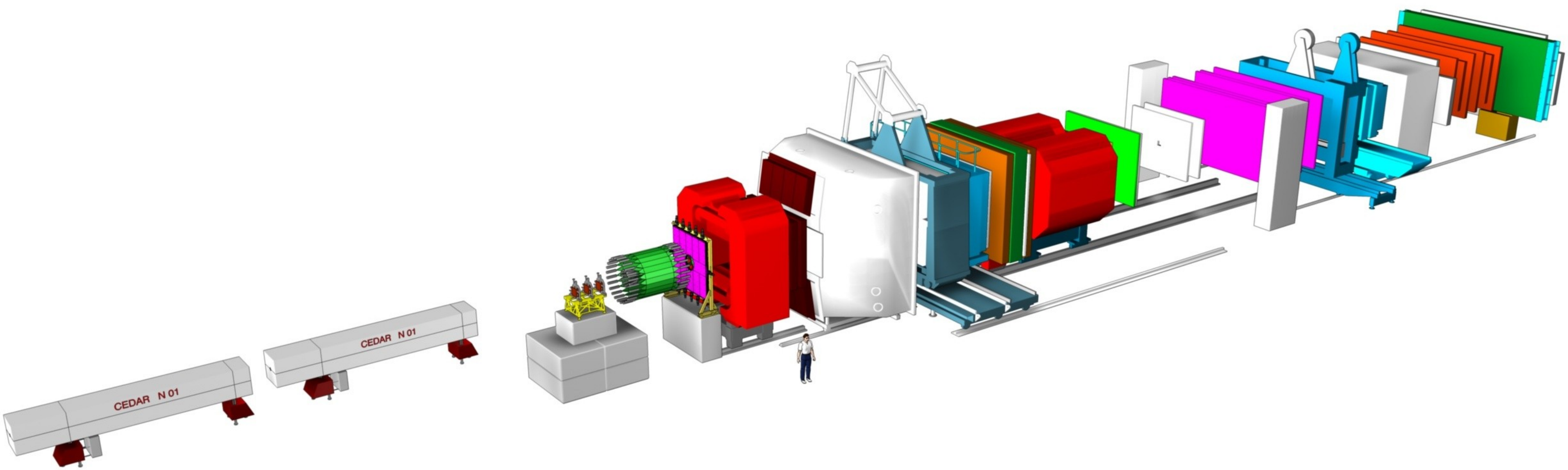
PWA analysis of diffractively produced $K^- \pi^+ \pi^-$ events



The story behind...

Prometeusz Jasinski
Mainz COMPASS Seminar 13.12.2010

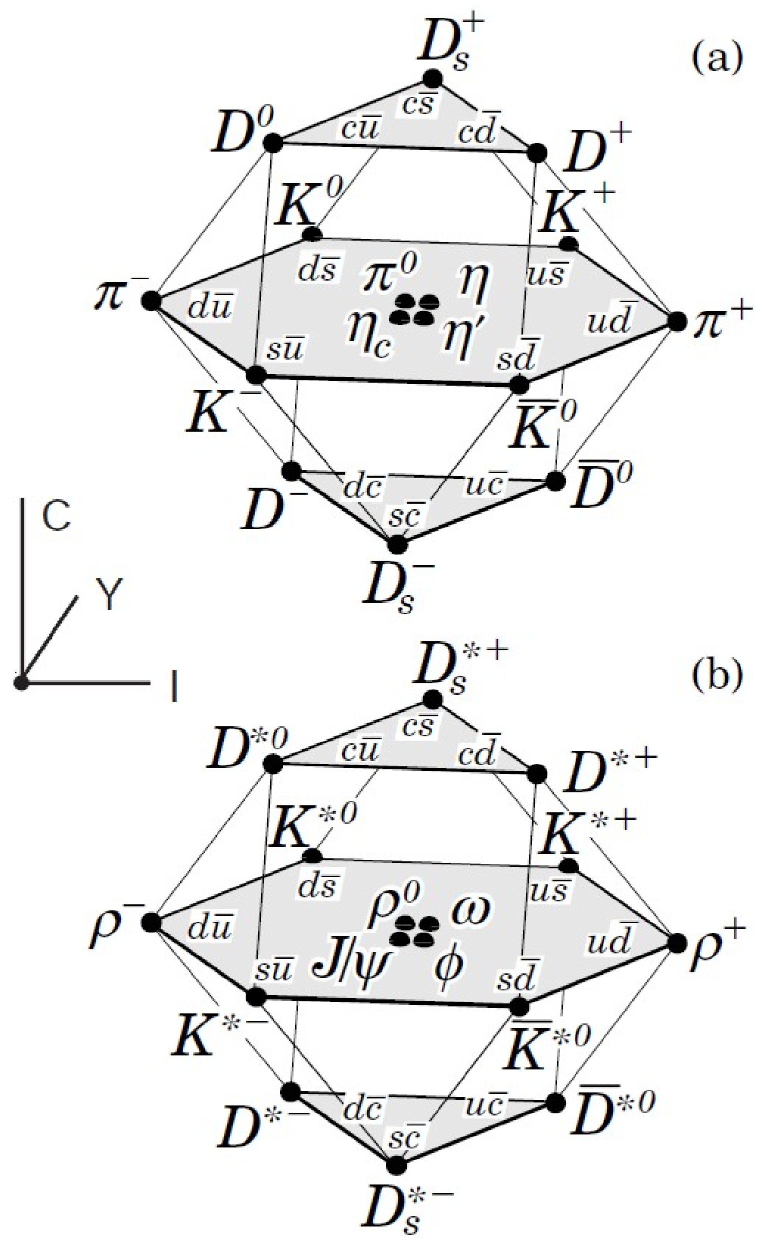
Topics

- The idea behind (strange) meson spectroscopy
- How resonances are assigned today
- Accessing resonances and the corresponding experiments
- Interesting topics in my specific channel

Once gain: the quark model fitting resonances into qqbar states

pseudoscalar mesons

vector mesons



Today's (2010) quark model association

$n\ ^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d}-u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f	$\theta_{\rm quad}$ [°]	$\theta_{\rm lin}$ [°]
$1\ ^1S_0$	0^{-+}	π	K	η	$\eta'(958)$	−11.5	−24.6
$1\ ^3S_1$	1^{--}	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$	38.7	36.0
$1\ ^1P_1$	1^{+-}	$b_1(1235)$	K_{1B} †	$h_1(1380)$	$h_1(1170)$		
$1\ ^3P_0$	0^{++}	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$		
$1\ ^3P_1$	1^{++}	$a_1(1260)$	K_{1A} †	$f_1(1420)$	$f_1(1285)$		
$1\ ^3P_2$	2^{++}	$a_2(1320)$	$K_2^*(1430)$	$f_2'(1525)$	$f_2(1270)$	29.6	28.0
$1\ ^1D_2$	2^{-+}	$\pi_2(1670)$	$K_2(1770)$ †	$\eta_2(1870)$	$\eta_2(1645)$		
$1\ ^3D_1$	1^{--}	$\rho(1700)$	$K^*(1680)$		$\omega(1650)$		
$1\ ^3D_2$	2^{--}		$K_2(1820)$				
$1\ ^3D_3$	3^{--}	$\rho_3(1690)$	$K_3^*(1780)$	$\phi_3(1850)$	$\omega_3(1670)$	32.0	31.0
$1\ ^3F_4$	4^{++}	$a_4(2040)$	$K_4^*(2045)$		$f_4(2050)$		
$1\ ^3G_5$	5^{--}	$\rho_5(2350)$					
$1\ ^3H_6$	6^{++}	$a_6(2450)$			$f_6(2510)$		
$2\ ^1S_0$	0^{-+}	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$		
$2\ ^3S_1$	1^{--}	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$	$\omega(1420)$		

† The $1^{+\pm}$ and $2^{-\pm}$ isospin $\frac{1}{2}$ states mix. In particular, the K_{1A} and K_{1B} are nearly equal (45°) mixtures of the $K_1(1270)$ and $K_1(1400)$. The physical vector mesons listed under 1^3D_1 and 2^3S_1 may be mixtures of 1^3D_1 and 2^3S_1, or even have hybrid components.

$$f' = \psi_8 \cos\theta - \psi_1 \sin\theta$$

$$f = \psi_8 \sin\theta + \psi_1 \cos\theta$$

$$\psi_8 = \frac{1}{\sqrt{6}}(u\bar{u} + d\bar{d} - 2s\bar{s})$$

$$\psi_1 = \frac{1}{\sqrt{3}}(u\bar{u} + d\bar{d} + s\bar{s})$$

The 'ground state' = lightest in mass

$n\,^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d},\ \bar{u}d,\ \frac{1}{\sqrt{2}}(d\bar{d}-u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s},\ d\bar{s};\ \bar{d}s,\ -\bar{u}s$	I = 0 f'	I = 0 f	θ_{quad} [°]	θ_{lin} [°]
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$1\,^3P_1$	1^{++}	$a_1(1260)$	$K_{1A}{}^{\dagger}$	$f_1(1420)$	$f_1(1285)$		
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$1\,^1D_2$	2^{-+}	$\pi_2(1670)$	$K_2(1770)^{\dagger}$	$\eta_2(1870)$	$\eta_2(1645)$		
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$2\,^1S_0$	0^{-+}	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$		
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$$f = \psi_8\,\sin\theta + \psi_1\,\cos\theta$$

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† The $1^{+\pm}$ and $2^{-\pm}$ isospin $\frac{1}{2}$ states mix. In particular, the K_{1A} and K_{1B} are nearly equal (45°) mixtures of the $K_1(1270)$ and $K_1(1400)$. The physical vector mesons listed under 1^3D_1 and 2^3S_1 may be mixtures of 1^3D_1 and 2^3S_1, or even have hybrid components.

strange meson spectroscopy

$n\,^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d}-u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f	$\theta_{\rm quad}$ [°]	$\theta_{\rm lin}$ [°]
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$1\,^3D_2$	2^{--}		$K_2(1820)$				
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$1\,^3G_5$	5^{--}	$\rho_5(2350)$					
$1\,^3H_6$	6^{++}	$a_6(2450)$			$f_6(2510)$		
$2\,^1S_0$	0^{-+}	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$		
$2\,^3S_1$	1^{--}	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$	$\omega(1420)$		

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How to produce resonances

some examples…

e+ e- annihilation

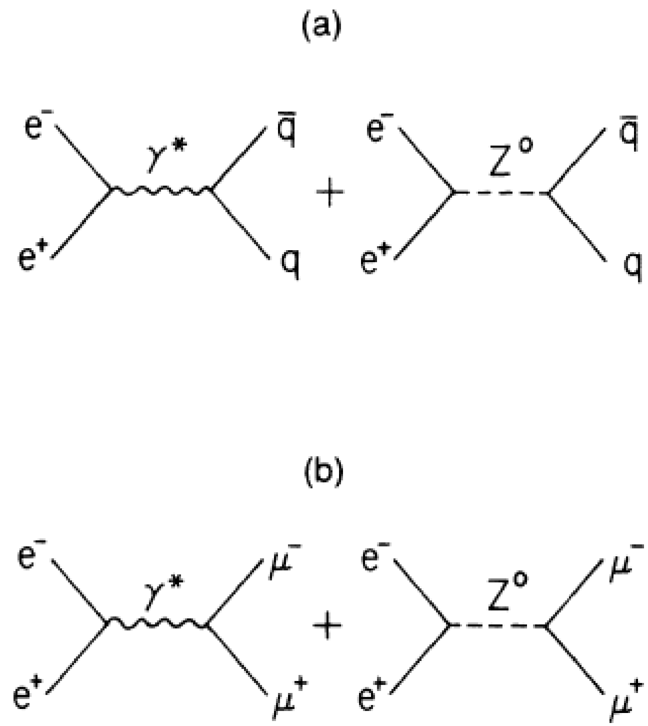

FIG. 1. (a) The lowest-order diagram for the process $e^+e^-\rightarrow q\bar{q}$. (b) The lowest-order diagram for the process $e^+e^-\rightarrow \mu^+\mu^-$.

Direct access to JPC = 1-- via gamma

$n\,^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d} - u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f	θ_{quad} [°]	θ_{lin} [°]
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$1\,^3D_1$	1^{--}	$\rho(1700)$	$K^*(1680)$		$\omega(1650)$		
$1\,^3D_2$	2^{--}		$K_2(1820)$				
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$2\,^3S_1$	1^{--}	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$	$\omega(1420)$		

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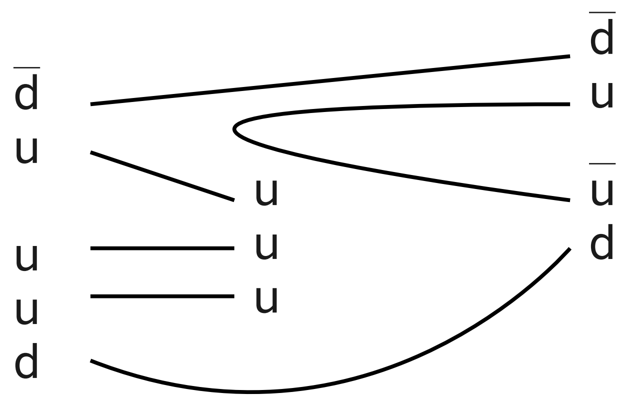
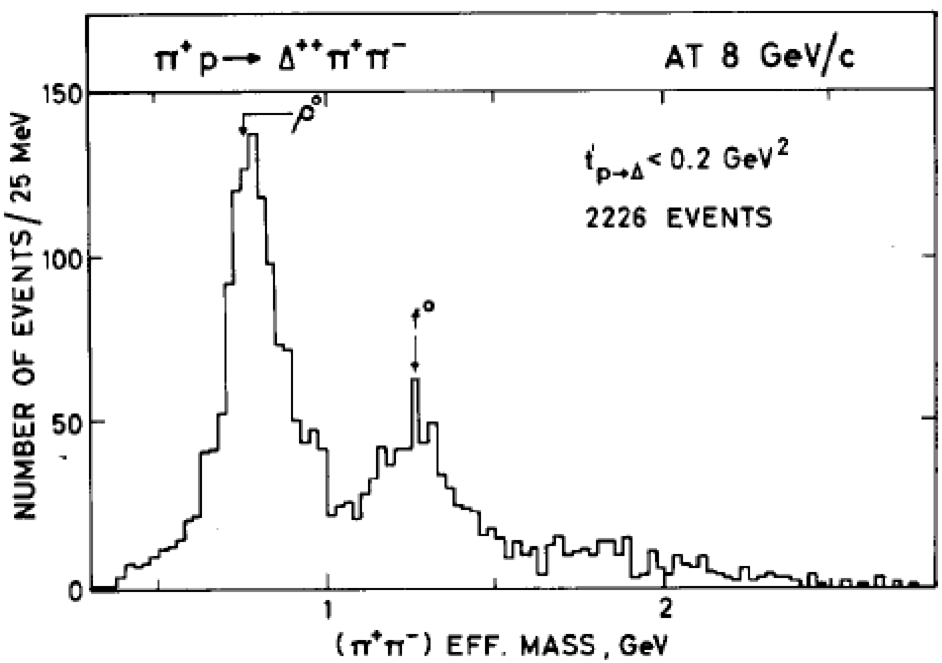
deep inelastic scattering

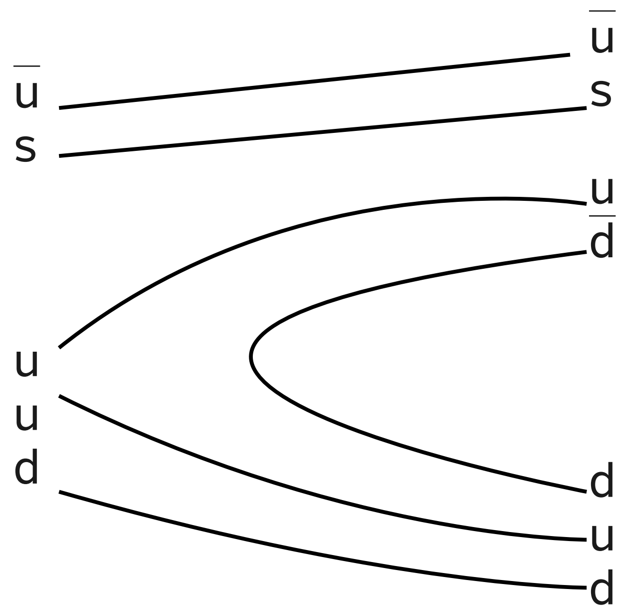


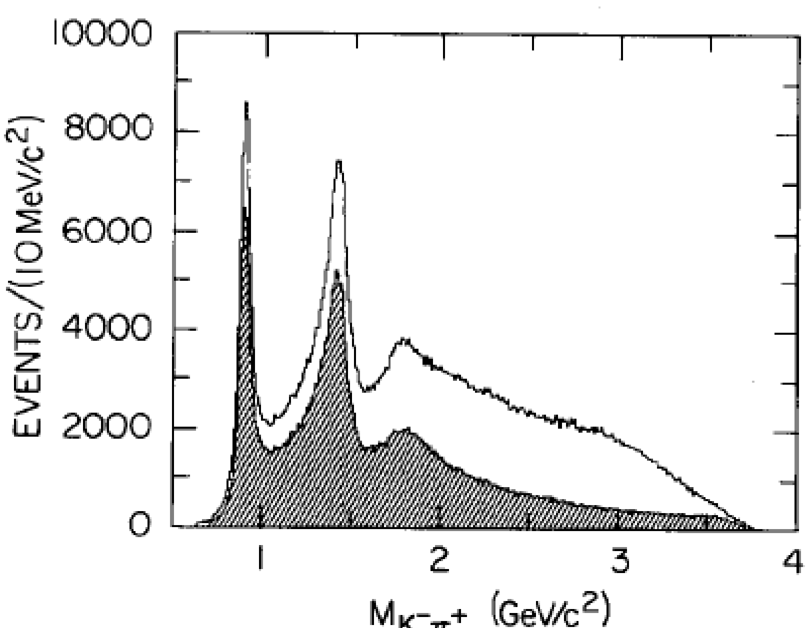


s-WAVE INTERFERENCE IN THE f^o RESONANCE REGION

Aachen-Berlin-CERN Collaboration

deep inelastic scattering with open strangeness (pion exchange)





385 000 events

A STUDY OF $K^-\pi^+$ SCATTERING IN THE REACTION $K^-p \rightarrow K^-\pi^+n$ AT 11 GeV/c *

The LASS Spectrometer

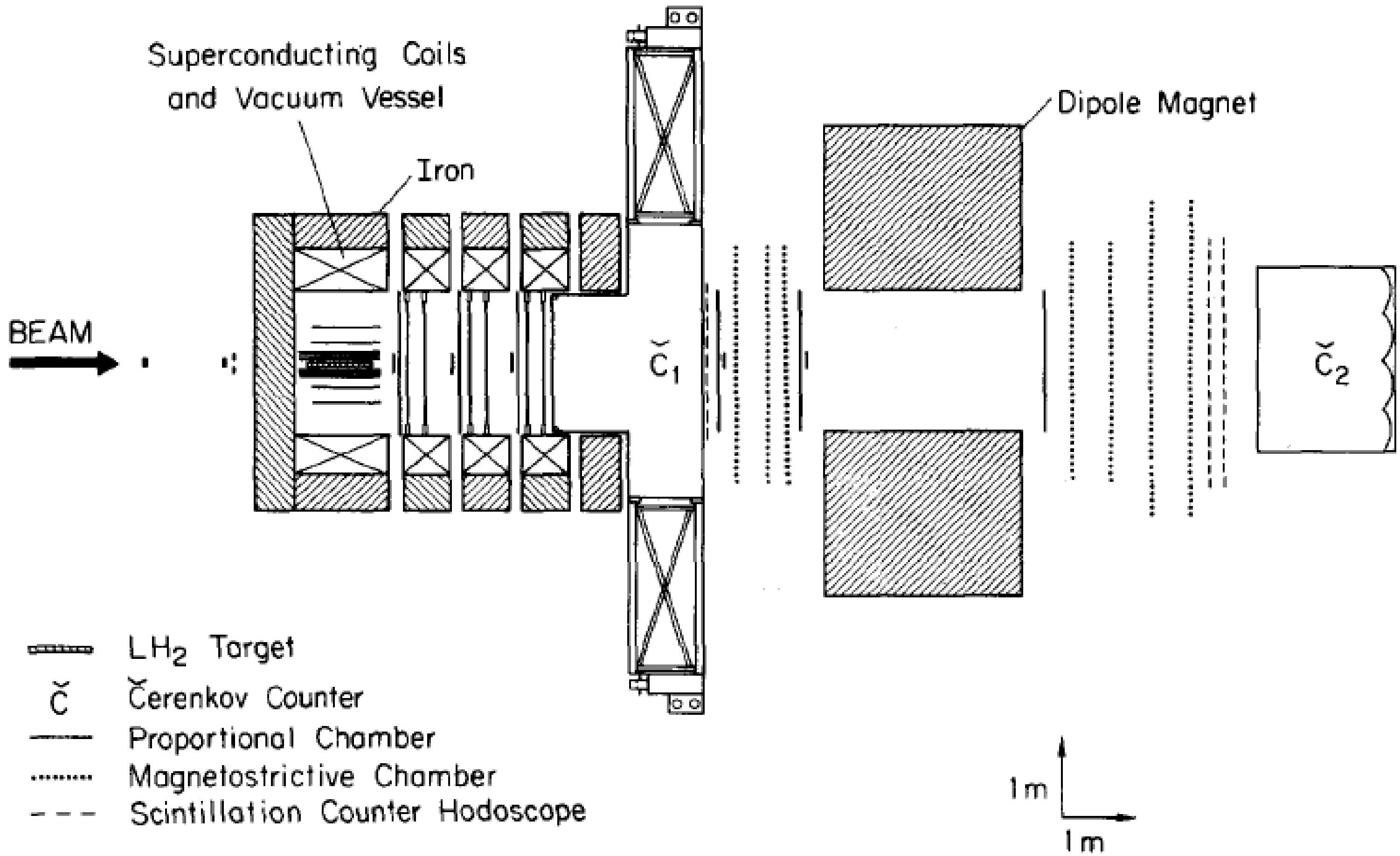
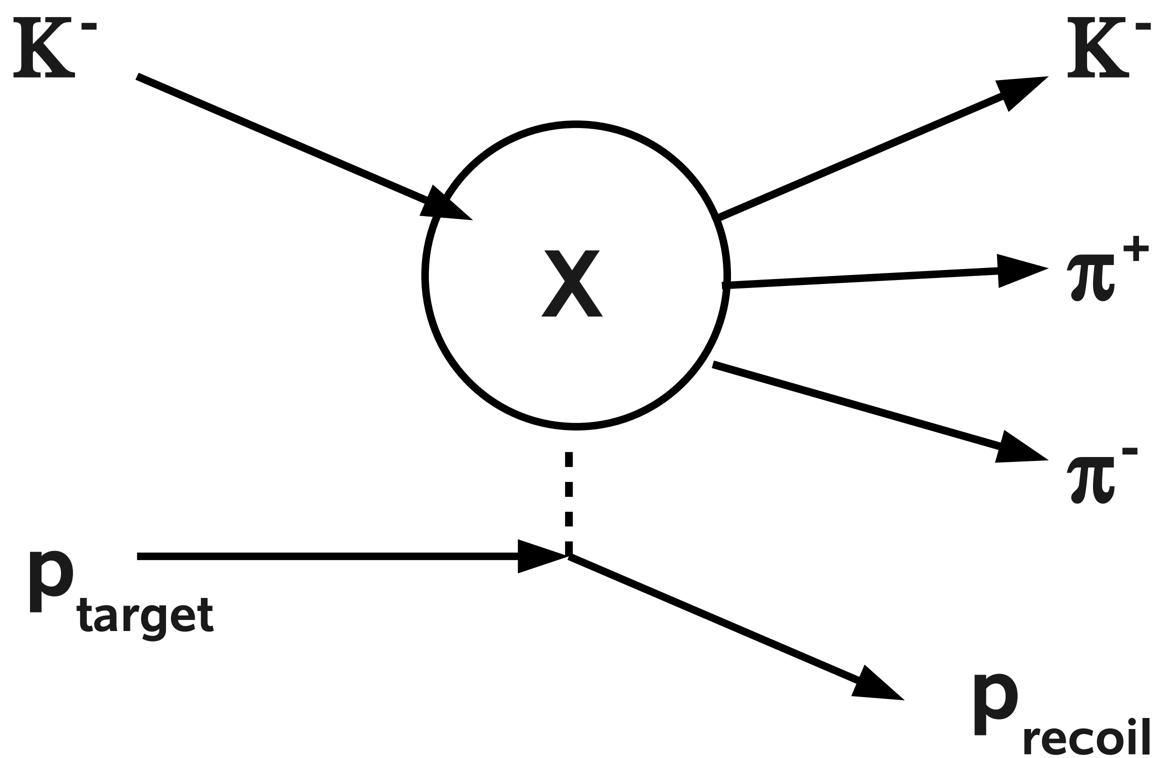


Fig. 1. Plan view of the LASS spectrometer.

Diffractive scattering via pomeron exchange



Measurements on the charged channel sector (at Serpukhov Proton Accelerator)

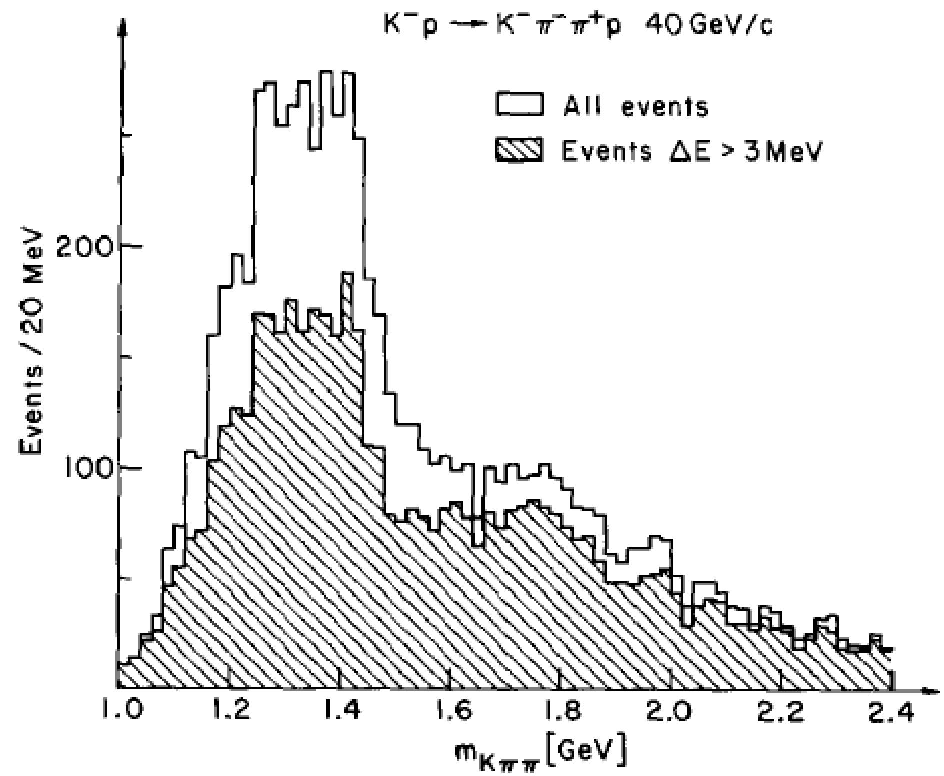
ANALYSIS OF THE REACTION $K^- p \to K^- \pi^- \pi^+ p$ at 40 GeV/c

Yu.M. ANTIPOV *, G. ASCOLI **, R. BUSNELLO ***,
M.N. KIENZLE-FOCACCI ***, W. KIENZLE ‡, R. KLANNER ‡‡,
L.G. LANDSBERG *, A.A. LEBEDEV *, P. LECOMTE ***,
M. MARTIN ***, V.N. ROINISHVILI ‡‡‡, R.D. SARD **,
A. WEITSCH # and F.A. YOTCH *

CERN-IHEP Boson Spectrometer

Institute of High Energy Physics, Serpukhov, USSR
European Organization for Nuclear Research, Geneva, Switzerland
University of Illinois, Urbana, Illinois, USA ¶

Received 23 September 1974



Statistics of the events used in the analysis

Running period	Incident momentum (GeV/c)	Number of raw triggers	Number of $K\pi\pi$ events	Number of inc. K-mesons
October 1971	40	81 500	1 662	1.59×10^8
October 1971	25	21 000	485	0.42×10^8
January 1972	40	120 000	2 489	2.34×10^8
April 1972	40	180 000	3 345	3.92×10^8
April 1972	25	100 000	2 196	1.91×10^8

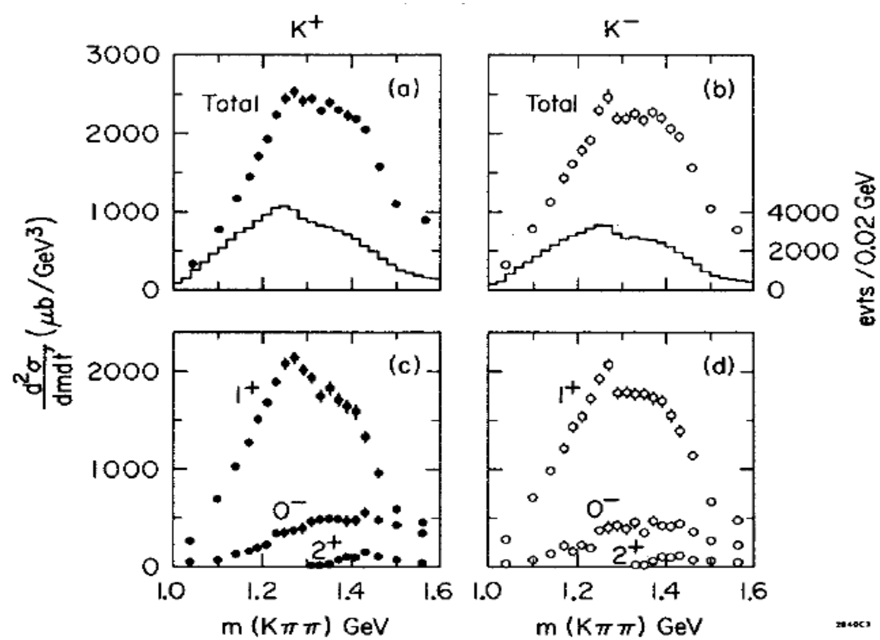
Measurements on the charged channel sector (at SLAC)

SLAC-PUB-1697
December 1975
(T/E)

OBSERVATION OF TWO STRANGENESS-ONE AXIAL VECTOR MESONS*

G. W. Brandenburg†, R. K. Carnegie††, R. J. Cashmore†††,
M. Davier‡, W. M. Dunwoodie, T. A. Lasinski, D.W.G.S. Leith,
J.A.J. Matthews‡‡, P. Walden‡‡‡, S. H. Williams, and F. C. Winkelmann††

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305



$72,000\ K^+\pi^+\pi^-$ $56,000\ K^-\pi^+\pi^-$

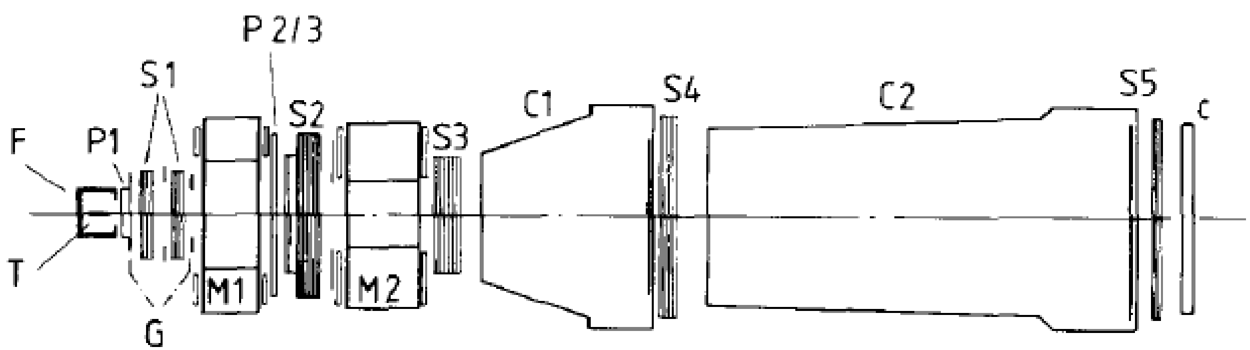
Measurements on the charged channel sector (at CERN)

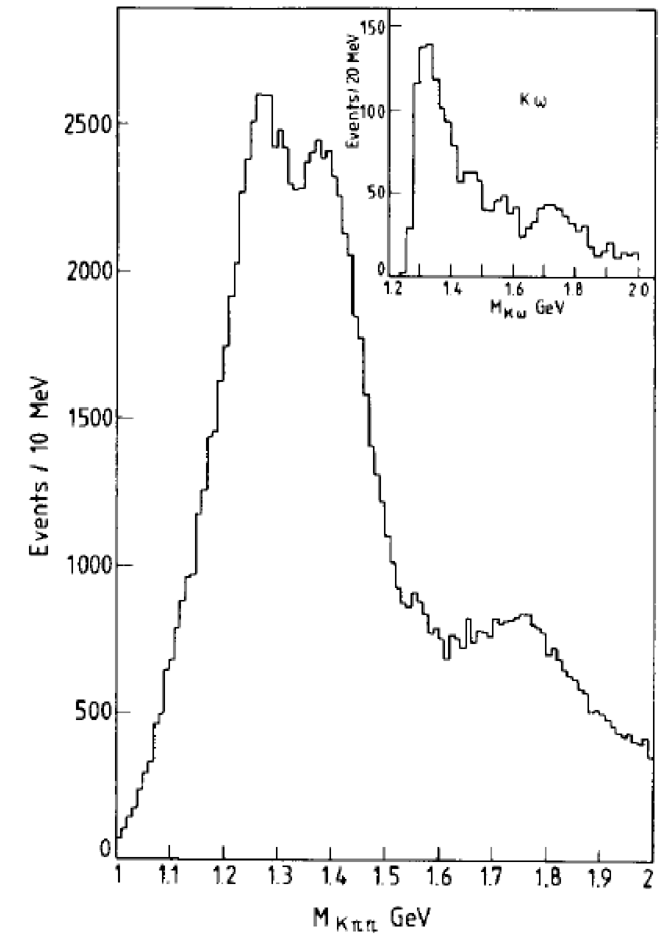
DIFFRACTIVE PRODUCTION OF STRANGE MESONS AT 63 GeV

The ACCMOR Collaboration

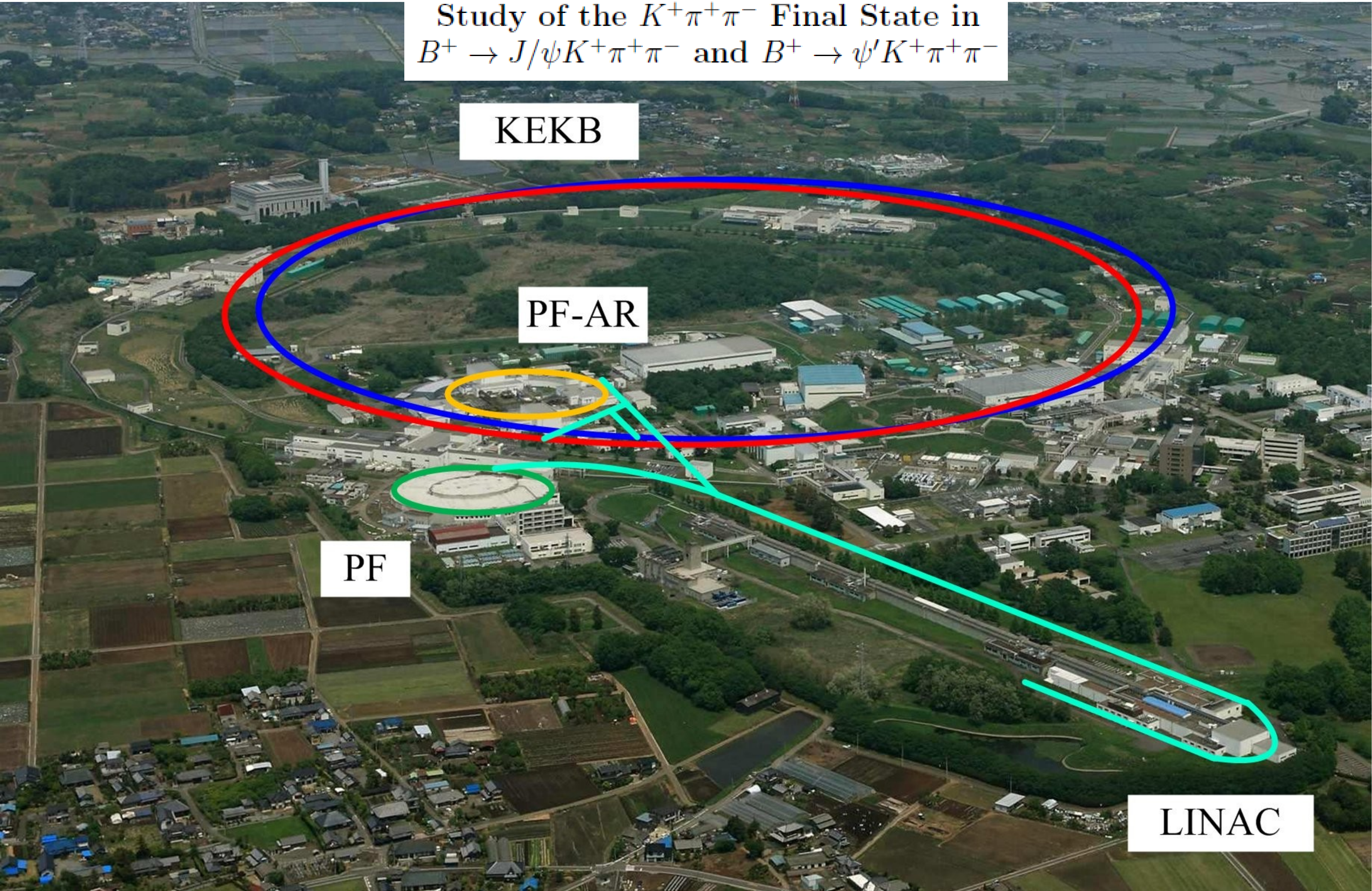
Received 19 December 1980

Nearly 200 000 examples of the diffractive process $K^-p \to K^-\pi^-\pi^+p$ at 63 GeV have been obtained using a two magnet spectrometer equipped with Čerenkov counters for secondary particle identification. In addition some 2000 examples of the process $K^-p \to \omega K^-p$ have been obtained.





Latest publication from BELLE detector at KEKB



Latest publication from BELLE detector at KEKB

Study of the $K^+\pi^+\pi^-$ Final State in $B^+ \to J/\psi K^+\pi^+\pi^-$ and $B^+ \to \psi' K^+\pi^+\pi^-$

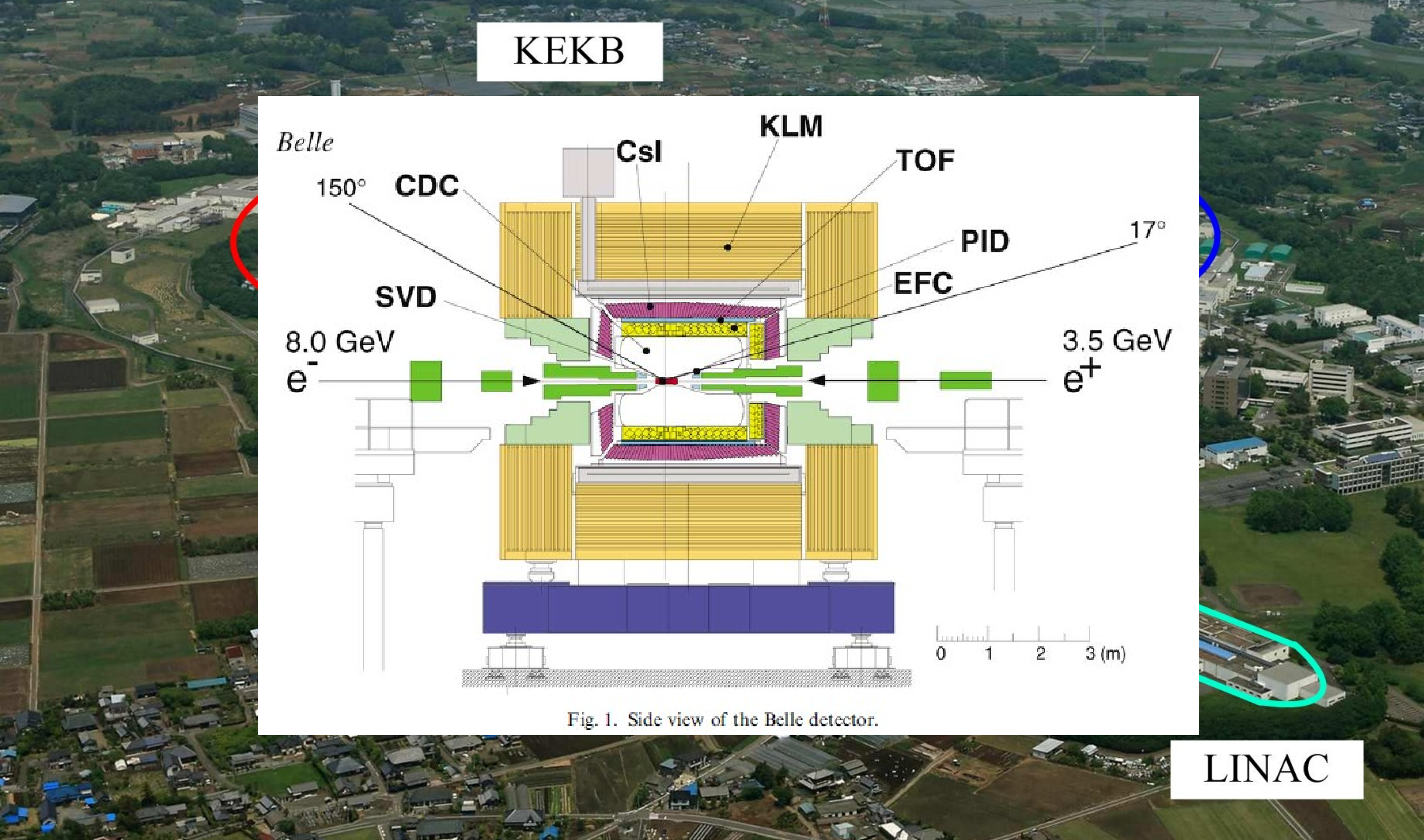


Fig. 1. Side view of the Belle detector.

Results obtained at KEKB

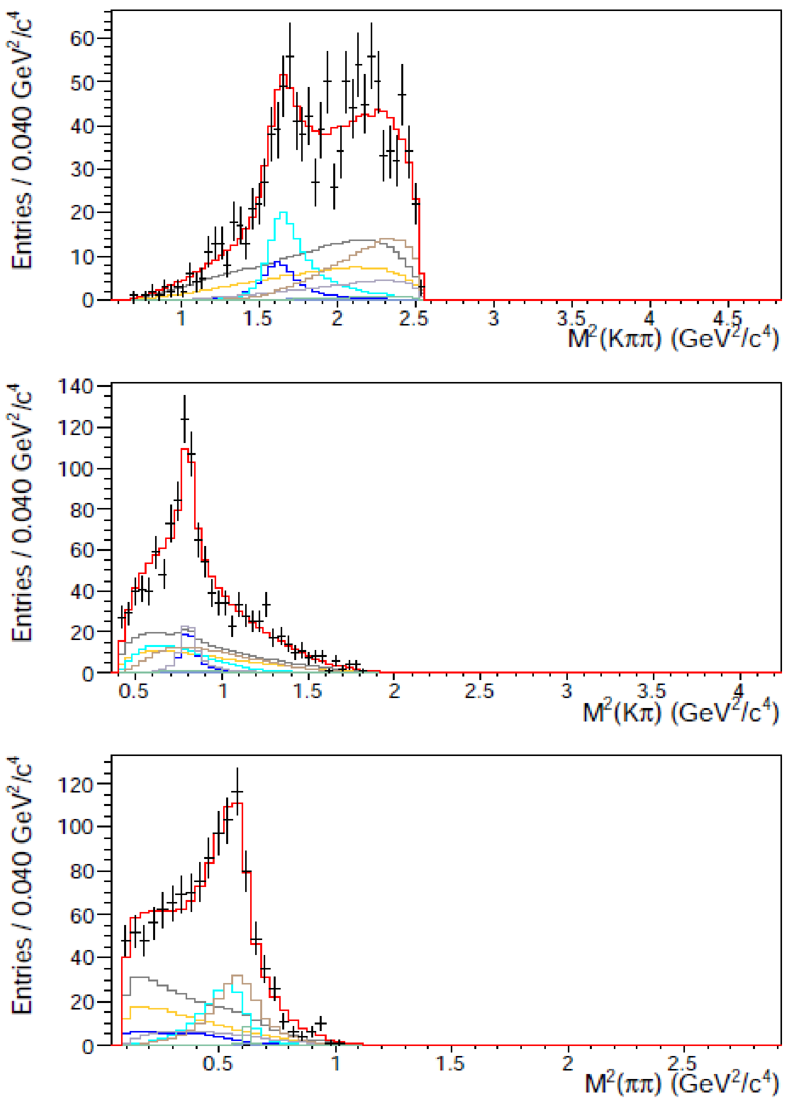


FIG. 20. Results of signal-region fits for $B^+ \to \psi' K^+\pi^+\pi^-$. Data (points) and fits (histograms) are shown projected onto the three axes. The fit components are color-coded as shown in Fig. 19.

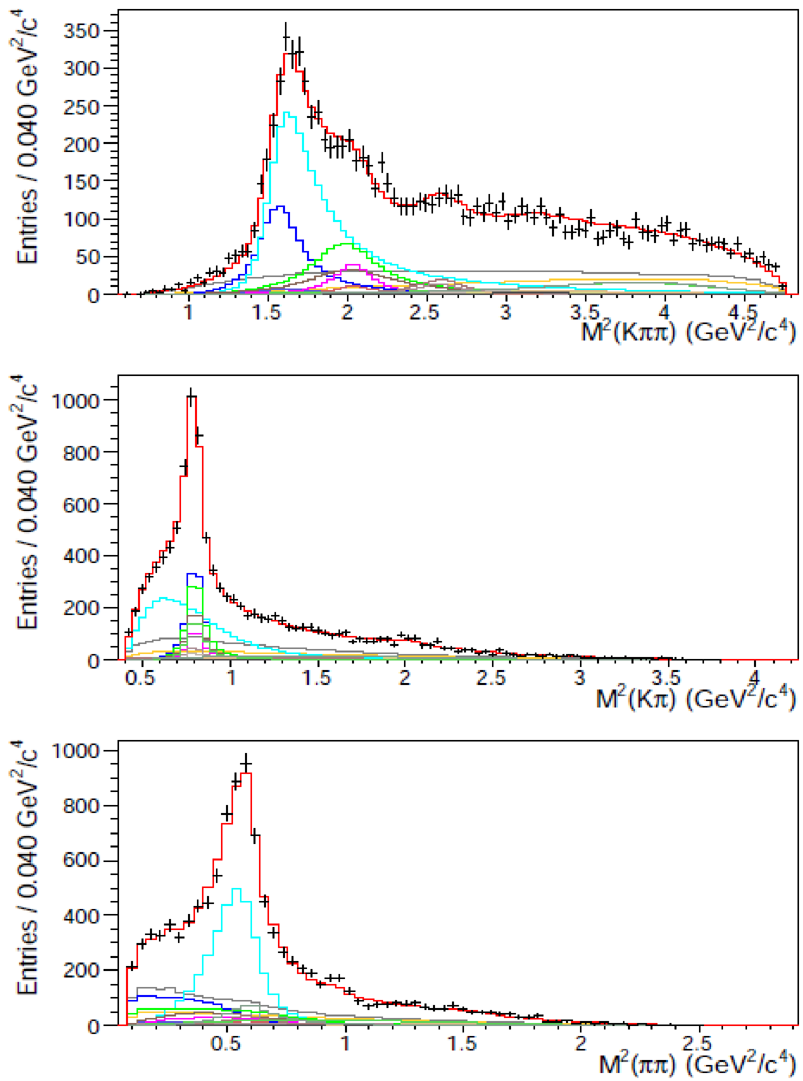


FIG. 21. Results of signal-region fits for $B^+ \to J/\psi K^+\pi^+\pi^-$, with the mass and width of the $K_1(1270)$ floated. Data (points) and fits (histograms) are shown projected onto the three axes. The fit components are color-coded as shown in Fig. 19.

What do we search for?

Resonances reported but not confirmed

$K_1(1650)$

$I(J^P) = \frac{1}{2}(1^+)$

OMITTED FROM SUMMARY TABLE

This entry contains various peaks in strange meson systems ($K^+\phi$, $K\pi\pi$) reported in partial-wave analysis in the 1600–1900 mass region.

$K_1(1650)$ MASS

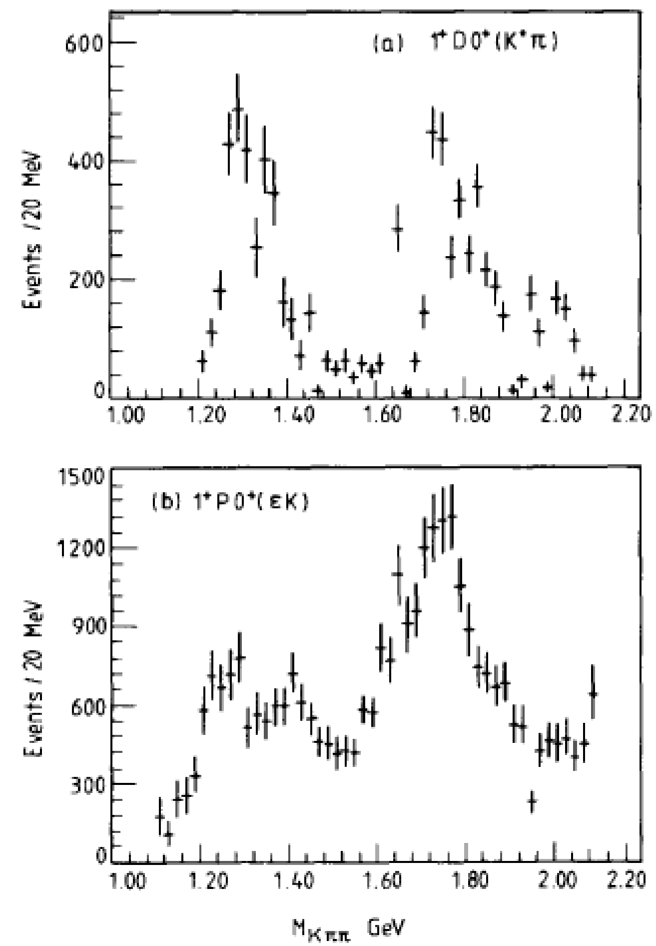
VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
1650±50	FRAME	86	OMEG	+	13 $K^+ p \to \phi K^+ p$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
∼ 1840	ARMSTRONG	83	OMEG	−	18.5 $K^- p \to 3K p$
∼ 1800	DAUM	81C	CNTR	−	63 $K^- p \to K^- 2\pi p$

$K_1(1650)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
150±50	FRAME	86	OMEG	+	13 $K^+ p \to \phi K^+ p$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
∼ 250	DAUM	81C	CNTR	−	63 $K^- p \to K^- 2\pi p$

$K_1(1650)$ DECAY MODES

	Mode
Γ_1	$K\pi\pi$
Γ_2	$K\phi$



Resonances reported but not confirmed

$K(1460)$

$I(J^P) = \frac{1}{2}(0^-)$

OMITTED FROM SUMMARY TABLE

Observed in $K\pi\pi$ partial-wave analysis.

$K(1460)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 1460	DAUM	81C	CNTR	$-$	63 $K^- p \rightarrow K^- 2\pi p$
~ 1400	[1] BRANDENB...	76B	ASPK	$\pm$	13 $K^\pm p \rightarrow K^+ 2\pi p$

[1] Coupled mainly to $K f_0(1370)$. Decay into $K^*(892)\pi$ seen.

$K(1460)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 260	DAUM	81C	CNTR	$-$	63 $K^- p \rightarrow K^- 2\pi p$
~ 250	[2] BRANDENB...	76B	ASPK	$\pm$	13 $K^\pm p \rightarrow K^+ 2\pi p$

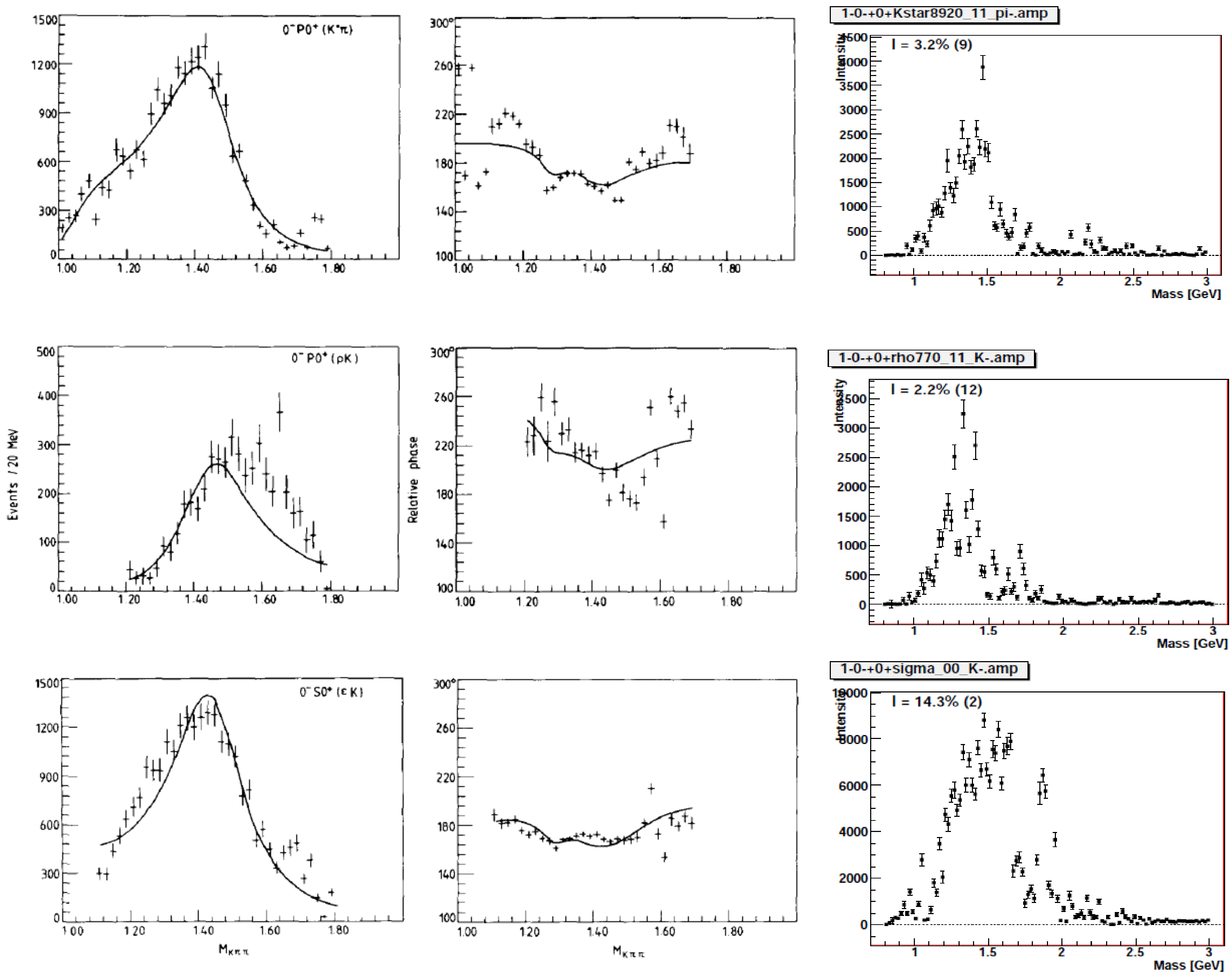
[2] Coupled mainly to $K f_0(1370)$. Decay into $K^*(892)\pi$ seen.

$K(1460)$ DECAY MODES

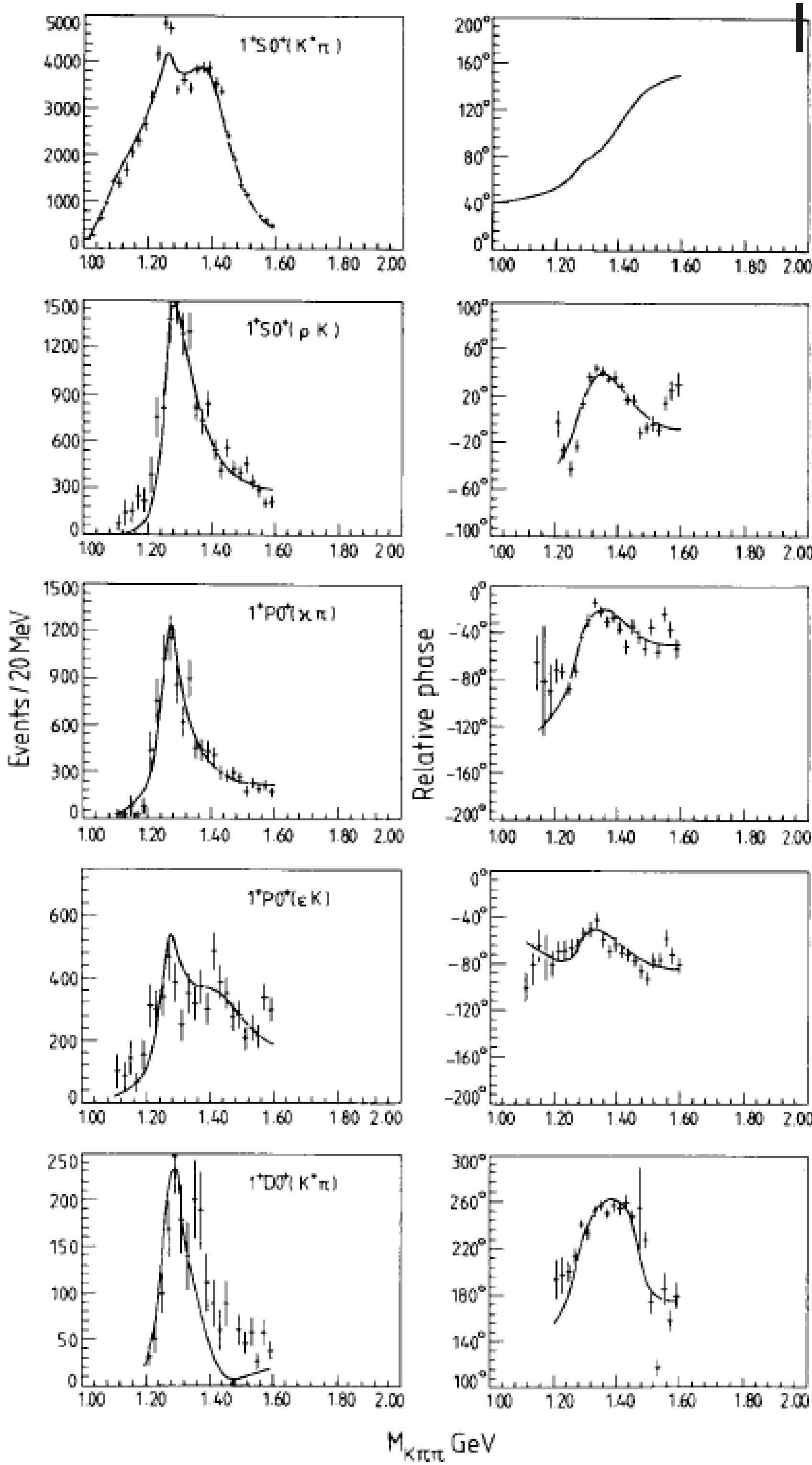
	Mode	Fraction (Γ_i/Γ)
Γ_1	$K^*(892)\pi$	seen
Γ_2	$K\rho$	seen
Γ_3	$K_0^*(1430)\pi$	seen

Resonances reported but not confirmed

K(1460)



Interpretation of the double structure of K_1



$$K_1(1270) = K(1^3P_1)\sin\theta_K + K(1^1P_1)\cos\theta_K$$
$$K_1(1400) = K(1^3P_1)\cos\theta_K - K(1^1P_1)\sin\theta_K$$

Could it be that these are 2 resonances?

Clues for the existence of two $K_1(1270)$ resonances

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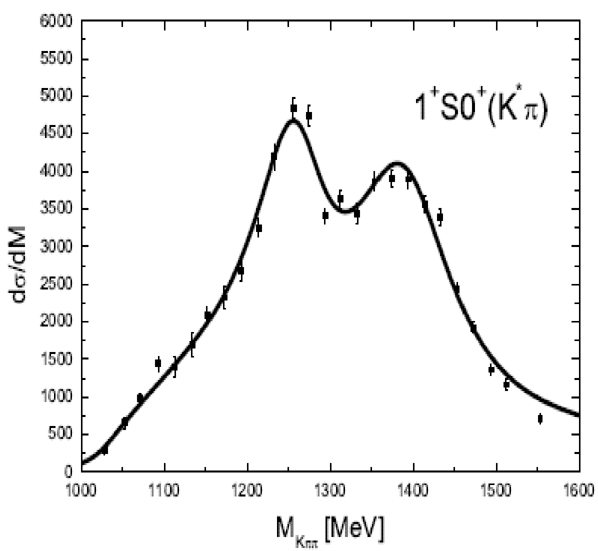
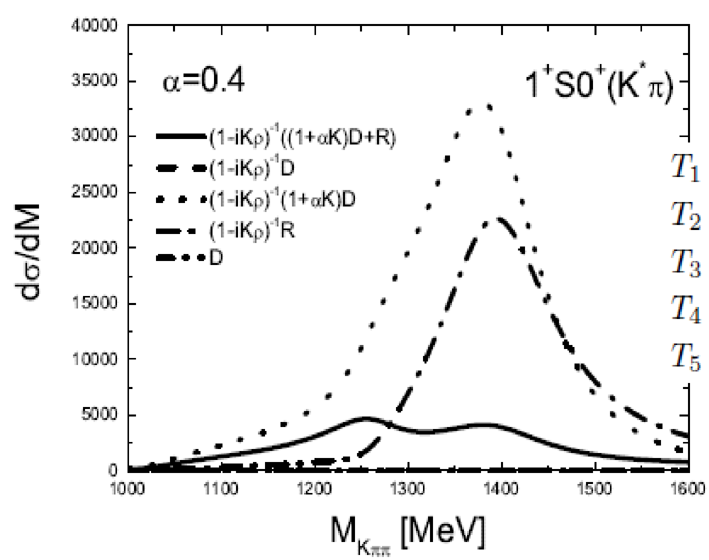
The axial vector meson $K_1(1270)$ was studied within the chiral unitary approach, where it was shown that it has a two-pole structure. We reanalyze the high-statistics WA3 experiment $K^- p \to K^- \pi^+ \pi^- p$ at 63 GeV, which established the existence of both $K_1(1270)$ and $K_1(1400)$, and we show that it clearly favors our two-pole interpretation. We also reanalyze the traditional K-matrix interpretation of the WA3 data and find that the good fit of the data obtained there comes from large cancellations of terms of unclear physical interpretation.





$$
\begin{aligned}
T_1 &= (1 - iK\rho)^{-1}((1+\alpha K)D + R) \quad \text{the full amplitude} \\
T_2 &= (1 - iK\rho)^{-1}D \quad \text{the unitarized Deck background} \\
T_3 &= (1 - iK\rho)^{-1}(1+\alpha K)D \quad \text{the full background} \\
T_4 &= (1 - iK\rho)^{-1}R \quad \text{the direct production amplitude} \\
T_5 &= D \quad \text{the pure Deck background}
\end{aligned}
$$

Background (T3) is problematic

Thanks for your patience