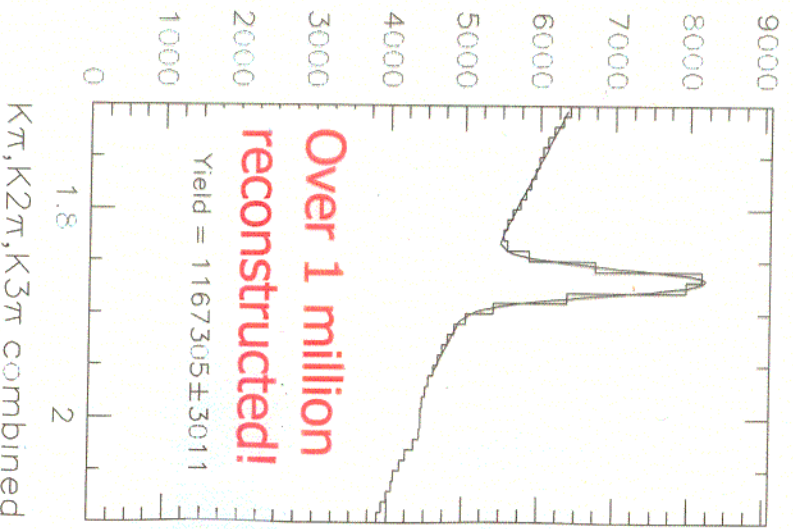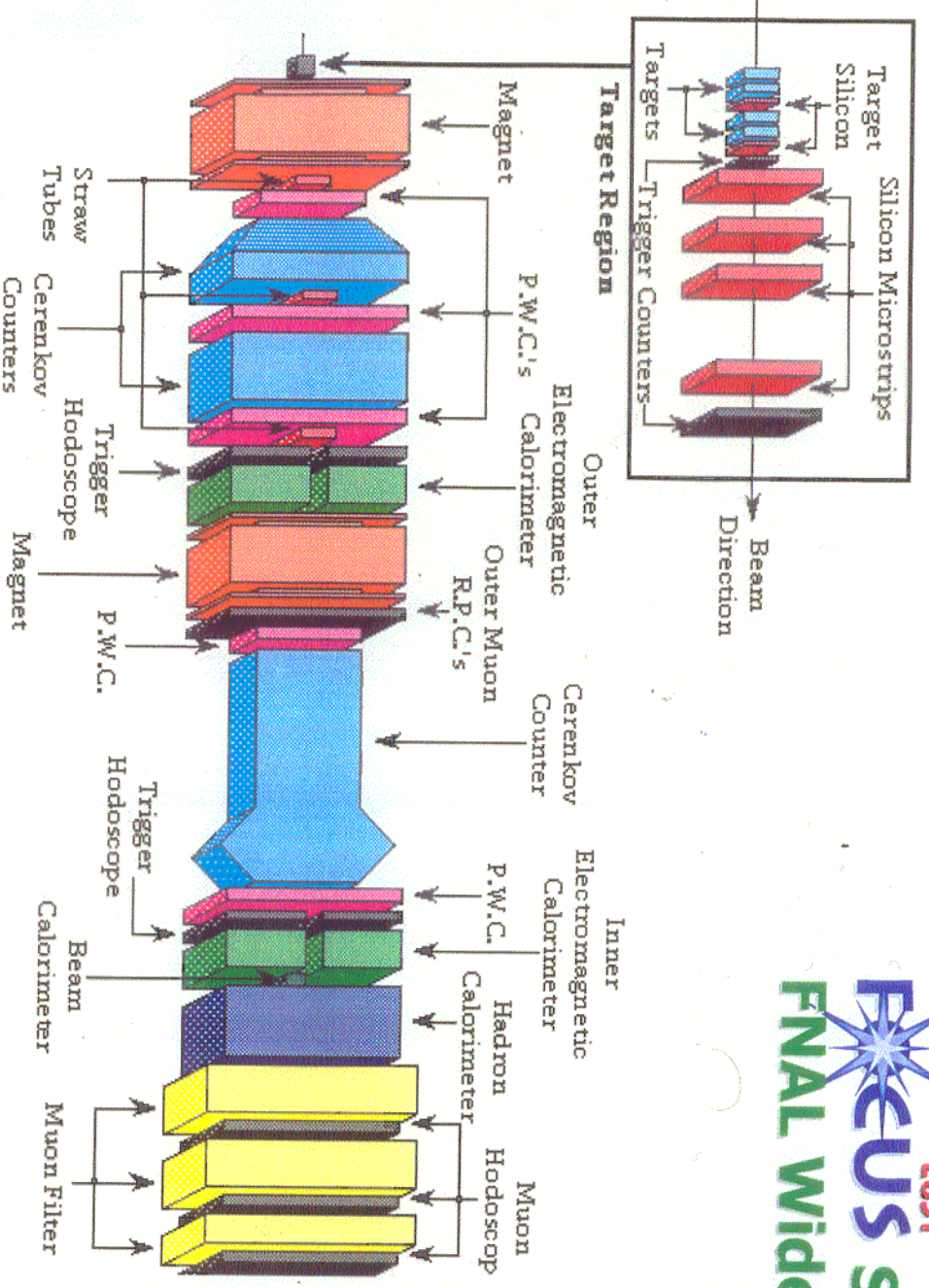# Light Quark Spectroscopy Results from FOCUS

Stefano Bianco

Laboratori Nazionali di Frascati – INFN
on behalf of the FOCUS Collaboration

- The FOCUS experiment
- $\pi^+\pi^-$ final states   (P.L.Frabetti et al.,Phys.Lett. B 514, 240 (2001)).
- $3\pi^+ 3\pi^-$ final states   (R.Mitchell for the FOCUS Coll., DPF 2002).
- K^+K^- final states

FOCUS Spectrometer at FNAL Wide Band Photon Beam

Successor to E687. Designed to study charm particles produced by ~200 GeV photons using a fixed target spectrometer with updated **Vertexing, Cerenkov, EM Calorimeters,** and **Muon id** capabilities. Member groups from USA, Italy, Brazil, Mexico, Korea.
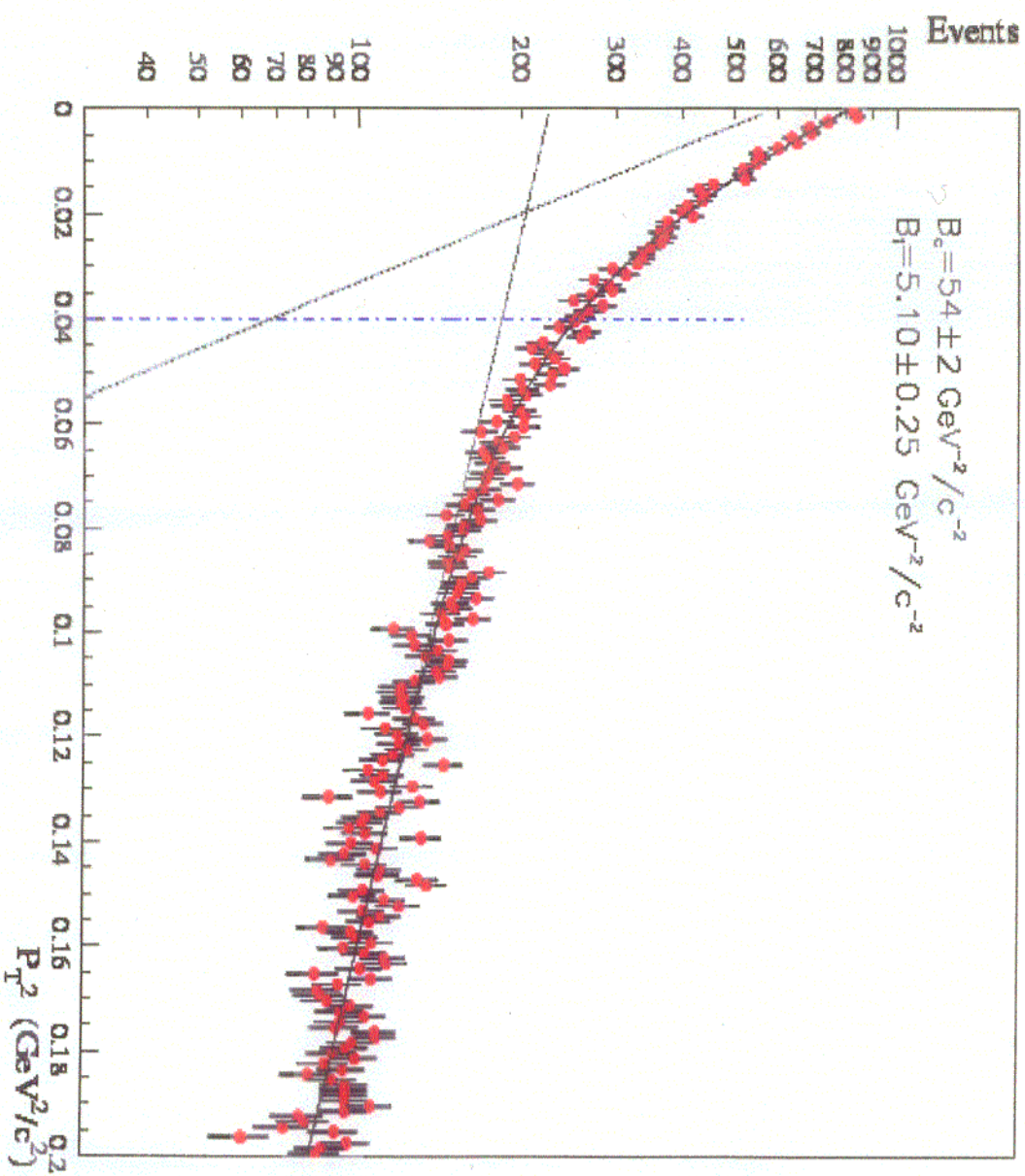
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Over 1 million reconstructed!

Yield = 1167305±3011

$K\pi, K2\pi, K3\pi$ combined

2

$n(\pi^+_\pi\pi^-) / K^+K^-$ Data Selection

- Vertex in target
- No extra reconstructed photons
- No extra reconstructed tracks
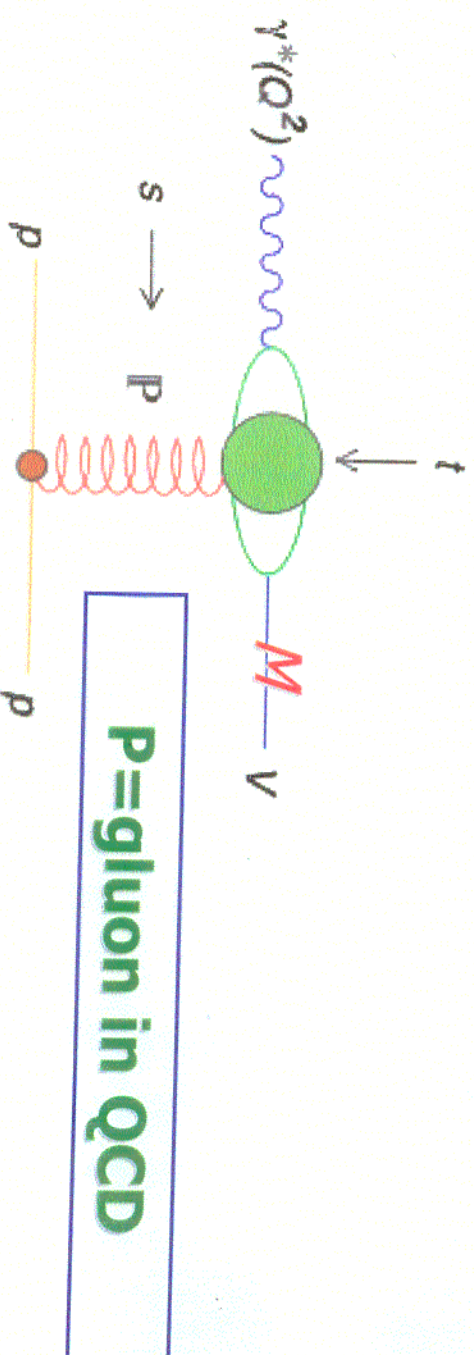- All particles are identified by Cerenkov information as kaons /pions

P^2_T Distribution ($3\pi^+ 3\pi^-$)

Events

$B_c = 54 \pm 2$ GeV^{-2}/c^{-2}

$B_f = 5.10 \pm 0.25$ GeV^{-2}/c^{-2}
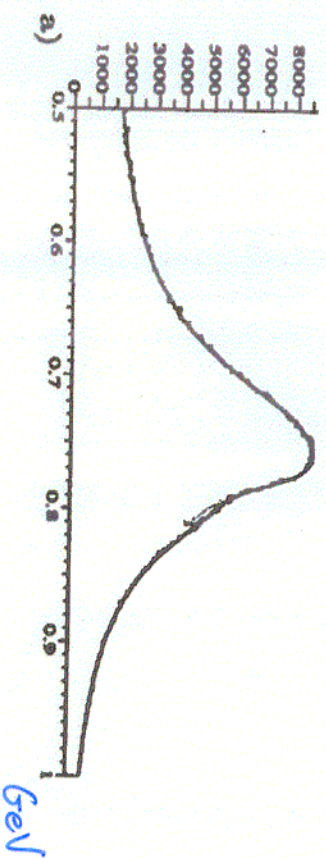
P_T^2 (GeV^2/c^2)

DIFFRACTIVE PHOTOPRODUCTION

- $\gamma\, T \rightarrow M\, T$ at low t and low $(M/E_\gamma)^2$ photon's quantum numbers are transferred to meson V
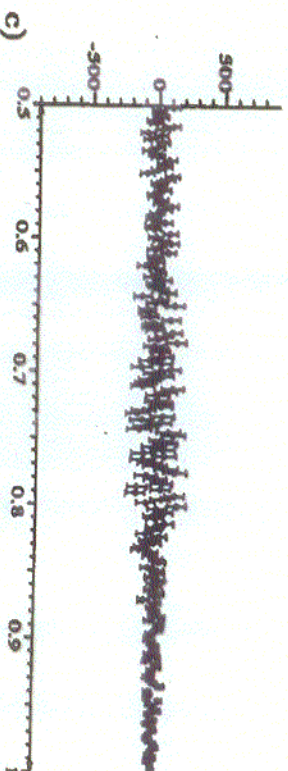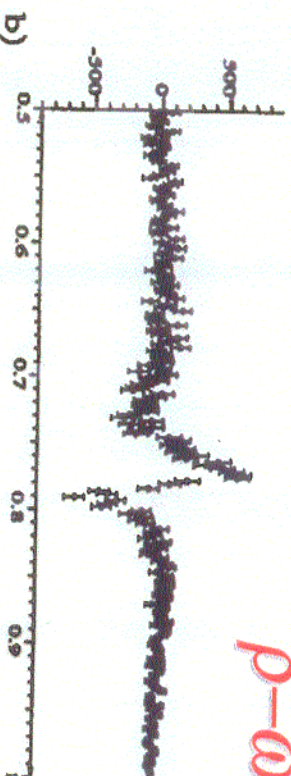

$$\boxed{\text{P=gluon in QCD}}$$

- Virtual transition $\gamma \rightarrow$ vector meson V + V elastic scattering on the target

E687 $\pi^+\pi^-$ diffractive photoproduction

$\rho-\omega$ interference

GeV

E687 $3\pi^+ 3\pi^-$ Mass Distribution

Events/10MeV/c^2

•ECAL cut
• >=4π definite ID

•ECAL cut
• >=4π definite ID
• P$_T^2$>0.200(GeV/c)^2

$M_{6\pi}$(GeV/c^2)
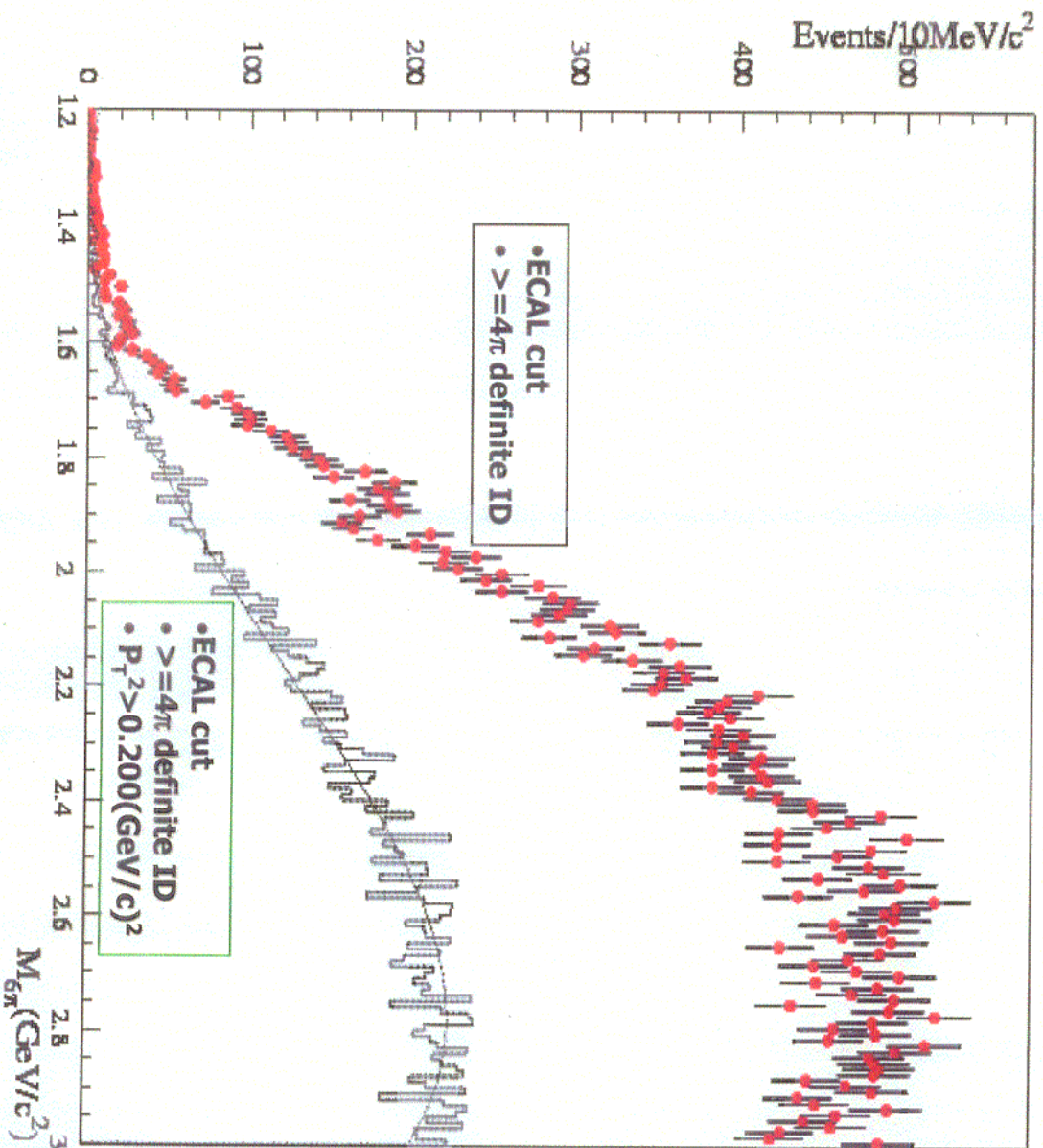
Fitting the data in the 1.6 ÷ 2.2 GeV mass range

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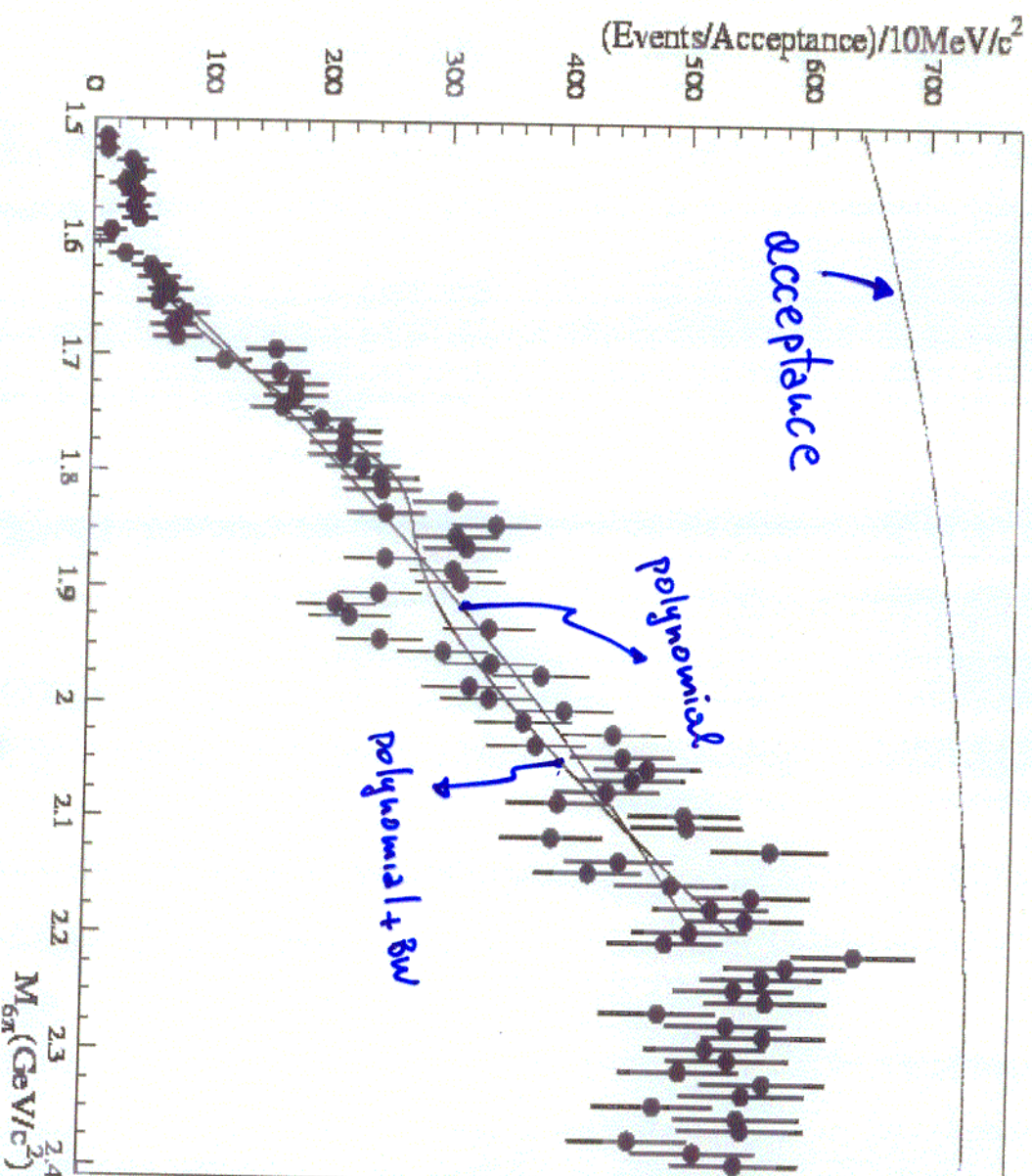
Confidence Level distribution
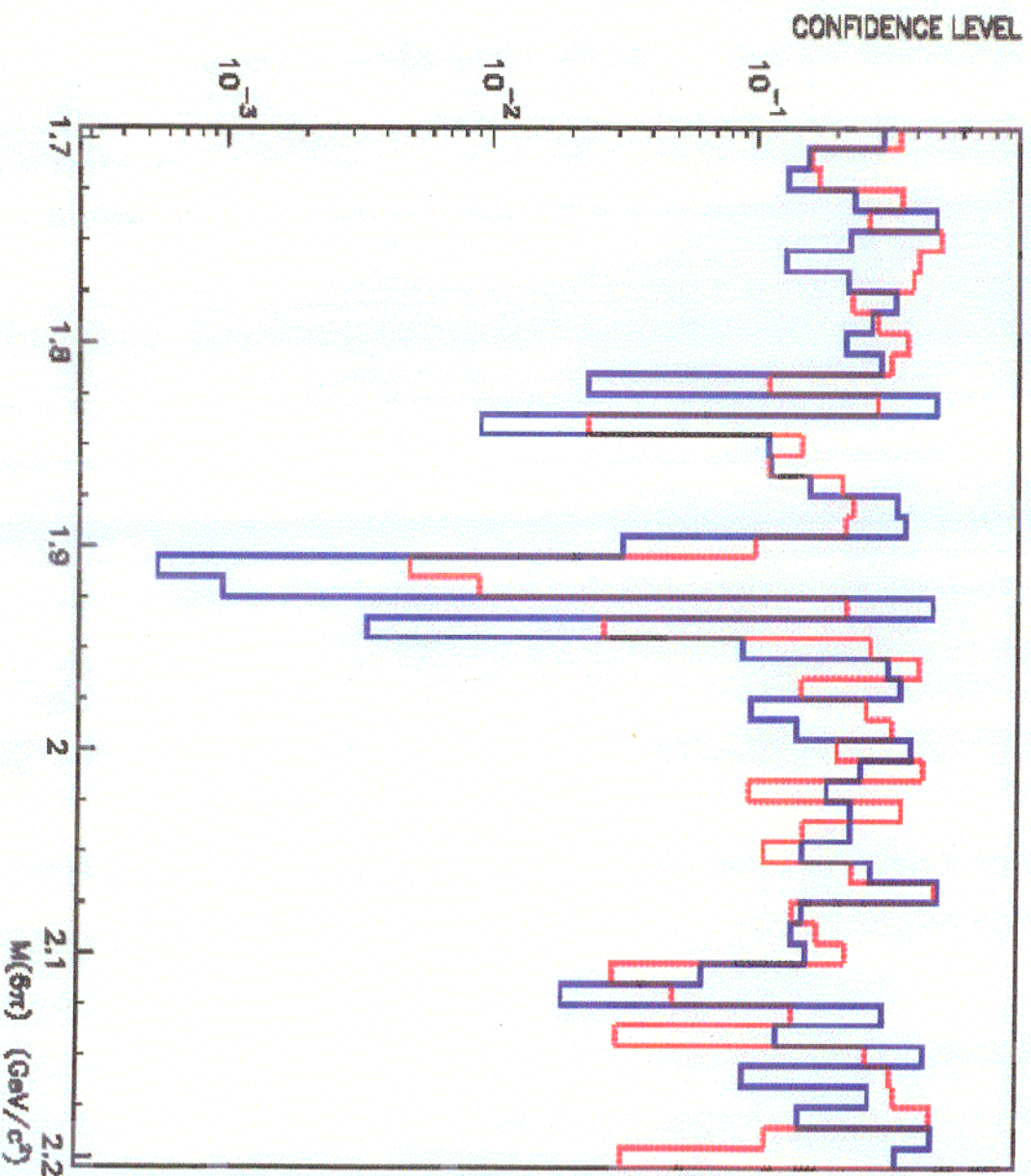
Blue = poly.
Red = poly.+BW

$3\pi^+ 3\pi^-$ Mass distribution

(mass resolution unfolded $E.Sjontoft$ NIM 163 (1979) 519)

$M = 1911 \pm 4$ MeV

$\Gamma = 29 \pm 11$ MeV

$$A(H) = \delta_{ss}(H) + a_r \frac{-M_r \Gamma e^{i\phi}}{M - M_r^2 + i M_r \Gamma}$$

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One resonance fit parameters

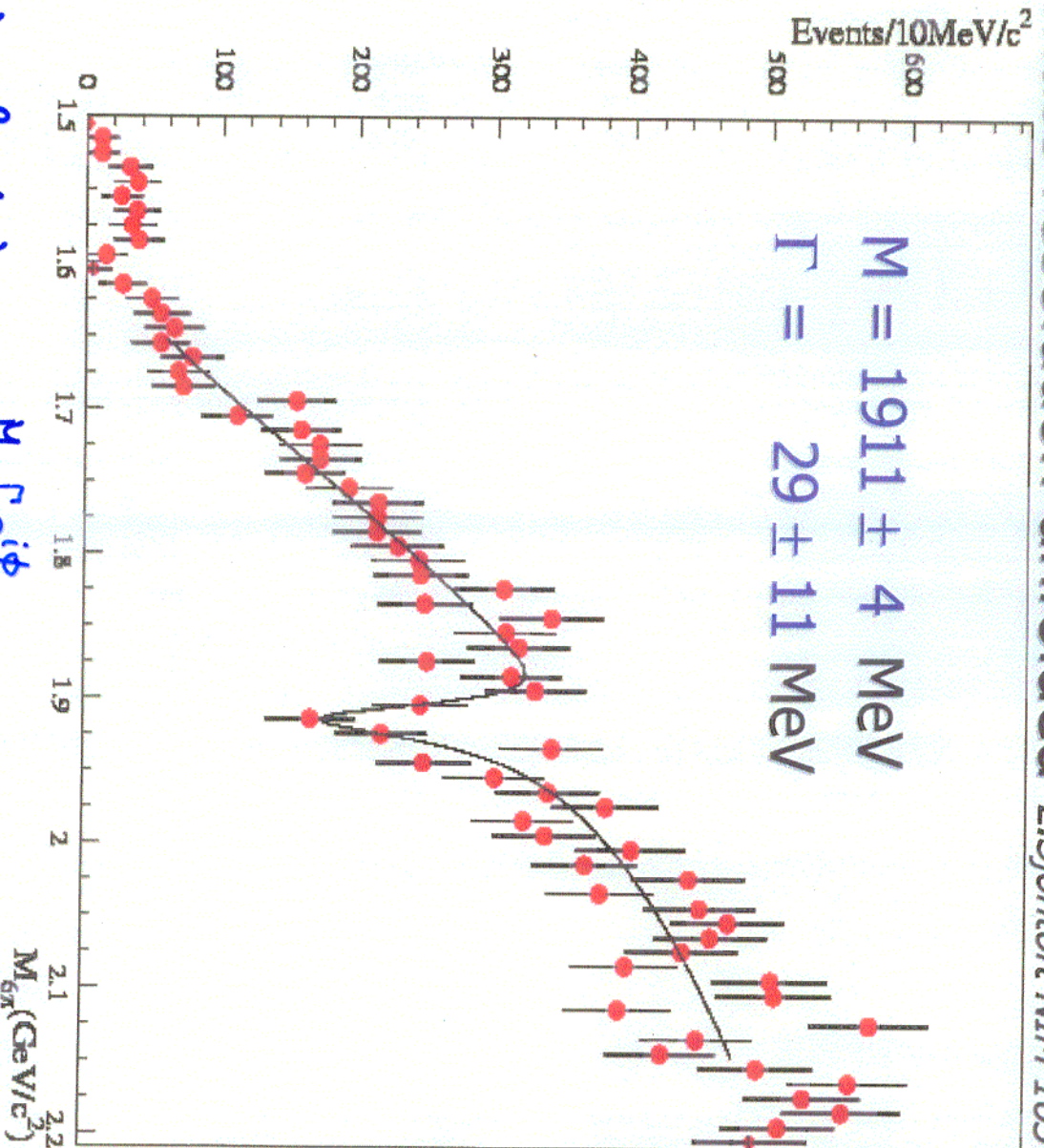|	
M_r (GeV/c^2)	$1.911 \pm 0.004 \pm 0.001$
Γ (MeV/c^2)	$29 \pm 11 \pm 4$
$a_r/f_{JS}(M_r)$	0.31 ± 0.07
ϕ(deg.)	62 ± 12
χ^2/dof	1.1
M_0	1.49 ± 0.02
c_0	0 ± 50
c_1	960 ± 80
β	0.5 ± 0.3
α	1.8 ± 0.2

The K+K- Mass Spectrum

A large φ signal, as expected.

Mass(k⁺k⁻)

Events / 10 MeV
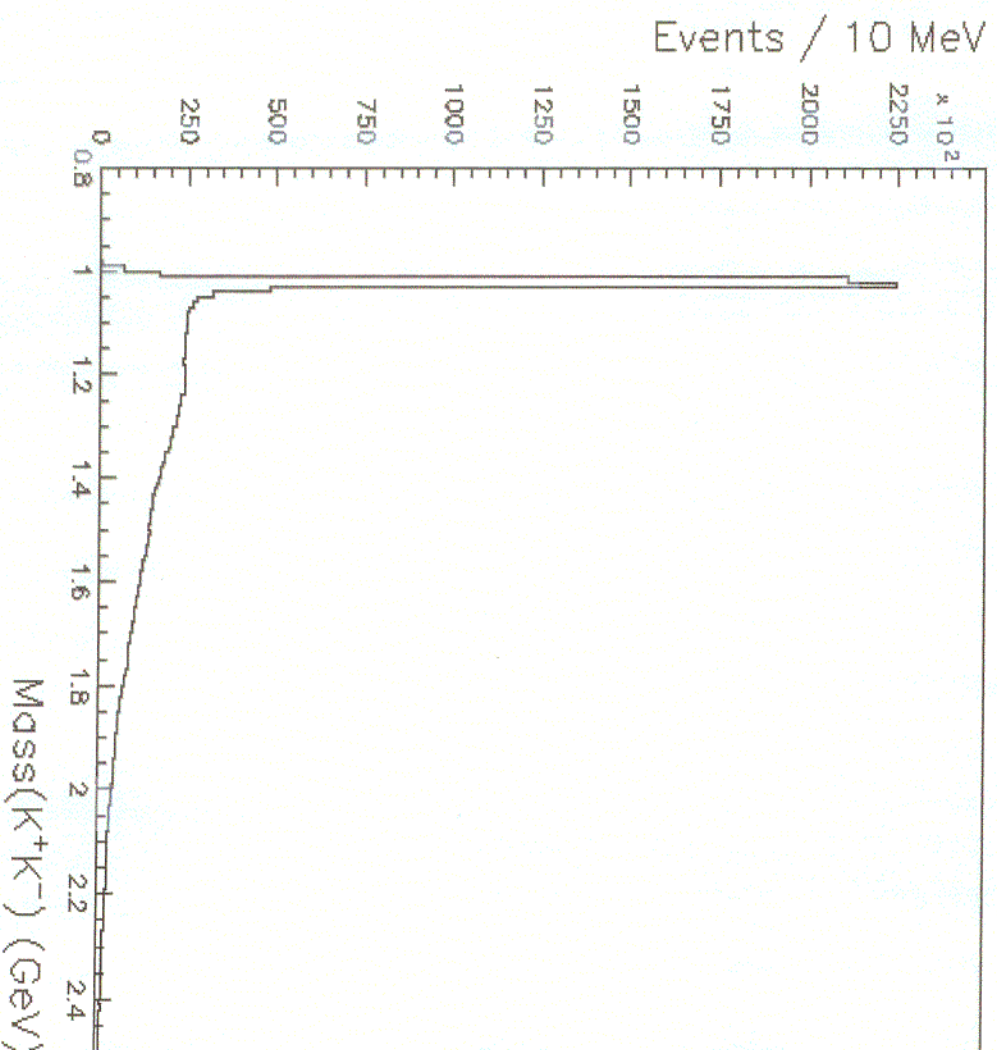
The K+K- P_t Spectrum

The P_t spectrum shows diffractive peaks.

$$P_t^2 \approx t'(K^+K^-) \ (GeV^2)$$

$B_c = 70.8 \pm 2.50 \ GeV^{-2}$
$B_i = 4.4 \pm 0.19 \ GeV^{-2}$

Preliminary

P_t Spectrum for φ and $x(1750)$

φ region

1750 region

$P_t(K^+K^-) \ (GeV)$

Events / 10 MeV

Mass(K⁺K⁻) (Pₜ < 0.15 GeV/c)

M = 1753.5 ± 1.5 ± 2.0 MeV

Γ = 122.2 ± 6.2 ± 8.0 MeV

Y = 11,700 ± 480

acceptance
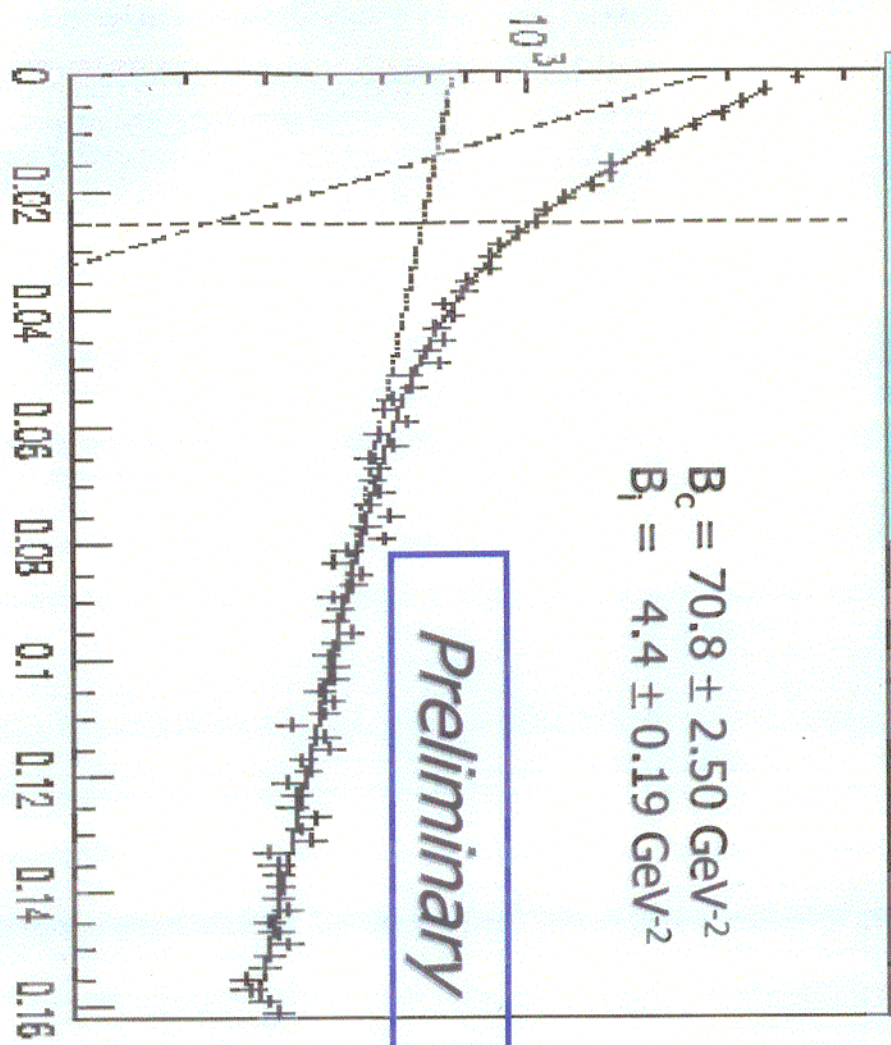
preliminary

Mass(K⁺K⁻) (GeV)
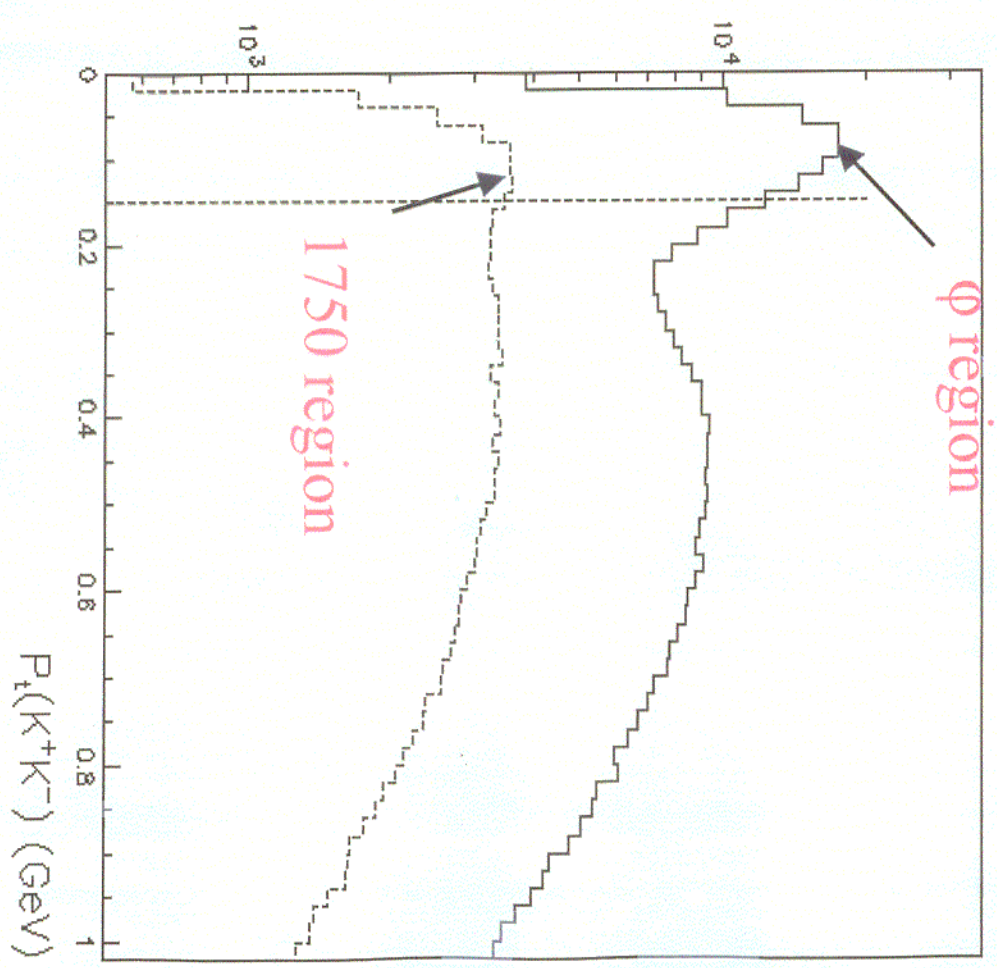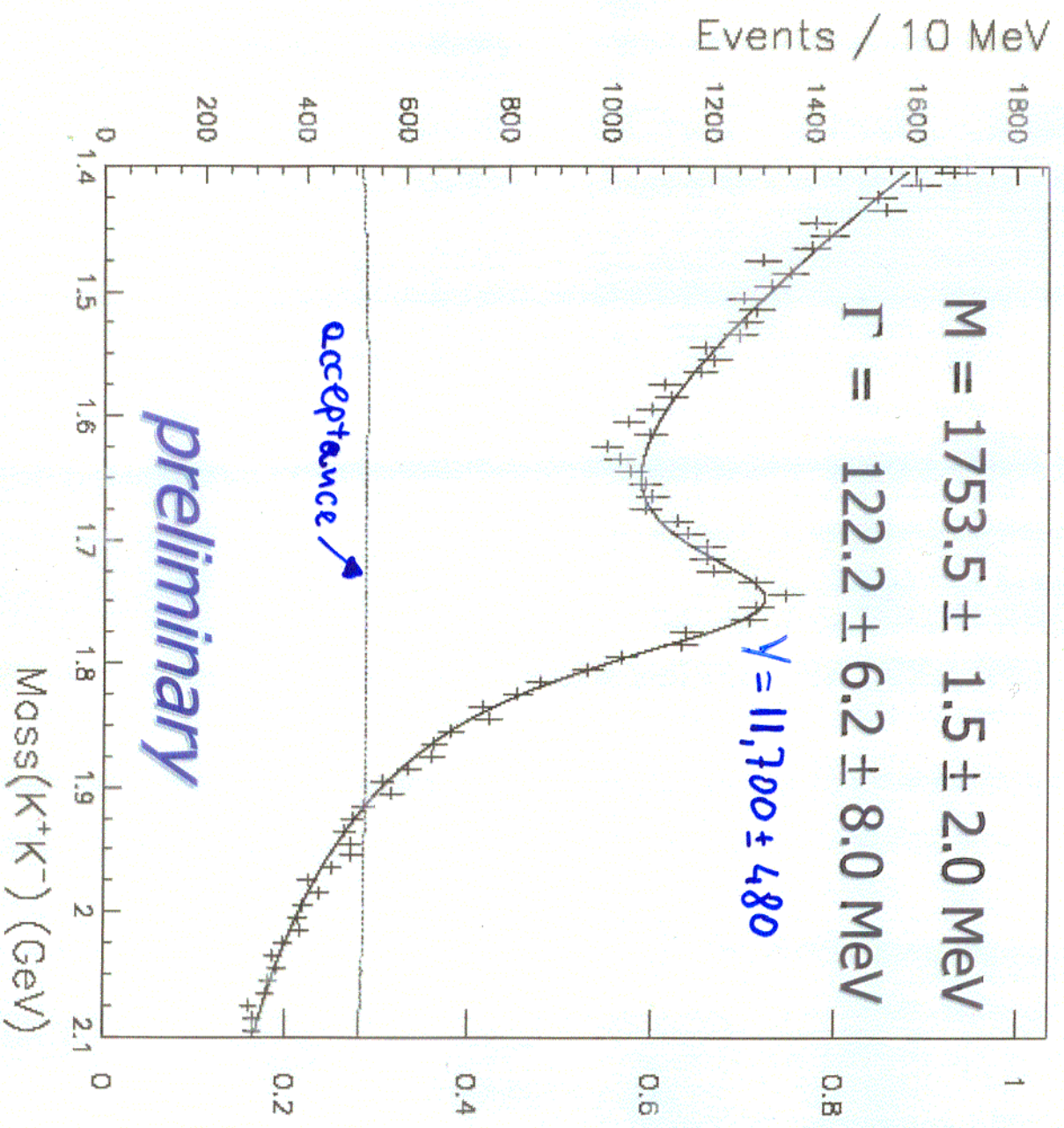
Syst.error :
• Pt cuts
• ID cuts
• BW shape
• backgr shape

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History of the X(1750)

OMEGA 1981
1690 ± 10 MeV
(1748 ± 11 MeV)

E401 1989
1726 ± 22 MeV
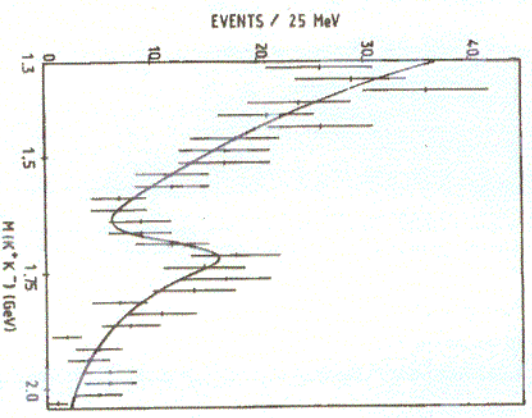
OMEGA 1985
1760 ± 20 MeV

E831 2002
1753.5 ± 1.5

PRELIMINARY

The PDG lists this under the φ(1680)....

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$\phi(1680)$

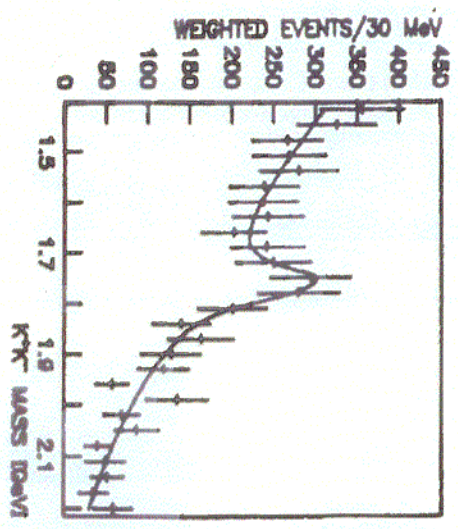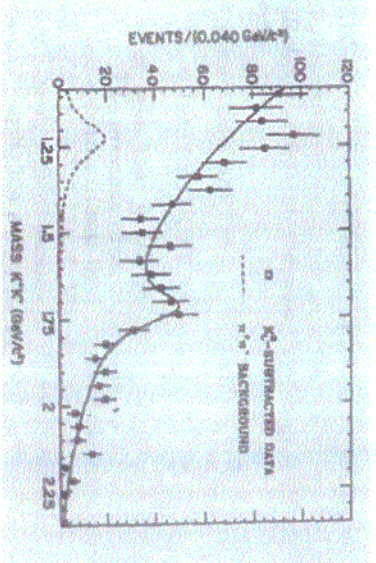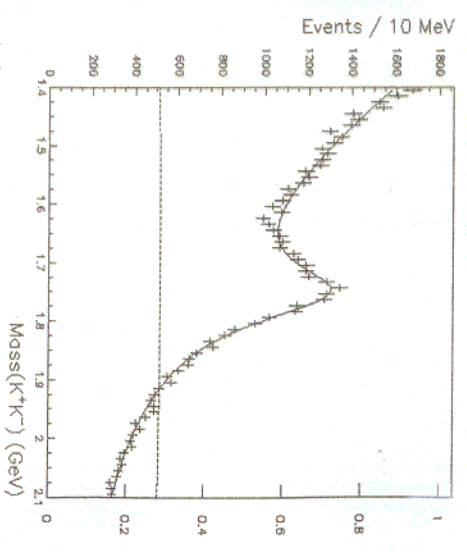$$I^G(J^{PC}) = 0^-(1^{--})$$

$\phi(1680)$ MASS

e^+e^- PRODUCTION

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1680±20 OUR ESTIMATE					
1681± 8 OUR AVERAGE					
1700±20		[1] CLEGG	94	RVUE	$e^+e^- \to K^+K^-$, $K_S^0 K\pi$
1657±27	367	BISELLO	91C	DM2	$e^+e^- \to K_S^0 K^\pm \pi^\mp$
1680±10		[2] BUON	82	DM1	$e^+e^- \to$ hadrons

• • • We do not use the following data for averages, fits, limits, etc. • • •

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
~ 1500		[3] ACHASOV	98N	RVUE	$e^+e^- \to \pi^+\pi^-\pi^0$, $\omega\pi^+\pi^-, K^+K^-$
~ 1900		[4] ACHASOV	98H	RVUE	$e^+e^- \to K_S^0 K^\pm \pi^\mp$
1655±17		[5] BISELLO	88B	DM2	$e^+e^- \to K^+K^-$
1677±12		[6] MANE	82	DM1	$e^+e^- \to K_S^0 K\pi$

PHOTOPRODUCTION

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • • •

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1726±22	BUSENITZ	89	TPS	$\gamma p \to K^+K^- X$
1760±20	ATKINSON	85C	OMEG	20–70 $\gamma p \to K\overline{K}X$
1690±10	ASTON	81F	OMEG	25–70 $\gamma p \to K^+K^- X$

[1] Using BISELLO 88B and MANE 82 data.

[2] From global fit of ρ, ω, ϕ and their radial excitations to channels $\omega\pi^+\pi^-$, K^+K^-, $K_S^0 K_L^0$, $K_S^0 K^\pm \pi^\mp$. Assume mass 1570 MeV and width 510 MeV for ρ radial excitations, mass 1570 and width 500 MeV for ω radial excitation.

[3] Using data from IVANOV 81, BARKOV 87, BISELLO 88B, DOLINSKY 91, and ANTONELLI 92.

[4] Using the data from BISELLO 91C.

[5] From global fit including ρ, ω, ϕ and $\rho(1700)$ assume mass 1570 MeV and width 510 MeV for ρ radial excitation.

[6] Fit to one channel only, neglecting interference with ω, $\rho(1700)$.

$\phi(1680)$ WIDTH

e^+e^- PRODUCTION

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
150±50 OUR ESTIMATE	This is only an educated guess, the error given is larger than the error on the average of the published values.				

• • • We do not use the following data for averages, fits, limits, etc. • • •

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
300±60		[7] CLEGG	94	RVUE	$e^+e^- \to K^+K^-$, $K_S^0 K\pi$
146±55	367	BISELLO	91C	DM2	$e^+e^- \to K_S^0 K^\pm \pi^\mp$
207±45		[8] BISELLO	88B	DM2	$e^+e^- \to K^+K^-$
185±22		[9] BUON	82	DM1	$e^+e^- \to$ hadrons
102±36		[10] MANE	82	DM1	$e^+e^- \to K_S^0 K\pi$

Fits to K*K
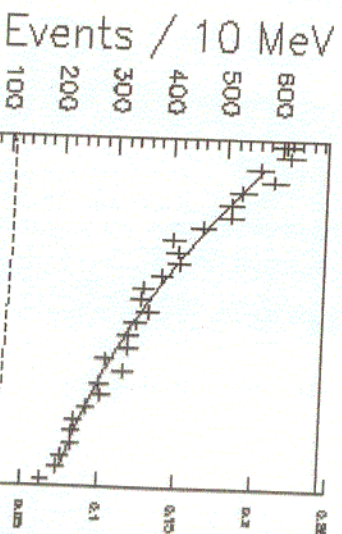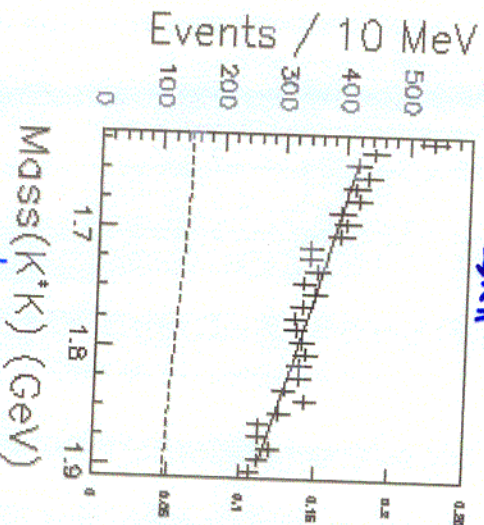
There is no evidence for any structure in the 1750 region.

After detailed MC acceptance studies, upper limits to the K*K/KK branching have been set ($\lesssim 15\%$).

K*K Fits
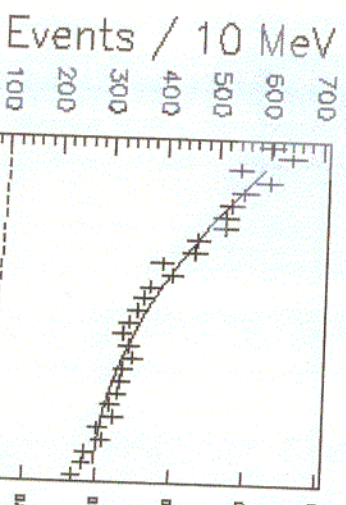
Conclusions

- FOCUS claims evidence for a new structure in **$3\pi^+3\pi^-$** at :

$$M = 1911 \pm 4 \text{ MeV}$$
$$\Gamma = 29 \pm 11 \text{ MeV}.$$

P.L.Frabetti et al.,Phys.Lett. B 514, 240 (2001)

- The existence of the **1.75** GeV enhancement in **K+K-** is confirmed with a factor **100** increase in statistics.

- No evidence of this state in **$K_S K_\pi$** .

- The interpretation of the X(1750) remains uncertain.