Inclusive $K_S^0 K_S^0$ Resonance Production in ep Collisions at HERA

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on behalf of

ZEUS Collaboration

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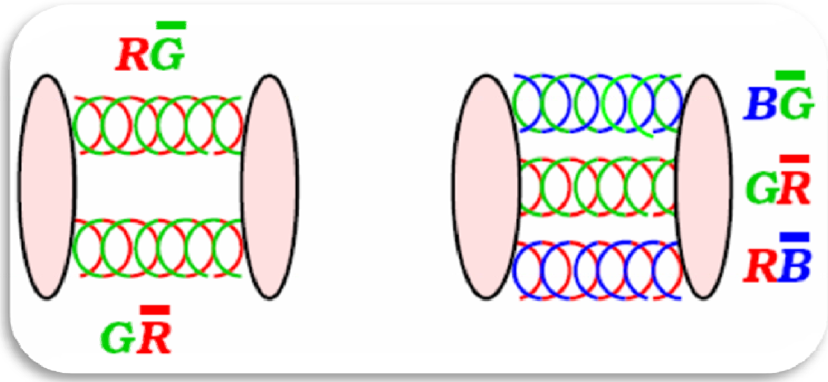
Outline

- Analysis motivations
- Previous publication and results
- Experimental setup and observation principle
- Data sample selection and K^0_s mass distribution
- $K^0_sK^0_s$ spectra with interference fits
  - Non-interference function
  - Interference function
- Summary and conclusion

Motivations

- The Standard Model explains the existence of hadrons well.
- The Standard Model allows for the existence of particles made by gluons.
- A gluon carries both a color and an anti-color.
- Either two or three gluons may confine together as color singlet GLUEBALLs



Examples of glueballs

Motivations (Cont.)

- The $K^0_s K^0_s$ system is expected to couple to scalar and tensor glueballs
  K^0_s: has S=0, P=-1, C=+1
  $K^0_s K^0_s$: has P=+1, C=+1 → J = even

$K^0_S K^0_S$ **bound states** $\Rightarrow J^{PC}: \; 0^{++}$ **(scalar)**; 2^{++} **(tensor)** . . .

Question: What is the mixing fraction of mesons and glueballs?

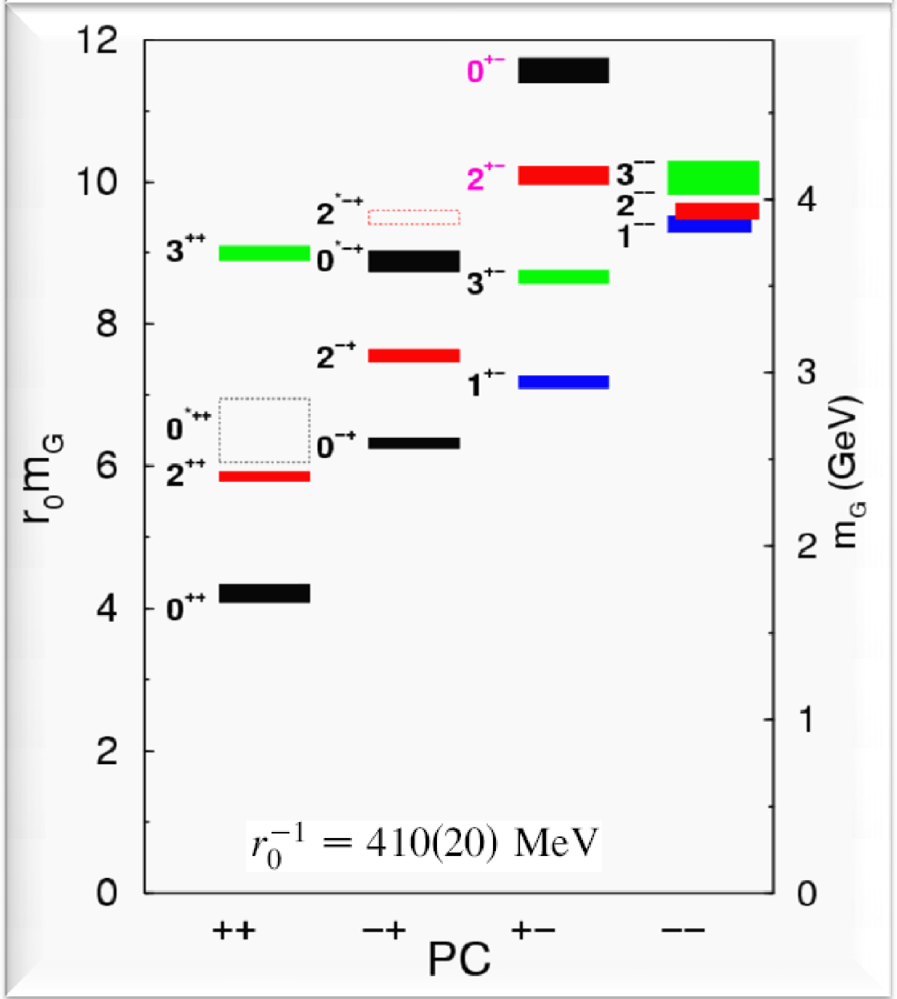
Hybrid? Tetraquarks? Flavor octet states?

P = $(-1)^{(L+1)}$	Parity
C = $(-1)^{(L+S)}$	Charge Conjugation
J = L $\oplus$ S	J: Total Angular Momentum
	L: Orbital Angular Momentum
	S: Total Spin ($q\bar{q} \Rightarrow$ 0, 1)

Motivations (Cont.)

Lattice QCD predictions

C. Morningstar, M. Peardon, Phys.Rev.D60(1999)



Lightest glueball candidates:

$J^{PC} = 0^{++}$

$\Rightarrow$ **mass range: 1730 $\pm$ 100 MeV**

$J^{PC} = 2^{++}$

$\Rightarrow$ **mass range: 2400 $\pm$ 120 MeV**

Experimentally, four states with

$J^{PC} = 0^{++}$ and $I = 0$ have been

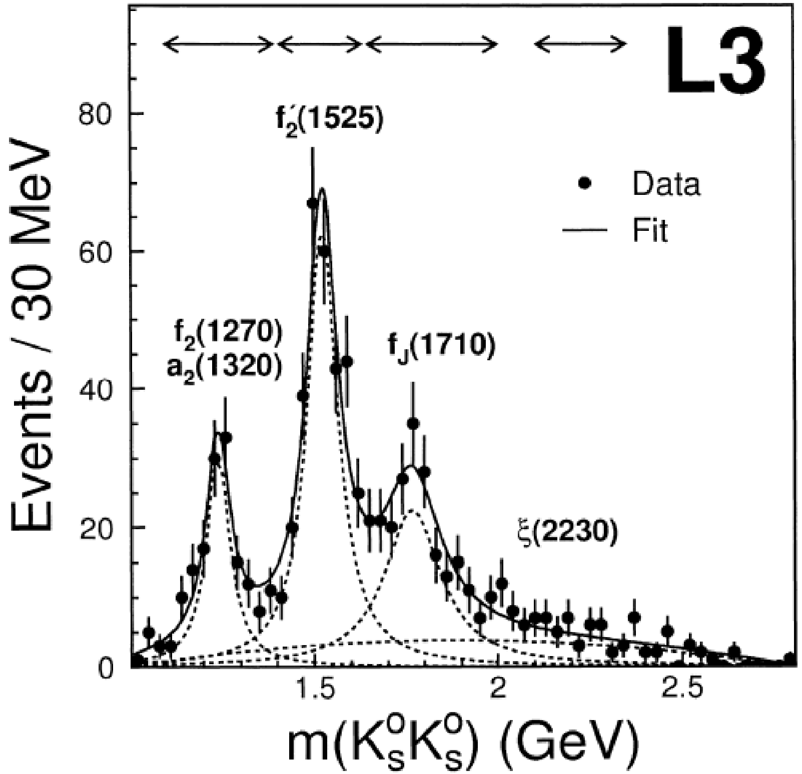
established

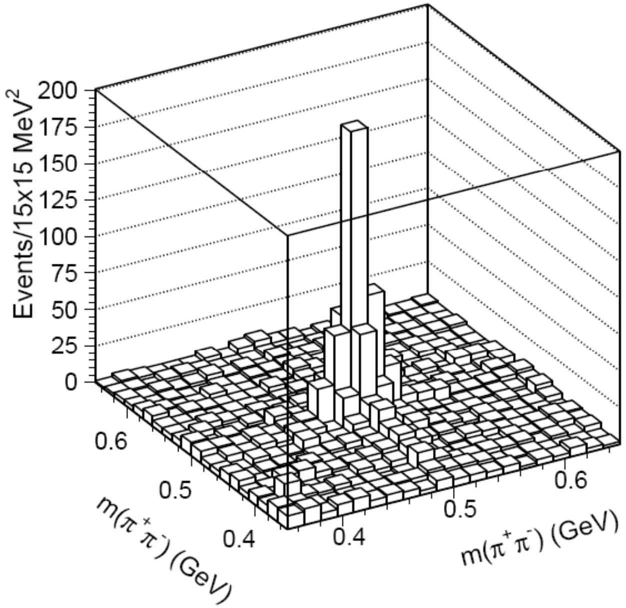
: $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$.

K. Hagiwara et al., Phys. Rev. D 66 (2002) 1

Previous Publication

- **"K0sK0s Final State in two photon collisions and implications for glueballs" (L3)** Published in **Phys.Lett.B501:173-182,2001 (hep-ex/0010037)**

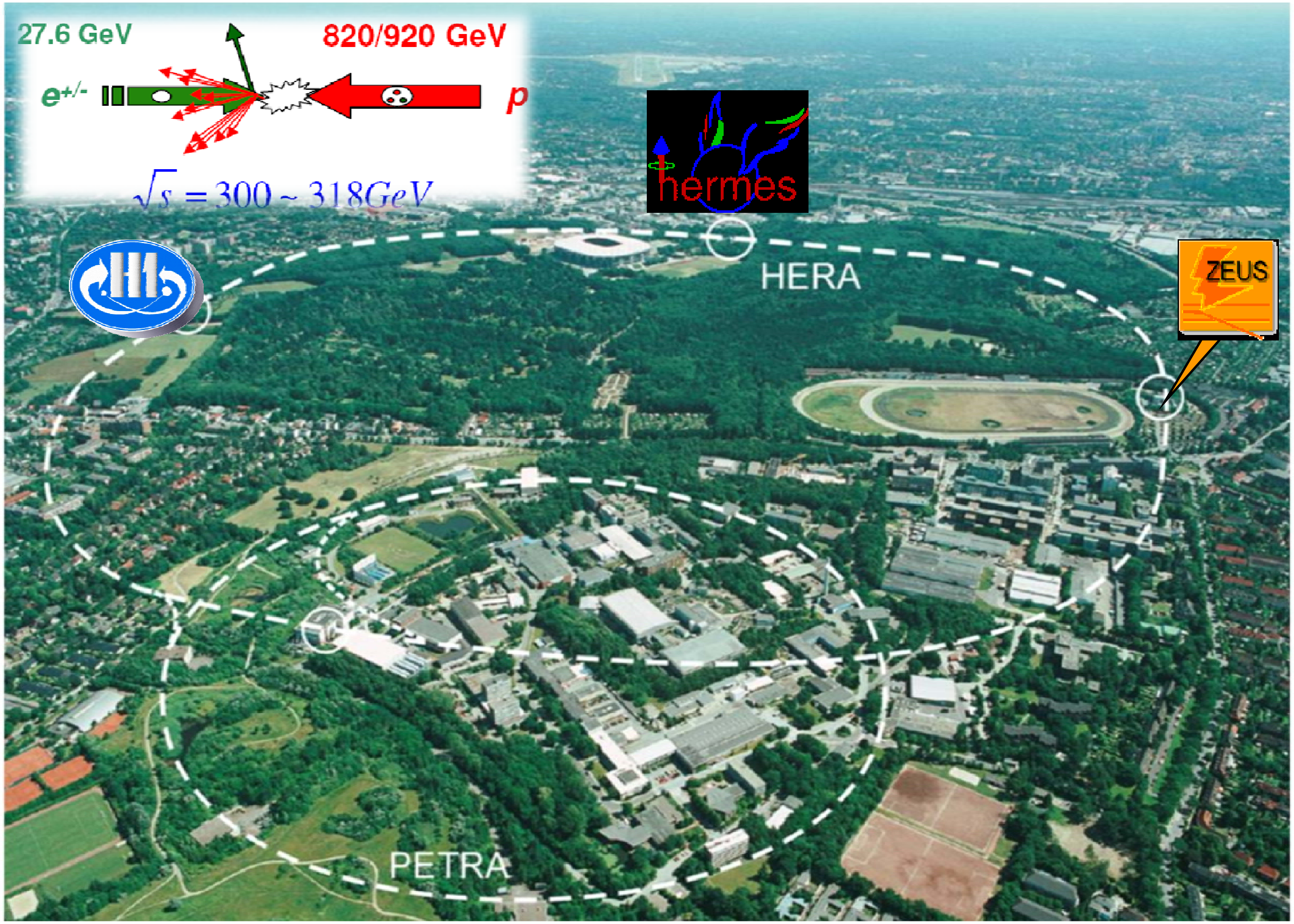




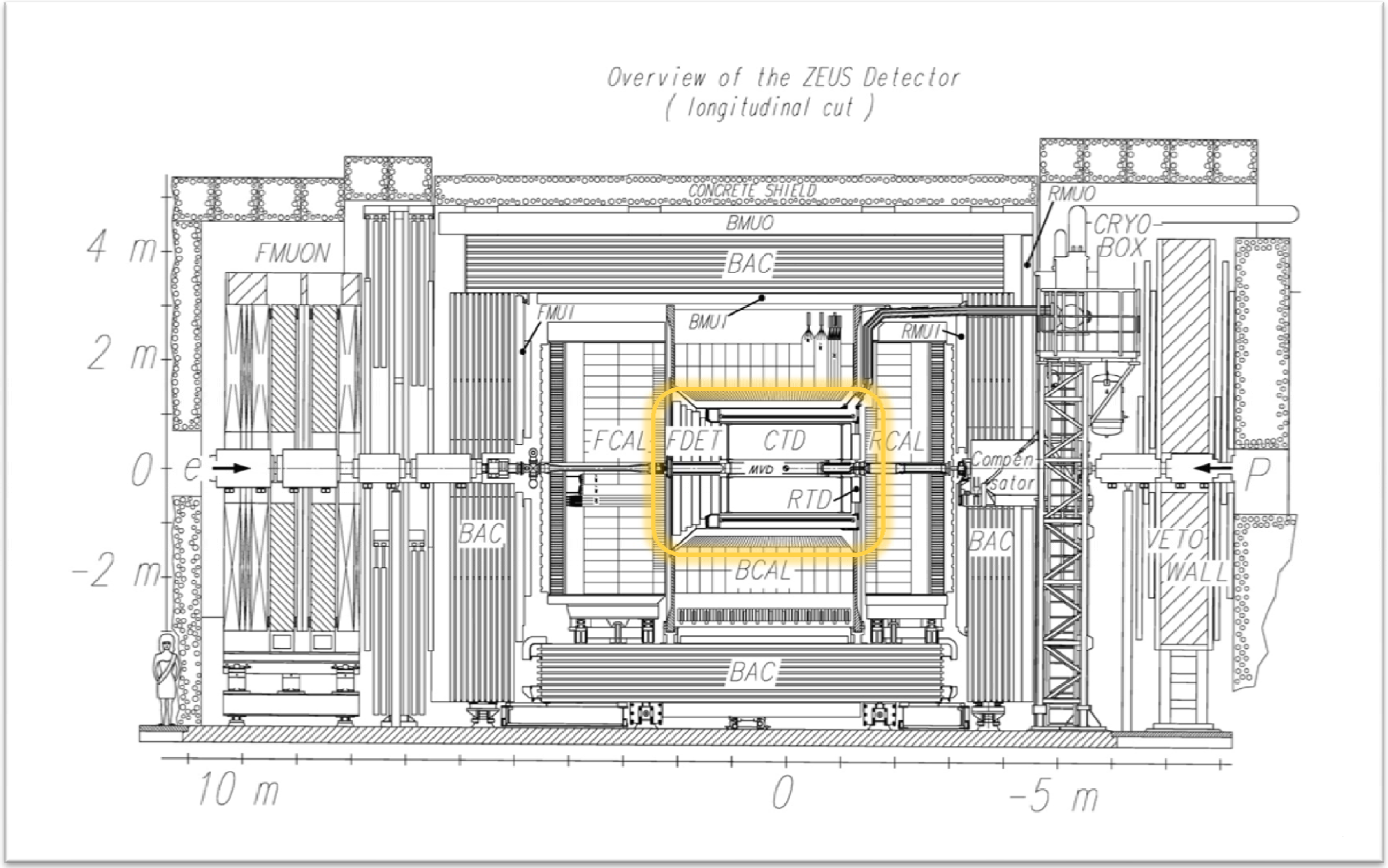
	$f_2(1270)$-$a_2(1320)$	$f_2'(1525)$	$f_J(1750)$
Mass (MeV)	1239 ± 6	1523 ± 6	1767 ± 14
Width (MeV)	78 ± 19	100 ± 15	187 ± 60
Area	123 ± 22	331 ± 37	220 ± 55

~4σ for $f_J(1710)$

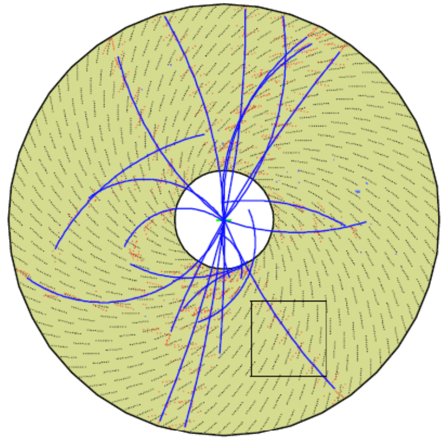
HERA


27.6 GeV
820/920 GeV
$e^{+/-}$
p
$\sqrt{s} = 300 \sim 318 GeV$
hermes
HERA
ZEUS
PETRA

HERA and ZEUS

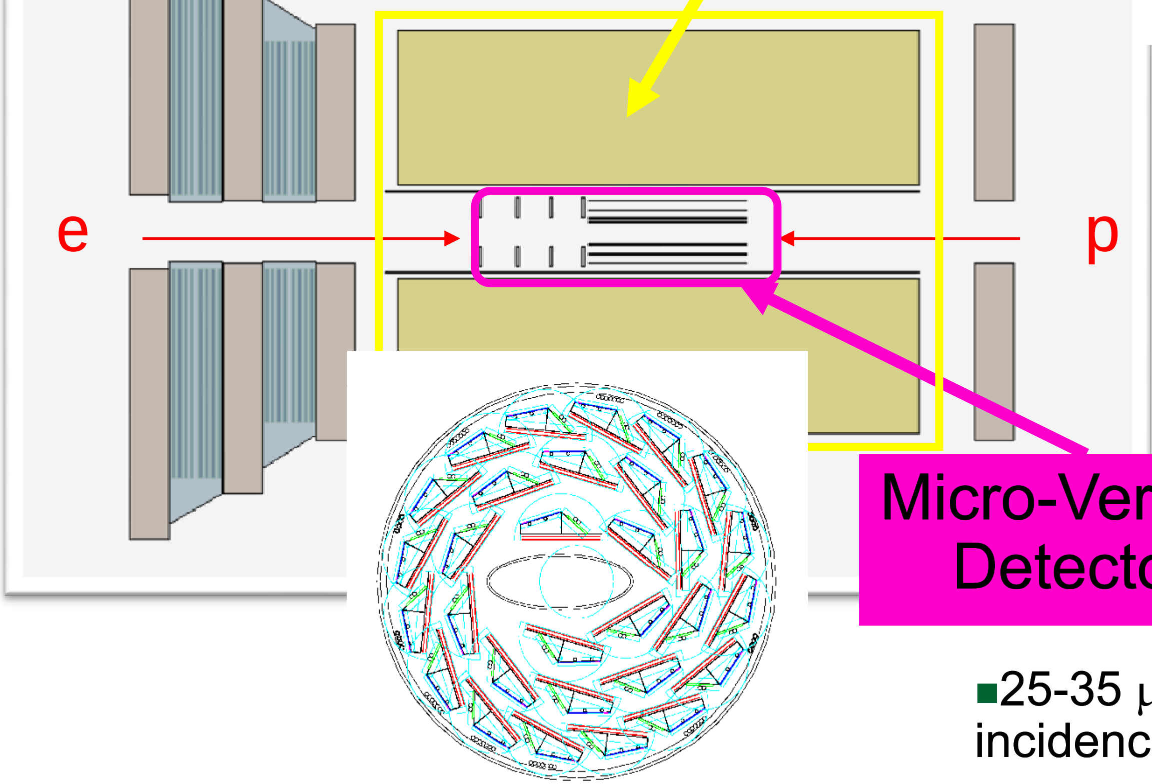


Tracking Detector



Central Tracking Detector (CTD)

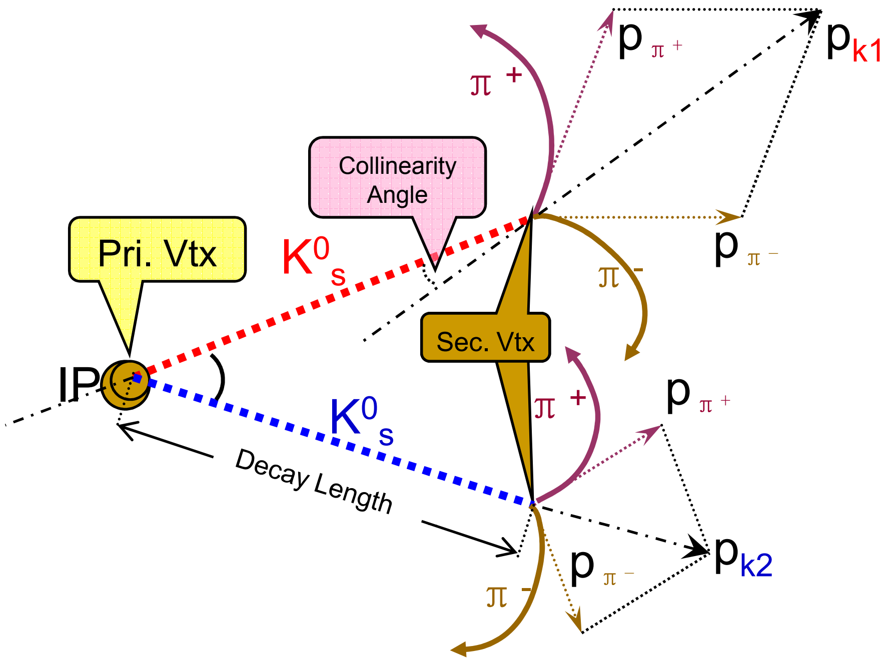
- official coordinate resolution ~160 μm



Micro-Vertex Detector (MVD)

- 25-35 μm resolution for vertical incidence

$K^0_s K^0_s$ states observation principles



Two V0 candidates

Particle	Main Decay	Mass (GeV)	Decay Length (cm)	Lifetime (10^{-8} sec)
K_S^0	$\pi^+\pi^-$	0.497	2.68	0.89
Λ	$p^+\pi^-$	1.112	7.89	2.63

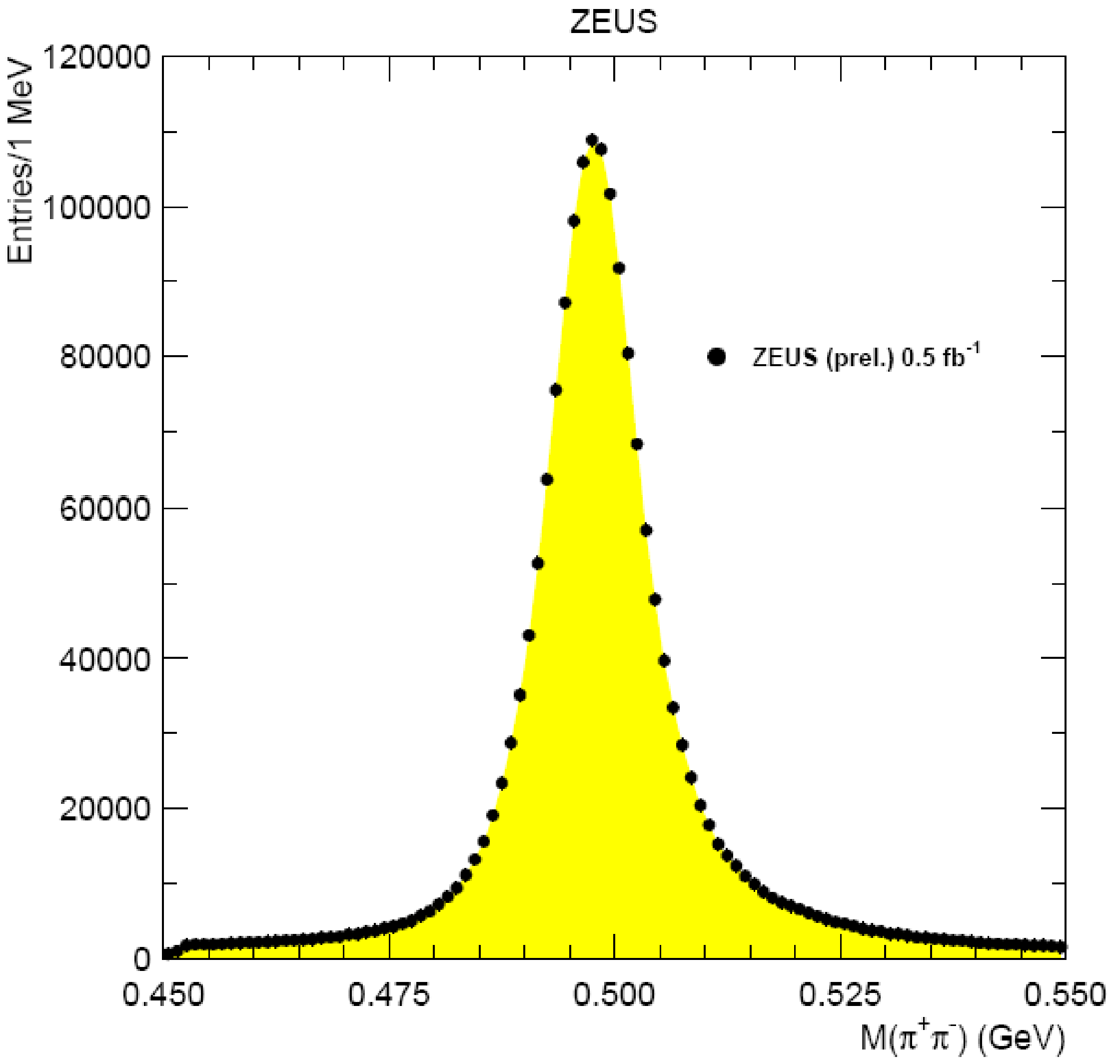
DATA Sample and Event Selection

Luminosity		
HERAI	HERAII	Total
121.6 pb^{-1}	**401.68 pb^{-1}**	**≈ 0.5 fb^{-1}**

Tracking Quality Cuts	
P_T(pion) (GeV)	> 0.14
η(pion) $\eta = -\log\left(\tan\frac{\theta}{2}\right)$	(-1.75,1.75)
K^0_s Selection Cuts	
P_T(kaon) (GeV)	> 0.25
η(kaon)	(-1.6,1.6)
Decay Length (cm)	(0,30)
Collinearity(2D)	< 0.12
Inv_ππ (GeV)	(0.4806,0.515)

The data sample is dominated by 90% photoproduction, while 10% is Deep Inelastic Scattering

K^0_s mass distribution



Full sample contains:

1300509 K^0_s →
672418 $K^0_s K^0_s$

Fitting functions

- Modified Relativistic Breit-Wigner (MRBW) function:

$$F(M) = \sum_{i=1}^{3} C_i \left(\frac{m_{*,i}\Gamma_{d,i}}{(m_{*,i}^2 - M^2)^2 + m_{*,i}^2 \Gamma_{d,i}^2} \right)$$

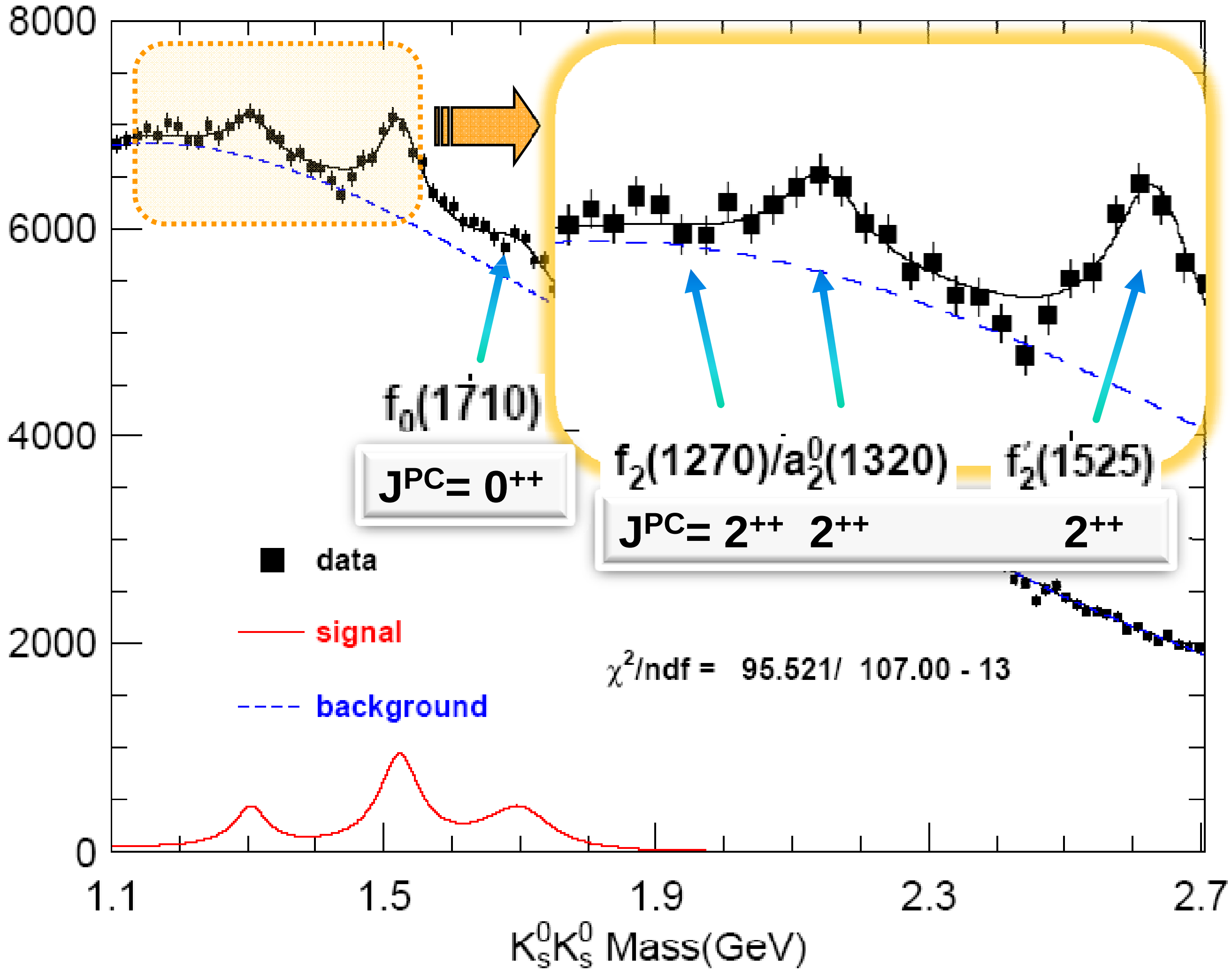
- C_i is the amplitude of the resonance
- $m_{*,i}$ is the mass of resonance
- $\Gamma_{d,i}$ is the effective resonance width
- M is the $K^0_s K^0_s$ invariant mass

- Background function:

$$U(M) = A \cdot (M - 2m_{K^0_S})^B \cdot \exp\left(-C(M - 2m_{K^0_S})\right)$$

- A, B, C are free parameters
- m_{K0s} is the K^0_s mass from PDG

Fitting using Breit-Wigner with no interference

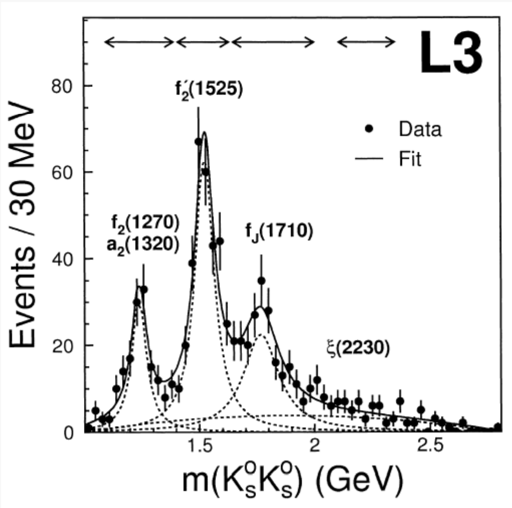


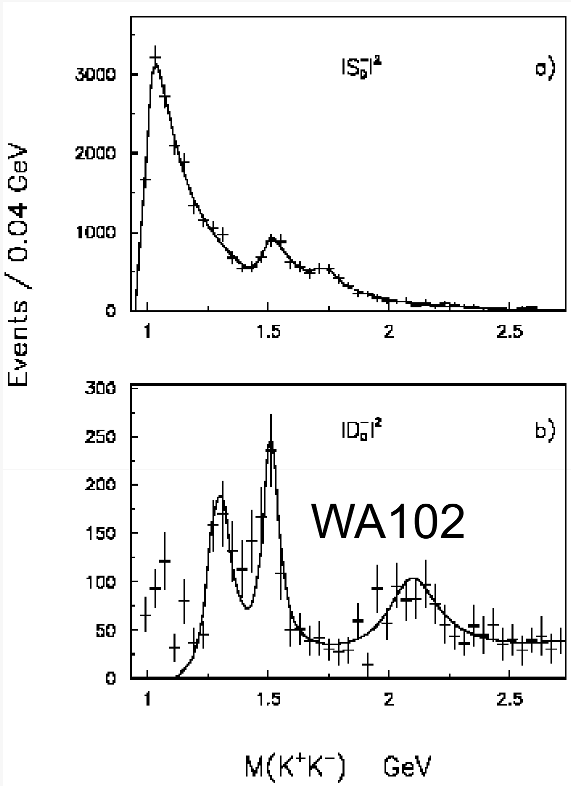
The structure around 1270 region is due to the destructive interference between $f_2(1270)$ and $a_2(1320)$

The dip between $f_2(1270)/a_2(1320)$ and $f_2(1525)$ is due to the constructive interference between the states.

Fitting using Breit-Wigner with interference

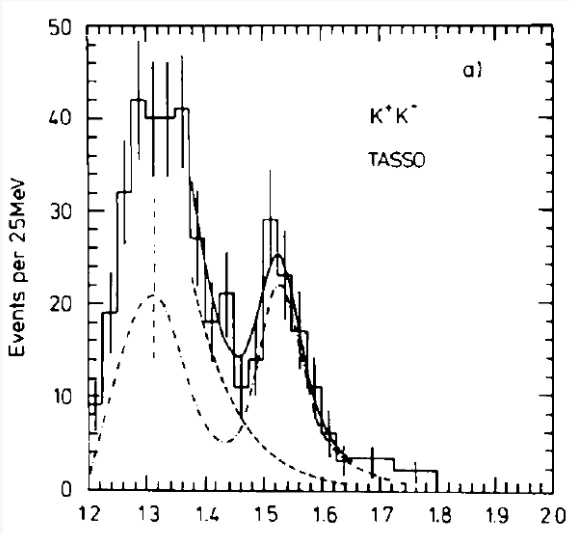
No interference fit





Barberis D *et al* 1999 *Phys. Lett.* B **453** 305;

Interference fit



Althoff, M. and others, Phys. Lett. **B121**, 216 (1983)

Fitting using Breit-Wigner with interference

	Coherent States		
	$f_2(1270)$	$a_2(1320)$	$f_2(1525)$
Isospin I =	0	1	0
Quark Content	$(u\bar{u}+d\bar{d})/\sqrt{2}$	$(u\bar{u}-d\bar{d})/\sqrt{2}$	$s\bar{s}$
Charge Factor	$(\frac{2}{3}\times\frac{2}{3}+\frac{1}{3}\times\frac{1}{3})\frac{1}{2}$	$(\frac{2}{3}\times\frac{2}{3}-\frac{1}{3}\times\frac{1}{3})\frac{1}{2}$	$\frac{1}{3}\times\frac{1}{3}$
Amplitude ratio	5 BW	-3 BW	2 BW

Function = a {5 * BW_f_2(1270) – 3 * BW_a_2(1320) + 2 * BW_f_2(1525)}^{2}
+ b {BW_f_0(1710)}^{2}
+ c Background U(M)

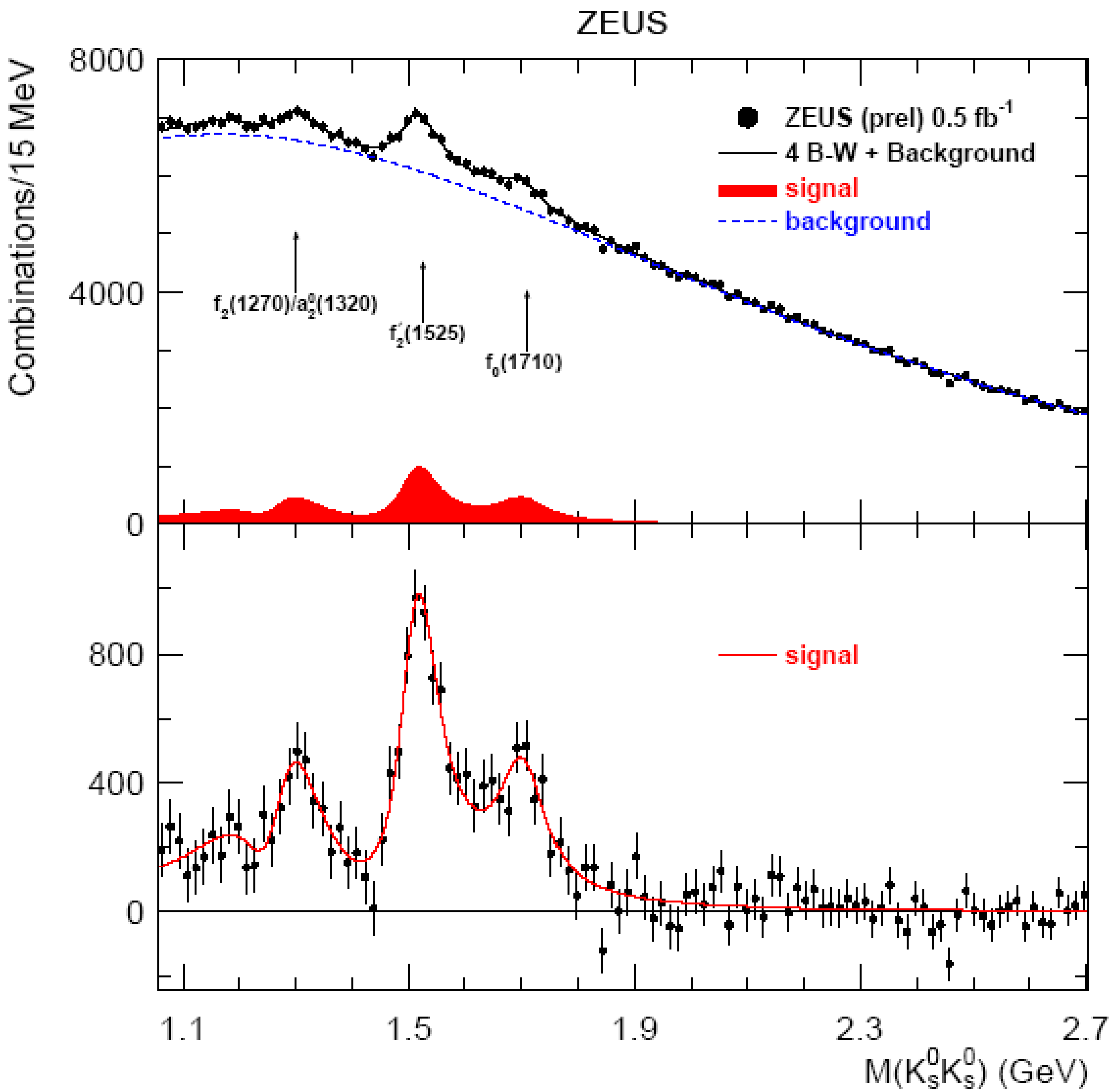
a b c are free parameters

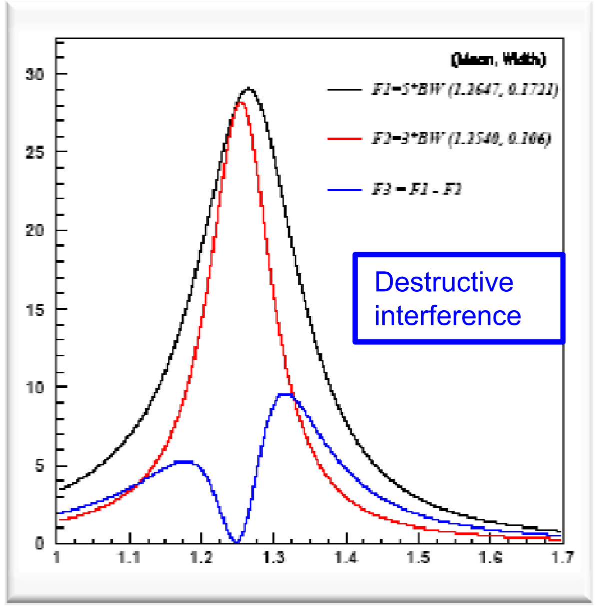
BW is Relativistic Breit-Wigner function:

$$F(M) = \frac{m\sqrt{\Gamma}}{m^2 - M^2 - im\Gamma}$$

Faiman, D. and Lipkin, H. J. and Rubinstein, H. R., Phys. Lett. **B59**, 269 (1975)

Fitting using Breit-Wigner with interference





$X^2/ndf = 86/110$

Improved fitting in 1270 and 1420 region, where destructive and constructive interference are well described.

Summary

in MeV	$f_2'(1525)$	$f_0(1710)$
mass	$1512 \pm 3^{+2}_{-1}$	$1701 \pm 5^{+5}_{-3}$
width	$83 \pm 9^{+5}_{-4}$	$100 \pm 24^{+8}_{-19}$
Particle Data Group 2007 Values		
mass	1525 ± 5	1724 ± 7
width	73^{+6}_{-5}	137 ± 8

Table 1: *The measured peaks and widths for $f_2'(1525)$ and $f_0(1710)$ mesons in ep collisions (DIS and photoproduction) using $K_S^0 K_S^0$ decays. Both statistical and systematic uncertainties are quoted. Also quoted are the PDG2007 values for comparison.*

Conclusion

- Inclusive $ep \rightarrow K^0_s K^0_s X$ decay production was studied with all ZEUS statistics (0.5 fb^{-1})
- Clear evidence for $f'_2(1525)$ and $f_0(1710)$ resonance state with large statistical significance
- Very competitive measurements on peak position and width for $f'_2(1525)$ and $f_0(1710)$ are done with interference fit and compared well with the PDG values

End