Hadron Spectroscopy Experiment with High Momentum Charged Kaon Beam

JHF Workshop, KEK, Dec.10-12, 2001

T. Tsuru (KEK)

1. Present Status of this Physics Field
2. Some Topics
   i) Glueballs and Hybrids
   ii) Jpc=1-+ exotics
   iii) Chiral Symmetry Breaking Particles, σ (sigma) etc.
   iv) Multiquark states and others
3. Status of Mesons explicitly including Strange Quark and Necessity of their Study

   High Quality and High Statistics Data are expected.

   Some Topics: 1-+ ssbarg Hybrid, κ (kappa) etc.
4. High Momentum Charged Kaon Beam Line at JHF and Spectrometer

   (cf. OKA Plan at IHEP 70 GeV PS (Protvino, Russia))

1. Present Status of Hadron Spectroscopy Experiment (~~exp~~. Meson)

Much data are accumulated:

Many incident beams: π, p, pbar, γ, Kaon etc.

Many reactions: CEX, diffractive, annihilation etc.

Many decay modes: $\pi\pi$, πK, $\eta\pi$, $\eta\eta$, 3π, $\eta\pi\pi$, K$\pi\pi$

etc.

Many ~~extra~~ excess states which cannot be accommodated in conventional qqbar nonets, are confirmed.

	Isovector(1x3)	Isoscalar(2)	isospinor(1x4)
0-+	π	η, η'	K
1--	ρ	ω, ϕ	K*(890)
1++	a_1	f_1, f_1', E	K_{1F}(1270)
2++	a_2	f_2, f_2', 1565	K_2^* 1430
1-+	b_1	h_1, h_1'	K_1(1400)
0++	a_0(980) 1450	σ 980, 1370, 1500, 1710	K_0^*(1430), κ
0++(rad. excited)			
0-+(rad. excited)	π(1300) 1800	η, $2\eta'$	K(1460)
1--(rad. excited)	ρ(1450) 1700	ω(1420) ϕ(1680) 1600	

?!

etc.

2^{++}

2^{-+}

π_1(1400), π_1(1600)

0^{--} 0^{+-} 1^{-+} 2^{+-} never $q\bar{q}$

2. Some Topics

i) Glueballs and hybrids

0++(scalar): $f_0(1500)$ GAMS, XtalBarrel etc.

supported by Lattice QCD

2++: near 2200 MeV BES(Beijing) etc.

ii) 1-+ exotics: never qqbar state

1400 MeV: $\eta\pi$ KEK, BNL, IHEP (Russia)

1600 MeV: $\pi\eta'$ etc. BNL, IHEP

iii) Chiral Simmetry Breaking Particles, σ (sigma) etc.

σ 500-700 MeV: $\pi\pi$ in pp central, $J/\Psi \to \omega\pi$

κ 900 MeV: $K\pi$ in D+ decay (FNAL)

$\pi^- p \to \eta\eta n$ 38 GeV/c GAMS

Scalar glueball

1983

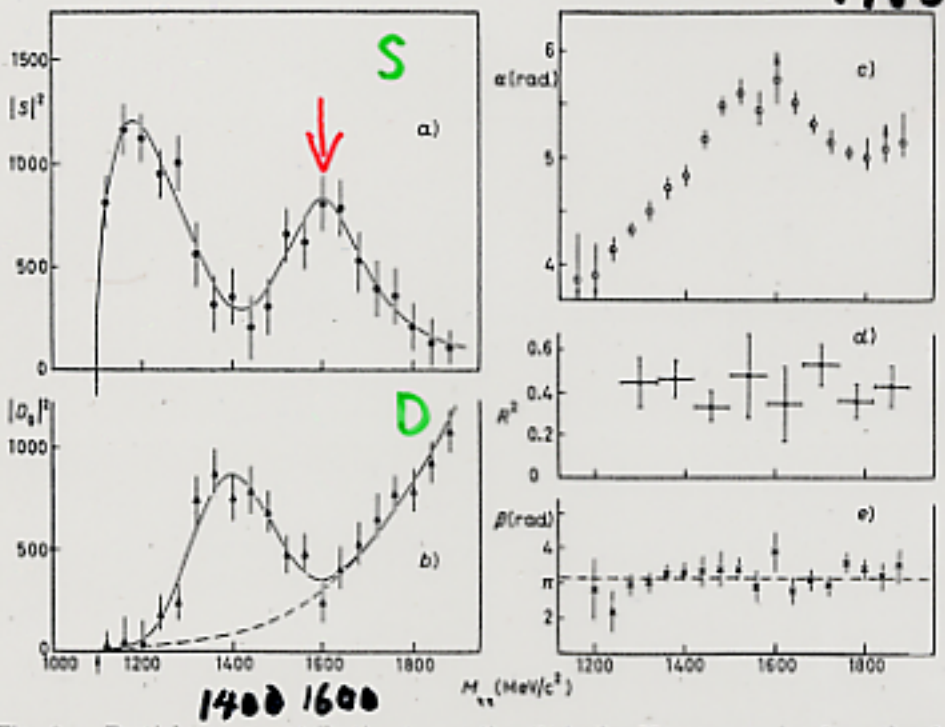


Fig. 6. – Partial waves contributing to reaction (1) in the $M_{\eta\eta}$ mass region from threshold (indicated by an arrow) up to 1.9 GeV/c². *a*) Intensity of the S-wave, *b*) intensity of the D_0-wave, *c*) relative phase between S-wave and D_0-wave, *d*) depolarization parameter R for $\beta = \pi$, *e*) phase β for R^2 fixed at 0.4. The full curve in *a*) is the S-wave obtained with the parametrization (9). The full curve in *b*) is the D_0-wave obtained from parametrization (12), the dashed curve is the background contribution ($\sim p_0^5(M)$).

$\eta\eta'$

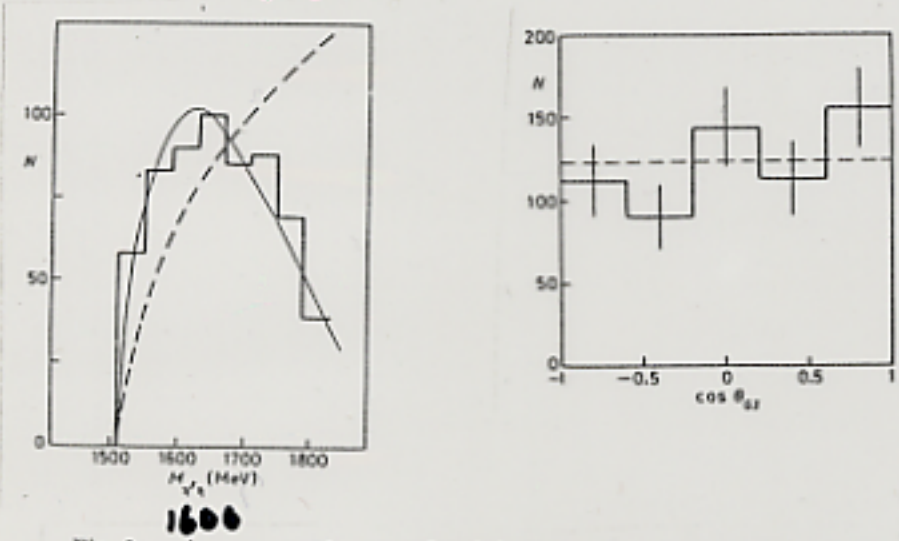


Fig. 2. – $\eta'\eta$ mass spectrum produced in reaction $\pi^- p \to \eta'\eta n$ from the threshold to 1.83 GeV. In this figure and in the next one, N has been corrected for efficiency ($\varepsilon \sim 0.25$). The full line is a Breit-Wigner fit (4) with parameters (5). The dashed line is the phase space normalized to the number of events in the measured mass interval.

Fig. 3. – Polar angular distribution of $\eta'\eta$ decay in the Gottfried-Jackson frame. 1.51 GeV $< M_{\eta'\eta} <$ 1.83 GeV. $\vartheta_{GJ} = 0$ corresponds to the trajectory of η' along the beam direction.

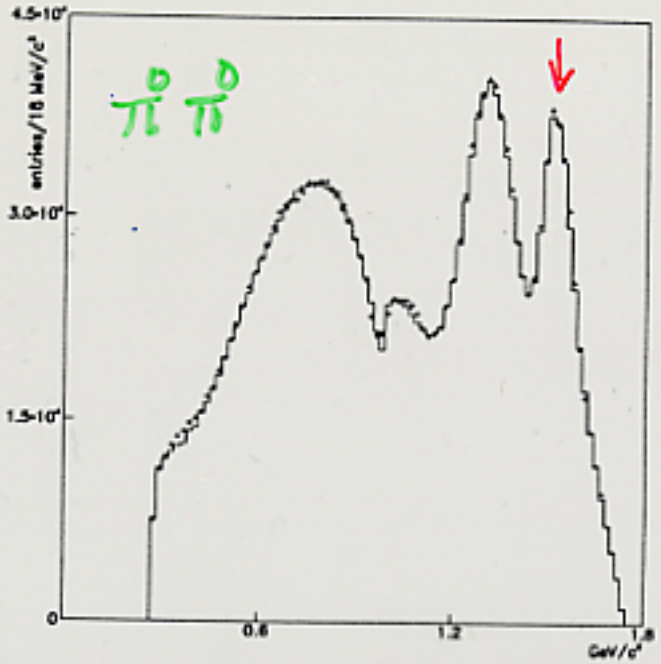


Fig. 2. The $\pi^0\pi^0$ invariant mass distribution. The solid line represents the fit.

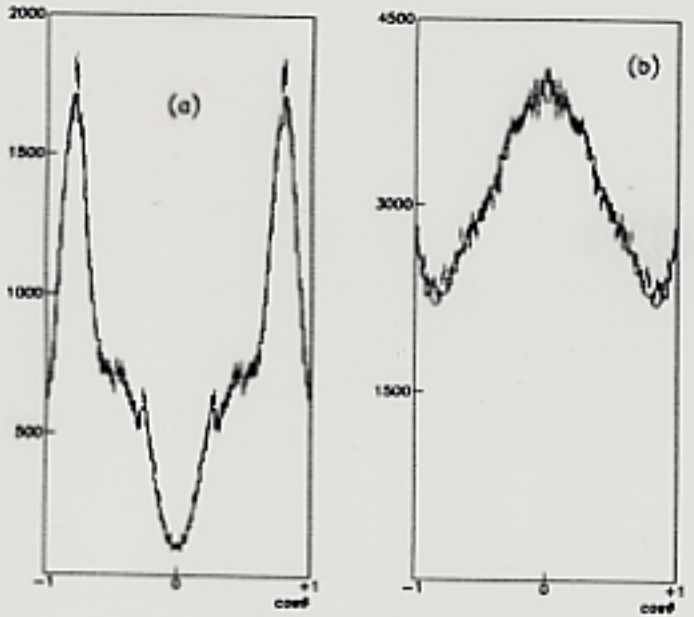
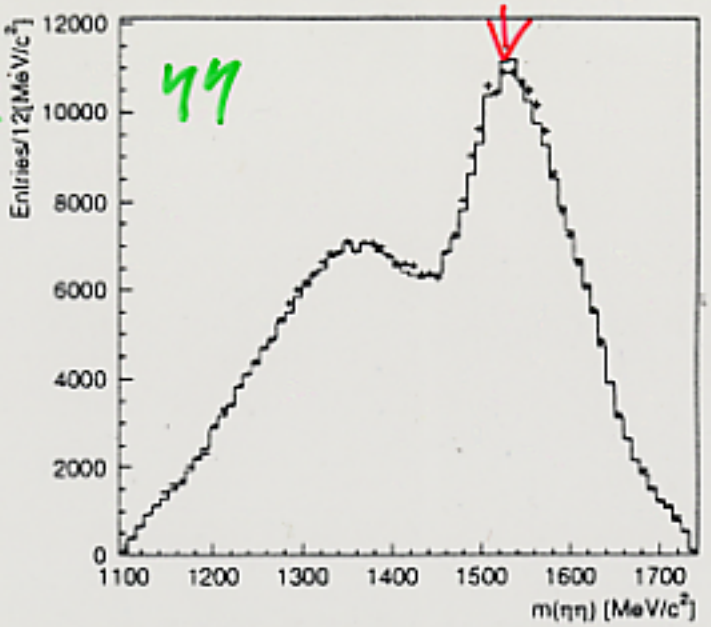


Fig. 3. Angular distributions around the $K\overline{K}$ threshold (a) and around 1500 MeV (b). The solid line represents the fit.

$\bar{p}p$ at LEAR

Xtal Barrel



scalar glueball

Fig. 3. The projection of the $\eta\eta$ system with fit superimposed (crosses: data, histogram: fit described in the text).

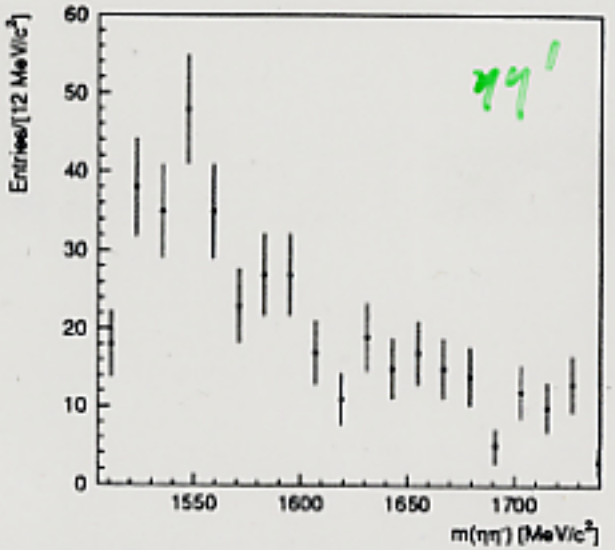


Fig. 4. The $\eta\eta'$ projection derived from the reaction $\bar{p}p \rightarrow \pi^+\pi^-\eta\eta\pi^0$ exhibits the same features as the $\eta\eta'$ spectrum in Fig. 3.

glueball
0^{++} (2^{++})

Mass & width of 0^{++} glueball by LATTICE Cal.

IBM : 1740 ± 71 MeV ($M_{2^{++}} = 2359 \pm 128$)

UKQCD : 1550 ± 50 MeV ($M_{2^{++}} = 2270 \pm 100$)

width of 0^{++} : 100 ~ 150 MeV

$M_{2^{++}} / M_{0^{++}} \fallingdotseq 1.5$

Tensor glueball

BES (Beijing)

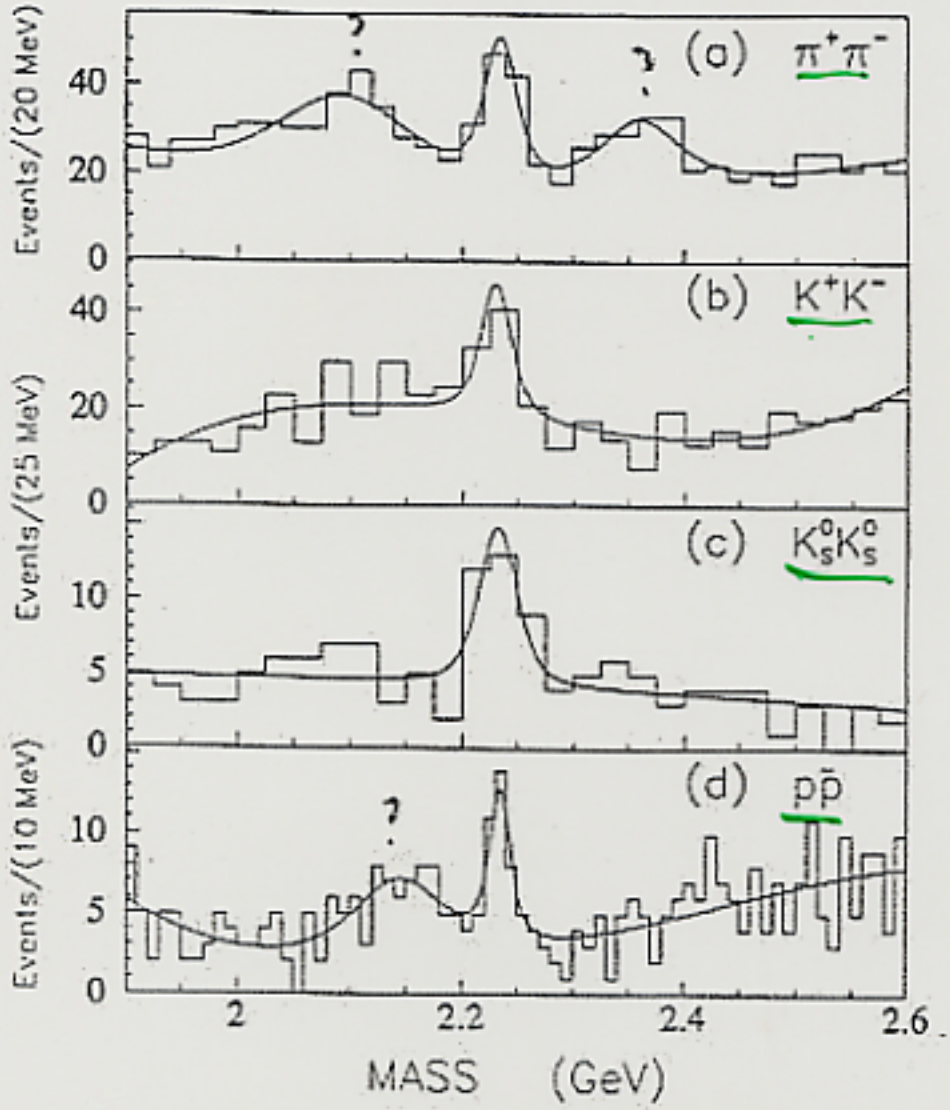


FIG. 2. Fitted invariant mass spectra of (a) $\pi^+\pi^-$, (b) K^+K^-, (c) $K^0_SK^0_S$, and (d) $p\bar{p}$.

$\pi^- p \to \eta \pi^- p$

KEK

BNL-E852

VES

(IHEP)

Russia

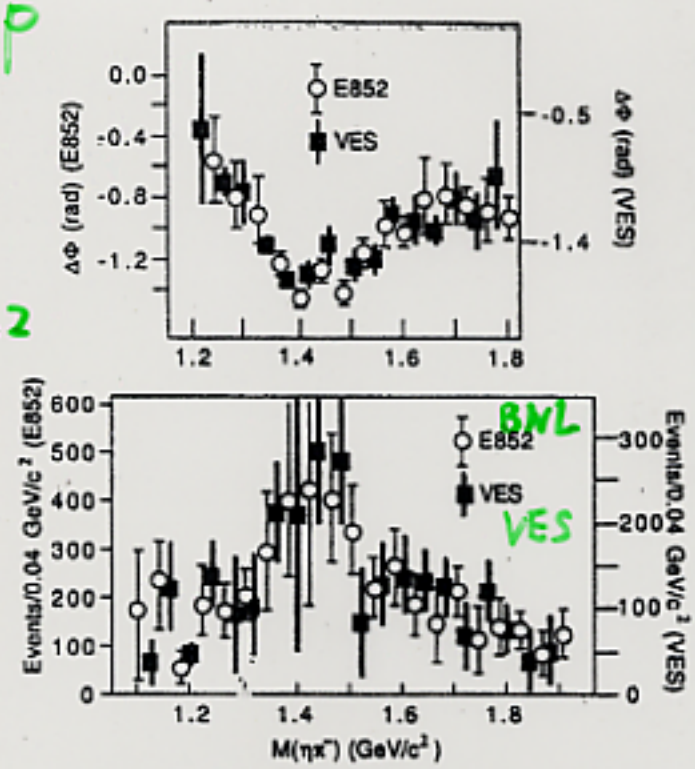


Figure 24 - Comparison of the results of this amplitude analysis with the VES experiment.

$J^{PC}(1400)$

in

$\eta \pi^-$

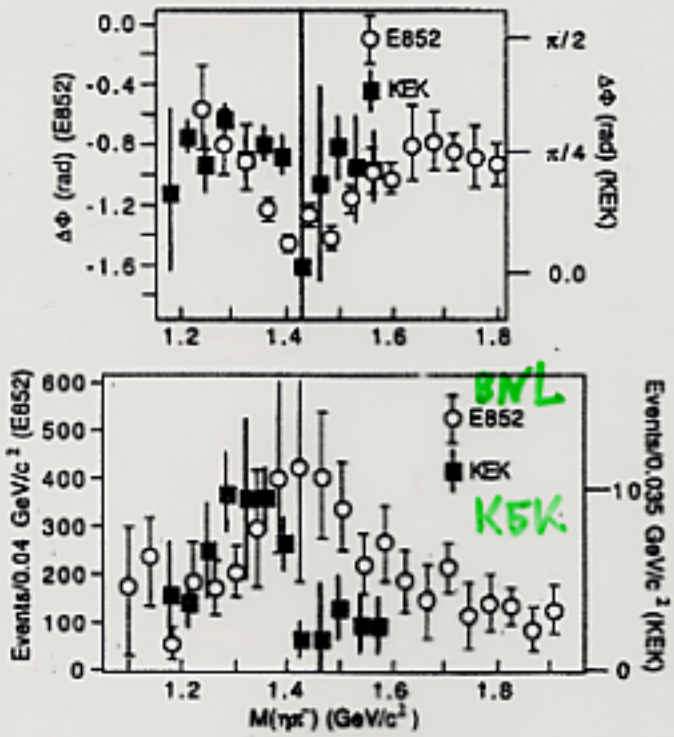


Figure 25 - Comparison of the results of this amplitude analysis with the KEK experiment.

I^{PC} non $q\bar{q}$

$\eta'\pi^-$

$\pi^- p \to \eta' \pi^- p$ BNL 18 GeV/c

$\pi_1(1600)$ I^{-+} non $q\bar{q}$

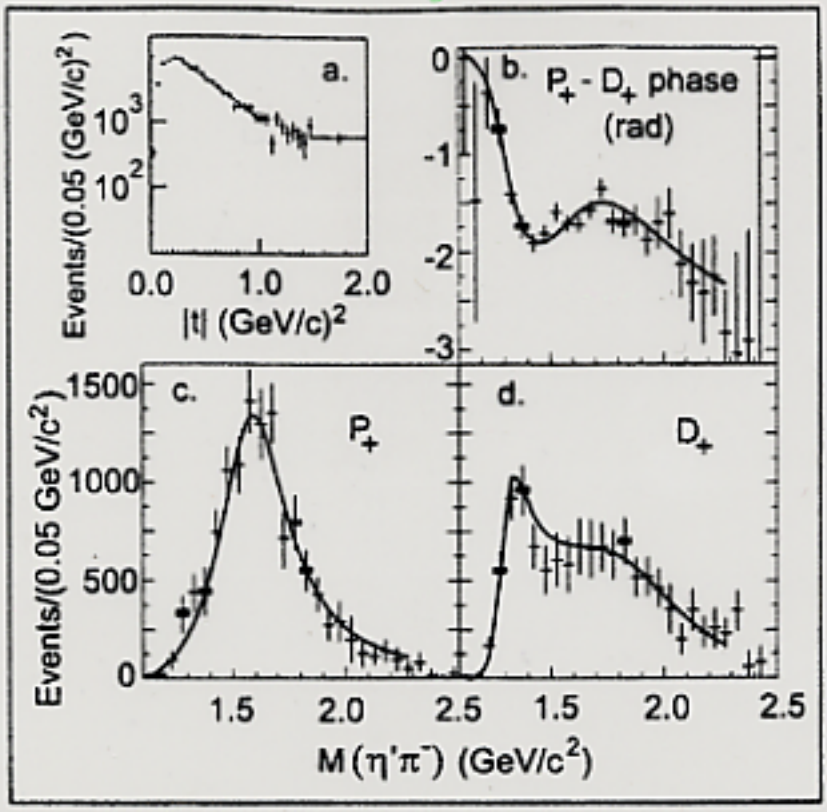
$$f(t) = a\, e^{b|t|}$$

$$b = -2.93 \pm 0.11 \ (\mathrm{GeV/c})^{-2}$$

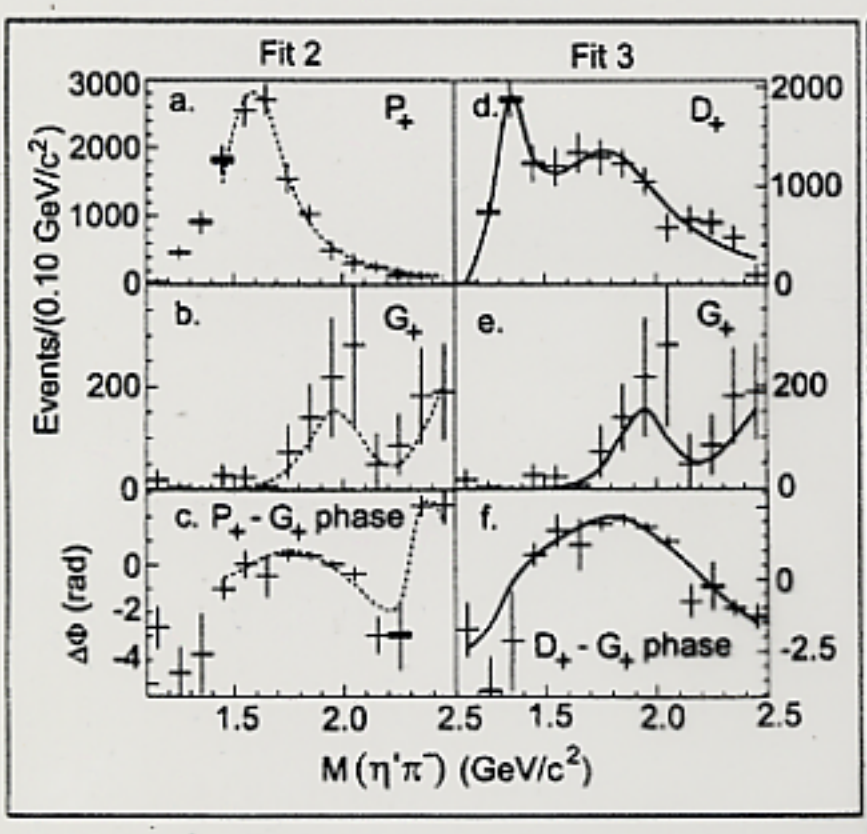
Fit1: P_+ and D_+

Fit2: P_+ and G_+

Fit3: D_+ and G_+



Fit 1



$$P_+ \ (1^{-+})$$

$$M = 1597 \pm 10^{+45}_{-10} \ \mathrm{MeV}$$

$$\Gamma = 340 \pm 40 \pm 50 \ \mathrm{MeV}$$

$$D_+ \ (2^{++})$$

$$M = 1318 \pm 8^{+3}_{-5} \ \mathrm{MeV}$$

$$\Gamma = 140 \pm 35 \pm 20 \ \mathrm{MeV}$$

$$G_+ \ (4^{++})$$

$$M = 2000 \pm 40^{+60}_{-20} \ \mathrm{MeV}$$

$$\Gamma = 350 \pm 100^{+70}_{-50} \ \mathrm{MeV}$$

Hadron2001

$pp \to p_f \pi^0 \pi^0 p_s$ at 450 GeV/c

GAMS 1995

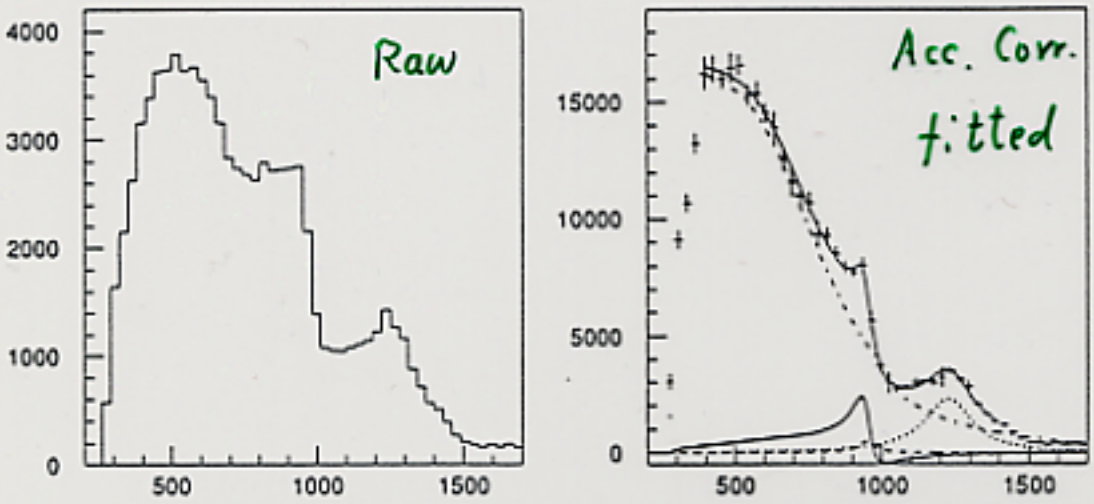


Figure 1: mass distribution (a) not corrected for acceptance (b) corrected

Table 1: Observed Mass, Width and Cross Section of Each Resonance

	mass(MeV)	width(MeV)	$\sigma(pp \to ppX^0)BR(X^0 \to \pi^0\pi^0)$
$f_0(975)$	951±6	76±19	39±20 nb
$f_2(1275)$	1233±4	185±17	480±50 nb
f_c	~500	~500	7.3±0.8μb

$f_0(975)$

$f_2(1275)$

f_c added

M = 590 ± 10 MeV

T = 710 ± 30 MeV

$J/\psi \to \omega\pi^0\pi^0,\ \omega\pi^+\pi^-$ DM2 σ

σ in $\pi^0\pi^0$

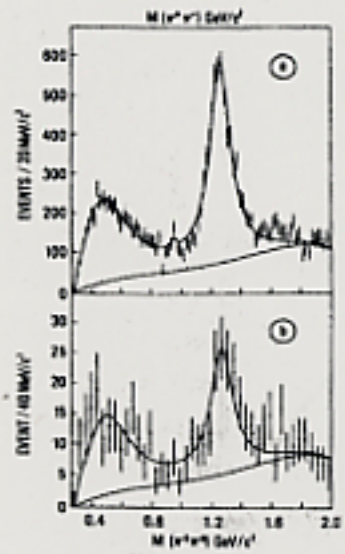


Fig. 2. Fit of the $\pi\pi$ distribution (a) for $J/\Psi \to \omega\pi^+\pi^-$:(b) for $J/\Psi \to \omega\pi^0\pi^0$.

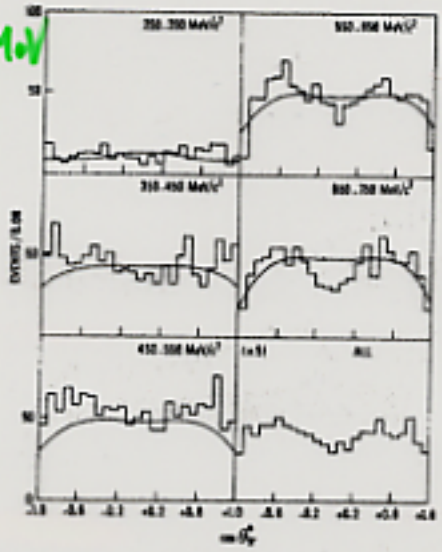


Fig. 3. $\cos\theta^*_\pi$ distributions in several $\pi^+\pi^-$ low-mass ranges for $J/\Psi \to \omega\pi^+\pi^-$. The curves represent the Monte Carlo acceptance for 0^+ events.

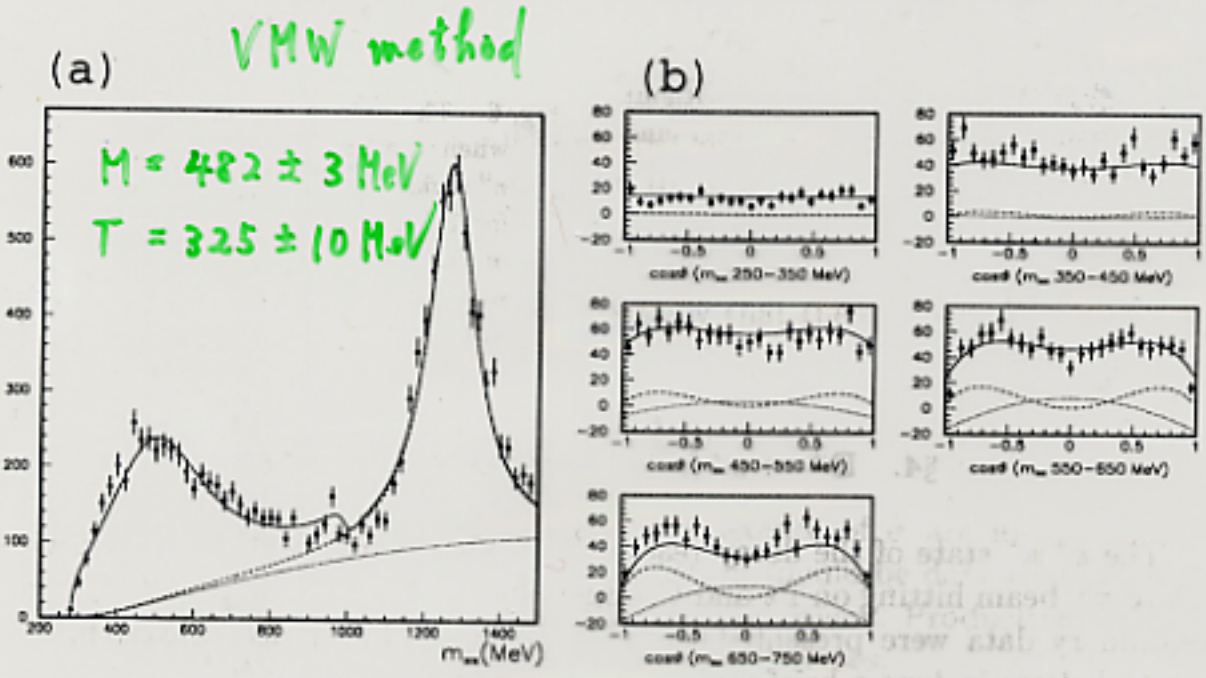


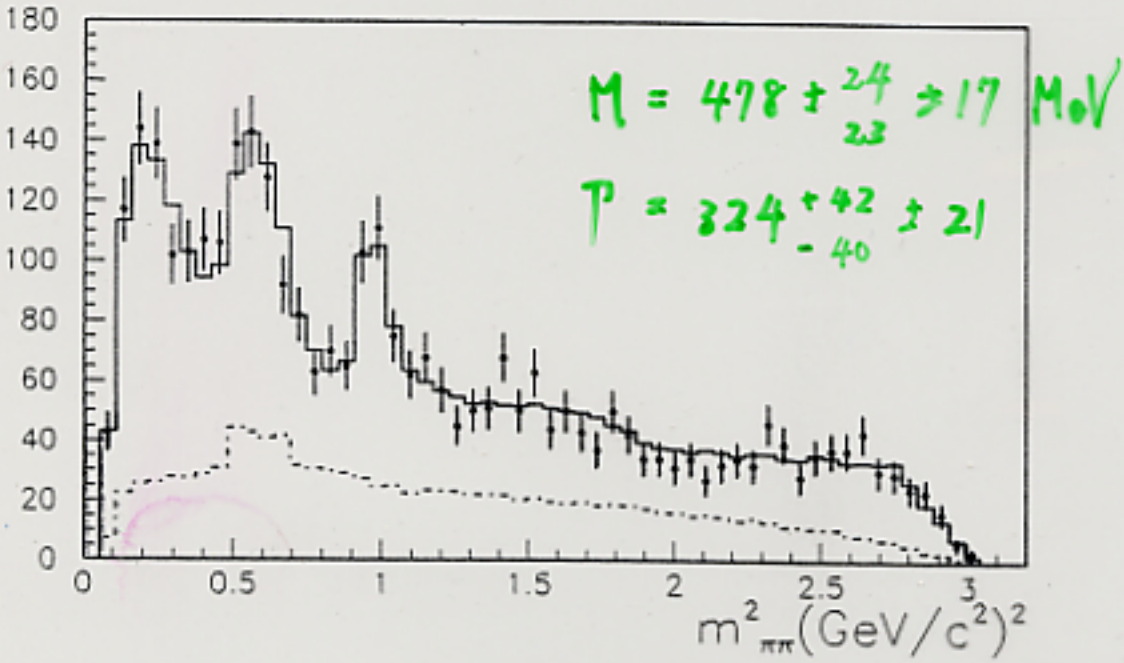
Fig. 4. (a) The fit for effective mass distribution by VMW-method shown by a solid line. The dashed line is D-wave connection coming from $f_2(D_{f_2})$ and $b_1\pi$ decay(D_{BG}). Dotted line shows D_{BG} contribution. (b) The fit for $\cos\theta_\pi$ distribution by VMW-method shown by a solid line. The dashed lines are D-wane contribution $|D_{f_2}|^2 + |D_{BG}|^2$, while dotted lines are interference of and S-wave state, $|SD_{f_2}|$. Data are taken from ref. [4]

are obtained for relative phases between the low mass and f_2, respectively. The qualitative features of data are reproduced well by VMW, by including interferences between the S-wave and S tail of D-wave from $f_2(1270)$, whose contributions are shown by dotted lines in the figures.

$D^+ \to \pi^-\pi^+\pi^+$ Results

Fit Quality with $\sigma\pi$ amplitude

$$\chi^2/\mathrm{dof} = 0.9 \to CL = 76\%$$



Summary of $D^+ \to \pi^-\pi^+\pi^+$ Analysis

- Model without $\sigma\pi$: high NR, bad fit quality
- σ appears with low mass, large width
- $\sigma\pi$ is the dominant channel; small NR
- $\rho^0(1450)\pi^+$ becomes negligible

$\Rightarrow$ VERY GOOD DESCRIPTION AT LOW $\pi\pi$ MASS

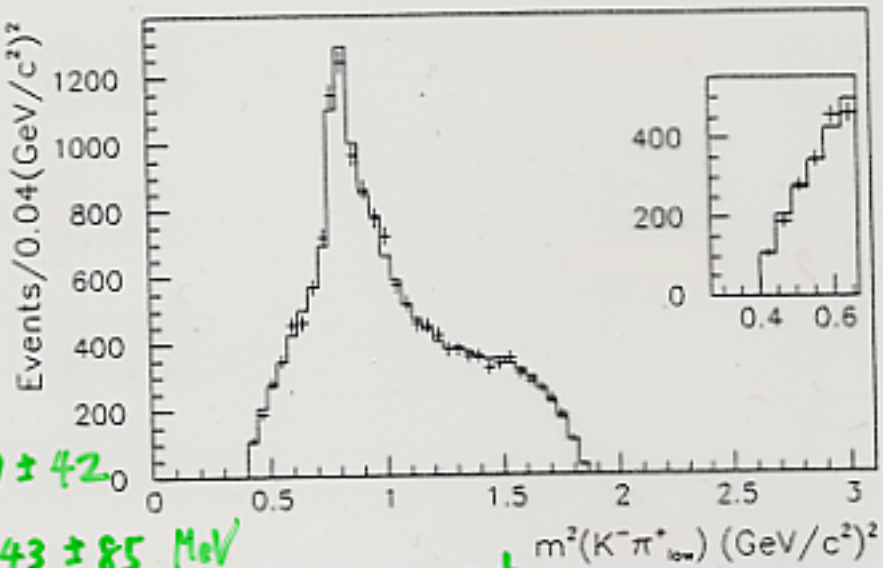
K

$D^+ \to K^- \pi^+ \pi^-$

Fit Quality with $K\pi$

FNAL E791

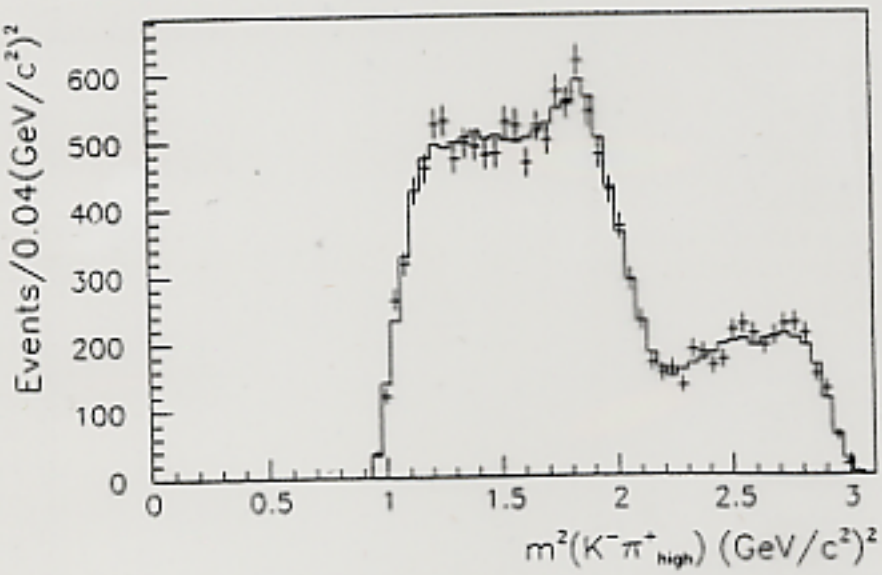
$$\chi^2/\mathrm{dof} = 0.73 \to CL = 95\%$$



M = 797 ± 19 ± 42

Γ = 410 ± 43 ± 85 MeV

$K^-\pi^+_{low}$



3. s-quark explicitly included Mesons: K^*, K_1 etc.

Very few extra states are reported.

High statistics data: done 20 years ago.

LASS at SLAC, 11GeV/c K^- beam

Sensitivity: 4.1 ev/nb

It was difficult to claim extra states in those days.

Of course, we have data from many decays modes.

4. Hadron Spectroscopy Experiment with High Momentum charged K Beam at JHF.

i) Systematic study of s-quark included mesons

K*, K_1 etc. excess states will be good candidates.

Topics: κ, 1-+ ssbarg hybrid

ii) high intensity machine and then beam is available.

Development of technology can be used:

Detectors working under high rate circumstances

Wire chambers, gamma detectors etc.

Electronics

DAQ

=> construct modern spectrometer

Higher statistics (> two order) and quality data will be hopeful.

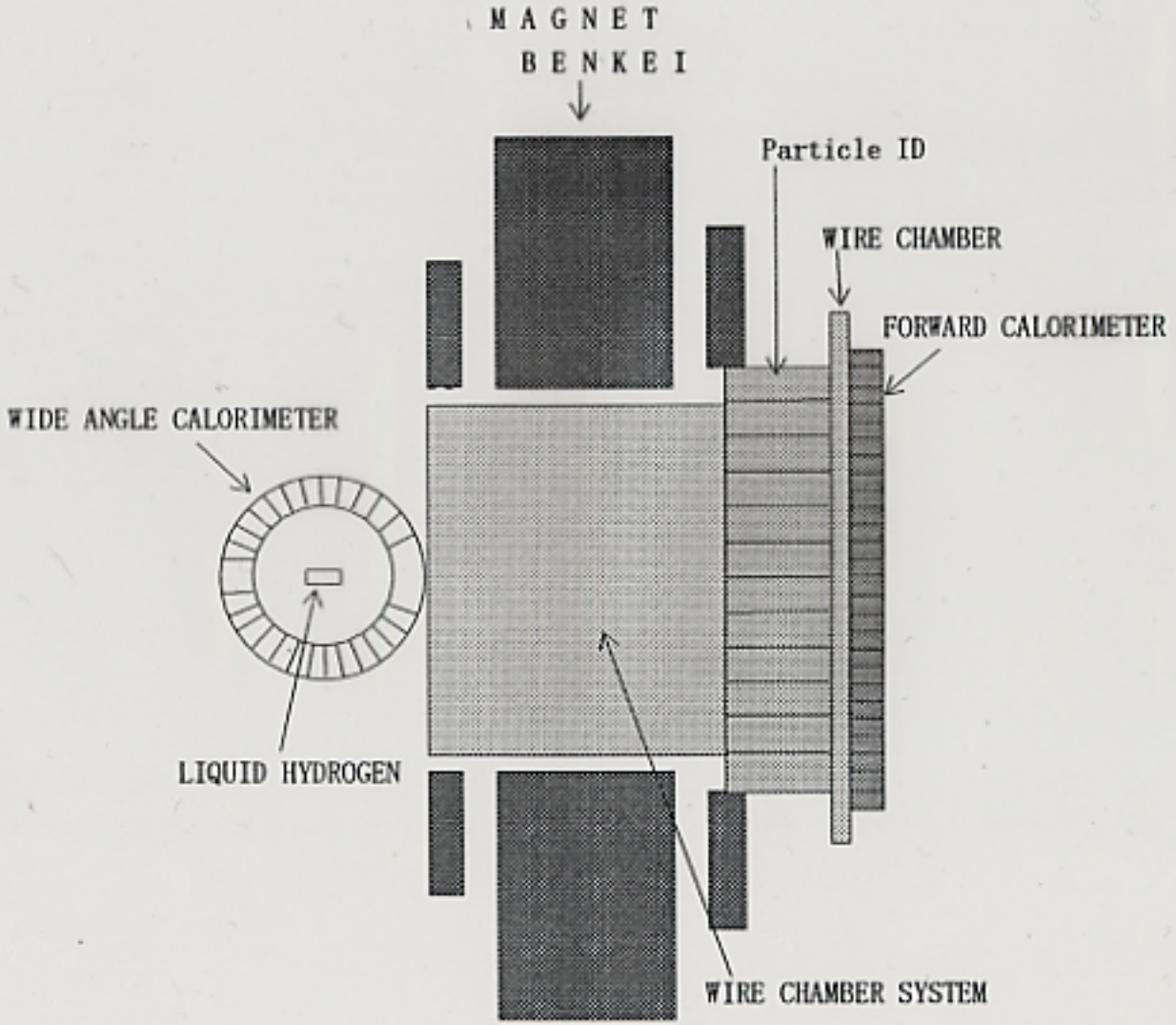
iii) good quality K beam line with RF-separator (<10 GeV/c) and spectrometer are required.

cf. OKA plan at IHEP(Protvino,Russia)

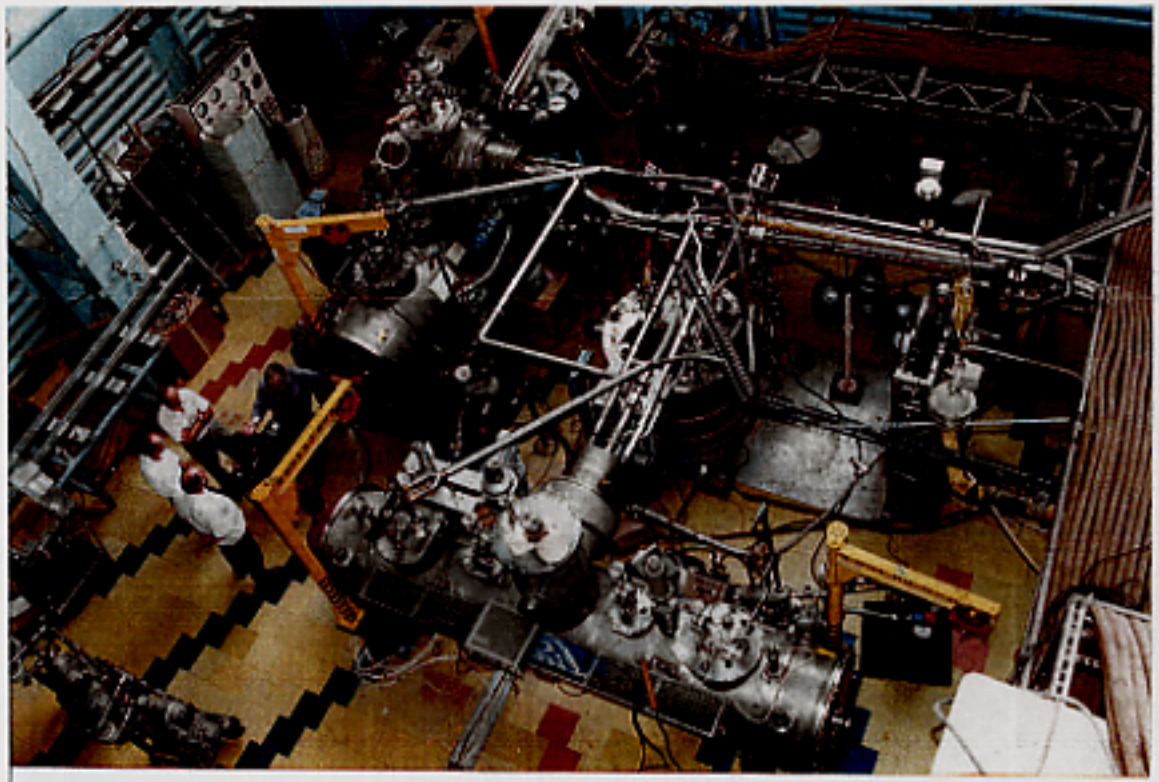
Hadron spectrosocoy (and K-decay experiment).

(10-15 GeV/c(18 Max.) K beam line with RF-separators

Schedule : beam line completed at the end of 2003


MAGNET
BENKEI
Particle ID
WIRE CHAMBER
FORWARD CALORIMETER
WIDE ANGLE CALORIMETER
LIQUID HYDROGEN
WIRE CHAMBER SYSTEM

OKA (IHEP, Protvino) plan

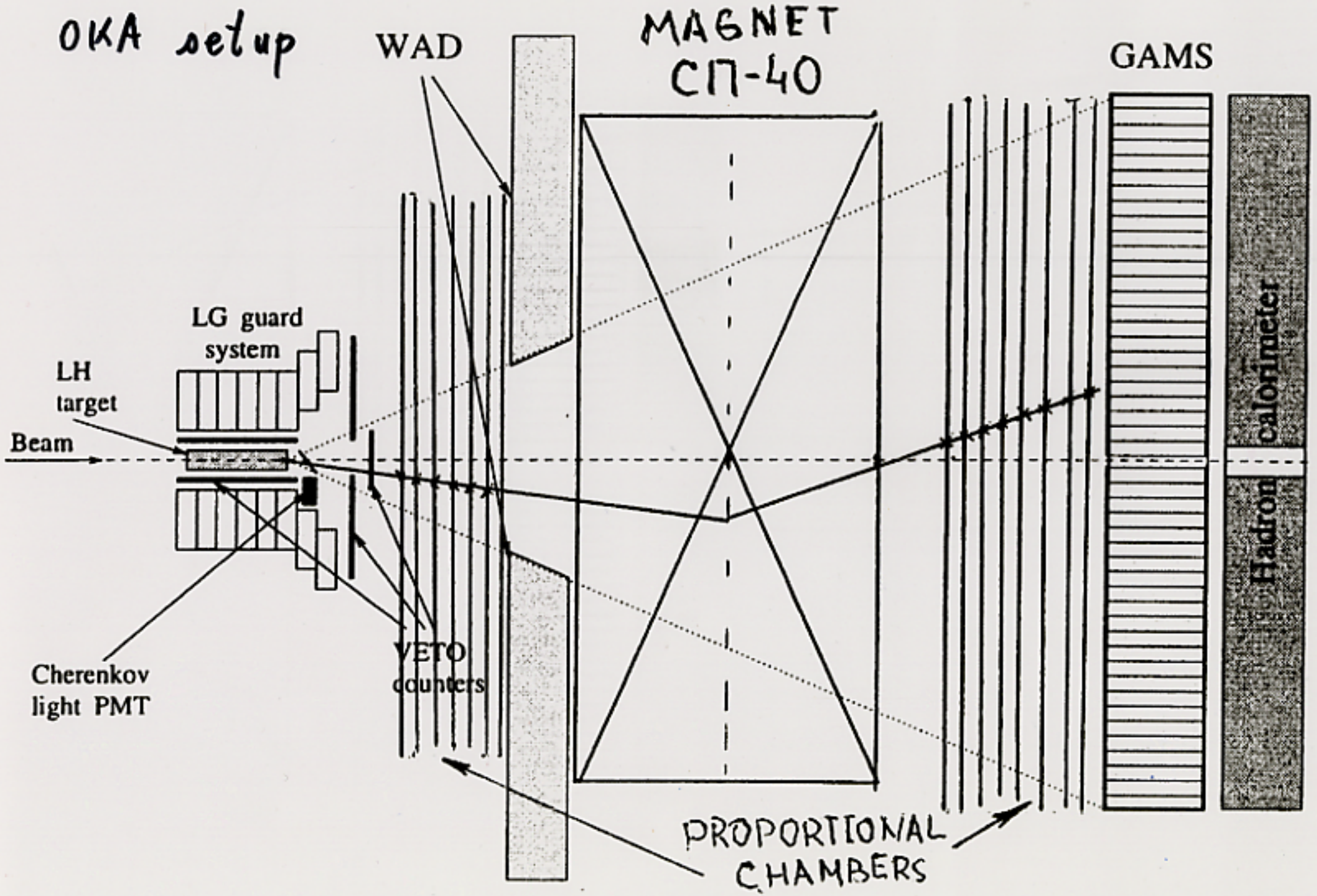


SC RF-separators
in test at Protvino

$K^{\pm}$ beam
10 ~ 18 GeV/c
~5 X 10^6 /spill

PS 70 GeV
10^{13} ppp

the end of 2003


OKA setup
WAD
MAGNET
СП-40
GAMS
LG guard
system
LH
target
Beam
Hadron calorimeter
Cherenkov
light PMT
VETO
counters
PROPORTIONAL
CHAMBERS