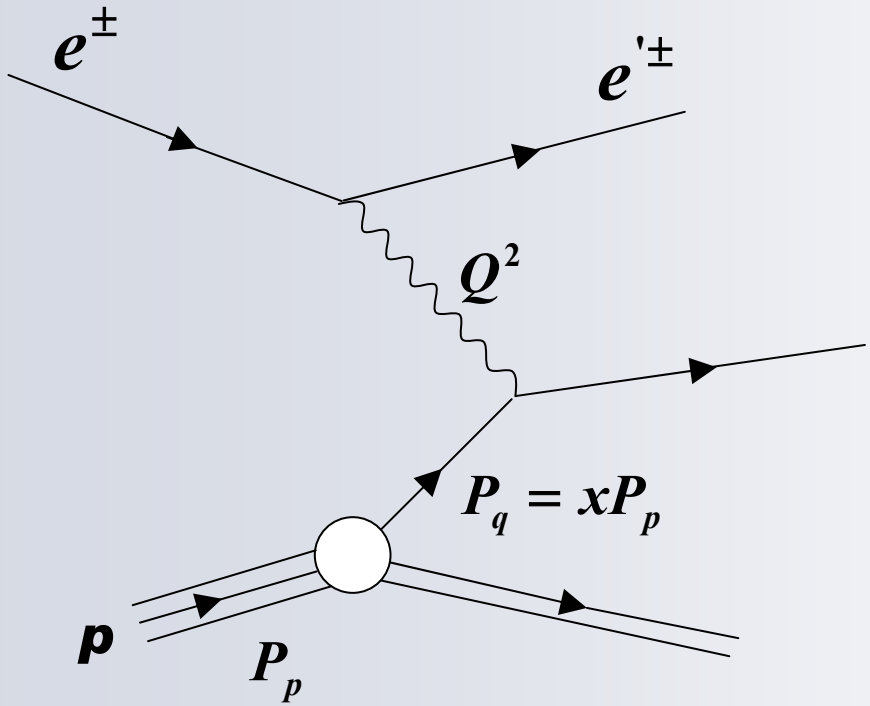

Odderon exchange

Gluon rich

Gluon poor

# Event Selection

DIS variables




$Q^2$ = photon virtuality

x = Bjorken scaling variable

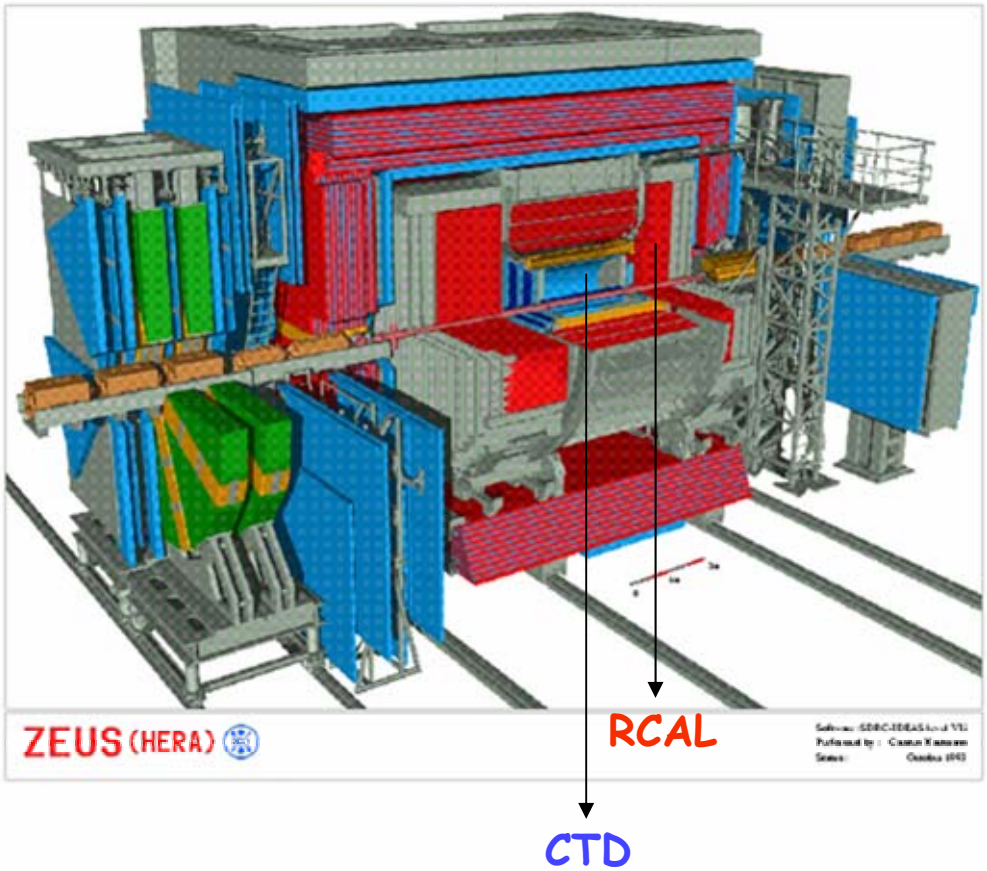
y = fraction of the lepton energy transferred to the proton in the proton rest frame

$$Q^2 = xys$$

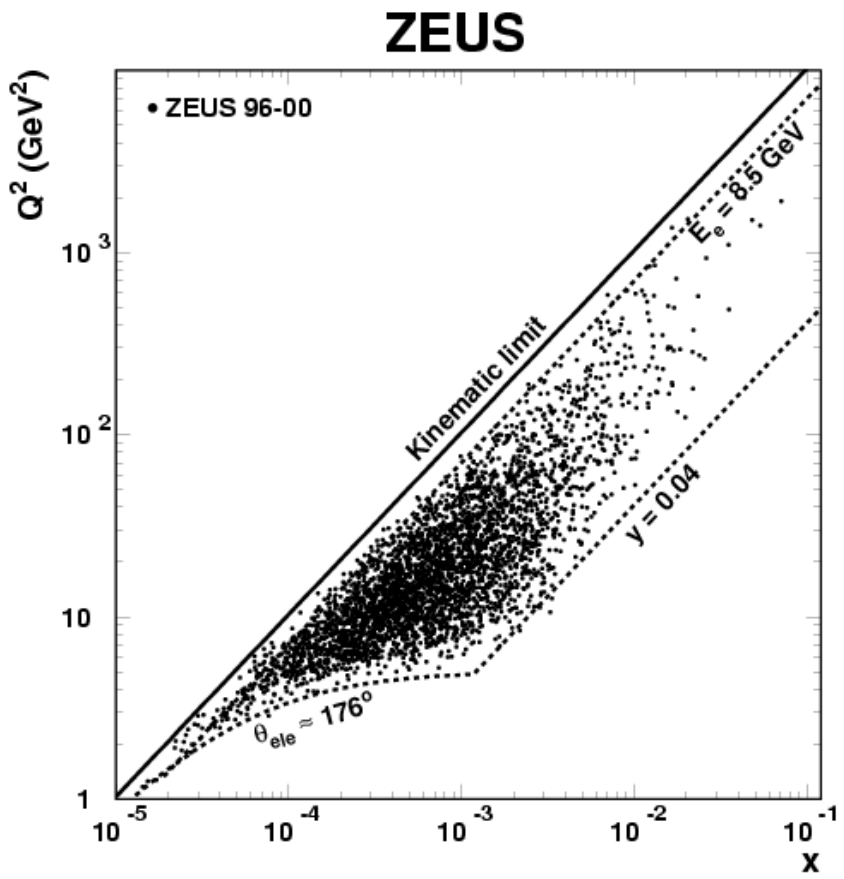
$$\sqrt{s} = c.m.s.\ energy$$

# Event Selection

- Integrated luminosity of 120 $pb^{-1}$ (1996-2000 data);
- Events with scattered $e^-$ ($e^+$) in Rear Calorimeter (RCAL);
- Use only good tracks measured with the Central Tracking Detectors (CTD).

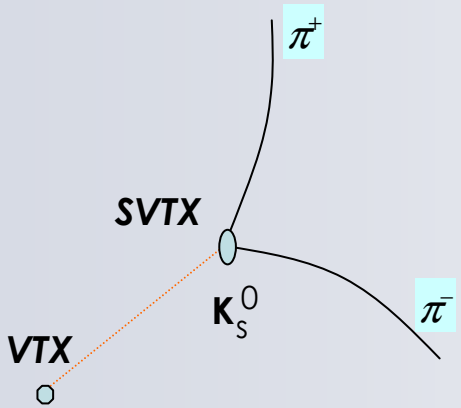


# Event Selection

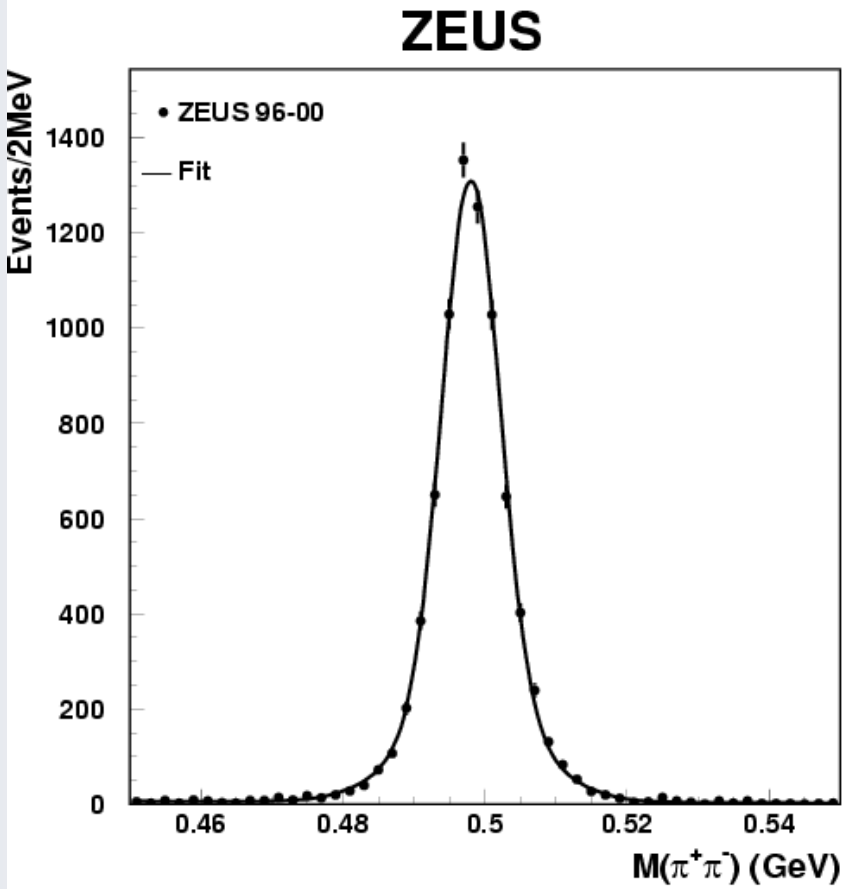



Kinematical region limited by event selection requirements and limit for HERA running with 920 GeV protons.

# Event Selection




- Take only $K_s^0$ in the region of 10 MeV around the fitted $K_s^0$ mass;

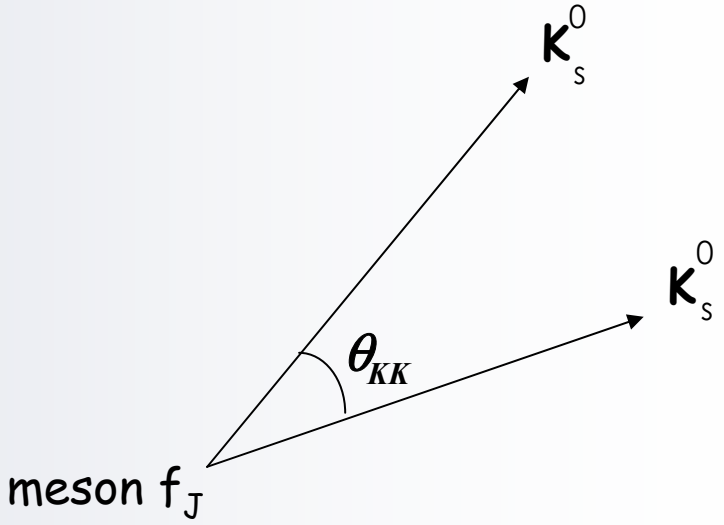


# Event Selection

Remove enhancement at $K^0_S K^0_S$ invariant mass threshold due to the presence of the $f_0(980)/a_0(980)$ state.

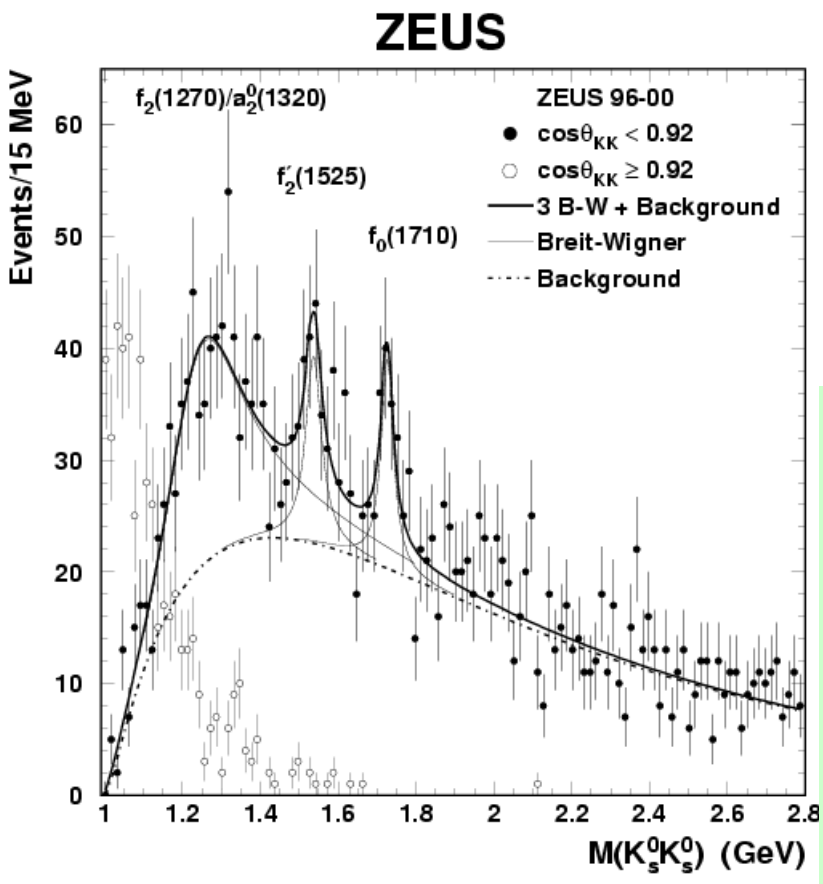
$$\cos\theta_{KK} < 0.92$$

$K^0_S K^0_S$ system does not open at threshold




2553 $K^0_S K^0_S$ candidates found in the range
$0.995 < M(K^0_S K^0_S) < 2.795$ GeV

# Results / Discussions




**Fit with 3 modified relativistic Breit-Wigners and a background function.**

$$F(M) = \frac{dN}{dM} = \sum_{i=1}^{3}\left(\frac{m_{*,i}\Gamma_{d,i}}{(m_{*,i}^2 - M^2)^2 + m_{*,i}^2\Gamma_i^2}\right) + A\left(M - 2m_{K_s^0}\right)^B e^{-C\sqrt{M-2m_{K_s^0}}}$$

- First observation of $J^{PC}=(even)^{++}$ in DIS. Two states are observed:
  - a state consistent with $f_2'(1525)$
  - X(1726) ( is this the $f_0(1710)$ ? )
- A third state is observed in the (problematic) 1300 MeV mass region, consistent with the $f_2(1270)/a_2^0(1320)$ interference.

# Results / Discussions

**ZEUS fit values (MeV)**

| $\chi^2/N$ | $f_2'(1525)$ | | | $f_0(1710)$ | | |
|---|---|---|---|---|---|---|
| | mass | width | events | mass | width | events |
| 0.97 | $1537^{+9}_{-8}$ | $50^{+34}_{-22}$ | $84^{+41}_{-31}$ | $1726\pm7$ | $38^{+20}_{-14}$ | $74^{+29}_{-23}$ |
| 0.96 | $1539\pm10$ | 76 | $107\pm30$ | $1727\pm7$ | $39\pm20$ | $76^{+28}_{-24}$ |
| 1.02 | $1536\pm8$ | $49^{+30}_{-21}$ | $85^{+38}_{-27}$ | $1726\pm13$ | 125 | $122\pm40$ |
| 1.02 | $1538\pm10$ | 76 | $108^{+31}_{-29}$ | $1728\pm13$ | 125 | $120^{+41}_{-38}$ |

**PDG 2002 values (MeV)**

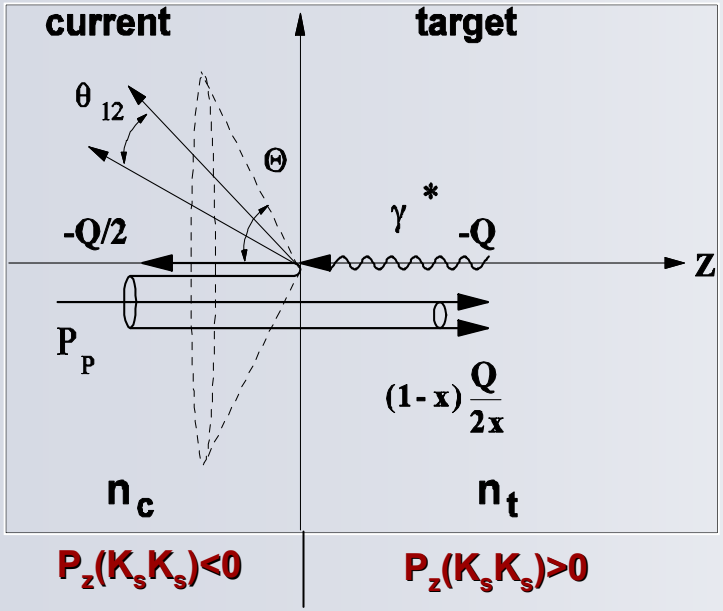
| | mass | width | mass | width |
|---|---|---|---|---|
| | $1525\pm5$ | $76\pm10$ | $1713\pm6$ | $125\pm10$ |

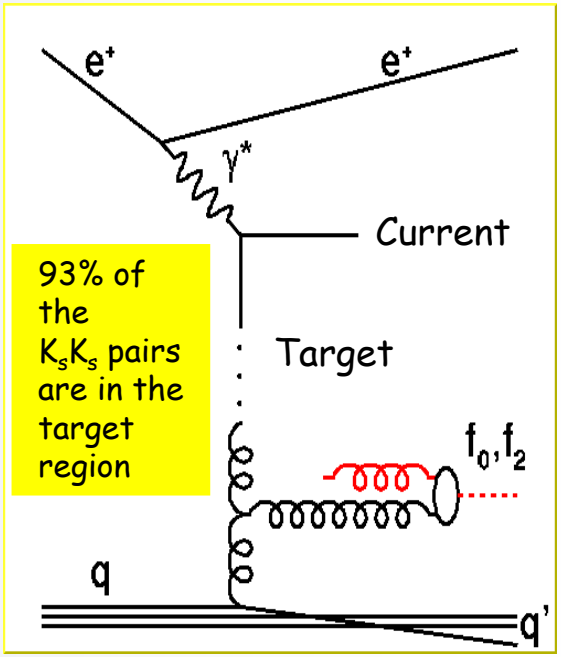
- **Correlations between the parameters are accounted;**
- **Sensitivity of the data to the widths of the resonances is checked.**

# Results / Discussions

## Breit Frame

Current region in DIS is equivalent to an $e^+e^-$ hemisphere



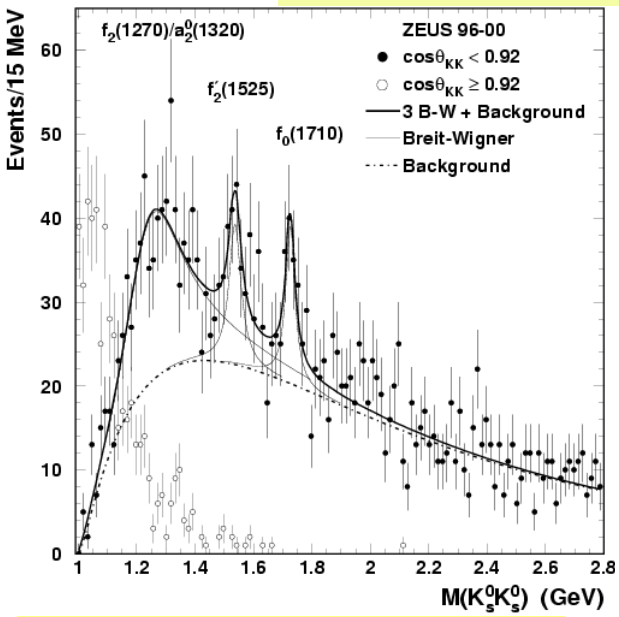




93% of the $K_sK_s$ pairs are in the target region

**93% of the $K^0_sK^0_s$ production is in a region where sizeable initial state gluon radiation may be expected.**

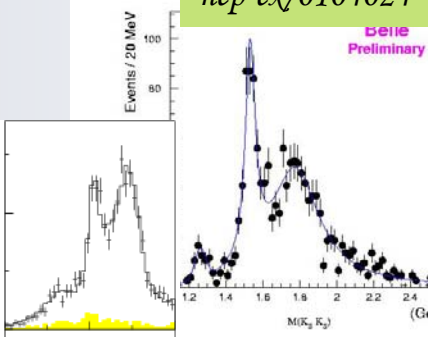
# Results / Discussions

## Confronting L3, BELLE, BES and ZEUS

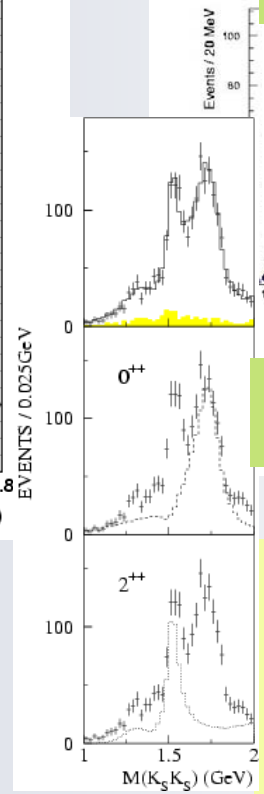



*ZEUS*
*Submitted to Phys. Lett. B*
*Hep-ex/0308006*

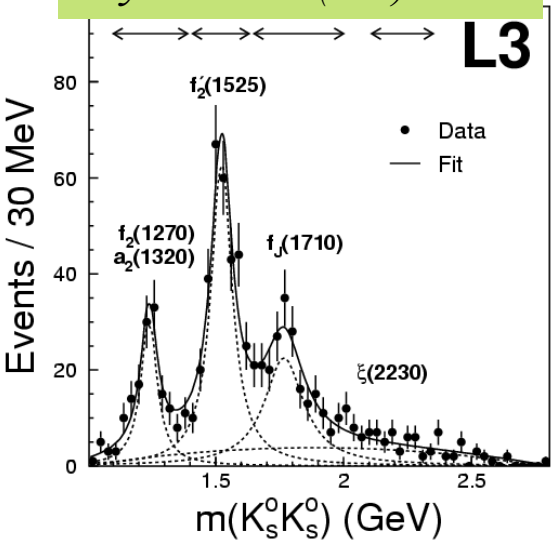
*BELLE*
*hep-ex/0104024*




*BES*
*hep-ex/0307058*




*L3*
*Phys. Lett. B501 (2001) 173-182*




**1700 MeV mass region**

**L3: mass 1767±14 MeV; width 187±60 MeV**
**BELLE: mass 1768±9.6 MeV; width 323±29 MeV**
**BES: mass 1722±17 MeV; width $167^{+37}_{-29}$ MeV**
**ZEUS: mass 1726±7 MeV; width $38^{+20}_{-14}$ MeV**

# Summary

- First observation of resonances in $K^0_s K^0_s$ final state in DIS was reported;
- An enhancement is observed in the 1300 MeV mass region, but its measurement is affected by the cut to eliminate the presence of the $f_0(980)/a_0(980)$ at threshold;
- A state is observed in the 1500 MeV mass region consistent with the $f_2'(1525)$;
- Another state X(1726) is observed, probably the $f_0(1710)$ (a glueball candidate), but more statistics is needed to establish its width;
- The states are produced in a region where sizeable initial state gluon radiation is expected.